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ERS-1 Mission

Announcement of Opportunity

Experiment Summaries

issue 1

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PREFACE

The ERS-1 Announcement of Opportunity for basic scientific research studies and application-oriented projects issued in 1986 resulted in approximately 250 Proposals-Principal Investigators (PI's) being accepted within the ERS-1 Science and Application Plan.

This document provides a short summary of each individual experiment, including the main objectives and experiment plans, ERS-1 data requirements, anticipated results, work schedules and deliverable items. It is intended not only for consultation by those who are involved in the management of the overall exercise, but also as an information document for all those who wish to learn more about the various fields of application and scientific research on which the availability of ERS-1 data will have a major impact.

Readers should bear in mind that, besides providing an appreciation of the interest raised in the scientific and application community by the observation and measurement potential of the ERS-1 mission, this document testifies the continuous interaction of the mission team with the user community, over a period of more than four years; this cooperation will be pursued during the lifetime of ERS-1 and ERS-2 . Each experiment, in its final layout and organization as described hereafter, is the result of this interaction, which has materialized also in a number of plenary and more restricted meetings over the last few years.

Experiment summaries are arranged according to the following major subject areas:

- I Calibration Studies
- II Oceans and Climate
- II Sea Ice and Climate
- IV Glaciology
- V Meteorology and Atmospheric studies
- VI Forestry
- VII Agriculture and Soils
- VIII Hydrology
- IX Cartography
- X Geology
- XI Geodesy and Geodynamics

Each individual experiment has been described in one, and only one, of the above chapters, although several of them span different topics.

The experiment coding scheme adopted by ESA involves the use of country codes followed by numbers which distinguish the individual experiments (e.g. D8, F1, UK2-1, etc.). In addition, the code 'INT 'is used for international experiments, and the code 'PIP'

is used for experiments within the extensive PIPOR programme of sea ice experiments.

Many experiments are defined in terms of absolute dates. These dates were given in the original proposal, and in subsequent updates when the launch date was situated between October 1990 and the beginning of 1991. The dates have not been updated, but at the time of the final editing of this document the launch date was known to be in the first half of May 1991. Correction of the dates for the various experiments requires further interaction with the proposers, which is in hand, but to have awaited its completion would have delayed the issue of the document considerably.

This document has been compiled under the responsibility of the ERS-1 Mission Management Office.

I Calibration and Validation Studies

CND5

A PROPOSAL FOR TECHNICAL CONSIDERATIONS OF GENERAL UTILITY FOR ERS-1 SAR DATA

Principal Investigator:
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Co-Investigators:
D.Goodenough/ L.Gray/ C.Livingston/ N.Davis/ N.Denyer (CCRS), S.K.Parashar (Canadian Space Agency, Ottawa)

Objectives:

(1) Evaluate techniques of calibration and standardisation of SAR data using a reference site and applications sites, based on the use of the CCRS ERS-1 processor and on an experimental SAR processor, and with comparison of results from other ERS-1 processors.
(2) Explore innovative SAR techniques such as two-pass interferometry over test sites, and study scene response to imaging variables capable of being adjusted for ERS-1.

Experiment Plan:

The calibration site near Sault Ste. Marie is to be used for controlled calibration measurements using active and passive reflectors and distributed scattering. It is jointly operated by US investigators (agreement pending) and CCRS, and is to serve ERS-1, SIR-C and RADARSAT. Calibration data will be analysed to compare point verses distributed scattering. Application sites include those at Cranbrook, B.C., and Melfort, Saskatchewan. Cranbrook is mountainous and forested, whereas Melfort is agricultural. Data from both sites will be analysed to evaluate algorithms for geocoding, speckle reduction and classification based on calibrated reflectancies as well as texture. Transfer of calibration from the Sault Ste. Marie site to these sites will be assessed. Given availability of suitable pairs of images, interferometric analysis will be investigated for these sites. The CCRS airborne SAR will provide ancillary radar coverage of these sites during the ERS-1 mission.

ERS-1 Data Requirements:

Calibration/ Sault Ste. Marie (46°30'N, 84°30'W)
SAR image once every 12 days during the Calibration Phase, and once every 2 months thereafter. Request 2 pairs of passes (at 3 day intervals) using SAR mode on Day n, and Scatt/Wave mode on Day n+3, with the wave mode image on site.
Application/ Cranbrook (50°N +/- 30', 115°W +/- 1°)
SAR image every 2 months during the mission (as close as possible in time to the passes of the Calibration site). For coverage during the 3 day repeat phase, passes separated by 3, 6, 12, 24 and 48 days are requested., to support time sensitive analysis of two-pass interferometry, June-September preferred. (n.b If the site is not in the 3 day repeat footprint, an alternative site will be used).
Application/ Melfort (53°N, 104°W)
Data requirements are the same as the 3, 6, 12, 24, 48 day sequence for Cranbrook. Since the area is agricultural, late spring/ summer coverage is prefered. (n.b If the site is not in the 3 day repeat footprint, an alternative site will be used).

Facilities to be Deployed:

CCRS CV-580 with C- and X-band digital SAR systems, on-board processing and digital recording of all data and flight motion parameters. Active and passive reflectors on the sites.

Anticipated Results:

(1) Contributions to the technique and results of ERS-1 SAR calibration using point reflectors, and inter-comparisons with similar results obtained from other investigators using other ERS-1 processing systems.
(2) Contributions to the issue of point verses distributed calibration for SAR, with assessment of the transfer accuracy between sites separated by thousands of kilometers.
(3) Contributions to two-pass SAR interferometry, particularly regarding terrain sensitivity, and time separation sensitivity.

Milestones/Deliverables:

December 1990	Experiment plan.
December 1991	Report on calibration phase.
December 1992	Progress report.
December 1993	Final report.

Coordinator: Lawrence

D2

ATSR: NEW ALGORITHMS VALIDATION

Principal Investigator:
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Co-Investigators:
K.Strübing ((DHI, Bernhard Nocht Str. 78, D-2000 Hamburg 4), G.H.Ruppersberg/ Th.König (DLR, Oberpfaffenhofen, D-8031 Weßling), Raschke (IGMK, Universität zu Köln, Kerpener Straße 13, D-5000 Köln 41), H.Quenzel (MIM, Theresienstr 37/II, D-8000 München 2)

Objectives:
This proposal is concerned with the development and validation of algorithms for the extraction of information from the Along Track Scanning Radiometer (ATSR). Three rather different climatic variables are of main interest:
(1) Sea and land surface temperatures.
(2) Atmospheric aerosol particles over the sea.
(3) Clouds over sea, land and ice.
In all cases model calculations will be combined with airborne and satellite data.

Experiment Plan:
During the commissioning phase the study aims to improve ATSR performance by:
(1) A validation campaign mainly consisting of airborne radiometer measuremnts for the calibration of distinct channels.
(2) Derivation of precise coefficients in algorithms established prior to launch.
(3) Issueing of a North Sea SST map.
(4) Compiling a comprehensive climate variable data set to be used as mesoscale model input.
Measurements are planned to be carried out in the North Sea and the Atlantic Ocean off West Africa.

ERS-1 Data Requirements:
Commissioning phase
(1) Raw data at 2 angles for a North Sea area.
(2) Raw data at 2 angles for a calibration area off West Africa.
(3) Geometrically corrected data for the North Sea area after successful application of algorithms.
(4) Raw and geometrically corrected data for cloud classification purposes over land areas.
Exploitation phase
(1) Geometrically corrected data for SST map generation.
(2) Raw data for special projects (i.e. development of new algorithms for new applications in combination with other ERS-1 or NOAA-N radiometers).

Anticipated Results:
(1) New coefficients for established SST and Aerosol Algorithms.
(2) An operational SST map of the North Sea and larger areas.
(3) SST; Temperature of land surfaces; Cloud amount; Low, middle and high cloud amount for Mesoscale Model Input -
It is anticipated that the ATSR data will allow much better estimates of the downward solar radiation and the longwave radiation budget, providing , in conjunction with mesoscale modelling, a powerful means to determine surface heat and momentum flux.

Coordinator: Llewellyn-Jones

D11-1

RADIOMETRIC ERS-1 SAR (IMAGE MODE) CALIBRATION CONCERNING LAND APPLICATION

Principal Investigator:

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Co-Investigators:

H.Kietzmann (DLR), M.Reich (INS University of Stuttgart).

Objectives:

(1) Absolute scaling of backscattered signals by means of passive and ative external calibrators.
(2) Measurement of the operational SAR antenna pattern.
(3) Mutual radiative coupling of clutter surrounded point targets.
(4) Penetration measurements for land use.

Experiment Plan:

Trihedral corner reflectors and the active radar calibrators are deployed within the Oberpfaffenhofen test site for the purpose of absolute image calibration. Some of the corners are standing within one resolution cell, others with increasing distance between them, are in different resolution cells. This enables the investigation of the influence of multiple coupling on the calibration process.
The calibration receivers are deployed across track over some 200km for registration of the mainlobe of the operational antenna diagram.
In the second phase of the experiment the receivers will be deployed at different heights in dense vegetation for pentration measurements.
Scatterometer measurements of vegetation cross sections will be carried out in support of all experiments.

ERS-1 Data Requirements:

(1) Results of internal ERS-1 calibration.
(2) High precision orbit data (Postflight).
(3) Raw data covering the Oberpfaffenhofen test site.
(4) Image data of the Oberpfaffenhofen test site.

Facilities to be Deployed:

42 Trihedral high precision corner reflectors (0.25-1.0 m); 22 Calibration receivers; 6 Active Radar Calibrators; 1 Dielectric probe; 1 Polarimetric C-band scatterometer.

Anticipated Results:

(1) Absolute calibration of SAR image data.
(2) Operational antenna pattern for better elimination of range-dependent intensity variations.
(3) Influence of clutter and mutual coupling on the quality of the calibration process.
(4) Better understanding of penetration mechanisms.

Milestones/Deliverables:

August 1989	DC-8/E-SAR Preparatory Measurement Campaign with 46 Di/Trihedral Corner Reflectors, test of calibration-receiver and ARC prototypes.
1990	Preparatory scatterometer measurements. Finishing of calibration receiver and ARC series.
1991	First measurements of operational antenna diagrams using the new calibration receivers and ARC's within another DC-8/E-SAR campaign.
	Absolute image calibration using Trihedral Corner Reflectors and ARC's.
	Starting main experiments with ERS-1.

Coordinator: Nithack

I2

ASPECTS OF LBR SENSORS VALIDATION IN THE MEDITERRANEAN SEA

Principal Investigator:
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Co-Investigators:
B.Fiscella (University of Turin, Department of Physics), P.W.Woiceshyn (JPL, Pasadena, CA,USA)

Objectives:
To study the physics and characteristics of the scatterometer and altimeter backscattering measurements in semi-enclosed seas using ERS-1 data.

Experiment Plan:
The focus of the experiment is the physics of the scatterometer and altimeter measurements. For the 3-year period of the ERS-1 mission, CNR in venice will also be taking a time series of C-band scatterometer measurements at their Adriatic Sea platform. Comparisons will also be made at 2 major semi-enclosed sea basins: the Mediterranean and the combined Gulf of Mexico/Carribean Sea.

Primary areas of study are:
Mediterranean - 30°N to 60°N; 10°W to 40°E.
Gulf of Mexico/Carribean Sea - 10°N to 32°N; 60°W to 100°W.

Also, comparisons will be made with North Sea sites.

ERS-1 Data Requirements:
Scatterometer directional wave spectra, winds, radar backscatter, Kp, altimeter wave height and wind speed co-located with comparable in situ and analysis data. The co-located comparison data should include air temperature, sea surface temperature and surface pressure.

Facilities to be Deployed:
Instruments on the Adriatic Sea CNR platform, including a C-band scatterometer, and others for wave, wind flux and capillary wave measurements.

Anticipated Results:
Scatterometer and altimeter algorithms modified to include physics applicable to semi-enclosed and warm seas.

Milestones/Deliverables:
(1) Study report (1 year after completion of measurement programme).
(2) Papers in geophysical journals.
(3) Methodology and algorithms for the use of the alt-scatt data in Mediterranean monitoring and modelling.

Coordinator: Frassetto

I7

ERS-1 SAR DATA ANALYSIS FOR LAND THEMATIC MAPPING

Principal Investigator:

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Co-Investigators:
S.Vetrella (Istituto di Gasdinamica Universita di Napoli), C.Cafforio (DEE Universita di Bari).

Objectives:
(1) Short and long term calibration of ERS-1 AMI SAR data by means of passive and active calibrators placed on a test site near Matera, Italy.
(2) Understanding of the impulse response of the whole SAR system by studying the focussing processes.
(3) Knowledge of the SAR transfer function through simulation processes.

Experiment Plan:
The selected test site will be organised on a semipermanent basis near Matera. Passive and active calibrators will be used over extended periods of time to acquire calibration data at 6 month intervals.
Existing calibration procedures will be adapted to ERS-1 Raw Data Sets, as well as the "Field Migration Algorithm" to analyze the Point Spread Function and its variations within the scene.
Computer simulations will be performed to study platform attitude effects, sensor performances and backscattering behaviour of complex targets to derive the AMI SAR Transfer Function. Scatterometer data acquisition on the test site is being considered.

ERS-1 Data Requirements:

ERS-1.SAR.RAW	2 sets during the commissioning phase (if available); 1 set 6 months later.
ERS-1.SAR.PRI	1 set during the commissioning phase (if available); 1 set 6 months later.

Facilities to be Deployed:
Active radar calibrators, Corner reflectors, Ground receivers, Scatterometer (TBD).

Anticipated Results:
(1) Collection of calibration data for radiometric and geometric corrections of ERS-1 SAR data.
(2) Evaluation of radiometric and geometric characteristics of ERS-1 SAR imagery.
(3) Assessment of SAR system performances.

Milestones/Deliverables:
(1) Status reports January 1991 and every 6 months to December 1992.
(2) Experiment preparation and ground truth data collection.
(3) Updataing of the existing software to meet the sensor charcteristics.
(4) Papers to be published during 1992-4.

Coordinator: Attema

INT8-12

ERS-1 ALTIMETER CALIBRATION OVER LAND ICE IN GREENLAND

Principal Investigator:
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Co-Investigators:
A.Dodson (U. Nottingham, UK), B.Douglas (NOAA/NOS, USA), S.Ekholm (Geodetic Seismic Div. , Denmark), N.Gundestrup (Geophys. Inst., U. Copenhagen), H.Sunkel (U.Graz, Austria)

Objectives:
Ice core drilling takes place in Greenland at a site located at latitude 72°6' and longitude 32°35' every summer during 1990-93 (late May to July). An area to the east of this site is very flat (0.1m per km slope) and is to be used for calibration of the ERS-1 altimeter.

Experiment Plan:
(1) A point fixed in the relatively deep ice will be established and used as a fix point. Its height will be determined by GPS.
(2) Three E-W profiles spaced 0.2km in the northern direction and 10km long will be established, consisting of points spaced 0.2km apart. The height will be measured differentially relative to the fix-point mentioned above. Each height determination will take about 10 minutes. Assuming stable ionospheric conditions the observations will be carried out within a week.
(3) The profiles should be measured in 1991, 1992 and 1993. In 1991 between June 1 and June 7.
(4) Data will be processed very fast, and may be delivered to ESA by Fax as soon as the observations are completed, if necessary.
(5) GPS instruments are available from Kort- og Matrikelstyreelsen (National Survey and Cadaster, Denmark), who also have staff to carry out the survey.

ERS-1 Data Requirements:
Processed ground heights from Altimeter data over Greenland.

Coordinator: Thomas

NL3

CALIBRATION AND INTERPRETATION OF ERS-1 SAR IMAGERY OVER LAND

Principal Investigator:
P.Hoogeboom Physics and Electronics Laboratory, TNO, PO Box 96864, The Hague, The Netherlands

Co-Investigators:
J.Groot (as above)

Objectives:
The main objective is to investigate the usefulness of data gathered by the ERS-1 SAR instrument for land applications in remote sensing. For this investigation, two areas have been selected in the Flevopolder and the Veluwe. The Flevopolder is a reclaimed land area mainly featuring large (typically 10ha) flat lying agricultural fields. It has been extensively studied in past remote sensing experiments. The Veluwe consists of forests, lakes and municipal areas.

Experiment Plan:
(1) Calibration of the data using 3 different approaches: (a) by using corner reflectors, (b) by using transponders (possibly); (c) by comparing the ERS-1 SAR data with data obtained with the multiband airborne scatterometer DUTSCAT from homogeneous distributed targets (agricultural fields).
(2) Classification of land use (i.e. forestry, agriculture) using, for example, non-linear speckle reducing filters and textural features.
(3) Agricultural crop identification using SAR images obtained throughout the growing season.
(4) Forest monitoring/inventory, including the detection of disease (e.g. willows suffering from water mark disease).
(5) Agricultural crop growth monitoring for yield prediction.
(6) Monitoring of vegetation in Nature Areas.

ERS-1 Data Requirements:
Monitoring experiments require 8-bit SAR images from every pass over Flevoland/The Veluwe throughout the growing season (May 1 - August 31). The 35 day cycle provides images of this area every 8/9 days, so this amounts to 13-16 images in one growing season.
The forest monitoring experiment also requires 1 image obtained during the winter.

Facilities to be Deployed:
For calibration purposes several corner reflectors will be placed in the Flevopolder. The DUTSCAT airborne scatterometer will be deployed 3 times to enable indirect calibration of the SAR. Also ground truth collection will be carried out.

Milestones/Deliverables:

1990	Development of a monitoring system using a GIS to facilitate the interpretation of SAR images with respect to monitoring of Flevopolder and The Veluwe.
	Preparatory study of land use classification.
1991-92	Deployment of corner reflectors/transponders. DUTSCAT
	DUTSCAT underflights and data processing.
	ERS-1 SAR calibration.
	Usage of monitoring system for interpretation of ERS-1 data.
	Evaluation of land use classification algorithm(s).
1992-93	Final reports of research.

Coordinator: Sieber

PIP.CAL1

PROVISION OF AIRBORNE DATA FOR ERS-1 AMI VALIDATION

Principal Investigator:
C.E.Livingstone CCRS, 2464 Sheffield Road, Ottawa, Ontario, Canada K1A 0Y7

Co-Investigators:
R.K.Hawkins/ A.L.Gray/ T.Lukowski (CCRS)

Objectives:

Validation Period

(1) To provide airborne SAR and scatterometer data for the validation of the ERS-1 AMI imaging mode.
(2) To assess the ability of the CCRS SAR system to function as a mobile calibration transfer standard for AMI distributed target scenes.

Operational Period

(1) To assess the value of the ERS-1 Roll Tilt mode for enhancing iceberg detection in the open ocean.

Experiment Plan:

Michigan/Ontario Calibration Site

The proposed ERS-1 calibration site near Sault St. Marie is located in agricultural land which is in close proximity to large tracts of forest and a large lake.
A selected segment of an ERS-1 pass which images the calibration site will be under-flown by the airborne C/X band SAR system and C-band scatterometer during an ERS-1 pass and again in close time proximity.
The airborne sensor flight pattern will be designed to characterise the scattering cross section of selected, large distributed targets within the ERS-1 swath. Both internal references and external reference targets will be used to verify the airborne sensor calibration. Airborne data will be reduced to normalized scattering cross section statistics which will be compared to the statistics derived from an ERS-1 SAR image of the targets characterized. One or more scattering profiles will be defined across the ERS-1 swath to verify the range uniformity of ERS-1 calibration.

Other Site(s)

One or two similar programs will be conducted over other target areas. Each area will be selected to provide a range of target types where each target type is present over a large fraction of the ERS-1 swath. If three programs are flown, it is preferred that one of these be conducted during an orbit that images the ERS-1 calibration site but is displaced several hundred kilometres along the swath. The other would be conducted over a region several orbits removed from calibration site coverage and would provide a test of the short term stability of ERS-1 calibration. A total of six flights will be flown and a total of three ERS-1 images will be required for comparative analysis.

Facilities to be Deployed:

(1) CCRS Convair 580: C/X-band SAR systems, C-band scatterometer, RC-10 mapping camera, lidar altimeter, SAR based radar altimeter (flight altitude measurements).
(2) Airborne SAR reference targets: 8 x12 inch Luneburg lenses,2 x 18 inch Luneburg lenses,4 corner reflectors, C-band ARC, X-band ARC.

Anticipated Results:

From airborne SAR calibration experiments it is anticipated that scattering cross section estimates valid to within ± 1.5 dB will be readily obtainable from the data.
It is probable that better accuracies will be possible by the ERS-1 launch window and the ERS-1/airborne SAR comparisons will be constrained primarily by the radar textures of the scene segments used.

Milestones/Deliverables:

(1) Sets of airborne SAR data within each ERS-1 frame used (real time processed images,and a small quantity of precision processed images.
(2) Scattering cross section measurements for selected target areas.
(3) Airborne SAR/ERS-1 AMI comparison report.

Coordinator: PIPOR

UK3

INLAND WATER, LAND AND TRANSPONDER ALTIMETRY, INCLUDING CALIBRATION OF THE ALTIMETER RANGE BIAS

Principal Investigator:
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Co-Investigators:
M.A.J.Guzkowska/ I.M.Mason/ W.Cudlip/ S.Laxon (as above), R.J.Powell/ A.R.Birks (Rutherford Appleton Laboratory, Chilton, Didcot, OXON), P.A.Cross (Department of Surveying, University of Newcastle upon Tyne, Old Brewery Building, Haymarket, Newcastle upon Tyne, NE1 7RU), K.Blyth (Institute of Hydrology, Maclean Building, Wallingford, OX10 8BB)

Objectives:
This proposal addresses the development of two new aspects of satellite radar altimetry; namely, the analysis and interpretation of the echo waveform data to study the surface elevation and backscatter characteristics of inland water and land surfaces for both scientific and applications purposes, and the use of ground-based transponders for the calibration of the altimeter range bias as a means of obtaining highly accurate relative vertical position measurements, and in relating ocean surface altitude measurements to fixed positions on land.

Recent work has shown that , in a two month period in 1978, the Seasat radar altimeter gathered some 10^6 "readily interpretable" inland water and land echo waveforms. Depending on the surface type, estimates of surface elevation may be derived with a precision in the range 0.1 - 1 m, and with an absolute geodetic accuracy of about 0.5m. This far exceeds the accuracy of typical map data, and covers many areas of the world for which no map data are available.

Experiment Plan:
The activities proposed in support of ERS-1 will include the detailed definition of altimeter (and related ATSR/SAR) observing requirements, the implementation of ground campaign work (including the deployment and geodetic survey of transponders, measurements of levels of water and land surfaces, the measurement of vertical incidence backscatter characteristics, etc), and the analysis and interpretation of the ERS-1 and surface data. The level of activity wiill be particularly high during the Commissioning Phase, when it will be necessary to establish the technical performance of the ERS-1 altimeter over inland water, land, and transponders, prior to carrying out variety of geophysical calibration and validation experiments. However, it is anticipated that the development of new techniques and data products will continue throughout the Exploitation Phase.

ERS-1 Data Requirements:
Data requirements include sequences of the altimeter waveform, land elevation/backscatter, and the vertical position of transponder products, and selected ATSR and SAR images, all to be generated by the UK PAF.

Anticipated Results:
The scientific and applications significance of the proposed programme of work derives primarily from the potential for inland water and land surface elevation measurements of unprecedented accuracy and coverage.
The water level data will be of value to climate research and resource monitoring studies. The land data will revolutionise our knowledge of sutrface elevations in many areas of the world, permitting, for example, the generation of drainage basin contour maps, the unification of height datums, and the detection of elevation changes.
The determination of highly accurate orbit arc information over ocean areas will permit the measurement of the sea state bias correction, and the detection of small changes in the elevation of the ocean surface due to tides, atmosphere effects, and ocean flows (i.e. currents or mesoscale activity).

Coordinator: Duchossois

UK14-15

NORTH SEA VALIDATION EXPERIMENT

Principal Investigator:

P.L.Woodworth Institute of Oceanographic Sciences, Broad Road, Wormley, Godalming, Surrey, UK

Objectives:

Validation of geophysical measurements obtained from altimeter data.

Experiment Plan:

The North Sea was successfully used as a validation area for SEASAT in a study in which several European laboratories collaborated. The in-situ techniques required for such a validation (tide gauges, tide surge models etc.) have since been maintained and developed, and will once again be employed in this role for the validation of GEOSAT, ERS-1 and TOPEX/Poseidon data. ERS-1 is likely to be well tracked in this area which will be well equiped with satellite laser ranging equipment, PRARE stations and radar transponders.

The North Sea is an ideal region for determining the utility of radar altimetry.

ERS-1 Data Requirements:

Altimeter GRD data for the North Atlantic.

Facilities to be Deployed:

Coastal tide guage and pelagic recorder.

Coordinator: Srokosz

UK14-16

CALIBRATION OF ERS-1 HEIGHT OVER THE WESTERN MEDITERRANEAN

Principal Investigator:

T.H.Guymer — James Runnell Centre for Ocean Circulation, Gamma House, Chilworth Research Centre, Chilworth, Southampton SO1 7NS, UK

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Objectives:

To determine the orbital height of ERS-1 above the Western Mediterranean Sea to 10-20cm by exploiting the special characteristics of the region.

Experiment Plan:

It is planned to analyse ERS-1 altimeter data over the Mediterranean (primarily the western part) where it is known that sea level changes are small. Both collinear track and crossover point analyses will be employed - the latter being suitable only when ERS-1 is out of its 3 day repeat mode. Oceanographically-related contributions to sea level changes (tides, geostropic currents, inverse barometric effect, sea-state bias) are expected to be very small in the region, compared with the open ocean. Experience with Seasat and Geosat data has confirmed this. Even so, their values will be monitored using tide guage data, atmospheric pressure from coastal stations, and by analysis of the altimeter dataset itself. Atmospheric corrections will be applied, including ATSR-derived water vapour measurements.

A particular advantage of the Western Mediterranean is that the geoid is comparatively uniform and shipborne gravity survey data are available for fine tuning so a 10cm geoid is probably attainable. It also means that errors arising from gradients between tracks which do not repeat exactly will be very small.

This study complements the ESA altimeter height calibration proposed for Venice and the North Sea validation study.

ERS-1 Data Requirements:

Altimeter sea surface topography data, including preliminary orbit and all corrections, will be required for the whole Mediterranean and for the entire mission. Range data from selected PRARE stations will also be needed (those capable of tracking ERS-1 while it is over the W. Mediterranean).

Anticipated Results:

(1) A scheme for correcting ERS-1 tracks across the W. Mediterranean to better than 10cm accuracy.
(2) Production of 10cm mean sea surface and its variance (which can then be related to oceanographic features).
(3) Absolute determination of ERS-1 height over the W. Mediterranean to an accuracy of 10-20cm.
(4) Provision of datum for one end of tracks passing through NE Atlantic (ascending) and Central/S. Atlantic (descending).

Milestones/Deliverables:

CCT containing height of ERS-1 above the reference ellipsoid in the Western Mediterranean for all tracks provided by ESA. Details of the technique and results of analyses will be documented in an IOSDL report.

Coordinator: Srokosz

UK14-31

EFFECT OF RAIN ON ALTIMETER MEASUREMENTS

Principal Investigator:
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Objectives:
To assess the effect of atmospheric liquid water on altimeter returns and, if possible, to provide an effective means of flagging and correcting data.

Experiment Plan:
In the retrieval of wind speed from altimeters it is usual to assume that the measured sigma nought is a function of surface wind speed alone. However, atmospheric liquid water, particularly in the form of rain, can produce sigma nought changes which result in large errors in wind speed. The study will examine the effect of liquid water (including precipitation) on ERS-1 altimeter returns, in particular the retrieval of reliable wind speeds. By using data from microwave radiometers (including ATSR/M), ships and atmospheric models, occasions of high rain probability will be identified and the waveforms and sigma nought values of the ERS-1 altimeter will be examined to quantify the effects and investigate possible rain flagging schemes. It is anticipated that the major consequence will be a reduction in the backscatter intensity leading to an overestimate of wind speed, particularly for winds> 12m/s. The possibility of correcting the altimeter winds using the liquid water content values will be investigated and, where possible, tested against external data sets, e.g. high quality in situ data.

ERS-1 Data Requirements:
Altimeter waveforms; 1Hz wind speed, waveheight and sea level data; and ATSR atmospheric water data for selected areas. These to be chosen off-line using ship reports, satellite cloud imagery and other ancillary data. About 100 such areas will be selected from any part of the global ocean so as to span the main precipitation regimes, e.g. tropical convection, mid-latitude fronts and depressions, polar lows. The amount of data required on each occasion is a 100km segment of altimeter track and the corresponding ATSR/M data plus IR data from the ATSR centred on the mid-point of the altimeter segment.

Facilities to be Deployed:
NERC research ships (and routine ship reports) for precipitation and wind speed data.

Anticipated Results:
(1) A technique for flagging altimeter data contaminated by rain.
(2) A scheme for improving altimeter wind speed determinations in conditions of high atmospheric liquid water content or rain.

Milestones/Deliverables
Much of the study is concerned with developing techniques which should improve the exploitation of the dataset rather than in the generation of altimetric products themselves.
The main output of the study will therefore be validation datasets:
(1) Rain flag verification product (comparisons of occasions when rain flag is set with independent determinations of rainfall occurrence).
(2) Rain-affected wind speed validation product (comparisons of altimeter wind speeds with in situ data for a range of wind conditions, with and without an atmospheric correction applied).
Details of comparisons, results of analyses and any relevant algorithms developed in the course of the work will be documented in an IOSDL report.

Coordinator: Srokosz

US6-3

MONITORING THE ALASKAN STREAM (A MESOSCALE OCEAN RESPONSE EXPERIMENT)

Principal Investigator:
F.I.Gonzales NOAA Pacific Marine Environment Laboratory

Objectives:
Bottom pressure recorders (PBRs) and environmental data buoys (EBs) will be used to investigate issues critical to ERS-1 altimeter calibration.

Experiment Plan:
Five PBRs will be deployed in the deep ocean, on or near ERS-1 satellite altimeter tracks in the northeast Pacific. Three of these instruments will be deployed in a triangular array with approximately 200km sides, with vertices located at satellite altimeter crossover points. Two of the five stations, including one in the triangle, will be located near deep ocean EBs operated and maintained by NOAA. The in situ deep ocean BPR/EB instrumentation will provide measurements of ocean bottom pressure, atmospheric pressure, sea state, wind speed and direction, air temperature and sea surface temperature on an hourly basis during the two-year mission of the satellite.

ERS-1 Data Requirements:
Altimeter data for the North Pacific.

Facilities to be Deployed:
BPRs and EBs.

Anticipated Results:
Results addressing ERS-1 calibration issues such as (1) the accuracy of tidal corrections in the deep ocean, and (2) the inverse barometer effect in the deep ocean.

Milestones/Deliverables:
Report on analysis of coincident altimeter/BPR/EB data set.

Coordinator: Tapley

AUS6-12

MICROWAVE RADIATION

Principal Investigator:
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Co-Investigators:
I.S.F.Jones/ M.L.Banner/ I.R.Young (as above)

Objectives:
Accurate determinations of ocean surface elevation wavenumber spectra for short waves are needed to answer a number of important questions of fundamental and technological interest. Little in known about the directional wavenumber spectral distribution of short waves, particularly as they are modulated by underlying ocean swell components under wind forcing. This information forms the basis of acoustic and electromagnetic backscattering from the ocean surface for low roughness (no shadowing) conditions.
A new technique has been developed, based on stereophotogrammetric principles, to extract the wavenumber spectrum of short gravity waves for the wavelength range of order 1cm.
Stereo images of the ocean surface will be made to determine wavenumber spectra and the radar cross-section and its modulation at the same time as an ERS-1 SAR image is taken over the platform site. Auxiliary radar measurements of the ocean surface and observations of the prevailing environmental and ocean conditions will also be collected. These data will then be utilised in a comparison study of the fundamental mechanisms of microwave scattering from the ocean surface.

Experiment Plan:
Measurements of the ocean surface, over an area of approximately 2m by 2m, will be made from the oil rig platform at a number of times during an ERS-1 SAR overflight. The platform has been in use by the Ocean Technology Group for over ten years of observation using a wide range of oceanographic and environmental instrumentation. The measurements to be made from the platform during the overflight periods are:
(1) stereo images of the ocean surface
(2) auxiliary measurements of large scale waves using an acoustic sounder device
(3) absolute radar cross-section and propagation loss using a C-band transponder (see AUS6-13 for details of the transponders)
(4) wave period and significant wave height using a Baylor wave gauge
(5) wind vector data
(6) temperature profiles through the water column from a series of thermistor strings

ERS-1 Data Requirements:
Essential
ERS-1 SAR images on overflight pass cycles of the oil platform. The data are required from the first 35 day repeat orbit cycle (approximately 7-8 SAR images).
Desirable
ERS-1 simulated SAR scene.

Facilities to be Deployed:
Directional wave measuring equipment that is fully operational and available continuously (Located on oil platform).

Anticipated Results:
(1) Improvement in understanding SAR imaging mechanisms through the use of simultaneous stereophotogrammetry and ocean image data.
(2) Contributions to fundamental properties of gravity waves.

Coordinator: Nilsson

AUS6-13

JINDALEE OVER-THE-HORIZON RADAR STUDIES

Principal Investigator:
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Co-Investigators:
Anderson (as above)

Objectives:
(1) Mutual validation of wind and wave modes of ERS-1 with JINDALEE HF radar measures.
(2) Investigation of extremes in ocean behaviou (eg tropical cyclone detection and forecasting).
(3) Ocean sea surface forecasting and air-sea interactions.
(4) Ship-borne detection of internal waves and their SAR imaging.
(5) SAR imaging mechanisms.
(6) Validate calibration techniques using active and passive targets.

Experiment Plan:
(1) To measure wave spectra with ship-based equipment for comparison with JINDALEE skywave and ERS-1 SAR data in an area off Australia's north-west coast.
(2) To compare skywave and SAR measures of the ocean surface.
The experiment will also take advantage of calibrated transponder and passive targets to validate calibration techniques.

ERS-1 Data Requirements:
Essential
(1) ERS-1 wind/wave mode data for north-west ocean area (general area from 12°S, 125°E to 20°S, 116°E); ideally ascending and descending passes for 3-day repeat orbit for 3 periods of one month in first six months, thereafter weekly.
(2) ERS-1 SAR images in above area alternating on each re-visit with wind/wave mode data for a period to be defined, while HMAS Cook on station; and otherwise one pass per month.
(3) ERS-1 SAR images over a salt lake area (approx 31°S, 140°E) for active and passive calibration.
Desirable
(1) ERS-1 wind-wave mode data for Bass Strait, both ascending and descending passes for 3-day repeat orbit for 3 periods of one month in first six months, thereafter weekly.
(2) ERS-1 SAR images in above area alternating with wind/wave mode data (both 6-day interval) for period of 4 weeks while data gathering facilities on ESSO/BHP oil recovery platform are manned.
(3) ERS-1 SAR images in above area at rate one per month.

Facilities to be Deployed:
(1) HMAS Cook for ship-borne measurements, including Waverider buoy and deployment of calibrated transponder(s).
(2) calibrated transponder(s) and passive reflectors.
(3) island weather stations.
(4) wave measuring equipment on two oil platforms.

Anticipated Results:
(1) JINDALEE skywave measurements of wave spectra will be compared with ERS-1 SAR and wind/wave data and ground-truthing; to test and refine SAR wave imaging models.
(2) Usefulness of SAR and skywave monitoring of ocean patterns for cyclone detection.
(3) Testing and refining models of SAR imaging of internal waves.

Milestones/Deliverables:

1990	Detailed planning for experiment.
1991-92	Prepare and conduct experiment.
1992-94	Develop improved model for SAR imaging of waves and internal waves; calibration evaluation.

Coordinator: Nilsson

D1

VALIDATION OF MODELS FOR EXTRACTING WIND AND WAVE INFORMATION FROM AMI DATA

Principal Investigator:

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Co-Investigators:

V.Wismann (as above), G.Valenzuela (Code 4234, Naval Research Laboratory, Washington D.C. 20375-5000, USA

Objectives:

(1) To validate models for extracting wind and wave information from AMI data.
(2) To validate SAR/RAR models for the current perturbed ocean surface; to investigate the nature of "slick-like" features on the continental shelf and the refraction and modulation of ocean waves by the Gulf Stream.

Experiment Plan:

(1) Measurement of the wind field along ERS-1 tracks in the Norwegian Sea by the airborne C-band scatterometer (RACS) during Cal/Val Campaign in autumn 1991.
(2) Improvement of the C-band wind scatterometer model by comparing sigma nought values acquired by AMI and RACS with in-situ measured wind speeds.
(3) Validation of the SAR imaging mechanism of ocean waves by comparing in-situ measured ocean wave spectra with simulated and measured SAR image spectra.
(4) Conduct an ocean field experiment in the Gulf Stream area off the US coast for studying the current-wave interaction by in-situ and airborne measurements.

ERS-1 Data Requirements:

(1) All ERS-1 scatterometer sigma nought triplets acquired during the Cal/Val period in the experimental site in the Norwegian Sea.
(2) All ERS-1 SAR images acquired during this period in the Cal/Val area.
(3) One SAR image over the North Atlantic every day for a period of one year, starting January 1st 1992.
(4) All ERS-1 SAR images acquired over the Gulf Stream region bounded by the coordinates:
(42°N, 75°W) (35°N, 78°W) (35°N, 65°W) and (30°N, 73°W) in the periods June 10-24, 1991, July 15-26, 1991 and September 10-25, 1991.

Facilities to be Deployed:

(1) RACS C-band scatterometer on a Dornier 128 aircraft.
(2) Several airborne radars and in-situ sensors in the Gulf Stream region.

Anticipated Results:

(1) Improvement of the C-band wind scatterometer model function.
(2) Refinement of the velocity bunching model for describing the SAR imaging of ocean waves.
(3) Improved understanding of the modulation of short surface waves by variable surface currents associated with tidal flows over bottom topography, internal waves, oceanic eddies and fronts.
(4) Vaidation of models describing the refraction and modulation of ocean waves by the Gulf Stream.

Milestones/Deliverables:

Sept - Nov 91	RACS measurements during the Cal/Val campaign.
Oct.91 - Dec 92	C-band wind scatterometer model tuning by using the data from the Cal/Val Campaign.
Oct 91 - Dec 92	Monte-Carlo simulation studies for validating the ocean SAR imaging model on the Cray 2 computer of the Max Planck Institut für Meteorologie, Hamburg.
June - Sept 91	Intensive aircraft and ship measurements.

Coordinator: Attema

D6

TOWER EXPERIMENT: WAVE DIRECTIONALITY BASED ON ERS-1 SAR DATA

Principal Investigator:

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Co-Investigators:

J.Guddahl (DMNI, Bergen), K.Richter (BSH, Hamburg), V.Wisman (Hamburg),

Objectives:

(1) Validation of satellite SAR observation by tower and ship based radar and numeric wave models of the 2nd and 3rd generation.
(2) Measurement of the Modulation Transfer Function with a tower based radar.

Experiment Plan:

Tower based instruments will include a radar for the measurement of the 2D wave field and a C-band scatterometer for the measurement of the MTF. These will be operational on the Gullfaks C rig from August 1991 until the end of 1991.
An intensive measurement campaign is planned for the last 2 weeks of November 1991. A ship will be operating in the Haltenbanken area equipped with imaging radar for 2D wave measurements. Wave direction buoys and wind sensors will be deployed at fixed locations.

ERS-1 Data Requirements:

(1) SAR wave mode during the full Cal/Val period at Gullfaks C (ascending and descending).
(2) SAR image mode for some paths covering the Gullifaks C area.
(3) SAR wave mode during the intensive measurements at Haltenbanken.(end November 91).
(4) SAR image mode for at least 2 days during the last 2 weeks of November 91.
(5) Scatterometer mode at Gullfaks C during the Cal/Val period.

Facilities to be Deployed:

Tower based wave imaging radar and C-band scatterometer, ship based wave imaging radar and wind sensors, and 2 wave direction buoys.

Anticipated Results:

(1) Validation of the 2 dimensional imagery of wave fields by ERS-1.
(2) Measurement of "MTF Ground Truth" during Cal/Val.

Milestones/Deliverables:

Progress reports for ERS-1 workshops (as required).

Status report in spring 1992.

Scientific papers in period 1992-4.

Coordinator: Attema

F8

PROGRAMME D'ÉTALONNAGE ET D'ÉVALUATION DE L'ALTIMÈTRE ET DU DIFFUSIOMÈTRE DE ERS-1

Principal Investigator:
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Co-Investigators:
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Objectives:
(1) Altimeter derived sea-state validation.
(2) Scatterometer calibration/validation.
(3) Scatterometer model tuning.
(4) Air-sea interactions and physical process studies in high wind situations.
(5) Validation of scatterometer measurements in terms of momentum fluxes.

Experiment Plan:
(1) Participation in the cal/val experiment off Norway.
(2) In-situ data validation and use for cal/val.
(3) Participation in the SOFIA/ASTEX (Spring-Summer 1992) and SEMAPHORE (Autumn-Winter 1993) experiments off the Azores.

ERS-1 Data Requirements:
Sigma nought(s), AMI winds and altimeter SWH and sigma noughts off Norway during the cal/val experiment.
World FDP for the whole mission, with special emphasis over the Atlantic during SOFIA(92) and SEMAPHORE (93) experiments.

Facilities to be Deployed:
SOFIA and SEMAPHORE experiments will include ships, turbulence instrumented planes, drifting and moored buoys.

Anticipated Results:
(1) Scatterometer model tuning.
(2) Increased understanding on the moemtum fluxes integration at increasing scales.
(3) New methods of satellite data use for scientific and operational projects.

Milestones/Deliverables:
Progress reports at 6 month intervals.
Presentations at ERS-1 workshops and meetings.
Scientific publications.

Coordinator: Attema

N7

TECHNICAL SUPPORT FOR THE GEOPHYSICAL VALIDATION OF ERS-1

Principal Investigator:

T.I.Bern
Oceanographic Company of Norway A/S, Pirsenteret, N-7005, Trondheim, Norway
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Objectives:

Preparation and deployment of the buoy network during the Rehearsal and Commissioning Campaigns in the dedicated site experiment.

Experiment Plan:

(1) TOBIS buoy development and test.
(2) Production of TOBIS buoys for Rehearsal Campaign.
(3) Rehearsal Campaign mobilization, execution and demobilization.
(4) Production of TOBIS buoys for the Commissioning Campaign.
(5) Commissioning Campaign mobilization, execution and demobilization.

ERS-1 Data Requirements:

Wind and wave fast delivery products.

Facilities to be Deployed:

10 TOBIS buoys equipped with 2 wind sensors and one wave sensor. Each wind sensor is connected to separate on-board buoy data processing hardware and software. This includes data transmission to shore in near real time of contiguous measurement series.

Anticipated Results:

A data set consisting of in-situ measurements covering 3 months to be used by the analysis team for evaluation of the satellite's wind and wave products.

Milestones/Deliverables:

Spring 1990	Rehearsal Campaign report.
Winter 1990/1	TOBIS buoy production report.
Autumn 1991	Daily and weekly reports based on transmitted data during the Commissioning Campaign.
Winter 1991	Commissioning Campaign Report, including survey reports from buoy surveys.

Coordinator: Attema

NL6

VALIDATION OF THE WAVEDIRECTIONAL SPECTRA OBTAINED BY ERS-1

Principal Investigator:
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Co-Investigators:
G.J.Wensink (Delft Hydraulics "De Voorst", PO Box 152, 8300 AD Emmeloord, The Netherlands)

Objectives:
(1) To measure wavedirectional and 2D frequency spectra with SHIRA (SHIps RAdar).
(2) To compare the SHIRA data with the ERS-1 SAR wave image data, airborne radar data and in-situ data.

Experiment Plan:
The SHIRA system will be mounted on an oceanographic research vessel (probably the "Gauss") at or near the crossover point in the "Haltenbank" area near Norway. The measurements of wavedirectional spectra by SHIRA and the buoy data will be performed simultaneously with those taken by ERS-1. A comparison will be made between the SHIRA data, the ERS-1 data, airborne radar (RESSAC) data and the in-situ measurements.

ERS-1 Data Requirements:
Wind wave data, image data and raw SAR data for the Haltenbank area.

Facilities to be Deployed:
Ships radar.

Anticipated Results:
Increased understanding of the transfer functions between SAR wave directional spectra, SHIRA spectra, airborne radar data, and in-situ data.

Milestones/Deliverables:
Status report - February 1992.
ERS-1 workshop/conference reports.
Scientific papers.

Coordinator: Attema

US8-2a

WAVE MODE VALIDATION

Principal Investigator:
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Tel: 613 998 9060

Co-Investigators: R.C.Beal/D.Tilley (APL), F.Jackson (NASA/GSFC), F.Dobson/W.Perrie/S.Smith (BIO), R.Keeley (Marine Environmental Data Service, Ottawa), G.Morrissey (Atmospheric Environment Service, Ottawa)

Objectives:
(1) To provide validation data, both remote (airborne SAR and ROWS) and in situ (wave and meteorological buoys and marine radar), for validation of the AMI wave mode, and full image mode data.
(2) To assess the ability of an airborne SAR to predict the performance of a spaceborne SAR for observation of ocean waves.
(3) To assess the ability of a spaceborne SAR system to measure useful ocean wave parameters, in particular, to determine the potential for spaceborne SAR to obtain global estimates of the ocean surface wave directional spectrum.

Experiment Plan:
Wave and meteorological buoys will be moored at the SAR cross-over point (about N46.5° W51°) off the East coast of Newfoundland for a three week period during the ERS-1 commissioning phase orbit (3-day repeat, 24.365° phase). The preferred timing is a three week window between October and April since the wave field may be expected to be most extreme in nature at that time of the year.
The intensive measurement program involves wave buoy measurements, ship-mounted marine radar, meteorological buoy measurements and ERS-1 underflights by CCRS SARs (6 to 8 flights) and the NASA ROWS (6 to 8 flights). In addition, wind and wave fields over the entire Grand Banks area will be modelled using the BIO version of the WAM model. All on site measurements will provide a best estimate of the sea state at the time of ERS-1 SAR passes. This will be cross-checked with airborne SAR and ROWS results and related to the ERS-1 measurements using well documented procedures.
Using ERS-1 data from both the imaging mode amnd the wave mode, wind roughed scenes containing no long waves will be used to determine the stationary wavenumber response of the ERS-1 SAR through the platform range to velocity ratio. ROWS estimates of absolute directional wavenumber spectra and wind speed will guide development of SAR models and conversion algorithms.

Facilities to be Deployed:
One ship with mounted wind stress measurement package, marine radar, 2 Datawell "Wavec" directional wave buoy and 3 Coastal Climate "Minimet"meteorological buoys; CCRS Convair 580 with C/X-band SAR systems; NASA T-39 with Radar Ocean Wave Spectrometer.

Anticipated Results:
(1) A good characterisation of the oceanographic and meteorological conditions for estimating errors in AMI derived geophysical products.
(2) A data set to lead to further understanding of SAR imaging of ocean waves and an opportunity to determine limits on a high altitude SAR platform for global monitoring of ocean waves.
(3) A SAR imaging model based on velocity bunching and coherent scattering will be extended to include facet bunching and transient specular reflection. A better understanding of short scale wind and wave interactions will result as the limits of the model are defined over a variety of sea states.

Milestones/Deliverables:
(1) Sets of ocean wave spectra corresponding to each ERS-1 pass over the experiment site as derived from ROWS (when present during the pass), as well as image spectra derived from the ERS-1 SAR data and the CV-580 SAR data (when present during the pass).
(2) ERS-1 and CV-580 SAR image spectra processed to directional waveheight spectra using well documented techniques.
(3) Intercomparisons and cross-correlations (or at least some meaningful quantitative intercomparisons between all spectra collected).
(4) A preliminary report on the results of the iterative processing of ERS-1 and CV-580 SAR data with the objective of extracting more (and better) ocean surface information and recommendations concerning the extraction of useful wave information from ERS-1 SAR data will be provided to ESA within 12 months of receiving data.
(5) A final report or open literature manuscript will be completed within 24 months of receiving data.

Coordinator: Freeman

F14

VALIDATION GEOPHYSIQUE DES DONNEES ALTIMETRIQUES ET OBSEVATION DE LA TOPOGRAPHIE DYNAMIQUE DES OCEANS

Principal Investigator:
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Co-Investigators:
M.Lefebvre/ Y.Menard/ C.Perigaud/ C.Brossier/ M.Bacca/ J.Benveniste/ A.Cazenave/ P.de Mey/ P.Mazzega/ N.Mognard (CNES)

Objectives:
(1) La validation géophysique du vent altimétrique et de la correction du biais électomagnétique et la validation du signal de topographie dynamique.
(2) Analysis de la topographie dynamique et de sa variabilité de la mésoéchelle à la grande échelle.

Experiment Plan:
(1) Validation géophysique du vent altimétrique.
(2) Validation géophysique du biais electomagnétique.
(3) Validation géophysique des données de hauteur de la mer à la mésoéchelle.
(4) Observation de variabilité de la topographie dynamique à la mésoéchelle.
(5) Observations de la variabilité à la grande échelle.

ERS-1 Data Requirements:
Données altimétriques.de niveau 2, y compris les corrections, et à une parte des données de niveau 1,5 (validation du biais e.m. , y compris les formes d'onde).

Anticipated Results:
(1) Les résultats de validation géophysique devraient permettre de tester la stabilité des mesures à long terme, et la qualité des corrections. Les améliorations possibles seront proposées aux PAF concernés.
(2) Les observations de topographie dynamique seront publiées pour utilisations dans d'autres études, notamment d'assimilation dans des modéles dynamiques.

Coordinator: Minster

F11

LA MEDITERRANEE: UN ZONE D'EXPERIENCES POUR L'ALTIMETRE ERS-1

Principal Investigator:
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Co-Investigators:
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Objectives:
L'objectif de la proposition est centré sur le test de deux fonctions de la mission de ERS-1 en Méditerranée occidentale:
(1) Etalonnage de l'altimètre laser en Méditerranée entre la Corse et le sud des côtes françaises. Il est proposé d'installer une station laser mobile en Corse dans le cadre d'une coopération européenne à préciser ultérieurement.
(2) Validité de la restitution de la trajectographie dans cette zone.

Plusieurs autre études prevent être faites dans ce contexte, soit à caracrère océanographique (effets marins) soit à caractère géophysique (interprétation des accidents du géoide). Par ailleurs, le rattachement géodésique des maragraphes de la région entre eux et relativement aux stations laser, pourrait contribuer à des études intéressantes sur le niveau moyen des mers.

Experiment Plan:
(1) Trajectographie locale la plus précise possible au-dessus de la Méditerranée.
(2) Etalonnage de l'altimètre ERS-1.
(3) Le rattachment géodésique des marégraphes méditerranéens aux réseaux laser grâce au système GPS.
(4) Interprétations géophysiques.
(5) Dynamique de la mer (quantification des différentes circulations).

ERS-1 Data Requirements:
(1) Les données altimétriques (1 mesure par seconde) recueillies d'une part avec l'orbite répétitive de 3 jours mais aussi avec les autres orbites espérées, permettant notamment une résoltion spatial pouvant descendre au niveau de 15km.
(2) Les données de trajectographie (laser-PRARE).

Coordinator: Minster

II Oceans and Climate

AUS6-17

COASTAL WAVE EXPERIMENT (AT LOW AND HIGH LATITUDE)

Principal Investigator:

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Co-Investigators:

C.B.Fandry/ J.Reid (CSIRO), S.J.Buchan (Steedman Science and Engineering)

Objectives:

To observe the normal and extreme wave climates of the North West Shelf of Australia and the Southern Ocean about Macquarie Island, using SAR and wave scatterometer from ERS-1 satellite. Compare the remote sensing data with in situ instrument observations. Use the updated and temporal data to better understand the wind wave generation and dissipation processes, particularly in shallow water. Surface stress, white capping and bottom friction are of concern. Both areas are subject to extreme storms - severe tropical cyclones and severe gradient intensification. Comparisons between the low and high latitude storms will also be made. Second generation spectral wave models will be utilised to examine the physical processes.

Experiment Plan:

To measure the shelf edge (-100m depth) wind and waves and examine the changes in amplitude, period and direction of the wave trains. The experiment will employ proven and reliable wave recorders and processing techniques. The satellite information will provide spatial detail and the point measurement(s) will give detailed in situ characteristics. The experimental results will be compared with existing spectral models developed for severe tropical cyclones and gradient intensification storms.

ERS-1 Data Requirements:

Assuming a longitude phase of -128.2° for the 3-day cycle periods beginning January 1992.

Essential

(1) ERS-1 SAR for North Rankin 'A' Area: 360km swath (say 1 min) centred on 19°37'S, 116°06'E on descending passes during the 3-day repeat period January 1992 to March 1992. Minimum requirement - 6 passes.
(2) ERS-1 SAR for Macquarie Island Area: Centred on 54°25'S, 158°48'E during 35 day repeat cycle - 360km swath (1 min) - minimum requirement 6 passes over 9 months. Dependant on Hobart TERSS station.
(3) Wave scatterometer data available for above two areas for 12 months. AMI wave mode sampling phase adjusted to best cover above locations.

Desirable

(1) ERS-1 SAR for North Rankin, as above, but 15 passes over 3 months (3 day 'ice' phase).
(2) ERS-1 SAR for Macquarie Island, as above, but 18 passes over 9 months (35 day cycle).

Facilities to be Deployed:

Available as part of the existing services and operations:
(1) Ships for deployment/recovery and service.
(2) Existing surface meteorological observations.
(3) Ocean wave measuring equipment and calibration facilities.

Anticipated Results:

Surface wave observations of the shallow water effects on wave trains. Observations of severe storm wave generation and dissipation. The observations will be used to validate spectral wave models with local scale intense cyclonic and mesoscale gradient intensification wind fields.

Milestones/Deliverables:

1990-91	Detailed planning for equipment and final approvals.
1991-92	Installation of some equipment and conduct experiments and reporting.
1993-94	Analysis of data and model validation and reporting.

Coordinator: Nilsson

CND3

THE WIND-DRIVEN UPPER OCEAN WAVE AND MIXED LAYER DYNAMICS

Principal Investigator:
M A.Donelan — National Water Research Institute, CCIW, 267 Lakeshore Road, PO Box 5050, Burlington, Ont., Canada, L7R 4A6 Tel: 416 336 4879

Co-Investigators:
38 Scientists

Objectives:
To improve our understanding of:
(1) The detailed physics of the wind-wave generation process.
(2) The dynamics of the evolution of wind-generated waves.
(3) Wave dissipation.
(4) The influence of waves on mixing and other aspects of upper ocean dynamics.
(5) The effect of long waves on the microwave radar response.

Experiment Plan:
This experiment is tied to a large field experiment funded primarily by the US Office of Naval Research and NASA. The Surface Wave Dynamics Experiment will be conducted from October 1990 to March 1991, and will include surface measurements of waves, fluxes and winds, and aircraft measurements at selected times.
The aircraft data will be analysed to some degree in flight. The wave buoy data will be recorded on optical discs and will be accessible by radio on command from an overflying aircraft. The meteorological buoys report twenty minute averages via Argoes. Thus the analysis will proceed during the experiment and will include a substancial meteorological and wave modeling program. The ERS-1 scatterometer and SAR data will be assimilated into the models. Further, there will be extensive comparisons of simultaneously collected ERS-1, aircraft and buoy data.

ERS-1 Data Requirements:
Wind Scatterometer and SAR data.

Facilities to be Deployed:
(1) A spar buoy with detailed wave directional and surface flux capability.
(2) Two pitch-roll buoys with meteorological and surface flux capability.
(3) Ten mean meteorological buoys.
(4) Five aircraft with various remote sensors, including Surface Contour Radar, Radar Ocean Wave Spectrometer, SAR, several scaterometers and Laser Altimeter.

Anticipated Results:
(1) Detailed investigation of the source functions in the wave energy balance equation - particularly the wind input source function. The ERS-1 scatterometer will be particularly useful in establishing surface wind fields used in testing source function sensitivity in the wave models, and the SAR and Altimeter in verifying the models.
(2) Improvements to mixed layer modeling methods derived from exploring the velocity and thermal response of the mixed layer to very well monitored surface fluxes. The scatterometer data will be assimilated in establishing the surface winds.
(3) Further validation of the scatterometer, SAR and Altimeter using the extensive SWADE data both from surface platforms and from aircraft.
(4) Improved understanding of radar response to the ocean surface. The very detailed information on the wave field and surface fluxes will enable the refinement of algorithms for ERS-1 and sebsequent remote sensors.

Milestones/Deliverables:
(1) A report analysing the comparison of SAR, scatterometer and altimeter data with SWADE surface data will be delivered in March 92.
(2) Preprints of all SWADE manuscripts using ERS data for submission to journals .

Coordinator: Freeman

N2

NORWEGIAN CONTINENTAL SHELF EXPERIMENT

Principal Investigator:
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Co-Investigators:
R.A.Shuchman/ C.Rufenach (ERIM, Michigan, USA), H.Johnson (FORUT, Troms_, Norway), K.Davidson (Naval Postgraduate School, Monterey, California, USA), K.Barthel (as PI)

Objectives:

(1) Study variabilities in the mesoscale oceanic circulation pattern and wind field pattern.
(2) Study ERS-1 SAR wave imaging capabilities.
(3) Study long-wave/ current interaction.

Experiment Plan:

(1) SAR image expressions of surface current features and rapid wind shifts will be classified, followed by an attempt to quantify the geophysical variables.
(2) The limitations of wave imaging capabilities due to azimuth cutoff will be evaluated.

Study area is the Norwegian offshore region centred on Haltenbanken (64°30'N, 9°E). A pilot study will be conducted in the cross-over area at about 58°N, 3°30'E.

ERS-1 Data Requirements:

SAR image mode, ATSR and altimeter data for the Haltenbanken area during 1991, and especially for the cross-over area in early July 1991.
Additional coverage of the Barents Sea and/or Greenland Sea is required to validate SAR detection capability of Polar Lows.

Facilities to be Deployed:

Wind turbulence and wind stress buoy; current meter and thermistor chain moorings; surface drifters; pitch and roll buoys; WAVESCAN buoys; ship mounted current profiler and surface thermistor; ship mounted wind turbulence and stress sensors; ship mounted X-C-L band scatterometer; ship mounted video camera; ship mounted CTD; ship mounted towed Seasoar; airborne SARs.

Anticipated Results:

(1) Increased understanding of SAR imaging capabilities.
(2) Validation of SAR imaging capabilities of mesoscale current patterns, rapid wind shifts and waves.
(3) Validation of RA surface slope measurements in studies of mesoscale circulation.
(4) Validation of ATSR surface temperature measurements.

Milestones/Deliverables:

January 1991	Experiment plan.
Aug & Dec 91	Field reports.
91-94	Papers for ERS-1 workshops, IGARRS meetings and journals.

Coordinator: Attema

PIP.LAB7

SAR/OCEAN SURFACE WAVES IN THE MARGINAL ICE ZONE

Principal Investigator:
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Co-Investigators: B.Eid (MacLaren Plansearch Ltd., Halifax, N.S.), W.Perrie (BIO), W.Winsor (Centre for Cold Oceans Resource Engineering, St. John's Nfld.

Objectives:
(1) To observe surface gravity waves in the marginal ice zone using ERS-1 SAR, CCRS airborne SAR, wave-induced ice motion time series, marine radar, directional spectral measurements of the impinging wave field, and ice properties.
(2) To utilize these data to develop an understanding of SAR imaging physics for ocean waves for the case of waves-in-ice (which is much simplified over the general open ocean case).
(3) To utilize these data to allow modelling of the physical processes within the marginal ice zone.
(4) To make steps towards a detailed understanding of the coupling between the wind input, the planetary boundary layer and wind stress, nonlinear transfer due to wave-wave interactions, and dissipative mechanisms such as wave breaking in the marginal ice zone.

Experiment Plan:
Geographic area: Southern Labrador Sea - Northern Grand Banks of Newfoundland (approx. 47.3°N - 51°N, 50°W - 55°W). On site measurements will be made in conjunction with the CSS Baffin (BIO) cruise for LIMEX III which is currently being planned for March 1992. The ship will be fitted with a marine radar and deploy equipment on the ice and near the ice edge (depending upon ice conditions and edge location). On site measurements will be correlated with results from ERS-1 SAR imagery and multi-geometry underflights by the CCRS airborne SAR systems. Models which account for physical processes within the marginal ice zone will be developed, implemented, and results compared with the on site observations.

ERS-1 Data Requirements:
Repeat SAR coverage (3 days) over a three week period (yet to be defined in detail) during March of 1992 (note: with ERS-1 ice orbit of 3 day repeat and 128.2° phase) along the Canadian East Coast. This requirement is consistent with other Labrador Sea ice-related ERS-1 programs. Signal data from specific scenes will be required for SAR processing experiments (about 5 scenes will be specified based upon content as judged by the airborne SAR data and ERS-1 SAR quick-delivery products). Wave mode data (interleaved scatterometer and SAR) along the pass leading up to the main SAR acquisition region and along adjacent passes is desirable. 3 scenes every 3 days for 3 weeks = 21 scenes (descending)

Facilities to be Deployed:
CSS Baffin to deploy, monitor and recover equipment over a three week period in March 1992 (as a part of the LIMEX III program). Possible participation of a second ship. Instruments include ship-mounted marine radar and TSK altimeter, directional wave buoys, meteorological buoys, wave induced ice motion package, ice beacons with anemometer, wind profiler and ice property measurement equipment.
CCRS Convair 580 with C/X-band SAR.

Anticipated Results:
(1) Improve understanding of SAR ocean wave imaging physics.
(2) Developed ability to use SAR imagery of waves-in-ice to study geophysical problems such as wave attenuation and wave spectral evolution within the marginal ice zone.
(3) Developed ability to use SAR data to validate and test theoretical and model predictions of physical processes within the marginal ice zone.

Milestones/Deliverables:
(1) Waves-in-Ice program data report.
(2) Sets of ocean wave spectra corresponding to each ERS-1 pass over the experiment site as derived from direct wave motion time series measurements (via wave buoy and/or ice motion package) and marine radar as well as image spectra derived from the ERS-1 SAR data and the CV-580 SAR data (if present during the pass).
(3) Papers in the open literature.

Coordinator: PIPOR

UK14-1

INVESTIGATION OF SPATIAL SCALES OF WAVE HEIGHT

Principal Investigator:
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Objectives:
To establish spatial scales in the wave field over the world's oceans.

Experiment Plan:
In order to look at spatial variations along altimeter tracks it is necessary to remove any temporal variation. For periods when ERS-1 is in a short repeat, wave height from repeat tracks will be averaged in time; the longest period over which the averaging can safely be done is about a month so orbit periods longer than about 6 days will be unsuitable for this method since an average of at least 5 passes is needed to reduce temporal variation. Longer repeat periods will make analysis much more difficult as short term temporal variability will be confounded with the seasonal variation in the spatial scales. If it is not possible to model the seasonal effects and hence remove the short term variations, only the short repeat period data will be analysed. Given the present orbit scenario, information on spatial scales of wave height will only be available during the N. Hemisphere winter and one other season depending upon the date of the launch.
Once the temporal variability has been removed the next problem is to decide over what regions the wave field can be considered spatially stationary, and then to quantify the variation by means of autocorrelation functions or some equivalent measure.

ERS-1 Data Requirements:
All the altimeter geophysical data for repeat periods of less than 10 days. For longer repeat periods, just for the Atlantic.

Anticipated Results:
Autocorrelation functions (or their equivalent)) for areas of the ocean that can be considered stationary. Maps of these areas will also be produced.

Milestones/Deliverables:
Report on spatial scales of waveheight over the world's oceans.

Coordinator: Srokosz

UK14-2

WAVE CLIMATE STUDIES

Principal Investigator:

D.J.T.Carter Institute of Oceanographic Sciences, Broad Road, Wormley, Godalming, Surrey, UK

Objectives:

(1) Investigate variations in significant wave height (Hs) worldwide on time scales of months to years.
(2) Begin to build up a wave climatology to determine long-term trends in global wave heights.
(3) Determine whether these variations can be related to wind speed.

Experiment Plan:

(1) Before the launch of ERS-1, procedures will be developed to perform routine checks on the radar altimeter (1 sec) estimates of Hs and sigma nought. Also, it is hoped to select an algorithm to estimate surface wind speed from sigma-nought.
(2) The altimeter values of Hs will be used to estimate monthly mean values of Hs over the world's oceans. Different spatial scales will be examined.
(3) Variation of Hs within a year will be investigated by fitting a model with annual and semi-annual cycles to the monthly means.
(4) As several years' data becomes available, the inter-annual variability will be determined from differences in the above model parameter values. Comparisons will also be made with the Geosat data.
(5) Overall global variability will be investigated by calculating the total global wave energy, from estimates of Hs.
(6) If altimeter winds prove to be satisfactory a similar analysis of surface wind speed will be carried out, and relationships between mean Hs and wind speed will be investigated.

ERS-1 Data Requirements:

All radar altimeter level 2 data.

Anticipated Results:

The analysis will give values, more accurately than any previously obtainable, of the global annual mean Hs and the magnitudes and significance of the annual and semi-annual components of Hs. In particular it will establish the significance of the semi-annual component of the Southern Oceans, following the work of van Loon and others. Results should provide a useful test of wave height prediction models.
These analyses, taken together with those from the Geosat data, will form a basis for establishing any long-term trends (over decades) in the climate of wave height throughout the world's oceans.
If a satisfactory relationship can be established between monthly mean Hs and monthly mean wind speed in parts of the world, then this could be used to estimate changes in wave height likely to result from changes in the wind speed climate.

Milestones/Deliverables:

It is intended to produce monthly maps of the global mean Hs values, and possibly sea surface wind speeds from altimeter data.
Papers will be published giving the results data analysis, as outlined above.

Coordinator: Srokosz

UK14-29

RELATIONSHIP BETWEEN SURFACE ROUGHNESS, WIND AND WAVES

Principal Investigator:
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Objectives:
To develop a more realistic physical model of the spectrum of sea surface roughness, which interacts with ERS-1 microwave sensors, using stereoscopic measurements of the surface.

Experiment Plan:
Simultaneous pairs of images of the sea surface will be taken with digital cameras. These images will be analysed automatically to produce contour maps of surface height and hence short wave spectra. Simultaneous measurements of the wind stress will be made (by the dissipation technique) and these will be related to the wave spectrum to produce a better understanding of the relationship between wind stress and the high wavenumber wave spectrum. These experiments will be timed to coincide with overflights of ERS-1. The radar returns will be correlated with the surface measurements to give a better understanding of their relationship to surface conditions.

ERS-1 Data Requirements:
Scatterometer and Altimeter data for overpasses of experimental equipment. Possibly some SAR data.

Facilities to be Deployed:
IOSDL stereo imaging system comprising a pair of Videk Megaplus digital cameras and computer equipment to capture the images.
Multimet meteorological package including fast response anemometer for measurements of wind stress.

Anticipated Results:
Improved understanding of the relationship between wind stress, wave spectrum and radar return. Hence better algorithms can be developed.

Milestones/Deliverables:
IOS report detailing conclusions.

Coordinator: Srokosz

UK14-30

NON-LINEAR WAVE PARAMETERS AND SEA-STATE BIAS

Principal Investigator:

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Tel: 703 766184 Fax: 703 767507

Objectives:

To examine the feasibility of extracting wave parameters other than significant waveheight, such as wave period, skewness and cross-skewness, from ERS-1 altimeter waveform data and to provide improved estimates of sea-state bias in the altimeter height measurements.

Experiment Plan:

The 20 Hz waveform data from the ERS-1 altimeter will be analysed using a Maximum Likelihood Estimator algorithm. Estimates of non-linear wave parameters will be made and the sea-state bias (of the altimeter height measurement) will be calculated. An atttempt will be made to relate the geographical distributions of the non-linear parameters to the position and intensity of storms that generate waves. For comparison sea-state bias will also be deduced using an empirical technique, which relies on the analysis of repeat track data to look at the relationship between residual height (i.e the height after removal of the mean) and significant waveheight. Particular attention will be paid to occasions when the changes in parameters occur on very short space scales, which minimises the effects of orbit error. Comparisons of the wave parameters estimated from the waveform data will also be made with those estimated using stereo-photographic techniques (see UK14-29).

ERS-1 Data Requirements:

Altimeter waveform data (20Hz) and GDRs (1Hz) over specified regions (Venice tower, during the commissioning phase; NE Atlantic and Southern Ocean subsequently).

Facilities to be Deployed:

Stereo-photographic equipment and analysis facilities, and a ship for deployment.

Anticipated Results:

The confirmation (or otherwise) of the ability to extract wave parameters, in addition to significant waveheight, from radar altimeter waveform data, and the development of appropriate algorithms for this purpose.
An improved method for correcting altimeter height measurements for the effects of sea-state bias.

Milestones/Deliverables:

Algorithms for the extraction of non-linear wave parameters from ERS-1 altimeter waveform data and for the correction of sea-state bias.

Coordinator: Srokosz

UK14-36

INVESTIGATION OF THE RELATIONSHIP BETWEEN REMOTELY SENSED OCEAN SURFACE FEATURES AND OCEANOGRAPHIC STRUCTURE

Principal Investigator:
J.C.Scott/G.E.Keyte — Ocean Science Division, Admiralty Research Establishment, Portland, Dorset DT5 2JS/ Space Department, Royal Aircraft Establishment, Farnborough, Hampshire GU14 6TD, UK

Objectives:
The proposal aims to investigate the relationship between SAR images of deep ocean features such as fronts, eddies and internal waves, and the detailed sub-surface structure of these features. In-water measurements will be made using a 400m thermistor chain, with a range of complementary measurements. Aircraft will carry additional radar and infra-red imaging equipment, for relating to the satellite measurements.

Experiment Plan:
It is planned to have at least one oceanographic ship located in a frontal region which will be imaged frequently (i.e. every 3 days), over a period of at least 28 days. The region chosen, between Iceland and the Faeroes, is known to be abundant in frontal structures, being in the zone where the warm high-salinity northwards-moving Atlantic waters encounter colder deeper fresher water of Norwegian Sea origin as it escapes southwards over the Iceland-Scotland system of ridges.
The period of survey needs to be at least 28 days to be reasonably sure of a wide range of changes in meteorological conditions, as well as significant changes in water structure. The measurements planned aim to define in detail the thermal structure of major boundaries, as well as that of any secondary features such as boundary meanders and eddies. The ocean currents related to these structures will also be measured, both with fixed current meter moorings and with on-board acoustic Doppler current profiler.

ERS-1 Data Requirements:
SAR data. The progress of the investigation may be enhanced by use of UK data acquisition facities (at RAE West Freugh) and the UK Earth Observation Data Centre at Farnborough. Use of these facilities will enable ERS-1 data to be processed and examined rapidly, with the consequence that the oceanographic ship could be re-directed to obtain measurements in specific locations where significant features have been observed on SAR or ATSR images.

Facilities to be Deployed:
Survey ship with thermistor chain (with temperature, pressure and conductivity sensors along its 400m length), acoustic doppler current profiler, bathythermograph (XBT) probes, wave buoys, current meters and accurate positioning system.

Coordinator: Srokosz

US1-5c

APPLICATION OF SAR DERIVED OCEANIC SURFACE WAVES TO OPERATIONAL FORECASTING IN ALASKA

Principal Investigator:
G.L.Hufford National Weather Service, Box 23, 222 W 7th Ave., Anchorage, Alaska 99513

Objectives:
The National Weather Service has a requirement to forecast oceanic surface waves in Alaska waters. Use of SAR data is to improve accuracy of wave forecast in high seas and to use oceanic wave data in coastal wave model for nearshore forecasts.

Experiment Plan:
Identification of wavelengths; FFT to utilisable format; input to wave model.
Dissemination of data in National Weather Service marine forecasts for Alaskan waters.

ERS-1 Data Requirements:
Near real-time images over the Gulf of Alaska and the Bering Sea.

Anticipated Results:
Direct improvement in wave forecasts for waters of the Gulf of Alaska and Bering Sea, resulting in increased safety to mariners, especially commercial fishermen.

Milestones/Deliverables:

April 1991	Development of algorithms.
July 1991	Utilisation of SAR data in forecasts.
April 1992	Verification of SAR derived waves to forecasts.

Coordinator: Weller

US3-3

CALCULATION OF OCEAN WAVE AND WIND STRESS DISTRIBUTIONS

Principal Investigator:
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Co-Investigators:
Donelan/ Graber/ Pierson (JPL)

Objectives:

(1) Determining the sensitivity of wave prediction models to errors in the wind forcing.
(2) Explore the influence of non-local gravity waves on the wind stress distribution.
(3) Improve surface wind velocity estimates from the ERS-1 scatterometer by using forecasted waves and allowing for long-wave/short-wave interactions and spatially varying winds in calculating wind velocity from observed backscatter cross-sections.

Experiment Plan:

The effects of long waves both on the speed/stress and on the backscatter/stress relationships will be examined through iterative assimilation of ERS-1 scatterometer winds into wave prediction models. These wave prediction models will be refined and tested, first with simulated data and then with actual wind measurements from ERS-1. The model of Donelan (1977) will be extended to include non-local swell and adapted for use in the North Atlantic; the parametric model of Graber (1984), which includes the effects of bottom topography will also be used, as will an update version of the existing U.S. NMC global wave prediction model. Since locally generated wave energy is schematically proportional to the fourth power of wind speed, small errors in ERS-1 winds will be amplified as errors in predicted wave fields. Model errors will be quantified by comparisons with wave heights measured from the ERS-1 altimeter (and from other altimeters that may be flying such as Geosat and Topex/Poseidon), directional spectra from the ERs-1 SAR wind/wave mode, and from operational coastal and ocean buoys in the North Atlantic and Pacific Oceans. Iterative techniques will then be used to adjust the backscatter/stress and wind/strss relationships embodied in the ERS-1 scatterometer model function and the wave generation models, respectively, in order to bring model predictions into agreement with data.

ERS-1 Data Requirements:

Requirement for US3-1 - US3-8.

Full misssion WSC (UWI, IWI), ALT (URA) and available ATSR/M data globally over the ocean. Minimum requirement is for 1 year of data.

All available SWM (UWA) data obtained in the North Atlantic and over the Antarctic Circumpolar Current south of 40°S for the full mission. Minimum requirement is selected SWM data obtained in the North Atlantic over a period of 6 months.

Anticipated Results:

(1) Improved knowledge in the relationship between backscatter and wind stress (the basis for scatterometry), and hence an improved C-band model incorporating the effects of long surface waves.
(2) Improved understanding of the modifications to surface stress caused by long waves that are not in equilibrium with the wind, and hence in improved bulk parameterisations of the wind speed/wind stress relationship.
(3) Refined and improved regional and basin-scale wave prediction models.

Coordinator: Freilich

US8-2c

ERS-1/SIR-C INTERCOMPARISONS: SPATIAL EVOLUTION OF OCEAN WAVE SPECTRA

Principal Investigator:
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Co-Investigators:
D.Tilley (APL), F.Jackson/E.Walsh (NASA), R.K.Raney/ J.Chilar/ A.L.Gray/ R.Hawkins/ G.E.Livingstone/ M.C.Mouchot (CCRS), J.F.R. Gower (IOS), C.Mason (BIO), R.Keeley (MEDS), N.Freeman (DFO)

Objectives:
(1) To determine the ability of spaceborne SAR (both ERS-1 and SIR-C) to track the spatial evolution of ocean wave spectra in regions where substantial and abrupt changes in the spectrum might be caused by current shear boundaries and bathymetric effects. These coastal regions are difficult to model, and often present serious marine hazards in the form of extreme waves.
(2) To gather SAR imagery and in situ ocean surface measurements in support of gaining a detailed understanding of SAR imaging physics for a variety of ocean surface conditions and SAR geometries, using SIR C/X-SAR and ERS-1 spaceborne SAR data, coincident airborne SAR underflights and in situ ocean measurements.

Experiment Plan:
(1) The primary geographic region of interest will be the western North Atlantic. The ideal sets of satellite passes will travel normal to the Shelf break (ascending for ERS-1; descending for SIR-C), passing through deep water, the Gulf Stream, and across the Continental Shelf. Reference spectra from either the NASA Surface Contour Radar (SCR) or the Radar Ocean Wave Spectrometer (ROWS) will serve as primary standards of comparison.
(2) The second study will take place at two sites, depending upon the time of the year of the SIR-C/X-SAR flight. The first site corresponds to a nominally winter SIR-C/X-SAR flight, and is centred on the edge of the marginal ice zone off the coast of Newfoundland. The second site corresponds to a nominally summer SIR-C/X-SAR flight, and is off the west coast of Vancouver Island near the entrance of Juan de Fuca Strait.

Facilities to be Deployed:
(1) SIR-C SAR, set of descending passes, currently scheduled for June 1993.
(2) BIO and IOS will deploy directional wave buoys at the Newfoundland and Juan de Fuca Straits sites, respectively. CCRS will provide overflights with the CV-580 C/X-band SARs. In the case of the east coast site, ice motion sensing buoys will be placed on the ice. At both sites conductivity-temperature-depth (CTD) surveys will be carried out across the study area to assess the probability of observing mesoscale oceanic structures.

Anticipated Results:
(1) Global monitoring of the spatially evolving wave spectrum will be vital to update and validate operational wave forecast models in the 1990's. In addition, for this particular experiment, such estimates of the directional spectrum in the vicinity of the Gulf Stream potentially can yield quantitative estimates of the position and velocity of the Stream, wave energy enhancement due to the stream, and the migration of the spectral peak across the Continental Shelf, which can be related to energy dissipation. Also, improved understanding of the nature of the SAR ocean wave modulation transfer function (MTF) as a result of detailed spectral intercomparisons from both satellite platforms over a range of environmental conditions.
(2) The major conclusions to be derived from this multi-sensor data set will be an improved understanding of SAR ocean surface wave imaging physics, and consequently improved algorithms for the reduction of raw SAR wave imagery into reliable waveheight spectra. In addition, optimal SAR geometries and processing schemes for the observation of internal waves, mesoscale features, wind signatures and hard targets in sea clutter will be established.

Milestones/Deliverables:

Dec 1990	Draft experiment plan.
12 months	Preliminary report 12 months after receipt of data.
24 months	Final report or open literature manuscript.

Coordinator: Freeman

AUS6-10

MAPPING OF SUB-SURFACE FEATURES

Principal Investigator:
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Objectives:
The aim of the project is to locate seamount positions in the ocean areas around Australia, in particular those locations of possible interest to the Australian fishing industry.
Our present knowledge of Southern Ocean bathymetry, and in particular of seamount locations and characteristics, is based almost entirely upon sporadic ship surveys. It is likely that a significant number of uncharted or mislocated seamounts exist throughout the area. The use of radar altimeter (RA) data is a most effective means of locating such bathymetric features given a sufficient groundtrack coverage.

Experiment Plan:
The region of the Southern Ocean to be studied is bounded by latitudes 10°S and 50°S and longitudes 100°E and 160°E. The uncharted "altimeter-defined" anomalies, considered promising for fisheries, resource development, will be verified by ship cruises. Improvements will be made to the algorithms for seamount anomaly detection during the project.
RA data from the 35 day repeat cycle (and any other longer repeat cycle) will be most suitable for seamount location. The first year of RA data will be processed through a standard crossover analysis package to form a mean sea surface model. This model will be combined with previous results from other altimeter missions. Individual altimeter profiles will then be high-pass filtered to provide short wavelength geoid anomalies. The geoid anomalies will be correlated with existing bathymetric data within the wavelength band of 40-400km to map the sub-surface features.

ERS-1 Data Requirements:
ERS-1 RA data (after orbit processing) for the area 10° - 50°S, 100° - 160°E; from launch to the end of the first 35 day repeat cycle; additional RA data from any longer period (eg. 176) repeat cycle.

Facilities for Data Analysis:
Altimeter preprocessing and analysis software.

Anticipated Results:
In broad terms, the results of the project will be:
(1) Detailed bathymetric validation and improvement.
(2) Identification of possible commercially viable fisheries resources. Success is difficult to assess in terms of fisheries potential, but certainly the detection of possible mislocated/uncharted features has been demonstrated in the Great Barrier Reef area (Coleman, 1985, unpublished data for the Department of Fisheries).

Milestones/Deliverables:

1990-91	Software enhancement and preliminary data processing
1991-92	RA analysis and sub-surface feature mapping
1993	Investigation of uncharted features

Coordinator: Nilsson

I1

MODELLING OF MICROWAVE INTERACTION WITH SEA SURFACE AND ATMOSPHERE: INTERPRETATION OF SAR IMAGES OF SELECTED SITES OFF ITALIAN COASTS

Principal Investigator:
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Co-Investigators:
B.Fiscella/ G.D'Auria/ E.Salusti (as above)

Objectives:

(1) Methodological study of ERS-1 images of Italian seas.
(2) Microwave interaction with sea surface and atmosphere.
(3) Interpretation of physical marine phenomena related to straits and coasts.
(4) Study of SAR echo intensity behaviour against the presence of slicks over the sea.

Experiment Plan:

Test site: Vesima (44°24'30"N, 8°42'15"E).
Planned for 4 times a year:
(1) Sea truth measurements.
(2) Measurements of sea echoes with a 3-band (L, S and C) radar.
(3) Spilling of a surfactant for coverage on SAR swath.

ERS-1 Data Requirements:

SAR precision images for the Mediterranean Sea between latitudes 36°30'N and 44°30'N, which include the Vesima site.
Once during the Commissioning phase, preferably in April.
Every 3 months during the 35-day cycle.
Altimeter and scatterometer data will be obtained from another PI studying the Mediterranean.

Coordinator: Frasseto

INT8-7

ALTIMETRY AND GEOPHYSICS IN THE BARENTS AND ADJACENT SEAS

Principal Investigator:
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Co-Investigators:
D.MacAyeal (Dept. of Geophysical Sciences, University of Chicago), L.Greischar (Meteorology and Space Sciences, University of Wisconsin-Madison)

Objectives:
To measure and map the height of the marine geoid with respect to the ellipsoid throughout the Barents Sea, compute and map the associated gravity anomaly field, and analyse the results. The scientific objective is to employ the regional distribution of geoid distortion and the gravity-anomaly field as a means of addressing the problem of whether extensive grounded ice sheets existed in the Barents and adjacent seas during the Last Glacial Maximum (LGM) about 18,000 years BP. If so, isostatic imbalance should be an observable effect of past deglaciation, which would have caused continuing viscous flow within the earth's mantle and associated distortion of the gravitational potential field.

Experiment Plan:
(1) Incorporation of new ERS-1 data with available gravity data.
(2) Mapping of the data onto regular grids using optimum interpolation methods.
(3) Decomposition of the anomaly fields into its Fourier components to identify wavelengths caused by incomplete glacio-isostatic adjustment.
(4) Application of forward and inverse modeling methods to identify the range of past glacial load histories compatible with the data.
The main areas of interest are the Barents and Kara Seas (68-82°N, 10-70°E), and the Chukchi, East Siberian and Laptev Seas (66-78°N, 160°W to 112°E).

ERS-1 Data Requirements:
Radar altimeter data backscattered from open water throughout the above regions are needed during times of zero or minimal sea ice cover. For the Barents Sea: 12 months per year throughout ERS-1 operation. For the Kara, Chukchi, East Siberian and Laptev Seas: all data during August and September of each year.
Data processed to the equivalent of NASA level 2 and 3 are required.

Coordinator: Thomas

J5-1

IMPROVEMENT OF MARINE GEOID

Principal Investigator:
Y Ganeko — Satellite Geodesy Office, Geodesy and Geophysics Division, Hydrographic Department, Maritime Safety Agency, Japan

Objectives:
The objective is to obtain an improved detailed marine geoid in the Pacific region using ERS-1 Altimeter data. The improved geoid will be of use for understanding the gravitational field in the area, which can be used to investigate sea bottom structure, sub-bottom structure, and structure of the lithosphere. The geoid surface can be the reference surface of the sea surface topography, and to contribute much to ocean dynamics.

Experiment Plan:
Terrestrial gravity data will be combined with the Altimeter data to study the detailed structure of the geoid. The three dimensional deodetic coordinates of oceanic islands obtained by SLR observations will be used as the control points of the geoid.
Since the precise orbit determination of ERS-1 and the calibration of the Altimeter data are very important, the SLR stations of the Hydrographic Department will observe ERS-1, and the SLR data will be supplied to the facility responsible for the ERS-1 orbit determination. The SLR data will be used for the calibration of the Altimeter in conjunction with ocean tide and oceanographic data.

ERS-1 Data Requirements:
Altimeter data acquired using 35 day and 176 day repeat cycles.

Facilities to be Deployed:
Fixed and mobile SLR stations of JHD which are currently employed for geodetic purposes.
Ocean tide stations which are operating continuously on the coasts of the mainland and islands of Japan.
Survey vessels will make cruises to obtain oceanographic data for taking surface truth.

Milestones/Deliverables:

Pre-launch	Recalculation of detailed geoid using surface gravity data.
Post launch	SLR observations.
	Survey vessels will make cruises to obtain oceanographic data throughout the lifetime of ERS-1.

Coordinator: Fujita

NL11

APPLICATION OF ERS-1 RADAR ALTIMETER MEASUREMENTS TO GLOBAL PRECISE ORBIT COMPUTATIONS, AND SEA SURFACE MODELLING AND OCEAN CURRENT DETECTION IN THE ATLANTIC, WEST PACIFIC AND ANTARCTIC

Principal Investigator:
K.F.Wakker Faculty of Aerospace Engineering, Delft University of Technology, The Netherlands.

Co-Investigators:
B.A.C.Ambrosius/ M.W.A.van der Kooij/ M.C.Naeije/ R.Scharroo/ P.N.A.M.Visser (as above), R.Rummel/ R.H.N.Haagmans/ D.Oskam/ E.J.O.Schrama (Faculty of Geodesy, Delft University of Technology), W.P.M. de Ruijter (Institute of Meteorology and Oceanography, Utrecht University), E.Vermaat (Observatory for Satellite Geodesy, Delft University of Technology), J.T.F.Zimmerman (Netherlands Institute for Sea Research), J.W. van der Made (Tidal Waters Division, Rijkswaterstaat)

Objectives:
This Dutch altimetry investigation forms part of a long-term research programme that aims at the application of ERS-1 and TOPEX/POSEIDON altimeter data for a variety of orbit mechanics, geodetic, geophysical and oceanographic purposes.

Experiment Plan:
(1) Regular tracking of ERS-1 by the Dutch MTLRS-2 mobile laser system, preprocessing and the data distribution.
(2) Regular tracking of ERS-1 by the Dutch PRARE system.
(3) Analysis of the tracking performance of all global laser and PRARE systems involved in the ERS-1 mission.
(4) Computation of precise orbits from the laser, PRARE and altimeter measurements.
(5) Comparison of orbits computed at Delft University and other institutes from different sets of tracking data.
(6) Development of tailored gravity model(s) from the laser, PRARE and altimeter measurements.
(7) Dedicated altimeter calibration tracking campaign at Venice using the Dutch MTLRS-2 mobile laser and possibly the Dutch PRARE system.
(8) Computation of extremely precise short-arc orbits over the Venice region and the analysis of tracking, altimeter and local geophysical data for calibration purposes.
(9) Analysis of the altimeter height and cross-over difference residuals of the reference orbits, and the separation of geoid and orbit errors.
(10) Computation of dense sets of all cross-over differences over selected areas from ascending and descending tracks of ERS-1, GEOSAT and TOPEX/POSEIDON.
(11) Computation of mean sea surface models for these selected areas and the determination of sea surface variability.
(12) Comparison of these models with detailed available geoid, bathymetry and marine gravity-anomaly data sets.
(13) Analysis of the optimal combination of altimeter measurements over the oceans with geodetic measurements over the continental geoid.
(14) Application of the altimeter data to check and improve existing tidal models for selected areas.
(15) Computation of the dynamic ocean surface topography in selected areas, and the measurement of mesoscale dynamic sea surface features.
(16) Determination of the semi-permanent global ocean circulation.

ERS-1 Data Requirements:
(1) Global PRARE range and range-rate tracking data and ESOC S-bamnd range-rate tracking data.
(2) Operational ERS-1 orbits as computed by ESOC.
(3) Precise ERS-1 orbits included on the ERS-1 altimeter Geophysical Data Record (GDR).
(4) All global fully-preprocessed altimeter measurements over seas and oceans in a well-defined GDR format.
(5) The full altimeter dataset for the Venice calibration experiment.

Milestones/Deliverables: The status of the research project and preliminary results will be presented at progress meetings, workshops, etc. organised by ESA, and at relevant scientific congresses, symposia, etc. The team will publish results in appropriate journals and will also contribute to ESA publications dealing with the results of the ERS-1 mission.

Coordinator: Minster

UK14-22

ANALYSIS AND INTERPRETATION OF SURFACE ROUGHNESS FEATURES IN SHALLOW SEA SAR IMAGES

Principal Investigator:
I.S.Robinson — Department of Oceanography, The University, Southampton SO9 5NH
Tel: 0703 593438 Fax: 0703 593939

Objectives:
(1) To measure the dependence of the radar backscatter cross-section on the short wavelength sea surface roughness.
(2) To investigate the capability of SAR images to reveal subsurface dynamical processes and to map shallow sea bathymetry.

Experiment Plan:
Pre Launch
Techniques are being developed to measure the sea surface roughness using a laser slopemeter, and using an enhanced sensitivity marine radar. Digitally processed Seasat SAR images of UL waters will be surveyed and analysed to catalogue bathymetric and dynamical features, and to identify the conditions necessary for imaging of these features to occur.
Post Launch
Initially, a survey will be made of the first UK coastal SAR images from ERS-1 to identify test sites. Repeat images of a few select sites will be analysed in detail. At these selected sites, field measurements will relate surface roughness to the flow field associated with bathymetry and dynamical processes, and with SAR images when coincident with the *in situ* data.

ERS-1 Data Requirements:
DIgitally processed SAR data:
(1) General coverage of all UK waters.
(2) Regular coverage of specific sites: Solent(50°30'-51°30'N, 0°30'-3°0'E), Dover Straits(50°30'-51°30'N, 0°30'-3°0'E), Norfolk/Suffolk Banks (51°30'-53°0'N, 1°0'-2°20'E).
(3) Pre-planned coverage of selected sites within the areas defined above to enable coincident fieldwork to be planned, during years 2 and 3 after launch.

Facilities to be Deployed:
Departmentally provided ship time in Solent and Dover Straits, with current meters, marine imaging radar and laser slopemeter.

Anticipated Results:
Definition of the conditions required for SAR imaging of bathymetry and shallow sea features. Specification of the accuracy of dynamical or bathymetric information which can be recovered from SAR images. Elucidation of the SAR ocean imaging mechanisms.

Coordinator: Srokosz

UK14-33

EAST ANGLIAN BATHYMETRY

Principal Investigator:

B.D'Olier/N.Lynn Thames Polytechnic, London/ Royal Naval College, Greenwich, London.

Objectives:

To use ERS-1 sensors, particularly SAR but also the Altimeter and ATSR, to evaluate and assess the their performance as oceanographic tools. This will concentrate on an assesment of the possibility for measuring bathymetry from SAR images, discovering the vertical and horizontal measuremnts of the various elements that constitute the bottom topography, and seeking to specify the wind, tide and wave parameters which control the detection of such features. These features will include: coastal and offshore sandbanks; sandwaves; sandwave megaripples; wide, wave dominated sand fields and related sandribbons; bedrock features including varying bedrock type and roughness, buried channels and large wrecks.
In the case of the various sand features, mobility and its potential for measurement are of prime importance, whilst with the other features, it is the initial identification and conditions of resolution which are of most importance.

Experiment Plan:

To measure wave, tide, wind, water, temperature, salinity and bathymetric parameters simultaneously with ERS-1 overflights and to compare the repeat coverage. This will enable areas of mobility to be identified and resurveyed at a later stage during further overflights.

ERS-1 Data Requirements:

SAR images. All data covering the site of investigation which coincides with data gathering activities, plus some additional images.

Facilities to be Deployed:

Survey ship with side-scan sonar, direct reading current meters, salinity-temperature bridges, wave buoys, tide guages and accurate postion fixing equipment.

Anticipated Results:

Useful information pertaining to the oceanographic parameters which are able to be detected by SAR, and to the rates, volumes and direction of sand transport features are expected.

Coordinator: Srokosz

AUS6-1

THE FLOW AND STRUCTURE OF THE EAST AUSTRALIAN CURRENT

Principal Investigator:
C.S.Nilsson — CSIRO Division of Oceanography, G.P.O. Box 1538, Hobart, Tasmania, 7001, Australia
Tel: 61 02 206244 Fax: 61 02 240530

Co-Investigators:
G.R.Cresswell (as above)

Objectives:
To observe repeatedly the East Australian Current (EAC) and its warm-core eddies with SAR and near-simultaneous NOAA AVHRR and ship studies in order to improve both interpretation of ocean SAR data and understanding of the EAC.

Experiment Plan:
The R.V. Franklin will be deployed for one cruise of at least twelve days during the commissioning phase of ERS-1 off the N.S.W. coast near 32°30'S, 152°40'E. The three day repeat cycle is needed to obtain a number of passes over one area of the EAC during one cruise under different weather conditions. The specialised instruments aboard R.V. Franklin will be used to measure large and small scale motions to relate to the SAR data. NOAA AVHRR sea surface temperature images and FDP SAR will be sent to the ship in near real-time to enable most appropriate surface truth data to be obtained. During most of the lifetime of ERS-1 SAR, the EAC will be monitored and SAR data compared with NOAA AVHRR and data from ships of opportunity.

ERS-1 Data Requirements:
Essential
During commissioning phase over two weeks of ship cruise, a two-minute SAR transmission on ascending orbit over Eastern Australia every three days. During 35 day repeat cycle period for twelve months, two descending and one ascending two-minute passes overEAC area per cycle (Total SAR 70 min per year). Priority coverage during SIR-C flight.
Desirable
Extension of above for second year. Increased SAR coverage for whole or part of year to three descending and two ascending passes per 35 day cycle. Access to all appropriate LBR data.

Facilities to be Deployed:
(1) NOAA AVHRR satellite receiving and image processing facilities at CSIRO Marine Labs. in Hobart
(2) R.V. Franklin oceanographic research vessel with normal complement instrumentation plus acoustic doppler current profiler and GPS navigation giving real-time readi-out of absolute currents to 200m depth
(3) ERS-1 HBR receiver and FDP at Alice Springs

Anticipated Results:
Much improved knowledge of oceanographic interpretation of SAR data regarding mapping of currents and fronts under varying wind and wave conditions. This knowledge is needed before SAR can be used to study the much more inaccessible ocean regions such as the Antarctic Circumpolar Current (ACC). The operational value of SAR in determining the flow pattern of major current system such as the EAC during periods of prolonged cloud cover will also be demonstrated.

Milestones/Deliverables:

1991	Conduct first cruise and initial analysis of ship and SAR data.
1992 - 93	Conduct second cruise and analyse first year of SAR data. Demonstrate operational use of SAR for monitoring currents. Complement SIR-C. Apply results to study of ACC.
1993 - 94	Publish results.

Coordinator: Nilsson

AUS6-2

MESOSCALE STRUCTURE IN THE SOUTHERN OCEAN

Principal Investigator:

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Tel: 61 02 206244 Fax: 61 02 240530

Co-Investigators:

E.Lindstrom (as above)

Objectives:

To observe repeatedly the Antarctic Circumpolar Current (ACC) and its eddies with SAR and near-simultaneous NOAA AVHRR and ship transects to determine the scales, frequencies and intensities of these eddies. To estimate the eddy hear flux in the region 50° - 60°S, 140° - 170°E.

Experiment Plan:

Maximum Value Composite NOAA AVHRR sea surface temperature data will be used to attempt to monitor eddy formation and evolution in the ACC region and to relate these data to SAR image data. Because of persistent cloud cover in this region, NOAA data alone will not be sufficient. Coverage by ERS-1 SAR will be regular, albeit sparse, and both sets will be combined to give much better monitoring. Improved knowledge of the interpretation of oceanic current boundaries from experiment Aus6-1 will be incorporated into the analysis. Ship transect data from the companion experiment Aus6-3 will also be combined with timely image data around 140°E to improve the analysis of both. Coleman et al. (Experiment Aus6-11) will use radar altimeter data in conjunction with Aus6-1, 6-2 and 6-3.

ERS-1 Data Requirements:

Essential

For two spaced 70 day periods: during each 35-day cycle, five ascending and five descending three-minute passes (120 min over five months). For remainder of year, two ascending and two descending three-minute passes per cycle (78 min over seven months). Access to all appropriate LBR data.

*Desirable*As above for first year, ie 200 min SAR data; for second year: 30 min SAR data per 35 day cycle for 12 months (300 min per year).

Facilities to be Deployed:

(1) NOAA AVHRR satellite receiving and image processing facilities at CSIRO Marine Labs. in Hobart.
(2) R.V. Franklin oceanographic research vessel with normal complement instrumentation plus acoustic doppler current profiler and GPS navigation giving real-time read-out of absolute currents to 200m depth.
(3) The experiment is dependant on the establishment of a Tasmanian Earth Resources Satellite Station (TERSS) being set up at Hobart.

Anticipated Results:

The experiment will provide much better knowledge of what SAR does and does not show in the Southern Ocan, in particular: the apparent scales and frequencies of eddies south of Australia and how these measures relate to altimeter spectra; the ability of SAR to track the Antarctic Circumpolar Current; the usefulness of combined SAR and thermal AVHRR in these latitudes. The SAR data will improve estimates of the eddy hear flux into Antarctic waters.

Milestones/Deliverables:

12/1991	Hydrographic section No. 2 along 140°E south of Australia completed (as for Aus6-3). Initial analysis of Southern Ocean SAR data. Review of data requirements for 1992
12/1992	Hydrographic section No. 3 along 140°E south of Australia completed (as for Aus6-3). Analysis of data continues. Review of data requirements for 1993.
1993 - 94	Collaboration with those making altimeter studies of Southern Ocean region. Final analysis of 1991-92 SAR data. Publication of results.

Coordinator: Nilsson

AUS6-3

MERIDIONAL STRUCTURE IN THE SOUTHERN OCEAN

Principal Investigator:

E.Lindstrom CSIRO Division of Oceanography, G.P.O. Box 1538, Hobart, Tasmania, 7001, Australia
Tel: 61 02 206222

Co-Investigators:

C.Nilsson (as above)

Objectives:

This project supports an Australian contribution to the World Ocean Circulation Experiment (WOCE). The principal aim of the WOCE projects will be to estimate the mass transport and heat flux of the Antarctic Circumpolar Current (ACC) south of Tasmania.

Experiment Plan:

The plan for this project is that during the quinquennial 1990-95 an annual hydrographic section will be occupied along approximately 140E from Tasmania. During the middle of this period (1991-94) time series of velocity, pressure, temperature, and salinity will also be obtained using arrays of moored instrumentation. Altimetric measurements from ERS-1 will contribute to the plan by providing a time series of sea surface height that can be combined with various pressure measurements to estimate ACC transport.

ERS-1 Data Requirements:

Essential
Altimetry data in the region from 30S-67S and from 110E-170E
Desirable
SAR data alaong between Tasmania and Antarctica 40S-67S, 130E-50E

Facilities to be Deployed:

The program will collect a comprehensive set of hydrographic measurements across the entire Southern Ocean from Australia to Antarctica and, in cooperation with USA WOCE investigators, proposals will be submitted to deploy instrumentation for time series measurements of velocity, pressure, temperature, and salinity along one transect. The primary focus of resources would be along a single section between Tasmania and Antarctica.

Anticipated Results:

An estimate of the transport and heat flux of the Antarctic Circumpolar Current south of Australia.

Milestones/Deliverables:

Nov 1991	Bottom pressure gauge deployment at Tasmania and Antarctica
Nov 1992	Service pressure gauges: Deploy T/S, current meter moorings: Deploy moorings for measurement of electric field in ACC region.
Nov 1993	Service pressure gauges
Nov 1994	Recover pressure gauges: Recover T/S, current meter moorings: Recover E/M moorings

Coordinator: Nilsson

AUS6-5

HEAT FLUXES IN THE SOUTH PACIFIC AND INDIAN OCEANS

Principal Investigator:
J.S.Godfrey CSIRO Division of Oceanography, G.P.O. Box 1538, Hobart, Tasmania, 7001, Australia

Co-Investigators:
M.Nunez (as above), G.Meyers (Geography Department, University of Tasmania, Hobart)

Objectives:
Test if ERS-1 data can be used for a heat budget study of the surface layer in the seas north of Australia, by comparison to in situ data.

Experiment Plan:
It is planned to use in situ methods of measuring hear storage in the ocean under auspices of TOGA, and to evaluate how much of the variability is caused by surface heat fluxes estimated from operational weather products (ECMWF) and satellite data (GMS). The heat storage data are provided by expendable bathythermographs from ships of opportunity. ERS-1 data, converted to gridded fields of wind, SST, surface humidity and sea level will be used to provide an independent set of purely satellite-based fluxes and estimates of the mixed layer heat storage.

ERS-1 Data Requirements:
Gridded fields of sea surface temperature, surface humidity, wind and sea level.

Facilities to be Deployed:
Australian research vessel "R/V Franklin" for directly measured radiative fluxes; possibly some short duration direct measurements of turbulent fluxes.

Anticipated Results:
Comparisons of ERS-1 products with in situ data and with the "hybrid" ECMWF and GMS estimates of fluxes.

Milestones/Deliverables:

1990 - 91	Analysis of the heat budget using TOGA XBT's, ECMWF and GMS products.
1991 - 93	Receive first allotments of ERS-1 data, and start comparison of ERS, in situ hybrid products.
1993 - 94	Evaluate heat budget from ERS data for a two-year period.

Coordinator: Nilsson

AUS6-7

OCEANIC SUBDUCTION AND CIRCULATION IN THE INDIAN OCEAN

Principal Investigator:
T.J.McDougall CSIRO Division of Oceanography, G.P.O. Box 1538, Hobart, Tasmania, 7001, Australia

Objectives:
To understand and quantify the rate at which mixed-layer water enters the thermocline of the Indian Ocean, and to deduce the strength of the mean circulation.

Experiment Plan:
Two cruises, separated by two months, will be conducted to map the neutral surfaces in the subtropical Indian Ocean. This will involve towing Bunyip, a vertically undulating device for measuring a range of the water column while underway, and it will also hopefully involve the deployment of some neutrally buoyant floats. An array of CTD stations will be taken so that the mean flows in this region can be deduced by inverse methods. The ERS-1 scatterometer data (or at least the derived wind stress) will be used to determine the vertical Ekman pumping velocity as a function of space and time. These data are required for the whole length of the ERS-1 mission because we need to know the variability of the Ekman pumping within a year and also between different years.

ERS-1 Data Requirements:
Essential
The LBR scatterometer data for the whole Indian Ocean, including the Indian sector of the Southern Ocean. These data are needed for the whole lifetime of ERS-1.
Desirable
The same LBR scatterometer data for the whole South Pacific Ocean, including the Pacific sector of the Southern Ocean. These data are needed for the whole lifetime of ERS-1. This South Pacific data will be used in a comparison study along with the Indian area where the field work will take place.

Facilities to be Deployed:
Research vessel (R.V. Franklin) to conduct oceanographic research in the subtropical Indian Ocean.

Anticipated Results:
An understanding of the relative roles of the wind and buoyancy forcing in ventilating the thermocline in the Indian Ocean, together with an estimate of the mean circulation in the Indian Ocean. For example, it is known in the North Atlantic that the mean circulation transports between two and five times as much water as is deduced from Ekman pumping alone. It is important to determine the extent of this increased recirculation (presumably due to buoyancy forcing) in other oceans.

Milestones/Deliverables:

1990	A trial subduction cruise is approved for November 1990. This will test our ability to make the required oceanographic measurements with Bunyip. This test cruise is actually happening in the south Tasman Sea between Australia and New Zealand.
1991	Begin using the ERS-1 data to make maps of the Ekman pumping velocity each week or so in the Indian and South Pacific Oceans. Analyse the data of the 1990 test cruise.
1992 - 93	Continue the above, and also do the oceanographic field work in the Indian Ocean.
1993 - 94	Analyse the cruise data in conjunction with the scatterometry to determine the rates of renewal of thermocline water and the rate of homogenization of potential vorticity in the Indian Ocean.

Coordinator: Nilsson

AUS6-8

NUMERICAL MODELLING OF CONTINENTAL SHELF CIRCULATION AND OCEAN WAVE SPECTRA

Principal Investigator:
C.B.Fandry — CSIRO Division of Oceanography, G.P.O. Box 1538, Hobart, Tasmania, 7001, Australia
Tel: 61 02 206222

Co-Investigators:
J.R.Hunter/ P.D.Craig/ J.S.Reid (as above)

Objectives:
(1) To predict the wind-driven circulation on Australia's continental shelves using ERS-1 wind fields.
(2) To predict ocean wave spectra at selected sites in Southern Ocean, using ERS-1 windfields and to compare these with wave scatterometer and in situ measured wave data.

Experiment Plan:
The wind-driven circulation in one or several regions of the Australian continental shelf will be modelled using surface winds obtained from ERS-1. The predictions will be compared with measured current meter data, and an assessment will be made as to whether these predictions are more accurate than those using conventional surface wind fields.
A similar plan is envisaged for the prediction of ocean wave spectra. In this case, however, the predictions will be compared with both in situ measured wave buoy data, and wave scatterometer data. Furthermore the ERS-1 wave data will be compared with the wave buoy data as part of a calibration - validation exercise.

ERS-1 Data Requirements:
Accurate (±2ms-1) surface winds with a spatial and temporal resolution of 50km and 3h respectively.
ERS-1 wave scatterometer data for the north west Tasmanian region (off Cape Grim).

Anticipated Results:
(1) An assessment of ocean models for the prediction of wind-driven currents and ocean wave spectra using ERS-1 surface wind data.
(2) Intercomparison of measured ocean wave data at several locations in the Southern Ocean using wave buoys and wave scatterometer data.

Coordinator: Nilsson

AUS6-11

OCEAN CIRCULATION

Principal Investigator:
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Co-Investigators: I.S.F.Jones/ I.R.Young (as above).

Objectives:
Of all of the ocean basins' circulation, that of the Southern Ocean region is the least understood. Most of our knowledge is based on a sparse hydrographic data base, with few direct velocity observations using current meters or drifting buoys. The broad objectives are to better understand the ocean areas surrounding Australia, ie the Indian Ocean, western South Pacific Ocean and the Southern Ocean. More specifically, these are:-
(1) To estimate the time variability (on seasonal and interannual time scales) in the surrounding ocean regions.
(2) To examine the structure and mesoscale variability of the regional circulation features such as the East Australian Current, Tasman Front, West Australian Current and the Leeuwin Current.
(3) To study and map the distribution of eddy kinetic energy within the region.
(4) To study the wave generation due to tropical cyclones and the numerical prediction of the cyclone wind-waves.

Experiment Plan:
One of the principal steps of the project is to develop refined procedures and software to reliably estimate the ocean dynamic information from the RA data. Techniques for obtaining stationary and temporal features of the ocean surface have been extensively documented in the scientific literature. In order to achieve the above oceanographic objectives, improvements and modifications to our existing computer software will be made during the early part of the project. This part of the project will focus on:-
(1) Updating the existing software to take into account an efficient database stream, improved algorithm and modelling developments and problems specific to the Australian study region, such as wide continental shelf regions.
(2) Incorporating techniques to reduce local orbit errors such as the use of tide gauge stations as constraints.
(3) Investigating methods to improve orbit resolution in altimeter analysis, in particular trying to remove the geographically correlated orbit error.
These developments will then allow the final processing of ERS-1 RA data to proceed and the variability of the ocean circulation to be computed with some degree of confidence.
An allied problem to be studied in part of this region is the wave generation due to tropical cyclones and the numerical prediction of the cyclone wind-waves. Procedures and results of studies off the Australian coastline have been given in Young and Sobey (1981, 1985). Some 10-12 tropical cyclones form each year during the summer months in the northern ocean areas off Australia. It is proposed to use the ERS-1 RA and SAR data to develop a predictive capability in the region.

ERS-1 Data Requirements:
Essential
(1) All available Level 2 RA data collected in the region 10°N to 82°S, 20°E to 290°E; RA data from launch to mission end.
(2) AMI wind/wave mode data for a nominated period during the passage of about three (3) tropical cyclones off the northern coastline of Australia (of order 3 one week periods during the summer months - November to March).
(3) ERS-1 SAR images of the same area at the closest possible time period to the AMI wind/wave data collected at (ii).
*Desirable:*Tapes of simulated ERS-1 SAR and LBR products.

Anticipated Results:
(1) Quantitive estimate of the seasonal and interannual variability of the major current systems of the Southern Ocean regions.
(2) Detailed maps of the mesoscale variability and eddy kinetic energy levels.
(3) Better description of the ocean dynamics of the Southern Ocean region, especially in the Australian region leading to improved ocean and weather forecasting.
(4) Improvement in ocean numerical models and forecasting of tropical cyclones.

Milestones/Deliverables:

1990-91	Development and enhancement of altimeter software
1991-93	Processing of data for ocean circulation studies

Coordinator: Nilsson

AUS6-14

NORTH AUSTRALIAN TROPICAL SEAS CIRCULATION STUDY

Principal Investigator:
D.M.Burrage — Australian Institute of Marine Science, PMB No.3, Townsville M.C., Queensland, QLD 4801, Australia

Co-Investigators:
M.Inoue (CSI, LSU)

Objectives:
This is a regional study of geostropic and wind-driven circulation in the coral sea. Seasonal and mesoscale variability will be studied using ERS-1 radar altimetry and scatterometry combined with a reduced gravity numerical model of the wind-driven circulation.
(1) To assess seasonal variability of geostrophic currents in the Coral Sea and identify seasonal changes in location of the bifurcating South-Equatorial Current (SEC) using the ERS-1 radar altimeter.
(2) To apply a reduced gravity numerical model of the Coral Sea forced by winds derived from the ERS-1 altimeter and scatterometer, and compare the results with altimetric sea levels.
(3) To assess mesoscale variability in the Coral Sea, determine its association with the major current systems and identify the role of mesoscale energy in forcing shelfbreak exchange.

Experiment Plan:
(1) Determine a mean and time variable (residual) sea level from time series of corrected radar altimeter values at repeat interval ground track crossings.
(2) Compute changes in surface geostropic currents and combine these with sub-surface geostropic currents determined from ship-board hydrographic data using thermal wind relation.
(3) Determine the sea level signatures and locations of the major current systems and compute the corresponding geostropic transports.
(4) Determine the sea level signatures and locations of the major current systems and compute the corresponding geostropic transports.
(5) Integrate Topex/Poseidon tidal determinations with ERS-1 radar altimeter corrections.

ERS-1 Data Requirements:
Radar altimetry: Baseline Ocean Product - All GRDs for full 3 year period, sea surface topography D.SSTOP, Sea Surface Height Models D.SSHM, ERS-1 Gravity model D.EGM and Oceanic Geoid D.OG.
Wind scatterometry: Gridded, geolocated wind strength and direction for study region over full 3 year period corresponding to RA data.
Orbit requirements: All orbit phases are of interest.

Milestones/Deliverables:

1990	Logistical planning and algorithm development based on GEOSAT ERM data and launch of ERS-1.
1991	Conduct of first ERS-1 Coral Sea cruise and commencement of altimeter data processing.
1992	Final processing of 1991 ERS-1 RA data. Adaption of algorithms to Topex/Poseidon. Launch of T/P.
1993	Final processing of 1992/3 ERS-1 data and application of T/P tidal corrections.
1994	Final analysis of results, reporting and writing of scientific papers.

Coordinator: Nilsson

AUS6-15

MESOSCALE VARIABILITY IN THE WESTERN CORAL SEA

Principal Investigator:
D.M.Burrage — Australian Institute of Marine Science, PMB No.3, Townsville M.C., Queensland, QLD 4801, Australia

Co-Investigators:
M.Inoue (CSI, LSU)

Objectives:
This is a tropical ocean validation study of the ERS-1 ATSR in which the performance and usefulness of the ATSR high resolution (1km x 1km) and averaged (50km x 50km) SST products will be evaluated. This will be done by comparing the observed spatial and temporal scales of oceanic and atmospheric variability with those obtained from ground truth and AVHRR studies. in the region.
(1) To validate ERS-1 ATSR data for applications to mesoscale ocean circulation studies using shipboard radiometry, in situ monitoring stations and hydrographic surveys.
(2) To develop and evaluate cloud-screening and radiometric correction techniques making use of the unique conical scanning features of the ATSR.
(3) To assess the usefulness of 1km x 1km and 50km x 50km ATSR image products for studies of weak ocean thermal fronts, and for mapping sea surface temperature in the western Coral Sea and Great Barrier Reef.

Experiment Plan:
(1) Develop and test ERS-1 ATSR radiometric and geometric correction algorithms.
(2) Validate sea surface temperature measurements derived from ERS-1 ATSR against NOAA AVHRR, ship-mounted radiometers and in situ monitoring stations.
(3) Assess reliability of mesoscale circulation variability estimates based on ATSR and AVHRR systems and ground truth.
(4) Determine western Coral Sea and shelf break mesoscale circulation on time scales of several weeks to several months.
(5) Investigate the role of mesoscale circulation in forcing shelf break exchange processes in the GBR.

ERS-1 Data Requirements:
(1) All available ATSR radiometer image data within the study region during the commissioning period and all data available from 4 periods of 3 weeks intensive studies on a seasonal basis and over at least a 12 month period. Products needed include ATSR Radiometer Raw Data, High Resolution (1km x 1km) geolocated and radiometrically corrected data and the averaged (50km x 50km) SST product.
(2) ATSR Microwave radiometer data during the commisssioning phase and subsequent intensive field studies. Products needed include raw data, column-integrated atmospheric water vapour and liquid water content and rain detection data.

Milestones/Deliverables:

1990	Logistical planning and algorithm development.
1991	Launch, validation and execution of two research cruises in western Coral Sea. Preliminary ATSR and AVHRR data analysis.
1992	Data and reliability analysis of 1991 ATSR, AVHRR and ground truth.
1993	Production of SST maps and estimates of mesoscale current activity, reporting.

Coordinator: Nilsson

AUS6-16

SUB-MESOSCALE CIRCULATION STUDY

Principal Investigator:
D.M.Burrage Australian Institute of Marine Science, PMB No.3, Townsville M.C., Queensland, QLD 4801, Australia

Co-Investigators:
E.Wolanski (as above)

Objectives:
This study will assess the capability of ERS-1 SAR imagery to reveal features of sub-mesoscale circulation associated with the interaction of tidal streams and sub-tidal currents with the reef matrix of the Great Barrier Reef (GBR), with surface bio-slicks and with internal waves. The imagery will be acquired for 4 ground truth sites located in the northern, central and southern regions of the GBR.
(1) To use shipboard hydrographic survey, Lagrangian drifters, NOAA satellite imagery and hydrodynamic models at selected sites to assess the capabilities odf ERS-1 SAR imagery to reveal sub-mesoscale flow featues, including complex reef-induced water circulation and associated algal and coral spawn slicks.
(2) To use ERS-1 SAR imagery to investigate sub-mesoscale circulation processes in the western Coral Sea, East Australian Current and GBR lagoon including eddies, island wakes and jets of tidal origin, frontal waves, shear instabilities and shelfbreak eddies associated with sub-tidal currents, and super-tidal internal waves.

Experiment Plan:
(1) Acquire and process ERS-1 SAR imagery for 4 study sites, one each in the northern, central and two in the southern GBR region of north-east Australia.
(2) Conduct ground truth field operations designed to provide surface and sub-surface auxiliary relevant to phenomena under study and to validate corresponding SAR imagery.
(3) Enhance corrected SAR imagery, identify and map sub-mesoscale featues and compare them with features revealed by NOAA AVHRR imagery.
Selected sites: 1. Ribbon reefs (15°30'S, 145°45'E);
2. Bowden Reef (19°S, 147°54'E);
3. Rattray Island (20°S, 148°34'E);
4. Swains Reefs (22°S, 152°48'E)

ERS-1 Data Requirements:
SAR Image Mode Data: Approximately 16 SAR precision images 1 Look and 3 Look.
Preferred times: Site 1 - 1992; Site 2 - 1991,2; Site 3 - 1992; Site 4 - Feb 1992.

SAR Wave Mode Data: 3 Look data at some time during in situ recording over selected sites including imagettes, wave spectra and related products.

Milestones/Deliverables:

1990	Logistical planning and algorithm development.
1991	Cruise in November (period chosen to correspond with predicted time of Coral Spawning at Bowden Rf.) employing Lagrangian drifter studies and short term current meter mooring spanning period of interest.
1992	Cruise in February (period of expected maximum seasonal stratification in southern GBR for internal wave studies) employing intensive CTD profiling, hydrographic survey and short term current moorings.
1993	Final data analysis, reporting and scientific papers.

Coordinator: Nilsson

CND2a

SAR OCEAN FEATURE MAPPING

Principal Investigator:
J.Gower — Institute of Ocean Sciences, PO Box 6000, Sidney, B.C. V8L 4B2, Canada
Tel: 604 356 6558

Co-Investigators:
J.Aspel/R.Gasparovic (APL), R.Thompson (IOS), C.Mason/M.Ikeda/P.Smith (BIO), N.Freeman (DFO), S.Peteherych (AES), M.El-Sabh (U. Quebec), M.C.Mouchot (CCRS)

Objectives:
(1) Evaluate SAR for locating and tracking mesoscale ocean features.
(2) Study seasonal and sea surface temperature effects.
(3) Study SAR imaging mechanisms.

Experiment Plan:
Compare SAR imagery collected in east (Gulf Stream) and west (Gulf of Alaska) test sites, with eddy fields deduced from ERS-1 altimetry (see related project CND-2b), and from thermal and visible satellite imagery (including ATSR), altimeter and scatterometer winds, and ship data. Data collection periods to be spread through the first year of ERS-1 operation.

ERS-1 Data Requirements:
Altimeter and ASTR data, plus other wind/wave data from the AMI as mode sharing allows.

Facilities to be Deployed:
(1) Numerical model runs of Gulf Stream and west coast areas.
(2) Research vessels (US and Canada).
(3) Research aircraft flights with AXBT, wave and wind sensors.

Anticipated Results:
Demonstration of value and limitations of SAR imagery for mapping ocean surface features in contrasting regions where visible and thermal satellite data are limited by cloud cover (Gulf Stream with strong shear and thermal contrast, less energetic Gulf of Alaska). Assessment of seasonal and water temperature effects on this capability. Comparison with altimeter dynamic topography.

Milestones/Deliverables:
Full project report with imagery examples and supporting data.
Recommended and tested algorithms for SAR image enhancement for maximising feature visibility.
Date of delivery one year after end of data collection.

Coordinator: Freeman

CND2b

OCEAN CIRCULATION

Principal Investigator:

J.Gower — Institute of Ocean Sciences, PO Box 6000, Sidney, B.C. V8L 4B2, Canada
Tel: 604 356 6558

Co-Investigators:

J.Aspel/R.Gasparovic (APL), R.Thompson (IOS), R.Hendry/C.Mason/M.Ikeda/R.Clarke (BIO)/ W.Moon (U.Manitoba)

Objectives:

(1) Demonstrate mesoscale ocean feature mapping and tracking with the ERS-1 altimeter.
(2) Study large scale eddy activity in the oceans, and the tidal and wind-driven dynamics of a large shallow sea (Hudson Bay).
(3) Study the coupling of motions of the atmosphere, ice, sea water and the earth's crust in Hudson Bay.

Experiment Plan:

Process altimeter data using techniques already developed for GEOSAT data to map and track mesoscale ocean eddy and front features. Compare the results with numerical model output and with data from the visible, thermal and SAR images. For Hudson Bay, wind data from ERS-1 and from coastal stations will also be required.

ERS-1 Data Requirements:

SAR and ATSR data.

Facilities to be Deployed:

(1) Numerical model runs of Gulf Stream, Gulf of Alaska and Hudson Bay areas.
(2) Research vessels time shared with proposals CND-2a and CND-3.

Anticipated Results:

Time series of maps of eddy fields, with statistical data on generation, kinetic eddy density, and tracks for comparison with numerical models and to be used as input to climate models. Observed surface topography changes in Hudson Bay will be used to assess the influence of bottom friction and ice cover.

Milestones/Deliverables:

Full project report with mesoscale eddy maps and supporting data. Recommended and tested algorithms for computation of ocean dynamic topography from ERS-1 altimeter data. Date of delivery one year after end of data collection. Report on bottom friction and ice effects for application in other areas.

Coordinator: Freeman

E1

EVALUATION OF ERS-1 MICROWAVE SENSORS CAPABILITY IN THE STUDY OF OCEANIC FRONTS

Principal Investigator:
J.Font — Instituto de Ciencias del Mar, P. Nacional s/n, 08039 Barcelona, Spain.
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Co-Investigators:
I.Robinson (U.Southampton, UK), T.Guymer (IOSDL, Wormley, UK), J.J.Martinez-Benjamin (UPC, Barcelona, Spain), R.Arbiol (ICC, Barcelona, Spain), G.Parrilla (IEO, Madrid, Spain)

Objectives:
To observe the location and evolution of surface density fronts by using SAR imagery and altimetry.

Experiment Plan:
SAR and altimeter will be analysed in 2 regions of the western Mediterranean where permanent density fronts exist: the shelf/slope off the Ebro river delta (Catalan Sea) and the Almeria-Oran area (Eastern Alboran Sea):
(1) Field and AVHRR studies of the dynamics of the fronts and their surface signature, in both areas.
(2) Study of the mesoscale features in SEASAT SAR images of the western Mediterranean.
(3) Oceanographic cruise in the Ebro area (June) and analysis of SAR images collected during the ERS-1 commissioning phase.
(4) Oceanographic cruise in the Alboran Sea (including airborne measurements and moored current meters) and analysis of ERS-1 SAR and altimeter data.

ERS-1 Data Requirements:
(1) SAR images (level 2 CCTs) of the Ebro-Ibiza region during the commissioning phase. A minimum of 5 consecutive passes are required (coincident with the cruise).
(2) SAR images and altimeter data of the Alboran region, a strip 100km wide and 150km long centred on the line 36° 30'N 2°W - 35°30'N 1°W during a minimum 2 month period (probably September-October 1992). Approx. 10 passes.

Facilities to be Deployed:
R/V "Garcia del Cid" with oceanographic equipment.

Anticipated Results:
Development of a method to extract the identification of mesoscale frontal features from SAR images and altimeter data, and to evaluate its sensitivity under different conditions.

Milestones/Deliverables:
Implementation of the method.
Reports and scientific papers 1992-95.

Coordinator: Frassetto

F10

STUDY OF THE OCEAN TIDES BY MAREGRAPHIC AND SATELLITE ALTIMETRIC DATA ASSIMILATION INTO A HYDRODYNAMIC NUMERICAL MODEL

Principal Investigator:
C.Le Provost — Institut de Mécanique de Grenoble, BP 68 - 38402 St Martin d'Heres, France
Tel: 76 44 82 63

Co-Investigators:
P.Mazzega (GRGS/CNES, 18, Avenue Edouard Belin, 31055 Toulouse).

Objectives:
(1) To develop a method to process all the existing and future altimeter data in order to improve knowledge on mean sea level and tides.
(2) To use this method to establish new cotidal charts for the main tidal constituents, over the ocean and the continental shelves, with centimetric accuracy.
(3) To develop from these results, and validate by checking with observations, a model for prediction of the tidal contribution to the sea-surface variability under the altimeter satellite tracks, over particular areas of interest.

Experiment Plan:
The method to process the altimeter data is based on three components:
(1) A procedure to invert the altimeter and maregraphic data (1st constraint).
(2) A hydrodynamical model of ocean tides (2nd constraint).
(3) A variational method to assimilate the hydrodynamical model.
This is likely to lead to the best possible solution for the different tidal constituents.

The method will be tested over the North East Atlantic, with presently available satellite altimeter data, plus eventually with ERS-1 and TOPEX/POSEIDON data. Priority will then be given to the North Atlantic, the South Atlantic, the Indian Ocean, and the part of the Antarctic Circumpolar current between Drake passage and Australia. Some in situ tidal measurements are also planned.

ERS-1 Data Requirements:
Quasi global altimeter data together with error characteristics.

Anticipated Results:
(1) Establishment of new charts of mean sea surface of the ocean and an atlas of all the significant tidal constituents.
(2) The production of a model for tidal predictions with error bars.
(3) Global maps for amplitudes and phases of self-attraction and loading tidal potentials, of solid earth deformation under the tidal loading, and tidally induced gravity anomalies.

Coordinator: Minster

F25

STUDY OF THE DYNAMICS AND THERMODYNAMICS OF THE ATLANTIC OCEAN AND ADJACENT SEAS

Principal Investigator:

M.Crépon — Laboratoire d'Oceanographie Dynamique et de Climatologie, Université P6, T14, 4 place Jussieu 75005 Paris Tel: 33 1 44273873 Fax: 33 1 44275307

Co-Investigators:

Le Treut/B.Barnier/J.Merle/C.Millot/J.Delloue

Objectives:

(1) To studythe processes which affect the dynamics of ocean basins and the thermodynamics of their surface layers with numerical models. Allthese studies have a common need for wind stress data on a regular grid.
(2) To compare the ERS-1 scatterometer wind stress with meteorological model wind stress.
(3) To investigate the possibility to improve the geophysical model to obtain the ERS-1 scatterometer wind stress by using techniques employed in artificial intelligence.
(4) To validate ERS-1 data with an O.T.H. radar.

Experiment Plan:

(1) Ocean models will be forced with daily ERS-1 scatterometer wind stress and the ocean response be compared with ocean models forced by climatological wind stress.
(2) Testing whether ocean models can be forced with direct ERS-1 products or whether it is necessary to interpolate the ERS-1 scatterometer wind stress on a regular grid.
(3) Comparison of meteorological model output to ERS-1 scatterometer wind stress to check for systematic differences.
(4) Construction of an operational algorithm by using neural tecnics and comparing its efficiency with the existing algorithms.

ERS-1 Data Requirements:

ERS-1 scatterometer wind stress on the Atlantic Ocean and the Mediterranean Sea during the whole experiment.

Facilities to be Deployed:

O.T.H radar.

Anticipated Results:

(1) Improved understanding of the dynamics of the ocean and of the role played by small space and time scale structures of the wind field.
(2) Dramatic improvement of the computational time of the scatterometer wind stress.

Coordinator: Minster

I5

PROPOSAL FOR THE STUDY OF THE MEDITERRANEAN SEA: MODELLING AND DATA ASSIMILATION

Principal Investigator:
G.M.R.Manzella — CNR ISDGM, c/o ENEA, PO Box 316, 19100 La Spezia, Italy
Tel: 39 187 536312 Fax: 39 187 970585

Co-Investigators:
N.Pinardi/ A.Navarra (CNR IMGA), R.Santoleri (CNR IFA), A.Bergamasco (CNR ISDGM)

Objectives:
(1) Monitor the synoptic evolution of the basin wide surface circulation.
(2) Develop the conceptual picture of merging in-situ and satellite data with models.
(3) Produce data sets of sufficient quality and space time density to be used in ocean forecast/nowcast.

Experiment Plan:
The combined suite of sensors in the ERS-1 and other satellites can be incorporated into the analysis of 'in-situ' data and into models. Intensive hydrographic survey has been started to map the synoptic variability of the Mediterranean Sea.

ERS-1 Data Requirements:
LBR data covering the entire Mediterranean acquired during the 35 day cycle 1991 - 92.

Facilities to be Deployed:
Current meters, pressure guages and drifting buoys for the study of currents.
Bathysondes, XBT, thermistor chains for the study of thermohaline characteristics.

Anticipated Results:
(1) Establishment of a comprehensive description of the circulation of the Mediterranean Sea.
(2) Climatology of the Mediterranean circulation.
(3) Data assimilation system.

Milestones/Deliverables:
Status reports: June 1991 and December 1992.
Scientific papers: 1990-92.
Climatological atlases.

Coordinator: Frassetto

IND1-6

INVESTIGATION OF OCEANIC INTERNAL WAVE RELATED PHENOMENA IN THE SEAS AROUND INDIA USING ERS-1 SAR DATA

Principal Investigator:
S.M.Bhandari SAC, Ahmedabad, India

Co-Investigators:
A.Narain/ H.I.Andharia (as above)

Objectives:
(1) To study ocean internal waves with respect to generation, propagation and dissipation.
(2) To evaluate the role of internal waves in the mixing of the ocean upper layer.
(3) To study the role of internal waves in phytoplankton bloom/enhancement in the ocean top layer.
(4) To study the role of internal waves in relation to cyclonic wind stress.

Experiment Plan:
ERS-1 SAR data will be used along with visible/IR data to study internal waves and be compared with in-situ measurements to develop models.

Test sites:
1. 91°93°E, 5°-15°N
2. 83.5°-84.5°E, 17.7°-18.5°N
3. 75°-76°E, 11.5°-12.5°N
4. 81°-83°E, 16°-17.5°N
5. 73°-74°E, 15°-17°N

ERS-1 Data Requirements:
SAR.UI16, SAR.GEC, SWM.UWA, ALT.OPR, ALT.TOP, ALT.CIR, ATS.SST
Site 1 : Aug-Dec 91, Apr-Dec 92, Apr-Dec 93, Apr 94 - 2 scenes per month.
Site 2 : May-Jul 91 - 2 scenes per week (3 day interval).
Site 3 : May-Jul 91 - 1 scene per month.
Site 4 : Jan-Mar 92/94 - 1 scene per week.
Site 5 : Jan-Mar 92/94 - 1 scene per week.

Milestones/Deliverables:
Reports of study, analysis and results.

Coordinator: Ninan

IND1-8

STUDY OF ARABIAN SEA EDDIES DURING THE MONSOON SEASON

Principal Investigator:
M.M.Ali SAC, Ahmedabad, India

Co-Investigators:
M.S.Narayanan/ N.K.Vyas/ P.K.Pal (as above)

Objectives:
To study Arabian Sea eddies with respect to their formation, development, movement and dissipation.

Experiment Plan:
Thermal data will be used to locate eddies and they will be studied using wind data from the scatterometer, slopes from the altimeter and SST from the ATSR. Mathematical modelling will be employed to relate these parameters.
Test area: 40°-110°E, 25°N - 25°S.

ERS-1 Data Requirements:
WSC.VWI, ALT.VRA, ALT.OPR, ALT.SSH, ALT.TOP, ALT.OGE, ATS.CIR, ATS.PST, ORB.PRC
Daily data will be require for the first 12 months, and thereafter from May to September of each year.

Milestones/Deliverables:
Reports on analysis, techniques and results.

Coordinator: Ninan

INT2

MODELLING THE OCEAN WITH REMOTE SENSING FROM ERS-1 (MORSE)

Principal Investigator:

P.J.Minnett — Applied Oceanography Group, SACLANT ASW Research Centre, Viale San Bartolomeo 400, I-19026 San Bartolomeo (SP), La Spezia, Italy
Tel: 39 187 540 253

Co-Investigators:

Members of the Applied Oceanography Group

Objectives:

The principal objective of MORSE is to use ERS-1 data in conjunction with numerical ocean circulation models to ultimately be able to forecast oceanic structure and circulation. The use of satellite data with large and complex numerical models poses many problems concerning the optimum use of remotely-sensed data with databases of conventional data, and with the models themselves. In solving these problems, many important steps will be made in understanding and demonstrating the utility of satellite measurements in such model simulations.

Experiment Plan:

ERS-1 measurements will be used together with data from conventional sources to:
(1) Monitor the large-scale and mesoscale circulation and air-sea exchanges in the Greenland-Iceland-Norwegian (GIN) Sea.
(2) Study specific physical processes in the GIN Sea.
(3) Provide forcing and validation fields for numerical ocean models.

ERS-1 Data Requirements:

Altimeter, Scatterometer, ATSR and SAR data of the GIN Sea.

Anticipated Results:

(1) A demonstation of the utility of ERS-1 data in an ocean forecasting scheme using numerical models.
(2) An improved understanding of the physical oceanography of the GIN Seas, in particular of air-sea interaction, frontal dynamics, cross-frontal exchanges, and the role of Atlantic Water in the area.
(3) An assessment of the utility of ERS-1 data in measuring the ocean-atmosphere heat exchange in the GIN Sea area.
(4) Validation of ERS-1 measurements by direct comparison with in-situ observations.
(5) Validation of ERS-1 measurements through the verification of the numerical ocean models.

Coordinator: Minster

J3-3

STUDY OF WIND EFFECT ON THE OCEAN CURRENT IN THE SEA ADJACENT TO JAPAN

Principal Investigator:
K.Okamoto — Communications Research Laboratory, 2-1 Nukui-kitamachi 4-chrome, koganei-shi, Tokyo, 184, Japan Tel: 81 423 27 7543 Fax: 81 423 27 7594

Co-Investigators:
H.Nishida (Maritime Safety Agency), H.Ishii (as above).

Objectives:
Understanding the process of short-term variation of wind-driven current:
(1) Examination of the applicability of Ekman's theorem in various settings.
(2) Estimation of vertical eddy viscosity.
(3) Examination of the change of structure of ocean front/ current field after the wind blowing.

Experiment Plan:
Field data (current profiles, temperature, etc.) will be collected during routine cruises conducted by the Hydrographic Department of the Maritime Safety Agency. ERS-1 data and these field data will be compared and analysed.
The experimental site is Lon. +12500 to +15000, Lat. +02500 to +04500.

ERS-1 Data Requirements:
Wind vector data from the Wind Scatterometer (off-line).
Surface topography and wave data from the Altimeter (off-line).
Data required covering a full year.
Delivery within 1 month of data collection.

Facilities to be Deployed:
More than 100 patrol vessels of the Hydrographic Department of the Maritime Safety Agency for the collection of meteorological and oceanographical data.

Anticipated Results:
(1) Verification of the existance of the surface Ekman layer.
(2) Estimation of the magnitude of vertical eddy viscosity.
(3) Understanding of the process of wind-driven change of oceanic structure in the sub-surface layer.
(4) Improvement of analysis method for the observed current data.

Milestones/Deliverables:
1988-90 Detailed planning of the experiment and production of data analysis programme by using the simulated products.
1991-92 Prepare and conduct experiment, data analysis and evaluation.

Coordinator: Fujita

J5-2

IMPROVEMENT OF THE TIDAL CHART

Principal Investigator:

Dr.Y.Ganeko — Satellite Geodesy Office, Geodesy and Geophysics Division, Hydrographic Department, Maritime Safety Agency, Japan

Objectives:

Although the ocean tides around shores and in shallow water are well known, those in the deep ocean are still not known adequately. The tidal charts around Japan, drawn by using tidal data at islands, differ slightly from the numerical global models of Hendershott and Schwinderski. The objective of the research is to investigate the tides in deep ocean and obtain reliable tidal charts to allow more detailed study of tidal phenomena occurring around Japanese islands and in marginal seas. Since the orbit of ERS-1 is sun-synchronous, attention will be focussed on moon-related components of tides.

Experiment Plan:

Orbital error may be variable from path to path, and this will be checked using observed sea level data from tide stations. All the tide data available in Japan wil be used in checking, and a regressive method will be used to separate the periodical part of the data. The accuracy of the results will be dependent on the number of data available for each location. Long term data is required.

ERS-1 Data Requirements:

Not yet specified.

Facilities to be Deployed:

All the ocean tide stations currently operational, (about 100) will be employed. Fixed and mobile SLR stations owned by JHD will be used to observe ERS-1.

Milestones/Deliverables:

(1) Ocean tide stations will provide continuous tide data, which will be digitized and filed during the period of research.
(2) SLR observation will start at the launch of ERS-1, and will be used for calibration of the Altimeter.

Coordinator: Fujita

J5-3

VALIDATION OF THE CAPABILITY OF OCEAN CURRENT DETECTION

Principal Investigator:
Y.Ganeko — Satellite Geodesy Office, Geodesy and Geophysics Division, Hydrographic Department, Maritime Safety Agency, Japan

Objectives:
The objective is to investigate the capability of satellite altimeter data for detecting sea surface topography caused by the oceanographic dynamic phenomena such as ocean currents and eddies. The monitoring and forecasting of the Kuroshio, which is one of the strongest currents in the world, and the Pacific counterpart of the Gulf Stream, are very important, both for gaining knowledge on the effect of the current on biological and meteorological natural environments, and for safe/economical navigation.

Experiment Plan:
The investigation will involve the use of a variety of data sets, in addition to those obtained from the Altimeter, these will include dynamic sea heights derived from oceanographic data, current speed data, precise geoid data, ocean tide data from islands in the Kuroshio area, and ocean surface remote sensing images. The Altimeter data near Japan will be calibrated using SLR and ocean tide data.

ERS-1 Data Requirements:
Altimeter data acquired using a 35 day repeat cycle (preferable).

Facilities to be Deployed:
Survey vessels will make cruises along the sub-satellite tracks of ERS-1 to obtain sea truth data by using XBT, CTD and Doppler current meters. Tide stations will be operated continuously. SLR stations of JHD will be employed to observe ERS-1.

Milestones/Deliverables:
(1) Data handling of altimeter data is to be tested using GEOSAT data.
(2) The cruises for collecting sea truth data will be made shortly following the launch of ERS-1.
(3) There will be a continuous research effort throughout the lifetime of ERS-1.
(4) Research results can be expected 1 year after the ERS-1 mission.

Coordinator: Fujita

UK14-7/8

INVESTIGATION OF VARIATIONS IN SOUTHERN OCEAN SEA LEVELS AND CIRCULATION

Principal Investigator:
T.F.Baker/J.M.Vassie Proudman Oceanographic Laboratory, Bidston Observatory, Birkenhead, Merseyside, UK

Objectives:
Investigation of the spatial and temporal variations of sea surface topography in the South Atlantic and southern Indian Oceans, with particular regard to the study of the variability of the Antarctic Circumploar Current (ACC). The study is to be carried out as part of the World Ocean Circulation Experiment (WOCE).

Experiment Plan:
Distibutions of altimetric sea surface height anomalies will be produced to be analysed in combination with tide guage measurements. In addition, anomalies of geostrophic surface currents obtained from altimetry will be compared to those determined from sea level differences between tide guage pairs, including those across the three inter-ocean basin 'choke points' of the ACC. Oceanographic interpretation will be made in combination with other measurements and model studies, in particular those of the UK Fine Resolution Antarctic Model (FRAM).

ERS-1 Data Requirements:
Global altimeter GRD data.
Scatterometer data assimilated into meteorological GCM's for air pressures and winds.

Facilities to be Deployed:
Installed tide guages throughout the South Atlantic, including those at Ascension, Tristan da Cunha, St. Helena, Signy (South Orkney), Port Stanley (Falklands) and Faraday (Antarctic).
Negotiations are underway for a PRARE tracking station to be located at Port Stanley.

Anticipated Results:
A contribution towards the development of adequate ocean models which provide a proper description of current climate and potential climate change.

Coordinator: Srokosz

UK14-9

CONTINENTAL SHELF AND SLOPE CIRCULATION EXPERIMENT

Principal Investigator:
J.M.Huthnance — Proudman Oceanographic Laboratory, Bidston Laboratory, Birkenhead, Merseyside,UK

Experiment Plan:
Investigations will be made of deep ocean areas bordering the north-west European continental shelf. These studies will include the transfer of sea surface gradients across the continental shelf and slope as a function of longshore scale and frequency. Previous measurements suggest that a direct transfer from ocean to shelf occurs for some scales and frequencies, that extra variability on the shelf can prevent the reverse inference of oceanic levels from coastal values, and that determination of scale dependent behaviour requires the spatial coverage of satellite altimetry. The North East Atlantic studies will also include an investigation of the complex water masses of the UK-Iceland-Greenland gap, which will form part of UK WOCE activities.

ERS-1 Data Requirements:
Altimeter GDR data for the North Atlantic.

Facilities to be Deployed:
Coastal tide guages and pelagic recorder.

Coordinator: Srokosz

UK14-10

GLOBAL AND REGIONAL OCEAN TIDES

Principal Investigator:
P.L.Woodworth Institute of Oceanographic Sciences, Broad Road, Wormley, Godalming, Surrey,UK

Objectives:
The aim is to use TOPEX/Poseidon and ERS-1 data to produce regional, and possibly global, distributions of the major lunar and solar tidal constituents.

Experiment Plan:
ERS-1 being almost perfectly sun-sunchronous, provides an ideal lunar tidal analyser, while TOPEX/PPOSEIDON will provide a rich spectrum of both lunar and solar tides; distributions of the major constituents should be extractable if the data from all satellites are analysed in combination. The algorithms expected to be employed for this work will be adaptions of methods developed for SEASAT and GEOSAT analysis. Comparison will be made to existing tidal models and disagreements resolved. In areas such as the North West European continental shelf it may be possible to assimilate the altimetric tidal measurements into existing numerical models of the area.

ERS-1 Data Requirements:
Global altimeter GDR data.

Facilities to be Deployed:
Coastal tide guages.

Anticipated Results:
The production of new models to an accuracy sufficient for other UK oceanographic research purposes during WOCE and beyond.

Coordinator: Srokosz

UK14-11a

ASSIMILATION OF ALTIMETER DATA INTO OCEAN MODELS

Principal Investigator:
P.Killworth Robert Hooke Institute, Parks Road, Oxford, OXON, UK

Objectives:
The primary objective is to develop methods to assimilate satellite altimeter and other data into models of the ocean circulation in order to obtain synoptic pictures of the ocean circulation. To achive this it will be necessary to:
(1) Develop models of the ocean circulation which are suitable for assimilating the altimeter data and the data from other instruments. The models must also accurately model both the large scale currents and the meso-scale eddies within the ocean, and the effect of topography on these currents.
(2) Develop new methods of data assimilation and develop further existing methods so that they are robust and effective in assimilating the surface and in-situ data that will become available.
Sources of data expected to be used include satellite altimeter and scatterometer data, hydrographic data from the WOCE (World Ocean Circulation Experiment) program, XBT, current meter and tide guage data.

Experiment Plan:
Model Development
The numerical model used for most studies of the ocean circulation is the primitive equation model first developed by Bryan and Cox. When this model was developed it was decided for computational efficiency to filter out tidal and surface waves by placing a rigid lid on the surface of the model ocean. Although this appears drastic, the effect on the large scale circulation of the ocean is small.
However surface elevation, the quantity measured by the altimeter becomes a derived quantity and as a result it is not possible to assimilate such data into the model and the modification necessary of the adjoint and other methods becomes impractical.
It is planned, therefore, to develop a new version of the model with a physically realistic free surface but which is not computationally much more expensive than the present model. This is being done by solving the vertically integrated equations using a short time step and keeping a long time step for the baroclinic equations.
At the same time studies with the FRAM Fine Resolution Antarctic Model will be used to improve other aspects of the model, including the representation of the eddy field and vertical mixing schemes.
Assimilation Scheme Development
It is planned to use adjoint methods to assimilate the data in the numerical model. The methods will initially be developed using small regions of ocean and need to be suitable for assimilating both the regular surface satellite data and the dispersed and infrequent in-situ data.
It is planned that the first of these regions will be the JASIN area in Rockall Trough. Where possible boundary conditions of the reduced area models will be obtained from larger scale models currently being run within Europe.

ERS-1 Data Requirements:
(1) Altimeter data and supporting instrument data for the Atlantic and Southern Oceans during the life of ERS-1.
(2) Similar scatterometer data, but preferably in a form assimilated into the ECMWF or similar forecasting GCM.
(3) Sea surface temperature for the Atlantic and Southern Oceans during the lifetime of ERS-1.

Anticipated Results:
(1) The development of better models of ocean circulation suitable for assimilating altimeter and other satellite/ in-situ data.
(2) The development of adjoint and other data assimilation schemes suitable for use with primitive equation models and with satellite and in-situ data.
(3) The use of the models and methods to determine the synoptic current and density field of the ocean. Initially this will be for small regions of ocean, but as methods and computing power develop, the Atlantic and Southern Oceans.

Coordinator: Srokosz

UK14-11b

THE EQUATORIAL WAVE GUIDE PROJECT

Principal Investigator:
P.Bigg University of East Anglia, Norwich, Norfolk, UK

Objectives:
The primary objective is to develop methods to assimilate satellite altimeter and other data suitable for use in equatorial regions. The data will be assimilated into specialised models of the equatorial circulation and will be used to investigate the generation and propogation of equatorial wave systems such as those associated with the development of the El Niño in the Pacific Ocean. In order to achieve this it is necessary to:
(1) Develop models of the equatorial ocean which are suitable for assimilating data from the altimeter and other instruments.
(2) Develop new methods of data assimilation and develop further existing methods so that they are robust and effective in assimilating the surface and in situ data that will become available.
Sources of data expected to be used include satellite altimeter and scatterometer data, XBT and hydrographic data from the TOGA (Tropical Ocean Global Atmosphere) programme, current meter, ocean temperature and tide guage data.
The programme will concentrate on regions within 10 degrees of the equator but the processing will require data from up to 30 degrees on either side of the equator.

Experiment Plan:
Model Development
Because of the relatively simple response of the ocean to atmsopheric forcing within the equatorial waveguides regions, the models used to assimilate data within these regions may be much simpler than those required at high latitudes.
UK oceangraphers have been closely involved with the TOGA experiment and especially in developing models of the Indian and Pacific Oceans. It is planned to develop and improve the models further, using the data obtained during the TOGA experiment.
Assimilation scheme development
Again because of the simple form of its response the equatorial ocean will greatly simplify the assimilation of satellite altimeter and wind stress data. Assimilation schemes based on the adjoint scheme are being developed for use with the equatorial models. Assimilation schemes are presently being used with XBT data and will be extended to altimeter data as this becomes available.

ERS-1 Data Requirements:
(1) Altimeter data and supporting instrument data for the Pacific, Indian and Atlantic within 30 degrees of the equator during the life of ERS-1.
(2) Scatterometer data for the same region.
(3) Sea surface temperature data for the same region.

Anticipated Results:
(1) The development of adjoint and other data assimilation schemes suitable for use with equatorial models and with satellite altimeter and wind stress data.
(2) The development of schemes to determine the synoptic current and density fields of the equatorial ocean and the generation, propagation and decay of equatorially trapped waves.
(3) A better understanding of the equatorial system including the waves associated with the El Niño and the other coupled ocean-atmosphere systems of the Indian and Atlantic Oceans.

Coordinator: Srokosz

UK14-12

THE FINE RESOLUTION ANTARCTIC MODEL

Principal Investigator:
D.J.Webb Institute of Oceanographic Sciences, Wormley, Godalming, Surrey, UK

Objectives:
The ERS-1 component of the Fine Resolution Antarctic Model project (FRAM) is designed to test ocean circulation models using ERS-1 altimeter data. The data will be used to calculate the eddy energetics field for the Southern Ocean and to determine the position and movement of fronts. These observational results will be compared with the predicted energies and positions from the model run in order to test the realism of the model. The reasons for any differences will be investigated and used to develop better models.

Experiment Plan:
(1) Develop, run and analyse the results from the Fine Resolution model of the Antarctic Ocean. The model covers all the ocean south of 25° at a resolution of 0.25° in the north-south direction and 0.25° east-west. The model has 32 layers in the ocean in order to accurately represent the ocean topography.
(2) Develop methods for processing the altimeter data to provide the required fields, including the corrections for satellite position, orientation, sea wave bias, tides and the other sources of error. This is in progress.
(3) Develop methods to plot the sea surface temperature data to determine the position of fronts.
(4) Apply the analysis methods to the ERS-1 data and investigate the discrepancies with the FRAM results.

ERS-1 Data Requirements:
(1) Altimeter data and supporting instrument data for the Southern Ocean during the life of ERS-1. The model covers the region south of 25°S, but for analysis altimeter data is required for all of the ocean south of 10°S.
(2) Scatterometer data for the same region (with wind stresses assimilated into an atmospheric GCM).
(3) Sea surface temperatures for the same region.

Anticipated Results:
(1) The development of better models of ocean circulation suitable for climate studies.
(2) Improved understanding of the Oceanography of the Southern Ocean and its interaction with the surrounding oceans.

Coordinator: Srokosz

UK14-13

STUDY OF MEAN OCEAN CIRCULATION AND EDDIES FROM SATELLITE ALTIMETRY

Principal Investigator:
J.C.Marshall Department of Physics, Imperial College, London SW7 2BZ

Objectives:
To develop an objective analysis technique to form a mean sea level surface, taking account of the errors in the various fields to use: (a) as a reference surface for monitoring mesoscale (geostropic eddy) variability in eddy rich regions of the world ocean (NW Atlantic and Antarctic Circumpolar Current); and (b) in conjunction with fine resolution non-altimetric geoids to study the mean circulation in limited regions where there are strong surface currents.

Experiment Plan:
It is proposed to extend further the development of present objective analysis techniques, and to use them with ERS-1 data to form a mean sea surface to be used as a reference surface for oceanographic studies. In particular the data will be used to study the variability of the meso-scale eddy field in regions where the eddy energy is high, such as the N. Atlantic. The mean sea surface will also be used in conjunction with geoids obtained from non-altimetric sources such as sea surface gravity measurements, to study strong surface currents.
It is also proposed to extend the data assilation techniques to study how effective the altimeter data is in constraining multi-level eddy resolving ocean current models. These techniques will be used with the ERS-1 data after correcting with the non-altimetric geoids and the objective analysis methods will be further used to give improved geoids.

ERS-1 Data Requirements:
Altimeter data and precise orbit parameters - sea surface height plus corrections.

Anticipated Results:
Maps of mean and eddy ocean currents. Improved geoid of NW Atlantic.

Milestones/Deliverables:
Pre-launch
Theoretical studies to continue using numerical models and model generated data. Some preliminary investigations are being carried out using SEASAT and GEOSAT data.
Launch year
Collaborate with other proposals in validating ERS-1 altimeter and scatterometer data. Carry out first tests of mean sea level program. Initial plots of sea level variability and mean circulation. Tests using combined ERS-1 and GEOSAT data.
Year after launch
Main runs of mean sea level programs, variability and mean circulation programs. Analysis of results.

Coordinator: Srokosz

UK14-17

TO EXPLOIT THE USE OF ERS-1 PRECISION PRODUCTS FOR THE CALCULATION OF THE OCEAN/ATMOSPHERE SURFACE FLUXES BOTH FOR DIRECT USE AND FOR VALIDATION

Principal Investigator:
P.K.Taylor — James Runnell Centre for Ocean Circulation, Gamma House, Chilworth Research Centre, Chilworth, Southampton SO1 7NS, UK
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Objectives:
To use ERS-1 data in determining the surface fluxes of heat and momentum over the North Atlantic and the Southern Ocean.

Experiment Plan:
Surface flux values cannot be obtained to the accuracy required for experiments such as the World Ocean Circulation Experiment (WOCE) using ERS-1 data alone, or in conjunction with other satellites. Nor can adequate flux values be obtained on a world-wide basis from *in situ* sources such as the Voluntary Observing Ships (VOS). It is probable that the best global flux estimates will be produced by atmospheric forecast models which use satellites and *in situ* data as input, however at present the model derived fluxes are not accurate enough. It is therefore necessary to adopt a step-wise approach.
(i) investigate and if possible improve the accuracy of the VOS observations so that, where available, these can be used to validate ERS-1 data and model derived estimates.
(ii) improve our understanding of the satellite data; in particular the relationship between scatterometer wind mode data and surface stress, and the relationship between the bulk sea surface temperature (used in parametric formulae for flux calculation) and the surface skin temperature measured by the ATSR sensor on the satellite.
(iii) validate the satellite sea surface temperature and surface wind data.
(iv) compare the resulting flux estimates with climatological estimates, and with model derived surface fluxes.

Although the ultimate aim is to obtain surface flux estimates over the world ocean, two areas have been chosen for investigation. The North Atlantic is an area where comparatively many *in situ* observations are available. The Southern Ocean is a data sparse area of great scientific importance because of it's role in the world's climate.

ERS-1 Data Requirements:
AMI wind and ATSR off-line precision products.

Facilities to be Deployed:
The platforms used for *in situ* data collection will include Research Ships operated by the Natural Environment Research Council and other agencies, and ships of opportunity.

Milestones/Deliverables:
The results of the project will be published in project reports and scientific papers. Appropriate subsets of the data and results will be placed on magnetic tape in the GF3 data exchange format.

Coordinator: Srokosz

UK14-25

INTERNAL TIDES AND WAVES WITH SAR

Principal Investigator:
J.M.Huthnance Proudman Oceanographic Laboratory, Bidston Observatory, Birkenhead, Merseyside,UK

Objectives:
Oceanographic objectives are to ascertain the formation, propagation and distribution of internal tides and waves over and around the NW European continental shelf, especially near the shelf edge where most internal tide generation is believed to occur. Dependencies on shelf-edge topography, stratification and depth-mean tidal current strengths are sought.

Experiment Plan:
The location, intensity and dimensions of rough and smooth bands on SAR images will be compared with simultaneous in situ observations. Ship's radar images along sections through a wave train will provide the most direct comparison. Echo sounding and temperature/depth records in the same sections will relate these to internal conditions through the train. Current profiles, from acoustic doppler current profiling, and thermistor chain time series will further quantify the wave current and temperature fields. Subsequently, SAR images will be used to infer the sources, propagation, strength and extent of internal tides and waves over and around the NW European shelf, through acquired knowledge of the relationship between image and wave currents.
The in situ measurements will be ship-borne and include sections with ship's radar images, echo sounding, temperature/depth records at the time of satellite pass, acoustic doppler profiles and thermistor chain time series. Current and moored thermistor chain records will continue for approximately two weeks according to ship scheduling, and will relate the images to sea currents.

ERS-1 Data Requirements:
SAR imagery with timing to coincide with ship data collection.

Facilities to be Deployed:
Research ship with instruments and equipment for measurement, analysis and interpretation at sea.

Anticipated Results:
Confidence and better interpretation of SAR images should follow from the in situ observations relating images to the surface current conditions which are believed to be their cause. In situ ship's radar, echo sounding and thermistor chains should confirm the oceanographic interpretation, with the ship's radar in particular providing a link between the remote and in situ observations.
An assessment of internal waves around the whole NW European shelf edge should result.

Coordinator: Srokosz

UK14-40

WORLD OCEAN CIRCULATION EXPERIMENT

Principal Investigator:
W.J.Gould — Deacon Laboratory, Institute of Oceanographic Sciences, Broad Road, Wormley, Godalming, Surrey, UK

Objectives:
The overall objective is the UK scientists to work towards an assessment of the role played by the oceans in the earth's climate. ERS-1 is central to the objective since it provides the global coverage by altimeter, ATSR and Scatterometer, and to a higher latitude than other planned earth observation satellites.
The UK WOCE plan will focus on objectives in the Southern Ocean and in the North Atlantic and will be carried out within the framework of the international project.

Experiment Plan:
Global Description
High quality CTD sections will be occupied in the North and South Atlantic Oceans. These will be supplemented with measurements of chemical tracers and nutrients. The data will be part of the global WHP survey. In the N.Atlantic there will be a significant effort devoted to the measurement of the exchanges between the N. Atlantic and Norwegian Sea. Coupled global ocean/atmosphere models at the UK Metrorological Office will require accurate surface flux data. This will be derived from ERS-1 wind data.
Southern Ocean
A Fine Resolution Antarctic Model (FRAM) is running and will use observational in situ and satellite data as part of its validation process. Southern ocean wind stress data from ERS-1 will be used. Sea surface height variability from the altimeter will be compared both with FRAM model results and with sea level data from islands and off-shore guages.
Gyre Dynamics
The UK WOCE community will make a large contribution to the study of the dynamics of the N.Atlantic Gyre. Altimeter, Scatterometer and ATSR data will be used in the study of the response of, particularly, the sub polar gyre to changing surface forcing on seasonal and interannual time scales. The N. Atlantic will be used as a test bed for the improvement of determination of air-sea fluxes from in situ and remotely sensed (ERS-1) data.
The observational phase will commence in 1990 and continue until 1996/7.

ERS-1 Data Requirements:
Data from the altimeter, scatterometer and ATSR will be required, primarily for the N.Atlantic and Southern Ocean, but also for other areas of the World Ocean.

Facilities to be Deployed:
Research vessels of the UK NERC fleet, including the RRS Charles Darwin, RRS Discovery and RRS James Clark Ross. Each of these vessels is eqipped with a full range of modern oceanographic equipment and capable of working in the deep oceans of the world.

Anticipated Results:
The goals of the WOCE programme are long term, and ultimately are, the production of improved models of the role of the oceans in the earth's climate. In the immediate future, the UK programme will achieve a better physical understanding of the dynamics of the Antarctic Circumpolar Current and the role of the Southern Ocean in the earth's climate.

Coordinator: Srokosz

US1-5b

APPLICATION OF SAR DATA TO HIGH LATITUDE OCEANIC FRONTS

Principal Investigator:
T.C.Royer/T.J.Weingartner   Institute of Marine Science, University of Alaska, Fairbanks, Alaska 99775-1080
Tel: 907 4747835/7993

Co-Investigators:
K.Ahlnaes (Geophysical Institute, University of Alaska)

Objectives:
Determine the applicability of SAR data to ocean front detection.

Experiment Plan:
Satellites employing infra-red thermal imaging systems have limited ability to detect oceanic dynamic features at high latitudes because the density contrasts are determined primarily by salinity rather than by temperature. Moreover, the high frequency of occurrence of cloud cover at these latitudes limits the number of useful thermal images that can be obtained. The high rates of precipitation and/or runoff and sea-ice melt in Alaska's coastal waters establish strong density gradients (fronts) which are associated with circulation features. SAR data will be used to map these features in the Gulf of Alaska, and the Bering, Chukchi and beaufort Seas.

ERS-1 Data Requirements:
3-day repeat cycle datasets will be required at the selected monthly intervals for the Gulf of Alaska and Bering Sea shelves. 3-day repeat cycle during selected intervals between data will be required during selected intervals between May and October for the Chukchi Sea shelf.

Anticipated Results:
A description of the temporal variability of the oceanic fronts occurring in these regions.

Milestones/Deliverables:
Time series of the positions of the oceanic fronts which are determined. Comparisons of these positions with available and historical hydrographic data.

Coordinator: Weller

US1-6b

MARINE GEOLOGY AND COASTAL CIRCULATION ON THE ALASKAN CONTINENTAL SHELF

Principal Investigator:
K.Dean/W.Stringer   Geophysical Institute, University of Alaska, Fairbanks, Alaska 99775-0800
Tel: 907 4747364

Objectives:
(1) To identify and describe sea ice distribution and movements, geology, features of coastal circulation and water quality parameters of the continental shelf along the Alaskan Beaufort Sea coast.
(2) To integrate SAR imagery of sea ice, coastal geology and marine circulation with optical satellite imagery (Landsat and SPOT) and field observations.

Experiment Plan:
For approximately 15 years the University of Alaska has been involved in an on-going project, funded by NOAA, to study and monitor environmental conditions on the Alaskan outer continental shelf. Remote sensing data including NOAA AVHRR imagery, Landsat, aerial photography and airborne SLAR have been used to monitor sea ice, oceanic circulation, sea surface temperatures, suspended sediments and other aspects of water quality. The ERS-1 SAR imagery will be included in the analysis of the Alaskan continental shelf. SAR imagery will be analysed on an image processing system to enhance data related to specific features such as barrier islands, shoals and coastal circulation.
The general area of interest is the entire Alaskan continental shelf. Specific target areas will vary from year to year depending upon areas of interest.

ERS-1 Data Requirements:
SAR data. Every 3 or 7 days for short periods, with an annual average of 1 scene per month for 2 years.

Anticipated Results:
Environmental data on the Alaskan Continental Shelf which will be used to assess the environmental impact of oil exploration on the region.

Milestones/Deliverables:
(1) Progress reports as required.
(2) Final report including image products.

Coordinator: Weller

US2

OCEAN CURRENT SHEAR FROM SAR

Principal Investigator:
T P.Barnett — Ocean Research Division, Scipps Institute of Oceanography, La Jolla, California, USA

Objectives:
(1) Develop a double inverse technique for converting SAR image swaths to estimates of current shear.
(2) Validate the method against direct measurements.

Experiment Plan:
It is planned to use the SAR on ERS-1 to obtain "snapshots" and time series of horizontal current shear cross sections through the Gulf Stream. If a mobile station capable of receiving SAR image mode data is available, the methodology can be extended to observations of the spatial/temporal structure of the Antarctic Circumpolar Current.
This unique approach to shear measurement is possible because ocean wind waves refract in a shear current. The SAR on ERS-1 will measure wave direction in the open ocean as a function of position. The resulting observations of directional change in deep water waves, when subjected to an inverse modelling operation, allow estimation of the horizontal shear that gave rise to the refractive effects. A theoretical feasibility study shows shear estimates accurate to 5-25% can be obtained under favourable geometries of wave-current interactions for the major current systems of the world's oceans. The wave conditions necessary for the measurement occur at least 15% of the time in the least favourable localities and perhaps 50% of the time in more favourable localities.

ERS-1 Data Requirements:
SAR Wave Mode spectra for selecting optimal conditions for shear flow estimation. Ideally available daily.
SAR Image Mode data for estimation of high resolution wave spectra for input to the inverse model. Required at 5-10 day intervals.

Anticipated Results:
Near instantaneous "snapshots" of the shear across the Gulf Stream and at least one section of the Circumpolar Current at roughly 10-day intervals for 1 1/2 years.

Coordinator: Freilich

US3-4

TROPICAL AIR-SEA INTERACTIONS

Principal Investigator:
M.H.Freilich JPL, M-S, 300-323, 4800 Oak Grove Drive, 91109 Pasadena CA, USA

Co-Investigators:
Busalacchi/ Cane/ Cardone/ Halpern/ Legler/ O'Brien/ Zebiak (JPL)

Objectives:
(1) Characterise error structures in conventional tropical wind products and ERS-1 scatterometer winds in the tropics, and develop transfer functions describing the propagation of these errors through tropical ocean and air-sea interaction models.
(2) Develop objective assimilation techniques tuned specifically to the tropics for production of 5-day blended tropical wind fields using ERS-1 and conventional data.
(3) Characterise actual errors in ERS-1 winds and derived products based on model-data comparisons in the data-rich tropical Atlantic.
(4) Conduct descriptive and model-based studies of tropical winds and air-sea interactions in all tropical oceans.

Experiment Plan:
In the tropics, the upper ocean appears to respond directly to wind forcing. Tropical upper-ocean motions are associated with strong, time-varying sea-surface temperature and surface height signals which can also be measured remotely from satellites. Simple ocean models are capable of reproducing about 40% of the variance associated with observed sea level and dynamic topography in the tropics, and recent analyses conclude that inaccuracies in the wind fields used to drive the models are the single largest source of error in tropical ocean model predictions. Spatial and temporal error structures of existing tropical wind products are being assessed to establish a baseline against which ERS-1 products will be evaluated. Characteristic errors are estimated by examining differences between the various products, and detailed analyses will be conducted to quantify the importance of typical error scales and magnitudes on ocean model predictions. Techniques for producing the 5-day tropical wind analyses by Florida State University (presently based on conventional data only) will be refined to accommodate ERS-1 products, and 5-day analyses will be produced regularly after launch.

ERS-1 Data Requirements:
Requirement for US3-1 - US3-8.
Full misssion WSC (UWI, IWI), ALT (URA) and available ATSR/M data globally over the ocean. Minimum requirement is for 1 year of data.
All available SWM (UWA) data obtained in the North Atlantic and over the Antarctic Circumpolar Current south of 40°S for the full mission. Minimum requirement is selected SWM data obtained in the North Atlantic over a period of 6 months.

Anticipated Results:
Pre-launch work will identify error scales in conventional products, establish transfer functions between inacuracies in the wind measurements and resulting errors in ocean model predictions, and refine techniques for producing high quality blended analyses of tropical winds with a 5-day time scale. After launch and validation of ERS-1, 5-day analyses of tropical surface winds will be produced operationally, within 10 days following the end of the month for the entire month's data. Tropical ocean and air-sea interaction models will be driven by the ERS-1 winds as well as by non-ERS-1 data. Predictions of sea level and SST from the models will be compared with ERS-1 and Topex/Poseidon altimeter and available SST data. Discrepancies will be related through the transfer functions to inaccuracies in the wind fields, thus providing an indirect validation of ERS-1 wind data in the tropics. ERS-1 wind products will be used to drive an advanced model of Indian Ocean circulation to examine air-sea interactions associated with the Arabian Monsoon.

Coordinator: Freilich

US3-5

RESPONSE OF THE ANTARCTIC CIRCUMPOLAR CURRENT TO WIND FORCING

Principal Investigator:
M.H.Freilich JPL, M-S, 300-323, 4800 Oak Grove Drive, 91109 Pasadena CA, USA

Co-Investigators:
Chelton/ deSzoeke/ Fu/ Richman (JPL)

Objectives:
(1) Describe and model the wind-driven dynamics of the Antarctic Circumpolar Current (ACC).
(2) Determine the wind-driven oceanic heat flux in the Southern Ocean.
(3) Characterise the structure and variability of wind stress over the Southern Ocean.

Experiment Plan:
The Southern Ocean, including the ACC, plays a crucial role in the transfer of heat from the tropics to high southern latitudes and is therefore improtant to the global heat budget. Wind stress over the ACC is exceptionally high, and because of its zonally unbounded nature, the AC seems to respond directly and barotropically to variations in zonal wind stress on time scales lessthan about 1 year. Conventional wind observations in the Southern Ocean are totally inadequate to define the temporal and spatial scales of variability. Refined numerical models of the ACC are being developed, based on existing quasi-geostrophic eddy-resolving channel models of McWilliams et al. (1978). The models will be modified to include realistic bottom topopgraphy, increased vertical resolution, and time-varying wind stress forcing. Future modifications will result in a primitive-equation model that will allow investigation of Ekman transport of heat and momentum through the upper Southern Ocean. Models will be tested with synthetic wind fields after launch to determine model sensitivities and establish principal scales of variability and effects of mixing dynamics. Results will be used to establish requirements on interpolated ERS-1 wind fields produced in the Basin-Scale Wind Field task. After launch, 1 year of ERS-1 data will be analysed to characterise actual scales of variability appropriate for eddy Ekman flux models and to determine a preliminary picture of the seasonal patterns of wind stress over the Southern Ocean. Model runs, forced by measured winds, will be used to isolate the physical mechanisms controlling the ACC and its variability. Altimeter data from ERS-1 will be used to test directly the models' predictions of sea level.

ERS-1 Data Requirements:
Requirement for US3-1 - US3-8.
Full misssion WSC (UWI, IWI), ALT (URA) and available ATSR/M data globally over the ocean. Minimum requirement is for 1 year of data.
All available SWM (UWA) data obtained in the North Atlantic and over the Antarctic Circumpolar Current south of 40°S for the full mission. Minimum requirement is selected SWM data obtained in the North Atlantic over a period of 6 months.

Anticipated Results:
This study will provide the first-ever accurate characterisation of the seasonal vaiability of wind stress over the Southern Ocean. Through data assimilation into advanced models of the ACC, the physics of the time-varying currents and surface fluxes will be isolated and identified, thus allowing the role of the ACC in global ocean circulation and climate to be better understood.

Coordinator: Freilich

US3-6

WIND-FORCED, MID-LATITUDE OCEAN CIRCULATION

Principal Investigator:

M.H.Freilich JPL, M-S, 300-323, 4800 Oak Grove Drive, 91109 Pasadena CA, USA

Co-Investigators:

Crepon/ Fu/ Holland/ Koblinsky/ LeProvost/ LeTreut/ McWilliams/ Vazques (JPL)

Objectives:

(1) Investigate, using classical modelling techniques, the manner in which spatial and temporal variability in wind forcing is felt by the mid-latitude ocean in terms of its physical response.
(2) Estimate the absolute geostropic velocities in the ocean from wind and hydrographic observations.

Experiment Plan:

Classical and inverse modelling techniques will be used, in conjunction with ERS-1 wind and hydrographic data, to model the general circulation of the ocean on basin-wide scales. After launch, an eddy-resolving quasi-geostrophic model will be used to examine direct wind forcing od mesoscale currents in mid-ocean regions. Model response will be tested initially using ERS-1 ALT data. The relative effects of wind stress and bottom topography on the large-scale circulation will be examined primarily in the Atlantic. After 1 year of ERS-1 data are available in either the Atlantic or the Pacific, inverse modelling using a modified Sverdrup relation taking topography into account will be used to compute geostrophic velocity directly from wind and hydrographic data.

ERS-1 Data Requirements:

Requirement for US3-1 - US3-8.
Full misssion WSC (UWI, IWI), ALT (URA) and available ATSR/M data globally over the ocean. Minimum requirement is for 1 year of data.
All available SWM (UWA) data obtained in the North Atlantic and over the Antarctic Circumpolar Current south of 40°S for the full mission. Minimum requirement is selected SWM data obtained in the North Atlantic over a period of 6 months.

Anticipated Results:

Both classical and inverse models for large-scale circulation will be driven with ERS-1 winds and compared (model-model as well as model-data comparisons will be undertaken). Techniques for spinning-up classical models without using limited-duration measured forcing data will be developed. Principal scales in the wind field and transfer functions quantifying model sensitivity to wind errors will be identified.

Coordinator: Freilich

US3-7

REGIONAL OCEANOGRAPHIC PHENOMENA

Principal Investigator:
M.H.Freilich JPL, M-S, 300-323, 4800 Oak Grove Drive, 91109 Pasadena CA, USA

Co-Investigators:
Beardsley/ Carter/ Cornillon/ Graber/ Kelly (JPL)

Objectives:
Investigate the role of local and non-local wind forcing on:
(1) Dynamics of sub-tidal circulation in the Californian Current and over the continental margin off the west coast of North America.
(2) Upwelling along the Brazilian coast.
(3) Dynamics of the Brazil current from Cabo Frio to the convergence with the Falklands Current.
(4) Dynamics of the Gulf Stream from Hatteras to the Grand Banks.
(5) Formation of 18°C water in the Sargasso Sea.
(6) Location and evolution of the main front of the subtropical convergence in the Sargasso Sea.

Experiment Plan:
Wind forcing plays a role in many sub-basin-scale oceanographic phenomena, but existing wind data lacks the spatial and temporal coverage (as well as resolution) required to allow unambiguous identification of the specific mechanisms by which the wind forcing drives the upper ocean. Several regions will be studied, in both the Northern and Southern hemispheres where extensive satellite SST or existing in situ data exist and where ERS-1 wind data could provide key indications of the probable mechanisms of wind forcing.

ERS-1 Data Requirements:
Requirement for US3-1 - US3-8.
Full misssion WSC (UWI, IWI), ALT (URA) and available ATSR/M data globally over the ocean. Minimum requirement is for 1 year of data.
All available SWM (UWA) data obtained in the North Atlantic and over the Antarctic Circumpolar Current south of 40°S for the full mission. Minimum requirement is selected SWM data obtained in the North Atlantic over a period of 6 months.

Anticipated Results:
For each of the case studies identified, high resolution interpolated maps of surface winds and stress from ERS-1 will be used in conjunction with satellite measurements of SST (from NOAA orbiters) and other operational satellite and in situ data to qualitatively characterise the relationship between local and non-local wind variations and the oceanographic phenomena of interest, after which comparisons of data with predictions of models forced by the ERS-1 winds will be conducted.

Coordinator: Freilich

US3-8

WIND-DRIVEN UPPER-OCEAN HEAT ADVECTION

Principal Investigator:
M.H.Freilich JPL, M-S, 300-323, 4800 Oak Grove Drive, 91109 Pasadena CA, USA

Co-Investigators:
Barnett/ Liu/ Niiler (JPL)

Objectives:
(1) Assess the accuracy of using ERS-1 wind, ATSR/M -derived sea surface temperature , and ATSR/M-derived water vapour measuremnts for the determination of momentum and latent heat fluxes.
(2) Develop an optimal scheme by which ERS-1 data can be combined with other satellite data (e.g. DMSP/SSMI water vapour, NOAA/VISSR radiative fluxes) to study the heat balance of the upper ocean.

Experiment Plan:
Surface currents in the ocean can be modelled based on wind forcing, but this requires accurate and extensive measurements both of the wind stress and air-sea fluxes that influence the thermodynamic structure of the air-sea system. Vector winds from the ERS-1 scatterometer will be used to provide kinematic forcing, and wind speeds coupled with sea surface temperatures from the ATSR/M and water vapour (derived in part from the microwave channels of the ATSR/M, but also from operational DMSP/SSMI data) will be used to calculate air-sea heat fluxes. In the ocean, models of large-scale surface momentum convergence will be developed so that wind-driven currents can be predicted from ERs-1 and other data. The model outputs will then be used to compute surface heat advection due to currents. Methods for using statistics of the synoptic wind field to predict monthly mean momentum convergence will also be examined.

ERS-1 Data Requirements:
Requirement for US3-1 - US3-8.
Full misssion WSC (UWI, IWI), ALT (URA) and available ATSR/M data globally over the ocean. Minimum requirement is for 1 year of data.
All available SWM (UWA) data obtained in the North Atlantic and over the Antarctic Circumpolar Current south of 40°S for the full mission. Minimum requirement is selected SWM data obtained in the North Atlantic over a period of 6 months.

Anticipated Results:
Large-scale comparisons of month-to month variations of surface stress, total heat flux, and SST have never before been possible because of a lack of data over the ocean. By the end of the ERS-1 mission, sufficient monthly mean stress, SST, and columnar water vapour (and hence latent heat flux) will be available to allow examinations of seasonal cycles and their influences on interannual variability of ocean circulation and climate. The basin-scale mean monthly maps of momentum and heat fluxes produced in this task will be made available to the oceanographic and climate community.

Coordinator: Freilich

US6-1

RESPONSE OF THE ANTARCTIC CIRCUMPOLAR CURRENT TO WIND FORCING

Principal Investigator:
D.B.Chelton Oregon State University

Co-Investigators:
J.G.Richman (Oregon State University), Lee-Lueng Fu (JPL)

Objectives:
The overall goal of this investigation is to understand the dynamics of the large-scale circulation and mesoscale variability in the Southern Ocean and to relate these to meridional fluxes of heat and momentum.

Experiment Plan:
(1) Use the altimeter data to describe the seasonal variability of the geographical distribution of mesoscale and large-scale, low-frequency variability of sea level and surface geostropic velocity in the southern hemisphere, with particular emphasis on the Southern Ocean (35°S to 70°S).
(2) Use the ERS-1 scatterometer data to describe the spatial and temporal variability of surface wind stress and wind stress curl in the southern hemisphere.
(3) Relate the wind forcing and sea level/ surface geostropic velocity response using various statistical techniques.
(4) Develop a simple model of the circulation of the Southern Ocean.
(5) Force the model with wind stress fields obtained from the ERS-1 scatterometer and compare the model response with sea level/ surface geostropic velocity fields estimated by the ERS-1 altimeter.

ERS-1 Data Requirements:
All ERS-1 scatterometer and altimeter data for the southern hemisphere between the equator and 72°S. Vector wind data are crucial for this investigation.
A minimum period of one full year is required to study seasonal variability. Ideally, data are required for the full period of the ERS-1 mission to establish the most reliable estimate possible of the seasonal cycle, and to gain some understanding of the magnitude and importance of year-to-year variability.

Anticipated Results:
Products produced by the study will include fields of vector wind stress and wind stress curl computed from the ERS-1 scatterometer data, and fields of the variability (about an indeterminant mean) of sea level and surface geostropic velocity generated from the ERS-1 altimeter data.
Southern hemisphere 1° resolution statistics of sea level variability will be calculated for 3 month periods throughout the ERS-1 mission. Amplitude and phase of annual plus semi-annual harmonics defining the seasonal cycles of wind stress and sea level on the spatial grids of each variable will also be produced.

Milestones/Deliverables:

3 months	Gridded fields of surface stress and sea level wil be generated.
1 year	Preliminary estimate of the seasonal cycles (annual plus semiannual variability) will be determined by harmonic analysis.
	Development of a preliminary model of the wind-forced circulation of the Southern Ocean.
2-3 years	The seasonal cycle will be refined.
	Ocean circulation model will be modified to assimilate the altimeter observations of sea level variability.
	Three dimensional fields of ocean current velocity generated to investigate fluxes of momentum and heat in the Southern Ocean.

Coordinator: Tapley

US6-2

A PROPOSAL TO DETERMINE GLOBAL SEA LEVEL VARIABILITY FROM ERS-1 ALTIMETRY.

Principal Investigator:
R.Cheney NOAA/ National Ocean Service

Co-Investigators:
B.Douglas (as above)

Objectives:
ERS-1 data will be analysed using techniques developed for GEOSAT. Variations of global sea level as a function of time will be determined, and analyses will be performed to produce descriptions in terms of statistics, spectra and time series. Data from other satellites operating during the ERS-1 mission will be used to extract the maximum space time resolution. Particular attention will be given to the tropical ocean/atmosphere system.

Experiment Plan:
ERS-1 data will be analysed together with in situ observations to derive time series of sea level in the tropical Pacific, Atlantic and Indian Oceans. Data from ERS-1 and other measurement systems will be regularly assimilated into primitive equation ocean models. The resultant fields will be used for ocean climate diagnoses and as initial conditions for coupled ocean atmosphere simulations that will be used for experimental seasonal and ENSO forecasts.

ERS-1 Data Requirements:
Altimeter data for the tropical Pacific, Atlantic and Indian Oceans.

Anticipated Results:
Information on sea level variability, combined with surface wind observations, will improve knowledge of the mechanisms and processes associated with the ocean's role in weather and climate variability.

Milestones/Deliverables:
Operational sea level products for the three tropical oceans (i.e. within 1 - 2 weeks of observation).
Maps of sea level anomaly and other analyses distributed each month through the NOAA Climate Diagnostics Bulletin and other international organisations.

Coordinator: Tapley

US6-4

EQUATORIAL OCEAN CIRCULATION AND HEAT TRANSPORT

Principal Investigator:
D.Halpern JPL, 4800 Oak Grove Drive, Pasadena, CA

Objectives:
This experiment is concerned with understanding the role of ocean circulation in the dynamics of large-scale, month-to-month, equatorial sea surface temperature (SST) variations, which is of utmost importance because of the association with El Niño Southern Ocean Oscillation phenomena and consequently with regional and global atmospheric circulation disturbances.

Experiment Plan:
(1) *Equatorial Kelvin Wave Motion and Onset of El Niño.*
The sea surface height topography over the tropical oceans will be described from ERS-1 measurements, emphasising analyses of equatorial Kelvin waves which are generated by variations in the zonal component of the surface wind stress.
(2) *Generation and Propogation of Equatorial Mixed Rossby-Gravity Wave Motion.*
Mixed Rossby gravity waves are generated by barotropic instabilities of the large scale tropical ocean currents. Sea surface height measurements from altimeter data will be used to analyse the longitudinal variation of equatorially trapped mixed Rossby-gravity wave motion.
(3) *North Equatorial Countercurrent Dynamics.*
The ageostropic current component due to local wind stress will be estimated from ERS-1 scatterometer data. The degree of Sverdrup balance of the NECC will be estimated with computation of wind stress curl from ERS-1 scatterometer data.
(4) *Equatorial Undercurrent Dynamics.*
ERS-1 altimeter and scatterometer data will be used to examine the correlation between eastward pressure gradient established by water piled up on the western side of the ocean by easterly winds, and the surface wind stress.
(5) *Arabian Sea Cooling.*
ERS-1 altimeter data will be used to determine the shape of the sea surface associated with the annual cooling in the northwest Indian Ocean during the southwest monsoon.

ERS-1 Data Requirements:
Altimeter data for tropical oceans (n.b. scatterometer data to be acquired for another experiment involving the same PI).

Milestones/Deliverables:
Time series of sea surface height in the tropical zone.

Progress reports at 6 monthly intervals.

Paper describing the annual cycle of variations in sea surface height along the equator and in the NECC, approximately 6 months after initial receipt of the data.

At least one research paper and presentation of results at major meetings expected each year for five years.

Coordinator: Tapley

US6-5

WIND FORCED, SEASONALLY VARYING CIRCULATION IN THE SOUTHERN OCEAN

Principal Investigator:
J.M.Klinck Old Dominion University

Objectives:
The measurement of sea surface elevation and surface winds by ERS-1 provides an ideal opportunity to quantify ideas about the wind driven variability of the Antarctic Circumpolar Current (ACC) with simultaneous measurements of the forcing and the response. Major questions to be addressed by the research include the following:
(1) How well can the variability of the free surface of the Southern Ocean be reproduced by a wind driven one layer numerical model forced by scatterometer winds?
(2) What is the character of the variability of the measured winds as compared to averaged monthly climatologies? Equivalently, how important to the circulation of the Southern Ocean are the variations in wind forcing on small scales and short times compared to the large scale, monthly averaged winds?

Experiment Plan:
Proper specification of the wind forcing for a Southern Ocean model presents a problem because of the lack of observations at extreme southern latitudes. Wind estimates from surface ship observations and other sources will be used to force the wind driven model to understand how the different spatial and temporal content of the winds affect the ACC circulation.
The model solution obtained by forcing with the scatterometer winds will be compared to the observed altimetry observations. Given problems in determining the geoid, the first comparisons will be observed along track altimetry changes. Later comparisons will use an estimated geoid so that the surface topography can be compared directly.

ERS-1 Data Requirements:
Surface wind stress and surface elevation from the altimeter.

Anticipated Results:
This project will provide across check between the scatterometer winds and the surface elevation measurements from the altimeter. It is expected that this will lead to a greater understanding of the time and space scales over which the ACC changes. Finally, it will be possible to use this model to consider assimilating surface elevation into a simple numerical model to see how the wind forcing should be changed to improve the estimated surface elevation field. This will lead to a better understanding of where wind information from the scatterometer is less reliable.

Coordinator: Tapley

US6-6

OBSERVATIONS OF MID-LATITUDE SEA LEVEL VARIABILITY

Principal Investigator:
C.J.Koblinsky GSFC, Code 624, Greenbelt, MD

Co-Investigators:
J.G.Marsh (GSFC), F.Sciremammano (Rochester Institute of Technology), T.Keffer (University of Washington, Seattle)

Objectives:

This project seeks to study mid-latitude ocean circulation processes through the use of ERS-1 altimeter data. These processes include mesoscale variations, basin scale fluctuations, and interactions between the general circulation and the eddy field. The principal focus is on annual and interannual timescales. ERS-1 altimeter data will provide a source of sea surface observations between the flights of GEOSAT and TOPEX/POSEIDON, as well as provide significant complementary measurements concurrently with TOPEX after 1992.

In the last three years a description of global mesoscale sea level variations has been successfully extracted from GEOSAT data, as well as deriving a method for estimating the fluctuations of sea level at basin and global scales. ERS-1 measurements will permit these estimates to be refined, and add to a multiyear time series of sea surface change. This data set will provide a useful proving ground for models of global ocean change during the decade from 1985 to 1995.

The results from computations with the ERS-1 altimeter data will be compared with in situ measurements for validation and for analysis of the ocean processes that cause the observed changes in the sea surface. The role of air-sea fluxes of heat, buoyancy, and momentum will be examined with diagnostic models. A description of the annual and interannual variations in sea surface topography during the ERS-1 observation period will be documented. Atmosphere-ocean interactions at this scale will receive special attention.

Experiment Plan:

For determining variations in sea surface topography at wavelengths from 0 to 5000km, conventional collinear or cross-over analyses are used. Studies with GEOSAT altimetry show that these methods effectively filter out the large scale errors caused by poor orbit predictions and isolate short scale variations with adequate accuracy to study most processes. At larger scales, which are important for basin studies, the errors from the orbit determination are merged with the oceanographic signal. A technique has been developed which separates these signals and reduces the orbit prediction errors. This technique uses the altimetry measurements as both surface height information and an alternative source of satellite tracking data. The absolute surface dynamic topography of the ocean is estimated simultaneously with improved estimates of the orbits within an orbit determination procedure. In addition, the earth gravity model, ocean tide models, and altimeter range corrections can be improved.

ERS-1 Data Requirements:

Altimeter data with the corrections necessary to convert altimeter range measurements to corrected sea surface height. Access to ERS-1 satellite tracking information from PRARE and Laser. Access to laser tracking data is especially crucial because it will allow the determination of a consistent set of station coordinates between the various altimeter missions over the past two decades.

Milestones/Deliverables:

Gridded maps of absolute sea surface topography at wavelengths greater than 2000km on a monthly basis throughout the ERS-1 observing period and improved gravity fields and geoids that include ERS-1 altimetry and satellite tracking to spherical harmonic degree and order 50.

1 year after data delivery. Preliminary version of the above deliverables.
2 years after data delivery. Final products.

Coordinator: Tapley

US6-7

A STUDY OF VARIATIONS IN THE ALASKA GYRE AND ARCTIC BASIN APPLYING ERS-1 ALTIMETER DATA

Principal Investigator:
G.S.E.Lagerloef — Science Applications International Corp.

Co-Investigators:
T.C.Royer — University of Alaska

Objectives:

(1) Measure the gyre-wide seasonal and interannual sea surface topography variations in the Alaskan Gyre by analysing ERS-1 altimeter data during the nominal two year mission.
(2) Merge the altimeter analysis with data from WOCE and other coincident field measurement programmes in various parts of the study area, which are anticipated to be underway during the ERS-1 mission. These will provide a more comprehensive analysis of gyre dynamics and provide corroborating measurements to compare with the altimeter results.
(3) Evaluate high resolution wind stress curl (WSC) fields from NMC, FNOC or other accessible model wind data base. These will be correlated with ERS-1 derived gyre-wide sea surface topography to develop and test hypothesis for the gyre variations.
(4) Develop an understanding of the relationship between altimeter height measurement over sea ice, and the desired sea level measurement.

Experiment Plan:

To measure the gyre-wide sea level variability with ERS-1, conventional repeat track analyses of the 35-day and various 3-day repeat segments of the mission will be undertaken. The cross-point least-squares technique will also be evaluated, which analyses variation in sea level at the cross point between ascending and descending altimeter orbits.
Various errors affecting altimeter measurements will be addressed. Orbit error biases will be reduced with a standard cross point analysis technique. The sea state bias will be given special consideration because of the high wind/wave conditions which dominate the region. Approaches to measure the sea state bias from altimeter waveform analysis or through the use of altimeter sigma nought data will be studied and applied. Other sensor corrections (e.g. wet and dry troposphere, ionosphere, atmospheric loading, tides) are expected to be included in the geophysical data record (GDR), and will be carefully evaluated. Field measurements acquired through WOCE and other separately funded programmes will include multiple current moorings, several coastal tide or bottom pressure guages, and seasonally repeated hydrographic transects running north-south across the gyre. These and other data will be merged with the results of the ERS-1 altimeter analysis in a collaborative effort aimed at achieving a more complete understanding of gyre dynamics.
Analysis of altimeter data over sea ice will consider two different approaches. Firstly, altimeter waveform characteristics over ice, and alternative tracking algorithms, will be evaluated using ERS-1, Geosat and Seasat data. Secondly, there will be a study of the relationship of Ku-band ranging over sea ice to the underlying sea level with airborne instruments. These will include a radar altimeter, laser altimeter, microwave radiometer with SSM/I frequencies and GPS positioning.

ERS-1 Data Requirements:

ERS-1 altimeter data are required together with a geophysical data record (GRD) similar to previous altimeter data (e.g. Seasat , Geosat). Access to the global data set will be required to compute long arc orbit corrections. Altimeter waveform data are required for the Alaska Gyre and the Arctic sea-ice covered regions.

Milestones/Deliverables:

Year 1	Implementation of altimeter data analysis schemes on the initial available data, processing model wind and in situ data over the Alaska Gyre, and conducting initial aircraft sea-ice measurements in the Arctic.
Year 2	Thorough analysis of sensor errors and corrections, including study of sea state bias processing algorithms, analysis of continuing data from ERS-1 and preliminary synthesis with field measurement data.
Year 3	Completion of the analysis of the two-year ERS_1 and model wind data sets, merge the long-term results of the field measuremnts, and report on combined observations of the Alaska Gyre variability and its relation to wind stress curl.

Coordinator: Tapley

US6-8

STUDIES OF TROPICAL OCEAN DYNAMICS USING ERS-1 ALTIMETER DATA

Principal Investigator:
R.Lukas University of Hawaii

Co-Investigators:
G.Mitchum/ K.Wyrtki (University of Hawaii), T Busalacchi (GSFC)

Objectives:
Main objectives are to improve the description of the North Equatorial Counter Current (NECC) variability, improve the description of heat content variation and explore the time-space distribution of synoptic variability.

Experiment Plan:
Improve description of NECC variability
Presently it is unknown how the NECC varies in space and time. The results of this improved description will be used to address questions of the dynamics of the current.
Improve description of heat content variation
Analyses of the sparse sea level and XBT data in the Pacific suggest modes of heat content variability which may be important in the El Niño/Southern Ocean phenomena. A more comprehensive description is desired since it is not known how well the existing data distribution can resolve the important variability in space and time.
Explore time-space distribution of synoptic variability
While a start has been made on the study of tropical Pacific sea level space-time variability, the sparse data distribution has forced a concentration on the central and western Pacific. Eastern Pacific variability may be different. Presently, we are unable to even begin such studies in the Atlantic and Indian Oceans. The ERS-1 altimeter-derived sea level will permit a basin-to-basin comparison of the meridional and temporal variability of the synoptic scale sea level variability. How well this can be done depends on the orbital characteristics of the mission.

ERS-1 Data Requirements:
Processed altimeter data for the entire mission for the region between 20°N and 20°S. Processed data needs to be corrected for orbital, atmospheric and tidal variations.

Milestones/Deliverables:
Quarterly progress reports.
Research papers.

Coordinator: Tapley

US6-9

VARIATIONS OF DYNAMIC TOPOGRAPHY ACROSS CRITICAL OCEAN AREAS

Principal Investigator:
G.A.Maul NOAA/Atlantic Oceanographic and Meteorological Laboratory

Co-Investigators:
D.V.Hansen/ J.R.Proni (as above)

Objectives:
This is a WOCE proposal to apply a combination of ERS-1 data and data from two key NOAA projects in ocean aspects of climate dynamics to the study of modes of variability of two intensive current regimes, viz., the zonal current system in the equatorial Pacific Ocean and the subtropical western boundary current regime in the North Atlantic Ocean. While directly aimed at supporting the already developing efforts in predictive ocean modelling in these basins, the experience gained in this work should be useful also for ERS-1 applications in other strong current regimes in the world. These regimes have been pinpointed as critical for the understanding of climatic variability.

Experiment Plan:
Substantial work with both conventional and recently developed techniques (including space-based observations) has helped to define questions of significance both for the problem of monitoring of climate change, and for the specification and verification of modelling requirements for the purposes of climate prediction; questions for which the prospects of solution will be enhanced significantly with the availability of ERS-1 observations. Specifically we need better definition of the energetics and spatial and temporal scales and characteristics of the dominant perturbation models in the proposed study regions. While the study will encompass use of any available data types, the focus will be on the maximal and optimal use of inverted echo sounder/pressure guage (IES/PG) and/or tide guage combinations together with satellite altimetry, and the determination of wind fields from ERS-1 scatterometery. A major effort will also be devoted to identification of the dynamic nature of the dominant perturbation modes, particularly wind forcing, and of approaches to deal with them in the context of modelling and observation of climate change.

ERS-1 Data Requirements:
The data required are SAR (3 images), Scatterometer data (1 tape), Altimeter (1 tape), ATSR (3 images) and Microwave Sounder (1 tape).
Study areas are: 1). 10°S-10°N, 100°W-160°W, 2). 20°N-35°N, 60°W-85°W.
Every image of the ATSR with cloud cover less than 50% is requested, after water vapour corrections and mapped onto a mercator projection.

Anticipated Results:
(1) Definition of optimal strategies for mixed data interpretation, and for the design of climate monitoring systems.
(2) Characterisation of fluctuations regimes essential for specifying model requirements and testing model performance for important sub-regimes in equatorial and subtropical domain numerical ocean models.

Milestones/Deliverables:
Analysis of the in situ historical data is now in progress, and will give the information necessary to fully plan the locations of sea level/ weather stations and IES/PG sites, determine T-S correlations for using XBTs to estimate dynamic height, and to comput the mean dynamic topography.

Coordinator: Tapley

US6-10

ANALYSIS AND PREDICTION USING DATA ASSIMILATION

Principal Investigator:
R.Miller Oregon State University

Objectives:
Data assimilation, i.e., the use of data in conjunction with numerical models for the purpose of analysis and prediction of the state of the ocean, is a new problem in physical oceanography, and elementary questions remain. Development of data assimilation systems for use with satellite data requires extensive study based on historical data.
This investigation consists of two basic components: analysis and prediction of sea level height in the tropical ocean, and analysis and prediction of the mesoscale eddy field. Both of these tasks require wind and surface elevation data. Models of the tropical ocean suitable for analysis of SST data require a thermodynamic component and are therefore more complex than the shallow water models which have been used for sea level height analysis. Such models with coupled thermodynamics are planned, but their development will lag that of the purely mechanical models by as much as two years. The work with ERS-1 data forms part of a data assimilation component of several coordinated projects within the WOCE framework.

Experiment Plan:
Altimeter data will be used in the form of averaged crossover differences as described by Fu and Chelton (JGR, 1985). A method based on the Kalman filter has been developed for using these temporal differences directly for model aided sea-level height analysis without explicitly transforming the altimetric differences to raw sea level heights (miller, Dyn. Atmos. Oceans 1989).
These techniques will be applied to a suite of models of the Antarctic Circumpolar Current (ACC), beginning with a quasi-geostropic eddy resolving periodic channel model similar to McWilliams, Holland and Chow (1978).
Data assimilation models of the tropical ocean have been developed using the Kalman filter and a simple linearised shallow water model (Miller and Cane, JPO 1989). A more sophisticated model, that of Cane and Patton (JPO 1984) is currently being implemented with the Kalman filter.

ERS-1 Data Requirements:
Altimeter and scatterometer data.

Anticipated Results:
(1) A suite of models and data assimilation schemes suitable for use with remotely sensed data.
(2) Maps of sea level height, and perhaps other dynamically interesting quantities, with verified error estimates, for the regions under study.
(3) Quantitative estimates of data sufficiency, i.e., answers to the questions: when are remotely sensed data sufficient to determine the quantities of interest, and, when remotely sensed data are insufficient, how much more data are required?

Coordinator: Tapley

US6-11

MESOSCALE OCEAN CIRCULATION MODELING AND PREDICTION STUDIES

Principal Investigator:
C.N.K.Mooers University of New Hampshire

Objectives:
(1) Assessing the utility of the ERS-1 altimeter data for describing mesoscale variability.
(2) Assessing the utility of introducing ERS-1 altimeter data to a data-assimilative ocean circulation model for improving the descriptions of mesoscale variability.
(3) Conducting Observing System Experiments (OSEs); i.e., using actual (ERS-1 and other) observations to evaluate the impact of various potential ocean observing system designs.

Experiment Plan:
It is planned to use ERS-1 altimeter data in a data-assimilative model for the North Atlantic. The Princeton primitive equation ocean circulation model will be used. The model will run in a data-assimilative mode with mesoscale resolution, and the surface boundary layer dynamics will be included. Particular emphasis will be given to the Northwest Atlantic subdomain (e.g., Gulf Stream, Gulf of Maine and Gulf of Mexico regions).

ERS-1 Data Requirements:
All ERS-1 altimeter data for the North Atlantic is required. Access to scatterometer data or analysed products is also requested, to help estimate wind stress for driving the ocean circulation model, including its upper boundary layer).

Milestones/Deliverables:
Annual summaries of data processing and analysis.
Scientific papers, at the rate of about one a year, dealing with mesoscale data analysis, data assimilation and OSE studies.
Samples of the data assimilative output.

Coordinator: Tapley

US6-12

INVESTIGATIONS UTILISING ERS-1 ALTIMETER AND SCATTEROMETER DATA

Principal Investigator:
J.J.O'Brien Florida State University

Co-Investigators:
M.E.Luther/ D.M.Legler (as above)

Objectives:
This investigation seeks to improve our understanding of short-term climate (or interannual) variability, such as the El Niño/Southern Oscillation (ENSO) phenomenon and variability in Indian monsoon rainfall, through the use of ERS-1 altimeter and scatterometer data in conjunction with numerical models of the wind-forced ocean circulation.

Experiment Plan:
Altimeter data
Sea surface heights derived from ERS-1 altimeter data will be assimilated into existing ocean models for the Indian Ocean, the tropical Pacific, and the California Current system. The variational data assimilation method is similar to that of Talagrand and Courtier (Q.J.R.Meteorol. Soc. 1987) except that a primitive equation reduced gravity model is used (Smedstad, 1989, J.Geophys. Res. Oceans). Using this technique , the models of the tropical Pacific and Indian Oceans can assimilate observations of sea surface height changes along repeat tracks and at cross-over points directly.
Since the models assimilate information on sea surface height changes, an accurate determination of the geoid is not crucial. Since these models also will use the ERS-1 scatterometer data in their forcing fields, they will effectively meld the altimeter and scatterometer data to give a dynamically consistent picture of the upper ocean circulation and its time variability. The higher resolution ERS-1 data, both from the scatterometer and the altimeter, will make it possible to examine smaller scale features than previously possible, such as generation of the great whirl and other eddies in the Somali Current, and tracking of ocean waves associated with El Niño events.
Scatterometer data
ERS-1 scatterometer data will be melded with in situ ship data using the direct minimisation approach of Legler etal. (Mon. Wea. Rev.,1989) to produce 1° by 1°, 5-day maps of surface wind fields for the tropical oceans.

ERS-1 Data Requirements:
All available altimeter and scatterometer data for the tropical band (30°N - 30°S) in near real time. Repeat track differences and cross-over differences (with all corrections applied) are desired for the entire mission.

Milestones/Deliverables:

Pre-launch	Continue refinement of data assimilation technique using Geosat data. Finalise the technique before launch. Interact with other members of the ERS-1 team.
Post-launch	Use ERS-1 data as early as possible to test techniques and make any necessary adjustments. Test for validation at different times of the year using available in situ data.
	Pacific and Indian Ocean wind analyses will be prepared and distributed within two weeks to TOGA and WOCE investigators and other interested parties.

Coordinator: Tapley

US6-13

MONITORING THE ANTARCTIC CIRCUMPOLAR CURRENT VARIABILITY WITH ERS-1 ALTIMETER DATA

Principal Investigator:
F.Sciremammano Rochester Institute of Technology

Co-Investigators:
C.Koblinsky (as above)

Objectives:
The primary thrust of the research is to simultaneously monitor both the large scale and mesoscale variability of the Antarctic Circumpolar Current (ACC). This will be used to assess the relation between these two distinct wavenumber bands, to address related questions regarding the ACC dynamics and energetics, and to assess the significance of the mesoscale field in regards to both the ACC dynamics and meridional transport processes.

Experiment Plan:
It is proposed that the mesoscale variability be identified, characterised and temporally monitored through the use of the mesoscale variance calculated along collinear ground tracks. This is the integral of the wavenumber spectrum of the oceanic variability as measured in the along track direction. It has been found to be a good indicator of the presence of coherent mesoscale features. The use of this parameter will allow for a monitoring of the spatial variability as a function of longitude and the time history of changes at any particular longitude or in any longitude band. It does not allow for a resolution of the latitudinal dependence. This is not a serious drawback when looking at an essentially zonal current system, such as the ACC. In addition, standard root mean square sea height variability will be calculated and utilized for data screening and hot spot identification. The larger scale variability, which also occurs over longer temporal scales, will be monitored with the Fu and Chelton (1985) cross-over technique. This will provide a time series of sea height changes at orbit cross-over points which can be used to infer changes in sea height gradient across the ACC and, hence, the zonal geostropic transport of this current system.

ERS-1 Data Requirements:
Along track height measurements from altimeter data, with all corrections and the best available orbit determinations, at a frequency allowing spatial sampling at least once every 10km. All such data south of 35°S are requested over the entire mission.
Additionally, waveform data is requested for the first 6 months of the mission, including a Northern Hemisphere winter for the regions 20°-60°N, 120°-160°E, and 30°-70°S, 120°-160°E. The purpose of the waveform data is to examine the electromagnetic and/or sea state bias. Tracking data for at least one year of the mission are also required.

Milestones/Deliverables:

Pre-launch	Technique refinement, software development, initial data verification and validation, and related tasks (to continue during the initial 6 months of data delivery).
6 months	Preparation of a detailed report on analysis to date and the potential for meeting study objectives. Analysis and monitoring of both mesoscale and large scale variability will begin and continue in "near real time" to the mission end.
1-3 years	Publication of significant results regarding technique development as well as analyses of the temporal and spatial scales of variability.
3 years	Finalisation of data products and publication of final results.

Coordinator: Tapley

US6-14

EQUATORIAL AND EASTERN BOUNDARY CURRENT VARIABILITY IN THE NORTH AND SOUTH PACIFIC OCEAN

Principal Investigator:
P.T.Strub Oregon State University

Co-Investigators:
M.Levine/ D.Enfield (as above)

Objectives:
ERS-1 altimeter data will be used as part of a long-term study of the temporal and spatial variability of the eastern Pacific Ocean current systems; the Eastern Boundary Current system (EBC), the eastern part of the Equatorial Current System (ECS) and the eastern part of the West Wind Drift (WWD).
Goals include the analysis of both large scale and mesoscale circulation patterns. "Large-scale" refers to basin-scale fluctuation at annual and interannual time scales; "mesoscale" refers to variability with periods less than 60days, regardless of the spatial scale.

Experiment Plan:
Large-scale study
(1) To quantify the horizontal structure and annual/interannual variability of the upper-ocean geostropic transports in each region.
(2) To determine the covariability between the EBC and the eastern extents of the WWD and ECS in each hemisphere, and to estimate the coherence of these currents with the wind field.
Mesoscale study
(1) To quantify the annual/interannual variability of the mesoscale energy in each region, and to determine the relation between the mesoscale variability and wind forcing.
(2) To examine the eastward propogations of fluctuations with periods around 50 days along the equator and continuing poleward along North and South America.
(3) To track selected mesoscale features with a combination of altimeter and satellite temperature (AVHRR) fields.

The total error in fields derived from altimeter data depends on altimeter measurement errors, the analysis methods used and the sampling pattern of the altimeter. The effect of the sampling pattern on the error will be examined using the range of spatial/temporal characteristics of the three altimeters, TOPEX/POSEIDON, Geosat and ERS-1, covering repeat periods of 3, 10, 17 and 35 days. Thus, use of the ERS-1 data will allow an evaluation of which analysis methods are optimum for a given resolution using arange of sampling characteristics.
In addition to a systematic error analysis, techniques will be developed for incorporating auxiliary data into the altimeter analysis. It is planned to use AVHRR data with altimeter observations to track mesoscale features. Coastal and island tide guage data will provide an important check on altimeter results. The ability to make this comparison is especially promising in the S.E. Pacific Ocean where there is a network of tide stations recently augmented by the EPOCS and TOGA projects.

ERS-1 Data Requirements:
The study requires altimeter data from over the equatorial and eastern Pacific Ocean in the northern and southern hemispheres. Data from the initial 3-day repeat and from the 35-day repeat are required.
There is no need for very rapid delivery of the data. Delivery of the data within 6 months of collection will be adequate.

Milestones/Deliverables:

1990-91	Study altimeter errors and analysis methods appropriate for the stated objectives, using Geosat data; Begin acquiring and processing tide guage data; Determine the existence and availability of other historic oceanic data in the region; Identify and collect best wind and surface heat flux data.
1992-95	Initially examine short period variations - compare current systems of North and South Pacific - Compare the resolution of features using Geosat, ERS-1 and T/P data in both hemispheres; Combine altimeter observations with auxiliary data (e.g. sea level, hydrographic and wind data); Quantify the annual cycle and interannual variability; examine forcing by local and large-scale winds and surface heat.

Deliverables will include: (1) reports on data use; (2) progress reports on investigations conducted; (3) information on the comparisons made to coastal and island tide guage data, and to velocity fields derived from AVHRR data; (4) a final report.

Coordinator: Tapley

US6-15

CALIBRATION, ORBIT DETERMINATION AND GRAVITY FIELD/ GEOID MODEL IMPROVEMENT FOR GENERAL OCEAN CIRCULATION AND GEOPHYSICAL INVESTIGATIONS.

Principal Investigator:
B.D.Tapley Center for Space Research, University of Texas, Austin, Texas, USA

Co-Investigators:
C.K.Shum/ B.E.Schutz (University of Texas), D.T.Sandwell (Scripps Institute of Oceanography), J.G.Marsh (GSFC), D.C.McAdoo (NOAA), G.H.Born/ G.W.Rosborough (University of Colorado)

Objectives:
The objective of this investigation is directed toward studies of the basin-scale general ocean circulation, the mesoscale ocean variability, and their time-varying components using ERS-1 data.

Experiment Plan:
The research will use altimeter, scatterometer wind and ATRS/M derived sea surface temperature data in a combined data approach to modeling and predicting changes in ocean circulation. Precision orbit determination techniques will be used to produce an improved model for the Earth's gravity field and the marine geoid as an aid to computing a precise ERS-1 ephemeris. Altimeter calibration activities will be performed with regard to the determination and monitoring of the height bias and its drift, and the altimeter time tag bias. Other geophysical research activities such as the refinement of the ocean tide model, the high resolution marine geoid, and the study of atmsophere/ocean interactions will be performed. The ERS-1 laser and PRARE tracking data, the altimeter data, the scatterometer wind data and the ATSR/M temperature and water vapour content data will be required to carry out this investigation. The scope of the investigation will also incorporate altimeter and tracking data from other satellite missions.

ERS-1 Data Requirements:
(1) Global altimeter data in the form of a Geophysical Data Record for the entire mission are required. Fast delivery (FD) data are also requested for the the Gulf of Mexico, Northwest Atlantic (20°-45°N, 50°-80°W) and Kuroshio (15°-50°N, 120°-180°E).
(2) The complete set of global laser and PRARE tracking data is required for orbit determination and gravity model improvement.
(3) Scatterometer wind products are required for studies in the wind-driven ocean/atmosphere interaction for modeling of ocean circulation.
(4) ATSR/M data are required to obtain the temperature profile, to provide a wet tropospheric correction to the altimeter, and to investigate global water vapour distribution.

Milestones/Deliverables:

Pre-launch	Development of an improved Earth's gravity field model and surface force models for precision orbit determination.
	Testing of an ability to perform ocean circulation modelling by integrating altimetry, imagery, temperature, pressure and other data.
	Data processing modelling techniques will be validated using Geosat and other data.
Post-launch	Analysis of the precision ERS-1 orbit will be performed by including ERS-1 data to produce and improve the gravity model.
	Ocean circulation research will be performed as soon as the ERS-1 data become available.

Deliverables will include: (1) an improved Earth gravity field model complete to degree and order of at least 50; (2) time series of basin scale general ocean circulation topography, nominally at seasonal intervals; (3) a high resolution and accurate global mean sea surface (marine geoid); (4) products associated with regional studies of wind-driven, atmosphere/ocean interacted modelling of the ocean circulation.

Coordinator: Tapley

US6-16

STUDIES OF THE OCEAN CIRCULATION BY SATELLITE ALTIMETRY

Principal Investigator:
C.Wunsch Massachusetts Institute of Technology

Objectives:
To combine altimetric air/sea flux and in situ data on a global basis with dynamical models to estimate the global scale ocean circulation and its variability. The work is directed at the central goals of WOCE.

Experiment Plan:
The investigation requires detailed understanding of data errors, how best to remove them, and the construction of dynamical models in the special forms necessary for use with noisy data. It is planned to attempt all these things, with Geosat data, prior to the launch of ERS-1, so that at the time of ERS-1 launch effective models and procedures have been found. The focus of attention will be the ERS-1 altimetry, the in situ tide guage data, the ECMWF winds, WOCE hydrography and floats, and a dynamical model constructed by D.Haidvogel.

ERS-1 Data Requirements:
Global altimetry with the best possible orbits, and adequate information to make known correctable errors. The data are needed at one/second intervals.

Milestones/Deliverables:

Pre-launch	preparation of software adequate to reduce the data in conjunction with a simple dynamical model on aglobal scale.
18 months	Produce a global dynamically consistent estimates of the absolute oceanic flows, and their variability on monthly and longer time scales.

Deliverables will include maps, with error bars, of the global scale absolute circulation and large scale variability, in numeric form.

Coordinator: Tapley

US6-17

TIME VARYING AND TIME-AVERAGED OCEAN SURFACE CURRENTS FROM ERS-1 AND TOPEX ALTIMETRY

Principal Investigator:
V.Zlotnicki JPL, 4800 Oak Grove Drive, Pasadena, CA.

Objectives:
(1) To estimate mean surface geostropic currents, averaged over at least one year, at wavelenghts ranging from 50km to basin scale, using both the ERS-1 and TOPEX/POSEIDON altimeters. Best results are most likely in the N. Atllantic, NW Pacific, and between Australia and Antarctica, because those are the areas with the best existing coverage of ship gravity data.
(2) Continue a current investigation of the time changes in sea level differences across the Gulf Stream and Kuroshio, to monitor current strength and heating signals.

Experiment Plan:
(1) Obtain gravity data from NOAA - National Geophysical Data Center, subject them to crossover comparisons and adjustments (e.g. Zlotnicki, 1983). Acquire overlapping ERS-1 and TOPEX/POSEIDON altimetry with a one year duration. Check the data for consistency, blunders, correlation with possible path errors (water vapour, ionosphere). Compute mean sea surface and compare to Seasat and Geosat results to detect errors. Perform gravity computation. Compare resulting surface absolute currents to expected results from WOCE ship deployments.
(2) Acquire ERS-1 altimetry data. Perform computations already set up. Compare to wind stress curl from ECMWF or other sources.

ERS-1 Data Requirements:
This study requires global altimeter heights above reference ellipsoid, geolocated, with path corrections (ionosphere, troposphere), calibrated for instrument bias and sea state, and with tidal corrections. Ideally, one year of ERS-1 data exactly overlapping in time with TOPEX would be used.
If the supply of ERS-1 data has to be restricted, the priority areas are: 1) 15°W-45°E, 280°-350°; 2) 15°W-45°E, 120°-200°,; 3) 15°W-45°E, 110°-200°.

Milestones/Deliverables:

1/91-6/91	Assemble gravity data set.
6/90-6/91	Adapt all software currently used for Geosat to ERS-1 and TOPEX constraints.
6/91-6/92	Receive and process ERS-1 altimetry for Gulf Stream-Kuroshio study. Compute Gulf Stream and Kuroshio transports.
6/92-6/93	Receive and process ERS-1 altimetry for gravity study.
6/92-6/93	Receive and process TOPEX/POSEIDON data.
12/92-6/93	Compute increasingly more complete mean sea surface and gravity residuals.

Deliverables will include: a) the publication of results in the refereed literature, and b) grids of mean circulation in the N. Atlantic and N.Pacific, every 1°.

Coordinator: Tapley

US11

REMOTE SENSING OF THE VARIABILITY OF THE NET HEAT AND FRESH WATER FLUXES IN THE TROPICAL PACIFIC OCEAN

Principal Investigator:
Catherine Gautier California Space Institute, Mail Code A-021, UCSD, La Jolla, CA 92093, USA

Objectives:
(1) Development and validation of new algorithms for estimating the surface net heat and fresh water fluxes.
(2) Assessment of the causes for low-frequency variability of the surface heat and fresh water fluxes in the tropical regions, particularly over warm SST regions.
(3) Assessment of the role of the net heat and fresh water fluxes in the maintenance of the Western Pacific warm pool.
(4) Improved understanding of the effects of the net heat and fresh water flux variability on the upper ocean density structure.

Experiment Plan:
Study of the surface net heat and fresh water flux variability in the tropical Pacific during TOGA COARE experiment. Observations from ERS-1 sensors, as well as other satellite sensors on GMS and DMSP, will be used to develop new algorithms for estimating the net heat and fresh water fluxes over the tropical regions over 100km and 10-day scales. The satellite estimations will be validated with in situ measurements taken from research vessels, aircraft or instrumented buoys or island sites during the enhanced monitoring period of TOGA-COARE (November 91 - October 93).

ERS-1 Data Requirements:
All available data for the Western tropical Pacific (180°-100°E, 30°N- 30°S).

Anticipated Results:
(1) New tested algorithms for estimating the surface heat and fresh water fluxes in the tropical regions, from combinations of satellite sensor data.
(2) Validated monthly mean surface heat and fresh water flux maps for the western tropical Pacific.

Coordinator: Freilich

US12

OCEAN CIRCULATION IN THE CARIBBEAN SEA AND ADJACENT REGIONS

Principal Investigator:
G.A.Maul — NOAA/ Atlantic Oceanographic and Meteorological Laboratory, 4301 Rickenbacker Causeway, Miami, FL.

Objectives:
This proposal is to validate ERS-1 measurements of sea surface topography, wind velocity, current boundaries and significant wave height for physical oceanography and climate studies in the Caribbean Sea and Adjacent Regions (CSAR). This will address the following CSAR needs:
(1) Local-scale circulation and wave climate including marine meteorology.
(2) Basin-scale surface currents and fluxes of heat, salt and water.
(3) An intensive effort in training, education and mutual assistance.

Experiment Plan:
With the many islands in the CSAR, sea level differences can potentially be used to nowcast average surace currents and volume transport between sea-level/weather stations. But with a spatial resolution of several hundred kilometers between stations, more detailed data are needed. Although other satellites (GEOSAT, NROSS, TOPEX/POSEIDON) can provide some of the temporally detailed sea surface height and wind data that are needed, it is anticipated that ERS-1 can best provide the resolution necessary.
Also unique to ERS-1 is the ability to simultaneously measure other variables. Significant wave height from altimetry, for example, will provide improved wave climatology to further understand sediment transport. ERS-1 SAR data could provide images of wave patterns along island and continental coasts (if the data can be acquired) and could be used to study radar lineations associated with current boundaries.
The Intergovernmental Oceanographic Commission (IOC) network of sea-level/weather stations, as well as existing coastal and island sea level and weather stations, will be used in validating ERS-1 coverage of the CSAR. ERS-1 data will be supplemented by satellite tracked drifters, so as to develop a time history of sea surface currents for general understanding of the basin-scale flow, and for detailed patterns along coasts and islands. Ships from three IOC meber states will obtain approximately 6 ship months of in situ data per year, with particular emphasis on inflow/outflow quantification so that CSAR can be numerically modeled with continuity closure. Ancillary data from the ERS-1 microwave sounder and the ATSR will be reviewed as an integral aspect of this science, applications and validation study.

ERS-1 Data Requirements:
Altimeter, scatterometer and microwave sounder digital data are required for one year for the verification phase. Area of coverage is approximately: 3°-35°N, 50°W- 98°W.
Processing is not planned for real time, in all cases the 6 months lag time for PAFs will be in phase with other data collection and processing times.

Milestones/Deliverables:
The results of the work will be reported in refereed journals, in data reports, and in summary reports of IOC conferences.

Coordinator: Tapley

US13

KUROSHIO EXTENSION REGIONAL EXPERIMENT (KERE)

Principal Investigator:

J.L.Mitchell — Naval Oceanographic and Atmospheric Research Laboratory, Code 321, National Space Technology Laboratories, Mississippi

Co-Investigators:

D.Johnson (as above)

Objectives:

This program is an investigation of the dynamics of western boundary currents, comparing results and hypotheses derived from Gulf Stream studies to the Kuroshio Extension. Specific issues which have been identified during on-going Gulf Stream studies, include: a). The importance of a Deep Western Boundary Current, governing the current's separation from the coast and theextent of the Gulf Stream's eastward penetration; b). The role of wind stress curl forcing in governing the path of the Gulf Stream; c). The ability to simulate the dynamics of the Gulf Stream mesoscale with only a few vertical modes; d). The impact of bathymetry in governing the regional distribution of both deeop and surface eddy kinetic energy.

The Kuroshio Extension Regional Experiment (KERE) will focus on the above issues and derive a better understanding of western boundary currents by determining the causes of similarities and differences between the Kuroshio Extension and the Gulf Stream.

Experiment Plan:

KERE represents a coordinated programme involving the major techniques of remote sensing, field experiment and ocean circulation modelling. Key data types supporting the KERE are satellite altimetry from SALT, TOPEX/POSEIDON and ERS-1, scatterometry and wave image analysis from ERS-1, and infrared imagery from ERS-1 and NOAA satellites. In situ data will come from Inverted Echo Sounders with bottom Pressure Guages (IES/PSs), current meters, current drifters, and AXBT/XBT surveys. As in the earlier Guf Stream study, data synthesis and analysis will proceed through the use of regional, eddy resolving numerical models of the ocean circulation. Field experiment design will be largely motivated by (and its strategy planned) using numerical model simultations. Field efforts will include mooring arrays near the separation of the Kuroshio from the Honshu coast.

The vast quantities of altimeter-measured sea surface topography available from the altimetric satellites will allow improved analyses dependent upon model assimilation schemes. Scatterometer-derived winds from ERS-1 will allow a detailed examination of the role of the surface wind forcing in modulating a western boundary current. Analysis of these satellite data will proceed in both Kuroshio Extension and Gulf Stream systems, while the collection of insitu data will be made in the Kuroshio Extension only.

ERS-1 Data Requirements:

Data required for effective completion of the project include altimeter GDR, scatterometer GDR, wave number spectrum GDR and ATSR IR GDR. Data are required for the entire mission to develop altimeter reference surfaces and wind stress model spin-up data.

For comparison of Gulf Stream and Kuroshio Extension dynamics, the areas of coverage for AMI and ATSR data are: 1) NW Pacific: 15°N-55°N, 120°E-150°W; 2) NW Atlantic: 20°N-55°N, 20°W-100°W.

For the altimeter GDR, global data coverage in required in order to correct for radial orbit errors in the geographic areas of interest.

Milestones/Deliverables:

1990-91	Planning for KERE.
1990-92	Model and simulation development for KERE.
1992-94	Field activities in the NW Pacific.
1993-	Analysis, presentation of results.

Deliverables include annual progress reports on data use, final reports on investigations, reports and presentations to the final workshop and attendance at PI meetings.

Coordinator: Tapley

B2

CORRÉLATIONS ENTRE LES DONNÉES MÉTÉO-MARINES ET LA DYNAMIQUE DES PLAGES: CONTRIBUTION DE LA TÉLÉDÉTECTION (ERS-1)

Principal Investigator:
A.Ozer Laboratoire de Geomorphologie, Universite de Liege, Place du 20 Auot, 7, Liège, Belgium

Co-Investigators:
G.DeMoor (Univ. Gand.), G.Fierro/ A.Ramella (Univ. Genova), A.Marini (Univ. Cagliari), D.Bay (Station océan de Calvi et Univ. de Liège), M.Erpicum/ J-P.Donnay (Univ. Liège)

Objectives:
Le but de cette recherche est d'obtenir une meilleure compréhension, grâce aux informations télédétectées par le satellite ERS-1, des relations existant entre les conditions météorologiques (vent) et le plan de houle d'une part, et le transport littoral d'autre part, en vue d'établir le bilan sédimentaire de quelques plages-test.
Les secteurs de recherche sont choisis en fontion de leur intérêt géomorphologique, de leur fragilité liée à des activités anthropiques, de leur accesssibilité pour les vérités-terrains et des données qui ont déjà été récoltées. Il s'agit de 5 plages dont voici les localisations:

A. deux plages du littoral ligure (Italie) exposées an secteur méridional:
  1. la plage de Finale-Ligure (ouest de Genova)
  2. la plage de Lavagna (est de Genova)

B. Deux plages des fles de Méditerranée occidentale exposées au secteur septentrional:
  3. la plage de Sorso (Sardaigne septentrionale)
  4. la plage de Calvi (Corse septentrionale)

C. Une portion du littoral belge (Mer du Nord) comprise entre le port de Zeebruge et la frontiére néerlandaisle.

Experiment Plan:
Pour tiutes ces plages, les sources d'alimentation en sédiments seront identifiées (apports de rivières, de torrents, érosion marine de dépôts quaternaires - terrasses marines et fluviatiles pléistocènes ou de dépôts de pente). Ces apports seront quantifiés et leur répartition sur la plage en fontion du type de houle et du plan de houle. L'impact des ouvrages d'art littoraux ou autres constructions sur le transit sédimentaire par le courant de dérive sera évalué.
Enfin, outre l'aspect scientifique, l'apport de cette recherche pourrait être très utile pour une meilleure gestion des plages.

ERS-1 Data Requirements:
SAR. Ilest souhaité obtenir un passage par saison pour chaque plage-test, chacun se limitera à environ 5km de littoral avec la meilleure définition (30x30m).
En outre, en cas de tempête, il est demandé d'obtenir avant (en différé) pendant et après (intervalle de 3 jours).

Coordinator: Cuq

F15

APPLICATIONS DE GENIE CIVIL MARITIME SUR LA CÔTE MARITIME

Principal Investigator:
C.Valerio — Département Laboratoire Régional d'Aix en Provence, C.E.T.E. Méditerranée, Zone Industrielle d'Aix en Provence, BP 39 - 13762 Les Milles Cedex

Co-Investigators:
M.Cotel, M.Petrini, Serres, M.Longe

Objectives:
L'objectif de la proposition est d'evaluer les possibilités de l'ensemble SAR, imageur et mode vague complété de l'altimétre radar pour le dimensionnement et l'entretien des ouvrages d'aménagement et de protection du littoral méditerranéen.
Elle portera donc sur des besoins très concrets, quotidiens, de gestion des ouvrages à la mer. Son objectif est d'intégrer des données satellitaires aux autres outils déjà disponibles comme les instruments de mesure en mer (houlographe, marégraphe) et les modèles mathématiques et physiques de simulation du champ de houle (plan de vague).
Une évaluation économique des gains envisageables au niveau de la réalisation et de l'entretien des oouvrages à la mer, due à une meilleure connaissance de la grandeur des phénomènes intervenants, sera effectuée.

Experiment Plan:
Trois thèmes essentiels ont été retenus:
Thème 1 - Connaissance de la houle pour le dimensionnement des ouvrages d'aménagement et de protection du rivage méditerranéen.
Thème 2 - Transport sédimentaire et érosion du littoral.
Théme 3 - Mise en place d'un réseau d'enregistrement des données océanologiques de la côte méditerranéenne permettant d'une part de valider les données des capteurs d'ERS-1 et d'uautre part de les compléter en vue des pr½½visions (état de la mer) de surveiller le milieu, et d'apporter des éléments d'étude aux 2 thèmes précédents.

ERS-1 Data Requirements:
SAR et l'altimètre radar pour la littoral méditerranéen.

Coordinator: Cuq

F16

ANALYSE DES PROCESSUS GÉODYNAMIQUES DE L'ÉVOLUTION DES LITTORAUX MEUBLES

Principal Investigator:
F.Cuq Laboratoire IMAGEO, UPR 30 CNRS, 191, rue Saint Jacques 75007 Paris
Tel: 16 1 43 29 31 99

Objectives:
Analyse de l'action de la houle sur les littoraux meubles, etude de la morphologie sous-marine, processus dynamiques de transport sédimentaire.

Experiment Plan:
(1) Analyse des déformations de la houle à la côte et étalonnage du SAR pour l'estimation de la direction et de l'amplitude des vagues. 2 sites retenus sur la côte atlantique française:
France 1 (Ouessant) 5°15'W - 4°30'W, 48°20'N - 48°50'N.
France 2 (Pertuis) 1°45'W - 1°W, 45°40'N - 46°20'N.
(2) Impact de la houle à la côte, analyse de la morphologie sous-marine. 1 site retenu en Mauritanie:
Mauritanie (Banc d'Arguin) 16°W - 18°W, 19°15'N - 21°15' N.

Les données SAR seront étalonnées au moyen de mesures effectuées en mer par des bouées directionnelles, marégraphes courantomètres et houlomètres, sondeurs de précision et sonde multicapteurs. La calibration de l'amplitude des houles fait l'objet d'une étude sur modele réduit et in situ.

ERS-1 Data Requirements:
En fonction de la date de lancement, les données requises (uniquement images SAR 16 bits) sont les suivantes:
FRANCE 1: Orbite a 35 jours, couverture partielle de la zone, 1 à 2 images par mois en 91 et 92, de septembre à mars, 20 images au maximum.
FRANCE 2: Orbite à 3 jours (phase de commissionement), en fonction de la période de lancement, sélection des images de tempête sur zone de validation de l'ESA, maximum 10 images.
MAURITANIE: Orbite à 35 jours, couverture totale de la zone au moins une fois, plus 10 images/an en période hivernale, soit 30 image maximum.

Anticipated Results:
Mise en évidence et quantification des paramètres caractéristiques de la houle côtiére (estimation de la direction et de l'amplitude); caractérisation de l'action de la dérive littorale, analyse des turbidités, cartographie de la morphologie sous-marine du Golfe d'Arguin (Zone non levée).

Milestones/Deliverables:
Avant le lancement
Amélioration des logiciels existants et préparation des plans de mission à la mer; montage administratif de projets de soutien et mise en place des collaborations.
Après le lancement
Evaluation rapide de la qualité des images (Dans les trois mois après la réception des premières données), adaption des logiciels et début de l'étalonnage (année 1992), repport définitif (début 1993).

Un rapport d'activité tous les 6 mois, un rapport final à l'issue de l'étude. Les principaux résultats obtenus seront publiés dans des revues scientifiques.

Coordinator: Cuq

I6

OCEANOGRAPHIC EXPERIMENT

Principal Investigator:

P.Murino — Ist. di Aerodinamica, Universita di Napoli, P. la Tecchio 80, I-80125 Napoli, Italy
Tel: 081 7682351 Fax: 081 632044

Co-Investigators:

L.Mirabile (Ins. di Oceanologia, 1st Universitario Navale, Napoli)

Objectives:

To improve the knowledge of the regime of long gravity waves along the shores of the Gulf of Naples and adjacent seas.

Experiment Plan:

To measure the long wave field through submarine tide guages and wave-recorders and use the data to feed a numerical model for the propagation of long waves that take into account nonlinearity, phase dispersion, refraction and diffraction. The waves near the coasts will therefore be calculated from the knowledge of the far field and compared with observations.

Test areas are the Gulf of Naples (Centre: 40°40'N, 14°10'E; diameter 60km) and the Gulf of Salerno (Centre 40°20'N, 14°30'E; diameter 80km).

ERS-1 Data Requirements:

SAR data required for the period October - April, every 35 days (both ascending and descending modes).

Facilities to be Deployed:

Boat for deployment of Aandera submarine tide guages and Datawell wave-recorder working with real time radar transmission and acquisition of data.

Anticipated Results:

Oceanographic observations of waves will be combined with ERS-1 SAR data to initialize and validate a model for the propagation of long waves.

Milestones/Deliverables:

1990-92	Planning and conduct of the experiment: development of the mathematical model.
1992-94	Feeding the model with combined oceanographic and ERS-1 data.

Coordinator: Frasseto

NL8

MEASUREMENTS OF LAND/SEA TRANSITION FROM ERS-1 SAR AT DIFFERENT PHASES OF TIDAL WATER

Principal Investigator:
B.N.Koopmans ITC, 350 Boulevard 1945, PO Box 6, Enschede, The Netherlands

Objectives:
(1) To establish the extent to which land/water boundaries are mappable from ERS-1 SAR imagery.
(2) To establish the extent to which the bottom configuration can be deduced from patterns visible on radar imagery and their visibility under different tidal and weather conditions.

Experiment Plan:
SPOT data will be used in the preparatory phase to select test areas and locations for corner reflectors.
Simultaneous with radar acquisition, ground data will be collected concerning water/land boundaries, morphometric characteristics of land and water and water level measurements. An aerial photograph underflight will be carried out during the lowest tide simultaneous with radar acquisition. A topographic model will be produced.
Radar images acquired during low tide will be used for monitoring morphodynamic processes on a yearly basis.
The study also aims to monitor changes in coastal configuration over longer periods in the Waddensea, and particularly in the Zeeland delta area. This will establish areas of sedimentation and erosion, and dynamic changes in the stream and gully patterns.

ERS-1 Data Requirements:
6-8 SAR images obtained during different stages of the tidal cycle.

Anticipated Results:
Evaluation of the usefulness of SAR for the survey and morphological analysis of tidal flats to make optimum use of the fundamental characteristics of the areas.
The study has a direct practical implication on the understanding of the coastal processes in the Rhine delta area. Monitoring by imaging radar on a bi-monthly basis during low water will contribute to the understanding of the changing dynamics in this zone during the different seasons around the year.

Coordinator: Cuq

PIP.BCB12

NOAA COASTAL OCEAN PROGRAM: COASTAL ECOSYSTEMS AND COASTWATCH

Principal Investigator:
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NOAA/National Environmental Satellite Data and Information Service(NESDIS), Room 302, SPC, Washington, D.C. 20233, USA Tel: 301 763 4244

Objectives:
Coastal Ecosystems
(1) Ice Edge Ecosystems: Determine role of Bering and Chukchi sea ice in controlling Arctic ecosystems.
(2) Fisheries-Oceanography Coordinated Investigations (FOCI): Study the simultaneous biological and physical processes which occur in walleye pollock egg and larvae patches.
Coastwatch
Demonstrate the utility of SAR data within NOAA Coastwatch for environmental systems management in Alaskan coastal waters.

Experiment Plan:
Coastal Ecosystems
(1) Use NOAA field research activities to provide surface truth data for evaluation of features in SAR imagery.
(2) Use SAR data tactically to plan and guide observation and sampling programs and interpretively to determine local-scale eddies, current systems, frontal boundaries, surface wind and waves, and internal waves.
(3) Study relationship between variation of maximum ice extent and seasonal ice retreat and the variability in biological productivity of the Bering and Chukchi Seas.
(4) Improve ability to predict year-class strength of walleye pollock by studying how variability in the physical and biological environment affect larval and egg survival and how available in-situ and satellite data analysis can be used to monitor the relevant environmental factors. Techniques of SAR interpretation will be developed first for the FOCI activities in the Shelikof Strait before attempting a more ambitious Bering Sea study.
CoastWatch
(1) CoastWatch is an environmental information delivery and analysis system for aiding environmental management decision making.
(2) Use SAR data in an applications demonstration to evaluate usefulness in a PC-based workstation environment for environmental monitoring and assessment.
(3) Assess the utility of SAR data for applications such as oil spill mapping, fishing vessel tracking, iceberg tracking, and general environmental quality monitoring.

ERS-1 Data Requirements:
SAR data:
Coastal Ecosystems: Bering and Chukchi Seas Ice Edge Melt Zone - Spring Breakup; Anadyr Strait - Spring to Autumn; St Lawrence Is. and Norton Sound Polynyas - Winter and Spring; Shelikof Strait, Aleutian Basin Slope and Adjacent Continental Shelf - Late Winter to Autumn
CoastWatch: Beaufort Sea Alaskan Coast - Summer to Autumn; Prince William Sound and Cook Inlet - All year

Facilities to be Deployed:
In Shelikof Strait, there will be CTD surveys, three current moorings, two island-based weather stations, and satellite and Loran-C tracked drifting buoys. Similar field equipment will be used in the Bering Sea surveys.

Anticipated Results:
(1) Ice edge, eddy and current information obtainable from SAR data will be valuable in understanding environmental processes that lead to variability in biological productivity and enhanced or reduced recruitment.
(2) Information derived from SAR on currents, ice, surface and internal waves, frontal boundaries, eddies, ship wakes, and oil slicks will be useful for the monitoring of environmental quality and the management of environmental systems.

Milestones/Deliverables:

1991	Limited test data for analysis and development.
April-Aug.1992	Major data collection and analysis activities

Coordinator: PIPOR

PIP.LAB6

CASP 2 - COASTAL OCEANOGRAPHIC EXPERIMENT/ SIR-C

Principal Investigator:

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Co-Investigators:

M.Ikeda/ C.Anderson/ C.Tang/ C.Mason (BIO)

Objectives:

To observe and model wind-driven ice motion and circulation on the northern Grand Bank and Newfoundland Shelf using SAR and altimeter data.

Experiment Plan:

To measure the circulation (esp. near surface), wind and density fields and ice distribution in a small region on the northern Grand Bank and Newfoundland Shelf near the Hibernia oil field. The experiment will employ moored instruments, ship-borne current and hydrographic profilers, and validate an eddy-resolving wind-driven model of the circulation and ice motion.

ERS-1 Data Requirements:

Essential

(1) ERS-1 SAR for the Hibernia area (45-50° N, centred on 47°N, 49°W); ascending and descending passes for 3-day repeat orbit (24.360°); 15 February - 15 March , 1992.

(2) ERS-1 Altimeter for the Hibernia area; Dec. 1991 - April 1992.

Desirable

(1) ERS-1 SAR for Hibernia region; ascending and descending passes for 3-day repeat orbit; 1 Jan - 15 March, 1992.

(2) ERS-1 SAR for Hibernia region (45-53°W); ascending and descending passes for 17-day repeat orbit; 15 March - 30 April, 1992.

Facilities to be Deployed:

(Available as part of the CASP 2 Experiment).
Ships to deploy/recover instruments and conduct survey.
6-10 current meter moorings, including at least 2 bottom-mounted current profilers (ADCP).
Ship-borne current profiler (ADCP), Batfish CTD.
2 Minimet buoys + moorings.

Anticipated Results:

Oceanographic observations of the current, density field, sea ice and surface wind distributions will be combined with ERS-1 SAR and altimeter data plus NOAA infrared imagery to initialize and validate a coupled ice-ocean model driven by wind, tide and upstream forcings.

Milestones/Deliverables:

1990-91	Detailed planning for experiment
1991-92	Prepare and conduct experiment
1993-94	Provide fully-tested model for circulation and ice-motion based on ERS-1 and oceanographic data sets.

Coordinator: PIPOR

US8-2b

COASTAL OCEANOGRAPHIC EXPERIMENT WITHIN THE CANADIAN ATLANTIC STORM PROGRAM (CASP II)

Principal Investigator:

P.C.Smith/F.W.Dobson — Department of Fisheries and Oceans, Physical and Chemical Sciences (PCS), Bedford Institute of Oceanography (BIO), PO Box 1006, Dartmouth, N.S., B2Y 4A2, Canada Tel: 902 426 3474(Smith) 3584 (Dobson)

Co-Investigators:

M.Ikeda/ C.Tang/ W.Perrie/ S.D.Smith/ C.Anderson/ C.Mason (as above)

Objectives:

(1) To observe and model sea ice motion and circulation in the vicinity of the Hibernia oil field on the northern Grand Bank and Newfoundland Shelf using SAR imagery and altimeter measurements.
(2) To examine the relation between scatterometer measurements and the surface wind and wave fields observed in the open Northern Atlantic during winter.

Experiment Plan:

Deploy moored and ship-borne intruments in the Grand Banks study area (45°-50°N, 45°-53°W) to measure oceanic curents and density fields, sea ice distribution, properties and motion, directional surface wave spectra and surface wind. Conduct the field measuremnts in cooperation with the Atmospheric Environment Service (AES) during the winter of 91-92 as part of Phase II of the Canadian Atlantic Storms Program (CASP II).

Facilities to be Deployed:

8 current meter moorings, 3 acoustic Doppler cuurrent profilers (ship and bottom mounted), hydrographic profilers (towed Batfish and winch-mounted CTD's), 3 surface meteorological buoys with near-surface current meters, directional wave buoy, ship-mounted anemometers and ship-mounted wave-detecting radar.

Anticipated Results:

(1) Oceanographic observations of currents, density field, sea ice and surface wind distributions will be combined with ERS-1 SAR and altimeter data and NOAA infrared imagery to initialize and validate a coupled eddy-resolving ice-ocean model driven by wind, tides and upstream forcing.
(2) Measurements of surface waves and wind will be used to relate airborne (CCRS) and ERS-1 wind/wave mode observations to surface wind and sea state.

Milestones/Deliverables:

Dec 1990	Draft experiment plan.
6 months	Preliminary report 6 months after receipt of data.
24 months	Final report or open literature manuscript.

Coordinator: Freeman

D10

UTILISATION OF SAR FOR INVESTIGATION OF FRONTAL ZONES, OIL POLLUTION AND COASTAL BATHYMETRY, AND THEIR APPLICATIONS TO SERVICES IN THE NORTH SEA

Principal Investigator:
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Co-Investigators:
G.A.Becker/ J.Dippner/ K.Figge/ H.Franz/ H.Heinrich/ K.Richter (as above), W.Alpers (University of Bremen)

Objectives:
(1) To detect hydrographic fronts, to describe the development of these fronts, and to produce statistics by means of SAR images.
(2) To chart bottom structures in the North Sea by means of SAR images.
(3) To detect and trace oil pollution by means of SAR images.

Experiment Plan:
The area of interest includes the German Bight with the North and East Frisian coastal zones and the adjacent sea areas of the open North Sea (53°15' - 55°30' N, 6° - 9°E).
During the prelaunch period, on-going oceanographic and geomorphologic investigations will be continued with special regard to ERS-1 requirements. This includes cruises of the research and survey vessels, aircraft surveillance, and the development and improvement of numerical models.
The photogrammetric evaluation of SAR images produced as "Fast Delivery Products" will be carried out manually. Off-line products, such as the GCP corrected digital images, together with temperature data of other space-based data sources will be processed on workstation analysis systems.

ERS-1 Data Requirements:
SAR data and images of the North Sea. Images should preferably be GCP corrected, but there is no need to apply all geophysical corrections to the data prior to dissemination.

Anticipated Results:
It is expected that the results will help to assess to what extent space-based radar data can be used for the monitoring of hydrographic fronts and oil pollution.

Milestones/Deliverables:

Prelaunch	Regular investigations in the German Bight, installation of a workstation for image processing linked to DLR computer facilities.
ERS-1 mission	Intensive data collection in the German Bight.
Post mission	Data processing, evaluation and analysis.

Coordinator: Cuq

J3-1

OIL POLLUTION DETECTION AND WAVE OBSERVATION IN THE SEA ADJACENT TO JAPAN BY SAR IMAGES

Principal Investigator:
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Co-Investigators:
T.Kozu/ Dr.T.Ojima (as above).

Objectives:
(1) To evaluate the oil slick detection capability by C-band SAR. Simultaneous observation of artificial oil slick by spaceborne, airborne and shipborne microwave sensors and comparison with sea truth data.
(2) Imaging mechanism of long gravity waves by SAR using data obtained simultaneously by the oil detection experiment.

Experiment Plan:
Artificial oilslicks will be produced using oleyl alcohol. Two or three different size oilslicks will be produced from a ship running perpendicular to the wind direction.
The experiment will be carried out in two different seasons of the year to obtain data under different wind conditions.
The proposed experimental site is the Pacific Ocean about 30-400km south of the coast of Shikoku Island (Lon. +13250 t0 +13450, Lat. +02900 to +03300).

ERS-1 Data Requirements:
Full Imaging Mode FD SAR image (2 images per experiment, with 2 experiments per year).
Wave Mode Intermediate Product (Data from 2 passes per experiment, with 2 experiments per year).
Data delivery within 1 month of each experiment.

Facilities to be Deployed:
9.53GHz VV-polarised SLAR, 18 channel airborne MSS, L,C,X-band multi-polarisation FM-CW scatterometer, wave rider, radio buoy data, shipborne meteorological instrument data.

Facilities for Data Analysis
ACOS-850/20 large computer system for general data processing/analysis.

Anticipated Results:
(1) Oil detection capability of C-band SAR will be evaluated under various conditions of wind vector, coupled with ancillary data.
(2) SAR imaging mechanism of waves will be eluciated from the comparitive analysis of SAR and SLAR images of long gravity waves for oil-covered and clear surfaces.

Milestones/Deliverables:

1988-90	Data analysis of existing data (SEASAT, SIR-B) and the production of data analysis program by using the simulated data products. Oil slick detection experiment using airborne X-band SLAR.
1991-92	Prepare and conduct experiment, data analysis and evaluation.

Coordinator: Fujita

N4

SHIP TRAFFIC MONITORING USING THE ERS-1 SAR

Principal Investigator:

T.Wahl — Norwegian Defence Research Establishment (NDRE), Box 25, N-2007 Kjeller, Norway
Tel: 47 2 737662

Co-Investigators:

K.Aksnes/ K.Eldhuset/ J.Gj_rven/ A.Sk_elv (as above)

Objectives:

The project aims at a through study of the visibility of ships and wakes in SAR images together with a demonstration of near real-time ship traffic monitoring using the ERS-1 SAR. Software development and scientific analysis will be carried out at NDRE. The automatic system for ship detection in SAR images will be run at Troms_ Telemetry Station where, according to the Norwegian National Space Plan, SAR signals will be received and processed. The feasibility and basic elements of such a system have been assessed in an ESA Contract Study recently carried out at NDRE.

Experiment Plan:

The following experimental activities are planned during the post launch phase:
(1) A well controlled experiment on ship detection in connection with an oceanographic/ meteorological campaign similar to a 1988 campaign at Haltenbanken.
(2) Sporadic collection during the ERS-1 flight of data from ships predicted to be inside the SAR swath. Video or photographic documentation of the wakes. Weather and sea state reports.
(3) Running of an experimental near real-time system for detection of ships in the Norwegian Economic Zones based on SAR images processed at Troms_ Telemetry Station. Comparison of detection results with coastguard reports.

It will be attempted to equip some ships with Argos buoys and to position these ships with the doppler positioning system installed in Troms_.

ERS-1 Data Requirements:

Extensive coverage of SAR over the North Sea, the Norwegian Sea and the Barents Sea. The exact locations of the areas to be covered are quite flexible as the actual areas of interest are very large. If possible, coverage from both ascending and descending passes should be acquired for areas in the far north to provide coverage twice during a 3 day cycle.
As the plans call for local SAR processing at Troms_, there is no requirement for SAR image processing by ESA.

Anticipated Results:

Visibility	Assessment of the ERS-1 ship and ship wake detection capability in terms of: Ship size - ship speed - wind speed - wave height - aspect angle - ionospheric activity - presence of grease ice - topography (fiords)
Surveillance	Demostration and testing of operational aspects of satellite SAR surveillance, including automatic ship detection and information extraction.
Modelling	The project will supply critical test results on imaging models for the various wake components.

Milestones/Deliverables:

1990	Pre-launch experiments, including software development.
1991	Major experiment. System testing. Data analysis.
1992	Data analysis.

Coordinator: Johannessen

N5

REMOTE SENSING OF OIL POLLUTION

Principal Investigator:
R.B.Olsen — Oceanographic Center, SINTEF group, Trondheim, Norway.

Co-Investigators:
S.E.S_rstr_m (as above), K.Buer (Norwegian Computing Center, Blindern, Oslo), E.H_ygaard (State Pollution Control Authorities, Oslo), H.Johnsen (FORUT, Troms_), R.Shuchman (ERIM, Ann Arbor, Michigan, USA)

Objectives:
(1) Study the capabilities of the ERS-1 sensors in detecting oil pollution.
(2) Study how different environmental conditions (waves, wind) affect the observations.
(3) Develop methods for analysing and using the remote sensing data for oil detection, surveillance, drift prediction and combat purposes.

Experiment Plan:
It is planned to carry out prelaunch and postlaunch experimental oil spills on Haltenbanken, in order to determine the possibilities for detecting oil pollution with the ERS-1 sensors. Statistical analysis methods will be developed for extracting vital information from the data. The exoperiment will be carried out in conjunction with the NORCSEX programme of wind, wave and current observation.

ERS-1 Data Requirements:
SAR images of the experimental site at Haltenbanken. Approximately 4-5 preprocessed images are required during the 3 day cycle.

Facilities to be Deployed:
2 research vessels, 1 "oil tanker" for transport and spillage of the oil and 2 motor launches for performing the in situ measurements.

Anticipated Results:
(1) Establish how well oil spills can be detected with satellite sensors, especially SAR.
(2) Devise a system for assimilating remote sensing data for operational forecasting of oil drift.
(3) Develop methods for analysing SAR images for textures and extracting time and space correlated information.

Coordinator: Johannessen

UK14-27

DETECTION OF OIL SLICKS

Principal Investigator:

J.Abbott — Warren Springs Laboratory, Gunnels Wood Road, Stevenage, Herts, UK

Objectives:

(1) To determine if oil slicks can be detected by SAR and Wind Scatterometer.
(2) To determine if slicks can be distinguished from other surface features, e.g. biogenic slicks
(3) To investigate the practical application of the techniques for monitoring accidental spillages and operational discharges of oil.

Experiment Plan:

(1) Make controlled releases of oil that simulate discharges that occur following accidental releases and operational discharges.
(2) Make controlled releases of chemicals that simulate biogenic slicks.
(3) Examine SAR imagery of areas where oil is know to be discharged during operational activities, e.g. Shetlands Basin. Determine whether oil is detected, compare with results of airborne surveys.

ERS-1 Data Requirements:

SAR imagery and scatterometer data. Some fast delivery products will be required to ensure the experimental plan can be modified to take account of the results obtained. Off-line high precision data will be required, primarily in the form of computer compatible tapes, but some hard copy will also be required.

Facilities to be Deployed:

(1) WSL Research Vessel.
(2) Aircraft fitted with IR/UV scanner and SLAR.
(3) Equipment for processing airborne imagery.
(4) Equipment for recording environmental conditions - wave buoy, current meter, wind speed/direction, etc.

Anticipated Results:

(1) SAR imagery and scatterometer data showing the presence of oil slicks of different quantities.
(2) SAR imagery and scatterometer data showing the presence of artificial slicks.
(3) Procedures for distinguishing between oil slicks and other surface slicks.

Milestones/Deliverables:

Procedures for interpreting SAR imagery to detect oil slicks and for distinguishing oil slicks from other surface phenomena. An evaluation of the role of SAR in marine pollution monitoring and how it can be integrated with other techniques such as airborne and ship surveys.

Coordinator: Srokosz

US1-5a

OCEAN SAR IMAGING IN THE GULF OF ALASKA

Principal Investigator:
O.H.Shemdim — Ocean Research and Engineering, 255 South marengo Avenue, Pasadena, California 91101
Tel: 818 5681800 Fax: 818 5681804

Co-Investigators:
D.Kasilingam/ D.Hayt (as above)

Objectives:
(1) SAR imaging of surface waves in storms.
(2) SAR imaging of ship wakes along the Valdez-San Francisco Sea Lane.
(3) Surface slicks, both natural and man-induced from Oil Tankers.

Experiment Plan:
(1) The Gulf of Alaska experiences some of the most severe oceanic storms in the northern hemisphere. SAR provides information on the directional wave number spectra of surface waves which will be used to validate the available wave generation models.
(2) The Valdez-San Francisco sea lane is active in supertanker traffic. The supertankers will be used as ships of opportunity to investigate ship wakes in sea states ranging from calm to storm conditions. The SAR will provide valuable insight for this investigation.
(3) The SAR data will be used to investigate the presence of oil slicks and the process of their dissipation. The area of interest for this study is: 50°-60°N, 130°-160°W.

ERS-1 Data Requirements:
As many SAR images as possible are requested for a triangular area (50°N,130°W; 50°N, 140°W; 60°N, 140°W).

Facilities for Data Analysis:
Computer and image analysis facilities at Ocean Research and Engineering.

Anticipated Results:
(1) Validation of storm wave prediction models with SAR directional wave data.
(2) Improved understanding of the mechanisms responsible for SAR imaging of the turbulent wake art of ships in various sea states.
(3) Improved understanding of SAR imaging of surface slicks. The area where surface slicks are found will be identified in relation to the sources of pollutants.

Coordinator: Weller

III Sea Ice and Climate

F24

STUDY OF AIR-SEA-ICE INTERACTIONS IN THE FRAM STRAIT AND GREENLAND SEA

Principal Investigator:
J.C.Gascard Laboratoire d'Oceanographie Dynamique et de Climatologie, L.O.D.Y.C, University of Paris 6, 4 Place Jussieu, 75252 Paris Cedex 05, France Tel: 1 43 36 25 25 x4969

Co-Investigators:
C.Kergomard/ C.Richez (as above), M.Fily (Laboratoire de Glaciologie et Géophysique de l'Environnement, St Martin D'Heres), A.Chedin (Laboratoire de Météorologie Dynamique, Palaiseau)

Objectives:
The so-called ARCTEMIZ Project will be carried out as a contribution to the Greenland Sea Project (GSP) and to the Programme for International Polar Ocean Research (PIPOR). Main objectives are to understand, both from a dynamical and thermodynamical point of view, the sea-ice seasonal and interannual cycle of the transpolar sea-ice drift in the Nansen Basin, when approaching the Fram strait, and the fate and consequences of this drift in the Greenland-Barents Seas.

Experiment Plan:
(1) To observe ice field motion, surface winds field and subsurface currents, sea-ice growth and decay, concentration and thickness distributions. This will involve use of ARGOS buoys and SOFAR floats for in situ observations and high resolution remote sensing (SAR-ATSR-AVHRR).
(2) To develop a hierarchy of ice-ocean coupled models dedicated to precise estimates of ice-ocean fluxes of momentum, heat and salt under proper atmospheric forcing resulting from detailed analysis of meteorological observations (TOVS - AMSU - SCAT).

ERS-1 Data Requirements:
SAR (highest priority), Scatterometer and ATSR data. SAR image mode data after geometric and radiometric correction.

Milestones/Deliverables:
1990/1 In situ measurements on the ice in April and on the adjacent ocean in September.

Coordinator: PIPOR

N3

SIZEX: SEASONAL ICE ZONE EXPERIMENT

Principal Investigator:
O.M.Johannessen — Geophysical Institute, Nansen Remote Sensing Centre, University of Bergen, Norway

Co-Investigators:
E.A.S.Svendsen (Nansen Remote Sensing Centre), T.Vinje (Norwegian Polar Research Institute, Oslo), R.Shuchman (EMIM, USA), W.J.Campbell (USGS, Tacoma, USA), W.D.Hibler III/ P.Gloersen(NASA Goddard Space Flight Centre, Washington, USA), K.Davidson (Naval Postgraduate School, Monterey, USA), N.Mognard (CNES, Toulouse, France), J.Hawkins/ D.Johnson (Naval Ocean Research and Development Activity, Mississippi, USA) plus 14 other scientists in Norway, USA, Canada and UK.

Objectives:

The overall objective is to perform ERS-1 sensor signature studies of different ice types in order to develop SAR algorithms for ice variables, including ice concentration and ice type discriminations. ERS-1 retrievals in real time of such variables in conjunction with other atmospheric and oceanic variables will be used as input a mesoscale coupled ice-ocean forecasting models for the Barents Sea. Furthermore, the SAR images will be used for estimation of ice volume flux from the Arctic Ocean to the Greenland and Barents Sea.

Experiment Plan:

The investigations consist of pre- and postlaunch experiments in the Barents Sea, Fram Strait and Greenland Sea.
The postlaunch 1991 experiment in the Barents Sea will involve the integration of ERS-1 observations with underflying remote sensing aircraft, helicopters and in situ remote sensing and physical observations of ice, atmosphere and ocean variables. During the ERS-1 operational period, ice forecasts will be made for the Barents Sea.
During the large SIZEX postlaunch experiment in Feb/March 1991, the ERS-1 data received and real-time precessed in Troms_ and/or Kiruna will be transmitted to the land coordination centre as soon as possible for intercomparison to aircraft remote sensing data, and also for real time steering of the field investigation. Similar real time data transfer will be used during periods of ice forecasting.

ERS-1 Data Requirements:

SAR, Scatterometer and Altimeter and ATSR data for the Barents Sea, Fram Strait and Greenland Sea.
The area of interest for SAR data is represented by the ice covered parts (varying by season) for the region 70°N - 84°N, 20°W - 60°E. The area of interest for Scatterometer, Altimeter and ATSR data is mainly within the open water parts of the same region. Coverage of the complete Norwegian - Greenland Sea is required for surface winds and wave height studies using scatterometer and altimeter data.

Anticipated Results:

(1) Improved SAR algorithms for retrieval of ice variables (ice concentration and ice type discrimination) and ERS-1 validation of these variables.
(2) Demonstrate operational ice-ocean dynamic and thermodynamic forecasting for the Barents Sea and the need for ERS-1 type data as input for realistic forecasting.
(3) Demonstrate the unique advantage of all-weather information for the study of sea ice climatic variables, and consequently for planning of industrial activities.
(4) Improved statistical knowledge of ice conditions in the Barents and Fram straits region, and especially ice conditions hazardous for future oil installations.

Milestones/Deliverables:

Prelaunch	MIZEX experiments. Design and evaluation of algorithms and model development.
Postlaunch	Major SIZEX experiment in February/March 1991, in addition to regular field investigations carried out by the Norwegian Polar Research Institute.

Coordinator: Johannessen

N8

SEA ICE CLIMATIC VARIABLES

Principal Investigator:
T.Vinje — Norwegian Polar Research Institute, Box 158, N-1330 Oslo Lufthavn, Norway

Co-Investigators:
R.Colony (Polar Science Center, University of Washington, Seattle, USA), _.Finnekasa/ Å.S.Johnsen/ B.Rudels (as PI), M.Kristensen (Norwegian Meteorological Institute, Blindern, Oslo), N.McIntyre (EOS, Fleet, UK)

Objectives:

The main objectives of the Sea Ice Climatic Variables (ICECLIMA) programme are:
(1) To estimate the climatic important, and highly variable movement of ice from the Arctic Ocean into the Greenland and Barents Seas.
(2) To estimate the changing surface energy balance associated with the thin ice found in lee polynyas, in loosely compacted ice fields and at the ice edge.
(3) To investigate the morphology of the ice fields and drifts of icebergs in the Barents Sea to meet with industrial and national management requests.
Important sea ice variables in this connection are edge position, concentration, motion and deforamtion, and the distribution of thickness, age, ridges, floe size and icebergs.

Experiment Plan:

(1) Ice motion will be evaluated by visual tracing of ice floes as well as by the use of a automated cross-correlation method.
(2) Estimation of the rate of ice growth and corresponding bottom water formation, to determine the heat balance of a lee polynia.
(3) The ice thickness distribution observed by upward looking sonars will be compared with SAR images to obtain an algorithm for indirect ice thickness estimations.
(4) Field measurements to get a better undersatnding of the return signal of the altimeter in sea ice mode.
(5) An experiment to demonstrate the feasibilty of oil spill identification and tracing from SAR images.

ERS-1 Data Requirements:

SAR and Altimeter data. Frequent SAR coverage for areas in the Fram Strait and Barents Seas.

Anticipated Results:

(1) The proposed investigation will demonstrate the unique advantage of all-weather information for the study of sea ice climatic variables. This will be particularly important for the estimation of ice velocities over large areas on a regular basis.
(2) As the influx of thicker ice from the Arctic Ocean affects the navigation during the following periods, the monitoring of this flux also will have importance for long term sea ice forecasting and consequently for long term planning of industrial activities.
(3) Better algorithms for the estimation of ice thickness distribution as well as ridge frequency.
(4) The potential of monitoring iceberg drift, oil spill movement, ridge and ice floe distribution has clear industrial applications.

Coordinator: PIPOR

PIP.ARC1

ODEN HIGH ARCTIC EXPEDITION PROGRAM: REMOTE SENSING, SEA ICE

Principal Investigator:

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Co-Investigators:

M.Hallikainen, M.Leppärauta (Finland), S.Löseth/T.Vinje/B.Erlingsson (Norway), R.Ramseier (Canada), H.Hoeber (BRD).

Objectives:

Ground truth investigation of ice properties to validate ERS-1. Investigation of the usefulness of ERS-1 for studies of Arctic ice properties in relation to:
(1) ice physics, surface wetness.
(2) ice motion, floe size distribution, ice ridge characterization.

Experiment Plan:

Observations of radar properties, ice physics and morphology along the Oden-91 route (subject to approval from USSR). The observations will concentrate on three areas (between latitude 80° and 84°N and longitude 65° and 100°E) where SAR data in real time is requested. Barents Sea coverage as acquired by the PIPOR group during the expedition time. Approximate time period depending on the ice situation is August 1 - September 15.

ERS-1 Data Requirements:

FD SAR-data from Kiruna
12 scenes over area 1, latitudes 80° - 82°N, longitude 92° - 96°E
4 scenes in three consecutive orbits per day during 12 days for each of areas 2 and 3. Orbits to be determined when 35-day phase is decided. Latitudes 83° to 84°N, long 65° to 100°E
Approximate dates, to be updated later: Area 1: August 1-3, 1991, Area 2: August 5-17, Area 3: Sept 5-17.
Total of 156 scenes: The number of scenes can be decreased if specification of orbit can be given at short notice taking into account the uncertainties of the route planning. Signal data is required for a limited number of scenes for analysis of dihedral corner reflectors.
Radar altimeter data over area 1 and Barents Sea.

Facilities to be Deployed:

Ice breaker Oden with laboratory space etc.
Helicopterborne scatterometer, video, still photo, laserprofilometer.
Ground truth equipment for snow and ice properties.
Reference corner reflectors.

Anticipated Results:

(1) Improved understanding of ice properties, ice kinematics in areas presently not very well known.
(2) Improved understanding of electromagnetic interaction with the snow/ice interface during the melt period and validation of ice classification algorithms.
(3) Improved understanding of ice morphology effects on SAR image properties in relation to ice motion algorithms.

Milestones/Deliverables:

Jan 1992	Data report and preliminary evaluation of field work.
Dec 1992	Satellite data analysis completed.
1992, 93	Results presented at scientific meetings and in journals.

Coordinator: PIPOR

PIP.ARC2

CLIMATE - CRYOSPHERE INTERACTIONS IN POLAR REGIONS: SCALE RELATIONSHIPS OF PROCESSES AND OBSERVATIONS

Principal Investigator:

R. Barry — CIRES and Department of Geography, University of Colorado, Campus Box 449, Boulder, CO 80309

Co-Investigators:

J A. Maslanik/ J R.Key/ M. C.Serreze/ R. L.Weaver (CIRES), K. Steffen (Geographisches Institute ETH, Zurich, Switzerland)

Objectives:

Determine process-oriented relationships between small-scale polar ice features (leads, melt ponds, floes) and larger-scale observations of ice characteristics (ice concentration, ice divergence, heat budget terms) as observed via ERS-1 and other platforms.

Experiment Plan:

(1) Collect a range of image types (different spatial and spectral coverage) co-located in space and time.
(2) Calibrate (as necessary) and map imagery to a common polar stereographic projection (eg the SSM/I grid).
(3) Through both empirical, statistical, and modelling studies, summarize the effects of field-of-view, spectral channel, look angle, orientation, and atmospheric conditions on the detection and mapping of open water features (leads, polnyas) and ice surface features (floe shaped, ridges, surface melt) using a suite of multispectral imagery.
(4) Using time-sequences, compare the effects of atmospheric forcing mechanisms on the features observed at different scales.

ERS-1 Data Requirements:

Northern Baffin Bay, Canada Basin, Beaufort Sea, Chukchi Sea, and Bering Strait with coverage of the interior pack, MIZ, first year ice, young ice, and leads and polynas. Approximate locations: 80°N, 160°W and 76.5°N, 72.5°W.

Anticipated Results:

Summary of effects of sensor factors and viewing conditions on open-water detection using different image types. Identify difficulties (eg open water/young ice/first-year ice discrimination) and investigate potential solutions.
Assessment of ability of medium and low-resolution (eg AVHRR and SSM/I) sensors to provide accurate open-water information applicable to albedo and heat-flux estimates.

Milestones/Deliverables:

(1) Notification of planned ASF acquisitions.
(2) Landsat/SPOT/MOS-1 acquisitions scheduled.
(3) SAR preprocessing software modified.
(4) Details of acquisitions from ASF and others.
(5) AVHRR, DMSP-OLS and SSM/I acquired for study areas.
(6) Images received and reformatted.
(7) Multisensor data registered to common projection.
(8) Analysis.
(9) Summary and final report. Deliverables include final report and merged multisensor data sets (imagery, derived products) on optical or magnetic media.

Coordinator: PIPOR

PIP.ARC3

ACTIVE-PASSIVE MICROWAVE SEA ICE OBSERVATIONS AND AIR-SEA-ICE PROCESSES IN COASTAL POLYNYAS

Principal Investigator:
D. Cavalieri GSFC, NASA, Greenbelt, Maryland, USA

Co-Investigators:
F.Carsey/ J.Crawford (JPL), R.Onstott (ERIM), D.Eppler (NORDA), S.Martin (UW), K.Steffen (ETH)

Objectives:
(1) To determine optimum methods for thin ice observations using spaceborne active and passive microwave observations.
(2) To understand the role of coastal polynyas in oceanic heat loss, sea ice production, and Arctic Intermediate and Deep Water Production.

Experiment Plan:
(1) Apply multidimensional analysis to spatially and temporally coincident data from ERS-1 SAR and SSM/I.
(2) Devise algorithm to exploit variability of ice type as expressed in the satellite variables.
(3) Calculate heat fluxes through the thin ice formed and exported from coastal polynyas of the Eurasian Basin and the Sea of Okhotsk utilizing archived meteorological and oceanographic data.

Three case studies of coastal polynyas are planned. Two will take place in the Eurasian Basin and one in the Sea of Okhotsk. One study will be carried out each year, with each being 1 winter month in duration (preferably February).

ERS-1 Data Requirements:
SAR and ATSR data acquired during the 3 day repeat cycle (not necessarily precise).

Milestones/Deliverables:

March 1992, 93, 94	Data Reports
Feb 1993	Preliminary Algorithm Analysis
Feb 1994	Preliminary Heat/Salt Flux Analysis
June 1994	Final Algorithm Analysis
September 1994	Summary of Polynya Heat/Salt Fluxes

Coordinator: PIPOR

PIP.ARC4

VALIDATION OF SEA ICE INFORMATION DERIVED FROM NUMERICAL MODELS AND REMOTE SENSOR ALGORITHMS

Principal Investigator:
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Co-Investigators:
D J.Cavalieri (NASA), L.D.Farmer/ Ruth H.Preller (NOARL), W. B.Tucker (CRREL)

Objectives:
Improve numerical sea ice models and algorithms developed to process satellite remote sensor data using ice concentration information derived from ERS-1 SAR images as ground truth data.

Experiment Plan:
(1) Initialise ice models in the Barents and Greenland Sea regions, and validate model predictions using ice concentration information derived from ERS-1 SAR imagery.
(2) Verify ice concentrations retrieved from SSM/I data using ERS-1 SAR images; use ERS-1 data as a basis for investigation anomolous algorithm retrievals.
Specifically, investigate ice characteristics that produce anomolous multi-year ice concentrations in regions of 100% first-year ice along the Alaskan coast; map synoptic changes in area of highly deformed multi-year ice adjacent to Canadian Archipelogo where SSM/I algorithms underestimate multiyear concentrations by more than 50%.

ERS-1 Data Requirements:

Beaufort Sea (69° - 75°N)	Oct-May
Chukchi Sea (67° - 75°N)	Oct-May
Arctic Ocean (75° - 85°N)	Yearound (3 scenes/day)
Barents Sea (70° - 81°N)	Jan-Mar (1.4 scenes/day)

Facilities to be Deployed:
Aircraft platforms for validation of field regions by coincident sensors.

Anticipated Results:
Demonstration of ice model forecasts derived by including SAR data in the model initialisation field; demonstration of model verification, particularly the ice edge, from comparison of SAR with model results.
Verification of lead opening and closing, as predicted by model ice drift forecasts, using sequential SAR images.

Milestones/Deliverables:

1992, 93, 94	Data Reports
1993	Model Hindcast results using ERS-1 input
	Evaluation of SSM/I AND ERS-1 first year ice signatures
1994	Assessment of lead forecast capability using ERS-1 input to models
	Analysis of deformed ice regions mapped with ERS-1 and SSM/I
	Final Report (modelling effort)
1995	Final Report (SSM/I effort)

Coordinator: PIPOR

PIP.ARC5

POLAR OCEAN SURFACE FLUXES

Principal Investigator:
D.Rothrock — Applied Physics Laboratory, University of Washington
Tel: 206 545 2262 Fax: 206 543 6785

Co-Investigators:
R.Barry (U.Col), N.Maynard (NASA/Goddard), R.A.Brown/ M.Steele (UW), F.Carsey (JPL), D.Winebrenner (UW), S.Martin

Objectives:
(1) Combine SAR, passive microwave, visible & IR satellite image data, satellite sounder data, and buoy surface & sub-surface ocean data to provide estimates of surface fluxes of heat, salt, CO_2 in both ice-covered and ice-free high-latitude oceans.
(2) Use data on surface fluxes, ice motion and open-ocean wind stress to drive ocean models and investigate water-mass formation and ocean circulation.

Experiment Plan:
The plan is to develop several models and algorithms and to combine them into a single model of upper ocean, ice cover (where present), and atmospheric boundary layer. The models include an upper ocean model with multi-layer vertical resolution and a planetary boundary layer similarity model. The ice model willl combine the ice thickness distribution, the ice type (or age) distribution and an ice thermodynamic and flux parameterisation. To assimilate satellite and other data into these models, the Kalman filter will be used. Algorithms will be developed for recognizing thin ice from SAR and passive microwave imagery.
The investigation will begin with the northern hemisphere, and be extended to the southern hemisphere. Attention will be focussed on ERS-1 SAR data from Siberian shelves, where buoy data and knowledge of ice conditions and motion are lacking, but are thought to be particularly important for the formation of Arctic water masses which precondition the formation of deep water in the Greenland Sea.

ERS-1 Data Requirements:
The data requirements assume that coverage of the Artemiz region north of Spitzbergen, and the Greenland, Barents and Bering Seas are requested by other investigators.
(1) Descending orbit in the Kara Sea (68° - 81°N), from Oct to April, 5 orbits/month, 15 scenes per orbit.
(2) Descending orbit in the Kara Sea (74° - 81°N) from May to Sept, 5 orbits/month, 8 scenes per orbit.
(3) Ascending orbit in the E. Siberian Sea (71° - 77.5°) all year, 5 orbits/month, 9 scenes per orbit.
(4) Descending orbit in the E. Siberian Sea (69° - 76°) all year, 5 orbits/month, 8 scenes per orbit.
(5) Descending orbit in the Kara Sea (72.5° - 81.5°) all year, 5 orbits/month, 10 scenes per orbit.

Anticipated Results:
The first result will be an estimate of high latitude surface fluxes of heat, salt, and CO_2 on a spatial resolution of about 100km and a temporal resolution of several days.
The second result will be an improved understanding of how the circulation of the Arctic Ocean is maintained and what conditions are necessary for the formation North Atlantic Deep Water in the Greenland Sea.

Milestones/Deliverables:

Jan 1990	Complete thin ice SAR algorithm
June 1990	Demonstrate ice/ocean model
Dec 1991	Provide field of ice motion from SAR & buoys
Feb 1992	Collect SSM/I data for 1991
June 1992	Run ice/ocean model for period through 1991
June 1992	Provide surface fluxes for 1991
Dec 1992	Analyze model ocean circulation for 1991

Coordinator: PIPOR

PIP.ANT1

AIR-SEA-ICE INTERACTION IN THE WEDDELL SEA

Principal Investigator:
E.Augstein — Alfred Wegener Institute for Polar and Marine Research, Am Handelshafen 12, D-2850 Bremerhaven, W.Germany Tel: 49 471 4831400

Co-Investigators:
Peter Lemke (as above)

Objectives:

Determine the values and the spatial and temporal variability of heat and mass fluxes in the Weddell Sea, and use these as an input and validation of model calculations of air-sea-ice interactions. Specifically, use ERS-1 data, primarily SAR, to improve determination of spatial and temporal variability of ice conditions in response to atmospheric forcings in the Weddell Sea.

Experiment Plan:

(1) Obtain SAR low-resolution imagery on weekly basis across Weddell Sea from ice edge to Fichner Ice Shelf starting June 1991.
(2) Obtain SAR high-resolution imagery in three selected area corresponding to POLARSTERN operations in May (western Weddell), July (eastern Weddell), and November (southern Weddell) 1992.
(3) Use imagery to help interpret results of ARGOS buoy, current moorings (including upward looking sonar), and POLARSTERN-based ocean, met, and ice studies.
(4) Incorporate ice information derived from SAR data in air-sea-ice interaction model.

ERS-1 Data Requirements:

(1) 01/06/91 - 31/12/92	One track per week, through central Weddell from ice edge to shelf (340 min).
(2) 25/04/92 - 30/05/92	Three tracks per week, in western Weddell (40 min).
(3) 20/06/92 - 25/07/92	Three tracks per week, in eastern Weddell (50 min).
(4) 05/11/92 - 05/12/92	Three - four tracks per week, in southern Weddell (20 min).

Facilities to be Deployed:

(1) POLARSTERS research platform, including onboard HRPT-station and ship-borne helicopter.
(2) Current moorings and ARGOS buoys.

Anticipated Results:

(1) Ice extent and ice concentration from low-res SAR to compare/combine with SSMI and AVHRR data.
(2) Ice motion and deformation from high-res SAR data.
(3) Floe size distribution from high-res SAR data.
(4) Evaluation of use of SAR data in modelling in the Weddell Sea.

Milestones/Deliverables:

End 1993	Report to ESA..
	Journal Articles.

Coordinator: PIPOR

PIP.ANT2

DYNAMICS AND CHARACTERISTICS OF EAST ANTARCTIC SEA ICE

Principal Investigator:
I.Allison — Australian Antarctic Division, University of Melborne, Parkville, Victoria, Australia
Tel: +61 3 344 6914

Co-Investigators: N.Young, T.Jacka (as above).

Objectives:
(1) Document the development of the seasonal sea ice cover through a complete annual cycle within the area including Prydz Bay from the coast to 55°S latitude and between longitudes 55°E and 90°E.
(2) Determine the effect of forcing by oceanic circulation and weather systems on the distribution and areal extent of sea ice, particularly on the nature and extent of thin ice and open water and investigate the processes which control the rate of production and growth.
(3) Investigate the heat, mass, and salt budgets of the surface layers of the ocean.

ERS-1 Data Requirements:
Study area is within the limits: Antarctic coast to 55°S latitude and between longitudes 55°E and 90°E. Repeat imagery along descending swaths will be used to determine westward and northward components of the sea ice motion and characteristics of the sea ice. Ascending swaths are essential to determine the eastward motion in the northern part of the study area and in the marginal ice zone. The amount of data required along each sub-track will depend on sea ice extent which varies through the year. Estimates of maximum data requirements are given below.

July 1991 — *Pilot study period*

One group of four overlapping swaths of SAR imagery from consecutive pseudo-3-day repeat orbits between the coast and 62°S latitude, between longitudes 68°E and 76°E. One swath is to be extended to the ice edge at 57°S latitude.
An additional three swaths of SAR imagery collected on ascending passes on consecutive days between the coast and the ice edge. Each swath is to intersect with the long descending swath requested above.

1992: — *Main study period*

Observation periods in April, June, August, October.

For each observation period a set of SAR imagery is requested to form four groups, or strips, of imagery across the study area. Each group of imagery is to include four swaths from consecutive pseudo-3-day repeat subcycles of the 35-day orbit such that swaths will overlap and precess westwards.

Observation period in December.

Four swaths are requested, one from each of four consecutive days, between the coast and the outer margin of the sea ice.

Facilities to be Deployed:
Sea ice buoys and mini automatic weather stations on icebergs are to be deployed in 1991 and 1992. Shipboard observations are to be made in the sea ice zone in 1992 at about the time of maximum sea ice extent from "Aurora Australis:, which will commence operations for the Australian Antarctic Division in 1990.

Anticipated Results:
The primary science interest in the study region lies in the interaction of the sea ice with the atmosphere and ocean and the resultant impace on ocean structure, weather and climate. It is expected to identify and quantify processes which control: the horizontal extent of the sea ice; its development and modification under forcing from the atmosphere and ocean; and the extent of thin ice and open water. The resultant data sets will assist in the development of dynamic models of the sea ice and are important in improving atmospheric models of the region.

Milestones/Deliverables:

1989-90	Detailed planning for ERS-1 program; completion of feasibility studies using SEASAT SAR and SIR-B imagery; construction of buoys and mini automatic weather stations.
1992	Collection of five 12 day sets of SAR data at regular intervals through year. Analysis of buoy, AWS and SAR imagery for pilot program, preparation of preliminary report.
1994	Delivery of final report on ERS-1 phase of program, publication of papers in scientific journals.

Coordinator:PIPOR

PIP.ANT3

ANZONE LARGE-SCALE AIR-SEA-ICE INTERACTIONS

Principal Investigator:
M.R.Drinkwater JPL, 4800 Oak Grove Drive, Pasadena, CA, USA Tel: 818 354 8189

Co-Investigators:
A.Gordon (LDGO)

Objectives:
(1) To determine ice conditions and surface fluxes in the Anzone region of the Weddell-Cosmonaut Seas.
(2) To advance our quantitative knowledge of the interannual variability of the surface fluxes that couple the ocean and atmospheric through the Southern Ocean ice.

Experiment Plan:
(1) Analyse SARdata for ice motion and type using the automated Geophysical Processor System, and express results on a fixed grid.
(2) Compute surface fluxes over the grid using buoy (if available) or predicted winds and surface temperatures.
(3) Merge results with oceanographic data acquired by other elements of Anzone study.

ERS-1 Data Requirements:
Total of 2 minutes SAR data per day over the period of the austral winter, July through September.
Data takes to be optimised using descending and ascending passes in order to track easterly and westerly components of ice drift.
Requirement is subdivided into 2 pairs of data strips (max 4 mins/strip) each week taken at approx 3 day intervals. Image 'pairs' will enable ice motion tracking, one for the east and west.
Descending passes may be used for westward motion in the east and south of the Weddell Gyre. Ascending passes are required to capture eastward motion components in the north and west of the region.

Anticipated Results:
Quantification of surface fluxes in relation to the large-scale climatology. When coupled with oceanographic data this will enable calculations of horizontal and vertical heat, salt, and momentum exchange.

Milestones/Deliverables:

Oct 1991, 92, 93	Data Reports
Jan 1993, 94	Gridded Ice Fields
June 1993, 94	Surface Fluxes on Grid
Sept 1994	Anzone SAR Data Report

Coordinator: PIPOR

PIP.ANT4

MICROWAVE RADAR OBSERVATIONS OF ANTARCTIC SEA ICE

Principal Investigator:
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Co-Investigators:
S.Ackley (CRREL), P.Gogineni/ R.K.Moore (University of Kansas)

Objectives:
Field observations have shown that distinctly different sea ice types are associated with the different oceanic regimes of the Weddell Sea. The aim is to use ERS-1 SAR and altimeter data to identify and ultimately monitor these different ice types as proxy indicators of the regional ocean environment.

Experiment Plan:
Ship based Ku- and C-band radar data will be collected in the Weddell Sea during September and October of 1989. These data will be analysed during 1990 to test the hypothesis that Antarctic frazil and congelation ice have unique microwave signatures. Based on analysis of surface observations as well as on GEOSAT altimeter and KOSMOS 1500 RAR data, there will be an investigation of the utility of ERS-1 SAR and altimeter data for regional monitoring of Weddell Sea frazil, congelation and multi-year ice.

ERS-1 Data Requirements:
(1) Altimeter waveforms over the Weddell Sea are requested seasonally.
(2) SAR data requested for September/October 1990 and 1991 (4-look and complex data).
Minimum requirements are for data along these 2 orbits:
(1) 62°S 60°W to 73°S 20°W
(2) 75°S 60°W to 55°S 10°E

Facilities to be Deployed:
Ku- and C-band radars as well as field equipment for sampling ice surface roughness and internal structure.

Anticipated Results:
Measurement of the microwave properties of Antarctic sea ice. This will be used to extract information on the spatial distribution of sea ice types found in the Weddell Sea from spaceborne SAR and altimeter data.

Milestones/Deliverables:

Fall 1989	Surface experiments in the Weddell Sea.
Summer 1990	Analysis of field data completed.
Winter 1990/91	Analysis of GEOSAT and KOSMOS RAR data completed.
Winter 1991/92	Preliminary assessment of ERS-1 data for monitoring antarctic sea ice

Coordinator: PIPOR

PIP.ANT5

SEA ICE AND POLYNYA OBSERVATIONS IN THE VICINITY OF SYOWA STATION

Principal Investigator:
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Co-Investigators:
M.Wakatsucki (ILTS), T.Yamanouchi (NIPR), H.Enomoto (Kitai Tech. Univ), K.Okamoto (Communication Res. Lab.), I.Noguchi (Hydro Dept. MSA)

Objectives:
To investigat dynamics and thermodynamics of Antarctic Sea ice. ERS-1 SAR data will bc compared with surface and aircraft observations and satellite data from NOAA, MOS-1 and J-ERS-1.

Experiment Plan:
(1) The coastal sea-ice and polynya area off Syowa Station (30-45E, 66-70S) JARE/ACR. Sea-ice project will be carried out in 1990-93, including air-dropped buoy, AXBT, and surface weather observations.
(2) Cosmonaut Polynya Area: Ice distribution and dynamics along 35-50E, 61-66S.
(3) Weddell Polynya Area: Ice formation along 10W-10E, 63-70S
(4) Ice Edge process off the 1 & 2 orbit.

ERS-1 Data Requirements:
SAR:
(1) Off Syowa, (2) Cosmonaut Polynya area: 4 min/twice/month 1991-1993
(3) Weddell Polynya area: 4 min/once a month of June- October
(4) Additional 2 min in winter time (June- September)/once month (to 1 + 2).

Facilities to be Deployed:
Syowa receiving station.

Anticipated Results:
(1) Ice floe distribution in Polynya Areas
(2) New information on different remote sensing data comparison especially C-band and L-band SARs.

Milestones/Deliverables:

1992	Comparison analysis with surface/Aircraft Observation and MOS-1.
1993	Combination data set analysis with MOS-1/MOS16 Passive Microwave Radiometer.
1994	Combination data set analysis with J-ERS-1 L-Band SAR.

Coordinator: PIPOR

PIP.ANT6

COMBINATION OF ACTIVE AND PASSIVE MICROWAVE SIGNATURES OF THE WEDELL SEA

Principal Investigator:
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Co-Investigators:
M.Collins/ Irene Rubinstein (AES/ISTS), T.Viehoff/ P.Lemke (AWI/Bremerhaven), K.Struebing (DHI/Hamburg)

Objectives:
(1) To combine ERS-1 SAR with SSM/1 (Special Sensor Microwave/Imager) data to significantly enhance the information content in conventional regional ice charts.
2) To test hypothesis of using SAR data beyond SAR swath boundaries within the SSM/I data field.
3) Provide the input of this combined data set into a research (operational) ice forecasting model.

Experiment Plan:
The project will follow four phases as follows:
(1) Develop algorithms to extract ice information from the combined SSM/1 - ERS-1 SAR data set. This will follow a multispectral approach (ie overlapping digital image data will be treated as separated spectral channels of the same scene).
(2) Establish spatial and temporal tolerances for the time separation of the digital image data. These tolerances will determine whether incoming image data can be incorporated into the current ice chart or if a new chart must be generated.
(3) Test the hypothesis that some components of the high resolution SAR information may be extrapolated beyond the boundaries of the SAR data from the same area.
(4) Develop a strategy for assimilating the microwave measurements into a regional, operational ice forecasting model. Particular attention will be paid to the spatial and temporal scales of the data versus those required by the model in order to provide reasonable estimates of ice characteristics.

ERS-1 Data Requirements:
On the PIPOR orbit (3-day repeat), the data collection pattern would be 2 passes per day within the shortest time cycle possible from approximately 62°S to the coast. The exact sequence of these data-takes should be coordinated with sampling of the Weddell Sea program.

Anticipated Results:
The study will provide a new year-around characterisation of ice conditions for both display in ice products by operational ice services and input to more sophisticated operational ice forecasting models. It essentially will bridge the basic problem of inadequate SAR coverage, but will make use of the much higher resolution of the SAR data.

Milestones/Deliverables:
Initial milestones by ISTS will be the preparation of the software to combine airborne SAR and AIMR data and the preparation of the software for the regional integration of satellite passive microwave data with the high resolution data. This will take place prior to launch. One year after launch ISTS and AWI will present the results from element (1) in the experiment plan, 18 months from launch (2) and (3) by ISTS and AWI, and 4 years from launch (4) by all participants.

Coordinator: PIPOR

PIP.BAL1

VALIDATION AND DEMONSTRATION OF ERS-1 SAR IN SEA ICE MAPPING IN THE BALTIC SEA

Principal Investigator:
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Tel: 358 0 331044

Co-Investigators:
J.Vainio (FIMA), Y.Rauste (Technical Research Centre of Finland), M.Hallikainen (Helsinki University of Technology)

Objectives:
(1) Calibration and validation of ERS-1 SAR imagery of brackish water ice in the Baltic Sea.
(2) To evaluate the usefulness of ERS-1 SAR real-time imagery in operational ice information service, aboard icebreakers, and in use of numerical ice models.

Experiment Plan:
The experiment will be performed in the northern part of the Baltic Sea in January - March 1992. In the calibration/validation there will three bases: the Finnish research vessel Aranda and two coastal sites, one in the Gulf of Bothnia and one in the Gul of Finland. At all bases there will be scientists with instrumentation for observing the structure, small scale surface roughness and electromagnetic properties of snow and ice. Scatterometer and laser profilometer measurements will be made from helicopters and aerial photography from an airplane.
The application/demonstration experiments will be carried through in March 1992 and March 1994. Near real-time SAR imagery will be transmitted from Kiruna to Helsinki. The imagery will be processed and used for ice charting in the Finnish Ice Service and sent to Finnish icebreakers via a mobile telephone system. The data are also used in the numerical ice forecasting model in the Ice Service.

ERS-1 Data Requirements:
SAR data of the Baltic Sea, Gulf of Bothnia and Gulf of Finland.

Facilities to be Deployed:
Research vessel Aranda, helicopters (leased), ice laboratory, scatterometer, laser profilometer, side-looking airborne radar, equipment for ground truth in the field, Argos Buoys, waverider buoys, equipment for near real-time processing of FD data and sending the data to icebreakers, image station aboard icebreakers, numerical ice model.

Anticipated Results:
(1) Scatterometer calibration of ERS-1 SAR.
(2) Algorithms for using ERS-1 SAR data in brackish-water ice.
(3) Analysis of the operational usefulness of SAR data in ice information service products.
(4) Analysis of ERS-1 SAR data real-time transmission and processing systems.

Milestones/Deliverables:

1990-91	Analysis of airborne SAR imagery, backscatter modelling, development of field measurement techniques. Results of preparatory work. Experiment plan.
1992	Post experiment report. Data report.
1993	Data analysis completed.
1994-95	Final report.

Coordinator: PIPOR

PIP.BAL2

COMBINATION OF ACTIVE AND PASSIVE MICROWAVE SIGNATURES OF THE GULF OF BOTHNIA

Principal Investigator:
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Co-Investigators:
M.Collins/ Irene Rubinstein (ISTS), T.Thompson/ A.Omstead (SMHI/Norrkoping), K.Struebing (DHI/Hamburg)

Objectives:
(1) To combine ERS-1 SAR with SSM/1 (Special Sensor Microwave/Imager) data to significantly enhance the information content in conventional regional ice charts.
2) To test hypothesis of using SAR data beyond the boundaries of the SAR swath within the SSM/I data field.
3) To provide the input of this combined data set into operational ice forecasting models.

Experiment Plan:
The project will follow four phases as follows:
(1) Develop algorithms to extract ice information from the combined SSM/1 - ERS-1 SAR data set. This will follow a multispectral approach, ie overlapping digital SAR data will be treated as separated spectral channels of the same scene.
(2) Establish spatial and temporal tolerances for the time separation of the digital image data. These tolerances will determine whether incoming image data can be incorporated into the current ice chart or if a new chart must be generated.
(3) Test the hypothesis that some components of the high resolution SAR information may be extrapolated beyond the boundaries of the SAR swath by using statistical analysis of the active-passive ice signatures and previous SAR data from the same area.
(4) Develop a strategy for assimilating the microwave measurements into a regional, operational ice forecasting model. Particular attention will be paid to the spatial and temporal scales of the data versus those required by the model in order to provide reasonable estimated of ice characteristics.

ERS-1 Data Requirements:
On the PIPOR orbit (3-day repeat), the data collection pattern would be 2 passes per day within the shortest time cycle possible from approximately 59 to 66°N and 17 to 26°E. The exact sequence of these data-takes should be coordinated with the SMHI and DHI project requirements.

Anticipated Results:
The study will provide a seasonal characterization of ice conditions for both display in ice products by operational ice services and input in more sophisticated operational ice forecasting models. It essentially will bridge the basic problem of inadequate SAR coverage, but will make use of the much higher resolution of the SAR data.

Milestones/Deliverables:
Initial milestone by ISTS will be preparation of the software for the regional integration of satellite passive microwave data with the high resolution data. This will take place prior to launch. One year after launch ISTS will present the results from element (1) in the experiment plan, 18 months from launch (2) and (3) by ISIS and SMHI and 4 years for, launch (4) by all participants.

Coordinator: PIPOR

PIP.BAL3

USE OF ERS-1 SAR DATA FOR SEA ICE RECONNAISSANCE AND OPERATIONAL ICE SERVICE IN THE WESTERN BALTIC

Principal Investigator:
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Tel: 49 40 31905157

Objectives:
In the western Baltic, brackish water of 10-20ppt dominates. Although the possibility for extensive ice cover is only about 25% of all years, the area is very sensitive to ice because of the very intensive marine traffic. The number of vessels passing the main laneways during the months when ice is present (Jan-March) may total 15,000 to 20,000. Daily real time ice information is essential for navigation in this area. Microwave data are especially important for observing sea ice in this area, due to the often dark, or fggy conditions. The utility of SAR information to provide timely and useful ice information for ship routing will be proved through application demonstrations as part of the project.

Experiment Plan:
SAR data wil be collected on 2 passes during the "ice orbit" portion of the ERS-1 mission in 1992 and 1994. If possible, the information will be used as a fast delivery product, and its use as an operational aid will be evaluated by the ice service. A field programme is planned during the satellite overpasses in the winter of 1992.

ERS-1 Data Requirements:
SAR data from 2 passes during the "ice orbit" portion of the ERS-1 mission in 1992 and 1994.

Facilities to be Deployed:
Receive-only station for FD SAR scenes (?).
HRPT/AVHRR receiving station (Terra Scan System)

Anticipated Results:
The demonstration of the utility of SAR data for ice forecasting and ship routing in the western Baltic Sea.

Milestones/Deliverables:

1990-91	Preparation; simulation with BEPERS and other SAR data; tests of new hardware systems.
1992	Experiments; start of data analysis.
1993	Data analysis continues; final report.
1994	Operational activities; back-up of 1992 campaigns.

Coordinator: PIPOR

PIP.BAL4

DEMONSTRATION OF THE POTENTIAL OF SATELLITE SAR DATA FOR OPERATIONAL SEA ICE ACTIVITIES, INCLUDING GEOPHYSICAL VALIDATION.

Principal Investigator:
T.Thompson — Swedish Meteorological and Hydrological Institute (SMHI), 601 76 Norrkoping, Sweden.
Tel: +46 11 158 468

Co-Investigators:
Jan Askne (Chalmers University of Technology), O.Faest (Swedish Space Corporation), H.Ottersten (National Defence Research Establishment)

Objectives:
(1) To validate ERS-1 SAR data with respect to important sea ice parameters such as ice concentration, water openings, surface roughness and motion.
(2) To demonstrated the usefulness of ERS-1 SAR data in operational sea ice service in support of icebreading activities and navigation in ice.

Experiment Plan:
The experiment will be divided into three phases:
(1) A calibration/validation exercise mainly carried out during January and February 1992. Two experiment areas which will be covered by ascending as well as descending orbits will be selected. In the Bay of Bothnia an icebreaker will be used as a base and in the north part of the Baltic Proper a base will be established on an offshore island using helicopter for transportation out to the ice. The programme will include an underflight segment including air photography, radiometry, scatterometry and laser profiling and a ground segment including measurements of snow and ice properties. Basically it will closely follow the BEPERS-88 programme.
(2) An applications demonstration programme to be carried out during March 1992. During this period FD SAR data will, if possible, be received in real-time at SMHI and assimilated into the operational sea ice products which are disseminated to users. It is also intended to transmit processed SAR images to some selected icebreakers. During a period of one to two weeks, two parallel schemes will be set up, one using only the traditional data and the other also using ERS-1 SAR data. The quality of the two sets of output products will then be compared in co-operation with the users.
(3) In 1994, a more operationally oriented demonstration program will take place over the full period of the PIPOR orbit (January - March). The ERS-1 FD SAR data will then be fully integrated into the production scheme and assimilated into the output products.

ERS-1 Data Requirements:
For calibration/validation the data requirements will be restricted to two research areas, one in the Gulf of Bothnia and the other in the Baltic Proper (i.e.one week's duration for each of the months January, February and March).
For the application demonstration experiments, one in March 1992 and the other January - March 1994, a large amount of data is required for locations which depend on the actual ice situation at the time.

Facilities to be Deployed:
Icebreaker with helicopter to be used as field experiment base; Field base with helicopter; Field equipment for geophysical measurements on ice; Airborne instruments such as scatterometer, radiometer, laser profiler and IR scanner; Laboratories at 3 locations; Fully operational sea ice service with data collection and dessemination facilities.

Anticipated Results:
From the Calibration/Validation phase an increased understanding is expected of the radar backscatter relative to the more important sea ice parameters and the ice movements from consecutive SAR images.
The applications demonstration is expected to give valuable experience in assimilating SAR data into the sea ice analysis and forecast products of the Sea Ice Service. It will also give an indication of expected improvements due to the inclusion of SAR data.

Coordinator: PIPOR

PIP.BCB1

SEASONAL TRANSITION MONITORING IN LANDFAST FIRST-YEAR SEA ICE

Principal Investigator:
Susan Argus — Canada Centre for Remote Sensing, 2464 Sheffield Road, Ottawa, Ont., Canada

Co-Investigators:
F.Carsey (JPL)

Objectives:

(1) To describe the seasonal cycle of first-year fast ice of Alaskan and Canadian waters and the first-year of the Beaufort Sea.
(2) To determine the utilty of SAR monitoring of fast ice to predict the thermodynamic state of the pack ice and the on-set of breakup.

Experiment Plan:

(1) Monitor SAR data to determine seasonal cycle of backscatter and identify key transitions in the stages of melt of landfast and pack undeformed first-year ice.
(2) Determine the SAR responses to ice features, such as leads, ridges, thaw holes and seal breathing holes, as they are changed by variations in water distribution during the melt season.
(3) Resolve meridional behaviour in the seasonal cycle as observed in the first year fast and pack ice.
(4) Monitor breakup in the fast and pack ice in the coastal areas of different latitudes and examine the relationship between the SAR-observed changes in the ice and the onset of breakup.

ERS-1 Data Requirements:

SAR data every 3 days for 2 areas in the Beaufort Sea for June through August and twice per month for the remainder of the year for the lietime of ERS-1.

Milestones/Deliverables:

Jan 1992,93,94	Data reports
March 1993	List of stages in melt detected by SAR and associated physical manifestations for selected locations in sample swaths.
Sept 1994	SAR signatures for each melt stage.
Nov. 1994	Charts showing progression of melt stages and break-up times for regions of fast and pack ice covered by SAR swaths.

Coordinator: PIPOR

PIP.BCB2

ERS-1/SPOT DATA INTEGRATION PROJECT

Principal Investigator:

Susan Argus — Canada Centre for Remote Sensing, 2464 Sheffield Road, Ottawa, Ont., Canada

Co-Investigators:

S.Patterson (as above)

Objectives:

(1) Develops technique(s) for the integration of ERS-1 and SPOT data.
(2) Explore the value of integrating ERS-1 with SPOT data for the extraction of sea ice features for both the Marginal Ice Zone (East coast of Canada) and the Arctic (Beaufort Sea). Predict the thermodynamic state of the pack ice and the onset of breakup.

Experiment Plan:

The study sites will be the Labrador Sea/Grand Banks region and Beaufort Sea/Mackenzie Delta region. ERS-1 and SPOT data will be acquired for these areas, along with complementary airborne SAR data. For the Labrador Sea/Grand Banks region SAR data will be acquired by the CV-580 as part of the proposed LIMEX '92 and the Beaufort Sea/Mackenzie Delta region complementary airborne X-band SAR will be obtained from the Intera ice reconnaissance system.

ERS-1 Data Requirements:

SAR data:
(1) Along the Labrador/Newfoundland coasts during March of 1992 (ERS-1 Ice Orbits).
(2) For the Beaufort Sea/Mackenzie Delta region during April 1991.
ERS-1 data must be acquired on identical days and for the same geographical area as the SPOT data, therefore data acquisition must be on relatively cloud free days (<20% cloud cover). All data must possess land for the registration of the data sets.

Milestones/Deliverables:

(1) Procurement of ERS-1, SPOT, CV-580 SAR and/or Intera SAR for both the Beaufort Sea and East Coast regions.
(2) Selection of several SAR and SPOT images for both the East Coast region and the Beaufort Sea.
(3) Completion of preliminary digital processing (corrections and enhancements) on both ERS-1 and SPOT data.
(4) Interpretation of ice features from all data sources for the study areas,
(5) Development of technique(s) for the integration of ERS-1 data and SPOT data.
(6) Report on the value of integrating ERS-1 data with SPOT data for sea ice feature extraction.
(7) Report on the utility of SPOT data for extraction of sea ice information. The sea ice information is as follows; ice concentration, floe size and distribution, eddies, shear zones, rubble fields, ice type classification and ice bergs. This includes an analysis of SPOT data alone, and as integrated with the SAR.
(8) A final report will be written for ESA. It will be submitted as a paper for publication in a refereed journal, and may be presented at a symposium.

Coordinator: PIPOR

PIP.BCB3

ASSIMILATION OF ERS-1 DATA INTO ICE-OCEAN MODEL FOR THE SOUTHERN BEAUFORT SEA

Principal Investigator:
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Tel: 604 356 6330

Co-Investigators:
G.Fleming (Department of Physics, Royal Military College Colwood, B.C.), A.F.Bennett (School of Oceanography, Oregan State University Corvallis)

Objectives:

(1) To verify the Beaufort Sea ice-ocean model.
(2) To assimilate ERS-1 data into ice-ocean model.
(3) To use assimilating model to interpolate between swaths.
(4) To assess the influence of ice rheology on ice-ocean interaction on the Beaufort Sea continental shelf.

Experiment Plan:

It is intended to use GPS preprocessed data for the region between 68° - 76°N and 115° - 170°W to conduct the assimilation/modelling study. The study will utilize year-round data.

ERS-1 Data Requirements:

(1) Ice motion/classification product for (69°-76°N, 115°-170°W) CAL/VAL (1990/91), PIPOR (Jan-Mar, 1992), 35-day repeat April-December, 1992 on CCT, total of 2400 frames.
(2) Geocoded, Low-res, SAR for (69-76°N, 115-170°W) for Jan 1992 from PIPOR 3-day repeat orbit on CCT, total of 160 frames.
(3) Geocoded, Low-res, SAR for (69-76°N, 115-170°W) for July, 1992 from 35-day repeat orbit on CCT, total of 160 frames.

Anticipated Results:

The study will provide a coupled ice-ocean modelling system capable of assimilating ERS-1 data for the purposes of prediction and analysis. The observability and error analysis to be performed will help improve the accuracy and efficiency of current ice forecast models for the southern Beaufort Sea

Milestones/Deliverables:

Sept. 1990	Availability of Ice-Ocean model.
Sept. 1991	Availability of data assimilation software.
Sept. 1992	Preliminary report on assimilation results.
Sept. 1993	Final report.

Coordinator: PIPOR

PIP.BCB4

SEASONAL CYCLE OF THE BEAUFORT SEA ICE COVER AS OBSERVED IN MICROWAVE DATA

Principal Investigator:
F.Carsey JPL. 4800 Oak Grove Drive, Pasadena, CA, USA

Co-Investigators:
Ben Holt (JPL)

Objectives:
(1) Determine the microwave response of sea ice of the Beaufort Sea as a function of season.
(2) Determine the optimum procedure for monitoring climate change by microwave observation of key transitions in the Beaufort Sea ice cover during the seasonal cycle.

Experiment Plan:
(1) Determine points of transition of ice properties in the seasonal cycle.
(2) Acquire SAR and supporting data from SSM/1, SPOT or Landsat and surface meteorological stations for the transition periods of first 2 years of ERS-1.
(3) Form time series of property changes and hypothetical corresponding microwave behaviour changes over the annual cycle.
(4) Devise means of testing inferred microwave climatology of ice cover during third year of ERS-1.

ERS-1 Data Requirements:
Much of the data needed for this project will be acquired by the basic PIPOR program.
Observations of old ice and first-year ice of the Beaufort Sea every few days over the year.

Milestones/Deliverables:

Jul 1992, 93, 94	Data Reports.
Oct 1993	Report on Trial microwave climatology of Beaufort Sea ice.
Oct 1994	Comparison of Trial and observed sea ice climatology.

Coordinator: PIPOR

PIP.BCB5

USE OF ERS-1 DATA IN A DEMONSTRATION OF OPERATIONAL SUPPORT FOR FIELD ACTIVITIES

Principal Investigator:
J.Falkingham AES Ice Centre, 373 Sussex Drive, Block E, 3rd Floor, Ottawa, Ontario, Canada K1A 0H3

Co-Investigators: T.Mullane/ D.Mudry (AES Ice Centre Climatology Division), Lyn McNutt (RADARSAT Project Office)

Objectives:
(1) To test the data acquisition, delivery, throughput and dissemination of ERS-1 Fast Delivery Products into an operational ice forecast simulation in support of offshore activities.
(2) To evaluate the ease of assimilation of ERS-1 data into operational ice forecast products.
(3) To evaluate methods of using ERS-1 data as an aid to supporting field activities for planning shipboard activities and aircraft deployment for scientific research.
(4) To evaluate the complementarity of satellite and aircraft in a complete ice information system.

Experiment Plan:
During a one to two week period in summer 1991, ERS-1 data will be collected for the Beaufort Sea, and will be included in the data stream through the Ice Data Integration and Analysis System (IDIAS) to users onboard an offshore facility and an icebreaker as well as onshore at an operations facility. The information received will be used to guide the activities of the ships and aircraft during the period. An evaluation of the data will be made, as well as an assessment and recommendations on the provision of information for planning field exercises as part of the ERS-1 scientific activity. A second data collection and evaluation will be conducted in the Lancaster Sound region in support of shipping activity in the fall of 1991. An evaluation will be made of the use of the aircraft and satellite information to aid ship navigation, and recommendations will be made as to the most efficient use of combined information from satellites, aircraft and shipborne sensors.

ERS-1 Data Requirements:
The dates for these activities will largely be determined by climatological conditions, and the presence of the ships and aircraft at the sited mentioned. Both activities are planned to occur during the 35 day repeat cycle of the ERS-1 satellite, and since part of the evaluation is to compare the ERS-1 data to the aircraft sources, assurances must be made that all ERS-1 data for the two week period will be collected within the experiment site. If the data cannot be collected, then the evaluation of the information will not be complete, and the results could be biased.

Facilities to be Deployed:
The AES operational SAR-equipped aircraft. Real-time analyses will be made as part of the ice forecasting mandate of the Ice Centre, and information wil be passed to the participants via normal product dissemination systems.

Anticipated Results:
(1) An evaluation of the front end delivery of ERS-1 FD products to IDIAS and their assimilation into the data stream.
(2) An evaluation of the ease of combining the data sets from aircraft and satellite sensors.
(3) An evaluation of the accuracy of data derived from the SAR and their utility in guiding operations.
(4) Recommendations for the use of ERS-1 and future satellite systems as complementary data sets in an overall ice information system, specifically in support of field operations.

Milestones/Deliverables:
(1) During the data collection, the ice nowcast charts from IDIAS and downlinked aircraft SAR information will be available as part of the routine operations.
(2) After the data collection period, a listing of all the archived data sets will be available as a package from the Ice Climatology Division of AES.
(3) During the data collection period, both the ERS-1 information and the aircraft data will be used to guide ships and/or field parties to interesting ice features as seen on the imagery. The ability of the ships to reach the feature of interest, and the timeliness of the data will be evaluated in a report to ESA.
(4) A report recommending data collection and analysis techniques, and detailing the complementarity of the data sets for aircraft, shipborne and satellite sensors to aid in navigation and in support of field operations will be prepared.

Coordinator: PIPOR

PIP.BCB6

VALIDATION OF ICE TRACKING ALGORITHMS

Principal Investigator:
J.Falkingham Ice Centre, Environment Canada, Ottawa, Ontario Tel: 613 996 4552

Co-Investigators:
T.K.Hirose (Noetix Research Inc, Ottawa), S.Prinsenberg (Bedford Institute of Oceanography, Halifax), V.R.Neralla (MSRB, Environment Canada, Toronto)

Objectives:
This program proposes to validate the robustness of sea ice tracking algorithms and demonstrate their utility to support users operating in ice infested waters.

Experiment Plan:
This program proposes to study sea ice dynamics in two areas.
(1) The sea-ice rheology from northern Labrador to southern Newfoundland is ideal for evaluation tracking algorithms while providing strategic information to the shipping industry.
(2) The marginal ice zone in the Beaufort Sea will provide complementary information where large rotation of floes occur.

ERS-1 Data Requirements:
(1) Repeat coverage (3 days) over a 3 week period during March of 1992 along the Canadian East Coast.
(2) Repeat coverage (3 days) over a 3 week period during the Spring-Summer of 1991 in the Beaufort-Mackenzie Delta region.

Facilities to be Deployed:
Complementary data will be captured by the AES Ice Data Integration and Analysis System (IDIAS) and archived for future reference.

Anticipated Results:
(1) Refine ice tracking techniques within specific ice regimes.
(2) Improved, and in some cases, new products for users operating in the ice environment and ice forecasters.
(3) Validation and improvement of sea ice models.

Milestones/Deliverables:
(1) An evaluation report on the ability of the algorithms for extracting ice kinematic information over different ice regimes.
(2) A report detailing the methodology for implementing components of ice motion extraction techniques and products into AES operations.
(3) Archive of remotely sensed imagery (ERS-1, NOAA, airborne SAR), meteorological data, sea ice model output, ice beacon, and ice analysis charts for the duration of the program.

Coordinator: PIPOR

PIP.BCB7

INTERACTION OF WAVES AND OCEAN FEATURES WITH THE MARGINAL ICE ZONE

Principal Investigator:
B.Holt JPL 300-323, Pasadena, California 91109, USA Tel: 818 354 5473

Co-Investigators:
A.Liu (GSFC), M.Drinkwater (JPL)

Objectives:
Examine the interaction of waves and circulation features, such as mesoscale eddies, with the marginal ice zone from ERS-1 SAR imagery, and the effects of waves and ocean features on ice breakup, ice melt, ice distribution, and radar ice signatures.

Experiment Plan:
It is planned to examine the use of ERS-1 SAR imagery of the outer ice margin of the Bering Sea during winter and of the Chukchi and Beaufort Seas during periods of summer ice retreat when there is considerable open water, waves and circulation features detectable within the ice margin. Wave spectra will be derived using the ASF GPS wave product algorithm and examined for changes in wave refraction, attenuation, and dispersion due to interaction with ice cover. These changes will be compared with wave-ice interaction models. The effects of waves and circulation features on ice breakup, ice melt, ice distribution, and the radar ice signatures will also be determined. From mesoscale eddies, the surface velocity field will be determined by tracking the rotation of detectable floes within the eddies and by wave refraction through wave-current interactions. Preliminary work on waves will include validation of GPS wave products from data acquired in the Gulf of Alaska which can be compared with wave buoy measurements. An examination will also be made of the SAR imaging mechanisms of both waves and circulation features. A similar study of SAR imagery from the Weddell and Ross Seas will also be made.

ERS-1 Data Requirements:
ERS-1 SAR imagery:
(1) Gulf of Alaska ocean imagery of waves during two storm events: 2-4 data takes 1-2 minutes long over a 4 month period.
(2) Imagery of the Bering Sea ice margin: 8-10, 1-2 minute data takes during winter.
(3) Imagery of the Chukchi and Beaufort Sea: 8-10, 1 minute data takes during summer ice retreat.
(4) Imagery of the Weddell and Ross Seas at about these same volumes.

Anticipated Results:
Comparisons of SAR derived wave spectra with wave-ice interaction models and NDBO buoy data. Determination of the effects of waves and circulation on ice distribution, melt and breakup and radar signatures.

Milestones/Deliverables:

Year 1	Validation of ASF GPS wave products algorithm.
Years 2&3	Examination of several wave and circulation events at the various ice margins. Validation of wave-ice interaction model. Papers published in referred journals.

Coordinator: PIPOR

PIP.BCB8

STUDIES OF CLIMATE PROCESSES USING REMOTELY SENSED IMAGERY

Principal Investigator:
E.F.LeDrew/D.G.Barber Earth Observations Lab., Institute for Space and Terrestrial Science, Department of Geography, University of Waterloo, Canada

Co-Investigators:
R.De Abreu/ D.Flett (as above)

Objectives:
The primary objective is to assess the use of climatological variables, derived from microwave length remote sensing imagery, for modelling climate processes in the Arctic. Two interrelated research themes will be pursued:
1) The effect of atmosphere-cryosphere interaction on the development of synoptic systems in the Beaufort Sea and the feedback to ice dynamics, specifically with respect to the Beaufort Sea Gyre of the Canada Basin.
(2) The specification of climatological parameters (eg albedo. enthalpy flux, ice thickness, snow cover, etc) derived from microwave imagery directly or as proxy data, in a form which can be utilized in numerical models of climate processes.

Experiment Plan:
Theme 1
(1) Through numerical simulation of specific synoptic events, examine the role of atmosphere-cryosphere feedbacks on the development and maintenance of the Beaufort Sea Gyre, and the August reversal of that gyre. Of particular importance is the effect of ice divergence on the atmospheric processes through regulation of the surface enthalpy flux and frictional contrasts.
(2) Through sensitivity studies, determine the spatial scale of surface anomalies (frictional and thermal discontinuities) which is significant in terms of these feedbacks. For example, does a one-half kilometre wide lead have an influence at the scale of synoptic evolution through the enhanced enthalpy flux, or is this a transient event from the perspective of the history of a weather system?
(3) Include accurate data regarding surface characteristics derived from satellite imagery at the appropriate scale (determined above) to simulate these feedbacks. These data will be used to calculate the heat flow through the ice and from the open water, and to model the effect of the frictional contrasts between water and ice, and different types of ice.
(4) Apply the numerical model to a multi-year time series of aerial and satellite-derived data to examine the interannual variability of the atmosphere-cryosphere system and to understand the forcing parameters of that variability.
Theme 2
(1) Evaluate context sensitive spatial statistics for Sea Ice feature extraction from ERS-1 imagery.
(2) Assess the stability of spatial statistics for derivation of proxy indicators required for numerical climate models.
(3) Conduct a bivariate analysis to assess the interrelationships between active and passive microwave climatological proxy indicators through time and space.
(4) Develop a procedure for mapping climatological albedo and net radiation from microwave imagery. Assess the integration requirements of these data into climatological data banks in a form appropriate for climate studies.

ERS-1 Data Requirements:
From March to October 1992, coverage every 3 days for 72° to 80°N ,110°-130°W. Descending passes are needed every 3 days, coincident with NOAA, LANDSAT, SPOT, SSM/I; and during a field program.

Anticipated Results:
This research will contribute to improved understanding of the relationships between ice and ocean on atmospheric forcing and the possible feedbacks. This will be facilitated through development of the climatological proxy measures of appropriate spatial scale from ERS-1 and SSM/I microwave imagery. An important issue is the extrapolation of high resolution data derived from ERS-1 imagery to the synoptic scale coverage of the SSM/I imagery. Development of suitable spatial statistics for deriving the proxy measures will allow these image types to be used in global change modelling, thereby improving our understanding of the atmospheric systems in this region.

Milestones/Deliverables:
Technical and journal publications: (1) Data calibration for climatological parameters; (2) Assessment of mapping capabilities; (3) Verification of climatological maps.

Coordinator: PIPOR

PIP.BCB9

CORRELATES FOR ICE THICKNESS IN SAR IMAGES OF PACK ICE

Principal Investigator:
H.Melling — Institute of Ocean Sciences, Box 6000, Sidney B.C. Canada V8L 4B2
Tel: 604 356 6552

Objectives:
(1) To obtain detailed profiles of thickness and bottom topography of pack ice using moored subsea instruments.
(2) To map sonar-derived tracks onto SAR images of the top surface of pack ice.
(3) To explore the correspondence between SONAR and SAR views of the same ice.

Experiment Plan:
(1) Deploy ice-measuring sonars at 2 sites in the southeastern Beaufort Sea for at least 3 years starting in March 1990. The sonars will measure the motion (hourly) and thickness (every 20 seconds) of drift ice at fixed locations.
(2) Deploy satellite-tracked platforms on the ice for measurement of atmospheric pressure and corroborative ice displacements.
(3) Map the track surveyed by the sonar onto navigated SAR images from ERS-1.
(4) Extract the SAR pixel values along and adjacent to that track for further study.

ERS-1 Data Requirements:
(1) Three-day Repeat Orbit (Jan-March, 92, and during Cal/Val Phase)
(2) One SAR scene (100km x 100km) every 3 days, for 90 days: scene centre at 71°N, 132°W, (approx).
(3) Geocoded, full resolution SAR product is required, on CCT.

Facilities to be Deployed:
This project will utilize equipment, vessel support and personnel of the Department of Fisheries and Oceans, Canada, at the Institute of Ocean Sciences.
Logistic support at Tuktoyaktuk on the Arctic coast of Canada is anticipated from the Polar Continental Shelf Project of Energy, Mines and Resources, Canada.

Anticipated Results:
(1) Phenomenological and statistical relationships between ice type/thickness, and ridge and lead frequencies, widths and 'intensities' (read accordingly as draft, or as radar cross section) as determined by subsea sonar and satellite radar sensors.
(2) Radar-image ice classification in terms of practically important ice parameters (thickness distribution, ridge frequencies, leads).

Milestones/Deliverables:
On the assumption that images are available on a 3-day repeat cycle early in 1992, and that sonars are successfully recovered in April 1992:

Autumn 1992	Data report.
Autumn 1993	Final report, including quantitative sensors comparisons, statistical summaries and selected classified images.

Coordinator: PIPOR

PIP.BCB10

STUDIES OF THE AUTUMNAL FREEZE-UP OF THE CHUKCHI SEA

Principal Investigator:
S.Martin School of Oceanography WB-10, University of Washington, Seattle, WA 98195

Co-Investigators:
P.Wadhams (Scott Polar Research Institute), B.Holt (JPL), Susan Frankenstein (University of Washington)

Objectives:
To understand the role of frazil and pancake ice in the ice freeze-up of the Chukchi Sea. The importance of this region is that it is the place where the Pacific Water transported north through the Bering Strait loses heat and gains salinity before entering the Arctic Ocean. SEASAT imagery and ship cruises show that large areas of frazil and pancake ice form in the Chukchi. The aim is to understand how these ice types affect the heat transfer.

Experiment Plan:
Images of openwater, ice and grease ice are requested at weekly intervals through freeze-up, 15 October - 1 December, for the study area (66-70N, 165-172W). These will be analyzed to determine areal extent of frazil and pancake ice, and the interaction of these ice types with surface waves.

ERS-1 Data Requirements:
SAR swaths from within the Chukchi (66-70N, 165-172W) are required at one week intervals during this period 15 October - 1 December, 1992 and 1993.

Anticipated Results:
Our analysis of these images should yield information on the role of frazil and pancake ice in the freeze-up of the Chukchi Sea.

Milestones/Deliverables:

Oct 1992	SAR coverage begins.
Jun 1993	Preliminary analysis is complete
Oct 1993	Second year coverage begins, with swath requests modified by experience of previous year.
Jun 1994	Preliminary analysis of second year is complete.
Dec 1994	Final analysis is complete.

Coordinator: PIPOR

PIP.BCB11

STUDIES OF POLYNYA AND ICE EDGE PROCESSES IN THE WINTER BERING SEA

Principal Investigator:
S.Martin School of Oceanography WB-10, University of Washington, Seattle, WA 98195

Co-Investigators: E.D'Asaro (University of Washington), D.Cavalieri (NASA/GSFC)

Objectives:
To understand the processes within the Bering Sea polynyas and at the Bering Sea ice edge. The polynyas of interest include the St Lawrence Island polynya, the Cape Rodney polynya in Norton Sound, and the Gulf of Andyr polynya. It is also planned to study the winter Bering Sea ice edge, in an attempt to determine the growth, deformation and decay of the ice edge bands.

Experiment Plan:
(1) St Lawrence Island Polynya (63.5°N, 170°W): During Feb-March 1992, an icebreaker experiment is planned within the polynya south of St Lawrence Island. The experiment is called 'SLIP' for St Lawrence Island Polynya. From the icebreaker, process studies of Langmuir circulation, brine rejection, and salt production will be carried out. It is also hoped to obtain aircraft overflights of the region with the NASA DC-8. The radar observations should supplement this study with a larger scale view than our ship and aircraft based measurements.
(2) Cape Rodney Polynya (64.5N 167W): This is also a large polynya influenced by powerful winds which are focussed by the Cape. Study duration will be Jan-April 1992 and 1993.
(3) Gulf of Anadyr Polynya (64.5N, 178W): This is the least studied of the Bering Sea polynyas; and appears to contribute strongly to the Arctic Ocean surface waters. A monitoring effort is planned only during Jan-March 1992-93.
(4) The Ice Edge Studies (approx 60N, 170W): An investigation of the nature of the Bering Sea ice edge during the period Jan-March 1992 and 1993. Specifically, determination of the dynamic and physical mechanisms which control the transition from ice cover to open water. To obtain data on the ice physics, there is a request for successive passes of data, with intersection of the ice edge. This data would be compared with surface weather data, and with ship-of-opportunity data to resolve the ice edge response to winds.

ERS-1 Data Requirements:
(1) St Lawrence Polynya is located at approximately 170W, 63N. Ship is planned to be at the polynya for about one month in the period Feb-March 1992. Overall SAR coverage of the polynya is required from Jan-April; and specific coverage during the period when the ship is in the polynya. Pairs of swaths collected at the shortest possible repeat period are also requested, where the swaths map the same area, to determine the behaviour and evolution of the Langmuir circulation.
(2) Cape Rodney Polynya (64.5N, 167W): swath taken along the same path during Jan-March 1992 and 1993.
(3) Gulf of Anadyr Polynya (64.5N, 178W): swath taken along the same path during Jan-March 1992 and 1993.
(4) The Ice Edge Studies (approx 60N, 170W): swaths along the same path during Jan-April 1992 and 1993.

Facilities to be Deployed:
For the St Lawrence Island Polynya study, it is planned to have an icebreaker, moored current meters, possible aircraft overflights, and intensive surface and sub-surface observations.

Anticipated Results:
It is hoped that the SLIP study will provide detailed knowledge of the physical processes which govern the ice production, Langmuir circulation, and brine rejection within a polynya. The ERS-1 radar images will complement the small scale field investigation by providing information on the large scale behaviour of polynyas, as well as details of what goes on outside of the immediate study region. The other polynya studies will help resolve the nature of the ice and open circulation in the Cape Rodney and Gulf of Anydyr regions, and the ice edge study will help resolve the nature of the Bering Sea ice edge.

Milestones/Deliverables:

Jan 1992	SAR coverage begins.
Feb-March 1992	SLIP polynya experiment takes place.
Dec 1992	Analysis of ship data is complete, comparison with radar data begins.
Dec 1993	Analysis and comparison of data is complete. Publication of results.

Coordinator: PIPOR

PIP.BCB13

SEASONAL ICE ZONE PROCESSES: ICE DYNAMICS AND POLYNYAS

Principal Investigator:
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Co-Investigators:
R.Muench (SAIC, Bellevue, WA), Carol Pease/ B.Walter (NOAA/PMEL)

Objectives:
(1) The hypothesis to be investigated is that development and changes in regional ridge and lead patterns are directly related to the deformation pattern of the atmospheric wind field or the coastline orientation. Case studies using SAR imagery on the formation of ridges and leads in response to atmospheric forcing will provide valuable information and ice dynamics for development of regional ice models.
(2) To study the processes of ice formation under windy conditions in the St Lawrence Island Polynya and other Arctic coastal zones. Ice type information from SAR data is an important source of data in studying the physics of ice formation, and in relating the mesoscale variations of ice type downwind of the polynya to the effects of upstream topography on the surface wind fields.

Experiment Plan:
(1) The ice dynamics component will focus on the Beaufort Sea during the Mar-Apr 1992 time period. An array of meteorological stations will be deployed to measure regional pressure fields. Case studies will be done where visible and IR imagery from polar orbiter satellited will be integrated with the SAR data from ERS-1. During the intensive LEADS field effort the NOAA P-3 research aircraft will be used to map the atmospheric structure, and make measurements of turbulent fluxes from leads. The second region of interest is the vicinity of Bering Strait during the winter seasons of 1991-1994.
(2) The polynya component will focus on the study of ice formation processes in the polynya in the lee of St Lawrence Island in the Bering Sea. Near real time processed full resolution SAR data from the ASF will be required for field experiment coordination and planning. Measurements from ships and a moored array collected during ice formation in the polynya will provide comprehensive ground truth for the SAR data. The intensive field experiment will be carried out during Feb-Mar 1992.

ERS-1 Data Requirements:
Both components require as frequent image overlap as possible, including partial overlaps. SAR data should be collected from October to June. Coordinates for data collection are 58°N-76°N and 180°-120°W. All derived products will be required, especially ice concentration, ice vectors, and ice type. A small subset of this data will be selected for intensive case studies.

Anticipated Results:
(1) Improved sea-ice rheology for ice-forecasting and climate models.
(2) Improved understanding of: Langmuir cells in the polynya; the interaction of secondary circulations in the atmospheric boundary layer with the ocean Langmuir cells; the processes governing salt rejection to the ocean; and effects of polynyas on regional climate.

Milestones/Deliverables:

Spring 1991	Data collection for test case.
Winter 1992	Main field programmes.
1993	Completion of analysis of SAR and in situ data.
1994	Results to be incorporated in a regional sea ice model.

Coordinator: PIPOR

PIP.BCB14

ARCTIC SEA ICE MICROWAVE SIGNATURE AND GEOPHYSICAL PROCESS STUDIES

Principal Investigator:
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Tel: 313 994 1200 x2590

Co-Investigators:
R.A.Shuchman/ C.C.Wackerman (ERIM)

Objectives:
Emphasis concerns sensor, algorithm, and EM model verification and validation, and geophysical analysis. One key element is the study of the inter-regional, regional, and temporal variation of the microwave sea ice signatures.

Experiment Plan:
Coordination of in-situ microwave and scene characterization measurements with airborne SAR and ERS-1 data collections. These data will be used to determine ice type classification accuracy and signature variability and temporal evolution. Data will also be used to support studies to retrieve or determine lead distribution and orientation, surface winds in polynyas, kinematics (high-resolution) associated with eddies, ice rheology around eddies and shear zones, and wind-wave-current forcing using SAR derived ice edges.

ERS-1 Data Requirements:
Geographical regions of interest include the Bering, Chukchi, Beaufort, Greenland and Barents Seas and Central Arctic. Many of the data requests will be limited to the sites supported by in-situ and air-borne measurement programs. These sites required coverage as continuous as possible:
(1) ASF high and low resolution image and GPS ice concentration and type products.
(2) ERS-1 SAR at up to six "Super Sites" with two data takes 1-2 minutes every three days over 3 month period.
(3) ERS-1 SAR at up to six "Super Sites" with two data takes 1-2 minutes every 35 days. Absolute radiometric calibration of 2db

Facilities to be Deployed:
(1) In-situ microwave property measurements using scatterometer radiometer (helicopter-borne and surface and multiple frequencies).
(2) In-situ EM oriented scene characterizations.
(3) ERIM/NADC P-3 L-C-X Band Polarimetric SAR (ie underflights).
(4) EM scattering model analysis and support.
(5) Visible and infrared ground truth (helicopter-borne).

Anticipated Results:
(1) Accuracy estimates of ice type classification and identification of problem areas.
(2) Improved determination of relationships of MW signature variations to physical properties and ability to invert signatures to physical properties.
(3) Improved knowledge of temporal and regional variability and relationship between signatures and region-formation conditions.
(4) Enhanced ability to extract geophysical products.
(5) Application of EM scattering model prediction to SAR satellite data and model analysis/validation and enhanced ERS-1 SAR simulation model.

Milestones/Deliverables:

Mar 1992,93,94	Data reports.
Feb. 1993	Preliminary algorithm analysis.
1994	Preliminary geophysical and temporal signature analysis; Final algorithm analysis.

Coordinator: PIPOR

PIP.BCB15

COMBINATION OF ACTIVE AND PASSIVE MICROWAVE SIGNATURES OF THE BEAUFORT SEA

Principal Investigator:
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Co-Investigators:
M Collins/I Rubinstein (ISTS/York University), B Burns (AWI/Bremerhaven), P Gudmansen (Technical University of Denmark), H Hoeber/J.Meincke (University of Hamburg), K.Struebing (DHI Hamburg)

Objectives:
(1) To combine ERS-1 SAR with SSM/I (Special Sensor Microwave Imager) data, and in some cases with AIMR (Airborne Imaging Microwave Radiometer) and Intera STAR-2 SAR data, to significantly enhance the information content in conventional regional ice charts.
(2) To test the hypothesis of using SAR data beyond SAR swath boundaries within the SSM/I data field.
(3) To provide the input of this combined data set into operational ice forecasting models.

Experiment Plan:
The project will follow four phases as follows:
(1) Develop algorithms to extract ice information from the combined SSM/1 - ERS-1 SAR data set. This will follow a multispectral approach, ie overlapping digital image data will be treated as separate spectral channels of the same scene.
(2) Establish spatial and temporal tolerances for the time separation of the digital image data. These tolerances will determine whether incoming image data can be incorporated into the current ice chart or if a new chart must be generated.
(3) Test the hypothesis that some components of the high resolution SAR information may be extrapolated beyond the boundaries of the SAR swath by using statistical analysis of the active-passive ice signatures and previous SAR data from the same area.
(4) Develop a strategy for assimilating the microwave measurements into a regional, operational ice forecasting model. Particular attention will be paid to the spatial and temporal scales of the data versus those required by the model in order to provide reasonable estimated of ice characteristics.

ERS-1 Data Requirements:
On the PIPOR orbit (3-day repeat) the data collection pattern would be 2 passes per day within the shortest time cycle possible from approx 80°N to either the coast or the southern ice edge. The exact sequence of these data-takes should be coordinated with sampling of the Alaska coast and further into the Arctic Basin.

Anticipated Results:
The study will provide a new year-round characterisation of ice conditions for both display in ice products by operational ice services and input in more sophisticated operational ice forecasting models. It essentially will bridge the basic problem of inadequate SAR coverage, but will make use of the much higher resolution of the SAR data.

Milestones/Deliverables:
Initial milestones by ISTS will be the preparation of the software to combine airborne SAR and AIMR data and the preparation of the software for the regional integration of satellite passive microwave data with the high resolution data. This will take place prior to launch. One year after the results from the experiment plan(1) will be presented, 18 months after launch (2) and (3), and 3 years after launch element (4)

Coordinator: PIPOR

PIP.BCB16

NOAA ICE CENTRE APPLICATIONS DEMONSTRATION PROGRAM

Principal Investigator:
G.Wohl NOAA Ice Centre Tel: 301 763 5972

Co-Investigators:
W.Pichel (NOAA NESDIS), Sharolyn Young (NOAA Ice Centre)

Objectives:
Develop the capabilities to employ SAR imagery of sea ice for operational applications.
(1) Image compression.
(2) Ship routing product.
(3) Knowledgeable interpretation.
(4) Ridge and lead statistics.
(5) Ice shelf monitoring.
(6) Algorithm applications.

Experiment Plan:
Six projects , dealing with each of the above topics, have been identified to examine the utility of SAR imagery in support of on-going operations and to explore new avenues of sea ice support for the operational community.
The Ice Centre's interest in SAR coverage includes all the seas surrounding Alaska within the following approximate temporal guidelines:Beaufort Sea (all year), Chukchi Sea (October through July), Bering Sea (November through June), Cook Inlet (December through April).

(1) Test several algorithms and/or different compression ratios.
(2) Transmit timely sea ice analyses to subject vessel.
(3) Compare guidance products issued by NOAA Ice Centre for SAR imaged and conventionally imaged areas.
(4) Provide pre-analysed examples of sea ice products.
(5) Develop SAR interpretation course on workstation.
(6) Statistics of lead and ridge frequency, spacing and length for selected regions.
(7) Prepare monthly or seasonal climatology of lead and ridge statistics.
(8) Monitor changes in the location of ice shelf fronts and the size of major crevasses or rifts.
(9) Use SAR imagery of Alaskan glaciers to prove the concept for eventual application to Antarctic ice shelves.

ERS-1 Data Requirements:
NOAA Ice Centre operations will be supported by the Alaska SAR Facility via a direct link to a NOAA SAR workstation. This link will provide NOAA with at least 2 min of quick-turn-around data each day. Primary forms will be on the ice edge and marginal ice forms in the Bering, Chukchi, Beaufort and East Siberian Seas. Full resolution products from selected sites in the ASF station most will be coordinated with ASF.

Anticipated Results:
Image compression will be used to facilitate data transmission to the NOAA Ice Centre and to determine the quality of ice analysis prepared from compressed imagery. Image compression may have future applications in reducing processing times associated with automated ice analysis algorithms. Direct ship support is a straightforward program in which new products based upon SAR images will be derived and provided to operational elements in the Alaska region.
SAR images will enable the Ice Centre to accurately plot the edge of the ice shelf and detect major crevasses and rifts that might precede a calving event.

Coordinator: PIPOR

PIP.BCB17

DYNAMICS AND THERMODYNAMICS OF THE PACK ICE OF THE ALASKAN SHELF SEAS

Principal Investigator:

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Tel: 907 474 7280

Co-Investigators:

C.Olmsted/ R.Wade (GI/UAF), G.Maykut (Department of Atmospheric Sciences, University of Washington, Seattle)

Objectives:

The program proposes to couple ice deformation and ice type information, obtained by processing ASF SAR data on the Geophysical Processor System (GPS), with modelling calculations that are driven by meteorological data. The purpose is to ultimately extend the geophysical capabilities of the GPS by estimating changes in the ice thickness distribution, the chemical and physical profile properties of the ice types present, and the local and regional salt and heat fluxes at the ice/ocean and ice-air interfaces.

Experiment Plan:

The year-around study focuses on the area of pack ice between Banks and Wrangel Islands that is also located within 400km of the Alaskan coast. As the southerly boundary of the region of interest is fixed by the ice edge, during the winter the study area will expand southward through the Bering Strait into the Bering Sea. The 100m resolution imagery from this general region will then be processed via the GPS to obtain both ice motion and ice type variations. It should be noted that it is quite likely that modifications of the ice types software will be required before an adequate estimate of this parameter can be obtained. The resulting data, will, in turn, drive an auxiliary modelling effort that will run concurrently on the Interactive Image Analysis System (IIAS) at ASF and, by utilising meteorological information from the Unidata system, generate heat and salt flux estimates, ice property descriptions and ice thickness distributions.

ERS-1 Data Requirements:

On the Venice orbit (3-day repeat), the ideal data collection pattern would be 2 passes each day from approximately 75-76°N, south to either the coast or the southern edge of the ice pack. This means that during a 3 day repeat cycle there would be a total of 6 data-takes. The exact sequence of these data-takes should be coordinated with sampling further offshore in the main basin and with a variety of other studies that are being proposed for the general area of the Bering Sea.

Anticipated Results:

The study will provide heat and salt fluxes, ice thickness changes and ice properties a year-around characterization of sea ice behaviour, over the Alaskan continental shelf of Beaufort, Chukchi and Bering Seas. This is an area of highly dynamic ice behaviour and variability containing regions of both consistant divergence and deformation. Of particular interest\will be ice behaviour in the highly deformed near shore shear zone located north of the Beaufort Coast and the temporal changes in the ice deformation patterns which we hope to characterize by utilising fractal techniques.

Milestones/Deliverables:

Pre-launch	completion and testing of IIAS software for calculating deformation parameters; ice growth, ice property and thickness.
6 months	progress report on data processed plus preliminary report on results as well as possible recommendations for modifications in GPS software.
1 year	initial results presented at scientific meeting and submitted to a journal.
1 1/2 years	2nd progress report on data processed plus results.
2 years	final report on data processing, GPS recommendations for future missions, and final submission of papers to technical journals.

Coordinator: PIPOR

PIP.GSP1

LARGE SCALE SURFACE PROCESSES IN THE GREENLAND SEA PROJECT

Principal Investigator:
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Co-Investigators:
C.Morris/ J.Crawford (JPL), F.Carsey/P.Wadhams, J.C.Gascard/H.Skriver, L.Toudal

Objectives:

(1) Determine the rate and temporal nature of the thermohaline forcing of Greenland Sea ventilation.
(2) Determine the surface vertical and horizontal fluxes of heat, brine and fresh water in the Greenland-Barents-Nansen Sea Region.

Experiment Plan:

(1) Refine algorithm for ice thickness changes in thin ice regime using SAR and SSM/I data (if necessary).
(2) Compute time series of ice motion and thickness for the Greenland Gyre.
(3) Compute ice concentration for the Greenland/Nansen Sea region.
(4) Perform validation with Danish A/C data, Norwegian ice motion buoys and upward looking SONAR data.
(5) Compute heat fluxes for the Greenland/Nansen Sea Region meteorology and oceanography data from archived data sources with satellite data.
(6) Calculate net ice flux into the region using the ASF-GPS or its JPL twin.
(7) Estimate brine fluxes and freshwater fluxes for the region.
(8) Compare brine flux data in the gyre with moored oceanographic data from GSP.
(9) Supply results to ice dynamics modelers in GSP.

ERS-1 Data Requirements:

For intensive period December through March 1992, 1993, 1994:
Descending orbit data over Greenland Sea, = 2 minutes every day.
Ascending orbit data over the Fram Strait 1 pass = 1 minute every day.
For monitoring period, November and April, 2 data takes per 16 days, 4 minutes each data take.

Facilities to be Deployed

(1) Danish SAR equipped aircraft for validation program March-April 1991.
(2) Proposed ship participation in validation by German research vessel.

Milestones/Deliverables:

June 1991	Data report for aircraft studies
July 1991/2/3	Data reports for GSP
Sept 1991/2/3	Free motion and ice thickness analysis
Nov 1991/2/3	Brine Production analysis for GSP
April 1994	Final report

Coordinator: PIPOR

PIP.GSP2

COMBINATION OF ACTIVE AND PASSIVE MICROWAVE SIGNATURES OF THE GREENLAND SEA

Principal Investigator:
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Co-Investigators:
M Collins/I Rubinstein (ISTS/York University), B Burns (AWI/Bremerhaven), P Gudmansen (Technical University of Denmark), H Hoeber/J.Meincke (University of Hamburg), K.Struebing (DHI Hamburg)

Objectives:
(1) To combine ERS-1 SAR with SSM/I (Special Sensor Microwave Imager) data, and in some cases with AIMR (Airborne Imaging Microwave Radiometer) and Intera STAR-2 SAR data, to significantly enhance the information content in conventional regional ice charts.
(2) To test the hypothesis of using SAR data beyond SAR swath boundaries within the SSM/I data field.
(3) To provide the input of this combined data set into operational ice forecasting models.

Experiment Plan:
The project will follow four phases as follows:
(1) Develop algorithms to extract ice information from the combined SSM/1 - ERS-1 SAR data set. This will follow a multispectral approach, ie overlapping digital image data will be treated as separate spectral channels of the same scene.
(2) Establish spatial and temporal tolerances for the time separation of the digital image data. These tolerances will determine whether incoming image data can be incorporated into the current ice chart or if a new chart must be generated.
(3) Test the hypothesis that some components of the high resolution SAR information may be extrapolated beyond the boundaries of the SAR swath by using statistical analysis of the active-passive ice signatures and previous SAR data from the same area.
(4) Develop a strategy for assimilating the microwave measurements into a regional, operational ice forecasting model. Particular attention will be paid to the spatial and temporal scales of the data versus those required by the model in order to provide reasonable estimated of ice characteristics.

ERS-1 Data Requirements:
On the PIPOR orbit (3-day repeat) the data collection pattern would be 2 passes per day within the shortest time cycle possible from approx 66°-82°N and 15°E to the coast of Greenland. The exact sequence of these data-takes should be coordinated with sampling of the Greenland Sea program.

Anticipated Results:
The study will provide a new year-round characterisation of ice conditions for both display in ice products by operational ice services and input in more sophisticated operational ice forecasting models. It essentially will bridge the basic problem of inadequate SAR coverage, but will make use of the much higher resolution of the SAR data.

Milestones/Deliverables:
Initial milestones by ISTS will be the preparation of the software to combine airborne SAR and AIMR data and the preparation of the software for the regional integration of satellite passive microwave data with the high resolution data. This will take place prior to launch. One year after the results from the experiment plan(1) will be presented, 18 months after launch (2) and (3), and 3 years after launch element (4).

Coordinator: PIPOR

PIP.LAB1

SHEAR AND CONVERGENCE OF LABRADOR SEA PACK ICE

Principal Investigator:
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Co-Investigators:
T.Hirose (Noetix), S.Prinsenberg (BIO), G.Crocker (C-CORE), S.Patersonn (CCRS), J.Falkingham (AES)

Objectives:
In LIMEX'87 and LIMEX'89, shear zones were observed to develop in compact pack ice in the near-shore zone. The shear zones were observable on airborne SAR imagery during the period of the experiment when air temperatures were above 0°C. The zones represent abrupt transitions in pack advection rates, and may represent abrupt changes in physical pack characteristics. Rafted ice is commonly observed and is thought to be associated with shear.
(1) To locate shear zones in the Labrador Sea ice using SAR data.
(2) To locate convergence zones in the Labrador Sea pack using SAR data.

Experiment Plan:
(1) Determine the detectability of ice shear and convergence as it changes with seasonal change.
(2) Monitor relative pack advection and ice convergence using buoys and SAR motion algorithms in areas of compact pack separated by shear zones.
(3) Monitor the existence, development, location and duration of shear zones features in the SAR data for pack ice in offshore Newfoundland during the period of maximum ice extent.
(4) Determine changes in pack characteristics across shear zones.

ERS-1 Data Requirements:
SAR data from every pass that covers near-shore pack ice on East coast of Newfoundland from 46° to 52° N, for month of March.

Anticipated Results:
(1) Charts showing advection rates for pack areas defined by shear zones.
(2) Charts of shear zones for each SAR pass.
(3) Conclusions showing shear zone detectability in SAR data as a function of temperature.
(4) Conclusions detailing change in pack ice characteristics across shear zones.

Milestones/Deliverables:

March 1992	Data collection
Sept. 1992	Data report

Coordinator: PIPOR

PIP.LAB2

EXTRACTION OF ICE EXTENT, FLOE SIZE AND DISTRIBUTION USING DIGITAL METHODS

Principal Investigator:
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Co-Investigators:
T.K.Hirose (Noetix, Ottawa), S.Argus (CCRS, Ottawa)

Objectives:
This program proposes to extract multi-year ice floes from SAR iamgery, and map their size distribution using digital techniques.

Experiment Plan:
The study will be performed in the Beaufort Sea / MacKenzie Delta region. Complementary radar data will be acquired from the Intera airborne X-band system in support of AES Ice Branch. Other information will include NOAA imagery, ice analysis charts and surface pressure charts.

ERS-1 Data Requirements:
SAR data will be required during the spring-summer period of 1991 when off-shore operators are active. Scheduling for the acquisition of ERS-1 data will be driven largely by the availability of surface observations and airborne reconnaissance flights.

Facilities to be Deployed:
Intera airborne X-band SAR

Anticipated Results:
(1) Improved accuracy of ice analysis charts.
(2) Improved ice information to off-shore oil producers.

Milestones/Deliverables:
(1) An evaluation of the results for the extraction of multi-year ice in the study area will be presented in a report.
(2) An archive of the remote sensing data and ancillary information will be available through AES.

Coordinator: PIPOR

PIP.LAB3

SEA ICE FLUX OVER THE LABRADOR SHELF

Principal Investigator:
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Objectives:
(1) To measure southward sea ice and heat fluxes to the Labrador Shelf with time scales of a week to season.
(2) To understand mechanisms to transport sea ice and heat southward.

Experiment Plan:
(1) Deploy ice beacons and current meters around Hamilton Bank and monitor movement and growth of ice as well as ocean currents.
(2) Measure water properties when the beacons are deployed.
(3) Measure ice thickness by electromagnetic method.

ERS-1 Data Requirements:
SAR: Jan.1 - Mar.31 1992 (3 day repeat) ascending pass.
Altimeter: All dates other than Jan.1 - Mar.31 1992 (35 day repeat) both passes.

Facilities to be Deployed:
Ice beacons, current meters, CTD stations and electromagnetic ice thickness sensor.

Anticipated Results:
(1) Obtain heat and ice balances over the Labrador Shelf, including both alongshore advection and cross-shore exchanges as well as air-sea interactions.
(2) Processes of heat and ice balances to be reproduced in numerical models.

Milestones/Deliverables:

1994	Data report of ice drifters and ice thickness.
1995	Results from numerical modelling.

Coordinator: PIPOR

PIP.LAB4

AN EVALUATION OF ERS-1 DATA TO MONITOR CHANGES IN REGIONAL ICE CONDITIONS ON THE CANADIAN EAST COAST AS RELATED TO STORM TRACK CLIMATOLOGY

Principal Investigator:
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Co-Investigators:
J.Falkingham/ D.Mudry (AES Ice Centre)), T.Hirose (Noetix Research, Canada)

Objectives:
(1) To investigate changes in the ice properties on a north-south transect along the coasts of Newfoundland and Labrador, including the pattern of ice advance and retreat, and the changes to floe size and ice type distributions within the pack ice.
(2) To relate observed changes to the effects of storm passage in the area, and associated effects of air temperature and precipitation on a regional scale.
(3) To evaluate the potential of satellite information to contribute to monitoring regional ice characteristics, and the contribution to environmental monitoring of ERS-1 data, and follow on systems such as RADARSAT and ERS-2.

Experiment Plan:
(1) Ice Charts will be prepared every three days using information from ERS-1 SAR and aircraft borne SAR. These charts will include visual observations from ships and aircraft, as available, and will be used to ascertain the patterns of ice advance and retreat, and the development of shore leads and polynyas.
(2) Storm tracks will be determined from the surface pressure charts and, combined with air temperatures from AES\, will be used with the Ice Charts to evaluate the use of the SAR for determining the effects of storm track climatologies in preparing ice climatologies for the Canadian East Coast.
(3) Coincident aircraft SAR and ERS-1 information will be identified, and an analysis made of changes to the floe size distributions will be made along the ERS-1 swath.
(4) An estimate of the distribution of multiyear ice, and icebergs will be made from selected ERS-1 and aircraft SAR data and visual observations to evaluate the ability of the sensors to characterize the ice pack.
(5) The potential use of the various RADARSAT swaths to characterize different aspects of the pack ice will be made, and recommendations will be made on the use of RADARSAT and ERS-2 to collect data on East Coast ice conditions in support of airborne reconnaissance, and ship operations.

ERS-1 Data Requirements:
During the Ice Orbit for ERS-1 in January to March 1992, data should be taken every three days along the track which passes along the Newfoundland/Labrador Coast. The length of this pass should remain consistent whether ice is present or not, as the oceanographic information contained on the imagery is important to the objectives of another proposal (PIP.LAB3).

Anticipated Results:
(1) During the data collection, the ice nowcast charts from IDIAS will be available for the Canadian East Coast as part of the routine operations.
(2) After the data collection period, a listing of all the archived data sets will be available as a package from the Climatology Division of AES.
(3) A comparison of historical records to the 1992 ice season will be generated so that the analysis can be performed in the context of the ice conditions as encountered.
(4)The storm track climatology for 1992 will be prepared from the surface pressure charts from Gander, Newfoundland.
(5) Suitable coincident aircraft and ERS-1 SAR data will be identified, and analysis of floe size distribution, multiyear ice fraction and iceberg counts will be combined into a report which compares the utility of the sensors.
(6) A report recommending data collection and analysis techniques for the use of aircraft, shipborne and satellite sensors to monitor environmental conditions on the East Coast of Canada will be prepared.

Coordinator: PIPOR

PIP.LAB5

COMBINATION OF ACTIVE AND PASSIVE MICROWAVE SIGNATURES OF THE CANADIAN EAST COAST

Principal Investigator:
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Co-Investigators:
M Collins/I Rubinstein (ISTS/York University), B Burns (AWI/Bremerhaven), P Gudmansen (Technical University of Denmark), H Hoeber/J.Meincke (University of Hamburg), K.Struebing (DHI Hamburg)

Objectives:
(1) To combine ERS-1 SAR with SSM/I (Special Sensor Microwave Imager) data, and in some cases with AIMR (Airborne Imaging Microwave Radiometer) and Intera STAR-2 SAR data, to significantly enhance the information content in conventional regional ice charts.
(2) To test the hypothesis of using SAR data beyond SAR swath boundaries within the SSM/I data field.
(3) To provide the input of this combined data set into operational ice forecasting models.

Experiment Plan:
The project will follow four phases as follows:
(1) Develop algorithms to extract ice information from the combined SSM/1 - ERS-1 SAR data set. This will follow a multispectral approach, ie overlapping digital image data will be treated as separate spectral channels of the same scene.
(2) Establish spatial and temporal tolerances for the time separation of the digital image data. These tolerances will determine whether incoming image data can be incorporated into the current ice chart or if a new chart must be generated.
(3) Test the hypothesis that some components of the high resolution SAR information may be extrapolated beyond the boundaries of the SAR swath by using statistical analysis of the active-passive ice signatures and previous SAR data from the same area.
(4) Develop a strategy for assimilating the microwave measurements into a regional, operational ice forecasting model. Particular attention will be paid to the spatial and temporal scales of the data versus those required by the model in order to provide reasonable estimated of ice characteristics.

ERS-1 Data Requirements:
On the PIPOR orbit (3-day repeat) the data collection pattern would be 2 passes per day within the shortest time cycle possible from approx 47-60°N and 45-60°W.

Anticipated Results:
The study will provide a new year-round characterisation of ice conditions for both display in ice products by operational ice services and input in more sophisticated operational ice forecasting models. It essentially will bridge the basic problem of inadequate SAR coverage, but will make use of the much higher resolution of the SAR data.

Milestones/Deliverables:
Initial milestones by ISTS will be the preparation of the software to combine airborne SAR and AIMR data and the preparation of the software for the regional integration of satellite passive microwave data with the high resolution data. This will take place prior to launch. One year after the results from the experiment plan(1) will be presented, 18 months after launch (2) and (3), and 3 years after launch element (4).

Coordinator: PIPOR

PIP.SOJ1

THE STUDY OF SEA ICE IN THE SEA OF OKHOTSK, JAPAN

Principal Investigator:
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Co-Investigators:
M.Wakatsuchi (ILTS), M.Aota/ K.Shirazawa (SIRL, Hokkaidi University), S.Hayashi (Tokyo University of Merchant Marine), M.Kashiwai (Hokkaido Rgional Fisheries Research Lab), K.Okamoto (Communications Research Lab), I.Noguchi (Hydro Department, Marine Safety Agency), S.Martin (University of Washington), W.Weeks (University of Alaska, Fairbanks)

Objectives:
To investigate the dynamics and thermodynamics of sea ice and polynyas in the Okhotsk and Japan Seas in the following areas: the Okhotsk coast of Hokkaido, the Tarter Strait of the Japan Sea, the Kashevarova Bank area, the northwest coast of the Okhotsk Sea, the East coast of Sakhalin Island, and the Kuril Basin. These data will be received at the NASDA Earth Observation Centre in Hatoyama, outside Tokyo.

Experiment Plan/ Data Requirements:
Region 1. Ice Dynamics near the Hokkaido Coast
(140-145E, 43-46N): Sea ice along this coast is monitored by three land-based radars which are operated by the Sea Ice Research Laboratory in Mombetsu. These radars cover a coastal strip of 250km along the coast by 50km wide. For validation of the SAR with these sea-ice radars, pairs of swaths covering this region every two weeks from January to April are required.
Region 2. Ice Growth in the Tartar Strait
(138-142E, 45-53N): The sea ice formation in the Japan Sea occurs mainly in the Tartar Strait between Sakhalin Island and the USSR mainland. This is the only ice-covered region which feeds cold, salty water into the Japan Sea.
Region 3. Dynamics and Thermodynamics of the Kashevarova polynya
(145-147E, 55-56N): The SAR data will be used to determine ice circulation in the region, and to assess the new ice formation in polynyas.
Region 4. Ice Formation in the Northwest Coast Polynya
(135-155E, 55-60N): This experiment will determine the nature of the ice formation in coastal polynyas fior comparison with passive microwave data. Ice transport and ice growth characteristics will also be studied. This is an important study area due to the dense water formed here which contributes to the North Pacific and the Oyashio Current.
Region 5. Ice Drift and Polynya at the East Coast of Sakhalin
(140-145E, 45-55N): These polynya areas are unstudied to date and the SAR will offer the first opportunity to study them in detail. The ice produced in these polynyas contribute strongly to the amount of ice which reaches the Hokkaido Coast.
Region 6. Ice Eddies in the Kuril Basin
(145-155E, 43-50N): These large eddies also contribute to water mass modification and by oxygenating the water column, thereby increasing biological productivity in the Okhotsk.

Facilities to be Deployed:
NOAA receiving station.
Shore-based radar.
Field equipment for ice observations.

Anticipated Results:
The first SAR-based assessments of ice production and processes in the six regions listed above. Also the first rigorous comparison of a shore-based radar and SAR for observing ice on an operational basis in an area of intense activity.

Coordinator: PIPOR

UK4

AIR-SEA-ICE INTERACTION STUDIES

Principal Investigator:
A.M.Cowan Scott Polar Research Institute, Lensfield Road, Cambridge, UK

Co-Investigators:
C.H.Harrison/ P.Wadhams (as above)

Objectives:

(1) To assess the area-averaged vertical heat flux through the ice in the Antarctic and European sector of the Arctic by determination of open water production and destruction rates.
(2) To improve understanding of basic mechanisms and characteristics of the ice motion in the Arctic and Antarctic.
(3) To map the spatial distribution, size distribution and field of motion of icebergs in regions where they pose a threat to shipping.
(4) To monitor a number of ice characteristics in specific regions where an industrial application is well defined.

Experiment Plan:

(1) Various algorithms have been developed recently to extract ice floe kinematics from repaeat orbit SAR passes over the same geographic location. These algorithms will be assessed and where necessary optimised and improved for pack ice regions of the Antarctic and European Arctic. The final algorithm will enable routine and (semi-)automated estimates of ice divergence and convergence to be made.
(2) The algorithms developed to extract kinematic information from the superposed SAR images will be used to derive eddy vorticity statistics and mass transport estimates for ice flowing through Fram strait in the Greenland Sea.
(3) It is proposed to count and study the distribution of iceberg sizes in SAR imagery from the Weddell sea, open southern Ocean, and Greenland Sea.
(4) Other studies will be carried out to measure the floe size distribution in marginal ice regions where offshore operations are planned, the measurement of lead orientations and polynya distributions for icebreaker probes into polar pack ice, and intercomparison of sensor performance in ice edge position measurement.

ERS-1 Data Requirements:

SAR. Maximum possible coverage of ice-infested ocean within range of SAR receiving stations at Kiruna, West Freugh and those in Antarctica. Data as hard copy and full resolution digital imagery.
ATSR. Brightness temperatures with clouds flagged for Arctic and Antarctic waters.
Altimeter and wind scatterometer. Estimates of ice margin position from altimetry data. Wind vectors within 200km of the ice-ocean margin.

Coordinator: PIPOR

UK16

SEA ICE RESEARCH USING ERS-1 DATA

Principal Investigator:
J.Turner British Antarctic Survey, High Cross, Madingley Road, Cambridge, UK

Objectives:
The main objective is to determine the large-scale mean seaa-ice drift in the Weddell Sea and to guage the seasonal and inter-annual variability about the mean.

Experiment Plan:
(1) Ice motion will be determined from digital images using pattern matching and image deformation analysis techniques.
(2) Validation of SAR sea ice identification, ice type classification and sea-ice motion algorithms.
(3) Sar data of the Weddell Sea at intervals of 3 to 9 days will be analysed in conjunction with the available in situ buoy and research vessel data to determine ice motion vectors and the relevant climatology.

ERS-1 Data Requirements:
SAR coverage of the Weddell Sea with a 3 to 9 day repeat period.
ATSR.

Coordinator: PIPOR

US1-1a

POLYNYA AND ICE/OCEAN EDDY LIFE-CYCLES AND DISTRIBUTIONS IN THE BEAUFORT AND CHUKCHI SEAS

Principal Investigator:
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Co-Investigators:
P.Gloersen (NASA/GSFC), O.M.Johannessen (Nansen Remote Sensing Center, Bergen, Norway), E.G.Josberger (USGS, Tacoma, WA), N.M.Mognard (CNES, Toulouse), P.G.Teleki (USGS, Reston, VA), P.S.Chavez (USGS, Flagstaff, AZ)

Objectives:
(1) To determine the life-cycle, structure, distribution, and motion of polynyas (areas of low ice concentration) in the Beaufort Sea during late summer and autumn and in the Chukchi Sea during late autumn and winter.
(2) To determine the distribution, structure, and evolution of ice/ocean eddies during late summer and autumn in the Beaufort and Chukchi Seas.

Experiment Plan:
(1) Polynyas — The 15 year passive microwave observations from Nimbus 5 and 7 have shown that large ploynyas form, move and disappear in a cyclic fashion in the Beaufort and Chukchi Seas, especially during late summer, autumn and winter. Simultaneous passive and active microwave observations from satellites (ERS-1 SAR and radar altimeter, DMSP-ssM/I, Geosat radar altimeter) and available aircraft (NASA DC8, CV130 or P3) will be acquired to permit a detailed analysis of the life-cycle, structures and motion of these polynyas.
(2) Eddies — Although sporadic observations of ice/ocean eddies in the Beaufort and Chukchi Seas have been made by aircraft, a firm knowledge of their number, size, motion, structure and evolution does not exist. The plan calls for simultaneous and repetitive active and passive microwave observations of these eddies by the ERS-1 SAR and radar altimeter, DMSR-SSM/I and Geosat radar altimeter.

ERS-1 Data Requirements:
SAR images, and radar altimeter data
Minimum time between scenes (i.e. 3 day cycle or 3 day subcycle of 35 day cycle).
Polynyas - Beaufort Sea - mid-August to end-September.
Polynyas - Chukchi Sea - October through December.
Eddies - mid-August to Late September

Facilities to be Deployed:
NASA DC-8, P-3 or CV-130 equipped with GSFC passive microwave ensemble and JPL multispectral SAR.

Anticipated Results:
(1) Structures of polynyas (i.e. floe size distributions, ice concentration variations).
(2) Motion of polynyas (i.e. advection, weather effects, tidal oscillations).
(3) Distribution of polynyas.
(4) Number, type and size of eddies.
(5) Eddy growth, translation and decay.
(6) Eddy floe size distribution and wave penetration.

Milestones/Deliverables:
Experiments planned for August/September 1991, 92 and 93.
Reports giving the results of each experiment will be distributed within 1 year of execution.

Coordinator: Weller

US1-1b

ICE DISTRIBUTION AND MOVEMENT IN THE BERING, BEAUFORT AND CHUKCHI SEAS

Principal Investigator:
H.J.Niebauer Institute of Marine Science, University of Alaska, Fairbanks, Alaska 99775-1080 Tel: 907 4747832

Co-Investigators:
V.Alexander/ S.Hendrichs (as above)

Objectives:
(1) Document and measure fine scale ice position, type and movement at the marginal ice edge zone and in polynyas in the Bering, Chukchi and Beaufort Seas.
(2) Coordinate and relate these measurements with surface truthing ship board oceanographic and meteorological measurements in ongoing and planned projects in the Bering, Chukchi and Beaufort Seas.

Experiment Plan:
(1) Using the level 3 Ice Motion/Class data to compare with cruise data (biological, meteorological and physical oceanographic) that are being proposed to be gathered at the marginal ice edge zones in the Berring, Chukchi and Beaufort Seas over the next few years.
(2) As above, but the site of operations to be polynyas.

ERS-1 Data Requirements:
SAR data products for the marginal ice edge zone in the Berring, Chukchi and Beaufort Seas, and the St. Lawrence Island Polynya.
3 day repeat cycle, covering the ice edge in the Berring Sea at 57°N in March/April to 70-72°N in August.

Facilities to be Deployed:
University of Alaska ship (R/V Alpha Helix).

Anticipated Results:
(1) Progress in understanding the driving forces for the formation and movement of ice in the marginal ice edge zones and in polynyas.
(2) Relating ice processes to biological production and bio-chemical processes observed in the marginal ice edge zones and polynyas.

Milestones/Deliverables:
(1) Time series of the advance and retreat of the marginal ice edge zone.
(2) Time series of the opening and evolution of the St. Lawrence Polynya.

Coordinator: Weller

US1-1c

INTERACTION OF MASSIVE ICE FEATURES WITH OFFSHORE OIL PRODUCTION PLATFORMS IN THE ARCTIC

Principal Investigator:
M.O.Jeffries — Geophysical Institute, University of Alaska, Fairbanks, AK 99775-0800
Tel: 907 4745257 Fax: 907 4747290

Co-Investigators:
W.M.Sackinger (as above)

Objectives:

(1) Conduct a census (numbers, locations, size, degradation and production rates) of ice islands and multi-year landfast sea ice floes in the Arctic Ocean, and determine their physical and SAR characteristics.
(2) Determine maximum values for lateral forces of those extreme ice features against offshore oil exploration and production platforms in the Beaufort and Chukchi Seas.
(3) Assess the utility and capability of SAR to detect and track these ice masses in order to reduce the risks to offshore structures and transportation systems.

Experiment Plan:

(1) Identify potential ice island and multi-year landfast sea ice floe production sites, detect ice islands and multi-year landfast sea ice floe calving events, and identify factors contributing to calving events from the ice shelves and multi-year landfast sea ice of the north coast of Ellesmere Isalnd and Axel Heiberg Island, NWT, Canada.
(2) Detect old ice islands and multi-year landfast sea ice floes in the Arctic Ocean, particularly along the margin of the Canadian Arctic Archipelago and the coastal waters of the Canadian and Alaskan Beaufort Sea and the Chukchi Sea.
(3) Track the drift of old and new ice islands and multi-year sea ice floes, including their numbers, and changes in area and mass.
(4) Determine multi-year pack ice floe size distributions along the margin of the Canadian Arctic Archipelago, the coastal waters of the Canadian and Alaskan Beaufort Sea and the Chukchi Sea.

ERS-1 Data Requirements:

(1) SAR images of Northern Ellesmere Island and Axel Heiberg Island: Quarterly images (Jan., April, July, Oct.) for ice calving detection. 1991-93.
(2) SAR images of the Arctic Ocean margin for the Canadian Arctic Archipelago, Canadian and Alaskan Beaufort Sea and Chukchi Sea: Images in January and July for multiyear floe size distribution. 1991-3.

Anticipated Results:

(1) Size distribution of ice islands and multi-year pack ice floes along Canadian and Alaskan coastal regions.
(2) Population density of ice islands, multi-year shelf sea ice floes, and proportion of multi-year sea ice to annual sea ice.
(3) Establish maximal values of lateral forces on offshore structures which would be preduced by such features.
(4) Trajectory analyses for such ice features.

Coordinator: Weller

US1-2

SAR DETECTION AND CHARACTERISATION OF ICEBERG PRODUCTION AND DRIFT TRAJECTORIES IN PRINCE WILLIAM SOUND, ALASKA

Principal Investigator:
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Co-Investigators:
M.O.Jeffries (as above)

Objectives:
(1) To determine the rate of iceberg production from glaciers in Prince William Sound, Alaska, and its relationship to dynamic oceanographic, meteorological and seismic events.
(2) To observe drift trajectories of icebergs and their relationship to currents and winds in Prince William Sound, Alaska.

Experiment Plan:
(1) Observe production rate and drift trajectories of icebergs from the Columbia glacier and other tidewater glaciers in Prince William Sound, using SAR imagery.
(2) Instrument the floating glacier tongue upper surface with strain meters to detect fluxural vibrations.
(3) Acquire seismic, meteorological and tidal data for correlation with the above SAR data.

ERS-1 Data Requirements:
SAR images of Prince William Sound, Alaska (100km x 100km area centred on 60°N, 147°W) - 3 day repeat cycle for 3 month period, any time of the year.

Anticipated Results:
(1) Correlation of calving of icebergs with dynamic oceanographic, meteorological and/or seismic events.
(2) Correlation of iceberg drift trajectories with tidal currents and winds.

Coordinator: Weller

US1-6c

THE INFLUENCE OF THE HYDROLOGIC CYCLE ON THE EXTENT OF SEA ICE WITH CLIMATIC IMPLICATIONS (SAR ANALYSIS)

Principal Investigator:
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Tel: 907 4747364

Co-Investigators:
W.Stringer/ T.Weingartner (as above)

Objectives:
To analyse the role of the hydrologic cycle and its influence on forcings and fluxes between the marine environment and the atmosphere along the Alaskan coast and the Mackenzie River delta. The influence of river dischanrge on the albedo, thermal balance and distribution of sea ice will be investigated, and quantitative atmospheric models will be developed to describe these processes in the coastal zone. Implications of a predicted climatic warming will be assessed and analysed. SAR imagery will be used to monitor the extent of sea ice and open water.

Experiment Plan:
The major goal of the project is to study the linkages between river discharge, extent of ice fee areas and atmospheric heat exchange in the coastal zone. SAR imagery will be used to analyse the extent of open water offshore from rivers during the spring melt and fall freeze-up in the Arctic Ocean. Cloud penetration capabilities of the SAR sensor and the high frequency of ERS-1 coverage will provide excellent observations that cannot be acquired with present systems.

ERS-1 Data Requirements:
SAR data for the Mackenzie River estuary and the Alaskan Beaufort Sea coast. Every 3 days (May and June, and Sept. 15 to Nov.15) and 1 scene every 1-2 weeks in July and August.

Anticipated Results:
The expected outcome of this project will be a dataset that will be analysed to determine the influence of water discharge by major rivers in the spring melting, and hence the extent of sea ice offshore of Alaska and of Canada in the vicinity of the Mackenzie River estuary. The magnitude of the influence of Arctic river discharge and the possible consequences of a climatic warming will be assessed. The transfer of heat and moisture to the atmosphere will be estimated. A thermal model o the river discharge and its influence on ice cover will be developed using satellite imagery and field data.

Milestones/Deliverables:
(1) Progress reports as required.
(2) Final report including image products.

Coordinator: Weller

IV Glaciology

AUS5-1

DYNAMICS OF LAMBERT GLACIER/ AMERY ICE SHELF, ANTARCTICA

Principal Investigator:
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Co-Investigators:
I.Allison (as above)

Objectives:
To investigate the dynamics of Antarctic outlet glaciers and determine the stability of the glacier system comprising the Lambert Glacier drainage basin, its outlet glaciers and the Amery Ice Shelf.

ERS-1 Data Requirements:
The main study area is contained within a 500km x 900km rectangle aligned along the axis between 68°S 73°E and 76°S 61°E. One complete coverage by overlapping swaths on descending passes is required to be collected early in the mission over a short time interval. Overlap is required to allow mosaicing and inclusion of accurate ground control from fixed rock outcrops and deployed reflectors. One swath is to extend a further 500km to the south to investigate the surface properties of the interior.
An additional four separate swaths from ascending passes are required to provide an alternative look direction at crevasses, rifts and other structures which have anisotropic distributions, and to cover the lateral extension of the large interior ice streams. These data can be collected separately in the austral summer months when the space craft will not be in eclipse.
A second set of overlapping swaths is required to be collected after a period of at least one year has elapsed. It is anticipated that the data take for this set can be reduced following analysis of the first complete set of imagery.
Estimated total SAR data requirement is 60 (100km x 100km) scenes (descending), plus 20 scenes (ascending) for the first set, and 30 - 40 scenes for the second set.

Facilities to be Deployed:
Surface observations and direct measurements of ice velocity and ice thickness are being made on air-supported surveys in the study region. Data on the properties of the ice sheet in the interior of the Lambert Glacier basin are being collected by over-snow trqverse. Automatic Weather Stations will be deployed from the traverses.

Anticipated Results:
These investigations will provide a basic data set on ice sheet characteristics, velocity, strain rate, driving stresses, etc. for this dynamically active region. Combined with similar data sets from other regions, such as Wilkes Land, East Antarctica, the results will enable the development of detailed numerical models of the ice sheet with which studies can be made of its development over time, its interaction with the ocean and atmosphere and hence possible future changes. Such models and data are also used in the interpretation of climatic records deduced from ice core studies.

Milestones/Deliverables:
1989-90   Detailed planning for ERS-1 program; completion of feasibility studies using SEASAT SAR imagery of Greenland, completion of air-supported surveys on the Amery Ice Shelf and northern part of theLambert Glacier, commencement of over-snow traverse surveys from Mawson.
1994   Delivery of final report on ERS-1 phase of program, publication of papers in scientific journals.
ASF = Alaska SAR Facility at University of Alaska.

Coordinator: Nilsson

INT8-1

TOPOGRAPHIC MAPPING OF THE ANTARCTIC AND GREENLAND ICE SHEETS

Principal Investigator:
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Tel: 483 274111 Fax: 483 278312

Co-Investigators:
W.Cudlip/ D.Mantripp/ I.Mason/ C.Rapley/ J.Ridley/R.Scott (MSSL), N.McIntyre (Earth Observation Sciences)

Objectives:
Topographic mapping of the Antarctic and Greenland ice sheets with detailed studies of certain areas of particular interest, e.g. the major Antarctic ice shelves (Amery, Ronne-Filchner, Ross and Larsen) where it is hoped to identify the grounding line, crevasses and areas of surface roughness.

Experiment Plan:
(1) Topographic mapping using repeat track data over the catchment areas for the Lambert Glacier, the Siple Coast Ice Streams, the Rutford Ice Stream, the Slessor and Recovery Glaciers, and the Pine Island and Thwaites Glaciers which all feed into the major ice shelves.
(2) Comparison of ERS-1 data with that from Geosat and Seasat to examine mass balance changes concentrating on areas with low slope errors such as ice shelves.
(3) Regional and temporal mapping of radar penetration to indicate: (a) variations in surface snow conditions, (b) as an input to mass balance studies, and (c) to investigate a penetration correction for altimetry. This will require further development of our techniques of penetration analysis using waveform shape and averaged values of the first derivative of the waveform.
(4) Estimation of surface temperatures from ATSR microwave and infrared data. This is still an area of research, but it is hoped that the 2 brightness temperatures can be combined to correct for the surface emissivity to produce an absolute surface temperature.

The Filchner Ronne Ice Shelf is of particular interest due to comprehensive fieldwork being undertaken by the Filchner Ronne Ice Shelf Project.

ERS-1 Data Requirements:
Altimeter: A minimum of 1 years worth of the Altimeter Ice Sheet Product is required from penetration studies and comprehensive mapping. The waveform foundation product will probably be needed for a 35 day repeat (minimum) in areas of specific interest - Filchner Ronne Ice Shelf.
ATSR/M: Coverage for the brightness temperature product.
SAR: A number of scenes (probably <20) over the Filchner Ronne Ice Shelf at specfic times to be selected at a later date, but which would ideally coincide with planned fieldwork.

Facilities to be Deployed:
MSSL -built scatterometer wil be deployed in the fieldwork.

Anticipated Results:
(1) Topographic map of the Filchner Ronne and other ice shelves.
(2) Regional/temporal estimates of radar penetration over selected areas of Greenland and Antarctica.
(3) Surface temperature estimates over selected areas of Antarctica and Greenland.

Coordinator: Thomas

INT8-2

DYNAMICS AND MASS BALANCE OF THE WEST ANTARCTIC ICE SHEET

Principal Investigator:
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Tel: 608 2621922 Fax: 608 2620693

Objectives:
Study of the configuration and height of the West Antarctic Ice Sheet as they are related to the dynamics and mass balance of that ice sheet.

Experiment Plan:
(1) Primary concern will be the "Ross Ice Streams" D and E and their surroundings. The work will be tied closely to a continuing program of measurements on the ground and from aircraft. By the time ERS-1 is launched it is expected to have surface elevations over extensive areas to an accuracy of about 1m.. This will provide a good network for validation of the radar altimetry from the satellite. The satellite data will provide more extensive and repeat coverage suitable for detecting ice volume changes.
(2) It is also planned to examine the poorly-known glaciers and ice streams that drain across the Amundsen Sea and Pacific Ocean coasts of Marie Byrd Land, especially Thwaites Glacier and Pine Island Glacier, which are very fast moving and may play a crucial role in the mass balance of the West Antarctic Ice Sheet. The ice streams will be mapped using the SAR images, and disturbed ice features will be relocated on repeat coverage to determine velocities.

ERS-1 Data Requirements:
(1) A complete set of retracked Altimeter elevation data south of 77°S and between 90° and 160°W, repeated at 1-yearly intervals.
(2) SAR coverage of the West Antarctic coastal strip north of 78°S and between 90° and 110°W. Monthly coverage.

Anticipated Results:
Topographic maps of the 2 areas, together with thickness change rates.

Coordinator: Thomas

INT8-3

SAR MAPPING OF GREENLAND ICE SHEET

Principal Investigator:
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Fax: 301 2862717

Co-Investigators:
J.Crawford/M.Drinkwater (JPL), K.Jezek (Ohio State University), P.Gogenini (University of Kansas)

Objectives:
To map the extent of snow facies and ice margin of the Greenland Ice Sheet as baseline data to monitor temporal changes.

Experiment Plan:
Use image analysis algorithms incorporating intensity and textural variation to achieve a standardised regional classification of snow facies and edge detection schemes to identify the ice sheet margin and snow line. Calibration/Validation activities will include the use of transmitters to measure penetration of radar into snow at a number of sites in different snow conditions along a transect from the ice sheet margin to the summit.

ERS-1 Data Requirements:
Complete SAR coverage of Greenland during both the winter (October-April) and summer (June-August) seasons.

Anticipated Results:
(1) Databases of boundaries between major regions.
(2) Catalogue of SAR imagery over Greenland.
(3) Digital Elevation Model of Greenland.
(4) Algorithms to derive classification products.

Coordinator: Thomas

INT8-4

GLACIER MASS BALANCE STUDIES

Principal Investigator:
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Co-Investigators:
K.Arnason/ S. Bjornsson/ F.Palsson (University of Iceland)

Objectives:
Study of the mass balance of ice caps in Iceland.

Experiment Plan:
(1) Studies of glacier variation and flow through determination of changes in glacier surface elevation, glacier extent, surface features, flow structures and comparison with previous satellite images and recent digital maps of the glacier surface.
(2) Studies of changes in mass balance through determination of the firn line and glacial facies and comparison with relevant data collected in annual expeditions on the ice caps.

ERS-1 Data Requirements:
One set of altimeter data per annum, preferably in the autumn (August-September). RA data of the elevation of the subglacial lake Grimsvotn in the interior of Vatnajokull are requested as frequently as possible.
Two complete SAR coverages of the 4 ice caps, one in May and one in September.

Coordinator: Thomas

INT8-5

RESPONSE OF THE ANTARCTIC ICE SHEET TO CHANGES IN CLIMATE

Principal Investigator:
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Tel: 223 61188 Fax: 223 62616

Co-Investigators:
A.Cooper/ J.Paren (BAS)

Objectives:
ERS-1 data will be applied to the problem of the response of the Antarctic Ice Sheet to changes in climate. Ice sheet elevations and surface features will be monitored to find the regions that are growing, decaying or are stable within the resolution of the sensors.

Experiment Plan:
(1) The radar altimeter will be used to provide surface elevations for topographic mapping in the region 29°-90°W. Precise positioning of the satellite is needed to obtain the best accuracy for detailed studies. A long repeat period for the orbit (>30days) is required to give adequate spatial coverage.
(2) Radar altimetry of Ronne and Filchner Ice Shelves will be used to construct contour maps of surface elevation. These will be compared with ice thickness data from airborne and ground based surveys.
(3) Detailed topography on Rutford Ice Stream close to Ellsworth Mountains will be obtained by a SAR interferometric technique controlled by radar altimetry where available.
(4) Ice movement and margins will be monitored by a combination of radar altimetry and SAR.
(5) Surface properties of the ice sheet will be investigated with ATSR and AMI data.

ERS-1 Data Requirements:
(1) All altimetry data.
(2) SAR coverage of Rutford Ice Stream (78-85°W, 77-79°S). At least 2 separate images of the same area are required for the interferometric technique to be used.
(3) SAR images of Wordie Ice Shelf (74°S, 67°W); George VI Ice Shelf (75°S, 69°W); Eklund Islands (73°S, 72°W) and Brunt Ice Shelf (75.5°S, 27°W); once a year.
(4) ATSR/AMI data.

Anticipated Results:
(1) Topographic maps of Ronne/Filchner Ice Shelves, Rutford Ice Stream and other selected regions of the ice sheet.
(2) Estimated changes in ice surface elevation in selected parts of the ice sheet.
(3) Measured changes in ice margins in selected regions.

Coordinator: Thomas

INT8-6

ANTARCTIC ICE SHEET MODELLING

Principal Investigator:

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Co-Investigators:

C.Ritz (LGGE)

Objectives:

Snow accumulation rate and surface temperature data for Antarctic Ice Sheet modelling.

Experiment Plan:

The area of prime interest is East Antarctica.

ERS-1 Data Requirements:

ATSR

Complete coverage of 10km x 10km data, once a week.

Complete coverage at full resolution, once a month.

SAR

3 images located at 140°E between 67°S and 70°S.

Coordinator: Thomas

INT8-8

COASTAL CHANGES OF ANTARCTICA

Principal Investigator:
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Co-Investigators:
J.Ferrigno/ R.Williams (USGS, Reston, Va)

Objectives:
The objectives of the project are the acquisition of SAR imagery for an analysis of the state of the Antarctic coastline and the measuring of outlet glacier velocities. This research is important because changes in the area and volume of polar ice sheets are intricately linked to changes in global climate, and ice sheet melting may severely impact the densely populated coastal regions on Earth. In spite of its importance, the mass balance of the ice sheets is poorly known, and we are not yet certain whether the Antarctic ice sheets, particularly the ice edge zones are growing or sinking.

Experiment Plan:
Initially it is planned to prepare an accurate 1:5,000,000 scale map of the coastline of Antarctica using Landsat images. This map will be unique in that it will show the coastline in two states, one depicting its configuration in the mid 70's and the other its configuration in the late 80's. The SAR images acquired by ERS-1 in the early 90's will be used to detect further changes and to verify possible trends of decreasing or increasing shelf ice.
The measuring of outlet velocities and their advance or retreat is also currently being carried out using Landsat images. It is planned to extend the base of measureable glaciers by use of ERS-1 SAR images, which will yield information for areas where other cloud free satellite images are scarce.

ERS-1 Data Requirements:
SAR imagery of the entire Antarctic coastline which is accessible to Antarctic ERS-1 SAR receiving stations.
Earliest possible acquisition, with repeat coverage 3 years later.

Anticipated Results:
The results will serve the basic scientific objective to monitor, understand and ultimately predict global climatic change.

Milestones/Deliverables:
Reports on coastal changes, glacial velocities and glacier calving to be completed 18 months after receipt of the data.

Coordinator: Thomas

INT8-9

ICE SHEET RESEARCH

Principal Investigator:
W.G.Rees — Scott Polar Research Institute, University of Cambridge, Lensfield Road, Cambridge CB2 1ER, UK
Tel: 223 336540 Fax: 223 336549

Co-Investigators:
J.Dowdeswell/ M.Gorman (as above)

Objectives:
Glacier ice research studies in Greenland and Svalbard.

Experiment Plan:
(1) Construct topographic maps of ice surface for regions of Greenland and Svalbard.
(2) Assess surface snow/ice condition (grain size, temperature, wetness).
(3) Compare stereophotogrammetric images with RA surface profiles and SAR images.
(4) Field validation of SAR imaging and RA penetration over snow and ice.
(5) Assess long-term (decadal) temporal changes in ice volume.
Areas of interest are:
(1) 500km strip extending NW (parallel to ERS-1 ground track) from near DYE-3 (65°N, 44°W) to the west coast of Greenland.
(2) Nordaustlandet, Svalbard (area approximately 200 km square, centred on 80°N, 23°E).

ERS-1 Data Requirements:
(1) All RA data for study areas.
(2) Monthly averaged ATSR data for test areas.
(3) SAR coverage 3 or 4 times a year.

Anticipated Results:
(1) Spatially registered topographic maps of study areas.
(2) Estimates of long-term changes in ice volume.
(3) Measurement of C-band and Ku-band attenuation lengths for snow/ice surfaces.
(4) Calibrated airborne sigma nought values and corresponding glaciological parameters (grain size, water content, detailed surface topography, dielectric constant) for Greenland test site.
(5) Measurement of thermal infrared emissivity of snow/ice surface as a function of glaciological parameters.
(6) Validated and spatially registered SAR image for Greenland test site.

Coordinator: Thomas

INT8-10

VALIDATION/ CALIBRATION PLAN OF THE ALFRED WEGENER INSTITUTE FOR THE USE OF ERS-1 ALTIMETER DATA OVER ICE SHEETS

Principal Investigator:
H.W.Schenke Bremerhaven

Objectives:
(1) Comparison of altimeter heights with measured heights on an ice sheet.
(2) Study of the signal quality in the transition zone from the sea to the ice sheet.
(3) Study and analysis of the altimeter wave form over ice and development of a sophisticated retracking technique.

Experiment Plan:
Installation of a height test field at the Filchner Station covering an area of 40km x 40km between the shelf ice edge of the Ronne Ice Shelf and Filchner Station. The high precision survey will be performed with Differential GPS techniques in the Kinematic mode in combination with motorised trigonometric levelling.

ERS-1 Data Requirements:
Most precise orbit information, precise ephemerides from PRARE and/or Laser Tracking.
Complete altimeter data, wave form data, altimeter heights, all applied corrections, GDR's and SDR's. Data and information necessary for retracking of altimeter data.

Coordinator: Thomas

INT8-11

DETECTION AND INTERPRETATION OF GLACIER SURFACE FEATURES

Principal Investigator:
K.Shibuya National Institute for Polar Research (NIPR), 9-10 Kago 1-chrome, Itabashi-ku, Tokyo 173, Japan Tel: 03 962 2529 Fax: 03 962 4711

Objectives:
The main science objective is the detection and interpretation of surface features from the last glacial stage around the Yamato mountains region by the comprehensive study of satellite data.
The main area of interest is the polygon bounded by 70.5°-72.5°S and 30°-38°E.

Experiment Plan:
(1)Altimeter data in the 2 full cycles of "ice mode" together with 2 full cycles of "ocean mode" passes in the summer season (November/February) will be cross-over adjusted to obtain satellite orbits for the global ocean area.
(2) Retracked elevation data for cross-over adjusted :"ice-mode" passes will be superimposed onto the study area to produce grid data by the Brigg's algorithm and subsequent contouring of the surface topography.
(3) The PRARE range and range rate data at Syowa station will be used for fine tuning elevation data.
(4) Return pulse waveform data will be used to pin-point the location of chain-like step relief of 200km length in the study area.
(5) SAR data will be used to map "windscoop-like" features which are associated with the step relief.
(6) ATSR and SCAT data will be used to relate the radiance and backscatter characteristics to blue-ice region, surface features and topographic undulations.

ERS-1 Data Requirements:
SAR, RA, SCAT, ATSR data for the study area.

Anticipated Results:
Topographic and surface features maps of the study area.

Coordinator: Thomas

INT8-13

MAPPING OF THE MARIE BYRD LAND PORTION OF THE WEST ANTARCTIC ICE SHEET

Principal Investigator:
I.M.Whillans — Byrd Polar Research Center, 125 South Oval Mall, Ohio State University, Columbus, OH 43210, USA
Tel: 614 2926531 Fax: 614 2924697

Co-Investigators:
C.Merry (as above)

Objectives:
(1) Conduct field mapping of Marie Byrd Land portion of West Antarctic ice sheet at two scales.
(2) Conduct an analysis of crevasse patterns on ice streams.
(3) Conduct a study of blue ice near the Allan Hills, Antarctica.

Experiment Plan:
Ice sampling at 50km spacing to determine positions, elevations, firm density profile, accumulation rate, etc.
Determine relative elevations at 1km spacing.
Test area is the Allan Hills (76°30' - 77°10'S, 155° - 162° E).

ERS-1 Data Requirements:
SAR image products during the austral summer. Special requirement for three different look angles over ice streams.

Coordinator: Thomas

INT8-14

MAPPING OF ICE SHEET TOPOGRAPHY AND ELEVATION CHANGE

Principal Investigator:
H.J.Zwally — Oceans and Ice Branch, NASA/GSFC, Greenbelt, MD 20771
Tel: 301 2868239 Fax: 301 2862717

Co-Investigators:
R.Bindschadler/ C.Lingle/ S.Stephenson (NASA/GSFC)

Objectives:
Studies of ice sheet mass balance and the relations to changes in climate and global sea level.

Experiment Plan:
(1) Retracking of ERS-1 waveform data using Goddard retracking procedures developed for Seasat and Geosat to compare results with other retracking techniques and validate the accuracy of ERS-1 relative to the other satellites.
(2) Preparation ice sheet elevation maps in contour and digital formats.
(3) Determination of changes in ice sheet elevation by comparison with Seasat and Geosat elevation data sets.
(4) Study of variations in ice sheet surface temperature.

ERS-1 Data Requirements:
(1) All altimeter data over ice, including waveforms and precision orbits.
(2) Geophysical data records over oceans (or orbit corrections from adjustment to ocean surface).
(3) Monthly averaged ATSR data.

Coordinator: Thomas

US1-3a

SYNTHETIC APERTURE RADAR INVESTIGATION OF ALASKAN GLACIERS

Principal Investigator:
B.F.Molnia USGS, 917 National Center, Reston, VA, USA 22092
Tel: 703 6484120

Co-Investigators:
J.E.Jones (as above)

Objectives:
(1) Monitor changes in the areal extent of Alaskan glaciers.
(2) Identify features of Alaskan glaciers.
(3) Build a reference collection of specfic features that can be used in other locations where ground truth and airborne data do not exist.

Experiment Plan:
The geographic area of interest is the south-east/ south-central area of Alaska, especially the glaciers of the Coast Range, the Fairweather Range, and the Chugach- St.Elias Mountains. It is planned to compare SLAR images in previously studied area, with ERS-1 SAR to understand the backscatter characteristics and visual appearance of these features on ERS-1 SAR imagery. Once a calibrated data set is available, it is proposed to examine glaciers in other parts of the ASF station mask area that have no other data sets for correlation. The ultimate goal will be to move the study area to modern glaciers in remote areas (Tibet/China, South America, Antarctic Peninsula) where no investigations of any kind have been performed and develop a classification of glacier features and processes. At first, full resolution data will be required on a quarterly basis. This requirement will be adjusted as a result of initial analyses.

ERS-1 Data Requirements:
SAR data. Seasonal data (quarterly) is requested for the first cycle of data collection. The frequency and timing of later data collection will be reevaluated.

Anticipated Results:
Recent studies with SLAR SAR have revealed substancial new information about surface morphology, crevasse density, ice flow characteristics, and glacier landforms for Malaspina, Bering and Grand Plateau Glaciers. The combination of repetitive ERS-1 SAR data with SLAR will greatly expand the geographical area and seasonality aspects of the glacier feature analysis project. Examples of the type of information to be gathered: extent and positional changes in seasonal snow cover, development of stagnant ice - thermokarst features, monitoring of surge location and frequency, classification of sedimentary features and products, surface water pathways and migration, and others.

Milestones/Deliverables:
(1) Progress reports to be prepared 3 months after each data set is delivered.
(2) A photo atlas depicting key features and comparing them with SLAR and aerial photography, 6 months after delivery of data.
(3) Revised atlas and report to be prepared annually.
(4) USGS parer prepared and published.

Coordinator: Weller

US1-3b

SOUTHCENTRAL ALASKA RADAR STUDY

Principal Investigator:
J.E.Jones/B.F.Molnia USGS, 917 National Center, Reston, VA, USA 22092
Tel: 703 6484138/4120

Co-Investigators:
R.M.Krimmel (Water Resources Division, Tacoma, Washington)

Objectives:
To study existing techniques and develop and document improved techniques for:
(1) Mapping and identifying glacial and periglacial features (both surface and sub-glacier bedrock) and processes using remotely sensed data, with emphasis on airborne, satellite, and ice penetration radar.
(2) Image processing and geographic information system analysis and presentation of sub-arctic terrain features and processes.
The study area is the Malaspina Glacier, west of Yakutat, Alaska, and a series of marine terrace sequences west of the Alsek River, on the coast of southcentral Alaska.

Experiment Plan:
Stage 1. Continue the field investigations of the Malaspina Glacier begun in 1988 through the field season (August-September) of 1991, including conventional surveying of the glacier's surface, ice penetration (40 MHz) radar transects (planned for 1989-90) and possibly airborne profiles in 1991 with a 1 MHz system currently under development by the USGS. Digital analysis of the X-HH SLAR (1986, 1980 and 1976)., and L-HH Seasat (1978) radar data coverage is also continuing. Other areas along the coast of Alaska are also being analysed for this study.
Stage 2. Begin analysis of ASF SAR data (1990-91) and compare the SAR data with the results from the field investigations and image processsing of the SLAR and other remotely sensed data.
Stage 3. Depending on the success of both Stage 1 & 2, an extension of the study to other warm glaciers in 1990 and cold glaciers in 1991.

ERS-1 Data Requirements:
SAR data.
Priority 1. August and/or September coverage of the Malaspina Glacier located at 60°N 140°W. Coverage in January through March would also be desirable for comparison.
Priority 2. August and/or September coverage of various areas (Bering. Hubbard, and Grand Plateau Glaciers and coastal marine terraces) along the 500km coast of Alaska from Cape Suckling to Cape Spencer, located between 60°N 144°W and 58°N 136°W. Coverage in January through March would also be desirable for comparison.
Priority 3. August or September coverage of the Juneau Ice Field and adjacent areas along the AK panhandle.

Facilities to be Deployed:
Some limited recording capability is currently in place at both the Hubbard and Bering Glaciers.

Anticipated Results:
It is anticipated that analysis of the SAR data, subsequent to the research currently in progress, will enable the investigators to develop a model (incorporating fluid flow equations) for estimating volume of subarctic ice sheets using SAR and other remotely sensed data sets. This model will incorporate wave amplitude (topographic highs and lows), velocity vectors, area and other parameters as input to mass balance studies to support global change research. Further, SAR data would be compared to the known subarctic terrain features for mapping applications.

Milestones/Deliverables:
Quarterly progress reports will be submitted and papers/abstracts will be prepared for presentation and publication.

Coordinator: Weller

US1-3c

ANALYSIS OF SAR DATA FOR ASSESSMENT OF GLACIER MASS BALANCE IN THE WRANGELL - ST. ELIAS MOUNTAINS

Principal Investigator:
D.K.Hall/ C.S.Benson NASA/GFSC, Greenbelt, MD 20771/ Geophysical Institute, University of Alaska, Fairbanks, AK 99775-0800

Co-Investigators:
L.R.Mayo (U.S Geological survey, Fairbanks)

Objectives:
To employ SAR data from ERS-1 along with Landsat MSS and TM data, and SPOT data, to identify and monitor annual changes in surface and subsurface features of glaciers, including those aspects of glacial facies which may be discernable. This is expected to enable determination of changes in glacier mass balance on a regional scale.

Experiment Plan:
The Wrangell - St. Elias Mountain system contains numerous glaciers, some of which are quite dynamic. ERS-1 SAR data will be required 6 times a year to assess and measure the position of some of the glacier facies boundaries. Analysis of data during late August or early September should determine if the SAR data are useful for locating the equilibrium line through surface snow cover. Late August or early September will be used to compare the surface and sub-surface expression of the facies boundaries, as determined from SAR data, with the surface expression as determined from Landsat TM and/or SPOT data. However, sometimes fresh snow obscures the surface expression of the equilibrium line. Some evidence has shown that Landsat MSS and TM data may be of limited utility in determining small amounts of glacier retreat for glaciers with debris-covered termini because of the lack of contrast between the terminus and the surrounding terrain. SAR data may be useful in detecting sub-surface ice below a debris covered glacier terminus, and thus enable an improved determination of terminus movement.

ERS-1 Data Requirements:
SAR data are required 6 times per year for at least 3 years. SAR data will be needed over study sites in the Wrangell Mountains in February, May, July, late August/early September, October and December. The research area includes the entire Wrangell Mountains from Mt.Drum (62°N, 145°W) to Mt. Bear (approx. 61°N, 141°W) and selected sites in the adjacent St. Elias Mountains extending to Mt. Seattle (approx. 60°N, 139°W).

Anticipated Results:
SAR data have been shown to detect subsurface features in glaciers and ice sheets. However, the radar returns that have been measured have not yet been identified unambiguously. This study will help to determine the utility of the SAR data for measuring selected facies boundaries and the glacier terminus position. It is anticipated that SAR data will be especially useful in providing repeated coverage at predetermined times during complete annual cycles. This will be a major advantage over past attempts to work with aerial photographs or individual Landsat images obtained when weather permitted. The potential of obtaining planned sequences of images to show the annual variability of glaciers will be useful in determination of glacier mass balance in the Wrangell - St. Elias Mountains system. The accumulation area ratio (AAR) of the whole of the Wrangell Mountains will be determined in each year of the study. The techniques developed should be transferrable to other glaciers outside of the Wrangell - St. Elias system.

Coordinator: Thomas/Weller

US1-3d

ANALYSIS OF SYNTHETIC APERTURE RADAR DATA FOR IDENTIFICATION OF TRANSIENT GLACIER PROCESSES IN ALASKA

Principal Investigator:
L.R.Mayo USGS, 800 Yukon Drive, Fairbanks, AK 99775-5150
Tel: 907 4795673

Objectives:
To analyse SAR data for detection of significant changes in glacier behaviour such as the passage of kinematic waves, onset and progression of unstable flow, change of glacier margin position, formation and release of ice-impounded water, accumulation of landslide debris, and position of transient equilibrium lines.

Experiment Plan:
Glaciers of the Alaska Range, Wrangell Mts., and the St. Elias -Chugach Mts. of Alaska commonly undergo significant changes of dynamics that alter their surface texture, ice mass distribution, and run-off pattern. Although the chances of a large change in dynamics of a single glacier taking place during a few years of study is low, the large number of glaciers in the area undergoing periodic changes makes it possible to find and document several examples of changes during any year by aerial photography and then analyse SAR data to determine whether an observed change can be recognised from it. Conversely, a change in glacier behavior with SAR data can be investigated by aerial photography for confirmation.
Oblique, high resolution aerial photography will be obtained at 2 month intervals from March to September for 3 years during SAR data acquisition by ERS-1. Recent SAR images will be studied before each flight.

ERS-1 Data Requirements:
SAR data will be required in March, May, July and September for 3 years. The area includes the glacial regions of Alaska and adjoining Canada from 58° to 64°N and from 133° to 154°W. Specific sites within that area will be determined during the study by actual glacier events taking place.

Anticipated Results:
An atlas will be prepared showing documented glacier changes and SAR data of the same events. Each SAR image pair that has the potential of showing a major glacier change will be analysed in detail to determine the change resulting in the SAR data from the event. The anticipated results will be useful for developing parts of a glacier monitoring strategy ay global scale.

Coordinator: Weller

US1-4a

MAPPING PLEISTOCENE GLACIATION OF ALASKA USING SAR IMAGERY

Principal Investigator:
J.E.Beget — Dept. of Geology and Geophysics, University of Alaska, Fairbanks, Alaska 99775-0706
Tel: 907 4747565

Co-Investigators:
K.Dean (as above)

Objectives:
To delimit the extent of Pleistocene glaciers and the Cordilleran Ice Sheet in south-central and southwest Alaska and the Kenai and Alaska Peninsulas using SAR imagery.

Experiment Plan:
The distribution and dynamics of Pleistocene glaciers in Alaska are poorly known because of difficulties and expense of traditional field mapping. However, analysis of radar imagery can be used to map glacier events. The differences in relief and surface texture between glaciated areas and non-glaciated terrains can be used to rapidly delimit the maximum extents of Pleistocene glaciers. Preliminary studies of the experimental side-look radar imagery currently available for the Ugashik quadrangle indicate that, in some cases, high quality radar imagery can distinguish between sub-units within glaciated regions so that preliminary stratigraphic relationships can be determined. In addition, some elements of glacial geomorphology, including drumlins, moraines, outwash plains, eskers and kames can be identified, allowing estimates of ice-flow directions and reconstructions of glacial sedimentary environments. These features will be mapped on SAR high resolution imagery of the Alaska and Kenai Peninsula and the Mat-Su lowland.

ERS-1 Data Requirements:
Single SAR scenes of the Seward Peninsula, Bering Strait and Chukotsk Peninsula.

Anticipated Results:
The SAR imagery will be used to produce a regional map showing the extent of late Pleistocene glaciers on the Alaska Peninsula and in south and southwest Alaska. This is a critical region for understanding the character of climate change in Alaska during the Pleistocene. Glaciers in this area were, at least locally, marine-based. Regional mapping with SAR imagery will help elucidate the relationship between global and local climate change, glacier and ice sheet growth on the Alaska Peninsula and on the continental shelf of the northern Gulf of Alaska, and global sea level changes.

Coordinator: Weller

US1-4b

GLACIAL HISTORY OF NORTHWESTERN ALASKA AND SIBERIA, AND ASSOCIATED CLIMATIC AND ECOLOGICAL IMPLICATIONS

Principal Investigator:
D.Hopkins Geology Department, Brooks Building, University of Alaska, Fairbanks, Alaska

Co-Investigators:
J.Brigham-Grette (as above)

Objectives:
(1) To map and refine glacial history of the Seward Peninsula, Alaska and the Chukotsk Peninsula, Siberia.
(2) To correlate the glacial history of Alaska to that in western Siberia.
(3) To analyse climatic and ecological regimes based on the Alaskan and Siberial geologic record.
(4) To derive regional atmospheric circulation maps of the region.

Experiment Plan:
(1) SAR and optical satellite imagery will be used in conjunction with field observations to map glacial landforms on the Seward Peninsula, Alaska and the Chukotsk Peninsula, western Siberia. Analysis of the satellite imagery in Alaska with field observations will provide the experience required to analyse the Siberian imagery where little or no field observations will be acquired.
(2) Stratigraphic relationships, radiometric dating, and pollen and fossil samples collected in the field will be used to establish the chronology of glacial advances on the Seward Peninsula.
(3) Stratigraphic relationships interpreted on the satellite imagery and the chronology identified in Alaska will be used to establish the Siberian Chronology.
(4) Samples collected in the field will also be used to analyse the glacial and interglacial climate and ecology of the region.
(5) Regional glacial and interglacial atmospheric circulation maps will be derived based on the distribution and orientation of glacial landforms seen on the imagery and inferences from field samples.

ERS-1 Data Requirements:
Full resolution SAR data.
The mapping area includes terrestrial areas between 144°-166°W, and 54°-61° N.

Anticipated Results:
(1) A refined map of the extent of glacial advances in the region.
(2) Glacial events on either side of the Bering Strait will be compared and correlated.
(3) Ecological conditions during glacial and interglacial periods will be modeled.
(4) Atmospheric circulation from the Pacific Ocean into the Arctic Basin will be modelled based on the geologic record.

Coordinator: Weller

US1-7

THE INFLUENCE OF THE ACTIVE AND PERMAFROST LAYERS ON RADAR BACKSCATTER

Principal Investigator:

T.Osterkamp — Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska 99775-0800
Tel: 907 474 7548;

Co-Investigators:

K.Dean (as above)

Objectives:

Radar will penetrate the ground under very dry conditions due to the influence of the complex dielectric constant on the signal. Frozen ground will also be conducive to radar penetration for the same reason. Thus, a difference in the backscatter signal can be expected as the subsurface moisture regime changes seasonally, especially when the active frost layer couples with the underlying permafrost. If a backscatter signal related to the active/permafrost coupling can be detected on the imagery, then by monitoring the timing of this coupling over many years the influence of climatic changes can be monitored.

The objective of this project is to investigate characteristics of the active and permafrost layers, and their influence on radar backscatter. Characteristics of the frost layers include the presence of taliks, water, temperature and coupling of the active and permafrost layers.

Experiment Plan:

(1) To acquire radar imagery throughout an annual cycle of selected areas where permafrost conditions have been described and are monitored from bore holes.
(2) To compare radar backscatter signatures to data from bore hole instrumentation that detect changing conditions in the active and permafrost layers and its timing within the annual cycle since it would provide a method to monitor changing climatic conditions.
(3) To quantitatively describe radar backscatter signatures at the respective sites with an annual cycle.

Test areas: Arctic Coastal Plain, Alaska Pipe Line Corridor (148°20' - 148°50' W, 70°10' - 68°40' N).
Yukon Uplands Alaska Pipie Corridor (150°10' - 150°50' W, 67°0' - 66°0' N).

ERS-1 Data Requirements:

SAR data of the two test areas, with the following timing:
(1) Twice a month throughout the annual cycle.
(2) Every three days at critical periods September/October/November and May/June/through July 15.

Anticipated Results:

The timing of the coupling of the active and permafrost layers is sensitive to climatic changes. If this can be detected on radar imagery then a practical and cost effective procedure will have been discovered to monitor climatic change on a global scale at high latitudes where the affects of climatic change will be most strongly felt.

Milestones/Deliverables:

Progress reports as required.
Final report including image products.

Coordinator: Weller

US14

RADAR ICE STRESS AND MOTION EXPERIMENT

Principal Investigator:
R.M.Goldstein JPL, 4800 Oak Grove Drive, Pasadena, CA 91109, USA
Tel: 818 3546999

Co-Investigators:
B.Kamb (CalTech), H.Zebker (JPL)

Objectives:
To use interferometric synthetic aperture radar to obtain topography and motion of the ice surface at selected sites. Separate estimates of topography and motion will be made for each 30 x 30 m resolution element in the scene.

Experiment Plan:
The method depends on measurements of the phase of corresponding picture pixels in pairs of SAR images made from data acquired on repeat orbits, typically 3 days apart. If the radar path repeats nearly exactly (say within 100m) and if the resolution elements (rezels) are then the phase difference between corresponding pixels will be the same for all pixels in the image pair. The radar frequency standard on ERS-1 need only be stable enough to ensure small phase drifts in the internal of one time-of-flight of the radar pulse (about 5 ms). However, if the rezels of the scene have moved relative to each other during the orbital repeat time, then the phase difference will not be equal and it will be possible to detect motion. For a signal-to-noise ratio of 10, a cross track motion of 0.45 cm is readily discerable. Only the component of motion along the line-of-sight is observed; any component at right angles produces no effect. It is planned to solve for a complete description of the motion of each rezel by including data from both ascending and descending pass pairs of ERS-1, which permits observation of the same ground region from 2 different directions. A vector motion then follows from combining these 2 line-of-sight motion measurements.

ERS-1 Data Requirements:
SAR data. 1 look complex images of about 30 x 30km are required for each of about 8 sites. Each site must be covered 3 or 4 times to allow good separation of topography and motion. Best results will be obtained if data from both ascending and descending orbits are used. Interferometry requires repeat orbits. The 3 day repeat cycle of the Commissioning phase is most desirable.

Anticipated Results:
(1) Larger-scale motions of sea-ice have been observed previously by measurement of the change in location of ice structures in successive Seasat images. However, the micro-scale observations will form a new data type which is expected to be most useful for studing the build-up, break-up and general stress of the ice sheet.
(2) It is planned to demonstrate the interferometer technique by producing image maps of ice topography, ice motion and loss of correlation for sites over the northern ice sheets and glaciers.

Milestones/Deliverables:
Progress reports every 6 months.
First topographic and motion maps will be presented 12 months from receipt of data.
A final report, in the form of a journal article, will be prepared at the end of the project.

Coordinator: Thomas

V Meteorology and Atmospheric studies

D4

APPLICATION OF ERS-1 WIND AND WAVE DATA TO PRODUCE (1) GLOBAL, GRIDDED FIELDS OF SURFACE STRESS AND SURFACE WAVES AND (2) WIND AND WAVE FORECASTS

Principal Investigator:
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Tel: 104 4114(1) x236

Co-Investigators:
S.Hasselmann (as above), W.Rosenthal/ H.Günther/ L.Zambresky (GKSS Forschungszentrum Geesthacht), W.Zahel/ E.Bauer (Institut für Meereskunde, Hamburg)

Objectives:
This project represents the German contribution to several international programmes with similar goals:
(1) An international Air/Sea Working Group has been established under the chairmanship of the PI, to produce global gridded flux data (momentum - i.e. surface stress - and sensible and latent heat) during the operational life time of ERS-1 and satellites NROSS and TOPEX/Poseidon.
(2) The WAM (Wave Modelling) Group has developed a global third generation wave model which will be applied both globally and regionally in a quasi-operational mode using ERS-1 wind and wave data. The WAM group is currently carrying out several projects to develop appropriate data assimilation methods in preparation for ERS-1.
(3) Support of campaigns. A number of experimental campaigns are planned to test the ERS-1 sensor package, algorithms, etc. Modelling and data assimilation activities will be carried out in support of these programmes to test the consistency of the sensor data with conventional data by subjecting both data sets to additional dynamical consistency tests.

Coordinator: Hollingsworth

F13

ETUDE DU BILAN D'ÉNERGIE A LA SURFACE OCÉANIQUE. INFLUENCE DE LA DISTRIBUTION SPATIALE DE L'EVAPORATION SUR LA DYNAMIQUE GENERALE ATMOSPHERIQUE

Principal Investigator:
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Tel: 33 1 45294903 Fax: 33 1 45296052

Co-Investigators:
C.Klapisz/ A.Weill (as above), K.Laval (LMD, Paris), K.Katsaros (University of Washington, Seattle, USA), N.Mognard (University of Puget Sound, Tacoma, USA)

Objectives:
(1) To study the impact of ERS-1 data on the surface flux determination, using numerical weather forecast models.
(2) To improve the flux parametrisation in models by studing their dependence on the sea state.

Experiment Plan:
ERS-1 data of SST, surface wind and water vapour will be merged into model fields (ECMWF global model and PERIDOT mesoscale model of the French Met. Office) in 2 ways:
(1) Modification of the analyses to fit them with satellite data, and compute surface fluxes using the current flux parametrisation. Flux quality will be checked by comparison with available surface data, and through global consistency (climatology).
(2) "Assimilation" of satellite data, to test their impact on the model forecast of meteorological fields and surface fluxes (n.b. water vapour only, some effort being conducted elsewhere for the surface wind and SST). This will use the PERIDOT model.
Tests on the parametrisation scheme will be performed using experimental data of fluxes and sea state characteristics acquired during the ASTEX campaign (June-July 1992). Experimental data will be used to validate the previous work on assimilation.
It is planned to study 4 different meteorological situations (at 3 month intervals), with the exact dates being selected according to the precise meteorological conditions in order to include events such as fronts, cyclones, etc.

ERS-1 Data Requirements:
For each test, at least 7 days of global data are necessary: surface wind SST, sea state (altimeter and wave mode), water vapour and cloud liquid water. Only off-line products are required.
The same data set is also required over the Atlantic Ocean (tropical and North) during the ASTEX campaign.

Facilities to be Deployed:
Wave buoy and possibly a ROWS (RESSAC radar) for surface measurements of sea state, ship sodars and tethered balloon for the measurement of local fluxes of heat and momentum, and aircraft measuremnts of turbulence and fluxes.

Anticipated Results:
(1) Validation of the assimilation method for water vapour.
(2) Improvement of the surface flux parametrisations.
(3) Estimation of the surface energy budget during SOFIA/ASTEX.

Milestones/Deliverables:

1991	First results on the model humidity field modification (PERIDOT - SSM/I).
1992	Model assimilation tests and ASTEX campaign implementation.
1993	Model assimilation tests for the ASTEX campaign.

Coordinator: Minster

F17

ETUDE DE L'ECHANGE DU GAZ CARBONIQUE ENTRE L'OCEAN ET L'ATMOSPHERE

Principal Investigator:
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Tel: 33 1 44275021 Fax: 33 1 44273805

Co-Investigators:
P.Delécluse/ L.Merlivat (as above), V.Garçon/ J-F.Minster (UM39)

Objectives:
To determine the carbon dioxide flux exchanged between ocean and atmosphere on a global scale, and to monitor its time variations (seasonal and inter-annual).

Experiment Plan:
(1) The wind speed deduced from the scatterometer data will be used to deduce the CO_2 exchange coefficient at the air-sea interface on a global scale. The accuracy will be improved by using the SST deduced from ATSR. An attempt will be made at deriving directly the exchange coefficient from the scatterometer sigma nought.
(2) The CO_2 partial pressure gradient at the air-sea interface will be determined, at least on a regional scale, by models including both the physical and biogeochemical processes acting in the ocean. The model will use the available in-situ CO_2 measurements and SST measured by the ATSR. It will be forced by the wind speed field derived from the scatterometer.
(3) The two parameters (exchange coefficient and CO_2 partial pressure gradient) will be combined to derive maps of the CO_2 flux exchanged at the air-sea interface.

ERS-1 Data Requirements:
Whole of the scatterometer sigma nought and wind speed measurements along the orbit (FDPs). The wind speed processed off-line in the equatorial belt (40°S-50°N, all longitudes).
Averaged global SST maps (ATS 2P600) for the lifetime of the satellite.
Selected SST images (ATS 2P100).

Anticipated Results:
(1) Monthly global maps of the exchange coefficient for the spacecraft lifetime.
(2) Improved knowledge of the sigma nought/ exchange coefficient relationship.
(3) Regional maps of the CO_2 partial pressure gradient at the air-sea interface as a function of time.
(4) Corresponding maps of the CO_2 flux exchanged between ocean and atmosphere.

Milestones/Deliverables:
Progress reports every 6 months.
Participation in ERS-1 workshops and conferences.
Scientific papers.

Coordinator: Minster

F18

AMERS: "ASSIMILATION MÉTÉOOCÉANIQUE DES DONNÉES ERS"

Principal Investigator:
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Co-Investigators:
F.Delsol (EERM, Boulogne), V.Cassé/A.Guillaume (DMN/SCEM/PREVI/NUM, Paris), C.Boissier (SHOM/GRGS, Toulouse), P.De Mey(CNES/GRGS/UM39, Toulouse), H.Roquet (EERM/CNRM).

Objectives:
AMERS is a multidiscipinary research project involving meteorologists, oceanographers and wave modelers. Its first natural objective is to develop an in-depth understanding and assessment of ERS-1 LBR data, through original contributions to external calibration, validation, quality control, inversion and scientific processing of microwave measurements of wind, waves and ocean topography, during and beyond the commissioning phase. The confidence gained in ERS-1 data is expected to provide a sound basis for a number of regional and global data assimilation experiments using innovative assimilation techniques and a hierarchy of numerical models for weather, mesoscale ocean circulation and sea state prediction. The cross-testing of data and modelling inherent in such investigations will in turn guide the selection and tuning of the most efficient numerical tools, to be implemented at DMN for real -time operational assimilation/prediction of global weather and regional sea state, or on-board ships for monitoring and prediction of ocean mesoscale patterns.

Experiment Plan:
The experiment plan relies strongly on the capabilities and background of operational NWP models operated by DMN, on computer resources used for simulations, software development and testing, numerical modelling in research mode, and probably on campaigns in the deep ocean. The on-going pre-launch activities are based on ERS-1 simulations, SEASATand GEOSAT data analysis and available models and software, and also on the results of the pre-ERS-1 ATHENA 88 oceanographic campaign implemented in the North Eastern Atlantic, to demonstrate the feasibility of real-time prediction of mesoscale circulation, based on the real-time routing of GEOSAT topographic data to ships at sea. The software developed during the commissioning phase, in particular for the calibration of the C-band scatterometer model, will be used in combination with NWP model outputs and in-situ reference measurements, for analysis and CAL/VAL activities.
The post-launch research will focus first on the computation of reference topographic surfaces and various statistics, prior to case studies and parallel model runs preparing for real-time experiments at DMN and pilot projects at sea.

ERS-1 Data Requirements:
Global FD products from the Altimeter, Scatterometer and SAR Wave Mode. Also some ATSR data.
Selected off-line products.

Anticipated Results:
The reliability and accuracy of ERS-1 LBR data will be documented. The impact on modelling and prediction of mesoscale ocean circulation, sea state and weather in real-time or research mode will be throughly assessed, using advanced techniques, thereby providing guidance for optimising the design of ERS-1 follow-up satellites and for the further development of the related applications.

Coordinator: Hollingsworth

IND1-4

UTILISATION OF ATSR AND MWS FOR ESTIMATION OF SST AND CLOUD HEIGHT

Principal Investigator:
V.K.Agarwal SAC, Ahmedabad, India

Co-Investigators:
M.Mohan/ S.Basu/ A.K.Mathur/ S.Ilanthirayan (as above)

Objectives:
(1) To retrieve SST over the Indian Ocean using ATSR multichannel, multiview observations.
(2) To use VIS and IR cloud images to delineate cloud fields.
(3) To use multiview ATSR observations along with postfacto orbital and attitude information to obtain the geometric height of the cloud field.
(4) To obtain a cloud classification using MWS moisture fields, and the cloud characteristics by stereoscopy and radiative measurements.
(5) Using surface winds from the scatterometer along with SST, to estimate air-sea interaction bulk calculations.

Experiment Plan:
Using both multichannel and multiview techniques, accuracy of SST estimation with reduction of atmospheric effects will be carried out. After registering ATSR and INSAT VHRR images, cloud height analysis will be carried out taking advantage of the scan geometry. Cloud heights, cloud top temperature and moisture content will provide cloud radiational properties from the climatology point of view. Additional information on surface winds will help study the bulk level air-sea interactions.
Test area: 40°-120°E, 10°S - 25°N.

ERS-1 Data Requirements:
(1) ATSR calibration data.
(2) ATSR raw counts on CCTs.
(3) Retrieved total water vapour image.
(4) Surface winds from the scatterometer.
(5) Orbital and attitude information, and any available propagation model.

Coordinator: Ninan

IND1-12

IMPACT OF SURFACE WINDS OVER THE OCEANS ON MEDIUM RANGE FORECAST OF INDIAN MONSOON

Principal Investigator:
M.S.Narayanan SAC Ahmedabad, India

Co-Investigators:
P.C.Joshi/ P.K.Pal (as above)

Objectives:
To assess the improvement in medium range monsoon forecast using ERS-1 surface winds.

Experiment Plan:
Including ERS-1 surface wind data as an input to the General Circulation Model is expected to improve the accuracy of forecast.
Test area: 30°-120°E, 40°N - 40°S.

ERS-1 Data Requirements:
Global wind data (WSC.VWI) daily for the months of May to September.

Milestones/Deliverables:
Reports on techniques and results.

Coordinator: Ninan

INT7

USE OF ERS-1 PRODUCTS AT ECMWF

Principal Investigator:
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Co-Investigators:
D.Burridge, M.Jarraud, P.Woiceshyn, H.Gunther (all ECMWF)

Objectives:
Assist ESA in calibration and validation of the fast delivery wind and wave products from ERS-1: Near real-time evaluation of the performance of the scatterometer wind model function and dealiasing module on a global basis, and in the major climatic regions of the globe, through cross-validation with in-situ data, and with meteorological data-assimilation fields. Similar evaluation for the wind and/or wave products from the Altimeter and the AMI in wave mode.
Cross validation of the ERS-1 wind and wave products with each other, through the use of the data assimilation systems.
Study of the benefits of a coupled wind/wave assimilation for improved exploitation of the scatterometer data.
Studies of the impact of the ERS-1 data on the prediction of intense synoptic-scale atmospheric phenomena such as explosive cyclogenesis, hurricans, polar lows, and their associated ocean wave fields. Exploitation of the data for real-time wind and wave assimilation, for both prediction and climate purposes.

Experiment Plan:
A specific dedicated effort by ECMWF staff and visitors (from the WAM wave modelling group and from JPL) to complement the ESA CAL/VAL campaign(s) by a global assessment of the performance of the fast delivery products, through exploitation of the in-situ data, and the wind/wave assimilation fields available at a major weather prediction facility. This effort will be continued at a reduced level for the life-time of the satellite, to provide long-loop monitoring.

ERS-1 Data Requirements:
Real-time delivery of CAL/VAL wind and wave field observations.
IWI, UWA and URA fast delivery products.
ATSR data in real-time if possible.

Anticipated Results:
(1) Assistance to ESA in CAL/VAL.
(2) Effective and rapid monitoring of data quality.
(3) Demonstration of the value of the data for improving wind and wave analyses and forecasts.

Milestones/Deliverables:

4Q 90	Software installed to receive and process FD products.
2Q 91	Global evaluation of FD wind/wave products.
3Q 91	Studies of the impact of the FD products in wind-wave assimilations.
4Q 91	Use of data in operational analyses.
2Q 92	Use of data in advanced assimilation methods.

Coordinator: Hollingsworth

J3-2

VALIDATION EXPERIMENT OF WIND VECTOR OBSERVATION BY WIND SCATTEROMETER IN THE SEA ADJACENT TO JAPAN.

Principal Investigator:
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Co-Investigators:
H.Nishida (Maritime Safety Agency), H.Ochiai (Toba Merchant Marine College), A.Shibata (Meteorological Research Institute), M.Saiki (Japan Meteorological Agency).

Objectives:
(1) To verify the applicability of the mathematical model to sea surface wind vector observation adjacent to Japan by comparing scatterometer-measured and surface measured wind vector data.
(2) To study the interaction of microwaves with the rough sea surface in order to understand physical processes involved in the derivation of the mathematical model.

Experiment Plan:
Surface truth data of wind vectors and other related meteorological and oceanographical data of the sea surface will be acquired for (a)2 test sites in the Pacific Ocean and (b) for a wider study area from ships and meteorological buoy data.

The 2 test sites are:	Off the coast of Kochi (Lon. +13415, Lat. +03230, 100kmx100km)
	Kumano-nada area (Lon. +13650, Lat. +03345, 25kmx25km)
The general study is:	Lon. +12500 to +15000 Lat. +02500 to +04500.

ERS-1 Data Requirements:
Wind Scatterometer FD products. Off-line products (AMI wind mode, wind speed and direction). Intermediate products of the Wind Scatterometer.

Facilities to be Deployed:
9.53GHz VV-polarised SLAR, 18 channel airborne MSS, L,C,X-band multi-polarisation FM-CW scatterometer, shipborne meteorological instrument data.

Anticipated Results:
(1) The validation of the applicability of the existing mathematical model to wind data in the sea adjacent to Japan.
(2) Study of the relation between the sigma nought triplet and wind speed vector to improve the existing mathematical model.
(3) Understanding of the physical processes behind the mathematical model by combining surface measured data from ships, remotely measured data by airborne and shipborne microwave sensors with ERS-1 scatterometer data

Milestones/Deliverables:

1988-90	Detailed planning of the experiment and production of data analysis programme by using the simulated products.
1991-92	Prepare and conduct experiment, data analysis and evaluation.

Coordinator: Fujita

J3-4

VALIDATION OF THE USEFULNESS OF WIND VECTOR AND WAVE DATA BY AMI SAR, SCATTEROMETER AND ALTIMETER FOR MARINE METEOROLOGY AND OCEANOGRAPHY IN THE PACIFIC OCEAN

Principal Investigator:
K.Okamoto — Communications Research Laboratory, 2-1 Nukui-kitamachi 4-chrome, koganei-shi, Tokyo, 184, Japan Tel: 81 423 27 7543 Fax: 81 423 27 7594

Co-Investigators:
A.Shibata (Meteorological Research Institute), M.Saiki (Japan Meteorological Agency).

Objectives:

(1) To estimate the effects of ocean wave heights and ocean currents on the measurement accuracy of suraface wind by the Wind Scatteroemeter.
(2) To confirm the usefulness of the scatterometer data for understanding accurate meteorological phenomena occurring over the ocean surface.
(3) To confirm the reliability of the wave analysis conducted by the JMA, in particularly inside typhoon and developed lows by using Altimeter data.
(4) To improve the SST forecast model of JMA by use of Wind Scatterometer data.
(5) To investigate the AMI SAR image by comparing it with sea truth data obtained from both JMA buoys and wave directional buoys.

Experiment Plan:

The wind vector fields from the scatterometer are to be compared with weather surface charts obtained by thw JMA. The significant wave heights obtained by from the altimeter will be compared with wave analysis by the JMA.
The experimental site is the western North Pacific Ocean (Lon. +12000 to +18000, Lat. +00000 to +05000).

ERS-1 Data Requirements:

Intermediate and off-line products from AMI SAR, Wind Scatterometer and Altimeter.
SAR: East China Sea.
Wind Scatterometer and Altimeter: western North Pacific Ocean.
Delivery required within 3 months of acquisition of raw data.
Data requested for a 3 year period.

Facilities to be Deployed:

JMA buoys providing wind speed and direction, air temperature, SST and wave height data.
JMA wave directional buoys providing wave height, wave period, wave direction and height spectrum.
Facilities to be deployed and ancillary data obtained simultaneously.

Anticipated Results:

(1) Improvement in the understanding of the effects of wind heights and ocean currents on the accuracy of surface wind measurement.
(2) The reliability of the wave analysis by the JMA inside typhoons and developed lows will be determined using Altimeter data.

Milestones/Deliverables:

1988-90	Detailed planning of the experiment and production of data analysis programme by using the simulated products.
1991-92	Prepare and conduct experiment, data analysis and evaluation.

Coordinator: Fujita

J4-1

RETRIEVAL OF WATER VAPOUR CONTENT AND PATH DELAY BY MICROWAVE SOUNDER OF ATSR/M

Principal Investigator:
T.Ojima — Communications Research Laboratory, Ministry of Posts and Telecommunications, 4-2-1 Nukui-Kitamachi, Koganei, Tokyo

Co-Investigators:
M.Fujita, K.Okamoto, K.Nakamura, J.Awaka, T.Kozu, T.Ihara, A.Shibata, H.Kuroiwa

Objectives:
Validation of MS data by comparing with radiosonde data.

Experiment Plan:
Radiosonde Stations are as follows:

Chichi-jima	(142.2°E, 27.1°N)
Minamidaito-jima	(131.2°E, 25.8°N)
Minamitori-shima	(154.0°E, 24.3°N)

Water vapour content and path delay will be retrieved from the ATSR/M data, and calculated from the radiosonde data. This will be lead to a comparison with error analysis.

ERS-1 Data Requirements:
Measured antenna temperatures of the Microwave Sounder of the ATSR/M within ±1° long. and lat. of the radiosonde stations.
At least ten observations per year.

Facilities to be Deployed:
Radiosonde station equipment.

Anticipated Results:
(1) Correction for path delay in Altimeter data.
(2) Bias errors in antenna temperatures of the Microwave Sounder.

Milestones/Deliverables:

1990	ERS-1 Launch
1991	Preliminary report
1992	Final report.

Coordinator: Fujita

J4-2

RAIN MEASUREMENTS BY ERS-1 ATSR MICROWAVE SOUNDER AND ALTIMETER

Principal Investigator:

T.Ojima — Communications Research Laboratory, Ministry of Posts and Telecommunications, 4-2-1 Nukui-Kitamachi, Koganei, Tokyo

Objectives:

To investigate the feasibility of estimating rain rate distribution with a combination of microwave radiometer and radar altimeter.

Experiment Plan:

Rain rate distribution is estimated from microwave brightness temperature based on a model computation. Surface echo strength is computed from the model and is compared to that measured with the Radar Altimeter. The model will then be refined. This procedure is expected to give good estimates of rain rate distribution.

ERS-1 Data Requirements:

Engineering products of the ATSR Microwave Sounder and Radar Altimeter over the following area:
Lon. +13500 to +14200 Lat. +03000 to 04000.

Facilities to be Deployed:

No plan to deploy equipment within the test area. Rain condition over the area is routinely monitored by the Japan Meteorological Agency with Mt. Fuji weather radar.

Milestones/Deliverables:

March 90 Estimation of rain rate distribution in progress using MOS-1 MSR (Microwave Scanning Radiometer).

Coordinator: Fujita

N1

UTILISATION OF ERS-1 SURFACE WIND AND WAVE INFORMATION

Principal Investigator:
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Co-Investigators:
L.A.Breivik, M.Reistad, J.Sunde, K.H.Midtb_

Objectives:
Impact assessment from using ERS-1 data in model production wind and waves.

Anticipated Results:
Weekly performance analyses.
LBR data impact on models.

Coordinator: Hollingsworth

NL9

OPERATIONAL APPLICATIONS OF ERS-1 WIND DATA IN REGIONAL METEOROLOGICAL MODELS

Principal Investigator:
L.Hafkenscheid KNMI, POBox 201, 3730 AE De Bilt, The Netherlands

Co-Investigators:
A.Stoffelen (as above)

Objectives:
(1) Further improvement of the model's (HIRLAM) analysis scheme for the effective assimilation of ERS-1 scatterometer winds.
(2) Evaluation of the operational impact of scatterometer winds in regional numerical weather prediction (NWP).

Experiment Plan:
(1) Study on assimilation of asynoptic, high density and correlated single level observations.
(2) Programming of infrastructure and processing facilities.
(3) Parallel assimilation and forecasts to study the impact of the winds on NWP, also in combination with TOVS.
(4) Functional comparison of the winds with high spatial ($50x50km^2$) and temporal (3 hours) resolution analyses and guess fields.
(5) After the cal/val phase estimates of the error and error correlations of the scatterometer winds will be carried out, and (3) be repeated.

ERS-1 Data Requirements:
Scatterometer winds in the North Atlantic area in a real-time fashion with the smallest possible delay.

Anticipated Results:
(1) Improved assimilation techniques for scatterometer winds in a regional meteorological model.
(2) A better understanding of the merits of scatterometer winds for regional NWP.

Milestones/Deliverables:
Collocation statistics of scatterometer winds and regional meteorological analyses and guess fields.
Papers and presentations.

Coordinator: Hollingsworth

NL10

INTERPRETATION OF WIND SCATTEROMETER SIGNALS

Principal Investigator:
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Co-Investigators:
D. van Halsema (TNO, The Hague), L.Krul (Technical University Delft), C.Calkoen (Delft Hydraulics)

Objectives:
The project consists of a comparison of satellite scatterometer data interpreted with a new algorithm with both standard ESA interpretation and in situ data obtained by other ERS-1 AO participants. The algorithm is presently being developed in a Dutch/German co-operative experimental and theoretical research programme called VIERS-1. The objective of the project is to improve the reliability of the interpretation of scatterometer data by introducing more basic physics.

ERS-1 Data Requirements:
ERS-1 scatterometer data (LBR NRCS data) and any available ground truth data over a total period of about 3 weeks. Data are requested for a number of periods in which the satellite crossed a sea area where ground truth is available, covering a range of environmental circumstances.

Anticipated Results:
A more accurate and more consistent interpretation of scatterometer data.

Milestones/Deliverables:
Reports and papers containing an intercomparison of ERS-1 scatterometer data analysed according to the standard ESA procedure and analysed according to the VIERS-1 algorithm which is presently being developed.

Coordinator: Hollingsworth

NZ1-3

THE INTERACTION OF SATELLITE DATA WITH MARINE METEOROLOGICAL OPERATIONS

Principal Investigator:
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Co-Investigators:
D.K.Purnell/ M.Revell/ M.Uddstrom (as above)

Objectives:
(1) To assess the impact of satellite derived wind and wave data on operational sea-state and atmospheric models.
(2) To validate the ERS-1 wind and SST data against drifting buoy winds in the Tasman Sea and Southern Ocean.
(3) To investigate ocean wave characteristics in the Southern Ocean.
(4) To compare the ATSR/M data with AVHRR/TOVS data and the resulting SST and moisture products.

Experiment Plan:
The ERS-1 wind and wave data will be assimilated into the various atmospheric and wave models. The impact will be assessed by comparing verifications of forecasts made from initial fields with and without these data.
Sea surface temperature and moisture data will be compared with the present operational products from the AVHRR and TOVS/ATOVS and the drifting buoy SSTs. The wind data from drifting buoys will be validated in a separate experiment.
The accumulation of wave data will allow a wave data base to be set up for the Southern Ocean.

ERS-1 Data Requirements:
ERS-1 FD products in near real time from the AMI/SAR wave and AMI/wind scatterometer modes and radar altimeter (wind and wave). Wave spectra and ATSR/M (SST and moisture) data from the PAFs. All to cover the area 30S-70S, 155E-170W.

Facilities to be Deployed:
Drifting buoys with wind sensors deployed in the Tasman Sea and Southern Ocean region. Up to 6.

Anticipated Results:
Improved NWP products and wave model products. The ability to routinely accommodate satellite based marine wind and wave observations into operational products. A data base of wave conditions in the Southern Ocean/Tasman Sea.

Milestones/Deliverables:

1989-90	Drifting Buoy wind sensor assessment
1990	Development of assimilation techniques
1990-91	Validation of ERS-1 surface winds vs buoy winds
1991-92	Assessment of impact of ERS-1 wind and wave data
1992-93	Assessment of ATSR/M data
1993-94	First wave climatologies for Southern Ocean region

Coordinator: Nilsson

UK5

A PROPOSAL FOR METEOROLOGICAL RESEARCH AND GEOPHYSICAL PRODUCT CALIBRATION AND VALIDATION IN THE POLAR REGIONS

Principal Investigator:
J.Turner British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET

Co-Investigators:
T.Endoh (Inst. Low Temperature Science, Japan), E.Rasmussen (Geophysical Institute, University of Copenhagen, Denmark), C.N.Duncan (Dept. of Meteorology, Edinburgh University), M.Lystad (Norske Meteorologiske Institut, Oslo, Norway

Objectives:
Calibration and validation of the ATSR and scatterometer surface wind measurements. The application of ERS-1 geophysical products to meteorological research in the polar regions.

Experiment Plan:
Cal/val activities through the collection of data on the British Antarctic Survey ships. Research into high latitude atmospheric processes through diagnostic and case studies using ERS-1 data and other satellite and in situ measurements.

ERS-1 Data Requirements:
BAS - ATSR SSTs over the ship tracks for cal/val purposes.
Univ. of Copenhagen - ATSR SSTs and cloud top temperatures fields plus SCATT surface winds for case studies of polar lows.
Univ. of Hokkaido - ATSR SSTs and cloud top temperature fields plus SCATT surface winds for case studies of mesoscale systems in the Sea of Japan.
Univ. of Edinburgh - SCATT surface winds for use in a major diagnostic study of the Southern Hemisphere atmospheric flow. Up to 2 years of data may be required.

Facilities to be Deployed:
Surface and possibilty upper air meteorological observing facilities on the 2 ships of the British Antarctic Survey (BAS). A downward looking radiometer on the BAS vessel RRS Bransfield for measuring sea surface temperature.

Anticipated Results:
(1) Improved sea surface temperature fields through the development of more accurate ATSR algorithms.
(2) Insight into the mechanisms behind the development of polar lows and other mesoscale vortices in polar airstreams.
(3) Greater understanding of the large scale flow of the Southern Hemisphere.

Milestones/Deliverables:
A cal/val study of ATSR SSTs based on comparisons with ship borne radiometer data.
Papers in the open literature on all the above topics, plus presentations at conferences and ESA symposia.

Coordinator: Hollingsworth

UK18

THE USE OF ERS-1 PRODUCTS IN OPERATIONAL METEOROLOGY

Principal Investigator:
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Tel: 344 856227 Fax: 344 854412

Co-Investigators: D.Offiler/ C.Hall/ R.J.Purser/ R.A.Bromley/ D.Ffiler/ R.W.Saunders (as above)

Objectives:
(1) To assist ESA in the calibration and validation of ERS-1 instruments.
(2) To assess the wind, wave, and sea-surface temperature data, and the derived analyses, for their accuracy and utility, so that informed decisions can be made about future operational satellites.
(3) To incorporate these data in analyses for climate, ocean, and wave modelling studies.
(4) To use the data to improve operational forecasts.

Experiment Plan:
(1) The Met Research Flight C130 aircraft, which has radiometric, temperature, humidity, and wind instrumentation, will be used to assist in the cal/val of the ATSR, scatterometer and other instruments. Data from the global assimilation system will be provided for the cal/val of the scatterometer.
(2) Processing methods to derive wind information from scatterometer data will be developed, and run in real-time. Derived observations will be assesed for accuracy, and incorporated in operational surface wind analyses (these analyses are used in operational wave forecasting, and are archived for climate research). The utility of the data in enhancing the accuracy of these analyses will be assessed. Assimilation methods, to optimise the impact on NWP forecasts, will be developed, and the impact assessed.
(3) The radar altimeter gives information about wave height and wind speed. This will be assessed for quality, and used to validate wave-forecasting models. Methods for assimilating the data into models to improve forecasts will be developed and tested.
(4) ATSR derived sea surface temperature observations will be acquired in near real-time, and compared with other observations and operational analyses. The data may be incorporated in analyses for operational forecasting and climate research.

ERS-1 Data Requirements:
IWI intermediate scatterometer wind product; FD altimeter wave and wind data; ATSR data.

Facilities to be Deployed:
Met Research Flight instrumented C130 aircraft.

Anticipated Results:
(1) Assessment of the observations' accuracy and utility.
(2) Archived analyses incorporating the observations.
(3) Improved forecasts.

Milestones/Deliverables:
(1) Position, time, pressure, wind temperature, humidity, and radiometric sea-surface temperature data from flights of the C130 aircraft during the Cal/val campaign.
(2) A global dataset of wind scatterometer IWI, and winds from independent analyses, covering the cal/val period, and/or statistics from this.
(3) A report on the accuracy and reliability of ESA FD scatterometer winds, and winds calculated locally from the IWI sigma nought values, derived by comparison with data from the operational data assimilation. An assessment of the impact of one of the above on analyses and forecasts.
(4) A report on the accuracy and reliability of ESA FD altimeter wave heights and wind speeds, derived by comparison with data from the operational wave model and wind analyses. An assessment of the impact of these data on wave analyses and forecasts.
(5) A report on the accuracy and reliability of ATSR sea surface temperatures, derived by comparison with independent observations, and the operational analysis.

Coordinator: Hollingsworth

US3-1

PREPARATION OF BASIN-SCALE WIND AND STRESS FIELDS

Principal Investigator:
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Co-Investigators:
Beardsley/ Chelton/ Esbensen/ Graber/ Kelly/ Large/ Wentz (as above)

Objectives:
(1) Develop accurate and efficient objective methods for space-time interpolation of scatterometer data onto basin-scale grids.
(2) Characterise the error structure of the resulting fields, taking into account the scatterometer measurement accuracy as well as errors resulting from the interaction of irregular scatterometer sampling with the natural variability of surface winds.
(3) Produce gridded fields and error maps for the global ocean using scatterometer data during the ERS-1 mission for use in driving ocean models.

Experiment Plan:
This experiment will develop statistical methods for space-time interpolation/extrapolation of wind scatterometer data in order to produce gridded, basin-scale surface wind velocity and stress fields using scatterometer data alone. The gridded fields will then be made available for use by oceanographers for driving large-scale ocean models. Interpolation schemes based on Gandin's theory of optimal estimation are being developed in the pre-launch period using simulated scatterometer data and operational analyses from ECMWF and the U.S NMC as "truth". The space-time scales that can be accuratly resolved by the ERS-1 satellite will be quantified.

ERS-1 Data Requirements:
Requirement for US3-1 - US3-8.
Full misssion WSC (UWI, IWI), ALT (URA) and available ATSR/M data globally over the ocean. Minimum requirement is for 1 year of data.
All available SWM (UWA) data obtained in the North Atlantic and over the Antarctic Circumpolar Current south of 40°S for the full mission. Minimum requirement is selected SWM data obtained in the North Atlantic over a period of 6 months.

Anticipated Results:
Pre-launch work, using simulated scatterometer data (with appropriate swath widths, spatial resolution, and anticipated measurement errors) and operational weather analyses will result in accurate, "tested" schemes for the optimal interpolation. In addition, these simulations will identify important space and time scales that can be quantitatively resolved by the scatterometer in typical ERS-1 orbits. Post-launch work will further test and refine the pre-launch simulations using actual ERS-1 scatterometer data. Gridded fields (with resolution anticipated to be better than 2° lat. x 5° long., and weekly-monthly frequency will be produced and made available for use by oceanographers.

Coordinator: Freilich

US3-2

METEOROLOGICAL STUDIES

Principal Investigator:
M.H.Freilich JPL, M-S, 300-323, 4800 Oak Grove Drive, 91109 Pasadena CA, USA

Co-Investigators:
Atlas/ Brown/ Dalcher/ Duffy/ Ghil/ Helfand/ Hoffman/ Isaacs/ Katsaros/ Louis (as above)

Objectives:
(1) Develop techniques to maximise the beneficial impact of ERS-1 scatterometer data in global and regional NWP models.
(2) Make a clear evaluation of the impact of scattterometer data on NWP.
(3) Develop and evaluate the capabilities of a coupled surface/Ekman layer planetary boundary layer model when inverted to use surface stress from scatterometers as input.
(4) Conduct numerical and diagnostic studies of atmospheric phenomena over the oceans, especially the dynamics and thermodynamics of midlatitude cyclones.

Experiment Plan:
Advanced research global analysis/forecast models are being developed at GSFC/GLAS, and four-dimensional assimilation schemes (based on variational techniques) and three-dimensional approaches (based on optimum interpolation) are under evaluation and test with simulated ERS-1 data. In parallel with these prediction model-oriented studies, investigations into the structure and dynamics of the marine planetary boundary layer (PBL) are being conducted. An inverse PBL model is nearing completion, using measurements of surface winds or stress from a scatterometer as input and yielding the vertical profile of winds through the boundary layer (and hence the surface pressure). The model is being tested using available Seasat scatterometer data in the southern hemisphere. After launch, both the assimilation scheme and the PBL model will be re-tuned using actual ERS-1 data, and the impact of ERS-1 wind data will be evaluated quantitatively using a series of carefully controlled observing system experiments. Studies of marine cyclones will then also be conducted, including calculations of surface divergence, curl, and fluxes from both typical and atypical storm systems.

ERS-1 Data Requirements:
Requirement for US3-1 - US3-8.
Full misssion WSC (UWI, IWI), ALT (URA) and available ATSR/M data globally over the ocean. Minimum requirement is for 1 year of data.
All available SWM (UWA) data obtained in the North Atlantic and over the Antarctic Circumpolar Current south of 40°S for the full mission. Minimum requirement is selected SWM data obtained in the North Atlantic over a period of 6 months.

Anticipated Results:
Studies evaluating the assimilation of scatterometer data into global and regional analysis/forecast models will quantify the impact of the surface wind data on large-scale NWP, and will resolve many of the long-standing issues raised by the short, flawed, Seasat data set. The outputs of the NWP models are gridded, regular data that are applicable for use in driving ocean models. In this sense, the dynamically basedNWP model studies complement the statistical studies, and the surface wind/stress fields (and associated error estimates) will be made available to ocean researchers. The PBL study will allow direct preparation and comparison of surface pressure fields derived from ERS-1 scatterometer data with those derived from conventional means. The study of storms and marine cyclones will allow detailed characterisation of key features of observed synoptic events on scales heretofore unobtainable over the global oceans, and will provide input for studies of mixed layer dynamics in the ocean.

Coordinator: Freilich

US8-7

SHORT RANGE REGIONAL FORECASTING USING ERS-1 SCATTEROMETER OCEAN SURFACE WIND SPEED AND DIRECTION DATA

Principal Investigator:
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Tel: 416 667 4815

Co-Investigators:
J.Spagnol (Pacific Weather Centre), J.Bullas (Western Arctic Meteorological Centre), K.MacDonald (Maritimes Weather Centre), A.G.Earle (Newfoundland Weather Centre), R.Cross (Directorate of Meteorology and Oceanography)

Objectives:
(1) Assess the impact of near real-time scatterometer wind speed and direction data on short range regional weather forecasting.
(2) Assess the quality of ERS-1 de-aliasing algorithm.
(3) Development of improved data assimilation techniques.

Experiment Plan:
ERS-1 scatterometer wind speed and direction data will be delivered in sufficiently timely manner (i.e. less than 3 hours from observation to delivery) to Weather Centers on Canadian coasts. Each weather centre will use these data for short range regional forecasting and sea-state forecasting. These data will be assimilated into the subjective forecast production procedures using techniques developed from earlier research projects involving impact of Seasat scatterometer wind data for short range regional forecasting.
The value of the data will be assessed in several ways:
(1) Subjective assessment by the forecasters of improvement in surface analyses and forecasts.
(2) Comparison using standard verification techniques before and after the wind data become available.
(3) Special case studies of significant storms conducted after the event. These studies will be used to develop new data assimilation techniques.
In addition, the data obtained for this experiment will be used for development of techniques to assimilate scatterometer data into Numerical Weather Prediction (NWP) models and for application with the AES regional forecasts.

Facilities to be Deployed:
AES will provide resources to conduct this study which includes the delivery of data to Regional Weather Centres as well as meteorological analysts and facilities for each Regional Weather Centre involved in the study.

Anticipated Results:
Improvement in the surface analysis and in forecasts as demonstrated by subjective techniques and standard verification techniques.
Improvement in data assimilation techniques.

Milestones/Deliverables:
(1) Communications and project planning in place at launch.
(2) Data to Weather Centres as soon as available.
(3) Learning phase for meteorologists will be less than two working weeks.
(4) Monthly and sub-project internal reports.
(5) Preliminary publication will be presented within one year of start of project.

Coordinator: Freeman

VI Forestry

AUS3

BACKSCATTER MODELLING AND CHANGE ASSESSMENT OF AUSTRALIAN NATIVE FORESTS

Principal Investigator:
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Tel: 61 61 688592 Fax: 61 62 688443

Co-Investigators: A.K.Milne (Centre for Remote Sensing, University NSW, Kensington, NSW), M.Imhoff (GSFC)

Objectives:

(1) To develop an understanding of the interaction of microwave energy with forest stands, via the development of suitable radar backscatter models for typical Australian tree morphologies. These models will be used in radar image interpretation and to provide information on forest biophysical characteristics.
(2) To investigate the utility of spaceborne radar for monitoring renewable forest resources subject to changes caused by phenological conditions, disease, human occupance and natural hazards such as bushfire and flood.

Experiment Plan:

Three Australian sites have been chosen for this study, covering a range of ecosystems and tree morphologies:
(i) coastal eucalypts and pine plantations in the state of Victoria in south-eastern Australia, for which multiple incidence angle SIR-B data are available; (ii) the arid zone Mallee ecosystem in south-central New South Wales; (iii) coastal mangroves in north western Australia.
Building upon previous studies by the investigators, backscatter models that suit the complicated branching structures of the trees of interest are near completion. In the pre-mission phase during 1990 these are to be tested against historical SIR-B data and against aircraft radar data recorded over an Alaskan field site by IFIT (International Forest Investigations Team) in March 1988. When validated, models for different tree structures will be used to help identify and map the distribution of major forest communities and to measure and monitor changes in the areal extent and condition of forest biomass. Other pre-mission activity includes site measurements of soil moisture and complex dielectric constants as inputs to the models, along with physical tree characteristics, including branching angles, stand densities and tree size distribution. Shortly before the mission, baseline mapping of stand characteristics will be carried out as an epoch for the dynamic aspects of the study. This will be based initially on high resolution optical image data, supplemented by ERS-1 SAR when available. During the mission, active radar calibrators (ARC) and passive corner reflectors are to be deployed at all sites. At least 6 ARC's will be used to obtain estimates of the extinction coefficients of eucalypt and pine canopies. Regular mapping of the field sites will be carried out during the mission to support the dynamics study, and for comparison against model predictions.

ERS-1 Data Requirements:

SAR image data as follows:
Victorian Test Site (centred on 38°00'S, 146°45'E): Essential: One winter and one summer acquisition annually, both imagery and raw signal data if possible. Desirable: Up to 10 data takes at 3 day intervals for one winter and one summer acquisition.
New South Wales (Mallee) Test Site (centred on 32°30'S, 143°20'E): Essential: One winter and one summer acquisition annually. Desirable: Mapping coverage (ie contiguous swaths) to cover a reasonable sample of this sparse ecosysystem.
Northern Australian Test Site (centred on 12°50'S, 132°15E): Essential: 35 day coverage to allow characterisation of seasonal and annual variability.

Anticipated Results:

Assessment of the utility of C-band, low incidence angle radar image data for mapping and monitoring forest dynamics, and of the effectiveness of backscattering models of random tree morphologies when used to explain C-band VV data.

Milestones/Deliverables:

1989-90	Model development
1990-91	Baseline forest mapping and site charactisation
1991-92	Model validation and image interpretation
1992-94	Dynamics study, supported by fully validated model

Coordinator: Nilsson

CND4

FOREST FIRE DETECTION, FIRE MANAGEMENT AND FIRE DAMAGE ASSESSMENT USING THE ERS-1 SAR AND INFRARED RADIOMETER

Principal Investigator:
G.Lawrence Intera Kenting, Ottawa, Ontario, Canada

Co-Investigators:
R.Brown (CCRS), A.Jeffrey (Canadian Interagency Forest Fire Centre, Winnipeg), D.Leckie (Petawawa National Forest Centre, Ontario), T.Lynham (Great Lakes Forestry Centre, Ontario)

Objectives:
To evaluate the utility of ERS-1 SAR and infrared radiometer data for forest fire detection, forest fire mapping, fire management and post fire damage assessment.

Experiment Plan:
ERS-1 data received from the Gatineau receiving station will be geometrically and radiometrically corrected on the MAGIC image analysis system. Image analysis procedures will include the generation of statistical and image histograms, the evaluation of spectral signatures, and the use of maximum likelihood and parallel piped classifiers. All data will be threshold classified and this threshold detection technique will be applied to detect and locate low level pixel numbers which may be associated with small fires. All data will be mapped onto standard fire management maps. The data will be compared to any fire detection information derived by operational fire detection flights. Fire size and burn intensity will be determined.

ERS-1 Data Requirements:
Essential
Three to six passes of ERS-1 radiometer data over selected active fire areas over 20,000 ha in size occurring throughout Canada during the summer period 1991 or 1992.
Desirable
Both SAR and radiometer data over a zone of active fire activity or over a recently burned area, one pass near the time of fire termination, one pass post leaf and one pass during winter.

Facilities to be Deployed:
Airborne infrared linescan system (subject to availability).

Anticipated Results:
(1) Mapping of active fire areas from the radiometer data as well as a comparison between radiometeric signatures of non-burned areas vs burned over areas.
(2) Mapping of burn over areas based on microwave backscatter variances between burned and non-burned areas.
(3) The comparison between airborne thermal infrared imagery with the radiometer data over active zones of intense burning.

Milestones/Deliverables:

1990-91	Detailed experiment plan.
1991-92	Coordinate and conduct experiment in association with co-investigators. Produce computer generated imagery from the SAR and radiometer data and transfer to a map base. Recommend uses of ERS-1 data for fire mapping and management based on results.
1992-94	Utilise ERS-1 data on an operational basis in support of forest fire managaement.

Coordinator: Lawrence

F23

EVALUATION OF THE ERS-1 MULTITEMPORAL SAR RESPONSES TO VEGETATION

Principal Investigator:
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Co-Investigators:
A.K.Fung (University of Texas), J.Riom (INRA Pierroton, France).

Objectives:
(1) An increased understanding of the interaction between microwaves and vegetation.
(2) An assessment of the potential of orbital SAR's for monitoring vegetation dynamics.
(3) An overall assessment of the use of information derived from spaceborne SAR in ecosystem models.

Experiment Plan:
(1) Modelling of radar backscatter of forests with emphasis on the extraction of forest information. This modelling phase requires a complete set of ground data to be collected in the training test site.
(2) Development of algorithms to retrieve forest characteristics from SAR images (i.e. forest type, density, height, age class, biomass).
(3) Verification of the algorithms on other test sites and refinement of algorithms.
(4) Evaluation of the contribution of ERS-1 data in forest ecosystem models.

Main test site:	Landes Forest (F)	: coniferous species in temperate region.
Other test sites:	Duke Forest (N.Carolina, USA)	: coniferous species in temperate region.
	Central Alaska	: boreal forest
	Manaus (Brazil)	: tropical forest
	Muarabungo (Sumatra, Indonesia)	: tropical forest, deforestation
	Pissila (Burkina Faso, W.Africa)	: Sahelian forest/savannah transition

ERS-1 Data Requirements:
SAR data are requested for all 6 test sites. In addition, for 3 test sites (Landes forest, Manaus and Pissila) Wind Scatterometer data are requested for a specific study. The aim of the study consists in assessing the use of low resolution data to map vegetation types at a global scale together with high resolution data (SAR) at sampling places to have detailed information on vegetation characteristics. The scatterometer data will cover large areas including the SAR scenes requested.
Temporal coverage:(1) Landes forest - Seasonal coverages: Nov1-March15 (1 scene), March15-July15 (2 scenes), July15-Sept15 (1 scene), Sept15-Oct30 (1 scene); (2) Duke forest - 1 scene between June15 and Sept15; (3) Alaska - 1 scene between July1 and August31; (4) Manaus - 1 scene at any time; (5) Muarabungo - 1 scene at any time;(6) Pissila - 1 scene in November.

Anticipated Results:
(1) Assessment of the ability of SAR to discriminate different forest types and conditions and to monitor their dynamics: determination of validity domains of backscatter models; sensitivity of backscatter signals to forest parameters; backscatter signal saturation conditions with respect to forest characteristics (e.g. density, height); possibility of inversion for input parameters of ecosystem models.
(2) Assessment of the ability of SAR to map forest at a global scale: effect of forest type and ecological conditions on the inversion algorithm, evaluation of the joint use of low resolution (scatterometer) and high resolution (SAR) data for forest inventory.
(3) Evaluation of the contribution of radar data in ecosystem models (integration of the forest type, areal extent and parameters derived from SAR data in ecosystem models).
(4) Complementarity of radar and optical data for forest studies.

Milestones/Deliverables:
(1) Communications in dedicated symposia and workshops, and publications in international journals.
(2) The team also proposes to participate in specific studies related to the calibration/validation of ERS-1. One of the possible studies is the analysis of data on tropical rain forest with a high temporal coverage.

Coordinator: Sieber

INT4

INTERNATIONAL FOREST INVENTORY: THE GLOBAL FOREST ECOSYSTEM AS VIEWED BY ERS-1

Principal Investigator:
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Co-Investigators: J.B.Way (JPL, USA), F.Ulaby/ C.Dobson/ D.Gates (University Michigan, USA), J.Richards/A.Milne (University N.S.W, Australia), J.Cihlar/ F.Ahern (CCRS, Canada), D.Simonette (University of California Santa Barbara, USA), Th Le Toan (CESR, Toulouse, France), Ph.Hartl (University Stuttgart, Germany), M.Sami (Politecnics di Milano, Italy), E.Kasischke (ERIM, USA), P.N.Churchill (as PI)

Objectives:
To perform coordinated global forest experiments designed to use the unique properties of SAR to characterize the physical nature of forest stands. Multidate SAR data will be used in concurrent studies of forests with other active microwave data (SIR-C, aircraft SAR and field scatterometers) and optical data (primarily Landsat Thematic Mapper, aircraft AVIRIS and SPOT). The research programme of IFIT is directed toward the development of a forest information system in the 1990's and beyond for operational global studies of forests both for their own sake and for input to global ecosystem and climate models.

Experiment Plan:
(1) To quantify the temporal range of radar returns from a variety of forest canopy types under different growth stages, environmental and seasonal conditions.
(2) To unfold the components of backscatter from a forest stand using the observations made under a variety of environmental conditions.
(3) To quantify radar signatures in terms of physical forest ecosystem characteristics including above-ground phytomass, canopy geometry (size, shape, angular orientation), canopy moisture condition, and surface boundary layer state.
(4) To map and monitor human impacts on forest canopies, including (a) acid deposition damage in Europe, (b) biomass burning in Australia and Alaska, and (c) deforestation in the northern US, Canada and Brazil.
Test Sites: Black Forest, Germany (48°N, 8°E), Toolik Lake, Alaska (69°N, 149°30'W), Manley Hot Springs, Alaska (65°3'N, 151°10'W), Bonanza Creek, Alaska (64°45'N, 148°15'W), Raco, Michigan, USA (46°20'N, 84°40'W), Duke Forest, North Carolina, USA(36°N, 79°W), Darwin, Australia(12°52'S, 132°E), Gippsland, Australia(37°45'S, 147°8'E), Weipa, Australia(14°S, 142°15'E), Pooncarrie, Australia(32°S, 143°15'E), Whitecourt,Canada(54°30'N, 115°40'W).

ERS-1 Data Requirements:
Multi-date SAR data are required for all test sites: *Commissioning phase:* (calibration sites) - Black Forest, Manley Hot Springs, Toolik Lake, Raco, Duke Forest require data every 3 days. Some night data required for Black Forest, Manley Hot Springs and Raco. *35 Day Repeat:* Black Forest, Bonanza Creek, Raco, Duke Forest, Whitecourt, Darwin, Weipa, Pooncarie and Gippsland - 2 scenes per cycle; Black Forest, Bonanza Creek, Raco, Duke Forest, Whitecourt and Gippsland - 1 night scene per cycle. *Ice Phase:* Delta Junction requires data every 3 days.
Roll-tilt mode: Black Forest, Bonanza Creek, Raco, Duke Forest, Whitecourt, Darwin, Weipa, Pooncarie, Gippsland.

Facilities to be Deployed:
Airborne SARs, imaging spectrometers and multi-spectral scanners. Calibration devices and dielectric probes.

Anticipated Results:
(1) Area extensive validation of external SAR data calibration techniques on a repetitive basis.
(2) Improved radar models through the use of variable environmental conditions.
(3) Development of multi-temporal "change detection" methodologies for reduction of data volume and for inferring changes in scene physical and biophysical conditions.
(4) Provision of a baseline data set for long-term monitoring and assessment of forest resources.
(5) Establishment of a research environment conducive to accelerated development of target/sensor interaction models.

Milestones/Deliverables:
Status reports every 6 months after launch. ERS-1 workshop/conference papers and othe scientific papers.

Coordinator: Sieber

US1-10b

FOREST BIOMASS OF THE PORCUPINE INVENTORY UNIT

Principal Investigator:

J.Yarie — Division of Forest Science, Agriculture and Forestry Experimental Station, University of Alaska, Fairbanks Tel: 907 4746714

Co-Investigators:

K.Winterberger (US Forest Service, Anchorage, Alaska)

Objectives:

To determine forest biomass within the Porcupine Inventory Unit of the U.S. Forest Service which will be covered by both ascending and descending swaths and the crossover area.

Experiment Plan:

Existing data on forest biomass and productivity from 529 0.4 hectare plots in the Porcupine and Upper river drainages of northeastern Alaska will be used as ground truth to develop relationships with full resolution SAR data. The geographic location is a 300 km square centred on 67°N, 145°W.

ERS-1 Data Requirements:

SAR data. 4 scenes in spring, summer, fall and winter.

Anticipated Results:

The ability to use SAR data to track changes in forest biomass over large land areas.

Milestones/Deliverables:

1992 Forest biomass map of the study area.

Coordinator: Weller

VII Agriculture and Soils

B1

SYNERGIC USE OF ERS-1 SAR WITH OPTICAL SENSING (SPOT, TM) FOR CROP MONITORING AND LAND COVER MAPPING IN BELGUIM.

Principal Investigator:

R.Gombeer — Land Management, Remote Sensing and Land Information Laboratory, Faculty of Agricultural Sciences, Katholieke Universiteit Leuven, Kardinaal Mercierlaan 92, B-3030 Haverlee, Belguim Tel: 016 220931 Fax: 016 221855

Objectives:

(1) To study the complementary exploitation of optical sensors and microwave data for monitoring crop condition and land use classification.
(2) To develop methods for crop monitoring throughout the agricultural growing season in the absence of clouds.
(3) To map crop types and land use categories based on multitemporal SAR data and to provide agricultural statistics on the mapped surface classes.

Experiment Plan:

Image processing facilities will be used to investigate the multitemporal registration and analysis of SAR data. The overlay with optical SPOT and LANDSAT images will also be investigated in a way that vegetation indices and backscatter data can be directly compared with crop type and bare soil on individual fields (e.g. effects of plant cover, crop height, soil moisture, biomass etc.)
Standard procedures for ground data collection (soils,crops) will be applied, and in addition a field radiometric campaign (visible and near infrared) will be organised.
Time evolution series of SAR backscatter (ERS-1) and of soil surface and vegetation reflectances (SPOT,TM) will be produced for a number of training fields. They will be correlated with ground inventories and measurements through modelling and multivariate statistics. It is intended to search for complementary image indices and/or procedures that are helpful for monitoring plant condition and mapping soil moisture under intermittent cloudy situations. To achieve this, methods for internal image calibration using natural reflectance surfaces will be investigated both for SAR and optical data, or in combination.
The description of the land use and the study of landscape typology are also a major concern. the chosen test area (Leuven) includes very small to large agricultural fields with various shapes and boundary types. Certain parts of the test area are very homogeneous in land cover or are well structured. They allow the study of image texture and structure, and their influence on the detectability of important landscape features, such as topographic lineaments and field edges that are related to erosion, run-off etc. Land cover statistics will be evaluated using a geographic information systems(ARC INFO).

ERS-1 Data Requirements:

SAR Image Mode : Images every 15/30 days in the period 1/1/90 to 31/12/92.

Anticipated Results:

The plant condition assessment and the mapping of agricultural crops from satellites is considered to be an important tool for improving agricultural statistics. However, special efforts must be made in small parcelled areas and the latter are very common in Belgium. Moreover, frequent cloud cover hampers regular observations by optical sensors. In this respect, the combined exploitation of the high resolution of SPOT data, the spectral bands of TM data and the high visibility of ERS-1 data, is expected to contribute strongly to an improved monitoring capability of crops and land surface dynamics.

Milestones/Deliverables:

1991 & 1992 — Field campaigns (ground surveys and field radiometry.
Acquisition of SPOT and TM data.
Analysis of SAR imagery and modelling of spectral, multitemporal and multisensor signatures.
Crop and land cover mapping.
Production of agriculture and land use statistics.

Coordinator: Gombeer

BRA1

INTERACTION MECHANISMS BETWEEN MICROWAVE RADIATION, BARE SOIL AND CROPS

Principal Investigator:

H.J.H.Kux — Instituto de Pesquisas Espaciais, Av.dos Astronautas, 1758, Caixa Postal 515, 12201, SĨo José dos Campos, Brazil

Co-Investigators:

U.W.Palme/ J.V.Soares/ G.J.F.Banon (as above)

Experiment Plan:

(1) Development of a model of soil moisture, and possible also of vegetation moisture, based essentially on field data (dielectric constant, physical and chemical soil data, agrometeorological data etc.) from two distinct floodplain ("varzeas") areas in NE (Pernambuco State) and SE (S.Paulo State) Brazil.
(2) Based on these models, and using as well bulk and radiometrically corrected ERS-1 SAR images, an analysis and evaluation of the information content of spaceborne SAR to monitor soil moisture and vegetation will be performed.

ERS-1 Data Requirements:

SAR data covering the complete 6 month growth cycle of the irrigated areas under investigation is needed. A total of 12 SAR scenes, with a time interval of 15 days, are requested (bulk and radiometricaly corrected).

Milestones/Deliverables:

1990	Construction and calibration of a frequency domain reflectometer.
	Field campaigns for soil moisture data collection including measurements of dielectric constants.
1991	Field campaigns parallel to ERS-1 data acquisition.
	Evaluation of ERS-1 data.
1992	Final report.

Periodic progress reports will be prepared, including a description of the research activities running, the open problems and a discussion of possible solutions.

Coordinator: Attema

CND6

USE OF ERS-1 DATA IN CANADIAN RENEWABLE RESOURCE APPLICATIONS

Principal Investigator:
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Co-Investigators: *Agriculture:* J.Cihlar/ C.Prevost/ R.Mussakowski/ J.A.Fisher (CCRS), A.R.Mack (Agr. Canada), R.Protz (Univ. Guelph), P.J.Howarth (Univ. Waterloo), K.P.B.Thompson (Univ. Laval), Q.H.J.Gwyn (Univ. Sherbrooke), J.Whiting (Sask. Res Council). *Forestry:* Y.J.Lee (Pac. Forestry Cen.), R.J.Hall (Nrtn Forestry Cen.), W.C.Moore/ R.A.Sims (Can. Forestry Serv.), D.G.Leckie (Env. Canada), F.J.Ahern/ T.T.Alfoldi (CCRS)

Objectives:

(1) Crop identification and crop area estimation.
(2) Crop condition and yield assessment.
(3) Locating and characterising catastropic events.
(4) Detecting and mapping forest change and define methodologies for operational forest monitoring and map updating.
(5) A synergistic role with visible and infrared data.

Experiment Plan:

Agriculture: To collect airborne and ERS-1 SAR data over several comprehensive agricultural test areas across Canada selected to represent the diverse agro-climatic regions of the country. Resources of several agencies have been combined to increase the amount of ground data that may be collected. These sites have been used since 1988 as part of an on-going Canadian Radar Data Development Programme. The ERS-1 data will allow for extrapolation of the airborne results over a large area and for evaluation of small incidence angle C-band SAR data for the various application areas.
Forestry: SAR data will be collected over several test area across Canada which are representative of different forestry regimes. Ground data on relevant forest parameters such as species, species mix, density, height, age and understorey and ground cover type will be acquired. The optimum times for detecting change will be investigated. The SAR data will be supplemented by extensive ground data and measurements taken with a ground based scattereometer (Ku,C,L).

ERS-1 Data Requirements:

Agriculture: SAR data for 7 test sites once every 17 days (subcycle of ERS-1);period April 15 to Sept. 30 first 2 years of mission.
Forestry: SAR data for 7 test sites approximately once every 3 months for the 2 years, with 2 additional images in July and August of both years at 2 of the test sites.

Anticipated Results:

(1) It is anticipated that multitemporal data will contribute significantly to crop type discrimination and that single date SAR, in conjunction with VIR data, will also be shown to be a desirable data set for this purpose.
(2) It is anticipated that the SAR data will be useful for soil moisture estimation (modelling surface roughness) and that multitemporal data will be able to follow crop development and direct our future research on the use of this data source for crop condition assessment.
(3) It is anticipated that the study will enable better definition of the accuracy of SAR data for change detection and of the conditions under which they may be used operationally.
(4) It is anticipated that procedures will be specified to combine SAR and VIR imagery for forest type mapping.

Milestones/Deliverables:

Agriculture - Detailed project plan (Mar 90); Preliminary/Final report on preprocessing methodology (Dec91/Jun92); Preliminary/Final report on classification (Apr92/Jan93); Report on impact of incorporating SAR data into a crop information system (Mar93); Preliminary/Final report on correlation between soil moisture and radar backscatter (Nov91/Nov92).
Forestry - Report on analysis of single date SAR for locating changes.(Dec91); Report on correlation between stand parameters and radar backscatter.(May92); Specification of optimum data set for forest mapping.(Dec92) ;Complete classification of data for forest change and specify optimum data set.(May93); Report on the usefulness of vegetation indices and principal component analysis for species determination (Jun93).

Coordinator: Lawrence

D11-8

ESTIMATION OF STAGE OF MATURITY AND YIELD PERFORMANCE IN AGRICULTURAL CROPS BY MEANS OF MULTI-TEMPORAL ERS-1 DATA

Principal Investigator:
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Co-Investigators:
G.Kupfer/ W.Förstner (Institut für Photgrammetrie, University of Bonn), W.Wiesbeck (Institut für Höchstfrequenztechnik und Elektronik, Universität Karlsruhe)

Objectives:

(1) To detect temporal changes in radar backscatter of winter wheat and sugar beet crops from images generated from ERS-1 SAR data and signatures measured with a ground-based scatterometer.
(2) To understand radar backscattering in terms of physical and biochemical parameters of plants and underlying soil.
(3) To compare scatterometer and ERS-1 SAR data.
(4) To determine suitable configurations of SAR systems in terms of wavelength, polarization, incidence angle and look direction for monitoring plant parameters at different growth stages with no or negligible influence of the soil.
(5) To combine ERS-1 SAR and Landsat TM optical data for the identification of crop type and estimation of yield vitality and yield performance.

Experiment Plan:

Backscattering data from winter wheat and sugar beet fields will be established from ERS-1 SAR and ground-based measurements with a scatterometer which will be operated several times during the crop growing season. Simultaneously, plant and soil parameters will be collected, including plant biomass, LAI, stand height and water content, and soil density and moisture. Correlations between these parameters and canopy backscattering will be calculated. The SAR data used will be corrected geometrically and radiometrically. Additionally, Landsat TM data will be processed and combined with ERS-1 SAR data to improve identification of crop type and vitality.
Test area: Köln-Aachener-Bucht area, Germany (50°30'-51°10'N, 6°30'-7°20'E).

ERS-1 Data Requirements:

Multitemporal SAR images for the test area.

Anticipated Results:

(1) Better understanding of relationships between radar backscattering and plant/soil parameters.
(2) Definition of suitable combinations of wavelength, polarisation, incidence angle and look direction for monitoring crops at different growth stages.
(3) Evaluation of the utility of scatterometer and ERS-1 SAR data for estimating crop vitality and yield performance.
(4) Evaluation of the utility of SAR and VIS/IR sensor data combinations for an improved crop identification and estimetion of crop vitality and yield.

Milestones/Deliverables:

Status reports every 6 months from July 1990 to December 1993.
ERS-1 workshop/conference abstracts.
Scientific papers.

Coordinator: Nithack

D11-12

RESEARCH ON LAND USE, PEDOLOGY AND SOIL MOISTURE USING MULTITEMPORAL ERS-1 AMI DATA

Principal Investigator:
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Objectives:

(1) To conduct a pilot study on the utility of multi-temporal ERS-1 AMI data fro the determination and modelling of the plant water status and the spatial distribution of evapotranspiration, which is one of the major components of the hydrologic cycle.
(2) The information content of the ERS-1 AMI data concerning land use, pedology and soil moisture will be determined in a 50 km2 study area in the Upper Rhine Valley near the city of Frieburg.
(3) Development of techniques to combine ERS-1 data with SPOT Pan and Landsat TM data to enhance their information content.

Experiment Plan:

Commissioning phase and 35-day repeat cycle AMI data will be used to monitor land cover changes in the study area during the 91/92 growing season. This will be backed up by intensive ground data collection, including a crop inventory of the study area, weekly measurements of plant parameters (biomass, LAI, stomatal conductance) of the most important crops in the study area, continuous recording of soil moisture status at 12 sites and simultaneous measurement of the soil moisture distribution on selected fields using microwave (L-band) dielectric probes. Surface roughness will be determined through the digital processing of stereo video images. Plant coverage will be monitored weekly on selected fields using video cameras and through classification of the digitised images. Correlations between the gathered ground data and the change in AMI signal will be conducted to extract functional relationships betwen AMI signal and plant cover, plant architecture and soil moisture depending on differences in soils. The extracted information from the multi-temporal AMI data will be integrated into a GIS. An existing model will be run to determine the evapotranspiration of the surface with and without the AMI-derived information and the results compared.

ERS-1 Data Requirements:

Multi-temporal images of 2 scenes (ascending and descending) of AMI SAR data from the Upper Rhine valley near the city of Freiburg (48°N, 7°38'E) during the Commissioning Phase and the 35 day repeat cycle through the life-time of the ERS-1 mission.

Anticipated Results:

(1) Increased understanding of dynamic hydrologic processes and their variability in space. The ERS-1 AMI data are expected to be of particular value for hydrologic applications because of their weather independence and their potential for soil moisture determination.
(2) Experience in the integration of SAR data in existing geographical information systems for the modelling of land surface processes.
(3) Basic knowledge of the information content of single frequency multi-date SAR data for hydrologic and agricultural applications.

Milestones/Deliverables:

Status reports.
ERS-1 workshop/conference abstracts.

Coordinator: Nithack

D11-13

REGIONALISATION OF SOIL WATER CONTENT BY MEANS OF ERS-1 DATA

Principal Investigator:
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Co-Investigators:
C.Prietzsch (as above)

Objectives:
(1) Correlation of soil water contents (ground measurements) with radar backscattering values.
(2) Parameterization of the soil roughness and canopy status and examination of their influence on radar backscatter.
(3) Retrieval of soil water values from SAR data.
(4) Incorporation of regionalised soil water values into ecological models for water fluxes.

Experiment Plan:
Field experiments during the satellite passes give ground truth values for the soil water content, the surface roughness and the canopy. These and other soil parameters like the soil bulk density, the matrice potential, the unsaturated water conductivity and the pore volume will be examined in respect of their contribution to backscattering. Static and variable parameters are to be regarded separately. The regionalised soil water content is important as an additional parameter about near surface soil water measurements with tensiometers, which are employed as initial values for ecological water flux models.
Proposed investigation areas are those at Uelzen, Salzgitter, Schorfheide-Chorin and Dedelow.

ERS-1 Data Requirements:
Multi-date SAR data of one of the proposed investigation areas acquired in the Commissioning Phase and/or in the 35 day repeat cycle, preferably during the harvest season.

Facilities to be Deployed:
Time Domain Reflectometer for soil water measurements, and instruments for surface roughness measurement.

Anticipated Results:
(1) Increased understanding of the contribution of the soil water content, the surface rougness and canopy parameters to the backscattering coefficient.
(2) Inflence of variable and static parameters on the backscattering.
(3) Large area regionalisation of soil water content.

Milestones/Deliverables:
ERS-1 workshop/conference abstracts.
Scientific papers.

Coordinator: Nithack

F1

USE OF ERS-1 WIND SCATTEROMETER OVER LAND SURFACES: ANALYSIS OF THE SPATIAL DISTRIBUTION OF RAINFALL EVENTS THROUGH THE CHARACTERISATION OF THE HYDRIC STATE OF SOIL AND VEGETATION IN SUB TROPICAL WESTERN AFRICA

Principal Investigator:
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Co-Investigators:
J.Lagouarde/B.Seguin (INRA, Montfavet, France), J.Imbernon (IRAT, Montpellier, France), O.Taconet/Vidal-Madjar (CRPE, Issy Les Moulineaux, France).

Objectives:
The aim of this experiment is to test the possible use of the ERS-1 Wind Scatterometer over land surfaces for the determination of soil moisture and soil roughness.

Experiment Plan:
The experiment relies upon the characteristics of the sensor (namely C-band, 2 antenna, data acquisition every 3 days). This configuration will allow the determination of 3 sigma nought triplets for every pixel corresponding to 2 different angles. The slope and intercept of the line sigma nought vs angle are related to the surface roughness and moisture as well as to the vegetation cover. A relatively high acquisition frequency should allow the influence of vegetation to be taken into account and to monitor rainfall events through the changes in soil moisture.
The methodology will consist in studying the evolution of the slope and intercept of the sigme nought vs angle line over different points in West Africa. The results will be compared to data collected by the ATSR as well as to climatological data (AGRHYMET Network) and to the output of hydric budget models. Whenever possible, data from METROSAT, NOAA/AVHRR, MOS-1 will also be used. They will allow quantification of vegetation, surface temperature evolution and cloud cover as well as allow the study of possible synergisms.
If the method proves to be accuracte enough, the results will be extended to the whole area seen by the sensor.

ERS-1 Data Requirements:
The study area is located in West Africa, in the Sudano Sahelian area (lat 20°W to 5°E; long 5°N to 20°N). The main test site is proposed to be located in Niamey (Niger) and in an area 40km north of Niamey (Danguey Gourou 13°50'N 2°5'E). Other test sites will be considered in Burkina Faso and Mali.
All ATSR and Wind Scatterometer data covering the study area over the rainy season (May-Oct) are requested. The AMI Wind Scatterometer data should be in the form of fully calibrated and geometrically corrected sigma nought triplets, with indication of the corresponding viewing angles for each. If possible, the ATSR data should be geometrically corrected and fully calibrated, and if available, corrected for atmospheric effects.
The study period will be the first rainy season (May-Oct) after launch. It would be useful to have an acquisition frequency of 3 days, especially at the start of the rainy season.

Anticipated Results:
Main results will be in the form of algorithms and rainfall/soil moisture maps.

Milestones/Deliverables:
Pre-Launch
June-Nov89 Field experiment in Niger.
Nov89-March90 Data analysis, processing of remotely sensed data.
Post-Launch
1st rainy season Acquisition of ERS-1 data; collection of ground data and satellite data from other sources.
After the rainy season Algorithm development, data analysis, publication of results.

Coordinator: Sieber

F12

EXTRACTION DES PARAMETERS DE SURFACE TEMPÉRATURE ET ÉMISSIVITÉ SPECTRAL ET ANGULAIRE, DES SOLS Á PARTIR DES DONNÉES ATSR DANS L'INFRAROUGE THERMIQUE.

Principal Investigator:
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Co-Investigators:
F.Becker (Professor of Physics, ENSPS), M.Raffy (Professor of Mathematics, ENSAIS).

Objectives:
(1) To investigate the possibility of extracting surface parameters, temperature and emittance from the multispectral and double angle data obtained by ATSR over continental areas.
(2) To develop methods and algorithms for satellite data processing, and develop fieldwork in order to validate the procedure.
(3) To investigate the possibility of an efficient temperature/ emittance decorrelation technique for further analysis of land surface parameters and temperature monitoring.

Experiment Plan:
ATSR has been designed for accurate SST measurements. If the ATSR is to be used successfully over land surfaces, as AVHRR has been, there are a number of important areas of concern. Firstly, the conical scanning geometry in new and needs to be carefully studied. Secondly, but of a more fundamental nature, are the problems related to the surface parameters: variability and high dynamic range of the surface temperature, and insufficient knowledge of the radiative behaviour of land surfaces. Third, the perturbations introduced by the atmsophere are not independent of the surface parameters because of the reflection of the downward atmospheric radiation.
There are 3 main components to the work plan:
(1) Thermal infrared radiometry and field campaign: 2 aspects will be given particular attention (a) spatial variability of the spectral emissivity and (b) angular variation of the emissivity of land surfaces.
(2) Atmospheric correction: regression methods developed for AVHRR data will be adapted to the characteristics of ATSR and to the particular area of interest.
(3) Decorrelation between emissivity-temperature and scaling problems: new methods for emissivity/ temperature decorrelation have been developed for aircraft and AVHRR data. The same procedure will be applied to ATSR data.
Test areas
For validation studies: Albacete in Spain; For complementary local studies: La Crau, southern France; For thematic studies: Niger sites at Niamey and Tahoua(Ibecetene).

ERS-1 Data Requirements:
ATSR data covering the test areas. Full resolution (1km x 1km), 3 channels (3.7μm, 11μm, 12μm) day/night.

Anticipated Results:
(1) Field radiometry: Local measurements of emissivity (spectral and angular variation). Spatial variability of emissivity, surface temperature, brightness temperature. Atmospheric downward radiation at ground level.
(2) atmospheric corrections: Algotithms for surface parameter retrieval.
(3) Emissivity-temperature decorrelation: Mapping of surface parameters at regional scale. Mapping of surface temperature for thematic analysis.

Milestones/Deliverables:

1990	Theoretical studies for atmospheric correction.
	Preliminary field campaign and selection of specific test sites.
1991	Main field campaignin Spain (May/June). Analysis of aircraft and satellite data.
1992	Complementary field campaign in Spain for control and validation. Field campaign in Niger.

Coordination: Gombeer

F22

UTILISATION DU RADAR A OUVERTURE SYNTHETIQUE DE ERS-1 POUR LE SUIVI DES BILANS HYDRIQUE ET HYDROLOGIQUE

Principal Investigator:
G.Guyot Station de Bioclimatologie, INRA, B.P.91, Montfavet, France

Objectives:
A l'intérieur de ce projet deus thèmes complémentaires seront abordés. Ils corresponent à deux états hydriques différents des sols: sols saturés et sols non saturés.
(1) Calage et validation de modèles de bilans hydrologiques de bassins versants à l'échelle agricole.
(2) Estimation et cartgraphie de l'humidité volumique de surface d'un sol.
Le premier thème sera complété par une étude agronomique destinée à déterminer l'impact de la sursaturation des sols en période hivernale sur la phase d'implantation des céréales.

Experiment Plan:
Le site expérimental
Le site expérimental initialement prévu en Beauce a été déplacé à l'ouest en fonction des informations obtenir sur les orbites de ERS-1. La zone d'expérience est ainsi située en bordure de la côte atlantique, au nord de la latitude de La Rochelle.
Calage et validation de modèles de bilans hydrologiques de bassins versants à l'échelle agricole
Une première phase du travail consistera à caractériser l'état hydrique du bassin versant en confrontant des mesures effectuées à 3 échelles différentes: a). des mesures locales an sol, b). des mesures aéroportées selon des axes (diffusiomètre ERASME du CRPE et radiothermomètre), c). des mesures satellitaires (ERS-1, AVHRR, METOSAT). Une seconde phase consistera à tester différents modèles hydrologiques plus ou moins complexes. Certains d'entre eux ont été modifiés afin d'y inclure une information sur l'état hydrique du bassin versant.
Estimation et cartgraphie de l'humidité volumique de surface d'un sol.
L'étude se fera sur un nombre limité de parcellas tests d'environ 10 ha. Les critères de choix seront établis de manière à privilégier les effets de la rugosité et de la texture. Une analyse sur la variabilité spatiale de la teneur en eau de surface de chaque parcelle devrait permettre d'établir un protocole d'échantillonnage au sol.
A chaque passage du satellite, des mesures d'humidité au sol seront effectuées sur chaque parcelles. Ces mesures seront ensuite confrontées aux données satellitaires et devraient permettre d'établir les relations: himidité de surface = f (sigma nought, rugosité, texture) ainsi que la précision que l'on peut en attendre.
En appliquant ces relations aux cartes de sigma nought et en las superposant aux cartes d'occupation des sol et pédologique, on peut obtenir une cartographie de l'himidité de surface. Il est prévu de procéder à quelques contrôles sur des parcelles différentes des parcelles tests afin d'estimer la qualité des cartes produites.

Coordinator: Sieber

I3

MODELLING MICROWAVE/SOIL INTERACTION FOR INTERPRETATION OF SAR DATA IN THE ITALIAN OROGRAPHIC AND CLIMATIC CONDITIONS

Principal Investigator:
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Tel: 39 55 4378512 Fax: 39 55 430893

Co-Investigators:
R.Cassinis (Inst. of Geophysics, Univ. of Milan), D.Solimini (Dept. of Electronics, Tor Vergata University, Rome), S.Paloscia (as PI)

Objectives:
(1) The study of SAR contributions to the measurement of certain geophysical parameters, such as the soil moisture, roughness, vegetation indices and snow cover, which influence the radar backscattering and are of fundamental interest in geophysical applications.
(2) To evaluate the possibility of separating and measuring these parameters on a spatial and dynamic scale which is appropriate for the Italian orographic and climatic conditions.

Experiment Plan:
(1) Physical and statistical scattering models, developed to relate some basic geophysical parameters to SAR data, will be implemented in order to obtain suitable specifications (accuracy, dynamic range, resolution) for hydrologic applications in Italy.
(2) Backscattering values of homogeneous zones will be estimated by the analysis of multi-temporal SAR images and compared with ground truth data and model predictions.
(3) Simultaneous measurements of emissivity carried out by means of an airborne Multiband Microwave Sensor Package (MMSP) will be collected to test theoretical relationships between emissivity and backscattering, and to study the contribution of radiometry in radar calibration.

ERS-1 Data Requirements:
Multi-temporal SAR images of one scene in both Central and Northern Italy acquired with the 35 day repeat cycle at 23° or 35° incidence angle (at least 3 observational periods in different seasons).
SAR FDPs as well as geometrically and radiometrically corrected SAR images are requested.

Facilities to be Deployed:
Helicopter-based passive microwave sensors, and instruments for ground truth measurement of soil moisture, roughness and vegetation parameters.

Anticipated Results:
(1) A better knowledge of the relative contribution of volume and surface backscattering to the total backscattered energy from natural surfaces (soil/vegetation/snow).
(2) A contribution for the extraction of geophysical parameters within a margin of error acceptable for hydrologic applications.
(3) It is expected to develop a capability for discrimination of 3-4 levels of soil moisture on bare soil, 2-3 levels of roughness and 2 states of snow (wet/dry).

Milestones/Deliverables:

1991	Detailed planning of the experiments, simulations and preliminary test of the models.
1991-92	Experiments with ground truth campaigns and airborne sensors. validation of models. Evaluation of the results.

Status reports and scientific papers.

Coordinator: Nithack

IND1-1a

MAPPING AND ESTIMATION OF SOIL MOISTURE IN DRYLAND FARMING AREAS

Principal Investigator:
L.Venkataratnam NRSA, Hyderabad, India

Co-Investigators:
R.S.Dwivedi/ B.R.M.Rao/ T.Ravi Shanker/ S.S.Thammappa/ N.Bhagat (as above)

Objectives:
To detect soil moisture in dryland farming areas and to map it.

Experiment Plan:
For different land cover types identified from Landsat/SPOT/IRS data, ground measurements of soil moisture will be made using dielectric probes and gravimetric analysis. This will be correlated to SAR images using visible and digital techniques. Soil mapping over larger areas will be attempted.
Test area: 16°20' - 17°10'N, 81°25' - 82°15'E.

ERS-1 Data Requirements:
SAR images (UI 16) and photographic products.
May-Jul 91 - Once every 6 days, total 15 scenes.
Aug-Dec 91 - Once every 35 days for 2 sites (Godavari Delta and Hyderabad area), total 10 scenes.
Jan-Mar 92 - Once every 6 days, total 15 scenes.
Apr-Dec 92 - Once every 35 days for the 2 sites, total 18 scenes.

Anticipated Results:
(1) A methodolgy for soil moisture estimation from SAR data.
(2) Relationships between soil moisture measurements from SAR under different soil parameters such as soil type, surface roughness, soil depth, topography, etc.

Coordinator: Ninan

IND1-1b

MAPPING AND ESTIMATION OF SOIL MOISTURE IN DRYLAND FARMING AREAS

Principal Investigator:
S.Mohan, SAC, Ahmedabad, India

Co-Investigators:
R.L.Mehta/ P.Patel (as above)

Objectives:
(1) To conceptualise and develop a soil moisture retreival algorithm for dryland farming and irrigated areas.
(2) To estimate the sub-surface soil moisture by modelling.
(3) To analyse the suitability of 1dB and 2.5dB radiometric resolution data for soil moisture detection.

Experiment Plan:
SAR images will be calibrated to provide backscattering coefficients, and these will be related to ground values of soil moisture. Using the 3 day repeat cycle, changes in soil moisture will be analysed, assuming that other soil parameters remain the same. Using 100m spatial resolution and 1dB radiometric resolution, the relative importance will be assessed regarding spatial and radiometric resolution. Physical modelling will be attempted for sub-surface soil moisture estimation.

Test areas:	1. 27° - 28°N, 77°30' - 78°30'E.
	2. 27°40' - 28°40'N, 76°30' - 77°30'E.
	3. 22°15' - 23°15'N, 72° - 73°E.

ERS-1 Data Requirements:
SAR.UI16, SAR.PRI, photographic products for all sites.
Also, 1dB radiometric resolution image data over test sites 2 and 3 once each during May 92 and May 93.

May-Jul 91:	Area 1 - 2 times a month with 3 day repeat.
Aug-Dec 91:	Areas 2 & 3 - Once every month.
Jan-Mar 92:	Area 2 - 3 times a month with 3 day repeat.
Apr 92 - Dec 93:	Areas 2 & 3 - Once every month.
Jan-Mar 94:	Area 2 - 3 times a month with 3 day repeat.
Apr- 94 - Mar 95:	Areas 2 & 3 - Once in Apr, Sep, Dec 94 and Mar 95.

Milestones/Deliverables:
(1) Reports on ground based experiments and the use of SAR.
(2) A status note on methodology.
(3) Final report.

Coordinator: Ninan

J2

REMOTE SENSING OF RICE CROPS AND VEGETATION PENETRATION MEASUREMENTS BY ERS-1 SAR.

Principal Investigator:
M.Fujita Communications Research Laboratory, 4-2-1 Nukuititamachi, Koganei, Yokyo

Co-Investigators:
M Satake, T Kurosu

Objectives:
(1) To investigate the feasibility of rice crop remote sening with a C-band space SAR and of crop classification.
(2) To evaluate C-band microwave penetration into a vegetation canopy.

Experiment Plan:
Quantify backscattering intensity from rice fields using corner reflectors and active radar calibrators, and relate to crop conditions. Compare image intensities of standard targets inside and outside of a vegetation canopy.

ERS-1 Data Requirements:
SAR image (engineering products) covering the study area, which includes farm land at Ohgata Mura (40°00'N, 140°00'E) and the disused Akita Airport (39°42'N, 140°05'E). (Reserve study area :Kashima area - 35°57'N, 140°40'E). Data acquisition interval of approximately 2 weeks is preferable (i.e. as possible using 35day repeat cycle).

Facilities to be Deployed:
Square trihedral corner reflectors, active radar calibrators, ground based L,C and X-band scatterometer.

Milestones/Deliverables:
Active radar calibrators will be developed by early 1990.
Scatterometer measurements of rice crops will be made simultaneously with SAR observations during the growing season of rice crops, which is mainly June-Oct.

Coordination: Fujita

UK8

UTILISATION OF ERS-1 SAR IMAGERY FOR AGRICULTURE APPLICATIONS

Principal Investigator:
N.Veck Marconi Research Centre, GEC Research Ltd., West Hanningfield Road, Great Baddow, Chelmsford, Essex

Co-Investigators:
A.J.Rye/ G.Auker (as above), S.Quegan (Sheffield University), Ms.A.Wielogorski (Hunting Technical Services), G.Holmes (Cambridge University).

Objectives:
(1) Crop identification and classification.
(2) Crop monitoring (stat, disease,age).
(3) Crop yield forecasting.

Experiment Plan:
The work undertaken during the ERS-1 campaign will asses how the multi-temporal aspect of the data can be employed to help achieve the long term objectives.
The project will require development and testing of image processing software in order to interpret the multi-temporal data.
The development of backscatter models will aid information extraction from the ERS-1 data. Numerous types of model have been developed, these include empirical, semi-theoretical and theoretical models.
The results of using crop classification routines using SAR will be assesed against those obtained using optical imagery.

ERS-1 Data Requirements:
SAR data for the Feltwell/Thetford site is required for the study. However, if ERS-1 mission considerations make this unsuitable, any SAR data covering agricultural/forestry areas of the East Anglia region, UK, will be requested as an alternative.
All possible images of the test site from April to September for at least 2 consecutive growing seasons are required.

Facilities to be Deployed:
(1) Ground based C-band scatterometer.
(2) Agricultural ground data collection team, including a) dielectric measurements, b) crop, soil moisture measurements, and c) crop, soil geometry etc.
(3) Corner reflector targets and possibly a C-band transponder.

Anticipated Results:
Depending on the success of the study to assess crop types and states from the ERS-1 SAR data it is the aim of MRC to present examples of how SAR data may be used in the future to produce land use maps.

Coordinator: Gombeer

UK13

CHANGE DETECTION APPLIED TO THE ESTIMATION OF THE YIELD OF CEREALS

Principal Investigator:
S.Quegan Department of Applied and Computational Mathematics, University of Sheffield, Sheffield, UK

Co-Investigators:
G.Foody/ P.Curran (University of Swansea).

Objectives:
(1) Use of ERS-1 data for land cover mapping and differentiation of cereal crops.
(2) Modelling the relation between backscatter and cereal biomass.
(3) Assessing relevance of the model to harvest yield predictions.

Experiment Plan:
(1) Accuracy analysis of extracted RCS measurements, and its impact on classification using SAR data alone or in combination with other sensors.
(2) Data gathering guided by model restraints.
(3) Empirical and physical modelling of observations to extract biomass (training and control groups used).
(4) Testing of predictions.

ERS-1 Data Requirements:
All available SAR images of the Feltwell, UK test site during the main growing season (March to August) over both years of operation of the satellite (more if the satellite lifetime is extended). Minimum revisit time is 2 weeks.

Anticipated Results:
(1) Rigorous assessment of the basis and methods for deriving time-series of RCS values of cereal fields from ERS-1 data, including statistical significance and standard error of measurements.
(2) Application of such time-series to modelling backscatter and yield.
(3) Development and assesment of map and multi-sensor image matching techniques.
(4) Assessment of possible classification accuracies using SAR alone and in combination with other sensors.

Milestones/Deliverables:
Precise schedule depends on launch data, its relation to the growing period, and lag times in SAR data reception. A large part of the growing season in each year will be taken up with data-gathering and laboratory analysis. Data analysis will be undertaken mainly over the autumn and winter periods. Deliverables (in the form of reports) will be every 6 months of each year, probably in November (ground data results) and April (SAR analysis results). There will be a final report produced mid-way through 1993.

Coordination: Gombeer

US10

MEASUREMENT OF SPACEBORNE RADAR SIGNAL PENETRATION IN NATURAL SURFACES AND COVER

Principal Investigator:
T.G.Farr JPL, 4800 Oak Grove Drive, Pasadena, CA Tel: 818 3549057

Co-Investigators:
C.Elachi/ J van Zyl/ S.Wall (JPL), P.Hartl (Institute for Navigation, University of Stuttgart), J.Nithack (DLR), G.Schaber (USGS, Flagstaff)

Objectives:
To measure C-band microwave penetration in a variety of natural surfaces in order to better understand the physics of microwave interaction with natural volumes and to support the quantitative interpretation of ERS-1 image data.

Experiment Plan:
It is planned to use compact self-contained receivers and transponders deployed at varying depths within the volumes. Areas of interest will include arid regions (north Africa, southwest US), vegetation covered regions (Black Forest) and permafrost regions (Alaska).

ERS-1 Data Requirements:
Most of the data for the proposed research will be acquired directly by the receivers. Therefore, the main requirement on ERS-1 is that the SAR be transmitting at specific times to illuminate the sites of interest. A limited number of full-resolution SAR images will be required in order to map buried features, make use of the active transponders, and as ancillary data to assist in location of receivers relative to beam centre and to assess the uniformity of target conditions. Coverage of the sites in several seasons will be required.

Facilities to be Deployed:
The receivers have been designed to be compact and rugged enough for field use (built by Institute of Navigation, University of Stuttgart).

Anticipated Results:
It is expected to obtain measurements of C-band microwave attenuation in soils as a function of soil moisture and structure, in vegetation as a function of type and density, and in permafrost as a function of season. These data will then be used as input to existing microwave interaction models to improve quantitative interpretation of ERS-1 SAR images.

Coordinator: Weller

VIII Hydrology

A1

SNOW AND ICE PROPERTIES BY AMI SAR DATA

Principal Investigator:
H.Rott — Institute of Meteorology and Geophysics, University of Innsbruck, Innrain 52, Innsbruck

Objectives:

(1) To determine the capabilities of spaceborne C-band SAR for the detection of physical and morphological properties of the snow cover and of glaciers.
(2) To study the use of multitemporal SAR data and to develop suitable algorithms for change detection regarding snow cover and glaciers.
(3) To develop and test radargrammetric methods for SAR data analysis and for generation of thematic products for mountain regions and for glacier areas.

Experiment Plan:

For the extraction of physical properties of snow and ice from SAR data it is necessary to achieve high radiometric accuracy by averaging over sufficiently large homogeneous areas. For this reason a glacier plateau with the side length of 4km in the Alps at Ötztal, Austria, has been selected as the main test area. A research station of the University of Innsbruck is located at Ötztal and it is planned to carry out detailed in situ measurements over one full summer season. Backscatter and emission properties of the firn area in C-band and X-band will be measured from a tower; dielectrical and textural properties of the snow cover and glacier ice will be measured at various locations of the test site. Radargrammetric investigations are planned for the Ötztal test site and for the test site at Hofsjokull in Iceland. For the Iceland test site radargrammetric studies have previously been carried out using Seasat data. The work will include the development and testing of geocoding algorithms for complex terrain and for the generation of multi-temporal data sets. Multi-sensor data sets based on SAR and high resolution optical data will also be generated and analysed.
The capabilities of spaceborne SAR for accurate mapping of glacier boundaries, of accumulation/ablation areas, of the seasonal snow cover, and of features of glacial morphology will be studied. The final goal is the development of optimum procedures for the extraction of thematic information from SAR and for the integration of the products in geo-coded information systems.

ERS-1 Data Requirements:

SAR: every 16 days from June to October, with day/night coverage of the Ötztal area desirable for one season.

Facilities to be Deployed:

Field equipment for measurement of dielectric properties, snow and ice parameters, C/X-band backscattering and emission signatures.
Corner reflectors.

Coordinator: Rott

A2

ACTIVE MICROWAVE SIGNATURES OF THE POLAR ICE SHEETS BASED ON ERS-1 AMI WIND SCATTEROMETER DATA

Principal Investigator:
H.Rott Institute of Meteorology and Geophysics, University of Innsbruck, Innrain 52, Innsbruck

Objectives:

(1) Mapping of the backscatter properties of Antartica and Greenland for studies of physical snow and ice parameters, of snow accumulation rates, and of melting features.
(2) Comparison of ice sheet properties derived by AMI wind mode data with AMI SAR data and in situ measurements over limited areas.
(3) Support of sensor calibration.

Experiment Plan:

As expected from theory, clear differences in backscattering wil be observed between melting and dry snow zones so that the extent of summer melt areas can be mapped. In dry snow, because of the deep penetration, the backscattering data will provide information on the physical properties of the snow volume. This information will be of value for the radar altimeter studies and for the analysis of accumulation rates which are a key element for the dynamics of the ice sheets. The analysis of the scatterometer data will be carried out for Antarctica and Greenland.
The permanently dry parts of the ice sheets hold great potential for external calibration of active microwave sensors. As concluded from the study of passive microwave data, it is expected that the backscattering coefficient is very stable in time in these areas. The Ronne/Filchner ice shelf in Antarctica, which shows no surface melt and is very flat and homogeneous, is proposed as an external target for monitoring of sensor stability. Because of this homogeneity, this area will also be suitable for comparing AMI wind mode and SAR mode. For calibration purposes it is necessary to get the wind mode data of the test site with high temporal frequency.
The information content of AMI data at high and low spatial resolutions (SAR mode and wind mode) will be assessed over the ERS-1 test area south of the German Antarctic station covering a wide range of snow and ice types as well as ice-free mountains. Detailed in situ measurements are planned in this area for comparison.

ERS-1 Data Requirements:

Complete AMI wind mode coverage of Antarctica and Greenland in different seasons (at least winter and summer)
AMI wind mode and SAR data for Filchner/Ronne ice shelf, and Ekström ice shelf/Ritscher Upland (once a month for wind mode, and 4 SAR scenes per year).

Facilities to be Deployed:

Field equipment for measurement of dielectric properties, snow and ice parameters, C/X-band backscattering.

Coordinator: Rott

CH2

ERS-1 AMI DATA FOR SNOW COVER ESTIMATION AND RUN-OFF FORECASTING

Principal Investigator:
H.Häefner   Remote Sensing Laboratories, Department of Geography, University of Zürich, Winterthurerstrasse 190, Zurich

Co-Investigators:
Scientists at six Swiss Research Institutes.

Objectives:
The main purpose of the experiment is a careful investigation of the potential of ERS-1 AMI data to improve the accuracy and forecasting precision of an already functioning operational snowmelt run-off model. During the period of April/May when run-off rates are highest in the Alps, the cloud cover problem is particularly severe. Both scientific validation and application oriented objectives are being addressed.

Experiment Plan:
The main test area, the "Rhein-Felsberg" basin, where the run-off model is already implemented, is located in the eastern part of the Swiss Alps and has a size of 3249 km^2. In addition the prealpine "Thur River" basin is also subject to hydrological research programs including snow cover accumulation and meltwater run-off studies.
Scientific validation includes the testing of the feasibility of the AMI data to retrieve snow cover parameters, especially the area covered by wet snow. Both SAR and the wind scaterometer (with optimised spatial resolution) are to be tested.
Application validation will examine the possibility to improve the snowmelt run-off forecasting by implementating snow cover information from the AMI data into existing operational systems in near real time under the boundary conditions of the actual flight and management conditions of ERS-1.
The experiment is well coordinated with other European projects on the same topic to get a full understanding of ERS-1 applications for snow hydrology with special reference to the Alps, and it combines all major Swiss institutions active in snow hydrology, run-off forecast modelling and/or remote sensing.

ERS-1 Data Requirements:
SAR: day/night, every 16 days, near real time.
AMI wind mode: Experimental, large area coverage.

Facilities to be Deployed:
Field equipment for dielectric measurements, snow parameters and soil properties. Also, multi-frequency microwave scatterometer/radiometer 2-12 GHz.

Coordinator: Rott

SF2

APPLICATION OF ERS-1 ACTIVE MICROWAVE INSTRUMENTATION DATA TO REMOTE SENSING OF SNOW

Principal Investigator:
M.T.Hallikainen — Laboratory of Space Technology, Helsinki University of Technology, Otakaari 5, Espoo, Finland

Co-Investigators:
B.Goodison (Atm. Env. Can.).

Objectives:
To evaluate the feasibility of ERS-1 Active Microwave Instrumentation (AMI) to remote sensing of snow cover. Snow cover extent, snow water equivalent, snow depth, snow liquid water content and snow surface properties are all of special interest. The four main aspects of the investigation are:
(1) Use of test sites with different land cover categories (one in Finland, others in US/Canada).
(2) Use of several different instruments (active and passive microwave, gammaray) for airborne measurements at the two test sites during two winters.
(3) Use of additional satellite data.
(4) Extensive field measurements at the test sites.

Experiment Plan:
The main land cover at the Finnish test site is sparse coniferous forest with open areas (bogs, clear-cut areas, and tundra). US/Canadian test sites are located in different climatic regions from the Praries to the Arctic region.
The airborne measurements will be carried out as underflights at the time of ERS-1 passes. Well documented transect lines are being surveyed as well as imaging large areas with SLAR/SAR.

ERS-1 Data Requirements:
SAR: one image per week per region.
AMI wind mode: experimental

Facilities to be Deployed:
Field equipment for dielectric measurements and snow parameters. Scatterometer and microwave radiometer.
Helicopter (Finland) with 5/10 GHz scatterometer, 5/35 GHz radar polarimeter and 6 frequency MW radiometer.
9.5 GHz SLAR (Finland)
SAR 580 (Canada)

Coordinator: Rott

UK7

ERS-1 HYDROLOGY AND WATER MANAGEMENT

Principal Investigator:
K.Blyth Institute of Hydrology, Maclean Building, Wallingford, OXON, UK

Co-Investigators:
E.C.Barret (Bristol Remote Sensing Unit), J.W,Finch/ C.J.Holwill/ J.B.Stewart/ J.S.Wallace (Institute of Hydrology)

Objectives:
(1) To test the ability of the ERS-1 SAR to monitor soil moisture, snow and river flooding under changing ground conditions.
(2) To develop methods of incorporating SAR data into existing hydrological models and forecasting procedures to improve their performance.
(3) To test and improve the methodology of hydrological ground data collection over large areas for satellite SAR validation.

Experiment Plan:
SOIL MOISTURE:: Flat grassland sites will be used as the most seasonally stable reference surface within which soil moisture will be either measured directly with neutron or dielectric probes or calculated using water balance models and local meteorological measurements. Sites representing the major soil groupings will be selected with reference to : a) the quality of available soil moisture data, and b) their ease of identification on SEASAT and LANDSAT data as areas of permanent pasture. The sites will be monitored over at least one annual cycle of wetting and drying and any changes in surface roughness and vegetation state will be monitored. Mean backscatter values for homogeneous grassland areas under changing soil moisture conditions will be extracted from the SAR data. These data will be compared with ground validation measurements and also with predicted soil moisture values from a number of hydrological models. After calibration of the SAR data over arange of soil moisture conditions, grassland sites will be used on both a catchment and regional scale to gain better understanding on soil moisture distribution.
SNOW: For a number of test sites in the Scottish Highlands, a range of ground data (including spectro-radiometric measurements) relating to snow parameters (e.g. depth, water equivalent) will be collected at the overpass time of ERS-1. The ground information, together with NOAA AVHRR and, if possible, Landsat TM imagery, will subsequently be compared with ERS-1 SAR data. The potential for the definition of snow conditions will then be assessed, and calibration of SAR data to specific parameters attempted. High quality digital terrain data will also be employed to explore the influence of terrain on microwave signatures, and the importance of vegetation and other surface types will be investigated. The results will be used to formulate standard techniques for snow monitoring using ERS-1 SAR imagery alone or in combination with AVHRR data. Similar techniques will be employed in a lowland area where the snow pack is likely to be shallower and wetter and where snow distribution is less affected by altitude.
RIVER FLOODING: The ability of the ERS-1 SAR to delineate the extent of floodwater will be tested against ground observations and low level aerial photography taken co-incidentally with satellite overpasses.

Facilities to be Deployed:
(1) Soil moisture measurement - neutron probes, capacitance probes, tensiometers, volumetric sampling equipment, soil analysis equipment, evaporation equipment, meteorological stations.
(2) Snow measurement - lysimeters, heated raingauges, snow corers and samplers, meterological equipment.
(3) Aerial photography - light aircraft modification to provide 35mm vertical photography in up to 4 wavebands plus continuous CCTV monitoring.

Milestones/Deliverables:
Largely dependent on SAR duty cycle. Peak activity period for ground data collection probably March 1992 - March 1993.

Coordinator: Gombeer

US1-6a

RIVER AND COASTAL PROCESSES AND GEOMORPHOLOGY

Principal Investigator:
L.W.Gatto — USACRREL, 72 Lyme Road, Hanover, NH 03755-1290
Tel: 603 6464273

Co-Investigators:
E.Chacho/ D.Calkins/ D.Lawson/ R.Mellor (CRREL), D.Carter (USGS)

Objectives:

(1) Monitor glacial sedimentation processes and river, estuarine and coastal ice processes and conditions.
(2) Map and analyse changes in fluvial, coastal and glacial geomorphic features during the ERS-1 mission.

Experiment Plan:

The SAR imagery will be analysed and compared with results from ground studies and from analyses of other remotely sensed data currently underway. Since the processes to be studied are highly seasonal, key periods throughout the year will be chosen to quantify their seasonal variability. The data produced will serve as a base against which future changes can be compared.
Other satellite imagery, including Landsat TM, NOAA-AVHRR, DMSP, aerial photography and microwave imagery will be used to correlate SAR image features with surface conditions. Analysis of the specific geophysical characteristics that produce variations in SAR images will be the major thrust of the project. Extensive ground studies will be necessary to adequately accomplish this.

ERS-1 Data Requirements:

SAR data with weekly repeats in February, March, May, July, August and November.

Anticipated Results:

A better quantification of high-latitude, geomorphic processes resulting from interactions of weather, land, river and coastal sea ice processes. Maps delineating coastal geomorphology, sediment patterns and coastal ice formation, distribution and movement. A data set that can be used for improving current models for predicting glacial river bed changes. Improved understanding of arctic estuarine ice growth and transport processes. A data base for developing models relating glacier movements and geomorphic and sedimentary processes.

Milestones/Deliverables:

Annual fieldwork and related data collection.
Anually technical papers and end-of-year report.
Bi-annual project reports.
Final project report.

Coordinator: Weller

US1-6d

SURFACE HYDROLOGY AND ENERGY BUDGET ON THE NORTH SLOPE, ALASKA

Principal Investigator:
G.Wendler/ D.Kane   Geophysical Institute, University of Alaska, Fairbanks, Alaska 99775-0800/ Civil Engineering Department, University of Alaska.
Tel: 907 4747378/7808

Objectives:
To obtain a better understanding of the hydrology and surface energy budget of the North Slope. More specifically, SAR data will supply information on the characteristics of the snow cover, including its wetness during break-up, and possibly its liquid water content, the appearance, development and possibly the depth of the active layer throughout the summer season (the maximum depth is 30-40 cm in late summer) and the state of soil moisture within the active layer.

Experiment Plan:
Field data are presently collected at 3 places north of the Brooks Range: Toolik Lake in the foothills, one intermediate station, and Franklin Bluff in the tundra. Hydrological data including snow cover, depth of active layer and soil moisture as well as radiative and meteorological data are available for these 3 points and will be compared with the satellite data.

ERS-1 Data Requirements:
SAR data.
3 day repeat during maximum snow cover period in April.
3 day repeat during melt in May.
Several passes during the summer (June - August) to determine the penetration of the active layer.
Several passes during the freezing of the active layer (fall).
At least 1 scene during Midwinter.

Anticipated Results:
A better understanding of the hydrological cycle and the surface energy budget will be obtained. The satellite data will be especially helpful in extending point measurements over larger areas on the North Slope of Alaska, and in similar terrains where few measurements are made on the ground.

Milestones/Deliverables:
Annual reports and published papers.

Coordinator: Weller

US1-6e

USE OF ERS-1 SAR DATA FOR DETERMINING ARCTIC SURFACE WATER DEPTHS

Principal Investigator:
J.C.Mellor Bureau of Land Management, 1150 University Avenue, Fairbanks, AK 99709
Tel: 907 4742378

Objectives:

(1) Compare the use of ERS-1 SAR with airborne SLAR used to determine Alaskan Arctic Lake Depths.
(2) Determine the utility of ERS-1 SAR data to expand its use in the Canadian Archipelago and Siberian Arctic for regional surface water depth interpretation.

Experiment Plan:

SLAR has been useful in determining ice thickness and lake depths in Northern Alaska, based on changes in the intensity of SLAR signal returns from the zone in which ice cover contacts the lake bottom. This intensity is a function of physical and dielectric properties of the snow, ice, water, bottom substrates, and ice inclusions within these lakes. To study this further, it is proposed to:
(1) Obtain sequential SAR coverage of the Alaskan North Slope at monthly intervals from September 1990 through August 1991.
(2) Obtain September, December, March and April SAR images over Canadian Archipelago, and Siberian Arctic that span the season of ice formation.
(3) Compare Alaskan SLAR, aerial photographs, and depth determinations with Alaskan SAR. Also compare Alaskan SAR with Canadian/Siberian SAR.

Anticipated Results:

(1) Determine the usefulness of sequential ERS-1 SAR images in refining depths of 21,000 Alaskan lakes interpreted with SLAR data.
(2) Determine the usefulness of sequential SAR images for interpreting ice thickness on other Alaskan North Slope and Yukon/Kuskokwim Delta lakes.
(3) Determine the usefulness of ERS-1 SAR for interpreting surface water depths outside Alaska (Canada and USSR).

Coordinator: Weller

US1-10a

FEASIBILITY OF C-BAND SAR FOR ARCTIC/ALASKA WETLAND STUDIES

Principal Investigator:
J.P.Ormsby NASA/GSFC, Hydrological Sciences Branch
Tel: 303 286 6811

Objectives:
To determine the potential usefulness of C-band radar as a tool to ascertain better wetland extent and vegetation delineation in conjunction with visible, near- and middle-IR data.

Experiment Plan:
The main study area will consist of wetland areas in southern Alaska, with special emphasis on the Cook Inlet near Anchorage. Radar and high resolution visible, near- and middle-IR data will be used to study the temporal and spatial changes of wetland areas. Ground truth information on location of vegetation types, spatial distribution and biomass production will be correlated with visible, near- and middle-IR spectral and microwave responses.
Study area is 100x100km centred on 61°N, 151°W.

ERS-1 Data Requirements:
SAR images. Three day repeat coverage once a month, April - September. One or two images October - March.

Anticipated Results:
Accurate delineation of wetlands and information about the extent and types of vegetation distribution, in addition to a map of vegetation roughness.

Milestones/Deliverables:

Year 1	Data collection and analysis/ Report.
Year 2	Data collection and analysis/ Update of results.
Year 3	Data collection and analysis, including vegetation maps showing the biomass and roughness.

Coordinator: Weller

ERS-1 Hydrology

US1-11

TERRESTRIAL ENVIRONMENTAL CONDITIONS THAT AFFECT RADAR BACKSCATTER

Principal Investigator:

K.G.Dean Geophysical Institute, University of Alaska, Fairbanks, Alaska 99775-0800
Tel: 907 4747364

Co-Investigators:

D.Kane (as above)

Objectives:

(1) To identify terrestrial conditions that modify radar backscatter throughout an annual cycle.
(2) To relate geologic, hydrologic or biologic processes to those condtions that inflence radar signatures.
(3) To quantify how surface phenomena affect the radar signatures.

Experiment Plan:

(1) Initial Reference SAR image - Acquire calibrated, full resolution ERS-1 SAR imagery that covers an area within a 50 mile radius of the Alaskan SAR Facility and the Department of Energy (DOE) long term environmental monitoring site on the Arctic Coastal Plain. These images will be used as a reference for comparison with subsequent SAR images collected throughout an annual cycle.
(2) Targeting of Radar Signatures Modified by Environmental Conditions - Acquire SAR images every few days throughout the annual cycle and compare these images to identify areas where the radar signature has changed.
(3) Analysis of Environmental Conditions that have Modified Radar Signatures - Immediately after the detection of a modified radar signature a team will be sent to the affected area to asses environmental changes that affected the radar signature. The team will consist of experts in arctic hydrology, geology and biology that are familiar with the local environment. In areas where instrumentation is being used to monitor environmental changes the imagery will be compared to recorded field data.

ERS-1 Data Requirements:

SAR data required for 2 sites: one centred on the ASF, Fairbanks, Alaska and the other a swath extending from Toolik Lake to the Beaufort Sea coast on the Arctic Coastal Plain. Imagery at both sites should be collected every 3 days in the first year, especially during criitical periods such as in the spring and fall, and once a week in the second year.

Anticipated Results:

(1) A better understanding of terrestrial, environmental conditions that influence radar signatures.
(2) Evaluation of seasonal factors that influence radar signatures.
(3) Provide a basis to select the optimum time to record specific environmental conditions.

Coordinator: Weller

IX Cartography

AUS4

EVALUATION OF THE USE OF SAR IMAGE DATA IN CONJUNCTION WITH A GEOGRAPHIC INFORMATION SYSTEM FOR MAPPING IN A TROPICAL ENVIRONMENT

Principal Investigator:
N.Divett — Department of Geographic Information, PO Box 40, Woolloongabba, Qld 4102, Australia

Co-Investigators:
R.Priebbenow/ T Danaher (as above).

Objectives:

(1) To investigate the suitability of radar imagery for topographic mapping and map revision.
(2) To analyse the positional accuracy of data produced from SAR imagery.
(3) To investigate data formats appropriate for topographic mapping.
(4) To investigate the incorporation of SAR data with data from other sources through geographic information systems.
(5) To investigate costs and cost effectiveness of SAR data for topographic mapping and map revision.

Experiment Plan:

To develop a methodology for the geometric modelling of SAR imagery. Then, using this model, to rectify the imagery with the aid of a digital terrain model.
Assessment of the geometric properties and information content of the imagery with respect to topographic mapping requirements. Also assessment of the suitability of SAR imagery for the production of ortho-image maps.

ERS-1 Data Requirements:

First preference: Study site bounded by latitudes 16°20'S to 17°30'S and by longitudes 145°10'E to 147°00'E.
Second preference: A tropical coastal land area in Queensland which has forest cover predominantly, but also including some agricultural areas.

Anticipated Results:

An assessment of the characteristics of SAR imagery, as relates to topographic line map production and revision, and image map production. An analysis of the cost effectiveness of SAR imagery for these purposes.

Milestones:

1990	Preparation of software for data processing.
1991	Receipt of data, processing of imagery and assessment of suitability for mapping. Cost benefit analysis.

Coordination: Nilsson

D5

RADARMAP OF GERMANY

Principal Investigator:
R.Winter German Remote Sensing Data Center, DLR, Oberpfaffenhofen, Wessling, Germany

Co-Investigators:
W.Markwitz (DLR), G.Konecny (Institute of Photgrammetry and Engineering Surveys, University of Hannover), H-P.Bähr (Institute of Photogrammetry and Remote Sensing, University of Karlsruhe), H.Schmidt-Falkenberg (Institut für Angewandte Geodäsie, Frankfurt)

Objectives:

(1) Investigations concerned with mosaicing and radiometric correction of the geocoded products of the Processing and Archiving Facility of the German Remote Data Center.
(2) Investigations of the usefulness of C-band SAR data in combination with optical satellite data for small scale topographic and thematic mapping.
(3) Testing SAR data for update of 1:100,000 scale topographic maps.
(4) Evaluation of the texture description of the radar signal.
(5) Regional land use mapping in different seasons.
(6) Land use mapping of Germany in one season.
(7) Image mosaic of Germany.

Experiment Plan:

It is planned to generate a radar map of Germany at the same scale as available Ordnance Survey maps. The first product will be an image mosaic of Germany at a smaller scale. This will be produced as soon as a complete coverage of Germany is archived. A special tool for the operational mosaicing of the different data sets will be developed, including radiometric adjustment and geometric selection from the various scenes.
Land use maps of Germany are planned, using new and special methods for the classification of SAR data.
Mosaics will be combined with different remote sensing and other vector data sets.

ERS-1 Data Requirements:

Complete coverage of Germany during 3 different seasons with the same orbit geometry (approx. 90 scenes per season).
Data from the 35 day cycle.
Additional datasets with the opposite orbit geometry.

Anticipated Results:

(1) 57 map sheets at a scale of 1:200,000 of Germany.
(2) Land use map of Germany.
(3) Large mosaic of the complete area.

Coordinator: Nithack

D11-4

GEOMETRIC CORRECTION OF SAR IMAGE DATA, INCLUDING THE PROCESSING AND ARCHIVING OF A GEOCODED DATABASE

Principal Investigator:
V.Sasse   Institut fuer Photogrammetrie und Ingenieurvermessung, Universitat Hannover

Objectives:
Geometric correction of SAR image data, including the processing and archiving of a geocoded database containing cartographic and land application data. This will include elimination of the radiometric influence of incidence angle.

Experiment Plan:
SEASAT data will be used in an initial phase of the project, using Bonn or Oberpfaffenhofen as the study area. ERS-1 data of the same area will be used. Digital elevation models are already available, with a resolution of 1' inlongitude and latitude.
ERS-1 ephemeris data will be be used for geometric correction, as well as ground control points.
Optical satelite data (TM or SPOT), or aerial photography, will be used for studies in flat areas..

ERS-1 Data Requirements:
SAR images of Bonn or Oberpfaffenhofen areas.

Coordinator: Nithack

E2

DETECTION OF CHANGES USING ERS-1 IMAGES

Principal Investigator:
F.Gonzales Alonso — National Institute of Agronomic Research (INIA), Apartado 8111, 28080 Madrid, Spain
Tel: 207 80 40 x305

Co-Investigators:
R.L.Pomares/ J.M.Cuevas Gozalo/ D.S.Lopez Soria (as above)

Objectives:
The investigation is concerned with the development of a methodology to describe the evolution of a flooding area using a change detection strategy with ERS-1 images.
The results will be compared with those obtained in a parallel investigation carried out with visible-infrared images.
The study area is in the Doñana National Park (36°50' - 37°06' N, 6°16' - 6°33' W).

Experiment Plan:
(1) Delimitation of the study area.
(2) Image selection.
(3) Geographic registration of the images.
(4) Selection of the method of change detection.
(5) Comparison with visible-infrared data.
(6) Cartography and quantification of the flooding level.
(7) Interpretation of results and study of viability of the operational implementation of the methodology.

ERS-1 Data Requirements:
A total of 10 SAR images of the National Park are required; preferably 2 winter, 4 spring, 2 summer and 2 autumn images.

Anticipated Results:
(1) Using the proposed methodology, changes in the Park will be mapped independently of atmospheric conditions.
(2) The feasibility of the operational implementation of the methodology will be evaluated to improve the management of the Park.

Milestones/Deliverables:

Year 1	Acquisition of basic information, image processing and experimentation with methodology.
Year 2	Analysis results and study of the feasibility for operational implementation.

Coordinator: Sieber

UK6

TOPOGRAPHIC MAPPING WITH SAR DATA

Principal Investigator:
I.J.Dowman Dept. of Photogrammetry, University College London, Gower Street, London

Co-Investigators:
P.Muller/ J.Iliffe (as above), A.Sowter (GEC Marconi Research Laboratories)

Objectives:
The aim of the project is to carry out research which will enable SAR data to be used to describe the characteristics of the natural (topographic) and man-made (cultural) features of the surface of the earth in terms of accurate spatial coordinates. The development of such a system will allow geocoding of the SAR data without a separate DEM, it will allow other information about the land surface cover and geology to be represented correctly and will allow mapping and map revision to be carried out from satellite data which is available in all states of cloud cover; it will allow the integration of data from other sources, including satellites and existing map data, with SAR data and it will allow synoptic map coverage of large areas of the earth where no such cover exists at the moment.
The emphasis of the work is to be on the extraction of spatial coordinates of cultural features and of digital elevation models using SAR data and other ERS-1 data by itself or in conjunction with data from optical sensors such as SPOT.

Experiment Plan:
Precise terrain geocoding depends on the availability of a digital elevation model (DEM). DEMs are not universally available, and indeed are available in a suitable form in very few parts of the world. It is thud essential that provision should be made for deriving DEMs. A system has been developed at UCL for the derivation of DEMs from stereo pairs of SPOT data, which would be ideal for use with SAR geocoding systems, however there are problems in obtaining stereo SPOT coverage, even in mid-latitudes covering areas such as Europe, and therefore SAR itself must be used to overcome the problems of cloud cover. Because of the uncertainty of how much stereo SAR will be available from ERS-1 it is intended to develop methods which will use SAR with SPOT (or other optical sensors) in order to derive DEMs.
The geometry of SAR and SPOT has many similarities; images from both are formed over aperiod of time during which the platform moves and range lines in SAR have a similar configuration to an array in SPOT. A particular difference is the accuracy to which the orbit is known; this will be much higher for ERS-1. This means that agood initial orientation will be available for SAR by geocoding to the ellipsoid, this will not be possible for SPOT without one or two initial control points; the possibility of using the SAR image for this will be investigated. After the initial model is formed, a precise model can be formed by relaxing to conjugate points in both models, using weights if necessary to allow for differing precisions in the two images. It is undesirable to resample images more than necessary, therefore the use of anchor points will be investigated whereby the transformation parameters are computed for points on a grid and the surrounding detail transformed to allow the identification of conjugate points. Final resampling using the derived DEM could then take place as a single process. The use of matching techniques with SAR data will be investigated. Another aspect is to refine the orbit of ERS-1 within a short time period, using PRARE and altimeter data.

ERS-1 Data Requirements:
SAR images for two test areas: 1). Sheffield, UK, 2). Montagne Ste Victoire, Provence, Southern France (5°-6°E, 43°-44°N). One SAR scene of each of the two test areas is required early in the 35-day repeat cycle. One further scene of each area in normal mode shortly before the period of the roll tilt mode and a further scene in roll tilt mode with the maximum difference in look angle.
Additionally, altimeter data for three orbits before and after SAR data acquisition, and any PRARE data recorded within 3 orbits of SAR data acquisition.

Milestones/Deliverables:

1/90-6/91	Definition of mathematical model; preparation of software; implementation of Sun workstation; testing using Seasat SAR, Varan-S SAR and SPOT; building up data base of ground control and other supplementary information; incorporation of work on matching and orbits.
7/91-12/92	Testing geocoding algorithms on SAR; testing sensor models on SAR/SPOT, SAR/SAR; refinement of algorithms; extraction of information from SAR.

Deliverables include progress reports due 31/12/90 and 31/1291, and a final report to be available for the final PIs meeting.

Coordinator: Gombeer

X Geology

F7

UTILISATION DU SAR POUR LA SURVELLANCE ET LA GESTION DES RESSOURCES TERRESTRES NON RENOUVELABLES

Principal Investigator:

J.Chorowicz — Laboratoire de Géologie Structurale, Universite P. et M.Curie, 4 place Jussieu, Tour 26, F-75230 Paris Cedex 05 Tel: 1 43268246

Co-Investigators:

G.Colas (Laboratoire Central des Ponts et Chaussees, Section Géologie au Laboratoire d'Aix-en-Provence, Les Milles), M.Pausader (Service de Cartographie Aérospatiale Numérique, Saint Mande), Ph.Rebillard (Society Europeene de Propulsion, Puteaux), J.Y.Scanvic (Bureau de Recherches Geologiques et Minieres, Orleans), F.Jarrige (Institut Francais de Recherche Scientifique pour le Developpement en Cooperation, Paris), J.L.Dizier (Bureau pour le Developpement de la Production Agricole, Paris), C.de Royer (TOTAL CFP, Paris), J.P.Xavier (Societe Nationale Elf Aquitaine, Pau)

Objectives:

Les travaux porteront sur L'étude des possibilités et des limites d'application du SAR de ERS-1 sur les parties terrestres dans les domaines suivants: la cartographie topographique, la cartographie géologique, celle des formations superficielles, de la géomorphologie et de la géologie structurale, la comparaison de ces données avec celles des autres capteurs portés par avion ou satellite pour les projets d'aménagement du territoire (routiers ou environnnement), ainsi que L'evaluation du pré-traitement SAR.

Experiment Plan:

Etude 1 Cartographie topographique (Applications).
Etude 2 Cartographie géologique structural, géomorpologique (Applications).
Etude 3 Cartographie géologique des formations superficielles, aménagement du territoire (Applications).

Les méthodes d'exécution des travaux, variées selon les applications et les équipes. Les résultats attendus vont, dans tout les cas, vers une utilisation apérationnelle des données de ERS-1.

ERS-1 Data Requirements:

Le volume de données requises est de 64 SAr scénes réparties sur 4 saisons de 2 années. Les différentes équipes participant à cette réponse insistent sur l'intérêt de l'orbite à 35 jours pour leurs applications. Elles montrent de plus, tout ce que peut apporter le SAR, au niveau des applications, en région inter-tropical, là oú la couverture des stations de réception prévues actuellement est malheureusement trés incomplète. Enfin, dans la plupart des cas, une couverture stéréo des scénes apparaît indispensable.

Coordinator: Gombeer

IND1-3

GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING FOR MINERAL EXPLORATION

Principal Investigator:
N.S.Mehta SAC, Ahmedabad, India

Co-Investigators:
A.S.Rajawat (as above)

Objectives:
Case studies in the use of C-band SAR for geological/ geomorphological mapping and mineral exploration.

Experiment Plan:
Base maps will be prepared from topographic maps and IRS/SPOT data. SAR imagery will be analysed for geological/ geomorphological information and compared and combined with visible data. Correlations with known mineral deposits will be attempted.

Test Areas:
1. 74°25" - 74°45'E, 25° - 25°35'N.
2. 75° - 75°40'E, 25°15' - 26°N.
3. 91° - 94°E, 25° - 26°30'N.
4. 70°10' - 71°20'E, 26°45' - 27°40'N.

ERS-1 Data Requirements:
SAR.PRI and photographic products required for all areas.
SAR.GEC required for areas 1 & 2.
Seasonal coverages in Oct-Nov 91 and Apr-May 92.
2 scenes are required for areas 1 & 2, and 10 scenes for areas 3 & 4.

Milestones/Deliverables:
Reports on data analysis, interpretation methodologies and final results.

Coordinator: Ninan

UK2

MONITORING ARID ZONE SEDIMENTATION TRANSFER PROCESSES USING ERS-1 AMI DATA

Principal Investigator:

G.Wadge — NERC Unit for Thematic Information Systems, Department of Geography, University of Reading, Reading RG6 2AB, UK
Tel: 734 875123 x7764 Fax: 734 755865

Co-Investigators:

A Millington (Department of Geography, University of Reading), N Quarmby (NUTIS, Department of Geography, University of Reading)

Objectives:

(1) To detect temporal changes in surface sediment distribution in south central Tunisia from difference images generated from ERS-1 AMI data.
(2) To understand these changes in terms of the physical parameters affecting backscattering and the geomorphological results of sediment transfer.
(3) To evaluate multidate SAR imagery as a monitoring tool for arid zone sediment transport in comparison with visible and short wave infrared data and in synergistic combination with them.

Experiment Plan:

Multidata AMI images of a single scene (100 x 100km) in south central Tunisia are required. This scene covers the northern part of the Chott Djerid, a large playa, and the bordering mountains (i.e scene centre= Long.: +00835 Lat. : +03355).
Previous studies with Thematic Mapper and AVHRR data indicate that substantial sedimentary changes occur on the playa each year and to a much lesser extent in the hillslopes and alluvial fans. The expression of this sedimentation in terms of backscattering response in the SAR data will be explored by field measurements of surface roughness, soil moisture and dielectric constant at control sites. Geometrical and radiometrical corrections will be made to the SAR data using a digital elevation model. The requirement from the PAF is thus for ortho-image products. The ortho image will be co-registered to contemporary and archive Thematic Mapper data and their information contents analysed.

ERS-1 Data Requirements:

Multidata images of one scene of AMI SAR data from south central Tunisia acquired in the 35-day repeat cycle from April 1991 to December 1992.

Multidata Frequency:	April-May	1991	:	1 image/cycle = 2 images
	June-Aug	1991	:	1 image = 1 image
	Sept-May	1991-2	:	1 image/cycle = 8 images
	June- Aug	1992	:	1 image = 1 image
	Sept-Aug	1992	:	1 image/cycle = 3 images
				Total = 15 images

Facilities to be Deployed

(1) Institute of Hydrology Capacitance Probe for Dielectric Constance measurement.
(2) Instruments built in-house for surface roughness measurement.
(3) Field spectroradiometer (GER Single Field of View IRIS)

Anticipated Results:

(1) Increased understanding of arid zone sediment transfer processes, particularly for playas.
(2) An evaluation of the utility of multidate SAR data for geomorphological monitoring and change detection.
(3) New insights into methods of combining geocoded SAR and visible/SWIR sensor data for improved information extraction from mineral-rich surfaces.

Milestones/Deliverables:

(1) Status reports. January 1990 and every 6 months to December 1992.
(2) ERS-1 workshop/conference abstracts. As required.
(3) Papers in internationally refereed journals. 3-4 papers expected during 1992-4.

Coordination: Sieber

US1-8

FAULT MAPPING IN LOW RELIEF TERRAIN

Principal Investigator:
J.P.Ford JPL, MS 300-233, Pasadena, CA 91109 Tel: 818 3546735

Co-Investigators:
L.D.Carter (USGS), F.F.Sabins (Chevron Oil Field Research Co.)

Objectives:
Observe and interpret surface structure and previously undetected features in low-relief terrain, evaluate plate tectonic relations and structural hazard potential.

Experiment Plan:
ERS-1 images will be used to interpret structural control of landscape features. Studies to be made in tectonically active areas of low relief (e.g. northeast arctic coastal plain). Key elements include integration with field mapping and comparative analyses with optical and IR image data sets. Experience from coastal plain studies will be extended inland (e.g. Yukon-Tanana lowlands).

ERS-1 Data Requirements:
SAR data. Adjacent swaths for areas of interest (e.g. northeast arctic slope; Yukon and Tanana lowlands) needed for mosaicking. Snow-free summertime scenes of lowlands preferred.

Anticipated Results:
(1) More detailed structural interpretation in areas that are unknown or mapped at reconnaissance level.
(2) Criteria for identification of geologic structures in low-relief arctic terrain.
(3) Relation of observations to natural hazards.
(4) Extension and refinement of plate tectonic models.

Coordinator: Weller

US1-9

ANALYSIS OF THE ASH-FLOWS AND VOLCANIC STRUCTURES IN THE NOVARUPTA/MT.KATMAI/10,000 SMOKES AREA (ALASKA) FROM ERS-1 AND OTHER REMOTE OBSERVATIONS

Principal Investigator:
D.Evans — JPL, 4800 Oak Grove Drive, Pasadena, CA 91109
Tel: 818 3542418

Co-Investigators:
P.Mouginis-Mark (University of Hawaii)

Objectives:
(1) Structural mapping of both the Novarupta and Mt. Katmai vent areas, St.Augustine, and other Aleutian volcanoes using ERS-1, Seasat, SIR-C and DC-8 radar data.
(2) Investigate the distribution of alteration products on the surface of the ash flow (using Landsat and SPOT) to provide physical parameters that will then be used to model numerically the emplacement of this deposit, thereby providing additional insights into the dynamics of the 1912 eruption.

Experiment Plan:
ERS-1 and SIR-C radar images and supplemental remote sensing data (visible, infrared and microwave) will be utilised to further understanding of the regional characteristics of explosive volcanic eruptions in the Alaskan Peninsula. The primary study areas are Mt. Katmai, which is the only historic caldera-forming eruption in the Aleutian volcanic arc which occurred at Novarupta caldera in what is now Katmai National Park, and St. Augustine.

ERS-1 Data Requirements:
SAR data.
3 day repeat coverage once a month April to September.
1 or 2 data sets October to march.

Anticipated Results:
(1) Maps of the distribution of surficial faults and fissures in the Norarupta Basin and on volcanoes in the less accessible parts of the Aleutian chain.
(2) Maps of lithologic textural variation produced by the varying degrees of welding of the ash-flow surface, and the distribution of pheatic explosion craters within the ash-street at Valley to Ten Thousand Smokes.
(3) Numerical models of processes related to explosive volcanic eruptions.

Coordinator: Weller

XI Geodesy and Geodynamics

AUS1

ORBIT DETERMINATION AND GEODETIC POSITIONING IN AUSTRALIA USING PRARE

Principal Investigator:

C.Rizos — School of Surveying, University of New South Wales, P.O. Box 1, Kensington, NSW 2033, Australia   Tel: 61 2 697 4192   Fax: 61 2 663 1222

Objectives:

To operate one or more PRARE tracking systems in Australia, and to process the data, in conjunction with tracking data acquired by other globally distributed PRARE stations, to determine high precision ERS-1 orbits in the Australian region and the geodetic positions of the Australian PRARE station(s).

Experiment Plan:

The dominant focus of the project is to determine ERS-1 satellite orbits to a high precision for the support of radar altimetry (RA) studies in Australian waters (selected projects under AUS-6). The project is largely one of software development, followed by tracking data analysis.

The PI's organisation will be the operator of one PRARE receiver unit (owned by D.G.F.I , the German institute responsible for the operation of PRARE), and the coordinator of a possible local experiment involving several PRARE stations brought to Australia for a short campaign.

The PI will be working closely with other Australian RA investigators.

ERS-1 Data Requirements:

Essential: 35 day repeat orbits for the entire mission.

(1) Local PRARE tracking from the Australian station(s).

(2) Global PRARE tracking data, through data transfer arrangements with DGFI.

Desirable:

(1) Global "normal point" Satellite Laser Ranging (SLR) data, by arrangement with DGFI.

(2) Local RA data to be used as tracking data (to be obtained from Australian CI).

(3) PRARE data for 3 day repeat orbit period, by arrangement with DGFI.

Facilities to be Deployed:

(1) By DGFI: one PRARE tracking station, to be located at either Townsville (for Tropical studies), or Hobart (for Southern Ocean and Tasman Sea studies)

(2) By PI: computer, logistical and maintenance support for the PRARE station

Anticipated Results:

At an operational level, the PI's operation of the PRARE receiver will assist DGFI's global operations (a network of 25-30 stations). The data exchange will permit the PI's tracking data analysis capability for high precision orbit determination to be fully developed and validated. These orbits will assist Australian RA investigations. If a short campaign involving imported PRARE receivers is mounted, high precision geodetic positioning of the stations could be carried out as a by-product of the data analysis.

Milestones/Deliverables:

1990-91	Detailed planning of the experiment, including preliminary GPS survey of candidate tracking sites (with DGFI) and testing prototype software on GPS data.
1991-92	Prepare and conduct experiment, including data collection by Australian PRARE station and transmission to ESA Orbit Centre, and the validation of software using PRARE data (possibly at DGFI).
1992	Steady refinements, including incorporation of SLR and RA data, close collaboration with RA investigations, execution of short multi-PRARE campaign in Australia. Developing an operational high precision orbit computation capability within Australia, and valuable tracking support for ERS-1 through its mission life.

Coordinator: Nilsson

CND8

THE THERMAL-TECTONIC EVOLUTION OF THE CANADIAN SHIELD AS CHARACTERISED BY ERS-1 RADAR DATA

Principal Investigator:
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Tel: 613 952 2742 Fax: 613 952 9783

Co-Investigators:
J.W.Head/ K.D.Card/ A.Davison/ W.Fahrig/ R.A.F.Grieve/ A.Rencz/ P.B.Robertson/ J.Garvin/ P.D.Lowman/ A.E.Beswick/ D.H.Rousell/ V.Singhroy/ B.C.Dressler/ B.Bruce/ J.Harris/ J.Hornsby

Objectives:
This is a geological investigation of parts of the Canadian Precambrian Shield using ERS-1 data with other supporting digital data sets. The study has four components: 1) structural mapping problems, 2) association of brittle fractures and diabase dyke swarms with plate tectonic concepts, 3) the Sudbury Impact Structure compared with other impact sites, 4) Engineering- Terrain mapping and the location of industrial minerals.

Experiment Plan:
The SAR images will be coregistered with geology, geophysical, geochemical and terrain elevation data for qualitative and quantitative analysis. Analysis techniques will be developed and evaluated. Derived thematic maps will serve as a basis for fieldwork.

Test site	*Latitude N*	*Longitude W*	*Area*	
Sudbury Region	45°30'-47°30'	80°0'-83°0'	250x250km	
Sudbury Basin	46°35'	81°10'	60x40km	
Manicouagan	51°23'	68°42'	200km circle	
Clearwater West	56°13'	74°30'	64km circle	
Clearwater East	56°5' 74°7'	44km circle		
Mistastin	55°53'	63°18'	54km circle	
Charlevoix	47°32'	70°18'	92km circle	
Slave Province	65°-66°	110°-112°30'	120x120km	
Nelson Front	54°30'	98°30'-99°	Northern limit	
	56°		97°-97°30'	Southern limit
				80x200km

ERS-1 Data Requirements:
SAR images. For all sites other than the Sudbury Basin, a single coverage in ascending and descending orbits is required between May and October. For the Sudbury Basin, 3 ascending and 3 descending coverages are needed in the months of April, July and October.

Anticipated Results:
(1) A good understanding of ERS-1 SAR and the kinds of geological information that may be extracted from it.
(2) Development of a comprehensive digital database of the Sudbury Region.
(3) A better understanding of how plate tectonic processes contributed to the formation of the Structural Provinces of the Canadian Shield. Brittle fracture studies will demonstrate how such fractures are formed and how they are genetically linked to diabase dykes and to the movements of crustal plates.
(4) A 3D model of the Sudbury Basin will be created to compare with Magellan radar images of Venus and to develop an understanding of the constraints to crater survival and the relative stability of cratonic areas.
(5) Engineering-Terrain studies will provide an improved understanding of how SAR interacts with the terrain morphology, with soil moisture and with vegetation.

Milestones/Deliverables:

1989-91	Acquisition, digitisation and geocoding of relevant datasets.
1991-92	Receive and incorporate SAR data into the database. Database analysis.
1992-93	Final assessment. Model development. Final report.

Coordinator: Lawrence

D3-1

CALIBRATION AND VALIDATION OF THE ERS-1 RADAR ALTIMETER USING GPS AND A PRECISE GEOID OVER THE NORTH SEA

Principal Investigator:
G.W.Hein Institute of Astronomical and Physical Geodesy, University Munich, Werner-Heisenburg-Weg 39, W-8014 Neubiberg, Germany

Objectives:
(1) To calibrate the radar altimeter using Global Positioning System (GPS) observations in a buoy array laid out in the North Sea.
(2) To determine a high-precision geoid in the North Sea for validation purposes, using all available gravimetric and altimetric data.

Experiment Plan:
(1) Determination of instantaneous sea surface and wave heights using differential GPS in three buoys (and one GPS station on land) at the crossover point 56°2'N, 7°44'E during the ERS-1 commissioning phase assuming a precise orbit through laser tracking.
(2) Computation of a high-precision geoid from a combination solution using all available data.

ERS-1 Data Requirements:
(1) Raw altimeter data and precise laser-tracked orbits during the commissioning phase.
(2) Comparison with RA geophysical records.

Facilities to be Deployed:
Four GPS receivers and tilt sensors (three on buoys).

Anticipated Results:
(1) Most precise calibration of the radar altimeter during the commissioning phase.
(2) Validation of the radar altimeter in the North Sea.

Milestones/Deliverables:

August 90	Successful GPS test in the North Sea.
May-July 91	Observations for instantaneous sea surface and wave height calibration.
July 91-July 92	Analysis

Coordinator: Koch

D3-2

SPECTRAL ANALYSIS OF ERS-1 RADAR ALTIMETER DATA FOR GEOSCIENTIFIC PURPOSES

Principal Investigator:
D.Lelgemann — Institute for Geodesy and Photogrammetry, TU Berlin, Sekr. H12, Straße des 17 Juni 135, D-1000 Berlin12 Tel: 030 314 3205

Objectives:
Radar altimeter data over the sea are the total sum of several signals with different spectral behaviour, in particular the radial component of orbit perturbations, earth and ocean tides, sea surface topography due to oceans currents etc., and the geoid undulations. Theoretically derived spectral expressions of the different signals, in particular the quasi-stationary part (e.g. mean sea surface) and the orbital perturbation part due to the gravity field will be compared with the spectrum of the real data.

Experiment Plan:
1) Derivation of analytical spectral expressions of the different types of signals e.g. orbital perturbations.
2) Definition of those parts of the signals which cannot be expressed in terms of harmonic functions e.g. second order orbit perturabations, development of reduced algorithms.
3) Spectral analysis of the observations using Fast Fourier techniques and least squares spectral analysis techniques; investigations of specific problems such as data gaps over land.
4) Comparison of the theoretical and real amplitudes and frequencies, and determination of orbital corrections.
5) Comparison with and validation of standard products.
6) Combination with Seasat, and in the future with Topex data, to obtain a better separation and determination of different signals.

ERS-1 Data Requirements:
Global RA data, level 2; data from 4 complete 3 day cycles is requested.

Anticipated Results:
1) Algorithms and computer programs for the analysis of RA data in the spectral domain and for determination of geoscientific relevant information.
2) A better insight into the information content of satellite tracking data for geoscientific problems.
3) Validation of standard products for the test period using a completely different analysis technique.

Coordinator: Koch

D3-3

DETERMINATION OF THE TIME VARAIBLE SEA SURFACE TOPOGRAPHY WITH RESPECT TO THE GEOID

Principal Investigator:
K.R.Koch Institute for Theoretical Geodesy, University of Bonn, Nussallee 17, D-5300 Bonn 1, Germany

Co-Investigators:
N.Arent/ G.Hückelheim/ J.Rieken/ F.Zurawski (as above)

Objectives:
The altimeter measurements of ERS-1, together with the orbit computation of the satellite, provide the heights of the ocean topography above a reference ellipsoid. The heights shall be analysed to separate the component associated with ocean currents from the component associated with the gravity field of the earth, and so to determine the the ocean geoid.

Experiment Plan:
The ocean currents are modelled by the quasi-geostropic equations, an approximation of the Navier-Stokes equations. The unknown parameters are the heights of layers of this model at an initial state. The heights refer to the geoid. To estimate the heights of the geoid and the heights of the model, the quasi-geostropic equations have to be integrated numerically, and statistical methods using prior information have to be applied.

ERS-1 Data Requirements:
Altimeter data for the 35 day repeat cycle in selected ocean areas, including the North Atlantic.

Anticipated Results:
Geoid undulations for selected ocean areas.

Milestones/Deliverables:

1991	Development and testing of the analysis method.
1992	Evaluation of data.

Coordinator: Koch

D3-4

SEPARATION OF GEOID AND SEA SURFACE TOPOGRAPHY IN SHALLOW WATER REGIONS

Principal Investigator:
E.W.Grafarend — Geodätisches Institut der Universität Stuttgart, Keplerstraße 11, D-7000 Stuttgart 1
Tel: 711 121 3390 Fax: 711 121 3500

Co-Investigators:
M. Metzner (Institut für Meereskunde der Universität Hamburg)

Objectives:
Analysing Radar Altimeter (RA) data to separate the marine geoid and the sea surface topography in shallow water regions in the North Sea, the Baltic Sea and around islands of Indonesia by taking into account both local and regional effects on the sea surface.

Experiment Plan:
The dominant focus is to use a database with a very high resolution for sea areas, eg. ERS-1 RA data , for determining the geoid to a high precision in shallow water regions.
The project is largely one of software development, followed by verifying data analysis in conjunction with results of an ocean circulation and gravitational model.

ERS-1 Data Requirements:
(1) Regional RA data for determining the time independent geoid and sea surface.
(2) Regional wind data of the scatterometer as forcing for an ocean circulation model.
(3) Regional PRARE data to determine high precision ERS-1 orbits.
Main requirement is for data from 35 day and 176 day orbits, because of the dense coverage of the study areas.
Data from the 3 day repeat orbit is required for validating the software and to study rapid changes of the sea surface topography.

Anticipated Results:
(1) Improvement in knowledge of the marine geoid in shallow water regions.
(2) Study of the time scale and special variability of the sea surface in order to determine the vertical datum, especially for the islands of Indonesia.

Milestones/Deliverables:

1990-91	Development of computer programs: graphical routines and programs for correcting RA data (initially with GEOSAT data), for analysing the future RA data, preprocessing of bathymetric data.
1991	Validation of software using the first available ERS-1 RA data.

Coordinator: Koch

D3-5

DETERMINATION AND UNIFICATION OF VERTICAL HEIGHT DATUMS

Principal Investigator:

E.Groten — Institute of Physical Geodesy, Technical University Darnstadt, Petersenstr. 13, D-6100 Darmstradt

Objectives:

Use of ERS-1 altimetry and precise orbit information for determination of mean sea level in the European region and deriving a common vertical reference level for Europe.

Experiment Plan:

The project will focus on the evaluation of ERS-1 altimetry data concerning the sea level surrounding Europe. Additionally, high precision orbit determination as well as a global altimetry data set will be needed. These data will be combined with tide guage readings, GPS observations at tide guages and gravity field information as well as levelling data.

ERS-1 Data Requirements:

(1) ERS-1 altimetry of the whole mission.
(2) High precision orbits.

Anticipated Results:

Computational methods for unification of different vertical datum systems will be developed and tested. As a first step, height of tide guage stations around the Baltic Sea will be computed using a common system.

Milestones/Deliverables:

1990-1	Software development, theoretical studies, GPS survey of tide guage stations in the Baltic Sea region.
1991-2	Evaluation of altimetry data and collection of additional data (tide guage readings) in the Baltic Sea region. Combination with gravity field information.
1992-3	Investigations and tests concerning the application of a European unified vertical datum system.

Coordinator: Koch

D3-6

PRECISE RELATIVE GEODETIC POSITIONING WITH PRARE IN THE GERMAN GEODETIC NETWORK

Principal Investigator:
C.H.Reigber German Geodetic Research Institute, Marstallplatz 8, D-8000 München 22, Germany
Tel: 089 23031 x106

Objectives:
The capability of PRARE for precise positioning will be evaluated by directly comparing the results with an already existing high precision geodetic three dimensional network in Germany. This geodetic network has been established by GPS.

Experiment Plan:
Data analysis will be based on three different evaluation procedures:
1) Dynamic orbit determination.
2) Short arc techniques.
3) Differencing techniques exploiting the simultaneity of PRARE measurements.

ERS-1 Data Requirements:
PRARE full range and range rate data. ERS-1 predicted and precise orbit.

Anticipated Results:
1) Interstation vectors of various lengths.
2) Estimates for internal and external precision resulting from analysis precision estimates and comparison with results from independent techniques.
3) Comparison of various analysis techniques (dynamic, semi-dynamic and geometric modes).

Coordinator: Koch

D3-7

GEODETIC-GEODYNAMIC INVESTIGATIONS WITH PRARE IN THE CENTRAL MEDITERRANEAN

Principal Investigator:
C.H.Reigber German Geodetic Research Institute, Marstallplatz 8, D-8000 München 22, Germany
Tel: 089 23031 x106

Objectives:
The PRARE system will be used to observe a geodynamic network in the Mediterranean, which has alraedy been repeatedly surveyed by GPS. This will provide a contribution to the measurement of the motions of plates in the Mediterranean and to the understanding of the mechanism of the causal processes.

Experiment Plan:
A network of about 12 ground stations in an area of about 600 x 600km will be repeatedly observed with PRARE observations. One observation period will take one week to one month, depending on the availability of equipment. The repetition frequency is once a year, throughout the ERS-1 mission lifetime.

ERS-1 Data Requirements:
PRARE Precise range and range rate data. Precise orbit determination.

Anticipated Results:
As aresult of a single observation campaign, precise (relative) positions of the observation station will be obtained. The accuracy of the computed coordinates is estimated to be in the centimeter level. From a series of repetitive campaigns, a linear velocity of point motions to the same level of accuracy, will be derived.

Coordinator: Koch

D3-8

MEDITERRANEAN ISLAND RADAR ALTIMETER CALIBRATION: LAMPEDUSA EXPERIMENT

Principal Investigator:
G.Weber — Institute for Applied Geodesy, Richard Strauss Allee 11, Frankfurt am Main, Germany
069 6333 1

Co-Investigators:
P.Wilson (as above)

Objectives:
The calibration of the radar altimeter by a mobile laser positioned on the Isle of Lampedusa is proposed.

Experiment Plan:
Tide guage observations will be available. A precise geoid exists and GPS observations will be made for positioning.

ERS-1 Data Requirements:
PRARE range and range rate data obtained during the 35 day cycle.

Coordinator: Koch

DK2

GEODESY PROPOSAL FOR : GEOID DETERMINATION, MAPPING OF GREENLAND ICE CAP SURFACE AND SEA-ICE EFFECTS ON RADAR ALTIMETER.

Principal Investigator:

C.C.Tscherning — Geodaetisk Institute, Geodaetisk Afdeling I, Gamlehave Allé 22, DK-2920 Charlottenlund, Denmark Tel: 45 1631833

Co-Investigators:

R.Forsberg, P.Knudsen/F.Madsun/N.Gundestrup (Geodaetisk Institut), F.Sanso, B.Benciolini, R.Barzaghi, B.Betti (Instituto di Topografia, Milan), R.H.Rapp (Dept. Geodetic Science and Surveying, Ohio State University), D.Arabelos (Dept. Geodesy and Surveying, University of Thessaloniki), M.Vermeer (Finnish Geodetic Institute)

Objectives:

Use of the radar altimeter, PRARE and lasers for carrying out a full geodetic exploration of the North Atlantic and Norwegian/Greenland Seas(Lat. 54°N to 81°N), the North Sea, the Baltic Sea, the Mediterranean Sea and on the Greenland Ice Cap.

Experiment Plan:

Pre-Launch

(1) Computation of sub-decimeter geoids for the areas.
(2) Development of a versatile software package for ultra-precise geoid determination using any combination of gravity field-related data.
(3) Refinement and implementation of recent theoretical developments in the field of geodetic utilization of satellite altimetry.
(4) Investigate the use of satellite altimetry for geophysical exploration using Seasat data and geophysical data from the North Sea and the Norwegian and East Greenland Ice Shelf.
(5) Collection of supplemental information (levelling, GPS, gravity, bathymetry, ice-heights).
(6) Preparation of data collection programs at coastal sites and at oil-drilling platforms in the open sea.
(7) Acquisition of PRARE ground station to be operated in a network with several Norwegian receivers.

Commissioning phase

(8) Participation in the validation of the altimeter by providing sea surface heights and tracking data for an area between Norway, Faroe Islands, Denmark and Scotland.
(9) Providing reference heights and tracking data for a selected area on the Greenland Ice Cap.

Post-Launch

(10) Updates of the preliminary geoids every half year.
(11) Production of new gravity maps for areas with sparse sea-gravity coverage.
(12) Mapping of the Greenland Ice Cap topography for the update of existing maps.
(13) Study time variations of the height of the Ice Cap in a selected area.
(14) Study sea-ice effects on radar altimetry using data in the Greenland and Baltic Seas.
(15) Operate and maintain the PRARE station.

ERS-1 Data Requirements:

A global altimeter data set is required.

Facilities to be Deployed:

PRARE ground station.

Coordinator: Parsons

F5

GEOPHYSICAL (SOLID EARTH) INVESTIGATION WITH ERS-1 ALTIMETER DATA

Principal Investigator:
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Objectives:
To conduct geophysic studies relative to the structure of the oceanic lithosphere and mantle: Formation and evolution of coastal plates (crustal accretion at mid-ocean ridges, thermal and mechanical structure, interaction with mantle plumes); Mantle convection (small-scale convection).
These phenomena produce mainly short-wavelength signatures in the geoid and need dense coverage of the oceanic geoid to be studied.

Experiment Plan:
(1) Analysis of altimeter data: computation of 2D geoid and altimeter-derived gravity maps using classical methods of interpolation and inverse methods.
(2) Development of theoretical models (ex. convection models).
(3) Quantitative comparison between observed and predicted geoid; Determination of best-fitting models parameters; Geophysical interpretation.

ERS-1 Data Requirements:
Essential
(1) A full year of ERS-1 Altimeter data of the 35 days orbit (global coverage).
(2) ERS-1 Altimeter data of the 176 days orbit (global coverage; full cycle).
Desirable
3 months of ERS-1 Altimeter data of the 3 days orbit (global coverage).

ERS-1 Altimeter data from the first part of the mission (3 and 35 day orbits) will be used with GEOSAT ERM altimeter data to compute 2D geoid and gravity maps. 'Mean arcs' will be computed on a global basis by averaging individual cycles over selected periods (ex one year, for the 35 days orbit altimeter data). This will allow part of the scientific objectives to be fulfilled while waiting for the 176 day ERS-1 Altimeter data.

Anticipated Results:
High resolution geoid data will be used together with other geophysical data (bathymetric, magnetic, seismic, etc.) to constrain geophysical models. Anticipated results will concern:
1) Accretion processes at mid-ocean ridges.
2) Properties of the shallow low-viscosity zone beneath oceanic plates.
3) Small-scale convection and mantle plumes.

Milestones/Deliverables:

Pre-launch	Analysis of the ERM GEOSAT data.
-2yr.	Analysis of the 3 and 35 day orbit ERS-1 altimeter data (pre-processing and filtering). Computation of a global geoid using combined ERS-1 and GEOSAT data. Preliminary scientific analyses.
-4yr.	Analysis of the 176 day orbit ERS-1 altimeter data. Computation of the high resolution geoid. Full scientific investigation.

Coordinator: Parsons

I4

USE OF SAR DATA FOR SOLID EARTH PHYSICS STUDIES

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Objectives:
A combined analysis of PRARE laser ranging and radar altimeter data for precise orbit determination of ERS-1, monitoring of regional geodetic networks and calibration of the radar altimeter.

Experiment Plan:
(1) Geophysical validation of the PRARE data by direct comparison with laser ranging data. The setup requires colocation of a dual frequency PRARE receiver with the laser and VLBI station at Matera using both software and logistic facilities already available from a recent colocation experiment.
(2) Precision orbit determination using data from all stations tracking ERS-1, and intensification of the WEGENER geodetic network in Southern Italy, Northern Africa, Ellenic arc and Turkey using PRARE data from fiducial (i.e. with known coordinates) and test stations.
(3) Exploitation of the on-board positioning capabilities of PRARE using two different networks: a small net in southern Italy already surveyed by GPS terminals and a medium size reference network identified as the MEDLAS site visited by European mobile laser systems.
(4) Calibration of the radar altimeter by laser and PRARE tracking from a site to be established on the island of Lampedusa.

ERS-1 Data Requirements:
Minimum requirements are the data from all available PRARE stations together with coordinates.

Coordinator: Parsons

INT3

INVESTIGATION OF PRECISE ORBIT DETERMINATION

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Objectives:
This investigation concerning precise orbit determination for ERS-1 includes activities for processing of ERS-1 tracking data and altimetry which will build on and apply the tools and experience gained in a multi-year programme initiated in ESOC in 1985 to develop the capability to support future ESA missions having stringent requirements on orbit accuracy. The project is centred around internally developed software for orbit determination and covariance analysis containing state-of-the-art models for awide range of orbit perturbations and measurement types, and permitting estimation and error analysis of geophysical and geodetic parameters in addition to the orbital states of the satellites.

Experiment Plan:
Precise Ephemeris Generation: All available tracking data types (laser, PRARE, altimetry, S-band) will be considered in the solution, and the best possible accuracy compatible with that of the tracking data and the available models will be sought. An intensive period of data assessment, solution intercomparison and model tuning is foreseen during the first 6 months after launch. This will include a limited investigation on gravity model tuning; however, development of a complete gravity model for ERS-1 is excluded. Special emphasis will be given to the development of an improved tidal model for the satellite dynamical motion. Normal points will be generated from the raw laser and PRARE data.

Operational Precise Orbit Determination: The emphasis will be on providing a fast, reliable response to user requirements for precise orbits. This is therefore an analogous activity to the routine orbit determination support being provided by ESOC in its capability as MMCC for ERS-1. An automated approach is envisaged as far as possible. A regular evaluation of the various tracking types will be generated in this process.

Altimetry Processing: Altimeter data will contribute to at least one of the orbit solutions to be derived. This will require computation of appropriate measurement corrections and generation of cross-over differences from the direct height measurements. A bi-product of the use of altimeter data in the orbit solution will be a spherical harmonic development of the mean sea surface topography, and possibly additional terms to cover the main lunar tides. There will be a strong emphasis on the cross-over technique as a means of monitoring and reducing radial orbit errors,

ESA S-band Network: Precise orbit solutions will be used to obtain improved estimates of the geocentric coordinates of stations of the ESA S-band network. A related investigation will aim at analysing and improving the accuracy of ionospheric model corrections for the S-band tracking data.

ERS-1 Data Requirements:
Rapid access to the laser and PRARE tracking data.
Fast delivery altimeter data will be available directly in the MMCC. Processed altimeter data for limited periods of the mission may also be required.

Milestones/Deliverables:
Following the ERS-1 launch, a period of 6 months will be dedicated to initiation of the various investigations and studies.
An operational phase will cover the remaining year and a half of the nominal mission.

Coordinator: Minster

N6

GEODETIC APPLICATIONS OF THE ERS-1 PRARE, RA AND LASER SYSTEMS

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Objectives:
To use PRARE, laser and radar altimeter data for accurate orbit determination, point positioning and geoid determination over Norway and Norway's economic ocean zone.

Experiment Plan:
Global ERS-1 orbits will be computed with NDRE's orbit software based on all available PRARE and laser data during selected intervals. In support of point positioning and altimetry in the area of interest, very precise short orbit arcs will be derived from near-simultaneous PRARE measurements at 3 reference stations at Stavanger, Troms_, Jan Mayen and/or Svalbard. A fourth mobile PRARE station will monitor the positions of tidal guages along Norway's coastline and of an oil platform offshore.

ERS-1 Data Requirements:
(1) Minimum requirement is RA and PRARE data over the ocean between Norway and Iceland. The data are required from all passes during at least 10 cycles of the 3 and 35 day orbits and on all accessible passes of the 176 day orbit.
(2) RA and PRARE data with the same frequencies as above for the ocean between N.Norway and Greenland, provided that a PRARE station will be operating at Swalbard.

Facilities to be Deployed:
Tidal guages along the coast of Norway and on oil platforms for routine collection of mean sea surface data.
Three or four PRARE stations.

Anticipated Results:
Simulations have shown that with simultaneous data from three PRARE stations at Stavanger (or Svalbard), Troms_ and Jan Mayen the satellite height over roughly the area between the stations can be determined to between 5cm and 10cm, assuming a range error of 5cm rms. The same accuracy can be expected in the local geoid derived from the RA data and in the point positioning. For the global orbit, an accuracy of between 30cm and 50cm appears achievable.

Milestones/Deliverables:

1990-91	Detailed planning of experiment, completion and testing of software, deployment of PRARE stations.
1991-92	Prepare and conduct experiment, initiate data analysis.
1992-93	Finish data acquisition and analysis.

Coordinator: Parsons

S1

ARCTIC GEODYNAMICS: ERS-1 SATELLITE ALTIMETER EXPERIMENT

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Objectives:
To measure the gravity field in the Arcic Ocean and related arctic areas and carry out an interpretation in respect of the geophysical and geological lithosphere, mantle structure and dynamics, and arctic tides.

Experiment Plan:
Obtain all related satellite altimetty, available surface gravity, shipborne gravity and bathymetry data, and to deduce a detailed gravity and geoid map of the arctic region. Based on thes results, to carry out interpretations using lithosphere and mantle rheological numerical modeling.

ERS-1 Data Requirements:
Essential
All ERS-1 Altimetry data above 60°N latitude.
Desirable
All ERS-1 Altimetry data (global), related sea-ice SAR data from the arctic area above 60°N latitude, Precise PRARE orbit data above 60°N latitude.

Facilities to be Deployed:
Arctic survey ship may be available for gravity survey.

Anticipated Results:
(1) Gravity model of the Arctic Ocean.
(2) Models related to geological structure of Arctic Ocean seafloor and related areas together with a geodynamic interpretation.
(3) Detailed gravity data useful for geophysical analysis.
(4) Arctic tide analysis.

Milestones/Deliverables:

1990-91	Detailed experiment planning.
1991-92	Altimeter data analysis.
1993-94	Completion of gravity modeling and geophysical interpretation.

Coordinator: Parsons

UK17

GEODYNAMICS STUDIES USING ERS-1 ALTIMETRY.

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Objectives:

To use ERS-1 radar altimeter data to study small-scale mantle convection, the tectonics of mid-ocean ridges, and the thermal evolution of the oceanic lithosphere.

Experiment Plan:

Multiple passes of ERS-1 altimeter data along a single ground track will be averaged. These mean arcs will be mixed with existing Geosat meana rcs, adjustments will be made to minimise cross-over errors, and global and regional gravity fields derived using both simple transform and inverse methods. Ship gravity will be incorporated in the latter method, if doing so significantly improves data coverage.

At the same time, numerical models of mantle convection and mid-ocean ridge processes will be developed, and possible observables, e.g. gravity and surface topography, derived from the models. Qualitative comparisons with the ERS-1 derived geoid and gravity fields will enable significant effects to be identified. Where the form of observed behaviour and that predicted by the models is sufficiently close, the estimation of model parameters may be warranted.

ERS-1 Data Requirements:

Global coverage of radar altimeter data for 35 and 176 day orbits are needed. It would be desirable to also have global coverage of altimeter data from the 3 day orbit. Geophysical analyses will make use of mean sea-surface heights obtained by averaging multiplre passes along a common ground track. At least a full year of 35 day orbits will be needed before robust averages can be obtained. The mean sea-surface heights from the ERS-1 35 day repeat cycle, together with those from the Geosat 17 day cycle, will enable the objectives to be met, at least partially. Definitive results require the 176 day cycle which will provide the dense coverage, and hence high resolution.

Anticipated Results:

The improved coverage of altimeter data that will be provided by ERS-1 itself, and in combination with existing altimetry (e.g. Geosat), will reveal features in the short-wavelength gravity field that have not been mapped to date. The recognition of features identified as due to small-scale convection will be mapped in more detail, and it is possible that these will be found in areas than those known at present. The improved coverage will enable the gravity field over mid-ocean ridges to be systematically explored, and questions about mid-ocean ridge tectonics like the dependence on spreading rate, the effect of nearby upwellings in the mantle, and the relationship of along-ridge variations to off-ridge features like those due to small scale convection, will be addressed.

Milestones/Deliverables:

1990	Development of programs and methods of analysis using Geosat data.
1991	Assuming a launch date in January 1991, preparatory work will continue until altimeter data begins to be delivered, when pre-processing will commence.
1992	When a full year of 35 day orbit data has been received, mean sea-surface heights along each ground track will be derived, mixed with mean sea-surface heights from Geosat, and a global geoid and gravity field produced. Geophysical analyses can begin at this point.
	The mean sea-surface heights will continue to be updated as more altimeter data is received. Global and regional gravity fields will be recomputed periodically. When a full cycle of 176 day orbit altimeter data is available, this will be adjusted to fit the accurate reference grid provided by mean sea-surfaces from the ERS-1 35 day cycle and Geosat 17 day cycle. A high resolution gravity field will be derived at this point.

Coordinator: Parsons

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