esa BR-36

# ERS-1

## EUROPEAN REMOTE SENSING SATELLITE






esa BR-36
ISBN 92-9092-019-X
November 1989

# ERS-1

EUROPEAN REMOTE SENSING SATELLITE

## *A new tool for global environmental monitoring in the 1990's*

**european space agency / agence spatiale européenne**
8-10, rue Mario-Nikis, 75738 PARIS CEDEX 15, France

# *A new tool for global environmental monitoring in the 1990's*

There is increasing concern that man's activities are starting to affect the sensitive thermodynamic and ecological balance of our planet. One of the most crucial of these effects is the increase in the atmosphere's carbon dioxide concentrations due to the burning of fossil fuel and deforestation. It has been predicted that mean global temperatures may rise by as much as 2 or 3° C over the next 50 years, accompanied by major shifts in regional weather and vegetation patterns. This would lead to a partial melting of the polar ice caps, with many densely populated areas becoming inundated by rising sea levels.

These major problems confronting mankind can only be addressed effectively if we understand the complexities of our global environment to a much greater degree than at present. Complex interactions have to be unravelled in order fully to understand the processes that are involved, and this requires thorough investigation of the physical behaviour of the atmosphere, oceans, ice and land surface cover. The magnitude and rate of change of many of the processes involved cannot yet be reliably measured, let alone predicted.

Both global and repetitive observations are needed to resolve the broad range of space and time scales involved in the monitoring and preservation of the environment. These requirements are very wide-ranging, and Earth Observation from space may be the only viable and cost-effective means of acquiring much of the necessary input data for climate models, and for monitoring the Earth's surface conditions on local, regional and global scales.

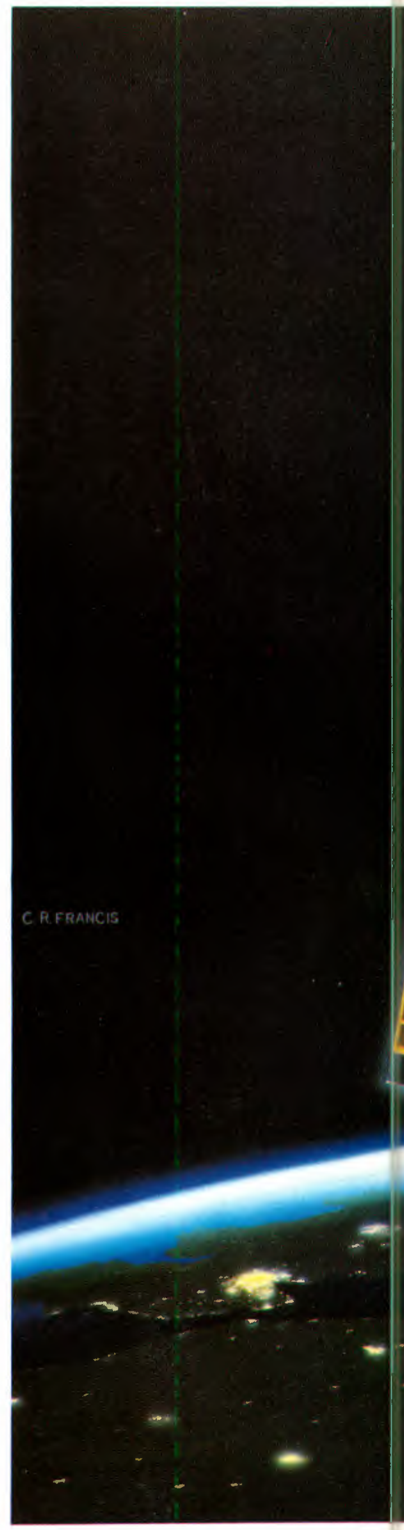
The first European Remote Sensing Satellite (ERS-1) is the forerunner of a new generation of space missions planned for the 1990's which promises to make a substantial contribution to scientific study of our environment.

- ERS-1 uses advanced microwave, or radar techniques which enable global measurements and imaging to take place independently of clouds and sunlight conditions; such techniques have been used previously only by the short Seasat mission in 1978 and during brief Space Shuttle experiments.
- ERS-1 will undertake the measurement of many parameters not covered by existing satellite systems, including those of sea state, sea surface winds, ocean circulation and sea/ice levels, as well as all-weather imaging of ocean, ice and land.

Significantly, much of the data will be collected from remote areas such as the polar regions and the southern oceans, for which there is little comparable information.

The ERS-1 mission will provide essential data for addressing a wide range of primary environmental problems, contributing to:
- improved representation of oceans/atmosphere interactions in climate models;
- major advances in the knowledge of the ocean circulation and transfers of energy;
- more reliable estimates of the mass balance of the arctic and antarctic ice sheets;
- better monitoring of dynamic coastal processes and pollution; and
- improved detection and management of land use change.

ERS-1 has been designed to satisfy operational requirements for data products within a short timeframe, and will also make significant contributions to operational meteorology, sea state forecasting and monitoring sea ice distribution for shipping and offshore activities. Land resource management and some aspects of solid earth research will also benefit.

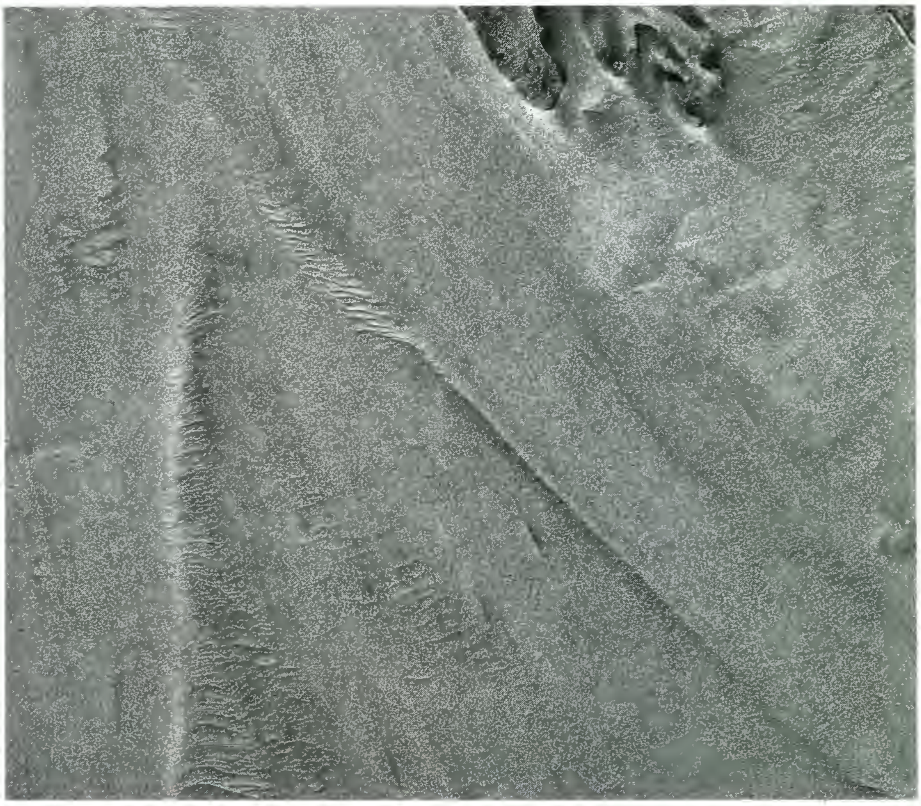


# Scientific Potential

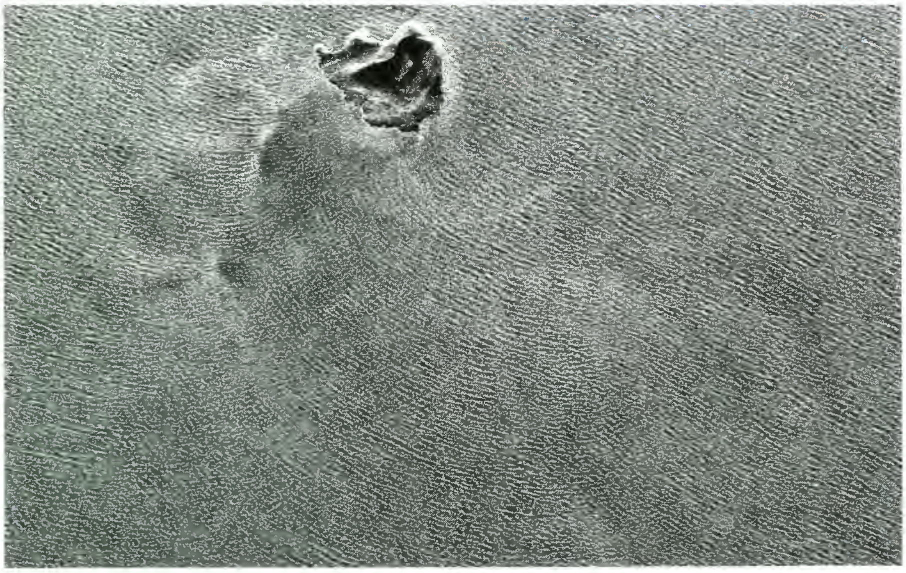
## Physical Oceanography and Glaciology

The capability of ERS-1 to acquire vast global data sets and imaging of ocean and ice phenomena, where previously scientists have had to rely on sporadic measurements from ships and buoys, will have a profound effect in such disciplines as oceanography, glaciology and geodesy. Significant advances are expected in the scientific knowledge of many aspects of the ocean environment, including:

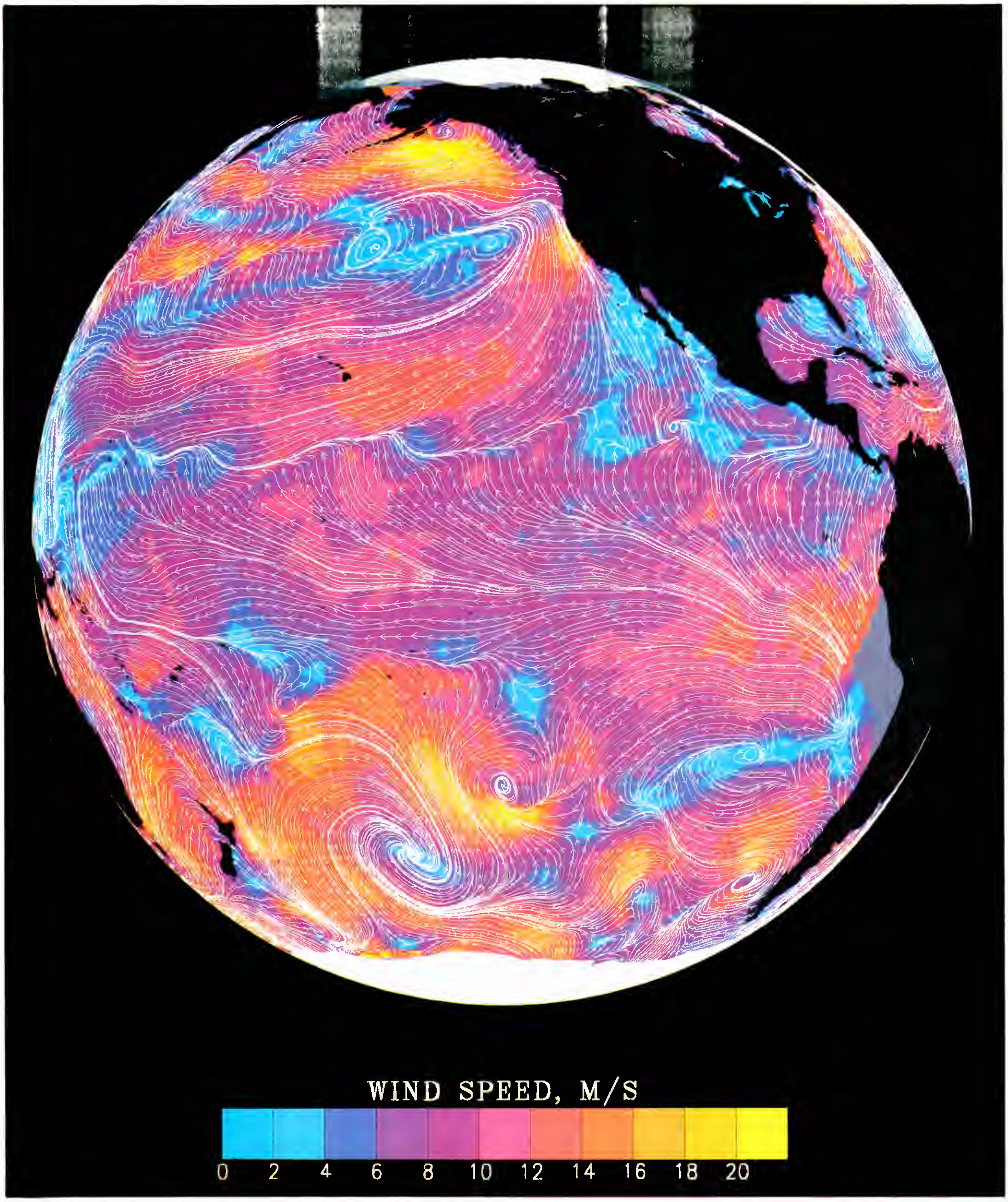
- ocean circulation, currents and tides and the propagation of internal waves
- global wind/wave relationships
- ocean floor topography and the marine geoid
- shallow water bathymetry
- polar ice sheets and sea ice



***Bathymetry.*** *A Seasat SAR image of the English Channel showing surface roughness patterns related to tidal flow over sandbanks at a depth of approximately 30 m. ERS-1 will provide comparable images.* (Processed by DLR/Oberpfaffenhofen for ESA/Earthnet).



***Ocean Waves.*** *A Seasat SAR image showing refraction of waves around Foula Island, Shetlands (Scotland).*

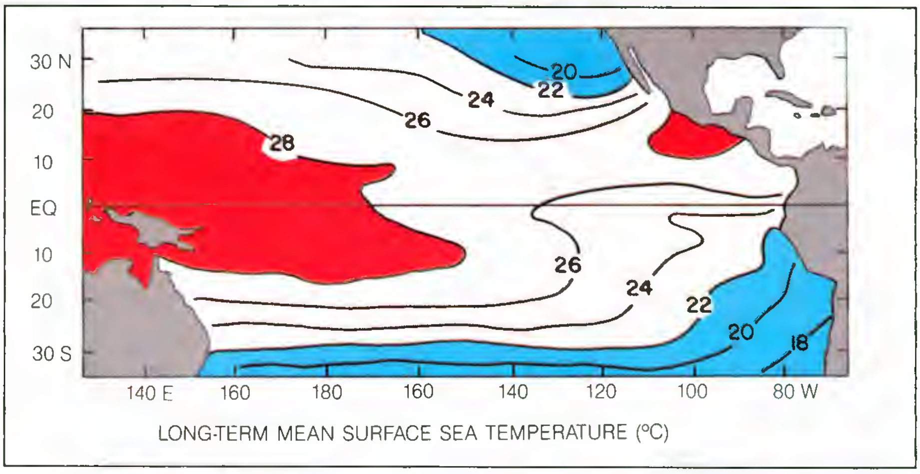


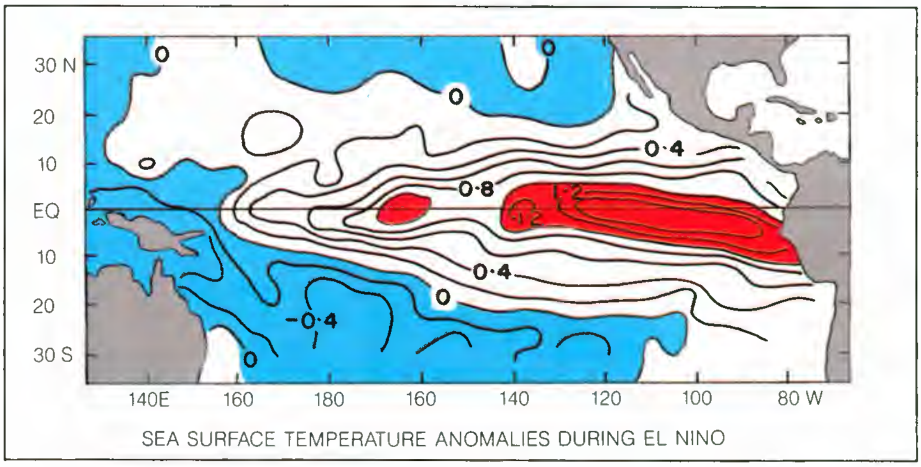

*Global Wind Field. Sea-surface wind speed and direction over the Pacific Ocean on 14 September 1978 as measured by Seasat. ERS-1 will provide similar measurements to users within a few hours of data acquisition.* (Courtesy P. Woiceshyn, *JPL*, M. G. Wurtele, *UCLA* and S. Peteherych, *AES/CDN*).

## Climatology

At a time when there is increasing concern that man's activities are starting to affect the sensitive climatic balance of our planet, ERS-1 data will have a particularly important role to play in the study of interrelationships of oceanographic and climatic phenomena, and their influence on global climatic change and weather conditions. Global measurement of sea-surface winds and temperatures, ocean/atmosphere heat exchange, ocean currents, and the monitoring of the polar regions are all important in this context.

Significant contributions will be made to large scale experiments of the World Climate Research Programme: TOGA (Tropical Ocean and Global Atmosphere) for monitoring climatic anomalies such as El Nino and the Southern Oscillation, and WOCE (World Ocean Circulation Experiment) for estimating and modelling the ocean's global heat and water circulation to the precision necessary for evaluating its climatic impact.




*Sea-Surface Temperatures. Sea-surface temperatures of the Pacific Ocean and anomalies during El Niño in 1982–83, as measured from NOAA AVHRR images. The El Niño phenomenon involves a rapid warming of the sea off the coast of Ecuador and Peru, associated with a breakdown in the normal pressure systems and trade winds in the Pacific. Such events cause disastrous changes in local weather, and give rise to anomalous global weather patterns. ERS-1 will use improved scanning and calibration techniques for precise measurement of sea surface temperatures.*

## Solid Earth

The combined use of various ERS-1 instruments, leading to accurate orbit determination, will substantially contribute to Solid Earth studies, including :

- accurate determination of the ocean geoid;
- geophysical studies of the oceanic lithosphere (e. g. tectonic, thermal and mechanical structure) and of the convection in the Earth's mantle;
- precise relative geodetic positioning.

## Coastal processes

The changing patterns of coastlines, the behaviour of the sea in proximity of coasts, the sea-bed profiles, can all be monitored by a combination of ERS-1 instruments, in particular in areas not easily accessible and in cloud-covered regions.

# Operational/Experimental Applications

ERS-1 will provide global infomation in near real-time, suitable for use in established operational systems for forecasting of weather, sea state and ice conditions. Significant benefits are expected in improved efficiency and safety of all ocean related activities, including:

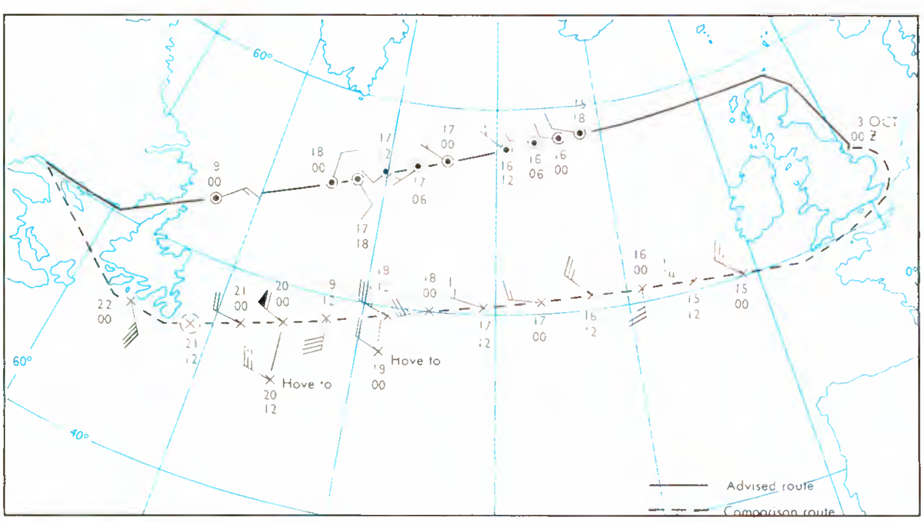
- offshore exploration
- ship routing
- fish resource management
- design of ships and offshore equipment

## Weather forecasting

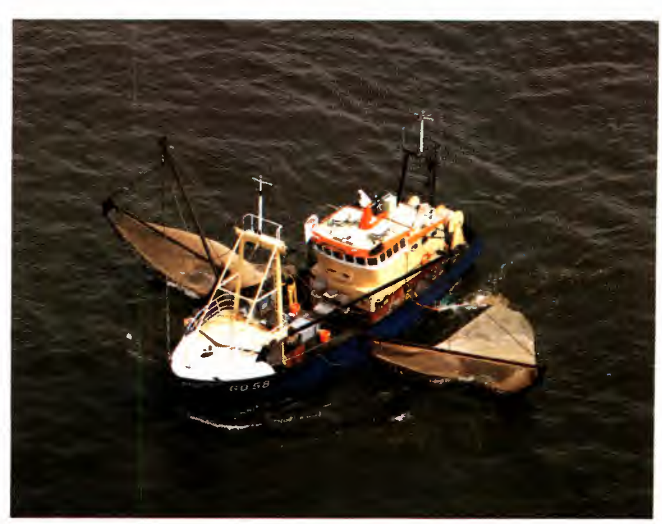
The virtual lack of quantitative data over the open ocean has been a major limitation to forecasting of short and medium-term weather developments. ERS-1 will provide forecasting services with important new measurements of surface wind speed and direction, supplemented by those of sea-surface temperature and water-vapour content.

## Sea-state forecasting

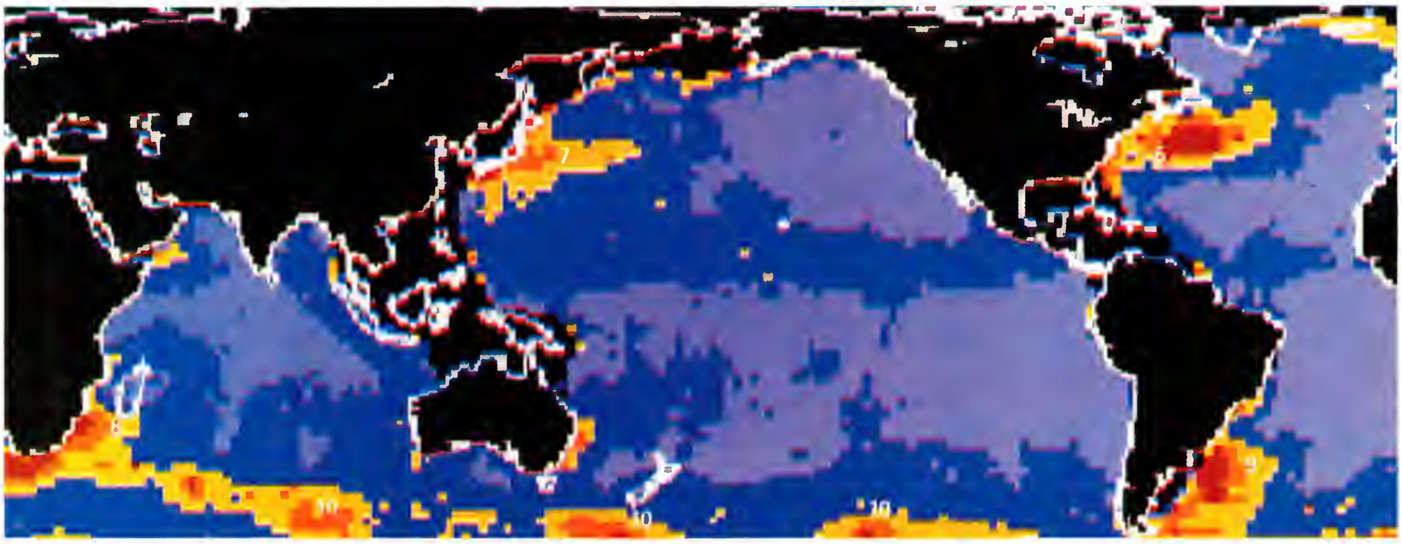
Since most wave models use wind field data as a primary input parameter, global measurements of wind speed and direction will also significantly improve forecasts of sea conditions. Further, ERS-1 provides an excellent opportunity to check and tune the models with direct measurements of wave height, length and direction.



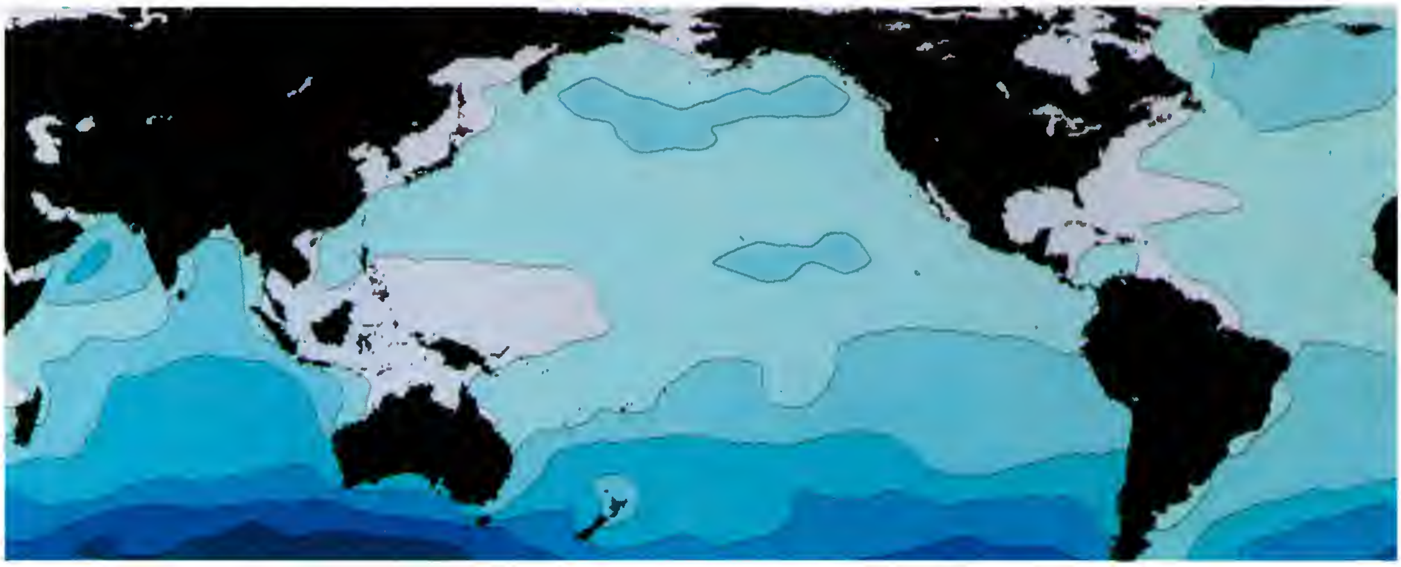

*Ship Routing. A comparison of ship voyage time between advised route (based on forecast conditions) and the most direct route, giving a 3-day saving in sailing time. ERS-1 measurements of surface winds and waves will provide valuable new data for improving short- and medium-range forecasts for ship routing, offshore activities and other operations at sea.*




*Ocean-Surface Topography.* *The topography of the ocean floor is reflected in the topography of the ocean surface. This Seasat derived relief map of the ocean reveals the mid-Atlantic ridge (1) and associated fracture zones (2), the Kuril, Marianas and Tonga Trenches (3), the Hawaiian island chain (4) and the older Emperor seamount chain (5).* (Photo courtesy NASA).



*Ocean Circulation.* *A map of variations in mean sea level over a 4-week period in Sept./Oct. 1978 as measured by Seasat. Largest variations of up to 25 cm shown in red are associated with strong currents, including the Gulf Stream (6), Kuroshio (7), Agulhas (8), Falkland (9) and Antarctic Circumpolar (10) currents.* (Photo courtesy NASA)



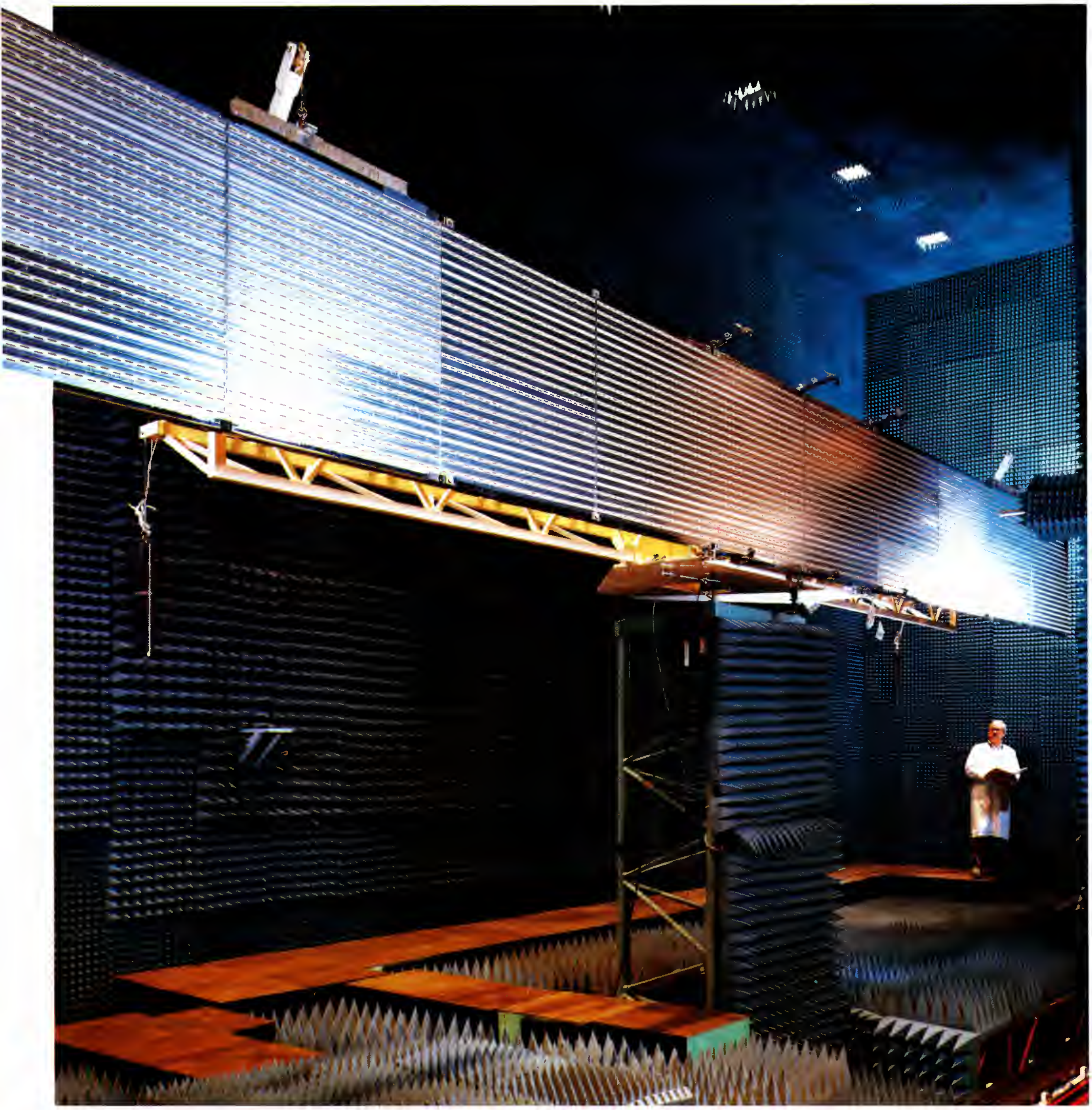
*Global Wave Height.* *Averaged Significant Wave Height during the period July to September 1978 as measured by Seasat. ERS-1 will provide global measurements of Significant Wave Height suitable for producing similar maps on a weekly basis* (Courtesy D. B. Chelton, Oregon State University and NASA/JPL).

## Land Applications

The ERS-1 imaging radar offers excellent opportunities for land applications within fields such as agriculture, forestry, geology and glaciology. All-weather imaging has particular benefits for crop monitoring and snow and ice studies, because of the strong requirement for frequent and reliably timed images and the fact that adverse meteorological conditions often prevent the use of optical sensing techniques. Radar has a special sensitivity to surface roughness characteristics and topography which is important in the context of both forest and geological mapping.

*Agriculture and Forestry. Agricultural fields and a forested area (light toned area along left edge of image) in Flevoland, The Netherlands, as seen on Seasat. ERS-1 will provide regular imaging for crop monitoring throughout the growing season Potentially important forestry applications include forest mapping and change detection, and the discrimination of compartments of different tree species and age.*


*Geology. An arid area of folded and thrusted sedimentary rocks in Western Sinkiang, China, as imaged by the Shuttle Imaging Radar in 1981.*



ERS-1 Synthetic Aperture Radar antenna during planar near-field tests

# The Satellite

## The Platform

- Based on an existing design developed for the French SPOT programme

- Attitude and Orbit Control
  - 3-axis stabilised, yaw steering, nadir pointing
  - roll tilt option

- Power supply
  - 1.8 kW from solar array after 2 years
  - 4 × 24 Ah batteries

- Communications and Data Handling
  - monitoring and control via S-band TT&C link

## The Instrument Payload

**An Active Microwave Instrument (AMI)** which operates in three different modes:

1. **Synthetic Aperture Radar (SAR) Image Mode** for the acquisition of wide swath images over the oceans, polar ice caps and land areas.

2. **SAR Wave Mode** yielding 5 km x 5 km images at regular intervals along track for the derivation of length and direction of ocean wave.

3. **Wind Scatterometer Mode** using three separate antennae for measurements of sea-surface wind speed and direction.

A **Radar Altimeter** providing accurate measurement of sea-surface elevation, significant wave heights, sea-surface wind speeds and various ice parameters.

An **Along-Track Scanning Radiometer and Microwave Sounder (ATSR)** combining infrared and microwave sensors for the measurement of sea-surface temperature, cloud-top temperature and cloud cover and atmospheric water vapour.

**Precise Range and Range-Rate Equipment (PRARE)** for the accurate determination of satellite position and orbit characteristics, and for geodetic 'fixing' of ground stations.

A **Laser Retro-Reflector (LRR)** enabling measurement of satellite position and orbit using laser ranging stations on the ground.

The **Payload Data Handling System** transmits instrument data via 2 X-band links. An onboard tape recorder allows storage of low-bit rate data (from all instruments other than the SAR in image mode).

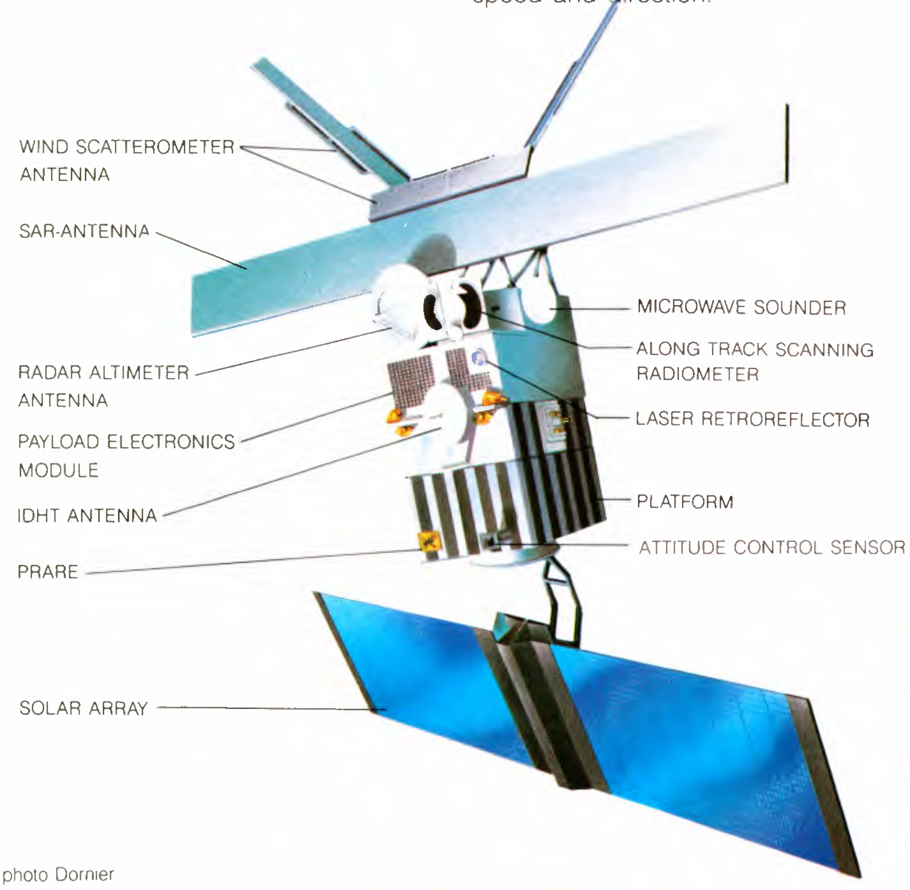
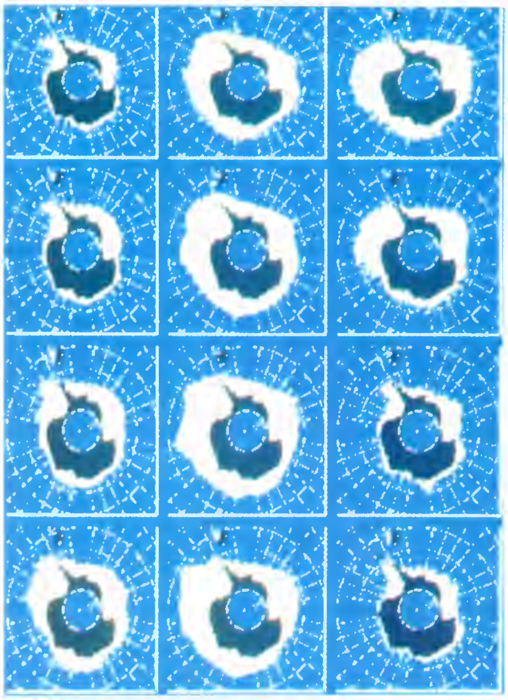



photo Dornier

| | |
|---|---|
| Total mass | 2400 kg |
| Overall length | 11.8 m |
| Solar Array | 11.7 × 2.4 m |
| SAR Antenna | 10.0 × 1.0 m |
| Scatterometer Antennas | |
| – Fore/Aft Antenna | 3.6 × 0.25 m |
| – Mid Antenna | 2.3 × 0.35 m |
| Radar Altimeter Antenna | 1.2 m diameter |

*Physical Dimensions*



## Ice Mapping

The all-weather, day and night sensing capability of active microwave instruments is particularly critical in the context of polar studies, because these parts of the world are frequently obscured by clouds or fog, and shadowed by darkness (polar night) for long periods. Both periodic mapping of the distribution and motion of sea ice, for marine navigation purposes, and mapping of the extent of glacial ice and surface features, for climatic studies, will be important applications of ERS-1 data.

*An annual sequence of 12 plots of Antarctic sea ice obtained from Geosat radar altimeter data. ERS-1 will have a excellent capability for periodic mapping of sea ice.* (Courtesy S. Laxon, Mullard Space Science Laboratory).

## Pollution Monitoring

Oil slicks have a dampening effect on surface waves which is detectable by radar. ERS-1 will complement existing operational airborne radar systems by providing large area monitoring of oil pollution

## Ship Detection

Ships and associated ship wakes are easily detected using imaging radar. ERS-1 offers good possibilities for ship surveillance over extensive sea areas.

*Oil slick near the island of Pantelleria, south-east of Sicily. (Seasat image 1978).*

*A Seasat image showing calving glaciers within a mountainous part of the coast of East Greenland. Small ice floes or mini-icebergs occur as small bright tones within the sea area.*

*Ships and ship wakes in the English Channel, as detected by the Seasat imaging radar.*

# The Instruments

## Active Microwave Instrument (AMI)

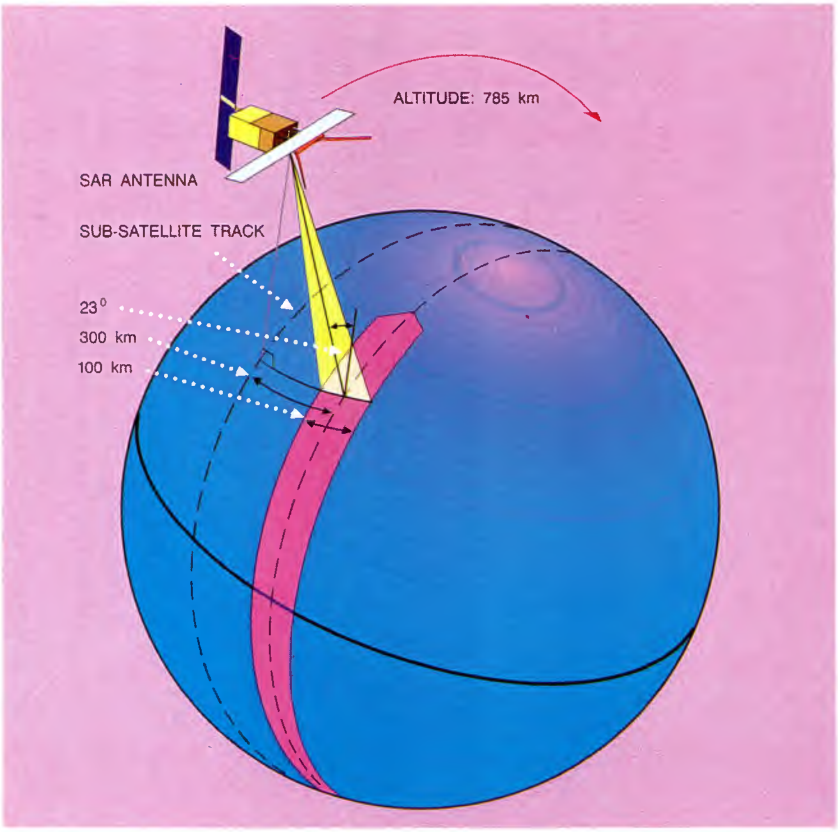
### SAR Image Mode

In image mode the synthetic aperture radar will obtain strips of high-resolution imagery 100 km in width to the right of the satellite track. The 10 m long antenna is aligned parallel with the satellite orbit to direct a narrow radar beam sideways and downwards onto the Earth's surface over the 100 km swath. Imagery is built up from the strength of the return signals, which depend primarily on the roughness and dielectric properties of the surface.

Operation in image mode is exclusive of other AMI operating modes, and power considerations limit operating time to a maximum of 10 minutes per orbit. The data rate is too high to allow on-board storage, so images can only be acquired for areas within the reception zone of a suitably equipped ground station.

The mid-swath incidence angle of the radar in normal operation is 23°. However, the satellite has a 'roll tilt' capability which makes it possible to operate at 35° incidence angle on an experimental basis. This incidence angle is of special interest for some land applications.

*Image Mode Geometry*




### SAR Wave Mode

Operation of the synthetic aperture radar in wave mode provides small 5 km × 5 km images ('imagettes') at intervals of 200 km along track. It provides a global sampling of wave spectra suitable for the daily measurement of the wavelengths and directions of the main ocean swell wave systems.

The relatively low data rate in comparison with operation in 'wide-swath' image mode enables on-board storage of data sets from a complete orbit before downloading to a ground receiving station. Sample size and sample rate have been chosen to give useful global data on ocean waves, but kept small enough to facilitate rapid data processing. There is an option to supply 10 km × 5 km imagettes after on-board range compression.

Imagettes show differences in radar backscatter from the sea surface which are related to the dominant wave lengths and directions of wave systems. Automatic processing is carried out to derive information related to wave spectra.

*Image Mode Technical Specifications*

| | |
|---|---|
| Frequency | 5.3 GHz (C-band) |
| Polarisation | VV |
| Incidence angle | 23° at mid-swath |
| Spatial resolution | 30 m |
| Radiometric resolution | 2.5 dB at −18 dB |
| Swath width | 100 km |
| Data rate | <105 Mbps |

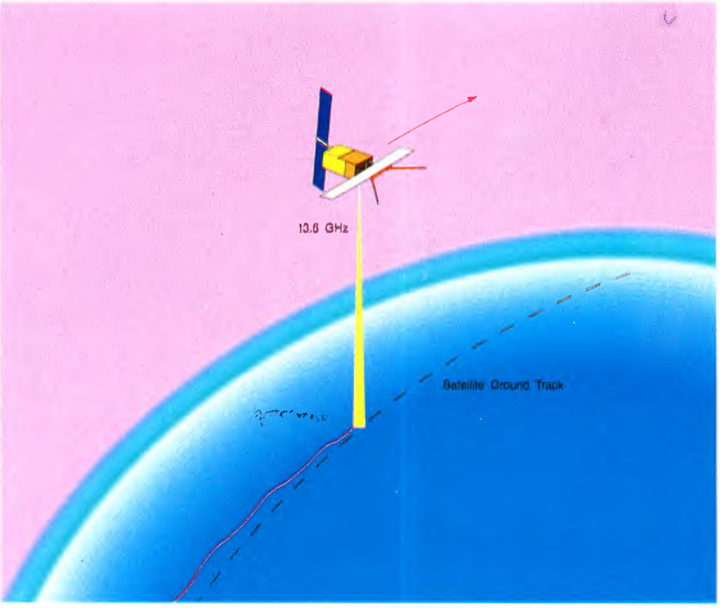
# Radar Altimeter

The Radar Altimeter is a nadir pointing pulse radar designed to measure the echoes from ocean and ice surfaces. In Ocean Mode it will be used to measure wave height, wind speed and sea-surface elevation, the latter of which is appropriate to the study of ocean currents, the tides and the global geoid.

In Ice Mode the instrument operates with a coarser resolution to determine ice sheet surface topography, ice types and sea/ice boundaries.

- Altitude measurements are obtained from the time delay between transmission and reception of a pulse, after correction for atmospheric and other effects.
- Significant Wave Height is measured from the slope of the leading edge of the return waveform.
- Wind speed over sea surfaces and sea/ice boundary location is derived from the power level of the return signal.

On-board processing of the return echoes from sea surfaces will provide the time delay, waveform slope and power level 20 times per second. These measurements are averaged during the data processing to typically yield one-second mean values. Quasi real-time estimates of ocean parameters are therefore possible. However, ice parameters can only be derived from subsequent data analysis. Some experimental use of altimeter data over the land and inland water is also planned, most notably for altimetric measurement of lake levels.




*Radar Altimeter Geometry*

*Radar Altimeter Technical Specifications*

| | |
|---|---|
| Frequency | 13.8 GHz (Ku-band) |
| Bandwidth | |
| – ocean mode | 330 MHz |
| – ice mode | 82.5 MHz |
| Beamwidth | 1.3° |
| Altitude measure | |
| – range/accuracy | 745 – 825 km / 10 cm |
| Significant Waveheight | |
| – range/accuracy | 1 – 20 m/0.5 m or 10% |
| Backscatter coefficient | |
| – radiometric resolution | 0.7 dB rms |
| Echo waveform samples | 64 × 16 bits at 20 Hz |

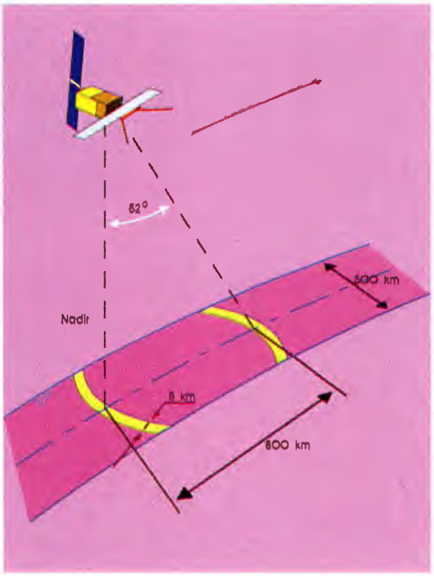
# ATSR

The **Along-Track Scanning Radiometer (ATSR)** with Microwave Sounder is a passive instrument consisting of an advanced four-channel infrared radiometer providing measurements of sea surface and cloud-top temperatures, and a two-channel microwave sounder providing information on the total water content of the atmosphere.

The ATSR uses infrared channels delivering higher accuracies than similar instruments flown on previous satellites; this is possible thanks to the conical scanning technique and improved black-body calibration sources.

The new scanning technique enables the Earth's surface to be viewed at different angles (0° and 52°) in two curved swaths 500 km wide and separated by about 700 km. Data from the two swaths are then combined to provide an accurate atmospheric correction for the calculation of sea-surface temperature.

The Microwave Sounder is a nadir viewing passive radiometer operating at 23.5 and 36.5 GHz to measure the total water content of the atmosphere within a 20 km footprint. This is used to improve the accuracy of sea-surface temperature measurements, and also to provide accurate tropospheric range correction for the Radar Altimeter.




*ATSR Geometry*

*ATSR Technical Specifications*

| | |
|---|---|
| IR Radiometer | |
| – swath width | 500 km |
| – spectral channels | 1.6, 3.7, 11 and 12 μm |
| – spatial resolution | 1 km × 1 km |
| – radiometric resolution | 0.1 K |
| – predicted accuracy | 0.5 K over a 50 km × 50 km square with 80% cloud cover |
| Microwave Sounder | |
| – channels | 23.8 and 36.5 GHz |
| – instantaneous field of view | 20 km |
| – predicted accuracy | 2 cm |

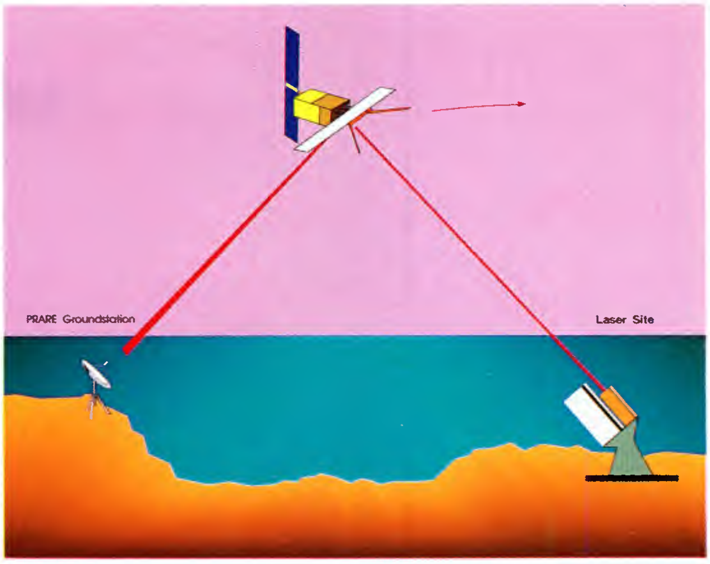
# PRARE and Laser Retroreflector

The main role of these instruments is to provide precise orbit determinations for the referencing of height measurements made by the Radar Altimeter.

The **Precise Range and Range-Rate Equipment (PRARE)** is an all-weather microwave ranging system operating at centimeter accuracy levels for the measurement of satellite to ground range and range rate. The PRARE system involves two-way dual frequency measurement between the satellite and a network of small, mobile ground tracking stations using 0.6-m antennae.

The **Laser Retroreflector** on the satellite enables the slant range to the satellite to be measured from ground-based ranging stations, which use high-power pulsed lasers.

*PRARE and Laser Retroreflector range measurements*

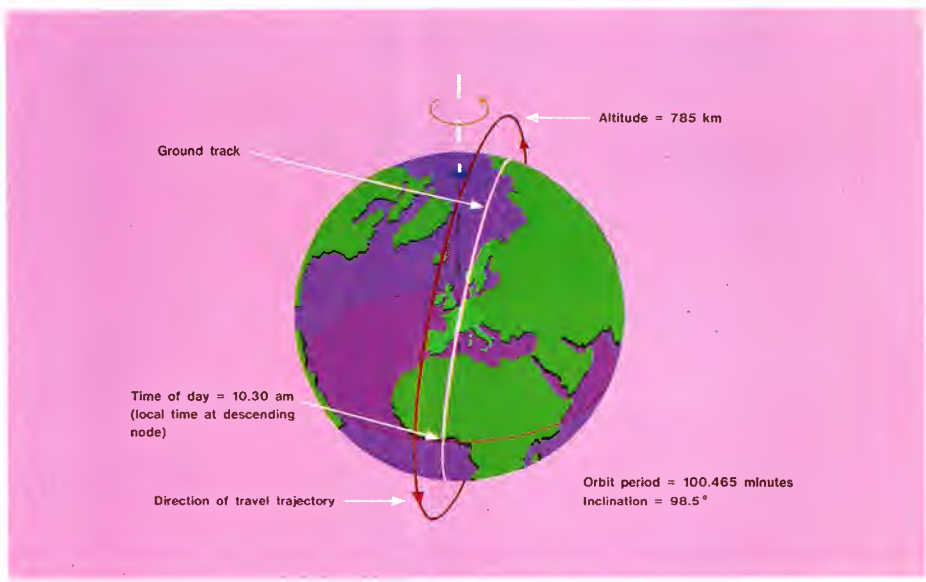


# Orbits and Coverage Patterns

ERS-1 has a sun-synchronous circular orbit (quasi-polar) at a mean altitude of 785 km and an inclination of 98.5°. The local mean solar time at the crossing of the equator from north to south (i.e descending node) is 10.30 am.

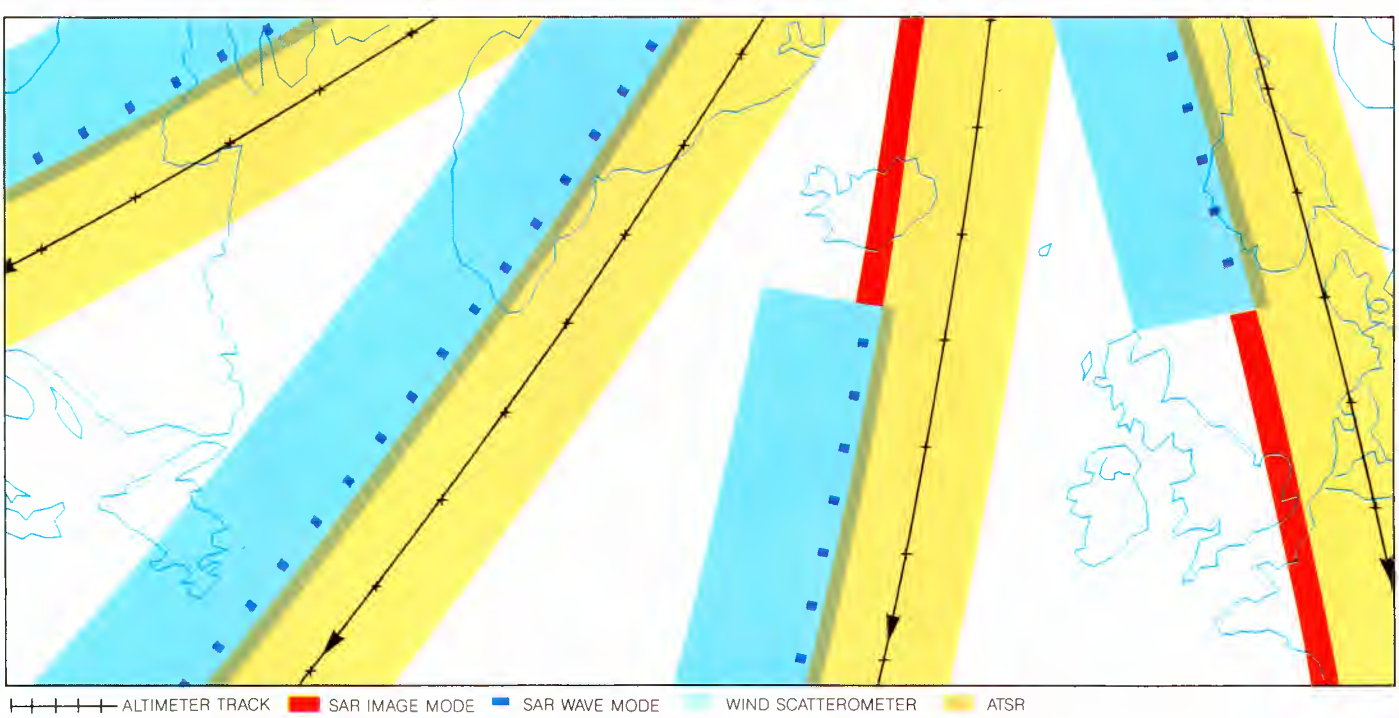
The ERS-1 mission will include a number of adjustment manoeuvres to synchronise the orbital period with various requirements for ground coverage. During the initial three-month commissioning phase the satellite will have a 3-day repeat cycle at an altitude of 785 km (called the 'reference orbit'). Subsequent satellite height adjustments can provide various repeat cycles between 3 and 176 days.

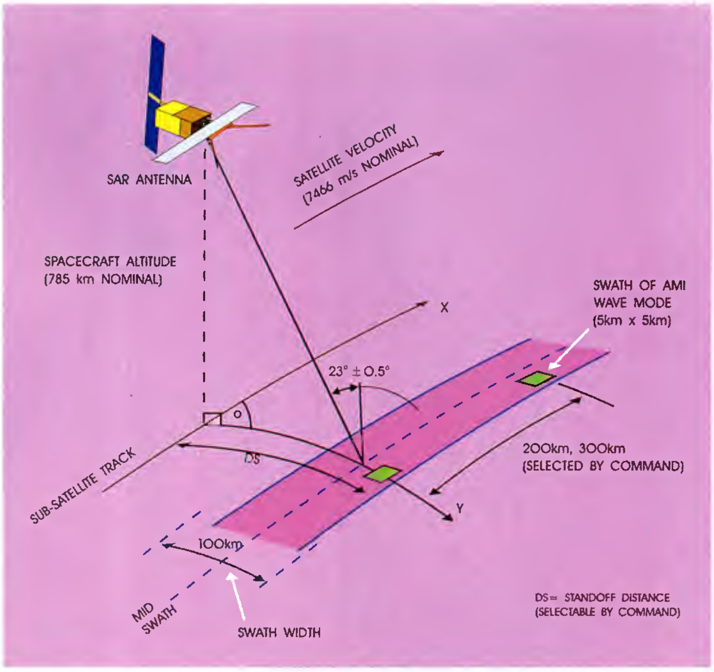
The majority of the rest of the mission will be performed in a 35-day repeat cycle, with some transition back to three days and a final 176-day orbit towards the end of the mission.




*The ERS-1 Reference Orbit*

*Comparative positioning of the swath coverage for different instrument measurement modes*






*Wave Mode Geometry*

*Wave Mode Technical Specifications*

| | |
|---|---|
| Frequency | 5.3 GHz (C-band) |
| Polarisation | VV |
| Incidence angle | 23° / ±0.5° |
| Sample size | 5 km × 5 km |
| Sample spacing | 200 km |
| Wave direction | |
| – range/accuracy | 0 – 180° / ±20° |
| Wave length | |
| – range/accuracy | 100 – 1000 m / ±25% |
| Onboard range compression (optional) | 10 × 5 km imagettes |

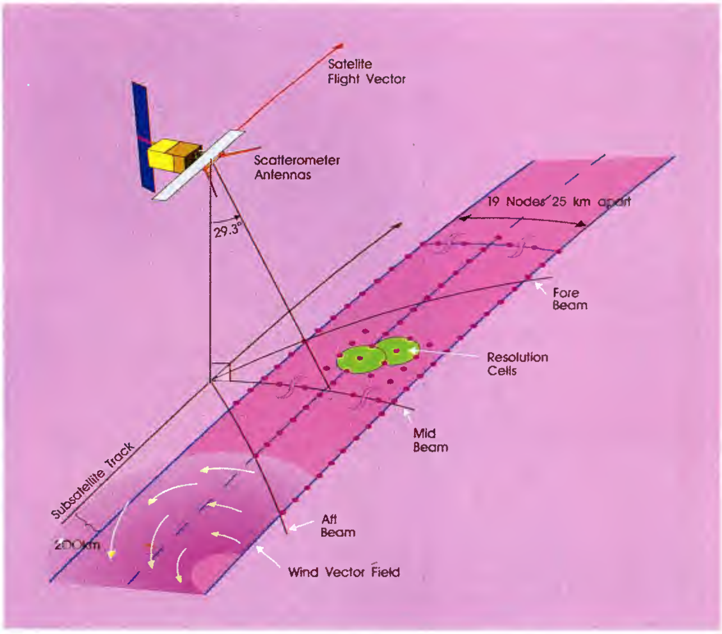
## Wind Scatterometer Mode

The wind scatterometer uses three sideways looking antennae (beams); one pointing normal to the satellite flight path, one pointing 45° forward and the third pointing 45° backward. These antenna beams continuously illuminate a swath 500 km wide as the satellite advances along its orbit and each provide measurements of radar backscatter from the sea surface for overlapping 50 km resolution cells using a 25-km grid spacing.

The result is three independent backscatter measurements relating to cell centre nodes on a 25-km grid, which have been obtained using the three different viewing directions and are separated by only a very short time delay. Calculation of the surface wind vector in terms of speed and direction takes place using these so called 'triplets' within a mathematical model which defines the relationship between backscatter, wind speed, wind direction and incidence angle of the observation.

Operation of the wind scatterometer can be interleaved with SAR wave mode for the acquisition of wind/wave data. Data for the whole orbit can be stored on the satellite before downloading to a receiving station.

*Wind Scatterometer Geometry*




*Wind Scatterometer Technical Specifications*

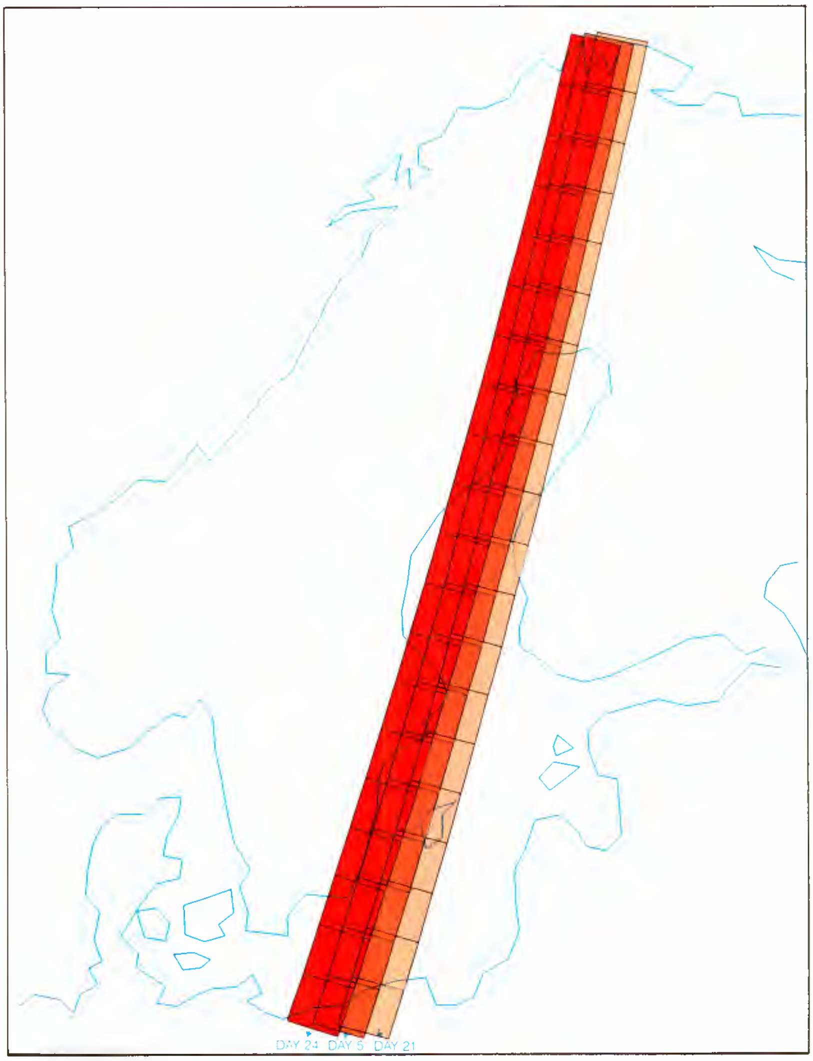
| | |
|---|---|
| Frequency | 5.3 GHz (C-band) |
| Polarisation | VV |
| Incidence angle range | fore/aft beams 25° – 59°<br>mid beam 18° – 47° |
| Swath width | 500 km |
| Spatial resolution | 50 km |
| Grid spacing | 25 km |
| Wind direction | |
| – range/accuracy | 0 – 360° / ±20° |
| Wind speed | |
| – range/accuracy | 4 – 24 m/s / 2 m/s or 10% |

## 35-day cycle

The main limitations of a 3-day cycle are the restricted global coverage for the imaging SAR and the wide separation of the Radar Altimeter tracks. A 35-day repeat cycle provides SAR imaging of every part of the Earth's surface, with at least twice this frequency of coverage at middle and high latitudes. Further, the density of altimeter tracks increases to give a separation between ground tracks of just 39 km at 60° latitude.

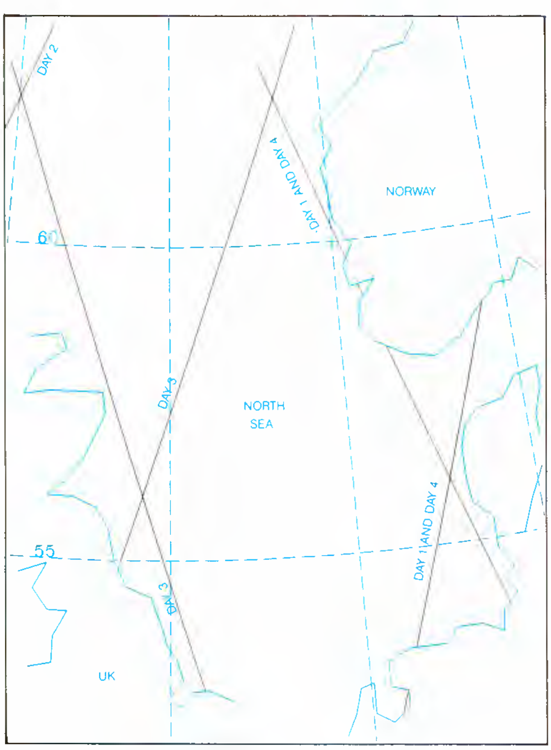
## 176-day cycle

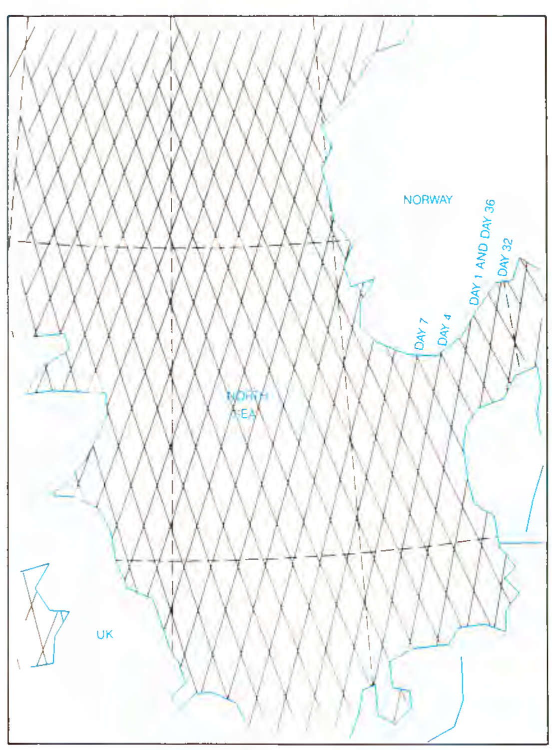
A 176-day cycle is favoured for measurement of the mean sea surface and ocean geoid, because of the very high density of altimeter tracks. However, conflicts with other requirements mean that such an orbit configuration can only be employed late in the mission.




*Overlapping SAR image coverage with a 35-day repeat cycle. All parts of the Baltic Sea are imaged 4 times during the 35 days*

*A comparison on the density of Radar Altimeter tracks over the North Sea using 3-day and 35-day repeat cycles.*



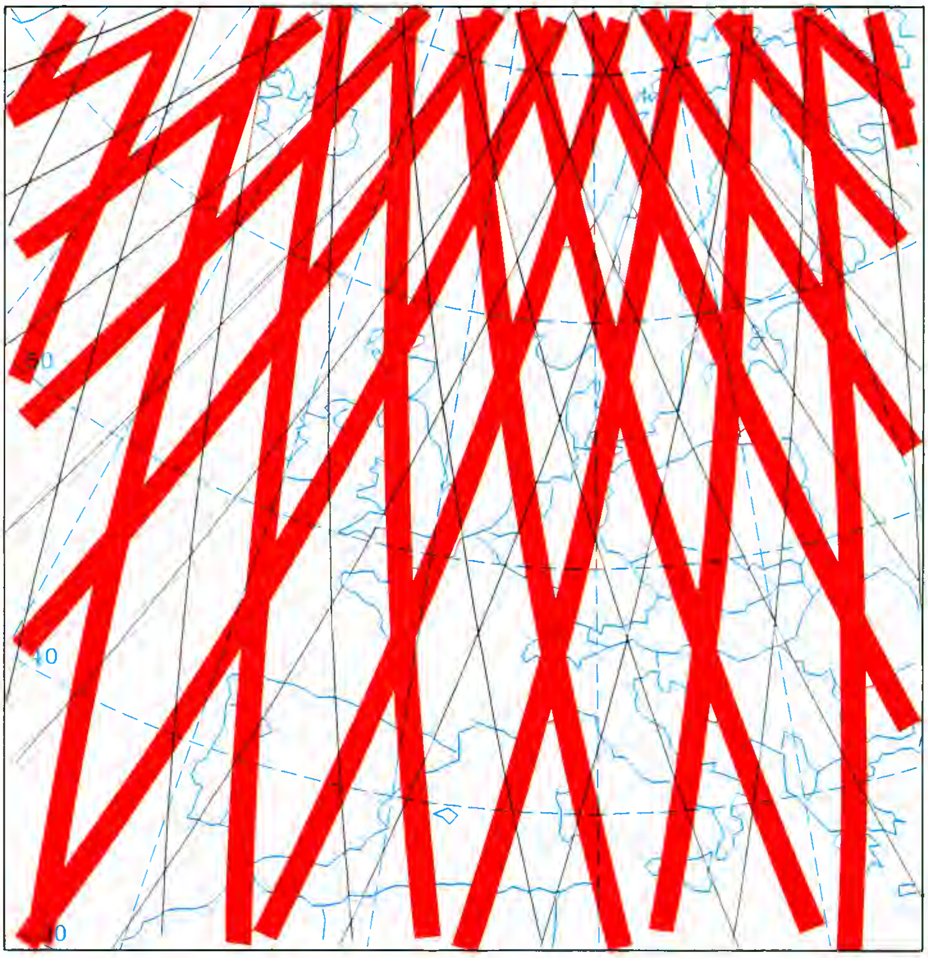
# Ground Segment Overview

The ERS-1 Ground Segment includes capabilities for satellite control and operations, for reception, archiving and processing of the instrument data, and provides services to satisfy user requirements for fast delivery and special products.

The **Earthnet ERS-1 Central Facility (EECF)** at ESRIN (Frascati, Italy) will carry out all user interface functions, including cataloguing, handling of user requests, payload operation planning, scheduling of data processing and dissemination, quality control of data products and sensor performance monitoring.

The **Mission Management & Control Centre (MMCC)** located at ESOC (Darmstadt, FRG) will carry out all satellite operations control and functional management, including instrument operational scheduling. Communication control links are via the ground station at Kiruna.

**ESA Ground Stations** at Kiruna (Sweden), Fucino (Italy), Gatineau (Canada) and Maspalomas (Canary Islands, Spain), will provide the main network for data acquisition and the processing/dissemination of fast-delivery products. Together these stations will ensure the acquisition of the global dataset for the low-bit rate instruments using the on-board data storage facility.



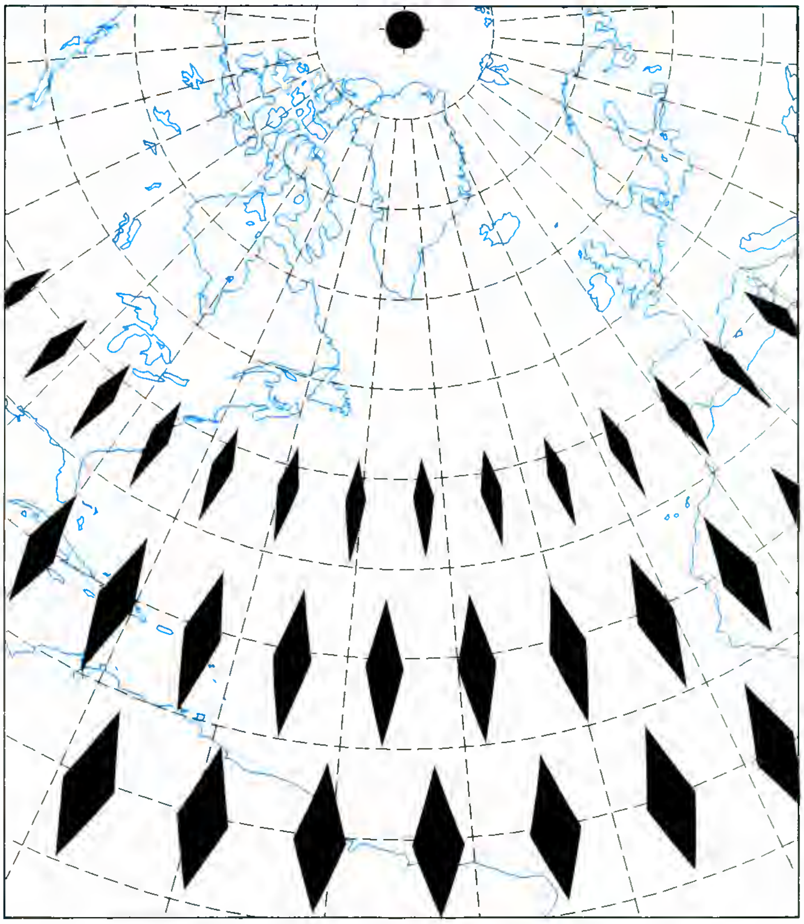
SAR Image (red tracks) and Radar Altimeter (thin black lines)coverage for Europe using the 3-day repeat cycle fixed to Venice, Italy, which is used for the commissioning phase.

## 3-day cycle

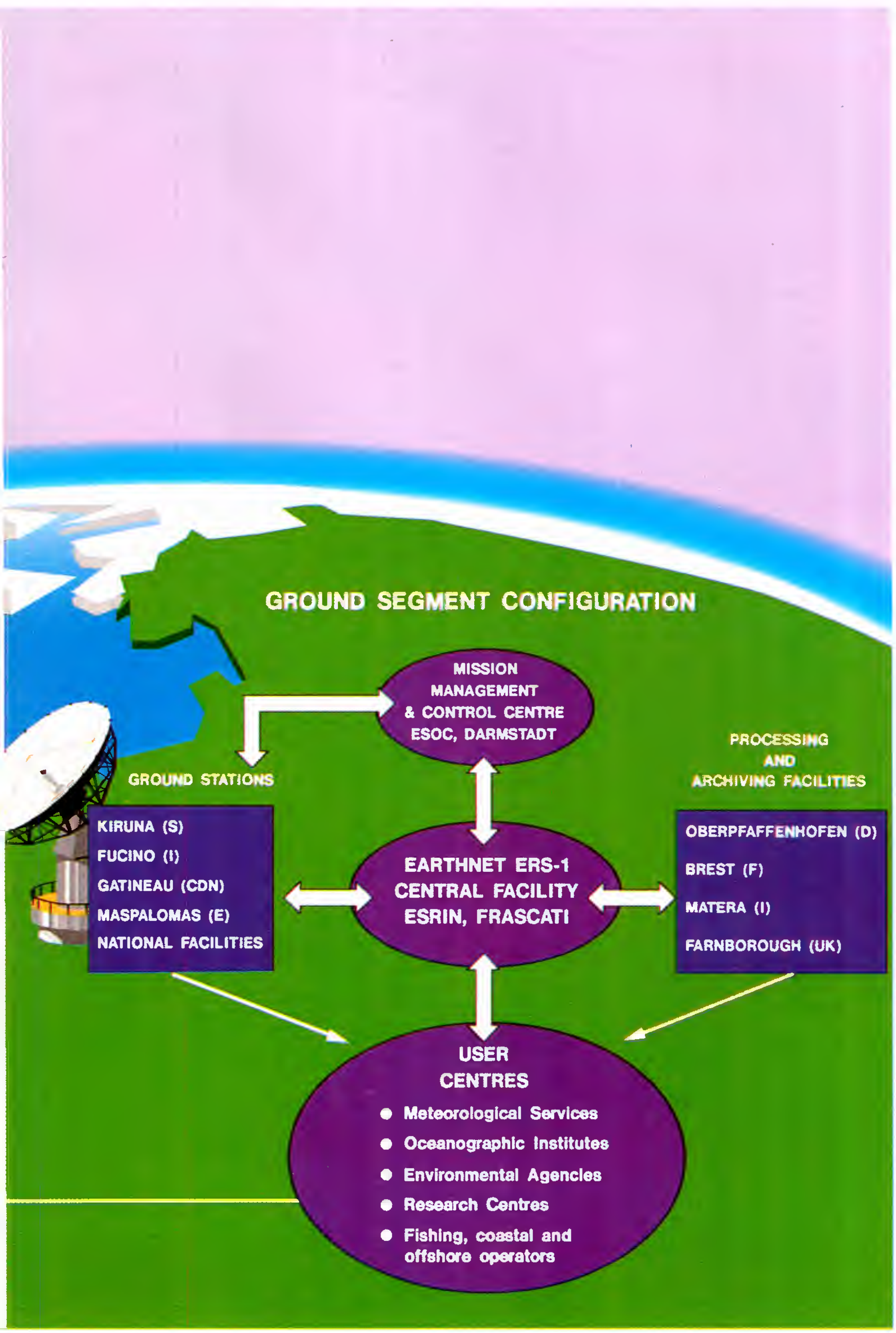
At a satellite altitude of 785 km, the earth's rotation causes a spacing of 909 km at the equator between successive tracks, and after completing 43 passes in 3 days the satellite orbit is such that it returns to exactly repeat the same pattern of coverage.

A 3-day repeat cycle is chosen for the commissioning phase because it provides frequent revisiting of dedicated calibration sites under constant geometrical and illumination conditions. Phasing of the orbit will be adjusted to provide a sub-satellite track over the radar altimeter calibration site near Venice, Italy.

A similar 3-day cycle will operate for limited periods twice during the mission with slightly different longitudinal phases to ensure highly repetitive coverage of ice zones during arctic winters.



*Gaps in Wind Scatterometer coverage for the northern hemisphere with a 3-day repeat cycle. The wide swath coverage of both the wind scatterometer and the ATSR provide quasi-global coverage every 3 days.*



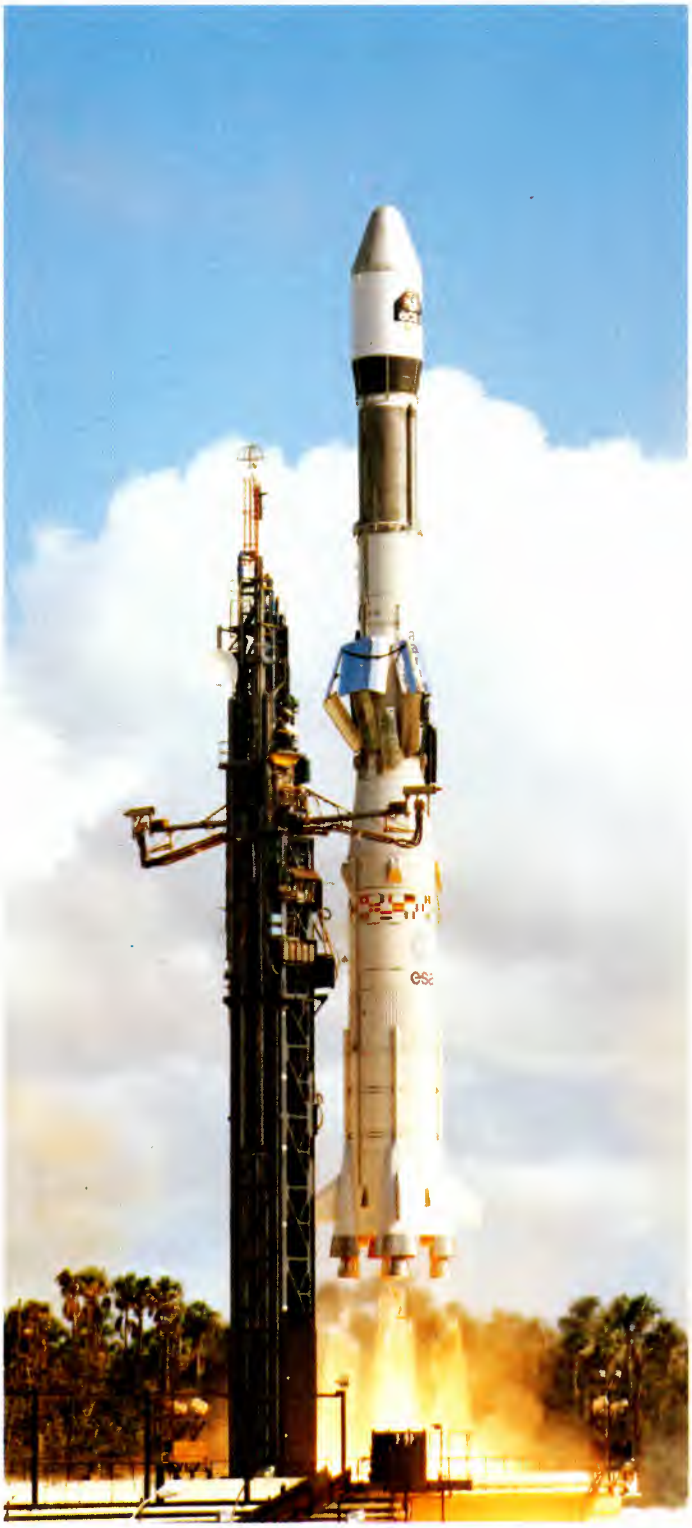

Other Ground Stations within and outside Europe will also receive ERS-1 data by arrangement with ESA, and this will extend the coverage potential in respect of the high-resolution imaging mission.

Four Processing and Archiving Facilities (PAF's) located at DLR (Oberpfaffenhofen, FRG), IFREMER (Brest, France), BNSC (Farnborough, UK) and ASI (Matera, Italy), will be the main centres for the generation of off-line precision products and archiving of ERS-1 data and products.

Individual Users and User Centres such as National and International Meteorological Services, Oceanographic Institutes and various research centres will receive products directly from the ground stations and PAF's, according to requirements submitted to the ERS-1 Central Facility.

*The ERS-1 Ground Segment and User interfaces.*

# Satellite Control and Operations



## Satellite Launch and platform control

Launch takes place from the Kourou Space Centre in French Guyana by Ariane-4. Satellite orientation and stabilisation, including deployment of the solar array and antennas, are performed in a pre-programmed sequence by on-board computer. After acquisition of the precise orbit, a series of tests will be performed and calibration campaigns and performance evaluations carried out to fully commission the ERS-1 system.

The on-board computer is capable of sophisticated control and monitoring of the whole satellite and communicates with MMCC via the Kiruna ground station using S-band telemetry. These functions include platform attitude control, implementation of instrument schedules and instrument reconfiguration.

Orbital adjustment manoeuvers will be carried out during the lifetime of the mission to maintain orbital phasing, to change the orbit repeat cycle and to operate the experimental roll-tilt mode.

## Programming of instruments

The programming of instrument operations on the ERS-1 satellite will be a particularly challenging task because of the large number of different operating modes and the relatively high power consumption of active microwave instruments.

Satellite design permits the storage of a command programme to cover 16 consecutive orbits, more than 24 hours, with a single uplink during the 7.5-minute contact with the Kiruna station.

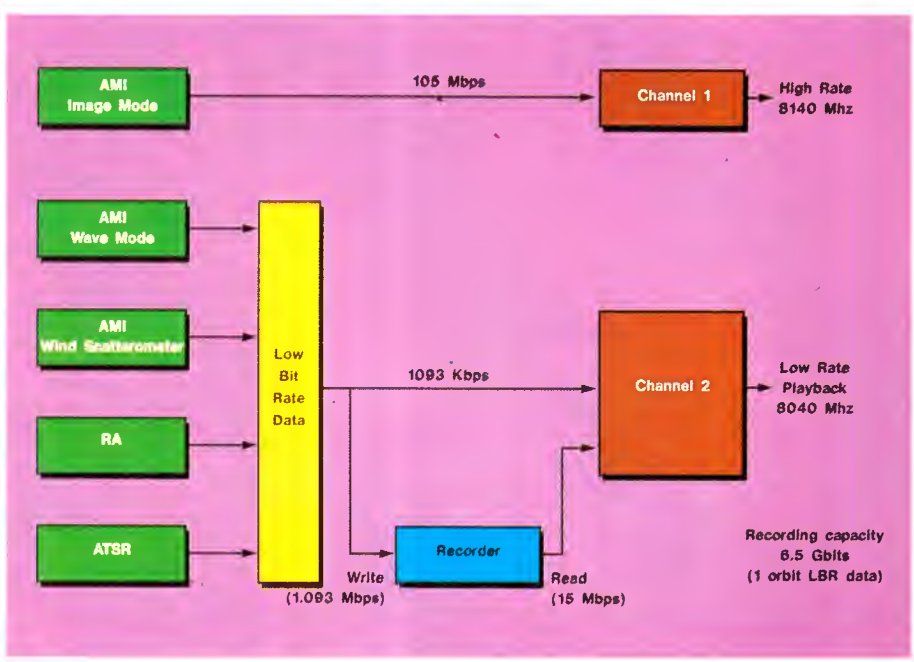
The expected mission capabilities after two years in orbit will allow global acquisition of ocean wind/wave and surface-temperature data, in combination with systematic operation of the Radar Altimeter and ATSR over Arctic and Antarctic regions, as well as SAR imaging on a regional basis.

*Operations Room at the Mission Management and Control Centre (MMCC), ESOC Darmstadt.*

## Data handling and transmission

These on-board operations include instrument data collection, data multiplexing, data storage on tape recorders and data transmission via X-band channels either directly or in playback mode.

SAR image data are transmitted via a dedicated high bit rate channel in real time. The low-bit rate data from all other instruments are multiplexed using packet telemetry on a single data stream. These data will normally be recorded on-board before downloading, but can also be transmitted directly in real time. Recording capacity allows data storage for at least one complete orbit. Data playback will take place in visibility of one of the ESA ground stations.




*Instrument Data Handling and Transmission (IDHT) sub-system.*

# Data Acquisition and Fast Processing

*ERS-1 Antenna at Kiruna.*

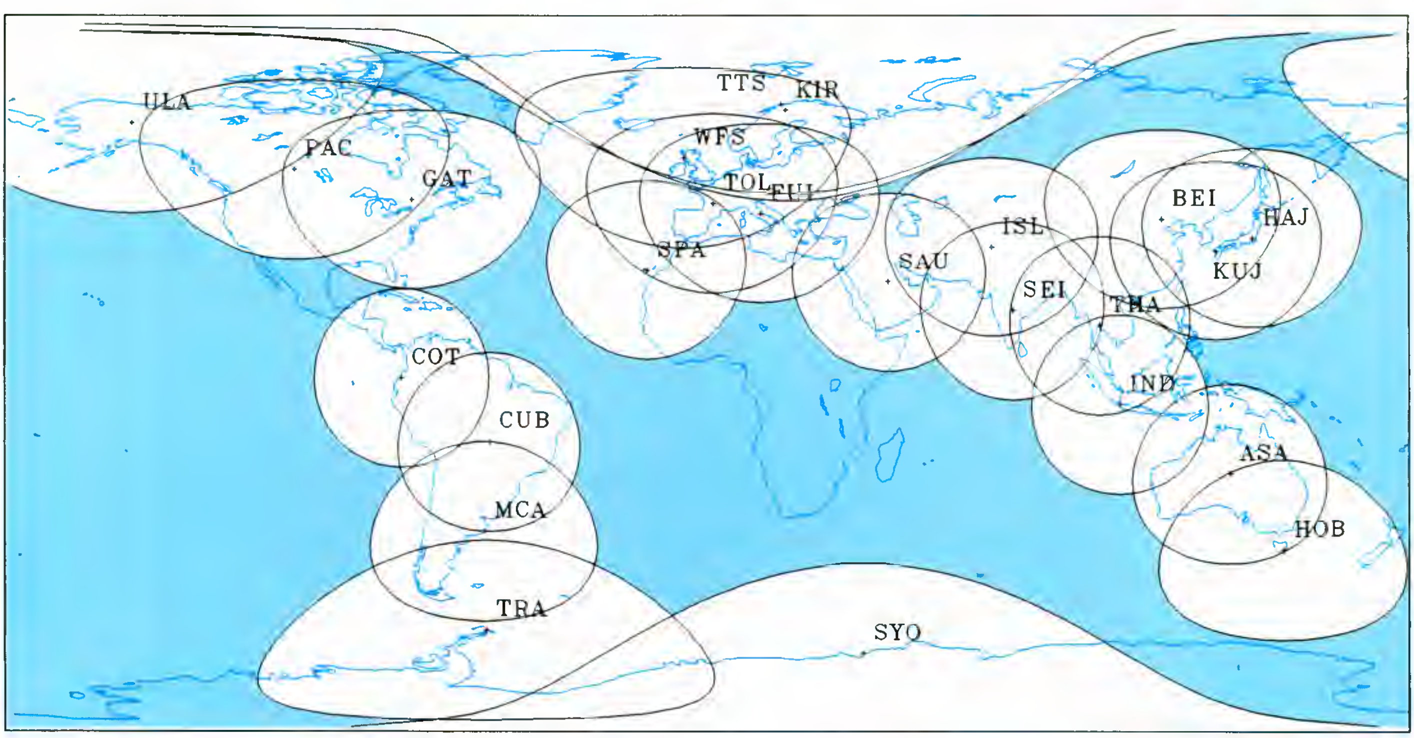
## ESA Ground Station Network

Ground stations at Kiruna (Sweden), Fucino (Italy), Gatineau (Canada) and Maspalomas (Canaries, Spain) will be the main facilities for the acquisition and rapid processing of ERS-1 data.

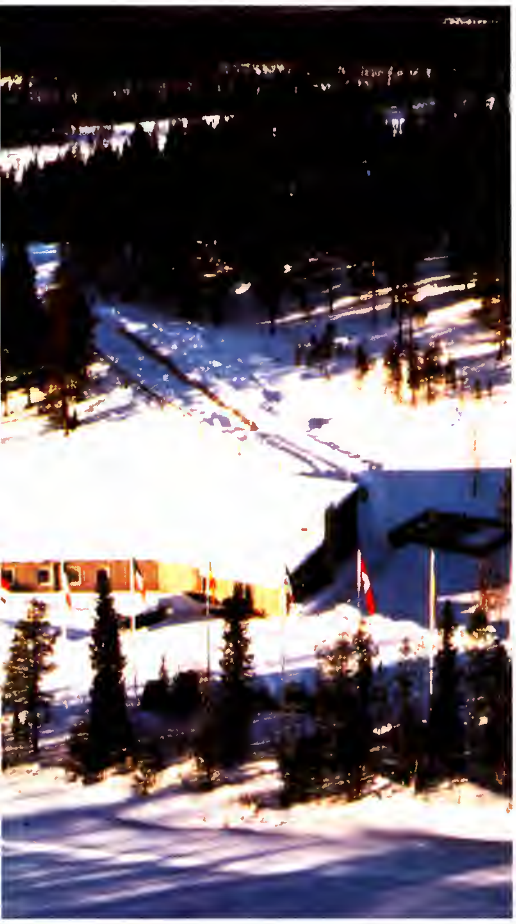
The Kiruna station in northern Sweden will play a primary role because its high latitude position provides visibility to 10 out of every 14 daily orbits. Both instrument real time and on-board recorded data will be acquired by the station, with the raw data being stored on High-Density Digital Tapes (HDDT's). Fast-delivery processing facilities comprise two processing chains devoted to SAR processing (i.e. image and wave mode) and one devoted to the processing of the data from other instruments.

The Fucino station is to be used primarily for the acquisition of SAR image data and real-time low-bit rate data over the Mediterranean Sea. Stations at Gatineau and Maspalomas will be used for the acquisition of recorded low bit rate data. All three of these stations will have data recording and fast delivery processing facilities similar to Kiruna.

This network of stations will together be able to acquire the global low-bit rate dataset.




*Coverage Zones for proposed ERS-1 Ground Stations.*



## Other Ground Stations

A large number of additional ground stations will increase the world coverage for SAR images. These include the planned stations in Alaska, Ecuador, Argentina, Brazil, Antarctica, Australia, Japan, India and Pakistan, plus others...

There will also be additional stations in some ESA Member States, including Tromsø in Norway, Aussaguel in France and West Freugh in the UK. Gatineau and Prince Albert (Canada) will operate as national facilities for the acquisition of SAR data.

*ERS-1 Antenna at Maspalomas.*

ASA : Alice Springs, Australia
BEI : Beijing, China
COT : Cotopaxi, Ecuador
CUB : Cuiaba, Brazil
FUI : Fucino, Italy
GAT : Gatineau, Canada
HAJ : Hatoyama, Japan
HOB : Hobart, Australia
IND : Jakarta, Indonesia
ISL : Islamabad, Pakistan
KIR : Kiruna, Sweden
KUJ : Kumamoto, Japan
MCA : Mar Chiquita, Argentina
PAC : Prince Albert, Canada
SAU : Riyahd, Saudi Arabia
SEI : Secunderabad, India
SPA : Maspalomas, Spain
SYO : Showa, Jap./Antarctica
THA : Bangkok, Thailand
TGS : Greenbelt, USA
TOL : Aussaguel, France
TRA : Esperanza, Arg./Antarctica
TTS : Tromsö, Norway
ULA : Fairbanks, Alaska
WFS : West Freugh, UK

*Fast-Delivery Processing Facilities at the Kiruna Ground Station.*

# Fast-Delivery Products

The Fast-Delivery (FD) Products are generated and distributed from ground stations within three hours from instrument observation.

## SAR Image Mode FD Product

- approx. 100 km × 100 km image
- 20 m interpixel distance in ground range
- 16 m interpixel distance in azimuth direction
- available in 16 bit or 8 bit/pixel data formats

Each SAR Fast-Delivery Processor has a throughput of 3 high-quality images in less than 90 minutes.

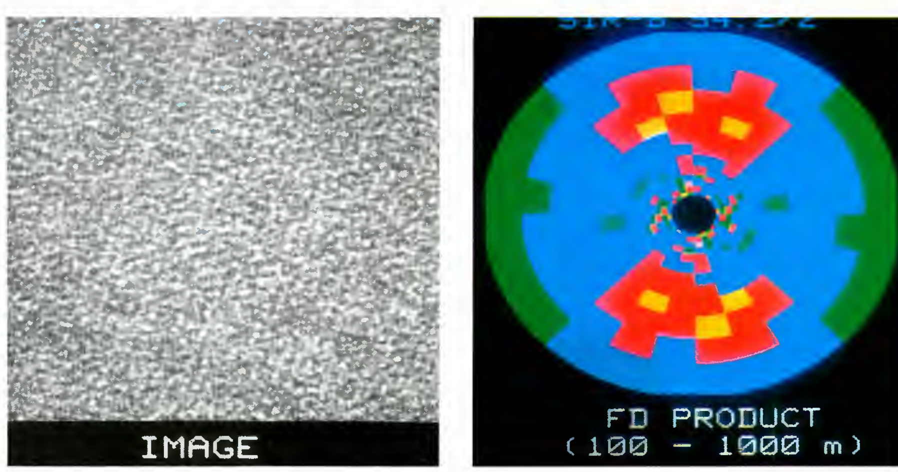
*SAR image of Vancouver, Canada, processed from Seasat raw data in 30 minutes using the ERS-1 SAR Fast Delivery Processor.*

## SAR Wave Mode FD Product

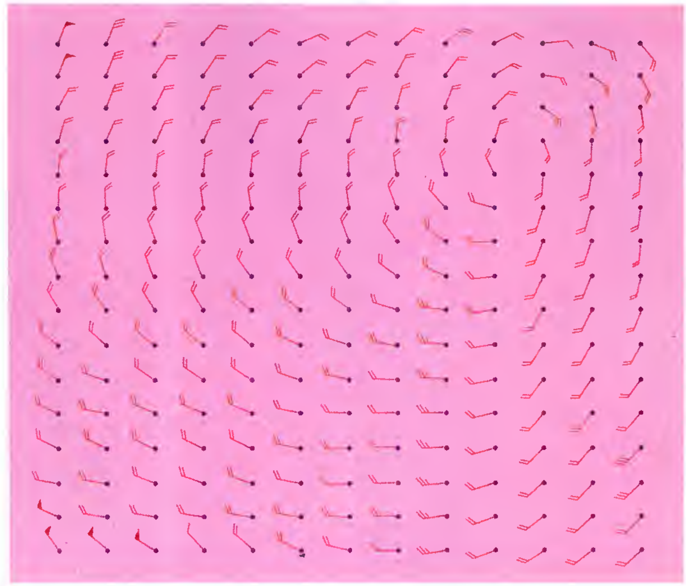
Power spectra of 5 km × 5 km imagettes expressed in polar co-ordinates, with:

- 12 8-bit amplitude levels in logarithmic form corresponding to spatial wavelengths between 100 m and 1000 m.
- 12 angular sectors of 15° between 0° and 180°, with an angular resolution of 30°.

Each SAR Fast-Delivery Processor can generate up to 150 spectra per orbit.




*SAR Wave Mode imagette and derived FD Power spectrum displayed in 'log polar' format with the wave energy colour coded and the radial distance proportional to the ocean wavelength.*



*Wind vectors for a 500 km × 500 km area.*

## Wind Scatterometer FD Product

The scatterometer product consists of wind vectors for a grid of 19 × 19 points distributed over a 500 km × 500 km area. Wind speed and wind direction are provided for all grid points except those corresponding to resolution cells for which the percentage of land is above a given threshold.

Up to 70 of these 500 km × 500 km areas can be processed in the time period between two consecutive passes.

## Dissemination of FD Products

The SAR FD images will require a high-speed satellite data dissemination channel.

Low-bit rate data distribution will be based on the use of existing networks.

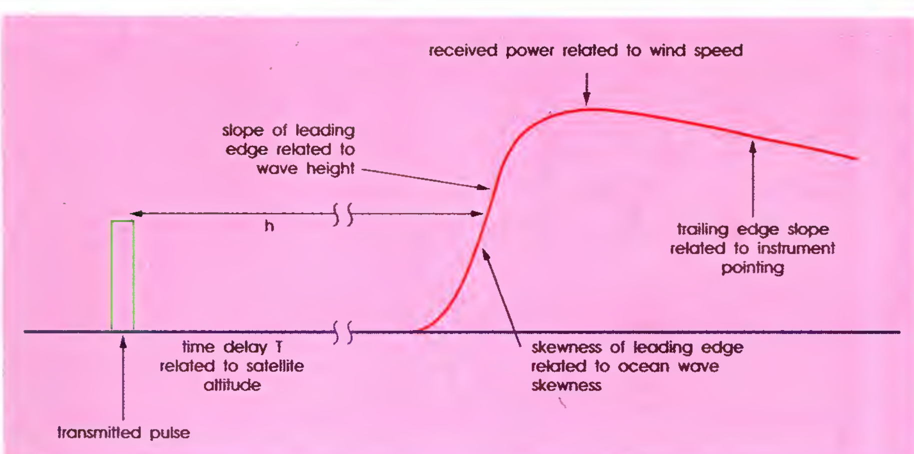
Fast-delivery products are only disseminated to a limited number of national centres in participating countries.

## Radar Altimeter FD Products

Three FD products will be obtained from the Radar Altimeter, each of which are in the form of one-second averaged measurements (i.e. over 6.5 km on the ground).

- Wind speed over the ocean
- Significant wave height
- Altitude over the ocean

Processing of up to 80 datasets for 500 km sections of ground track will be possible for each orbit.



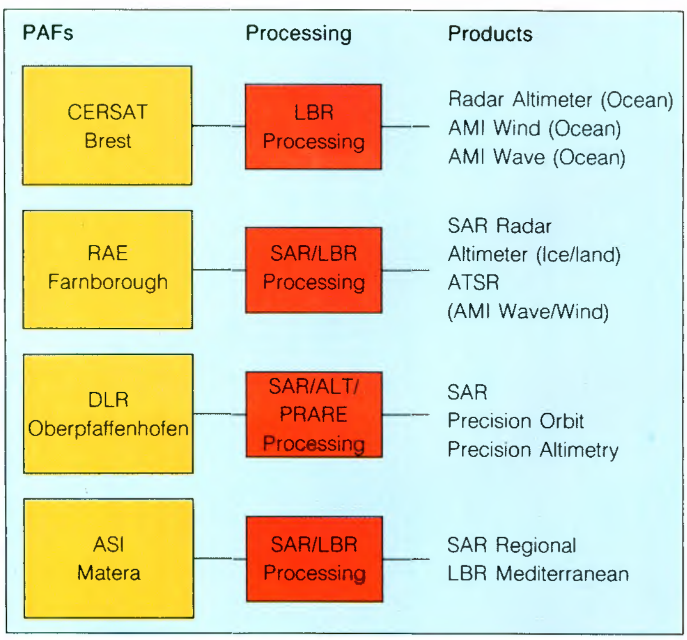

*Typical radar-altimeter ocean echo waveform used to derive the fast-delivery products.*

# Processing and Archiving Facilities

PAFs are located at remote-sensing centres of four ESA member states:
- the French PAF (CERSAT) at Brest, managed by IFREMER
- the Italian PAF at Matera, managed by ASI
- the German PAF at Oberpfaffenhofen, managed by DLR
- the UK PAF at Farnborough, managed by RAE

Their main functions are:
- long-term archiving and retrieval of ERS-1 raw data, auxiliary information and relevant surface data;
- generation and distribution of off-line geophysical and precision products;
- support to long-term sensor performance assessment, calibration and geophysical validation, demonstration campaigns and pilot projects;
- interface with the Central Facility for up-dating of the catalogue and supporting user services.

PAFs will share responsibilities for product generation in order to make more efficient use of national expertise.




*Main responsibilities of the PAFs for processing of off-line products*

# Off-line Products

A wide variety of different off-line products will be generated by PAFs and other national facilities to satisfy specific user requirements.

Categories of off-line products will include:
- basic products of similar quality to fast delivery products (i.e. particularly SAR images);
- precision products using refined auxiliary data such as in-flight calibration data, precise attitude and orbit parameters, ground control points, digital elevation models, etc.;
- thematic products specific to particular applications.

**SAR**
- Annotated Raw Data
- Basic Single-Look Image
- Precision Image
- Geocoded Image

**AMI Wave Mode**
- Precision Imagette
- Image Spectrum

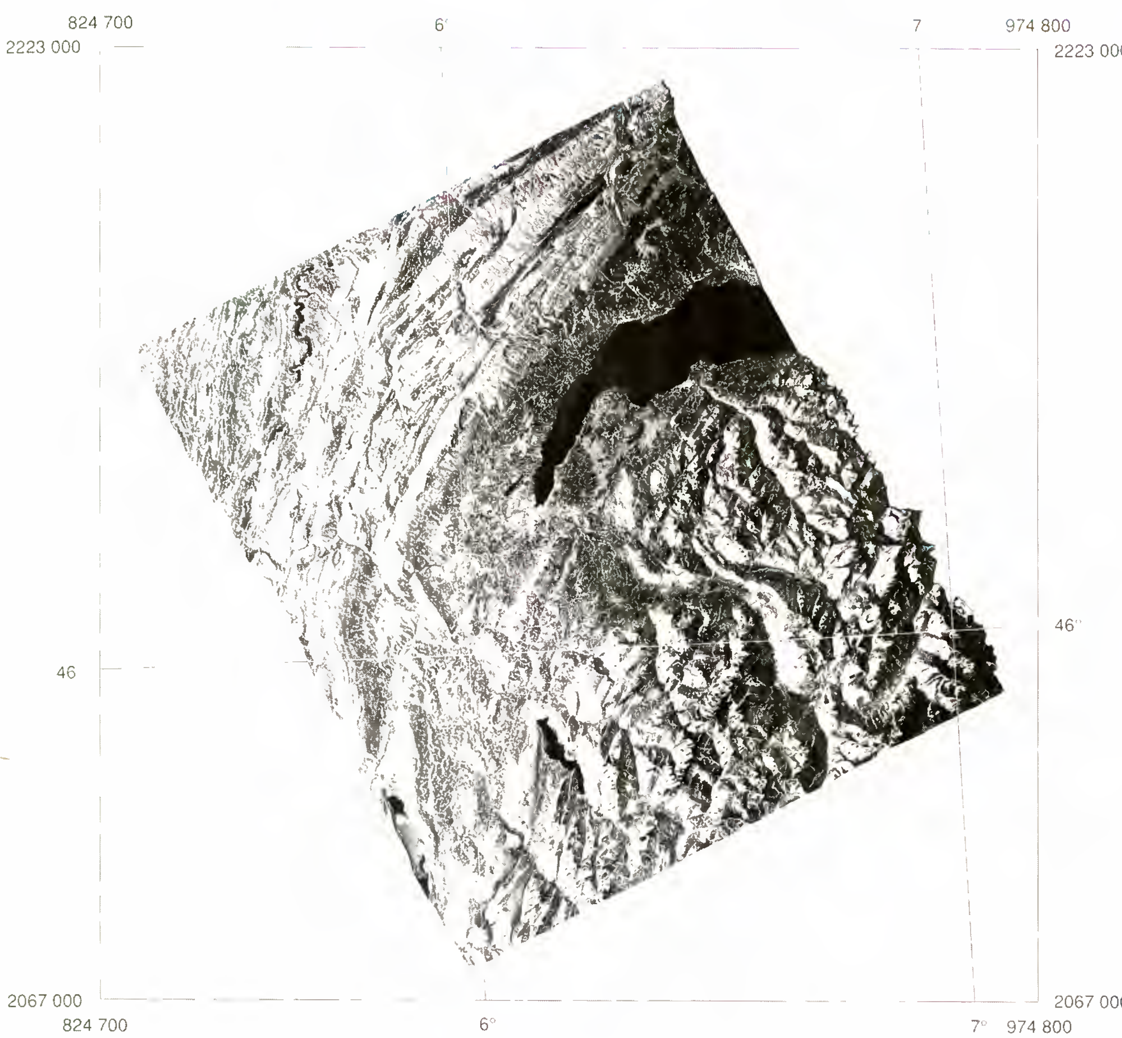
**AMI Wind Mode**
- Sigma-nought Triplets
- Wind Field (large/local scale)

**Radar Altimeter**
- Sensor Record
- Ocean Product
- Augmented Ocean Product
- Sea-Ice Product
- Land-Ice Product
- Land Product
- Lake Elevation
- Sea-Surface Height
- Sea-Surface Topography
- Oceanic Geoid

**ATSR**
- Calibrated Radiances
- Corrected I-R Image
- Sea-Surface Temperature Image
- Cloud-Top Temperature Image
- Precision Sea-Surface Temperature Image
- Microwave Brightness Temperatures
- MW Water-Vapour & Liquid Water Content

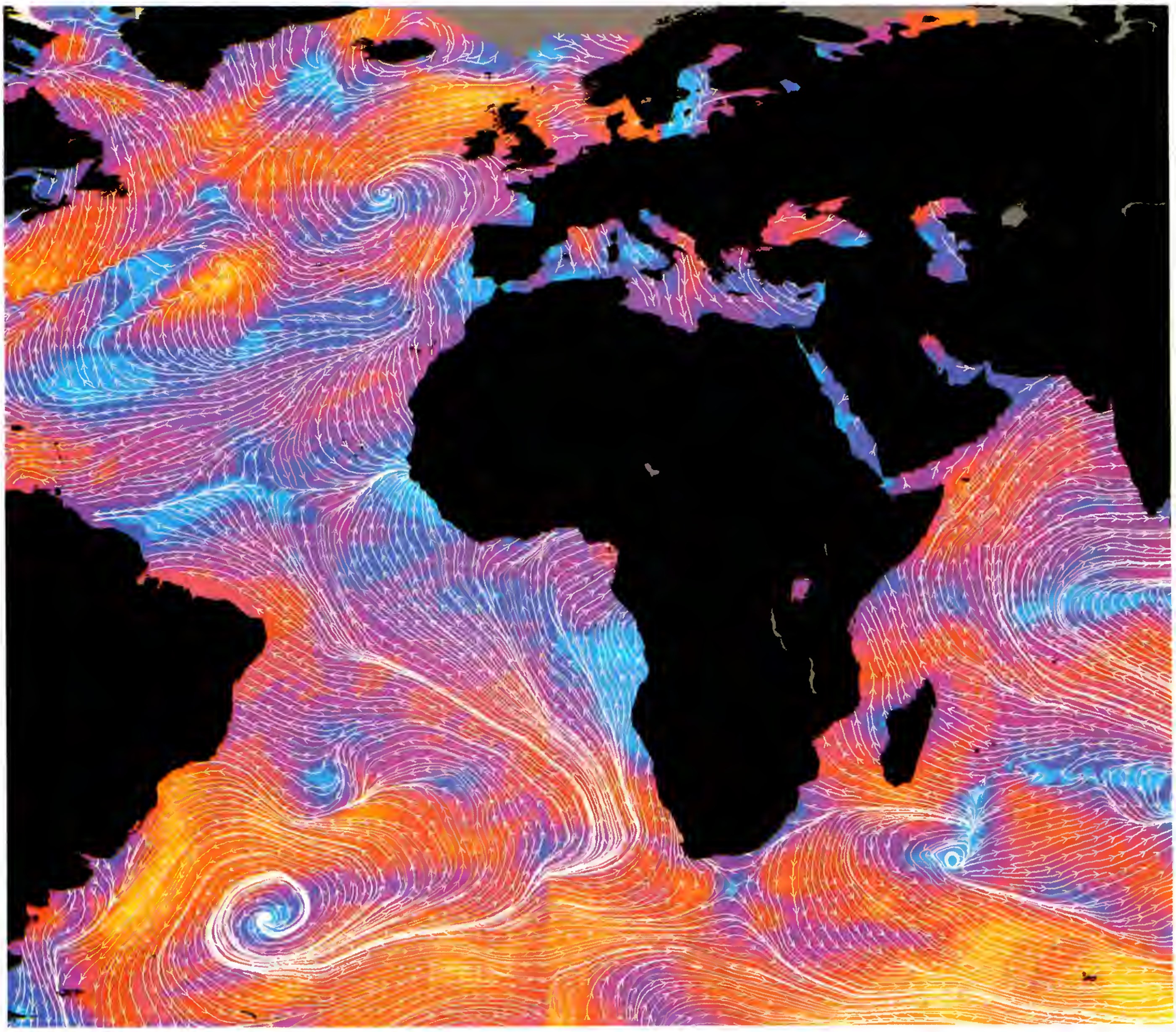
*Preliminary list of off-line products*

Seasat image of the Geneva/Mont Blanc area showing considerable relief distortion.




## Geocoded SAR image

Geocoded product derived from the above image showing how distortions in areas of mountainous or hilly terrain can be removed by complex processing using a digital terrain model. PAFs will generate similar products from ERS-1 SAR images.

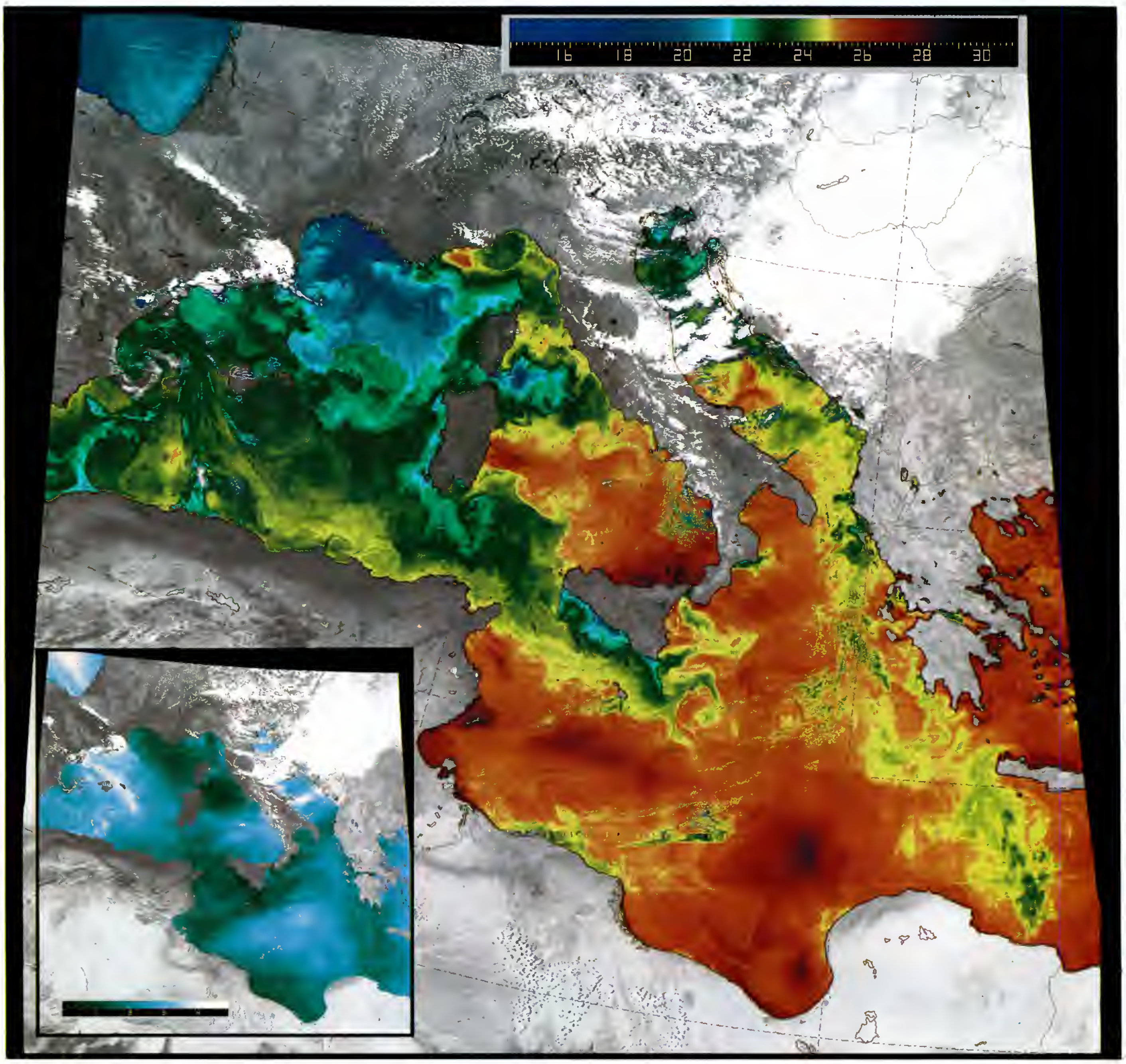


## Large-Area Wind Field

*Surface wind field in the Atlantic on 14 September 1978, as derived from the Seasat scatterometer.* (Courtesy P. Woiceshyn, *JPL*, M. G. Wurtele, *UCLA* & S. Peteherych, *AES/CDN*).

## Ocean Topography

*Precision sea-surface topography for part of the South Atlantic including the mid-Atlantic Ridge, the Walvis Ridge and sea mounts.* (Derived from Seasat data by DUT, The Netherlands).




## Sea-Surface Temperature

*Image of sea-surface temperature of the Mediterranean on 5 August 1987 produced from AVHRR imagery, with an inset showing differences in atmospheric humidity. PAFs will generate similar products to improve accuracy levels from the ATSR.* (Courtesy DLR, Oberpfaffenhofen).

# Central Facility

## Central User Service

The ERS-1 Central User Service will be a real-time management system dedicated to the supervision of all activities concerning ERS-1 mission data acquisition, product generation and dissemination of data and products to the user community. It will integrate all components of ERS-1 ground segment, and provide an efficient centralised set of functions catering to worldwide user needs:

- on-line tools for definition of payload operation plans
- payload data acquisition, production and dissemination management
- a worldwide catalogue of data and products
- product order handling system

*Customer browse facilities at ESRIN.*

## Operations Planning

Central User Services will generate and maintain a Global Activity Plan for the entire mission, covering the future operation of the different instruments and ground facilities. Sections of this global plan will be constantly updated, modified and refined, based on users' requests. The information will be transmitted to the MMCC for definition of the detailed mission operation plan. Following this definition, ground stations will be provided with acquisition schedules for data reception, as well as processing and dissemination schedules for the fast-delivery products.

On-line facilities will provide the user with direct access to both these outline and detailed mission plans.

## Central Catalogue

The ERS-1 Catalogue will provide information on the availability of all data and products, as well as the planned acquisitions. It will be available for worldwide access 24 hours a day.

The user interface will incorporate a powerful information retrieval system, making it possible, for instance, to rapidly identify all data products derived from a specific instrument for a particular area within any specified time frame. Most searches will involve geographical referencing directly by latitute/longtitude or other map co-ordinate systems.

## Browse Service

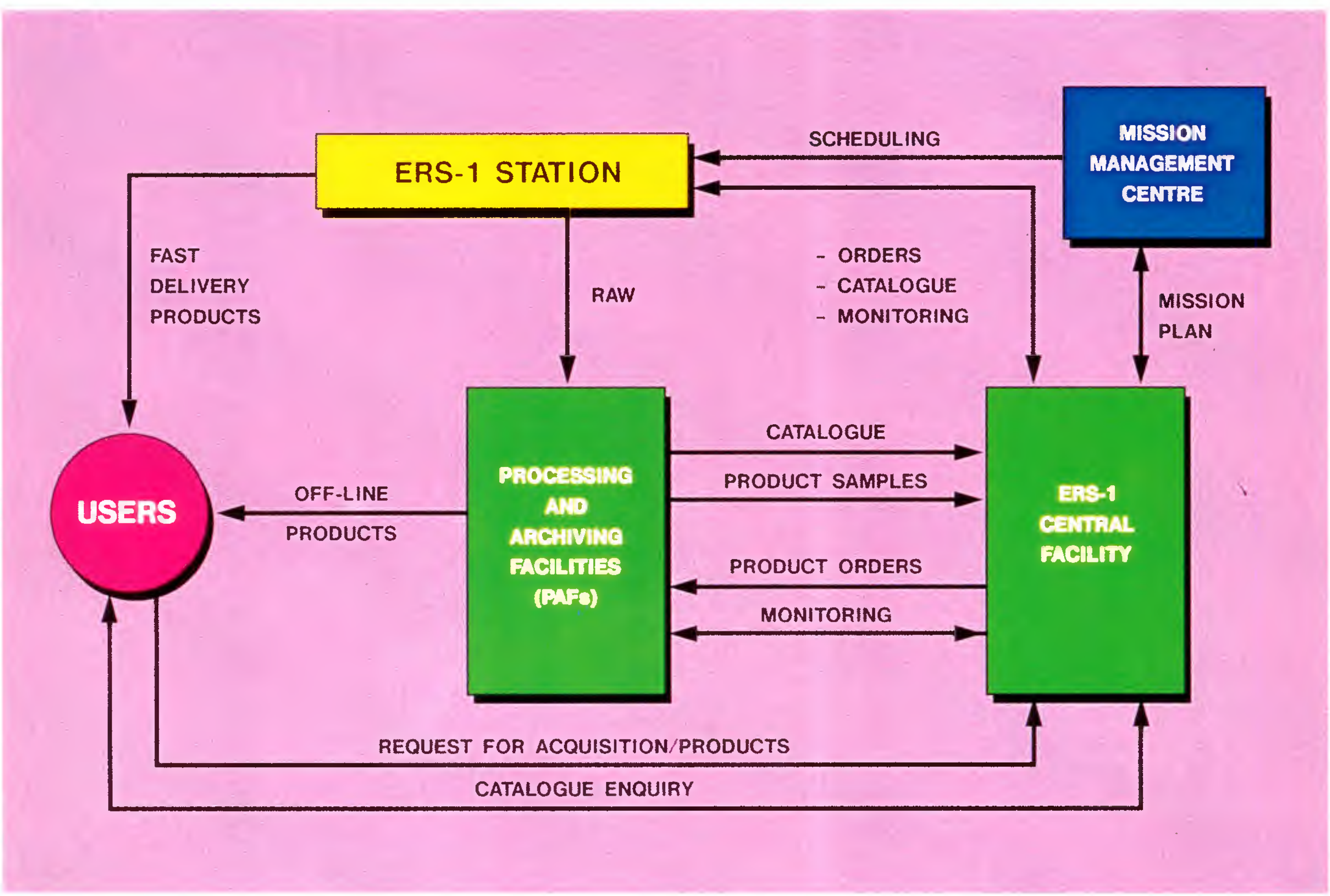
The Browse Service is a local facility allowing visitors access to the Central Catalogue and providing demonstrations of the ERS-1 system capabilities and products. It will provide a centralised archiving facility for mission, system and user documentation, and make available sample products and mission-related information.

## Product Control Service

The Product Control Service is responsible for the co-ordination of activities in the following areas:

- algorithm development and software maintenance
- quality assessment and control
- calibration and validation
- long-term sensor performance assessment.

This will be achieved by routine sampling and evaluation of ERS-1 raw data and products. A historical record will be maintained of all sensor engineering parameters used for product generation and calibration.




*The ERS-1 Central Facility / Users Interfaces*

# Calibration and Validation

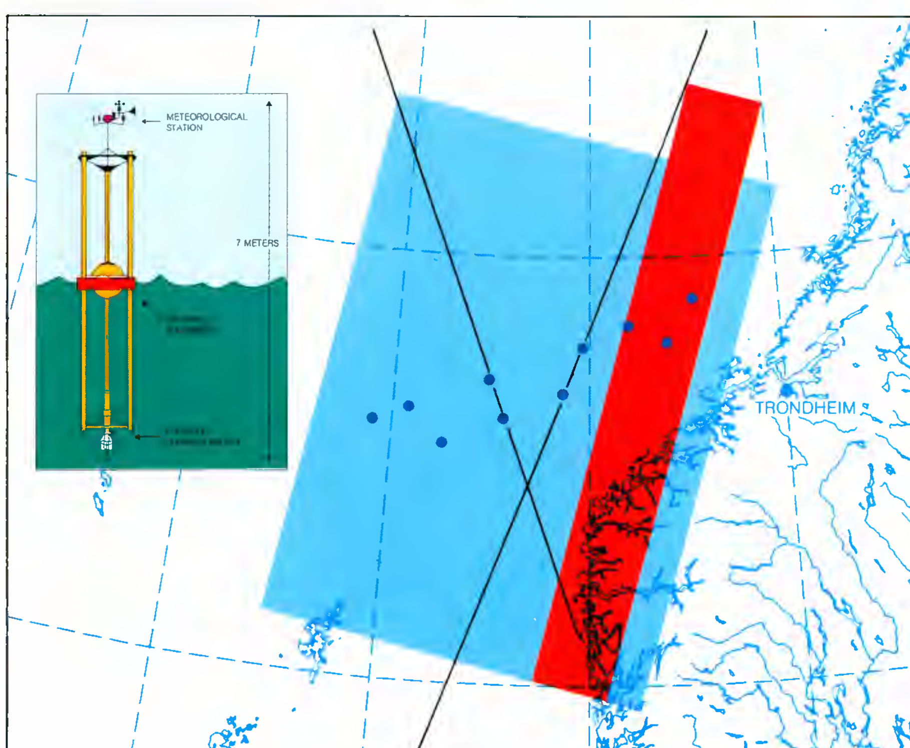
Microwave techniques involve sophisticated processing of the return signals to derive geophysical parameters. The calibration of instruments and long-term verification of geophysical measurements are therefore vital components of the ERS-1 programme. A wide range of activities are planned, including those investigations selected in response to a worldwide ERS-1 Announcement of Opportunity.

*The prototype radar transponder to be used as a calibration target.*

## AMI

The Active Microwave Instrument will be periodically calibrated using ground-based artificial targets, including specially designed transponders.

Geophysical validation experiments will check the radar-derived estimates of surface winds and waves against actual sea surface measurements. An area off the west coast of Norway is to be the primary site, with an array of meteorological and directional wave buoys being deployed for this purpose. There will also be supporting airborne instruments operated during satellite overpasses.




*Wind and omnidirectional wave buoy.*

*Norwegian geophysical validation site showing positions of buoys and coverage zones for SAR Image Mode and Wind Scatterometer (only one pass shown).*

## Radar Altimeter

Height measurements from the Radar Altimeter have a designed long-term stability of 5 cm. The main calibration experiment uses the Venice Tower which is located 15 km offshore and fixed to the sea-bed in 16 m of water. In situ measurement of the sea surface will be undertaken at the time of satellite overpass. A network of five laser ranging stations will be used for the required precise measurement of satellite position.


Radar Altimeter calibration using the Venice Tower and satellite laser ranging stations.


The Venice Tower of the Italian CNR

*Summary of ERS-1 Geophysical Measurements and Performance Parameters*

| Geophysical Parameter | Range | Accuracy | Main Instrument |
|---|---|---|---|
| Wind Field | | | |
| – Velocity | 4 – 24 m/s | ± 2 m/s or 10% whichever is greater | Wind Scatterometer & Radar Altimeter |
| – Direction | 0 – 360° | ± 20° | Wind Scatterometer |
| Wave Field | | | |
| – Significant Wave Height | 1 – 20 m | ± 0,5 m or 10% whichever is greater | Radar Altimeter |
| – Wave Direction | 0 – 360° | ± 15° | SAR Wave Mode |
| – Wavelength | 50 – 1000 m | 20% | SAR Wave Mode |
| Earth Surface Imaging | | | |
| – Oceans<br>– Coastal Zones<br>– Sea-Ice<br>– Land | 100 km | Geometric/Radiometric Resolutions:<br>a) 30 m/2,5 dB<br>b) 100 m/1 dB | SAR Image Mode |
| Altitude | | | |
| – Over ocean | 745 – 825 km | ± 10 cm | Radar Altimeter |
| – Polar Ice-Sheets | | < 1 m | |
| Satellite Range | | ± 10 cm | PRARE |
| Sea Surface Temperature | 500 km swath | ± 0,5 K | ATSR (IR) |
| Water Vapour | in 25 km spot | 10% | μW Sounder |

*Photo credit (Cover)* : John Heseltine *(Winter landscape; View along the cliffs of Normandy coast; Woodland stream)*
Graham Ewens *(Cloud formation at sunset in South Atlantic)*
Martin Dohrn *(Wave and shingle patterns on a beach in Dorset, UK)*
Doug Allan *(Iceberg floating in the Ross Sea, Antarctica)*


| | |
|---|---|
| *Technical Coordination by:* | Mike Wooding & Stefano Bruzzi |
| *with contributions by:* | Evert Attema, Gianna Calabresi, Maurizio Fea, Richard Francis |
| *Edited by:* | Duc Guyenne |
| *Cover design & layout:* | Carel Haakman |
| *Graphics:* | Willem Versteeg |
| *Published by:* | ESA Publications Division, ESTEC, NL 2200 AG Noordwijk |
| *Copyright:* | © European Space Agency 1989 |
| *Price:* | Dfl. 20 (or 10 US$) |

***ESA BR-36 — ISBN 92-9092-019-X*** (November 1989)

**european space agency**
**agence spatiale européenne**
8-10 rue Mario-Nikis,
75738 Paris Cedex15, France