Highlights of the ERS-Envisat Symposium 2000

– The Achievements of ESA's Earth Observation Programme

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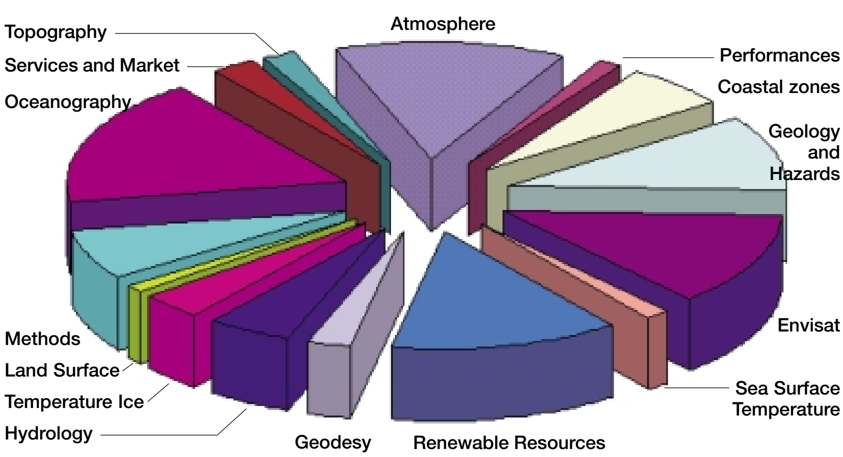
The ERS-Envisat Symposium 'Looking Down to Earth in the New Millennium' – organised by ESA and hosted by Chalmers University of Technology – took place in Gothenburg, Sweden, from 16 to 20 October 2000. This was the fourth ERS Symposium (after Cannes in 1992, Hamburg in 1993 and Florence in 1997) and the first Envisat Symposium, and it was open to all interested parties, from scientists to operational commercial users and service providers. It provided the 540 participants with an opportunity to familiarise themselves with the current status of ERS applications and the capabilities of the follow-on Envisat mission now being readied for launch in mid-2001, and to provide feedback from their own particular domains.

Introduction

The Gothenburg Symposium provided an ideal opportunity to review the European Remote Sensing Satellite (ERS) Programme's achievements in terms of both science and applications after close to ten years of satellite data exploitation. In addition, it provided a timely opportunity to review the imminent Envisat mission, its data products, and the approaches being applied to calibration and validation. The Symposium's Scientific Committee, composed of eminent scientists and ESA experts, had evaluated 460 submitted Abstracts in establishing the final programme. Following the themes of the Envisat Announcement of Opportunity, they grouped the accepted contributions into 42 Sessions (Figs. 1 and 2). Each session was chaired by a leading scientist in that particular field of application, and co-chaired by an ESA Earth-observation expert.

This article presents a summary of the highlights of the Symposium, grouped under the themes of Atmosphere, Land, Ocean and

Figure 1. Overview of the Symposium content



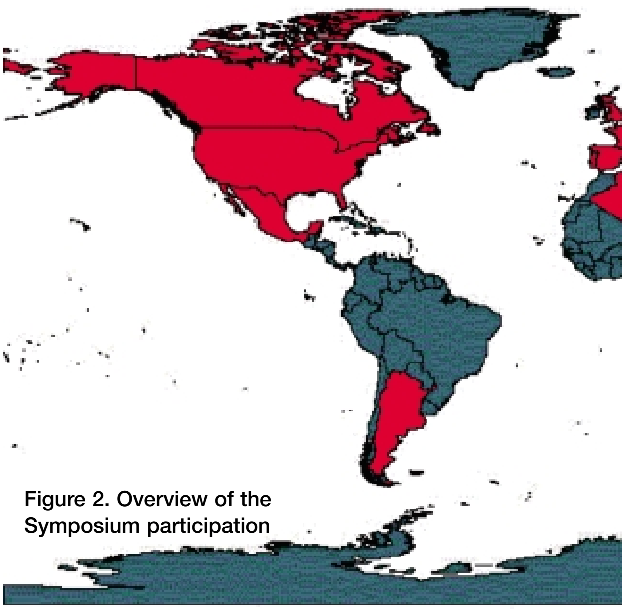


Figure 2. Overview of the Symposium participation

Envisat. The detailed summaries and recommendations prepared by the chairs and co-chairs of each Session are being published in the Symposium Proceedings (ESA SP-461, available from ESA Publications Division).

Highlights of the Atmosphere Session

"A Growing Community using GOME Data"

A total of 58 presentations (34 papers and 24 posters) were dedicated to the demonstration of scientific and application achievements by using the data from the ERS-2 Global Ozone Monitoring Experiment (GOME) instrument. GOME, a forerunner of future European atmospheric satellite instruments, is still the only spaceborne spectrometer capable of observing the entire spectral range from 240 to 790 nm with high spectral resolution. The presentations covered the retrieval of ozone, UV radiation, trace gases other than ozone, the characterisation of cloud and aerosol information, calibration and data assimilation techniques.

Ozone
GOME total ozone measurements were used to detect a mini ozone hole over northwestern Europe on 30 November 1999, and to observe the deepest ozone hole ever over Antarctica in the third quarter of 2000. Besides the total ozone, ozone profiles are derived from the GOME spectra to provide height-dependent ozone information down to the Earth's surface. Improved processing schemes have demonstrated the possibility to provide this information to users in near-real-time, so that it can be used to support measurement campaigns and for assimilating ozone data into numerical forecasting models (Fig. 3).

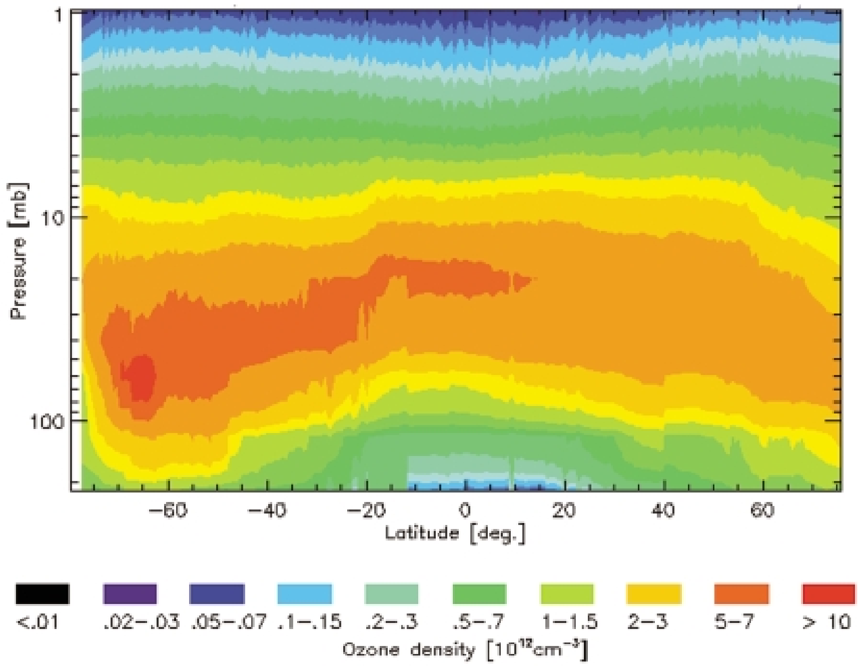
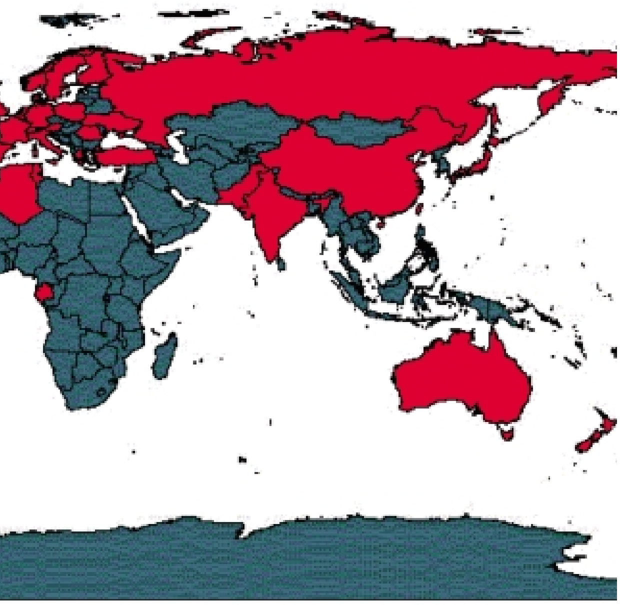


Figure 3. GOME ozone profiles retrieved within 3 h from one ERS orbit on 5 October 2000 (courtesy of Royal Netherlands Meteorological Institute)

Atmospheric constituents
Owing its nadir-viewing geometry, GOME provides the possibility to measure atmospheric constituents both in the troposphere and in the stratosphere. Formaldehyde (HCHO) in the troposphere could be retrieved for the first time on a global scale from space. The detection and the monitoring of SO_2 emissions due to volcanic events/industrial pollution and NO_2 emissions due to biomass burning/industrial pollution extracted from experimental retrieval algorithms down to the troposphere has been demonstrated. This newly-gained capability of observing tropospheric trace-gas distributions is a revolutionary step in terms of technical development and will lead to a significant enhancement of our ability to investigate the chemistry and physics of the troposphere (Fig. 4).

Minor trace gases, like BrO in the troposphere or OClO activation in the stratosphere, responsible for ozone depletion have been successfully retrieved from GOME measurements, providing greater insight into ozone chemistry (Fig. 5).

Global maps of the H_2O column above oceans and land have been retrieved. In the future, a tropospheric profile with limited spatial resolution will also be available. The feasibility of generating global and regional UV radiation maps was demonstrated. In combination with assimilation models, this will facilitate future UV forecasting services.



Algorithms for the retrieval of various types of cloud and aerosol information are increasingly based on instrument synergy. New cloud algorithms were presented for extracting cloud

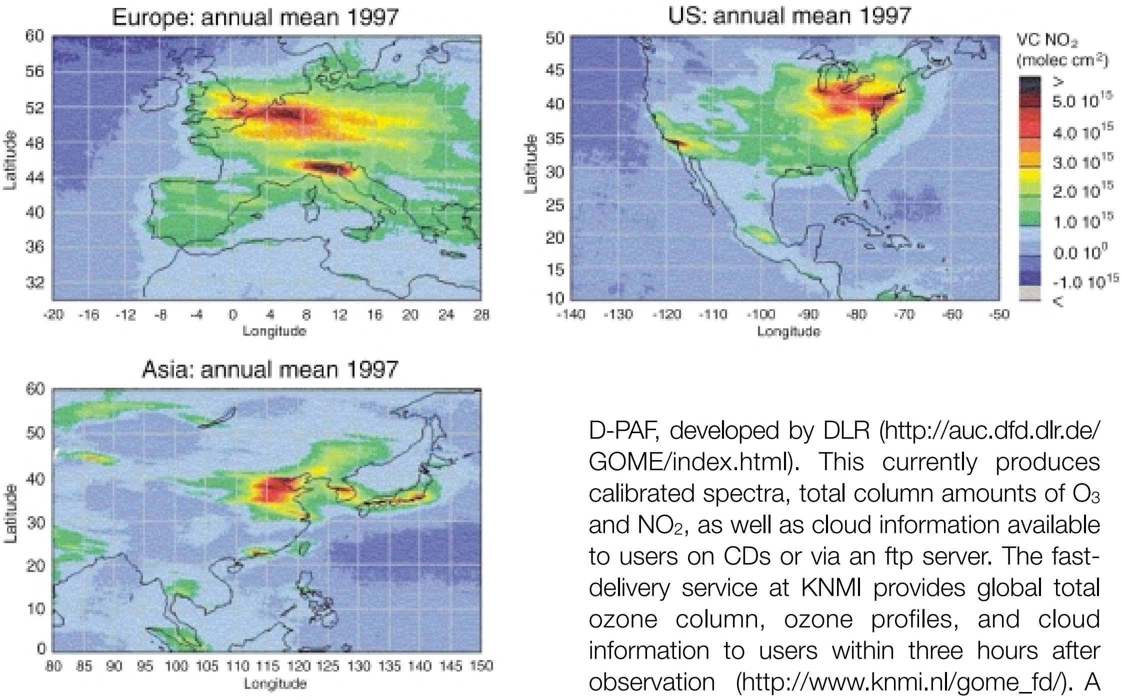


Figure 4. Regional yearly maps of nitrogen dioxide from GOME, showing air pollution from emissions over industrial areas (courtesy of Univ. of Bremen)

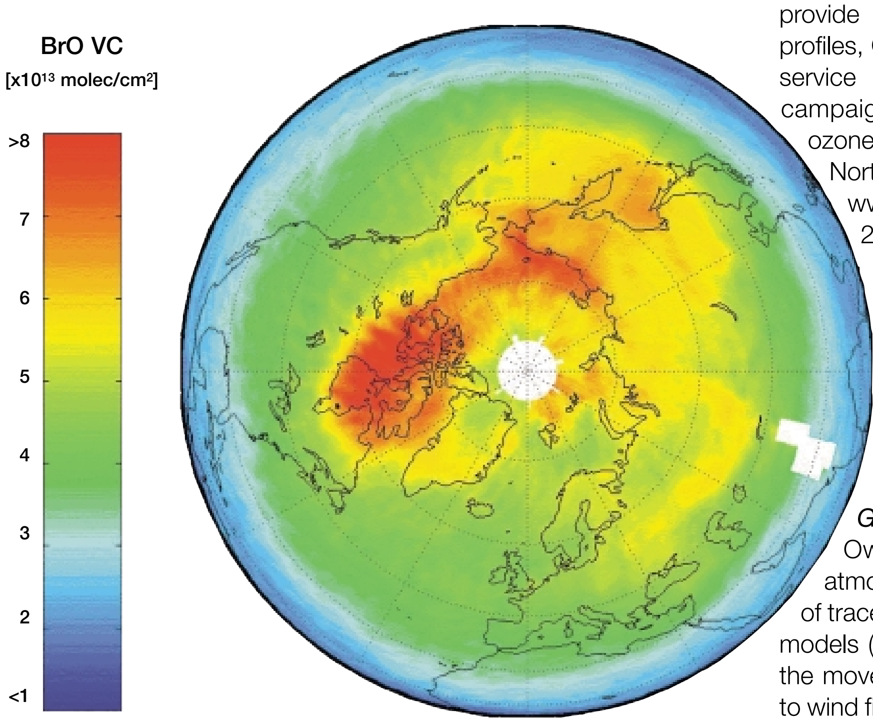


Figure 5. Monthly GOME bromine monoxide map over the North Pole for March 2000, showing tropospheric BrO plumes (courtesy of Belgian Institute for Space Aeronomy)

fraction and cloud-top height from GOME, Sciamachy and ATSR. Meteorological institutes have evaluated sample products. Further investigations will require the refinement of the definition of cloud parameters, and consolidation of libraries of aerosol classes, in order to simplify comparisons between different instruments and techniques

Services

An important issue has been the setting up of new data-delivery services in addition to the existing offline operational processing at the D-PAF, developed by DLR (http://auc.dfd.dlr.de/GOME/index.html). This currently produces calibrated spectra, total column amounts of O_3 and NO_2, as well as cloud information available to users on CDs or via an ftp server. The fast-delivery service at KNMI provides global total ozone column, ozone profiles, and cloud information to users within three hours after observation (http://www.knmi.nl/gome_fd/). A service has been set up by the University of Bremen (supported by ESA and DLR) to provide preliminary GOME data (e.g. ozone profiles, OClO, BrO, etc.) in near-real time. This service supports international measurement campaigns for investigating stratospheric ozone at mid- and high latitudes in the Northern Hemisphere in springtime (http://www. iup.physik.uni-bremen.de/gomenrt 2000/).

New radiative transfer models, generating simulated backscatter intensities and weighting functions, have been developed and applied to improve GOME retrieval algorithms (e.g. Air Mass Factor calculation).

GOME data assimilation

Owing to the high variability of the atmosphere, the generation of global maps of trace gases is not a trivial task. Assimilation models (e.g. 4-D VAR) are taking into account the movement of the measured trace gas due to wind fields related to different heights, and its dependence on the actual chemical state of the atmosphere. It was demonstrated that by using GOME ozone measurements such a tool is able to propagate information into regions where there are no measurements, thus producing a consistent picture of the entire globe. Furthermore, reliable ozone forecasting over a time period of about 5 days has been demonstrated.

All of the experience that has been gained in the exploitation of GOME data can be directly applied to the use of the future European atmospheric instruments on Envisat: GOMOS, MIPAS and Sciamachy.

Highlights of the Land Session

"A Wide Range of Land Applications"

The widespread use of space-based Earth observation over land – in particular the use of ERS SAR/InSAR data, – was demonstrated by the large number of presentations in this Session (131 papers). The tandem exploitation of the ERS-1 and ERS-2 satellites (1 day repeat cycle) has provided a unique data set for the development of the repeat-pass interferometry (InSAR) technique.

Seismic studies
SAR interferometry (InSAR) has allowed scientists to obtain surface-displacement maps and to construct complex fault models that could not be generated from seismological data and conventional geodetic techniques alone. SAR data have been a primary source of information after earthquakes in remote areas where little or no in-situ information was available, such as Western China, Iran and Tibet. Research is in progress to overcome the loss of coherence in the vicinity of the surface rupture. A major development has been the successful use of InSAR data to study interseismic deformation, the averaging of several interferograms allowing a detection level of better than 1 mm/year in line-of-sight change (Fig. 6).

Volcano monitoring
A number of attempts based on the processing of InSAR archived data have been made to monitor volcanic deformation. One of the examples, the computation of a series of differential interferograms has shown the deformation on the surfaces of four volcanoes in Alaska over several multi-year intervals in the 1990s.

Landslides
The Symposium also illustrated the state of art of SAR applications for landslide mapping and monitoring, focussing particularly on surface characterisation and the measurement of slow slope movements by means of SAR interferometry. ERS-1/ERS-2 tandem data sets, as well as 35-day repeat interferometric data sets, have helped to map landslides.

Land subsidence
The technique of SAR differential interferometry has been used for the monitoring of subsidence created by water/oil pumping, mining and excavation. Subsidence rates ranging from millimetres to more than 1 m per year have been observed. GPS measurements and mathematical models were used to validate the measurements. The results clearly show the considerable potential of remote sensing.

Some limitations of the SAR interferometric technique may be overcome by the emerging Permanent Scatterers technique pioneered by Politecnico di Milano, which is ready to be used in pre-operational applications where a long time-series of SAR images is available for the area of interest (Fig. 7).

Forest mapping
ERS InSAR (tandem coherence 1-day) products were shown to be an excellent Earth-observation product for forest/non-forest delineation. It was also shown that for some special meteorological conditions, ERS coherence is also correlated with the boreal forest stem volume. An extensive example was presented from the SIBERIA project (SAR Imaging for Boreal Ecology and Radar Interferometry Applications), which aimed to map the central-Siberian forest using three Earth-observation radar satellites. This was a joint effort by the German Aerospace Centre (DLR), ESA, and the Japanese Space Agency (NASDA) to collect ERS-1 and -2 and JERS-1 data via a mobile receiving station located in Mongolia. More than 550 ERS scenes and 890 JERS-1 scenes were used to demonstrate the semi-operational use of radar remote sensing for very-large-area forest mapping. The final results, derived from ERS-1/ERS-2 tandem coherence and JERS intensity, include geo-referenced maps with six land classes, three of which indicate different levels of timber volume (Fig. 8).

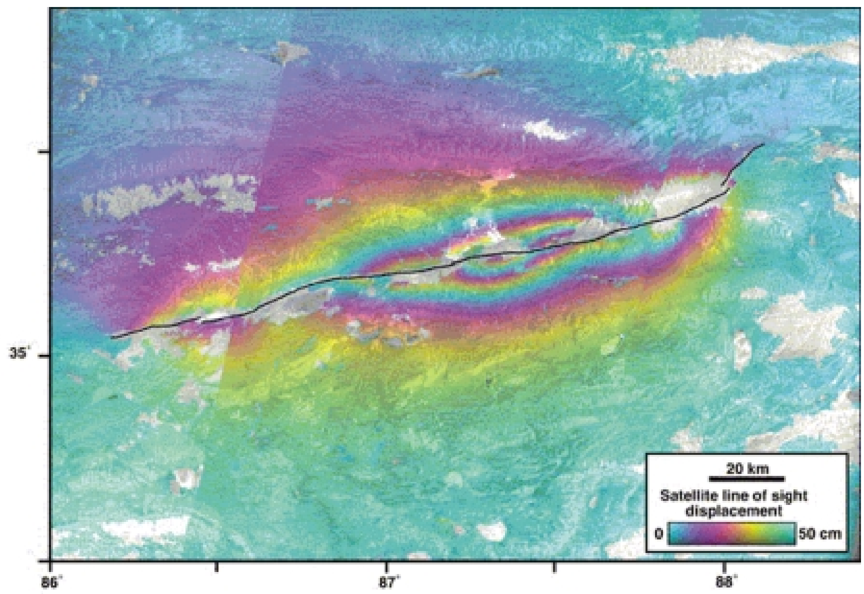


Figure 6. Three-track mosaic covering the 170 km-long section of the fault that ruptured during the Manyi earthquake (Tibet) on 8 November 1997 (courtesy of Jet Propulsion Laboratory)

Damage assessment
ERS coherence derived using the tandem data was revealed to be an excellent tool for

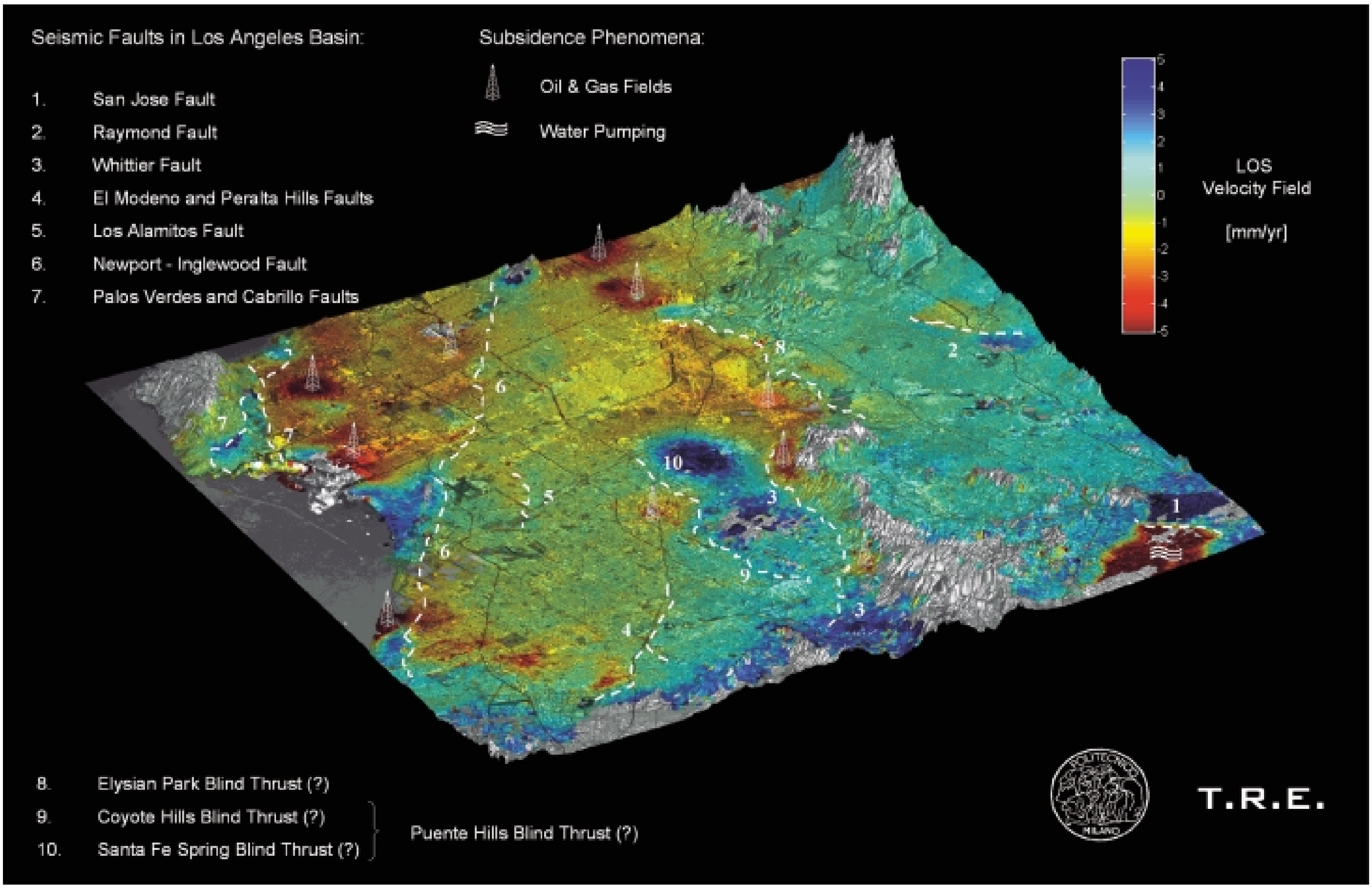


Figure 7. Subsidence map of the Los Angeles area obtained by applying the Permanent Scatterers technique to 56 ERS images. It shows the average subsidence rate, due mainly to oil/gas extraction, water pumping and seismicity, over the period 1992 to 1999. The colour scale indicates motion of up to 5mm/yr with an accuracy of better than 1mm/year (courtesy of Politecnico di Milano, TRE)

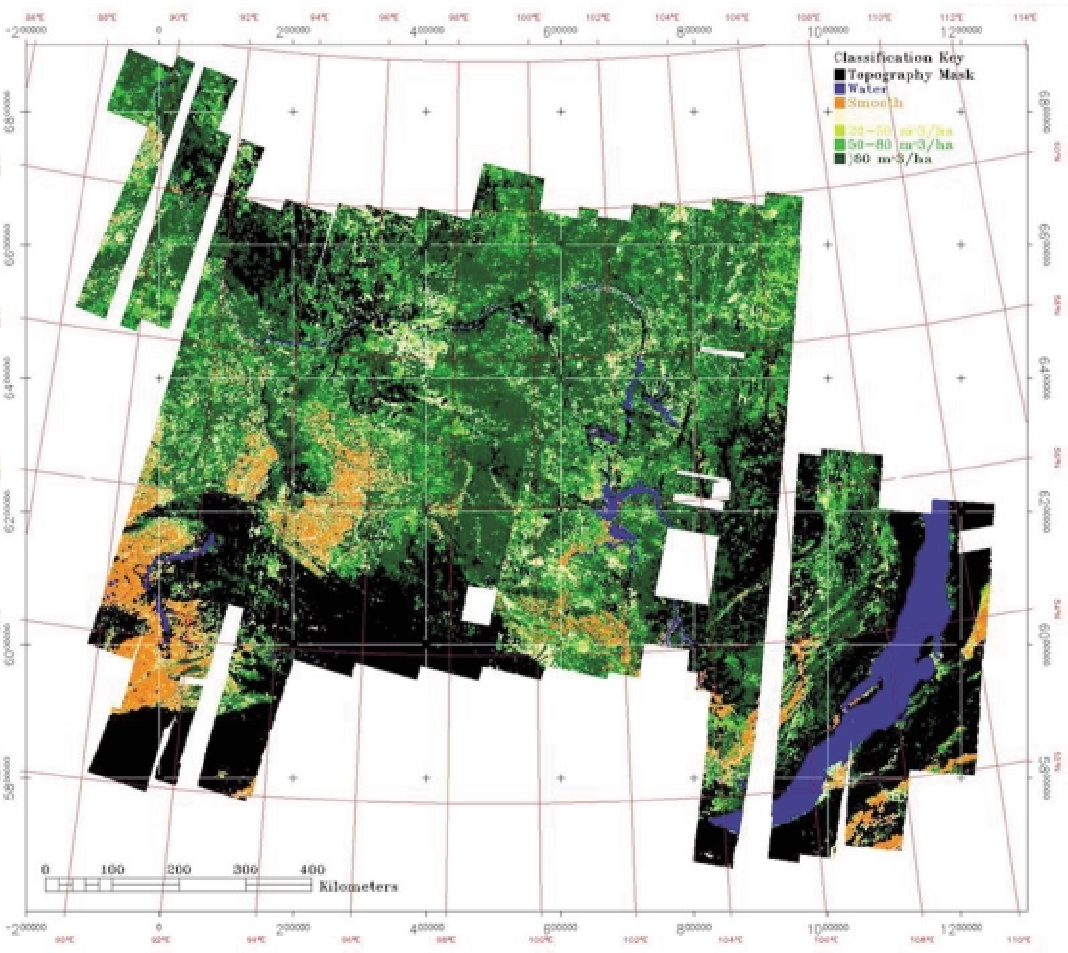


Figure 8. Mosaic image showing forest stem volume and land use in the Siberian forest, derived from ERS-1/ERS-2 tandem coherence and JERS intensity (courtesy of EU CEO Project, SIBERIA)

mapping burnt areas (Canada and Madagascar) and for assessing forest damage due to storms (Switzerland). The examples presented illustrated that this approach has potential for service development (Fig. 9).

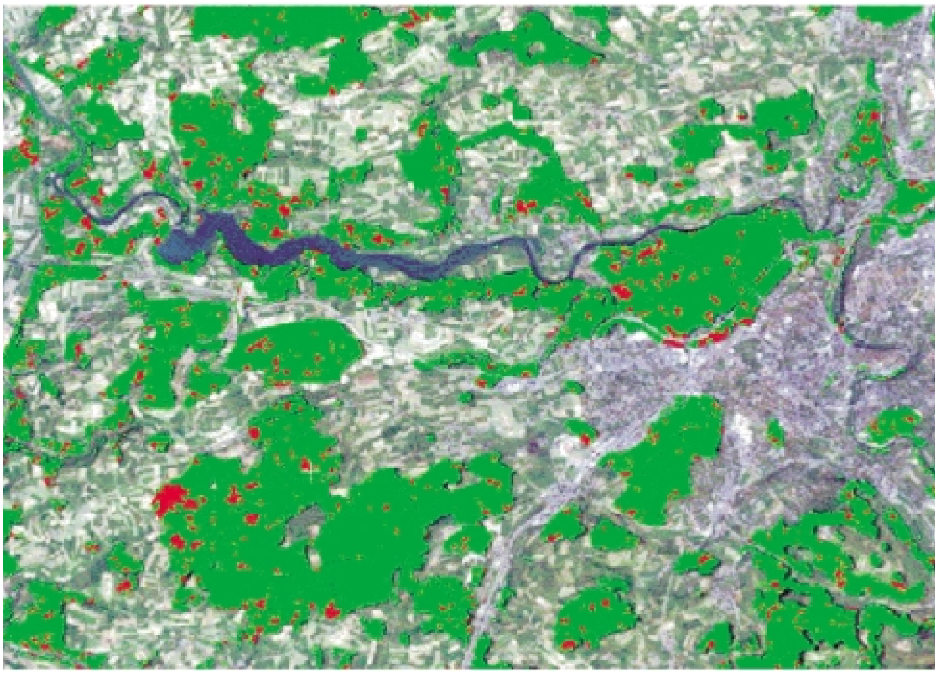


Figure 9. Storm-damage map of Switzerland, from winter 1999/2000, derived from ERS SAR tandem coherence combined with a Landsat TM image as background. Forested areas are in green and damaged forest areas are in red (courtesy of Gamma Remote Sensing, Spot Image, Swiss Federal Institute of Technology Zurich, and SERTIT)

Flood mapping and soil-parameter retrieval

The flood-application presentations demonstrated the contribution that ERS SAR data can make to the development of an operational flood-management information system. It has been shown that it is possible to produce SAR-based flood-extent maps. The synergy of using SAR-based flood-extent maps with Very High Resolution (VHR) optical data for the production of precise Land-Use Maps brings a significant improvement in terms of damage assessment and provides valuable information for the visualisation of the flood damage (Fig. 10). In addition, historical series of ERS SAR data are proving to be an essential information source for flood prevention and are serving as reference data for the elaboration of flood-prevention plans.

The use of multi-polarisation SAR data for soil-roughness assessment was presented, along with a promising technique for retrieving roughness from ASAR data. The use of spatial models of soil-vegetation-atmosphere (SVAT) processes, based on realistic-vegetation growth models, has been successfully applied for retrieving the soil moisture beneath vegetation.

Rice mapping and monitoring

Rice-crop mapping and monitoring appears to be one of the main agricultural applications for ERS SAR data. Its potential for this application had already been demonstrated in the past. A major step towards operational monitoring has been the development of user tools and the transfer of knowledge to users. Algorithms and processing chains have been set up for rice mapping and yield prediction. It is now possible to achieve mapping within a few days after satellite data acquisition. Future developments will focus on methodological refinements for large-scale mapping and data assimilation into crop-growth models.

Snow mapping and snow-melt runoff

Time sequences of ERS SAR data have been incorporated into an automatic classification algorithm to generate precise snow maps. These maps have then been applied successfully for accurate real-time forecasting of snow-melt run-off in mountainous areas, confirming the high operational potential of this technique (Fig. 11).

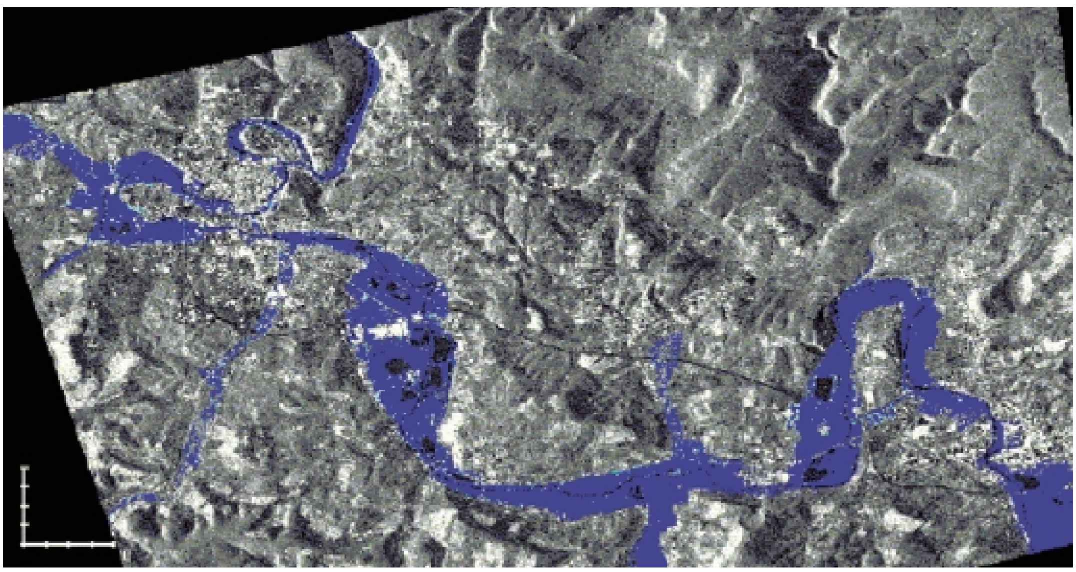


Figure 10. Flood-extension map of a portion of the River Meuse (F), which was subject to flooding in 1993/94 (blue) and 1995 (cyan). The map was generated from a multi-temporal combination of ERS SAR images (courtesy of SERTIT)

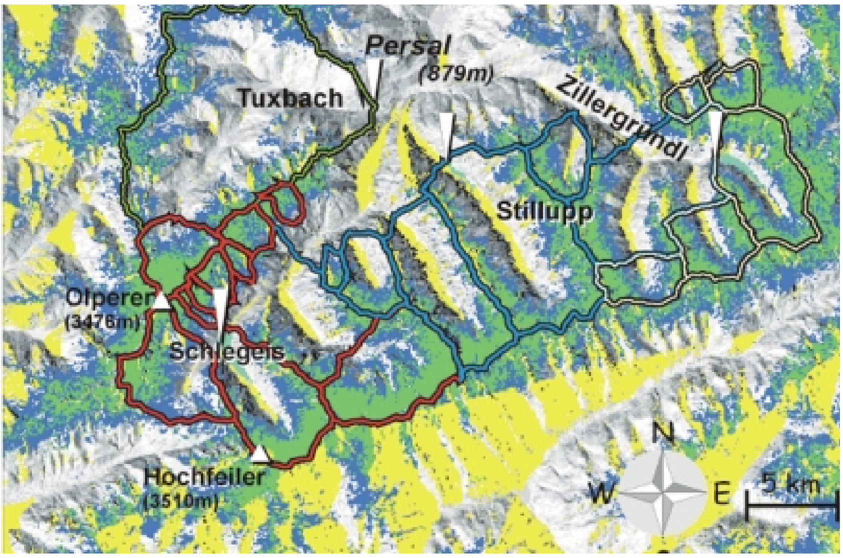


Figure 11. Snow map generated from ERS SAR ascending and descending images. The snow extent on 1 May 2000 is in blue and green, that on 6 June 2000 is in green, and areas where no information could be retrieved are in yellow (courtesy of Univ. of Innsbruck and SCEOS)

Ice mapping
Thanks to the combination of data from ERS's InSAR and Radar Altimeter, changes are being detected after several years of observation in the glaciers in West Antarctica. The benefit of reliable time series of data for monitoring the subtle changes occurring in the polar ice sheets has been amply demonstrated. An example was presented for Svalbard in Norway, where a sequence of interferograms over a glacier covering a period from 1992 to 1998 showed the complete cycle of a glacier surge, from initiation through fast flow to quiescence (Fig. 12).

Topography
The generation of accurate height measurements from both the Radar Altimeter and SAR for topography mapping continues to be demonstrated for large areas. ERS Radar Altimeter ice-mode data were shown to provide accurate terrain-height information (70% of cross-over measurements agree to < 5 m). A Digital Elevation Model has been generated for the whole of the British Isles, using ERS tandem interferometry. The DEM generation process itself is fully automatic and the model has been validated as having a typical accuracy of 8–14 m rms. The resulting DEM is being used successfully in both hydrological and geological applications.

ERS tandem data have also been used successfully to produce a wide-area DEM for the telecommunications sector in Switzerland. The customer has validated the product.

Highlights of the Ocean Session

"Development of New Services"

ESA Earth-observation data are being used operationally, and have been demonstrated to be a valuable source of information, for coastal-zone mapping and monitoring.

Service development
ERS SAR data have been used to update coastal maps for areas where SHOM (French Marine Mapping Agency) has mapping responsibility. As an example, a 1:50 000 map of the coastal region around Cayenne, in

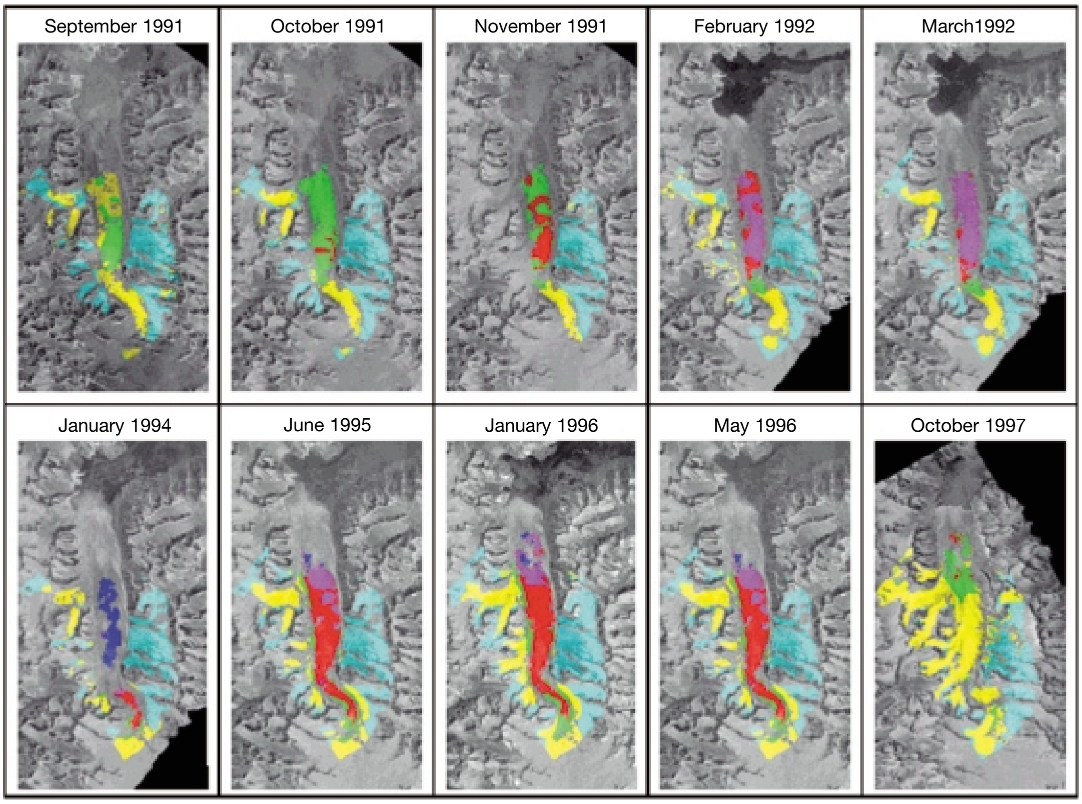


Figure 12. Temporal sequence of geocoded displacement maps of a glacier in Svalbard (24 km x 45 km). The magnitude d (in m/day) of the three-dimensional displacement rate is shown with the following colour scale: d < 0.1 cyan, 0.1 < d < 0.4 yellow, 0.4 < d < 0.7 green, 0.7 < d < 1 red, 1< d < 1.3 violet, d > 1.3 blue (courtesy Univ. of Wales, Gamma Remote Sensing, Univ. of Leeds)

French Guiana, has already been issued by SHOM. Further work is in progress, including an analysis of the legal implications inherent in the use of Earth-observation data for chart and map updating (Fig. 13).

The Dutch company ARGOSS has applied the bathymetry assessment system based on the use of ERS SAR data in Indonesia. The average measurement error was found to be around 10–11 cm. Discussions with business partners are underway and it is expected to start full operations in 2001.

The Tromsø Satellite Station (TSS) in Norway provides an operational oil-spill detection service for customers from both government and offshore oil companies. This was developed using ERS and is based on joint use of Radarsat and ERS SAR imagery. The availability of Envisat is expected to make a significant contribution to the service's capability in terms of both update times and service area covered. A change in legislation, which requires oil companies to undertake environmental-monitoring activities, is expected to add to demand for this service.

NOAA is presently demonstrating near-real-time services to a range of government users in Alaska, including the Department of Fisheries and the National Weather Service. The present services cover coastal wind-field data and fishing-vessel surveillance based on Radarsat. It is planned to use ASAR data once Envisat is launched and to expand the service provided to include sea/river ice monitoring and oil-spill surveillance. About one year will be required to investigate the capabilities of ASAR before joint exploitation of ASAR and Radarsat is possible.

Ocean dynamics
The Ocean Dynamics session demonstrated that projects are moving from instrument-capability to application demonstration. Results were presented from a variety of missions (ERS, Topex Poseidon, GFO) as well as from different instruments on board ERS-2 (RA, ATSR, SAR), dealing with oceanographic phenomena at different spatial and temporal scales.

The continuing improvement in the ERS Altimeter data, both in terms of operational timeliness and ability to identify processes that would not have been possible even in the recent past, was highlighted by the ocean-dynamics community. A noteworthy illustration is the real-time monitoring of the tropical Pacific. Meanwhile, the 1997 El Niño data is still being used for research in this field (Fig. 14). There was also a presentation of a novel synergistic use of altimetry, sea-surface temperature, and ocean colour. A new automated method has been used to identify Rossby waves, a special class of planetary waves, and calculate their phase speed.

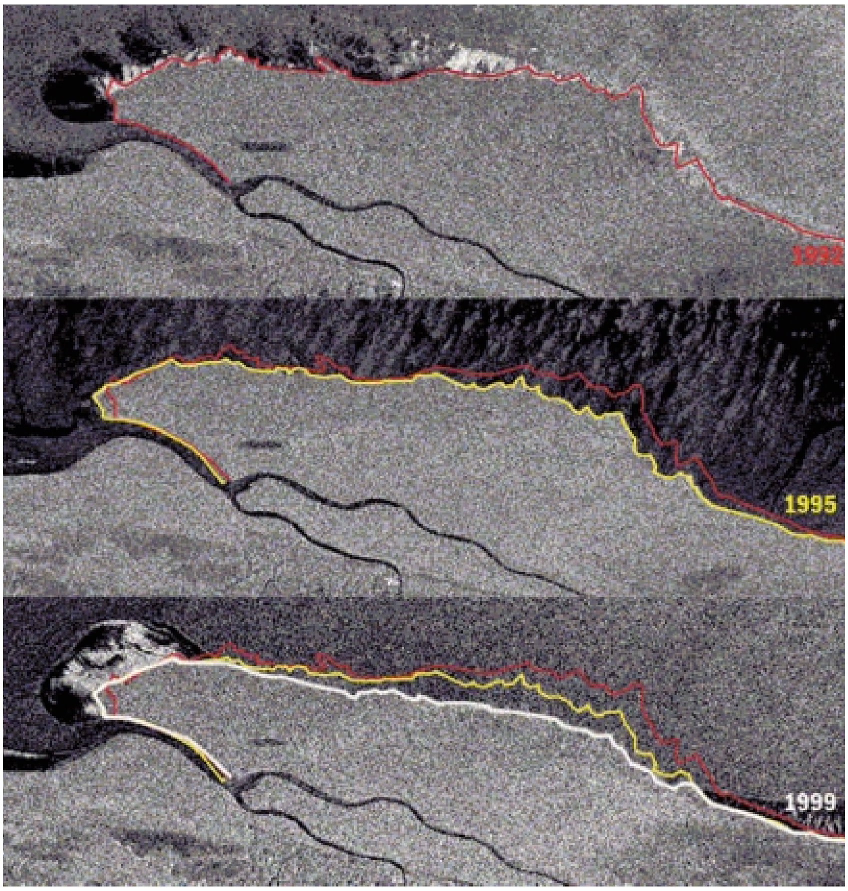


Figure 13. This sequence of ERS SAR images acquired between 1992 and 1999 shows the evolution of the coastline in French Guiana, with displacements ranging from hundreds of metres to several kilometres (courtesy of University of Marne La Vallée)

Significant progress has been made in the classification of different types of sea features commonly observed in SAR images (Fig. 15). The Norwegian Defence Research Establishment has been acquiring images along the coast of Northern Norway since the early days of the ERS-1 mission. The continuous and long-term nature of their SAR image analysis for the continental shelf gives the possibility to assess the signatures and observabilities of various features during the various seasons of the year. Quantitative information extraction is often dependent on multi-sensor approaches using SeaWiFS, AVHRR and/or combinations of SAR data with ocean models. Frequent coverage of selected sites should be pursued to learn more about the variability of the features and their signatures in SAR images.

Wind and waves
Scientific progress was demonstrated for wind- and wave-field retrieval from the three main sensors – altimeter, scatterometer and SAR – in both image and wave mode (Fig. 16). Altimeters have provided estimates of the wind speed and the significant wave height for potential operational services. The Ocean and Sea Ice Satellite Application Facility (OSI SAF

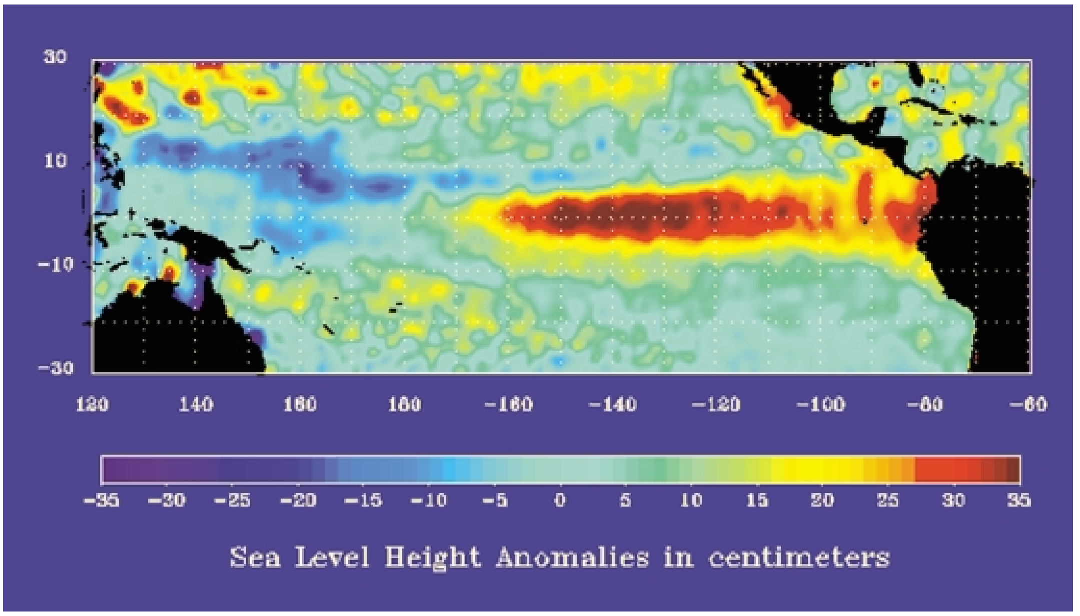


Figure 14. Sea-level elevation anomalies measured with the ERS-2 Radar Altimeter over the tropical Pacific during the last El Niño event. Sea-level anomalies are averaged over 7 days with 1 degree resolution. There is an abnormally high sea level near the West Coast of South America along the Equator (red, +35cm), which leads to the disappearance of fish and a radical switch in the regional climate in terms of rainfall. At the same time, the sea level drops in the Western Equatorial Pacific (deep blue, -20cm), where extreme droughts devastate crop yields and increase fire hazards (courtesy of DEOS, Delft University, and ESA/ESRIN)

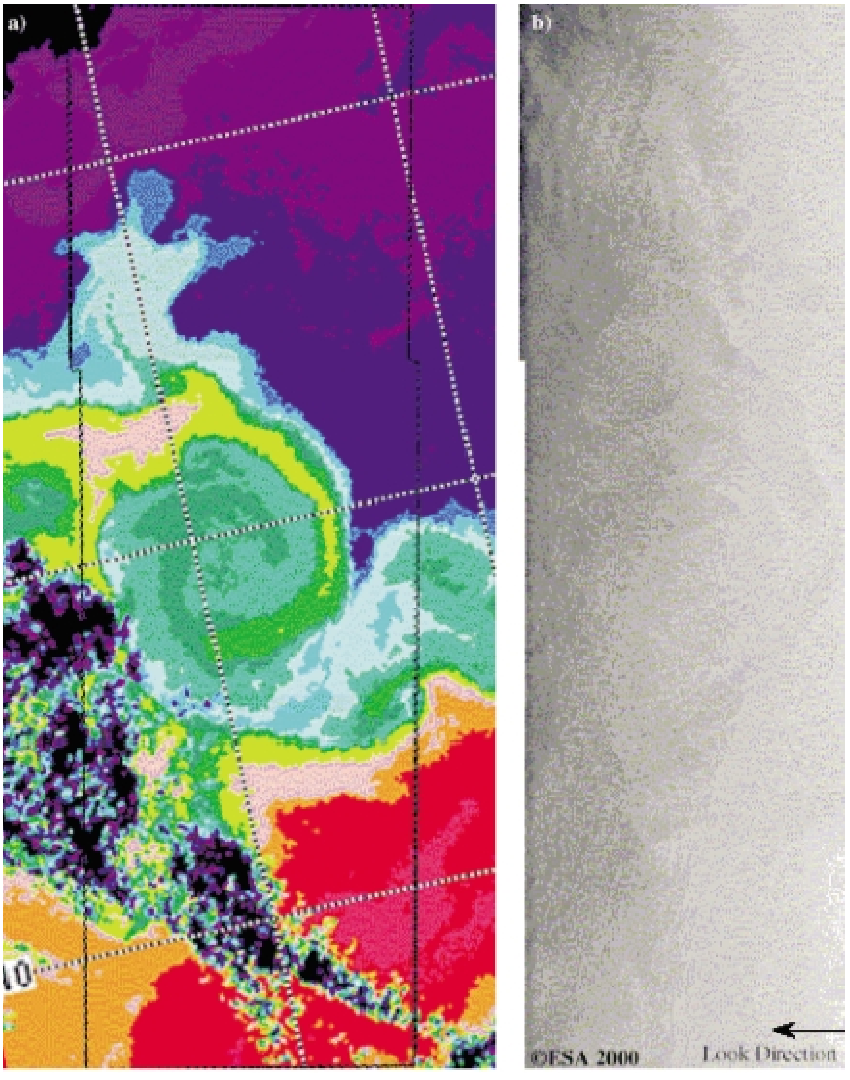


Figure 15. A NOAA-15 AVHRR thermal image and an ERS-2 SAR image acquired in February 2000. Both images show the features of mesoscale surface circulation in the northern portion of a subarctic front south of Vladivostok. Colour scale: violet: 0^0C, blue: 1°C, green: 2°C , yellow: 3°C, red: 4°C (courtesy of Pacific Oceanological Institute, Russian Academy of Sciences)

supported by Eumetsat and hosted by MeteoFrance) is preparing a pre-operational wind product based on ERS-2 scatterometer data. Preparatory work is in progress for the wind product from the ASCAT scatterometer to be flown on Metop. The potential of ERS SCAT fast-delivery products for detecting and monitoring cyclones has been demonstrated. 74% were retrieved with an average of two alarms per day.

Different methodologies have been applied in extracting wind and wave fields from image- and wave-mode data. Possibilities for the success-ful extraction of wind fields were shown for a grid of about 1 km x 1 km for wind direction and 0.1 km for wind speed. The Tromsø Satellite Station (TSS) provides an operational service for high-resolution wind-field observations based on cross-spectral analysis. Current numerical models provide wind information at a resolution of 25 km, while the new SAR wind service can provide information with 12 km resolution.

Operational use of ScanSAR Radarsat wind maps is in place at the Danish Meteorological Institute. A similar Envisat ASAR 500 km x 500 km wind product is required.

Sea ice

The Canadian Sea-Ice Service has demonstrated using ERS and Radarsat the importance of a fully operational end-to-end sea-ice information system. ASAR data from Envisat will provide a complementary source of data and bridge the gap to Radarsat-2. Scientific research for sea-ice thickness estimation is in progress using ERS Radar

Altimeter measurements as well as ERS SAR imagery. Use of ERS SAR and ATSR in combination has been shown to be successful in detecting sea-ice freezing, melting, evolution, and kinematics.

Sea-Surface Temperature (SST)
Responding to the primary objective of the ATSR mission, ATSR/SST is being used successfully to evaluate the long-term (1991–2000) change in Sea-Surface Temperature on a global scale. A clear warming is observed in the Western Pacific, whereas a cooling down is observed in the Eastern Pacific. The Atlantic is also warming up, but to a lesser degree. According to the results so far, the global SST is increasing by about 0.1 deg per year and the sea level is rising by about 0.1 cm per year.

Wind scatterometer
Global products are generated at CERSAT derived from the ERS AMI-Wind instrument, complemented by data from similar sensors on non-ESA platforms. In particular, a global-wind atlas and a sea-ice atlas have been produced and distributed worldwide as a major contribution to climate studies. In particular, the wind atlas, distributed to 1500 users, has been included in the WOCE dataset as a reference for wind measurement.

Geodesy
ERS Altimeter data, especially those from the geodetic mission, are being used to compute very detailed gravity-anomaly maps. Recent developments have shown improvements in coastal regions and extension towards the pole. A near-global gravity-anomaly field map is now available at 2'x2' resolution. Cross-validation against in-situ data indicate that the accuracy of the field is around 6 mgal even in shallow oceans and around topographic features. Work is in progress to improve resolution and accuracy, especially in areas with strong meandering currents. At the same time, mean sea-surface models are being produced and compared.

Highlights of the Envisat Session

"Getting Ready for Launch"

Gothenburg was the first combined ERS/Envisat Symposium. The Envisat Programme was therefore presented in the Plenary Session, and there was a special session devoted to the overall Envisat calibration/validation approach (15 papers). A full day was devoted to sessions on the opportunities for science and application development offered by the Envisat sensors (37 papers).

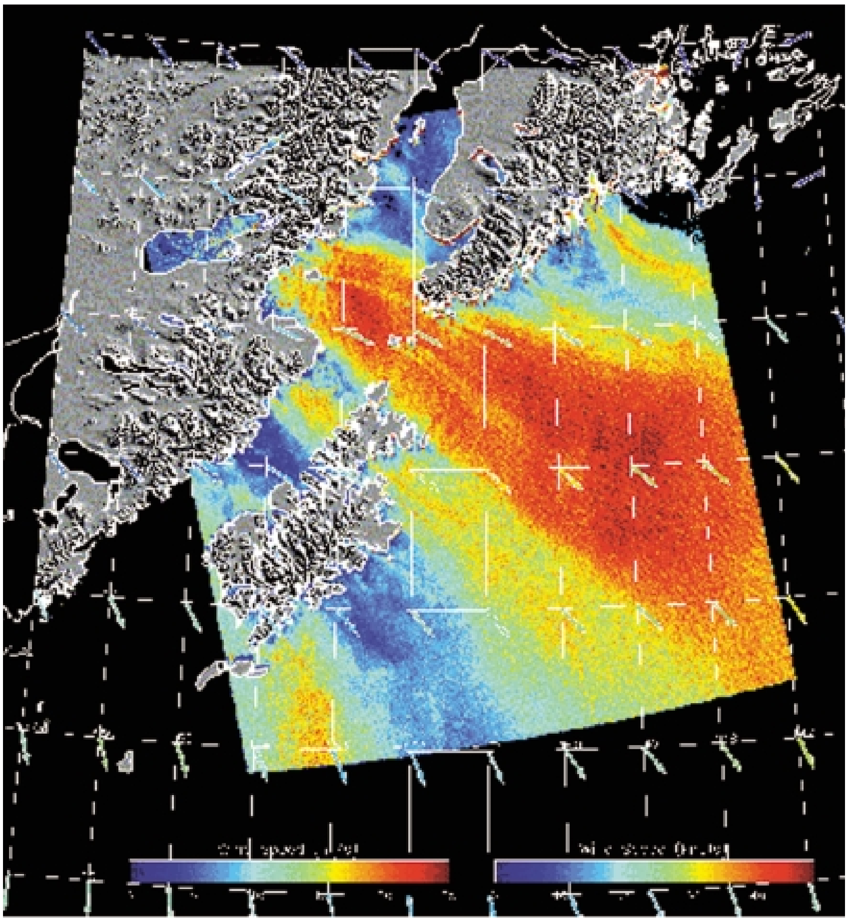


Figure 16. High-resolution SAR wind map of the Gulf of Alaska near Cook Inlet. This map was derived from a Radarsat wide-scan SAR scene collected on 24 December 1999 in preparation for the validation of Envisat ASAR wind fields. The arrows show the wind field predicted from the Global Atmospheric Prediction Model (NOGAPS) (courtesy of John Hopkins Univ. Applied Physics Laboratory)

In preparation for this new and challenging mission, a number of different actions were taken, ranging from public-relations activities (movie, pins, posters, stands, 1:10 scale-model display, etc.) to the distribution of technical documentation (leaflets, brochures, science reports for each Envisat instrument) and the opening of a web site for monitoring and reporting on the 674 projects selected in the framework of the Envisat Announcement of Opportunity.

A set of 10 CDs containing Envisat simulated products and a tool (called 'EnviView') designed to open, display and navigate the products, were distributed to each participant to help users familiarise themselves with the content and format of future Envisat data products. For ESA, this early distribution of EnviView was intended to promote feedback and recommendations on how to improve the tool's capabilities before the launch. EnviView will be maintained throughout the mission and will be offered free to all Envisat users (Fig. 17).

The special Envisat session was mainly devoted to the calibration and validation of the mission instruments and products. The number of instruments to be calibrated and the wide range of geophysical products to be validated make this task an unprecedented challenge. ESA is committed to delivering products to

Figure 17. A set of the Envisat Simulated Product CDs

the users starting 6 months after launch, which is currently scheduled for mid-2001. Within the first 6 months in orbit (so-called 'Commissioning Phase') and after a first few weeks dedicated to switch-on and data acquisition (so-called 'SODAP Phase'), a number of teams of experts will carry out the core calibration and validation programme, under ESA's responsibility and overall co-ordination. The aim is to achieve the release of good-quality products starting at the end of the Commissioning Phase. The detailed plan of action and the techniques and strategies that will be used were presented in detail by various speakers representing the calibration and validation teams.

ASAR

The ASAR calibration approach is based on the successful ERS approach. The challenge lies in the increased number of instrument modes and products that the ASAR on Envisat will deliver.

Already initiated calibration studies were reported, as well as results concerning the use of polarimetry for land-use classification. The use of airborne C-band and dual-polarisation data, experimented with in Denmark with the airborne EMISAR data, significantly improves crop-type classification, paving the way for a potentially successful Envisat application.

Important experiments will also be performed within the ASAR calibration/validation scheme, with the possibility of performing SAR interferometry using wide-swath-mode data and of performing interferometry between Envisat and ERS-2.

RA-2

RA-2 will be inter-calibrated with respect to several other altimeter systems, in particular ERS-2 and Jason-1. In addition, absolute range calibration will be carried out to the level of 1 cm residual inaccuracies, using the northwest Mediterranean Basin as a reference surface. For the first time, the sigma-zero absolute calibration will be attempted. A synthesis of methods and tools to cross-calibrate all geophysical parameters retrieved from altimeter data has already been initiated, as well as results from cross-calibrating ERS-2 and Topex-Poseidon. Another group involved in the absolute calibration campaign presented an indirect approach using tide gauges, together with a direct approach using GPS buoys. GPS buoys are also used for altimeter drift monitoring. Taking advantage of the two frequencies on RA-2, a new parameter is being estimated: the Ku-band backscatter attenuation; its definition and validation were also presented.

ESA presented the significant improvements in RA-2's capabilities over previous altimetric missions and the major conceptual evolution of the ground processing strategy. This evolution leads to highly enhanced data products, particularly in terms of the quality of the near-real-time data for supporting international climate-study programmes such as GODAE and GOOS.

AATSR

The calibration studies for the Envisat AATSR have demonstrated that the instrument satisfies the strict performance criteria required to meet its scientific goals: the global measurement of sea-surface temperatures to an accuracy of 0.3 K, the monitoring of global vegetation coverage, and the retrieval of cloud properties. The need for high-accuracy shipboard devices for a proper validation of AATSR sea-surface temperatures was highlighted. The development of an algorithm and the validation of the generated product for providing global LSTs were presented.

Sciamachy, GOMOS and MIPAS
As for Sciamachy, the GOMOS and MIPAS validations are carried out through a combination of balloon campaigns, high-altitude aircraft campaigns, model assimilation (both Numerical Weather Prediction Model and Chemical Transport Models), satellite inter-comparison, and ground-based measurements. The validation of the GOMOS, MIPAS and Sciamachy products is being co-ordinated by a single group, the Atmospheric Chemistry Validation Team.

MERIS
The Medium Resolution Imaging Spectrometer (MERIS) is the first space-borne European optical sensor dedicated to the observation of ocean colour. It features 15 spectral bands, programmable in width and position, coupled with a resolution of 300 m that will provide data of outstanding radiometric precision and scientific interest. The in-flight instrument calibration of MERIS will use on-board sunlit calibration diffuser plates, which have been characterised to an absolute accuracy of 1%. The validation of Top Of the Atmosphere (TOA) radiance measured by MERIS will be achieved by comparison with TOA radiances derived from vicarious calibration methods. The ocean chlorophyll concentration will be validated using open-ocean dedicated ship campaigns in several coastal waters (mainly European) and long-term measurements from fixed buoys. The new water-vapour and cloud products will be validated through model assimilation and a dedicated helicopter campaign. The wide community of 322 Principal Investigators, selected via the Envisat Announcement of Opportunity, using MERIS data will contribute to the development of a variety of scientific and operational applications.

User recommendations and feedback
The Gothenburg Symposium provided the opportunity to capture the recommendations expressed by ERS/Envisat data users, both in the specialised sessions and during the final closing session.

Having noted that the algorithms have evolved and products have improved, users expressed the need for reprocessing of some ERS data sets such as the Radar Altimeter data from ERS-1. The ERS SAR tandem data archive remains a unique source of data for numerous applications presented at the Symposium, and use and exploitation of this archive is expected to continue to grow. The Envisat data will ensure ERS data continuity for a number of key applications, and for global-change monitoring in particular. The user needs for new products and services have been gathered, with many users stressing the development of new user tools and encouraging further development of on-line services. The need for continuous and timely access to data is a key factor for developing applications: Envisat will respond to this need thanks to the availability of onboard solid-state recorders and data relay through Artemis, and the near-real-time processing capability.

Every Symposium participant received a questionnaire aimed at soliciting their comments on ESA Earth-observation data exploitation and their expectations in terms of future ESA technical support. Some 180 responses were collected and the detailed results will be published in February 2001. The questionnaire also informed participants about the new Category-1 (CAT-1) Web site (Fig. 18), which under the new ERS-Envisat data policy

Figure 18. The ESA Earth Observation Exploitation Projects Web Site

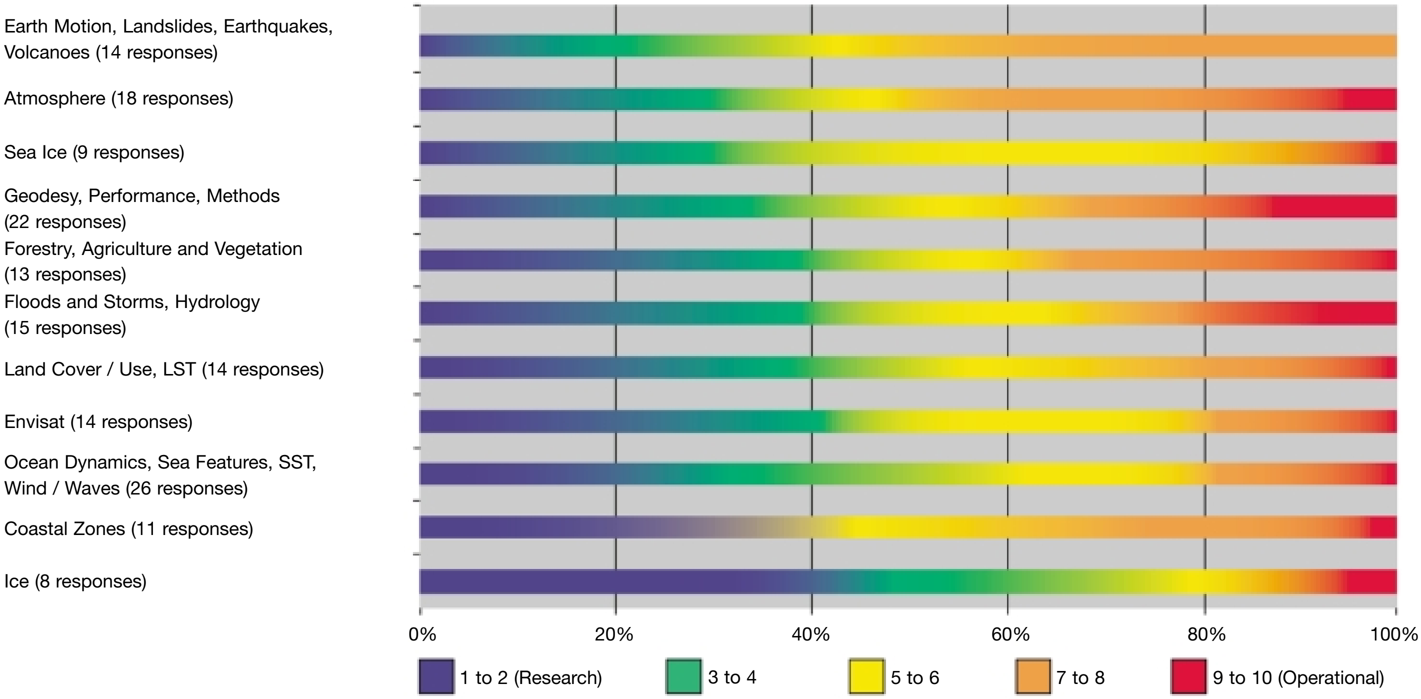


Figure 19. Evaluation by Principal Investigators of the status of their projects, classified by application theme. Blue and green refer to projects at the research stage, while yellow and orange indicate matured projects. Red indicates that Principal Investigators feel that their product, algorithm or service is ready for operational use

allows users to submit scientific project proposals at any time to ESA for use in research and application development in support of the mission objectives. The proposals are peer-reviewed by the Category-1 Advisory Group formed by external scientists (35 members) using web-based tools. The selected Principal Investigators (PIs) can get access, after signing ESA standard terms and conditions, at reproduction cost or even free of charge subject to the approval of the Earth Observation Programme Board.

The PIs were asked to evaluate the status of their projects with the following question: “On a scale of 1 (pure research), 5 (pilot project) to 10 (ready for market), how to operational do you think your project is?” Their responses are summarised, by application domain, in Figure 19. The graph shows that the ERS and Envisat AOs cover a wide spectrum, from pure research to applications development. The PIs expressed a need for continuous research. There is a clear indication that, in domains such as forest mapping, hazards, atmosphere, coastal zones, methods, floods and storms, a number of PIs felt their project had attained its research objectives. In the future, specific thematic workshops will be organised by ESA to support and foster science and application development where appropriate.

Conclusion

The ERS-Envisat Symposium provided a unique opportunity to demonstrate the contribution of the ERS-1 and ERS-2 missions to the monitoring of our environment and to the continual development of Earth-observation applications since 1991. The presentations made during the Symposium ranged from pure research, to the demonstration of applications and development of services and markets. The feedback collected from the Symposium attendees will be used to improve ESA’s products and services.

The Envisat mission is now being readied for launch. It will ensure ERS data continuity and will enhance the European capability to monitor our environment. The new and improved Envisat sensors, algorithm and products will further develop the use and exploitation of Earth-observation data and will allow users to derive high-level information and products. ESA is preparing itself to work closely with the 674 Envisat Principal Investigators, with the support of its Earth-observation application engineers. The Envisat PI’s reporting web site has already been opened for this purpose.

Acknowledgements

We would like to acknowledge the hospitality of the Chalmers University of Technology in hosting the Symposium, and the Scientific Committee, Chairs/Co-chairs for their work in supporting the programme preparation. Special thanks go to the Organising Committee for setting up a unique infrastructure, which greatly facilitated information exchange. We also acknowledge all attendees of and exhibitors at the Symposium for their presentations and feedback. We would also like to thank the ESA staff involved in the Symposium’s organisation and in the preparation of the Proceedings.