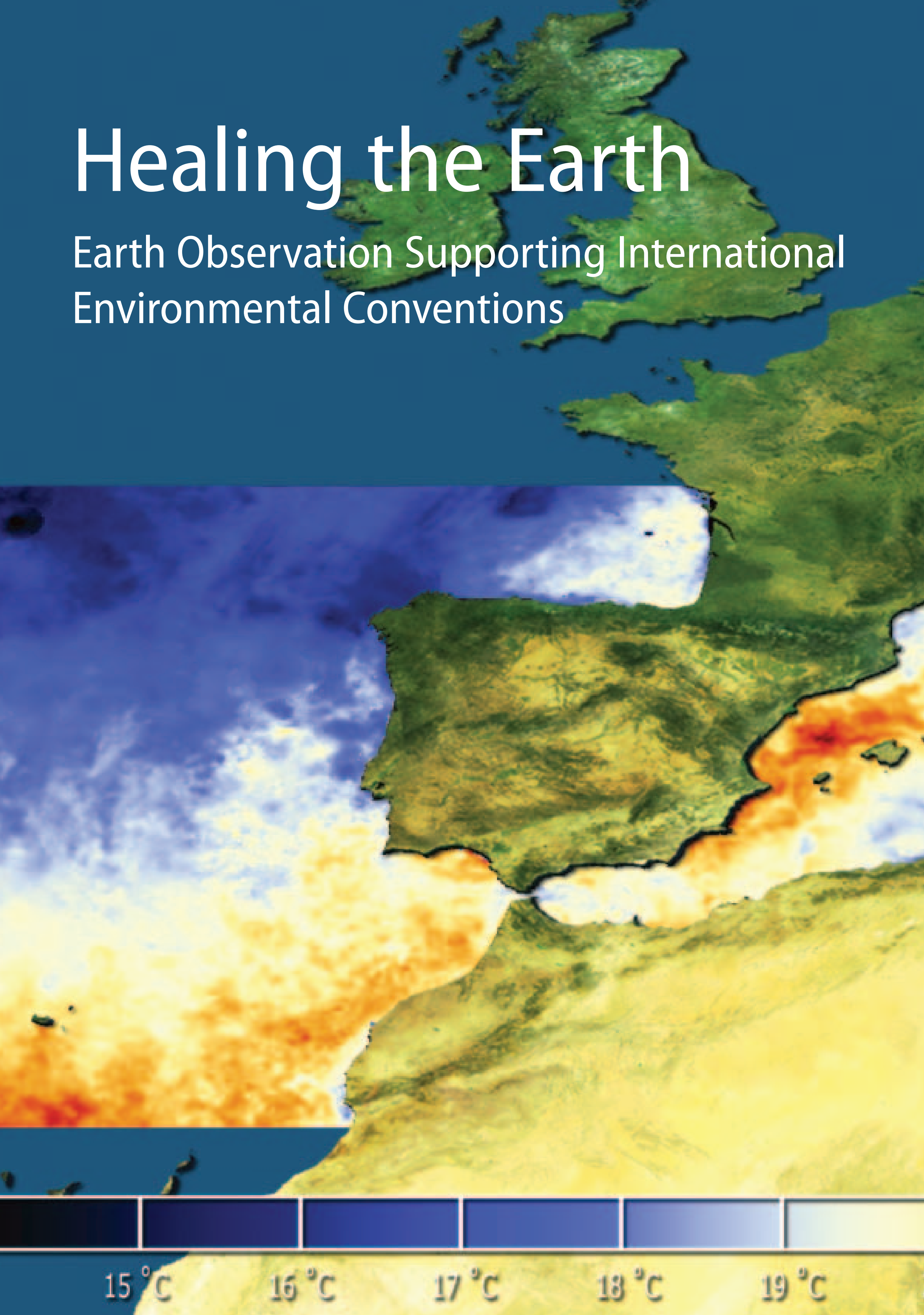
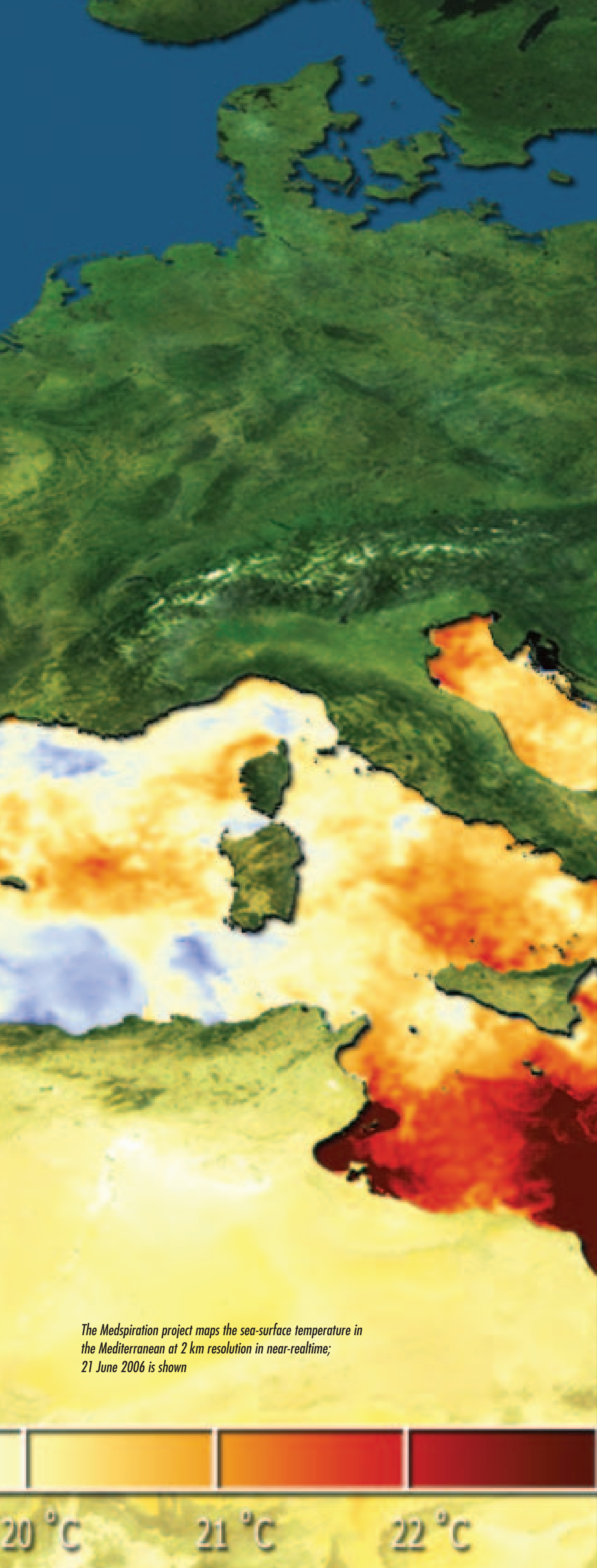
Healing the Earth

Earth Observation Supporting International Environmental Conventions





The Medspiration project maps the sea-surface temperature in the Mediterranean at 2 km resolution in near-realtime; 21 June 2006 is shown

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ESA is building long-term relationships with several user communities that can benefit from the Agency's Earth observation programmes. Since 2000, ESA has been working in close collaboration on three international environmental conventions. Here we see how its Earth observation activities are benefiting these conventions.

Introduction

Dramatic environmental problems affecting our planet have mobilised governments, scientists, private companies and environmental organisations over the whole world. As a result, several multilateral environmental agreements (MEAs) have been signed that aim at reducing environmental degradation.

An example is the United Nations Conference on Environment and Development (UNCED), also known as the 'Earth Summit', held in Rio de Janeiro, Brasil, in 1992. It resulted in the definition of the 'Agenda 21' plan of action and the subsequent signature of different multilateral agreements such as the UN Convention to Combat

Desertification (UNCCD), the UN Convention on Biodiversity (UNCBD) and the UN Framework Convention on Climate Change (UNFCCC).

The road started in 1992 continued in the World Summit on Sustainable Development in Johannesburg, South Africa in 2002. There, many governments reinforced their commitment to sustainable development at the local, regional, national and international levels, and recognised MEAs as useful for achieving that objective.

Implementing these Conventions requires the collection, analysis and understanding of a huge amount of environmental information, from local to global scales. This information provides a better understanding of the scientific background of the problems faced, helps decision-making and enables environmental plans to be put in place. It also allows the Convention Secretariats and related bodies to improve their assessment of the performance of the Conventions and apply enforcement procedures if necessary.

Earth observation (EO) technology can significantly contribute by:

– improving the scientific knowledge of the environmental problems;
– improving the execution of National Action Plans;
– improving MEA performance;
– broadening the political process;
– contributing to the creation of common databases and reporting procedures among different conventions (see the table for a summary).

However, today's limited use of EO technology in implementing MEAs contrasts with its large potential. To explore the potential, and promote the use of, EO technology in supporting environmental conventions, ESA launched the 'Treaty Enforcement Services using Earth Observation' (TESEO) initiative in 2001. These studies have been followed by larger implementation projects, such as the Kyoto Inventory, GlobWetlands and

Potential contributions of Earth Observation in implementing multilateral environmental agreements

	Ramsar Convention	UNCCD	UNFCCC
Improving scientific knowledge	• Understanding wetlands, e.g. water cycles, vegetation status • Understanding global wetlands distribution • Understanding interrelations between wetland areas, the surroundings and whole catchment areas	• Understanding expansion and retraction of deserts • Understanding causes and consequences of land degradation • Understanding water cycle at global scale • Understanding the causes and effects of drought	• Understanding the carbon (by providing global model input parameters such as global leaf area and vegetation indices, statistics on global fires) • Understanding the causes and effects of global warming and climate change
Improving execution of resolutions, declarations and obligations	• Improving inventories, e.g. by mapping land cover, land use and base information • Assessing environmental character, e.g. by estimating and mapping hydrological and vegetation parameters • Monitoring (continuous mapping of changes in vegetation status, land cover or water table)	• Improving reliability and capability of early warning systems of drought by providing timely information over large regions on agriculture and land cover, temperature, albedo, etc. • Improving land degradation assessment and monitoring by providing timely and continuous information on land cover and use and its dynamics by estimating vegetation status over large areas on a regular basis	• Improving forest and land cover inventory capabilities at national scales • Improving identification and estimation of de- and reforestation phenomena • Improving estimation capabilities of over-ground biomass, greenhouse-gas emissions, carbon stocks in 1990 (baseline year) by allowing mapping of forest areas and types
Improving MEA performance and reporting mechanisms	• Improving derivation of geo-information and environmental parameters required in the Ramsar site sheets, e.g. base maps, location of wetlands, land cover and land use, hydrology, wetland types • Producing comparable maps and environmental indicators of Ramsar sites in one country, and among different parties • Creation of a database of geo-information and a Ramsar information system including comparable information for all Ramsar sites	• Estimating indicators to measure Convention performance based on measurable environmental phenomena, e.g. increases in forest area of improvements in vegetation status • Allowing joint reporting to the Convention Secretariat (e.g. common report of Annex IV countries) providing comparable information from different countries • Improving derivation of geo-information, environmental indicators and statistics so countries report quantitatively rather than qualitatively on progress towards their objectives	• Improving reliability and comparability of reporting information • Allowing verification by independent bodies of the information reported by parties • Improving capabilities of independent bodies to auditing Clean Development Mechanism projects (e.g. verification of forest extent and state over time)
Broadening the political process	• Illustrating problems affecting wetlands worldwide and increasing awareness	• Illustrating problems of desertification at global, regional, national and sub-national levels to increase awareness • Illustrating problems related to drought at global, regional and national levels to increase awareness • Deriving geo-information and statistics to quantify the problems and induce political support	• Illustrating effects of global warming at different scales (especially global) to increase awareness • Deriving statistics and geo-information at global level to prove to policy-makers the urgent need for action and induce political support
Common reporting	Deriving common environmental information, such as base maps, land cover maps, land cover maps, change-detection maps, environmental indices, global statistics, for different conventions)		

DesertWatch, addressing key needs expressed by different users within the convention communities. This article focuses on the UNFCCC, the Ramsar Convention on Wetlands and the UNCCD.

UN Framework Convention on Climate Change

Climate change is a global issue that must be addressed with global models – and global data are needed as input to these models. Earth observation satellites are uniquely able to provide such global datasets continuously. They also provide data at national and local scales, which can help the implementation of conventions and protocols, and help the members in their reporting duties. In addition to providing adequate satellite data, ESA has begun a number of activities to demonstrate how 0satellite data can support the UNFCCC objectives.

Global observations from satellite

The importance of systematic global observation for understanding climate change has always been recognised by the UNFCCC. Improvements in technology have made it possible to measure systematically, globally and homogeneously many of the variables essential for understanding and monitoring the climate system. ESA has initiated several global-scale projects that transform satellite data into meaningful parameters to provide insight into climate change.

Important variables that satellites can measure over land are daily global 'albedo' (the fraction of sunlight reflected back from Earth), vegetation levels, fires and burnt areas, snow cover, elevation of ice-sheet surfaces, glacial evolution and land cover. Some of these factors are required as inputs for carbon cycle models, and others give an immediate view of the impact of climate change.

Vegetation cover, fire location, timing and areas affected, as well as additional information on the vegetation growth cycle, are being estimated globally within ESA's GlobCarbon project. They are used as input to carbon-assimilation models. Worldwide fire locations have been analysed for 10 years on a monthly basis: data are freely accessible in the *World Fire Atlas*. at *http://dup.esrin.esa.it/ionia/wfa/*. This atlas has been used by more than 70 scientific teams, most of them in atmospheric modelling. A global land cover map at 300 m resolution is being developed within the GlobCover project using Envisat data from 2005 (see the title spread of this article).

The large volume of data acquired from 20 years of satellite observations of sea-surface temperature (SST) has given scientists a uniquely detailed view of the changing physical characteristics of the surface of the oceans, sampled at a rate impossible with only ship-based observations. The Medspiration project combines data measured independently by several different satellite systems into a set of products that represent the best measure of SST, presented in a form that can be assimilated into ocean forecasting models.

Portugal's Diário de Noticias *highlights the warming of the Mediterranean Sea between 2 July and 2 August 2006, with the headline 'Mediterranean water at 30°C full of jellyfish'*

Ocean algae absorb thousands of tonnes of carbon, forming one of its most important and long-lasting removal routes. By precisely measuring ocean colour, we can accurately gauge the concentrations of phytoplankton globally. Coupling ocean colour with atmospheric aerosol and trace gas measurements will also yield new insights into the chemical links between ocean and atmosphere. A long time-series of global ocean-colour information will be provided by the GlobColour project.

The polar regions are especially sensitive to changes in climate, and models consistently predict future warming to be much more significant there. Many variables can be observed from satellite, in particular by exploiting radar's ability to see through clouds. The GlobIce project is providing information based on satellite data for the polar regions.

Greenhouse gases and aerosols are the primary agents in forcing climate change; continuous observations spatially and temporally homogeneous are therefore required. Since 2003, the TEMIS consortium has been providing measurements of ozone and greenhouse gases, including carbon dioxide (currently a research field) and methane, by exploiting satellite data. GlobAerosol aims to provide a daily global aerosol product over land and water from several satellites.

Land use and forestry

Mankind's land use and forestry have a significant effect on the net emissions of carbon. Measuring these activities is a main function of the Kyoto Protocol, which obliges the Annex 1 countries (who agreed to cut their 1990-level

A dedicated Kyoto Protocol land-use map of Switzerland was completed in the Kyoto Inventory Project and is being refined in the GSE Forest project

greenhouse-gas emissions by an average of 5.2% by 2008–2012) to report on them during the first commitment period of 2008–2012 and to establish the baseline for 1990. ESA began working with the UNFCCC Secretariat in 2001 to produce the required maps and statistics, based on satellite images combined with ground measurements and other data.

So far, more than a 100 million hectares have been mapped, and the same amount will be added by ESA's Global Monitoring for Environment and Security Services Element Forest Monitoring (GSE-FM) service by 2008. All of Switzerland and The Netherlands was mapped for the baseline year of 1990 and two other years, in addition to large parts of Italy, Germany, Spain, France, Greece, Denmark and Poland. The changes in land use and forestry between these years were also mapped.

Standards and best-practices have been established, and all the maps were verified using aerial photos, forest inventory data and other field measurements, and their utility assessed by the ministry or agency in charge of the Kyoto Protocol reporting of each country.

ESA is also working with non-Annex 1 countries (those not obliged to cut greenhouse gases) on their national communications under the UNFCCC. Forest projects under the Kyoto Protocol's Clean Development Mechanism can also be supported by satellite images by, for example, identifying sites, establishing baseline scenarios and verifying plantation evolution. ESA is working in Uganda and Paraguay to demonstrate the usefulness of such services.

Currently, avoiding emissions from deforestation and forest degradation in developing countries is a priority for the UNFCCC. ESA, through GSE-FM, has started to address this. Satellite images can be used both in establishing a historical deforestation baseline and in continuously monitoring deforestation and degradation. Pilot cases to assist in policy formulation for this issue are being developed. This is an example of EO influencing the policy-making process.

Ramsar Convention on Wetlands

The objective of the Ramsar Convention on Wetlands, signed in 1971 (in Ramsar, Iran), is 'the conservation and wise use of wetlands by national action and international cooperation as a means to achieving sustainable development throughout the world'. The wise-use concept is understood to be 'the sustainable utilisation for the benefit of humankind in a way compatible with the maintenance of the natural properties of the ecosystem'. This complex and challenging task requires all national and international agencies involved to:

- better understand wetland areas, their internal processes and their significance in the global environment;
- manage wetland areas efficiently so that they may yield the greatest continuous benefit to present and future generations;
- inform the general public and policy makers of the importance of wetlands and promote their conservation and protection worldwide.

Existing and future EO technology plays an important part in providing reliable and cost-effective synoptic information to monitor and assess these critical ecosystems worldwide.

How can EO support Ramsar?

Parties implementing the Ramsar Convention and taking advantage of EO technology range from international

agencies and scientists to wetland managers and local communities. However, the type of information required varies significantly.

The table shows the different geo-information products that can be derived from EO data for the Ramsar community. The community has been categorised according to the scope of the organisation: global, regional, national or local. User requirements are split into two groups: global and local.

For global needs, the nature of EO data makes it a unique tool for providing global information to users on a regular basis. For local needs, EO provides an efficient source of continuous and synoptic information not only for wetland sites, but also for entire basins supplying the wetlands. This provides a novel capability to EO users, for instance, to extend inventory information and monitor activities through catchment areas of wetlands to identify and monitor threats upstream that could potentially damage the wetland site.

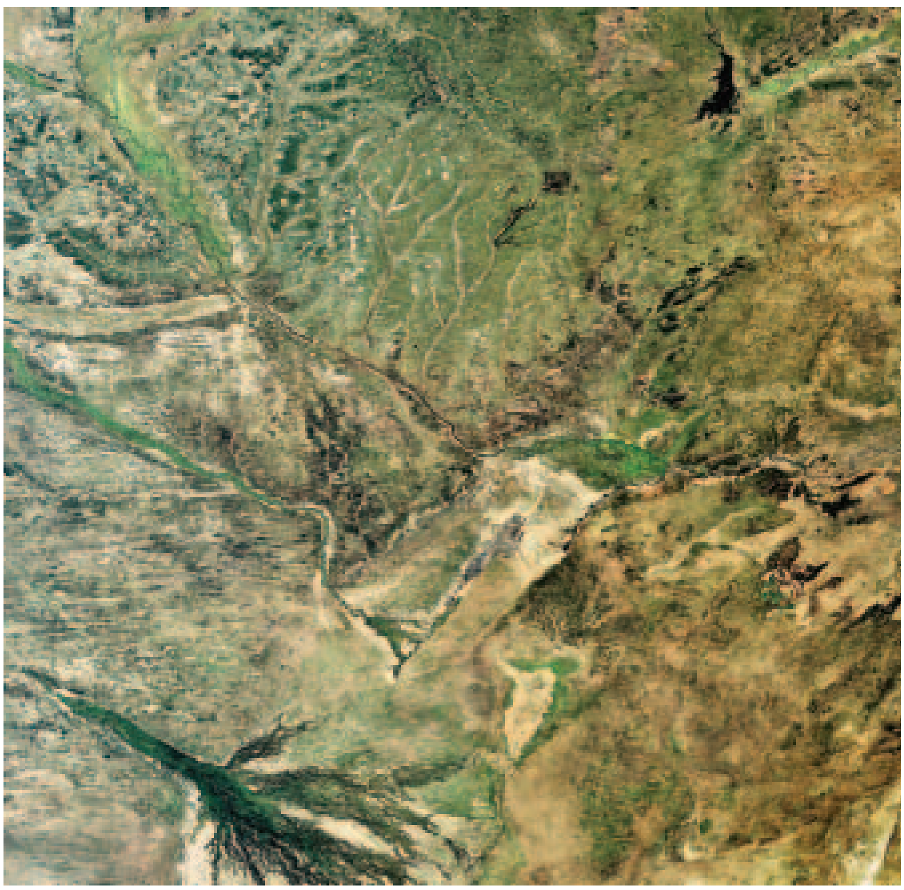
In some cases, managing large wetlands and the corresponding catchment areas involves the inventorying, assessment and monitoring of a huge geographic area, such as the Okavango Delta. In these cases, and even though in the table it is mentioned as local information, this actually requires collecting and analysing information at national and even regional scales, which often can only be done by using EO technology.

The GlobWetland project

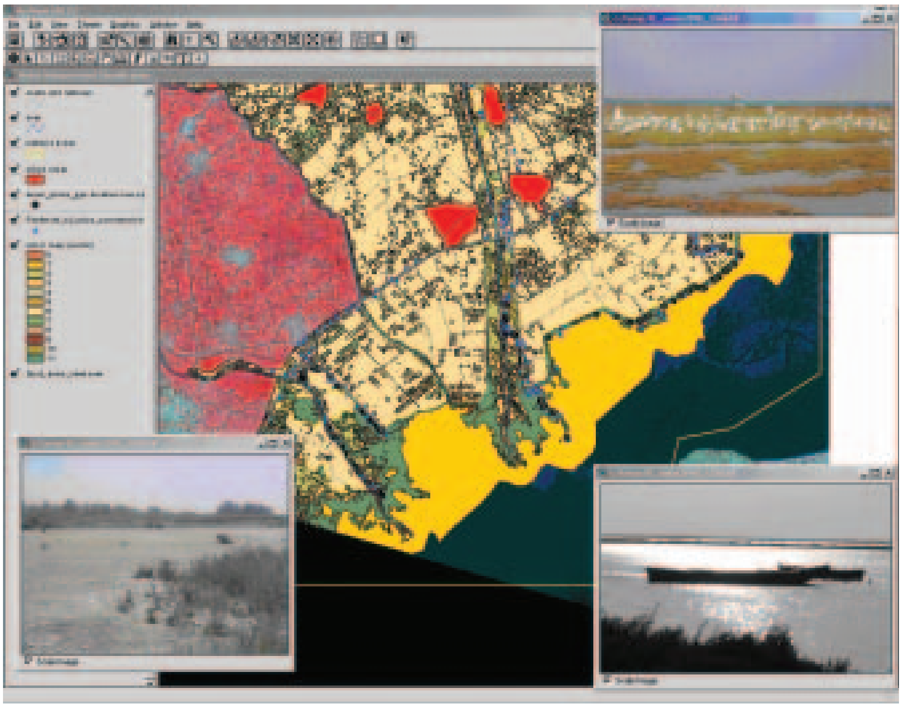
As a large-scale demonstration of these capabilities, ESA launched the GlobWetland project in 2003. It is developing and demonstrating an EO-

Earth Observation potential contributions to the Ramsar Convention

Scope	End-user	User requirements where EO can contribute
Global	Ramsar Bureau, UN agencies, international non-governmental organisations (NGOs) and international research organisations, scientific community	Global extent of wetlands and their temporal variations (seasonal, multi-year) as an input for global environment models (carbon, methane production, etc.); global monitoring of wetlands with respect to global environmental changes; global inventory of wetlands.
Regional	Regional policy makers (e.g. European Community), regional developing agencies (e.g. African Development Bank), regional environmental agencies (e.g. European Enviroment Agency)	Inventories and maps of: • wetland boundaries, e.g. size and variation; • land cover/use of wetland site and catchment area; • digital elevation model of site and catchment area; • water regime, e.g. periodicity, extent of flooding; • water chemistry, e.g. colour, transparency; • biota (vegetation zones and structure); • location of potential threats to the wetland (at site and in catchment area); • additional information, e.g. infrastructures Assessment activities such as: estimation of biological (e.g. vegetation condition) physical (e.g. water table) and chemical (e.g. chlorophyll) parameters that characterise the ecological condition of a wetland. Monitoring activities such as: identifying and monitoring changes in biological, physical and chemical condition of wetland site, threats in the wetland site and the corresponding catchment area, which may affect the wetland condition (e.g. alien species, overgrazing, urban expansion, agricultural activities, industrial pollutants). Rapid reaction to catastrophic events, such as floods and pollution emergencies. Implementation of management (e.g. rehabilitation) plans, such as: • basic information for inventories and as a basis for planning and decision-making (e.g. base maps); • change analysis to monitor the efficiency of the taken actions and impact assessment.
National	National focal points, related national ministeries, implementing agencies national NGOs	
Local	Scientific community, local authorities, local wetland managers, local basin authorities, local NGOs, land owners, local communities, farming and fishing associations	



The 'jewel of the Kalahari': Botswana's Okavango Delta is highlighted in the lower left corner of this Envisat MERIS image, acquired on 2 July 2006. The world's largest inland delta is a labyrinth of lagoons, swamps, channels and islands and a home to a vast array of wildlife. The Okavango River flows inland and irrigates 15 000 square km of the Kalahari Desert. Such wetlands are the most biologically diverse ecosystems on Earth, more productive even than tropical rainforests



An example of the GlobWetland Information System for Axios, Greece

based information service to help wetland managers and national authorities respond to the requirements of the Ramsar Convention. The project involves 50 wetlands in 21 countries, and relies on the direct collaboration of several regional, national and local conservation authorities and wetland managers.

A set of EO-derived products was defined based on the requirements of individual wetland managers and national focal points of the convention (mainly environment ministries). Core products include: land-use and land-cover maps; long- and short-term change-detection maps; and water-cycle regime maps. Site-specific products include leading-edge EO applications such as the analysis of biophysical parameters within water bodies, coastal erosion, subsidence, peatland burned areas and digital elevation models.

The main products, focusing on wetland land cover and water-table dynamics, are based on semi-automated processing techniques that make use of multiple types of EO data, user-supplied data and field information. Space sources include synthetic-aperture radar (SAR) and optical data at various resolutions from Envisat Advanced SAR and MERIS, Radarsat, Spot, Landsat, Ikonos, Quickbird, CHRIS/Proba and ASTER. Observations were tailored to the individual sites, ensuring maximum coverage of wetland vegetation and capture of the changes in water extent using SAR data.

The impact of these EO products on the daily work of wetland managers and conservation authorities has been significant. It is not possible to isolate the management of wetlands from the land use and water management regime within their catchment areas. All freshwater wetlands depend upon a net positive water balance determined by the relative contributions of rainfall, evapotranspiration, abstraction, groundwater exchange and surface flows. These in turn (even rainfall) are strongly influenced by the land use and land cover in and around the wetland which, along with water management objectives, form part of the information base of management plans necessary for the conservation and wise use of wetlands.

Geo-information is vital to wetland management. The Convention advises that it should be organised at different scales. Level-1 is for information on a broad scale, such as a river basin. Resolution becomes progressively higher through a wetland region (Level-2), wetland complex (Level-3) and wetland habitat (Level-4). This approach is taken in GlobWetlands to maximise the efficient use of geo-information and reserve the most expensive imagery for relatively small areas where detailed assessment is required.

Wetland managers and ecologists use many information sources to determine ecological change and to target their interventions, through negotiation of land use and water allocations within stakeholder-based catchment planning. Combining the strategic use of EO-derived geo-information with ground data, for example, local land ownership, water-gauging information or species counts is now considered to be an essential partnership for sustaining these vital reservoirs of life and opportunity.

UN Convention to Combat Desertification

The international community has, with the UNCCD, launched an innovative initiative to reverse and prevent the mismanagement of the world's drylands. Where past 'Plans of Action to Combat Desertification' ignored the complex interplay of socio-economic influences behind dryland over-exploitation, the UNCCD confronts them directly. The convention suggests a new 'holistic' and participatory approach aiming for sustainable development of drylands. In this respect, the convention has some unique features compared to other environmental treaties. By stating that desertification is primarily a problem of sustainable development, it draws attention to the interface between sustainable natural resource management and economic development issues, notably in poor countries with scarce and/or overexploited natural resources.

The UNCCD is not an ideal legal instrument to combat desertification. Desertification remains a poorly understood concept – notably the complexity of the phenomena and the interaction between poverty and land degradation. It involves a very complex set of interactions and issues, with few easily identifiable causes or tidy solutions. Moreover, estimates of the areas involved range from a third of the world to close to half; and people affected from 1-in-6 to 1-in-3.

A better use of EO data is, therefore, becoming more critical to understanding desertification processes and man-made effects on natural ecosystems, and can ultimately contribute to improving policies. Areas of UNCCD implementation that could directly benefit from use of spaceborne EO technology are:

- the collection and analysis of short-term and long-term data and information to identify causal factors, both natural and human, contributing to land degradation, desertification and/or drought;
- increased knowledge of the processes leading to land degradation, desertification and drought, and better understanding of the interaction between climate and desertification and assessment of the effects of drought on desertification;
- the systematic observation of the environment to assess qualitative and quantitative trends in natural resources, evaluating the causes and consequences of desertification, notably ecological degradation, and monitoring the effects of these to improve the value of combating strategies;
- the establishment and/or strengthening of early warning systems to evaluate the impacts of natural climate variability on regional drought and desertification, and generate seasonal-to-interannual climate predictions to improve the efficiency of drought-mitigation programmes on affected populations.

The DesertWatch project

Following the TESEO project and the consultation with national delegations during the 2003 Conference of the Parties in Havana, Cuba, ESA launched DesertWatch in 2004. This project aims to develop a tailored, standardised, commonly accepted and operational information system based on EO technology. It will support national and regional authorities of Annex IV countries (the North-Mediterranean Region) in reporting to the UNCCD and assessing and monitoring desertification and its trends over time. It will help:

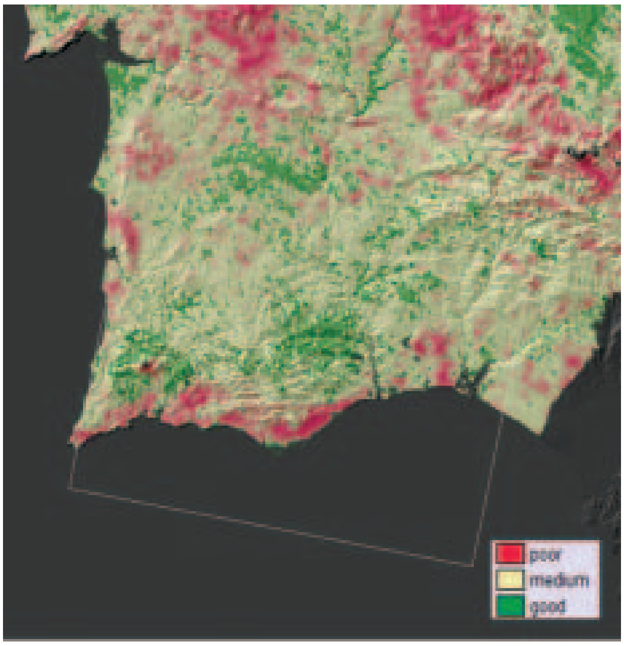
- to create standard and comparable national geo-information products on the status and trends in desertification;
- to create a common framework for reporting to the UNCCD for Annex IV countries;
- to create a common basic infrastructure as a base for further developments where EO plays a key role;
- the development of a common methodological approach for all Annex IV countries to assess and monitor desertification problems and identify trends and potential scenarios.

To this end, the National Committees to Combat Desertification of Italy, Portugal and Turkey have helped in the preparation of the project, defining the main information needs and validating the results. Their participation is critical to ensure the full integration of the final system into the daily working practices of national and regional administrations. The project follows a 'develop-operate-transfer' approach to support the full transition from a research phase to an operational phase, where selected national and regional technical centres continue operations, thereby ensuring sustainability.

Based on preliminary user needs, DesertWatch information is being organised in autonomous layers that can be integrated and combined in suitable models to derive different thematic products on three scales: pan-European, national and sub-national.

The products include some land use indices, derived from Landsat and MERIS data, aimed at identifying key drivers, pressures and impacts on land degradation processes, such as deforestation, forest fragmentation, forest fires, irrigation, urbanisation and land abandonment. With additional socio-economic data and other information, these indicators form the basis for deriving information on the risk and status of desertification.

A second component of the system includes a number of biophysical indexes measuring the density of



Example of a land degradation index from MERIS data covering southern Portugal

vegetation and the soil/rock abundance ratio. The former and its trends over time are key towards a better understanding of the vegetation status and its stress with respect to rainfall and climate variations. The second can be considered as a substitute for erosion indices; it is an accurate indication of the proportion of developed soils and parent material, which provides the basis for determining the degree of soil erosion.

A Land Degradation Index derived from meteorological and Envisat MERIS data has been developed to highlight the degree of soil degradation. The index is relative to the soil type and the local conditions: an arid soil can be considered as 'good' even with only a few rainfall episodes because of the vegetation growth for that type of soil and local conditions.

The temporal component is a key factor to understanding desertification processes today in the Mediterranean area. The project is investigating the variations of the last 20 years through a trend analysis using EO archives. The above indicators will be generated at three different dates showing the evolution of the main pressures and impacts related to land degradation since 1984.

Finally, the system will provide users with a tool to explore different future scenarios in land use and cover, and impacts on land degradation due to different environmental policies and management practices. The project must include modelling components for poten-tial land-use evolution forecasts based on previous land-use maps, socio-economic data and a number of user-defined rules.

Conclusion

Earth observation technology offers many ways to improve the implementation of multilateral environmental agreements, such as the continuous provision of global data, historical data archives, observations of several environmental parameters at global, national and local scales, and the provision of synoptic and comparable information without infringing on national sovereignties.

In spite of these benefits, EO support of MEAs is still limited and, in many cases, restricted to research and demonstration projects. This is because of several factors in the environmental and EO sectors. The gap between these two worlds has hampered the integration of this technology into the common operational practices of environmentalists and governments in many fields. However, more integration of related technologies, such as geo-information systems and information technology, as well as wider awareness within the environmental community and the technological developments in the space sector, offer a promising future.

The next generation of EO satellites will provide novel and advanced capabilities to monitor the world's environment on a regular basis. The success of new technologies depends on the parties involved in the space sector (space agencies, value-added companies and research institutions) developing user-driven, cost-effective operational applications.

ESA's Earth observation programmes will continue in this direction, supporting governments, scientists and all those pursuing the goals and targets of environmental conventions. ESA is continuously consulting the international user community via themed workshops and participation in the Conference of the Parties of the different conventions. Also, new activities addressing the information needs of other major conventions, such as the UN Convention on Biological Diversity, are ready to be launched. They will open the door to the development of new and more efficient EO-based information services, reinforcing the international community with new tools to deal with the key environmental problems that confront our planet.

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