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**ON THE ROLE AND CONTRIBUTION OF REMOTELY SENSED INFORMATION
TO MONITORING AND REPORTING ON ENVIRONMENTAL PROBLEMS
ACROSS EUROPE**

Discussion paper by the Institute for Environment and Sustainability
Joint Research Centre of the European Commission¹

Introduction

1. Remote Sensing (RS) can play an important role in approaching the issue of monitoring and reporting on environmental problems, in particular when the target of such observations is to assess large space scales over long time periods, i.e. the regional, continental or even global scales, over the entire seasonal cycle for a number of years.
2. The European Commission (EC) has long recognized the potential of RS techniques for the development of its environmental policies. As a consequence, the Joint Research Centre (JRC) of the EC has been active over the years in the field of space applications and spatial information management, in support of such policies. In particular, the newly established Institute for Environment and Sustainability (IES) is currently carrying out a number of projects that have direct relevance on this issue.
3. The recognition of the role and importance of RS, in combination with other sources of environmental information, has recently led the EC, together with the European Space Agency

¹ This document was not formally edited.

and a number of partners, at the European and national level, to promote an initiative on Global Monitoring for Environment and Security (GMES). The initiative should lead, within the present decade, to the establishment of operational systems providing information of essentially geographic nature, to describe in an integrated way either natural processes developing in space and time, or the impact of anthropogenic activities.

4. In the following, after a brief introduction to the mission and main activities of the JRC, and of the IES in particular, concerning environmental applications of RS techniques, the current projects capable of a potential contribution in this field will be reviewed in some detail. The initial list of priority themes to be developed in the GMES framework will also be presented. Finally, a set of proposals on the role and contribution of RS information to monitoring and reporting on environmental problems across Europe and beyond, based on such activities and themes, will also be detailed.

I. THE JOINT RESEARCH CENTRE OF THE EC

5. The JRC is an integral part of the EC and a partner of the EC Directorates-General (DGs) in charge of policy. It serves the common interest of EU Member States and European citizens, while remaining completely independent from individual, commercial and national influence. Its task of providing the scientific and technical support needed for European policy-making puts it at the heart of the decision-making process.

6. The JRC activities combine short-term technical support with longer-term strategic research. Its scientific [work programme](#) focuses on the needs of EU policies and is planned in close co-operation with customer DGs. Much of this work is carried out with partners across Europe, including Member State institutions, research institutes, universities and hi-tech businesses. Networking plays a substantial role in the responsibilities that the JRC is taking on in the European Research Area (ERA) initiative. In doing so, JRC operations support the creation of a common scientific and technological reference system for policymaking, a vital ingredient for the ERA.

7. Environmental issues are a fundamental component of the JRC concerns. In particular, the IES, one of the seven Institutes composing the JRC, has the mission to provide scientific and technical support to EU strategies for the protection of the environment and sustainable development. In order to support the development of suitable environmental policies, which are the main instrument for achieving sustainable development, the IES investigates the level and fate of contaminants in the air, water and soil; assesses the effects of these contaminants upon the environment and individuals; and promotes a sustainable energy supply. Its integrated approach combines expertise in experimental sciences, modelling, geomatics and remote sensing. This puts the Institute at the forefront of European research for the attainment of a sustainable environment.

8. The IES principal activities include:

- climate change, analyzing processes and developing tools for implementation of international agreements;
- vegetation monitoring, providing information on environmental degradation and depletion of natural resources;

- European landscape, providing the basis for a European geo-information infrastructure, including the impacts of natural hazards;
- European soil and water resources, carrying out research on soil and waste as well as inland and marine waters;
- renewable energies, giving advice on technological issues to support introduction of renewable energies;
- physical pollution, tackling issues such as noise, electromagnetic pollution, ultra-violet radiation and radioactivity in the environment,
- emissions and health, studying in particular the main causes and effects of air pollution.

II. JRC (IES) PROJECTS USING RS ENVIRONMENTAL INFORMATION

9. The following Projects, currently under development at JRC (IES) as part of the EC 5th Framework Programme for Research, make use of remotely sensed information to monitor and report on environmental problems in Europe and beyond.

- ***Natural Hazards (NaHa)***
The NaHa project provides scientific and technical support (risk indicators, damage maps) for the implementation and monitoring of EU policies linked to the protection of citizens against floods and forest fires (improving existing practices in disaster management for prevention & after crisis phase). JRC (IES) Project O36.
- ***Geo-Information for Development & Environmental Monitoring (EUROLANDSCAPE)***
The EUROLANDSCAPE project uses EO data/GIS/models to analyze the pan-European landscape and the complex interactions within and between its components, which are influential for sustainability & diversity in habitats for flora and fauna, and for the local/regional water balance. JRC (IES) Project 039.
- ***Coastal Monitoring & Management (COAST)***
The COAST project targets the implementation and monitoring of EU policies by providing integrated products and tools to assess the sustainable exploitation of marine resources, pollution prevention and water quality control, and decision support in the management of coastal areas. JRC (IES) Project 043.
- ***European Soil Bureau (ESB)***
The ESB project aims to provide harmonized and coherent information on European soils to policy makers and other users, addressing both the current status and the indicators of future changes in soil quality, and collecting available geo-referenced pan-European soil data in a common format. JRC (IES) Project 105.
- ***Global Environment Information System (GEIS)***
The project provides information on changes in the world's vegetation cover and marine primary productivity as needed for EU policy in the areas of environment, development and external affairs. The focus is on aid & development programmes and implementation of environmental conventions. JRC (IES) Project 049.
- ***Ultraviolet radiation, Noise Indoor exposure and Electromagnetic fields (UNIE)***

The project is building, among other things, a climatology of the surface UV radiation over Europe from 1984 to present, with daily maps with spatial resolution of 0.05 deg, obtained by radioactive transfer modelling and using EO data. The data set is intended to support impact studies on human health and the environment. JRC (IES) Project to be decided.

- ***GI and GIS: Harmonization & Interoperability (GI/GIS)***

The GI/GIS project focuses on Geographic Information and Geographic Information Systems, and aims to the creation of a European Spatial Data Infrastructure. This covers the policy, organizational, technical and financial arrangements necessary to support access to geographic information. JRC (IES) Project 084.

III. GMES PRIORITY THEMES

10. The following 9 Priority Themes, which foresee the use of remotely sensed information to monitor and report on environmental problems at the European and global scales, have been identified as the main items for the GMES initial list of potential developments.

European Regional Monitoring:

A. Land Cover Change in Europe

Characterization of land cover changes (1950-2000) in the EU and accession countries (EU 15+), and of representative nature protection sites, ecosystems and landscapes; urban areas; coastal zones.

B. Environmental Stress in Europe

Identify, map and characterize “hot spot” areas of EU 15+ environmental stress, with respect to: oil spills; organic pollution in European seas; coastal erosion; soil degradation and desertification.

Global Monitoring:

C. Global Vegetation Monitoring

Monitoring the world’s vegetation in view of: (a) detecting events and measuring changes in global forest cover with particular attention to the tropical and boreal forests; (b) contributing to assessment of food security world-wide; (c) assessing carbon fluxes and stocks in the biosphere.

D. Global Ocean Monitoring

Improve tools to produce global ocean information, based upon existing monitoring capabilities, to support seasonal weather predictions, global change research, commercial oceanography, defense.

E. Global Atmosphere Monitoring

Deliver regular assessments of state of the atmosphere with particular attention to aerosols, UV radiation and specific pollutants in close co-ordination with ground-based networks.

Security-Related Aspects:

F. Support to Regional Development Aid

Contribute to the generation and transfer of know-how and technology in the context of the PUMA programme (Meteosat 2nd generation) focusing on land applications in Africa.

G. Systems for Risk Management

Deliver operational systems to support risk management (early warning, impact assessment and reaction) in EU sensitive areas for floods, forest fires, oil spills, man-made structures stability.

H. Systems for Crisis Management and Humanitarian Aid

Develop an information system to deal with crises management and humanitarian aid with particular attention to (a) basic cartographic data with relevant information layers, (b) diffusion, use, and updating of information through interactive systems.

Horizontal Support Action:

I. Information Management Tools and Contribution to the Development of a “European Spatial Data Infrastructure”

Address information management (acquisition, access, sharing and use of environmental and geo-referenced data) and create harmonised info-structures with common portals to info-services. For data acquisition, focus on topography (digital terrain models, hydrological network) and land cover, at a scale apt to support decision making from local to EU 15+ scale. For infrastructures and tools, focus on advanced data systems, data fusion, data warehousing, data mining, and topic maps based on platform/domain-independent information and open standard meta-information systems.

IV. EXAMPLES OF THE ROLE AND CONTRIBUTION OF RS

11. Remotely sensed information can play an important role in monitoring/reporting on environmental problems across Europe. The following examples of quasi-operational applications are based on the current experience deriving from the extensive JRC (IES) activities in the field of space applications and spatial information management, and on the foreseen developments in the GMES framework.

A. Natural vegetated areas vs urban areas

12. The results of the JRC (IES) Project EUROLANDSCAPE suggest that 3 main topics could be developed into a large-scale, continental assessment exercise:

- forest mapping and monitoring,
- grassland and other natural vegetation mapping and monitoring,
- urban areas and transport corridor mapping and monitoring.

13. Two kinds of experimental forests maps could be developed, following this approach. The first is based on NOAA AVHRR data, covers the Pan-European area and shows the forest proportion/probability, with 1 km resolution (Figure 1). The second is based on IRS WIFS data and maps the EU in 3 forest classes with 200 m resolution. Both kinds of map can be used to assess the structural diversity of forest areas and their patchiness. They can be combined with other datasets, like digital terrain models or soil types, to provide regional forest type maps for bio-diversity assessment.



Figure 1. AVHRR-derived forest proportion map of the EU

14. Forest and other wooded land cover approximately 40% of the EU, while grasslands and other natural vegetation cover another 15 to 20%. As it would be obvious to make sure that the area and variety of these (rather stable) land cover types are permanently monitored, it can be envisioned to extend the mapping above to include also grassland and other natural vegetation in order to provide a coherent picture of the Pan-European area.

15. Similarly to vegetated areas, urban areas and transport corridors can also be mapped, classified and monitored (Figure 2). Even if many major cities are already covered by current monitoring activities, at JRC (IES), the majority of build up areas still need to be included using the same methodology. Urban sprawl and establishment of transport networks have severe impacts on the surrounding environment and should be analyzed in combination with the forest, grassland and natural vegetation works as parts of an integrated assessment.

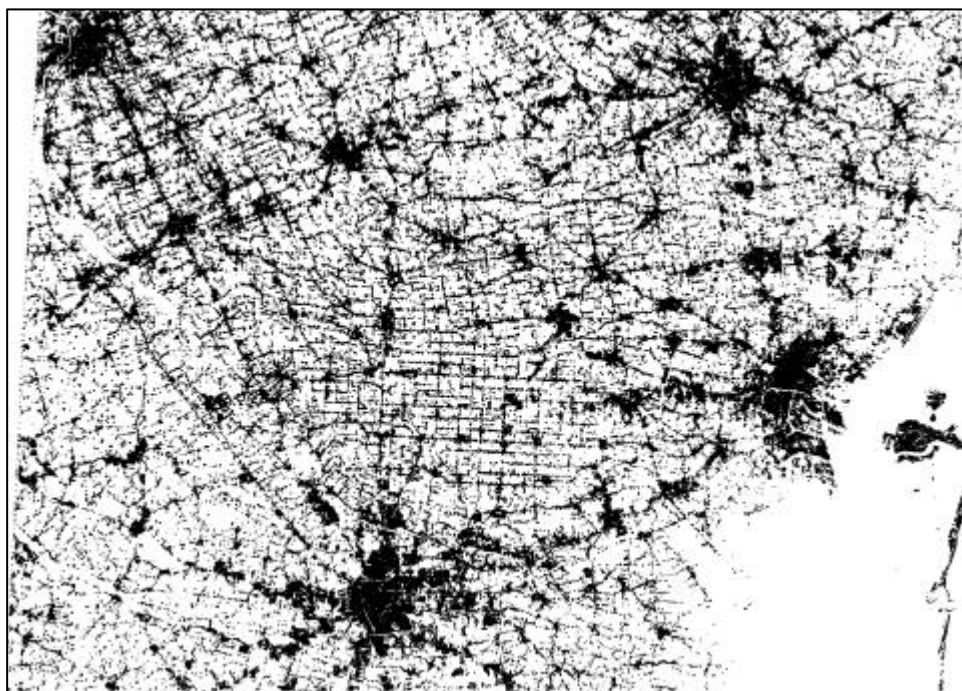


Figure 2. Area, structures and patterns of build-up areas in NE Italy (Venice in the far right)

B. Towards global vegetation monitoring

16. The concepts above can be readily exported and applied in other regions of the world, as the JRC (IES) Project GEIS is doing for Eurasia with the Sib-TREES initiative, a joint venture with the International Forest Institute of Moscow, Russia, to monitor Siberian-Eurasian Taiga Forests. The aim is to improve understanding and knowledge of current conditions and evolution of the Siberian forest in the context of international conventions, in particular in the framework of the Kyoto Protocol to the UN Framework Convention on Climate Change. This adds to existing information (on the current status of the boreal Eurasian forest and its dynamic processes), particularly concerning carbon budget assessment, and feeds a comprehensive information system to provide harmonized data for the entire ecosystem on a repetitive and systematic basis.

17. RS offers a unique opportunity to update existing forest maps and statistics, and to develop a monitoring system tuned to the particular conditions of the Siberian/boreal ecosystems. While most of the technological elements of such a monitoring system already exist, the assembling of a reliable information system still requires a good deal of operational development. Emphasis needs to be put on harmonizing forest information at continental and regional scales using a range of data sources compatible with the geographical extent of the territory: 13 Million km² of which 8.6 Million km² are forested (only in Russia). Given the insufficient awareness of the forest conditions in Siberia and a potentially rapid evolution of the forestry sector in Russia, the exercise will be supplemented by detailed analysis of specific areas, where changes are known to be taking place. The dimension of the exercise requires that a powerful data management and information system be established.

C. Soil degradation

18. In a complementary development, the JRC (IES) Project ESB provides examples on the use of RS to support soil degradation modelling and monitoring, particularly focusing on

semi-arid and sub-humid conditions (as typically occurring in the countries of Mediterranean basin, but also in neighbouring regions such as south east central Europe, Middle east/western Asia). Over large areas, from the regional to the Mediterranean scale, modelling can be used to assess the development of erosion risk using RS-derived vegetation cover density as dynamic input to calibrate and condition the vegetation growth and decomposition part of the model (Figure 3).

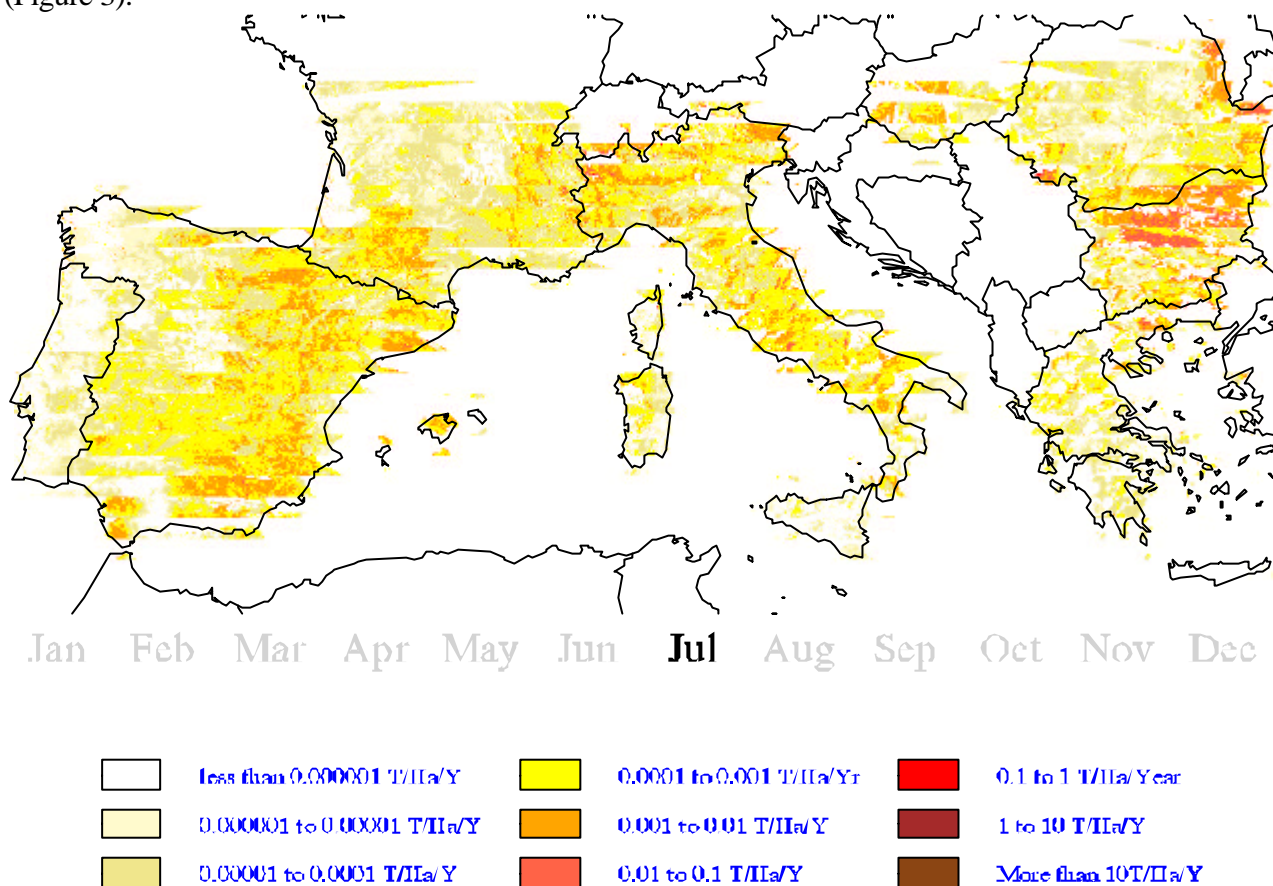


Figure 3. RDI modeled regional erosion risk in the Northern Mediterranean (based on recent climate 1993) as indicator for current degradation

19. The Regional Degradation Index (RDI) modelling concept is based on the use of a one-dimensional hydrological model with 1 km² grid cells, providing a dynamic estimate of potential vegetation and organic soil biomass, based on land use and monthly climate. Vegetation cover is then used to define erosion thresholds in the context of local climate (mainly distribution of extreme rainfalls), relief and soils as derived from Digital Elevation Models and the European Soil Information System. These simulations are compared with actual land cover from RS, to show the extent of actual perturbation by human impact. The model provides a rational method for estimating not only current relative levels of desertification, but also the sensitivity to changes in land use or climate.

20. The RDI approach has been applied so far primarily for soil erosion by water. Mosaics of NOAA AVHRR data with 1 km resolution are used to give periodical values (*e.g.*, at monthly or decadal intervals) of vegetation cover and surface temperature, to estimate land cover and/or biomass. New or future systems (VEGETATION, MODIS or MERIS) could also estimate other soil properties. The results of the modelling are compared with soil degradation levels in specific test sites assessed by high-resolution RS data (Landsat TM). Eroded soils are often recognized

through typical colour changes, which are due to the removal of topsoil. The intensity of the changes, and the organic matter content of the topsoil, provide important diagnostic features for the spectral identification of a majority of undisturbed (Mediterranean) soils. Erosion produces truncated soil profiles, with decreasing amounts of iron oxides and organic carbon, while the proportion of parent material increases. Most parent materials differ spectrally from developed soil substrates, in particular due to specific spectral absorption features and increased albedo levels. The resulting concept, which is based on exploiting through spectral mixture modelling the spectral contrast between developed substrates and parent materials, provides a widely applicable framework for relating spectrally detectable surface phenomena to soil conditions.

D. Land use & land cover

21. Land use and land cover change varies in space and in time. Both are major causes for climate change and loss of bio-diversity, while strongly affecting socio-economics and sustainability of human/environmental interactions. It is important to identify and understand the processes of land use change, of anthropogenic impact on land cover and of landscape transformation. This is particularly true for critical areas with competing uses, as verified by the JRC (IES) Project GI/GIS.

22. The assessment of land use and land cover changes over time is vital for an effective management. A time series database on land use and land cover changes is an important tool to understand the impact of human activities, as well as that of different sectoral policies, on the environment. As an example, prototype databases have been developed already, providing information on land cover changes between 1975 and the 1990's in selected European coastal zones (Figure 4).

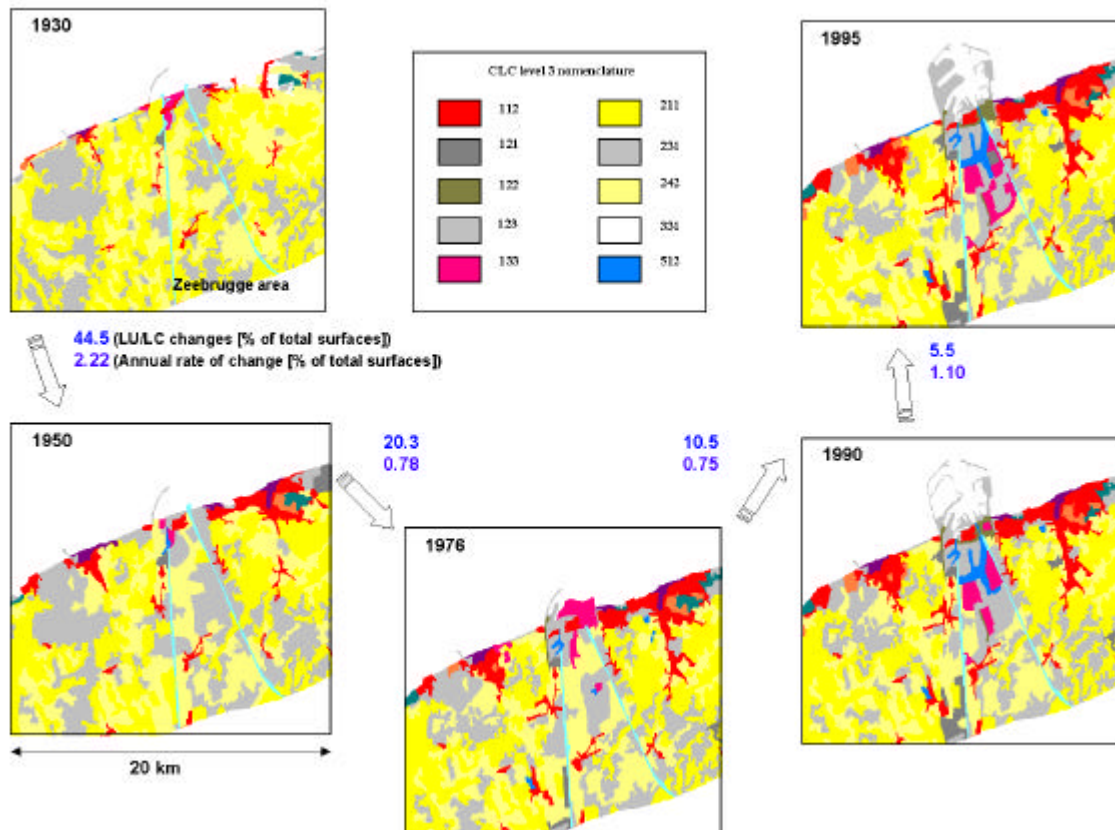


Figure 4. Land cover changes along the Belgian coastal zones between 1930 and 1995

23. For a comprehensive analysis of the impact of environmental policies on the landscape, it is not enough to know that the area of arable land or that of pastures has decreased in a certain period. It is important to know the area that changed from natural vegetation or from pastures to arable land, and the area that changed from arable land to pastures or to urban. RS data can be used for the statistical estimation of such changes. However, the link between mapping and estimation is not obvious. For example, if in a given area there is a mixture of parcels, out of which 30% are arable, 40% woods and 30% permanent crops, and after a few years the proportion becomes 50% arable, 25% woods and 25% permanent crops, it may be correct to consider that there has been no change from a mapping point of view (as the whole area can be classified as heterogeneous agricultural landscape), but there is an important change from a statistical point of view (Figure 5).

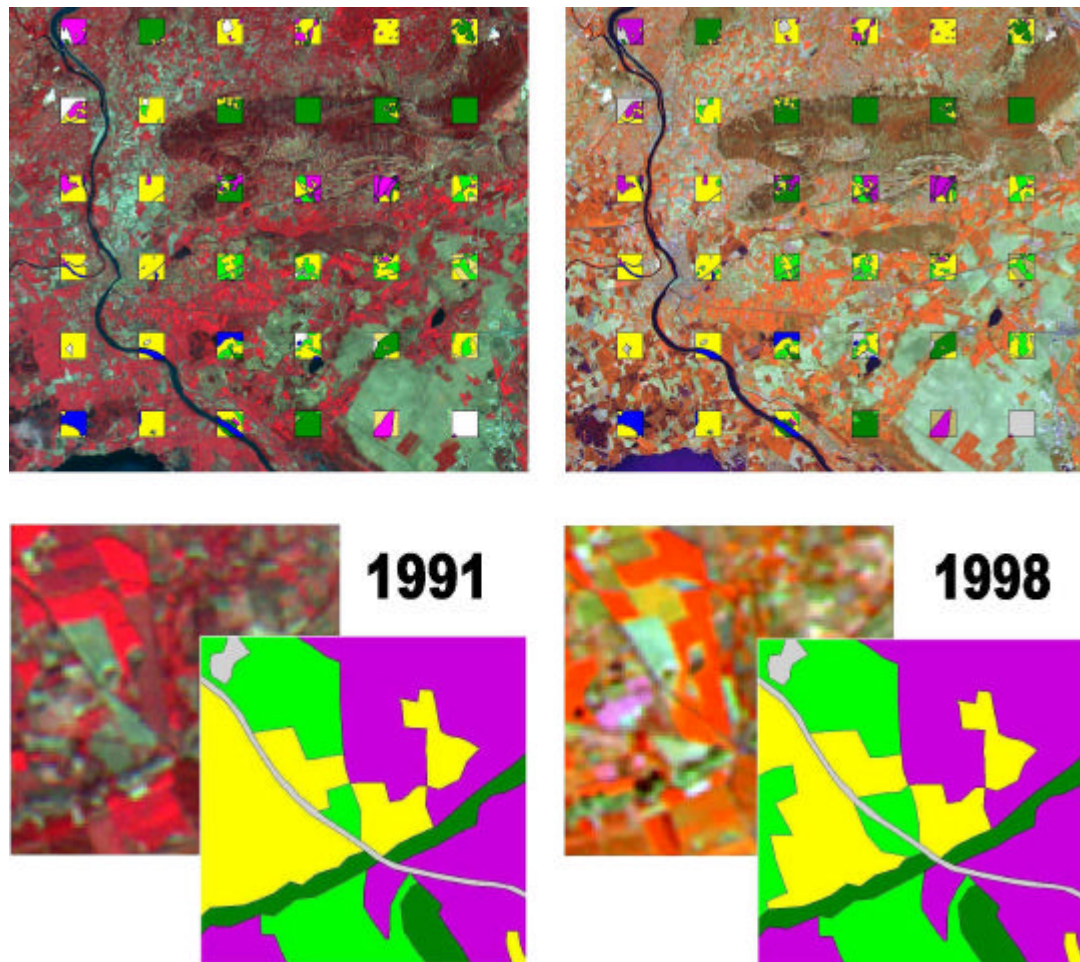


Figure 5. Assessing Land Cover Changes on MARS Site "Arles", France.
Visual photo-interpretation on segments of 2x2 Km

E. Marginal and enclosed seas

24. The development of RS techniques using orbital sensors has shown that a novel view of coastal zones, marginal basins and enclosed seas, combining both terrestrial and maritime elements, can be obtained from space. In the maritime realm, RS offers a wide range of capabilities, complementing conventional *in situ* data gathering, for the synoptic and systematic assessment of interacting bio-geo-chemical and physical processes at the regional - as well as global - scale. However, single RS-derived images of the sea surface, although spectacular, are seldom enough for a sound approach to the exploitation of the technique information potential. The real advantage of marine RS is to be found in the long-term, large-scale monitoring of entire basins. The highly dynamical nature of many coastal and marine processes requires that this kind of information be analyzed on a statistical basis, and hence starting from historical time series, for the assessment of environmental trends over suitable periods of time. New data can then be used for monitoring anomalies, which diverge from the statistical conditions described by climatologies.

25. The JRC (IES) Project COAST provides excellent examples for the application of these concepts, with activities ranging from the integration of RS data in coastal zone management, to the sustainable management of marine resources, to water quality (eutrophication, turbidity)

assessment and mapping, to the monitoring of global primary productivity as a key component of understanding the carbon balance. In general, for marginal and enclosed seas, historical time series of satellite-based observations, collected by a suite of sensors over the last 20 years, can be used to differentiate between geographical provinces shaped by coastal patterns and plumes, mesoscale features, and large-scale structures. The time series of RS data show the main trends of environmental parameters in these provinces, and can be combined into comparable data sets, statistics, indicators integrated as sound scientific information at various geographical scales (Figure 6). These observations provide insights on the role played by anthropogenic activities, geographical setting, and atmospheric forcing in establishing the observed space/time distribution of surface parameters, and their potential impact on continental margins of coastal seas. In turn, the availability of such information can support actions concerning citizen's health, preservation of natural resources and bio-diversity, as well as protection against natural disasters and/or anthropogenic damages along the coast and in open seas.

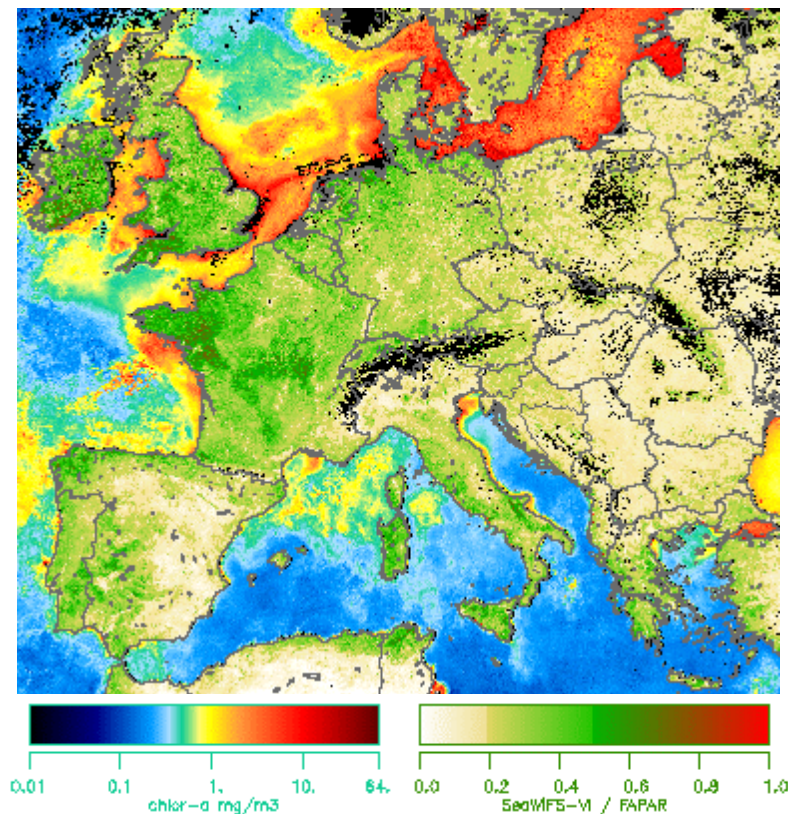


Figure 6. Indices of marine and terrestrial vegetation for the European continent for April 2000: Chlorophyll-like Pigment Concentration (CHL), in marine surface waters, and Fraction of Absorbed Photo synthetically Active Radiation (FAPAR), over land surfaces.

F. Surface UV Radiation

26. The JRC (IES) Project UNIE aims at generating climatology of the surface UV radiation levels over the entire European continent, for a quarter of a century (1984 to present). This provides an example of how to support impact studies on the environment (e.g. effects on plants, marine and freshwater biology) and human health (e.g. sunburns, skin cancer, eye diseases). The RS assessment complements the network of UV measuring instruments by providing high

geographic coverage and resolution, while the ground instruments remain the reference in terms of accuracy.

27. The methodology is based on radioactive transfer modelling, and uses information on the atmospheric and surface parameters derived from various sources, including RS. The total column ozone amount is taken from TOMS or GOME; the cloud optical thickness and the surface albedo are derived from full resolution METEOSAT images. The climatology is composed of maps of instantaneous UV irradiance and daily doses, over Europe and with a spatial resolution of 0.05 deg. Various UV doses can be generated by applying spectral weighting functions (action spectra), specific to the UV impact to be studied (e.g. erythral action spectrum for effects on human skin, or action spectra related to DNA damage, mortality of phyto and zooplankton, *etc*). Figure 7 illustrates a first element of the climatology; showing the year to year variability in mean erythral UV radiation daily dose in March, for the years 1990 to 1999.

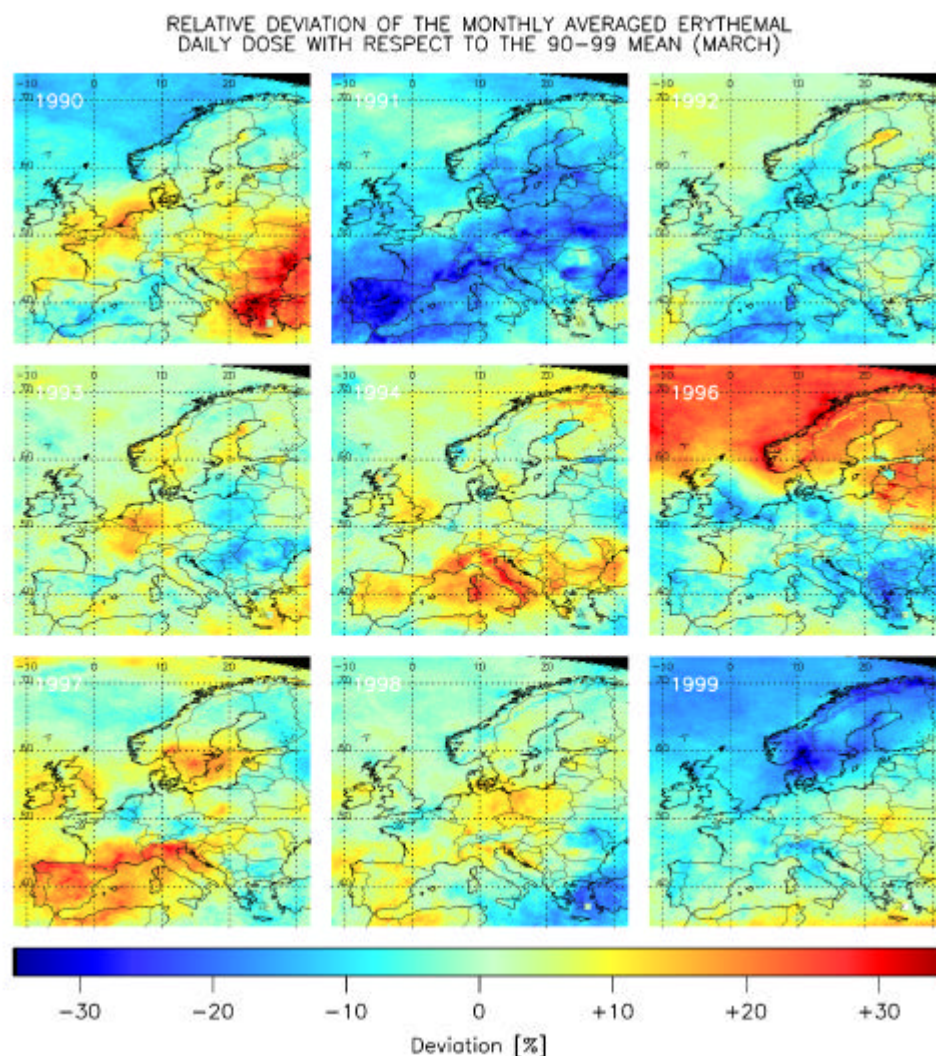


Figure 7. Example of variability in mean erythral UV radiation daily dose in March, for the years 1990 to 1999.

G. Natural Hazards: forest fires

28. Forest fires are a concern at global and local scales. At the local scale, fires cause large economic and environmental damages. At the global scale they contribute to large-scale phenomena such as deforestation and land degradation. One of the main problems is that information on forest fires does not exist at the international scale. The problem to be tackled is to monitor forest fires in order to minimize the devastating effects at all the scales. Comprehensive monitoring of the fire phenomena requires intervention on all the phases of the problem, before (prevention and preparedness), during, and after (burnt area mapping and damage analysis).

29. Information from RS is an important component of the methodology to monitor forest fires. It can be used in the different phases of fire monitoring. Unique information can be obtained for the preparedness phase and the post-fire evaluation of damage extent, including a precise analysis of damage to vegetation. As shown by the JRC (IES) NaHa Project, RS data provide a spatial element otherwise unattainable, in this equation, enabling the combination with others data sets and the subsequent analysis, and scenario modeling, to be presented spatially (Figure 8). This is essential for the planning process. If RS data were not available, the information gathering would be far more costly and almost certainly would not be comprehensive in the spatial domain.

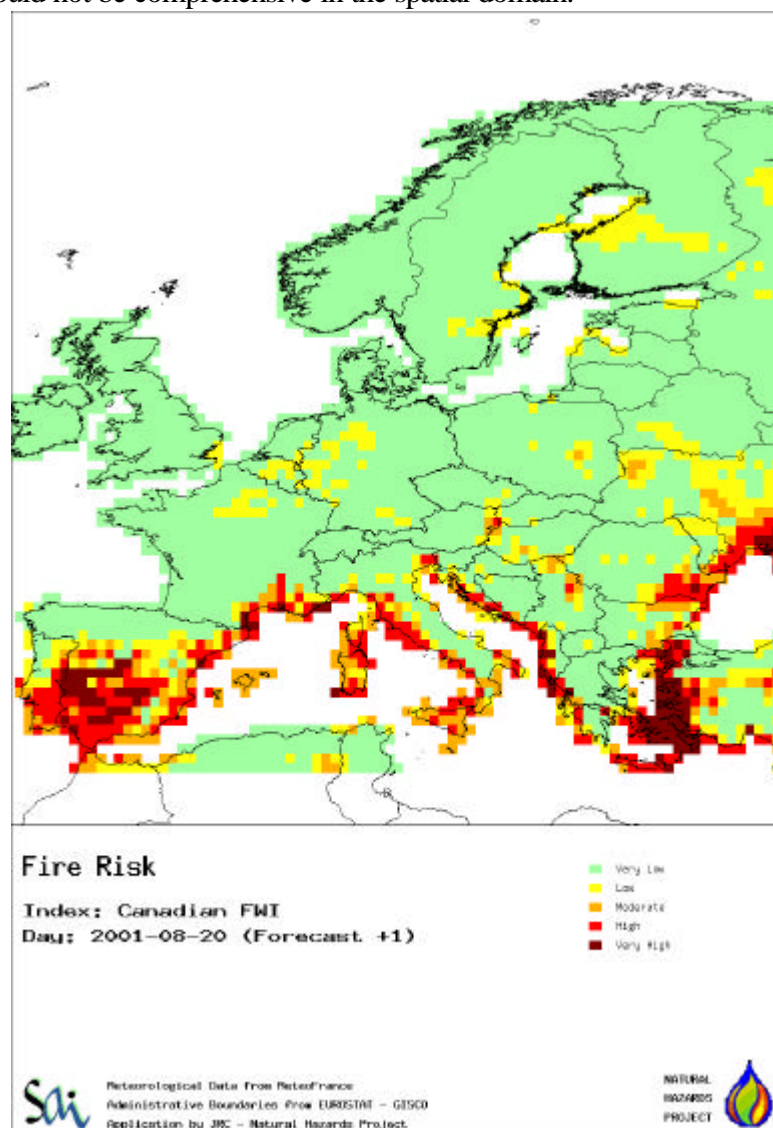


Figure 8. Spatial distribution of a Fire Risk Index in the Mediterranean basin (20 August 2001).

H. Natural Hazards: river floods

30. Floods are one of the most devastating natural hazards worldwide. Floods have a natural cause as a result of meteorological events and are part of the general water cycle. However, increased building pressure (urbanization) on natural river floodplains, river straightening for transport, loss of natural retention areas by dike construction, human induced land-use changes like deforestation and agricultural practices, and climate change effects (temperature and precipitation rise) are the most important drivers for an increased risk of flood damages.

31. Flood prevention strategies/action plans require a complex interaction between spatial planning, hydraulic and hydrological services and agriculture and forestry services. Prevention, prediction and impact assessment will depend on the availability of advanced modeling tools (for scenario development) and basic data and associated information. RS information on land cover, land use, and topography are components of the methodology used for flood risk mapping (prevention) and for flood forecasting (preparedness phase), as well as the most important component for the post-crisis phase, dealing with flood extent mapping and damage assessment, provided by flood extent maps using radar data combined with land cover.

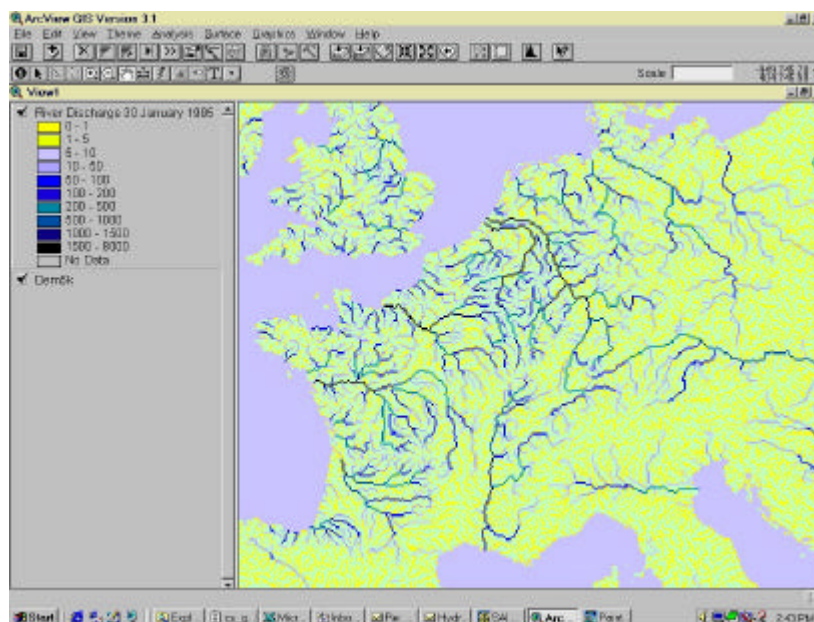


Figure 9. Example of a 10-day flood forecast for all major European rivers.

V. CONCLUSION

32. A number of current projects, in particular those conducted by specialized entities such as the JRC (IES), provide examples of the contributions of RS techniques in environmental applications. Accordingly, the initial list of priority themes to be developed in the GMES framework covers most of such contributions. A set of proposals for potential fields of RS information use in monitoring and reporting on environmental problems across Europe, and

beyond, can be derived from the current experience of the extensive JRC (IES) activities in the field of space applications and spatial information management, and on the foreseen developments in the GMES framework. Again, as already outlined above, RS data provide a unique spatial dimension, enabling the combination with other data sets and the subsequent analysis and scenario modeling to be presented spatially. The lack of this features would increase the cost of information gathering for most environmental problems, and would certainly prevent the use of comprehensive information in the spatial domain.