ANNUAL·REPORT·92

Institute FOR Remote Sensing Applications

JOINT RESEARCH CENTRE

COMMISSION OF THE EUROPEAN COMMUNITIES

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The global environment is constantly in a state of flux; indeed there is considerable concern that changes to the earth's environment, as a result of either man's intervention or natural occurrences, will have a long term effect on the global climate. In addition regional, national and international government continue to seek to maximise the use and benefit of their renewable and non-renewable resources. In order to fully address these needs there is a requirement for timely, accurate information, often at regional to continental scales; data from earth observing satellites can provide an important source of such information.

In order to address this requirement the Institute for Remote Sensing Applications (IRSA) has been set a number of objectives:

- to evaluate and demonstrate possible applications of remote sensing in support of the sectorial policies of the Commission of the European Communities (CEC) in areas such as:
  - Common Agricultural Policy (CAP) (agricultural statistics, land use),
  - Environmental Policy (land and sea protection),
  - Development (food resources and environmental protection in developing countries),
  - Fisheries (resources evaluation and conservation),
  - Regional Aid.
- to undertake research on advanced methods for the interpretation and utilisation of satellite data including their integration with geographical data.
- to help to stimulate the scientific community in the use of earth observing satellites such as ERS-1, SPOT and the Polar Orbiting Platforms; this objective is complementary to that of the European Space Agency (ESA).

The scientific, regulatory and administrative bodies of the Commission are IRSA's main users. This takes a number of forms, the main one of which is the Specific Programme which incorporates a body of research which is defined and approved by the CEC Member States via the JRC's Governing Board.

The second, and increasingly more important form is the work that IRSA undertakes as Scientific and Technical Support to the Sectorial Policies of the Commission. As such IRSA undertakes research on behalf of Directorates General (DG) of the Commission, the objectives of the research being given by the DG. Currently IRSA undertakes such work for DG I (International Affairs), DG VI (Agriculture), DG VIII (Development Aid) and DG XI (Environment).

The third element of IRSA's programme is entitled Exploratory Research. This is a percentage of the Specific Programme that allows IRSA scientists to test new ideas that are not currently contained within the Specific Programme, but that show promise for future applications. This research is selected by the JRC's Governing Board on the basis of proposals made by JRC scientists.

In addition IRSA's programme provides the opportunity for national government and private cooperations to utilise IRSA's resources to carry out contract research. With facilities and expertise unique in Europe, IRSA serves a special role as a resource for organisations whose research needs exceed their own internal capacity or who wish to benefit from the availability of specific IRSA facilities.

On this basis IRSA has set out to address a number of specific issues of importance to Europe using the full range of satellite data that is now available from earth observing satellites.

1.1 INSTITUTE STRUCTURE

The Institute currently incorporates 87 permanent staff with an additional number of doctorate and post-doctorate students, visiting scientists and detached national experts. These staff are divided into five Units:

Agriculture Information Systems

Some 127 million hectares of Europe is classified as agricultural. Decision and policy makers in the CEC require accurate and timely data on these areas in order to execute the Common Agricultural Policy (CAP).

Using conventional data gathering techniques this is not always possible. IRSA is therefore undertaking a study on behalf of Directorate General VI (Agriculture) and the European Statistical Office (EUROSTAT) to define and demonstrate how remote sensing can be used operationally to supplement, interpret and standardise data provided by conventional techniques.

Remote sensing has several advantages for agricultural monitoring. The technique is objective and centralised, but at the same time the same methodology is applicable in any part of Europe. In addition a range of scales can be addressed, from individual fields to the entire continent, and short term changes can be monitored and in the hands of the analysts within days of data acquisition.

A number of specific actions are currently being undertaken within this context. This includes an annual inventory of areas under crop in a number of European regions, including regions in Portugal, France, Spain, Greece and Italy. Each inventory region covers between 2 and 8 million hectares and is situated in the most agriculturally productive parts of the country concerned. This study has helped a number of regional and national governments to integrate remote sensing into the national system of agricultural statistics.

In addition earth observation data has been used to monitor the condition and development of vegetation at a continental scale. Status bulletins are provided to Directorate General VI (Agriculture) at 10-day intervals giving up-to-date information on the state of the vegetation over the whole of Europe. These data are collected at low spatial resolution (one kilometre at nadir), and can be used as an indicator of crop condition allowing the monitoring and mapping of the extent and severity of drought or frost.

Obtaining yield (and hence production) figures from remotely sensed data is not easy. A far better source of information on yield is an agro-meteorological model of plant growth. These models use observed environmental conditions to simulate crop growth and to derive yield. Their results can be used to complement the information from satellites or conventional sources. IRSA is therefore undertaking a study to provide this essential information by means of agro-meteorological models at a continental scale. These models function with a grid-cell size of the order of 50 kilometres on a side.

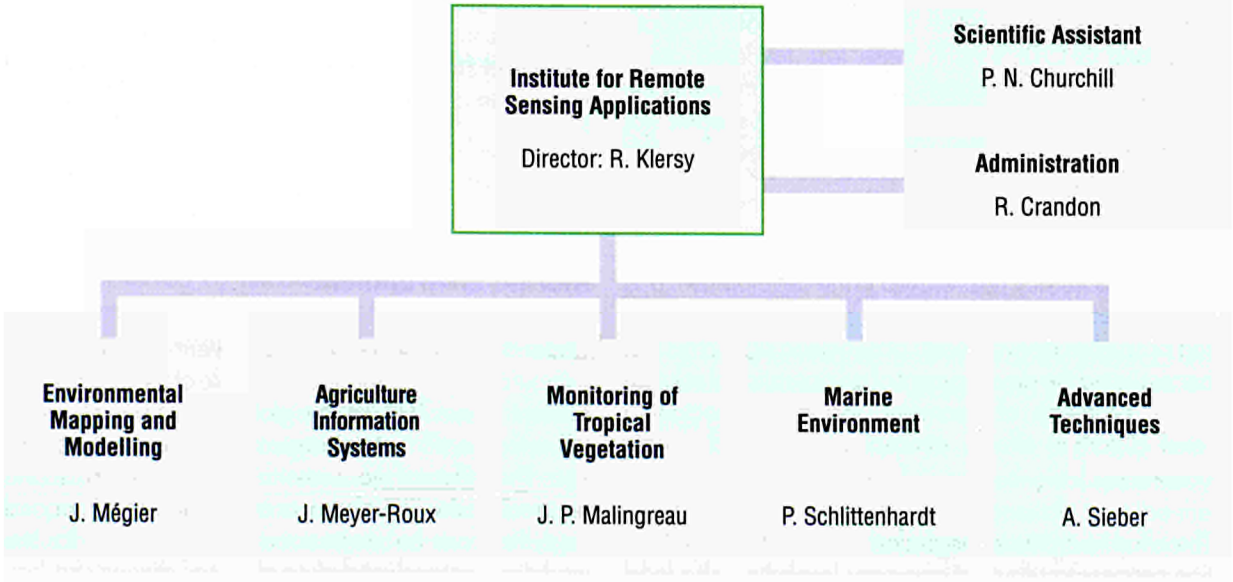


Fig. 1.1. Institute organigramme

In order to satisfy Directorate General VI's (Agriculture) need for frequent updates on the probable areas under various crops as the season progresses, IRSA is undertaking a study to provide rapid estimates of changes in acreage and potential yield using high-resolution satellite data at sample sites scattered over Europe. A team of interpreters examines each new image as it arrives to identify as accurately as possible each crop. Early images tend to contain more general information (spring or winter crops, for example), and the information gets more precise as the year goes on. Agricultural status bulletins are published by fax every 2 weeks between April and October.

Finally, in order to control agricultural surfaces within the new CAP regulations and to produce registers of a number of agricultural crops remote sensing techniques, mainly using satellite imagery, but also aerial photography when needed, are used to establish and maintain registers on vineyards, olive groves and citrus orchards. Earth observation satellites are also used to help in the control of crop declarations. Their main contribution is in reducing the ground work required and increasing the objectivity of the controls.

Environmental Mapping and Modelling

Considerable emphasis is placed on the analysis of problems connected with operational land cover mapping in European less favoured - or marginal - areas by applying automatic processing to second generation earth observation satellites (Landsat Thematic Mapper (TM) and SPOT). Within these less favoured areas Mediterranean landscapes are predominant within the European Community, and it is upon this particular geographical region that efforts have been concentrated to date.

Mapping land cover in such complex areas with a sufficient accuracy has resulted in the development of a range of techniques related to the multitemporal processing of satellite derived earth observation data. This has necessitated the development of an operational solution of the problems of geometric registration (including relief distortion effect), atmospheric and radiometric calibration.

The effort to increase the performance of the classification process to required accuracy levels has also lead to a thorough examination of new methods of data processing, such as the perceptron paradigm in neural network approaches or expert system techniques to complement spectral information by image and geographic context in the classification procedure.

In all of these areas IRSA has acquired extensive experience which has been applied to projects in the fields of agricultural statistics, environmental mapping and the updating of the European land cover data base CORINE.

Mapping vegetation land cover in Mediterranean areas (which in fact cover approximately half of the present European Community) means also acquiring the experience of classification processes applied to extensive natural vegetation categories such as evergreen or deciduous forest, permanent grassland, bushes and garrigue. These categories are often mixed, with varying ground coverage percentages (i.e. they are also mixed with bare soil). The challenge is then to be able to map mixtures of classes even within individual satellite pixels. IRSA is progressing in this direction by studying and evaluating spectral mixture modelling techniques applied to operational satellites (Landsat TM and SPOT) and to high spectral resolution airborne imaging spectrometers.

On this basis an activity has been launched to undertake Mediterranean land resources and land degradation mapping with soil erosion as an extreme landscape condition. Landsat TM data accumulated over 8 years will permit the start of a long term monitoring and change detection study, while the extensive investigation and utilisation of imaging spectrometry data will permit the mapping of mineral components of soils and rocks and the mapping of biochemical components of vegetation communities.

Marine Environment

Understanding the earth as a system is not possible without a good knowledge of the role of the oceans. The oceans cover 70% of the globe and have a crucial influence on all meteorological and climatic phenomena. The different processes in the ocean at local and regional scales are elements of the global system and must therefore be understood and observed for the modeling and understanding of global climate change, and equally for local investigations and applications.

Within this context remote sensing can be a key element in the observation and understanding of the ocean as a part of the global climate system, as well as playing an important role in providing data for environmental protection at a local scale.

On this basis IRSA is developing, demonstrating and validating methodologies for the use of data from space and airborne observations in both, operational applications and scientific investigations related to the marine environment. Basically this involves an investigation of two main parameters that can be derived from earth observation sensors, and their role in different oceanic processes.

The first is ocean colour, which is an expression of the substances in the near surface water layer and the biological activity in the euphotic zone. The second is the sea surface temperature, which is an indicator of the heat energy budget at the sea / air interface and is an element of the general hydrodynamic processes.

Within this context three main activities are being undertaken by IRSA. Firstly, ocean colour data, as collected by the Coastal Zone Colour Scanner (CZCS) from 1978 to 1986, represent an important source of information for understanding bio-gechemical and physical processes in the sea. These data over marine regions of European concern are being pre- processed to a standard format and archived. From these data geophysical parameters are derived in order to create a data base of bio-optical information on the marine environment.

Secondly remote sensing techniques are being applied in the northwest African upwelling area to help to evaluate the important oceanic phenomenon where cold nutrient rich water flows to the surface resulting in high biological activity. The water masses in these areas are characterised by low temperature and high phytoplankton concentrations, two parameters which can be observed by remote sensing techniques. The remotely sensed data describe the temporal and spatial distribution of coastal upwelling and related processes.

Finally the role of the ocean in the global system is being investigated using remote sensing techniques. The test site off the North West African coast has been selected for particular investigation where ocean dynamics, including upwelling phenomena and air-sea exchange, and the primary productivity of the marine biota are under analysis.

Monitoring Tropical Vegetation

Due to the immense scales involved, the monitoring of vegetation in tropical and sub-tropical areas is an area where remote sensing can play an important role in supplying accurate and timely data.

Monitoring changes in the forests of the tropical belt, for example, represents a formidable challenge for remote sensing. Indeed, these changes are taking place over large areas and are sometimes accelerating in pace. A recent FAO evaluation indicates that the rates of deforestation in the 1981-90 period (168.000 km^2/year) may be nearly double that of the 1976-80 period (92.000 km^2 /year).

In order to address this problem research has concentrated upon the use of low spatial resolution data for assessing changes in the tropical forest canopy via the Tropical Environmental Ecosystem observations by Satellites (TREES) project. This objective is seen as the first step in preparing a global forest inventory and monitoring exercise.

In addition fire is a natural feature of many ecosystems; the African savannahs for example are often identified as fire climax ecosystems. Indeed fire has major impacts on local, regional and global ecosystems. Burning almost instantaneously changes the vegetation characteristics of the burned area and repeated burning can effectively alter the spatial boundaries of ecosystems forcing transition from one to another.

If the spatial distribution and timing of fire in an ecosystem remains constant these effects are usually in a state of equilibrium. However pressures of population growth, economic demands and demographic shifts are likely to change burning patterns. This can alter the balance and make fire an agent of environmental destruction. Burning patterns are therefore useful indicators of environmental change over large areas.

In order to map and monitor these effects at a regional scale techniques have been developed to identify active fires using 1km spatial resolution data of West Africa. These techniques result in the ability to extract fire statistics and to describe the areal and thermal characteristics of the fires.

In order to extend this work to a continental scale study of fire for the whole of Africa it is possible to utilise the 4km spatial resolution data together with the 1km data, where the latter can act as a 'control' to quantitatively evaluate the quality of the 4km data product.

Work is also being undertaken to monitor environmental conditions in large watersheds. Water resources depend on precipitation and on the water cycle on the surface. This cycle is driven, to a large extent, by the surface characteristics of the environment among which the vegetation cover is by far the most important. Any changes affecting the vegetation cover will therefore have a consequence on the water resources. It is in this frame that research activities are currently being conducted to evaluate the impact of vegetation change on the hydrological regimes of large river basins in Africa.

The work relies on the use of a time series of low spatial resolution data to monitor seasonal and inter-annual changes in land surface characteristics, plus the use of hydrological models for the analysis of these dynamics in terms of the impact on surface hydrology. This work has shown that there is a correlation between the dynamics of surface conditions as derived from the satellite data and changes in the hydrological regimes of river basins.

Remote sensing-based methods for assessing rainfed foodcrop production in Sahelian Countries is also being undertaken. This includes the derivation of acreage and yield estimates from satellite measurements combined with field observation at scales ranging from the administrative district to the sub-continent.

In addition this Unit is addressing the problem of modelling and monitoring global climate change using earth observation and ancillary data. This includes investigations related to climate and human impact upon terrestrial ecosystems with particular emphasis being given to mathematical modelling of the physics of radiation transfer leading to the development of vegetation indicies. Further, methods of numerical inversion for the extraction of surface parameters relevant to climatic processes have been explored.

Advanced Techniques

Besides the development of applications of proven space borne sensors in the visible and infra-red range there is a need for the evaluation and promotion of more advanced remote sensing techniques, involving basic, systematic and long-term research.

This is particularly true for microwave remote sensing. Spaceborne microwave systems will play an important role in remote sensing in the immediate future as is clear from the launch of the ERS-1 and JERS-1 satellites and the announcement of the ERS-2 and Radarsat systems, plus the Shuttle based systems SIR-C and X-SAR. These systems are a first important step towards the introduction of microwave remote sensing to a larger user community throughout the next decade.

Currently, however, there is neither the technology nor the fundamental knowledge of the information content of the backscattered signal to either fulfill the requirements of the user community or to specify the requirements for advanced microwave systems in the future.

In order to begin to address this IRSA has begun a coordinated research programme within Europe. This programme is based upon a number of elements including the implementation of a European microwave signature laboratory (EMSL), the implementation of a European Airborne Remote Sensing Capability (EARSEC), the promotion of application orientated airborne experiments in collaboration with ESA and national institutions, the development of application orientated radar data interpretation algorithms, and the promotion of application based pilot projects.

In addition new techniques for earth observation are being evaluated, such as imaging spectrometry. This technique, which splits visible and infra-red light into high spectral resolution channels, is seen as extremely important for the future development of earth observation.

1.2 REPORT STRUCTURE

The report is divided into Chapters, with a Chapter dedicated to each of the Institute's Units.

Each Chapter follows the same format with an Introductory section defining the overall objectives of the Unit, its resources and the number of publications it has produced in 1992.

This is followed by sections on each of the activities of the Unit. These also follow a common form with a description of the objectives of the activities, a series of milestones for 1992 and a description of the work undertaken in 1992.

2 AGRICULTURE INFORMATION SYSTEMS

Staff

Scientific and Technical Support	12
Secretarial Support	2
Scientific Visitors	2
Students	4
Total	20

Publications

Journal Papers	10
Conference Papers	45
JRC Reports	5
Books/Chapters	1
Total	61

Facilities

- Micro Vax 3900 with MARS-PED software to process data for agricultural statistics, and ERDAS image pro-cessing software
- Matra/SUN 3 to develop AVHRR pre-processing software
- SUN 4 with ARC/INFO and I²S software
- SUN SPARC IPC with SPACE software

Some 127 million hectares (1.25 million square kilometres) of Europe is classified as agricultural. The economies of the larger agricultural member nations of the Commission of the European Communities (CEC) depend on agriculture for some 25 billion ECU per year, and subsidies for certain crops can be worth many millions of ECUs per year.

In order to execute the Common Agricultural Policy (CAP) the CEC must have timely, accurate data on the areas under economically important crops, especially on those subsidised by area, and it needs to estimate regional production in near-real time. Each member nation collects and analyses its agricultural statistics in a unique way, and it is difficult to compare the results at a European level.

Remote sensing has number of advantages to offer in the collection of these statistics:

(1) it is objective and centralised;
(2) it can be applied in any part of Europe;
(3) it can detect single fields or monitor the continent;
(4) very short-term changes can be monitored;
(5) certain data can be in the hands of the analyst within days.

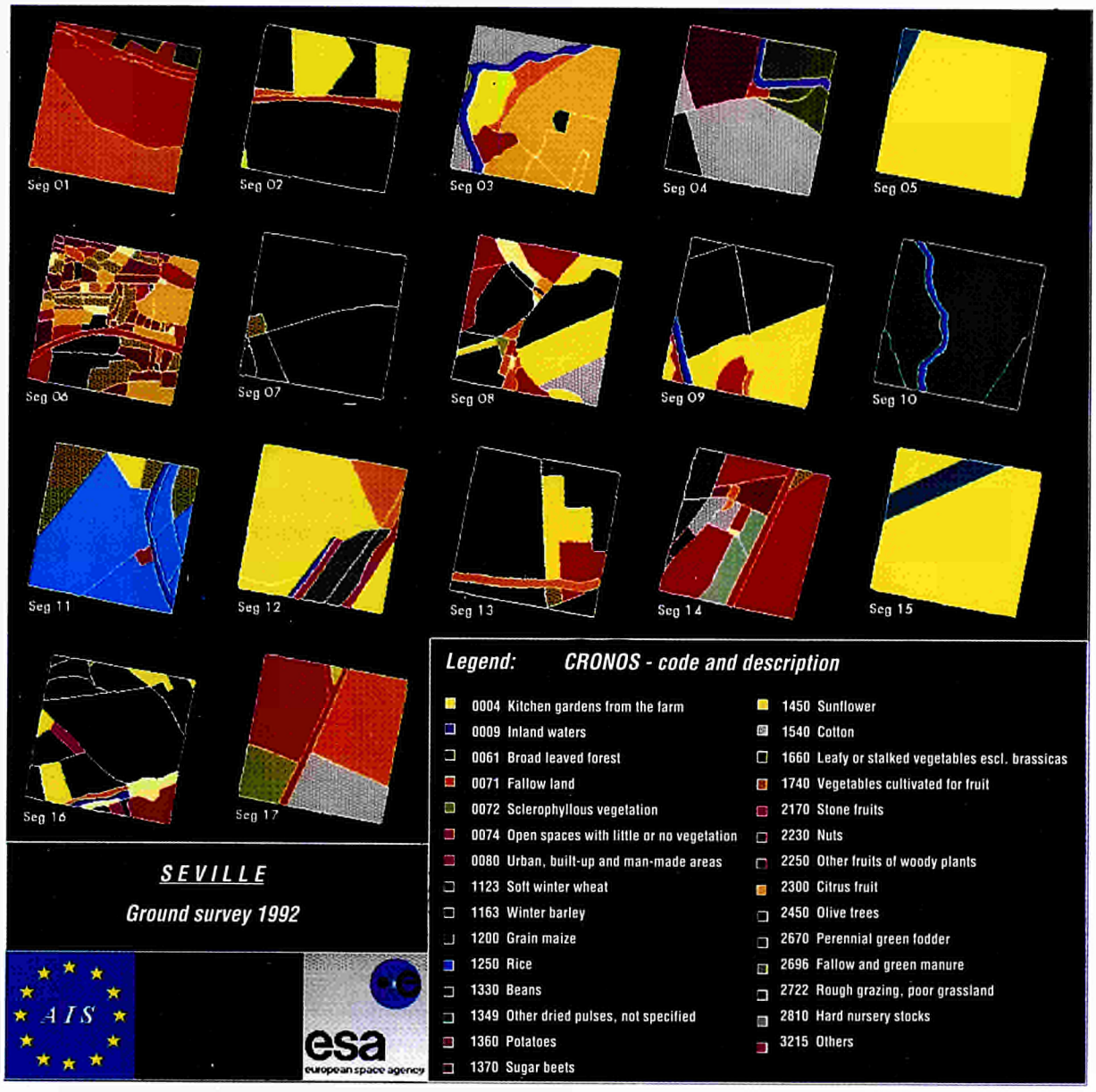


Fig. 2.1. Results of the 1992 ground survey, 29 land use (CRONOS) classes

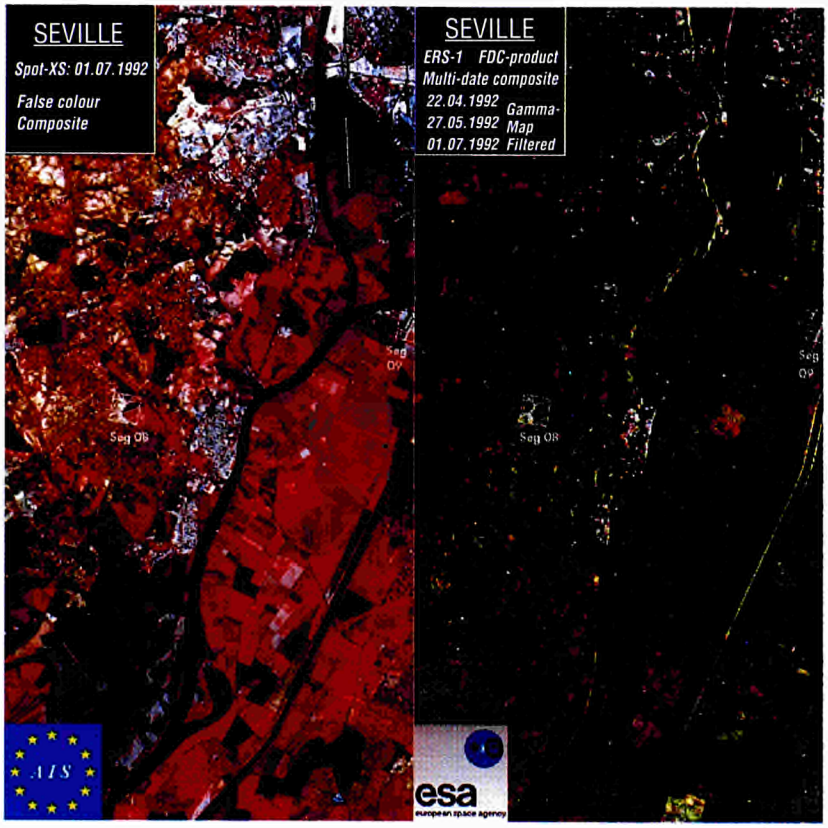


Fig. 2.2. Area south of Seville (town), False-Colour Composite, SPOT-XS (01.07.1992) and multi-date composite, 3 ERS-1-FDC channels (22.04,27.05,01.07), Gamma-map filtered

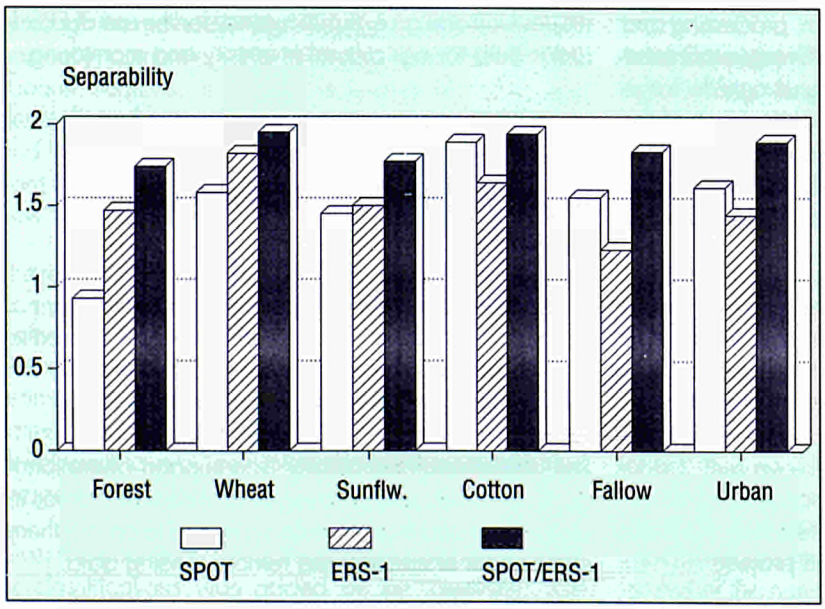


Fig. 2.3. Signature Separability Index. The figure shows the separability index of 6 land-use/cover classes against rice. Good separability means values above 1.9; this can only be achieved by the combination of SPOT and ERS-1

Monitoring Agriculture With Remote Sensing (MARS)

On 26 September 1988 the Council of Ministers approved a budget covering five years (1989-93) to finance a "Pilot Project for the Application of Remote Sensing to Agricultural Statistics". The project is funded and directed jointly by the Directorate General VI (Agriculture) and the Statistical Office of the CEC (EUROSTAT). The Joint Research Centre (JRC) has responsibility for this project entitled Monitoring Agriculture with Remote Sensing (MARS).

The objective of the MARS project is to define and demonstrate how remote sensing can be used operationally to supplement, interpret and standardise data provided by conventional techniques. Where appropriate, the project is to help regional or national organisations to implement its methods. In order to achieve these objectives the work has been broken down into seven main Actions:

Action 1: Regional inventories of crop acreages using a combination of high spatial resolution satellite data and ground work.

Action 2: Near-real-time monitoring of vegetation condition on a continental scale using low spatial resolution data from meteorological satellites.

Action 3: Agro-meteorological modelling of plant processes to forecast yield on a regional scale.

Action 4: Rapid estimates of change in acreages and potential yield using image interpretation of high spatial resolution satellite images of sample sites.

Action 5: Advanced Agricultural Information System integrating the products of all the other actions.

Action 6: Systematic ground data collection for the purposes of classification and interpretation of satellite data.

Action 7: Long-term research into new systems (e.g. microwave) or software (e.g. parallel processors) and the use of Geographic Information Systems for agricultural monitoring.

The project is to apply the techniques to the following crops:

Group 1: durum and soft wheat, barley, rape seed, and dried pulses.

Group 2: sunflower, maize, cotton, tobacco, sugar beet, potatoes, rice and soy beans.

This project breaks new ground in several ways. It is the first time that a project has a mandate to provide operational agricultural statistics from remote sensing.

In addition the objectives of the project require a novel, industrial approach to data acquisition, processing and analysis. In many cases this has led to requirements for software which are not normally found outside large private companies or military installations; much of the software for image processing, for example, has had to be designed to function automatically, with little or no human intervention, in order to cope with the volume of data.

Finally, in many cases the requirements of the project concern not only large volumes of data, but tight and demanding schedules, which means that huge amounts of high-quality work must be carried out rapidly and continuously.

Each of the four main Actions are described in detail in the following Sections, however progress has also been made in the supporting Actions of the project:

Action 5: Advanced agricultural information system: the integration of the data from remote sensing, modelling and conventional surveys.

In the future, the main area of development will be the integration of the data from high- and low-resolution satellite radiometers, information from agro-meteorological models, and data from conventional sources into one coherent whole. The plan for this "Advanced Agricultural Information System" is developed in outline, but the contribution of the various data sources cannot be made explicit before more of the initial results of Actions 1 to 4 are analysed.

Action 6: A unified system for collecting ground data for the classification and interpretation of satellite data.

The activities in Action 6 have been described under the headings of Action 1 and Action 4.

Action 7: Research whose results will be applicable to agricultural monitoring during the life-span of the project.

Most of the work in Action 7 has taken place in the field of Geographic Information Systems. Some has also focussed on the automatic segmentation of images for the purposes of Action 4 and Action 1. The project also prepared a joint proposal with the Advanced Techniques Unit and an external agency for the use of ERS-1 radar data for agricultural inventory and monitoring.

Registers And Control Of Agricultural Surfaces

In addition to the MARS project the Agricultural Information Unit is providing scientific and technical support to DG VI (Agriculture) in the use of remote sensing for the registers and control of agricultural surfaces.

The objective of this activity is to support operational applications by setting up registers of declared areas in agriculture, and thus providing a means to control them using aerial or spaceborne remote sensing data.

2.1 ACTION 1: REGIONAL INVENTORIES OF CROP ACREAGES

(in support of DG VI Agriculture and EUROSTAT)

Summary of Objectives

To implement and improve a method, based on area frame sampling and correction of the estimates with the help of data from satellites images, to estimate crop areas and production.
To provide technical support to countries in the EC that are using this method.
To extend this activity to countries outside the Community.
To assess other applications of the method.

1992 PROGRAMME OF WORK

Introduction

Action 1 was established to inventory areas under crops in several regions annually, each inventory region covering between 2 and 8 million hectares. The inventory regions are situated in the most agriculturally productive parts of the country concerned.

The project has now developed to the stage where the method has been developed and provided to the regions to operate. IRSA's role is now becoming more of one of technical support, although the technique is currently being modified by IRSA to accommodate the requirements of central and eastern European states.

1992 Milestones

May	Stratification work completed for the regions studied in 1992
July-Sept.	Ground survey area estimates ready
Nov.-Dec.	Remote sensing results and farm survey estimates ready when applied

Methodological Development

Although the method for deriving Regional Inventories is basically complete, and is being operated by the various Regions, it is still necessary to continually develop and improve the technique as requirements and technology evolve. This covers a range of areas from the development of new software to the testing of new methodologies.

The results of this work for 1992 are summarised below.

Software development

The main software used in the context of Action I to estimate crop areas through area frame sampling and satellite images is called MARS-PED. This software was developed to provide statistical results and had few image analysis functions.

Over the course of 1992 the ability to display images or classifications was added on an X-terminal; this included an ability to overlay vector information from field survey documents, strata or administrative units. Some statistical functions were also added to accommodate changes in the technique, the most significant being to allow a sampling unit to straddle boundaries between strata or administrative units.

Stratification By Interpretation Of Satellite Images

In the course of the year a method was developed, using Arc-Info and ERDAS, to stratify zones for area frame sampling. The method was used to stratify Tras-os-Montes (Portugal), Thessalia, Voiotia, Ftiotida (Greece), Bohemia and Moravia (Czechoslovakia). The resulting Arc-Info vectors can then be imported into MARS-PED.

Area Estimates Of General Land Use

Until the beginning of this year, all the regional inventories focused on arable land and permanent crops. In 1992 the method was adapted for general land use statistics, with the accent on environmental parameters. This technique was tested in Catalonia.

Compared to a specialised agricultural survey, the general survey demands more detailed stratification and a higher sampling rate in the non-agricultural strata. Smaller segments were tested in the urban areas. For segments in high mountain areas without any arable land, recent aerial multispectral images were interpreted, thus avoiding the need to visit the area.

The technique gave satisfactory results, and detailed agricultural inventories were achieved in parallel with surveys of the non-agricultural area. The marginal cost of extending the survey in this way was limited to the cost of the additional segments. It was also found that the efficiency of the survey was increased by stratification.

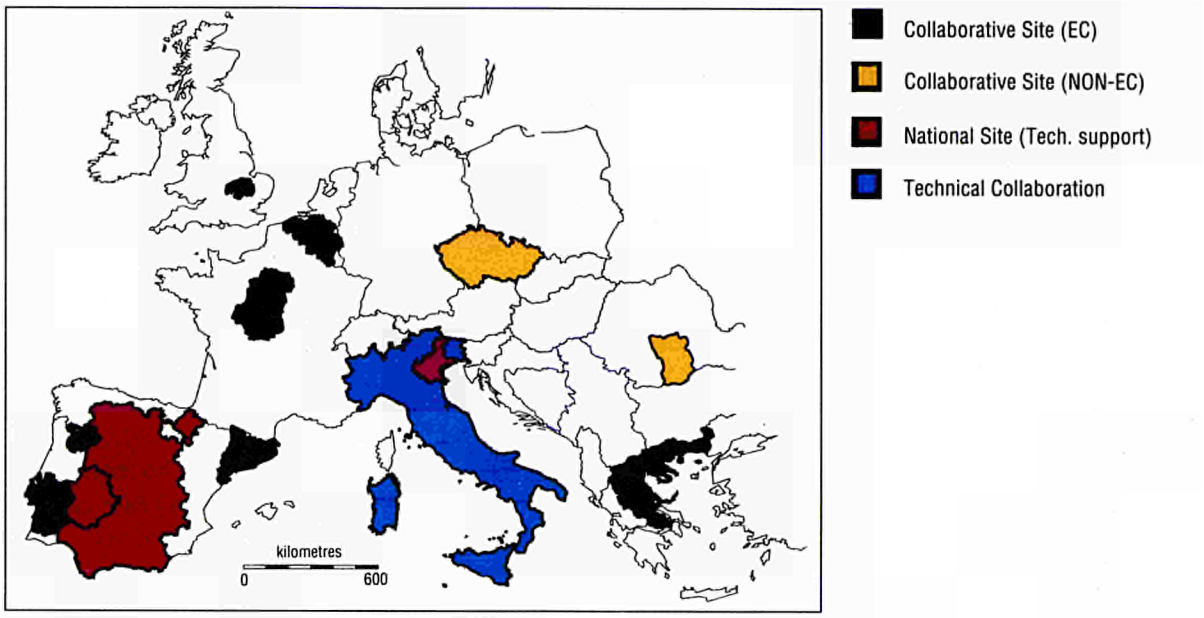


Fig. 2.4. Action 1 sites 1992

Point Samples In Place Of Area Samples

The French Ministry of Agriculture uses point samples rather than area samples in its national land use survey "Ter-Uti". In 1992 the method of image classification and regression was adapted to this type of ground data, and applied to some test cases. The statistical results derived from this modified method are currently being examined. If the method gives satisfactory results this will add a significant new technique to the current array.

Technical Support To The Regional Inventories Activity

IRSA is currently supplying technical support to the Regions, DGVI and EUROSTAT in the implementation of the Regional Inventories methodology. This was started in EC Member States, but is now being extended to Central and Eastern European states.

European Community Member States

BELGIUM

With the exception of the Brussels region, where agriculture is insignificant, the whole of Belgium has been surveyed in a collaborative effort involving the Ministry of Agriculture, the Belgian SPPS (Service de Programmation de la Politique Scientifique) and the MARS Project. The official agricultural regions were used as strata. Two different sampling rates were used for more or less intensively agricultural regions.

UNITED KINGDOM

The three counties of Bedfordshire, Cambridgeshire and Northamptonshire were surveyed in 1992. The ground data were obtained from a FEOGA pilot activity in the frame of set-aside and the validation of oilseed declarations. The area is agriculturally homogeneous and was not stratified.

FRANCE

The regions "Ile de France" and "Centre". have been surveyed since 1990 using area frame segments. The areas are not stratified, though the "Département" can be considered as a stratum. The ground data was collected by the SCEES (Ministry of Agriculture).

GREECE

The Ministry of Agriculture is implementing Regional Inventories throughout the agriculturally important regions of Greece. In 1992 the Ministry surveyed Makedonia, Thraki, Thessalia and two nomos of Sterea Ellada. At the same time, the Peloponissos and Euboia were stratified and will be surveyed next year.

PORTUGAL

The Portuguese Ministry of Agriculture is progressively extending the area frame survey. In 1992 Alentejo, Ribatejo-Oeste and Tras-os-Montes were surveyed.

ITALY

The AGRIT Project, operated by the Ministry of Agriculture, is based on an area frame sampling with irregular (cadastral) segments. Continuous contact has been maintained with the Ministry for technical discussion and exchange of experiences.

The Veneto administration is independently surveying its region, using square segments and the MARS-PED software. Technical support for this work has also been provided.

SPAIN

Apart from the environmental work in Catalonia, the regional Administration of Navarra has been helped to undertake an area frame sampling and remote sensing programme. This work includes both operational and research aspects. In this area the Institute is particularly interested in comparing results derived from square and irregular (cadastral) segments.

The Ministry of Agriculture is also being advised in its surveys of Castilla y Leon, Castilla-La Mancha, Madrid, and Andalucia. These areas cover more than half of Spain.

EASTERN EUROPE

In Eastern Europe, political changes are resulting in major changes in agricultural structures. The methods that were used for estimating crop areas and production before these administrative changes are not always well-adapted to the new circumstances. Methods developed for regional inventories in the EC were adapted to take into account the particularities of the zone.

CZECHOSLOVAKIA

Area frame sampling in the west part of Czechoslovakia (the region that is now the Czech Republic) provided objective estimates of crop areas and production. By maintaining the same sample it will be possible to monitor changes in the next few years. The segments were particularly large, corresponding to the size of the fields.

ROMANIA

Five Judetz and the Ilfov Agricultural Sector around Bucharest were surveyed in 1992.

Perspectives for 1993

The MARS Project will be active in research aimed at improving methods, and in developing specialised software for Regional Inventories. In other respects IRSA's role will be reduced to one of technical support. This will include training personnel to run regional inventories in and beyond the EC.

At the same time the area covered by such surveys will be extended into those southern countries of the EC that are interested in implementing the method in new areas. Possible areas of interest include Peloponissos and Euboia in Greece, the Beira litoral in Portugal, and some areas of Spain. It is expected that the surveys in the Czech republic will be improved, and then extended into Roumania.

In addition a Euro-Course will be held in Athens. There will also be a major contribution to a course organised by the Spanish Ministry of Agriculture in Madrid, and to the Italian Institute of Statistics in Stresa.

The development of MARS-PED will also be continued with the major aims being to make it easier to use, and to improve its links with other related packages, mainly the ones developed for updating the CORINE land cover and the software for monitoring farmer's declarations for FEOGA.

Finally it is planned to study the optimum size of segments and develop methods for combining segments with a detailed stratification.

2.2 ACTION 2: VEGETATION CONDITION AND YIELD INDICATORS USING LOW-RESOLUTION SATELLITE DATA

(in support of DG VI Agriculture and EUROSTAT)

Summary of Objectives

To develop the capability within the services of the Commission to use Advanced Very High Resolution Radiometer (AVHRR) data for vegetation monitoring.

To develop software for pre-processing AVHRR data.

To develop software to use the pre-processed data as an indicator of vegetation condition.

To promote research into the agricultural use of AVHRR data, especially for monitoring vegetation condition and indicating yield.

1992 PROGRAMME OF WORK

Introduction

The objective of Action 2 is to supply DGVI with status bulletins at 10 day intervals giving up to date information on the state of the vegetation over the whole of Europe. The data are derived from the Advanced Very High Resolution Radiometer (AVHRR). These data are collected at low spatial resolution (1 kilometre at nadir), and can be used as an indicator of crop condition allowing the monitoring and mapping of the extent and severity of drought or frost.

In 1992 Action 2 was mainly concerned with organising data purchase and undertaking software development, with some effort devoted to thematic work.

Data purchase

The data were purchased from stations in the ESA/ESRIN family throughout 1992. DLR provided real-time data for the whole of the year, while the University of Dundee supplied historic data from their archives.

Software Development

Advanced Very High Resolution Radiometer (AVHRR) data are provided in a format called SHARP, uncalibrated and in the satellite projection. The atmosphere contaminates the signal. To calibrate the data, remove the effects of the atmosphere, and correct the geometry, the MARS project created SPACE (Software for Preprocessing AVHRR data for the Communities of Europe). This software was delivered in 1991.

1992 Milestones

Jan.	Preprocessing starts
Feb.	Work starts on SCAN
May	Parallel version of SPACE completed
July	Preprocessing halted
Sept.	Landmark ready for use
Nov.	First interpolated images of Europe created

SPACE

Most of the effort in 1992 has concentrated on developing and improving SPACE, first under contract with Tecnodata of Italy, and then with EOS of the UK. Several areas of potential improvement were identified, and the highest priority was given to corrections to parts of the code giving incorrect results, followed by changes making the software faster and more flexible.

Two algorithmic errors were discovered and corrected in 1992. One concerned the calculation of solar illumination, the other the projection of remapped data.

Much of the effort to improve the performance of SPACE focussed on the slowest parts of the data-correction process: locating the image (geometric correction) and projecting it into the final mosaic (remapping). The improved geometric correction routine locates the image faster and with greater accuracy than before. The redesigned remapping module halves the time for this step, significantly improving the productivity of the software.

SPACE was designed for use in Europe, and is unsuitable for other parts of the globe. In 1992 one of our aims was to increase the applicability of the software. This work focussed on transferring tables from the code to user-accessible files, providing utilities to update those files, and writing code to access them. The

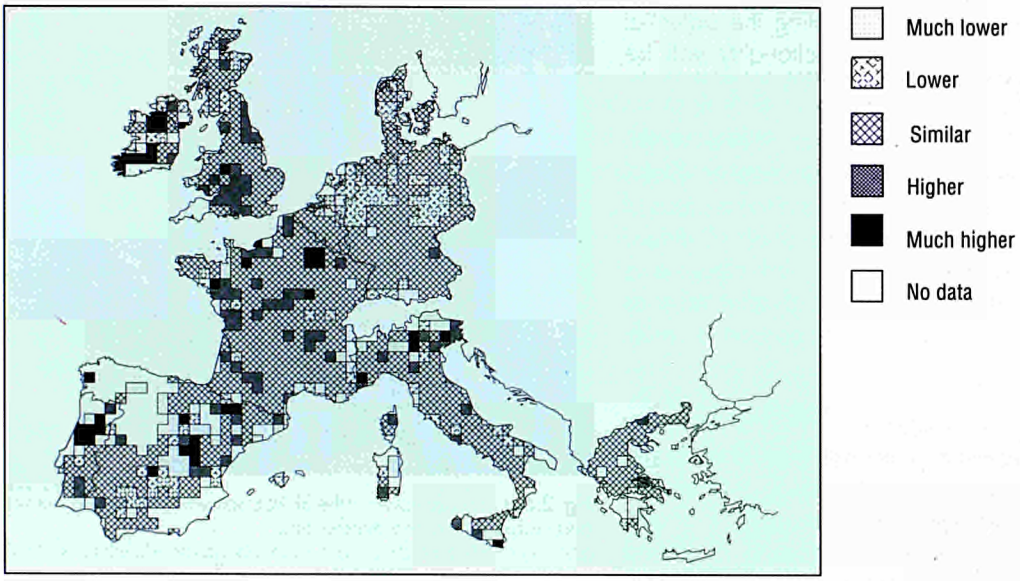


Fig. 2.5. Difference in time between the NDVI recorded on the 30/4/93 and the time (in days) for which the same NDVI was recorded in the previous year

beneficiaries are the routines for calibration and atmospheric correction. This work is complete; the code is now cleaner and more flexible.

In short, in the course of 1992 solutions have been implemented for all of the functional difficulties that have been identified.

SCAN

SPACE creates mosaics of data from which the agricultural information must be extracted. Software is then required which can use these raw data to construct time profiles of various indices for pre-defined zones of Europe. These profiles can then be interpreted or used to construct maps of vegetation development. Over the course of 1992 the requirements were specified for this software, and a prototype was built and tested. This software, called SCAN (System for Condition Assessment using NOAA data), extracts the data from the mosaics and prepares them for plotting by Arc-Info. By the end of 1992 SCAN was ready for acceptance testing, and should be operational early in 1993.

Landmark

In 1992 new software was provided for generating a library of ground-control points used for the geometric registration of the images. This software combines ease of operation with rapidity, letting the user quickly establish a custom-built library for his application. Once this package was tested and delivered, work began on extracting suitable ground control points and testing them for use with SPACE.

Parallel Version Of SPACE

In collaboration with JRC's Institute for Informatics and System Engineering (ISEI) a version of SPACE running on a parallel computer has been developed. This software demonstrated a significant improvement in calculation time, although the processing time was limited by I/O operations. Further development in this direction could lead to the possibility of rapid pre-processing of the 12-year AVHRR archive.

Preprocessing

While it was being improved, an operational version of SPACE was used routinely to process over 1500 scenes in the first half of 1992. Operational processing was halted in mid year once sufficient experience had been gained with the capabilities and limitations of the software. Processing will be restarted after acceptance testing of the new version of SPACE.

The pre-processing work resulted in an archive of one-day mosaics from early February 1991 to July 1992 and demonstrated the capacity of the system to process up to 150 incoming scenes each working week.

By adding functionality to the system handling the optical juke box, the autonomy of operation could be

extended to about 20 hours, doubling the potential throughput of the system. This functionality will be added early in 1993.

The mosaic archive indicates the potential of the AVHRR instrument for vegetation monitoring in Europe. Cloud obscures most scenes; in the 1991 data some areas of northern Europe were only imaged 8 or 10 times. Cloud leads to a fragmented mosaic, with clear views clustered around certain dates. In strongly affected parts of northern Europe, inter-annual comparison is unreliable.

The geometry of the image is corrected partly by comparing the image coastlines with their location in a digital map. The geometric correction works well provided that the image shows fragments of coast which correspond to elements in the library of ground control points. The ground control point (GCP) library will be expanded in 1993.

The SPACE software has not yet been distributed because it is still a prototype, and not a fully-operational system. Also the present code is too difficult to modify by external users. In the future the software and documentation will be supplied to organisations who request SPACE; the recipients will be asked to recommend additional functionality or improvements to the code.

Thematic Applications

Modelling Vegetation Indicies

The most significant advance in the thematic study of the AVHRR came with the presentation of a final report by INRA/LERTS of France covering the modelling of time profiles of vegetation indices from the AVHRR. This work demonstrated that it is possible to extract a considerable amount of useful thematic information from the AVHRR signal despite the mixture of targets contained in the typical AVHRR pixel. This work should lead to interesting new applications of the data.

Creation Of Sample Zones

Any area of Europe is characterised by a mixture of vegetation types. Each mixture responds characteristically to the seasons. The radiometric effect of these responses can be monitored with the AVHRR and used to define the limits of the zone. Each zone can then be treated as a single monitoring unit. Its radiometric changes can then be followed through the year, to detect abnormal vegetation responses. Work to develop these zones continued throughout the year.

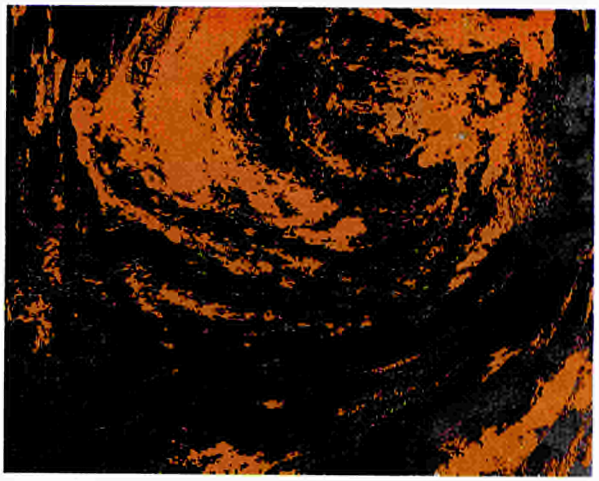


Fig. 2.6. Cloud detection of the SPACE software done using thermal and visible criteria and thresholding

Perspectives For 1993

Work in 1993 will again focus on software, the key to the automatic processing of the data.

The geometric correction routine, which currently works on single 4-minute SHARP-1 scenes will be adapted to work on the whole sequence of scenes making up the pass. In this way it will be possible to recover some of the data on heavily clouded scenes. This work will be completed in the first quarter of 1993.

It is also now time to take stock of the work; to stop development, to document, and to clean up the software. This work is scheduled for 1993.

In parallel the new version of SPACE will be used for routine pre-processing; this will be delivered in early 1993.

A set of functions will also be implemented, independent of the existing software, which will make it easier to access and extract the pre-processed data.

In 1993 and following years the attention will focus on the agricultural uses of the data, and will respond to the requirements of the users. The delimitation of homogeneous zones is essential for this development. The aim is also to improve the reliability, automatisation and autonomy of the system for data acquisition, delivery, and processing.

2.3 ACTION 3: AGROMETEOROLOGICAL MODELLING

(in support of DG VI Agriculture and EUROSTAT)

Summary of Objectives

To develop agro-meteorological models which simulate the growth of crops to monitor crop state and forecast yield in a timely fashion using meteorological data from ground stations

To complement and cross-validate satellite derived results

To develop a comprehensive and consistent database of geographic information concerning weather, soils and crops for the whole of the EC

1992 PROGRAMME OF WORK

1992 Milestones

Jan.	Generic agro-meteorological model delivered
April	System to receive, quality check, interpolate, summarise and present meteorological parameters operational
May	First validation of generic agro-meteorological model
Sept.	Generic agro-meteorological model operational

Introduction

While satellite imagery can be used to estimate crop acreages and to derive yield indicators, quantitative yield estimates have still to be derived on the basis of information about environmental conditions, including soils, topography and meteorology. The goal of Action 3 is to develop agro-meteorological models which simulate crop growth by processing this environmental information to derive estimates of crop state and production. The results of these models can be used to complement and cross-validate satellite derived results. By the start of 1992 the software to model crop growth had been largely coded, and parts of the software were being tested.

A large volume of environmental data are required as input to these agro-meteorological models. Action 3 has therefore devoted considerable effort to developing a comprehensive and consistent database of meteorological, pedological and crop parameter information. This database was essentially complete by the start of 1992. It is now probably the most complete agriculturally oriented Geographical Information System in the EC.

Development Of Algorithms

Algorithm development is a major research area for Action 3. Parameters such as potential evapotranspiration, solar radiation, and soil water balance are key inputs to any agro-meteorological model. Unfortunately they are not normally directly measured routinely at meteorological stations. Instead, parameters such as vapour pressure, temperature and cloud cover are routinely available, and we may also have access to soil maps from various sources. It has therefore been necessary to develop and refine algorithms to calculate the key input parameters for the models; algorithms for other parameters such as estimated planting date are still to be developed.

The meteorological database contains daily observations from 350 stations stretching back over 30 years. It was developed in 1989-1991, when data were only available through 1989. Since mid 1991, daily real-time meteorological data from over 700 stations have been received covering not only the EC but part of Eastern Europe and Scandinavia. An operational system for the reception and quality checking of these data is now in place.

The meteorological parameters are collected at stations scattered irregularly over the land area of the EC and its bordering countries and seas. The models must work well over all of the EC, not just at meteorological stations. Currently, therefore, methods are being developed and refined for interpolating these point source data to a regular grid. The EC Support Group for Agrometeorology ('SuGrAm'), composed of experts in agrometeorology and chaired by the World Meteorological Organisation, is providing guidance and advice for the development and validation of the algorithms and interpolation approach.

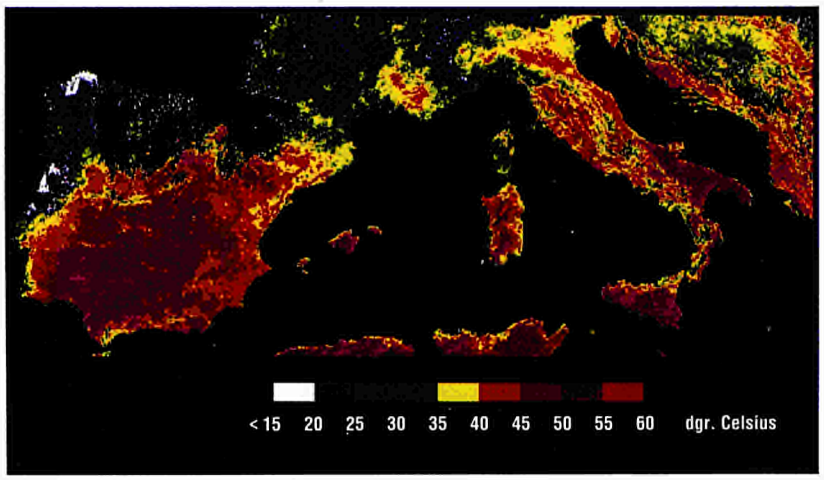


Fig. 2.7. Surface temperature estimated from NOAA AVHRR data of 29 July 1992. Black areas in the North of Spain and in Portugal represent clouds

Software

In 1992 the generic agro-meteorological model was implemented and validated, consisting of a set of purpose built algorithms which use all of the environmental parameters listed above to calculate crop state and production estimates on the European scale.

Products

The following products, mapped on a 50 by 50 km grid, are now available every 10 days:

- (agro-)meteorological conditions for the present growing period, both for the current year and as a deviation from long term mean conditions
- estimated crop state and growth indicated for the present season for a generic crop, both for the current year and as a deviation from long term mean conditions.

Meteorological Database

In 1992, Action 3 acquired data to fill the gap in the meteorological database from 1989 to 1992. From the time of their reception to the end of 1992 (and continuing into 1993), the quality of these data has been checked and the data have been integrated into the historical database. Work has also been started to restructure the meteorological database with the aim of merging the historical and real-time archives into one easily accessible ORACLE database. These data will be used not only by Action 3, but also by other parts of the MARS project.

Soils database

In the course of 1992 the soils database was expanded to Eastern Europe. With the guidance and advice of the "Soils and GIS Support Group", Action 3 has begun to digitise and code the soils maps of most of the Eastern European countries. While the same methodology has been used in each country, work remains to integrate the different maps to resolve border differences and to harmonise the result with the existing EC soil map.

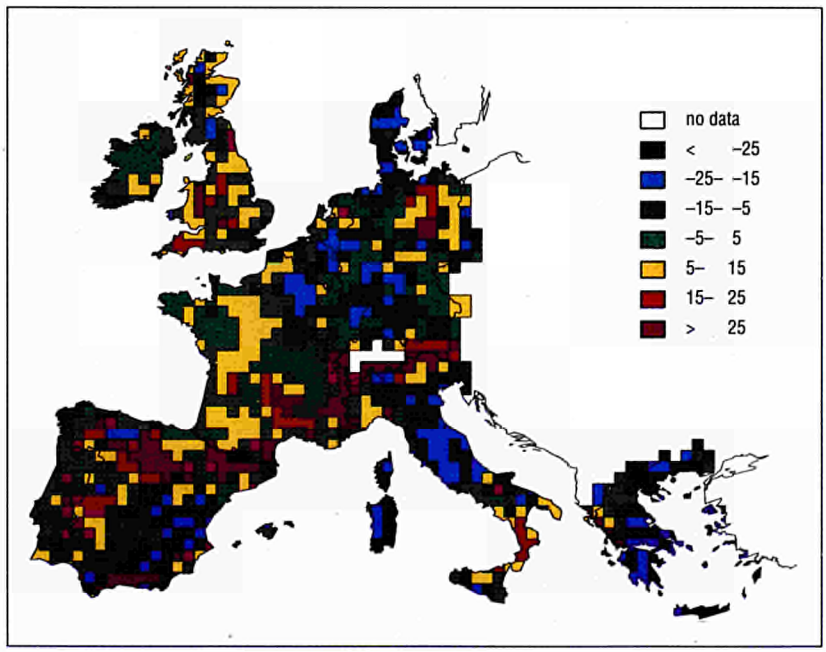


Fig. 2.8. Cumulative weight above ground biomass percent deviation from long term mean 1992. First decade of September cumulated since the first decade of January

Crop State Models

The Action 3 generic crop model simulates the growth of a cereal crop through the season on the basis of water and radiation inputs. The needs of the crop are derived from crop parameters which vary according to phenological stage as the season advances. The parameters presently used in the model correspond to winter wheat. In order to validate the results, a comparison has been undertaken with historical crop statistics collected by Eurostat.

Sugar Content In Wine Grapes

In cooperation with DG VI and with wine experts from several EC countries, an agrometeorological model has been developed and validated specifically for wine grapes. This model estimates the long-term mean regional grape sugar content in wine grapes on the basis of the historical meteorological database. This model will help provide an indicator for use in a zonation of wine growing areas.

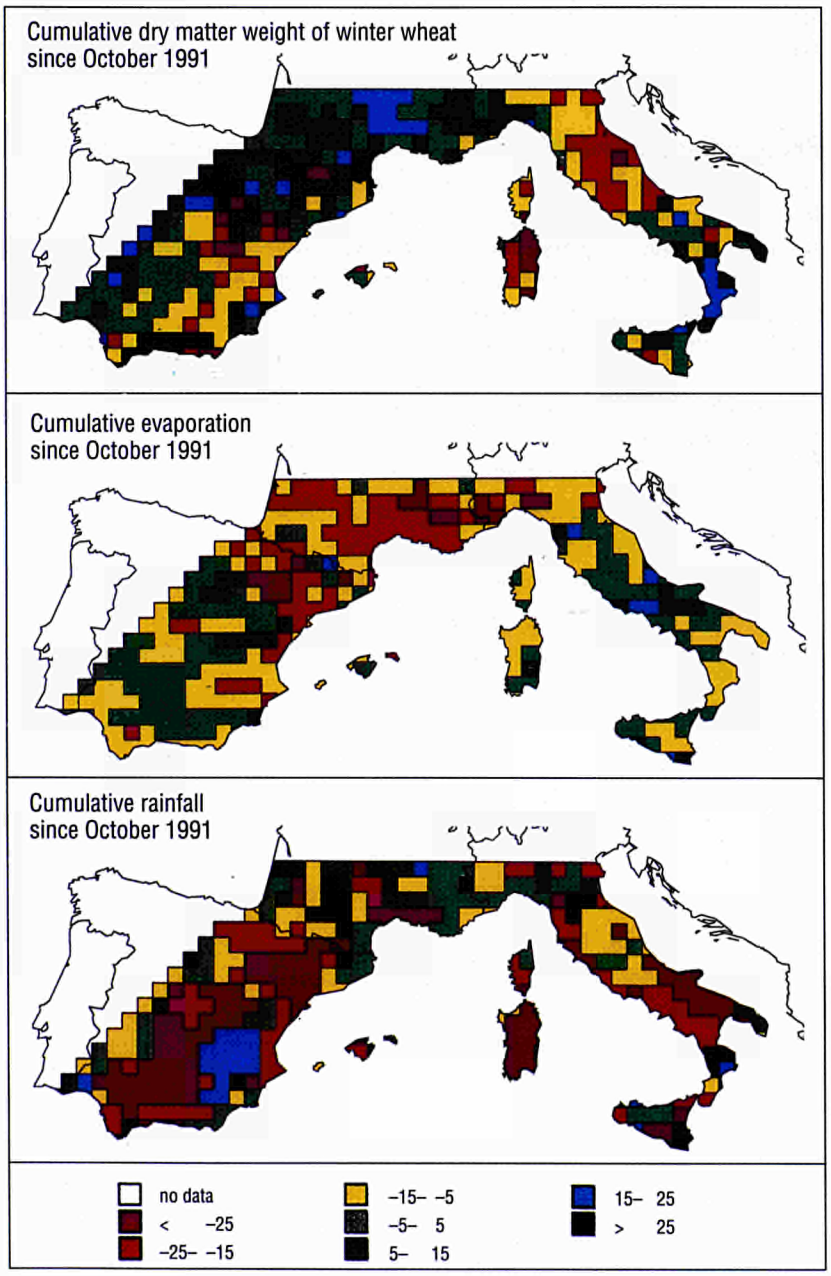


Fig. 2.9. Regional monitoring of hydrological conditions in the Mediterranean. Dry matter, evaporation and rainfall compared to long term mean values. Situation at the end of August 1992

Support Groups

Action 3 has continued to coordinate the two EC support groups which work in the areas of "Soils and GIS" and "Agro-meteorology" (SuGrAm). These groups are composed of scientists who contribute their expertise and advice to the MARS programme. The members have contributed towards algorithm development and validation, and have contributed particularly to the soils database, to calculating parameters such as potential evapotranspiration, and to the interpolation of meteorological data.

Third Party Work

Headed by the staff of Action 3, the Agricultural Information System Unit submitted a successful proposal for third party work. This major contract, which is part of a project called HYDRE, centres on monitoring water resources for 5 Mediterranean regions. It will involve the use of agro-meteorological models with a refined

resolution and the use of low resolution (AVHRR) satellite data contributed by Action 2.

Perspectives For 1993

The main agro-meteorological model will be adapted to accept a variety of parameters representing several different crops and to calculate results specific to these crops. The results will also be stratified on the basis of published statistics of area devoted to each crop type.

In the context of the third party contract, the EC-oriented methods will be adapted to produce finer resolution outputs for the Mediterranean regions concerned. Techniques will also be developed to integrate satellite data into the models, and to use the satellite data to ensure that the results correspond to the reality.

Algorithms will be developed to estimate solar radiation on the basis of data routinely available from meteorological satellites.

By the end of 1993 the meteorological database will be restructured to make it more useful for a variety of other applications.

2.4 ACTION 4: RAPID ESTIMATES OF CHANGES IN CROP ACREAGES AND POTENTIAL YIELD

(in support of DG VI Agriculture and EUROSTAT)

Summary of Objectives

To provide DG VI and EUROSTAT, in the course of the growing season, with estimates at the European scale of changes in the acreages planted with various crops.

To develop and implement techniques for estimating the yield of the same crops at the European scale

To develop software which will increase the objectivity, repeatability and rapidity of interpretation and estimation

To adapt the design and software of Action 4 for future operation by other services of the Commission.

1992 PROGRAMME OF WORK

Introduction

Action 4 uses high resolution SPOT XS and Landsat Thematic Mapper (TM) images, supplied by SPOT Image and EURIMAGE respectively. These images are acquired over 53 sample sites throughout Europe. No more than 4 images of each site are acquired each year. The schedule is determined by "windows of opportunity", based on local crop calendars, to maximise the chance of discriminating between crops at the site. The image companies inform SOTEMA, our main contractor, whenever they acquire a cloud-free image of a site within a window of opportunity. This closes the window for that site. The image is rapidly processed and shipped by to SOTEMA, which corrects the calibration and geometry of the image, analyses it, and extracts the relevant information.

Every two weeks agricultural statisticians compare the latest information with the corresponding data from the previous year, and send this information by fax to the JRC, the DG VI and EUROSTAT.

Ground data are collected to validate the image interpretation at the end of the year.

1992 Milestones

Jan.	Ground data from 1991 incorporated
Feb.	All 53 sites ready for analysis
March	First bulletin for 1992 published
June	Adoption of new method for calculating areas
July	GRIPS operational for SPOT images
Oct .	Final bulletin published
Dec.	Final report for Phase 3 received

Result Of The 1992 Campaign

1992 was the first year full-scale operational test for Action 4, with 53 sites contributing to the estimate.

179 high resolution images were analysed in the campaign. Images of 48, 53 and 51 sites were acquired in the first 3 windows. Thematic results were so good that acquisition was stopped for all but 35 sites, of which 27 were imaged.

More than half of the images were acquired and analysed within 10 calendar days. Analysis was delayed when too many images arrived during spells of clear weather or when problems with the data meant that the image had to be sent back to source.

The results are in agreement with the end of year data provided by EUROSTAT, which are compiled from sources independent of Action 4. Our area estimates are consistently within 3% of the EUROSTAT figure for crops such as soft wheat, hard wheat, barley, and maize. Close similarity was also found with production estimates. For most crops the estimates varied little after May.

Software Status And Development

As well as constantly increasing the rapidity and objectivity of the analysis, Action 4 continuously improves the performance, functionality, robustness, quality and maintainability of its software.

ESPAS

Developed for Action 4 over the course of 1989 and 1990, the ESPAS software has served most of the basic image analysis requirements. ESPAS, which runs under VMS, is a working prototype and is currently scheduled to be replaced in 1994 by improved software running under Unix.

CANDY
A method for automatic classification of satellite images was developed by LERTS of France and integrated into the processing chain in 1991. This software was used throughout 1992 in the background, in parallel with the work of the interpreter, thus saving time. It has fulfilled its early promise and increased the productivity of the team.

GRIPS
One of the bottlenecks in the operation was the geometric correction and calibration of images. Previously, this step was executed by IGN Espace of France. In June 1992 CISI of Italy delivered software developed jointly with Geodesign under contract to IRSA. The software can accurately and rapidly correct 4 SPOT images concurrently. A TM module is due in early 1993, after which all Action 4 images will be processed on site, with little operator intervention, streamlining the operation and reducing costs.

Status Of Software For The Extrapolation Of Site-Specific Data
Early in 1992 IRSA asked SOTEMA to develop software to overcome the three main obstacles in the way of using image data from sample sites to estimate areas under crops in Europe: (1) Image interpreters cannot always distinguish between crops, since two or more crops at a site may have similar or identical radiometric characteristics in the available channels. (2) At any given date, there may not be access to images of one or more sites at which a particular crop is present. (3) The contribution of a site to the estimate for a particular crop depends on the area covered by the crop at that site relative to its extent at other sites. A statistical model and decisional rules has therefore been developed which has contributed much to the success of Action 4.

Research

The importance of Action 4 to European agriculture and to the space industry has meant that it has been strongly supported externally and it has been possible to find partners in development. For example, in 1992 research on Action 4 was funded principally by CNES of France.

TOPASE
TOPASE is a knowledge-based system which uses archived radiometric and classification information to help the interpreter to decide how to class the contents of each field under review. It provided support to the interpreters throughout 1992. In parallel, we have sought to develop the capacity of the software to make many of the decisions currently made by human interpreters.

Fig. 2.10. Vineyard register. Alfiousse test site (Greece / 13.03.92)

Mid Infra-Red
The image interpreters have not used the mid-infra red channel 5 of TM in the interests of compatibility with the SPOT images, which do not have a channel in the corresponding part of the spectrum. Studies in 1992 showed that the mid infra-red contributes significantly to the discrimination and classification of crops. It is therefore planned to use this information once SPOT 4, equipped with the channel, becomes operational in 1996.

Yield
In 1992 further research was undertaken into estimating yield from high resolution images in the context of Action 4. This research, carried out by ESAP, has demonstrated the sensitivity of yield models to initial conditions. It suggests that yield cannot be estimated quantitatively under these conditions from high resolution images on their own.

Image Segmentation
If it was possible to automatically detect fields in an image, it would be possible to classify by field instead of by pixel, which should lead to improved separation of classes, better estimates of areas under crops, and advances in the automatic identification of crops. In the context of Action 4 several techniques have been commissioned and tested for automatic image segmentation. An algorithm developed by Arkemie was extensively tested, with excellent results.

Perspectives For 1993

The work in 1993 will centre on providing timely estimates to Brussels and Luxembourg, using data from all 53 sites. The main research interest in this exercise will be to determine whether the excellent results of 1992 will be repeated in a year with a different weather pattern.

The system's capacity will also be tested to see if it is possible to consistently produce accurate results early; if so, resources could be focussed on the early part of the year, and only a few images would be purchased later in the year for information on the remaining crops in specialised sites. Accurate estimates this early in the growing season would confirm Action 4 as an invaluable addition to the set of techniques available to the agricultural services of the Commission.

As a result of requests from the end users, some structural changes, and changes in information content will be introduced to the crop status bulletin.

Various functions will be made available to ESPAS in the early part of 1993. In the course of the year the main development work will be the definition of the future system to replace Action 4 when the operation is handed over from the JRC to the DG VI. At this stage, the system should be robust and require as little human expertise as possible, thus making it cheaper to operate and more objective. It is therefore necessary to concentrate on developing the detailed requirements specification for the future operating software, and working those requirements into an invitation to tender for software development.

2.5 REGISTERS AND CONTROLS OF AGRICULTURAL SURFACES

(in support of DG VI Agriculture and EUROSTAT)

Summary of Objectives

To use airborne or spaceborne remote sensing techniques to manage and monitor agricultural subsidies and interventions in the market for sectors in which the control is exercised through area planted: set aside, arable land, vineyards, olives and citrus fruit.

Introduction

1992 will remain in the memory of the European farmer as the year of the reform of the Common Agricultural Policy (CAP). Subsidies that were paid on the basis of production are now paid by area.

The MARS project has been closely involved in this change, and has especially helped in defining new technological solutions to the problem of evaluating farmer's declarations. To provide this assistance the project brought to bear its experience in the field of agricultural statistics and in following up the citrus, olive and vineyard registers.

1992 Milestones

April	Start of the citrus pilot study in Portugal Check of declarations of arable land starts
Aug.	Check of arable land declarations ends: 15000 files from 10 member states were examined
Sept.	End of the vineyard pilot studies in Portugal and Greece
Oct.	Attribution of the olive pilot studies in Portugal and Greece
Dec.	End of the land register evaluation studies End of the citrus pilot study in Spain

Arable Land Declarations

Once the national administration has received a request for subsidy from a farmer, it must decide whether or not the farmer is eligible. Remote sensing can help in this decision in the following ways:

- it can reduce the number of spot checks and hence reduce the cost of the operation;
- it can identify which declarations are valid and hence identify the farmers who need not be visited by the ground teams;
- it can identify the declarations which are clearly false or for which some legitimate doubt exist, and hence focus the spot checks;
- it can provide additional information to help the ground teams in their decisions.

More than 15,000 declarations were checked using satellite data in all of the member states with the exception of Luxembourg.

Two high resolution (SPOT or TM) satellite images were acquired at different times of year for each of the areas monitored. Interpreters used this information to determine the crop types in every one of the fields listed in the declarations and classified these declarations as "false" (one third of all declarations), "doubtful" or "legitimate". Spot checks of all "false" declarations were then carried out, and in almost every case the declaration was subsequently rejected. Some of the "doubtful" and "legitimate" declarations were also checked; these were almost all found to be acceptable by the national authorities.

Vineyard, Olive And Citrus Registers

The registers contain agronomic data on varieties, crop conditions, density, age and agricultural practices applied to permanent crops. They are keyed geographically to fields and farms with the help of aerial photographs or cadastral maps. These geographically-oriented data bases on permanent crops are used in the management and monitoring of sectorial policies.

In its contribution to the registers, the MARS project has:

- defined and tested new methods for constructing and maintaining the data bases, with the twin aims of reducing the cost of the operation and increasing the timeliness of the information. In 1992, case studies were implemented in Greece, Spain and Portugal on the vineyard and citrus registers;
- examined the potential of satellite imagery to detect

illegal vineyards or to check that vineyards said to have been removed have indeed been removed. To do this, we interpreted multi-temporal high-resolution (SPOT Panchromatic and multispectral) satellite imagery and combined the product with cadastral maps.

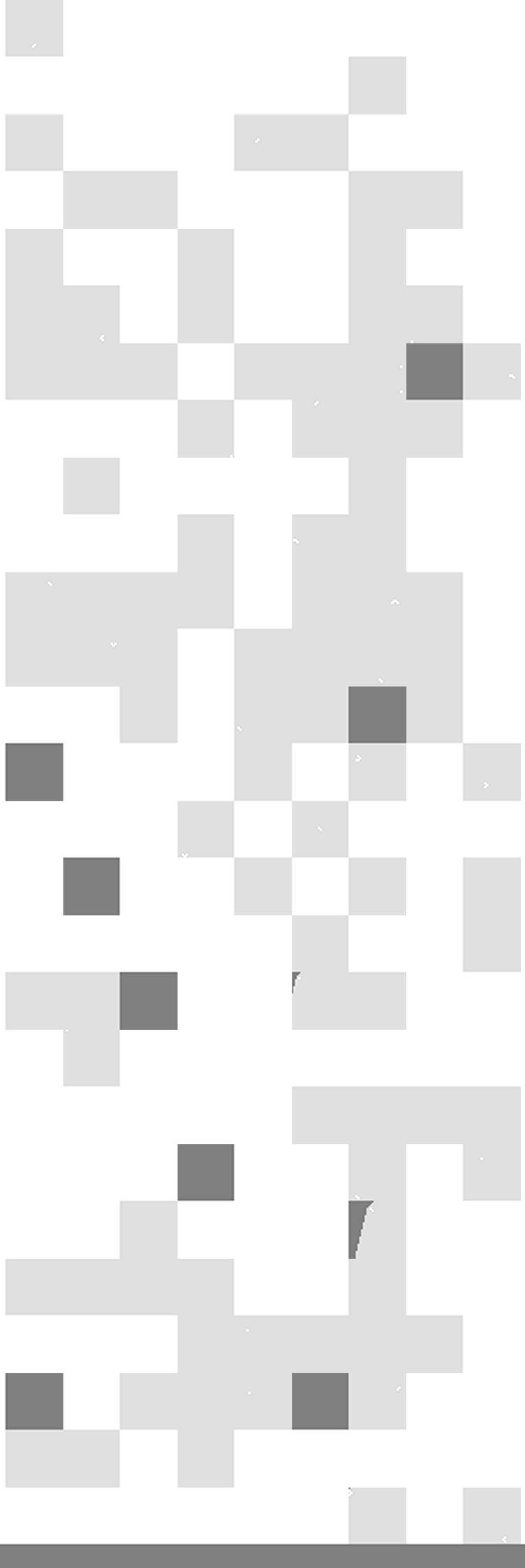
The results, stored in a geographic information system, can easily be coupled with similar information from other registers.

Perspectives For 1993

The Commission regulation 3887/92 established the "integrated system of management and control" of agricultural activities in Europe. By 1996 each Member State should have implemented its own integrated system.

In 1993, in anticipation of this change, the MARS project will:

- check some 40000 declarations using satellite images;
- develop specialised software to automate some of this work;
- define image acquisition strategies;
- integrate satellite data with digitised aerial or SOYUZ photographs;
- compare the relative precision of ground-based and satellite-based measurements;
- evaluate the costs and benefit of Global Positioning Systems for ground teams;
- derive and evaluate satellite-based documents for use in declarations;
- define and evaluate alternative methods for integrating and updating registers.



3 ENVIRONMENTAL MAPPING AND MODELLING

Staff

Scientific and Technical Support	13
Secretarial Support	1
Visiting Scientists	3
Students	4
Total	21

Publications

Journal Papers	2
Conference Papers	14
JRC Reports	8
Books/Chapters	1
Total	25

Facilities

- DEC VAX 4000/300 and VAX 4000/200 computers in cluster with 12 Gbyte of disk storage capacity plus magnetic tape and optical disk drives. These machines are reachable from all workstation on the Unit's Ethernet. ERDAS image processing software is available
- SUN Sparcstation-II (UNIX) workstation
- DECStation-5000 (UNIX) workstation
- SUN-4 (UNIX) workstation with image display (ERDAS) and GIS software (ARCI/INFO)
- Personal Computers with ORACLE database system to support image archive
- Specialised software packages for development of knowledge-based system (FLEX), neural networks (MIMENICE) and analysis of imaging spectrometry data (SIPS, GENESIS)
- TEKTRONIX colour image printers
- Television-Tracking automatic video digitising system
- CALCOMP 9100 digitising table
- OCE-G1835 A0 size large format plotter
- In-house software packages for image display (PC-DIS), image colouring (TINTORETTO), image analysis (LIP software), integrated GIS and image analysis (PC-Imega), neural networks development and knowledge-based reasoning (C-REASON)

The main emphasis of the work in the Environmental Mapping and Modelling Unit (EMAP) concerns mapping of the various components of the European landscape and on development of methods for applying remotely sensed data and geographical information systems to management and protection of the European environment.

During 1992 several projects and programmes have been brought to a conclusion (eg the Ardèche experiment, the first part of the CORINE land cover updating experiment and the European Collaborative Programme). In addition several new activities have been started. The new activities include a project on mapping of Mediterranean land degredation, one on integrated landscape ecological mapping and experiments on forest and grassland ecosystems mapping.

Fig. 3.1. A view of a typical complex Mediterranean landscape in Portugal. Remote sensing can make a significant contribution to the mapping and monitoring of such areas and in assisting protection of the environment

The Unit has carried out a major restructuring of its hardware and software facilities in 1992 in order to better meet the present and future demands of scientific development and experimental applications, and in order to facilitate the work carried out by the many scientists and students who visit the Unit both for brief and long term research projects.

Much of our work is concerned with the production of thematic maps from satellite data by means of traditional approaches such as image classification, segmentation, smoothing and generalisation. However, newly available kinds of data, eg from imaging spectrometers, demand physically validated approaches rather than traditional concepts of mapping relative grey level variations in terms of information classes that were often forced on the data. The Environmental Mapping and Modelling Unit is particularly interested in research on efficient data interpretation schemes which can fill the gap between modelling approaches and parametric mapping techniques. Recently, spectral mixture analysis has emerged as an approach which may provide a new framework for the extraction of environmental indicators from remotely sensed data. Thematic applications comprise land degradation studies with major emphasis on mapping soil erosion hazards and vegetation parameters in areas threatened by desertification.

There continues to be a strong need for a cooperative Programme taking care of the spread of know-how to less favoured regions of Europe. Also the close link between scientists developing methods of remote sensing applications and the actual and potential end-users has to be continued. However, it is evident that this cannot just be a responsibility of a single research unit. It has been decided to include such aspects into the new Programme on integrated European landscape ecological mapping, especially into the forest and grassland components, which to a large degree will build upon local participation in accordance with the subsidiarity principle.

During 1992 the EMAP Unit initialized some very interesting and promising feasibility studies on applying remotely sensed data integrated with digital terrain data for mapping and run-off modelling in mountain headwater areas and also for hydrological management in Mediterranean catchment areas. The first steps towards research on application of various remotely sensed data in coastal areas were made as well.

By the year 2000 Earth remote sensing satellites will generate over 100 million million bits of information every day. For this reason, the effective utilisation of remote sensing data will demand the most advanced possible computation and data analysis techniques and the latest generation of computer hardware systems.

It is against this background that the Environmental Mapping and Modelling Unit is also undertaking research on advanced computation techniques applied to remote sensing. This includes projects concerning the development and application of neural networks, knowledge-based systems, geographic information systems and the development of parallel processing techniques.

One of the aims of these activities is to take advanced computation techniques developed in other fields (e.g.

computer vision, robotics, industrial automation) and to apply them in an original way to satellite remote sensing thus contributing to the inter-disciplinary transfer of know-how.

Efforts are also currently being made to strengthen links across Europe between teams with common interests in the area of environmental mapping by creating research networks for the exchange of both information and students and for the initiation of co-operative research and development ventures. One of the aims of this activity is to bring together research groups from different disciplines in order that a greater awareness of scientific potential can be achieved e.g. through the inter-mixing of environmental science groups and advanced computing groups, and cartographic science groups etc.

The work of the Unit has also benefitted considerably in 1992 from fruitful cooperations with researchers from outside the European Community. During the year the Unit hosted two visiting scientists from the People's Republic of China and one from the United States of America.

3.1 DEVELOPMENT OF METHODS FOR ENVIRONMENTAL OBSERVATION, MAPPING AND MODELLING

(Specific Programme)

Summary of Objectives

Development of land cover maps for European Less Favoured Areas from multi-temporal earth observation satellite data

Application of regression estimation for obtaining improved area statistics from the combination of ground observations and classified satellite images in complex landscapes

1992 PROGRAMME OF WORK

Introduction

Land cover and land use refer to different concepts. While 'land cover' denotes the natural or artifical coverings of the land surface, 'land use' is related to the management of ecosystems by human society. Since land use is not consistently detectable from remote sensing data, normally a mixture of land cover and land use classes is taken into consideration.

1992 Milestones

June	Comparison between multi-temporal and single-date classification reveals the necessity of using time-series for achieving acceptable mapping results
Sept.	Analysis of regression-estimates for obtaining improved area statistics on land use finished. Results show that multi-temporal approaches also improve the performance of the regression estimator
Dec.	Final report

Land Cover Mapping

Results from a classical single-date image analysis have been previously reported. Not surprisingly, the overall classification accuracy was only 53.6%, although post-classification sorting within the previously defined agro-phenological zones was applied to compensate some obvious classification errors. However, the major drawback was that a direct comparison to the multi-temporal data set was impossible since the spectral classes of the single-date experiment could not be consistently redefined. It was therefore decided to completely redesign the experimental setup for this study, so that a direct comparison between the single- and multi-date approaches in terms of classification performance would become possible.

It was found that the number of spectrally detectable classes largely expands as a direct consequence of using multi-temporal data. The considerably increased information content requires that cover class mapping must be conducted with a much greater number of classes than would ever be possible with single images. Examination of spectrally detectable sub-classes clearly demonstrates that the increased information content is not primarily a statistical effect which simply augments class variance by a mixture of information and noise components. There exists clear evidence for physically determined class variations (variable phenological cycles, different soil background reflectance, changing illumination according to terrain morphology).

It was beyond the scope of this study to systematically compare the performance of different classification methods. Assuming that classification errors are caused by lack of information (ie spectral separability) rather than conceptional differences of particular classification methods, it was considered more important to analyse possible improvements of classifications results via the increasingly significant spectral information being obtained through multi-temporal image series. In this context, the classification method must primarily be competitive in terms of processing speed. As it is known that a minimum-distance-to-mean classifier (Euclidian distances) may, due to the usual lack of normality in the data, perform similarly or even better than the maximum-likelihood algorithm, it was decided to use this classification method which is able to efficiently cope with both high-dimensional data sets and a large number of cover classes.

The results obtained from this experiment give clear evidence for the importance of multi-temporal approaches. Since accuracy was evaluated for each of the 155 available ground observation segments, it is possible to identify the performance variations across large and variable test sites. While the majority of

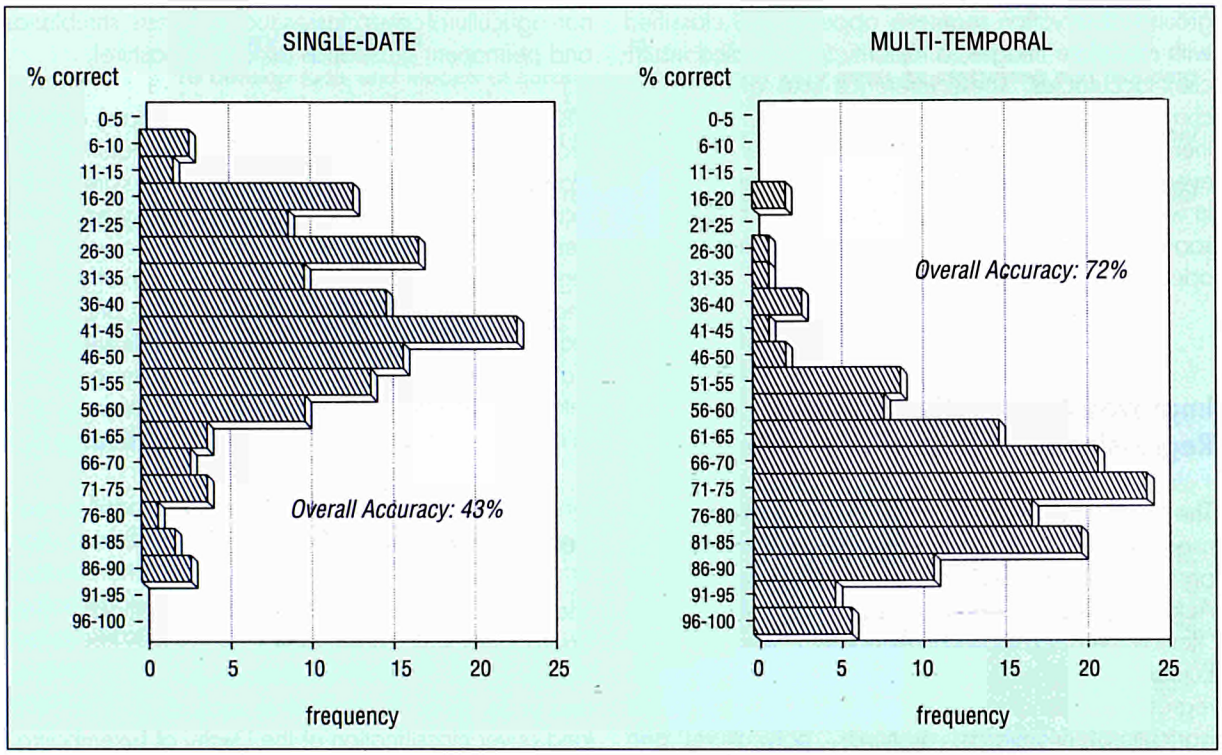


Fig. 3.2. Comparison of single-date and multi-temporal classification results as deduced from the 155 available observation segments

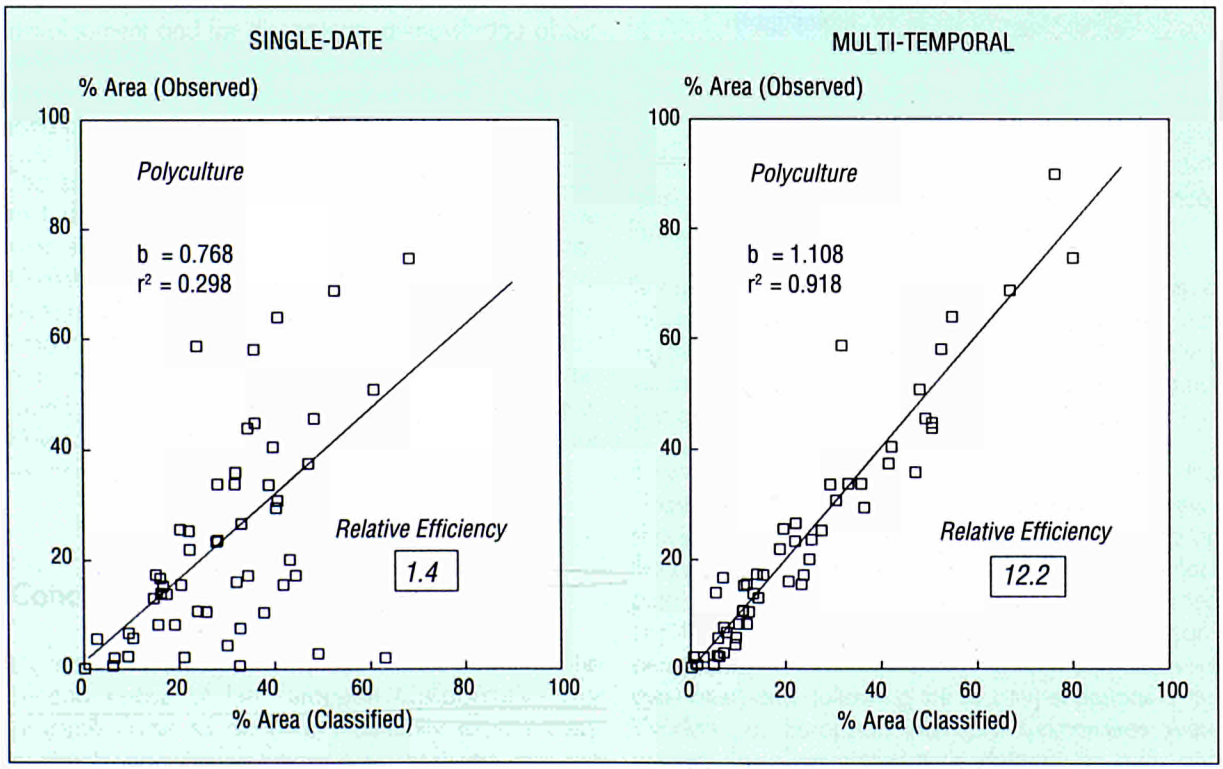


Fig. 3.3. Regression estimate for the class "Polyculture" (cultivated areas other than vineyards and orchards), resulting from single-date and multi-temporal classification approaches

ground observation segments appears well classified with multi-date images, a minority still revealed insufficient accuracies. These reference sites are normally characterised by extremely small field dimensions. It therefore becomes obvious that land cover mapping, even when accuracies of 75% and better are achieved in well-structured verification areas, will be deficient as soon as ground conditions become too complex to be adequately resolved.

Improved Area Statistics through Regression Estimates

The regression estimate is probably the most widely used method to get nearly unbiased area estimates for agricultural land use. It has therefore been chosen for Action 1 ("Regional Inventories") of the pilot project on "Remote Sensing Applied to Agricultural Statistics" of the European Communities. Here, surface estimation through regression estimators was applied to a variety of agricultural (vineyards, orchards, polyculture) and non-agricultural cover classes such as forests, shrublands and permanent grasslands (extensive pasture).

It is important to note that regression estimates already provide limited improvements with single-date images. However, for most strata, relative efficiencies are smaller than 2, which is below the suggested limit of economic benefit. In the multi-temporal approach, however, the regression analysis between ground observations and image classification provided much better and highly indicative correlations for most classes. It is suggested that the method, when applied to multi-temporal data sets, can distinctly improve general land cover statistics in difficult regions.

Perspectives for 1993

The project concluded in 1992, but the methodological approaches which were developed during this experiment have already been used successfully other projects, and under different conditions, such as multi-temporal land cover classification of the Duchy of Luxembourg.

EUROPEAN COLLABORATIVE PROGRAMME

(Specific Programme)

Summary of Objectives

To develop tools and models at European, regional and local levels for classifying and mapping landscapes by identifying and quantifying their properties.
To provide spatial geo-information for management decisions and actions for regional development and environmental protection.
To analyse and define fields where remote sensing could supply new insight into environmental processes.

1992 PROGRAMME OF WORK

Introduction

The Collaborative Programme started in 1985. It originally aimed at linking JRC remote sensing activities to Institutes and Laboratories throughout the EC member States who were interested in developing methods for the application of remote sensing data to land use assessment and land use planning in less favoured areas of Europe.

The first phase of the Programme concentrated on cooperative joint studies on the application of second-generation Earth observation satellite data on a regional basis. It was used as a means for both method development and for disseminating knowledge about remote sensing, as well as raising interest in applying this tool on a regional and more local level in practical land use management.

The second phase, 1989/90-1993, was more directed towards thematic approaches. The Programme was restructured into five themes (Agriculture, Forestry, Grassland and Natural Vegetation, Environmental Protection, GIS and Training). During the second phase emphasis was given to the development and application of integrated GIS and remote sensing in the management of less favoured areas, to assist economic development and especially to provide remedies for environmental protection in these areas.

1992 Milestones

March	Follow up working group meeting from the workshop on forestry
April	Workshop on the application of remote sensing to European grassland mapping, Paris
	Presentation of the forest eco-systems mapping programme
June	Launch of initial forest eco-systems mapping programme
Aug.	Definition of the Trans Eurasic land degradation programme
Nov.	Launch of initial grassland eco-systems mapping programme
Dec.	Beginning of the final reporting on the first and second phases of the European Collaborative Programme

Concluding the Second Phase

During 1992 most of the actions and studies under the second phase of the European Collaborative Programme came to an end. Practically all the study contracts under the five themes have been received and evaluated. The reports from both the first and second phases are presently being edited into a homogeneous form suitable for presentation to a larger audience. Publication is scheduled for late 1993.

Plenary Meetings were used during the first phase as a means for assisting the Programme management; during the second phase Workshops and Steering Committee meetings created the basis for Programme coordination and management.

It was stated under the first phase that Forest and Grassland - seen from an environmental point of view - should have special consideration. The Workshop on the Application of Remote Sensing in Grassland Mapping, held in May 1992, strongly recommended continuing the Programme, under a more "European" perspective. Initiatives taken during the first phase were evaluated, and, following the recommendations of the Workshops, European Advisory Committees were formed. The Committees have defined the aims and objectives of the newly launched European Eco-system Mapping Experiments.

European Landscape Mapping

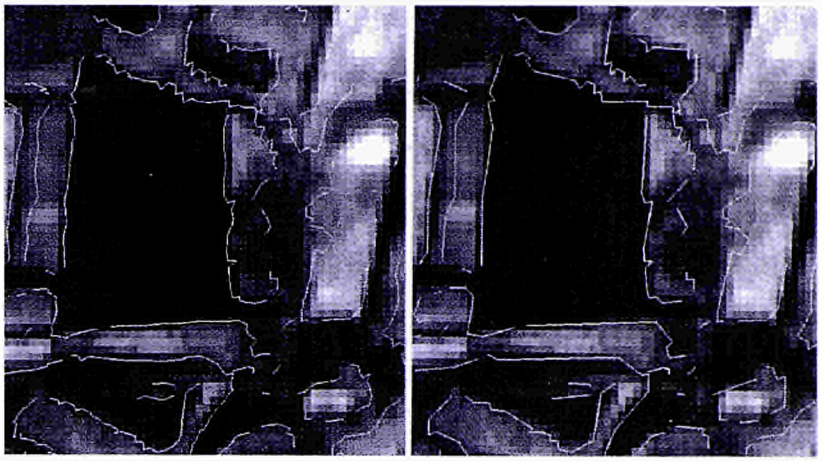


Fig. 3.4. Automatically generated sub-pixel boundaries (left) used for generating primary delineation of forest areas and for forest map updatings by automatic vectorisation (right)

Experience from the first two phases of the Collaborative Programme clearly shows that it would not often be possible to obtain useful thematic maps on single parameters from remotely sensed data alone, as it is simply not possible to extract spatial information on single landscape elements in an operational way. This is precisely the reason for the growing interest in integrating remote sensing and geographical information systems. It is necessary to integrate many and various sources of information to be able to manage the environment in a sustainable way.

Discussions have led to a Programme structure which will consist of three single themes: Grassland, Forest and Natural Vegetation plus a more GIS-oriented work on Alpine (or mountaineous) environments and coastal environments. The two latter themes were primarily defined out of a need for integrated hydrological based modelling on a large regional scale.

Perspectives for 1993

Programme redefinition will be completed: the aim is to set up the agreed collaboration on the "European environmental mapping and monitoring system" which will be primarily devoted to developing methods for the application of remote sensing data to environmental management in the following area:

- European Landscape Ecological Net: Forest and grassland classifications will be developed to be used for high accuracy mapping for environmental and ecological planning and protection.

- Remote sensing applied to the management, control and protection of headwaters and catchments, especially in mountaineous areas and environments which are of special concern.

Studies on hydrological mapping and coastal eco-systems will be defined and initialised parallel to the development of soil and land degredation mapping.

3.3 IMAGE AND MAP DATA PROCESSING
(Specific Programme)

Summary of Objectives

Development of pratical methods for mapping European landsacpe from space using integrated remote sensing and GIS data.
Development of methods for the generalisation of image products for cartographic applications.

1992 PROGRAMME OF WORK

Introduction

1992 Milestones

March Completion of prototype expert system for image analysis

Sept. Development of new methods for generalisation of thematic map products from imagery

A new method for the generalisation of satellite data was developed in 1992 based on the use of a combined filtering and region-growing technique. Typically the results from the classification of satellite imagery are noisy and contain pixels which are mis-classified. Also many pixels simply cannot be classified well because they are spectrally too mixed -i.e. on the ground the area covered by the pixel takes in several different kinds of land cover. This often gives image products which are spatially very complex with lots of "salt and pepper" noise. Such products are not easy to use as maps and a spatial simplification (or generalisation) process must be carried out to give a product closer to that expected by a map-user.

A typical technique which has often been used to perform this task is Iterative Majority Filtering (IMF). This is a technique in which the neighbourhoods of each pixel are examined. If the pixel under consideration has a different class from a majority of its neighbours, the class of the pixel is changed so that it joins the class of its neighbours. This is effectively a low pass filtering technique which removes isolated mis-classified pixels and produces a better thematic product.

However, there is a significant drawback to this method. It is frequently found that certain image classes only exist as small groups of isolated pixels (e.g. collections of

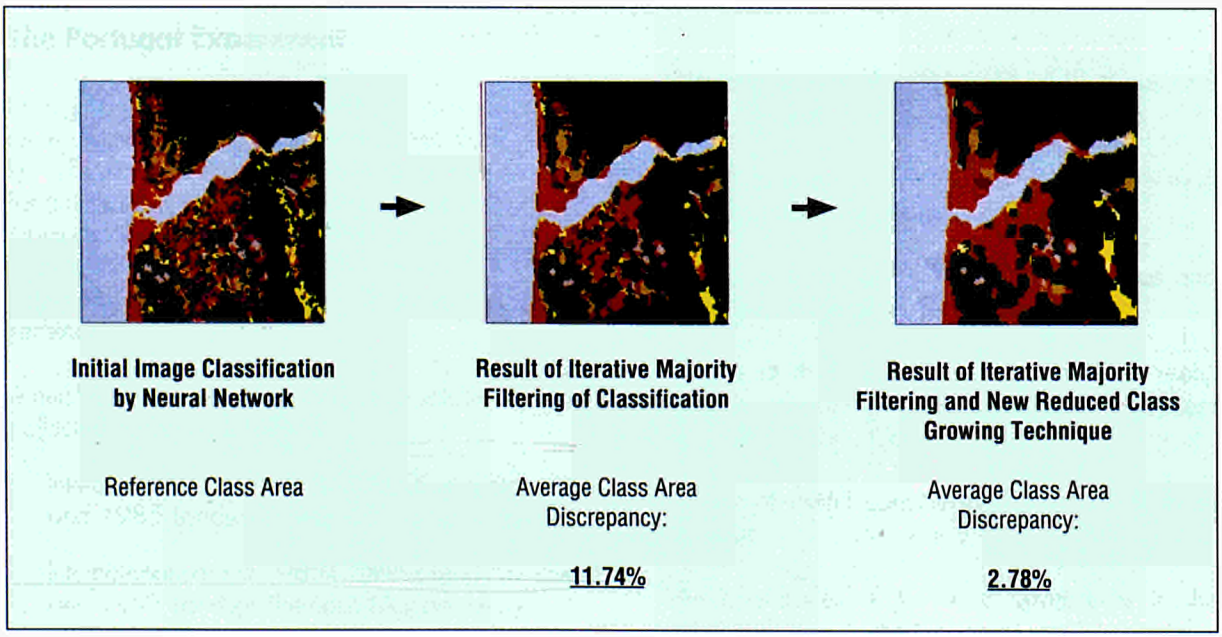


Fig. 3.5. Effect of a new generalisation process combining iterative majority filtering and new region growing techniques. After the combined procedure the error in class areas is significantly reduced and the thematic map is much smoother

farm buildings in extensive agricultural areas). In such cases the IMF technique can remove a large number of the pixels of such classes thus seriously changing the class area coverage in the thematic product.

In order to overcome this problem a new technique was developed known as Iterative Reduced Class Growing whose basic function is to grow back pixels of the classes whose populations have been reduced. This re-growing procedure starts from the few remaining pixels of the reduced classes and is carried out iteratively. The class population balances are monitored continuously throughout the procedure to decide when to stop. The overall procedure has the effect of maintaining a much better class population balance compared to the use of the IMF technique alone and yet still smoothes the thematic map considerably. The minority classes are effectively concentrated in the regions in which they are most common and so a genuine process of cartographic generalisation is carried out.

Perspectives for 1993

The activity for 1993 will focus on developing integrated methods for classification of data, for use of spectal mixture information, and on the process of creating maps directly from satellite information by automatic analysis, including generalisation.

3.4 UPDATING OF THE CORINE LAND COVER DATABASE

(in support of DG XI Environment)

Summary of Objectives

Development of pratical methodology for updating the CORINE Land Cover database using remote sensing.

Investigation of future possibilities for automatic continental scale land cover mapping.

1992 PROGRAMME OF WORK

Land use and land cover maps can be derived from satellite data through different methods. Visual analysis of satellite imagery still remains an efficient means to obtain maps at scales from 1:1,000,000 to 1:100,000. For example, one of the major tasks of the Commission's CORINE Programme (Coordination of Information on the Environment, established through Council Decision No. 85/338/EEC, O.J. No. L. 176, 6.7.1985) is the establishment of a computerised inventory of land cover. The methodology consists of the photo-interpretation of earth observation satellite images, the results of which are subsequently digitised.

The scope of the JRC work has been to investigate techniques for making automatic or semi-automatic updates of land cover directly from digital satellite imagery. Experiments have been conducted for this purpose in Luxembourg and Portugal.

1992 Milestones

Feb.	Land cover classifications made for Portugal from Landsat data
May	Intercomparisons of image products and CORINE maps in Portugal
May	Preparation of a homogeneous multi-temporal data set in Luxembourg through the application of radiometric normalisation techniques. Spectral mixture analysis succesfully used for data reduction
July	New method produced for generalising image products for mapping
Aug.	Technical specification made for prototype updating system
Sept.	Land cover classification for Luxembourg completed through automatic classification of multi-temporal Landsat images
Nov.	Contractor selected for development of prototype system in 1993
Dec.	Final report of EMAP studies on automatic updating

The Portugal Experiment

During 1991 an extensive set of field data and imagery were obtained from test sites in Portugal all within ~50 km. of Lisbon. During 1992 these data sets were used for a number of experiments to understand the possible methods for updating the CORINE land cover database and to understand the limits to and possibilities of fully-automatic land cover map updating from remote sensing.

A number of intercomparisons were made between the collected datasets as follows:

- Intercomparisons of 1985 CORINE land cover map and 1985 Landsat Thematic Mapper Imagery.
- Intercomparisons of 1985 CORINE land cover map and 1991 Landsat Thematic Mapper Imagery.
- Intercomparisons of 1991 field survey maps and 1985 Landsat Thematic Mapper Imagery.
- Intercomparisons of 1991 field survey maps and 1991 Landsat Thematic Mapper Imagery.
- Intercomparisons of 1985 CORINE land cover map and classified image products (10 classes).
- Intercomparisons of 1991 field survey maps and classified image products (10 classes).

The results of these comparisons gave much useful information concerning the possible updating process for the CORINE Land Cover Maps.

A number of useful conclusions came out of these experiments:

- The boundaries of the land cover units in the CORINE land cover map produced by photo-interpreters are very difficult to reproduce independently -this indicates the subjectivity of the

Fig. 3.6. Intercomparison of map units from 1985 CORINE Land Cover Map and Landsat Thematic Mapper image. The image shows that the landscape has changed

photo-interpretation process and the difficulty of reproducing the same maps by automatic means.

- The classification of remotely-sensed imagery cannot yield classes which match all those used in the CORINE land cover project.
- In many cases, it is difficult to reliably decide which land cover class to assign to a given land cover unit given the complexity of the landscape in many parts of Europe. Considerable differences were found between classes assigned in the original 1985 maps of Portugal and those assigned in the field survey of 1991 even where the land cover had apparently not changed.
- The proportion of land cover units which have changed between 1985 and 1991 is relatively low suggesting the possibility of selective updating.

The Luxembourg Experiment

In 1991 an experiment was initiated that uses automatic classification of multi-temporal Landsat Thematic Mapper data to produce a land cover map for the state of Luxembourg. The experiment applied the methodological approach that was developed during past years in the context of the so-called "Ardèche Experiment". It could be confirmed that multi-temporal satellite data provide an excellent tool for highly precise land cover mapping.

Classification results for agricultural and natural vegetation classes (ie different forest types) are better than those which can be derived from human photointerpretation. A limitation of multi-spectral classification approaches is that artificial surfaces cannot be reliably attributed to the required sub-classes (ie continuous urban fabric, discontinuous urban fabric etc), although in general they can be mapped with excellent accuracy. In particular for these cover classes, an efficient integration of automatic mapping and human intepretation will be required.

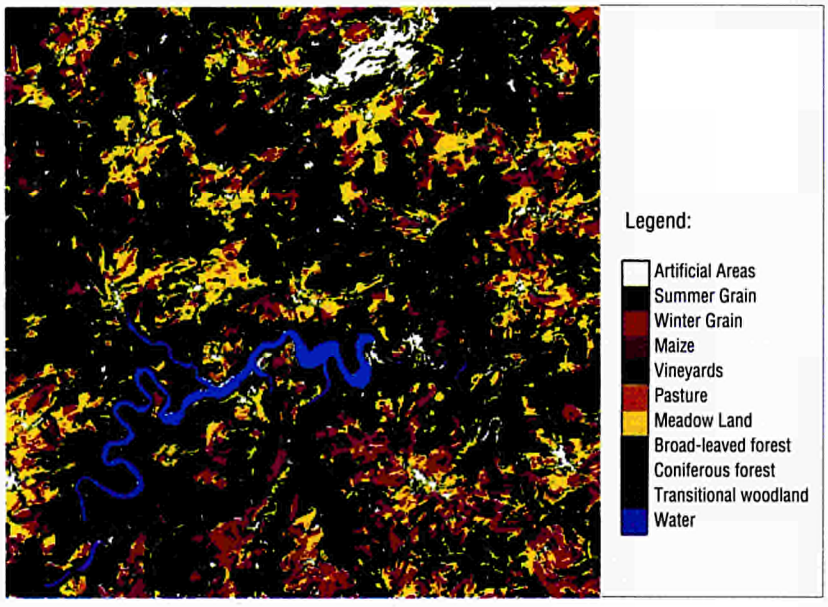


Fig. 3.7. Automatic mapping of land cover in Luxembourg

An additional advantage of multi-temporal approaches is that classification results are less noisy than those obtained from single images. The application of post-classification filtering to remove this "salt-and-pepper" effect is unnecessary in most cases. Future work should concentrate on the development of techniques which allow a human operator to

integrate these results for further generalisation and mapping refinements, in particular areas that are dominated by man-made objects (urban areas, industrial zones etc).

It should be emphasised that visual interpretation and automatic mapping approaches are complementary rather than contradictory to one another. Effective updating of existing land cover data bases should benefit from an efficient combination of both approaches.

Perspectives for 1993

In 1993 the emphasis of the work will be directed towards the development of a prototype semi-automatic land cover map updating system to be evaluated by national teams. This will concentrate on a computer method for use by photo-interpreters.

This will lead on to the implementation of an operational system at a subsequent stage. Also alongside this activity, work will continue on the investigation of fully-automatic methods for mapping from satellite imagery encompassing new approaches in image understanding.

3.5 NEURAL NETWORKS FOR REMOTE SENSING

(Exploratory Research)

Summary of Objectives

Investigation of advanced image classification methods.
Development of connectionist computing for remote sensing.
Furthering European capability in neural systems applications.
Analysis of very large data sets.

1992 PROGRAMME OF WORK

The main goal of this activity has been to develop advanced methods of data analysis in remote sensing which can take advantage of parallel computing in order to be able to process very large operational data sets. During 1992 the research on neural networks led to several useful advances which will be useful in future application studies.

In comparison to earlier work, there were several new studies in 1992 concerned with exploring different types of neural networks and applying them to a wider variety of problems. Also during 1992 the use of the neural network classifiers was demonstrated for several different applications such as land cover, forestry, agriculture and conservation zone mapping.

1992 Milestones

Jan.	Development of improved classifier based on hybrid multilayer perceptron and learning vector quantisation systems for land cover mapping
May	Demonstration of neural network capability for high accuracy forest class discrimination
June	Successful application of Kohonen feature maps to cloud recognition
June	Visiting Scientist from China begins collaboration on neural networks
July	Improved classification of imagery using funtional link networks
Aug.	Demonstration of possibility of geometrical rectification of imagery by neural network
Nov.	Method developed for integration of neural networks and conventional statistical classifiers

Hybrid Classifiers

A number of studies undertaken both in the Joint Research Centre and elsewhere have demonstrated the power of multi-layer perceptron (MLP) networks in performing image classification. Such networks are supervised pattern recognition systems. In general such networks have been found to give good results often achieving of the order of 80% accuracy with 20 or more classes. Since a number of alternative neural network models exist for supervised pattern recognition some experiments were performed in the early part of 1992 to see if improvements in classification accuracy could be achieved by using hybrid classifiers based on a combination of the multi-layer perceptron model with other methods.

MLP networks were combined with Kohonen Learning Vector Quantisation (LVQ) networks. In this hybrid procedure, outputs from the second hidden layer of neurons of an MLP net were fed in parallel both to the output layer of the MLP and also to the inputs of a LVQ network. The LVQ network was then trained with the data fed from the hidden layer of the MLP. Afterwards the classification performance was compared by examining the results derived at the outputs of the MLP network and at the LVQ network output. Interestingly the experiments demonstrated that the use of the LVQ method to replace the final layer of the MLP network gave increased total classification accuracy of the order of 1 - 2%.

The MLP network is essentially a method for learning hyper-planes in pattern feature space to separate the classes in the data. The LVQ method is based on the learning of prototype pattern feature vectors to represent the separate classes. The results showed that the prior use of the MLP network to pre-set class separation surfaces in feature space makes it easier for the LVQ method to adapt its own model of the image class characteristics.

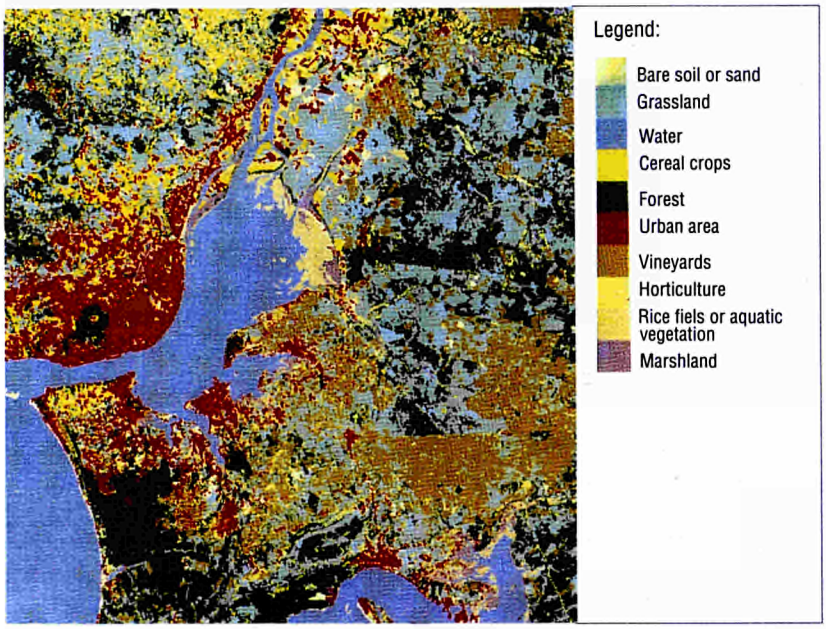


Fig. 3.8. Classification of Landsat Thematic Mapper image of Lisbon area from Functional Link Neural Network (image date: 17 June 1991)

Development of Functional Link Networks

One of the main difficulties in using neural networks for image classification is that they are often slow to train. This problem arises partly from the fact that large numbers of training pixels are usually needed to give a good representation of class variety and also partly from the need to use large neural networks for classification problems which involve high numbers of classes.

For example, experience has shown that a typical land cover classification problem involving 20-30 classes normally requires an MLP network with ~50-100 processing nodes and of the order of 1000 interconnections. The training of such a network thus involves the iterative learning of 1000 separate weights.

In order to streamline the learning procedure some new experiments were undertaken in 1992 using the Functional Link Network model. The functional link network is similar to the multi-layer perceptron except that it uses a much reduced architecture. This is achieved by initially augmenting the input pattern feature vector with higher order terms (usually polynomial power terms).

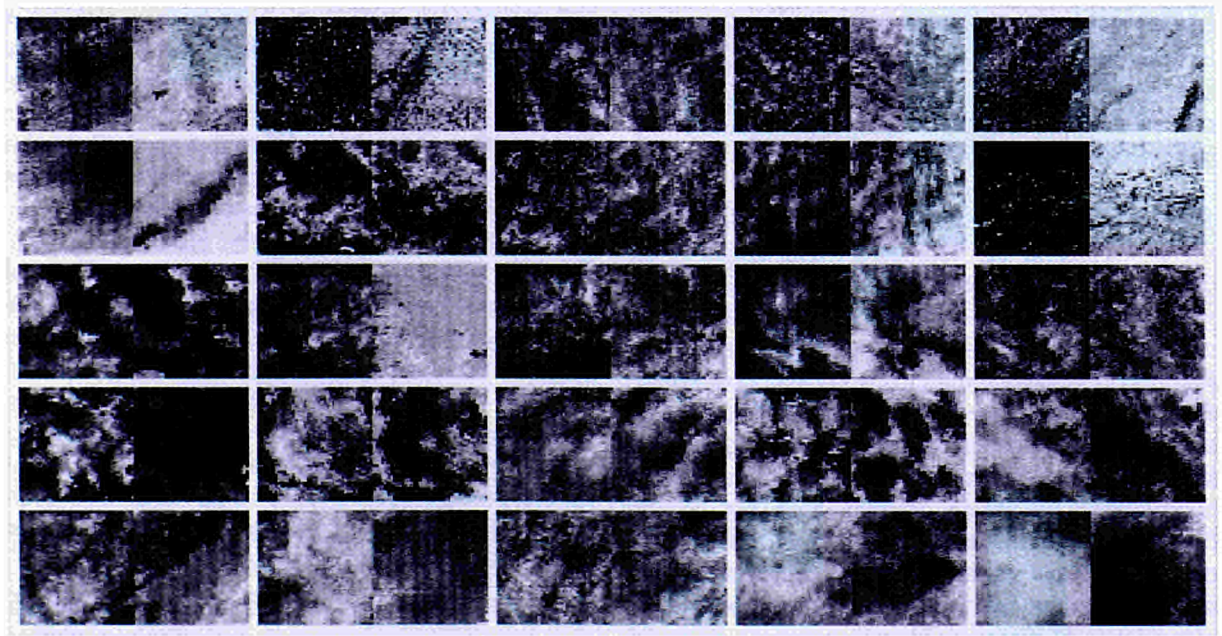


Fig. 3.9. The 25 prototype cloud fields extracted from NOAA-AVHRR imagery of the North Atlantic ocean by the topological map network. The prototypes are shown as pairs giving a visible and an infra-red image

By using an enhanced feature vector as input, the neural network can be made simpler yet still achieves the same results as a much bigger MLP network with only a basic input feature vector. A number of experiments were carried out and demonstrated that good classification results could be achieved with quite simple networks. The functional link network normally does not need any internal hidden layers of nodes and the total number of interconnections can be reduced significantly (see table 1).

Table 3.1 Comparison of MLP network and Functional Link Network in classifying a Landsat Thematic Mapper image into 10 classes.

	Total No. of Network Nodes	Total No. of Interconnections	Classification Accurancy Achieved (10 classes)	Training Time
Conventional Multilayer Network	54	668	85.1%	5200s.
Functional Link Network	51	410	85.3%	1200s.

Geometrical Operations on Imagery by Neural Network

Geometrical rectification of satellite imagery is normally carried out by selecting control points in the image and in a reference map in a desired cartographic projection, and then determining a polynomial function which can be used to map the image coordinates into map related coordinates.

The functional link neural network was also found to be useful in carrying out geometrical rectification of imagery since it could effectively be used to undertake the same kind of operations. Instead of numerically solving a set of equations to determine a polynomial mapping, the network was trained using the control point data so that it learned a set of weights which would encode the transformation between the input image coordinates (and their power terms) and the desired map related coordinates. The neural method does not encode precisely the same mapping as the standard polynomial method because of the non-linear behaviour of the activation function used for the perceptron nodes at the output layer. In a number of experiments it was found that overall the neural network gave better spatial precision than the more conventional method.

Clustering of Oceanic Clouds

The neural network method was also applied to an unsupervised pattern recognition problem, that of identifying the main types of cloud fields which could be identified in NOAA Advanced Very High Resolution Radiometer (AVHRR) imagery taken from the North Atlantic Ocean. For this purpose the Kohonen topological map algorithm (or self-organising map) was used. In this method a network of competitive nodes is iteratively trained so that each node learns the characteristics of a particular cluster (cloud field type) in the data set.

A data set of 362 small cloud field images (30 x 30 pixels) at AVHRR Global Area Coverage resolution (approx. 4km) were used as a training set for the network and feature vectors were created using both visible and infra-red spectral channel values for the pixels. The network was designed to extract and learn the characteristics of the 25 most significant cloud field types in the data set. The topological map network appears to offer a good method for initial clustering of complex data prior to subsequent classification.

Perspectives for 1993

The work conducted in 1992 has demonstrated that neural systems can play many roles in the analysis of remotely-sensed data. In most experiments they have been found to give results of higher quality and accuracy than those obtainable by more conventional methods. In other cases they give results which are comparable to other approaches. Overall, they appear to be of significant value and should be used alongside other data analysis approaches in remote sensing.

The main future priority is to raise the general level of knowledge about this field and also to stimulate the application of neural systems in operational situations in Europe. These aims will be furthered through special research workshops and dissemination of software products specifically aimed at the remote sensing community. On the research front, the development of parallel processing systems is an area which needs high priority because of the future explosion in the quantity of data available from satellite-borne sensors.

3.6 SPECTRÀL MIXTURE ANALYSIS FOR ENVIRONMENTAL MAPPING

(Exploratory Research)

Summary of Objectives

Investigation on the use of linear spectral mixture analysis as a new framework for the interpretation of remotely sensed data in environmental mapping applications.

Investigations on the complementarity of high spectral resolution systems (imaging spectrometers) and operational earth observation satellites for environmental research.

Development of mapping approaches based on spectral mixture analysis, in particular for the detection of soil degradation processes, erosion hazards and the abundance of green vegetation (fractional cover).

Analysis of large time series from earth observation satellites (i.e. Landsat MSS and TM) for land degradation and desertification mapping.

1992 PROGRAMME OF WORK

Mediterranean land degradation mainly results from damage to the vegetation cover due to overgrazing, wood collection, burning, or inappropriate agricultural practices. Accelerated degradation of the soil resource due to erosion hazards, and salinisation of irrigated lands strongly affect health and reproductive capacity of the plants through the disruption of plant-water relations. If erosion is not stopped, further increase in runoff, sheet and gully erosion on sloping ground will ultimately destroy the productive value of the land. Mapping and repeated monitoring of degradational processes and erosion hazards forms the basis for a sustained use of mediterranean land resources.

One of the main objectives is therefore the development of mapping capabilities that fully exploit the spectral and spatial resolution capabilities of modern earth observation systems, i.e. providing mapping scales of at least 1:100,000 to 1:200,000. An additional important requirement is that the method uses widely standardised processing parameters, in order to be regularly applicable for monitoring under a range of conditions. The mapping results should also be standardised, either in the form of direct physical parameterisation (i.e. percent cover of green vegetation) or through compatibility with international soil taxonomy systems (such as FAO nomenclature).

1992 Milestones

March	Application of spectral mixture analysis to imaging spectrometry data from NASA's Multiple Airborne Sensor Campaign in 1991. Succesful mapping of soil degradation levels and erosion hazards in mediterranean environments
June	Successful application for detecting degraded soil and erosion hazards with operational earth observation systems (Landsat Thematic Mapper)
Aug.	Development of a modified mixing algorithm which handles multiple endmember sets for improved vegetation mapping with imaging spectrometry data
Sept.	Successful experiment on the use of standardised processing parameters for the application of mixing models in different test site conditions
Oct.	Visiting scientist from the United States begins collaboration on spectral mixture analysis
Nov.	Eurocourse on "Imaging Spectrometry as a Tool for Environmental Observation" (Scientific Coordination)

Spectral Mixture Analysis

Spectral mixture analysis assumes that most of the spectral variation in multi-spectral images is caused by mixtures of a limited number of surface materials with distinct reflectance spectra (i.e. vegetation, soil), and that these components vary in brightness according to changing illumination and the amounts of shade. In remotely sensed images, they commonly mix at the sub-pixel scale, producing mixed-pixel spectra. As a first approximation, spectral mixing may be modelled as a linear combination of pure component ("endmember") spectra. Linear mixing assumes that the surface components are large and/or opaque enough to allow photons to interact with only one component. Spectra can then be unmixed by inverting the linear mixing equation using a least squares regression, while con-

straining the sum of the fractions to one. The objective is to isolate the spectral contributions of important surface materials ("endmember abundance") before these can be edited and recombined to produce thematic maps.

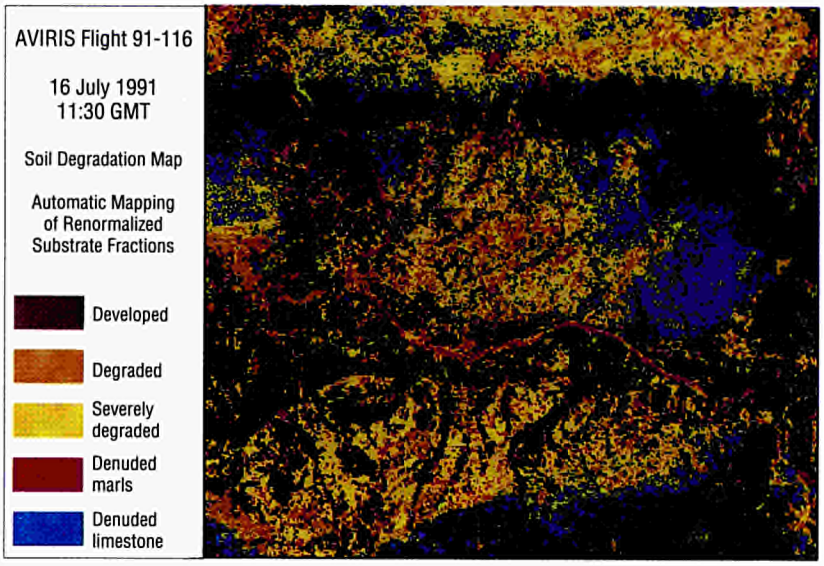


Fig. 3.10. Soil development and degradation mapping in a mediterranean test site, obtained through the application of spectral mixture analysis to imaging spectrometry data

Soil Degradation and Erosion Hazard Mapping

Spectral mixture analysis by itself imposes the need to develop physically valid concepts for the analysis of remotely sensed data. Our approach refers to basic concepts of soil-geomorphic research which considers soil development to be either progressive or regressive with time. Under progressive development, soils become better differentiated by horizons, and horizon contrasts become stronger. Regressive pedogenesis refers to the addition of material to the surface at a rate that suppresses soil formation, or suppression of pedogenesis by surface erosion. Both progressive and regressive pedogenesis cause alterations of the soil surface that, to a certain extent, are spectrally detectable. It seems that the brunification (rubification) of the topsoil constitutes a most important diagnostic feature for the spectral identification of progressive pedogenesis, while eroded weakly developed soils are rather dominated by spectral characteristics of the parent rock.

Assuming, that spectral unmixing can help to identify such reflectance contributions, a five-endmember-constrained mixing model (green vegetation, soil, two rock and shade spectra) was applied to high spectral resolution (AVIRIS) data from NASA's European ER-2 deployment (MAC Europe) in 1991. It was succesfully demonstrated that important soil degradation levels and erosion hazards could be mapped with high precision.

With respect to traditional mapping approaches, spectral unmixing has the great advantage that identical parameters (endmember spectra) can be used for different instruments, thereby offering a high degree of standardization. The only modification required is to convolve the used endmember spectra to match the spectral bands of the particular system.

In order to investigate the compatibility between high spectral resolution systems and operational space-borne sensors an experiment was conducted that applied the convolved AVIRIS endmember set to multi-temporal Landsat Thematic Mapper data. The results showed high precision (better than 75 % accuracy), and were absolutely comparable to those obtained with imaging spectrometry, thus indicating important application scenarios for operational space instruments.

Mapping Green Vegetation Abundance

The identification and quantification of green plant material is of great interest since leaves and needles are the site of photosynthesis and the prime link between the biosphere and the atmosphere. Since plants have a distinct spectral signature with low reflectance in the visible and short-wave infrared part of the spectrum and high reflectance in the near-infrared region, attempts have been made to estimate green vegetation cover and biomass through various spectral indices. A common problem for all indices is their sensitivity to reflectance contributions from the soil background.

Given the sensitivity of spectral mixture analysis to varying background spectra it was believed that mixing models may also provide better solutions for biomass surveys in complex ecosystems. We have applied a mixing model with multiple endmember sets to high spectral resolution data (AVIRIS), and it was found that this approach actually provided a better direct estimate

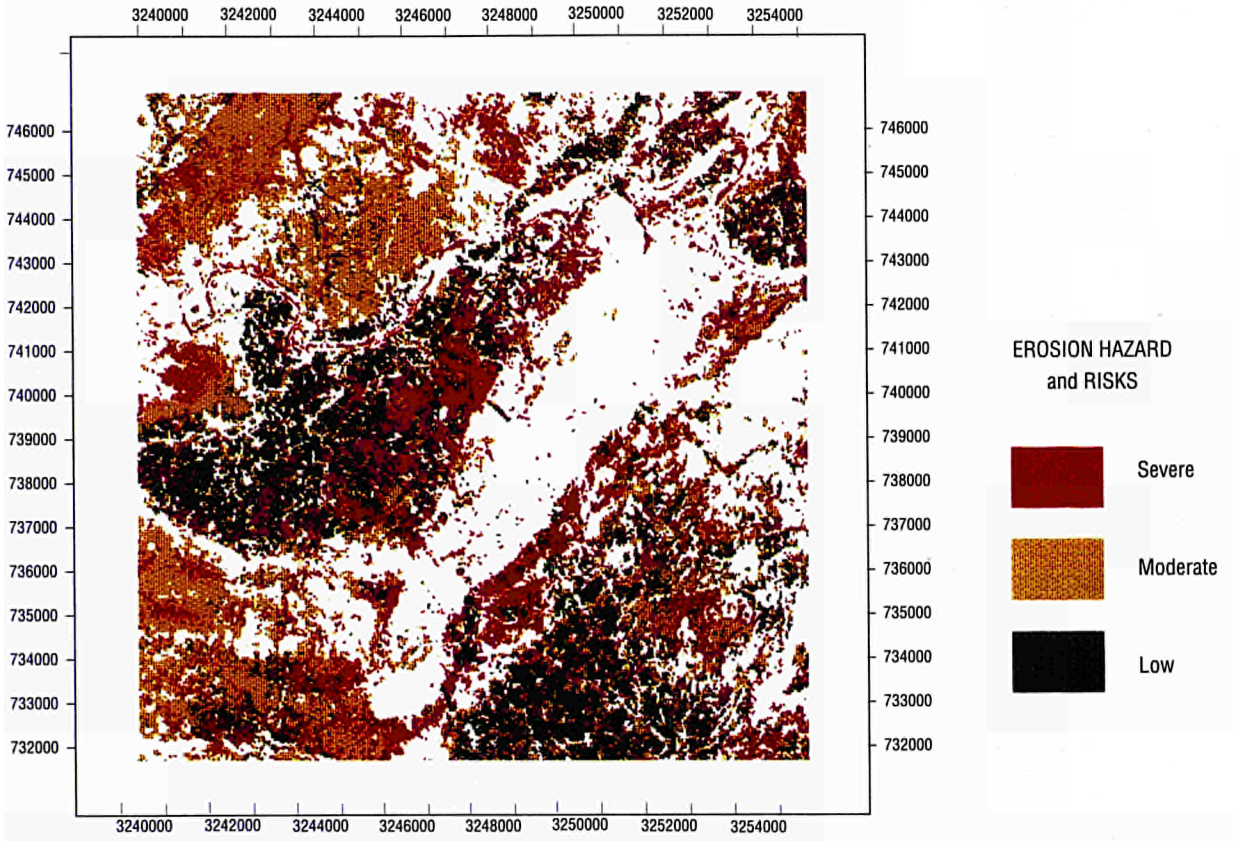


Fig. 3.11. Soil erosion hazards in a mediterranean environment. The accurate map (better than 80%) was produced through spectral mixture analysis of multi-temporal Landsat Thematic Mapper images

of fractional green vegetation cover than any other vegetation index. Moreover it was also possible to identify areas with a large amount of senescent vegetation which, with a single set of spectral endmembers, had been erroneously identified as soil. Further studies and method developments are needed to better control the use of multiple spectral endmember configurations.

Perspectives for 1993

The work which has been conducted in 1992 suggests that spectral mixture analysis can take an important role in the future use of remote sensing for environmental mapping. The approach has the potential to be largely standardised in terms of the required processing parameters, and it appears particularly suited to complement available large-scale surveys of soil erosion risks by providing detailed inventories of the existing soil degradation processes and erosion hazards. It is also believed that mixing models with multiple endmember sets may provide better solutions for biomass surveys in complex ecosystems, while the background reflectance of soils may significantly affect estimates from conventional vegetation indices.

However, further verification experiments under variable environmental conditions are required to draw a final conclusion on its future operational applicability. Some of these studies have already been initiated. If the results confirm the conclusions which can be drawn from this year's pilot studies, the method might become a substantial element of regional land development programmes, and take a major role in mediterranean land degradation monitoring.

In 1993, more work will be done on the compatibility between various sensor systems. The improved identification of non-photosynthetically active (senescent) vegetation components is another important issue which will primarily be pursued with high spectral resolution data. It is again to be emphasised that spectral mixture analysis interprets remotely-sensed images in the context of physically validated constraints, since the data analysis is directly controlled by spectroradiometric field and laboratory measurements. Major priority will therefore be given to the use of spectral libraries for environmental mapping.

4 MARINE ENVIRONMENT

Staff

Scientific and Technical Staff	12
Secretarial Support	1
Visiting Scientists	2
Students	2
Total	17

Publications

Journal Papers	12
Conference Papers	26
JRC Reports	1
Books/Chapters	2
Patents	1
Total	42

Facilities

- Vax 4000 with ERDAS image processing software (including software development in-house for CZCS and AVHRR data processing
- PC's with ERDAS and in-house image display
- SUN Sparc station for CZCS data archive and data processing

Understanding the earth as a system is not possible without a good knowledge of the role of the oceans. The oceans cover 70% of the globe and have a crucial influence on all meteorological and climatic phenomena.

The different processes in the ocean at local and regional scales are elements of the global system and must therefore be understood and observed for the modeling and understanding of global climate changes, and equally for local investigations and applications.

Remote sensing can play a keypart in the observation and understanding of the ocean as a part of the global climate system as well as for observations and environmental protection at local scales.

The scope of the Marine Environment Unit is to develop, demonstrate and validate methodologies for the use of data from space and airborne observations in both operational applications and scientific investigations related to the marine environment.

The Marine Environment Unit is basically involved in the study of two main remotely sensed parameters and their role in different oceanic processes:

- the ocean colour as an expression of the substances in the near surface water layer and the biological activity in the euphotic zone,
- the sea surface temperature as an indicator for the heat energy budget at the sea/air interface and as an element of the general hydrodynamic processes.

An important aspect of the activities is the development of hydrodynamic models to assimilate remote sensing data for process studies and as a contribution to global models.

To reach this overall objective four main activities have been defined.

Ocean Colour European Archive Network (OCEAN)

The OCEAN project is a joint IRSA/ESA initiative to promote the use of ocean colour data in studies of the European Marine environment.

Ocean colour data, as collected by the Coastal Zone Color Scanner (CZCS) from 1978 to 1986, represent an important source of information for understanding biogechemical and physical processes in the sea.

CZCS data over marine regions of European concern is pre- processed to a standard format and archived to extract geophysical parameters and to create a data base of bio- optical information on the marine environment.

The OCEAN 'data policy' provides for the production of CZCS higher level data and their use in a core group of application demonstration projects concerning regions of the North Atlantic Ocean, the Mediterranean Sea, the North Sea and the Baltic Sea.

The OCEAN project provides also a substantial European contribution to the International Space Year 1992 through the Productivity of the Global Ocean activity.

The project is carried out in support of Directorate General XI (Environment).

Coastal Monitoring

This studies promote the development and improvement of methods for the analysis of ocean colour data and the application in European coastal areas. The advanced features of the upcoming SeaWiFS sensor at the end of 1993 will lead to significant improvements in the discrimination of different substances in the water, including the difficult cases of coastal areas.

The studies are concentrated in the development and validation of algorithms for SeaWiFS data to estimate Phytoplankton pigments, suspended sediment and yellow substances in coastal waters.

This research activity will develop via a research proposal entitled "Alternative Methods for the Determination of Optically Active Concentrations in Marine Water", selected as an investigation in NASA's research program "SeaWiFS: Global Ocean Primary Production ". It is proposed to develop a new set of atmospheric and pigment (level 2) algorithms, based on the use of generalised water optical models, giving the subsurface reflectance as a function of all optically active materials in the water.

Study of the Northwest African Upwelling Area

This is an application of remote sensing in an important oceanic phenomenon where cold nutrient rich water flows to the surface resulting in high biological activity.

The water masses in upwelling areas are characterised by low temperature and high phytoplankton concentrations, two parameters which can be observed by remote sensing techniques.

Analyses of remotely sensed data are used to describe the temporal and spatial distribution of coastal upwelling and related processes. A major effort has been invested into the extension of multiannual time series of daily sea surface temperature images and meteorological data and their derived products in a Test Site off the North West coast of Africa.

A better understanding of the upwelling phenomenon and its driving forces may contribute to the evaluation and to management of fishery resources.

This activity is carried out in support of Directorate General I (International Relations) and in collaboration with Morocco.

Contribution of Marine Studies to the Analysis of Global Change

This project follows the objectives of major international programmes focussing on the study of Global Change through three relevant studies:

A number of smaller activities and studies are focused on coastal monitoring and in-situ measurements of remote sensing relevant parameters.

- Sea surface temperature and marine heat flux:
  For a better understanding of the surface - bulk temperature difference and for validation of ERS-1/ ATSR an experiment has been undertaken as part of a WOCE investigation off Portugal and Morocco.

- Marine primary production and ocean colour:
  This study has focused on the implementation of an bio-optical model for the estimation of primary production and will be used to assimilate ocean colour derived chlorophyll concentrations.

- Hydrodynamic modeling related to marine processes and remote sensing data assimilation:
  A new 3-dimensional, baroclinic circulation model (Ispra-Mix) has been developed and will be used, together with other models, to investigate the circulation and biological dynamics derived from remote sensing data. The study area is the East Atlantic, including the NW African upwelling zone.

4.1 CONTRIBUTION OF MARINE STUDIES TO THE ANALYSIS OF GLOBAL CHANGE

(Specific Programme)

Summary of Objectives

To develop, and extend where possible, algorithms that relate variables from remote sensing, ocean platforms and ship surveys to processes occuring in the water column such as heat flux and primary productivity.

To generate, archive and analyse multi-annual time series of satellite derived observations and other related meteorological and in-situ data.

To assimilate satellite data in local and regional models for process studies and for contributions to global models.

1992 PROGRAMME OF WORK

Introduction

Global Change studies examine the interactions between the physical, chemical and biological processes that regulate the Earth's system and that are most susceptible to human pertubation. Two major international programmes are focussing on the study of global change are the International Geosphere Biosphere Programme (IGBP) of the International Council of Scientific Unions (ICSU) and the World Climate Research Programme (WCRP) of the World Meteorological Organisation (WMO). Thus the participation by the Institute for Remote Sensing Applications (IRSA) is designed to provide contributions to the research objectives of core projects of these programmes and in particular the Joint Global Ocean Flux Study (JGOFS) and the World Ocean Current Experiment (WOCE).

Three activities are particularly relevant to global studies:

- SST and marine heat flux;
- marine primary production and ocean colour.
- modelling related to marine processes amd remote sensing data assimilation.

Each of these activities are described briefly below in the following sections.

1992 Milestones

June	Initiation of feasibility study on cloud characterisation using neural networks.
Sept.-Oct.	Joint campaign on CSS Hudson, in the framework of JGOFS, to investigate primary production and dimethylsulphide production.
Sept.	Proposal of a interface flux model.
Sept.-Oct.	Inter-Institute campaign with IfO (Warnemunde) on RV A. von Humbolt to NE Atlantic to study sea surface temperature (SST).
Oct.	International Symposium on "Dimethylsulphide, Oceans, Atmosphere and Climate" sponsored by the JRC.
Nov.	Completation of the hydrodynamic tool ISPRAMIX for application in the NE Atlantic.

Sea Surface Temperature (SST) and Marine Heat Fluxes

A second joint measurement campaign (with the Institute for Baltic Sea Research - Warnemunde) was undertaken on the A. von Humbolt in September-October 1992 in the Iberian and Northwest African upwelling areas.

The experience of the 1991 SST study during the course of Atlantic Measurement of Oceanic Radiation (AMOR91), including improved measurement equipment and a rationalisation of the data management system.

The measurements during AMOR92 in the Northeast Atlantic were made in two phases:

- 09.09 - 26.09: in the region 32 - 40°N and 8.5 - 14°W and
- 28.09 - 06.10: in the region 31°, 30' - 30°,00' N and 10°,10' - 12°, 00' W

In parallel to the acquisition of new data, a new interface model has been developed describing the transfer processes within the so-called viscous sublayer of a thickness in the order of tenths of a millimeter both

side the interface. Best knowledge of these processes is of primary importance for explaining and computing the skin temperature effect influencing the precision of remote sensed SST, and, especially also for computing climate relevant trace gas fluxes, which in general are governed by waterside transfer resistance. The cruise data will be used for further validation. The model is also implemented in ISPRAMIX for computing the local and time depending skin effect.

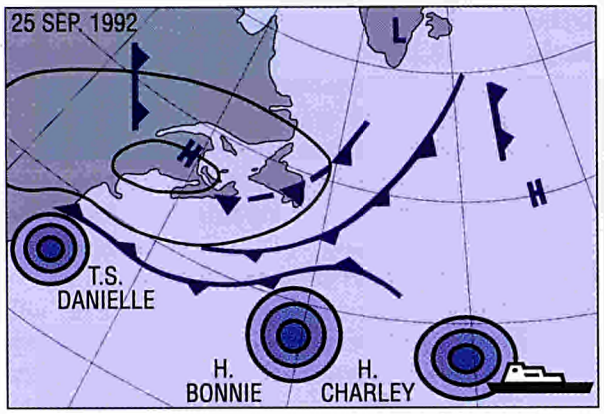


Fig. 4.1. Weather encountered during CCS Hudson campaign, September 1992

Marine Primary Production and Ocean Colour

There are three main activities in this study:

- In-situ campaigns
- Investigation of marine primary production
- Cloud characterisation using neural network techniques

In-situ campaigns

The IRSA has recently been invited by JGOFS to become an official observer to the programme. It was agreed, in conjunction with the Bedford Institute of Oceanography (BIO) Canada, to sponsor a joint research cruise in the summer-autumn period 1992 in the north east Atlantic in the framework of JGOFS activities. This is particularly valuable because it is an area where the JRC has been working for a number of years using satellite techniques.

Three specific aspects have been specifically considered: firstly, satellite observation for the estimation of biomass, and for cloud detection and characterization; secondly, development of numerical models for assessing SST and primary productivity using satellite, meteorological and in-situ (sea truth) data from the North-west African upwelling area; and thirdly, analysis of multi-annual time series of satellite observations to investigate long-term regional and temporal variations. Further, in collaboration with other JRC Institutes, IRSA is contributing to the development of studies of cloud characterisation linked to DMS production.

In support of this activity a scientific programme was carried out on board the Canadian research vessel CSS HUDSON in September-October 1992. The programme employed various state-of-the-art in-situ and invitro techniques to characterise the bio-optical properties of the upper ocean (including spectral irradiance profiles, distribution, biomass and productivity of marine phytoplankton and microbial activity) and studied details of the atmospheric-ocean sulphur cycle through on-board measurements of various physical (aerosols) and chemical (NOx, ozone etc) atmospheric parameters, and satellite detection of clouds and their characterisation.

This activity was carried out in cooperation with the German research vessel A.v.Humbolt which took was irradiance profiles and yellow substance in the same area.

Investigation of Marine Primary Production

The northwest coast of Africa has been selected as a regional test site to study marine phytoplankton productivity, whose distribution in space and time can lead to a better understanding of the role of upwelling areas on the air-sea exchanges of carbon dioxide and other important gases for global climate. The main activity in 1992 was to test a model developed in 1991 from existing algorithms. Basically, a non-linear representation of phytoplankton photosynthesis in the oceans is combined with a spectral model of solar irradiance to try and account for the variability of atmospheric parameters over various marine environments.

The model used such information, as well as on the bathymetry, to define several provinces. In most of the provinces, an homogeneous vertical profile of chlorophyll was assumed, whereas in province 3, evidences of a deep chlorophyll maximum has been observed from in-situ data. The resulting map of primary production shows similarities with the chlorophyll image, particularly in off-shore regions. Close to the coast, however, phytoplankton production tends to increase at

the shelf break (between the 200 and 2000 m isodepth lines), although chlorophyll concentrations are higher along the coast. Absolute daily rates of primary production estimated by the model are well correlated with in-situ measurements, and also with the general dynamics of upwelling phenomenon, which bring up new nutrients for phytoplankton preferentially at the shelf break.

Cloud characterisation using neural network techniques

An important objective in obtaining a better understanding of the main biogenic cycles is to more precisely identify the main active and passive reservoirs, and to estimate their capacity, turnover times (lifetime) and sensitivity to external influence, including feedback mechanisms, on the system.

One possible example of a potential feedback mechanism linked to primary productivity is that of the marine biological production of dimethylsulphide (DMS). Some common species of phytoplankton are known to be the main source of oceanic emissions of this sulphur containing compound. Production of DMS is estimated to add about 30 million metric tons of sulphur per year, or about 30-50% of the sulphur which enters the atmosphere from fossil fuel burning. In the atmosphere, DMS is oxidized to the low vapour pressure products sulphuric acid and methanesulphonic acid (MSA), which are known to efficiently form cloud condensation nuclei (CCN). In relatively distant uncontaminated marine environments, atmospheric cloud condensation nuclei from such a source could, it is proposed, be an important mechanism for the generation of more and brighter clouds, (what types of clouds?) which in turn may influence global albedo and thus the Earth's radiation balance.

Mapping of such cloud types could be undertaken using remote sensing data, for example by applying neural network techniques. The visible channels of the AVHRR provide cloud reflectance information related to optical thickness and the infra-red channels provide brightness temperature information which is related to cloud height. However, the recognition of clouds types also depends on their their spatial texture which can also be extracted from imagery. The cloud recognition problem in satellite images is thus a difficult discrimination problem involving multi-parameter pattern recognition.

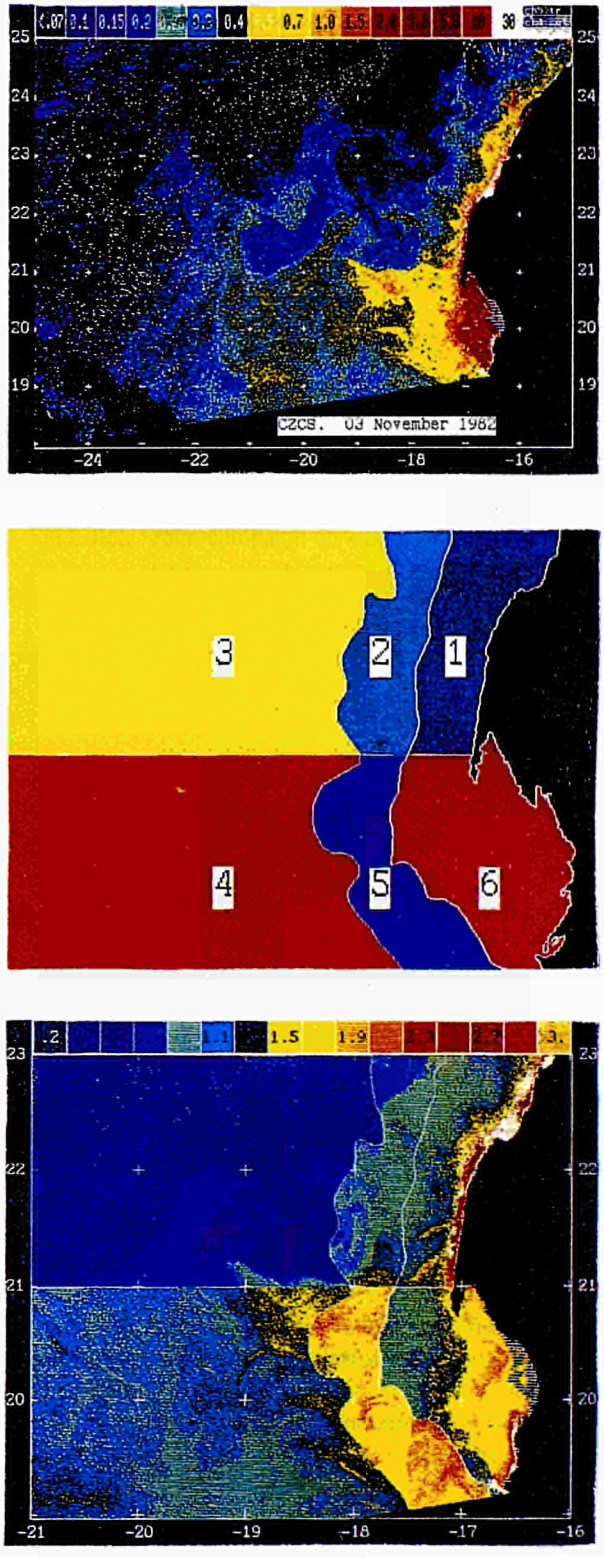


Fig. 4.2. Water column integrated primary production off Mauritanian coast as estimated from CZCS data.
a) CZCS chloropyll distribution ($mg.m^{-3}$).
b) Identification of bio-geo-chemical provinces.
c) Satellite-derived primary production ($gC.m^{-2}.d^{-1}$)

Modelling Related to Marine Processes and Remote Sensing Data Assimilation

The modelling activities continued in 1992 have been concentrated on the completion of a reference version of the computer code ISPRAMIX for regional circulation modelling; the completion of a modelling study at three typical shelf/shelf break geometries in the upwelling area offshore NW Africa including a joint application of CZCS data and numerical simulation; the implementation of a module providing heat and momentum fluxes at the air-sea interface; the development of an interface flux model.

ISPRAMIX is a baroclinic model for (combined) shallow and deep sea applications, based on the primitive equations, the hydrostatic approximation and the Boussinesq assumption with respect to the effect of variable density. Vertical transport by turbulence is computed with the turbulent kinetic energy obtained from the solution of the corresponding transport equations and with the mixing length obtained from the application of well-known parametrisation principles. Variable grid spacing in all three dimensions is possible in order to comply with scientific and economic requirements.

The model has been applied to investigate upwelling (related) processes at three typical positions at the NW African coast with simplifying 2-D offshore sections (at 21.0N, 22.5N and 24.0N). The wind forcing was extracted from weather data provided by the European Centre for Medium-Range Weather Forecast (ECMWF). The results obtained with the model show typical upwelling features like the "doming" effect on the shelf (a column of colder water from deeper water layers reaches the surface, a phenomena which can be clearly identified also from SST images), but also the influence of different shelf/shelf break geometries.

CZCS data and the results of the numerical model have been used in a joint application for estimating the cross-shelf transport of particulate organic carbon (POC). Mean chlorophyll concentrations have been derived from the CZCS data and furtheron the POC concentrations from the chlorophyll data. Based on the numerical results for the current field the transport of POC across the shelf has been estimated and thus providing an information on the export of organic matter to adjacent deep waters (a possible sink for carbon). This is an important aspect in regard to global change studies as the quantity of organic material available for exporting from upwelling zones is 10 to 100 times higher than in other ecosystems.

The circulation model has been complemented by a module, which allows - starting from the ECMWF meteorological data, the computation of the air-sea interface fluxes needed as boundary conditions for solving the momentum and heat transport equations. Based on standard methods known from the literature, the turbulent fluxes of momentum, latent and sensible heat are computed as functions of the wind velocities, the sea-atmosphere temperature difference, the relative humidity and the atmospheric pressure. Also methods for computing the short and long wave radiative fluxes at the interface level are implemented, assuring due correction of the solar heat flux for atmospheric humidity and for cloud cover.

Perspectives for 1993

In 1993 the cruise data acquired in 1991 and 1992 will be used for further validation of the new interface model which has been developed to describe the transfer processes within the so-called viscous sublayer. The model will also be implemented in ISPRAMIX for computing the local and time depending skin effect.

The model will be applied to the Northeast Atlantic test region (5-40W, 0-40N), using in-situ data collected during a joint cruise IRSA-Bedford Institute of Oceanography, Canada (see JGOFS activities) conducted in Sept.-Oct. 1992. Historical seasonal and interannual variations of phytoplankton production (based on CZCS archives) will be investigated by combining the model with two other JRC on-going studies in the same area: hydrodynamic (ocean current) modelling and cloud recognition from satellite data.

4.2 COASTAL MONITORING

(Specific Programme)

Summary of Objectives

Development and improvement of methods for the analysis of remote sensing data on sea colour.
Development and improvement of bioptical algorithms relating sea colour to water composition.
Search for new applications which extend the usefulness of marine remote sensing.
Study of small-scale phenomena specific to the coastal zone.
Monitoring of typical coastal pollution situations (state and dynamics).

1992 PROGRAMME OF WORK

Introduction

Until now remote sensing of ocean colour has yielded reliable information on chlorophyll-like pigments concentration and suspended sediment concentration in the euphotic layer of oceanic (i.e. "case 1") water. The main source of data has been the Coastal Zone Color Scanner (CZCS) whose operation terminated in 1986. The use of CZCS data of coastal waters has been problematic, while no direct information could be obtained on yellow substance absorption.

The advanced features of the forthcoming SeaWiFS should lead to significant improvements in the remote sensing of chlorophyll and suspended sediment, including the coastal zone ("case 2" water) and allowing yellow substance discrimination.

It is of interest to anticipate types of retrieval algorithms appropriate for use with SeaWiFS data, as well as their effectiveness in the most adverse situations, i.e. in coastal waters.

The 1992 activity concentrated on the study of the SeaWiFS potential for marine application including:

- performance of theoretical investigations
- planning of experimental activities.

Both aspects are summarised in the following paragraphs.

Algorithms using SeaWiFS data for the retrieval of phytoplankton pigments, suspended sediment and yellow substance in coastal waters were studied in 1992.

The study was based on numerical simulations using a three-component model of sea colour. The coastal zone was realistically modelled as a water body with

Milestones

Aug.	Investigation of SeaWiFS potential for remote sensing of "case 2" coastal waters
Dec.	Definition of a collaboration agreement with Stazione Zoologica "A Dohrn", for remote sensing studies in the Gulf of Naples.

"site-specific" correlations among chlorophyll, suspended sediment and yellow substance, subject to wide "fluctuations" due to local phenomena (river outlets, urban effluents, etc.)

The site-specific correlations used for the computations were those measured in the coastal waters of the Gulf of Naples. Local fluctuations of the correlations were assumed in the range from 0.25 to 3. Coherently with the features of the optical model the two chlorophyll concentration ranges $0.025 \leq C(mg\ m^{-3}) \leq 1$ and $1 \leq C(mg\ m^{-3}) \leq 40$ were treated separately.

The algorithms for the retrieval of phytoplankton pigments concentration, suspended sediment concentration and yellow substance absorption which have been set up operate on optimised band reflectance (OBR) variables. For instance, the variable selected for chlorophyll retrieval in the low concentration range was $Xc=(R2/R5)(R1/R3)^{-1.2}$ where R=reflectance and 1, 2, 3, 5 = SeaWiFS band. The sensitivity to the variability of the optical properties (absorption and scattering) of chlorophyll and sediment was also analysed, as well as the error induced by the uncertainty of the remote sensing data.

The algorithms were tested on randomly generated sets of SeaWiFS band reflectances.

The results obtained indicate that the proposed OBR algorithms can operate effectively in realistic coastal water conditions. In the low C range all the algorithms

seem to withstand the large fluctuations of the basic correlations expected in coastal waters, as well as important variations of the absorption and scattering properties of chlorophyll and suspended sediment, still yielding data of satisfactory accuracy, i.e. well within a factor of two (± 40% error) in most of the considered situations. In the high C range chlorophyll and yellow substance are retrieved with a somewhat higher error (about twice as large), while the sediment retrieval error remains practically unchanged.

Despite their simplicity the OBR SeaWiFS variables and algorithms seem to yield errors comparable, if not lower, than those caused by the use of more cumbersome data analysis methods (e.g. principal component analysis). Other advantages: the algorithms' constants are readily obtained from standard irradiance measurements in the water column carried out locally; no computed correction or adjustment of the values yielded by the algorithms is required.

Collaboration agreement with Stazione Zoologica "A Dohrn", Naples

The aims of this collaboration are two-fold:

- development of methods for the interpretation of remote sensing data in coastal waters, with specific reference to the use of SeaWiFS;
- evaluation of the relationships between spectrum of available light and phytoplankton dynamics in the coastal environment.

The problems to be addressed, as well as the experimental and theoretical activities required for their solution, have been defined in detail.

The collaboration contract is foreseen to become effective at the beginning of 1993 and will last two years (renewal clause included).

Perspectives for 1993

Extension of the studies related to the SeaWiFS performance, with the support of the experimental data which will be provided through the collaboration agreement with Stazione Zoologica.

- Contribution to NASA supported SeaWiFS project (mainly bio-optical algorithms development).
- Pilot project for identification of macroalgae coverage in shallow waters along the Morocco coast through the analysis of Thematic Mapper data.

4.3 STUDY OF THE NORTH-WEST AFRICAN UPWELLING AREA

(in support DG I International Affairs)

Summary of Objectives

Application of remote sensing for studying coastal upwelling off north-west Africa.
Analysis of remotely sensed data are used for describing temporal and spatial distribution of coastal upwelling.
Analysis of meteorological data for improving the understanding of coastal upwelling as a naturally ocurring phenomenon.
Integration of remote sensing data with other data sources in view of long term application in fisheries management.

1992 PROGRAMME OF WORK

In order to derive information about the variabilities in time and space of coastal upwelling along the north-west African coast an upwelling index was extracted from the data base of sea surface temperature (SST) satellite images.

During 1992 a similar but independent index was

1992 Milestones

May	Extraction of upwelling indices from meteorological data
Aug.	Analysis of seasonal variabilities
Dec.	Analysis of interannual variabilities

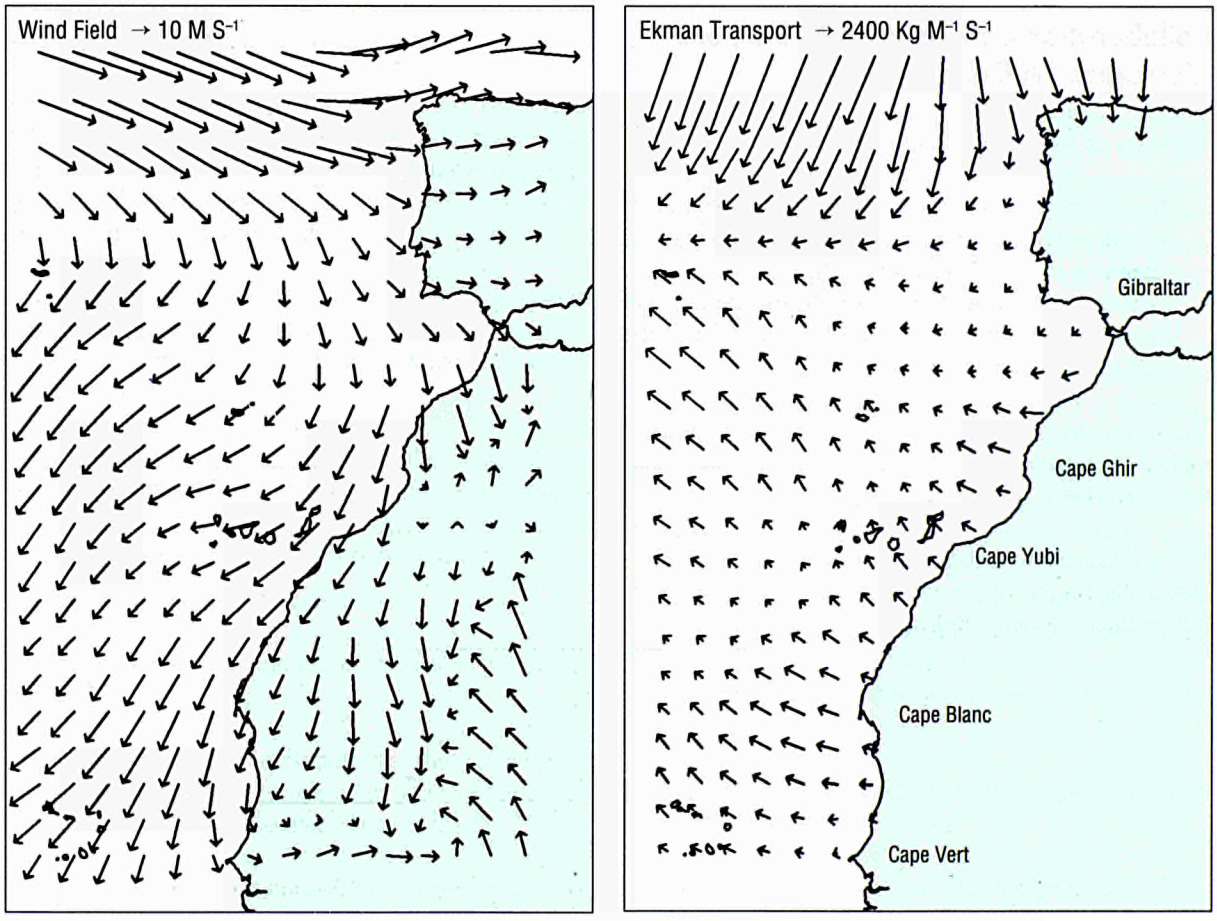


Fig. 4.3. (left) An example of the wind field from ECMWF - (right) The Ekman Transport computed from the wind field

extracted from a data base of meteorological data. The data, from the European Centre for Medium Range Weather Forecast (ECMWF), Reading, UK, comprise a global data set of various atmospheric parameters at or near the sea surface. Since the coastal upwelling is believed to be a wind driven phenomenon the surface winds have been of primary interest. The wind field provided by ECMWF is derived by means of an analysis of meteorological observations and a 6-hour forecast obtained with a numerical model. The winds are given at 10 m height above the sea surface at 12 UTC for each day in the period from September 1982 to June 1991. The spatial resolution is 1.875 degrees latitude and longitude before May 1985 and 1.125 degrees after May 1985.

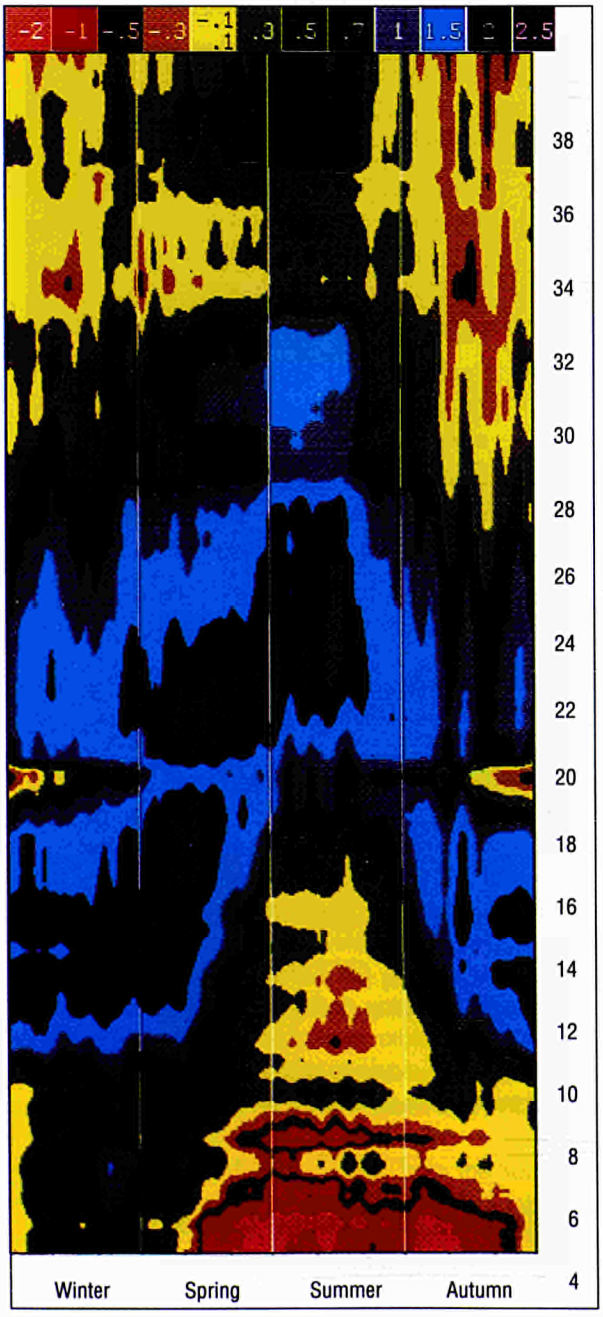


Fig. 4.4. Mean annual Ekman upwelling index

The Ekman upwelling index has been compared to the SST upwelling index derived from satellite images. The comparison has been carried out for describing seasonal variabilities as well as interannual variabilities. At the large spatial scale the indices compare well, while at smaller spatial scales discrepancies occur particulary in the vicinity of capes and major headlands.

In the temporal domain the SST index is frequently delayed relative to the Ekman index. The delay may be as large as 1-2 month as for instance observed off Portugal and off Cape Ghir. Interannual variabilities of considerable strength are observed south of Cape Blanc, which may be related to major global variabilities such as El Nino in the south Pacific Ocean.

A second utilization of the data base of SST images has been carried out in the frame of the CEC's MAST 0031 project. A subset of monthly images covering the waters surrounding the Canary Islands has been extracted and special software has been developed for examining the seasonal changes in the SST field. This work is carried out in collaboration with the University of Las Palmas.

Perspectives for 1993

The analysis of seasonal and interannual variabilities will be finalised. This includes processing further SST images and wind data to bring the data base to cover the period up to 1992. The methods to be applied should be able to quantify some of the anomalies observed in the data rather than just indicate their existance. This analysis will be coordinated with other JRC efforts in hydrodynamic modelling to explain the reason for the observed phenoma.

Furthermore, seasonal maps of SST will be produced for a comparison with known atlases of surface parameters and air/sea fluxes. Ocean colour data will be included in the multiannual database of observations off north-west Africa from the JRC/ESA OCEAN project for the period from 1979 to 1986.

4.4 OCEAN COLOUR EUROPEAN ARCHIVE NETWORK (OCEAN) PROJECT

(in support of DG XI Environment)

Summary of Objectives

Preparation of algorithms to extract geophysical parameters from ocean colour data, and of methodologies for their archival, management and exploitation.

Compilation of a bio-optical data base on the marine environment.

Using historical CZCS data, to promote the use of ocean colour data in an Application Demonstration Programme devoted to marine regions of European interest.

Realization of a scientific ocean colour 'network' in Europe, in support of current research activities and in preparation of future space missions.

1992 RESULTS

Introduction

The Ocean Colour European Archive Network (OCEAN) Project, a joint initiative of the Institute for Remote Sensing Applications (IRSA) and of the European Space Agency (ESA), was established to promote the use of ocean colour data towards an improved understanding of the European marine environment. The objectives of the Project include both the exploitation of historical data - essentially all those collected by the Coastal Zone Color Scanner (CZCS), in the period 1978/1986, over marine regions of European concern - in support of current research activities, as well as the development of tools and structures in preparation for future ocean colour missions. The OCEAN Project has carried out the archival of all CZCS data available in Europe (level 1 data); the processing of all suitable data, using ad hoc algorithms, to the final geophysical parameters of interest (level 2 data); the preparation of geo-coded, composite and statistical images of such parameters (level 3 data). The Project aims at distributing all value-added data within the scientific user community through an Application Demonstration Programme (ADP).

1992 Milestones

Jan.	Start of OCEAN level 3 software development
April	1st OCEAN Project ADP Participants Meeting
June	Level 1/2 data (1979) selection for ADP
July	Start of level 1/2 data (1979) distribution
Sept.	End of level 1/2 data (1979) distribution
Sept.	Conclusion of OCEAN level 3 sw development
Oct.	OCEAN CODE definition and start of development
Nov.	Start of level 3 data production
Nov.	Level 1/2 data (1980) selection for ADP
Dec.	Start of level 1/2 data (1980) distribution

Development of OCEAN Algorithms and Systems

The definition of standard OCEAN format and processing software for historical image data (level 1/2/3) has been completed. The final component (level 3) of the value-adding algorithms (i.e. a compilation of improved CZCS geometric correction, remapping and statistical compositing algorithms) has been defined, together with interfaces, format, and suitable procedures for verification and output data validation. The relevant software developmemt (level 3) has been completed, and functional tests performed. All software developed in the framework of the OCEAN Project (i.e. the level 1 and level 2 packages, developed in past years, together with the recently completed level 3 component) is now being integrated into a single system, provisionally named OCEAN CODE, that will provide the backbone for the data processing systems of future ocean colour sensors. The compilation of a final CZCS value-added data archival has progressed, while the generation of the OCEAN Data Catalogue and Quick-look Browsing System, including all historical CZCS image data available in Europe, has been completed and made available for consultation to all the interested scientific groups.

The OCEAN Application Demonstration Programme (ADP)

The OCEAN ADP was established following the release of an Announcement of Opportunity (AO) concerning the exploitation of the CZCS data Archives

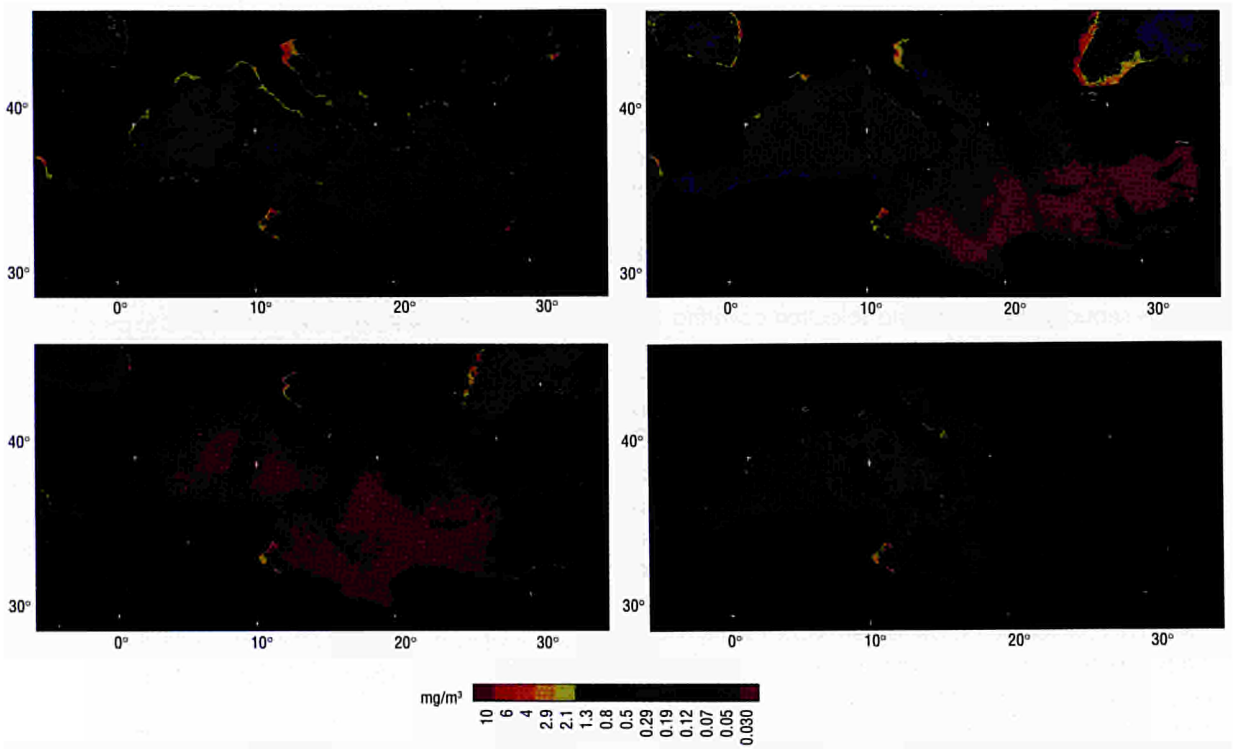


Fig. 4.5. Composite seasonal images of the Mediterranean basin, statistically derived from 267 Coastal Zone Color Scanner (CZCS) original scenes. The images show chloropyll-like concentration and highlight the differences between various sub-basins of the Mediterranean and between different seasonal periods

generated by the OCEAN Project. The response to the AO has been large, and continued throughout the past year, while Letters of Intent and/or Research Proposals for participation in the ADP are still being received after any public presentation of the OCEAN Project achievements. Currently, after evaluation of the proposals received, the ADP accounts for more than 30 Projects to be assisted with CZCS data deliveries. The Projects concern all the major marine basins of European interest, grouped into three main regions:

- the northern European basins, covering essentially the North Sea, the Baltic Sea, and various adiacent areas (NEUR);
- the Mediterranean basin, including both the Mediterranean Sea proper, and the Black Sea (MEDI and BLKS);
- the northeastern Atlantic basin, from the subpolar area to the equatorial area, subdivided into two main regions: North West Africa near-coastal area and North East Atlantic Ocean (NWAF and NEAT).

The main research activities approached in the framework of such Projects concern the assessment of pigment patterns, and their variability in both space and time; the relationships between plankton pigments and nutrients; the evaluation of plankton biomass and production; surface circulation and water constituent dispersion, including sediment transport; currents, bathymetry and islands interaction; upwelling dynamics; coastal runoff and plumes; the monitoring of potential pollution sources; and fisheries applications.

The 1st OCEAN Project ADP Participants Meeting was held at IRSA, JRC CEC, on 7-8 April 1992, in order to establish the operational procedures and timetable for the actual data delivery. Following that Meeting, the ADP started its level 1/2/3 data distribution to those Participants who made specific data product selections and requests. Subsequently, the data distribution proceeded in the following manner: first, the original CZCS data have been divided into main geographical groups (i.e. NEUR, MEDI, BLKS, NWAF, NEAT). Second, for each year of CZCS operations, and for each geographical group, a selection of all of the images judged of some interest was performed, on the basis of operational criteria taking into account

- marine area covered by each image,
- surface features appearing in the image quicklook,

- acceptable cloud cover,
- other parameters related to geographical coverage, seasonal period, image acquisition mode and satellite attidute (these criteria are essentially those used for the selection of a data set suitable for the generation of level 3 data products, and do not reflect the specific needs of any of the ADP Participants in particular). And third, each ADP Participant who did not provide a list of desired data products was sent copies of the data selection covering the geographical area of interest.

At present, aside from special requests coming from a few of the ADP participants, all 1978, 1979 and 1980 level 1/2 data have been delivered. The 1981 selection will come next, followed by that for 1982 and so on, in a time sequential mammer. Further, all data included in the selection (about 800 to 1000 data products per year, on average subdivided approximately as 15% for the NEUR region, 35% for the MEDI and BLKS areas, and 25% each for NWAF and NEAT sites) are being processed to level 3. The delivery of level 3 data has been started with the 1979 selection, and will continue in the same way as that for level 1/2 data.

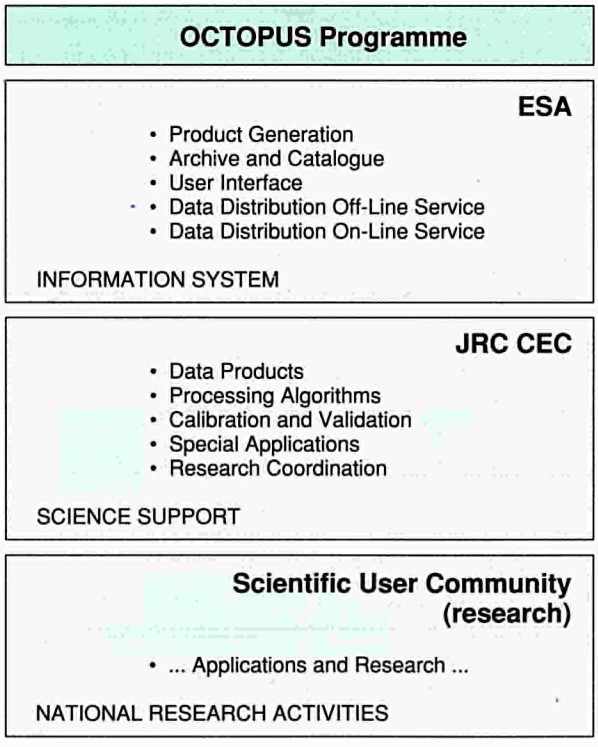


Fig. 4.6. The OCTOPUS Programme main components

The OCTOPUS Programme

As stated above, the OCEAN Project was set up with the aim of developing in Europe a 'network' of scientific groups and facilities in preparation for future space missions. The exploitation of the experience gained by the Project will allow to take advantage of the upcoming Sea-viewing Wide-Field-of-view Sensor (SeaWiFS), that will become operational with the SeaStar satellite mission, in late 1993 or early 1994, and to prepare for the Medium Resolution Imaging Spectrometer (MERIS) mission planned for the end of this decade. The IRSA has proposed, in a joint venture with the ESA, and in collobaration with other European scientific partners (i.e. the OCEAN ADP Participants), to pursue this goal through an European SeaWiFS Programme on Ocean Colour Techniques for Observation, Processing and Utilization Systems (OCTOPUS). The OCTOPUS Programme is centered on (i) the use of scientific tools developed by the OCEAN Project and (ii) the availability of high-resolution SeaWiFS data to European receiving facilities.

The Programme integrates three main components, devoted to data collection, management and distribution (ESA task); to data processing techniques, science applications and coordination (IRSA task); and to research activities to be conducted in various European Institutions. Such Programme should allow the exploitation of ocean colour and concurrent remote observations of the sea surface (e.g. temperature, roughness and topography) from complementary space missions, contributing to large data systems being developed -in Europe and elsewhere- for environmental monitoring.

Perspectives for 1993

The OCEAN Project will conclude its activities by completing (i) its software development (OCEAN CODE); (ii) all data processing, validation and archival operations, with final release of the complete OCEAN Data Archives; and (iii) its data distribution, in support of the research activities related to the OCEAN ADP.

Further, initial steps will be taken for the establishment of the OCTOPUS Programme, centered on the use of the SeaWiFS data that will become available in late 1993 or early 1994. The following activities are envisaged:

- preparation and coordination of a final OCTOPUS Proposal with other Programme participants, includ-

ing the development of the study A preliminary assessment of ocean colour applications to marine environmental issues: perspectives for the OCTOPUS Programme, and the organization of two scientific workshops on the same topic;
development of the investigation Alternative methods for the determination of optically active material concentrations in marine water, submitted under NASA NRA-92-OSSA-7 and selected (ref. n. 2683-SEAWFS-0073) for the research programme 'SeaWiFS: Global Ocean Primary Production'; integration of the resulting algorithms into the OCEAN CODE final release;

- planning of the OCTOPUS Programme, for the establishment of a SeaWiFS European Algorithm Set (SEAS), and a SeaWiFS European Archive and Data Information System (SEADIS), based on the experience and facilities established through the OCEAN Project.

Finally, research activities and scientific applications, aiming at the exploitation of the newly available SeaWiFS data, shall be established with the collobaration of other European scientific partners (e.g. the 'network' of OCEAN ADP participants).

5 MONITORING TROPICAL VEGETATION

Staff

Scientific and Technical Support	8
Secretarial Support	1
Scientific Visitors	–
Students	3
Total	12

Publications

Journal Papers	11
Conference Papers	17
JRC Reports	–
Books/Chapters	8
Total	36

Facilities

- Compaq 386/33 with ERDAS and AVHRR pre-processing software
- Tape drives
- Daily archive of GAC AVHRR data for Africa 1981 - 1989
- Daily archive of GAC AVHRR data for Asia 1986 - 1989

The general objectives of the MTV Project are:

- use remote sensing derived information in conjunction with other data sources for studying surface features related to vegetation distribution, functioning and conditions. Fields of applications are : ecosystem productivity, biogeochemical cycles, biomass burning, continental land cover, tropical forest monitoring.

- develop remote sensing based method for monitoring changes in vegetation with emphasis on tropical areas.

- derive surface physical characteristics from remote sensing data and interface such information with atmospheric, climatic and biosphere models in a Global Change perspective.

During 1992, the Project has pursued its activities dedicated to the study of tropical ecosystems with particular reference to the analysis of vegetation dynamics at continental to global scales. The expansion of the range of activities undertaken in this framework, as well as the rapid growth of the staff have led to an organisation of the research teams along three main groups having each a specific focus of study. These groups are:

- Remote Sensing of Tropical Ecosystems (RE7) (ecosystem monitoring and biomass burning)
- Terrestrial Environment and Atmosphere Monitoring (TEAM)
- Tropical Ecosystem Environment Monitoring by Satellites (TREES)

These three research groups are supported by a data and information management unit (DAMI) dedicated to the setting, maintenance and operation of the necessary computing facilities. The management of a sizable and growing satellite data collection is also in the hands of the Group DAMI.

Individual sections of the present report describe the detailed activities of each of the above groups.

Linkages between the various research teams is maintained at the MTV level through a convergence of research objectives, interactions between modelling and observations, the sharing of data sets and as much as possible continuous interactions between staff members.

At the MTV Project level itself several staff members have been actively involved in research and development leading to improved approaches to global vegetation monitoring. This includes in-house research per se but also participation in international research groups, the organisation of a European Global Vegetation Monitoring Initiative, contributions to instrument scientific committees at NASA and ESA, and the more classical participation to relevant seminars, conference and workshops. The MTV Project has, among others, been participating actively in events related to the International Space Year.

Contacts with the General Directorates of the Commission have expanded in parallel with the geographical interests of the MTV Group. Close collaboration with the DG VIII for Africa has been maintained and a new collaboration with DGI for Southeast Asia and Brazil has been initiated.

The number of Institutions in the tropical world with which MTV is collaborating is also growing; the range of those contacts is directly related to the needs for field reference investigations, the interest expressed by some non-european institutions for the approaches developed in MTV and exigencies of the Support to the Commission.

The MTV Project has grown substantially during the year 1992; as the remainder of the report will show, attention has been paid in order to maintain the original research objectives, that is those related to the study of vegetation dynamics in tropical environments, while making sure that innovative approaches to the analysis of remote sensing data are being constantly developed and applied.

Strengthening the links between the study of surface conditions and climate/atmospheric models in the framework of the global change research activities has represented an important and far-reaching strategic orientation of the Project. This new orientation has clearly shown that while improvements in remote sensing techniques and surface-atmosphere modelling can be conducted in significant steps, enhanced consideration must be given to establishing and nurturing linkages with vegetation ecology and land use issues. A better integration of the large existing body of knowledge on plants and plant communities in current remote sensing and modelling work is now essential. This will represent an important objective of MTV for the year 1993.

5.1 MONITORING OF BIOMASS PRODUCTION IN SAHELIAN COUNTRIES

(in support of DG VIII Development Aid)

Summary of Objectives

To develop remote sensing based methods of biomass productivity assessment in Sahelian Countries at scales ranging from the regional to the subcontinental level.

To apply those methods to agricultural, herbaceous and woody production.

1992 PROGRAMME OF WORK

Introduction

The objective of this activity is to develop remote sensing based methods for assessing biomass production in Sahelian Countries. The research covers rain fed food crops, as well as herbaceous and woody production.

While the long term goal is to provide assessments at scales ranging from regional to sub-continental, specific experiments have also been carried out at more local scales and used as reference.

These regional experiments were carried out with the effective support of local partners in the framework of the collaborative agreement established between the Institute for Remote Sensing Applications and the Interstate Committee for Drought Control in the Sahel (CILSS) - AGRHYMET Centre.

The activities pursued in 1992 include:

- calibration of vegetation indices in terms of vegetation cover,
- comparison of vegetation indices with crop phenology and yield,
- prospective study to extend the methods to natural vegetation and to expand geographically to the sub-continental level.

1992 Milestones

March	Report on AVHRR - Agricultural Yield multiyear analysis at subcontinental level.
May	Completion of the Bobo-Diolasso (Burkina) multiscale and remote sensing data sets and preparation of visual/digital method of vegetation percentage cover assessment.
June	Start of analysis of AVHRR and vegetation conditions for Niger (1990-91).
June	Intialisation of the systematic extraction of information from the larger Bobo-Diolasso 91 data set for vegetation percentage cover assessment.
Oct.	Distribution of "Directory of Institutions involved in Crop and Biomass Assessment with Remote Sensing over Sahelian Regions".

Vegetation Indices And Cover Percentages

A data set was assembled for a test-site in Burkina Faso. It includes geographically corrected satellite imagery (SPOT, Landsat TM and AVHHR) covering the 1991 rainy season, as well as colour and black and white large scale air photographs. Intensive ground survey was carried out at the same period.

The objective of the analysis is to measure vegetation cover percentage from large scale (1/800) air photos, to associate these measurements to various vegetation indices derived from high resolution satellite imagery, and then to extrapolate to low resolution satellite data (AVHRR).

Two methods of fractional cover measurement were used and compared : digital classification of rasterised air photos, and visual interpretation using a sampling grid superimposed to the photos. This last approach was found more efficient because it allows vegetation types to be distinguished and the shadow effect to be minimised.

Preliminary analyses suggest the possibility of calibrating vegetation indices not only with ground references, but also with the intrinsic data scattering in the green , red and infra-red spectral domain.

Vegetation Indices, Crop Phenology And Yield

The activity of this year has focused on the combined analysis of daily AVHRR 1 km satellite imagery provided

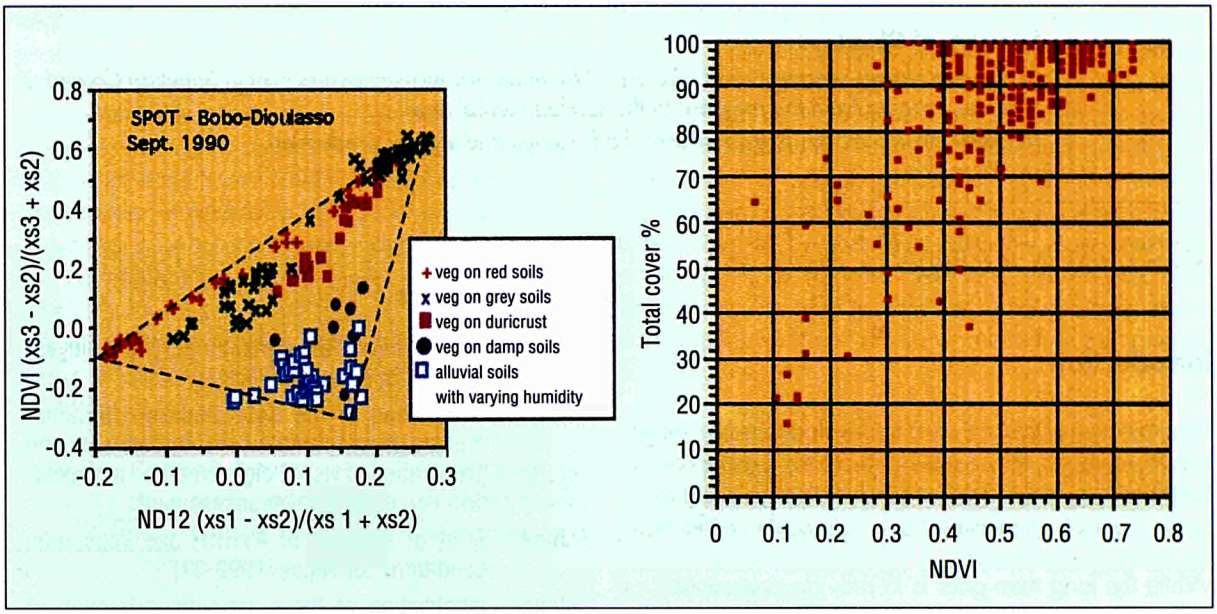


Fig. 5.1. Calibration of vegetation indices for fractional cover assessment. Left: NDVI values against Normalized Difference between green (XS1) and red (XS 2) channels for SPOT data over the Bobo Dioulasso test-site. The right diagram shows vegetation for 250 sites of 150x150 m each as a function of SPOT vegetation indices at full vegetation development (21/09/91)

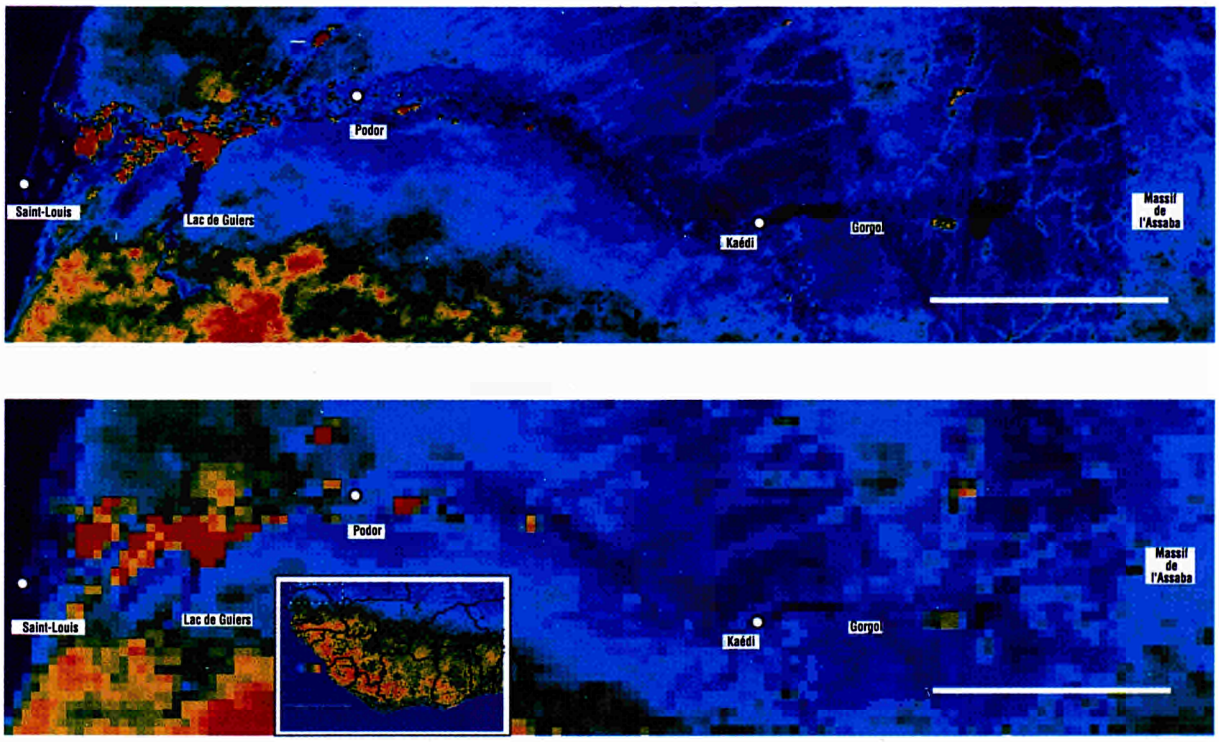


Fig. 5.2. AVHRR vegetation index. Senegal River and surroundings areas. The graphical scale is 100 km long. The upper image at 1 km (full HRPT) resolution and with high geometric accuracy allows vegetation patterns to be monitored at the local scale, as showed in the valleys, on the right side of the pictures. The lower image in GAC mode (4x4 km) allows only general information to be retrieved at the regional scale

by the Maspalomas and Niamey stations and an extensive data set including crop phenology and yield measurements. These data were collected on 25 reference sites in Niger; during the 1990 and 1991 rainy seasons.

The handling of this large amount of data (total input is about 40 Gigabyte) was carried undertaken on a processing chain developed by the project, and completed by the end of 1992.

Generalisation Of The Methods And Geographic Expansion

A prospective analysis has been started in order to define the most appropriate ways of expanding primary production assessment at the continental level with low resolution satellite time series. This includes a review of the methodological aspects, access to and organisation of appropriate data sets, and an assessment of the resources needed to carry out the work, both at JRC, and by an appropriate network including European and African partners.

Perspectives For 1993

Three major research directions are identified for 1993:

- Analysis of the Burkina Faso data set: empirical analyses of the relationship between fractional cover and several vegetation indices will be carried out (at high and low resolution). The results are expected to help in the definition of data collection scheme to be proposed at the sub-continental level.
- Processing and analysis of AVHRR and ground data will continue according to availability of new data.
- Extrapolation of methods developed for crop yield estimations to the assessment of primary productivity and natural vegetation status at sub-continental scales will be attempted. This will include a survey of ground data availability and the organisation in a GIS of the existing data sets.

5.2 MONITORING OF BIOMASS BURNING

(in support of DG VIII Development Aid)

Summary of Objectives

The overall objective of the biomass burning research is to develop remote sensing based methods for the monitoring of fires in the tropical belt and to use the derived information to address the following questions:

- *has biomass burning significantly increased at continental level in the last decade (Case of Africa)*
- *has it increased in all ecosystems or has fire affected new ecosystems in recent times?*
- *can fire activity be used as an indicator of environmental changes, thereby giving information on changing relationships between man, vegetation and climate?*
- *how is fire influencing lower atmospheric chemistry in the savanna-forest transition zone of Africa?*

1992 PROGRAMME OF WORK

Introduction

Fire is a natural feature of many ecosystems; the African savannas for example are often identified as fire climax ecosystems. Indeed fire has major impacts on local, regional and global ecosystems. Burning almost instantaneously changes the vegetation characteristics of the burned area and repeated burning can effectively alter the spatial boundaries of ecosystems forcing transition from one to another.

If the spatial distribution and timing of fire in an ecosystem remains constant these effects are usually in a state of equilibrium. However pressures of population growth, economic demands and demographic shifts are likely to change burning patterns. This can alter the balance and make fire an agent of environmental destruction. Burning patterns are therefore useful indicators of environmental change over large areas.

In order to map and monitor these effects at a regional scale techniques have been developed to identify active fires using 1km AVHRR data of West Africa. These techniques result in the ability to extract fire statistics and to describe the areal and thermal characteristics of the fires.

Methodological Developments

The detection of active fires using NOAA-AVHRR data has been further refined at the HRPT/LAC resolution for specific West African conditions and at the GAC resolution for the whole African Continent. The method is based upon multiple thresholding and uses both thermal and visible AVHRR data.

1992 Milestones

Feb.	Field compaign in Southern Guinée.
March	Establishment of scientific collaboration with the DECAFE Programme.
Oct.	Analysis of time series of NOAA AVHRR data of Africa for fire detection.

In addition a field campaign was organised in southern Guinée to collect ground information related to fire types and their impact in the savanna-forest transition area.

All the spatial information that has been collected from the ground campaigns and from the remote sensing analyses has been organised in a Geographical Information System to help in the analysis of biomass burning patterns. The layers include vegetation, ecosystems, conservation areas, national parks, hydrographic network, national boundaries.

Analysis Of Biomass Burning Patterns

At continental scales NOAA-AVHRR time series for the years 88/89 have been analysed to derive temporal and spatial distribution of fire activity for the whole African continent. Starting with daily fire distribution products , monthly, seasonal and annual syntheses have been prepared. The product has been systematically evaluated to assess the effect of the GAC sampling upon the detection of fire points.
At the regional scale the temporal fire distribution of the major part of the Niger Basin (Guinée, Mali) has been studied using the 1 km resolution AVHRR HRPT data.

Various "fire regimes" have been identified; a quantitative analysis of those regimes has provided useful environmental indicators of land use conditions in the watersheds.

External Collaboration

A scientific collaboration has been established with the international DECAFE Programme (Dynamics and Chem-

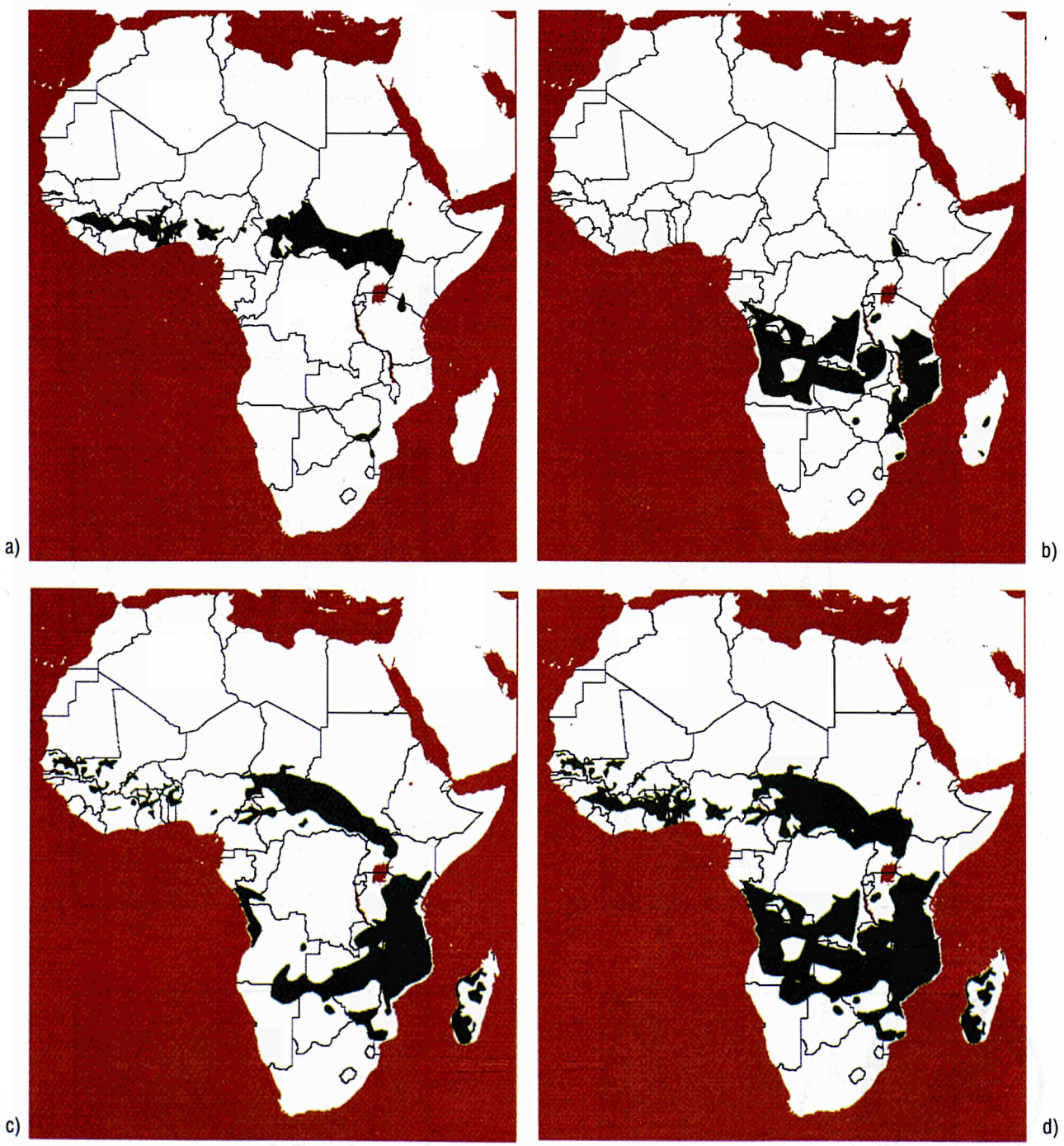


Fig. 5.3. Continental patterns of bush fire distribution in Africa as derived from NOAA-AVHRR-GAC time series. Black areas show where the number of fires, detected on the satellite imagery, has been particularly high sometimes during the following periods:
a) January 1989 to March 1989;
b) June 1989 to August 1989, plus September 1988;
c) October 1988 to December 1988;
d) September 1988 to August 1989

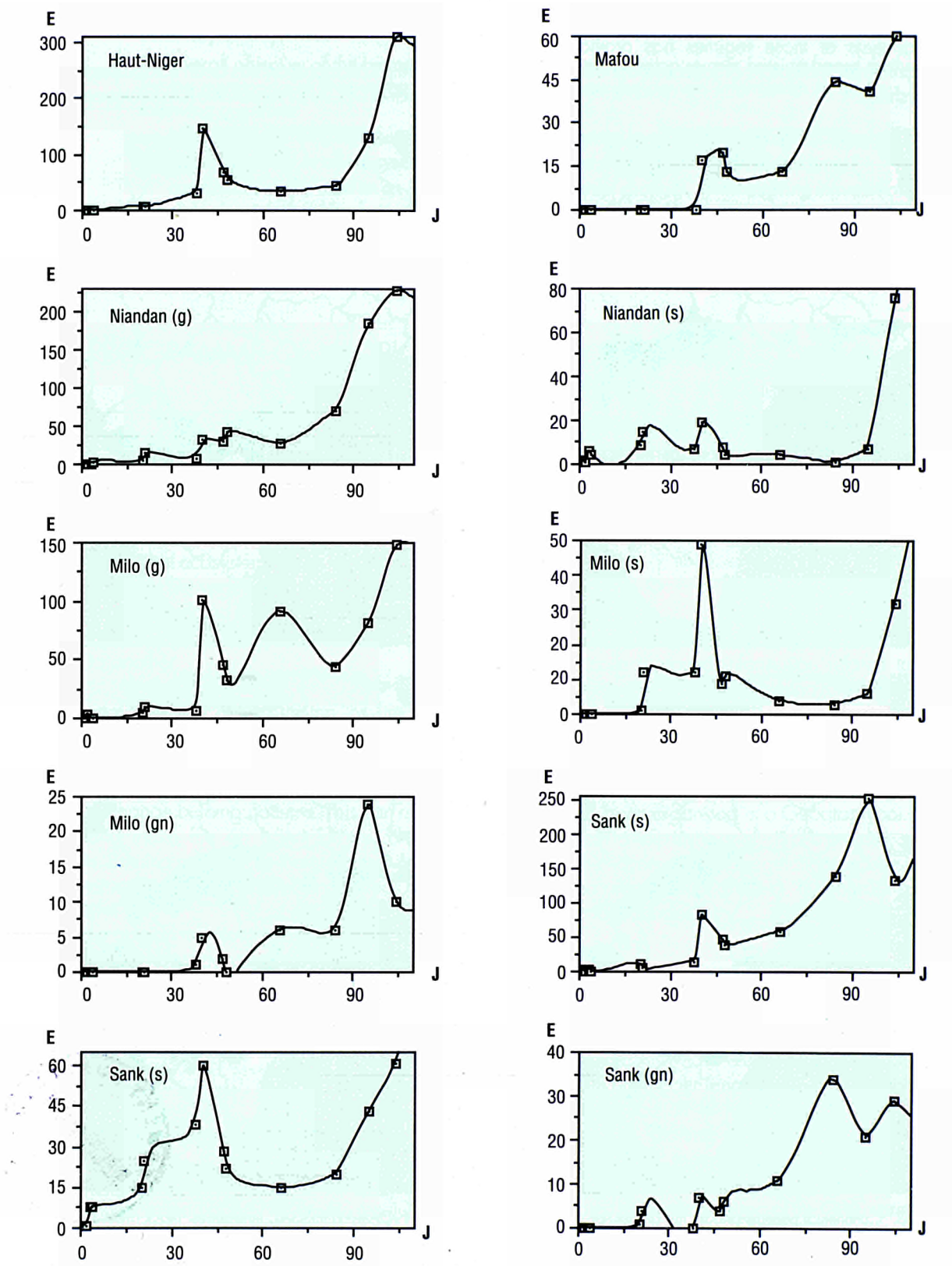


Fig. 5.4. Temporal distribution of active fires (E = number of fires) as detected using NOAA-AVHRR-HRPT time series over 10 sub-basins of the Niger watershed. J = number of days after the beginning of the 1987/88 burning season (J_1 = 03.11.1987)

istry of the Atmosphere in Equatorial Forests). The objective of the collaboration is to evaluate the possible role of biomass burning as a source of atmospheric disturbance in the tropical forest environment (application to Central Africa).

Perspectives For 1993

Biomass burning research will focus in 1993 on

- a complete analysis of fire patterns at the Africa Continent scale using the 1981-89 AVHRR GAC daily products. Regional patterns of fire activities will be characterised in the continental context. Possible changes in the spatio-temporal distribution of fire activity will be documented and analysed; links with ecosystem conditions will be established.
- in the framework of the DECAFE Programme, the distribution and timing of active fires as detected by the AVHRR instrument will be correlated with the ozone profiles measuring during the Central African campaigns.
- the use of fire as indicators of deforestation fronts will be investigated in collaboration with the TREES Project.
- a field experimental campaign will be conducted in collaboration with DECAFE and NRI of the UK, in Ivory Coast. Controlled fires and real time reception/analysis of AVHRR data will be used to validate methods of active fire detection and characterisation.
- preparation work for a fire assessment at the tropical belt level using AVHRR 1km data produced under the IGBP-DIS auspices will be undertaken.

5.3 CONTRIBUTION OF TERRESTRIAL ENVIRONMENT AND ATMOSPHERIC MODELLING (TEAM) TO GLOBAL CHANGE

(Specific Programme)

Summary of Objectives

To develop physically based models and numerical algorithms to extract quantitative information from satellite remote sensing data.

To investigate biosphere-atmosphere interactions, both to improve the representation of biological and environmental processes in general circulation models of the atmosphere, and to assess the effect of climatic variability and changes on the biosphere.

To contribute to the research needed to address global change issues, paying special attention to the integration of modelling and remote sensing techniques.

To collaborate with Space Agencies (ESA, NASA) on the design and implementation of scientific algorithms for the optimal exploitation of new sensors.

1992 PROGRAMME OF WORK

Introduction

The scale, intensity and persistence with which human activities have affected the environment and changed the composition of the atmosphere have raised questions about the sensitivity of the climate system to these perturbations, and the likelihood of large scale and long term effects. Widespread concerns result from the fact that these changes may be largely undesirable and unpredictable. No consensus has been reached yet in the political arena on the need to take action, or even on the extent and severity of the measures that might be adopted, but there is widespread agreement on the need for a much better understanding of the processes involved and for a reduction in the uncertainties associated with current predictions.

Many of the relevant scientific issues revolve around the interactions between the biosphere and the atmosphere, in particular the exchanges of heat, water and carbon at the surface. A high priority is currently given to the understanding of these issues at a regional to global scale, and for time periods of years to decades, although scientific research is also needed at other space and time scales. This effort is coordinated, on a worldwide basis, under the aegis of the International Geosphere Biosphere Program (IGBP), also known as the Global Change Research Program. This international research programme is centred around a number of priority areas, including the modelling and monitoring of the global environment, and the investigation of past changes to evaluate how the climate-environment system has evolved under stress previously.

The Terrestrial Environment and Atmosphere Modelling (TEAM) group has been set up within the Monitoring Tropical Vegetation (MTV) unit for the purpose of advancing the level of scientific understanding needed to address Global Change issues, and in particular to help clarify the role of the biosphere in the global climate system and the impact of climate and human induced changes on the biosphere. To achieve this goal, TEAM will be developing or improving models and advanced techniques to study biosphere-atmosphere interactions, taking full advantage of the availability of remote sensing data sets.

1992 Milestones

May	Development of a new vegetation index, the Global Environment Monitoring Index (GEMI).
June	Development of a strategy to validate physically based bidirectional reflectance models against simulated and actual remote sensing data.
Oct.	Preliminary design of a ray-tracing model to represent the transfer of radiation through arbitrarily complex scenes.

Objectives

The fundamental scientific objective of TEAM is to contribute to a better understanding of the interactions between terrestrial ecosystems and the atmosphere, and in particular to investigate the role of the biosphere in the climate system and its sensitivity to changes and perturbations.

Within this broad framework, TEAM scientists will focus on the following specific objectives:

- In the field of remote sensing, develop new or improve existing methods to derive reliable quantitative information on the state and evolution of the Earth's surface and the atmosphere from existing data sets;

- In the area of environmental modelling, advance the state of the art in biological and ecological models, with particular emphasis on the exchanges of energy, water and biogeochemicals with the atmosphere, and on the evolution of the biosphere at large spatial scales; bridge the gap between biological and atmospheric sciences;

- With respect to climate and global change issues: use climate and environmental models to study the impact of climatic and human perturbations on terrestrial environments, and the role of land surfaces and its changes in the climate system; contribute to the IGBP research programme.

Approach

The realisation of these objectives rests on the definition and implementation of a scientific strategy, centred around the development of mathematical models of the environment and the extraction of physical information on this environment from remote sensing data. Basically, the issue is to better understand the nature, structure and evolution of the terrestrial environment, using fundamental scientific knowledge and appropriate monitoring techniques. At the space and time scales of interest, environmental information may be conveniently provided by satellite sensors, provided the radiation measurements can be interpreted. This is possible only by using models of radiation transfer that describe the relevant processes.

A considerable amount of research on these issues is occurring worldwide, but much if not most of it is focused on very small space and time scales. TEAM scientists will specifically address these issues over a wider range of scales and attempt to bridge the gap between the knowledge and experience acquired locally and the regional and global models already in existence to describe the state of the atmosphere or the global carbon cycle, for instance.

Sensors located on satellite platforms are the only observational means that provide global in coverage, with a spatial, temporal and spectral resolution high enough to be adequate for local, regional, or continental studies. These data sets therefore constitute a key element in the strategy to study biosphere-atmosphere interactions across a wide range of scales, provided they can be interpreted quantitatively. Accordingly, part of TEAM's research will focus on extracting reliable information from the satellite remote sensing data sets, and on enhancing the contribution of remote sensing to our knowledge of the Earth's surface.

While the accurate determination of the radiative properties of natural surfaces is interesting in its own right to support investigations of climate processes, one crucial motivation for these studies is to derive a better understanding of the biosphere and its interactions with the atmosphere. To this end, TEAM will develop models of these interactions at the appropriate scales, and attempt to bridge the gap between the scales and resolutions studied by physicists of the atmosphere and climate system and those studied by biologists and ecologists.

The models and algorithms developed along these lines will enable TEAM scientists, in collaboration with other groups of MTV and other institutions, to address significant issues in the area of climate impact on the ecosystems and of the role of these environmental changes on the climate itself (e.g., biomass burning or deforestation).

Results

The Global Environment Monitoring Index (GEMI)

The development of physically-based models to describe the radiative properties of the joint atmosphere-surface system is progressing, but will require further effort to extend their applicability to heterogeneous terrestrial surfaces. In the mean time, pressing issues are being investigated with the help of vegetation indices. These indices are simple mathematical formulae to compute a numerical index on the basis of spectral measurements. These indices are then empirically related to vegetation properties as they are observed in the field.

The Global Environment Monitoring Index (GEMI) has been developed to address the limitations of the most commonly used indices, namely their sensitivity to atmospheric perturbation and to soil colour changes resulting from top soil moisture variations. The GEMI is

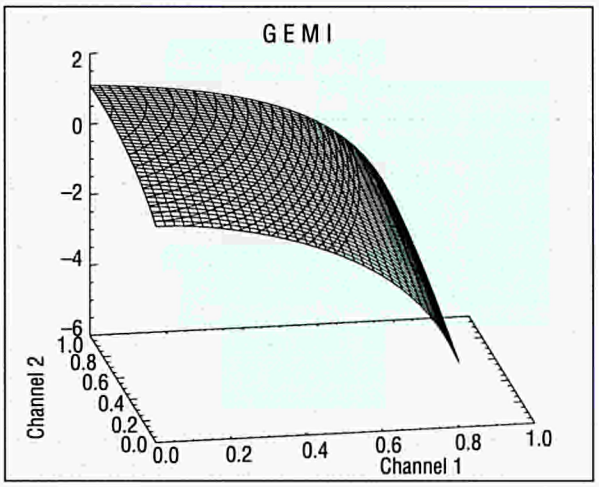


Fig. 5.5. Spectral dependency of the Global Environmental Monitoring. Index (GEMI) on the red (Channel 1) and near-infrared (Channel 2) reflectances of AVHRR

currently under evaluation but preliminary results show that its value computed on the basis of space measurements is closer to that which would be obtained in the absence of atmospheric or soil contamination than that of traditional indices.

Bi-Directional Models

A number of mathematical models have been developed to describe the anisotropy of the reflectance of natural surfaces, i.e., the fact that these surfaces do not reflect sunlight equally in all directions. Most of these models are capable of simulating this directional effect, but that does not imply that these models correctly describe the physical processes at work.

A strategy for model validation, based on the inversion of bidirectional models against reflectance data has been developed. A physically-based model is truly validated if the values of the model parameters retrieved by inversion against reflectance data sets do in fact correspond to measured properties in the laboratory or in the field. This strategy has been described in the literature and successfully applied to the models previously developed by TEAM.

Genetic Algorithms

Optimisation methods are needed to implement this validation strategy. While standard mathematical algorithms do exist, they are based on iterative approaches which are often sensitive to the selection of initial guesses and the presence of local minima.

A new approach, combining the speed and local efficiency of traditional methods with the exploratory capability of Genetic Algorithms has been designed to overcome these deficiencies.

Collaborations

The scientific issues outlined above largely exceed the human and material capabilities of a single group or even institution, and their international character implies from the start the active participation of scientists from all parties concerned, if the results from these studies are to be used to support policies and management practices. While TEAM will assemble a core group of scientists with a wide range of backgrounds, much of the work will be performed in collaboration with other research groups, both within and outside of the JRC.

Active collaborations are currently in place with the Universite Blaise Pascal in Aubiere, France, the LERTS in Toulouse, France, the University of Michigan in Ann Arbor, Michigan, the NASA Goddard Space Flight Center in Greenbelt, Maryland, and the National Center for Atmospheric Research in Boulder, Colorado.

Members of TEAM are also participating in the design of data analysis algorithms to extract useful information from new satellite instruments such as ESA's MERIS in Europe and NASA's MODIS in the United States. A proposal for joint research is also being pursued with the ProClim programme of the Swiss Academy of Sciences. The work of TEAM will contribute directly to some of the priority research items of the IGBP.

Perspectives For 1993

Research will continue on the fundamental principles of remote sensing and their application to concrete issues. The exploitation of angular variations in the observed data as a source of information about the surface will be actively pursued through the development of coupled surface-atmosphere bidirectional reflectance models.

The recently developed GEMI will be applied to actual AVHRR data and its performance with respect to the estimation of biospheric parameters will be evaluated, both in absolute terms and relative to other existing indices.

The development of a new biosphere-atmosphere surface exchange model will be initiated. This effort will result in the definition of a third generation surface package which will be integrated in global atmospheric models but also function in stand-alone mode to address energy, water, and carbon fluxes between the surface and the atmosphere.

5.4 TROPICAL ECOSYSTEM ENVIRONMENT OBSERVATIONS BY SATELLITE (TREES)

(Hors Programme)

Summary of Objectives

- *Development of techniques for a global tropical forest inventory using AVHRR and ERS-1 as the main sources of data supplemented by high spatial resolution optical data (SPOT and Landsat)*
- *Development of techniques for the detection and monitoring of the active deforestation areas; measurement of deforestation rates in critical areas.*
- *Development of a comprehensive Tropical Forest Information System to support the modelling of tropical deforestation dynamics.*

1992 PROGRAMME OF WORK

Introduction

Monitoring change in the forests of the tropical belt presents a formidable yet vital challenge for remote sensing order to address this issue a special project, funded with financial resources outside of the framework programme, has been initiated entitled the TREES Project (Tropical Ecosystem Environment observation by Satellite).

The TREES project has been oriented towards the study of tropical forest dynamics at regional to global scales using remote sensing techniques. Data derived from both the National Oceanographic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) low spatial resolution instrument and the ESA ERS-1 synthetic aperture radar (SAR) instrument are considered in the TREES project. The optical and thermal channel imagery of the AVHRR instruments are used for regional scale mapping and condition-determination of tropical forests. Higher spatial resolution imagery from both the all weather SAR system on-board ERS-1 and optical systems on-board SPOT and Landsat have been used to verify the patterns observed, and the classifications derived from the AVHRR imagery.

AVHRR Data Analysis

The assembly of the data set necessary for conducting the TREES baseline analysis has remained an important activity of the TREES Project. In the absence of an organised network of satellite receiving stations, specific arrangements were made by the Project with selected stations around the tropical belt. The large volumes of data generated by those stations have been manually screened and assembled in series for analysis.

1992 Milestones

Feb.	Acquisition of the basic AVHRR data set for the year 1991 and 1992 over Continental and parts of insular Southeast Asia, West and Central Africa and Central/South America.
May	Analysis of AVHRR data sets leading to the production of validated vegetation maps over continental Southeast Asia, Sumatra and Central Africa.
June	Development of validation methods using high resolution data as means of calibrating low resolution AVHRR analysis.
Aug.	Establishment of the basis of a Tropical Forest Information System (TFIS) including the collection of an extensive vegetation related data base and analytical tools for interfacing with remote sensing data.
Sept.	Reception of the first sample of ERS-1 SAR data.
Oct.	Presentation of the ERS-1 Part of the TREES project in a Special Session during the 'First ERS-1 Symposium', Cannes.

Data preprocessing (geometric, radiometric rectification) has been carried out in-house.

Intensive analysis and classification for Continental Southeast Asia was essentially based upon changes in radiometric characteristics (visible, NIR and thermal channels) of the forest cover with the progress of the dry seasons. Evergreen and semi-seasonal formations were thus separated.

Over Central Africa, the spectral contrast between closed and degraded or open forest cover has been digitally enhanced to produce image documents which are manually analysed. Results are then digitised in the data base.

An intensive validation exercise was undertaken using sampled high resolution Thematic Mapper images distributed across the Southeast Asian Continent. A forest-non forest interface typology was used as a guide in the selection. Regression analysis between results provided by the satellite data at the AVHRR 1 km and the TM 30m resolution data were made. Results were transformed by correction coefficients, which were then applied to the forest area determined on AVHRR images. This exercise is proceeding throughout the tropical belt. It is supported by extensive field work by the JRC Staff and contractors.

A systematic comparison is being carried out between the AVHRR results and the WCMC (World Conservation Monitoring Union) maps and other documents derived from national surveys when available. Major difficulties have remained in comparing AVHRR classifications with other information sources. These problems have indicated the necessity to reexamine the problems of classification in the light of global vegetation surveys.

Intensive observation of the equatorial belt by the NOAA satellite has led in three years to the assembly of an almost adequate set of data; problems of cloud cover remain but it is believed that its negative impacts upon the objectives of the TREES Project can be overcome through a systematic observation approach (daily passes for several years).

The Tropical Forest Information System now contains more than global and regional data sets. This information is fully available to the analyst while conducting the AVHRR part of the forest classification.

ERS-1 Data Analysis

To date emphasis has been placed so far on the generation of a number of ERS-1 SAR data processing modules in the fields of 'data alignment', 'association and correlation' and 'identity fusion'. This has been

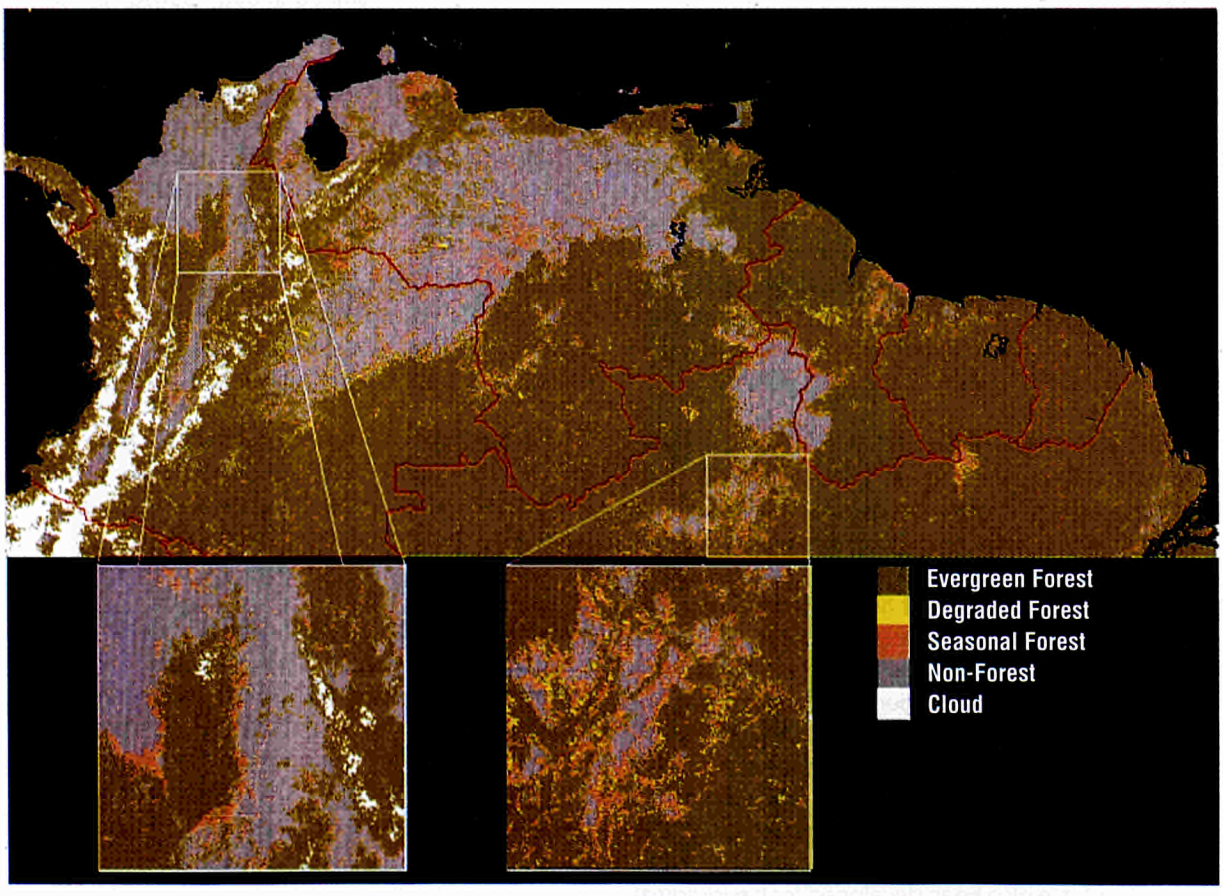


Fig. 5.6. Forest classification at 1 km resolution over northern part of South America

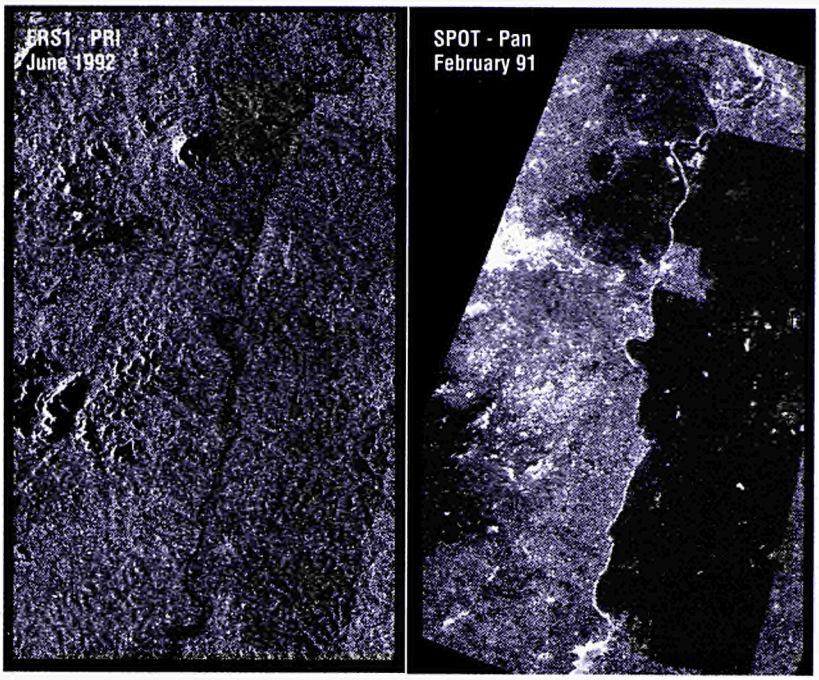


Fig. 5.7. Sassandra forest reserve, Ivory Coast: comparison between ERS-1 SAR imagery, June 1992 (left) and Spot panchromatic image, February 1991 (right)

undertaken in parallel with validation activities and feasibility studies on the JRC test sites for which ERS-1 SAR data was available.

One of the most underestimated steps in a data fusion environment is the validation of the input data. For ERS-1 SAR data extensive testing of several parameters such as the spatial coverage of the acquisition, the ancillary sensor - platform data associated with the signal data and the signal data were of great importance.

The coherent nature of the SAR imaging process introduces the well known 'speckle' effect in the SAR data. This reduces significantly the accuracy with which a correct estimate of the mean backscatter value over a SAR resolution cell can be obtained In order to begin to overcome this problem a filter has been developed that takes into account simultaneously a statistical speckle noise model, a statistical model for the scene reflectively and the number of independent looks. Moreover, the filter is spatially adaptive to preserve the textural characteristics of the SAR data. The filter operates on both detected and complex valued ERS-1 SAR data and is under continues revision and improvement.

Techniques have also been developed for the radiometric calibration of the ERS-1 SAR data. These follow different approaches depending upon the ERS-1 SAR data type used for analysis. The single-look complex, slant-range SAR data product (SLC), one of the main products used to date, demands a full calibration, including antenna pattern correction, range dependency correction and corrections (temporal gain offsets) at sensor and processor level in time.

In addition geolocation techniques have been developed in order that the data can be related to a geographical coordinate. This is of great importance, particularly in undulating or mountainous terrain. From the geolocated data 'geocoded' image data can be generated where to every grid value of a digital elevation model (DEM) a SAR pixel value is assigned through a resampling and mapping algorithm.

The lack of generally available topographic information such as a DEM, judged a prerequisite for the level 1 processing of the ERS-1 SAR data, initiated a research activity on on the generation of topographic information from ERS-1 data through techniques such as multi-path SAR interferometry . Results of this activity indicate the potential for using multi-path ERS-1 SAR to derive over certain stable areas (and with a number of restrictions regarding orbital characteristics and local topography) estimates of the projected slant-range pixel size.

Finally, the data fusion architecture implemented so far for the ERS-1 part of TREES supports several unsupervised clustering algorithms and supervised non-parametric classifiers which interact through a prototype interface with the user.

A first limited test has been carried out in order to evaluate some of the algorithms in the data fusion model over a test site in West Africa. The results demonstrate the importance of the geolocation of the data. Further tests are currently being undertaken on other parts of the tropical forest, including also an evaluation of a time series of ERS-1 SAR data.

Perspectives For 1993

During the last year of the Project, TREES will focus upon:

- the finalisation of the AVHRR analysis, including validation, over the three continents with priority to South America;
- the incorporation of "seasonality" information in the forest classification; this information will be chiefly derived from the analysis of time-series of AVHRR GAC data sets;
- the finalisation of the Tropical Forest Information System, with emphasis upon its analytical functions;
- the development of spatio-temporal models of deforestation;
- the preparation of TREES-II (1994-96), which will represent a big step towards the operationality of a tropical forest monitoring system;
- the development of techniques to achieve ERS-1 data volume reduction;
- the development of a flexible cataloguing, archiving, browse and retrieval system for use on wide-area networks;
- the implementation of a rigorous data validation system for the ERS-1 SAR data;
- the implementation of an automatic change detection technique based upon the derived feature vectors or directly on the time-series of input SAR data.

6 ADVANCED TECHNIQUES

Staff

Scientific and Technical Support	23
Secretarial Support	1
Scientific Visitors	–
Students	2
Total	26

Publications

Journal Papers	7
Conference Papers	29
JRC Reports	–
Books/Chapters	2
Total	38

Facilities

- Data processing facility based on SUN, incorporating in-house software for microwave data analysis
- Software tools including relational data bases and GIS
- Interim Signature Laboratory
- European Microwave Signature Laboratory (in construction)
- Plant physiology laboratory
- Radiometry laboratory
- Fluoroscence laboratory

The Advanced Techniques Unit faced a number of very important milestones in 1992:

- the preparation and implementation of a new programme on canopy chemistry and canopy structure by means of optical spectrometry, including experimental and theoretical methods. This new initiative followed on from the activities on laser induced fluorescence, which are to be finished by the end of 1992.

- the inauguration of the European Microwave Signature Laboratory (EMSL), its commissioning and its calibration phase. This included the successful proposal of this unique facility as Large Scale Installation in the "Human Capital and Mobility" programme of the Commission of the European Communities.

- the intensive work on the first set of ERS-1 SAR images over European and African test sites.

- the launch of the last key elements of the European Airborne Remote Sensing Capabilities (EARSEC) components, including the prototype SAR geophysical SAR processor and the contract for upgrading the EARSEC SAR sensor to a **two-frequency** fully polarimetric system.

These elements had all been approved by an international advisory committee at the end of 1988. With these steps the Advanced Techniques Unit finished the implementation phase of its work and started in the second half of the year its consolidation and operational phase.

1993 will centre around advanced uses of remote sensing techniques by integrating all available programme elements. Such activities will include:

- use of ERS-1 SAR signatures to support the monitoring of environmental damage to the North Sea;

- use of ERS-1 SAR information to set-up a forest signature catalogue, in close collaboration with an international team of expert groups;

- use of the forest signature catalogue for the monitoring of the deforestation in relevant regions and areas, such as the tropical belt;

- use of advanced methods (interferometric SAR data correlation) for the estimation of forest biomass over relevant areas in flat and mountainous regions;

- synergy of high resolution airborne multisensor data with spaceborne SAR data sets from ERS-1 and J-ERS-1 for improved information on ecological units at different scales. This will be complemented by the evaluation of the potential advanced optical spectrometer methods;

- use of the first geophysical radar signal processor for land applications.

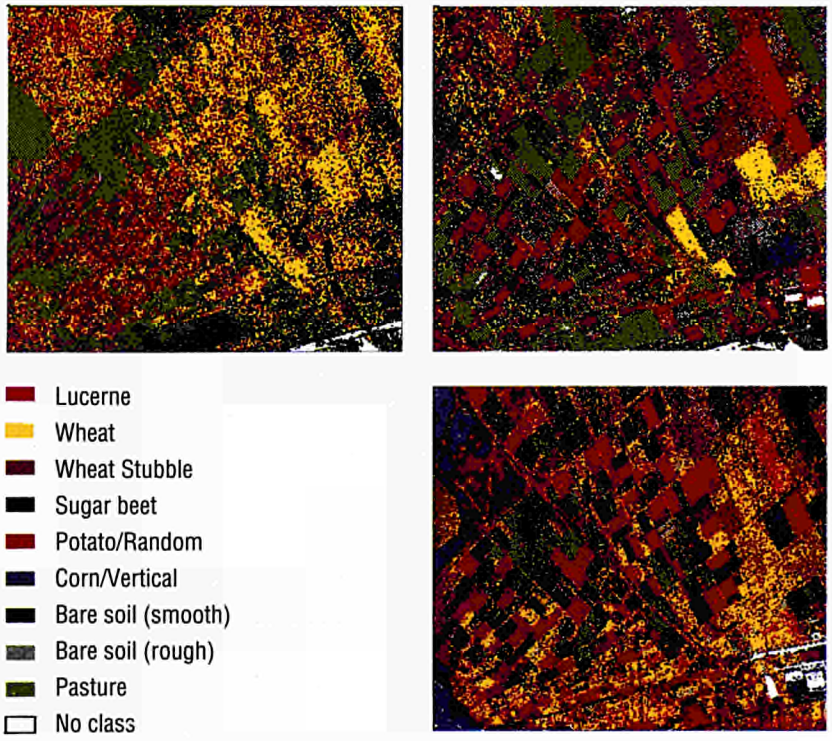


Fig. 6.1. Polarimetric contrast classification. Multi-frequency thematic mapping

6.1 SAR DATA ANALYSIS

(Specific Programme)

Summary of Objectives

Investigation of processing algorithms for polarimetric multifrequency SAR data.
Analysis of experimental polarimetric SAR data.
Development of software tools to support the analysis.
Preparation of the EARSEC data processing network.
Calibration of airborne and satellite borne radar data.
Analysis and interpretation of multitemporal and multisensor data.

1992 PROGRAMME OF WORK

Data Analysis

The main points of focus of the research in 1992 have been:

- application of the OPS (Optimum Polarisation State) theory to speckle reduction and the detection of geometric features in natural targets.
- characterisation of the polarimetric radar backscattered signal for a forested area, using modeling and experimental data, with an emphasis on the influence of terrain topography.
- experimental study of the performance of two fully polarimetric supervised classifiers, when applied to different classification scenarios.

With respect to the first objective an original algorithm for speckle reduction was developed and characterised experimentally using the MAESTRO 1 data set. The algorithm is in principle an estimator of the true reflectance through a combination of the 3 polarimetric channels. Since the weights in the non linear combination of the channels are changed from pixel to pixel according to some optimisation criterion, the process is called adaptive polarisation synthesis.

The algorithms was found to achieve a good reduction of the speckle strength, and to satisfactorally preserve point targets and linear features.

Also it was demonstrated how the statistical distribution of the OPS from a random target can be used to detect geometrical features; in particular the signature of the ploughing direction in agricultural fields was investigated.

For the characterisation of the polarimetric radar backscattered signal for a forested area a study was performed on the MAESTRO 1 airborne SAR data acquired over the German Black Forest. The data set was georeferenced and a digital elevation model overlaid in such a way as to have for each slant range pixel the local incidence angle and the terrain slope angle. Forest stands were defined from the available ground truth. Finally the polarimetric radar return (in the form of the polarimetric covariance matrix) was systematically characterised as a function of forest class and terrain slope angle. The experimental results were also compared with results from a multi layer forest model based on the radiative transfer theory and developed by the Wave Scattering Centre at the University of Texas Arlington.

An experiment to determine the canopy attenuation using a tone generator was performed during the MAC Europe campaign June overflight of the Freiburg test site. The experimental results will be compared with modeling and will be presented at the 1993 MAC Europe workshop.

1992 Milestones

Feb.	MAESTRO 1 Final workshop (4 contributions submitted)
Feb.	Start of the EARSEC SAR Sensor development
May	IGARSS 92 Conference (4 contributions presented on polarimetry)
June	JPL AIRSAR Workshop (preliminary results of the MAC Europe campaign)
July	First Scientific Summer in Ispra S²I EARSEC SAR Processor Call for Tender
Sept.	CEOS Calibration/Validation Workshop
Nov.	Launch of the first development phase of the EARSEC data processing network prototype
Nov.	First ERS-1 Symposium - Cannes
Dec.	Start of the EARSEC SAR Processor development

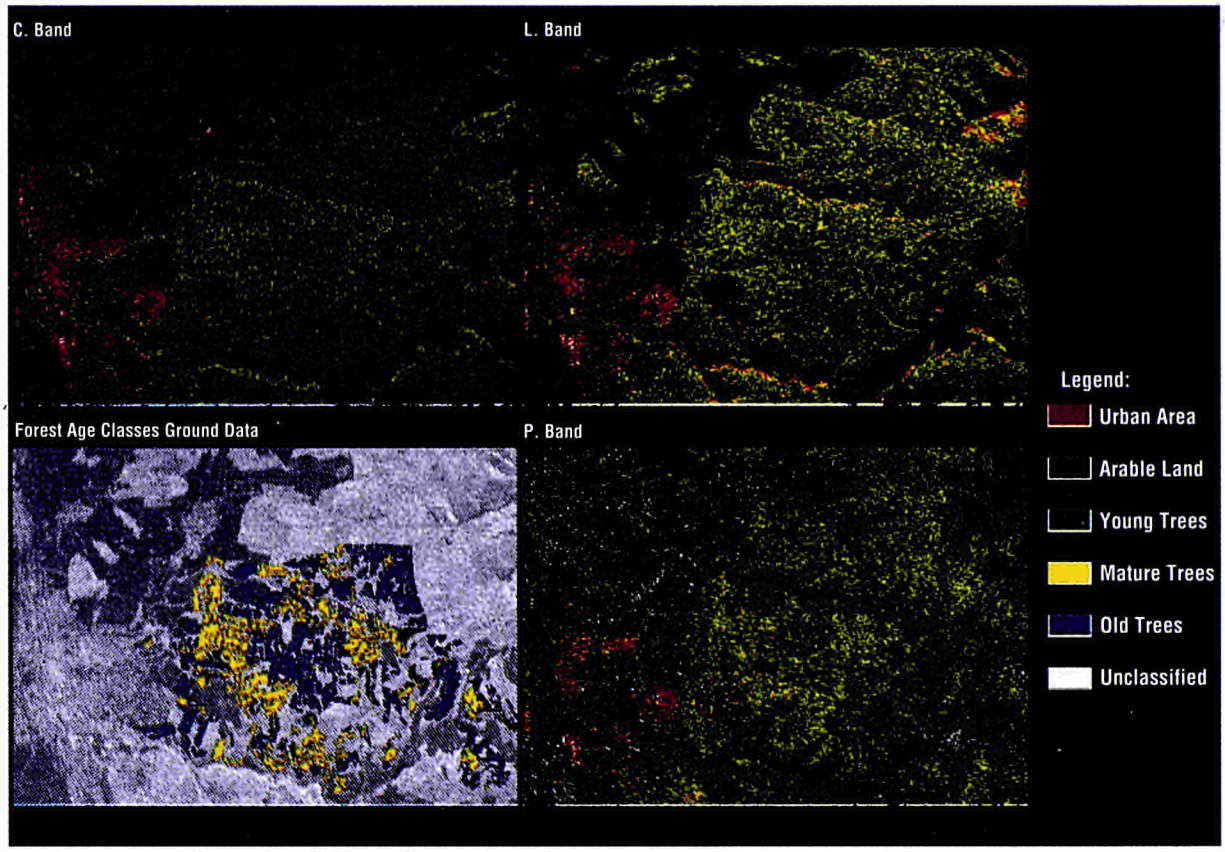


Fig. 6.2. Classification results of MAESTRO 1 multifrequency JPL-AIRSAR data

Finally a study was made on the application of polarimetric supervised classification techniques to the case of a forested area where the influence of topography is important. Two classification schemes were considered: one is of the classical Bayes type, the second one based on the concept of maximum contrast. The dependency of the classification accuracy on a number of parameters, such as calibration, feature vector dimensions and covariance matrix representation was studied. Also the influence of topography on classification was considered and a method suggested to improve the classification results using a priori knowledge of the terrain slope.

The results of the data analysis were consolidated via the first Scientific Summer organised by IRSA in July 1992.

The participants came from the following Universities:

- University of Freiburg (D)
- University of Hannover (D)
- University of Davis, CA (USA)
- University of Munich (D)

The data acquired over the Black Forest test site by optical and microwave sensors were analyzed to define the degree of complementarity and additionality of the information achievable by using multi-band sensors.

The ground data available for the area were also examined and compared with the information derived from the sensors.

The analysis of polarimetric radar data was primarily based on the study of Particular Polarization State (PPS) of the radiation back-scattered by the vegetation. Maps of polarization angles resulting in power and contrast extrema help in understanding the spatial distribution of the main branches in the forest.

This year was also the first year of ERS-1 SAR data availability. During the satellite Commissioning Phase the Black Forest test site was continuously surveyed, allowing the monitoring of the temporal evolution of the forest radar backscattering over a four month period. Results of this analysis were presented at the First ERS-1

Workshop organized by ESA and held in Cannes in November.

Software development

The polarimetric data analysis software (POLTOOL) was consolidated in release 7, with the addition of several features, such as a polygon and chip processor, and an interface to PV-WAVE (a commercially available software package for data visualisation).

A better documentation set has also been produced.

Finally a user's workshop was organised in Ispra on June 92.

Calibration and validation of airborne and satelliteborne radar data

1992 has been devoted to the calibration and validation of data sets acquired during airborne campaigns (i.e. MAC-EUROPE 91 and MAESTRO 1989) and satellite borne surveys (i.e. ERS-1).

The collaboration with international institutions such as the European Space Agency is continues to contribute to the achievement of high quality for the SAR data products distributed by the European Processing and Archiving Facilities.

The results achieved by IRSA in polarimetric and radiometric calibration were presented at the CEOS SAR Calibration Workshop held in Ottawa (Canada) in September 1992 and at the First ERS-1 Workshop held in Cannes in November.

European Airborne Remote Sensing Capability (EARSEC) SAR

During 1992 the actual development phase of the EARSEC programme started.

In February 1992, IRSA signed a contract with a European Economic Interest Group (EEIG), EARSEF (European Airborne Remote Sensing Facility) for the improvement of an existing SAR sensor to a fully polarimetric, dual frequency SAR The sensor is unique in Europe.

After a definition of the sensor parameters, in July 1992, a call for tender was distributed to the major institutes and companies for the development of a prototype for SAR data processing. Such a prototype is to be developed as a reference processor for polarimetric SAR with unique phase preserving features.

In December 1992 IRSA signed a contract for the development of such a processing system.

The concept of a multi member data processing network for the EARSEC sensors, comprising several steps of processing, from raw data to the end user's product, was formulated. Within this broad scenario, several prototypes that will pave the way to the final system are under study. In particular as far as the SAR sensor is concerned, specifications were laid down and a contract launched for the first phase in the implementation of a prototype geophysical processor; the first phase will include the correlator, calibration and georeferencing.

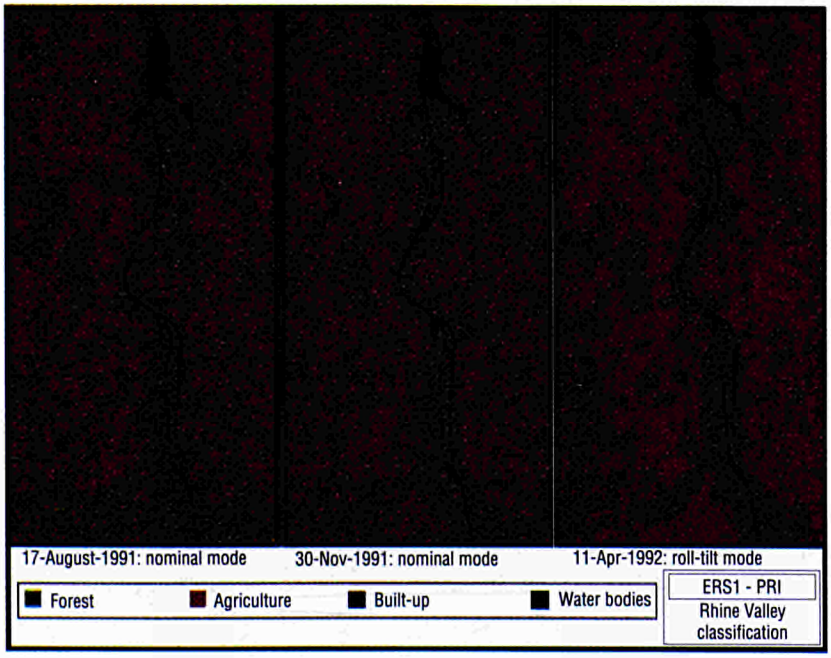


Fig. 6.3. Segmentation results on nominal mode and roll-tilt mode ERS-1 SAR images, illustrating how roll-tilt mode enhances radiometric separability of land use classes

Perspectives For 1993

Polarimetric Data Analysis

A project for multi-temporal data analysis, based on the MAC Europe data, is foreseen. Multi-temporal SAR remote sensing data provide potential means to monitor the evolution of geophysical parameters of natural targets (e.g. soil moisture content, above ground biomass, frozen/thaw state) caused by meteorological and phenological cycles. Moreover since more information on the structural and dielectric properties of the scatterers can be inferred, they can also augment the separability of different types of natural targets. The project is aimed at investigating techniques, and proving them experimentally, to exploit the above mentioned capability.

An important topic to be addressed will be the characterisation of the spatial statistics. Spatial statistic of distributed target in SAR data is complicated by the fact that the intrinsic variability of the target is modulated by the coherent impulse response of the radar system. Suitable models and assumptions must be worked out to be able to make an estimate of the accuracy of the textural parameters (variance and autocorrelation of texture).

EARSEC data processing network

The first phase of the geophysical processor will be completed with the installation and test of the prototype. Specifications lay out and procurement of the second phase will be made. In this phase the prototype will be augmented by several post processing steps, which are necessary for the derivation of a number of geophysical parameters from the SAR data.

6.2 EUROPEAN MICROWAVE SIGNATURE LABORATORY (EMSL)

(Specific Programme)

Summary of Objectives

- *To develop, calibrate and operate an experimental facility with performances unique both in terms of measurement hardware and data processing tools and to make it available to research and industrial users at a world-wide level.*
- *To undertake polarimetric radar measurements on natural and man made targets aimed to complement air- and spaceborne experiments by providing stable and reproducible environmental conditions and flexible measurement modes for well controlled experiments.*
- *To identify dominant scatterers and characterise them as a function of measurement parameters for different classes of targets.*
- *To validate scattering models by comparing theoretical results with experimental data.*
- *To perform measurements dedicated to industrial applications for the determination of material properties, characterisation of antennae and EMC testing.*

1992 PROGRAMME OF WORK

The EMSL Facility

The construction of the EMSL, including preliminary tests on the proper functioning of the facility, was completed in March and the official inauguration took place on 13 April. After this, the commissioning phase has started consisting of a series of systematic tests on the individual electro-mechanical components, on the radar measurement system and on the control software in order to verify the operation according to the specifications. As a result of this phase the Provisional Acceptance Certificate has been released to the contractor and the facility was handed-over to IRSA.

In August a comprehensive programme of test measurements aimed at fully characterising the measurement system of the laboratory was undertaken.
The main test series concerned the following:

- Stability performances: the various potential influences on the microwave instrumentation have been investigated. This included the effects of ambient temperature variations, instrumentation warm-up, long term stability of the measurement chain as well as repeatibility with respect to mechanical movements of the sleds carrying the sensors. The overall results are satisfactory and the measurement system works as expected according to the specifications.

- Dome antennae system: the correct functioning of the network of the antennae installed on the hemispherical dome of the EMSL has been checked. All the hardware connections and related software drivers have been verified by using testing procedures specifically designed for the EMSL characteristics. In addition, for each antenna the signal propagation time and the direct coupling with the transmitting antennae has been measured and recorded. The acquired data will be used to establish the most appropriate procedure for the data calibration.

- Quiet zone of the anechoic chamber: the extension of the "quiet zone" of the chamber, that is the volume around the measurement focus free from multiple echos, has been investigated. Test measurements were made using a metallic sphere as a probe placed in a regular test grid of points surrounding the focus of the chamber.

1992 Milestones

March	Completion of the construction phase
April	Official inauguration of the EMSL.
May-June	Commissioning phase for the electro-mechanical components and the measurement system.
Aug.-Sept.	Test Series for the evaluation of the stability of the overall system.
October	First calibrated measurements on natural targets.
November	Test Series for the characterisation of the Dome Antennae System.
December	Start of the measurements for the characterisation of the quiet zone of the anechoic chamber.
	Recognition of the EMSL as an European Large Scale Installation, in the frame of the CEC programme Human Capital & Mobility

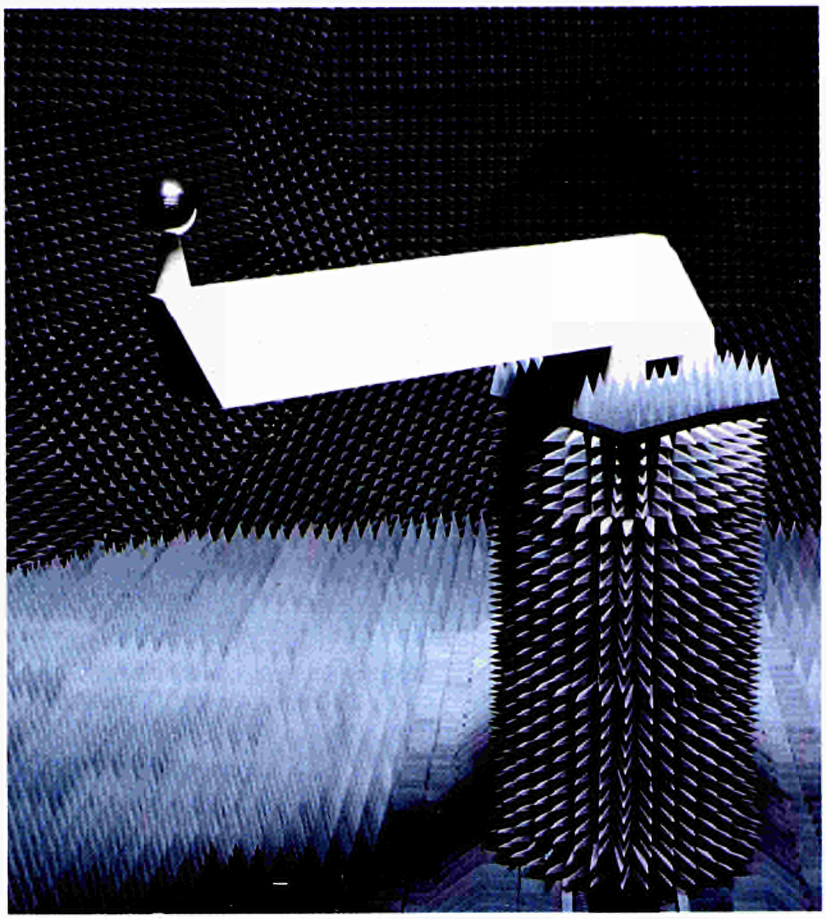


Fig. 6.4. Verification of the "Quiet Zone" of the EMSL using a metallic sphere as a probe mounted on a rotating arm

Measurement Of Natural Targets

Preliminary measurements have been undertaken on a crop sample of wheat in order to verify operational aspects such as loading/unloading of the samples, target holder adaptation etc.

Calibrated measurements have also been undertaken on a crop sample (1 m^2) of maize. The measurements include polarimetric back- and forward scattering at different incidence angle. The main objective of this experiment was the assessment of the effect of the canopy structure on the phase of the radiation propagating into the canopy.

Collaboration With External Institutes

In April an Announcement of Opportunity was launched inviting national and international institutes to submit research proposals related to the experimental capabilities of EMSL. A total number of more than 20 proposals have been received from research institutes all over Europe and USA. The proposed experiments range from the characterisation of active and passive radar calibrators, to the validation of scattering models, up to the investigation of new bistatic calibration techniques.

These documents will be screened in early 1993 by an International Advisory Committee, together with the experiments proposed internally by different research groups in IRSA, in order to prepare a coherent measurement plan for the EMSL.

The EMSL has also been accepted by the Commission of the European Community as European Large Scale Facility. This status allows the employment of additional personnel in the frame of the Human Capital and Mobility Programme. It opens additional perspectives of scientific collaboration with external research groups.

Study Contracts

During 1992 three study contracts have been placed in relation to the activity of the EMSL.

The first contract, placed with the University of Karlsruhe, refers to the development of a software package for the calibration, processing and analysis of the data acquired in the EMSL. The package will provide a user-friendly interface to different software modules already developed at IRSA and it is especially designed for an interactive analysis and visualisation of the measured data. The completion of the work is foreseen for the beginning of 1993.

The second, placed with the company Ingegneria dei Sistemi - Pisa, deals with the numerical simulation of the bistatic response of a metallic wire mesh. This kind of

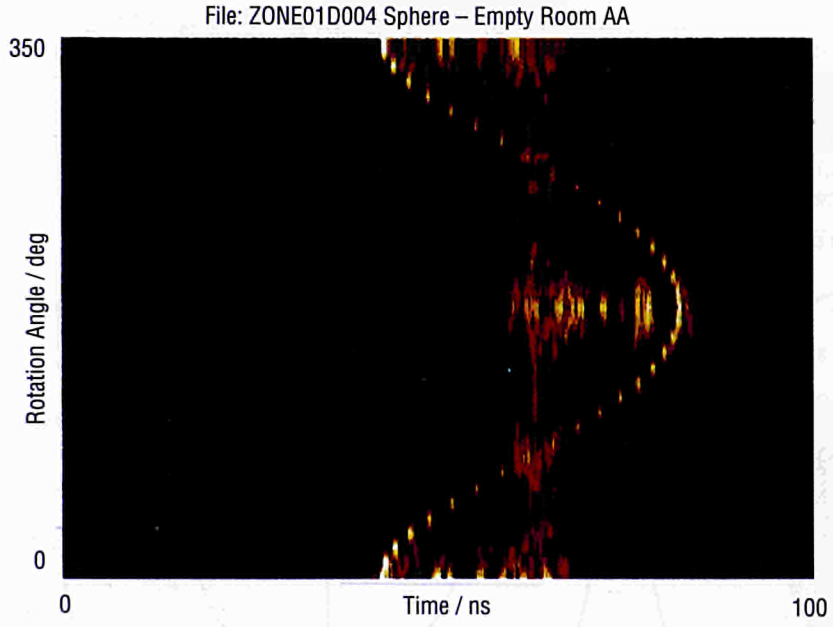


Fig. 6.5. Measured response (Raw Data) of the metallic sphere (photo) as a function of travelling time for different positions along a circle surrounding the centre of the measurement chamber

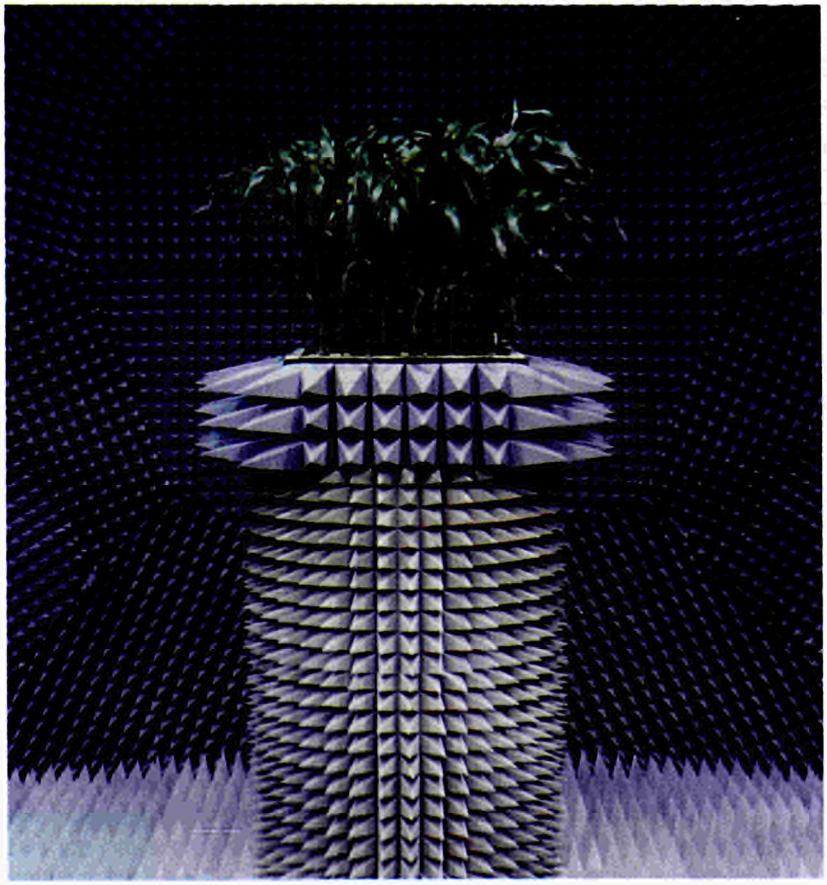


Fig. 6.6. A crop sample (1 m^2) of maize mounted on the target positioner in the anechoic chamber ready for the measurements

object has polarisation characteristics which make it suitable for bistatic polarimetric calibration of the EMSL measurement system. The conclusions of the study show that this application is feasible, but further investigation is needed.

The third, placed with the company Syrea - Milano, is for the development of a software package for the implementation of the EMSL Monitoring System. This system collects information from different sources in order to give to the operator a complete representation on a monitoring screen of the different control and environmental parameters concerning the laboratory.

Perspectives For 1993

In 1993, after the completion of the last characterisation tests, the EMSL will be ready to start the operational activity. A detailed measurement plan will be prepared at the beginning of the year on the basis of the proposals accepted by the International Advisory Committee and of the priorities dictated by the optimum utilisation of the laboratory capabilities.

An upgrading of the measurement system is foreseen in 1993 by the replacement of some key components with more advanced units in order to improve the laboratory performances in terms of system sensitivity and measurement speed. The replaced old equipment will be usedto setup a small system dedicated to the measurement of the dielectric characteristics of natural and artificial materials and to the characterisation of microwave components

such as antennae, cables and amplifiers.
From a preliminary evaluation of the experiment proposals, a tight schedule is expected for 1993 for preparing the experiments, undertaking the measurements and analysing the acquired data. A close collaboration with external research groups will be established, this will include work in the frame of the Human Capital and Mobility Programme.

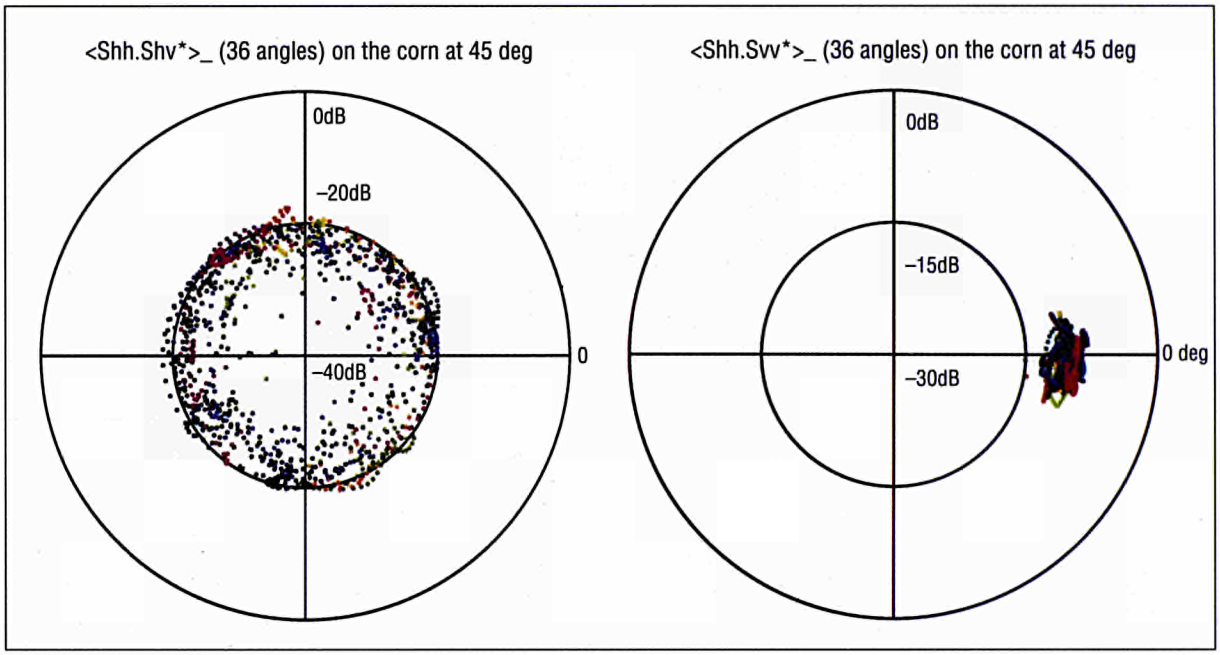


Fig. 6.7. Measured backscattering data on a maize sample (photo) represented in amplitude (dB scale) and phase. The colours correspond to different frequencies in the band 4-10 GH_z. The clustering of the left plot shows the high correlation between the copolar channels (HH and VV)

6.3 ADVANCED SPECTROMETRY
(Specific Programme)

Summary of Objectives

- *Evaluation of the use of high resolution spectroscopy for a detailed analysis of ecosystem status.*
- *Assessment of the use of spectral signatures to evaluate the content of chlorophyll, water and other biochemical components such as lignin, cellulose, nitrogen, and proteins in vegetation.*
- *Specific evaluation of the usefulness of complementary information from directional measurements to estimate canopy structure and the biochemical components of vegetation.*

1992 PROGRAMME OF WORK

Introduction

The 1992 programme concentrated on:

- Laboratory reflectance measurements on leaves/needles to study the influence of the water content on the spectra.
- Development and/or improvement of models to describe the leaf reflectance.
- First analysis of HSR- data from the EARSEC and AVIRIS -MAC EUROPE campaign 1991.
- Preparation and execution of the Scientific Summer workshop S^2 I.

The work undertaken in each of these is summarised below.

1992 Milestones

Jan.- March	Definition of the new programme on: Spectroscopy for the Estimation of Canopy Structure and Biochemical Components of Vegetation".
April - June	Installation of laboratories for spectral signature analysis and design of the Goniometric Facility.
July	Scientific Summer Workshop S^2 I
September	Laboratory studies at leaf level to support the modelling activities.

Water Content And Reflectance Measurements

First measurements were performed on vegetation samples such as leaves and spruce needles in the laboratory. An experiment is being carried out on the spectral behaviour of spruce needles during their annual phenological cycle, which should give indications regarding the potential of high resolution spectral measurements to follow growth patterns of vegetation by means of a precise evaluation of its spectral components.

The effect of the water content of these samples was studied by drying the samples in an oven and repeating the measurements. The objective of this exercise is to provide an extensive data set to test and validate the methods for the estimation of the water content from the characteristic absorption features in the infrared. The investigations carried out so far indicate that there are several ways of retrieving optical parameters which are related to the water content but their exact meaning (in terms of relative water content,equivalent water thickness) and their robustness when applied to different types of vegetation has still to be established.

Modelling Of Leaf Reflectance

A model describing the canopy spectral reflectance has been implemented . It is built on the basis of the PROSPECT model (leaf reflectance), coupled to the models SOILSPEC (soil reflectance) and to SAIL (canopy structure). These models have been modified to run on IRSA systems, and to be usable with IRSA software (in particular with various inversion routines).

In parallel, radiative calculations aimed at describing the reflectance of single and stacked leaves and including the biochemical components, have been tested.

Imaging Spectrometer Data Analysis Relating To Biochemistry

Multitemporal AVIRIS data -sets of the Black Forest test site and of the Rhine valley region were analysed to test

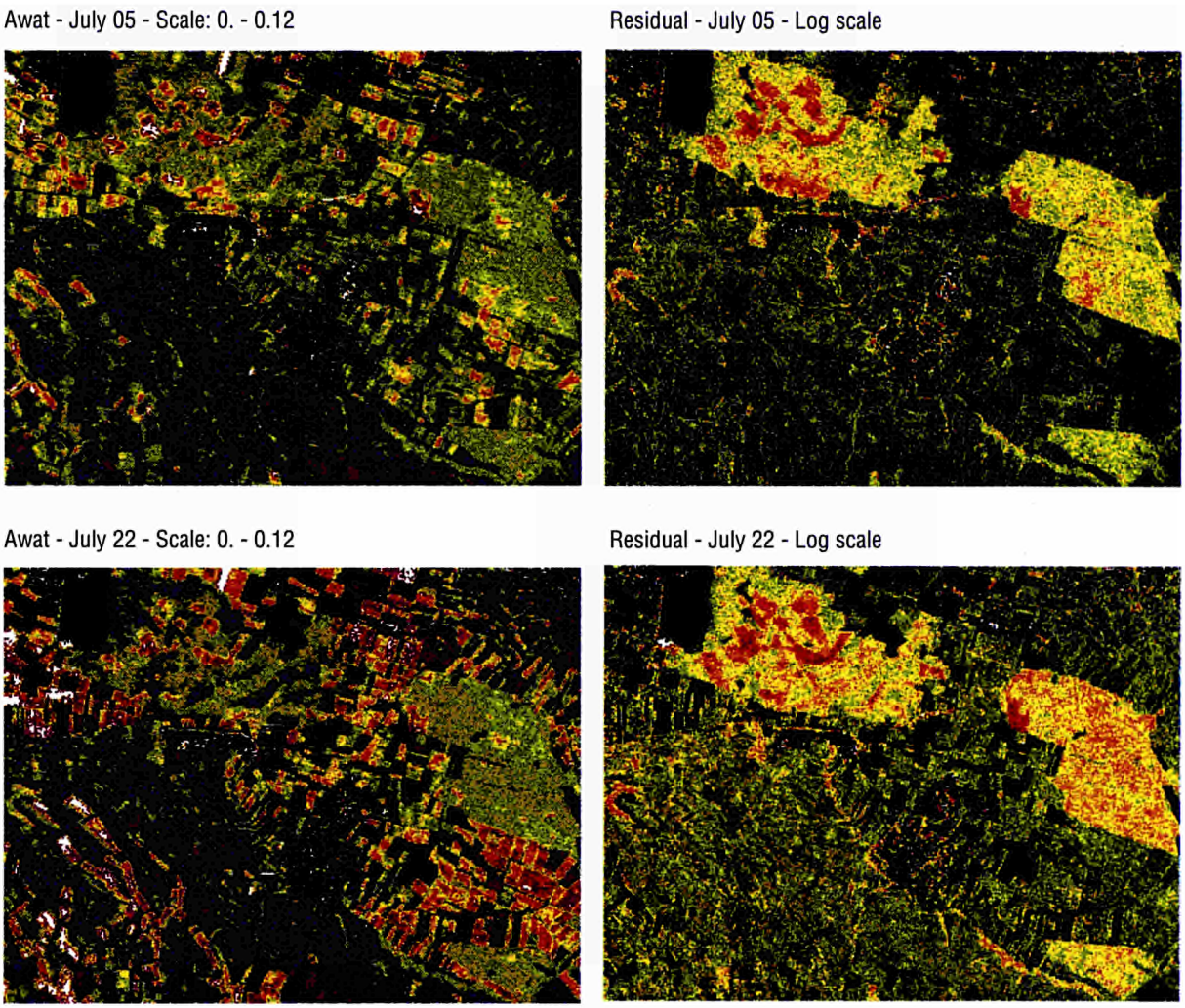


Fig. 6.8. The water parameter together with the 1.7 µm residual, represented over a fraction of the Freiburg test site for the 5th and 22nd of July (data source: MACEUROPE 1991, AVIRIS - data)

the current hypothesis that high spectral resolution allows the detection of biochemical components of vegetation canopies. The multitemporal images of AVIRIS data were acquired on July 5th, July 22nd and July 29th, in the frame of the EARSEC and MAC-EUROPE 1991 campaigns.

The biochemical indices of the Black Forest test site were found to be very stable from the first to the third overflight. Temporal differences exist in the equivalent water thickness, which is due to different meteorological conditions between the overflights.

Of major interest are three well documented plots within these test sites, of which two have been fertilised with ammonium sulphate of different concentration for the last three years. According to our analysis, effects of fertilisation were not detected from the biochemical indices.

On the contrary, the analysis of the AVIRIS-data of the agricultural units in the Rhine Valley show temporal changes in the indices for water and biochemistry, explained by seasonal changes of vegetation, by human impact and by relatively heavy precipitation events between the three overflights.

Scientific Summer At Ispra S^2 I

The overall objective of the summer workshop S^2 I was to build a multidisciplinary working group of scientists to

evaluate the complex datasets of optical and microwave data collected over the Black Forest test site.

The radiometrically calibrated optical data were first corrected for atmospheric effects, using an empirical method for the GER II data and the Atmospheric Removal Procedure for the AVIRIS data. The radar images were calibrated and georeferenced. Various vegetation indices were then produced. According to literature, these indices are sensitive to a variety of canopy characteristics such as biomass (leafy and woody), water content and tree growth stage (structure, damage). The retrieved indices were correlated with the available ground information on these variables and their performance was assessed for this particular test site.

As some of these indices are also supposed to measure the same parameters, they were cross-compared. In particular the compatibility and respective sensitivities of NDVI, GEMI and radar backscatter power were examined for biomass estimation. In the same way, the MSI and equivalent water thickness were compared as indicators of the canopy water content. These optical indices were also related to particular polarimetric states of the radar images in an attempt to understand the influence of water content (therefore of the dielectric constant) in the matter/radiation interaction.

Prospectives for 1993

The objectives for 1993 are:

- Spectral measurements of pure biochemical components using a high precision spectrophotomer to contribute to establishing reliable specific absorption curves to be included in the models.

- Spectral measurements on selected leaves and other plant material, whose biochemical components have been quantified by the Environmental Institute. These data will be used to test the models.

- Production of experimental data sets on small canopies in the laboratory, using a moderate size goniometric facility which is presently being constructed. These data will include simultaneously the directional and high resolution spectral information simultaneously. These measurements will be useful for the assessment of the structural effects on the canopy spectrum.

- Preparation and execution of a campaign over the BEMA-test site (Environmental Institute) to collect airborne, and ground based, high spectral resolution data over natural canopies.

6.4 LIDAR FLUOROSENSING

(Specific Programme)

Summary of Objectives

Completion of the development of a time-resolved LIDAR (TRLF) to monitor the marine environment, with the purpose of:

- *identifying the type of oil present in a slick on the sea surface*
- *characterising the sea water with respect to its optical attenuation coefficient and its suspended matter content, dissolved organic matter and phytoplankton.*

1992 PROGRAMME OF WORK

Introduction

The analysis of the data collected in the last campaign (Gulf of Trieste), demonstrate that the application of the high temporal resolution to the characterisation of the water column permits the discrimination of superficial stratifications in the water body.

With respect to oil identification a laboratory study proved that after three days of weathering at sea it is still possible to classify the oil into 3 classes (light to heavy).

The Airborne Time Resolved Lidar Fluorosensor

Campaigns were made in the Gulf of Trieste in December 1991. The data analysis, which started in January this year, pointed out some peculiar characteristics of the time resolved system.

During a flight in an industrial harbour (Monfalcone), performed at low speed (10 knots) corresponding to a distance of 2.6 m between two consecutive shots all the signals were recorded and the full analysis was possible. For part of the flight line backscattering and Raman diffusion signals were found clearly showing a fast superficial response followed by a slower decay. This effect can be explained by a superficial stratification of the water body.

Status Of The Instrument

Due to bad storing conditions (the temperature decreased to -5° c) the TRLF was seriously damaged. To allow the campaign in the Gulf of Trieste a fast revision was made changing the damaged parts with spare ones and with components of the laboratory system.

1992 Milestones

Jan.-Feb.	Analysis of the data gathered during the measurment campaign in the Gulf of Trieste
Jan.-March	Repair of the TRLF damaged before and during the last campaign
May	Preparation of a complete series of laboratory measurements of the weathering effect on oil
June	Improvement in the optical gain of the streak camera to make possible field measurements of chlorophyll with a 532 nm laser output
September	Improvement of the instrument for in-field switching of the exitation wavelength (355-532 nm).
	Preparation of the instrument for a campaign at sea and on the lake.
October	Start of the system components analysis towards an industrialised version
November	Organisation of simulation measurements in Ispra as substitution for the cancelled test campaign, to determine the capability of the TRLF to remotely identifying algae.

Returning from the campaign a complete revision of the TRLF started resulting in a fully operational system by the end of April.

Systematic tests were performed with the artificial water column (facility), measuring the system response and the optical efficiency.

A new intensifier with high gain was ordered and mounted in the streak camera in order to make possible the measurements of algae with the 532 nm exitation wavelength.

A series of tests were made in the facility and by

analysing the intensity of the Raman diffusion signal return, the sensitivity of the instrument to detect chlorophyll was estimated in 1 µg/l.

A number of improvements have been brought to the instrument in order to facilitate the switching of the exitation wavelength from 355 to 532nm, and the positioning of the filters at the streak camera input.

Laboratory Studies

A study to evaluate the effects of the weathering on the fluorescence properties, and by consequence on the fingerprinting possibilities , was undertaken.
A specialised institute the "Stazione Sperimentale dei Combustibili in S. Donato - Milano" has provided samples of three oils: zarzaitine (light), Arabian Medium (medium) and Arabian Heavy (heavy).

Each oil was analysed in three samples: fresh and weathered through a procedure reproducing the effect of one and three days at sea. The fluorescence measurements performed show that the three days weathering produces a slight shift of the emission spectrum towards the longer wavelengths and a decrease of about 10% in the decay times.It clearly results that such changes do not endanger the classification of oils into three classes that is the realistic objective of remote oil fingerprinting.

Perspectives For 1993

1993 will see the conclusion of the Third Party Work contract with Agusta s.r.l..

1993 will also see the production of the final report on the work executed in the frame of the contract and the results obtained.

7 ANNEXES

7.1 ADVISORY COMMITTEE OF THE INSTITUTE FOR REMOTE SENSING APPLICATIONS

The Institute for Remote Sensing Applications has an Advisory Committee, the objective of which is to provide the Institute Director with advice and expertise in scientific and technical matters relevant to the work of the Institute. In addition it is the role of the Committee to ensure that the work of the Institute is geared to the real requirements of its customers and users, and that a high scientific standard is maintained within the Institute.

To this end the Institute Advisory Committee has a number of particular concerns:

- to evaluate progress of on-going scientific work in the Institute and proposals for new tasks and projects;
- to ensure exploitation of existing facilities and to evaluate proposals for important new scientific equipment and installations;
- to examine market relations and new opportunities for the Institute;
- to evaluate associations between the Institute and laboratories in Member States;
- to examine the 'valorisation' opportunities for the results of the research;
- to advice the Institute Director on the selection of grant holders and visiting scientists.

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7.4 GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ADP	Application Demonstration Programme (of OCEAN)
AIRSAR	Airborne SAR flown by JPL
AIS	Agricultural Information Systems Unit of IRSA
ARC	Active Radar Calibrator
AMOR	Atlantic Measurement of Oceanic Radiation (sea truth campaigns 1991 and 1992)
AO	Announcement of Opportunity
AT	Advanced Techniques Unit of IRSA
ATSR	Along Track Scanning Radiometer (a sensor on ERS-1)
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Advanced Visible Infra-Red Imaging Spectrometer
BDRF	Bi-Directional Reflectance Factor
BIO	Bedford Institute of Oceanography Canada
CAP	Common Agricultural Policy
CASI	Compact Airborne Spectral Imager
CCT	Computer Compatible Tape
CEC	Commission of the European Communities
CI	Coordinating Investigator
CILSS	Comité Permanent Inter-Etats de la Lutte contre la Secheresse au Sahel
CORINE	Coordination of Information on the Environments
CPS	Characteristic Polarisation State
CZCS	Coastal Zone Colour Scanner
DG	Directorate General (of the European Community)
DMS	Dimethlsulphide
DTM	Digital Terrain Model
EARSEC	European Airborne Remote Sensing Capability
EARSeL	European Association of Remote Sensing Laboratories
ECMWF	European Centre for Medium Range Weather Forecasting
ECU	European Currency Unit
EDF	European Development Fund
EEIG	European Economic Interest Group
EISAC	European Imaging Spectrometer Airborne Campaign
EMAP	Environmental Mapping and Modelling Unit of IRSA
EMSL	European Microwave Signature Laboratory
EPO	Earthnet Project Office (of ESA)
ERDAS	Earth Resources Digital Analysis System
ERS-1	European Remote Sensing satellite number 1
ESA	European Space Agency
ESRIN	European Space Research Institute (of ESA)
EURACS	European Radar Cross Section data base
Eurostat	European Statistical Office
FAO	Food and Agriculture Organisation (of the United Nations)
FI	Fire Index
FLI	Fluoroscence Line Imager
FOV	Field Of View
GAC	Global Area Coverage (of AVHRR data)
GCP	Ground Control Point
GEMI	Global Environmental Monitoring Index
GER	Geophysical Environmental Research Cooporation
GERIS	Geophysical Environmental Research Imaging Spectrometer
GIS	Geographical Information System
GSFC	Goddard Space Flight Center (a NASA centre)
HIRIS	High Resolution Imaging Spectrometer
HRIS	High Resolution Imaging Spectrometer
HRPT	High Resolution Picture Transmission (of AVHRR)
HVR	High Visible Resolution (sensor on SPOT)
ICSU	International Council of Scientific Unions
IFI	International Forest Investigation
IGARSS	International Geoscience and Remote Sensing Symposium
IGBP	International Geosphere-Biosphere Programme
IML	Interim Microwave Laboratory
INPE	Istituto Nacional Pesquicias Espacias (Brazil)
IRSA	Institute for Remote Sensing Applications
ISEI	Institute for Systems Engineering and Informatics
ISY	International Space Year
JERS-1	Japanese Earth Resources Satellite number 1
JGOFS	Joint Global Ocean Flux Study
JPL	Jet Propulsion Laboratory
JRC	Joint Research Centre
LAC	Local Area Coverage (of AVHRR)
LVQ	Learning Vector Quantisation
MAC-Europe	Multiple Airborne Campaign (Europe)

MAESTRO 1	Multiple Airborne Experiments Towards Radar Observations - campaign number 1
MARS	Monitoring Agriculture with Remote Sensing
ME	Marine Environment Unit of IRSA
MERIS	Medium Resolution Imaging Spectrometer
MLP	Multi-Layer Perceptron
MSS	Multi-Spectral Scanner (on the Landsat Satellite)
MTV	Monitoring Tropical Vegetation Unit of IRSA
NASA	National Aeronautical and Space Administration
NDVI	Normalised Difference Vegetation Index
NIR	Near Infrared part of the electro-magnetic spectrum
OBR	Optimal Band Reflectance
NOAA	National Oceanographic and Atmospheric Administration
OCEAN	Ocean Colour European Archive Network
OCTOPUS	Ocean Colour Techniques for Observation, Processing and Utilisation Systems
OPS	Optimum Polarisation State
PC	Personal Computer
PGO	Productivity of the Global Ocean
PI	Principle Investigator
POC	Particulate Organic Carbon
POLTOOL	Polarimetric data analysis Tool
RCS	Radar Cross Section
SAFISY	Space Agency Forum of the International Space Year
SAR	Synthetic Aperture Radar
SCAN	System for Condition Assessment using NOAA data
SEAS	SeaWifs Environmental Algorithm Set
SEADIS	SeaWifs Environmental and Data Information System
SeaWifs	Sea-viewing Wide Field of View Sensor
SGEOS	Second Generation Earth Observation Satellites
SIR-C	Shuttle Imaging Radar C
SNR	Signal to Noise Ratio
SPACE	Software for Pre-processing AVHRR data for the Communities of Europe
SPOT	Systeme Probatoire pour l'Observation de la Terre
SST	Sea Surface Temperature
SWIR	Short Wave Infrared part of the electro-magnetic spectrum
TM	Thematic Mapper (on the Landsat Satellite)
TREES	Tropical Ecosystem Environment Observations by Satellites
TRLF	Time Resolved Lidar Fluorosensor
UV	Ultra-Violet part of the electro-magnetic spectrum
VIS	Visible part of the electro-magnetic spectrum
WCRP	World Climate Research Programme
WFW	World Forest Watch (Pilot Project of ISY)
WMO	World Meteorological Organisation
WOCE	World Ocean Circulation Experiment

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Policy decision makers need an understanding of where new developments may lead, the mechanism of adjustment processes and the potential impact of different policy options.

The public must be aware of the potential impacts of changes as a result of either man's intervention or natural occurrences and policy decision makers are under scrutiny from the general public.

Space data can provide such information for specific aspects of human activity and Europe has invested heavily in earth observing satellites through national Space Agencies and the European Space Agency (ESA).

In order to create useful information from those data, methods and models have to be developed, verified and evaluated.

The first objective of the Institute for Remote Sensing Applications is to evaluate and demonstrate possible applications of remote sensing in support of the sectorial policies of the Commission of the European Communities (CEC) thus playing a complementary role of ESA. This is actively done in support to the Directorate General Agriculture (VI), Development Aid (VIII), Environment (XI) and External Affairs (I).

These ongoing developments have already led to an operational use of space data specially in the agricultural sector.

In order to support such applications more fundamental research is needed in the understanding and utilisation of such data. To stimulate future development in Earth observation systems, advanced sensors have to be tested either in laboratories or simulation flights.

The Institute for Remote Sensing Applications through its applications projects and supporting research is becoming a focal point in Europe for the stimulation of policy makers as well as scientists in the use of space earth observing systems.