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Institute FOR Remote Sensing Applications

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1 EXECUTIVE SUMMARY

Staff

Scientific and Technical Support:	74
Administrative Support:	7
Secretarial Support:	9
Scientific Visitors:	13
Students:	46
Total:	149

The Institute for Remote Sensing Applications' (IRSA) objective is to develop techniques for derivation of relevant, timely and accurate information on the state and evolution of Earth surface characteristics from satellite observations. The biosphere, lithosphere, atmosphere and hydrosphere are all considered in this context, with work ranging from fundamental research to the operational use of remote sensing.

Fulfilling this objective involves

- supporting the sectorial policies of the European Union in areas such as agriculture, environment, aid to development and regional aid,
- supporting the European scientific and applications communities in the utilisation of Earth observation satellite data, {complementing the objectives of ESA, other European and national space agencies, international scientific programmes and those of other institutions},
- and research and support into the development of methods and advanced techniques for the interpretation and application of satellite derived data.

The Institute's work is spread over four domains. These are

- Institutional Research, the Specific Programme (where research themes, defined and approved by the European Union's Member States via the Joint Research Centre's Governing Board are addressed),
- Institutional Support (where IRSA provides scientific and technical support to the sectorial policies of the Commission. This involves research on behalf of various Directorates General (DG) where the objectives are specifically set by the DGs),
- Exploratory Research (this is a percentage of the Specific Programme funds which IRSA staff use to explore research themes which show promise for future applications, but are not currently contained in the Specific Programme),
- Competitive Activities (under the Third Framework Programme this was restricted to contract work performed for national governments, public and private companies etc. who wished to use IRSA's resources. In the Fourth Framework Programme IRSA, along with all JRC Institutes, is encouraged to participate in the EC's Shared Cost Actions, Concerted Actions and Competitive Support to the Commission, in addition to non framework programme initiatives and work for third parties). This participation in competitive activities will introduce new levels of flexibility into IRSA's overall research programme.

The 1994 programme of Work

To meet IRSA's institutional role and comply with the subsidiarity principle, the work is mainly accomplished through development of large applications projects. Examples include the Monitoring of Agriculture with Remote Sensing (MARS), Tropical Forest Monitoring (TREES), management and development of marine environmental data sets (OCEAN and OCTOPUS) and the mapping and inventory of European temperate forests (FIRS).

The work of these large applications projects, and the research required to generate new applications of remote sensing, is performed by the Institute's five Units.

Agricultural Information Systems

The Agricultural Information Systems unit (AIS) focuses on the development of remote sensing techniques for the monitoring of Europe's 127 million hectares of agricultural land. Much of this work is on behalf of Directorate General VI (Agriculture) and the European Statistical Office (EUROSTAT). In 1994, part of the AIS Unit's activities, mainly those related to crop inventories and rapid estimates of planted areas, became operational and were transferred to the Member States (crop inventories) and to DG VI (rapid estimates). The crop state monitoring and early yield forecasting activities were still in a validation stage, though monitoring was performed out on a pre-operational scale by the Unit.

Environmental Mapping and Modelling

The Environmental Mapping and Modelling Unit (EMAP) concentrates on the mapping and monitoring of various European landscape components. During 1994 EMAP's mapping and monitoring activities specifically addressed forest monitoring on a pan-European scale, and land degradation in the Mediterranean Member States. Associated with these thematic issues was more fundamental research concerning the development of image understanding techniques. The FIRS Project (Forest Information from Remote Sensing) began work on the regionalization and stratification of European forest ecosystems, definition of a workable, unified European nomenclature of forest and the compilation of a geo-referenced forest information directory.

Marine Environment

The work of the Marine Environment (ME) Unit falls into two closely linked areas. Firstly the unit concentrates on the development, implementation and validation of methodologies for derivation of ocean colour and sea surface measurements from remotely sensed data. Secondly ME is developing hydrodynamic models that, assimilating the remotely sensed measurements, can be used for the study of different oceanic processes and contribute to global models. In 1994 the ME Unit made significant progress in linking dynamic models with remote sensing data, developed new bio-optical algorithms for data processing, implemented major data archives of both raw and processed satellite imagery and finalised the processing and archive chains in preparation for the next generation of marine environmental data from space.

Monitoring of Tropical Vegetation

The Monitoring of Tropical Vegetation (MTV) Unit addresses issues related to the study of vegetation using data derived from earth observation instruments. The fields of applications are: ecosystem distribution and productivity, continental land cover/land use assessment, tropical forest monitoring and biomass burning. The tropical belt is the geographical focus of study as this region contains the most actively changing of all the Earth's ecosystems. For example, in 1994 the MTV Unit's TREES project completed the analysis of a pan tropical satellite image data set and produced an up-to-date tropical rain forest classification map. The unit has maintained close collaboration throughout the year with DG VIII (Development) on Africa and ACP Countries and with DGI (External Affairs) and DGXI (Environment) on tropical forest issues.

Advanced Techniques

The Advanced Techniques (AT) Unit concentrates on the long-term research needed to support the development of remote sensing applications. This Unit is also responsible for the European microwave signature laboratory (EMSL), an equivalent facility operating at optical wavelengths - the European Gonimeter (EGO), and the implementation of a European Airborne Remote Sensing Capability (EARSEC). 1994 was the commissioning phase for several crucial elements of an overall integrated information system based on air- and space borne remote sensing data sets. For example, the design and development of a geophysical SAR processor was completed. Oil slick detection, ship traffic monitoring, forest change detection and soil parameter analysis were proposed as SAR processor demonstrators.

Centre for Earth Observation

The work of the IRSA Units embraces common themes of data management, data dissemination, and research driving new applications. Such issues are fundamental to a new project, the Centre for Earth Observation (CEO), part of a joint initiative with ESA and the Member States called the European Earth Observation System. The CEO will foster the development of applications of Earth observation data that fulfil the specified information requirements of scientific, operational and commercial users.

The CEO project was in the Pathfinder phase for all of 1994. The Pathfinder phase is overseen by a Steering Committee (PPSC) composed of delegates of the Member States of the European Union (EU) and the European Economic Area (EEA) countries. The PPSC is also observed by the European Environmental Agency (EEA), EUMETSAT, the European Space Agency (ESA) and relevant organisations of the EC such as EUROSTAT, plus other space data providers such as Eurimage and Spot Image.

The Pathfinder Phase is managed and co-ordinated by a Project Team based in IRSA. The CEO Project team has direct links with the thematic work of the IRSA Units, maintains close links with DGXII-D4 (Space Unit) which provide strategic and policy input to the CEO, and works with staff from other JRC Institutes [the Institute for Systems Engineering and Informatics (ISEI); Environment Institute (EI) and Safety Technology Institute (STI)] on specific aspects of the Pathfinder Phase.

The 1994 IRSA Report

The following chapters describe the work of the five IRSA Units and the CEO Project Team. Each chapter follows the same format, with an introductory section defining the overall objectives of the Unit / Project, its staff and facilities. The Institute's publications for 1994 are reproduced from the official list of JRC publications in 1994. These are given in annex 8.1

There is an expanding European Earth Observation science programme. New sensors from Europe and elsewhere will be launched in the coming years. New applications of remote sensing and requests for information regularly emerge. IRSA is receptive to these developments. The work reported here shows that the Institute, through a combination of fundamental and applied remote sensing research, is ready to meet these developments and react to them in a positive way.

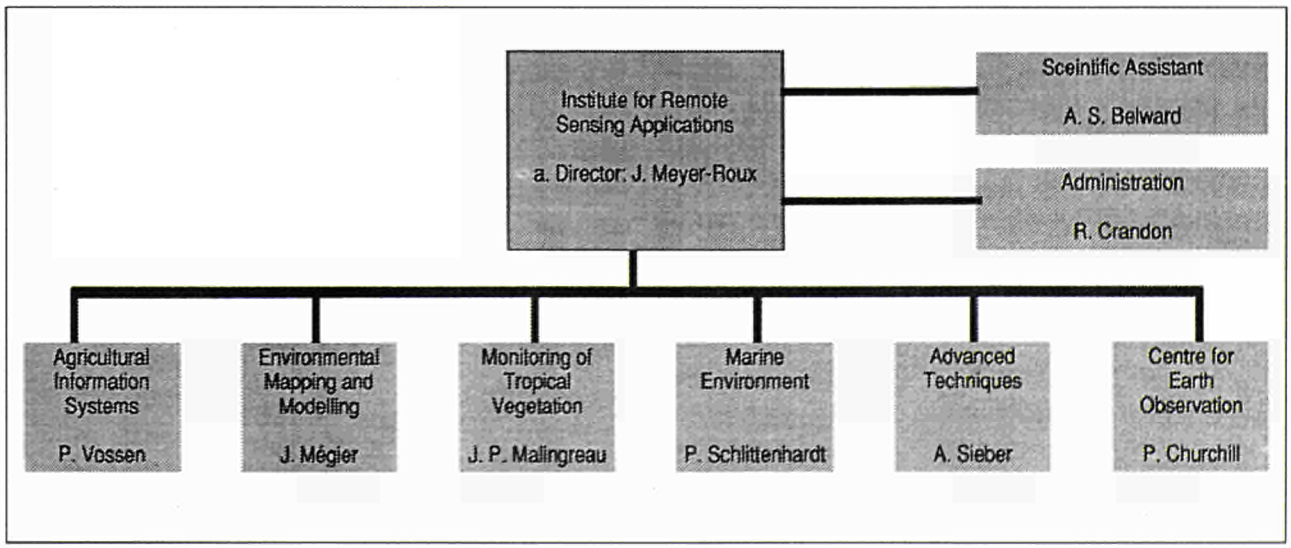


Figure 1.1 The Institute for Remote Sensing Applications' Organigramme

2 AGRICULTURAL INFORMATION SYSTEMS

Staff

Scientific and Technical Support:	12
Secretarial Support:	2
Scientific Visitors:	3
Students:	6
Total:	23

Facilities:

- Micro Vax 3900 with MARS-PED software to process data for agricultural statistics, and ERDAS image processing software.
- Matra/SUN 3 to develop AVHRR pre-processing software
- SUN 4 with ARC/INFO and I2S software
- SUN SPARC IPC with SPACE software
- Network of SUN microsystems, DEC/VMS and PC's with ORACLE RDBMS, ARC/INFO, image processing software (ERDSA and PCI)
- 500 GB on-line storage
- Operational software for crop growth modelling GCMS,
- SPACE low resolution satellite data processing
- Ground inventories support MAGDA
- Remote sensing control and support system, MESSA

The ten-year programme for the Application of Remote Sensing to Agricultural Statistics was established with the decision of the 26th of September 1988 of the Council of Ministers of the E.C. This Project is commonly referred to as the MARS Project (Monitoring Agriculture with Remote Sensing) and was initiated by the Directorate General for Agriculture in co-operation with the Statistical Office of the European Communities. IRSA's Agricultural Information Systems (AIS) Unit is responsible for implementing the programme in close co-operation with national laboratories and organisations.

Monitoring Agriculture with Remote Sensing : The MARS Project

Soon after the start of the MARS Project in 1988, its approach and methods have attracted the attention and interest of institutions outside the strict frame of the Commission policy. Since 1992, MARS has been actively involved in a number of collaborations aiming at the transfer of (parts of) the methods, techniques developed and the acquired experience. Relations were thus established with non E.U. Member States in North, Central and Eastern Europe, in the Maghreb Region and, inside the E.U., with several regions. In addition, collaborations were established on a thematic basis with other Services of the Commission such as the Directorate General I (on Illicit Crops), DG XI (on the CORINE Programme) and with scientific partners such as the Universities of Quebec (Canada), the Central Service for Surveys and Statistics (SCEES) in France, the European Space Agency, etc.

Summary of the principal objectives

The principal objectives of the Project relate to three major fields:

- The improvement of agricultural statistics through the use of remote sensing techniques. All these activities are grouped in the MARS-STAT sub-project.
- The use of remote sensing and related techniques in support to the implementation of the Common Agricultural Policy. These activities are grouped in the MARS-CAP sub-project.
- To support transfer of methods to other geographical regions outside of the E.U, and the adaptation of those methods to new themes. These activities are grouped in the sub-project on the MARS-Extensions.

The MARS-STAT Sub-Project

The objectives of MARS-STAT activities are :

- the quantitative estimation of the acreage occupied by the various crops in a given region or country,
- the monitoring of vegetation and crop state,
- the timely crop yield forecasting of mean crop yields for a given region,
- the rapid and timely estimation of the total production of the most economically important crops.

This sub-project is organised into 5 Activities:

Activity A: Regional inventories. Consists of the assessment of , mainly crop acreage with high resolution remote sensing imagery (mainly SPOT and Landsat TM images);

Activity B: Rapid estimates at the European scale of actual planted areas of the main annual crops, as compared to the previous season. This activity also include the support activity Area Surveys.

Activity C: The Advanced Agricultural Information System, which is meant to combine in a single framework the crop area estimates, the vegetation and temperature indices derived from low-resoluti on NOAA-AVHRR satellite data and agrometeorological crop growth simulation model outputs for improved quantitative crop yield and production estimations;

Activity D: The assessment of foreign agricultural production;

Activity E: The development of new methods and techniques for image analysis and testing of the usefulness for agricultural purposes of new space born sensors such as the European Remote Sensing satellite, ERS-1.

The methods developed within the framework of these activities are tested on fairly large areas in order to put into operational use.

The crops targeted are those in which there is the biggest market, with the exclusion of crops consumed on the farm, such as fodder crops. Representativeness is sought not only at Community level, but at national and regional level too.

In addition the MARS project is involved in third party work in the framework of the Hydre project and provides support to non-EU countries through the transfer of MARS methods and technologies (MARS geographic extensions).

The MARS-CAP Sub-Project

The MARS-CAP sub-project involves activities related to crop identification by satellite remote sensing as well as activities with a broader scope such as :

- the assessment of the precision and reliability of plot location and limits,
- the conceptual development of Integrated Administration and Control Systems.

This sub-project is organised into 3 major groups of MARS-CAP Activities :

Activity F: Control with Remote sensing. The MARS project developed a methodology of "control with remote sensing". The methodology has been rigorously tested and has been passed to the Member States for the operational implementation.

The method is based on the use of multi-date high-resolution satellite images to verify, without any contact with the farmer his declaration for area aids. This enables to sort the declarations, and to concentrate field control on the non-conform or suspicious dossiers and parcels.

Through its implementation by the different Member States, the Control with Remote Sensing became one of the main operational uses of remote sensing in Europe. On an annual basis more than 200 high resolution images (SPOT, TM, ERS-1) are processed and analysed by a large number of European contractors, all using the same methodologies.

In this framework, the technical assistance of the MARS project to DG VI is made up of:

- Optimising methodologies, for automatic classifications, the use of new sensors, etc.
- Providing technical specifications and homogenised decision tables for the Member-States,
- Technical follow-up, checking and quality control of the contractors,
- Technical supervision of the development, for this application, of a dedicated software.

Activity G: Integrated Administration and Control System (I.A.C.S.) The new Common Agricultural Policy requires, within the Member-States, the implementation of an Integrated Administration and Control System (I.A.C.S.) The IACS will serve to manage and control the declarations made by the farmers. Since 1993, the integrated system generalised the application of area based subsidies to farmers and covers most of the arable lands (cereals, oilseeds, proteagineous crops, set-aside) and the forage area (fodder crops, grasslands).

The IACS is made up of different databases, containing information on the farms, on the identification of the agricultural parcels, the land use declared, on the live stock, etc.
The MARS Project provides support to the DG VI and Member States in the database design and database management. More in particular, a management system is developed for parcel identification, the use of cadastral documentation and maps and the creation of an agricultural cadaster. The system provides a declaration support, on the basis of satellite or airborne remote sensing data, for the measurement of parcels.

Activity H: Agricultural Registers. The Agricultural Registers have been implemented in the European Union to provide a tool for the management of the market and of the subsidies to farmers cultivating vineyards, olive trees, or citrus. The three registers are separated and are made up of detailed and yearly updated databases, containing a census and describing all the holdings and fields with these productions. The implementation of the agricultural registers requires the creation or the use of large scale mapping coverages, and their updating.

The Mars project provides in this context, a technical assistance to the DG VI to:

- develop new methodologies, especially in the regions where land registers are not available, not updated, or not suitable;
- follow up the contractors or National Administrations in charge of the registers;
- evaluate the quality and the updating of the databases and maps.

Although not exclusively, most of these activities are carried out in direct support to the Directorate General Agriculture. Other main users in 1994 were the European Statistical Office (EUROSTAT) for what concerns the MARS-STAT products and the E.U. Member States for what concern technical and scientific support in the field of MARS-CAP

Part of the activities, mainly those related to crop inventories and rapid estimates of planted areas, are operational and were transferred in 1994 to the Member States (crop area inventories) and to the E.U's Directorate General Agriculture (rapid estimates). The crop state monitoring and early yield forecasting activities are still in a validation stage and are carried out on a pre-operational scale by the Joint Research Centre. In this report, the methods, results as well as examples of outputs of the various activities during 1994 are presented and an evaluation is made of their state of advancement and the needs for improvement or further development. Future perspectives, mainly related to the integrated use of the various Actions into one Advanced Agricultural Information System and for the development of a system for foreign crop production forecasting are indicated.

1994 Milestones

1994 was for the MARS Project a key-year, with the following major milestones:

1 Jan. 1994:	start of the second phase 1994-1998.
31 March 1994	:publication of the first "MARS Bulletin", integrating both the rapid estimates of crop acreage at European Scale and the yield forecasts within one monitoring bulletin. It was published from March to October and send to the Services of the Commission within 10 days after the acquisition of satellite and meteorological data.
May 1994:	transfer to Directorate General Agriculture of the MESSA software, which permits the operational selection and management of the areas selected for the control of farmers declarations by remote sensing.
7-11 Oct. 1994:	Joint organisation of the international conference on operational techniques for national crop yield forecasting, together with FAO and EUROSTAT.
Oct. 1994:	end of the Agricultural Campaign. The MARS-CAP project has indirectly contributed to the checking of 42000 declarations in 10 Member States.
14 Nov. 1994:	adoption of the Council Decision N° L299, published on 22 November 1994, confirming that the Activities A and B are operational and transferring them to the Directorate General for Agriculture.
Nov. 1994:	Eurocourse for representatives from 16 PHARE and TACIS countries, on the use of the MARS approach for agrometeorological yield forecasting.

As in the previous years, institutions from the Member States, private and public have largely contributed in 1994 to the conception, development, validation and implementation of these various activities.

2.1 MARS-STAT : ACTIVITY A: REGIONAL INVENTORIES

Summary of Objectives

To develop and improve methods based on area frame sampling techniques and high resolution satellite image interpretation for agricultural or other land-use inventories at the level of the region.

To support regions in the Member States with the implementation of an operational system for land-use inventories.

To support the implementation of regional inventories in the Central European countries which are subject of the PHARE programme of the EC (Poland, Hungary, Czech Republic, Slovakia, Rumania and Bulgaria).

To organise and, or collaborate in this context to training and support activities.

1994 PROGRAMME OF WORK

Introduction

For several years a number of regions in the EC carried out regional inventories using the methods developed by the MARS project. The MARS project assured the follow-up of these activities and kept on investigating possible enhancements of the methods applied. 'The transfer of the methodology to the regions which was seen as the major objective of the activity at the start of the MARS Project, was completed for several regions in 1994. From 1993 onwards and continued in 1994 a gradual geographic shift of the MARS projects support activities took place towards the former communist Central European countries and certain regions in southern Europe. In 1994 the MARS project continued to supply technical support to the regions in the EC and to intensify its collaborations and training activities to the PHARE countries.

Methodology

The method adopted establishes close links between satellite data and observations on the ground. Development and evaluation focus on the so-called regression estimator method. The action comprises two components:

Component 1:
objective observations in the field with a sample design established or enhanced by remote sensing;

1994 Milestones

Activity A implemented in the Czech Republic (national funding), in Slovenia (joint national and MARS funding) and in parts of Greece and Romania.

Cconclusions reached regarding the comparison of segment sampling against point sampling, the definition of optimal segment size and sampling distances

Conclusions reached on cluster estimation techniques for aligned systematic sampling with stratification.

Component 2:
automatic classification of the satellite data in order to improve the estimates generated by the ground surveys, using the regression method. This involves stratification using satellite images and with existing topographical documents and maps as support; selection of a sample of 600 square segments of 50 hectares; survey on the ground on the basis of aerial photographs; simultaneous acquisition of a full coverage of the region by SPOT and Landsat-TM images; automatic classification of the satellite data in order to improve the estimates generated by the above-mentioned ground surveys, using the regression method; analysis of the results.

Remote sensing also comes into play in providing the enumerator with documents enabling him to identify plots of land accurately on the ground. This component was further developed as part of the backup support activity Area Survey Systems.

Throughout 1994, the MARS project continued providing training and technical support to a number of Member-States through the development of software systems.
Furthermore, the MARS Project conducted a series of studies in order to improve the existing operational methodologies.

Perspectives for 1995

The activity on the Regional Inventories will be continued in the JRC on a reduced scale when compared to the previous years. The MARS project will continue to supply technical support to the regions in the Member States and the PHARE countries essentially through the development or enhancement of ad-hoc software systems based upon specific requirements of the regions.

2.2 MARS-STAT : ACTIVITY B: EUROPEAN RAPID ESTIMATES OF ACREAGE AND POTENTIAL YIELDS

Summary of Objectives

To provide decision makers in the DGVI and EUROSTAT with early information at Community level on changes in crop acreage each year with respect to the previous year, as well as indicators of potential yields.

1994 PROGRAMME OF WORK

Introduction

High-resolution satellite imagery from SPOT and the Thematic Mapper is used to provide rapid estimates of annual changes in area under various important crops in Europe. The information in the images is also to be used to provide estimates of the potential yield of these crops. The results, produced throughout the crop year, are transmitted to the Directorate General of Agriculture of the Commission of the European Union and to the Statistical Office of European Union, where they help to provide precise and up-to-date information on agricultural production.

In 1994 the Activity B on Rapid Estimates continued generally along the same lines as 1993.

Based upon the end-user requirements small modifications were made regarding the frequency of reporting and the inclusion of experimental estimations at the National level for a limited number of crops.

The operational services of Activity B processed and analysed in 1994 a total of 155 high-resolution SPOT and Thematic Mapper images over the 53 sites (1600 km2) to sample the EC agricultural land cover.

Methodology and Results

The method consists in analysing a sample of sites - 53 for the European Community - obtaining and interpreting high-resolution satellite images (about three or four each year) of the sites and extracting the agricultural crop area occupation.

1994 Milestones

March till Oct:	Monthly publication of the results in the MARS Bulletin
14 Nov. 1994:	Adoption of the Council Decision N° L299, published on 22 November 1994, confirming that Activity B is operational and transferring them to the Directorate General for Agriculture.
Dec. 1994 :	Completion of the 1994 ground col-lection validation data campaign.

Following the requirements of the end-user, the Directorate-General VI - Agriculture, the Activity B contributed between March and November 1994 with area estimates for 12 economically important agricultural crops to in total 8 monthly reports on crop status, the so called "MARS Bulletin."

Although Activity B has been conceived with the purpose to estimate crop area at the scale of the EC, also area statistics at the national for the cereal crops have been published as an experimental result in 1994.

The accuracy of the Activity B statistics throughout the agricultural season is evaluated by comparing them against the reference statistics published at the end of the year by the EUROSTAT services. Taking into account the sampling error for the different crops, the results showed in general to be according expectations for especially small grain cereals and root crops. The 1994 results were less accurate for oil seed crops such as sunflower mainly due to combined effect of the sensitivity of the site extrapolation methodology with respect to the representativity of the sample for this particular crop and the difficulty with which the crop can be identified as a homogeneous class from remote sensing images. (Table 2.1).

Action4 -	EUROSTAT (%)	+/- Error %
Soft Wheat	0.6	1.9
Durum Wheat	1.8	2.5
Barley	3.0	1.8
Other cereals	-3.0	3.0
Maze-grain	-2.6	4.1
Total cereals	0.7	1.3
Sunflower	-11.3	9.2
Sugar beet	2.2	4.7
Potatoes	-3.0	4.7

Table 2.1 : Difference of the evolution for area between the Activity B results at the end of the campaign (07.11.94) against the EUROSTAT reference (21.10.94) and the sample error at a 90 % confidence interval.

Nevertheless, the timeliness of the information and especially the early dates for which already stable, and rather precise estimates could be obtained when compared to other sources of information, contributed significantly to the satisfaction of the end-user.

The lack of prediction data at national level is inherent in the sampling method. For countries that have ten or so sites, the prediction for two or three crops appears to be roughly valid. Such information at sub-European level, however, must be viewed with caution, as the sample is not designed for this purpose.

Perspectives for 1995

In support to the operational Activity B, for which evaluated and proven data analysis methods are being used, research on quantitative yield estimation, the integration of new sensors and innovative statistical sampling methods continues in 1995 on Activity B sites.

More varied applications will be introduced, including the introduction of a modified and larger sample, to assess fallow land and the setting-aside of arable land.

The new Common Agricultural Policy regulations related to set-aside land will have major impacts on the agricultural pattern of the E.U., i.e., in terms of crop (type) distribution and their relative importance in the various European regions, regarding the soil types selected by farmers for their crops and relation to crop rotation. The study of these impacts becomes a priority, because they may significantly affect the interpretations and results.

The delivery and installation of the ORCA system (Orbital Remote Sensing of Crop Area) around July 1995 at the JRC. The ORCA system has been developed throughout 1994 and will replace from 1996 onwards the existing satellite image processing and analysis chain of Activity B.

3 MARS-STAT : ACTIVITY C: THE ADVANCED AGRICULTURAL INFORMATION SYSTEM.

Summary of Objectives

To aid the assessment of crop state and yield estimates at the level of the E.U, the Member States and regions, through the development, implementation and testing of agro-meteorological models.

To assess the synergistic use of temperature and vegetation indices derived from low-resolution satellite data with the output products of the agro-meteorological models for more precise quantitative yield estimation and alarm identification.

1994 PROGRAMME OF WORK

Introduction

This Activity consist of the following 3 components:

Component 1:
The assessment of vegetation conditions and yield indicators with low resolution meteorological satellite imagery

Component 2:
Yield prediction models

Component 3:
The integrated system

The originally adapted strategy was to work in two phases:

a) 1988-1993: development and implementation of basic systems for crop state monitoring and yield forecasting based on surface information, simultaneously with the development of the system for vegetation condition monitoring using low resolution satellite information.
b) 1994-1998: gradual improvement and possibly complete integration of both systems. Such improvements can for example be achieved by the use of satellite information derived solar radiation in agrometeorological models, by introducing improved techniques for the interpolation of rainfall data, by using remote sensing for the assessment of the spatial extent of (agro-) meteorological events, etc.

In 1994, a start has been given to the gradual integrated use of the outputs of both systems. The target is to eventually develop one single operational system by 1998. However, it should be mentioned that both individual systems (using remote sensing data or surface meteorological data alone) will be maintained so that they can be used in case of major problems (e.g., satellite breakdowns, excessive cost of meteorological data, etc.).

The development of the Advanced Agricultural Information system is a complex undertaking which requires in-depth knowledge on a wide variety of subjects ranging from soils sciences, meteorology, agronomy and remote sensing. In this context the MARS project invited scientists from those different domains to participate in scientific support groups which provide scientific and technical guidelines. In 1994 two scientific support groups, the "Support Group for Agro-meteorology"(SuGram) and the

1994 Milestones

March 1994 : Improved interpolation of daily meteorological data implemented in CGMS.
May 1994 : Installation of the CGMS 3.0 system
Aug. 1994 : An agro-pedological knowledge base for wheat became available.
Aug. 1994 : Former East-Germany added to the E.U soils data base.
June 1994 : Expansion of the CGMS model for crop specific outputs
July 1994 : Expansion of CMGS for either water-limited or irrigated conditions
Dec. 1994 : Start of planting date sensitivity analysis for CGMS
Dec. 1994 : 6 years of daily NOAA-AVHRR European coverages processed (1982 and 1990-1994)

"Support group on soils and geographical information systems" provided such a support to the project.

The systems and approaches of Activity C could have many applications, particularly for environmental problems. In this context the MARS project supplies contractual support to the Hydre project.

Component 1: Vegetation condition and yield indicators

The objective of this component is to use low-resolution satellite meteorological data for monitoring vegetation conditions and to provide indicators of the yields of the main crops.

The method consists in processing the satellite data to generate two indicators: a vegetation index and surface temperature. Since these indices are directly related to the state of vegetation and crops, a spatial and temporal comparison of these data with other years or areas should make it possible to assess comparative yield levels. In addition to the objectivity of the method, the main attraction is the possibility of providing such indicators at various geographical levels: local, regional, national and European.

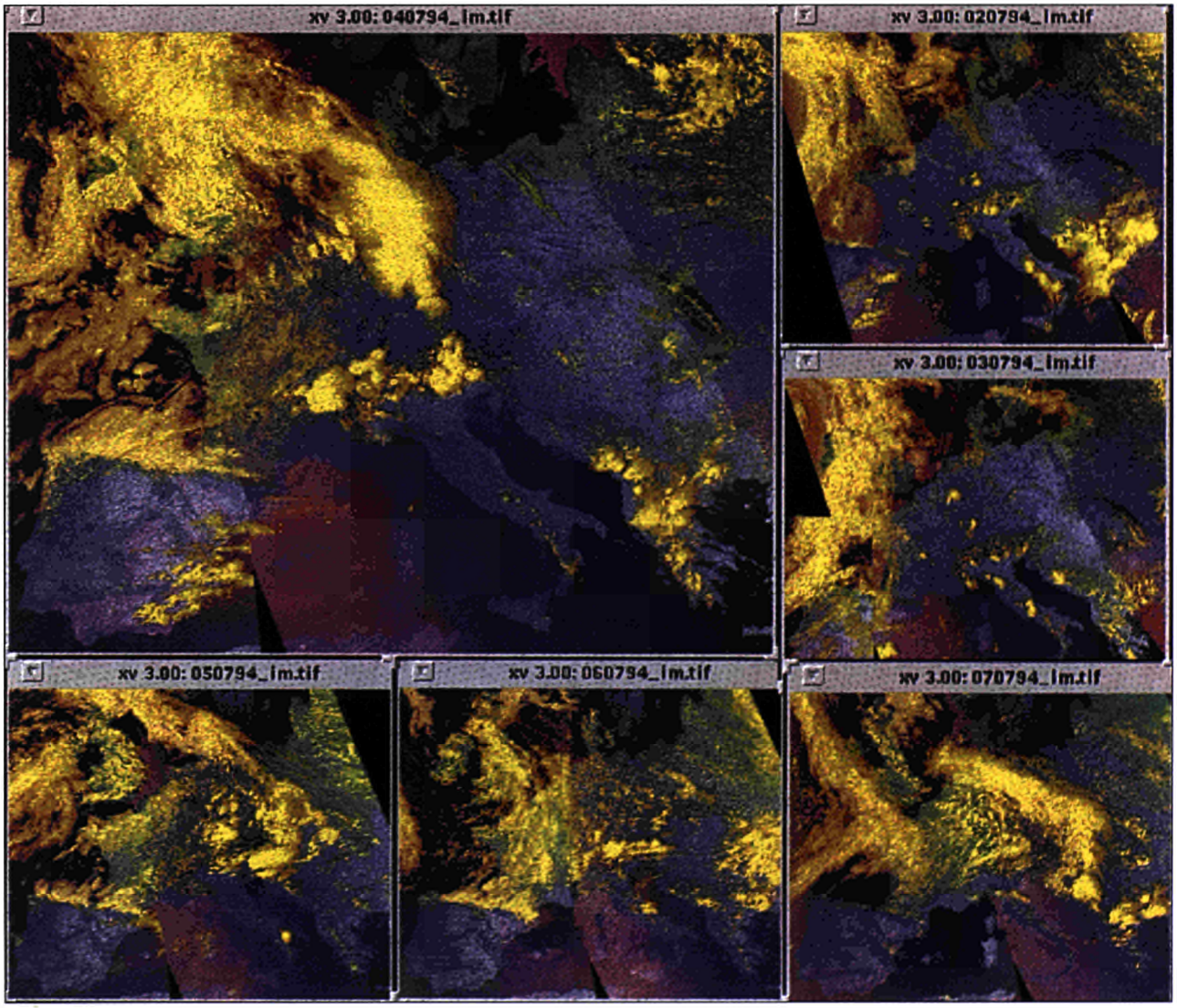


Figure 2.1 : A week of daily NOAA-AVHRR MARS Project Level 3 mosaics in a band 4, 3, 2 false colour representation.

Results

Since 1993, the NOAA-AVHRR processing chain SPACE (Software for Processing AVHRR data for the Communities of Europe) generates the following products:

- daily mosaics (see Figure 2.1) of the Community generated from NOAA-AVHRR data (level 3);
- a database which incorporates data for a homogeneous area and for a given period, e.g. ten days, and for generating a more elaborate synthetic product (level 4). These can be time profiles for a given area or cartographical products for a given period (see Figure 2.2).

In 1994 the SPACE system continued to update on a weekly basis the level 3 and level 4 databases and processed an additional 4 more years of historical data.
Presently an archive of 6 years of daily European coverages is available: 1982 and 1990-1994.

n 1994, it was possible to verify the usefulness and validity of some of the SPACE products, especially during the summer 1994 drought in southern Europe, the early season excess rainfall and limited radiation in northern Europe and the excessive August surface temperatures during the tasseling period of grain maize in France.

Component 2: Yield prediction models

The objective of component 2 is the development, testing and implementation of a system for timely regional crop state monitoring and yield forecasting of the following major E.U. crops: cereals, grain maize, rice, pulses, sunflower, soybean, potato, sugar beet, colza, wine, olive oil, apple, pear and citrus.

This component is divided into two separate subactions:

- the development of a semi-deterministic agrometeorological model for predicting annual crop yields;
- the development of a model for the prediction of vine (and olive) yields based on pollen count methods.

a. Agrometeorological crop growth simulation of annual crops.

CGMS, the Crop Growth Monitoring System, is the MARS agro-meteorological modelling system based on the WOFOST model which uses data concerning the soil and meteorological conditions to simulate the growth of crops. In 1994, this was expanded to enable the production of outputs for 10 different crops: winter wheat, soy beans, field beans, barley, maize, sunflowers, sugar beet, rice, potatoes, and oil seed rape. The system was partially re-engineered during 1994 and is now used on a regular basis to produce 10-day outputs and monthly summaries of crop state indicators including development

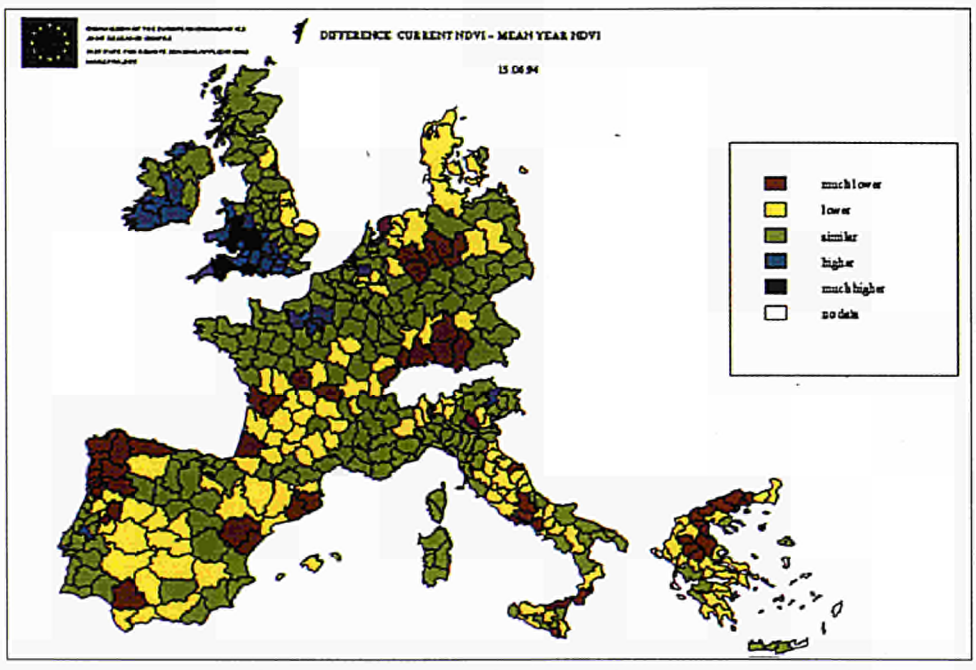


Figure 2.2 : An example of a cartographic output of the SPACE/SCAN System showing the difference of the current NDVI at the regional level against the mean NDVI level for the same year.

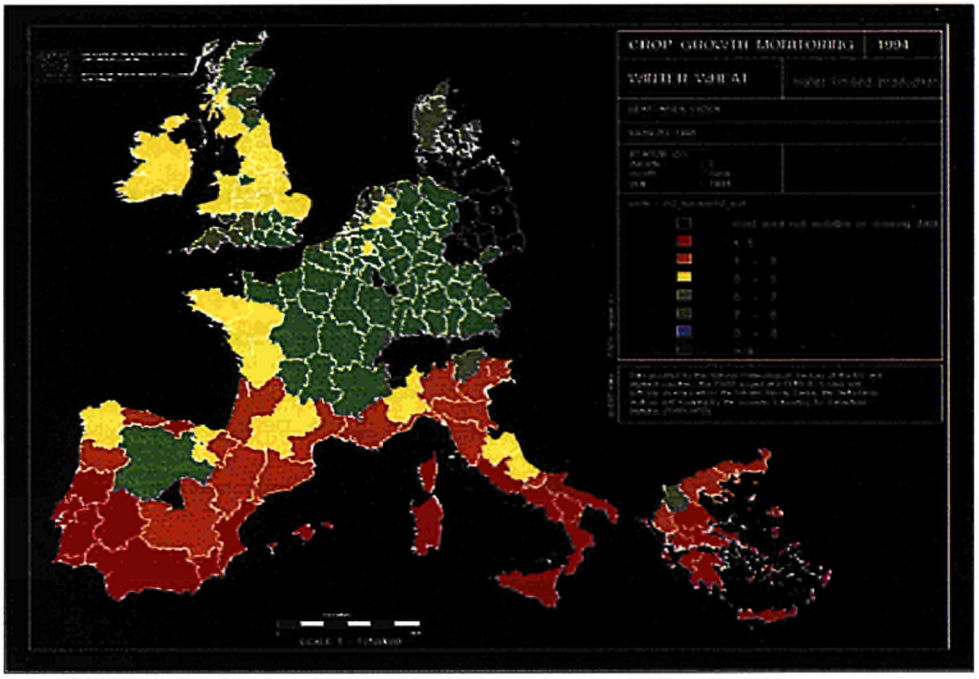


Figure 2.3 : An example of the cartographic representations of the crop specific indicators produced by the CGMS.

stage, leaf area index, soil moisture index, total biomass and storage organ biomass for either water-limited or irrigated conditions (see Figure 2.3). The outputs are made for each of these ten crops in cartographic format, on 50 km by 50 km grid square basis. CGMS can be used to produce these outputs to illustrate either the absolute values for the present season or to indi-cate the deviation between the present season and long term means. It can also combine these modelled crop state indicators with actual yield and production statistics from previous years to provide a quantitative yield estimate for the current season, on a national and European basis.

Results

Although the outputs of CGMS have already undergone preliminary validation, the system will require a complete sensitivity analysis. This could indicate the level of accuracy required for different input data and also the relative importance of adding modules to incorporate additional parameters into the model. This sensitivity testing has commenced with an evaluation of the importance of planting date.

Preliminary results show that by varying the planting data (which is presently held fixed), the results are significantly modified (see figure 2.4) This indicates that it will be necessary to develop a model for season-specific planting dates. A more complete sensitivity analysis is planned for 1995.

The technique for the interpolation of daily meteorological data from the synoptic network and applicable to the E.U. as a whole on a regular grid of 50 km x

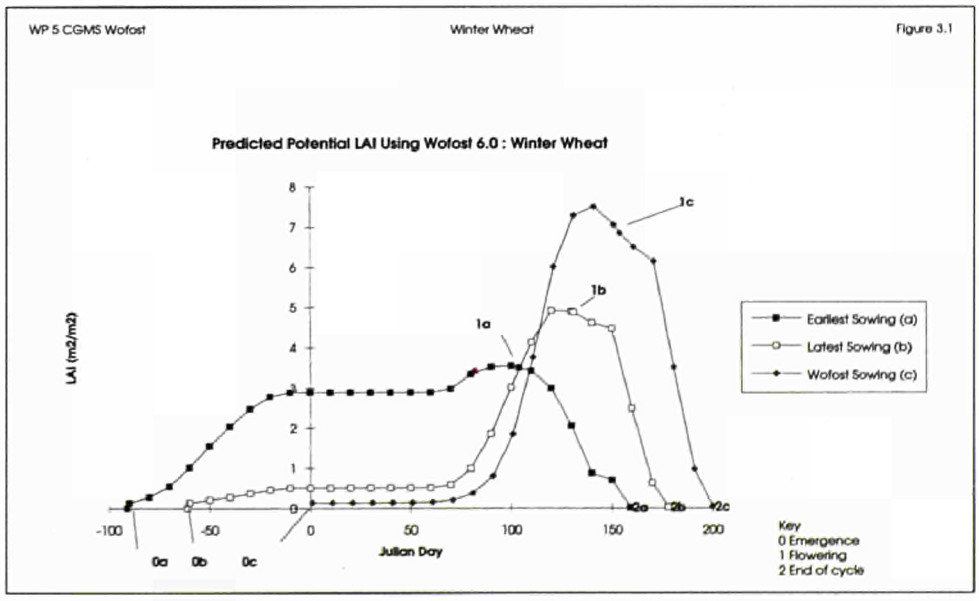


Figure 2.4 : WOFOST 6.0 Predicted potential Leaf Area Index Simulation for winter wheat showing the importance of sowing date.

50 km or 25 km x 25 km has been improved and refined.
The MARS agro-pedo-meteorological knowledge bases have been completed with a wheat knowledge base. Improved methods for the estimation of global radiation from cloud cover were developed and an algorithm for the estimation of the sugar content of vinegrape was implemented. (see figure 2.5)

The enhancement of the 1:1.000.000 E.U. soils data, through the co-operation with the National Agronomy Research Institute (France) and the "Support group on soils and geographical information systems" was completed and integrated in the MARS Crop Growth Monitoring System. It includes now also former East Germany. Work to integrate also the new Member States Finland, Sweden and Austria has started.

The operational version of the Crop Growth Monitoring System (CGMS, version 3.0) has been completed and installed. It is operational since March 1994. CGMS is now composed of 3 main modules:

I. The processing of daily meteorological data: quality control, formatting and replacement of missing values; calculation of derived parameters such as solar radiation (from cloud cover or sunshine duration), vapour pressure and potential evapotranspiration; interpolation to a regular grid of 50 km x 50 km; production of output maps of the meteorological conditions during a given 10-day period, month or season, both as actual values and as departures from the climatological normal conditions.

II. The agrometeorological crop growth simulation, for each of the major annual crop types that, accor-

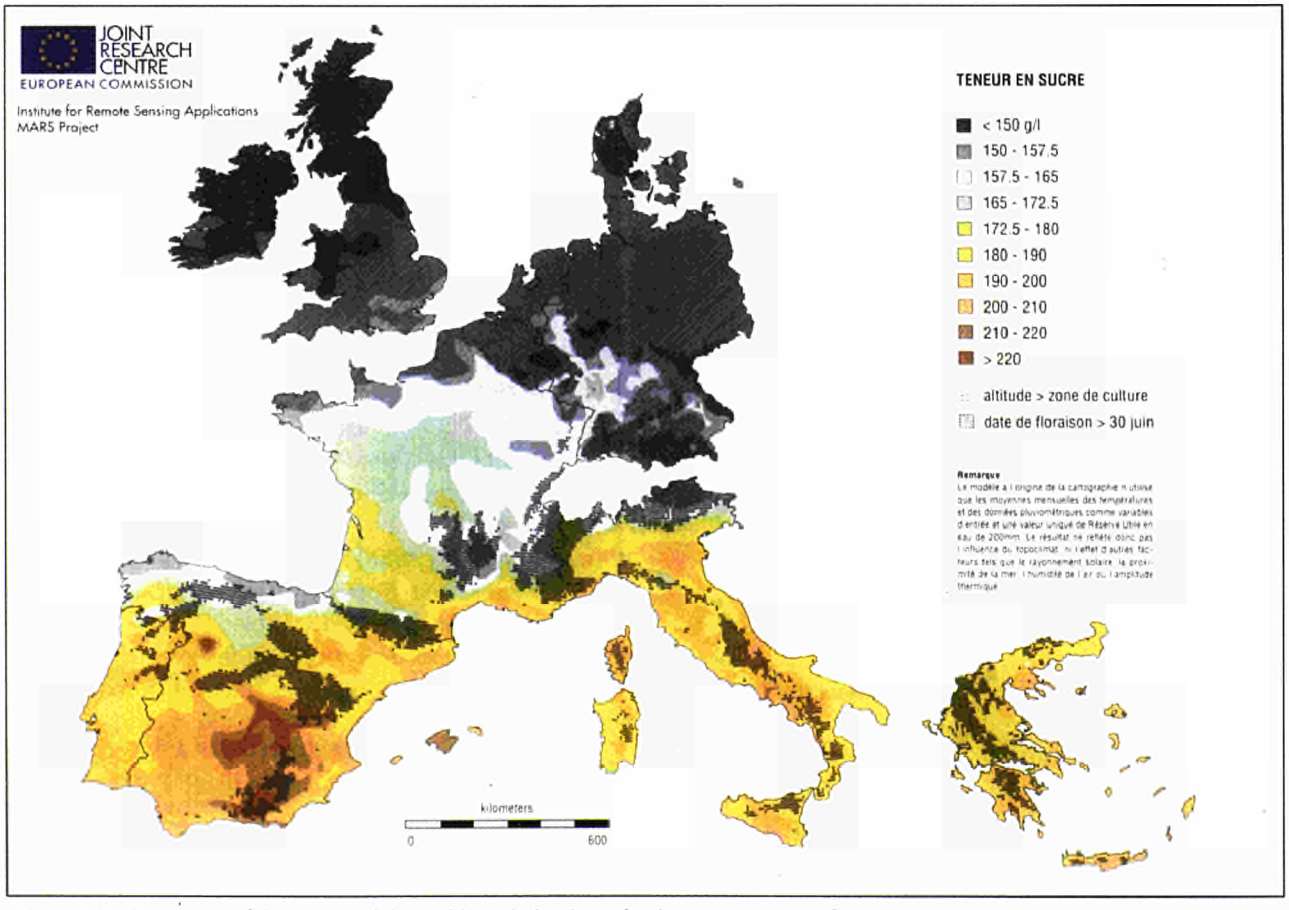


Figure 2.5 : Expansion of the agro-pedological knowledge base for the sugar content of vinegrapes

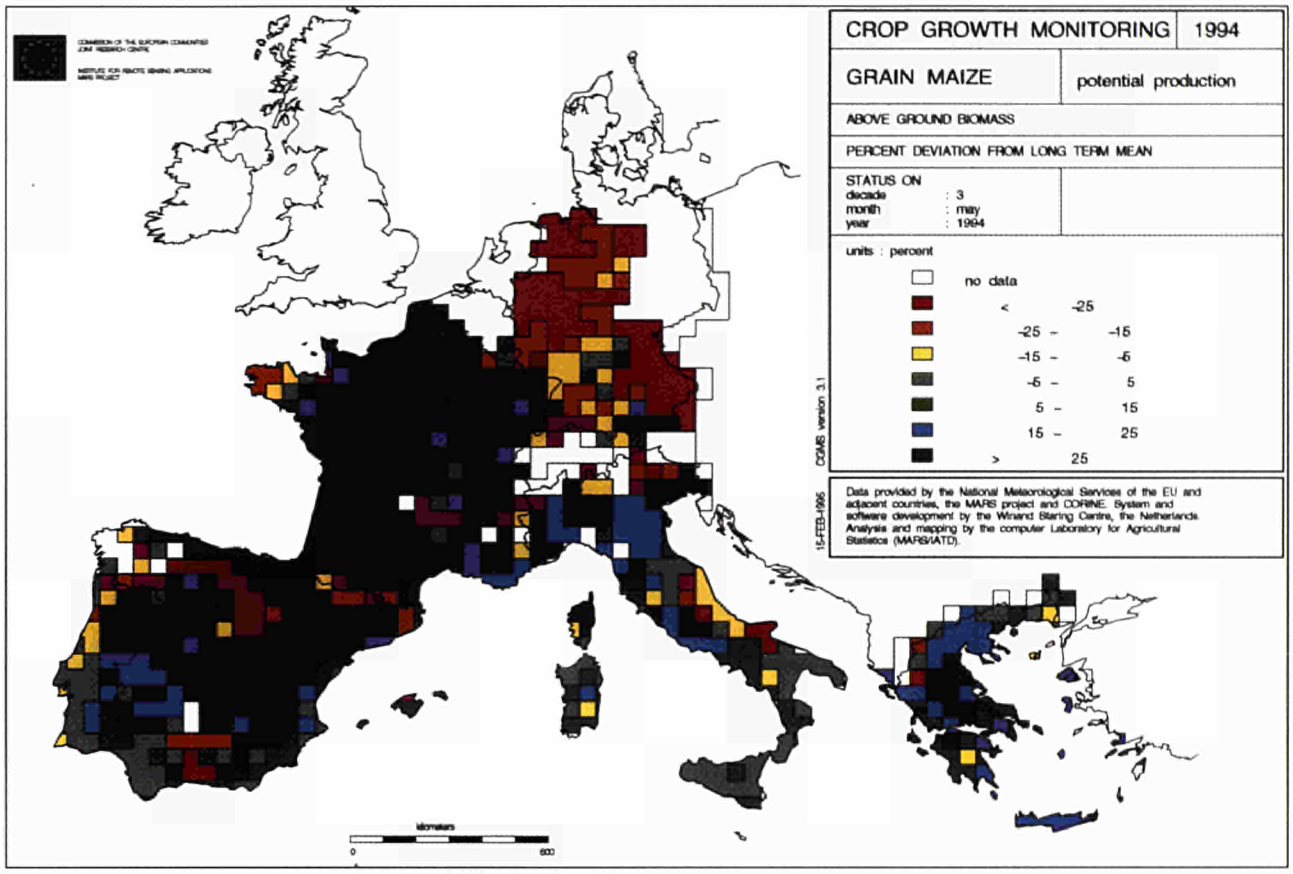


Figure 2.6 : The potential production of Grain Maize for given decade of 1994 shown by its predicted biomass.

ding to the crop knowledge bases, are likely to grow in a given 50 km x 50 km grid. Since various soil types and crop varieties coexist in a grid, outputs for a basic square are produced for each of the major soil types and profile available water capacities, so as to reach a representativity of approx. 80% of the suitable soil coverage.

III. The statistical module, relating the model outputs, through a regression analysis and possibly in combination with a technological time trend function drawn from historical yield data, to the series of regional yields available in EUROSTAT's REGIO data base. The regression analysis of past years is only used provided it gave satisfactory results in terms of significance of the multiple determination coefficient, the partial correlation coefficients, the stability of the regression coefficients and the error analysis; if not, the time trend function only or previous year's yield are used as predicted values.

The outputs of the system are threefold:

a) **Mapped outputs of agricultural season quality indicators:**

- Biomass and grain production (see figure 2.6) , under the actual rainfall conditions and as if all required moisture was available;
- estimated actual soil moisture reserve; differences as compared to the previous decade or month;
- state of advancement of the cycle during a given decade;

b) **Alarm warning:**

- Detection of abnormal weather conditions (during a given decade, or cumulated since the start of the season).

c) Tables, with calculated yield forecasts:

- including information on the quality of the regression equations such as the coefficient of multiple determination, the stability of the regression coefficients, the errors of the one year ahead predictions obtained for previous years, etc.

b. The pollen count model

The aeropalynologic or "capture of pollen in the atmosphere" method is used for the timely assessment of the production potential of grape wine and was conceived by P. Cour of the French Centre National de la Recherche Scientifique C.N.R.S. The method is already used by groups of wine producers for their own forecasts. It is based on the assumption that the number of pollen liberated into the atmosphere during the flowering period of certain crops, is a good indicator of the yield potential of the crop.

At the level of the MARS-STAT Project, the validation of the method and the tests for grapevine continued in 1994. Raw annual results were obtained for each pollen station. The series do not cover yet enough years to calibrate the results and determine a reliable relationship between production and pollen count. However, in France, where the network is most developed and where the stations are the oldest, a group of experts who were shown these results, predicted in July 1994 a wine production of 58 million ha which was almost identical to the official, expert based July forecast of 58.5 million ha.

Component 3: The integrated system

The objective of this component is to integrate the various actions and also incorporate conventional surveys in order to create a complete information system including the new methods described above. It therefore lies downstream of all the preceding Activities.

Results of the Integrated System : The MARS Bulletin

The Advanced Agricultural Information System produced the monthly MARS Bulletin from March to October 1994. The bulletin appears within 10 days of the acquisition of the raw satellite and meteorological data. It contains tables with forecasted crop acreage (at European level) and yields (at national level). The acreage are entirely derived from high resolution satellite imagery. The yields forecasts are established in three steps: first the raw outputs of the CGMS statistical module (national crop yield in kg/ha) are produced. This output, which is an automatic product, is then analysed by a team of agronomists and statisticians ("conjoncturists") as a function of the growing conditions indicated by the NOAA-AVHRR indicators NDVI and Ts. If necessary, the CGMS forecast is revised, according to the possible recent occurrence of unfavourable conditions depicted by SPACE. Examples are the abnormal high surface temperatures in Northern Europe during the tasseling period of grain maize in August 1994 and the excess humidity and low radiation that retarded crop establishment during the spring of 1994.

Crop		May	June	July	August	Sept.	U (10.94)
(E)	Wheat	5.5	5.4	5.6	5.6	5.5	5.4
(M)		5.2	5.3	5.2	5.2	5.2	
(E)	Common	6.2	6.0	6.2	6.2	6.1	6.0
(M)	wheat	5.9	5.9	5.8	5.8	5.8	
(E)	Durum	2.8	2.8	2.9	3.0	2.6	2.7
(M)	wheat	2.7	2.7	2.7	2.7	2.7	
(E)	Barley	3.9	3.9	4.0	4.0	4.1	4.0
(M)		4.0	4.1	4.0	4.0	4.0	
(E)	Grain	7.9	7.7	7.6	7.4	7.9	7.9
(M)	maize	7.8	7.8	7.6	7.6	7.5	
(E)	Sunflower	1.	1.6	1.6	1.6	1.5	1.6
(M)		1.1	1.4	1.4	1.4	1.4	

Table 2.2: Summary of the 1994 monthly yield forecasts for delected crops, as elaborated by the MARS project (yield = T/ha; E = EUROSTAT FIGURES; M = MARS estimates; the EUROSTAT assessments are the updates on 21.10.94).

Table 2.2 summarises the 1994 monthly yield forecasts for selected crops. and Figure 2.7 provides the general state of summer crops at the end of September 1994, integrating the map outputs of SPACE (NDVI and Ts) and of CGMS (simulated biomass and grain, state of advancement of the crop development, soil moisture left in the soil, etc.).

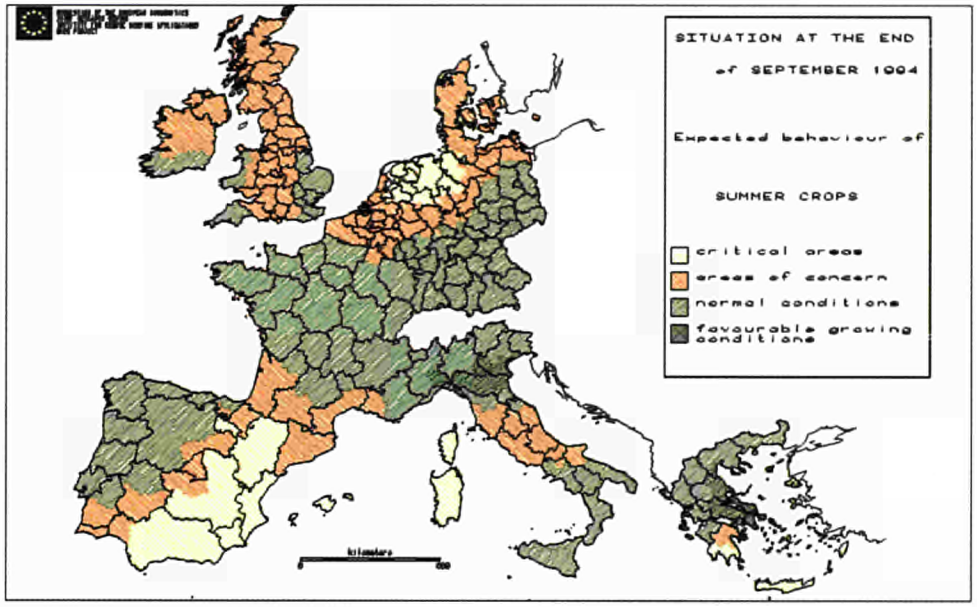


Figure 2.7: General state of summer crops at the end of the month of September 1994

SuGrAm: The 1994 activities of the MARS Support Group on Agro-meteorology

In its first three year period (1990-1993), the SuGrAm group provided advice to the MARS programme on the development of agro-meteorological models for crop state monitoring. As the MARS project is now moving towards the integration of these ground-based models with satellite-based techniques, the newly re-constituted SuGrAm group, also has a modified mandate. It is now charged with assisting the MARS project in the fields of both ground-based agro-meteorological modelling and the integration of these models with remote sensing methodologies. The membership of the group now includes a range of experts such as meteorologists, agronomists, and remote sensing scientists, all of whom have extensive professional experience in crop state monitoring with their respective tools. The group meets on a semi-annual basis to review and evaluate the work underway in the MARS project and to provide inputs and suggestions for its improvement and accelerated advancement.

The Soils Information Focal Point (SIFP)

Since 1989, the MARS project has been working to develop the EC Soils Database as an input to its agro-meteorological models. In April 1994, the activity was broadened with the establishment of the Soils Information Focal Point (SIFP), which aims to meet the broader needs of the different services and institutions of the European Commission soils information.

An inter-DG co-ordination group on the SIFP has produced a document entitled "Soils Information for Europe" which identifies the gaps between the needs of the Commission for consistent, reliable soils information and the data presently available. These un-met needs include expansion of the EC Soils Database to cover all of Europe up to the Urals, an improvement of the geographic resolution of European-wide soils data, the availability of information about the evolving characteristics of the soil, and a metadatabase indicating the various sources of soils data across the continent. The need for comparable, preferably standardised, information was also stressed, as was the importance of readily usable, interpreted parameters rather than just raw data.

Some of these needs may be met directly and in the near future by the SIFP itself, but most will require co-operative action between programmes in different DG, and above all with the soil data producers within the Member States and neighbouring countries. An expert working group has been constituted to formulate a long-term work plan. A meeting was also held with experts and heads of soil data centres in the countries, at which the creation of a more formal structure for collaboration was proposed.

Third party work : The Hydre project

The Hydre project on the "Monitoring Hydrological Resources in Mediterranean Regions" can be considered an excellent example where the methods and databases developed for the Advanced Agricultural Information System were adapted for a different environmental application.

The objectives of the Hydre project can be summarised as follows :

- To develop an integrated methodology for the real-time monitoring of hydrological resources in the Mediterranean regions of the European Union.
- To develop and adjust relevant tools in the fields of GIS, Remote Sensing and Database Management.
- To promote the establishment of a regional network so as to stimulate the exchange of expertise and experience.
- To create local expert groups which should guarantee the regular monitoring in the future

Hydre project : 1994 milestones :

- May - Nov.: Development of independent regional systems using regionally available data.
- June - Sep.: Structural analysis of water resources and demands in Andalucia.
- November: Termination of a study on the improved interpolation of meteorological data.
- December: Termination of the first complete regional system for the region of Andalucia.

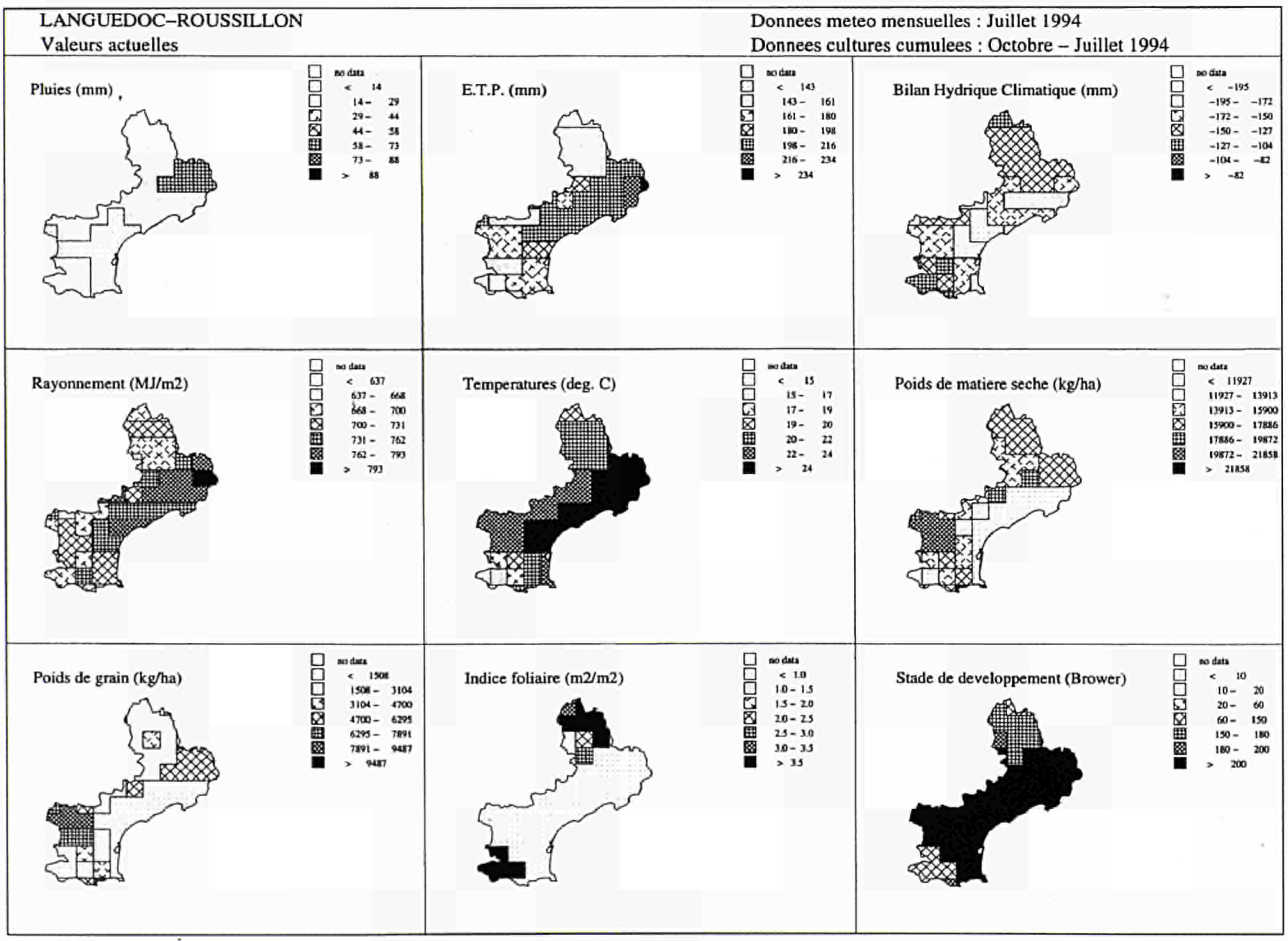


Figure 2.8: An extract of the Hydre Bulletin for the Languedoc-Roussillon region

Background

The Mediterranean region is characterised by a strong seasonal and inter-annual variability of precipitation, giving rise to regular events of droughts with adverse effects on the ecosystem and its hydrological resources. Moreover, the last decades have witnessed a permanently increasing demand for water, resulting in serious problems for an adequate provision of water during dry years.

In response to this situation the Conference of Peripheral Maritime Regions of the EU and the E.U. Directorate General of Regional Politics have launched the HYDRE project in order to promote the establishment of a regional network and to develop a methodology for the real-time monitoring of hydrological resources in the Mediterranean area.

Currently the MARS Project is collaborating with four pilot regions (Andalucia, Languedoc-Roussillon, Sardegna, Sicilia) in order to develop and implement an adequate methodology. Major tools are agrometeorological models and daily remote sensing data from the NOAA AVHRR. Since spring 1993 the project is issuing a monthly bulletin with maps on the regional distribution of various meteorological parameters, the development status of various crops as well as the vegetation index and the surface temperature derived from satellite measurements (see figure 2.8) All data processing from the daily raw data until the final map outputs is handled by MARS.

Perspectives for 1995

Where the acreage estimates at the European scale are operational products, the yield estimates at European and national scales are still in an experimental stadium: they will have to be validated for at least two more years (1995 and 1996) against the real observed yields and official national statistics.

The level of the results - by large region for yields, by 50x50 km grid for qualitative data - is not very satisfactory for certain regions or even countries, which would like to see a finer resolution. The models and systems developed are minimal ones; they can be enhanced locally where there are more reliable basic data. This can be done by transfer and local improvement of the model. At the same time, work must be done on the sensitivity of the models to see what obstacles lie in the way of further precision. If precision is limited by the input data, which is probable, it will be up to the Member States or regions, which sometimes have more detailed data, to improve the model.

Research is planned to achieve a closer integration of the various independent activities of acreage estimates with high resolution satellite imagery, crop yield indicators derived from low resolution meteorological satellite date and agrometeorological yield models.

Within the framework of the Hydre project stand alone systems will be installed in 1995 in each participating region allowing for the independent production of the relevant maps covering the region.
During 1995 the AIS Unit's responsibility should shift from the more technical aspects such as organising the network and the preparation of the regional systems, to the further scientific development of the system.

2.4 MARS-STAT : ACTIVITY D: FOREIGN AGRICULTURAL PRODUCTION FORECASTING

Summary of Objectives

To monitor and forecast before harvest the agricultural production of countries outside the E.U.

1994 PROGRAMME OF WORK

Activities in 1994 have been limited to the overall conception of the methodological approach to be implemented, to the continuation of the work related to the extension of the E.U. soils data base to the PHARE countries, and to prospective work on the collection of meteorological data for the PHARE, TACIS and MAGHREB Countries.

First feasibility studies are being undertaken regarding sampling schemes for high-resolution satellite data and the availability of low-resolution satellite data and meteorological data. The applicability of the MARS systems is being investigated in this context as well.

Perspectives for 1995

Further feasibility studies are planned for the monitoring of foreign crop production.

1994 Milestones

This Activity has not really started yet.

2.5 MARS-STAT : ACTIVITY E: NEW METHODS AND SENSORS

Summary of Objectives

To assess the potential of other remote sensing data to provide information on the area under agricultural crops, the crop state or specific geophysical parameters which can be used as an input for modelling purposes.

To assess the potential of new data analysis techniques for the objectives of the MARS project activities.

1994 PROGRAMME OF WORK

Introduction

During 1994 this activity focused mainly on research and feasibility studies on the analysis of synthetic aperture radar (SAR) data for agricultural purposes and on the prospective integration of the results in the other Activities of the MARS Project, mainly in the Rapid Estimates Activity. These efforts are justified given the fact that currently, the European ERS-1 SAR instrument is in orbit and has been successfully operating since 1991. It will be followed up by ERS-2 in early 1995 and by a suite of other space borne SAR instruments in the following years. Thus, SAR data acquisition is guaranteed far beyond the year 2000.

Throughout the year work under Activity E shifted gradually from experimental studies at the level of a single Activity B test site to more extended feasibility studies over different sites.

Methods and results

A first study concentrated on the complementarity of the ERS-1 SAR data to the optical SPOT-HRV and TM data for one MARS project Activity B site.

A time series of ERS-1 SAR data was pre-processed using software tools developed at IRSA and passed to the operational contractor of Activity B for evaluation in the operational framework. The computer-assisted image interpretation techniques utilised in the Activity B operations were unsuitable for the interpretation of the multi-temporal SAR data. It was also concluded that the exclusive use of ERS data seems to be impractical.

1994 Milestones

Feb. 1994 : Brainstorming exercise, involving European experts, at the JRC to determine the strategy to follow for integrating ERS-1 SAR data in the activities of the MARS Project

Oct. 1994 : Launch of a study on the identification of set-aside and fallow land on time-series of ERS-1 images acquired in the off-season

Nov. 1994 : Launch of a feasibility study on the integration of the results of ERS SAR data analysis, acquired throughout the fall, winter and early spring season for early area crop estimations.

Dec. 1994 : Conclusion of a study on the integration of ERS-1 SAR data in the operational framework of Activity B on Rapid Estimates

Internal research of the MARS project on the same data sets showed, on the other hand increased classification accuracy's when ERS data were combined with the optical data, and, for certain crop types the ERS data showed to have at least similar separation potential if proper data analysis techniques are used (see figure 2.9).

To better understand the different mechanisms involved in the interaction of the microwave signal and the vegetation, a study was launched on both the same site and an extended site in Germany, where extensive site knowledge is combined with advanced SAR data analysis techniques such as interferometry and microwave back scatter modelling.

A second line of research was initiated in the framework of IRSA's Exploratory Research activities. The basis of this activity lies in the fact that traditionally, early estimates of crop acreage are derived from optical remote sensing data sets. Because crop classification with optical data is carried out on the basis

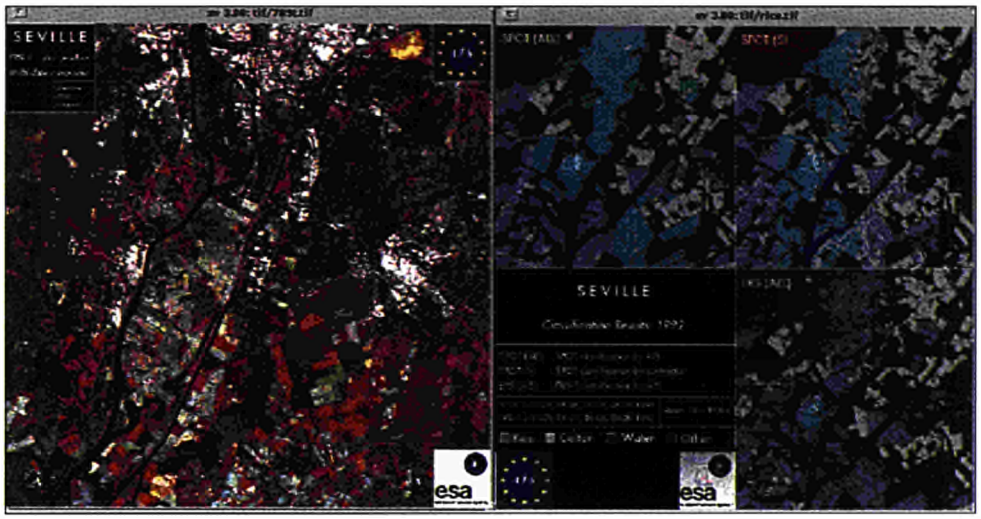


Figure 2.9 : A comparison of SPOT multidate classifications and ERS-1 SAR data classifications.

of spectral signatures of the characteristic vegetation canopies, image acquisition is restrained to the growing season.
The operationability of this approach is further limited by cloud cover, which can render imagery partly or completely useless.

It is well known that radar sensors, in particular SAR systems, are not sensitive to cloud cover, and can operate independently from sun illumination. The back scattered signal, which underlies SAR image formation is both sensitive to surface structure and material composition of the surface elements. Multitemporal SAR acquisition might, therefore, enable the detection of changes at the surface.

SAR imagery can be used to distinguish bare soils which vary in surface structure and moisture content. In fact, quite accurate back scattering models have been developed which can be used to support classification of bare fields in SAR imagery. Through monitoring of bare fields, tillage activities can be registered and, with the help of local ground data and other a priori information, linked to future crop types. Combined with classification results from the previous year, and (a combination of) early season optical and SAR data, it should be feasible to significantly increase the overall classification accuracy's and to obtain reliable crop acreage estimates at a much earlier point in time.

Following the same reasoning a more directly applicable feasibility study was launched with as the main objective the early estimate of non-agriculture land (set-aside, fallow, bare soils) in the framework of the Rapid Estimates of the European MARS project. The methodology used is based on the multi temporal analysis of both radiometric and textural properties of laboured fields, fallow and bare soils in ERS-1 images collected at regular intervals during the fall, winter of 1994 and the early spring of 1995, over three different sites of the MARS Activity B.

Perspectives for 1995

The results of the feasibility study on set-aside and fallow-land are expected to be fully validated by the end of July 1995. In addition, the in-depth research study on the Seville site will come to a conclusion by same time. Based upon the outcome of these studies the MARS project will define its strategy for the integration of the ERS-2 data in the operational context of Activity B.

In 1994 the MARS Project placed its activity B and C archives to the disposition of studies in the framework of the SPOT VEGETATION instrument. Throughout 1995 the MARS project plans to contribute to the research activities of several groups working on the SPOT IV preparatory programme.

In collaboration with international partners from Canada and the European Space Agency the MARS project plans to participate to pilot project studies in the framework of the RADARSAT preparatory programme.

2.6 MARS-STAT : ACTIVITY F: CONTROL WITH REMOTE SENSING OF ARABLE LAND SUBSIDIES:

Summary of Objectives

To support DG-VI, Agriculture, in charge of the European Agricultural Guidance and Guarantee Fund (EAGGF), in the definition and testing of methods for using remote sensing as a verification tool for farmer parcel declarations.

To provide the specifications and assure the follow-up of the development of the information systems which are used in the operational context of the control activities.

To assist the EAGGF in the monitoring of the 1994 operational activities

1994 PROGRAMME OF WORK

Introduction

The reform of the Common Agricultural Policy introduced in 1992, entails the determination of subsidies on the basis of cultivated area rather then on production volume. Within the introduction of "Integrated Administrative Control Systems " (IACS), remote sensing has been included as an optional tool to support the official monitoring and verification methods.

In this context, the main interests for "control with remote sensing" are the following:

- to reduce the number of applications to be visited in the field, focusing the on-the-spot checks to non-conform or doubtful applications and, within these dossiers, to the problematic parcels.
- to assist the field inspectors, providing them support such as cartographic and image products.

Based on the experience gained in the MARS-STAT activities of the project, methodologies have been tested and implemented since 1991. The approach proved to be efficient and was transferred to the DG VI and 10 Member States.

The 1994 Methodology

The following activities made up the methodology followed in 1994 :

Selection of control zones and image acquisition:

Control zones are confidentially selected by the Member-States in agreement with the Commission, using especially the GIS MESSA application. Three time windows for the acquisition of satellite images are defined according the crop calendar for multi-spectral images, plus a panchromatic Spot image in early campaign. Reference years are acquired when available for checking the eligibility of the parcels.

1994 Milestones

April 1994 : The MARS Project assured the transfer of the MESSA GIS application to the DG-VI

Aug. 1994 : Beta testing of the CACHOO software system.

By end 1994 : The controls with remote sensing techniques contributed to the verification of 42000 declarations

Preparation of data:

Declared fields are digitised according to the reference documents in use in the Member-States, either from cadastral or topographic maps, from aerial photo or directly on screen from satellite images... Satellite images are pre-processed and geometrically corrected to the highest accuracy, in order to ensure the best superimposition of all the data within a GIS.

Control with remote sensing:

The verification of the land-use within each declared parcel is traditionally carried out by "computer assisted photo-interpretation" (CAPI) (see Figure 2.10). In 1994, new automatic controls of parcels were developed, using both supervised or unsupervised methodologies. Classification accuracy were evaluated for spectral and spatial criteria so that around 40% of the parcels were automatically checked.

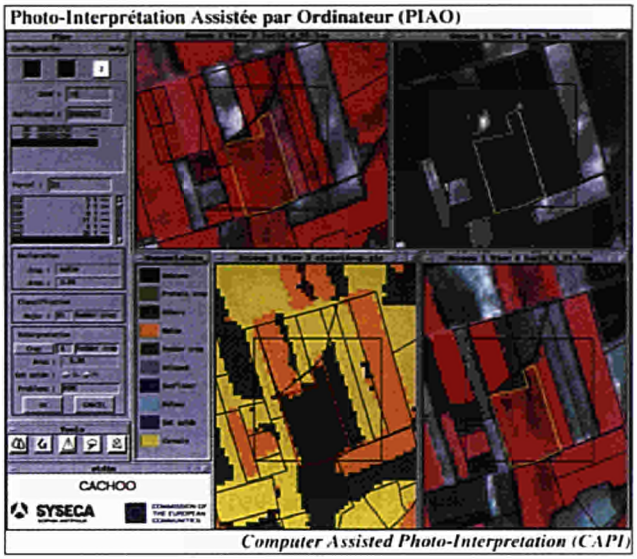


Figure 2.10 : CACHOO Software - Computer Assisted Photo Interpretation

Member States	Number of sites	Number of applications	Area verified (Ha)
Belgium	3	2037	66 805
Denmark	4	2977	108 476
France	3	1672	120 756
Germany	7	390	80 825
Greece	7	7495	25 427
Ireland	2	1016	48 835
Italy	10	9382	80 966
Netherlands	5	3025	32 145
Spain	9	11962	648 657

At the present time, control with remote sensing is one of the most important civil applications of remote sensing in Europe, with a 1995 proposed budget of 20 millions ECU (co-financed by the Member-States).

Dossier categorisation:

Applications are classified into 3 groups: conform, non-conform, doubtful, according to standardised rules and tolerances, taking into account the uncertainties in field measurement and crop identification by remote sensing. A detailed report is printed out for each dossier and image hardcopies are provided for the inspection of problematic parcels.

1994 Results

The 1994 campaign covered, all over Europe, 56 "sites" defined as a 25 km radius circle and implicated the "real time" acquisition and processing of around 250 satellite scenes (mainly SPOT data). According to the specific management of acquisitions, data were delivered to the contractors within 4 to 6 days after acquisition.

In 1994, Remote sensing verifications of arable-land-subsidies operationally covered 42 000 applications with a total budget of 15 Millions ECU (DG VI, EAGGF).

Direct support to the DGVI in 1994

The MARS project assured in 1994, the following tasks:

- definition of technical recommendations, in order to homogenise the methods and criteria used by the different contractors;
- technical monitoring of the operation, focusing on the new contractors;
- evaluation of the results and preparation of the 95 campaign;
- transfer of the MESSA GIS application to the Computer unit of the DG VI;
- technical follow-up and validation of CACHOO software.

The MESSA Application

In order to assist the selection and the programming of the sites to be controlled by remote-sensing, the MARS project developed, since 1991, a GIS application, using ARC-INFO, Oracle software and the two following Databases: GISCO administrative units and boundaries, Satellite coverage of Europe (MARS archive), containing Spot and Landsat grids and available images.

This application was run by the MARS Project in the 1991-1993 time frame to assist the EAGGF in the site selection procedure. It also archives the location of the sites controlled over the years.

The transfer to the DG VI was decided in order to increase the efficiency of the system:

- reducing the time between the different exchanges between the Commission and the Member States;
- and insuring the best confidentiality of the information.

The CACHOO Software

In order to sustain the competitive development of the Control by Remote-Sensing and to avoid monopolistic situations, DGVI (EAGGF) decided in 1992 to develop software dedicated to this application.
This software, named CACHOO , was developed in 1993 and 1994 according to the specifications of the MARS project.
The MARS project provided technical assistance during this development :
- for the phases of specification of the software,
- for the follow-up of the developments,
- then, for the validation and tests of the successive versions of CACHOO.

Beta tests were also prepared in 1994 and should be carried out, during the beginning of 1995, with 3 contractors experienced in Control with remote sensing.

Perspectives for 1995

The following lines of activity will be followed by the MARS project in 1995 :

New methodologies using aerial photographs

The development, specification, and evaluation of methods using aerial photographs to complement (area measurement) or to substitute satellite images (suitability to small structure, sampling strategy, ...). Three contractors used such data in 1994, this number is likely to increase in 1995.

Quality controls

To define, test and implement different procedures for a quality control of the contractors. Some of the controls will be conducted by the MARS project at the JRC, using CACHOO software, or transferred into the National administrations.

Increased direct support to national Administrations

Through visits made to the contractors at the request of National Administrations , but also through Training-courses and Workshops organised at IRSA

Software support and development:

According to the strategy of the EAGGF and the requirements of the Member States, the MARS project shall support the development, the maintenance, or the integration within the IACS of CACHOO software.

.7

MARS-STAT : ACTIVITY G: IMPLEMENTATION OF THE INTEGRATED ADMINISTRATIVE CONTROL SYSTEM WITHIN THE MEMBER-STATES.

Summary of Objectives

To provide technical support to DGVI in the definition and follow-up of the implementation of Integrated Administrative Control System within the Member-States

PROGRAMME OF WORK

Introduction

The new Common Agricultural Policy (CAP) set up in 1992, is based on direct subsidies to the farmer, calculated on the basis of declared areas. This system concerning most of the major European crops (cereals, oilseeds, proteagineous) and the fodder areas, is aims to reduce the agricultural production, while at the same time maintaining agricultural structures and promoting more extensive and environmentally sound cropping practices.

For this purpose, the Member-States expressed the need to define and implement appropriate Integrated Systems, dedicated to the administration and control of their farmer's declarations (IACS). This computerised systems will manage each year various databases related to farmers, their agricultural parcels and their livestock. The system will also provide summary statistics that will enable an overall monitoring of agricultural changes at a regional or macroeconomic level.

The IACS systems, dedicated to the administration, management and control of the area subsidies, should be implemented within the member-states before the 1 January 1996 (regulations 3508/92 and 3887/92). Such a system, relies on a parcel identification system. According to the national contexts, different choices have been made by Member-states, either to use existing maps (land registers, Ordnance survey or large scale topographic maps) or to create new reference maps and numbering systems (using aerial photographs and orthophotomaps, compiling the declaration of the farmers, etc.)

1994 Milestones

Feb. 1994 : Launch of the SIPGEM study

Sept. 1994 : Launch of pilot studies for the creation, in Greece and Portugal, of orthophotomaps and block identification systems

1994 Results

The activities of the MARS project in 1994 covered the followings points:
Visits to member states and evaluation of technical problems according to their choices.

The definition and launch of a study, SIPGEM which entails an analysis of the requirement of the regulations and of the functionalities of the parcel identification and management system.

Elaboration of technical recommendations on field measurements and tolerances. With the identification and the practical evaluation of a new technology using GPS (Global positioning systems). The MARS project expressed a high interest in the new code processing GPS used in differential mode. The low cost, the ease with which this equipment can be handled by single operators and the sufficient accuracy, makes this technology a strong candidate for future verification work.

Defining of specifications and monitoring of pilot studies for the creation, in Greece and Portugal, of orthophotomaps and block identification systems.

Perspectives for 1995

It is planned to make orthophotomaps for large areas in Greece and Portugal. The MARS project will support the EAGGF in defining the areas to be covered and to assure the project follow-up and quality control of the deliverables.
An evaluation study will be run to establish the feasibility of using GPS technology for the operational activities of the MARS project.

7.8 MARS-STAT : ACTIVITY H: AGRICULTURAL REGISTERS

Summary of Objectives

To provide technical support to DG VI and the Member-States for the implementation and management of

1994 PROGRAMME OF WORK

Introduction

In 1994 the MARS-CAP project acted as the technical adviser to the different units of DG VI in charge of the Market Common Organisation of Olive Oil (DG VI C4), of Vine and Alcohol (DG VI E2), and of Fruits (DG VI E1), for the implementation and the management of the three registers: Olive Tree, Vineyard and Citrus-Tree Registers.

1994 Results

In 1994, the activities have been strongly reduced by the Commission on the two last Registers, and the MARS-CAP activities were focused on the following points:

Vineyard registers:

The MARS project started the synthesis of 4 reliability surveys carried-out in 1993, over pilot sites, in France, Spain, Italy and Germany.

This study will remain an internal document for the use of the Commission, comparing and highlighting the results of theses national studies, in order to ease identification of relevant information and to provide a basis for the technical recommendations for the future preparation of a possible "simplified register" (presently discussed in the frame of the new M.C.O.)

Olive-tree registers:

The MARS project finalised the follow up and the evaluation of pilot projects carried out in Greece and Portugal by contractors. These operations present a detailed diagnosis of the difficulties and problems encountered and propose a strategy to solve them in the framework of National programs.
From these results, a first version of technical specifications was produced by the MARS-CAP project and is now been discussed between the Commission and the National Administrations.
In the other countries, (Italy, Spain, France), support was focused on the follow-up of the implementation or the updating of the registers:

- Spain: technical analysis of the 1994-97 plan for the setting up of the Olive tree register.
- Italy: technical analysis of the technical and financial proposal of EIMA for the updating of the register (in relation with 2158/92 regulation)
- France: support for the technical analysis on the computer equipment proposed by the SIDO.

Perspectives for 1995

The national programs for the creation of the Olive-tree Register are envisaged to begin mid or end of 1995.

After the completion of the Vineyard reliability studies, the activities on the Vineyard Register could be focused according to the new policies under discussion, in order to define the specifications of a so called "Simplified Register" which is mentioned in the project of regulation.

At the request of the Commission, the MARS project will carry-out a reflection on the complementarity and relationship between the Registers and the Integrated System. For some Mediterranean Countries, the two operations require important investments for the creation of large scale maps, and some of these costs could be reduced if a co-ordination is realised between the projects. The harmonisation of technical choices and programs should then be evaluated. More generally, the principle of the integrated system will require the implementation of cross-checks between the parcels registered within the different systems, Register or IACS. This will implicate, in medium to long term, to assess the feasibility and

interest of different levels of integration between these systems: simple exchange of data (compatibility of data bases and numbering systems), integration of the databases, simplification of the registration or of the updating process. In this context, the MARS project might launch, in relationship with the DGVI, a feasibility study on several pilot sites in Spain, Italy or Portugal.

.9

MARS GEOGRAPHICAL EXTENSIONS

Summary of Objectives

To support the transfer of MARS methods and technology to countries outside the E.U, with in order of priority, the PHARE countries, the TACIS and the Maghreb countries.

To establish close collaboration with those foreign states through joint activities and training programmes.

1994 PROGRAMME OF WORK

Introduction

The monitoring and forecasting of crop production outside the E.U was initiated in 1994 by the MARS project. First feasibility studies were undertaken regarding sampling schemes for high-resolution satellite data and the availability of low-resolution satellite data and meteorological data. The applicability of the MARS systems was investigated in this context as well.

Since 1991, the MARS Project has been extending some of its activities into Central and Eastern Europe. The collaborative efforts of the MARS project for the transfer of methods and technologies reached a higher level of activity in 1994.
In those countries where the agricultural structure is rapidly changing, consistent and updated agricultural statistics are required. The previously existing methods of data collection are not always well adapted to the new production systems and monitoring of ongoing changes is hard to be achieved. This is the main reason why some national institutions and the Ministries of Agriculture in particular, have been manifesting their interest to use the operational techniques and systems of MARS, adapted to the countries specific conditions.
The MARS project undertakes in this context activities in the framework of the MERA (MARS and Environmental Related Applications) Project, within the PHARE Regional Environment Programme. The MERA Project also includes activities, conducted by other Units of the Institute for Remote Sensing Applications, in the field of forest monitoring and soill erosion mapping.

1994 Milestones

June: Stratification of Slovenia. Regional Inventories activities in Czech Republic, Romania, Slovenia.

July: Technical specifications of the hardware/software configuration to be provided to 6 central eastern European countries within the PHARE Regional Environment Programme.

Sept.: Start of the MERA (MARS and Environmental Related Activities) Project in Poland: Regional Inventories and Agrometeorological Modelling.

Nov.: Workshop for central eastern Europe on "Agrometeorological Models Theory and Applications in the MARS Project", Ispra Joint Research Centre.

Regarding the institutional framework of MARS extension to Central and Eastern Europe, the main concepts are:

- The creation of comparable agricultural data bases and statistics in order to support the harmonisation of available information and the integration of the region with European Union countries,
- The transfer to Central Eastern Europe of methodologies used at operational level in the European Union.

The MARS - MERA project

The MARS MERA project includes activities of technical support to the countries, hardware-software transfer, supply of satellite imagery, organisation of training courses, workshops and conferences.

The 6 countries and respective National Focal Points of the MERA Project are: Poland (IGIK, Warsaw), Hungary (FOMI, Budapest), Czech Republic (GISAT, Prague), Slovak Republic (Soil Fertility Research Institute, Bratislava), Romania (Agriculture Remote Sensing Centre, Bucharest), Bulgaria (Ministry of Environment and Ministry of Agriculture, Sofia)

The following MARS training activities were executed within the MERA Project:
- Workshop for central eastern Europe on "Agrometeorological models theory and applications in the MARS Project", Ispra, Joint Research Centre, 21-25 November 1994
- "Training Course on MARS Regional Inventories, Theory and Applications", Prague 27-31 March 1995.

The MERA Project also includes a component of hardware/software transfer.
A hardware software configuration is being delivered to each National Focal Point of the 6 PHARE MERA countries. This equipment includes two work stations equipped with Image Processing, Geographic Information System and Relational-Data Base Management software. MARS dedicated software is also provided, in order to assist the acquisition and processing of the information collected in sampling points.

An area frame sampling technique has been implemented, complemented by high resolution satellite data, to obtain statistics on acreage and yields for the main agricultural crops, as well as information concerning ownership and exploitation structure of the land. For the past 3 years, results have been available in an operational way in Czech Republic and Romania.
These results were accepted by the national authorities and a decision was taken on the continuity of the activity, partially or totally financed by the country. Crop acreage figures were also produced in Slovenia in 1994 by the Statistical Office using MARS Regional Inventories methodology.

In 1994, MARS Regional Inventories methodology was applied to 79.000 km2 in Czech Republic (entire country), 45.166 km2 in Romania (about one quarter of the country) and 6682 km2 in Slovenia (one third of the country). In 1995, the area covered in Romania will be extended to 94.000 km2. The size of the sampling plots, called segments, may vary between strata and ranges from 400 m x 400 m in Slovenia to 1 km x 1 km in Czech Republic.

The possibility of monitoring and forecasting agricultural production is also of interest for national planning. This may be achieved by using the MARS agro-pedo-meteorological model, running in a GIS environment. Once implemented the necessary GIS and the database, with the required parameters, other environmental related applications can be developed, not only in the impact of agriculture in other land uses and in the environment, but also on other component of the land cover.

This GIS is used for agro-meteorological modelling and yield forecasting. This integrated system was implemented in the European Union and is being adapted to Central Eastern Europe. It uses meteo, soil and crop parameters and includes a crop growth model.

A soil data base was created for the European Union by improving and adding new attributes to the existing E.U. Soil Map (1:1 000 000 scale). This data base is being extended to Central Eastern European countries.
It covers presently Poland, Hungary, Romania, Bulgaria, Czech and Slovak Republic and will be used for agrometeorological modelling. This spatial data base will next be extended to Baltic States, Slovenia, Albania and Croatia. The GIS output data are agrometeorological products and yield forecast for selected crops.

It should also be mentioned that a co-operation with Russian Institute for Land and Ecosystem Monitoring has been performed, including a comparison between Russian and MARS models for yield forecasting.

Perspectives for 1995

Further feasibility studies are planned for the monitoring of foreign crop production.
The extension of MARS activities to Lettonia, Estonia, Lithuania, Albania and Slovenia is presently being considered within the 1995 PHARE Regional Environment Programme.

3 ENVIRONMENTAL MAPPING AND MODELLING

Staff

Scientific and Technical Support:	15
Secretarial Support:	1
Visiting Scientists:	-
Students:	8
Total:	24

Facilities

Unit local area network with

- 1 Sun-4 acting as mail server, main NIS server, Parsitec parallel computer front end.
- 5 Sun Sparcstations (SunOs 4.1.3).
- 3 Sun Sparcstations (Solaris 2.3)
- 3 DECstations (ULTRIX).
- 7 DEC AXP workstations (OSF/1).
- 10 IBM-compatible Personal Computers.
- 2 clustered DEC VAX 4000 (VMS) with TCP/IP/NFS acting as disk servers (13.6 GB), data backup servers, magnetic tape entry servers.
- Software licenses for ORACLE, ArcInfo, ERDas, PCI ENVI, Easi/Pace, IDL, software development tools for C language, FORTRAN, PASCAL, xpert system builder FLEX, neural network package MIMENICE, Imaging Spectrometry analysis software SIPS, GENESIS.
- A0 size pen plotter, digitising tablet, video digitiser.
- In-house funded PC based integrated GIS and image analysis package (PC-Imega).
- In-house software packages for: Image handling, statistics, format conversion, display; DTM-based geometric corrections; Atmospheric correction; Multispectral adaptive filtering; Segmentation and regionalising; Spectral unmixing; Multi-stage distance based classification; Neural Network image analysis; Knowledge based reasoning.

The research and development work carried out in the Environmental Mapping and Modelling Unit (EMAP) concentrates on two main themes. Firstly, mapping various European landscape components, and secondly, developing monitoring, management and protection methods based on the combination of remotely sensed data, dynamic models and Geographic Information systems.

During 1994 EMAP's mapping and monitoring activities specifically addressed forest monitoring and Mediterranean land degradation. Associated with these thematic issues was work on image understanding. This continued the development of automatic classification, mapping and map generalisation methods from remote sensing data. This developmental work is necessary if the full potential of remote sensing for Environmental monitoring and mapping is to be realised.

The Unit's work on Mediterranean land degradation mapping and monitoring stems from two technical opportunities:

a) Mapping complex "natural" landscapes from satellite imagery poses particular problems; the main components of the landscape are present at such fine scales that most pixels, even those from high spatial resolution data; contain mixtures of these components. However, EMAP together with a few other laboratories worldwide, is developing quantitative methods to deal with such problems.

b) There are now reasonable time series of suitable data (Landsat TM from 1983 on, SPOT from 1986 on) with which to study vegetation and soil dynamics.

In 1994 EMAP extended their work on the mapping of green vegetation, soil development states and rock outcrops (parent rocks) from the original test sites in the south of the Département Ardèche (F) and the Northern Pelopponese (GR) to new Spanish and Italian sites. A range of study areas is needed to test the methods as a means of analysing various European landscapes. In 1995 the investigation will also be extended to Crete and possibly to Tunisia.

The second thematic line, forest monitoring, stems from EMAP's research into the role of remote sensing for mapping the diversity of, and monitoring the behaviour of the large permanent vegetation communities of Europe: forest, grassland and natural vegetation. For example, forest mapping in the Grand Duchy of Luxembourg was successfully carried out from satellite imagery, once the effects of slope and exposure on radiometry were taken into account.

The FIRS Project (Forest Information from Remote Sensing) was continued. The major objective of FIRS is to contribute to the development of a unified European forest information system providing both sectorial (i.e., production related) and environmental (i.e., ecology related) forest information. This year priority has been given to the development of the three "Foundation Actions" of the project: regionali-

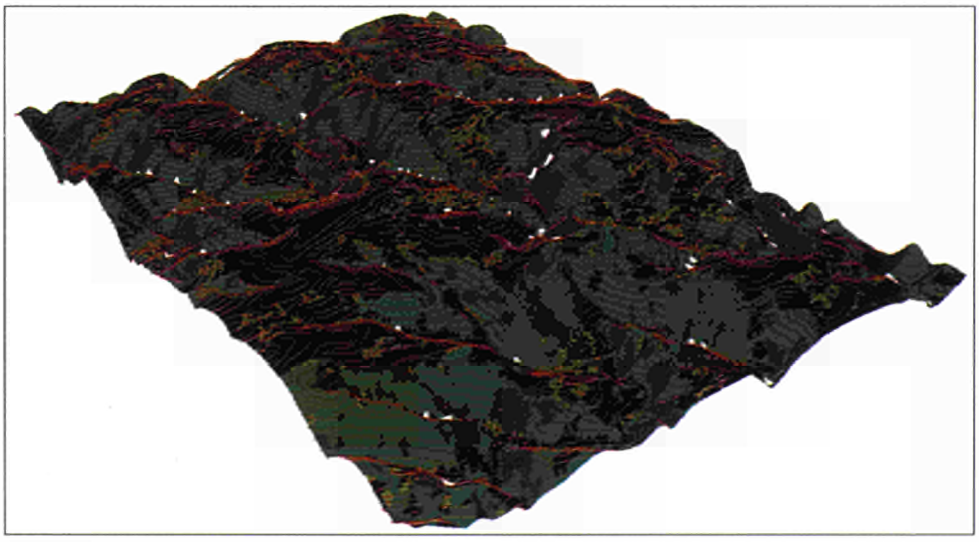


Figure 3.1: The Heiderscheid area in Northern Luxembourg has been used for studying the influence of illumination and shadow (in undulating terrain) on mapping forest types.
The result of the classification of multitemporal Landsat TM data is draped over the digital terrain model in a 3D perspective view (red level curves).
Green: deciduous forest
Grey - blue: coniferous forest
Yellow: bushes and shrubland
Black: non forested areas

zation and stratification of European forest ecosystems, definition of a workable, unified European nomenclature of forest and, to a lesser extent, the compilation of a geo-referenced forest information directory. As a support to the various actions of FIRS, the production of a forest map of Europe at a scale 1/1,000,000 has been initiated, using the NOAA AVHRR data processed as part of the MARS project (see chapter 2 of this report).

Participation in a network of Chinese and Russian research organisations, together with the IIASA institute (Vienna, A) for the study of the Arctic, sub-Arctic and temperate Eurasian ecosystems is still in a planning phase.

The activities in image understanding were conducted along four main lines.

Integrate neural network and statistical classifiers to optimise the performances of automatic classification by using feature space visualisation as a tool.

Approach the problem of land cover mixture classification by integrating neural network and fuzzy systems, as an alternative way to spectral mixture analysis.

Develop the use of neural networks for less explored problems such as cloud classification and geometric rectification including the detection of control points.

Continue the development on the generalisation of pixel based classification maps to vectorized parcel based products which turns out to be crucial for the further use of automatic classification and mapping products by planners and decision makers.

3.1 LAND DEGRADATION MAPPING IN MEDITERRANEAN ECOSYSTEMS

Summary of Objectives

Mapping and continuous monitoring of vegetation and soil conditions in the Mediterranean member states of the European Union.

Identification of the extension and time dynamics of degradation processes, including landslide mapping and monitoring.

Standardised interpretation of indices derived from satellite data for producing land degradation indicators.

1994 PROGRAMME OF WORK

1994 Milestones

Feb.:	Determination of vegetation cover using multiple model spectral mixture analysis strategies.
June:	Expert workshop on "Remote Sensing for Land Degradation and Desertification Monitoring in the Mediterranean Basin - State of the Art and Future Research", Valencia (Spain)
June-July:	Measurement campaign in test areas Valencia, Guadalentin basin, Montpellier, Southern Ardèche, with spectroradiometer and ground based multispectral CCD camera. Generation of a unique data base for studying spectral unmixing in terms of submeter scale spatial variability in natural environments.

Introduction

Vegetation cover is a key factor for estimating soil stability and soil formation potential. A reliable estimation of this parameter is therefore required. It is known that the Normalised Difference Vegetation Index (NDVI) is susceptible to soil spectral characteristics, particularly where vegetation cover is sparse. The photosynthetic vegetation fraction derived from spectral mixture analysis (SMA) provides an alternative measure of vegetation cover. Choice of adequate models (endmember sets) will eliminate the error induced by soil spectra mimicking vegetation spectral features.

An experiment for vegetation cover estimation was conducted using AVIRIS data acquired in 1991 over the Ardèche/ Gard site. Automatic choice of a "best" endmember set has proven to produce a vegetation fraction which estimates vegetation cover more reliably than NDVI. Endmember sets consisted of at most three spectra (shade, vegetation, background), and differed, for sets of three endmembers, only in the background spectra. The "best" endmember set was chosen to be the one which produced the smallest error between model and actual spectrum within a moving window with a predefined band width (ca. 50 nm).

As expected, the vegetation fraction so obtained proved a better estimator of vegetation cover than NDVI. A reliable estimation of vegetation cover through ground based survey or photo interpretation proved however to be difficult for our site; it is therefore not possible yet to give exact figures of accuracy on NDVI and SMA based vegetation cover estimation.

Concurrent automatic selection of photosynthetic vegetation endmembers was attempted as well: for each point, a "best" vegetation spectrum was determined as above, using models with a fixed set of four endmembers describing the remaining spectral variability; successively the best background endmember was determined using for each pixel the so determined vegetation spectrum as endmember. Results must still be evaluated quantitatively based on more reliable figures for true vegetation cover.

Understanding the limits and potential of SMA for our application requires detailed knowledge about how submeter scale spatial variability translates into the spectral composition of the observed signal. In collaboration with the Department of Geology, University of Washington (Seattle), a field campaign was car-

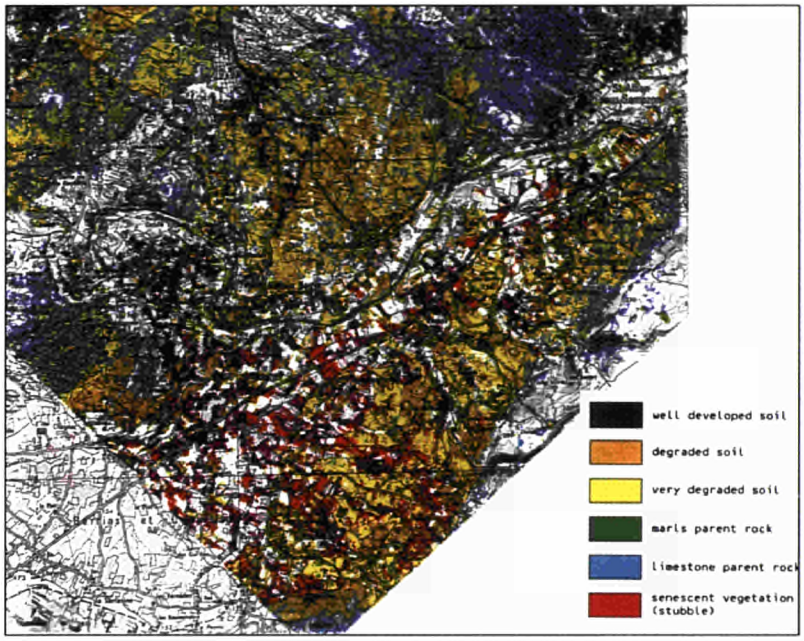


Figure 3.2: Map of various vegetation and soil conditions in the Ardèche test area (F) obtained by spectral mixture analysis with airborne AVIRIS (high spectral resolution imaging spectrometer) data. The white areas are those covered by more than 50 % green vegetation.

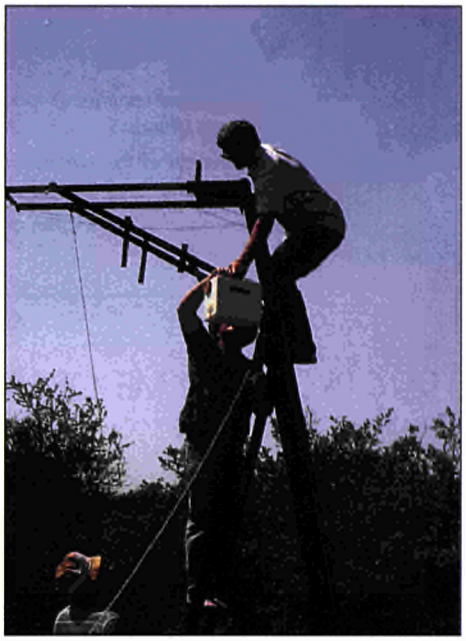


Figure 3.3: Ardèche test area. Mounting the field spectrometer on the 5m high ladder support.

ried out in various areas characteristic of Mediterranean ecosystems: Spectrally detailed measurements of ground patches were combined with data acquisitions of a high resolution multispectral CCD camera. These data will be used to study small scale spectral composition.

A study on landslide mapping and monitoring was initiated in 1994. The activity focused on areas of the Mediterranean region with moderate relief and sparse vegetation. The work, conducted with British and Spanish partners, was based on the analysis of Landsat TM and SPOT Panchromatic imagery in conjunction with high resolution airborne data from the Daedalus ATM system. Studies over test sites in Andalucia and Murcia (Spain) aimed at characterising diagnostic textural and spectral features for landslide mapping. Preliminary results showed that it is possible to map landslides larger than 200 m across from space borne data. The airborne data could map landslides of much finer dimensions.

Perspectives for 1995

The selection of representative observation sites will be finalised such that different processes and contexts of land degradation in the Mediterranean basin will be sampled adequately.

Portability of spectral libraries to geographically different areas of similar lithology and pedogenesys has been verified on a limited scale (Ardèche / Pelopponnese). Verification on additional areas is required. Concise regionalised spectral libraries will be compiled. These will allow combinations of standardised spectral mixture models to be applied. Interpretation will be based on SMA analysis consistent over the whole range of interest of Mediterranean landscapes.

Landslide mapping and monitoring will focus on development of automatic, semi-quantitative methods. SAR Interferometry techniques will also be investigated as a means of slope motion detection.

3.2 FOREST, GRASSLAND AND NATURAL VEGETATION MAPPING AND MONITORING

Summary of Objectives

To develop methods and models at continental and European regional levels for classifying and mapping landscapes, Forest ecosystems and biodiversity by identifying and quantifying their properties.

To provide spatial environmental geo-information for management decisions and actions for environmental protection and regional development .

To analyse and define fields where remote sensing could supplement new insight into environmental processes, especially within forest and grassland ecosystems and areas of natural vegetation.

1994 PROGRAMME OF WORK

Introduction

This chapter describes the work of the FIRS (Forest Information from Remote Sensing) Project. The Project's major objective is to contribute to the development of a unified European forest information system providing both sectorial (i.e. production related) and environmental (i.e. ecology related) forest information.

The geographical area of the FIRS Project stretches from Portugal in the west to the Urals in the east, and from Nordkapp in the north to the Mediterranean in the south. The project has been divided into two main parts; part one, Foundation Actions and part two, Specific Themes.

There are three Foundation Actions:

1. Regionalization and stratification of European forest ecosystems
2. Design of a system of nomenclature for European forest mapping
3. Compilation of a European georeferenced forest data directory

and six major themes:

1. European forest statistics
2. European afforestation monitoring
3. European forest mapping
4. European forest monitoring
5. European forest modelling
6. Mapping and monitoring of European grassland and non forest natural vegetation

1994 Milestones

Feb.: Kick-off Meeting for pan-European Forest Ecosystem stratification and Regionalization study contract.

May: First Interim Meeting for pan-European Forest Ecosystem stratification and Regionalization study contract.

June: International Workshop on 'Designing a System of Nomenclature for European Forest Mapping', Joensuu, Finland.

Sept.: Second Interim Meeting for pan-European Forest Ecosystem stratification and Regionalization study contract.

Sept.: Issue of the Invitation To Tender for study contract on 'Definition of a System of Nomenclature for Mapping European Forests and for Compiling a pan-European Forest Information System'

Sept.: EMAP launches Pilot Study to produce a 1:1,000,000 forest map of Europe.

A study on Eurasian ecosystem mapping and monitoring is also included in the second part of the FIRS Project.

Emphasis in 1994 has been placed on Foundation Actions 1 and 2. Preliminary work has begun on Themes 3 and 4, supported by the development of a 1:1,000,000 forest map of Europe.

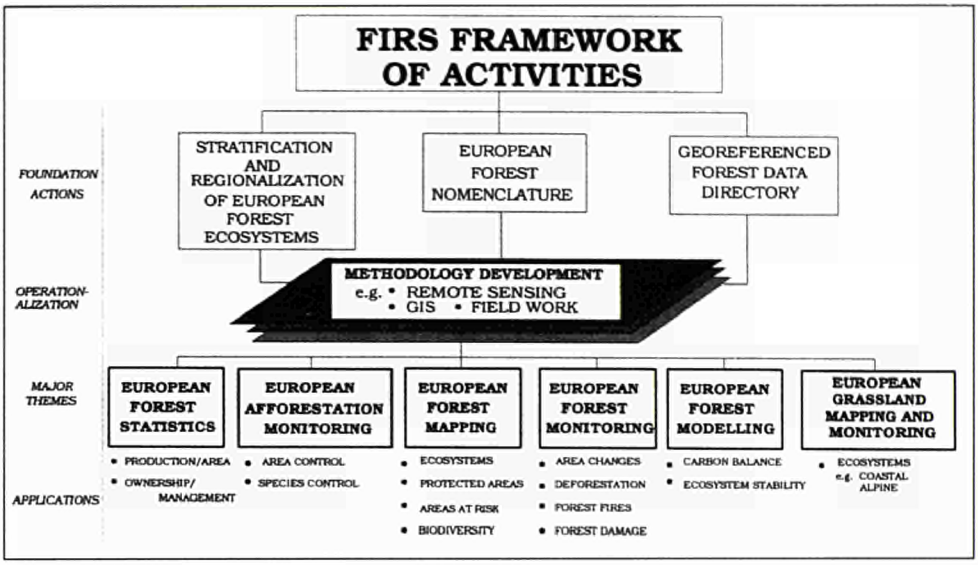


Figure 3.4: Structure of the FIRS Project

Foundation Actions

Regionalization and stratification of European forest ecosystems

The objectives of the study were to determine forest ecosystem regions for Europe, and to sub divide these regions into strata which will be used as the basis both for an area frame sampling for statistical assessments, and selection of representative forest ecosystem test areas for developing mapping and monitoring methods using remotely sensed data. It has been carried out under contract by a consortium of companies lead by Scot Conseil and GAF mbH, and will be completed in January 1995. The final products will include maps, GIS digital data sets and detailed descriptions of the forest ecosystem regions, the strata and the test areas.

Regionalization

A first level of regionalization has been undertaken using information on geophysical variables i.e. climate and topography. A second level of regionalization was based on potential forest ecosystems. A total of twenty two regions have been delineated and validated by regional experts. There are six core regions, 13 transitional regions and three Orobiom (mountainous areas). The Boreal Region is the largest region with a total area of more than 1,800,000 km2. Within each of the regions, test areas will be selected by regional experts.

Stratification

Each region has been subdivided into strata which are homogeneous in terms of pre defined criteria which characterise the forest and have a minimum area of 25,000 km2. 17 criteria ('variables') were identified within two groups and listed in order of decreasing priority. Group A describes the appearance of the forest and includes variables such as forest fragmentation, major species groups and stand density. Group B contains variables describing forest management practices and the function of the forest.

A total of 115 strata have been delineated. The Moderate Temperate Region possesses the largest number of strata (22), while some of the smaller transitional regions contain only a single stratum.

Test sites will be selected within each of the strata for the purpose of statistical assessments initially for three variables: forest / non-forest, forest structure or type and timber volume.

Design of a system of Nomenclature for mapping European Forests

This action will be started at the beginning of 1995. Preliminary discussions on the definition of this Foundation Action took place at an International

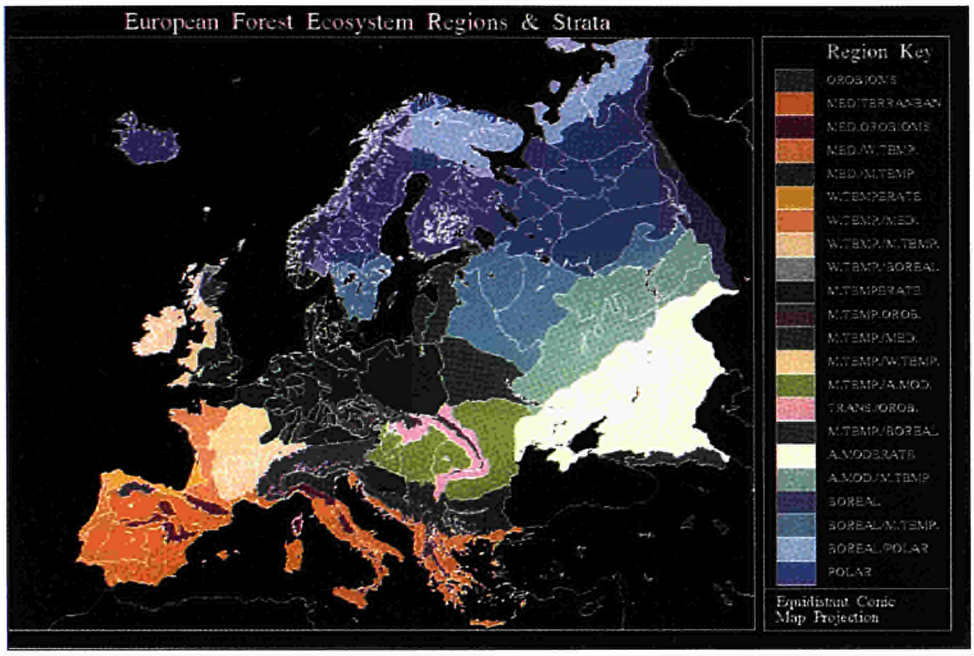


Figure 3.5: European Forest Ecosystem Regions and Strata

Workshop held at the European Forest Institute (EFI) in June 1994. The major aim of this Foundation Action is to provide a system of nomenclature which can be used across Europe for mapping and monitoring forests, based primarily (but not exclusively) on the use of remotely sensed data. Where possible, the system will follow the development of other large forest programmes, such as the UN-ECE (United Nations Economic Commission for Europe) and FAO (Food and Agriculture Organisation) Forest Resources Assessments Project. It will also address the requirements of EUROSTAT and the EFICS (European Forestry Information and Communication System) Programme.

Compilation of a European Georeferenced Forest Data Directory

The action is divided into two parts. The aim of the first part, which is being carried out in co-operation with the UNEP-GRID (United Nations Environment Programme Global Resource Information Database) in Geneva, is to assess and document the type and availability of georeferenced forest data in Europe and to identify the main data providers. A map survey is being conducted by means of a questionnaire. All information describing the maps (e.g. legend, scale) is stored in a database which will be incorporated into the on-line meta database held at UNEP GRID, Geneva and at the WCMC (World Conservation Monitoring Centre) in the UK. The second part will focus on the accuracy evaluation of the georeferenced data and its comparison with information extracted from remotely sensed data.

Forest map of Europe at scale 1:1,000,000

The EMAP Unit is currently undertaking a project to produce a map of European forests at a scale of 1:1,000,000 to support FIRS Project Themes 3 and 4. The NOAA AVHRR (pixel dimension of approximately 1 km at nadir) instrument is being used as the main source of information. This work is being carried out in close co-operation with the AIS Unit.

Methodology

The forest map will use multi_temporal European coverage AVHRR mosaics (geometrically and radiometrically preprocessed). These have been compiled on a daily basis by the MARS Project since 1990. Maximum value NDVI composites for each month will be produced to reduce undesirable atmospheric,

off_nadir sensing and illumination effects. They will be analysed in a stratified manner by following the forest ecosystem regions defined in Foundation Action 1.

Classified Landsat TM scenes and pre_existing ground information (e.g. CORINE Land Cover) will be used to provide sample estimates of European forest cover. The TM scenes will be selected by examination of forest responses in the AVHRR data. They will be classified and used to develop spatio-temporal relationships between the percentage forest cover and the AVHRR pixel spectral values. These relationships will then be extrapolated to the rest of the AVHRR data lying in each forest ecosystem region.

SILVICS Forest Classification Software

The development of SILVICS (Satellite Image Land Vegetation Integrated Classification System) continued. The software provides an environment for preprocessing and classifying multispectral multiseasonal optical satellite imagery, for the purposes of mapping and monitoring European forest cover types.

At present, SILVICS provides procedures for correcting multi-date Landsat TM and SPOT imagery for the effects of varying sun elevation, topography and atmospheric conditions, carrying out various spectral transformations, compiling a database of spectral-phenological profiles, classifying the imagery using various distance measures, and assessing classification accuracy.

Perspectives for 1995

The Foundation Action 1 final report and all digitized data sets will be handed over to the FIRS Project in February 1995. The final cartographic outputs will be:

- A colour overview map at a scale of 1:12,500,000 displaying the forest ecosystem regions and strata (mainly for presentation and advertising purposes).

- A coded map (at a scale of 1:6,000,000) plus digitized data sets for the forest regions, the strata, the test sites and the test areas. Each information layer will be accompanied by a detailed written description relating to the code assigned to the regions, strata, test sites and test areas respectively.

- Digitized GIS layers for the geo-physical variables used in the regionalization procedure.

Foundation Action 2 contract will be launched in March 1995.

Foundation Action 3 will involve strengthening the links with UNEP-GRID, Geneva and consolidation of the preliminary map survey carried out during 1994. The ecosystem information collected for each of the test areas as part of Foundation Action 1 will also contribute to this study.

The response of large forested areas will be examined with respect to the 22 different forest ecosystem regions identified in Foundation Action 1. Statistical analyses will be performed using monthly maximum value NDVI composites. Examination of these data will allow inferences to be made concerning the spatial and temporal variability of the remotely sensed response of forest. The regions found to have significantly different responses will be identifed as being suitable for test site location where higher resolution Landsat TM data can be analysed. Estimates of percentage forest cover will be made from the classified Landsat TM data and used to model the spatio_temporal response of forest regions located in the AVHRR data. The regional models will be applied to the AVHRR data to produce a European percentage forest cover map.

SILVICS will incorporate a number of extensions, in particular image segmentation (per field classification), neural network classification, and ERS_1 SAR analysis.

It is planned to hold the first FIRS Project Meeting in 1995. The main purpose of this meeting will be to present the work which has already been completed under the Foundation Actions and to discuss the detailed definition of the FIRS Project Themes.

3 IMAGE UNDERSTANDING

Summary of Objectives

To develop techniques for exploiting complex remotely-sensed imagery for environmental mapping and monitoring purposes including:

- *improvement of methods for multi-sensor data fusion*
- *processing and reducing image data sets of high feature dimensionality*
- *development of advanced visualization and interaction methods*
- *integrated exploitation of novel neural network and fuzzy systems*

1994 PROGRAMME OF WORK

Introduction

Within the period 1995–2000 the volume of data generated by Earth observation satellites is expected to pass the level of 10 terabytes (1012 bytes) per week –mostly in the form of images. In view of the trend towards the use of multi–sensor and multi–temporal image data sets for environmental applications, it is becoming increasingly necessary to develop fast fully–automated analysis techniques. Ideally these techniques should be suitable for parallel processing, should exploit the best mathematical models, and use machine "intelligence" whenever possible in order to take over tasks that would otherwise be done very slowly by human interpreters. The general goal of developing such techniques is covered by the specific research programme on image understanding.

1994 Milestones

March: Protoype multi-dimensional image data set visua lization experiments completed

June: Experiments completed on using SAR textures for land cover classification in combination with optical satellite data

Sept.: Collection of ground data in Scotland for mixed forest and natural landscape mapping experiments using neural network and fuzzy systems

Nov.: Prototype neural network cloud recognition system completed.

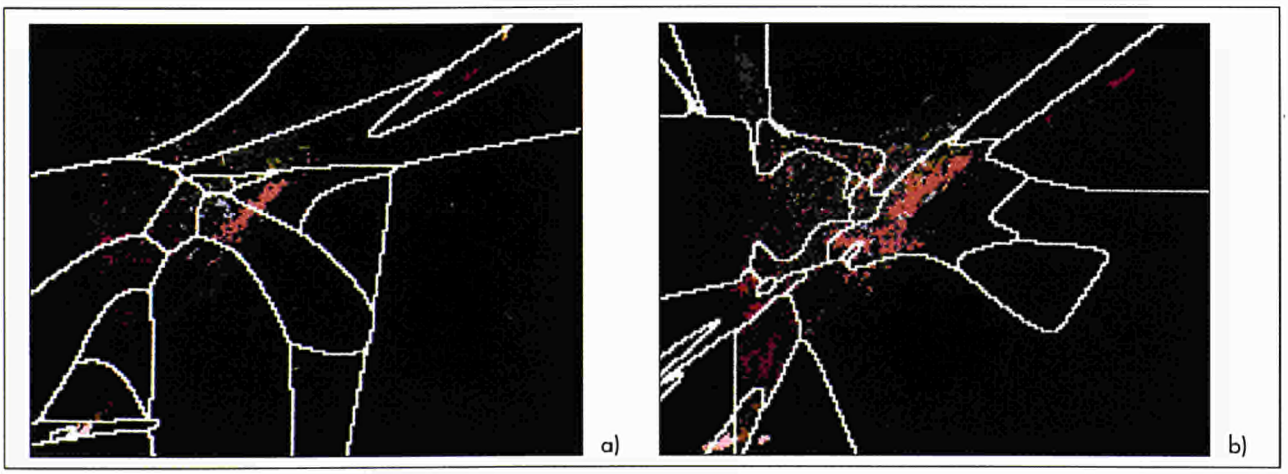


Figure 3.6 (a-b): Illustration of the differences between class discrimination curves in a two dimensional feature space arising from a statistical (maximum-likelihood) classifier (left) and a neural network classifier (right)

Neural or connectionist computing methods feature highly in this research because of their wide capabilities in signal and pattern processing. Indeed one of the main results of the work in 1994 has been a general appreciation of just how wide that applicability can be. In addition a variety of topics have been investigated related to improving the exploitation of imagery such as the development of high quality spatial generalization procedures for mapping purposes and the development of data visualization techniques.

Neural Network Applications

Neural networks can be used to encode many different kinds of mathematical transformations and hence have a variety of uses in remote sensing. One of the main activities in 1994 was a study of the comparative behaviour of neural networks and statistical classifiers using feature space visualization. This work has led to a better understanding of the reasons for the differences between neural and non-neural classifiers which arise from the underlying mathematical models and the topology of the class discrimination surfaces. In addition some unusual neural network architectures were used in image analysis experiments such as counterpropagation networks.

A further significant activity during the year was the development of a neural network method for the detection of linear and curved features in images which could form the basis for geometrical rectification. This was achieved using Kohonen map networks which were used to perform a clustering of the direction and curvature of significant edge fragments. This procedure demonstrated that neural networks could be used for the detection of control points contributing to one of the main steps in geometrical correction. This generated additional confidence that connectionist approaches could be used not only in radiometric processing but also in geometric image operations.

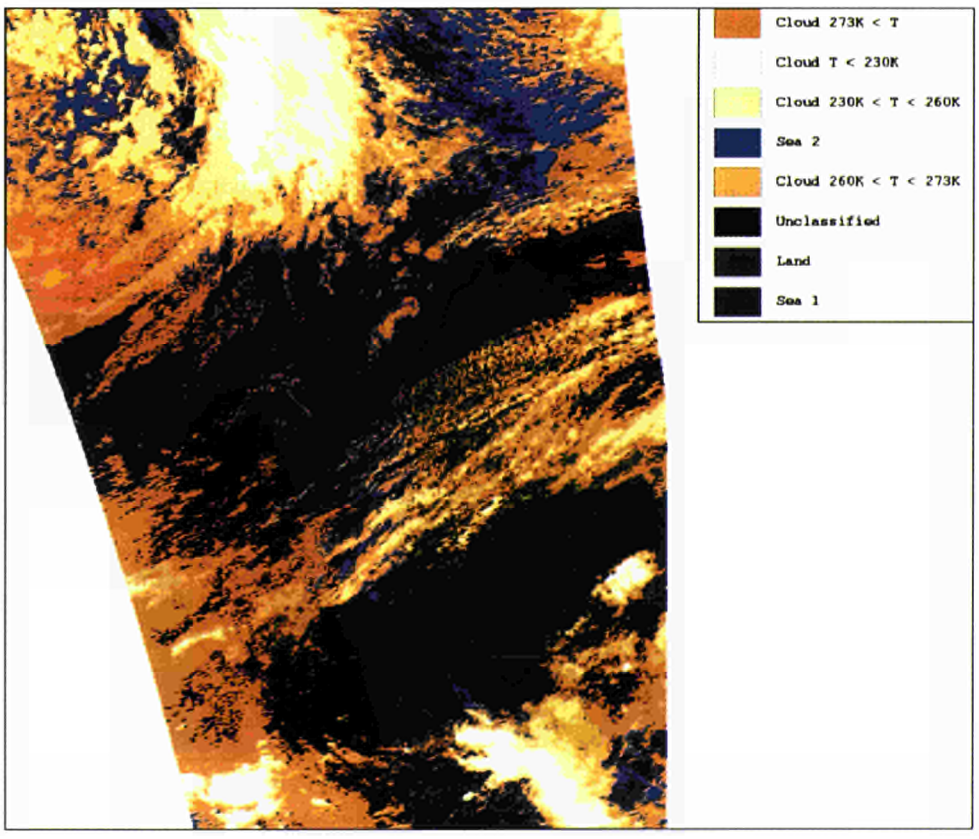


Figure 3.7: Classification of clouds in an Atlantic Ocean AVHRR scene based on an initial clustering procedure using a Kohonen map network with radiance and texture input.

Other work on neural networks demonstrated their potential in a wide variety of supervised and unsupervised classification tasks. This included classification of clouds in NOAA-AVHRR imagery of the North Atlantic Ocean, and classification of land cover using integrated Landsat Thematic Mapper and ERS-1 Synthetic Aperture Radar images. Tests were also carried out on the use of texture measures derived

from ERS-1 SAR images as additional features for land cover classification in multi-layer perceptron networks. Work also began on the integration of fuzzy systems and neural networks in order to carry out land cover mixture classification–primarily for European forest mapping.

Generalization for Mapping

Ultimately most image products from remote sensing need to be expressed in the form of maps and integrated into Geographical Information Systems. This requires spatial generalization from pixel-based products to vectorized parcel-based products. During 1994 work was carried out on developing fully automated generalization procedures in association with the University of Leicester, UK. Although various techniques for raster generalization have been developed in the past, there is still a need for approaches which take into account mapping needs and human knowledge about how to perform good cartographic generalization. The approach under development combines low level and high level (knowledge-based) raster processing.

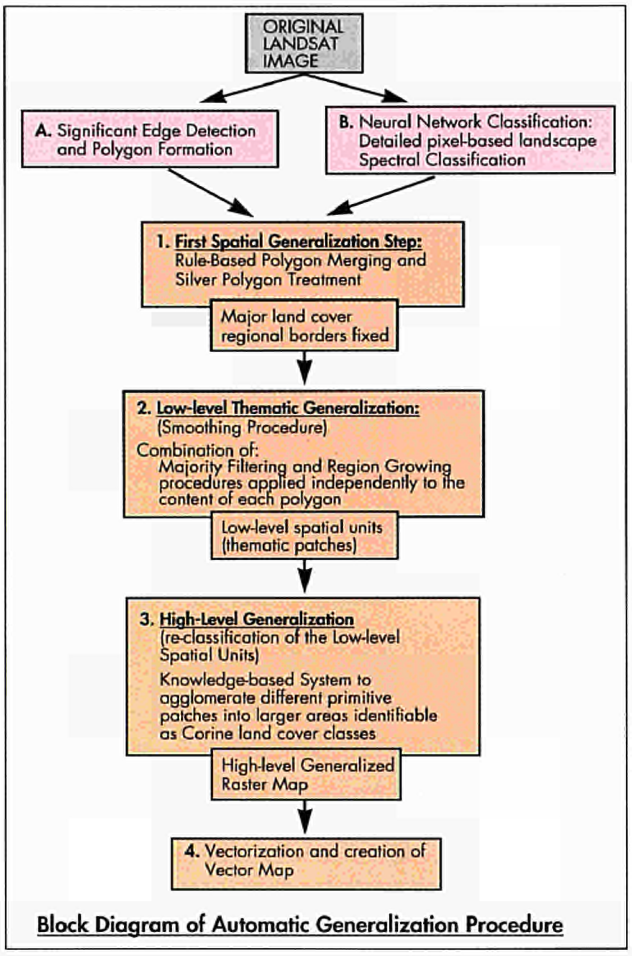


Figure 3.8: Intelligent raster generalization procedure under development for automated mapping.

Perspectives for 1995

It is planned to extend the image understanding activities in the following ways:

- investigation of the technical limits to image classification based on neural and non-neural systems in connection with high dimensionality data sets
- integration of neural and fuzzy systems for land cover mixture analysis
- development of improved visualization and interaction methods
- completion of operational spatial generalization method.

4 METHODOLOGIES FOR UPDATING THE CORINE LAND COVER DATABASE BY REMOTE SENSING

Summary of Objectives

To develop and evaluate the possibilities and limitations of fully automated techniques for land cover mapping and land cover map updating

1994 PROGRAMME OF WORK

Forest Mapping Experiment in Luxembourg

Classical approaches to automatic determination of land cover classes are particularly prone to errors in mountainous areas where variation of illumination will distort observed spectra, causing misclassification. Attempts to correct for sun illumination geometry assuming Lambertian reflection, as reported in the literature, cannot satisfactorily resolve these ambiguities. As an alternative we implemented an integrated atmosphere/illumination geometry correction algorithm which takes into account sun illumination geometry, altitude, and both anisotropic and isotropic diffuse illumination components, retaining the assumption of Lambertian reflection. The validity of this correction has been tested on a site in Luxembourg characterised by deeply cut meandering valleys and consequently a large variation of illumination conditions. The discrimination potential between deciduous and coniferous forests have been compared on TM scenes recorded on four dates (May - December) in 1989, using three classification algorithms (Euclidian Distance, Maximum Likelihood and Neural Network). The accuracies of discrimination range from 85% to 90% with an improvement in discrimination compared to results with uncorrected illumination effect ranging from 3% to 20%.

Corrections for illumination geometry taking into account the anistropic diffuse component appears hence to be more important than the differences between the actual bidirectional reflectance properties of forest stands and their approximation by lambertian reflectance characteristics.

Automated Image Change Detection

Apart from efforts devoted to the development of semi-automated procedures for updating CORINE l

1994 Milestones

Jan.: Development and implementation of image change detection measures

Feb.: Forest mapping experiment in Luxembourg: successful test of atmospheric and illumination correction methodology for land cover classification in mountainous areas.

Aug.: Completion of prototype region based change detection algorithm for use in land cover map updating

and cover maps, work was carried out in 1994 on the possibility of automatically detecting land cover change for use within a computerised procedure. For this purpose a variety of image analysis algorithms, some originating from machine vision research, have been investigated as candidates for parcel based change detection. The detection of changes between separate images at different dates is a complex problem since many factors can influence the differences seen between individual pixels. For example, pixels belonging to the same class demonstrate a significant variance of spectral signatures even within the same scene. Also class-based change detection at the pixel level is highly sensitive to errors produced by the classification process itself. In such circumstances pixel based approaches and reliance on single change detection measures are clearly unsatisfactory. A more realistic approach is to work on the basis of parcel based change detection and on a consensus between a variety of change detection measures. These measures should use a combination of radiance, textural and structural features.

In this work a number of image change detection measures were implemented including:

- image entropy change; cross-correlation; Spearman rank correlation; Average Mutual Information index; Multi-scale salience distance transform (based on detected corner and edge fetures); Pixel differencing based on principal components; Vegetation index differencing.

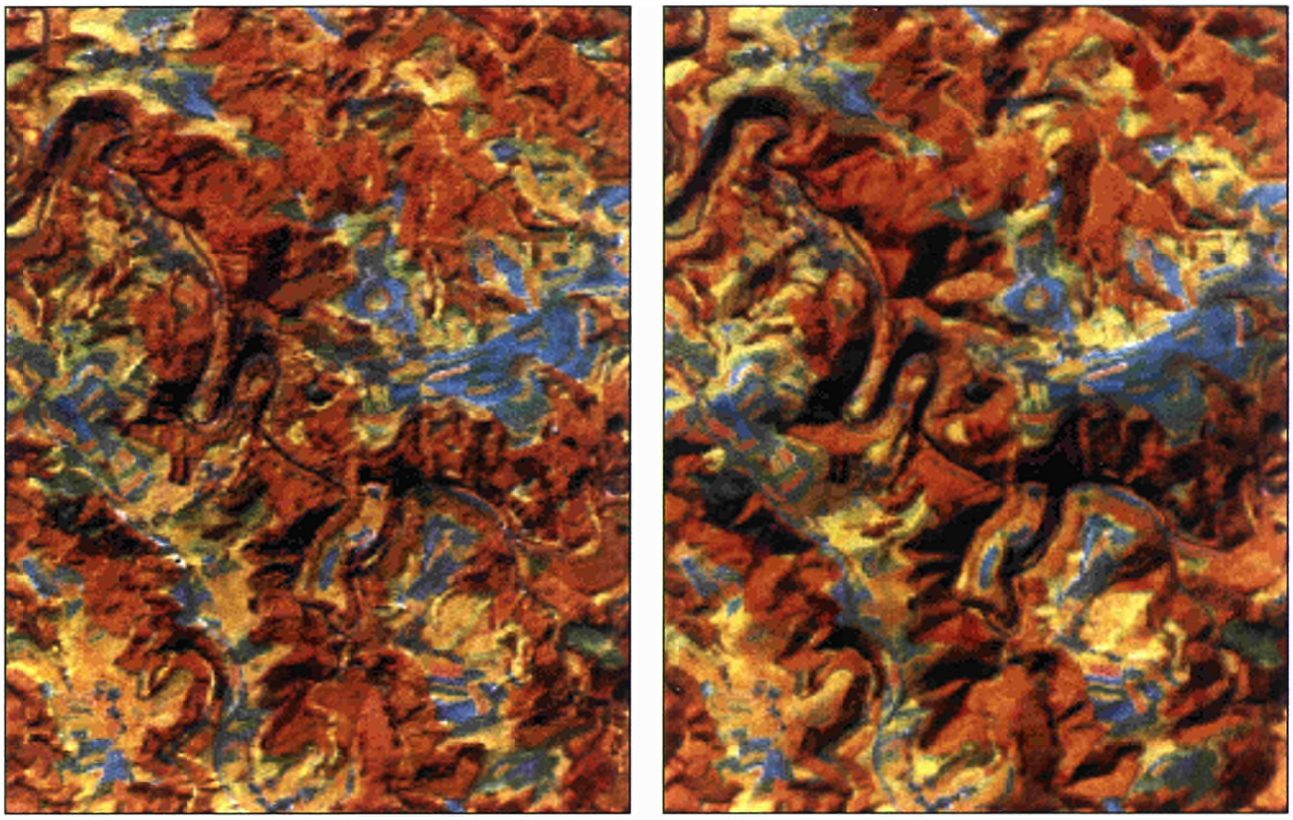


Figure 3.9 (a-b): TM images of the Heidersheid study area without (right) and with (left) illumination correction.

The investigations demonstrated that each measure gave different indications of the likelihood of changes being present in the imagery. In order to create a system capable of exploiting all the measures simultaneously, experiments were conducted on training neural networks to recognize real change areas using the various change measures as input features.

Perspectives for 1995

The algorithm developed for integrated atmosphere / illumination geometry correction is not yet satisfactory for low sun incidence angles (< 55 degrees) or shadowed areas. Improvements are expected by better modelling the distribution of diffuse radiation components.

Larger training data sets, needed to optimize neural network classifyer performance will be construced.

Figure 3.10: Parcel-based land cover change likelihood map derived from principal components analysis of Landsat TM imagery of 1985 and 1991 in Portugal (darker areas indicate higher likelihood of land cover change)

5 FRACTAL MODELS FOR ANALYSIS OF REMOTE SENSING AND GIS DATA

Summary of Objectives

To undertstand the potential and limitations of analytical methods based on fractal mathematics in the processing of satellite imagery and other environmental data.

To stimulate the exchange of ideas at a European level on the application of fractal techniques in remote sensing.

1994 PROGRAMME OF WORK

Introduction

The activities of 1994 related to fractals were concerned primarily with understanding the role of fractals in remotely sensed image analysis and their potential limitations. This goal was achieved by means of technical studies and by the convening of a high level technical meeting with invited experts from all over Europe.

The technical meeting, organized in association with the European Association of Remote Sensing Laboratories (EARSeL) was set up to examine the scope for fractal techniques in remote sensing. Whilst fractals are now being studied and applied in many different disciplines, in remote sensing it has become relatively clear that there is a great deal of controversy about their potential value. The technical meeting addressed such issues as:

- standard and advanced multifractal techniques
- fractal and multi-resolution analysis techniques
- image texture recognition using multifractals
- mapping spatial variability in landscapes
- applications of L-systems in canopy reflectance modelling
- fractal modelling of fall-out dispersion
- fractal evaluation of relief mapping techniques
- characterization of fractal topography.

The technical presentations demonstrated that fractal or self-similar patterns exist widely in nature allowing fractal techniques to be applied in several contexts in remote sensing – such as in the analysis of landforms and simulation of natural objects (e.g. vegetation canopies) for image analysis and synthesis. Generally agreement was reached that "monofractal" techniques are not sufficient for most analytical or modelling activities in remote sensing and that the more sophisticated "multi"-fractal techniques are both more powerful and necessary for most purposes. It was established that fractal scaling laws play a large role in determining what is observable and measurable by satellites and that such scaling laws need to be taken into account when comparing images obtained from different satellites at different resolutions. Interestingly, although the fractal model was proposed as the basis for understanding scale change in remote sensing, this view was not universally accepted and alternatives have been put forward.

1994 Milestones

April: Joint JRC/EARSeL expert meeting on Fractals in Geoscience and Remote Sensing held at Ispra.

Nov.: Technical study completed in association with Cambridge University on the potential of fractal analysis of remotely sensed imagery for soil erosion susceptibility mapping.

Dec.: Completion of technical study by City University, London, on the development of fractal geometry tools for remotely sensed images

Apart from the expert meeting, the technical studies completed in 1994 also demonstrated the potential uses of fractal techniques in remote sensing. The technical study carried out in collaboration with the University of Cambridge demonstrated the potential of fractal techniques in soil erosion risk assessment. In this study, comparisons were made on test sites in southern France and southern Italy between classifications of the landscape into erosion classes using spectral mixture models and fractal image texture models. Using a five class system for classifying erosion risk, the comparisons demonstrated complete agreement between the two alternative methods in 40–50% of cases and of the order of 65% agreement within plus or minus one erosion class. Although the correspondence is far from perfect, it is clear that some useful

information is extracted by the fractal method. Overall, as was also demonstrated clearly in the expert meeting, fractal techniques can be used in a variety of ways in remote sensing, but the results of their application do not so far appear to offer something which other non-fractal methods can not provide.

Perspectives for 1995

The full proceedings of the expert meeting will appear in 1995 as an official publication of the European Commission.

Figure 3.11: SPOT image (band 2) from Basilicata region, southern Italy, May 1990 used for erosion risk evaluation (Original satellite data (c) SPOT Image).

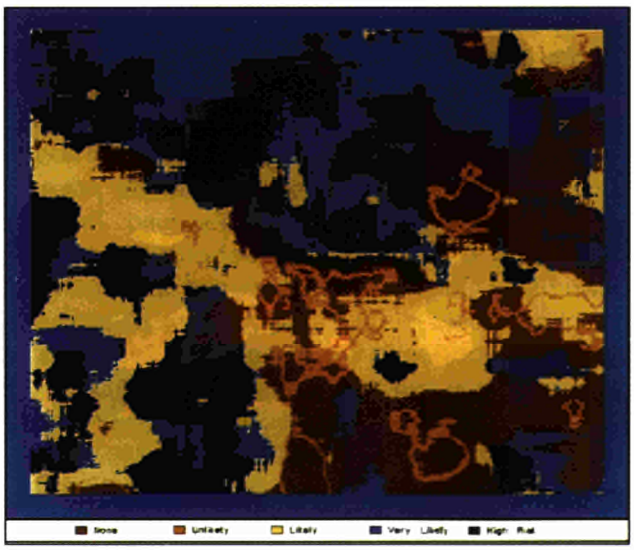


Figure 3.12: Soil erosion risk map for Basilicata region derived from fractal texture analysis of SPOT imagery (from technical collaboration study performed by the Scott Polar Research Institute, University of Cambridge).

4 MARINE ENVIRONMENT

Staff

Scientific and Technical Staff	13
Secretarial Support:	1
Visiting Scientists	2
Students:	10
Total:	26

Facilities:

- Vax 4000 with ERDAS image processing software (including software developed in-house for CZCS and AVHRR data processing).
- PC's with ERDAS and in-house image display.
- SUN Sparc stations for CZCS data archive and data processing.
- DEC ALPHA Workstations for data, image analysis and graphics

Understanding the earth as a system is not possible without sound knowledge concerning 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 modelling and understanding of global climate change, and equally for local investigations and applications.

Remote sensing can play a key part in the observation 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 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 simulation of marine processes to assimilate remote sensing data in process studies and as a contribution to global models.

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

Contribution of Marine Studies to the Analysis of Global Change

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

– Marine biochemical cycles as seen from space:
  This study is focused on implementation of a bio-optical model for the estimation of primary production and phytoplankton dynamics. The model is used to assimilate ocean colour derived chlorophyll concentrations.

– Application of numerical modelling related to marine processes and the assimilation of remote sensing data including:

  - The simulation of marine processes in windows in the Atlantic, with boundary conditions derived from general circulation studies of the Atlantic.
  - Numerical experiments with models for data assimilation.
  - Process studies.

A number of smaller activities and studies are contributing and supporting international projects such as the International Geosphere Biosphere Programme's Joint Global Ocean Flux Study (JGOFS).

Coastal Monitoring

These studies promote the development and improvement of methods for the analysis of ocean colour data and the use of these data in European coastal areas. The advanced features of the upcoming Sea-viewing Wide-Field-of View Sensor (SeaWiFS) sensor will lead to significant improvements in the discrimination of different substances in the water, including the difficult cases of coastal areas.

In 1994 work concentrated on the development and validation of algorithms for SeaWiFS data processing to estimate phytoplankton pigments, suspended sediment and yellow substances in coastal waters. This research activity includes the measurements of the scattering by mineral particles and the light transmission of plankton cells suspended in the water.

Studies on the bio-optical properties of the Baltic Sea through joint experimental campaigns have also been conducted within this activity.

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.

Remotely sensed data are used to describe the temporal and spatial distribution of coastal upwelling and related processes. A major effort has been invested in the extension of multi-annual 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 management of fishery resources. This activity is carried out in support of Di-rectorate General I (International Relations) and in collaboration with Morocco.

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 Colour Scanner (CZCS) from 1978 to 1986, represent an important source of information for understanding biogeochemical and physical processes in the sea. CZCS data over marine regions of European concern are 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 project concerning regions of the North Atlantic Ocean, the Mediterranean Sea, the North Sea and the Baltic Sea.

The experience gained by the OCEAN project provides the basic platform for the development of the OCTOPUS project centred on the application of the SeaWiFS data.

Measurements have been initiated on a fixed offshore platform in the Adriatic Sea to generate a reference set of ocean colour related calibration/validation data.

4.1 CONTRIBUTION OF MARINE STUDIES TO THE ANALYSIS OF GLOBAL CHANGE

Summary of Objectives

To develop, and extend where possible, algorithms that relate remote sensing, ocean platforms and ship suveys, to processes occurring in the water column such as heat flux and primary production.

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

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

1994 PROGRAMME OF WORK

Introduction

Global Change studies examine the interaction between the physical, chemical and biological processes that regulate the Earth's system and that are most susceptible to human perturbation. Two major international programmes that are focusing 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).

The participation by the Marine Environment unit is designed to provide a contribution to the research objectives of core projects of these programmes and in particular to the IGBP's Joint Global Ocean Flux Study (JGOFS).

A scientific network, under the Human Capital and Mobility Programme, was accepted at the end of 1993. The project entitled "Integration of remote sensing, in-situ observations and numerical modelling applied to the Northeast Atlantic" is for a period of 28 months. The networking of data archives using the World Wide Web (internet) has been set up among the six partners, for eventual use with process models investigating the upwelling area.

The following activities have been developed in the framework of the above objectives:

- Joint Global Ocean Flux Study (JGOFS),
- Marine primary production and ocean colour,
- Applied numerical modelling related to marine processes and remote sensing data assimilation,

1994 Milestones

- Contribution to Joint Global Ocean Flux Study (JGOFS),
- Continuation of primary production algorithm development, calibration and validation studies,
- Identification of bio-optical characteristics of NW Atlantic test zone,
- Application of ISPRAMIX model to study circulation in the Atlantic,
- First numerical data assimilation tests with the ISPRAMIX adjoint model,
- Process modelling: suspended sediment transport,
- Continuation of development of dimethylsulphide (DMS) modelling,
- Investigate neural network approaches to classify clouds.

- Other activities include the Centre for Earth Observation; AerosolCharacterisation Experiment (ACE II); Dimethylsulphide modelling,and cloud characterisation using neural network techniques.

Each of these activities are described below.

Global Change Activities: Joint Global Ocean Flux Study (JGOFS).

In 1994 IRSA was officially asked to provide remote sensing support to JGOFS. Initially, IRSA could actively contribute in the areas of ocean colour and derived products (on the basis of extended OCTOPUS activities - SeaWiFS), AVHRR and derived products (Sea Surface Temperature [SST], cloud characterisa-

tion), bio-geochemical process modelling, archiving, and provide resources for Visiting Scientists. Discussions have been initiated with the DG XII MAST Programme to define in more detail a joint support and its is expected that the agreement will be implemented after further discussions with JGOFS.

Marine Biogeochemical Cycles: A View From Space

Photosynthesis in the oceans is of prime importance as the basis of marine food chains and for its role in the global biogeochemical cycles. At the same time, it is recognised that marine photosynthesis and the burial of carbon in marine sediments may be instrumental in long-term fluctuations in atmospheric CO2 and global temperatures.

In this framework, remote sensing can contribute significantly, allowing us to detect changes in the distribution of key-parameters at scales compatible to that required for global change studies. It can also be used to estimate fluxes among the main pools, including atmospheric CO2. And finally, it may be used in models that couple physical, chemical and biological processes at regional and basin scales.

Primary production in the Northeast Atlantic Ocean

The production and fate of organic matter in the oceans are closely linked to the structure of the pelagic biota in the water column. Therefore, knowledge concerning large scale changes in the vertical distribution of chlorophyll is a prerequisite for the derivation of primary production from space borne observations. In 1994 the ME Unit continued work linking remotely sensed measurements in a semi-analytical model to determine the daily rate of photosynthesis integrated over the entire illuminated layer of the North West Africa study area.

Some 326 two-minute CZCS scenes from 1983 were obtained and were processed into maps of chlorophyll-like pigments at the surface, and further analysed to retrieve the integrated primary production in a large area including the major upwelling centres along the Northwest coast of Africa. Figure 4.1 shows seasonal distribution of these quantities. Although strong similarities occur between phytoplankton biomass (fig 4.1.a) and primary production (fig 4.1. b), local differences tend to show the importance of the transition coastal-open ocean areas for productivity. Note also the yearly-permanent feature of high productivity off the coast of Mauritania which extend in southern latitudes during winter and autumn coinciding with the periodicity of upwelling phenomenon in that region.

Phytoplankton dynamics in coastal upwelling

Ocean colour imagery has shown to be important for determining the temporal and spatial variability of the chlorophyll distribution and oceanic primary production. However, understanding the causes of this variability may have a significant impact in predicting the role of the ocean in global carbon cycle and global change studies. To achieve this goal, a coupled bio-physical model has been developed to study the time-dependent vertical structure of the phytoplankton biomass along a transect in the upwelling system off the coast of Mauritania.

As a first attempt, the biological component of the model is restricted to evaluate the biomass and the photosynthetic rate of phytoplankton as a function of light only. Sink terms are maintained constant describing grazing by zooplankton, sinking of phytoplankton cells, and their respiration. Biological and optical formulations are then combined with a 3-D hydrodynamic model (ISPRAMIX).

The coupled bio-physical model has been run to yield a 10-day time-series showing the variation in the vertical structure of the biomass (figure 4.2). Ocean colour images (CZCS) of the biomass field are used in the initialisation and validation of this ecosystem model. In other words, the model output is directly compared with CZCS estimates of the biomass after a 10 day model run. In open ocean (Fig. 4.2 a), the model output shows very good agreement with satellite-derived data, emphasising the necessity to join modelling activities to satellite intelligence to get a synoptic knowledge on plankton ecology. In coastal waters (Fig. 4.2 b), however, the variability in the vertical distribution of biomass seems strongly affected by physical forcing as the coupled model tends to change promptly the structure of the profile. calculated from the CZCS imagery.

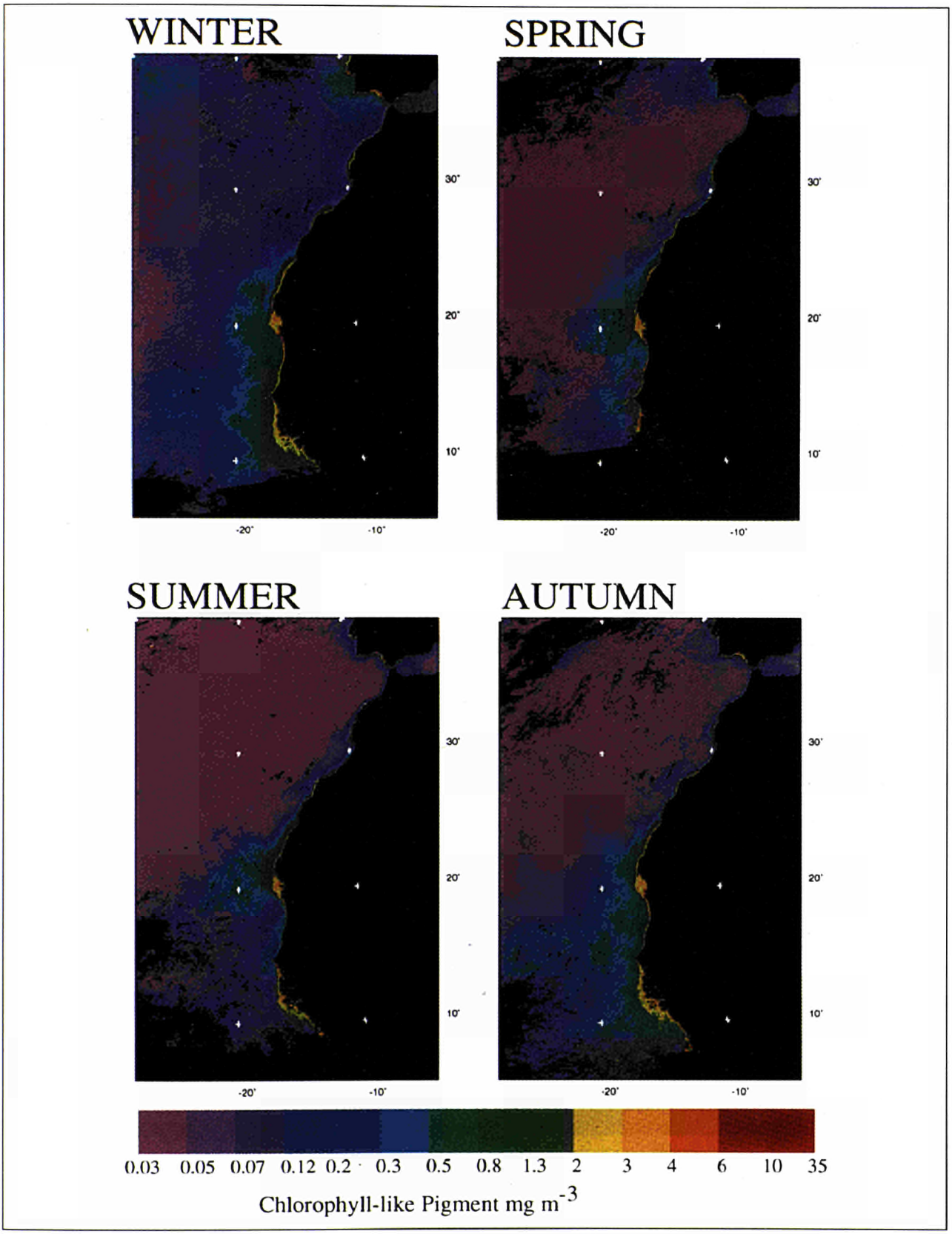
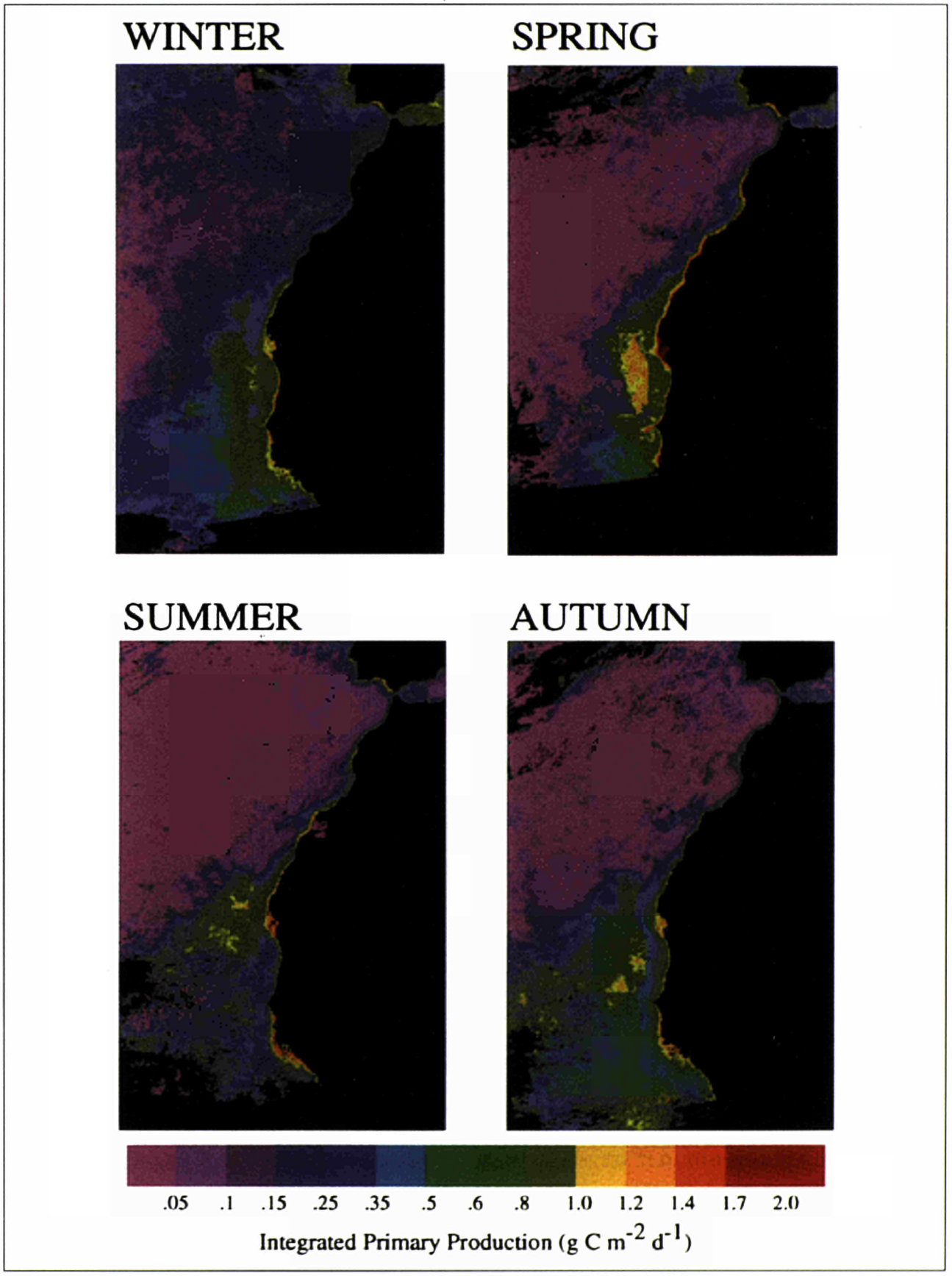


Figure 4.1: Seasonal composites (1983) of chlorophyll-like pigment (mg.m-3) at the surface in the Northeast Atlantic Ocean as derived from CZCS and water column integrated daily rate of primary production (mgC.m-2.d-1) as computed using a spectral semi-analytical model.


WINTER
SPRING
SUMMER
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.05 .1 .15 .25 .35 .5 .6 .8 1.0 1.2 1.4 1.7 2.0
Integrated Primary Production (g C m-2 d-1)

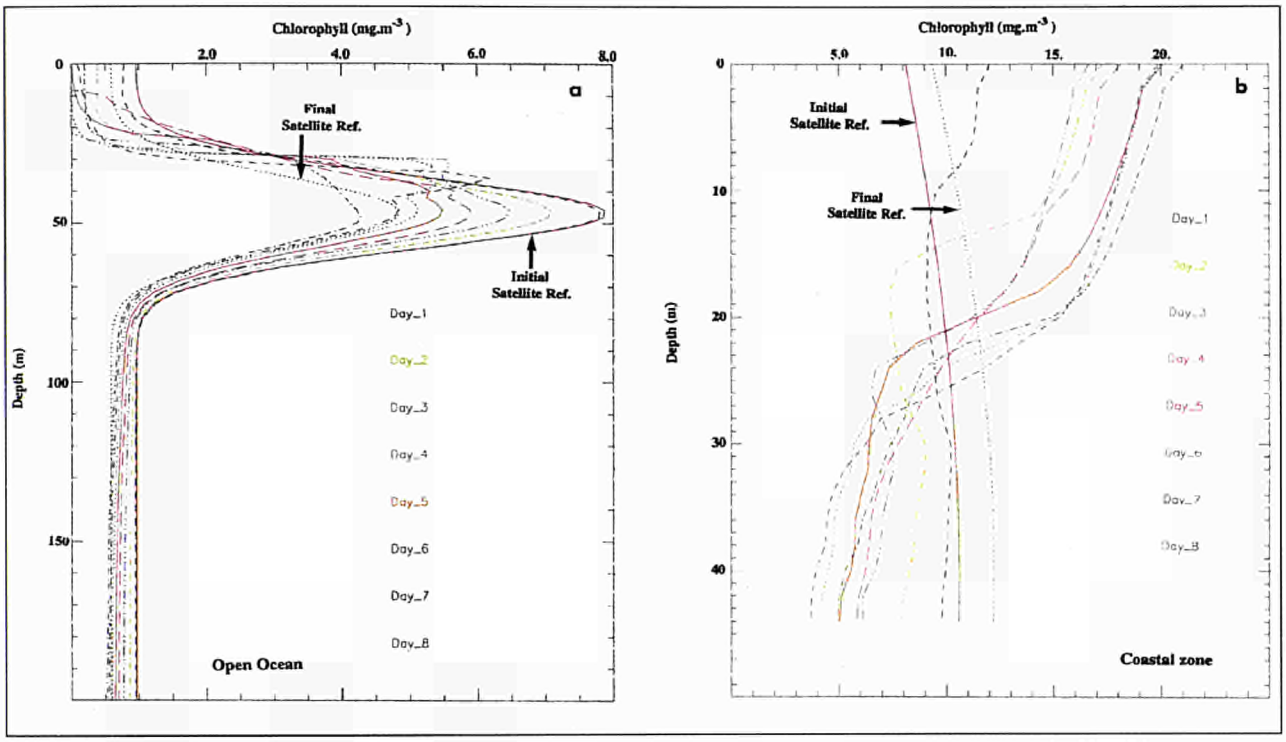


Figure 4.2: Variability in the vertical distribution of chlorophyll during a 10-days run of a coupled bio-physical model applied along a transect off the coast of Mauritania. Results are shown for a station in open ocean (a) and coastal waters (b).

Applied Numerical Modelling Related To Marine Processes And Remote Sensing

The simulation of marine processes by using data assimilation requires a number of preparational steps. In 1994 two essential components of the model systems needed for this were completed. These were firstly a tool providing the boundary conditions for the ME's Atlantic study site (This tool consists of a model of a large part of the Atlantic), and secondly a tool for data assimilation (Starting from the circulation model ISPRAMIX, through line by line transcription).

General Circulation Studies In The Atlantic

The upwelling off the coast of Northwest Africa occurs in response to the North-East trade Winds and has biological implications of considerable ecological and economic importance. The marked effect that wind has on upwelling and hence primary productivity in the surface waters of the Canary Current off Northwest Africa is visible in the satellite data. Our understanding of this local process can therefore be increased by performing satellite data assimilation on this specific area with a fine resolution hydrodynamic ocean model. However, this kind of application on a restricted ocean domain needs specific treatments along the mathematical open boundaries. In order to give appropriated boundary conditions to a window located off the African coast between 10 N° and 35N°, the ocean model ISPRAMIX has been extended to cover the whole Atlantic basin (from 30°S to 60°N) with an horizontal grid-resolution of 1°x1° and 40 levels in the vertical.

To test the ability of the model to reproduce the general features of the global Atlantic circulation, we have performed an annual mean forcing simulation. The temporal behaviour of the model is shown in Figure 4.3, and figure 4.4 shows the vertically integrated horizontal transport of the ocean. Although this simulation is based on a coarse grid-resolution (1°x 1°), it nevertheless produces a fairly detailed description of the circulation. For example, the general structures of the North Atlantic sub polar gyre (_ 10 Sv1) and the large -scale anticyclonic circulation of the North Atlantic, with a simulated Gulf Stream transport of about 70 Sv, are both present.

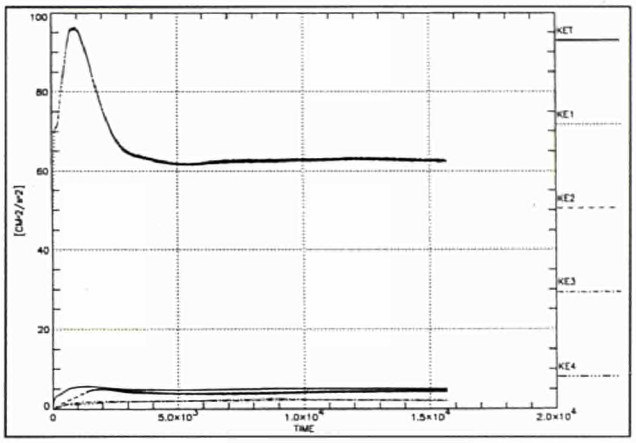


Figure 4.3: Kinetic energy of the model as a function of time. The total mean kinetic energy of the basin (KET) is compared with the averaged kinetic energy of four different depth range: 0-150m (KE1); 150-1000m (KE2), 1000-3200m (KE3) and 3200-8000m (KE4). Units are in cm2 s-1.

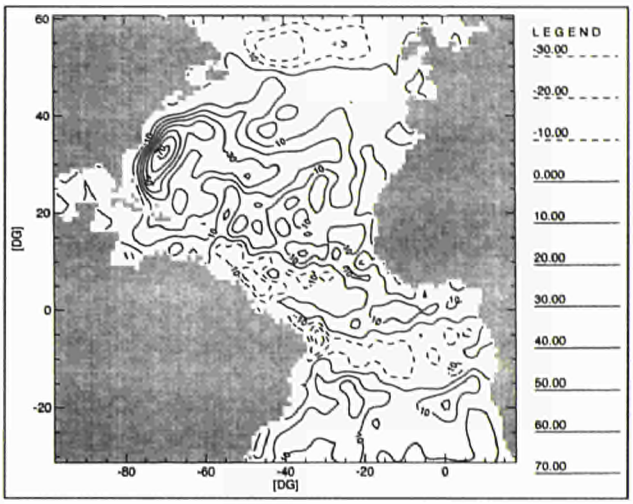


Figure 4.4. Volume transport stream function evaluated from the divergence-free part of the depth-integrated flow. Units are in Sv.

Data Assimilation

In 1994 a tool for data assimilation was generated. Starting from the ISPRAMIX circulation model, through line by line transcription, an adjoint model has been developed. The data assimilation system (consisting of the direct and the adjoint model) has been tested and will be used in 1995 for assimilation studies. Figure 4.5. shows a schematic representation of the ISPRAMIX data assimilation system.

Process Studies

The simulation of physical and bio-geochemical processes on a meso-or regional scale requires parametrisation of the underlying processes (e.g. the turbulence in the surface mixed layer and in the bottom friction layer, the fluxes of heat, momentum and substances across the air/sea interface) and requires detailed understanding and description of the particular phenomena under study (e.g. sediment transport, algae blooms, pollution). In 1994 the ME Unit concentrated on improving the understanding of the physics of sediment transport in the marine bottom boundary layer.

Suspended Sediment Transport

Suspended sediment transport is a research topic of increasing importance in the frame of coastal problems (e.g. coastal erosion, interaction biology - sediment, aggregation of heavy metals to fine sediments, delta formation, navigation). Suspended sediment together with chlorophyll, contributes to the radiation budget in the visible range. Hence, an improved assessment of suspended sediment transport in coa-

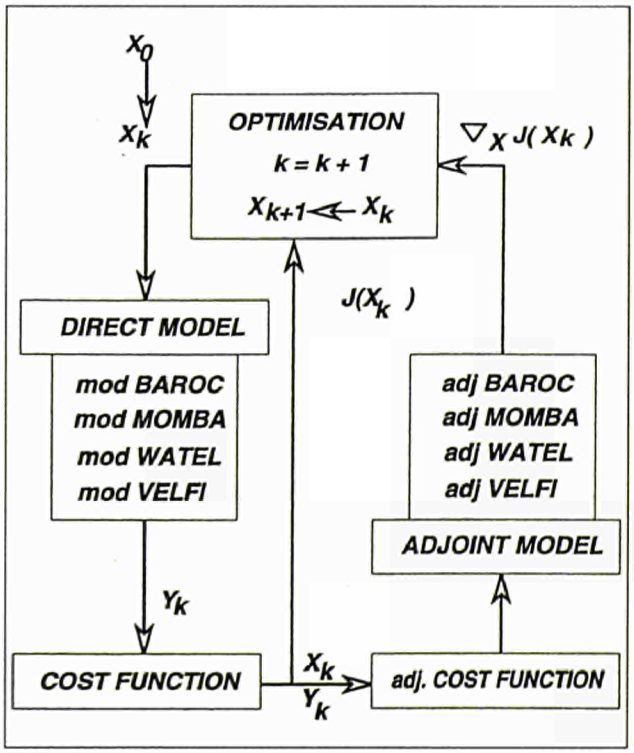


Figure 4.5: Schematic representation of the ISPRAmIX data assimilation system.

stal waters will certainly contribute to better calibration and interpretation of remote sensing data.

This work was performed in collaboration with the P.P. Shirshov Institute of Oceanology, St. Petersburg Branch (Russian Academy of Sciences). Results obtained in 1994 are very promising: A basic model for the universal structure of the sediment laden bottom boundary layer has been formulated and implemented. This new model allows for a better analysis of the interaction between mean velocity, suspended sediment concentration and turbulence characteristics which is not taken into account in conventional approaches.

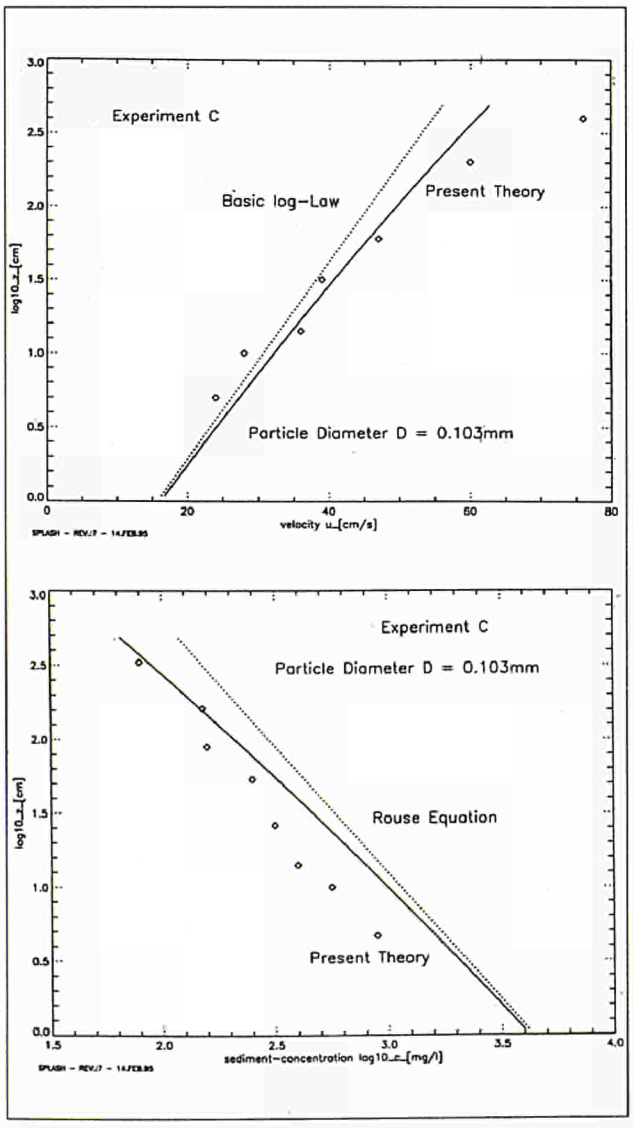


Figure 4.6: Comparison of theoretical and experimental results (experiment D of Soulsby and Wainwright, particle concentration).

The model has been tested using numerical experiments published in literature. Figure 4.6 for example, shows that the present theory more closely matches the true tendencies of the data than those previously published: in figure 4.6, Z is the distance from the sea bottom, u is the horizontal velocity, and c is the particle concentration.

The marine sulphur cycle

Two aspects of Di-Methyl Sulphate (DMS) research are being developed. Firstly modelling of the cycling of DMS in the euphotic zone and its link to primary production and ocean colour. Secondly, neural network characterisation of clouds from AVHRR/Meteosat imagery and their micro-meteorological interpretation. DMS is a product of biological activity in the ocean and acts as cloud condensation nuclei. Thus, increasing levels of biological activity should be linked to increasing cloud cover.

DMS modelling

The DMS modelling was performed as part of a Human Capital and Mobility Network. The aim is to estimate DMS production in upwelling areas. The upwelling area off the coast of Mauritania was chosen as a test site. The model used CZCS ocean colour images as estimators of primary productivity, AVHRR images for sea surface temperatures, and ECMWF data base for wind speeds. Three modules (primary productivity, biological food chain and hydrodynamic models) have been developed, and these will all be interfaced to give an overall model.

The primary production module evaluates the daily rate of primary production in the euphotic zone, with the chlorophyll distribution estimated from a CZCS image, the irradiance budget at the sea surface, and some biological parameters known for the area. The output is then used as input for the biological module. The biological module includes the primary production in the food chain and models the processes involved in the DMS production. ISPRAMIX is used as the hydrodynamic model. The efficiency of the biological model is being tested with two CZCS images. The first provides a primary production initial value input in the model, the second is used as a test comparison with values from the model.

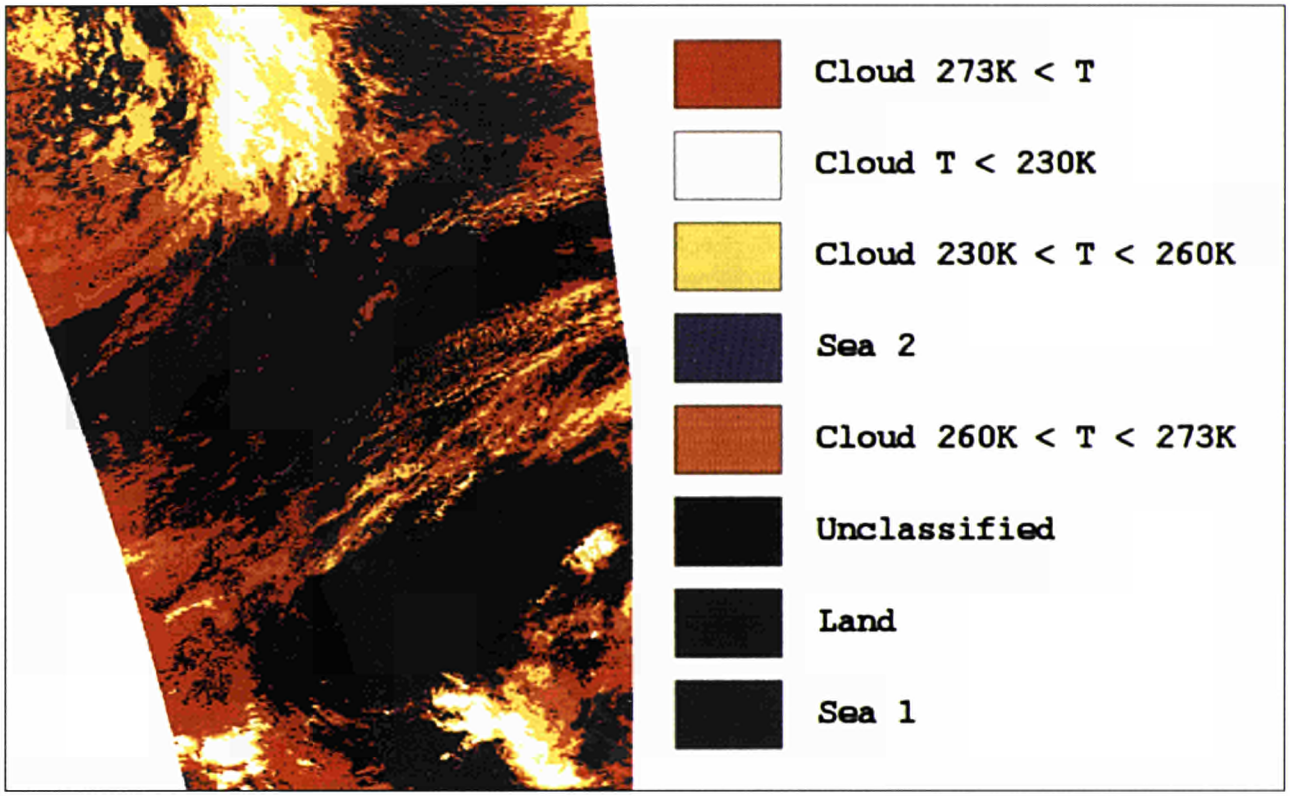


Figure 4.7: Hand classification after 5000 iterations (all channels).

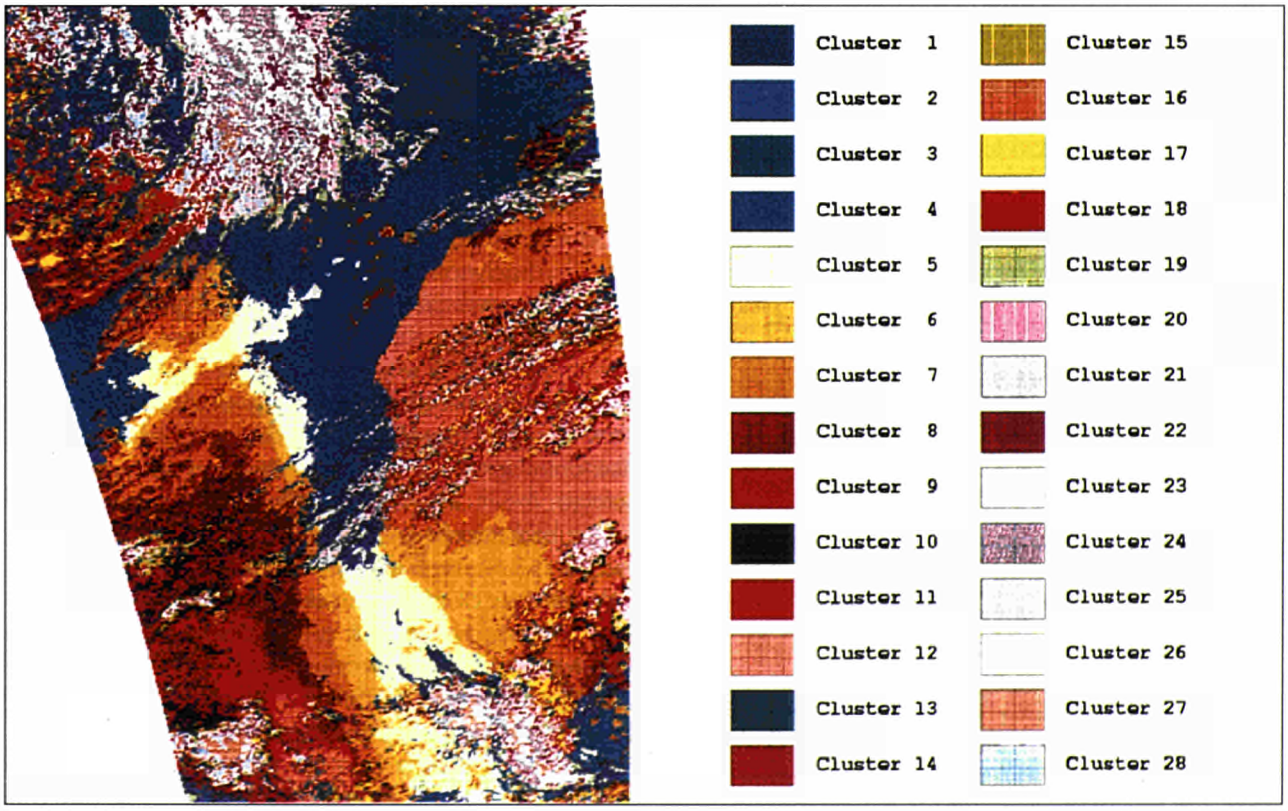


Figure 4.8: Unsupervised clustering after 3000 iterations.

Cloud characterisation

This study aims to establish the validity of using neural networks for cloud classification. task, and if so, to implement such a classifier and run a sample set of remotely sensed images extracted from the IRSA marine database.

An unsupervised self organising Kohonen map was used. The network is made up of a variable number of input channels and 28 output clusters arranged in a mono-dimensional array. Initially all five AVHRR channels were employed (Figure 4.7), though subsequently only channels 2, 3 and 4 together with some textural features were used. Results (Figure 4.8) highlight the fact that Neural Networks are, indeed, a suitable tool for cloud identification and classification.

Perspectives for 1995

Future work will focus on the development of a detailed plankton model to be coupled with hydrodynamic formulations to determine the role of this important upwelling area in the global carbon cycle.

On the other hand, some effort will be used to estimate the photosynthetic rate in other marine regions of European interest.

In 1995 the single components of the model system developed for simulating the process in a specific Atlantic window, will be put together. After defining the window and the time period, ISPRAMIX will be used for simulating the respective general circulation conditions; then a fine grid window model is used with the ISPRAMIX data assimilation system, to determine the small scale characteristics in the window, guided by the assimilation of the remote sensing SST.

On the level of process modelling, the work related to sedimentation will be continued and the embedding of an ecosystem model into ISPRAMIX initiated.

.2 COSTAL MONITORING

Summary of Objectives

Development and improvement of methods for the analysis of remote sensing data on sea colour.

Development and improvement of bio-optical algorithms relating sea colour to water composition.

Study of small-scale phenomena specific to the coastal zone.

Monitoring of typical coastal pollution situations (state and Dynamics).

Development of suitable pre processing routines for the planned SeaWiFS instrument

Identification of the factors controlling the underwater light energy and their variability in coastal waters where phytoplankton, detrital material, sediments, and dissolved organic matter are most often not correlated.

1994 PROGRAMME OF WORK

Introduction

For any satellite remote sensing mission simulated sensor data are necessary to design and test the data flow from the instrument to the user. One of the most important aspects on this flow, especially in the case of an ocean colour mission, are the atmospheric correction of the data and the retrieval algorithms for the concentrations of optically active materials (OAM) in the ocean surface layer. During the reporting period we have developed an atmospheric correction algorithm for SeaWiFS level 1 data and used simulated data to test its feasibility and its sensibility with respect to variability of important atmospheric parameters.

Coastal zone modelling work in 1994 focused on laboratory measurements of optical properties of aquatic particles (phytoplankton, suspended sediment) needed to develops optical models of the sea, as support to bio-optical algorithms development. Two main actions were taken:

The Measurement Of Backward And Total Scattering By Mineral Particles Suspended In Water

Optical models of the sea are a fundamental support to remote sensing based water quality surveys. Modelling of the complex environment, typical of the coastal zone, requires a physical description of the phenomena. This should take into account the individual contributions of the optically relevant substances in the water, such as phytoplankton, organic detritus, mineral suspended sediment and dissolved organic matter.

1994 Milestones

Measurement of optical properties of aquatic particles.

Development of an atmospheric correction algorithm for SeaWiFS level 1 data

The knowledge of the optical properties of mineral sediment is becoming increasingly important in view of the planned SeaWiFS sensor, scheduled for launch during 1995. The scanty information currently available has been obtained from the interpretation of complex sets of data measured in-situ. This procedure is both laborious and costly.

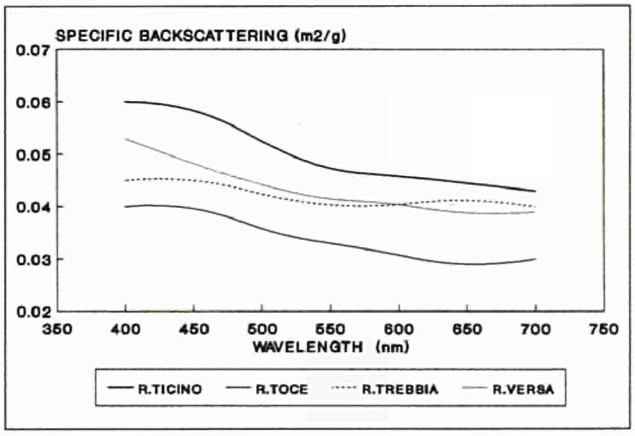
This work has focused on the search for a method for derivation of total and backward scattering of dilute suspensions of aquatic particles. The procedure has been derived and tested with reference to commercially available instrumentation, namely a PERKIN-ELMER LAMBDA 19 dual-beam spectrophotometer. The experiment consisted of two sequential measurements performed a) on particles retained in a glass-fiber GFF filter, and b) on an aqueous particle suspension contained in a plane-parallel quartz cell.

In order to test the validity of the proposed method, a series of measurements was performed on water samples taken in the rivers Ticino, Toce, Trebbia and Versa. Rivers Ticino and Toce flow from the Western Alps into lake Maggiore, through areas

with dominant crystalline rocks. Rivers Trebbia and Versa flow very close to each other from the Apennines mountains to the Po river, crossing a territory rich in limestone.

Figure.4.9 (a-b) presents the experimental results, plotted versus wavelength in the 400-700 nm range. The parameters displayed are: the specific backscattering coefficient, bb(l) (Fig.4.9a) and the specific total scattering coefficient, b(l) (Fig.4.9b).

The proposed procedure for the measurement of total scattering and backscattering coefficients of mineral sediment suspended in water, was found to provide a useful experimental tool. It is both labour saving and faster than the cumbersome and costly in-situ measurements usually used.



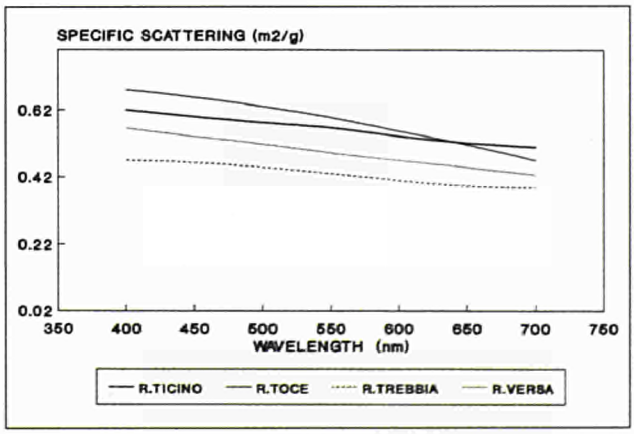


Figure 4.9: Experimental results: a) specific back scattering coefficient, bb (l), (b) specific scattering coefficient, b (l), of a suspended sediment from the rivers Ticino, Toce, Trebbia and Versa

Light-Transmission Measurements Of Picoplankton Particles

In recent years ocean biologists have shown a growing interest in those extremely small plankton organisms, cumulatively defined as picoplankton, and including such important classes as the cyanobacteria and the prochlorophytes.

The large fraction of cells with less than 1 mm diameter, which characterises picoplankton, implies that currently used glass-fiber filters, such as the WHATMAN GFC with 1.2 mm retention efficiency, are not adequate to retain these phytoplanktonic cells for accurate quantitative analyses.

In these situations GFC filtering causes a loss of particles that leads to an underestimate of the actual particle concentration in water. The inadequacy of the filter negatively affects also the measurement of the "in-vivo" particle absorption, yielded by light-transmission measurements carried out on the particles retained on glass-fiber filters. Thus we considered it appropriate to test whether 0.22 mm Millipore membranes can be effectively employed for these, nowadays widespread, measurements, or reasons of various kind prevent their practical use.

The light-transmission measurement is generally carried out by a spectrophotometer, provided with dual-beam action. The instrument compares the fluxes induced by the beams crossing the sample and a "reference", respectively. The "reference" is normally a new filter, equal to that used to retain the particle sample.

The results of the measurements are shown in Figure 4.10, as plots of the particle suspension absorbance versus the absorbance of the particles retained on either the Millipore membrane or the GFF glass-fiber filter. On the whole the performance of the 0.22 mm Millipore membrane in light-transmission measurements appears to be comparable (for several aspects superior) to that of the currently used WHATMAN GFF glass-fiber filter. No reasons for discouraging its practical use have been found.

The results of a number of experiments stress the importance of the absorption by aquatic particles with less then 0.7 mm diameter and support the use of the 0.22 mm Millipore membrane in light-transmission measurements.

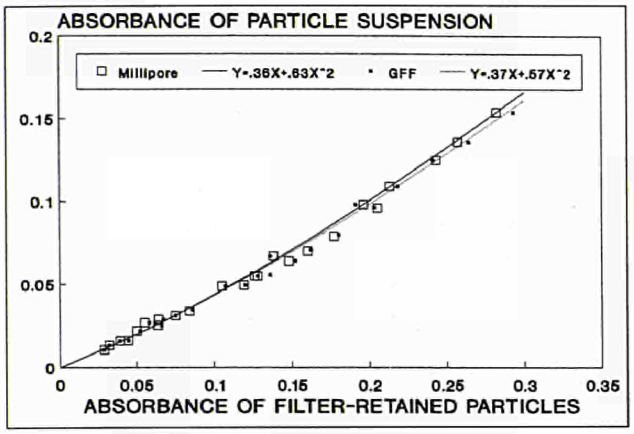


Figure 4.10: Absorbance of filter-retained particles.

Data Simulation And Atmospheric Correction And Computer Code Development

The development of an atmospheric correction algorithm for SeaWiFS level 1 data was based on an improved model for data simulation and atmospheric correction plus an improved model for the atmospheric scattering based on multiple scattering approximation using published tables.

Data Simulation

For data simulation the concentrations of the optically active materials in the water and the aerosol data of the atmosphere are given. The radiance emerging from the ocean surface is the sum of contributions from radiance from below the water surface, the sun glitter radiance, and the radiance reflected from oceanic foam which is formed at higher wind speeds.

For simulating the aerosol path radiance we use the "optically thin" layer formula with an aerosol Phase function which includes contributions to the path radiance due to reflection of scattered photons and reflected direct sunlight.

For calculating Rayleigh path radiance Gordon's exact multiple scattering tables (derived for the CZCS and transformed to the SeaWiFS wavelength bands) are used. Finally digital counts are calculated from total radiance, taking into account the noise equivalent radiance and the saturation radiance of the sensor.

Atmospheric correction

For atmospheric correction the digital counts are given; from them the total radiance is evaluated using the calibration data. Total radiance becomes the measured quantity from which the water leaving radiance, and from this the concentrations of optically active materials (Chlorophyll like pigments, total suspended matter and dissolved organic matter) have to be evaluated.

The simplest way to obtain an atmospheric correction algorithm for SeaWiFS is to introduce the improvements of the ocean-atmosphere model mentioned above into the algorithm developed by the ME Unit for correction of CZCS data. The main change is that the aerosol optical thickness must be calculated for each pixel so as the Rayleigh-Aerosol coupling factor can be evaluated.

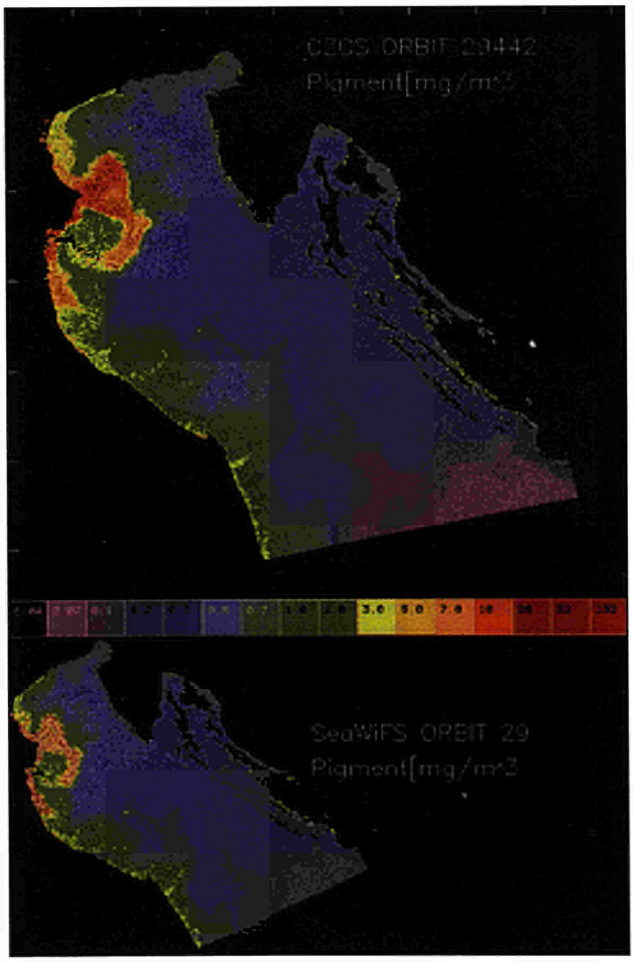


Figure 4.11: Example of a simulation and a successive atmosphere correction.

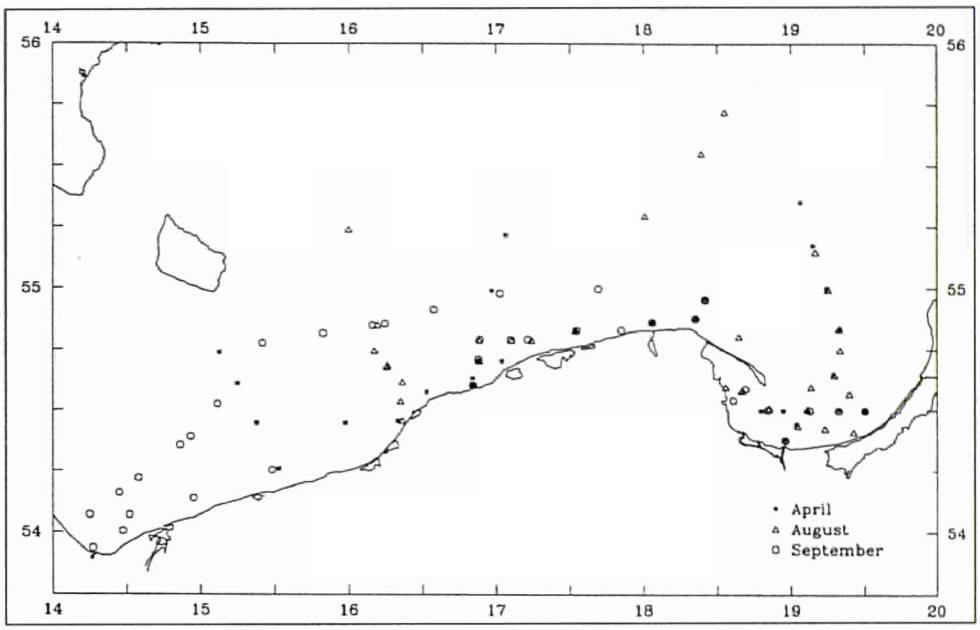


Figure 4.12: Sampling stations in the Southern Baltic Sea during the 1994 R/V "Oceania" bio-optical cruises as part of the joint programme between the Joint Research Centre of Ispra and the Polish Institute of Oceanology in Sopot.

For the moment the atmospheric correction neglects the radiances due to sun-glitter and foam reflectance since the SeaWiFS is tilted by 20 degrees and foam radiance below wind velocities of about 7 m/s correspond to less than 1 SeaWiFS digital count. However, in principle both effects can be introduced into the algorithm if required and if the wind velocity is known. Figure 4.11 shows an example of a simulation and a successive atmospheric correction: the upper part shows the geometrically corrected pigment concentration map of a CZCS scene of the northern Adriatic Sea as obtained from the standard CZCS algorithm together with the aerosol reflectance field and the Angstrom exponent. Using these data as input in combination with typical orbit parameters for SeaWiFS for a pass over the area we calculate a simulated SeaWiFS level 1 product and apply the above described atmospheric procedure for atmospheric correction to this data. The results are maps of water leaving radiance, aerosol path radiance, Angstrom exponent and pigment concentration. The latter is shown in the lower part of the figure.

Conclusions

The concepts of an atmospheric correction algorithm for the SeaWiFS sensor have been elaborated and tested on simulated data. The result is an improved, with respect to CZCS, but still rather simple algorithm which allows the retrieval of the concentrations of optically active materials in water of type case 1 and in two-component waters, such as present in upwelling areas. The simulation and retrieval calculations have shown that the accuracy of the retrieval can be expected to be better than 50 % if the aerosol phase function is known, otherwise errors may be much higher. The effects of sun-glitter and foam reflectance on the atmospheric correction are negligible for wind velocities below about 7 m/s. The use of a two-component model in the retrieval algorithm leads to an important improvement with respect to CZCS: it provides an algorithm from which chlorophyll-a and detritus products can be determined independently. The algorithms developed exist in two forms: a program package written in Borland Pascal 7.0 for PC and a translation of it into C, running on an Alpha DEC station under OSF/2 and on SUN stations under UNIX. This translation was performed by CISI under contract. A simplified version of the atmospheric correction algorithm was given to ESA and will be used for the development of a SeaWiFS Quick-Look and browsing system.

Bio-Optical Characterisation Of The Southern Baltic

Studies on the bio-optical properties of the Baltic Sea started in 1993 as a joint programme with the Institute of Oceanology of the Polish Academy of Sciences in Sopot, Poland. The main purpose of this project is to determine the factors controlling the underwater light energy and their variability in time and space in such peculiar waters where phytoplank-

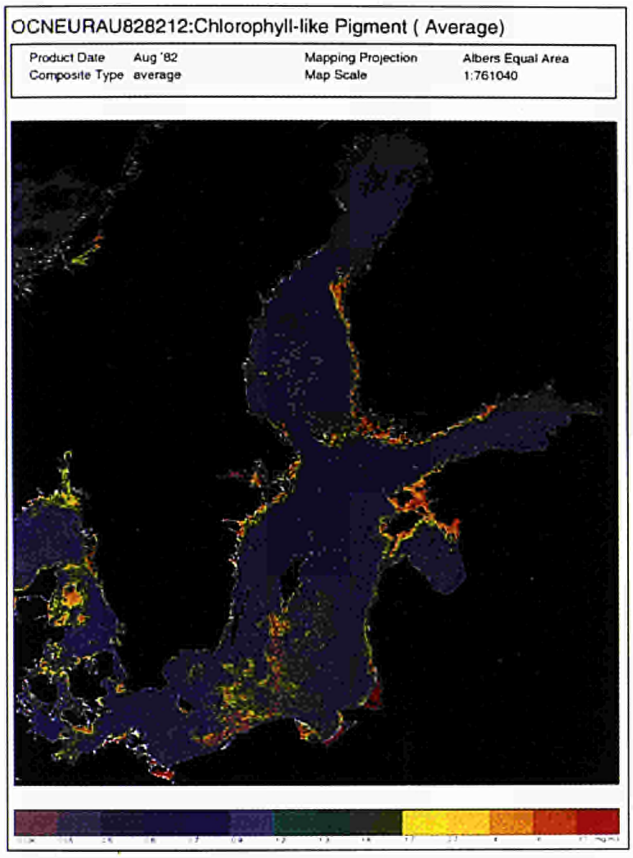


Figure 4.13: CZCS composite image of the chlorophyll-like pigment in the Baltic Sea in August 1982. Note the patch of high chlorophyll values in the southern Baltic corresponding to a bloom of Cyanobacteria

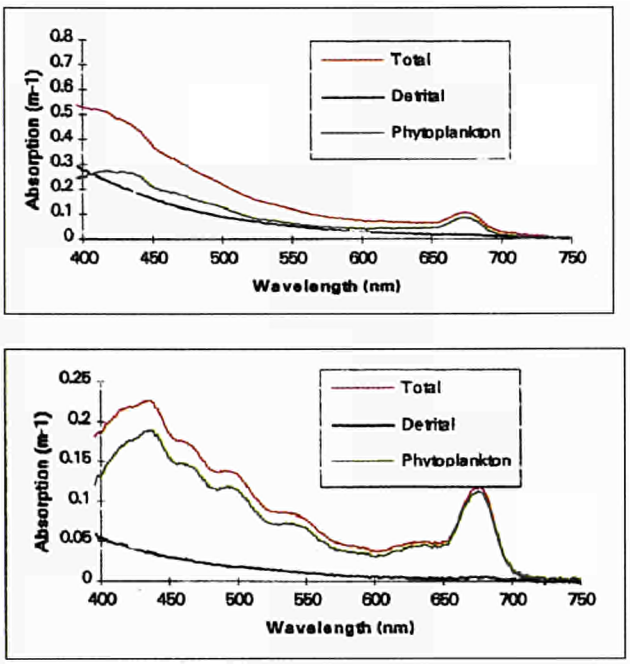


Figure 4.14. In vivo absorption spectra of the total particulate matter taken at two locations in the southern Baltic (March 1994). The effect of Cyanobacteria (in no-blooming condition) on the shape of the spectrum at 550 nm can be observed in the lower panel when compared with a common spectrum (upper panel) mostly influenced by detrital material.

ton, detrital material, sediments, and dissolved organic matter are most often not correlated. In turn, this information will be used to improve algorithms to estimate biogeochemical elements and their related processes in the entire basin from satellite.

In 1994, three cruises were conducted at different periods of the year (Figure 4.12) on board the Polish research vessel "Oceania". A large part of the Southern Baltic was covered to measure all parameters related to optical properties of the water and its productivity. Specific measurements included detailed analyses of the photosynthetic pigments, in vivo absorption spectra of phytoplankton and non-living material, yellow substance assessment (fluorescence, absorbance), total suspended matter (dry weight, X-ray geochemical analyses), particle size distribution (using a Coulter Counter), spectral down welling and upwelling radiances, primary production (standard C14 technique). In addition to the importance of yellow substance in controlling the underwater light field, significant results were obtained on the following:

Cyanobacterial impact

Blooms of Cyanobacteria occur regularly in the Baltic during summer as shown in Figure 4.13 representing chlorophyll-like pigment concentration at the surface for August 1982 as derived from the CZCS. A patch of high chlorophyll values (2 - 3 mg.m-3), identified from literature to be cyanobacteria, is clearly extended over the major part of the Southern Baltic. Apart from being toxic for some fish species, cyanobacterial blooms affect the light distribution in the water column and the reflectance at the surface because of the specific optical properties of the cells. Cyanobacteria absorb the available light through their photosynthetic units which contain, in addition to the ubiquitous chlorophyll-a, a large amount of phycobiliprotein pigments representing 40 to 50 % of the total cellular protein. Among those pigments, phycoerythrin is widely distributed in various species and present a maximum absorption at 550 nm affecting the overall shape of the in vivo absorption spectrum of natural communities in the Baltic (Figure 4.14). In

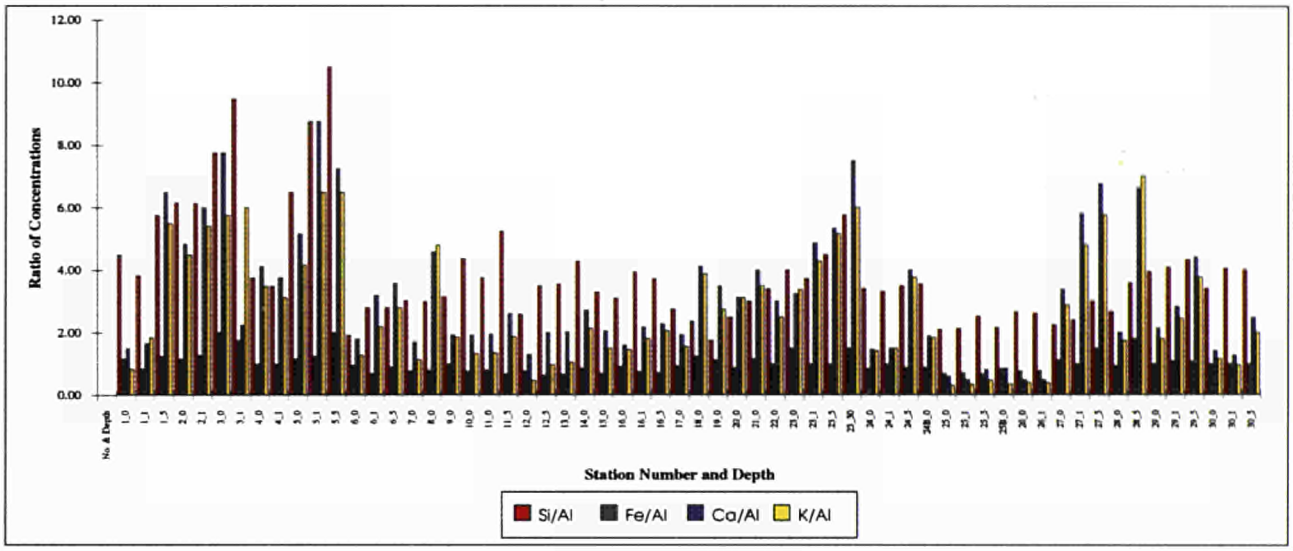


Figure 4.15: Plot showing geomineralogical ratios in total suspended matter at different stations along the southern Baltic during the R/V "Oceania" cruise in April 1994

blooming conditions, cyanobacteria would thus have a significant contribution to the water reflectance and their properties should be taken into account in the development of algorithms to derive phytoplankton biomass from satellite.

Total Particulate Matter.

The penetration of light in Baltic waters, and thus the amount of energy available for photosynthesis and its quality, vary as a function of the particle load as well as the structure of the particles. Particles resulting from local marine activities will affect the light field in a different manner to mineral sediments of terrestrial origin; in fact one of the main goals of geochemical analyses on the total suspended water is to differentiate the sources of this material. Geochemical analysis gives the concentration of a range of compounds including Si, Al, Fe, Ti, Ca, K, Mg, and P. The various ratios of the concentrations of these compounds provide strong indicators of certain oceanographic environments.

Figure 4.15 indicates the distribution of four chosen ratios at different stations roughly plotted, along the x-axis, from the eastern to the western part of the southern basin (see Fig. 4.12). Higher values of Si/Al and Ca/Al ratios are usually observed in near-coastal stations and within river plumes. In this particular environment, further differentiation can be done between Si and Ca dominant sediments: particulate matter originating from limestone bedrock has a higher Ca/Al ratio when compared to Si/Al ratio (this can be seen at station 6 ,corresponding to the mouth of the Utska river); the opposite is true for sediments originating from siliceous drainage basins (e.g. station 25, at the entrance of the Vistula river). On the other hand, the open Baltic Sea is characterised by an increase in the values of the K/Al ratio when compared to other ratios. Knowing the extension of these various types of particle and their variability in time allow us to tune bio-optical models that use reflectance data from satellites.

Dissolved Organic Carbon

It is recognised that yellow substance (or Gelbstoff, or CDOM) represents a major component modifying the light field in Baltic waters, as well as in other coastal areas. The fact that CDOM absorb more strongly at 410 nm than at 443 nm, whereas the opposite is true for healthy phytoplankton cells, represent an opportunity to develop CDOM algorithm for future remotely-based sensors such as SeaWIFS, OCTS or MERIS with high wavelength resolution and low signal-to-noise ratio. Moreover, CDOM can be used directly as an indicator for predicting the total dissolved organic carbon in the water (Figure 4.16) which is known to be an important element in the carbon cycle of the Baltic Basin.

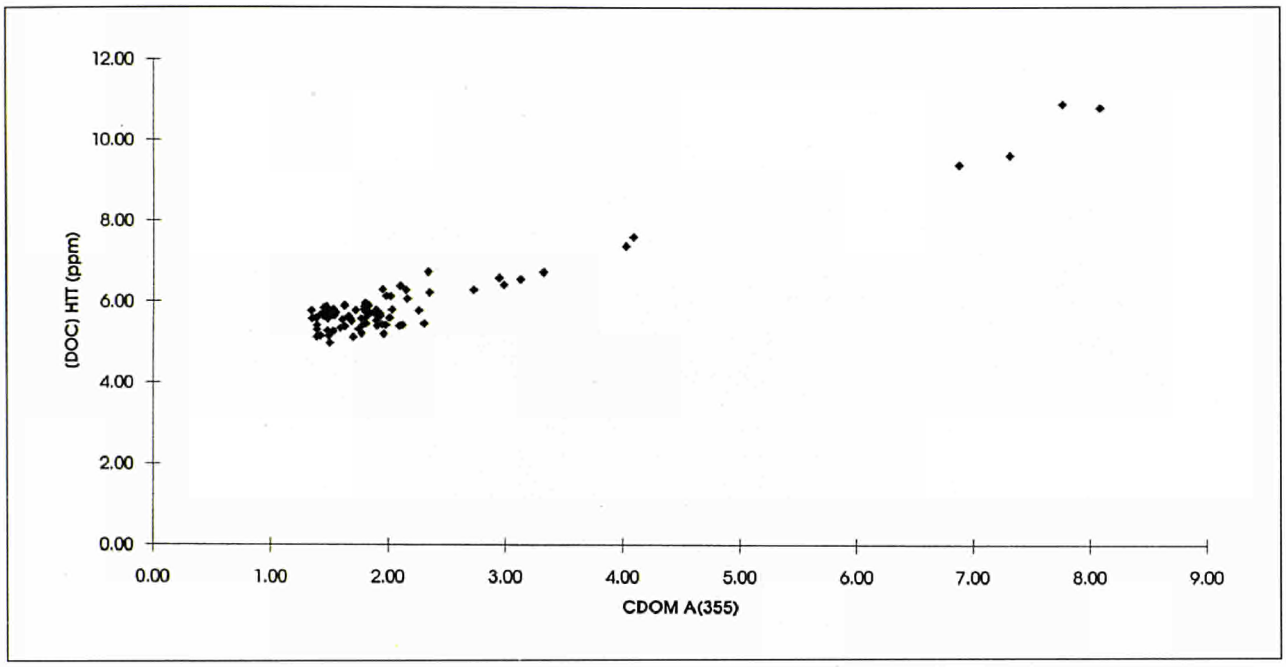


Figure 4.16: relationship between total dissolved organic carbon (as measured with high temperature technique) and the absorption coefficient of the colored dissolved organic matter (yellow substance) at 355 nm.

Perspectives for 1995

The 1995 activity should concentrate on the ongoing studies related to SeaWiFS within the collaboration agreement with Stazione Zoologica. The main goal will be determination of a comprehensive set of accurate bio-optical data, to provide a benchmark for validation of SeaWiFS interpretation models.
Although detailed analyses of bio-optical cruise data will continue, a large effort will be used to derive appropriate algorithms to retrieve biogeochemical compounds of importance in the definition of the carbon budget of the Baltic Sea from satellite ocean colour data.

3 STUDY OF THE NORTHWEST AFRICAN UPWELLING AREA: THE CLOUD AND OCEAN REMOTE SENSING AROUND AFRICA (CORSA) PROJECT

Summary of Objectives

To provide a coherent and quality controlled data set of surface, atmospheric and cloud parameters over a relatively long time period and at a resolution not available from any other data source for:

- *coastal upwelling analysis*
- *comparison of different coastal upwelling systems and their large scale climatic beha-viour*
- *identification and mapping of Sahara desert storm events*
- *analysis of cloud cover and cloud optical properties*
- *air-sea interactions.*

1994 PROGRAMME OF WORK

Introduction

The work in 1994 has been devoted to the pilot phase of the Cloud and Ocean Remote Sensing around Africa (CORSA) project. The main goals have been to develop, implement and validate the data archive and production of SST for a one year period and prepare the methodology for the mass production of the whole archive. The pilot phase of CORSA has been implemented and validated during 1994. The work packages for CORSA pilot phase are described below.

Optical archive strategy and software development

The archive of NOAA AVHRR Global Area Coverage (GAC) data currently exists on magnetic tapes (CCT's). The estimated archive size is 13000 individual scenes on 1100 CCT's. The scenes vary in size but a typical scene size is 10 Megabytes, thus the total archive size is 130 Gigabytes. The scenes will be written to a central 12" Write Once Read Many (WORM) optical disk server (an EPOCH system) in order to preserve the data, which otherwise will be lost due to deterioration of the CCT's. This will also facilitate processing and reprocessing of the data as algorithms evolve. Different hardware configurations were tested and evaluated in terms of tape retrieval, loading, storing, job scheduling, network load and operator interventions.

1994 Milestones

- Definition and implementation of archiving structure.
- Development of cloud identification.
- Production and validation of SST fields.

Data archiving:

All GAC scenes for the year 1984 have been archived on the EPOCH server.

Data processing software modification:

Data processing is based on the Terascan software package. Terascan is a commercially available software package designed to process, visualise and analyse data from AVHRR and other satellites. As well as having its own analysis programs it provides libraries of utilities which allow specific algorithms to be rapidly developed. The product generation software in CORSA uses Terascan programs for raw image reading, calibration and geometric correction. The necessary modifications have been completed for cloud masking and SST calculations. An innovative part of the cloud masking has been the use of pattern recognition techniques for connectivity of poorly

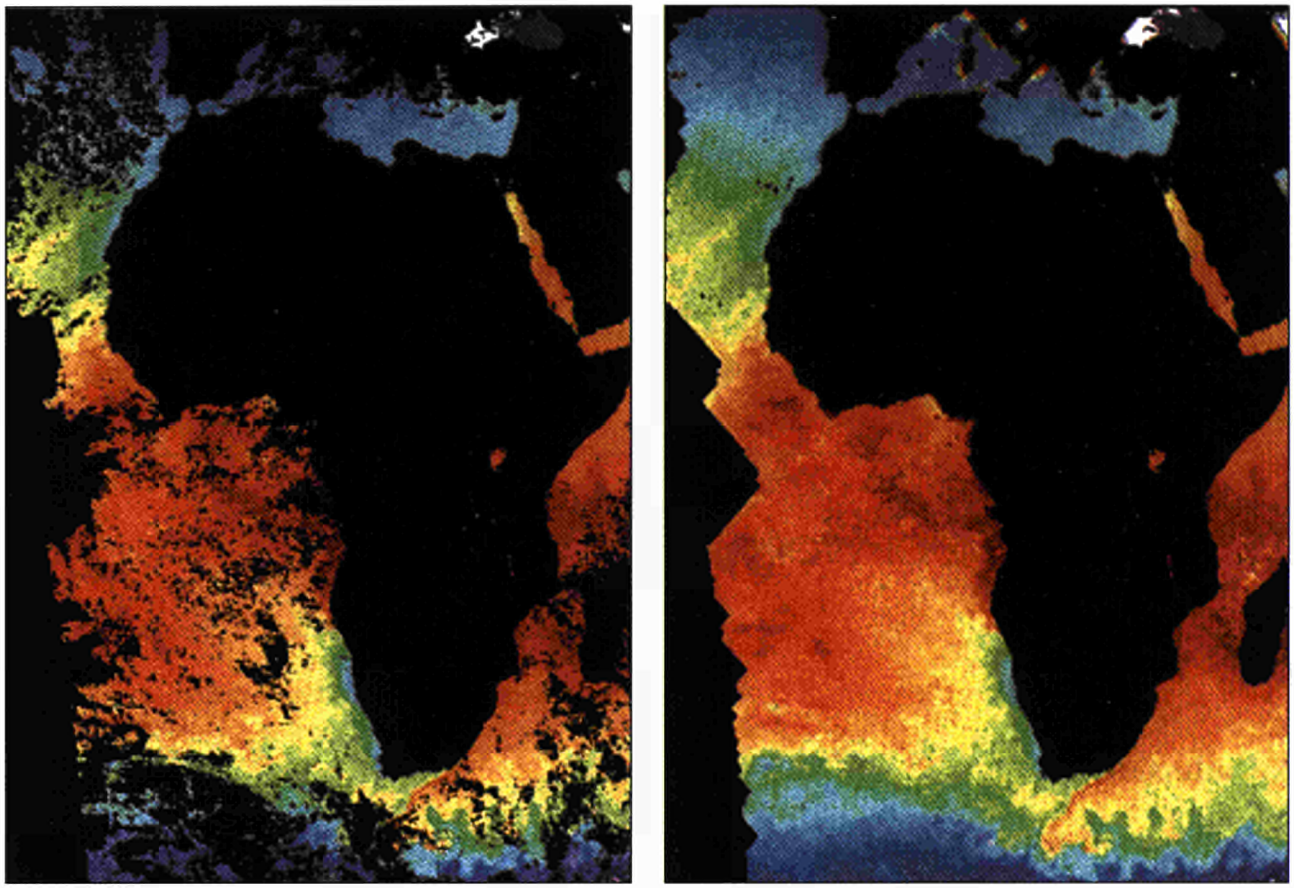


Figure 4.17: Weekly Sea Surface Temperature composites before and after interpolation and region filling.

defined regions and interpolation to eliminate gaps in the SST field. Figure 4.17 illustrates the advantage of this particular technique.

Data processing software validation

This has been undertaken for the monthly SST fields by comparison of data from 1984 to the following SST data sets for the same period:

a. Comprehensive Ocean Atmosphere Data Set (COADS), 2x2 degrees resolution
b. NASA/JPL/PODAAC - NASA AVHRR SST data, 1x1 degrees resolution
c. National Meteorological Center SST data (IGOSS), 1x1 degree resolution
d. Global Ocean Surface Temperature Atlas (GOSTA), 1x1 degrees resolution

Software adaptation for mass production

This has been completed for cloud masking and SST calculation. The mass production software produces as standard products weekly and monthly composites. The software has been designed to minimised disk storage requirements and to eliminate operator interventions. Test cases reveal that one month's data, approximately 100 individual satellite passes, can be processed to weekly and monthly SST products in less than 4 hours on a Sun Sparc10 worstation. Modules for cloud classification and optical properties of clouds will be developed as classification algorithms become available.

Mass production

This has been undertaken for weekly and monthly composites for 1984. An animation sequence has been developed to display the weekly SST products. This animation sequence is visible on the WWW experimental server of the Centre for Earth Observation (CEO; see chapter 7).

Perspectives for 1995

During 1995 it is foreseen to finish the archival of all raw images on the EPOCH. The processing of the archive will continue and the generation of all SST level 3 products i.e. all weekly and monthly composites for the period 1981 to 1992 will be completed. The analysis of the SST data will first be carried out as a large scale statistical analysis with the aim of comparing the major wind and SST patterns over the Eastern Atlantic Ocean. This comparison is carried out in the framework of a scientific collaboration with University of Cape Town, South Africa. In a second stage the analysis will concentrate on local upwelling areas and preferably involve biological data as well. The development of algorithms for deriving cloud and atmospheric level 3 products will be co-ordinated with studies carried out by European research establishments in collaboration with IRSA.

4.4 OCEAN COLOUR PROGRAMMES

Summary of Objectives

The development of Ocean Colour data sets:

Development of tools for ocean colour data set exploitation in the characterisation of marine ecological processes and relationships.

Research activities using Ocean Colour and ancillary data.

Realisation of a scientific Ocean Colour network in Europe, to support current research activities.

To prepare for future ocean colour space missions.

1994 PROGRAMME OF WORK

Introduction

In 1994 much effort was invested in promoting the exploitation of long-term, basin-wide time series of remote sensing data (plus other ancillary data), for the evaluation of environmental trends and the general characterisation of European Seas. In order to do so methods were developed to transform the original time series into value-added archives of geophysical parameters.
Progress was also made in the development of an active interface, composed of algorithms and models, to generate value-added data products from a suitable combination of remote sensing and ancillary data.
Such activities can be seen as a way to channel existing resources in the general direction of preparations for future space missions (in particular, those of sensors operating in the visible and infrared spectral range, such as those to be deployed by ESA.

In this framework, two main lines of action have been followed, firstly conclusion of the Ocean Colour European Archive Network (OCEAN) Project, and secondly setting up a follow-up programme on Ocean Colour Techniques for Observation, Processing and Utilisation Systems (OCTOPUS). Related activities, carried out in the general framework of the OCTOPUS Programme, include the establishment of an in situ data collection and analysis calibration and validation (CAL/VAL) programme, and the development of studies centred around an OCEAN COLOUR software simulator.

1994 Milestones

Feb.: Start ocean colour simulator development activities.

June: Completed CZCS data set update from NASA.

Aug.: Coasts Project initial set up.

Sept.: Release of first SeaWiFS OCEAN code version.

Oct.: Conclusion of all CZCS data processing for OCEAN Project.

Nov.: Primary Production model included in OCEAN code.

All year level-1/2/3 data distribution to OCEAN ADP

The OCEAN Project

The OCEAN Project, jointly developed with the ESA, was established to promote the use of ocean colour data for an improved understanding of the European marine environment. Main goals of the Project are the exploitation of historical data - collected by the CZCS, in the period 1978/1986, over marine regions of Europe, as well as the development of tools and structures in preparation for future ocean colour missions.

The OCEAN Project includes 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 carries out the distribution all value-added data within the scientific user community through an Application Demonstration Programme (ADP).

The OCEAN ADP was established following the 1991 release of an Announcement of Opportunity (AO) concerning the exploitation of the CZCS data archives generated by the OCEAN Project. The response to this Announcement of Opportunity has continued throughout 1994. Currently, the ADP participation accounts for more than 30 research groups, carrying out an even larger number of projects assisted with CZCS data deliveries. The Projects concern all the major marine basins of European interest, grouped into a few main regions (Figure 4.18): (i) the northern European basins, covering essentially the North Sea, the Baltic Sea, and various adjacent areas; (ii) the Mediterranean basin, including both the Mediterranean Sea proper, and the Black Sea; (iii) the north-eastern 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 compilation of the final CZCS value-added data archive was also completed in 1994. Consequently, the ADP has more or less concluded its level-1/2/3 data distribution of standard and/or special data selection. At present, all standard requests coming from the ADP participants have been satisfied by the delivery of the complete 1979-1985 level-1/2/3 data sets, while special requests are still being handled on a case by case basis. Plans have also been drafted for allowing direct on-line access to the OCEAN Data Catalogue and the quick-look browsing system, as well as to the level-3 data collection, via the Internet.

Finally, all software developed in the framework of the OCEAN Project (i.e. the level-1/2/3 packages, developed over the last few years) has been integrated into a single system; OCEAN code. The system has been completed with the inclusion of a bio-optical semi-analytical model, which allows the evaluation of primary production on the basis of the ocean colour data and suitable ancillary information. Work on a new version of the system, including software for the processing of future data, has also been initiated. The new OCEAN code version will provide the backbone for handling data generated by a score of future ocean colour sensors.

The OCTOPUS Programme

The OCTOPUS Programme, another joint venture with the ESA and other European scientific partners (such as the OCEAN ADP Participants), aims at the development of a European interface between user communities and the ground segments of the upcoming Sea-viewing Wide-Field-of-view Sensor (SeaWiFS; USA), Ocean Colour and Temperature Scanner (OCTS: Japan), Medium Resolution Imaging Spectrometer (MERIS; ESA).

The OCTOPUS Programme is centred 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 co-ordination (IRSA task); and to research activities to be conducted in various European Institutions. A collaboration agreement has also been reached with the NASA SeaWiFS Scientific Programme, in order to ensure the free exchange of SeaWiFS imagery, ancillary data, algorithms and models between user communities, world-wide and throughout the SeaWiFS mission. The Programme will allow the exploitation of ocean colour and concurrent in situ and remote observations of the sea surface, contributing to large data systems being developed - in Europe and elsewhere - for environmental monitoring.

The activities carried out in the general framework of the Programme have already provided input on data products and algorithms requirements for the SeaWiFS ground segment, currently under development at the ESA. A general consensus, inspired by the OCEAN user community, has been reached on the need to generate parameters of the same kind as those available in historical time series (such as the OCEAN archives), but to derive these from new and improved algorithms (a SeaWiFS European Algorithm Set, or SEAS). The system that will be used to provide proper user interfaces in the ground seg-

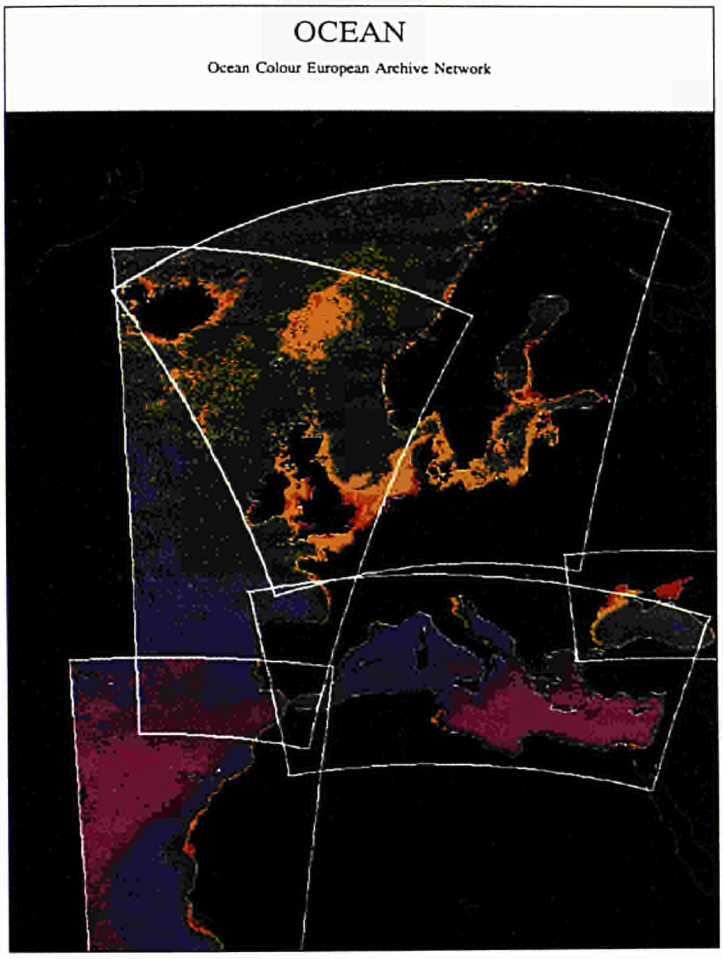


Figure 4.18: Composite ocean colour image of the European Seas, derived from 6436 individual scenes collected by the CZCS, from 1979 to 1985. The original data were processed to apply sensor calibration algorithms, to correct for atmospheric contamination, and to derive chlorophyll-like pigment concentration (shown by the colour coding as mg/m3). Each image was then remapped to the same geographical equal area projection, with fixed spatial resolution (1 km2 pixels). Finally, the data set was composited by averaging all of the processed and remapped images on a pixel by pixel basis. The present image shows all of the annual means of chlorphyll-like pigment concentration developed in the OCEAN Project framework, remapped together using a Mercator projection. The composite highlights the differences between the main European basins, and some recurrent features such as river plumes, permanent gyres, and coastal upwelling.

ment context will be essentially an extended version of the OCEAN code originally developed for CZCS data, coupled to the new SEAS. This system will include options to generate a series of parameters and data products, up to maps of primary production. Interfacing such system with marine dynamical models is also being considered. These activities aim at providing tools and support in the use of ocean colour data in general, of relevance also for subsequent (e.g. MERIS) missions.
The OCTOPUS Programme is ready to issue an Invitation for Research Applications (IRA), soliciting letters of intent and proposals from the ocean colour user community interested in SeaWiFS data.

In Europe, access to SeaWiFS Local Area Coverage transmissions will be provided by the OCTOPUS network of receiving stations organised by the ESA. While operational and commercial activities will be regulated by an ad hoc system, it is planned to distribute data for scientific purposes (at a nominal data reproduction fee) under the umbrella of c specific agreement with NASA. Such an agreement will include the exchange of both LAC and GAC SeaWiFS data, of in situ data, and of algorithms, models, dedicated software. In order to satisfy the requirements of the agreement, the IRA will request all applicants to sign a copy of Appendix B of the Dear Colleague Letter (DCL) issued by the NASA to discipline the scientific use and dissemination of SeaWiFS data.
The IRA conditions (e.g., the request for progress reports on the use of SeaWiFS data) will have to be agreed upon, by all applicants, 'on top' of those foreseen by the DCL. Points still to be clarified are (1) the procedures and (2) the restrictions (e.g., on real time data access) to be followed by the OCTOPUS Programme for SeaWiFS data distribution. Finally, the signature of a formal letter of intent, or similar document of understanding, between the OCTOPUS partners (EC and ESA) and NASA could also be required.

CAL/VAL Activities

A series of in situ measurements, including both oceanic and atmospheric parameters, has been initiated, using advanced instrumentation on a fixed offshore platform in the Adriatic Sea. The campaign will be conducted with the support of an Italian Institute of the Consiglio Nazionale delle Ricerche based in Venice, and in the frame of a wider co-operation agreement with other European groups (the Coastal Atmosphere and Sea Time Series, CoASTS, Project; see Figure 4.19). Different measurements are foreseen, some continuous and some at regular time intervals. A one-year test phase will be used to evaluate instruments in use and time series obtained. The general aim of this initiative is that of generating a reference set of coupled oceanic and atmospheric data, that will be used in the framework of SeaWiFS and/or OCTS CAL/VAL activities. The development of such a reference data set is primarily seen as a pre-requisite for satisfying the future MERIS CAL/VAL needs. An extension of the campaign, including parallel measurement series from other platforms (i.e. in the North Sea and North East Atlantic), and over flights with suitable airborne instrumentation, is also being planned.

OCEAN COLOUR Simulator

Progress has been made in the definition of the steps needed for the development of a OC end-to-end simulator (see Figure 4.20), at the present stage particularly devoted to SeaWiFS simulations. Such action takes advantage of the experience and databases derived from the analogous MERIS study already conducted by the ESA. The current development will lead to a 'prototype' simulator, which would include the outcome of atmospheric studies being conducted by other co-operating research groups. An assessment will then be made on the real need and possibilities to proceed further. Even though the simulator will be exploited extensively in the OCTOPUS Programme, it should be considered as a 'laboratory tool' for internal use, and not a data production tool. As such, it will not be made available in general to third parties external to the Programme (i.e. contrary to what will happen for sharing SEAS software, the simulator should not be released under the agreement with the NASA). Finally, the SeaWiFS (and MERIS) end-to-end simulator will also undergo suitable adaptations, in order to make it applicable to the study of land surfaces. Two specific activities are currently planned: the development of a module to generate the radiances at the entrance of the instrument over typical terrestrial surfaces, and the design of new products specific to land applications capable of exploiting the enhanced spectral resolution of the new sensor(s).

Perspectives for 1995

The OCEAN Project will conclude its activities by completing its data distribution, in support of the research activities related to the OCEAN ADP. A final (3rd) OCEAN Project ADP Participants Meeting, to be held in the second half of 1995, is planned in order to review all the achievements of the Project. Selected presentations of the results obtained by the ADP Participants will be published in a special issue of a relevant scientific magazine.

Further, the OCTOPUS Programme will become operational, in order to allow the use of SeaWiFS data. The following activities are envisaged:

- SeaWiFS data products definition and algorithm development,
- data/algorithms calibration and validation (by extension of the CoASTS Project),
- development of special applications and research co-ordination,
- in collaboration with the ESA and other European scientific partners.

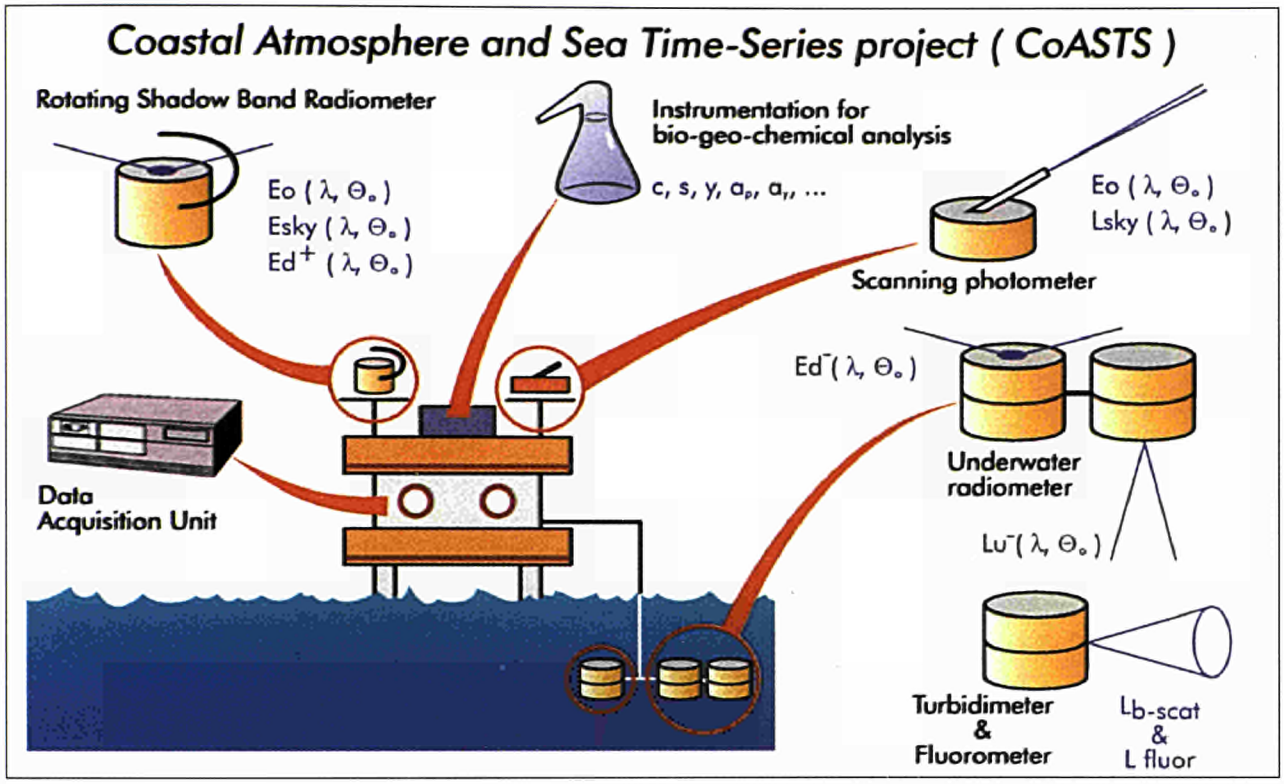


Figure 4.19: Coastal Atmosphere and Sea Time Series, CoASTS, Project: offshore platform instrumentation set up and planned measurements.

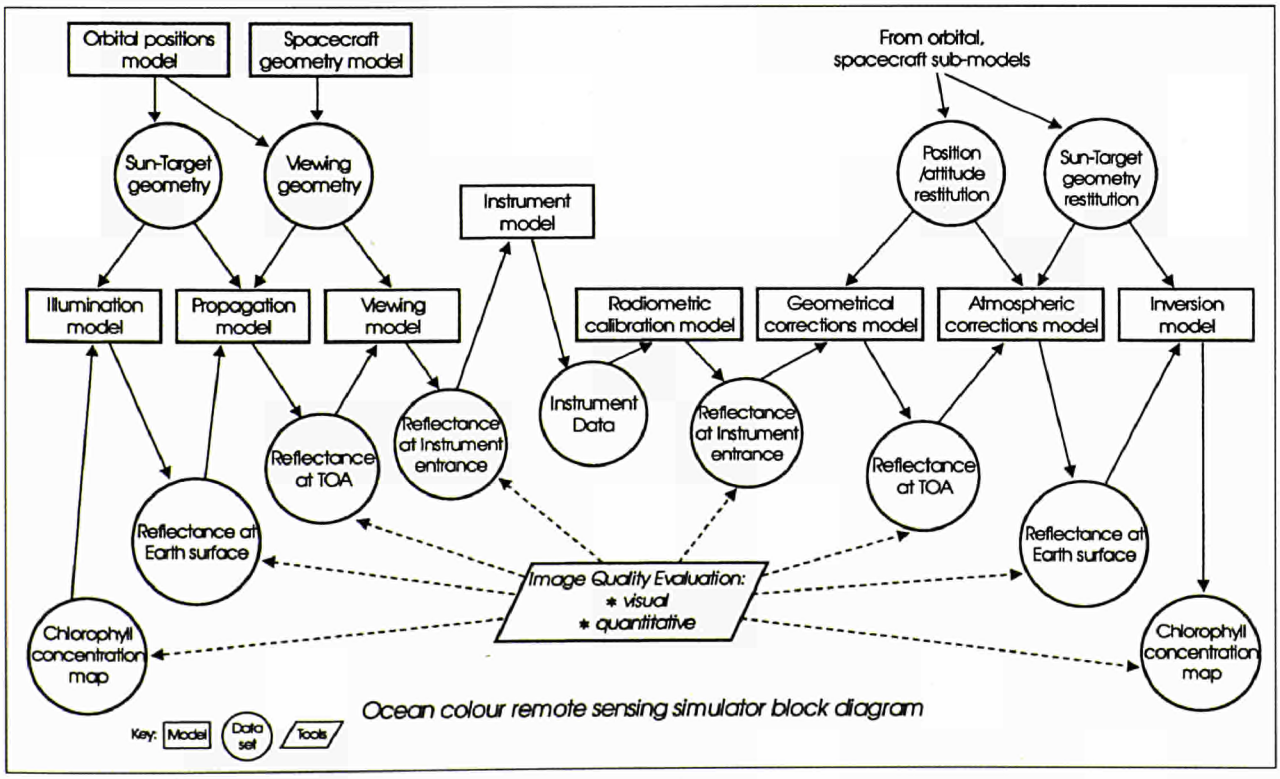


Figure 4.20: OC end-to-end simulator: block diagram of the main module.

5 MONITORING OF TROPICAL VEGETATION

Staff

Scientific and Technical Support:	10
Secretarial Support:	1
Scientific Visitors:	4
Students:	14
Total:	29

Facilities:

Servers for satellite data storage and processing:
- 2 SUN Sparc 10
- 2 SUN Sparc 20
- IBM Risc 6000

Workstations for image analysis, GIS and modelling:
- 11 SUN Sparc 2/5/10 and 8 IBM Risc 6000
- 2 Workstation GIS using Arc-Info
- 0 Workstation ERDAS
- 7 Workstation for modelling

X terminals: 3 Sun Sparc X
20 PCs (Apple/Mac and DOS/Windows) for office work
4 Colour printers and 7 laser printers
Juke-Box MO holding 180 Gigabytes of data (currently: GAC Archives Africa)
Hard-disk distributed over the Local Area Network: approx. 100 Gigabytes.
Taper drives: CCT, exabyte 8mm, DAT 4mm, QIC.

Operating systems supported:
- on SUN: SOLARIS 2.x and SUN OS 4.1.3
- n IBM Risc 6000: AIX 3.2
- DOS/WINDOWS
- APPLE System 7

Software:
- IDL, Softbench, Compilers
- Oracle 7, GMS data management system
- Custom developed applications software.

The Geographic Information System (GIS) general functions are:
research of different data sets (type, quality, scale)
acquisition and update of the database
data management: storage, cataloguing, research and analysis
integration of GIS cartographic information with thematic information derived from satellite data:
support to main research activities of the MTV unit.

The overall objectives of the Monitoring of Tropical Vegetation (MTV) Unit are

- to address issues related to the study of vegetation at the surface of the earth using, as a first priority, data derived from earth observation instruments. The fields of applications are: ecosystem distribution and productivity, continental land cover/land use assessment, tropical forest monitoring and biomass burning.

- to develop new remote sensing based methods for monitoring vegetation dynamics

- to derive land surface physical characteristics from remote sensing data and interface such information with atmospheric, climate and biosphere models.

As in previous years, the research carried out in the MTV Unit addresses the above objectives on regional to global scales. In this sense the MTV Unit expects to contribute both to a better understanding of changing patterns of vegetation distribution and biomass, and also provide the knowledge base needed to produce relevant satellite derived global products. The tropical belt has continued to be the geographical focus of study as this region contains the most actively changing of all the Earth's ecosystems.

The MTV Unit is divided into three projects which have well identified sets of specific objectives. The project research activities are described in detail in this chapter. The MTV projects are:

- the TREES/FIRE Project (tropical forest and biomass burning monitoring),

- the MERCATOR Project (continental land cover/land use characterisation),

- the TEAM Project (physics of remote sensing, surface atmosphere interactions, biosphere modelling and canopy characteristics).

Members of the MTV Staff have increasingly been involved in research and development related to future earth observation missions and instruments. This includes the co-ordination of the SPOT 4 -VEGETATION International Users Committee as well as participation in reviews and task forces related to this global vegetation monitoring mission.

The Unit has also actively participated in the ESA MERIS Scientific Committee as well as being involved in the ATSR (Along Track Scanning Radiometer instrument on board ERS-1) application development.
MTV Staff have contributed to the NASA MODIS Land Working Group. A tight link has been maintained with the NASA (Advanced Very High Resolution Radiometer (AVHRR) Pathfinder activity with respect to the AVHRR Global Area Coverage (GAC) data processing, and staff have contributed to the Land Cover and Validation Working Groups of the International Geosphere Biosphere Programme (IGBP) Data and Information System (IGBP-DIS).

MTV has been active in developing links with institutions and experts in developing countries through field

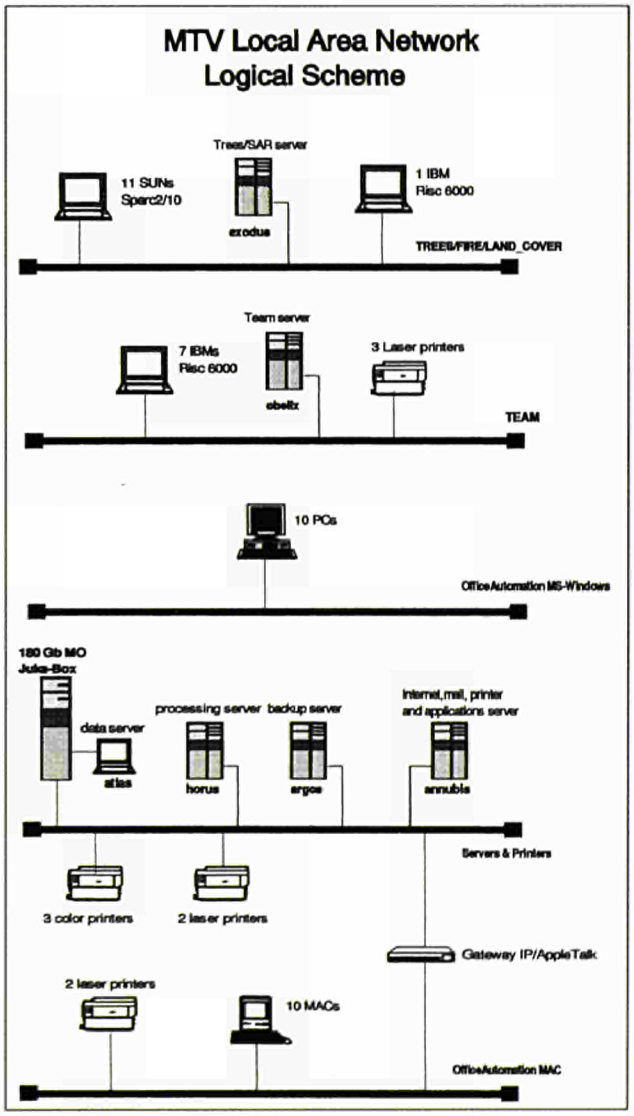


Figure 5.1: MTV computer facilities - local network

work, participation in workshops and conferences and mutual consultation. The range of contacts in these countries is directly linked to the needs for field investigations (validation) and to the interest expressed by non-European institutions for sharing approaches developed by the MTV Unit. In Africa field campaigns have been conducted in the framework of the TREES Project in Ivory Coast and, for the FIRE project, in Madagascar and the Central African Republic. Contacts with various institutions in West Africa has been maintained with respect to the MERCATOR activities. In Asia, TREES related field work has been carried out in China, Papua New Guinea and Thailand.

Contacts with the General Directorates of the Commission have expanded in parallel with the geographical interests of the Unit. A close collaboration with DG VIII (Development) on Africa and ACP Countries and with DGI (External Affairs) and DGXI (Environment) on tropical forest issues has been maintained.

The Unit has enjoyed considerable success throughout the year. Particular highlights include

- Completion of the processing of 10 years of AVHRR daily GAC data over Continental Africa. The data set has supported a) analysis of continental land cover and land cover change detection using Normalised Difference Vegetation Index (NDVI) and surface temperature outputs, and b) the establishment of continental fire distribution patterns for three years.
- Completion of the analysis of the pan-tropical 1 km resolution AVHRR data set. Production of the tropical rain forest classification map.
- Setting up and successful operation of a portable field AVHRR receiving stations for biomass burning studies (in collaboration with the UK's Natural Resources Institute (NRI).
- Design, installation, testing and operation of an ERS-1 processing chain for the construction of the Central African ERS-1 mosaic (this is based on some 430 ERS-1 images).
- Implementation of a comprehensive ray tracing model using the latest ray tracing graphics technique; successful application to describe the transfer of radiation in complex vegetation scenes.
- Publishing of two reference works; 1) Modelling Deforestation Processes- a review, and 2) Collection and pre-processing of NOAA-AVHRR 1 km resolution data for tropical forest resources monitoring.
- Organisation of a Special Session on "Design and Evaluation of Vegetation Indices" at the American Geophysical Union Fall Meeting.
- Development of the RETINA image analysis platform, with implementation of a prototype AVHRR pre-processing chain.

As a whole the MTV project has been able to pursue its specific objectives during 1994 keeping in mind that this has been a year of transition between two framework programmes, and that new JRC working rules were in preparation for the IVth Framework programme (1995-98).
The rule which foresees an increased reliance of JRC Projects on competitive funding will strongly affect the modus operandi of the projects undertaken during the years to come.

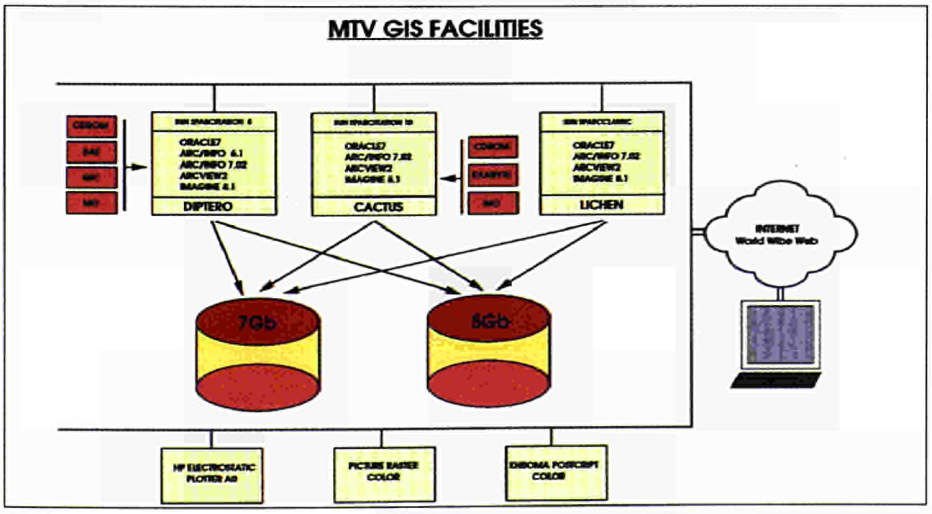


Figure 5.2: MTV GIS facilities

5.1 CONTINENTAL LAND COVER / LAND USE CHARACTERISATION (THE MERCATOR PROJECT)

Summary of Objectives

To describe and explain the state and recent changes of the inter tropical environment at a regional to continental scale with emphasis on land surface conditions (land cover and land use).

1994 PROGRAMME OF WORK

Introduction

The activities which previously focused on biomass production assessment in tropical regions have been expanded to include land cover mapping over large areas (small scales). In particular, the objectives of the IGBP-DIS Global Land Cover Project have been taken into account in designing the new orientation of the project. This change is reflected in the adoption of the new project name MERCATOR (Monitoring Ecosystems with Remote Sensing and Cartography in African TrOpical Regions).

Results

Data acquisition and management

Validation of small scale land cover maps cannot easily be carried out by direct field observations, especially when sub-continental coverages are considered. The only pragmatic option is to rely on existing information, such as maps, air photographs or high resolution satellite imagery. For this reason a survey of "historical" documentation was carried out over West Africa. This focused on thematic maps produced during the past 20-30 years by various agencies. A report was prepared, which contains all data sets detained or produced by a selection of the most famous institutions active in the region. Thanks to this study the most useful reference material could be identified and ordered. This effort will be continued in 1995 for the rest of the continent.

Knowledge concerning data availability has become a critical issue at MTV. Because of the expansion of the unit, it has become essential to set up a data base of all types of collected documentation.

1994 Milestones

une: AVHRR 10 year Africa GAC data processing completed.
Aug.: Delivery of the prototype HRPT Processing chain on RETINA completed.
Sept.: Analysis of GAC data performed for continental land cover and change detection
Dec.: hardware delivered for processing large scale HRPT data sets

The GMS software developed by Da Vinci Consulting was selected after a broad invitation to tender. This
offers a geographical interface to the ORACLE database software, and allows information to be accessed through World Wide Web using the Mosaic software. Currently most of our map library has been registered into the system. Next steps foreseen for 95 will include the inventory of all GIS and remote sensing data files, as well as other information.

Satellite data analyses

10 years of daily continental GAC images were assembled in 10-day and monthly syntheses. Year to year comparisons and average situations were processed and a map of actual biomes of Africa was produced (Figure 5.3). In addition, change maps were prepared for further comparison with field historical observations.

In 1994 MTV started an effort to update the software environment of its AVHRR High Resolution Picture Transmission (HRPT) processing chains. These were developed using FORTRAN language. As a result of diverse user requests, several versions were available. These deal for example with different data input formats, geographic areas and produce different geophysical parameters. The increasing number of versions lead to difficulties in software management. It was thus decided to develop in object-oriented lan-

guage, RETINA, a remote sensing data handling platform, on which all requested functions are developed in a modular manner. In 1994 not only was this core was developed, but also a prototype HRPT processing chain; the latter based on algorithms available in previous packages. In 1995 the effort will be focused on expanding the capacities of this new processing chain.

In parallel to this effort our data set of AVHRR HRPT imagery was completed over selected regions of Africa, namely the Central African Republic, and Western Africa. Parts of these data were already processed to test software quality of the above-mentioned prototype. In 1995 the whole data set will be re-processed on a systematic basis, and land cover analysis will be carried out.

Perspectives for 1995

Activities in 1995 will focus on the following:

- production of land cover maps over Central African Republic and West Africa transect.
- mass processing of the IGBP 1 km AVHRR data over the whole African continent for continental land cover classification using the individual spectral channels of the AVHRR.
- validation of results using a to be established network of correspondents over field sites.
- comparison between satellite derived land cover pattern and model predicted potential vegetation.
- design of integrated data bases.
- implementation of the GAC-Asia Processing Chain (in collaboration with the FAO).

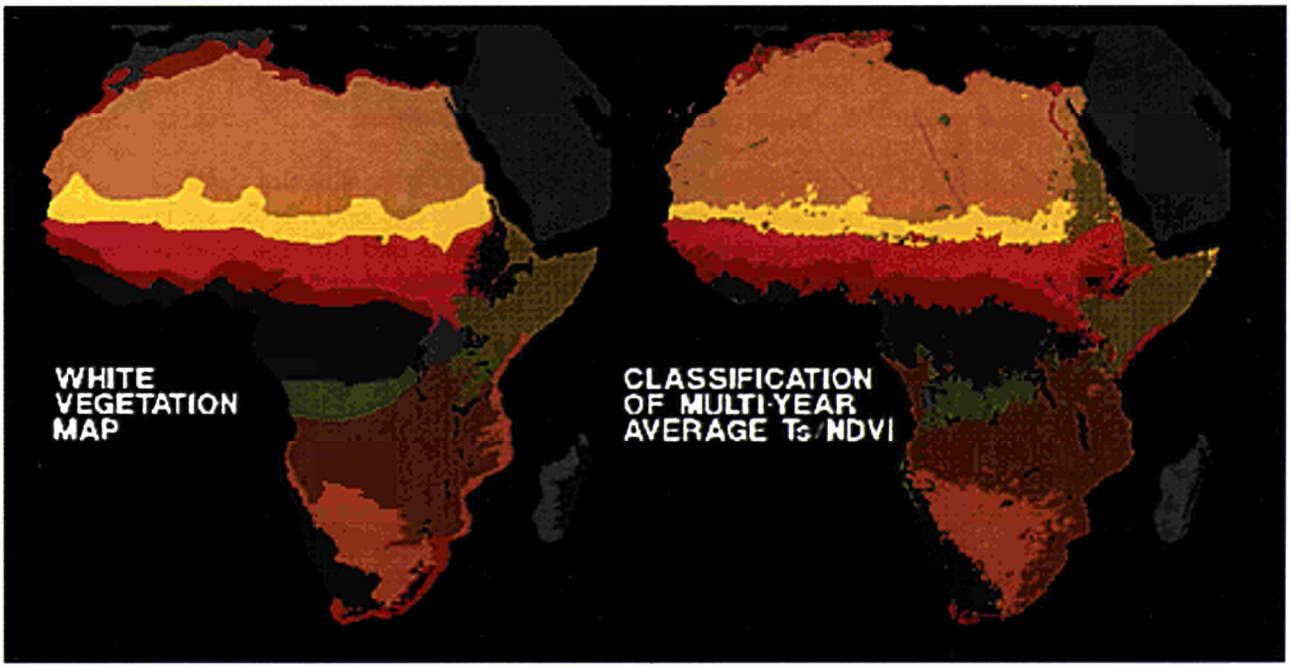


Figure 5.3: Comparison of the level 1 White's map of the vegetation of Africa (UNESCO: 1983) with the multitemporal, supervised classification of the 10 year average (1982-1991) data of the ratio between monthly maxima of surface temperature and the normalised difference vegetation index. The overall agreement between the two maps is 75%.

.2 MONITORING OF BIOMASS BURNING (THE FIRE PROJECT)

Summary of Objectives

To develop remote sensing based methods for the monitoring of vegetation fires,

To apply such methods to document temporal and spatial distribution of fires at regional, continental and global scales

To analyse such distribution patterns with relation to a series of determinant or impacts such as land cover-land use dynamics, atmospheric chemistry, climate change and environmental management policies

1994 PROGRAMME OF WORK

Introduction

The consequences of biomass burning are extremely diverse. It affects atmospheric chemistry, climate, vegetation distribution and, of course human activities. The ecological, environmental and economic effects of biomass burning occur across all scales, from the local to global.

Much of the existing literature on fire has concentrated on individual fire events, or on characterising the process of combustion itself. It is now recognised that fire should be studied on scales which match the global nature of the phenomenon. Detailed regional and global histories of fire activity, fire characteristics and effects are required, along with improved predictive capabilities to examine future trends and impacts. This information is not currently available. For this reason the MTV Unit has launched the Fire In global Resource and Environmental monitoring (FIRE) project.

1994 Milestones

Feb.-March:	the concept of a global fire product has been elaborated and preliminary tests are being performed using the IGBP 1 km AVHRR product.
June:	documentation of biomass burning patterns using a series of AVHRR data at 1 and 4 km resolution. Continental patterns have been derived for a five year period from the AVHRR GAC daily passes over Africa. Analyses of the Madagascar daily fire situation has been performed using the !km data received by a local portable station. A preliminary look at Southeast Asia fire patterns has been performed.
Aug.:	the Vegetation Fire Information System has been designed and is being put into practice.
Jan. and Nov.:	the validity of using the portable NRI AVHRR receiving station has been further confirmed by field work in Madagascar and the Central African Republic. The data obtained by the station provide a unique guide for assessing biomass burning in a national environmental management perspective.

Results

Fire patterns

Documenting biomass burning patterns has been pursued at three levels of investigation:

At the global level the test phase of the development of a Global Vegetation Fire Product has been initiated and will deliver by mid-95 the results of processing of 1 week of global data (14 complete NOAA - AVHRR orbits) and a processing chain designed to handle global data sets at 1 km resolution.

At the continental level, a series of 10-day maps of fire distribution have been produced over Africa using the resampled 4 km GAC data for the years 1984 to 1989. The results have been analysed with respect to rainfall patterns (more than 900 stations) and vegetation types. The role of fire activity in the savannah domain as a source of chemical contamination in precipitation over equatorial African forest has been assessed. The fire patterns detected on the satellite imagery have been merged with the land

cover map produced with the same satellite data source (Figure 5.4). The correlation between biome distribution and fire patterns has been studied.

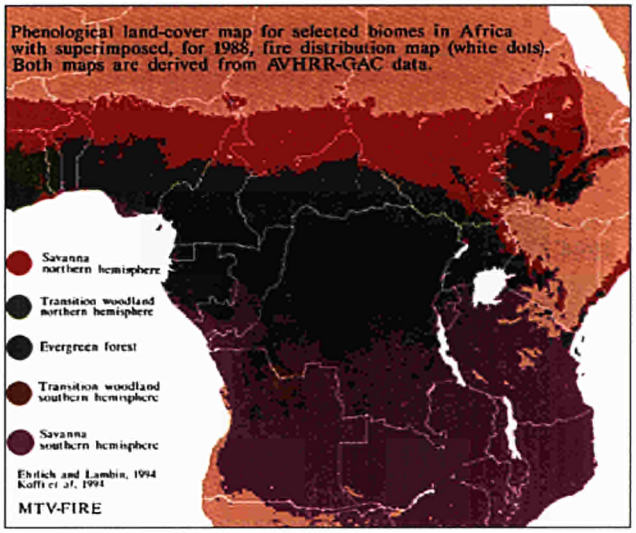


Figure 5.4: Phenological land-cover map for selected biomes in Africa with superimposed, for 1988, fire distribution map (white dots). Both maps are derived from AVHRR-GAC data

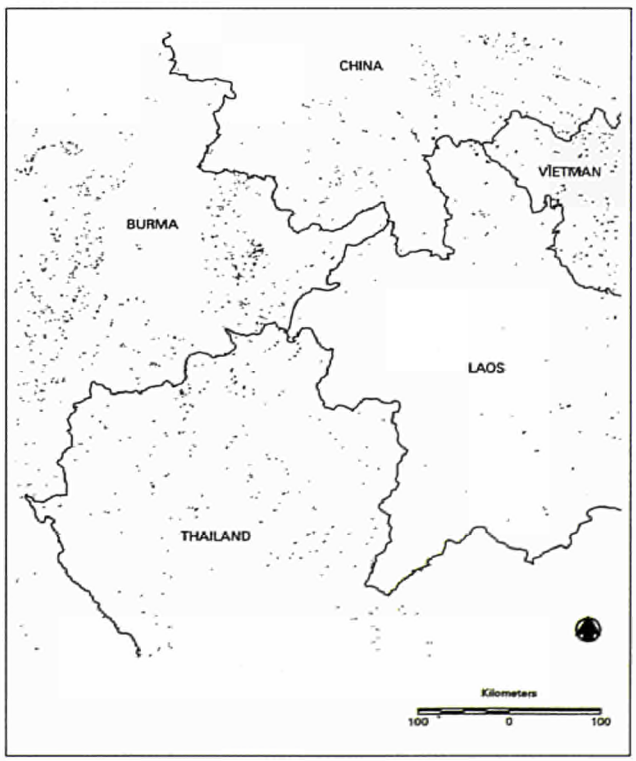


Figure 5.5: Distribution of fires (black dots) in northern continental Southeast Asia, 9 February 1991, determined using NOAA AVHRR 1 km resolution data.

Still at the continental level but in Southeast Asia, preliminary investigations have identified the main areas of vegetation fire concentration. Specific attention has been given to Laos, Vietnam and Southern China (Figure 5.5).

At the local level the analysis of fire dynamics and distribution has focused mainly on Madagascar and Central African Republic which were visited in the course of field campaigns.

Methods

Tools and methods were further refined to cope with the move towards fire analysis on a global scale. Conceptual work and the integration of various items of current knowledge and expertise have been performed in the framework of the definition of the global fire product. Similarly, innovative approaches to the analysis of satellite data were developed for the study of fire patterns using the resampled GAC data. The Vegetation Fire Information System has been conceived in direct line with recommendations made in the framework of IGBP-IGAC-BIBEX (An experiment of the IGBP's International Global Atmospheric Chemistry [IGAC] project. This system will provide a unique tool for displaying, interpreting and analysing fire patterns and their impact upon the landscape or the chemistry of the atmosphere.

New satellite data sources have been examined. The ATSR in particular has represented an important source of data for the study of fire scars; preliminary results show that large fire scars are better defined on ATSR than on AVHRR. An investigation has started on the use of ERS-1 SAR data for the detection of fresh fire scars in the African savannah.

EXPRESSO

An important activity of the FIRE Project is related to its participation to the international EXPRESSO Experiment. EXPRESSO (Experiment for Regional Sources and Sinks of Oxidants) is an official IGAC project. The MTV Unit's contribution to this campaign is threefold: documenting the active fire distribution in Central Africa during the projected 1996 campaign, assessing the burnt biomass during those events and implementing the Vegetation Fire Information System.

Fire Management

The feasibility of using fire monitoring techniques in programmes dealing with the management of protected areas and the conservation of primary forests has been demonstrated in the particular case of Madagascar. A proposal has been made to implement such a system on an operational base.

Perspectives for 1995

- The first tests of a processing chain leading to a global fire product will be performed. The continental analyses will continue over Africa and will be initiated over Asia using a new processing chain currently implemented.
- The analysis of continental fire patterns will be conducted with respect, mainly, to rainfall patterns, climatic events and land cover/ land use practices.
- An extension of the analysis of 1 km AVHRR data over Asia will be pursued in order to stratify the continent with respect to fire dynamics, density and distribution. Field campaigns will be organised.
- The preparation of the EXPRESSO Campaign will be continued during 1995, with frequent visits to the field sites in Central African Republic. Emphasis will be put on obtaining quantitative assessments of burnt biomass in the woody and shrub savannah ecosystems of the forest-savannah transition zone.
- A prototype of the Vegetation Fire Information System will be installed and tested. Geophysical approaches to surface parameter analysis will be applied to the 10 years of fire points derived from the GAC data for Africa.
- Investigation will be pursued to integrate the information of ATSR and ERS-1 SAR into the range of data sources available for fire and burnt scar analysis. Pre-processing tools for ATSR2 will be further developed.
- FIRE will continue its contribution to IGBP Core Project activities through the IGAC - EXPRESSO and DEBITS projects and through the implementation of the global fire product using the IGBP-DIS data.

3 TROPICAL FOREST MONITORING (TRE TREES PROJECT)

Summary of Objectives

To develop techniques for 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).

To develop techniques for the detection and monitoring of active deforestation areas; measurement of deforestation rates in critical areas.

To develop a comprehensive Tropical Forest Information System to support the modelling of tropical deforestation dynamics.

1994 PROGRAMME OF WORK

Introduction

Monitoring change in the forests of the tropical belt presents a formidable challenge for remote sensing, yet such a task is vital from ecological, environmental and economic perspectives.
In order to address this issue the TREES Project (Tropical Ecosystem Environment observation by Satellite) was initiated in 1991. TREES is funded via financial resources outside the framework programme. 1994 was the last year of the first phase of TREES.

The TREES project is oriented towards the study of tropical forest dynamics at regional to global scales using remote sensing techniques.
Data derived from both the NOAA 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 over South East Asia, Central and West Africa and South and Central America (Figures 5.6 and 5.7). Higher spatial resolution optical imagery is used to verify the patterns observed, and the classifications derived from the AVHRR imagery. The use of ERS-1 SAR data has been tested on a set of representative sites.

1994 Milestones

April: ERS-1 SAR '94 study kick-off workshop held in Paris. This involved studies on 18 selected sites in Latin America and Southeast Asia and over a full mosaic of Central Africa.

June: the validation and calibration exercise finalised. High resolution imagery are used to determine the accuracy of the estimated global forest area figures.

Nov.: the base line assessment of the global tropical forest cover using NOAA AVHRR 1 km data is finalised.

Results

The AVHRR Data Base

Apart from the ESA-Earthnet network and the IGBP-DIS Land Cover Initiative,
there was no systematic effort in the collection of a pan tropical AVHRR data set answering the needs of the TREES Project.

In 1994 the TREES AVHRR data sources were as follows:

- Africa: Maspalomas, Niamey and Nairobi stations via Eurimage, LAC data via NOAA
- Southeast Asia : Bangkok station via UNEP-GRID Bangkok, Townsville station via CSIRO (Australia), Manila station via Eurimage and Chinese stations through the Chinese Space Agency
- South and Central America: LAC data via NOAA-NESDIS, Baton Rouge station via the Louisiana State University

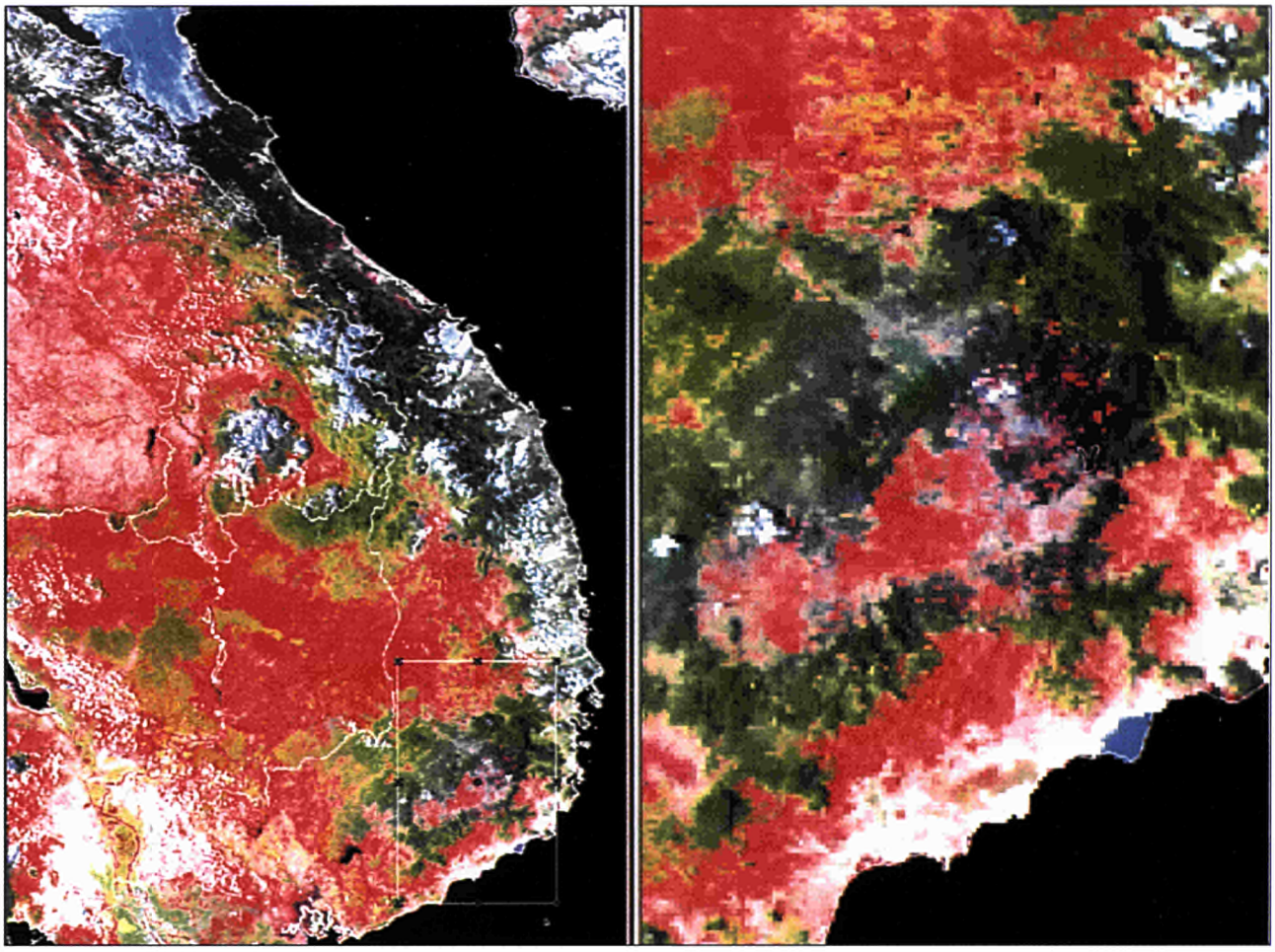


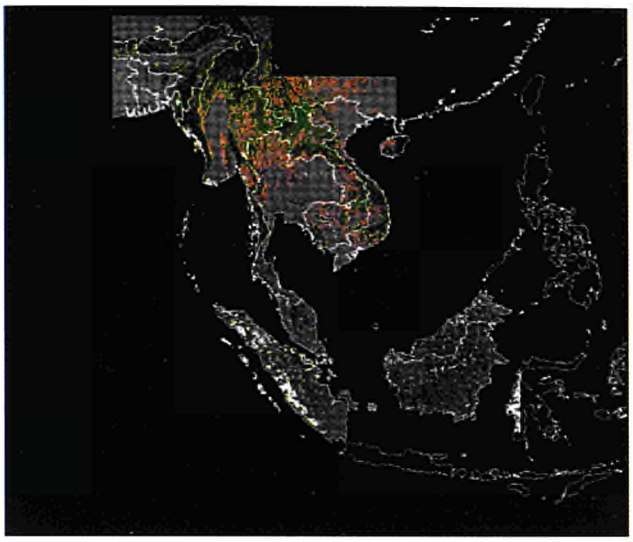
Figure 5.6: NOAA AVHRR 1 km resolution image of the 06 March 1993 covering the Southern Vietnam and part of the Mekong Basin in Cambodia and Laos.
Green = vegetated areas (Evergreen forests and irrigated areas)
Red = dry areas (seasonal forests and agriculture)
The zoom shows an area of active fires (red dots) associated to burned areas (black) and smoke (thin blue). Those fires are taking place inside a forested area (pine forest).

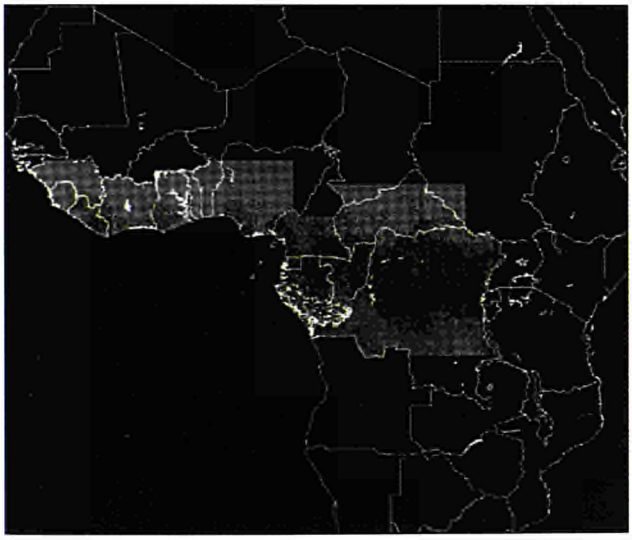
Region	Number of AVHRR scenes 1990-93
Southeast Asia	320
Africa	250
South America	130

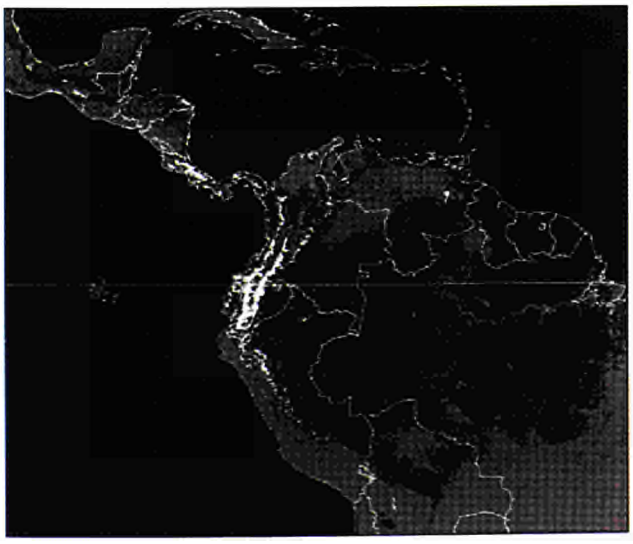
The result of this intensive pan tropical data collection effort is summarised in the following table:

These data are held in the TREES raw data collection. 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.

A technical document describing the methods of collection and pre-processing of NOAA-AVHRR 1 km resolution data was published at the end of the year.







AVHRR Data Analysis

The 1 km resolution forest cover classification for Southeast Asia, Latin America and Africa have been finalised. The following regions have been completed and updated : Insular Southeast Asia (Kalimantan and Irian Jaya / Papua -New Guinea) and Peru window.

The methodology adopted for South and Central America is similar to that adopted for insular Southeast Asia. The results and methodology will be described in a future technical document under preparation.

A collaboration with the Chinese Academy of Forestry has been carried out for the analysis over the Xichuanbana area of the Yunnan province.

Validation and Calibration Processes

The acquisition of high resolution data sets covering a wide range of forest-non forest interfaces was given priority (18 Landsat TM images for Asia, 7 for Africa and 8 for Latin America have so far been selected).

Principal sampling Units of 90 x 90 km's have been defined. A fragmentation index allows stratification of the 1 km classification into homogeneous sampling Units.
Regressions have then been calculated on the basis of the forest/non-forest classified TM and AVHRR pixels using 15x15 km secondary sampling units. The FAO Forest Resources Assessment Grid-points results have been included in the study.
A complementary method has been developed using a two steps correlation process based on a fragmentation index.

Figure 5.7: TREES 1 km forest classification over the three continents.
Legend :

dark green	=	dense evergreen forest
light green	=	fragmented evergreen forests
brown	=	seasonal forest
grey	=	non-forest

Results of both methods show that the accuracy of the estimation of the global tropical forest areas are highly satisfactory (within 5%). The existing methods have to be refined to achieve good regional or national estimations.

Modelling and seasonality

Research has focused on:

a) spatio temporal modelling of forest cover changes through literature review: publication of a technical document "Modelling Deforestation Processes - A review".
b) AVHRR time series analysis for change and seasonality assessment : for these purpose the GAC 5 km 10-years daily data set over Africa were used.

ERS-1 SAR Data Analysis and Interpretation

The TREES ERS-1 study '94 was initiated in early 1994 with the objective of assessing the relevance and the usefulness of ERS-1 SAR in the framework of a system of global tropical forest monitoring.

MTV's approach is to perform a systematic investigation of tropical forest parameters on a pan-tropical scale. 18 study areas have been defined over the tropics and corresponding investigators have been selected. A work plan for 1994 has been presented at a workshop held at ESA headquarters, end of April 1994. MTV is co-ordinating the completion of the objectives set at the ESA meeting.

The feasibility of mapping vegetation from SAR data with respect to forest-related and environmental parameters was investigated . A data management, processing and analysis chain was set up for undertaking the analysis of a mosaic of more than 400 ERS-1 scenes over the Central African Basin (Figure 5.8)

Perspectives For 1995

- The results on the study concerning the relevance and usefulness of ERS-1 SAR data for tropical forest monitoring will be published following a workshop to be held in February 1995.
- A CD-ROM including the TREES-1 products will be published.
- A catalogue of forest/non-forest interfaces will be published.
- The joint use of low and high resolution data sets will be developed.
- The Tropical Forest Information System will form the basis of an operational deforestation monitoring system.
- AVHRR data Collection on a Pan-tropical basis will continue as part of the Monitoring Phase (TREES-2).
- Research methodologies will be tested concerning a) testing on selected hot-spots areas where rapid change is taking place, b) Integrating biomass burning information into TREES analysis (link with the FIRE Project).
- The existing and planned high/low resolution remote sensing systems will be assessed as data sources (including ERS, SPOT, ATSR-2 and Vegetation) and their relevance and usefulness for TREES-2 will be studied.
- TFIS will be further developed.

Figure 5.8: ERS-1 SAR image of 16 August 1994 over Central Africa (South Zaire; geographic co-ordinates: 5.496 South 25.627 Eas

5.4 TERRESTRIAL ENVIRONMENT AND ATMOSPHERE MODELLING (THE TEAM PROJECT)

Summary of Objectives

To develop and evaluate advanced physically-based models and numerical algorithms to extract reliable quantitative information on terrestrial environments from satellite remote sensing data in the optical domain.

To demonstrate the use of these advanced methods in practical applications, and to contribute to the research needed to address Global Change issues, paying special attention to the integration of modelling and remote sensing techniques.

To investigate biosphere-atmosphere interactions, 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 collaborate with national and international Space Agencies (e.g., ESA, NASA) on the design and implementation of scientific algorithms for the optimal exploitation of new sensors.

1994 PROGRAMME OF WORK

1994 Milestones

June: A comprehensive ray tracing model is implemented and successfully applied to describe the transfer of radiation in complex scenes, using L-systems to describe the architecture of plants.

Dec.: A special session on the design and evaluation of vegetation indices is organised at the American Geophysical Union meeting in San Francisco, the performance of the Global Environment Monitoring Index is confirmedlgorithm for use in land cover map updating

Introduction

The first goal of the Terrestrial Environment and Atmosphere Modelling (TEAM) group is to develop new or improve existing methods to derive reliable quantitative information on the state and evolution of the Earth's land surface and the atmosphere from existing remote sensing data sets. Substantial progress has been achieved in this respect over the last few years and in 1994 in particular. A wide panoply of complementary models is progressively becoming available to describe the transfer of radiation through the atmosphere and its interaction with terrestrial environments, including simple physically-based and empirical models, as well as computational models such as Monte Carlo ray-tracing tools. A deeper understanding of the nature and potential usefulness of vegetation indices has also been gained.

Results

Ray Tracing

Of particular interest is the development of a Monte Carlo ray tracing model, suitable to describe in great detail the transfer of radiation in arbitrarily complex three-dimensional media. This model takes advantage of the latest ray tracing computer graphics techniques, and has been developed specifically to simula e the propagation of light in terrestrial environments over a variety of spatial scales including (1) the micro-scale, which represents explicitly the structure and optical properties of scattering elements; (2) the meso-scale, which ranges from the structure of a single plant to the vegetation canopy; and (3) the macro-scale, which includes the topography and the large scale landscape organisation. This model can be considered as a ``virtual laboratory'', capable of generating reflectances and absorption profiles of complex targets, where all geometrical and physical quantities can be controlled explicitly. So far, this model has been used to carry out sensitivity studies on synthetic trees generated with the L-systems technique, and to assess the accuracy of simpler reflectance models both in direct and inverse mode. An example of a forest canopy, generated with L-systems techniques, is shown in Figure 5. 9, which demonstrates the level of detail already achievable. The computer code for this virtual laboratory has been adapted for parallel processing environments to take advantage of multi-processor machines.

The Message Passing Interface (MPI) standard is followed for this purpose.

Applications development

The second objective of TEAM is to demonstrate the performance and usefulness of these new tools and techniques in practical applications. Preliminary studies have shown the advantages of the Global Environment Monitoring Index (GEMI) over the traditional Normalised Difference Vegetation Index (NDVI). This results from the built-in atmospheric correction incorporated in the GEMI. A special session of the American Geophysical Union (AGU) Fall meeting was dedicated to the design and evaluation of vegetation indices. This event provided an international forum to discuss these issues and the desirable characteristics of these spectral tools.

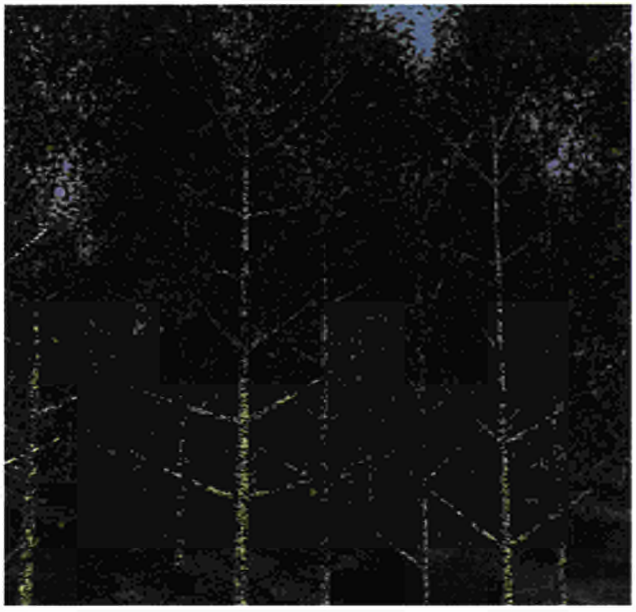


Figure 5.9: Example of an artificial forest patch as used by the Raytran program to compute the scattering of light by a plant canopy. Each tree is generated with L-systems. This scene is composed of 520,000 objects, and is illuminated by a simulated sun at a zenith angle of 40 degrees.

Bidirectional reflectance characterisation

A new activity started in 1994, aiming at detecting the presence of dense dark vegetated areas in a scene, and at characterising their bidirectional reflectance in the first two spectral bands of AVHRR. This study will provide valuable information on the reflectance properties of dense forests, and will permit or improve the retrieval of the aerosol optical thickness over these regions.
Preliminary analyses are focusing on the forests of the Congo basin and Northern Finland. This study also contributes to TEAM's effort in support of the MISR instrument.

Global vegetation models

The third goal of TEAM is to develop global vegetation models usable to study the interactions between the biosphere and the atmosphere. A first version of the ecological submodel (EMU, Ecological ModUle) of the operational biosphere model (TGV, Transient Global Vegetation model) has been developed. This model currently generates a global potential vegetation distribution in equilibrium with the specified climate.
The respective advantages of modeling and remote sensing can be discussed in relation with Figure 5.10, which shows the potential Leaf Area Index (LAI) predicted by the EMU model (on the left) on the basis of climatic information only, and the apparent distribution of this parameter as estimated from remote sensing data (on the right). The model often provides better estimates of this parameter than remote sensing over tropical forests, as a result of the well known saturation of AVHRR channel data over deep forests. On the other hand, remote sensing data could help drive the model in drier regions, where climate is much more variable from year to year.

The second half of 1994 also saw the development of a coupled carbon cycling, soil-water balance and terrestrial vegetation model to study the impact of water stress on the seasonal exchange of CO2 on a global scale. Remote sensing data (GVI) are used to estimate fractional cover of vegetation. The predicted seasonality in the wet-dry tropics has been successfully compared to atmospheric CO2 measurements through the Max Planck Institute for Meteorology atmospheric tracer transport model. A further application has been to study the impact of physiological differences in the photosynthetic pathway (C3 vs. C4) on the isotopic composition of atmospheric CO2 (C13 / C12).

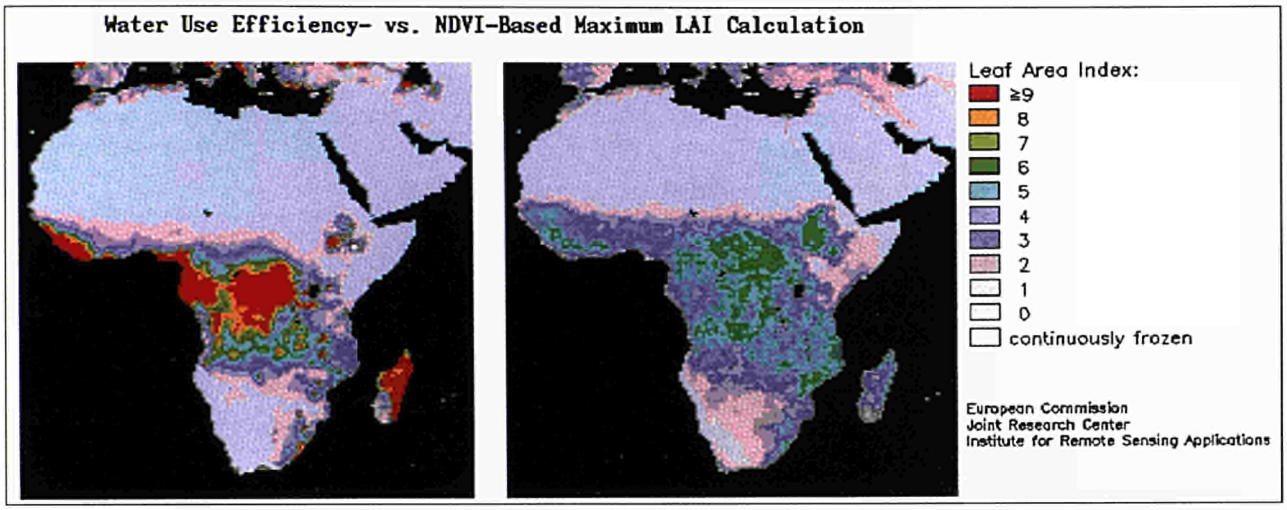


Figure 5.10: Comparisons between two leaf area index (LAI) maps: one obtained with EMU, the Ecological ModUle, a global vegetation model designed to use the full potential of satellite data, and one computed from NDVI calculating first the fraction of photosynthetically active radiation (FPAR) using a linear regression relating FPAR and NDVI, and then a logarithmic function of FPAR. The two maps differ in terms of intensity and areal coverage. Intensity differences are explained by the saturation of NDVI-based LAIs at values around 6, a physical fact which is well documented. This version of EMU does not discriminate well between low LAI values. This explains differences in areal coverage. The lessons learned from such a simple comparison exercise actually open new avenues for the verification of global biosphere by remote sensing.

Perspectives for 1995

High priority will be given to the exploitation of existing tools and models in applications of direct interest to other MTV projects. These could include, for instance, the documentation of the directional and atmospheric contributions in the observed seasonal patterns of tropical forest reflectance, the development or improvement of techniques of land use and land cover change assessment, or the estimation of the amount of vegetation that could burn or that remains after the passage of a fire front.

Similarly, the development of the TGV model will be pursued to generate an operational biosphere model oriented towards the explanation of current vegetation distribution and conditions, and the prediction of future states under changing environmental conditions. This will require, in particular, the upgrade of EMU from a static to a dynamic, time dependent model.

Work on the carbon cycle will continue to develop a fully predictive model where various parameters, such as timing of leaf onset and shedding, seasonal cover fraction of green biomass, or plant water status, are provided by remotely sensed data. Thus, the combination of physical measurements with knowledge about physiological processes can be used to monitor vegetation functioning on a continental to global scale and thereby provide urgently needed data to test water and carbon fluxes models of terrestrial vegetation used climate and carbon-cycle research.

Radiation transfer studies at the milli-scale will be pursued to investigate the importance of the leaf chemical composition and internal cell structure on the spectral signature at various wavelengths. Moreover, macro-scale effects will be explored, first in the case of forest canopies. This study will help improve our current understanding of the space and time processes controlling radiometric characteristics in various tropical forests.

Research will be initiated to develop new methods to exploit future sensors. These methods will capitalise on the improved radiometric resolution, larger spectral resolution, and better angular coverage of the new sensors. In particular, specific products will be investigated to retrieve quantitative information about the nature and evolution of the vegetation from remote sensing data. An AVHRR simulator will be constructed to allow the investigation of observed seasonality patterns, and the specifications for a scene simulator to generate typical scenes at the top of the atmosphere, as they would be measured by various space instruments, will be drafted.

6 ADVANCED TECHNIQUES

Staff

Scientific and Technical Support:	21
Secretarial Support:	1
Scientific Visitors:	1
Students:	7
Total:	30

Facilities:

- Data processing facility based on SUN, incorporating in-house software for microwave data analysis.
- Software (SAR and Optical processor, Geophysical processor) tools including relational data bases and GIS.
- European Microwave Signature Laboratory (EMSL).
- Microwave Test Laboratory.
- European Goniometric Facility (EGO).

1994 was the commissioning phase for several crucial elements of an overall integrated information system based on air- and space borne remote sensing data sets within the "Advanced Techniques" Unit. Such components, under development by contractors under guidance of the "Advanced Techniques" Unit , included:

- the advanced European Airborne Remote Sensing Capabilities (EARSEC) airborne Synthetic Aperture Radar (SAR) processor was finalised,
- the extension of this for ERS-1 SAR data processing,
- the EARSEC electro-optical processor for the processing of multi-channel imaging spectrometry data sets was finalised,
- the first polarimetric SAR development in C-band and the provision of the first polarimetric SAR images, obtained with the EMISAR sensor, were finalised,
- the provision of the first multi-channel EARSEC imaging spectrometry images taken with the DAIS 7915 sensor,
- the design and development of a geophysical SAR processor for four application tasks, selected as demonstrators. These are oil slick detection, ship traffic monitoring, forest change detection and soil parameter analysis. This unique software tool includes advanced algorithms such as coherence analysis for object characterisation, automatic change detection measures and sub-surface probing methods,
- the fusion of information resulting from space- and airborne SAR data sets.

Several validation projects with advanced airborne sensors were undertaken in the frame of the EARSEC project, such as single pass interferometry, oil spill detection and ship monitoring.

The work with these low spatial resolution tools has been complemented by extensive work in the European Microwave Signature Laboratory (EMSL), the optical Goniometer laboratory and radiation laboratory. These laboratories are linked to the previously mentioned software tools through relevant signature data bases. These are also accessible to outside users by remote access tools.

The reporting period was also the last year for the Human Capital & Mobility (HC&M) project for access to the unique large scale European research facility, the EMSL. A detailed report is available documenting the results of this network.

This period was also the last year for investment in the EARSEC project. Again, a complete report is available.

6.1 SIGNAL PROCESSING

Summary of Objectives

Management of the signal processing and informatics systems and facilities.

Technical support in the setting up of processing chains and network for specific applications and projects (i.e. EMSL and EARSEC) within the Unit.

Investigation of advances in the information extraction techniques from the radar signal for remote sensing applications.

1994 PROGRAMME OF WORK

Radar Signal Analysis

This area of the AT Unit's activities involved work with both external contractors and in-house research.

Studies on Interferometry

The follow-on of the contract established last year with the University of Zurich focused on the analysis of the interferometric correlation as a means of classifying homogeneous test areas such as agricultural fields and forest stands and for detecting changes in such cover types. Results show this technique has considerable potential for distinguishing different forest types such as coniferous, deciduous and mixed forest stands. Research was also started on the retrieval of the effective interferometric forest stand height with ERS-1 repeat-pass SAR images. Work in this direction is currently in progress. Vegetation height reconstruction is also the subject of the experimental flight carried out in collaboration with Dornier (D) with the single-pass airborne interferometry configuration.

Oil-slick detection and ship-traffic monitoring

The modeling and characterisation of sea-surface scattering was used in the study of oil-slick detection. A specific aim was to determine those conditions where automatic detection could be carried out using SAR images. In the study a 1-D model of the gravity-capillary ocean wave energy spectrum was reconstructed and modified following an oil spill, under known environmental conditions (wind speed and direction, sea state). Results were sufficiently conclusive for the method to be implemented in the Geophysical SAR processor under development as part of the EARSEC programme. In this context, an airborne campaign was organised in October to collect SAR data over the English Channel coincident with controlled oil spilling (Figure 6. 1).

1994 Milestones

Jan.:	Start of the Geophysical SAR Processor development
Feb/March:	Release of Phase 2 of studies on interferometric techniques with University of Zurich. Successful evaluation by DG XII-D of the proposal on 'Natural processes inducing slope instability and erosion in two geographic regions of the Mediterranean basin in Italy and Greece.
April/May	Support to the interferometric experiment carried out in collaboration with Dornier (airborne single pass interferometry).
June/July:	Setting up of the oil-slick detection workstation Geophysical SAR Processor : completion of phase 1 on algorithm selection and system requirements, goahead for Phase-2.
July/Sept.:	Validation and Testing of the EARSEC SAR Processor.
Sept.:	CEOS SAR/CAL Workshop - Participation and presentation of papers on EARSEC SAR and EMSL calibration and Validation activities. Installation of the EMSL Information Management System.
Oct.:	First EARSEC SAR Network meeting EARSEC Seminar Status.
Nov./Dec.	Final Acceptance of the EARSEC SAR Processor.

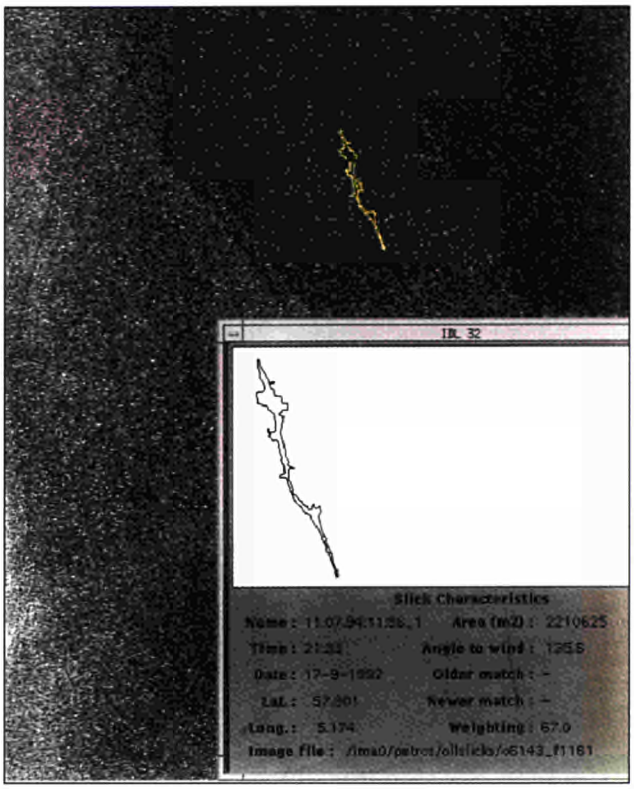


Figure 6.1.: Detection and location of an oil slick in the open sea using ERS - 1 image.

In parallel, SAR data were also collected to monitor ship traffic in the area. Surveillance from the British Coast Guards ensured that 'sea truth' data (ship position, size , speed and direction) were available for validation purposes. Results were again very encouraging and the ship-detection algorithm is also being operationally implemented in the EARSEC Geophysical SAR Processor.

In June, the oil-slick workstation, developed by EOS (UK) for the Defence Research Agency (UK), was installed for validation purposes. Several ERS-1 images have been processed. Discussion with the workstation developers concerning the results of these tests is on-going.

IFIT Project - Forest Change Detection

A time-series of ERS-1 data over the Black Forest Test site was processed and co-registered to contemporary optical imagery from the SPOT satellites. Forest stand parameters and meteorological data were also available. Analysis of the statistical correlation between the environmental parameters (including forest phenological stages) and radar measurement were conducted. Results showed that changes in backscatter observed by ERS-1 are related to variation in meteorological parameters such as precipitation and temperature. Furthermore, the investigations demonstrated that ERS-1 data are sensitive to tree age (at least for young deciduous and coniferous plantations in temperate climates), and therefore also variables such as tree height and woody biomass. This study concludes that combining the ERS-1 SAR data with optical data provides greater potential for forest stand age classification than is possible using either datum alone. (Figure 6. 2)

Electromagnetic Modelling

Theoretical and technical support was given to the EMSL for the analysis and validation of in-door collected data sets. This involved electromagnetic modeling and validation/calibration activities. Quality analysis studies were performed on fully polarimetric SAR images collected in the EMSL to assess the system response function. Real and virtual features were interpreted by simulating the scattering mecha-

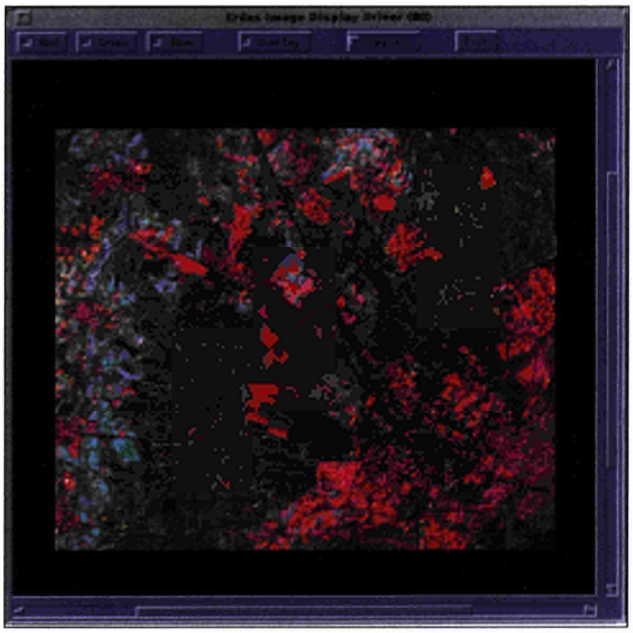


Figure 6.2: Multisensor (SPOT, ERS - 1) , multiband image from a region in the Black forest.

nisms taking place in the image. Edge diffraction and multiple scattering effects were considered as explanations for 'ghost effects' and to quantify the radiometric and polarimetric quality of the measured images. A theoretical model of bare soil is currently under development as a side activity to the soil measurement programme which will be performed in the EMSL.

SAR Processing

Technical and scientific support was also given by the signal processing section to the EARSEC contract for contract management and in the design, construction and validation of the SAR processing and post-processing chain. In particular, June and July were dedicated to the testing and validation of the EARSEC SAR Processor. Raw data sets collected by three different SAR systems were processed to assess the 'multi-sensors' capabilities of the software. Data from DOSAR, EMISAR and CCRS were successfully processed. The phase validation testing was approached by simulating raw data sets and comparing the expected theoretical phase at a given range gate with the phase value measured on the processed image at the same range gate. An accuracy of less than 0.2 degrees was found. This far exceeds the design requirements where a figure of 5 degrees was required. Furthermore, data sets collected in the EMSL at different incidence angles were processed and the interferometric fringes were reconstructed. Neither phase bias nor deviations introduced by the processing were observed and the achieved results were in excellent agreement with those obtained by other processors well recognised for interferometric applications.

Informatics Management

In addition to the day to day Informatics management (general system maintenance and upgrades), several machines, and the database developed for the EMSL and EARSEC programmes, were installed. The EARSEC SAR Processing chain uses advanced SPARC 1000 SUN computers that are easy to upgrade, and allow multi-users operability thanks to the multi-processor configuration. The system will form the basis of the EARSEC network test-bed, currently under implementation. The EMSL Information Management System was successfully installed in September and is currently being interfaced to an existing database in order to furnish a homogeneous information container for the Advanced Techniques Unit. An analogue system is under development for the European Goniometric Facility. The final configuration of the signal processing will include the processing chain implemented in the EARSEC programme (i.e. : SAR and Optical processors and Geophysical SAR Processor), existing and new database (EURACS, EMSL-IMS and EGO-IMS), in a homogeneous Unix based environment. This system will be potentially ready to host external researchers.

Perspectives for 1995

Completion and validation of the SAR Geophysical processor is expected. Validation and operational use of the EARSEC SAR processor will be achieved through its distribution to a processing network. Work will continue on the development of interferometric techniques for the estimation of biomass from SAR data. Differential interferometry for monitoring of terrain slope instability will be assessed, and studies continued to model the back scattering by sea waves when modified by the presence of an oil film.

6.2 EUROPEAN MICROWAVE SIGNATURE LABORATORY (EMSL)

Summary of Objectives

- *Operation of the EMSL test facility with high resolution, multi-frequency polarimetric measurements on natural and man made targets, to complement airborne and space borne experiments by providing stable, reproducible environmental conditions and flexible operation modes for controlled experiments.*
- *Research on radar signatures to support development of remote sensing applications.-Collaboration with external research institutes in the framework of the EMSL User Group to harmonise experiments for the optimum utilisation of the laboratory.*
- *Integration and standardisation of data acquisition, processing and analysis tools for signature research and applications, by means of the EMSL Information Management System, IMS.*

1994 PROGRAMME OF WORK

EMSL Operation and Progress in Experiment Preparation

During 1994 a total of 25 experiments were performed in the EMSL facility, including 13 User Group experiments.- - 6 in-house studies or demonstration tests - - 6 facility checks or calibration tests (D-tests)

Throughout 1994 much effort was invested in improving the performance of the measurement system in terms of measurement speed, sensitivity and bandwidth. New subsystems, namely a Monitoring System and a Frame Grabber, were integrated in the EMSL Operation System. The capability of the facility for measurements at lower radar frequencies was checked with a test series using P-band antennas (log.-periodic and dipole) mounted on the sensor sleds of the EMSL. The measurements in the range of 0.45 to 1.0 GHz gave very satisfactory results with respect to sensitivity and resolution.

In order to meet the demands of the various experiments proposed by the EMSL User-Group, new material had to be provided and a number of new methods for target preparation developed. Once complete, these will upgrade the experimental potential of the EMSL. These improvements include the installation of systems to freeze water and dry extensive surfaces as well as the surface shaping of soil targets. This latter involves the use of moulds with well defined roughness structures. Software was developed which creates the desired stochastic surface and then passes the generated data files to a milling

1994 Milestones

Jan. - Oct.: - Continuation of the experimental activity in the frame of the Thematic Subgroups "Imaging Techniques" and "SAR Interferometric Techniques". Completion of the antenna pattern characterisation of the EMSL sensors. Demonstration tests for the monitoring of road conditions and obstacle detection. Demonstration tests for detection of anti-personnel mines (APMs).

March: - 2nd Meeting of the EMSL Advisory Committee.

May: - 1st Working Meeting of the thematic Subgroup "Scattering Properties of Non Vegetated Terrain". Start of the preparation activities for the relevant experiments. Second issue of the EMSL Newsletter.

June: - First multi-baseline SAR interferometric experiment in the EMSL aimed at characterisation of volume scattering.

Sept.: - First 3-D microwave tomographic image obtained from EMSL data. 3rd issue of the EMSL newsletter.

Oct.: - Final acceptance of the EMSL Information Management System; start of the installation phase. Start of the measurements for the experiments on "Surface Scattering".

Nov.: - 3rd Meeting of the EMSL Advisory Committee. Study contract awarded to AT on the state of technology on the reconnaissance and localisation of APMs. Workshop on Detection of Anti Personnel Mines (APMs)..

Dec.: - 4th issue of EMSL Newsletter.

machine for the mould fabrication. Three different moulds were produced for the experiments, having a slightly rough, a medium and a very rough surface. One of the moulds was made in aluminium and will have an integrated cooling circuit for freezing the soil sample.

Research in collaboration with External Institutes

'SAR Interferometric Techniques' Subgroup

This subgroup examined the effects of surface roughness and volume scattering on the coherence of the interferogram and the use of multi-baseline interferometry to discriminate pure surface scattering from volume scattering. A first evaluation of the data shows that, as expected, the coherence decreases when the surface becomes rougher. However a small difference still remains between the experimental and the theoretical results. In this respect, the role of volume scattering needs to be investigated more deeply. To this aim a specific experiment was performed, and the data analysis is in progress.

'Imaging Techniques' Subgroup

One dedicated experiment was performed creating microwave data to validate a 3-D imaging algorithm. The activity progressed during 1994 with important contributions from AT's staff, especially concerning the refinement of EMSL-customised imaging processors (antenna pattern correction, radiometric calibration). A major achievement was the creation of a 3-D tomographic image of an assembly of metallic spheres with a resolution of some 3 cm in each dimension . This result demonstrates the excellent performance of the focusing algorithm and the high quality of the measured data. Such a tomographic approach can now be applied to subsurface sensing. This is the case for example for the location of objects hidden in soil.

'Scattering Properties of Non Vegetated Terrain (NVT)' Subgroup

At the first working meeting proposals falling under this theme were reviewed and a subset identified which together covered all the scientific objectives of the proposals at a whole. These included

- Validation of surface scattering models.
- Retrieval of soil moisture profiles using multi-frequency polarimetric radar data.
- Polarimetric radar response for frozen/thawed soil.
- Wave propagation in high volume scattering media.
- Polarimetric signatures of volcanic terrain.

A time schedule and the preparatory work for the experiments of the NVT series was defined. The preparatory activities were started in close collaboration with the external interested groups. The microwave measurements on surface scattering started in October.

Internal Research

The activities followed four main lines: (1) supporting experimental work, (2) developments in signal analysis, (3) theoretical research and (4) studies within the HC&M programme.

Support to the experiments

Data processing and analysis. All the data acquired in the EMSL experiments for the User Group and for internal activities were calibrated and pre-processed using the software tools specifically developed for this purpose. The collected and processed data are now temporary saved on magnetic media in view of their future implementation in the EMSL Information Management System

A Quick Look software package for the experiment data was developed. This tool allows preliminary visualisation and calibration of the data acquired in the EMSL. The raw data can easily be handled for all processing techniques, such as background corrections, complex calibrations and gateing (applying a time gate). The experience gained in the implementation of this application was also used to establish guidelines for the development of the EMSL Information Management Systems' standard processing tools.

The ***antenna characterisation*** of the EMSL sensors was determined in a dedicated experiment. From the measurement data an analytical model of the polarimetric antenna pattern (monostatic case) was derived. The results will be used for correcting both the scatterometric and the imaging measurements at the EMSL.

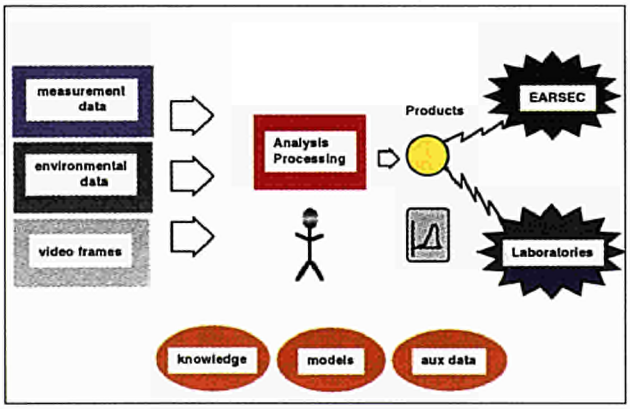
Stochastic Surface Model software was developed. This generates a digital elevation model (DEM) of a surface with defined stochastic roughness structures and properties such as mean elevation, correlation length and boundary conditions at the borders. The DEM's are needed for the creation of the moulds to shape soil targets; see "EMSL Operation and Progress in Experiment Preparation" above, and figure 6.3.

Figure 6.3.: Preparing a soil surface scattering experiments at EMSL. The target is shaped with the mould, seen in the upper part. The mould gives an exactly defined statistical surface with determined stochastic roughness parameter.

Developments in signal analysis

The EMSL ***Information Management System (IMS)*** has been developed as a workbench for signal analysis. The IMS, shown schematically in Figure 6.4, provides uniform and controlled access to a number of components, among them a data base including the measured data, the multimedia documentation (such as optical images of the target) and the environmental data of the performed experiments. In addition, a set of processing tools is fully integrated in the system and will be available to the users. These tools present standardised input/output interfaces and can be used as building blocks to construct more complex processing chains. Access to the IMS will be possible either from local workstations or from remote terminals. The system was delivered and tested in October 1994 and its final implementation/configuration has started. This phase is expected to be completed by March 1995 with all the previously acquired experimental data loaded in the system. The actual storage hardware consists of an optical juke-box with a capacity of 114 GBytes of data available on-line and virtually unlimited off-line archiving capability.

New ***imaging techniques*** have been investigated, based on advanced data processing techniques and on the experimental EMSL microwave data. Significant progress was made for SAR and ISAR



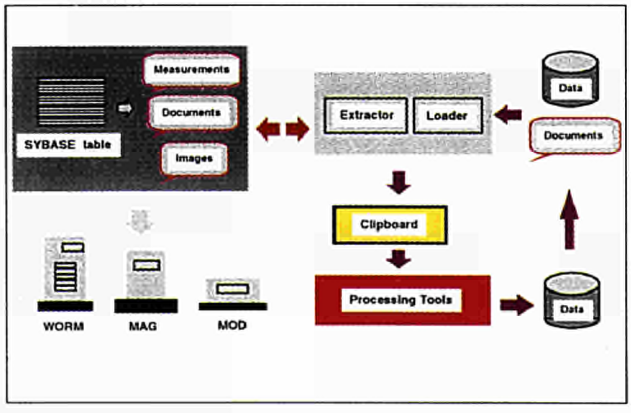


Figure 6.4: The system architecture of the IMS Information Management system.

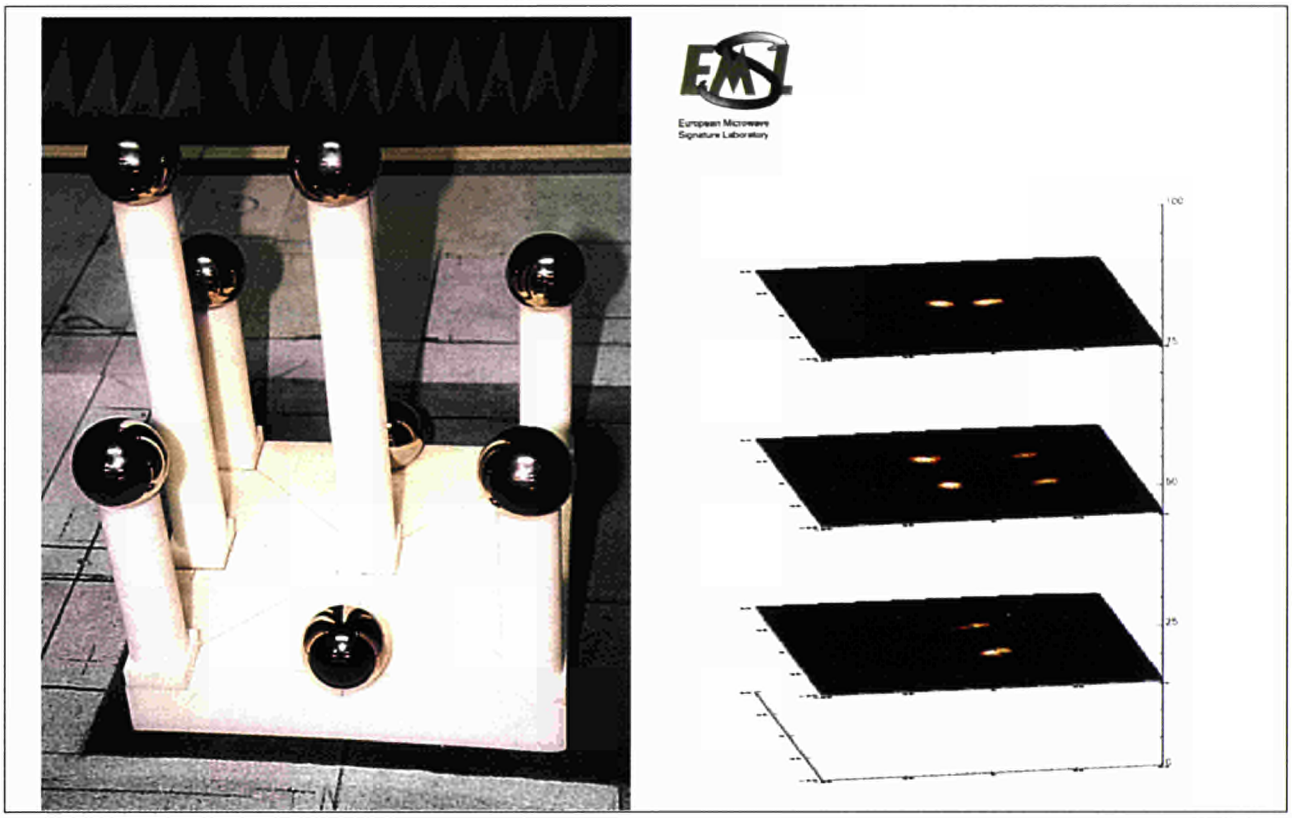


Figure 6.5: Tri-dimensional target arrangement of metallic spheres for the radar measurements at the EMSL (left) and the tomographic image (right) reconstructed from the data by means of the developed imaging algorithm.

imaging with the development of Quicksar, a fast algorithm for a near-field SAR processor. The algorithm is a modification of the known Inverse SAR technique. It takes into account the spherical curvature of the incident and scattered waves and makes efficient use of Fast Fourier Transform (FFT) techniques to drastically reduce the computing time for synthesising the SAR image. Other developments in imaging techniques centred on the 3-D tomographic imaging algorithm development. The first images from this can be seen in figure 6.5.

Theoretical studies

An analytical scattering model for ensembles of simple objects has been implemented. Based on a new approach this is able to tackle the mutual interactions of a large number of scatterers. The model may represent an efficient way for modelling complex targets such as vegetation. A further study was performed to describe wave scattering from fractal objects. The scattered electromagnetic field of such objects can be constructed by iteration procedures, similar to those at the base of the fractal structure construction. This approach offers great potential as fractal constructions have been shown to successfully describe vegetation or geographic structures.

HC&M 1992-94 Programme: Access to Large Scale Installations

All the activities related to the EMSL research have gained momentum thanks to the support obtained from this programme. In October 1994 a new Post-Doctorate grant holder started work, joining the other three young scientists who started in 1993. These scientists have been involved in two aspects of the EMSL activities:

- Improvement of the laboratory performances and data quality (measurement speed, system sensitivity, calibration).
- Data analysis (polarimetric signatures, scattering mechanisms).

In particular the following four research projects have been defined:

- *Investigation of the Frequency Diversity Radar System for Different Land Applications.*
  The activity addressed a number of studies to enhance and improve the measurement features at the EMSL. In particular the operation system and the instrumentation components have been tested/modified to optimise the hard- and software configuration for best sensitivity and performance. Furthermore, with the method of 'equivalent antenna' measurements the sensitivity of the laboratory was determined. Than, the wall reflections and laboratory characteristics at lower frequencies (450 to 1000 MHz) have been verified; low frequency antenna equipment for the EMSL was specified and ordered. Finally, different methods of measuring the dielectric properties of materials have been tested and used to characterize those materials used in the EMSL's surface scattering experiments.

- *Analysis of multi-polarised, multi-frequency and multi-temporal SAR data.*
  The investigation proved (a) the gain in image quality of a polarimetric SAR product of EMSL data focused with a w-k processor, analysed (b) the scattering mechanisms present in the image, and derived (c) a model to estimate the impact of scatterer interaction on the cross-polar products.

- *Implementation of a bistatic polarimetric calibration procedure for the EMSL.*
  The state-of-art for indoor calibration methods was reviewed with respect to EMSL applications. The current monostatic in-focus calibration has been extended to off-focus points and was verified on EMSL experimental data. For the bistatic calibration an extension of the simple polarimetric procedure was derived and results were compared to the monostatic case. Progress was made with the definition of a general calibration strategy and with the specific investigation of the polarimetric response of a metallic wire mesh in view of its utilisation in auxiliary polarising calibration.

- *Analysis of polarimetric scattering of complex targets.*
  This study started in September 1994. The work concerned the application of analysis methods such as 'optimum polarisation states' and the 'target decomposition theorem' for automating the experimental data analysis procedure.

The EMSL Advisory Committee

In 1994 the committee meet twice in Ispra; on 15th March and on 12th November. The experimental programme at EMSL, the User Group's activities, the priorities in the research topics as well as the staff situation with respect to external visitors and grants were all examined. A number of suggestions and recommendations were given:

- *Network of Radar Experiment Facilities.* The development of co-operation between radar experiment facilities was strongly recommended. The EMSL is complementary to other facilities in the European Union. In order to fully benefit from this overall potential in the EU, it would be helpful if there was good co-ordination between programmes and activities of the EMSL and of other European facilities. The ESTEC Workshop scheduled for autumn 95 was suggested as a starting point. At this workshop a special session could be organised for the EMSL and the radar chamber user community.
- *New Thematic Subgroups*. The AC recognises, that new thematic sub-groups must be established for the future EMSL experimental activities. A new Announcement of Opportunity, based on expert consultations, will be prepared for a call for proposals. The AO results evaluation should be available in autumn 95.
- *The Education/Formation* aspect provided by the EMSL is a strong point and has to play an important role. The significance of the HC&M program 1992/94 was highlighted as an example; 5 Post-Doctoral grants were made available to the EMSL through this. The AC recommends that in the future the EMSL should also support short training visits from young researchers.

EMSL Demonstration Tests

During 1994 the EMSL performed a number of demonstration experiments. The measurements concerned topics such as the detection of road surface conditions, of traffic obstacles and of anti-personnel mines by means of radar signature analysis. These demonstration tests show the potential of the EMSL facility in domains of interest for third party work, see Figure 6.6 and 6.7. Significant results were obtained which have found considerable interest from outside (for example a Workshop on :"Detection of anti - per-

sonnel mines " was successfully held in November 1994).

Perspectives for 1995

In 1995 the collaboration with external institutes will continue in the EMSL User Group with the completion of the experiments already planned by the present thematic subgroups. This experimental activity will focus on the following topics:

- Validation of surface scattering models.
- Retrieval of soil moisture profiles using multi-frequency polarimetric radar data.
- Signal decorrelation due to changes of soil conditions.
- Polarimetric radar response for frozen/thawed soil.
- Wave propagation in high volume scattering media.
- Wave synthesis and near-far field transformations.

The procedure suggested by the Advisory Committee will be followed to establish new thematic subgroups: First a consultative workshop will be organised with potential users to identify the most interesting research topics. Then, a new call for experiment proposals on those specific subjects will be launched.

The in-house research will focus on the following activities:

- Application of tomographic techniques to sub-surface sensing in different environments.
- Final installation of the IMS (Information Management System).
- Upgrading the hardware of the measurement system (lower frequency band).
- Establishment of a polarimetric bistatic calibration procedure.
- Analysis of polarimetric scattering of complex targets.

Furthermore, co-operative activities in two new areas are planned for the EMSL team:

- Investigations on radar applications for traffic management, for which co-operation with industrial partners will be established.
- Radar signature studies for the detection of buried dangerous objects; this activity will be performed in co-ordination with a consortium of external institutes.

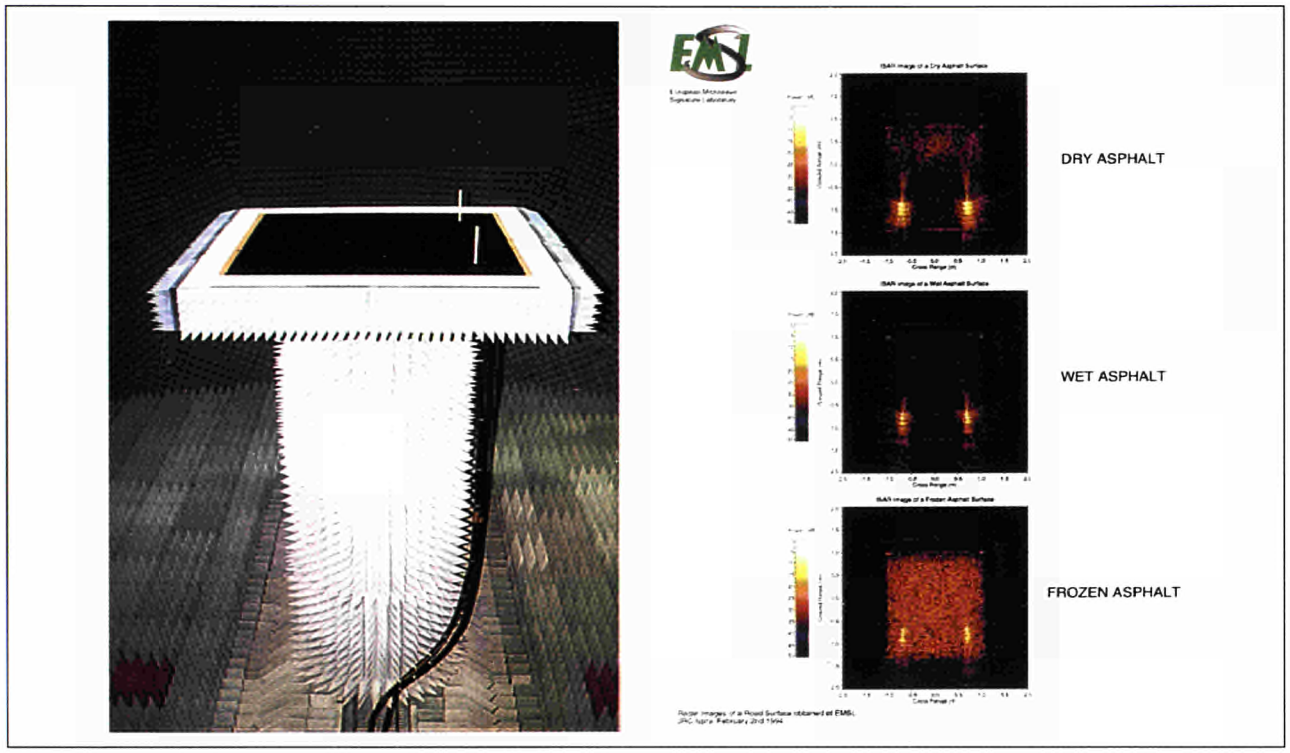


Figure 6.6: The road asphalt target (left) was investigated at EMSL with wet, dry and ice-coated surface conditions. The radar images (right) obtained from these data shows 'visible' differences suggesting that Radar could be used, e.g. in traffic management systems, to warn against dangerous road conditions.

Figure 6.7: Demonstration test for APM detection at the EMSL. The photo shows the target scenario with four different terrain samples on which are layed anti-personnel mines for the radar measurements. These objects can be detected in the radar images following the polarisation information (from top: HH, VH and VV) and identified by taking into account the differences in the radar signatures.

6.3 ADVANCED SPECTROMETRY

Summary of Objectives

- *Completion and analysis of LOPEX for the retrieval of biochemical components of vegetation from high spectral resolution data.*
- *Improvement/extension of existing leaf reflectance models in the NIR part of the spectrum.*
- *BDRF measurements in the European Goniometric facility (EGO) on various targets of interest for the interpretation of remotely sensed data.*
- *Study of the synergy of remotely sensed data (accepted network in the frame of the Human Capital and Mobility program {HC&M}).*

1994 PROGRAMME OF WORK

Leaf Optical Properties EXperiment (LOPEX)

In order to complete the experiment on leaf optical properties a number of data sets have been produced on 120 vegetation samples. The photometric determination of photosynthetic pigments (chlorophyll a, b and total carotenoids) was performed at the University of Karlsruhe and the results were included in the data set.

Some of these vegetation samples were dried and ground to a fine powder using a grinder equipped with a 10 micrometre filter. Part of the powders were then compressed, formed into pastilles and oven dried. Their spectral characteristics were subsequently measured in a spectrophotometer. In all, 94 pastilles were measured in this way. Analysis of the results will be completed in 1995. This will yield important information on the role of the internal structure in the reflectance and transmittance characteristics of leaves and other material.

A small part of the powdered vegetation samples were used for analysis of elemental composition. The elemental analyses were made at the bioclimatology laboratory of INRA Clermont Ferrand (F). The elements of interest were Carbon (C), Hydrogen (H), Nitrogen (N) and Oxygen (O). The results of these analyses have also been included in the data set

.

The experimental data have been classified and archived for future use in the LOPEX dataset which will be made available to the research community in 1995. Figure 6.8 shows the overall structure of this dataset.

Multiple stepwise linear regression analyses procedures have been applied to the data set in order to relate leaf biochemical components (lignin, cellulose, nitrogen and starch) to leaf optical properties. In general total proteins, cellulose and lignins are reasonably estimated with R2 higher than 0.70 with five wavelengths and R2 higher than 0.85 with ten wavelengths. Information on starch content, which is only present in leaves in very small amounts (< 3% of dry matter) is far more difficult to retrieve on the basis of optical measurements. Figure 6.9 shows the

1994 Milestones

Jan. - March:	Completion of LOPEX; Begin data processing.
March:	Kick - off meeting of the HCM - network " Synergy of remotely sensed data ", held at AT / IRSA.
May:	Proposal for the extension of the HCM - network to include Central and Eastern European counties
May - June:	First test measurements on soils and vegetated targets in the European Goniometer (EGO).
Oct.:	First workshop of the HCM - network at AT / IRSA.
Nov.:	Installation of the database structure of EGO.
Dec.:	Final dataset of LOPEX. Goniometric measurements for modelling purposes.

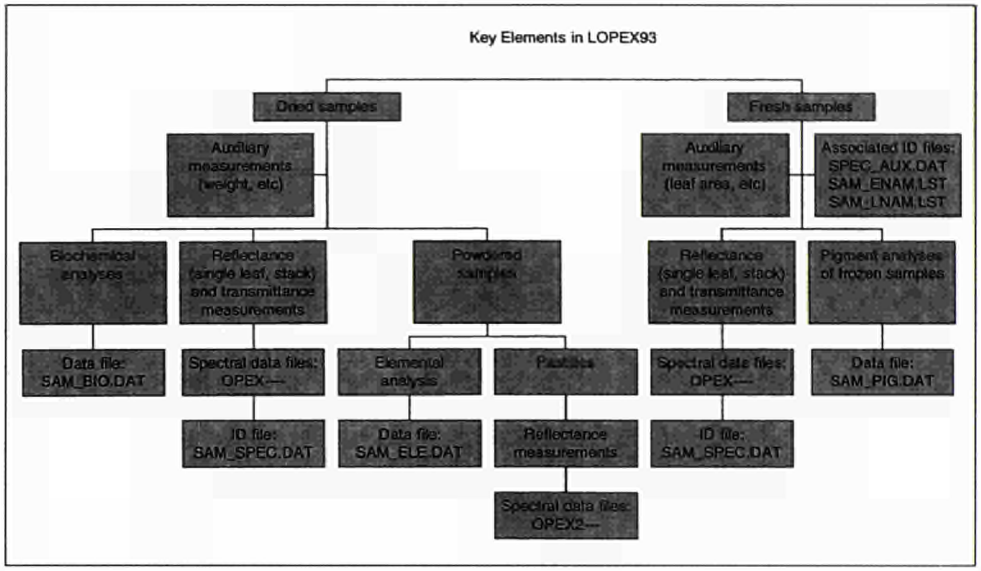


Figure 6.8: Overall structure of the LOPEX dataset.

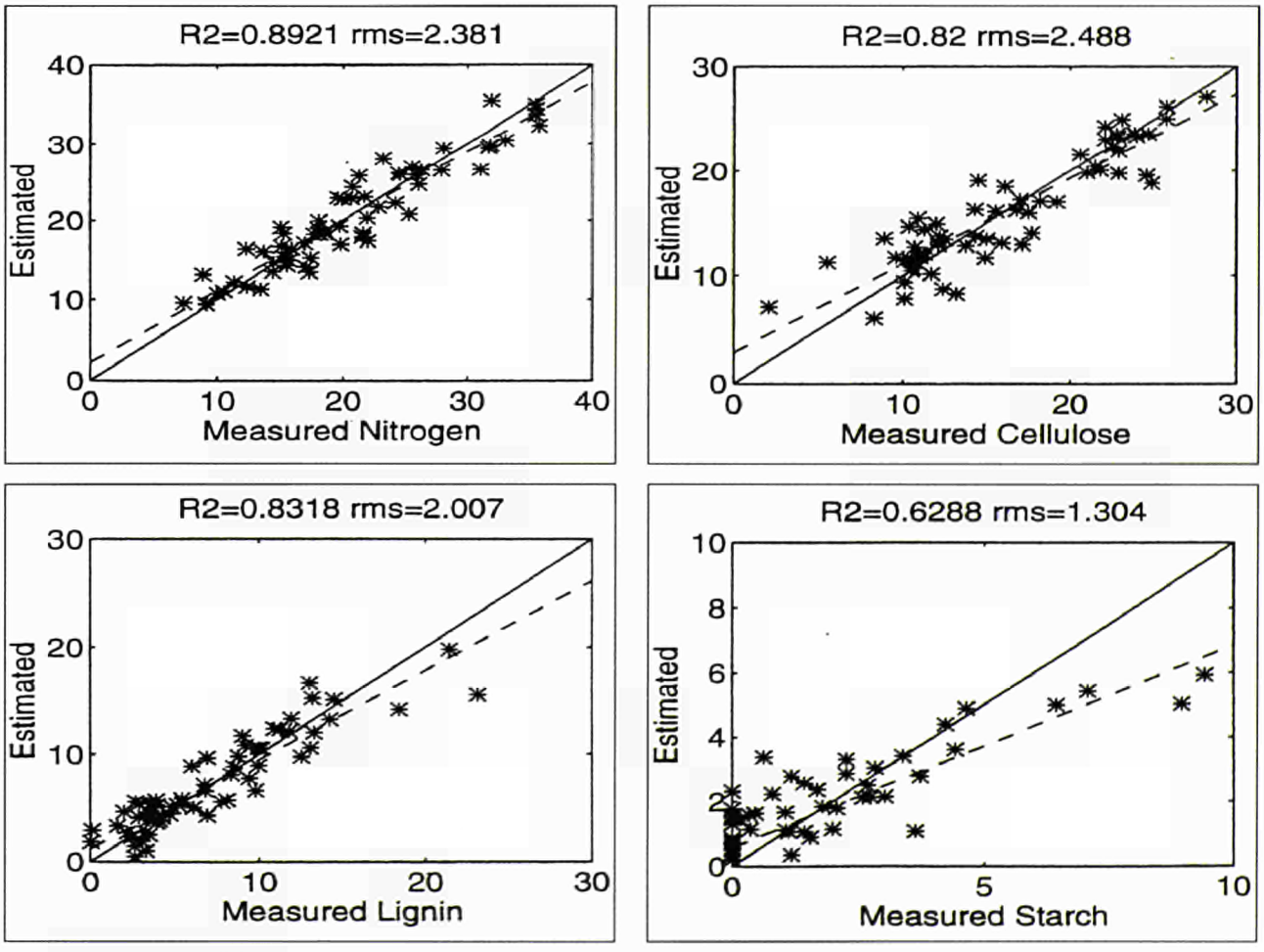


Figure 6.9: Proteins, cellulose, lignin and predicted concentrations (fresh individual leaves, 10 wavelength) versus concentrations according to wet chemical analyses.

potential for predicting chemical concentrations over a wide range of conditions: the plots all indicate a good distribution for biochemical components and a low bias in the regression as shown by the symmetry of points about the 45º line through the origin. As expected, dry material and optically thick samples provided respectively better results than fresh material and individual leaves.

BRDF measurements in The European Goniometer (EGO)

In 1994 the first test measurements were performed in the European Goniometer on reference panels and on vegetation canopies. The calibration of field spectroradiometer measurements requires accurate knowledge of the reflectance of a reference panel for all look angles. Recognising this need, a set of measurements have been performed in the EGO facility to characterise the bidirectional reflectance factor (BRF) of a Spectralon panel. The light source used was a collimated laser beam at 632.8 nm and a precision silicon photodiode as a detector. The results for the principle plane demonstrate a consistent non lambertian behaviour of the panel. This is particularly evident in the enhancement of the forward scattering when the incident angle increases Figure 6.10 a). Measurements were also performed on a clover canopy and on different soil targets, opening the procedure for BRF measurements on natural surfaces (Figure 6.10 b).

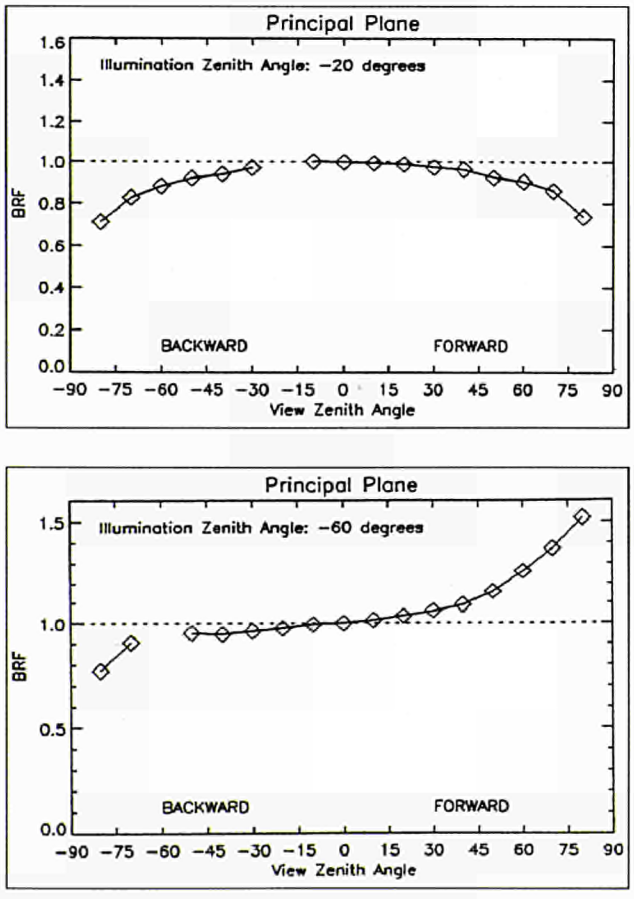


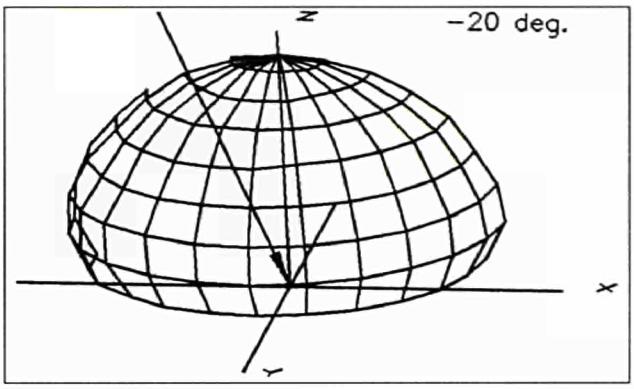
Figure 6.10 a: Bidirectional reflectance factor measurements on a Spectralon reference panel.

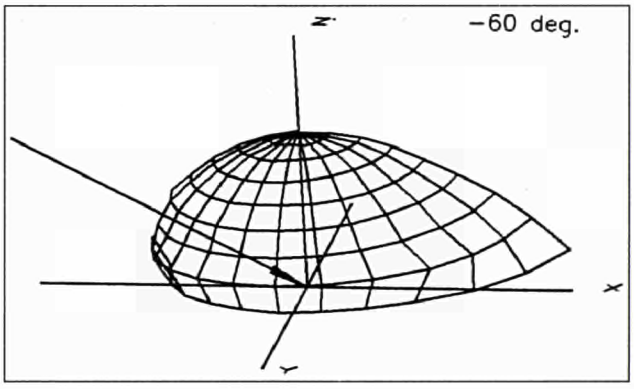
In addition to the day to day operation of the EGO facility, an EGO Information Management System (EGO-IMS) was installed. This system is devoted to maintenance of the archive of experimental data and to facilitate their manipulation and analysis. Measured data obtained from the detector system are acquired and stored in a structured archive. The relationships amongst data objects are also maintained to ease, through a graphical user interface, their aggregation, correlation and processing. The system ensures security and protection to data access according to a proper user configuration and management. The EGO-IMS is a distributed system in which functions are organised according to a client sever architectural model to achieve flexibility, expandability, service availability and to adapt to the existing network facilities of the local environment.

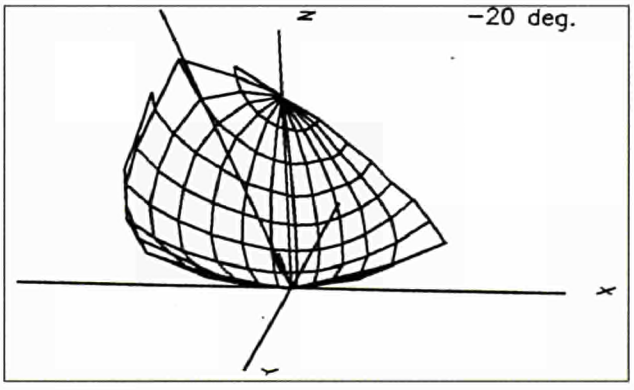
Modelling of vegetation reflectance in the VIS / NIR of laboratory and airborne data

This work package describes two different modelling approaches in order to analyse High Spectral Resolution (HSR) data in view of plant biochemistry.

The first approach is based on simplified radiative transfer theory (such as the Kubelka-Munk formulas) and classical mixture analysis. As water and chlorophyll, the biochemical components, are introduced in the model using their specific absorption coefficients and concentrations. However, these specific absorption coefficients are not known and determining them is a major part of the problem. This question was studied by analysing the high quality laboratory data set described above . These data were used in an attempt to deduce empirical "in vivo" absorption coefficients for proteins, cellulose and lignin. These coefficients were then used in the inversion of the model with the purpose of determining the







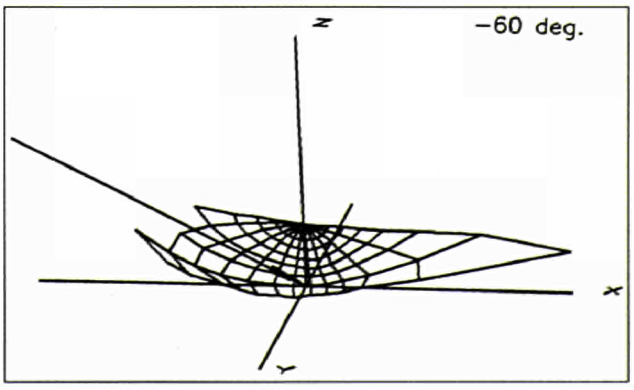
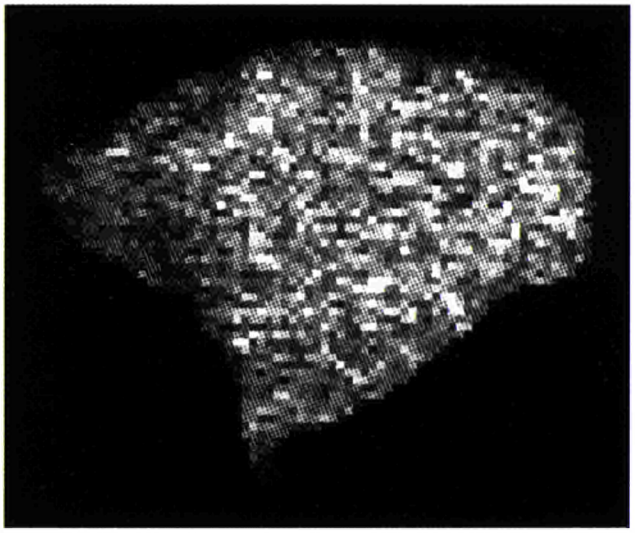


Figure 6.10 b: BRDF measurements over a clover canopy.

biochemical composition from the reflectance spectrum. This inversion was performed both on laboratory spectra and AVIRIS data collected over Blackhawk Island in 1992 (Figure 6.11) The procedure succeeded in retrieving the foliar relative water content. The biochemical signature, on the contrary, appears as a very intricate combination of the constituents absorption features and the inversion is not yet successful in determining the relative concentrations.

The second approach concerned the analysis of plant biochemical content by improving / extending the existing leaf reflectance model, PROSPECT.



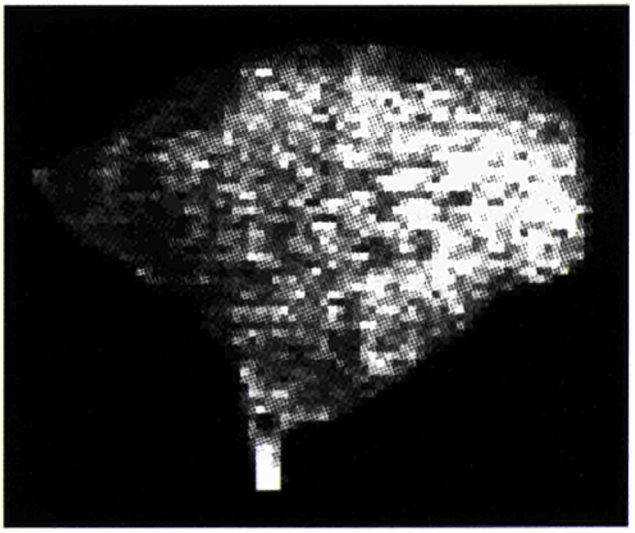


Figure 6.11: Retrieved relative water content image (a) and apparent canopy scattering coefficient image (b) from AVIRIS data over Blackhawk Island.

This radiative transfer model, representing the optical properties of leaves from 400 nm to 2500 nm , describes the leaf reflectance using structural -, pigment - and water - parameters as input. Instead of using absorption coefficients of the pure biochemical components the specific absorption coefficients of these components were deduced from measurements on the leaves themselves and included in the model. The validation resulted in a very good correlation for pigments and water, a certain sensitivity for cellulose and lignin but no sensitivity was noticed for proteins. In summary an accurate reconstruction of reflectance and transmittance for different types of plants with this extended version of the PROSPECT model was possible (Figure 6.12).

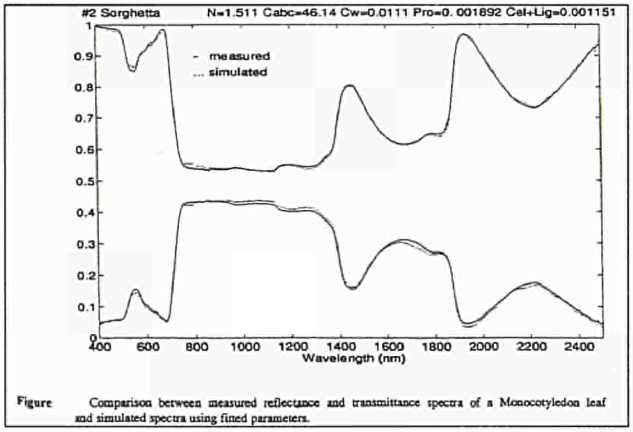


Figure Comparison between measured reflectance and transmittance spectra of a Monocotyledon leaf and simulated spectra using fitted parameters.

Figure 6.12: Comparison between measured reflectance and transmittance spectra of a monocotyledon leaf and simulated spectra using fitted parameters.

HCM - network: Synergy of remotely sensed data

The work described here constitutes the share of the AT Unit in the scientific and technical co-operation network entitled "Synergy of Remotely Sensed Data". The network is made up of 12 research and university centres across the member states of the European Community. including groups from the Netherlands, Germany, Italy, and United Kingdom. The general objective of the network is to determine the additional value remotely sensed data can bring to natural resource monitoring and managing when different remote sensing data sets are used synergistically and when such data are combined with ancillary data such as topography or phenology.

The first phase of the work developed at the AT Unit centres on the study of the synergy of optical and microwave data provided by the airborne sensors AVIRIS and AIRSAR for assessment of forest resources. A second phase will deal with space borne remotely sensed data.

The site selected for this project is the Black Forest, test site of Villingen-Schwenningen, for which MacEurop '91 campaign data were available (Figure 6.13). The aim of the project is the stratification of the forest into age classes from which other forest parameters could be derived. The project was structured in four parts: (1) characterisation of the age classes, design of the sampling scheme, and determination of the optimal sample size; (2) processing and classification of AVIRIS data; (3) processing and classification of AIRSAR data; (4) processing and classification of the joint data set, and comparison of the output with the results obtained from classification of the optical and microwave data separately. Comparison of the performance of maximum likelihood and neural network approaches for classification of the existing data sets will be performed. This comparison will be carried out using Kappa statistics derived from the error matrices obtained from each classification.

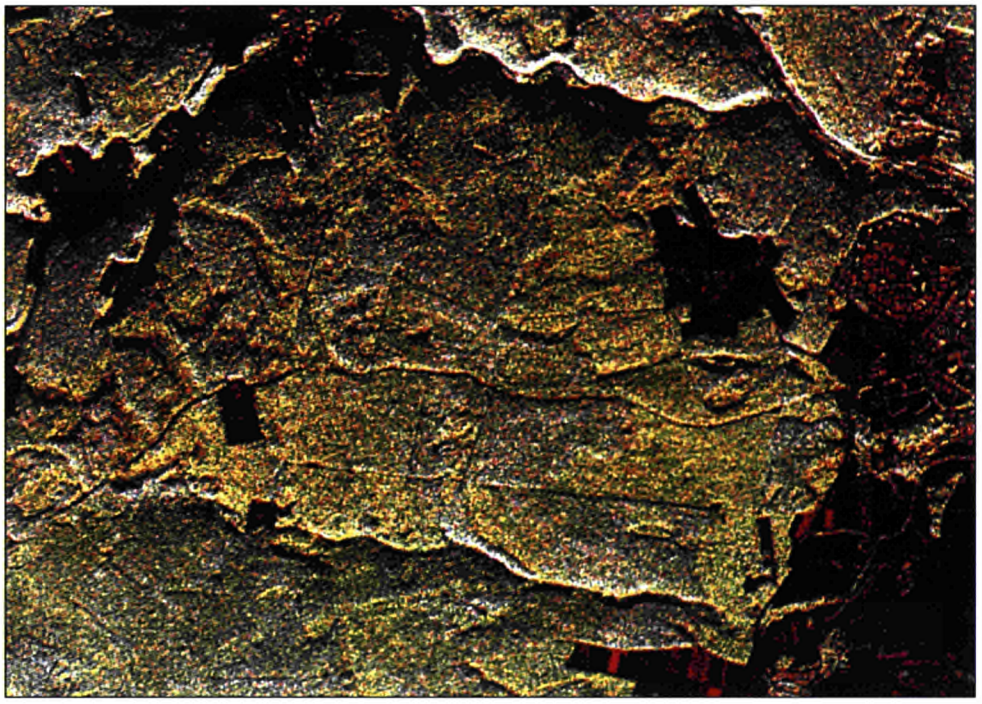
The first part of the project has already been accomplished. Forest resources were successfully stratified into 10 age-classes of 20 years interval each. Species composition was analysed for each of the age classes. It was found that all age classes except class 1, trees under 20 years of age, were relatively homogeneous in species composition, with about 70-80% cover of spruce, 10-15% pine, 5-10% fir, and less than 5% other species. Since a ground truth map of the forest stands was available, true proportions for each of the age-classes in the study area were known.

Perspectives for 1995

Work will focus on the following:
Continuation of the activities within the HCM - network on " Synergy of remotely sensed data ". The first phase of the project, i.e. synergy of airborne remotely sensed data, will be completed during 1995. The second phase, dealing with synergy of

space borne remotely sensed data will start in 1996.

- Studies on the complementarity of directional (CAESAR sensor) and high spectral resolution data (AVIRIS sensor) over forested and agricultural areas will be carried out.
- Signature research in the optical domain using the EGO will continue. These will examine soil, vegetation and artificial targets.
- A European user community will be established for optical data acquisition using the EGO.



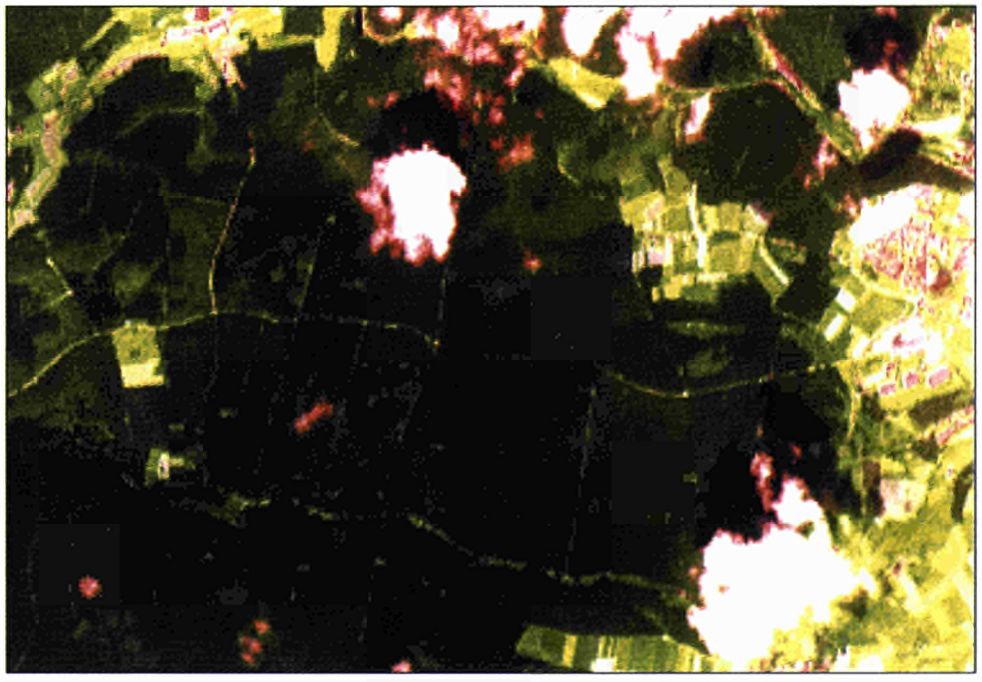


Figure 6.13: Colour composites of AIRSAR and AVIRIS data over the study area. Above, AIRSAR bands C, L, P (HV polarisation), and below AVIRIS bands 15, 28 and 39.

6.4 THE EUROPEAN AIRBORNE REMOTE SENSING CAPABILITY (EARSEC)

Summary of Objectives

- *Completion of the EARSEC airborne optical system DAIS-7915.*
- *Completion of the C-band SAR (fully polarimetric) and development of the L-band SAR (fully polarimetric).*
- *Completion of the optical and SAR EARSEC processors.*
- *Development of the SAR geophysical processor.*
- *Set up of the EARSEC SAR processing network.*
- *Identification and procurement of the EARSEC-SAR platform.*

1994 PROGRAMME OF WORK

European Airborne Remote Sensing Capability (EARSEC) Optical Imaging Spectrometer

During the first part of the year the improvement phase of the system at the GER premises continued. However, a test flight on May 11th 1994 showed that the performance of the system was unacceptable. This was mainly due to the low signal/noise ratio in the spectral domain 2.0 -2.5 um (SWIR-2). GER proposed to procure a novel array detector for the SWIR-2. Nevertheless the expected time needed for the delivery of this detector, estimated to be a few months, gave DLR the opportunity to carry out a conditioned training/acceptance test in USA. Following signature of a supplementary agreement between DLR and GER and consultation with the EARSEC management, it was decided to transfer the system to the DLR at Oberpfaffenhofen. At the DLR laboratories, the DAIS-7915 was radiometrically, spectrally and geometrically calibrated in the spectral domains which were correctly performing.

The DAIS-7915 was then installed in the Dornier 228 of the DLR and tested in flight. In November GER was able to substitute the SWIR-2 detector at Oberpfaffenhofen. However, in the following test flight mechanical interference at low frequency decreased the data quality. This finding prevented the performance of the final European acceptance test planned for 1994. A new anti-shock mounting has to be designed and tested and the final test is now scheduled for Spring 1995.

1994 Milestones

Jan.:	Start of phase 1 of the geophysical SAR processor development.
Feb.:	Meeting of European aircraft operators for the selection of a suitable EARSEC-SAR platform.
March:	C-band SAR ready for applications.
May:	Test flight of the DAIS-7915 in USA (only partially successful).
June:	Transfer of the DAIS-7915 from USA to Germany at DLR. Start of SAR processor testing and validation.
July:	Completion of geophysical SAR processor phase 1 on algorithm selection and system requirements, go-ahead for phase 2. Publication in the Official Journal of the call for proposal for a suitable platform for the EARSEC-SAR.
July--Dec.:	Calibration of the optical sensor at DLR.
Aug.:	Installation of the DAIS-7915 in the Dornier 228 of the DLR.
Oct.:	Second EARSEC Status Seminar. Completion of the EARSEC optical processor. First EARSEC SAR network meeting.
Nov.:	Change of the SWIR detector in the DAIS-7915 and test flight.
Nov.-Dec.:	Final acceptance of the EARSEC SAR processor. Technical Selection of the EARSEC SAR platform.

In the meantime, the EARSEC optical processor was completely developed and tested. Difficulties were induced by the lack of complete DAIS-7915 data sets: they were substituted by simulated data, obtained from AVIRIS. These data were used for the acceptance test of the optical EARSEC processor.

European Airborne Remote Sensing Capability (EARSEC) SAR

During 1994 important technical and scientific contributions, in terms of management and expertise, were given to the contract with EARSEF EEIG for the development and procurement of the airborne EARSEC-SAR. The fully polarimetric C-band SAR was completed, and is now ready for use. The development of the fully polarimetric L-band SAR continued.

Much effort was put into the selection of a suitable platform for the EARSEC-SAR. This involved: a meeting at Ispra with various European aircraft operators; the issue of two feasibility studies as result of the meeting with the aircraft operators; the publication in the Official Journal of an open procedure and the subsequent issue of an invitation to tender (ITT); the technical selection of the best valid offer for the EARSEC-SAR platform.

Much effort was also devoted to the monitoring of different phases of a number of contracts regarding the SAR processing and post-processing chain:

EARSEC SAR Processing System

The development of the EARSEC SAR Processor continued in 1994. After the delivery of the prototype in MATLAB language occurred in November '93, the final operational version, coded in C++ language for the Solaris 2.3 SPARC 1000 SUN computer, was completed in June '94. From July until September '94 the SAR Processor was validated and tested with simulated data to verify the multi-sensors capabilities. This also allowed the full characterisation of the system in terms of performance and data quality assessment with different imaging conditions (i.e. variable frequency, platform speed, altitude from ground and so on). In October the system acceptance testing was performed using real data sets from different airborne sensors. Data from EMISAR (DK), DOSAR(D) and AIRSAR (NASA/JPL) were processed to verify the conformity of the system with respect to the technical requirements. The system was finally accepted in December 1994.

EARSEC Geophysical SAR Processor

In January 1994 the development of the EARSEC Geophysical SAR Processor (G-PROC) started. The first phase of the development was devoted to the selection of the algorithms for the four selected application areas (i.e. Oil-slick detection, ship traffic monitoring, soil moisture and vegetation discrimination) and for the automatic change detection module. In February '94 , a workshop of European experts was organised by EOS (UK) to assess the state of the art on each application area. Phase-1 of the contract was completed in June 1994 with the final definition and selection of the algorithms and with the design of the operational frame of the G-PROC. In particular the user front-end (Graphical User Interface) and the Input/Output Library were subject to in-depth design and analysis to allow user-friendly operation and multi-sensor, multi data (even non remote sensing data) file interface. In June '94, the prototype version of the algorithms in MATLAB language was delivered by the contractor. In September the first issue of the GUI was installed on the in-house SPARC 1000 for further refinements of the requirements. Iterative learning procedures and interface to the existing EURACS database were added.

The development is still on-going. The first provisional delivery of the overall system is expected by the end January 1995 and, after a validation period of about two months, the final acceptance testing should occur in end-March '95.

EARSEC SAR processing network

A call for proposal for the establishment of the EARSEC processing network (SAR part only) was issued in June 1994. The driving force behind this idea was to set up a network of processing nodes, which will ingest signal and ancillary data from sensors, derive calibrated and geo-referenced products, eventually merge with the processing information coming from other sources such as GIS and controlled reference data from the EMSL, and finally derive geophysical quantities that are of interest to the end user. The network of selected European laboratories will receive the software packages developed for EARSEC in order to allow uniform processing and product quality.

The creation of the network will evolve into two phases. In the first phase (test-bed or prototype phase), the nodes will receive the SAR Processor software. They will then have the opportunity to test the processor using a wide range of data. This will determine the full functionality of the processor. The second phase will include eventual commercial and marketing involvements and the network will assume its real operational aspect.
The first meeting of the EARSEC SAR processing network was held at Ispra on October 1994. The overall processing system of the EARSEC project is shown in Figure 6.14.

Airborne activities 1994

Interferometry

The first European airborne single-pass / dual antenna interferometric SAR experiment was performed in 1994 as a collaborative project between the AT Unit, the Remote Sensing Laboratories of the University of Zurich and the Dornier GmbH. The goal of the study was the validation of the DOSAR system as a tool to derive high precision digital elevation models using interferometric techniques.
The preliminary results of this campaign demonstrate that the system can be used as a standard sensor for interferometric investigations and to generate high precision and high resolution digital elevation models. The high coherence of the forested regions achieved with single-pass interferometry is a distinct advantage compared with dual-pass techniques, which suffer from temporal decorrelation. The results of the first experiment also demonstrate that the strong influence of the phase noise to the height resolution, caused by the small interferometric baseline of this system, can be compensated by the multi-look technique without reducing the spatial resolution.

Campaigns for the validation of the GPROC

An airborne SAR campaign was performed over the English Channel and the North Sea in order to get data for the purpose of validation of two modules (oil slick detection and maritime traffic monitoring) of the EARSEC SAR geophysical processor. The measurements for the ship-detection were taken in conjunction with ERS-1 over-passes, while for the oil-detection an ad-hoc experiment was undertaken by the University of Hamburg with controlled oil-spilling and in conjuction with X-SAR/SIR-C over-passes.

The first data sets of the experiment were delivered to EOS (UK) in December 1994. The results from the validation will be delivered directly to AT in 1995.

Perspectives for 1995

- Final European Acceptance Test of the DAIS-7915 is expected. The fully polarimetric L-band SAR will be completed. Final delivery of the Geophysical Processor is also planned for. The EARSEC Processing Network will be set up. A platform for the EARSEC -SAR will be acquired and validation flights with EARSEC sensors performed. Finally, a series of campaigns for the years 1996-1998 will be planned.

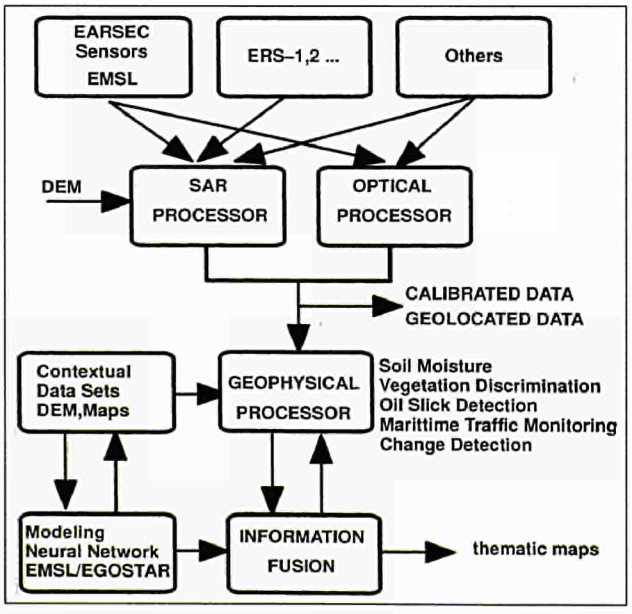


Figure 6.14: The overall EARSEC processing system.

7 THE CENTRE FOR EARTH OBSERVATION

Staff

Scientific and Technical Support:	1
Secretarial Support:	1
Scientific Visitors:	3
Students:	1
Total:	6

Facilities

- Personal Computers
- Printers
- Desk top publishing software

The European Space Agency (ESA) and the European Commission (EC) have agreed to work towards a more efficient and cost-effective use of Earth observation data, by combining their expertise with that of their Member States plus other relevant European organisations such as EUMETSAT to establish a co-ordinated, decentralised Earth observation network called the European Earth Observation System (EEOS).

The objectives of EEOS are:

to improve the ability to monitor and understand the Earth System on local, regional and global scales,

to enable through Earth Observation derived information, the European Union (EU), the Member States, including those of the European Economic Area (EEA), and ESA to implement their own policies and programmes more efficiently,

to enable European Earth Observation industry to be more robust in European markets and more competitive on the world markets.

EEOS will link with international initiatives such as

NASA's Earth Observation System Data and Information System (EOSDIS) and Japan's international satellite data management and information system (EOIS).

In this collaboration ESA and the national space agencies shall take responsibility for receiving data from satellites, and for the pre-processing and supply of these space data.

The EC contribution to EEOS is the Centre for Earth Observation (CEO). The CEO Project should be viewed as a programme of work contributing to the successful establishment of an operational system (the EEOS).

Within the EEOS the CEO will foster the development of applications of Earth observation data that fulfil the specified information requirements of scientific, operational and commercial users. This will ensure that relevant higher level products and information are produced and made available.

Associated with the application development are various services. These will include services that permit access to data and information, and help preserve the data and information.

CENTRE FOR EARTH OBSERVATION

7.1 THE CEO PROJECT ORGANIZATION AND STATUS

Summary of Objectives

To encourage communication and exchange of services between individual users and between user communities.

To stimulate the creation of high level products, where and when necessary.

To promote improved data standardisation and quality assuranceó

To co-ordinate the design and operation of existing and future decentralised data archives and data bases and data delivery services.

To improve the accessibility and availability of Earth observation data, services and expertise.

1994 PROGRAMME OF WORK

Project Status

The CEO project is divided into 3 phases:

- Feasibility Study	1992-1993
- Pathfinder Phase	1993-1995
- Design and Implementation Phase	1996-1998

The CEO project was in the Pathfinder phase for all of 1994.

The goal of the Pathfinder phase is to produce a project plan for the Design and Implementation phase containing sufficient information and understanding of the system to bring the CEO successfully into being. The work of the Pathfinder phase has been described in a Project Plan; the Project Plan has been presented to and discussed with the Pathfinder Phase Steering Committee (PPSC).

The Pathfinder Phase is organised by Activities each with contributory deliverables. There are 5 Activities, of which the first two (Activity 1: Survey and understand the present infrastructure status, and Activity 2: Capture user requirements) take place simultaneously at the start of the Pathfinder phase. The third Activity (Synthesis) starts during Activities 1 and 2, and ends when the implications of those Activities are fully assimilated. The fourth Activity (Plan the Design and Implementation phase) then starts. Throughout the Pathfinder phase, the fifth Activity (Cost and Benefits of the CEO elements of the system) maintains an up-to-date estimate of the probable cost of the programme.

1994 Milestones

Febr.: 2nd Meeting of the Pathfinder Phase SteeringCommittee (PPSC).
Feb.: Workshop on the current status of Earth observation infrastructure.
April: 3rd Meeting of the PPSC.

Sept.: 4th Meeting of the PPSC.

Dec.: Networks and networks services workshop.

In support of these Activities a number of contracts have been let in 1994 with European organisations. Further contracts are now in the process of being let.

Project Organization

The Pathfinder phase is overseen by a Steering Committee (PPSC) composed of delegates of the Member States of the European Union (EU) and the European Economic Area (EEA) countries. The members of the PPSC were nominated by the JRC Board of Governors. To date the PPSC has met four times, the last meeting being in mid September 1994.

The PPSC is also observed by the European Environmental Agency (EEA), EUMETSAT, the European Space Agency (ESA) and relevant organisations of the EC such as EUROSTAT, plus other space data providers such as Eurimage and Spot Image.

The Pathfinder Phase is managed and co-ordinated by a Project Team based in the JRC Institute for Remote Sensing Applications (IRSA). The Project Team has a number of roles, which include:

management and co-ordination of the Pathfinder Phase to ensure that the objectives of the Pathfinder Phase are achieved;

synthesis of the results of the Pathfinder Phase derived by the various contractors participating in the Pathfinder Phase, as well as the results derived by the Institutes of the JRC;

production of the plan for the Design and Implementation phase.

The Project Team also provides the technical and administrative support for the various study contracts given in support to the Pathfinder Phase.

In support of this activity DGXII-D4 (Space Unit) provide strategic and policy input. DGXII-D4 co-ordinate the contact with the Member States, and other appropriate international agencies and programmes. They also ensure co-ordination with other relevant services of the European Commission.

Within the JRC there is a wide range of expertise of relevance to the CEO Pathfinder Phase. This expertise is necessary to attain the objectives of the Pathfinder Phase, and is currently provided by four JRC Institutes:

- Institute for Remote Sensing Applications (IRSA);-
  Institute for Systems Engineering and Informatics (ISEI);
- Environment Institute (EI);
- Safety Technology Institute (STI).

Objectives And Assumptions

In conjunction with the PPSC a number of high level objectives have been set for the CEO.

The CEO shall promote the application of Earth observation in the EU and Member States by:

encouraging communication and exchange of services between individual users and between user communities;

stimulating the creation of high level products, where and when necessary;

promoting improved data standardisation and quality assurance;

co-ordinating the design and operation of existing and future decentralised data archives and data bases and data delivery services;

improving the accessibility and availability of Earth observation data, services and expertise.

Two main design constraints have also been set for the CEO:

the CEO shall pay due regard to, and take advantage of, established institutions and existing and planned networks and projects.

the CEO shall be designed to evolve and adapt flexibly to future needs of the users and to changes in data sources.

The above objectives imply a number of assumptions about the CEO. It should be stressed that these assumptions are preliminary in nature, and are currently being revised in the light of user requirements that have been collected.

Participating Entities

The entities that would benefit from the existence of the CEO include all organisations or individuals with a professional objective that may benefit by using information obtained from Earth observation. Such entities will include the Services of the Commission, National government organisations, regional, local and city government, universities and research centres, commercial companies and international consortia.

It is therefore expected that users of the CEO will be drawn from scientific, operational, policy and commercial areas.

Organization Autonomy

Organizations across Europe will participate in the CEO programme, and will ensure that the CEO is implemented according to the design criteria. However, there is no reason for the CEO faculty to

interfere with the autonomy of participating organisations, but rather the CEO faculty should leave participating organizations free to expand their expertise and infrastructure by using services and resources made available through the CEO programme.

Decentralised Approach

The CEO should be decentralised, and rely on as few central services as possible. In the early stages of the CEO project a central co-ordinating facility will certainly be necessary, although its role and responsibilities remain to be determined.

Standards

The CEO programme should ensure accessibility to data, information and services. To achieve this the CEO programme should in relevant cases recommend standards, formats or software.

Formats

The CEO should help users to access data and services across the full range of formats and standards available on the system. This may require the creation of specialised software, but there is no assumption about who should provide that software.

+Earth Observation Expertise

Earth observation expertise and data are distributed over many organisations. The CEO should make them more easily available to potential users.

Flexibility

User requirements for the CEO programme will change as new applications are introduced, as users become more expert in the analysis of Earth observation data, and as their understanding of the capabili-

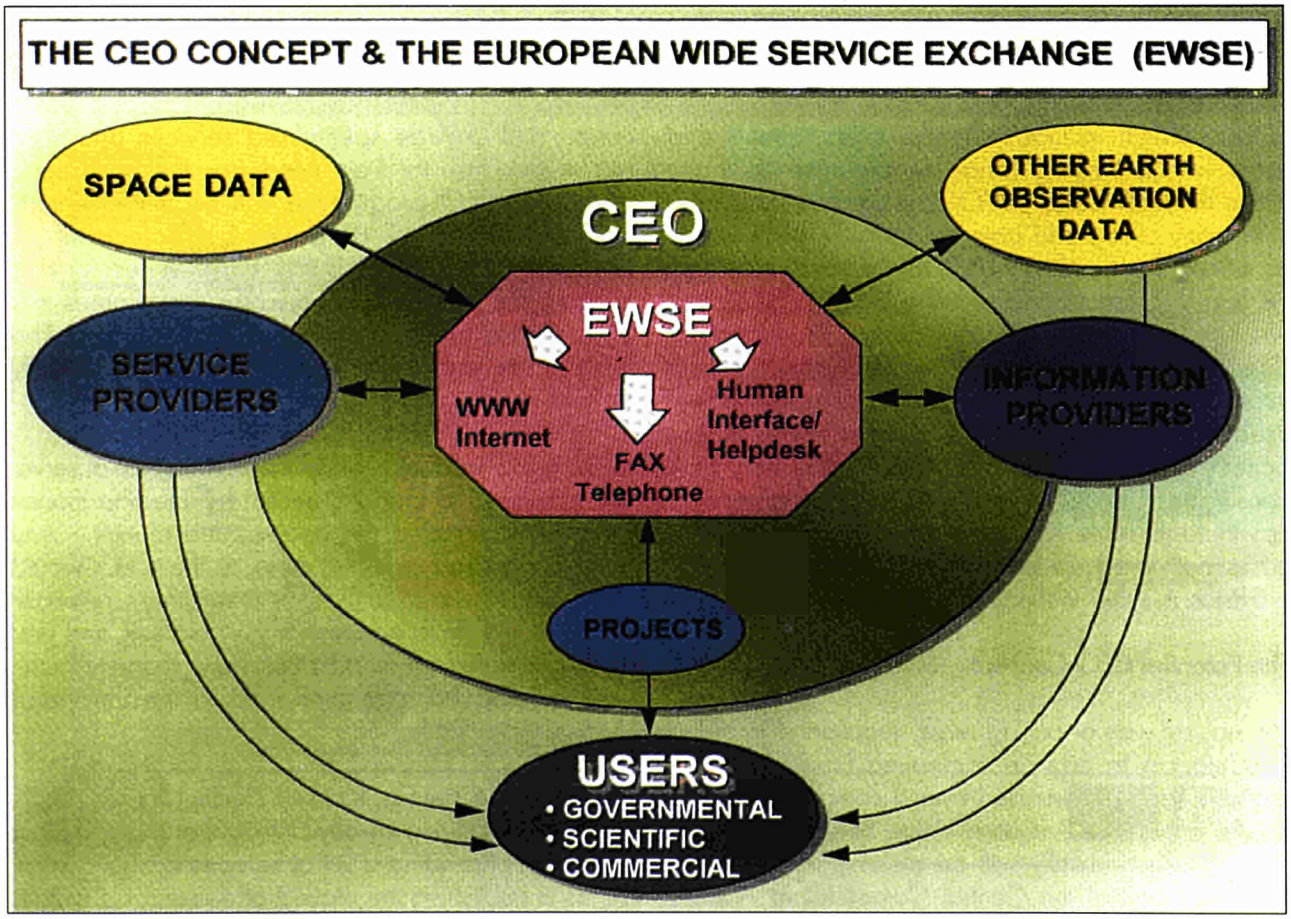


Figure 7.1: The CEO Concept

ties and potentialities of the CEO increases. The CEO should therefore be responsive to user requirements.

New Technology

New technology and its consequences must be continuously incorporated into or accommodated by the CEO programme.

Suggested Concept For The CEO

The architecture of the CEO will only become apparent once the results of the Pathfinder phase are available and analysed. Nevertheless, it is possible to suggest a concept that conforms to the objectives listed above, and which does not impose or imply any particular architecture. This concept has been used to stimulate user requirements, and will be modified as user requirements are collected.

The Present Situation

There are a number of current users of EO data in Europe which include potential users, clients and users with a varying range of expertise. In many cases the knowledge of EO data availability is poor with many clients and potential users deriving little or no benefit from currently available data. Clients may be linked to users (such as value added companies) who assist in providing the required information or data. Other users may hold their own data banks of information but these are in most cases poorly advertised or stored in a low level form which makes access difficult or extracting information very time consuming. Certain service providers may offer services through some type of network link but in other cases both the knowledge of and access to service provision is either ineffective or not present.

The Potential CEO Concept

The easiest way of putting users, suppliers and clients in contact is to provide a clearing house in which requests can be advertised over a computer network. This is termed the European Wide Service Exchange (EWSE) which initially will be developed and maintained as part of the Central Co-ordinating Agency or Facility. It may operate as an electronic bulletin board (exchange information in a sequential way), or as a telephone yellow pages (organised by theme) or as a dating agency (where the system aims to find a perfect match of user requirement and service provision).

The user of the European Wide Service Exchange must find it simple and intuitive to use. It should certainly provide context-sensitive help. The user advertising his need or the provider advertising a service should be able to define precisely the service required or offered. A specialised user committee could review new suggestions, and decide to add them permanently, delete them, redefine them, re-link them, or ask the user for clarification.

New services will appear on the market as a response to the demand from the users. Popular services will tend to be offered by several providers, thus stimulating healthy competition and improvement in the services. Such a system adapts naturally and without outside control to changing user requirements.

Projects and Services

Within the proposed CEO concept it is proposed to develop the idea of Projects based on funding to create and provide specialised services and data sets in response to client needs, as the basis upon which the CEO programme will be implemented. The programme will be driven by projects which bring potential users or clients to awareness of and competence with Earth observation in the areas that they require for their professional objectives. The projects are established and financed under closely defined conditions.

A project is intended to stimulate the Earth observation market, in its broadest sense, by injecting money without unbalancing the value-added market. Any project launched in the context of the CEO would have certain responsibilities. Among these responsibilities would be to ensure that the data sets and products generated by its activities were properly archived, catalogued and interfaced to the European Wide Service Exchange.

The idea of a service is a key element for the CEO. A service is defined as any activity that is carried out for a user. Providing a list of services is also a service, as is publishing the request of a user for a certain service. Services may be provided by anyone; Earth

observation data suppliers, value-added companies, university departments, or various individual users of the system. Suppliers are free to offer to provide their service under whatever conditions they wish to impose, unless restricted by the decisions of a relevant user committee. Some of the services may be provided by the CEO programme or by the Central Facility itself.

In this manner the CEO provides a "shop window" for service providers which they are free to use or not use according to their wish. The CEO may initially provide some limited funding to give an impetus to attracting service providers to establish the system. However, for the provision of services the motivation/altruism/sales incentive of the service providers is recognised as the overriding driving force.

Co-ordination of the CEO: User Committees and Central Facility

In this concept of the CEO, the functioning of the programme remains largely in the hands of the users. Users may decide to form committees to co-ordinate the behaviour of users (including suppliers) in any given domain of the CEO. The exact terms of reference, method of operation and method of funding of these committees is still to be determined.

Certain functions of the CEO system may have to be co-ordinated centrally. This leads to the idea of a CEO Co-ordinating Facility (CCF), in which the appropriate Services of the Commission may have a significant role. The functions, responsibilities, staffing and financing of this CCF are not yet determined

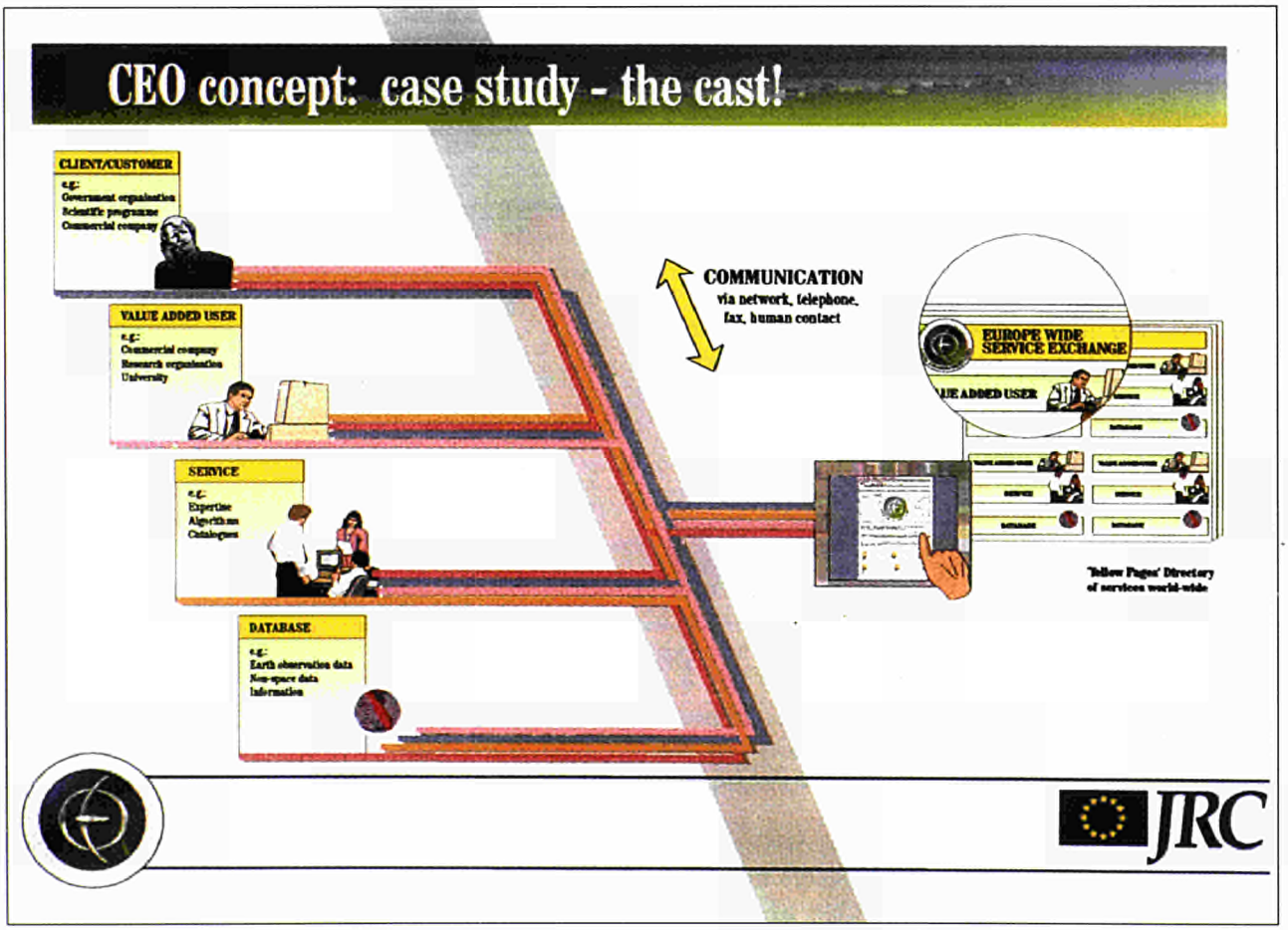


Figure 7.2: The CEO Concept and the European Wide Service Exchange.

and will probably change over time as the requirements of the system change. In the initial stages of the CEO most or all of the functions of the CCF shall probably be provided by the team responsible for the CEO Pathfinder phase or subsequent phases.

Expected Results

This concept of the CEO moves significantly towards several important goals.

It encourages potential users to become users.
It stimulates the market (in its broadest sense) by injecting money through the user. The Commission does not unbalance the value-added market.
It provides a full-scale test of the capacity of the system to respond and highlights any weaknesses.
It stimulates new services in areas where they did not previously exist.
It contributes to an awareness of the CEO among potential users.
It stimulates workers to collaborate internationally on projects. This causes users to work together to resolve common problems, encourages collaboration, opens the way for continued partnerships, and stimulates the flow of information and exchange of data.

Perspectives for 1995

1995 will see the completion of the Pathfinder Phase of the CEO. Activities 1 and 2 will be completed by the middle of the year, with the final deliverables of the Phase being produced by the end of the year.

It is considered that in order to achieve the objectives of the Pathfinder Phase, and in particular in order to understand the requirements of the user for the CEO, it is necessary to undertake a limited number of practical studies (Pathfinder Studies). These will be based on existing projects, both within the JRC and in organisations in the Member States. They will test the requirement for distributed access to earth observation and associated data. They will also test the requirement for making these data sets available.

In addition to the Pathfinder studies, it is also considered necessary to test the user requirement for individual technological developments. One example of this is the requirement to create and an on-line tool that will allow access to the various data sets and services provided by the CEO. It is considered that without a practical test of such technologies the full user requirement for such a tool could not be produced. Again the Institutes of the JRC have experience in developing such tools, and it is planned that this expertise will be combined with that of organisations within the Member States to undertake this task. An example of this is a prototype CEO World Wide Web information server; the Universal Resource Locator for this is: **http://www.ceo.org/**.

8 ANNEXES

8.1 INSTITUTE FOR REMOTE SENSING APPLICATIONS

Applications of Remote Sensing Techniques

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.2 ACRONYMS AND ABBREVIATIONS

ADP	Application Demonstration Programme (of OCEAN)
AIRSAR	Airborne SAR flown by JPL
AIS	Agricultural Information Systems Unit of RSA
AGU	American Geophysical Union
ARC	Active Radar Calibrator
AO	Announcement of Opportunity
APM	Anti Personnel Mines
AT	Advanced Techniques Unit of IRSA
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Advanced Visible Infra-Red Imaging Spectrometer
BDRF	Bi-Directional Reflectance Factor
BIO	Bedford Institute of Oceanography Canada
CAL/VAL	Calibration and Validation
CAP	Common Agricultural Policy
CAPI	Computer Assisted Photo Interpretation
CASI	Compact Airborne Spectral Imager
CCT	Computer Compatible Tape
CEO	Centre for Earth Observation
CEOS	Committee for Earth Observation Satellites
CGMS	Grop Growth Monitoring System
CI	Coordinating Investigator
CILSS	Comitée Permanent Inter-Etats de la Lutte contre la Secheresse au Sahel
CoASTS	Coastal Atmosphere and Sea Time Series
CORSA	Cloud and Ocean Remote Sensing around Africa
CPS	Characteristic Polarisation State
CZCS	Coastal Zone Colour Scanner
DG	Directorate General (of the European Community)
DMS	Dimethylsulphide
DTM	Digital Terrain Model
EAGGF	European Agricultural Guidance and Guarantee fund
EARSEC	European Airborne Remote Sensing Capability
EARSeL	European Association of Remote Sensing Laboratories
EC	European Commission
ECMWF	European Centre for Medium Range Weather Forecasting
ECU	European Currency Unit
EDF	European Development Fund
EEA	European Environment Agency
EEIG	European Economic Interest Group
EEOS	European Earth Observation System
EFI	European Forest Institute
EFICS	European Forestry Information and Communications System
EGO	European Goniometer
EISAC	European Imaging Spectrometer Airborne Campaign
EMAP	Environmental Mapping and Modelling Unit of IRSA
EMSL	European Microwave Signature Laboratory
ENVISAT	Environment Satellite (of ESA)
EOIS	Earth Observation and data Information System (of Japan)
EOSDIS	Earth Observation System Data and Information System (of NASA)
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)
EU	European Union
EURACS	European Radar Cross Section data base
Eurostat	European Statistical Office
EXPRESSO	Experiment for Regional Sources and Sinks of Oxidants
FAO	Food and Agriculture Organisation (of the United Nations)
FIRE	Fire In global Resource and Environmenta monitoring
FIRS	Forest Information from Remote Sensing (FIRS)
FLI	Fluoroscence Line Imager
FPAR	Fraction of Photosynthetically Active Radiation
FOV	Field Of View
GAC	Global Area Coverage (of AVHRR data)
GCP	Ground Control Point
GEMI	Global Environment Monitoring Index
GER	Geophysical Environmental Research Cooporation
GERIS	Geophysical Environmental Research Imaging Spectrometer
GIS	Geographical Information System
GPS	Global Positioning System
GSFC	Goddard Space Flight Center (a NASA centre)

HCM	Human Capital and Mobility programme (of the EC).
HRPT	High Resolution Picture Transmission (of AVHRR)
HVR	High Visible Resolution (sensor on SPOT)
IACS	Integrated Administration and Control System
ICSU	International Council of Scientific Unions
IFI	International Forest Investigation
IGAC	International Global Atmospheric Chemistry (project of the IGBP)
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 (of IGBP)
JPL	Jet Propulsion Laboratory
JRC	Joint Research Centre
LAC	Local Area Coverage (of AVHRR)
LVQ	Learning Vector Quantisation
MAESTRO 1	Multiple Airborne Experiments Towards Radar Observations - campaign
MARS	Monitoring Agriculture with Remote Sensing
ME	Marine Environment Unit of IRSA
MERIS	Medium Resolution Imaging Spectrometer
MISR	Multi angle Imaging Spectroradiometer (EOS am Platform instrument)
MLP	Multi-Layer Perceptron
MODIS	Moderate Resolution Imaging Spectrometer
MPI	Message Passing Interface
MSS	Multi-Spectral Scanner (on the Landsat Satellite)
MTV	Monitoring Tropical Vegetation Unit of IRSA
NASA	National Aeronautics and Space Administration
NDVI	Normalised Difference Vegetation Index
NIR	Near Infrared part of the electro-magnetic spectrum
NOAA	National Oceanic and Atmospheric Administration
OBR	Optimal Band Reflectance
OC	Ocean Colour
OCEAN	Ocean Colour European Archive Network
OCTS	Ocean Colour and Temperature Scanner
OCTOPUS	Ocean Colour Techniques for Observation, Processing and Utilisation Systems
OPS	Optimum Polarisation State
ORCA	Orbital Remote Sensing of Crop Area
PC	Personal Computer
PGO	Productivity of the Global Ocean
PI	Principle Investigator
POC	Particulate Organic Carbon
POLTOOL	Polarimetric data analysis Tool
PPSC	Pathfinder Phase Steering Committee (of the CEO project)
RCS	Radar Cross Section
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
SIFP	Soils Information Focal Point
SIR-C	Shuttle Imaging Radar C
SMA	Spectral Mixture Analysis
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
SuGrAm	Support Group for Agro-meteorology
SWIR	Short Wave Infrared part of the electro-magnetic spectrum
TEAM	Terrestrial Ecosystem and Atmospheric Modelling (of the MTV Unit)
TGV	Transient Global Vegetation model
TM	Thematic Mapper (on the Landsat Satellite)

TREES	Tropical Ecosystem Environment Observations by Satellites (MTV Unit)
TRLF	Time Resolved Lidar Fluorosensor
UNECE	United Nations Economic Commission for Europe
UV	Ultra-Violet part of the electro-magnetic spectrum
VIS	Visible part of the electro-magnetic spectrum
WCMC	World Conservation Monitoring Centre
WCRP	World Climate Research Programme
WFW	World Forest Watch (Pilot Project of ISY)
WMO	World Meteorological Organisation
WOCE	World Ocean Circulation Experiment
WORM	Write Once Read Many (Optical storage media)
WWW	World Wide Web
X-SAR	X band Syntheic Apperture Radar

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In 1994, the Institute for Remote Sensing Applications' (IRSA) research addressed themes from the Joint Research Centre's Specific programme including the monitoring of land resources and land use, coastal monitoring, development of advanced techniques for the analysis and interpretation of remotely sensed data, global change and the Centre for Earth Observation (CEO). (The CEO is part of a joint initiative with the European Space Agency and the Member States called the European Earth Observation System).

Research oriented to the development of operational remote sensing applications was carried out in support of the sectorial policies of various Directorates General (DG) of the European Commission. These included the application of remote sensing to marine productivity for DG I (External Affairs), the operational use of remote sensing techniques for provision of agricultural statistics for DG VI (Agriculture), use of remote sensing for the setting up of registers and the controls of declared areas, again for DG VI, monitoring of tropical vegetation and vegetation fires in association with DG VIII (Development Aid), development of semiautomatic update of the CORINE landcover database for DG XI (Environment) and generation of a European data base (OCEAN) containing bio-optical information on the marine environment, again for DG XI.

IRSA's programme of exploratory research continued, addressing a diverse range of themes including ray-tracing experiments, use of virtual reality technology for image analysis and fundamental work on instrument calibration. Exploratory research such as the development and implementation of a comprehensive ray-tracing model which successfully describes the transfer of radiation in complex scenes will be used in future Institutional research programmes.

Throughout the year full use was made of IRSA's large installations, such as the European Microwave Signature Laboratory (EMSL). For example, a full research programme within EMSL, guided by the international EMSL Advisory Committee, for example saw the first 3-D microwave tomographic image created from EMSL data.

The Institute continued to support a number of international initiatives, providing input to the work of the international Committee for Earth Observation Satellites (CEOS) and to a number of International Geosphere Biosphere Programme (IGBP) core projects throughout the year.

The Institute continued to act as the counterpart for ESA, other European and national space agencies in maintaining a strong applications oriented role. IRSA also continued to process and manage large archives of satellite imagery for both terrestrial and marine environments.

Finally, the Institute took account of the changes in the JRC foreseen as the European Commission's (EC) fourth framework programme begins. In the last months of 1994 IRSA began to participate actively in the preparation of bids for EC funds on a competitive basis.

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