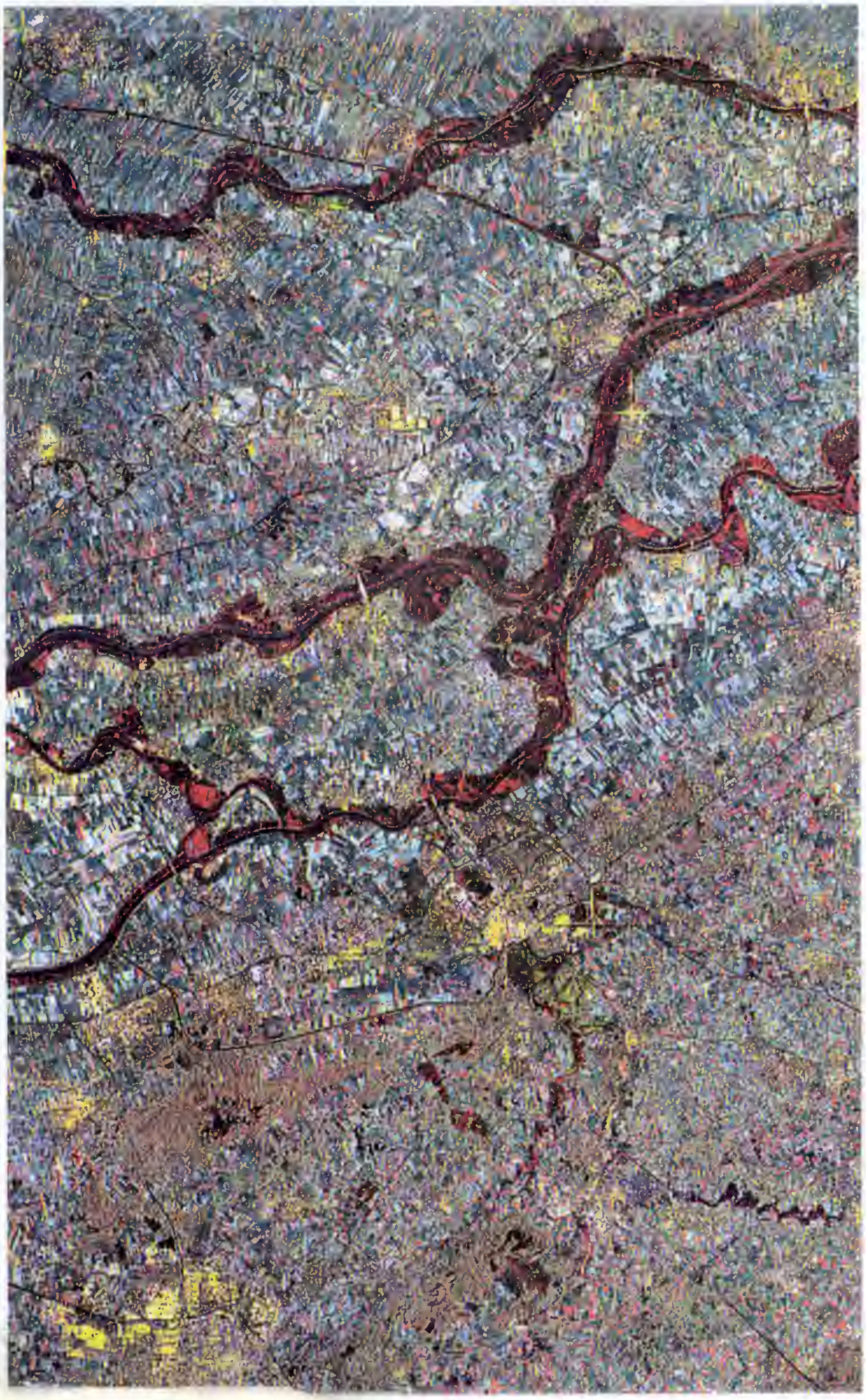
First ERS Thematic Working Group Meeting on FLOOD MONITORING

26-27 June, 1995 - ESRIN, Frascati - Italy

(REPRINT)



ESA06

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ESRIN

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ERS Thematic Working Group Meeting on
FLOOD MONITORING

26-27th June, 1995 - ESRIN, Frascati, Italy

Background

Flood Monitoring activities today foresee an ever increasing use of remote sensing data, in particular for:

- **Prevention** - the modelling of river basin dynamics for future planning
- **Monitoring** - the mapping of flood events to help manage quick emergency aid
- **Relief** - timely damage assessment and identification of risk areas

In recent years there have been many new developments in the field of SAR (Synthetic Aperture Radar) image analysis, also taking advantage of the uninterrupted availability from 1991 onwards of the data collected from ERS-1 the European Remote Sensing Satellite of ESA.

This data flow continuity is now ensured with ERS-2, the latest in the ERS family, launched on April 21st 1995 from Kourou, French Guyana.

Objectives

ESRIN's aim in organising this ERS Working Group Meeting has been to bring together parties interested in the monitoring and assessment of floods using remote sensing techniques.

It is hoped that not only those able to produce the information, but also those who utilise, or will utilise this type of data might benefit from attending.

The audience is made up from those representing the "Providers" of remote sensing information, the "Users" and those Parties interested in improving or expanding their sources to meet the flood management requirements.

The MEETING focuses mostly on the types, delivery and application of remote sensing information, rather than on image processing techniques and technicalities in general.

Outline of Meeting

The meeting consists of:

Five Sessions

Two main Sub-themes

- Flood Monitoring
- Flood Prevention and Assessment

Two types of Presentation

- The experience of Satellite Information providers
- User Views

Two Open Floors for Discussion of the Key Issues of Each Day

This is a collection of all material that the lecturers were able to provide to us in order to allow redistribution at the meeting in almost REAL-TIME!

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AGENDA

Chairman of all sessions: W. Jensen, ESRIN
Co-Chairman of all sessions : Juerg Lichtenegger, ESRIN

After each presentation time 10 min. (or more, if needed) will be allocated for Questions and Answers

Monday, 26th June, 1995

9.00 - 9.30
- Registration (at the Registration desk outside the Main Conference Room)

9.30 - 10.00
- Welcome by W. Jensen, Head ERS Exploitation Department, ESRIN
- Overview on the role of ESRIN in the Earth Observation Programmes of ESA
- Background and objectives of the Meeting

SESSION 1: FLOOD MONITORING: THE EXPERIENCE OF SATELLITE INFORMATION PROVIDERS

10.00-10.20
- The contribution of space technology to major risks

J-P Massue, EUR-OPA Major Hazards Agreement, Council of Europe, Strasbourg

10.30-10.50
- Use of SAR (Synthetic Aperture Radar) data for flood monitoring and mapping in Thuringia, Germany

A. Kannen, Deutsche Projekt Union, Eberswalde, Berlin, Germany

11.00-11.30
- ***COFFEE BREAK***

Session 1 Continued

11.30-11.50
- FLOODNET - a Telenetwork for acquisition, processing and dissemination of Earth Observation data for monitoring and emergency management of floods

K. Blyth, Institute of Hydrology, Wallingford, UK

12.00 - 12.20
- Monitoring flood events with remote sensing data: an example of ERS-1's contribution to flood events in Northern and Southern France regions

N Tholey, SERTIT, Service Regional de Traitement d'Images, Illkirch, France

SESSION 2: **FLOOD PREVENTION AND ASSESSMENT: THE EXPERIENCE OF SATELLITE INFORMATION PROVIDERS**

12.30 - 12.50
- Mapping of 1994 flood in Piemonte Region: an example of remote sensing and GIS application

E. Bonansea, CSI, Consorzio per il Sistema Informativo, Piemonte, Italy

13.00
- ***LUNCH***

Session 2: **Continued**

14.00 - 14.20
- Assessment of flood mapping capabilities with the aid of ERS-1 SAR data: an experience in Germany

R. Oberstadler, GAF, Gesellschaft fuer Angewandte Fernerkundung, Muenchen, Germany

SESSION 3: **FLOOD MONITORING: USER VIEWS**

14.30 - 14.50
- Studies of runoff processes by the use of remotely sensed data (including 1993, 94, 95 floods experience in the Rhine Basin)

F. Portmann, Federal Institute of Hydrology, Koblenz, Germany

15.00 - 15.20
- Overview on the cartography of inundable areas, as part of the activities of the Geology Data Bank Service in Piemonte Region

G. Bellardone, Assessorato alla Pianificazione, Regione Piemonte, Italy

15.30 - 15.45
- ***COFFEE BREAK***

Session 3: **Continued**

15.45 -16.05
- Overview on technical needs of insurance and re-insurance companies, with emphasis on flood risk aspects

M.T. Piserra, MAPFRE - RE, Madrid, Spain

16.15
- OPEN FLOOR DISCUSSION ON THE *KEY* ISSUES OF THE DAY

17.15
- END OF SESSIONS

17.45
- ***COCKTAIL AT ESRIN***

Tuesday, 27th June, 1995

SESSION 4: FLOOD PREVENTION AND ASSESSMENT: THE EXPERIENCE OF SATELLITE INFORMATION PROVIDERS

(cont. of session 2 day 1)

9.00 - 9.20
- Identification of flooded areas in the Rhone and Var river valleys, France, using ERS-1 data

S. Delmeire & L.Marinelli, Geoimage, Sophia Antipolis, France

9.30 - 9.50
- ERS SAR and LANDSAT Thematic Mapper data application to flood prevention and damage assessment in Italy

H. MacIntosh, University of Florence, Italy

10.00 - 10.20
- Issues of hydraulic model validation and design using remotely sensed data

P. Bates, Department of Geography, University of Bristol, UK

10.30 - 10.50
- Potential capabilities of microwave satellite information for the assessment of run-off risk over Mediterranean soils

C. King & A.Company, Bureau du Recherche Geologique et Miniere, Orleans, France

11.00 - 11.15
- ***COFFEE BREAK***

Session 4: Continued

11.15 - 11.30
- EARTHWATCH: a service provided by EURIMAGE - The flood case

R. Biasutti & A. Lombardi, Eurimage Consortium, Rome, Italy

11.40 - 12.00
- Characterisation of flood inundated areas and delineation of poor drainage soil using ERS-1 SAR imagery

M. Badji, Faculte Sciences Agronomiques, Univers. de Gembloux, Belgium

SESSION 5: FLOOD PREVENTION AND ASSESSMENT: USER VIEWS

12.10 - 12.30
- The use of remote sensed data in the study of flash floods and their effects

D. Risser, Centre Europeen sur les Risques Geomorphologiques, Strasbourg, France

12.40 - 13.00
- Estimation of discharge from three braided rivers using ERS-1 SAR

L. Smith, Cornell University, Ithaca, New York, USA

13.10	• ***LUNCH***	
Session 5:	**Continued**	
14.15 - 14.35	• Utilisation of airborne and spaceborne data for flood monitoring and assessment: present and future user requirements in Holland	
	L. Janssen, Rijkswaterstaat, Delft, The Netherlands	
14.45 - 15.05	• Operational, research and development aspects in the management of natural risks in general and floods in particular: the role and activity of the European Union	
	D. Vassaux, DG XII, European Union, Brussels, Belgium	
15.15 - 15.35	• Flood Modelling in the financial sector: Is satellite data the answer?	
	A. Mitchell, Greig Fester International, United Kingdom	
15.45 - 16.00	• ***COFFEE BREAK***	
16.00	• OPEN FLOOR DISCUSSION ON THE *KEY* ISSUES OF THE DAY	
17.00	• CLOSURE OF THE MEETING	

Day 1

Council of Europe
Conseil de l'Europe

Strasbourg, 29 May 1995

THE EUR-OPA MAJOR HAZARDS AGREEMENT OF THE COUNCIL OF EUROPE :

SPACE TECHNOLOGIES FOR RISKS MANAGEMENT

by J-P MASSUE
EXECUTIVE SECRETARY
OF THE EUR-OPA MAJOR HAZARDS AGREEMENT

In March 1987, the Committee of Ministers of the Council of Europe adopted Resolution (87) 2 establishing an intergovernmental Open Partial Agreement. Its main aim is to reinforce co-operation between Member States in a multi-disciplinary context to ensure better prevention, protection and organisation of relief in the event of major natural or technological disasters.

This Open Partial Agreement named " EUR-OPA Major Hazards Agreement" has to date 23 member States : Albania, Algeria, Armenia, Azerbaijan, Belarus, Belgium, Bulgaria, France, Georgia, Greece, Israel, Italy, Latvia, Luxembourg, Malta, Monaco, Morocco, Portugal, Russia, San Marino, Spain, Turkey, Ukraine. Japan has the status of observer.

The European Commission, UNESCO, WHO and the United Nations Department of Humanitarian Affairs participate in the Agreement. The International Federation of Red Cross and Red Crescent Societies is associated in its work.

The main aim of the Agreement is to promote cooperation between member States by calling upon present day resources and knowledge to ensure an efficient and interdependent management of major disasters. This Agreement is named "Open" because any non-member State of the Council of Europe may apply to accede to it.

There are three levels of action :

1. the political level with the periodical meetings of the Ministers of the Agreement and of the Committee of Permanent Correspondents which determine the co-operation policy corresponding to the objectives of the Agreement;

2. the scientific and technical level with :

. the "European Early Warning System"
. the "European Advisory Evaluation Committee for Earthquake Prediction"
. the Network of "Specialised European Centres"[1];

One of the focal points of this Agreement is the quest for ensuring a direct interest and participation of the member States by fostering the creation of European Centres. These structures facilitate a concrete contribution from the different partners, with common objectives, through the implementation of European information, training and research programmes.

3. specific programmes whose characteristics differ in relation to the activities of the first two levels in that they can call upon voluntary financial contributions.

During the 5th Ministerial meeting of the Agreement, the Ministers adopted the Moscow Charter and agreed the following :

"- to use the EUR-OPA Major Hazards Agreement of the Council of Europe as a suitable platform for co-operation between Eastern Europe, the South of the Mediterranean and Western Europe in the field of major natural and technological disasters;

- that co-operation between the member countries of the EUR-OPA Major Hazards Agreement shall cover scientific research activities and the training of specialists in the field of risk sciences, to be conducted by the European Centres of the Agreement and training establishments, as well as practical interaction in emergency situations using new technologies and the results of military conversion processes;

- that the activities of the EUR-OPA Major Hazards Agreement shall be organised in keeping with this political resolve and, in particular, in such a way as to avoid any overlap with the work of other international organisations.

During the 6th Ministerial meeting of the Agreement held in Brussels on 6 Ocotber 1994, the Ministers adopted Resolution 2 on the use of space technology to assit risk management.

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1. - The Higher Institute for Emergency Planning, Florival, Belgium
- The European Centre on Seismic and Geomorphological Risks, Strasbourg, France
- The European Centre on Insular Coastal Dynamics, Valeta, Malta
- The European Centre for Non-Linear Dynamics and Theory of Seismic Risk, Moscow, Russia
- The European Centre on Natural Disasters, Ankara, Turkey
- The European Centre for Disaster Medicine, San Marino
- The European University Centre for the Cultural Heritage, Ravello, Italy
- The European Centre for Geodynamics and Seismology, Luxembourg
- The European Observatory on Oceanology, Monaco
- The European Centre on Information Techniques to the Public in Emergency Situations, Madrid, Spain
- The European Centre on Prevention and Forecasting of Earthquakes, Athens, Greece

Taking into account existing or planned programmes using space equipment to assist risk management as part of the European Union, the European Space Agency, the United Nations and national programmes.
The Resolution request :

1. The continuation of the prospective study being undertaken on the use of space technology for the purposes of risk management, concerning monitoring, navigation, telecommunications as well as data collection and transmission,

2. The implementation of a series of significant demonstration projects using space equipment supplementary to other techniques in the area of natural and technological hazards.

The additional budgetary implications of these activities are to remain separate from the Special European Fund of the Agreement.

PROSPECTIVE STUDY

The European Space Agency has agreed to implement the prospective study in conjunction with the Commission of the European Communities. It will be carried out in four phases:

Phase 1:
identification of the information needs of decision-makers in the area of risk management;

Phase 2:
Inventory of existing or planned space technology facilities in Eastern and Western Europe and in other countries which might contribute to assistance for decision-making in risk management;

Phase 3:
On the assumption that optimal use is made of existing space technology facilities and that the need for additional space segments is demonstrated, an East-West space tool will be defined to meet users' needs;

Phase 4:
Cost-benefit analysis. A steering committee, co-chaired by the European Space Agency and the Commission of the European Union, has been set up to run the prospective study.

Scheduling of phases:

- Phase 1 from November 1994 to beginning July 1995,
- Phase 2 from November 1994 to beginning June 1995,
- Phase 3 from end June 1995 to end March 1996,
- Phase 4 from end November 1995 to end March 1996

The results of the prospective study conducted by the European Space Agency in conjunction with the Commission of the European Union are due to be presented at the next ministerial session of the EUR-OPA Major Hazards Agreement in April 1996.

In parallel to the prospective study and on the basis of the results of programmes already implemented or activities run within a limited timescale and geographical area, a number of demonstration projects are being conducted with a view to illustrating how space technologies can contribute to risk management. The following demonstration projects are to be conducted in the field of natural and technological hazards:

NATURAL HAZARDS

1. Floods

The aim of this project is to examine common methodologies which can be used, with the help of space technology facilities, to manage two types of flooding: flash-floods and plains flooding. It will be a Franco-Russian co-operation project comprising four phases:

1. Updating maps of zones at risk: responsibility of France with Russian support (pilot site: south-eastern France).

2. Supplementing warning systems through the satellite transmission of data logged by hydrological platforms.

3. Throughout the period of flooding:

- identification of flooded areas by processing satellite images obtained by all the satellites covering the flooded area (Ressurs O and F, Meteor, Russian Duci satellite, SPOT, ERS 1 and 2, NOAA, Argos collecting system and Meteosat),

- satellite transmission of critical data from the flooded area to the control centre: responsibility of France,

- identification by Russia of one or two sites of potential spring flooding.

4. Post-crisis analysis, evaluation of the consequences.

The final report is to be presented by 10 March 1996.

2. Earthquakes

The aim of this demonstration project is to show how the use of 'geographic information systems' (GIS) and data obtained through space technology can facilitate seismic risk management. In practical terms, the project will seek to demonstrate the value of GIS in the management of data relevant to seismic risks, the important contribution of remote sensing and GPS data as a supplement to existing ground data, and the fundamental role of satellite telecommunications systems. Different geographic information systems from Russia and Western Europe are to be used and several test regions taken into account (North Caucasus and Western Europe). The main partners would be:

. Russia.
. France (SPOT Image. IGN Espace. BRGM Marseille. SCOT Conseil. CESG Strasbourg)
. Greece (Earthquake Planning and Protection Organisation Athens. National Kapodistrian University Athens)
. Italy (Istituto de Richercna sul Rischio Sismico di Milano).
. European Space Agency.
. CERCO (European Committee of Heads of Official Mapping Agencies).

Budget support has been requested for this demonstration project within the framework of the TACIS-BISTRO programmes of the European Union.

TECHNOLOGICAL HAZARDS

Transportation of dangerous substances

Two demonstration projects are planned:

1. "UKRAINE" demonstration project. This entails co-operation between Belgium. Ukraine and the European Space Agency aimed at exploiting the PRODAT system in conjunction with space technology facilities to monitor seven vehicles transporting toxic products (2 lorries and a reconnaissance vehicle transporting radio-active waste from Chernobyl. 2 lorries transporting liquid chlorine and 2 lorries transporting ammonia).

The organisations responsible for implementing the project include: the European Space Agency for the space sector, Marecs A, SAIT Systems of Belgium s project manager and PRODAT communications operator, the Higher Technologies Institute of Ukraine, and FIAR-Italy which is responsible for the PRODAT terminals.

The project is scheduled to run between March 1995 and June 1995. with the final report drafted in July 1995.

2. Franco-Russian project: this involves monitoring dangerous cargoes with the help of Russian and French space technology systems: ARGOS. COSPAS-SARSAT. KURS. METEOSAT. GONETS. COSPAS-LUCH. Beacons will be placed at strategic points on the Russian and French rail systems. The base partners are RKA (Russia) and CNES (France).

Surveillance of nuclear power stations

Following up the proposal presented by the Russian Ministry for the Environment in conjunction with German partners (IRIS/Russia project). an initial operation has focused on the nuclear power station in Smolensk and a preliminary report has been passed on to the Executive Secretariat.

Telemedicine and emergency situations

A project has been prepared with the aim of using satellite telecommunications to enable Russian and French doctors to confer on diagnoses of children possibly suffering from cancer of the thyroid gland as a result of the Chernobyl accident. Funding is now being requested for the project.

USE OF SAR DATA FOR FLOOD MAPPING AND MONITORING IN THURINGIA, GERMANY

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In the last years several events of severe flooding along major rivers of the world resulted in deepened interest of governments and public in watershed management issues. In Germany beneath the areas along the Rhine and its tributaries other watersheds like Elbe and Werra/Weser experienced extreme water levels and flooding.

A key tool to improve flood management and minimize damages is appropriate land use planning. This requires accurate knowledge of flood extent as well as information about the dynamics of flood development. Within a DARA financed project the Deutsche Projekt Union (DPU) Ltd., Eberswalde, uses SAR data (XSAR, ERS-1.SAR) for flood extent mapping as well as monitoring flood stages for the flood event in april 1994 along the river Werra, Thuringia. This flood mainly resulted from a combination of high rainfall, snow melt and high saturation of soil water capacity.

This flood event offers excellent possibilities for a general study because aerial photography from flood peak are available for comparision with results of spaceborne SAR data analysis. The approach of this project is based on joint analysis of the different data sources, especially ERS.SAR and XSAR data. Usually it will not be possible to analyse large scale flood events just using one kind of data. For example cloud cover often limits the availability of airborne data. Combination of remote sensing data with other digital data sources offers the best methodology for analysis of flood dynamics.

Image processing for flood monitoring can be based on basic techniques like preparation of multitemporal data sets and visual interpretation but also include digital classification of multi-sensor data using texture based classifiers like EBIS or ANN for time efficient multitemporal monitoring.

The data set available for this study includes beneath airphotos from 15/04/1994 (day of peak flow), one XSAR data set from 14/04/1994 and ERS-1 data from 18/04/ and 24/04/1994. Additionally XSAR and LANDSAT-TM data covering normal water flow are available for data merges and visualization purposes. Combination of images covering flood situation and images covering normal water flow clearly depicts flooded areas by change detection. Usually water areas appear dark in SAR images while areas not

covered by water are characterized by lighter grey colours, resulting from higher radar backscatter of the surface.

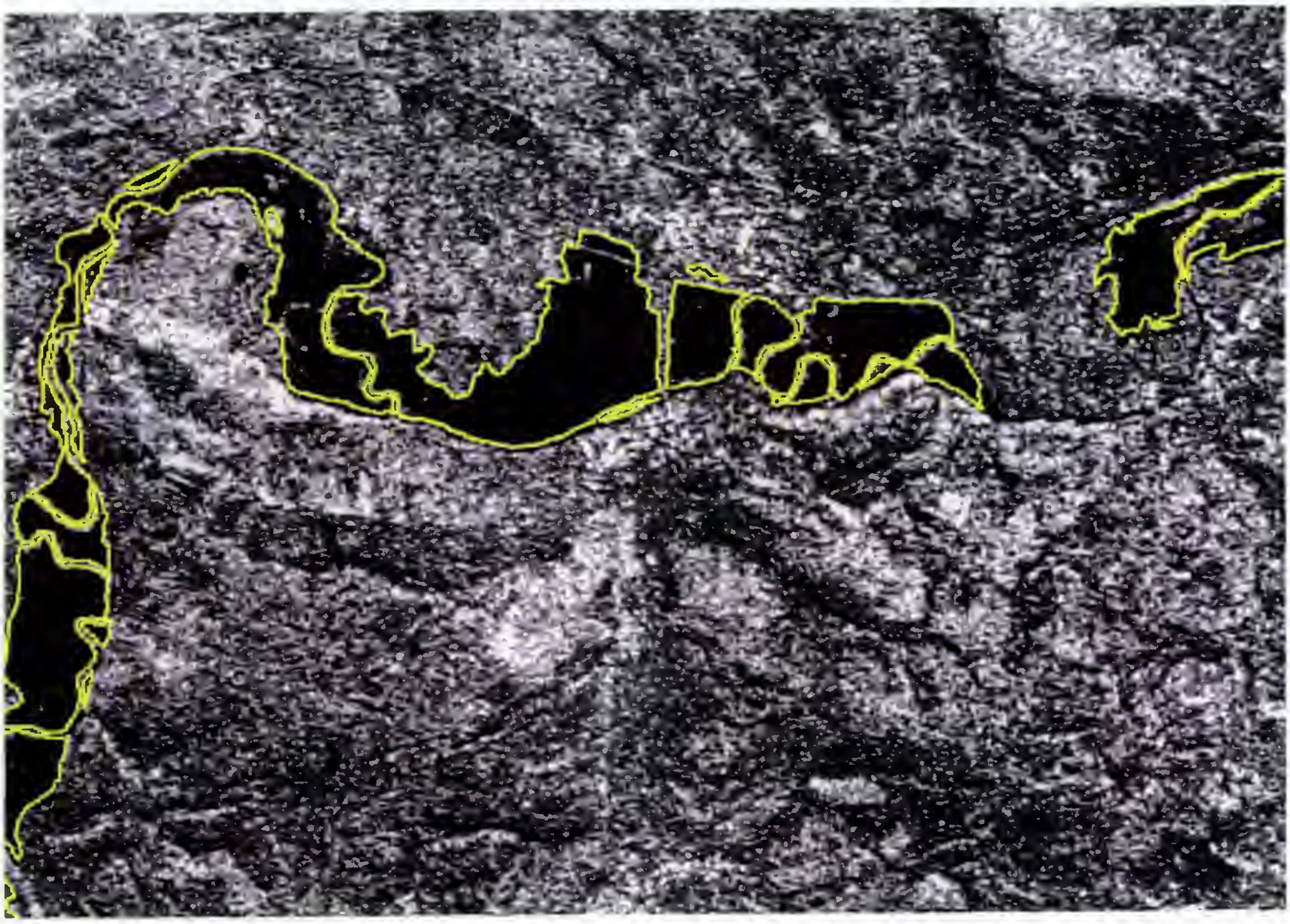
Thus, in the XSAR image from 14/04/ water areas appear in black (Ill. 1). To improve mapping accuracy this image was combined with XSAR data from 09/10/1994 which covers the normal water level of the Werra. Adding the ratio of both images enhances the flood information. In this combined image flood areas are clearly visible in dark blue (Ill. 3), which characterizes areas with high radar backscatter at 09/10 and low backscatter at 14/04. This multitemporal backscatter behaviour characterizes flooded areas.

Photo hardcopies of this image in 1:25000 scale were used for visual mapping of flooded areas on 14/04/1994. This covers flood extent some hours to one day before peak flow. Comparision with flood extent derived from airphoto digitization demonstrates two aspects:

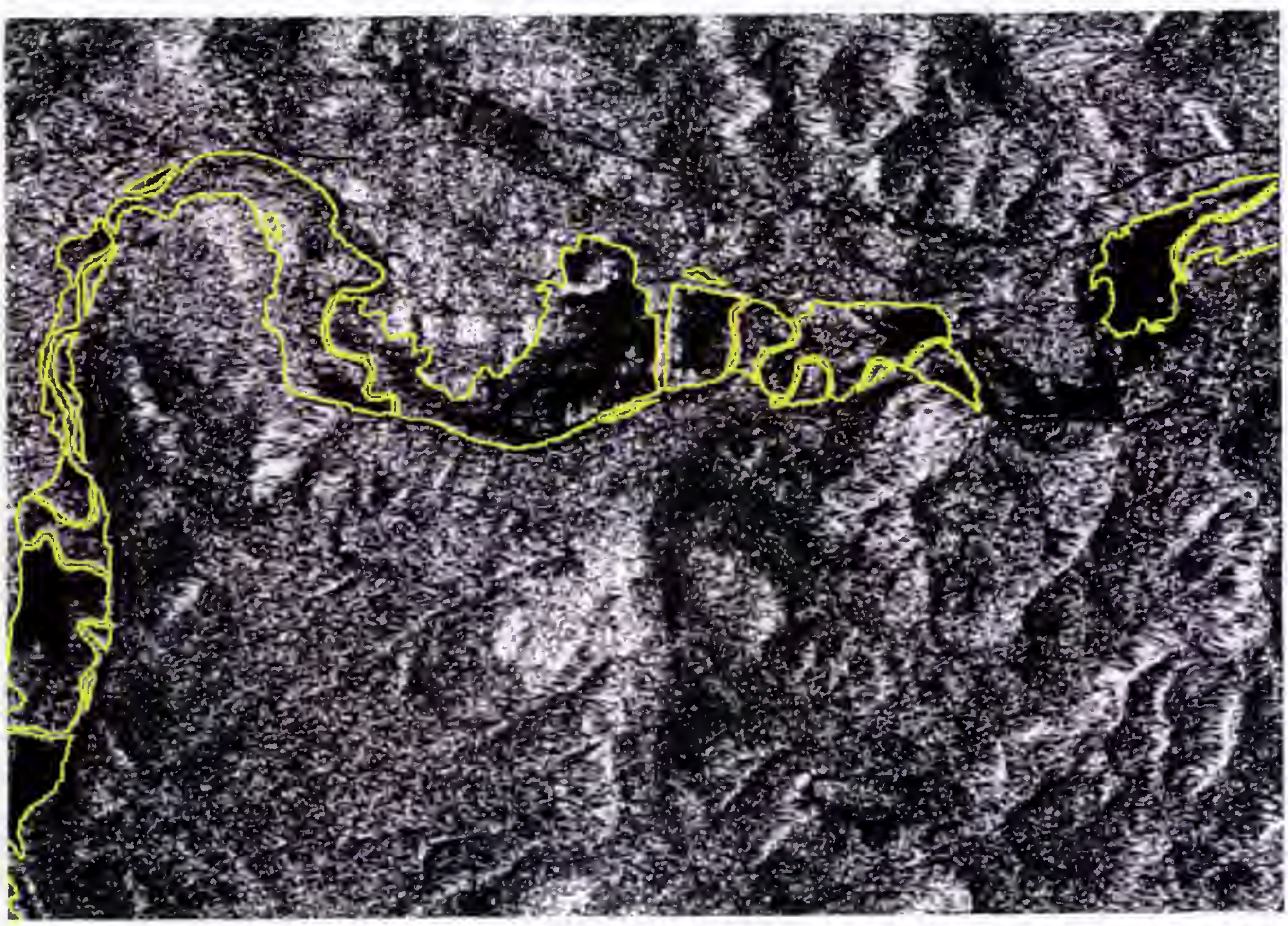
1. In some areas flooding is still a developing process and maximum level has not yet been reached. Clearly visible are weak points in the embankment system along the Werra where spill over leads to backward flooding into agricultural areas.

2. At fixed points like road embankments the mapping accuracy from spaceborne SAR data seems to be nearly as good as from airborne black and white photos. Some limitations should be made in urban areas where the much higher geometric resolution and the visibility of single buildings in airphotos lead to higher mapping security. On the other hand in some parts of the SAR image also very small flood areas can be delineated with help of topographic maps or airphotos (also from non-flood situations), combining their geometric resolution and topographic information with the spectral information from the SAR data.

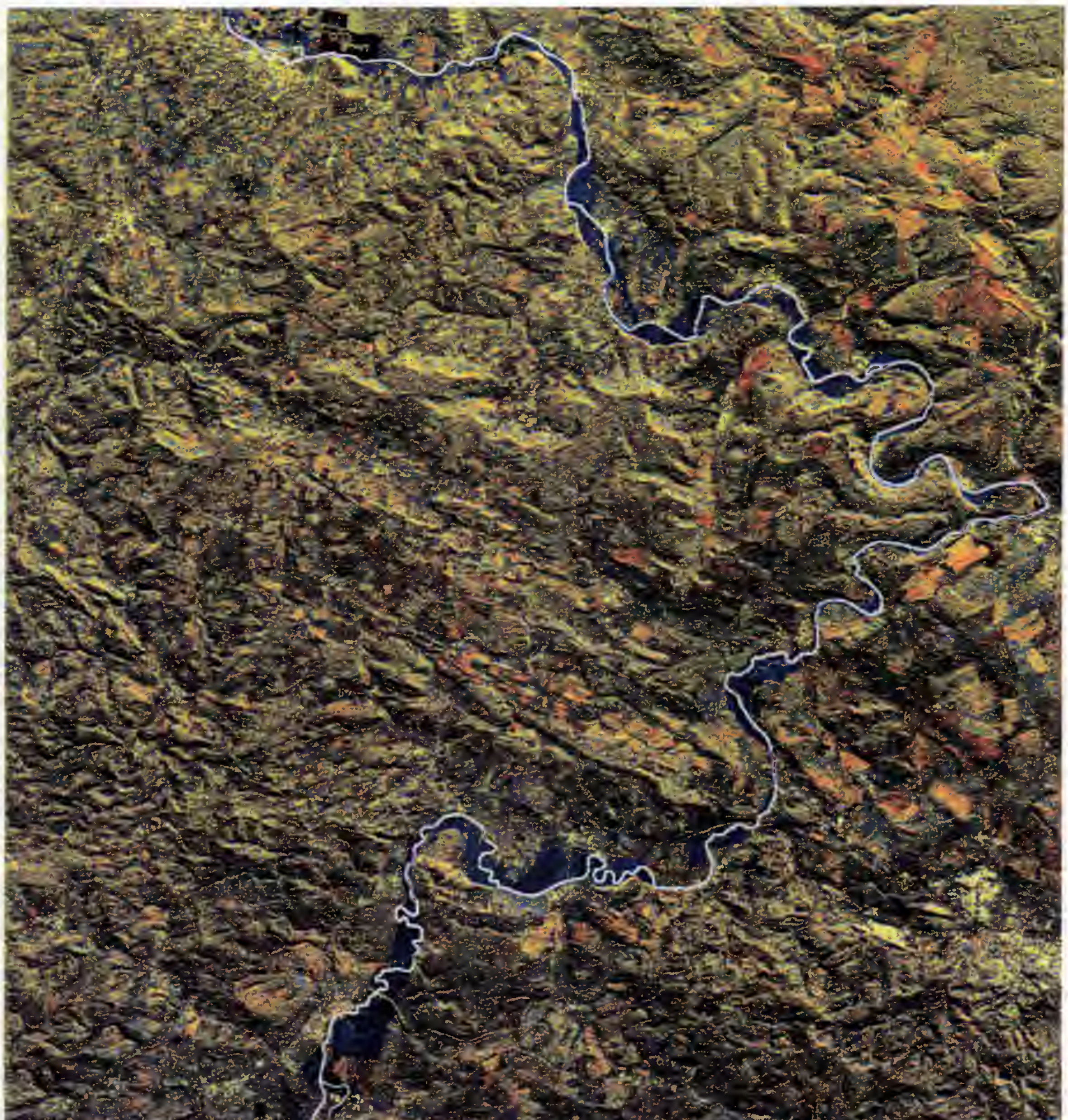
Between the peak of the flood at 15/04/1994 and 18/04/1994 the extent of the areas covered by flood water strongly decreased. Analysing the ERS-1 image from 18/04 enables the detection of areas which are only for a short time covered by water and areas where the standing water stays for a longer time. Partly the flood dynamics becomes visible in areas which were not flood affected on 14/04, but were flooded on 15/04 and still are water covered on 18/04 (Ill. 2). In the ERS-1.SAR image of 24/04/1994 only very few and small areas which are still covered by water can be detected. These observations from visual analysis are confirmed by automatic classification of a multitemporal data set consisting of XSAR from 14/04 and ERS-1.SAR from 18/04.



ILL. 1: XSAR image from 14/04/94



ILL. 2: ERS-1 image from 18/04/94, yellow = flood line from 14/04/94



ILL. 3: red = XSAR 14/04/94, green = XSAR 09/10/94, blue = ratio

FLOODNET: A TELENETWORK FOR ACQUISITION, PROCESSING AND DISSEMINATION OF EARTH OBSERVATION DATA FOR MONITORING AND EMERGENCY MANAGEMENT OF FLOODS

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Institute of Hydrology
Wallingford, UK

INTRODUCTION

The aim of FLOODNET will be to provide a communications and data distribution facility specifically designed to meet the demanding temporal requirements of flood monitoring. Currently, remotely sensed data are not fully utilised for flood applications because potential users are not familiar with the procedure for acquiring the data and do not have a defined route for obtaining help in processing and interpreting the data. FLOODNET will identify the potential user groups within the EU and will, by demonstration, education and the use of telematics, increase the awareness of users to the capabilities of Earth observation and the means by which they can acquire it. The network will encourage a user community and will facilitate cross sector information transfer, particularly between 'flood experts' and administrative decision makers.

BACKGROUND

The all-weather capability of high resolution satellite radar sensors for monitoring floodwater extent has been well demonstrated over the last few years when extensive flooding has occurred in many EU countries. Much of the satellite data recording floodwater extent has been collected on an ad-hoc, opportunistic basis and many of the likely end-users probably did not know of its capabilities prior to seeing photographs in the national press or other publications.. Of those that did, many would not know how to acquire the data or extract the necessary information from it. As more suitable sensors come on line within the next few years, such as on the ERS-2, Radarsat and Envisat satellites (Figure 1), together with the growing availability of sophisticated airborne sensors, a quick-response system which can cope with the specific requirements of the flood management community is badly needed. The aim of FLOODNET therefore, is the development of an EU-wide communications network which will help in the coordination of requests for Earth observation data required for monitoring river and coastal floods, and to determine how the data can be most efficiently processed, interpreted and disseminated to a wide range of hydrological and administrative organisations having different requirements.

USER NEEDS AND APPLICATION AREA

Each year, river and coastal flooding, worldwide, results in major loss of life and property. A requirement for two levels of flood extent monitoring can be identified which would augment current flood forecasting procedures which have been established over many years using conventional hydrological information. The first is a broad-brush approach which would look at the general flood situation within a river catchment or coastal belt with the aim of identifying areas at greatest risk and in need of immediate assistance. This type of information would be of great value to central government offices in assigning priorities to the overall

flood response For major floods especially, where ground communications may be severed, there is a need for rapid overview information on floodwater extent to prioritise :

- downstream warning response
- rescue/evacuation of residents and livestock
- supply of food/medical aid
- strengthening/repair to flood defences
- repair of communications
- repair of water supply, power and other infrastructure

. The second, less time-critical requirement, is for detailed flood extent maps which are needed for :

- hazard assessment
- input to hydrological / land use models
- insurance / risk evaluation

Both requirements are time critical and major savings in losses can be expected if suitable information can be distributed to the key authorities at the outset of flooding. It has been found that such information cannot be readily determined from the ground because of inadequate manpower availability and restricted access caused by floodwater and remote sensing by satellite and aircraft is now able to supply a more efficient method of flood mapping. Figures 2 and 3 show typical requirements in terms of satellite resolution and data delivery for different application areas.

In the longer term, detailed information of floodwater extent for floods of differing return period are required for the production of hazard assessment maps and for input to various types of hydrological and land use models. As a result of a number of major flood events within the EU in recent years, insurance companies are taking a critical look at the flood insurance sector and represent a major potential customer for the type of information which could be assembled within FLOODNET. Clearly then, there are a wide range of users to be identified and user needs to be addressed before a satisfactory design for FLOODNET can be evolved.

FLOODNET will act as a filter between users and satellite operation planners (Figure 4) by applying criteria, previously agreed by users, to the requests for satellite coverage of flood events. Requests will be assigned a level of importance, perhaps on scale of 1-5, after applying the criteria and will then be passed on to the satellite operators for consideration. This arrangement will be mutually beneficial as the satellite operators will be spared the task of assessing the importance of each request as it comes in, on the basis of little or no background information, whilst the users will be assured of receiving the highest priority for major flood events.

TECHNICAL ASPECTS OF FLOODNET

Technical aspects of the FLOODNET demonstrator will be guided by the results of a user requirements study. Some basic functionality can be defined, but this will have to be adjusted according to user needs.

The first users who will have information indicating that significant inundation may occur are the authorities responsible for rivers and coastal regions. It is envisaged that FLOODNET will be closely integrated with ground-based radar networks and river catchment rainfall / runoff models which can provide early warnings of saturation within contributing areas. Warnings would be issued to a central server which would interrogate European and other relevant satellite acquisition programmes to determine if the area under threat was programmed to be imaged by suitable satellite sensors. If no suitable satellite coverage was planned, requests could be placed for acquisition of data via the relevant space agencies. A previously agreed methodology for assigning a priority rating for each acquisition request would have to be in place, together with agreements covering payment for the data. The users would benefit by having a pre-defined methodology for requesting satellite coverage at short notice and the space agencies would benefit from a priority indicator of the importance of each request. Priority levels would increase as the prediction of flooding became firmer.

The FLOODNET information server will be based on Internet/WWW technology. On the user interface side, the choice is between a standard browser software (e.g. Mosaic, Netscape) or the improved European Wide Service Exchange interface currently developed by the Centre for Earth Observation team at JRC, Ispra. The choice will depend on the user needs which may either opt for a standard but less comfortable system (e.g. Netscape, Mosaic) or a more advanced, but still new and less proven system such as EWSE. For users who have no access to Internet, there will be a two options approach: either they will install an Internet connection (most likely with modem dial up) or they will receive the information via 'appropriate technology' means (e.g. via a fax server, e-mail, etc.). A special fax server will be installed for that purpose, which extracts information retrieved from the Internet-based (and well networked) system and distributes this in fax form to relevant flood early warning / emergency centres. On the data distribution side, the network would enable satellite data to be either delivered directly to the user who would process it to his own specification, or via an intermediary who would undertake this work on his behalf. The intermediary could be a national remote sensing centre or other government organisation, university or commercial company.

Figure 1. Planned and expected availability of satellite SAR suitable for Petrol monitoring

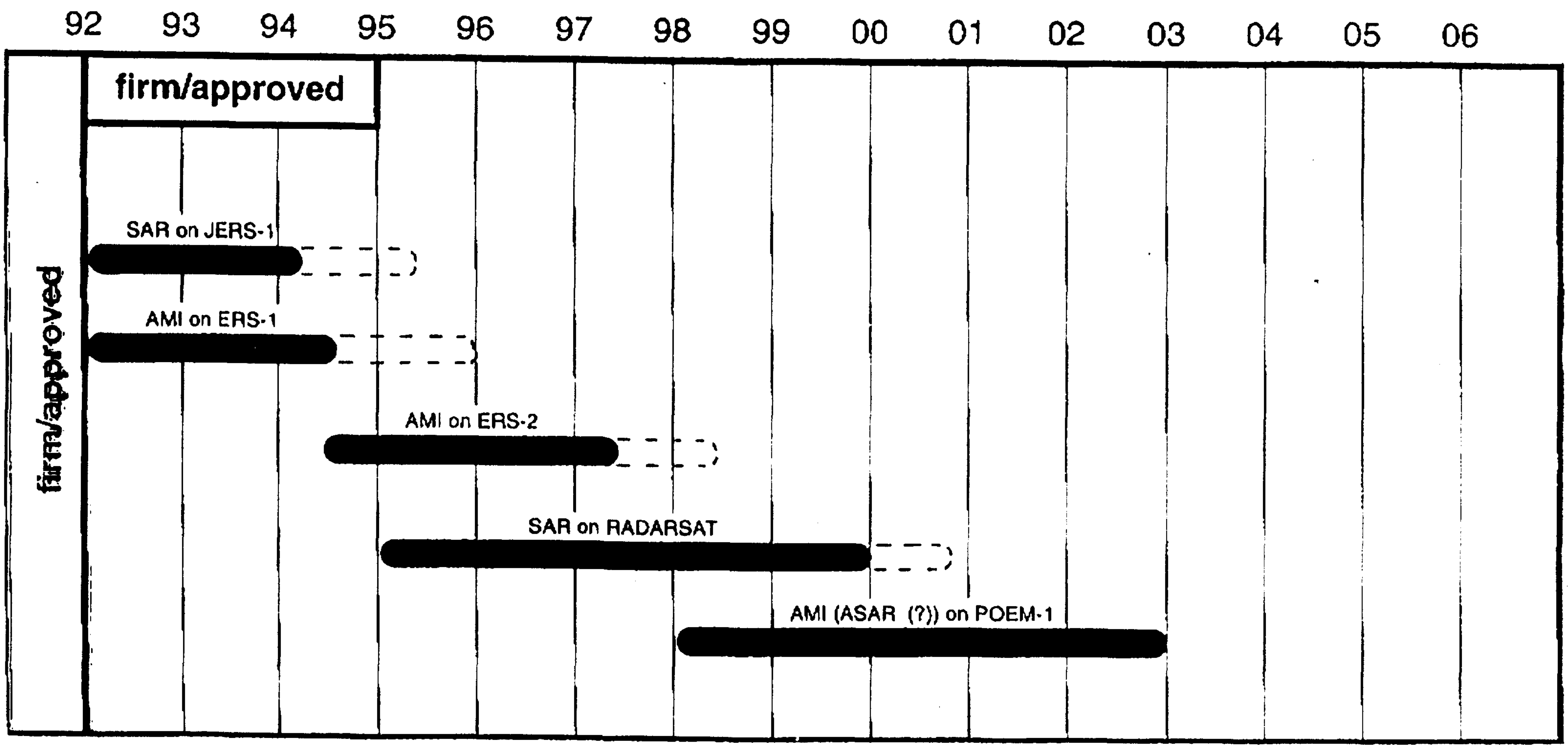


Figure 2

Maximum acceptable resolution range of satellite data for different flood requirements

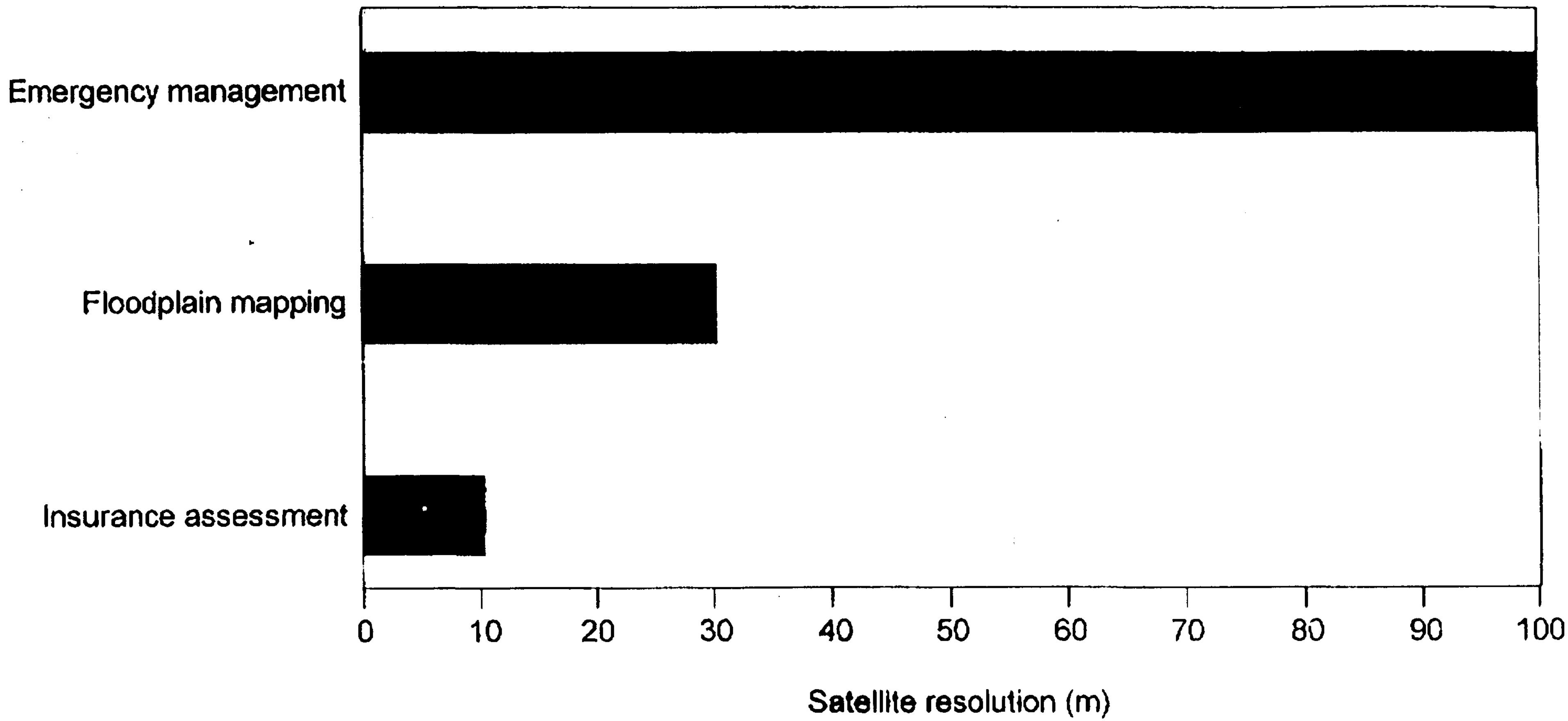
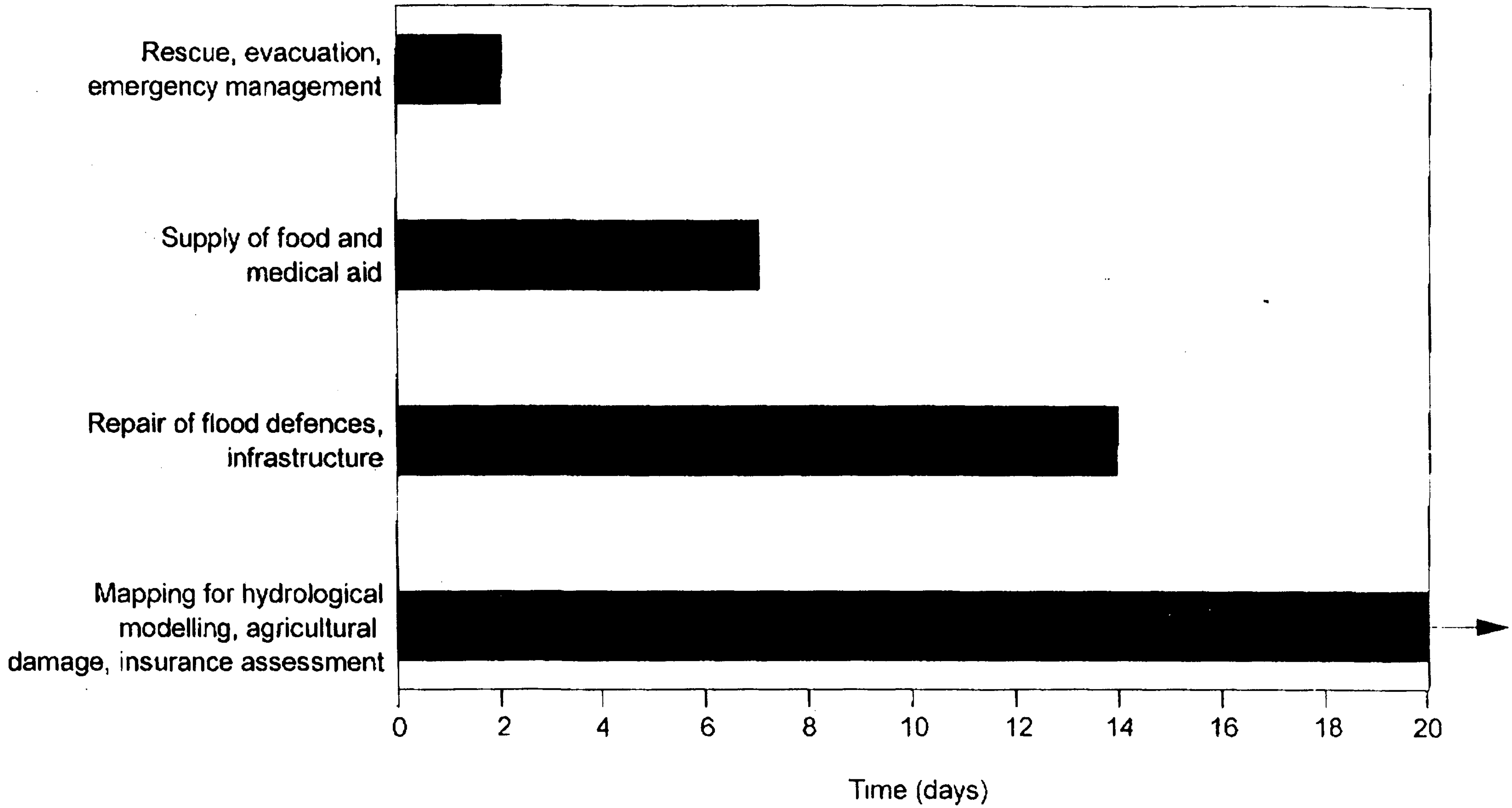
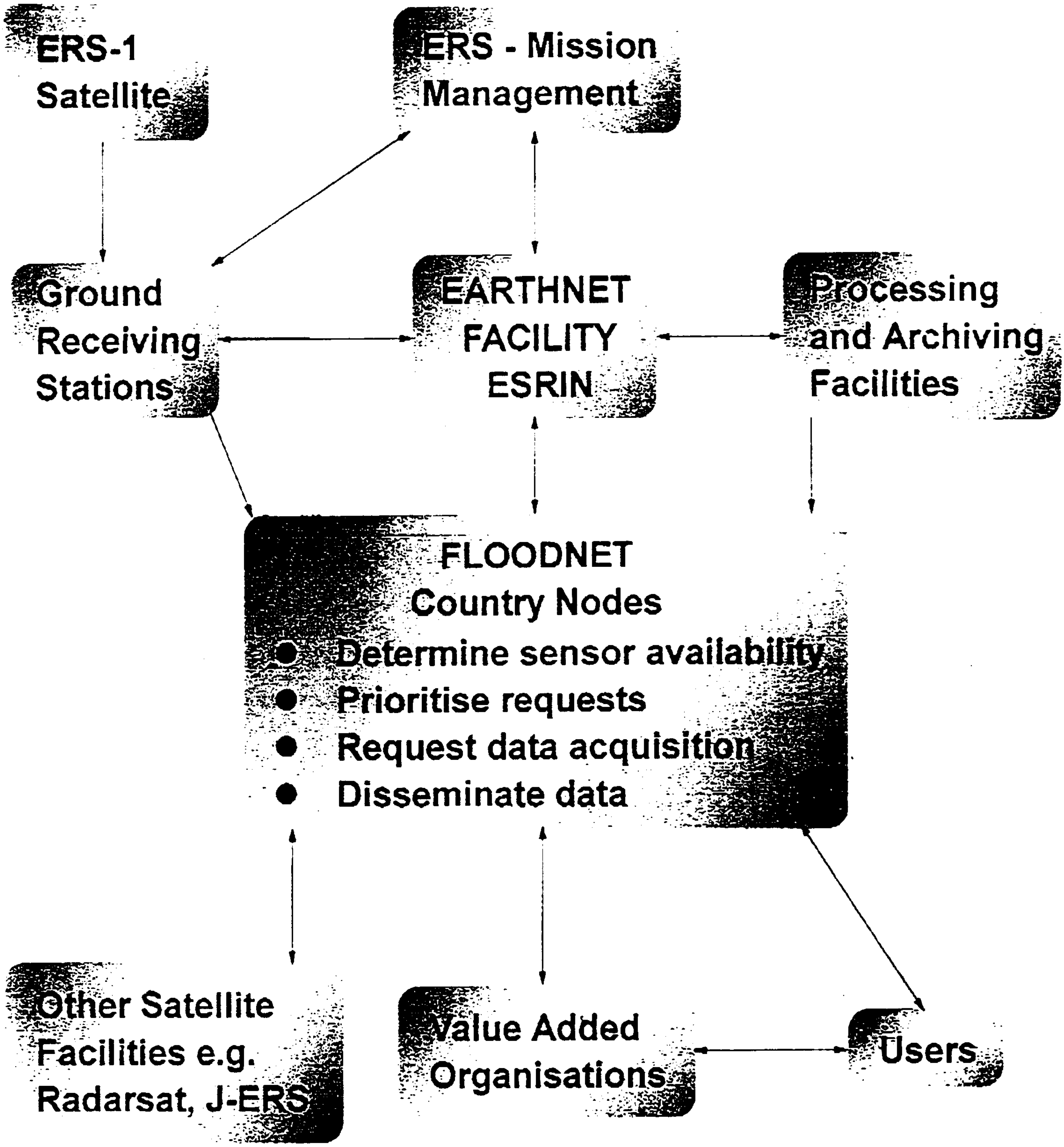


Figure 5

Typical turnaround time for acquisition, processing and dissemination of satellite data for flood requirements





Function of FLOODNET within existing satellite data network

Figure 4

MONITORING FLOOD EVENTS WITH REMOTE SENSING DATA : AN EXAMPLE OF ERS-1'S CONTRIBUTION TO FLOOD EVENTS IN NORTHERN AND SOUTHERN FRANCE REGIONS

N. THOLEY

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1. Flood events as seen through remote sensing

Presentation of case studies in the north-east and southern part of France :

- the Vaison-la-Romaine region and the Ouveze river flood of september 1992, a cartographic approach
- the Alsace and the Ill river flood of february 1990, a remote sensing approach using optical data
- the Camargue flood event of october-november 1993, a remote sensing approach using ERS-1 radar data

2. ERS-1 data's advantages

The primary advantages of ERS-1 SAR data in flood event recording and studies are presented:

- its high spatial resolution
- its good temporal coverage frequency
- its all weather day and night coverage
- its sensibility to soil moisture content which allows for the mapping of water bodies

3. What flood related information can be produced ?

Different kinds of flood related information can be produced, on one hand while exclusively using ERS-1 data and, on the other hand, within a GIS by merging ERS-1 derived information with other spatial information.

Using uniquely ERS-1 data :

- with one image :
  - one image of the flood zone can lead to the mapping of water bodies

- with multi-temporal images :
    - historic images of flooding period and non flooding period permits the distinction between permanent water bodies areas and flooded areas which gives the map extent of the flood;
    - several images of the flooding period allow the monitoring of a flood's evolution, both its rise and dissipation.

ERS-1 data within a GIS :

Complementary flooding and landuse impact studies can be carried out with the ERS-1 derived information after the integration of these data into a GIS with other thematic spatial information.

- with cartographic data such as administrative boundaries like communal limits, the flood affected communes can be listed ; with infrastructural maps, flooded roads can be pointed out.
- with up-to-date thematic information layers derived from remote sensing , the landcover of flooded and non flooded areas can be extracted and analysed.

4. Flood zone management within a GIS

- historical data allow a multi-year database management and analysis of flood prone areas and facilitates a flood risk evaluation assesment.

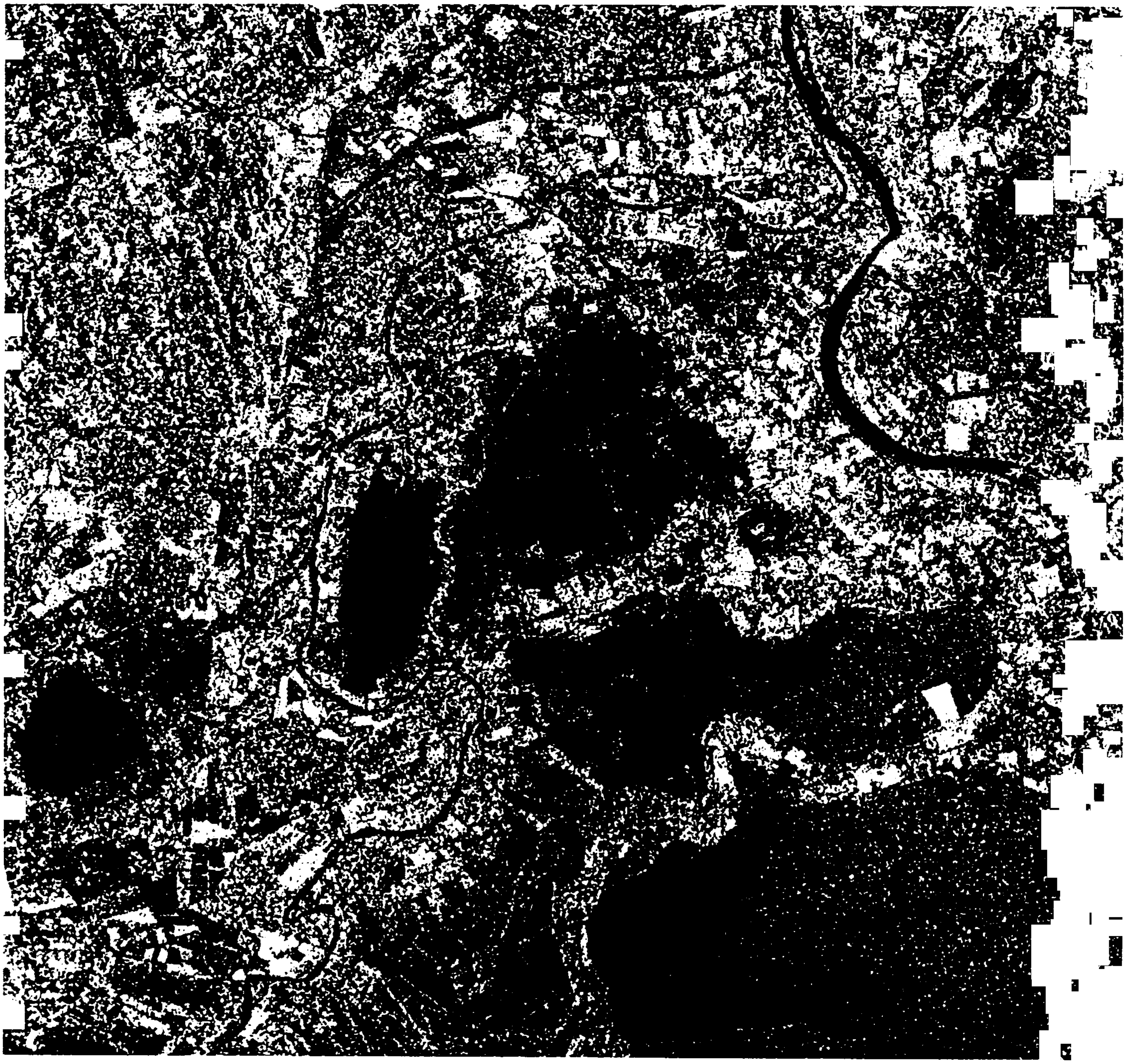
- via GIS modelisation, identification of risk areas and their flood hazard designation can be made using multi-thematic information available within the GIS; land slides risks, for example, and other information pertinent to hydrological models, can be estimated depending on sol types, landcover, slopes, rainfall... .

5. Application examples

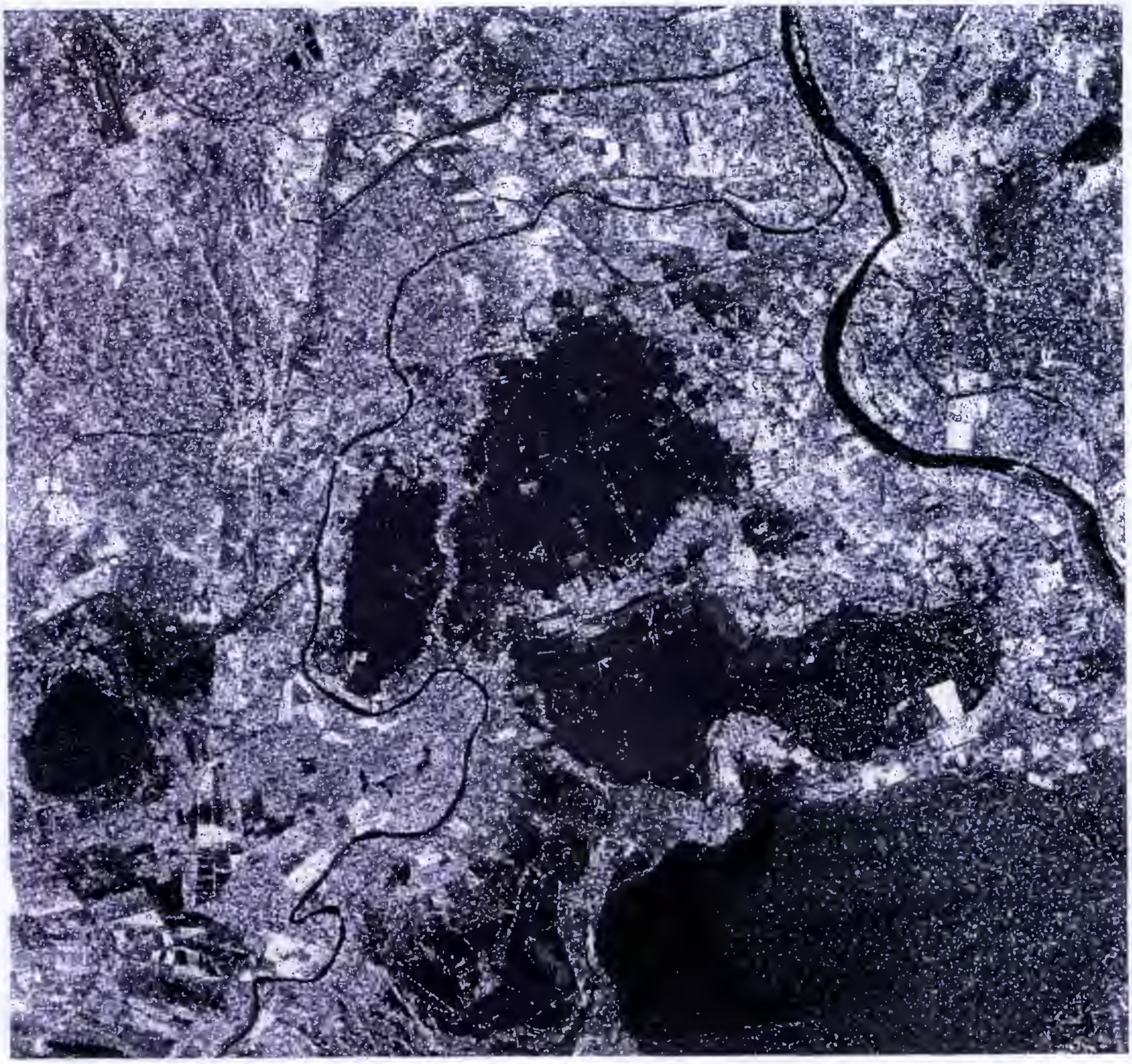
- the Alsace flood event of february 1990

- the Camargue flood event of october-november 1993

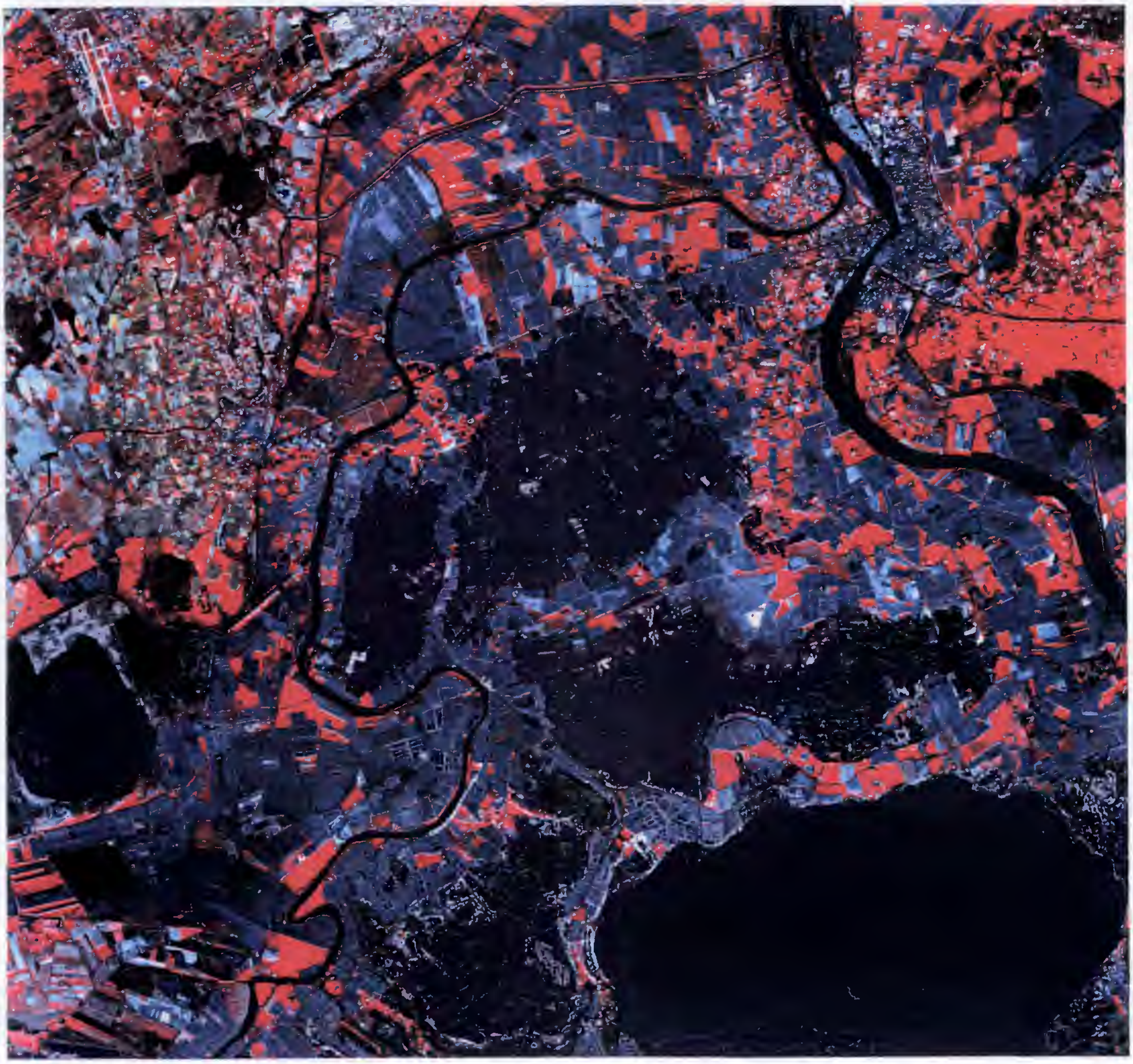
List of illustrations



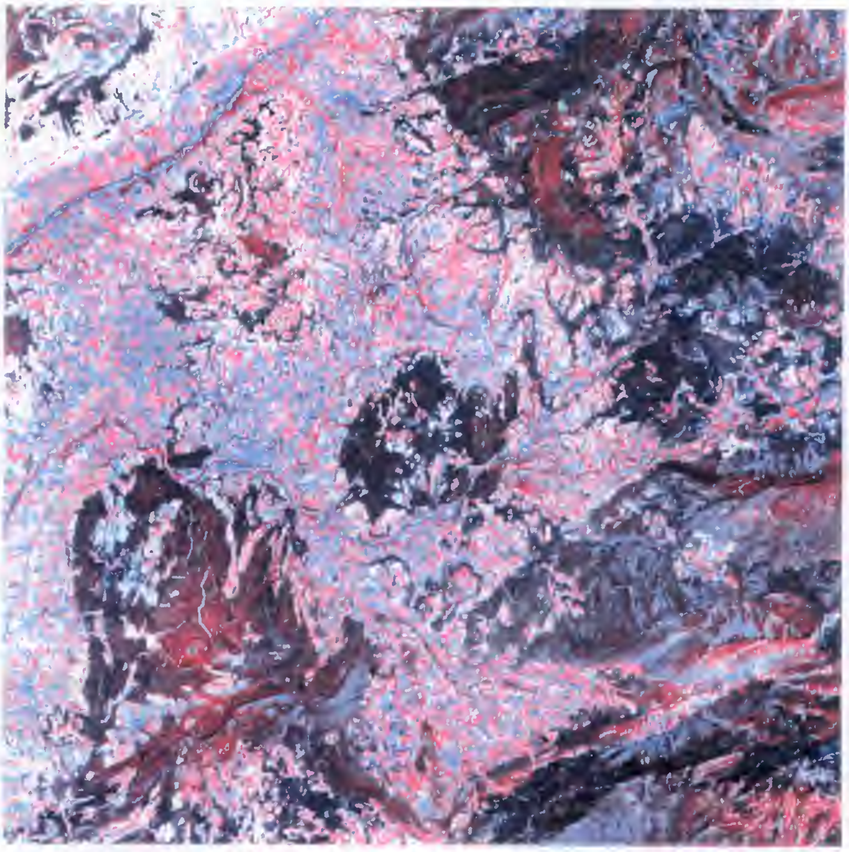
ERS-1 image : the Camargue october 1993 flood
Southern France (Camargue)

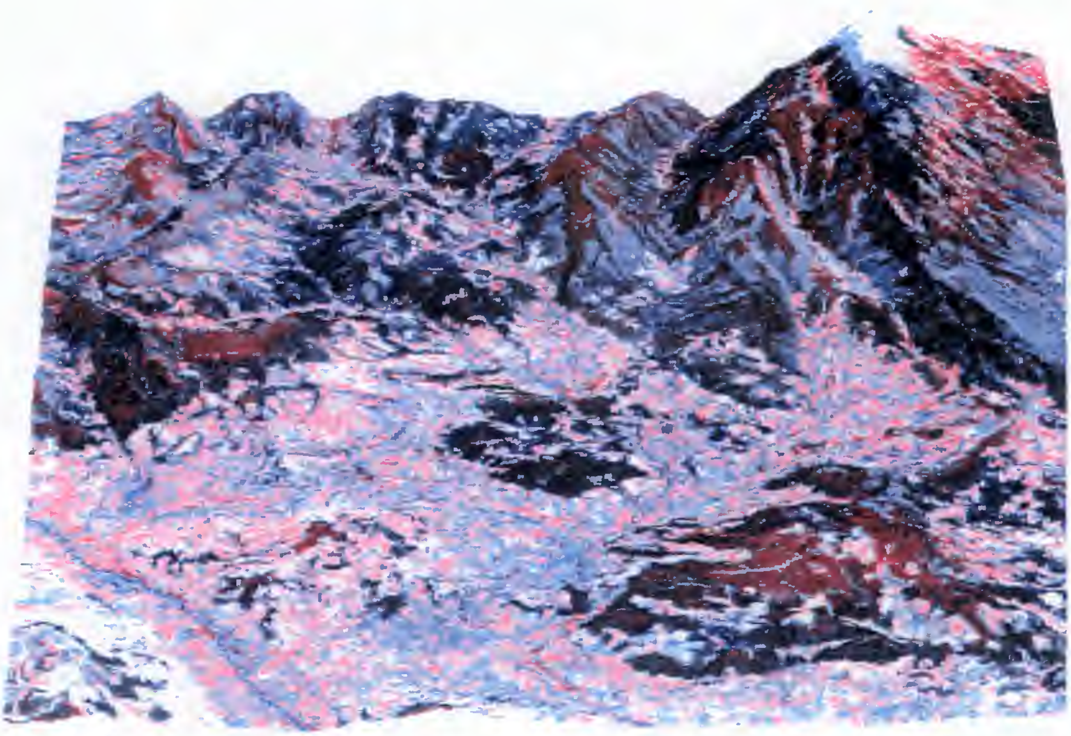


Flood extent derived from ERS-1 image
Southern France (Camargue)

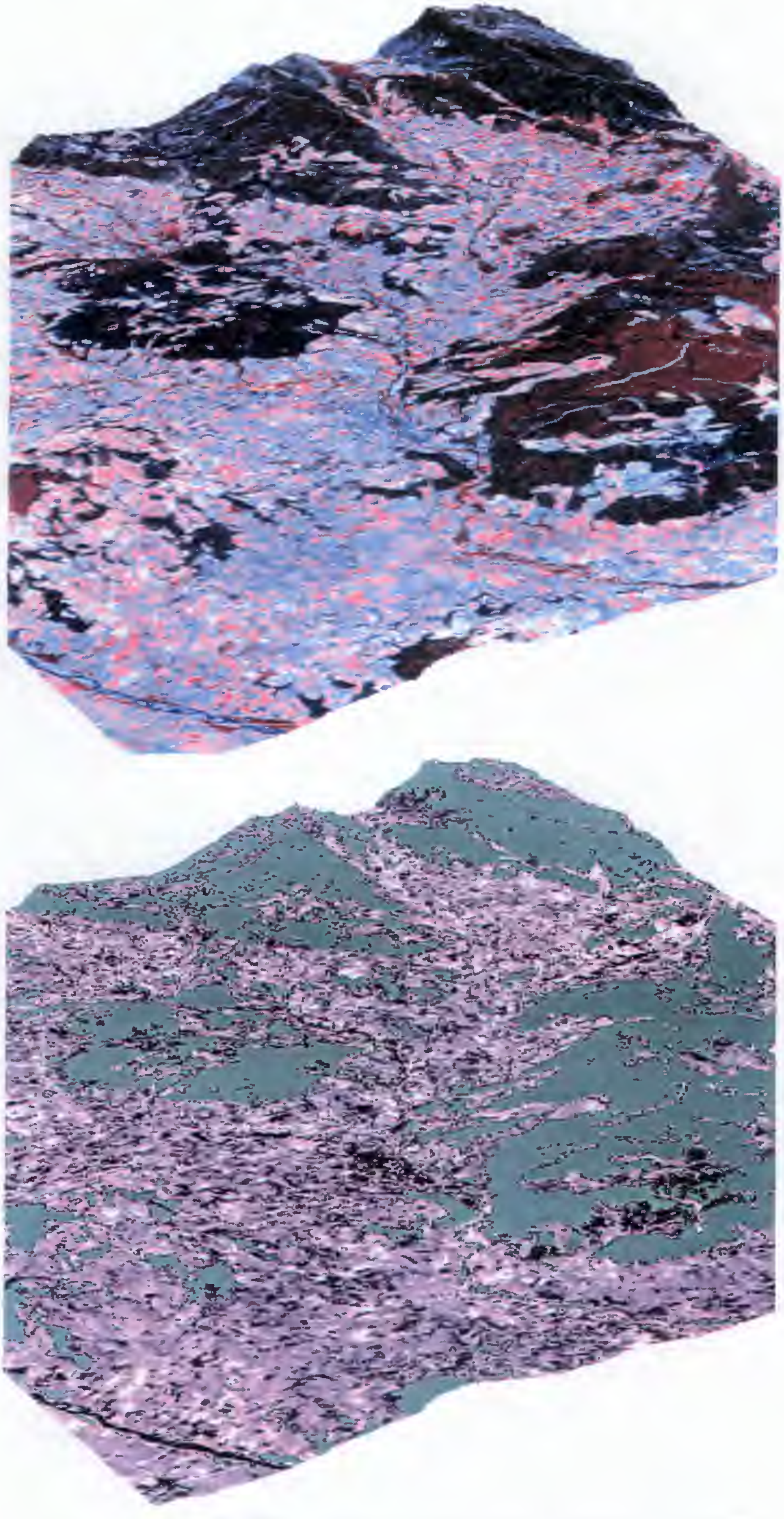


Landcover affected by flood
Southern France (Camargue)

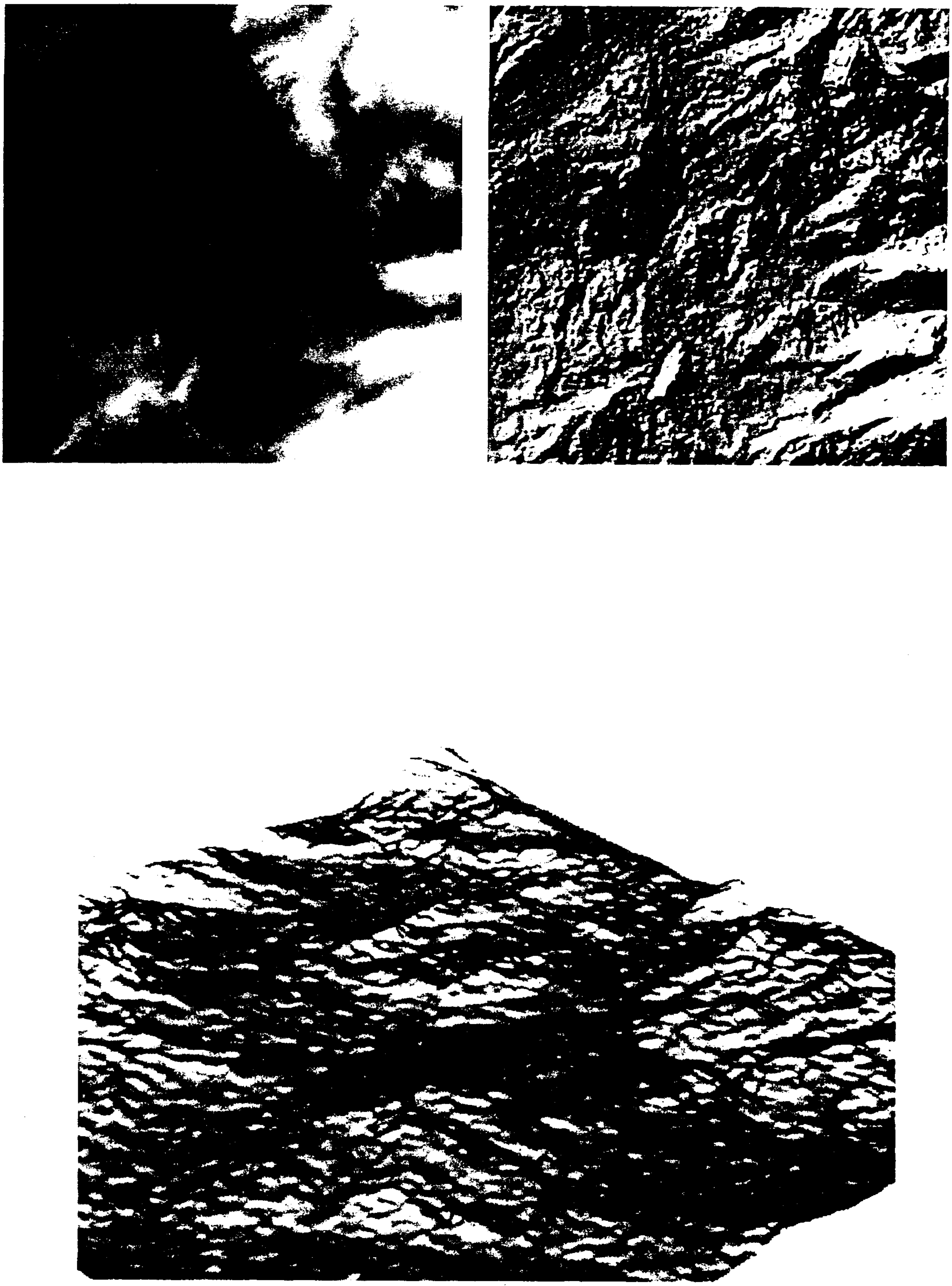




Landcover of the upper Ouveze basin
Southern France (Ouveze Basin)



Vegetation Landcover of the upper Ouveze basin
Southern France (Ouveze Basin)



Digital elevation model and slope model of the upper Ouveze basin
Southern France (Ouveze Basin)

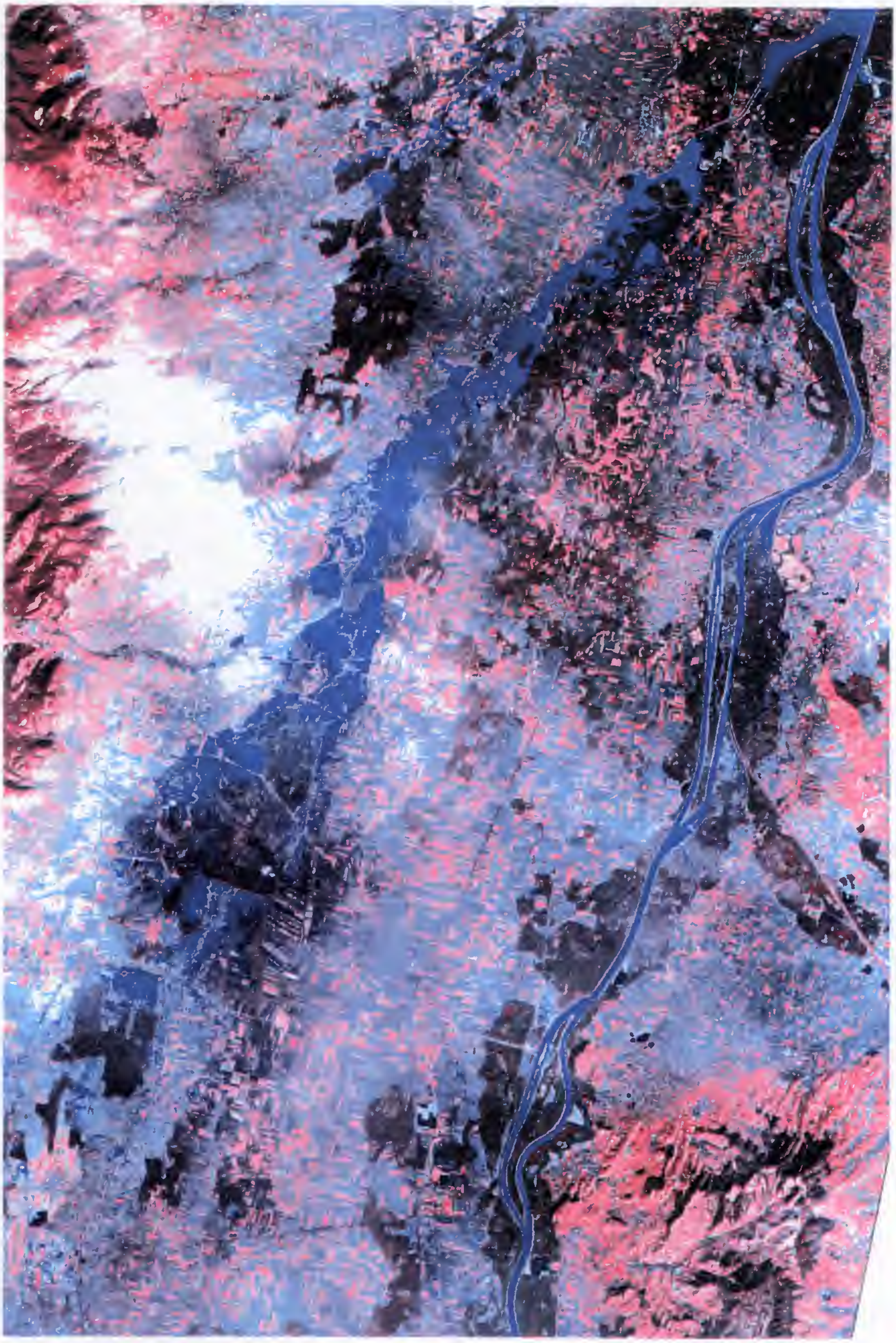
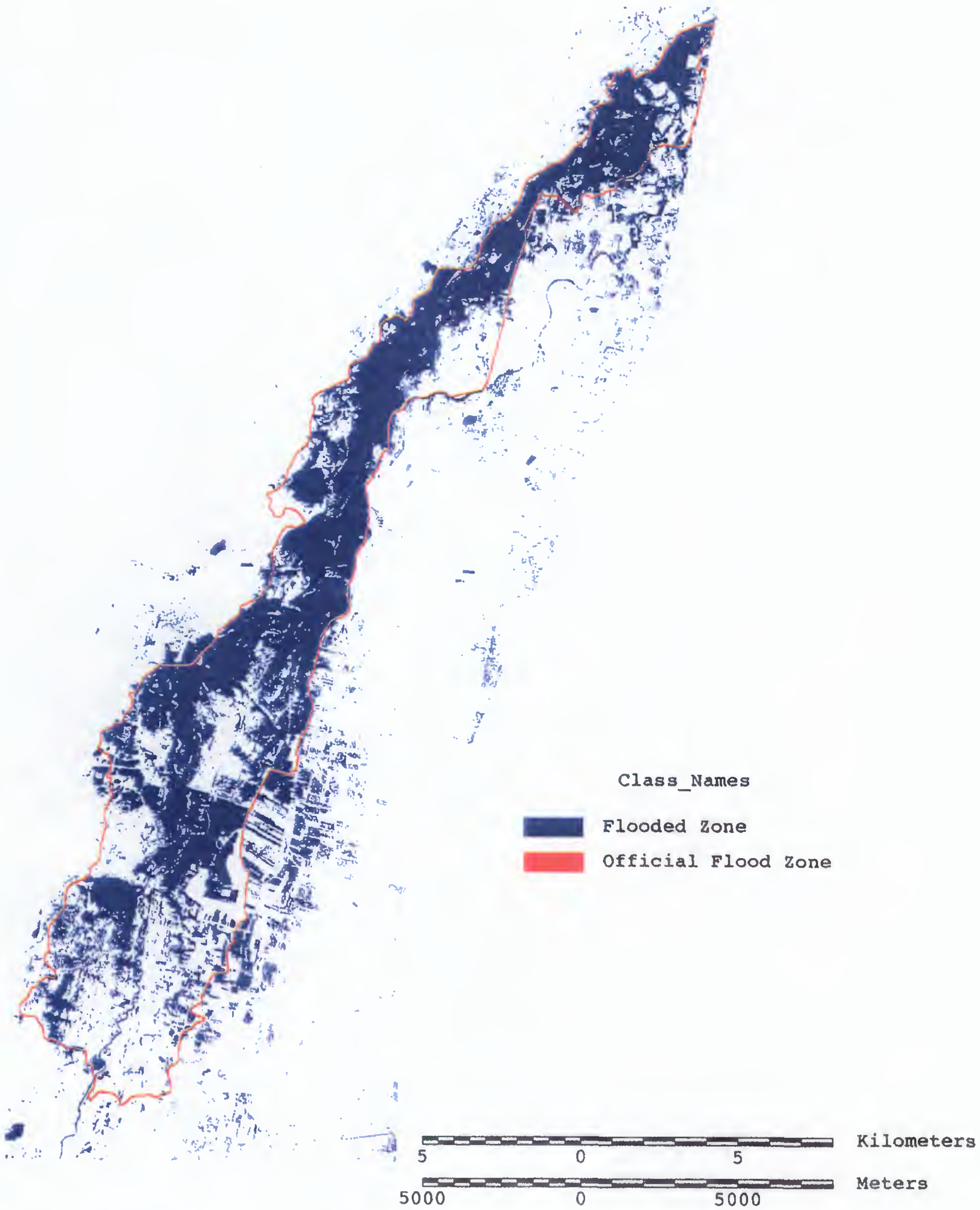
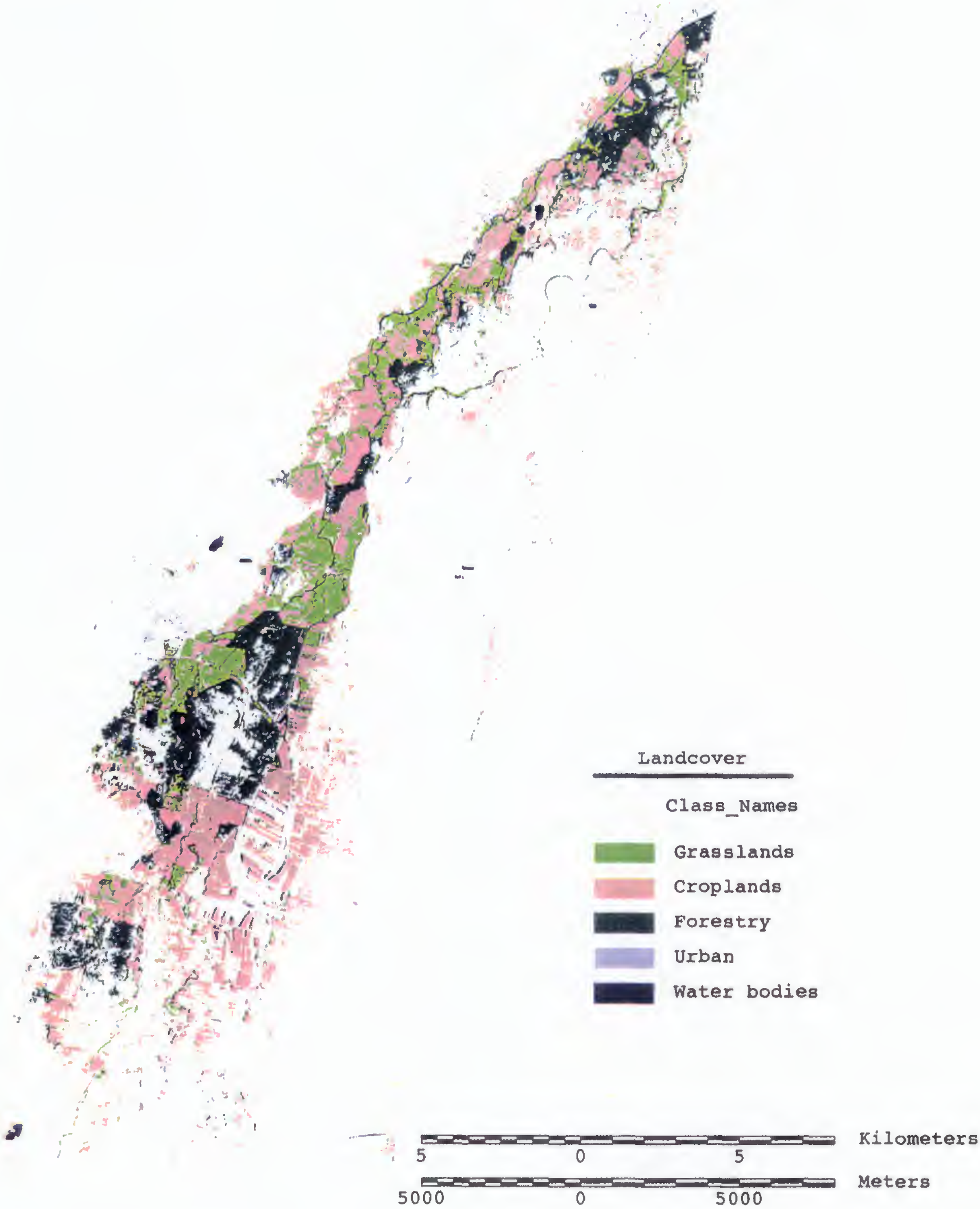


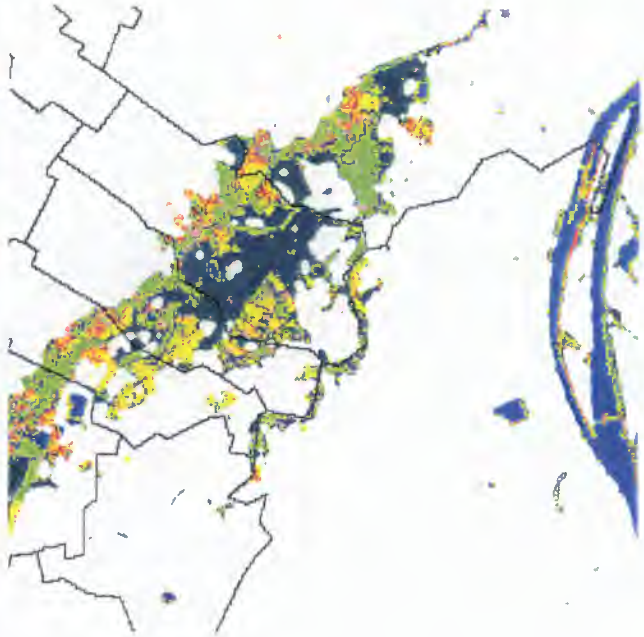
Image of the alsatian once-in-a-century february 1990 flood
Northern France (Alsace)

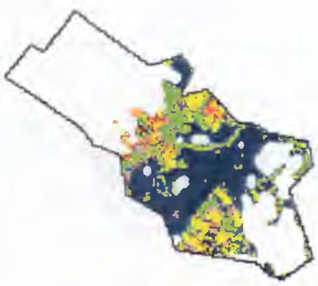


Comparison between administrative flood zone boundaries
and the percieved flood extent
Northern France (Alsace)



Flood affected landcover
Northern France (Alsace)





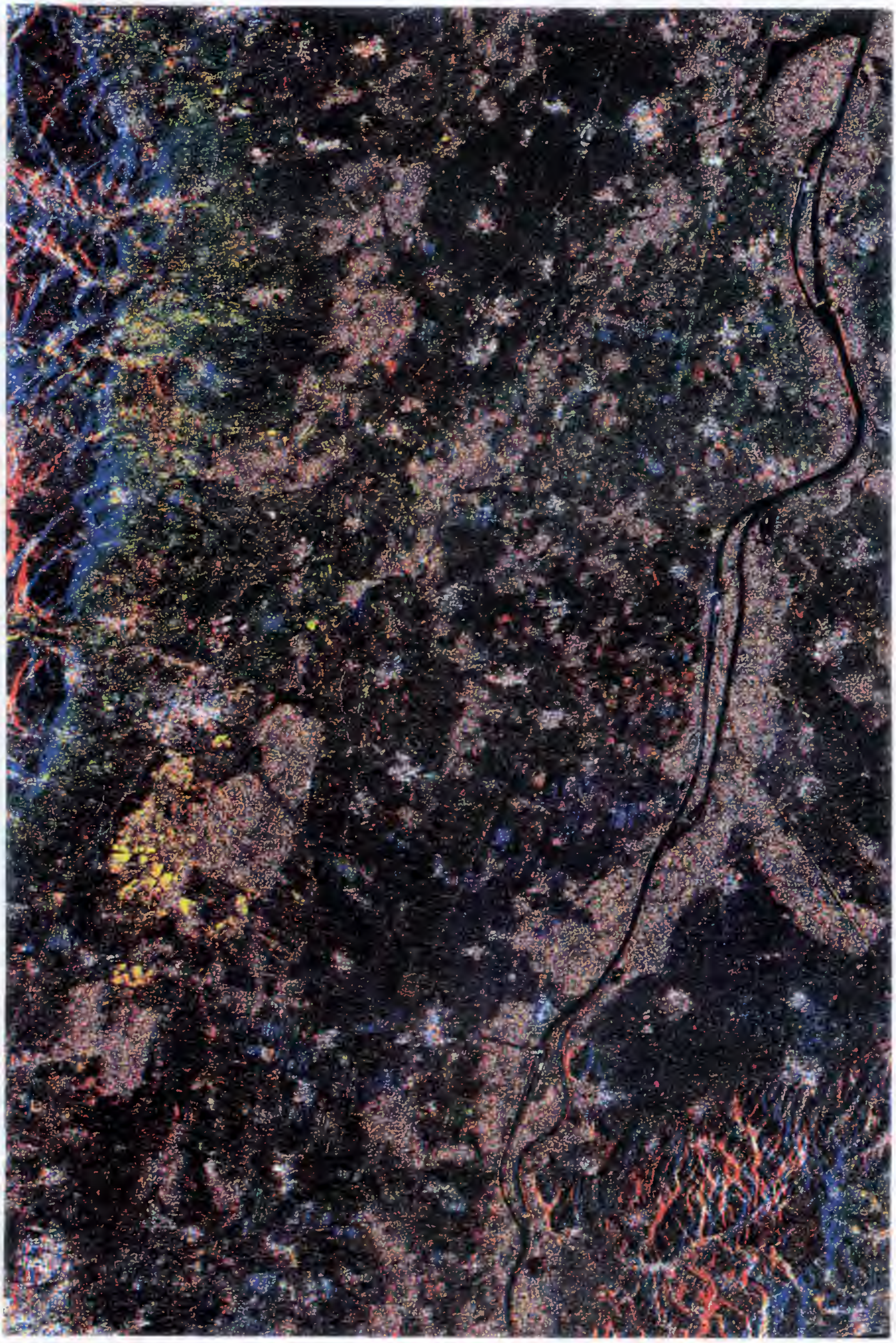
Commune of Osthouse

Surface	
Forestry	301.64 ha
Grasslands	90.52 ha
Urban/Bare soils	19.42 ha
Croplands	83.96 ha
Vineyards/Orchards	14.88 ha
Communal limits	

5 — 0 Kilometers

5000 — 0 Meters

Statistical and cartographical impact analysis by commune
Northern France (Alsace)



ERS-1 data : multitemporal color composite of the central Alsace flood zone
Northern France (Alsace)

Mapping of 1994 floods in Piemonte Region, Italy : an example of remote sensing and GIS application

E. Bonansea - CSI Piemonte - Settore Territorio - Torino (Italy)

The flood occurred in Piemonte (Northern Italy) on the days of 4th, 5th and 6th November 1994 was the most studied natural event in the recent years.
It has been, indeed, one of the worst disasters ever happened in the Region during the century.

The areas interested by the phenomena are those corresponding to the basins of the main rivers of Piemonte, i.e. Tanaro, Belbo, Bormida and also (partially) the Po river.

The primary goal after the flood was the generation, in the shortest possible time delay, of a correct map of the flooded area, to derive a first assessment of both, order of magnitudo and damages.

Remote sensing image interpretation proved to be the unique useful instrument to achieve such a goal, considering the wide flood extension (affecting approximately 2/3 of the entire Region), the emergency needs, and the urgency to study and evaluate the disaster extent and consequences.

Bad weather conditions during and after the flood, represented a constraint to the utilization of passive remote sensed data. In fact the first useful SPOT panchromatic data recording was on November 23. On the active sensors' side, instead, it was possible to use ERS-1 SAR data taken already on November 9.

Using SPOT data information, an entire map of flooded areas was obtained by means of visual interpretation. The high data resolution allowed the identification of dynamic river processes, such as meanders cutting, river bed changes, fluvial sedimentation and vegetation destruction.

ERS-1 SAR data represented, instead, a first control tool to verify in part the SPOT information. All areas in dark (low pixel values) were classified as still inundated areas at the date of ERS-1 satellite data recording (Fig. 1).

Radar technology proved to be a new interesting tool for environmental monitoring, with a great potential in several aspects of the earth surface change detection in general, and in flooding events monitoring, in particular.

The interpretation and classification work was supported by a GIS software able to compare quickly data taken at different time intervals, as well as to handle various GIS coverages related to rivers, roads, towns, land use and potentially inundable areas, and to generate new thematic maps as input to the final cartography.

The result is a map at 1:100.000 scale of the main alluvial plains in the Centre-South of Piemonte, generated directly from a numerical video output.

The map is integrated into the regional geographic information system and can be used in further studies and projects aimed at the evaluation of agricultural damages, at the comparison of today's situation with the town expansion in flooded areas during the past century, as well as for land use planning and monitoring activities in general.

Fig.1 - ERS-1 image of the Tanaro river 3 days after the flood in November 1994.
On the left, in light colour, is Asti, one of the most damaged towns.
Close to the river (direction east), the dark colour throughout corresponds to still inundated areas.
The classification of these areas, together with ground truth information and photointerpretation techniques, led to the generation of a thematic map.

Fig.2 - The Tanaro river, near the town of Alessandria
This map's section contains GIS information (raster based) combined with SPOT panchromatic and ERS-1 SAR data interpretation.
As a good example of multi-sensor data use, the SPOT image interpretation made from the panchromatic data collected only 17 days after the event, allowed to map the entire damaged area by means of the sensor response to the fine material sedimented during the flood. ERS-1 SAR data availability in almost near real time (November 9), allowed, instead, the flood event monitoring event soon after its occurrance. The various inundated areas (well visible in green) correspond to paleo meanders of the Tanaro.

The fluvial dynamic in these areas has always been considerable, compared to the less consistent urban growth, as it results from a research carried out on historical river bed changes. Considering the strong impact that fluvial dynamic can have on the environment, a systematic application of the GIS and remote sensing techniques already used in the above mentioned research, together with traditional cartography, can help significantly to monitor and control the phenomena.
(Extract from ''The flood event of 4-6 novembre 1994 in Piemonte : first map of flooded areas identified by means of satellite remote sensing techniques'' - Processing CSI Piemonte, copyright Assessorato alla Pianificazione Territoriale, Regione Piemonte)

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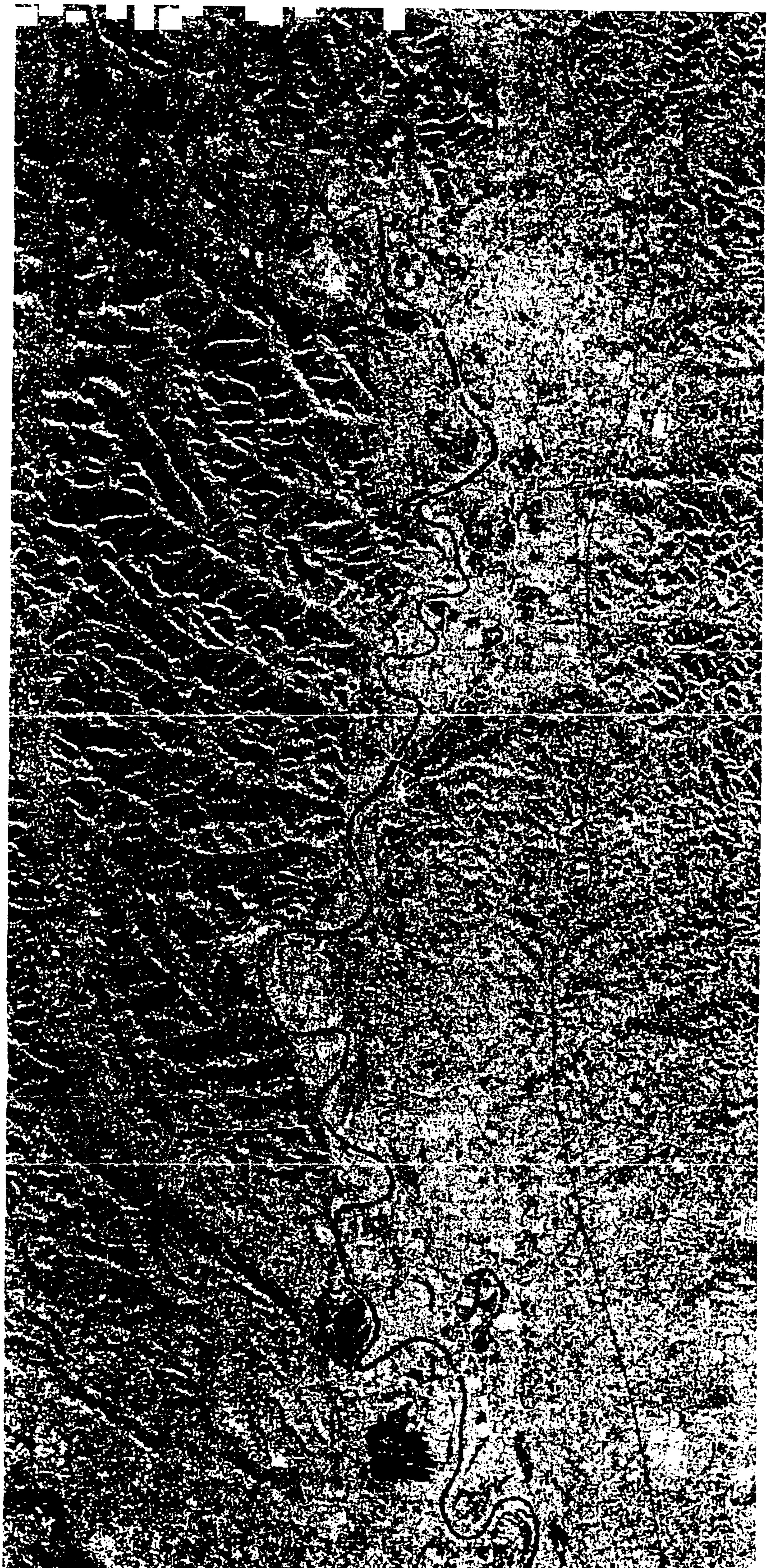

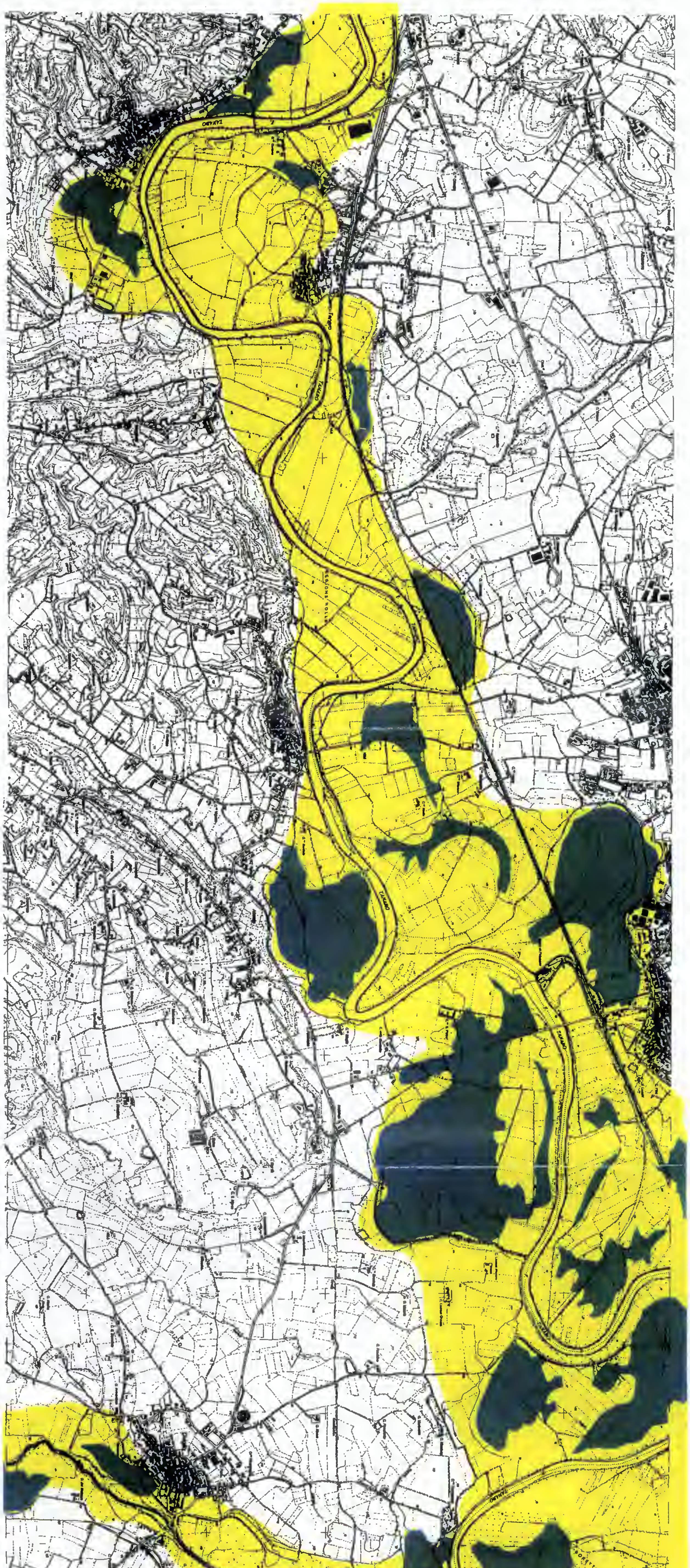

Assessment of the mapping capabilities of ERS-1 SAR data for flood mapping: an experience in Germany

Abstract

The company GAF (Company for Applied Remote Sensing), is actually investigating (under contract of DARA) the applicability of microwave satellite imagery for flood monitoring and mapping purposes under operational conditions. SAR data is used to map the flood event in the Rhine valley in winter 1993/94. The principle topic of the project is a comparison between the accuracy of manual field mapping practices and computer-aided mapping techniques using ERS-1 SAR data. Different methods will be assessed including visual and automatic classification procedures to retrieve the flood boundary and the total flooded area.

Close contact to the data producers and users (e.g. water authority boards, insurances and local communities), help to develop a user-specific operational concept for flood mapping wich can cope with the different geometric and temporal requirements of the various users.

Aerial photographs, Landsat TM imagery, digital mapsheets and Digital Elevation Models are further tools to be included as part of a GIS or adigital processing chain in order to achieve the ability for flood map production, calculation of corresponding flooded landcover, flood modelling (time series) and to deal with additional user requests.

Finally a future model for operational flood mapping on the basis of ERS-1 SAR data will be outlined.

1. Actual practices of flood mapping by the water authority boards

In Germany the supervision of the main waterways (Rhine, Mosel, etc.) is in the domain of the navigation offices which are the only competent authorities for flood mapping. Consequently the registration, mapping and control of flood events is part of their responsibilities. The actual practice to aquire flood data is to send out field workers who strike plugs every 500 m at the highest water level. Afterwards the plugs are measured whereby the geographical reference is achieved by striking the plugs in the profil. However an exact local reference of each plug is not provided.

This method is very precise and produces data sets that show hight precision ranging between 5 and 20 cm. Decimeter accuracies are essential for further calculations of the water volume, planning of dykes and groyne, for the establishment of retention areas and embarkement constructions.

Despite the high accuracy achieved through this method the water authority boards think about new possibilities of measuring the highest water level, because there are some negative aspects inherent to this method:

- the method is expensive because it is time-consuming and staff-intensive

- the data processing time is different for each country and takes about one year or more

- the mapping teams do not always catch the peak of the highest wave, e.g. if the wave arrives during the night or during holidays

- pedestrians often abuse the plugs though gaps in the data base arise

- no geographical reference exists for the plugs

- the highest water level is only marked in the profil; areas where the water has flown behind the dyke are neglected.

SAR data cannot provide datasets with decimeter accuracy, but they are appropriate to overcome some of the difficulties the navigation staff has to cope with: they can be obtained relatively quick enabling an immediate overview of the actual flood situation, the geographical reference is available and the data are easily combined with digital information like digital maps.

2. Investigation of ERS-1 C-Band Radar for flood mapping

The database for this investigation are three ERS-1 SAR scenes showing the flood event in Dec./Jan. 1993/94 on the Rhine river:

- ERS-1 SAR GTC product of 25.12.1993
- ERS-1 SAR GTC product of 31.12.1993
- ERS-1 SAR GTC product of 03.01.1994

The first scene demonstrates the situation of the worst flood peak which happened at the 25th of December. The following scenes document the decrease of the flood amount.
GTC products were chosen to ensure a good geometric quality and to enable the combination and modelling with digital maps and elevation datas.
The scenes which cover an area of 100 x 100 km between Duisburg and Koblenz show an acceptable radiometric quality. The resolution is about 30 m, the pixel size 12.5 x 12.5 m.
Three different river sections were chosen as project testsites, each of them covering an area the size of a mapsheet of 1:25.000. In accordance with the navigation offices, the testsites should meet special requirements: they should cover river shores which are not protected by walls or very steep and they should include areas where the water had flown behind the dyke as it has been the case at the Sieg river.
The topographical maps 5611 Koblenz (5511 Bensdorf), 5208 Bonn (including the Sieg river) and 5108 Cologne-Porz (5107 Brühl) seemed to be suitable for an investigation.

Koblenz was chosen for a first investigation because the testsite was also covered by areal photographs which were useful for a training and a check of the visual interpretation. Therefore all ongoing results refer to the Koblenz testsite.

During flood events Koblenz always suffers from inundation. The Neuwieder Becken north of Koblenz functions as a retention area: therefore parts of it are most of the time inundated during floods. However also the city of Koblenz is permanently affected from flooding, especially the housing areas around the "Deutsches Eck" and Oberwerth.

Settlements and forsted areas like in the Neuwieder Becken are critical areas for an investigation with radar data, because the bright backscatter of the houses and the leaf cover of the trees overlay the signal of the water. In addition wet arable land shows similar backscatter to flooded landcover.
Therefore Koblenz is an interesting testsite including different difficult interpretation situations.

An ERS-1 imagery from June (GTC, 19.06.1994) with low-normal water level, a Landsat TM (196/25, 04.09.1991) scene as well as aerial photographs were used as reference data.

2.1 Interpretation

2.1.1 Visual Interpretation

After converting each scene from the UTM reference systems to the Gauß-Krüger system the absolute coregistration with the digital topographic map layers was executed. The geometric correction was necessary for combining the satellite data with different additional data layers registered by different authorities as e.g. profiles, hectometer coordinates or elevation data.

Secondly each scene was visually interpreted, producing three different flood boundaries which document almost the highest water level and the decrease of the level of inundation.
The interpretation was carried out on the basis of the combination of one scene (e.g. GTC of 25.12.93) and a difference image between the imagery under investigation and the imagery of 03.01.1994, which provides best the normal situation and therefore the best difference. This data combination improved the interpretability of the single image. The imagery of June was used as radiometric reference.
The signatures of the flooded regions mostly can be separated from the remaining landuse classes. As mentioned before problems were caused by steep areas producing radar shadows and forests showing backscatter values as water. To disinguish between flooded areas and forest or radar shadows the information of the corresponding mapsheets proved to be useful. Interpretation problems were also caused by inundated settlements and one-family-housing areas with a high percentage of trees. The high backscatter of settlement completely overlays the signal of the inundated roads which sometimes are also to small to produce an own signature. Therefore a correct interpretation of these areas is problematic.

To test the reliability of the visual interpretation aerial photographs were interpreted. The comparison of both boundaries was surprising: the flooding lines were quite fitting despite the problematic sectors mentioned before.

On the whole the visual interpretation seems to be an appropriate method to get a quick overview on the flood situation and to derive the boundary of the flooded arable land and with some restrictions of settlement areas.
A comparison with the actual flooded area derived from the field measurements finally will demonstrate the accuracy of both, the water-boundary gained from the visual interpretations and the classification.
This is possible, if the flood boundary from the peak flood measurements of the water authority boards had been calculated which is still under work.

2.1.2 Automatic classification

For classification a new evidence based classification algorithm called EBIS (Evidence Based Interpretation of Satellite Images)(Lohmann, 1991) is used. The EBIS- classification, recently implemented as a new version in the ERDAS Imagine software package, is based on the mathematical concept of "evidentional reasoning" according to the "Dempster-Shafer-Theory". This structural, pixelbased algorithm deals with cooccurrence matrices as well as local histograms as feature spaces. These matrices describe in which frequency specific neighbourhood-relations a group of pixels occur. All feature spaces show an individual polynomial distribution from which the program simulates its own structured but randomly distributed class. Different distribution functions can be applied like the Gaussian distribution and the multinomial, window-based distribution. No enhancement or filtering is necessary to be applied before. Such operations would have a negative effect on the classification accuracy.
As it takes textural information into account EBIS is a sophisticated tool for the classification of radar imagery.

The first preliminary classification result was achieved by classifying two images, the GTC of the 25.12.1993 and the GTC of the 03.01.1994. Classification tests with only one acquisition data or with all three dates in combination produced poorer results. The classification of each scene demonstrating the decrease of the flooding will be worked out later.
Solely water and non-water classes were classified using about 10 different training classes applying the local histogram and multinomial distribution.
Concerning the accurate classification of the flooded landcover and the waterways the preliminary results were promising. However various water-misclassifications occured in the arable land. But though the exact delineation of the inundated area is of importance, the wrongly classified water inside the non-water classes can be neglected.
This first result demonstrates that EBIS is useful for a classification of radar data producing relatively quick acceptable results.

After classification various filtering steps were applied to make the flooded region more homogeneous, to close gaps inside the water and, if necessary, to extend the outer water boundary, because normally with EBIS the class boundaries are poorly re-

presented. The outcome of the filtering process was encouraging. A great amount of flooded surfaces could be adjoined to water.
Additionally the wrongly classified water inside the arable land had also increased. These areas were removed manually according to the topographical mapsheet.

To compare the classification accuracy with the results of the visual interpretation, the outer water-boundary of the filterd result was derived and overlayed with the boundary of the visual interpretation. The comparison shows that most of the obvious inundated areas had been classified. Forest and one-family-housing area as well as steep areas had also been included into the water class. Moreover all water-class boundaries had been poorely classified.
The preliminary classification result with EBIS brought encouraging results though they need to be improved. Especially for the problematic areas solutions have to be found to overcome the existing problems. Possibilities for an improvement could be the combination of the data with a digital elevation model, the application of further image enhancement steps or the use of additional data layers.

3. Planned further steps

The next steps will be the calculation of the flooded landuse classes combining the ERS-1 classification result with a Maximum-Likelihood classification result of corresponding Landsat TM data. Moreover the datasets of the water authority boards will be integrated to produce the flood line of the field measurements.
Also an integration of a digital elevation model is planned to calculate the water hight out of the SAR data.
Finally solutions for the critical interpretation areas as well as an analysis and comparison of the costs and the duration of the data production will be worked out. The final product will be a proposal for a suitable processing chain.

Literature:
LOHMANN. G. (1991): An Evidentional Reasoning Approach to the Classification of Satellite Images.-DLR, Forschungsbericht FB 91-29.

First ERS Thematic Working Group Meeting on
Flood Monitoring
26-27th June 1995, ESRIN Frascati (Rome), Italy

Studies of runoff processes by the use of remotely sensed data

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Abstract

In hydrological modelling of runoff processes including water balance several parameters and input data can be estimated or acquired by the use of remote sensing techniques. Synoptic areal information acquired by remote sensing is a key issue in hydrology, although ground-truth reference data are still needed. Especially all-weather cloud penetrating microwave techniques are promising tools for flood monitoring.

Hydrological models calculate runoff/water balance in drainage areas and do flow-routing within the flow channels. For the first issue - apart from hydrometeorological information - land use, soil moisture, digital terrain models are important. For the second issue, water level information, geometric information - e.g. of cross-sections for normal and for flood conditions, coefficient of roughness, velocity of flow and its distribution within the cross-section are required. Water level information (lower level and upper level) is additionally needed for shipping, and for design purposes.

During the last two major floods in Germany - December 1993/January 1994 and especially January 1995 - several areas on the River Rhine and in its drainage basin were covered with RS data (ERS1 and airborne radar, multifrequency microwave/TIR/UV-scanner, aerial photographs) during high flood conditions. The results still need to be fully evaluated. The co-ordination of the evaluation is done by the Federal Institute of Hydrology.
The following RS data were acquired:

12/25/1993	ERS1 (orbit 12778 / frame 2583), evaluated by GEOSPACE and GAF
01/30/1995	ERS1 (orbit 18531 / frame 2565)
01/30/1995	multifrequency microwave radiometer, TIR, UV - scanner (platform by the navy)
01/28-29/1995	SAR-radar (platform by DLR)
01/27-02/01/1995	b/w-Pan, b/w-NIR aerial photographs (platform by the air force)

At a test site in Northern Germany, the Federal Institute of Hydrology is studying the possibility of soil moisture estimation using ERS-SAR data. In an April 1995 campaign, soil moisture ground-truth data from TDR-probes were acquired parallel to an ERS scene (04/27/1995, orbit 19778, frame 2529).

1. General data requirements in hydrological modelling

In hydrological modelling of the quantitative part of the water cycle (Fig. 1), point information and areal information of several parameters and input data are fundamental elements. Often areal information is only derived by simple generalization from point data. Although hydrological models are of very different types and therefore require different sets of input variables and parameters, some generalizations can be made as to the basic features which have to be covered:

- characterization of hydrometerological situation
    - uniform or distributed precipitation depth or precipitation intensity, often needed as mean value for individual sub-basins
    - radiation / radiative balance
    - air temperature
    - humidity / saturation of the air
    - wind speed

- characterization of catchment area
    - land use
    - infiltration capacity, maximum soil moisture content, derived from soil maps
    - actual soil moisture, e.g. as percentage of maximum soil moisture content
    - slope/aspect of terrain, e.g. derived from a digital elevation model (DEM)
    - elevation (important for snow melt calculations and for differentiation of liquid or solid precipitation)

- characterization of flow channel
    - slope / longitudinal profile
    - geometry of cross-sections including potentially flooded areas
    - coefficient of roughness (Manning's n-value)

- water level and discharge at specific gauging stations.

For the calculation of water balance, the hydrometeorological and catchment data are the most important, for the calculation of runoff in drainage areas, besides hydrometerological and catchment data, flow channel and water level / discharge data are important, whereas for flow-routing and hydraulic computation only flow channel and water level / discharge data are needed.

The task of flood forecasting and flood assessment is done by mainly deterministic rainfall-runoff models and by hydraulic or stochastic flow-routing models. For these aims the high water level of a flood is required for calibration purposes, e.g. for calculations of volume for instationary models. Normally, the water level at the channel line (location of peak flow within an cross-section) is required, but only the levels at the banks can be measured, with a difference in height of -20 up to -30 cm. In Germany, usually the high water level is marked by pegs at 500 m intervalls, while high level gauges are rarely used. Due to difficulties of access and the time-consuming task of positioning the pegs, possibly several times during a flood, the pegs are not always positioned directly on the river banks nor in

regular intervals. So water level information, gained by survey after the flood has gone down, is not representative at all locations and has to be carefully evaluated and selected. RS techniques such as aerial photographs and SAR or altimeter information promise to help in this case.

Apart from the use in flood forecasting and flood assessment, water level information is required also for shipping and for design values in water resources.
In Germany, for shipping two characteristic water levels have to be determined:

1st equal value water level (GLW, gleichwertiger Wasserstand)
i.e. the (lower) water level fallen below on average at 20 days a year, calculated from discharge values

2nd highest water level for shipping
category I: shipping not allowed near the margins of the water courses
category II: terminal highest water level, no shipping allowed.

In water resources, flood water levels for specific return intervals are needed for

1st design of dam heights

2nd water level information for riverside residents.

Water levels are also needed for hydraulic 2D/3D models for the assessment of change due to planned structures in the water course.

2. Application of SAR and other RS information for flood monitoring

In the hydrological cycle (Fig. 1), several data needs can be covered by SAR and other RS data:

- soil moisture content
- generation of an digital elevation model via SAR interferometry or radar altimetry
- extent of water bodies and flooded areas
- land use
- rainfall / cloud cover.

For flood monitoring, actual information on rainfall/cloud cover, soil moisture content and extent of water bodies and flooded areas are especially important. Rainfall still cannot be estimated with sufficient accuracy from radar or satellite cloud cover and ground-truth data is still required.
For soil moisture and extent of water bodies, areal information derived from RS data would be an valuable source of information. Especially cloud-penetrating SAR, microwave radiometer or IR data are promising, as sunshine at the time of floods cannot be expected.

3. SAR and other RS data gathered during the 1993/94 and 1995 floods in the Rhine basin in Germany

During the last two big floods in Germany - December 1993/January 1994 and especially January 1995 - several areas on the River Rhine and in its drainage basin (Fig. 2) were covered with RS data (ERS1 and airborne radar, multifrequency microwave/TIR/UV-

scanner, aerial photographs) during flood peak conditions.

The following RS data were acquired:

12/25/1993	ERS1 (orbit 12778 / frame 2583), evaluated by GEOSPACE and GAF
01/30/1995	ERS1 (orbit 18531 / frame 2565)
01/30/1995	multifrequency microwave radiometer, TIR, UV - scanner (platform by the navy)
01/28-29/1995	SAR-radar (platform by DLR)
01/27-02/01/1995	b/w-Pan, b/w-IR aerial photographs (platform by the air force)

The results still need to be fully evaluated. The co-ordination of the evaluation is done by the Federal Institute of Hydrology.

During the 1993/94 flood, data acquisition was not co-ordinated, so only one ERS1-SAR scene covering the Cologne/Bonn Lower Rhine area on the 25th December could be evaluated by GEOSPACE and GAF regarding the flood mapping capabilities (see separate presentation on this meeting). The flood was generated by above-normal rainfall after the soil had already been saturated by preceeding rainfall. The rise was not instantaneous at all gauging stations, and Northern Germany was less affected (Figs. 3a and 4a)

During the January 1995 flood, several airborne sensors could acquire data during the high flood level between the 27th and 30th January, whereas the only valid ERS1-SAR scene only covers the Lower Rhine at the German/Dutch frontier but not the Cologne/Bonn area. On this flood event, the same effect of pre-saturation took place, combined with snow melt. The water level at several gauging stations rose at about the same time, while the spatial distribution of the floods was different from that one year before - the Neckar catchment was not extremely affected, the Cologne/Bonn area was more affected, especially by the rise of the River Sieg (Figs. 3b and 4b).

The data have not already been catalogued with respect to coverage and data quality, so only preliminary results of focus areas on the River Rhine are presented, especially the mouths of the River Main west of Frankfurt(Main) and the River Sieg near Bonn into the River Rhine.
The navy platform (Do228), originally designed for oil spill detection, carried scanning devices with multifrequency microwave radiometer (MWR, 18.7, 36.5, 89 GHz, i.e. 1.6, 0.82, 0.33 cm, resp.), thermal-IR(TIR, 8.5-14 μm)- and UV(320-380 nm)-detector, besides an SLAR whose data were not transmitted.
The DLR (German Institute for Investigation in Aviation and Space Technology) - platform carried an C-band VV SAR device.
The air force platform carried b/w-Pan and b/w-NIR camera devices with different viewing angles and lens systems.

On the 30th January at the inundated mouth of the River Main into the River Rhine, a riverside build-up recreation area was flooded (Figs. 5 and 6, taken from front-looking video camera on the navy aircraft). The C-band VV SAR imagery (DLR-platform) shows some inundated areas (Fig. 7), but with no reliable delineation of flooded area (Fig. 8 in dark blue / deep purple with possible confusion with vegetation). The MWR, TIR and UV of the navy platform shows interesting details (Fig. 9): The 89 GHz(0.33cm)-band with an geometric

resolution of 4.5 m clearly shows inundated areas, while the TIR marks the colder water temperature of the Main with respect to the Rhine, showing the right bank being inundated by water of the Main. The other MWR bands have less geometric resolution.

Some kilometers downstreams, the Island of Mariannenaue, clearly shows inundation by the SAR imagery (Fig. 10).

At the mouth of the River Sieg into the River Rhine, just downstreams of Bonn, the SAR imagery shows inundated areas (Fig. 11, in blue). An example of the b/w-NIR aerial photograph (air force platform) is given by Fig. 12 (in preparation).

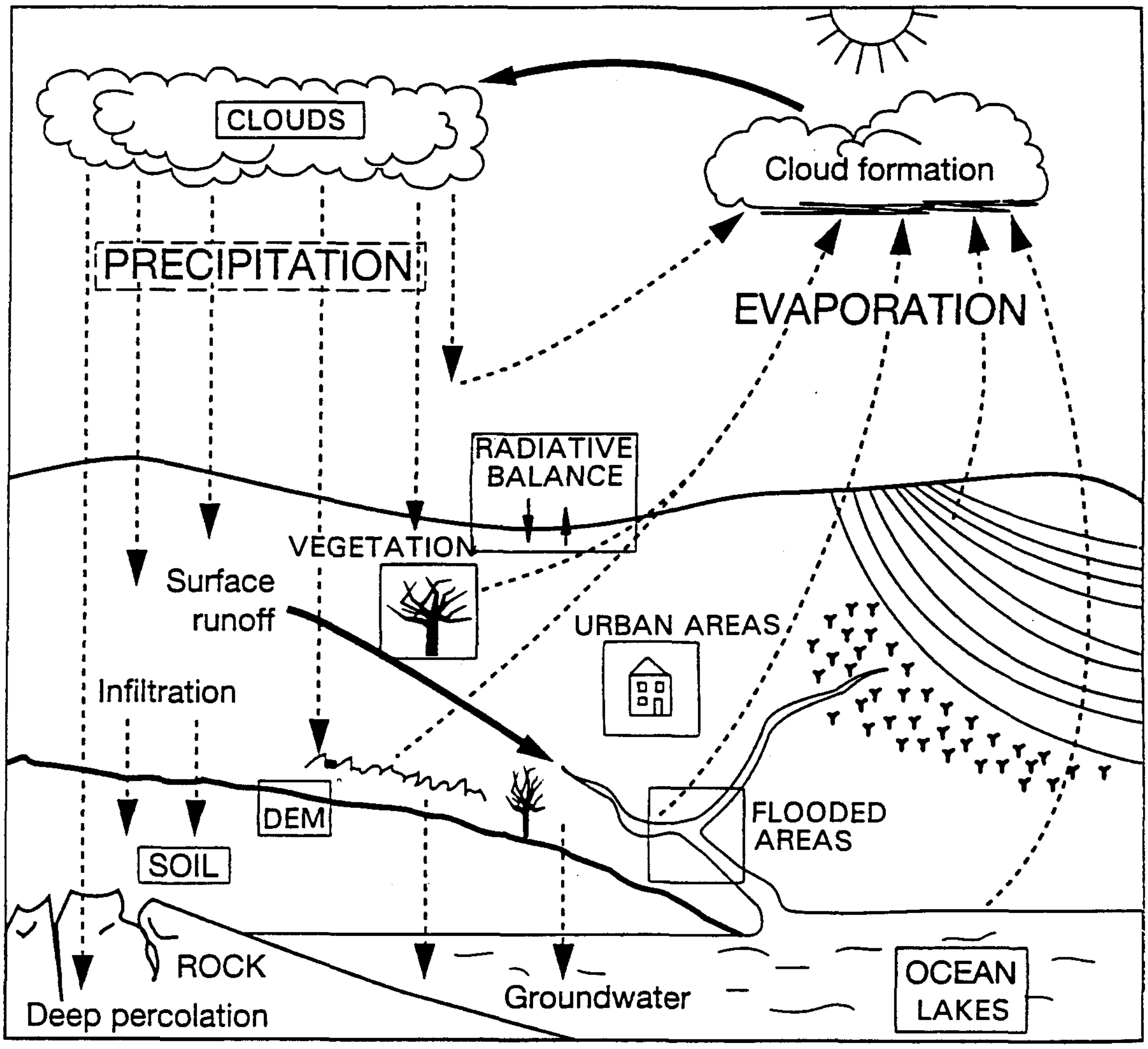
Though the delineation of flooded areas was quite good, especially with the MWR at 89 GHz/0.33cm, the geometric resolution given, microwave data up to now are not capable of fully replacing the conventional data.

4. Soil moisture estimation using ERS-SAR data

As the examples of the 1993/94 and 1995 floods in Germany show, soil moisture content and perhaps saturation is an key variable for flood prediction and warning. Though, it is only available at very few points. The surface penetrating capability of radar and the dependency of the backscattering on the water content are the key promising factors for soil moisture estimation using SAR data. At a test site in Northern Germany, near the River Elbe, the Federal Institute of Hydrology is studying this possibility using ERS-SAR data (Figs. 13 and 14). On 27th April 1995, soil moisture ground-truth data from TDR-probes were acquired parallel to an ERS scene (orbit 19778, frame 2529). The values gathered by the TDR-probes showed good accordance with gravimetric results (Fig. 15). The results of the ERS scene (Fig. 16, in preparation) have not yet been evaluated.

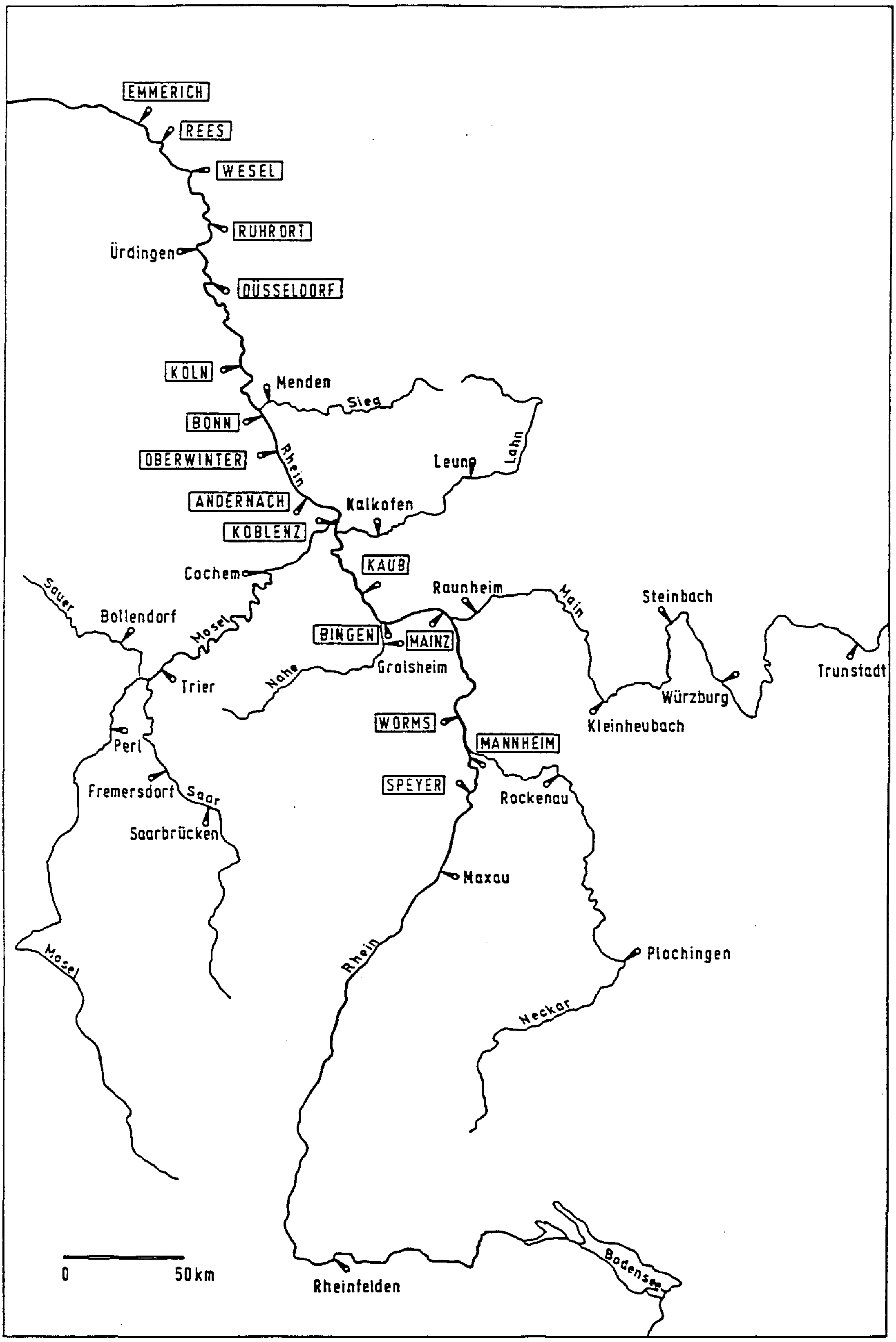
5. Summary, prospects and future requirements

The preliminary results of the 1993/94 and 1995 floods show that important information, especially the extent of flooded areas can be acquired by the use of SAR or microwave data. Additional RS data are valuable for interpretation, e.g. TIR for the mixing of flows. For the exact delineation of flooded areas required for hydrological models, microwave data still can not fully replace conventional data due to its geometric resolution. The combination with a digital terrain model (DTM, a DEM including relevant features) seems promising for the future, while actually available Raster-DEMs with an resolution of 20x30 - 50x50 m^2 may miss hydrological relevant linear features like small natural dams.
During the 1993/94 and 1995 floods, missing co-ordination of data acquisition was encountered. It was not evident, whether e.g. DLR and ESA would organize SAR data acquisition by themselves. So, as a consequence, it is proposed to prepare cooperation for cases of floods. In cases of flood warning, important warning data should be readily distributed and steps be taken to prepare data acquisition for the time needed. An European co-operation seems to be necessary.



The hydrological cycle.
The features that can be covered by remote sensing techniques are bordered.

Fig. 1



Das Rheineinzugsgebiet mit wichtigen Pegeln

The Rhine catchment with important gauging stations

Fig. 2

Flood wave of the River Rhine in January 1995

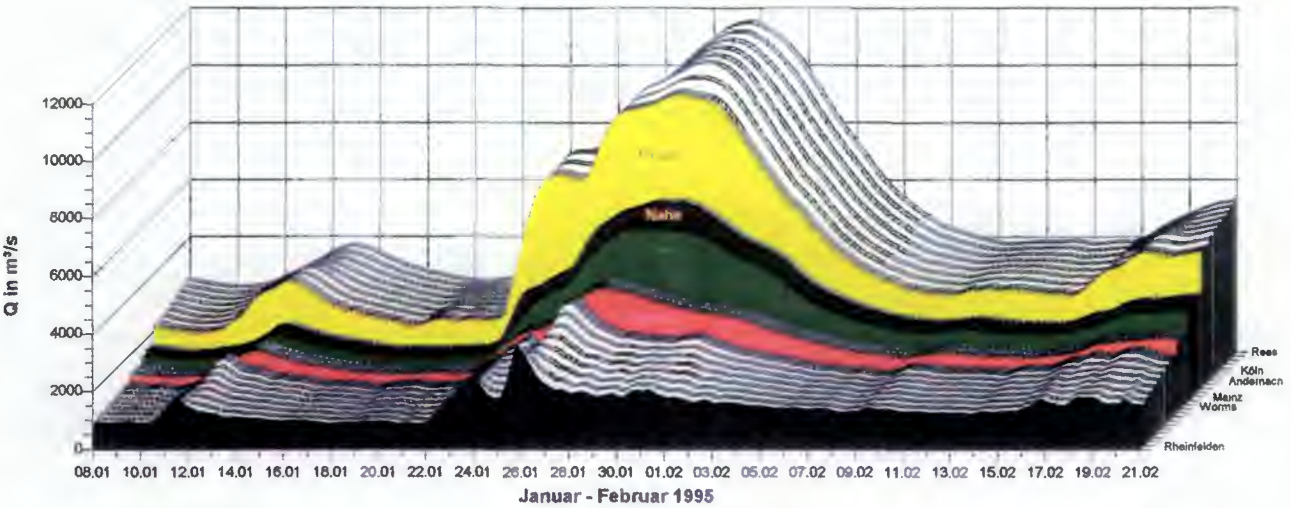


Fig. 3b

BfG, 03.04.1995
R-H-0195.XLS

Flood wave of the River Rhine in December 1993 / January 1994

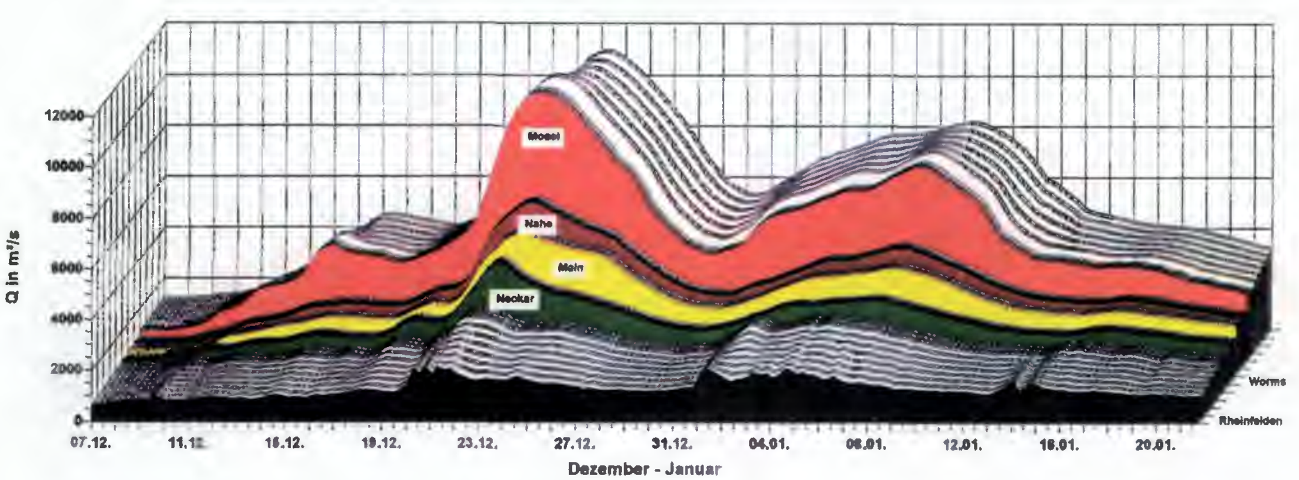


Fig. 3a

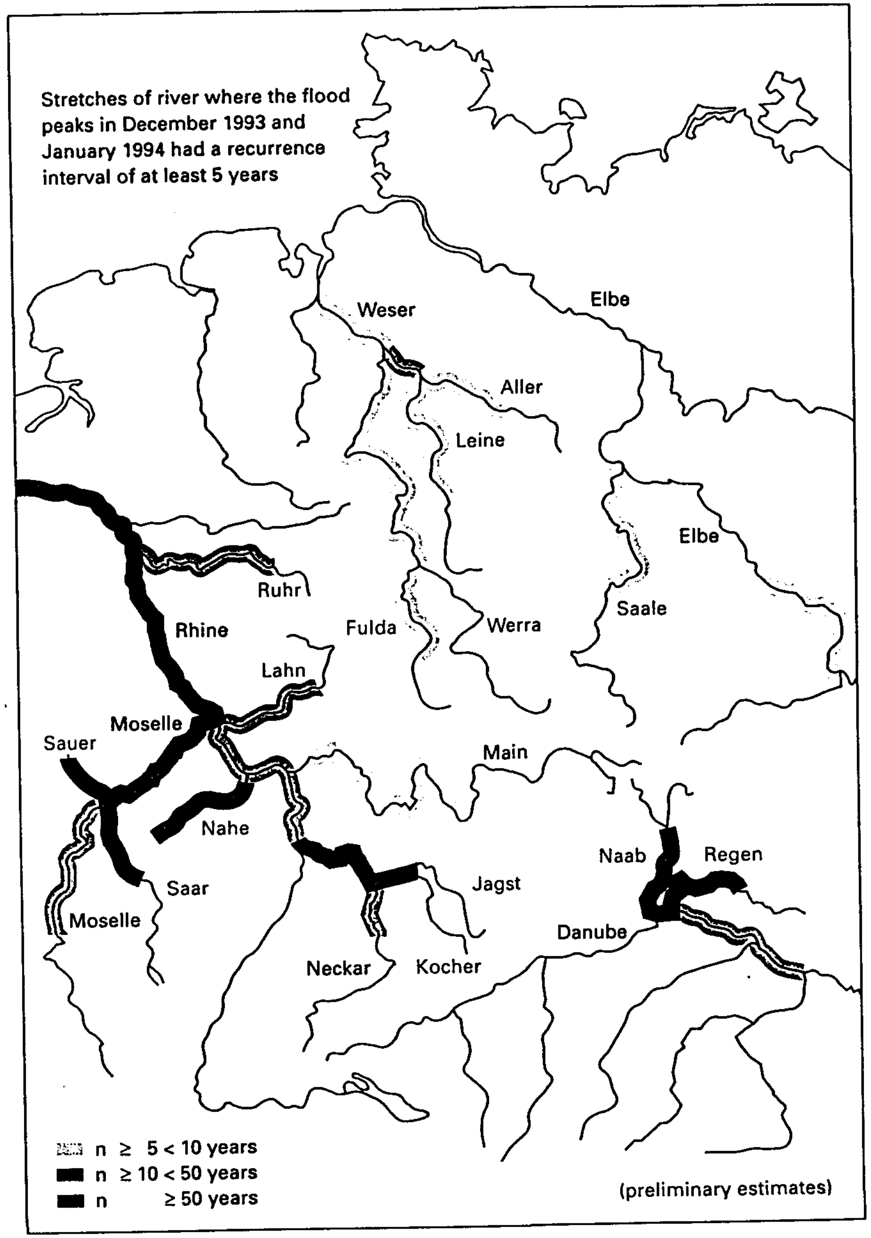


Fig. 4 a

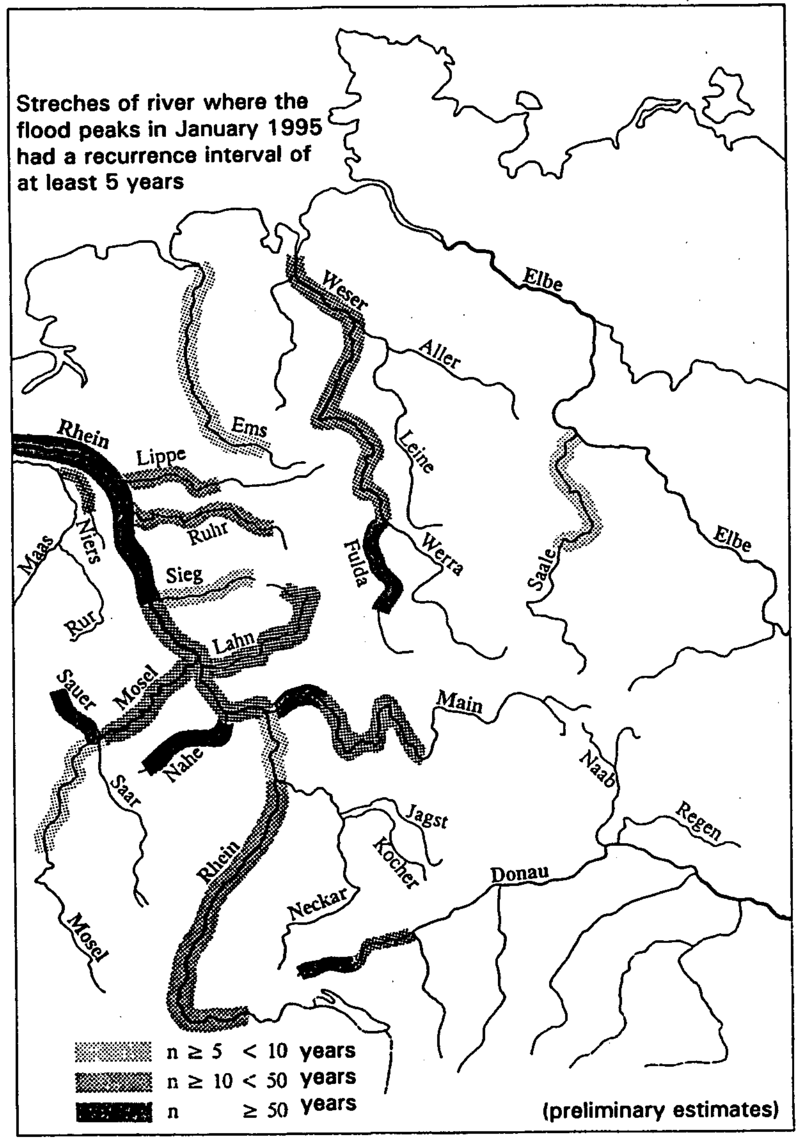


Fig. 4 ·

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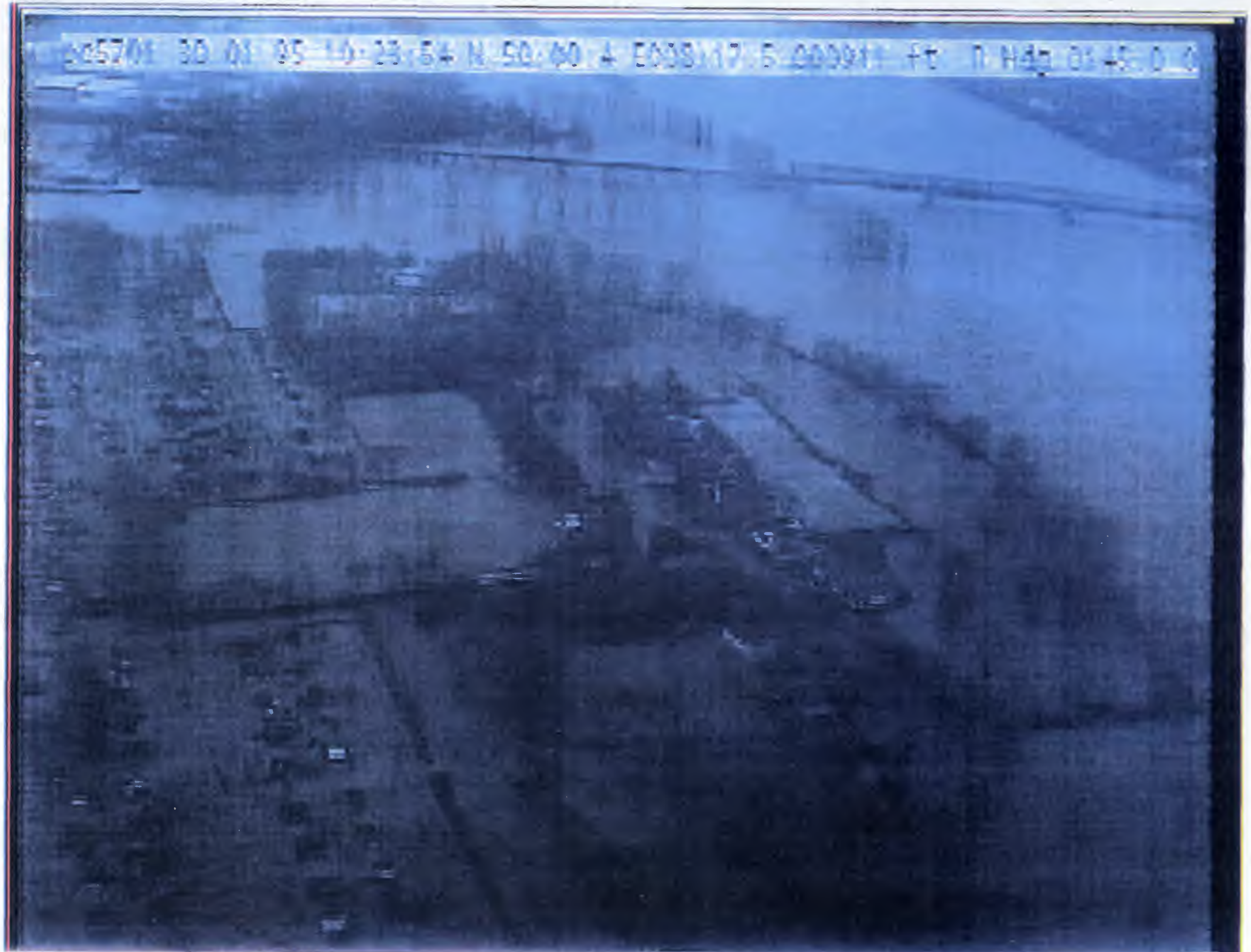


Videobild zu Target 015

Fig. 5

Fig. 7

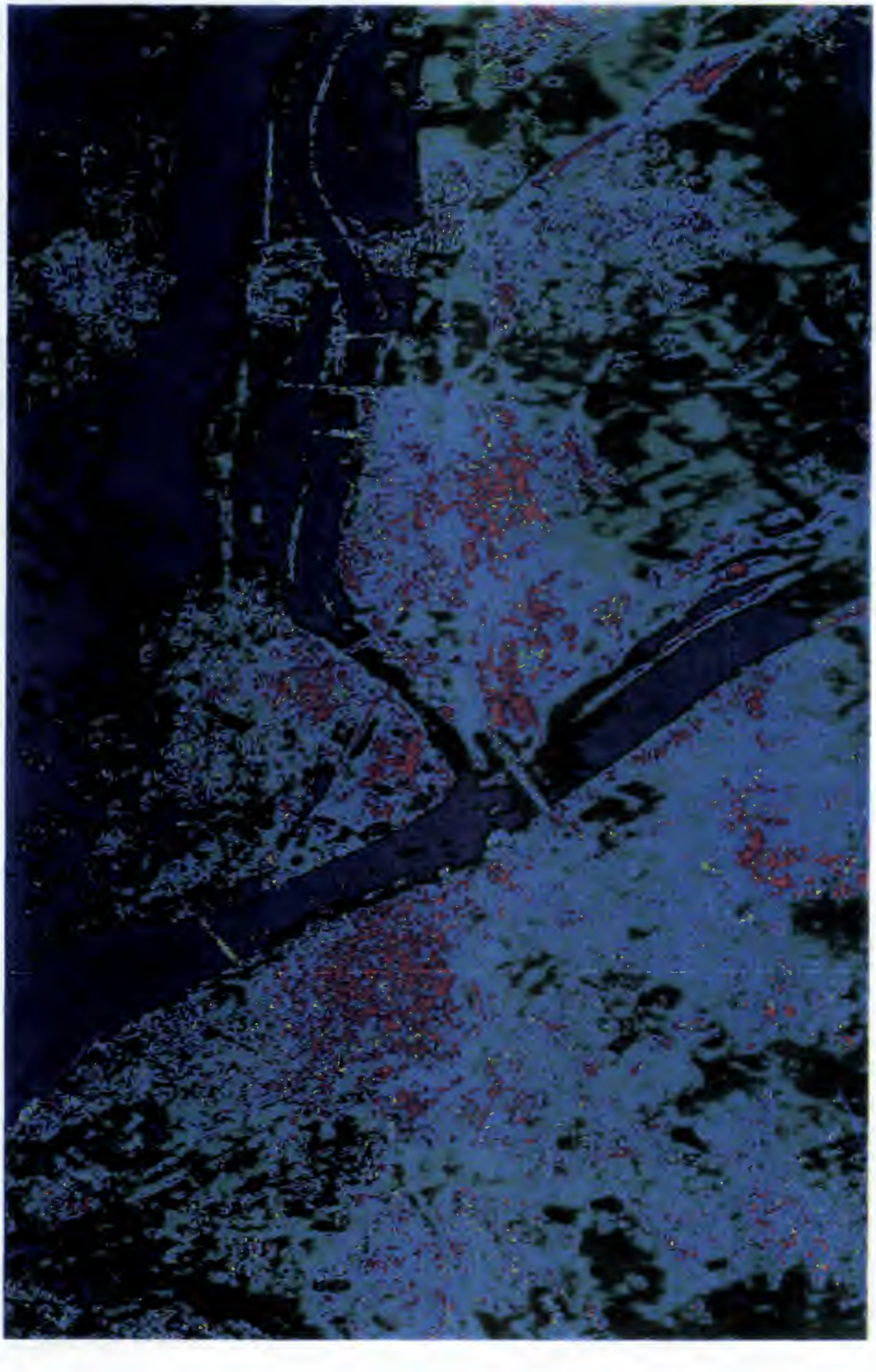
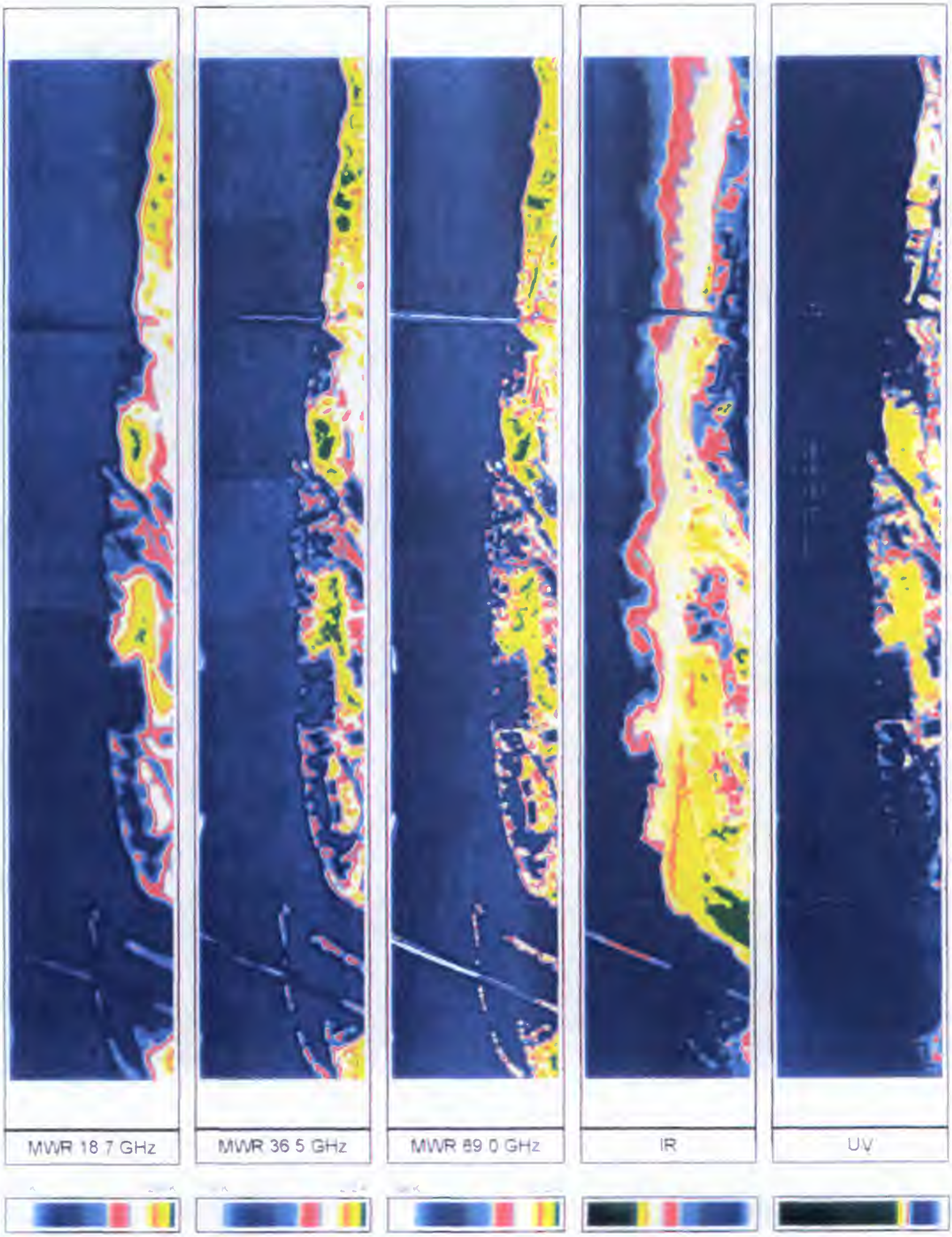


Fig. 8

Befliegung Hochwassergebiet Rhein

Main Mundung bei Mainz

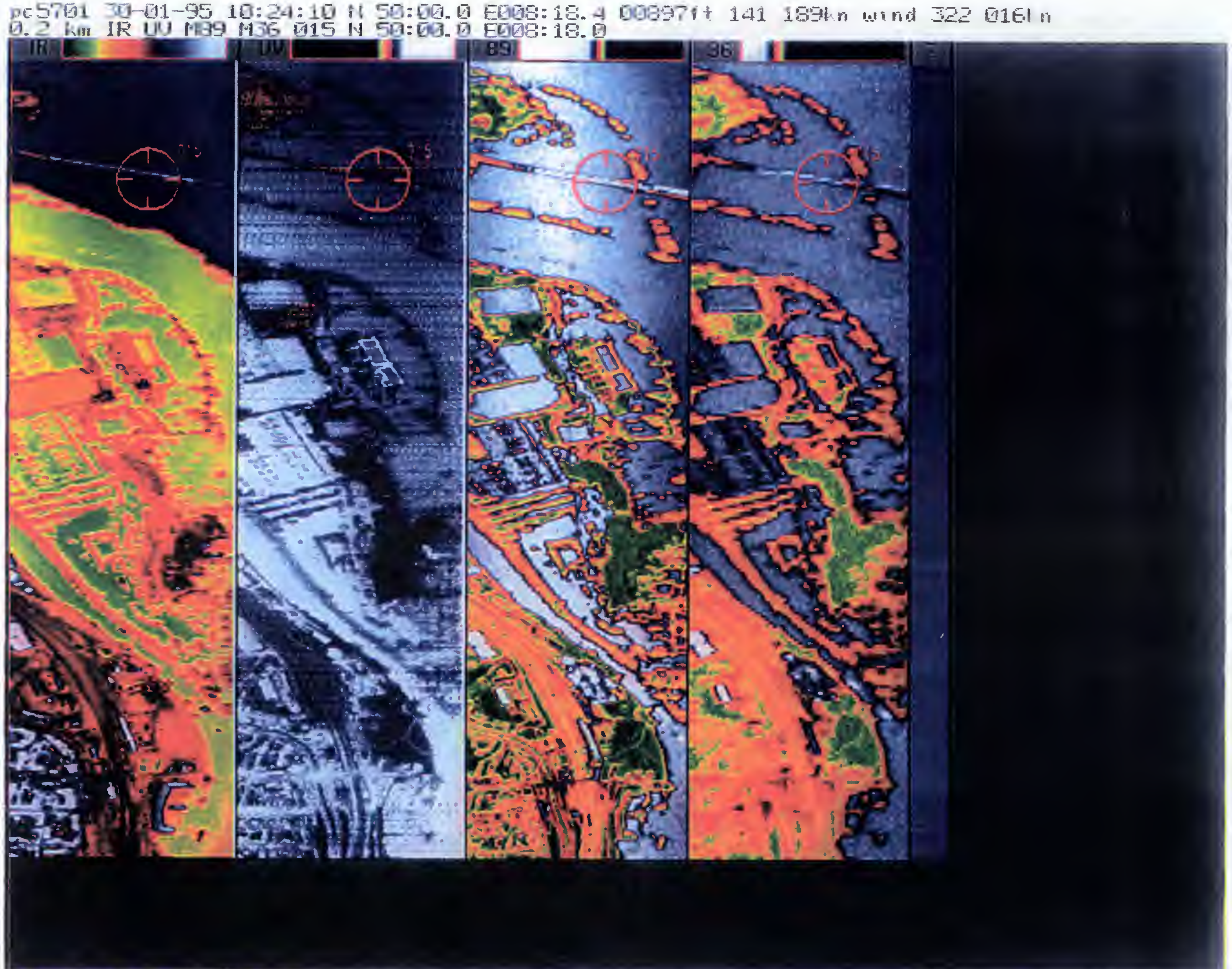
30 01 95 11 20 03 - 11 20 53



Projekt MERES

DLR

Fig. 1a



Zufluss Main bei Mainz

Fig. 96

Fig. 10

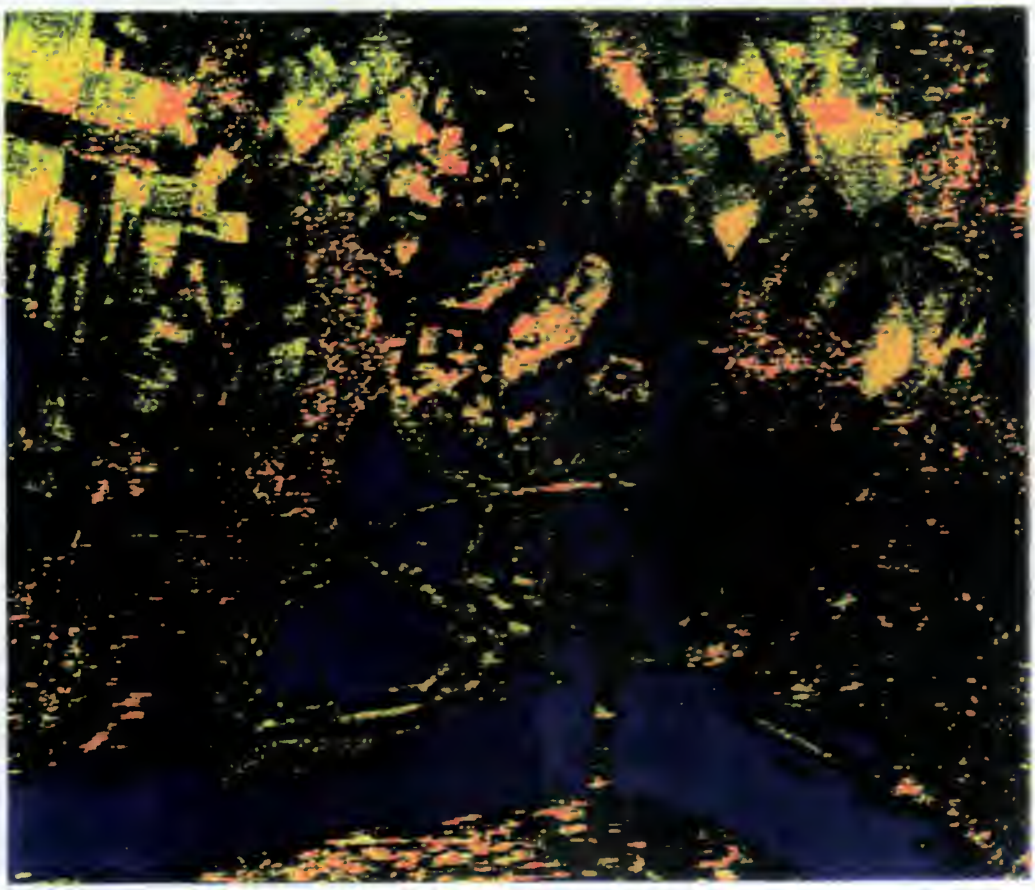


Fig. 11

Fig. 13

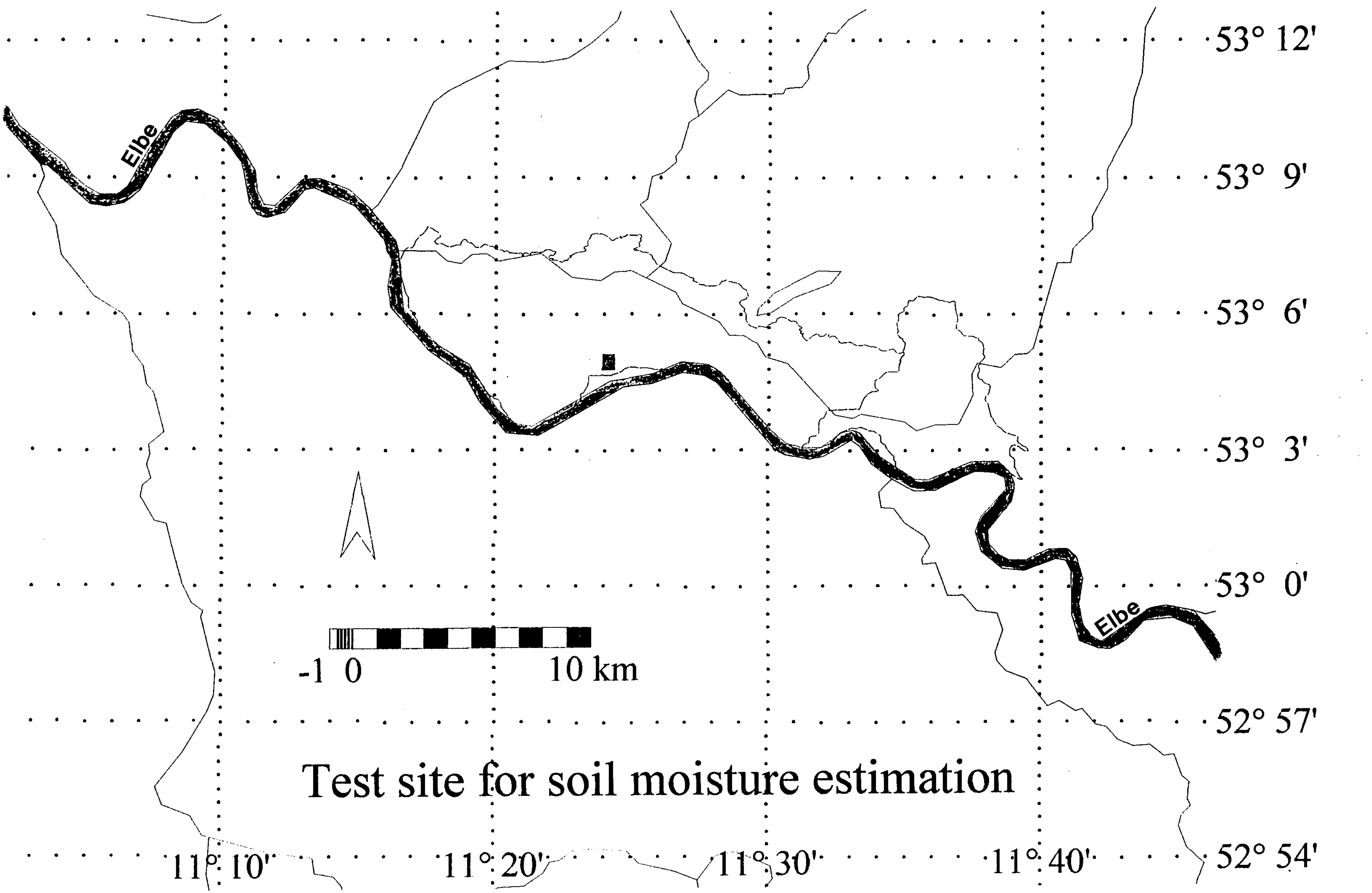

53° 12'
53° 9'
53° 6'
53° 3'
53° 0'
52° 57'
52° 54'
11° 10'
11° 20'
11° 30'
11° 40'
Elbe
Elbe
-1 0
10 km
Test site for soil moisture estimation

Fig. 14

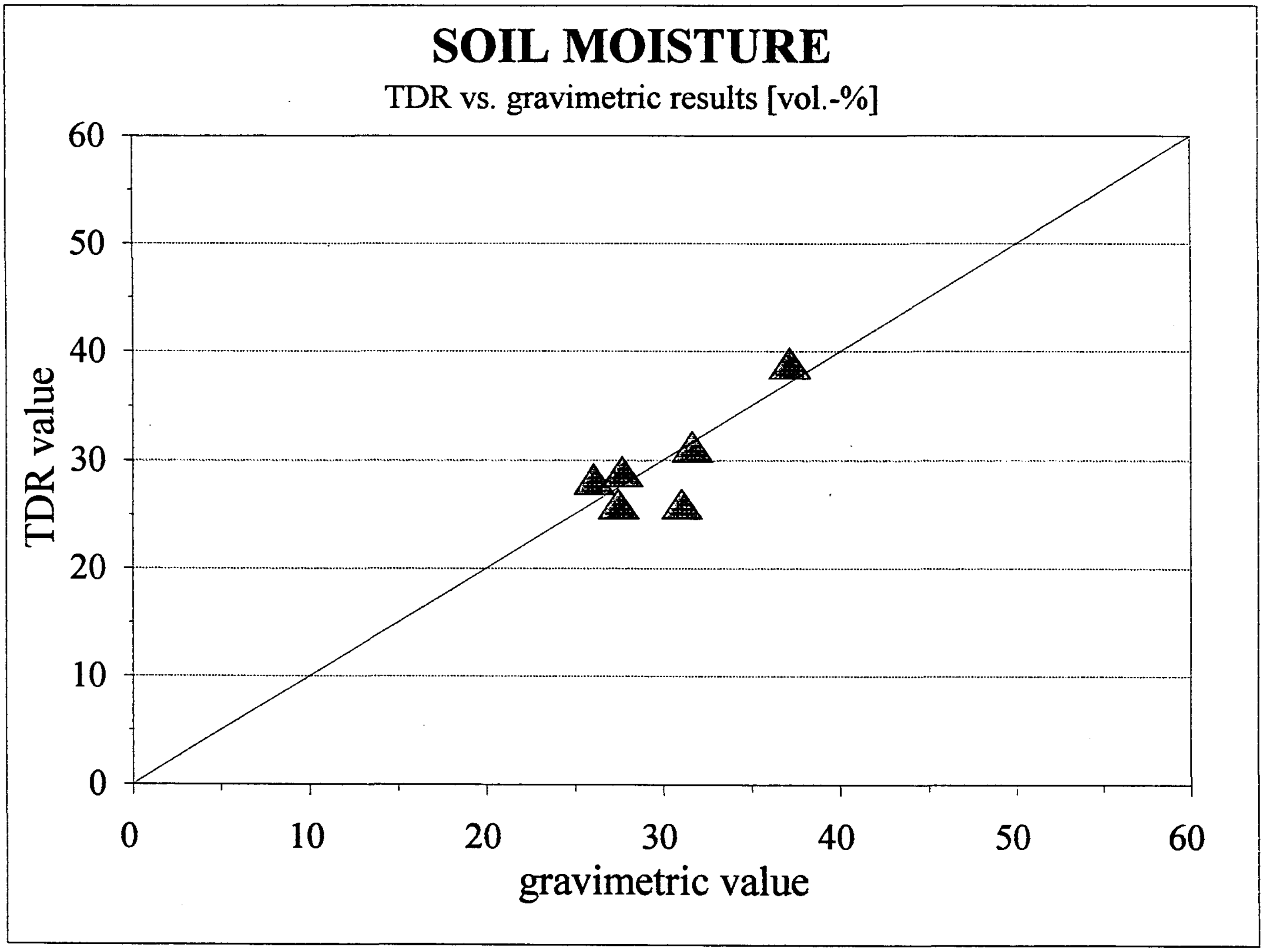

SOIL MOISTURE
TDR vs. gravimetric results [vol.-%]
TDR value
gravimetric value
0
10
20
30
40
50
60

Fig. 15

OVERVIEW ON THE CARTOGRAPHY OF INUNDABLE AREAS, AS PART OF THE ACTIVITIES OF THE GEOLOGY DATA BANK SERVICE IN PIEMONTE REGION: FLOOD INVESTIGATIONS, AVAILABLE TOOLS AND THEIR USE, OBJECTIVES AND RESULTS

G.Bellardone - Geologic, Meteorologic, Seismic Risk Prevention Sector of Assessorato Pianificazione, Regione Piemonte - Italy

ANALYSIS OF FLOOD EVENTS AND THEIR ASSOCIATED PROCESSES

The objective of the analysis is to evaluate the effects of floods occurrence inside and outside the banks, and to relate them to human activities in those areas, thus being able to establish the mutual interference of flood passage and infrastructures.

The result is the generation of final thematic cartography at 1:5.000 and 1:10.000 scales and the availability of information as input to the various computerised archives.

Aerial photographs and field analysis are utilised to achieve such output. The former are useful to a) monitor the effects of the flood within the channel; b) follow the directions of water propagation in the alluvial plain; c) observe the most evident flood effects, in general.

Area surveys are needed to verify the precise extent of flooded areas, in lack of easily identifiable morphologic features, and also to distinguish land areas flooded by the river from land surfaces with water stagnation due to granularometric characteristics of the soil.
The water level of the alluvial plain is measured during the ground survey, and information on the flood propagation as well as on historical floods is collected.

The availability of maps containing such information allows a better planning of the interventions for both, the reconstruction of damaged or destroyed infrastructures, installations, etc. -, and wider, long term initiatives. These may include land use utilisation changes according to the damage extent and to the delimitation of the areas to be left to the river course (downflow water ways), in the case of floods over banks.

The maps are also used to verify the satellite image interpretation, as well as to set up processing methodologies aimed at achieving an improved flood cartography of the areas, which becomes particularly important when the catastrophic events involve wide extensions.

By integration of the flood cartography with historical information, statistics on the events occurrence and on their spatial distribution can be derived.

A further goal is to use the obtained information to calibrate numerical models of the flood peak propagation for further utilisation by the civil protection. Such model inputs will remove the uncertainty connected with the selection of other parameters of the model itself.

MAPFRE RE
Madrid - SPAIN

OVERVIEW ON THE TECHNICAL NEEDS OF INSURANCE AND REINSURANCE COMPANIES, WITH AN EMPHASIS ON FLOOD RISK ASPECTS

Mª Teresa Piserra de Castro

Frascati, Italy - June 1995

ABSTRACT

The insurance and reinsurance industry is becoming aware of the great importance of the natural risks and perils that threaten the accurate control of their businesses. The insurer, directly responsible for the losses that arise from natural events in their portfolios in an individual country; and the reinsurers, as the supporters of the direct insurance companies distributed in many parts of the world. The cover for natural perils (floods, earthquakes, volcanic eruptions, tsunamis, hail, snow weight, etc) is given in many countries as an addendum to fire policies, these being extensively spread, but concentrated mainly in the cities and surroundings.

In respect of floods, many of the big conurbations of the world are usually located on floodplains or near the river mouths, where the landscape kindly offers flat areas, sands and water, good ingredients for a city to be erected. However, these settlements introduce a supplementary factor on the flood peril turning it into flood risk.

Although being conscious of the severe consequences that floods might cause on an insurance or reinsurance portfolio, their problem is the flood accumulation control of their policies, the study of the likely loss scenarios and the mostly accurate location of every individual policy. There is a point where the binomium insurers-reinsurers and scientists converge, where the former should be able to explain the latter their needs and what they could be provided with. On the other hand, scientists must do their best to delete the difficult formula and the long demonstrations, and be able to present easy applicable conclusions.

Several big aims of the insurers-reinsurers regarding remote-sensing facilities could be:

- the knowledge of the cost of catastrophic events in different loss scenarios in respect of their portfolios
- the simulation of different events (floods, earthquakes, etc) and evaluation of economic losses in their portfolios
- the perfect geographic location of their policies
- the assignment of different data to previously defined geographic units
- the possibility to use all the data, manage and combine them as required

All these ideas will be also illustrated with the recent experience of the A.F.R.A.I.D. project (A Flood Risk Analysis for Insurance Damages) developed by Nuova TELESPAZIO and promoted by an Italian insurance company, Cattolica, an Italian reinsurance broker, Ital Ri, an European reinsurance company, C.I.A.R., a Spanish reinsurance company, Mapfre Re and Nuova TELESPAZIO itself.

CONTENTS

As a scientist working for the reinsurance industry, I think it is very wise of you to convoke providers, researchers and likely users of the satellite information with the aim of promoting a better knowledge of the possible applications and the availability to cope with the needs of the present world.

I have been asked to expose to you the point of view of the insurance and reinsurance industry in this context. First of all, I had to learn what kind of information can or could be provided by the satellites that might be useful for us. The recent launch of the ERS-2 and the previous ERS-1 have opened a wide range of information that before was only available after collecting huge amounts of data in many singular places of the world. Now, a complete view of the planet is easy with the puzzle of satellite photographs.

Natural catastrophes are one of the nightmares of insurers and reinsurers because of the immense loss potential in a matter of hours. We normally become involved in what it is called "catastrophe business" through the fire cover, which is normally bought by most of you for your homes, industries or small businesses. In most of the countries that are exposed to one or several natural hazards, the possibility of buying catastrophe cover against earthquake, flood, windstorm, volcanic eruption, tropical cyclone, etc, is offered.

Insurers are usually involved in a single country market, but most of the reinsurers take shares in many countries, as their main task is to "insure" the "insurer" and their aim is to spread the risk; the wider, the better. As natural events never take into account the international borders, it is very common that a loss scenario includes several countries where a reinsurer is involved.

Historically, insurers and reinsurers have estimated a PML, Probable Maximum Loss of their portfolios in an individual country or in the scenario loss area which consisted on a percentage of damages depending on:

- class of business (homeowners, industrial, commercial,..)
- type of building (year of construction, building code,..)
- maximum expected event
- geographical location

I imagine that the last two points must be familiar for you, because they could be the **intersection between satellite information and the insurers-reinsurers needs**.

1. MAXIMUM EXPECTED EVENT

Our memory is not as good as it should be. We often consider the maximum expected event as the last one we can remember. That is the case of the Mexican earthquake of 1985, the Chilean earthquake of 1985, the Northern Europe windstorms of 1990, the hurricane Andrew of 1992, the Los Angeles earthquake of 1994, the Kobe earthquake of 1995, etc. Insurance and reinsurance underwriters usually consider these as the biggest, until they realize that an even greater loss has been caused by a catastrophic event.

Good research has already been done by engineers, seismologists, geologists and architects in respect of earthquake vulnerability of structures. But whenever a new tremor trembles the Earth, a new focal mechanism or an unknown fault is discovered.

But the behavior of our atmosphere and its implications onto meteorology and climate, escape our control. The climate change, the effect of *El Niño*, the Ozone Hole and the Greenhouse effect are concepts that began to reach the normal people when a wave of strong wind events (Gilbert 1988, Hugo 1989, Northern Europe Windstorms 1990, Andrew 1992, Iñiki 1992) struck long distanced parts of the planet.

We are not always aware of the advance of Science, so once I have summarized for you, our stormy relationship with natural hazards, I will try to relate our needs with your facilities.

WHAT INFORMATION SUPPLIED BY THE SATELLITE CAN BE USEFUL FOR INSURERS AND REINSURERS?

Everything related to prevention, prediction, assessment of hazards and risks, monitoring and evaluation of losses. A very simple division could be made for those activities related to oceans, to the atmosphere and to the Earth and the possibilities of these risks being insured and reinsured:

➡ RELATED TO OCEANS

- Monitoring of iceberg tracks. Optimization of maritime routes Weather forecasting on the sea.

The possibility of collision with an iceberg must be avoided in commercial and transport maritime routes. Cargo, material damages, accident and life insurance are involved.

- Sea level changes.

Many coastal areas are threatened by a possible elevation of the sea level. Many small towns, big cities, agricultural areas, industries and ports can be inundated. Flood insurance is involved.

- Monitoring of oil spills.

The oil spill extension can be monitored continuously and so, it is possible to apply the suitable countermeasures to avoid or reduce material and ecological damages in the surrounding areas. Cargo insurance, material damages and contamination insurance are involved.

- Measurement of the height of waves.

The design of oil platforms as well as those tubes that conduct waste waters offshore, sometimes depends on the highest wave that can hit them. The simultaneous measuring of the height of waves during big storms on the sea can help to reach the correct standards of construction. Material damages, accident and life insurance are involved.

- Temperature of the sea water.

There is a well known oceanic area at tropical latitudes where the sea temperature can reach 27°C or more. This is a marvelous environment for the tropical cyclones to develop. If these areas are enlarged because of the climate change towards higher average temperatures, they should be carefully monitored to simulate new scenario loss areas. Insurance for wind and flood is offered in most of the tropical countries. The historical tracks give some guidelines to imagine the likely groups of countries that might be affected by a single event. More studies about return periods, likely intensities, landfalling hurricanes and tracks are required.

- Oceanic stream variations.

Coastal climates as well as fish production are greatly dependent on oceanic streams. Any change in the normal pattern should be detected in order to prevent negative consequences as much as possible. A northwards drift of the Kuro-shivo stream in the Pacific Ocean was observed some years ago. It usually carries warm and salty waters, as the Gulf Stream. There still remains the doubt whether the heavy rains of 1993 summer in Mississippi are related to this episode.

➧ RELATED TO THE ATMOSPHERE

- Hurricane tracks, wind direction and speed.

Once a tropical depression is formed, an accurate monitoring must be followed in order to organize the preventive measures in the threatened areas. Teams of insurance and reinsurance adjusters must get ready to visit the loss areas so that indemnizations can be agreed as soon as possible.

- Atmospheric temperature.

Some climate evolution models predict an increase in the average temperature in the Poles more important than in the Equator. This would probably disturb the existing air-flow patterns and the moderate climate we enjoy in these latitudes.

- Atmospheric pressure.

One of the procedures to detect a "El Niño" event is the different distribution of high and low pressure in New Zealand and India: during normal times, atmospheric pressure over the South Pacific is high, while the pressure above the Indian Ocean is low; this difference in pressure boosts the Monsoons. When this situation is inverted, no rain-carrying Monsoons materialize over India.

- CO_2 content.

The content of CO_2 in the atmosphere is increasing since the industrial revolution. The possible influence on the climate change

has to be proved. CO_2 is also expelled to the atmosphere by volcanoes.

- Water vapor content.

In general terms, high water vapor content combined with an increase in average temperatures, can contribute to trigger more precipitations and flooding, thunderstorms, hailstorms and also tornadoes.

➡ RELATED TO THE EARTH

- Accurate terrestrial orbit determination.

There are several theories that relate the periodical slight changes (millions of years time) in the orbit variation with ice ages and climate change. The accurate determination of the terrestrial orbit will be useful for future climate evolution predictions.

- Terrestrial surface minimal variations.

The monitoring of the pulse of the Earth will detect any modification on the surface as a consequence of internal volcanic activity. This swelling as well as magnetic, gravimetric and thermal anomalies, will contribute to allocate likely volcanic eruptions. Loss of lives and economic damages can be saved. Volcanic eruption insurance cover is involved.

Another application of the synthetic aperture radar (S.A.R.) could be the control the subsidence caused by all means, such as isostatic uplift, weight of sediments, droughts (this happened in Great Britain some years ago and the insurance companies had to pay millions of pounds).

- Continental drift measurements.

Continental drift is mostly important in geological terms, but perhaps it is not essential for the daily life to know that the distance between Europe and America is increasing two centimeters every year because of the sea floor expansion. The theory of the constant radius of the Earth would say that two new centimeters in the Atlantic ocean plus the new nine centimeters of the Pacific ocean

created in the oceanic ridges would implicate that more oceanic crust should be consumed in the subduction zones. In general terms, this means more earthquakes, but perhaps it becomes science fiction. In any case, satellite images are useful to estimate the affected area after an earthquake. Earthquake insurance cover is involved.

- Crops prediction.

The consequences of the availability of predicting the quality of the crops are basic in the economic and social sense. For example, if is is possible to detect a *El Niño* event, several countries would be able to design a suitable cropping plan in respect of the rain that they will probably receive. Agricultural insurance is involved.

In respect of environmental problems, spaceborne remote sensing facilities will be able to detect the advance of desertification in several parts of the world.

- Tropical forests studies.

Tropical forests are usually covered by clouds, so that their study was difficult by means of aerial photographs. Satellites will provide data to allow suitable studies of the tropical areas.

- Bush and forest fires.

The location of fires in non populated areas as well as the estimation of damaged areas will be possible during bush and forest fires. Fire brigades and means would be ready to work as soon as the fire is identified and located.

- Land use planning.

The plan for land uses is designed with different data, such as topography, which can be provided by satellite photographs. Land use planning is essential for those areas that can be flooded. The correct use of soils and the suitable allocation of cities is elementary to prevent damages caused by floods.

- Floods prediction and loss evaluations.

My recent experience of the use of satellite data related to floods is summarized in the A.F.R.A.I.D. Project.

The presentation of the A.F.R.A.I.D. Project will take place in Rome the 27th of June of 1995 in the L.U.I.S.S. University of Rome. The acronym of the project was given by the scientists of Nuova TELESPAZIO, the space agency *per le telecomunicazioni spaziali,* who have played the main role in this joint venture. You might imagine that the insurers, reinsurers and brokers who have participated in the AFRAID project would never have chosen such a name, but it could be a lucky name for the project to be successful.

AFRAID means "A Flood Risk Analysis for Insurance Damages" and it is the result of a Consortium comprising an Italian insurance company Cattolica, the Italian reinsurance broker Ital Re, the European reinsurer and participated company of Mapfre Re C.I.A.R, Mapfre Re itself and Telespazio. The project has been developed by an interdisciplinary group composed of mathematicians, geologists, hydrologists and experts in computer design cartography.

Floods have already become a very important peril and risk in many parts of the world and especially in Europe and particularly in Italy. Although we could make a simple classification of the factors that characterize the causes and effects of floods in Northern Europe and in the Southern Mediterranean countries, the question is how to deal with them, how to face the consequences, how the rivers and rains behave and where they will accumulate.

The main tool of this study has been the data provided by the satellite photographs and remote sensing technologies that offer the facilities to manage all the selected data. Italy is completely digitalizated and so, the morphology of the river basins and the topography are absolutely controlled.

An additional difficulty is the scale of the study. The flood map will include the whole country, it will be based on a scientific map but it must be useful, accessible and user-friendly for the insurance and reinsurance underwriters.

That is why we have decided to design, firstly a map with a "pixel" as the minimal information unit with a resolution of a square kilometer, secondly a map of sub-basins of 200 to 300 square kilometers and finally, a map of flood hazard levels assigned to small provinces as the administrative division and useful unit. Anyway, this must be a decision of the insurance Italian market, as it will be the base of their accumulation control system for floods. As we are moving from pixel, to sub-basin and to province, we are loosing

quality in the information, but this is the only procedure that we have imagined.

We then had the Geographic Information Systems (G.I.S.), which allow the assignment of different data to every minimal information unit. This data would influence in the development of a flood, and summarizing, these have been chosen:

SLOPE, BASIN MORPHOLOGY, GEOLOGY, SOIL USES, DISTANCE TO THE NEAREST RIVER, MAXIMUM PRECIPITATIONS AND HISTORIC DATA.

All these are more or less easily available after a period of collection but the difficult step forward is how to mix them and interpret the result of the Flood Hazard Coefficient.

At present, the methodology has been applied to an individual river basin and it is being compared with other two. Our intention for the next 27th of June is to expose the methodology we have designed as a contribution to the knowledge of the behavior of floods. It could also be applied to other countries with the additional and necessary adaptations to every geographical area.

After summer and once the map is validated by all the interested parts, it is intended to print the final map with an additional memory which will detail the methodology applied .

➡ CORRELATION OCEAN - ATMOSPHERE - EARTH

- "El Niño" - Southern Oscillation (E.N.S.O.)

Somebody has called the Pacific as "the weather kitchen of the Globe" because of its great influence in the meteorology of all over the planet. Once it is identified, it is possible to predict its development for, at least, the following eighteen months, although the last one is lasting longer. Some of the direct effects of a El Niño event on insurance and reinsurance could be:

- ♦ Floods, windstorms and lightning can cause heavy damages on broadcasting equipment and transmission lines due to signal and reception interruption.

- Flash floods in arid and low-lying areas might cause erosion in foundations and collapse in tunnels or ditches for underground pipelines.
- Higher chances of rainfall or windstorm could lead to more cancellation of sports games, open air concerts and other outdoors events.
- Port and harbour installations are very vulnerable to storm surges, high tides, coastal flooding, erosion and severe hurricane. Docks and boats are also subject to damages due to warming waters and their increase in volume and height.

- Climate Change. Greenhouse effect.

The possible evolution of the climate towards an increase in the annual average temperature would accelerate the atmospheric heat engine, so that tropical cyclones, precipitations, flooding, thunderstorms, hailstorms and tornadoes would become more common and severe. This means that perhaps, not only the climatic conditions of the very well known countries that have been historically affected by all these phenomena will change, but also many new countries and areas will experience different catastrophic events. The first reaction of the population when suffering big losses from natural hazards is the growth in demand for insurance cover. The local insurance industry might react launching new policies without the technical and actuarial basis to develop a healthy portfolio, but their main problem is to find international reinsurance cover. After hurricane Andrew in 1992, there was a shortage of catastrophe reinsurance capacity, and this meant that international reinsurers were not interested in writing this kind of business for two reasons, among others:

- Insufficient premiums: these risks cannot be properly rated is there is not enough loss experience.
- The worrying predictions of the climate evolution during the following decades.

In spite of the pessimistic predictions, the reinsurer depends on the worldwide catastrophe capacity, never on the uncomfortable predicted future. It is a balance between supply and demand, the old story in every business.

In many countries, after the lack of international reinsurance capacity, the governmental institution in charge of the insurance

companies control (such as ANIA in Italy), have taken the initiative of creating a "pool of natural risks" following different schemes. In Spain, we have the Spanish Consortium of Insurance Compensation, which provides economic compensation for material damages caused by floods, earthquakes, windstorms, etc.

Should the private insurance and reinsurance industry or the governmental institution be responsible for the natural peril losses, a suitable technical and cartographic basis is fundamental.

2. GEOGRAPHIC INFORMATION SYSTEMS (G.I.S.)

Many businesses depend on geographic information. The development of insurance and reinsurance business is closely linked to geography. Here are some applications:

- Marketing strategies:
  - ♦ To plan the extension of portfolios to new areas where the competitors are already involved.
  - ♦ To analyze the suitability of a new product in respect of the characteristics (level of population, communication routes, standard of living) of an area.

    To plan the availability of assistance facilities (electricians, plumbers, hospitals, travel assistance) in case of loss or accident.

- Rating per zones: to analyze the suitability of tariffs in respect of different zones (cities-towns, natural hazards).

- Allocation of risks

  The underwriter of catastrophe business must have a suitable tool to allocate every risks he writes. Every risk has a sum insured for earthquake and/or flood and/or wind, etc. Every insured sum must be distributed into the reinsurance contracts. All this information must be managed over the geographic base.

- Evaluating catastrophe exposure.

The G.I.S. are a very interesting application for risk management. Because spreading risk is critical to any insurance-related strategy, it is important to

identify possible overexposure in those areas where any natural hazard is particularly high.

Once the hazards have been mapped, an overlapping with the portfolio will allow one to know the potential loss at any moment.

CONCLUSIONS

Summarizing, here are shown the weather conditions that might have direct and indirect influence in insurance and reinsurance:

Windstorms, Floods, Hail, Lightning, Droughts, Ice-Drift, Subsidence, Snow and Fog
IN
Agricultural, Homeowners, Industrial, Marine, Aviation, Engineering, Motor, Credit, Health and Life insurance

Independent of the traditional underwriting tools (charging a suitable price, deductibles, liability limits, improvement of claims settlement), the assessment of natural hazards can be considered as a triple problem:

- Risk and hazard evaluation and management.
- Knowledge of the phenomenon.
- Exposure modeling and accumulation control.

Disregarding the effects of a possible climate change, greenhouse effect and El Niño events, the statistics that are yearly published by the international reinsurers Munich Re and Swiss Re show a dramatic increase in losses due to natural disasters. The reasons that are usually attributed are:

- Increasing insurance demand and geographical density
- Improvement of standard of living
- Enormous concentrations of people and values in cities

- Rise in population
- Vulnerability of big cities
- Concentration of industrial businesses in areas exposed to natural hazards.

Insurers and reinsurers must prepare themselves for the increasing catastrophe risk, one way is the promotion of safety through lobbying for improvements in building codes in respect of natural forces, although the main role is played by market associations whose influence area is much wider. These usually publish brochures on different topics and provide the market with technical studies.

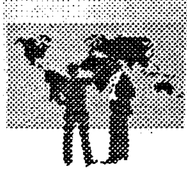
To demonstrate the important role of insurance and reinsurance industry to promote safety, just to remember that in April this year, the Climate Summit was celebrated in Berlin, during which, several European reinsurers made an important commitment, pledging to integrate environmental consideration into their business priorities. They will share environment-related information on a regular basis and at present, they are in process of drawing up a "Statement by the insurance sector on the environment and sustainable development", which will identify insurers´ commitments to environmental protection. This group will operate under the auspices of the United Nations Environment Programme (UNEP).

Let us hope that initiatives ~~meetings~~ like this and meeting like this, will promote a better understanding between scientists and the insurance-reinsurance industry.

I ERS Thematic Working Group Meeting
on Flood Monitoring. Frascati. Italy.

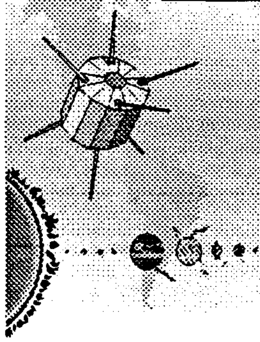
INSURANCE AND REINSURANCE

Overview on the technical needs, with an emphasis on flood risk aspects.



Mª Teresa Piserra de Castro

INTRODUCTION



- Data provided by ERS-1 and ERS-2.
- Natural catastrophes in insurance and reinsurance
- Relation insurer - reinsurer
- PML study:
  - class of business
  - type of building
  - maximum expected event
  - geographical location

MAXIMUM EXPECTED EVENT

- ✓ BAD MEMORY
- ✓ RESEARCH: Earthquakes
  Atmosphere
  (Climate Change, El Niño, Ozone Hole, Greenhouse effect.)
- ✓ SATELLITE info:
  - related to OCEANS
  - related to the ATMOSPHERE
  - related to the EARTH
  - ATMOSPHERE-OCEANS-EARTH

OBJECTIVES AND APPLICATIONS

NATURAL HAZARDS REDUCTION

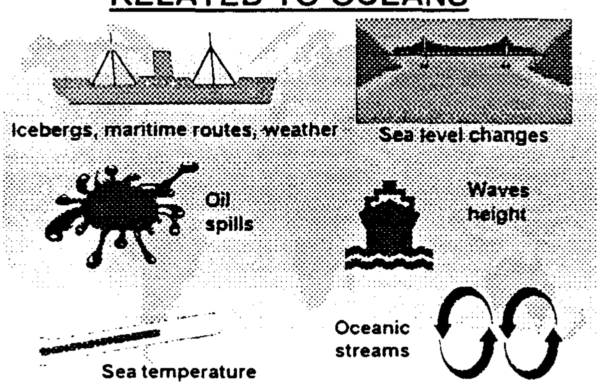
- KNOWLEDGE OF HAZARD BEHAVIOUR
- KNOWLEDGE OF HAZARD PRONE AREAS
- PREVENTION / MITIGATION
- MAXIMUM POSSIBLE LOSS
- FORECASTING
- DAMAGE ASSESMENT

REMOTE SENSED DATA- Space-, Air-, Groundborne.

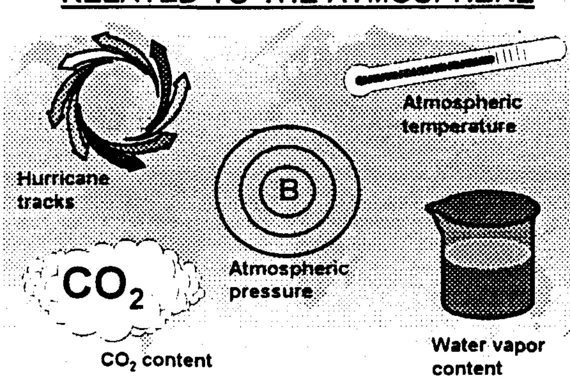
- HAZARD ASSESSMENT
- RISK ASSESSMENT
- HAZARD SIMULATION
- HAZARD FORECAST
- THEMATIC MAPPING
- ENVIRONMENTAL MONITORING

REDUCTION OF: HUMAN LOSSES, MATERIAL DAMAGES AND COSTS

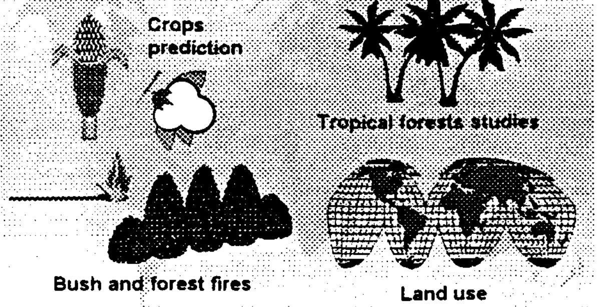
RELATED TO OCEANS



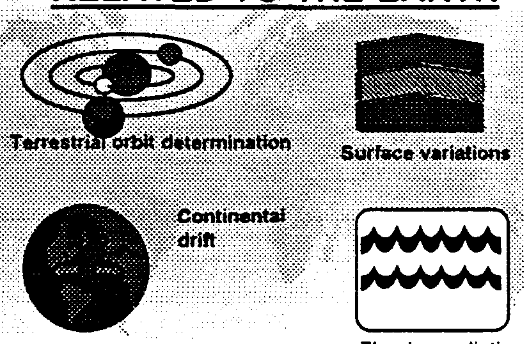
RELATED TO THE ATMOSPHERE



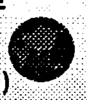
RELATED TO THE EARTH



RELATED TO THE EARTH



OCEAN-ATMOSPHERE-EARTH

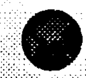


- **"El Niño" Southern Oscillation**

(Pacific = weather kitchen of the Globe)

  - Floods,windstorms, lightning on broadcasting and transmission lines.
  - Flash-floods: erosion, collapse in tunes and ditches.
  - Rain / windstorm: cancellation of outdoors events.
  - Storm surges, high tides, coastal flooding, hurricane, erosion: port and habour installations.

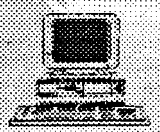
OCEAN-ATMOSPHERE-EARTH



CLIMATE CHANGE. GREENHOUSE EFFECT.

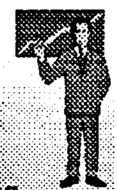
- More tropical cyclones, windstorms, flooding, thunderstorms, hailstorms, tornadoes.
- Increased intensity and new scenarios.
- Growing demand for insurance cover.
- New insurance products uncorrectly rated.
  - Worrying predictions
  - Insuficient premiums
- Some governments: Pool of natural risks
- CONCLUSION: Suitable scientifical and technical basis is required.

GEOGRAPHIC INFORMATION SYSTEMS (G.I.S.)



- MARKETING STRATEGIES
  - Extension of new portfolios
  - New products
  - Assistance planning
- RATING PROCEDURES
- ALLOCATION OF RISKS (Accumulation Control)
- EVALUATING CATASTROPHE EXPOSURE

CONCLUSIONS



- ☑ Increasing insurance demand
- ☑ Improvement of standard of living
- ☑ Concentrations p/v in cities
- ☑ Rise in population
- ☑ Vulnerability of big cities
- ☑ Concentration of industrial business in hazard prone areas

WEATHER - INSURANCE

- Windstorms
- Floods
- Hail
- Lightning
- Droughts
- Ice-Drift
- Subsidence
- Snow
- Fog

- Agricultural
- Homeowners
- Industrial
- Marine
- Aviation
- Engineering
- Motor
- Credit
- Health
- Life

INSURERS-REINSURERS ROLE

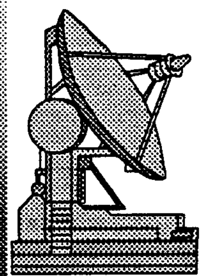
- ✓ Lobbying for improvements in building codes.
- ✓ Promotion of safety.
- ✓ Financing technical and scientifical studies (A.F.R.A.I.D. for instance¡¡).
- ✓ Reinsurance companies committee on environment - development.

PRESENTATION A.F.R.A.I.D PROJECT

Rome, 27th june
L.U.I.S.S. University

ESTA 95

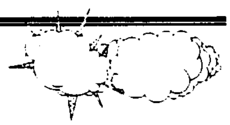
CONSORTIUM



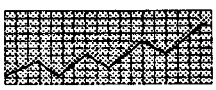
- Mapfre Re (Spain)
- C.I.A.R. (Italy)
- Cattolica (Italy)
- Ital Re (Italy)
- Nuova Telespazio (Italy)

ESTA 95

A.F.R.A.I.D.



- A
- FLOOD
- RISK
- ANALYSIS
- for INSURANCE
- DAMAGES



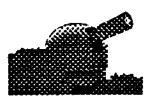
ESTA 95

NUOVA TELESPAZIO: Multidisciplinary team

MATHEMATICIAN

GEOLOGISTS | HYDROLOGISTS | ENGINEERS

TECHNICAL COMMITTEE



ESTA 95

A.F.R.A.I.D. PROJECT

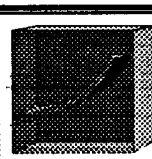
"PIXEL"

SUB-BASIN

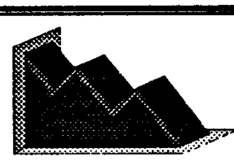
ADMINISTRATIVE DIVISION

ESTA 95

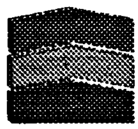
FACTORS



SLOPE



BASIN MORPHOLOGY



GEOLOGY

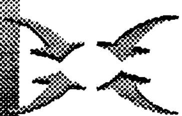
SOIL USES

ESTA 95

FACTORS (cont.)

MAXIMUM PRECIPITATIONS

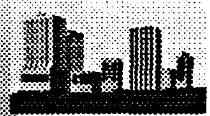
HISTORIC DATA



DISTANCE TO THE NEAREST RIVER

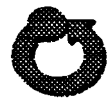
ESTA 95

EXAMPLE: SOIL USES

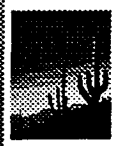


urban areas

forests



INCREASING CAPACITY OF INFILTRATION

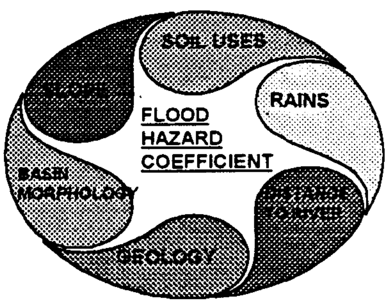


non vegetated areas

prairies

ESTA 95

FLOOD HAZARD COEFFICIENT



ESTA 95

A.F.R.A.I.D. PRESENTATION

- Your questions: next 27th June in Rome.

ESTA 95

Day 2

Identification of flooded areas in the Rhone and Var river, France, using ERS-1 data.

J.NOYELLE †, S.DELMEIRE ‡, L.MARINELLI ‡

† : Ministére de l'Environnement - FRANCE.
‡ : GEOIMAGE - Sophia-Antipolis - FRANCE.

INTRODUCTION

Following the numerous torrential floods which have affected the Southern "départements" in France since 1992, the Environment Ministry has reinforced its legislative policy concerning the prevention of natural risks and in particular of flooding, it has also initiated a programme of knowledge and cartography of the risk in relation to the rise of waters and to the urban rain flow in the thirty most concerned "départemnts" of the Mediterranean arc.

The previously established means which were based on a historical, geomorphological and hydraulic approach served to set up the first prevention and protection measures over the most vulnerable areas. But this type of study is not exhaustive and must be limited to certain areas due to the high cost involved.

Faced with this problem, the GEOIMAGE company endeavours to bring a solution to it by using remote sensing. The studies which GEOIMAGE carries out in this field aim at evaluating the rapidity and the trustworthyness of the flooding cartography with the help of satellite data.

GEOIMAGE has a particular interest in the data resulting from Synthetic Aperture Radar (SAR). In actual fact, the acquisition of data from conventional satellites (passive sensor) is seriously limited by the presence of clouds during the periods of flooding. However, the SAR which is an active sensor allows the acquisition of images by day or by night, and specially whatever the cloud cover may be. Moreover, the sensitivity to determine areas under water is a most important advantage concerning the cartography of the flooded areas.

In our study, we used the radar images from the European ERS-1 satellite because it offers an interesting geographical cover of the Rhone and of the Var valleys (South of France) and the available acquisition dates over these two zones correspond to the dates of the floods we wanted to map.

The aim of this study is to test and compare the cartography of the flooded zones from SAR images for both types of existing flooding : the oceanic floods which are slow and lasting floods, stretching over extensive areas and the torrential floods which are of high intensity but of short duration.

The selected test zones are the Rhone valley during the October 1993 and the January 1994 floods which show the characteristics of an oceanic flood and the Var valley during the November 5th, 1994 flood which presents the characteristics of a torrential flood.

METHODOLOGY

We used a multi-temporal approach to set out the flooded areas. That is to say, we use several images of the same area at different dates. One of the dates which is used must be after and the closest possible to the maximum of the flood. It is possible then, with the help of the characteristic response of the zones under water in the SAR images and by using one or two other images

(which were acquired before or after the flooding) to map the land under water at the time of the acquisition of the image showing the rise of the waters.

The response of the zones under water in the radar image will differentiate the cartography of an oceanic flood from a torrential flood one In actual fact, in the first instance the zones under water will be characterized by a low intensity response (dark pixels in the image), because in this type of flood the water being calm and flat will play the role of a mirror. On the contrary, during a torrential flood, the turbulence of the water will generate a response of high intensity in the radar image (light pixels in the image).

The images which we used are ERS-1 images in PRI mode. Before combining these images to extract the flooded areas we carried out some pre-processings.

Their aim was :

- to re-code the images on 8 bits to allow a processing with the GEOimage digital mapping workshop,
- to filter the images in order to diminish the noise caused by the speckles using a Lee's filter with a 7*7 window size,
- to modify the histograms in order to increase the contrast of the zones under water,
- to make the multi-temporal images perfectly overlapping.

These pre-processings are going to help us create a coloured composition from two or three images.

STUDY AREAS

The Rhone Valley - October 1993 and January 1994

The important floods which happened along the Rhone Valley in October 1993 and in January 1994 triggered many reactions concerning the need of having quick information at one's disposal to be able to understand the extent of the phenomenon.

GEOIMAGE was contacted at the time by various organizations which wanted to find answers to precise and urgent needs, as well as to evaluate to which extent remote sensing was able to represent a trustworthy means of mapping the flooded areas which could also be integrated as a standard tool in the study of such a phenomenon.

The Envirnment Ministry, through the DGE and the DGAD, wished to have a quick cartography of the flooded zones in order to have at their disposal a document which could be opposed to the SNCF, presenting the crossing between the flooded areas and the planned line of the Mediterranean High Speed Train.

The Compagnie Nationale du Rhone also wanted to have a cartography of the flooded areas over the whole of the Rhone Valley, between Lyons and the sea, and a cartography of the land use to be able to evaluate the impact of the flooding in economic terms.

Other more local requests also involved the same problem study. The coverage of such an important zone, even from satellite images, could represent for each of these organizations a very high cost, although a lesser one compared to the cost if the work had been carried out through traditional methods. For this reason, and as far as these various requests involved the same study area and concerned the same problem study, GEOIMAGE suggested to bring them together round a common data base and a part of the common processing.

The data base consist of :

1 - a 1/50 000th spacemap cover in 7 segments of the zone under study,
2 - a cartography of the land use according to the same cartographic gridding,
3 - a cartography of the flooded areas at the two previously mentioned times.

Concerning the January 1994 flood, we used 3 ERS-1 images. The first one, was acquired on January 3rd 1994, 4 days before the rise of the waters. This

image enabled us to locate the areas permanently under water. The two others were acquired during the flooding on January 12th and 15th.

Concerning the October 1993 flood, we used 2 images. One was acquired on October 16th, that is to say during the flooding and the other on November 16th 1993.

Plate 1 : Coloured composition on three dates over the Camargue (lower part of the Rhone Valley)

The date-channel associations are the following :

- 3rd January : red channel
- 12th January : green channel
- 15th January : blue channel

Since we are dealing with an oceanic type flood we must point out that in an image the zones under water will appear dark. From this statement we can draw the following analysis :

We can observe the rivers in black : the small Rhone and the large Rhone, the Vaccarès, Malagroy and Imperial water stretches as well as various marshes.

These water surfaces form the areas which are always under water therefore never flooded.

The magenta represents the areas under water on 12th January 1993. Therefore these areas correspond to the beginning of the flood in January. They are essentially located along the waterways and are probably caused by their overflowing.

The red represents the areas which were flooded on January 12th and 15th. We can see a large red spot located on the North-West part of the Etang de Vaccarès. It is located in the neighbourhood of marshy areas which are, therefore, more prone to flooding.

We can also observe areas which were flooded at the two dates all along the Rhone Valley. They are the result of a water surplus from the Rhone.

We can see, North of Arles, a completely straight limit of the flooded area. It corresponds to the banking of a railway line which limited the flooding and thus protected this line.

The yellow areas correspond to the areas which were only flooded on January 15th. We can locate them for instance round the big spot located on the North-West of the étang de Vaccarès.

Three hypotheses can be surmised concerning the presence of this water :

- either it rained again between January 12th and 15th,
- either water coming from the previously flooded Rhone Valley came down and spread over already flooded zones thus increasing the affected area,
- or both phenomena occured simultaneously.

Plate 2 : Spacemap of the Camargue (lower part of the Rhone Valley)

This spacemap was obtained through LANDSAT TM images from July 1993 which were satisfactory for a cartography of the vegetation and from 10m SPOT P images from February 1993 to determine the built up areas and the infrastructures.

On this spacemap we superimposed in orange the zones which were flooded on January 12th and 15th, 1994, and in yellow hatching the zones under water on October 16th, 1993. These data come from two coloured compositions which we produced from the ERS-1 images.

Plate 1 : Coloured composition on three dates over the Camargue.

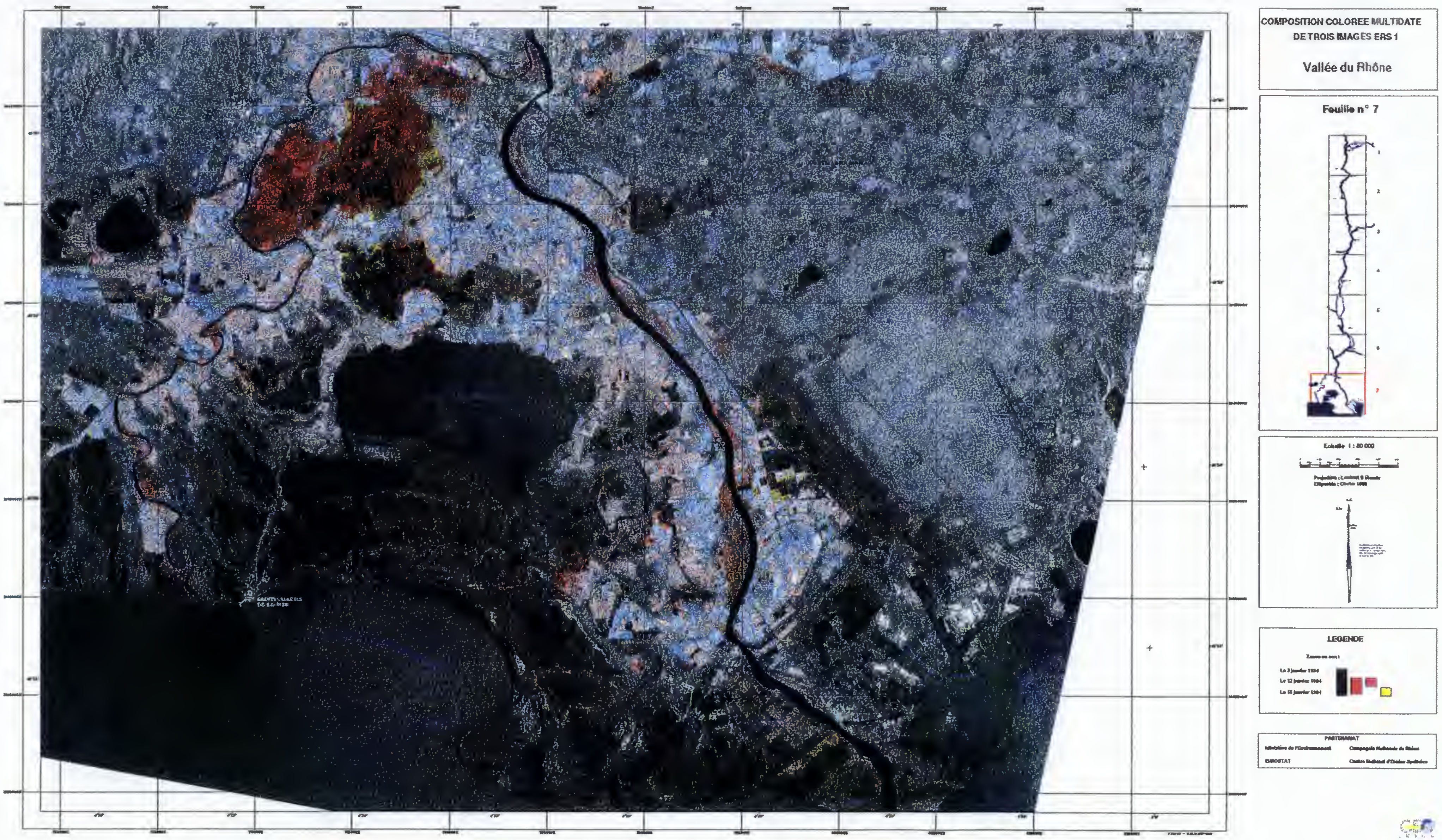


Plate 2 : Spacemap of the Camargue

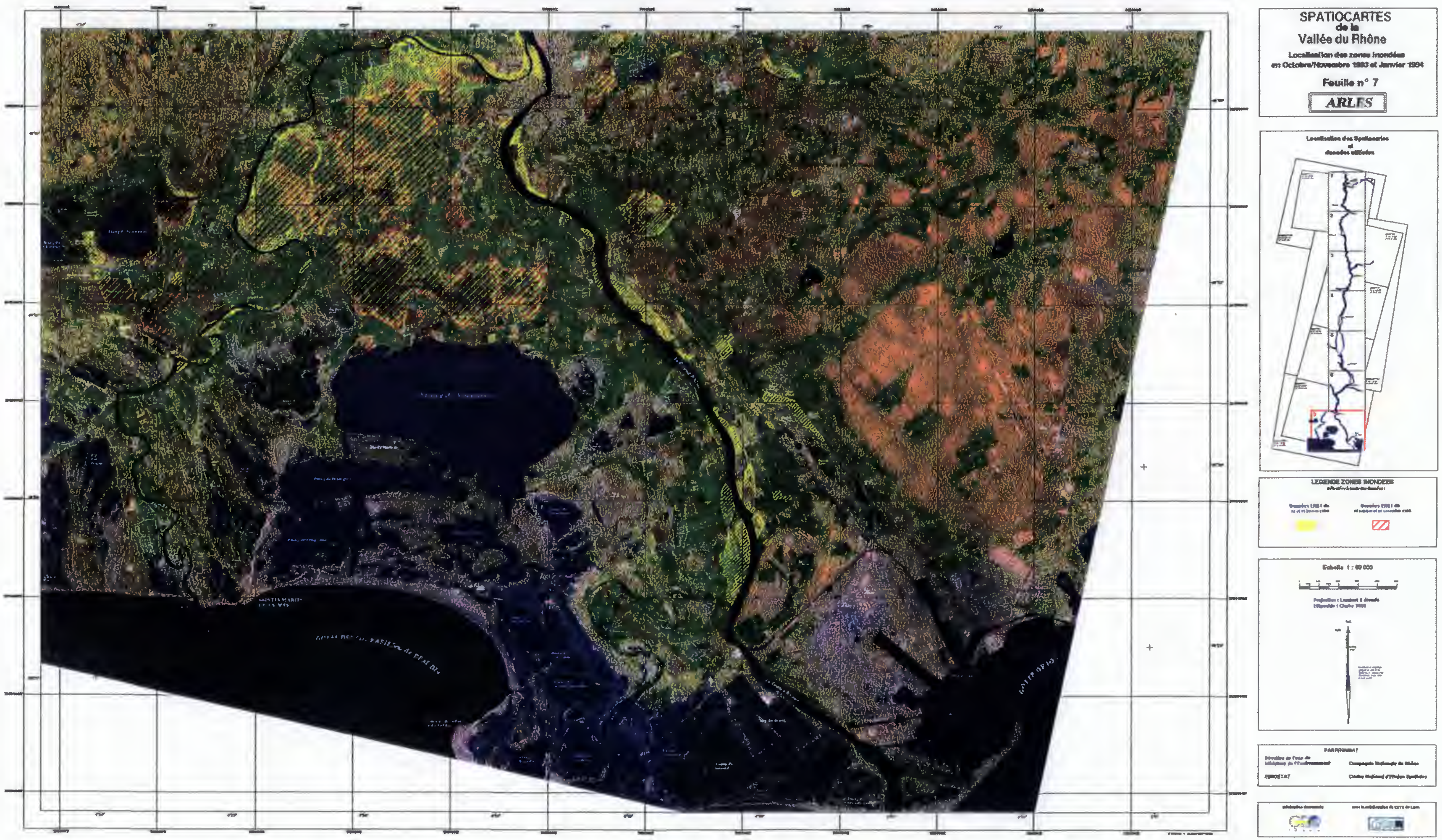


Plate 3 : Spacemap of the Avignon region (Rhone Valley)

This spacemap was obtained as previously from the combining of LANDSAT TM and SPOT images.

The areas under water on January 12th and 15th, 1994 were added in orange hatchings and the areas under water on October 16th, 1993, in yellow hatchings. The digitization of flooded zones on aerial photographs from 9th and 10th October 1993 allow a complementarity with the results which were acquired from ERS-1 images. These images are added to the spacemap and represented by an orange gridding.

Plate 4 : Spacemap of the Orange region (Rhone Valley)

This spacemap was also acquired from the combining of LANDSAT TM and SPOT images.

To this spacemap were superimposed in orange hatchings the areas under water on October 16th, 1993. In the same way as previously the areas under water acquired from photo-interpretation of aerial photographs on October 9th, 1993 were added in orange gridding. It can then be noted that the zones under water which were detected through SAR images and through aerial images correspond to each other. Thus, the cartographic technique of the areas under water from ERS-1 which is used in the case of oceanic type flooding is validated.

Var Valley - November 1994

The area of the Alpes-Maritimes on which GEOIMAGE had an important data base from remote sensing was selected due to the topographical and hydrological characteristics which are favourable to torrential type flooding.

At the beginning of 1994, a water rise of the most important river of the Var "département" took place. We, then, tried to map this water rise. To do this, we acquired two ERS-1 images. One from November 6th, 1994, that is to say the day after the beginning of the water rise. The other one before the water rise dating from October 20th, 1994.

But in this type of water rise, the cartography of the flooded areas seems to be more difficult than the cartography of an oceanic flood. In actual fact, in the case of the Var Valley, the rise was quickly limited by the relief and did not spread very much. Therefore, because of ERS-1 resolution, the floods generated by this type of water rise are not easily noticeable. Moreover, the lower part of the Var valley is located in an urban periphery and therefore, the strong spectral response of the buildings in the image affects its distinction from the water.

However, GEOIMAGE has started a study in collaboration with the Environment Ministry to establish a cartography of the flood risk.

To do this, a data base of the risk has been consituted from :

- a Digital Elevation Model produced from SPOT stereoscopic couples
- the land use

Taking the DEM into account it is possible to describe the relief by determining the slopes, the drainage basins and the hydrographical network.

All these parameters will then enable us to modelize the potential local or cumulated flowing into the hydrographical network. From this modelization, we can get a realistic simulation of a flood.

Plate 3 : Spacemap of the Avignon region (Rhone Valley)

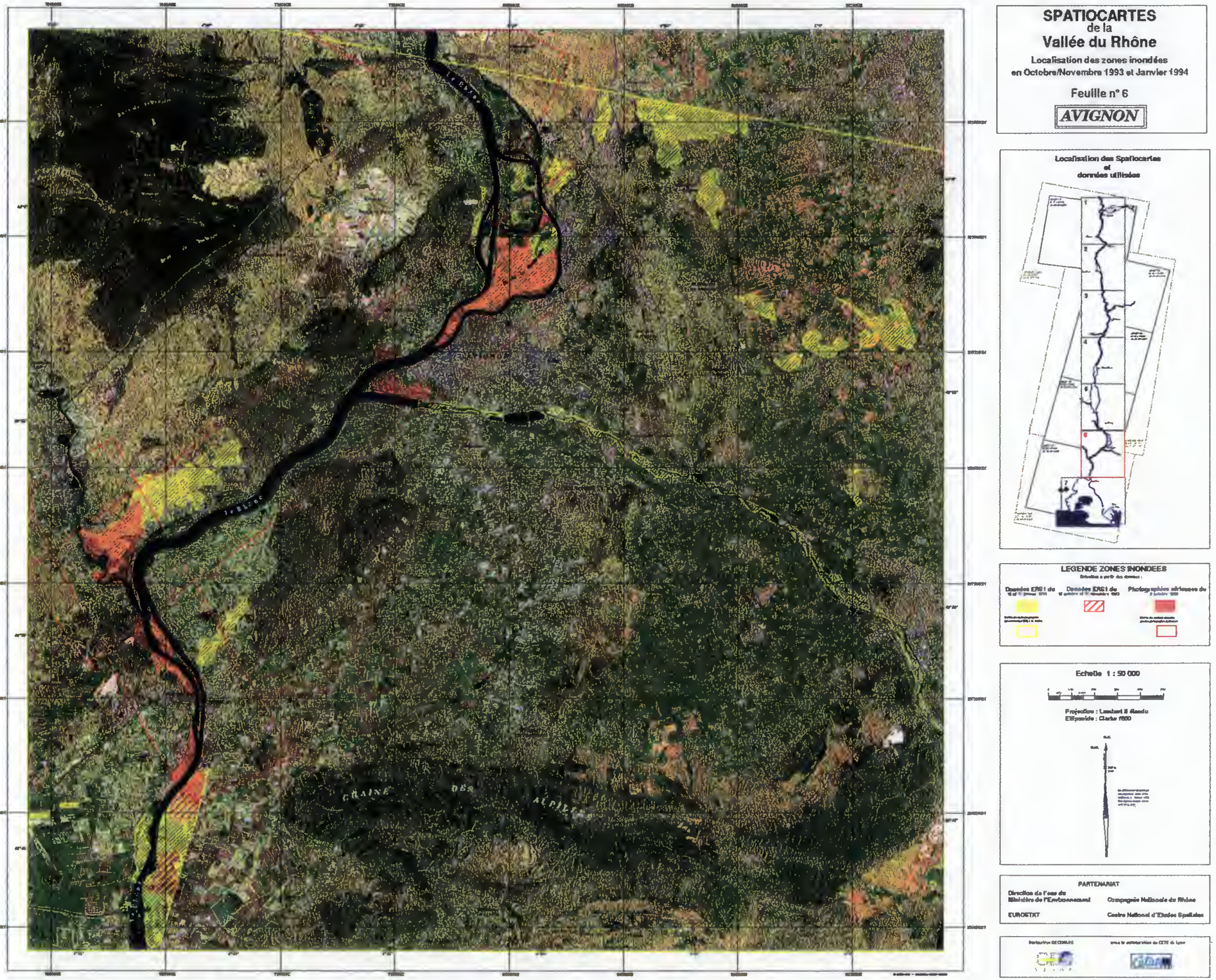
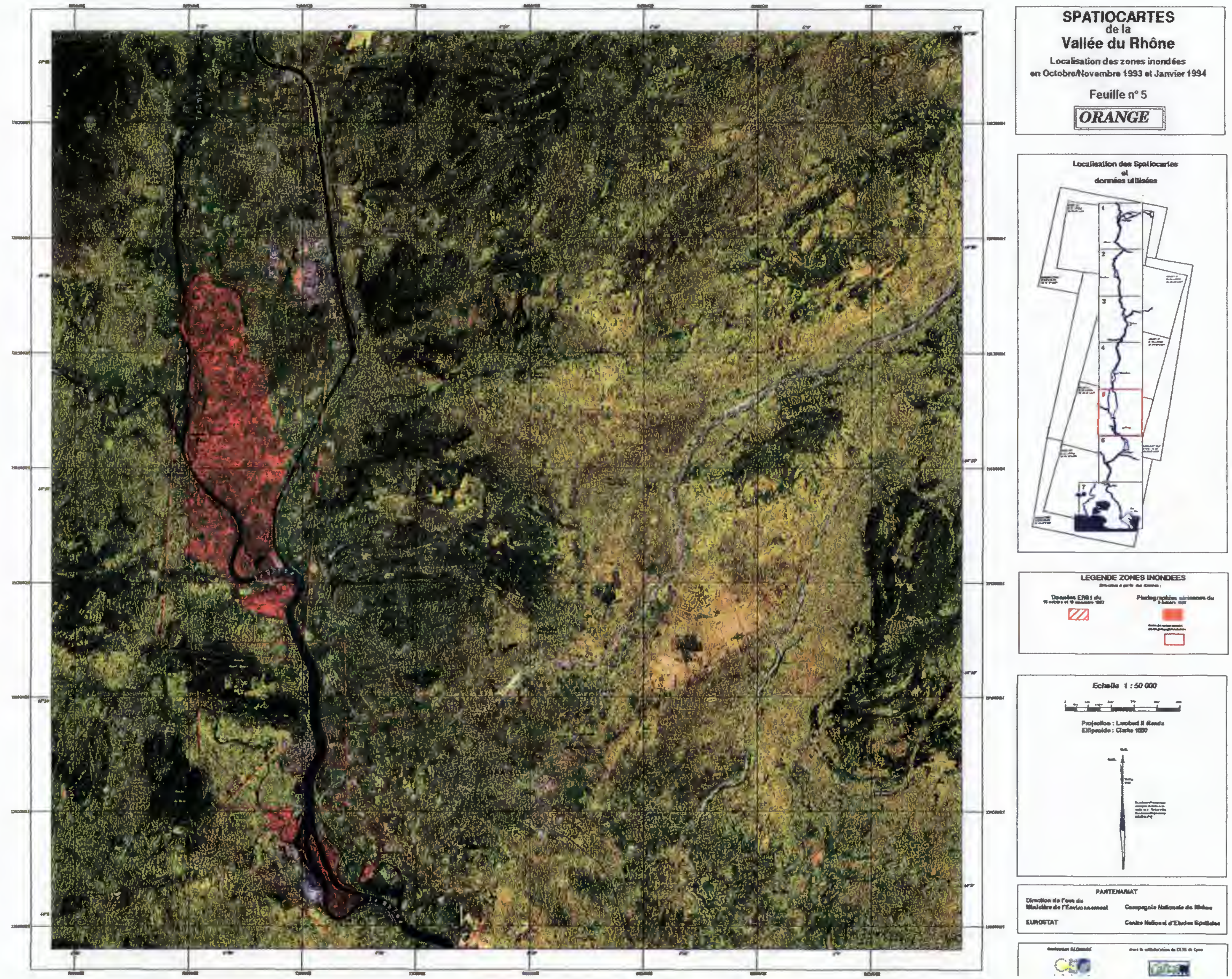


Plate 4 : Spacemap of the Orange region (Rhone Valley)



This simulation takes into account :

- the DEM
- the hydrographical network
- the water heights in the network which are determined from the real and weighed flow by real pluviometrical data;

The use of real data enables us to calibrate the model.

Plate 5 : Coloured composition of 2 dates on the Var Valley

The date-channel associations are the following :

- 6th November 1994 : red channel,
- 20th October 1994 : green channel,
- 20th October 1994 : blue channel.

Since we are dealing with the case of a torrential type water rise, we must point out the in an image the areas of the water rise will appear light. From this statement we can draw the following analysis :

The areas of the water rise appear in red in the image. But we can notice as we remarked previously, that it is diffcicult to distinguish the areas under water which are located outside the river bed. Normally, the Var river only occupies part of its bed.

Plate 6 : Realistic simulation of a flood in the Var Valley

In the drainage basin of the Var, we superimposed several simulations of water rise over a land use map. In dark blue, we get the limits of a flood in the case of a flow at the mouth which was obtained during a centenial water rise. In order to emphasize the visual effect, we placed in light blue the water rise obtained from a flow ten times higher and in cyan the water rise obtained from a flow 100 times higher than the centenial water rise one. By crossing the results with the land use, we can, in this way, deduce information about the potential damages caused by a flood.

FLOODING SIMULATION IN THE CATCHEMENT AREA OF THE VAR RIVER

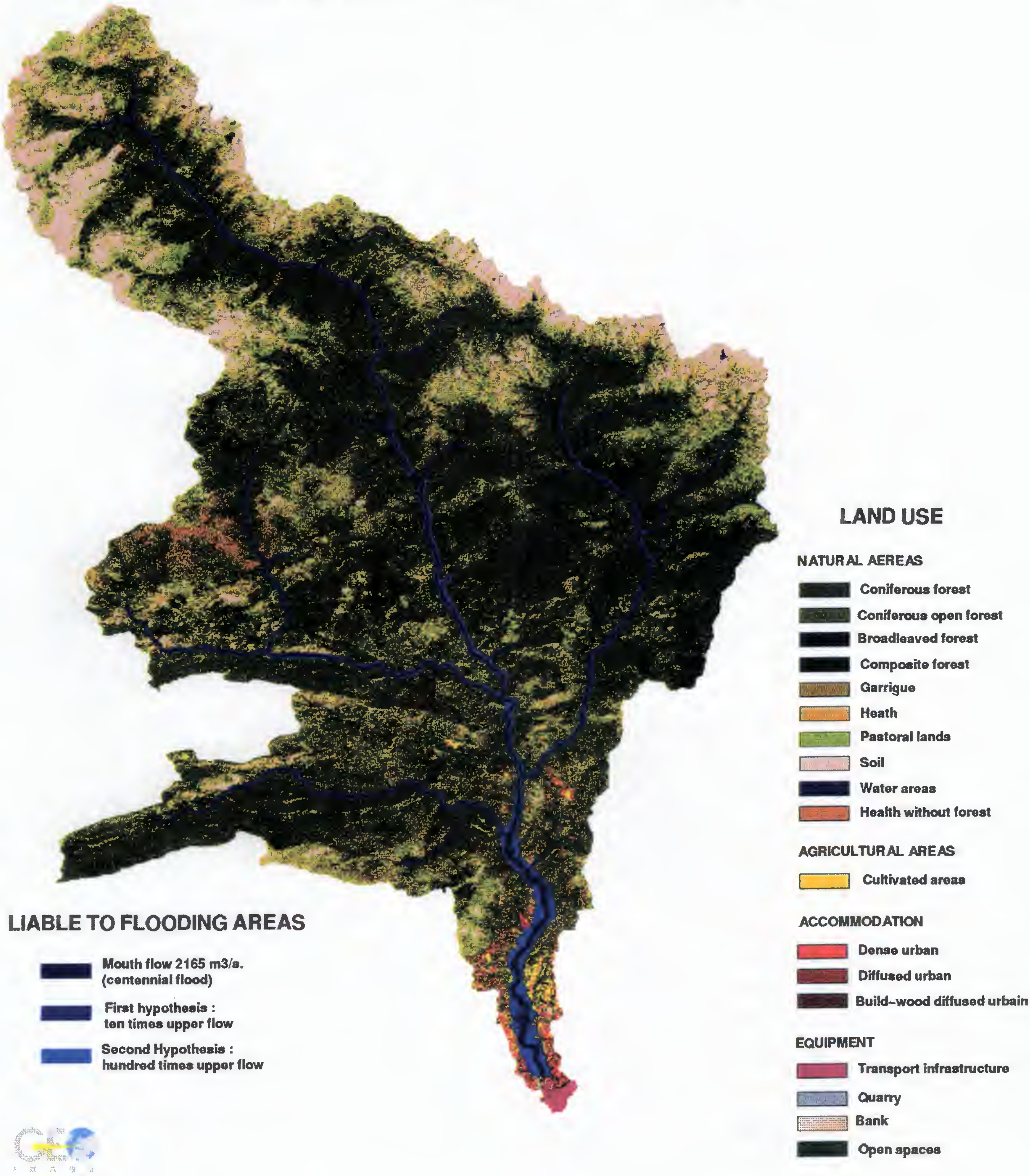


Plate 6 : Realistic simulation of a flood in the Var Valley

CONCLUSIONS

The cartography of the torrential type floods from SAR images does not give obvious results in the case of our study on the Var Valley. This is due to the small surface of the areas under water and to the difficulty in differentiating the response of the water from the land above water. The simulation can then be a help to the cartography of such floods.

However, in Camargue, where the perios of settling and removing of the phenomenon are spread over several weeks (oceanic type flood), even over several months, the radar datum offers a quick and precise mapping tool of the the zone which is affected by the flood.

In order to explore deeper into the possibilities of the radar images to map the flooded areas within oceanic or torrential type water rise, the CNES and the Compagnie Nationale du Rhone carry out a research programme, led by GEOIMAGE, on how to determine from radar or optical images "flood reoccurence" zones. In actual fact, if the radar images allow the discarding of the cloud cover problem, they are still affected by constraints of periodicity of acquisition. During the October 1993 floods, the ERS1 satellite was in image acquisition phase over the same geographical zone every 35 days. In the case of a torrential water rise, it made it nearly impossible to have images at a date sufficiently close to the maximum of the flooding in order to map the limits accurately. Therefore, it was necessary to try and set out in a direct way the submersion of a given area during the maximum of the flooding but which was not submerged at the (ulterior) date of the acquisition of the satellite image. Such a reoccurence phenomenon was already set out from optical (Spot XS) images during an important water rise in 1989 in the Sidi Bou Said region in Tunisia. The aim of the methodological study led by GEOIMAGE is to try and set out this same phenomenon on radar data which are acquired before and after the water rise.

Applications of Landsat TM and ERS SAR data to flood prevention and flood damage assessment

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Remote sensing data has recently become an important source of information for hydrological applications. In particular, the use of satellite imagery has been fundamental in the field of flood prevention and flood damage assessment. This paper is related to the current research activity of the Civil Engineering Department of Florence University on this field. The Department is presently co-ordinating a research project aimed at developing an advanced monitoring system of the Arno River basin (Tuscany, Italy). On this behalf, two investigations have been carried on concerning the use of remotely sensed data both in monitoring flood risk and in analysing flood events. These projects have been sponsored respectively by EOSAT and Eurimage. The following paragraphs deal mainly with the practical applications of the results, describing it to hydrologists which are looking for new sources of information.

Flood Prevention

The application of satellite data to flood prevention concerns the modelling of hydrological processes in a river basin. This task has a fundamental importance in river catchments characterised by fast response to storm events. In such basins, structural works are not sufficient to avoid the danger of floods, and real-time monitoring systems are necessary to improve flood danger forecasting and give the necessary advance notice to competent authorities.
Real-time monitoring systems are based upon hydrological models that are able to describe the processes occurring in a river catchment as a consequence of a storm event. Once the hydrological processes have been modelled with sufficient accuracy, it is possible to use rainfall measurements acquired on the ground and sent in real time to the processing centre to evaluate the risk of flooding. The modelling stage represents the main difficulty in building such a warning system. In recent times, the availability of powerful computer resources allowed the development of distributed hydrological models. In such models, the study area is divided into cells of adequate size, and for each cell both hydrological parameters and rainfall input are defined. Distributed models allow to describe the hydrological processes taking into account the spatial variability of soil properties in the study area and the distribution of rainfall in time and space.
The crucial problem in developing distributed models is related to data availability. Distributed models require the knowledge of hydrological parameters with high resolution in space and/or time over the study area.
Remote sensing represents the most promising solution to this necessity. Remote sensors do not measure directly hydrological parameters; however, they offer areal measurements, high resolution in space and/or time, and are economical. Space-borne sensors measure the average radiance reflected or emitted from a portion of the earth's

surface. They do not therefore measure directly hydrological parameters but provide information that may be related to them. Also, satellite data are areal measurements that are acquired at the same point in time on a regular grid. This represents an improvement upon the traditional ground measurements which are point based.

A research project on the applications of Landsat Thematic Mapper data to hydrological modelling has recently been carried on at the Civil Engineering Department of Florence University. The research has been sponsored by EOSAT's Grant Program.

The purpose of the work was to use Landsat TM images to obtain information on model parameters, such as maximum and minimum infiltration velocity, and model variables such as soil moisture. The sensor TM mounted on-board the actual Landsat satellite is able to detect and record the solar energy reflected from the earth's surface with a ground resolution of 30m by 30m in six wavelength intervals belonging to the visible and infra-red regions of the electromagnetic spectrum. It measures also the radiation emitted from the earth in one thermal infra-red channel with a ground resolution of 120m by 120m. The study area was the ValdiNievole watershed, a sub-basin of the Arno River basin (Tuscany, Italy).

The results obtained may be summarised as follows:

- *Hydrological parameters*

  In the present work, a correlation between hydrological parameters (infiltration velocity and accumulation capacity) and several indexes obtained from TM images has been carried on. A good relationship has been found. Once established, this correlation has been used to obtain estimates of hydrological parameters for neighbouring areas characterised by similar pedological and vegetation conditions. This methodology has been applied to two sub-basins of the ValdiNievole; the results obtained are visible in Fig. 1.

- *Soil moisture*

  The determination of soil water content is one of the main steps required in the simulation of watershed response to a storm event. Appropriate treatment of Landsat TM images allows to map soil moisture with a sufficient accuracy for modelling purposes. The best results have been obtained using spectral decorrelation techniques to extract soil response from the signal. It leads to good results if the training stage is carried on a set of several TM images acquired during a year, to obtain spectral signatures of surfaces in different vegetation cover conditions. An example of a soil moisture map is shown in Fig. 2.

The correlation between TM data and hydrological parameters/variables are related to the pedological class of the area under examination, and cannot be applied to areas characterised by different kind of soils. However, the methodologies proposed have general validity and may be applied to the hydrological modelling of any watershed.

Monitoring Activities: a case study

Landsat TM data is widely used to inventory flooded terrain's. Their usefulness is however limited by the presence of clouds over the damaged areas. Clouds interfere with the visible and infra-red radiation, and thus prevent this type of sensor from obtaining an image of the earth's surface. In this case, images acquired by radar systems are used.

A space-borne active radar system transmits signals in the microwave range of the electromagnetic spectrum. In contrast to visible and infrared remote sensing, imaging radar's generate and transmit a signal toward the surface and receive the returned signal after its interaction with the target. The radar signal can penetrate cloud cover mainly due to the fact that clouds are composed of droplets with a typical diameter much smaller than the microwave wavelength. Images acquired by radar sensors are very useful when bad weather conditions affect the area to be sensed as commonly occurs during and after a flood. This is particularly important in creating an inventory of the flooded areas immediately after the event.

This research was aimed at testing the utilisation of ERS-1 SAR (Synthetic Aperture Radar) imagery in discriminating flooded areas immediately after a flooding event.

In radar images, the strength of the returned signals from the surface is influenced by a number of ground parameters, the most important being the average surface roughness of the sampled area. Horizontal smooth surfaces, such as inland water bodies, reflect nearly all incidence waves away from the radar. The weak return signal is represented with a dark tonality on radar imagery, and it is easily distinguishable from the higher response of vegetation and land. The penetration capability of microwave radiation (up to several metres depending on the media type) allows for the precise location of swamped areas even if the water only partially covers the vegetation. Some difficulties may be found only when the flooded terrain is covered by a dense wood of tall trees. A high ground resolution (12.5m by 12.5m) is another advantage which enables the analysis of even the smallest events.

The study area is the Nievole River Basin, a sub-catchment of the ValdiNievole (Tuscany, Italy).

The time of study was during a period of heavy rainfall and consequent flooding in October/November 1992. Two SAR images were obtained for this period, one before the flooding occurred (16/10/92) (see fig. 3a), the other 4 days after the flood (04/11/92) (see fig. 3b).

Visually, the images showed a distinct temporal difference in the region of study, the post flooding image having a much darker tonality with greater coverage area. This feature of SAR imagery was used to obtain the following separate results:

1) the inventory of the flooded areas by the visual analysis of the image.

2) the prediction of the extent of flooding by the analysis of the signal variations.

The first method involved obtaining the level of correspondence between the ground truth data and the data received in the form of an image. The ground truth data was obtained by the human observation of the flooded areas and then drawn on to a map. These maps of the flooded area were digitised and then overlain onto the images. The ground truth data was found to have inaccuracies due probably to the use of only one map and one outline of flooding to show three years of flood data.

Past surveying methods as described above have proved an inexact art and are often time consuming. The research has therefore involved the development of a variety of methods to extract the cells that represent the flooded areas of an image. This can then be used in the production of a flood extent map (see figs. 4a and 4b).

Relief

Relief is perhaps one of the most important aspects of flood monitoring. The need to know the flood affected area, the amount and type of damage sustained, and what is

needed to relieve the immediate consequences, is uppermost. The swift evaluation of the situation would therefore allow more time to be allocated to the relief of the flood instead of the assessment. SAR imagery can provide such information (see below) as obtained by the research.
The flood extent map can be used in combination with the pedological map (fig.5a), the land use map (fig.5b), the digital terrain model (DTM) (fig.5c), and the channel network vector layer, and any consequent combination of these, to provide more detailed information on the flood statistics. Information such as average flood height and volume for each individual soil type and land use class can be provided and prove useful for the estimation of crop or structure damage. Flood path and life can be evaluated if there is a sequence of images covering the flood event. An example of information which can be provided is given below in the form of flood risk and damage assessment maps.
The flood extent map was firstly combined with a digitised pedological map of the area. The proportion of flooded area of each individual soil type to; total study area, total flooded area, and total area of respective soil type, was then obtained. From this, areas of high flood risk were determined. The area which was shown most at risk produced an 85% increase in water coverage and the area which was the least at risk only a 1% increase. It was shown that the high risk areas at this time, four days after the flood, were those occurring towards the outlet of the Padule, as would be expected. The final flood risk map, (see fig. 6a) contains, in order, the areas of soils which show a greater increase in water coverage at the time of the flood, and not the soils which have a greater percentage of their area under water since it is more important to know which areas would be the most affected. A vector layer of the channel network has been overlaid onto this map to demonstrate that the areas most at risk are also near a denser assembly of channels.
The same processes were carried out with a digitised land use map. With these results an assessment of the damages to crops and structures involved was determined and a map of the damages produced (see fig. 6b). The major casualty was the pastures and unproductive land with a 39% increase. These are already well known as flood risk areas and are therefore left uncultivated to lessen the economical effects of flooding. On the contrary, areas with greenhouses are located on land with a very small flood risk.

Conclusions:

Remote sensing data is a powerful tool for the provision of information for flood control purposes. Their application to flood prevention regards mainly the estimation of hydrological parameters and variables to build distributed hydrological models. A guideline methodology has been proposed to estimate such data, but their effectiveness depends on the characteristics of the study area and on the available ground truth.
The use of remote sensing data in the stages of flood extension monitoring is more standardised and is therefore of a greater value to the post flood relief. The final products can also be produced within a short time period. The flood extent maps can be ready within 1 day while more sophisticated analysis may require up to 3 working days from the time of acquiring the images (if ancillary data is already available). This efficient procedure improves dramatically the time needed for the survey evaluation. There is an availability of a variety of formats such as traditional cartography output on

paper or digitally, e.g. - raster: - ERDAS format, generic binary data, tiff; vector: - ARC/INFO format, dxf; or other specified by the client. Modern communication systems allows data to be transmitted electronically via modem, network or fax. The combination of all of these factors leads to a fast and efficient provision of a precision product to aid flood prevention and flood damage assessment.

References

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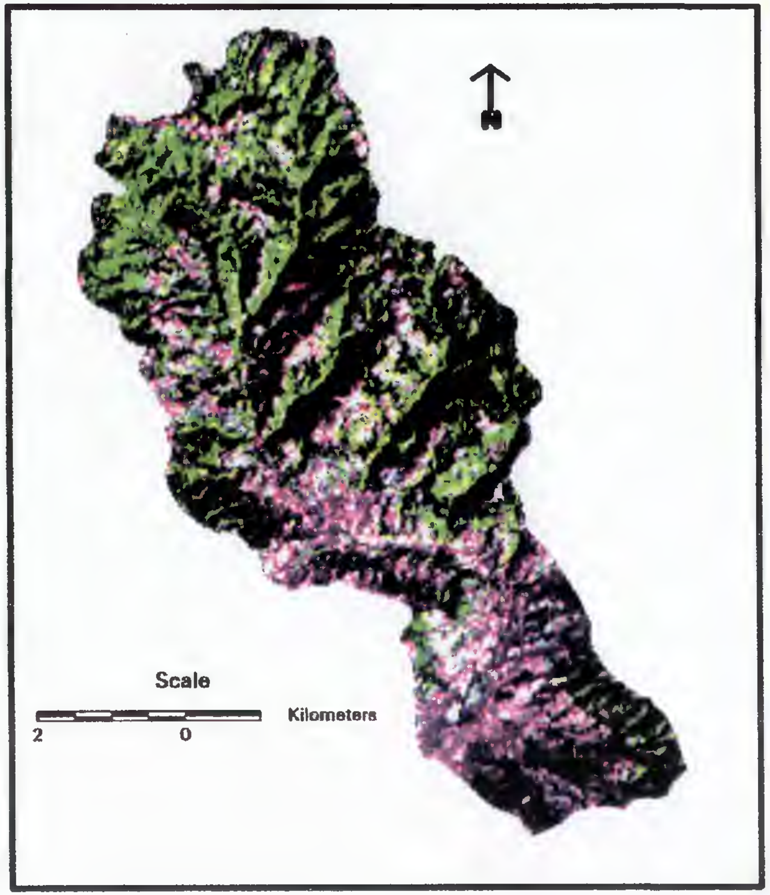
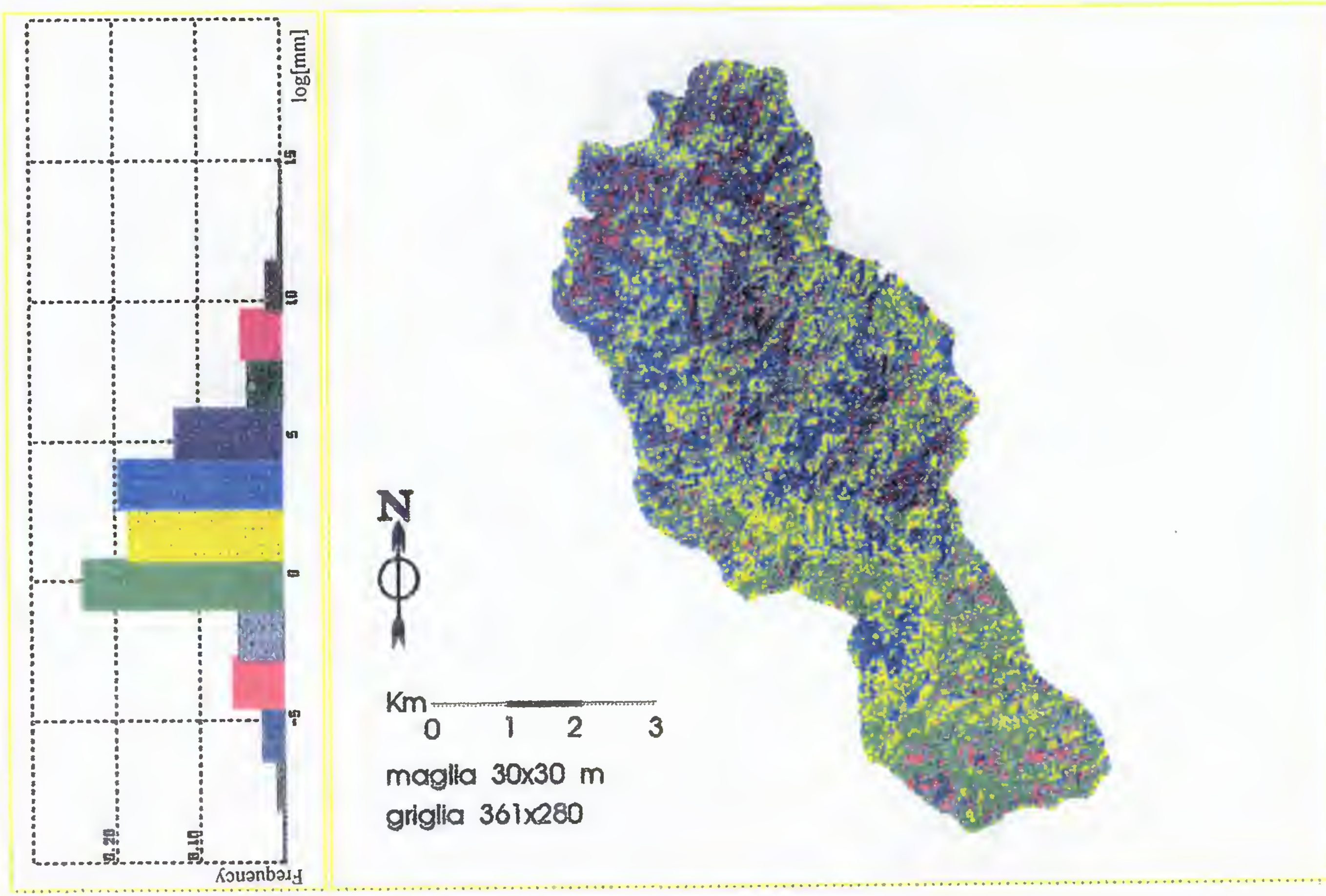
MacIntosh H. (1994) - *Remote Sensing Data Integration in Hydrological Modeling and Water Resources Management.* Eurimage Research Project, Final Report, 15 pp.



1.a



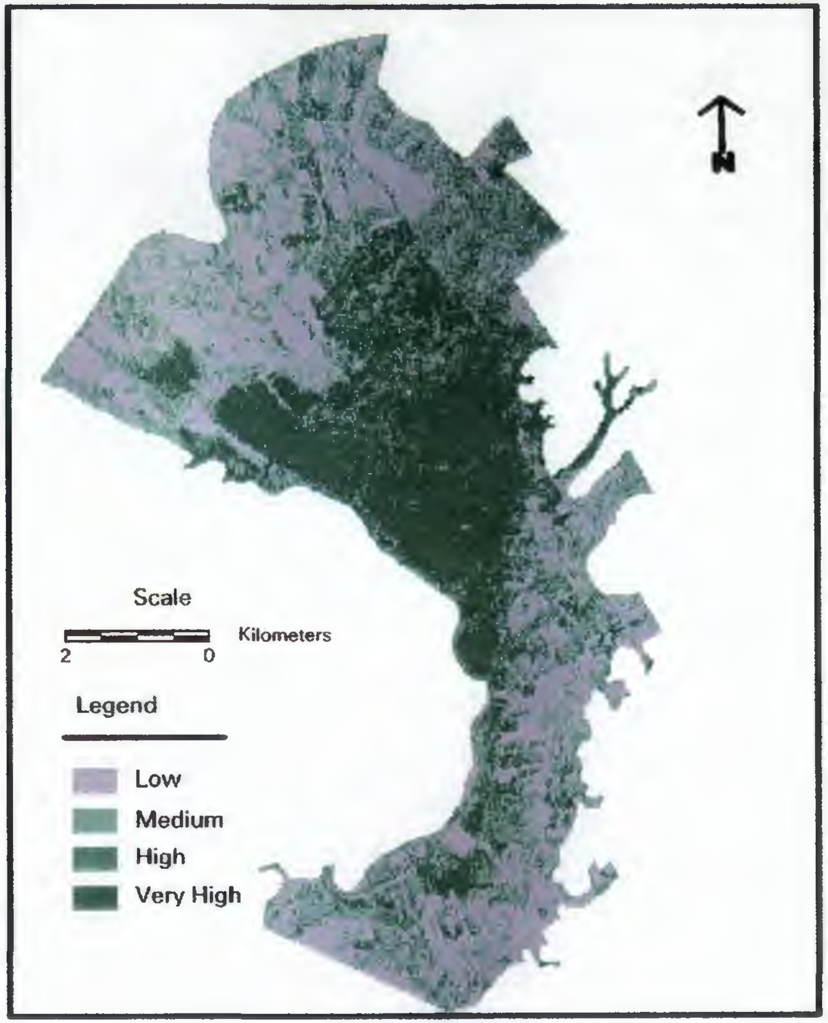
1.b

Figure 1.
Example of hydrological parameters' estimation through Landsat TM data: a map of maximum accumulation capacity of terrain.

1.a Landsat TM image of the Nievole River watershed (Tuscany, Italy) acquired on September 24, 1991. Colour composite: band 7 in red, band 5 in green, band 3 in blue.
Green areas correspond to vegetation; water is blue; bare soils and urban areas appear in different shadows of pink.

1.b Raster map of the maximum accumulation capacity of soils in the Nievole River basin [log_mm].

2a



2b

Figure 2

Example of soil moisture estimation by means of Landsat TM data

2a. Landsat TM image of the Fucecchio Marsh acquired on January 27, 1991. Colour composite: band 7 in red, band 5 in green, band 3 in blue. Green areas correspond to vegetation: moist terrain is black; bare soils and urban areas appear in different shadows of pink.

2b. Decorrelated Soil Moisture Index of the Fucecchio Marsh. Quantitative soil moisture maps are obtained calibrating this index with rainfall data.

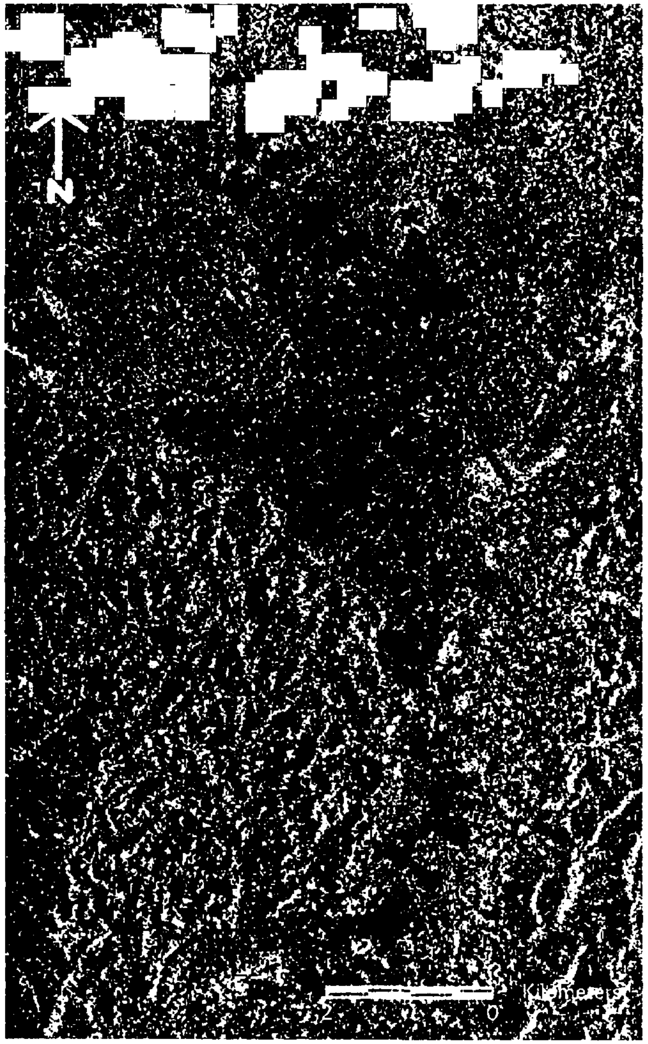


Fig.3a: ERS-1 SAR image, October 16th, 1992

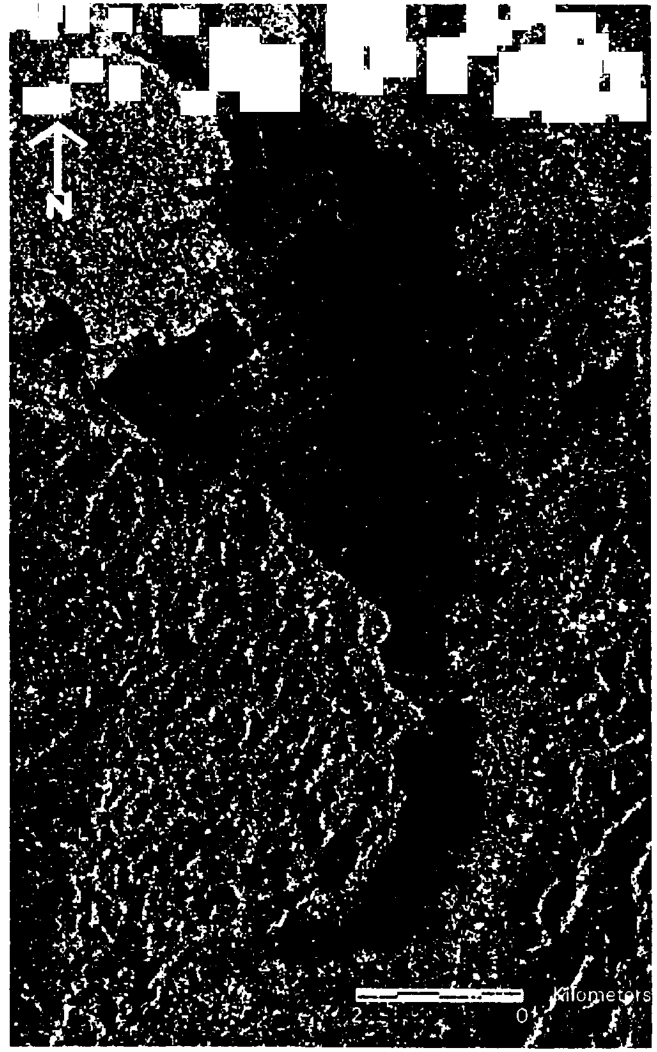


Fig.3b: ERS-1 SAR image, November 4th, 1992

Fig 3: These SAR images show the Fucecchio marsh before and after the flooding event of October 31st, 1992. Rivers and swamped areas are dark.

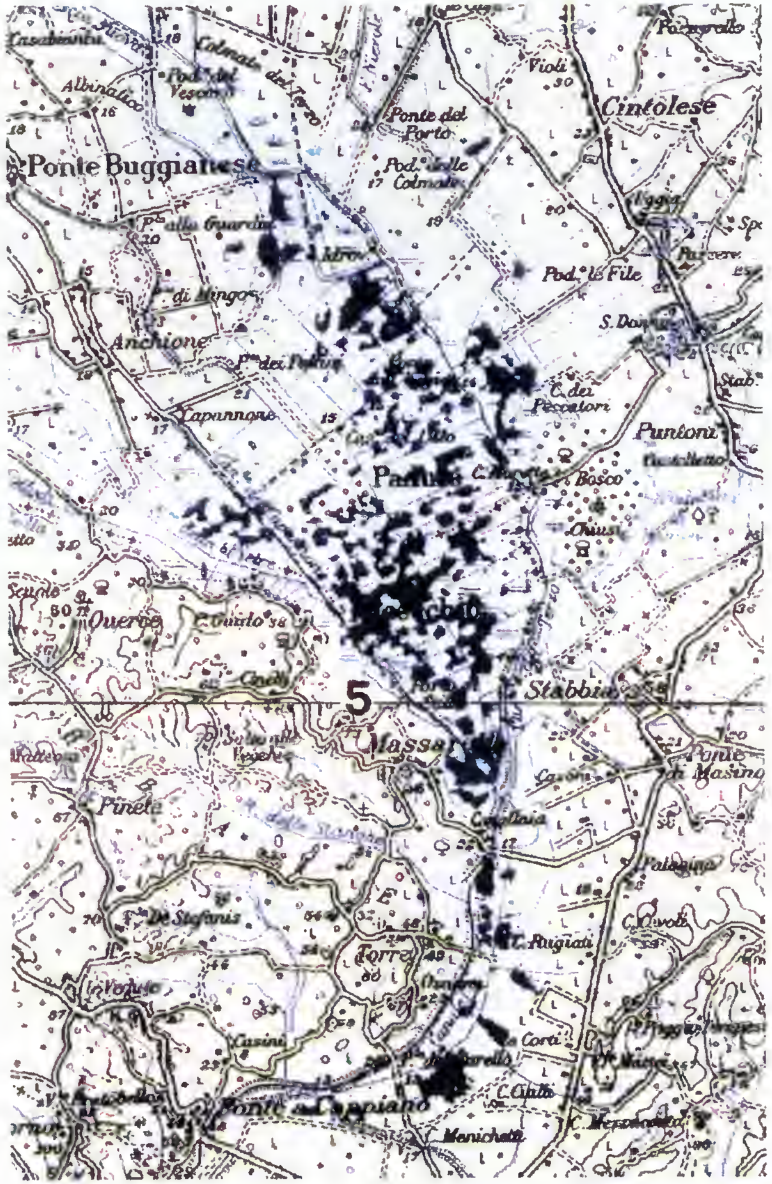


Fig.4a: Flood extent map of the Fucecchio Marsh.
Image info: Date - 16/10/92 Time - 10:02 Pix.res. - 20m.
Map info: No. - M691, Lucca 105 Scale - 1:100 000
Projection - U.T.M.
Areas in blue represent water and covers 4.94 sq. km.

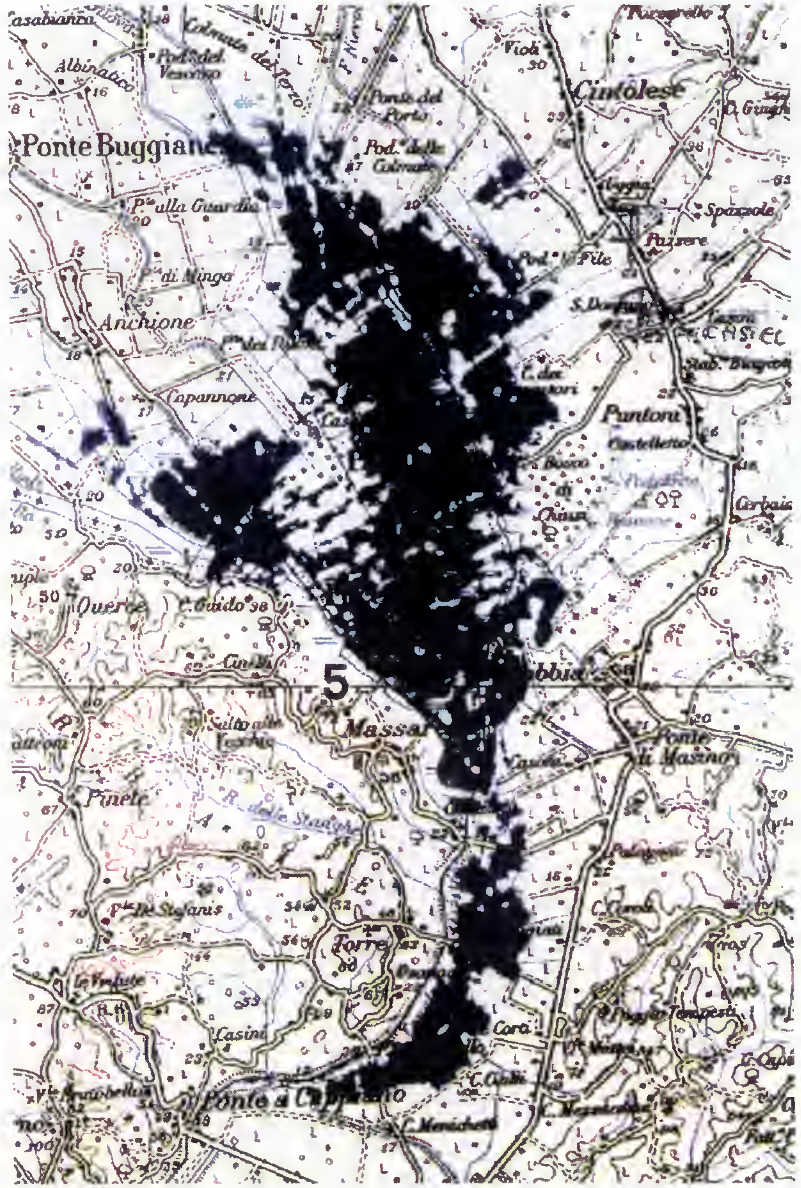


Fig.4b: Flood extent map of the Fucecchio Marsh.
Image info: Date - 4/11/92 Time - 10:05 Pix. Res. - 20m.
Map info: No. - M69, Lucca 105 Scale - 1:100 000
Projection - U.T.M.
Areas in blue represent water and covers 16.94 sq. km.

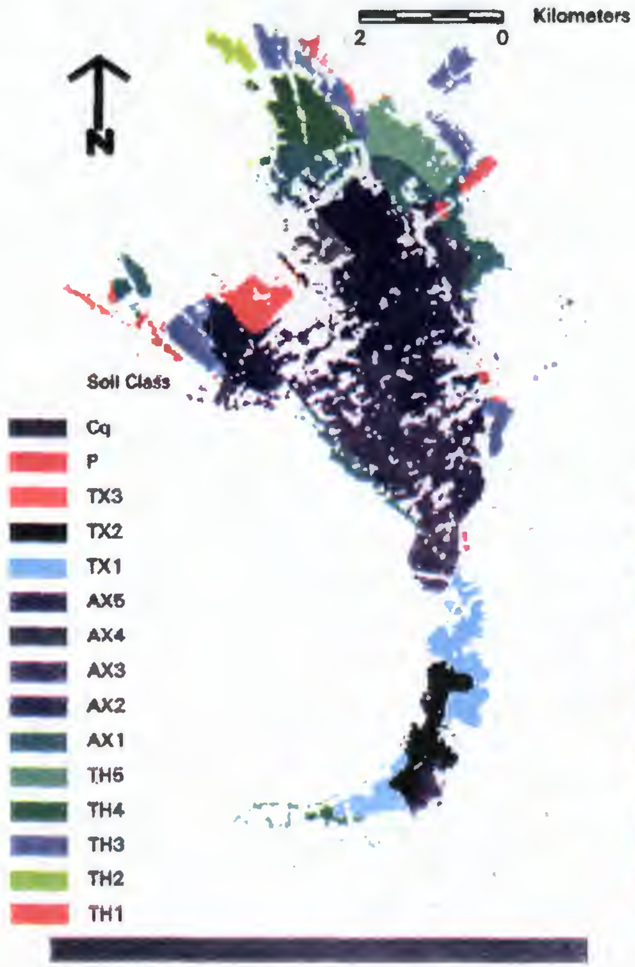


Fig. 5a: Flood map extent map (4/11/92) in combination with the pedological map of the Fucecchio Marsh.

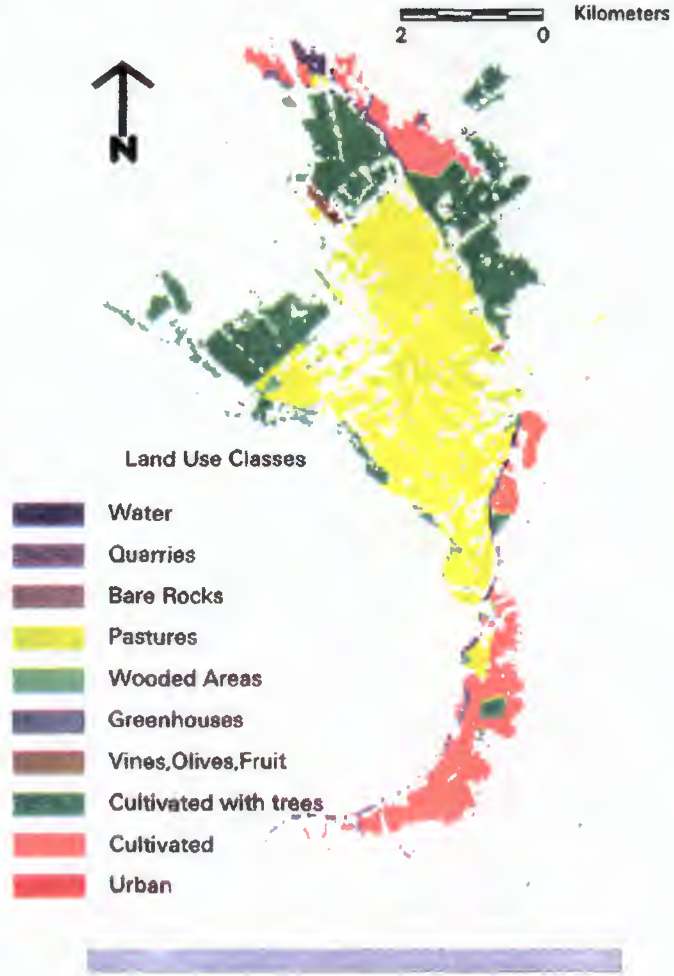


Fig. 5b: Flood extent map (4/11/92) in combination with the land use map of the Fucecchio marsh.

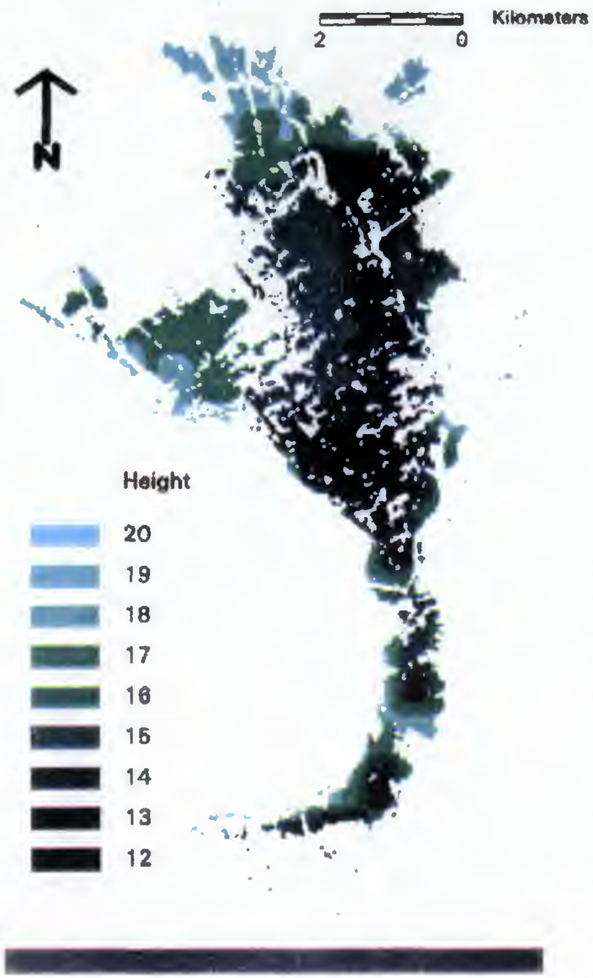


Fig. 5c: Flood extent map (4/11/92) in combination with the digital terrain model of the Fucecchio Marsh. Height is above sea level.

Fig.6a: Flood risk map of the Fucecchio Marsh as at 4/11/92, overlain with the river channel network. The various shades of green represent different soil types.

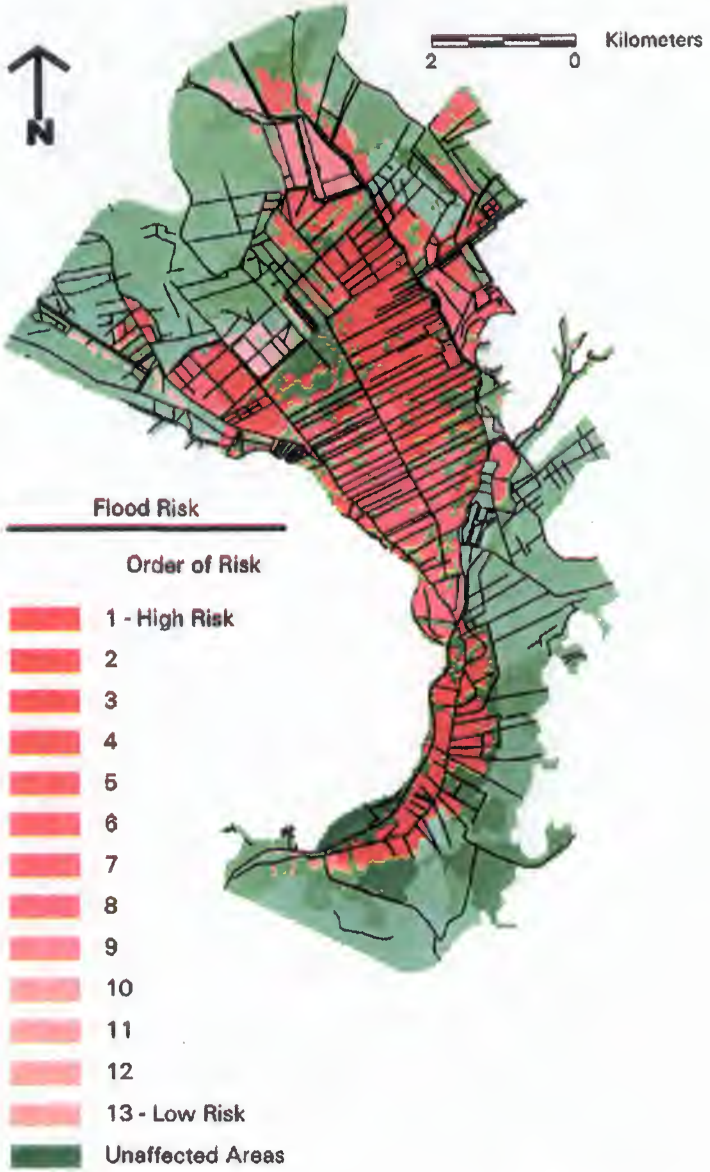


Fig.6b: Damage assessment map of the Fucecchio Marsh as at 4/11/92, overlain with the river channel network. The various shades of green represent different land uses.

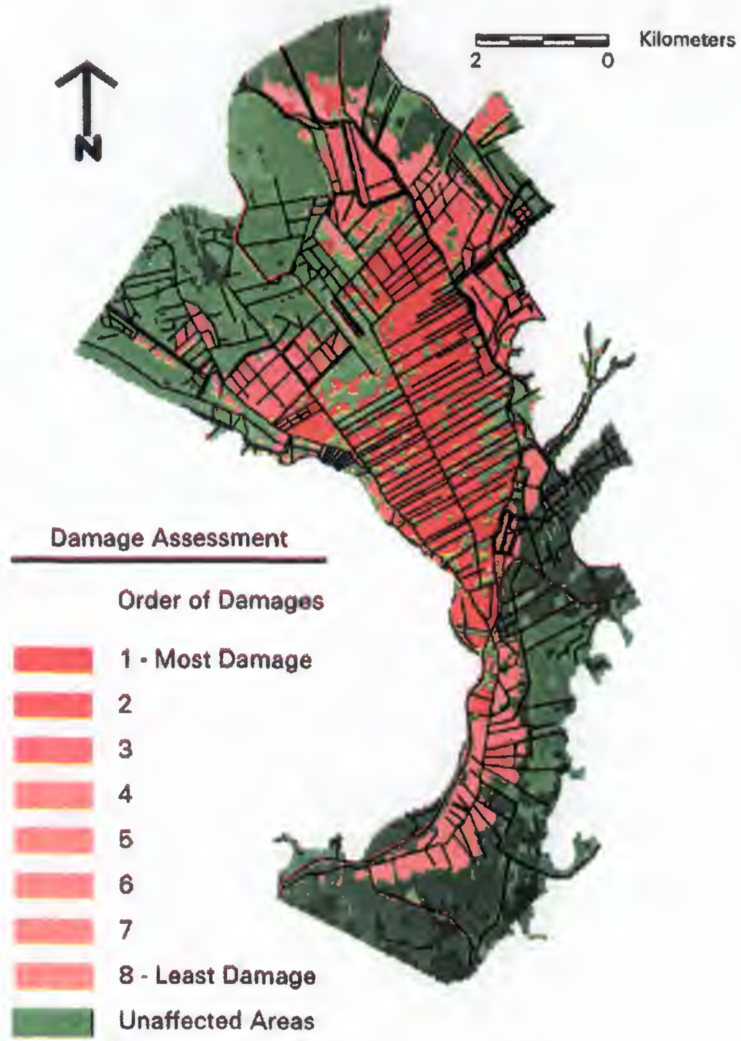


Fig. 6: Flood Risk and Damage Assessment Maps

First ERS Thematic Working Group Meeting on Flood Monitoring
26-27 June 1995, ESRIN, Frascati, Italy.

Issues of hydraulic model validation and design using remotely sensed data

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Abstract

A critical problem in the application of sophisticated high resolution hydraulic models to flood prediction problems is the poor availability of suitable validation data such as water surface elevations and time sequence maps of flood inundation extent. Until recently, the only sources for these data have been water stage recorders and infrequent air photography campaigns, both of which have relatively limited spatial coverage and may be susceptible to failure during extreme flow conditions. Remote sensing techniques now offer an opportunity to produce parameterization and validation data at a resolution commensurate with model predictions. This ability is shown to raise issues of hydraulic model design based on a more detailed specification of current modelling limitations.

1. Introduction

The construction of accurate prediction models for river flood flows remains a major research problem in hydraulics and hydrology. Such schemes can be of significant benefit to environmental managers engaged in engineering design, insurance risk assessment, hazard management or real-time forecasting, thus enabling more effective use of available resources. However, such benefits only accrue when model predictions and forecasts can be made with a sufficient degree of reliability.

Over the last decade two major developments have enabled the specification of a new generation of hydraulic models forriver channel and floodplain flow. Firstly, field and laboratory process studies have led to a greater understanding of the flow structure. A number of complex mechanisms have been identified including momentum transfer between main channel and floodplain flows (see for example Knight and Demeteriou, 1983; Shiono and Knight, 1991), complex flow interactions across meander loops (see for example Willets *et al.*, 1990; Sellin *et al.*, 1993; Ervine *et al.*, 1994) and turbulence effects (see for example Krishnappan and Lau, 1986). Secondly, numerical algorithm development and increases in computer power have enabled this enhanced process understanding to be translated into ever more sophisticated mathematical models.

Recent modelling developments have made available sophisticated flow prediction schemes capable of high resolution simulation of flood extent and water velocity over relatively long river reaches. However, these developments have occurred without commensurate development of data capture techniques. Traditional data sources may not provide sufficient information to fully validate such models and our ability to provide reliable model predictions in this critical area may therefore be compromised. It is in this respect that remote sensing techniques may provide a key input to the modelling process. This is the focus of this paper where we explore data needs for flood flow modelling, the utility of remote sensing techniques in the provision of this data and the potential for model re-design on the basis of this information.

2. Data requirements for flood hydraulic models.

Until recently the standard analytic tool for modelling river floods has been based on 1-dimensional flow equation (Samuels, 1990). This describes the river reach as a series of cross sections at which the model equations are solved to give a prediction of discharge and water surface elevation. Thus flow is simulated in the downslope direction only and complex topography between cross sections cannot be represented. Given these deficiencies models based on finite element solutions of the 2- or 3-dimensional flow equations would appear to

offer a number of significant advantages. This is due to their representation of complex topography with a minimum number of computational points and their ability to simulate known flow processes to a higher degree of resolution.

Two and three dimensional finite element models have therefore been the subject a major research effort to enable their application to river flood flows at a scale appropriate to management problems. This has necessitated numerical algorithm development to increase their maximum scale of application from 1-2 km to 10-60 km (see for example Gee *et al.*, 1990; Bates *et al.*, 1992; Bates and Anderson, 1993) and to enable the inclusion of dry areas within the computational domain. This latter development is essential if the lateral advance and recession of an inundation front is to be accurately simulated.

Application of such models to actual river channel/floodplain problems has now been achieved (see Anderson and Bates, 1994; Bates *et al.*, 1995) for a number of river reaches. Figure 1 shows a finite element mesh consisting of 6 500 computational points for an 11 km reach of the River Culm, Devon, UK At each computational point the elevation of the bed has been specified from an experimental 10 x 10 m Digital Terrain Model (DTM) developed by the UK Ordnance Survey. This gives a three dimensional reconstruction of the river channel topography. For this site a 1 in 1 year recurrence interval flood that took place over 15 hours on 30/1/1990 has been simulated using 27 000 time steps of 2 s duration. A two dimensional finite element model, TELEMAC-2D (Hervouet, 1989), was then used to calculate two dimensional flow velocities and water depths for each computational point at each time step. This gives a total of 5.26×10^8 predicted data values.

Traditional methods of evaluating this predicted data set involve the use of water stage recorders to measure flow variables and air photography campaigns to delimit the flood inundation extent. Using such sources model predicted at the downstream end of the mesh was compared to observed values (see Figure 2) and a reasonable comparison shown. Next a time sequence of floodplain inundation was obtained from the model (see Figure 3) and compared to air and ground photos taken during the event. This showed that the model predicted a pattern of inundation extent that was broadly correct, however maximum flooding was overestimated by 20%. It can be seen that while available data indicates considerable

potential for such a modelling approach, predictive reliability and future model development is perhaps limited by the lack of a high quality data source commensurate with the model resolution. In this example a model data set consisting of millions of predicted data points is compared to approximately 50 observed values. Thus errors associated with traditional data sources due to their limited spatial coverage, the difficulty of synoptic measurements and their susceptibility to failure during extreme flow conditions are currently a major impediment to progress in the practical application of high resolution hydraulic models of river flood flow.

3. The potential for remotely sensed data in river flood modelling

In this paper we consider two example applications of the use of remote sensing data in river flood modelling.

3.1 Topographic data

Topographic data is one of the major driving parameters necessary for the application of hydraulic models. However, current methods of estimating topography may include a number of uncertainties, particularly in low lying areas such as floodplains. The solution to this has traditionally been an extended field data capture programme using geodetic levelling. However this has considerable resource implications both in terms of cost and time. In this respect LiDAR (Light Detection And Ranging) techniques may offer a number of a significant advantages. This is an airborne system in which a laser beam is fired at the ground surface at a frequency of up to 2000 'shots' per second. Detection of the reflected beams and a precise knowledge of the aircraft position in three dimensional space is sufficient to obtain a very accurate picture of the ground surface topography. The University of Bristol has begun to explore the use of such data in a collaborative project with the US Army Corps of Engineers. This has entailed the development of a TELEMAC-2D flow model of 60 km of the Missouri River, South Dakota, USA (see Figure 4a) in order to simulate the large floods

of June/July 1993. The surface topography for this model was obtained using a LiDAR scanner and resultant steady state velocity vectors computed. Figure 4b shows an example of such velocity vectors at the confluence between the Missouri main stem and the James River. From this it can be seen that high resolution topography data allows complex flow features such as recirculation zones to be resolved in a manner that has not, hitherto, been possible.

3.2 Flood extent data

As noted in Section 2 a critical problem in the practical application of high resolution river flood flow models is the poor availability of suitable validation data. In particular synoptic time sequences of flood inundation extent are difficult to obtain using conventional sources yet are very easily extracted from model predictions. A possible solution to this problem is to use SAR (Synthetic Aperture Radar) data from the ERS-1 and ERS-2 satellites to delimit flow field boundaries. This is the subject of a joint project between the University of Bristol and the NERC Unit for Thematic Information Systems (NUTIS), Reading, UK to further develop algorithms to extract flood inundation extent from satellite images (see for example Touzi *et al.*, 1988). Such algorithms typically involve a first pass procedure to find a rough division between land and water. This mask is then used to exclude areas of the SAR image in order to reduce computational requirements. A more elaborate second phase edge detector can then be applied in areas of uncertainty and the full boundary determined. This may then be registered to ground co-ordinates and compared to predictions obtained from the numerical model. Work on algorithm and model development is currently under way and initial results are expected within 12 months.

As an extension to this work it has been proposed (Corr, 1983) that the combination of SAR flood inundation extent data and model simulations can be used to refine available Digital Terrain Models (DTM's). Here the elevation of the land/water boundary determined from the SAR image is assumed to be equivalent to the water surface elevation predicted by the numerical model at this point. In this way a sequence of images can be used to augment existing topographic data sources and undertake model refinement.

4. The future: model validation and design

An increased understanding of the ranges over which model predictions can be considered reliable is critical to the practical implementation of recent developments in hydraulic modelling. In particular, this paper has attempted to show that remote sensing techniques have the capability to overcome current major limitations in the application of high space/time resolution hydraulic models to river flood flow problems. Specifically, example applications have been presented which demonstrate the improvements in model parameterization and validation that can be obtained with the use of LiDAR and SAR data. This does however raise questions regarding the design and future development of hydraulic models for river flow processes. This can be achieved in two ways. Firstly, remotely sensed data can be used to refine existing models For example, the augmentation of topographic parameterization data described above. Secondly, and perhaps more fundamentally, critical evaluation of model capabilities facilitates revision of all aspects of the model structure. For example, it was noted in Section 2 that in order to apply high resolution flow models to river channel/floodplain problems a major research effort has been the development of algorithms that simulate the advance and recession of a wetting front over an initially dry area. A number of such schemes have been developed (see for example Lynch and Gray, 1980; Kawahara and Umetsu, 1986; Tchamen and Kawahita, 1994) however assessment of their relative merits at scales appropriate to flood inundation problems has been constrained by lack of data. Reliable synoptic time sequences of flood inundation data may allow modellers to discriminate between such approaches and suggest methods for their future development. The major advantage of remote sensing techniques in hydraulics is thus their ability to force refinement of modelling approaches

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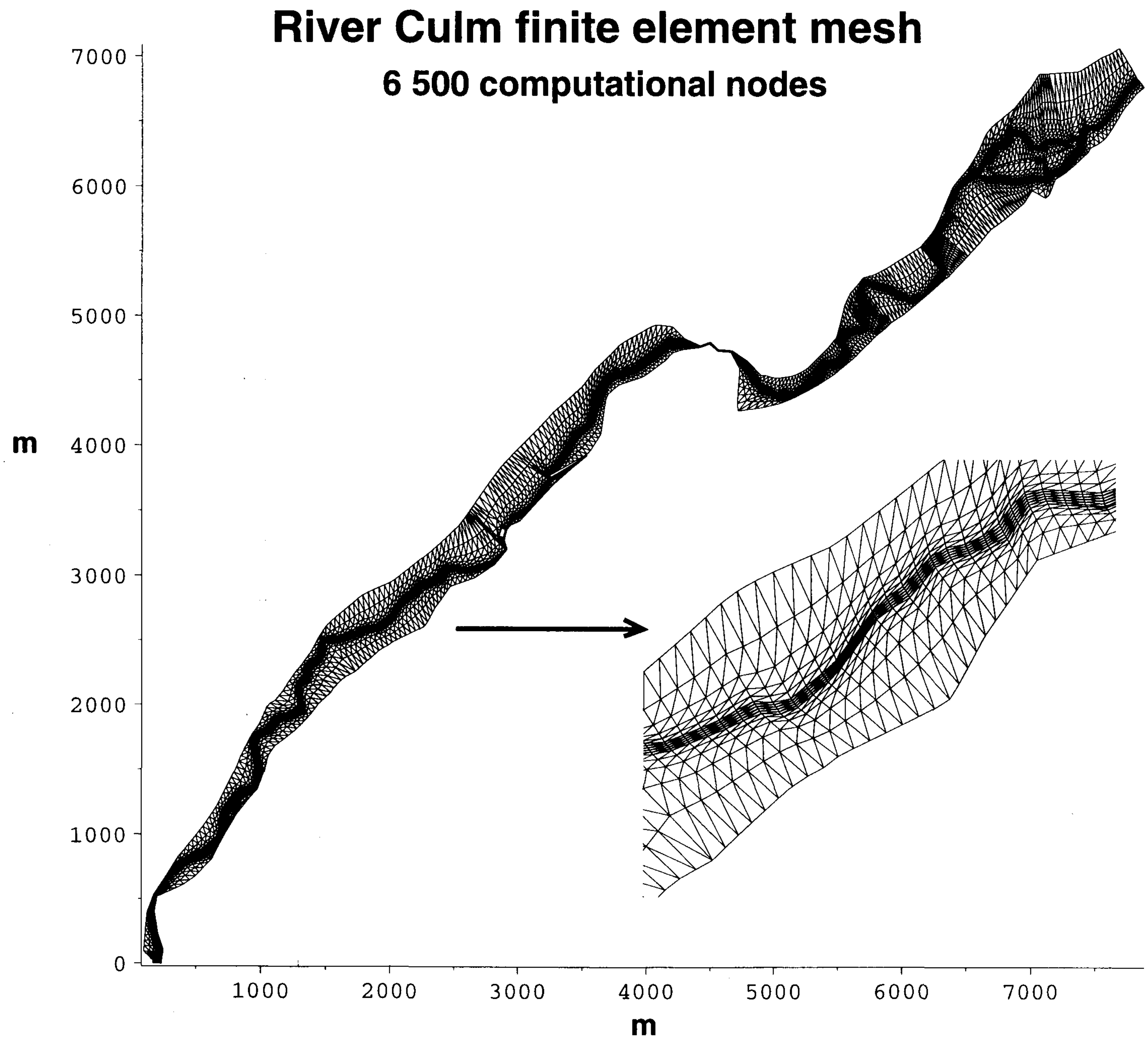
Illustrations

Figure 1: Two dimensional finite element model of the River Culm, Devon, UK.

Figure 2: Comparison of model derived predictions of flood discharge for a 1 in 1 year recurrence interval flood event with actual observations for the River Culm, Devon, UK. Three model scenarios are shown obtained using a variety of numerical solution algorithms and mesh resolutions.

Figure 3: Model predicted time sequence of flood inundation extent for a 1 in 1 year recurrence interval flood event on an 11 km reach of the River Culm, Devon, UK.

Figure 4: (a) Two dimensional finite element model developed for a 60 km reach of the Missouri River, USA. (b) Model predicted steady state velocity vectors.


River Culm finite element mesh
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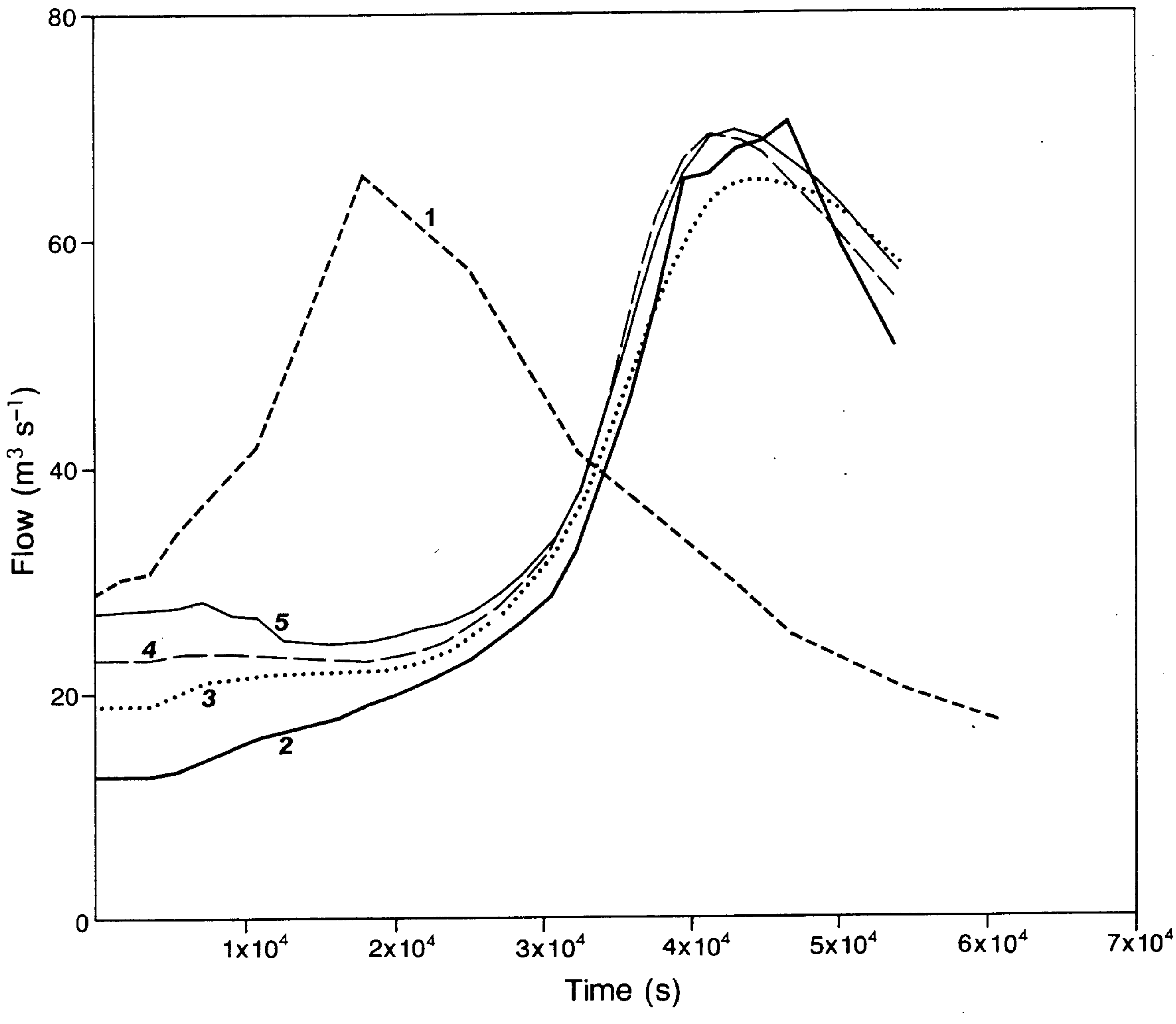


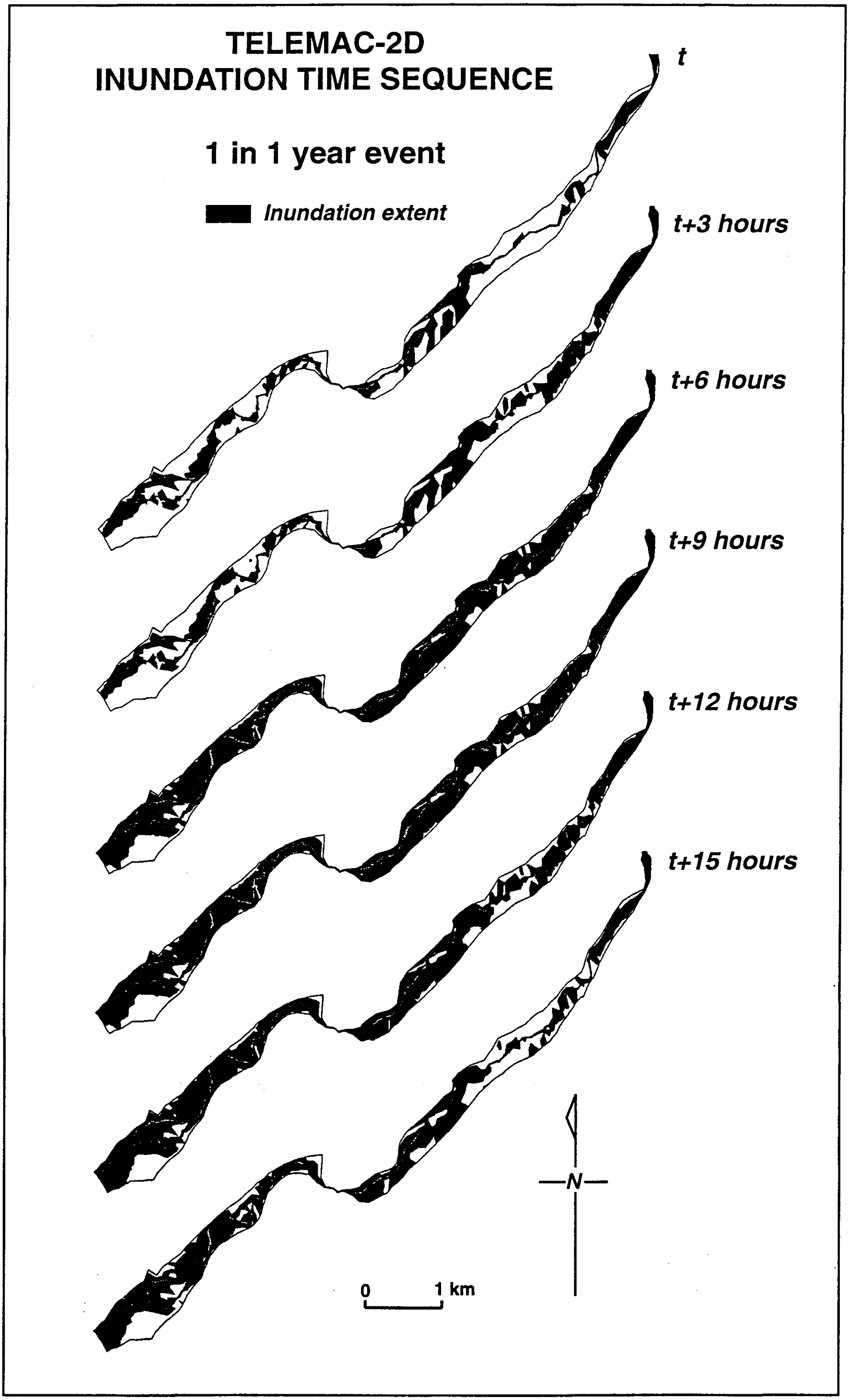
1. Observed upstream inflow discharge

2. Observed downstream outflow discharge
TELEMAC-2D downstream discharge predictions:

3. SUPG method + low resolution mesh

4. SUPG method + high resolution mesh

5. Hybrid method + high resolution mesh


TELEMAC-2D
INUNDATION TIME SEQUENCE
1 in 1 year event
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t+15 hours
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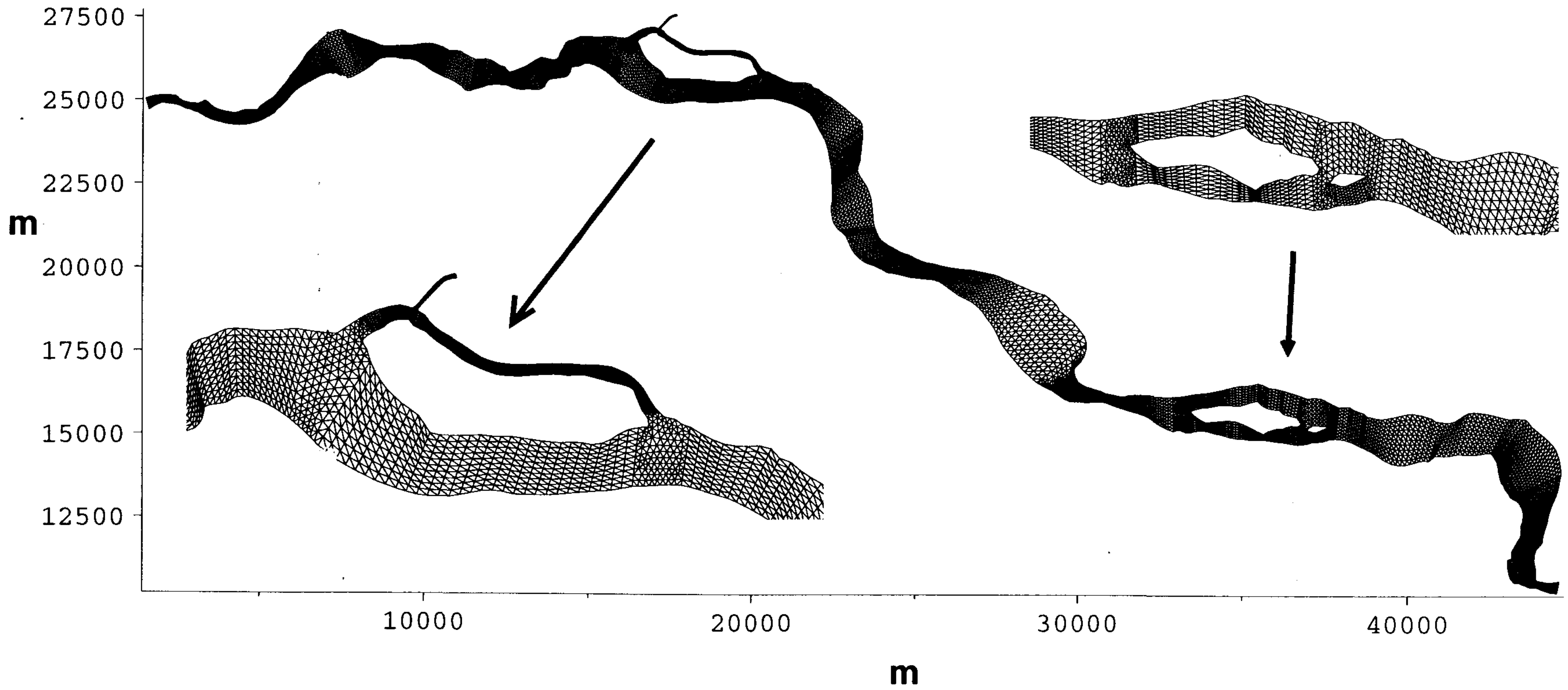
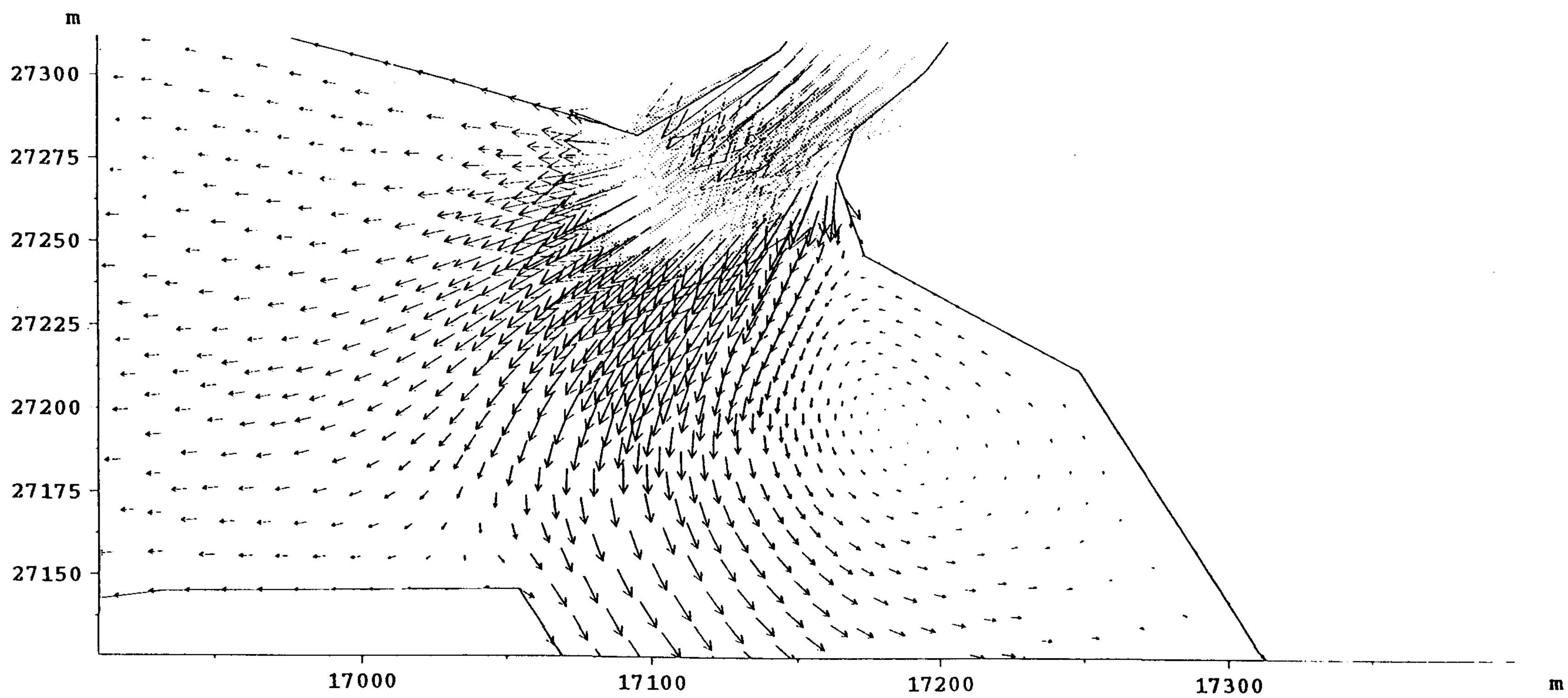
0
1 km

Missouri River finite element mesh

7000 computational nodes



James River - Velocity Vectors At Steady State



ERS Thematic Working Group Meeting on
FLOOD MONITORING

26-27 June - ESRIN, Frascati

Potential use of microwave information for the assessment of runoff risk over mediterranean soils

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33 38 64 34 34

Abstract

The recent problems of flooding in Europe can be issued from two different phenomena : one occur in alluvial conditions and is well illustrated by the hudge flooding of last winter in the northern Europe (Netherlands, Belgium, France); the other is a concentrated runoff in torrential flow (as an example in France : Vaison la Romaine in 1992). The main causes of these problems are different in every case, then the description of the catchment basins must be adapted. For prevention and predicting such phenomena, two main key points have to be monitored : (1) the causes of the creation of flood, and (2) the conditions of spreading, including the evolution of the drainage flow and the shape of the areas easily flooded.

Concerning the causes, the knowledge and monitoring of the precipitation are the most important requirement and are regularly controlled by specific meteorological organisms. But another factor could be taken into account and is not very often used as an help to the prevention of flooding : the **potential of runoff of the catchment basins**. This factor partly determines the net rain transformation into flows. Several studies are in progress for developing general deterministic or semi-empirical models, based on hydrological processes that result from the interaction between climate, relief, soil properties, unsaturated and saturated zone conditions, vegetation and farming methods (Bathurst J.C.1986, Foster G.R., 1990 , Morgan R.P.C.et al., 1994 ;).

Remote sensing could provide one or several parameters required as input in such models. Nowadays, the relief is delivered thanks to operational way through stereoscopic pair or in a near future by interferometric technic, as shown in the third part of this workshop. Furthermore it seems clear that vegetation coverage, land use and several indications on farming practices can be provided by optical satellite images (SPOT, Landsat) (De Jong S.J., 1992 ; Puech C., 1993 ; Leek R., 1994, King et al. 1994). A monitoring of the temporal variations of catchment basin parameters will provide a possible indicator of a new risk of runoff.

Roughness of soil surfaces is a important component which drives the dividing between runoff and drainage. ERS SAR images could contribute to the assessment of runoff contributing areas because of the signal is sensitive to soil roughness as established by theoretical modelling and demonstrated by previous experimental measurements (Ulaby et 1982, Beaudoin et al. 1990, Oh et al .1992, Fung et al.1992, Rakotoarivony et al.1994).

A test site in the south of France (fig.1) is a Mediterranean catchment basin where vineyards are wide-spread. This cultivation is particularly sensitive to runoff and erosion processes under the control of three levels of roughness : the relief (macro-roughness), the orientation of vine rows (periodic roughness) and the random roughness of the bare soil due to farming practices (Company A. et al., 1995).

fig. 1 Reart Basin Localisation

Our experiment tried to attempt the discrimination of the two last roughness using radar data. A temporal series of seven ERS1 SAR images has been acquired between april 92 and september 94 with simultaneous ground survey. These images have been overlaid and filtered thanks to adaptative filtering (MAPSAT software of Cril Ingenirie). In a first step, the σ^0 of only flat plots has been studied.

The **random roughness** due to agricultural practices affects the backscattering : the higher the roughness, the higher the backscattering (fig.2). But an important confusion exists and forbids the retrieval of the parameters by a first order inversion. A potential improvement is under study by using statistical parameters like RMS (s) and length correlation (l), which give a more accurate measurement of the soil roughness.

The **periodic roughness** modifies the backscattering too : it increases with the azimuth angle between the vine rows and the beam of the SAR antenna (fig 3) and confirms the results obtained thanks to airborne SAR data in L band and X band (Company A. et al., 1994).This approach would help to complete the description of catchment areas in terms of runoff through the discrimination of vineyards which gain access to a new parameter : the main directions of runoff.

These results are promising but not sufficient until now for the retrieval of all roughness parameters required by runoff models. For instance the best way for using ERS data for the characterisation of a catchment basin is to know a level of roughness for studying the other. In the future, the potential of multi-incidence of new SAR sensor like A-SAR could provide several configurations allowing the correction of relief effect on σ^0 and the extraction of roughness without preliminary knowledge. The final goal is to use SAR data as an help for characterize catchment basin in term of potential runoff.

Acknowledgements:

This paper, BRGM scientific publication No. 95032, is the result of a research project co-financed by the French National Space Remote Sensing Programme (PNTS) and the Direction of Research of BRGM .

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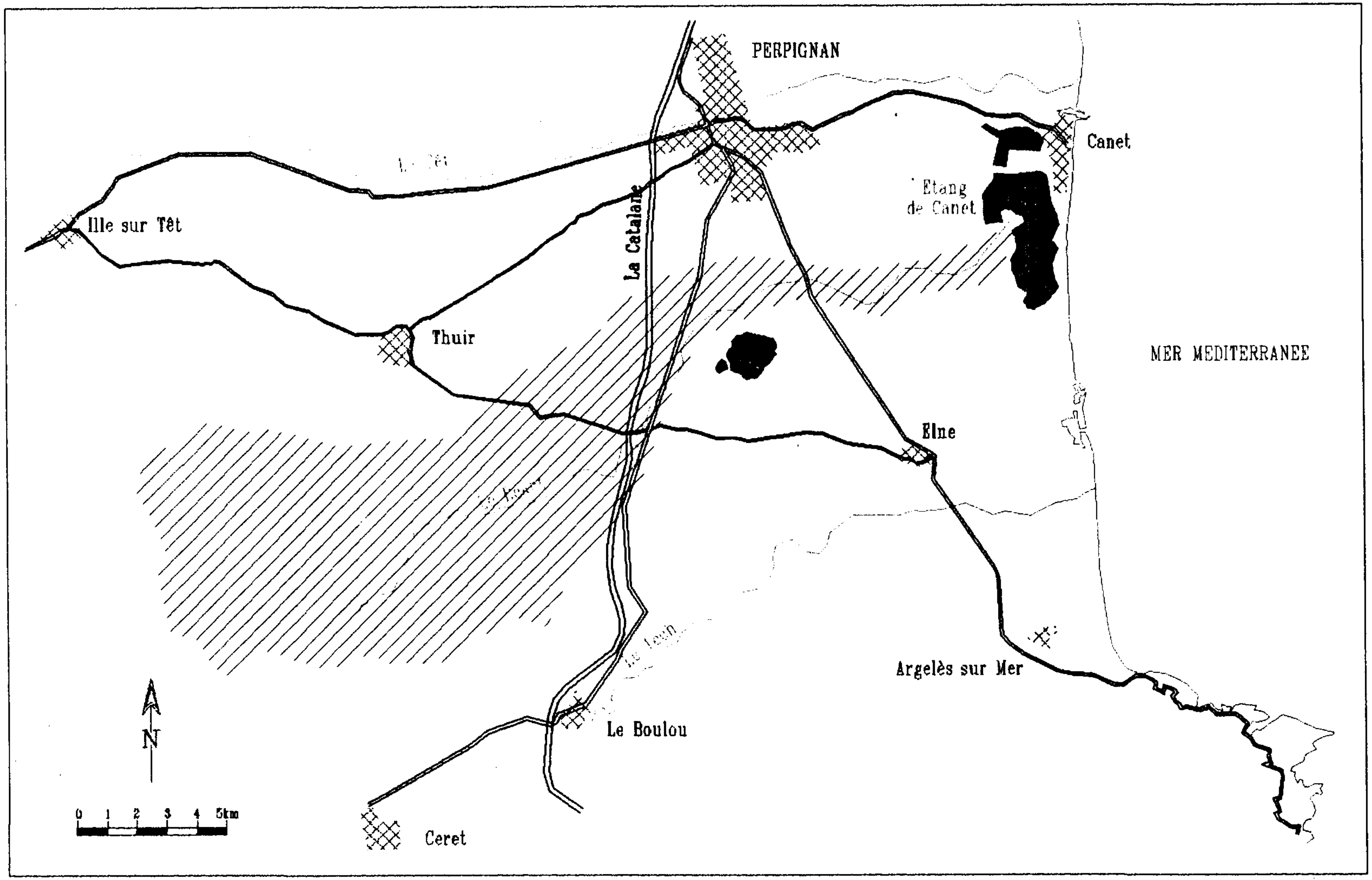
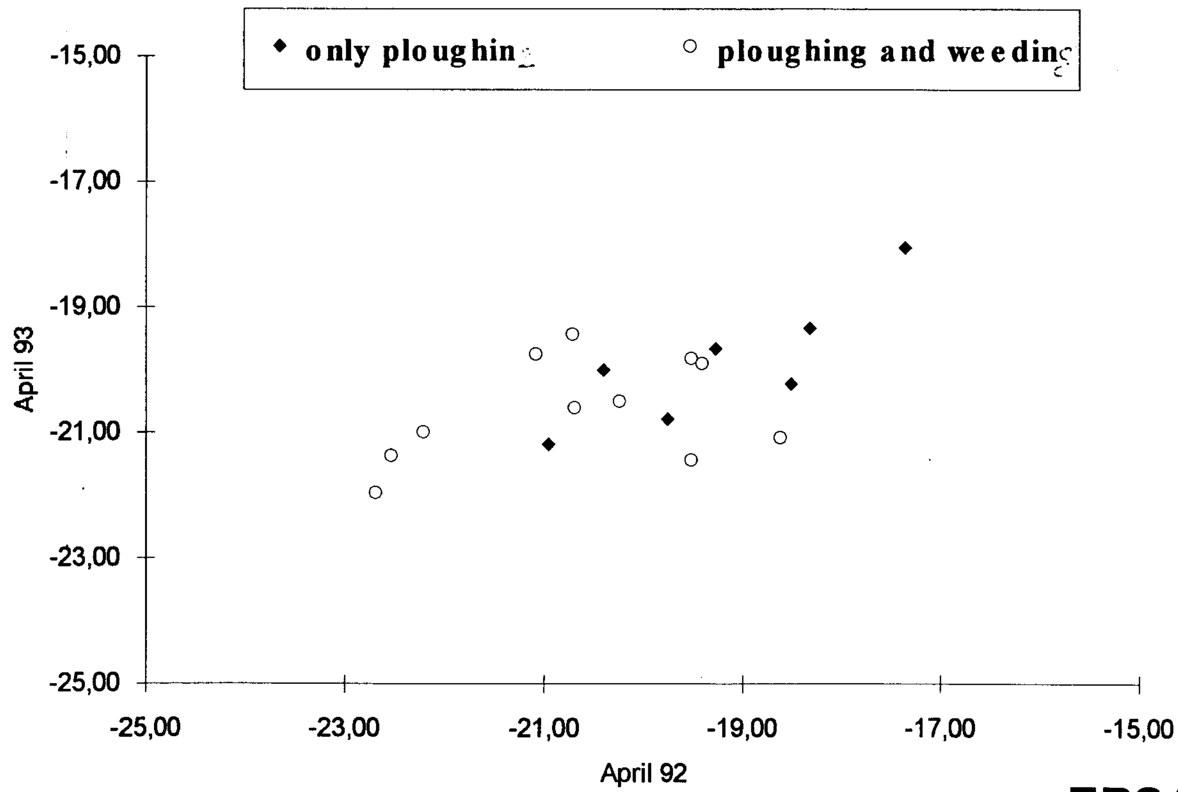
Figure 1 - Réart catchment basin (Roussillon France)



random roughness from agricultural practices

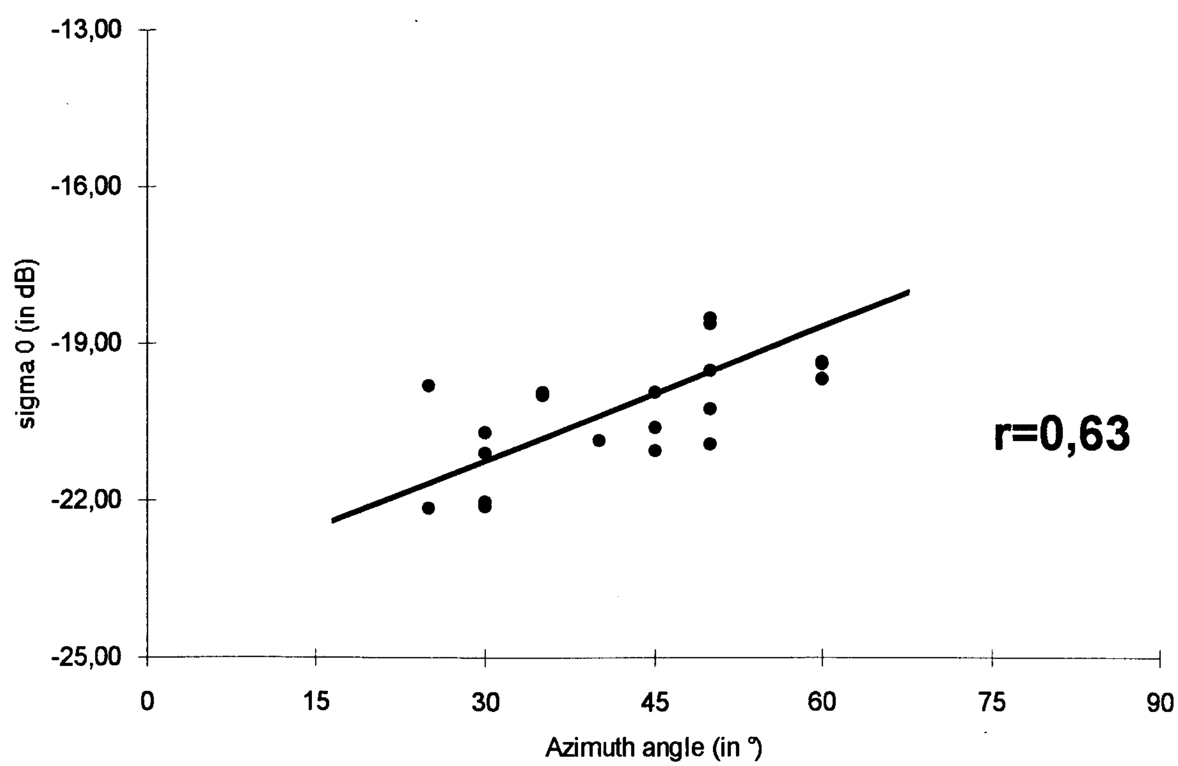
ERS1 April 93
σ0 en dB



ERS1 April 92
σ0 en dB

periodic roughness of vine rows

sigma 0 dB



azimuth angle (in°)

earth watching

a service by:

Eurimage

focused on earth

in collaboration with :

esa ESRIN

An 'eye' on the world

Earth Watching from Eurimage

An "eye" on the world

The flooding case

Biasutti Roberto - Earth Observation Engineer
Eurimage Technical development department - Italy

Each year storms cause flooding that does much damage to towns, roads and agriculture with a very high cost in lives. During these emergencies one of the biggest problems is to obtain an overall view of the phenomenon, getting a clear idea of the extent of the flooding and, if possible, predicting the way the flood will develop. Aerial surveys are often impossible due to the extreme weather conditions and, even when they are possible, would require long flying hours.

Eurimage has developed the Earth Watching service for two main reasons: to supply satellite data and pertinent information quickly in cases of natural disasters; and to demonstrate the benefits of remote sensing applications during emergencies, through images and articles. In short, Eurimage's Earth Watching program is all about stimulating awareness.

Satellite data can provide an overview of the situation quickly, as large areas can be covered in one pass, indicating zones already affected and those in danger. And once the situation has returned to normal, satellite data can be used to assess the damage, map affected regions and help devise prevention plans for the future.

The European Space Agency's ERS-1 and ERS-2 satellites carry a Synthetic Aperture Radar (SAR) instrument, which can collect data independently of weather and light conditions: it is an excellent choice for tracking the catastrophic winter floods that occur each year in Europe, as the weather at such times is always cloudy, dark and rainy.

Once alerted, the Earth Watching team quickly processes the data (within one day) to produce simple black and white images that can be used by the mass media and by the civil protection authorities to examine the situation. Image interpretations are prepared to accompany the images, and colour versions are prepared (within a few days) for use by magazines, etc.

The Earth Watching Structure

The Earth Watching Team is very small: just four, who, on receiving the alert, stop their normal work and start collecting information about the disaster through press agencies and through the Eurimage distributor network (39 distributors located in 27 countries covering Europe, North Africa and the Middle East). At the same time a satellite acquisition plan is made and the team prepare a fast data reception channel.

Once an image is generated, a low resolution image (whole or part) is put on Internet where it is accessible through the standard World Wide Web graphical interfaces (e.g. Mosaic or Netscape). Laser copies are quickly sent to newspapers and, if a magazine or TV station is interested, a photographic product is created. Normally the team are able to produce an image within 5-6 hours from acquisition.

The best tool for identifying flooded areas is a multitemporal image, using at least one ERS SAR image taken from before the flooding commenced, and at least one during the flooding. A merged image obtained by adding data from an optical sensor (like Landsat TM or Spot) is also often used to improve the clarity of the final image. One problem that we face is that it is often more difficult to obtain and process a archived reference image, than it is to acquire a fresh image of the disaster zone. To counter this we are contemplating the preparation of a reference archive of zones most liable to flooding so that we have good images ready to hand when we need them.

To better help people understand the image (most people are not very familiar with SAR images), an interpreted image is made, showing towns, highways, railways and rivers. Sadly, given our need to prepare these images quickly it is not possible to add a real GIS layer to the image, make a georeferenced image or make ground corrections through Digital Elevation Models.

Products used

Depending on the extent and the location of the phenomenon, different products are used and production paths followed. For ERS data we have used three different systems:

Product	*Reception system*
Low resolution images	Internet
Fast Delivery images (UI16)	BDDN
Precision Images	Off-line

1) Low resolution images
The Norwegian Tromsø Satellite Station is able to produce Low Resolution SAR images (100 m pixel size) in 16 bits within four hours from acquisition. The only constraint is that they normally need to be alerted some days before the data are required. However, for a special event, such a flooding, we have successfully used their data, without any prior warning, suffering a delay of only a few hours.

With this product it is possible to detect the flooded areas and give a very fast assessment of the damage. These images were successfully used for the Christmas '93 flooding over Cologne and Bonn (Germany) giving an overview in just a few hours: during the acquisition of the 25 December it was raining and snowing, so an aerial recognition was impossible (see Fig.1).

2) Fast Delivery images (UI16)
ESA has developed a high speed BDDN link (Broad-band Data Dissemination Network) between the Fucino and Kiruna ground stations and with its archiving

and processing centres. With this link a full resolution Fast Delivery SAR image can be sent in 10 minutes from the station to the ESA / ESRIN facility we made image processing. The constraint is that the transmission is planned once a day for each station near midday. If the need for the acquisition arises in the early afternoon we have to wait nearly 24 hours to receive the data. On very special events it is possible to plan another transmission to obtain data.

For a first flood assessment it makes not a big difference whether a SAR Fast Delivery or a PRI product are used, because beam and atmospheric corrections add no other information about the flooded areas. An example of this use was during the January '94 in the Camargue area (France); the satellite acquisition was in the morning and few hours later the data were available in ESRIN (see fig.2 and fig.3).

3) Precision Images

Due to the proximity of ESA / ESRIN to the Fucino Ground Station, sometimes it is more convenient to ask the station to send an HDDT tape with raw data via courier, and processed them at ESRIN. This is a special procedure that can be used only when the other two systems are not available. This system was used for the flooding that hit France, Belgium and the Netherlands at the end of January 1995. Both ascending and descending passes over a period of a few days were used to create multitemporal images (see fig.5).

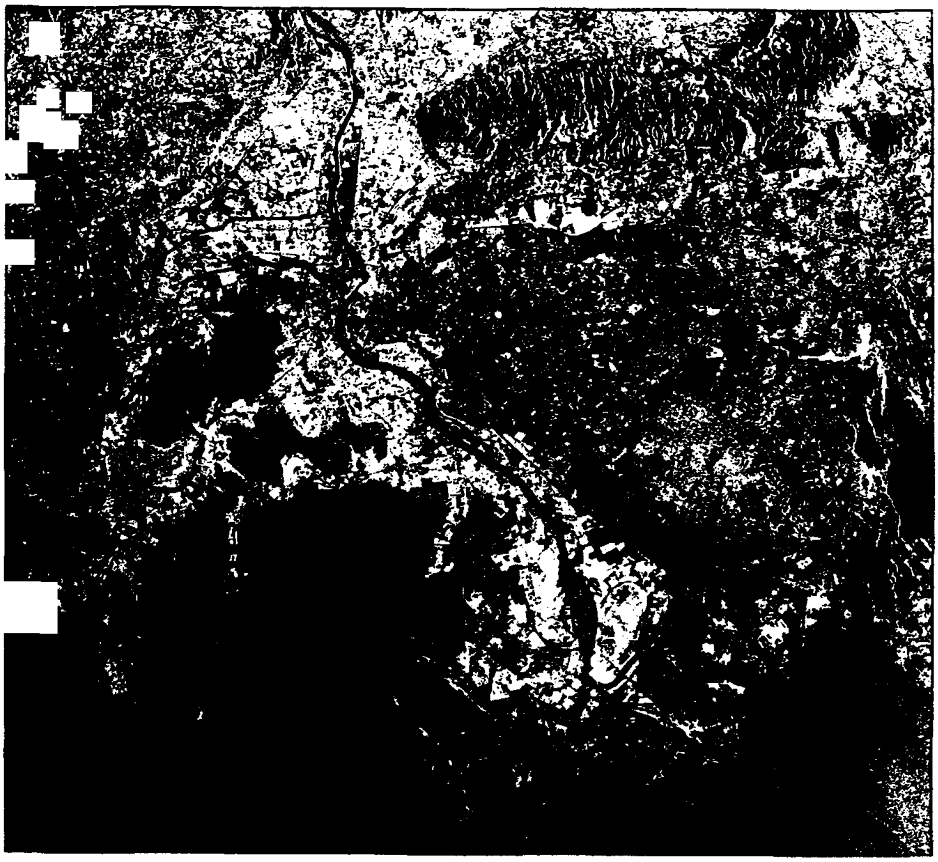
Conclusions

The Earth Watching Team after 18 month of activities in different fields (flooding, fires, oil pollution) has forged a strong link with ESA that allows us to receive and disseminate data in very short time scales, as requested by the mass media.

However, improvements can always be made, in particular in the following areas:

- The launch of new remote sensing satellites can dramatically improve the availability of data over the target areas.
- The diffusion of Internet connections, particularly at newspaper offices and TV studios, can simplify the distribution of the images, avoiding the very expensive production of high quality photographic prints, that requires some days. New higher speed connections will allow higher resolution images to be distributed more quickly.
- The distribution of satellite data from ground stations in countries not covered by the ESA ground stations is very problematical and to date it has not proved possible to operate the Earth Watching service in these areas. An improvement in International network throughput is needed to quickly obtain these data.
- A closer collaboration with the mass media can greatly improve the use of remote sensing data in these cases, revealing the value of these data to the general public and interested authorities with no previous experience of remote sensing. This in itself will help to put pressure on space organisations to launch other remote sensing satellites, especially with radar instruments, to better monitor our Earth.

Global Snapshot



Location: Delta of the Rhone River, France

Data gathered by: ERS-1, operated by the European Space Agency (ESA), Paris

Instrument: Synthetic aperture radar

Image distributed by: Eurimage, Rome

Image copywright: ESA, 1994

Project: Flood monitoring

Uses of information: ERS-1's synthetic aperture radar instrument is a valuable flood-monitoring tool. ERS-1 was able to capture before and after shots of flooding in the South of France during the early part of January 1994.

This radar image is a composite of data gathered on Jan. 3, 1994, when the river was running at an average level, and Jan. 12, 1994 when it was above flood stage.

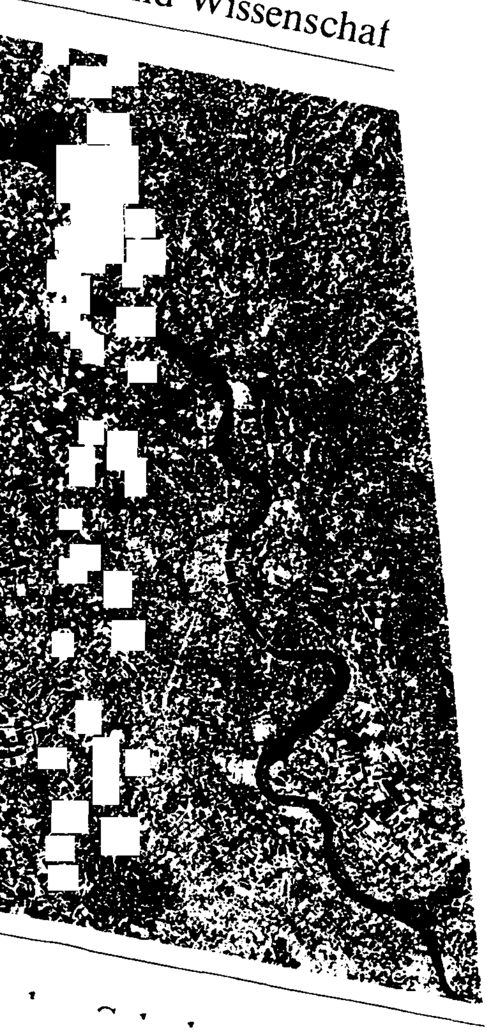
Dark magenta marks areas that have undergone the most drastic change and were flooded by Jan 12. Light magenta spots are likley swamps, lowland grasslands and fields that were partly submerged by water when data were gathered on Jan. 12.

Green signifies data from the Jan. 12 satellite pass, and likely is a sign of high-growing vegetation and tilled fields, and increased humidity. The slight change of colors in the dark purple of the lake and sea indicate there is only a light wind.

In this image, southwestern Provence, the Rhone River, its delta and the Mediterranean coastline are visible. The town of Arles is located at the juncture where the Rhone separates into two rivers — the Grand Rhone and the Petit Rhone.

The ERS-1 satellite, launched in the spring of 1991, carries three radar sensors. This image was received at a ground station in Fucino, Italy.

Natur und Wissenschaf



ERS-1 Lends a Hand to European Flood Clean-up

[illegible] Remote Sensing Satellite [illegible] recorded the [illegible] red during the Christmas holiday in the areas of [illegible] and Düsseldorf. ESA specifically equipped ERS [illegible] to collect data independently of light and weather con[illegible] it a valuable tool for natural disasters such as floods. Processed by ESA ESRIN Eurimage.

This is a view of the old part of the city of Köln [illegible] 23, 1993, which marked the highest level of [illegible] 10m, 63cm (32.8 ft. 25 in.) Looming in the back[illegible] is Köln's famous neo-Gothic cathedral, Koelner D[illegible] part of the cathedral dates back to 1248. Luckily [illegible] stopped just six meters short of the cathedral's [illegible] courtesy of the [illegible]

By Mary Jo Wagner

A[illegible]

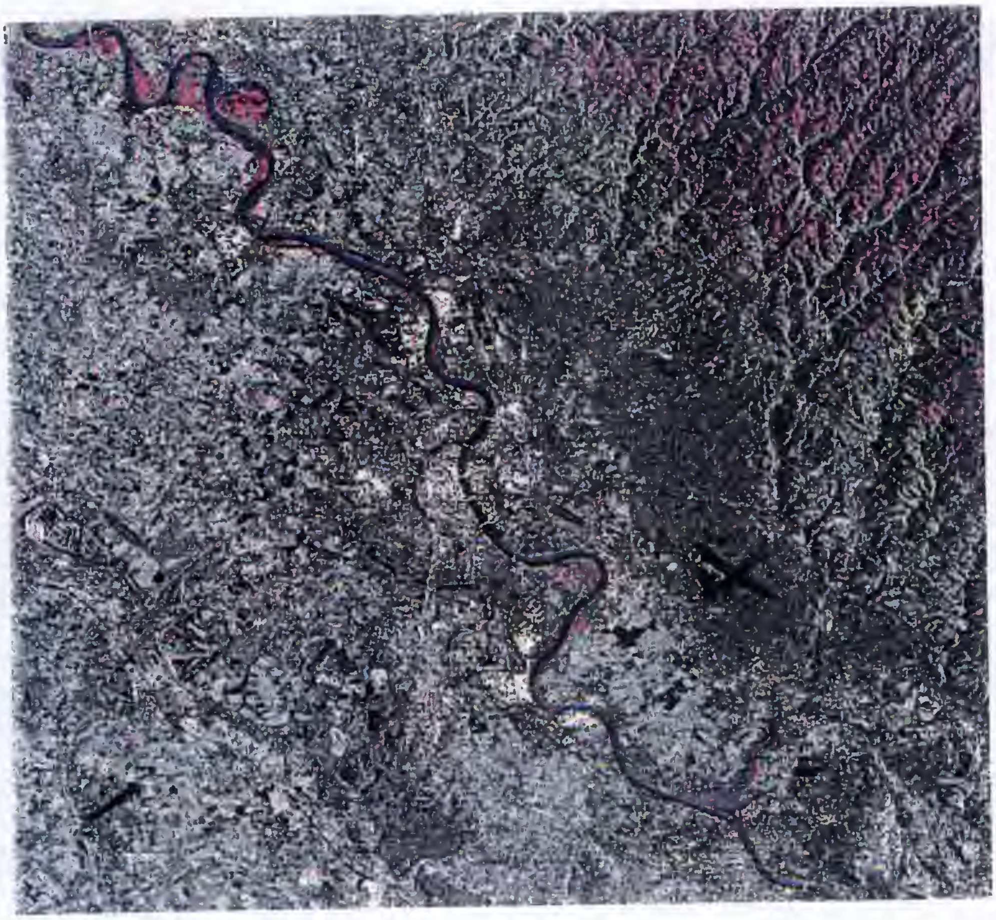


Fig. 1 Cologne area (Germany) - Christmas 1993 floods

This scene over Germany, composed of 3 Low Resolution SAR Images acquired at the Tromsø Satellite Station (N), shows the Rhine crossing from south-east to north-west. The round-shaped town of Cologne and the town of Bonn, marked by a bright area and their bridges, are situated near the centre of the image.
The weather situation was at all acquisitions very cloudy: on 25 December it was snowing down to 300m. The flooded areas or the hills covered by the fresh snow (top right) are shown in magenta.

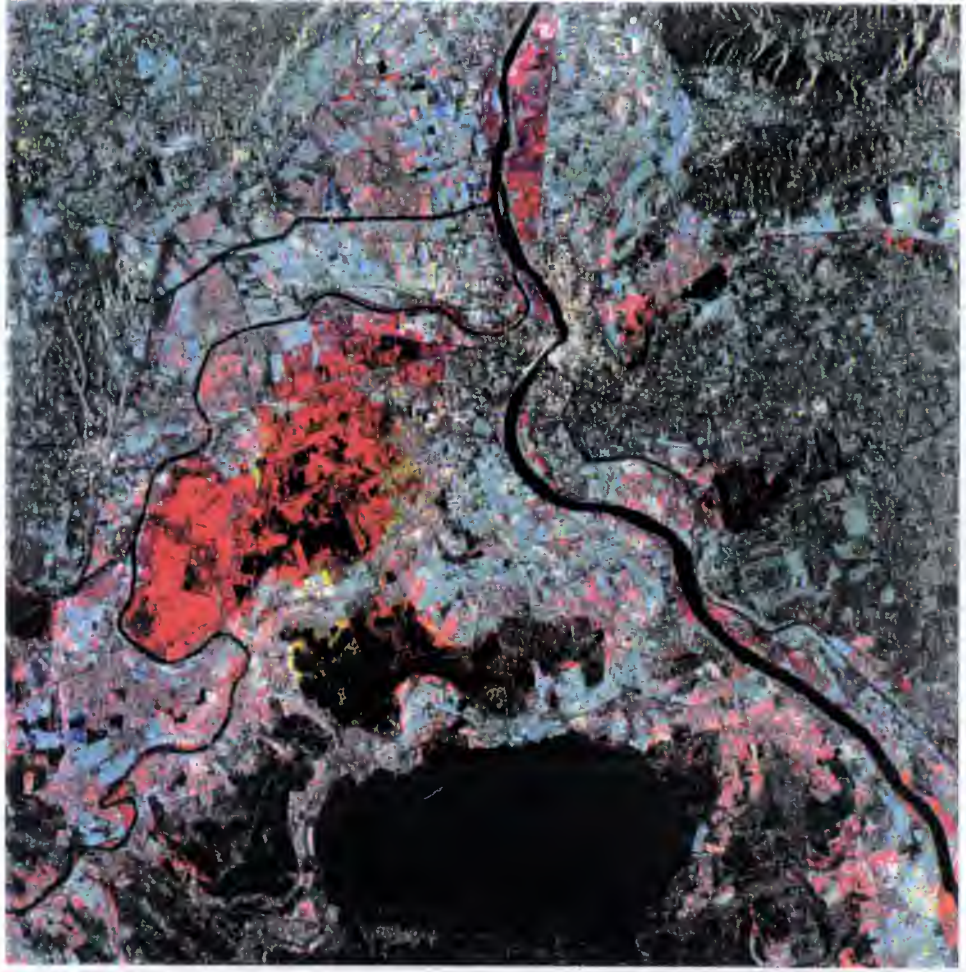


Fig. 2 Camargue area (France) - January 1994 floods

This SAR Fast Delivery multitemporal image represents the south-western part of the Provence with the Rhône river near its delta. The town of Arles, marked by many tiny white spots, is located in the centre of the image near the separation of the Rhône into Grand and Petit Rhône .
Goal of this image is to highlight the differences between a normal situation (3 January) and the flooding ones (12 and 15 January), in order to gain a fast and precise overview of the extent of the floods.
The various colours have the following meaning:

- in red areas flooded on the 12 and on the 15 January
- in magenta areas flooded only on the 12 January
- in yellow areas flooded only on the 15 January

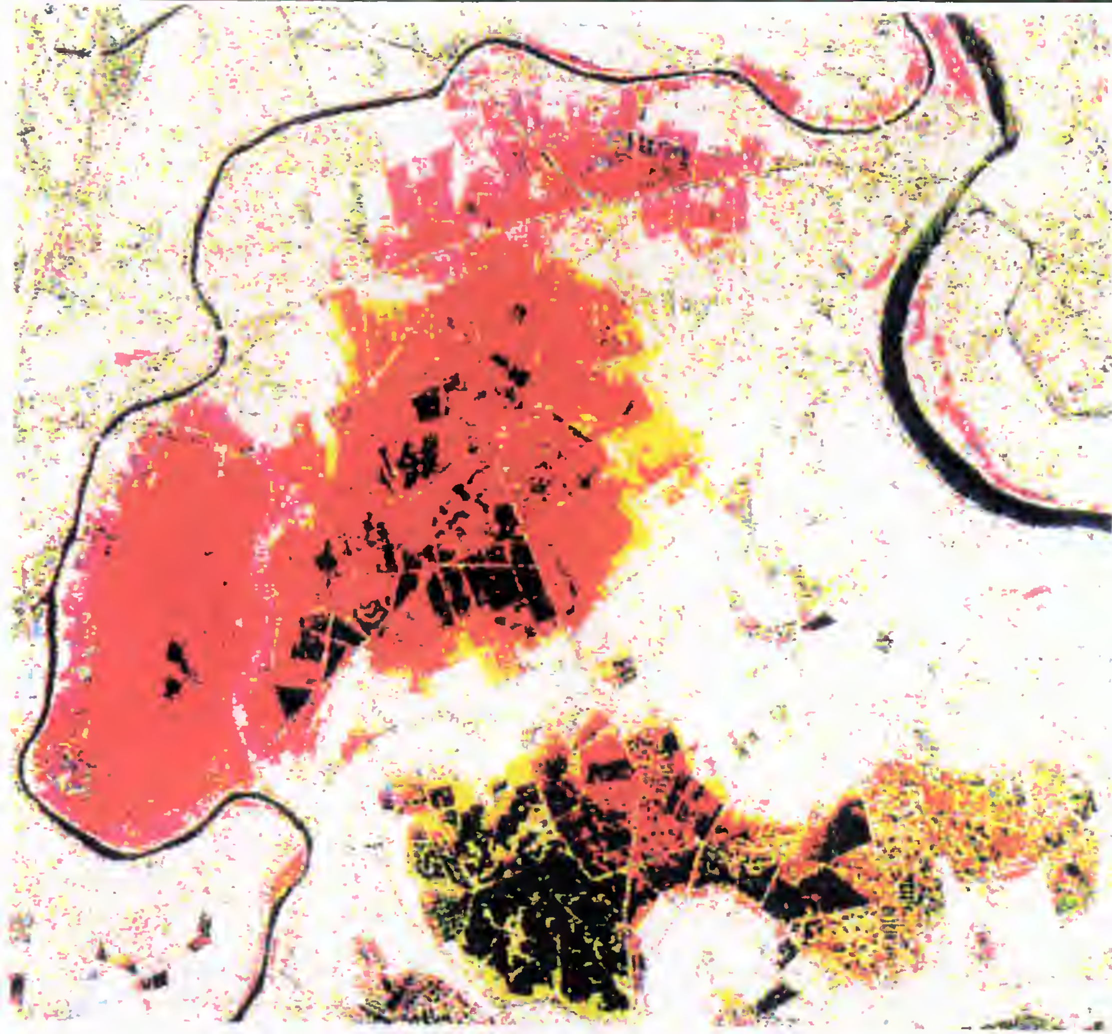


Fig. 3 Camargue area (France) - January 1994 floods

This image, extracted from Fig.2, shows with more details the flooding due to the overflowing of the Petit Rhône. The explanation of the colours is the same of Fig.2. It is clearly visible how the water flows southward leaving the areas near the river and moving to the Etang des Vaccares (at the bottom edge of the image).

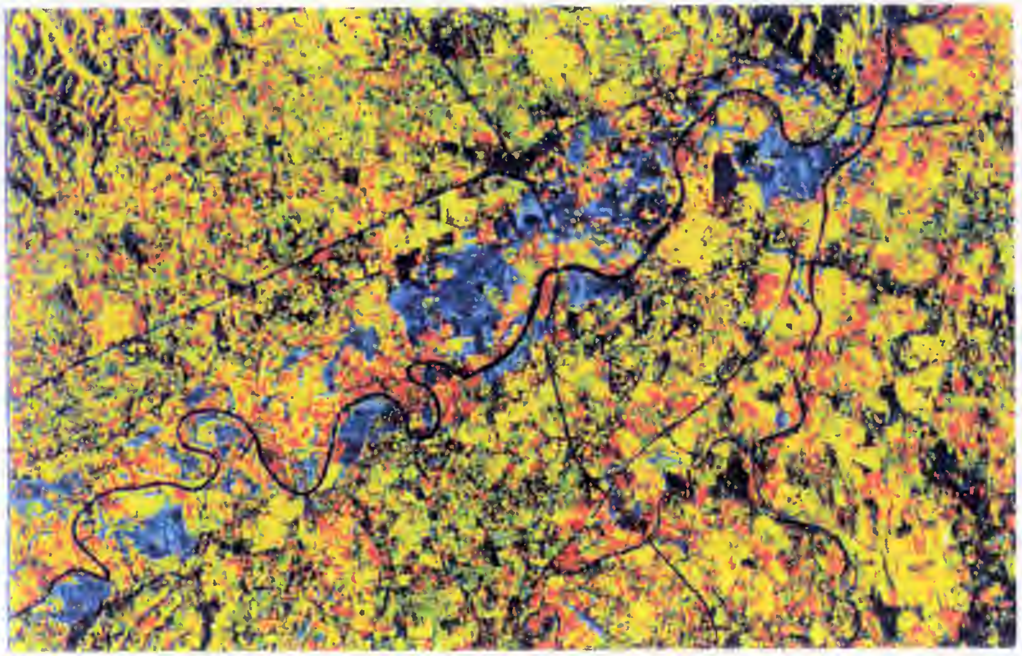


Fig.4 Alessandria area (Italy) - November 1994 floods

This SAR Fast Delivery multitemporal image represents the region of Alessandria, Piemonte. The Tanaro river flows from the left to the upper part of the image; near the top, just before the confluence with the Bormida river, lies the city of Alessandria, identifiable by yellow bright points. Two highways crossing themselves left to Alessandria are also clearly visible in the image.
The colours in the image are achieved by merging the two data sets (assigned to red and green), while in blue an artificial channel (second principal component of the two scenes) has been used. This allows to visualise also small changes between the two acquisition dates.
The most significant changes are marked in cyan and show the flooded areas, mainly located along the Tanaro river, representing a total surface within the image of 15, km^2. The other colours are mainly linked to the fact of much higher humidity on the 9 November respect to the 4 October: orange-red are bare soil, green are meadows and yellow settlements and orchyards (vineyards, etc.).

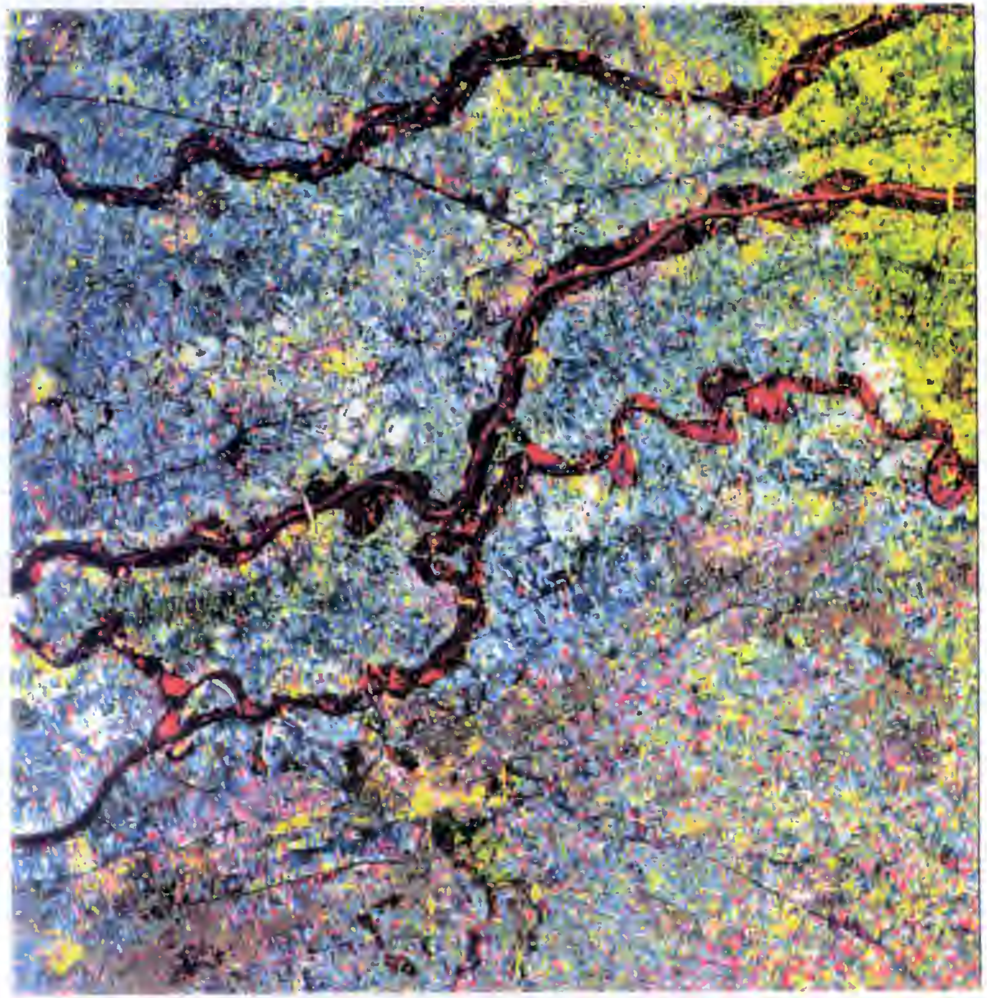


Fig.5 The Netherlands - January 1995 floods

This SAR Precision multitemporal image represents the region west of Nijmegen near the estuary of the Maas, Waal and Rijn rivers. The image is composed by two descending scenes and an ascending one, that does not cover the upper right corner of the image (visible in yellow-green).
The swollen rivers are shown in magenta, while the normal river courses are in dark blue. Red areas show areas re-emerged the 5 February, while green locates where flooding occurred between 30 January and 5 February.

CHARACTERISATION OF FLOOD INUNDATED AREAS AND DELINEATION OF POOR INTERNAL DRAINAGE SOIL USING ERS-1 SAR IMAGERY

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ABSTRACT

River flood observation and analysis by means of ERS-1 SAR imagery were made during the two successive winter periods of 1992-93 and 1993-94. This activity was carried out in the framework of a research/development project aimed at river flood extent assessment and mapping using ERS-1 SAR imagery, and at getting a better insight of dynamics of flood development. The analysis is based on SAR geocoded image pairs from which flood extent was assessed and mapped, and inundated areas characterized internally. The flood extent assessment and mapping were directly achieved through application of color composite techniques. The benefits for land use planning of such a remote sensing information are obviously the updating of river flood inundation maps. As regards the knowledge of dynamics of flood development, an index for multitemporal images was developped and applied to internally characterize the inundated areas. This index has proved to provide a means for inland waters (water courses, lakes) mapping. Moreover, a detailed comparison with soil class maps has shown that this index could be applied to delineate poor internal drainage soils defined by Belgian National Soil Survey Committee as soil classes c through i. Keeping in mind that poor internal drainage soils are characteristic of wetlands, and that wedland map is essential in land use planning, one can state that this finding provides an additional asset of ERS-1 SAR imagery for natural resources management.

1. INTRODUCTION AND OBJECTIVE

ERS-1 SAR imagery is used to study the development of flooding along the Lesse river located in the ecological region of Famenne-Ardenne (Southern Belgium) following a period of high rainfall at the beginning and the end of 1993. SAR data are known to provide a synoptic view of these events which would be very difficult to gain in any other way under the cloudy conditions prevailing in the region during winter periods.
This study forms part of an ERS-1 Pilot Project (BEDS 1078) aimed at hydrological applications of SAR imagery to the Lesse river catchment in Southern Belgium.
The principle is based on the fact that land and water surfaces generally have very different backscatter characteristics, thus providing the driving force to monitor the spatial development of a winter flood on the portion of the Lesse river between Houyet and Wanlin. The overall objective of the study is to demonstrate the feasibility of flood research project which could include other major Walloon lakes and rivers.

2. DATA BASE

2.1. Complementary data set

The complementary data base set to ERS SAR imagery consists of the following spatial and point data:

- **a digital stream course map**. It was constructed from the digitizing of a 1/10000 topographic map of the test-site. After digitizing, a raster layer with the same geometry and pixel size as the ERS-1 data set is created.

- **a digital floodplain boundary map** which was digitized from the Belgian National Soil Survey Committee 1/20000 maps. The soil maps are derived from 1/10000 topographic maps and are based on data which was gathered on a 75 m grid. These soil maps provide, among other data, information on soil texture, internal drainage and distinguishes clearly soil on floodplain. It is this latter information which is used to delineate the floodplain within the Lesse river catchment before digitization. The internal drainage class is a combined effect of many factors which influence the water table depth. This depth is conditioned by soil permeability and topography. The most common internal drainage classes within a floodplain are: class c (moderate internal drainage), class d (moderate to poor), h and e (rather poor), i and f (poor), and g (very poor).

The digital stream course map overlayed with that of the floodplain boundary is shown in Fg.3

- **stream water levels measurement at different gaging stations**. The gages along the Lesse river are regularly monitored by the Hydrologic Services of the Walloon Region. It was therefore possible to access the information on streamflows for any period, within the year or month, and to pick up the actual time of occurence of flood events. The data set related to the water levels at different gaging stations along the river during the months of January 1993 and December 1993 has confirmed the good fit of ERS-1 SAR image pair which was selected for the study.

2.2. ERS SAR images

- **a pair of SAR geocoded images** taken during the Phase C of ERS-1. These images result from a rectification of corresponding Precision Image products (PRI). PRI products are 3 looks georeference, digital images, corrected for antenna elevation gain pattern and range spread loss. The pixel size of the PRI products is 12.5 x 12.5 m. The rectification is performed in relation to UTM/WGS 84. The image pair is constituted of :
  - 8 December 1992 (frame 2601), taken before the flood event
  - 12 January 1993 (frame 2601), taken during the flood event

The data was calibrated based on the factors contained in the image report (header) files and converted into σ^{o}.

3. SPATIAL DATA ANALYSIS

The analysis of The ERS-1 SAR data set in combination with the ancillary geographic information system-based data on land is aimed to derive spatial patterns of flood inundation of the test-site. The approach underlaying the assessment of flood extent and analysis of the effect of soil internal drainage class is statistical.

3.1. Assessment and mapping of flood extent

Inundated areas are clearly seen on ERS-1 SAR image. This is a result of the fact that the generally smooth surface of inundation water gives a nearly specular reflection and will appear in dark gray tone. However, in areas characterized by a well marked relief, SAR images can show shadows, located at the foothills, which will also appear in dark gray tone resulting in a possible confusion with inundation water surfaces. That is to say that unless we apply change detection techniques to SAR imagery of the same ascending or descending phase nature, it will be rather difficult to distinguish between shadows and inundation water surfaces. Thus a change detection technique is recommanded (Badji et al., 1994) for flood inundation assessment and extent mapping where the relief is rather not flat.

In a case, like the assessment and extent mapping of flood inundation areas along rivers in non-flat topographic zones, and when a simple cartographic image has to be generated, the visual image enhancement is of most importance. As a consequence the change detection based on interpretation of colour composite image is the proper technique to apply. Fig.1. is a colour composite from a layerstack image made of the two ERS-1 SAR data of 8 December 1992 and 12 January 1993. The flood inundation areas are represented in red.

3.2. Approach to poor internal drainage soil delineation

3.2.1. Methodology summary

Change in surface reflection conditions can also be detected by applying difference in pixel values between two consecutive images. A radiometric enhancement independent of the degree of precision in assessing the parameters is given by the normalised difference index (ndi). This index approach is applied to characterize internally the flood inundation areas in order to get some more insight of the flood development dynamics. The applied expression for ndi is as follows :

$$ndi = 100\,(\sigma_{of}^{\circ} - \sigma_{f}^{\circ} + \varepsilon)/(\sigma_{of}^{\circ} + \sigma_{f}^{\circ} + \varepsilon)$$

where σ_{of}° and σ_{f}° are retrodiffusion coefficients of image at off- and during flood event period respectively, and ε is a small positive constant introduced to prevent the denominator from becoming zero.

3.2.2. Interpretation

Microwave remote sensing directly measures properties of the surface that are of interest to earth scientists like hydrologists and geographers. The strong dependence of dielectric properties of the earth's surface layer on its moisture content (Van De Griend and Engman, 1985; Ulaby et al., 1986) is the basis of this technology. Thus, measurement of the reflection

of microwave energy should indicate the moisture state of the earth's surface. It is important to recall that, in addition to moisture content, microwave response is dependent upon other target characteristics such as surface roughness, soil grain size and geometry and vegetation cover as well as characteristics such as wavelength, polarization and incident angle. This response will therefore show a complex non-linear pattern.
For any given wavelength, polarization and look angle, surface roughness, soil texture and structure and vegetation cover, radar backscatter coefficient increases as the soil moisture inscreases (Badji et al., 1994; Normand et al., 1994). Consequently a wet soil will induce a higher radar backscatter than a dry one.

A wetland, due to the rather poor internal drainage of its soil, will tend to remain moist for a long time. It will therefore result in a radar backscatter characterized by a high intensity value. When the area is inundated, because of the specular reflection nature of the smooth water surface, the resulting radar backscatter will have a very low intensity. By applying change detection principle based on normalised difference index, the soils which have remained moist before or after the flood event will be highlighted. As a consequence, this provides an interesting means for mapping wetlands in a floodplain. Fig.3. illustrates the distribution, within an inundated area, of soils different to each other from their backscatter characteristics which are likely related to soil internal drainage.

4. CONCLUSION

Floodplain inundated area can be assessed and its extent mapped by applying change detection based on interpretation of colour composite image. This method of flood inundation detection relies on the fact that colour change will occur in answer to the presence or the absence, in a multitemporal image, of an information which has actual influence on the land backscattering properties. This approach cannot be applied to achieve the goal of characterizing the inundated areas, through the delineation of different contributing soils, for some more insight of flood development dynamics. To this end, a more quantitative approach must be applied. This can be achieved through application of a normalized difference index to the multitemporal data set of ERS-1 SAR. Indeed, this index can be applied to highlight soils with rather poor internal drainage. These soils are characteristic of wetlands. As a consequence, it can be used to generate maps of wetlands within a floodplain from ERS-1 SAR images.

5. PROSPECTS

A contract applying the methodology above presented was implemented for the Walloon Ministry for Equipment and Transportation. It was aimed at providing inundated area map updates along the main rivers that are seen on ERS-1 images of Wallonia. These rivers are mainly the Meuse and two of its principal tributaries (Sambre and Lesse). ERS-1 SAR images are first used to delineate flood inundated areas along the rivers and main inland water bodies. The second step consisted in overlaying this information with a digital topographic map provided by the Ministry. An example of the achievement of the project is shown in Fig. 4.

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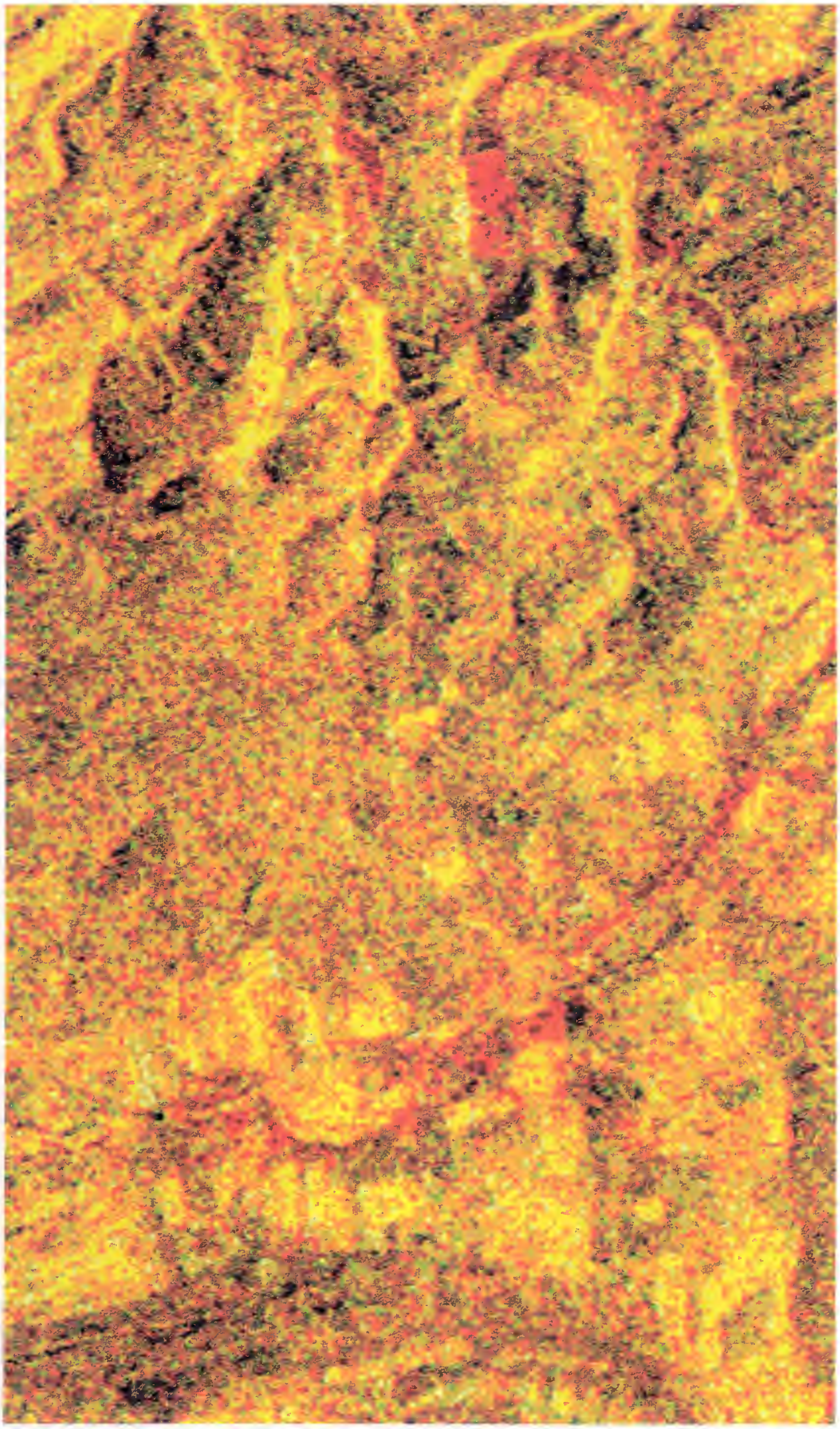


Figure 1

Flood extent along the river Lesse (red wide strip layer) between Houyet and Wanlin (color composite technique).

Figure 2

Soils of different poor internal drainage highlighted by the internal characterisation of an inundated area assessed from ERS-1 SAR multitemporal data of Phase D (3-day cycle). (Yellow = very poor; Blue = moderately poor; Reddish = poor)

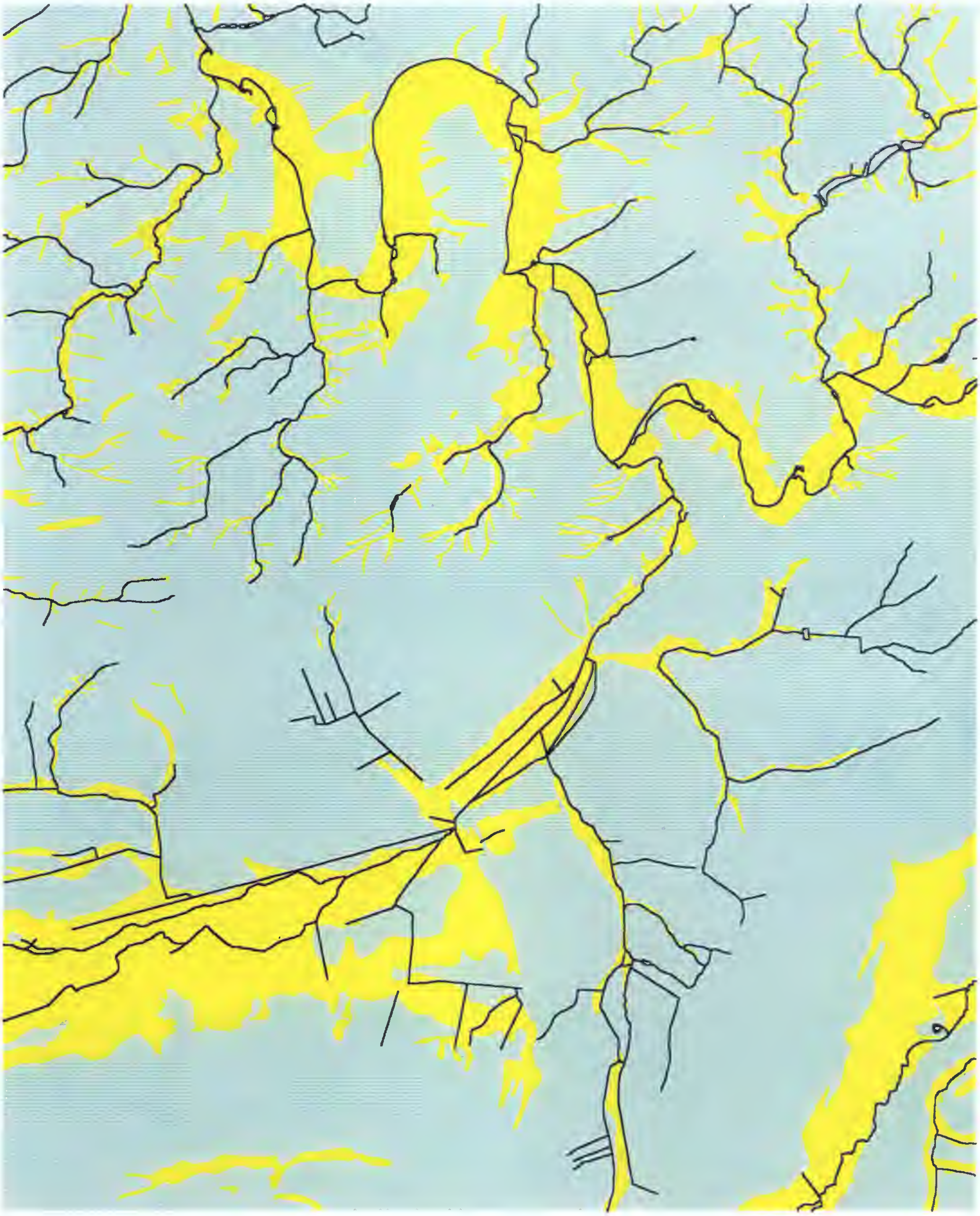
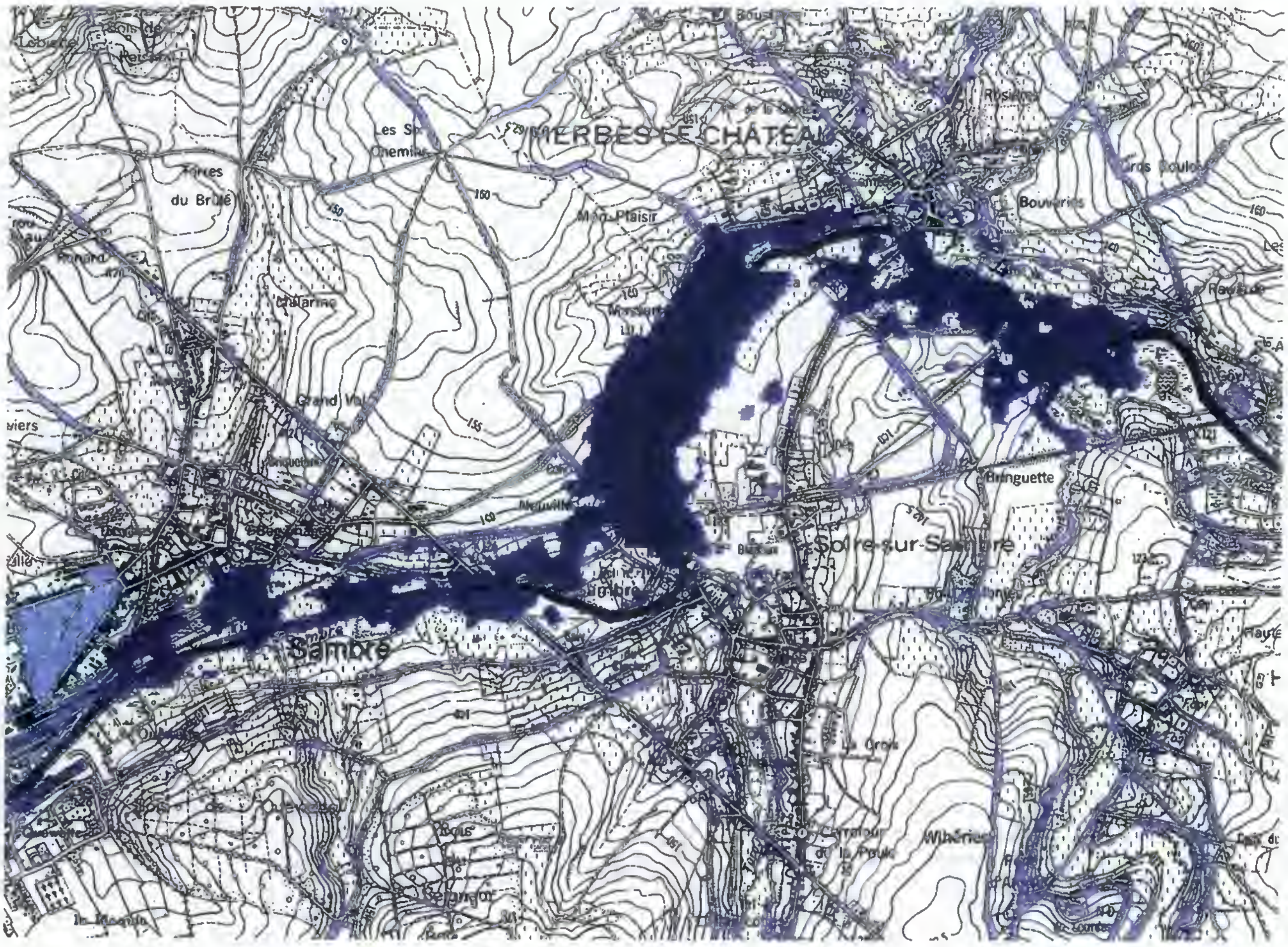


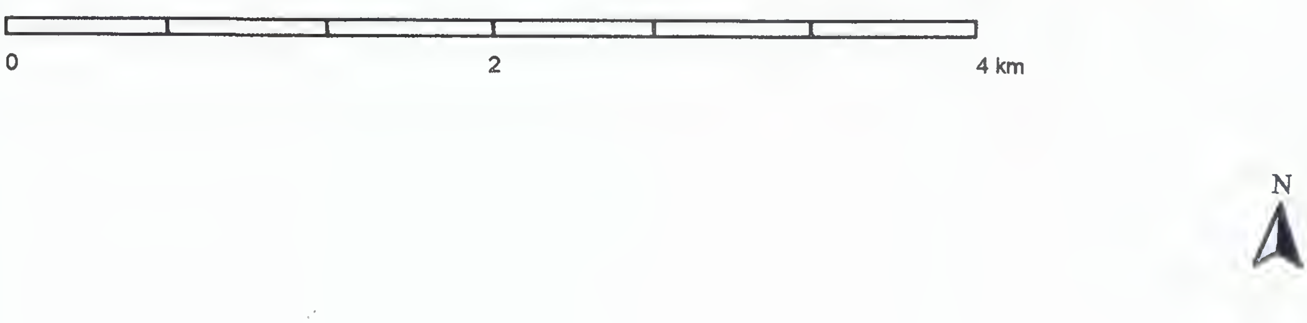
Figure 3

Digital floodplain map of test-site between Houyet and Wanlin

Figure 4

An example of inundation map along the river Sambre in the neighbourhood of Merbes-Le-Château, Walloon Region of Belgium. Inundated area (dark blue) is assessed through apllication of the a normalised difference index on ERS-1 SAR multitemporal data acquired during Phase D 3-day cycle.





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THE USE OF REMOTE SENSING DATA IN THE STUDY OF FLASH FLOODS. THE CASE OF THE OUVEZE RIVER FLOOD THE 22nd OF SEPTEMBER 1992 AT VAISON-LA-ROMAINE

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ABSTRACT

After the catastrophic flood of the Ouvèze river (south of France) in september 1992, the European Center on Geomorphological Hazards started an hydraulical and hydrological study of the Ouvèze basin to understand the causes of this catastrophe. The purpose of the approach is to result in an effective prediction of other similar events with the help of a rainfall-runoff relation, and in the definition of some preventives actions.
The data used are the following:
- SPOT data for the definition of the basins' morphological and biophysical characteristics (DEM, land-use,...) and for a potential runoff index of the Ouvèze basin;
- Weather Radar data to restore the rainfall dynamic on the whole basin.

The hydrological modelling uses the runoff informations and can give, for ungauged basins, a coherent flood hydrograph.

INTRODUCTION

The devastating flood, which hit the town of Vaison-la-Romaine (Vaucluse) on september the 22nd 1992, raised questions as to phenomena which caused the inundation: extremes rainfalls, land use, hydraulical desorders,...

The analysis of the phenomenan circumstanses began as soon as october 1992 and ended, in 1994, in an estimation of the discharge flood at the level of Vaison-la-Romaine thanks to hydraulic and hydrological study. The remote sensing data were integrated in this process; they complement the model and are usefull to balance the Transfer Function Basic Difference (TFBD)[1] coefficients in the hydological study.

I. AIM OF THE WORK

The stormy event of september 1992 didn't concern all the upstream basin of the Ouvèze river (Figure 1) with the same intensity (from 142.6 mm at Buis-les-Baronnies to 300 mm at Entrechaux). More over, the rainfalls measured in the Météo-France raingauge stations do not correspond to the real heights in the whole basin. Finally, the estimation of the flood discharge by a deterministic modelling (THALES soft based on St-Venant's equations) requires the upstream (discharge) and downstream (water level) conditions.

That's why we set off a work method (Figure 2) the aim of which is the estimation of

[1] in French: Différence Première de la Fonction de Transfert: DPFT (principe de convolution).

Fig. 1: **OUVEZE RIVER BASIN**

Sectors affected by the storm the 22/09/92

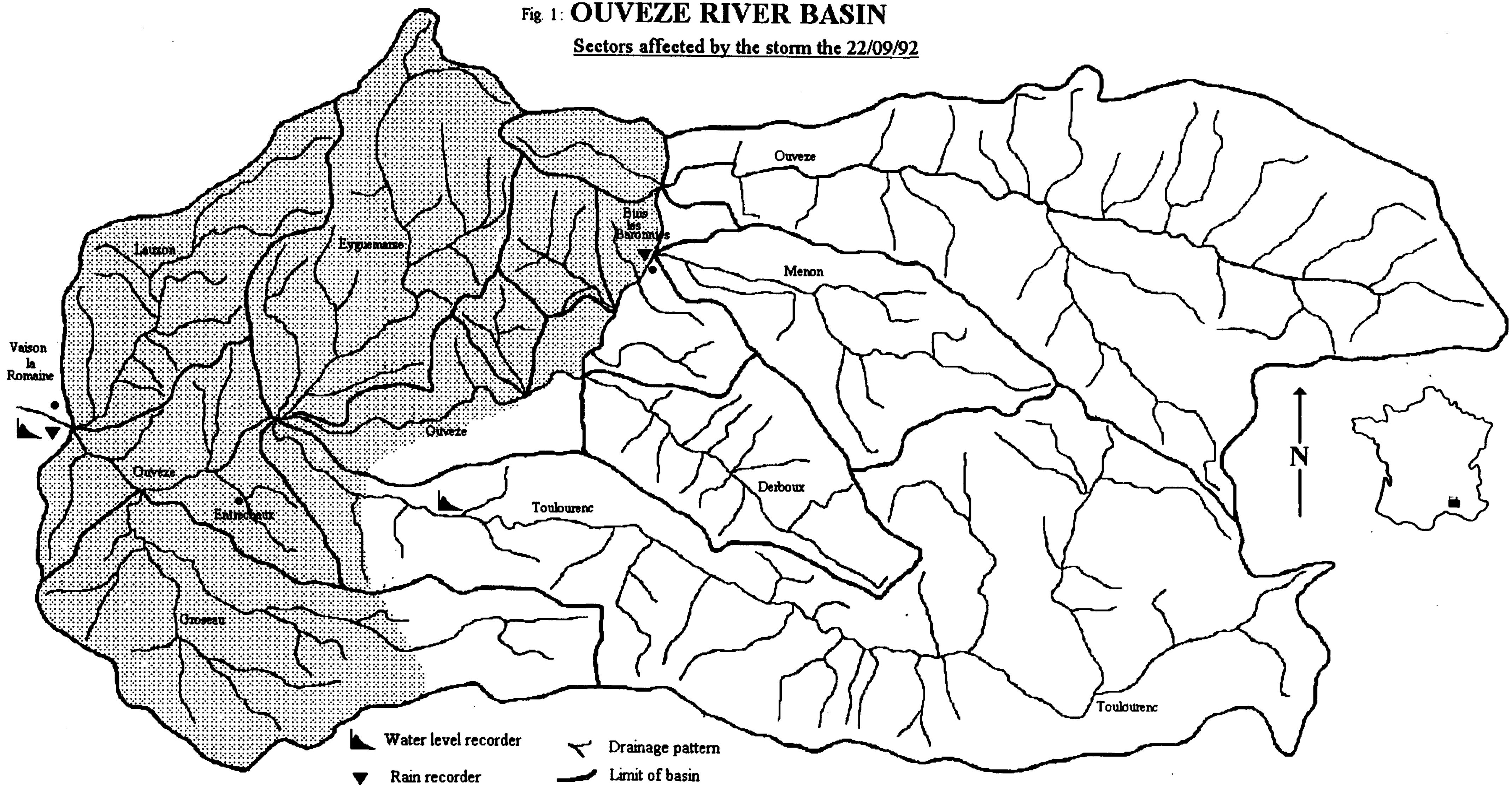
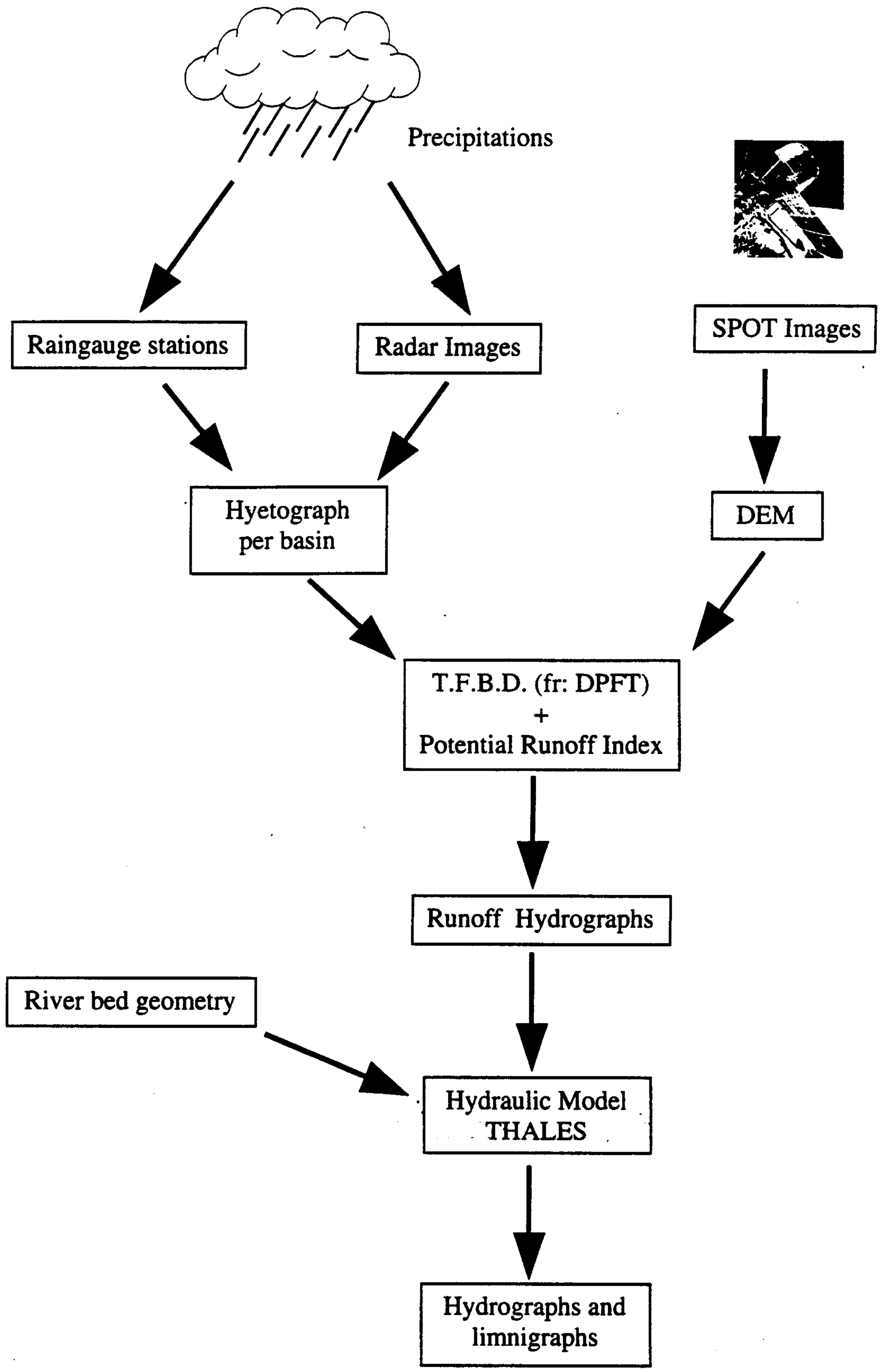


Figure 2 : Work method.



the flood discharge. The remote sensed data (Wheater Radar and SPOT) were used as a link between the theorical models and the facts in the fields.

II. THE REMOTE SENSING DATA

II.1. SPOT pictures :

SPOT data are available on the Ouvèze drainage basin and prove particularly intersting:

- a couple of stereoscopic multispectral images, with a spatial resolution of 20 m, recorded during summer 1992;
- a panchromatic image, with a spatial resoluton of 10 m, recorded at the beginning of october.

The pictures provide informations on :

- the perennial streams and water areas;
- landscapes and land use (naturel biotopes, agriculture, human settling, communication networks,...).

Each generic topic (hydrology, vegetation, inorganic areas) can be described according to the geographical fields or the environment:

- in the forest estate with informations on the species and the planting structures;
- in the rural estate by the analysis of parcel cultivation and the vegetation state;
- in urban areas with the structures and kind of buildings associated to the communication networks.

From the SPOT recordings, two kinds of analysis can be settled:

- by computed photo-interpretation;
- by image processing.

The second step was kept for the information treatment in an approach aimed at data integration:

- integration of the multisource data in order to provide an informative visual document;
- integration of the derived levels of each source in a data basis for a Geographical Information System-like approach.

Those informations over the whole basin furnished the data usable for the study of the biophysical occupation of the ground, and helped to produce, using the stereoscopical data, a Digital Elevation Model (DEM). Obtained thanks to ISTAR computation, the DEM has a 40 m resolution and allows the relief analysis (gradient, surfaces and slope of the basins,...). The mapping of the land use (multispectral data) makes it possible to value the vegetable cover and to estimate the runoff tendency of the different surfaces. Those two approaches permit to combine the spatial analysis of the slopes with the biophysical occupation of the ground. The combination of those data planes allows to define a potential runoff index associated to runoff paths. This index can than be affected to each sub-basin.

II.2. Radar data :

The MELODI Weather Radar (S-band) data of Nîmes-Manduel (ARAMIS network of Météo-France) used in the hydrological modelling have a time step of 5 minutes and a pixel

of 1 km². The radar data were used to restore the rainfalls dynamism, the accumulation being confirmed by pluviometric data collected at ground level in the different networks. A hyetograph can thus be elaborated for the Ouvèze basin and the sub-basin upstream Vaison-la-Romaine. This method brings in an important uncertainty but permit a spatial treatment of the pluviometric information.

III. HYDROLOGICAL AND HYDRAULICAL MODELLING

III.1. Hydrological analysis :

The analysis, which is based on the principals of the Transfer Function Basic Difference[1], tries to show the transformation of precipitation in flood discharge. Therefore, we used the informations from the Weather Radar of Météo-France, which, after processing, gave hyetographs available for each sub-basin. The information becomes then representative of an area.

The coefficients of the TFBD[1], which enable the reckoning of the transfer function and the effective rainfalls, are balanced by the potential runoff index issued of the image treatment processing. The model can thus provide coherent runoff hydrographs relevant to the different measures available in the Ouvèze basin.

III.2. Hydraulical analysis :

The representation of the propagation phenomenon of a flood wave needs a deterministic hydraulic modelling. It appeals to a transitory hydraulic model: THALES the formulation of which is set on the equations of Barré de St-Venant. A previous knowledge of the stream geometry and the upstreams and downstreams conditions is needed. The results issued of the hydrological modelling made it possible to initialize the model. The simulation supplied hydrographs and limnigraphs all along the different streams. As to the event of september, the 22nd 1992, the flood discharge could thus be estimated to 1200 m^3/s.

IV. THE FUTURE NEEDS OF REMOTE SENSING DATA

In all natural hazards management or observation system, the geographical information is in the limelight. It allows to locate, to measure and to spatially represent some phenomena. In the hydrologic estate, the morphological and biophysical characteristics of the basins have a determinative action on flows and their dynamic. An analysis of those conditions at the scale of the basin is frequently difficult to bring into play. Remote sensed images are a solution for this approach which registered in a proceeding for hazards forecast.

IV.1. The needs of SPOT data :

The importance of the morphological and biophysical factors in a basin hydrological response submitted to a storm, as well as the use of the basins' physiographical characteristics (altitudes, slopes, land use,...) in the hydrological models, led us to think about the satellite images ability (specially for SPOT) to provide this kind of informations. The current research aims at determine a way to exploit the SPOT images in order to extract, by image processing, relevant index usable in an hydrological modelling.

The needs of images can be the following:

- multispectral images recorded at any seasons so as to evaluate at best the land use, essentially agricultural areas which roughness is changeable.

Concerning the Mediterranean domain, its possible to be limited to images recorded at Autumn, unexpected arrival period of flash floods.

- a digital elevation model of the basins, with a good spatial resolution, in order to study, at best, the basins' morphometry.

IV.2. The needs in Weather Radar data :

The additional information, produced by the weather radar, must authorize the amelioration of the hydrological forecast quality. Indeed, the estimation of rainfall mean values over basins with the help of radar images, is validated by the rainfalls collected at ground level. The approximation problems of the classical interpolation methods are so avoided.

The using of radar data offers two approaches for the hydrological modelling:

- in real time: using, as soon as they are generated, the meteorological informations born of the detection of areas affected by rainfalls.

This approach offers only a little interest for the flood management and prevention, particularly for areas subject to flash floods. There is no significant time profit in the warning procedure.

- in forecast: some experimental methods try to forecast, for some hours, the rainfalls able to affect an area.

Those methods, complex to bring into play and sensitive to the storm's size, make their results being with difficulty integrated in a reliable rainfall-runoff relation. However, current researches, as the development of the Météo-France radar network, let us think that those methods will be more and more used in rainfall-runoff relations definition.

CONCLUSION

The results, issued by the different models, permit to specify the circumstances of the flood, but the values (discharges) have a dubiousness which can, with difficulty, be evaluated.

The principal interest of the methodology is in the comparison and in the complementary of the approaches: surface, hydrology and hydraulics. The analysis of the informations obtained by remote sensing data constitutes a proceeding which can be integrated in a research and localisation of flood hazards areas program. An applying on a geographical large scale area is achievable.

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Estimation of discharge from three braided rivers using ERS-1 SAR

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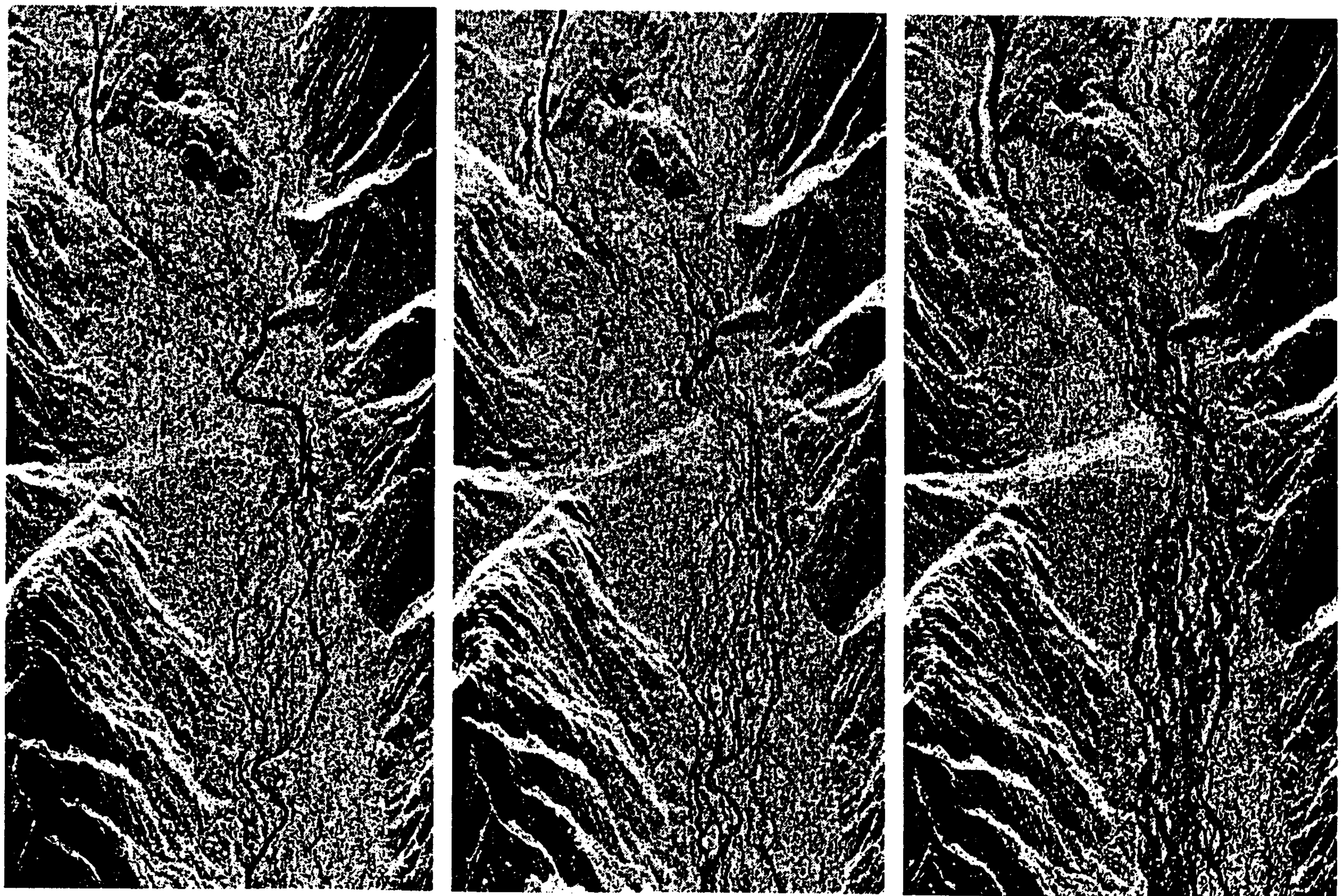
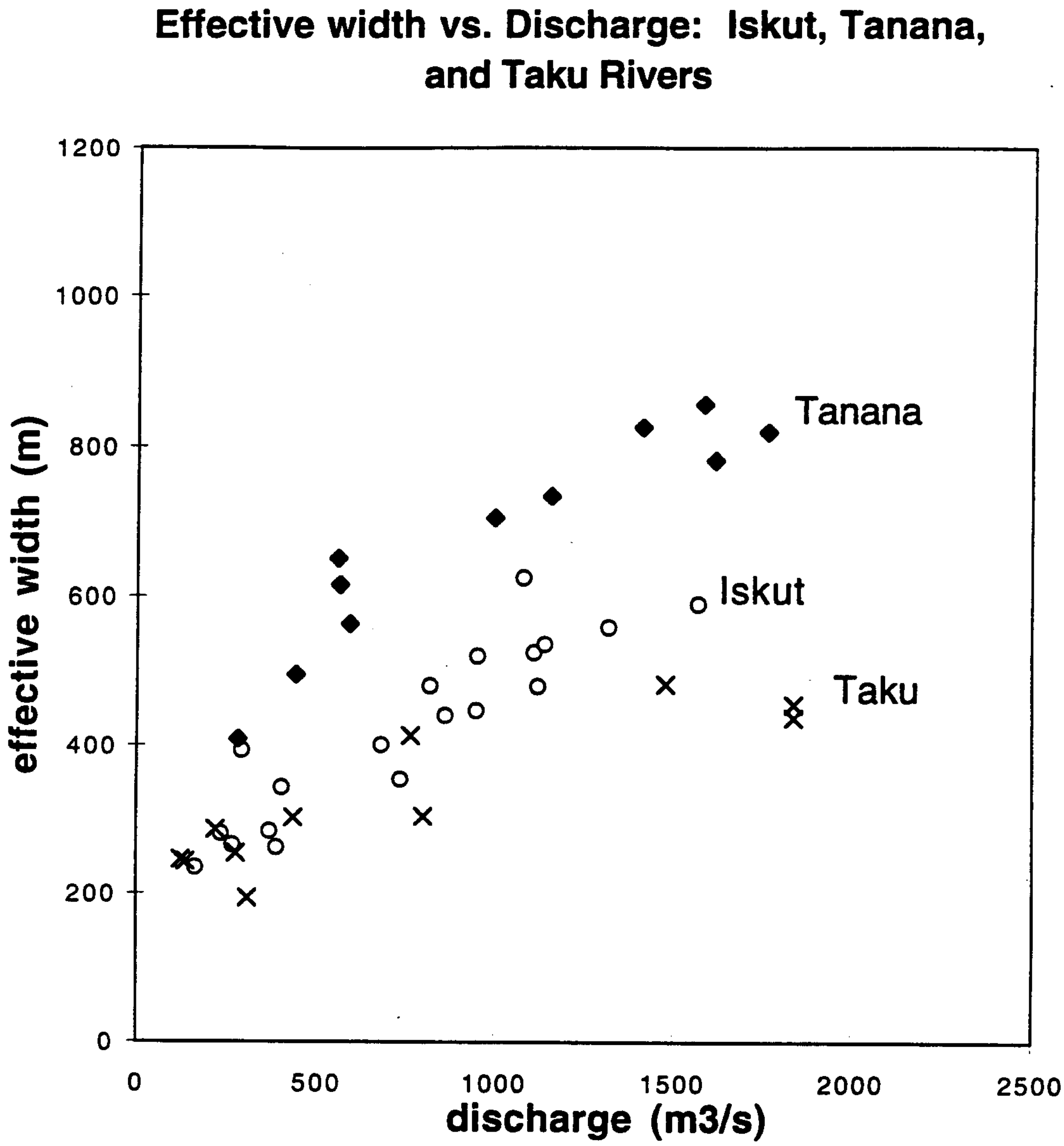
The water surface area on an unconfined braided floodplain increases or decreases in response to total river discharge. Field measurements on the braided Iskut River in British Columbia show that width is more sensitive than either depth or velocity to changing discharge. These effects are integrated over a two-dimensional area when total water surface area of a braided reach is measured and correlated with the total discharge through the reach. The surface area contributed by transient channels (which is also highly dependent upon discharge) is thereby included in the water surface area measurement, which is readily obtained using remote-sensing methods.

ERS-1 imagery and simultaneous ground measurements of discharge reveal a strong correlation between discharge and total water surface area for the Iskut, Taku, and Tanana rivers in NW British Columbia and Alaska. The satellite-derived 'area-discharge' rating curves integrate discharge-dependent changes in inundation area over km-scale reaches of braided floodplains and display little temporal or spatial variability, unlike at-a-station width/discharge relationships obtained in the field for individual braid channels. Differences in rating-curve slope indicate each river's propensity for widening, which appears to be a function of longitudinal river slope, grain size, and braid intensity.



May 5, 1993 | May 24, 1993 | Oct 27, 1993

1. Three ERS-1 SAR image acquisitions over the Iskut River, British Columbia, in 1993. River discharge increases from left to right. Each image is approximately 8 X 15 km.



2. Relationship between satellite-derived effective width (floodplain inundation area divided by length of reach) and ground measurements of river discharge for three large braided rivers. Each point is determined from a single ERS-1 SAR image. The Taku and Iskut rivers are located in northwest British Columbia, the Tanana River is in central Alaska.

WATER RESOURCES RESEARCH, VOL. 31, NO. 5, PAGES 1325–1329, MAY 1995

Estimation of discharge from braided glacial rivers using ERS 1 synthetic aperture radar: First results

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Abstract. Using multitemporal ERS 1 synthetic aperture radar (SAR) satellite imagery and simultaneous ground measurements of streamflow, a strong correlation ($R^2 = 0.89$) was found between water surface area and discharge for a braided glacial river in British Columbia, Canada. Satellite-derived effective width (W_e) was found to vary with discharge (Q) as $W_e = 27.5Q^{0.42}$, where W_e is defined as the total water surface area within a 10 km × 3 km control section, divided by the section length. This "area/discharge rating curve" yields instantaneous discharge estimates with a mean error of ±275 m^3/s for ground-measured flows that ranged from 242 to 6350 m^3/s.

Introduction

Increased interest in the hydrologic processes of the cryosphere has been stimulated by general circulation model (GCM) modeling, which predicts amplification of a CO_2-induced global temperature increase toward the poles [*Manabe and Wetherald*, 1980; *Manabe et al.*, 1991]. This widely accepted premise is supported by a recent small increase in northern hemisphere high-latitude temperatures [*Folland et al.*, 1990]. It has also been suggested that early indication of a global temperature change may best be observed in the cryosphere because of the sensitivity of snow and ice to climate [*Hall*, 1988]. River discharge measurements are essential for detecting such effects, as runoff is the primary mechanism by which mass is removed from snowpacks and glacier ice. Glaciers adjust to climate changes by storing or releasing water, producing higher mean streamflows during recession [*Young*, 1985; *Lawson*, 1993]. *Meier* [1984] suggested that the current global sea level rise of 1–1.5 mm/yr may be partly explained by the observed shrinkage of the world's small glaciers. Runoff modeling for a glacierized Himalayan basin predicted at least a 30% increase in summer streamflows as a result of a simulated 2°C increase in temperature [*Fukushima et al.*, 1991]. However, efforts to characterize river flows for most glacierized basins have been severely restricted by a paucity of discharge observations. This problem is due to a combination of (1) harsh weather conditions and low accessibility, (2) high costs associated with maintaining stream gauges in these remote areas, and (3) typical conditions of high bed load and rapid discharge fluctuations that create shallow, shifting braided systems that are virtually impossible to gauge using traditional stage-recording devices. In recognition of these difficulties, *Lawson* [1993] concluded that in order to understand the relationships among climate, glacier mass balance, and hydrology, new remote-sensing techniques are needed to replace expensive, labor-intensive ground measurements. Development of such techniques would also permit study of remote, high-latitude rivers for industrial or water supply purposes.

The complex hydrologic and sedimentologic processes that interact to form a braided channel configuration are topics of ongoing research [*Krigstrom*, 1962; *Fahnestock*, 1963; *Church*, 1972; *Mosley*, 1983; *Young and Davies*, 1990; *Maizels*, 1993; *Warburton and Davies*, 1994], but the end result of these processes is a relatively flat, unrestricted surface covered with multiple shallow channels that maintain similar geometries and flow depths despite frequent lateral shifting. Unlike single meandering channels that adjust primarily through flow depth (unless their banks are overtopped), braided streams accommodate changes in discharge through channel widening and adding or subtracting channels to the braid complex. Field measurements in small braided streams indicate that channel widths vary strongly as a function of discharge [*Rice*, 1979; *Mosley*, 1983; *Leopold*, 1985], a relationship also observed in experimental flume studies [*Schumm et al.*, 1987].

Advances in satellite technology have sparked efforts to assess river hydrologic conditions from space. *Bryan* [1981] identified lakes, wetlands, and rivers using Seasat and airborne synthetic aperture radar (SAR) imagery. *Koblinsky et al.* [1993] used Geosat radar altimeter waveform data to measure river stage in the Amazon. *Solomon* [1993] recommended the use of ERS 1 SAR for delineating river networks in densely forested areas, while *Brakenridge et al.* [1994] used ERS 1 to obtain stage estimates from the 1993 flooding along the Mississippi River. Although braided rivers are not well suited for traditional stage-recording devices, their spatial sensitivity makes them highly amenable to using remote sensing to detect changes in discharge. In this study, total water surface area within a 10 km × 3 km control section on a braided glacial river in British Columbia was repeatedly measured using multitemporal SAR imagery acquired by the first European Remote Sensing Satellite (ERS 1) in 1992 and 1993. These satellite-derived values were then compared to field measurements of river discharge measured by a Water Survey of Canada gauge located 10 km downstream from the control section. Their strong correlation indicates that it is possible to obtain good estimates of flow rates from space using this approach.

ERS 1 Satellite and the Study Site

ERS 1 was launched July 17, 1991, by the European Space Agency. In image mode its C band (5.3 GHz) SAR produces an 80–103 km swath with a processed pixel spacing of 12.5 m. ERS 1 is placed in a near-circular, polar, and Sun-synchronous orbit with 3-, 35-, and 168-day repeat cycles during its various

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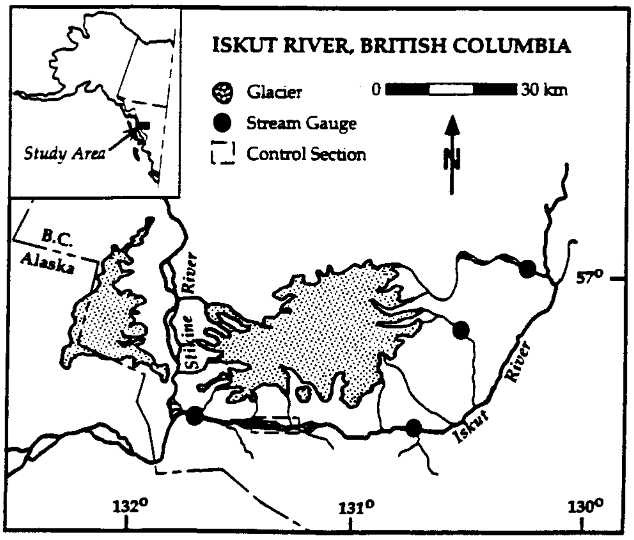

Figure 1. Map of the study area: Iskut and Stikine Rivers, British Columbia.

mission phases. SAR sensors are well suited for multitemporal hydrologic studies owing to their cloud-penetrating capability and strong sensitivity to surface moisture conditions. The former is a tremendous asset in chronically cloudy regions such as the Coast Mountains along the Alaska/British Columbia border. The Iskut River (approximately 57°N, 131°W) drains 9350 km^2 of this heavily glacierized area (Figure 1). Five helicopter-serviced stream-gauging stations have been installed in nonbraided reaches by the Water Survey of Canada. One of these stations is located only a few kilometers downstream of the prominent braid complex used for the control section in this study. Using two overlapping repeat pass orbits, ERS 1 SAR images were acquired over the control section from April 1992 to December 1993 by the NASA Alaska SAR Facility (ASF) in Fairbanks.

Data Processing

Using an ASF-provided program, each ERS 1 image was radiometrically calibrated to permit comparison of actual backscatter (σ^0) values between multitemporal images and also within a single scene. The calibration process removes variations in backscatter caused by sensor antenna pattern, range to target, and incidence angle for each image, using a satellite-derived noise versus range function and three calibration coefficients [*Bicknell*, 1992]. This information is provided in the Committee on Earth Observation Satellites (CEOS) format header file that accompanies each ERS 1 data take processed by ASF. All radiometric and geometric corrections are fitted to the ellipsoidal surface of the Goddard Earth Model (GEM06) geoid model. Surface elevation or departures of the true geoid from the ellipsoid are not considered, producing small but uncertain errors in mountainous regions.

Unlike lakes which can return a wide range of radar backscatter intensities with varying surface wind conditions [*Olmsted*, 1993; *Hall*, 1995], rapidly flowing streams such as the Iskut tend to have backscatter values that are spatially and temporally consistent. An upper threshold of −10.5 dB was used for classification of the water surface. This value approximately coincides with the mode of a right-skewed Gaussian distribution of data values typical for the control section. Although a bimodal distribution distinguishing water from gravel was not observed, the mode tends to behave as an inflection point, with distribution density to the left of the mode increasing with water surface area. Its relatively stable position at −10.5 dB permitted uniform application to all images acquired over the control section. From visual assessment, thresholds set lower than −10.5 dB tend to miss some water surface area; higher thresholds classify noncontiguous patches that do not appear to be channels.

Speckle was reduced using a 3 × 3 bimodal majority filter that was applied to each image to remove anomalous bright pixels from the channels and dark nulls from the surrounding floodplain surface; this approach is similar to that used by *Kellndorfer et al.* [1993]. Following calibration, classification, and filtering of each image (Figure 2), total water surface area within the control section was computed from a simple pixel count of cells classified as water. Division by the length of the control section (10 km) was used to normalize these areas, yielding an "effective width" (in meters) of the total water surface for each ERS 1 image.

Results

Twenty-eight ERS 1 SAR images were acquired over the Iskut River control section from 1992 to 1993. Hourly streamflows measured simultaneously on the ground ranged from 242 to 6350 m^3/s, including an extreme flood event on October 27, 1993, the largest recorded in the 34-year history of the gauging station. Peak annual flows normally do not exceed 2000 m^3/s. Effective width of the braided channel network grows or contracts in response to changing river discharge, as can be seen from three sample images in Figure 3. Satellite-derived effec-

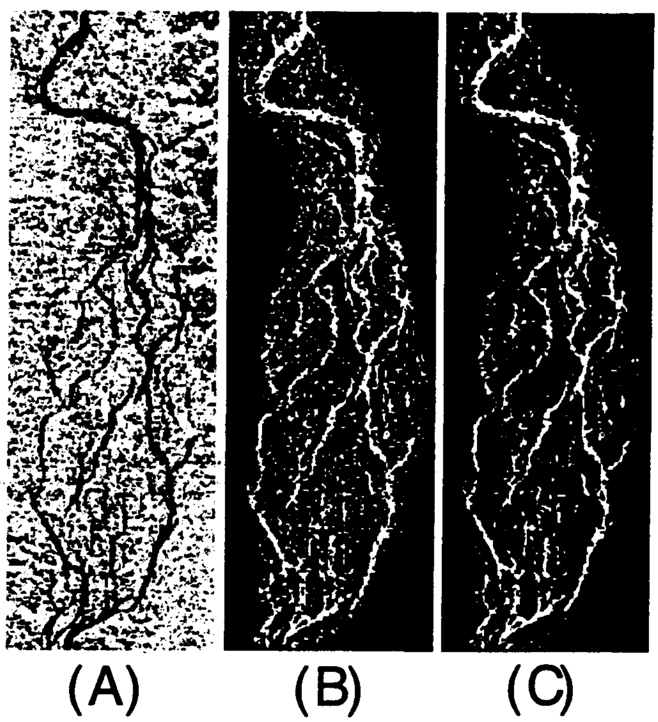

Figure 2. Processing of ERS 1 SAR data: (a) radiometric calibration; (b) water classification (−10.5 dB); and (c) speckle filtering. Braid complex is approximately 10 km × 3 km.

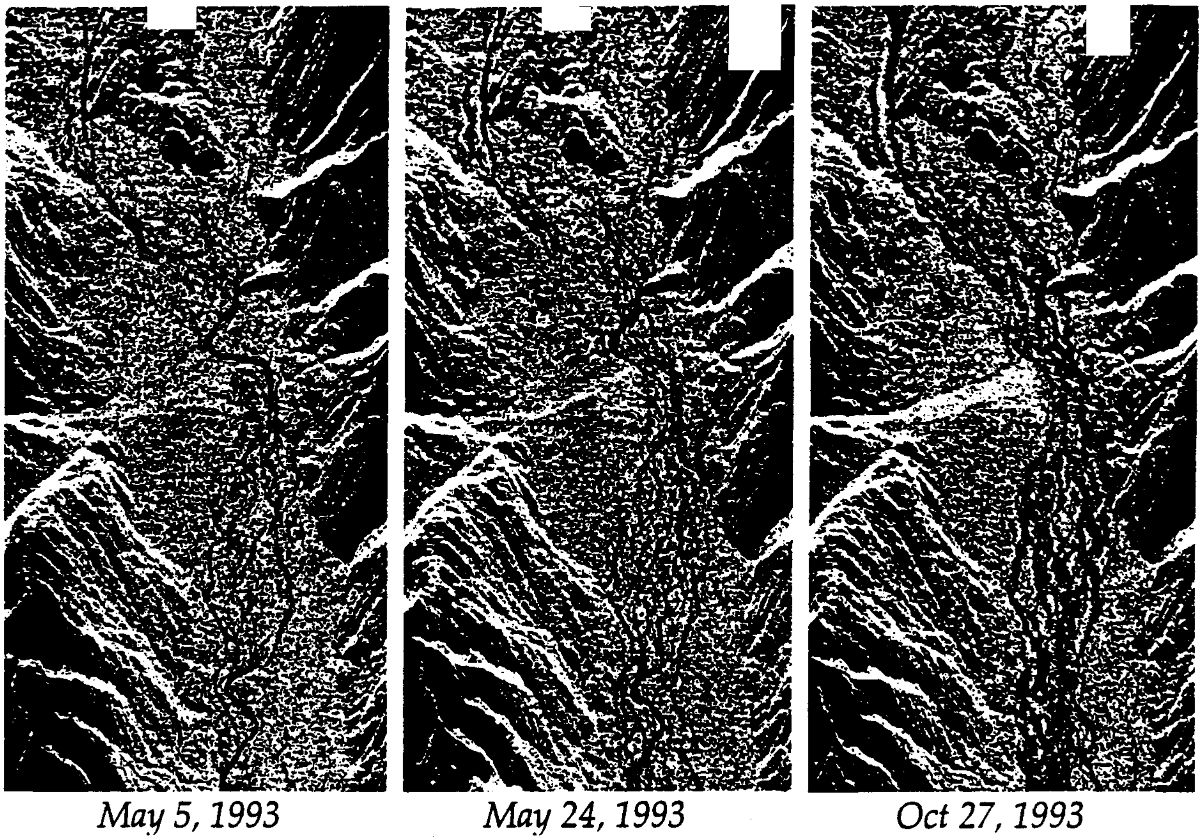

Figure 3. Three ERS 1 SAR images acquired over the Iskut River in 1993. Water surfaces are dark; river discharge increases from left to right. May 5 and May 24 are typical; October 27 was an extreme flood event. Each image is approximately 15 km × 8 km.

tive widths and actual river discharges are plotted in Figure 4. The relationship is log linear with 89% of the variation explained by the equation $W_e = 27.5Q^{0.42}$, using a 95% confidence interval. This plot constitutes a satellite-derived "area-discharge rating curve" for the control section with a mean error of ± 275 m^3/s.

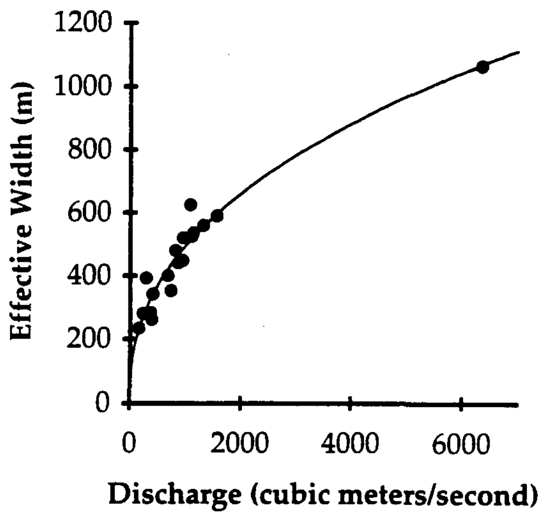

Figure 4. Relationship between satellite-derived effective width (W_e) and river discharge measured on the ground. The equation of the best fit curve is $W_e = 27.5Q^{0.42}$ ($R^2 = 0.89$). Each point is determined from a single ERS 1 SAR image. Outlier is an extreme flood event: maximum annual flows do not normally exceed 2000 m^3/s.

Changes in the braided network can be tracked through time. Although the main channels of the Iskut appear to be relatively stable, secondary channels appear and disappear, often with a new configuration. River ice can also be monitored, but this technique can not be applied during winter conditions because there is no unique relationship between river ice area and discharge. Ground discharge measurements, when available at all, are also of poor quality during winter conditions. Frozen channels typically appear bright instead of dark, but melting snow and ice during March and April cause low backscatter returns from much of the floodplain, including areas between channels. The extensive dark patches that result have low backscatter values and are easily misclassified as open water. For these reasons, only ice-free images (Table 1) were used to produce Figure 4.

Discussion

Previous studies have noted the strong correlation between channel width and discharge in the braided fluvial environment [*Rice*, 1979; *Mosley*, 1983; *Leopold*, 1985; *Schumm et al.*, 1987, chapter 5]. The relationship is typically described as a function of the form

$$W = aQ_c^b$$

where W is braid channel width, Q_c is channel discharge, and a and b are constants. The responses of channel depth and

Table 1. ERS 1 Synthetic Aperture Radar Scenes Used to Produce Figure 4

ERS 1 Orbit	ASF ID	Date
4424	75634	May 20 1992
4696	27431	June 08 1992
5197	83322	July 13 1992
5426	77526	July 29 1992
5698	75759	Aug. 17 1992
6199	81831	Sept. 21 1992
6428	81861	Oct. 07 1992
6929	81981	Nov. 11 1992
9434	83388	May 05 1993
9706	83425	May 24 1993
9935	83435	June 09 1993
10207	83458	June 28 1993
10436	83488	July 14 1993
10937	83530	Aug. 18 1993
11209	83565	Sept. 06 1993
11438	83606	Sept. 22 1993
11939	83833	Oct. 17 1993
12211	86023	Nov. 15 1993

ASF ID is Alaska SAR Facility (ASF) image identification number, and date is Greenwich Mean Time date of acquisition.

flow velocity are described by similar functions. The value of the width exponent *b* is an indicator of the sensitivity of a channel's width to changing discharge. Field measurements in small braided channels (with flows of the order of 1–15 m^3/s) and flume studies have yielded width exponents that range from 0.07 to 0.58, with typical values around 0.22–0.45 [*Fahnestock*, 1963; *Church*, 1972; *Cheetham*, 1979; *Rice*, 1979; *Mosley*, 1983]. The satellite-derived width exponent of 0.42 for the Iskut River is similar, despite the much larger scale (flows of hundreds to thousands of cubic meters per second) and integration over all channels in an entire braided reach. Width-depth ratios also tend to be similar among rivers of similar scale [*Fahnestock*, 1963; *Church*, 1972], but more comparative studies are needed to assess the potential of this technique for application to ungauged braided systems. Construction of effective width/discharge curves for other gauged watersheds will permit comparisons with the one derived in this study.

Layover, foreshortening, and radar shadow are common effects in SAR images acquired over areas of steep topography. Radar returns from the glaciers and mountain slopes surrounding the Iskut River valley are significantly affected by satellite position, requiring the use of repeat pass imagery for study of their changing surface conditions. However, minimal topographic distortions were found over the flat, wide floodplains of the Iskut and Stikine Rivers. Changes in viewing geometry do not significantly affect the detection of water surfaces, permitting the use of overlapping orbits to increase the temporal resolution of a monitoring program over these low-relief valley floors. The presence of river ice, however, presents a severe difficulty for both satellite and ground-based discharge estimates. This problem is mitigated by the fact that as much as 95% of the total yearly discharge for glacierized basins is released during the summer [*Lawson*, 1993], making winter measurements less critical to the assessment of annual water cycles. For the Iskut River, winter contribution to total annual streamflow is consistently less than 10% each year.

Annual streamflows in glacierized basins follow a predictable pattern, unlike watersheds dominated by stochastic rainfall events. Mean discharges swell over a period of months during the summer melt season with small, highly random deviations superimposed on a larger, relatively smooth trend that is remarkably similar from year to year. For this reason, discontinuous instantaneous discharge estimates tend to approximate the annual hydrograph more closely for snowmelt and ice melt rivers than for rainfall-controlled watersheds. It is hoped that future work will indicate some transferability of satellite-derived rating curves from gauged watersheds to ungauged rivers of similar morphology. If not, potential still exists for inferring relative changes in streamflow for a particular ungauged site, even if absolute values are not obtainable without a period of ground calibration.

Spaceborne SAR's such as the currently operating ERS 1 and Japanese Earth Resources Satellite (JERS) 1, and the anticipated ERS 2, JERS 2, and Canadian RADARSAT, are excellent sensors for multitemporal hydrologic studies due to their cloud-penetrating capability, high spatial and temporal resolution, and strong sensitivity to water. While it is not suggested that satellite-derived values will ever approach the accuracy or sampling frequency of traditional gauging methods, approximate and intermittent estimates of discharge from braided glacial outwash streams will provide assessment of hydrologic conditions at a regional scale not currently possible for these remote, climatically sensitive watersheds.

Conclusion

With our rapidly improving satellite technology and the prospect of abundant multitemporal data in the next century, new spatially based discharge estimation techniques show great potential for improving our understanding of hydrologic regimes in remote areas. ERS 1 SAR classifications of water surface area correlate well with ground discharge measurements for a braided river in British Columbia, indicating that approximate discharge estimates can be made from space. Potential exists for satellite monitoring of large remote or high-latitude glacial rivers, where flows may be sensitive indicators of regional or global climatic conditions.

Acknowledgments. Support for this work was provided by NASA through EOS grant NAGW-2638, SIR-C grant 958475, and a GSRP Fellowship NGT-51223. ERS 1 data were also provided by NASA through the Alaska SAR Facility (grant N0061BI), where Greta Reynolds greatly facilitated data acquisitions and special processing requests. Ground measurements of river discharge were obtained by the Water Survey of Canada; the speckle filter was written by C. C. Duncan. The manuscript was substantially improved from critical reviews by N. D. Smith and two anonymous readers. INSTOC contribution 216.

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(Received May 12, 1994; revised January 6, 1995; accepted January 12, 1995.)

Utilization of airborne and spaceborne observations for flood monitoring purposes

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Organization with respect to rivers

Rijkswaterstaat
Responsible for the river area between the dykes.
entities involved:
- local maintainance and construction depts ('dienstkring'): dredging, river bed
- RIZA: Measuring Systeem Water (real time, 50 stations) and predictions (curves, modelling)
- DNZ: remote sensing aircraft

Provinces (local water authorities)
Responsible for dykes and river neighbouring areas: maintaince of dykes

What happens in case of potential flood

Local & regional crises centra are established by the Provinces. Their main information sources are the real time data from MSW and the daily predictions (by RIZA).

During an actual flood

The information sources during an actual flood are:
- on-the-spot information, field survey (most important)
- MSW
- predictions from RIZA
- aerial photography (bl/wh) for mapping of flooded areas (during and post)

Potential of RS for operational purposes

In the past two years the Survey Dept has been promoting the use of aircraft remote sensing for flood monitoring purposes. Potential applications appear to be:
- aircraft TIR: determining the stability of dykes (seepage locations)
- aircraft SLAR: mapping of flooded areas (especially during bad weather conditions)
- aircraft MSS: mapping of sediment (spatial extent)

RS for research purposes

Aircraft remote sensing (detailed)
- optical data (photography, scanning): sediment, currents
- laser altimetry, dig. photography, SAR interferometry: DTM (volumes)
- along track interferometry (PHARUS): currents (velocity)

Satellite remote sensing (larger areas)
meteorology & hydrology

- hydrological modelling

RIZA: Int. Com. for the Hydrology of the Rhine: lowland part
-> lowland model based on RS-derived land use

potential use for calibration/validation purposes on parameters:
- evapotranspiration
- soil moisture

Project 'RS and catchment modelling' (VU, RIZA, MD)

What can be expected of present and future ESA/EUMETSAT missions for determining soil moisture and evapotranspiration ?

Evapotranspiration
based on thermal data
. clouds
. atmospheric correction
. model inversion requires albedo/NDVI
. spatial resolution
. availability of models (non-crop specific)

Soil moisture
based on SAR data
. only for 'bare soils'
. model inversion requires soil roughness
. relative inaccurate
. relationships between surface and sub-surface soil moisture

OPERATIONAL, RESEARCH AND DEVELOPMENT ASPECTS IN THE MANAGEMENT OF NATURAL RISKS IN GENERAL AND FLOODS IN PARTICULAR : THE ROLE AND ACTIVITY OF THE EUROPEAN UNION.

D.Vassaux, DG XII - European Union, Brussels - Belgium

To respond to emergencies caused by natural and technological disasters, the Member States have taken steps to prevent disasters and to be better prepared for those which do occur, and, in particular, have drawn up disaster relief plans to enable them to manage such emergencies.

As some problems are common to all Member States, or similar, cooperation in the field of civil protection has been developed at Community level.

The general objective of Community action in the field of civil protection is to help provide better protection for people, the environment and property in the event of natural and technological disasters. In line with the subsidiarity principle, these objectives are attained mainly by establishing a technical network of those responsible for civil protection in the Member States and by the extensive sharing of experience among them.

In practical terms, technical instruments are being developed (operational manual and pilot projects) as well as initiatives aimed directly at those involved in civil protection which help to increase their degree of preparedness (training, exchanges of experts and simulation exercises). The proposal aims in particular at consolidating and strengthening the development of pilot projects, which will be carried out primarily by small and medium-sized enterprises.

In addition to these actions, the E C has co-financed research and development activities.

The specific programme "Environment and Climate" of the 4th Framework Programme, will include several area covering issues related to natural hazard questions :

- development of technologies to forecast, prevent and reduce natural risks;
- methodological research and pilot project related to space techniques.

The specific programme of telematics does include activities related to the development of Integrated Environmental Emergency Management systems.

These R and D activities are a follow-on of 3rd Framework Programme projects.

Flood Modelling in the Financial sector: Is satellite data the answer?

A. Mitchell -
Greig Fester International Ltd.
London, UK

Forward

The Operating Environment

The insurance operating environment has changed. Natural hazards are becoming increasingly significant. Not only are we more aware of natural disasters through swift and widespread media reporting, but also that exposure is constantly increasing.
This is due to:

- increase in the world population
- development of technology and its application in exposed areas
- growing concentration of values in large cities and industrial areas

These have all greatly increased catastrophe potential.

The Business Environment

The insurance business environment continues to change.
There is:

- ever greater demand and expectation of profit from shareholders and investors
- increased pressure to maintain high solvency margins
- the need to match growth with underwriting control and selection
- ever increasing competition in the market place

Increased availability of information exacerbates these pressures. It is only by the effective management and utilisation of information that insurance companies will stay ahead of their competitors.

The Future

In managing the changing environment, insurers are using every option available to gain competitive advantage. Options which give competitive advantage are needed to manage portfolios efficiently, purchase reinsurance effectively, and ultimately to increase profits.

Geographic Analysis Project

Geographic Analysis Project

The increased number of natural catastrophes affecting more concentrated accumulations of risk has produced an unprecedented loss record.

This has highlighted the need for a more precise and scientific approach to analysing exposures and accumulations of risk. In particular there is a need for:

- analytical tools to promote better understanding of exposure
- loss estimate models for windstorm and flood
- data to devise better informed rating and marketing strategies
- reassessment of reinsurance requirements

To this end, Greig Fester's UK Division have developed some of the most sophisticated and advanced risk management tools that are currently available to insurers in the UK.

GAP encompasses two main areas:

- risk management
- portfolio management

Risk management comprises two models for investigating natural perils:

- flood model
- storm model

Both models are capable of producing loss estimates for worst case scenarios at a currently unparalleled level of resolution and accuracy.

Portfolio management comprises a series of tools for investigating insurance portfolios particularly with reference to:

- distribution
- market share
- rating
- sum insured
- socio-economic modelling

Coastal Flood Study

Coastal Flood Model

Background

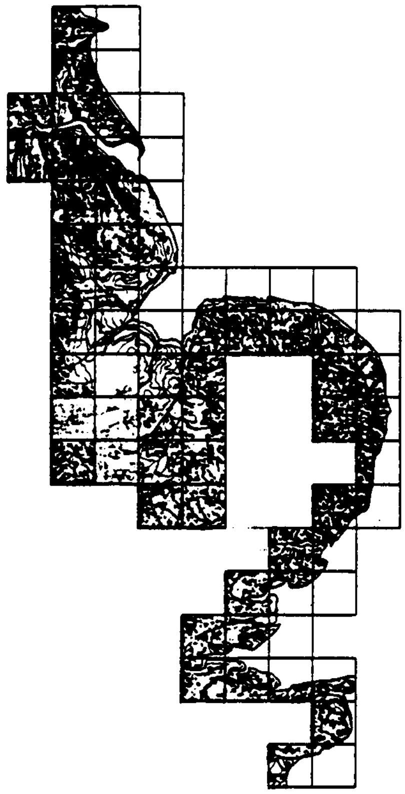
Historical information concerning flood is scarce. There has only been one major East Coast Flood this century, in 1953. However, recent floods in Perth, Towyn, Chichester and Paisley have provided valuable information as well as highlighting the serious threat that flood poses.

Objective

To investigate and quantify the risk of flood on the East Coast of England at the highest resolution and with the greatest possible accuracy.

Method

The coastal flood model investigates an area from just north of the Humber to Romney Marsh in Kent and as far up the Thames as Dartford (see diagram below). Future areas to be incorporated will provide analysis of other coasts and estuaries.



East Coast Flood Study Area
The illustration shows the range of Ordnance Survey 20km tiles containing the height data used to construct the model (blank tiles are sufficiently high enough ground to be excluded)

— form lines
— contour lines

Step 1 – calculating a 3-D surface

The area is divided into 20km by 20km squares which are then subdivided into 5m by 5m squares for further investigation. All these squares are referenced using the National Grid.

A three dimensional surface is calculated using raw height data from the Ordnance Survey.

Data used to calculate the three dimensional surface include:

- contour lines: at 10m intervals
- form lines: similar to contour lines, but provide extra information concerning heights in between the regular contour intervals; such as ridges, cliffs and river beds
- spot heights: individual points accurate to 1m
- detailed coastline: height details at 15m intervals

From these known height data we make a height calculation for each 5m square on the ground. Different amounts of data are available for different parts of the study area.

The accuracy of the height calculation is dependent on how much data is available.

This surface has been calibrated and checked against Ordnance Survey sheet maps to ensure its accuracy and integrity.

Benefits

Greig Fester's three dimensional surface is significantly more accurate than "off the shelf" models (which are generally accurate to only ±3m).

The surface produced has been calculated specifically for our own purposes allowing greater flexibility for further modelling.

Digital height data in a "flat" or 2-D format from the Norfolk area (taken from OS tile TG 22)
The data is used to construct the 3-D surface shown on page 5.

— form lines
— contour lines
area $1km^2$

Royal Mail postcode structure

zone	example	number	also know as
area	SW	123	outward
district	SW11	2,900 ■	outward
sector	SW11 5	9,200 ■	inward
unit	SW11 5HA	1,588,000 ■	inward

■ These numbers are approximate since changes are made to the system every month as property is built or demolished or the use of the postal service changes.

Step 2 - locating policies to ±100m

Greig Fester has calculated a dataset that details the location of every residential and non-residential property in the UK to an accuracy of ±100m. This dataset splits the UK into a grid of approximately ten million 200m by 200m squares.

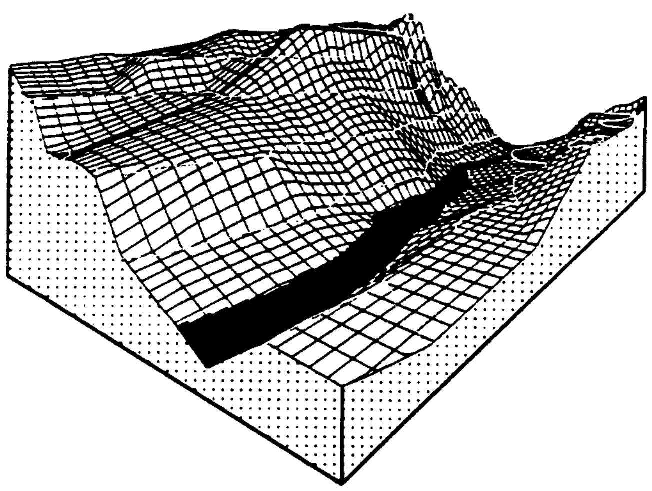
In addition, Greig Fester has developed a model to "dis-aggregate" insurance data by postcode district, sector, or unit and estimate a point distribution of risks based on the 200m by 200m squares in the grid surface described above.

Re-allocation is achieved through a weighted statistical model. Insurance data that are redistributed in this manner include the domestic and commercial policy count and sums insured.

These processes are described in more detail on page fourteen.

Step 3 - calculating height of policies

The three dimensional surface or Digital Terrain Model is overlaid with the property redistribution produced in step 2. This process allows us to attribute a height value to all unit postcodes, and hence to a property, which fall within the flood study area.



3-D surface constructed from height data as shown on page 4
In this illustration the vertical heights have been exaggerated by a factor of ten for easy viewing. The artificial river flood in the valley obscures the form lines.

— contour lines
— grid lines
■ artificial flood

Step 4 - simulating the flood

The three dimensional surface complete with property can then be "flooded." The National Rivers Authority has made available to Greig Fester two datasets:

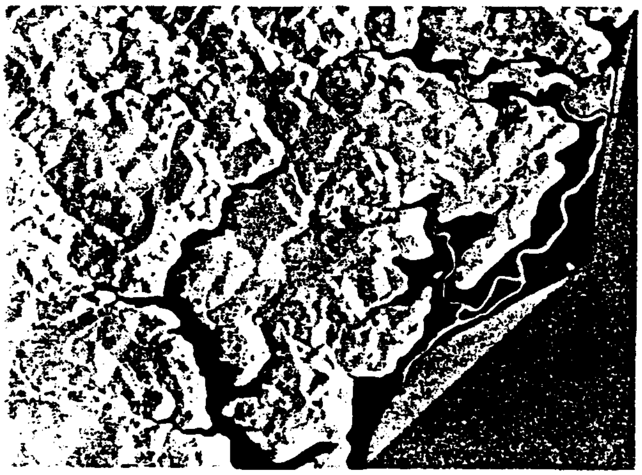
- detailing the height of water along the East Coast in the event of a 1 in 50, 1 in 100 and 1 in 250 year flood
- the Sea Defence Survey, detailing the location, height and state of repair of all flood barriers along the East Coast.

At present, this data has only been used to simulate the effects of the 1 in 250 year flood. The height of water along the East Coast is combined with the calculated height of the coastline and the land to determine the *region that would be affected by a 1 in 250 year flood (see diagram).*

For every 5m by 5m square we are able to calculate:

- the number of properties affected
- to what depth those properties are affected

A significant proportion of the East Coast flood barriers fall below the 1 in 200 year protection level. Consequently flood defences were not considered when simulating the 1 in 250 year event.



Detail from East Coast flood model
The extent of flooding from a 1 in 250 year flood on part of the Suffolk coast

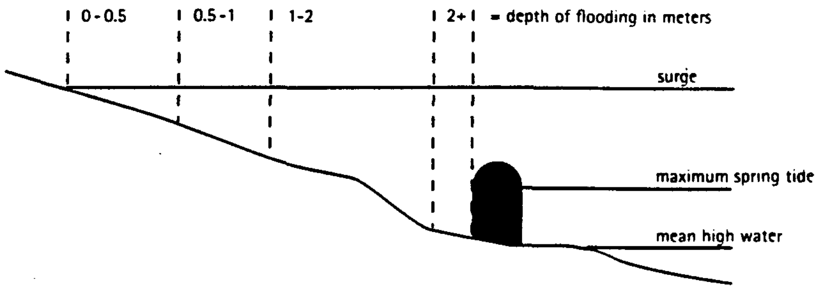
land not flooded
flooded land
sea

Step 5 - calculating the damage

A damage scale - derived from loss adjusters' experience including reports from the Perth, Towyn and Chichester floods - details the average financial loss associated with different depths of flooding.

This allows us to calculate an overall loss figure. The damage scale will be supplemented in the future by the findings of a detailed study of the Paisley flood of 1994.

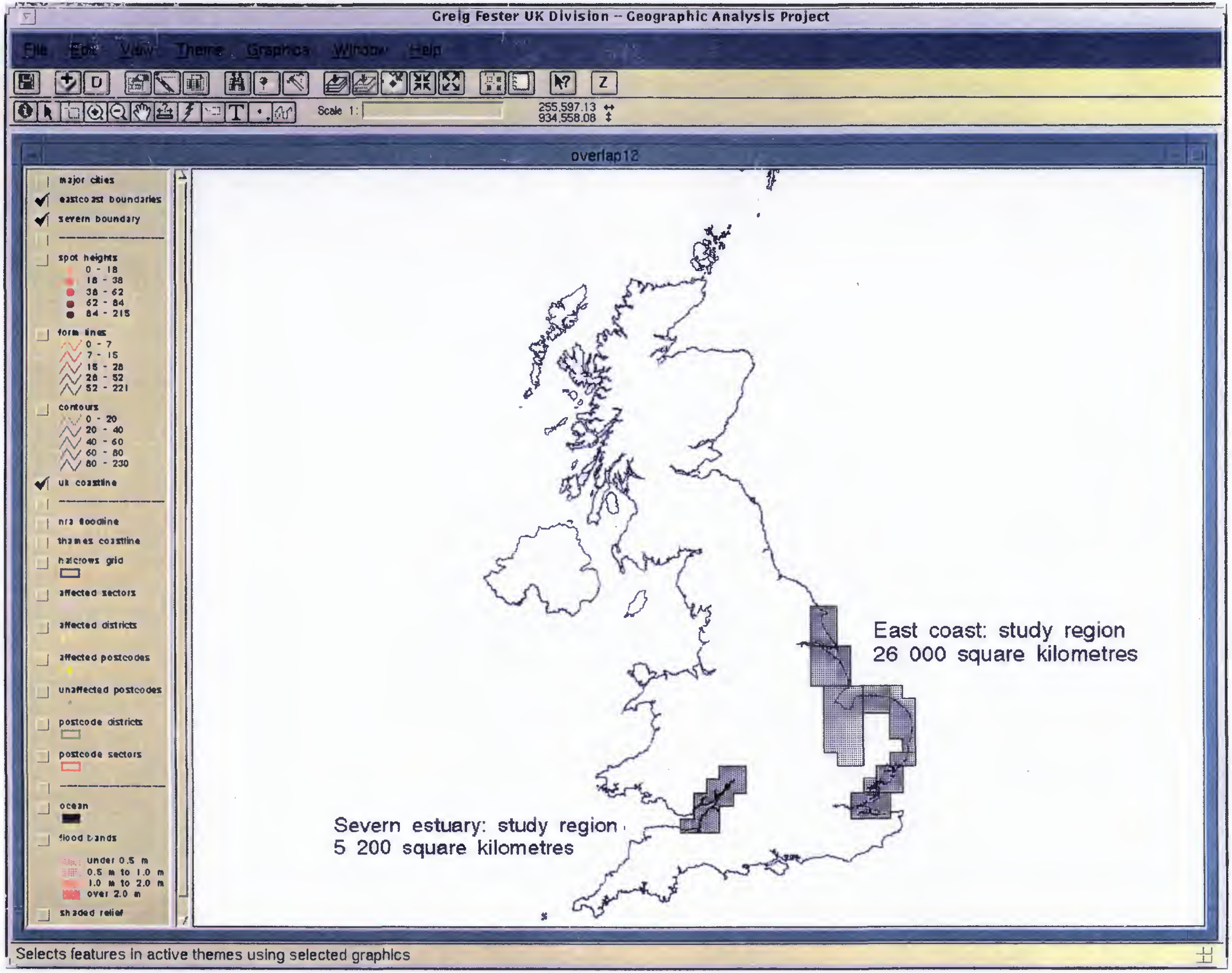
Flood depth bands
A different unit loss figure is used for each band to calculate the overall loss to a portfolio



Conclusion

No other flood model has attempted to investigate East Coast Flood at such a detailed level of resolution.

GAP has broken new ground in terms of calculating a realistic loss estimate for East Coast Flood, both for the UK property market as a whole as well as for individual insurance companies.


Greig Fester UK Division -- Geographic Analysis Project
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major cities
eastcoast boundaries
severn boundary
spot heights
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form lines
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contours
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20 - 40
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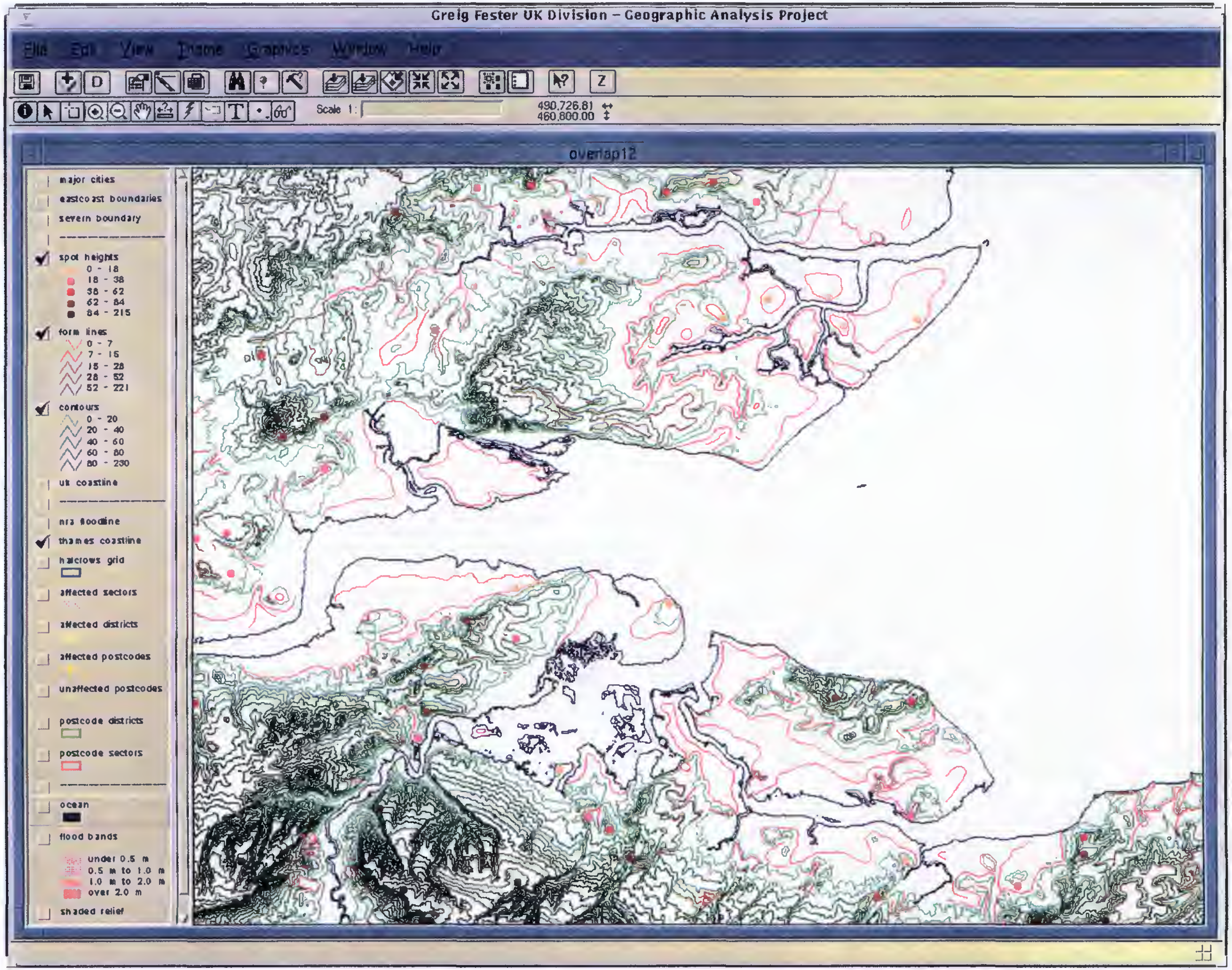
60 - 80
80 - 230
uk coastline
nra floodline
thames coastline
halcrows grid
affected sectors
affected districts
affected postcodes
unaffected postcodes
postcode districts
postcode sectors
ocean
flood bands
under 0.5 m
0.5 m to 1.0 m
1.0 m to 2.0 m
over 2.0 m
shaded relief
East coast: study region
26 000 square kilometres
Severn estuary: study region
5 200 square kilometres
Selects features in active themes using selected graphics



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over 2.0 m
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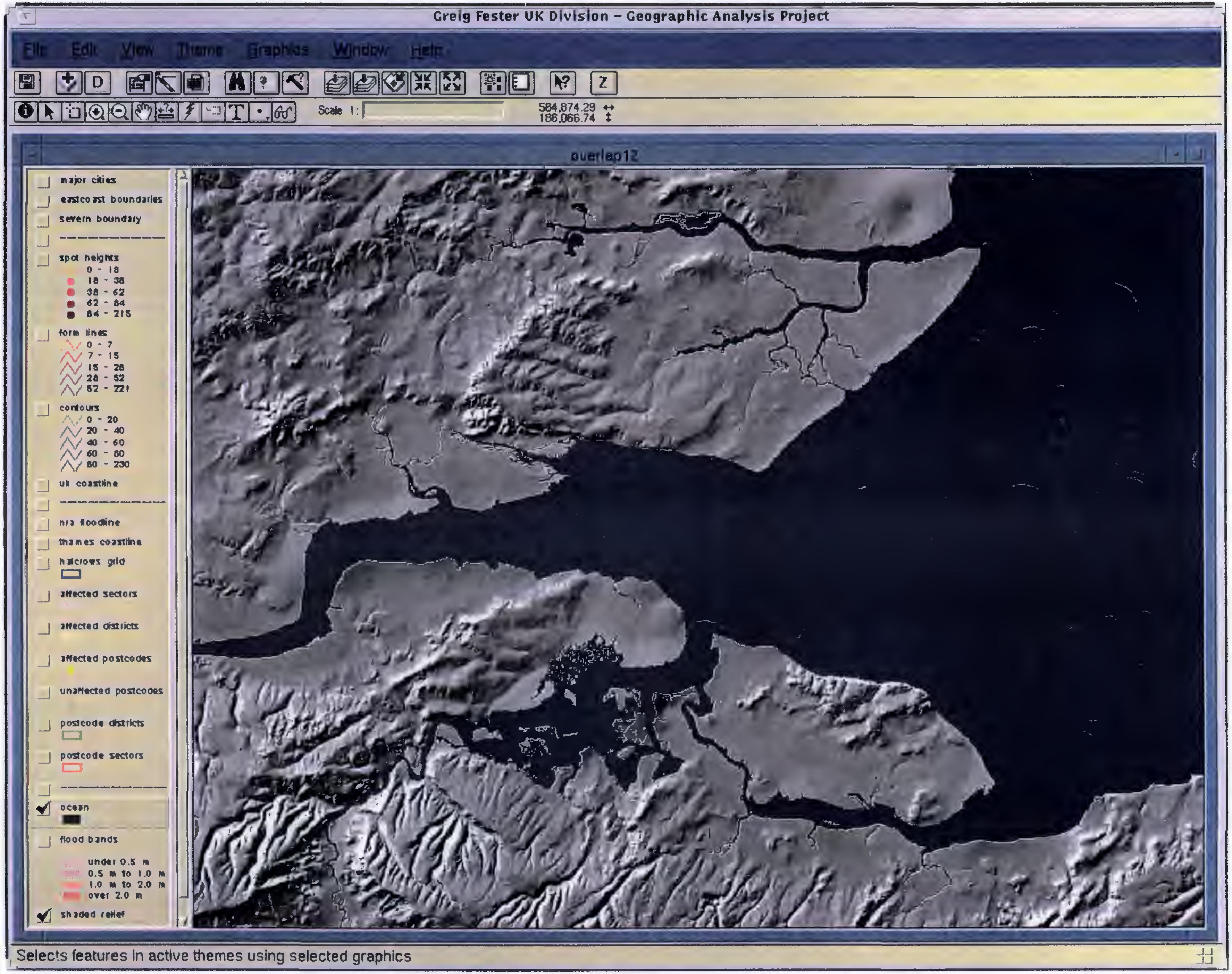

Greig Fester UK Division – Geographic Analysis Project
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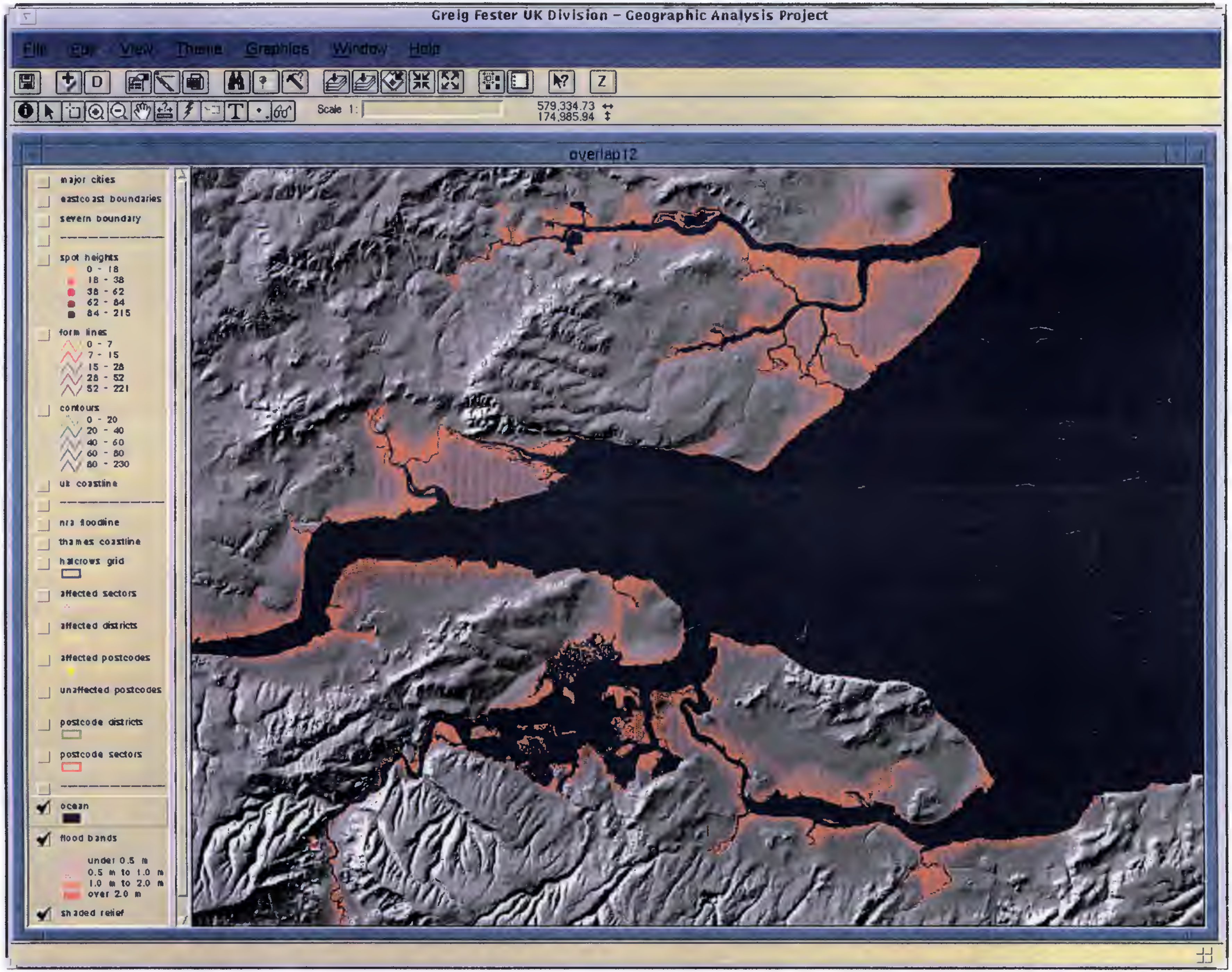
over 2.0 m
shaded relief
Selects features in active themes using selected graphics



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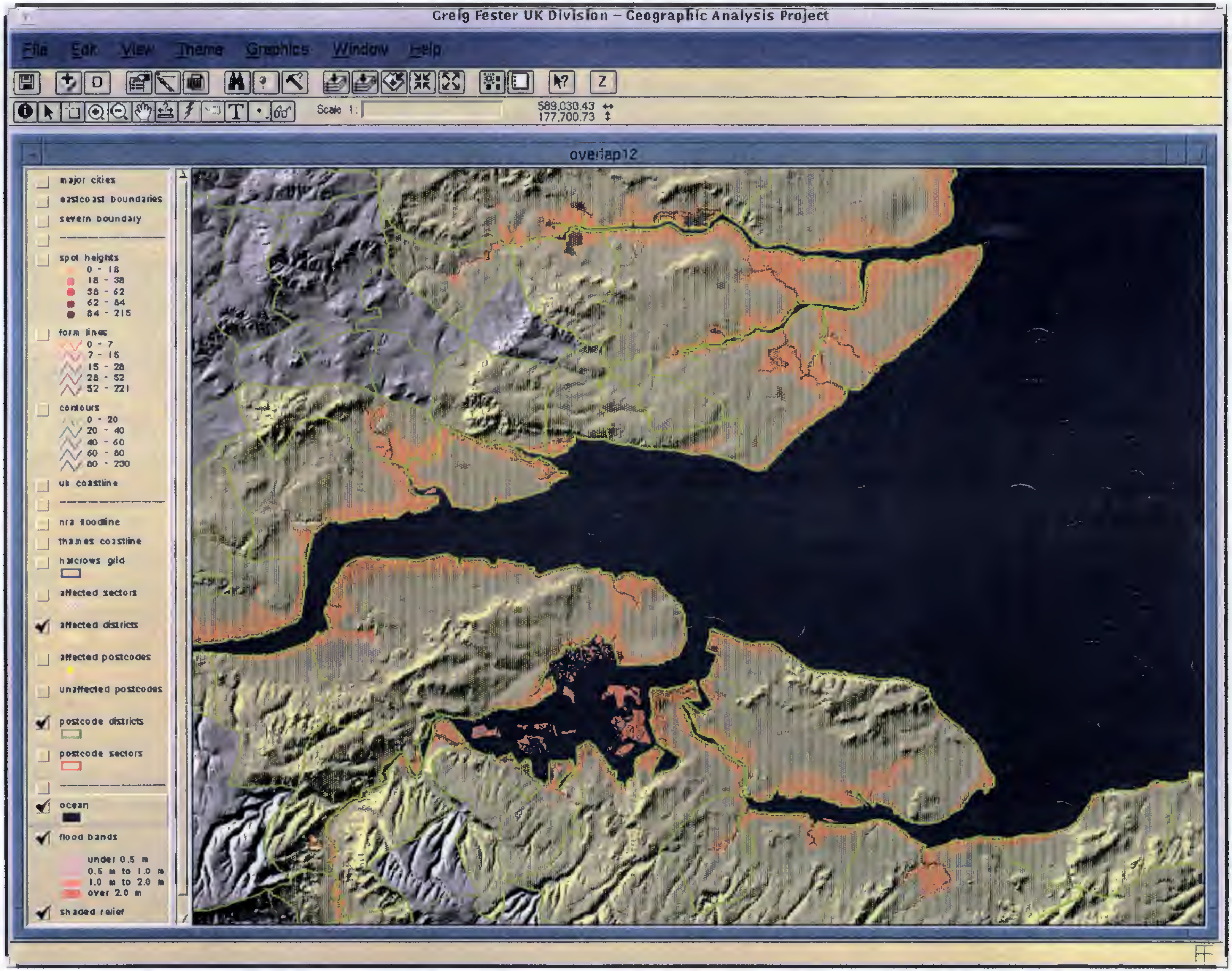
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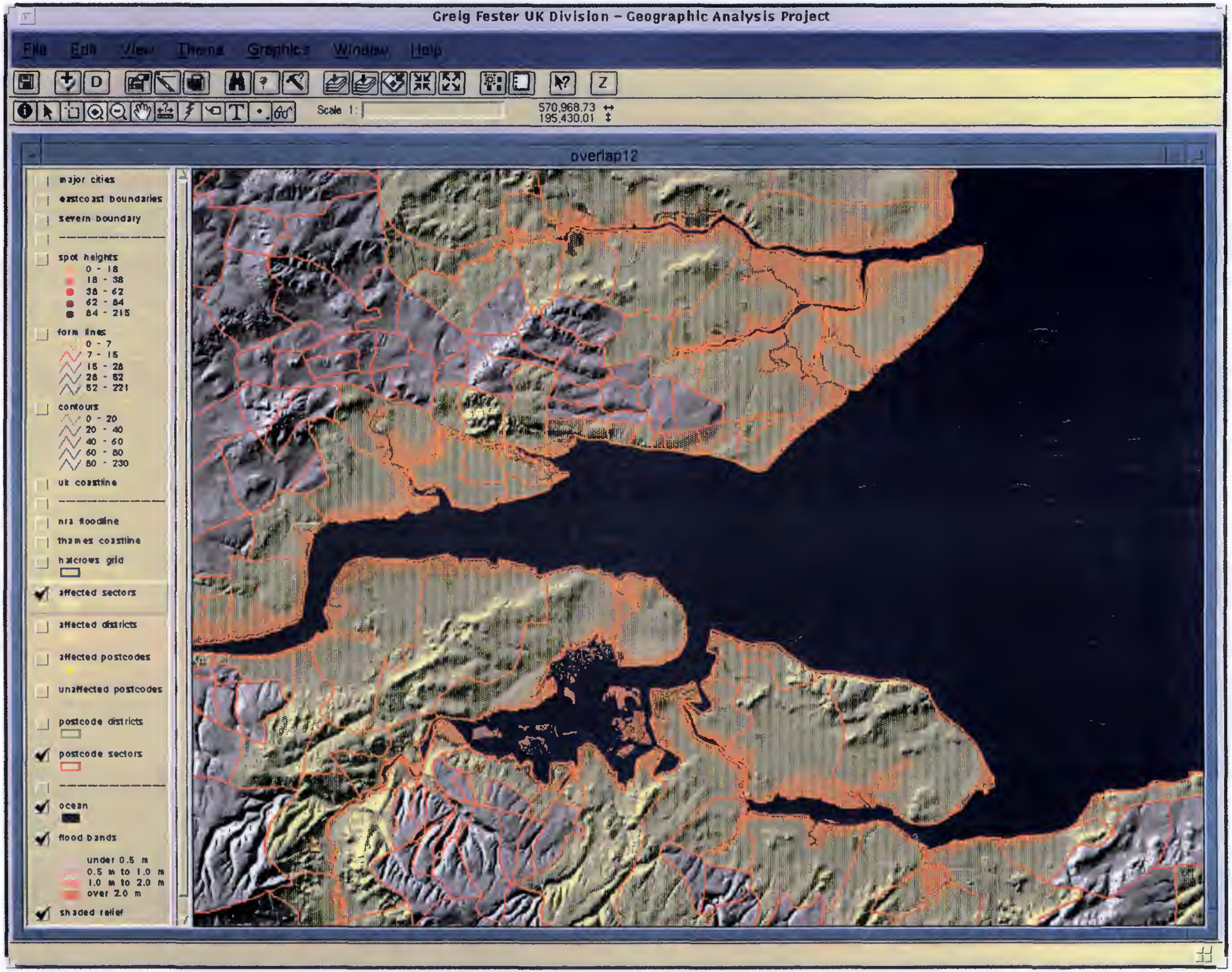

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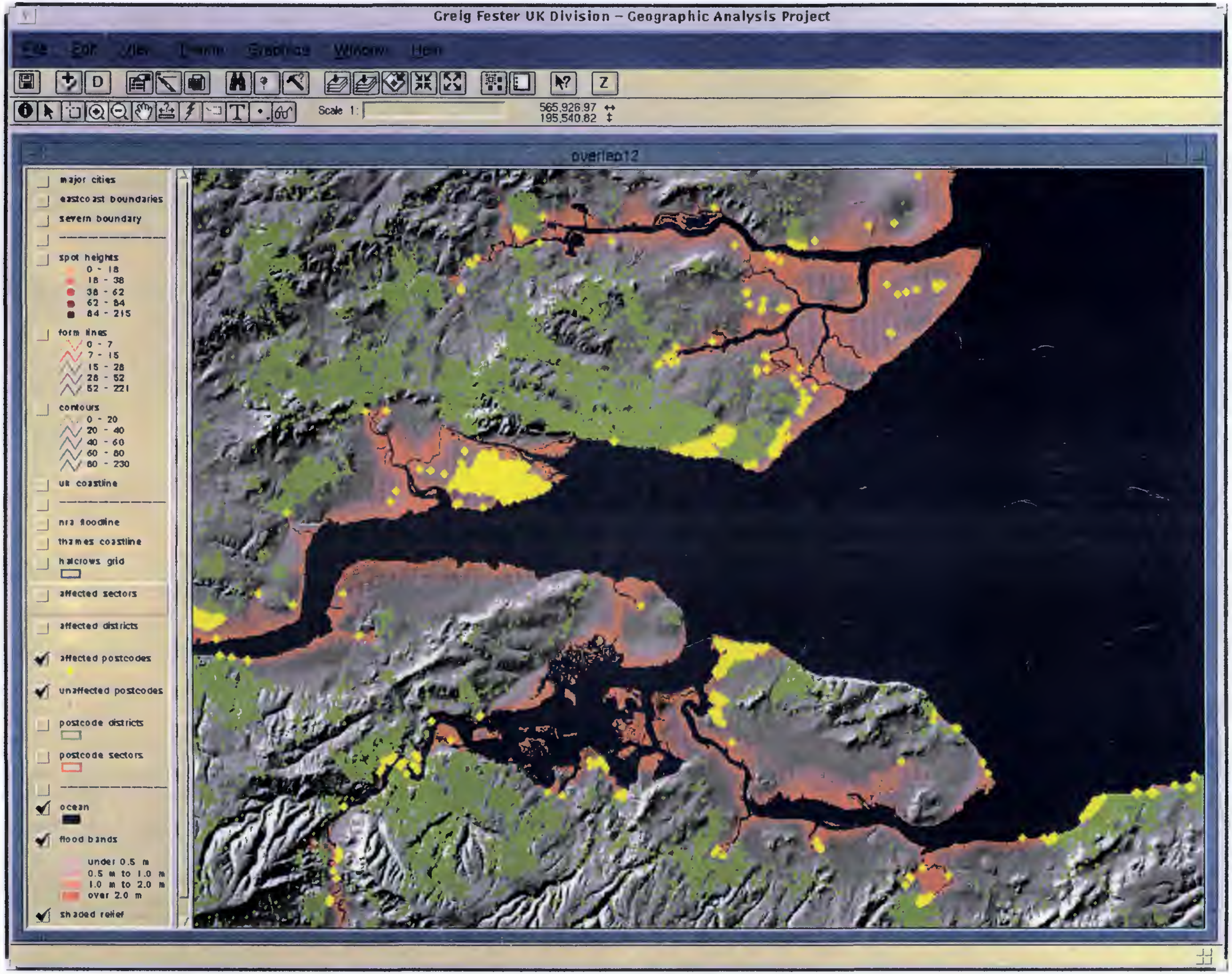
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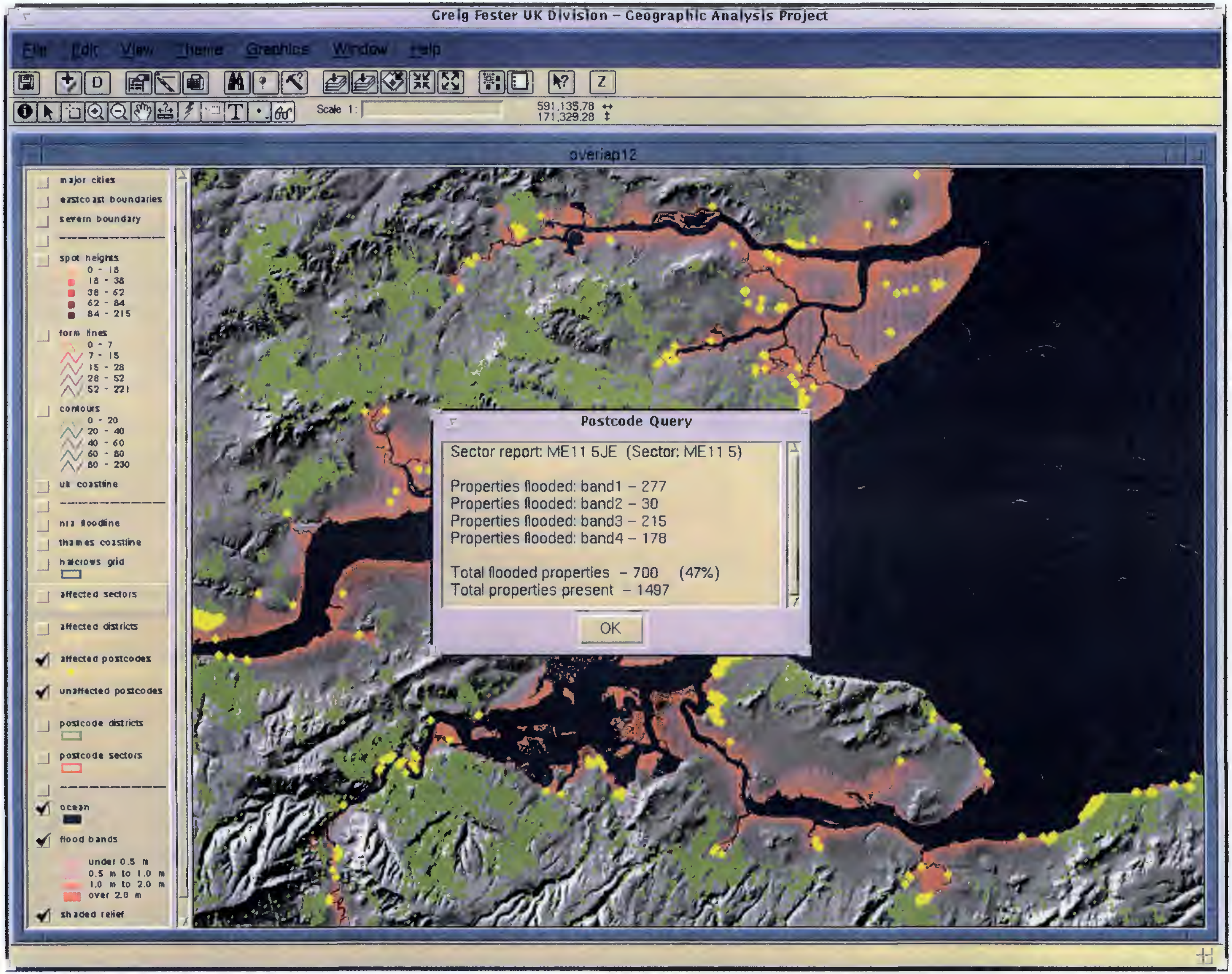
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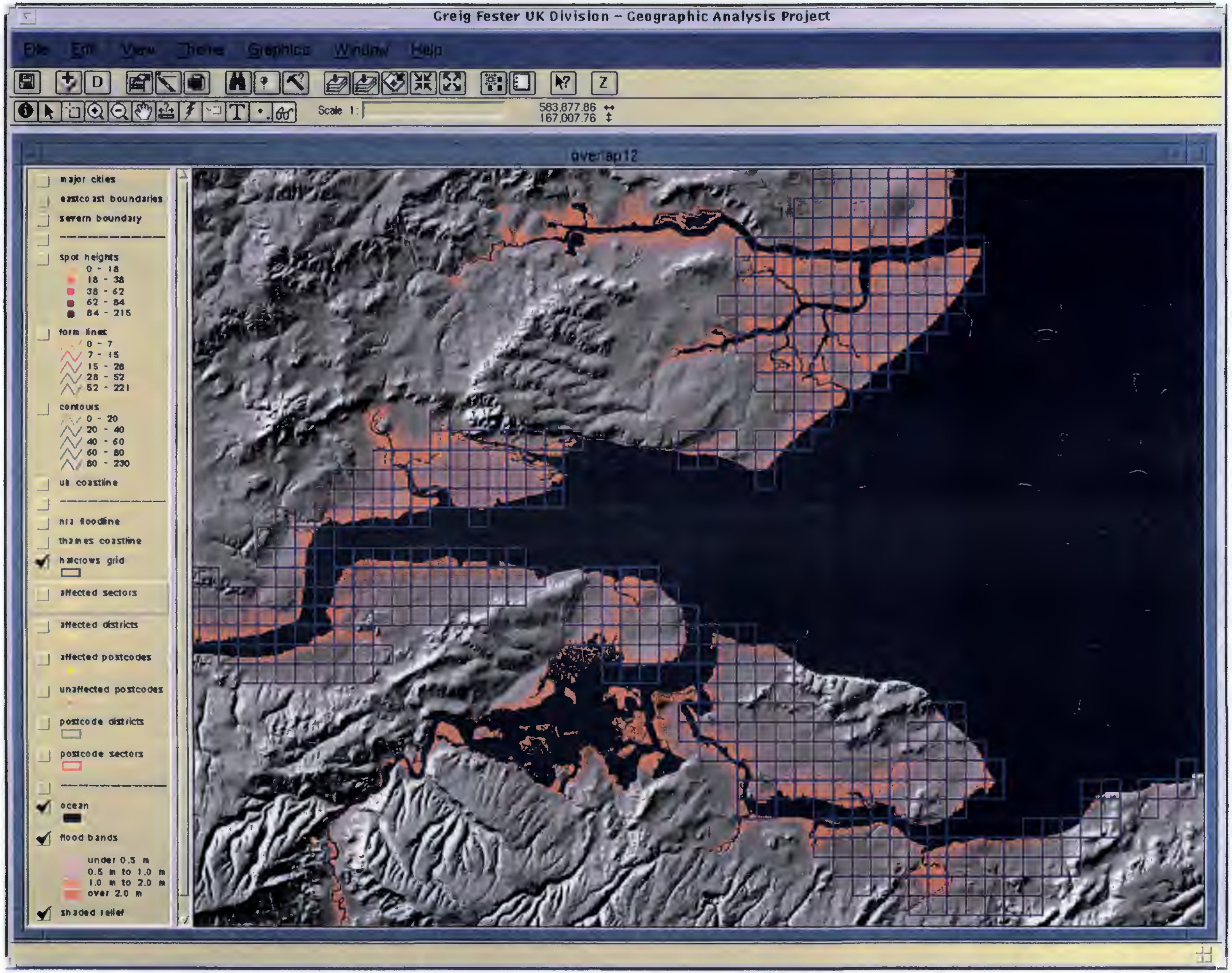
postcode sectors
ocean
flood bands
under 0.5 m
0.5 m to 1.0 m
1.0 m to 2.0 m
over 2.0 m
shaded relief
Postcode Query
Sector report: ME11 5JE (Sector: ME11 5)
Properties flooded: band1 – 277
Properties flooded: band2 – 30
Properties flooded: band3 – 215
Properties flooded: band4 – 178
Total flooded properties – 700 (47%)
Total properties present – 1497
OK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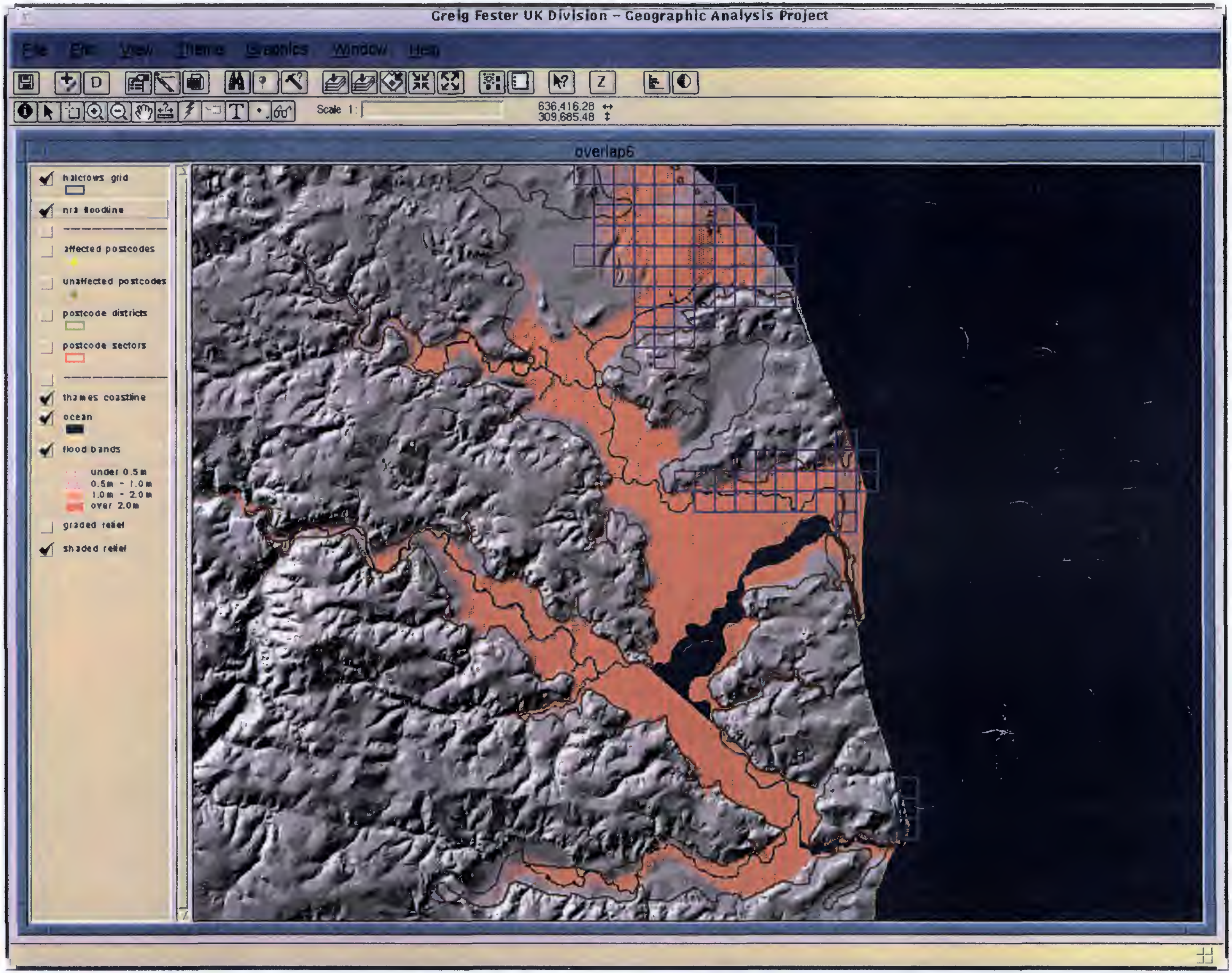
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affected postcodes
unaffected postcodes
postcode districts
postcode sectors
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ocean
flood bands
under 0.5m
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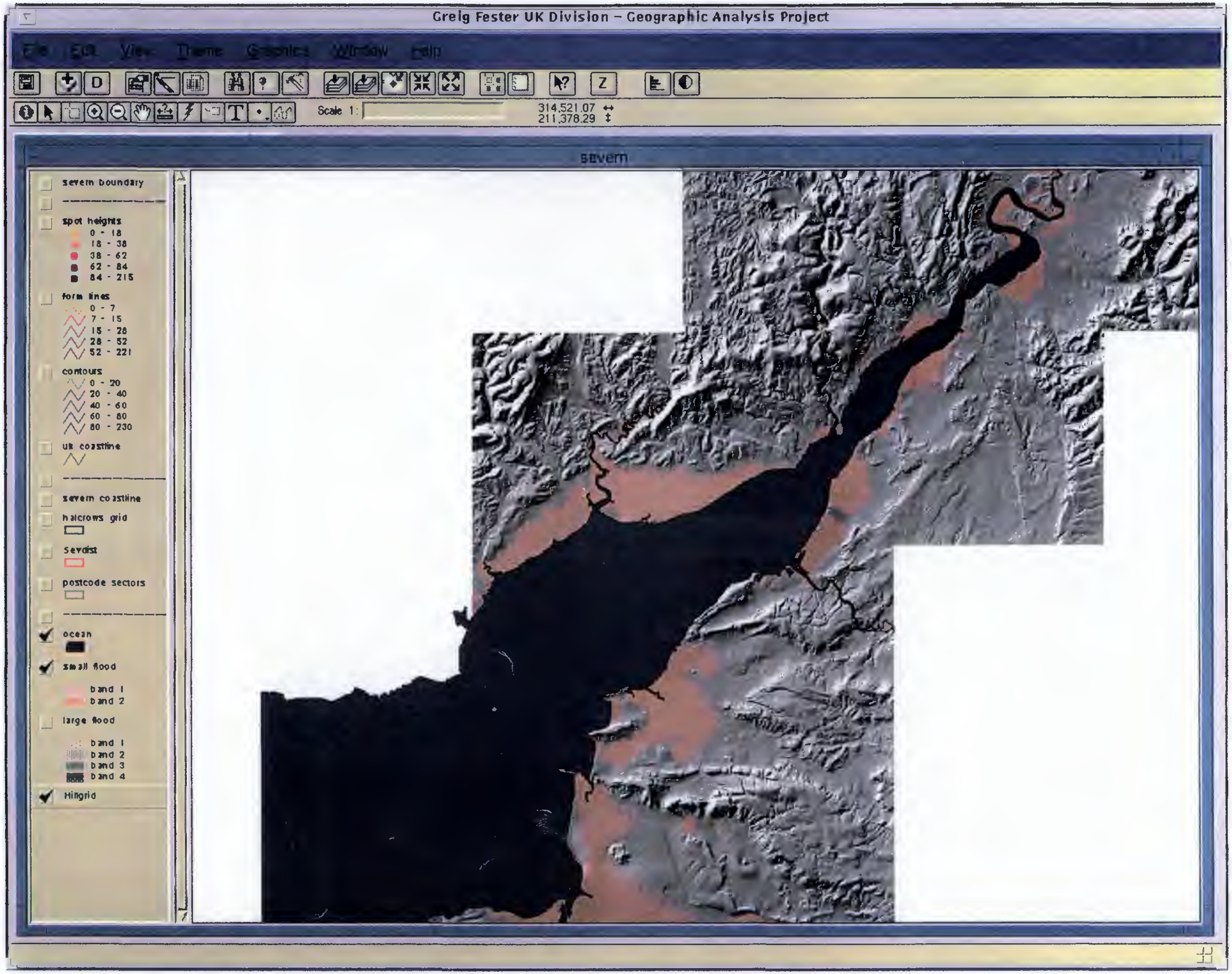
over 2.0m
graded relief
shaded relief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ocean
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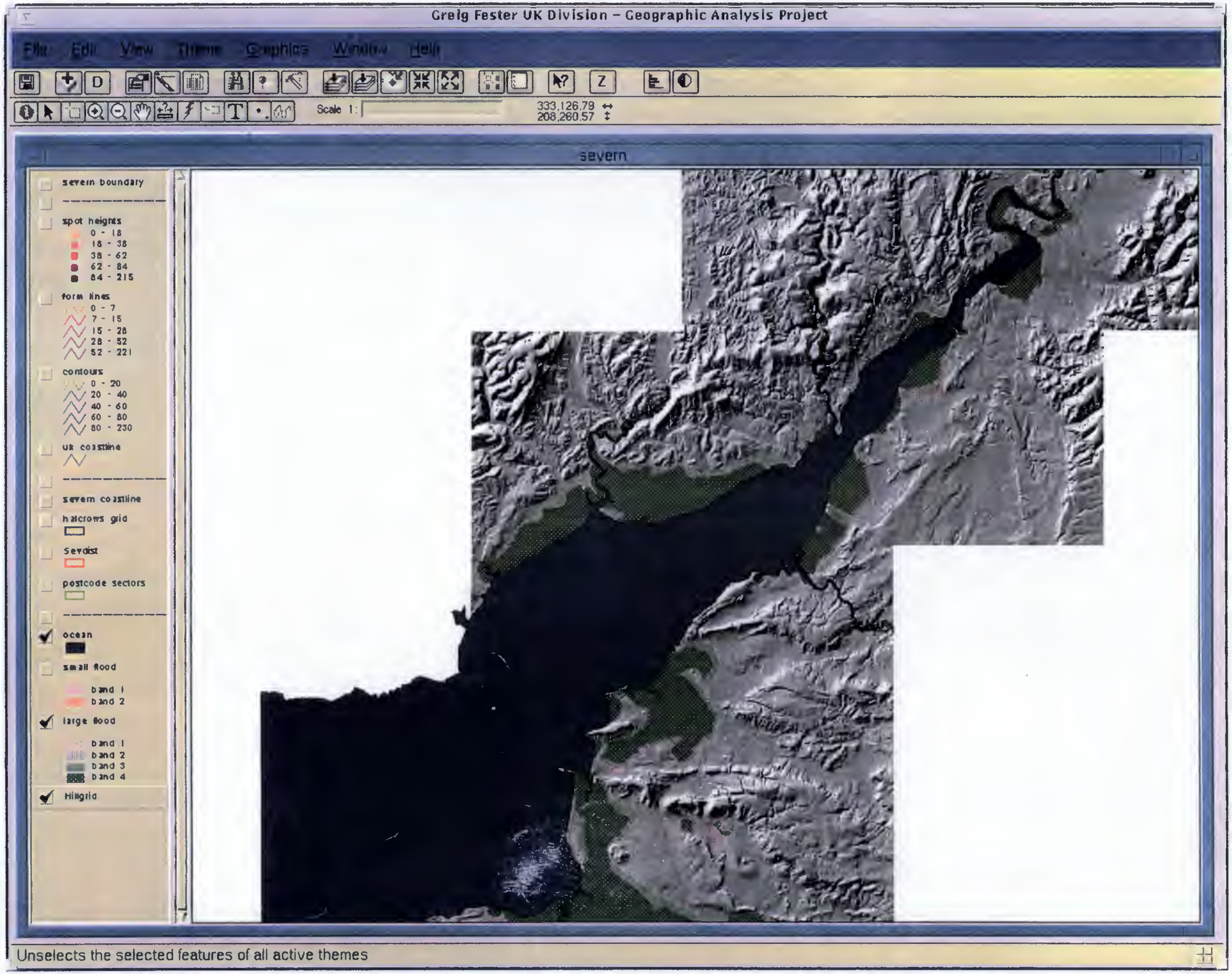
band 1
band 2
large flood
band 1
band 2
band 3
band 4
Hillgrid



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band 1
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large flood
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band 4
Hillgrid
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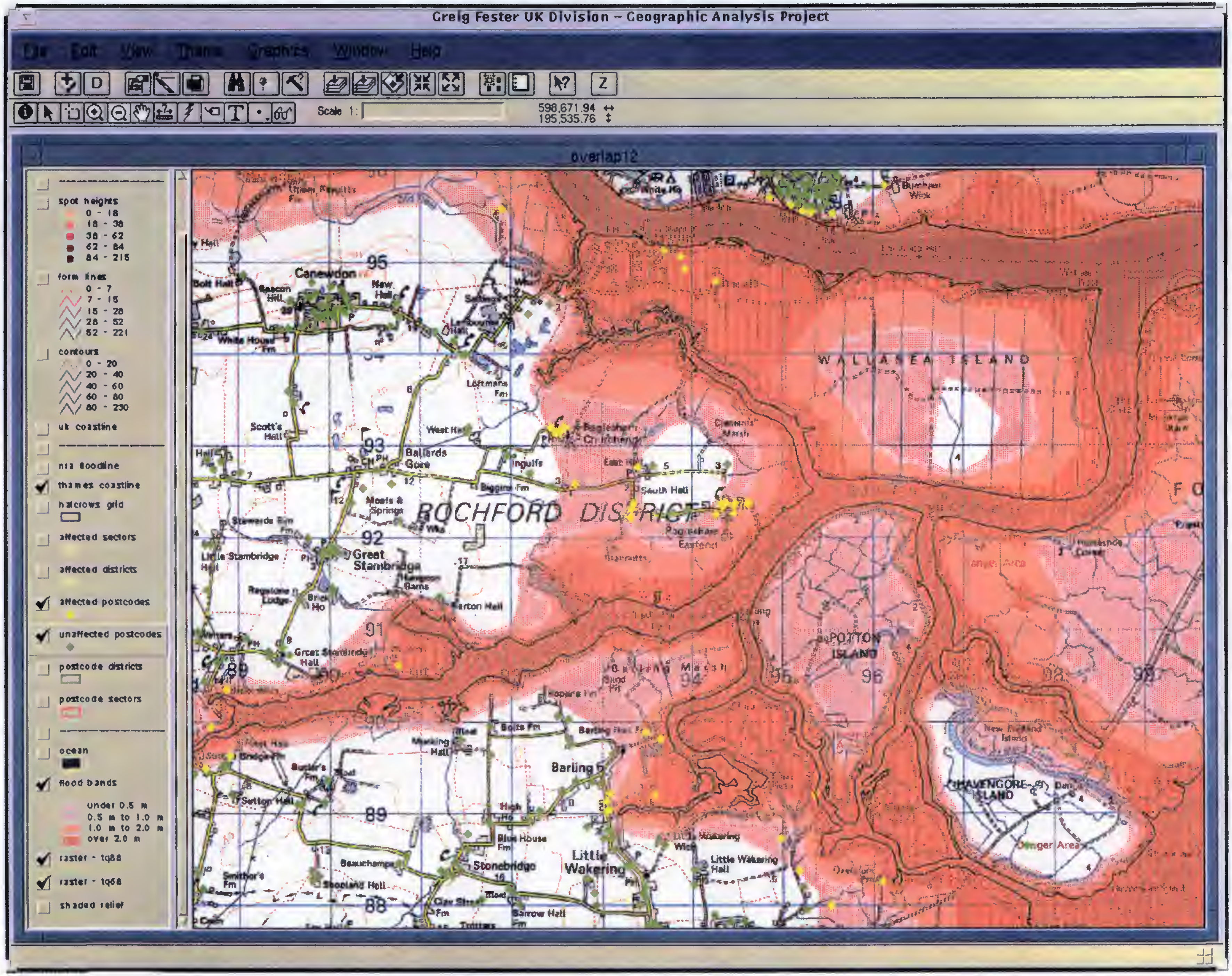

Greig Fester UK Division – Geographic Analysis Project
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unaffected postcodes
postcode districts
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flood bands
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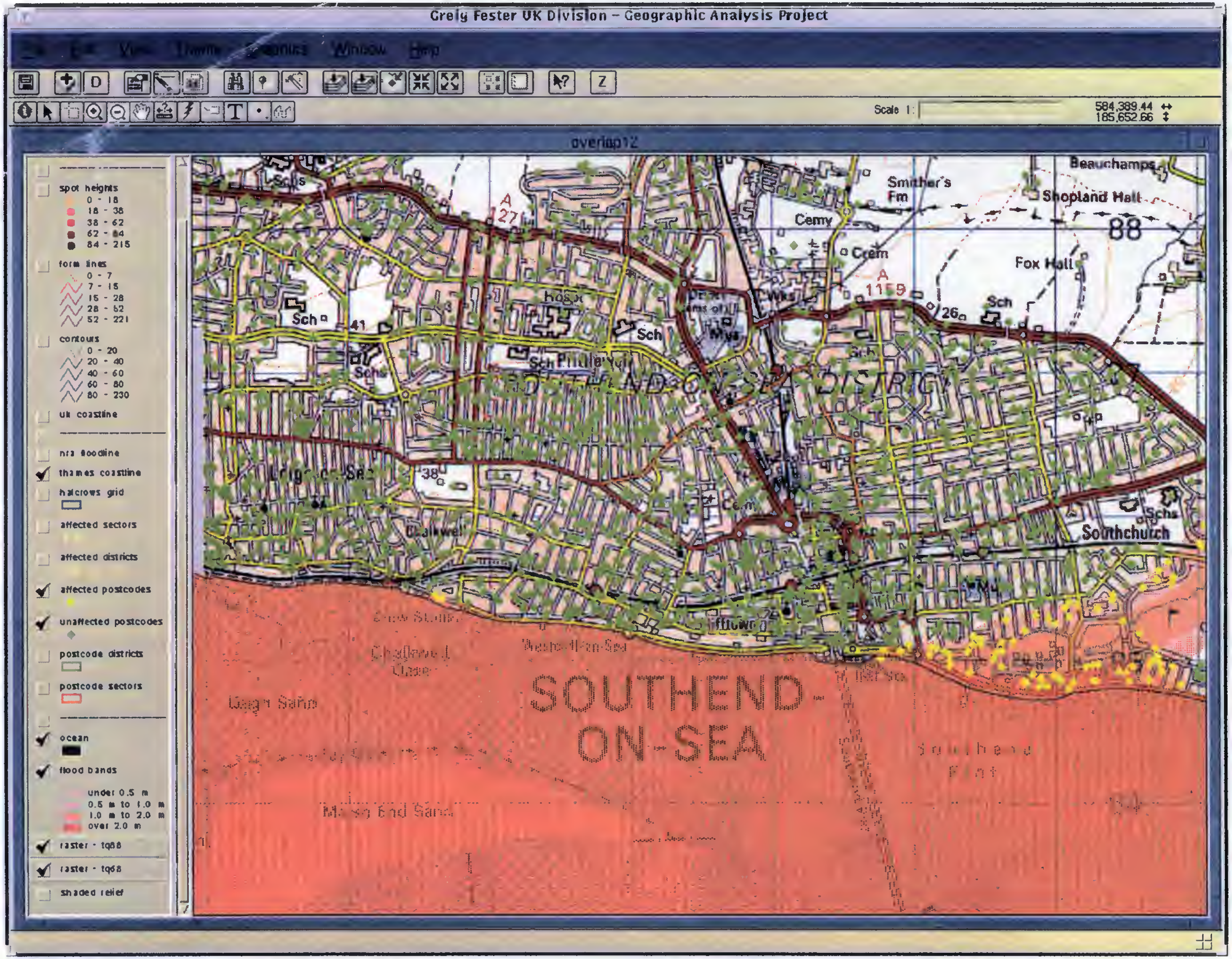
0.5 m to 1.0 m
1.0 m to 2.0 m
over 2.0 m
raster - tq88
raster - tq98
shaded relief
ROCHFORD DISTRICT
WALLASEA ISLAND
POTTON ISLAND
HAVENGORE ISLAND
Danger Area
Canewdon
Great Stambridge
Little Stambridge Hall
Ballards Gore
Barling
Little Wakering
Stonebridge
South Hall
Scott's Hall
Loftmans Fm
Little Wakering Hall
Barrow Hall
Blue House Fm
Sutton Hall
Beauchamps


Greig Fester UK Division - Geographic Analysis Project
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1.0 m to 2.0 m
over 2.0 m
raster - tq88
raster - tq68
shaded relief
SOUTHEND-ON-SEA
Southchurch
Shopland Hall
Beauchamps
Fox Hall
Smither's Fm
Cemy
Crem
Sch
88
A 127
A 1159

Flood Monitoring in Norway using ERS–1 SAR

At the moment, we are having a major flood in the Eastern part of Norway. It is probably the worst in this century here in Norway. The flood has caused large damage in agricultural areas as well as in towns located along the rivers. The two main rivers involved in the flooding are called "Gudbrandsdalslågen" and "Glomma", and they run more than 300 km from the high mountains in South–Norway, to the sea south of Oslo. The rivers have risen by several meters during the flooding period. The flood started at the very end of May, and is still present, although the culmination was on the 7 June.

We have ordered several ERS–1 FRI SAR images (processed at Tromsø Satellite Station in Norway) from the 4 and 7 of June. The images are from descending satellite pass and are covering large parts of the flooded areas.

From analyzing these satellite SAR images by using change detection techniques, we are drawing the following conclusions;

1) It is an advantage to have a SAR sensor because this is working independent of cloud and daylight conditions. In flooded areas there is likely to also be rain and clouds.

2) Combining the flooded image with other remote sensing images in a multitemporal manner, makes change detection possible in the flooded areas. However, the flooded areas will only be "visible" where the wind conditions are favorable with respect to detecting changes between land cover and water surface. This normally means that the wind should be very slight.

3) The present satellite systems are operating with a too low repetition frequency in order to aid the flood–release–team in the time–critical phase that normally lasts for only a few days.

4) It would be an advantage to use L–band rather than C–band SAR. This is because the water surface normally gives a smaller backscatter in L–band images than in C–band images.

5) If C–band is to be used, it would be and advantage to use higher incidence angles than 23 degrees (ERS–1 SAR) so that the water surface could give a smaller backscatter, also when the wind is blowing.

Kjeller, 14 June 1995,

Dan Johan Weydahl (Senior Scientist),
Email:Dan–Johan.Weydahl@ffi.no
Norwegian Defence Research Establishment