Contribution of remote sensing and geo-information systems in flood risk management in Romania

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METEO

ROMANIA

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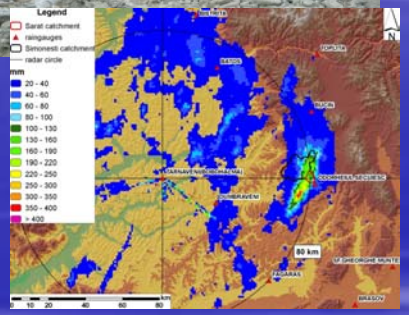
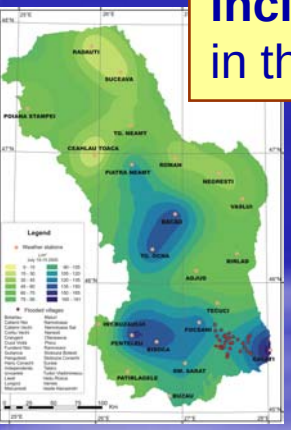
Introduction

In the latest years, river flooding occurred quite frequently in Romania, affecting wide areas of the country's territory.



A flood forecasting and warning system is already active in Romania, but the existing system **does not include a spatial component of the phenomena** both in the pre- and post-crisis phases.



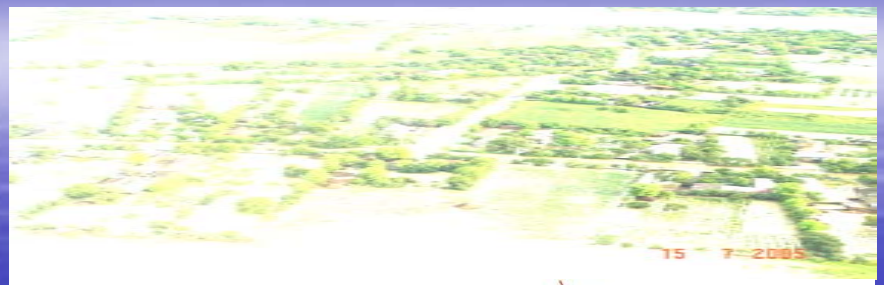
Recognizing the threat of floods and the need for further improvement of flood management the Romanian Meteorological Administration, under the framework of some **National and European - funded projects** started to develop an efficient and powerful **flood-monitoring tool,** based on satellite-derived products.

In this context the bases for a **flood mapping and monitoring service** was established.

Recent extreme floods in Romania (2005)

The big floods occurred in spring and summer of 2005, **the worst ones in more than 40 years**, have affected large regions of Romania.

From February to September 2005 the average discharges registered on many rivers exceeded the normal values; the floods waves have heavily affected many river basins.



18 – 24 August 2005
Areas with exceeded dangerous water levels

Some basins have been affected by intense flooding, more times during the year:

- e.g. Siret basin in July and August 2005,
- Teleajen basin in May and September 2005,
- Vedea basin in June and July 2005, etc.);

Much of the floods characteristics (peak discharge and/or volume) reached or even **surpassed historical values**.

Impressive damages: 76 causalities, 1734 localities affected, more than 90,000 houses destroyed or badly damaged, more than 9,500 km of national and county roads, the electric network, methane gas pipelines, sewerage systems affected, around 9,000 bridges and footbridges destroyed or damaged, 650,000 hectares of agrarian lands flooded.

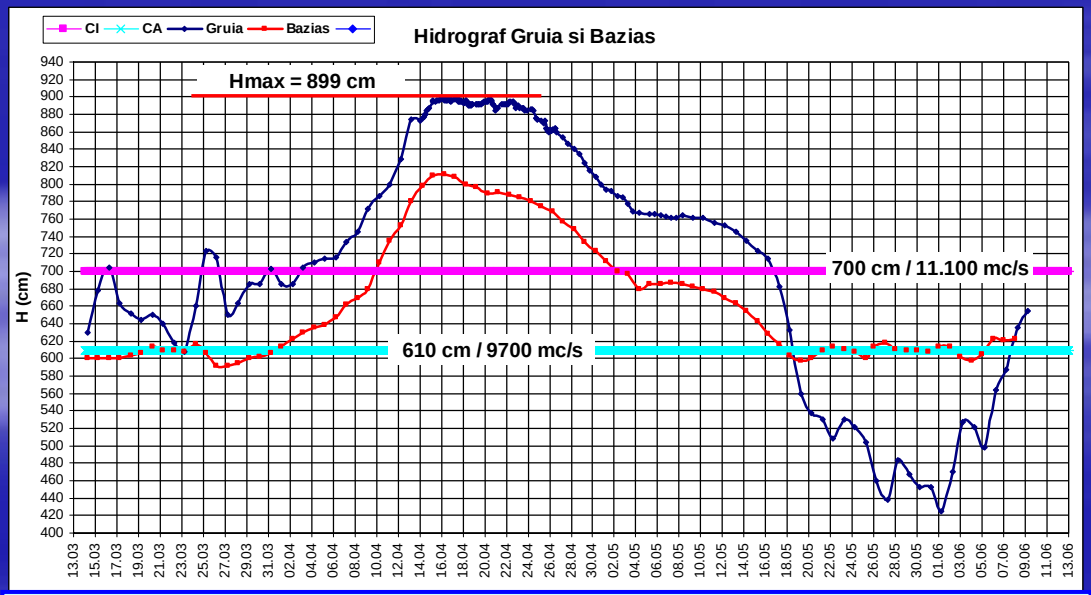
Recent extreme floods in Romania (2006)

A combined effect of snow melt with liquid precipitation and soil moisture background, contributed to the increase of Danube discharges as well as of the tributaries.

Due to composition and flood wave propagation effects, **historical discharges** have been recorded on the Danube River in Romania, causing important losses, more than 15,000 people being evacuated.

The Danube flood of March-May 2006 was **the greatest flood event ever registered upstream of Romanian sector of Danube** (Bazias – 15,800 m^3/s) as well as downstream Portile de Fier sector, in the last 150 years, having:

- the maximum discharge/stage;
- the longest duration of water stage, over the inundation thresholds.

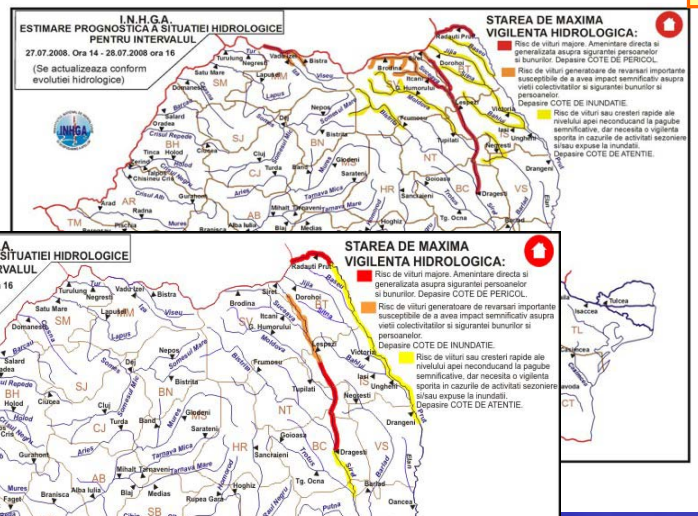


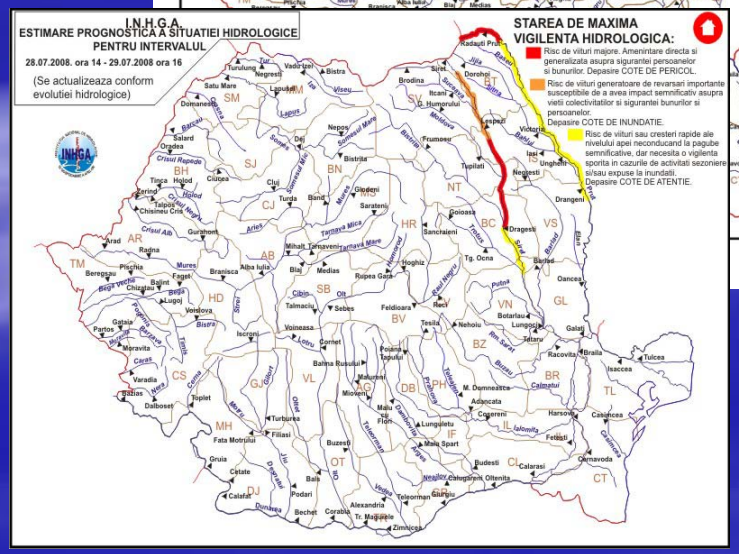
Stage hydrographs for Bazias and Gruia hydrometric stations

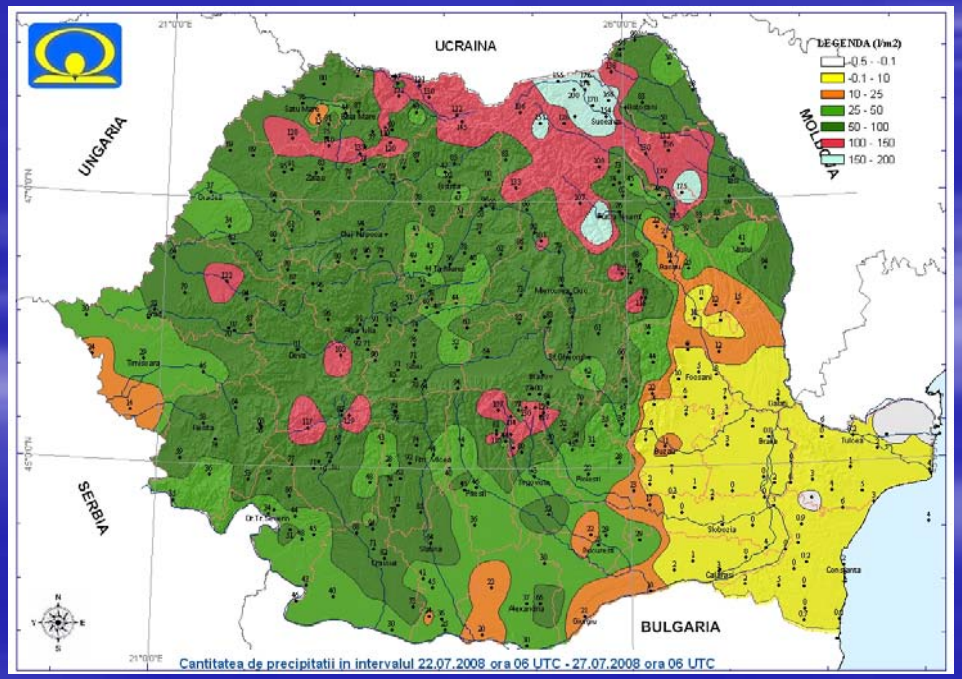
Section	2006	1970	1981
	Q.max (m^3/s)	Q.max (m^3/s)	Q.max (m^3/s)
Gruia	15775	13900	14700
Calafat	15495	14300	14100
Bechet	15825	13830	14250
Corabia	15730	13630	14300
Tr. Magurele	16500	14940	14400
Zimnicea	16900	14900	14800
Giurgiu	16500	14930	15000
Oltenita	16422	14640	14600
Calarasi	15760	15800	14800
Harsova (Vadul Oii)	15580	14790	15100
Braila	14670	15000	13700
Isaccea	14325	18000	14500

Recent extreme floods in Romania (2008)

- The north and north-eastern parts of Romania were severely hit (25-29 July, 2008) by storms and torrential rains (80-140 liters/square meter), causing massive flooding over vast areas.
- The major rivers (**Prut, Tisa, Suceava, Moldova** and **Siret**) surged to their highest levels in more than a century, bursting their banks in many areas including the historical regions of Maramures and Bukovina situated on the border with Ukraine.



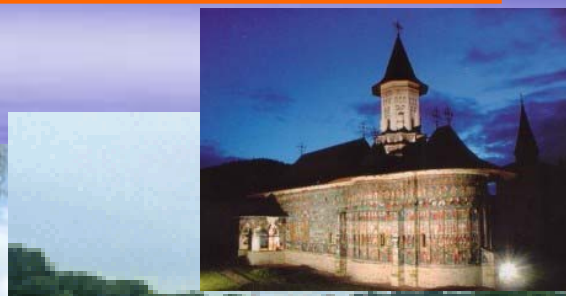


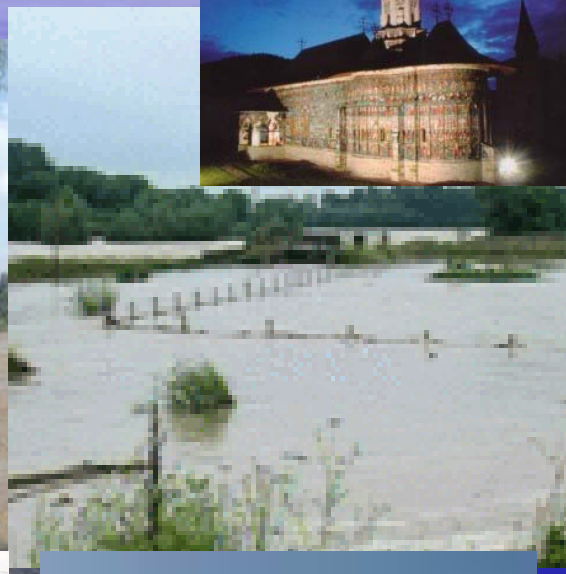


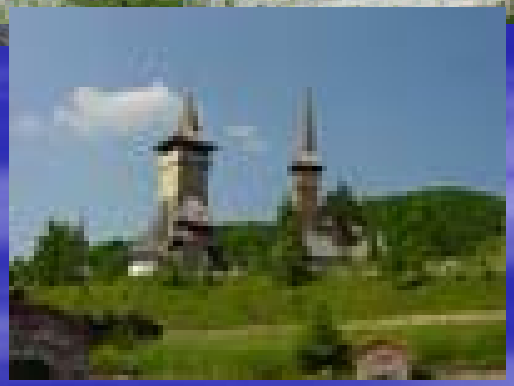
Recent extreme floods in Romania (2008)

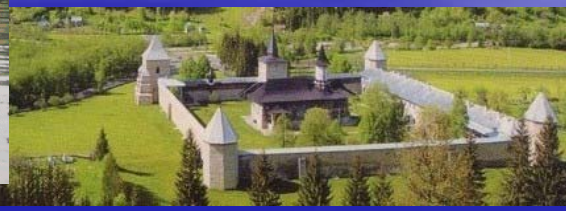
Damages

- 174 localities in seven counties (Maramures, Bistrita, Suceava, Botosani, Iasi, Bacau, Neamt) have been affected.
- 9,260 households flooded, 2,217 homes seriously e damaged, and 6,299 fresh water wells contaminated.
- 20,000 hectares of farmland flooded, destruction of 5 km of national main roads, 66 km of county roads, 507 km of village roads, 45 km of dykes and embankments, and 162 important bridges and overpasses.
- Massive landslides have occurred in two locations in Suceava County.





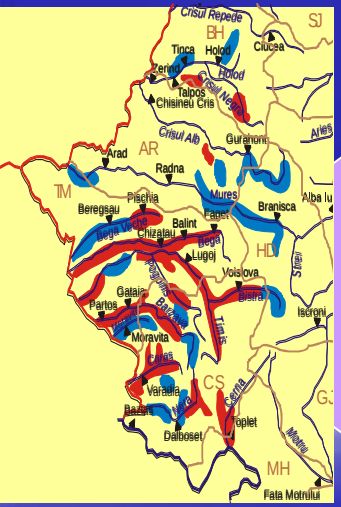




The Romanian National Flood Risk Management Strategy

The Romanian Ministry of the Environment and Sustainable Development has designed a legal frame for the mitigation of the effects of important flood events.

A National Flood Risk Management Strategy has been elaborated which settles the measures to be taken within this domain.



For the implementation of the National Flood Risk Management Strategy, a Program has been approved for fulfilling the **National Flood Effects Prevention, Protection and Mitigation Plan**, initiated in the Siret River hydrographic basin, to be pursued in every hydrographic basin.

The Romanian National Flood Risk Management Strategy

The frame document for preparing and adopting certain specific

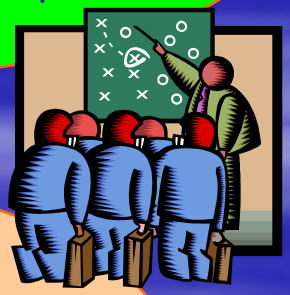
Measures and Actions

Main aim

Mitigating the impact of flood events on the population and property, through adequate planning and policy in accordance with the standards and expectations of the human community and protecting the environment

- **knowing the flood risk;**
- **monitoring the flood phenomenon;**
- **informing the population;**
- **taking into account the flood risk in every territory fitting activity ;**
- **adopt preemptive measures;**
- **preparing for emergency situations;**
- **engaging in reconstruction and learning from the prior experience**

The basis for the **central and local administration** to choose specific protective measures against flooding and in support of regional development



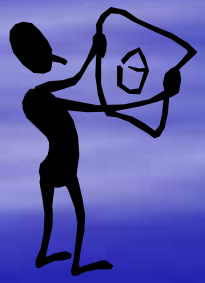
Defines the **specific operational and regulating responsibilities** of the central and local administrative authorities, of the population, the economic agents and the individuals, as well as the way they should cooperate, with true involvement of each party, according to its specific responsibilities.

The Romanian National Flood Risk Management Strategy

Flood management

- flood risk management;
- management of emergency situations generated by flood events.

- Flood management activities constitute an issue of politics, of short, mean and long-term plans and programs, aiming to protect life, property and environment against the floods.



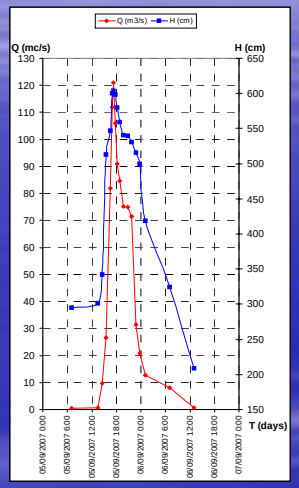
- **Flood Risk Management Plan is** elaborated at basin level;
- **National Flood Effects Prevention, Protection and Mitigation Plan** - elaborated at national territory level, based on the flood risk management plans built up at hydrographic basin / area.
- Operational intervention plans: the **plans at basin, county, city and commune level**, for the defense against flooding - elaborated in accordance with provisions of existing legislation in the field of emergency situations management.

Actions of the Romanian Ministry of Environment and Sustainable Development for the EU Directive implementation concerning the flood evaluation and risk management

Guiding Scheme of Hydrological Works and Management of a Hydrographic Basin

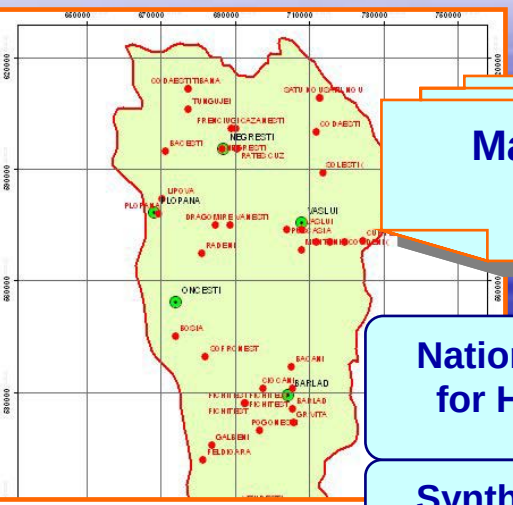
Management plan

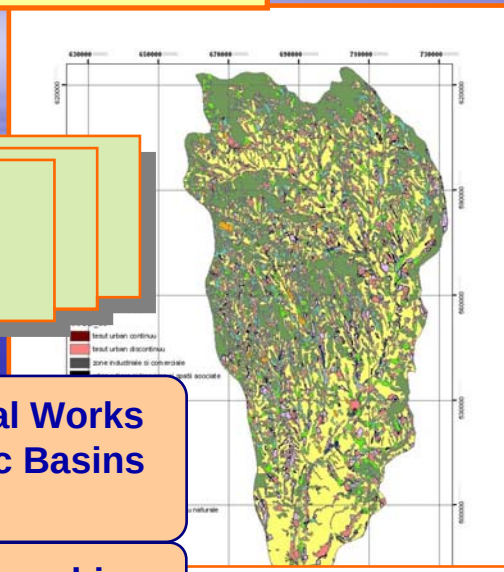
Hydrological works plan



- **Interdisciplinary studies** for the National Flood Effects Prevention, Protection and Mitigation Plan in accordance with the National Strategy of Flood Risk Management;
- **Hydrological works plans** as structural component of Guiding Scheme represent the basis for the preliminary evaluation of flood risk (hazard, risk maps);
- Hydrological works plans will contribute to **updating the operational intervention plans for defense against flooding** till the end of 2009.

Guiding Scheme of Hydrological Works and Management of a Hydrographic Basin





Management Plan

Hydrological Works

National Management Plan for Hydrographic Basins

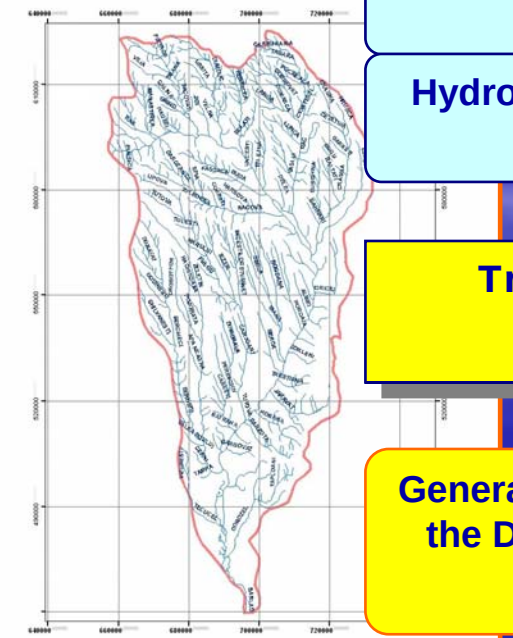
National Hydrological Works Plan of Hydrographic Basins

Synthesis of Hydrographic Basins Plans

Synthesis of hydrographic Basins Plans

Hydrographic Basins Plans

Hydrographic Basins Plans



Transboundaries problems

National Management Plans of Danube Countries

General Management Plan of the Danube Hydrographic District

Transmitted to EU

The plan of hydrological works for a hydrographic basin

Measures, actions, solutions and works for:

- ✓ Reaching the accepted flood protection level for dwellings and goods;
- ✓ Mitigating the effects of floods, aridity tendencies, humidity excess and soil erosion;
- ✓ Carrying out and maintaining the balance between water request and volume of water available from the sources;
- ✓ Diminishing the negative effects of natural phenomena on life, goods and human activities (floods, humidity excess, drought, soil erosion);
- ✓ Using the water potential for hydroelectric energy, navigation, aquaculture, tourism, recreation, etc.);
- ✓ Determining environmental requests as to water resources;.

- ➢ Inventorying the (natural) surface and ground water resources;
- ➢ Determining the actual use of water resources;
- ➢ Identifying the current hydrological works to provide sources with available water and comply with the main performance parameters;
- ➢ Determining the future socio-economic and environmental requests as to water resources;
- ➢ Identifying the options to keep a balance between available water at sources and water request at users;
- ➢ Carrying out a preliminary evaluation of potential flood risk within the hydrographic basin.

The main actors of the management of emergency situations generated by floods, hazardous weather phenomena and accidents at hydro-technical constructions, in Romania

National Meteorological Administration

- elaborates the forecasts and warnings concerning severe meteorological phenomena and their transmission;
- elaborates instructions concerning the establishment of critical thresholds for severe meteorological phenomena;
- ensures the safety functioning of the national meteorological measurements network.

National Institute of Hydrology and Water Management

- elaborates the hydrological forecasts and warnings;
- establishes the critical thresholds, and frequency of transmissions.

Ministry of the Environment and Sustainable Development

- Elaborates the national strategy for protection against floods, severe meteorological phenomena, accidents at hydro-technical structures;
- Coordinates and survey the construction of the hydrological structures with a defense role;
- Coordinates, at national level, the activity of protection against floods;
- Cooperates with other specialized international organizations, on the basis of the conventions signed by Romania, concerning the protection against floods, severe meteorological phenomena, accidents at hydro-technical structures;
- Ensures the functioning conditions of the Departmental Committee and the Operative Centre with permanent activity for emergency situations.

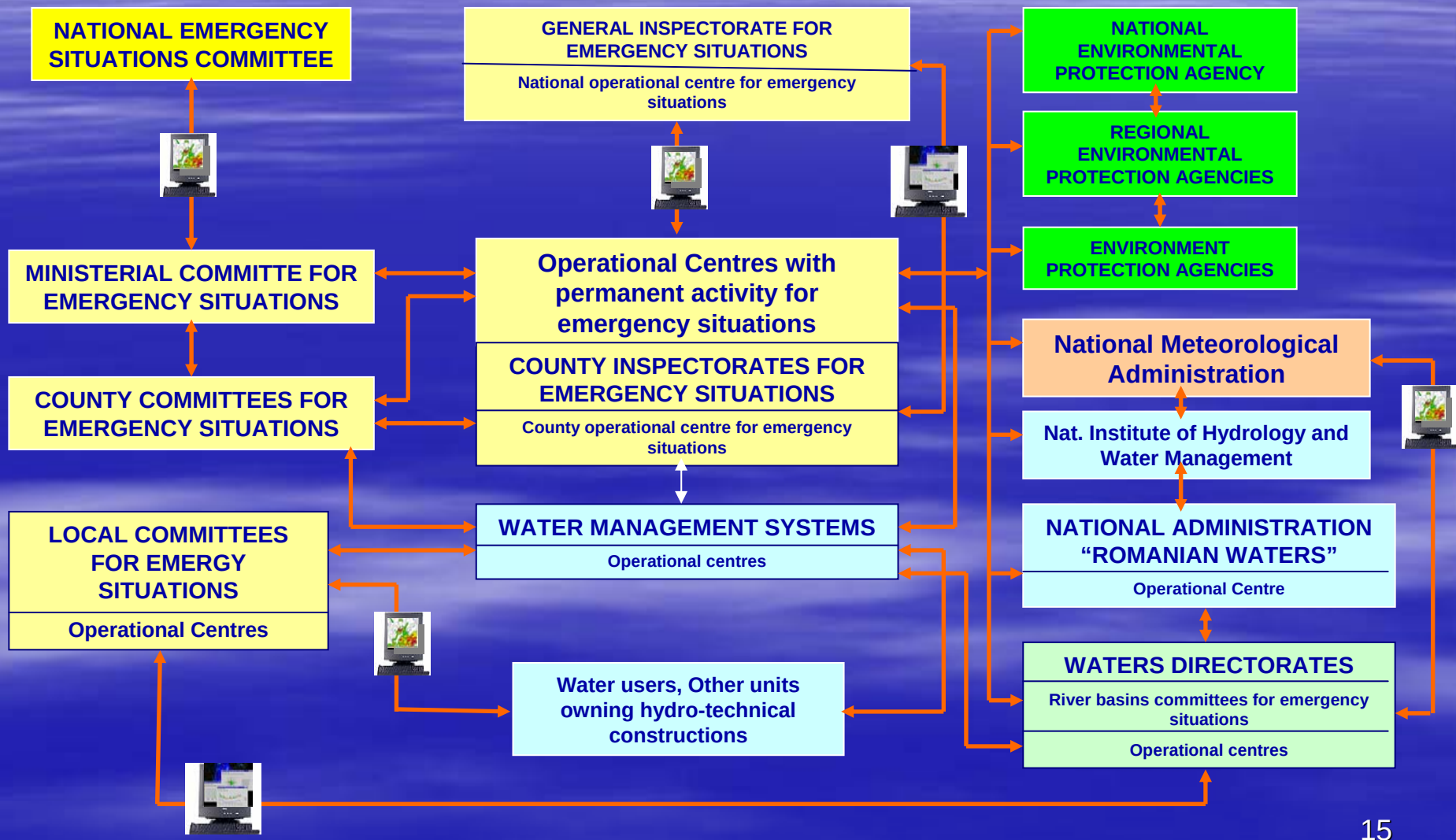
Inspectorates for Emergency Situations

- assure the public protection against flood disaster consequences;
- organize the sheltering and evacuation of population;
- assess of post disaster situation.

National Administration "Romanian Waters"

- provides technical assistance for the working out of town, district and communal planning against floods;
- elaborates plans to warn-alert localities and objectives downstream the basins;
- ensures the coordination of the Technical Support Groups for the management of risks, functioning within the District Committees.

Information and decision-making flux for emergency situations generated by floods, hazardous weather phenomena and accidents at hydro-technical constructions



Contribution of geo-information systems techniques for flood monitoring (1)

Flood management phases	Range of standard products which correspond to the most usual needs for flood management
Prevention Cartography of the risk exposed areas	➢ Flood map extent with optical high or very high resolution EO data (SPOT5, Ikonos, …) ➢ Derived land use maps under normal hydrological conditions - useful for vulnerability assessment ➢ Flood risk zonal mapping ➢ EO derived flood extent maps from past events - enables an improvement in the delimitation and risk assessment of flood risk zones. ➢ Flood extent maps overlayed with a map of a subset of a region or a town.
During the crisis: Near- real time delivery of the flooded areas	➢ Maps with the extent of the flood ➢ Flood extent evolution using multi-temporal satellite data

Contribution of geo-information systems techniques for flood monitoring (2)

Flood management phases

Range of standard products which correspond to the most usual needs for flood management

Post-crisis:

- **Damage assessment and analysis for feedback experience;**
- **Large area evaluations which allow to verify and improve the hydro model.**
- **The evaluation of flooded areas which enables improvements for planning**
- **Satellite – derived products useful for damage assessment.**

- **Flood extent map overlayed with a city map;**
- **Land cover / land use map intersected with flooded areas, resulting detection of affected areas, which have to be protected against flood events in future.**
- **Flood extent evolution using multi-temporal satellite data - allows the evaluation of flood events by chracterizing the spatial and temporal dynamic of a flood event.**

Methods for obtaining satellite-based products for flood risk assessment (1)

FLOOD RAPID MAPPING

- ✓ Various **image processing techniques** (classification, geo-referencing, filtering, and photo-interpretation) are used to combine the optical and radar images and map the flooded areas.
- ✓ The interpretation and analysis of remotely sensed data in order to identify, delineate and characterize flooded areas are based on the relationships between physical parameters such as reflectance and emittance and the features located on the surface.
- ✓ The classical **digital maps** (road network, localities, permanent water bodies, etc) are also used to obtain the final cartographic products.
- ✓ EO data, combined with the facilities provided by GIS and hydrological observations, are used for the assessment of the flood impact and for the damage evaluation.

SATELLITE DATA

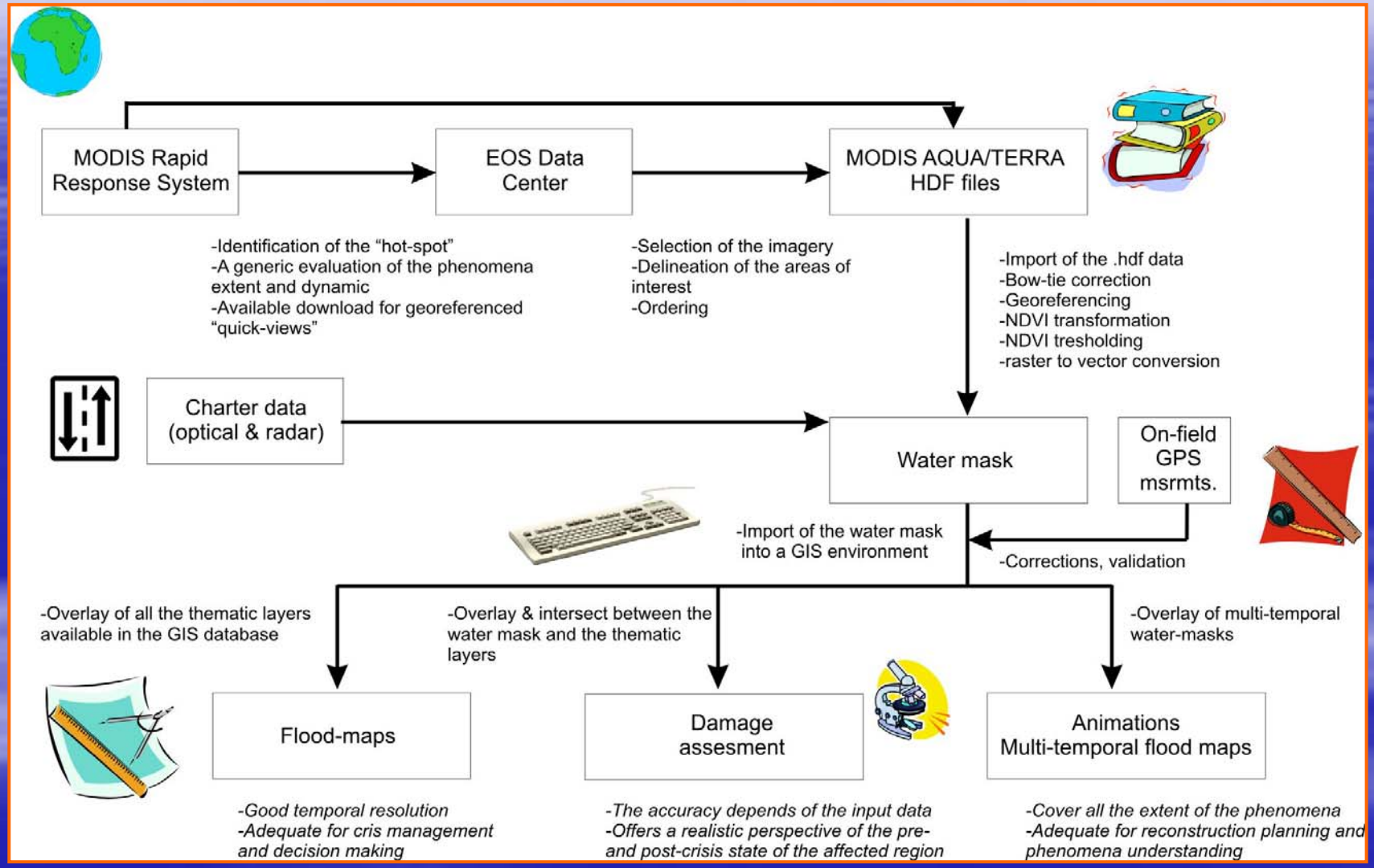
The type of imagery used for the flood monitoring is chosen considering:

- the dimension of the phenomena
- the temporal, spatial and spectral resolution of the imagery;
- the budget/human resources available.

Type of EO data:

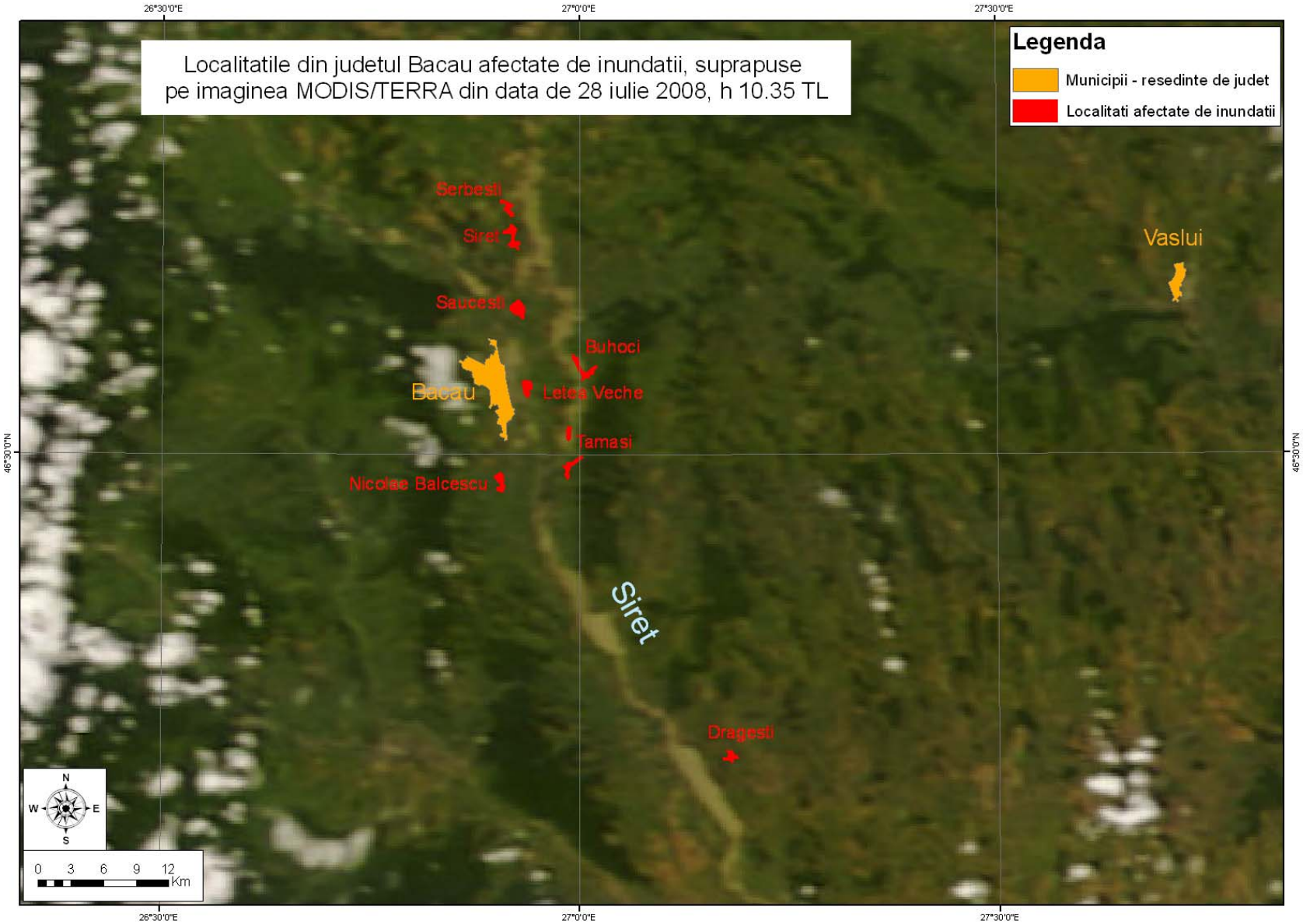
- **Medium resolution** imagery: 250m – 1km/px (MODIS, SPOT VGT, NOAA-AVHRR);
  - Determination of flooded areas (water-masks);
- **High-resolution** imagery: ~ 5 – 15m/px (ASTER, LANDSAT 7 ETM+, SPOT, IRS, Radarsat, ERS-2)
  - Determination of flooded areas (water-masks)
  - Up-to-date information about the land cover (for small areas)
  - Localization of points of interest
  - Thematic background

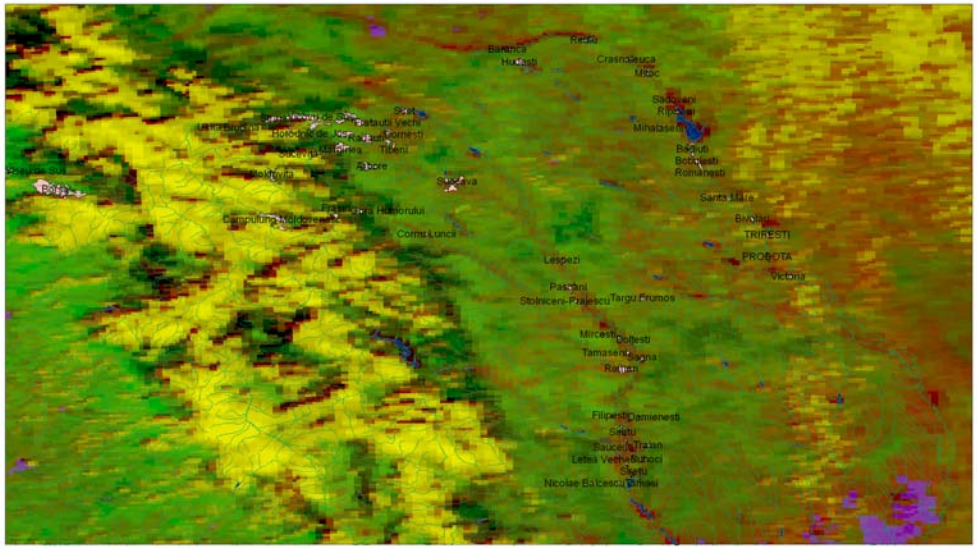
Flood mapping flow chart (MODIS)



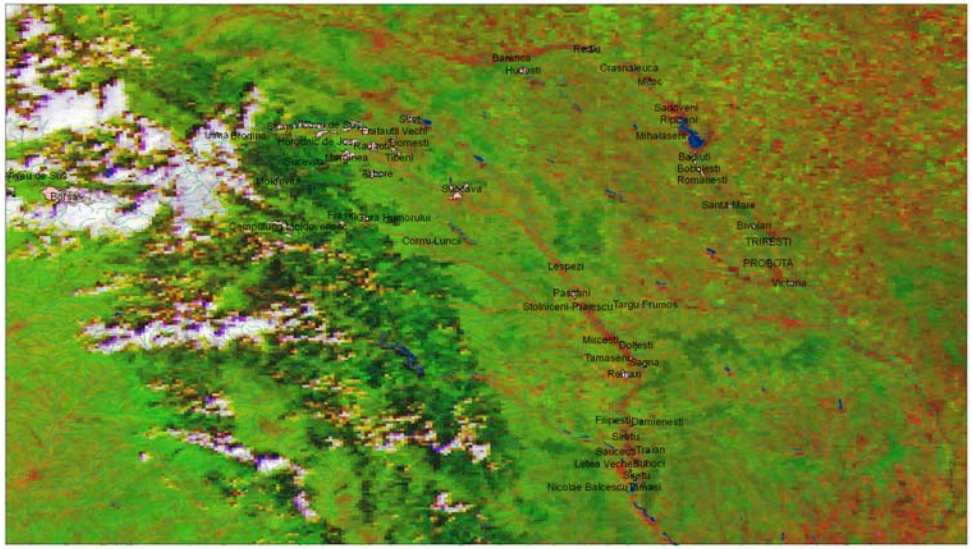
Maps of the flooded areas: MODIS-TERRA

Siret River – Bacau sector (28/07/2008)





Zonele inundate estimate din imaginea NOAA 18 din data de 2 august 2008 ora 14:59



Zonele inundate estimate din imagininea NOAA 17 din data de 3 august 2008 ora 11:46

LEGENDA

- riuri
- Localitati inundate
- lacuri
- Apa
- Nori

30 15 0 30 Kilometers

EXPLICATII

Suprafetele inundate au fost obtinute prin prelucrarea imaginilor NOAA din data de 2.08.2008 si 3.08.2008

Sistem de coordonate geografice Datum WGS 1984

ATENTIE:Acuratetea cu care au fost extrase zonele inundate este strins legata de rezolutia spatiala a imaginilor NOAA de 1 Km. Din aceasta cauza pot exista arealele acoperite cu apa, ce au o suprafata mica, care sa nu fie reprezentate.

CONTACT

Produs realizat de Administratia Nationala de Meteorologie si Agentia Spatiala Romana.

Pentru mai multe detalii ne puteti contacta la una din adresele vasile.craciunescu@meteo.inmh.ro, savin@meteo.inmh.ion.nedelcu@rosa.ro.

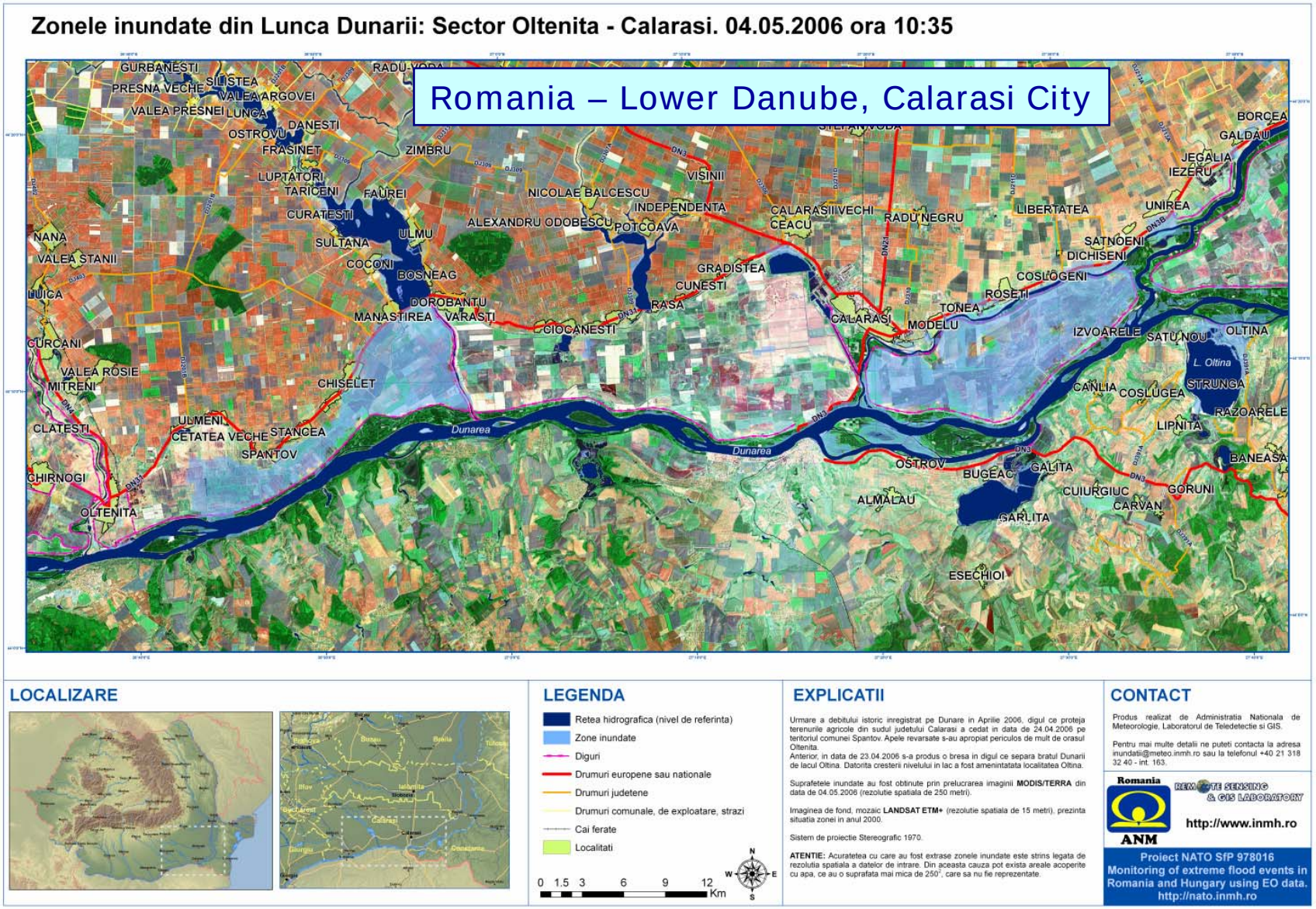
METEO ROMANIA

Proiect PNCDI2 SIGUR
Serviciu bazat pe Informatii satelitare pentru Gestionarea situatiilor de URgenta.
http://sigur.rosa.ro

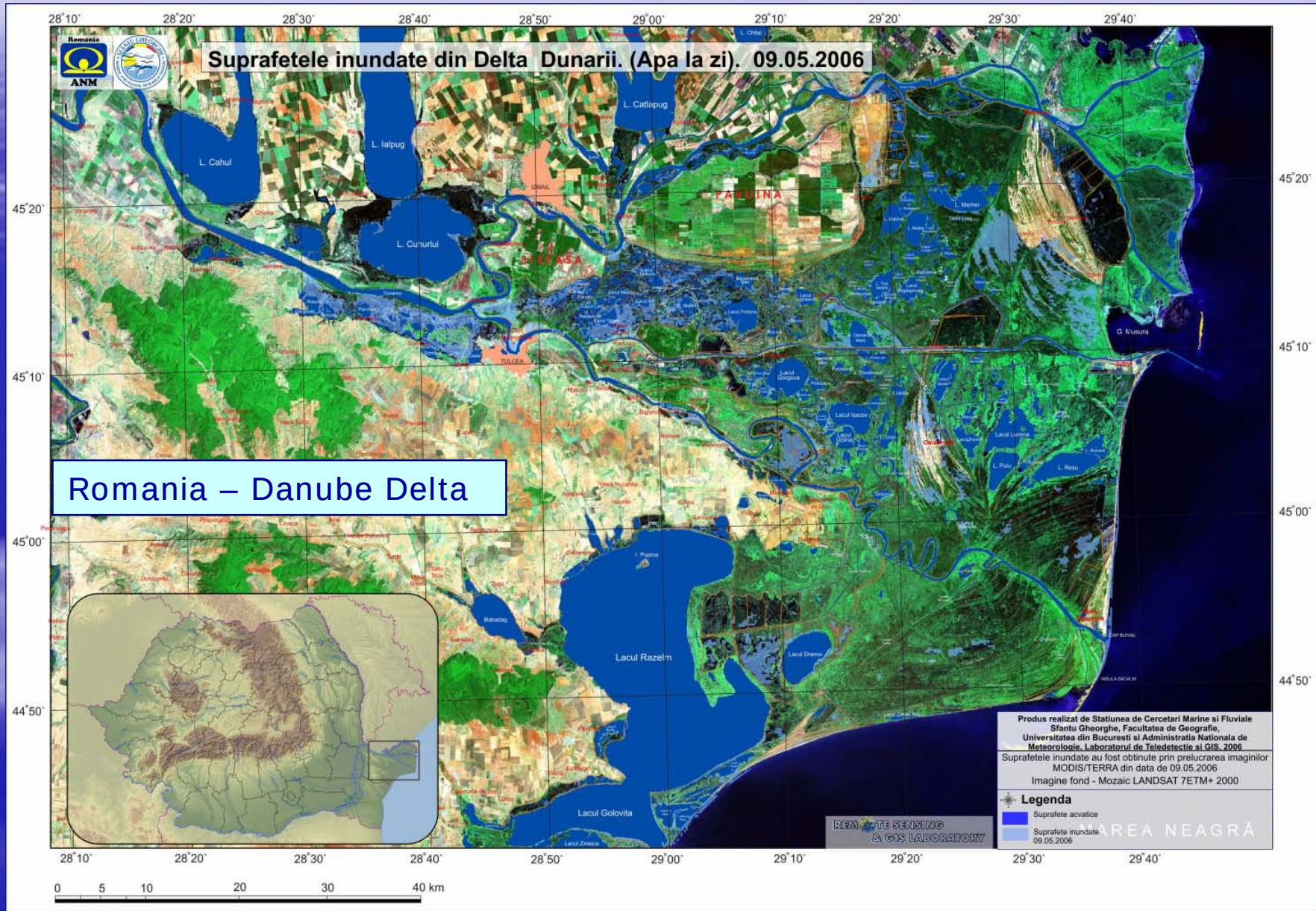
Maps of the flooded areas: AVHRR- NOAA.

Siret River, Prut River (2 - 3 August 2008)

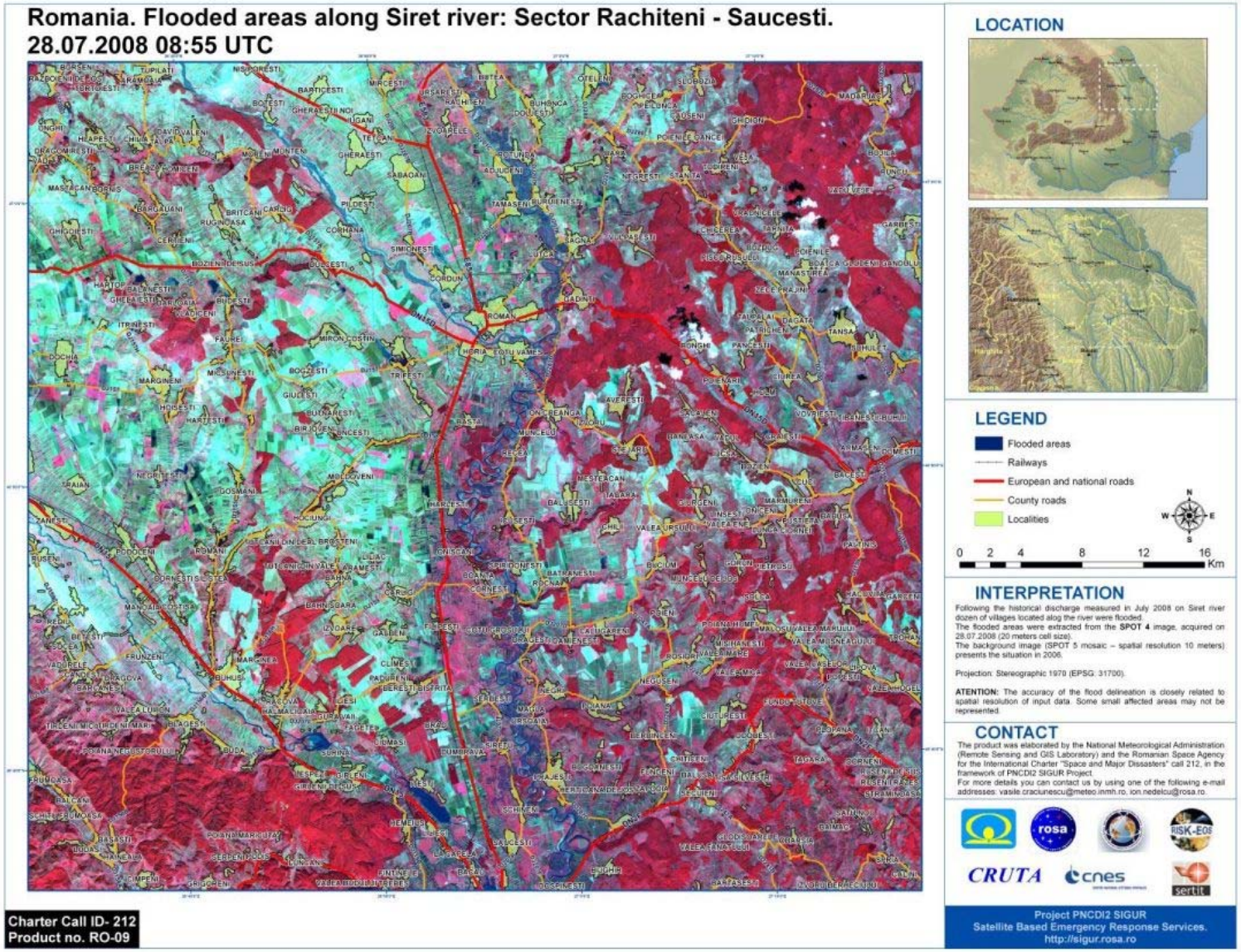
Maps of the flooded areas: MODIS-TERRA, background LANDSAT ETM+. Lower Danube – Calarasi sector (4 May 2006)



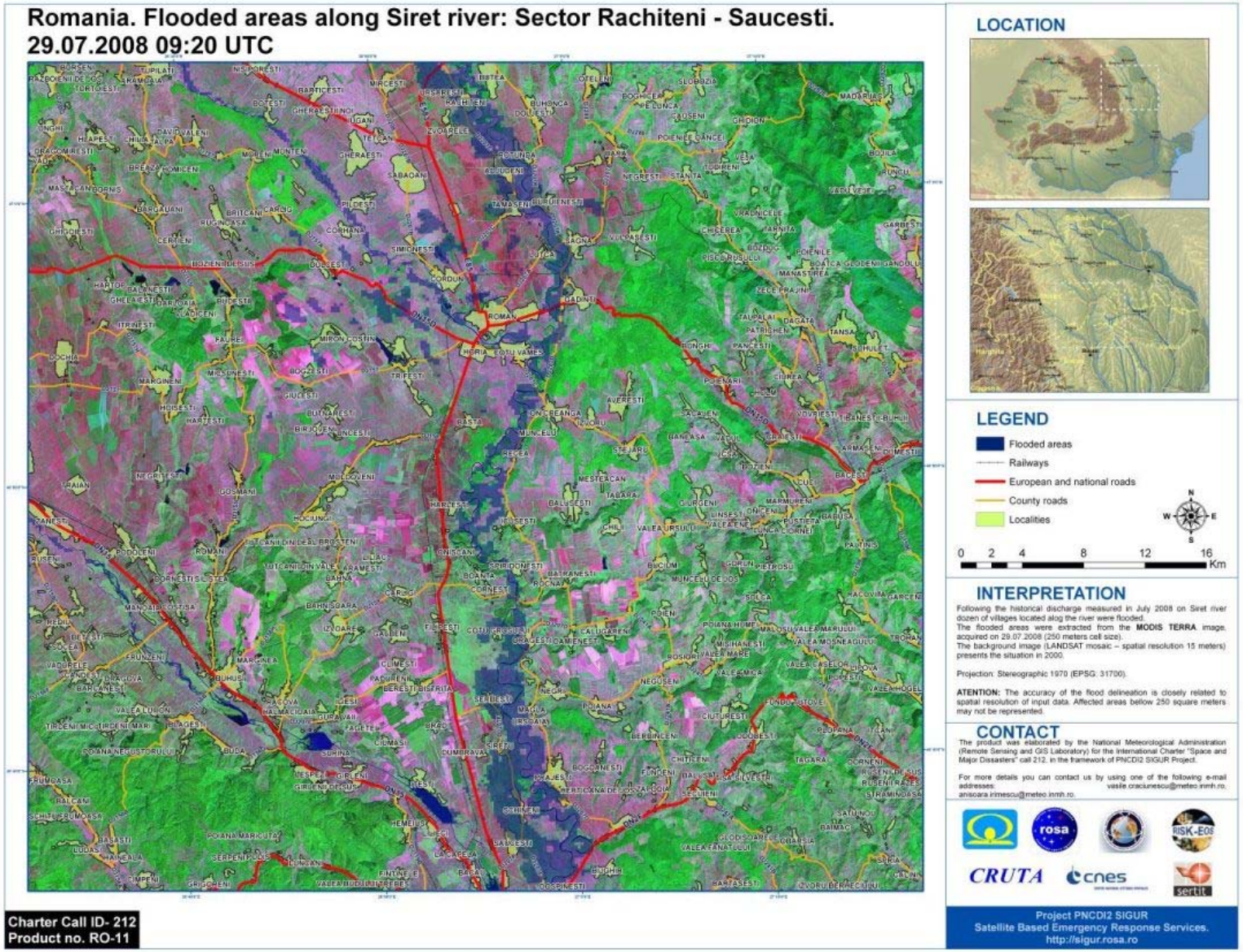
Maps of the flooded areas: MODIS-TERRA, background LANDSAT ETM+. Danube Delta (9 May 2006)



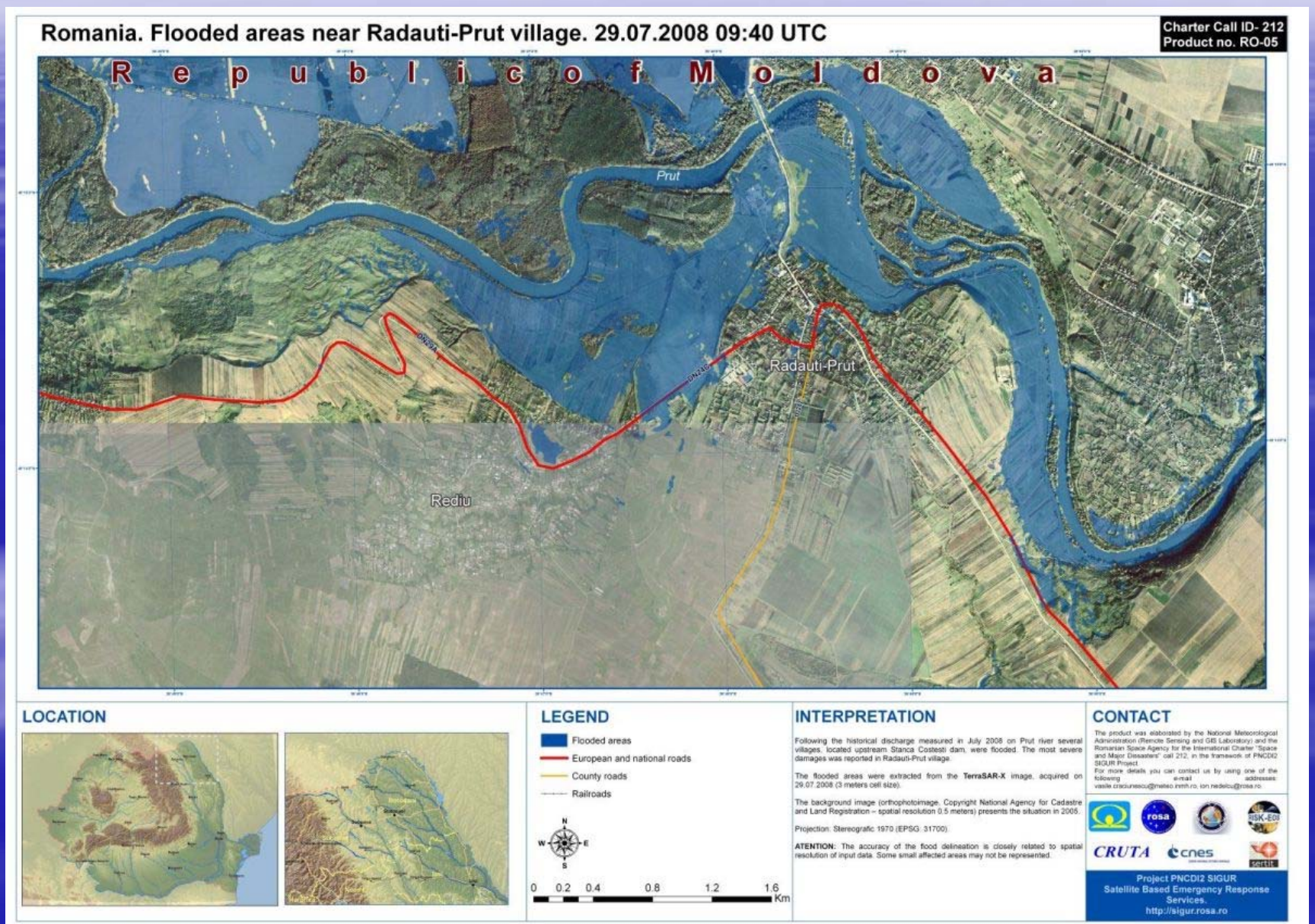
Maps of the flooded areas: SPOT 4, background SPOT 5. Siret River – Rachiteni-Sauceni sector (28/07/2008)



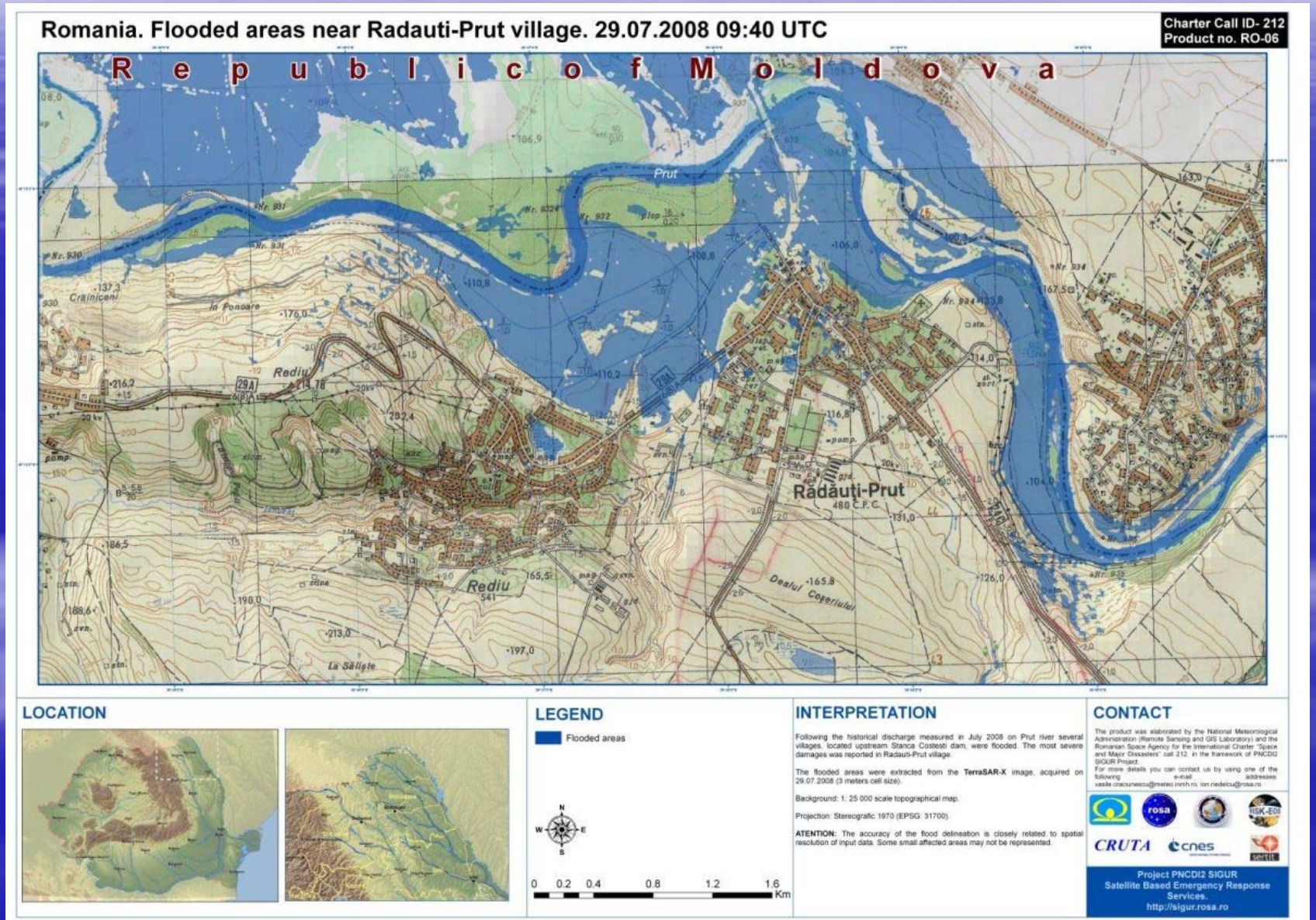
Maps of the flooded areas: SPOT 4, background LANDSAT ETM+. Siret River – Rachiteni-Sauceni sector (29/07/2008)



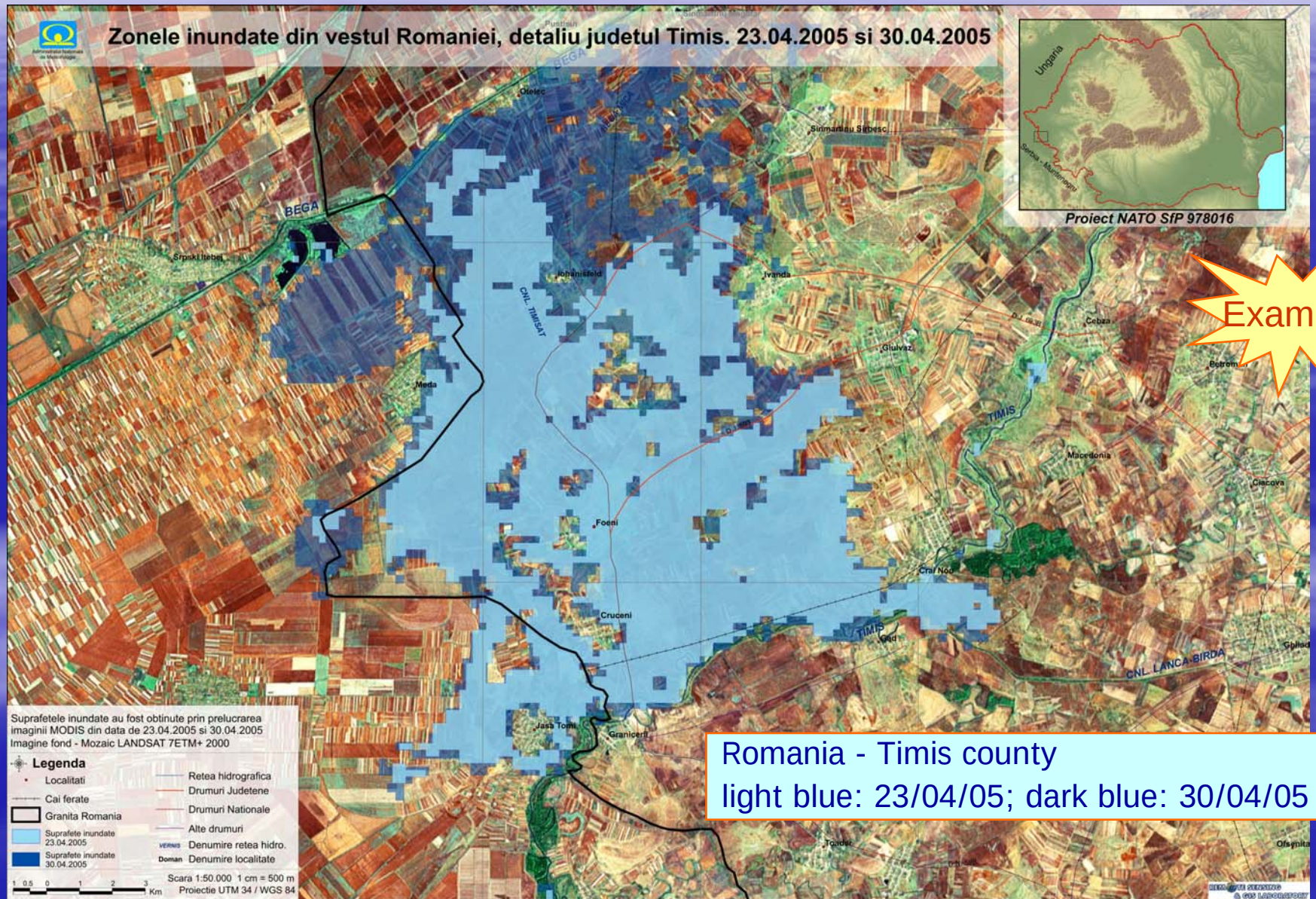
Maps of the flooded areas: TERRA-SAR X, background ortophoto mosaic. Prut River – Radauti sector (29/07/2008)



Maps of the flooded areas: TERRA-SAR X, background topo map 1:25,000. Prut River – Radauti sector (29/07/2008)



Dynamics of the flooded areas: MODIS-TERRA, background LANDSAT ETM+. Timis River (23/04 -30/04/2005)

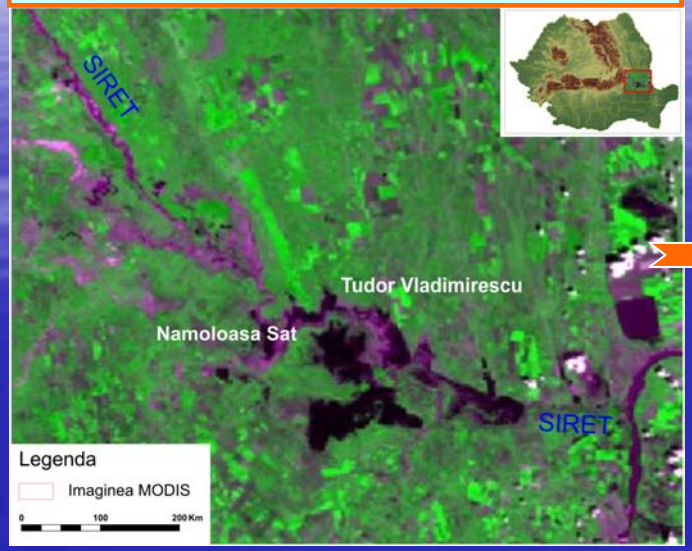


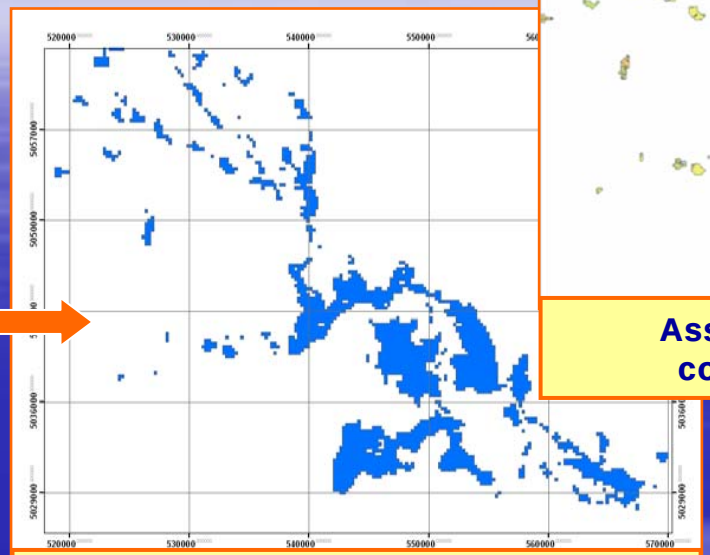
Examples

Romania - Timis county
light blue: 23/04/05; dark blue: 30/04/05

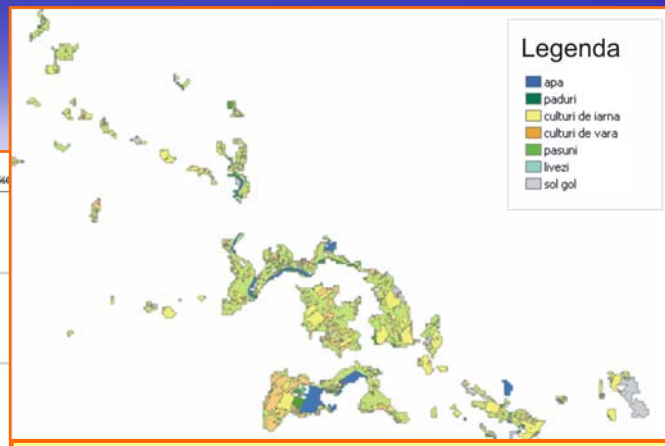
Estimation of the affected areas

Satellite image





Identification of flooded surfaces



Assessment of the land cover / use categories

	Affected areas (Ha):
Land Cover/Use	***23.04.2005***
Agricultural areas	291.290
Arable land	9815.577
Urban & industrial areas	384.368
Vineyardes & fruit trees	2405.903
total	**12897.138**

Methods for obtaining satellite-based products for flood risk assessment (2)

ASSETS MAPPING FOR FLOODS

To provide updated and accurate cartographic information in prevention, anticipation, crisis and post-crisis phases.

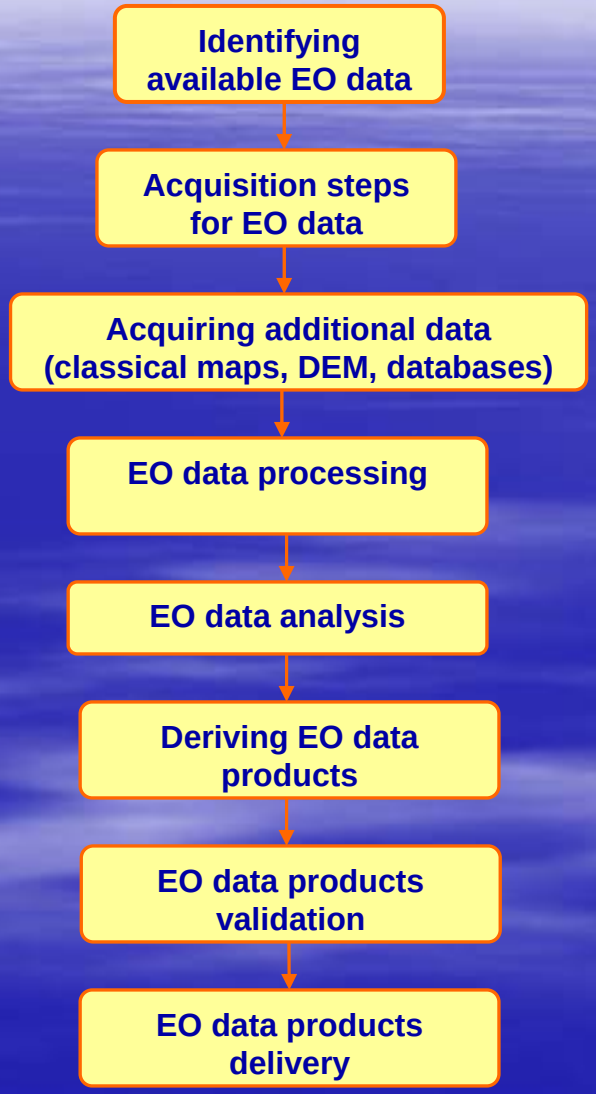
The products intend to watch the hazards area to floods on Romanian territory.

This will be possible by EO data derived information on urban and industrial areas, infrastructure, and other economical and social objectives, permanently updated and provided to civil protection services and decision makers authorities.

SATELLITE DATA

Type of EO data:

- **High-resolution** imagery: ~ 5 – 15m/px (ASTER, LANDSAT 7 ETM+, SPOT, IRS, Radarsat, ERS-2);
- **Very high-resolution** imagery: SPOT5, IKONOS, Quickbird.



Overall flow diagram of the processing steps

Urban Areas detection

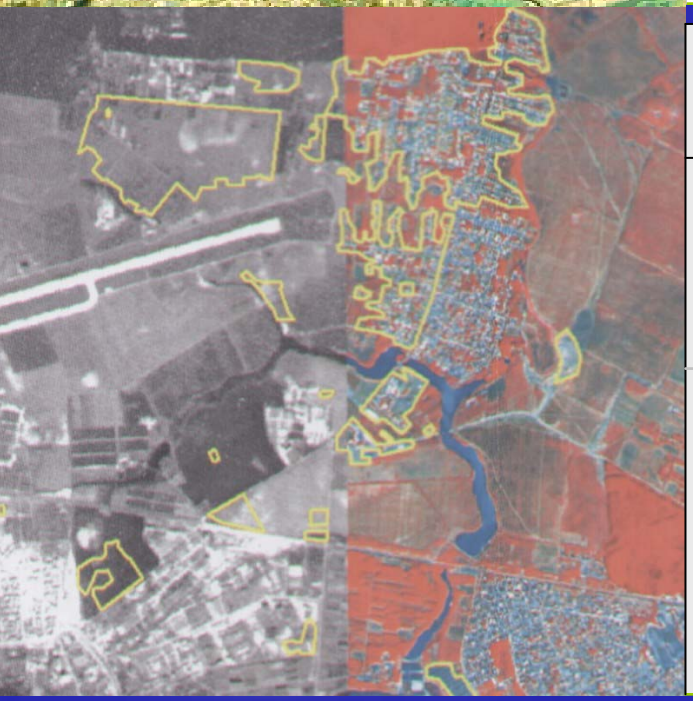
Product providing at 10m resolution the localization of urban areas at a given date.

Key performance parameters:	Frequency delivery:
Scale 1:50 000 *Resolution 6 m*	*Yearly delivery, 2-yearly (or on-request)* Format: *Raster or Vector*

EO data used: IRS LISS-3 + PAN

Other required information:

DTM to ortho-rectify the EO data, existing cartographic maps (in raster format), such as SCANS or topographic maps, existing ground truth or fields surveys.



Product providing at 10m resolution the localization of urban growth areas which are peri-urban changes between two dates.

Key performance parameters:	Frequency delivery:
Scale 1:25 000 *Accuracy 10 to 20 m* *Resolution 10 m*	*Yearly delivery, 2-yearly (or on-request)* Format: *Raster or Vector*

EO data used: SPOT2 – SPOT5

Other required information:

DTM to ortho-rectify the EO data

Existing cartographic maps (in raster format), such as SCANS or topographic maps.

Reference EO data to compare the changes between 2 dates.

Existing ground truth or fields surveys.

Importing HR/VHR image data

↓

Ortho-rectifying image data over DEM or topographic maps

↓

Setting classes

↓

Image classification

↓

Classification accuracy assessment

↓

Urban areas products

↓

Urban evolution products

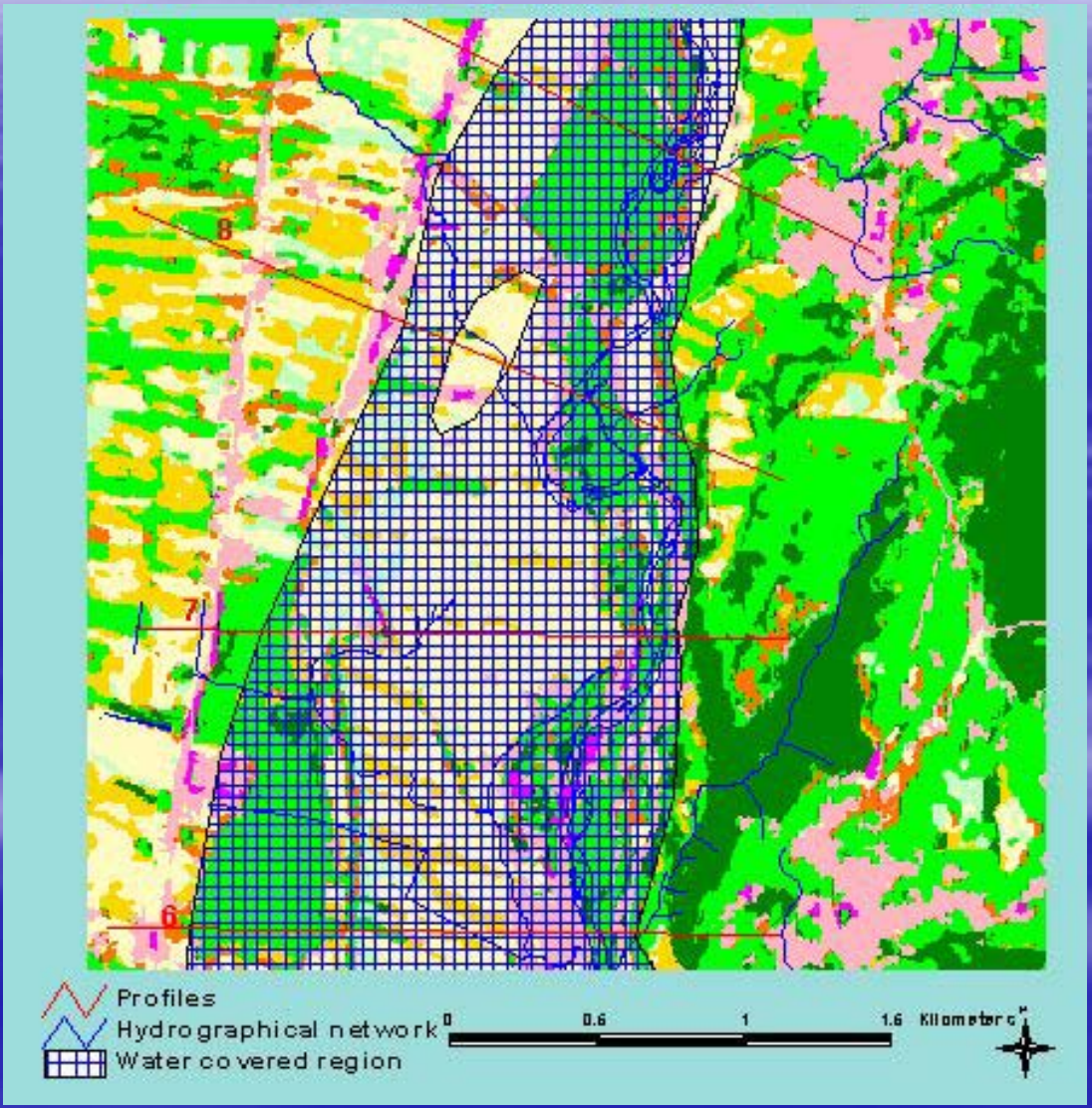
Urban area classification by pixel or object based methods

Flooding Risk Map

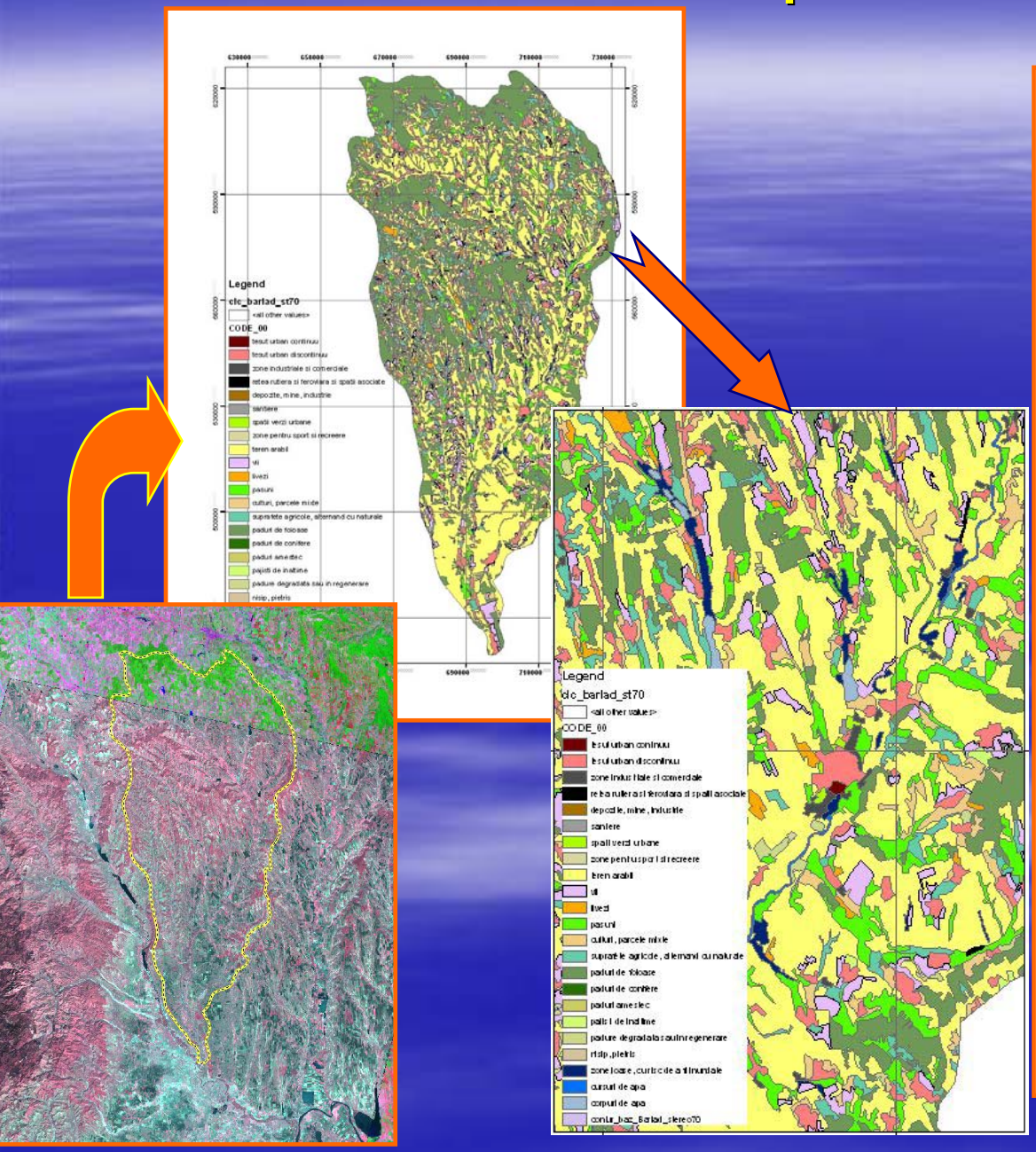
Arges basin

Mioveni sector

The surface covered by water, resulted from a hydraulic scenario of flood with 0.1% probability and delimitated from the DTM, merged on the land cover/land use map.



Updated landcover/land use maps



- The satellite-based methods improve the mapping of geomorphic elements and land cover/land use.
- Land cover/land use maps, combined with satellite derived maps of flood extension or with the outputs of hydrological forecasting model simulations permit a more precise evaluation of the areas affected by the flood hazard. This kind of information is suitable for pinpointing locations and the degree of damages.
- These products are useful also, in the recovery actions, taken to re-building destroyed or damaged facilities and adjustments of the existing infrastructure.

On-line support system for flood related geo-information management (FLOODSAT)

Architecture for the spatial data management System

FLOODSAT is a dedicated on-line system, based on satellite data and GIS technology, for flood related geo-spatial information management.

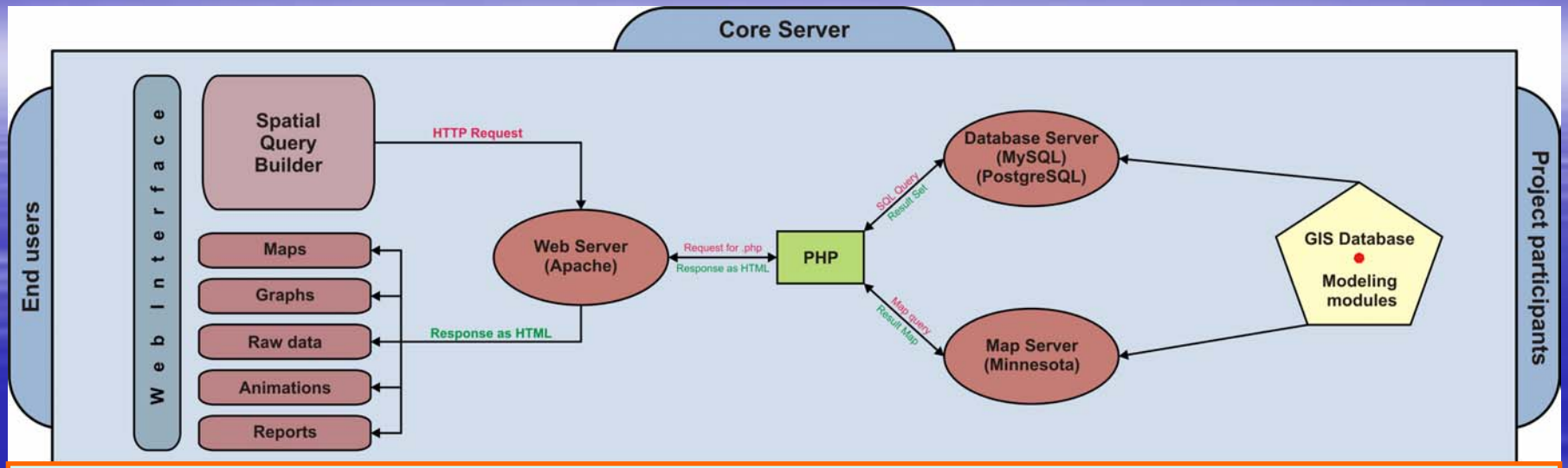
The GIS and satellite–derived data configured for Web uses, is based on a a three-tiered components:

- **a spatial data server** that can efficiently communicate with a Web server and is able of sending and receiving requests for different types of data from a Web browser environment;
- **a mapping file format** that can be embedded into a Web page;
- **a Web-based application** in which maps can be viewed and queried by an end-user/client via a Web browser.

Main functions

- Acquisition, storage, analysis and interpretation of data;
- Management and exchange of raster and vector graphic information, and also of related attribute data for the flood monitoring activities;
- Handling and preparation for a rapid data access;
- Updating the information (temporal modification);
- Data restoring, including the elaboration of thematic documents;
- Generation of value-added information (complex indices for flood prevention, risk maps);
- Distribution of the derived products to authorities, institutions, media, etc.

FLOODSAT



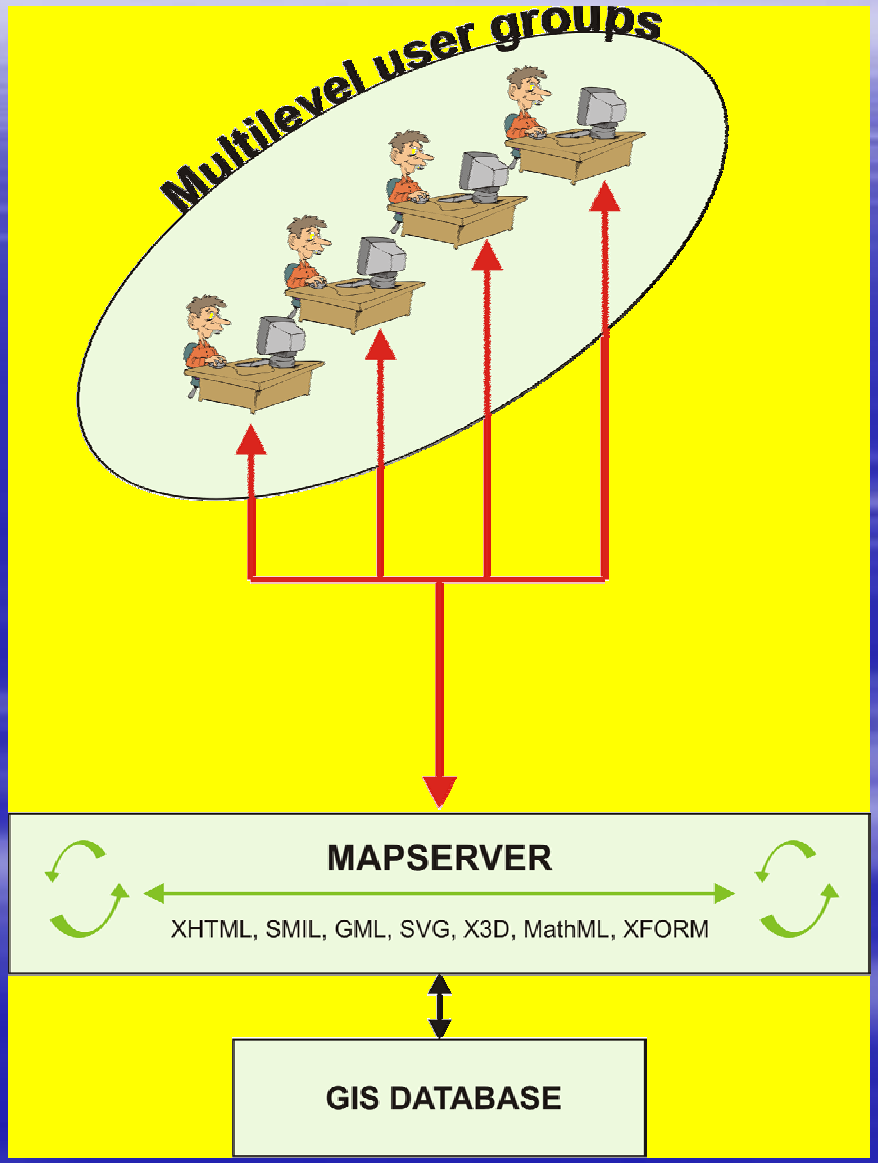
- The FLOODSAT system is Web-based, with a distributed architecture and consists in:
- Core server, which handles the interactions between the various modules, data display and manipulation:
  - ✓A Web server that manages the information to be distributed over the Web on requests from end-users and which is able to communicate with the database server and the Map server;
  - ✓A GIS database and the modeling modules;
- Project participants collect, process, archive, update and include into the system the satellite-derived products, hydrological/hydraulical model outputs, integrated in a GIS environment, etc.
- End-users can access the system using a simple Web browser (like Internet Explorer or Mozilla Firefox) to display, query, analyze and retrieve information.

Spatial data distribution over Internet

- The Web-based application has been developed using standard technologies:
  - * HTML, XML, JavaScript, PHP, SVG, COM;
- The Web-based application supports the **Open Geospatial Consortium** (OGC) and the **Open Web Services** specifications.

The web mapping interface has the following outline:

- basic display
- navigation and orientation
- querying data
- multi-scale
- multiple dynamically linked views



Conclusions (1)

- For Romania, flood represent the most damaging geophysical event;
- The Romania has designed a legal frame for the mitigation of the effects of important flood events;
- A National Flood Risk Management Strategy has been elaborated which settles the measures to be taken within this domain;
- For the implementation of the National Flood Risk Management Strategy, a Program has been approved for fulfilling the National Flood Effects Prevention, Protection and Mitigation Plan.

Conclusions (2)

- The April 2000 floods in the western part of Romania represented the starting point in creating a service/system capable to map and monitor the flood evolution using satellite data;
- The graphic and cartographic products obtained were used, during the crisis episodes, by the National Inspectorate for Emergency Situations, Ministry of Environment, Local River Authorities in the decision making process;
- The operational character of the service was enforced during the flood events in 2005, 2006 and 2008 when a lot of satellite data, including those provided by the International Charter have been used;
- In case of the flood rapid mapping various processing techniques are used to obtain the flood related products, during crisis, in 8–24 hours after the satellite image was acquired;
- In case of the assets mapping for floods, the aim is to provide updated and accurate cartographic information in prevention and post-crisis phases.

Thank you for your kind attention !