Contribution of earth observation to hydro-meteorological risk management in Romania

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Abstract. Recognizing the threat of extreme hydro-meteorological phenomena (like floods, severe convective storms, extreme frost and snowfall, hailstorms, heat waves and drought) the Romanian National Meteorological Administration, developed and implemented an efficient and powerful National Integrated Meteorological System (SIMIN). The paper presents the user-driven development of services, based on remote sensing and geo-information capacities, integrated in the SIMIN, targeted to develop an interoperable framework for the management of the available observation and forecasting meteorological geo-information, able to provide reliable and timely independent information for the hydro-meteorological related risk management to Romanian stakeholders. The spatial data architecture for operational management includes: an online system, based on open source applications, allowing the management of hydro-meteorological data in a geospatial context as well as the implementation of the data cataloguing component using the GeoNetwork Open source application. A dedicated Web-based Information System for Trans-boundary Flood Management (FLOODSAT), based on satellite data and GIS technology, was implemented in the Romania. An appropriate methodology was developed and tested, in order to process the raw data (satellite optical or radar, with medium and high range spatial resolution), to rapid mapping of event extent and finally integrate the information related to hydro-meteorological events into useful, standardized, cartographic products. Beside the maps of the risk exposed areas, phenomenon extent evolution, 3D flythrough and different animations were produced to get a more complex perspective on phenomenon dynamic and dimension. The results can be quickly disseminated, in digital form via Internet, using a dedicated webpage. Some examples of the implementation of the extreme hydro-meteorological events support system obtained during recent floods and flash floods in Romania are also presented.

Keywords. Earth Observation, risk management, extreme hydro-meteorological events, geo-information.

1. Introduction

The disaster risk due to extreme hydro-meteorological phenomena is made up of two main components: exposure to natural hazards and climate change, and social vulnerability. Whether natural events turn into disasters depends critically on the coping and adaptive capacities of governments [1].

The social and economic impacts of the natural hazards can be reduced through the cost-effective use of appropriate technologies. There is a wide range of space-based systems, which can offer significant potential for disaster prevention, preparedness, relief and reconstruction and such minimizing the impact of natural hazards. The satellites provide data that have proved useful for a wide range of applications for the severe hydro-meteorological events management and Early Warning Systems, due to various reasons: timeliness, repetitiveness, synoptic coverage, comparability of data, multi-spectral data, availability of data in digital format, free availability of certain datasets, improvements in methods for application of space technology, simple integration, analysis, modeling and visualization using GIS.

In recent years extreme hydro-meteorological events (like extreme precipitation, floods and flash floods, landslides, mudflows and falls, debris flows, severe convective storms, extreme frost and snowfall, hailstorms, heat waves and drought) occurred quite frequent in Romania, causing material damages and human losses. In particular, floods produced in several areas of the country were the most damaging.

2. The National Integrated Meteorological System (SIMIN)

The Romanian National Meteorological Administration (RNMA) has promoted a strategy of modernization of its functional infrastructure, materialized by a major investment program, the National Integrated Meteorological System (SIMIN). SIMIN addressed Romania's primary objective of modernizing and integrating various resources and real-time detection capabilities, and also facilitates the exchange of data at the local, regional and global levels. The main goals of SIMIN were to modernize and integrate meteorological surveillance sensors, enhance national and regional (local) forecaster's decision support systems of the integrated real time sensor information and improve the dissemination of meteorological forecasts, warnings and alerts to agencies and the public. Within SIMIN, several systems with major significance have been provided: meteorological DOPPLER radar network (5 S-band: WSR-98D, 3 C-band: 2 EEC and 1 Gematronik), automatic weather stations network, lightning detection network, satellite reception stations for MSG, telecommunication networks, processing capabilities including enhanced numerical weather forecasting platforms supporting ALADIN and COSMO modeling and visualization system (Nex-REAP) integrating all available information.

The SIMIN system is a distributed architecture with one national center, connected to multiple regional sites; there are 7 regional collecting centers (located in Sibiu, Bacau, Cluj, Timisoara, Craiova, Constanta and at RNMA HQ in Bucharest) corresponding to the regional forecasting centers. The SIMIN system supports all types of users, with a suite of tools dependent on the operational need of each user.

3. User-driven development of services, based on remote sensing and geo-information capacities

Recently RNMA initiated and started to implement user-driven services, based on remote sensing and geo-information capacities, integrated in the SIMIN, targeted to develop an interoperable framework for the management of the available observation and forecasting meteorological geo-information, able to provide reliable and timely independent information for hydro-meteorological hazards and associated risks management by following the European initiatives of this domain (INSPIRE, GMES).

The spatial data architecture for operational management includes an online system, based on open source applications, allowing the management of hydro-meteorological data in a geospatial context as well as the implementation of the data cataloguing component using the GeoNetwork Open source application. GeoNetwork supplies a complex metadata editor as well as advanced search functions for the data indexed on the basis of metadata, using descriptive and spatial criteria.

The application implements the most relevant international standards concerning the description of the geographic information: ISO 19139 (Geographic information -- Metadata -- XML schema implementation), FDGC (Federal Geographic Data Committee), Dublin core (Dublin Core Metadata Initiative).

The application's architecture is compatible with OGC (Open Geospatial Consortium) standards regarding the Geospatial Portal Reference Architecture and the CSW (Catalogue Service for Web).

Besides the CSW compliant certification, OGC awarded GeoNetwork the status of reference application for implementing the specification regarding the interrogation and retrieval of information coming from the web (CSW) catalogues.

3.1 The functionality of the online system, for the management of hydro-meteorological data in a geospatial context

The main functions of the online system, for the management of hydro-meteorological data in a geospatial context are:

- Searching geospatial data in local or distributed catalogues;
- Downloading and uploading geospatial datasets;
- It includes an interactive web mapping application which allows combining geospatial layers using the WMS (Web Mapping Service) standard. This application can also be used for introducing the spatial data search criteria;
- Online generation of maps and reports and their export in a PDF format;
- Programming CSW- compatible sampling sessions of metadata from the distributed servers;
- Synchronizing the metadata among the distributed catalogues;
- Managing the users and user groups;
- Defining policies for accessing data by user levels.

The cataloguing application supplies two interfaces for searching the indexed data:

- Simple (implicit): allows the search following key words and / or the geographic location.
- Advanced: supplies multiple search criteria including spatial ones, key words, temporal criteria, etc.

The cataloguing application supplies two possibilities for introducing metadata: using the online editor (selecting one of the three templates: ISO, FDGC or DC) or by importing XML metadata created with an external editor.

The metadata sampling is based on the unique universal identifier (uuid) concept. Each metadata set created with GeoNetwork, or with a CSW – compatible editor has such an indicator associated. Updating the metadata, from a network sampling nodes network is performed such that only those metadata sets are downloaded that have undergone modifications between the moment now and the last updating.

Propagation takes place from node to node and the metadata sampled until a certain moment by one node can also be transmitted to other nodes, without the need of those nodes to access the parent node.

4. Application for heavy rain and related flood management

A Web-based Information System for Trans-boundary Flood Management (FLOODSAT), based on satellite data and GIS technology, was already implemented in the Romania. The main functions of the FLOODSAT are: acquisition, storage, analysis and interpretation of data; preparation for a rapid data access; updating the information; elaboration of thematic documents; generation of value-added information; distribution of the derived products to end-users. The figure 1 presents the system architecture.

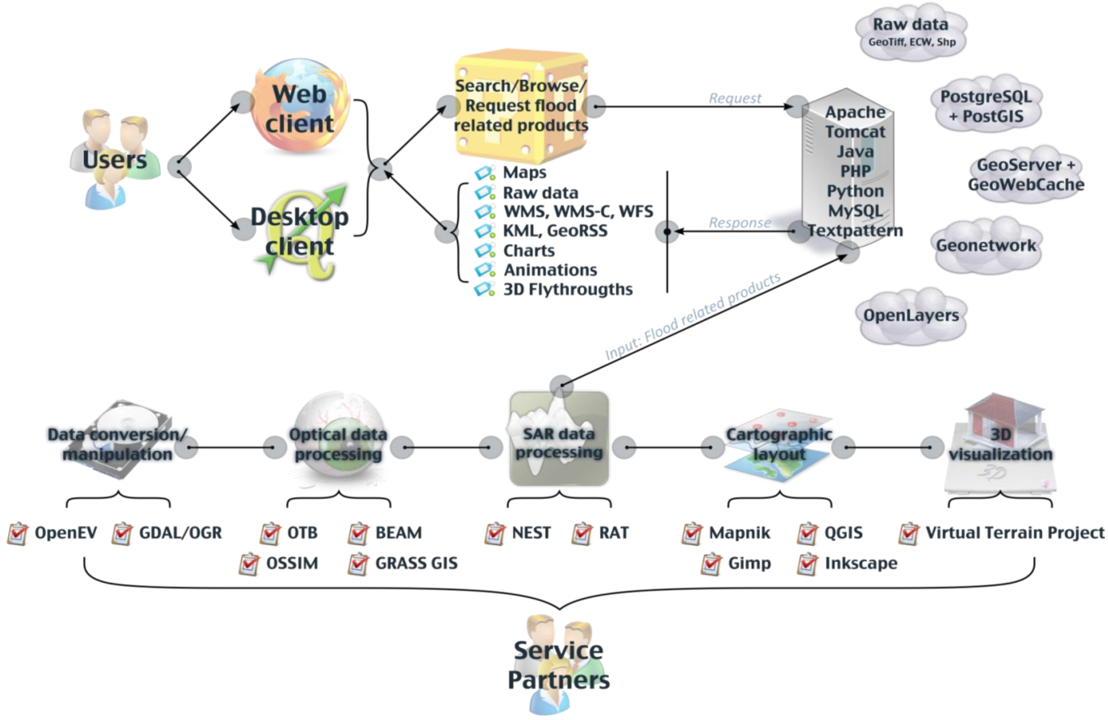

Figure 1. The FLOODSAT system architecture

The GIS and satellite–derived data configured for web uses, is based on 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.

The main functions of the FLOODSAT are:

- 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.

The entire FLOODSAT infrastructure was built using free and open source software: PostGIS (geospatial data storage), GeoNetwork Opensource (geospatial data catalog and metadata editor), GeoServer (standard geospatial server for serving data via WMS and WFS), OpenLayers (client webmapping application).

The data registered into the system is published through standard compliant services (WMS, WFS, GeoRSS, KML) and can be accessed/consumed by users via a thin web client or a thick desktop client , or even through 3D Virtual Globe applications like Google Earth.

Within the framework of flood surveying, optical and radar satellite images can provide up-to-date geographical information. Satellite-derived products and landscape descriptive information is helpful during the flood characteristic phases:

- before flooding - includes risk analysis and mapping; the satellite image enables the description of the land cover of the studied area under normal hydrological conditions;

– <u>during flooding</u> - the image data set provide information on the affected zones, flood map extent, flood's evolution;
– <u>after flooding</u> - the satellite image point out the flood's effects, showing the affected areas, flood deposits and debris, with no information about the initial land cover description unless a comparison is performed with a normal land cover description map or with pre-flood data.

For the assessment and mapping of the flooded areas (water-masks) we used mainly medium spatial resolution imagery (250 m – 1 Km/pixel), provided by MODIS Rapid Response, SPOT-VGT, and in some cases high resolution imagery (5 m – 15 m/pixel), from ASTER, LANDSAT 7 ETM+, SPOT, IRS, TERRA-SAR X.

For updating the land cover/land use (of the affected areas) and localization of some points of interest, high resolution satellite data have been used.

For the major flood events the International Charter was activated and we were able to use high-resolution images for the thematic background and for the water mask as well. In some cases the satellite data/products were provided by SAFER - the pre-operational European Emergency Response Core Service.

The general flood mapping flow-chart is presented in figure 2.

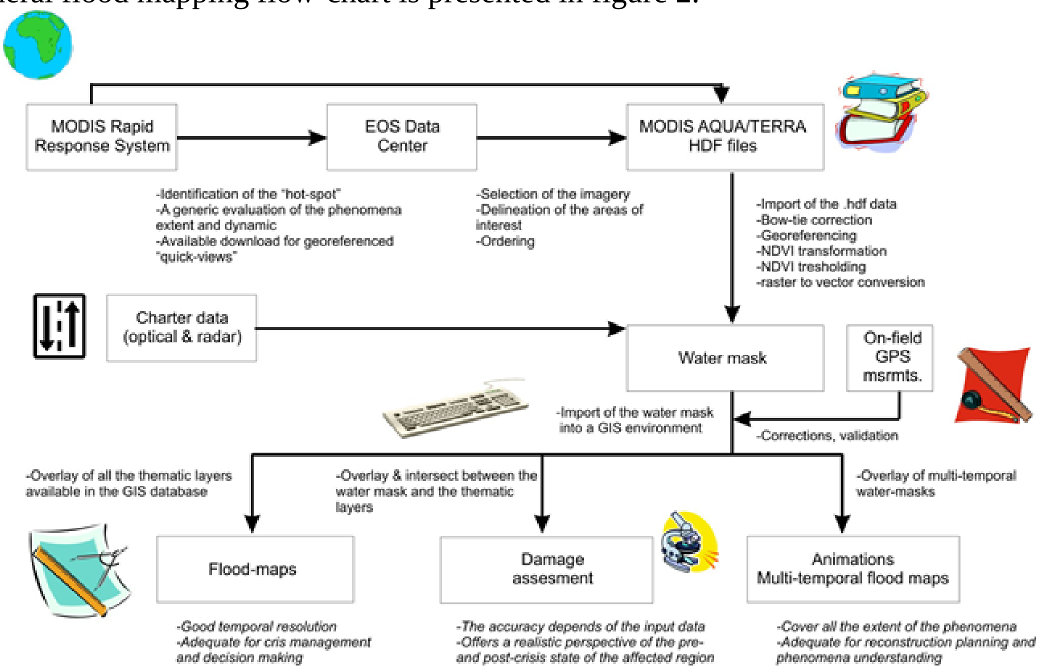

Figure 2. The flood mapping flow chart

A series of specific image processing operations were performed, using the ERDAS Imagine software: geometric correction and geo-referencing in the UTM or STEREO 70 map projection system, image improvement (contrast enhancing, slicking, spectral band combinations and re-sampling operations), statistical analyses (for the characterization of classes, the selection of training samples, conceiving classifications).

Optical high-resolution data have been used to perform the analysis of land for inventory purposes under normal hydrological conditions as well as for determining the hydrographical network. Using supervised classification methods or advanced segmentation of specific thematic indices, the geographical information was extracted and integrated within the GIS database [2].

In the case of radar images, multi-temporal techniques were considered to identify and highlight flooded areas. This technique uses radar images of the same area taken on different dates (and a reference image from the archive, showing the "normal" situation) and assigns them to the red, green and blue colour channels in a false colour image. The resulting multi-temporal image is able to reveal changes in the ground surface by the presence of colour in the image, the hue of a colour indicating the date of change, and colour intensity showing the degree of change.

The methodology to identify, determine and map areas affected by floods is based on the different classification procedures regarding satellite images. The advantage of using high-resolution satellite images consists in the possibility to select precise spatial information upon the respective area (through merging images) and to localize and define the flooded or flooding-risk areas (through classifications). Radar images can bring useful information regarding flooded areas, even during periods of abundant rainfall and clouds [3]. The multi-temporal image analysis combined with the land cover/land-use information enable us to identify the water-covered area (including the permanent water bodies) and then the flooded areas. Using this methodology to identify and map flooded areas allows monitoring and investigating flood evolution during different phases, but especially after the crisis, in order to make damage inventory and to take recovery actions [4].

The classical digital maps (road network, localities, permanent water bodies, etc.) are also used to obtain the final cartographic products. The Earth Observation (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.

The entire work-flow was fully optimized and usually we obtain the final product between 8 to 24 hours after the satellite imagery was acquired by the satellite sensor. The real processing time is around 1 – 2 hours, the major delay being related to the processing steps for the raw image, done by the satellite operator and data transfer. The typical products managed by the on-line system FLOODSAT are: numerical weather forecasting and warning, hydrological/hydraulical model outputs, satellite-derived products, radar-derived products, geographical maps, and other meteorological data. The satellite-derived products are mainly related with near real-time flood mapping, non-real-time flood mapping, maximum flood extend mapping, 3D flythrough, flooded area classification (relatively deep water, shallow water with vegetation, mud deposition), flood extent evolution using multi-temporal satellite data by 2D animations.

Also the satellite date has been used for assets mapping for floods; the aim of this service is to provide updated and accurate cartographic information in flood prevention, and post-crisis phase.

The data registered into the system is published through standard compliant services and can be accessed by users via a web or desktop client.

The final products are distributed to the interested institutions and media using a dynamic web page and in printed form for a more convenient manipulation on field.

Until now we produced a lot of thematic cartographic products for the big floods that occurred in the last years:

- April 2005 in the Timis county (Soth-Western of Romania): over 1,300 homes damaged or destroyed, 3,800 people evacuated and about 30,000 ha of agricultural land flooded;
- July 2005 in five counties situated in Eastern Romania: 11,000 homes inundated, 8,600 people evacuated, 20 lost lives, 53,000 ha farmland flooded, 379 bridges destroyed;
- April 2006 in 12 counties along the Danube River: 3 077 homes affected, 16,000 people evacuated, 5 lost lives, 144,000 ha agricultural land flooded;
- July 2008 in six counties from the North-Eastern of Romania 3,985 houses affected, 15,834 people evacuated and 35,084 ha of agricultural land inundated.
- June 2010, in the Prut and Siret River basins (Eastern and North-Eastern of Romania): 20 lost lives and hundreds people evacuated. Several roads and thousands of hectares of farmland were inundated.
- June 2011, in the Mures , Olt, Bistrita and Trotus river basins (central and Eastern of Romania): 16 localities from 9 counties were affected, 150 ha arable land were flooded.

– May 2012, in the Bega, Barzava, Caras, Mures Jiu, Arges and Ialomita river basins (Western and South of Romania) 103 cities and villages from 20 counties, seven national roads and 890 ha of agricultural land affected.

The figure 3, 4 and 5 present the satellite-derived cartographic products for flood assessment and monitoring.

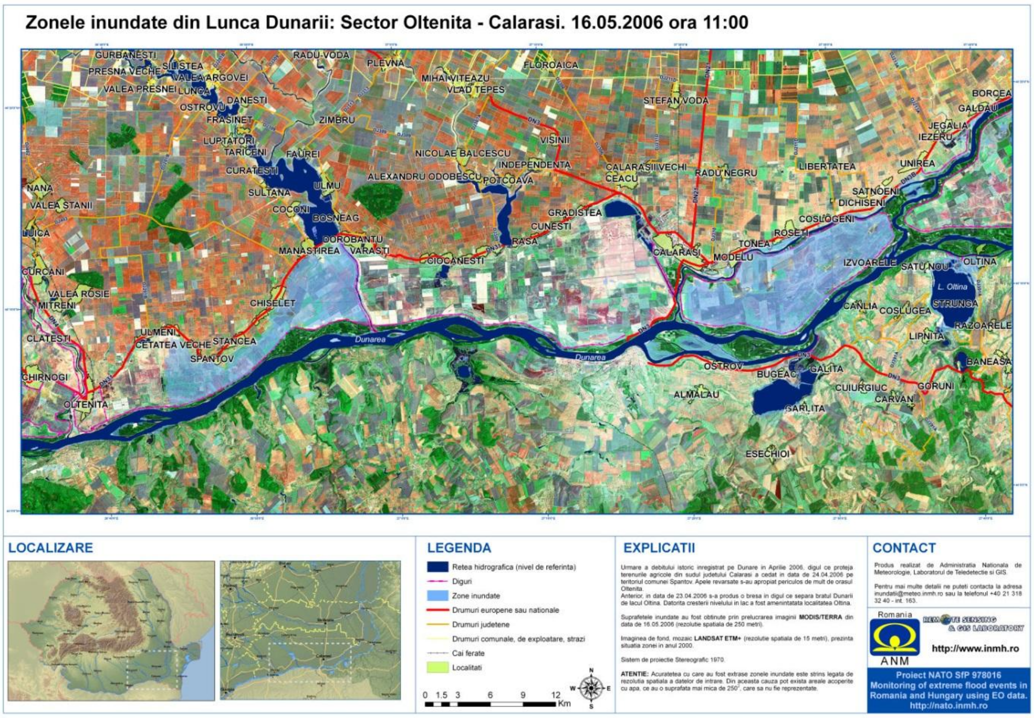

Figure 3. Flood extent of the Danube River, Calarasi sector, 16 May 2006; water mask issue from TERRA/MODIS (250 m resolution), background LANDSAT ETM+ (17 June 200, resolution 15 m)

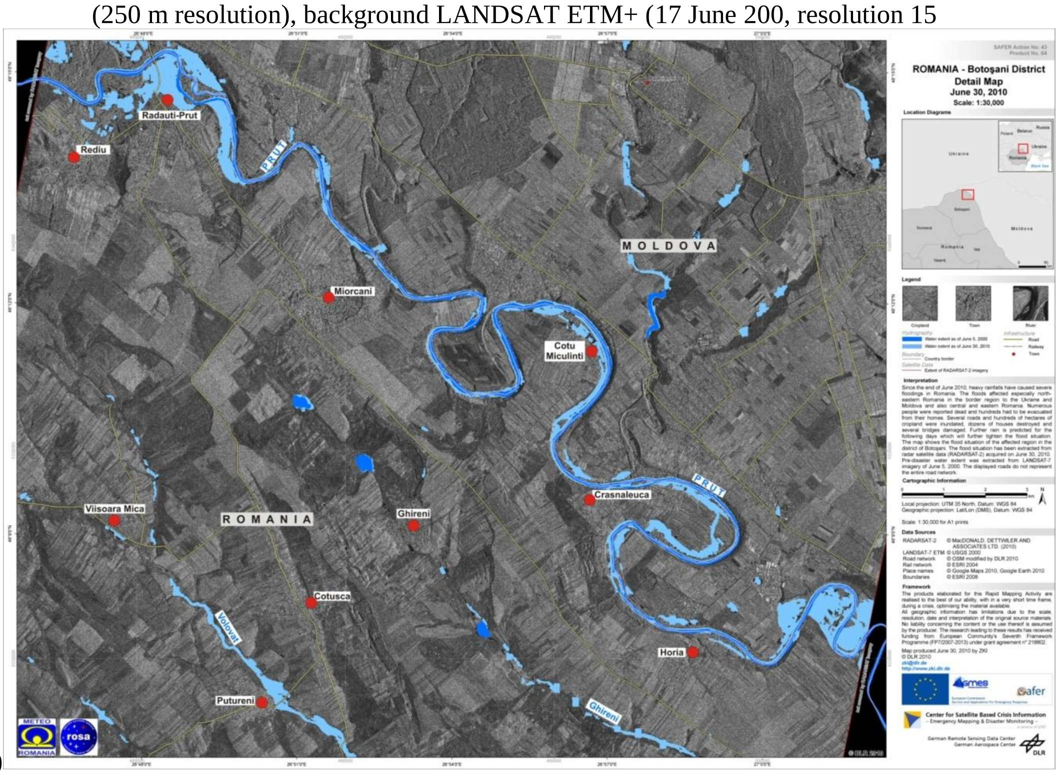

Figure 4. Flood extent of the Prut River, Botosani sector, 30 June 2010; water mask issue from RADARSAT 2 (light blue), pre-disaster water extent extracted from LANDSAT 7 ETM (5 June 2000)

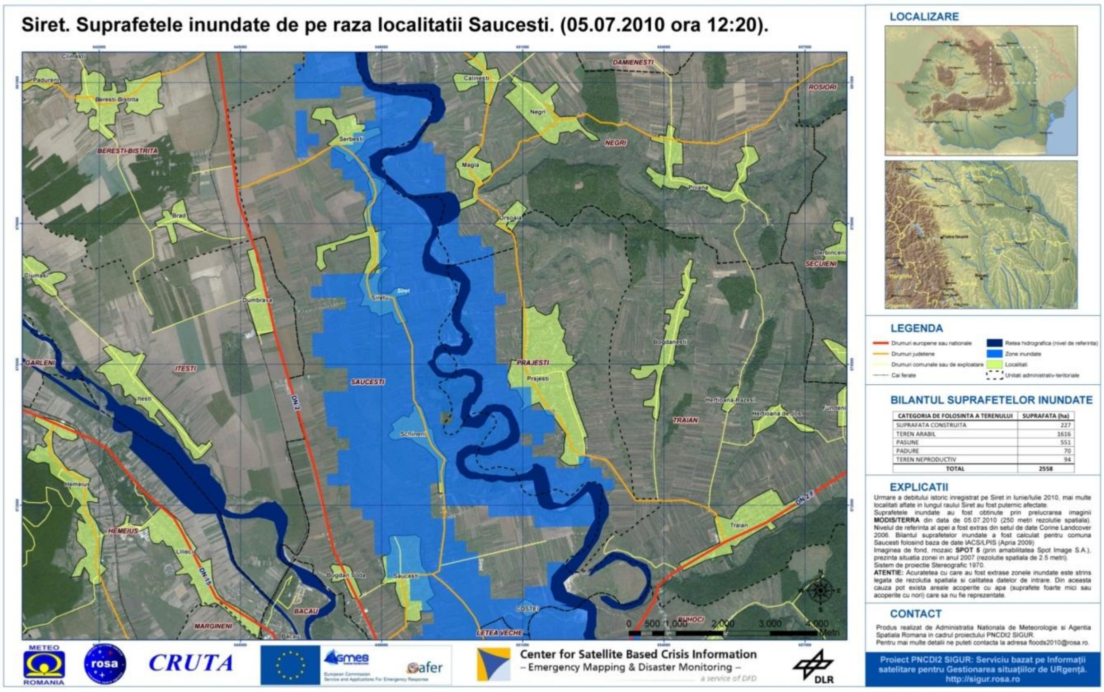

Figure 5. Flood extent of the Siret River, Saucesti sector, 5 July 2010 and evaluation of the affected areas; water mask issue from TERRA/MODIS (250 m resolution), pre-disaster water extent extracted from CORINE Landcover 2006, background SPOT 5 (10 June 2007, resolution 2.5 m)

An important result concerns the improvement of the interoperability between institutions, through the development of a set of specifications that support interoperable services and incorporated in a technical guidelines document. End-users interested in hydro-meteorological hazards thematic applications will be able to share and integrate data in standard format that can be transformed into useful information.

5. Conclusions

Recognizing the threat of extreme hydro-meteorological phenomena (like floods, severe convective storms, extreme frost and snowfall, hailstorms, heat waves, drought, etc) the Romanian Meteorological Administration, developed and implemented an efficient and powerful National Integrated Meteorological System (SIMIN). By enhancing the forecasting and nowcasting tools, as well as the Romanian national and local forecaster's decision support system, SIMIN highly contributed to improve the dissemination of forecasts and warnings. The satellite remote sensing and geo-information systems techniques have important contribution in managing flood connected phenomena by: detection of new flood events and public warnings, flood hazard mapping and rapid-response flood mapping and measurement.

In this context the bases for a flood mapping and monitoring service was established. A dedicated Web-based Information System for Trans-boundary Flood Management (FLOODSAT), based on satellite data and GIS technology, was implemented in the National Meteorological Administration.

An appropriate methodology was developed and tested, in order to process the raw data (satellite optical or radar, with medium and high range spatial resolution), to rapid mapping of event extent and finally integrate the information related to hydro-meteorological events into useful, standardized, cartographic products. Beside the maps of the risk exposed areas, phenomenon extent evolution, 3D flythrough and different animations were produced to get a more complex perspective on phenomenon dynamic and dimension.

The results can be quickly disseminated, in digital form via Internet, using a dedicated webpage. Some examples of the implementation of the extreme hydro-meteorological events support system obtained during recent floods and flash floods in Romania are also presented.

For Romania, such a system will strength the collaborative approaches between the existing expert institutions/groups in the domain of geo-information applications for disaster management and will contribute to the availability of critical information for the decision-makers and other end-users.

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