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Contribution of satellite remotely sensed data to flood risk mapping

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Introduction

In the latest years river flooding and accompanying landslides, occurred quit frequently in Romania, some of which isolated, others-affecting wide areas of the country's territory.

The flood forecast and defence related information in Romania is presently based entirely upon the ground-observed data, which are mostly collected by non-automatic hydrometeorological stations. Such data are somewhat limited in terms of spatial distribution, temporal detail, and speed of collection and transmission, and these limitations already started to be overcome.

Orbital remote sensing of the Earth is presently capable of making fundamental contributions towards reducing the detrimental effects of extreme floods [1]. Effective flood warning requires frequent radar observations of the Earth's surface through cloud cover. In contrast, both optical and radar wavelengths will increasingly be used for disaster assessment and hazard reduction. These latter tasks are accomplished, in part, by accurate mapping of flooded lands, which is commonly done over periods of several or more days. The detection of new flood events and public warnings thereof is still experimental, but making rapid progress; radar sensors are preferred due to their cloud penetrating capability [2]. Relatively low spatial resolution, but wide-area and frequent coverage, are appropriate; the objective is to locate where within a region or watershed the flooding occurs, rather than to map the actual inundated areas.

At the initiative of the Romanian Meteorological Administration, a project on "Monitoring of Extreme Flood Events in Romania and Hungary Using EO (Earth Observation) Data”, proposed to the NATO Science for Peace (SfP) Programme started in 2002 [3]. The project, including representatives of Romania, Hungary and USA, considers the setting up of a satellite-based surveillance system connected to a dedicated GIS database that will offer a much more comprehensive evaluation of the extreme flood effects. The main goal of the project is to reduce flood damages in the study area by improved flood forecasting and flood defence.

The paper presents the specific methods, developed in the framework of the NATO SfP “TIGRU” project “Monitoring of extreme flood events in Romania and Hungary using EO data**”** for deriving satellite-based applications and products for flood risk mapping.

The study area

The study area is situated in the Crisul Alb - Crisul Negru - Kőrős transboundary basin, crossing the Romanian – Hungarian border. This region suffers from flood damages on a regular basis [4], the losses including damages to houses, roads and railways, bridges, hydraulic structures, loss of domestic animals, and business losses.

EO data used

Apart from ground information on the occurrence and evolution of the flood, NOAA/AVHRR satellite data, microwave data from U.S. DMSP and Quikscat, as well as the high resolution images supplied by the orbital platforms (SPOT, IRS, LANDSAT, RADARSAT, QUIKSCAT, EOS-AM “TERRA” and EOS–PM “AQUA”), were available.

A Satellite Image Database (SID) provided by different platforms and sensors has been set up. The purpose of the SID is to gather information about the raw satellite scenes available as well as of the derived products and make it available in a simple format. This information is useful to test the processing and analysis algorithms for the water detection, mapping and analysis of flooding. The SID was build in Microsoft Works and will be available on-line on the file server, being updated as new satellite images are acquired. Each record of the database describe the characteristics of each satellite image: platform, sensor, date and time of data acquisition, duration of pass, spectral band, coordinates of the area covered, projection, calibration, size, bits/pixel, image file format, physical location (machine, directory), origin of data, type (raw/processed), type of processing applied, algorithm used, quick-look available, cloudiness.

Development of integrated methods, encompassing EO data and GIS facilities, for flood risk mapping

An important contribution of EO derived information in the topic of managing flooding connected phenomena could be envisaged at the level of mapping aspects. The geo-referenced information, obtained from optical and radar satellite images have been used to determine certain parameters required in an efficient flood management, such as the hydrographic network characteristics, water accumulation, snow cover, size of the flood-prone area, updated digital maps of the drainage network and land cover/land use, mask of flooded areas, multi-temporal maps of the flood dynamics, hazard maps with the extent of the flooded areas and the affected zones, etc. In order to obtain such high-level thematic products, the data extracted from EO images were integrated with other non-space ancillary data (topographical, pedological, meteorological data) and hydrologic/hydraulic models outputs. This approach may be used in different phases of establishing flood-sensitive areas such as: the management of the database that is constructed from the ensemble of the spatially geo-referenced information; the elaboration of the risk indices from morpho-hydrographical, meteorological and hydrological data; the interfacing of the models in order to improve their compatibility with input data; recovery of results and the possibility to examine scenarios; and the presentation of results as synthesis maps easy to access and interpret and which may then be combined with other information in the GIS database.

Different methods and algorithms for EO data processing and interpretation, needed for identifying, delineating and mapping water and excess soil moisture areas, were analyzed and tested.

A series of specific processing operations for the images 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, selective contrast, combinations between spectral bands, re-sampling operation), statistic analyses (for the characterization of classes, the selection of the instructing samples, conceiving classifications).

Optical high-resolution data have been used to perform the analysis for the inventory purposes under normal hydrological conditions as well as for determining the hydrographic network. The radiometric information contained in these images allows the derivation of both biophysical criteria and those from human activity, through supervised standard classification methods or advanced segmentation of specific thematic indices. Once extracted, these geographical information layers were integrated within the GIS for further water crisis analysis and management.

The interpretation and analysis of remotely sensed data in order to identify, delineate and characterize flooded areas was based on relationships between physical parameters such as reflectance and emittance from feature located on the surface: reflectance and/emittance decreases when a water layer covers the ground or when the soil is humid; also reflectance and/emittance increases in the red band because of the vegetation stress cause by moisture; reflectance and/emittance changes noticeably when different temperatures, due to thick water layer are recorded.

In the microwave region the water presence could be appreciated by estimating the surface roughness, where water layers smooth surfaces dielectric constant is then heavily correlated to soil water content. In case of radar images the multi-temporal techniques was considered to identify and highlight the flooded areas. This technique uses black and white radar images of the same area taken on different dates and assigns them to the red, green and blue color channels in a false color image. The resulting multi-temporal image is able to reveals change in the ground surface by the presence of color in the image; the hue of a color indicating the date of change and the intensity of the color the degree of change. The proposed technique requires the use of a reference image from the archive, showing the « normal » situation.

Conclusions

Flood risk analysis needs to make use of and integrate many sources of information. This approach is more demanded in case of a transboundary river. The integrated flood management approach is in harmony with the recommendations of the International Strategy for Disaster Reduction and that of the EU Best Practices on Flood Prevention, Protection and Mitigation.

Although satellite sensors cannot measure the hydrological parameters directly, optical and microwave satellite data supplied by the new European and American orbital platforms like the EOS-AM “Terra” and EOS–PM “Aqua”, DMSP, Quikscat, SPOT, ERS, RADARSAT, LANDSAT can supply information and adequate parameters to contribute to the improvements of hydrological modeling and warning.

Considering the necessity to improve the means and methods to flood hazard and vulnerability assessment and mapping, the paper presents the capabilities offered by remotely sensed data and GIS techniques to manage flooding and the related risk. The study area is situated in the Crisul Alb - Crisul Negru - Kőrős transboundary basin, crossing the Romanian – Hungarian border.

The specific methods, developed in the framework of the NATO SfP “TIGRU” project “Monitoring of extreme flood events in Romania and Hungary using EO data**”** for deriving satellite-based applications and products for flood risk mapping are also presented.

The satellite-based applications will contribute to preventive consideration of the extreme flood events by planning more judiciously land-use development, by elaborating plans for food mitigation, including infrastructure construction in the flood-prone areas and by optimization of the flood - related spatial information distribution facilities to end – users.

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