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NATO science for peace project on management of transboundary floods in the Crisul-Koros River System

By:
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Abstract

Experience of recent years indicates high occurrence of large and extreme floods in many parts of the world, including Europe. One region, which suffers from flood damages on a regular basis, is the transboundary area of the Crisul Alb and Crisul Negro rivers flowing from Romania into Hungary, where they are known as Kőrős rivers. Floods in this area typically start in the mountainous terrain of the upper parts of the basin in Romania and propagate to the plains in Hungary. To mitigate flood damages in this basin, NATO sponsored a Science for Peace project entitled Monitoring of Extreme Flood Events in Romania and Hungary Using Earth Observation (EO) Data. The project is conducted by a multi-national team comprising agencies from Romania, Hungary, USA and Canada. The main goals of the project are to reduce flood risks in the study area by:

- Improved collection and processing of satellite data,
- Developing integrated methods for hydrological modelling, EO data and GIS facilities for flood management before, during and after flood events,
- Refining a hydrological model to increase flood forecast accuracy and the lead-time of the forecasts,
- Developing new satellite based applications and products for end-users, including water management and civil protection authorities, environmental agencies and private users, and
- Delivering on NATO programmatic goals, including fostering international cooperation, training young scientists, disseminating results to the international scientific community, and applying key project results to another river basin.

The project is just past the mid-point of its duration (Apr. 2004), with a number of achievements, some of which will be reported in detail in other papers presented at this workshop. Specific accomplishments include inventory of image processing methods for analysis of extreme flood events; setting up an image database for testing and evaluation of image processing methods; establishing a dedicated information management sub-system, based on remote sensing and GIS; establishing main GIS info layers; establishing a flood database for the Crisul/Kőrős River System, including maximum observed flood discharges and synthesized (design) flood hydrographs; developing a methodology for land cover/use maps; updating the hydrological VIDRA model; completing the inventory of hydrotechnical structures and surveying of cross-sections in the Crisul/Kőrős basin; setting up the HEC/RAS model for flood routing in Hungary; and, delivering on programmatic tasks, including project visibility, collaboration with end-users, and involvement of young scientists. The progress achieved so far holds promise of successful completion and fulfillment of the main NATO objective – fostering scientific excellence and international cooperation in service to general population.

NWRI RESEARCH SUMMARY

Plain language title

Management of transboundary floods between Romania and Hungary

What is the problem and what do scientists already know about it?

Floods in the Crisul/Koros transboundary basin start in Romanian mountains and propagate to downstream plains in Hungary. To improve flood management in this basin, NATO sponsored a Science for Peace project entitled Monitoring of Extreme Flood Events in Romania and Hungary Using Earth Observation (EO) Data. The main goals of the project are to reduce flood risks in the study area by (a) Improved collection and processing of satellite data, (b) Developing integrated methods for hydrological modelling, EO data and GIS facilities, (c) Refining a hydrological model to increase flood forecast accuracy and the lead-time, (d) Developing new satellite-based applications and products for end-users, and (e) Delivering on NATO programmatic goals.

Why did NWRI do this study?

This study was done in support of the NATO Science for Peace program, which is funded by NATO.

What were the results?

At the mid-point of project duration, the progress achieved so far holds promise of successful completion and fulfillment of all objectives.

How will these results be used?

The results will be used by the river basin authorities in Romania and Hungary in managing transboundary floods and by other parties concerned about flood management.

Who were our main partners in the study?

The main partners were the Romanian Meteorological Administration (Bucharest, Romania), Dartmouth Flood Observatory (Hanover, USA), Romanian Water Administration (Bucharest, Romania), Hungarian Meteorological Service (Budapest, Hungary) and VITUKI Institute (Budapest, Hungary).

Projet du programme « La science au service de la paix » de l'OTAN sur la gestion des crues transfrontalières dans le réseau hydrographique Crisul-Kőrős

Marsalek, J., G. Stancalie, R. Brakenridge, V. Ungureanu, J. Kerenyi et J. Szekeres

Résumé

L'expérience des dernières années a montré que les crues fortes et extrêmes étaient très fréquentes dans de nombreuses parties du monde, notamment en Europe. L'une des régions régulièrement touchées par les crues est le secteur transfrontalier des rivières Crisul Alb et Crisul Negru, qui s'écoulent de la Roumanie vers la Hongrie, où ces rivières sont appelées les fleuves du Kőrős. Dans la région, les crues commencent en général dans les terrains montagneux des secteurs d'amont du bassin en Roumanie, pour se propager ensuite dans les plaines de Hongrie. Pour atténuer les dommages dus aux inondations, l'OTAN a parrainé, dans le cadre de son programme « La science au service de la paix », un projet de surveillance des crues extrêmes en Roumanie et en Hongrie faisant appel aux données d'observation de la Terre (OT). Le projet est dirigé par une équipe multinationale composée d'organismes de Roumanie, de Hongrie, des États-Unis et du Canada. Ses principaux objectifs sont de réduire les risques d'inondation dans la région à l'étude grâce aux activités suivantes :

- Amélioration de la collecte et du traitement des données satellitaires;
- Élaboration de méthodes intégrées pour la modélisation hydrologique, les données d'OT et les installations du SIG en vue de la gestion des crues avant, pendant et après les périodes de crue;
- Raffinement d'un modèle hydrologique en vue d'accroître l'exactitude des prévisions des crues et d'améliorer les délais des prévisions;
- Élaboration d'applications et de produits satellitaires nouveaux pour les utilisateurs finals, dont les responsables de la gestion des eaux et de la protection civiles, les organismes environnementaux et les utilisateurs privés;
- Atteinte des objectifs de programmes de l'OTAN, dont la promotion de la coopération internationale, la formation de jeunes scientifiques, la diffusion des résultats à la communauté scientifique internationale, et l'application des principaux résultats du projet à d'autres bassins hydrographiques.

Le projet, tout juste à mi-parcours (avril 2004), compte déjà à son actif quelques réalisations, dont certaines seront décrites en détail dans d'autres articles présentés dans le cadre de cet atelier. Parmi ces réalisations figurent l'établissement d'un inventaire des méthodes de traitement des images pour l'analyse des crues extrêmes; la création d'une base de données pour la vérification et l'évaluation des méthodes de traitement des images; l'élaboration d'un sous-système de gestion de l'information spécialisée basé sur la télédétection et le SIG; l'établissement de grandes couches thématiques du SIG; la création, pour le réseau fluvial Crisul/Kőrős, d'une base de données sur les crues donnant notamment les débits de crue maximum observés et des hydrogrammes de crue synthétisés (nominaux); l'élaboration d'une méthode de cartographie de la couverture terrestre et de l'utilisation des sols; la mise à jour du modèle hydrologique VIDRA;

l'achèvement de l'inventaire des structures hydrotechniques et de l'arpentage des sections transversales dans le bassin Crisul/Kőrös; l'adaptation du modèle HEC/RAS pour le détournement des eaux de crue en Hongrie; et la réalisation de certaines tâches programmatiques (p. ex. visibilité du projet, collaboration avec les utilisateurs finals et participation des jeunes scientifiques). Les progrès réalisés à ce jour devraient permettre d'atteindre les principaux objectifs de l'OTAN, qui sont de promouvoir l'excellence scientifique et la collaboration internationale au service de l'ensemble de la population.

Sommaire des recherches de l'INRE

Titre en langage clair

Gestion des crues transfrontalières entre la Roumanie et la Hongrie.

Quel est le problème et que savent les chercheurs à ce sujet?

Dans le bassin transfrontalier Crisul/Kőrös, les crues commencent en général dans les montagnes de Roumanie pour se propager ensuite en Hongrie. Pour améliorer la gestion des crues dans ce bassin, l'OTAN a parrainé, dans le cadre du programme « La science au service de la paix », un projet de surveillance des crues extrêmes en Roumanie et en Hongrie faisant appel aux données d'observation de la Terre (OT), dont les principaux objectifs sont de réduire les risques d'inondation dans la région à l'étude grâce a) à l'amélioration de la collecte et du traitement des données satellitaires, b) à l'élaboration de méthodes intégrées pour la modélisation hydrologique, les données d'OT et les installations du SIG, c) au raffinement d'un modèle hydrologique en vue d'accroître l'exactitude des prévisions de crues et les délais de prévision, d) à l'élaboration d'applications et de produits satellitaires nouveaux pour les utilisateurs finals, et e) à l'atteinte des objectifs de programmes de l'OTAN.

Pourquoi l'INRE a-t-il effectué cette étude?

Cette étude a été réalisée pour appuyer le programme « La science au service de la paix » de l'OTAN, financé par l'OTAN.

Quels sont les résultats?

À mi-parcours, les progrès accomplis semblent indiquer qu'on atteindra tous les objectifs fixés.

Comment ces résultats seront-ils utilisés?

Les résultats seront utilisés par les autorités des bassins hydrographiques de Roumanie et de Hongrie pour gérer les crues transfrontalières, ainsi que par les autres groupes intéressés par la gestion des crues.

Quels étaient nos principaux partenaires dans cette étude?

Les principaux partenaires sont l'Administration météorologique roumaine (Bucarest, Roumanie), le Dartmouth Flood Observatory (Hanover, États-Unis), l'Administration roumaine des eaux (Bucarest, Roumanie), le Service météorologique hongrois (Budapest, Hongrie) et l'Institut VITUKI (Budapest, Hongrie).

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Abstract

Experience of recent years indicates high occurrence of large and extreme floods in many parts of the world, including Europe. One region, which suffers from flood damages on a regular basis, is the transboundary area of the Crisul Alb and Crisul Negro rivers flowing from Romania into Hungary, where they are known as Kőrős rivers. Floods in this area typically start in the mountainous terrain of the upper parts of the basin in Romania and propagate to the plains in Hungary. To mitigate flood damages in this basin, NATO sponsored a Science for Peace project entitled Monitoring of Extreme Flood Events in Romania and Hungary Using Earth Observation (EO) Data. The project is conducted by a multi-national team comprising agencies from Romania, Hungary, USA and Canada. The main goals of the project are to reduce flood risks in the study area by:

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NATO SCIENCE FOR PEACE PROJECT ON MANAGEMENT OF TRANSBOUNDARY FLOODS IN THE CRISUL-KŐRÖS RIVER SYSTEM

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1. Introduction

Experience of recent years indicates frequent occurrence of large and extreme floods in many parts of the world, including Europe [1]. One region, which suffers from flood damages on a regular basis, is the transboundary area of the Crisul Alb and Crisul Negro rivers flowing from Romania into Hungary, where they are known as Kőrös rivers. Floods in this area typically start in the mountainous terrain of the upper parts of the basin in Romania and propagate to the plains in Hungary. Recent floods in this area include the two spring 2000 floods, which caused on the Romanian territory damages of more than $US 20 million [2]. These losses included damages to houses, roads and railways, bridges, hydraulic structures, loss of domestic animals, and business losses. On the Hungarian territory, a particularly notable flood occurred in the summer of 1980, with total losses of $US 15 million, including destruction of farmhouses and large losses in agriculture [2].

Historically, there has been a close co-operation between both countries in flood management in this area. The issues connected with the transboundary rivers crossing the Romanian – Hungarian border are covered by the bilateral Agreement for the settlement of hydrotechnical problems, which was issued on Nov. 20, 1986. This document includes eight specific regulations addressing flood defence, water quality protection, hydrological and meteorological data exchange, etc. To facilitate the implementation of this agreement, working groups from the Crisuri Water Authority in Oradea, Romania and Körös Valley District Water Authority (KOVIZIG) in Gyula, Hungary meet regularly to address the issues of mutual interest [2].

The flood forecast and defence related information provided by Romania to Hungary (downstream) 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 should be remedied.

Recognising the threat of floods and the need for further improvement of flood management in this area, at the initiative of the Romanian National Institute of Meteorology and Hydrology (now known as the Romanian Meteorological Administration), an international team was formed, with representatives of Hungary, Romania and USA, and proposed a project on "Monitoring of Extreme Flood Events in Romania and Hungary Using Earth Observation (EO) Data" to the NATO Science for Peace (SfP) Programme [2]. After some modifications, this proposal was accepted by NATO and the 3-year project started in November 2002. The paper that follows provides a brief overview of this SfP project, including the progress to date [3].

2. Study area: Crisul/Körös basin

The study area represents the Crisul Alb/Negru/Körös transboundary basin spanning across the Romanian–Hungarian border, with a total area of 26,600 km^2 (14,900 km^2 on the Romanian territory). In Romania, the catchment (basin) comprises mountainous areas (38%), hilly areas (20%) and plains (42%). About 30% of the catchment is forested. On the Hungarian side, the catchment relief represents plains. Annual precipitation ranges from 600-800 mm/year in the plain and plateau areas to over 1200 mm/year in the mountainous areas of Romania. This precipitation distribution can be explained by the fact that humid air masses brought by fronts from the Icelandic Low frequently enter this area. The orography of the area (Apuseni Mountains) amplifies the precipitation on the western side of the mountain range. Thus, the Crisuri Rivers Basin frequently experiences large precipitation amounts in short time intervals and the frequency of such events seem to be increasing in recent years [4].

In terms of hydrography, there is a marked difference between high rates of mountain runoff and low rates of runoff in plains. Thus, runoff flood waves formed quickly in the Romanian part of the basin move rapidly to the plains in the Hungarian part of the basin, which is characterised by relatively slow flows and a potential for inundation. In terms of flood forecasting, the Romanian part of the basin is of greater interest with respect to flood formation, which is also reflected in this paper. The hydrography of the study area is well established. There are 62 hydrometric stations on the Crisul Alb and Negru (and their tributaries); 7 of these stations have flow records longer than 80 years. The list of significant floods includes the events of June 1974, July-August 1980, March 1981, December 1995-January 1996, March 2000, April 2000 and April 2001. On the Hungarian territory, the hydrometric stations at Gyula and Sarkad are particularly of interest. A review of the significant stage and discharge data for the Körös Rivers at these two hydrometric stations shows some trends in the flood data. In Gyula, the flow was decreasing in time, but the stage was rising (this could be caused by hydrotechnical structures); at Sarkad, both discharge and stage were increasing (reflecting more natural conditions, without much change in the river channel geometry) [5].

Thus, the frequency and importance of floods in the study region require further work to reduce flood damages and improve flood monitoring by the agencies in charge of flood protection, such as government agencies, civil protection authorities or municipalities. To mitigate flood impacts in the study area, structural and non-structural measures have been undertaken in the past. The Romanian area is defended by dikes along the Crisul Alb River and Crisul Negru River. These dikes were built in the 19th century for a 20-year design return period and further improved in later years. Currently, the dikes on the right bank of the Crisul Negru River and the Teuz River (43 km) are designed for a 50-year return period, and on the Crisul Alb, 67 km of dikes on the right bank and 59 km on the left bank are designed for a 100-year return period. In spite of these improvements, in April 2000, the right bank dike of the Crisul Negru broke near the village Tipari (a 130 m breach) and caused significant flooding of, and damages in, the adjacent territory. Other structural flood protection measures include permanent retention storage facilities (total volume of 34×10^6 m^3) and temporary storage facilities (a total storage volume of almost $80 \times 10^6 m^3$) [4,5].

On the Hungarian side, in the Körös valley, high flood potential is recognised and exacerbated by low flood plains. Much of the area is, therefore, protected by flood dikes, of which construction started in the 18th century. More than 440 km of dikes are maintained by the KOVIZIG. Following the 1979 flood, construction of detention reservoirs started. Altogether, these reservoirs provide storage capacity of 188 million m^3 and serve to reduce critical flood levels. The reservoirs are activated during floods, by a controlled explosion opening a protected spillway (a side weir) in flood dikes. Detained water inundates areas with lower intensity of agricultural activities and causes limited damages. Nevertheless, the reservoirs are activated only when necessary to avoid higher losses caused otherwise [4].

The analysis and management of floods constitute the first indispensable step towards, and a rational basis for, the development of flood protection. Where certain flood risk levels are inevitable, the affected parties must know it and be appropriately warned. To reduce the frequency and magnitude of the damages due to flooding, comprehensive, realistic and integrated strategies must be developed and implemented.

The flood forecasting and monitoring systems existing in the study area do not reflect well the spatial distribution of floods and the related phenomena (pertaining to geographic distances or patterns) in both pre- and post crises phases. To mitigate these limitations, the SfP project was initiated with emphasis on a satellite-based surveillance system connected to a dedicated GIS database that will offer a much more comprehensive evaluation of the extreme flood effects. Also, so far, the flood potential, including the risk and the vulnerability of flood-prone areas, have not been yet quantitatively assessed. An inventory of the past floods observed by the EO facilities would allow a more cost-effective design of structural and non-structural measures for flood protection and disaster relief. Finally, such data also provide important validation of the hydrological modelling-based flood risk assessment, because they show the actual extent of past flooding [2].

3. SfP Project Objectives

The main goal of the project is to reduce flood damages in the study area by improved flood forecasting and flood defence, and to deliver on other programmatic criteria, including enhancing co-operation among scientific personnel in the participating countries, training young researchers, disseminating results to the international scientific community, and transferring the tools developed in the study area to another river basin.

A flood forecasting system (non-automated hydro-meteorological stations, which transmit data by phone or radiotelephone) already exists in the study area. Using the observed peak discharges in the headwaters of the Crisul Alb and Crisul Negru and their tributaries, a flood forecasting procedure based on time-lagging of the corresponding discharges is applied. The deficiencies of this method include limited lead-times of the forecasts and improper consideration of tributary inputs. Consequently, this forecasting procedure needs to be improved [2].

The success of risk management largely depends on the availability, dissemination and effective use of timely information. In flood risk management, orbital sensing technologies, used in conjunction with the traditional means, can greatly improve the management of flood hazards [6,7].

The SfP project aims to provide an efficient and powerful flood monitoring tool to a broad range of stakeholders, and thereby significantly improve the efficiency and effectiveness of the action plans for flood defence. Apart from ground information on the occurrence and evolution of the flood, locally received NOAA/AVHRR satellite data, microwave data from the U.S. DMSP and Quikscat and follow-on satellites, and the high resolution images supplied by the European and American orbital platforms (SPOT, ERS, LANDSAT-7, EOS-AM "TERRA" and EOS-PM "AQUA"), will substantially contribute to determining the flood-prone areas. Furthermore, the information obtained from optical and radar images will be used in determination of certain parameters required in flood monitoring, such as the hydrographic network, water accumulation, size of the flood-prone area, and land cover/land use features [5].

A database containing EO data, as well as hydrological and meteorological parameters related to significant flood events, will be established and used to test the processing and analytical algorithms, in order to establish an operational methodology for the detection, mapping and analysis of flooding.

The management of remote sensing data related to river flooding largely relies on the functional facilities provided by the GIS, in combination with satellite data and hydrological models. The SfP project adopted this integrated approach, in order to establish a methodology that would allow the assessment of the flood risk on the basis of representative regional indices [2].

The project will provide the decision-makers with updated maps of land cover/land use, hydrological networks and more accurate/comprehensive thematic maps at various spatial scales, indicating the extent of the flooded areas and affected zones. Due to the upcoming release of the NASA SRTM topographic data for this part of Europe, the SfP project may also provide updated and badly needed information concerning the detailed topography of the study area and especially of the low-relief floodplains.

The proposed hydrological forecasting model will increase the lead time and thereby provide additional time for implementing the measures needed to protect the human life and property in the study area. Thus, the use of the recorded rainfall in the model will provide extra time, varying from 6 to 12 hours, depending on the storm duration. Consequently, the time available to the emergency personnel in flood defence will be considerably increased. This will lead to direct and indirect reduction of economic losses and an earlier flood warning for the Hungarian territory, which is affected by the Crisul Alb and Crisul Negru floods [2]. Also, the newly proposed model allows the assessment of hydrograph shape, which is needed for hydraulic computations, but is not available in the traditional methods applied in the past.

Finally, the project results described here could also help in restoration and rehabilitation of some river courses, which were adversely altered by floods, and also in the future analysis and selection of structural flood protection works [7].

The SfP project will greatly benefit from an ongoing Phare Project on Flood Prevention in the Crisuri Basin. The main objective of the Phare project is to implement a new system for automatic weather radar and ground surface measurements and data transmission of meteorological and hydrological parameters in the Crisuri basins. The telemetry system will provide continuous measurement and transmission of main hydrometeorological data (precipitation, air temperature and water levels) received from 28 automatic stations. Thus, these stations will provide, in real time, input data to the flood forecasting model, with further increase in lead times.

Specific objectives of the SfP project are described in more detail below [2].

3.1 OBJECTIVE 1

To analyze, adapt and test methods and algorithms for processing and interpretation of the medium and high spectral and spatial satellite resolution data, from the optical and microwave regions (provided by the existing platforms like NOAA-AVHRR, DMSP, SPOT, IRS, ERS, RADARSAT and by the newly available ones such as TERRA-MODIS, TERRA-ASTER and QUIKSCAT). The specific goal is to identify, delineate and map floodwater and excess soil moisture areas. The selected algorithms and methods for satellite data processing and interpretation that are dedicated to the analysis of severe flooding will improve the scientific and technological capabilities of the Romanian and Hungarian remote sensing teams.

3.2 OBJECTIVE 2

Development of a dedicated sub-system, based on remote sensing and GIS technology, to improve flood management and mitigate flood effects in the Romanian – Hungarian transboundary study area. This sub-system will allow the storage, management and exchange of raster and vector graphic information, and also of related attribute data for the flood monitoring activities. This dedicated information sub-system will contribute to the regional quantitative risk assessment (using flood hazard and vulnerability characteristics), and will serve for monitoring and hydrological validation of risk simulations. Another important result will be the preventive consideration of flood events in land development and special planning of the flood-prone areas.

3.3 OBJECTIVE 3

Development of integrated methods, encompassing hydrological modelling, EO data and GIS facilities, for flood management before and after flood events, and their adaptation to local conditions in the Crisul Alb and Crisul Negru transboundary basins. These methods will include a statistical model of flood wave hydrographs of various frequencies of occurrence, algorithms for flood hazard mapping (using representative parameters obtained from historical images and other geo-referenced data) and objective documents for post-crisis analysis and damage assessment.

3.4 OBJECTIVE 4

Adaptation of a semi-distributed rainfall-runoff model to the study area and its improvement with respect to increasing the flood forecast accuracy and lead-times. The model outputs are stage and discharge hydrographs in the sections chosen by the user. The model will be provided with an updating procedure and a routine assessment of the effects of the storage reservoirs (permanent and temporary reservoirs) on the peak flood discharge. The forecasted hydrograph will serve as the input to a hydraulic model for computing transport and transformation of flood waves along the river, using descriptions of the geometry and hydraulic characteristics of the river channel.

3.5 OBJECTIVE 5

Development of new satellite-based applications and products in the study area, for water management and civil protection authorities, environmental agencies and private users: updated digital maps of the hydrological network and land cover/land use, hazard maps at various spatial scales (1:200,000 to 1:5,000) with the extent of the flooded areas and the affected zones in detailed scales and with the possibility of managing and displaying the geographical database and observing rainfall-runoff model outputs. These products will contribute to preventive consideration of flooding in land development and special planning in the flood-prone areas, and for optimising the distribution of flood-related spatial information to end-users.

3.6 PROGRAMMATIC OBJECTIVES

While the first five objectives were of the scientific/technical nature, the programmatic objectives include the general objectives of the NATO SfP Programme, such as fostering international cooperation, training young scientists, disseminating results to the international scientific community, and applying key project results in another river catchment.

4. Progress achieved at half-time of project duration

4.1 IMAGE PROCESSING FOR FLOOD ANALYSIS

EO images have wide applications in flood analysis, in such tasks as producing catchment maps, detecting water surface and soil moisture, detecting inundated areas, and assisting with remote flow measurement [6,7]. Thus, image processing is important for developing such products and using them in flood analysis and management. Towards this end, the project team undertook an inventory and documentation of image processing methods, set up an experimental image database, tested and evaluated processing methods, initiated the selection of the best processing method, and conducted training in image processing [3].

General methods and algorithms used for EO data processing and interpretation, needed for identifying, delineating and mapping water and excess soil moisture areas, were analysed and tested [4,5]. An image database with high spectral and spatial satellite data was established, and the images were analysed with respect to correct identification of water bodies, accurate estimation of flooded (inundated) areas, and the dynamic monitoring of flood processes. In this work, emphasis was placed on medium spatial resolution (e.g., obtained from NOAA-AVHRR and TERRA-MODIS).

MODIS (Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites. Terra MODIS and Aqua MODIS view the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or in groups of wavelengths. The data available from MODIS are highly suitable for flood warning and management, because they are available in real time (or nearly real time), can be rapidly processed and disseminated, cover a wide area, and are abundant and inexpensive, which is important when dealing with longer duration floods [4].

In processing MODIS data, major technical challenges include proper water classification and the development/refinement of the MODIS-based hydrological monitoring system (detection of changes, and satellite stream gauging stations). MODIS provides very accurate geo-coding, clouds can be removed by composition techniques, and the data are distributed via the EOS Gateway. In water classification, strong water/land differentiation is needed. The Romanian Project team has developed a methodology, which allows co-processing the ASTER and MODIS data, essentially by superposing the degraded ASTER mask over the MODIS water mask and obtaining a MODIS mask with the "percentage of water" pixels.

The algorithm serving to create a water mask using a threshold technique on multispectral MODIS images was adopted from the Dartmouth Flood Observatory (Hanover, USA) and further modified in early 2004 [5]. The objective of these modifications was to develop an automatic method for creating the water mask using multispectral MODIS images. An algorithm was developed to detect pixels that were either 100% water or partial water, using a threshold technique and investigating the spectral characteristics of the pixels individually, without taking into account the adjacent pixels. Calibrated shortwave images with 250 and 500 m spatial resolution were used for this purpose. The 1.6 μm-channel data were used, because they are characterised by the lowest water reflectance and are independent of turbidity, which is typical for flood waters. However, the 1.6 μm channel allows separating water from low-land areas, but not from snow in mountainous areas. To mask out snowy areas, a threshold on the 0.87 μm channel was used [4,5].

The other problems encountered were caused by orographic and cloud shadows, and by melting snow. Their spectral characteristics were quite similar to those of water, so only partial separation was achieved. Large, clear water surfaces without vegetation have NDVIs (Normalised Difference Vegetation Index) < -0.2 and can be easily separated from shadows. However, using this threshold would mask out not only the shadows but also many pixels containing water, such as the pixels with high vegetation fractions, turbid waters, and mixed pixels along the coasts. To avoid the loss of such pixels, a NDVI threshold > -0.2 had to be used. After experimenting with different threshold values, the best suited values were adopted [5].

4.2 DEVELOPMENT OF A DEDICATED SUBSYSTEM (DSS) BASED ON REMOTE SENSING (RS) AND GIS

The main functions of this subsystem are acquisition, analysis and interpretation of data; management of data; handling and preparation of data for rapid access; updating of information; data restoring, and preparation of value-added information [8]. The proposed DSS system is based on both remote sensing and GIS. A central platform information DSS server was set up at the NIMH, where satellite data are received and processed, and further distributed, e.g., to the end-users. Several satellite data providers were incorporated into the Project and other EO data can be accessed via FTP from European and American satellite database centres. The dedicated subsystem allows data exchange among the Project partners. Standardized products and project results are also distributed via the central network Internet interface [4].

A GIS database needs to be created for the study area (the catchments of the Crisul Alb, the Crisul Negru and the Körös Rivers). In preparation for GIS construction, the data needs were assessed, the existing map data were inventoried, and the needs for their updating from satellite images or field measurements were identified. The structure of the GIS was designed to meet the Project requirements with respect to evaluation and management of the information pertinent to flood occurrence and development, as well as for the assessment of damages caused by floods. In this regard the database contains a spatial geo-referenced information ensemble, with satellite images, thematic maps, time series of meteorological and hydrological parameters data, and other data. The GIS database will be connected with the hydrological database, which will facilitate synthesized representations of the hydrological risk using separate or combined parameters [5].

While the Hungarian team activities concerning the GIS development are only in the planning stage, the Romanian team proceeded with developing a GIS for the entire Romanian study area of the Crisul Alb and Crisul Negru basins using cartographic maps in the scale of 1:100,000. Recognising that the information in such maps may be outdated, it was updated on the basis of recent satellite images (e.g., the hydrographic network, land cover/land use) and/or by field measurements (e.g., dike and canal network) [5].

As being currently developed, the GIS database contains the following info-layers: (a) sub-basin and basin limits; (b) land topography (organised in DEM); (c) hydrographic network, dikes and canals networks; (d) transportation network (roads, railways); (e) municipalities; (f) meteorological station network, rain-gauge network, hydrometric station network; and, (g) updated land cover/land use.

Inventories of all meteorological and hydrometric stations, hydrotechnical structures (including dikes, drainage works, agricultural drainage, irrigation systems, flood retention reservoirs, and polders) in the Crisul Alb and Crisul Negru basins have been completed. Also, cross-sectional profiles of main river beds, corresponding to the Crisul Negru, Crisul Alb, White, Black and Double Koros, have been completed through field measurements. The GIS info-layers related to the meteorological and hydrometric station networks in the Crisul Alb and Negru basins are shown in Fig. 1.

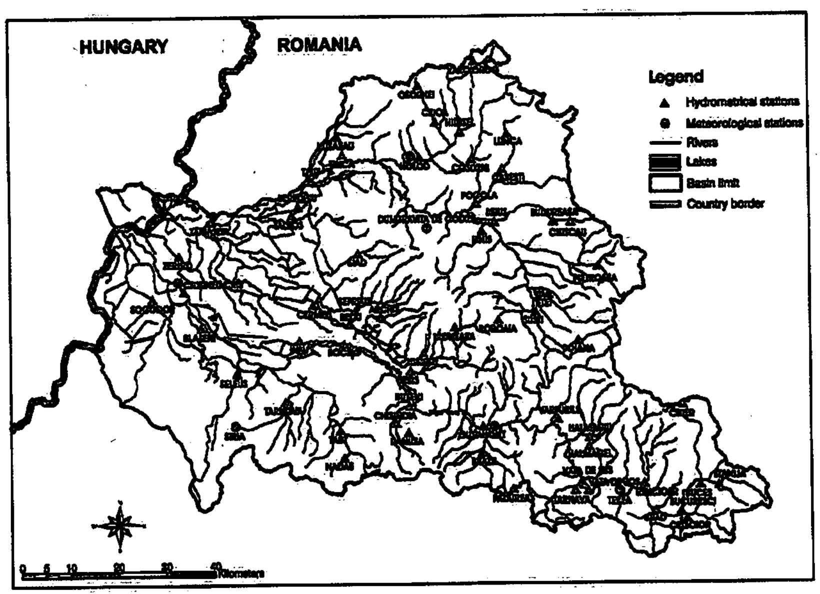

Fig. 1. The GIS info-layers related to the hydrometeorological station network in the Crisul Alb and Crisul Negru basins [5]

4.3 INTEGRATED METHODS FOR FLOOD MANAGEMENT

In this task, a flood data base was established for the study area (from the Romanian and Hungarian national databases) and validated, maximum discharges of various return periods were calculated, synthetic flood hydrographs were developed, and land cover/land use maps are under preparation.

The characteristics of extreme floods, i.e., peak flows, volumes and durations, and their probabilistic distributions, are needed and were determined by the Flow (Q)-Duration (d)-Frequency (F) method. The estimates of low-frequency flood quantiles were produced by the GRADEX method, in which maximum rainfall distributions are used to extrapolate hydrometric data [3,5].

For each flood event, characteristic flows were determined, partial-duration series of these variables were fitted by the exponential law, and extrapolated to lower frequencies by gradually replacing the flow distribution slope by the rainfall gradex.

Synthesized (design) flood hydrographs are needed as inputs to hydraulic models for establishing flood maps and were derived with hydrograph shapes consisting of two segments; the linear rising limb with a time to peak ≤D, where D is defined as the median value of flow durations corresponding to the 10-year flood peak, and the falling limb, of which shape is determined from threshold discharges of the same occurrence and various durations. Examples of synthetic flood hydrographs for return periods varying from 10 to 1000 years are given in Fig. 2.

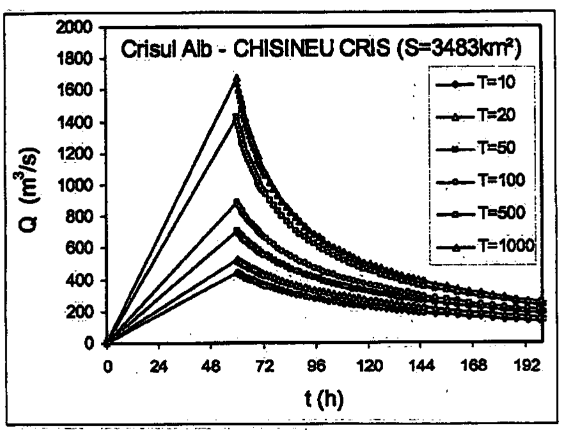

Fig. 2. Synthetic Mono-Frequency Hydrographs at the Chisineu Cris gauging station (Crişul Alb River) [4]

Finally, for updating the land cover/land use in the study area, TERRA/ASTER data were used and were found suitable for producing detailed maps of land cover/land use, especially when using the visible and near infrared bands (1, 2, 3B) data with a 15-m resolution. The method for the land cover/land use mapping based on the TERRA/ASTER data included three steps: (a) Geo-referencing of the ASTER data, (b) Detection of clouds and water surface, and (c) Data classification, in which both supervised and unsupervised classifications were tested. Better results were obtained with the unsupervised classification, in which different numbers of classes and iterations were tested.

Some progress was reported on starting the Digital Terrain Model (DTM) construction and integration into the GIS database [9,10]. DTM is a dataset representing ground surface elevations (bald earth), without portraying any above ground objects. For the Hungarian catchment, a DTM is available with a 50 x 50 or 10 x 10 m frame distance, and the following ranges of the vertical accuracy: hilly area (slope > 6%) < 5.0 m; medium relief areas < 2.5 m; and, flat areas < 0.8 m. A digital map of the Hungarian study area produced may have resolution which is inadequate for the Project. In the (Romanian) area vulnerable to flooding, which is situated in the floodplain regions of the Crisuri River basin and demarcated at its eastern boundary by the Ineu-Talpos and its northern boundary by the Crisul Repede basin, the most refined DTM will be developed.

There are several techniques for DTM generation: Shuttle Radar Topography Mission (SRTM) products, radar interferometry, lidar altimetry and DTM construction from topographical maps. The final DTM will be constructed in a UTM projection, with reference to the Baltic Sea, and cell resolutions of < 7 m in the horizontal plane and < 1 m in the vertical plane [5].

4.4 METHODOLOGIES FOR FLOOD FORECASTING

Two types of models are used in the project – a flood forecasting model VIDRA on the Romanian territory and the output hydrographs from this model will be routed in the Hungarian part of the catchment by the HEC-RAS model of the U.S. Army Corps of Engineers. The VIDRA model [6] simulates the rainfall-runoff processes taking place in a watershed by conducting the following computations:

- Sub-basin snowmelt estimation, using the degree-day method;
- Computation of the average rainfall in each sub-basin, by weighting the rainfall and snowmelt data measured in the meteorological network;
- Calculation of the effective rainfall over each sub-basin by subtraction of infiltration and evapotranspiration abstractions from the average water inflow, using the deterministic reservoir model PNET;
- Integration of the effective rainfall on hill slopes and in the primary river network, which results in runoff hydrograph formation in each sub-basin, using the instantaneous unit hydrograph as a transfer function of the hydrographical system;
- Superposition of the flood waves formed in each sub-basin and their routing along the main river channel using a non-linear model based on the analytical solution of the Muskingum method; and,
- Flood wave attenuation through reservoirs, using a reservoir co-ordinated operation method.

The VIDRA model has a variable computational step (from one to 24 hours) and simulates all the main hydrological processes taking place in a watershed [5].

4.5 PROGRAMMATIC OBJECTIVE ACHIEVEMENTS

So far, great progress has been achieved towards meeting the programmatic objectives [3]. Project visibility is maintained through a number of presentations at various international meetings and the project web site. There are about 15 young scientists working on various project tasks at the five agencies involved. Also, staff members have been trained at the Dartmouth Flood Observatory (USA), DHI (Denmark), and elsewhere.

5. Concluding observations

The NATO Science for Peace Programme provides an important mechanism for supporting scientific research in the transition countries in Central and Eastern Europe. The project featured here is helping deliver on that programme and is particularly worthwhile because of its focus on research with high societal value (protection of human life and property), conduct of leading-edge research in terms of Earth Observations and their use in flood management, enhancing collaboration between the neighbouring countries and others, and fostering collaboration among international experts. The progress achieved under this project so far holds promise that all these goals and objectives will be met.

6. References

1. Marsalek, J. (2000). Overview of flood issues in contemporary water management, in J. Marsalek, W.E. Watt, E. Zeman and F. Sieker (eds.), Flood Issues in Contemporary Flood Management, NATO Science Series, Vol. 71, Kluwer Academic Publishers, Dordrecht/Boston/London, pp. 1-14.
2. Brakenridge, R.G, G. Stancalie, V. Ungureanu, A. Diamandi, O. Streng, A. Barbos, M. Lucaciu, J. Kerenyi and J. Szekeres (2001). Monitoring of extreme flood events in Romania and Hungary using EO data, project plan. September. Bucharest, Romania.
3. Marsalek, J. (2004). Monitoring of extreme flood events in Romania and Hungary using EO data - Technical Progress Report No. 3. NWRI, Burlington, Ontario, Canada, August.
4. Brakenridge, R.G, G. Stancalie, V. Ungureanu, A. Diamandi, O. Streng, A. Barbos, M. Lucaciu, J. Kerenyi and J. Szekeres (2003). Monitoring of extreme flood events in Romania and Hungary using EO data. Progress report, May. Hanover, NH, USA.
5. Brakenridge, R.G, G. Stancalie, V. Ungureanu, A. Diamandi, O. Streng, A. Barbos, M. Lucaciu, J. Kerenyi and J. Szekeres (2004). Monitoring of extreme flood events in Romania and Hungary using EO data. Progress report, May. Hanover, NH, USA.
6. Brakenridge, G.R., B.T. Tracy and J.C. Knox. (1998). Orbital SAR remote sensing of a river flood wave. Int. J. Remote Sensing, 19(7), 1439-1445.
7. Muller, E., H. Decamps and M.K. Dobson (1993). Contribution of space remote sensing to river studies. Freshwater Biology 29, 301-312.
8. G. Stancalie, A. Diamandi, V. Ungureanu, V. A. Stanescu (2003). Sub-system based on remote sensing and GIS technology for flood and related effects management in the framework of the NATO SfP "TIGRU" project. First Annual Session of the NIHWM, Bucharest, Sep. 22-25, 2003. Proc. of the 1st Annual Session of the NIHWM, Bucharest, Romania (CD-ROM).
9. G. Stancalie, Corina Alecu, Vasile Craciunescu, Andrei Diamandi, Simona Oancea, G. Robert Brakenridge (2004). Contribution of Earth Observation data to flood risk mapping in the framework of the NATO SfP "TIGRU" project. International Conference on Water Observation and Information System for Decision Support, Ohrid, FY Republic of Macedonia, May 25-29, 2004. Proc. of BALWOIS Conference, Ohrid, FY Republic of Macedonia. (CD-ROM).
10. G. Stancalie (2004). Contribution of Earth Observation Data to Flood Risk Analysis", XXII-nd Conference of the Danubian Countries on the Hydrological Forecasting and Hydrological Bases of Water Management. Brno, Aug. 30- Sep. 3, 2004. Proc. of the XXII-nd Conference of the Danubian Countries, Brno, Czech Republic (CD-ROM).

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