Flooding management: Research and implement the GIS database of the water level for the annual flooding area in Mekong delta – Vietnam

Gregoire Vandenschrick[1], Frederick Lupo[1]

[1] Da Vinci Division of Spacebel, Angleur (Belgium).

1 Introduction

Flooding of the Mekong River and its tributaries are recurrent events and cause each year in varying degrees damage to agricultural production, rural infrastructure and human settlements, which can reach disastrous proportions with serious losses in food production and human lives. The floods occur the monsoon period from August till November. They are caused by the heavy tropical storms and typhoons.

The project aims at promoting the investigation and design of a flooding management system combining an Earth Observation-based layer and a GIS database of the water level for the annual flooding area in Mekong delta, with as finalization developing operational services to the user community.

2 Objectives

The objectives are:

1. To propose an integrated system allowing the integration of existing water level measurements data, remote sensing and ancillary flooding information in order to provide quick support to the decision makers in Mekong Delta.
2. To demonstrate the feasibility of an accurate and quick evaluation system (flooded area) during the flood event.

3 Background

Many studies and projects have already been conducted in order to better manage and prevent flood crisis (UNDP 1992). The need to integrate satellite data and in situ data into hydrological models for flood forecasting has been identified (CEOS 2002) and considerable work devoted to develop the approach needed has been done.

Correspondence to: Frederick Lupo.

Frederick.Lupo@spacebel.be

The challenge was also to develop fully integrated floods system such as a Geographical Information System (GIS) incorporating Earth Observation data and disseminating flood-related data through Internet. Such system has been connected to relevant agencies and delivered real time/ rear real time information and synoptic views to key decision-making bodies to adequately mitigate flood events.

Among others projects, the European Community (EC) Research on Floods in the framework of environmental research has funded the WAMM project aimed to develop a reliable methodology for the mapping of floods and for the evaluation of the near-surface soil moisture in Europe. A normalized difference image between two Synthetic Aperture Radar (SAR) images was calculated and next classified in order to produce a flood map. A SAR images processing tool designed as an automated mapping (AM) system, has been developed in both C++ and ESRI ArcView™ software programming language. The SAR-derived flood maps were planned to be use to validate the hydrological and hydraulic model MIKE11 flood simulations. Another good example of such EC project was the FloodMan project (2002) which aimed at near real time flood forecasting, warning and management system based on satellite radar images, hydrological and hydraulic models and in-situ data. The FLOODMAP project was also used as a principal reference.

The DECIDE Belgium Flood project (Earth Observation Technologies for DECIsion Support DEmonstrations - The Flood Case) funded by the European Space Agency (ESA/ESRIN) aimed at promoting the integration of an Earth Observation-based layer as support to an existing and operational user DSS (WACONDAH: WAter CONtrol DAta for Hydrology and water management) applied to the flood disaster management.

These new demonstration services are suited to both the flood management phases (i.e. the flood prevention, emergency and assessment phases) and WACONDAH; they are constituted by the use of both hydrological/hydraulic models and SAR (Synthetic Aperture Radar) images for the soil moisture evaluation (indicator for early flood warning - models initialisation), the river flow (already existing in WACONDAH) and flood extent forecasting and for the flood extent/potential damage assessment.

The MIKE11 model was used to forecast the flood extents. This was technically demonstrated on historical floods since there was no flood event during the DECIDE pre-operation phase.

In term of results and applications, another reference was the FAME service which aimed at meeting the flood and spatial information needs of the water and insurance industry.

In term of decision-making bodies, Rego (2001) has reviewed and compared the work that has been done in some of the Asian countries setting up disaster management information systems over the last few decades.

Operational flood management and planning of flood protective structures require detailed spatial and temporal information of inundation when flooding is active or in different design flood conditions. Space borne sensors produce valuable information for environmental monitoring and forecasting purposes at different spatial and temporal scale. Due to the high spatial and temporal coverage, satellites have a clear advantage compared to any other source of information.

4 Methodology

This algorithm is based on a flood seed image produced by threshold on SAR images analysis. Flood seed is used to characterize statistically and locally the flood area appearance in SAR image. The statistics are used in conjunction with flood seed to detect automatically the flood extend, on a pixel-scale basis. This technique is not applied directly on SAR image, but rather well on difference between a SAR image of reference, and a flood-situation SAR image.

4.1 Data acquisition

The search for archived images has been conducted through the ESA SSE portal (see http://services.eoportal.org/). This web based portal let the user select area of interest, satellite, sensor and further data type. The webpage dedicated to locate scenes let the user define the satellite and the sensor, or multiple ones to combine researched scenes in a treelike cascade. Dates of acquisition are defined, and tools to point the area of interest are provided in different ways (gazetteer, square area, free polygon…). Once this is done, the search results are given in another window panel. There all the characteristics of all compliant images are given. Selecting an image highlights its footprint in the map window, allowing checking the overlap of the image with the area of interest (see **Error! Reference source not found.**). Currently, no provision is done in the SSE portal to directly order the scenes.

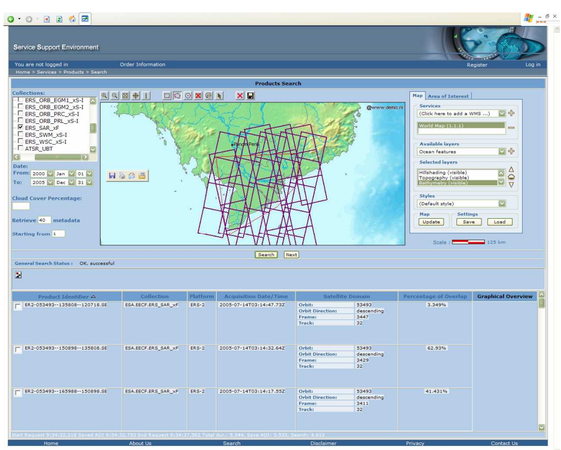

Fig. 1. Screen captures showing researches for ERS-2 scenes on the South Vietnam and Mekong River delta area using the SSE portal.

In order to provide necessary training support regarding data processing, the most recently ASAR data available has been acquired at several date in May / September 2003 and November 2003 respectively 2 dates before and 1 date after flooding according to the hydrological diagram taken from the Chau Doc gauging station – An Giang province (see figure 2).

A long time series of Landsat pictures (15 scenes from 1972 to 2003) has been acquired in order to update land use/cover maps. Six ERS-2 SAR.PRI were also bought to validate hydrological model running for the year 2000.

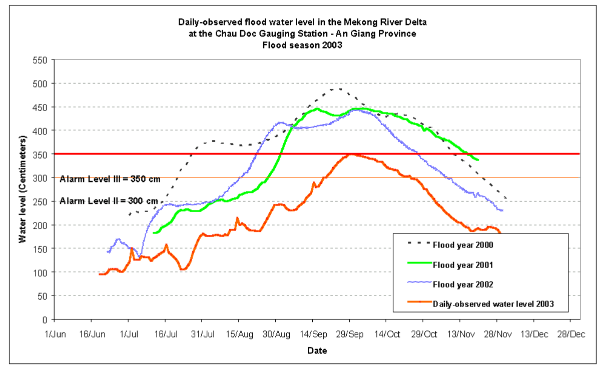

Fig. 2. Daily-observed flood water in the Mekong River Delta at the Chau Doc gauging station. Flood seasons 2000 to 2003.

4.2 Automatic flood detection

An automatic flood extraction algorithm has been produced. This algorithm is based on a flood seed image produced by threshold on SAR images analysis. Flood seed is used to characterize statistically and locally the flood area appearance in SAR image. The statistics are used in conjunction with flood seed to detect automatically the flood extend, on a pixel-scale basis. This technique is not applied directly on SAR image, but rather well on difference between a SAR image of reference, and a flood-situation SAR image

The flowchart of the process is given hereafter in figure 3. This first step is concerned only with the production of the "seed" image obtained from the "Dry" image reference and the Flood image.

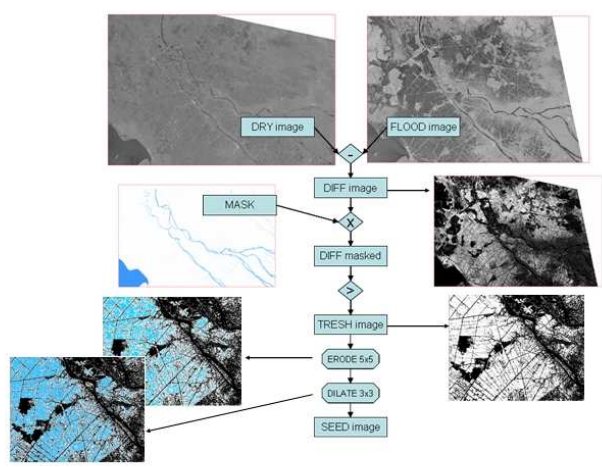

Fig. 3. First steps in the automatic flood recognition.

The flowchart below (see figure 4) explains the entire routine. This method presents the advantage to be quick, and to treat all patterns in all possible extension directions at the same time. The concepts are easier to understand, and the module is globally easier to adapt to the needs of the user. The flood extension detected was a simple binary layer (see figure 5).

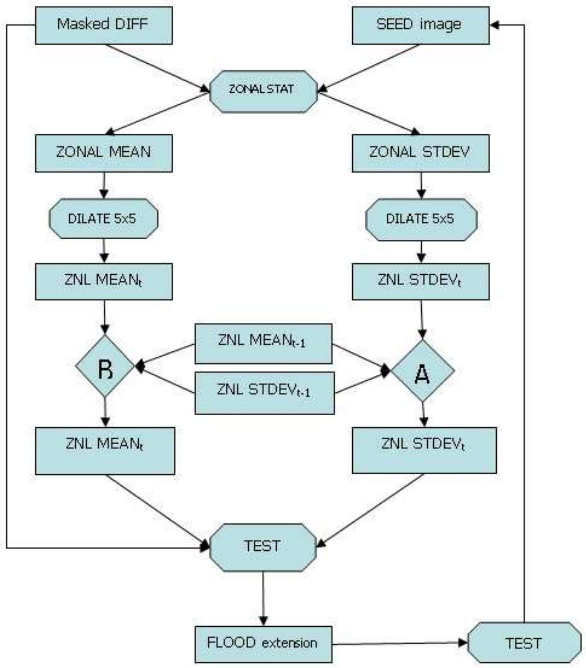

Fig. 4. Main algorithm of the flood detection routine.

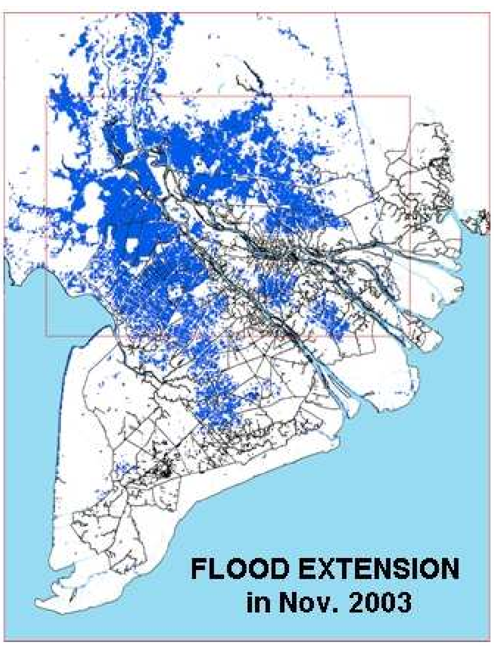

Fig. 5. Flooded area extracted for annual flooding in 2003.

4.3 Hydrological feature extraction

The capability of very high spatial resolution images from remote sensing origin to detect and help update the hydrological features database has been assessed over the area of interest (Mekong Delta). Features to be detected are water bodies, such as channels and rivers. An attempt at detecting the dams was done as well.

With no reality records from the field (Land use / Land cover checkpoints), the methodology to classify the satellite image could not be of the supervised kind (designation of training zones in the image). The **ISODATA** approach was thus taken, with some contrast enhancement before it. This was done to maximize the ability of the method to extract and differentiate the classes.

The ISODATA classification produced 20 (arbitrary and mandatory) classes. ISODATA try to create the most homogeneous classes, regarding the Spectra of the contained pixels. Classes too similar were fused, Classes with too wide spectrum values repartition were splitted. Once the iterative process of classification was finished, each class was compared with the original Landsat ETM and SPOT images, on the entire area of its appearance. From this, the interpretation of the content of the class in terms of land use and land cover was done.

Such approach is interesting as it does not introduce a bias in the classification by defining arbitrary entraining zones. The system tries to create the most homogeneous groups of pixels based on their spectral signal. After that, the human interpretation of each class is more robust since each class covers an area which is the most homogeneous possible. The precision of the classification is obviously dependant on the spatial and spectral resolution available. To improve the precision it was possible to upscale the spatial resolution migrating from Landsat imagery (15m pixel size) towards SPOT image (5m pixel size).

When all the classes containing water were summed, we have extracted the water signal from the satellite image. This image contains a lot of different types of water that cannot be distinguished based only on their spectral response. For example, channel water, river water, and flood water have practically identical spectral response, at least when they have some depth. Very shallow water can be distinguished, and have been here excluded for this reason. If one could have used more than the three bands available in this SPOT image, it would have been possible that more differentiation could be done, on the sediment content (turbidity and water flow) of the water for example.

The resulting water extension was by no means synonym to a channels map. Huge areas of flood were still present. These areas show a lot of holes (non flooded zones). The white (no water) areas contained also small water points. This salt and pepper was due to spectral variability and features of size smaller than the pixel size (very small ponds for example, less than 25m²). The channels that the broadness was around the pixel size (5m), or less, were partly detected, some pixels containing a mixed information of water and dam and/or vegetation being classified as vegetation, or humid soil.

As such, the binary image has to be cleaned and mended for different irrelevant features for channels cartography. Hereunder, the following paragraph describes the techniques developed for that purpose.

In order to suppress automatically the large area covered with water, a directional special filter has been developed. 23 kernels of 7 by 7 pixels were used to enhance the aligned water pixels, while zeroing the continuous areas. Different size and numbers of kernel have been tested, but it was not possible in the imparted time to thoroughly explore all the possibilities given by this kind of filtering method. This choice was a compromise solution between developing time, working time, and precision. As such, the filter was efficient, and was only related to the number of pixel used, not the real size of the feature (in m). Its accuracy would have thus followed the gain in resolution associated with better spatial resolution available through Ikonos-II images or Quickbird images.

The same steps were executed for the **dams'** detection. Difference with water is that dams are only an artificial relief in the landscape. As such, we assumed the dams should be situated on both sides of the channels. We assumed also they would principally appear in the bare soil classes. These two assumptions are only based on common sense, and are not the results of thoroughly studied parameters, so they can induce some bias or poor detection. Hereunder, the same steps as for the water are displayed. It is absolutely sure that some dams were colonized by vegetation. Hence the dam's detection was not complete.

5 Results

Comparison between the results obtained from the remote sensing images analysis and treatments are compared with the existing data. Mismatches and discrepancies are analyzed to deduce their origin. The methodology should be tested on higher spatial and spectral resolution imagery, such as Ikonos-II and Quickbird satellites.

1. An automatic flood extraction (geographical extension) method and algorithm has been produced.
2. A method to extract semi-automatically features such as water and channels as well as dams from high resolution remote sensing imagery has been done.
3. The comparison between the new dataset and existing datasets tends to invalidate the already existing datasets, mainly because of outdated data and geo-referencing lack of precision during the mapping itself.
4. Comparisons with flood patterns tend to indicate the pattern of channels RS detected is the one sufficient to explain the flood extend.

Future work on higher resolution images would reinforce the strong point of the technique, as well as it would validate the first results obtained.

6 Product and services

As such, the results point towards a new way of mapping the Mekong Delta channels and dam network and toward the high potential of spatial imagery to be used in hydrological models (calibration, validation).

Acknowledgements: The present study has been carried out in the framework of the MEKOWALM project under the research contract BL/00/V05, a bilateral cooperation between the Belgian Scientific Policy Office and the Vietnamese Ministry of Science and Technology.

References

Proceeding of the International Workshop on Food Mitigation, Emergency Preparedness and Flood Disaster Management, June 1992, Hanoi, Vietnam. Ministry of Water Resources – Socialist Republic of Vietnam. United Nations Development Programme (UNDP).

Final report of the CEOS Disaster Management Support Group, 2002, the use of Earth observing satellites for hazard support: Assessment & scenario. National Oceanic & Atmosphere Administration, Dept. of Commerce, U.S.A.

Moeremans, B., B. Hanquet, C. Sohier and S. Dautrebande: Integration of the Use of Spaceborne Radar Images in WAMM Project (Water Management Model). Study carried out by the Department of Hydrology and Remote Sensing Gembloux Agricultural University - Belgium

Duizendstra H.D., 2002: FloodMan, a near real time flood forecasting, warning and management system based on satellite radar images, hydraulic and data-assimilation models and in-situ data. Proceedings NCR-days: NCR-publication 20-2003 p. 24. Netherlands Centre for River Studies, Delft (ISSN 1568-234X).

STEREO Research Project n° SR/20/22; FLOODMAP – Development of an operational system to support Flanders flood prevention policy, Final Report, Issue, February 2004.

DECIDE: Earth Observation Technologies for DECIsion Support DEmonstrations - The Flood Case.

Willems P., S. Thompson, M. Barbieri: 2003, FAME: Flood risk and damage Assessment using Modelling and Earth observation products. Study carried out by the Department of Hydraulics Laboratory, K.University of .Leuven, Research & Development Leuven, Belgium directed by P., Willems. Web site: http://www.kuleuven.ac.be/hydr/fame.htm

Rego A. J., 2001, National Disaster Management Information Systems & Networks: An Asian Overview. GDIN.