REAL TIME MONITORING OF FLOODED AREAS BY A MULTI-TEMPORAL ANALYSIS OF OPTICAL SATELLITE DATA

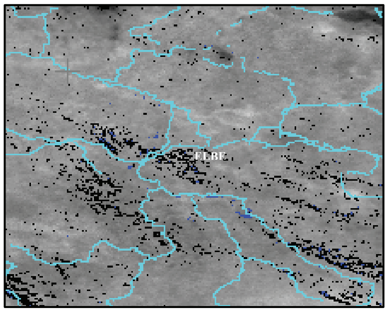
Faruolo M.[1,2*], *Coviello I.*[1], *Lacava T.*[1], *Pergola N.*[1,2] *and Tramutoli V.*[2,1]

[1] Institute of Methodologies for Environmental Analysis (IMAA), National Research Council, Italy - C.da S. Loja – 85050 Tito Scalo (Italy).
[2] Department of Engineering and Physics of the Environment (DIFA), University of Basilicata, Italy - Via dell'Ateneo Lucano, 10 – 85100 Potenza (Italy).
*Corresponding author: email: faruolo@imaa.cnr.it; phone: 0039 0971 427209; fax: 0039 0971 427271

ABSTRACT

Flooding is one of the most devastating natural hazards on the Earth's surface. Observations by sensors aboard satellites provide information that can be exploited to support the flood risk management cycle. These observations provide potential tools for improving the detection and monitoring of flooding events, particularly for those remote areas in the world where wide ground-based observation systems are still lacking. In such circumstances, meteorological satellites, thanks to their high temporal resolution (from hours to minutes, depending on orbital features), may play a crucial role to support civil protection activities when frequent situation reports are requested (e.g. in the emergency phase or for early warning purposes) [1][2][3].
In particular, satellite images, coming from meteorological platforms, despite their low spatial resolution (from a few kilometres up to a few hundreds of metres), may represent a fast and cheap tool to obtain real time information on floods. They could help people involved in the management of the flood risk, both during the emergency phase, as well as during the recovery phase, for the damage assessment [1][2].
Of course detailed ground information, at spatial resolution from tens of meters to tens of centimetres, can be achieved by medium to high spatial resolution optical satellite sensors (on board LANDSAT, DMS, SPOT, IRS, IKONOS, QuickBird, etc., - [2]) in absence of clouds. Active microwave satellite sensors (like SAR on board ERS, ENVISAT, RADARSAT, etc.) can also assure effective (with spatial resolution of tens of metres) and reliable maps of flooded areas also in the presence of (not raining) clouds. Unfortunately, up to now, both high spatial resolution optical sensors as well as active microwave sensors, are limited in the framework of a real time flood monitoring from they longer (from weeks to tens of days) revisiting time.
Among optical sensors aboard meteorological satellites, NOAA-AVHRR (National Oceanic and Atmosphere Administration) – Advanced Very High Resolution Radiometer) has been so far used for real time flooding disaster monitoring. Despite its relatively moderate spatial resolution (1.1 Km at nadir), in fact, its short revisiting time (less than 6 hours) and relative low costs for image acquisition, provide opportunities (even if only in absence of cloud coverage) for a detailed real time study and monitoring of environmental changes.
Recently a new AVHRR-based technique for mapping and monitoring flooded areas has been proposed, [4] [5]. It is based on the more general RAT (Robust AVHRR Technique) approach [6] - already applied with good results using microwave data in the framework of hydro-meteorological risk mitigation [7]-[9] - which exploits long-term multi-temporal satellite records in order to obtain a former characterization of the measured signal, in term of expected value and natural variability, providing a further identification of signal anomalies by an automatic, unsupervised change detection step. The different spectral response of the water and soil in the visible (channel 1, 0.58-0.68 μm) and near infrared (channel 2, 0.725-1.00 μm) AVHRR bands has been exploited to detect and monitor flooded areas. Results obtained, compared with other AVHRR traditional techniques [10]-[13], have indicated the actual potential of the proposed approach. Flooded areas, in fact, have been automatically recognized with a low rate of false alarms, discriminating also permanent water from inundated areas (fig. 1).
Exploiting its complete independence on the specific satellite platform, in this work the same technique (today named RST, Robust Satellite Technique, [14] [15]) has been exported to MODIS (Moderate Resolution Imaging Spectroradiometer) sensor. The main aim of such a work is to exploits its higher spatial resolution (up to 250m in the VIS-NIR spectral range) to increase the accuracy in the detection and mapping of flooded areas, giving, in this way, an improved and more effective support to the flood risk management cycle.

Some recent extreme flooding events that affected several parts of Africa have been selected as test cases. Results obtained using both AVHRR and MODIS data will be shown and discussed.


a)

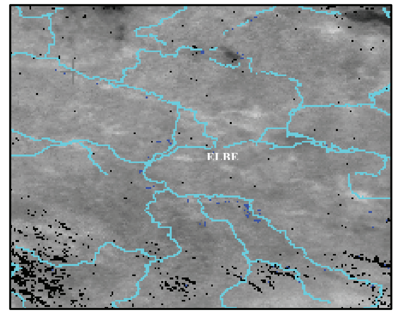

b)

Figure 1. Pixels automatically recognized as “flooded” by the proposed approach for the AVHRR images of 19 (a) and 21 (b) August 2002 12:00 GMT have been depicted in blue. Rivers have been coloured in cyan and clouds in black. The detected areas have been effectively been flood affected as a consequences of the intense precipitations which affected central Europe during August 2002. (see [5] and the references herein included)

BIBLIOGRAPHY

[1] CEOS (Committee on Earth Observation Satellites), “Disaster Management Support Project Earth Observation Satellites for Flood Management”- Flood Hazard Team Report 2001. Available online at http://www.ceos.org/pages/DMSG/2001Ceos/Reports/flood.html, 2001.

[2] CEOS (Committee on Earth Observation Satellites), “The Use of Earth Observing Satellites for Hazard Support: Assessments and Scenarios” - Final Report of the CEOS Disaster Management Support Group (DMSG). Available online at http://www.ceos.org/pages/DMSG/pdf/CEOSDMSG.pdf, 2003.

[3] T. Lacava, V. Cuomo, E.V. Di Leo, N. Pergola, F. Romano, and V. Tramutoli, “Improving soil wetness variations monitoring from passive microwave satellite data: the case of April 2000 Hungary flood” *Remote Sensing of Environment*, 96(2), pp. 135-148, 2005a.

[4] T. Lacava, N. Pergola, F. Sannazzaro, and V. Tramutoli, “Improving flood monitoring by RAT (Robust AVHRR Technique) approach: the case of April 2000 Hungary flood”, *International Journal of Remote Sensin*g, 2008 (accepted).

[5] M. Faruolo, I. Coviello, T. Lacava, N. Pergola, and V. Tramutoli, “Near real time flood monitoring by AVHRR data during the August 2002 Europe flood”, *Proceeding of 2008 IEEE Gold Remote Sensing Conference*, 22-23 May 2008, ESA-ESRIN Frascati (Roma), Italy (2008), (in press).

[6] V. Tramutoli, “Robust AVHRR Techniques (RAT) for Environmental Monitoring: theory and applications”, in Earth Surface Remote Sensing II, Giovanna Cecchi, Eugenio Zilioli, Editors, Proceedings of SPIE Vol. 3496, pp.101-113, 1998.

[7] T. Lacava, M. Greco, E.V. Di Leo, G. Martino, N. Pergola, F. Sannazzaro, and V. Tramutoli “Monitoring Soil Wetness variations by means of satellite passive microwave observations: the HYDROPTIMET study cases”, *Natural Hazards and Earth System Sciences,* Vol. 5, pp. 583–592, 2005b.

[8] T. Lacava, M. Greco, E. V. Di Leo, G. Martino, N. Pergola, F. Romano, F. Sannazzaro and V. Tramutoli, “Assessing the potential of SWVI (Soil Wetness Variation Index) for hydrological risk monitoring by satellite microwave observations”, *Advances in Geosciences*, Vol. 2, pp. 221–227, 2005c.

[9] T. Lacava, E.V. Di Leo, N. Pergola, and V. Tramutoli, “Space-time soil wetness monitoring by a multi-temporal microwave satellite records analysis”, Special issue on Time series analysis in hydrology. *Physics and Chemistry of the Earth*, Vol. 31, pp. 1274–1283, 2006.

[10] Q. Xiao, and W. Chen, “Songhua River flood monitoring with meteorological satellite imagery”, *Remote Sensing Information*, 37-41, 1987.

[11] J.P. Verdin, “Remote sensing of ephemeral water bodies in western Niger 1996”, *Int. Journal of Remote Sensing*, 17, 733-748, 1986.

[12] Y. Sheng, and Q. Xiao, “Challenging the cloud-contamination problem in flood monitoring with NOAA/AVHRR imagery”, *Photogrammetric Engineering & Remote Sensing*, 64, 191-198, 1988.

[13] Y. Sheng, and P. Gong, “Quantitative dynamic flood monitoring with NOAA AVHRR”, *International Journal of Remote Sensing*, 22, 1709-1724, 2001.

[14] V., Tramutoli, “Robust Satellite Techniques (RST) for natural and environmental hazards monitoring and mitigation: ten years of successful applications”, *The 9th International Symposium on Physical Measurements and Signatures in Remote Sensing*, Shunlin Liang, Jiyuan Liu, Xiaowen Li, Ronggao Liu, Michael Schaepman Editors, Beijing (China), ISPRS, Vol. XXXVI (7/W20), 792-795. ISSN 1682-1750, 2005.

[15] V. Tramutoli, “Robust Satellite Techniques (RST) for Natural and Environmental Hazards Monitoring and Mitigation: Theory and Applications”, *MultiTemp 2007*, Fourth International Workshop on the Analysis of Multitemporal Remote Sensing Images, July 18-20, 2007 Leuven, Belgium, doi: 10.1109/MULTITEMP.2007.4293057, 2007.