European Journal of Remote Sensing

ISSN: (Print) 2279-7254 (Online) Journal homepage: http://www.tandfonline.com/loi/tejr20

New perspectives in emergency mapping

Piero Boccardo

To cite this article: Piero Boccardo (2013) New perspectives in emergency mapping, European Journal of Remote Sensing, 46:1, 571-582, DOI: 10.5721/EuJRS20134633

To link to this article: https://doi.org/10.5721/EuJRS20134633

Published online: 17 Feb 2017.

European Journal of Remote Sensing - 2013, 46: 571-582
doi: 10.5721/EuJRS20134633
Received 30/05/2013, accepted 10/07/2013

European Journal of Remote Sensing
An official journal of the Italian Society of Remote Sensing
www.aitjournal.com

New perspectives in emergency mapping

Piero Boccardo

DIST, Politecnico di Torino, Viale Matteoli 39, 10125, Torino, Italy
Corresponding author, e-mail address: piero.boccardo@polito.it

Abstract
In recent years, growing attention is paid to remote sensing when used for disaster management applications. This is essentially due to the large variety of remotely acquired imagery available for the extraction of geometric and thematic features in order to map, delineate and grade natural disasters impacts. Another key point is the quick availability of those images in rapid mapping procedures in order to deliver the data (reference and thematic) to concerned users. This paper briefly describes the current state-of-the-art of remote sensing techniques usage in emergency mapping, paying particular attention, in the second part, to the GIO-EMS new operational service delivered by the European Commission.
Keywords: Disaster management, emergency mapping, remote sensing, spatial data infrastructure (SDI), data model, image processing.

General remarks
Starting with this editorial, the Italian Society of Remote Sensing (AIT) aims to favour an International debate related to the main geomatics (with particular attention to remote sensing) applications. The short papers that will be published in the next European Journal of Remote Sensing (EuJRS) issues are conceived to deliver basic and operational information to all EuJRS readers on different topics, highlighting potentialities (also in terms of possible financing coming from National and International opportunities) of these new application fields.
This first paper is related to geomatics and emergency management; applications on health, weather, atmosphere, climate change, water resources, energy, geology, cryosphere, forest, natural ecosystems, biodiversity, land cover, coastal, ocean and transportation, infomobility and Intelligent Transport Systems (ITS), will follow in the next months.

Introduction
Disasters can be defined as "a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources" [UNISDR, 2009].

Disasters can be classified according to their main cause, i.e. earthquakes, floods, cyclones, etc., but also whether they are "natural" disasters, or "human-made" disasters. The effects of natural disasters on the environment and on the population can be analyzed through the relevant statistics over the past years, in terms of both economic and human losses. The information collected by the Centre for Research on the Epidemiology of Disasters (CRED) at the School of Public Health of the Université Catholique de Louvain located in Brussels, Belgium, and more specifically the data stored in the EM-DAT database[1], highlight that in year 2010 a total of 385 natural disasters were registered, with more than 297,000 casualties [Guha-Sapir et al., 2012]. Over 217 million people were affected worldwide and $123.9 billion of economic damages were estimated. Similar to the average over the last decade, hydrological disasters (events caused by deviations in the normal water cycle and/or overflow of bodies of water caused by wind setup, i.e. Flood and Mass Movement events) were by far the most numerous disasters in 2010, representing 56.1% of the total disaster occurrence in that year, and together with meteorological disasters - the second most frequent calamitous event – accounted for 79% of total occurrence.
Economic damages from natural disasters in 2010 were over 2.5 times higher than in 2009 ($47.6 billion), and increased by 25.3% compared to the annual average for the period 2000-2009 ($98.9 billion). From a geographical point of view, some 89% of all people affected by disasters in 2010 lived in Asia. Nevertheless, the European continent faced the biggest increase in disaster occurrence, whereas Asia had the largest decrease, counting fewer disasters, victims and damages compared to the last decade's annual averages.
Geomatics definitively plays a crucial role in the Disaster Risk Management (DRM) cycle. Spatial Data Infrastructures (SDI) provide global reference geospatial data and services that are transversally exploited in all DRM phases (Fig. 1). Furthermore, the growing use of interoperable data formats based on international standards (e.g. Open Geospatial Consortium standards) facilitates the integration of local geospatial datasets. Early warning systems often rely on satellite remote sensing data to feed forecasting or nowcasting systems aimed "to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss" [UNISDR, 2009]. Undoubtedly, data acquired by ground measuring stations are also involved in the process, yet the accurate georeferencing of such information is a crucial feature.
From an operational point of view, recent major disasters (e.g. 2010 Haiti earthquake, 2010 Pakistan Flood, 2011 Japan tsunami and 2012 Italy earthquake) [Ajmar et al., 2008, 2011; Mahendra et al., 2010; Baiocchi et al., 2012; Bhattacharya et al., 2013] clearly demonstrated the potential role of geomatics in supporting emergency response and recovery, as already depicted in different papers published by EuJRS [Ajmar et al., 2008, 2011, 2012; Borfecchia et al., 2010; Dall'Osso et al., 2010; Pignatelli et al., 2010; Rivolta et al., 2010; Baiocchi et al., 2012; Laneve et al., 2012; Perez et al., 2012]. Remote sensing based analyses are nowadays frequently adopted to support both decision makers and responders in the field during disaster management activities, as clearly pointed out by the United Nations in the 2011 humanitarian appeal: "[…] Remote sensing in the hours and days after the Haiti earthquake yielded estimates of numbers of severely affected people that stood the test of time and allowed an unusually rapid flash appeal. [...] Similarly, in Pakistan, the plans in the revised flash appeal were mostly able to encompass the still expanding scale of needs

thanks to information management using remote sensing and other resources necessary for a situation of limited ground access." [United Nations, 2010, Section "Major natural disasters in 2010 and lesson learned"].

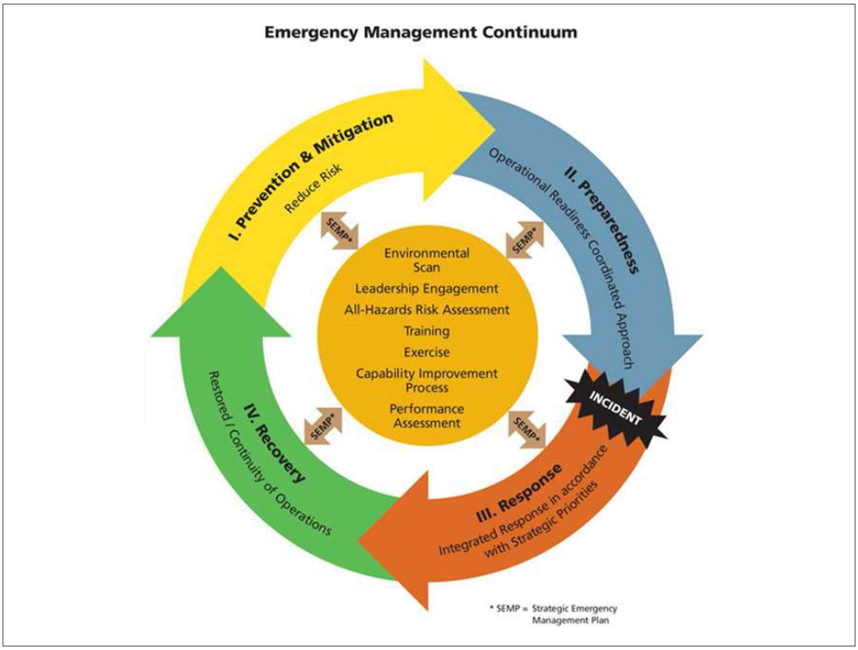

Figure 1 – The emergency management cycle.

Existing mechanisms

Focusing on the early impact stage, where geomatics plays a main role in rapid mapping, several mechanisms are already active.

The International Charter "Space and Major Disasters" aims at providing a unified system of space data acquisition and delivery to those affected by natural or man-made disasters through Authorized Users. Each member agency has committed resources to support the provisions of the Charter and thus is helping to mitigate the effects of disasters on human life and property. Several national Space Agencies participate to the International Charter: ESA, CNES, CSA, DLR, ISRO, CONAE, JAXA, USGS, BNSC/DMCii, CNSA. The International Charter manages activations in all types of natural and manmade disasters worldwide by means of all satellite missions available through the participating Space Agencies.

In its resolution 61/110 of 14 December 2006 the United Nations General Assembly agreed to establish the "United Nations Platform for Space-based Information for Disaster Management and Emergency Response - UN-SPIDER" as a new United Nations programme, with the following mission statement: "Ensure that all countries and international and regional organizations have access to and develop the capacity to use all types of space-based information to support the full disaster management cycle". The UN-SPIDER programme is achieving this by being a gateway to space information for disaster management support, by serving as a bridge to connect the disaster management and space communities and by being a facilitator of capacity-building and institutional strengthening, in particular for developing countries. The organizational model is implemented as an open network of providers of space-based solutions to support disaster management activities. Besides Vienna (where UNOOSA is located), the programme also has an office in Bonn, Germany and in Beijing, China. Additionally, a network of Regional Support Offices multiplies the work of UN-SPIDER in their respective regions. In 2009 the UN-SPIDER Programme initiated the SpaceAid Framework to help countries as well as international and regional organizations benefit from these technologies and this type of information, specifically to:

1. Ensure that all end users are able to access these mechanisms and initiatives, on a 24/7 basis, and that they also have the capacity to use all space-based information made available to support emergency events;
2. Provide guidance to the existing mechanisms and initiatives on the end users specific requirements and also on how they could improve and extend their support;
3. Establish additional opportunities beyond what is currently available within the existing mechanisms;
4. Provide information to those interested in bringing support, in terms of space-based information and expertise, on how they could channel their contributions and to whom. All the coordination effort is, by mandate, provided by UN OOSA.

UN-Spider SpaceAID can be triggered by authorized users (UN-SPIDER National Focal Points (NFP), UN-SPIDER Regional Support Offices (RSO) and UN Agencies) for any kind of natural and man-made disaster, offering a general guidance to existing operational mechanisms and initiatives and beyond them.

The Sentinel Asia is a voluntary initiative led by the Asia-Pacific Regional Space Agency Forum (APRSAF) to support disaster management activities in the Asia-Pacific region by applying web GIS technologies and using space based information such as earth observation satellites data. 24 different countries are directly involved as well as a certain number of International Organizations. Two are the main activities carried out by the consortium:

1. Emergency observation by earth observation satellites in case of major disasters - Currently participating satellites are expected to be ALOS (JAXA), IRS (ISRO), THEOS (GISTDA), KOMPSAT (KARI) and others;
2. Capacity building in satellite image/data usage for disaster management – in parallel with the activities above, capacity building for technical and emergency response agencies users of the Sentinel Asia system will be undertaken, primarily under coordination by Indian Space Research Organisation (ISRO), Asian Institute of Technology (AIT) and UNESCAP in Bangkok.

The organizational model is based on the cooperation of three communities: Space Community (APRSAF); International Community (UNESCAP, UNOOSA, ASEAN, AIT etc.); Disaster Reduction Community (ADRC and its member countries). All the participating organizations, if active, are Data Provider Node (DPN) or Data Analysis Node (DAN). DPN are in charge of the acceptance of observation requests; ALOS, IRS, THEOS and KOMPSAT accept observation requests for major disasters in the Asia-Pacific region from ADRC member organizations and representative organizations of JPT members. DAN are in charge of the production phase and the activation of a single DAN is on a voluntary basis.

Sentinel Asia can be triggered by authorized users for any kind of natural or man-

made disaster, yet it was identified that as a top priority the project should emphasize implementation of satellite-data production systems for wildfire, flooding and glacier lake outburst flood information, while other application fields should be developed offline by relevant research bodies and implemented subsequently.
Contributing missions are high & very high resolution SAR imaging missions with different radar bands for all weather, day/night and interferometry applications (ALOS/PALSAR), high resolution multi-spectral imaging missions (IRS- P6/Resourcesat, ALOS/A VNIR-2), very high resolution multi-spectral imaging missions (Formosat 2, IRSP5/Cartosat, ALOS/PRISM), medium-resolution land & ocean monitoring missions (MODIS, LANDSAT) and geostationary atmospheric missions and low earth orbit atmospheric missions (GOSAT).
SERVIR is the Regional Visualization and Monitoring System for environmental management and disaster response. Endorsed by governments of Central America and Africa and principally supported by NASA and the U.S. Agency for International Development (USAID), SERVIR places a strong emphasis on partnerships to fortify the availability of searchable and viewable earth observations, measurements, animations, and analysis. A SERVIR coordination office and rapid prototyping facility is located at the NASA Marshall Space Flight Center in Huntsville, Alabama. SERVIR is used to directly respond to natural disasters but also to capacity building in Central America and Africa.
The organizational model is based on a technical coordination centre based in the U.S., and three regional centers: the Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC) in Panama, the Regional Center for Mapping of Resources for Development (RCMRD) based in Kenya and the centre in Himalaya (ICIMOD). SERVIR has been triggered 35 times by authorized users; the greatest part of the activations were based in Latin America and the Caribbean.
SERVIR can be triggered by authorized users for any kind of disaster, but also for short term meteorological forecast, environmental analysis, air quality and a special service devoted to wild fires (very similar to the one implemented by Sentinel Asia).
Contributing missions are very high resolution multispectral imaging missions (LANDSAT), medium-resolution land & ocean monitoring missions (MODIS, NOAA), geostationary atmospheric missions and low earth orbit atmospheric missions (GOES).
On the European side, the EC has been very active in the last decade. In the first phase from 2003 to 2009, the projects RESPOND, PREVIEW and RISK-EOS contributed to the definition and structuring of the basic user requirements. The outcomes of this process were included in the Emergency Response Core Service (ERCS) Implementation Group Report that represented the foundation of the next preoperational phase: in the years 2009-2012, the projects SAFER and linkER together powered the pre-operational version of the GMES Emergency Response Service, implementing the Emergency Mapping (rush), Emergency Support Mapping (non rush) operational models and widening the user community accessing to the service to the 27 EU Civil Protection Authorities, non EU countries participating to the Civil Protection Mechanism, selected EC Services (DG ECHO / MIC, EEAS) and other Humanitarian Aid actors.

European Commission GIO-EMS (GMES Initial Operation - Emergency Management Service) programme

All the previous mentioned precursor activities have been relevant sources of legacies and

lessons learnt of a certain value for the actual operational implementation of the GMES (now Copernicus) Emergency Management Service in Rush mode service.
The GIO-EMS in Rush mode service aims at being the major European contribution to a global network of space based initiatives reacting to natural and man-made disasters, serving a wide range of Authorized Users active in the field of crisis management. The Authorized Users are EU Member States, the European Civil Protection Mechanism, the Commission's Directorates General (DGs) and the participating Executive Agencies, and the international humanitarian aid community.
The GIO-EMS in Rush mode service focuses on the post incident response phase, but the generated products can be potentially used even in all other phases, depending on the operational emergency management system implemented by the each single user. For example, dynamic flood extent information generated during a flood event might then be used during the recovery phase to estimate property losses and damages, but it can also contribute in updating risk models during the prevention and mitigation phase or enhancing hydraulic modeling in the preparedness (early warning) phase.
Compared to precursor initiatives carried out in the framework of GMES, the GIO-EMS in Rush mode service is different in terms of service operational provision objectives, enhancing timeliness, reducing the latency between the service activation and the delivery of the first crisis products. The innovating factor is the combination of both early warning and pre-alerting mechanisms coupled with an improved expansion to 24/7/365 stand by availability of the whole EO data access system under the GSC - DA mechanism enhancing integration by means of an improvement in the integration feasibility of the products generated by the GIO EMERGENCY RUSH with enhanced output delivery options in order to ease the outreach and use of the service itself both inside and outside Copernicus.
This service consists of the on-demand and fast provision (hours-days) of geospatial information to support emergency management activities immediately following an emergency event. The service is based on the acquisition, processing and analysis, in rush-mode, of satellite imagery and other geospatial raster and vector data sources. The products are standardized following a set of parameters the user can choose from when requesting the service.
Three different products can be requested by the authorized user:

1. Reference maps provide a quick updated knowledge on the territory and assets using data prior to the disaster. The content consists of selected topographic features on the affected area, in particular exposed assets and other available information that can assist the users in their specific crisis management tasks. A reference map is normally based on a pre-event image captured as close as possible prior to the event (Fig. 2);
2. Delineation maps provide an assessment of the event extent (and of its evolution if requested). Delineation maps are derived from satellite post-disaster images. They vary depending on the disaster type and the delineation of the areas impacted by the disaster (Fig. 3);
3. Grading maps provide an assessment of the damage grade (and of its evolution if requested). Grading maps are derived from post-event satellite images and include the extent, magnitude or damage grades specific to each disaster type. They may also provide relevant and up-to-date information that is specific to affected population and assets, e.g. settlements, transport networks, industry and utilities (Fig. 4).

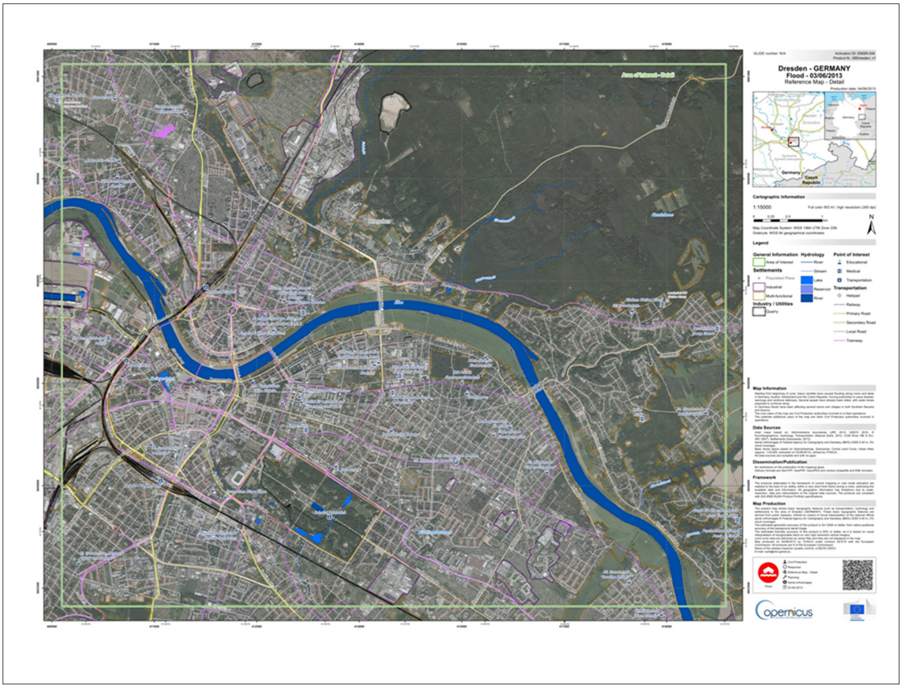

Figure 2 - Example of a reference map.

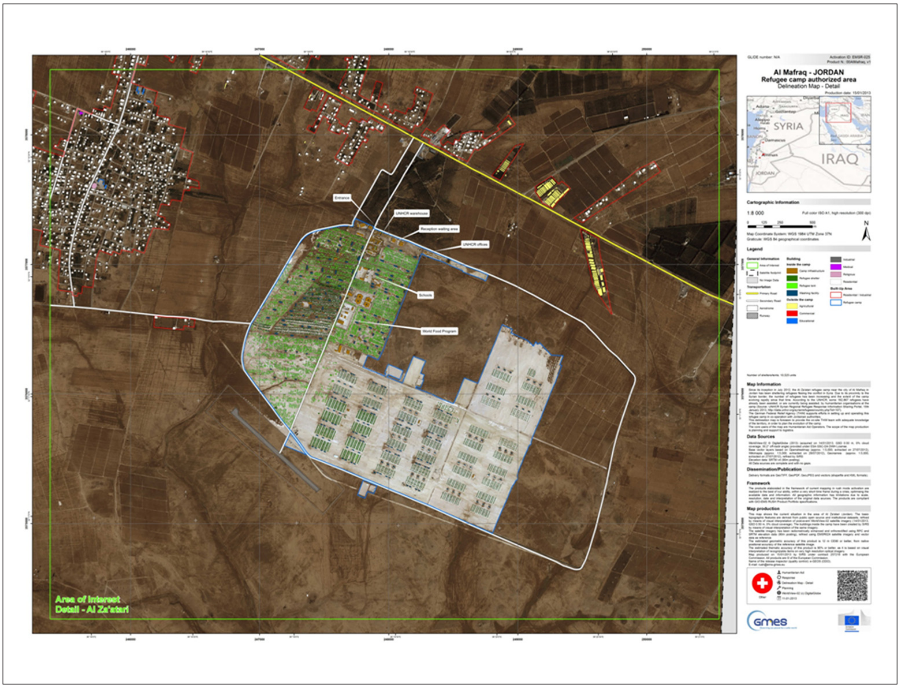

Figure 3 - Example of a delineation map.

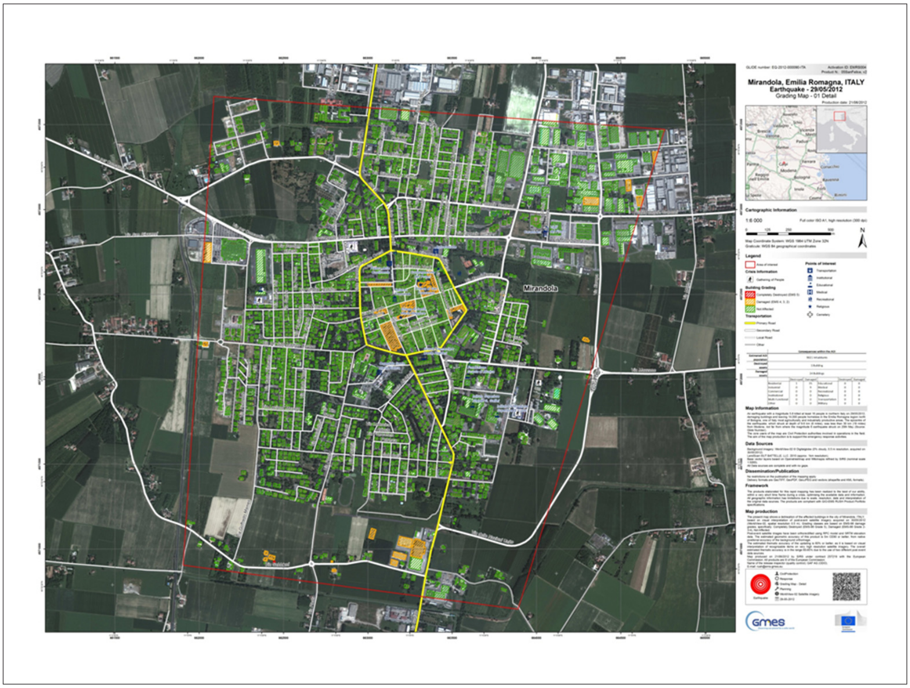

Figure 4 - Example of a grading map.

Even under technical aspects the timeliness of the service is one of the main challenges. The processing of large data volumes coming form a large number of varying sources within a short timeframe is of major importance. In most cases the reprocessing after a system failure will not be possible and any delay or loss of data will cause unacceptable delays for the ERC and the Authorized User. Therefore, the proven ability to process and handle this variety and volume of data**,** besides a good capacity in handling these tasks and possible problems, is a key element to the successful execution of the requests.

Meeting the user requirements and learning from user feedback is necessary for further improving the GIO EMS products and their acceptance in the future. Implementing a real time or near real time communication flow for feedback and, whenever possible, a procedure to immediately incorporate changes and improvements to the products still meeting the timelines, will be another challenge to constantly improve end user satisfaction and growing acceptance of the service.

A clear Quality Control (QC) mechanism distributed along the whole service production chain ensures that all the delivered products match the expected quality parameters of geometric and thematic accuracy.

Milestones gained and further possible developments

Stating that this kind of service needs timeliness production and analysis in order to fulfill user's requirements, here follows a list of the major improvements related to the service itself:

1. Large volume data handling should be ensured using a consolidated software and hardware architecture, allowing any possible backup measure in case of

failure and a well structured processing chain able to minimize pre-processing tasks (georeferencing and possible radiometric calibration especially when a pan sharpening is due) and thematic data crisis extraction layers (calibrating the efforts paid in terms of geometric vs spectral resolutions);
2. The adoption of a strict data model in all the products delivered provides the definition of a structured service that should generate consistent and self explicatory maps; that favours a full interoperability, where metadata (always delivered) describe the data itself and all the possible interpretation keys;
3. Quality control procedures (both from the internal and external point of view) give the users a clear view on the accuracies expected in the final products; this point is valid not only for the geometric point of view, but also for the thematic layers, giving the users the range of usability and guidance to possible merging with existing data;
4. In order to guarantee timeliness and consistency of the service (especially when shared between different production sites), one of the major advances is a routinely use of a consolidated Spatial Data Infrastructure (SDI) allowing full data sharing in real time, multiple and concurrent users and benchmarking capabilities (in term of timeliness and consistency performances);
5. Open source reference data integration should be considered a must in terms of interoperability, data consistency and updating; in Europe access to local geo portal and to Open Street Map (OSM) and Wikimapia for all the other countries outside Europe, guarantees a perfect match of the crisis layers and an updated situation;
6. The service has now full access to some European National data systems, granting, in the reference maps, the usage of updated and endorsed features [Boccardo and Giulio Tonolo, 2008; Boccardo, 2010a, 2010b; Tambuyzer et al., 2010; Boccardo, 2011; Boccardo and Rinaudo, 2011; Brovelli et al., 2012; Ghosh et al., 2012].

From the scientific and technical point of view some more implementations should be foresee in the next future, such as:

1. Improvement of automatic feature extraction algorithms allowing the digitizing from satellite imageries of reference data (hydrography, transportation, settlements and building blocks and footprints); many papers and examples of operational procedures have been published in recent years, but, unfortunately, most of them work only of very limited dataset, with rather long processing time, usually with a very limited topologic reconstruction capability and, last but not least, optimized to derive non cartographic data (such as building roofs that are definitely not footprints) [Boccardo and Comoglio, 1995; Boccardo et al., 2003, 2006; Mondino et al., 2004; Baiocchi et al., 2010; Jenerowicz et al., 2010; Casella et al., 2011; Godone and Garnero, 2013];
2. Being active sensors widely used due to their all weather capabilities, a possible full exploitation of such a data, also for “not water related” emergencies, should be strengthen also to extract reference data such as roads and settlements, especially when archive data are free-of-charge or rather inexpensive [Pulvirenti et al., 2010];
3. To complement the service, an operational approach should be carried on to provide a webGIS interface enabling users to access data in real time (once produced) and allowing, in the meantime, a full crowdsource approach, where external users could add and update data and information (not only in vector format but also by

means of geotagged pictures and textual information), validate the information conveyed and actively participating in the map production phase. That could be done only using consistent, reliable and performing platforms based on strict data model for data entry, allowing workload sharing and full interoperability when different data from satellite and satellite derived ones are concerned.

Note

[1]EM-DAT is a global database on natural and technological disasters that contains essential core data on the occurrence and effects of more than 17.000 disasters in the world from 1900 to present.

References

Ajmar A., Boccardo P., Disabato F., Giulio Tonolo F., Perez F., Sartori G. (2008) - *Early impact procedures for flood events February 2007 Mozambique flood*. Rivista italiana di Telerilevamento, 40 (3): 65-77. doi: http://dx.doi.org/10.5721/ItJRS20084036.

Ajmar A., Boccardo P., Giulio Tonolo F. (2011) - *Earthquake damage assessment based on remote sensing data. The Haiti case study*. Italian Journal of Remote Sensing, 43 (2): 123-128. doi: http://dx.doi.org/10.5721/ItJRS20114329.

Ajmar A., Albanese A., Disabato F., Miotto F. (2012) - *Integration of satellite and rainfall data for the identification of flood events in developing countries*. Italian Journal of Remote Sensing, 44 (1): 167-180. doi: http://dx.doi.org/10.5721/ItJRS201244113.

Baiocchi V., Brigante R., Radicioni F. (2010) - *Three-dimensional multispectral classification and its application to early seismic damage assessment*. Italian Journal of Remote Sensing, 42 (3): 49-65. doi: http://dx.doi.org/10.5721/ItJRS20104234.

Baiocchi V., Dominici D., Giannone F., Zucconi M. (2012) - *Rapid building damage assessment using EROS B data: the case study of L'Aquila earthquake.* Italian Journal of Remote Sensing, 44 (1): 153-165. doi: http://dx.doi.org/10.5721/ItJRS201244112.

Bhattacharya D., Ghosh J.K., Boccardo P., Komarkova J. (2013) - *Automated geo-spatial system for generalized assessment of socio-economic vulnerability due to landslide in a region*. European Journal of Remote Sensing, 46: 379-399. doi: http://dx.doi.org/10.5721/EuJRS20134622.

Boccardo P. (2010a) - *Introduction.* Italian Journal of Remote Sensing / Rivista Italiana di Telerilevamento, 42 (3): 33-36.

Boccardo P. (2010b) - *Gi4DM 2010*. GIM International, 24 (4): 21.

Boccardo P. (2011) - *Editorial of AIT president*. Italian Journal of Remote Sensing / Rivista Italiana di Telerilevamento, 43 (2): 3-4.

Boccardo P., Comoglio G. (1995) - *Integration of multispectral data acquired by aerial and satellite platforms for the study of the phenomena caused by the November 1994 flood in Piedmont (Italy).* Proceedings of SPIE - The International Society for Optical Engineering, 2585: 334-341.

Boccardo P., Giulio Tonolo F. (2008) - *Natural disaster management: Activities in support of the UN system.* Advances in Photogrammetry, Remote Sensing and Spatial Information Sciences: 2008 ISPRS Congress Book, pp. 385-396.

Boccardo P., Rinaudo F. (2011) - *Gi4DM-geo-information for disaster management-Torino, February 2010*. Applied Geomatics, 3 (2): 59-60. doi: http://dx.doi.org/10.1007/s12518-011-0051-3.

Boccardo P., Mondino E.B., Giulio Tonolo F. (2003) - *High Resolution satellite images position accuracy tests.* International Geoscience and Remote Sensing Symposium, 4: 2320-2322.

Boccardo P., Mondino E.B., Perez F., Claps P. (2006) - *Co-registeration and inter-sensor comparison of MODIS and Landsat 7 ETM+Data aimed at NDVI calculation.* Revue Francaise de Photogrammetrie et de Teledetection, 182: 74-79.

Borfecchia F., Pollino M., De Cecco L., Lugari A., Martini S., La Porta L., Ristoratore E., Pascale C. (2010) - *Active and passive remote sensing for supporting the evaluation of the urban seismic vulnerability*. Italian Journal of Remote Sensing, 42 (3): 129-141. doi: http://dx.doi.org/10.5721/ItJRS201042310.

Brovelli M.A., Boccardo P., Alvarez D. (2012) - *Geospatial responses to disasters: A holistic approach (Web-based GIS/mobile devices).* Photogrammetric Engineering and Remote Sensing, 78 (10): 1068.

Casella V., Franzini M., Padova B., Lingesso L., Pappani G., Gentili G. (2011) - *Leica ADS40 imagery for disaster management*. Italian Journal of Remote Sensing, 43 (2): 129-135. doi: http://dx.doi.org/10.5721/ItJRS201143210.

Dall'Osso F., Bovio L., Cavalletti A., Immordino F., Gonella M., Gabbianelli G. (2010) - *A novel approach (the CRATER method) for assessing tsunami vulnerability at the regional scale using ASTER imagery*. Italian Journal of Remote Sensing, 42 (2): 55-74. doi: http://dx.doi.org/10.5721/ItJRS20104225.

Ghosh J.K., Bhattacharya D., Samadhiya N.K., Boccardo P. (2012) - *A generalized geo-hazard warning system.* Natural Hazards, 64 (2): 1273-1289. doi: http://dx.doi.org/10.1007/s11069-012-0296-0.

Godone D., Garnero G. (2013) - *The role of morphometric parameters in Digital Terrain Models interpolation accuracy: a case study.* European Journal of Remote Sensing, 46: 198-214. doi: http://dx.doi.org/10.5721/EuJRS20134611.

Guha-Sapir D., Vos F., Below R., with Ponserre S. (2012) - *Annual Disaster Statistical Review 2011: The Numbers and Trends*. Brussels: CRED. Pp. 52. Available on http://www.cred.be/sites/default/files/ADSR_2011.pdf. (Last accessed: 18/07/2013).

Jenerowicz M., Kemper T., Pesaresi M., Soille P. (2010) - *Post-Event Damage Assessment Using Morphological Methodology on 0.5m Resolution Satellite Data*. Italian Journal of Remote Sensing, 42 (3): 37-47. doi: http://dx.doi.org/10.5721/ItJRS20104233.

Laneve G., Cadau E., Ferrucci F., Rongo R., Guarino A., Fortunato G., Hirn B., Di Bartola C., Iavarone L., Loizzo R. (2012) - *SIGRI - an Integrated System for Detecting, Monitoring, Characterizing Forest Fires and Assessing damage by LEO-GEO Data*. Italian Journal of Remote Sensing, 44 (1): 19-25. doi: http://dx.doi.org/10.5721/ItJRS20124412.

Mahendra R.S., Prakash C. Mohanty, Srinivasa Kumar T., Shenoi S.S.C., Shailesh R. Nayak (2010) - *Coastal Multi-Hazard Vulnerability Mapping: A Case Study Along The Coast of Nellore District, East Coast of India*. Italian Journal of Remote Sensing, 42 (3): 67-76. doi: http://dx.doi.org/10.5721/ItJRS20104235.

Mondino E.B., Giulio Tonolo F., Boccardo P., Bellone T. (2004) - *DTMs generation from satellite stereo images: Accuracy tests in mountain region*. Proceedings of SPIE - The International Society for Optical Engineering, 5574, art. no. 53: 341-350.

Perez F., De Stefano M., Disabato F., Vigna R. (2012) - *The ITHACA Early Warning System for drought monitoring: first prototype test for the 2010 Sahel crisis*. Italian Journal of

Remote Sensing, 44 (1): 181-195. doi: http://dx.doi.org/10.5721/ItJRS201244114.
Pignatelli C., Ferilli S., Capolongo D., Marsico A., Milella M., Pennetta L., Piscitelli A., Mastronuzzi G. (2010) - *Evidenze morfologiche ed applicazioni informatiche al fine della valutazione del limite di inondazione da tsunami*. Italian Journal of Remote Sensing, 42 (2): 129-142. doi: http://dx.doi.org/10.5721/ItJRS201042210.
Pulvirenti L., Pierdicca N., Chini M. (2010). *Analysis of Cosmo-SkyMed observations of the 2008 flood in Myanmar*. Italian Journal of Remote Sensing, 42 (1): 79-90. doi: http://dx.doi.org/10.5721/ItJRS20104217.
Rivolta G., De Rosa M., Marzano F.S. (2010) - *Precipitation Nowcasting from Geostationary Satellite: Neural Approaches Trained By Polar Orbiting and Ground-Based Data*. Italian Journal of Remote Sensing, 42 (1): 91-115. doi: http://dx.doi.org/10.5721/ItJRS20104218.
Tambuyzer H., Deleu J., Dosselaere N., Stephenne N. (2010) - *Building an Earth Observation flood risk analysis portfolio responding to the flood directive*. Italian Journal of Remote Sensing, 42 (3): 77-87. doi: http://dx.doi.org/10.5721/ItJRS20104236.
UNISDR (2009) - *Global Assessment Report on Disaster Risk Reduction. Risk and poverty in a changing climate. Invest today for a safer tomorrow.* United Nations International Strategy for Disaster Reduction Secretariat (UNISDR). Available on http://www.preventionweb.net/english/hyogo/gar/report/index.php?id=9413. (Last accessed: 18/07/2013).
United Nations (2010) - *CAP 2011 Launch & Press Conference, 30 November 2010.* Available on http://afg.humanitarianresponse.info. (Last accessed: 18/07/2013).