Working towards an Improved Monitoring Infrastructure to support Disaster Management, Humanitarian Relief and Civil Security

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Abstract – Experiences and results from the work within the International Charter "Space and Major Disasters" and in the context of the European Initiative on Global Monitoring for Environment and Security (GMES) as they were gathered within the German Remote Sensing Data Center (DFD) of DLR are reported. It is described how data flows, analysis methods and information networks can be improved to allow better and faster access to remote sensing data and information in order to support the management of crisis situations effectively. This refers to all phases of a crisis or disaster situation, including preparedness, response and recovery. Above the infrastructure and information flow elements, example cases of different crisis situations in the context of natural disasters, humanitarian relief activities and civil security are presented and discussed. This builds on the experiences gained during the last years. The active participation in the GMES Service Element RESPOND, focusing on Humanitarian Relief, within the network of Excellence on Global Monitoring for Stability and Security (GMOSS) and supporting the International Charter "Space and Major Disasters" has to be seen in this context. It is suggested to further improve the existing network of national and regional centers in order to advance local, regional and global monitoring capacities. Only when an optimized interoperability and information flow can be achieved among existing and upcoming systems and data providers on one hand side and the decision makers on the other, efficient monitoring and analysis capacities can be established successfully in the future.

Keywords: Disaster Management, Natural Disaster, Humanitarian Relief, Civil Security, GMES, GMOSS

1. INTRODUCTION

Due to the increasing occurrence worldwide of natural disasters, humanitarian emergency situations and civil endangerment, needs grow for timely information on rapidly evolving events. The experience of the past few years shows expanding demands for comprehensive, near-real-time, earth observation data covering wide areas, for a broad spectrum of civilian crisis situations. The reasons for this development are manifold and can be seen in the increasing vulnerability of societies and infrastructure and population growth (Murlidharan, 2003). Furthermore weather pattern most probably has been shifted to more extreme conditions. Additionally, regional and global cooperation of relief actors has been extended strongly. Satellite imagery can serve as a source of information in emergency, crisis or disaster situation. Having recognized this need, the German Remote Sensing Data Center (DFD) of the German Aerospace Center (DLR) established a service called "Center for Satellite Based Crisis Information" (ZKI) for linking its comprehensive operational remote sensing data handling and analysis capacities with national and international civil protection and humanitarian relief actors as well as with political decision makers. ZKI function is the rapid acquisition, processing and analysis of satellite data and the provision of satellite-based information products on natural and environmental disasters, for humanitarian relief activities, as well as in the context of civil security. The analyses are tailored to meet the specific requirements of national and international political bodies as well as humanitarian relief organizations. In order to provide up-to date and relevant satellite based cartographic information and situation analysis, it is necessary to establish efficient and operational data flow lines between satellite operators, receiving stations and distribution networks on the one hand and the decision makers and relief workers on the other. Service lines and feedback loops have been established to allow best possible data and information provision as well as optimized decision support. Beside response and assessment activities, focus is given on deriving geo-information for use in medium term rehabilitation, reconstruction and crisis prevention activities. ZKI operates in national, European and international contexts, closely networking with German public authorities at national and state levels (crisis centers, civil security, environmental protection), nongovernmental organizations (humanitarian relief), satellite operators and space agencies.

The current and long-term goals can be described as follows:

- Developing and establishing methods to generate customized information products and services for disaster management, humanitarian relief and civil security,
- Designing appropriate information technologies and infrastructure,
- Providing advice on establishing crisis information centers,
- Combining existing technical and scientific resources and expertise for effective and coordinated crisis management, particularly with DLR's Remote Sensing Technology Institute (IMF),
- Developing and setting up distributed European and international networks for satellite-based civil crisis information.

2. RAPID MAPPING SERVICE

After the occurrence of a natural or man-made disaster the necessity of fast and reliable spatial information is important not only for situation centers but also for relief organizations and rescue teams. Civil protection authorities have to meet the demand for adequate crisis information in order to ensure an appropriate decision process and an effective crisis management. Therefore all possibilities obtaining spatial crisis information have to be taken

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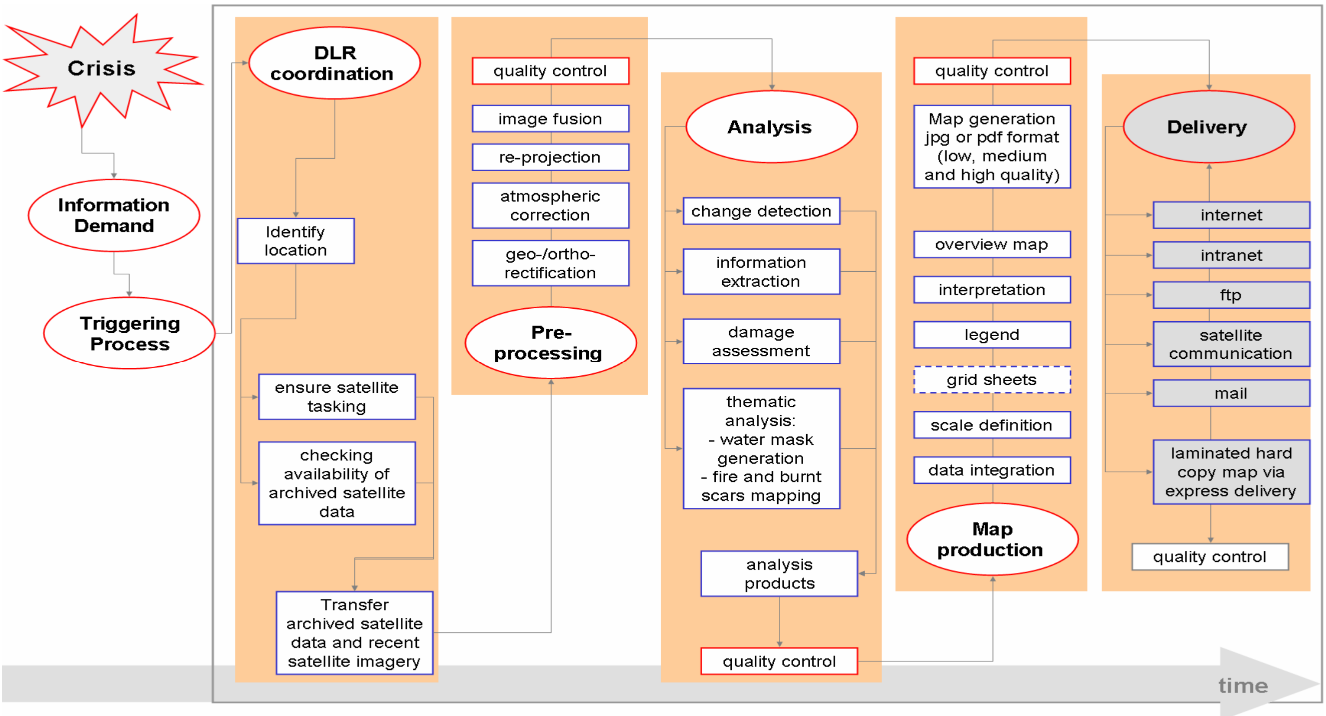

Figure 1. DLR Rapid Mapping Service – processing chain

into account, particularly earth observation data proved to provide significant information input. In order to cover these user requests in crisis situations, DLR set up a rapid mapping service (Fig. 1) to ensure fast access to available, reliable and affordable crisis information worldwide. After the mandatory decision process whether satellite analysis is appropriate for the respective crisis, the area of interest has to be defined and cross checked to avoid false geo location. Following this iterative process, it has to be assured that all applicable satellites are programmed for data acquisition. This can either be coordinated within the International Charter "Space and Major Disaster" by the responsible project manager or through commercial satellite tasking. Furthermore an enquiry for corresponding archive imagery has to be set up for later change detection analysis. Beside the procurement of satellite data it is necessary to check and prepare supplementing geo-data like population and infrastructure data, road network, contour lines and administrative boundaries. The experience of several activations and the user feedback shows that additional geo-information increases the satellite data analysis significantly. This includes place names, critical infrastructure, transportation network or further detailed specifications.

After receiving the archived and recently recorded satellite imagery, essential pre-processing has to be done. This includes geo- and ortho-rectification as well as atmospheric corrections (using ATCOR - Richter, 1996) and data format conversions. Data re-projection is necessary due to varying demands and standards. In the majority of cases a Universal Transverse Mercator Projection is used due to global applicability and following international standards. Dependent on user needs, crisis type and extent, different analysis process chains have to be applied. The derivation of water surfaces or general damage assessment is dependent on input data type, scale and possible availability of archived satellite imagery. Before and after image comparison allows the quantification of affected areas. This change detection method can either be applied for optical or radar imagery in order to derive areas where significant change can be stated. Following two Ikonos images from Banda Aceh region illustrate this approach for the severe Tsunami disaster in December 2004.

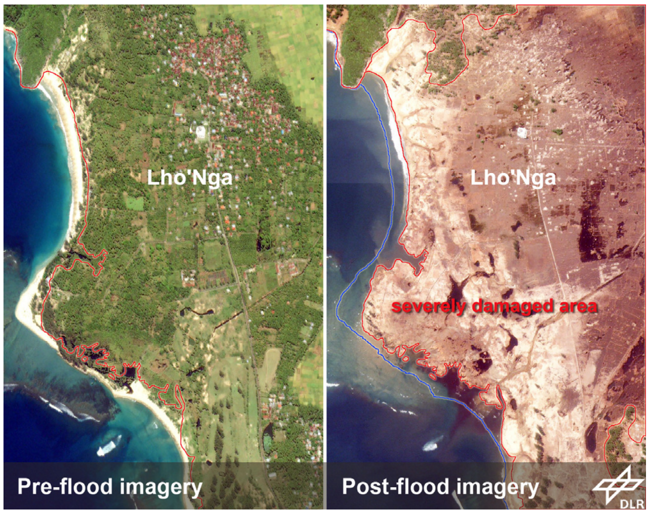

Figure 2. Change detection for Lho'Nga after Tsunami hit the area on December 26, 2004; Ikonos imagery of January 29, 2003 (left) and December 29, 2004 (right); blue line indicate former shoreline, red lines represent recent shoreline and damaged area (Image Source: CRISP Singapore)

Furthermore general image classification and differencing methods allows quantification of flooded areas, fire scars or damaged areas. The following example (Fig. 3) displays this analysis procedure for the Elbe flood 2002 near Dessau/Germany.

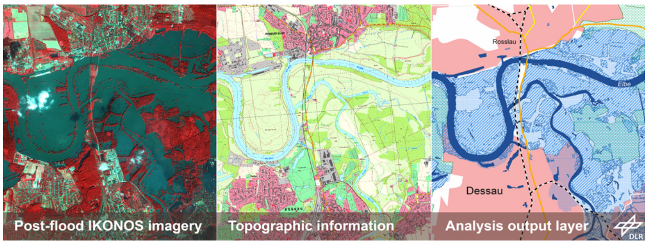

Figure 3. Generation of spatial crisis information for the Elbe flood 2002 (Dessau/Germany) using Ikonos images and topographic information (Image Source: European Space Imaging)

In order to translate complex satellite information in readable and coherent crisis information, situation and damage maps are generated. Following this map compilation an adapted map generation process is applied. Before publishing the information products a settled quality control process takes place. The map delivery is accomplished via internet, intranet, ftp, e-mail or satellite communication. Furthermore printed and laminated maps will be send via express delivery on request.

Beside the quality control during the processing steps, it has proved to be important to insert user feedback from field units. This means that map updating after having new and improved data available or implementing knowledgeable feedback is an important issue even though the maps are published and delivered.

During the past years it has also been shown, that training and consulting of decision makers and field workers plays a key role in proper understanding and accepting the space based information products as one information source for decision making or mission planning.

3. INTERFACING OF SPACE TECHNOLOGY AND RELIEF COMMUNITY

The acquisition, analysis and provision of earth observation data, especially when performed in very short time frames, is a complex task. It is the scope to facilitate and simplify the use of existing space technology and information sources for decision makers in the civil protection and the humanitarian relief sector. They often do not have access to these technologies, despite the urgent need for topographic base information or situation analysis.

One of the key elements of the process of linking space technology and the relief community is mutual education of needs, requirements and to carefully communicate the potential and the limits of space based technology. It often occurs that the capacities and capabilities of space systems are highly overestimated and it is difficult to overcome resentment, once expectations could not be met. Thus, it is of primary importance to keep up an open dialog to ensure that the geospatial sector does not oversell its capabilities and capacities to the relief community.

4. SUPPORTING THE INT. CHARTER “SPACE AND MAJOR DISASTERS”

DLR strongly supports the International Charter “Space and Major Disasters" through ZKI. The Charter is a major cooperative activity among national and international space agencies in the context of natural and man-made disasters. It is based on a frame work agreement between half a dozen space agencies to provide recent or archived satellite imagery in an informal way to authorized users free of charge. This Charter can be triggered through the member states, the UN or the European Union and it operates at 24/7 and best effort basis. After an initial phase, each Charter activation is coordinated by a so called project manager, who interfaces between the authorized user and the involved space agencies. DLR has committed itself to support the Charter through such project manager (PM) work and has coordinated and supported several Charter activations in Germany, Europe and worldwide. The role of the PM is to translate the user needs and the given disaster situation into appropriate satellite commanding, archive retrieval, image analysis and mapping. Whereas the Charter formally commits to provide raw satellite imagery it is commonly agreed that the end users can only make use of satellite imagery acquired from optical or radar satellites if they are transferred into satellite maps or thematic interpretations. Thus, the PM is also heavily involved in image interpretation and map production at his premises or mandates the tasks to third parties. DLR has set up a tight in-house network of image analysis experts from all thematic areas of Earth Observation, which can be consulted to support image analysis and interpretation at very short notice.

Since the severe flooding of the river Elbe in August 2002, ZKI has supported a number of Charter activations as project manager.

After devastating forest fires in central Portugal in July and August 2003 forced the Portuguese government to declare a public calamity for the affected districts, the International Charter “Space and Major Disasters" was activated. The purpose was to obtain and analyze satellite data of raging forest fires in central and south Portugal. Within three weeks, fire scars covered up to 300,000 hectares. The major causes for Portugal's worst fires in 20 years were persistent dryness, high air temperatures up to 48°C and strong winds which frequently changed direction. Most of the fires were assumed to be human induced (Riedlinger et al. 2003).

On December 27, 2003 the area of Bam in the Kerman Province located in south east Iran was struck by a severe earthquake in the early morning hours. Supporting the international relief activities undertaken by various humanitarian organizations in the area around the city of Bam and supporting the activation of the Charter, the first damage analysis maps based on Ikonos satellite imagery were made available. The satellite image showed extreme damages resulting from the earthquake. In some extremely affected areas, whole quarters of buildings were leveled.

5. HUMANITARIAN RELIEF

Because of the continuing refugee situation and the onset of the rainy season in western Sudan in August 2004, the humanitarian relief organizations, were in urgent need of up-to-date, detailed maps (Fig. 4). In consultation with UN-OCHA, the governmental disaster relief organization of the Federal Republic of Germany (THW) and the German Red Cross (DRK), the crisis regions around the cities of Al Fashir and Al Junaynah were mapped in short time. The focus was on ascertaining the road network, its condition, and the trafficability of possibly flooded wadis. Recording settlements and analyzing refugees’ camps and their current size was also of high interest. Automated algorithms were used to quantify the amount of shelters (Giada, 2003)). Satellite data for the maps were made available through the Int. Charter “Space and Major Disasters" and processed and interpreted in the framework of ESA’s GMES Service Element RESPOND.

In the early morning of December 26, 2004 a severe earthquake caused Tsunami flood waves in the Indian Ocean, which struck the coastal regions of Sumatra, Thailand, Sri Lanka and southern India. Due to the immense extent of the affected coastal areas, images from earth observing satellites have turned out to be a valuable support tool for international relief activities in the after-math of the disaster. In close cooperation with international partners, ZKI has taken over responsibility for the acquisition of satellite data, the generation of image maps, and their dissemination to

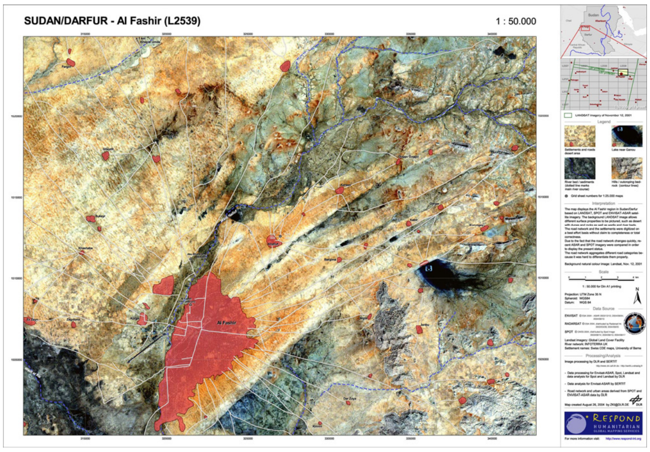

Figure 4. Al Fashir region in Sudan/Darfur based on Landsat, Spot and Envisat-ASAR satellite imagery.

various relief organizations. ZKI concentrates its activities on Sumatra and Thailand. This up-to-date mapping covering large areas enables disaster managers to achieve an overview of the recent situation, to assess the damage, and to supply local logistic teams with reliable information. The image maps provided through the ZKI website were produced both from archived pre-disaster imagery and from recent post-disaster satellite images. This combination allows easy and quantitative damage assessment by visual change detection (Fig. 2).

6. CIVIL SECURITY

On May 6, 2004 a military arms dump close to the village of Novobogdanovka in southern Ukraine exploded (Fig. 5). According to press statements 10.000 people in the surrounding villages

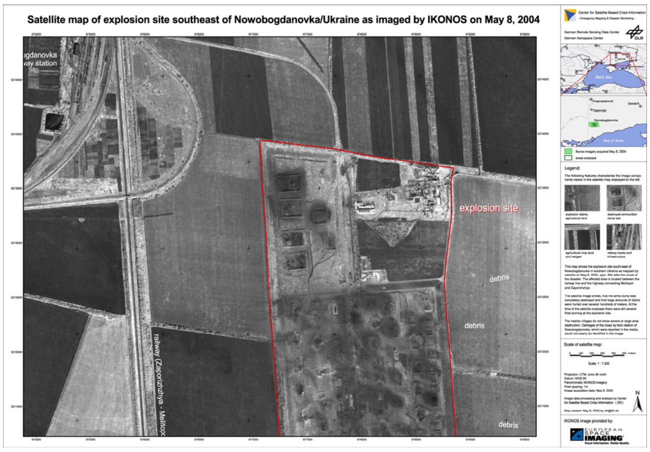

Figure 5. Explosion site south-east of Novobogdanovka in southern Ukraine in detail, as mapped by satellite on May 8, 2004.

had to be evacuated and a major highway and railway line connecting the cities of Melitopol and Zaporizhzhya had to be blocked. The arms dump was completely destroyed and large amounts of debris were hurled hundreds of meters and even kilometers into the neighboring villages and agricultural land. The satellite image showed that some fires were still burning 36 hours after the explosion.

This is only one example for the increased need for access to independent and up-to-date monitoring and information capacities in the context of human security for European and national decision makers. With increased availability of high resolution imagery through civilian systems such as Spot-5, IRS-P6, Ikonos, Quickbird, TerraSAR-X, Rapid-Eye, as well as military and dual-use satellites such as Helios, Pleiades, Cosmo-Skymed, SAR-Lupe, etc. advanced capacities for monitoring and analysis of even local events in the context of police tasks and civilian surveillance become available. Nevertheless, the great potential, even available with the systems existing today, is by far not yet fully developed. The ZKI is therefore involved in the security related EU network of excellence GMOSS (Global monitoring for Stability and Security) and the Preparatory Action on Security Research (PASR) with GeoCrew, which aim at integrating Europe's earth observation-based civil security research.

7. CONCLUSION

With the given examples it could be shown, that earth observation can successfully provide a beneficial support for disaster management, humanitarian relief and civil security. It was shown how satellite imagery can be acquired, processed, analyzed, assessed and turned into information products for decision makers within a short time frame. It was also discussed that research and operational gaps exist between current state of the art automated feature extraction and automated map generation on the one hand side and real world, near real time requirements in actual disasters events on the other. Space technology today is still very complex and the different satellite systems require sophisticated processing techniques, which can not be handled by an individual relief organization. As a consequence it is of primary importance that the space technology and geo information sector provides easy to use and ready to access information solutions to the relief community. Care has to be taken at all instances that overselling of capabilities has to be avoided by all means, in order to build reliability and credibility in the suggested high-tech solutions for often low-tech problems.

Due to the complexity not only of space technology but also of the geo-spatial information sector as a whole, efficient cooperation networks have to be established along the full data acquisition, analysis and provision chains in order to set up meaningful and acceptable geo-information solutions for the relief sector.

8. REFERENCES

T.L. Murlidharan, “Economic consequences of catastrophes triggered by natural hazards”, John A. Blume Earthquake Engineering Center, Report No. 143, 231p., March 2003.

R. Richter, “A spatially adaptive fast atmospheric correction algorithm”, International Journal of Remote Sensing, Vol. 17, No. 6, p.p. 1201-1214, 1996.

T. Riedlinger et al., “Multi-source satellite data facilitating disaster management during the 2003 forest fires in Portugal”, Proc., Euro-Mediterranean Forum on Disaster Prevention, Madrid 2003, www.proteccioncivil.org/centrodoc/foroeuromediterraneo2003

S. Giada, T. de Groeve, D. Ehrlich, “Information extraction from very high resolution satellite imagery over Lukole refugee camp, Tanzania”, International Journal of Remote Sensing, Vol. 24, No. 22, p.p. 4251-4266, November 2003.