INTERNATIONAL COOPERATION FOR DISASTER RAPID MAPPING THE AILA CYCLONE CASE STUDY IN BANGLADESH

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ABSTRACT:

Flood and cyclone disasters often have devastating effects not only on territory and infrastructure, but more importantly on populations and livelihoods. Assessing post disaster damages and related needs constitutes the main goal of emergency assessments. Disaster responders, including government agencies and international humanitarian organizations, require rapid and timely information on areas affected and areas 'worst affected' in the hours immediately following a disaster event. Such information is critical for allocating and targeting immediate assistance to affected populations, and also for guiding and focusing teams on the ground carrying out more in-depth assessments of damages and needs. ITHACA (Information Technology for Humanitarian Assistance, Cooperation and Action) is working in the post disaster early impact field since November 2006, producing several maps based on satellite imagery analysis. Through its partnership with the UN World Food Programme (WFP) - the world's largest operational humanitarian agency - ITHACA is dedicated to scientific research, delivering methodologies, analytical services and technical tools which improve the capacity of WFP and the wider International community in humanitarian early warning, early impact assessment and other related areas.
Cooperation between multiple stakeholder institutions is critical if rapid disaster mapping activities are to effectively inform and influence emergency response, including humanitarian relief and recovery operations. Stakeholder institutions include Satellite data providers, national Space Agencies, value added resellers, and end-users of the information such as emergency response staff working for national governments, and international humanitarian organizations.
The paper will focus on a case study based on the Cyclone Aila experience. Reference will be made to the specific activities performed during the few days following Aila's arrival on the Bangladesh coast, in late May 2009. Rapid mapping activities based on both low resolution MODIS optical data and high resolution COSMO-SkyMed radar imagery will be shown. The paper will also highlight examples of how satellite based data was integrated with complementary in-country data sets on population affected, numbers of deaths reported, numbers of people evacuating to shelters, and amounts of food and cash relief assistance provided to affected populations. The relationship between areas identified as affected through the satellite image analysis, and areas receiving relief assistance, will be examined in detail.

1. INTRODUCTION

After the occurrence of disasters such as floods, cyclones or earthquakes a complex phase devoted to emergency management, which firstly requires the indentification of the affected areas, begins. The following estimate of the damages to major infrastructures in the area and of the possible number of people involved is a crucial information for the proper identification and organization of rescue operations in the first hours after the event occurs. These operations are increasingly benefiting from the availability of images and data acquired by satellite platforms, which would be essential especially when the affected area is huge, a situation not unlikely in the case of floods or cyclones. The possibility to exploit this type of information is related to the availability of international cooperation mechanisms that should aimed to allow, especially to developing countries without proper infrastructures and adequate technical capacity to directly manage space missions, the access to services for the acquisition and distribution of satellite data or, alternatively, the possibility to have the satellite based value-added information. An example of international cooperation with the aforementioned goals is undoubtedly the "International Charter Space and Major Disasters", founded in 1999 by different space agencies, which aims at providing a unified system of space data acquisition and delivery to those affected by natural or man-made disasters. In the humanitarian field and international emergency response area, the United Nation World Food Programme (UN-WFP) is the largest operational agency, responding to more than 100 emergencies and natural disasters every year all over the world, through the distribution of goods essential for survival. In the framework of the partnership with WFP, ITHACA developed, among others, a project aimed at the creation of rapid maps necessary for the evaluation of the consequences of a catastrophic event through the use of satellite data. The early impact related activities have recently benefited from the support of the e-GEOS company (founded by the Italian Space Agency with Telespazio), which made possible the access to the COSMO-SkyMed space program. Specifically, the program consists of a constellation of 4 satellites in low orbit, equipped with Synthetic Aperture Radar (SAR) sensors that can monitor the surveyed area in all weather conditions, with high frequency in revisiting the same area and making the data available to the user in a very short time. This is the first satellite system intrinsically "dual", with both civil and security operational features. In the context of the civil domain, the system is essentially dedicated to civil protection, environment and coast monitoring, disaster prevention, agricultural, forestry and hydro-geological resources monitoring and cartographic applications. The paper is focused on the activities carried out by the three abovementioned parties - WFP, Ithaca and e-GEOS - within an international collaboration framework aimed at supporting the early impact activities related to the cyclone AILA that struck the coast of Bangladesh on May 2009.

2. RAPID MAPPING FOR EMERGENCY MANAGEMENT

The information mentioned in the previous section, required in a very short time and generally derived from satellite images, are typically provided and disseminated to end users in the form of cartographic products as well as georeferenced data. The applied research made by ITHACA allowed to establish standard procedures for the quick generation of value-added products that show the impact of events on the territory, specifically: the areas physically affected by the catastrophe (i.e., in case of floods or cyclones, flooded areas or areas under water are identified), the estimated number of people living in the affected areas, the damages to the infrastructures, with particular attention to the road network. The cartographic products, compliant with the Map Production Guidelines edited by the United Nations Geographic Information Working Group (UNGIWG), are subsequently made available to WFP and the broader international community working in the humanitarian field.

Medium and low geometric resolution optical satellite data are suitable to monitor and analyze events at a small scale. Usually data acquired by the MODIS (MODerate resolution Imaging Spectro radiometer) sensor, installed on both Aqua and Terra satellite platform are used. However these data, particularly in the case of floods, are often not suitable because of the persistent cloud cover present on the area during the event. On the contrary, the availability of high geometric resolution radar images is often essential to ensure the generation of cartographic products at an suitable map scale. Radar imagery can not only avoid the cloud coverage related issue but also allows to perform night acquisitions, significantly increasing the updating rate of the data.

Some peculiarities of the COSMO-SkyMed constellation make the use of the acquired radar data particularly effective for activities performed by ITHACA in the emergency response field. The COSMO-SkyMed system was developed by the Italian Space Agency in cooperation with the Italian Ministry of Defense and is based on a constellation of four identical satellites, equipped with synthetic aperture radar (SAR) working in the X-band (therefore capable to "see "through the clouds and in the absence of sunlight). The mission was designed to ensure: a comprehensive radar coverage in all-weather condition (daily and nightly), a large number of images acquired, high geometric resolution, high georeferencing accuracy, very high revisit and short response times and polarimetric and interferometric capabilities. The first and the second satellite of the constellation were launched respectively in June and December 2007, while the third is in orbit since October 2008. The completion of the constellation is expected by 2010. Once completed, the system will be able to acquire 450 images of the Earth's surface from each satellite per day, for a total amount of 1,800 radar images for the entire constellation, with at least two access opportunities at different incidence angles.

COSMO-SkyMed has a considerable flexibility of use. The sensor can acquire data in different ways: Spotlight (coverage of a few square kilometers, with geometric resolution up to 1 meter), Stripmap (a continuous strip is acquired, with medium resolution) or Scansar (this methodology allows to cover areas of 100 km or 200 km on each side, with geometric resolution of respectively 30m and 100m). In addition, there are different operating modes that allow a very short response time (time interval between the receipt of the acquisition request and the delivery of the requested product to the user), up to less than 18 hours in emergency conditions. Finally, COSMO-SkyMed is a multi-mission system, capable of integrating with other space systems to meet the needs of a large community of users.

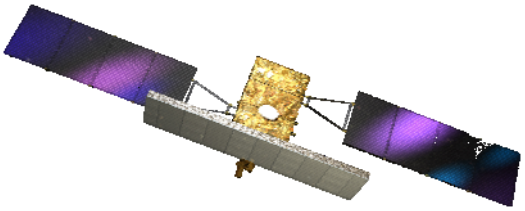


Figure 1 – Cosmo-SkyMed satellite platform – (c) ASI

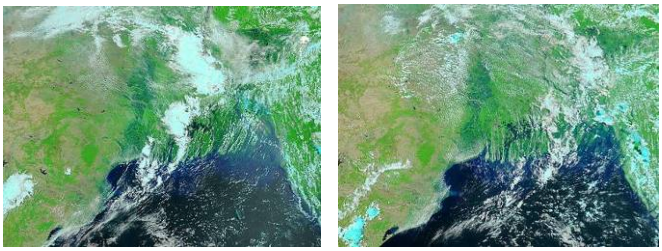
3. THE CYCLONE AYLA IN BANGLADESH

Cyclone Aila ripped coastal West Bengal on 25 May 2009 unleashing storms that uprooted trees, electricity poles and thatched homes, leaving a trail of destruction in its wake, killing approx 190 people and injuring thousands. A severe storm with a wind speed of 110 km/h accompanied by heavy rainfall preceded the cyclone.
The Emergency Capacity Building Project (ECB), a consortium of six international humanitarian agencies working in Bangladesh, reports that even three months after Cyclone Aila, hundreds of thousands of people remained homeless or displaced due to continued water logging in coastal communities.
Approximately one million Bangladeshi men, women and children were made homeless by Cyclone Aila, which ravaged 11 costal districts. An estimated 4.8 millions were directly affected and nearly three million acres of crops were destroyed.

3.1 Available data

The first optical data available after the event and covering the affected areas were acquired by the MODIS sensor from both Terra and Aqua satellite platforms, on May 27, 2009 respectively at 04.40 and at 7:50 UTC (Figure 3,a,b). In order to minimize the response time, the Real-Time Subset provided by the MODIS Rapid Response System have been processed. This dataset is geometrically corrected and is characterized by a Ground Sample Distance (GSD) of 250 m. The pre-event reference image was chosen according to the requirements of minimum time lag and minimum cloud cover: the MODIS scene acquired on May 21, 2009 by the Terra platform (**Figure 2**) was selected.

Figure 2 – Pre-event MODIS Aqua data (Image courtesy of MODIS Rapid Response Project at NASA/GSFC)



(a) (b)

Figure 3 – Post-event MODIS Aqua (a) and Tera (b) data (Image courtesy of MODIS Rapid Response Project at NASA/GSFC)

The Italian COSMO-SkyMed satellite constellation has also acquired, thnks to the technical support of e-GEOS, several radar images (30m geometric resolution) starting from May 30, 12 UTC to June 2, 2009, 12 UTC . Clearly visible the benefits coming from the availability of a constellation of three operational satellites, which has allowed to acquire, in just 72 hours, 8 SAR scenes with a minimum revisit time of 18 minutes. Figure 4 shows the first image acquired on May 30, 2009 at 12:06 UTC.

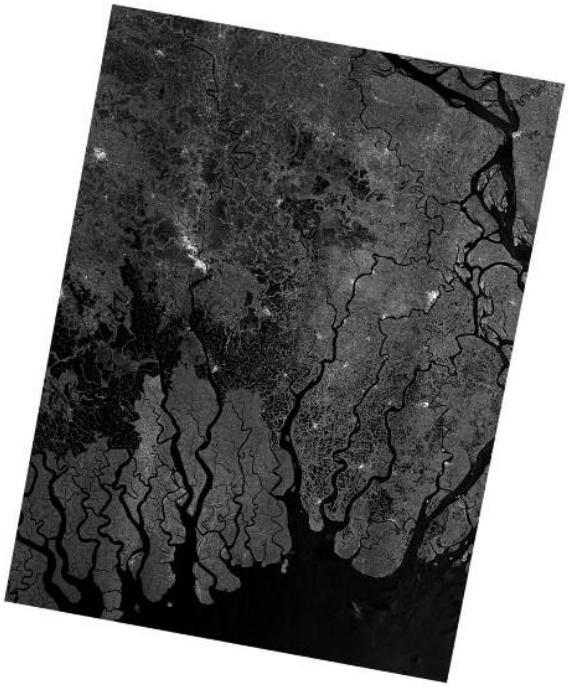
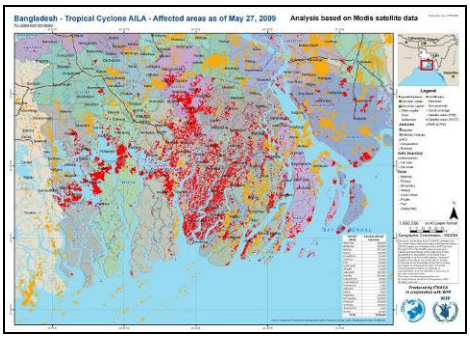


Figure 4 – Cosmo-Skymed post-image. Bangladesh coastal area (© ASI 2009)

3.2 Produced maps

The pre-event MODIS optical image was processed to identify the reference water present in the area of interest, crucial information required to correctly distinguish the flooded areas from the water bodies due to agricultural practices or seasonal flooding (both common in Bangladesh coastal areas). Because of the cloud coverage present on both the post-event images, it was necessary not only to identify the areas covered by water (red polygon in Figure 5,a), but also to generate a cloud mask (orange polygons in Figure 5,a) in order to highlight the areas where an early-impact analysis was not possible.



(a)

DISTRICT NAME	Estimated Affected Population
BAGERHAT	480,000
BARGUNA	390,000
BARISAL	357,000
BHOLA	128,000
CHANDPUR	91,000
COMILLA	94,000
FENI	30,000
GOPALGANJ	137,000
JESSORE	11,000
JHALOKATI	302,000
KHULNA	363,000
LAKSHMIPUR	29,000
LALMONIRHAT	13,000
MADARIPUR	2,000
MAGURA	1,000
NARAIL	5,000
NOAKHALI	116,000
PATUAKHALI	293,000
PIROJPUR	359,000
SATKHIRA	170,000
SHARIATPUR	3,000
SYLHET	62,000
TOTAL	3,436,000

(b)

Figure 5 – a) Map of the cyclone-affected areas based on MODIS data. b) Estimate of the affected population based on local census data

Water bodies identification on the MODIS scene was based on simple but effective histogram threshold techniques; those techniques exploit the behaviour of water in the infrared bands, where those surfaces have high absorption rates. Similar approach is valid also for radar images processing, due to the fact that, in case of calm water hit by an incident microwave beam, the specular response dominates the returned signal. The cloud mask is derived by means of thresholding applied on both visible and infrared bands. The availability of updated census data supplied by the WFP Country Office in Dhaka allowed to estimate the number of people affected by the event, using geo-processing tools to intersect the flooded areas polygons with the census data aggregated at the municipalities (Upazilla) level. This value-added information, crucial for the proper planning of relief activities, was then integrated in the generated cartographic products (Figure 5, b).

In the following days the SAR images acquired by the radar satellites of the Italian constellation COSMO-SkyMed have been processed. The scenes were characterized by a high temporal resolution (8 images in 72 hours) and a medium geometric resolution (30m). This analysis allowed the identification of the areas still covered with water 5 days after the event, highlighting areas of flood recession with receding water (orange polygons in Figure 6). Furthermore the GSD of the radar data allowed to extract more detailed information (up to 1:250,000 map scale, versus the 1:850,000 map scale allowed by the MODIS image, Figure 7).

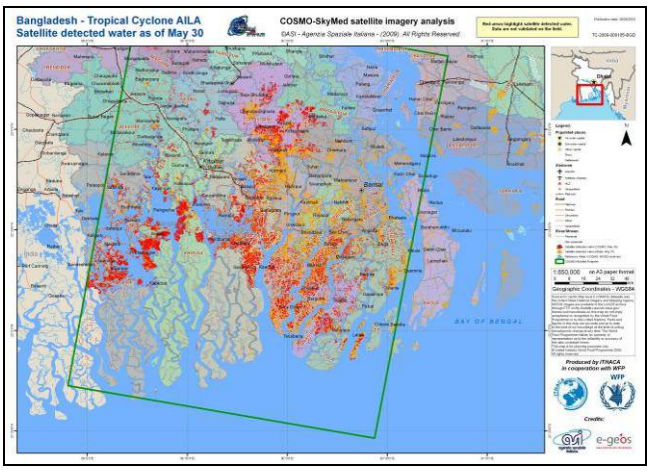


Figure 6 – Map product highlighting the areas with receding water, based on COSMO-SkyMed data processing.

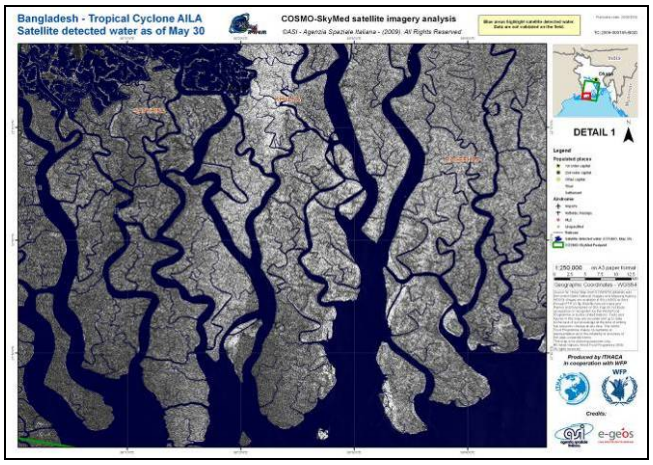


Figure 7 – Example of map product base on COSMO-SkyMed SAR data at 1:250,000 map scale.

4. CONCLUSIONS

The reported examples clearly show that an international cooperation involving entities responsible for different activities related to the emergency management is a key factor in responding effectively and quickly to catastrophic events such as the yclone Aila. Concerning the case study presented in this paper, the following synergistic roles have been highlighted:

• e-GEOS, the Italian company responsible for the activation of the radar satellites of the COSMO-SkyMed constellation and the subsequent distribution of the acquired data;

• Ithaca, a non-profit association in charge for both satellite data processing (aimed at extracting thematic and value-added information) and map layout preparation ;

• WFP Country Office in Dhaka, which has made available updated reference datasets at local level, keeping in constant touch with the people in the field and the relevant Government Agencies.

• CDMP (Comprehensive Disaster Management Programme), which continuously monitored the situation by means of regularly updated "Situation reports" and has made available updated field assessment.

In particular, the coordination work of WFP Country Office has allowed to validate the estimates of the population involved, by comparing the results based on satellite data with the figures derived from field assessments made by local authorities, such as the Disaster Management Bureau (DMB). It is important to highlight that the number of affected people estimated three days after the event (about 3.4 million people) is absolutely consistent with the total amount indicated by official reports resulting from surveys in the field performed one week after the hurricane (chart in Figure 8).

Sharing the georeferenced information in vector format also allowed the WFP Country Office in Bangladesh, with its own expertise in GIS, to generate additional value-added map products which best fit the needs of local users, including:

• indication not only on the number of people involved but also on the number of people dislocated in shelters and the percentage of damaged agricultural crops (table in Figure 8);

• indication on the proportion of food and economic aids addressed to the different affected areas (table and histograms in Figure 9).

The latter analysis enabled to perform an indirect validation of the information derived from satellite data, as it is evident that the largest percentage of aid has been allocated to the municipalities with a higher percentage of flooded areas (derived from satellite images).

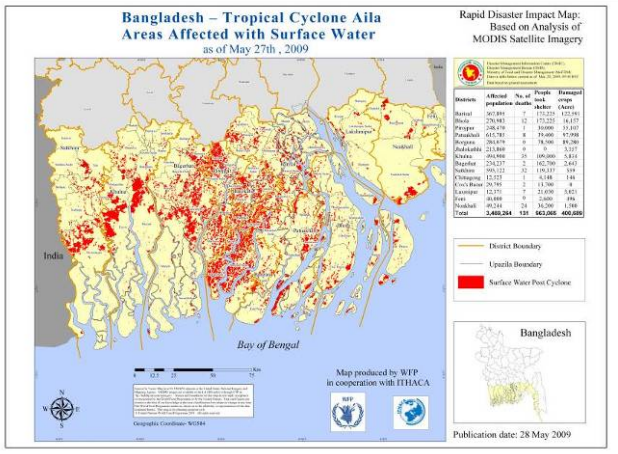


Figure 8 – Example of map product produced by WFP CO in Dhaka in cooperation with ITHACA and CDMP

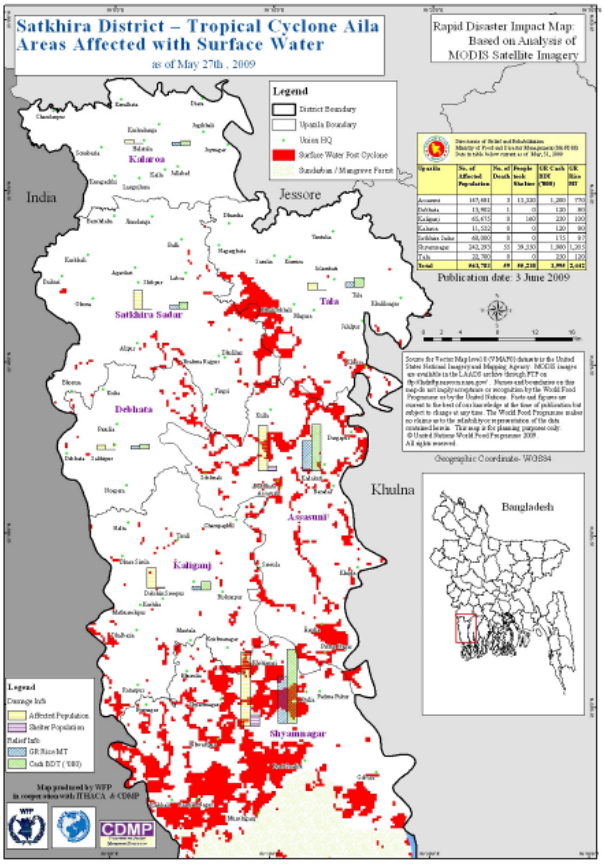


Figure 9 – Example of map product produced by WFP CO in Dhaka in cooperation with ITHACA and CDMP

The specific case study described in the paper also confirmed the crucial role of shared operating procedures pre-emptively established, with a specific focus on map templates (symbols, disclaimer, map scales). These procedures allow to minimize the time of dissemination of information, crucial in the emergency response.

Potential applied research fields are related to the primary data processing stage. In particular the authors are working on the

automation of the procedures aimed at identifying water bodies, with a specific focus on cloud masking, masking of shadows generated by clouds and orography, automatic identification of threshold values.

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