Satellite Remote Sensing Imagery for Tsunami Relief Operation and Damage Assessment

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Abstract: The 26 December 2004 Indian Ocean Tsunami has caused devastated destructions to many coastal areas fronting the Indian Ocean. The ground station at CRISP has received satellite imagery of the tsunami affected areas shortly after the event. Many of these images were placed on a dedicated web site for free access. Many of the images are in full resolution, JPEG compressed for ease of transmission over the internet. These images can be used by those involved in relief operations and for quick damage assessment. These images have been widely reproduced and distributed by the media and on the internet. Most importantly, same day delivery of the images acquired by CRISP has helped the Singapore relief team in their planning and execution of their relief and rescure effort, especially in the worst affected areas of Banda Aceh and Meulaboh. Damage mapping and assessment has also been carried out using the pre- and post- Tsunami images acquired by the high resolution SPOT5 and IKONOS satellites. Land uplifting and subsidence on the Andaman islands due to the earthquake have also been estimated. In this paper, we describe our efforts in image acquisition and the results of damage assessment.

1. Introduction

On 26th December 2004, at 00:58:53 UTC (07:58:53 local time) a magnitude 9.0-9.3 earthquake struck northern Sumatra, Indonesia, with the epicentre just north of Simeulue island. Analyses of seismic recordings indicate that rupture and slippage occurred 1200km northwestwards along the Sunda Trench, where the Indian place begins its subduction under the Sunda plate. The quake created a very large displacement of ocean water resulting in the Tsunami that impacted the coastal areas surrounding the Indian Ocean. Hardest hit were the countries of Indonesia, Sri Lanka, India (Andaman Island) and Thailand. The death toll of well over 265,000 was reported, making this event the one of the greatest disasters in modern history.

The ground station at CRISP received many satellite images from IKONOS, SPOT and TERRA/AQUA satellites a few days after the event. These images had been sent to the Singapore relief team for their planning and execution of relief and rescue efforts. Many of these images were also posted in CRISP website for free access. These images have been widely reproduced and distributed by the media and on the internet. The pre- and post- tsunami satellite images were later used for damage mapping and assessment.

2. Satellite Data Acquisition

The 26 December 2004 Tsunami occurred on a Sunday. Though the event happened in the morning, news of the disaster only broke out in the afternoon. After hearing the news, CRISP immediately started planning for satellite images of the affected sites, particularly Thailand's coast and Banda Aceh. Studying the satellite orbital track, it was found that the earliest possibility for IKONOS acquisition was 29 December 2004. For that orbit, the satellite had to be slewed to an off-nadir elevation angle of 55 degrees (elevation angle of 35 degrees) to image Banda Aceh. The

image resolution at this elevation angle was about 1.7m. SPOT 5 was available on 28 December over the Andaman and Nicobar Islands and over the Aceh province on 29 December, with a possibility to capture an image of the coastline of Thailand as well.

In requesting for IKONOS pass, due to overlaps in ground station coverage circles, CRISP had to bid for the pass with Space Imaging. CRISP was lucky to be on top of the ladder when bidding for the 29 December 2004 pass and thus, was granted the pass. For SPOT, the process was different. Since SPOT broadcasts its signals omni directionally, there is no need to deconflict the data reception with overlapping ground stations. However, potential conflicts with SPOT Image using of the on-board recorder still exist. As expected, the ESA Disaster Charter was also activated and SPOT Image had to serve the Disaster Charter's request as well. Since the Disaster Charter's request is of the same area, CRISP discussed with SPOT Image to downlink the data in real-time to the ground stations and then send the Disaster Charter's data via internet to SPOT Image. It was felt that this arrangement had provided the timeliest SPOT data to the relief and rescuer troops on the ground.

A lesson learnt in this event is the importance of timely data. Due to the sudden changes in topography after the Tsunami, maps immediately became out-of-date. Fresh satellite images became the only source of mapping information for the planning and execution of the relief and rescue missions. Because of this urgency, CRISP made all efforts to process and deliver all data acquired to the planning headquarters on the same day. Pre-Tsunami images of the same areas were processed as well, as they are also required for planning and assessment of the damage severity.

To check for the extent of the devastation, the wide coverage, 1km resolution, Terra MODIS was found to be very useful. Analysis of the post Tsunami MODIS data on 29 December 2004, we can estimate that the damage of the Sumatra coast stretches about 250km from Banda Aceh (5.55°N, 95.27°E) to Seumayam (3.75°N, 96.63°E) (fig 1), and the damage on Thailand's coast stretches from Phuket (latitude 7.7°N) to Ranong (latitude 10°N). Data acquisition for the following few days were concentrated over these devastated areas.

In addition to the data downlinked, requests were also made to NSPO of Taiwan and ImageSat International of Israel for their respective data over the affected sites. NSPO Taiwan provided us its Formasat-2 data over the Car Nicobar Island and ImageSat International provided us some EROS-A1 data over Banda Aceh.

Besides sending data to the ground troops, CRISP also posted some data on our website for the public to access. The images were speedily reproduced and posted in numerous other websites. Many media and magazines also requested the images for publication.

3. Damage Mapping and Assessment

CRISP has concentrated its image acquisition on the Thailand and Sumatra coast, including the Andaman and Nicorbar Islands. After the event, some efforts were made to study the damage caused by the Tsunami in Thailand, Sumatra and the Andaman and Nicorbar Islands.

3.1 Sumatra Coast

This was the worst hit area. The damage stretched over 250 km from Banda Aceh to Seumayam. The City of Banda Aceh had the greatest casualties. Its coastal aqua farms and several bridges and roads were totally destroyed. The town of Lho-nga was almost completely cleared (fig 2), with only the Mosque left standing. The south west coast was also heavily hit (fig 3). Vegetation up to 3-5 km from the coast was completely stripped and the road linking Banda Aceh to the coastal towns destroyed.

3.2 Thailand Coast

The Tsunami did not hit the whole west coast of the Kra Isthmus. The damage seems to be between the town of Ranong (10° latitude) in the North and Phuket in the South (about 7.5° latitude). The damage was also less severe than Sumatra. The hardest hit region in this area was the beach resort of Khao Lak. From the IKONOS images, we can see that the damage stretches about 1.5~2km inland (see figure 4). The sandy beach coast has almost completely dissappeared. Additionally, two resorts/hotels were also heavily damaged. However, the damage at Phuket was less severe. Patong bay seemed to be the worst hit for this area. Again, IKONOS images revealed that the sandy beaches were severely destroyed.

3.2 Andaman and Katchall Islands

Besides the damages to the vegetation along the coast, by comparing the pre- and post- Tsunami SPOT images, evidences of elevation and subsidence on separate parts of the coastline were found. For Katchall Island, it was noted that the two bays, one on the southwest and the other at the northwest of the island, had been enlarged. This suggested that the island might have subsided (fig 5). A more detailed study was done for Andaman Island. Here a pre-Tsunami image that had the same tide as the post-Tsunami image was selected for comparison. It was found from the analysis of the coastline that the northwest coast of the island had experienced uplift while the southeast coast subsided (fig 6). Using a shallow water model for backscattering, absorption and water depth [3], the uplift was estimated to be about 1m.

3. Conclusions

Although the impact of the Tsunami was sudden in the affected areas, it is generally believed that early warning systems could have reduced the casualties significantly, since one would be out of the affected zones simply by moving a few kilometers inland. However, it is still unclear if the best warning systems today will provide enough lead time for evacuation. It was also learnt from this event that the timely acquisition and delivery of data to ground troops is very important to the rescue and relief operations. The present arrangements for activations of satellite passes for imaging fall short of these requirements. The Earth Observation satellite community should examine how to do more.

References

[1] Chen P., S.C. Liew and L.K. Kwoh, 2005. Tsunami Damage Assessment Using High Resolution Satellite Imagery: A Case Study of Aceh, Indonesia , *Proc.IEEE International Geoscience and Remote Sensing Symposium 2005*, 25 - 29 July 2005, Seoul, Korea.

[2] Chia A.K., S.C. Liew, A.W.C. Heng and L.K. Kwoh, 2005. Satellite Observations of Coastline Changes in Andaman Islands after the 2004 Sumatra Earthquake, *Proc.IEEE International Geoscience and Remote Sensing Symposium 2005*, 25 - 29 July 2005, Seoul, Korea.

[3] Liew S.C. and A.W.C. Heng, 2005. Simultaneous determination of water depth, backscattering and absorption coefficients in IKONOS images of coastal waters, *Proc.IEEE International Geoscience and Remote Sensing Symposium 2005*, 25 - 29 July 2005, Seoul, Korea.

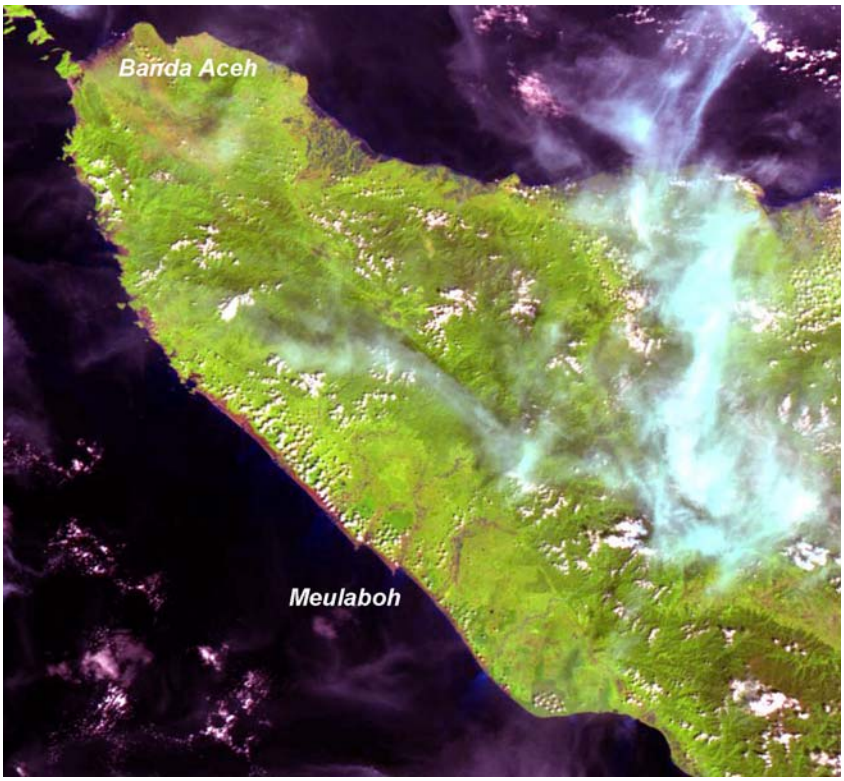

Fig 1 -- Terra MODIS Image of North Sumatra on 29 Dec 2004 showing extent of areas affected by the Tsuanmi

Fig 2 – IKONOS Image of Lhok-Nga, Sumatra, before (10 Jan 2003) and after (29 Dec 2004) Tsunami

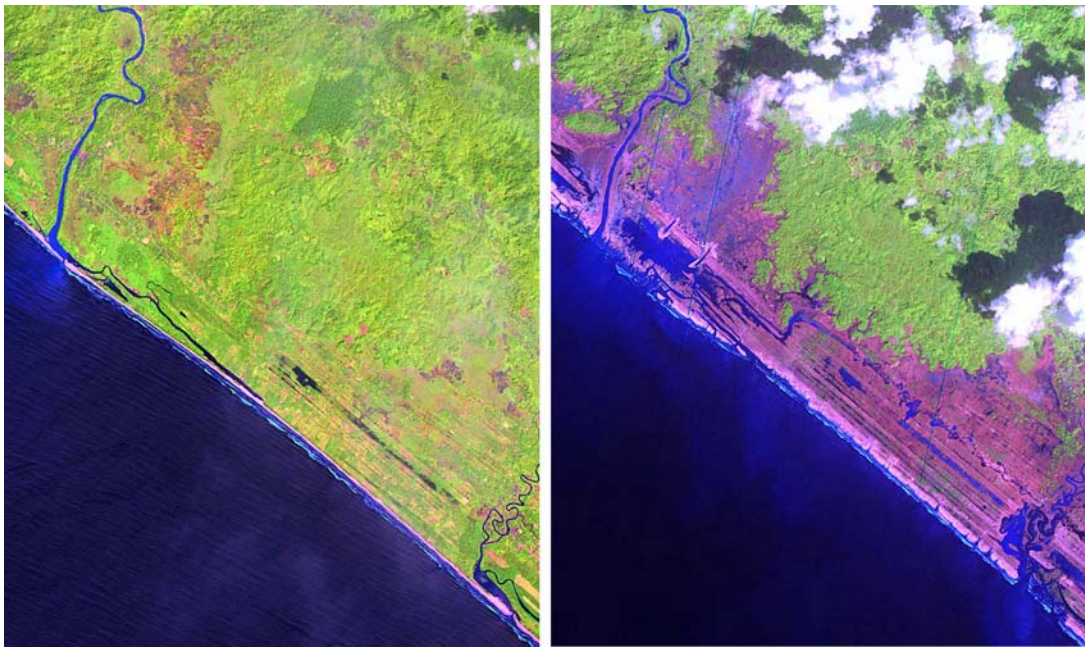

Fig 3 – SW coast of Sumatra, SPOT 5 images before (8 Dec 2004) and after (29 Dec 2004) Tsunami. (Image © CNES 2004)

Fig 4 – IKONOS Image of Khao Lak, Thailand, before (10 Jan 2003) and after (29 Dec 2004) Tsunami

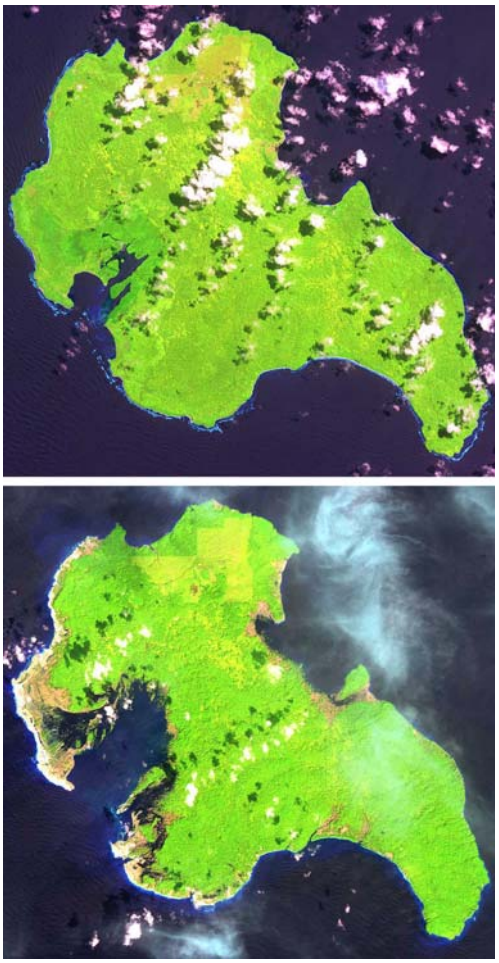

Fig 5 – Katchall Island, SPOT 5 images before (10 Jul 2004) and after (28 Dec 2004) Tsunami show evidences of subsidences. (Image © CNES 2004)

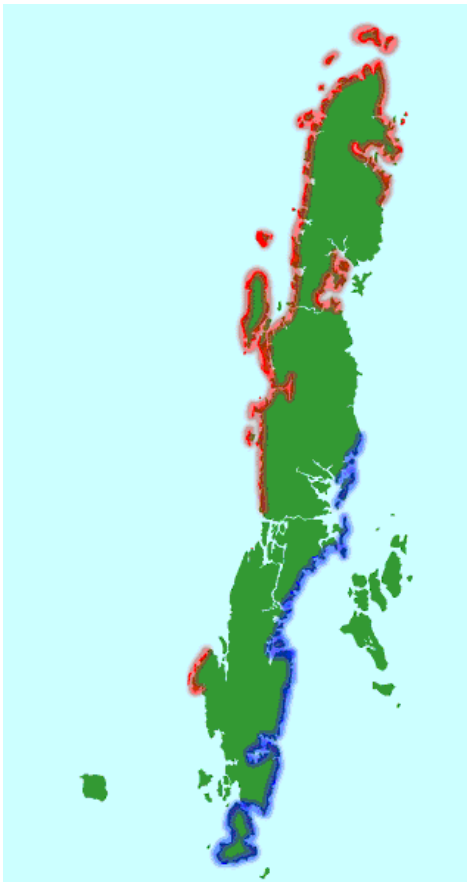

Fig 6 – Coastal change in the Andaman Islands. Red indicates uplift and blue indicates subsidence