# APPROACHES FOR MITIGATING FLOOD DISASTERS UTILIZING REMOTE SENSING INFORMATION

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**ABSTRACT:** Earth Observation satellites deliver information quickly about the areas of disaster caused by flooding. PASCO creates flood hazard maps, tsunami hazard maps, and other hazard maps that serve as basic data contributing to the enhancement of voluntary disaster prevention capability. The company's mitigation approaches consist of observing wide area information and 3D data creation, quick analysis of acquired data from different sensing systems, their visualization & supply, data transmission and immediate processing functions during and after the flood events. The created detailed estimated flood maps and the analyzed results are provided efficiently to the relevant ministries and several organizations including the disaster affected municipalities, private corporations, media, etc.

## 1. INTRODUCTION

### 1.1 Flood disasters and satellite information

Flood is one of the most devastating global natural hazards. In recent years, countries around the world have witnessed the frequent occurrence of disasters such as torrential rains and flooding events arising as a result of global warming and earthquakes. This has raised the importance of adopting prevention measures against various forms of disasters. In the event of such large-scale disasters, preventing and minimizing damage is of the utmost importance.

Earth Observation (EO) satellites deliver information rapidly about the areas of disaster caused by flooding in much detail and frequently. Flood mitigation work can be performed by utilizing the remotely sensed information from high resolution optical and synthetic aperture radar (SAR) satellites combined with supplementary datasets.

### 1.2 PASCO's involvement

PASCO creates flood hazard maps, tsunami hazard maps, earthquake hazard maps, and other hazard maps that serve as basic data contributing to the enhancement of voluntary disaster prevention capability. The company's approaches consist of observing wide area information and 3D data creation (for narrow area with high accuracy), quick analysis of the acquired data from different sensing systems, their visualization & supply, data transmission and immediate processing functions in the areas after occurrence of a disaster. The created detailed estimated flood maps and the analyzed results are provided efficiently to the relevant ministries and several organizations including the disaster affected municipalities, private corporations, media, etc.

### 1.3 Utilizing EO information

Satellite EO is one of the main activities of PASCO for monitoring the disasters. Currently, the company handles data from the dominant commercial EO satellites (17) launched throughout the world and owns 3 Ground Stations.

The weather independence and high resolution of the SAR satellites have made substantial contributions for the management of natural disasters in the recent years. Independent of weather conditions and illumination and frequent revisits of the TerraSAR-X (a reliable satellite with of high resolution, multi-polarization and multi-incidence angle capabilities) we can obtain highly valuable geospatial information for disaster monitoring. PASCO conducted several disaster related projects worldwide utilizing TerraSAR-X and other EO satellites' data. The current paper describes examples of Japan, Indonesia, Thailand, Philippines and Nepal and the approaches for mitigating the flood disasters by utilizing the spaceborne remote sensing information*.

* Post-Disaster Images Acquisition Project, PASCO CORPORATION, 2014. Addressing National Land - Threat of the Nature, Disaster Mapping for Emergency use, 2010-2013, pp.86.

## 2. APPROACHES FOR MITIHATING FLOOD DISASTERS

Flood is one of the most common types of natural disasters for which an immediate response is of an utmost importance. PASCO acquires emergency imageries of stricken areas by satellite and aircraft immediately after the occurrence of a disaster and provides information to the central and local governments and related organizations. It is crucial to acquire satellite images at different phases of disaster occurrence: namely, pre-disaster phase, post-disaster phase, and recovery phase. Eventually, it is ideal that people can access and effectively utilize the information. (Shibayama *et al*., 2008).

The satellite imageries are utilized to grasp an overview of flooded areas quickly and precisely to facilitate damage assessment and prevent secondary disasters and enable smooth reconstruction work. PASCO's adopted approaches for the geospatial flood area mapping provides range of flood water and depth on the land surface. Figure 1 depicts the approaches of the company by observing the wide area information, creation of 3D data, focusing on the narrow area with higher accuracy, quick analysis of the acquired data from various sensors and provision of information about the areas of disasters in a soonest possible time.

- Observing wide area information and creation of 3D data
- Speedy day/night observation and data creation
- Data creation for observing narrow area with higher accuracy
- Quick analysis of acquired data from various sensors, its visualization and provision
- Data relay and immediate processing in the areas after occurrence of a disaster

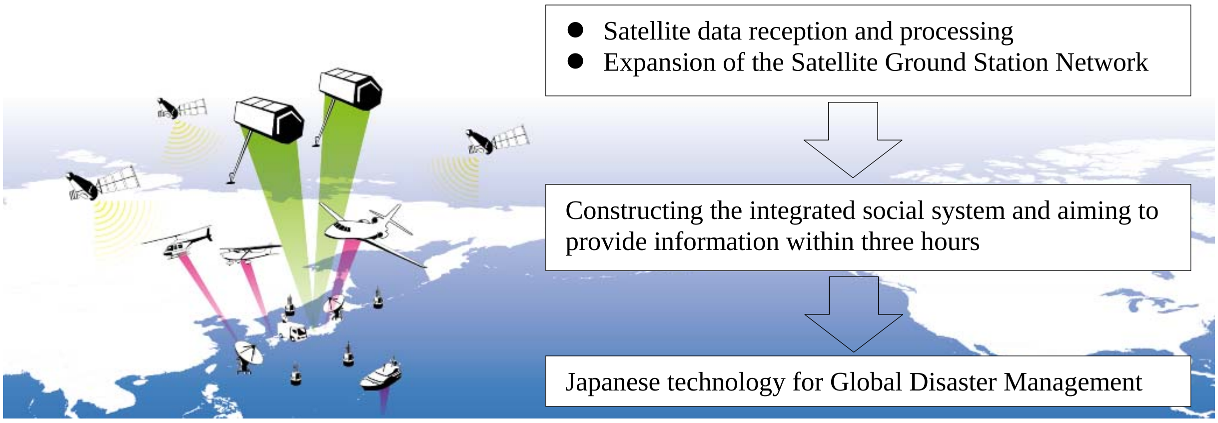


Figure 1. Approaches for mitigating disasters.

## 3. EXAMPLES OF THE CONDUCTED DISASTER MITIGATING CASES

The followings describe examples of Japan and four Asian countries for mitigating the flood disasters by exploitation of spaceborne information.

### 3.1 Tsunami after the Great East Japan Earthquake 2011

The Great East Japan Earthquake 2011 was the most powerful known earthquake to have hit the nation and one of the five most powerful earthquakes globally occurred. PASCO acquired the TerraSAR-X imagery at 06H00 on March 14, 2011. The maps were immediately created indicating coast's flooding (remaining water) caused by tsunami. Additionally, the difference (deformation of earth surface) between the imagery dated October 21, 2010 and archived imagery acquired for collection of the information pre-earthquake was extracted. The devastated tsunami damage was estimated by extracting the huge change in wide area between pre- and post-disaster. By comparing those dual temporal imageries, the tsunami arrival point was analyzed and estimated flooded map was produced. While the extent of damage had yet to be assessed, at the late hours of March 11, PASCO posted the information about the extracted areas with elevations of less than 10m.

PASCO also acquired imageries from other kinds of optical satellites, the extent of flooded areas caused by tsunami were analyzed. To understand the situation, a total of 194 scenes and about 560,000 square km were gathered, using satellite images acquired post-disaster from WorldView-1&2, RapidEye, ALOS AVNIR2, Spot 5, EROS-B and TerraSAR-X.

PASCO created more detailed estimated flooded map referring released aerial photographs of the Geospatial Information Authority of Japan. Disaster Monitoring information were provided within the shortest period of time, which could help to supply better disaster mitigation and restoration during the early stage of the huge disaster. In order to urgently processing the data, automatic change detection method was effective. The results were utilized by domestic disaster prevention organizations such as the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan. The company provided the analyzed information to several organizations including the disaster affected municipalities, private corporations, media, etc. Some created products after the Great East Japan Earthquake are shown in Figure 2.

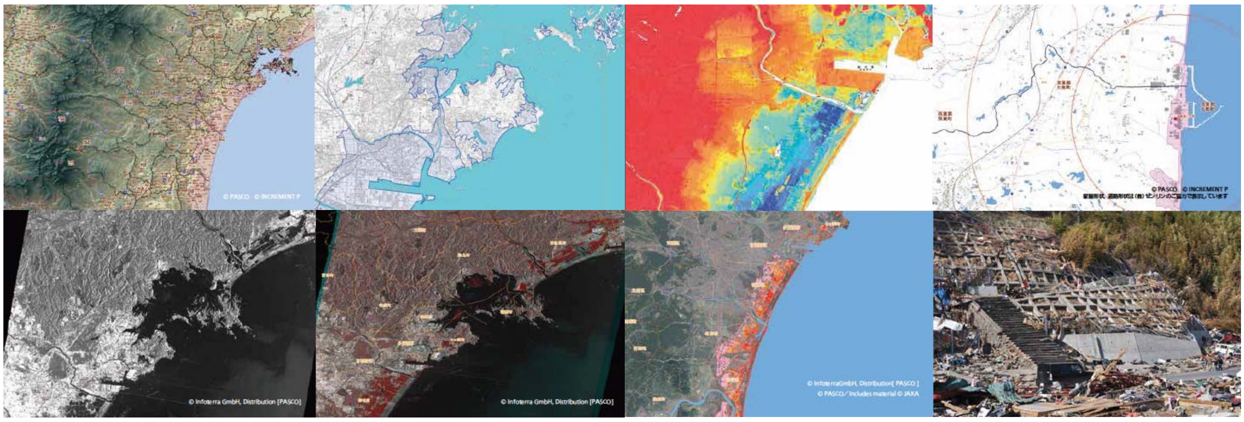

Figure 2. Products created after the tsunami.

### 3.2 Torrential rains from typhon Wipha (Ohima town Tokyo)

Typhoon Wipha (Typhoon No. 26) formed around the Mariana Islands at 3:00 a.m. on October 11, 2013 and headed north toward Japan while gaining strength, bringing heavy rains to an extensive area of the country from October 15 to 16. In particular, the Izu Islands (Oshima) saw record-setting rainfall totals, which caused river flooding and landslides, resulting in localized damages.

PASCO acquired the TerraSAR-X data (SpotLight Mode, HH polarization, incidence angle 55 degree) on October 26, 2013. The area seen in red within the image being analyzed shows where microwave reflections changing slightly between images acquired from February 2010 to October 26, 2013 (Figure 3). The blue colored area shows spots where radar reflections changed significantly over the same three and a half year period. The darker area in each case indicates changes in ground surface, which includes elements other than those that caused the landslides during the early morning hours of October 16.

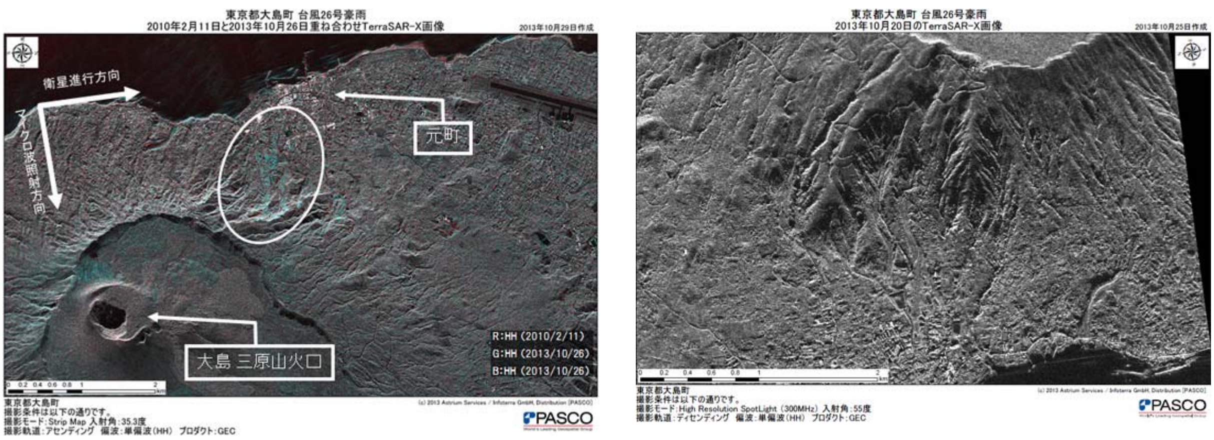


Figure 3. Analysis shows where microwave reflections changing slightly between images acquired from February 11, 2010 to October 26, 2013.

Oblique aerial photographs were also taken on October 16, 2013 (from the PALS). The PALS was specially designed and developed by PASCO to take oblique photographs. Images can be immediately uploaded to GIS after landing because the system records the direction of the photograph and center location of the objects and camera position simultaneously when shooting. A 3D model was created based on data from the PALS shot on Wednesday, October 16, 2013 (Figure 4). Status of damages was determined from 3D modeling*.

Figure 4. Oblique aerial photographs taken on October 16, 2013 (from the PALS). Statuses of damages were determined from 3D modeling.

### 3.3 Damages from the failure of a natural dam on Ambon Island in Indonesia

At around 10:30 a. m. on July 25, 2013 a natural dam on Ambon Island in Indonesia failed due to torrential rains that had continued from the previous day and the resulting flood damaged a village located downstream. PASCO checked the flood conditions from the natural dam using satellite imagery in December 2012. In conjunction with the imaging results of this natural dam failure, PASCO has released three phases of imagery that was acquired by TerraSAR-X on the dam failure. In addition, the MLIT carried out news conference on this natural dam using the same TerraSAR-X imagery on August 5, 2013.

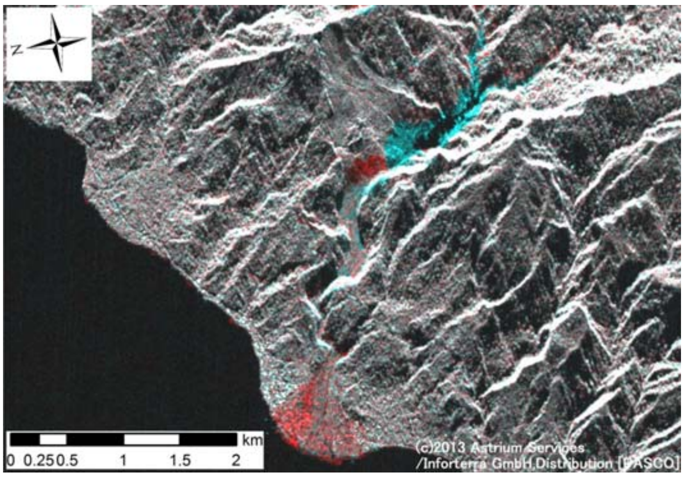


Figure 5. Differential analysis results for two phases.

PASCO checked the flood conditions from the natural dam using satellite imagery in December 2012. Differential analysis results for two phases after the failure of the natural dam is shown in Figure 5. The red shows the areas of eroded valley and houses etc., washed away where the backscattering intensity of radar was weaker due to the natural dam failure when compared the imageries after the natural dam was formed (December,2012) and after the natural dam collapsed (July, 2013).

Also in the Figure 5, the blue color represents the backscattering from water surface to land slope, it shows the area where the backscattering intensity was stronger. The black part included in blue part shows the area still in flood after the collapse.

### 3.4 Flooding in Thailand

The flooding that occurred in central Thailand from early October 2011 caused serious problems in 30 out of Thailand’s 77 municipal districts (excluding southern Thailand), gravely impacting 2.34 million people in over 760,000 households (as announced by the Thai government on October 8), with the damage subsequently spreading even further. These floods are believed to have had a major impact on Thailand’s industrial zones, into which foreign companies have made considerable investments, as well as affecting the world economy.

* October 2013 Torrential Rains from Typhoon Wilpha - http://www.pasco.co.jp/eng/disaster_info/131016/

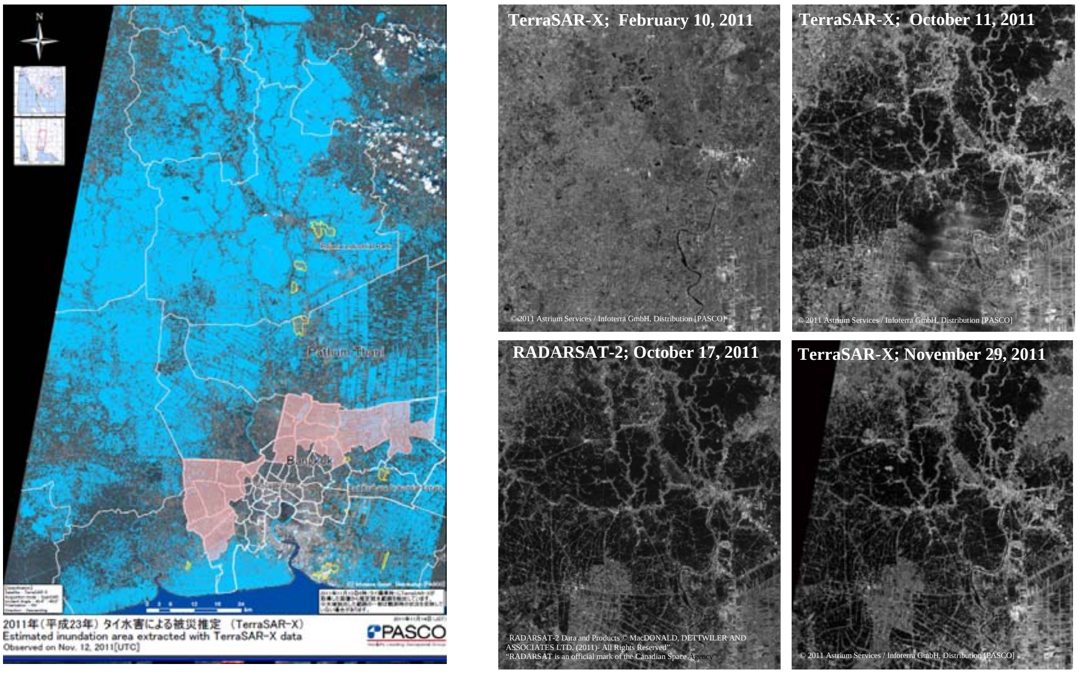


Figure 6. Temporal acquisitions conducted by utilizing TerraSAR-X and RADARSAT-2 satellites.

PASCO has conducted acquisitions of the spaceborne imageries utilization of the TerraSAR-X satellite as required, since October 10, 2011. The flooded area was extracted by processing pre- and post- flooding several ScanSAR imageries of TerraSAR-X and RADARSAT-2 satellites were acquired during October to November and created products demarcated the flooded and stagnant water areas, warning areas and industrial parks (Figure 6).

### 3.4 Damages caused by Typhoon Haiyan, in the Philippines

Typhoon Yolanda/Haiyan caused huge damage on November 8, 2013 in the Philippines. The estimated destructions were more than 1 million houses in the region and one of the deadliest natural disasters on record in the country. PASCO acquired high resolution imagery of the Pléiades satellite on November 15, 2013. The aftermaths of the destructions are visible in the enhanced images (Figure 7). Reports were prepared urgently and provided to the Embassy of Japan in the Philippines.


Figure 7. Pléiades imagery after the disaster and some conducted interpretations of the damages.

### 3.5 Monitoring of Glacial Lake Outburst Flood (GLOF) in the Himalayas since 2008

The Intergovernmental Panel on Climate Change (IPCC) has analyzed that glaciers located over Tibetan Plateau are likely to shrink at very rapid rates from 500,000 $km^2$ in 1995 to 100,000 $km^2$ by the 2035, if current warming rates are maintained. The number of glacial lakes that may collapse due to a rise in water level has been confirmed to be 20 in Nepal and 24 in Bhutan. Imja Glacial Lake is one of the biggest water storage glacial lakes that may collapse and its reservoir capacity is estimated to be 70 to 80 million $m^3$. Should it collapse, it is obvious that a tremendous disaster will occur in the densely populated area in the downstream basin. PASCO acquired the images of Khumbu Glacier and Imja Glacier around Mt. Everest several times since January 6, 2008 by TerraSAR-X. GLOFs are most dangerous in the monsoon season (June to August) when the temperature of the glacial lake rises. It is necessary to acquire the images during this period, but observation via optical satellite is difficult because the persistent cloudy weather during this season. Therefore observation of actual ground condition using SAR is effective since it can penetrate the cloud.

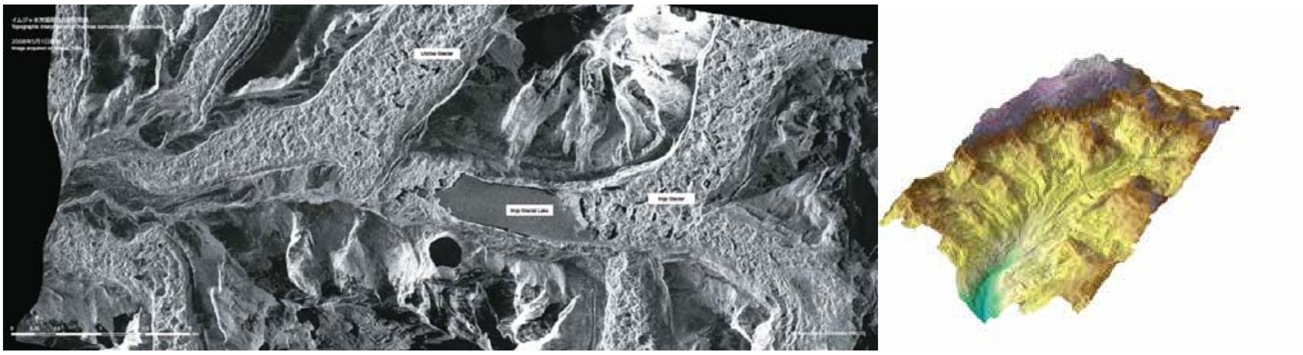

Figure 8. Lake Imja, TerraSAR-X image, acquired on May 1, 2008, and created DEM.

PASCO conducted the study to generate DEM by TerraSAR-X images by applying Interferometric Synthetic Aperture Radar (InSAR) processing and evaluating the quality of the DEMs by comparing them with SRTM data. DEM generated by TerraSAR-X image could acquire more detailed surface information of the mountainous region. The end and side of the moraine were recognizable with TerraSAR-X DEMs (Figure 8). It is expected that the InSAR DEM would be highly useful for monitoring purposes in the mountainous regions (Yamane *et. al.*, 2008).

## 4. CONCLUSIONS

While Japan is blessed with a rich natural environment, it is constantly under threat from natural disasters. PASCO's system captures the series of processes for landslides and floods in particular, from investigation and analysis, to planning, design, and post-construction management. The company has successfully monitored several disasters in the past few years by utilizing various EO satellites' imageries for both Japan and other countries. Utilization of multi-source and multi-temporal data, speedy processing, automatic change detection methodologies and rapidly information provision are the crucial aspects. Spaceborne derived information has witnessed the increasing initiatives aimed for wide area coverage and for the timely assessments. PASCO is committed to provide optimum services for mitigating disasters in Japan & globally. New technologies such as automatic feature or event extraction, change detection, 3D geospatial data simulation, quantity measurement and Big Data analysis are gaining demands. It is our mission to establish social infrastructure system to contribute to preservation and development of the national land with the provision of the best "decision" and prompt "action". We believe that a system of social infrastructure should be established at first to protect citizens' lives and properties from the disasters.

## RREFERENCES

Shibayama, T., Nonaka, T., Takagishi, S. and Sasagawa, T. 2008. Disaster information acquisition system using multi-platform remote sensing technlogy. In: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, ISPRS, Beijing, Vol. XXXVII, Part B8, pp.393-395.

Yamane, N., Fujita, K., Nonaka, T., Shibayama, T. and Takagishi, S. 2008. Accuracy evaluation of DEM by TerraSAR-X data in the Himalayan Region, In: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, ISPRS, Beijing, Vol. XXXVII, Part B7, pp.203-207.