Tsunami Responses in Phuket Island, Thailand: Land uses/Land covers and Facilities in 2010

Kamthonkiat, D.,[1] Koshimura, S.,[2] and Matsuoka, M.,[3]
[1]Department of Geography, Faculty of Liberal Arts, Thammasat University, Thailand
[2]Disaster Control Research Center, Graduate School of Engineering, Tohoku University, Japan
[3]GEO Grid Research Group, Information Technology Research Institute, National Institute of Advanced Industrial Science and Technology (AIST). Japan

Abstract
The study on tsunami responses was conducted in order to present the activities of land uses/land covers after the December 2004 Indian Ocean tsunami, and to prepare tsunami related facilities in Phuket Island, Thailand. Multi-temporal analysis on ASTER scenes acquired pre tsunami (Mar, 2004) and post tsunami (2005 and 2010) were classified into 6 main land uses/land covers; Agriculture, Beach, Built-up, Forest, Miscellaneous and Water body. It was observed that the tourist facilities in famous tourist beaches, such as Patong and Kamala, recovered by about 80% at the end of 2005. Most of the increased built-up areas in 2010 were located outside the tsunami inundated zone. Following the 2004 Indian Ocean tsunami, the tsunami warning system and related facilities, such as the Deep-ocean Assessment and Reporting of Tsunamis (DART), broadcasting towers, wave protection barriers and tsunami shelter or evacuation sites have been set up. In addition, bi-lingual (Thai-English) tsunami related notice boards and maps were placed since 2005. After the disaster, the tsunami awareness and evacuation procedures have annually trained and practiced with local residents, tourists and disaster related agencies in Phuket.

1. Introduction

On the 26th December, 2004, a number of popular destinations for tourism along the west coast of southern Thailand, namely Phuket, Krabi, Ranong, Phang Nga, Satun and Trang, were attacked by tsunamis caused by two strong earthquakes, with the magnitudes of 9.3 and 7.3 on the Richter scale, near Sumatra, Indonesia. Following the 2004 Indian Ocean Tsunami damage assessment, the Thai Government reported that the number of casualties (including unidentified bodies) reached 5,395 in the tsunami hit provinces. Nearly half of the casualties were foreign citizens from 36 other countries. For a broadened view, remotely sensed data from satellite were applied by many agencies for a quick assessment of the damages. Beyond the heavy death toll, the giant wave also caused enormous damage to mangroves, coral reefs, sand dunes, groundwater, forests, human settlements and agricultural lands along the west coast of Thailand. The highest death toll was from Phang Nga Province (78.3 % of the total casualties) while serious damage to housing sector and tourist facilities was reported in the Phuket Province (DDPM, 2008 and ONEP, 2006). Following the 2004 Indian Ocean tsunami, a number of rumors about a new tsunami coming to Phuket Island have continuously distributed by various sources, causing panic amongst the local residents and tourists about the safety living in Phuket and other tsunami attacked areas. Well-prepared strategies and facilities for an unpredicted tsunami in the future could convince people that Phuket is a safe place to stay. Consequently, the tsunami response and preparations in Phuket; land uses/land covers activities in the pre and post of the 2004 Indian Ocean tsunami and the available tsunami related facilities were observed in this study. The results from this study indicate the effects of tsunami and the response plans of Phuket.

2. Objective

The study on tsunamis responses was focused on the activities of land uses/land covers in Phuket, and the available facilities preparing for undesired tsunamis in the future. The detail objectives are;

2.1 To classify land uses/land covers changes in Phuket Province using multi-temporal ASTER imageries acquired in the pre- and post 2004 Indian Ocean tsunami (2004, 2005 and 2010).

2.2 To observe the tsunamis related facilities in Phuket Province.

3. Study Area

The Phuket Province, one of the most popular tourist destinations in Thailand, is the largest island

in the area and lies off the west coast of Southern Thailand. Phuket is quite hilly, with a few peaks reaching above 500 meters. The highest peak reaches 529 meters, and is called Mai Tao Sipsong. The highlands are covered by lush jungle; the lowlands are agricultural lands that consist of small patches of rice paddies, plantations of rubber, pineapple and coconut. The most beautiful beaches; Mai Khao, Kamala, Patong, Karon and Kata are located along the Andaman Sea, west coast of Phuket. Patong is well-known as the most popular tourist beach, with a variety of hotels, tourist service shops and restaurants. In term of administration, Phuket consists of 3 districts: Muang Phuket, Thalang and Khathu. The most popular beaches: Patong and Kamala are located in Khathu, as shown in Figure 1.

4. Materials and Methods

4.1 Materials

The necessary material consists of digital maps, software, satellite images and the following:

4.1.1 Remotely Sensed Data

ASTER imageries of Phuket Province, which were acquired on the 24th March, 2004, 8th February, 2005 and 6th February, 2010 from the GEO Grid, the National Institute of Advanced Industrial Science and Technology (AIST), Japan.

The changes of land covers in Phuket were analyzed using optical sensor namely ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) which were provided by GEO Grid, the National Institute of Advanced Industrial Science and Technology (AIST), Japan. ASTER consists of 14 bands; 4 bands in visible and near infrared (VNIR) with 15 meters spatial resolution, 6 bands in short wave infrared region (SWIR) with 30 meters spatial resolution, and 5 bands in thermal infrared (TIR) with 90 meters spatial resolution. Only the visible and near infrared of ASTER were selected for our analysis.

4.1.2 A topographic map in 2003 of Phuket Province at the scale 1:50,000 from the Royal Thai Survey Department (RTSD)

4.1.3 Existing reports which related to the tsunami victims, affected land uses/land covers, response plans, evacuation maps, warning system from the Department of Disaster Prevention and Mitigation (DDPM), Ministry of Interior, Thailand and some related sources.

4.1.4 Software; ENVI 4.6 and ArcGIS 9.2

4.1.5 Others; handheld Global Positioning System (GPS), cameras, etc.,

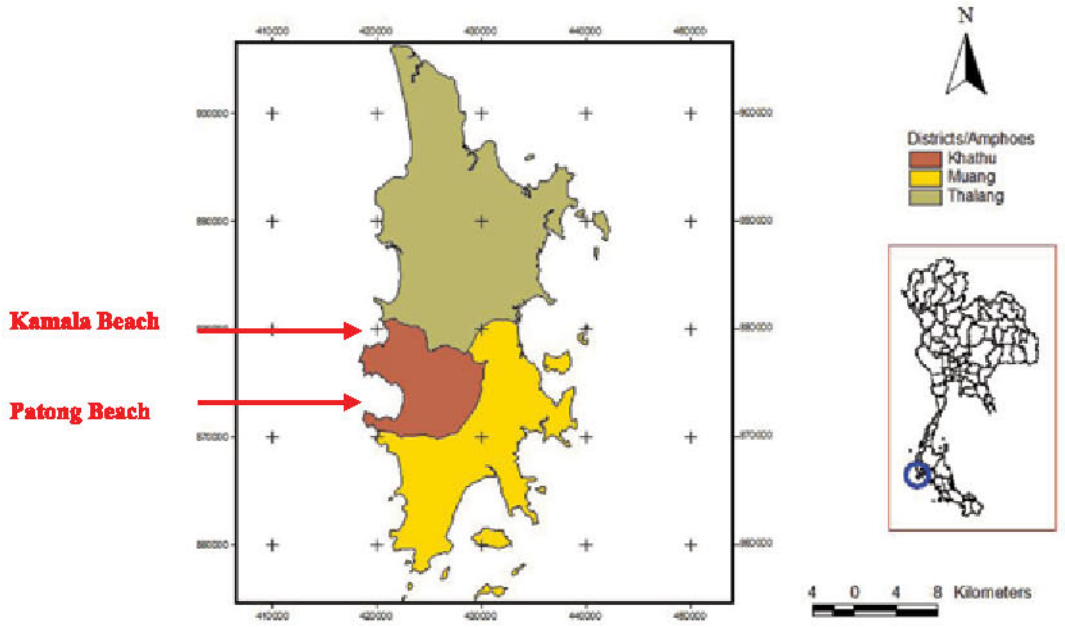

Figure 1: Study area: Phuket, Thailand

4.2 Methods

The study of tsunamis responses focused on the activities of land uses/land covers in Phuket and the available facilities preparing for undesired tsunamis in the future. Figure 2 presents the flow of research methodology of the first objective and consists of 4 parts; data preparation, Pre-processing, Processing and Post-processing. After preparing all necessary data mentioned in the section 4.1, the pre-process step was emphasized on multi-temporal ASTER scenes. The 2004 image was rectified to the topographic map in 2003 from RTSD (road layer). The rectified image was a base for co-registration with ASTER images which were acquired in February of 2005 and 2010. In the processing step, supervised classification was applied on the pre-processed images using the Maximum Likelihood method. The classified images presented 6 classes of land uses/land covers; Agriculture, Beach, Built-up, Forest, Miscellaneous and Water body. The accuracy assessments of these classified results were conducted in post-processing, using the reference maps and field observation data (during 2005-2010). According to cloud contamination in our ASTER images, that hinders the information of land covers, the overall accuracy of each classified image was accepted at 75%. In addition, the existing of tsunamis related facilities in Phuket, such as warning signboard, map, evacuation route, safety zone or tsunami shelter, early warning system and so on, were observed in this study through our field surveys and reports from tsunami related agencies.

5. Results

The results consist of 2 parts: 1) multi-temporal analysis of land uses/land covers in Phuket (2004, 2005 and 2010 in Figure 3), and 2) tsunamis related facilities in Phuket Province. The results were discussed respectively in the following sub-sections.

5.1 Multi-Temporal Analysis of Land uses/Land covers in Phuket

The classified land uses/land covers from ASTER 2005 were compared to the classified image of 2004. They implied that almost 50% of beach and built-up in 2005 appeared less than those of 2004, especially in the tsunami impacted areas along the west coast of Phuket. Most of the damaged built-up areas including seaside restaurants, shops and other services along the famous tourist beaches; Patong and Kamala had recovered for the high season of tourism at the end of 2005. It was found in the classified ASTER 2010 that the beach area resumed closer to the area in 2004, but not in the same shapes. In 2010, built-up had increased its area in the higher ground of Phuket, especially in the Kathu District (see Table 1).

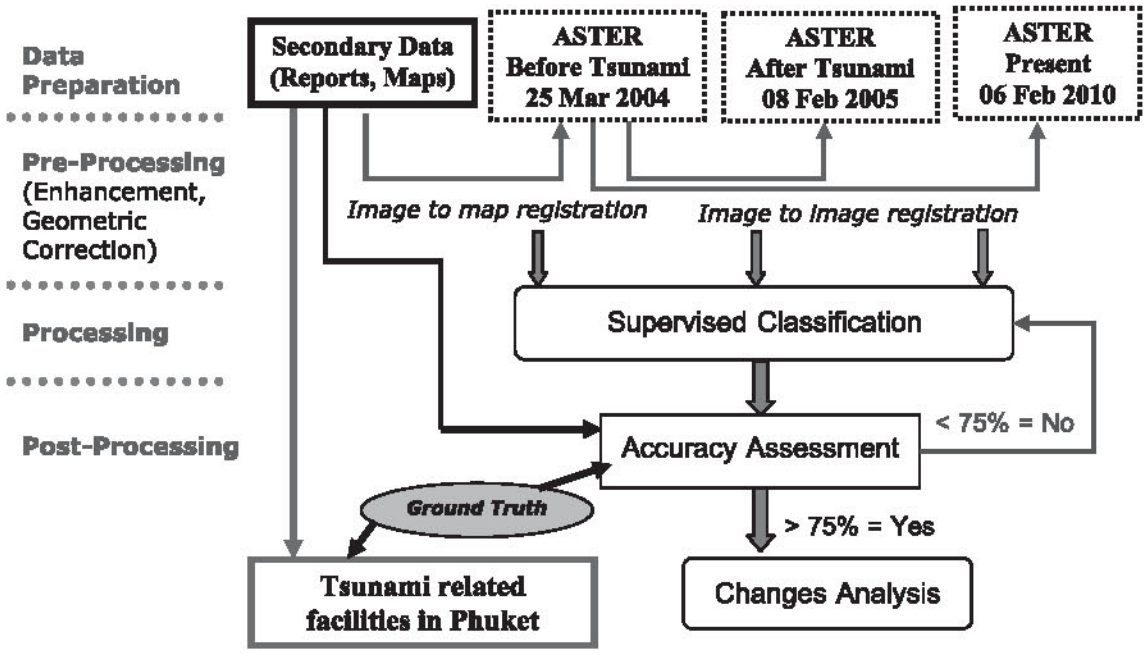

Figure 2: The flow of research methodology

Table 1: The classified areas of land uses/land cover using ASTER imageries

Land cover Class	2004		2005		2010	
	Sq.Km	%	Sq.Km	%	Sq.Km	%
Agriculture	230.65	43.06	112.52	21.01	136.82	25.54
Beach	2.29	0.43	1.54	0.29	1.98	0.37
Built-up	107.30	20.03	72.14	13.47	117.10	21.86
Forest	53.20	9.93	235.58	43.98	146.55	27.36
Miscellaneous	139.70	26.08	108.38	20.23	128.52	23.99
Water body	2.52	0.47	5.50	1.03	4.69	0.87
Total	**535.66**	**100.00**	**535.66**	**100.00**	**535.66**	**100.00**

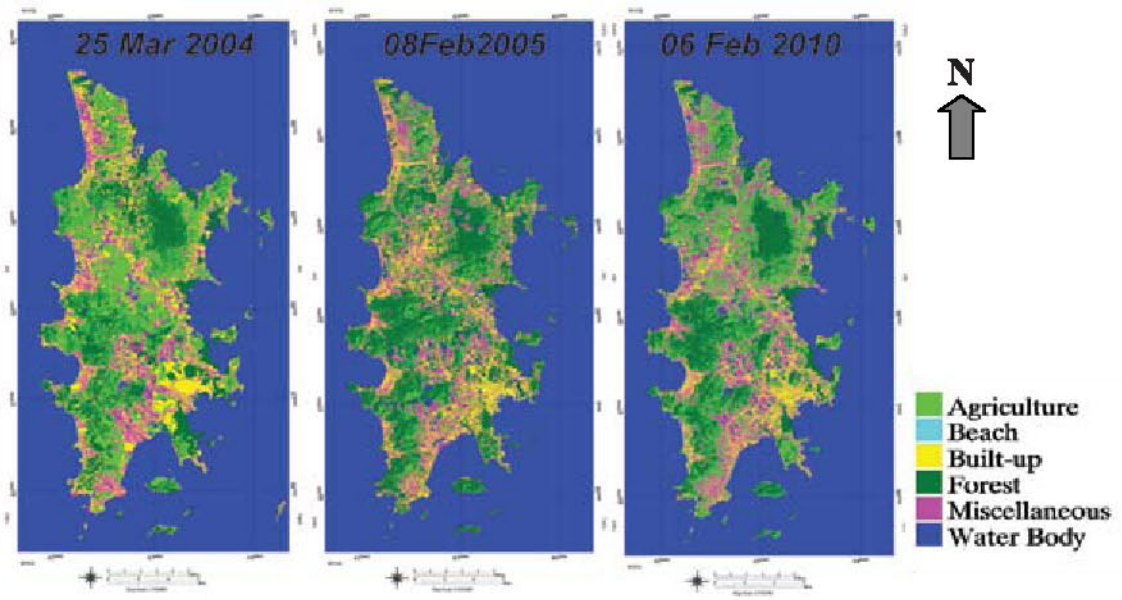

Figure 3: The classified land covers maps in 2004, 2005 and 2010

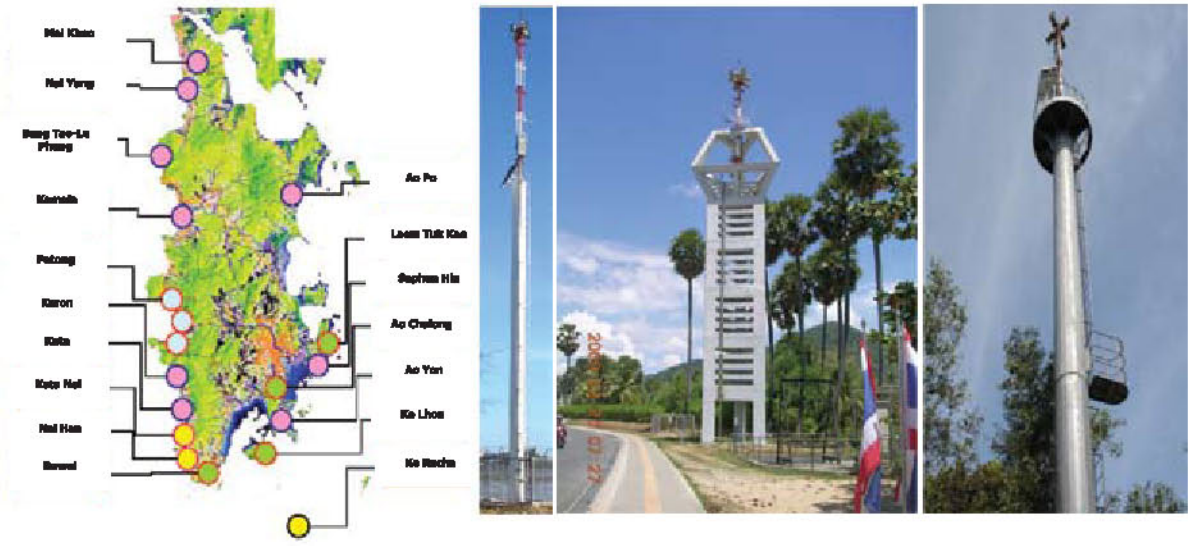

Figure 4: Broadcasting towers in Phuket (modified from DDPM, 2008)

The classified water bodies were increased in 2005 because the inundation from tsunami water still remained. The areas of inland water in 2010 became a half higher than the area in 2004. Since the information of ASTER 2004 was hindered by cloud, forest area was under estimated, while the over estimation appeared in the agriculture and miscellaneous sections. In 2005, agriculture, forest and miscellaneous areas were classified in square kilometers at 112.52, 235.58 and 108.38 respectively. Almost 20% of the forest area in 2005 had converted to built-up, agriculture and miscellaneous in 2010.

5.2 Tsunamis Related Facilities in Phuket Province

In a few months after the catastrophic disaster, artificial debris and dead victims were removed from the damaged areas by Thai government agencies, such as the Department of Disaster Prevention and Mitigation (DDPM), the Ministry of Interior (MOI), the Department of Marine and Coastal Resources (DMCR), the Department of Mineral Resources of the Ministry of Natural Resources and Environment (MONRE), nonprofit volunteers and a lot of international parties (Srivichai et al., 2007). After the first experienced Tsunami in 2004, the National Disaster Warning Center (NDWC) was settled in 2005 under the Ministry of Information and Communication Technology (ICT). The renovation of the damaged seaside restaurants, gift shops, pier and other services along the tourist beaches, especially at Patong and Kamala, had started. About 80% of them were resumed at the end of 2005. In parallel, the wave protection barriers were made from concrete, and were constructed around 2 feet high at some locations near the water front of the tourist beaches. Since 2005, nineteen broadcasting towers had located in Phuket (see Figure 4) for tsunami warning and communication on urgent matters to the local residents and tourists. Four of these towers were contributed by private sectors while other towers were supported by Thai government. The system maintenance and disaster related announcements were incorporated by disaster related organizations such as the NDWC of ICT, DDPM of MOI and the office of Phuket Municipality (NDWC, 2006). In December 2006, the first early warning system was installed in the Indian Ocean between Thailand and Sri Lanka. The Deep-ocean Assessment and Reporting of Tsunamis (DART) was developed by the National Oceanic and Atmospheric Administration (NOAA), USA. DART requires earthquake and volcano monitoring systems and deep-ocean buoys, rapid data analysis, and affective warning broadcast system hardware for transmitting warning messages to at-risk regions, including the use of any public notification hardware (see Figure 5). The warning of tentative tsunamis from this system has covered some of the countries located in South and Southeast Asia; the area impacted by the 2004 Indian Ocean tsunami. In 2010, two sets of the Deep Sea Tsunami Detection Equipment (or DART-2) were installed in the Andaman Sea, about 250 kilometers off the west coast of Phuket and about 230 kilometers away from Surin Islands, Phang Nga Province. These early warning systems were operated by Thai governors; the NDWC of ICT and the Royal Thai Navy, with the cooperation and supervision from DART's experts (Phuket Post, 2010). The existing early warning system, located off the west coast of Thailand, is linked to other operated sites (in regional to global networks) for providing the information on real-time or near real-time tsunami warning via the broadcasting towers to the local people. The detected location and magnitude of the earthquake is generated for the tentative areas attacked by the tsunami, the estimated high tide or wave height, the arrival time of tsunami depends on the distance from the epicenter. The information from the early warning system is crucial for people who live in risk areas in preparing their emergency kits, evacuating to the shelter or safe zones and then mitigation the loss of lives. After the first experienced tsunami in Thailand, tsunami awareness and response strategies were spread to local residents who live in the hazard zones. Plenty of media (poster, movie, report and etc.) on what tsunamis are, warning signs of the tsunamis occurrence, characteristics and powers of the waves and how to respond to the upcoming event, were issued and broadcasted countrywide. In Phuket Island, the information and maps of tsunami inundation zones, inundation heights, evacuation routes, safety zones/shelters and tsunami related notice boards were allocated all the way through the impacted area, and were available in both the Thai and English languages (see Figure 6). Beyond understanding tsunamis related media and maps, the residents in Phuket are requested to participate in an annual practicing on tsunami responses under the supervision of the NDWC, DDPM, the office of Phuket Municipality and other disaster related organizations; medical teams, rescue associations, polices and etc. The tsunami response activities are concerned issuing tsunami warning alarm, evacuating along the suggested paths to the allocated safe zones and include practicing rescue and first aid on injured people. The key to success is completing all activities within the expected deadline (DDPM, 2008).

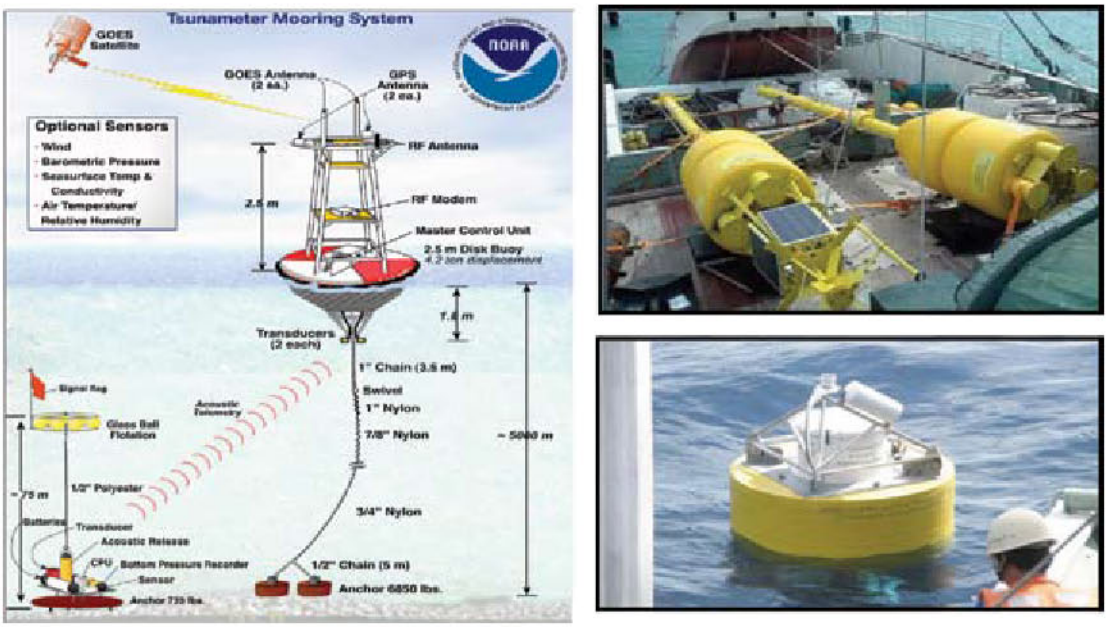

Figure 5: The tsunami warning and detection system near Thailand
(*Sources: National Oceanic and Atmospheric Administration, 2005 and Phuket Post, 2010*)

Figure 6: Tsunamis information, maps and notice boards in Phuket

6. Conclusions

The results of multi-temporal analysis using ASTER imageries in 2004, 2005 and 2010 presented that built-up areas, especially the tourist facilities and services, were quickly recovered at the same locations within a year after the disaster. However, the increased residential areas and transportations in 2010 were identified in the higher ground and outside the tsunami inundated zones. The tsunami awareness and response plan for unpredicted tsunamis in the future has developed as a hot issue since 2005. The early warning systems (DART and DART 2) were installed in Andaman Sea for the tsunami early warning in this region.

Most of the tsunami related facilities, such as communication towers, wave protection barriers, maps of tsunami hazard zones and safe locations, and including all tsunami related notice boards in both Thai and English languages, were installed in Phuket within 2 years after the tsunami catastrophe. However most of the maps, which were installed in the areas about 5 years ago, have faded and lost some information. Since 2005, the tsunami awareness and respond plan has educated local residents and disaster related agencies. Following the 2004 Indian Ocean tsunami, the evacuation and aid procedures have been practiced annually under

the assumed tsunami scenario. It was considered that the adaptations and responses in related to tsunami disaster in Phuket seem rather high.

Acknowledgements

This study received financial support through project ID 08E52010a, which is hosted by Tohoku University and supported by the New Energy and Industrial Technology Development Organization (NEDO) of Japan, for which the author is very thankful. The author also appreciates the support of the GEO Grid and the National Institute of Advanced Industrial Science and Technology (AIST) in providing the ASTER data.

References

DDPM, 2008, Final Report, Project Strengthening Thailand's Capacity on Tsunami Warning, This FY-2007 Cooperative project was undertaken by Department of Disaster Prevention and Mitigation (DDPM), Ministry of Interior, Thailand In collaboration with Asian Disaster Reduction Center (ADRC), 28 March 2008

National Disaster Warning Center (NDWC), 2006, Tsunami Early Warning Arrangement in Thailand: From Policy to Implementation. Report of Thailand's National Disaster Warning Center

Office of Natural Resources and Environment Policy and Planning (ONEP). 2006, 2 Years after Tsunami: Restoration of Thailand's Natural Resources and Environment. Ministry of Natural Resources and Environment. Bangkok. Thailand. 150 pages (ISBN 974-286-157-9)

Srivichai, M., Supharatid, S., and Imamura, F., 2007, Thailand Recovery Process in Thailand after the 2004 Indian Ocean Tsunami. *Journal of Natural Disaster Science*, 29 (1), 3-12.

Phuket Post, 2010. Deep - ocean Assessment and Reporting of Tsunami System in the Andaman Sea. Published on December 11, 2010 at http://www.phuketpost.com/, Last Accessed December 20, 2010.