



RECOVERY STATUS AND CHALLENGES IN SOUTHERN THAILAND AFTER THE 2004 INDIAN OCEAN TSUNAMI BASED ON SATELLITE IMAGES AND FIELD SURVEYS

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ABSTRACT: This study aimed to understand the 20-year recovery process in the Khao Lak area of Phang Nga Province in southern Thailand, which sustained severe damage from the Indian Ocean tsunami caused by the Sumatra earthquake on December 26, 2004, using optical satellite images and results from a total of seven field surveys. This area, where tourism and fishing are the main occupations, was still in the process of recovery when surveyed 10 years after the tsunami. However, in the latest survey 20 years after the tsunami, the resort area was bustling with foreign tourists, and the number of hotels and buildings had increased significantly. Meanwhile, no hard measures such as seawalls were seen in terms of tsunami disaster prevention measures, and instead, progress had been made in installing tsunami warning sirens and evacuation towers, and setting up evacuation routes. Tsunami museums and memorial sites had also been established to pass on the memory of the disaster.

Keywords: *2004 Sumatra earthquake, Satellite images, Recovery, Tsunami evacuation, Tsunami memorial*

1. INTRODUCTION

At 00:58 (UTC) on December 26, 2004, a massive earthquake measuring Mw 9.1 occurred off the coast of Sumatra Island, causing the largest tsunami disaster in history in a wide area along the Indian Ocean coast¹⁾⁻⁵⁾. A tsunami exceeding 10 m in height hit southern Thailand, which faces the Andaman Sea, about two hours after the earthquake, causing severe damage to resort areas and fishing villages in Phang Nga, Phuket, Krabi, and other provinces. As of October 2005, the Thai government confirmed that 5,395

people were killed and 2,817 were missing⁶). Approximately 70% of the dead and missing were in Phang Nga Province (excluding the 722 unidentified dead, the number was 2,741 Thais and 2,417 foreigners), indicating that many of the victims were tourists staying at resorts.

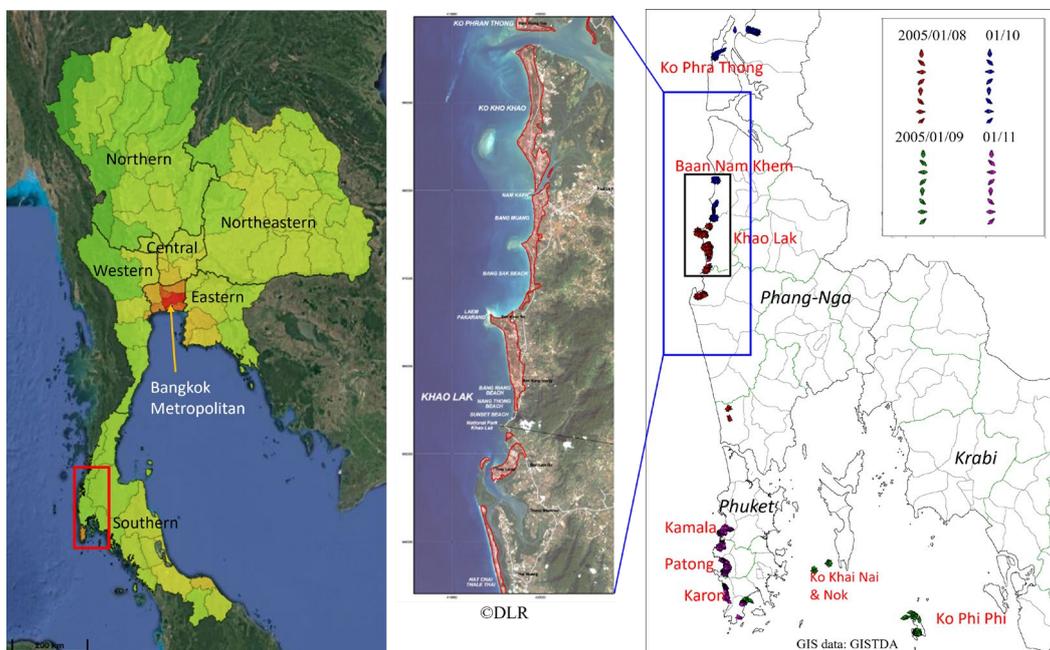
The authors conducted their first on-site survey on January 8–11, 2005, immediately after the earthquake, and have since conducted a total of seven on-site surveys^{7), 8)} in February and August 2005, December 2006 (2nd anniversary), January 2010 (5th anniversary), December 2014 (10th anniversary), and December 2024 (20th anniversary), and have acquired photos and videos linked to GNSS information. In addition, we have conducted research^{9), 10)} grasping the tsunami inundation areas in Phang Nga Province using ASTER optical satellite images and SRTM digital elevation models (DEMs).

This new survey was conducted as a part of the field trip of the 2nd Thailand Symposium on Earthquake Research (TSER 2024)¹¹⁾, which was held on December 11–13, 2024 in Khao Lak, Phang Nga Province, the area that was hit the hardest by the Sumatra earthquake tsunami. Khao Lak, which was surveyed this time, had seen a significant increase in the number of buildings since the previous survey 10 years ago, with many large hotels for foreign tourists in particular having been constructed, and the area appeared to be rapidly developing as a resort destination. Meanwhile, progress was also being made in the construction of facilities to commemorate the tsunami disaster, tsunami evacuation towers, and the setting up of evacuation routes.

This paper reports on the state of reconstruction in Phang Nga Province in southern Thailand 20 years after the Indian Ocean tsunami, based on multi-temporal optical satellite images and on-site survey photos including dates and location information. It also discusses the current situation and issues regarding tsunami disaster prevention measures in the region.

2. FIELD SURVEYS AND OPTICAL SATELLITE IMAGES OF THE TSUNAMI DAMAGE IN SOUTHERN THAILAND CAUSED BY THE 2004 SUMATRA EARTHQUAKE

Figure 1 shows the regional division of Thailand, the affected areas in southern Thailand by the 2004 Indian Ocean tsunami, and our first survey sites⁷⁾ in January 2005. The southern region of Thailand



(a) Regional divisions of Thailand with the coverage of (b) in red square (b) Tsunami inundation zone¹²⁾ and field survey points⁷⁾ in January 2005 by the authors

Fig. 1 Regional divisions of the Kingdom of Thailand, field survey locations in southern Phang Nga Province, and the study area

consists of 14 provinces, including 6 provinces facing the Andaman Sea such as Phang Nga, and 8 provinces facing the Gulf of Thailand. The survey immediately after the tsunami was conducted by a joint survey team⁷⁾ consisting of Fumio Yamazaki (Chiba University) and Masashi Matsuoka (Earthquake Disaster Mitigation Research Center (EDM) of NIED) from Japan, Shubharoop Ghosh from ImageCat Inc. from the United States, Pennung Warnitchai from Asian Institute of Technology (AIT), Supapis Polngam and Siam Lawawirojwong from the Geo-Informatics and Space Technology Development Agency (GISTDA) from Thailand, and Masahiko Honzawa, who had been dispatched to GISTDA by Japan International Cooperation Agency (JICA). The purpose of the survey was to collect on-site validation data to interpret the affected areas from satellite images. In the survey, optical satellite images with multiple resolutions were used as maps, and GPS-linked digital cameras were used to obtain photos with location information⁸⁾. The field survey was carried out for four days from January 8 to 11 in the affected areas of Khao Lak, Phuket Island, and Phi Phi Island, and the locations and directions where the photos were taken are shown in the figure⁷⁾.

On the 10th anniversary of the tsunami in December 2014, Yamazaki, Maruyama, Pennung, and Pisut Nakmuenwai (who was affiliated with GISTDA and a Ph.D. student at Chiba University at the time) visited almost the same area as the first survey in January 2005. Our impression at the time was that the tourism industry on Phuket Island seemed to have recovered almost completely, but the severely damaged areas of Phang Nga Province, such as Khao Lak, were still in the process of recovery, and many buildings and resorts were left as they were at the time of the tsunami.

The survey in Khao Lak in December 2024 was mainly for the purpose of participating in a conference tour to visit the tsunami museum and memorial sites¹¹⁾, and was not intended to observe the state of recovery of the damaged facilities. Therefore, for areas that we were unable to visit this time, we will refer to satellite images from multiple periods and past survey photos.

The central part of Phang Nga Province, from Ban Nam Khem fishing port through Pakarang Cape to Khao Lak Lamalu National Park, is an area with lowlands along the coastline and many large resort hotels. Landsat satellite images on Google Earth covering this area over time from before the tsunami to the present are compared in Fig. 2 for the black square area in Fig. 1 (b). The survey route in December 2024 is shown by a blue line in the January 2023 Landsat image. Yellow pins are placed at the main

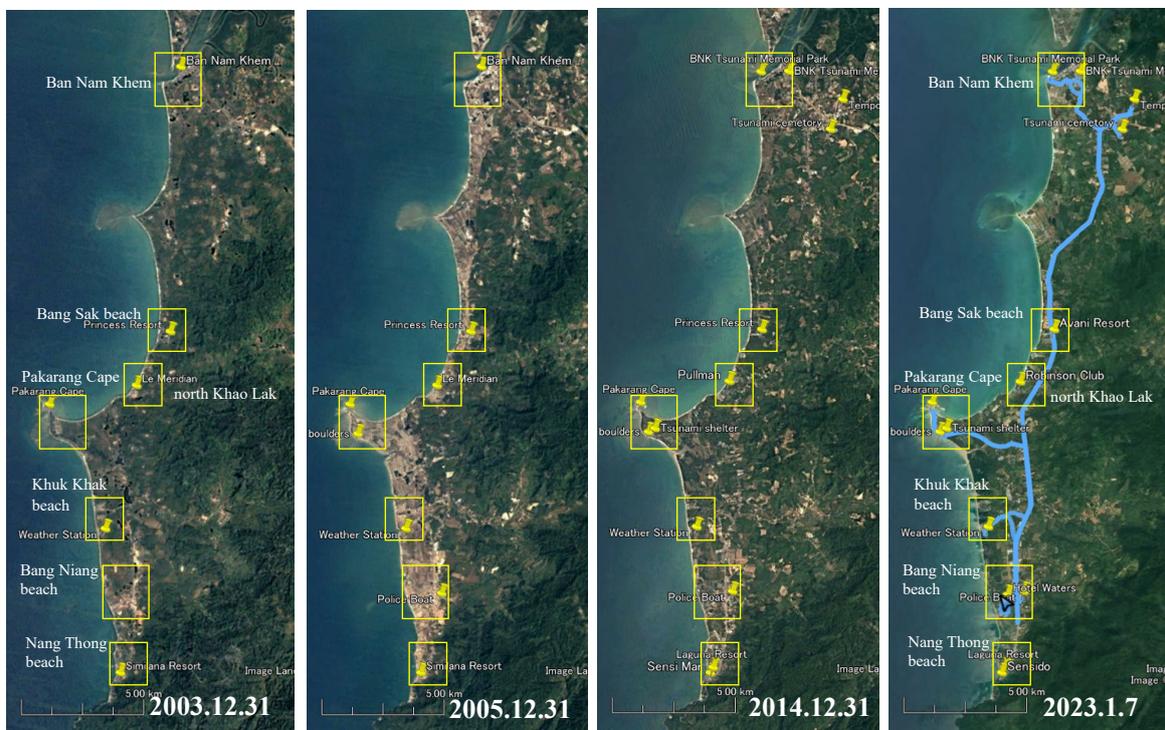


Fig. 2 Landsat satellite images of central Phang Nga province at four different times, main survey locations, and survey route in December 2024 (blue line)

survey locations, and the seven areas to be examined in the time-series high-resolution satellite images are shown by yellow squares.

The first three images were all taken on December 31, and the latest image was taken on January 7, so there is almost no influence of seasonal vegetation changes. In the image from 2003, one year before the tsunami, vegetation extends to the coastline, but in the image from 2005, one year after the tsunami, the vegetation appears to have withered. Moreover, in images taken in 2014, 10 years after the tsunami, the vegetation appears to have recovered to its pre-tsunami state. Below, we will divide the area into two regions, north and south, separated by Pakarang Cape, and conduct a detailed observation of the state of recovery in these areas based on high-resolution optical satellite images and field photos.

3. RECONSTRUCTION STATUS OF THE NORTHCENTRAL PHANG NGA PROVINCE

3.1 Ban Nam Khem

Figure 3 compares high-resolution satellite images of the area around Ban Nam Khem fishing port taken by Maxar (on Google Earth) for four time-instants after the tsunami. The locations where the on-site photographs were taken are included in the satellite image from a similar time period. The fishing port is located at the mouth of several rivers and faces a narrow strait between the port and Khao Island. This resulted in the concentration of tsunami energy and caused severe damage (photos **a** and **b**). The satellite images also show that the southern end of Khao Island was eroded by the strong ocean currents in the latter period (2018). At the time of the tsunami, about one-quarter of the villagers, which numbered 4,200, died, and about 80% of their homes were washed away^{13), 14)}.

The village was thus designated as a model district for recovery from the tsunami, and a memorial park was opened in 2006 (photo **c**). In 2017, the Phang Nga Provincial Tsunami Museum was also built on high ground outside the tsunami danger zone (photo **d**). The red and blue fishing boats, which have become symbols of the tsunami hazard, were originally left where they washed up, but a few years later they were moved to a site outside the museum. However, due to deterioration of the wooden boats, replicas are now on display. The museum has an exhibition room for crushed cars and other items, as well as a theater where educational videos can be viewed. The roof of the building also serves as a tsunami shelter where several hundred people can be accommodated. In Ban Nam Khem, temporary housing used at the time still remains. A cemetery for tsunami victims has also been set up in the location where many unidentified bodies were kept frozen in the period just after the tsunami.



Fig. 3 Multi-temporal high-resolution satellite images and on-site photos of Ban Nam Khem fishing port area

3.2 Ban Sak Beach

As we head south on National Highway 4, which runs north and south through Phang Nga Province, and the road approaches the coastline, we begin to see a number of large beach resorts. One of these is the area around Ban Sak Beach, shown in Fig. 4. At the time of the tsunami, there was Princess Resort with a row of cottages here, and a large hotel was under construction just to the north, but this area was totally destroyed by the tsunami (photos **a** and **b**). We visited this area again in December 2014, and found that it had been left as it was at the time of the disaster, with vegetation overgrown and turning it into a jungle (photos **c** and **d**). Although we only drove past the area during the survey in 2024, high-resolution satellite images and Google Maps showed that the damaged hotel under construction had opened in 2018 as the five-star Outrigger Resort, a three-story reinforced concrete building. We also learned that the old Princess Resort began rebuilding around 2018, and that it was renamed the five-star Avani Resort and opened around 2021. No hard countermeasures such as seawalls or raising the ground level have been implemented, so there is a high risk if another large tsunami hit the area. However, in the case of Avani Resort, a six-story reinforced concrete main building has been built, which appears to function as a tsunami evacuation building.



Fig. 4 Multi-temporal high-resolution satellite images and on-site photos of Ban Sak Beach area



Fig. 5 Multi-temporal high-resolution satellite images and on-site photos of northern Khao Lak area

3.3 Northern Khao Lak

Another large beach resort has existed since 2004 along the coast about 3 km further south from Ban Sak Beach on National Route 4. This is the luxury hotel Le Meridian, shown in Fig. 5. The hotel's main building escaped the tsunami because its main entrance facing the road in front is on the third floor, but the second and lower floors, cottages, and pools were hit by the tsunami (photos **a** and **b**). However, when we visited 10 years later in December 2014, it had been renamed Pullman Resort and had been completely restored (photos **c** and **d**). Looking at Google Maps, it has now been renamed again to a five-star resort called Robinson Club.

4. RECONSTRUCTION STATUS OF KHAO LAK IN PHANG NGA PROVINCE

4.1 Pakarang Cape

Pakarang Cape is a cape located in the northern part of the area called Khao Lak, jutting out into the Andaman Sea. Figure 6 shows Ikonos satellite images taken before and after the tsunami¹⁵⁾, and high-resolution satellite images by Maxar (on Google Earth) taken two times after the tsunami. During the 2004 Indian Ocean tsunami, the Bamboo Orchid Resort at the tip of the cape was hit by the tsunami from two directions and destroyed completely⁷⁾ (photos **a** and **b**). The tsunami height at the tip of the cape was reported to be nearly 9 m in some places¹⁶⁾. Two tsunami evacuation towers were subsequently built on the coastline of Khao Lak, one of which is located on this cape (photo **c**). One of the four evacuation warning siren towers built in Khao Lak is also located in this area.

The cape area was originally a resort with a wide sandy beach, but it was abandoned for a long time after the tsunami. However, at the time of the 2024 survey, port construction, which is thought to be the construction of a fishing port, had begun. What was confirmed for the first time during the 2024 visit was the group of tsunami boulders that spread across the west coast of the cape (photo **d**). These can be read even by enlarging the Ikonos image taken immediately after the tsunami. Goto et al.^{16), 17)} have already conducted detailed investigations through field surveys and numerical analysis, showing that the boulders in this area, up to 4 meters in diameter, are of coral reef origin and were carried by the tsunami and deposited here where the waves were broken in shallow waters and lost their energy.



Fig. 6 Multi-temporal high-resolution satellite images and on-site photos of Pakarang Cape area

4.2 Khuk Khak Beach

Figure 7 shows the surroundings of the meteorological observation facility located approximately 5 km south of Pakarang Cape. This single-story reinforced concrete building (photo a) is located approximately 200 m from the coastline and approximately 300 m from the river mouth to the north (photo b), and was hit directly by tsunamis that were higher than the roof⁷⁾. Traces of damage indicating the destructive power of the tsunami, such as bridges washed away and destroyed cottages, were spread all around the area, and as of the 2014 survey, buildings had been left almost untouched (photo c). The meteorological observatory building was designated as a tsunami memorial structure, and an evacuation warning siren tower was newly erected after the disaster next to the building (photo d).



Fig. 7 Multi-temporal high-resolution satellite images and on-site photos of Khuk Khak Beach area

4.3 Bang Niang Beach

Figure 8 shows the area around Bang Niang Beach, about 3 km south of the meteorological observatory. Flat land continues from the coastline in this area, and the tsunami came over National Route 4, which runs about 1 km inland. Because there was also a small river flowing, the tsunami went deep up the coast, and the police boat was washed up about 1.2 km from the coast (photos a and b). In recent years,



Fig. 8 Multi-temporal high-resolution satellite images and on-site photos of Bang Niang Beach area

large hotels have opened one after another in this area close to the coast (photo **c**), and it has become a popular resort. The washed-up police boat was later placed on a pedestal on land, and the surrounding area is open to the public as a tsunami memorial site (photo **d**). A tsunami museum run by an NPO has also been established nearby. A tsunami warning siren tower has also been installed in this area, but experts have pointed out that it is more than 1 km away from the coastline, so the sound will not reach resort guests on the beach.

4.4 Nang Thong Beach

Figure 9 shows the area around Nang Thong Beach, about 3 km south of Bang Niang Beach. The long sandy beach of Khao Lak ends here, and going further south, National Highway 4 climbs a slope and reaches the peninsula of Khao Lak Lamlu National Park. Similana Resort, which was open at the time of the tsunami, and the commercial facilities to the north were hit by a tsunami up to the height of one-story building roofs, causing devastating damage (photo **a**). The coast was also eroded by the tsunami, and debris carried by the tsunami was scattered around⁷⁾ (photo **b**).

When we visited again in December 2014, the hotel building had been renovated and was open under the name Sensi Mar, and Laguna Resort had opened to the north. The international conference to commemorate the 20th anniversary in December 2024¹¹⁾ was held at Laguna Resort. When we went to check on the hotel next door, we found that it was now operating under the name Sentido (photo **c**). The layout of the buildings and pools was the same as before, but it appears that it has undergone several renovations and has changed management. Sand has been brought in to the beach, and it has been restored to a well-maintained resort. This shows that the tourism industry has an extremely high level of resilience against tsunami disasters in Thailand.



Fig. 9 Multi-temporal high-resolution satellite images and on-site photos of Nang Thong Beach area

5. CURRENT STATUS AND ISSUES OF TSUNAMI DISASTER MITIGATION MEASURES IN SOUTHERN THAILAND

Through the field survey so far, we felt a little curious about the fact that reconstruction has been carried out without any hard measures such as seawalls or raising the ground level in this region, which suffered from severe tsunami damage. Therefore, we investigate the latest status of tsunami hazard assessment in this region. The current status of tsunami disaster mitigation measures that are actually being implemented is also investigated and future issues are discussed.

5.1 Tsunami hazard assessment

To evaluate the tsunami hazard in southern Thailand, it is necessary to investigate the tsunami history before the 2004 Sumatra earthquake. However, there are no records of past tsunamis in this region. Therefore, researchers from all over the world investigated tsunami deposits hidden in the strata^{18), 19)}. The west coast of Phra Thong Island (Fig. 1) in Phang Nga Province was selected as a suitable location for tsunami deposit investigation because the land has not been altered much. Figure 10 compares Landsat satellite images (on Google Earth) before and after the 2004 tsunami. The image taken in December 2005 shows that vegetation on the west and south coasts had decreased compared to that of December 2003, and these areas are believed to be inundated by the 2004 tsunami. During our survey in January 2005 (two weeks after the tsunami), we landed on the north coast by a small boat and surveyed the surrounding area (photo a). The coastline was clearly marked by the tsunami impacts, and even a short distance inland, buildings had been hit by the tsunami up to the ceilings on their first stories, with



Fig. 10 Landsat images of Phra Thong Island before and after the 26 December 2004 tsunami and field survey photos on 8 January 2005 (The red square indicates the area shown in Fig. 11.)

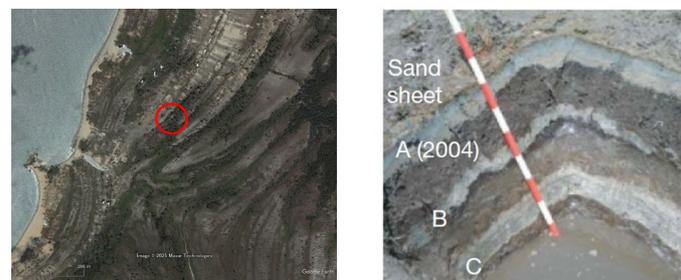


Fig.11 Excavation survey of tsunami deposits on Phra Thong Island¹⁸⁾ (The red circle in the left photo indicates the digging site of the right photo.)

everything except the foundations and pillars being washed away (photos **b** and **c**).

Figure 11 shows an example of pit and trench excavation surveys conducted on the west coast of the island to investigate paleo tsunami deposits. Three layers of sand were identified at this site and are considered to be tsunami deposits. A radiocarbon dating has estimated that the top layer-A is from the 2004 Sumatra earthquake tsunami, the layer-B below that is 550–700 years older, and the layer-C below that is 1,500–1,850 years older¹⁸). These results are extremely important, and indicate that large tsunamis that strike southern Thailand may occur at intervals of about 500 to 2,000 years.

This is much longer than the period of earthquakes in the Nankai Trough in Japan, and is close to the situation in which large tsunamis before the 2011 Tohoku earthquake in the Sendai plain and the Pacific coast of Fukushima date back to the 869 Jogan earthquake. In Japan, on the Pacific coast of the Tohoku region, construction and raising of seawalls has been underway since 2011 not only in Iwate Prefecture, which has been hit by four tsunamis in the past 130 years, but also in Miyagi Prefecture and south. Meanwhile, in Thailand, no construction of seawalls or raising of land levels has been seen, even in areas hit by the 2004 Indian Ocean tsunami, and no one has pointed out the need for such work. It is considered that most people believe that tsunami countermeasures are not necessary at present if the next tsunami will occur more than 500 years from now.

But the possibility of a tsunami from a different seismic source has been pointed out recently. This is the possibility of a mega earthquake exceeding magnitude 8 occurring in the Sunda Trench (off the coast of Myanmar), which is further north of the source zone of the 2004 megathrust earthquake shown in Fig. 12^{20), 21)}. The Arakan earthquake of M8.5 or more was recorded in this area on April 2, 1762, and the possibility of a recurrence of this earthquake has been pointed out²⁰⁾. In order to prevent another major disaster like the 2004 earthquake tsunami, which we were completely unprepared for, it is necessary to develop emergency tsunami evacuation measures based on the latest means of information transmission.

We must also not forget the rising sea levels and the increasing scale of meteorological disasters due to the effects of global warming in recent years. In May 2008, a cyclone that occurred in the Indian Ocean struck the southern lowlands of Myanmar from the west, instead of the usual route, causing severe damage from the storm surge^{22), 23)}. Areas facing the sea need to prepare for the possibility that the risk of storm surge disasters may increase in the future.

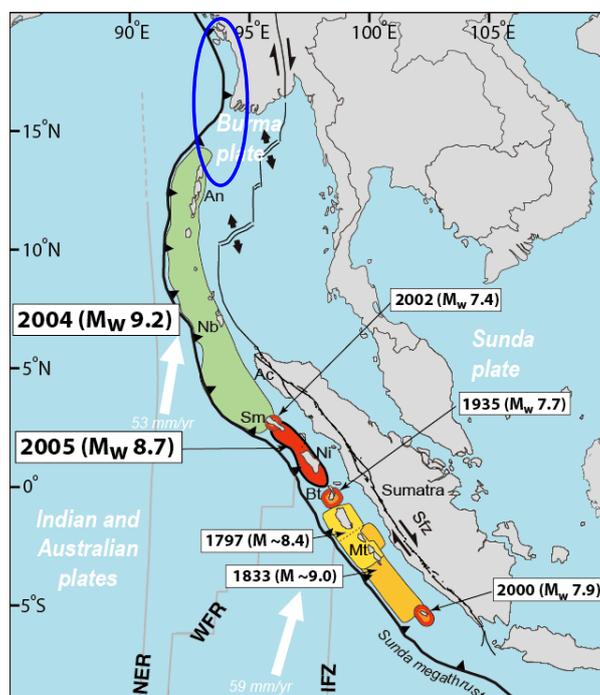
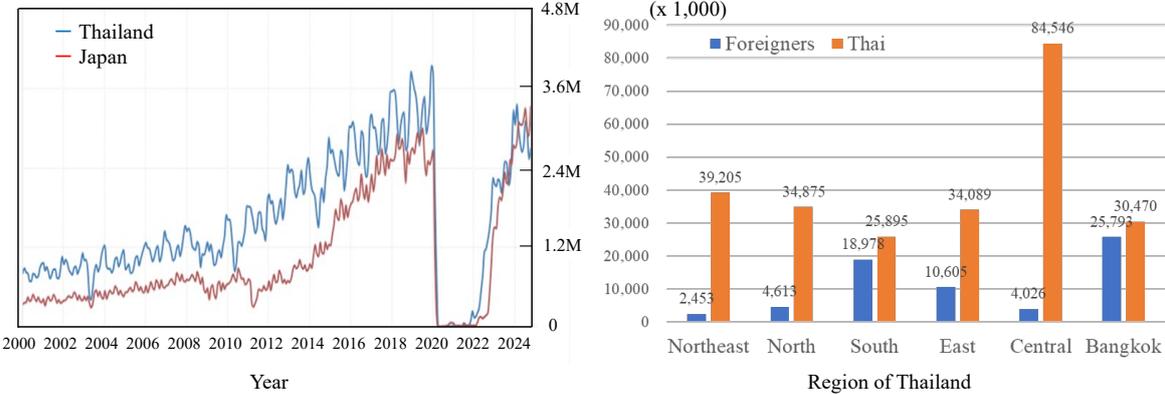


Fig.12 The trench off the coast of Myanmar where the recurrence of a mega earthquake is feared (The area of the blue ellipse)

5.2 Tsunami evacuation measures

Looking at the Kingdom of Thailand as a whole (1 metropolis and 76 provinces), the number of foreign tourists has been increasing for over 40 years, and the impact of the tsunami and political turmoil has not been seen. Figure 13(a) shows the number of people entering Thailand by month since 2000. The number of foreign visitors, which was 12.65 million in 2004, reached 39.92 million in 2019 before the COVID-19 pandemic, and fell to 430,000 in 2021, but recovered to about 35.55 million in 2024²⁴. Thailand's population is 66.09 million (2022), which is about half of Japan's population (127 million) at the same time.

However, the number of visitors, who are mainly considered tourists, has long far exceeded that of Japan, and Thailand continues to be one of the leading tourist destinations in Asia. Looking at the destinations of Thais and foreigners within Thailand (Fig. 13(b)), southern Thailand, including Phang Nga Province, will have 25.89 million Thais and 18.98 million foreigners in 2023, making it the region with the second highest proportion of foreign tourists in Thailand after the capital, Bangkok²⁵. The regional divisions in Fig. 13(b) basically correspond to those in Fig. 1(a), but the Central region represents the Bangkok metropolitan area excluding Bangkok City and 18 provinces in the Central and Western regions. These statistics also show that foreigners visit an average of 2.4 of the 1 metropolis and 76 provinces in one trip.



(a) Comparison of the number of arrivals to Thailand and Japan²⁴ (b) Regional breakdown of tourists in Thailand 2023²⁵

Fig. 13 Trends in the number of visitors to Thailand and Japan and Thai domestic travel destinations

In southern Thailand, few hard countermeasures against tsunamis have been seen, but emergency evacuation measures were started immediately after the 2004 Sumatra earthquake. In 2004, there was about two hours between the earthquake and the tsunami hitting southern Thailand, but the national government did not issue any warnings or evacuation orders. In response to this, many warning siren towers were installed on the coasts of Phuket and Phang Nga Provinces to encourage early tsunami evacuation. In addition, the construction of tsunami shelters (evacuation towers) has progressed, and signs indicating the evacuation direction have been installed in various places.

Figure 14 shows the locations of warning siren towers, evacuation routes, and evacuation sites in Khao Lak, where the highest tsunami actually hit. There are a total of four warning siren towers, but if the range where the voice can reach is a radius of 1 km, there are still many tsunami inundation areas that are not covered. In this regard, the current mobile phone penetration rate in Thailand is extremely high, and the smartphone penetration rate will exceed 98% in 2023. It would therefore be possible to create a system that sends warnings similar to Japan's Emergency Earthquake Alerts via mobile phones, and because social media is widely used, it is likely that people will also be able to contact family and acquaintances, so there should be no problem with transmitting information to people other than tourists on the beach.

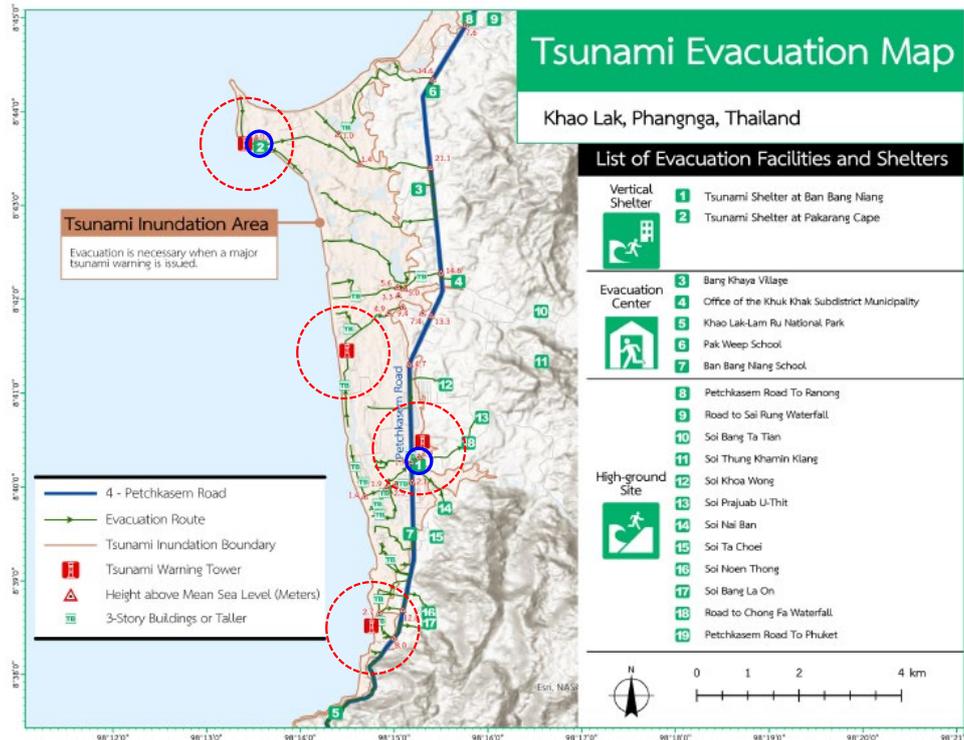


Fig. 14 Locations of the four warning siren towers in Khao Lak (the center of red circles), evacuation routes (green lines), and tsunami evacuation shelters (green squares)²⁶⁾



Fig. 15 Tsunami evacuation signs installed at Pakarang Cape (a, b) and a tsunami danger sign in front of the meteorological observatory (c: December 2014, d: December 2024)

There are many signs indicating evacuation routes and tsunami danger zones (Fig. 15), but some have become illegible after more than 10 years (photo d). Thus, the continuing maintenance of these evacuation facilities and equipment is a major issue. In the Khao Lak area shown in Fig. 14, the number of buildings in the flooded area in December 2004 was 2,434 in the 2003 statistics, but had almost doubled to 4,414 in the 2023 statistics²⁶⁾. As this increase includes large resort hotels, the population trapped in the flooded area may have increased several times over depending on the period of year. Providing information and guiding evacuation to foreign tourists who have no experience of earthquakes or tsunamis will be a major issue in the future.

Thus, communicating hazard information to foreign tourists is an important issue in Thailand, but for disasters such as tsunamis, where the next strike is uncertain, it is too expensive to build and maintain a dedicated disaster information system like Japan's emergency earthquake alert system or ocean bottom earthquake and tsunami observation network. One attempt was the "Development and implementation of DX promotion tools for tourism supply chain resilience considering the risk of natural disasters²⁷⁾," which was adopted as part of the Japan External Trade Organization (JETRO)'s "Japan-ASEAN Asia Digital Transformation (DX) Promotion Project²⁸⁾." Masahiko Honzawa, one of the authors, participated

in this project, which will be introduced here. The smartphone app²⁹⁾ developed using Phuket Island as a model area provides tourists staying at hotels with various information about tourism, as well as information on how to protect themselves in the event of a natural disaster and information that will be useful in the event of illness or traffic accidents while sightseeing, as shown in Fig. 16. When an earthquake tsunami occurs, the system shows the tsunami arrival time and the safest and shortest evacuation site from the current location on a tsunami inundation forecast map. Implementing such a system in tourist destinations and working to maintain and update it is considered an important safety measure.

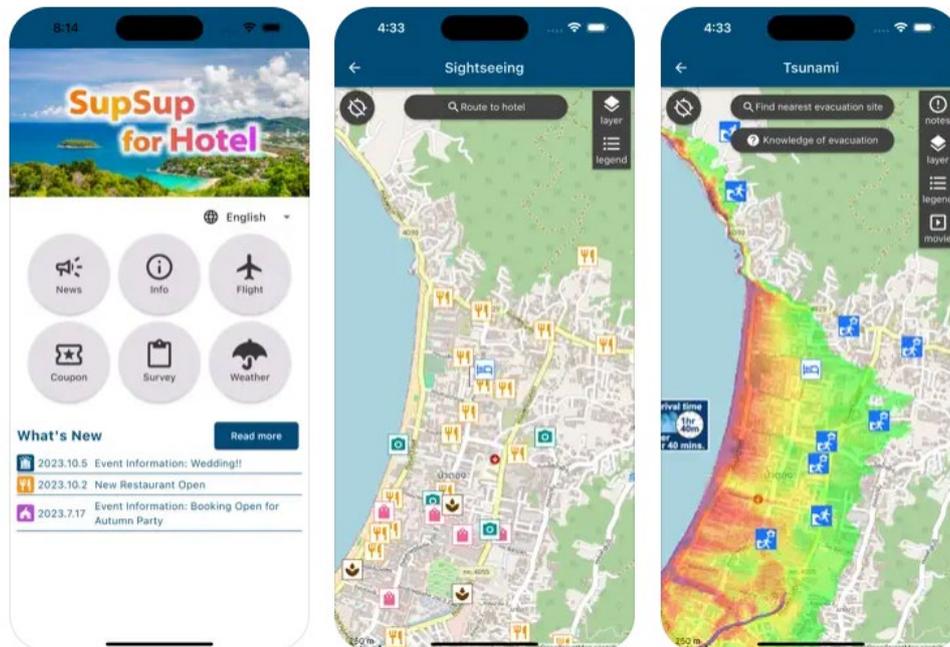


Fig. 16 Screenshots of a smartphone app developed as part of JETRO's Asia DX Promotion Project²⁹⁾ (From the left, the initial screen, tourist information, and tsunami information)

6. CONCLUSIONS

Based on optical satellite images taken at various times and seven on-site surveys, we attempted to grasp the 20-year reconstruction status of the Khao Lak area in Phang Nga Province, southern Thailand, which sustained serious damage from the Indian Ocean tsunami on December 26, 2004. In a survey conducted 10 years after the tsunami, many damaged facilities were left abandoned, and reconstruction was only half-done. However, in the latest survey conducted 20 years after the tsunami, the resort area was bustling with foreign tourists, and the number of hotels and buildings had increased significantly. In addition, tsunami museums and tsunami memorial sites had been established, and efforts were being made to pass on the memory of the disaster.

Tsunami deposit surveys of this area have shown that the tsunami history has a wide range of return periods from 500 to 2000 years. It has also been pointed out that there is a possibility of a mega earthquake occurring on the plate boundary north of the source region of the 2004 Sumatra earthquake. Therefore, measures are necessary in case a tsunami or storm surge strikes. There are no hard countermeasures such as seawalls as current disaster prevention measures, but it seems appropriate considering the tsunami hazard level there. Meanwhile, progress has been made in installing warning sirens and vertical shelters for tsunami emergency evacuation, and in setting up evacuation routes to high-altitude evacuation sites. However, because the evacuation sites are far away in some cases, it has been pointed out that there is a need to designate tsunami vertical evacuation buildings in tsunami hazard areas, prepare evacuation routes by car, and consider methods of transmitting emergency information, including to foreign tourists.

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