The Damages by the Great East Japan Earthquake and the Contributions by Space Technology

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KEY WORDS: Disaster, Earthquake, Tsunami, Damage, Observation Satellite

ABSTRACT: If the huge disaster occurs, it is very urgent action for disaster management organizations to identify the damaged area, to estimate damage amounts, to make response plan. The Great East Japan Earthquake brought down unprecedented heavy damages to very large area in eastern part of Japan with big shaking and tsunami at 11th March 2011. After the earthquake and tsunami, many space agencies started to observe the affected area with the schemes such as the Sentinel Asia and the International Disaster Charter. Those data were very useful for the response against this catastrophic disaster.

1. Natural phenomena

1.1 Earthquake

On 11th March 2011, at 14:46 JST (5:46 UTC), the eastern part of Japan was shaken by a massive earthquake of moment magnitude (Mw) 9. The point of the hypocenter was 130km off the Pacific coast of Tohoku region, 24km deep. Mw 9.0 is the fourth largest in the world since 1900 and largest in Japan since recording started 130 years ago (cf. 1960 Chile Earthquake Mw9.5, 1964 Alaska Earthquake Mw9.2, 2004 Sumatra Earthquake Mw9.2). The Japan Meteorological Agency (JMA) named this earthquake as "The 2011 off the Pacific coast of Tohoku Earthquake". JMA seismic intensity of 7 (max) [in the Japanese scale of 1 to 7] was recorded in Kurihara city of Miyagi prefecture. Moreover, the intensity of 6+ was recorded in 28 cities and towns in Miyagi, Fukushima, Ibaraki, and Tochigi Prefecture. The intensity of 6- or weaker was observed nationwide from Hokkaido to Kyushu islands.

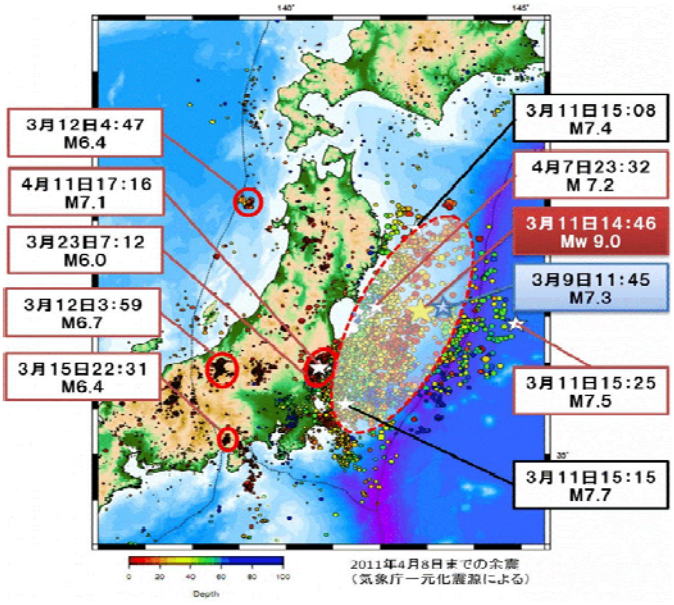

Fig.1 Aftershocks
Source: ERI, the University of Tokyo

1.2 Tsunami

The Mw. 9.0 earthquake at 14:46 and the series of large-scale earthquakes (Mw 7.4, 7.7, 7.5) that followed had resulted in multiple tsunami waves of unprecedented scales at the coastal areas of Hokkaido, Aomori, Iwate, Miyagi, Fukui, Ibaraki, and Chiba Prefectures. It has been reported that there were seven tsunami waves over a six hour period. Waves became more turbulent and more powerful upon reaching the inland areas. According to the experts, the fault rupture was about 500 kilometers long in a north-south direction and the tsunami waves hit the coastal areas

from different directions, one crossing over the other, explaining the destructive power of the tsunami.
Several scientific investigations are being conducted concerning the scale of tsunami. Initial survey by Tokyo University of Marine Science and Technology found that tsunami waves had reached the heights of 14 meters or 15 meters in many coastal areas, and as high as 38.9 meters in Miyako City, Iwate Prefecture. This is higher than the previous record of 38.2 meters in Ofunato City in the southern part of same prefecture during the 1896 Meiji Sanriku Earthquake Tsunami. It is generally believed that timber houses will be destroyed by tsunami waves higher than 2 meters. By contrast, concrete buildings can withstand 4 meters, or so, but will be destroyed if waves exceed 16 meters. Additionally, survey conducted by Tohoku University found that tsunami waves had reached as far as 5.5 kilometers inland of Sendai Plain. By using remote sensing technologies and GIS, the Geospatial Information Agency of Japan estimated the tsunami swamped areas to about 561 square kilometers covering the hardest hit prefectures of Aomori, Iwate, Miyagi, and Fukushima prefectures.

2. Damages

As of 6th September 2011, the government of Japan has confirmed 15,769 deaths, and 4,227 people missing as a result of the disaster. Most of people were killed by drowning, and elderly people failed to escape the disaster on time and were trapped by the tsunami. The disaster also damaged 830,000 buildings. Moreover, serious damage is recorded for infrastructure, such as bridges, transportation system, electricity, gas supplies, and communication services.
The estimated cost of damage, officially released by the Cabinet Office on 24 June, is 16.9 trillion Japanese yen (cf. Kobe earthquake: 10 trillion Japanese yen, Hurricane Katrina: 125 billion USD). This covers damaged houses, factories, lifelines, infrastructure (e.g. roads and bridges), the agricultural, fishery, marine farming and marine product industries.
According to those huge damages, the government of Japan officially named this biggest natural disaster as "Great East Japan Earthquake" following the decision made by the Cabinet Office on April 1st. Other names, such as the "Tohoku Region Pacific Coast Earthquake" or "Tohoku Earthquake", were used earlier.

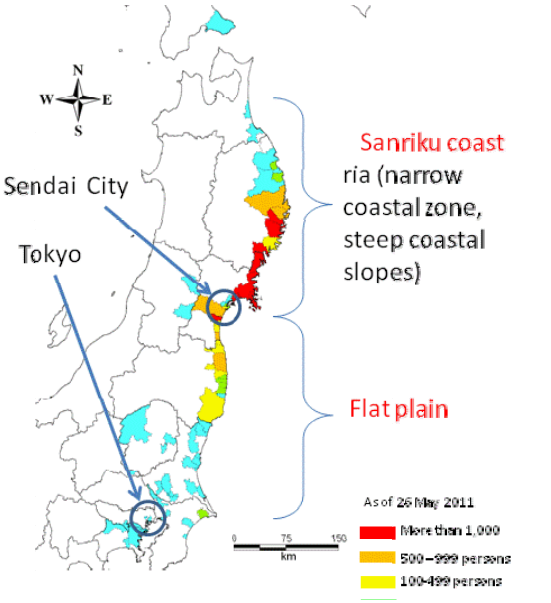

Fig.2 Casualties and areas

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Source: Cabinet Office (data taken from the webpages of prefectural governments and the National Policy Agency)

3. Disaster Affected Areas

The disaster-affected areas can be roughly categorized into three types based on their functioning capacity.

Type 1: Functions are not severely affected. These are cities or towns that suffered extensive damage but mostly in their coastal areas. Thus, the entire city or town can function relatively well. Sendai City and Natori City in Miyagi Prefecture fall under this type.

Type 2: Functions are partly paralyzed. These are cities or town centers that were heavily damaged and their functions were partly paralyzed. Ishinomaki City and Higashi-Matsushima City of Miyagi Prefecture and Ofunato City, Kamaishi City, and Miyako City of Iwate Prefecture fall under this type.


Fig.3 Wakabayashi Ward, Sendai city (March 22)

Type 3: Functions are totally paralyzed. These are cities or towns that were almost entirely devastated. Thus, their functions were totally paralyzed. Cities or towns of this type include those located in rather narrow land areas along sawtooth (rias) coastline. Minimi-Sanriku Town and Onagawa Town in Miyagi prefecture as well as Rikuzen-Takata City and Ootuchi Town in Iwate Prefecture fall under this type.

3.1 Type 1 (Wakabayashi Ward, Sendai City)

Wakabayashi ward is located in the eastern part of Sendai city facing the Pacific sea. Much of the area is flat plain used as rice paddies or fields with some scattered settlements. The local hazard maps were prepared for a tsunami of 3m high, but, in reality, a much higher tsunami, more than 10 meters, hit this area. It was along this area that tsunami waves reached as far as 5.5 kilometers inland. One of the intriguing findings from the field survey was that the embankment at West Sendai Road, about 5-6 meters high, parallel to and a few kilometers away from the coastal line, had been effective to stop tsunami waves from flowing further inland. Massive pile of debris was accumulated near the West Sendai Road.

Fig.4 Downtown area of Ishinomaki city (March 22)

3.2 Type 2 (Ishinomaki City and Higashi-Matsushima City)

Ishinomaki city is the second largest city in Miyagi prefecture with population about 170,000. Most of the city's downtown areas were inundated about 2 to 3 meters, damaging mostly the ground floors of buildings. Boats, vehicles, mud, and other types of waste were accumulated.

3.3 Type 3 (Onagawa Town and Minami-Sanriku Town)

Onagawa town is located in eastern Miyagi prefecture. The downtown area was totally destroyed by the tsunami. Along the coast, wooden houses were washed away, leaving only their foundations. Even reinforced concrete buildings collapsed. A hill just behind the fishing port was designated as an evacuation area. In the hospital, located on top of this hill which is nearly 16-17 meters high, traces of water were found. This indicates that tsunami waves were very high in this area perhaps because of topographical characteristics.

Minami-Sanriku town is located in northeastern Miyagi prefecture. The tsunami washed away most of the buildings, and the town was completely devastated. At Shizugawa Hospital located near the coast (some 200 meters inland), there were indications that the tsunami had reached the roof of a four storey building. In an apartment building near the seashore, which had been designated as a tsunami evacuation building, there were traces of water indicating that the tsunami had reached the 4th floor as well. The disaster management center of Minami-Sanriku, a three-story building, was designed to function as a tsunami evacuation building. When the tsunami struck, about 30 municipal officials evacuated to the rooftop, but only 10 survived. A young official who kept delivering evacuation notices to the villagers until the very last moment was among the casualties. It was generally believed that a three-storey reinforced concrete building could be designated as evacuation building. However, during this disaster, such kind structure was insufficient for protection.

Fig.5 The disaster management center of Minami-Sanriku town (March 23)

4. Contributions by Space Technology

After the earthquakes and tsunamis, cabinet office of Japan requested to observe affected areas to Japan Aerospace Exploration Agency (JAXA) and aerial survey companies. JAXA provided (1) disaster observation data such as emergency observation data and difference extraction information, (2) satellite geographical information including training, and (3) know-how on image analysis. The Sentinel Asia is the Asian initiative for effective disaster management by utilizing satellite technology. JAXA sent the

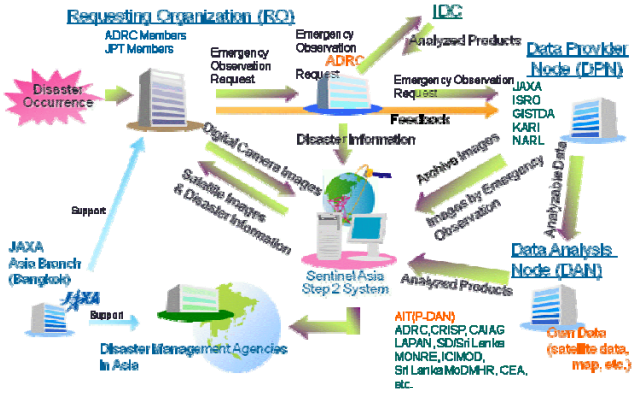

Fig.6 Mechanism of the Sentinel Asia and relationship with IDC

Emergency Observation Request (EOR) to Sentinel Asia, then also requested to the International Disaster Charter (IDC) within one hour after the main earthquake.
ALOS observed 400 scenes during March 12th to April 21st, and Sentinel Asia and IDC provided more than 5,000 scenes.
According to the utilizations of satellite images after the Great East Japan Earthquake, ADRC and JAXA is conducting the survey for effectiveness of space satellite data for disaster management in cooperation with Asia Air Survey and Yokoyama Space Information Institute. This survey covers seven prefectures affected by the earthquake and tsunami, especially, this survey focuses to utilize space images for damage estimation and making response plan. This survey will complete at the end of March 2012.

4.1 Survey 1: Comparing actual damages and satellite images, especially, the inundated area, changes in the crust and the ground, damages of buildings and structures

The places to be surveyed for inundation are port area, urban area, flat plain area, steep area, coastal forest, polder, and tideland. The places to be surveyed for changes in the crust and the ground are subsidence area, disappointed beach and scenic site, landslide, and liquefaction. The places to be surveyed for damages of buildings and structures are breakwater, embankment, roads, bridges, railways, aquaculture facilities, and public buildings. Analyzing damages by satellite images are useful but sometimes hard to identify them. The objective of survey 1 is to categorize damage types for future damage analysis by utilizing satellite images.

4.2 Survey 2: How satellite images were utilized in various organizations for their response and planning? Or why satellite images were not used?

Satellite images were provided to various organizations in and out of affected areas according to their requests, space agencies has expected that images would be useful for their response and planning. However those data were sometimes not utilized caused by limitation of data resolutions, GIS skills, PC power, data receiving time lag, and internet speed. This survey to actual users is necessary to promote the effective use of satellite images for future. The organizations to make interview survey are government, self-defense force, prefectures, municipalities, fisheries cooperatives, agricultural cooperatives, universities, institutions, private companies, and NPOs.

5. Conclusion

The East Japan Earthquake was the worst disaster in Japan, but damages were less than the Indian Ocean Tsunami. The disaster act, building code, tsunami wall, disaster drill, disaster education conducted in Japan should be evaluated. This information should be utilized in other countries.
The space technology can effectively contribute this kind of wide area disaster to identify damaged areas, but there is less feedback from user side. Therefore the contribution by space technology and the current situation of utilization of satellite images should be clarified. JAXA and ADRC will report the result of the survey in the next year.

References

Atsushi Koresawa, Yasuo Kawawaki, “Great East Japan Earthquake (GLIDE: EQ-2011-000028-JPN) Preliminary Observations”, May 2011, Asian Disaster Reduction Center and International Recovery Platform
Japan Metrological Agency (JMA), “The 2011 off the Pacific coast of Tohoku Earthquake -Portal-“, http://www.jma.go.jp/jma/en/2011_Earthquake.html (Sep. 9 2011)
Makoto Kawai, Japan Exploration Agency (JAXA), “The Great East Japan Earthquake”, Jul. 13 2011, The 4th JPTM for Sentinel Asia Step 2, Putrajaya, Malaysia July 12-14 2011
Prime Minister of Japan and His Cabinet, Government of Japan, “Information of “The 2011 off the Pacific coast of Tohoku Earthquake””, Sep. 7 2011, http://www.kantei.go.jp/saigai/pdf/201109061700jisin.pdf (Sep. 9 2011)