

Project Study on the Effective Countermeasures against Earthquake and Tsunami Disasters

Bulletin (No. 2)

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The 2011 Off the Pacific coast of Tohoku Earthquake and the Great East Japan Earthquake

This bulletin No.2 of the project study summarizes the 2011 of the pacific Coast of Tohoku Earthquake and the Great East Japan Earthquake.

1. Name of Earthquake and Disaster

Soon after the occurrence of strong earthquake on March 11, 2011, JMA (Japan Meteorological Agency) named the earthquake as "The 2011 off the Pacific coast of Tohoku Earthquake".

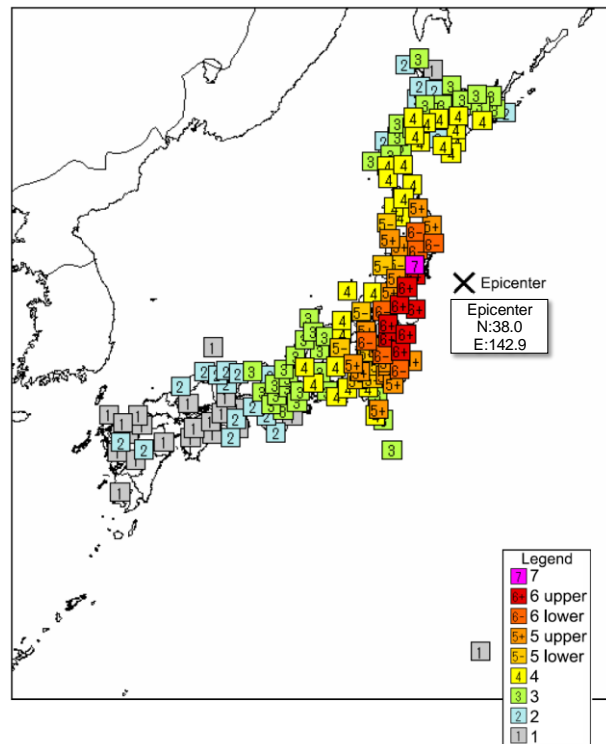
On April 1, 2011, Japanese Government officially decided the name of the disaster caused by the earthquake and the tsunami as "The Great East Japan Earthquake".

2. The Earthquake

A strong earthquake with Mw 9.0 occurred on March 11 at 14:46JST (5:46GMT) at a depth of approximately 25km, off-shore of Sanriku, the North-Eastern part of Japan. The event which has the largest magnitude ever recorded in Japan and 4th largest in the world (Figure 1), recorded a maximum seismic intensity 7 (JMA Seismic Intensity) at Kurihara City, Miyagi Prefecture as shown in Figure 2.

This event occurred on the plate boundary between the Pacific and the Continental plates near the Japan Trench subduction zone (Figure

3) and the focal mechanism showed a reverse fault with a compression axis in a WNW-ESE direction. In this region, a large-scale inter-plate earthquake with magnitude of 7.0 to



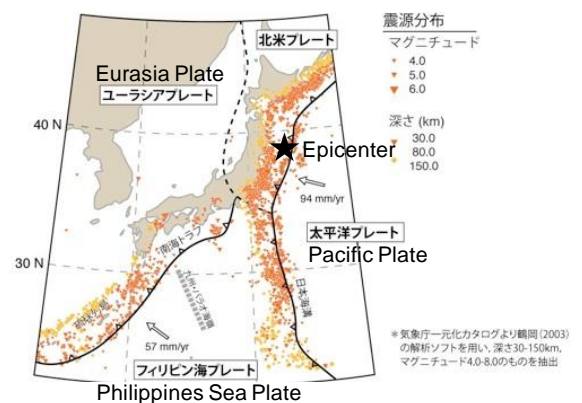
Source: http://www.jma.go.jp/jma/en/2011_Earthquake/2011_Earthquake_Intensity.pdf

Figure 2 Epicenter and JMA Seismic Intensity



Source: <http://www.geol.sci.hiroshima-u.ac.jp/~envi/link/TohokuEarthquake.html>

Figure 1 World Largest Earthquakes



Source: <http://www.geol.sci.hiroshima-u.ac.jp/~envi/link/TohokuEarthquake.html>

Figure 3 Plate Boundary near Japan

8.5 had been predicted to occur with 99% probability within 30 years. However, the earthquake of March 11 was much bigger than that of the predicted one.

More than 500 aftershock with larger than Mw5.0 were recorded mainly in the off-shore area of Iwate prefecture to Ibaraki prefecture with the area of 500km (NS-direction) and 200km (EW-direction) and the largest aftershock occurred at 15:15 on March 11 (JST) with Mw7.7 as shown in Figure 4 (as of April 18, 2011).

Crustal movements especially horizontal movement to the east-southeast and land subsidence have been observed after the earthquake in wide areas from the Tohoku to Kanto Region. The maximum horizontal displacement of approximately 5.3m to the east-southeast direction was observed at the Oshika station in Miyagi prefecture. The maximum subsidence of approximately 1.2m was also observed at the Oshika station.

3. The Tsunami

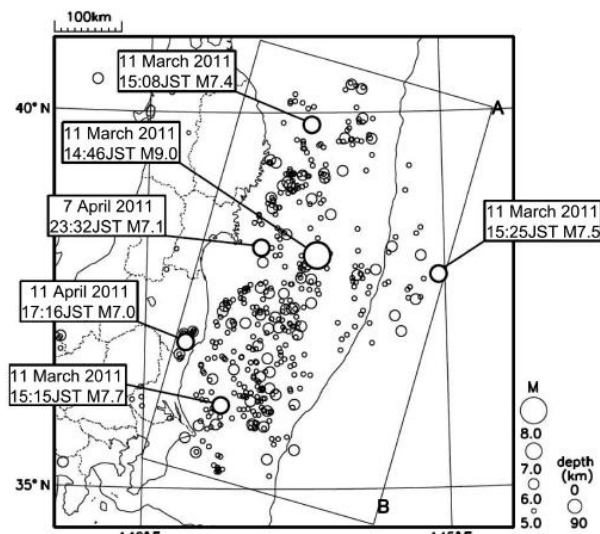
The earthquake generated a wide spread large scale tsunami. The tsunami reached to the coastal line of Sanriku area the nearest coast to the epicenter in about 30 min. The tsunami also propagated across the Pacific Ocean, and arrived at Hawaii in about 8 hours, the Pacific Coast of the USA in 9 to 12 hours and Chile in 22 hours (Figure 5).

According to the JMA report on March 12, the maximum recorded tsunami height was “more than” 7.3m at Soma Station and actual maximum height might be higher. As those stations operated by JMA were also affected very high tsunami and the tsunami height exceeded the recording range or the stations were damaged by the wave, JMA could not observe actual tsunami height.

To understand the actual height of the tsunami, researchers of universities and governmental institutes conducted a series of surveys and the survey results have been gathered and published by the Coastal Engineering Committee of JSCE (Figure 6).

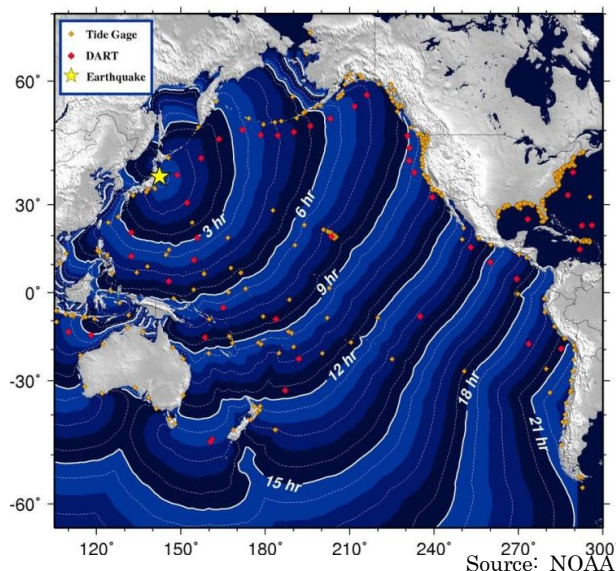
As shown in the Figure, the Sanriku coast

Period 12:00 JST, 11 March - 15:00 JST, 13 May, 2011
Depth <= 90km, Magnitude >= 5.0



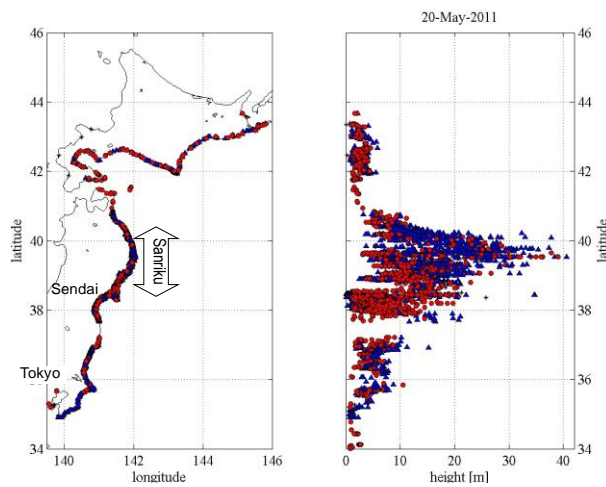
Source: JMA

Figure 4 Locations of Main Shock and Aftershock



Source: NOAA

Figure 5 Tsunami Travel Times



Note: not corrected for tides Source: JSCE

Figure 6 Surveyed Tsunami Heights

was affected by the very high tsunami with the maximum run-up height of more than 30m and more than 10m in average, while the tsunami height of the southern part of the coast was relatively low with less than 10 m.

GSI conducted the analysis of the tsunami inundation along the Pacific coast (Figure 7, Sample: results of analysis), and estimated that 561 km² was inundated by the tsunami.

4. Damages

The earthquake and the tsunami caused the serious damage especially along the Pacific coast of the North-eastern Japan. The Tsunami killed tens of thousands people, and destroyed the towns, infrastructures, lifelines and other livelihoods. As of May 13, the Japanese Government confirmed 15,012 death and the number of casualties are still increasing due to delay of activities especially in the area affected by the failure of Fukushima nuclear power plant. Table 1 summarizes the human and housing damages caused by the earthquake and the tsunami by prefectures and Figure 8 shows the human damage ratio by the local government level.

As shown in the Table, about 95% of the human damage concentrated in the three prefectures of Iwate, Miyagi and Fukushima where the tsunami heights were relatively high while the housing damages distributed to prefectures along the Pacific coast.

On the other hand, the tentative analysis for the damage ratio shows an intriguing result as relatively high value of damage ratio came at cities and towns where have been functioning as regional centers like Onagawa, Minmisanriku, Rikuzentakada, etc.

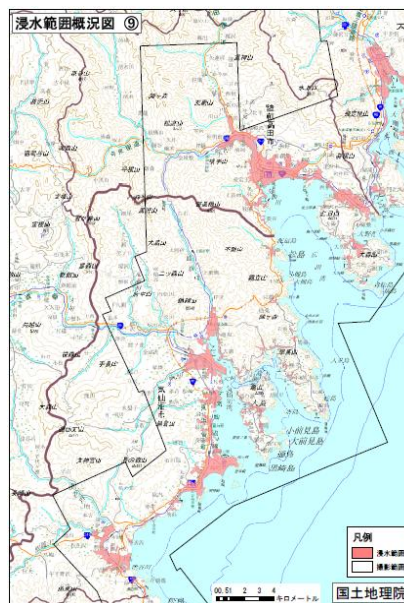
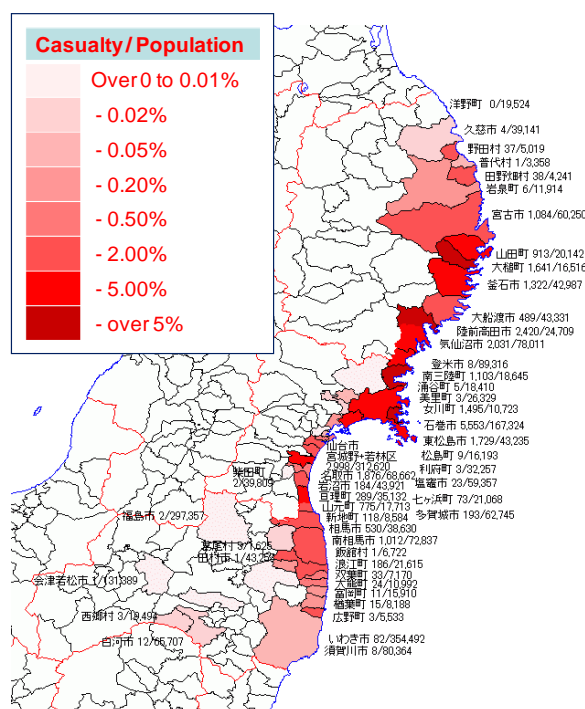


Figure 7
Results of Tsunami Inundation Analysis
Source: GSI



Note: Tentative Analysis Source: Study Team

Figure 8 Human Damage Ratios by Local Government

Table 1 Summary of Tsunami Damage

As of May 13, 2011

	Human Damage			Housing Damage			
	Death	Missing	Injured	Total Destroyed	Severely Damaged	Partially Damaged	Total
Aomori	3	1	61	273	987	74	1,334
Iwate	4,392	3,275	165	17,100	2,569	1,259	20,928
Miyagi	8,941	5,971	3,411	56,710	12,237	13,345	82,292
Fukushima	1,544	632	227	7,246	5,571	42,202	55,019
Ibaraki	23	1	693	1,321	6,518	103,510	111,349
Others	38	2	722	947	3,778	83,271	87,996
Total	14,941	9,882	5,279	83,597	31,660	243,661	358,918

Source: Emergency Disaster Response Headquarters

About 118,000 people are still displaced and forced to stay in temporary shelters even though the number of the displaced people is decreasing day by day. The number of the displaced people was said to be reached more than 400,000 in the peak period.

The earthquake and tsunami caused the great impact to the infrastructures such as road and bridges, railways, ports and airports and lifelines. Blackout extended approximately 8.9million houses and water outage affected about 2.2 million houses. Almost all harbors located in the pacific coast was lost its function by the tsunami.

Japanese Government estimated a total economic damage and published on March 23, and it was estimated at 16 to 25 trillion yen (USD195 to 305 billion) which is equivalent to 3.4% to 5.3% of Japan's GDP last year, and the estimates also mentioned that GDP is expected to be pushed down about 0.5% by this disaster due to the decrease in domestic production.

References:

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- (Some references are in Japanese only)

Abbreviations:

GSI:	Geospatial Information Authority of Japan
JST:	Japan Standard Time
JMA:	Japan Meteorological Agency
JSCE:	Japan Society of Civil Engineers



Yuriage area, Natori City ("A" on the map next page)

A tsunami with about 9m height arrived at the coast of Yuriage town, Natori City, and it washed out entire town. (Photo taken on Mar. 29, 2011 by Matsumaru)



Fudai Town

Tsunami protection dike with the height of 15.5m protected town.



Taro Town

Tsunami destroyed tsunami breakwater (down left) and arrived town with more than 20m, and washed the town away (down right).



Touni Town

Tsunami overtopped 12.5m height tsunami barrier (left) and destroyed the houses (right).



Yoshihama Town

Yoshihama suffered serious damage in the 1933 tsunami and moved the residential area to high-lands. Because of this, the village suffered damage mainly to the farmland, and almost none to houses.



Motoyoshi Town

About 10m tsunami arrived this area. Due to tsunami and land subsidence by the earthquake, sea water came into about 300m inland from original coastline.

(Photo: on Mar. 27, 2011 by Matsumaru)

Minami-Sanriku Town

Apartment designated as a tsunami escape building at the head of bay of Minami-sanriku Town. The tsunami came up to the roof of this building with the height of 15.5m

(Photo: on Mar. 27, 2011 by Matsumaru)



Destroyed Pier at Soma Port

Diffraction tsunami wave concentrated and destroyed piers. (Photo: Mar. 29, 2011 by Matsumaru)



Damaged roof parts of the apartment.



Damaged Seawall (not for Tsunami) at Isobe, Soma City ("C" on the map)

About 7m tsunami destroyed seawall. (Photo: Mar. 29, 2011 by Matsumaru)



Inside of Terminal Building of Sendai Airport ("B" on the map)

Terminal building is located about 1km from the coastline and was inundated about 3m.

(Photo: Mar. 29, 2011 by Matsumaru)