May 25, 2011

Tsunami Impacting Eastern Japan and Preparedness for Extraordinary Natural Disaster

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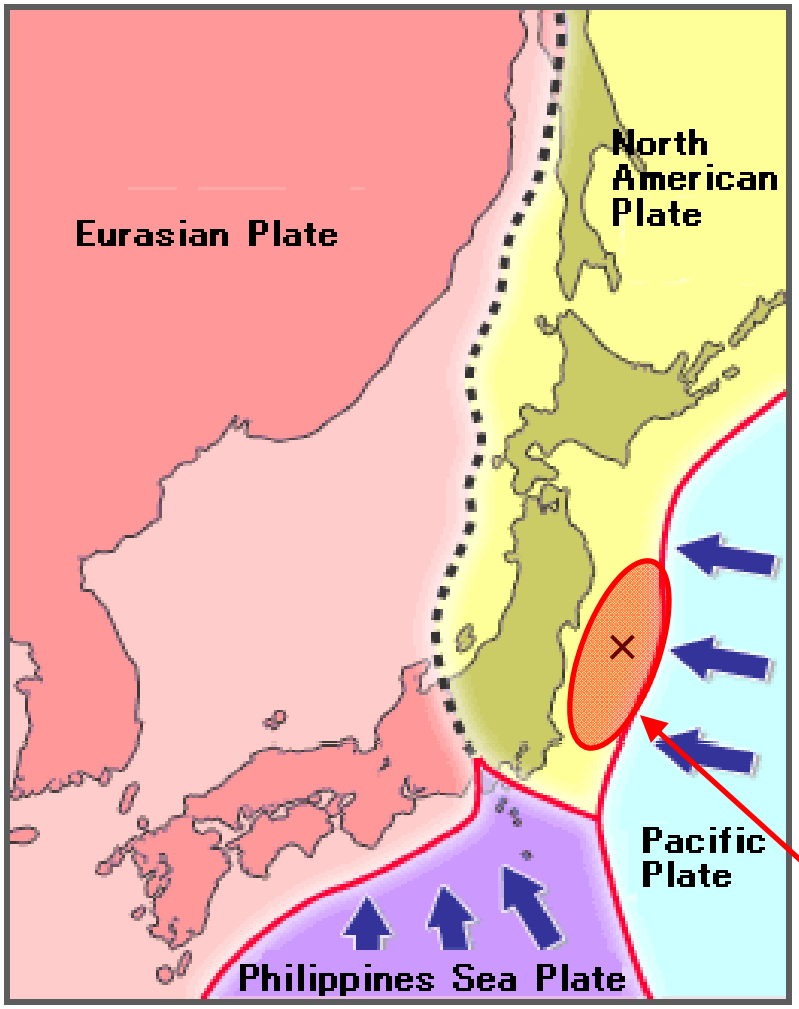
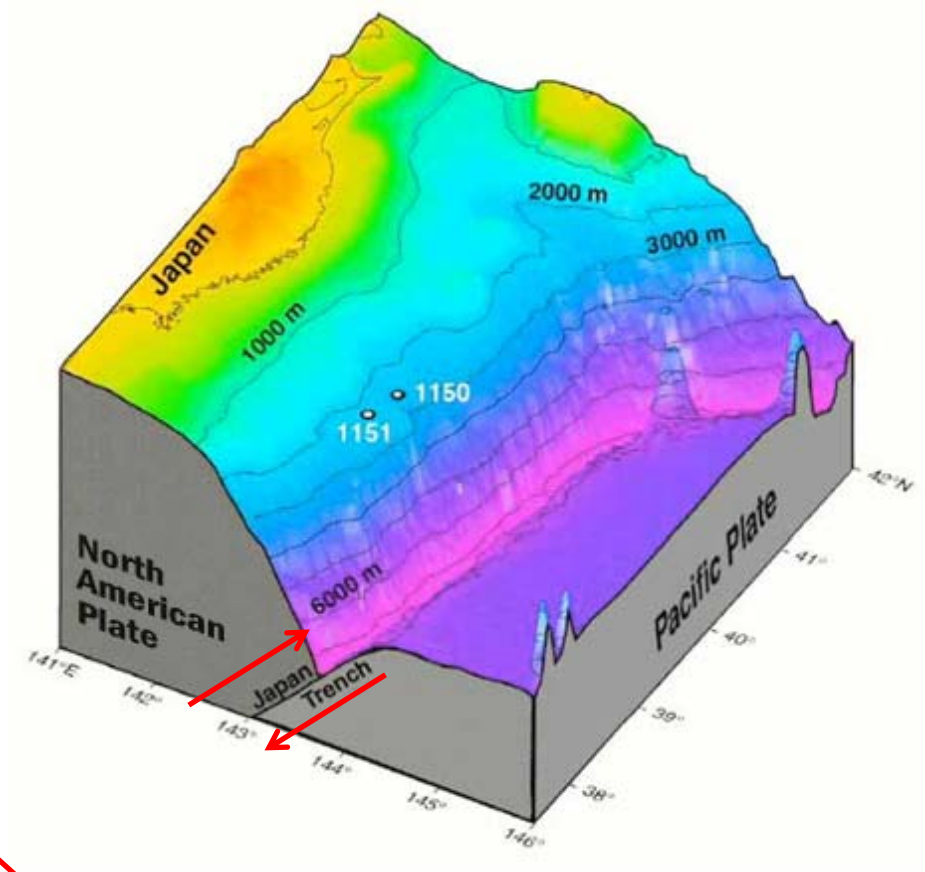
Source region of the earthquake



http://www.sonpo.or.jp



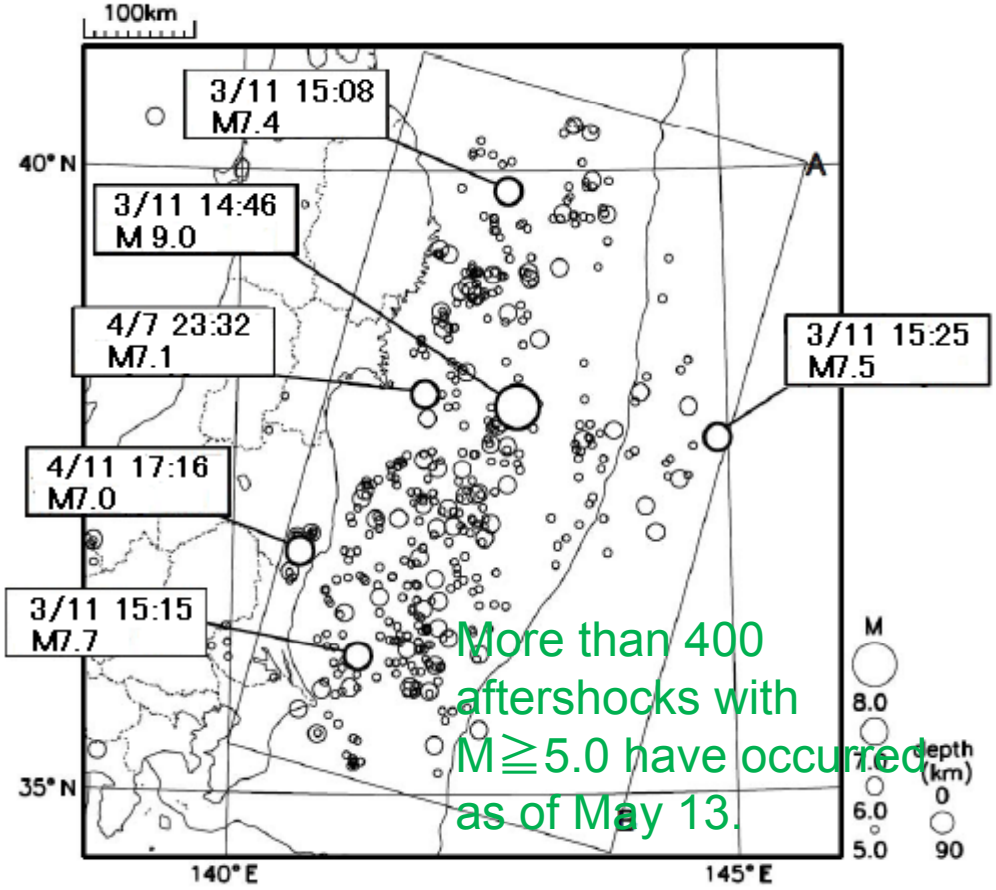
http://alterman47.wordpress.com

Approximate source region of the earthquake. ‘X’ denotes the epicenter.

The pacific plate is subducting beneath the continental plate at the Japan trench. The earthquake occurred between the two plates.

A large number of aftershocks

Distribution of aftershocks with M≧5.0

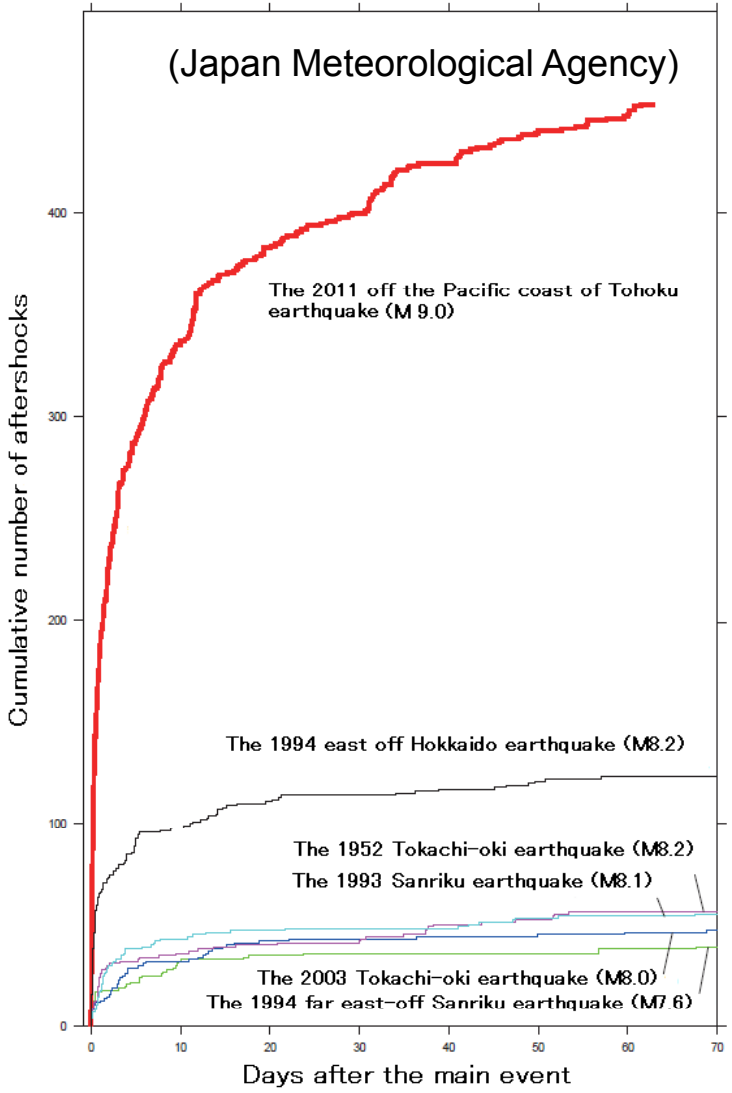


More than 400 aftershocks with M≧5.0 have occurred as of May 13.

(Japan Meteorological Agency)

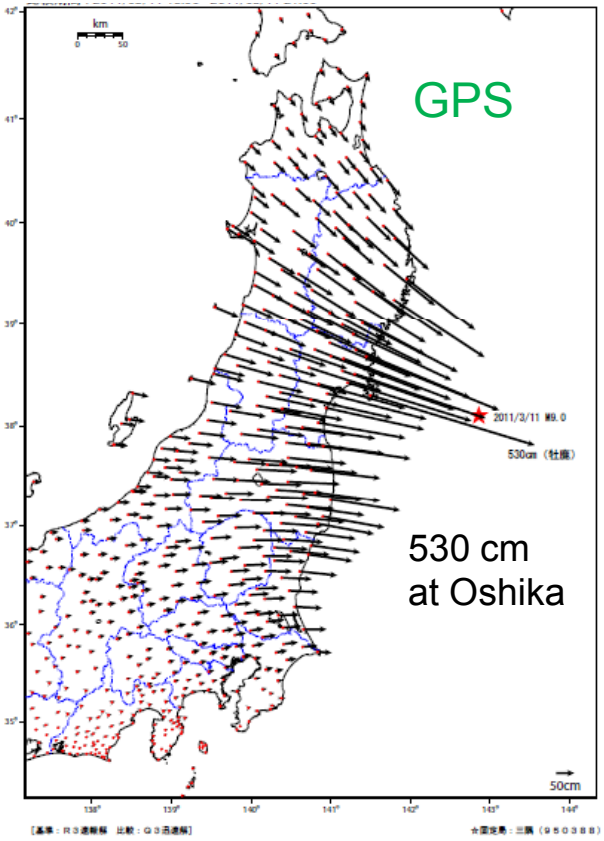
The size of the circle indicates earthquake magnitude. Five aftershocks with M≧7.0 have occurred as of May 13.

Cumulative number of aftershocks

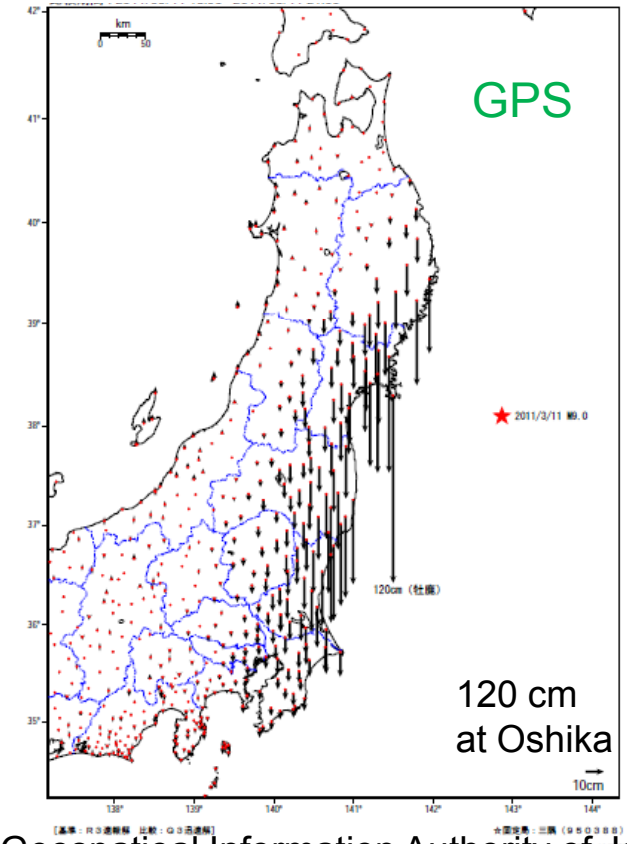


Great amount of subsidence due to coseismic slip

Horizontal displacement



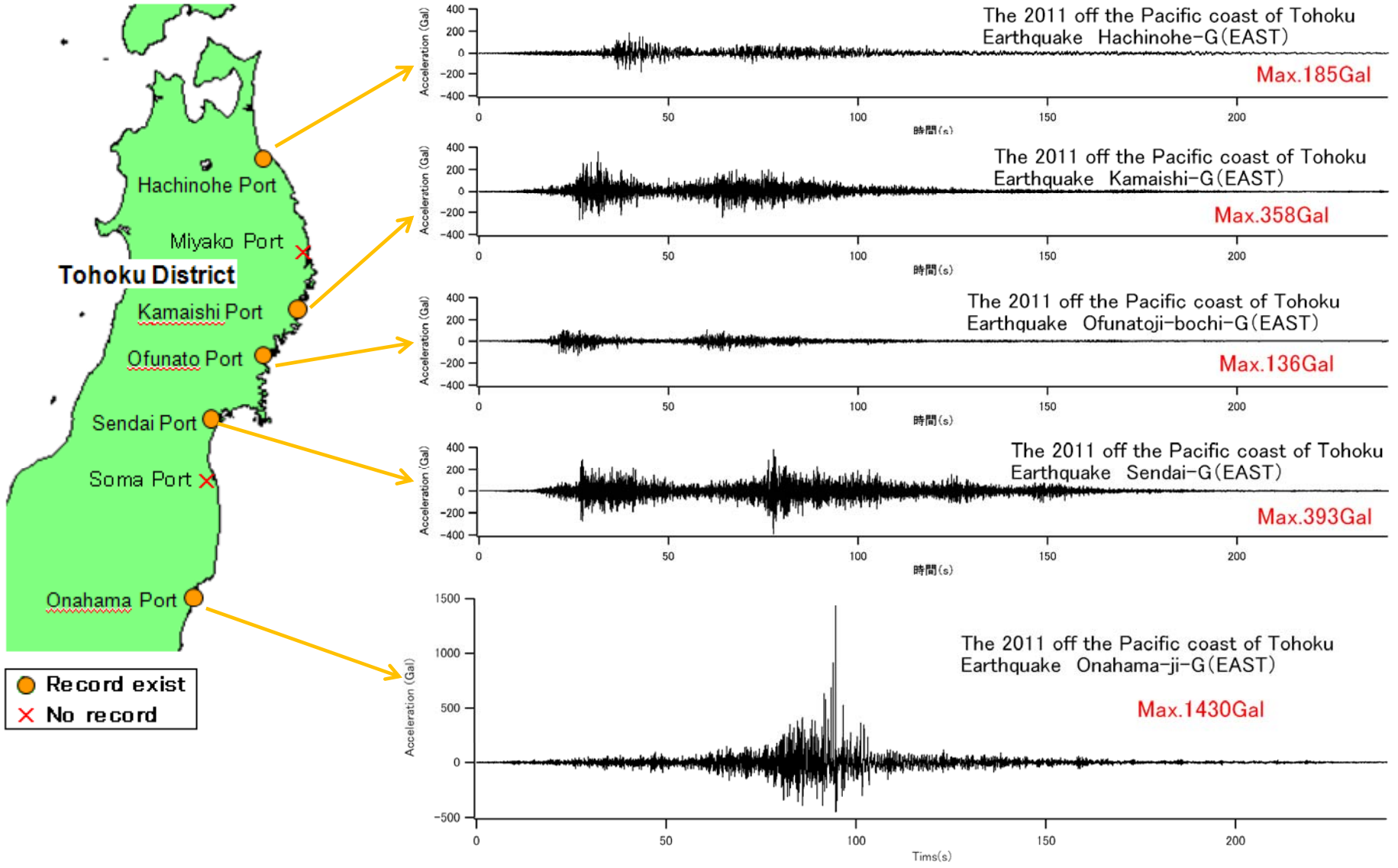
Vertical displacement



(Geospatioal Information Authority of Japan)

A great amount of horizontal and vertical displacement occurred due to coseismic slip. The Oshika Peninsula subsided about 120cm according to GPS observation by the Geospatial Information Authority of Japan. The sea floor around the epicenter moved 24m according to Japan Coast Guard. The movement was as large as 50m according to JAMSTEC.

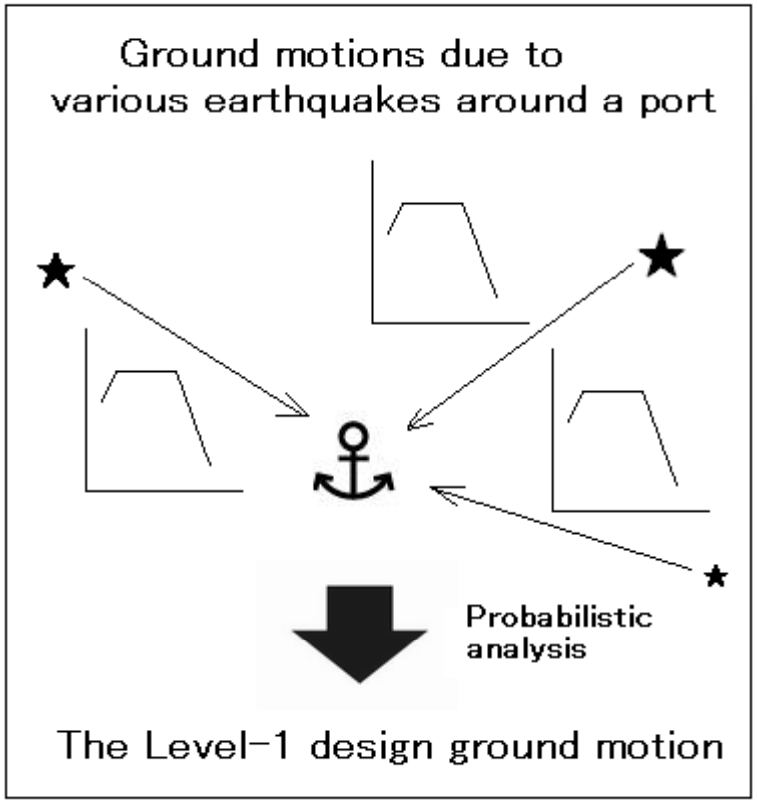
A large number of strong motion data was successfully recorded by the “Strong Motion Earthquake Observation in Japanese Ports”

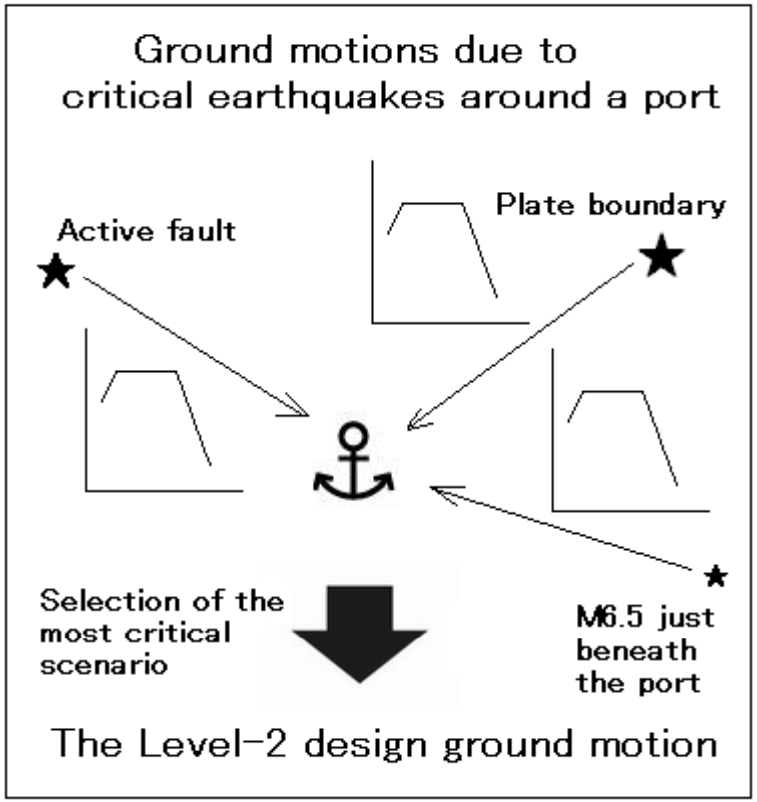


Design ground motions for Japanese Ports

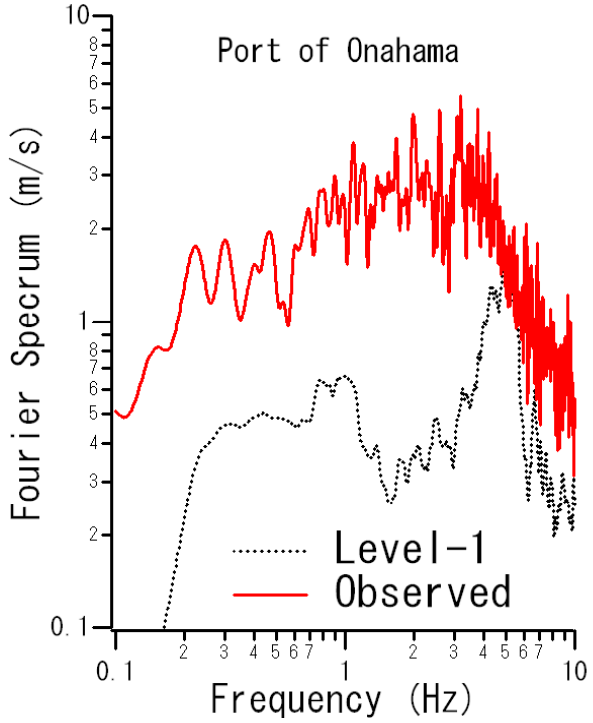
Two kinds of design ground motions are considered in the seismic design of Japanese port structures.

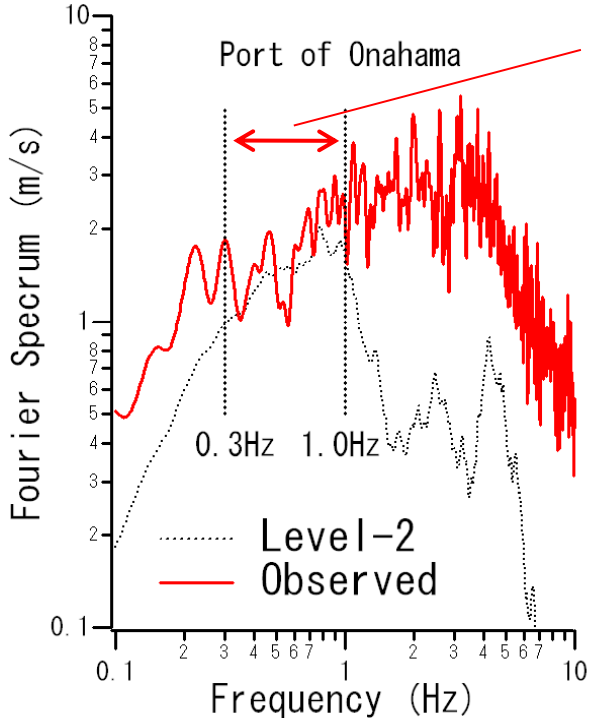
The Level-1 design ground motion is defined as a ground motion with the annual probability of exceedance of 1/75.
The Level-2 design ground motion is so called “the worst case scenario” ground motion.





Comparison with design ground motions
- The case of Onahama Port -

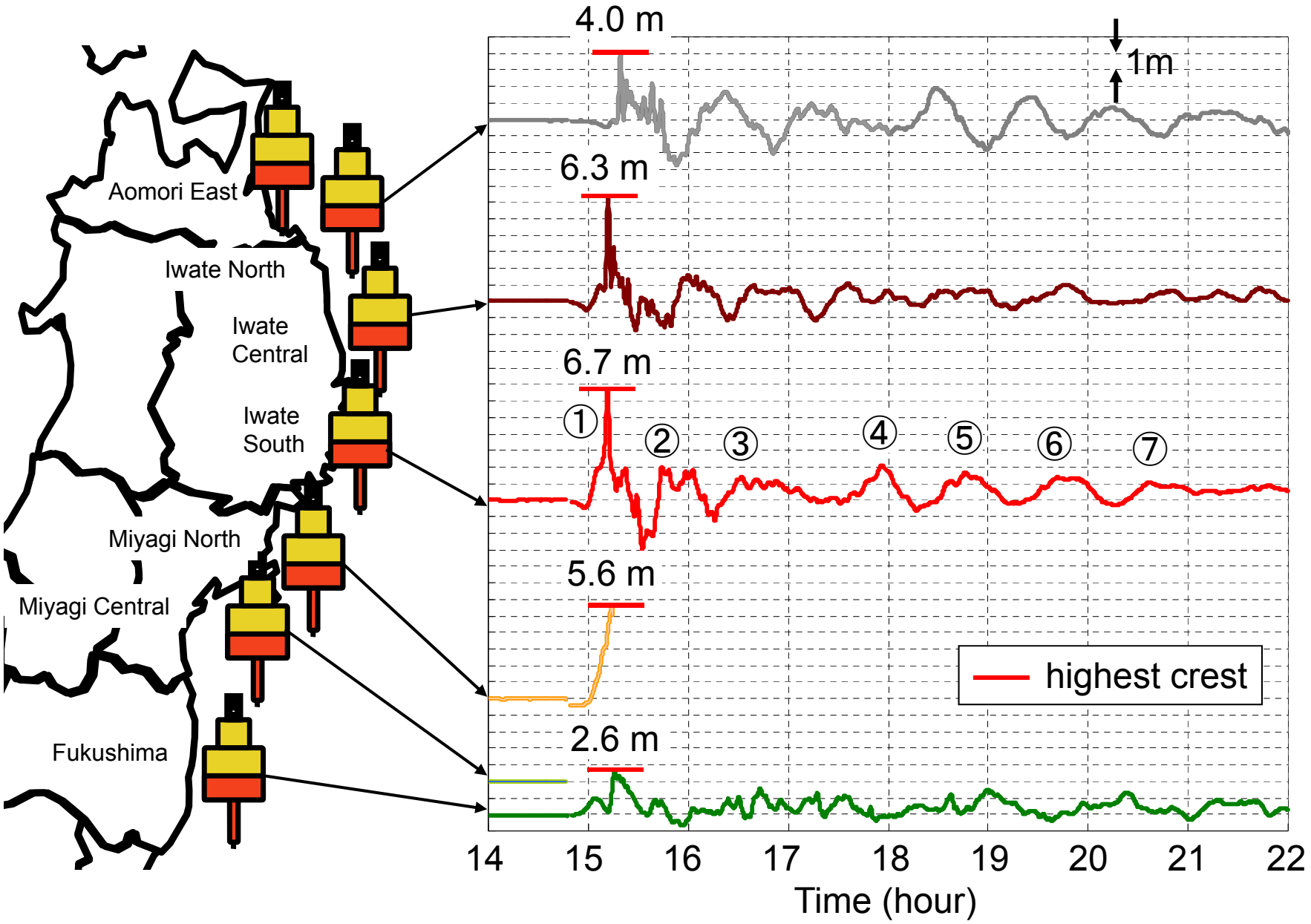




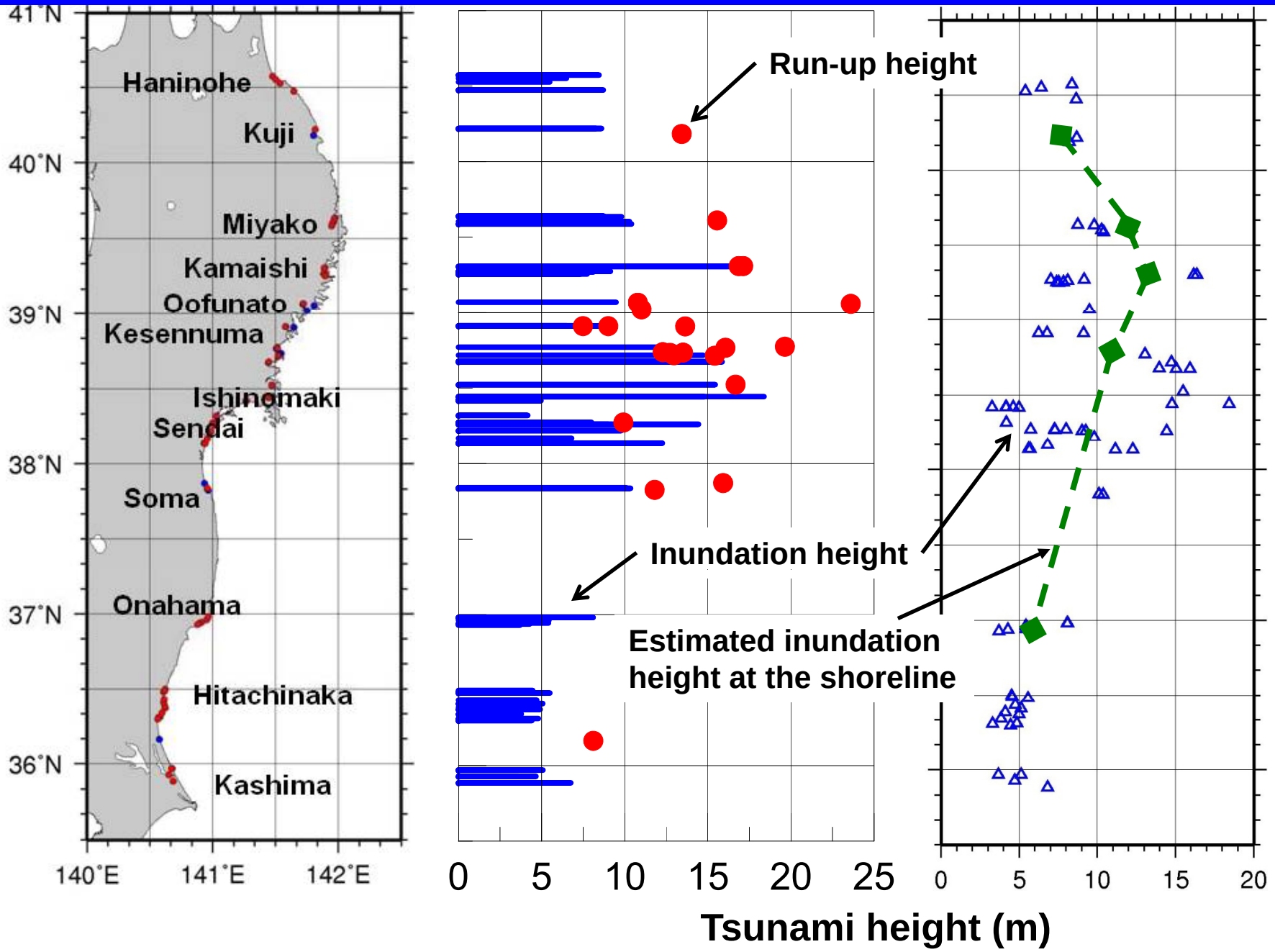
frequencies relevant to major damage to port structures

It is quite natural that the observed ground motion exceeded the Level-1 design ground motion. The observed ground motion was close to the Level-2 design ground motion at frequencies relevant to major damage to port structures (0.3-1Hz). But at higher frequencies, the observed ground motion exceeded the Level-2 design ground motion. In the case of Onahama, the Level-2 design ground motion was based on a scenario earthquake with magnitude 6.5 (but just beneath the port). The appropriateness of the scenario should be investigated once more.

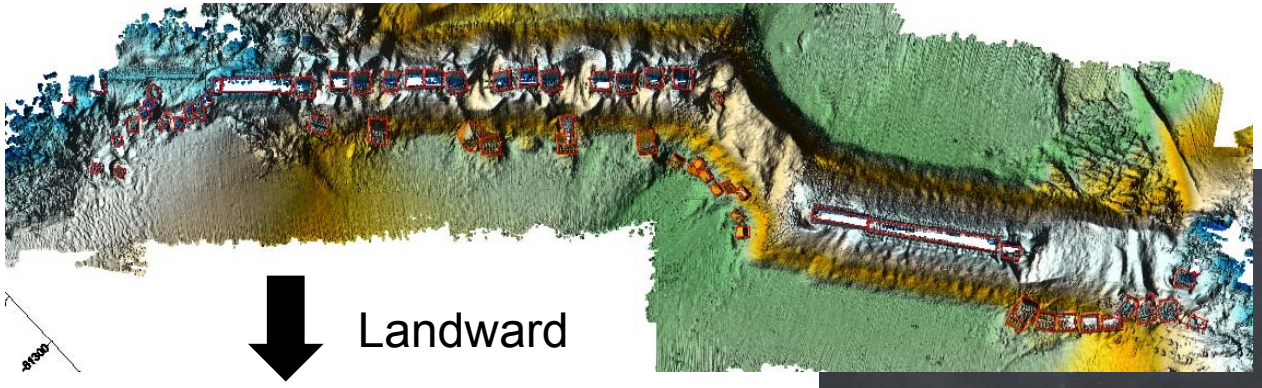
GPS-mounted wave buoy

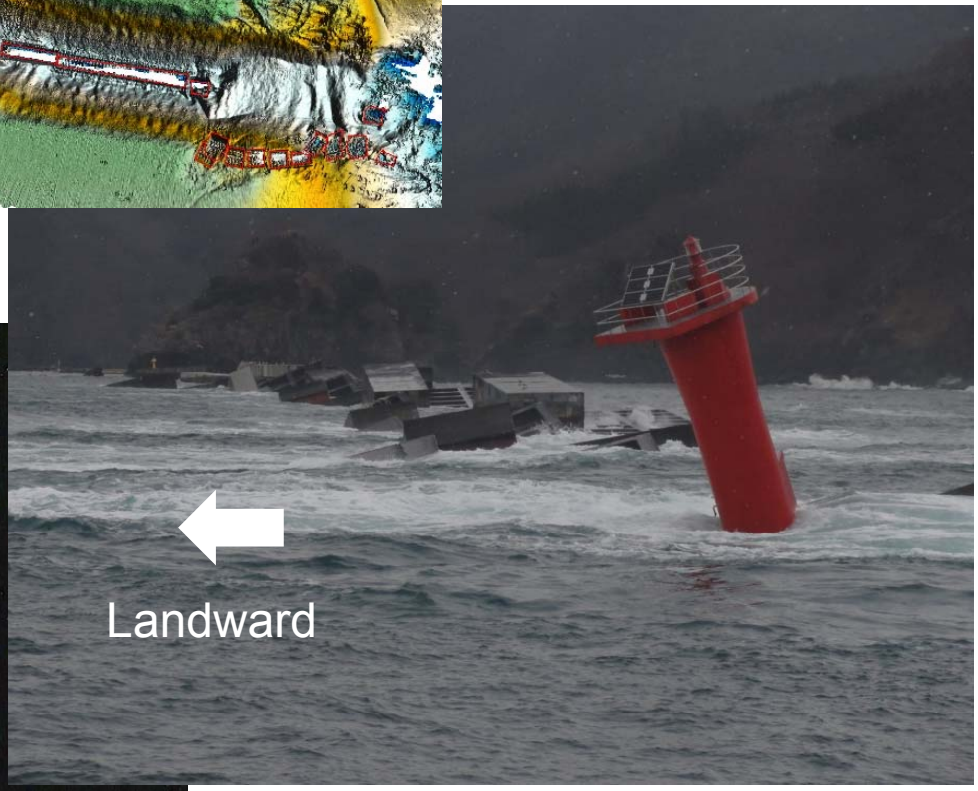


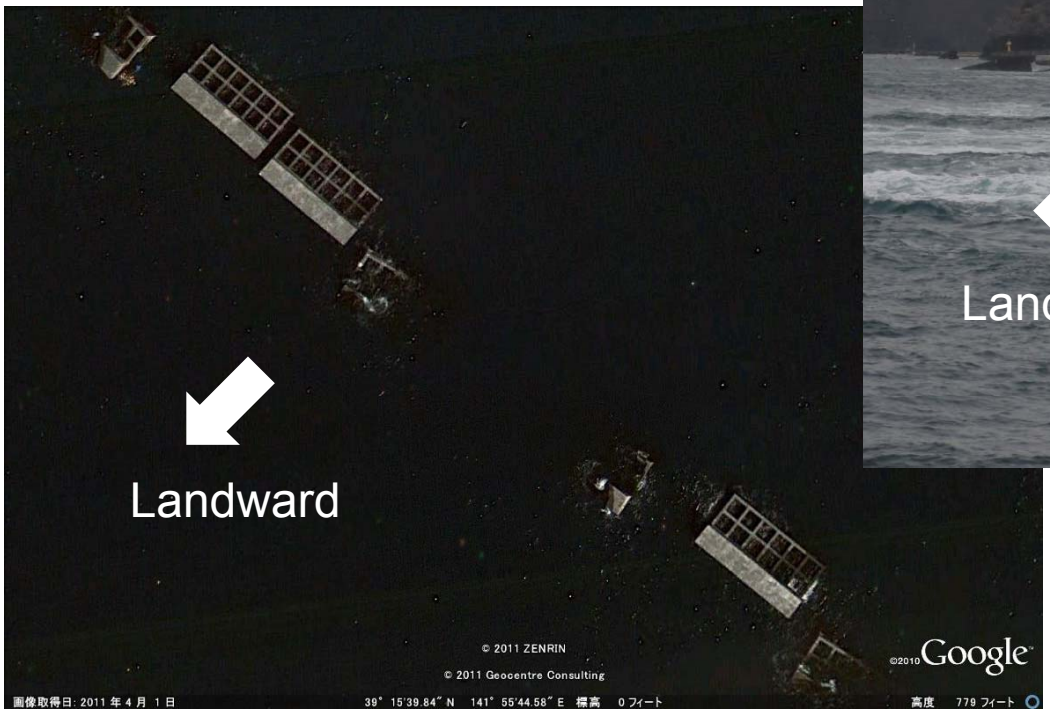
Tsunami height measured and estimated



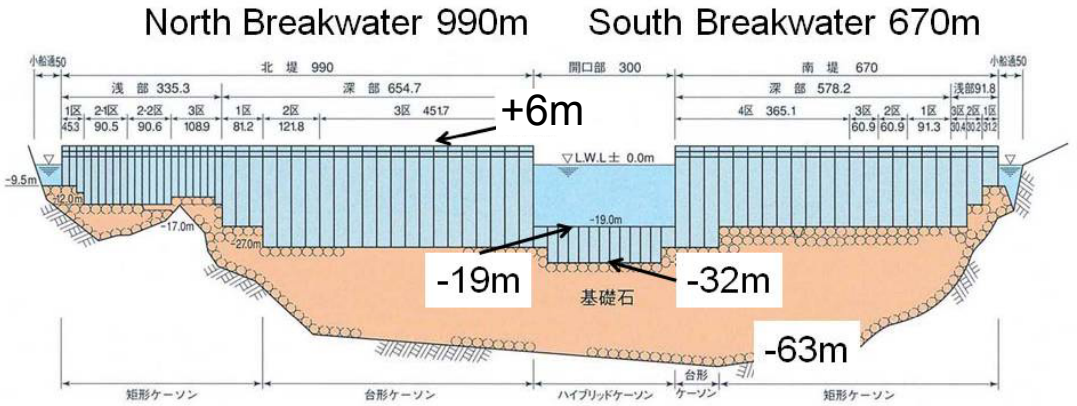
Damages of breakwater



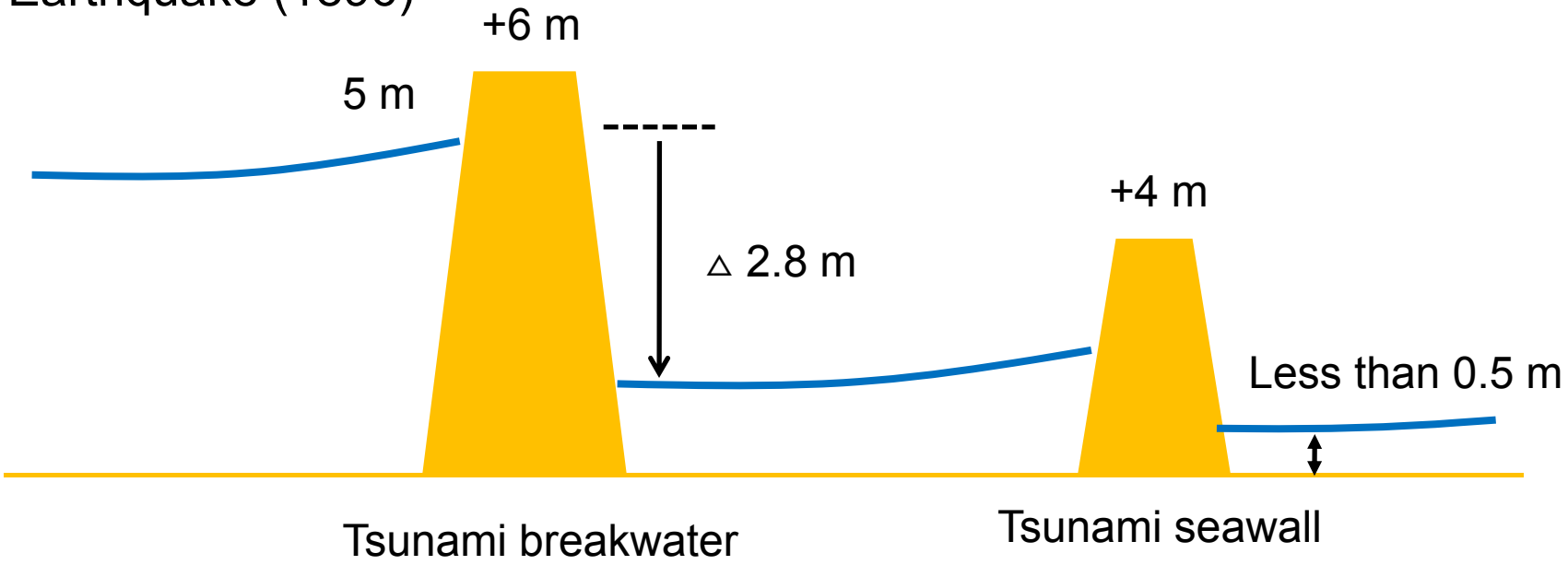




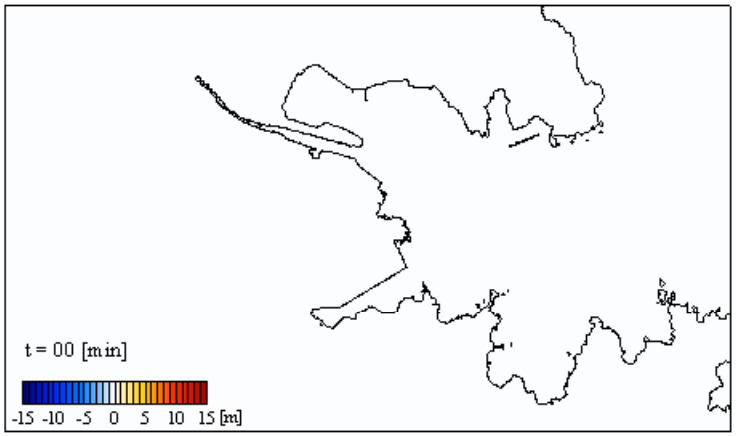
Kamaishi Tsunami Breakwater



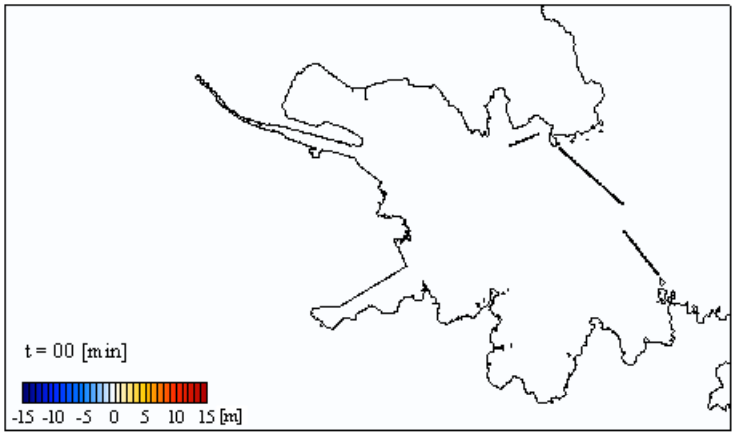
Meiji Sanriku Earthquake (1896)



Simulation results for the ToHoku Earthquake in 2011



Without Breakwater

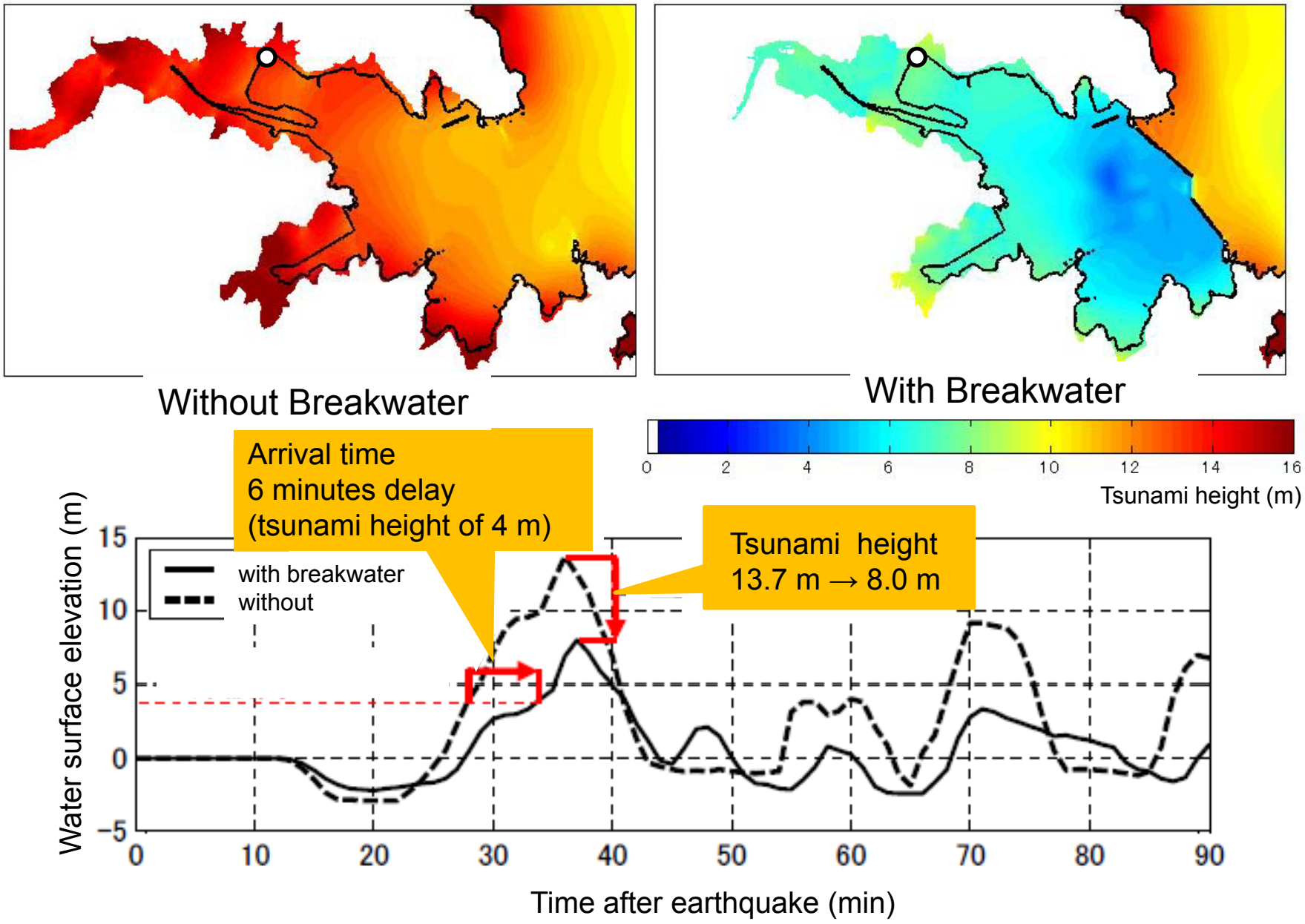


With Breakwater

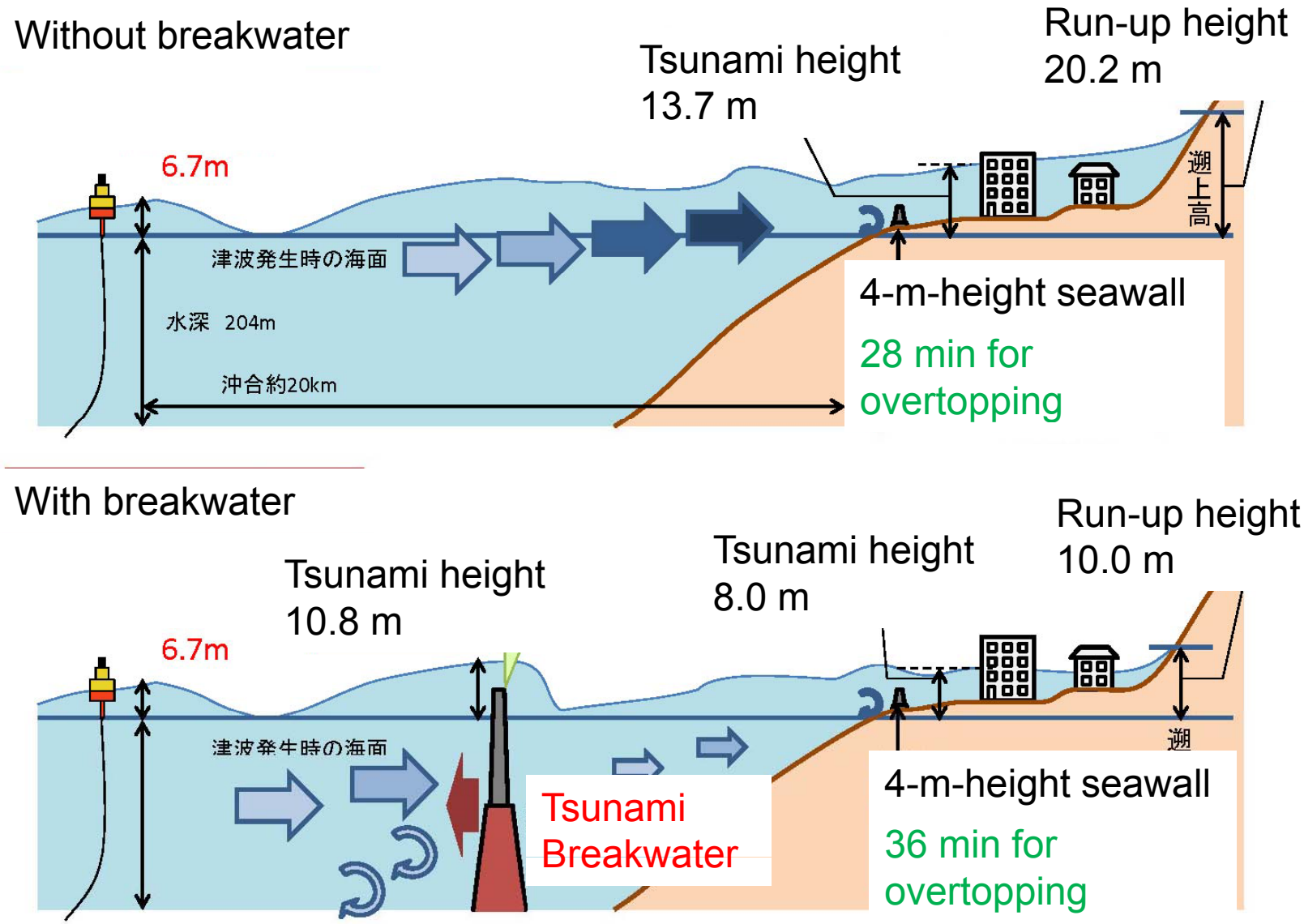
The 2011 off the Pacific Coast of Tohoku Earthquake (2011)

This tsunami simulation is conducted by ‘Storm Surge and Tsunami Simulator in Oceans and Coastal Areas (STOC)’, which is developed by PARI.

Effect of breakwater



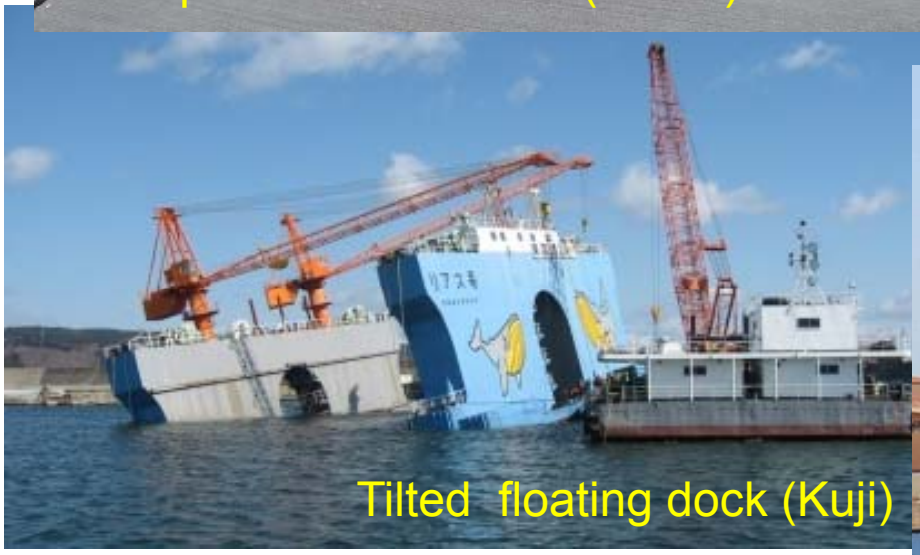
Effect of breakwater



Tsunami damages

Quay damaged by the combination of earthquake and tsunami (Soma)

Scattered containers (Sendai)



Tilted floating dock (Kuji)

Collapsed crane (Kashima)

Tsunami damages

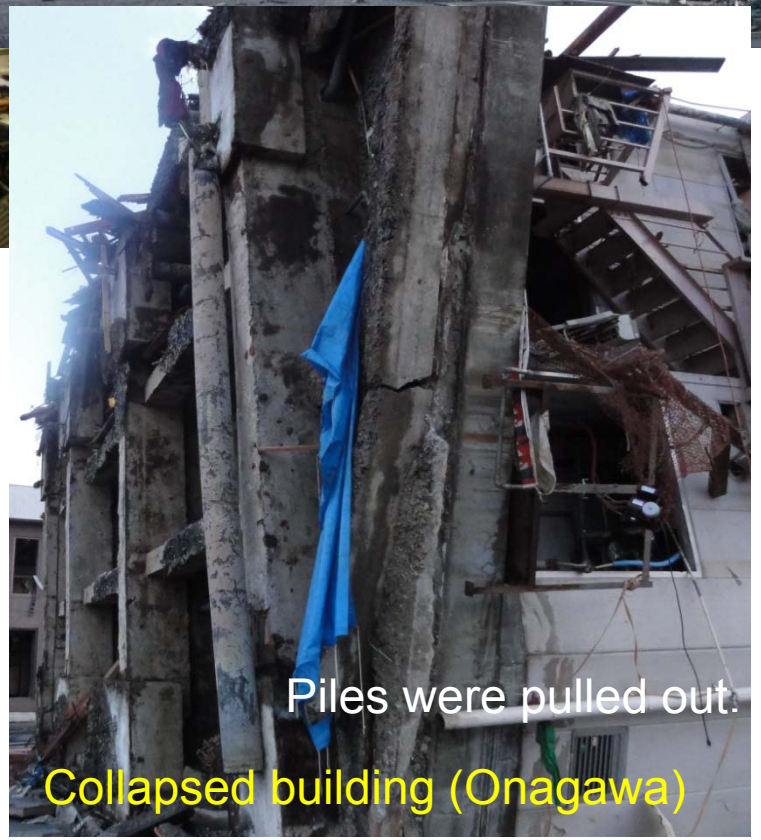
Drifted tank trucks (Sendai)

Ship drifted in a town (Kesennuma)

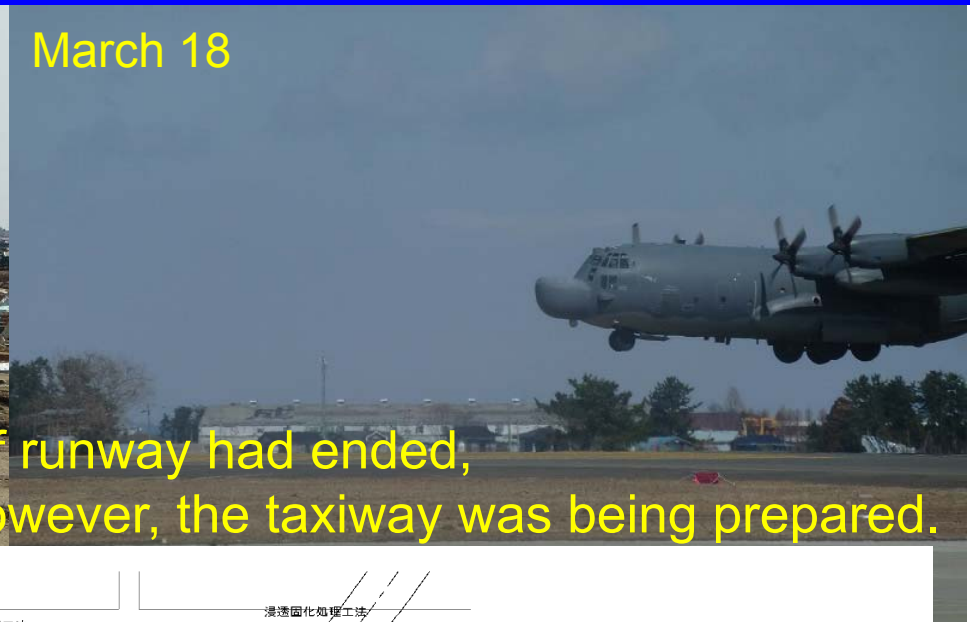
Destroyed seawall (Taro)

Smashed oil tank and oil spill (Kesennuma)

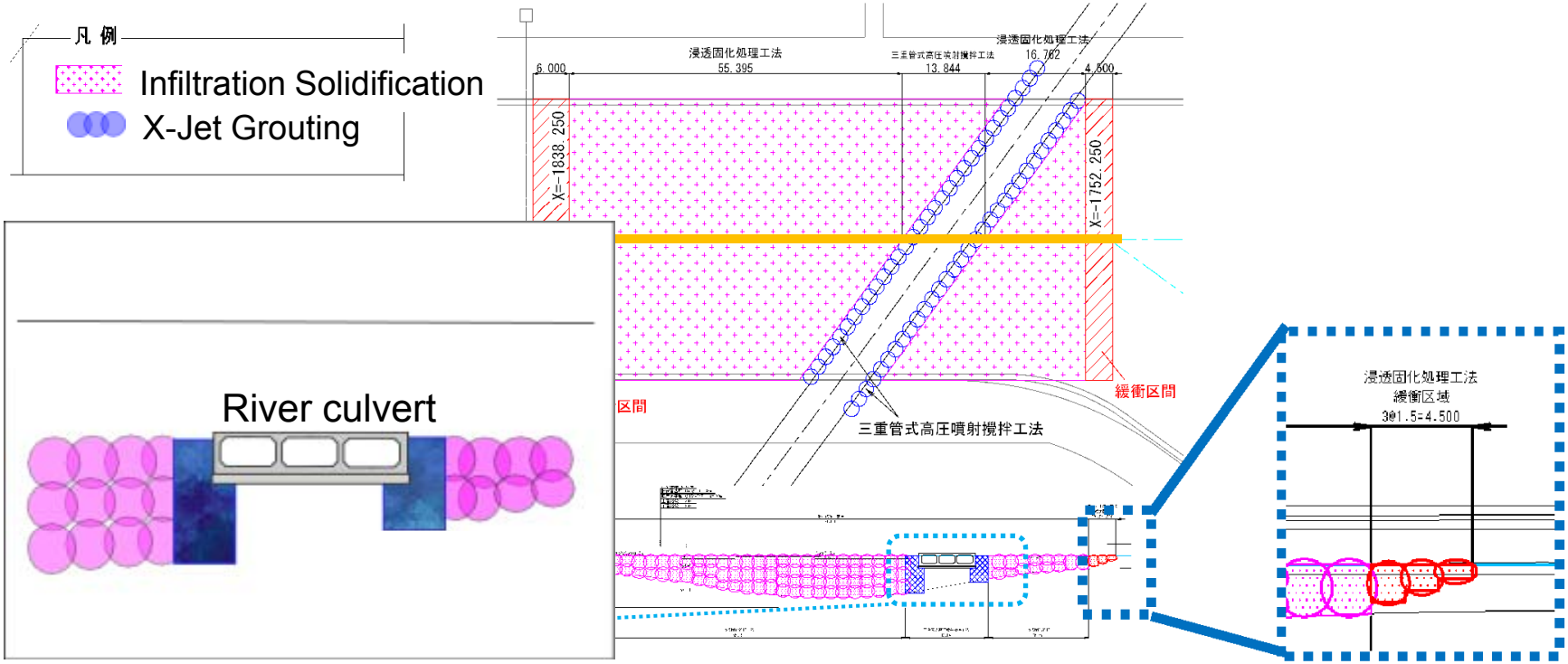
Tsunami damages



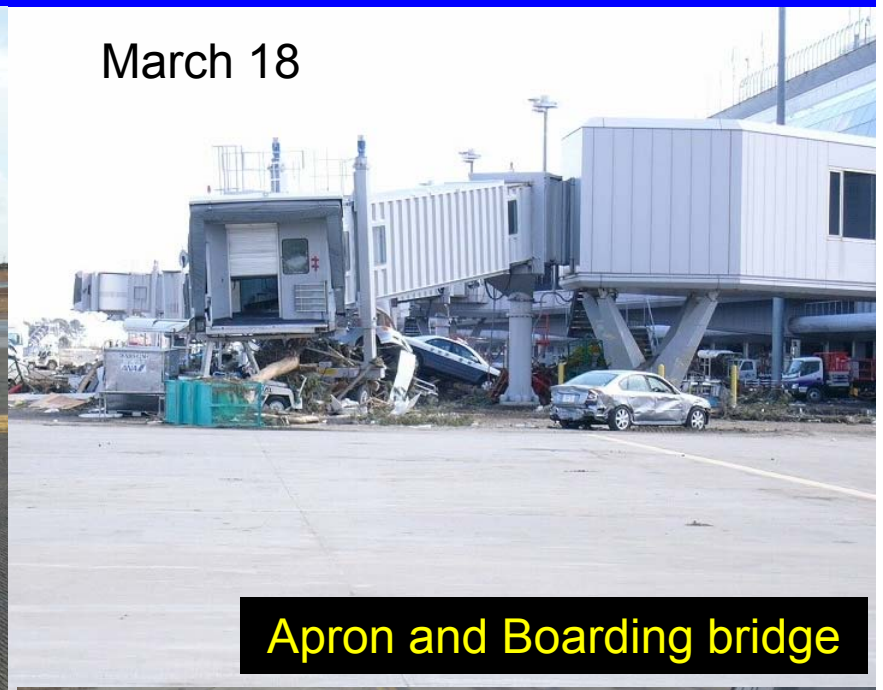
Liquefaction remediation Sendai Airport



The liquefaction counter measure of runway had ended,
however, the taxiway was being prepared.



Liquefaction remediation Sendai Airport



The runway keeps ‘Serviceability’ just after the Earthquake. However, It took one week to cleanup the debris due to Tsunami.

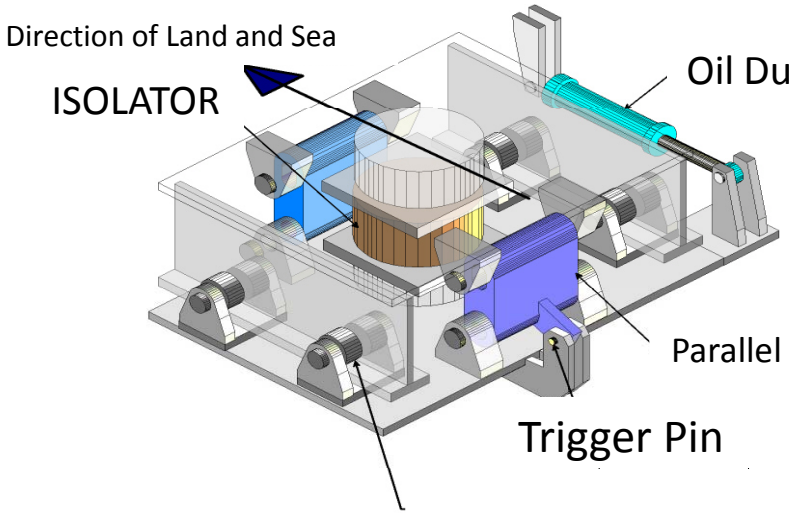
The operation of the passenger plane restarted on April 13.

There are serious subsidence, uneven settlements and clacks on the surface of un-improved taxiway.
It lost the ‘Serviceability’ and the ‘Reparability.’

Sendai Port: Base Isolated Gantry Crane

4 Gantry Cranes : 2 base-isolated cranes
2 non-base-isolated cranes

Damage occurred in one non-base-isolated crane

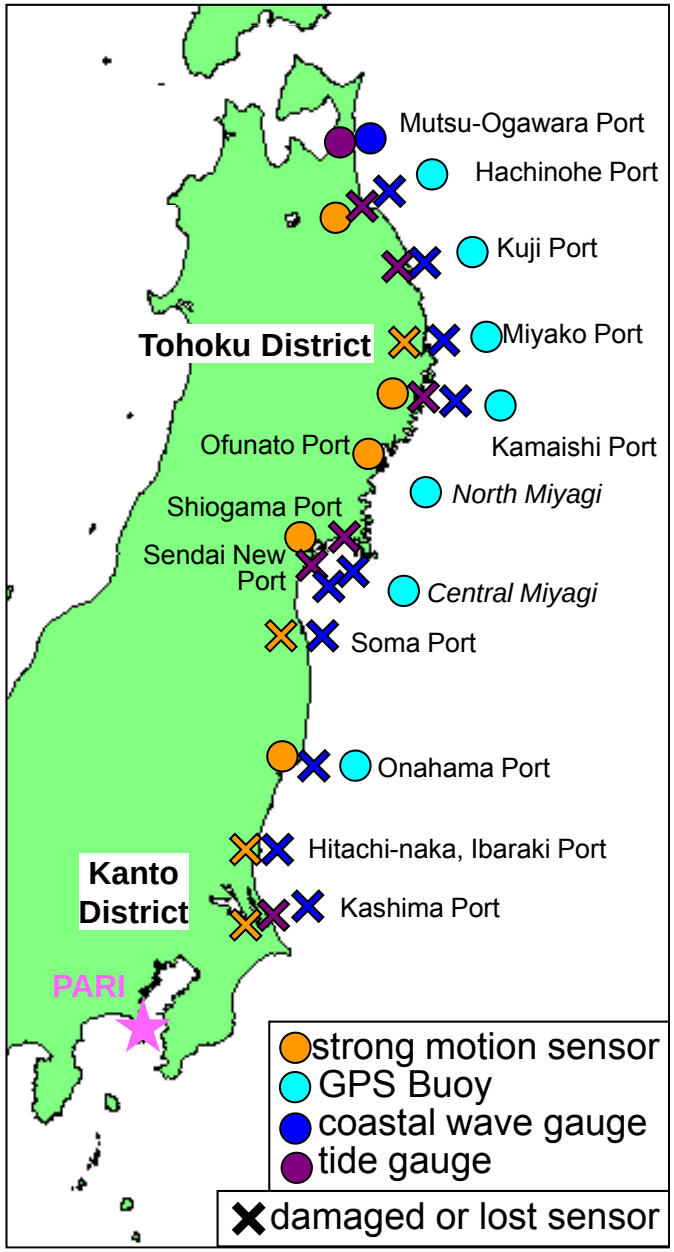


Base Isolation system

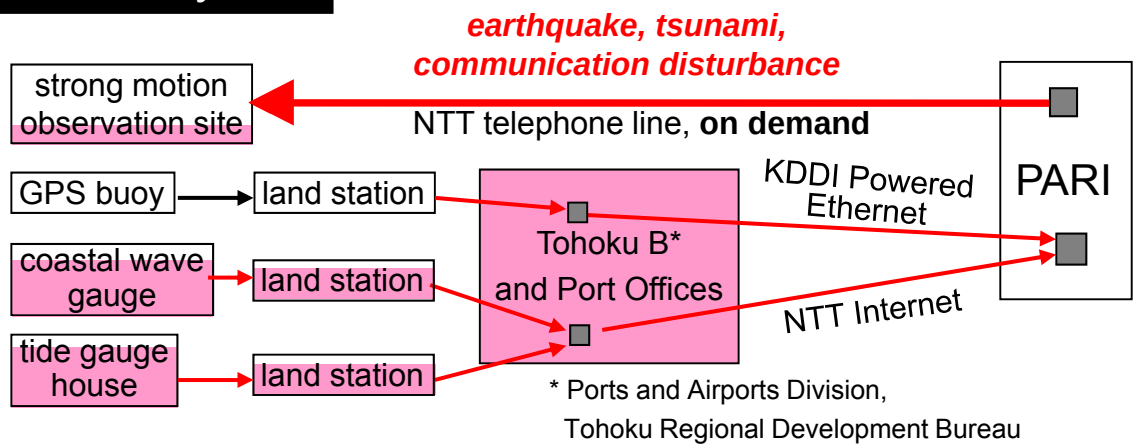
Patent holder : PARI and Mitsui Engineering & Shipbuilding Co, Ltd.

Base-isolated cranes: No structural damage

Future Improvement in Information Network

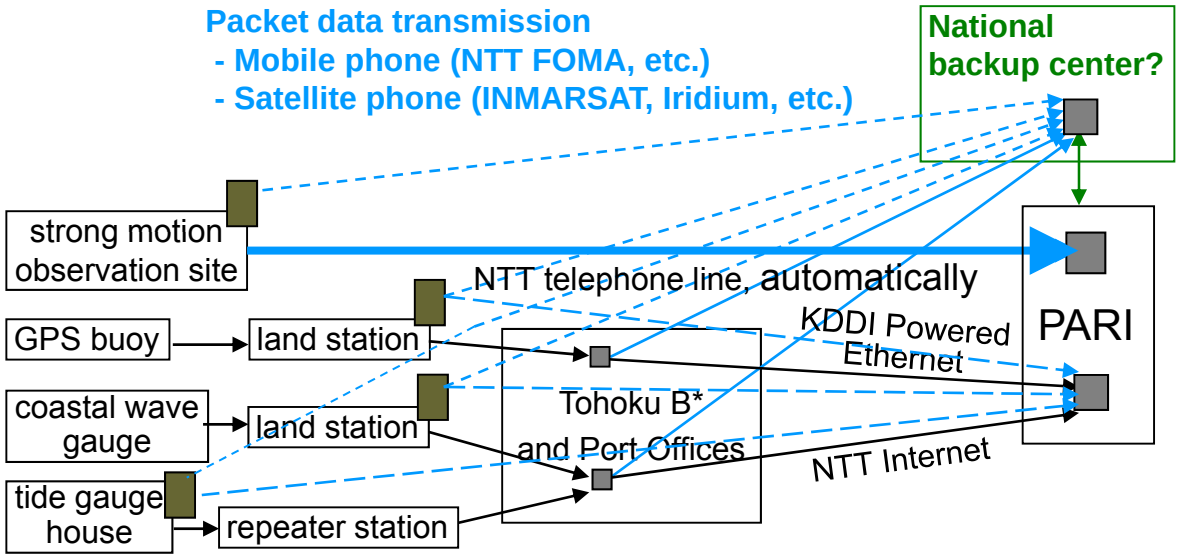


Present System



Idea for Future System

Toward redundant system !!



Recommended countermeasures against tsunami

	Design tsunami	Required performance
Level 1	Largest tsunami in modern times (return period: around 100 years)	• To protect human lives • To protect properties • To protect economic activities
Level 2	One of the largest tsunamis in history (return period: around 1000 years)	• To protect human lives • To reduce economic loss, especially by preventing the occurrence of severe secondary disasters and by enabling prompt recovery

Disaster prevention facilities such as seawalls should be safe against ‘Level 2 tsunami’. At least, in the event of ‘Level 2 tsunami’, the deformation of these facilities have to be not so large to maintain the performance to reduce tsunami.

Issues on Preparedness Against Extraordinary Tsunami

Hazard Map

- To prepare hazard maps and scenarios against tsunamis of levels 1 & 2.

Evacuation

- To develop and implement the real-time tsunami prediction based on the data observed by GPS-mounted wave buoys.
- To establish secure and reliable warning systems and evacuation routes in consideration of blackout and traffic.
- To prepare shelters that are secure even against level 2 tsunami.

Urban Plan

- To make higher grounds such as artificial grounds, embankment, and reclamation lands.
- To make houses rigid. Recommended material is not wood but concrete.
- To make local people to construct their houses at hill areas.
- To provide access from hill areas to commercial areas in coastal zone.
- To build tall buildings that have residential areas in upper floors and commercial areas in lower floors.