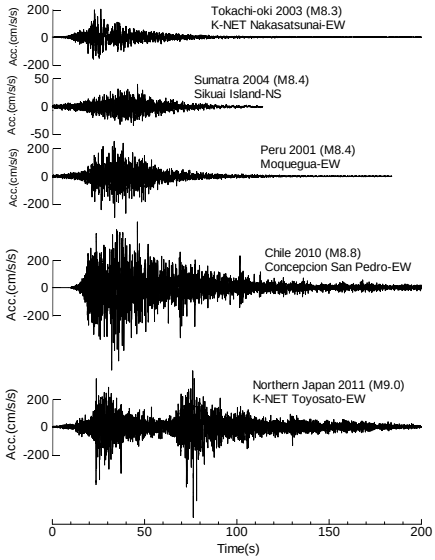
Symposium for Recent Earthquakes and Tsunami in Japan and Peru

The 2011 Tohoku Earthquake and Tsunami:
1) Earthquake and Strong Ground Motion



Saburoh MIDORIKAWA, Tokyo Institute of Technology

Tokyo Tech CUEE

The 2011 Tohoku Earthquake

Origin Time: 14:46, March/11/2011

Magnitude: M_w9.0

Number of dead and missing: approx. 20,000

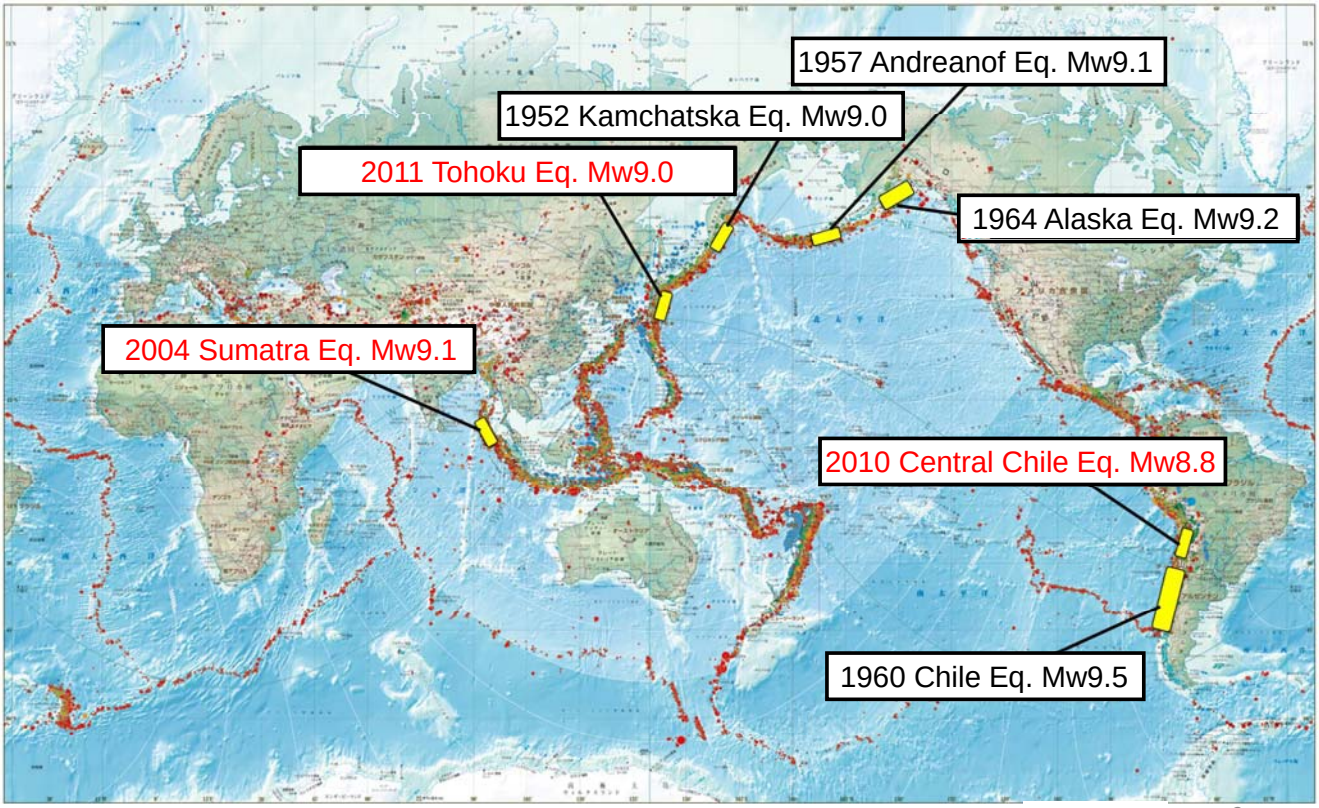
Number of displaced people: approx. 150,000

Number of damaged houses: approx. 800,000

Direct monetary loss: Approx. 200 billion US$

(as of August 15, 2011)

Recent Gigantic Earthquakes in the World



after ERI

HISTORICAL EARTHQUAKES IN PERU after Dorbath et al.(1990)

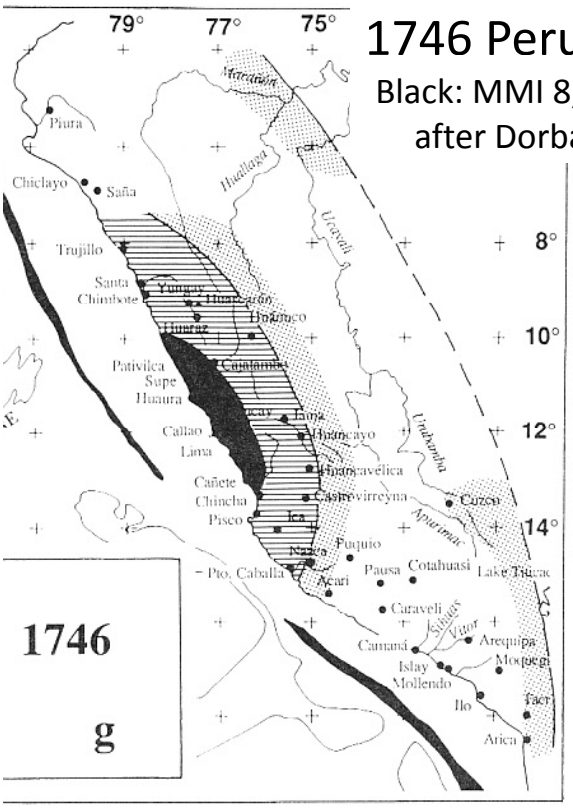
Year	L (km)	H_r (m)	$[M_w]$	$[M_t]$	M (Silgado)
1582	80	1–2	7.5	7.7–8.0	7.9
1586	175	5	8.1	8.5	8.1
1604	450	10–15	8.7	8.8–9.0	8.4
1619	100–150		7.7–8.0		7.8
1664	75		7.5		7.8
1678	100–150	5 (?)	7.7–8.0	8.5	
1687	300	5–10	8.4	8.5–8.8	8.2
1687	150 (?)		8.0		
1715	75		7.5		
1725	75		7.5		
1746	350	15–20	8.6	9.0–9.2	8.4
1784	300	2–4	8.4	8.0–8.4	8.0
1833	50–100		7.2–7.7		
1868	500	14	8.8	8.9	8.6
1940	180	3	8.1	8.2	
1942	200	3	8.2	8.2	
1966	100	2.6	7.7	8.2	
1974	140	1.6	7.9	7.9	

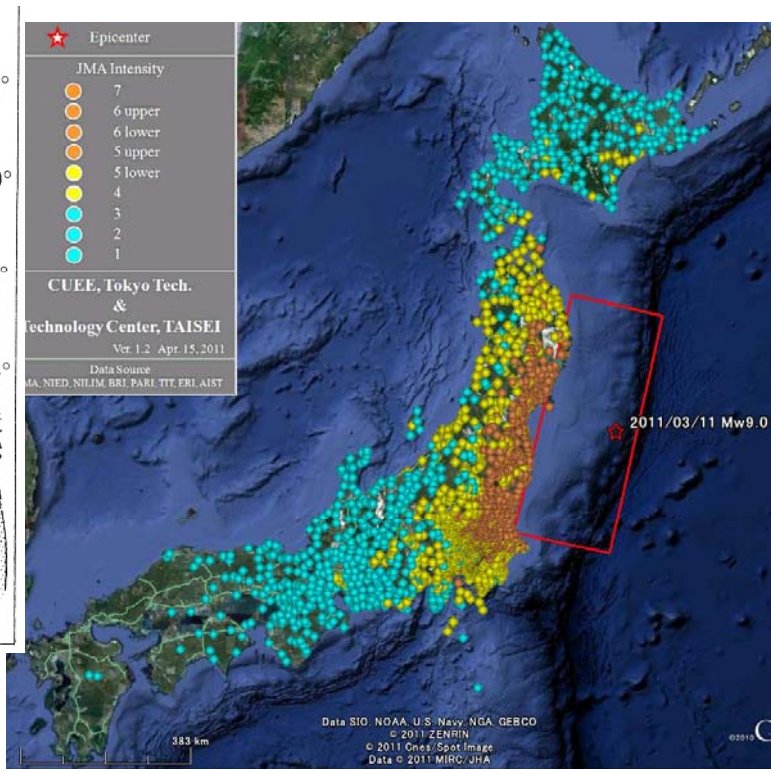
L = rupture length; H_r = local tsunami height; $[M_w]$ = estimate of moment derived magnitude; $[M_t]$ = estimate of tsunami magnitude.

Seismic Intensity Map
1746 Peru Earthquake

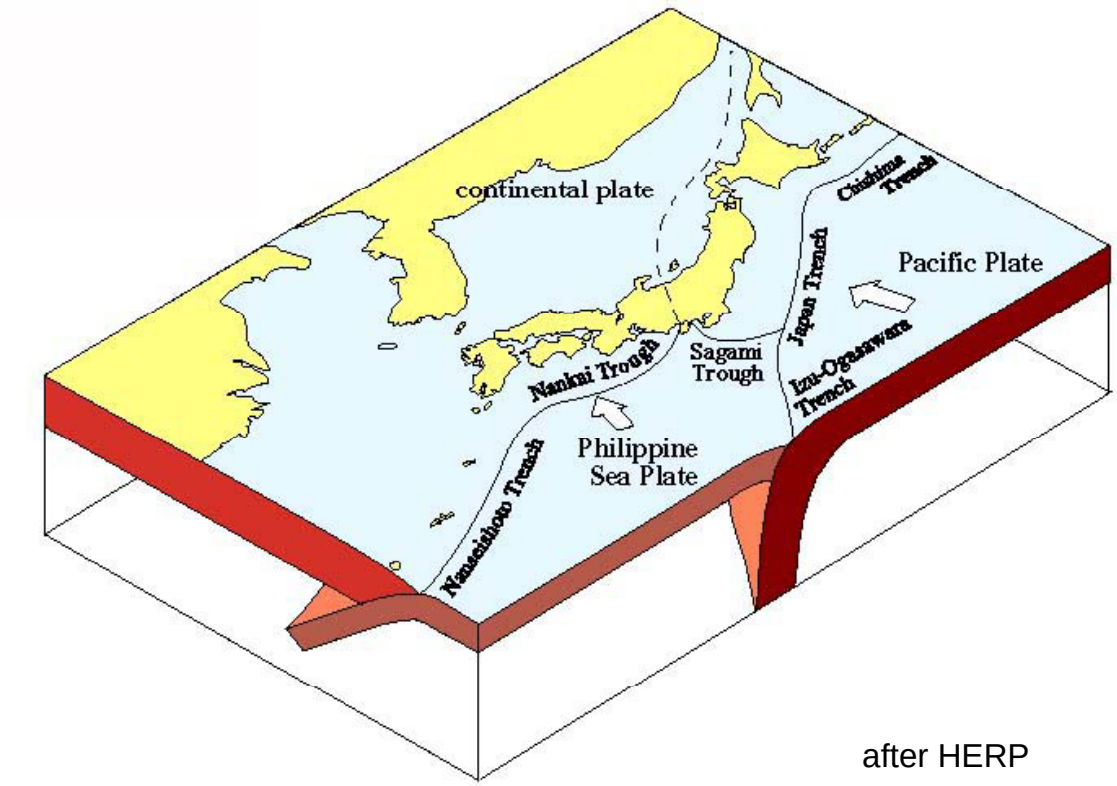
Black: MMI 8, Hatched: MMI 6

after Dorbath et al., 1990



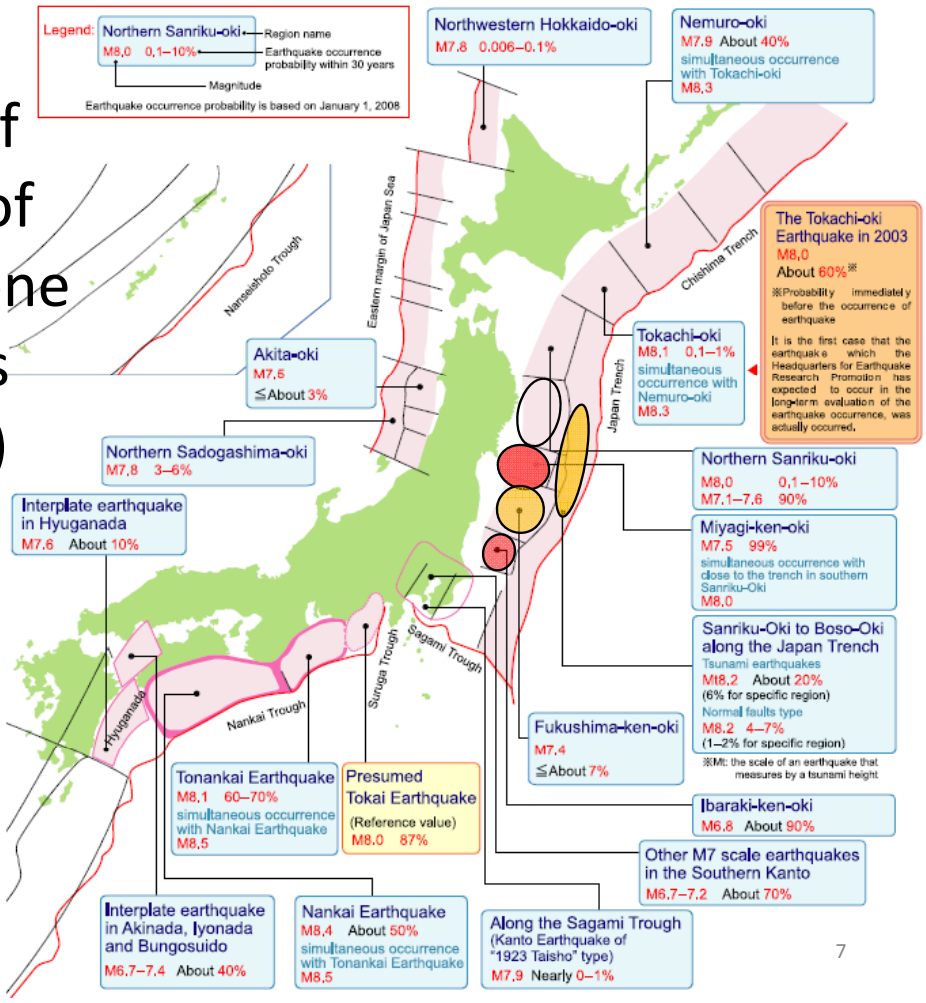


Tectonic Plates in the Japanese archipelago and surrounding areas

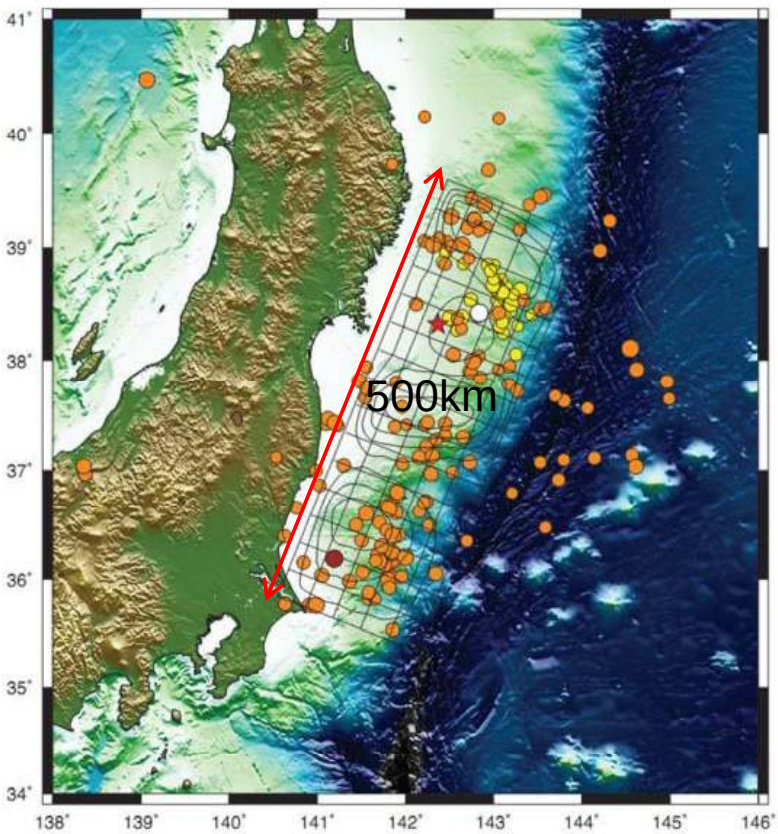


after HERP

Evaluation of Occurrence of Subduction-zone Earthquakes (after HERP)

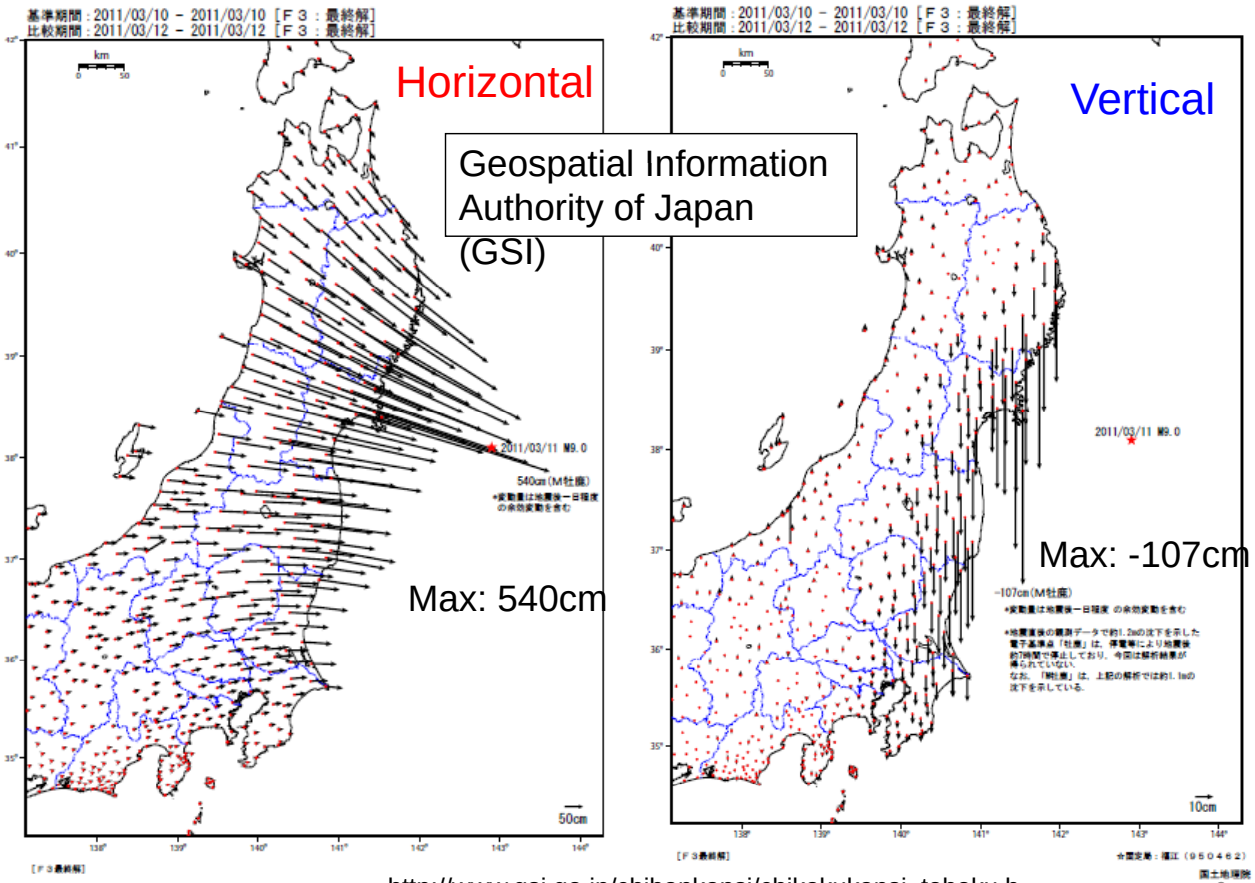


Aftershock Distribution



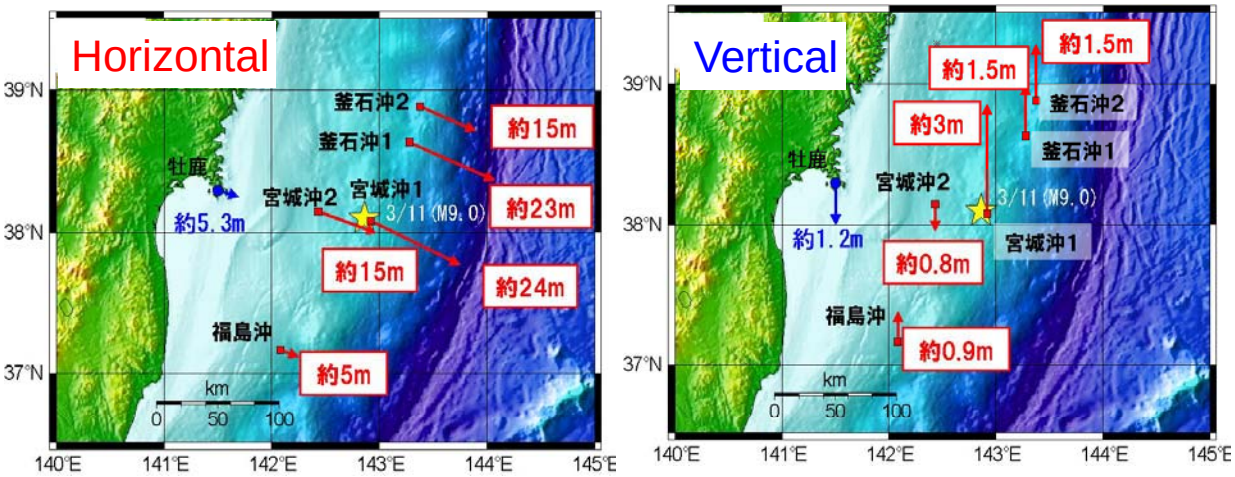
after ERI

Crustal movement by GPS measurement of GSI

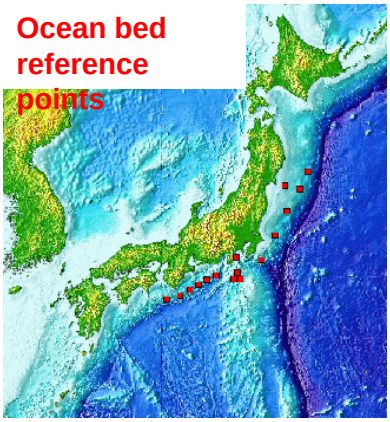


http://www.gsi.go.jp/chibankansi/chikakukansi_tohoku.h

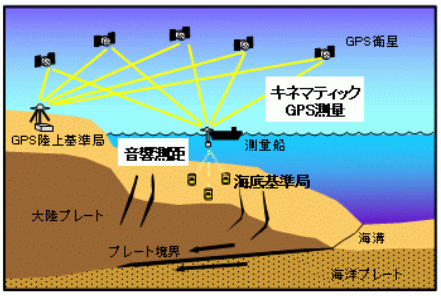
Crustal movement by observed by Japan Coast Guard



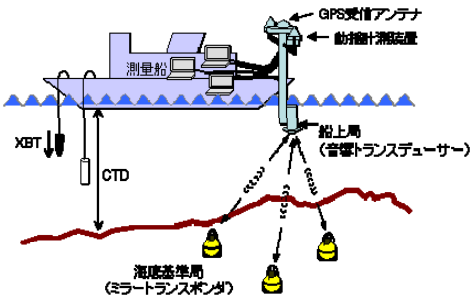
Ocean bed reference points



Kinematic GPS

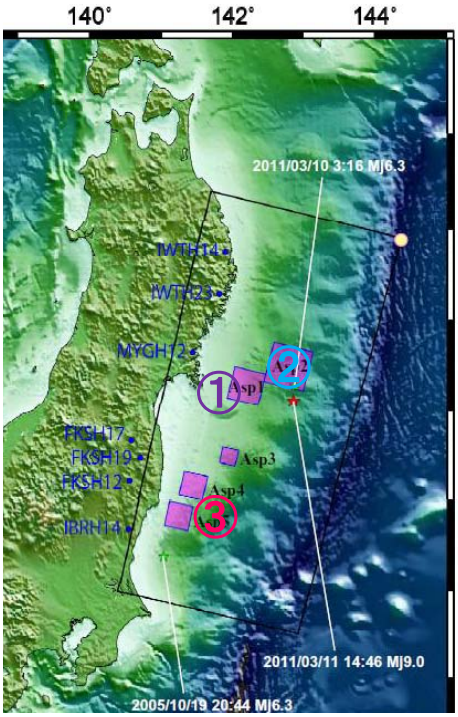


Sound transducer

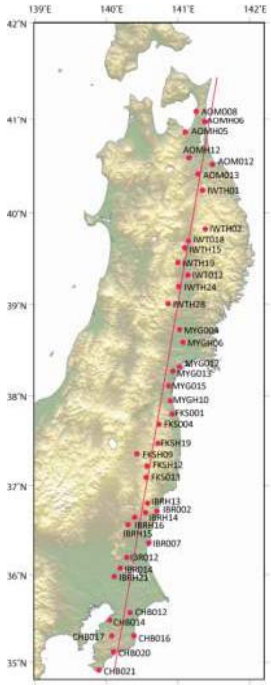


http://www1.kaiho.mlit.go.jp/GIJUTSUKOKUSAI/jishin/11tohoku/index.htm

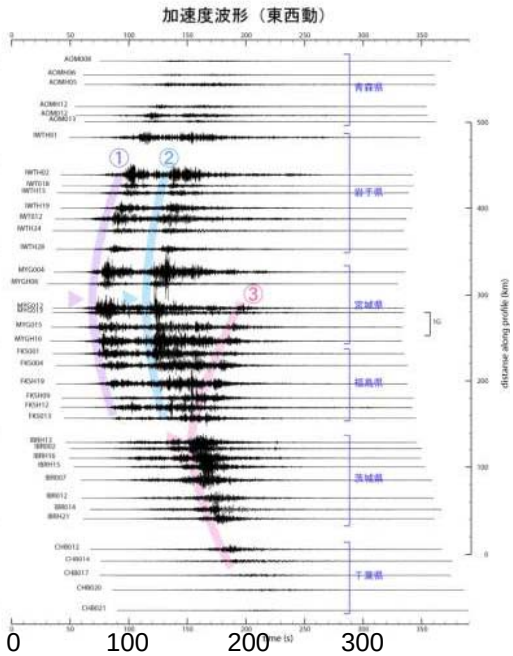
Past-up of Accelerograms and Rupture Process



after Kamae and Kawabe

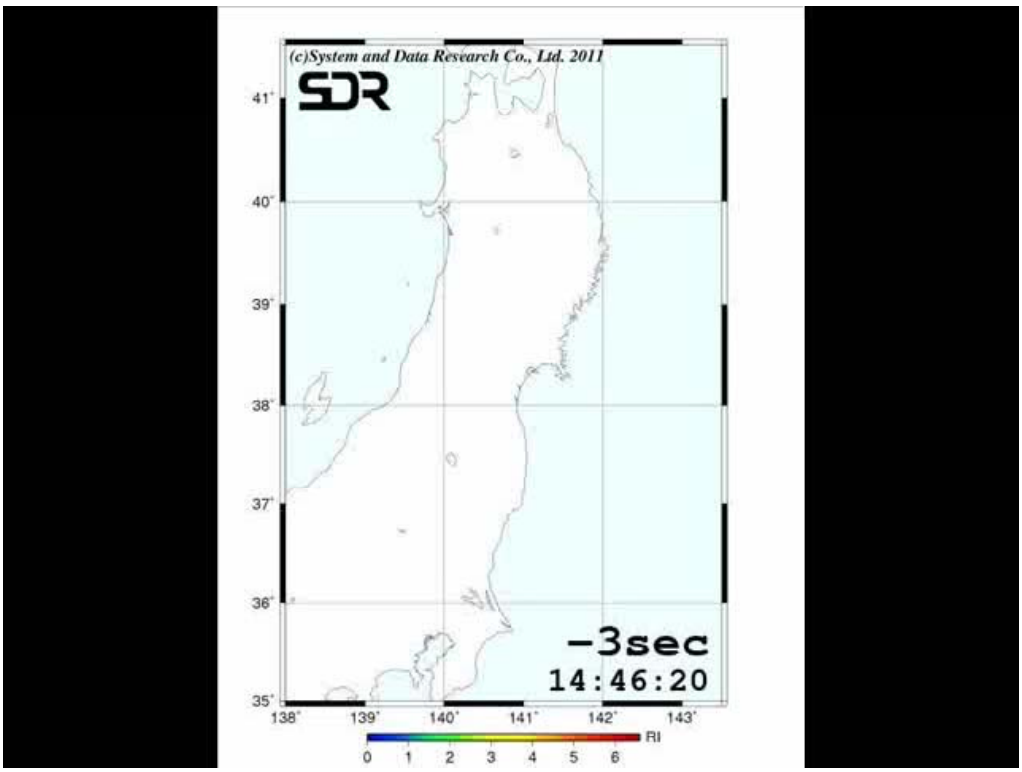


Acceleration Time History (EW comp)



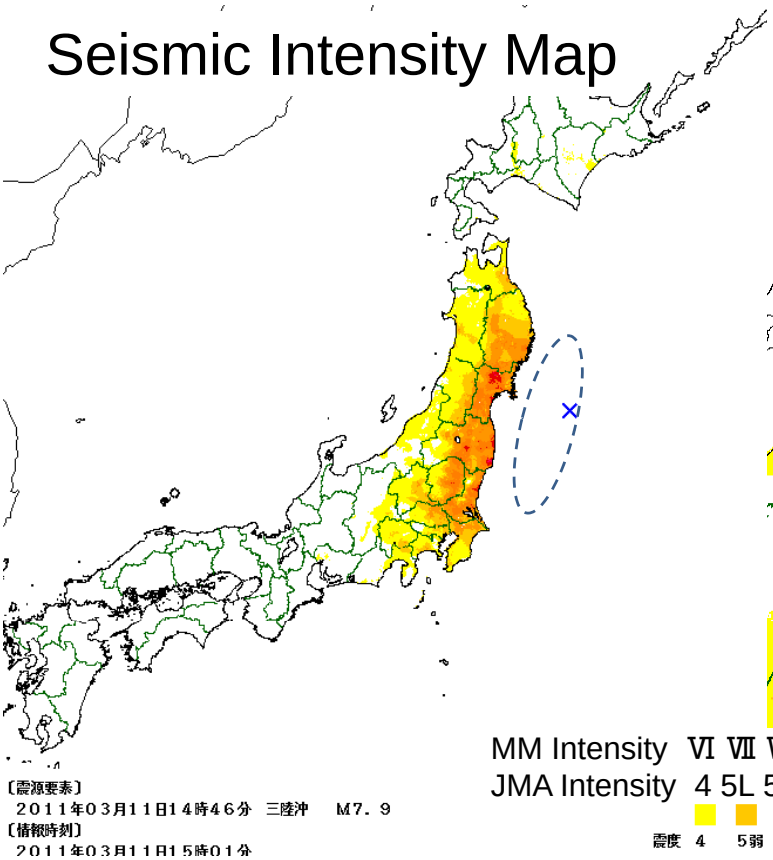
after ERI

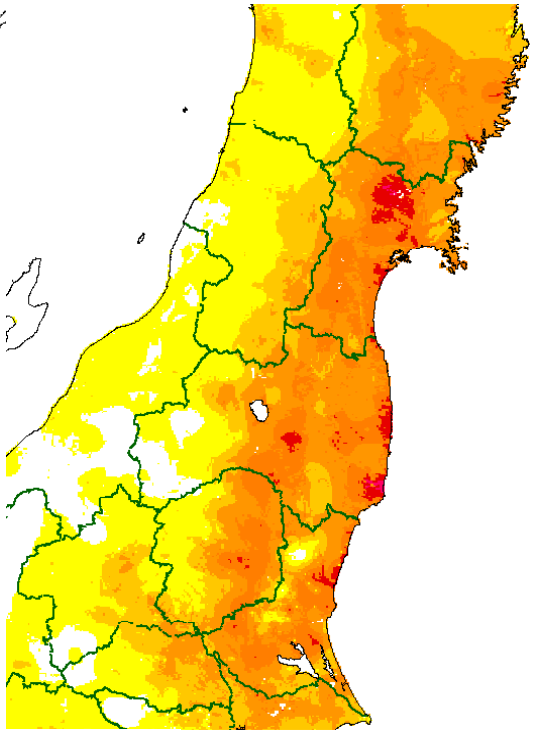
Propagation of Strong Shaking



after SDR

Seismic Intensity Map



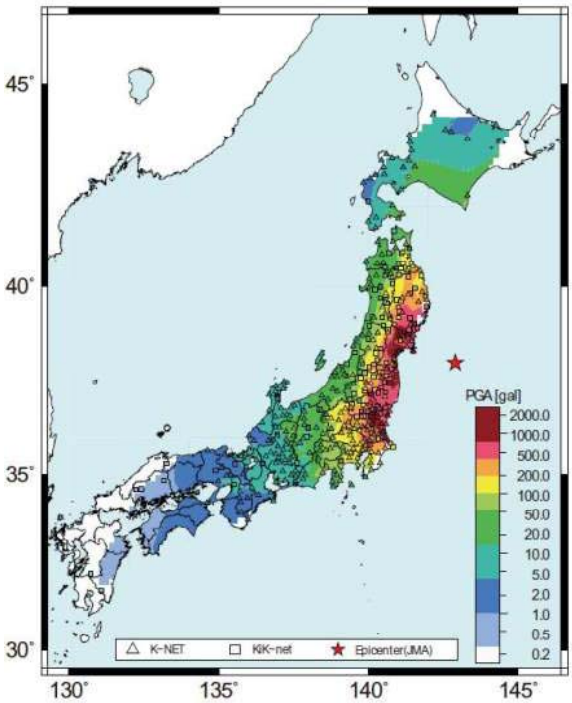


MM Intensity Ⅵ Ⅶ Ⅷ Ⅸ Ⅹ XI
JMA Intensity 4 5L 5U 6L 6U 7
震度 4　5弱　5強　6弱　6強　7

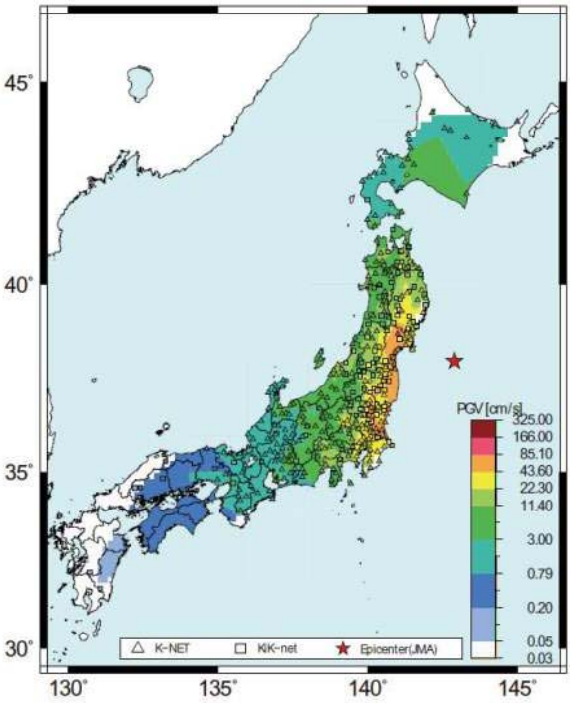
after JMA

The area of intensity 5 upper (MMI 8) or greater is approx. 35,000 km^2.

Strong Motion Records

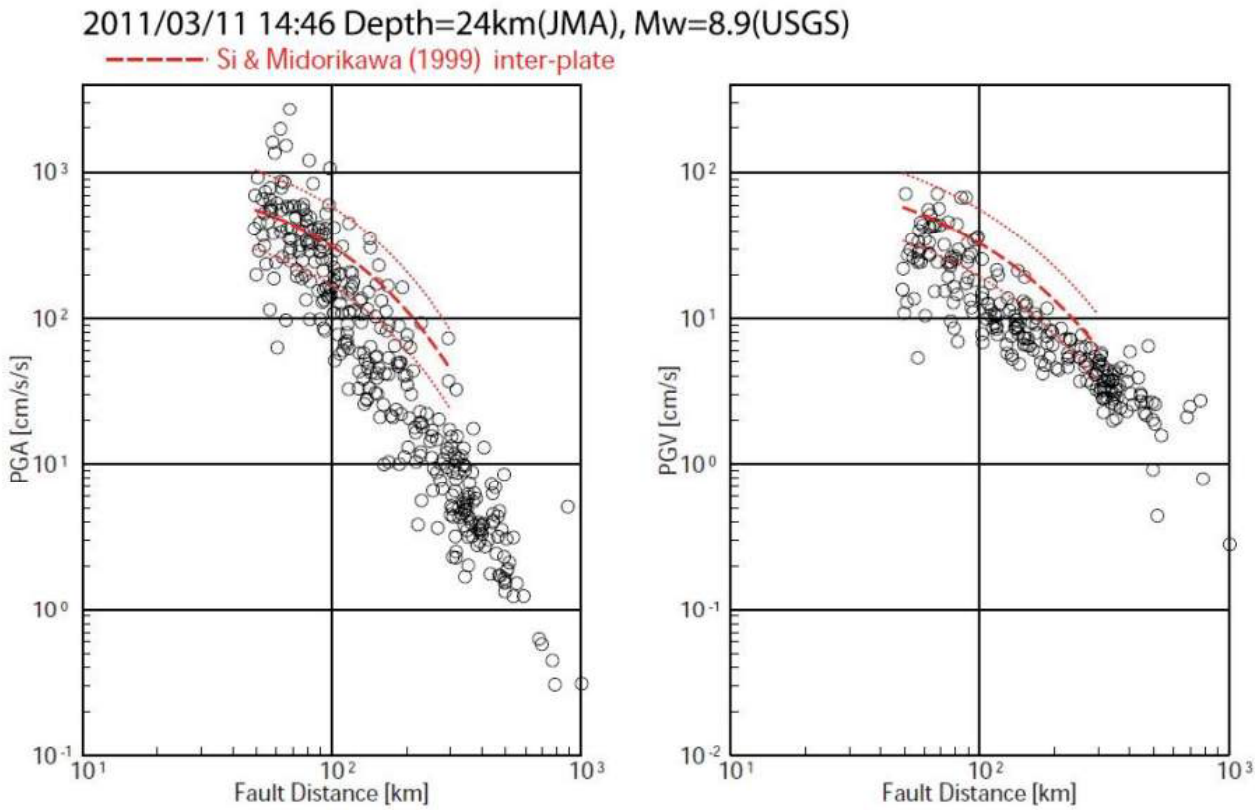


PGA Distribution



PGV Distribution

after NIED

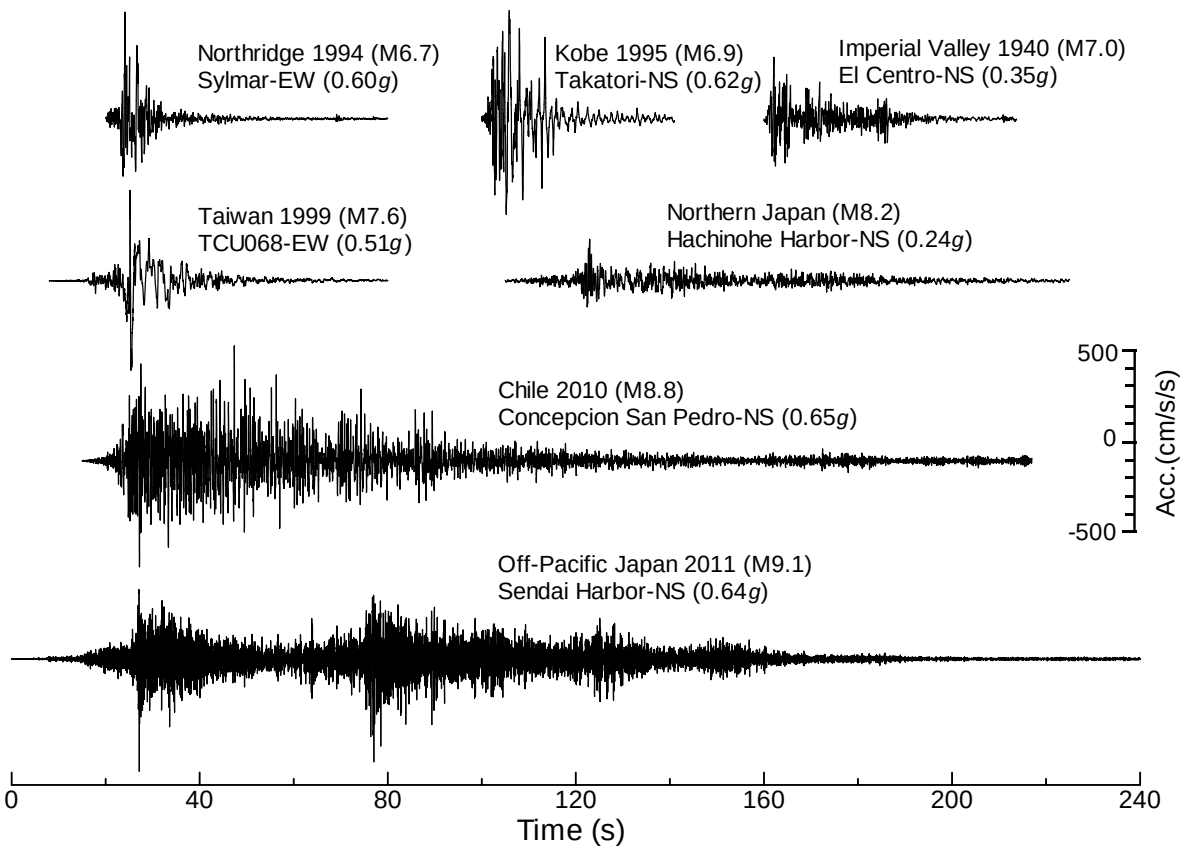


Peak Ground Acceleration

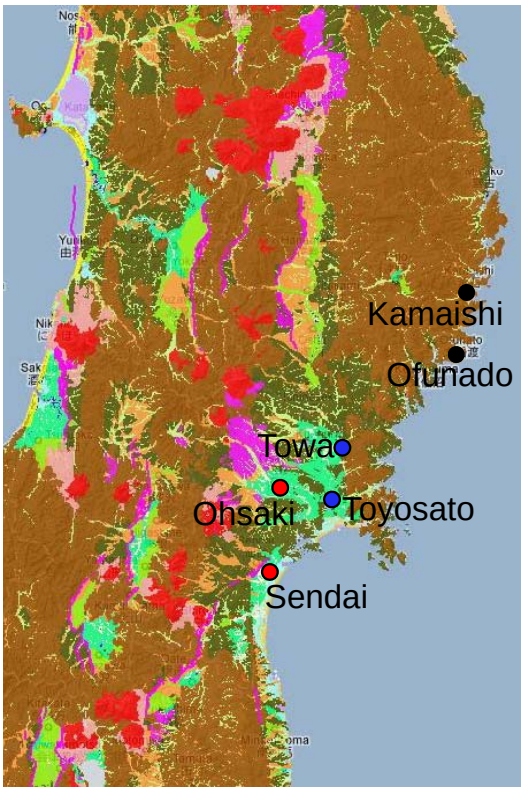
Peak Ground Velocity

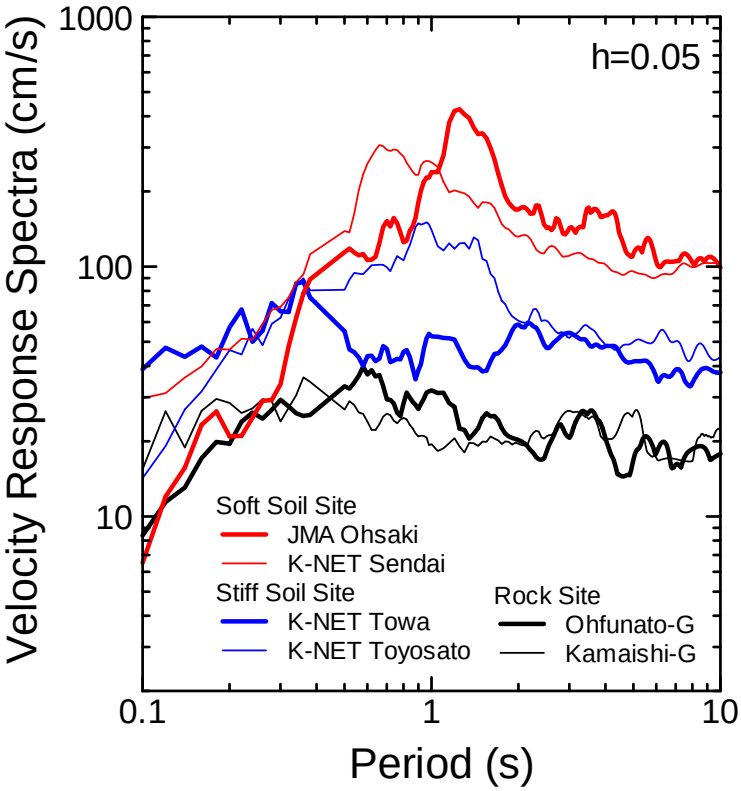
High Acceleration and Relatively Low Velocity

after NIED



Longer duration of longer than 2 minutes





Comparison of Velocity Response Spectra at Different Soil Conditions

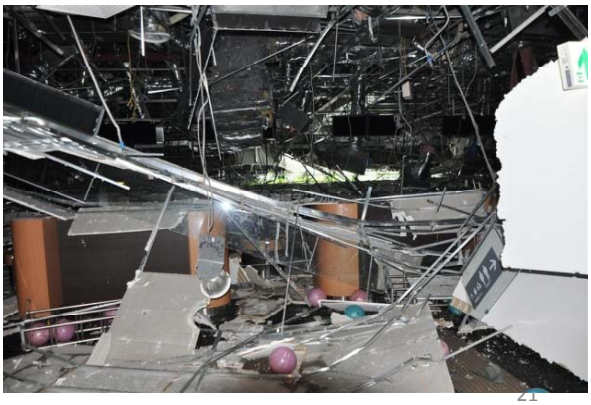
Building Damage at Furukawa, Osaki City

Building Damage at Lowland of Sendai City

Video of Strong Shaking in Tokyo

Damage of Ceiling in Tokyo Area



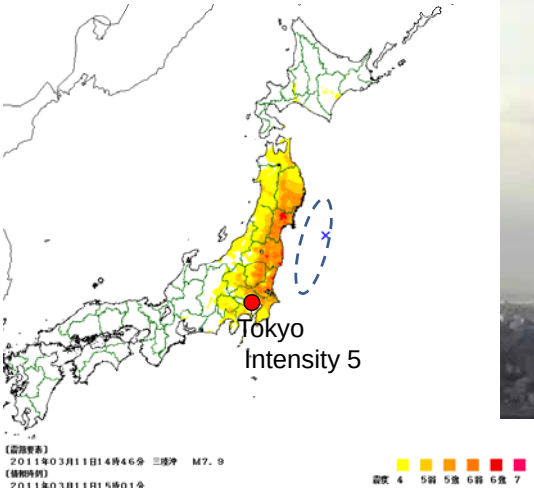
Soil Liquefaction in Tokyo




Long-period Ground Motion in Tokyo

approx. 150km far from the epicentral area

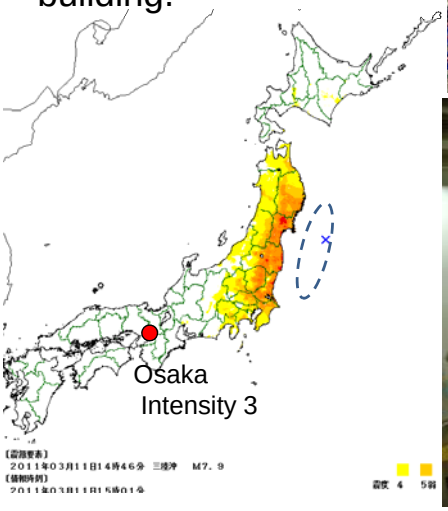
Displacement of 0.5 to 0.7 m was observed at the top of high-rise buildings.

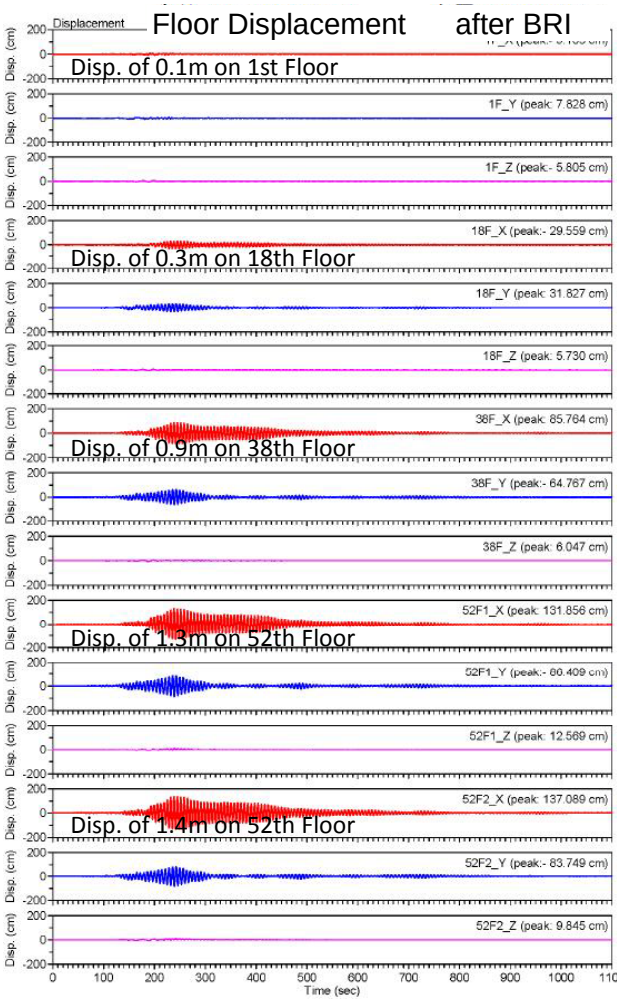


Long-period Ground Motion in Osaka

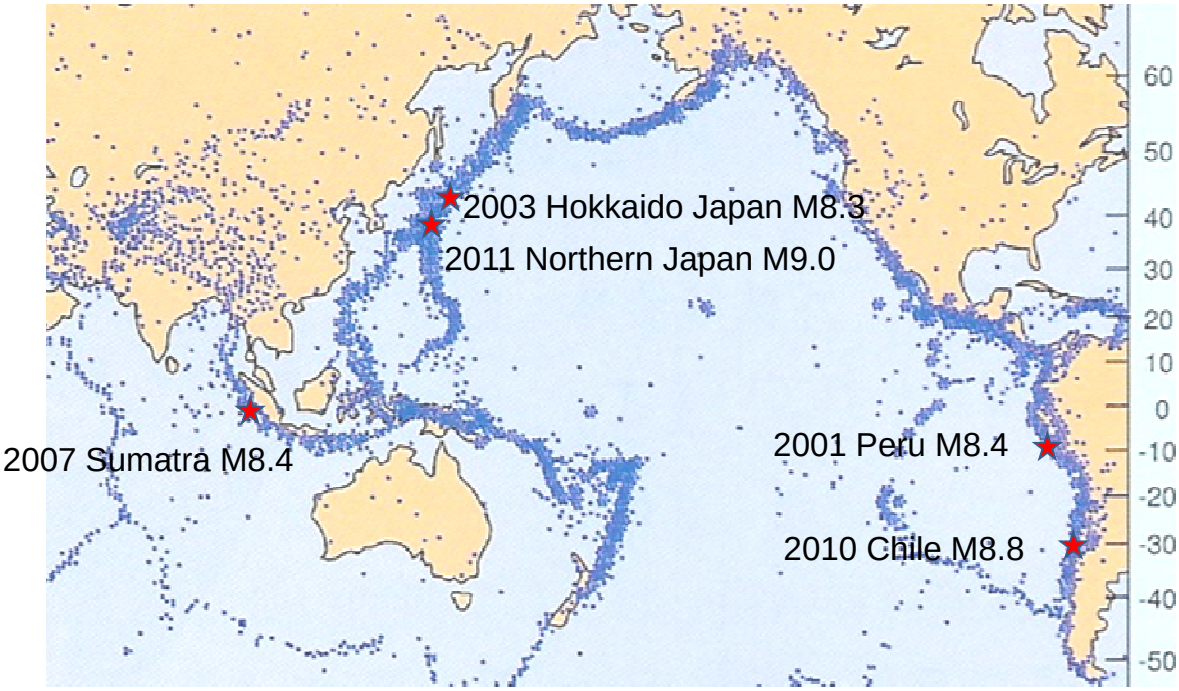
more than 500km far from the epicentral area

Displacement of 1.4 m was observed at the top of a 52-story high-rise building. Minor damage was observed in the building.

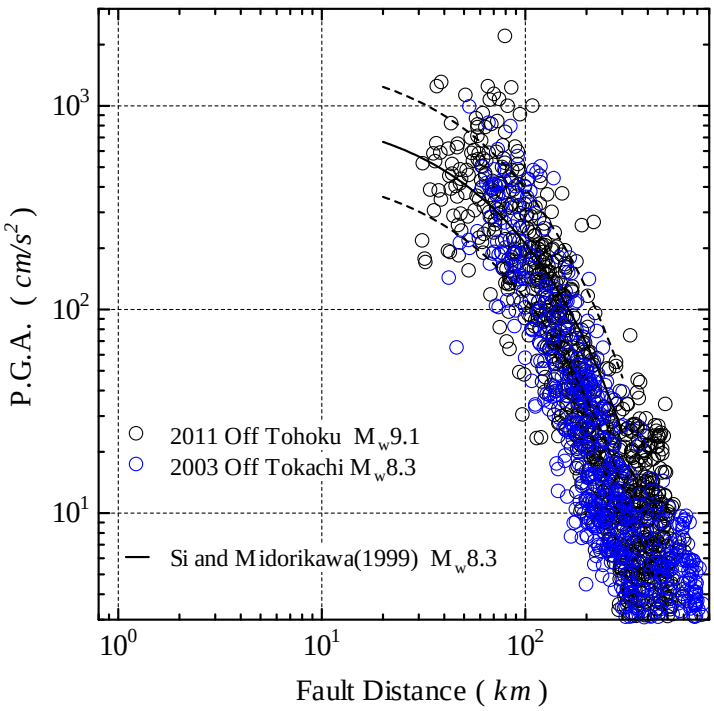




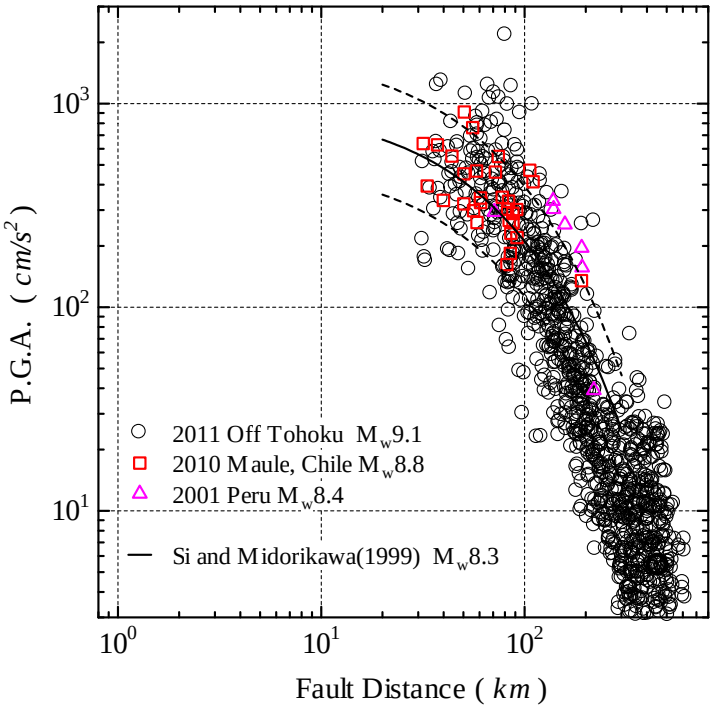
Comparison of Strong Motion Records of Gigantic Earthquakes



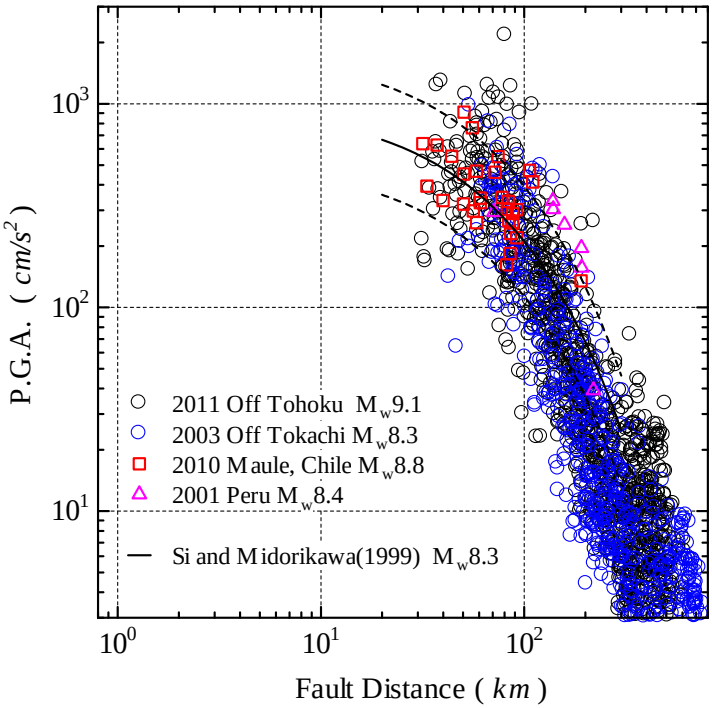
Comparison of Attenuation of Peak Accelerations for the 2011 Northern Japan Earthquake (M9.0) with the 2003 Hokkaido Japan Earthquake (M8.3)



Comparison of Attenuation of Peak Accelerations for the 2011 Northern Japan Earthquake (M9.0) with the 2001 Peru (M8.4) and 2010 Chile (M8.8) Events



Comparison of Attenuation of Peak Accelerations for the 2011 Northern Japan Earthquake (M9.0) with Other Gigantic Earthquakes (M8.3～8.8)



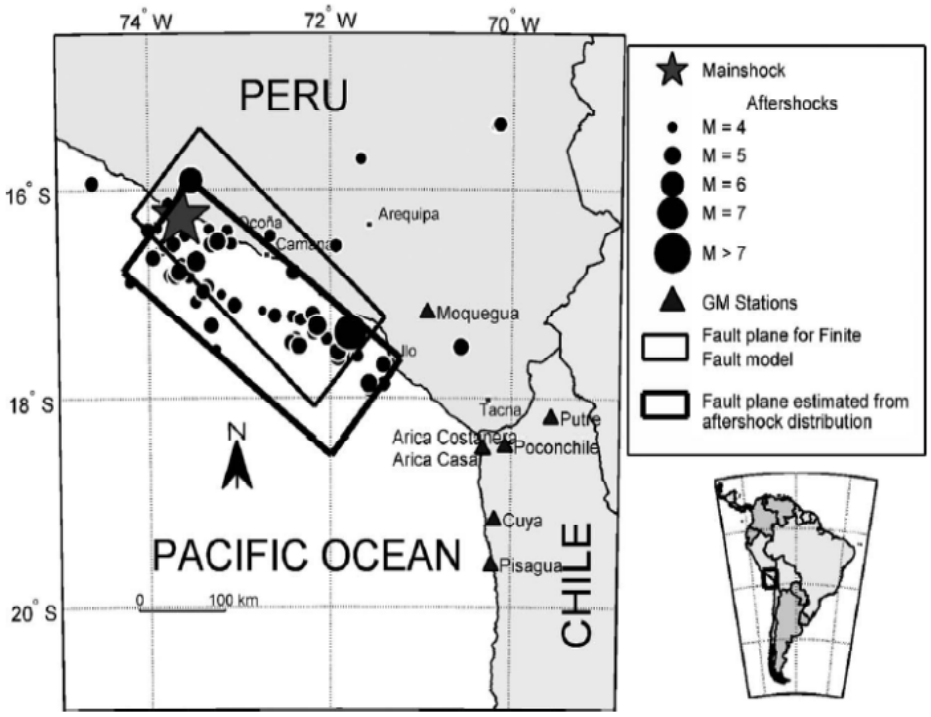
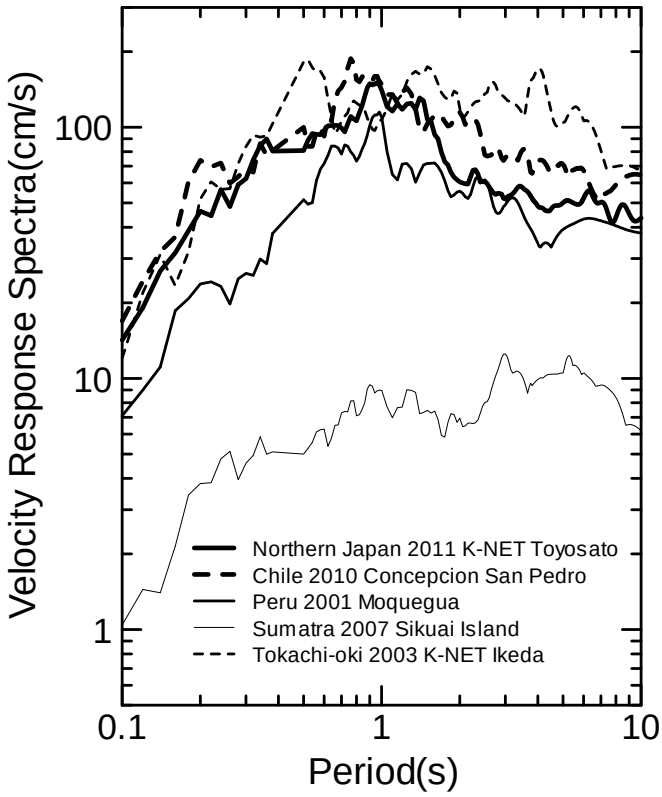
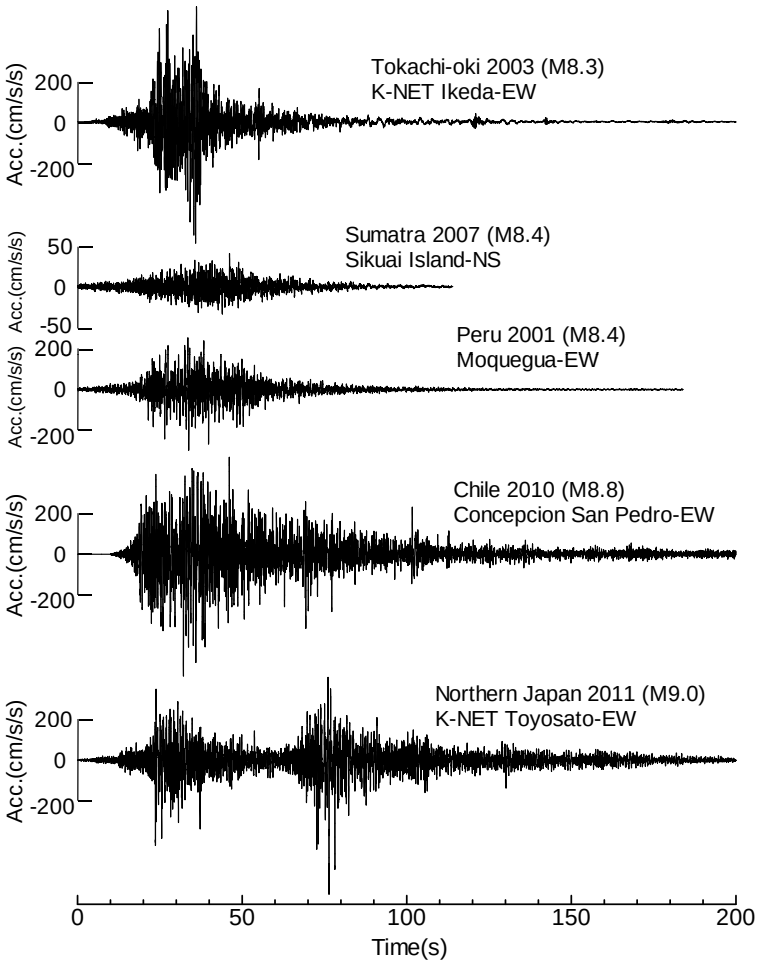


Figure 1. Map of the affected region showing the main shock epicenter as well as location of several aftershocks and the location of ground motion stations. Aftershock locations are obtained from the U. S. Geological Survey.

Comparison of Response Spectra on Stiff Soil Sites

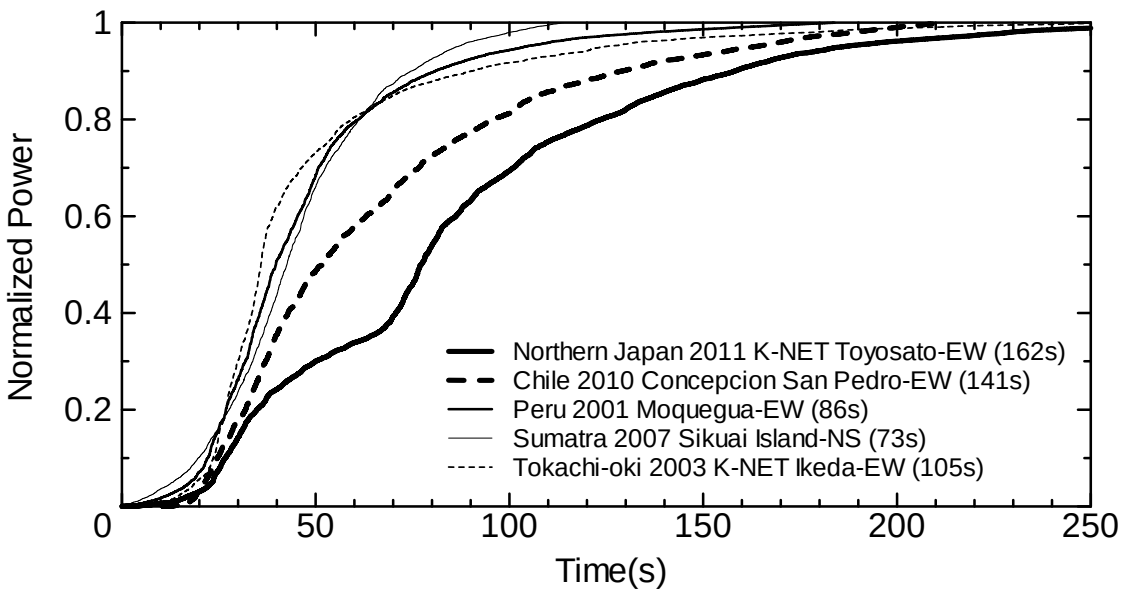


Comparison of Acceleration Time Histories

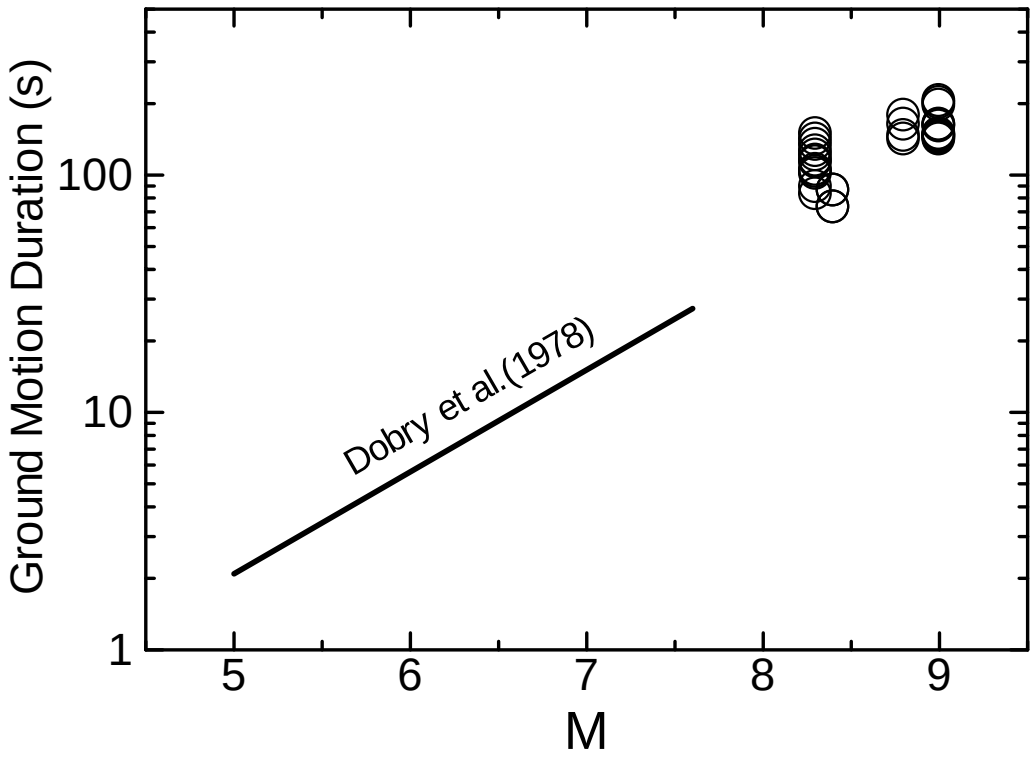


Comparison of Duration of Strong Shaking

cumulative duration which is the time interval during which the central 90% of the contribution to the integral of the square of the acceleration takes place.



M8.3-8.4 80-100sec., M8.8 140sec., M9.0 160sec.



Summary

- The 2011 off the Pacific coast of Tohoku earthquake produced strong shaking with high acceleration and long duration in large area. The area of intensity 5 upper (MMI 8) or greater is approx. 35,000 km^2. On soft soils, ground motion was stronger, which caused building damage.
- In Tokyo and Osaka which are far from the epicenter, long period ground motion and large response of high-rise buildings were observed.
- The strong motion records of this earthquake are compared with those from other earthquakes of magnitude over 8. The acceleration level and spectral shape are similar to each other, but the ground motion duration of this earthquake is longer.

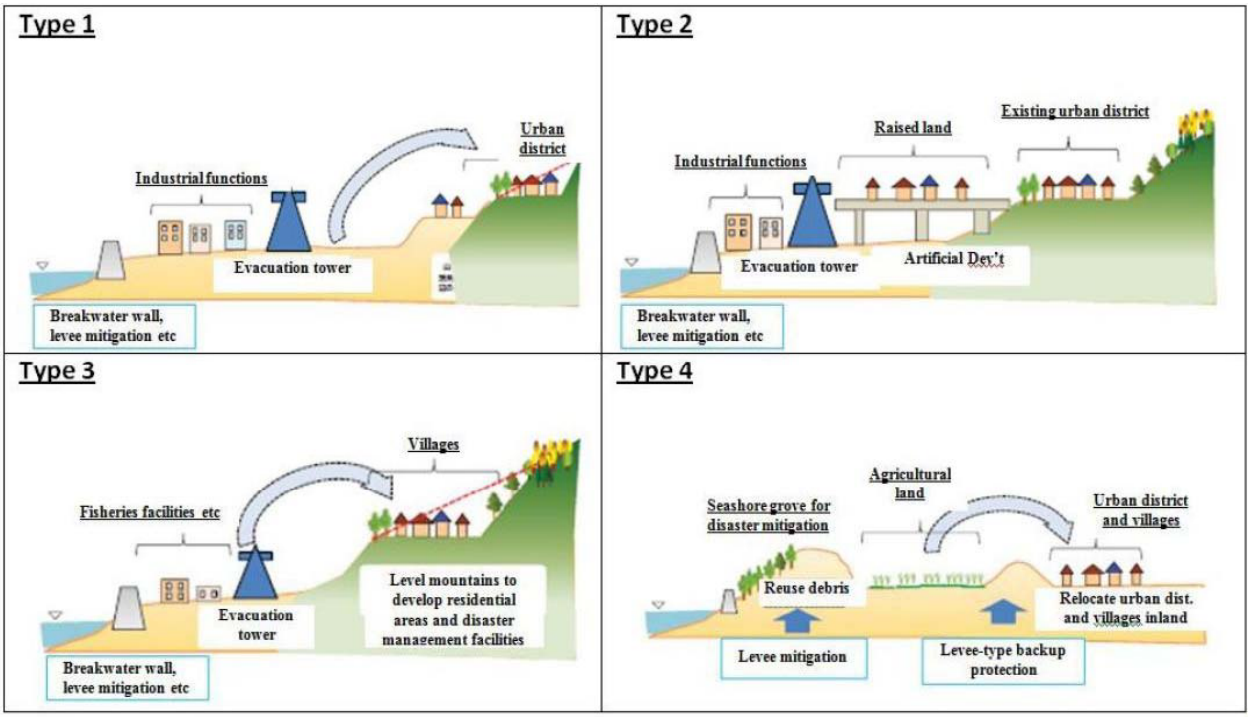


Figure 38. *Four of the reconstruction models based on damage types (source: Reconstruction Design Council, 2011).*

K-NET Tsukidate (MYG004)
Highest Acceleration Observed
2.7g in horizontal and
1.9g in vertical