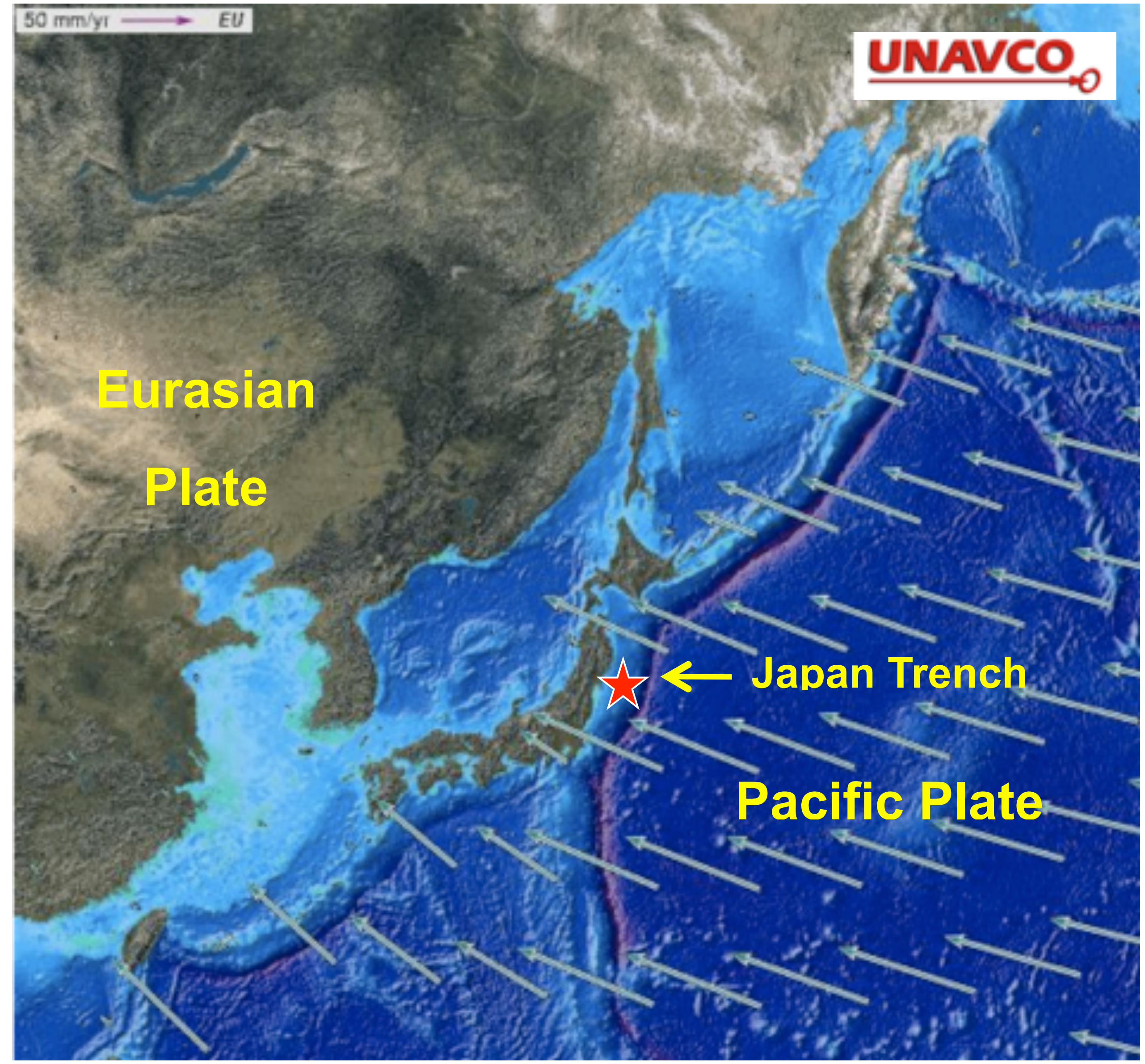
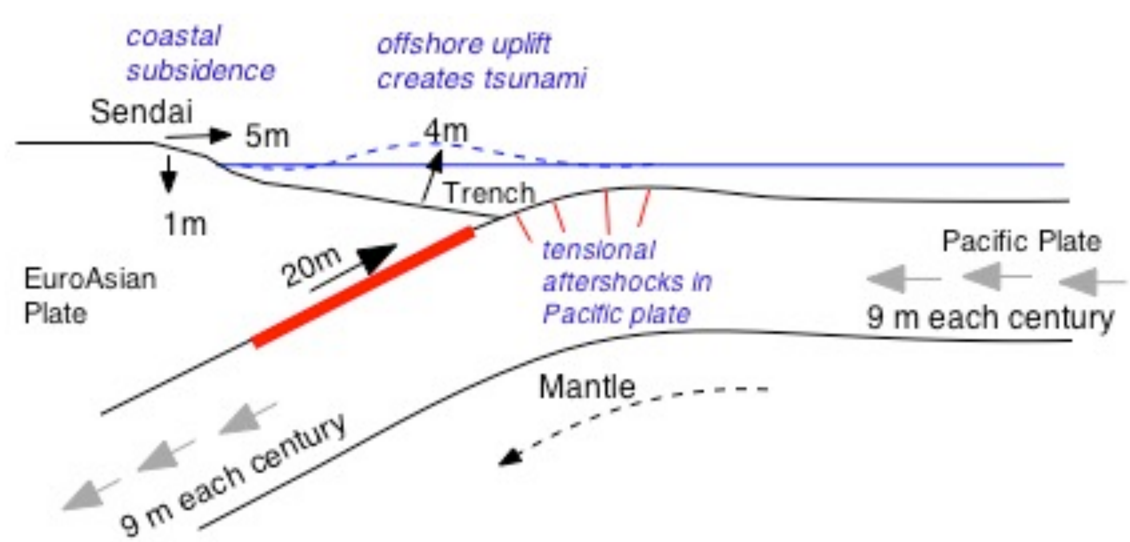
Tohoku-oki event: Tectonic setting

This earthquake was the result of thrust faulting along or near the convergent plate boundary where the Pacific Plate subducts beneath Japan.

This map also shows the rate and direction of motion of the Pacific Plate with respect to the Eurasian Plate near the Japan Trench. The rate of convergence at this plate boundary is about 100 mm/yr (9 cm/year).

This is a fairly high convergence rate and this subduction zone is very seismically active.

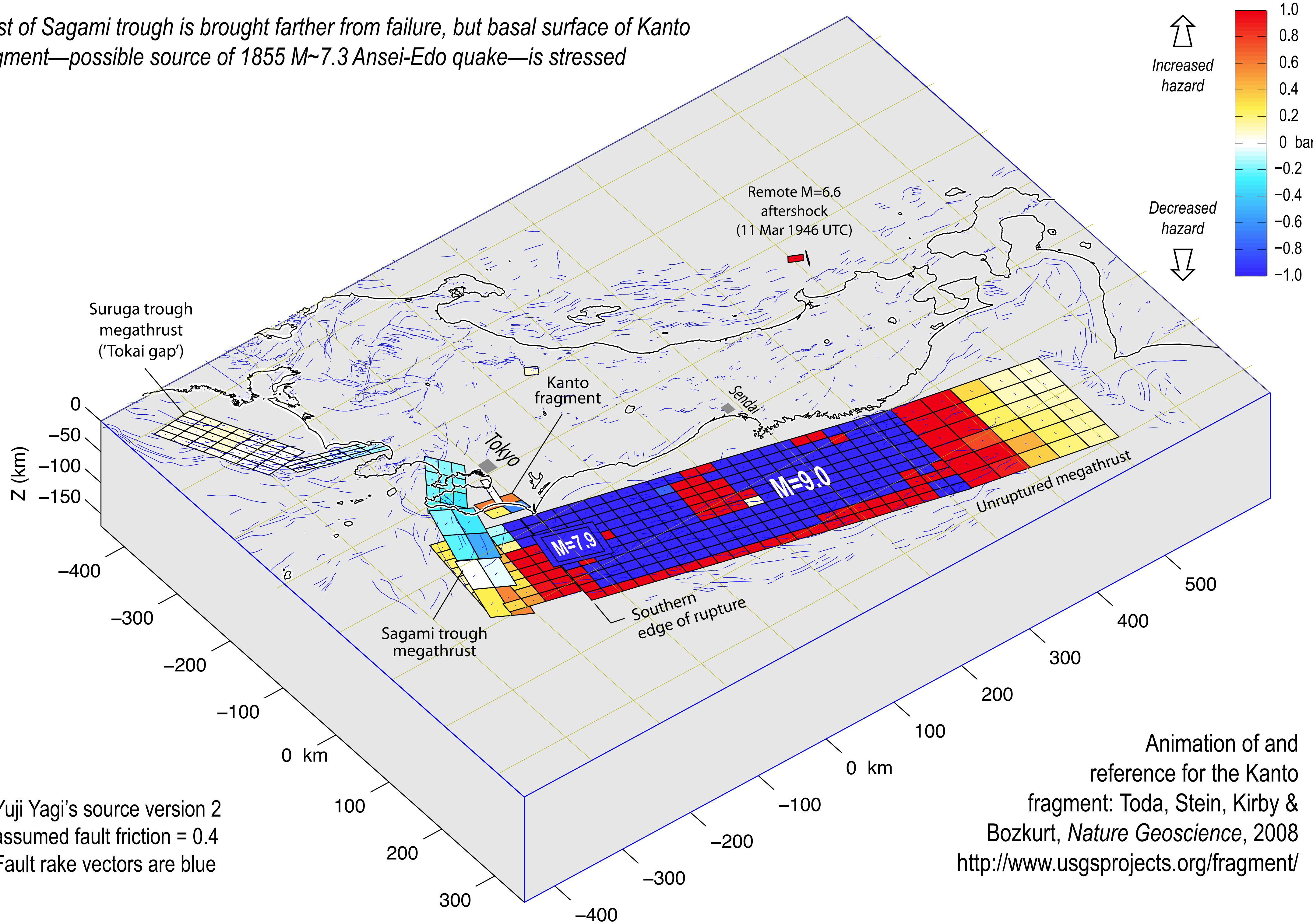




Dynamic rupture and stress transfer

Coulomb stress imparted by the M=9.0 Off-Tohoku rupture and its M=7.9 aftershock to Japan Trench, Sagami Trough and Kanto Fragment

Most of Sagami trough is brought farther from failure, but basal surface of Kanto fragment—possible source of 1855 M~7.3 Ansei-Edo quake—is stressed



Yuji Yagi's source version 2
assumed fault friction = 0.4
Fault rake vectors are blue

Animation of and reference for the Kanto fragment: Toda, Stein, Kirby & Bozkurt, *Nature Geoscience*, 2008
http://www.usgsprojects.org/fragment/

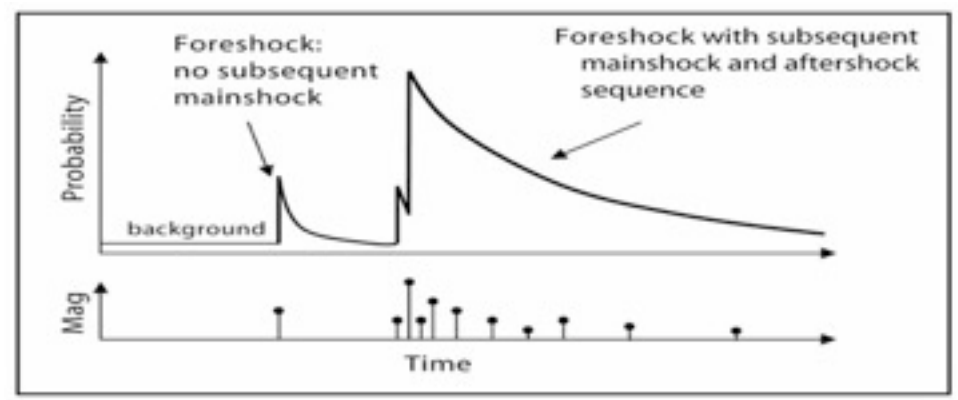
Ross Stein & Volkan Sevilgen (USGS) and Shinji Toda (DPRI, Kyoto Univ.) 18 Mar 2011 4:15 PM PDT

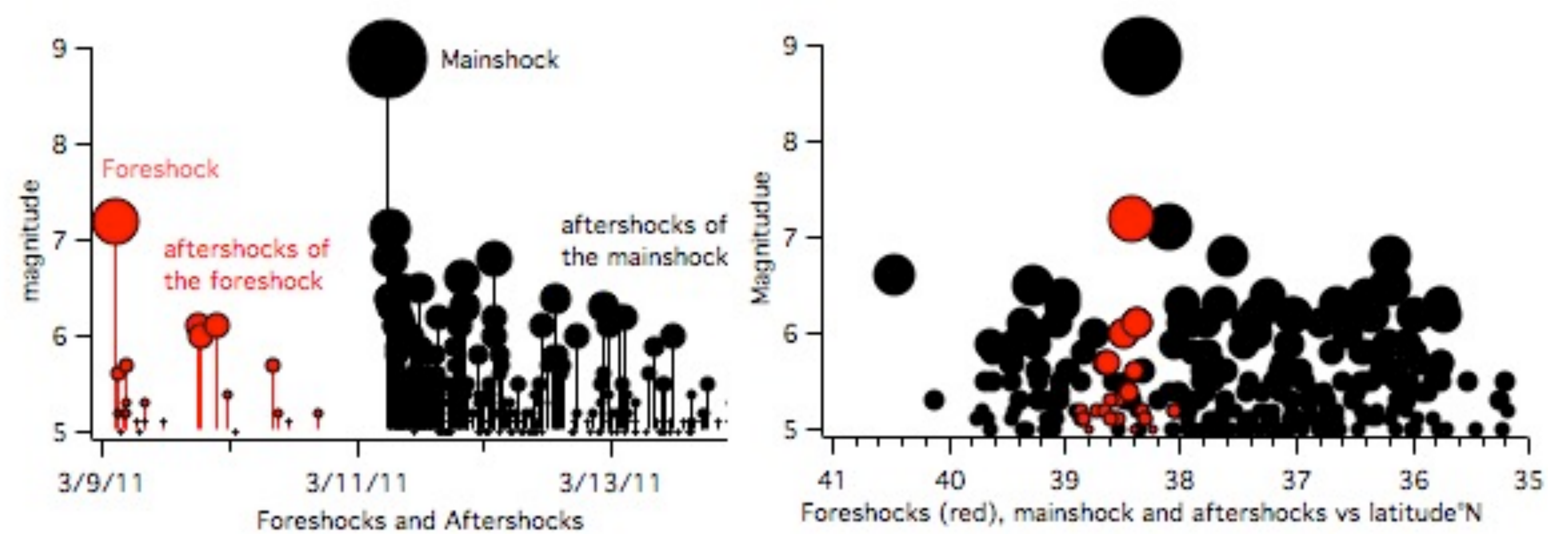
Aftershocks

Aftershock sequences follow predictable patterns as a group, although the individual earthquakes are themselves not predictable. The graph below shows how the number of aftershocks and the magnitude of aftershocks decay with increasing time since the main shock. The number of aftershocks also decreases with distance from the main shock.

Aftershocks usually occur geographically near the main shock. The stress on the main shock's fault changes drastically during the main shock and that fault produces most of the aftershocks. Sometimes the change in stress caused by the main shock is great enough to trigger aftershocks on other, nearby faults.

Image and text courtesy of the US Geological Survey





Historical seismicity and aftershocks

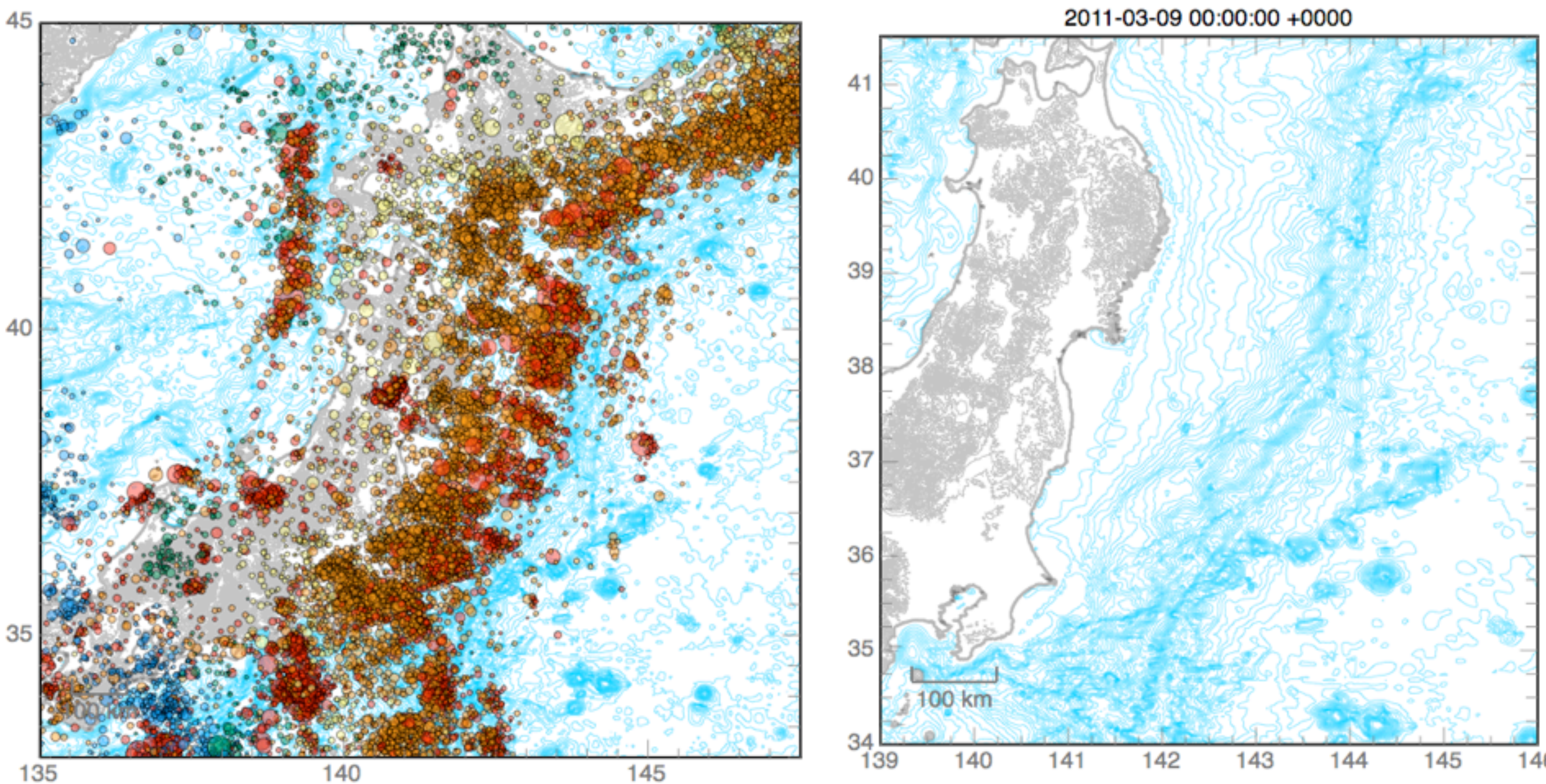
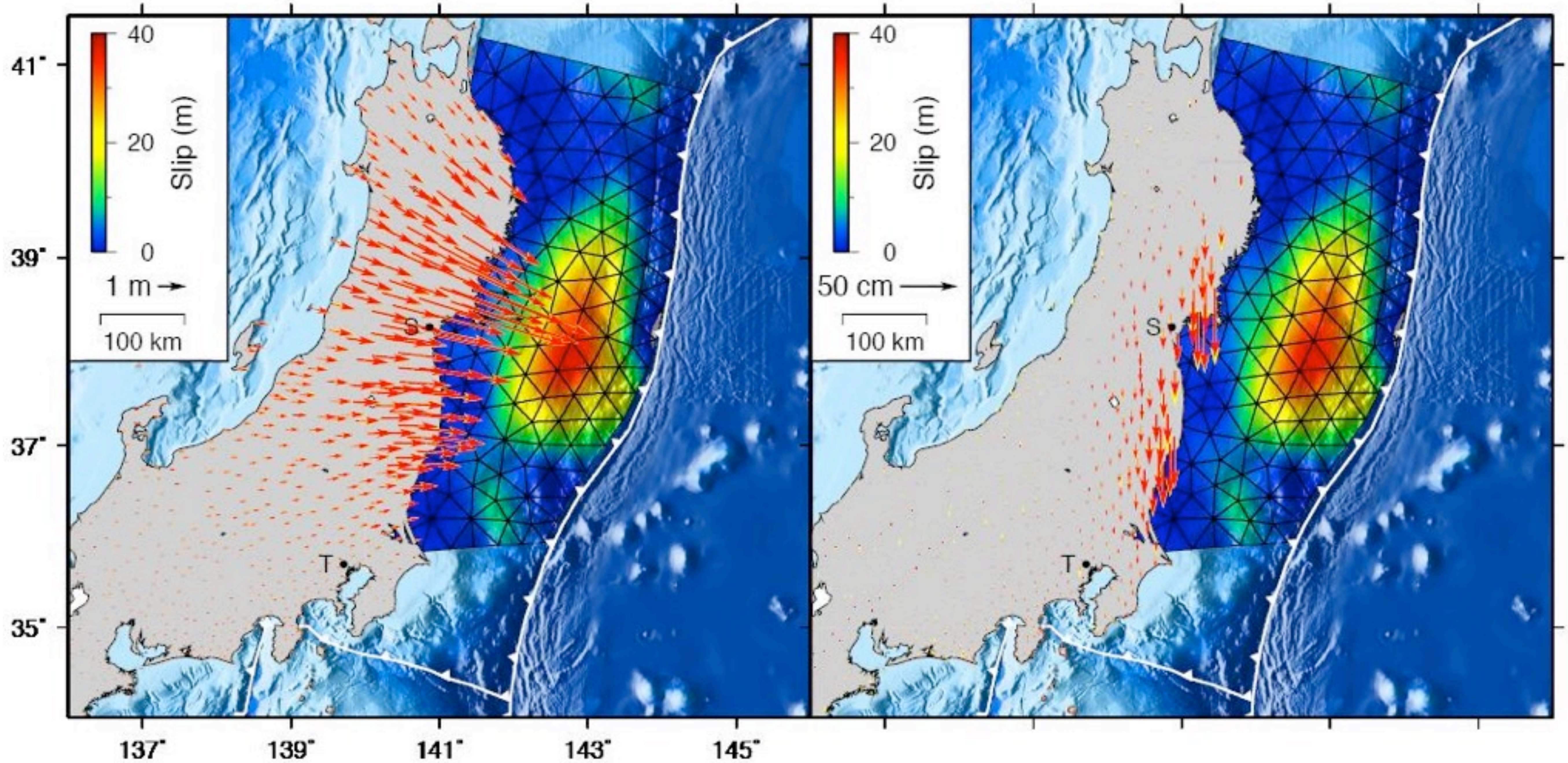


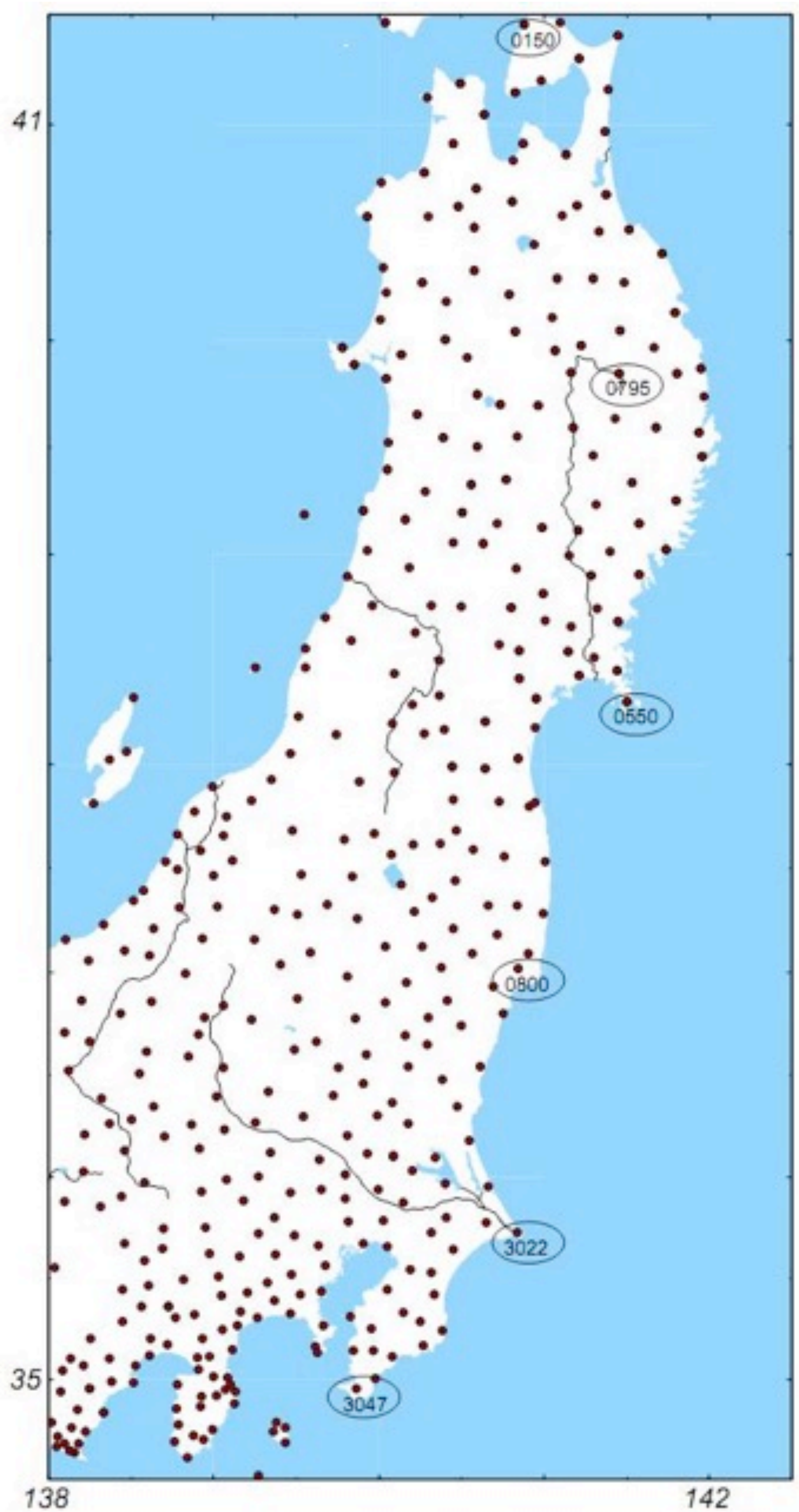
Image courtesy of Charles Ammon

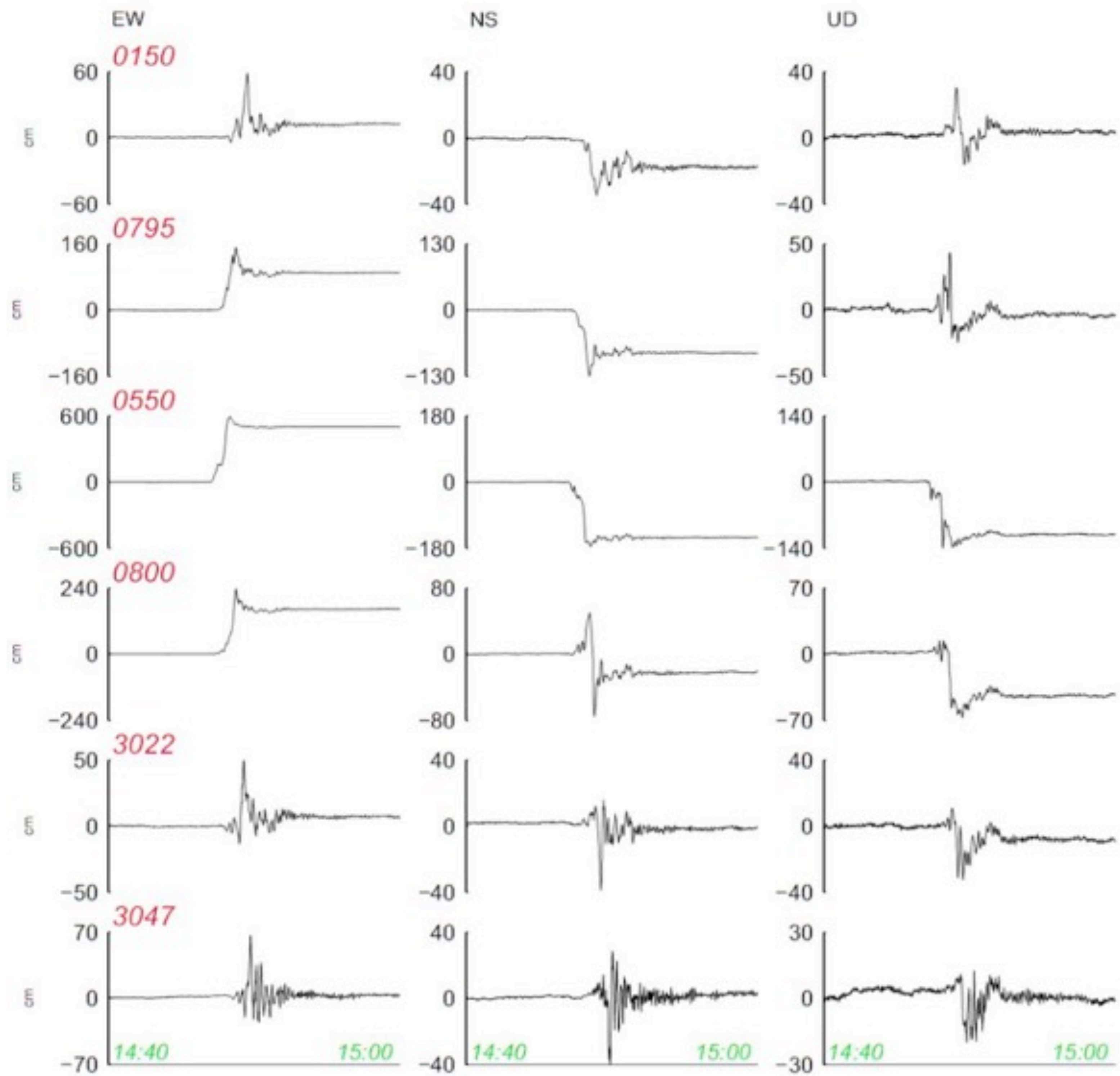
Co-seismic slip



M. Simons, F. Ortega, J. Jiang, A. Sladen, and S. Minson at Caltech as part of the ARIA project.
All orginal GEONET RINEX data provided to Caltech by the Geospatial Information Authority (GSI) of Japan.

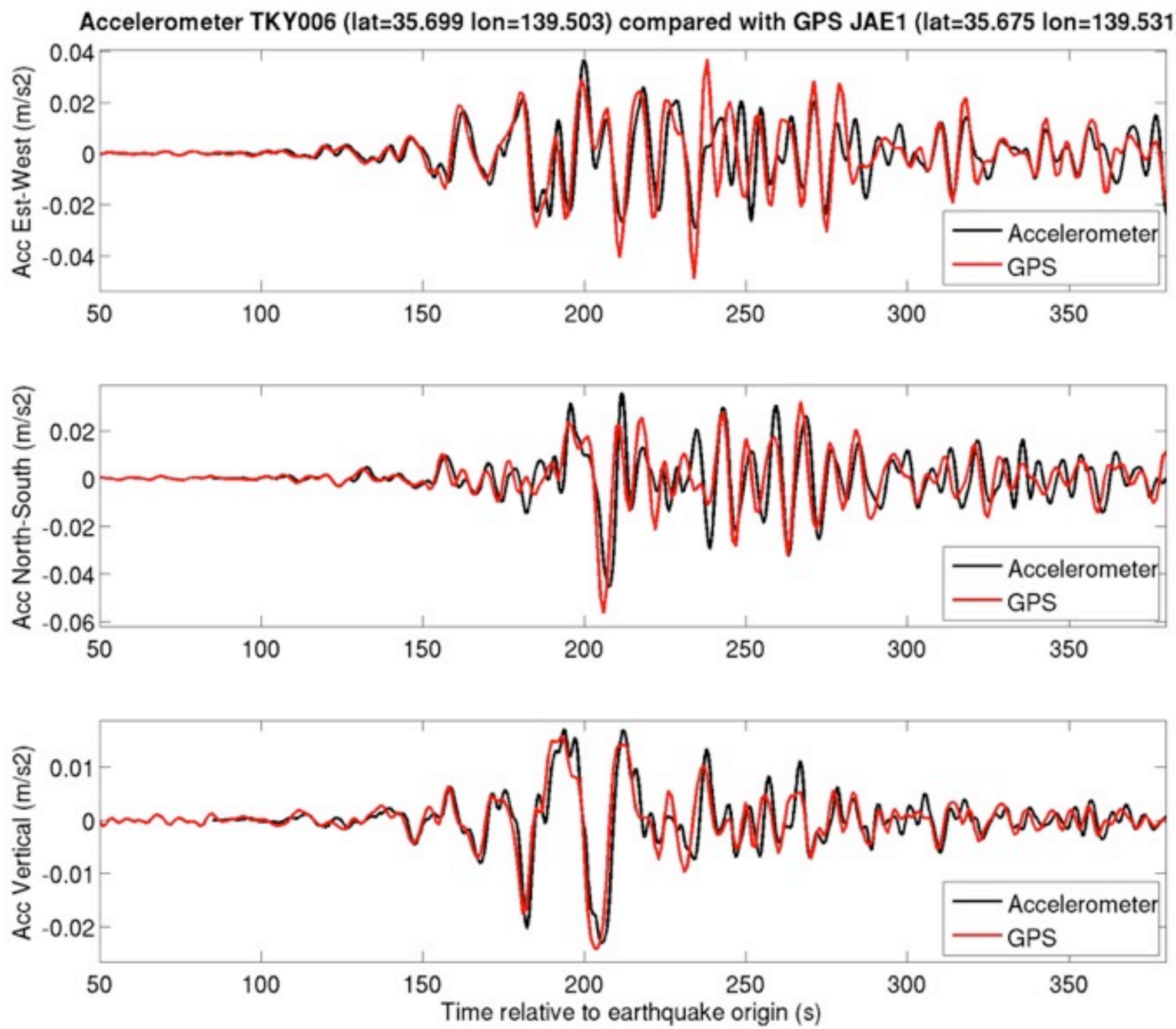
GPS waveforms





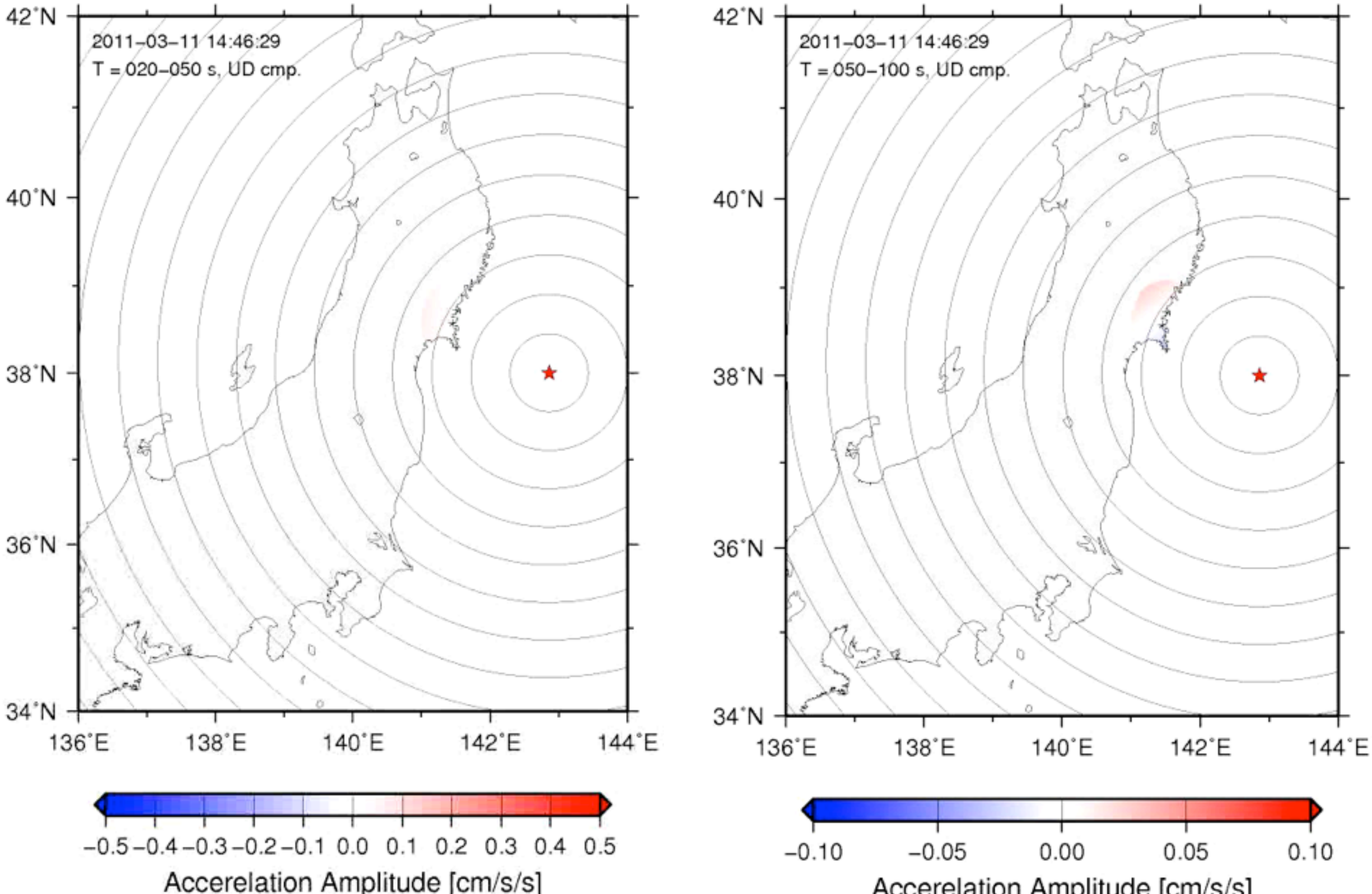
Analysis by Dr. Yokota using the GEONET data of Geographical Survey Institute

GPS and GM signals



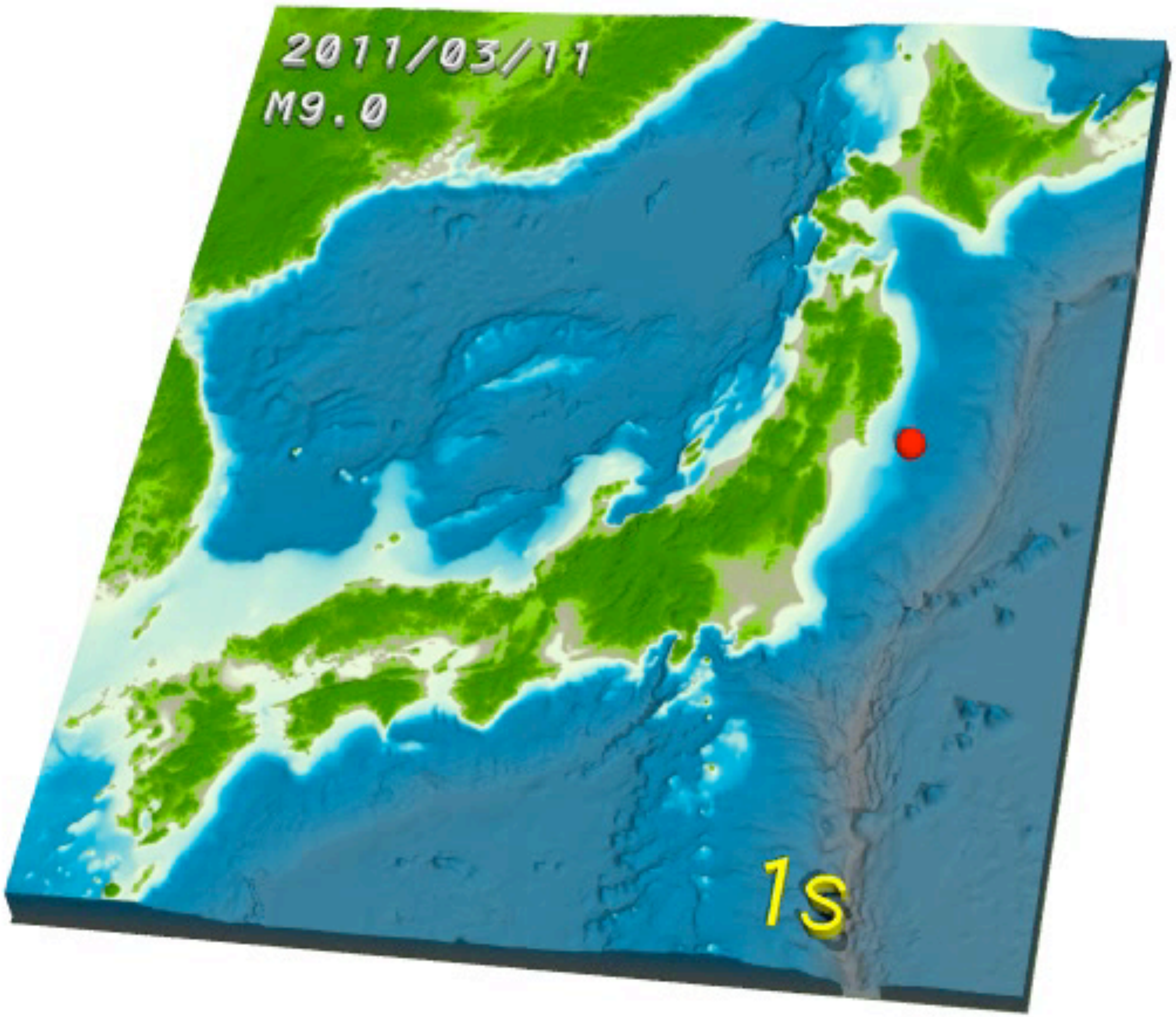
The figure shows the comparison between this GPS signal - twice differentiated - and the accelerometric signal, in the [0.005Hz - 0.125Hz] range.

Long period GM



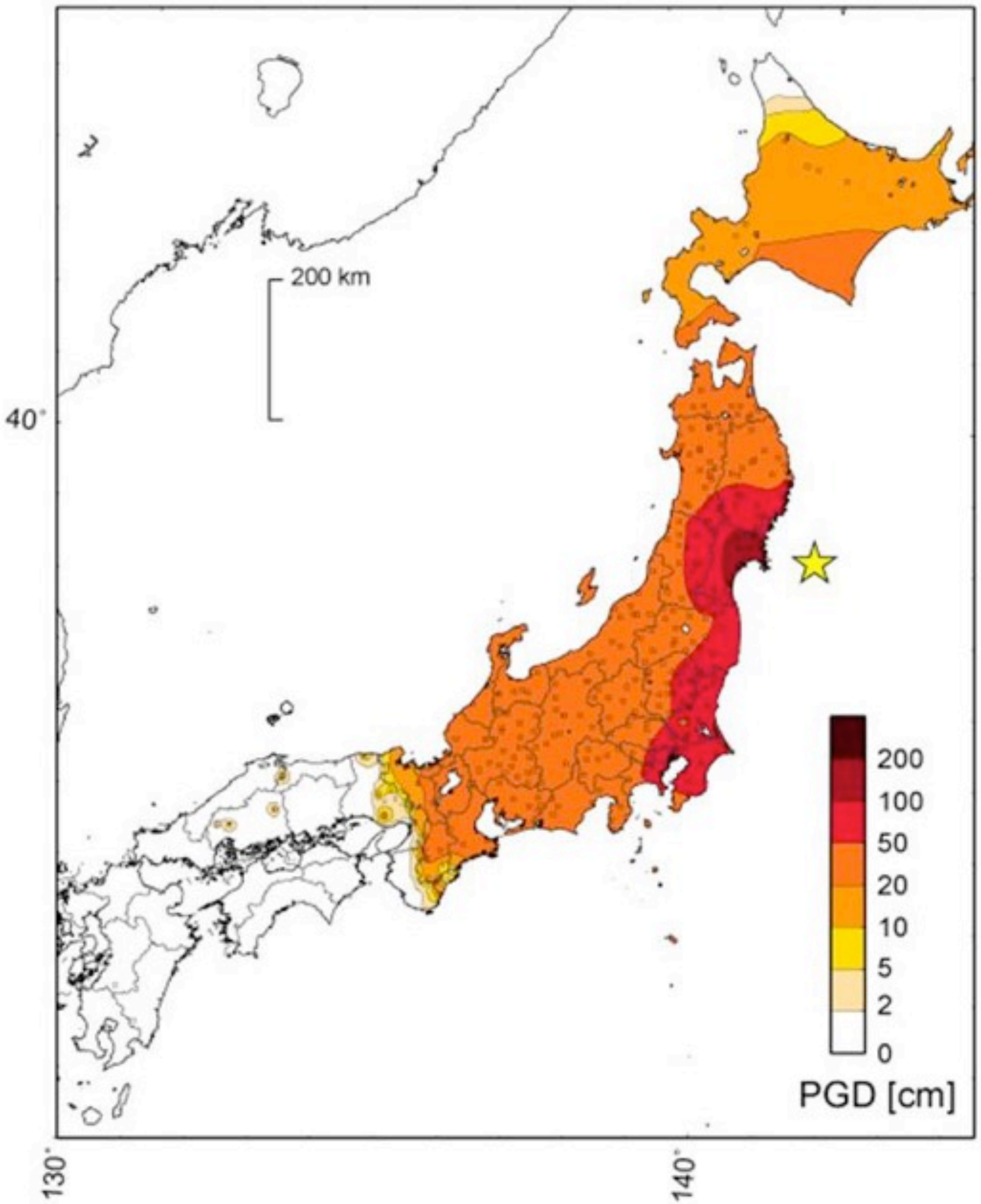
"Earthquake Research Institute, University of Tokyo: Dr. Furumura and Project Researcher Maeda

Ground motion animation: time scales...



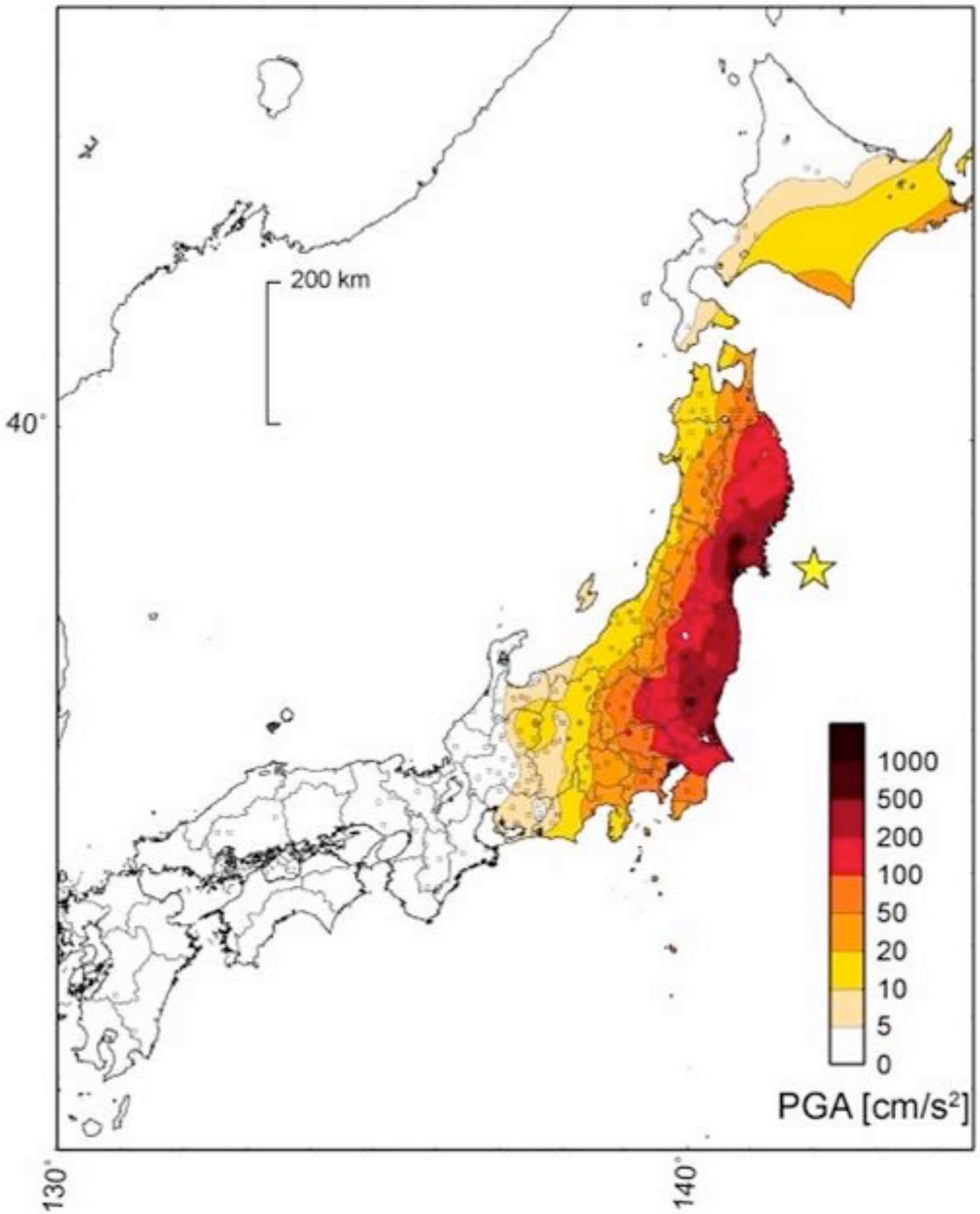
Courtesy of Takashi Furumura

PGD



- A strong ground acceleration of over 2933 cm/s/s was observed in K-NET Tsukidate observation station (Miyagi pref.) near the hypocenter, and a strong ground acceleration propagated in broad area from Ibaraki to southern Iwate. The distribution of strong ground acceleration is extending to three areas: between Iwate and Miyagi prefecture, Fukushima pref., between Tochigi and Ibaraki pref. Therefore, it is assumed that a huge fault slip have occurred on the east of these areas. The ground acceleration is decaying drastically just after the border of Itoigawa-Shizuoka Tectonic Line, and it suggests that the wave attenuated at around this area.

PGA



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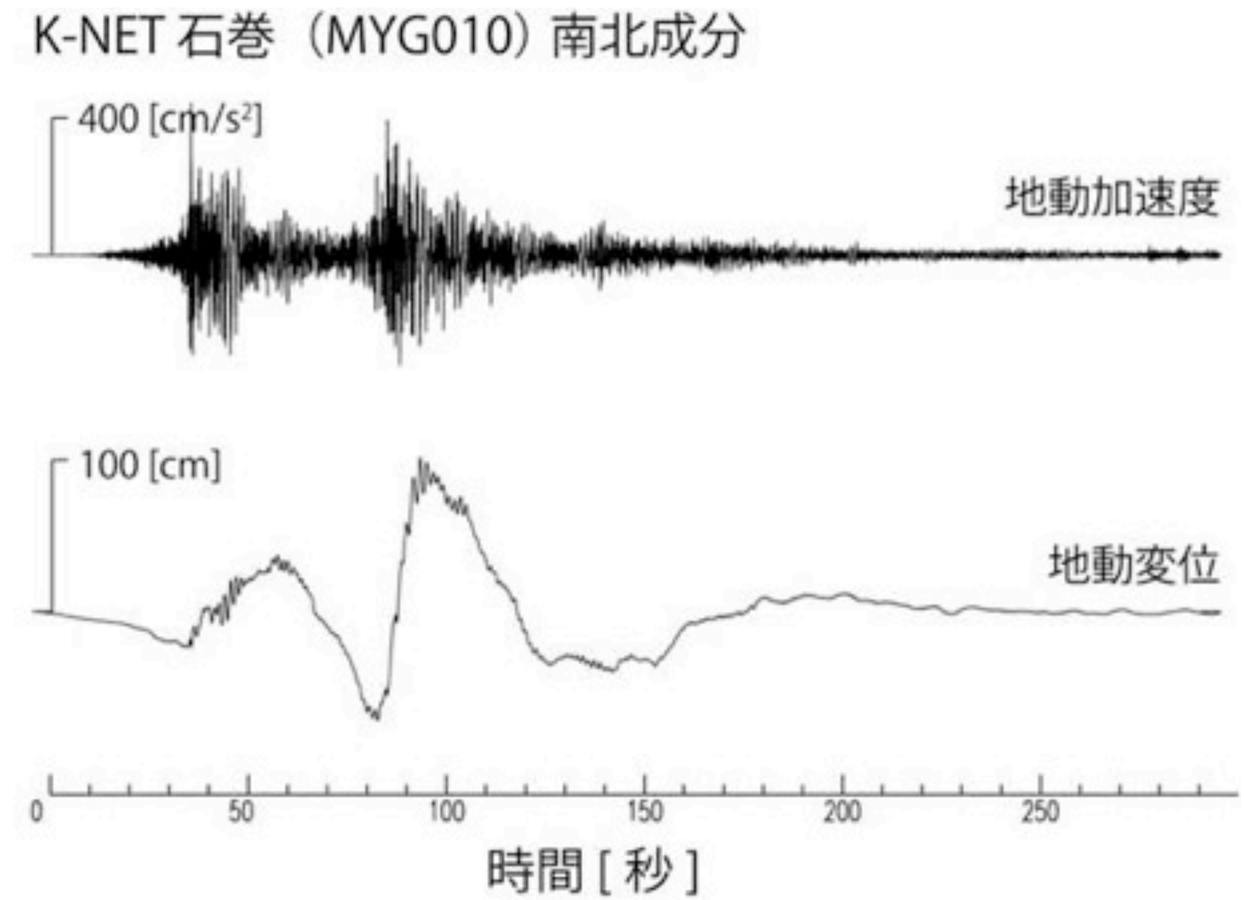
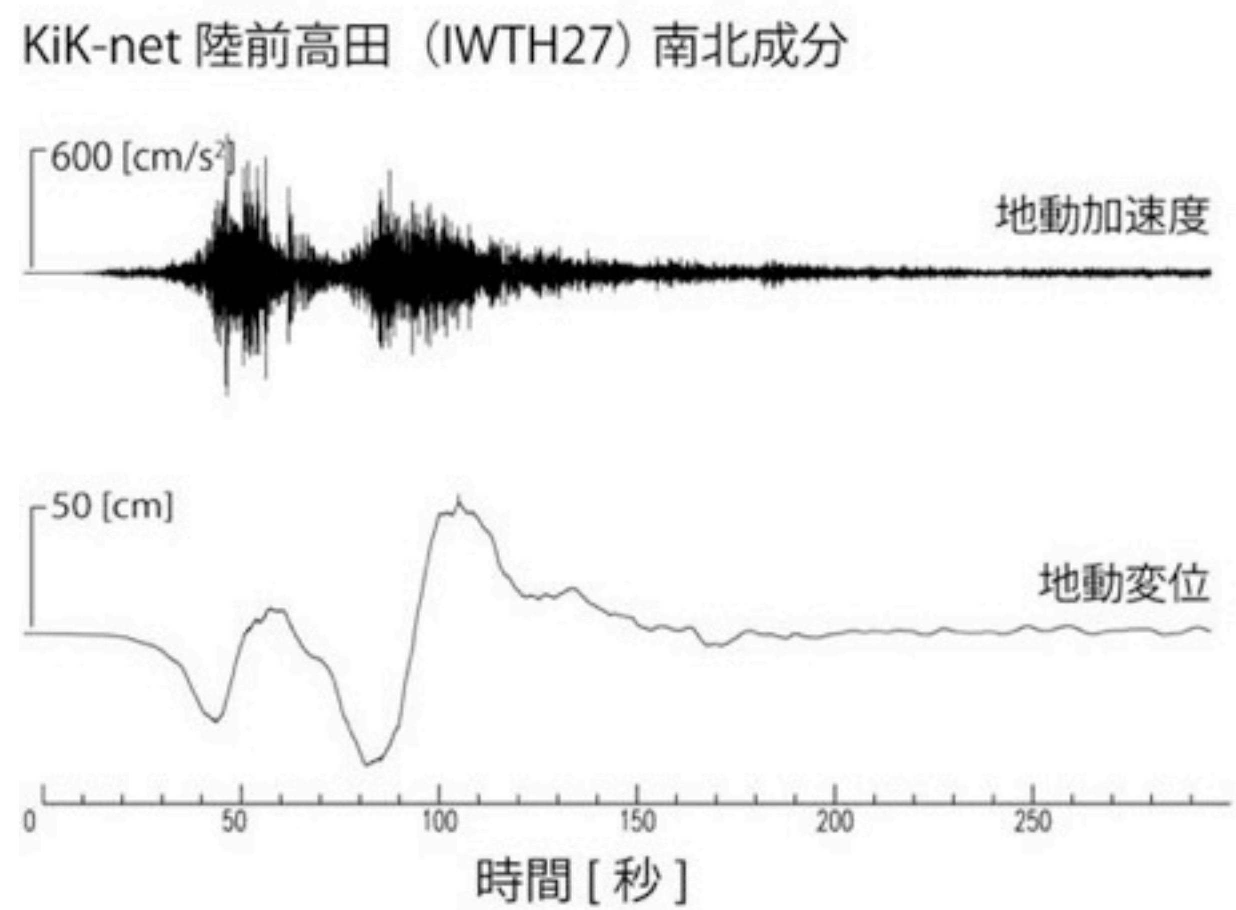
Waveforms

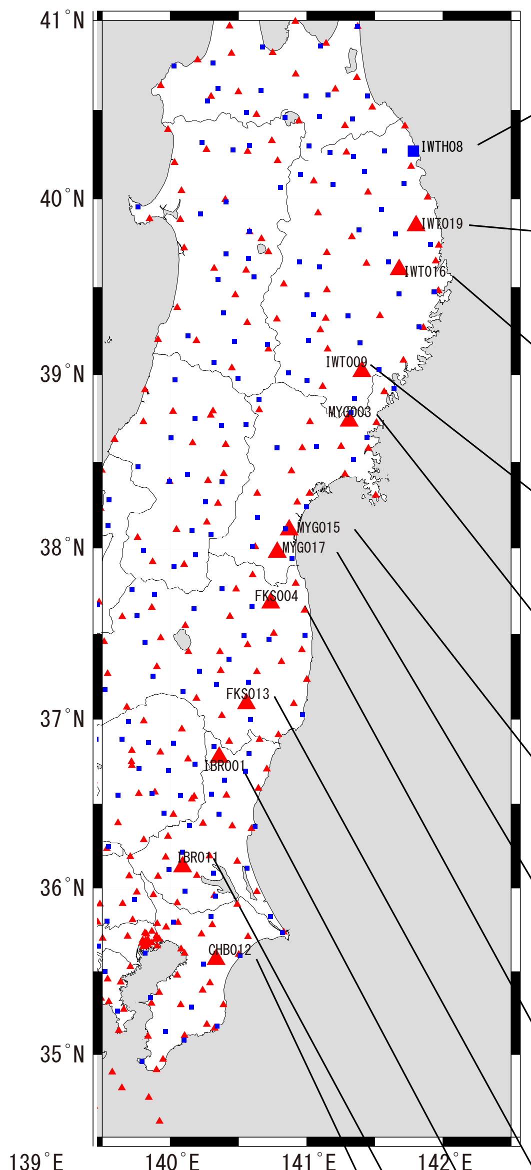
- Maximum acceleration and maximum displacement of ground motion in Ishinomaki and Rikuzentakata where ground motion was strong. The arrival of 2 strong seismic wave groups is seen after about 50 seconds. They suggest that a strong seismic wave was radiated from the 2 major asperities of the Miyagi coast and Iwate coast.

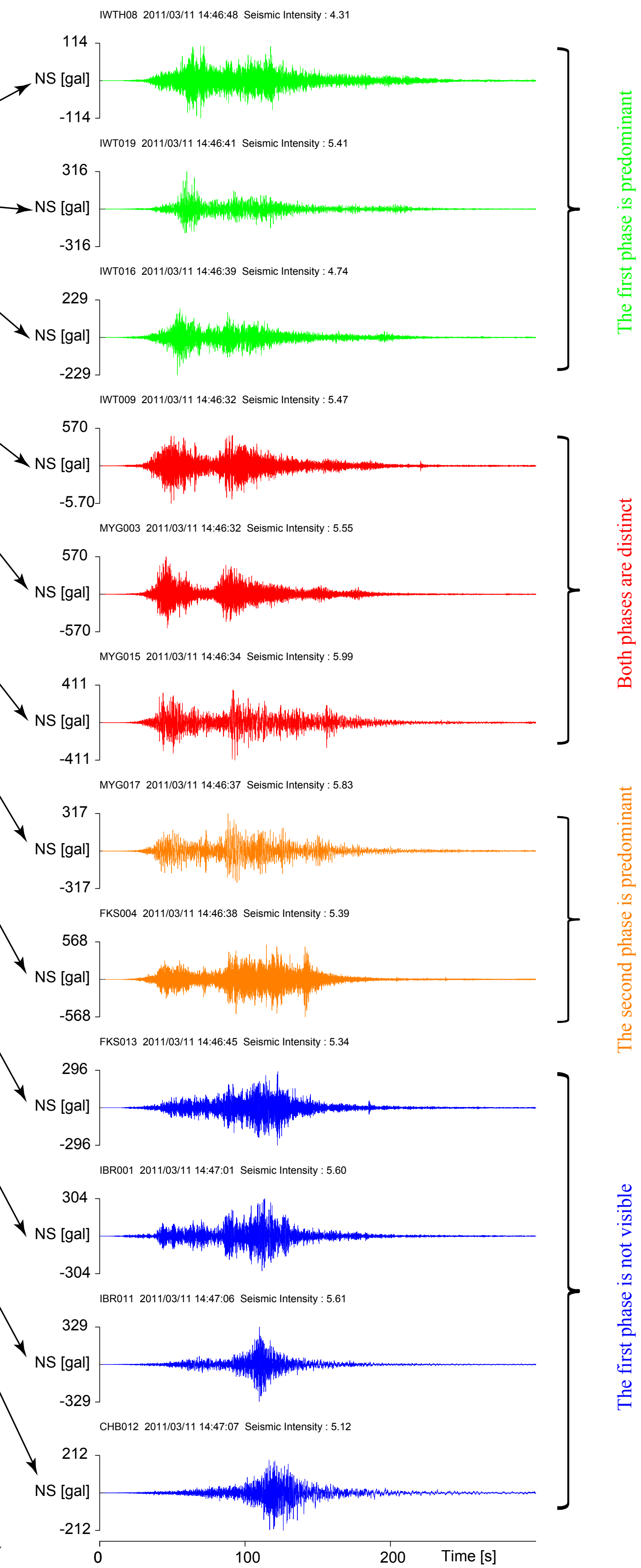
- Two long-period pulses (40-50 second) was found in ground displacement and its amplitude is more than 50 to 100cm. The long-period of ground motion that lasted for 100 and several tens of seconds, indicates the long time rupture process of the fault in this massive earthquake.





Rupture from ground motion





Near-source acceleration waveforms display two remarkable phases of ground motion which suggest the existence of a least two areas of large slip.

In the northern part of the source area the first phase is predominant while in the South this phase is not visible.

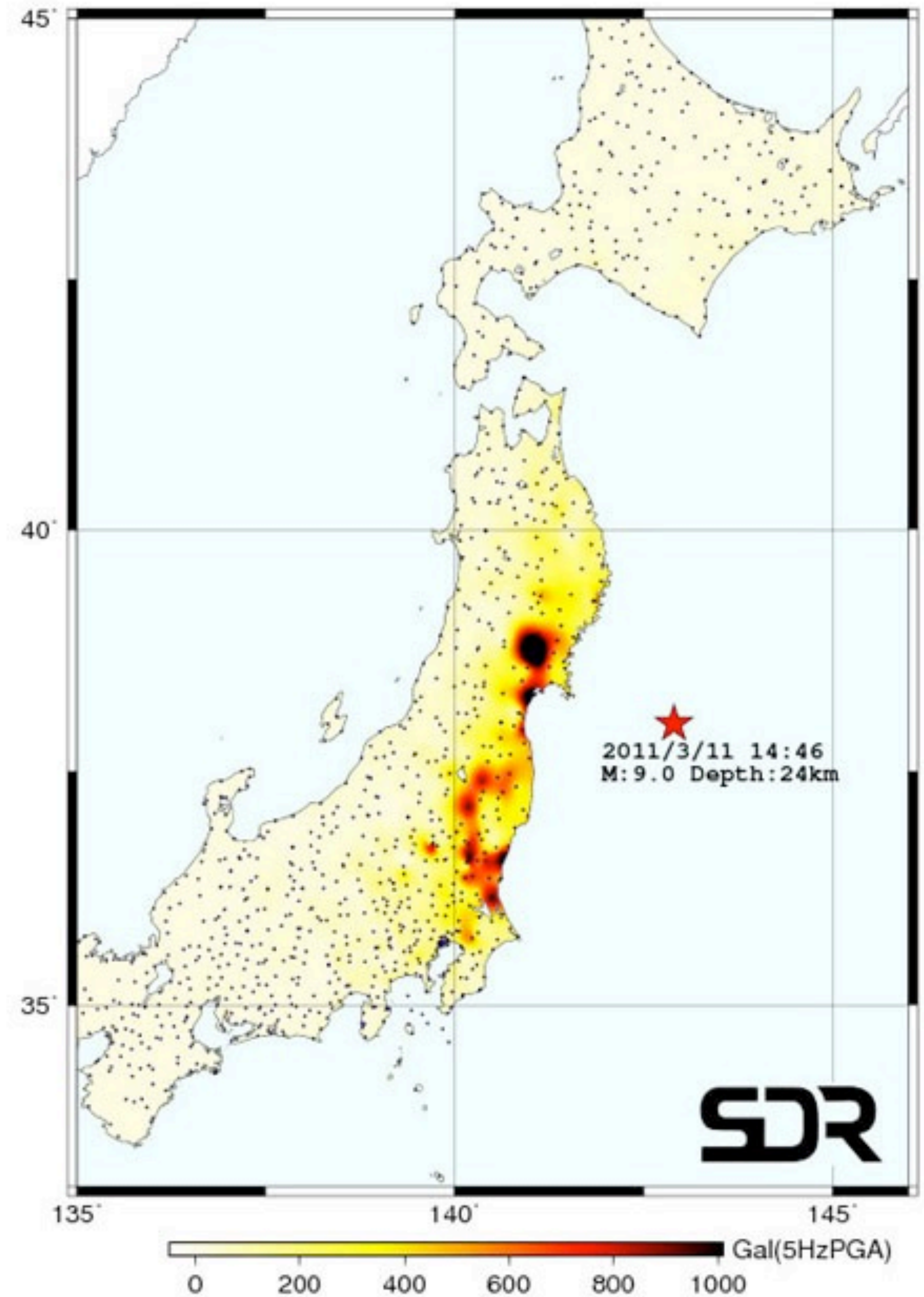
These two phases of ground motion suggest large slip areas in the North and South regions respectively.

The remarkable differences in grow characteristics of intensity values for the Miyagi and Ibaraki regions indicate they originate from different slip areas.

A small ground motion phase is observed between the two large distinct phase at some stations (FKS013, FKS004, MYG017, MYG015).

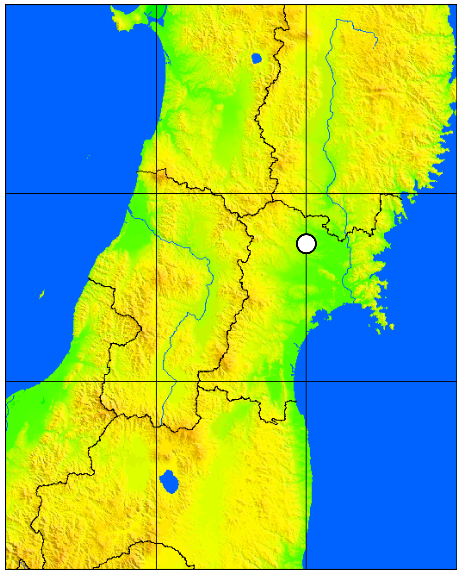
Other secondary phases are also observed suggesting a very complex source process

Source: Knet-NIED



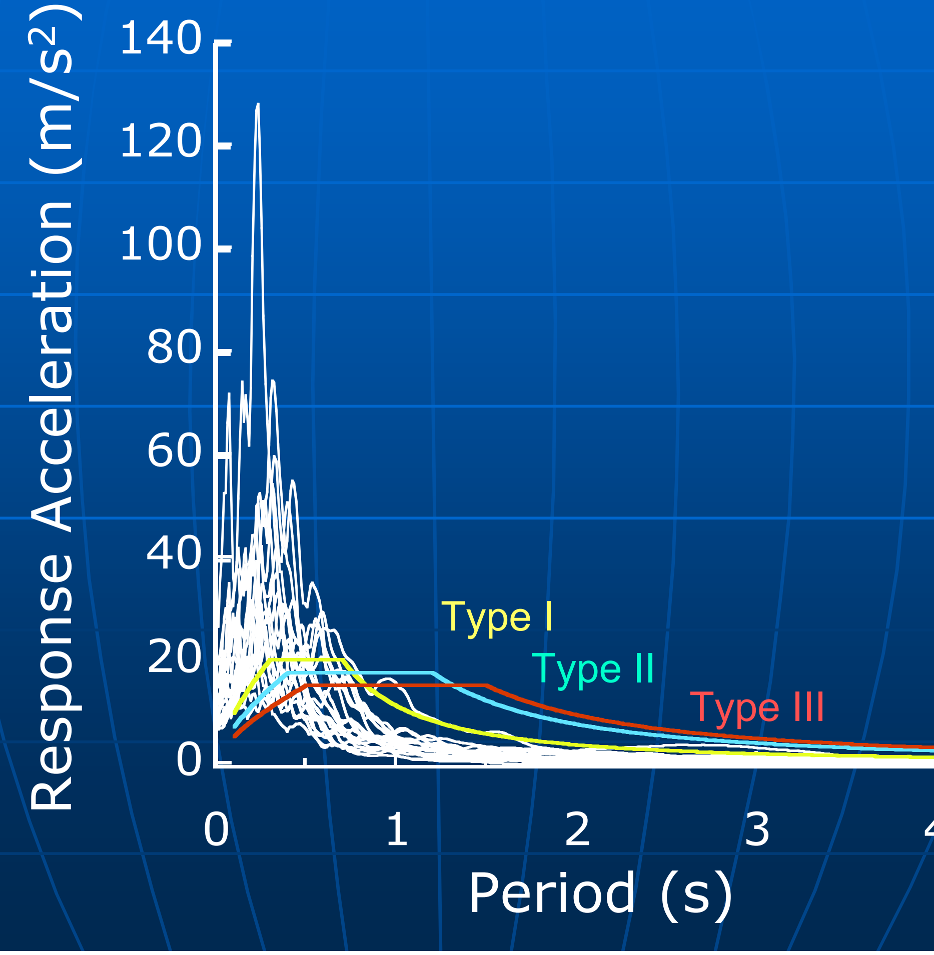
Strong motion distribution at Eastern Japan (5HzPGA)
This PGA is commonly used as an index for the alarm to stop the train operation.

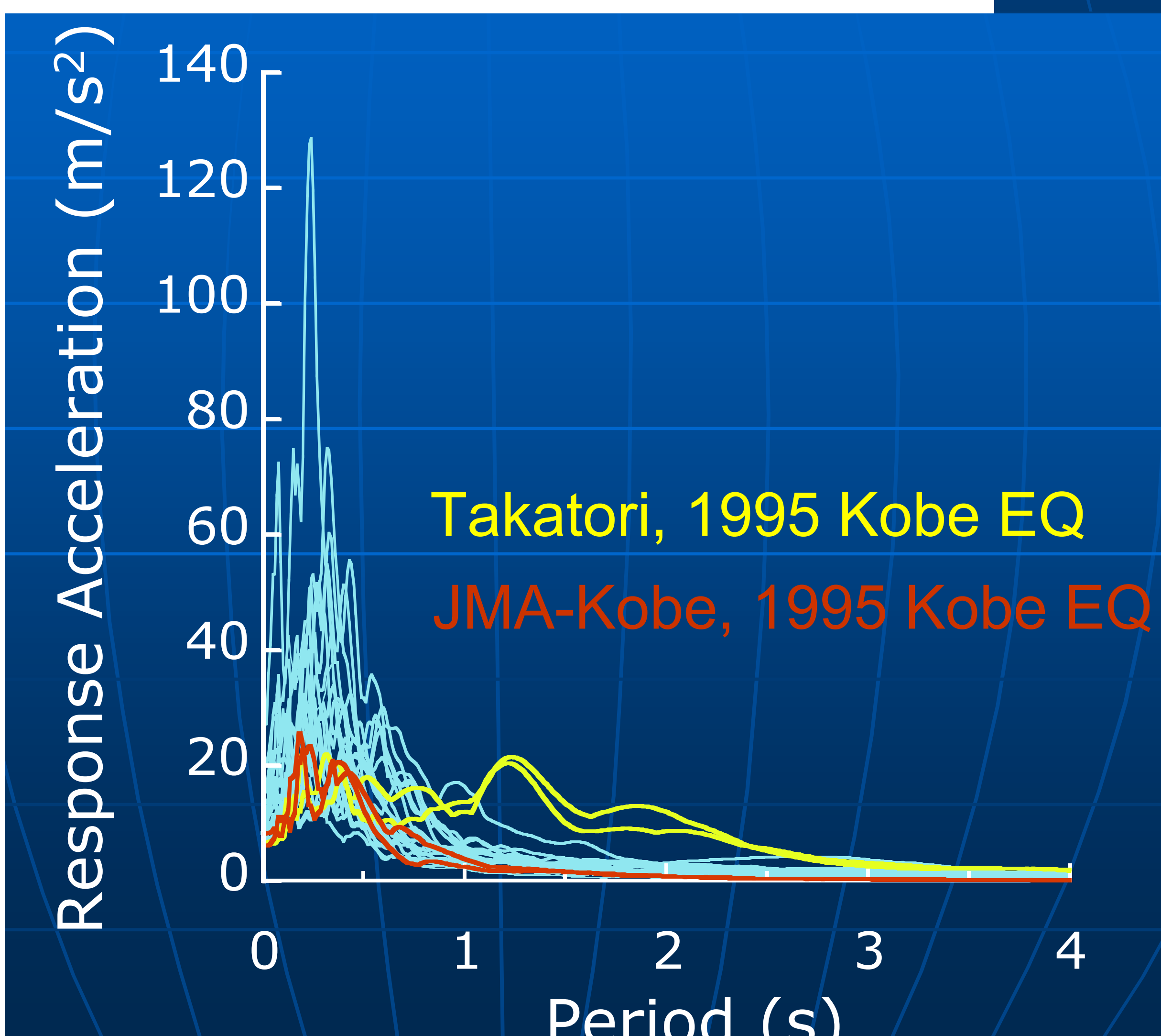
Tsukidate

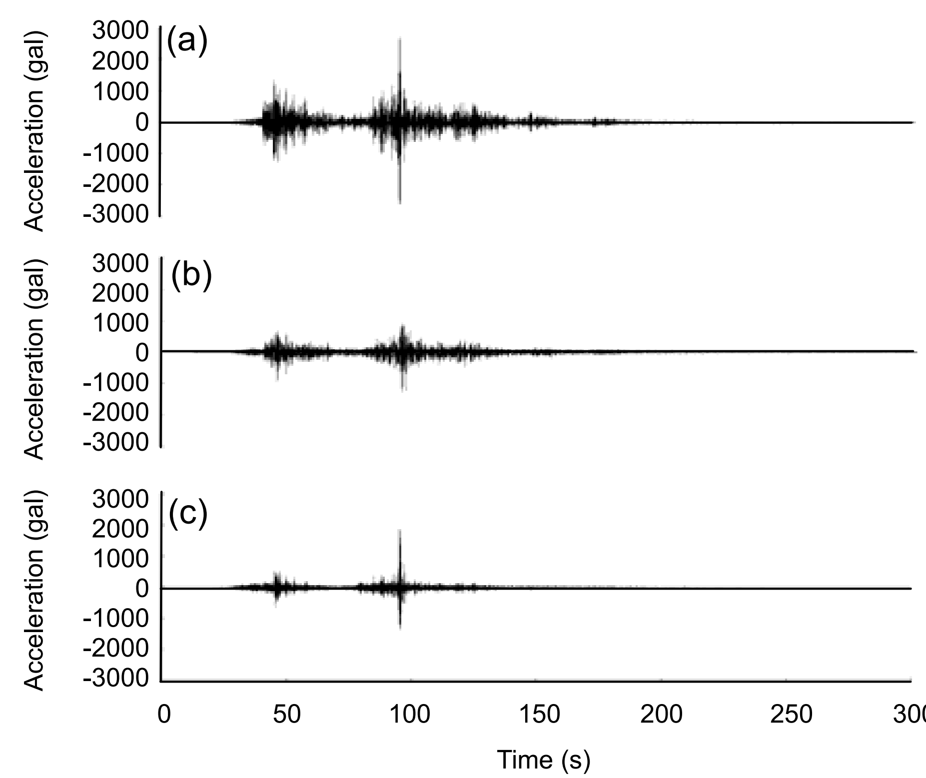


Courtesy of Kazuhiko Kawashima

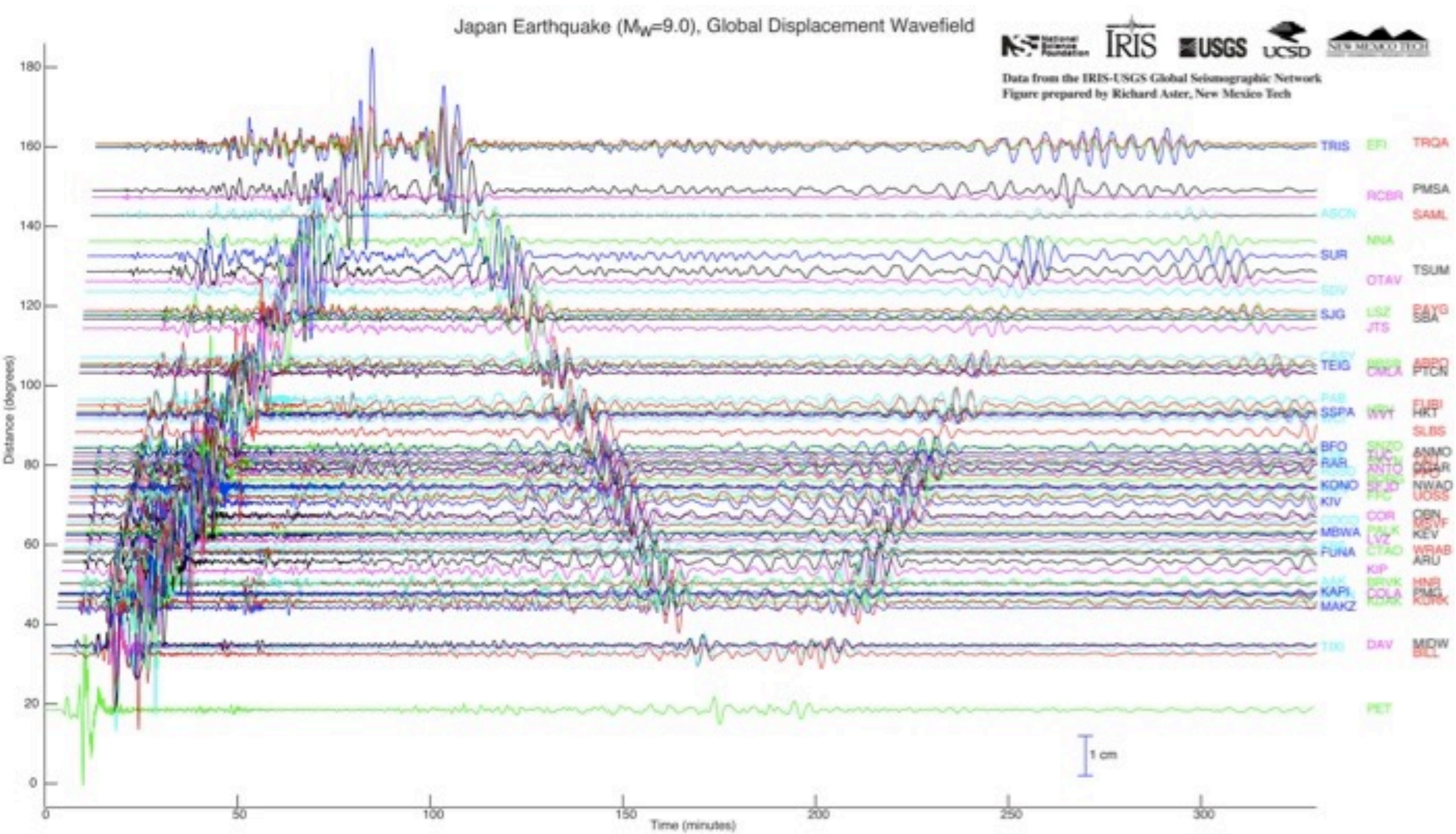
Comparison with Type II Design Spectra, JRA Design Specifications of Bridges





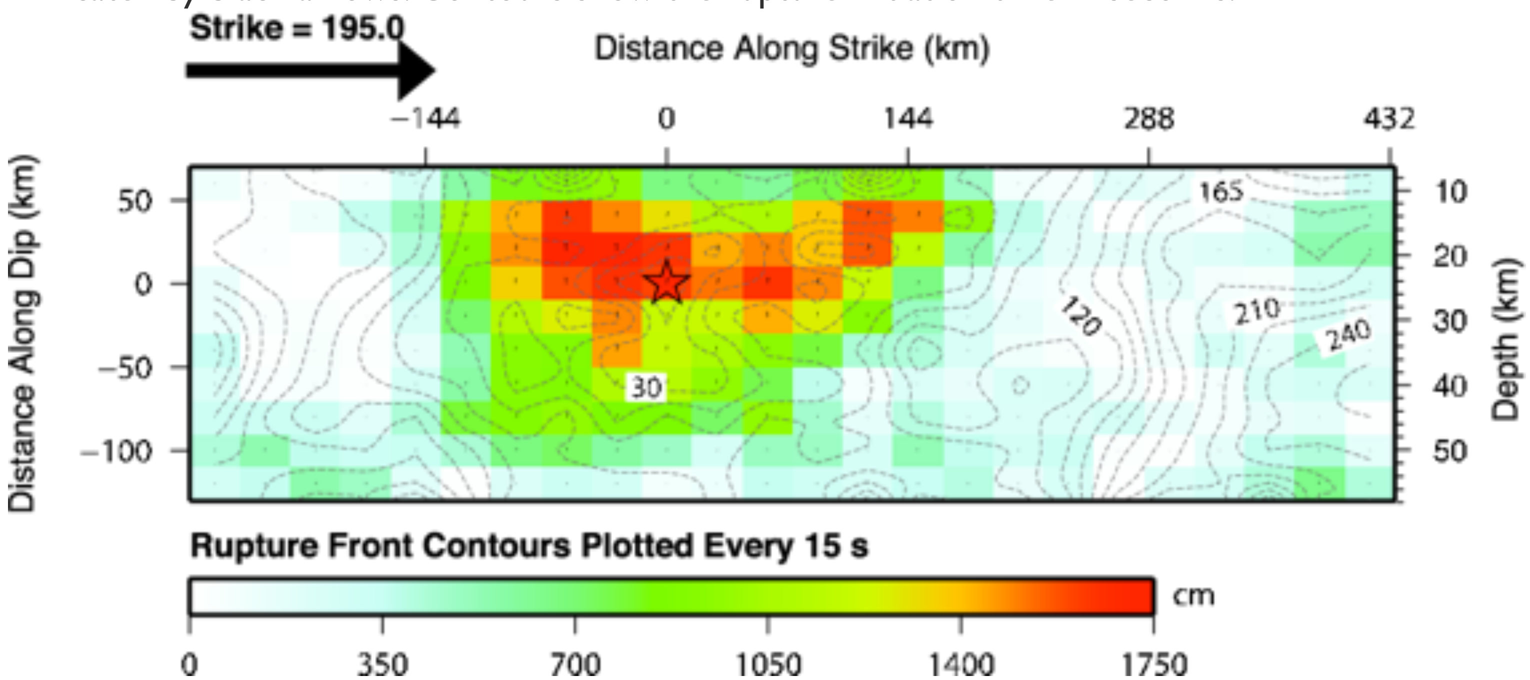


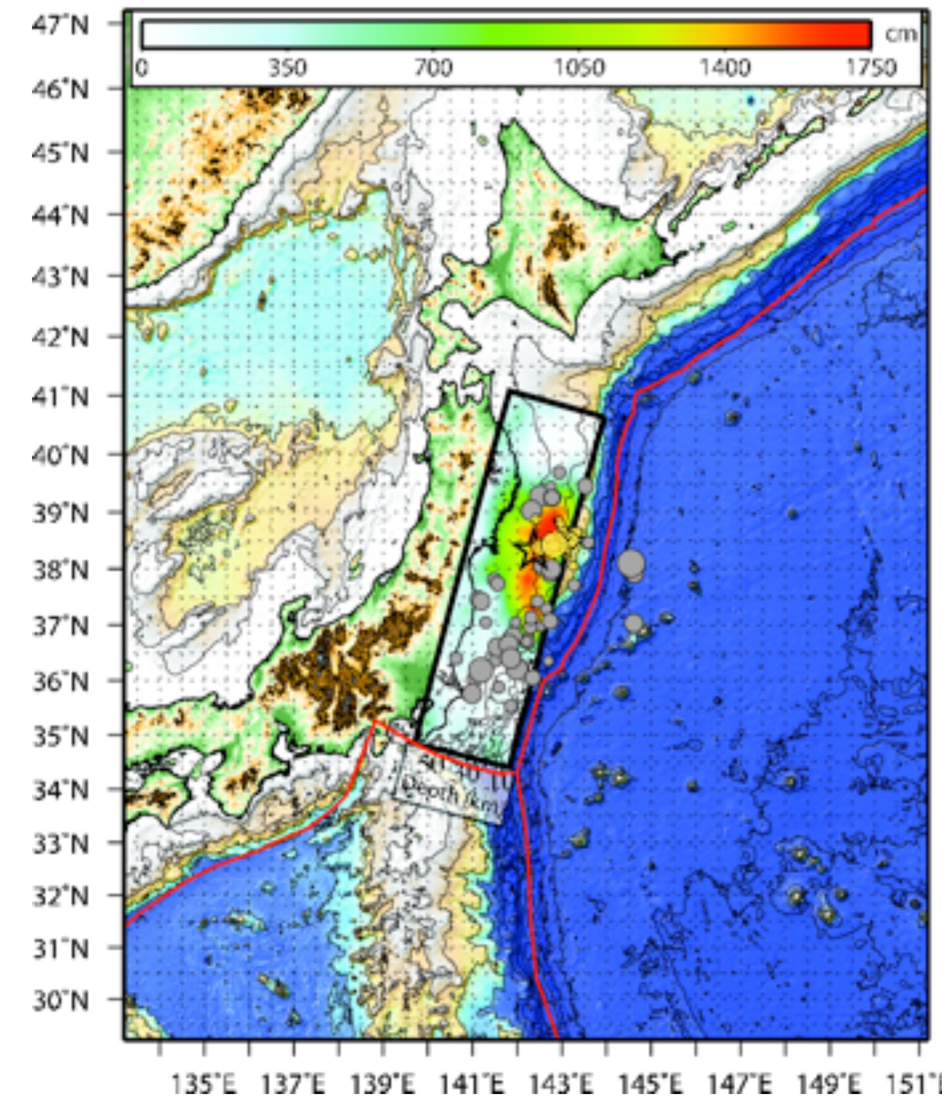
Ground motion - Worldwide

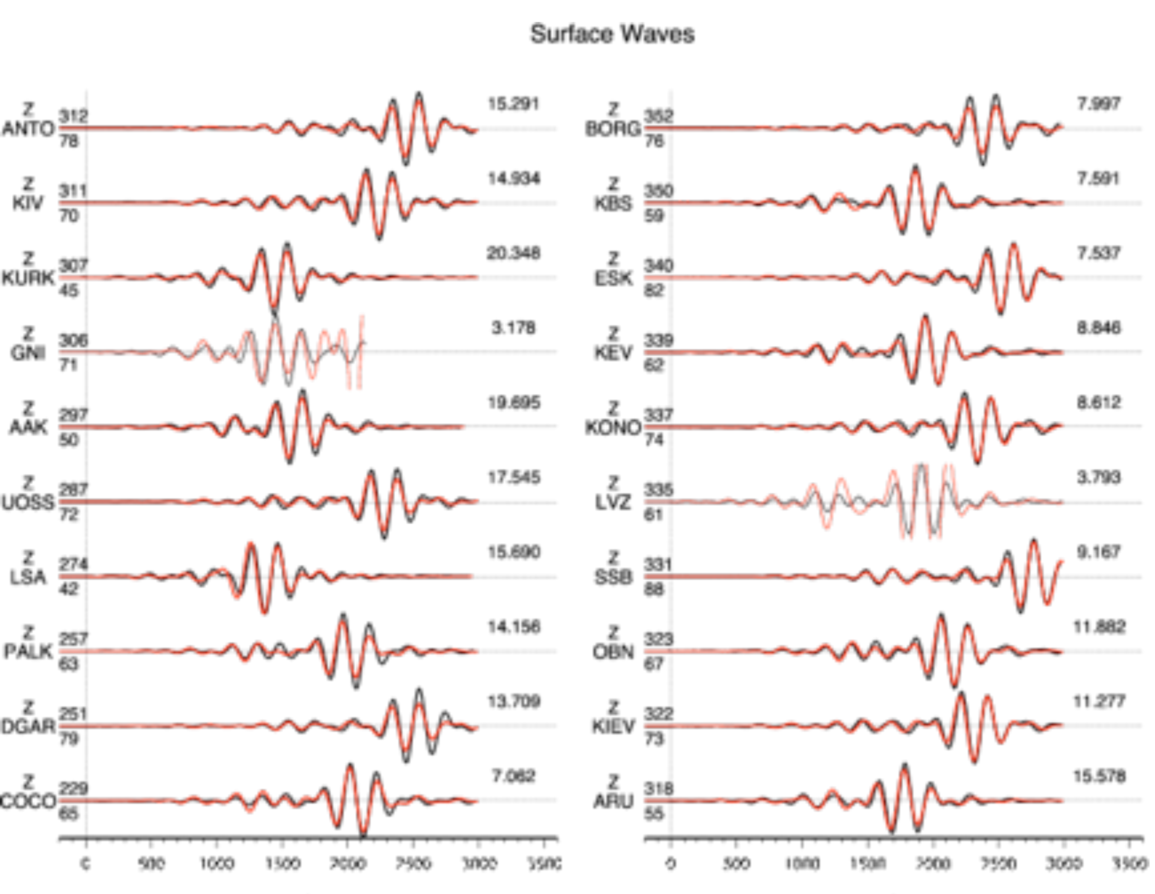


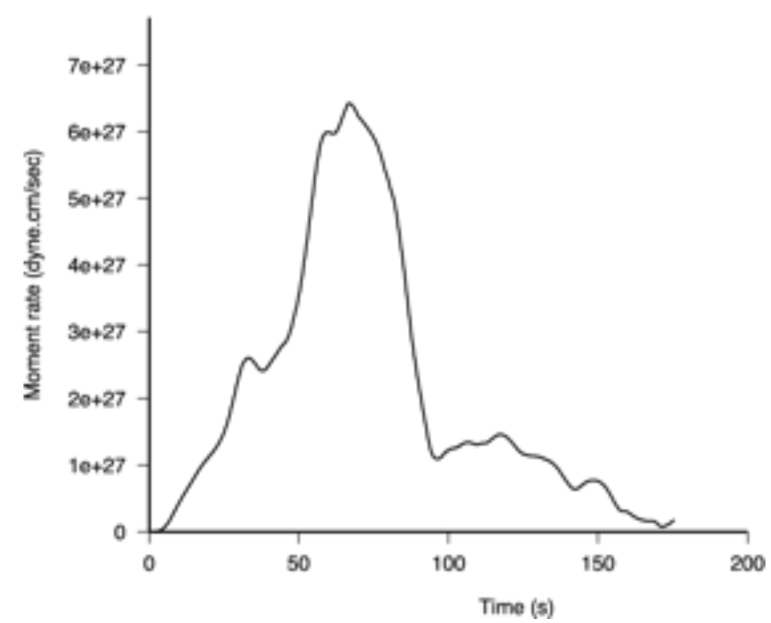
USGS - Finite fault model

Cross-section of slip distribution. The strike direction of the fault plane is indicated by the black arrow and the hypocenter location is denoted by the red star. The slip amplitude are showed in color and motion direction of the hanging wall relative to the footwall is indicated by black arrows. Contours show the rupture initiation time in seconds.

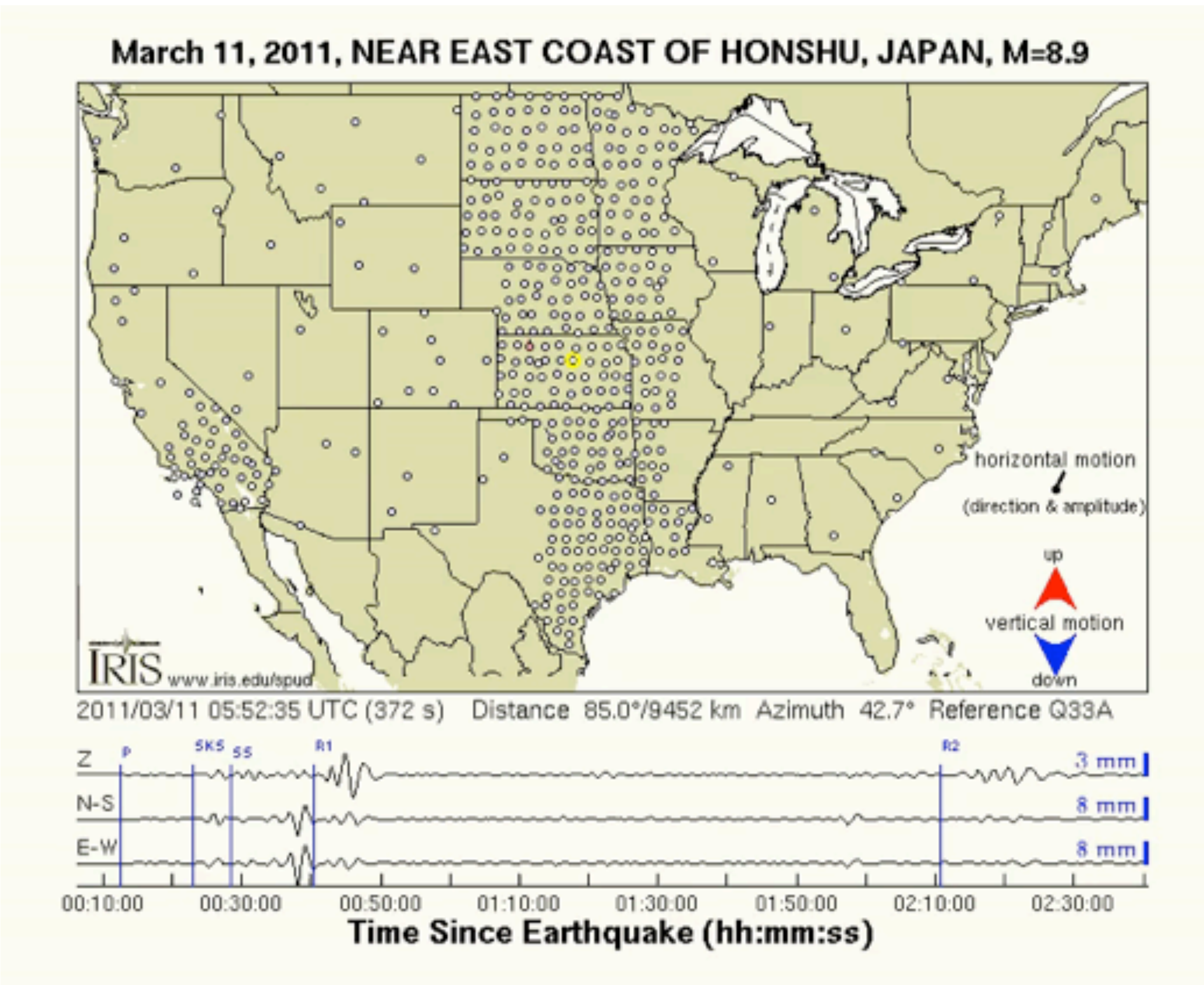


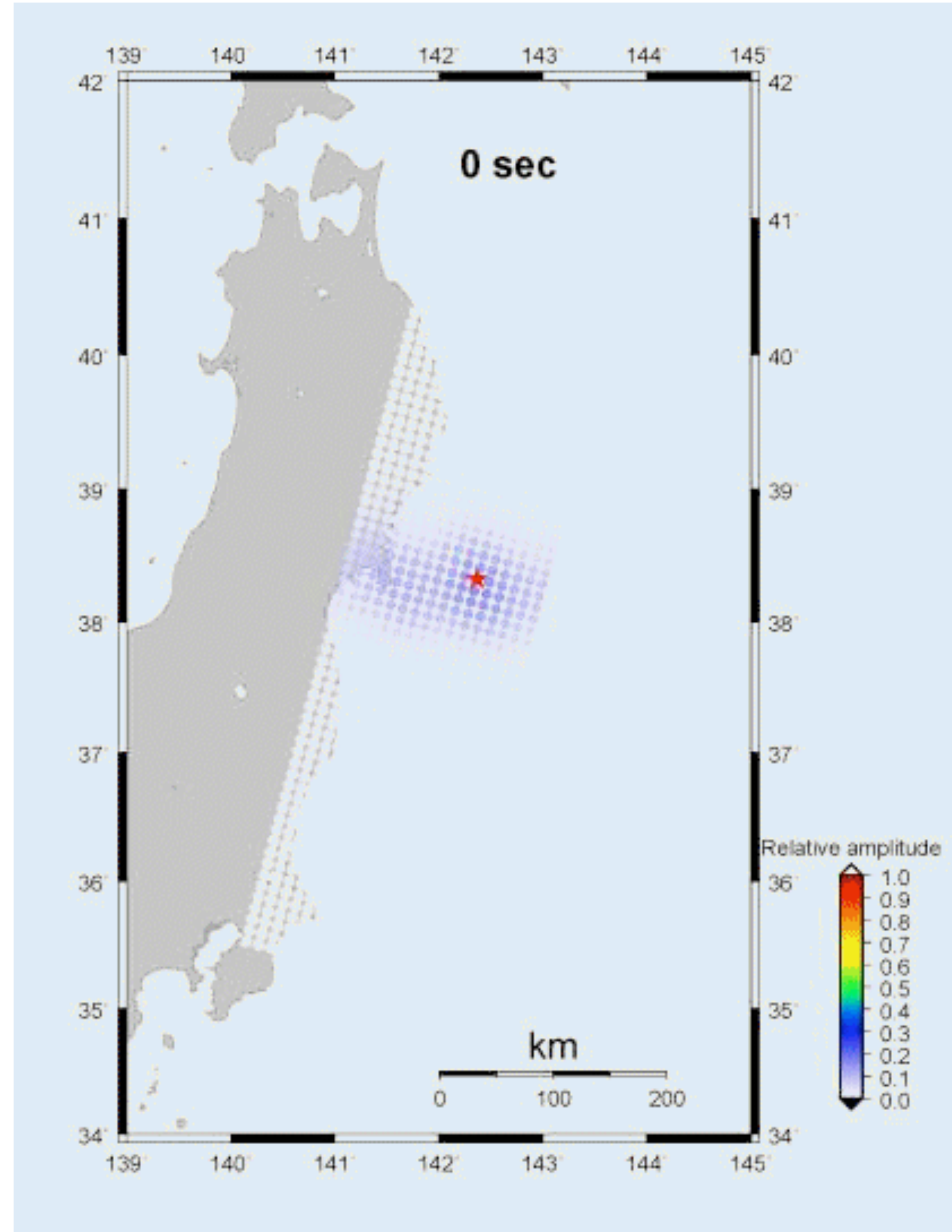






Ground motion - USA & backprojection





Courtesy of Dun Wang and Jim Mori