On the Preparation Process of the 2011 off the Pacific Coast of Tohoku Earthquake (Mw 9.0): A Perspective from GPS data

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Abstract The dense continuous GPS Earth Observation Network of Japan (GEONET) has been established by the Geospatial Information Authority of Japan (GSI) since 1994. In this study, to understand the mega earthquake preparation process, we have investigated the long-term surface motion prior to the 2011 off the Pacific coast of Tohoku earthquake (Mw 9.0). Precise daily coordinates of GEONET stations have been utilized. Long-term linear trends of continuous GPS records have been analyzed and clear deformation velocity changes starting from about 1.4 year before the mega event have been detected. These changes of the surface deformation velocities suggest accelerations of stress accumulation. The spatial distributions of deformation velocities have shown westward directional changes in a large area along the Pacific coast. Based on these results, we have proposed an additional stage which is asperity upgrowth (or asperities synchronization) in the generation cycle of mega subduction earthquake. The proposed stage may be an essential difference between a mega event and a large one. Our results may help to understand the processes of mega subduction events.

Results

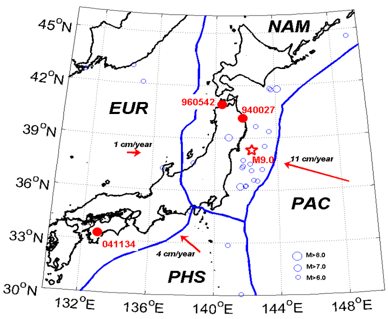

Fig.1. The location of the Mw 9.0 earthquake epicenter and tectonic settings of the Japanese Islands.

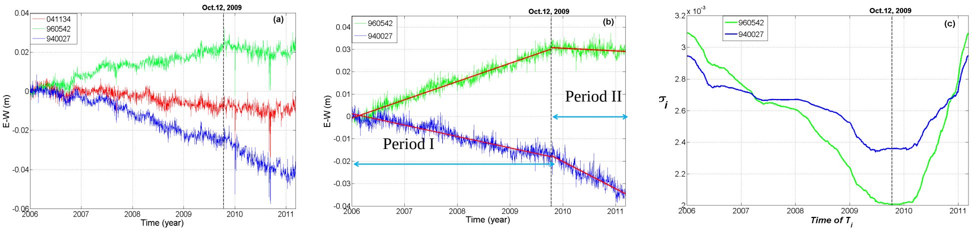

Fig.2. Time series of GPS deformations and trend detection. (a) E-W directional free GPS movements of the selected three stations in Fig.1. (b) E-W directional GPS deformations of the two stations in Tohoku relative to the reference station. (c) Results of the trend detection of the deformations in (b). In each figure, a vertical black broken line indicates the time when the trend begins to change. The positive direction in (a) and (b) is eastward.

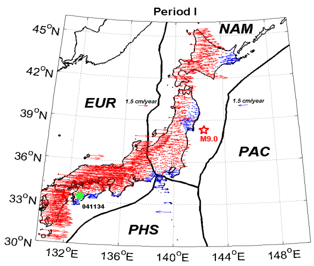

Fig.3. Spatial distributions of velocities of GPS deformations during Period I.

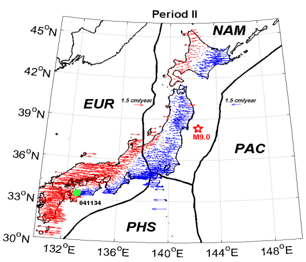

Fig.4. Spatial distributions of velocities of GPS deformations during Period II.

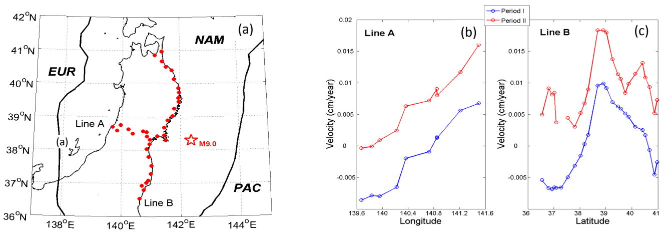

Fig.5. (a) Spatial distributions of the selected stations along Lines A and B in Tohoku. (b) Deformation velocities of Line A.
(C) Deformation velocities of of Line B.

Discussion

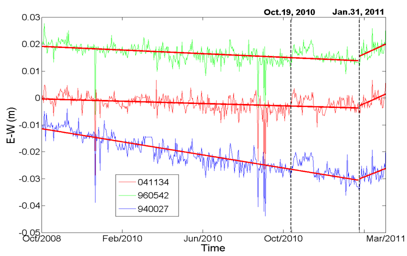

Fig.6 Time series of free GPS movements and trend detection.

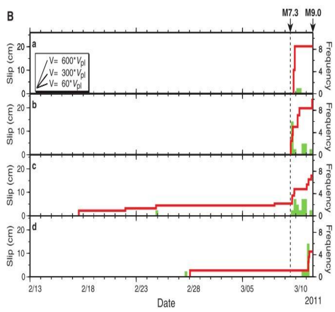

Fig.7 Pre-slip estimated from repeat earthquakes by Kato et al., 2012

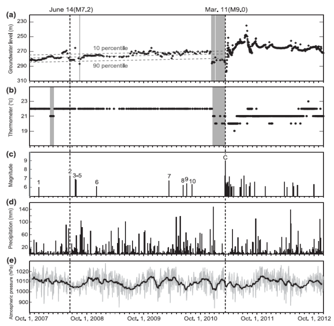

Fig.8 Ground water change observed in Iwate by Orihara et al., 2014

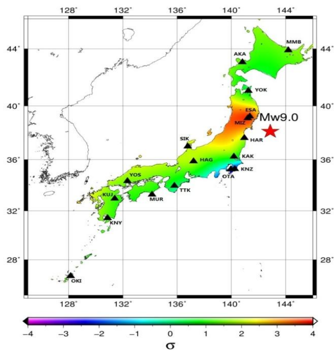

Fig.9 Geomagnetic anomalies reported by Han et al., 2015

Summary

Surface motion changes by using GPS data	This study	**2009, October; 2011, January**
Slow slip revealed from repeating earthquakes	Kato et al., 2012 Science	**2011, February**
Geomagnetic diurnal variations	Han et al., 2015 JAES	**2011, January**
Ground water level and temperature	Orihara et al., 2014 Scientific Reports	**2011, January**
Seismicity obtained by natural time analysis	Sarlis et al., 2013 PNAS	**2011, January**

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