Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

MIS036-P111 Room:Convention Hall Time:May 27 14:15-16:15

Change in seismicity beneath the Tokyo metropolitan area due to the 2011 off the Pacific Coast of Tohoku Earthquake

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We forecasted the seismicity rate changes in the Tokyo Metropolitan area due to the 2011 off the Pacific Coast of Tohoku Earthquake, by calculating the static changes of the Coulomb Failure Function (dCFF) on a nodal plane of focal mechanisms of past earthquakes. Among 30,000 previous events in this region with various depth and focal mechanism, almost 17,000 indicate significant increase of the dCFF while about 7,000 show significant decrease.

Increase in seismicity is predicted in southwestern Ibaraki prefecture and northern Chiba prefecture where intermediate-depth earthquakes occur, and in shallow crust of Izu-Oshima and Hakone. A comparison of seismicity before and after the 2011 event shows that the seismicity in the above regions indeed increased. This study successfully predicts the seismicity rate changes after the mainshock.

This study is based on the assumption that the focal mechanisms of the past and future events are similar. Thus, if earthquakes with unknown mechanisms occur, our method cannot forecast such an activity. For example, earthquake cluster took place in northern Ibaraki prefectures, where shallow crustal activity was very low and information of receiver fault mechanism was unavailable. The focal mechanisms in this cluster are dominantly a normal-type with T-axis in E-W direction, presumably induced by the extension of the upper plate of the gigantic thrusting. The dCFFs calculated on those focal mechanisms are significantly positive. Accumulation of focal mechanisms for small-magnitude earthquakes will enable us more reliable forecast.

When the spatial correlation between the dCFF due to large earthquakes and the subsequent aftershock distribution is discussed, two types of receiver faults have been assumed: a specified receiver fault and an optimally oriented receiver fault. However, the dCFF assuming receiver fault mechanisms generates large errors under a complex stress field in which various types of earthquakes occur (e.g. Toda, 2008; Ishibe et al., 2011). This study substantially reduced this uncertainty by using focal mechanisms of past earthquakes as receiver faults.

For the source fault, the variable slip model of the 2011 off the Pacific Coast of Tohoku Earthquake (Ozawa, personal communication) based on continuous Global Positioning System (GPS) observation, was used to calculate the dCFF. As the receiver faults, we used the 30,099 focal mechanism solutions determined from initial motion by the National Research Institute for Earth Science and Disaster Prevention (NIED) from July 1979 to July 2003 (Matsumura and Observation and Research Group of Crustal Activities in the Kanto-Tokai District, 2002). The Preliminary Determined Earthquake (PDE) catalog from February 1, 2011 to April 1, 2011 provided by JMA on April 2 was used to examine whether or not forecasted seismicity changes actually take place.

Our results are based on a preliminary source model and earthquake catalog. Various fault models based on tsunami waveform, far-field body waves, and strong motion seismographs are now being proposed and updated. In addition, the progress of significant afterslip is suggested from GPS observations. The PDE catalog of JMA that is used for post-mainshock seismicity will be revised later. Therefore, the correlation between the dCFF and changes in seismicity rate should be re-examined using final catalog and updated fault models.

Acknowledgments

We used variable slip model of the 2011 off the Pacific coast of Tohoku Earthquake provided by Dr. S. Ozawa of Geospatial Information Authority of Japan, preliminary determined earthquake catalog by JMA, and focal mechanisms by NIED. We also used the program by Okada (1992) for calculating dCFF. We thank all of these organizations and individuals. This study is supported by the Special Project for Earthquake Disaster Mitigation in the Tokyo Metropolitan Area from the Ministry of Education, Culture, Sports, Science, and Technology of Japan.

Keywords: the 2011 off the Pacific Coast of Tohoku earthquake, the static change of the Coulomb Failure Function (dCFF), Tokyo Metropolitan Area, seismicity