別紙４

報 告 番 号	※ 第 号

主　論　文　の　要　旨

論 文 題 目
Interplate Earthquake Potential off Western Java, Indonesia, Based on GPS Data
GPSデータに基づくインドネシア、ジャワ島西部沖のプレート間地震発生ポテンシャル

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論　文　内　容　の　要　旨

The Java Trench is a plate boundary where the Indo-Austraian plate subducts beneath the Sunda plate and many megathrust earthquakes as well as tsunami earthquakes repeatedly occur. In contrast with the Java Trench off Sumatra, the trench off Java has much less historical seismicity during last 300 years. However, since Java is the most populated area of Indonesia and there occurred significant tsunami earthquakes in 1994 and 2006 (both were M_w7.8), it is of great importance to evaluate potential of megathrust earthquake south off Java.

We use three years data from 5 January 2008 to 31 December 2010, from 13 newly installed continuous GPS sites of the Indonesia Geospatial Agency (BIG) and Institute of Technology Bandung (ITB) located in western Java and southern Sumatra. First, we process the GPS data with data from the 7 International GNSS Service (IGS) sites to obtain daily coordinate time series of each site in the International Terrestrial Reference Frame 2008 (ITRF2008) by using Bernese GPS Software Version 5.0 (Dach et al., 2007). Daily repeatability of 2.5-3.2 mm for horizontal and 9.1-12.5 mm for vertical components was achieved except for a few sites around the Sunda Strait. Then we fit a linear trend to each time series to estimate displacement rate vector at each GPS site. The displacement rate error is estimated assuming a white noise and precision of the estimated velocities is about 0.2-0.9 mm/year for the horizontal components and 0.6-2.1 mm/year for the vertical component.

The estimated velocities are transformed into the Sunda block reference frame (Simons et al., 2007), but the result is not consistent with the previous study. It is possible that the postseismic effects of the 2006 M_w7.8 Java tsunami earthquake and the 2004 M_w9.1 Sumatra-Andaman earthquake may be responsible for the changes. Since the old Sunda block reference frame is not directly applicable to our data, in order to avoid uncertainties regarding the reference frame, we use baseline length change rates for our analysis. On the other hand, we use the absolute vertical displacement rate in the ITRF2008 reference frame for our analysis.

We use the concept of interseismic deformation at subduction zones proposed by Savage (1983) to interpret the observed crustal movements in western Java. The observed surface deformation is attributed to distribution of fault slip deficit/excess with respect to a steady plate subduction on the plate boundary.

We presume a fault plane on the plate interface with a length of 500 km and a width of 225 km extending to the trench. We divide the fault plane into 720 subfaults with a uniform size of 12.5 km x 12.5 km. We assume the dip angle of the plate boundary based on model Slab 1.0 (Hayes et al., 2012). The fault rake angle is fixed to a value based on relative plate motion and the magnitude of slip deficit/excess is the only parameter to be estimated for each subfault. We apply a geodetic inversion method by Yabuki and Matsu'ura (1992) to estimate slip deficit/excess distribution with a prior constraint that the distribution of slip deficit/excess is spatially smooth. The optimum degree of smoothness is determined by the ABIC minimization principle (Akaike, 1980).

To test the reliability of the spatial resolution of the analysis, we conduct a checkerboard test. We invert a synthetic surface deformation data created from prescribed distribution of slip deficit/excess and compare the inversion result with the true distribution. The checkerboard test demonstrates that the slip deficit/excess rate is reasonably resolved up to ~100 km from the coast, corresponding to the slab depth of 20-30 km, within a fault size until 62.5 km x 62.5 km. The model cannot resolve patches smaller than 62.5 km x 62.5 km. Resolution for the shallow part (depth < 20km) and the resolving power for the periphery of the source region is very limited although we may be able to distinguish the existence of a slip deficit in the shallow part by enlarging the fault size.

The inversion result of the GPS data clearly shows a heterogeneous distribution of slip deficit/excess in both the strike and dip directions. We identify one slip excess patch and two significant slip deficit patches. The slip excess is located off Pangandaran near the rupture area of the 2006 M7.8 Java earthquake, in the depth range of 15~20 km, with a slip excess rate of 57-61 mm/yr. In depth range less than 20 km, the detailed slip distribution cannot be resolved by the on-land GPS. However, based on the resolution test, we assured that there is an ongoing afterslip of the 2006 M7.8 earthquake, 4.5 years after the main shock. The southward motion of CPMK and coastal extension is the supporting evidence of this inference. However, we cannot resolve whether the afterslip occurs inside the main shock rupture area or in the adjacent down-dip area. It is also possible that afterslip extend further to the east because of the absence of GPS data to the east of CPMK.

The first significant slip deficit patches is located off Ujung Kulon-Pelabuhan Ratu at 20 to 40 km depth, with a slip rate of 48 to 56 mm/yr, equivalent to 70-82% of the relative plate motion. We also obtain slip deficit to the shallow portion. Although our model cannot resolve detailed spatial distribution of slip deficit, we point out significant amount of slip deficit can exist in the shallow portion south off Java. Second, interplate coupling off Pangandaran at 37 to 45 km depth below the rupture area of the 2006 M7.8 earthquake with a slip rate of 48 to 55 mm/yr, equivalent to 75-80% of the relative plate motion. Existence of the slip deficit patch at depth is supported by the observed coastal uplift.

The absence of a megathrust earthquake for at least 300 years in this region implies seismic moment accumulation during this time period of 1.6×10^{21} Nm (~Mw 8.7) off Ujung Kulon-Pelabuhan Ratu, and 3.9×10^{21} Nm (~Mw 8.3) off Pangandaran, unless episodic slow slips release tectonic stress. Thus significant potential of megathrust earthquake exists in south off western Java.

Base on the inversion result, we propose two possible scenarios for future earthquake off western coast of Java. In the first scenario, earthquake nucleates from the slip-deficit patch at the intermediate depth, then propagates to the shallower portion of the plate boundary producing a large tsunami as the 2011 M9.0 Tohoku earthquake. In the second scenario, earthquake nucleates in the shallow part, generating a tsunami earthquake, and the down-dip portion will release stress by afterslip, as in the case of the 2006 M7.8 Java and 2010 M7.8 Mentawai tsunami earthquakes. In either case, there is a high potential of occurrence of interplate earthquake which rupture could propagate to the shallow part of the plate interface and generate a large tsunami.