GNSS observation around the shear zone in southern Kyushu (The third report)

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On the basis of strain rate estimation using GNSS velocities, an active shear zone with high shear strain rate more than 10^{-7}/yr is detected in southern Kyushu. However, obvious active faults in the shear zone are not identified. It is inferred that such high shear strain rate is caused by fault slip in a deep part of the earth’s crust. To investigate the crustal deformation in more detail, we installed 10 GNSS sites across the shear zone from north to south and started observations from March in 2016.
Four GEONET sites operated by Geospatial Information Authority of Japan were fixed as reference sites and daily coordinates from April 18, 2016 to November 24, 2018 were determined, using Bernese GNSS Software (ver.5.2). The time series of site coordinates were corrected by subtracting common mode bias, viscoelastic deformation caused by the 2016 Kumamoto earthquake and volcanic deformation due to Sakurajima and Kirishima volcanoes, from the original time series. Then, site velocities together with annual and semi-annual variations were estimated. As for the data before the 2016 Kumamoto earthquake, we also made corrections in time series of GEONET F3 solutions from October 1, 2007 to March 1, 2009, as processing the data acquired after the earthquake.
In this study, we applied site velocities to a vertical strike-slip fault model proposed by Savage and Burford (1973). This model illustrates that a fault is locked from the surface to a certain depth and is sliding at a uniform velocity which is relative rigid block motion below the locking depth. In this case, the profile of surface deformation normal to the fault strike is expressed as a function of arctangent across the fault. However, using the model, locking depth was estimated to be greater value than average thickness of the earth’s crust. Thus, we considered that the center of the shear zone is located more northern part than current assumed location, which means that two unknown parameters, central shift and fault slope toward the north of the shear zone, are added in the analysis in addition to slip velocity and locking depth.
At first, the initial values of above four unknown parameters were determined using the non-linear least-square method to minimize the residuals between observed and calculated velocities, then those unknown parameters were estimated from the 100,000 times sampling performed by the Metropolis-Hastings algorithm of Markov Chain Monte Carlo methods. On comparison of velocity profiles before and after the earthquake, it resulted that the patterns of those crustal deformation were clearly arctangent form and generally in good agreement with each other within 99% confidence limit, which also indicated that the left-lateral strike slip occurs there. The slip velocity and locking depth were estimated to be 12.4-14.3 mm/yr and 15.6-16.6 km. This shows that steady crustal deformation under the shear zone continues after the earthquakes. Meneses-Gutierrez and Sagiya (2016) investigated strain rate in central-northeastern Japan using GPS data before and after the 2011 Tohoku earthquake and observed inelastic deformation due to long-term EW shortening, which is independent of large earthquakes and continues throughout the whole time periods. The result also suggests that a similar phenomenon occurs at a deep region of the shear zone. Moreover, it suggests a possibility that the center of the shear zone is located about 10 km northward compared with the conventional consideration. While unknown parameters such as fault slope do not have a clear peak of posterior distribution, therefore it is necessary to note that there are large uncertainties in them.

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Keywords: active shear zone in southern Kyushu, GNSS observation, left-lateral strike slip, inelastic deformation, the 2016 Kumamoto earthquake

