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Surface deformation of South Korea after the 2011 Tohoku-Oki earthquake determined by GPS data: straining heterogeneity and seismicity

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The GPS-determined, coseismic crustal deformation of the Korean peninsula (Baek et al., 2012, Terra Nova) by the Tohoku-Oki earthquake (Mw 9.0; 11 March 2011), more than 1000 km away from its epicenter is dominated by dilatational deformation (or extensional; horizontal stretching rate larger than horizontal shortening rate). In contrast, the focal mechanism solutions of earthquakes indicate that South Korea has been at compressional regime dominated by strike- and reverse-slip faultings. In this study, we examined the velocity fields with 6-year GPS data after the earthquake and analyzed deformation patterns to see any effect of the Tohoku-Oki earthquake on the Korean crustal deformation and seismicity. To calculate the velocity gradient tensor of GPS sites, we used a gridding method based on least-square collocation (LSC). This LSC method can overcome shortcomings of the segmentation methods including the triangulation method. For example, an unintended, abrupt change in components of velocity field may occur at segment boundaries in the segmentation methods. It is also known that LSC method is more useful in evaluating deformation patterns in intraplate areas with relatively small displacements. Velocity vectors of South Korea, pointing in general to 113° in average before the Tohoku-Oki earthquake, instantly changed their direction toward the epicenter (82° in average) during the Tohoku-Oki earthquake, and then gradually returned to the original position about 2 years after the Tohoku-Oki earthquake. Based on these observations, we separated the velocity fields of the 6-year postseismic period into 2 stages; Stage A (transient) and B (long-term). Our calculation of velocity gradient tensors after the Tohoku-Oki earthquake shows that the stretching and rotating fields are quite heterogeneous, and that both stretching and shortening areas exist in South Korea. In the Stage A (transient stage in two years after the Tohoku-Oki earthquake), the relationship between the deformation pattern and geologic components as well as long-term seismic activity is not evident. In contrast, the area with a thicker crust shows a contracting surface deformation, while one with a thinner crust suffers dilating surface deformation, suggesting that the deformation pattern is permanent. Furthermore, the straining rate is larger in the areas with thinner crust. Although there is no one-to-one correlation between earthquakes and surface deformation, earthquakes tend to concentrate in areas with higher shear strain rates and lower rotation rates located between areas of higher rotation rates. In South Korea, the stress field inferred from earthquake data does not correlate with strain field calculated from GPS data. This suggests that stress orientation at the focal depth might be different from that on surface. Or the surface deformation measured by GPS data may represent interseismic elastic deformation for ‘large’ earthquakes to come while recent earthquakes without surface ruptures do not contribute to the surface deformation in South Korea.