# Crustal Deformation Process in the Mid-Niigata Region of the Niigata-Kobe Tectonic Zone as Observed by Dense GPS Network Before, During and After the 2011 Tohoku-Oki Earthquake

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The Niigata-Kobe Tectonic Zone (NKTZ) is a deformation zone in the eastern side of the Japan Sea, where localized geodetic E-W contraction ($10^{-7}$/yr, Sagiya et al., 2000), one order of magnitude larger than the long-term deformation rate in the area ($10^{-8}$/yr, e.g., Wesnousky et al., 1982) have been observed. Meneses-Gutierrez and Sagiya (2016) analyzed strain rate distributions in central Japan based on GPS data from GEONET in the preseismic and postseismic period of the 2011 $M_w$9.0 Tohoku-oki earthquake in order to characterized the source of deformation in the NKTZ. They found persistent localized contraction (4~10x$10^{-8}$/yr) in Northern NKTZ, demonstrating that deformation in the area is mainly inelastic and providing a solution to the discrepancy between geodetic and geological estimates in the area. However, complete characterization of the source of deformation was not possible with the available data set.

In 2010, the Association for the Development of Earthquake Prediction (ADEP), in collaboration with Nagoya University, constructed 20 continuous GPS sites in the Mid-Niigata area, in order to monitor crustal activity around the Western Nagaoka Basin fault, one of major active faults in this area where disastrous earthquakes have occurred recently. Analysis of this data in combination with GEONET allows a detailed description of the crustal deformation process in the area.

We evaluate the response of Mid-Niigata during the preseismic, coseismic, and postseismic periods of the 2011 Mw9.0 Tohoku-oki earthquake by analyzing strain distributions based on the available dense GPS network. Decomposition of the coseismic E-W strain according to its wavelength shows localized elastic extension in the short-wavelength component, while persistent localized contraction within a narrow zone (40- to 60-km width) is revealed before and after the event, in agreement with our previous results implying an ongoing inelastic process. However, differences in the amplitude and horizontal location of the localized deformation in the preseismic and postseismic period were also found. These differences suggested that elastic heterogeneities of the crust, acting in different sense before and after the earthquake, were embedded within the geodetic signal. We model localized deformation in the preseismic, coseismic and postseismic periods considering an aseismic fault slip and a weak elastic zone as the sources of deformation. Our kinematic models suggest vertical decoupling between the weak elastic layer and the basement rock, implying that the preseismic and postseismic strain rate patterns represent direct effects of the shallow portion of the crust in Mid-Niigata. Our simple model shows that both inelastic and elastic sources are essential in the deformation mechanism of the Mid-Niigata area in northern NKTZ.