Temporal changes of areal strains estimated from three continuous GNSS stations in the vicinity of faults before the 2011 Tohoku and the 2016 Kumamoto earthquake

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Temporal changes of areal strains were estimated from three continuous GNSS stations in the Tohoku region and Kumamoto regions. The areal strains for one year in each month were calculated using the 30-days averages of the coordinate values of GEONET F3 solution for the month and the month last year. The areal strain was calculated every month and integrated as time series.
In Tohoku region, the M9.0 huge earthquake occurred in March 2011. In the period before the earthquake from January 1998 to February 2011, the time series were calculated along the coastal area from Aomori to Ibaraki. In Kumamoto region, the M7.3 earthquake occurred in April 2016. The time series were calculated wide area in the period from April 1997 to March 2016. In order to increase the spatial resolution, wide triangle was divided into some small triangles using new GNSS stations and the time series with small triangles were calculated in the period from 2009 to 2016.
Major features of the temporal change of the estimated areal strain are listed below from the northernmost one in the Tohoku region.
At the range of Hachinohe to Kamaishi, the areal strain continued to decrease.
At the range of Kamaishi to Shizugawa, the areal strain had decreased continuously from 1998, however the downward trend of areal strain was changed to stagnant since the beginning of 2007 at the latest.
At the range from Soma to Iwaki, the downward trend of areal strain was changed to stagnant since mid-2006, and in some places it showed the increased trend.
At the range from Iwaki to Kashima(Ibaraki) on the south area, the areal strain did not show significant changes.
At Kumamoto region, the areal strain in the wide area showed decrease and increase repeatedly in a short period of time, then it was changed to the trend of decrease and continued until Kumamoto earthquake. From the analysis of small triangle, Before Kumamoto earthquake, the areal strain decreased continuously in the area around Hinagu Fault, and it became clear that the decrease tendency was large, especially in the triangle including the hypocenter of the main shock.
From the above results of Tohoku region, it is made clear that the downward trend of areal strain was changed to stagnant in some places. In the Tohoku region, there is the general tendency of the shorting to east-west direction due to the subduction of Pacific Plate and areal strain should be showed the decrease continually. Nishimura et al (2012) calculated the de-trend time series of east-west components of GNSS and suggested that deceleration was caused by weakening of the coupling offshore of Fukushima and Ibaraki prefectures. It is generally method to subtract a reference station which is stable during the analysis period from the observation station for calculating the time series of crustal deformation by GNSS. However, in the case of the long-term time series analysis, it is difficult to choose a reference station that be observed stable displacement for a long time. The areal strain of a triangle with three continuous GNSS stations have advantages because of the method without a reference station. The results of the areal strain are consistent with that of Nishimura et al.(2012).
In the Kumamoto region, there are some issues about this study, for example, to elucidate the mechanism of the phenomenon occurred before Kumamoto Earthquake.

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We believe that the time series analysis of areal strain is able to detect local space-time variations before an occurrence of an earthquake around a fault.

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