Postseismic crustal deformation of the 2011 Tohoku earthquake, obtained from tidal data analysis

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Introduction

Tidal observation data had been used for monitoring crustal deformation before 1990s. For example, Kato and Tsumura (1979) estimated long-term variations in vertical crustal deformation along Japan's coasts, by subtracting regional oceanic disturbances from observed tidal data. However, tidal data have not been used for crustal deformation analysis frequently these days because of the advance of satellite geodetic technology; in the case of the 2011 Tohoku earthquake, crustal deformation fields in Japan were understood by GNSS and InSAR data in detail (e.g., Ozawa et al., 2011; Kobayashi et al., 2011). It should be discussed whether tidal observation data can be utilized for understanding crustal deformation fields associated with the Tohoku earthquake.

Long-term tidal change at Katsuura, Chiba Prefecture

Thus, we analyzed tidal data observed along Japan's coasts in order to obtain vertical crustal deformation associated with the 2011 Tohoku earthquake. The tidal data observed at Katsuura (Chiba Prefecture) from 2003 to 2018 was chosen for our initial analysis, because the data have been continuously collected there even around the time of the earthquake. The effects of earth tide and barometric pressure change were first removed from the original tidal data, using the BAYTAP-G software (Tamura et al., 1991). The time series of the residual tidal change (i.e., the TREND component in the BAYTAP-G's result) was then used for estimating the annual, semi-annual and secular tidal changes under the least-squares method. The secular rate of the tidal change was estimated to be +0.4746 cm/year for the time series before the Tohoku earthquake, which mainly reflects the effects of plate motion and global sea level change. The secular rate was found to change to -0.7880 cm/year (i.e., by -1.2626 cm/year) after the Tohoku earthquake due to postseismic deformation.

Comparison with GPS data

We also estimated the secular variation rates of vertical coordinate from 2003 to 2018 at the Katsuura GEONET station (station number: 93041), using the F3 solution provided by Geospatial Information Authority of Japan. The secular variation rate of the vertical component was estimated to be +0.2609 cm/year for the time series before the Tohoku earthquake, which mainly reflects the plate motion effect. The variation rate was found to change to +1.5543 cm/year (i.e., by +1.2933 cm/year) after the Tohoku earthquake due to postseismic deformation. The postseismic rate of the vertical deformation (= +1.2933 cm/year) well agrees with that of the tidal change (= -1.2626 cm/year), although these signs are reversed since the tidal level is measured from the uplifting ground. This result means that the postseismic deformation due to the Tohoku earthquake can be accurately extracted from the tidal data observed at Katsuura.

Future works

We will next analyze the tidal data acquired at Ayukawa (Miyagi Prefecture) in the same process as described above, since significant crustal deformation has been observed due to the Tohoku earthquake near the tidal station (e.g., Ozawa et al., 2011). We will also compare spatial patterns of the secular variations between the tidal and GPS data, after analyzing tidal data acquired at many other stations along

the Pacific coast. In addition, we will verify the consistency of the spatiotemporal tidal variations with the crustal deformation model of Tobita (2016).

Keywords: tide, postseismic deformation, Tohoku earthquake, GNSS