

## Accelerated vertical crustal movements in the Tohoku region prior to the 2011 Tohoku-oki earthquake: discussion of GPS and tide gauge data

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It has been reported that horizontal crustal movements in southern Tohoku was accelerated toward the Japan Trench before the 2011 Tohoku-oki earthquake [Mavrommatis et al, (2014)]. They consider the aseismic slip acceleration on the plate interface as a possible trenchward accelerations source. If this slip acceleration occur on the plate interface, similar acceleration is expected in the vertical component. However, the previous study did not discuss the vertical crustal deformation in this region and when this acceleration start. Therefore we analyze vertical components of daily GPS coordinate data and tidal records in the Tohoku region. In regard to GPS data, we estimate the best-fit linear trend for the period 1996 to 2003 and 2003 to 2011 by using the least squares method. Then we compare the temporal change of those vertical displacement rates for each period to discuss the possible acceleration. About tidal records, we long term sea level change rates at 23 gauges obtained after removing oceanographic signals using Kato and Tsumura's method (1979). If we refer to the F3 solution in the absolute sense, the velocity changes between 2 periods appear to show systematic accelerated uplift (+2.8 mm/yr on average) in the western Tohoku region. We also find that similar systematic accelerated uplift in order part of Japan such as Kinki and Chugoku regions. However, we do not find that similar velocity changes in tidal records. Such an accelerated changes cannot be attributed to the plate subduction at the Japan Trench and we suspect these changes are related to the reference frame in the F3 solution. Thus we removed common-mode errors estimated from stations around the western Tohoku region. As a result, the vertical GPS velocity is consistent with the tide gauge data and we find accelerated subsidence along the pacific coast of Tohoku region. In particular, rapid subsidence acceleration (-3.0 mm/yr on average) occurred in the north of Oshika Peninsula. These accelerated subsidence is consistent with a deep seismic slip proposed by Mavrommatis et al. (2015) to interpret the horizontal acceleration. The estimated aseismic slip area appears to occur surrounding the coseismic slip area of the 2011 Tohoku-oki earthquake. This result suggest unfastening of coupling occur around the future coseismic slip area before Megathrust earthquake. Furthermore we estimate the vertical velocity for the period 1970 to 2011 using tide gauge data. As a result, we find significant accelerations from 1996 to 2011 as well as subsidence acceleration in GPS data. On the other hand, tidal records from 1970 to 1996 do not show significant accelerations. Consequently, the subsidence accelerations in GPS data are more likely to occur after the late 1990s.

Keywords: the 2011 Tohoku-oki earthquake, vertical crustal movement, accelerated deformation