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Frequency dependence of the variations of total electron content associated with earthquakes

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Variations of total electron content (TEC) associated with earthquakes have been reported [e.g. Calias and Minster,1995; Afraimovich et al., 2001]. The common feature of the variations of TEC is periodic variations with a period of several minutes which is caused by the atmospheric gravity waves. On the other hand, the spatial scales of these variations are not clear. Dense GPS network system, such as GPS Earth Observation Network System (GEONET), is very useful for studying the special scales of the variations. In the 2011 off the Pacific coast of Tohoku Earthquake occurred on 11 March 2011, TEC fluctuations spreading from the epicenter was observed using GPS-TEC data determined by GEONET.[Tsugawa et al., 2011]. This clear variation of TEC is rarely observed. In this study, spatial scales of the spectral density of the GPS TEC variation is examined for the earthquakes ($M > 6.0$) occurred in the inland and adjacent area of Japan during 2000. Ionospheric pierce points at the height of the 350 km are determined. FFT is applied to 32 minutes of TEC data obtained from GEONET receivers. As a result, the variation of TEC was observed near the epicenter of the earthquake ($M > 6:8$) in 15 events out of 19 events. The variation in the frequency of 4.17 mHz is frequently observed in particular. This frequency is consistent with the resonance frequency of the atmosphere and earth. Thus, the main reason of the variation is probably acoustic waves generated by the displacement of the ground or tsunami by the earthquake. Next, the relationship between the displacement of the ground surface and TEC oscillations is examined. The displacement of the ground surface is calculated from their acceleration which was measured from the seismometers installed by NIED when the earthquakes were occurred in the inland. When the earthquakes occurred in sea area of Japan, the height of tsunami around the epicenter is estimated from the wave gauge settled by Japan Meteorological Agency. Considering the distance between the wave source and the ionospheric pierce point which show the maximum value of TEC variations, h'F2 and foF2, the height of tsunami and the TEC variation are highly correlated each other.In addition, the propagation of TEC variations from the epicenter is observed in three events(the 2011 of the pacific coast of Tohoku Earthquake(M9.0), the Tokachi-oki Earthquake in 2003 (M7.4), Kii-hantou Earthquake in 2004 (M7.4). These three events are the top three tsunami heights. Considering that the TEC variations spread from the epicenter are due to gravity waves, it is estimated that the height of tsunami is correlated with the generation of the gravity waves. The variation of TEC is not correlated with the displacement of the ground surface in the earthquakes occurred in land or those without tsunami occurred in the sea. However, TEC variations are observed when the displacement of the ground near the source region is large.Therefore, the displacement of the ground is related to the variation.

Keywords: ionosphere, TEC, earthquake, atmospheric gravity wave, acoustic wave, FFT