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Numerical simulations of atmospheric pressure perturbations and ionospheric oscillations following the Tohoku earthquake

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Following the M9.0 Tohoku earthquake on March 11, 2011, oscillations of total electric content (TEC) was observed in the ionosphere. The oscillations had dominant periods of about 4 min in the vicinity of the epicenter [Saito et al., 2011] and tens of minutes in the distance from the epicenter [Tsugawa et al., 2011]. The maximum amplitudes of these oscillations were almost the same. Atmospheric pressure perturbations caused by Lamb waves were also observed at the ground level [Arai et al., 2011]. The source of the ionospheric TEC and the atmospheric pressure variations were assumed to be the oceanic surface displacement. The aim of this study is to simulate these variations numerically and to estimate the temporal and spatial scales of the oceanic surface displacement.

A three-dimensional non-hydrostatic atmosphere and ionosphere model is used for simulations. The source has a certain area and the center lies on the epicenter. The vertical wind velocity in the form of a damped oscillation is input in the source region. Simulations are performed for some source areas and periods. They show that Lamb waves with half wavelengths close to the source widths and ones with periods close to the source periods are excited near the ground level. The observed atmospheric pressure perturbations are well reproduced for the source with the period of 200 sec, and the width of 150 km along the trench and 100 km across the trench. In the ionosphere, the ratio of the amplitude of 4-min TEC oscillation to that of tens of minutes varies with the source area and period. The amplitude of the 4-min oscillation is larger by two orders for the above setting. It is necessary for the reproduction of the amplitude ratio to add propagating sources such as tsunamis.

Keywords: earthquake, TEC, acoustic wave, gravity wave, Lamb wave, tsunami