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Comparison of ionospheric variations associated with earthquakes observed by HF Doppler with a numerical calculation

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It is well-known that ionospheric disturbances after earthquakes are due to the acoustic and atmospheric gravity waves excited by ground motions or tsunamis. In this study, the relationship between ionospheric and ground disturbances associated with earthquakes is examined using HF Doppler and a network of seismographs. HFD observes the vertical drifts of the ionosphere at the middle points between the transmitter and the receivers. The altitudes of the reflection points are determined by the height profiles of the ionospheric electron density, which is estimated by the ionogram data and POLAN. The ground perturbations are obtained by the closest seismograph from the middle points. By comparison between vertical ionospheric drifts observed by HFD and vertical ground motions determined by seismographs, it is shown that the vertical ionospheric drift increases with the vertical ground motion. The vertical drift velocity of the ionosphere is proportional to the square root of vertical ground velocity.

In order to explain the relationship theoretically, the numerical calculation is very informative. Therefore, we have carried out numerical simulations of atmospheric waves. The simulation code is the same as Matsumura et al. [2011]. This is a nonlinear, two-dimensional, non-hydrostatic andcompressible numerical model. Input sources are the vertical wave disturbancesexcited by ground motions or tsunami associated with the earthquakes. The numerical simulations of atmospheric waves show that the atmospheric perturbations excited by impulsive sources have a spectrum peak around 4-5 mHz regardless of source frequencies. When the source is a monotonic wave, the atmospheric perturbations in lower altitudes also have a peak of the same frequency. In addition. the numerical simulations also show that the maximum vertical velocities of the atmospheric perturbations increase with the velocity of input perturbations. At 100 km, the maximum vertical velocity is shown by an approximate expression determined by a least-square method. At 300 km, two approximate expressions for larger and smaller inputs are determined, respectively. The maximum vertical velocities of the atmospheric perturbations are not proportional to the square root of the input velocity, as shown by the comparison between HFD and seismograph data.