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Observation of ionospheric gravity waves induced by the 2011 Tohoku earthquake and tsunami using GPS networks in Japan

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Recent observation results show the atmospheric gravity waves produced by both tsunami and earthquake can propagate upward to the atmosphere and interact with the plasma at the ionospheric height, leading to the generation of ionospheric disturbances. Carefully analyzing the propagation characteristics of ionospheric disturbances is necessary in order to distinguish the sources.

Here, we use the GPS total electron content (TEC) observations in Japan to detect the ionospheric disturbances after the 2011 Tohoku earthquake, respectively. The Tohoku (Japan) earthquake (Mw=9) occurred at 05:46 UT on 11 March 2011 and then triggered powerful tsunami. The fundamental work is to properly isolate the ionospheric disturbances from raw TEC observations. Here, a second-order number difference method is employed to extract disturbance series and analyze the propagation characteristics of the ionospheric disturbances. The results show there are two types of gravity waves in the ionosphere over Japan, which is produced by the tsunami waves and the seismic rupture process, respectively. The earthquake-driven ionospheric gravity waves are distributed around the epicenter (including the areas over and far from the ocean) whereas the tsunami-driven ionospheric gravity waves are observed above the ocean. The earthquake-driven ionospheric gravity waves have different horizontal velocities, including about 210 m/s and 170 m/s, and frequency of about 1.5 mHz. The tsunami-driven ionospheric gravity waves have velocity of about 280 m/s, which are faster than that of the earthquake-driven ionospheric gravity waves, and frequency of about 1.0 mHz. In addition, the tsunami-driven ionospheric gravity waves have similar propagation characteristics in terms of horizontal velocity, direction, travel time, waveform and frequency compared to the tsunami waves causing them.

In short, this study distinguishes the tsunami signals in ionosphere from ionospheric disturbances triggered by the earthquake event and confirms again that the ionosphere is sensitive to tsunami waves. The results show the tsunami-driven ionospheric disturbances have similar propagation characteristics in terms of velocity, period, direction and arrival time compared to the tsunami waves at sea level, which is the prerequisite to distinguish from ionospheric disturbances triggered by other sources.