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GPS detection and monitoring of underground nuclear explosions

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Previous studies by Park et al. (2011) revealed that an underground nuclear explosion (UNE) induces the acoustic-gravity waves, which disturb the ionosphere and generate the traveling ionospheric disturbance (TID). GPS technique allows for the ionospheric disturbance observation with high accuracy, which, in turn, enables detection of the TID induced by the UNE. This study suggests the detection and verification method of the TID using GPS observations.

TID waves can be identified from the continuous data span of the total electron content (TEC) along the ray path between the GPS satellites and the observing stations. Since the TID is a high frequency and low amplitude signal, it should be properly isolated from the raw TEC observation. In this study, we applied the numerical derivative method, referred to as the numerical third order horizontal 3-point derivative method. The detected TID-like signals can be verified by its array signature under the assumption that the TID induced from a point source tends to propagate with the constant speed. Moreover, the location of the point source can be computed using the array pattern of TID observations from multiple GPS stations.

In this study, two UNEs conducted by the U.S. in 1992 and two UNEs conducted by North Korea in 2006 and 2009 were investigated. The propagation speed of the U.S. UNEs was about 573 m/s and 740 m/s, respectively, while the recent North Korean UNEs propagation speed was less than 300 m/s. This result can be explained by the explosion yields and the depth of the UNEs: the depth of the US UNEs were about 0.3 km with the explosion yield of up to 20 kiloton, while the North Korean UNEs were at about 1 km depth with the yield of less than a few kilotons. In addition, we observed that the TID waves from these four UNE events were highly correlative, and distinguished from waveforms due to other types of events, such as an earthquake. As a case study, we selected the recent Tohoku earthquake of 2011, and investigated the wave property of the TIDs resulting from this event. From the spectral property of the TID from each event and the correlative properties between the events, it can be concluded that the TID from the UNE can be identified with rather high confidence. However, it should be emphasized that the discrimination of TIDs for certain events needs to be investigated further with more experiments, including various types of TID-generating geophysical events.

Reference

Park, J., R. R. B. von Frese, D. A. Grejner-Brzezinska, Y. Morton, and L. R. Gaya-Pique (2011), Ionospheric detection of the 25 May 2009 North Korean underground nuclear test, Geophys. Res. Lett., 38, L22802, doi:10.1029/2011GL049430