Atmospheric wave propagation observed by GNSS-TEC: Fireball explosion and atmospheric mode

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The electron distribution in the ionosphere is often disturbed by various phenomena in the atmosphere. They are observed as changes in TEC (Total Electron Content) along line-of-sight connecting GNSS (Global Navigation Satellite System) satellites and receivers. For example, large meteorites entering the Earth’ s atmosphere often explode and are recognized as fireballs. Sound waves and internal gravity waves excited by them propagate through the atmosphere, reach the ionospheric F region, and change TEC. A fireball appeared near Chelyabinsk, Russia, on February 15, 2013, one of the largest fireball events in the observation history, made significant disturbance signals in TEC observed with multiple GPS satellites and ground receivers. In our study, we first confirm the TEC signals in the 2013 Chelyabinsk event, and then look for the TEC disturbance signals following the emergence of a large-scale fireball over the Bering Sea in December 2018 using data from nearby GNSS stations. We found temporary positive TEC changes and continuous TEC fluctuations shortly after the fireball event. Although the numbers of satellites and stations were not sufficient, these signals are considered to have originated from this fireball event.

Next we obtained continuous TEC records in 2019 using the QZSS (Quasi-Zenith Satellite System) geostationary satellite (PRN07), which enables long-term stable TEC observations in and around Japan. We performed preliminary investigations to detect various kinds of TEC disturbances. First, we conducted spectral analysis of the QZSS-TEC time series with various time windows. As a result, we identified peaks such as the diurnal changes and its harmonics, and the rotation period of the sun. Ground observations of gravimeters and broadband seismometers revealed incessant excitation of the Earth's free oscillations. It was also found that the two components having periods close to the atmospheric modes with periods of 3- 4 minutes have significantly larger amplitudes than other components. This suggests the coupling between the solid earth and the atmosphere. It is possible that there are same frequency components in TEC variations, but it has not yet been confirmed. In this study, we examine if we can detect weak atmospheric modes by using continuous QZSS-TEC data.

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