Variations in the D-region ionosphere observed in fireballs occurred using VLF/LF transmitter signals

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Meteors and fireballs are known to ionize the D-region and lower E-region ionospheres at 80-120 km heights [Davies, 1966]. The fireballs are meteors that the magnitude of brightness is larger than -4 based on the IAU (International Astronomy Union) definition. TID (traveling ionospheric disturbance) associated with the Chelyabinsk meteoroid in Russia was reported based on GPS-TEC (total electron content) observations [Perevalova et al., 2015]. The amplitude of the TEC variations was 0.07-0.5 TECU, and the period was 10 minutes. The epicenter of the TID was airburst point at 20-30 km heights of the meteoroid, and the velocities were 250-660 m/s. However, few quantitative studies for the D-region ionosphere associated with meteors and fireballs have been reported. In this study, we investigate the variations in the D-region ionosphere during a fireball occurred in Hokkaido at 11:55:55 UT on 18 October, 2018, using VLF (very low frequency, 3-30 kHz) / LF (low frequency, 30-300 kHz) transmitter signals. The VLF/LF transmitter signals are reflected in the D-region ionosphere and are sensitive for variations in electron density in the lower ionosphere. The transmitters used in this study were JJY40kHz (Fukushima, Japan, 37.37 N, 140.85 E), JJY60kHz (Saga, Japan, 33.47 N, 130.18 E), and JJI (Miyazaki, Japan, 22.2 kHz, 32.05 N, 130.82 E). The receiver was located at RKB (Rikubetsu, Hokkaido, Japan, 43.45 N, 143.77 E). Periodic variations of 100-200 s were identified by a wavelet transformation of the signal intensities for the JJY40kHz-RKB, JJY60kHz-RKB, and JJI-RKB paths at about five minutes (12:01 UT) after the fireball. We consider that these variations of intensity were caused by the D-region variations due to acoustic waves in the atmosphere excited by the fireball. If the acoustic waves were excited at the luminous point (118 km altitude) or vanishing end point (25 km altitude) of the fireball, the propagation times of the acoustic waves from the exited point to the LF reflection point at 90 km height over RKB were calculated to be 138 s or 311 s, respectively. The arrival time (311 s) of the acoustic waves excited from the vanishing point roughly matched with the onset of the VLF/LF variations. From the onset of the VLF/LF variations, we estimated the location where the variations in the VLF/LF intensity along the paths. The estimated location was close to the RKB. The VLF/LF variations would be caused by acoustic waves excited at the vanishing end point. The acoustic waves obliquely propagated from the vanishing end point (25 km altitude) upto the D-region height (90 km altitude) at the south point of the RKB receiver.

