Fireball-associated variations in the D-region ionosphere observed 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 lower ionosphere associated with meteors and fireballs have been reported. In this study, we investigate the variation in the lower ionosphere during a fireball occurred in Hokkaido, 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 lower 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, 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. The phases of the JJY40kHz-RKB and JJY60kHz-RKB paths had similar periods of 100-200 s at that time. We consider that these variations of intensity and phase are 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), the VLF/LF reflection point (90 km altitude) or vanishing 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, 126 s, or 311 s, respectively. The arrival time (311 s) of the acoustic waves excited from the vanishing point at the 25-km altitude agrees with the onset timing of the VLF/LF variations (~5 minutes), suggesting that the acoustic waves excited from the fireball caused the variations in electron density in the D-region ionosphere. We will also show results with another fireball event over Nagano, Japan, at 13:00 UT on 12 November, 2019, and discuss the fireball effects on the lower ionosphere.

