Study of variations in the D-region ionosphere after the 2016 Kumamoto earthquakes using VLF/LF transmitter signals

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There have been many reports for the variations in the F-region ionosphere associated with earthquakes based on GPS-TEC (total electron content), ionosondes, SuperDARN(Super Dual Auroral Radar Network) Hokkaido HF (high frequency, 3-30 MHz) radars, and HF Doppler observations [e.g., Tsugawa et al., 2011].In the D-region ionosphere, oscillations of LF (low frequency, 30-300 kHz) transmitter signals with a period of 100 s were reported about five minutes after mainshock of the 2011 Tohoku Earthquakes [Ohya et al., JGR, 2018]. The reflection height of the LF waves was 67 km, and the LF oscillations were caused by acoustic waves excited by seismic Rayleigh waves based on simulation of neutral atmosphere. However, the D-region response after earthquakes was reported only in above case study, and more investigation is required. In this study, we investigate the lower ionospheric variations associated with the 2016 Kumamoto earthquake using VLF(very low frequency, 3-30 kHz)/LF transmitter signals. The foreshock (Mw 6.2) and mainshock (Mw 7.0) of the 2016 Kumamoto earthquakes occurred at 12:26:34 UT on April 14, and at 16:25:05 UT on April 15, 2016, respectively. The propagation paths were BPC(68.5 kHz, China)-SGR (Sasaguri, Japan), JJY60kHz(Saga, Japan)-SGR, and JJY40kHz(Fukushima, Japan)-SGR, and JJI(22.2 kHz, Miyazaki, Japan). In addition, we used vertical velocity data of seismometers of the F-net (Full range ,,,network) provided by the Data and Disaster Prevention Research Institute, Japan. As for the mainshock, variations in the LF intensity had a period of 100 s about five minutes after the maishock based on wavelet analysis. The duration of the LF variations was about six minutes. The onset of the LF variations was agreement with arrival time of acoustic waves excited by the Rayleigh waves below the LF path. The coherence between the JJY40kHz-SGR intensity and seismic velocity at SBR (Seburi, Japan) close to the JJY40kHz-SGR path (the distance: 35 km) was high to be 0.73 for the period of 128 s. It suggests that acoustic waves that propagated vertically from the location of the LF path caused the LF variations. In the session, we will also show the results of the foreshock, and discuss the cause of the VLF/LF variations in addition with the mainshock.

