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Three-dimensional propagation characteristics of MSTIDs obtained by HF Doppler sounding and GPS-TEC observations

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In Japan, MSTIDs frequently occur at nighttime in summer and daytime in winter. MSTIDs are caused by Perkins instability in summer and atmospheric gravity waves in winter (Otsuka et al.2021). Their period and velocities are 15 to 60 minutes and the velocity is 100 to 200 m/s respectively. However, the three-dimensional structures of MSTIDs are still unclear. Although there have been many studies about MSTIDs, most of them discuss horizontal characteristics. There are few studies about vertical characteristics. Therefore, the purpose of this study is to examine the three-dimensional structure of MSTIDs by HF Doppler sounding and GPS-TEC observations. HF Doppler sounding used in this study utilizes radio waves at different frequencies the vertical motions of the ionospheric plasma at different altitudes are obtained as Doppler shifts from the different reflected altitudes. It is also possible to calculate the horizontal propagation directions and propagation velocities of MSTIDs by comparing data from multiple receiving points. In this study, Doppler frequencies with a time resolution of 10 seconds observed at Sugadaira, Oarai, and Fujisawa by 5.006 MHz and 8.006 MHz radio waves were used .We also used GPS-TEC data for examining electron density variations at higher altitudes than HF Doppler sounding. The advantage of GPS-TEC data is that the disturbances occurred over wide area of Japan can be examined. In this study, GPS-TEC data with a time resolution of 30 seconds was obtained from 32 satellites and more than 1000 receiver combinations. The altitude of the ionospheric pierce points is assumed to be 300 km in this study. We analyzed the TEC fluctuations occurred on December 13, 2013 around the observation points Sugadaira, Oarai, and Fujisawa in the HF Doppler observations.

In the present event, the HF Doppler soundings observed the variations of Doppler frequencies of 5.006 MHz and 8.0006 MHz. Reflection height of these radio waves were 140 km for 5.006 MHz and 185 km for 8.006MHz. The directions of propagations at both altitudes were almost the same, but the propagation velocity was about 30 m/s faster at 185 km than at 140 km. Moreover, in the GPS-TEC observation, the direction of propagation was also in the southwest direction and the propagation velocity was over 200 m/s. These results indicate that the direction of propagation is the same regardless of altitude, but the propagation velocity increases with altitude.