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Periodic Oscillations of Doppler Frequency Associated with the Tonga Eruption in 2022

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The enormous eruption of Hunga Tonga-Hunga Ha'apai volcano on January 15, 2022, triggered giant atmospheric wave propagating around the Earth. In association with the passage of this wave, traveling ionospheric disturbances (TIDs) were observed. Although the atmospheric wave passed at about 11 UT in Japan, the TIDs were observed from approximately 7 UT. It is considered that the ionospheric disturbances connected to the other hemisphere along the magnetic field line. In association with the passage of this ionospheric disturbance, we have observed very characteristic oscillations of Doppler shift obtained by the HF Doppler observations. Figure 1 shows the temporal variation of the Doppler shift of the radio wave at 5006 kHz transmitted from Chofu (Tokyo) observed at Sarobetsu (Hokkaido). The propagation path is approximately in a north-south direction, and the distance between the transmitting and receiving points is 1074 km. As shown in Figure 1(a), two packets of disturbances with a period of about 4 minutes were observed from 8:40 to 9:10 and from 9:30 to 10:15. Because previous studies [1,2] have reported that TEC variations occurred over Japan during these periods, it is considered that ionospheric disturbances caused these oscillations. Although such short-period variations have not yet been reported in previous studies, analysis of 1-second sampling TEC data confirmed the existence of such periodic ionospheric variations. Therefore, the broadband fluctuations were transmitted from the magnetic conjugate point along the magnetic field lines to the opposite hemisphere. Figure 1(b) is an enlarged plot of the Doppler frequency of the variation from 9:30 to 10:00, as shown in Figure 1(a). It is worth noting that the temporal variation of the Doppler shift shows S-shape variations. This type of variation is observed when the radio waves are reflected at the sinusoidal concave surface in the ionosphere [3]. The ionospheric disturbance propagated almost east-west, and the wavefront of the TID was located almost parallel to the propagation path, which is thought to be why such fluctuations were observed.

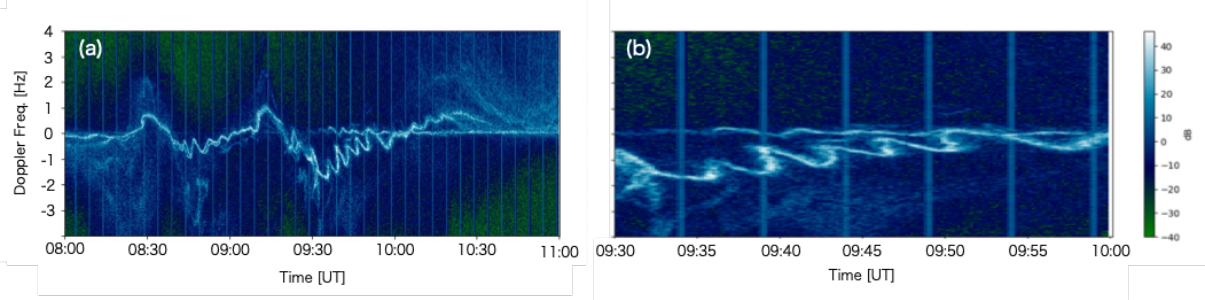

Figure 1. The temporal variation of the Doppler Frequency of 5006 kHz transmitted from Chofu (Tokyo) observed at Sarobetsu (Hokkaido Island). The right panel (b) shows an enlarged plot of the variation from 9:30 to 10:00, as shown in the left panel (a).

References

[1] S. Saito, "Ionospheric disturbances observed over Japan following the eruption of Hunga Tonga-Hunga Ha'apai on 15 January 2022," *Earth Planets Space,* **74**, 57, April 2022, doi:10.1186/s40623-022-01619-0.

[2] A. Shinbori, Y. Otsuka, T. Sori, M. Nishioka, S. Perwitasari, T Tsuda and N. Nishitani "Electromagnetic conjugacy of ionospheric disturbances after the 2022 Hunga Tonga-Hunga Ha'apai volcanic eruption as seen in GNSS-TEC and SuperDARN Hokkaido pair of radars observations," *Earth Planets Space* **74**, 106, July 2022, doi:10.1186/s40623-022-01665-8.

[3] K. Davies and D. M Baker "On frequency variation of ionospherically propagated HF radio signals," Radio Science 1, 5, May 1966, doi:10.1002/rds196615545.