Ionospheric response to the 2022 Tonga volcanic eruption based on global navigation satellite system-total electron content data

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An extreme eruption of the Hunga Tonga-Hunga Ha'apai (HTHH) volcano in Tonga, South Pacific that occurred at 04:15 UT on 15 January 2022 generated various kinds of global atmospheric and ionospheric disturbances [Wright et al., 2022] in addition to tsunamis [Kubota et al., 2022]. Shinbori et al. [2022] found that the traveling ionospheric disturbances (TIDs) propagating westward over Japan approximately 3 hours before an initial arrival of air pressure waves in the troposphere generated by the HTHH volcanic eruption. They also verified that the TIDs are driven by an external electric field due to an E-region dynamo propagating along the magnetic field lines from the Southern Hemisphere in the sunlit region based on an integrated data analysis of global navigation satellite system (GNSS)-total electron content (TEC), Super Dual Auroral Radar Network (SuperDARN) observations and a simple ionospheric model calculation. Zahang et al. [2022] also showed a similar result of ionospheric response to the HTHH volcanic eruption with several SuperDARN radar data to that reported by Shinbori et al. [2022]. In this study, we show several new results of ionospheric disturbances after the HTHH volcanic eruption on the basis of a further data analysis of GNSS-TEC, SuperDARN Hokkaido pair of radars and Himawari-8 satellite observations. As a result, the northward plasma flow showed long-periodic variation with an amplitude of 50–100 m/s during 07:50–15:00 UT on 15 January 2022 in addition to the short-periodic variation reported by Shinbori et al. [2022]. In this long-periodic variation, the timing of a change in negative and positive values of the northward plasma flow corresponded to the arrival of the air pressure waves that passed through the field-of view of the SuperDARN Hokkaido east radar. This result indicates that the ionospheric plasma flow variation was directly generated by neutral atmospheric oscillations in the thermosphere associated with a Lamb wave propagating in the troposphere. The amplitude of the northward plasma flow tends to increase with a decreasing range gate (a decreasing observation height), which implies that the plasma flow is larger in the E-region than in the F-region. Because the ion-neutral collision frequency is higher in the E-region than in the F-region, this result suggests that the plasma motion in the ionosphere is decoupled with the neutral motion with an increasing height. Further, the TEC variation at a magnetic conjugate point did not show a clear variation synchronized with the plasma flow variation observed in the Northern Hemisphere in the dark region. This result suggests that an E-region dynamo electric field is not effectively generated by the neutral oscillation due to low ionospheric conductivity.

References

[1] Wright, C. J., N. P. Hindley, M. J. Alexander, M. Barlow, L. Hoffmann, C. N. Mitchell, F. Prata, M. Bouillon, J. Carstens, C. Clerbaux, S. M. Osprey, N. Powell, C. E. Randall, and J. Yue, Surface-to-space atmospheric waves from Hunga Tonga–Hunga Ha'apai eruption, Nature, 609, 741-746, doi:10.1038/s41586-022-05012-5, 2022.

[2] Kubota, T., T. Saito, and K. Nishida, Global fast-traveling tsunamis driven by atmospheric Lamb waves on the 2022 Tonga eruption, Science, 377, 91-94, doi:10.1126/science.abo4364, 2022.

[3] Shinbori, A., Y. Otsuka, T. Sori, T. Tsugawa, and M. Nishioka, Temporal and spatial variations of total electron content enhancements during a geomagnetic storm on 27 and 28 September 2017, *J. Geophys. Res.*, **125**, e2019JA026873, doi:10.1029/2019JA026873, 2020.

[4] Zhang, J., J. Xu, W. Wang, G. Wang, J. M. Ruohoniemi, A. Shinbori, N. Nishitani, C. Wang, X. Deng, A. Lan, and J. Yan, Oscillations of the ionosphere caused by the 2022 Tonga volcanic eruption observed with SuperDARN radars, Geophys. Res. Lett., 49, 49, e2022GL100555, doi:10.1029/2022GL100555, 2022.