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

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To clarify the characteristics of electromagnetic conjugacy of traveling ionospheric disturbances just after the 15 January 2022 Hunga Tonga-Hunga Ha'apai volcanic eruption, we analyze global navigation satellite system-total electron content data and ionospheric plasma velocity data obtained from the Super Dual Auroral Radar Network Hokkaido pair of radars. Further, we use thermal infrared grid data with high spatial resolution observed by the Himawari satellite to identify lower atmospheric disturbances with surface air pressure waves propagating as a Lamb mode. After 07:30 UT, two distinct traveling ionospheric disturbances propagating in the westward direction appeared in the Japanese sector with the same structure as those at magnetic conjugate points in the Southern Hemisphere. Corresponding to these traveling ionospheric disturbances with the large amplitude of *0.5–1.1 TECU* observed in the Southern Hemisphere, the direction of plasma flow in the F region changed from southward to northward. At this time, the conjugate points in the Southern Hemisphere corresponded to the sunlit region at a height of the E region. The amplitude and period of the plasma flow variation are ~100–110 m/s and ~36–38 min, respectively. From these plasma flow signature, the zonal electric field is estimated as ~2.8–3.1 mV/m. Moreover, there is a phase difference of ~10–12 min between the total electron content and plasma flow variations. To clarify the physical meaning of existence of the phase difference between the TEC and plasma flow variations, we conduct a simple ionospheric model calculation which gives the external perturbations of the zonal electric field on the basis of the SuperDARN radar observation. The model calculation result reproduces the observed phase relationship between the plasma drift velocity perturbation and TEC perturbation. These results imply that the E region dynamo electric field driven by the lower atmospheric disturbances produces ionospheric disturbances at a height of the F region and propagates to the opposite hemisphere along magnetic field lines with the local Alfven speed, which is much faster than that of Lamb mode waves. Based on the above results, it can be concluded that the propagated electric field is a main cause of the traveling ionospheric disturbances appearing over Japan before the arrival of the air pressure disturbances, and that the generation mechanism of the traveling ionospheric disturbances triggered by the Tonga volcanic eruption is different from that of normal nighttime medium scale traveling ionospheric disturbances.

Keywords: Hunga Tonga-Hunga Ha'apai volcanic eruption, Traveling ionospheric disturbance, Electromagnetic conjugacy, Zonal electric field, E-region dynamo, GNSS-TEC and SuperDARN Hokkaido pair of radars observations