Ionospheric anomaly shortly before the 2022 Tonga volcanic eruption is a precursor?

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The Ionospheric anomalies around Japan was observed before and after the Hunga-Tonga volcanic eruption at 4:15 UTC on 15 January 2022. We use total electron content (TEC) from QZSS-3 and GNSS stations in Japan to observe electron density in the ionosphere. Then, in order to extract TEC anomalies, we use correlation analysis (Iwata & Umeno 2016) which is a general method to extract abnormal signals from complicated noise by correlating the prediction errors with nearby stations, and the analysis based on autoregressive (AR) process.

First, we describe ionospheric anomalies after the eruption. TEC and its correlation analysis show that TIDs (travelling ionospheric disturbances) propagated from the Hunga-Tonga volcano to Japan 10:30~15:30 UTC, Jan. 15. Also, the velocity was about 270 ~ 320[m/s], which is close to 300[m/s] measured after the 1991 Pinatubo eruption (Igarashi et.al. 1993) and the 2022 Hunga-Tonga eruption (Heki 2022). These results justify the analytical method.

Next, we discuss ionospheric anomalies *prior* to the eruption. The Dst index, which expresses the disturbance field parallel to the geomagnetic axis in mid-latitude regions, was -91[nT] on 23:00 UTC, Jan. 14 and remained below -60[nT] until 3:00 UTC, Jan. 15, so geomagnetic disturbances occurred shortly before the eruption. In the results of correlation analysis, ionospheric disturbances, which are different from common TIDs, were continuously observed 23:00 UTC, Jan. 14 ~ 3:00 UTC, Jan. 15, and are possibly related to geomagnetic disturbances, since the propagation direction and the shape of disturbance waves were not regular. Then, we explain the results of the analysis based on the AR process in which the error between the data predicted from the AR process for the TEC change time series and the measured value is taken as the TEC abnormality degree. The analysis showed that the prediction error was larger before the eruption and corresponded to a sharp decrease of the Dst index. These results indicate that anomalies appear in the ionosphere before the eruption in association with geomagnetic disturbances. TEC at many stations changed from a decreasing trend to an increasing trend just before the eruption. The scatter plots of the distance from Tonga to SIP (Sub-Ionospheric Point) and the time of the local minima of TEC for each station showed partially a *positive* correlation shortly before the eruption, while the correlation is generally negative for the other dates and times. The positive correlation means that the transition to an increasing trend of TEC begins earlier for stations with SIPs closer to Tonga, and this suggests that the TEC increased has a causal relation with the eruption. No obvious positive correlation was found for the other days when geomagnetic disturbances occurred.

Finally, we discuss the physical mechanism that relates geomagnetic disturbances to eruptions. During an eruption, magnetic minerals are heated as magma moves from deep underground to the surface, and then lose their magnetism when they exceed the Curie point. This causes a sudden change in the geomagnetic field and induces a geomagnetic disturbance; the positive correlation between the time of TEC minima and the distance from Tonga to SIP is consistent with such a physical mechanism to cause the eruption.

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