Statistical Analysis of Pre-Seismic Ionospheric Anomalies and their Characteristic

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Recently, many papers show various electromagnetic phenomena preceding earthquakes. For example, anomalous changes in ionospheric electrons observed by GNSS satellites (GNSS-TEC) have been reported worldwide. [Kon et al., 2011] performed statistical analysis on pre-seismic anomalies of the total electron contents (TEC) over Japan. Their results showed that significant positive anomalies appear 1-5 days before the earthquake.
On the other hand, GNSS-TEC data exist after the late 1990s. In this study, we focused on the ionosonde which is a ground-based ionosphere monitoring instrument that has long-term data (1958-) over Japan. We performed statistical correlation analysis between a sizeable earthquake and an anomaly in the ionospheric maximum electron density (NmF2) and its altitude (hmF2). The method of statistical analysis is Superposed Epoch Analysis (SEA). From the results of SEA.

We take 15 days backward median and its IQR for the definition of anomalies. If the observed data exceeds median+1.5IQR or median-1.5IQR, we define it shows anomaly.

Since ionospheric disturbances are also caused by geomagnetic storms, it is necessary to remove these effects. We checked the characteristics of ionospheric anomalies caused by geomagnetic storms in statistically and removed those effects based on the magnitude of storm and its generation time in local time.
We select earthquakes occurred within 1000 km and 350 km radius from the ionosonde station, and M >= 6 and D <= 40 km.

The results of SEA show that there are significant positive anomalies in NmF2 for 6-10 days before the earthquake within a radius of 1000 km and for 1-10 days within a radius of 350 km. On the other hand, no clear anomalies were found for hmF2.

Further, Molchan's Error Diagram (MED) analysis was performed to assess the precursory of NmF2. We applied MED analysis for the most significant anomalies such as 6-10 days in 5-day count and 7 days in 1-day count before the earthquake. As a result, MED showed a precursor to the earthquake in both cases.

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