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# Characteristics of precursory signatures in Ionospheric electron density changes related to large earthquakes observed over Japan

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Pre-seismic electron density anomalies have been a widely discussed phenomena in ionospheric studies. However, it is not well-known what causes these anomalies and what is the possible source mechanism. These are still having not been elucidated questions and more investigations are needed to make clear that phenomena. On the other hand, the another natural question is how to distinguish ionospheric anomalies from other disturbances such as geomagnetic storms. In many cases, simultaneous geomagnetic activities make it difficult to detect an earthquake precursor effect in the ionosphere. To overcome this problem, a characterization and classification of magnetic storm and earthquake signatures is necessary. For this purposes, in this study, we mainly focused on similar and differing effects of magnetic storms and earthquake preparation period on the ionospheric composition.

In this study, GEONET GPS-TEC, GIM-TEC (CODE), and Ionosonde (Kokubunji (35.71N, 139.49E),) data have been analysed for case and statistical studies over Japan area. We analysed both geomagnetic and seismic Ionospheric electron density anomalies.

For pre-seismic period, ionospheric NmF2 had mainly shown an enhancing characteristic even at night time, while for the storm cases, fluctuation was usual response after around few hours of storm onset time. Besides that, foEs values have found as changed suddenly over stations near the epicentre, however, for the storms foEs responses were irregular and was not so distinctive. The hmF2 values have increased, while before earthquakes it was not as much as affected. Moreover, the another observed difference was disturbance characteristic that after magnetic storms the ionosphere has been disturbed both negatively and positively, while before earthquakes positive disturbances and quiet weak negative disturbances were usually effective around the epicentre.

The statistical studies, based on the superposed epoch analysis (SEA).in TEC and Ionosonde data, show that there is a positve anomaly 1-5 days or 1-10 days before the earthquake with M>=6 D<=40 km, for TEC and Ionosonde, respectively. The Ionosonde response seems to be sensitive to the seismic events. The assessment for the effectiveness in the short-term earthquakes forecast using the Molchan's Error Diagram analyses have been also confirmed for both TEC and Ionosonde data.

In addition, we develop the 3D tomography method for disturbed Ionosphere. The pre-seismic anomalous changes show not only positive but also negative anomaly near the epicenter at height just below the F2 region. These anomalies stay for several hours and stable. It is different from anomalies related to the magnetic storms. These 3D structure gives us the hint for mechanism of earthquake-related anomalies. The drive force of the pre-eisimic anomalies could be the additive horizontal electric field or the vertical current. The details will be shown in the presentation.