

Ionospheric Anomalies Associated with Large Earthquakes during 1998-2011

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Many anomalous electromagnetic phenomena possibly associated with large earthquakes have been reported. TEC (Total Electron Contents) anomaly is one of the most promising phenomena preceding large earthquakes. Recently, some case and statistical studies have revealed that negative TEC anomalies significantly appear a few days before large earthquakes occurred in low geomagnetic latitude areas such as Indonesia, Taiwan, and China. On the contrary, in middle geomagnetic latitude areas such as Japan, Mexico, and Chile, positive TEC anomalies significantly appear a few days before large earthquakes. In this study, we investigate TEC anomalies before large earthquakes whether there is a geomagnetic dependence.

TEC values are computed by using the GEONET and GIM (Global Ionosphere Maps). In order to remove a daily variation of TEC, 15 days backward running average (TEC_{mean}(t)) and its standard deviation $\sigma(t)$ at a specific time are taken for the normalization. The normalized TEC, GPS-TEC*, (t) is defined as follows: $TEC^*(t) = (TEC(t) - TEC_{mean}(t)) / \sigma(t)$.

We investigate TEC anomalous variations in time and space for the 2011 off the Pacific coast of Tohoku Earthquake. GIM-TEC* anomalies exceeding +2 σ appear 3-4 days before the earthquake. The duration is more than 20 hours. This result is consistent with the previous statistical results that positive anomalies significantly appear 1-5 days before $M \geq 6.0$ earthquakes in Japan area.

SEA (Superposed Epoch Analysis) have been performed for the statistical analysis of TEC anomalies associated with $M \geq 6.0$ earthquakes occurred in low geomagnetic latitude (+15 to -15 degree) and middle geomagnetic latitude (+40 to +25 degree, -25 to -40 degree). For the low-latitude area, negative anomalies significantly appear 6-10 days before the earthquakes. For the mid-latitude area, positive anomalies significantly appear 1-5 days before the earthquakes. Furthermore, those anomalies depend on the magnitude of earthquakes. These results suggest that TEC anomalies before large earthquakes have geomagnetic dependences.

Keywords: Ionosphere, Earthquake