



Statistical and case studies of ionospheric TEC anomalies related to large earthquakes in Indonesia

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In order to examine earthquake-related TEC (total electron contents) anomalies, statistical and event analyses have been examined in Sumatra region, Indonesia. The analyzed period is about 10 years from May, 1998 to May, 2008. Earthquakes with magnitude greater than 6 and focal depth less than 40 km have been selected from USGS earthquake catalog. Eventual examples are the 2004 Sumatra-Andaman EQ and the 2007 Southern Sumatra EQ.

We use the IGS and SuGAr data for TEC computation, and GIM (Global Ionosphere Maps) for GIM-TEC computation in this paper. In order to minimize possible confounding effects of consecutive earthquakes and properly identify the abnormal signals, we computed the mean TEC (TEC_mean) and GIM-TEC (GIM-TEC_mean) values for the previous 15 days, and the associated standard deviation (σ) as a reference at specific times. Then, we derived the normalized TEC (TEC* and GIM-TEC*) values by the following equations. $TEC^*(t) = (TEC(t) - TEC_{mean}(t)) / \sigma(t)$, where the TEC* is derived every 2 min. and averaged every 60 min. $GIM-TEC^*(t) = (GIM-TEC(t) - GIM-TEC_{mean}(t)) / \sigma(t)$, with using linearly interpolations. The correlation of TEC and GIM-TEC variation at Sumatra found to be very good and it is confirmed we can use the GIM-TEC data in the 10-year statistical analysis. In this paper, to ensure that an observed TEC anomalous depression is earthquake related, we require that the reduction of the geomagnetic index Dst does not exceed -70 nT, otherwise it is considered to be geomagnetic storm related.

The result of the statistical analysis with superposed epoch analysis shows that the decrease anomaly of GIM-TEC* observed at Sumatra in 14-4 days before the earthquakes with $M \geq 6$ and R (epicentral distance) < 1000 km. In particular, the anomaly in day 6-4 before the earthquakes are the most significant.

The result of the 2004 Sumatra-Andaman EQ (M9.2) shows that the decrease anomaly of GIM-TEC* observed in day 24, 22, 21, 19-17, 15-12, 9, and 5 before the EQ. The spatial analysis of the day 5 before the EQ (Dec. 21, 2004) suggests that the extent of these reduction anomaly area reaches to the 30 degrees in latitude and 40 degrees in longitude.

The result of the 2007 Southern Sumatra EQ (M8.5) indicates that the decrease anomaly of TEC* observed in day 10-7 and 3 before the EQ and that of GIM-TEC*, in day 8 and 3 before the EQ around epicenter. The spatial analysis of the day 3 before the EQ (Sept. 9, 2007) shows that the extent of these reduction anomaly area reaches to the 10 degrees in latitude and 40 degrees in longitude.

These statistical and event analyses suggests that the decrease anomalies of TEC* and GIM-TEC* around epicenter is possibly affected by the earthquake with $M \geq 6$.