GPS Total Electron Content (TEC) for Ionospheric Observation

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Abstract

Total electron content (TEC) investigation is one of the powerful tools in ionsopheric study. Several case studies and statistical studies on storms, tsunami, earthquakes, and so on have been performed. To understand the mechanism, monitoring of three-dimensional distributions of ionospheric electron density is effective. In order to investigate the three-dimensional structure of ionospheric electron density, the neural network based tomographic approach is adapted to GEONET and ionosonde data. However, it is an ill‐posed problem in the context of sparse data, and accurate electron density reconstruction is difficult. The Residual Minimization Training Neural Network (RMTNN) tomographic approach, a multilayer neural network trained by minimizing an objective function, allows reconstruction of sparse data. In this study, we validate the reconstruction performance of RMTNN using numerical simulations based on both sufficiently sampled and sparse data. First, we use a simple plasma‐bubble model representing the disturbed ionosphere and evaluate the reconstruction performance based on 40 GPS receivers in Japan. We subsequently apply our approach to a sparse data set obtained from 24 receivers in Indonesia. The reconstructed images from the disturbed and sparse data are consistent with the model data, except below 200 km altitude. To improve this performance and limit any discrepancies, we used information on the electron density in the lower ionosphere. The results suggest the restricted RMTNN‐tomography‐assisted approach is very promising for investigations of ionospheric electron density distributions, including studies of irregular structures in different regions. In particular, RMTNN constrained by low‐Earth‐orbit satellite data is effective in improving the reconstruction accuracy.

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. In this study, TEC anomalies before large earthquakes have been investigated. TEC values are computed by using the GEONET and GIM (Global Ionosphere Maps). 15 days backward running average (TECmean(t)) and its standard deviation σ (t) at a specific time are taken for the normalization. The normalized TEC, GPS-TEC$*$(t) is defined as TEC$*$ (t) = (TEC(t)-TECmean(t))/σ(t). We investigate TEC anomalous changes in times and space from May1998 to May 2010 in case and statistical studies. Results show that positive anomalies significantly appear 1-5 days before M>=6.0 earthquakes in Japan area. In addition, we investigate the 2011 off the Pacific coast of Tohoku Earthquake. GIM-TEC$*$ anomalies exceeding +2σ appear 3-4 days before the earthquake. The duration is more than 20 hours. This result is consistent with the previous statistical results of positive anomalies for M>=6.0 earthquakes in Japan area.

To understand the mechanism, monitoring of 3D distributions of ionospheric electron density is considered to be effective. In this study, to investigate the three-dimensional structure of ionospheric electron density prior to large earthquake, the neural network based tomographic approach is adapted to GEONET and ionosonde data for the 2011 Off the Pacific Coast of Tohoku Earthquake (Mw9.0). As mentioned above, significant enhancements of TEC are found 1, 3-4 days prior to the earthquake. Especially, TEC increase of 3 days prior to the earthquake was remarkable. As a result of tomographic analysis, the reconstructed distribution of electron density was enhanced in sub-ionosphere to over F-region in comparison with 15 days backward median distribution. Moreover the enhanced area seems to be developed to upper ionosphere from sub-ionosphere with time. The rise velocity along magnetic field line was approximately 70 m/s. The tomographic results suggest the existence of some energy influx from the surface associated with seismic activity. Then, in order to understand the relationship of detected phenomenon and earthquake, we performed the tomographic analysis for other earthquakes occurred in Japan. The details will be shown in the presentation.