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Preseismic TEC changes for Tohoku-Oki earthquake in comparisons between simulations and observations

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Earthquake precursors can be used for earthquake prediction to reduce the loss of resources and human lives. Pre-earthquake ionospheric signatures have been reported by many scientists. Among those, Zhao et al., [2008] and Liu et al., [2009] reported that the total electron content (TEC) may anomalously decrease or increase up to 5 - 20% several days before 2008 Wenchuan earthquake (Mw7.9). Recently, Heki [2011] found that, ˜40 minutes before the Tohoku-Oki earthquake (Mw9.0), the Japanese GPS dense network detected clear precursory positive anomaly of TEC. Similar preseismic TEC anomalies were also observed in the 2010 Chile earthquake (Mw 8.8), 2004 Sumatra-Andaman (Mw 9.2) and the 1994 hokkaido-Toho-Oki (Mw 8.3) [Heki, 2011]. The finding of TEC variations near epicenter lacks the physical mechanism to explain those pre-earthquake ionospheric signatures.

In this presentation, we propose a mechanism to couple the pre-earthquake activity with the TEC anomalies. Before the break of rocks in the main shock of earthquake, rocks are continuously subjected to stress. The stressed rocks can activate positive holes as charge carriers and generate electric currents along the stress-gradient direction with current density [Freund, 2010]. The outflow of positive charge carriers from the stressed rock sets up a potential difference, which causes the unstressed rock to become positively charged relative to the stressed rock. The mobile positive charge carriers inside the unstressed rock repel each other electrostatically and will be pushed toward the surface. The positive charges carriers are accumulated over Earth surface, and associated electric field can drive current upwardly through atmosphere into ionosphere. We formulate an electrical coupling model for the stressed rock-Earth surface charges-atmosphere-ionosphere system [Kuo et al., 2011]. A three-dimensional atmospheric current system and a NRL ionosphere simulation code [Huba, 2008] are used to study the ionospheric dynamics based on the atmospheric electric fields and currents.

For the simulations of Tohoku-Oki earthquake, we assume that the stressed associated current started ˜ 40 minutes before the earthquake, linearly increased, and reached its maximum magnitude at the time of rocks breaks in the main shock of earthquake. Provided by geolocations of GPS stations in Japanese dense network and corresponding flight tracks of GPS satellites, TEC variations calculation uses the ray tracing method for our ionospheric simulations. The simulation results are compared to the observed TEC anomalies for available nearby GPS satellites. We will demonstrate simulations with different sizes of fault region and stressed current density over Earth surface. One of simulations is shown in figure. The panel (a) show the dTEC observation [Heki, 2011], while panel (b) for our simulations. The similarity and differences between TEC observations and simulations will be discussed in this presentation.

Keywords: Tohoku-Oki earthquake, Pre-earthquake ionospheric signatures, anomaly of TEC