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Title of Doctoral Dissertation

3D Tomography of Ionospheric Anomalies immediately before and after Large Earthquakes

巨大地震直前直後の電離圏異常の三次元トモグラフィー

In this study, I robustly estimate three-dimensional (3D) distribution of both pre- and post-seismic ionospheric anomalies of the 2011 M_w 9.0 Tohoku-oki and 2010 M_w 8.8 Maule earthquakes by tomographic inversions of electron density anomalies, revealed using slant-TEC residuals as inputs to 3D tomographic inversion. I compare the spatial and temporal distribution of the 3D structure of ionospheric electron density anomalies immediately before these two megathrust earthquakes together with another large earthquake (the 2015 M_w 8.3 Illapel) studied by He and Heki (2018). The tomography results showed that the pre-seismic ionospheric anomaly in each case has following similarities; (1) They are composed of pairs of low-altitude positive and high-altitude negative electron density anomalies. (2) They occur above the land area close to the submarine faults. (3) They have clear onsets a few tens of minutes before earthquakes (~40 min before 2011 Tohoku-oki, and Maule, and ~20 minutes before the Illapel earthquakes) and grow with decaying rates.

Muafiry & Heki (2020) hypothesized the physical process consistent with such 3D structure as follows. Electric fields made by surface positive charges reachs the ionosphere. The field generates electromotive forces and makes electrons move down along geomagnetic fields, and this upward current makes eastward/westward magnetic field in regions to the south/north of the epicenter before earthquakes in northern/southern hemisphere. The current will continue until the induced electric field cancels the external field made by surface charges, making the electric potential uniform along the magnetic field. The current will depend on the along-B component of the external electric field and the density of free electrons as a function of altitude. The nonuniform electric currents would result in convergence/divergence of electrons and make positive/negative electron density anomalies at the lower/higher ionosphere along the magnetic field, the structure consistent with those found for these three earthquakes by 3D tomography. I will also compare strengths and dimensions of the electron density anomalies before these three earthquakes.