Ionospheric TEC changes immediately before large earthquakes: Derivation of the standard curve and discussion on the physical mechanisms

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Shortly after the 2011 Tohoku-Oki Earthquake, Heki (2011) found that the ionospheric total electron content (TEC) started to change ~40 minutes before earthquake. Number of earthquakes showing similar immediate precursory TEC changes increased (e.g. He & Heki, 2017), but physical process behind the phenomenon has not been fully understood. Existence of such precursors suggest that the final size of an earthquake is largely prescribed when the fault rupture starts, which would be of sound seismological importance.

Why does the ionospheric TEC increase immediately before large earthquakes? We hypothesize that a certain process weakens the fault by sweeping the fault from one end to the other. It causes micro-scale cracks and dislocations, which cut peroxy bonds within rocks mobilizing positive holes. Electron movements let positive holes diffuse out of the rock and accumulate on the surface. They would make vertical electric fields (**E**) which may reach the ionosphere if the fault is large enough. High conductivity in ionosphere along geomagnetic fields (**B**) prohibits **E** along **B**. Thus, ionospheric electrons come down along **B** to cancel external **E**. This process would increase electron density at the bottom end of the geomagnetic field line and decrease electron density in higher regions. This hypothesis is supported by the 3-dimensional structure of the electron density anomalies just before the 2015 Illapel earthquake by He & Heki (2018).
In this study, we compare vertical TEC changes before and after the 18 earthquakes with Mw 7.3-9.2 that showed significant immediate preseismic TEC anomalies and explore scaling laws of various quantities. Then we derive the ‘standard curve’ of preseismic TEC changes by stacking the time series of individual cases after normalizing their horizontal and vertical axes. Comparing individual cases with the standard curve and highlighting their differences would help us characterize between-earthquake differences and get insight into their physical mechanisms. The current model suggests that the coseismic release of crustal stress would stop further generation of positive changes from faults and halt the TEC anomaly buildup. The derived standard curve suggested that the TEC does not show further increase after the earthquake occurrence time and remain almost constant until acoustic disturbances arrive. Also, the shapes of the pre-earthquake anomaly buildup curves may have regionality, reflecting e.g. the ocean-land proportion around the epicenter. Higher conductivity of the sea water will let electric charges diffuse rapidly and make the TEC anomaly reaches plateau earlier after its start. Comparison of the TEC change curves of individual earthquakes with the standard curve, however, showed that they are highly coincident in most cases with little significant differences in how the TEC anomaly builds up.

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