Large earthquakes and coseismic ionospheric disturbances: How far can GPS-TEC constrain source processes?

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Ionospheric Total Electron Content (TEC) can be easily measured with the phase differences between the L1 and L2 carrier waves from GPS satellites. TEC disturbances have been offering new views of various phenomena in earth sciences. Recent reports include the directivity and propagation velocity of coseismic ionospheric disturbance (CID) inferred from the 2003 Tokachi-oki earthquake (Heki and Ping, 2005), constraints on the source process of the 2004 Sumatra earthquake with CID waveforms (Heki et al., 2006), energy estimation of the 2004 Asama explosion (Heki, 2006), and radio occultation measurement of sudden increase of TEC by solar flares (Heki, 2007). Here I compare CIDs of various earthquakes, e.g. the 2003 Tokachi-oki earthquake, 2004 Sumatra-Andaman earthquake, an interplate earthquake in 2006 November and an outer rise normal earthquake in 2007 January in the Kurile Islands, and discuss how far GPS-TEC measurements of CID can constrain their source processes.

CIDs are the electron density perturbation at the F2 layer in ionosphere (about 300 km from the ground) driven by acoustic waves that have been excited by vertical crustal movements above the focal region and have propagated upward. They appear 10 minutes or so after the earthquake (this is the time required for the wave to propagate from the ground to the F2 layer height). They are characterized by waveforms with periods of 4-5 minutes and with positive (i.e. TEC increase) initial motion, and propagate as fast as ˜1 km/sec toward south in the northern hemisphere. For rupture of a fault longer than 1000 km, such as the 2004 Sumatra earthquake, CID waveforms become complicated because they are mixtures of CIDs from multiple asperities that ruptured sequentially along the fault in a certain propagation speed. By decoding such waveforms, we could constrain rupture propagation speed and relative magnitudes of asperities. Heki et al. (2006), by analyzing the CID in Thailand and Indonesia after the 2004 Sumatra-Andaman Earthquake, suggested that the rupture propagated as fast as 2.5 km/sec (1.7 km/sec, as suggested by tsunami, is ruled out from the CID point of view) and that the northern Andaman segments did rupture fast enough to excite acoustic wave with periods of 4-5 minutes (tsunamis should have been excited as well although they would have been smaller than in the south).

Two earthquakes occurred in the middle part of the Kurile Islands, that is, an interplate thrust earthquake in 2006 November and a normal fault earthquake in the oceanic lithosphere in 2007 January. It is a rare occasion that an M8 class normal fault earthquake occurs within the reach of GPS-TEC observations. In this study, we compare CIDs from these two earthquakes and discuss their differences steming from different source processes.

References

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