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Study of the ionospheric response to surface waves generated by large earthquakes

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Global Positioning System (GPS) is a powerful technique for monitoring the ionosphere. The quantity measured is the Total Electronic Content (TEC), that is the integrated quantity of the electronic density along the satellite - beacon ray path. Dense GPS networks like the Japanese network GEONET provide the proper sampling (∼ 10 km) for imaging seismogenic ionospheric waves (whose wavelengths are hundreds of kilometers) finely. In instrumented regions, changes in the surrounding GPS-TEC map are observed for almost all the large earthquakes (magnitude greater than 6) within ten minutes after the rupture. This time corresponds to the propagation delay needed by the forced atmospheric waves to reach the ionospheric altitudes. In some favourable configurations, an integrated, a “seismo-ionospheric” radiative pattern is visualized.

In the vicinity of a large earthquake the measured ionospheric seismic waves are two kinds : a slow wave at near field and a faster one at near and far field. They are easily identified by their group velocity, about 1 km/s and 3.4 km/s respectively. The first kind is directly relied to the acoustic pulse generated by the vertical displacements of the source. It takes the form of a plume, easily modelled by a ray tracing technique. Following this model, source informations like the fault spatial distribution can be extracted as illustrated by the case of the Sumatra giant earthquake of 200,4 December, 26th [Heki et al., 2006]. The wave trains of the second kind are excited by the Rayleigh surface waves up to teleseismic distance.

We are aiming here to investigate the potential of extracting informations on the source from this last type of waves. Their coupling with the atmosphere is very efficient and we observed at ionospheric level an overlap of the sound wave by the surface waves signal just after the Tokachi-Oki - 2003, September 25th Mw=8.1 earthquake. 3D synthetics of the atmospheric waves generated by surface waves are modelled by a normal modes summation method [Lognonné et al., 1998], where the solid earth is surrounded by an atmosphere with a radiative boundary condition. The geomagnetic field influence as much as the effect of ion drag are finally included in the three dimensional model developed according to the ionospheric coupling model after [E.A. Kherani et al., 2009].

[Heki et al., 2006] “Detection of ruptures of Adaman fault segments in the 2004 great Sumatra earthquake with coseismic ionospheric disturbances”, JGR 111
[Kherani et al., 2009] “Response of the Ionosphere to the seismic triggered acoustic waves: electron density and electromagnetic fluctuations,” GJI 176-1
[Lognonné et al., 1998] “Computation of seismograms and atmospheric oscillations by normal-mode summation for a spherical earth model with realistic atmosphere” GJI 135