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Tsunami Ionospheric warning and Ionospheric seismology

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The last decade demonstrated that seismic waves and tsunamis are coupled to the ionosphere. Observations of Total Electron Content (TEC) and airglow perturbations of unique quality and amplitude were made during the Tohoku, 2011 giant Japan quake, and observations of much lower tsunamis down to a few cm in sea uplift are now routinely done, including for the Kuril 2006, Samoa 2009, Chili 2010, Haida Gwai 2012 tsunamis. This new branch of seismology is now mature enough to tackle the new challenge associated to the inversion of these data, with either the goal to provide from these data maps or profile of the earth surface vertical displacement (and therefore crucial information for tsunami warning system) or inversion, with ground and ionospheric data set, of the various parameters (atmospheric sound speed, viscosity, collision frequencies) controlling the coupling between the surface, lower atmosphere and the ionosphere.

We first present the state of the art in the modeling of the tsunami-atmospheric coupling, including in terms of slight perturbation in the tsunami phase and group velocity and dependance of the coupling strength with local time, ocean depth and season. We then show the confrontation of modelled signals with observations. For tsunami, this is made with the different type of measurement having proven ionospheric tsunami detection over the last 5 years (ground and space GPS, Airglow), while we focus on GPS and GOCE observation for seismic waves. These observation systems allowed to track the propagation of the signal from the ground (with GPS and seismometers) to the neutral atmosphere (with infrasound sensors and GOCE drag measurement) to the ionosphere (with GPS TEC and airglow among other ionospheric sounding techniques). Modelling with different techniques (normal modes, spectral element methods, finite differences) are used and shown. While the fits of the waveform are generally very good, we analyse the differences and draw direction of future studies and improvements, enabling the integration of lateral variations of the solid earth, bathymetry or atmosphere, finite model sources, non-linearity of the waves and better attenuation and coupling processes. All these effects are revealed by phase or amplitude discrepancies in selected observations.

We then present goals and first results of source inversions, with a focus on estimations of the sea level uplift location and amplitude, either by using GPS networks close from the epicentre or, for tsunamis, GPS of the Hawaii Islands.