Seismic and Tsunami signatures in the ionosphere: what we learn from Sumatra 2004 to Samoa 2009

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After the Great Sumatra Earthquake and the consequent Indian Ocean Tsunami scientists put their attention to alternative methods in ocean monitoring to improve the response of the tsunami warning systems.

Improvement of classic techniques, as the seismic source estimation and densification of number of buoys over the oceans, was supported by a new effort in remote sensing, nominally the space altimetry observation of the tsunami in the open sea (Okal et al., 1999; Smith et al., 2005) and the tsunami detection by ionospheric monitoring. Today the Samoa tsunami declares, one times more, the importance to go forward in this direction.

The indirect tsunami observation by ionospheric sounding is based on the idea anticipated in the past by Hines (1972) and Peltier & Hines (1976) that tsunamis produce internal gravity waves (IGWs) in the overlooking atmosphere. During the upward propagation the IGWs are strongly amplified by the effect of the decrease of the density. The interaction of IGWs with the plasma at the ionospheric height produce strongly variation in the plasma velocity and plasma density observable by ionospheric sounding (figure 1).

The encouraging work of Artru at al. (2005a) on the detection of the peruvian tsunamigenic quake on June 23rd, 2001 (M=8.4 at 20:33 UT) in the total electron content (TEC) measured by the japanese dense GPS network GEONET opens the modern debate about the feasibility of tsunami detection by ionospheric sounding.

The giant tsunami following the Sumatra-Andaman event (Mw=9.3, 0:58:50 UT, December 26th, 2004 (Lay et al., 2005)), an order of magnitude larger than the Peruvian tsunami, provided worldwide remote sensing observations in the ionosphere, giving the opportunity to explore ionospheric tsunami detection

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with a vast data set. In addition to seismic waves detected by global seismic networks (Park et al., 2005); co-seismic displacement measured by GPS (Vigny et al., 2005); oceanic sea surface variations measured by altimetry (Smith et al., 2005); detection of magnetic anomaly (Iyemori et al., 2005; Balasis & Mandea, 2007) and acoustic-gravity waves (Le Pichon et al., 2005); a series of ionospheric disturbances have been reported in the recent literature using different techniques, such as Doppler sounding (Liu et al., 2006a), over-the-horizon radar (Occhipinti, 2006), GPS (Liu et al., 2006b; Lognonné et al., 2006; DasGupta et al., 2006) and altimeters (Occhipinti et al., 2006).

Most of the observations show the signature in the ionosphere of the propagation of Rayleigh wave and tsunami. Numerical modeling taking into account the coupling between the solid-Earth/ocean/neutral-atmosphere/ionosphere (Occhipinti et al., 2006, 2008; Mai & Kiang, 2009; Hickey et al., 2009) reproduce some observation proving the link between ionospheric disturbances and surface displacement produced by Rayleigh waves (Occhipinti, 2006) and tsunamis (Occhipinti et al., 2006).

Passing in review the recent advances in the tsunami detection by ionospheric sounding, we explore the TEC perturbation close to the epicenter of several tsunamigenic earthquakes from the Sumatra Earthquakes in 2004 to the recent event in Samoa (2009). We show that a systematic ionospheric perturbation close to the epicenter appear within 15 minutes after the rupture (Occhipinti & Rolland, 2010). This systematic signal push forward the debate about the role of ionospheric sounding in the early tsunami systems.

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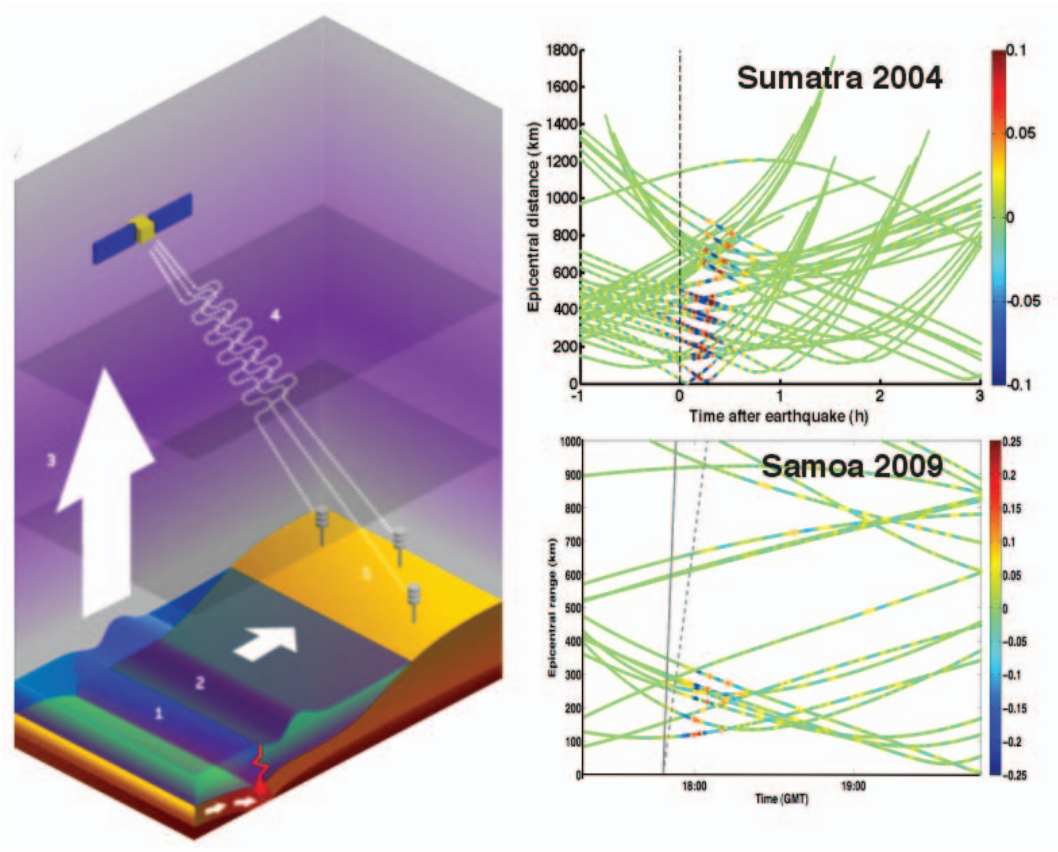

Fig. 1. Right: Cartoon of detection of tsunami by ionospheric sounding and coupling mechanism producing tsunamigenic internal gravity waves. Left: early signature of tsunamigenic earthquakes observed by GPS, monitoring the total electron content.

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