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Title:	Tsunamis warning from space :Ionosphere seismology
Author(s):	Larmat, Carene
Intended for:	promoting a starting program about ionosphere seismology

Tsunamis warning from space :Ionosphere seismology

Carène Larmat, LANL
Philippe Lognonné, Lucie Rolland, et al., IPGP, Paris France
Emile Okal, Northwestern University, IL
Jonathan Makela, University of Illinois, IL

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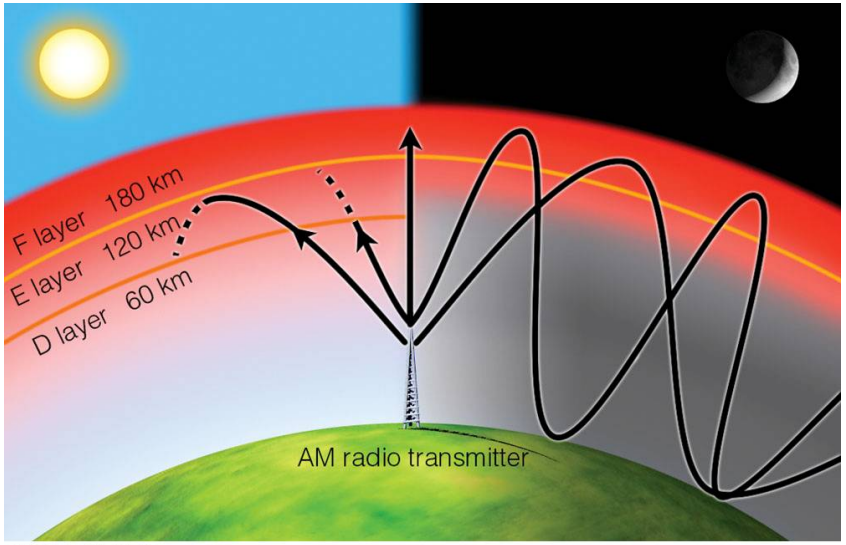
Ionosphere

- Layer of the atmosphere from about 85 to 600km containing electrons and electrically charged atoms that are produced by solar radiation
- Perturbations: layering affected by day and night, X-rays and high-energy protons from the solar flares, geomagnetic storms, lightning, **drivers-from-below.**
- Strategic for radio-wave transmission



Tsunamis

Challenges:

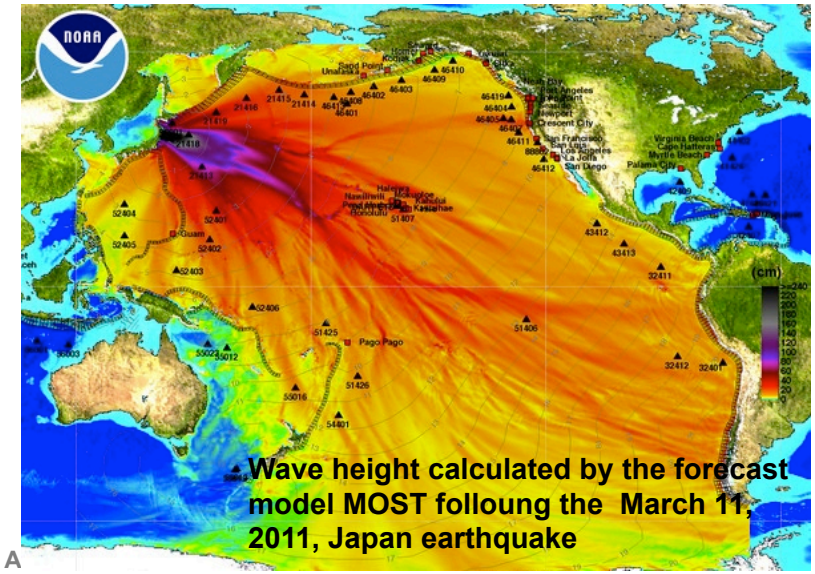
- *Sources*: earthquakes and landslides
- *Detection*: long wavelenghts, small amplitude (50cm for the 2004 Sumatra earthquake)
- *Modeling and Prediction:* amplitude and arrival times (Tsai et al., 2012)

Monitoring:

- Pressure sensors (bottom ocean) & GPS buoy systems (Gonzales et al., 1998), optical imaging of the arrival

QuickBird satellite image of a beach (southwestern Sri Lanka) showing the coming tsunami wave of Dec. 2004

Credit: Digital Globe

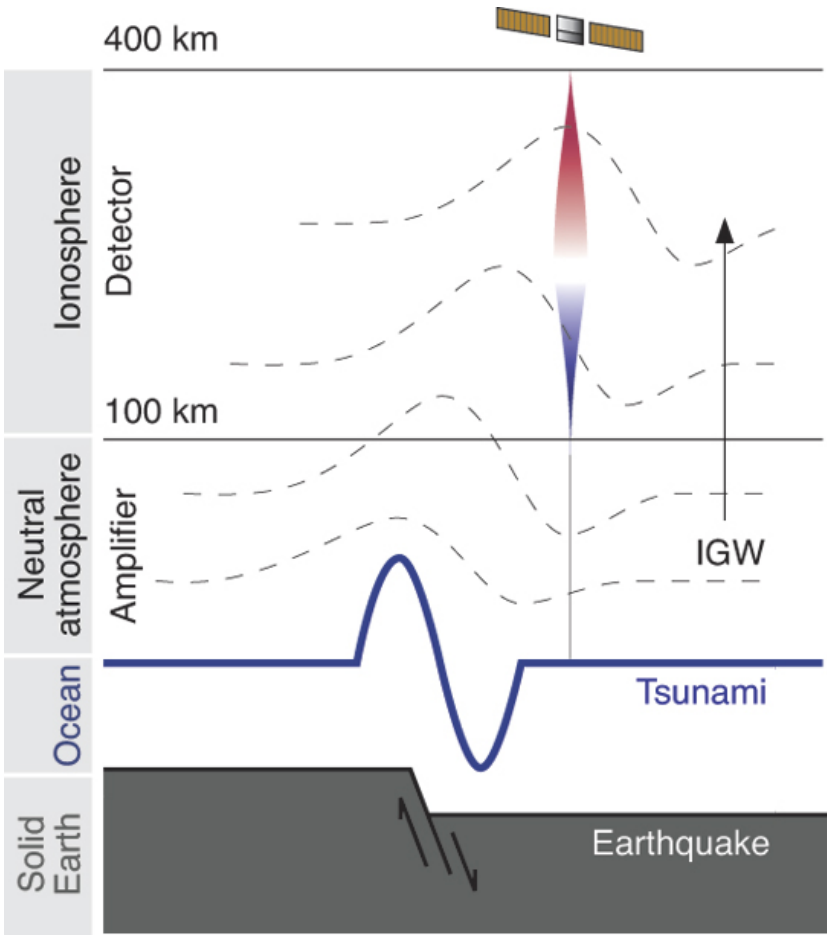


Wave height calculated by the forecast model MOST folloung the March 11, 2011, Japan earthquake

Monitoring tsunami with ionosphere signals

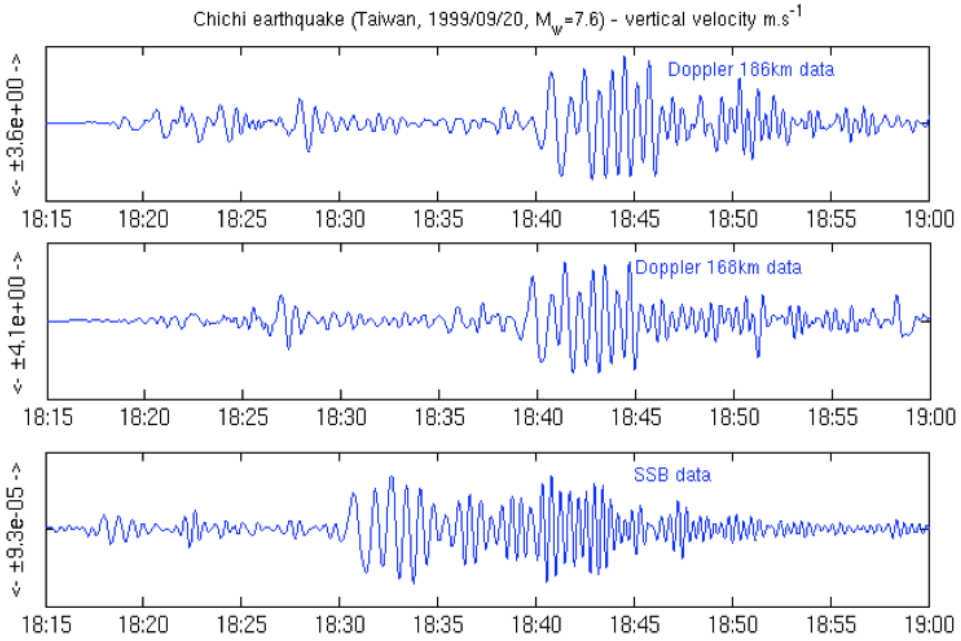
Pioneering work by the Canadian atmospheric physicist Colin Hines (1970s)

- Ionospheric Doppler sounding (Artru et al.,2004)
- total electron content (TEC) : variations in electron density along the satellite-receiver line-of-sight.
- Airglow (Maleka et al., 2011)



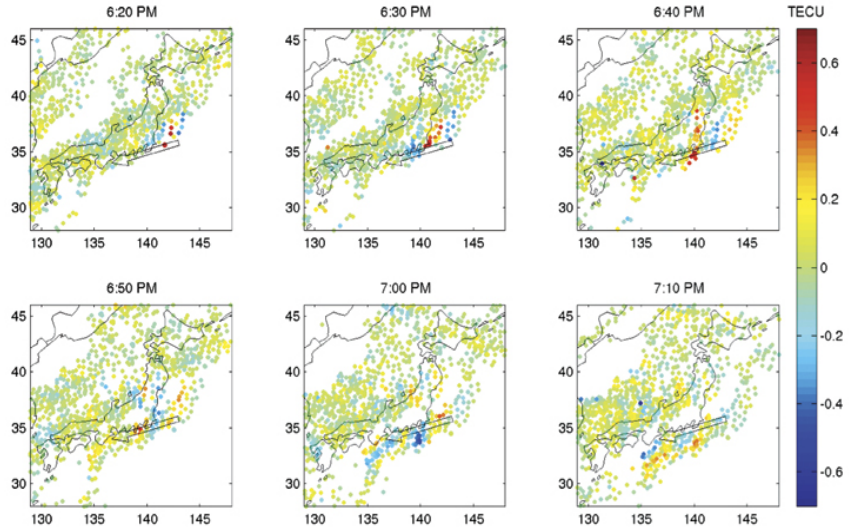
Some observations

Amplification and filtering of the tsunami signal : Ionospheric Doppler sounding (Artru et al.,2004)



Vertical motion of the ground (bottom) from SSB seismometer and of the ionospheric layers at altitudes of 168 and 186 km generated by the Mw-7.6 Chi-Chi earthquake (1999)

Following a propagating tsunami



TEC variations observed thanks to the continuous GPS network in Japan, GEONET of the tsunami generated by the 2001 Peru earthquake arriving on the Honshu coastline (from Artru et al, 2005)

Our project

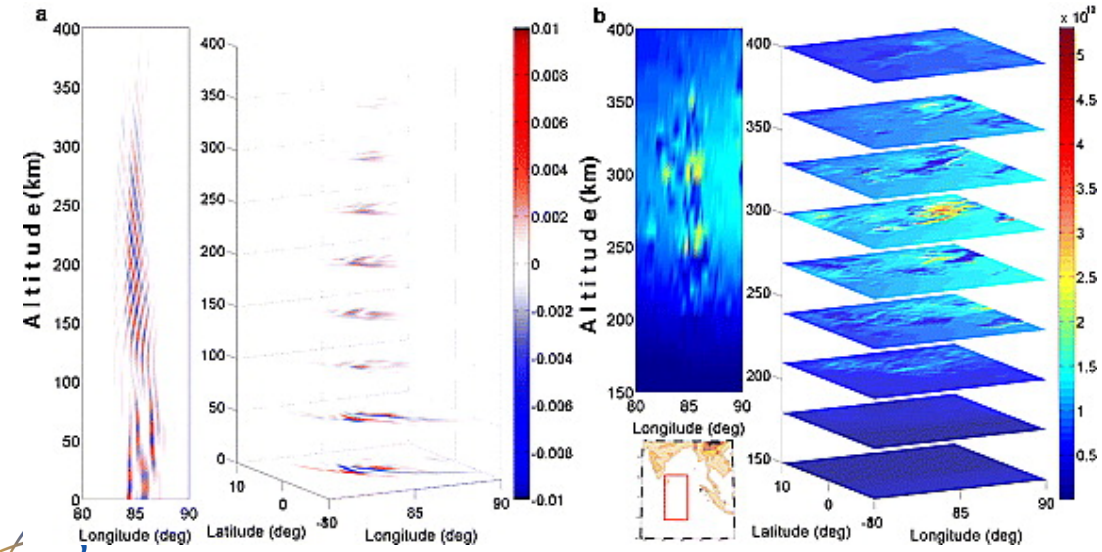
Philippe Lognonné, “planetary seismologist”, http://www.kiss.caltech.edu/workshops/seismo2009/video/lognonne/lognonne.html; http://insight.jpl.nasa.gov/

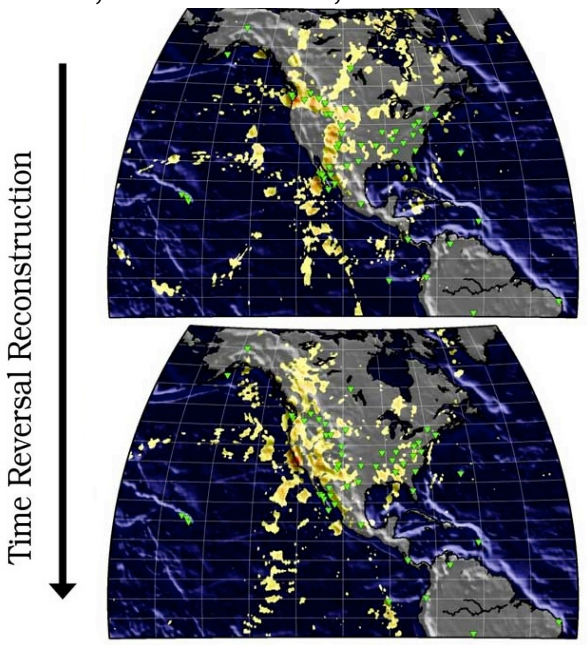
Inversion of ionosphere signals: tsunami wave amplitude and coupling parameters **Improving tsunami warning systems**

- Modeling capability of IPGP (Rayleigh wave *Lognonné et al., 1998, Artru et al., 2001, Rolland et al., 2011a;* explosion-generated acoustics waves *Dautermann et al., 2008, Lognonné, 2008*; tsunami gravity waves *Artru et al, 2005, Occhipinti et al., 2006, Occhipinti et al., 2008, Occhipinti et al., 2011*; ionospheric/neutral waves coupling *Kherani et al., 2009, Rolland et al., 2010*

- TR imaging and HPC resources LANL

Modeling of synthetic TEC data (Occhipinti, 2006)





TR reconstruction of the 2004 Parkfield earthquake (e.g. Larmat et al., 2010)

Japan

From Rolland et al., 2011.
(a) And (b) Travel-time diagrams of slant TEC timeseries filtered from 1 to 10mHz
(c) Sample of filtered TEC maps showing the gravity wave emitted by the rupture.