SSTDM 2014

International workshop on
Small Satellite and Sensor Technology
for Disaster Management

Design and Development of an Innovative Method for Tsunami Warning using Total Electron Count

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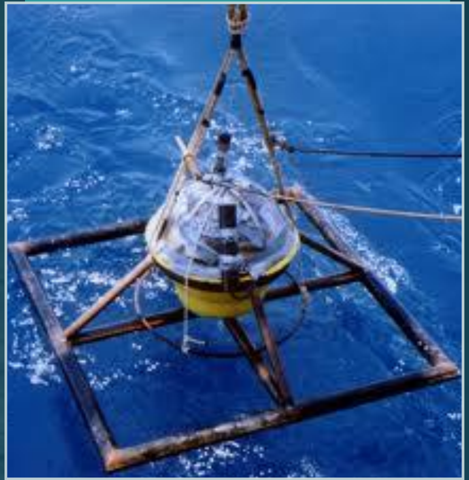
Current Technologies

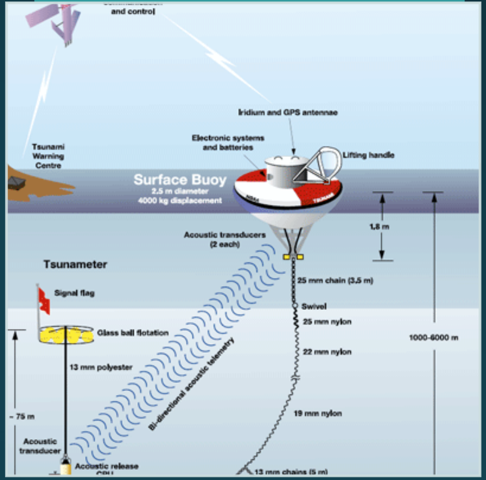
- Difficult to quantify amplitude and corresponding to earth quake, tsunami wave confirmation is difficult

Seismic Instruments



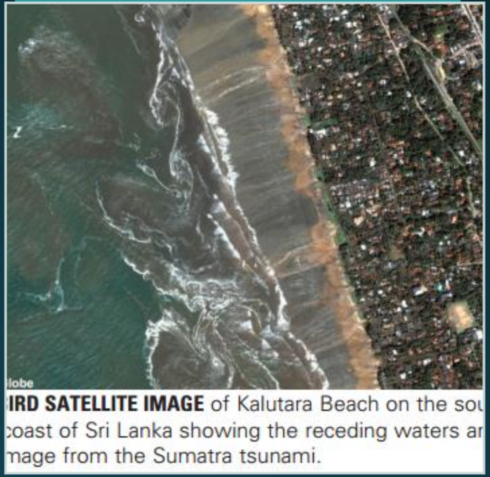
- Tsunami detection after several hours due to poor network and measuring technique

Ocean buoys and pressure sensors

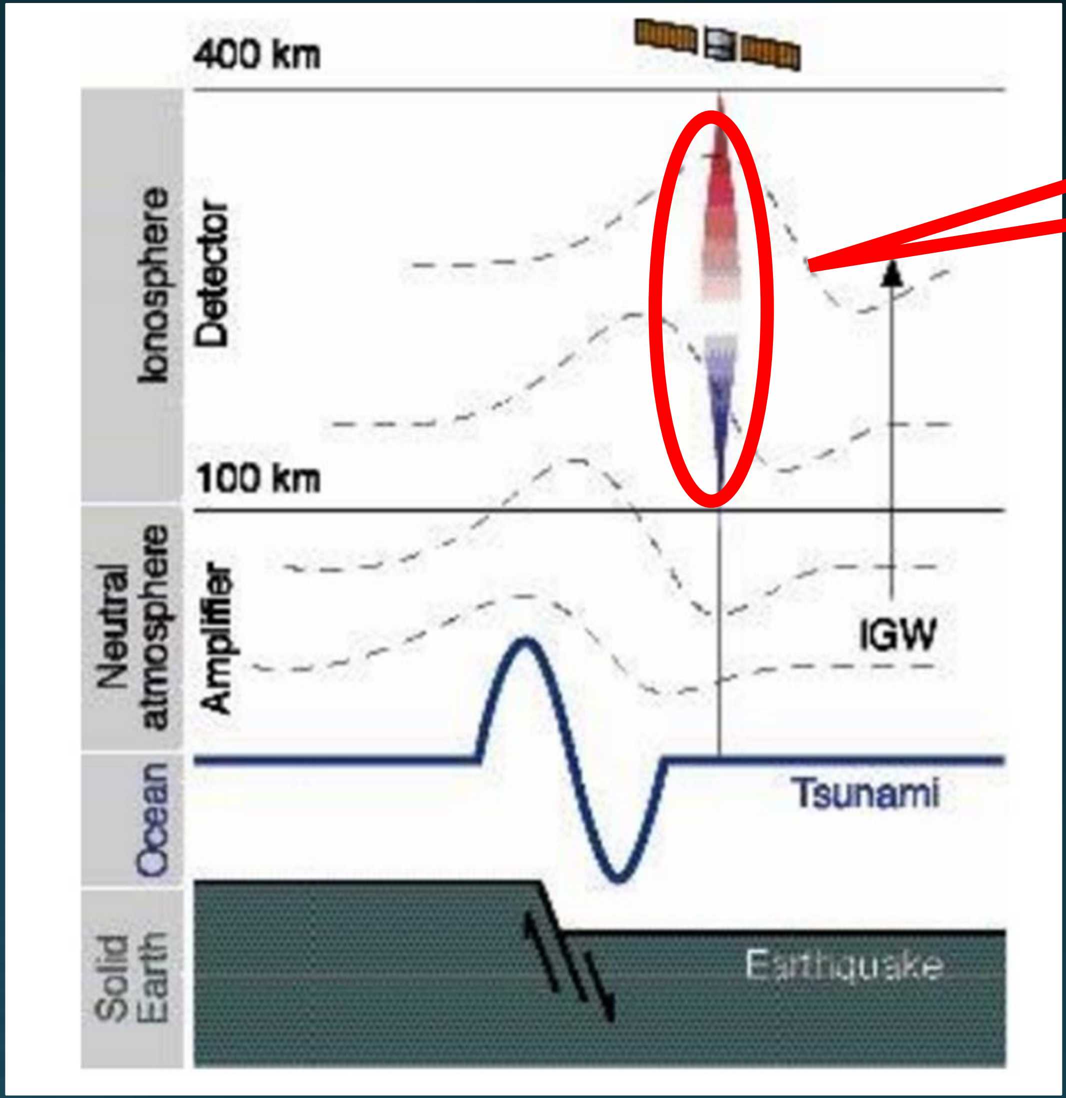


- Satellite altimetry also proved to be effective in detecting surface wave variation in case of large Tsunamis.
- It can only provide a few snapshots

Satellite altimetry



Proposed Method



Changes in TEC due to IGW

Change in TEC due to Earthquake

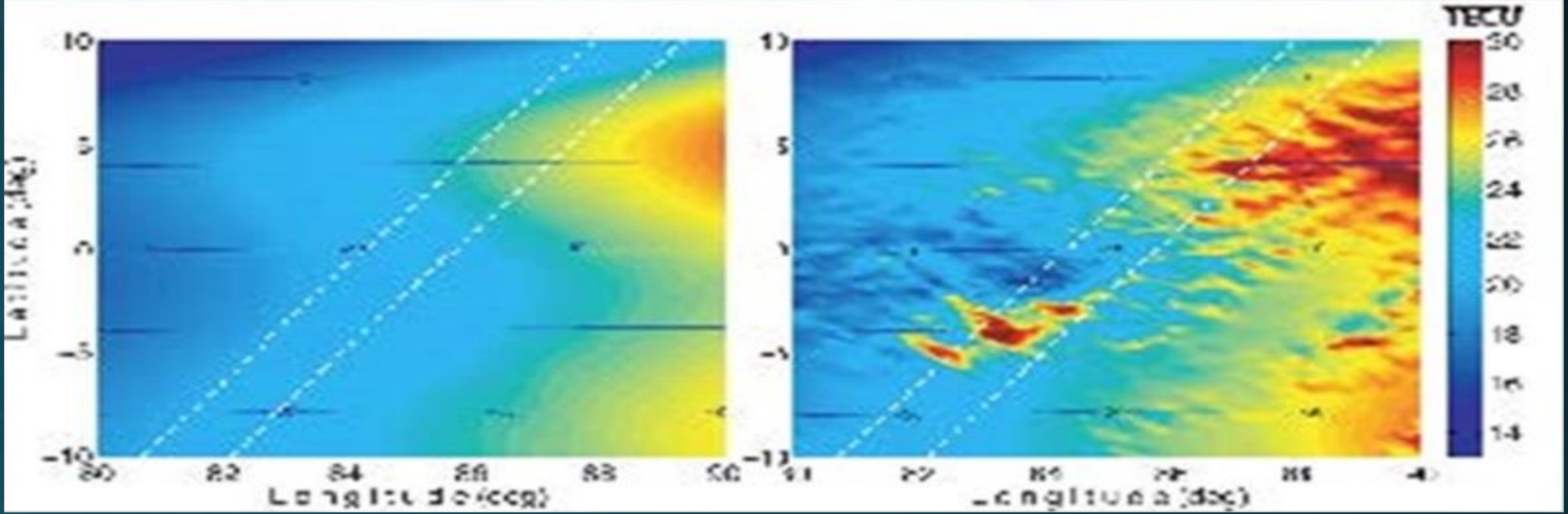


Fig. 2 TEC contours before and after Sumatra (26 December 2004) earthquake. The broken lines represent the Topex/Poseidon (left) and Jason-1 (right) trajectories.

Ref : Giovanni Occhipinti, Attila Komjathy, & Philippe Lognonné (2008), Tsunami Detection by GPS: How Ionospheric Observations Might Improve the Global Warning System.

Change in TEC due to Earthquake *(Tohoku 11th March 2011)*

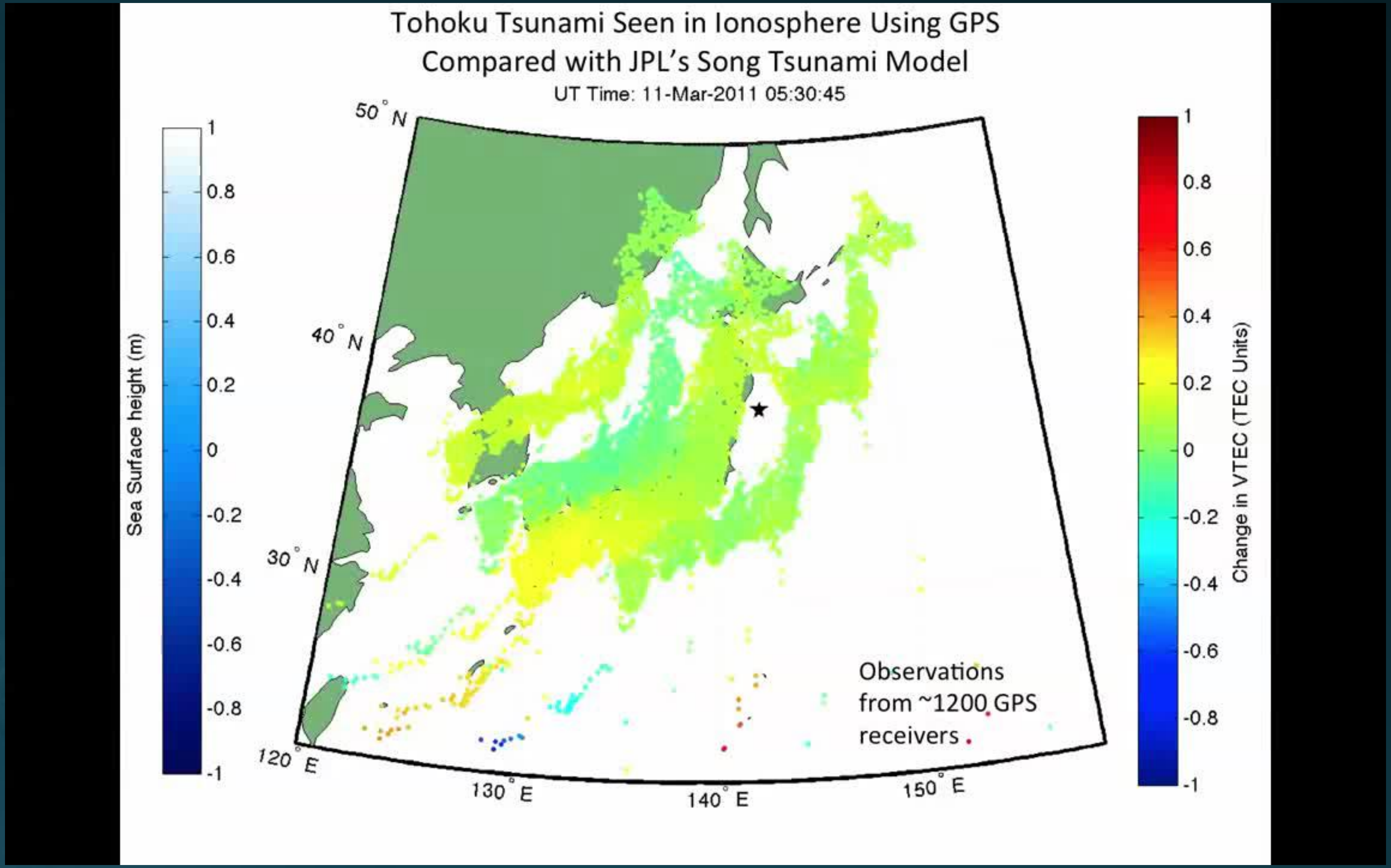


Fig. 3 TEC contours before and after Tohoku (11 March 2011) earthquake. Data taken from GPS receivers on ground

Ref : A. Komjathy, D. A. Galvan, P. Stephens, M. D. Butala, V. Akopian, B. Wilson, O. Verkhoglyadova , A. J. Mannucci, and M. Hickey, Detecting ionospheric TEC perturbations caused by natural hazards using a global network of GPS receivers: The Tohoku case study. Earth Planets Space,64, 1287–1294, 2012

Change in TEC due to Earthquake

Tokacho-Ok
(25 September 2003

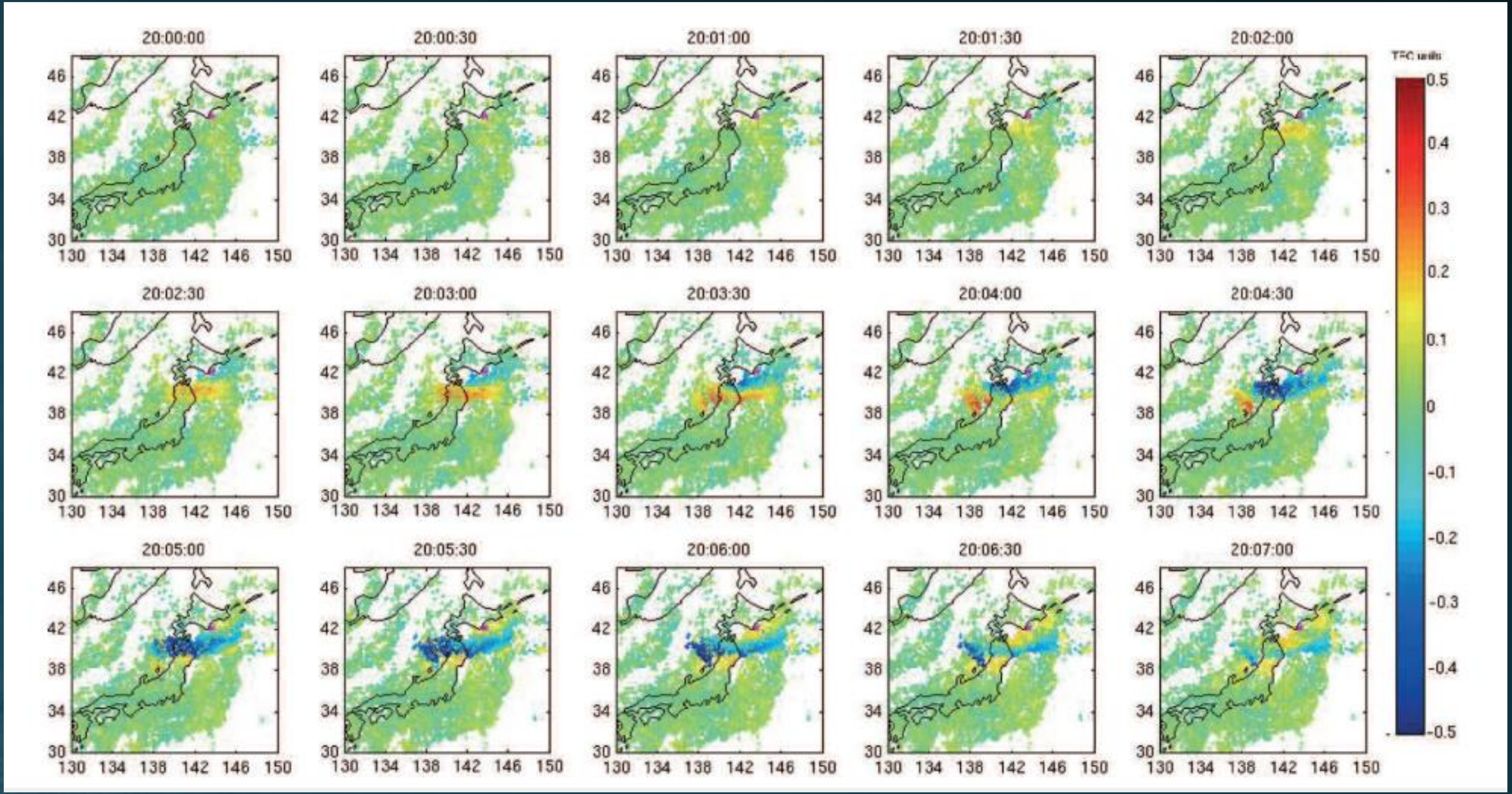


Fig. 4 TEC contours before and after Tokacho-Ok (25 September 2003) earthquake. Data taken from GPS receivers on ground

Ref : Philippe Lognonné, Raphael Garcia, François Crespon, Giovanni Occhipinti , Alam Kherani and Juliette Artru-Lambin, Seismic waves in the ionosphere

Faraday Rotation principle

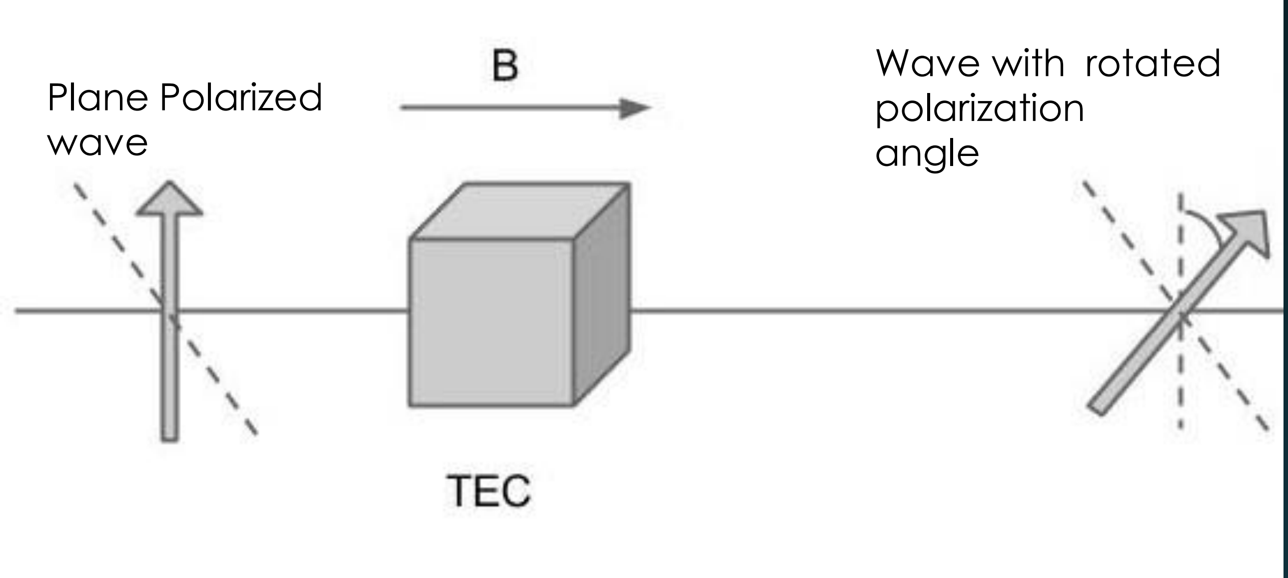


Fig. 5 Faraday Rotation Principle

$$\Delta\emptyset = 4.87 * 10^4 f^{-2} \int_{h_1}^{h_2} NBcos\theta \, dl$$

N : electron density (m^{-3}),
B : magnitude of magnetic field of earth (Tesla),
θ : angle between the radio wave and local magnetic field vector,
$\Delta\phi$: change in angle of rotation,
f : frequency of the wave (Hz)

Measurement Technique

Knowing initial angle of polarization ($\emptyset_0$) is difficult

$$\emptyset_1 - \emptyset_0 = \theta_1 \quad \emptyset_2 - \emptyset_0 = \theta_2$$

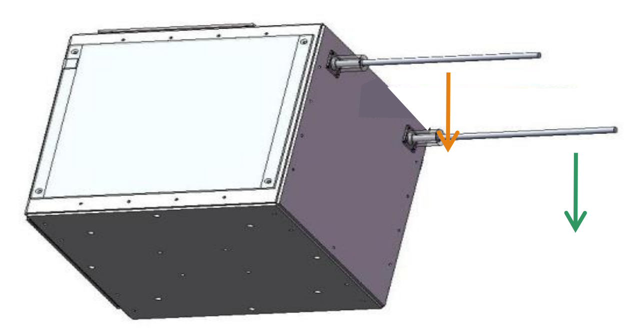
$$\emptyset_2 - \emptyset_1 = \theta_2 - \theta_1$$

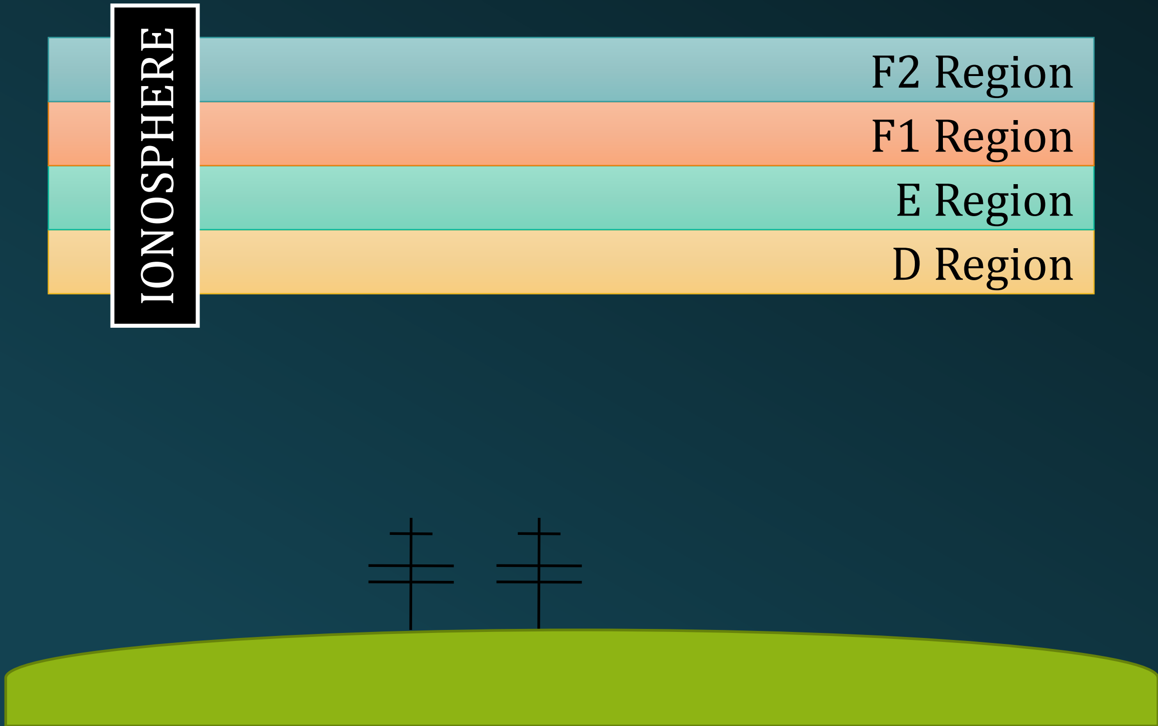
$$\theta_2 - \theta_1 = 4.87 * 10^4 (f_2^{-2} - f_1^{-2}) \int_{h_1}^{h_2} NB\cos\theta \, dl$$

ϕ_0: initial phase angle of both waves transmitted by satellite,

ϕ_1, ϕ_2 : final phase angle of the two waves measured at ground station

f_1 and f_2 : frequencies of both the waves in Hz





Benefits

- Minimum time difference - Coastal areas at a distance more than 20 minutes from epicenter
- Computation - No onboard computation for payload purpose
- Hardware - Only two monopoles each of 20.7 cm length for payload
- Power- Maximum 3.41 W-hr for downlink monopole and circuit
- EQ and Tsunami wave magnitude - The earthquake magnitude can be estimated using changes in TEC and hence tsunami wave amplitude using tsunami model
- The satellite need not be overhead the ground station but has to be in its FOV
- Time between 2 consecutive passes is 10 hours in case of Pratham

Social Goal, Collaboration

- To predict Tsunami generating earthquake, a ground station (GS) required near epicenter
- More the ground stations preferably near cost, good for payload
- Conducted a series of Ground Stations workshops (4)
  - Functional GS at 10 locations in India and at IPGP, France
- Satellite should have a pass (not necessarily overhead) near epicenter at the time IGW reaches ionosphere
- Due to benefits of this technology, any satellite can have this as a secondary payload

Student Satellite Society of India

iPGP
INSTITUT DE PHYSIQUE DU GLOBE DE PARIS

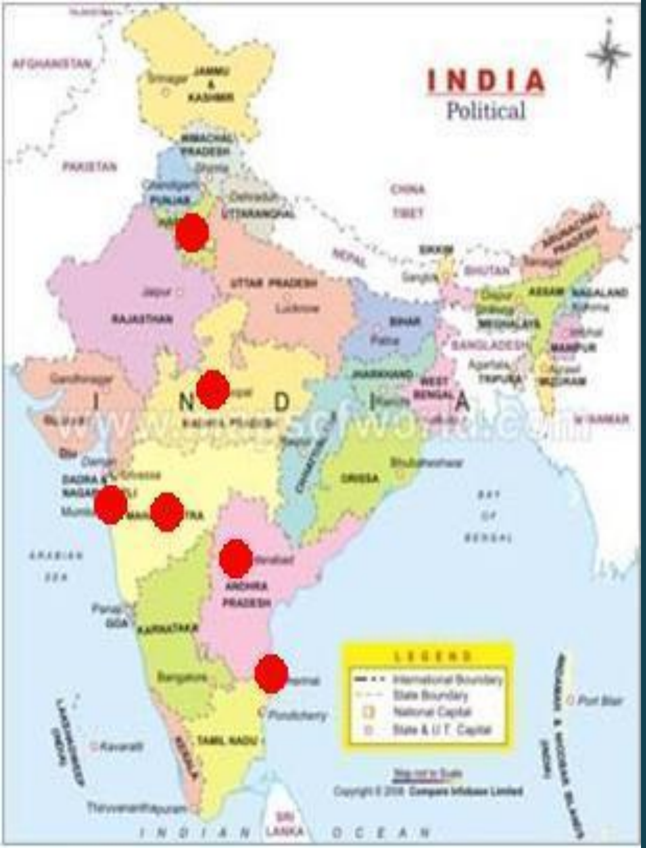
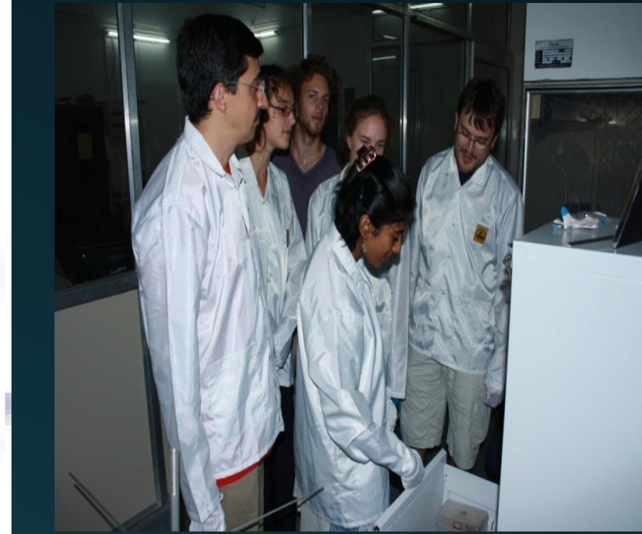


Fig. 6 Location of GS in India

Fig. 7 Student Satellite Society



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THANK YOU

GPS Receiver locations for TEC in India

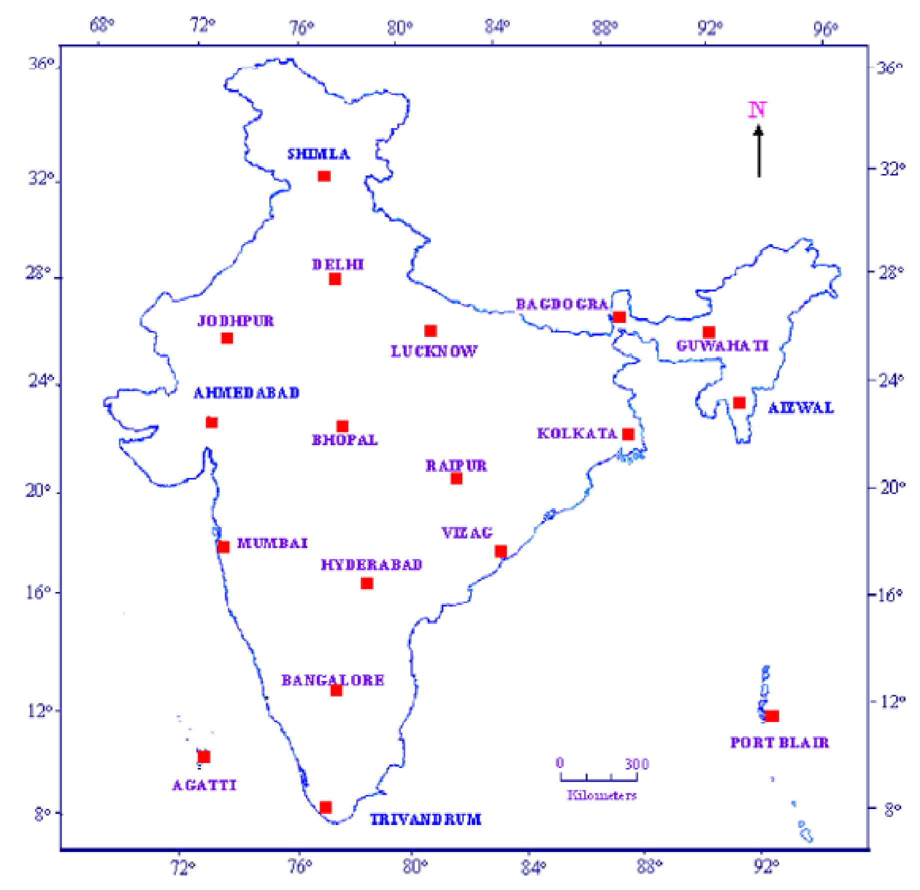

Fig. 8 GPS Receiver location for TEC in India