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

Shantanu Shahane, Manvi Dhawan, Tushar Jadhav
Team Pratham, IIT Bombay Student Satellite Program
Current Technologies

- Difficult to quantify amplitude and corresponding to earthquake, 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.

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

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

\[ \Delta \phi = 4.87 \times 10^4 f^{-2} \int_{h_1}^{h_2} NB \cos \theta \, dl \]

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

Knowing initial angle of polarization ($\phi_0$) is difficult

\[
\begin{align*}
\phi_1 - \phi_0 &= \theta_1 \\
\phi_2 - \phi_0 &= \theta_2 \\
\theta_2 - \theta_1 &= \phi_2 - \phi_1
\end{align*}
\]

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

$\phi_0$: initial phase angle of both waves transmitted by satellite,

$\phi_1$, $\phi_2$: 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

Fig. 6 Location of GS in India

Fig. 7 Student Satellite Society
THANK YOU
GPS Receiver locations for TEC in India

Fig. 8 GPS Receiver location for TEC in India