

Integrating GPS, strong motion and teleseismic data for tsunami early detection

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Introduction

The "GPS-aided Real-Time Earthquake And Tsunami (GREAT) Alert System", which utilizes coastal GPS data for estimation of submarine earthquake features and resulting tsunamis, has been set up and operated at JPL.

Advantages of GPS :

- ✓ Directly measure dynamic ground displacements at cm to mm level accuracy without saturation.
- ✓ Provide important constraints on the location and extent of the rupture plane, unambiguous resolution of the nodal plane

Limitations of GPS :

- ✓ Dense GPS network exists only in areas such as California and Japan
- ✓ Only part of the data is publicly available (see in Fig. 1)
- ✓ Earthquake signal decays very fast and can be beyond the detection ability of GPS

Research objectives:

To overcome the limitations of GPS by utilizing all available real-time data for rapid seismic source estimation and tsunami early warning.

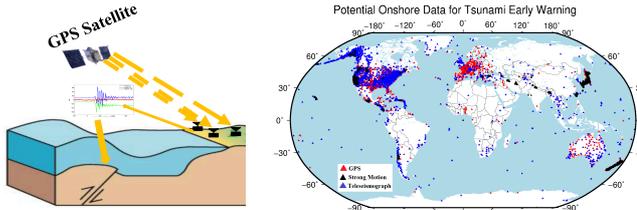


Fig. 1 : Illustration of GPS-based tsunami early warning at JPL (left) and distribution of publicly available GPS, strong motion and teleseismic data (right).

Data and Method

Strong motion data: accelerometers, low cost, high frequency (100-200 Hz), easy to install at key locations. More sensitive than GPS, but there is drift when integrating acceleration to displacements, which can be corrected by Kalman filter when collocated with GPS.

Teleseismic data: velocities, have the highest precision, designed to record motions at distant locations and globally distributed (see in Fig. 1). Most of the data are publicly available, but will saturate in near field.

Method: We have developed a strategy and an algorithm to integrate these three real-time data for rapid inversion of large earthquakes:

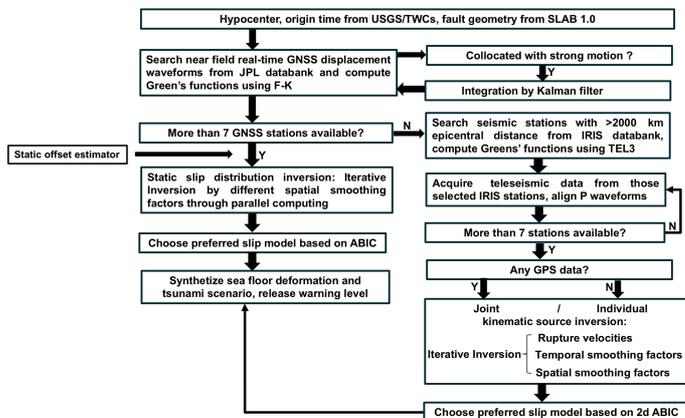


Fig. 2 : Diagram of earthquake source inversion and tsunami early warning using GPS, strong motion and teleseismic data.

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Results and Implications

Retrospective analysis of three historical events

Here we show three typical results by our method: the 2011 Tohoku tsunami with dense GPS network, the 2015 Illapel tsunami with sparse GPS network, and the 2016 Solomon tsunami without nearby GPS data (Fig.3).

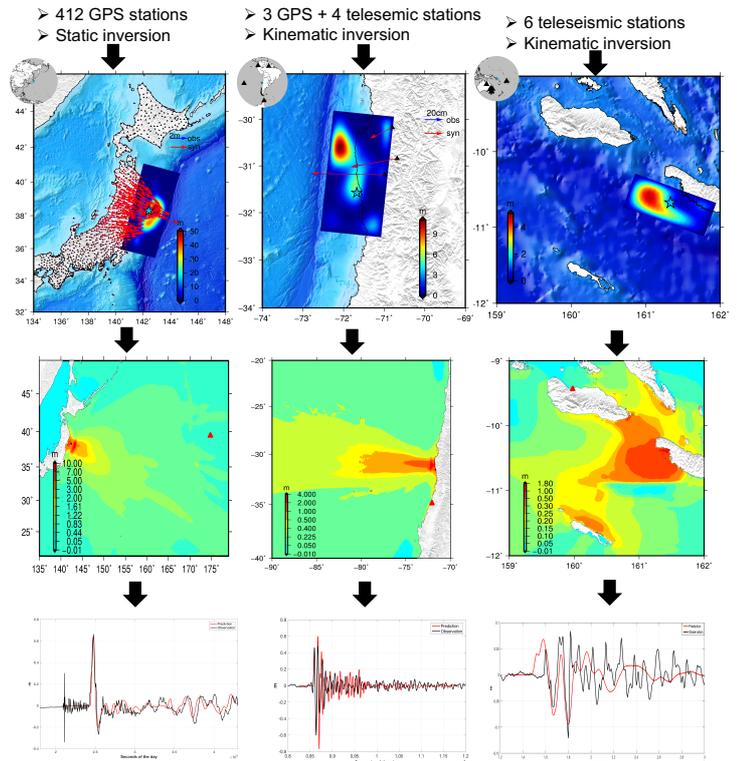


Fig. 3 : Slip distribution model (top), maximum tsunami wave amplitude (middle) and comparisons between predicted and recorded wave heights at selected tide gauges.

Improvement and future work

To show the improvement, we have analyzed all of Mw > 7.0 earthquakes (most are tsunamigenic subduction earthquakes) since 1990 by comparing the responding time (see in Fig. 4) for earthquake source inversion. As expected, near field GPS/strong motion data are not always available and may affect tsunami warning severely (left). By integrating with teleseismic data, the responding time can be reduce by a half (right). As an on-going project, we are testing and improving our algorithms for a more reliable tsunami early warning system.

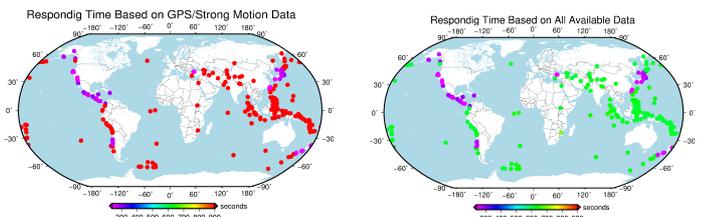


Fig.4 :Time needed for earthquake source inversion: (left) using GPS and strong motion data only, and (right) using all three data, for all Mw>7.0 earthquakes (color dots on the map) since 1990.