Real-Time PBO for Tsunami Early Warning along the Pacific Coast of North America

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The Pacific Coast of North America is exposed to potentially devastating tsunamis. Tsunamis originating from major earthquakes at the Cascadia subduction zone would result in very short warning times. Reliable tsunami early warning requires a rapid assessment of the tsunamigenic potential of an earthquake as well as a prediction of the likely propagation pattern of the tsunami. The tsunami potential of an earthquake depends on the displacement field of the ocean bottom and shelf areas (Figure 1). Low-latency availability of the coseismic Earth's surface displacements can support the assessment of the tsunamigenic potential of an earthquake and improve predictions of the propagation pattern of the tsunami.

Observational constraints for the estimation of the surface displacement field come from sufficiently dense GPS networks. The GPS network of the Plate Boundary Observatory (PBO) would allow for the low-latency estimation of the coseismic displacement field if a sufficient number of stations could be integrated in a real-time processing. Today, more than 100 GPS stations in the Western USA deliver observations in real time (Figure 2). These observations provide an excellent basis for rapid estimation of magnitude and displacement field.

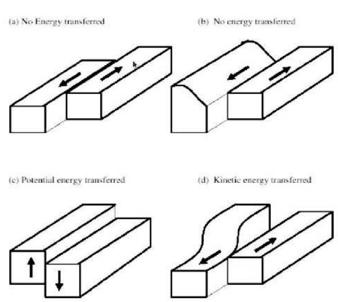

Figure 1: The tsunamigenic potential of an earthquake is determined by the potential and kinetic energy transferred to the ocean. Depending on the displacement field and the ocean bottom topography, an earthquake may transfer very little (upper cases) or large amounts of energy (lower cases).

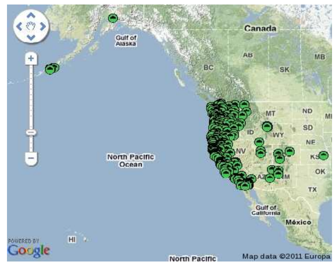

Figure 2: Data streams from more than 100 real-time PBO stations are today distributed using NTRIP. From http://pbo.unavco.org/-data/gps/realtime.

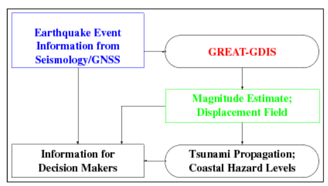

Figure 3: High-level architecture of a tsunami early warning system integrating GPS-determined displacements. For event detection, seismological observations are used, and the approximate epicenter location and time are provided to the component for the GPS-based magnitude and displacement field estimation (GREAT-GDIS). This component requires displacement time series from a sufficiently dense regional GPS network. The estimates of the magnitude and coseismic permanent displacement field for the ocean bottom are used in the prediction of tsunami amplitude and propagation pattern in support of the decision for which coastal areas to issue a tsunami warning.

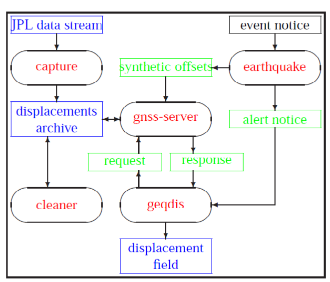

Figure 4: Architecture of the GPS-component of the GREAT alert system.

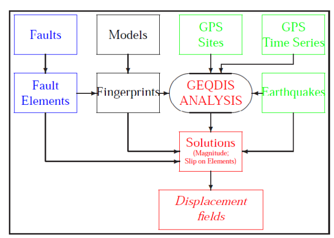

Figure 5: Structural elements of the Fingerprint analysis.

A fingerprint methodology for rapid determination of the displacement field: We have developed a fingerprint methodology for the rapid determination of the surface displacement field from GPS-determined displacements and implemented this into a prototype in the frame of the GREAT Alert System (Figure 3, Plag et al., 2010). The fingerprint methodology depends on a priori knowledge of the faults potentially involved in a rupture. The known faults are parametrized with standard elements and for each element so-called fingerprint functions are computed for unit strike and dip slips (Figure 4). After an event, the model space of all reasonable fault-element combinations is searched for the element-slip combination best fitting the observed displacements using GPS time series as observational constraints (Figure 5).

GPS-based rapid determination of displacement field can provide valuable constraints on the tsunami potential of an event: Application of the prototype to the recent large earthquakes demonstrates that the best estimate of the displacement field and earthquake magnitude consistent with observations provides a good estimate of the actual displacement field. The uncertainties in displacement field and magnitude estimates are a function of the GPS station network geometry. For the Pacific coasts of North America, the available real-time GPS network (Figure 2) holds the promise of effectively informing tsunami early warning with rapid accurate estimates of magnitude and displacement field. However, this would require the conversion of the BINEX data currently distributed by UNAVCO into displacement time series of sufficient quality.

References: Plag, H.-P., Blewitt, G., Hammond, W., Kreemer, C., Bar-Sever, Y., 2010. Rapid GPS-based determination of earthquake displacement field and magnitude for tsunami propagation modeling and warning. In *Proceedings of the 2010 IEEE International Geoscience and Remote Sensing Symposium,* IEEE, ISBN 978-1-4244-9564-1, pp. 3039-3042.