Rapid Determination of Earthquake Magnitude Using GPS for Tsunami Warning Systems

Geoffrey Blewitt[1], Corné Kreemer[1], William C. Hammond[1], Hans-Peter Plag[1], Seth Stein[2], and Emile Okal[2]

[1] Nevada Bureau of Mines and Geology, and Seismological Laboratory, University of Nevada, Reno, Nevada, USA.
[2] Department of Geological Sciences, Northwestern University, Evanston, Illinois, USA.

Abstract

The 26 December 2004 Sumatra earthquake (Mw 9.2-9.3) generated the most deadly tsunami in history. Yet within the first hour, the true danger of a major oceanwide tsunami was not indicated by seismic magnitude estimates, which were far too low (Mw 8.0-8.5). This problem relates to the inherent saturation of early seismic-wave methods. Here we show that the earthquake's true size and tsunami potential can be determined using Global Positioning System (GPS) data up to only 15 minutes after earthquake initiation, by tracking the mean displacement of the Earth's surface associated with the arrival of seismic waves. Within minutes, displacements of >10 mm are detectable as far away as India, consistent with results using weeks of data after the event. These displacements imply Mw 9.0 +/- 0.1, indicating a high tsunami potential.

Our results show greatly enhanced sensitivity to the magnitude of great earthquakes where the global IGS network is augmented by GPS stations in the near field, indicating the advantage of having real-time GPS networks near oceanic subduction zones. Fortunately many such networks exist, or are being planned, and so could be upgraded with real-time communications and incorporated into tsunami warning systems.

A key question we pose to this workshop is how such near-real time inversions from GPS for the earthquake source, hence the predicted vertical displacements of the ocean bottom, can be best implemented in future tsunami warning systems. Sensor networks for tsunami warning systems currently include seismometers and deep ocean pressure recorders that provide real-time data on earthquakes and resulting tsunamis to warning centers, which assess the possible threat and alert emergency managers who advise the public. The seismic data are important for the rapid detection and location of potentially significant events. GPS data could then be used to rapidly model the earthquake and thus initialize parameters for real-time modeling of tsunami generation. The tsunami models could then be validated and further constrained using ocean sensor data. Thus seismic, geodetic, and oceanic data could be truly integrated in tsunami warning systems.