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# Rapid Determination of Earthquake Magnitude using GPS for Tsunami Warning Systems

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Even far away from an earthquake epicenter, tsunami warning is a race against time. Within three hours after the great Sumatra-Andaman earthquake of 26 December 2004, a tsunami that crossed the ocean at the speed of a jet aircraft devastated the coasts of Thailand, Sri Lanka, and India. Because of this high speed, developing systems to provide timely warnings is a major challenge. Tsunami warning systems have several major components. Sensor networks including seismometers and deep ocean pressure recorders 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. Key initial information includes rapid estimates of the magnitude of an earthquake, which allow the assessment of the tsunamigenic potential of an event. For great earthquakes, initial seismic estimates of the magnitude tend to be too low thus severely underestimating the danger of an oceanwide tsunami. For example, for the Mw 9.2-9.3 Sumatra-Andaman earthquake, initial seismic magnitude estimates available within 15 minutes after the start of the earthquake were of the order of Mwp 8.0, thus incorrectly indicating that there was no danger of a major oceanwide tsunami. However, weeks of GPS data following the earthquake revealed that stations as far away as India were permanently displaced by more than 10 mm, indicating Mw 9.0-9.2. We show here that these static displacements, and hence the earthquake's true size and tsunami potential, could have been determined accurately using only 15 minutes of GPS data following the earthquake initiation. The rapidly estimated displacements agree to 7-mm RMS with estimates from longer GPS time series. These displacements constrain the rupture geometry and magnitude. Magnitude estimates based on

these near-real time displacements are $9.0 \pm 0.2$. This technique could be incorporated into tsunami warning systems via development of real-time GPS networks and analysis systems and would support the initial assessment of the tsunamigenic potential of particularly large events.