A208

Seismic dynamic and coseismic strains, distance decay rates, observation of major ruptures and propagation velocities of dynamic strain waves from high-rate GNSS with applications to the 2011 Tohoku Mw9.0 earthquake

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Abstract: Seismic dynamic strains with Global Navigation Satellite Systems (GNSS) were first observed at by Larson and collaborators in 2003. Little has been done since then to study the characteristics of seismic dynamic strains and their implications, with most work focused only on displacements. We investigate the seismic dynamic strains caused by the 2011 Tohoku Mw9.0 earthquake with GNSS precise point positioning (PPP) solutions. The major findings and results of this research are: (i) the biases of nonlinear dynamic strains are presented. High-rate GNSS can well reconstruct seismic dynamic and coseismic strains during the 2011 Tohoku Mw9.0 earthquake; (ii) the dynamic strain waves are of compressional nature and propagate concentrically from the epicenter of the earthquake at velocities between 3.44 and 4.04 km/s estimated with the first arrival times and between 3.29 and 3.73 km/s with the times of peak strains, respectively. The latter may be affected by different frequencies of strain waves; (iii) the dynamic strain waves from high-rate GNSS directly observe, at least five major ruptures and many smaller subevents in the source region of the earthquake; (iv) the largest values of dynamic strains in the East component, dilatations, the principal strains, maximum shears and total strains all occur between Miyagi and Niigata. The dynamic strains in the North component are also mainly compressional and the largest values occur at Tokyo Bay. Actually, Tokyo Bay has been subject to a long time of strains, which may explain severe housing and life line damage around Tokyo Bay; (v) while a large area between Miyagi and Niigata is subject to strong coseismic extension, the eastern part of Iwate and Tokyo Bay are subject to strong coseismic compression; and finally, (vi) the amplitudes of coseismic strains lead to an estimate of 3.12 to 3.76 for the decay rate, which is close to the theoretical value of 3.0. However, the near-field peak amplitudes of dynamic strains are shown to not fit the distance amplitude scaling law well, leading to a smaller decay rate and further implying that earthquake magnitudes could be significantly underestimated in earthquake early warning and disaster assessment with near-field dynamic data.

The full version of this talk has been submitted to Journal of Geodesy for publication (under review):

Xu, PL, Shibutani T, Shu Y, Y Shi (2026). Seismic dynamic and coseismic strains, distance decay rates, observation of major ruptures and propagation velocities of dynamic strain waves from high-rate GNSS with applications to the 2011 Tohoku Mw9.0 earthquake. Journal of Geodesy (under review).

The dynamic strain movies can be freely downloaded from Kyoto University Library: http://hdl.handle.net/2433/292151