Towards Using Dynamic Strain in Earthquake Source Characterization

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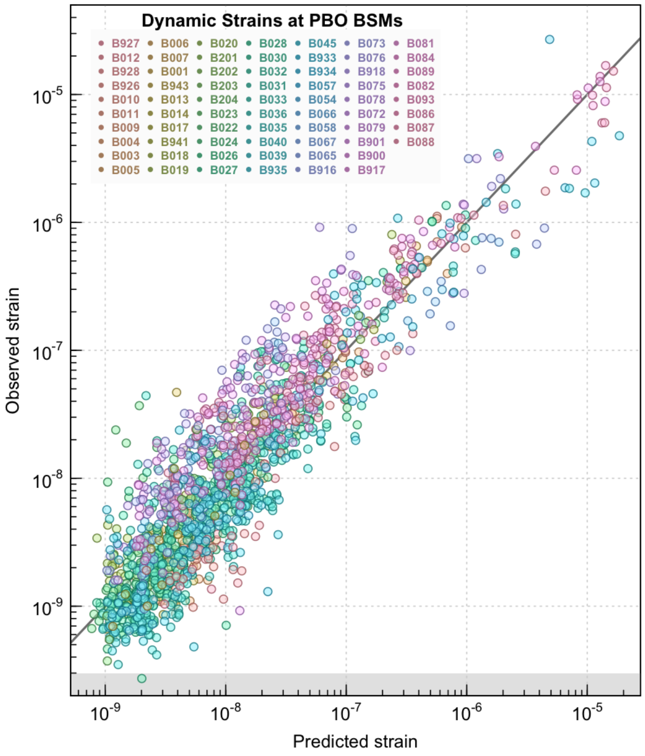
Measurements of static and dynamic deformation at the Earth's surface are fundamental signals used for characterizing earthquakes. In 'early warning' systems these signals are traditionally inferred from displacements on force-balance sensors (seismometers), and more recently with the inclusion of high-rate Global Navigation Satellite System sensors; however, direct strain measurements have yet to be considered.

The Plate Boundary Observatory (PBO) component of EarthScope operates 78 borehole strainmeters (BSMs) and 6 long-baseline laser strainmeters (LSMs) along the western United States and British Columbia. Including these PBO stations into current characterization efforts could significantly improve station density in regions with high seismic hazard. For example, 32 (41%) of the BSMs are located along the Cascadia subduction zone, where the probability of a **M**9 earthquake within 50 years might be as high as 15% and the probability of a smaller but still potentially damaging **M**8 event might be as high as 40% (Goldfinger, et al., 2012).

Here we examine high-frequency (1 Hz) strains from 180 earthquakes which occurred between from 2004 through 2012, recorded by 68 PBO BSM stations; these have magnitudes **M** ranging from 4.6 to 7.2, depths ranging from 12 to 32.7 km, and epicentral distances D ranging from 13 to 500 km. Coseismic strains seen at the BSMs may not be a reliable measure of static strain (Barbour, Agnew, and Wyatt, 2015), so we do not consider them here. But, peak dynamic strains seen at the BSMs, E, can be predicted from the magnitude of the earthquake and the logarithm of the epicentral distance between the earthquake and station, with high statistical confidence. Based on the root mean squared value of uncalibrated instrumental strains for all events, we find:



$$\log E \;=\; -7.78(0.14) \;-\; 2.65(0.04)\,\log D \;+\; 1.23(0.02)\,M,\quad 7.7\times10^{-10} < E_{predicted} < 1.8\times10^{-5}$$

with standard errors of the coefficients shown in parentheses. This yields a residual standard error of 2.16×10^{-9} ($dof = 1819,\ R^2 = 0.84,\ p < 2.2\times10^{-16}$) that can be reduced by either including calibration coefficients, or accounting for station effects in the regression. The figure above shows how the observed strains vary according to this scaling relationship; the points are colored by station name.

Agnew and Wyatt (2014) observe a similar magnitude-distance scaling relationship based on dynamic strain from the LSMs, indicating that in general strainmeters represent a viable source of data on ground deformation that could be complementary to existing seismo-geodetic techniques. With enhancements to telemetry robustness, accurate earthquake source parameters could be estimated in real time.