Improved Removal of Long-term and Seasonal Trends from PBO Borehole Strainmeter Data

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Abstract

The Plate Boundary Observatory borehole strainmeter (BSM) network in northern Cascadia is well-distributed to constrain the time-dependent slip distribution of slow slip events (SSE’s) on the subduction interface. Since 2007, four SSE’s have been recorded by up to six BSM’s. Each BSM produces two shear-strain time series containing transients of ten’s of nanostrain over three to 20 days, generally consistent with thrust displacement propagating along strike of the subducting slab at 30-40 km depth, simultaneously with large-scale tremor.

It has proven difficult, however, to process the BSM data so that the results may be used to constrain detailed models. The main challenges are calibration of the BSM data, removal of long-term borehole relaxation trends, and correction for seasonal signals.

Shear-strain transients from Cascadia SSE’s cannot be discerned without removing borehole relaxation trends of 10’s of microstrain per year. For many BSM’s, seasonal signals are at least as large as the strain transients from SSE’s. Roeloffs (JGR, 2010) showed that tidal calibration of some BSM’s requires improved tidal models; here the borehole relaxation trends and seasonal signals are addressed.

Although BSM’s exhibit random-walk noise at periods of several days or more, the borehole relaxation trend is recorded at high signal-to-noise ratio and can be modeled by fitting a linear trend plus a small nonlinear component, such as a fractional power of time. Seasonal variations are often common-mode signals similar on all four gauges, and can therefore be reduced even when modeling them is not possible.

Improved removal of long-term and seasonal trends preserves shear-strain offsets left by SSE’s, which helps answer two questions. First, do SSE’s represent pure thrust displacement, or instead oblique slip parallel to plate
motion? Second, do SSE’s stop near certain strainmeters, or are network
gaps simply missing continued propagation? Simple dislocation models
show that both questions require observing whether SSE’s leave permanent
strain offsets. For pure thrust slip, engineering shear strain in fault-
perpendicular and -parallel coordinates undergoes an excursion as the slip
front passes the BSM, but leaves no net offset, while oblique slip leaves
offsets of both shear strains. Engineering shear strain offsets are also caused
by edge effects if the slip front stops near the BSM. Combining these data
processing techniques with improved calibrations renders BSM data much
better able to constrain quantitative models.