The distribution of interseismic locking on the Cascadia Subduction Zone constrained by leveling, tide gauge, and GPS data

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Funding provided by USGS NEHRP
Objectives

• Infer the kinematic locking on the subduction interface from geodetic observations.

• Constrain the seismic hazard
  - Quantify the seismic moment accumulation rate
  - Identify the distribution and eastward limit of the locked zone

• Resolve along-strike variations in locking that might be tied to variations in frictional properties of the plate interface.

(Safer and Tobin, 2011)
Observations of Interseismic Deformation

- Uplift rates from spirit leveling
  - Observations span 1930-present.
  - Uplift referenced to eustatic sea level.
  - 1-σ uncertainties ~0.5 mm/yr.

(Burgette et al., JGR, 2009)
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- West from 20-km-depth slab contour (km)
  (Burgette et al., JGR, 2009)
Horizontal Observations of Interseismic Deformation

- Horizontal GPS Velocities from PBO data products and McCaffrey et al. (2007).
- Limited to stations with data for > 2 years
Horizontal Observations of Interseismic Deformation

Original Velocity Field

Rotation of Oregon Removed (pole of McCaffrey et al., 2007)
Horizontal Observations of Interseismic Deformation

Original Velocity Field  
Rotation of Oregon Removed  
(pole of McCaffrey et al., 2007)  
Compressional Strain Rate  
(nanostrain/yr)
Modeling Methodology

- Fixed parameters
  - Defined Convergence rate
    - JDF-OCR Euler pole for the southern end (Wells & Simpson, 2001).
    - JDF-NA Euler pole for the northern end (Mazzotti et al., 2003)
  - Plate geometry of McCrory et al. (2006).
  - Upper edge of locked zone begins at trench.
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- Backslip calculation (Savage, 1983).

- Free parameters
  - Depth of locking; Depth of transition zone.

- Optimization by grid search of parameter space
  - Step 1: Depths constrained along west-east leveling profiles (fit both uplift and strain).
  - Step 2: Optimize along-strike locking with entire dataset.
- Combined inversion (uplift and strain)
- Data misfit weighted by data uncertainties
Misfit for combined Leveling & Horizontal Strain

Slip Rate
Deficit (cm/yr)

Depth of locked zone (km)

Depth of transition zone (km)

Misfit ($\chi^2$)

1 3 5 7 9 11

1 3 5 15 25 35
The diagram illustrates the relationship between the depth of the locked zone and the depth of the transition zone, with a misfit ($\chi^2$) scale below. The map on the right shows the slip rate deficit (cm/yr) across different regions, including Oregon and California. The color bar indicates the slip rate deficit, ranging from 0 to 4 cm/yr.
Summary

• A Cascadia locking model constrained by leveling and horizontal strain rates from GPS.

• Wide locked zone in WA and CA; Narrow in OR.

• $M_o$ Accumulation Rate: $0.9-1.4 \times 10^{22}$ Nm/century

• $M_w$ Accumulation Rate: 8.5-8.7 per century

• Leveling data consistent with segment boundary offshore OR, although not uniquely resolved.