ERTH 491-01 / GEOP 572-02
Geodetic Methods

– Lecture 23 (finish): Modeling - Plate Kinematics –

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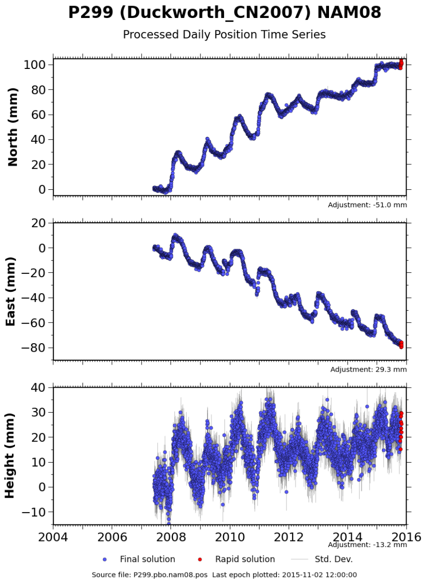
November 09, 2015

Guess The Process



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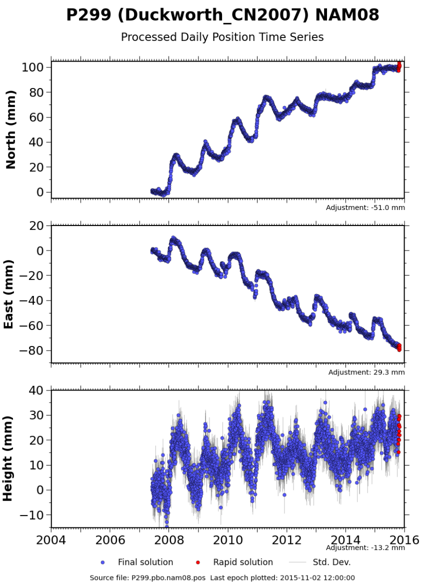
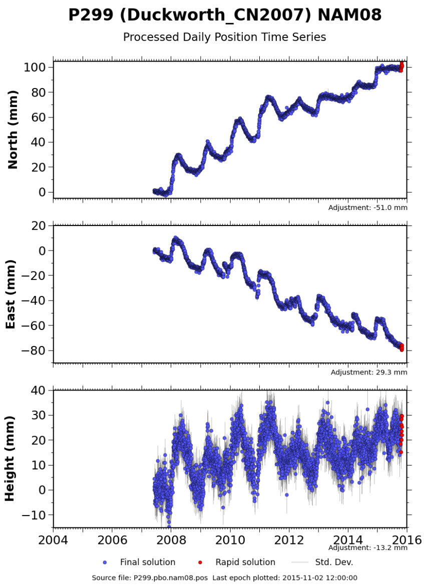
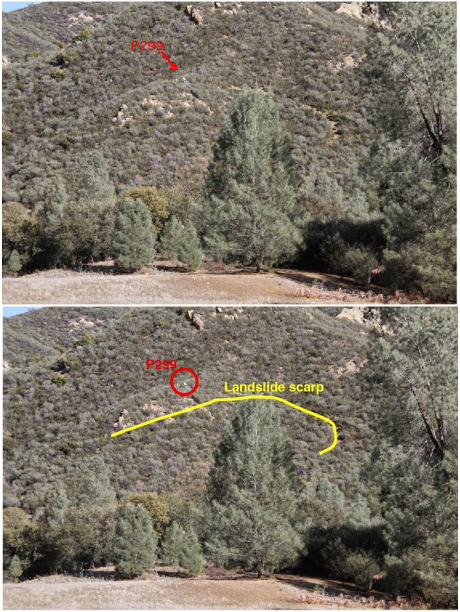


Guess The Process





UNAVCO

Guess The Process

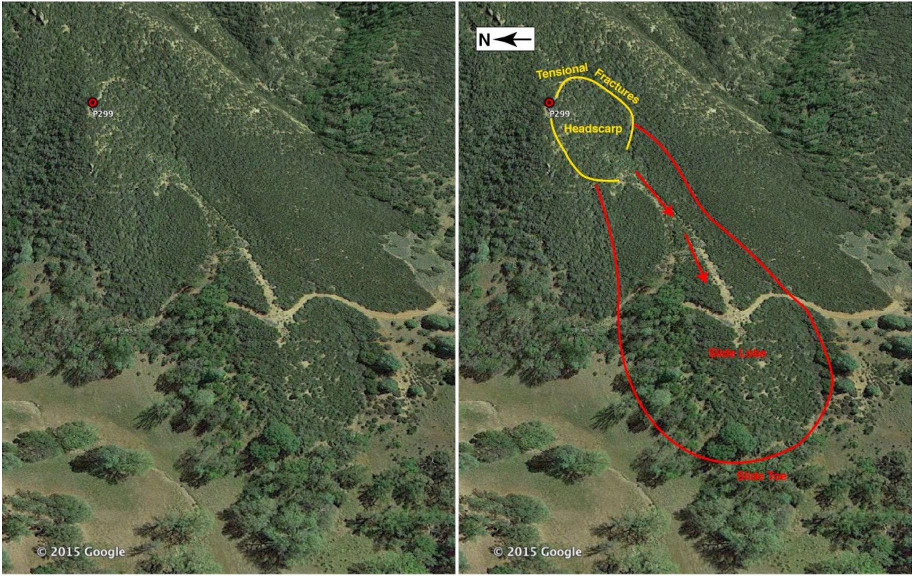


Figure 3. GoogleEarth view of P299 and landslide. The slide originates in the small bowl to the south of P299 and flow downhill into a lobe at the base. Original image (left) has been annotated to show extent of slide (right).

UNAVCO

Plate Fixed Reference Frames

- Velocities with respect to "PLATE-NAME"
- very convenient for visualization purposes and modeling of tectonic deformation
- To convert into plate-fixed frame we need plate motion and velocities in the same geodetic frame (e.g., ITRF2008)
- Transformation:

Plate Fixed Reference Frames

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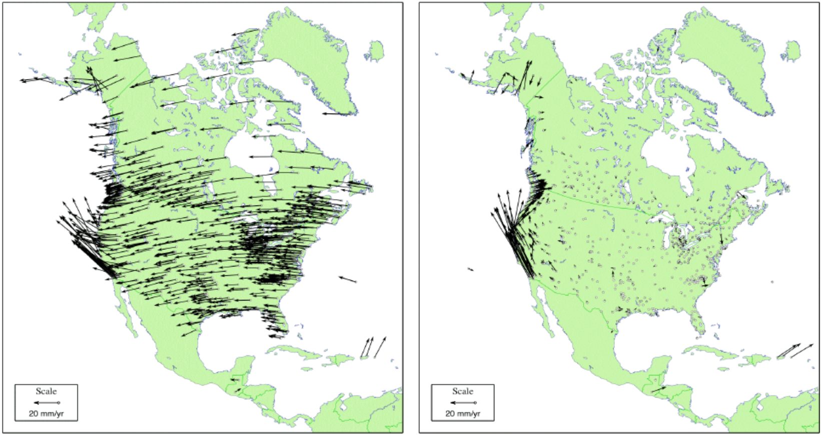
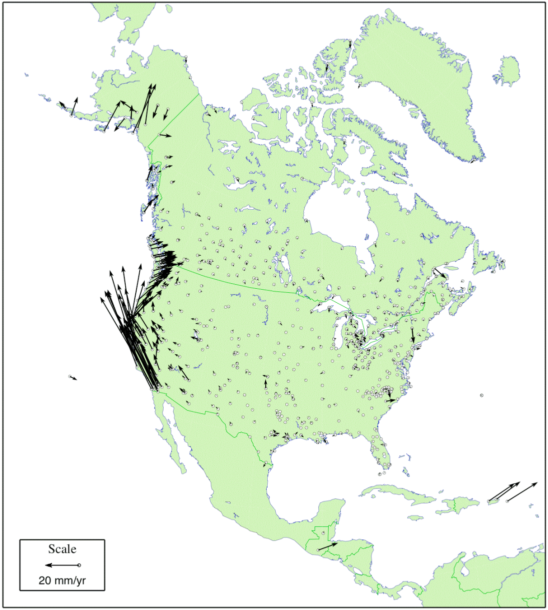
- very convenient for visualization purposes and modeling of tectonic deformation
- To convert into plate-fixed frame we need plate motion and velocities in the same geodetic frame (e.g., ITRF2008)
- Transformation: subtract predicted motion based on plate angular velocity from observed velocity

Reference Frames – ITRF vs. fixed (stable North America)



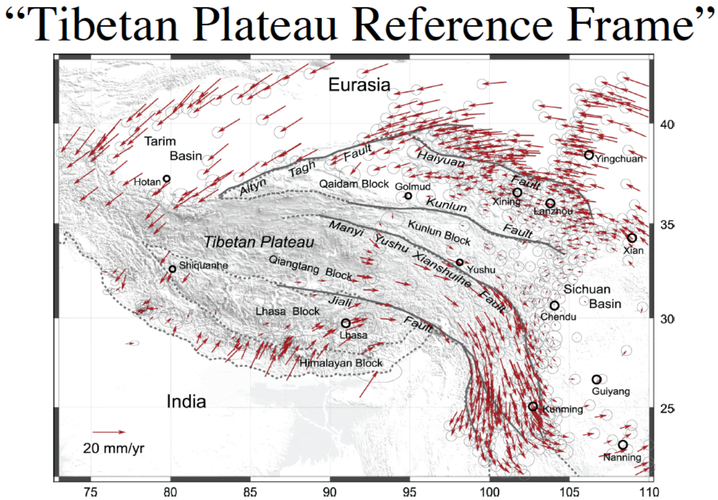
courtesy: Jeff Freymueller, UAF

Reference Frames – stable North America



- extension across Basin and Range
- Shear on San Andreas System
- Subduction strain in Cascadia, Alaska
- et al.

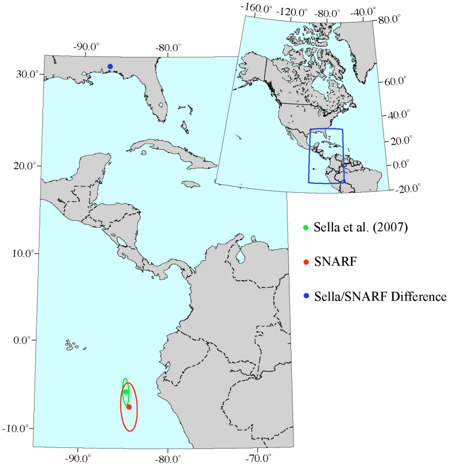
Reference Frames – Tibet



Gan et al. (2007) explained these motions in terms of a series of blocks separated by mostly strike-slip faults ➔ plateau is deforming, but not changing area.

courtesy: Jeff Freymueller, UAF

NOAM Poles



courtesy: Jeff Freymueller, UAF

- past studies: common that NOAM poles not within each others' confidence ellipses
- Difference between SNARF and Sella et al. (2007) is rotation about pole in SE US.

Why is NOAM Pole poorly determined?

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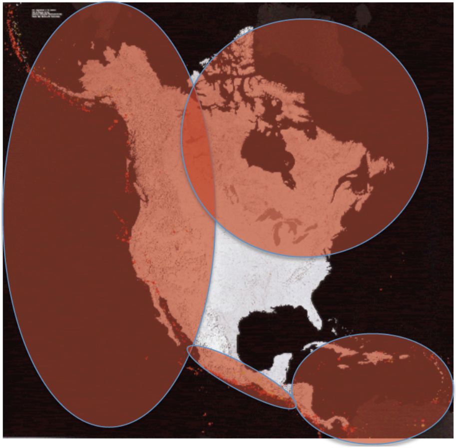
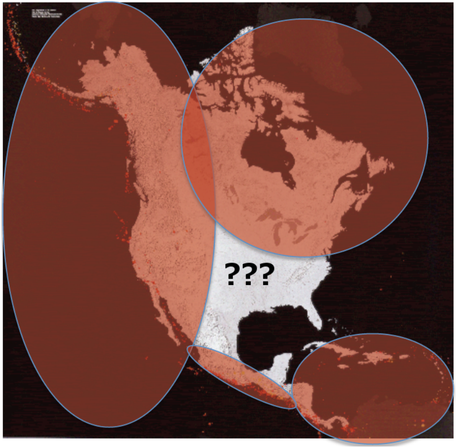


courtesy: Jeff Freymueller, UAF

Why is NOAM Pole poorly determined?



courtesy: Jeff Freymueller, UAF

- tectonics in western North America
- glacial isostatic adjustment in northern North America
- SE is thought to be stable on geologic and geodetic time scales
- limited area to determine plate angular velocity, susceptible to bias

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– Lecture 24: Modeling - Faults and Slip –

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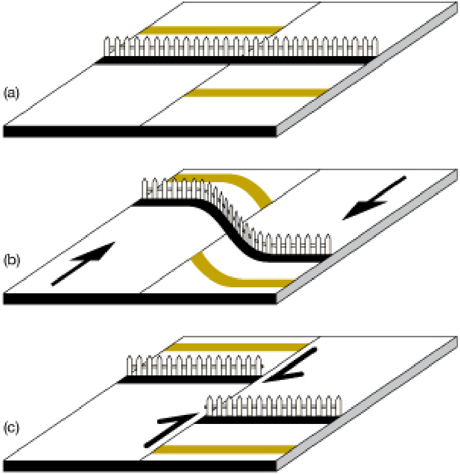
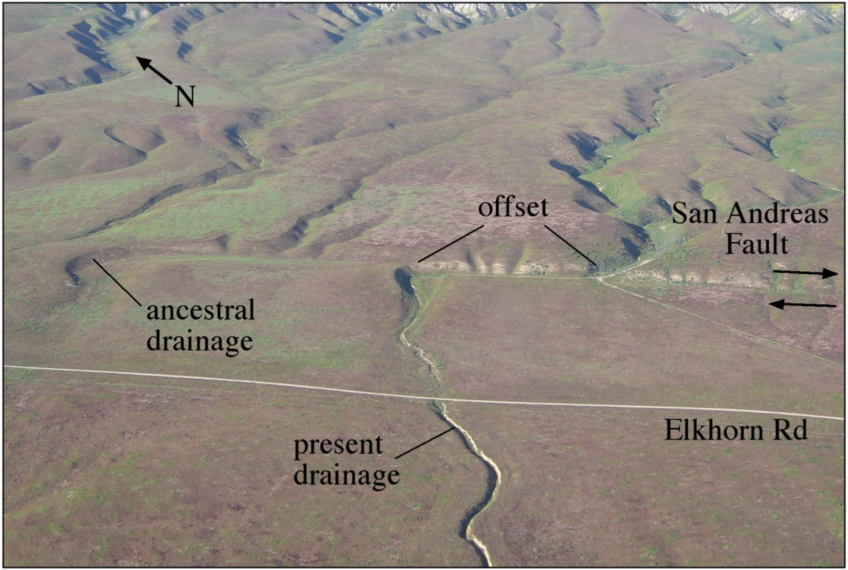
The Elastic Rebound Model



IRIS

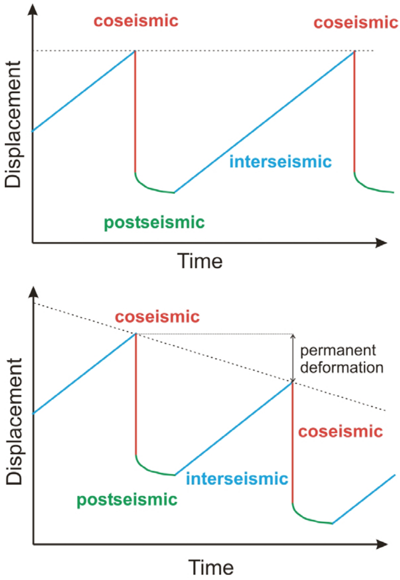
- Between earthquakes: steady motion on the fault
- Loads fault, strain accumulates in vicinity of fault
- During earthquakes: fault breaks, strain is released and fault vicinity catches up with far field motion
- Elastic system: interseismic strain accumulation is opposite of co-seimic strain release - no net straining.

Wallace Creek



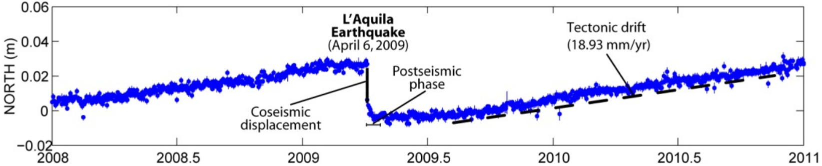
~ 100 yards

The deformation cycle



- Interseismic: constant velocity at given site - linear displacements
- Co-seismic: Step in timeseries controlled by magnitude, locking depth and distance of seismic rupture
- Post-seismic: afterslip, visco-elastic relaxation, poroelasticity; decay related to mechanism and lithospheric rheology

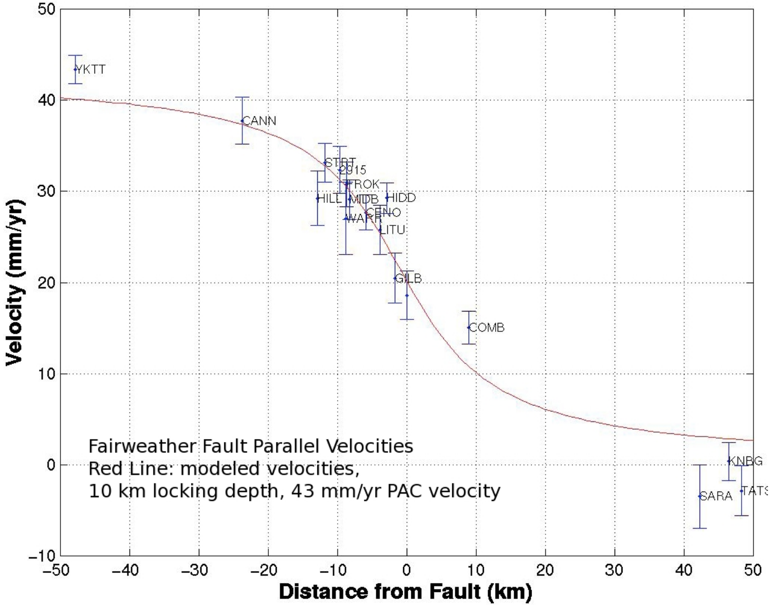
The deformation cycle



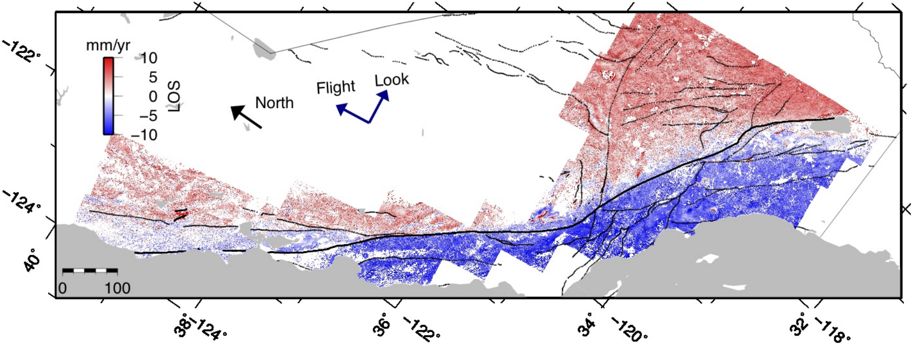
Roberto Devoti, INGV

- Earthquake: sudden slip on fault
- M_w 4-5: a few centimeters average slip on fault
- M_w 7: a few meters average slip on fault
- M_w 9: 10-20+ meters average slip on fault
- L'Aquila earthquake: M_w 5.9 - displacements depend on distance, magnitude, fault geometry

Deformation cycle: Interseismic (Fairweather Fault)



The deformation cycle: Interseismic



Tong et al, 2013, JGR

Co-Seismic: The 2002 M_w=7.9 Denali Earthquake

courtesy: *USGS*

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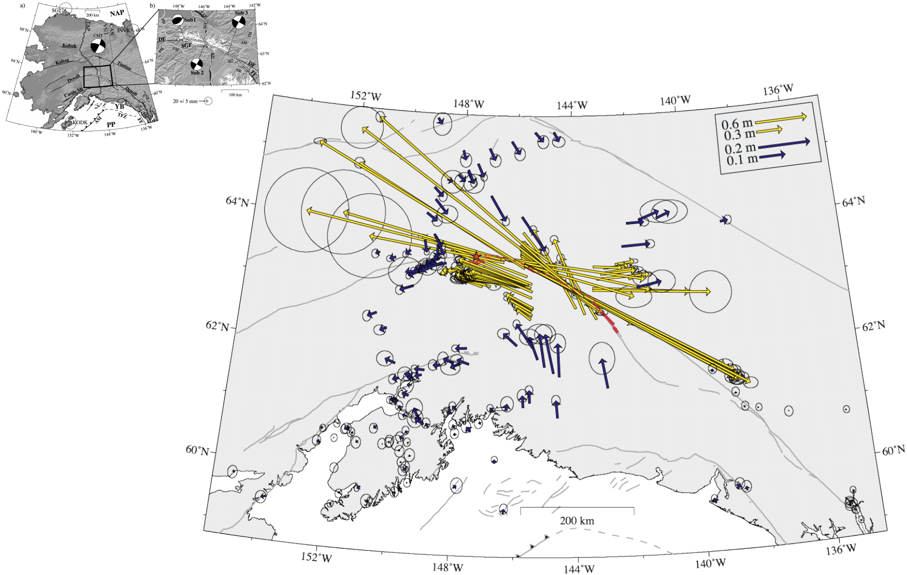
courtesy: *David Schwartz, USGS*

Co-Seismic: The 2002 M_W=7.9 Denali Earthquake



Hreinsdóttir et al., JGR, 2006

Co-Seismic: The 2002 M_w=7.9 Denali Earthquake

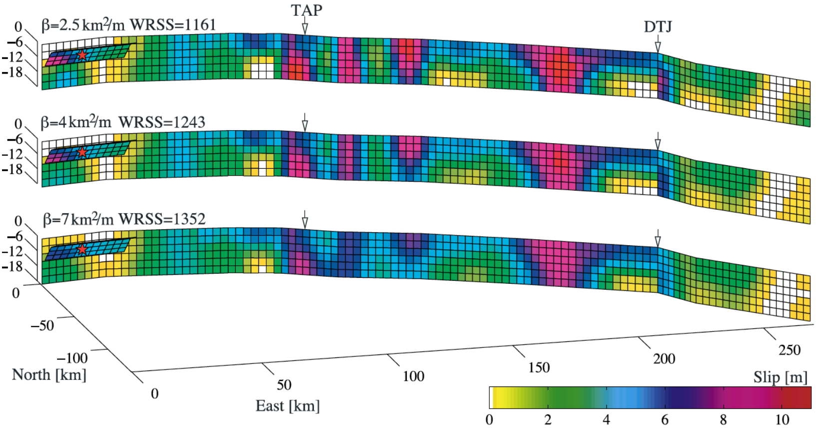


Figure 10. Range of reasonable coseismic slip models from the roughest (β = 2.5 km^2/m) to the smoothest (β = 7 km^2/m). The axes show easting, northing, and depth in km. TAP, Trans-Alaska pipeline; DTJ, Denali-Totschunda fault junction. Red star indicates the Denali Fault earthquake epicenter.

Hreinsdóttir et al., JGR, 2006

The deformation Cycle: Post-seismic

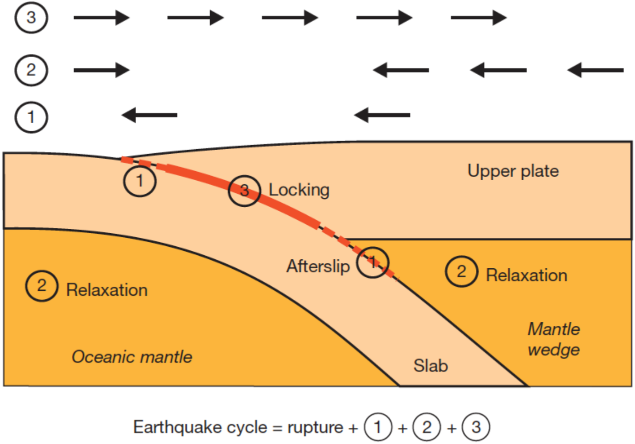


Figure 2 | Three primary processes after a subduction earthquake. (1) Aseismic afterslip occurs mostly around the rupture zone, (2) the coseismically stressed mantle undergoes viscoelastic relaxation, and (3) the fault is relocked. Arrows at the top show the sense of horizontal motion of Earth's surface, relative to distant parts of the upper plate, caused by each of these three processes.

Wang et al., 2012, Nature

The deformation Cycle: Post-seismic

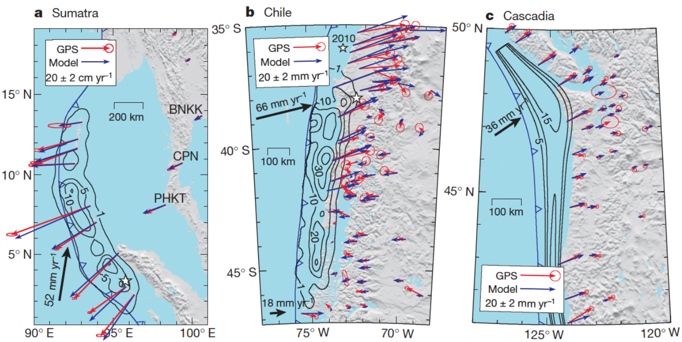
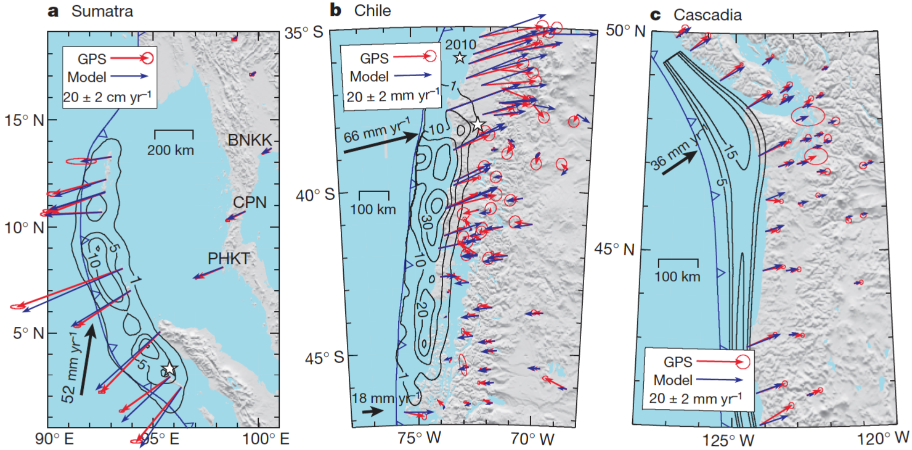


Figure 3 | GPS- (red) and model-predicted (blue) surface velocities for three subduction zones that are at different stages of the earthquake cycle. **a**, At Sumatra, one year after the $M_w = 9.2$ earthquake of 2004 (refs 20 and 21) (epicentre shown by star), all sites move seaward. Shown are ~1-year average GPS velocities. More recent data show the same pattern[22]. Coseismic fault slip (contoured in metres) is based on ref. 56. Longer (~3-years) time series from the three labelled far-field sites (BNKK, CPN, PHKT)[32] helped constrain afterslip and transient rheology (ref. 48). **b**, At Chile, four decades after the $M_w = 9.5$ earthquake of 1960, coastal and inland sites show opposing motion. Coseismic slip is from ref. 14. For sources of GPS data, see ref. 17. The northernmost areas show wholesale landward motion before the 2010 $M_w = 8.8$ Maule earthquake. **c**, At Cascadia, three centuries after the $M_w \approx 9$ earthquake of 1700, all sites move landward. The model is an updated version of ref. 8. A more comprehensive GPS compilation shows a similar deformation pattern[16].

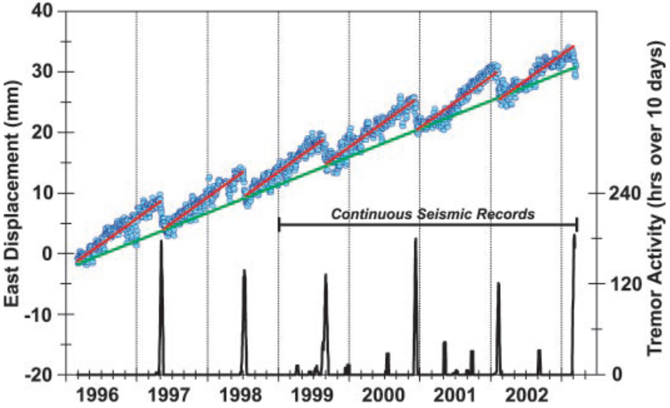
Wang et al., 2012, Nature

The deformation Cycle: Post-seismic



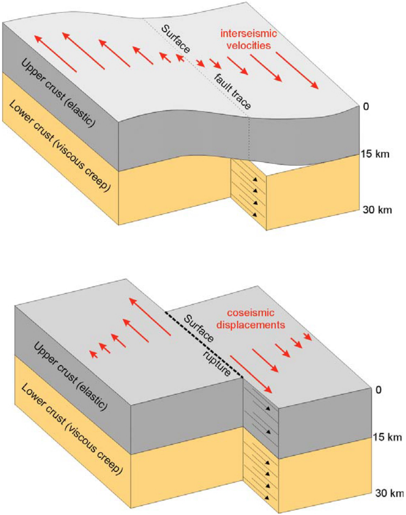
Wang et al., 2012, Nature

The deformation Cycle – Slow Slip



Rogers & Dragert 2003, Science

Physics of Faults

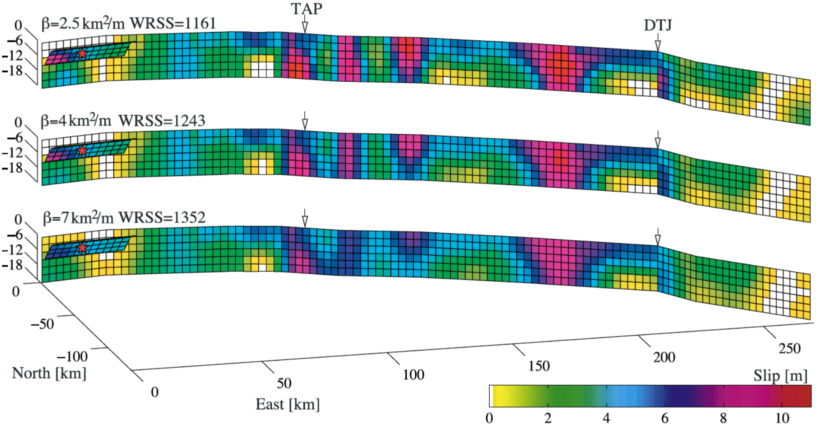


Eric Calais

- stick-slip sliding (seismic)
  - 2 sides of interface stuck together: friction
  - slip occurs when friction is overcome
  - slip controlled by dynamic friction, healing
- stable sliding (aseismic):
  - 2 sides slide continuously past each other
  - slip occurs all the time
  - slip controlled by plastic, ductile or viscous yielding
- transient slip also occurs (slow slip events)

Geodetic data → Slip on a Fault

How to get this?



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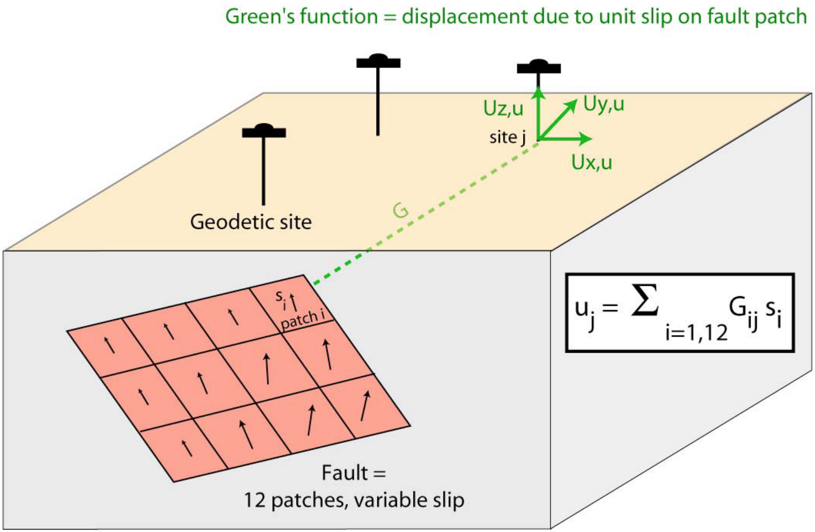

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