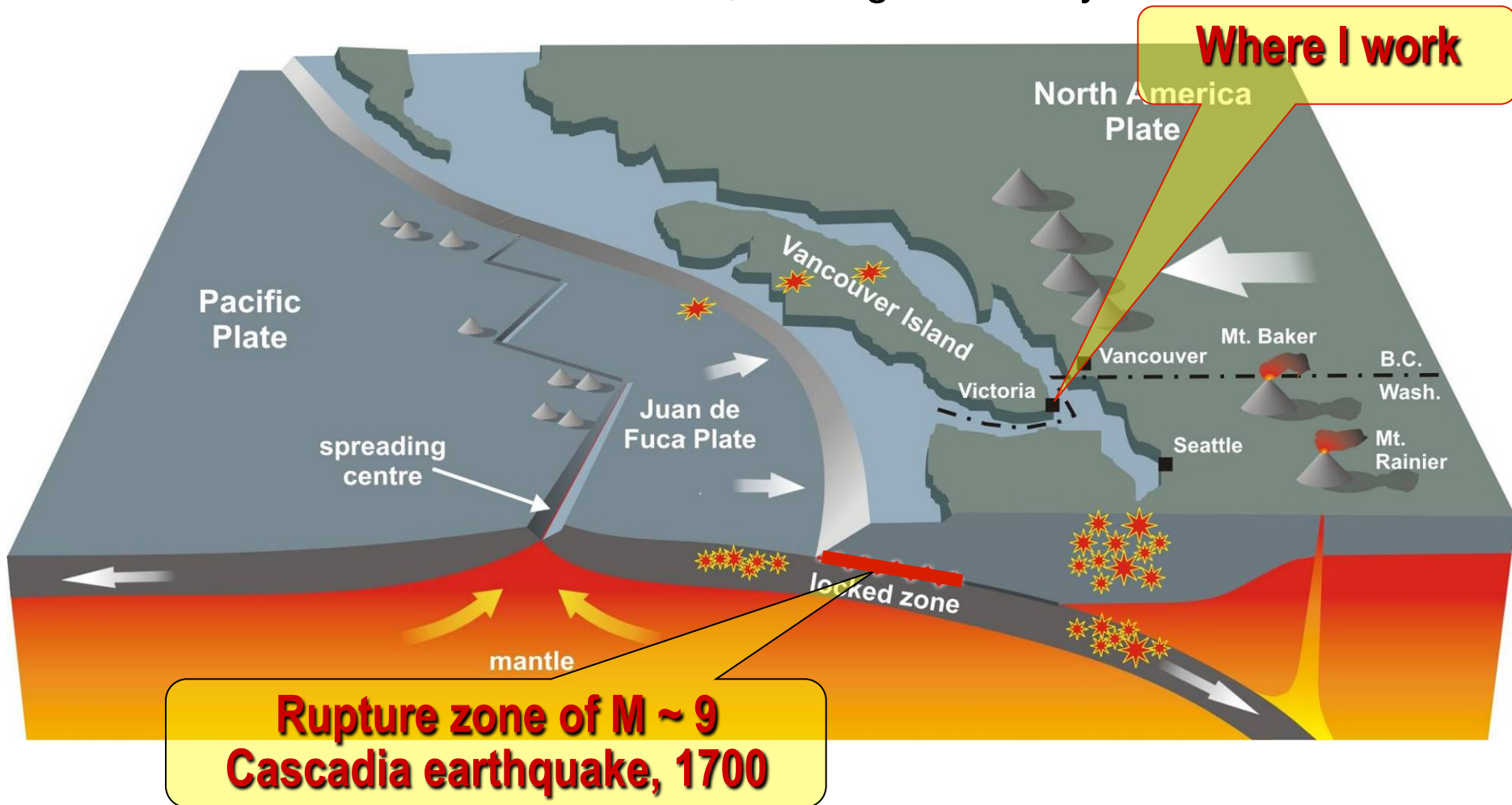


Great Subduction Earthquakes Along the West Coast of North America: Past, Present, and Future

Kelin Wang

Pacific Geoscience Centre, Geological Survey of Canada



Great Subduction Earthquakes Along the West Coast of North America: Past, Present, and Future

1. Great Cascadia earthquakes in the past
2. Monitoring the Cascadia megathrust fault at present
3. New scientific challenges for the future
 - Episodic Tremor and Slip
 - Tsunami hazard
 - What controls earthquake size

Great Earthquakes in the Past



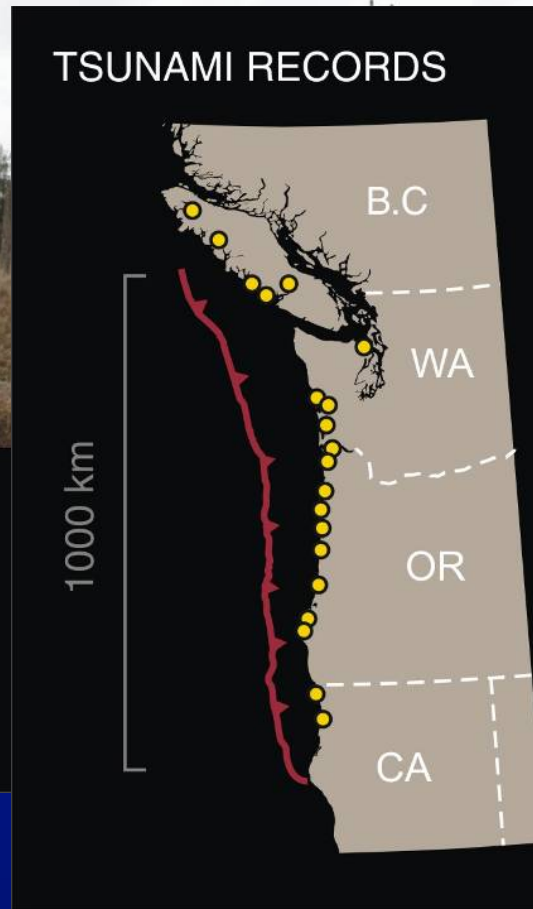
Great Earthquakes Recorded in Coastal Geology



LAND LOWERED SUDDENLY



TSUNAMI RECORDS

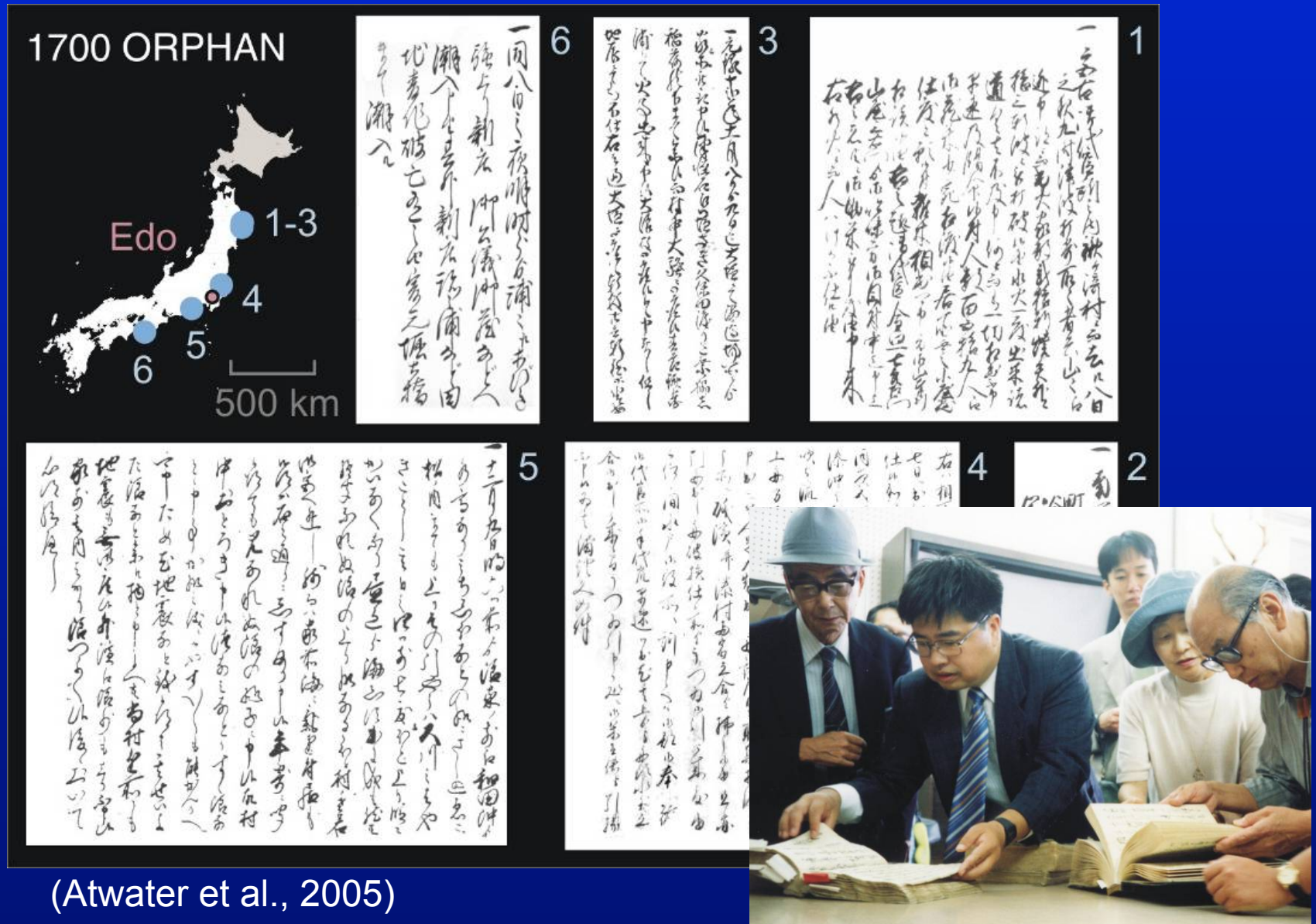


Salmon River, OR

Sand sheet 1680-1720

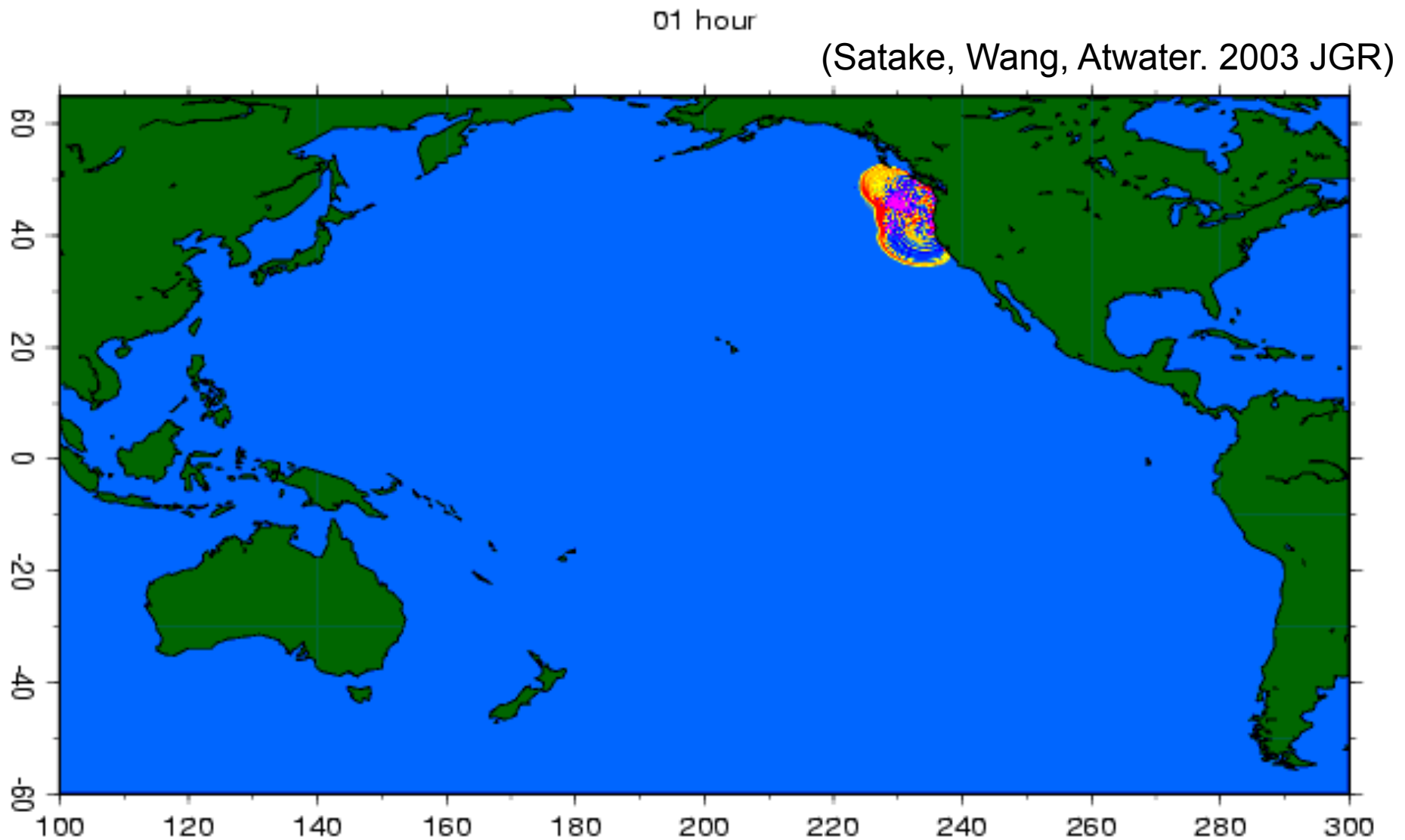
From Brian Atwater

Great Cascadia Earthquake of Jan. 26, 1700, Recorded in Japan

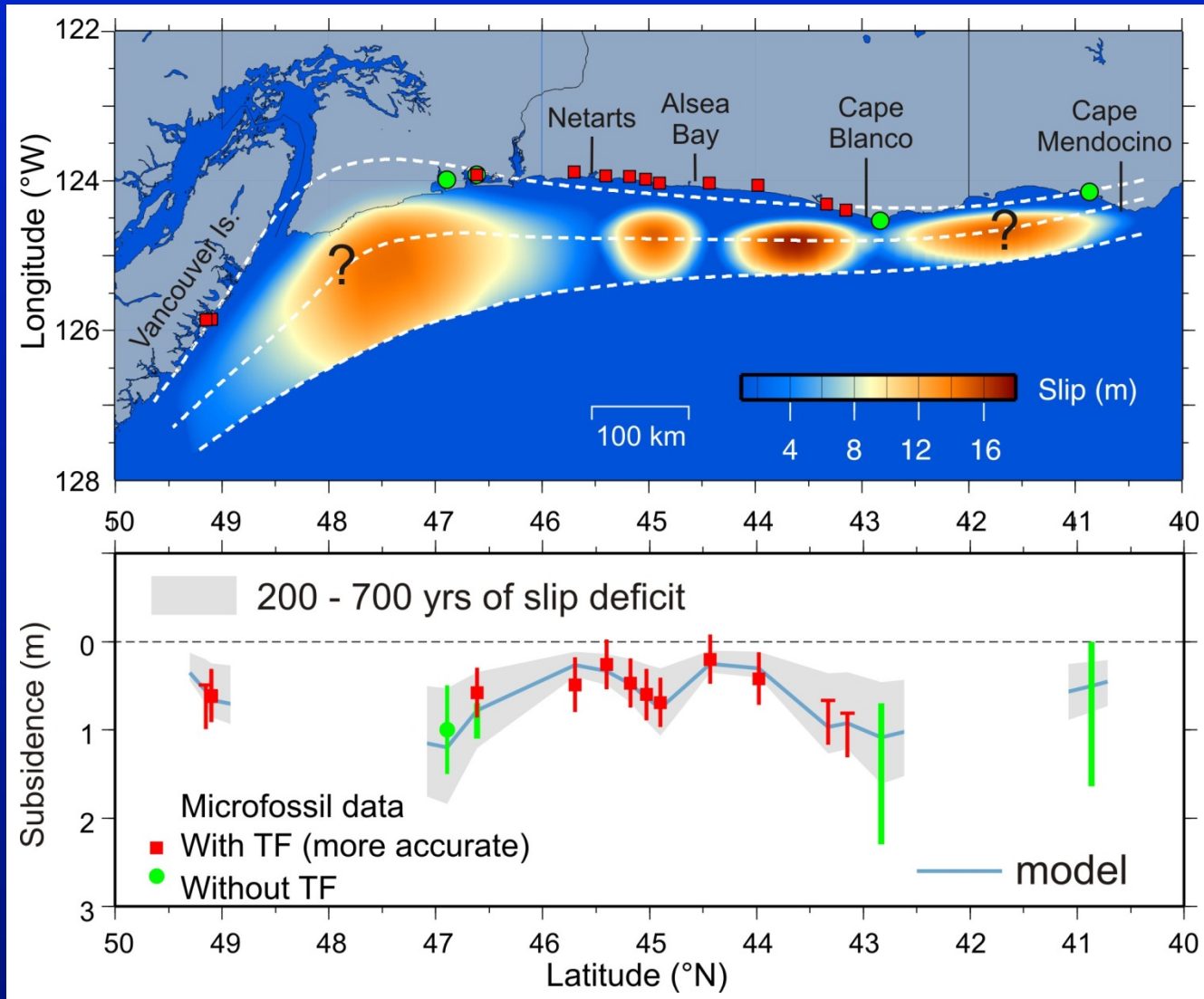


(Atwater et al., 2005)

Great Cascadia Earthquake of Jan. 26, 1700, Recorded in Japan

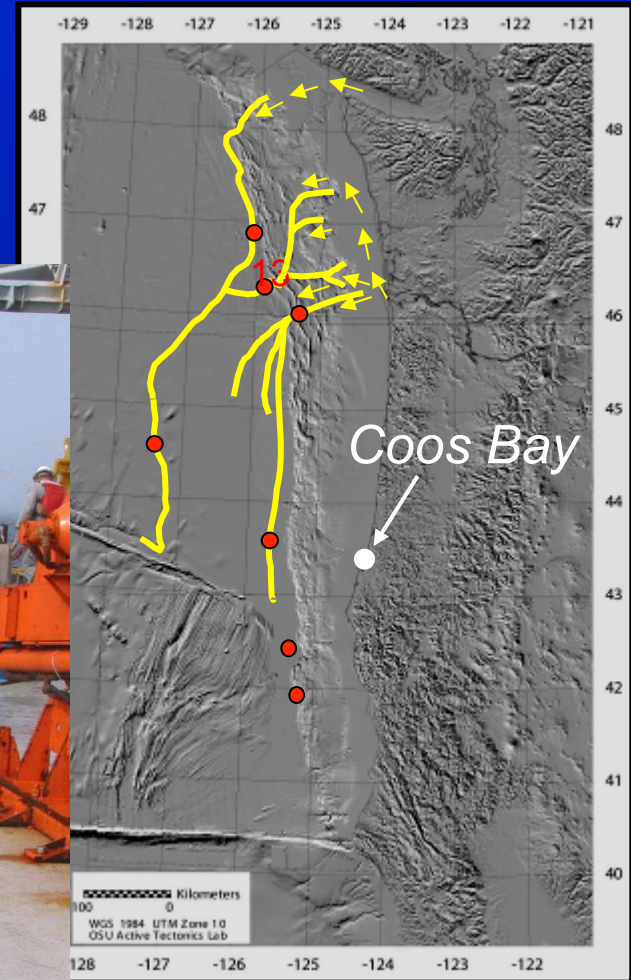
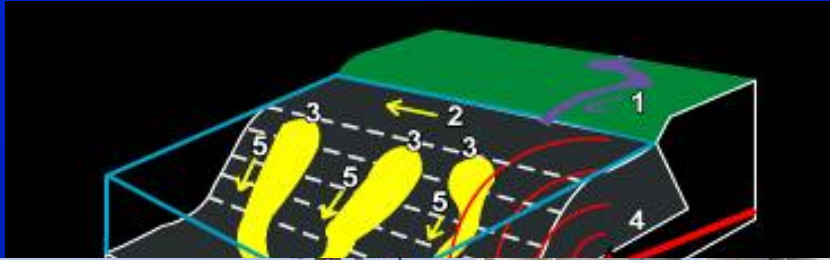


Better definition of 1700 rupture using microfossils



(Wang et al., 2013 JGR)

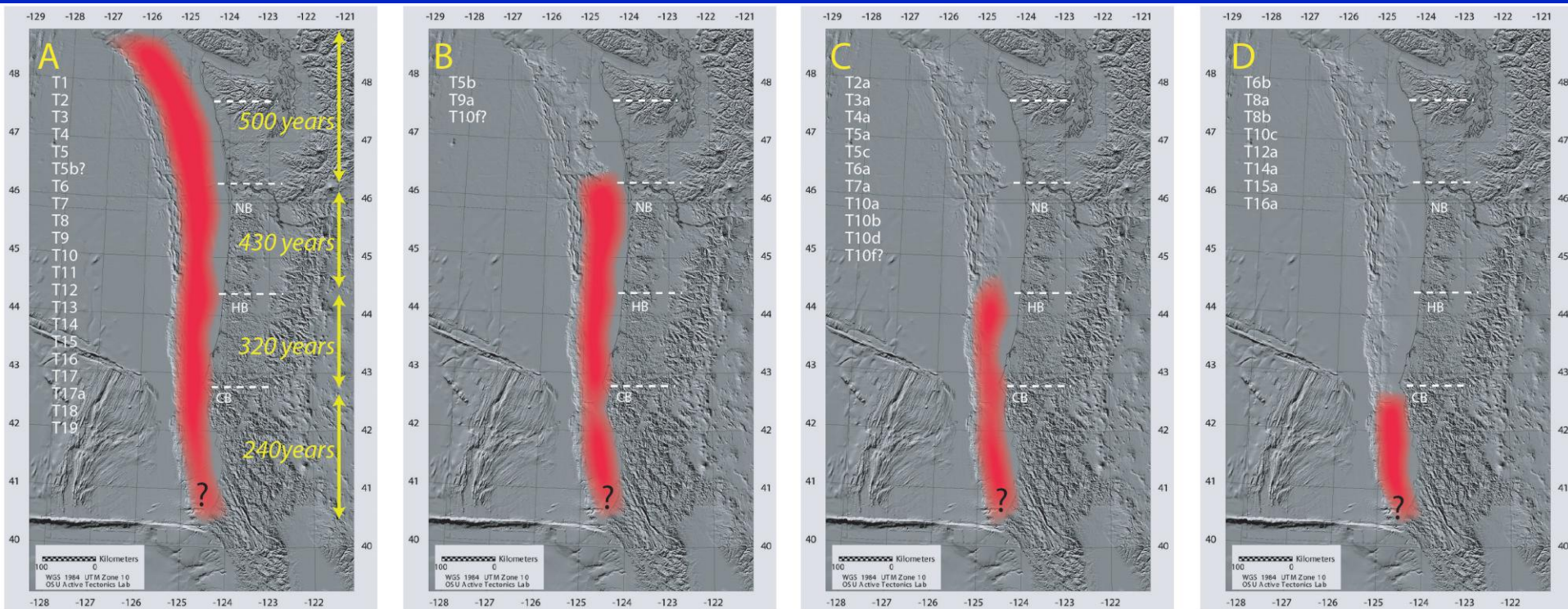
Great Earthquakes Recorded in Seafloor Sand Deposits



(Goldfinger et al., 2005)

Great Cascadia Earthquakes Recorded in Turbidite Deposits

~ 42 earthquakes over the last 10,000 years



M 8.8-9.2
~ 500 years

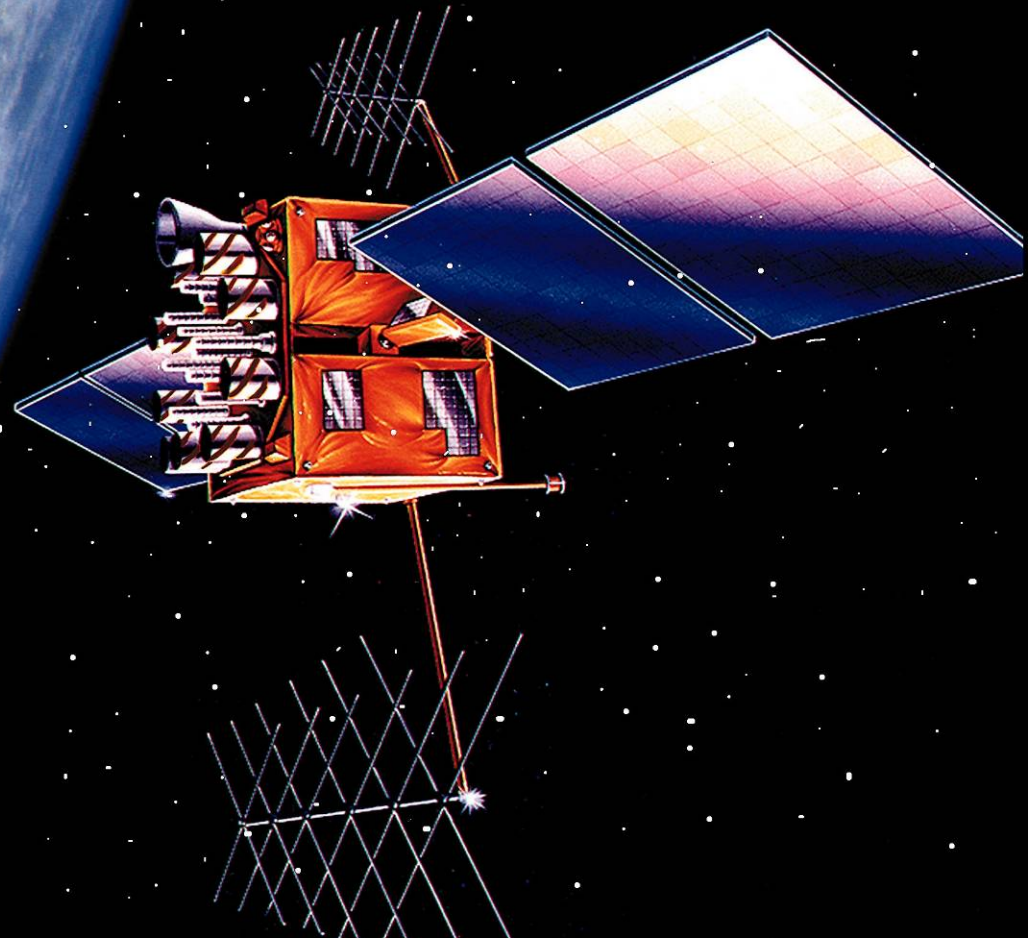
M 8.5-8.8
~ 430 years

M 8.3-8.5
~ 320 years

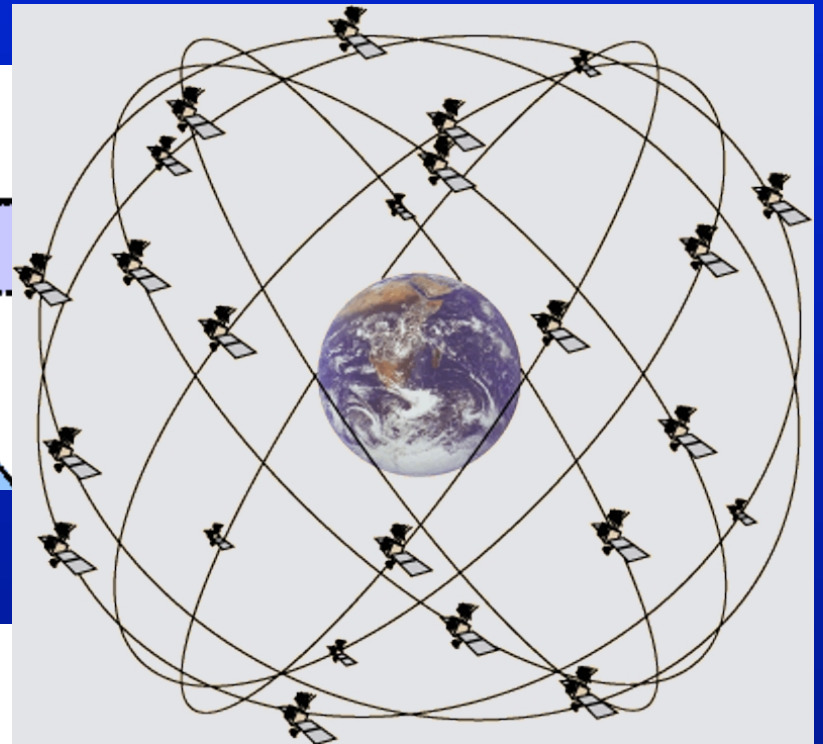
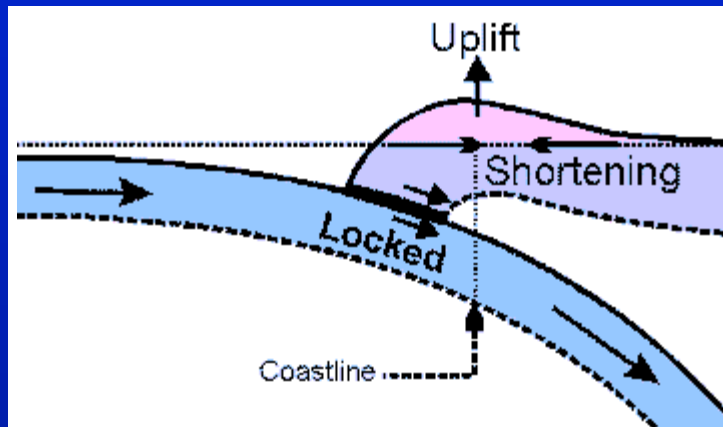
M 7.6-8.4
~ 240 years

(Goldfinger et al., 2012)

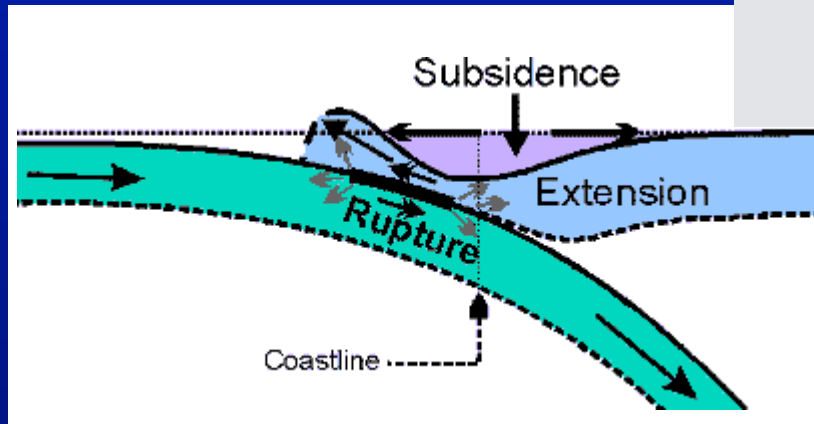
Monitoring the Cascadia Megathrust Fault



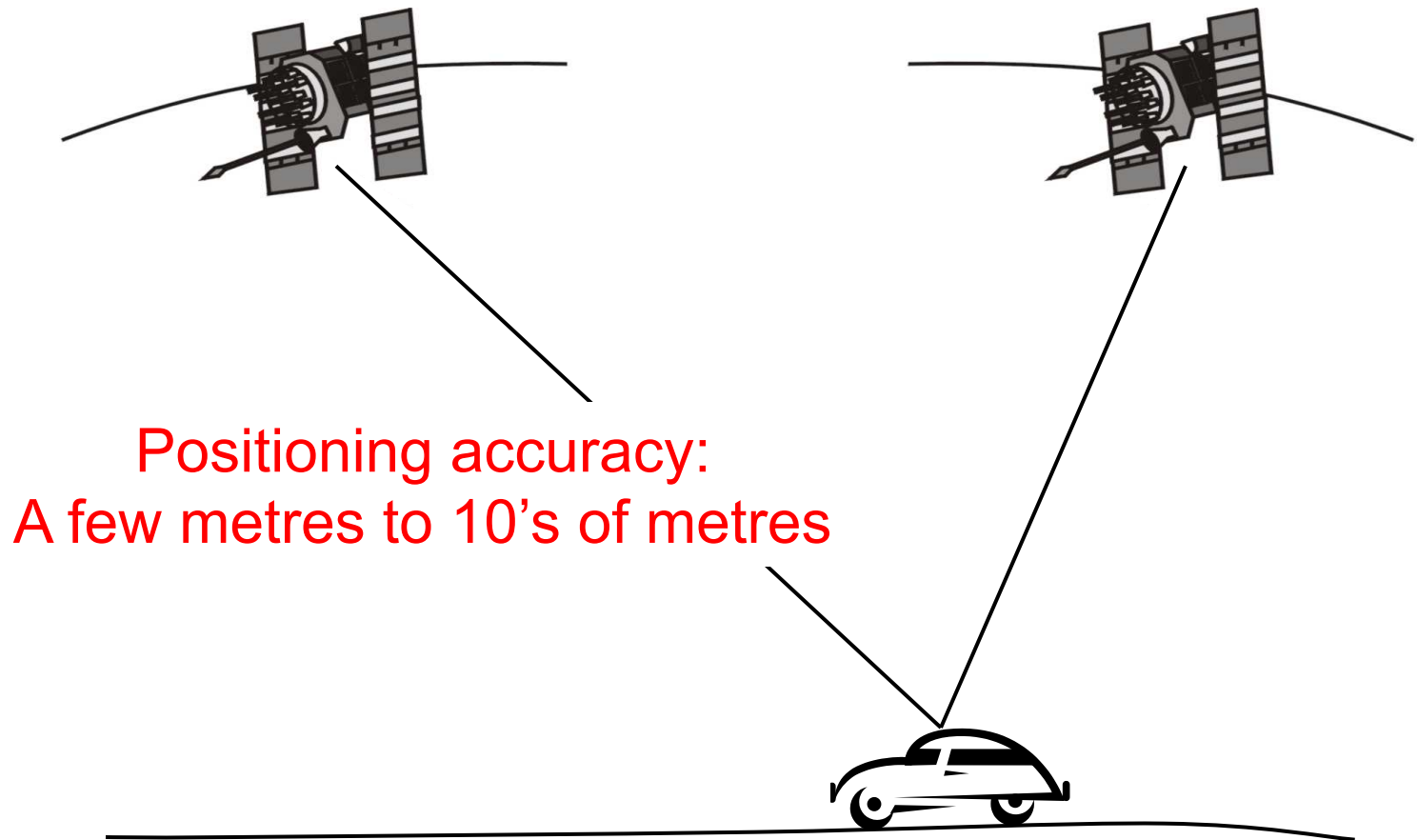
Between Earthquakes



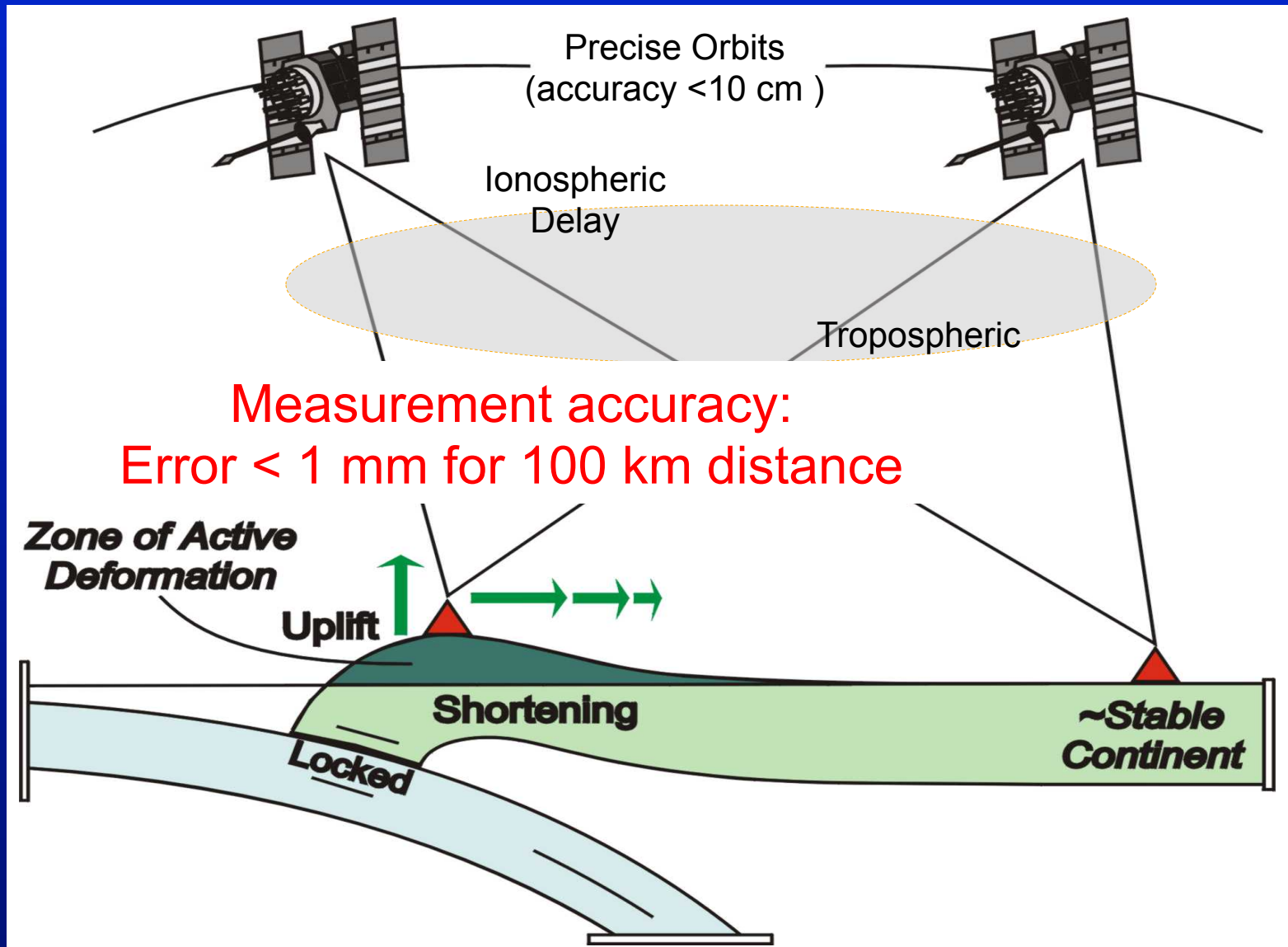
Earthquake



Using GPS to Position Yourself



Using GPS to Determine Distance and Crustal Motion



Continuous GPS Stations in 1994: Western Canada Deformation Array (WVDA) in operation



Image NASA
Image © 2008 DigitalGlobe
Image © 2008 TerraMetrics
Image State of Oregon

© 2005 Google

Continuous GPS Stations in 2008:

U.S. Plate Boundary
Observatory (PBO)
and Western Canada
Deformation Array
(WCDA)

There are also numerous temporary
stations (campaign sites).



Image NASA
Image © 2008 DigitalGlobe
Image © 2008 TerraMetrics
Image State of Oregon

© 2005 Google

What has GPS told us so far?

1. The megathrust fault is fully locked and is accumulating energy for the next great earthquake
2. Pacific Northwest is deforming also for other reasons (leading to other types of earthquakes)
3. Parts of the megathrust fault downdip of the locked zone slips silently and episodically

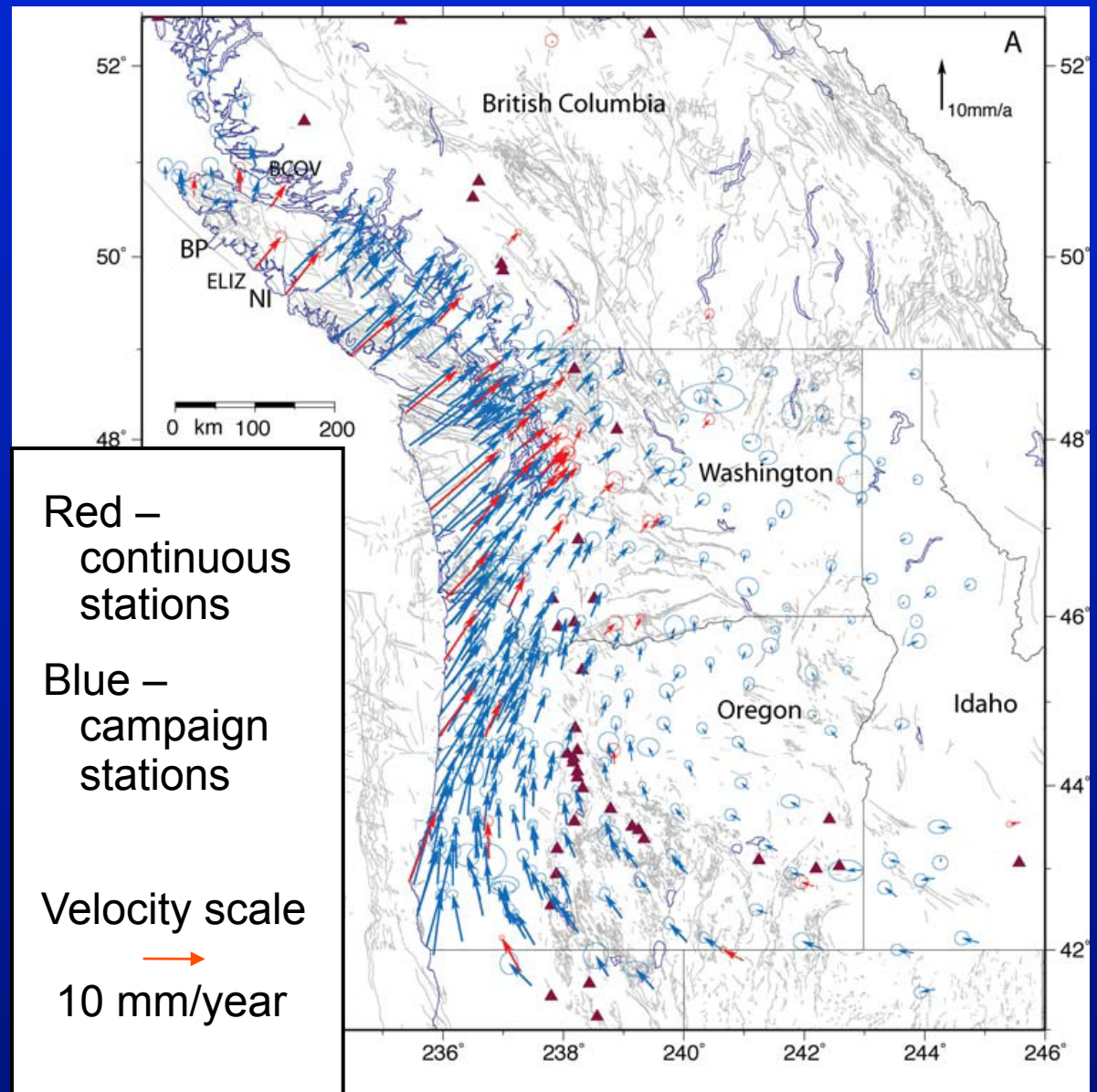
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GPS Observations (1991-2004)

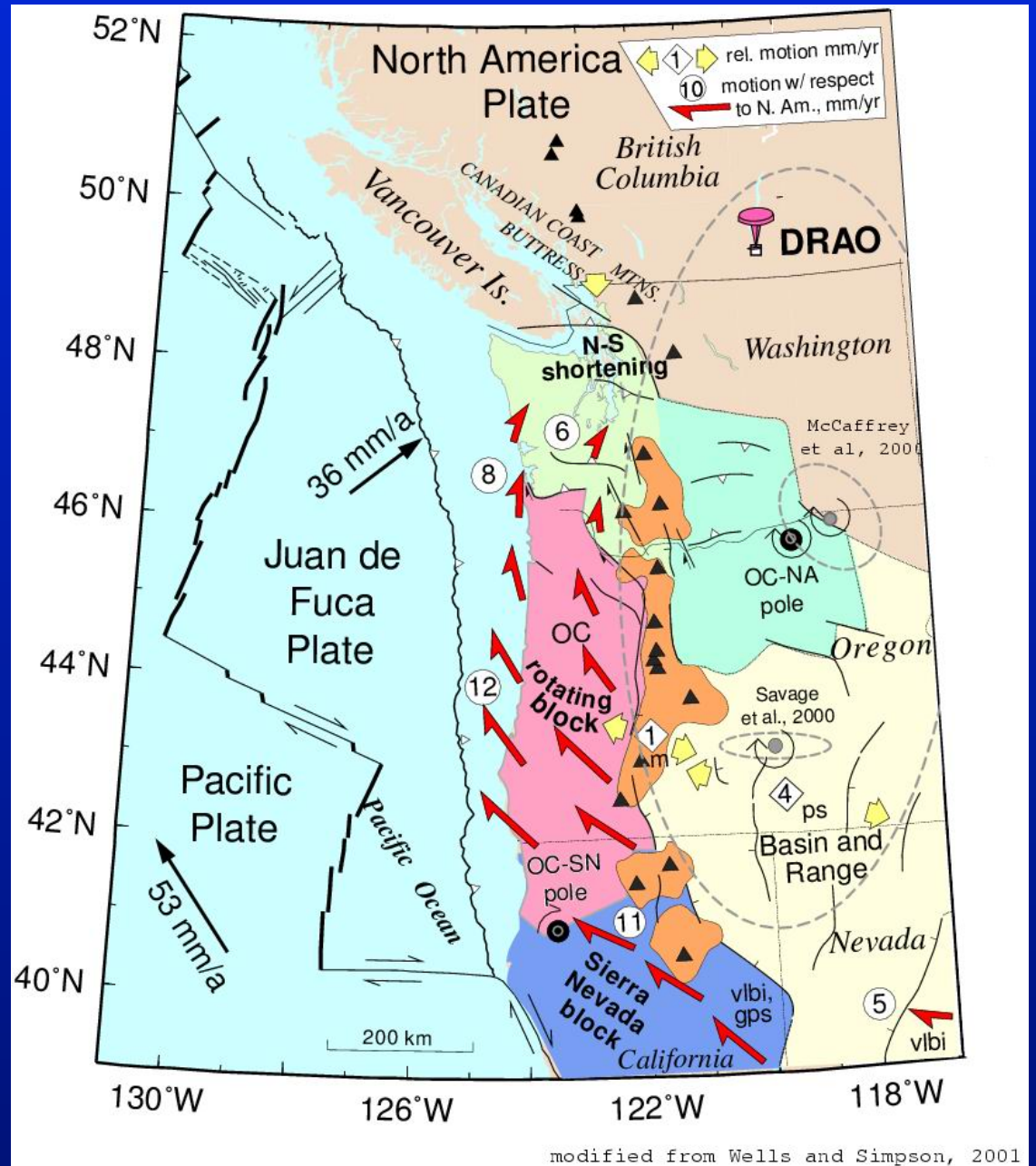
Station velocities
with respect to
stable North America

(Compiled by
McCaffrey et al., 2007)

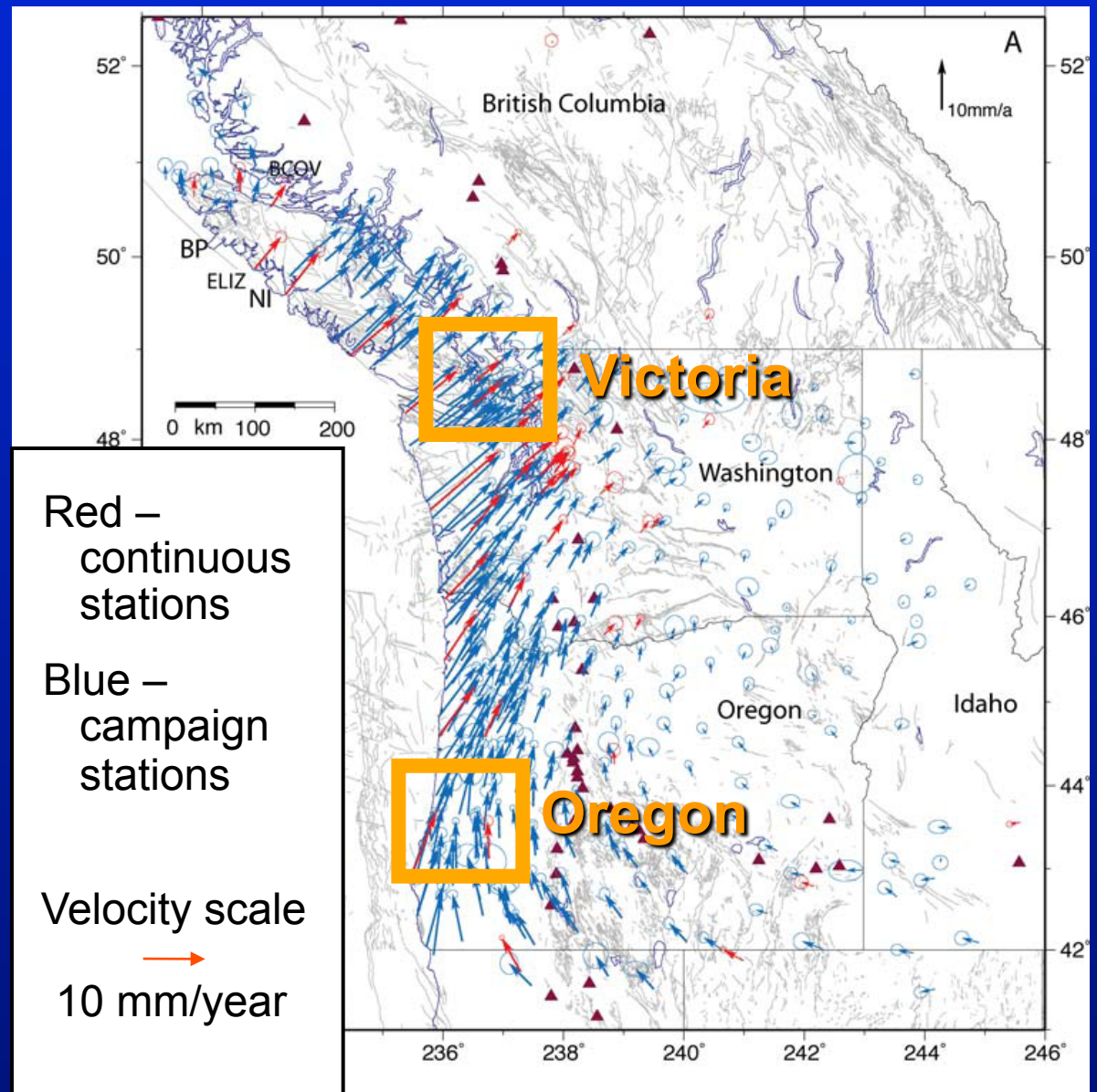


Secular motion of coastal region

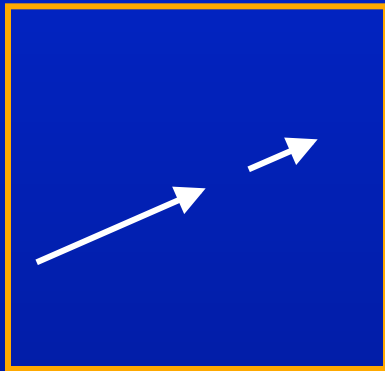
(Model of Wells et al., 1998, based on Earth's magnetic field recorded in rocks and other geological data).



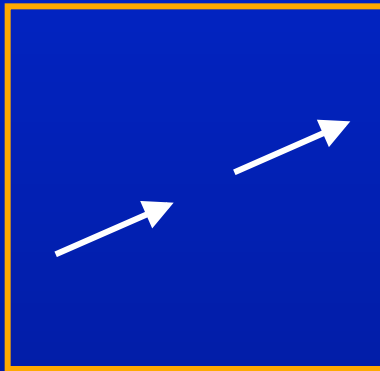
What do the GPS velocities tell us about energy accumulation in the present megathrust earthquake cycle?



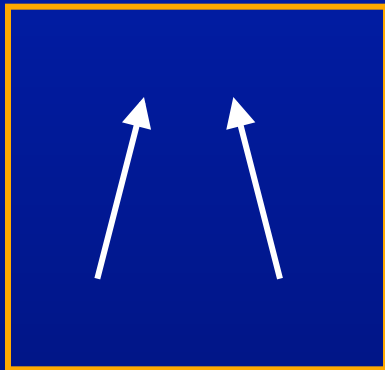
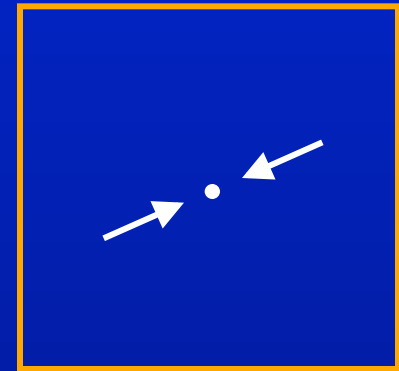
GPS velocity = Rigid-body translation + Deformation (strain rate)



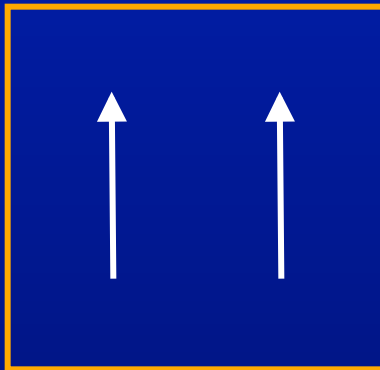
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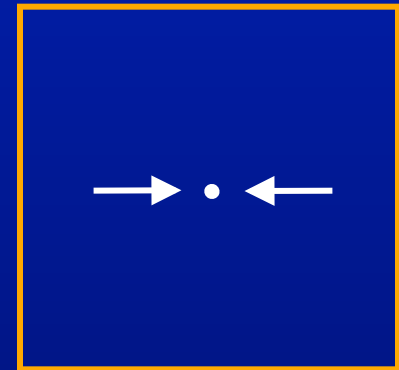
+



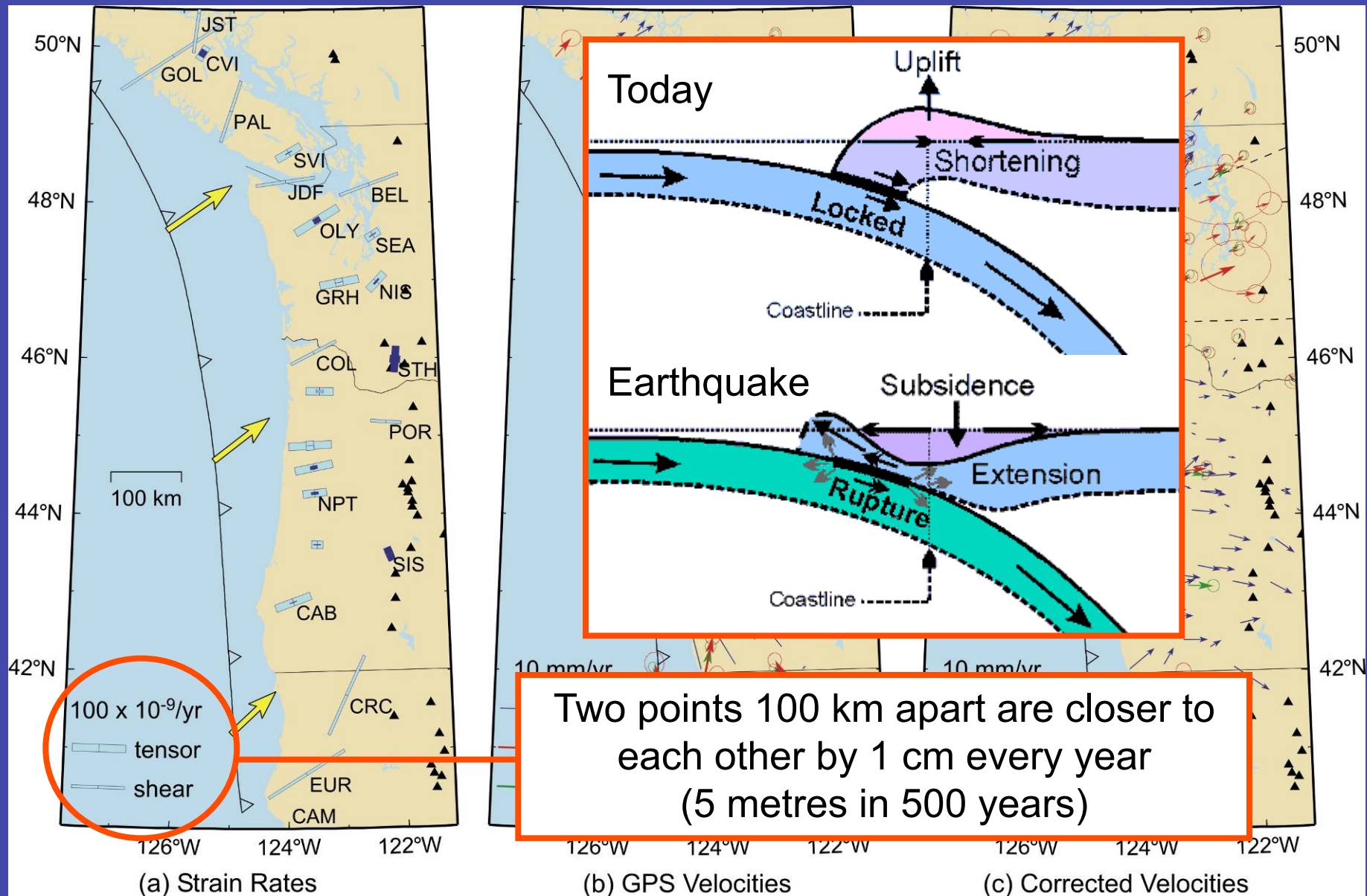
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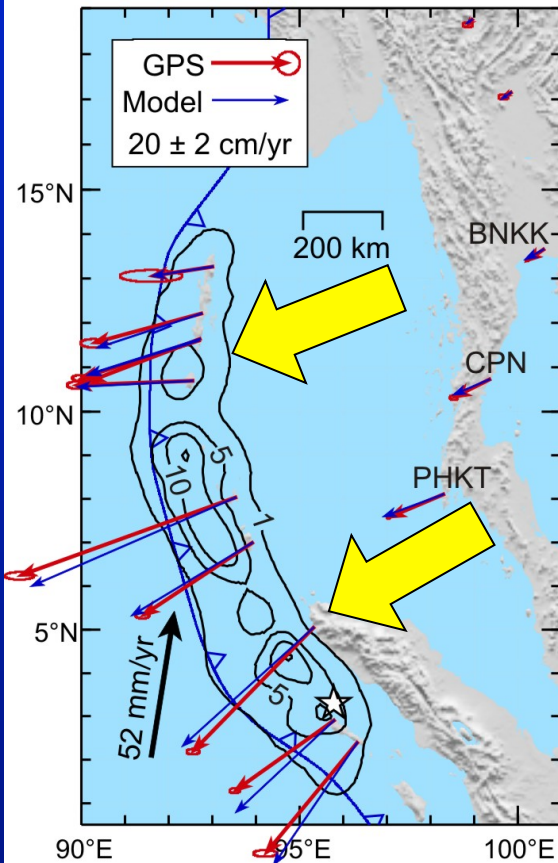
+



Interseismic Deformation

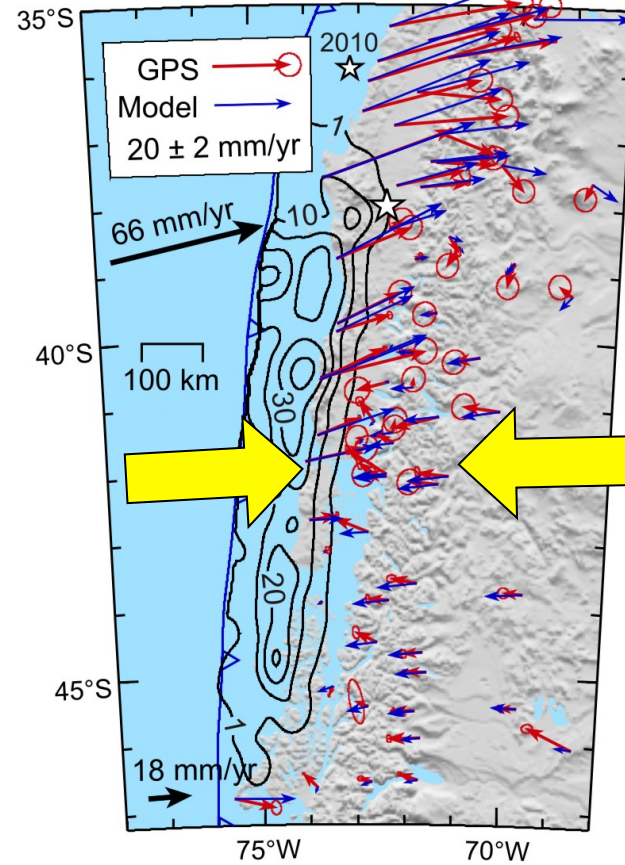


a. Sumatra



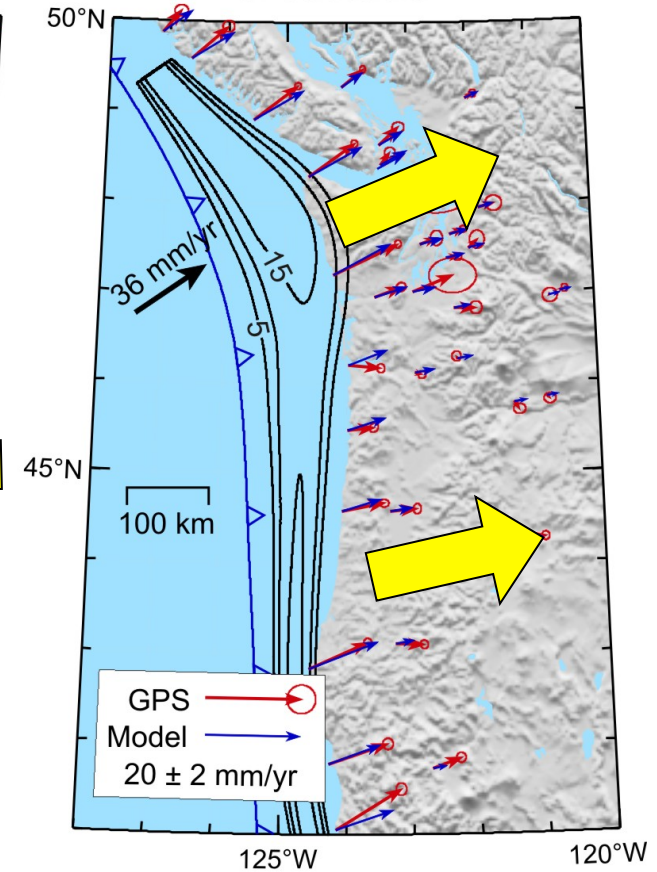
A couple of years

b. Chile



About four decades

c. Cascadia



Three centuries

Wang, Hu, He (Nature, 2012)

Coast line

Inter-seismic 2
(Cascadia)



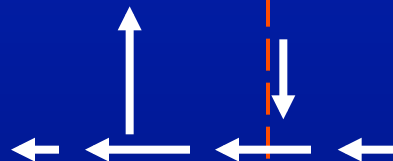
Inter-seismic 1
(Alaska, Chile)



Post-seismic
(Japan, Sumatra)



Co-seismic



Coast line

Cascadia since the 1700 earthquake



England and France began to fight in eastern North America (Queen Anne's War).



Captain Chirikov (Russia) landed on northwest coast of North America (Prince of Wales Island).



Captain Cook sailed along west coast of North America and traded with native people at Nootka Sound.



Dr. Wang lectures at ICTP Workshop on Megathrust earthquakes and Tsunamis

What has GPS told us so far?

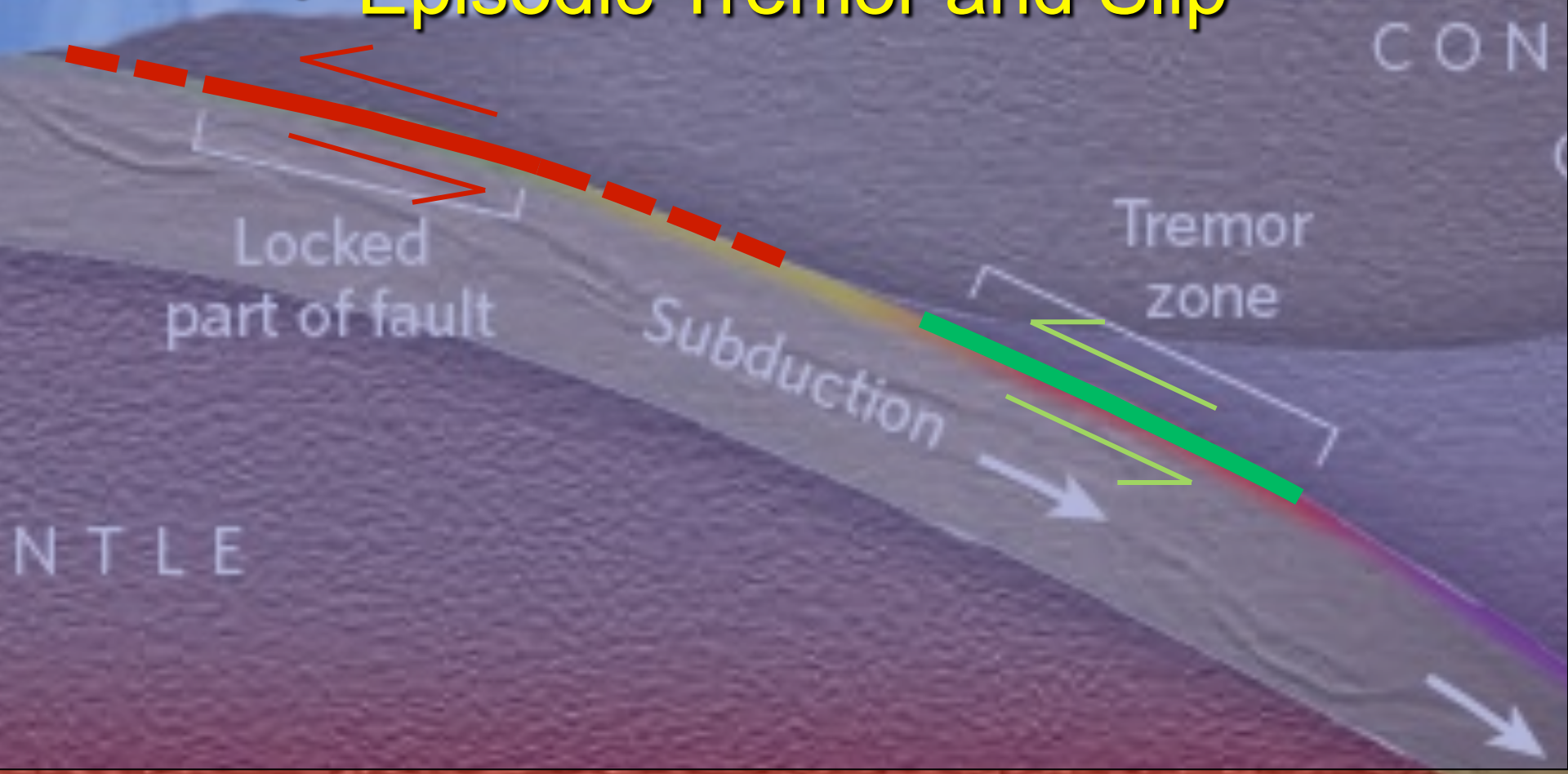
1. The megathrust fault is fully locked and is accumulating energy for the next great earthquake
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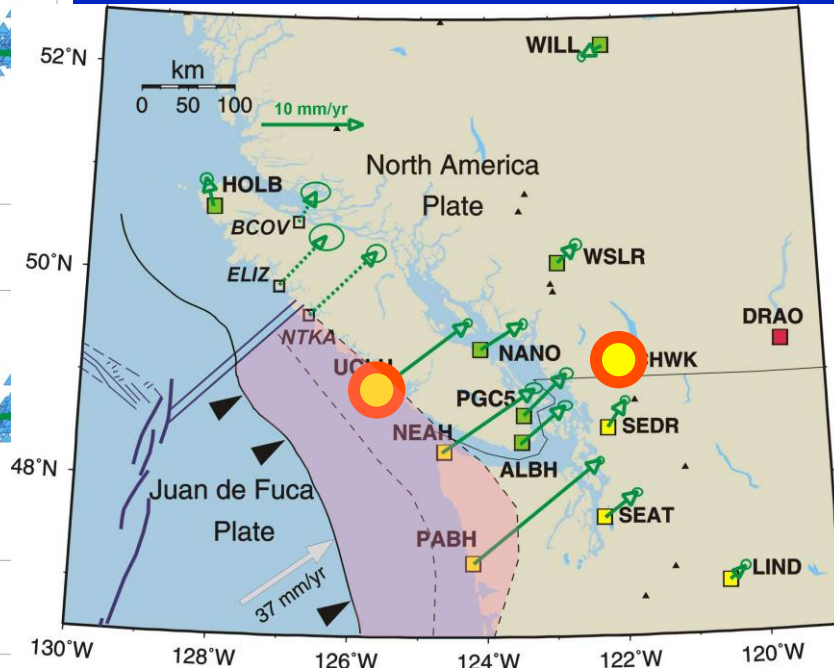
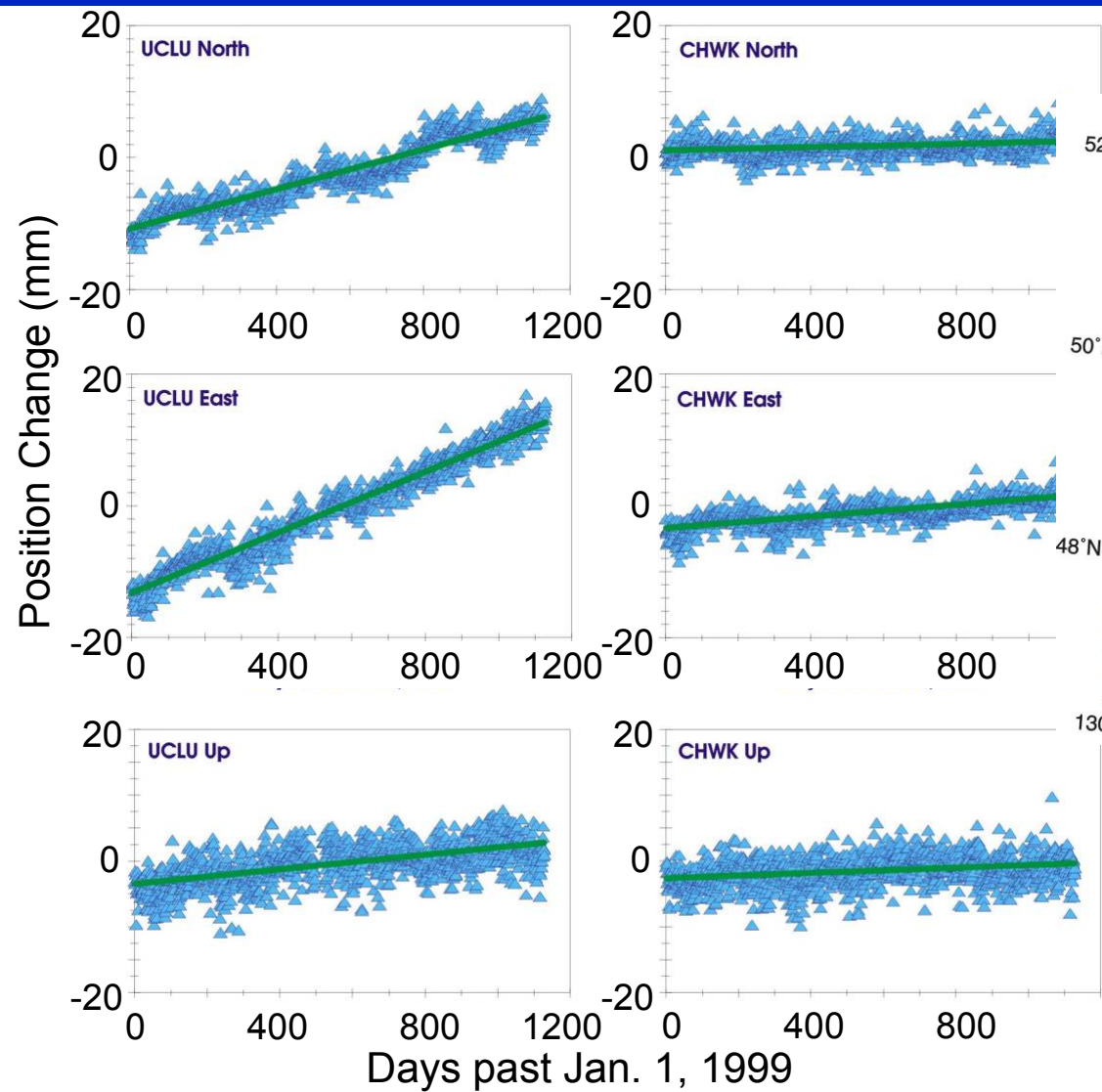
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New scientific challenges

- Episodic Tremor and Slip

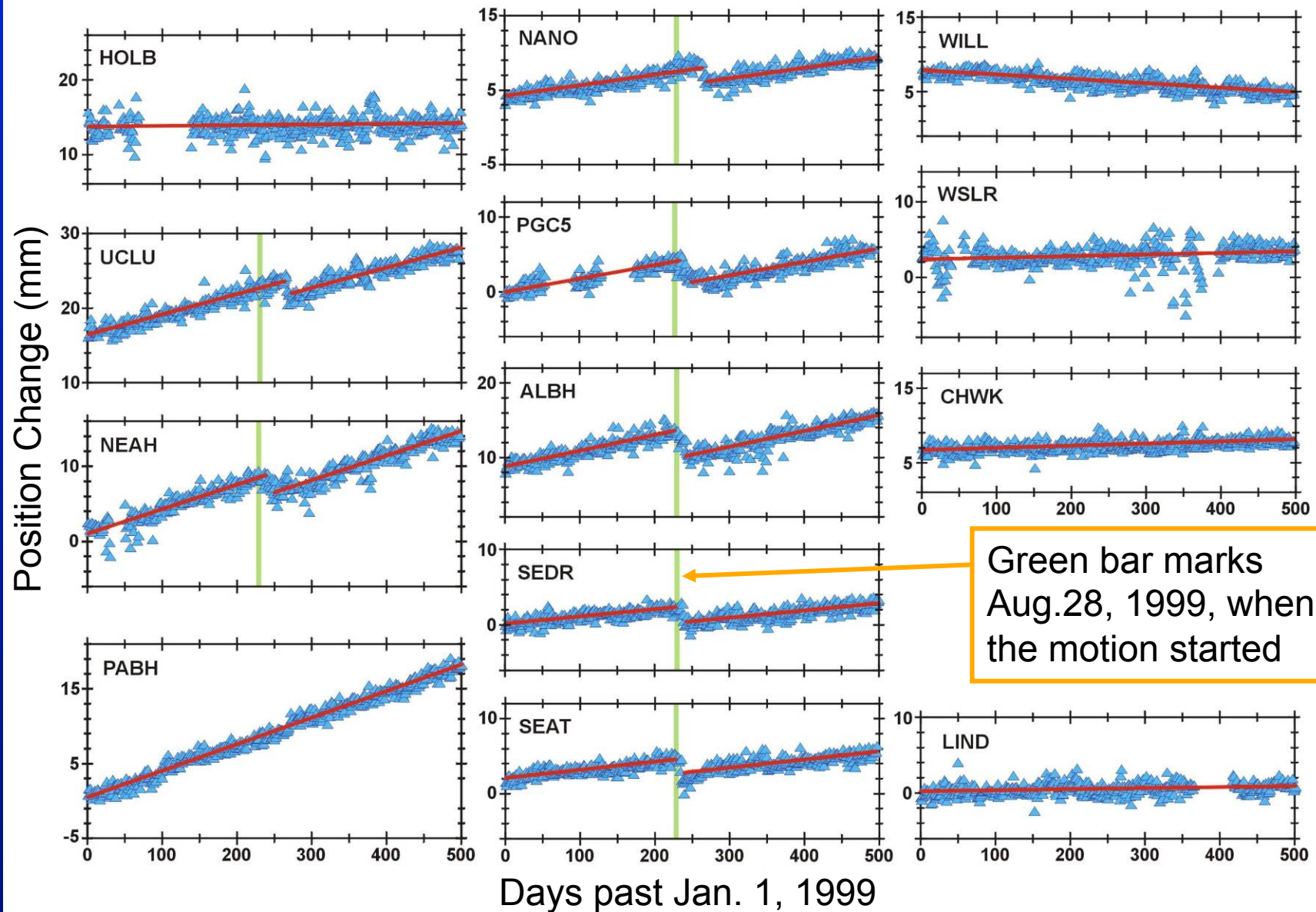


Daily positions of UCLU and CHWK with respect to DRAO (Penticton) for 1999-2001



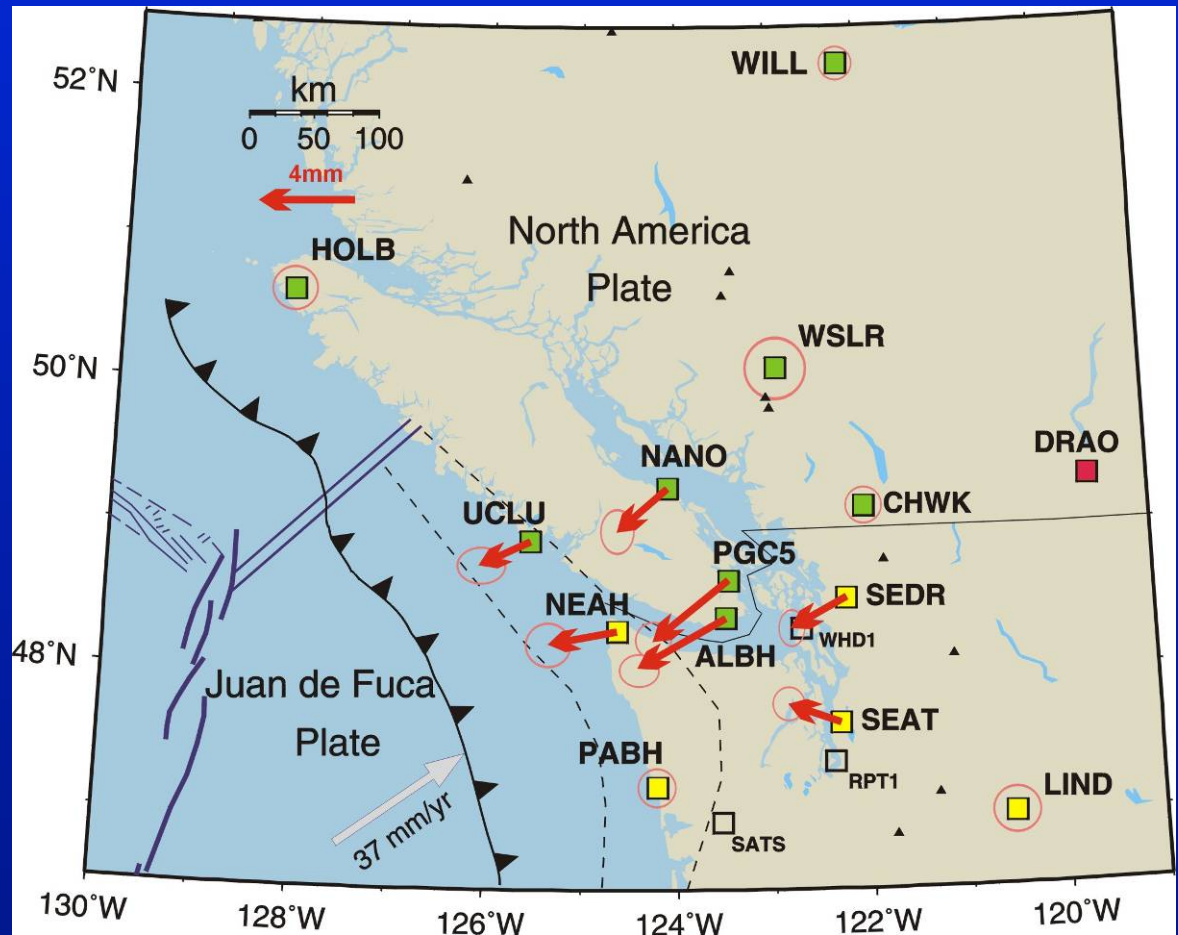
The “long-term” motions have been used to estimate the location and extent of locking across the megathrust

Changes in EW Components wrt DRAO for Aug. 1999 Slip

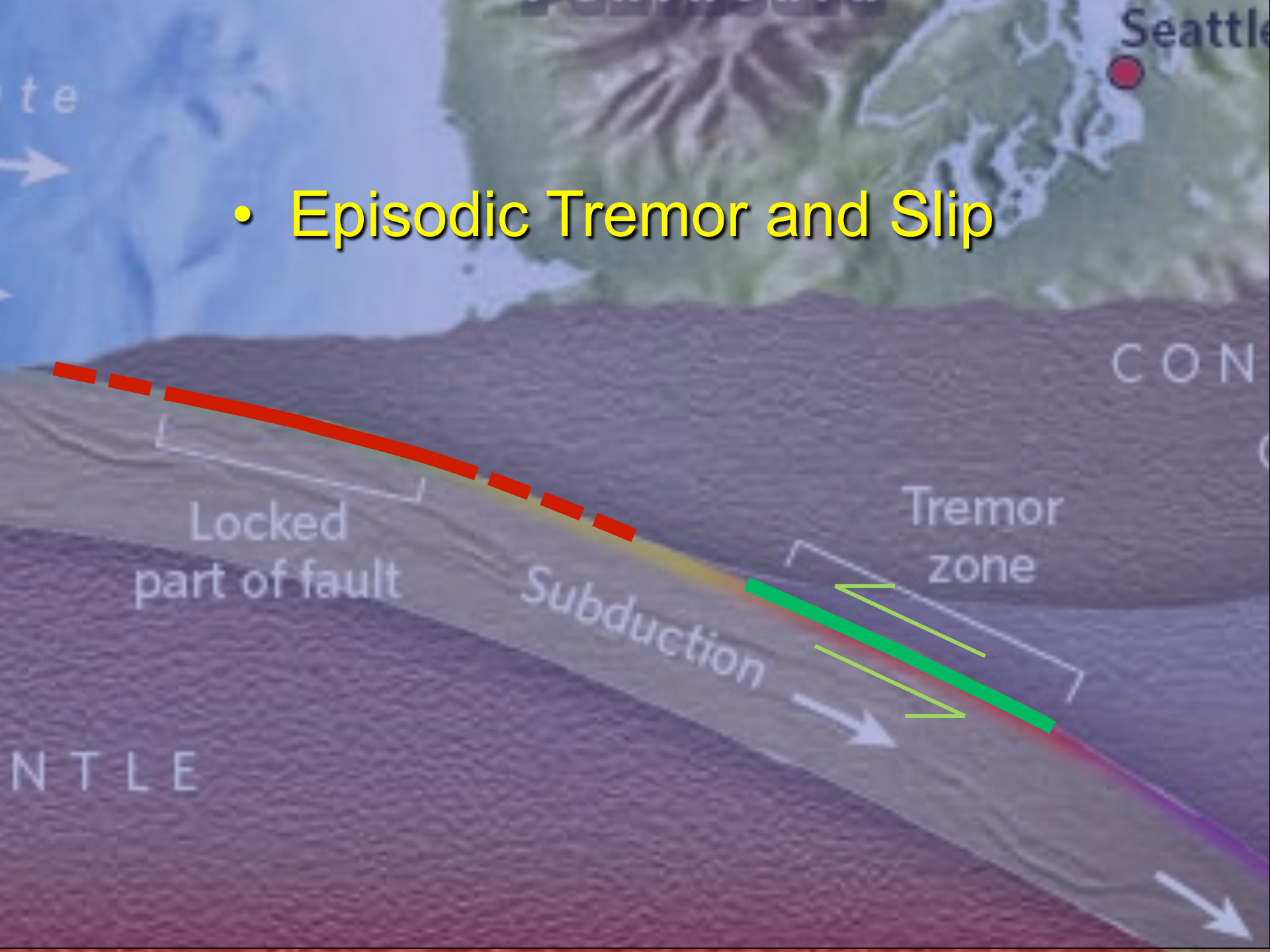


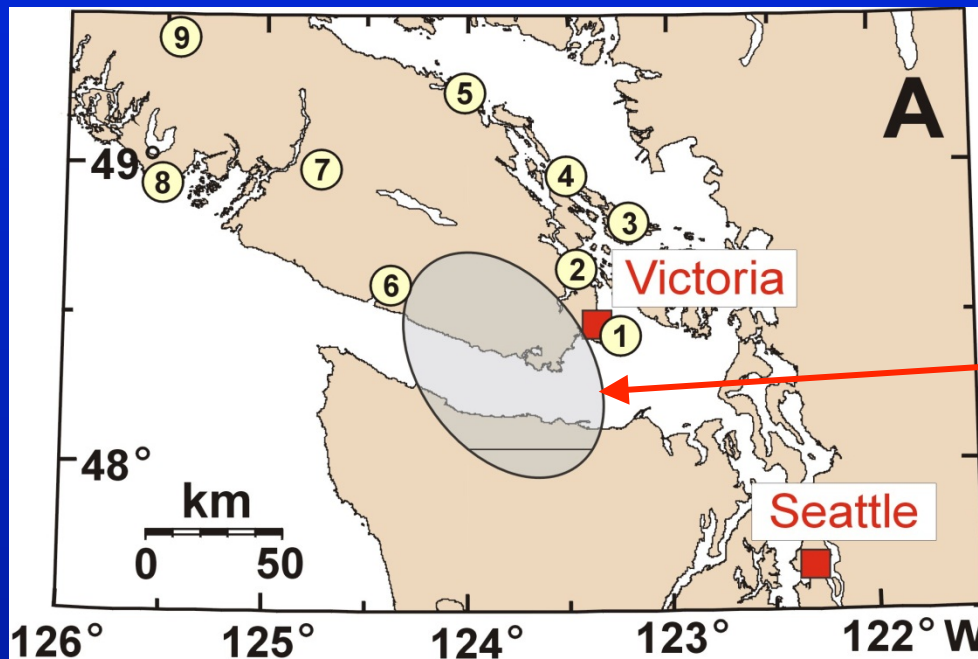
1999 Transient Displacements

Reversals of motion of individual sites up to 6 mm over a period of 1 to 3 weeks

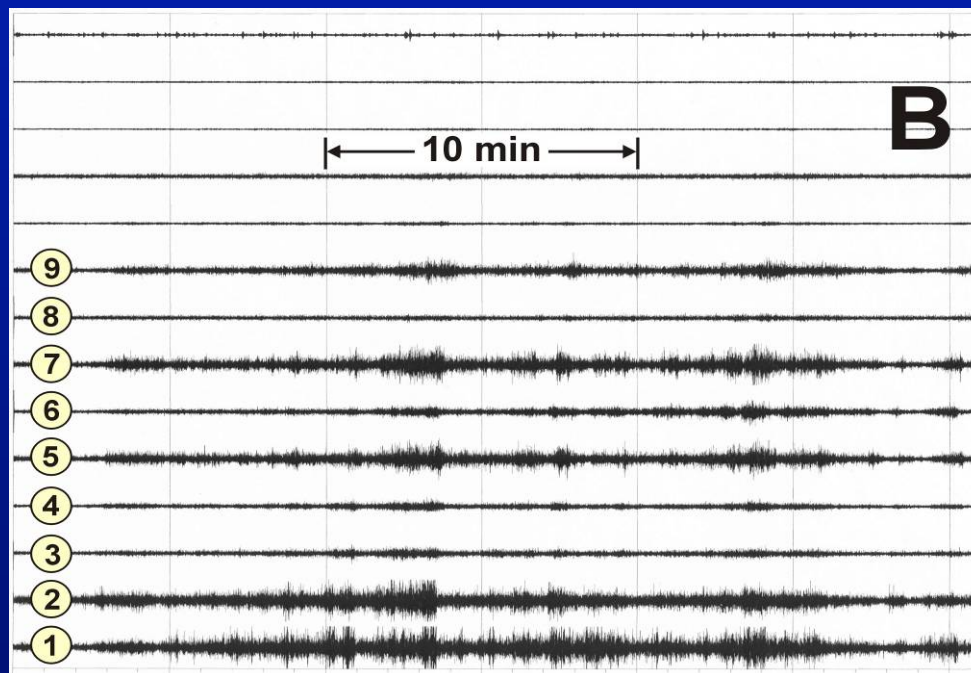


- Episodic Tremor and Slip



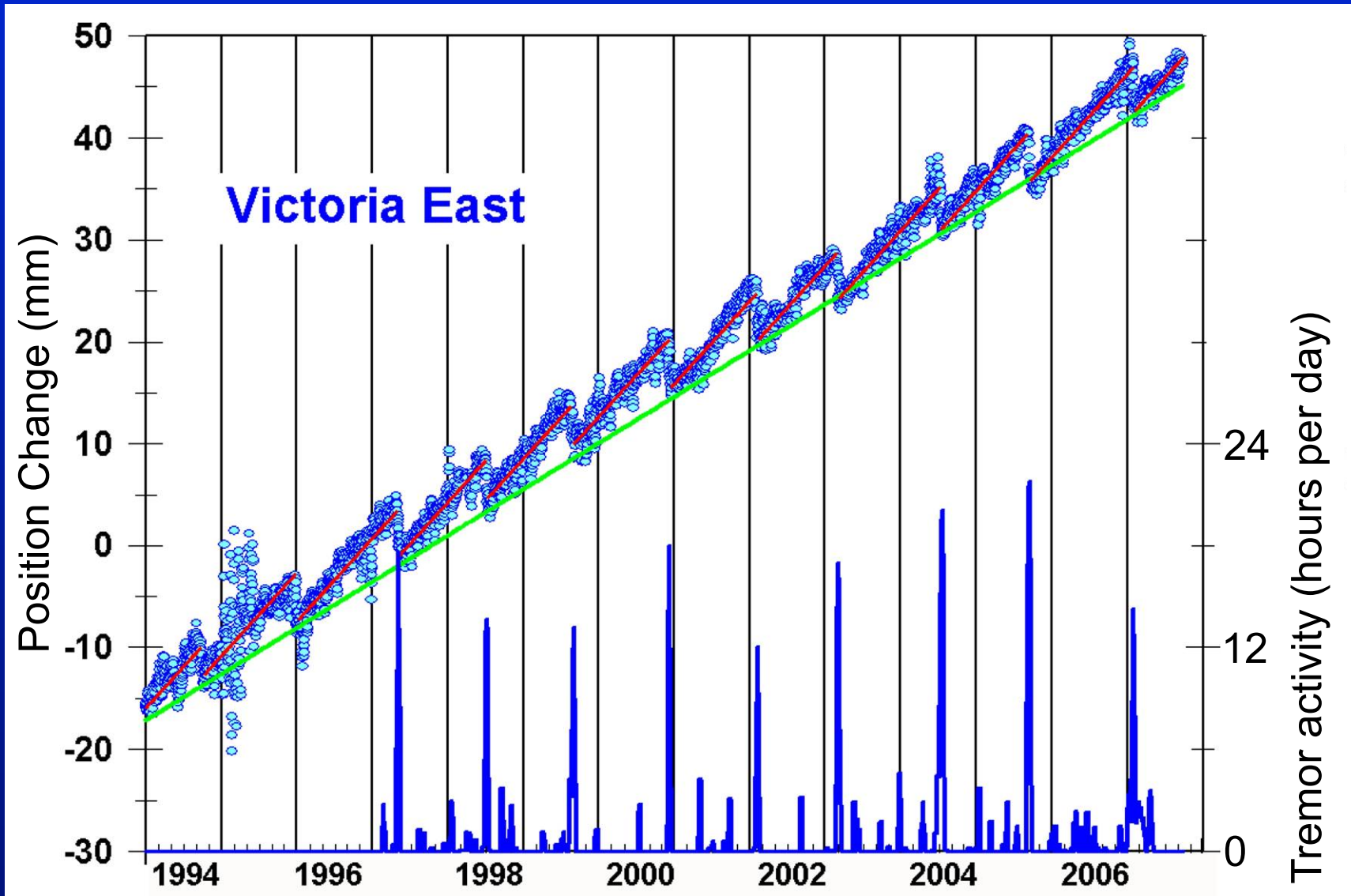


Tremor source area

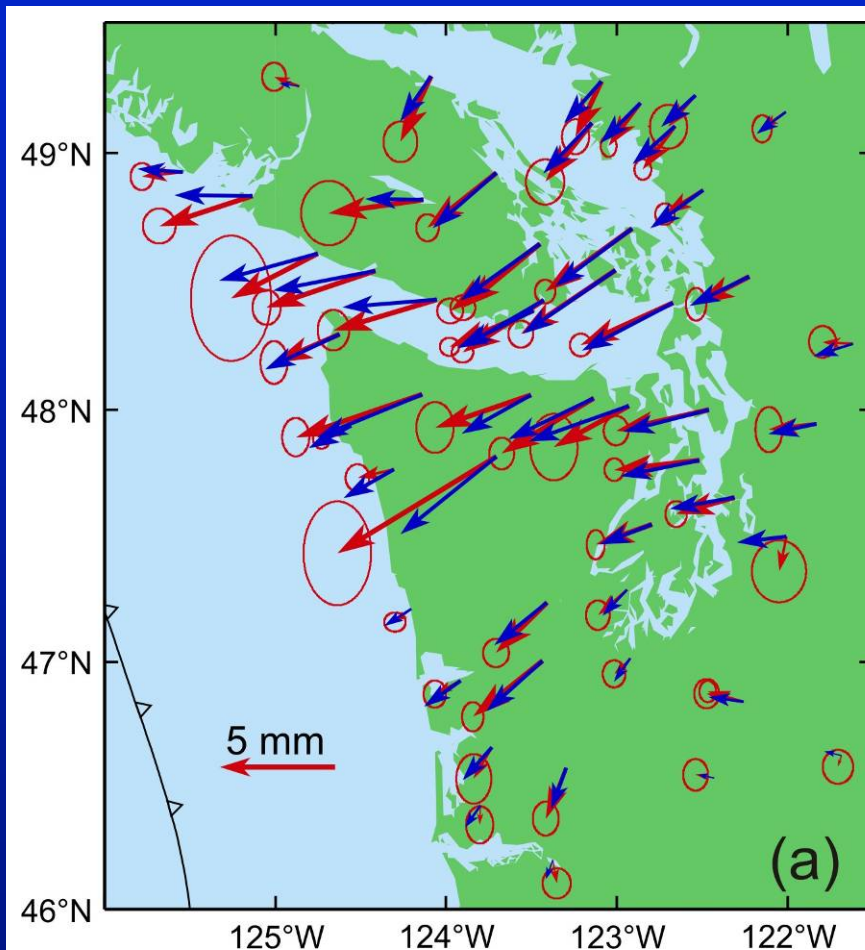


Rogers and Dragert
(Science 2003)

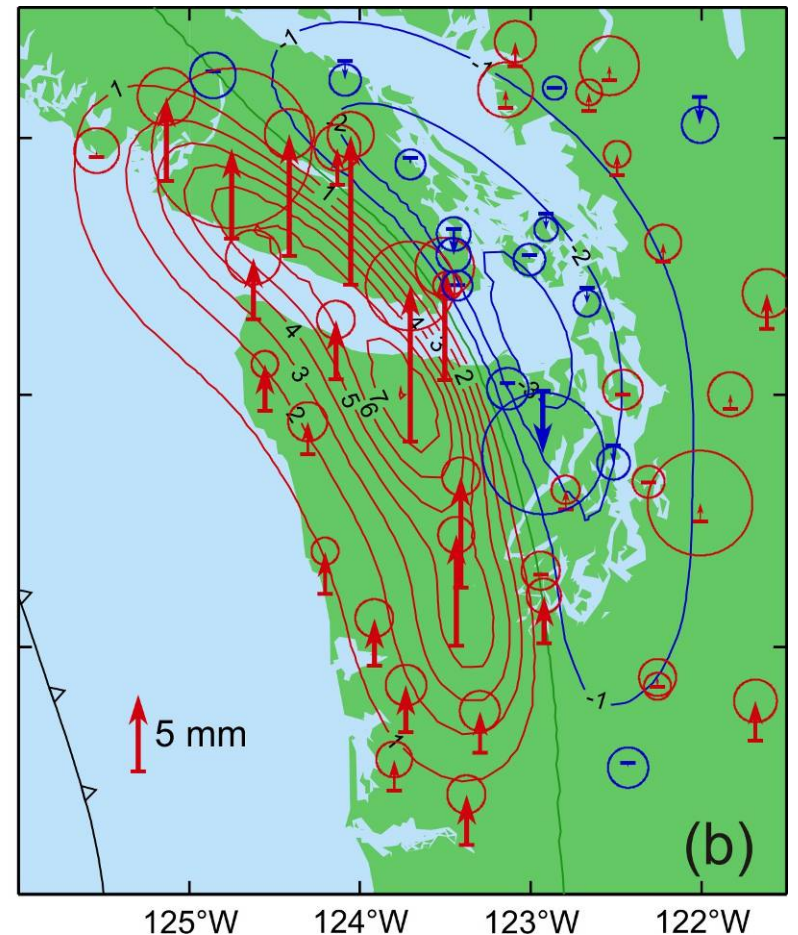
Episodic Tremor and Slip (ETS) on Vancouver Island



Northern Cascadia ETS event of May 2008

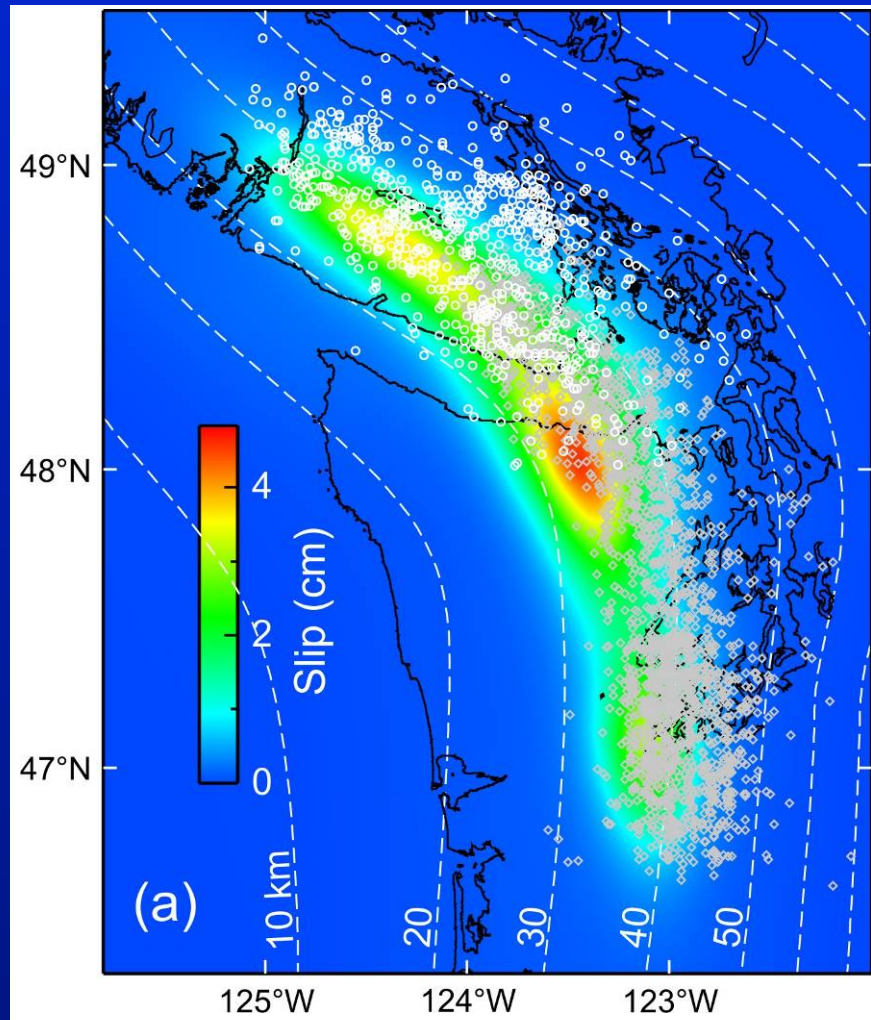


GPS (red) and model (blue)
horizontal displacements

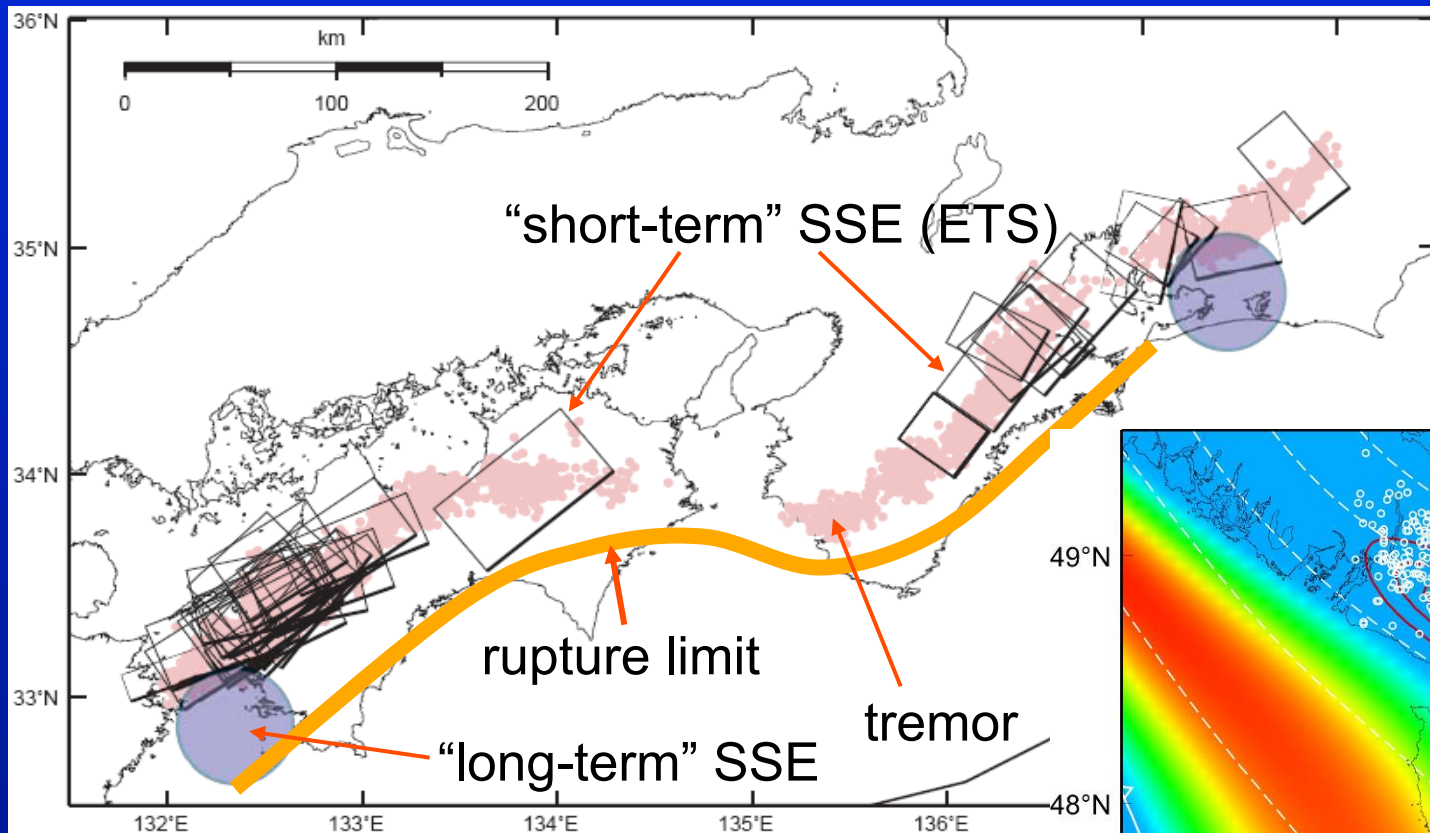


GPS (arrow) and model (contour)
vertical displacements

Northern Cascadia ETS event of May 2008

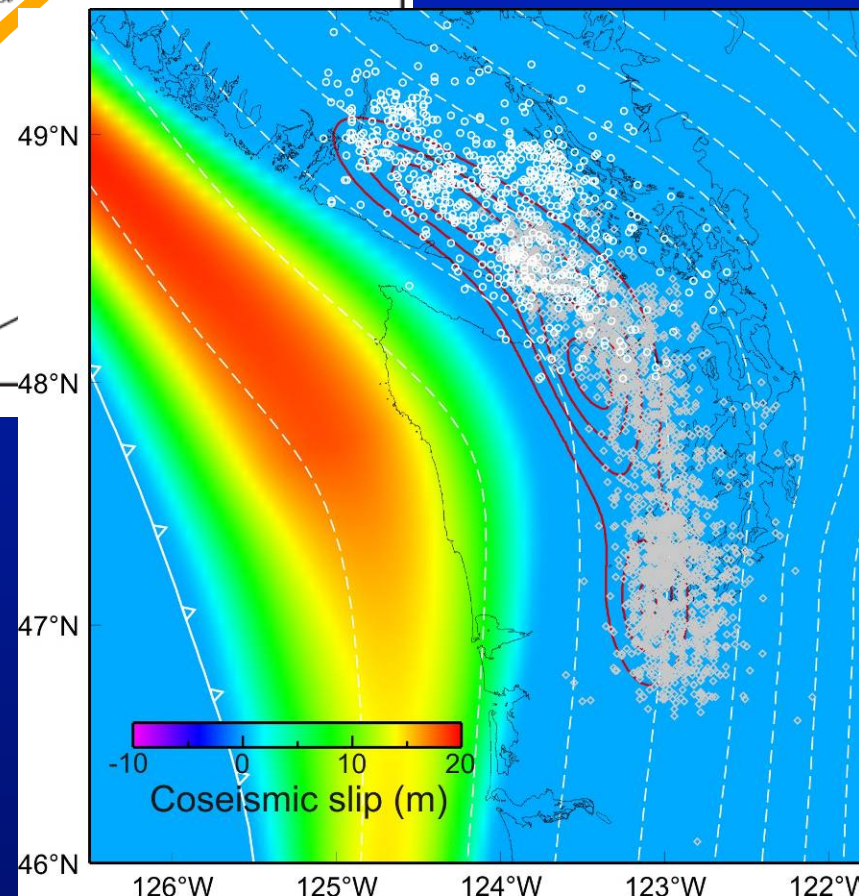


Dragert and Wang (2011)
With tremor locations from H. Kao and A. Wech



Southwest Japan

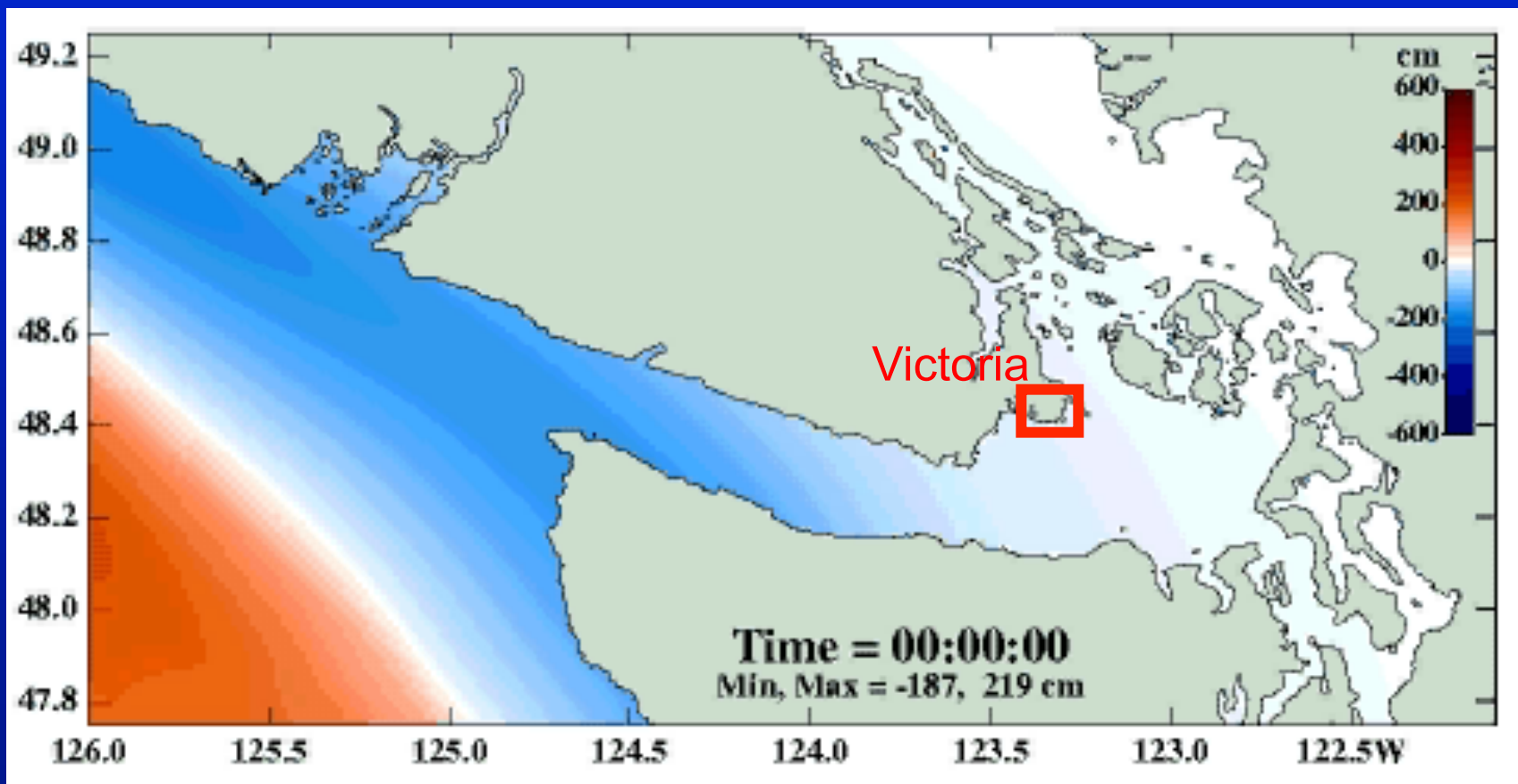
Northern Cascadia



New scientific challenges

- Episodic Tremor and Slip
- Tsunami hazard





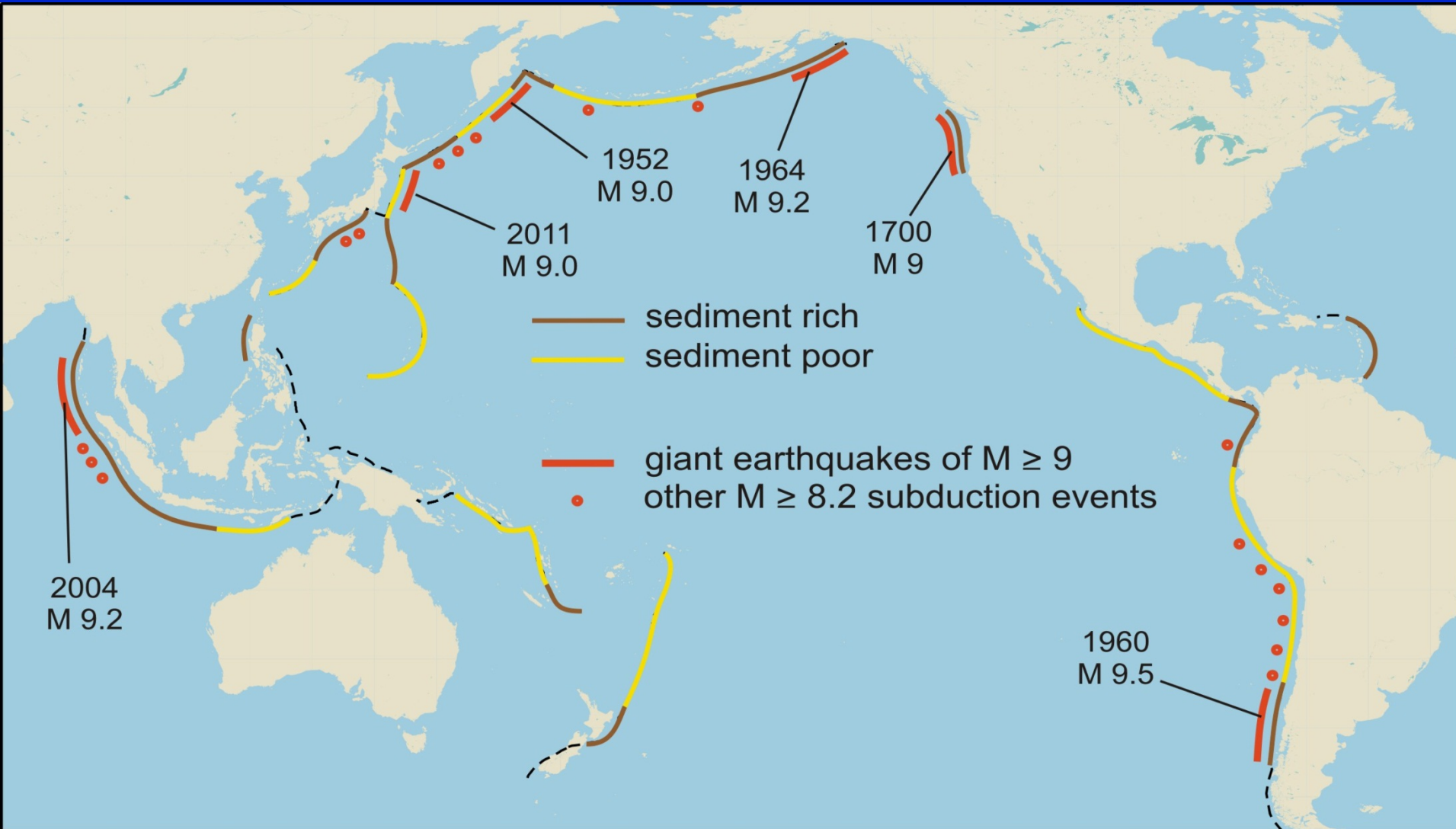
Tsunami wave propagation on the medium grid
(Cherniawsky et al., 2007)

New scientific challenges

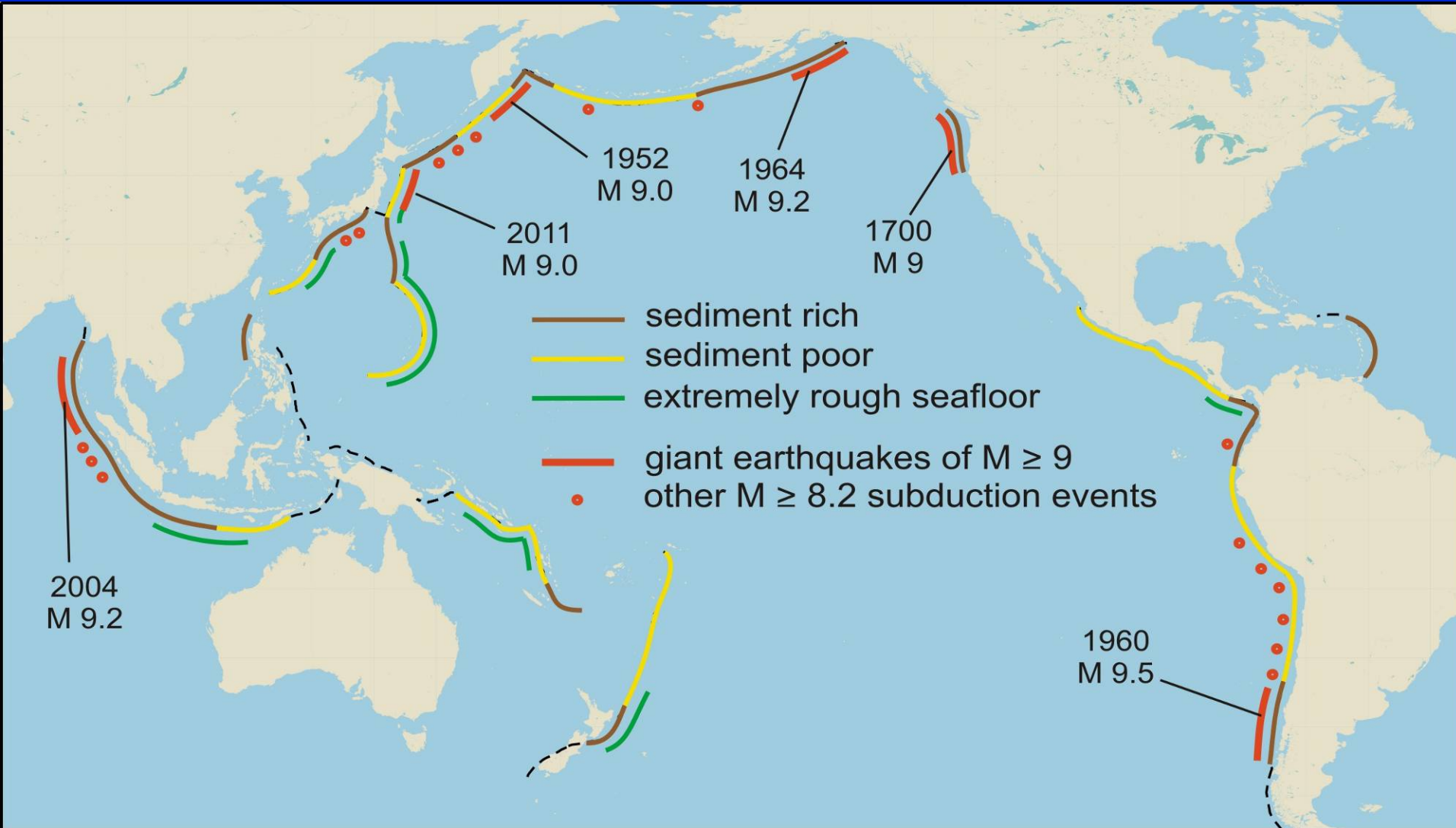
- Episodic Tremor and Slip
- Tsunami hazard
- What controls earthquake size

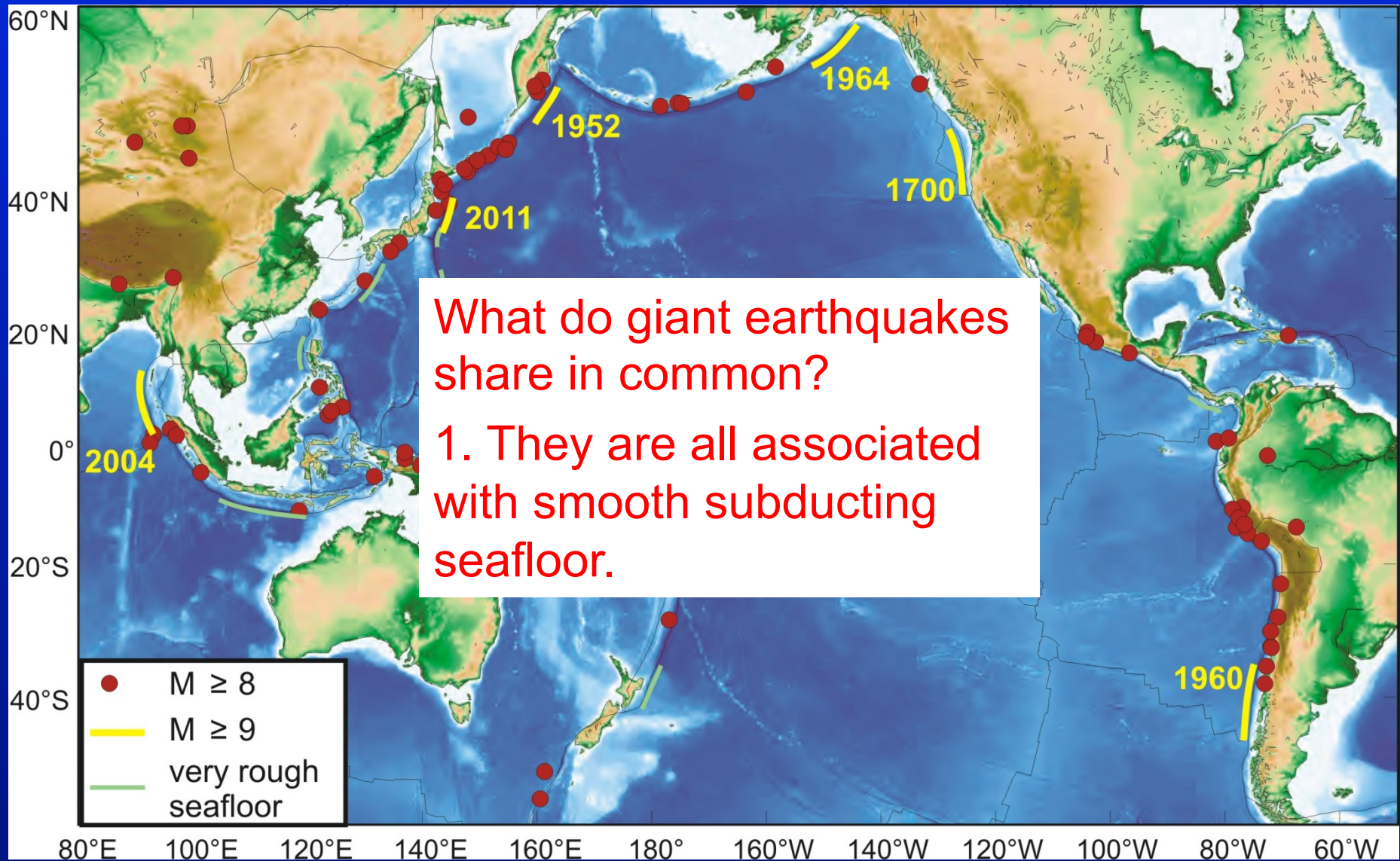


Correlation of large earthquakes with smooth subducting seafloor

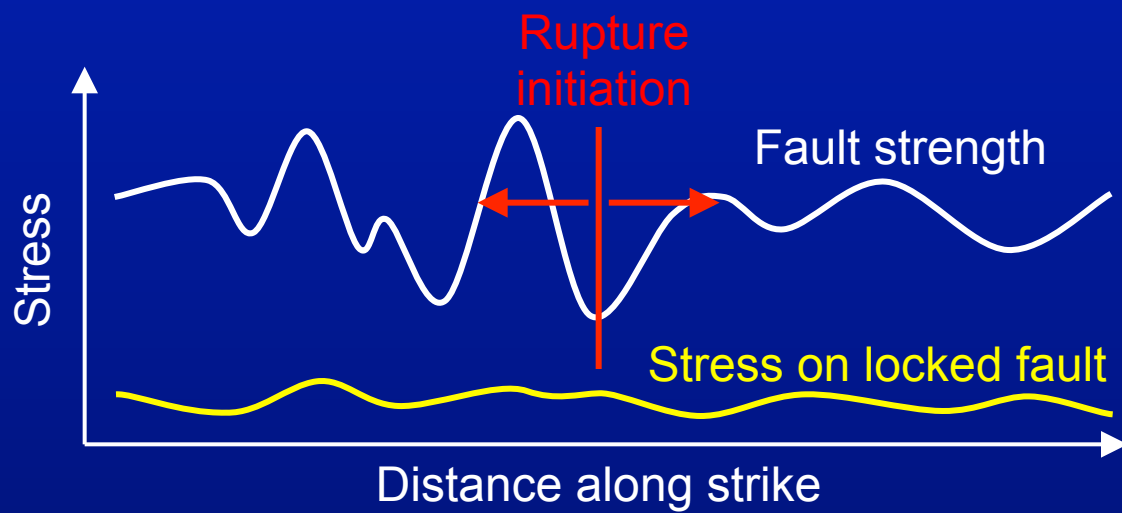
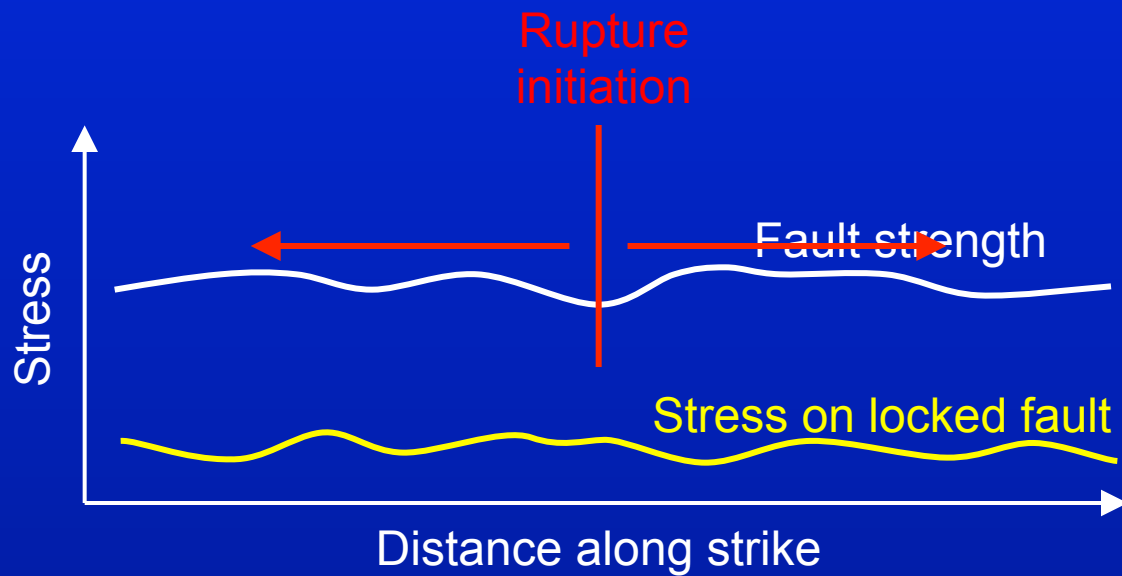
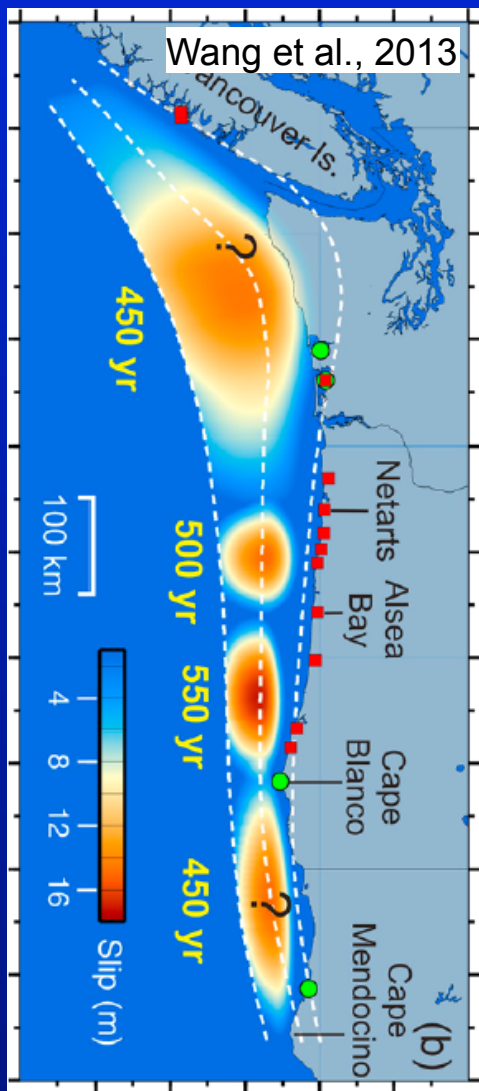


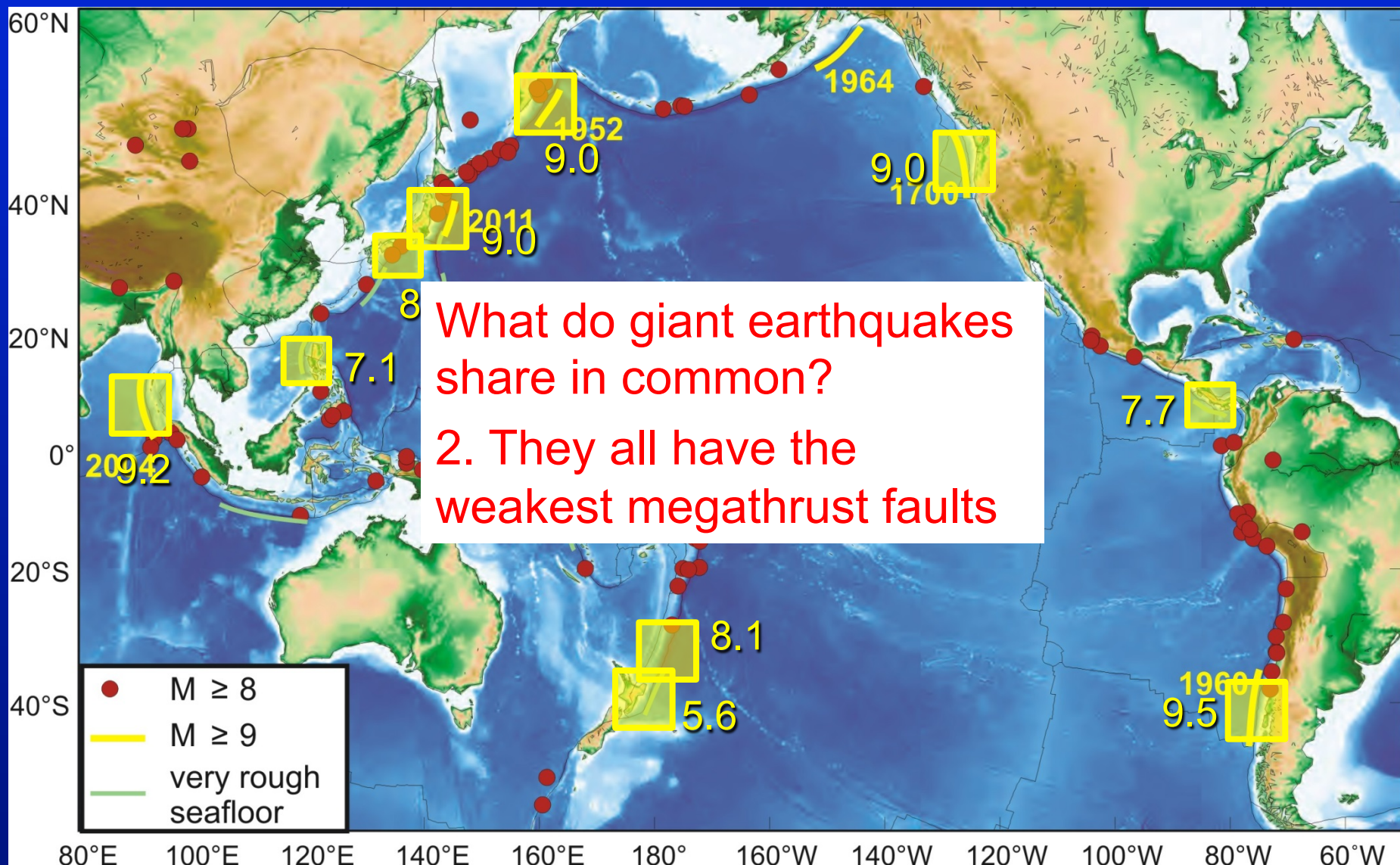
Lack of correlation with rough subducting seafloor



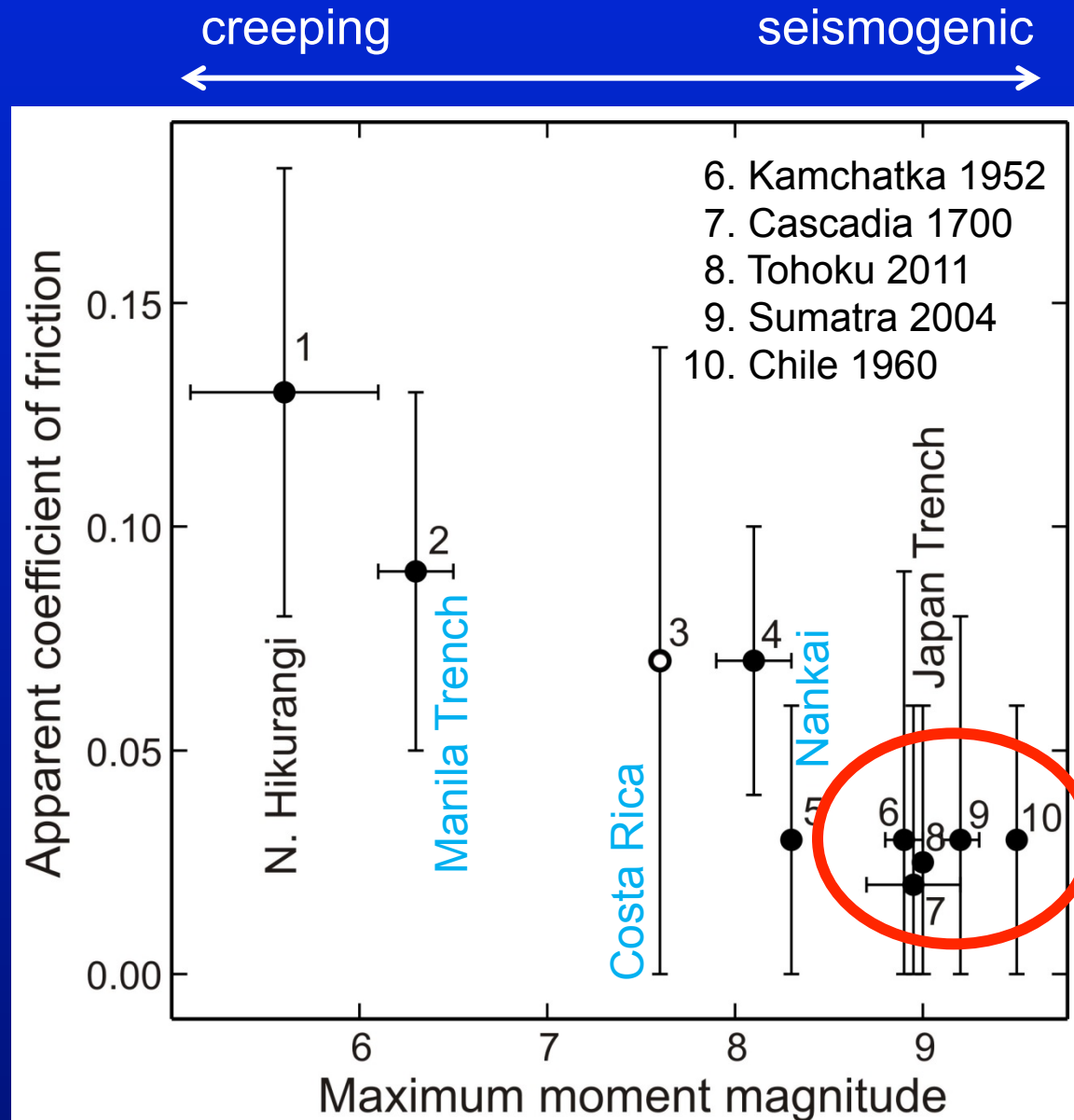


Wang and Bilek (2014, Tectonophysics)





Subduction zones with adequate heat flow data to constrain frictional heating



Gao and Wang (2014, Science)

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 - Tsunami hazard
 - What controls earthquake size
 - And many more

Sumatra M=9.2 earthquake and tsunami, 2004



The End

To

011

