Tsunami potential and modeling

GEORGE PRIEST

OREGON DEPT. OF GEOLOGY AND MINERAL INDUSTRIES

NEWPORT COASTAL FIELD OFFICE

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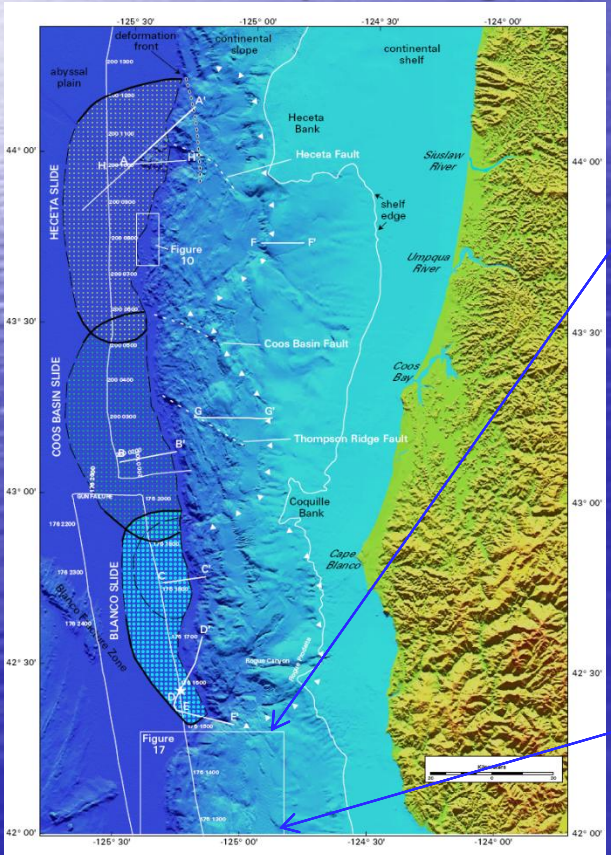
What creates most uncertainty for prediction of local tsunami hazard?

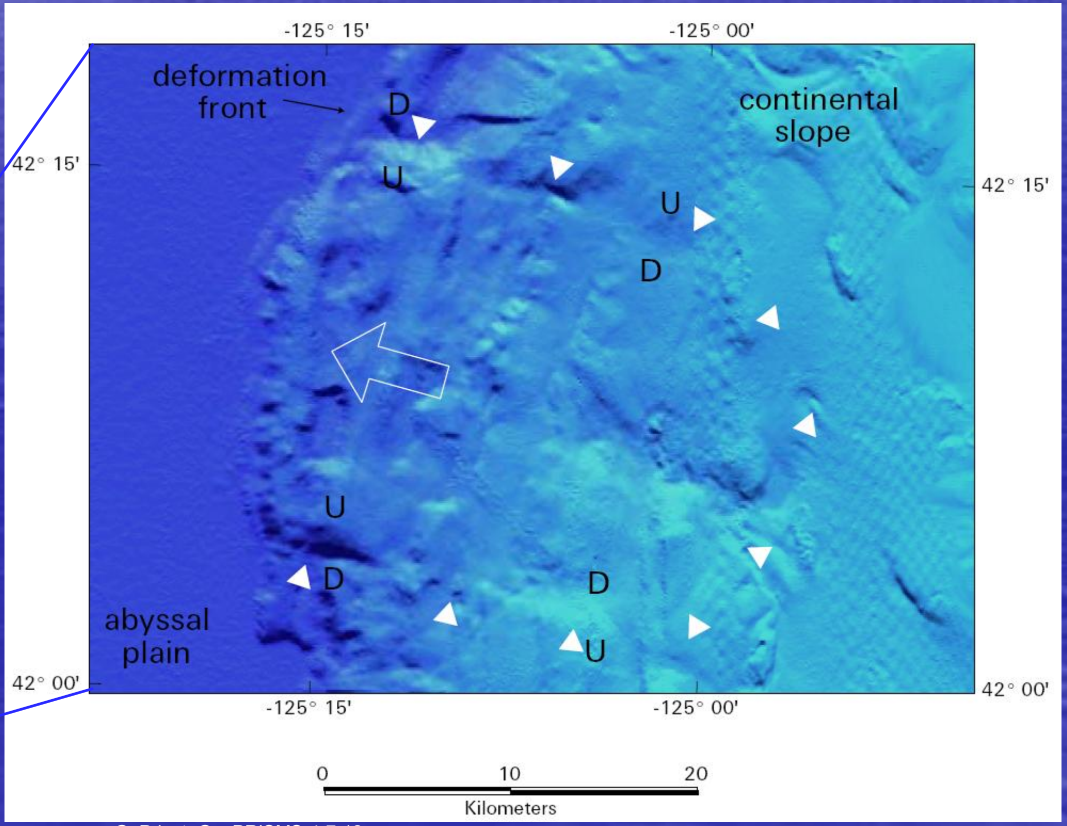
- Hydrodynamic model? **NO**

  Benchmark tests show similar results for similar grid refinement; findings:
  - Unstructured grids better at simulating critical coastal features (harbors, jetties, estuaries).
  - Model must be tailored to source (e.g. dynamic sources versus static sources).

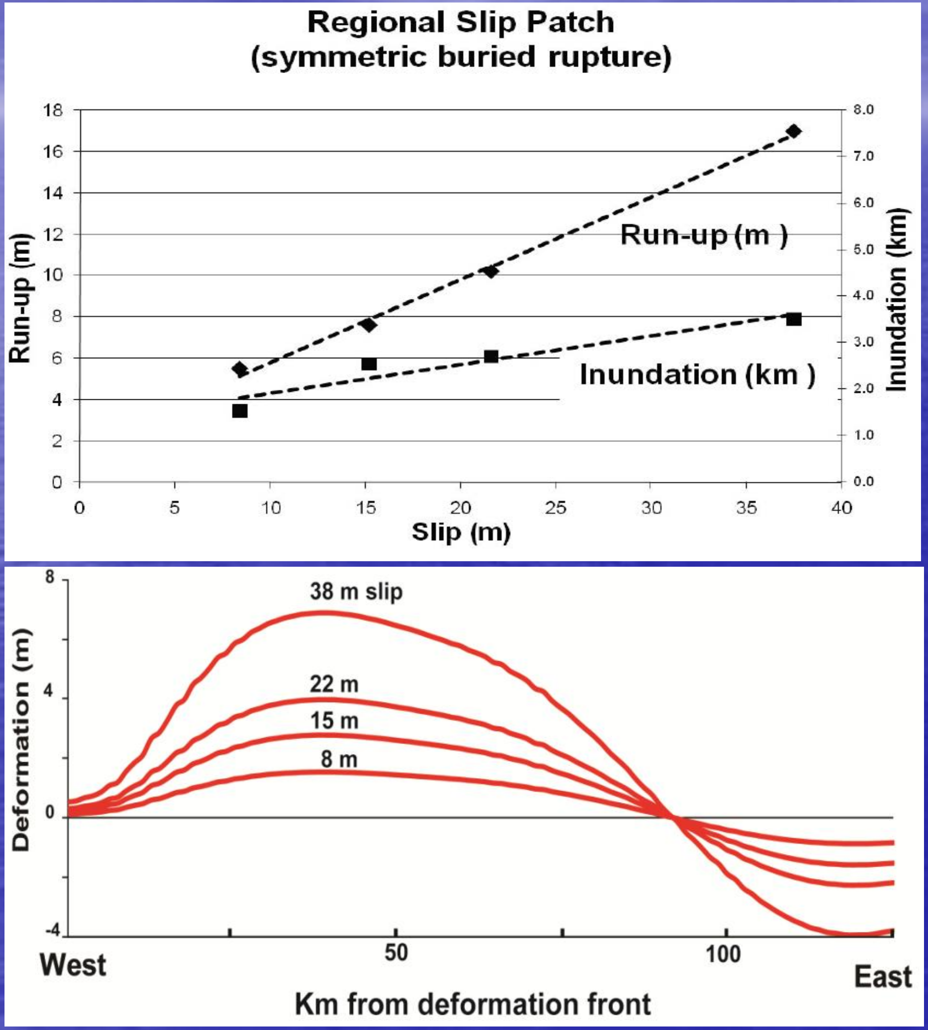
Source model? **YES**

- Landslides?
  - 350–850 ka Cascadia recurrence
  - 20 x 20 km incipient slump Gold Beach-Brookings (S. margin) (Goldfinger et al., 2000).



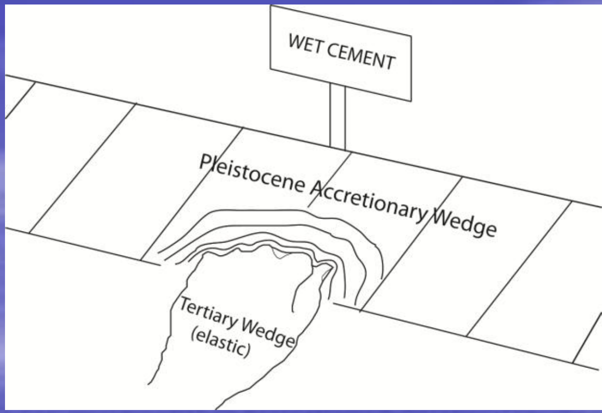


- Runup + inundation = dir. Proportional to **peak slip directly offshore** (est. fr. convergence rate, paleoseismic data.)

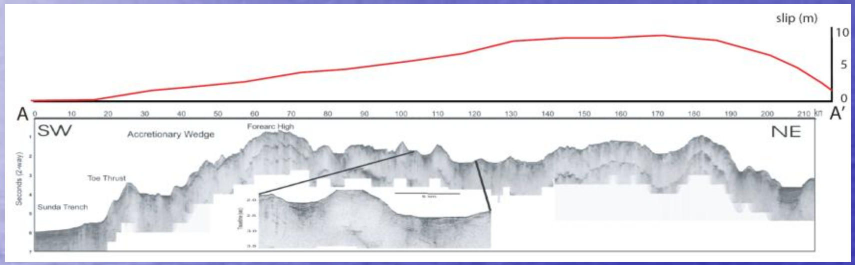


Example:
Cannon Beach, OR
(Priest et al., 2009)

Slip Distribution



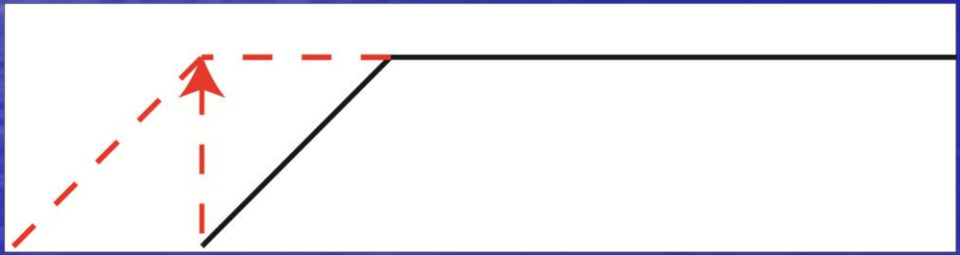
- Velocity strengthening (Pleistocene wedge)
  - minimizes slip to the trench;
  - maximizes elastic uplift landward of the trench;
  - deformation skewed to shallower water.



Slip – Sumatra, 2004 (Chlieh et al. (2007)

SEATOS line 1 (Fisher et al. (2007)

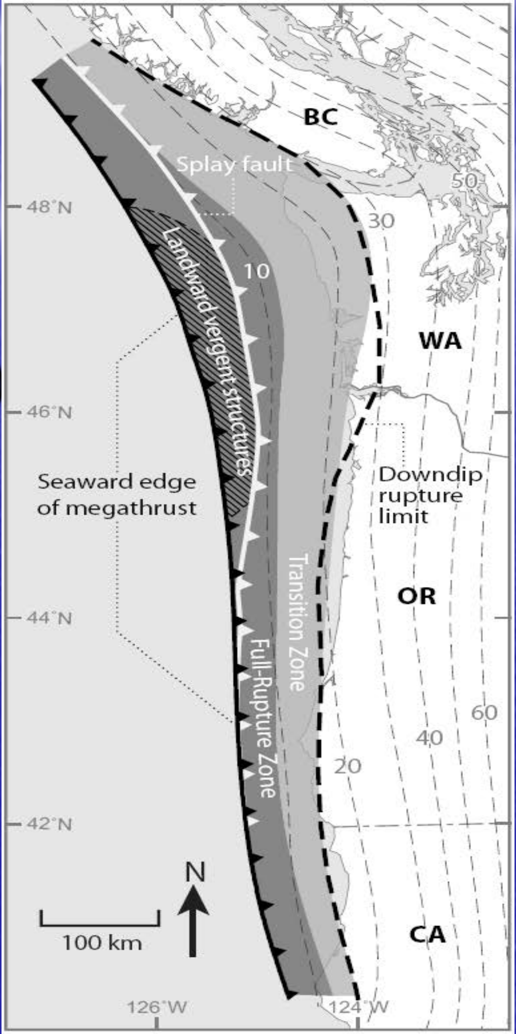
- Velocity weakening (no Pleistocene wedge)
  - maximizes slip to the trench;
  - deformation skewed to deeper water.
  - steep slope creates uplift when slope moves seaward;

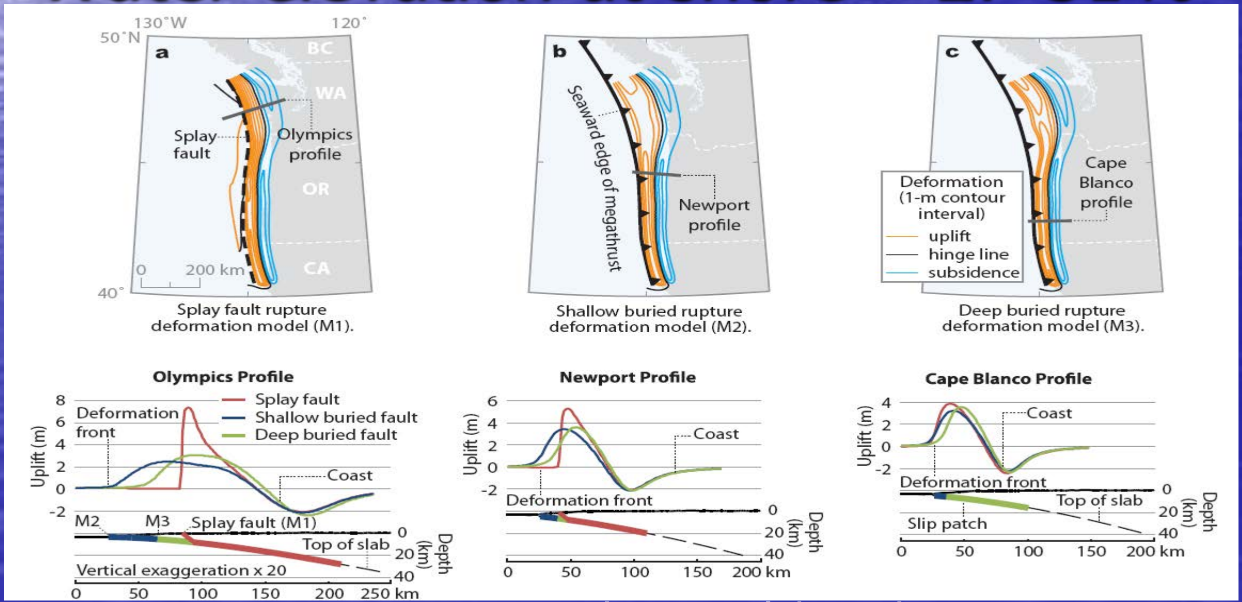


Schematic cross section – Continental slope moved seaward

Splay Faults

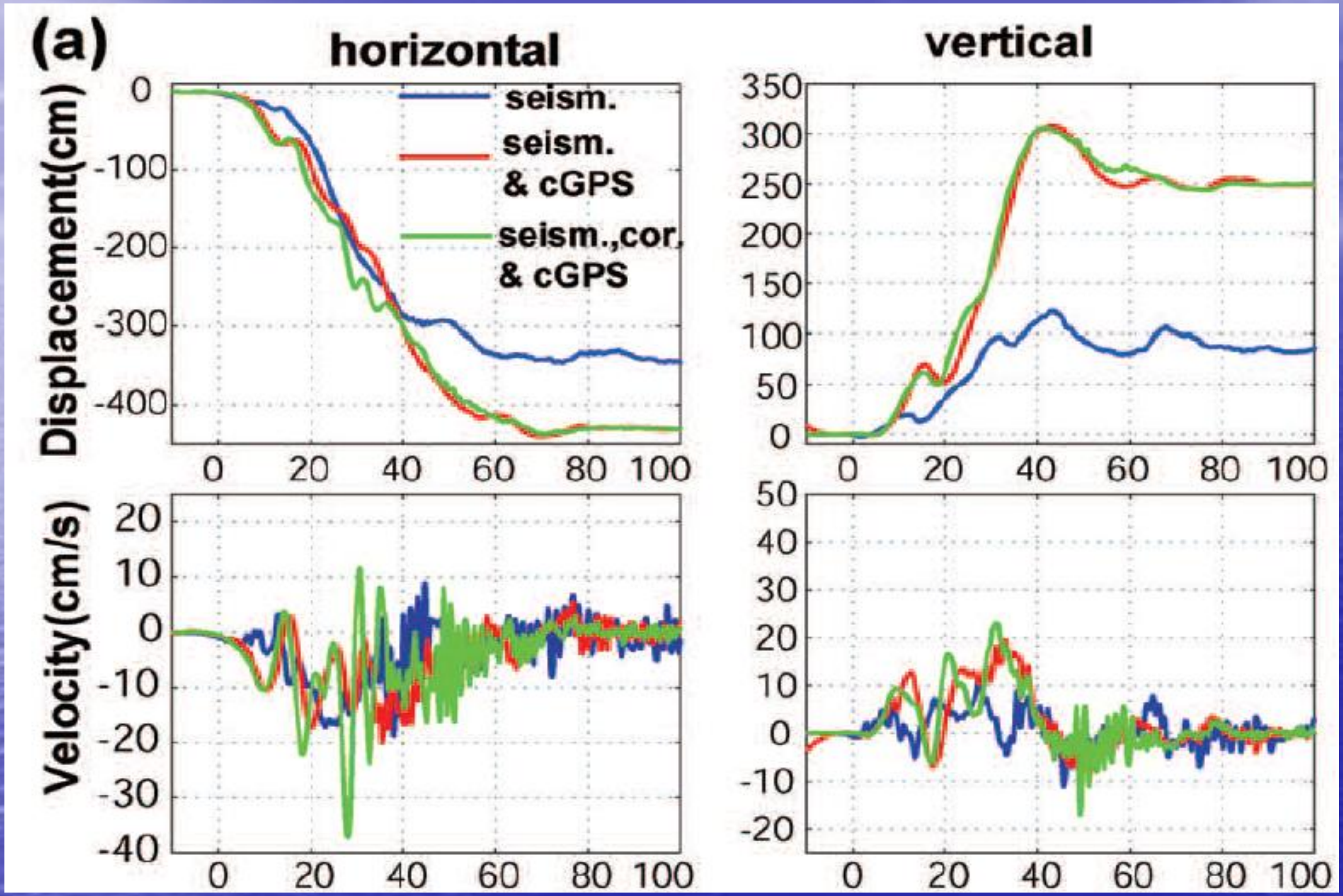
- Partition megathrust slip
- More uplift per meter of slip
- Cascadia amplification (Priest et al., 2009)
  - Inundation 6-20%
  - Water elevation at shore – 27-31%





Source: Witter et al (2011), DOGAMI SP43

Impulsive Energy

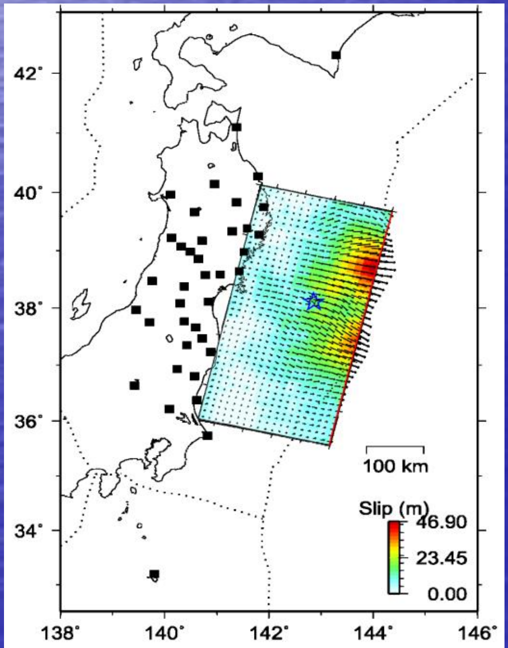


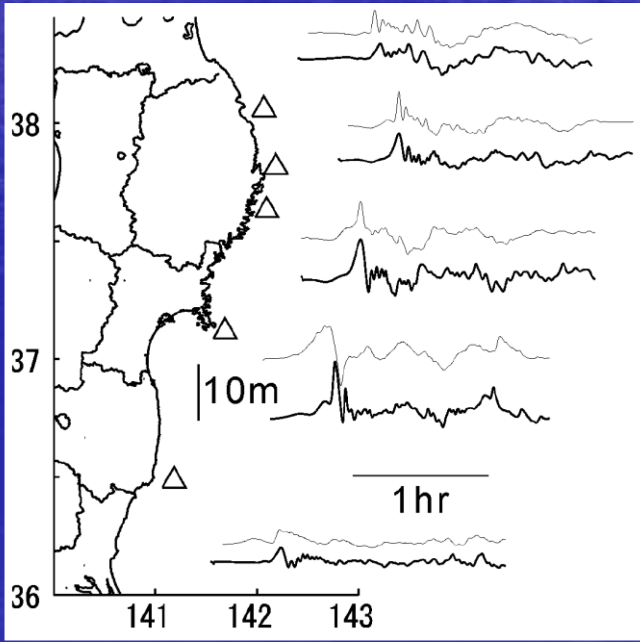
2005 Mw 8.6 Nias–Simeulue Earthquake (Konca et al., 2007)

- Horizontal component only important for steep slopes
- Vertical component critical for all slopes
- Too short in duration or scale to affect tsunami?

Tohoku Earthquake March 11, 2011

- Slow rupture velocity of 1.5 km/sec – seaward of hypocenter
- Ground acceleration up to 1000 gal
- Slip seaward skewed; partly a "tsunami earthquake"
- Max. slip ~50-70 m near trench; mean ~15 m.
- Vertical displacement >8 m
- 2-stage tsunami; 30-40 m run-up at max. slip patch





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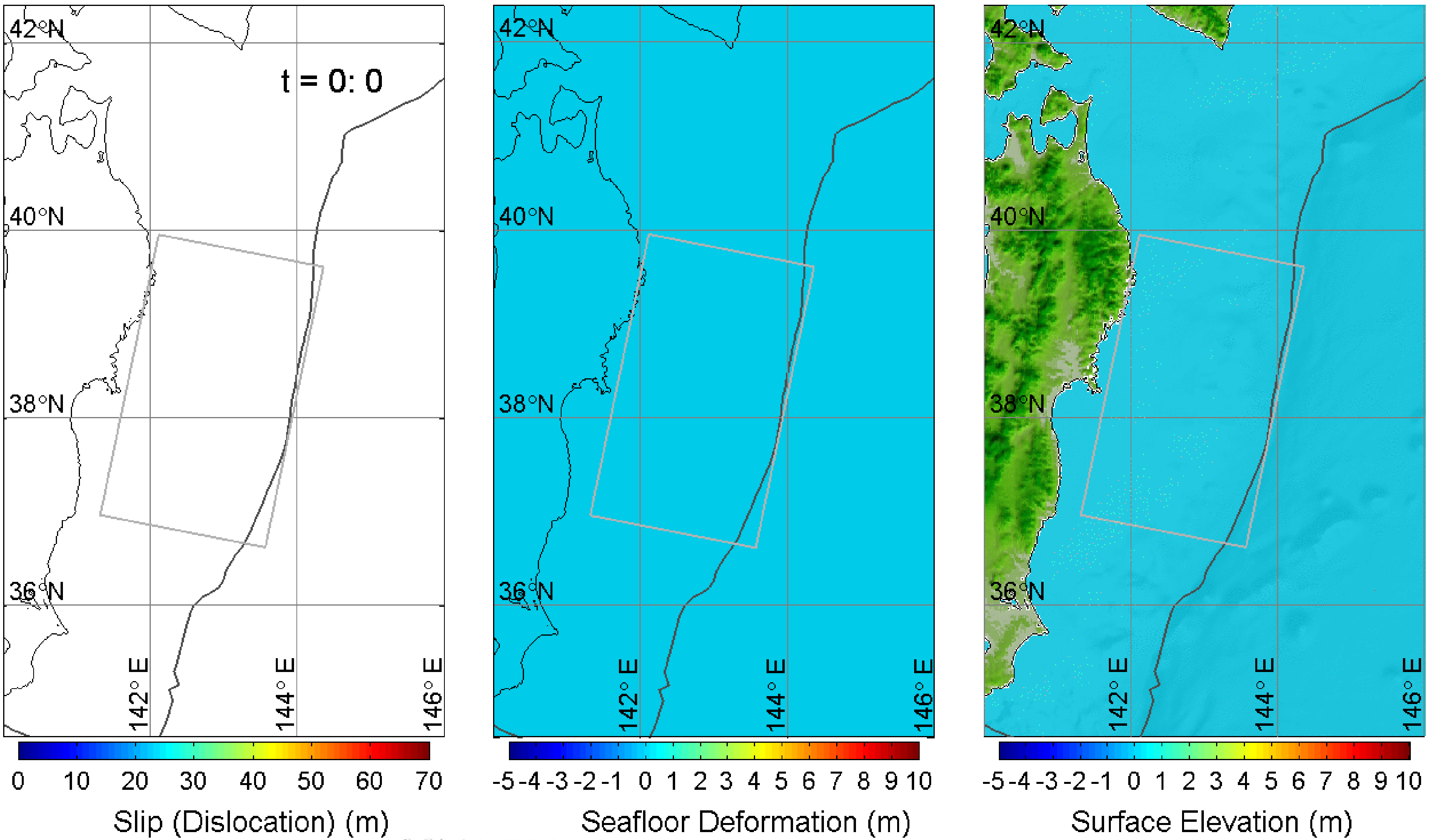
References: Lay et al. (2011), Petukhin et al. (2012), Satake et al. (2012); Yamazaki et al. (BSSA, in press)

Tohoku 2011
2-Stage rupture creates complex wave interference

Rupture Duration: 141 sec

Yamazaki et al (BSSA, 2012) in press



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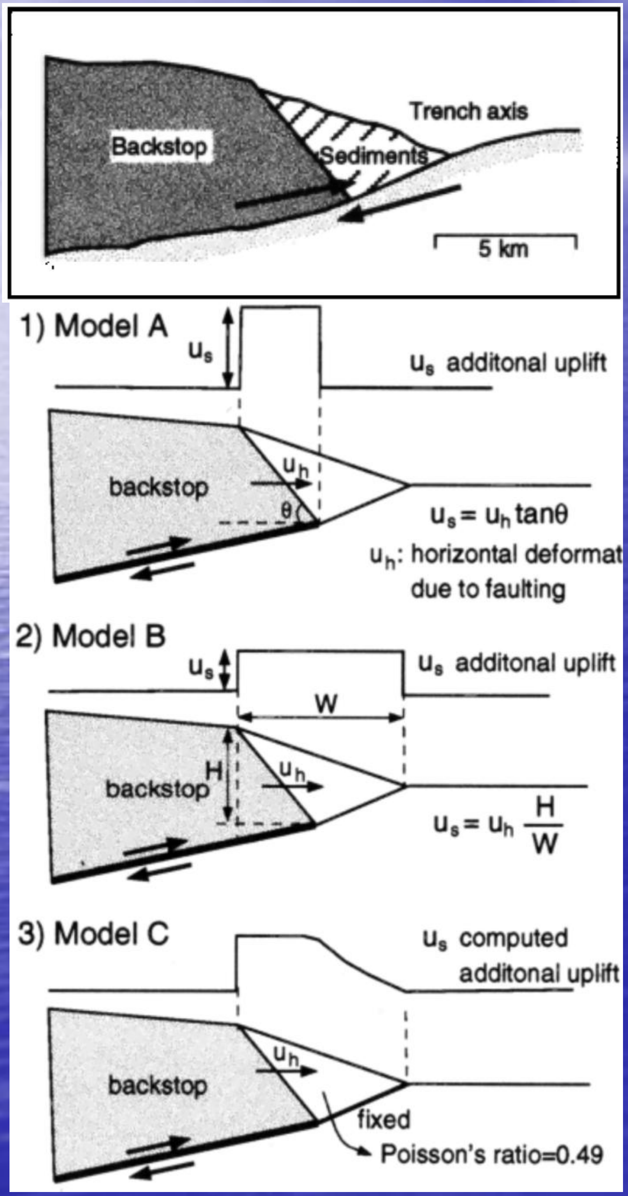
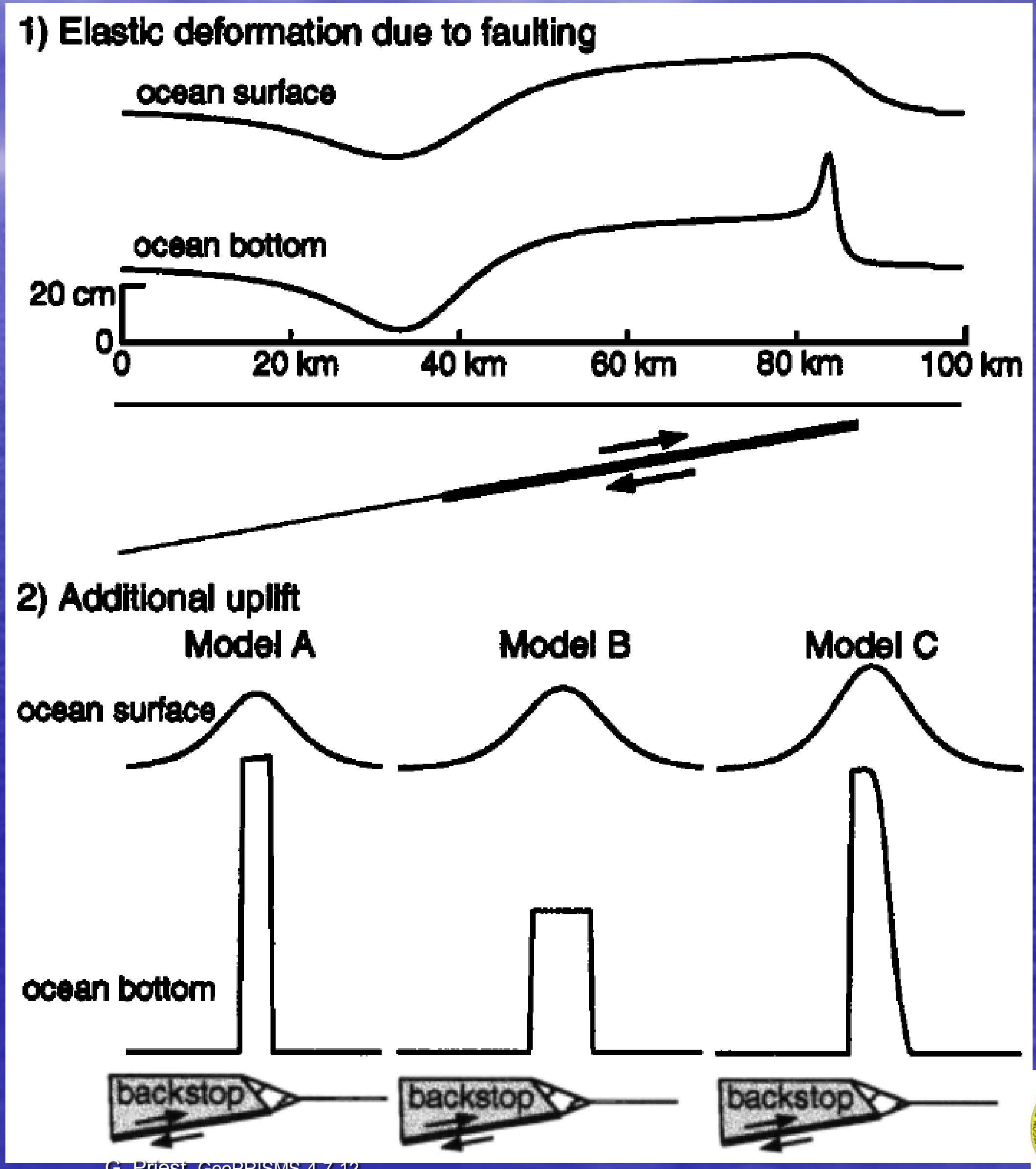
Question:

Is 50-70 m slip near Japan trench really needed to explain Tohoku tsunami?

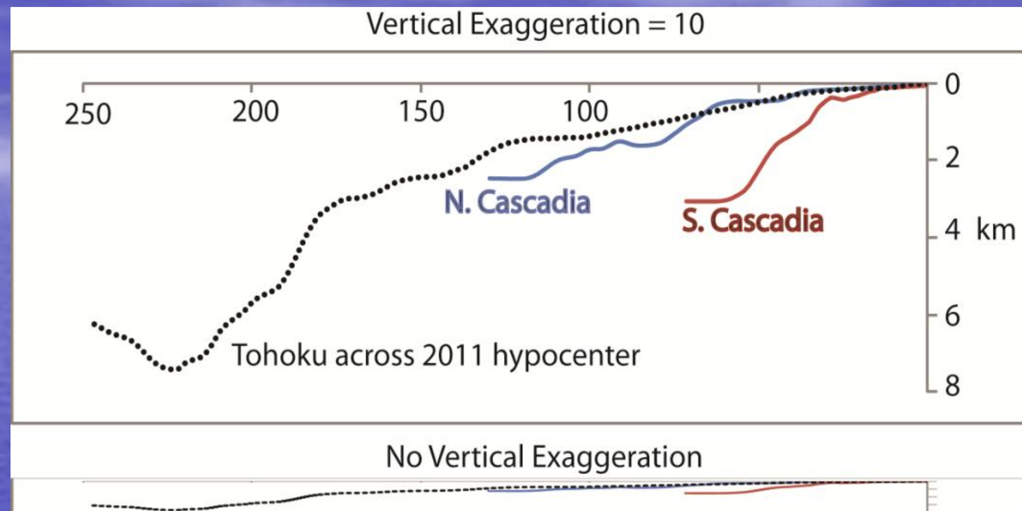
Small-scale wedge deformation can reduce needed slip e.g., 36-43 % for 1896 Sanriku tsunami (Tanioka and Seno, 2001)



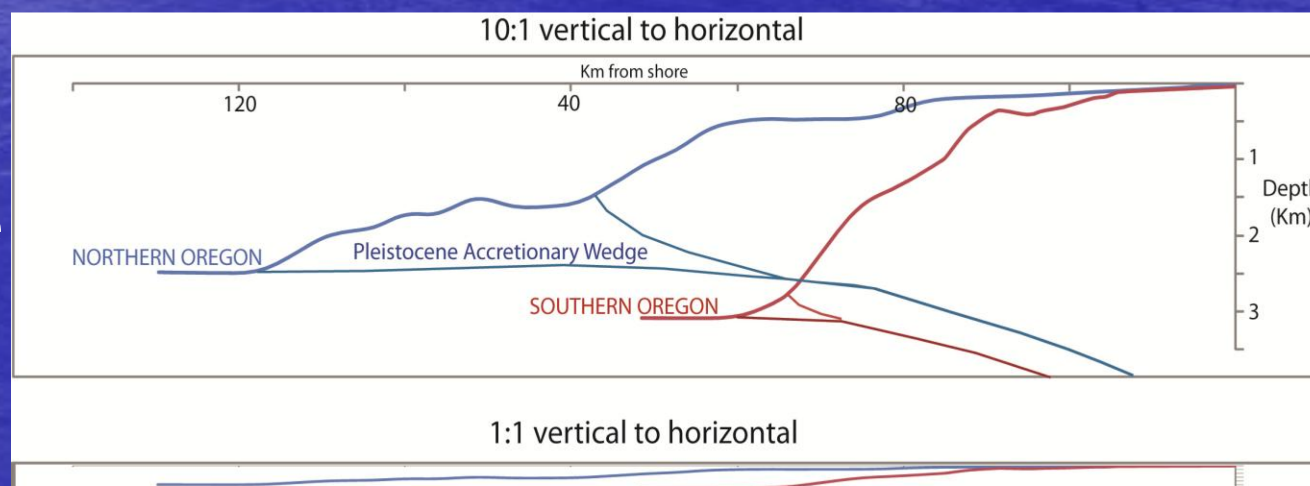


Is southern Cascadia like Tohoku?

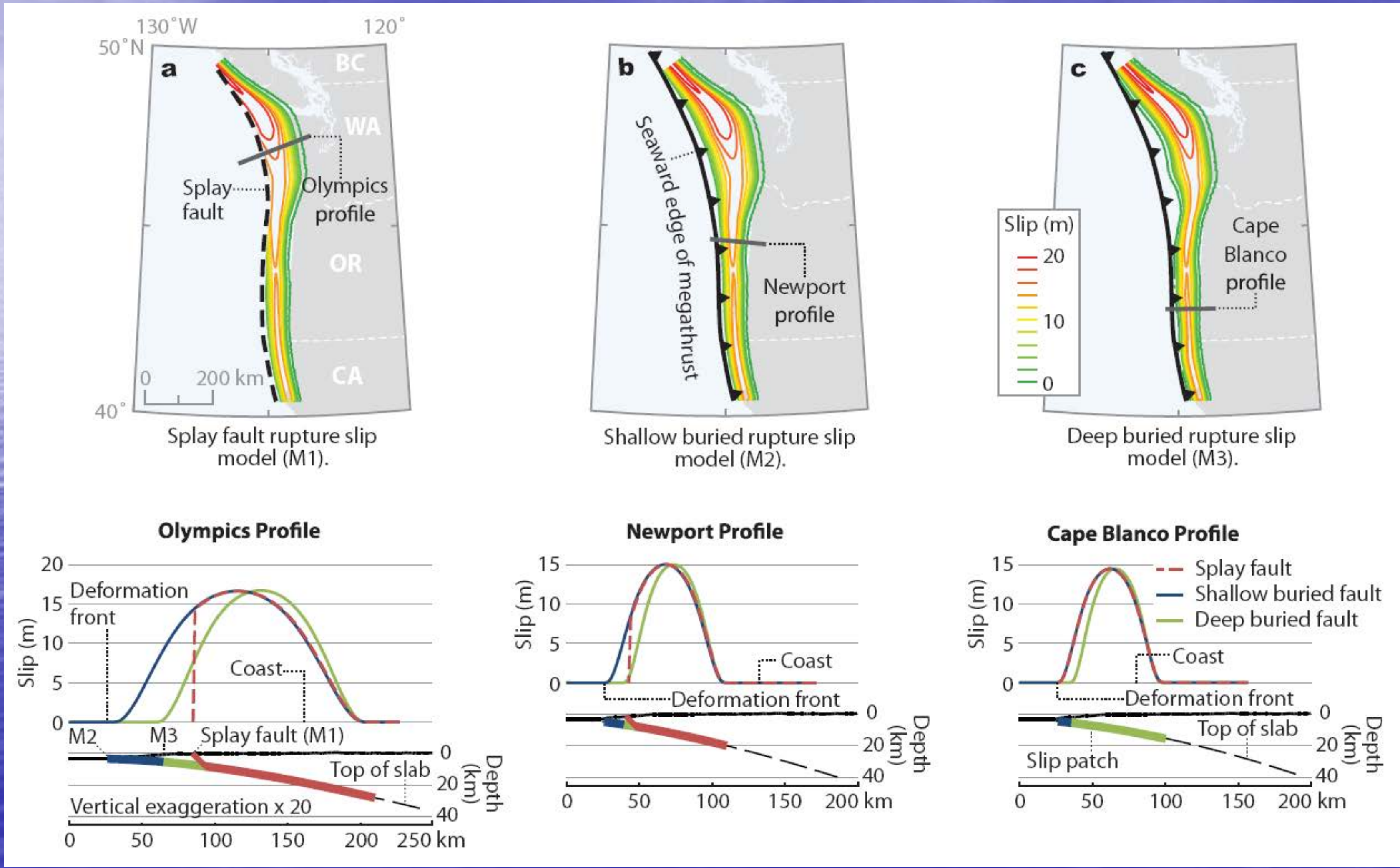
- Similar slope
- But shallower water



Small Pleistocene wedge in southern Cascadia

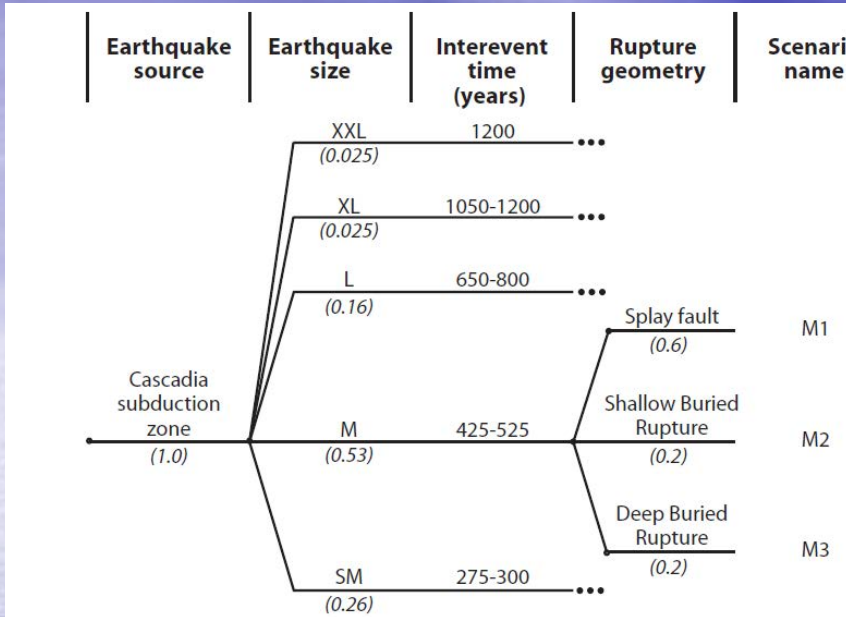


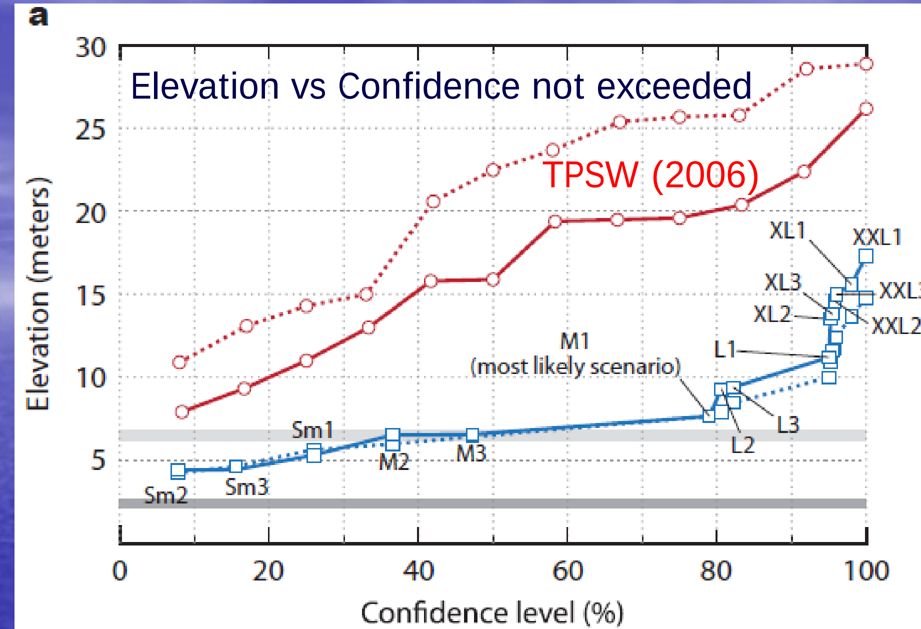
Coseismic Slip
Oregon Tsunami Simulations

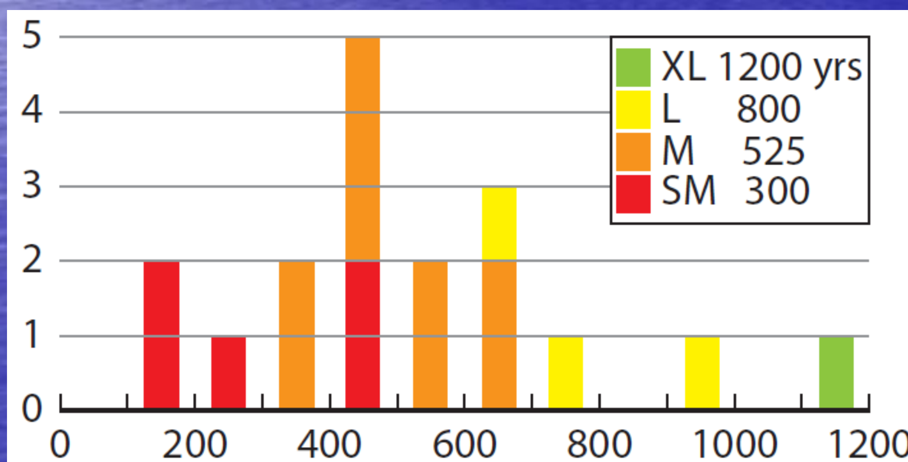


Source: Witter et al (2011), DOGAMI SP43

Cascadia Tsunami Hazard - Current Estimates





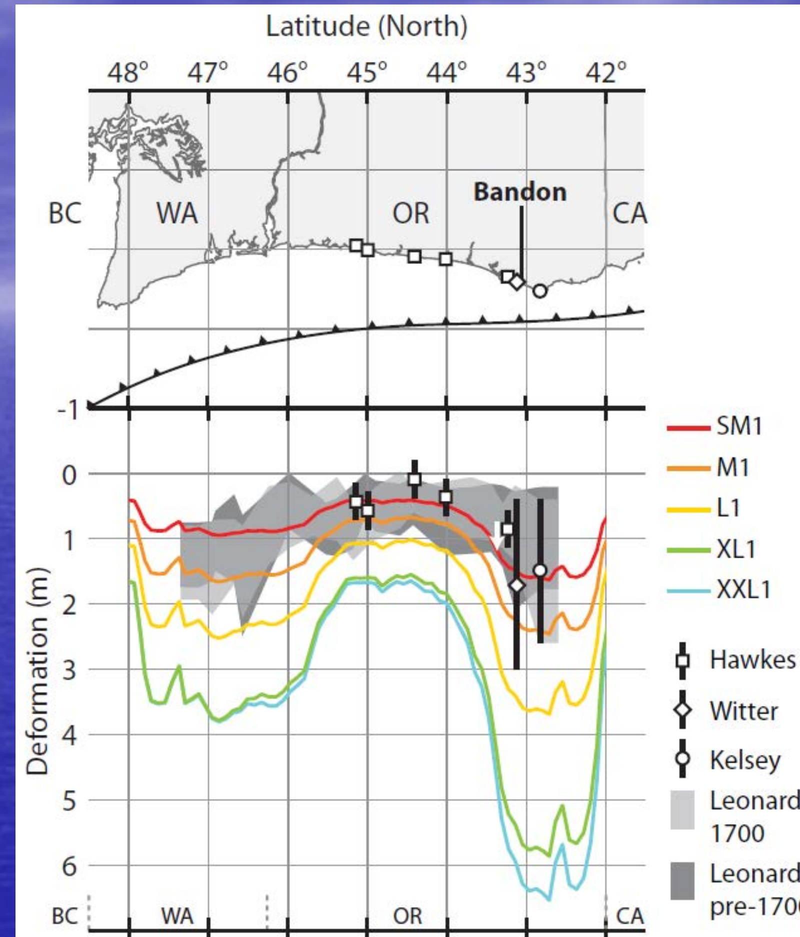


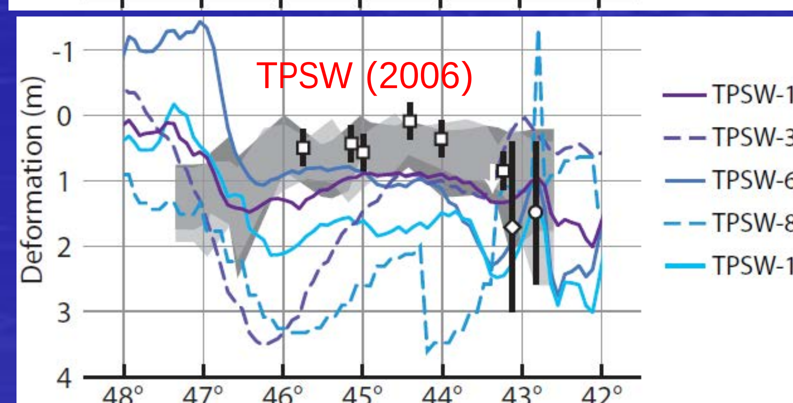
Basal branch of Logic tree:
Earthquake size frequency
from turbidite data of Goldfinger et al. (2012, USGS Prof. Paper 1661f)

Frequency over last 10,000 yrs
Earthquake size (turbidite mass) &
Follow times (turbidite record)

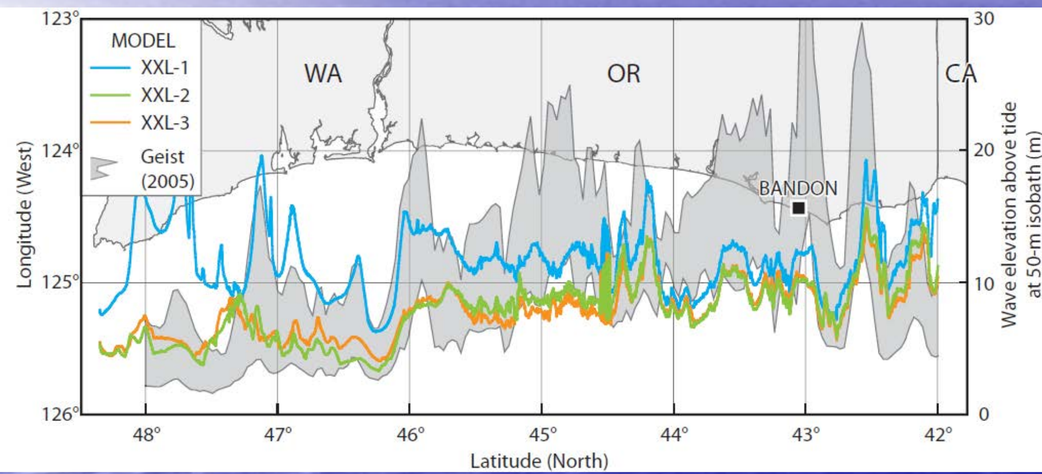
Source: Witter et al (2011), DOGAMI SP43

Coseismic Subsidence





Tsunami Size



XXL elevations at 50 m isobath (colored lines)
Geist (2005) peak near shore amplitude (gray band)

Source of figures: Witter et al (2011), DOGAMI Special Paper 43
Hawkes = Hawkes et al. (2011)
Witter = Witter et al. (2003)
Kelsey = Kelsey et al. (2005)
Leonard = Leonard et al. (2004)

RESEARCH NEEDS

- Southern Cascadia tsunami sensitivity tests
  - Near-trench deformation
  - Dynamic ruptures
  - Paleoseismic ground truth of source models (e.g. Bradley Lake)
  - Incipient landslide impact (Gold Beach-Brookings segment)
- Modern observations of
  - Coseismic deformation
  - Time histories of seafloor displacement.
  - Correlation of coseismic deformation to structure (wedge age, etc.)
- Cascadia splay fault + landslide mapping and ages
- Modeling dynamic ruptures (tsunami and fault dislocation)
- Probabilistic tsunami hazard analysis (PTHA) of :
  - Slip magnitude
  - Slip distribution
  - Dynamic ruptures
  - Landslides