



# The CRESCENT Dynamic Rupture, Earthquake Cycle, and Tsunamis Working Group (DET)

DET Leadership Team: Eric Dunham, Alice Gabriel, Brittany Erickson, Benchuan Duan, Ruth Harris, Ignacio Sepulveda, Yihe Huang, Yajing Liu, James Biemiller

## The 1700 Great Cascadia Earthquake

On January 26, 1700 at 21:00 PST a magnitude 9 earthquake occurred on the Cascadia Subduction Zone. The earthquake generated a tsunami that propagated across the Pacific Ocean, inundating the coast of Japan approximately nine hours later.

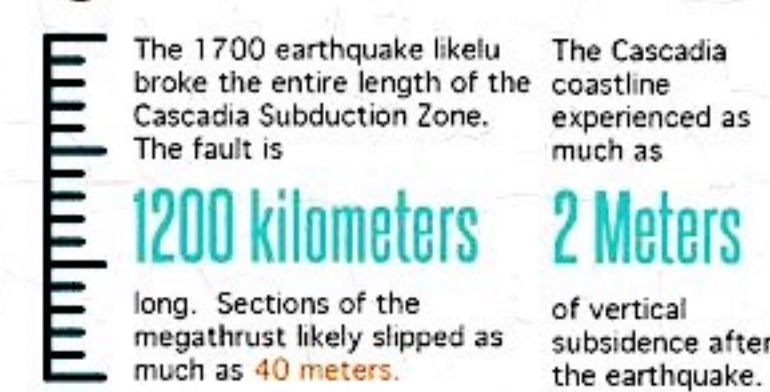
### The Earthquake

#### Magnitude



If it occurred today the 1700 earthquake would be the 5th largest earthquake recorded in instrumental times.

#### Deformation



#### Ground Motions



### The Tsunami

#### Speed

**800 km/hr**

The tsunami originated offshore Cascadia and took between **10 and 30 minutes** to reach the Pacific Coast. It also traveled across the Pacific Ocean and arrived in Japan about 9 hours after the earthquake occurred.



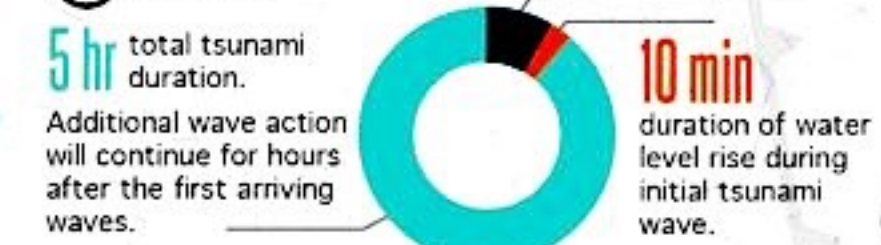
#### Height



#### Inundation

The tsunami propagated as much as **8 Kilometers** inland along existing rivers and estuaries.

#### Timeline



Strong ground motions would've occurred throughout Cascadia with extreme, violent shaking at coastal locations.



The 1700 Earthquake caused coastal subsidence along most of the Cascadia margin.

North America moved westward by up to **4 Meters**.



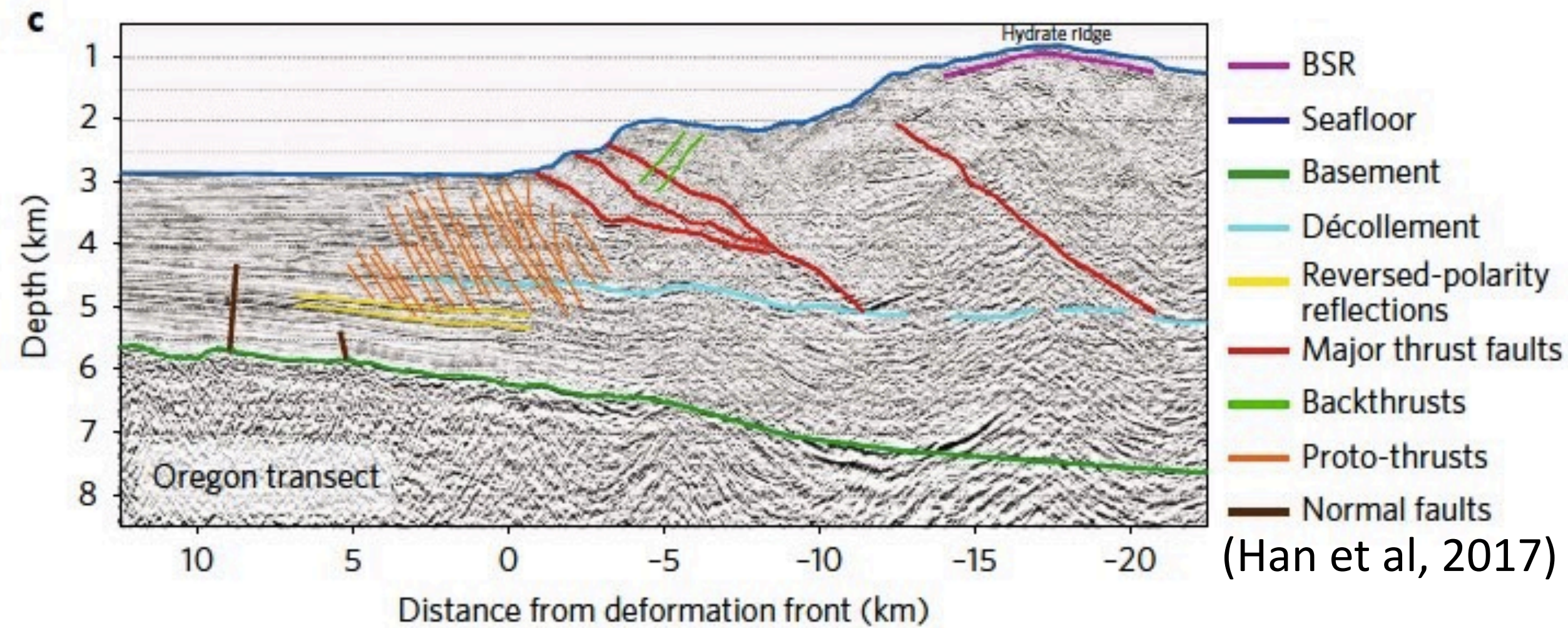
Strong ground motions likely caused significant ground failures such as landslides in the coast ranges.



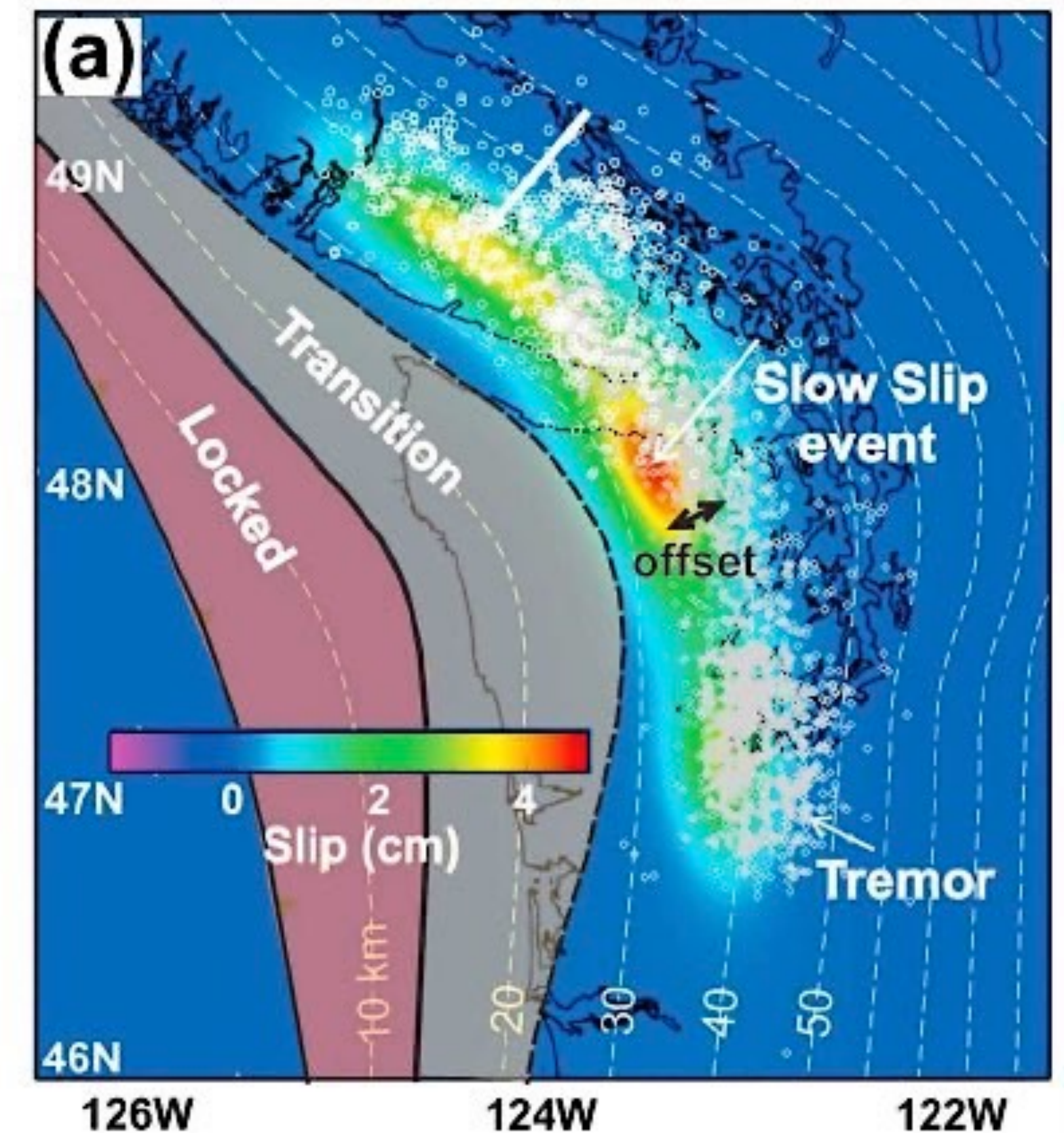
Widespread tsunami inundation all along the Pacific coast.

# Motivating science questions

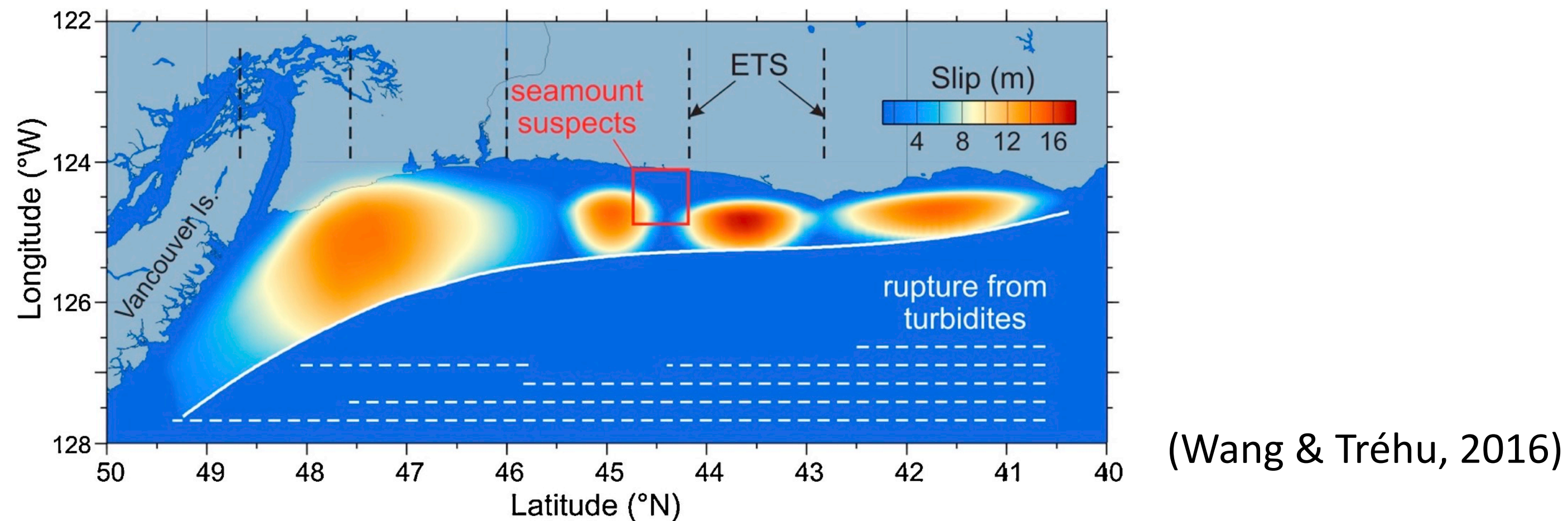
Shallow rupture behavior, splays and yielding and tsunami generation



Relation between megathrust ruptures, transition zone, slow slip & tremors



Controls on along-strike variations, segmentation and rupture extend

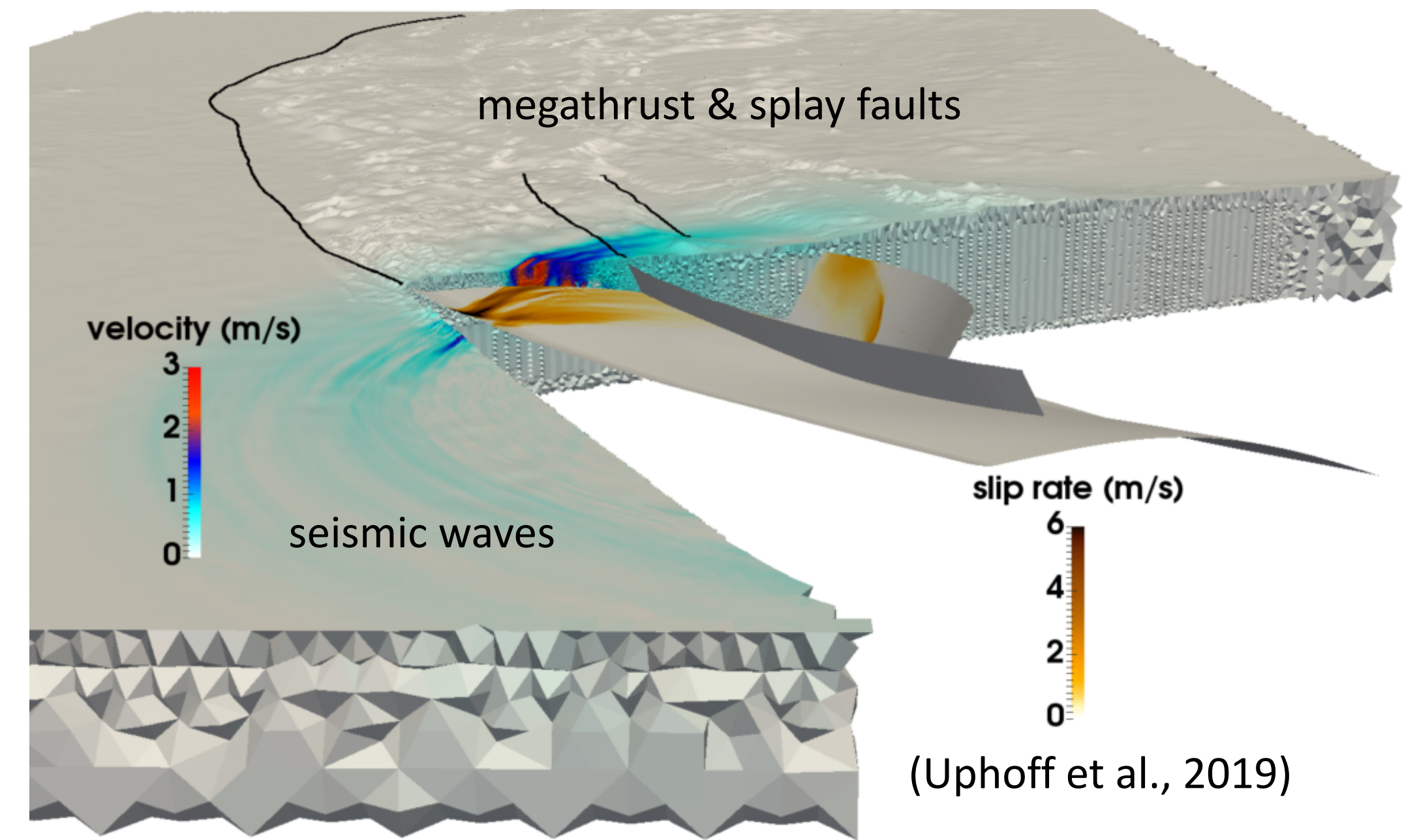


# DET Community Products

**Self-consistent earthquake dynamic rupture and tsunami models (it's the same source!)**

## **3D dynamic rupture simulations (SeisSol)**

- complex geometries (CFM, bathymetry)
- heterogeneous elastic properties (CVM)
- splay faults
- sediment yielding
- sources informed by coupling model
- validation with paleoseismology



**Tsunami generation as part of simulation (minutes), tsunami propagation (hours) with different codes**

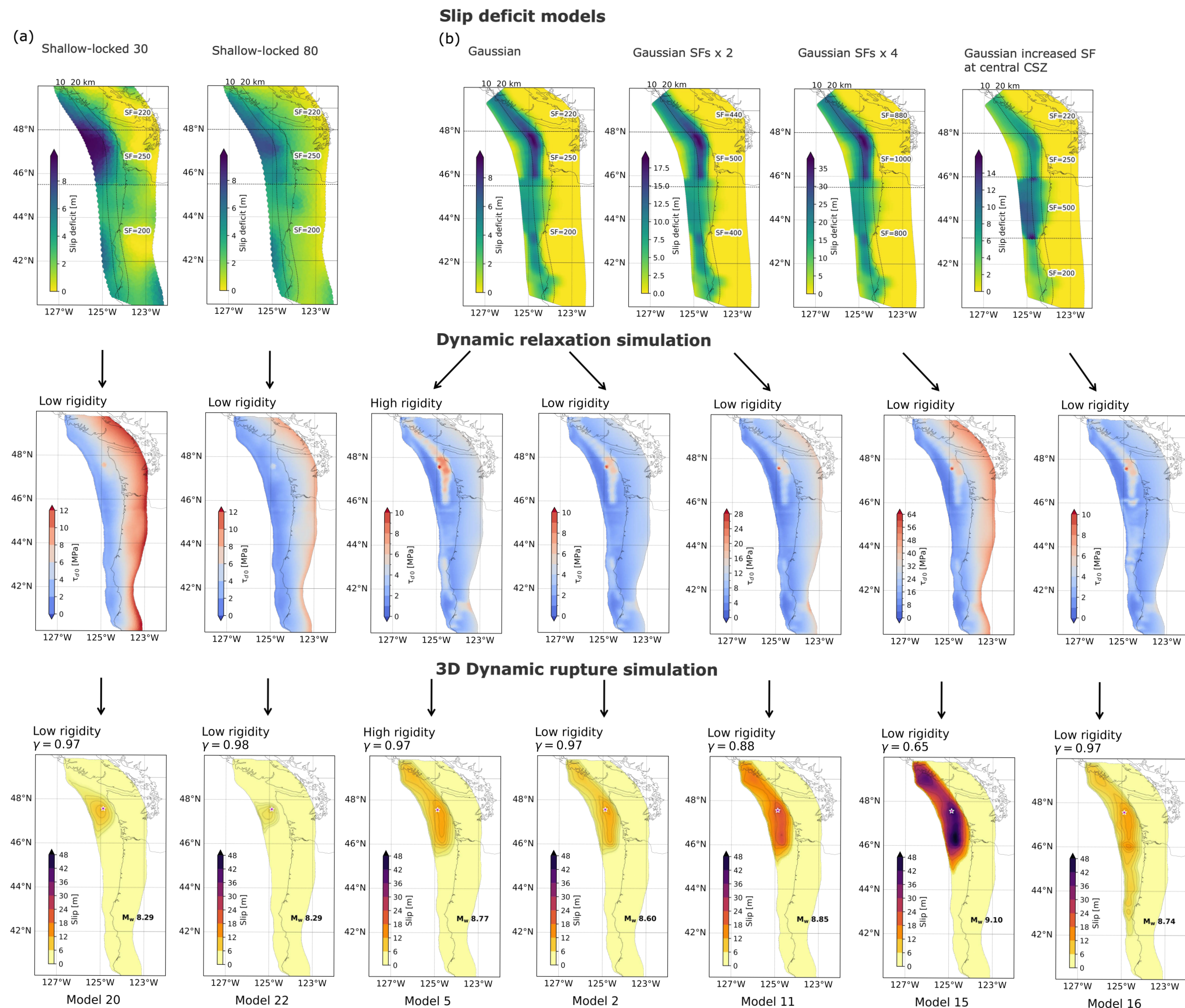
# DET Community Products

Self-consistent earthquake dynamic rupture and tsunami models (it's the same source!)

(Glehman, Gabriel, Ulrich, Ramos, Huang and Lindsey, *preprint*)

## 3D dynamic rupture simulations (SeisSol)

- complex geometries (CFM, bathymetry)
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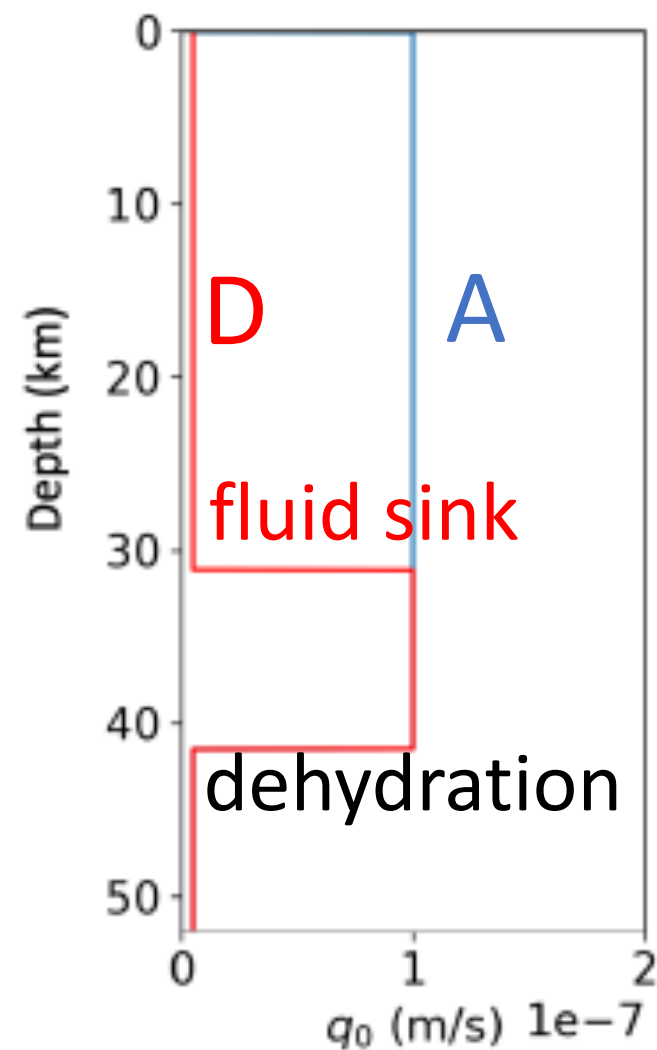


*Partial ruptures governed by the complex interplay between geodetic slip deficit, rigidity, and pore fluid pressure in 3D Cascadia dynamic rupture simulations*

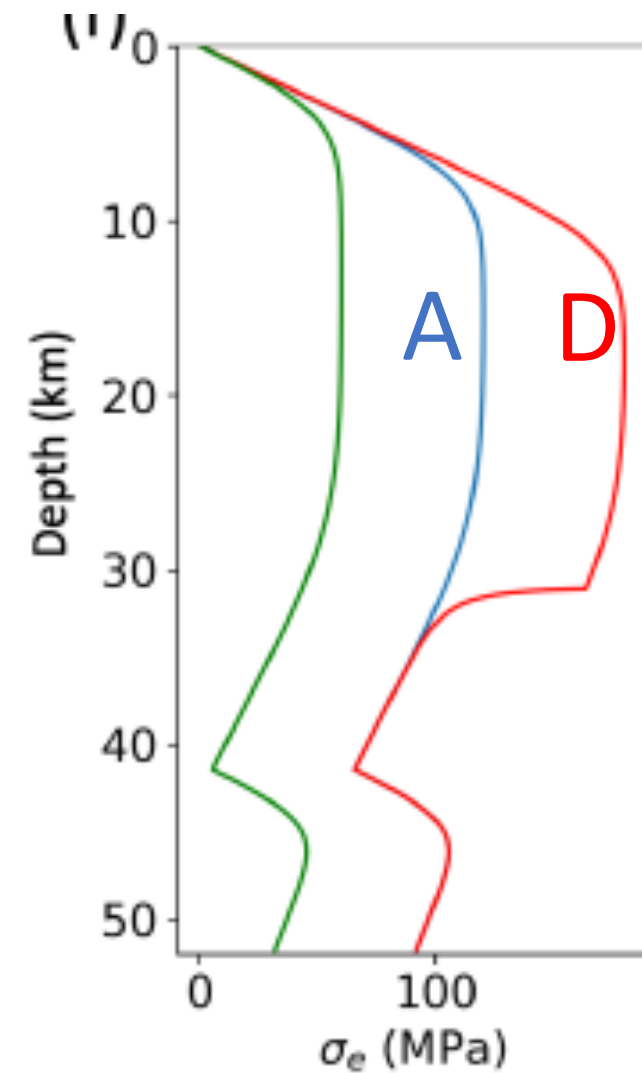
# DET Community Products

## 2D and 3D earthquake cycle models with fluid transport and viscoelasticity

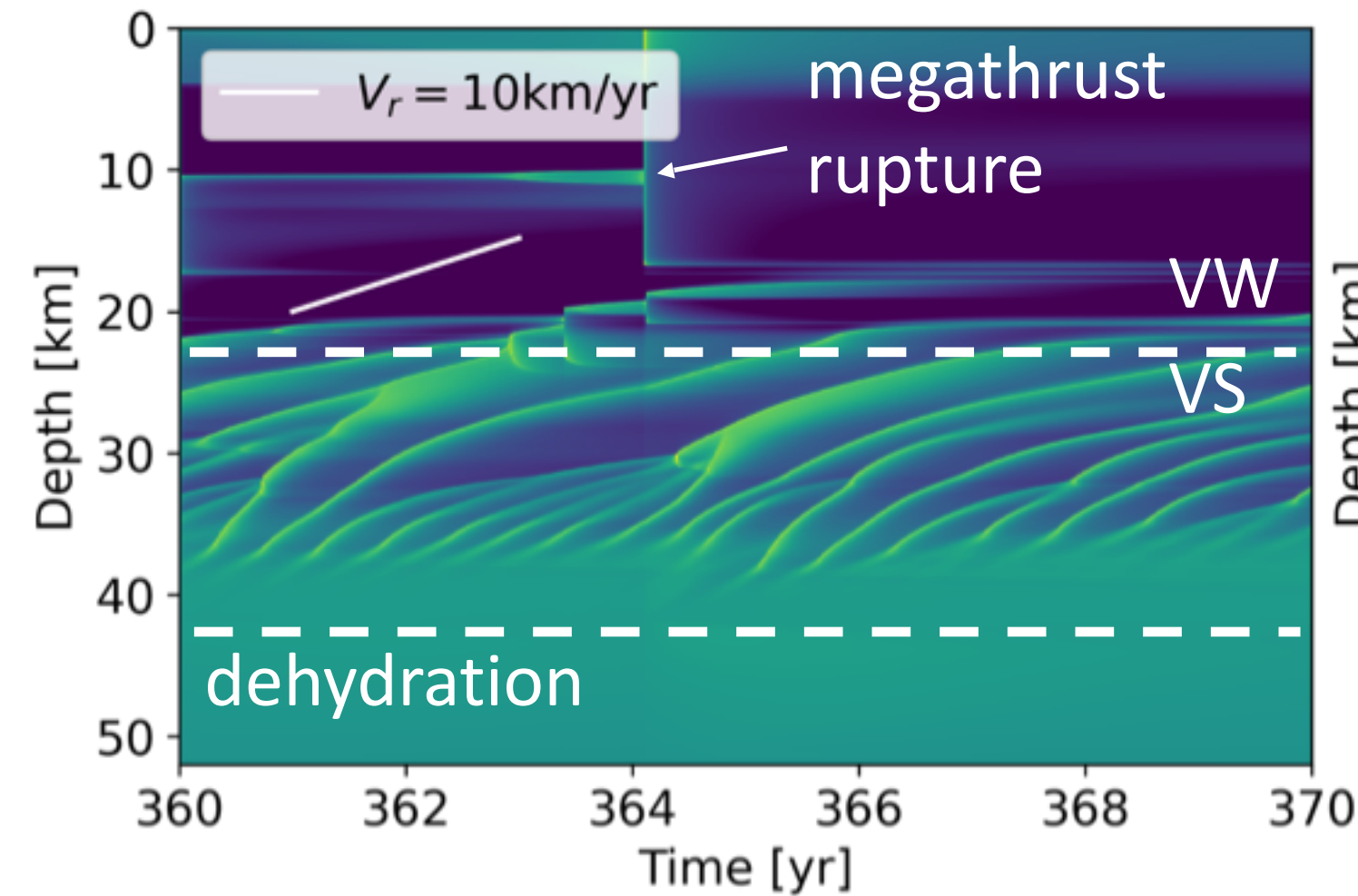
updip  
fluid flux



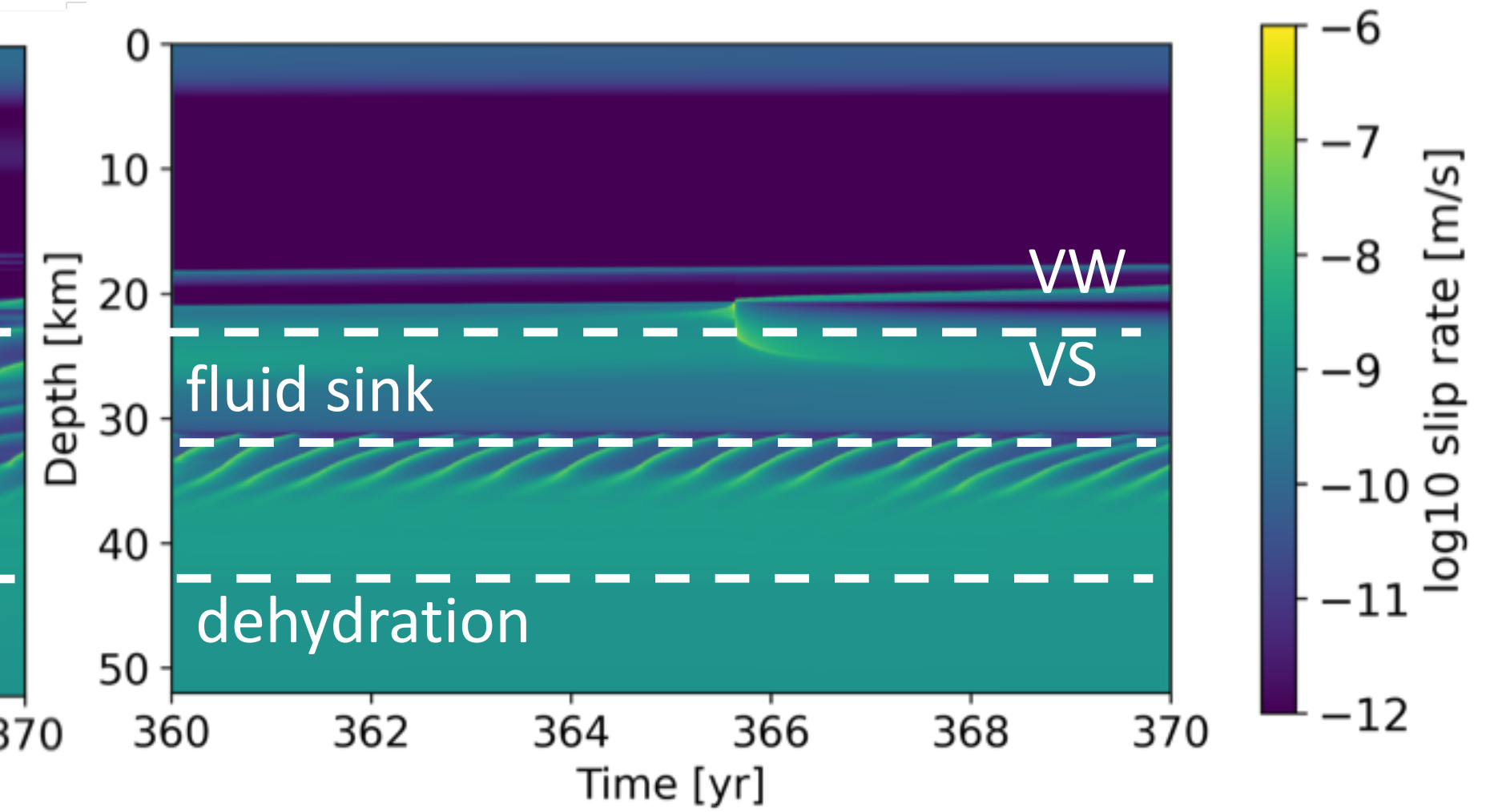
fault effective  
normal stress



(a) Model A



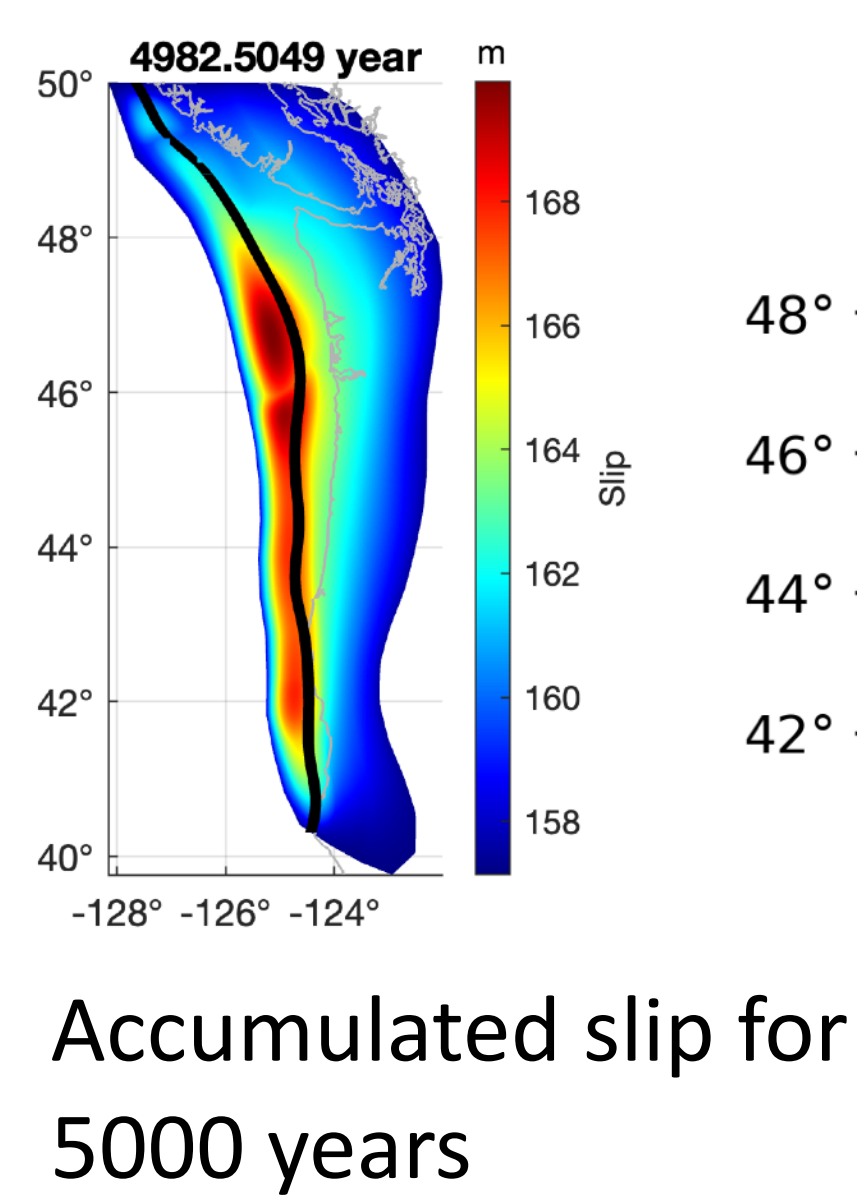
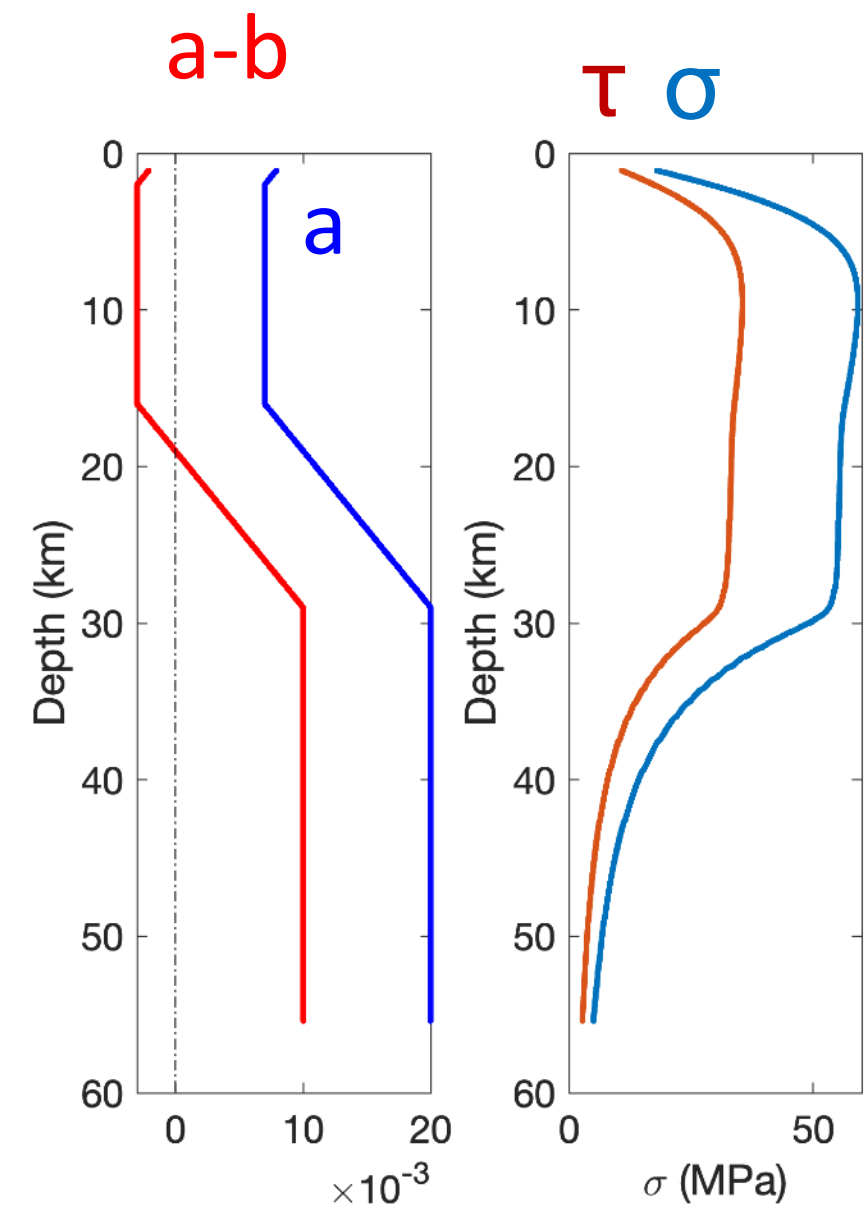
(d) Model D (fluid sink)



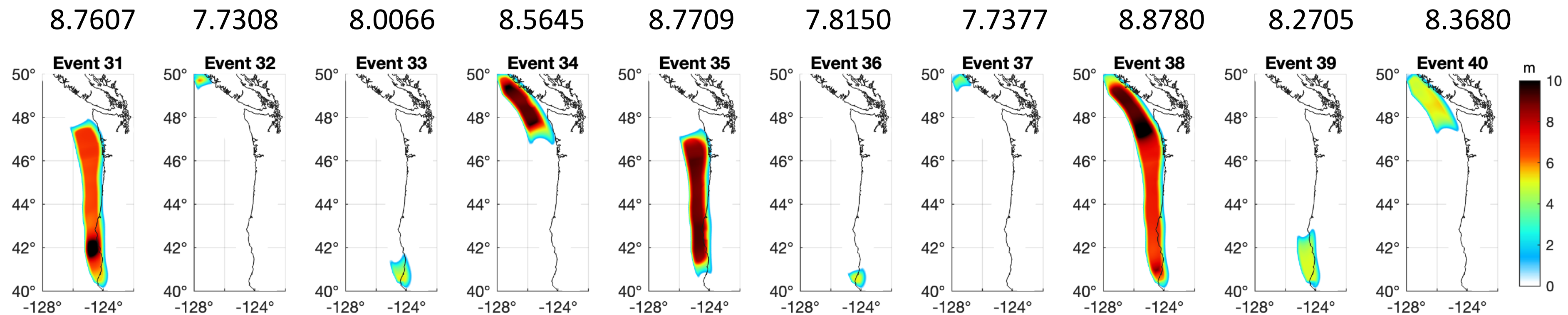
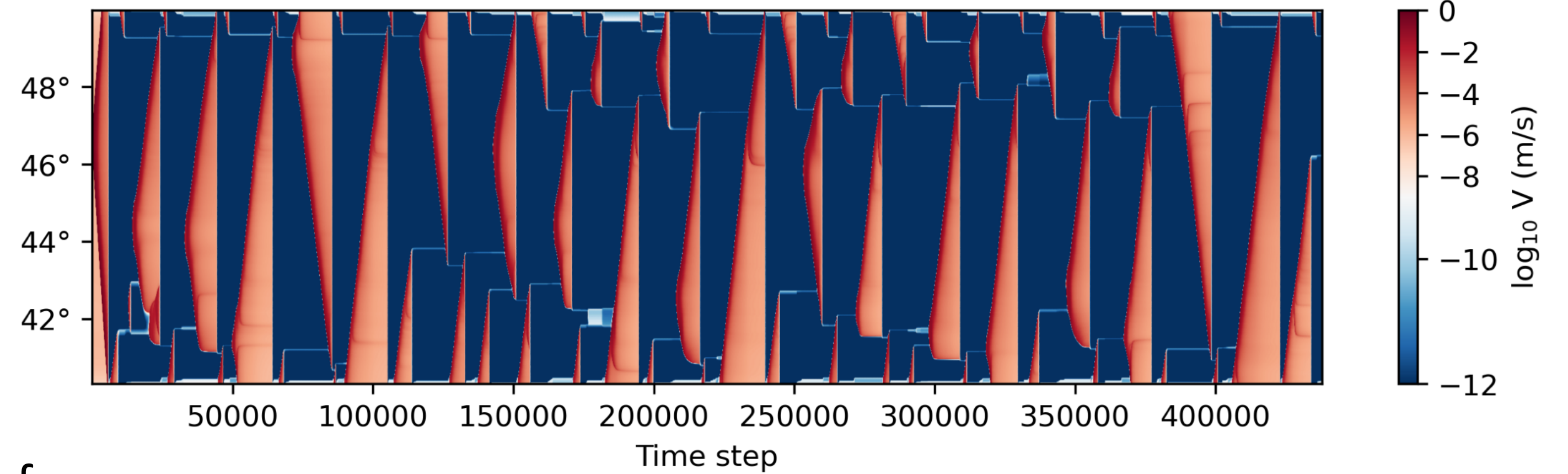
- initially 2D, then moving to 3D
- test hypotheses for slow slip events and their relation to megathrust ruptures
- self-consistency with fluid production and transport (Fluids SIG)

# 3D Cascadia earthquake cycle modeling with viscous flow

Zhang, Ozawa, Dunham (in progress)

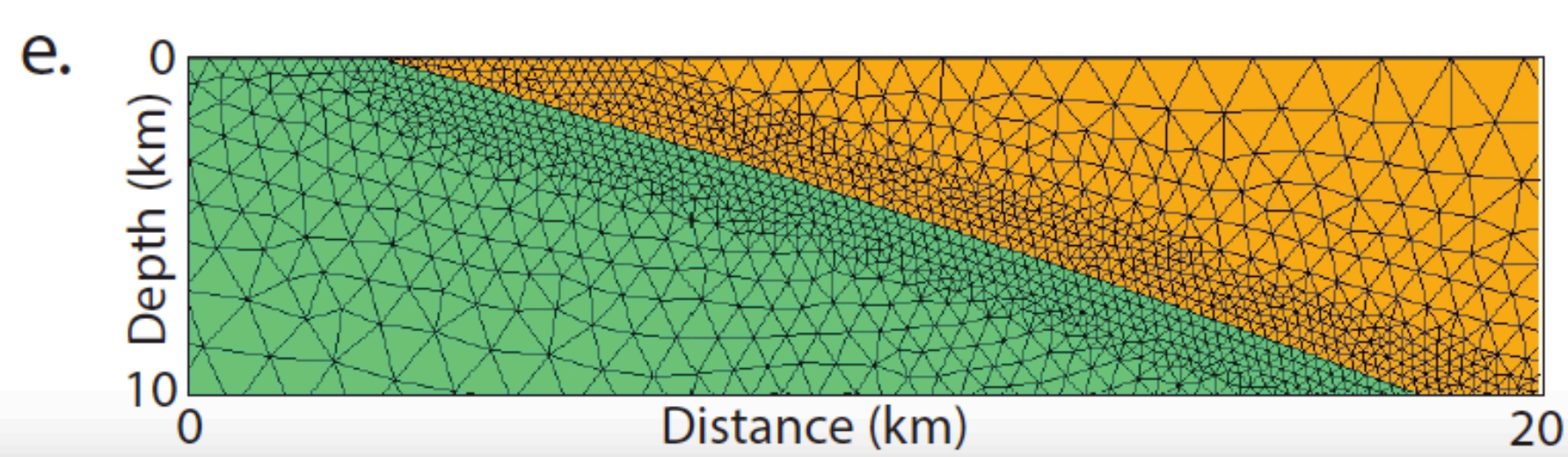
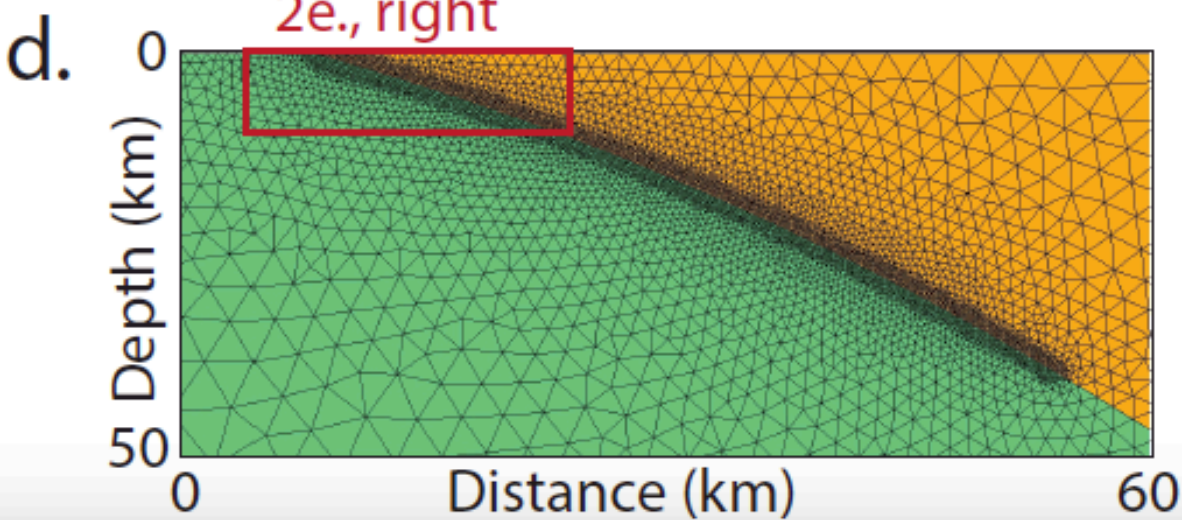
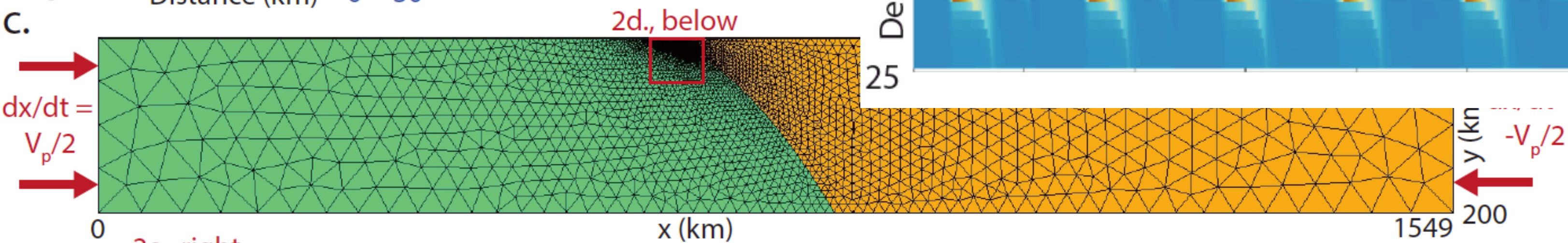
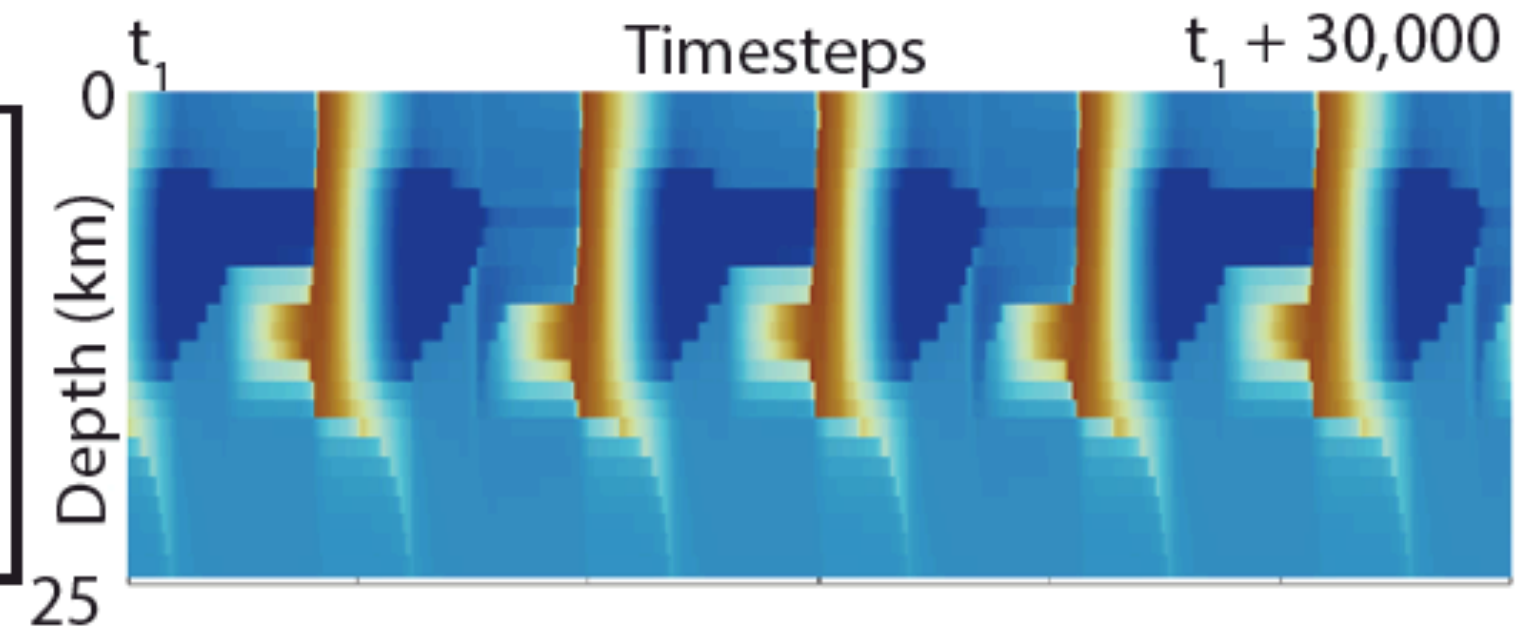
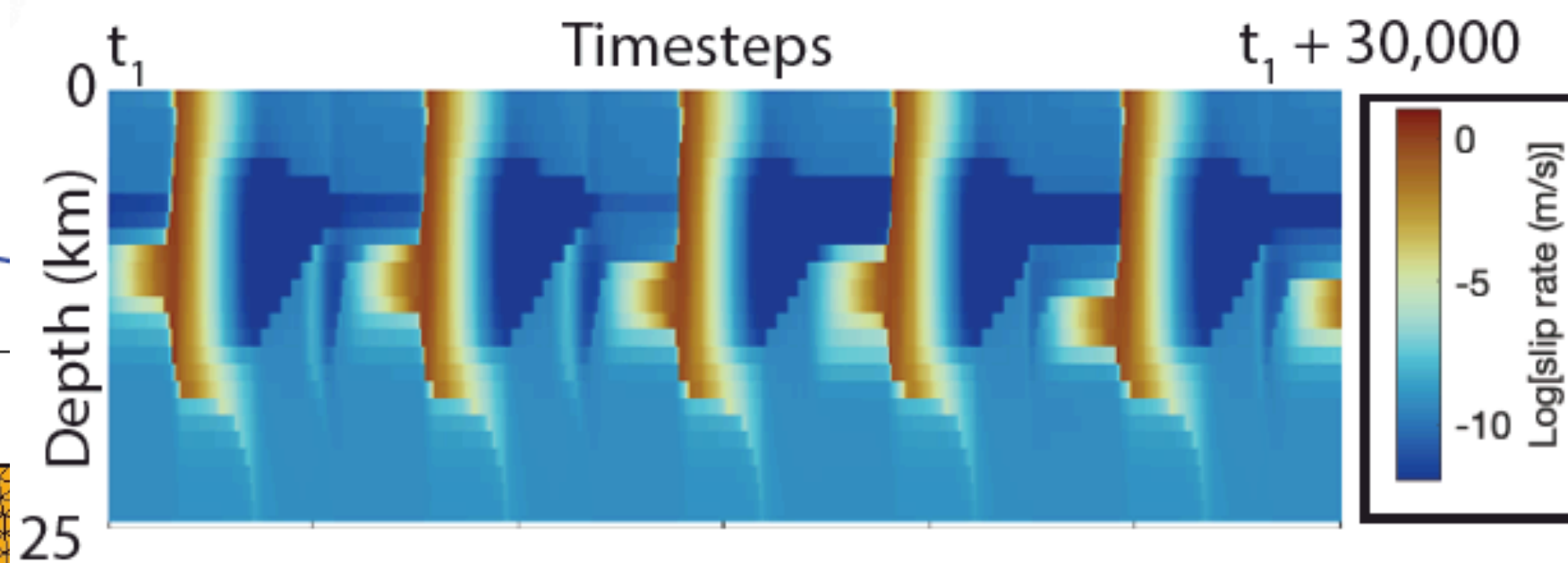
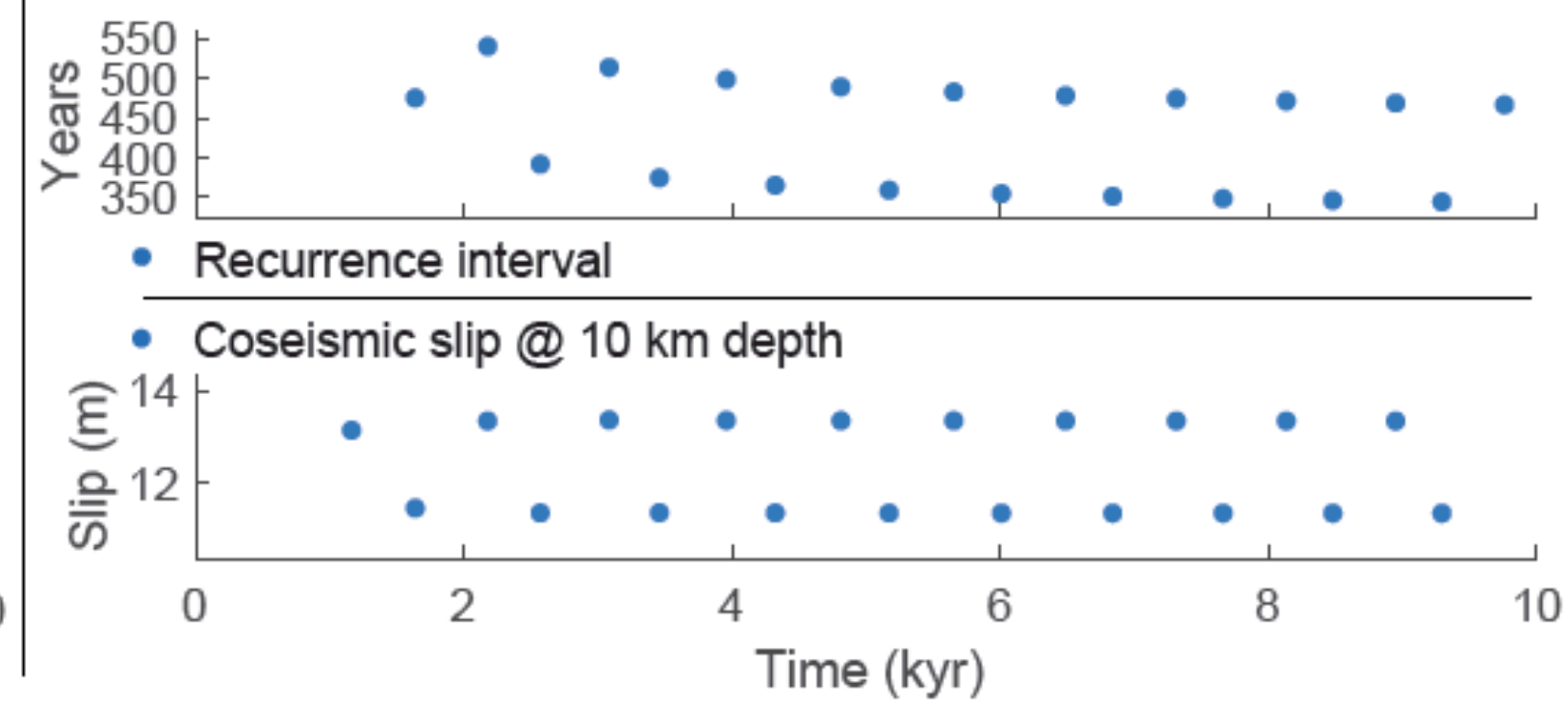
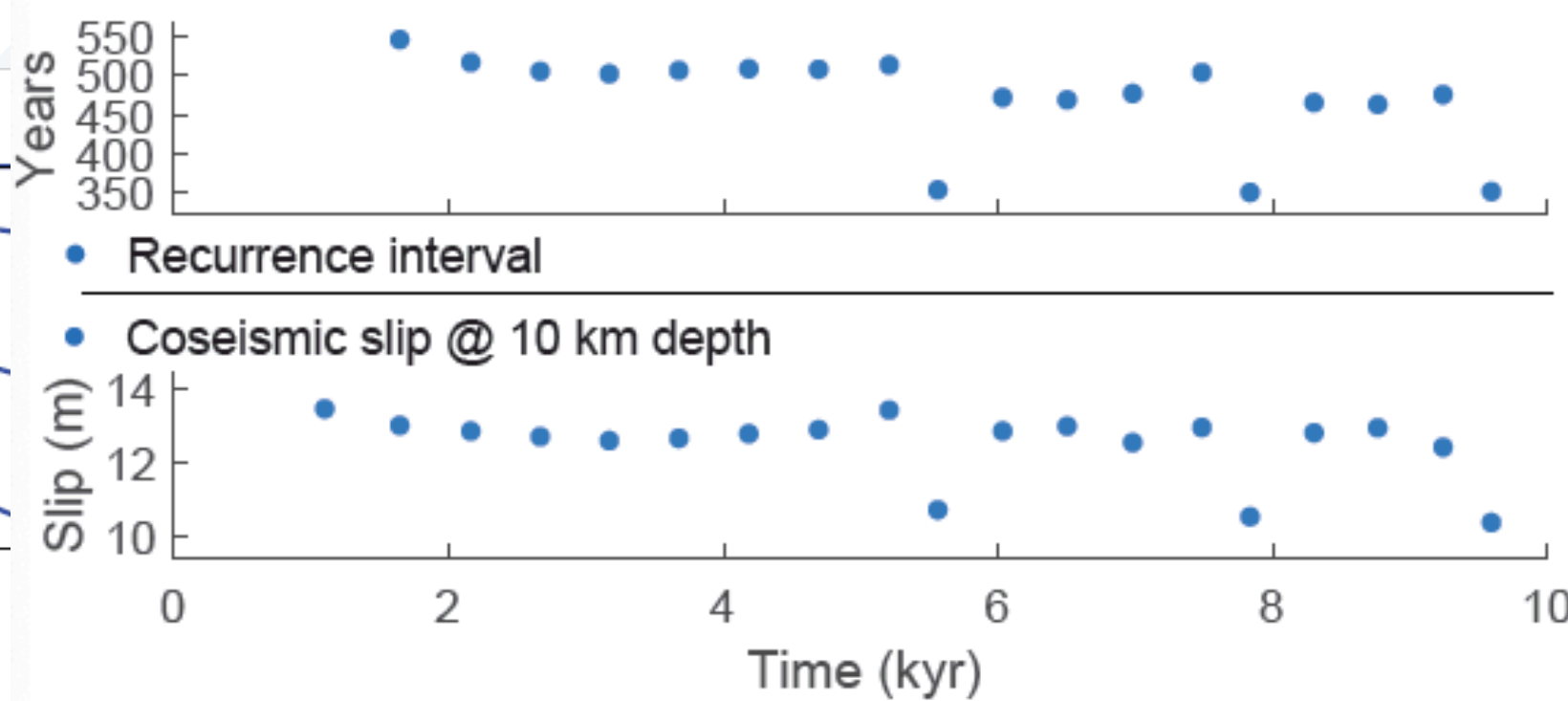
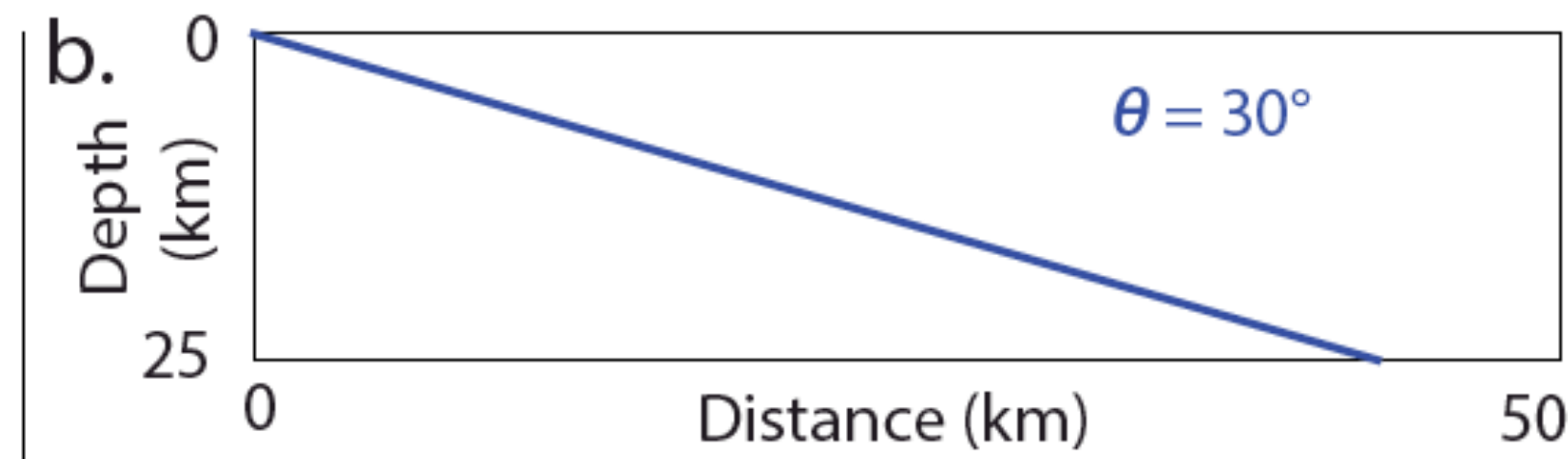
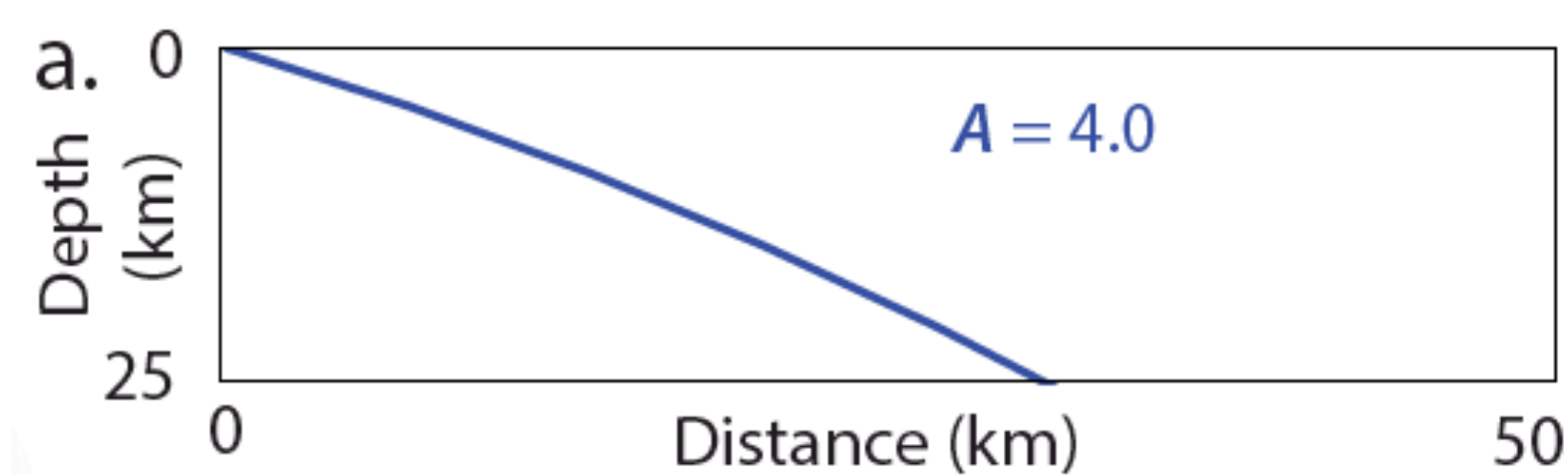
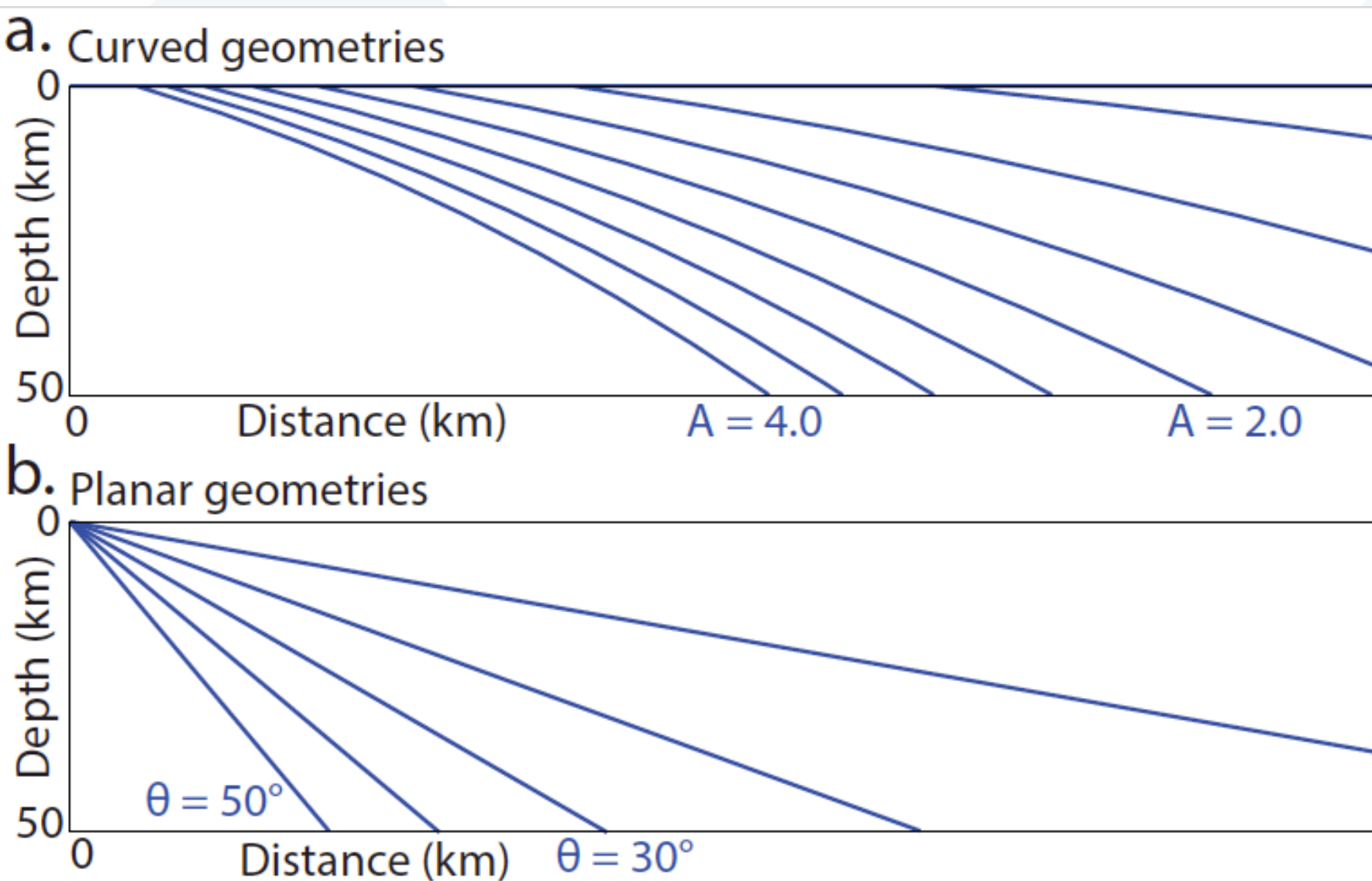


depth 10 km profile



# Earthquake cycle models

- 2D earthquake cycle simulations with *tandem*
- Varied megathrust dip & downdip curvature
- Max. earthquake size primarily  $f(W/h^*) \propto$  dip
- Curvature  $\rightarrow$  event variability & recurrence
- e.g. periodic, bimodal, or supercyclic events



Biemiller, J., Gabriel, A.-A., May, D., Staisch, L., Subduction zone geometry modulates the megathrust earthquake cycle: magnitude, recurrence, and variability. *JGR: Solid Earth*.

# Code verification through community benchmark problems and cross-comparison

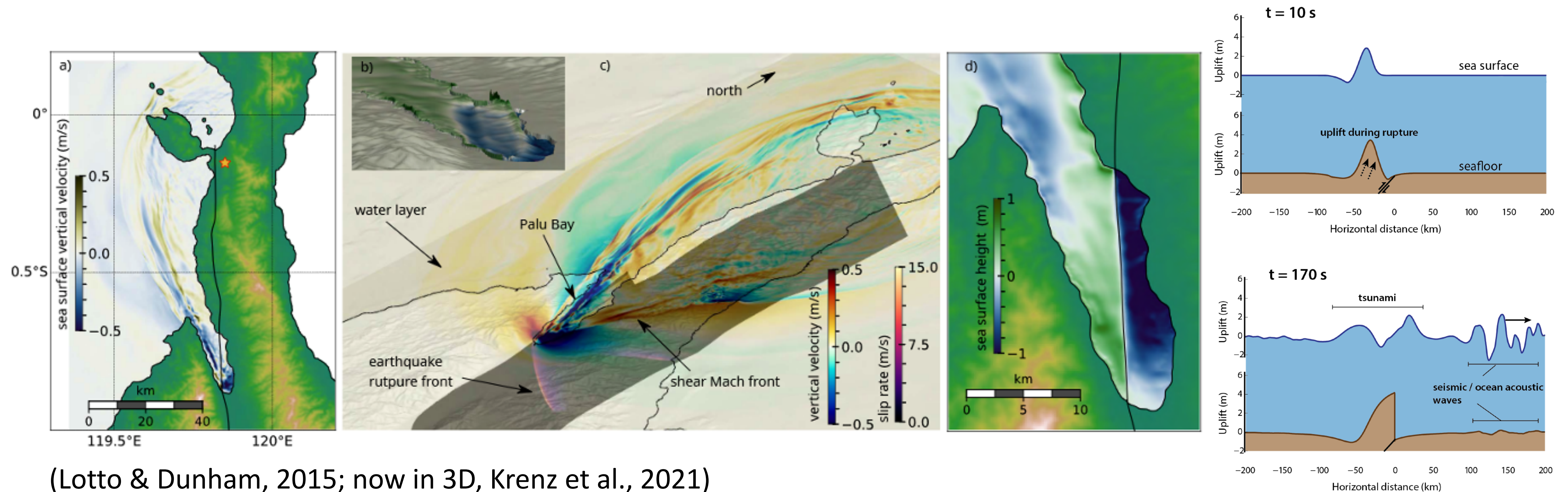
- Our current TPV36/37 benchmark is jointly organized and includes the calculation of seafloor uplift
- Upcoming in **Spring 2025**: added water layer (and off-fault plasticity?)

## Upcoming earthquake cycle benchmarks for megathrusts

YR 2. Elastic solid, general solution

YR 3. Elastic solid, focus on slow slip events

YR 4&5. Viscoelasticity and fault-zone fluid transport



(Lotto & Dunham, 2015; now in 3D, Krenz et al., 2021)



# Timeline and upcoming topical and training workshops

## Workshops:

- fluids and faulting (YR2)
- shallow rupture (YR3)
- slow slip (YR4)
- model validation with paleoseismic data (YR5)
- training for DET modeling software (YR5)

