Dynamic and Kinematic Modeling of Branch Faulting

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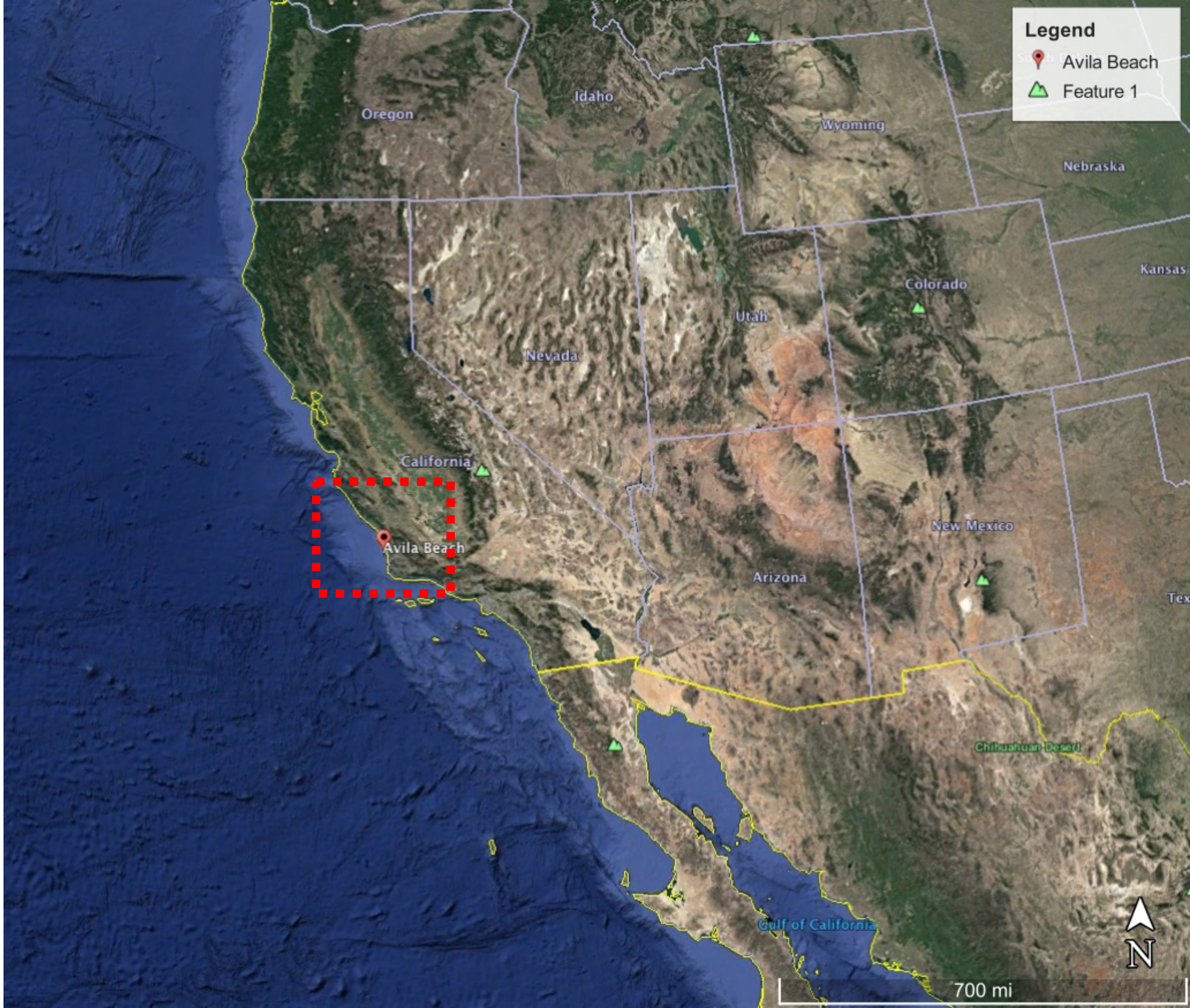
Outline

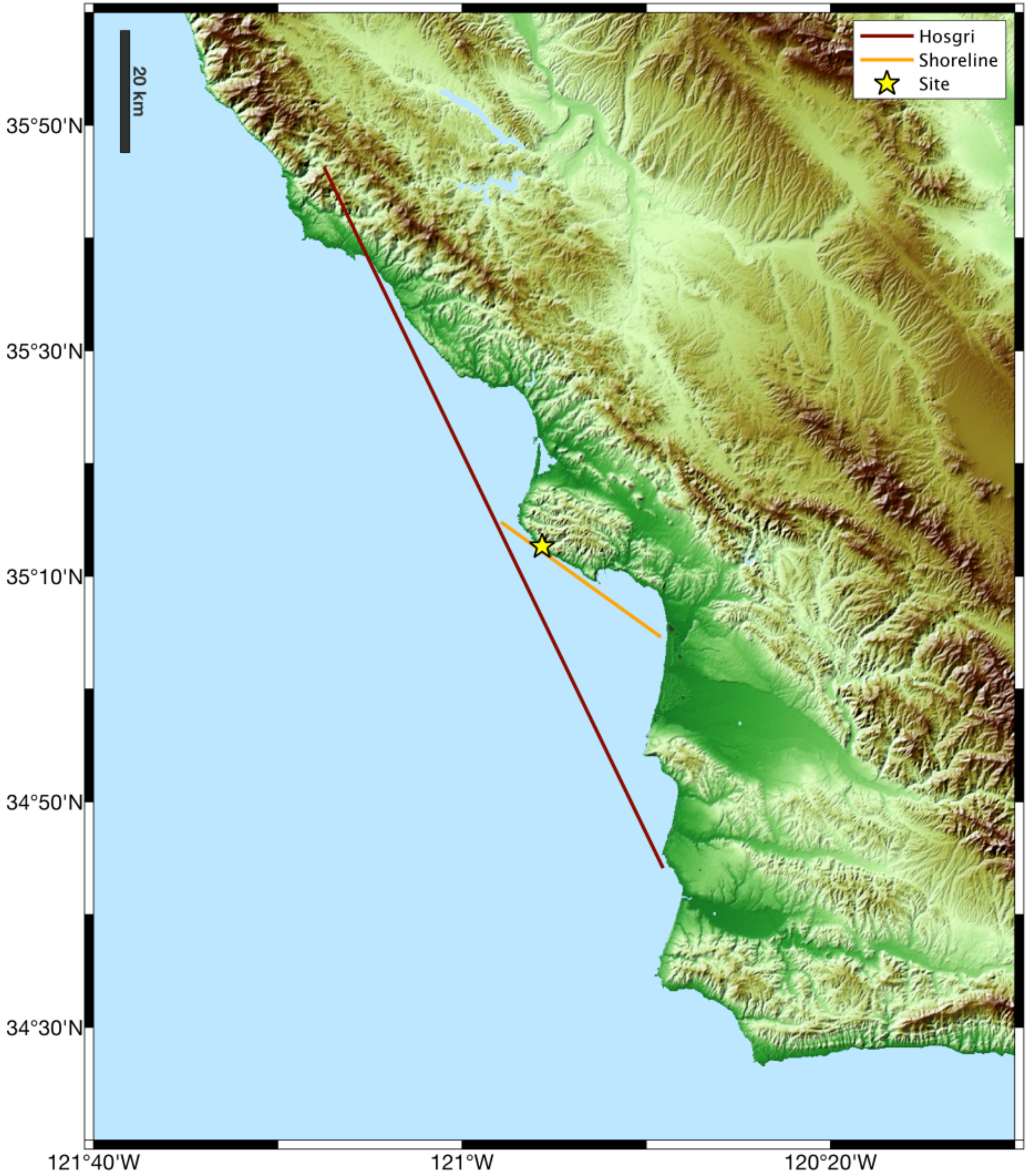
1. Hosgri-Shoreline strike-slip branch faulting scenario
2. Ventura-Lion backthrust scenario

Scenario 1: Hosgri – Shoreline Faults (Strike-Slip)

Where in the world…



Scenario 1: Hosgri – Shoreline Faults (Strike-Slip)



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Scenario 1: Hosgri – Shoreline Faults (Strike-Slip)

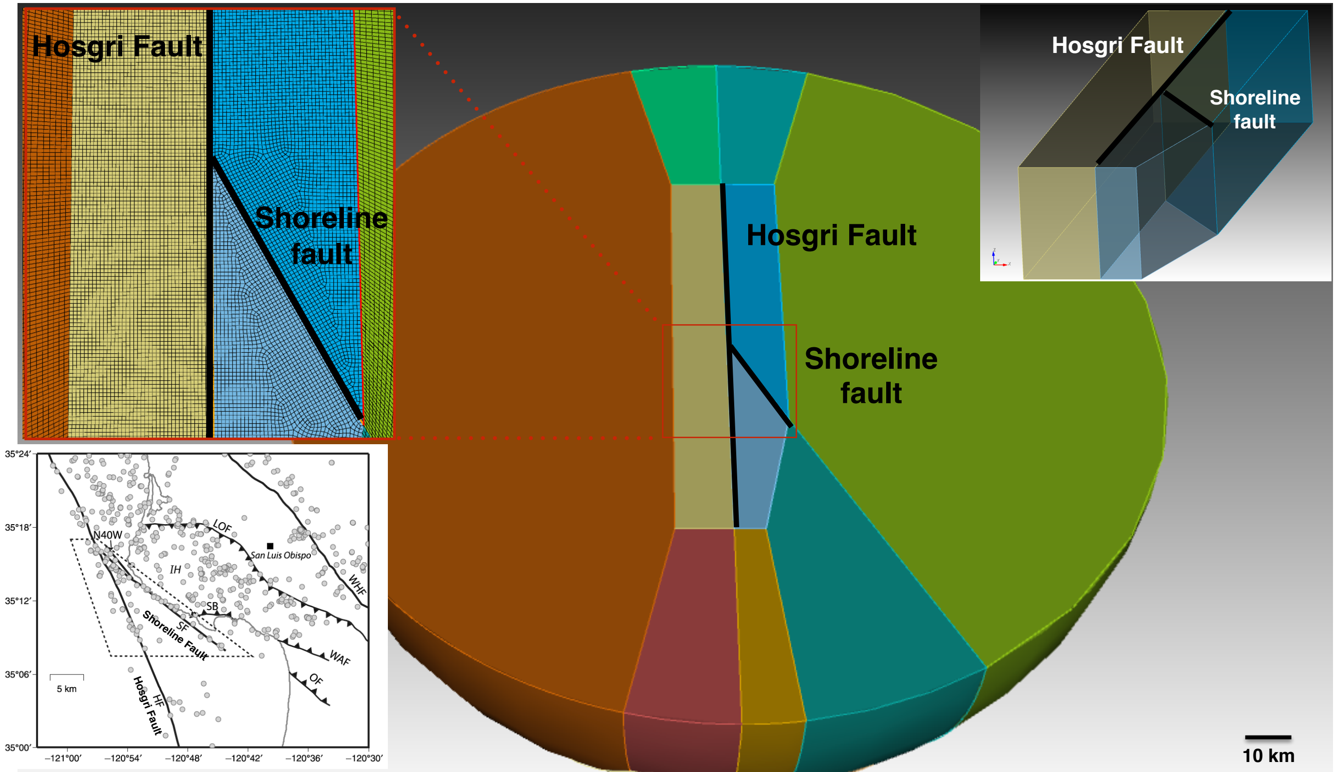
- We used dynamic rupture modeling to investigate the conditions under which branching strike-slip faulting can occur, and used that information to guide kinematic broadband ground motion simulations of branching strike-slip faulting.

- We performed multicycle dynamic earthquake rupture modeling with an unstructured 3-D spectral element method to model the Hosgri – Shoreline fault system and explored the conditions under which branch faulting occurs.

- We used information from the dynamic rupture simulations to kinematically model the location and timing of the branch rupture.

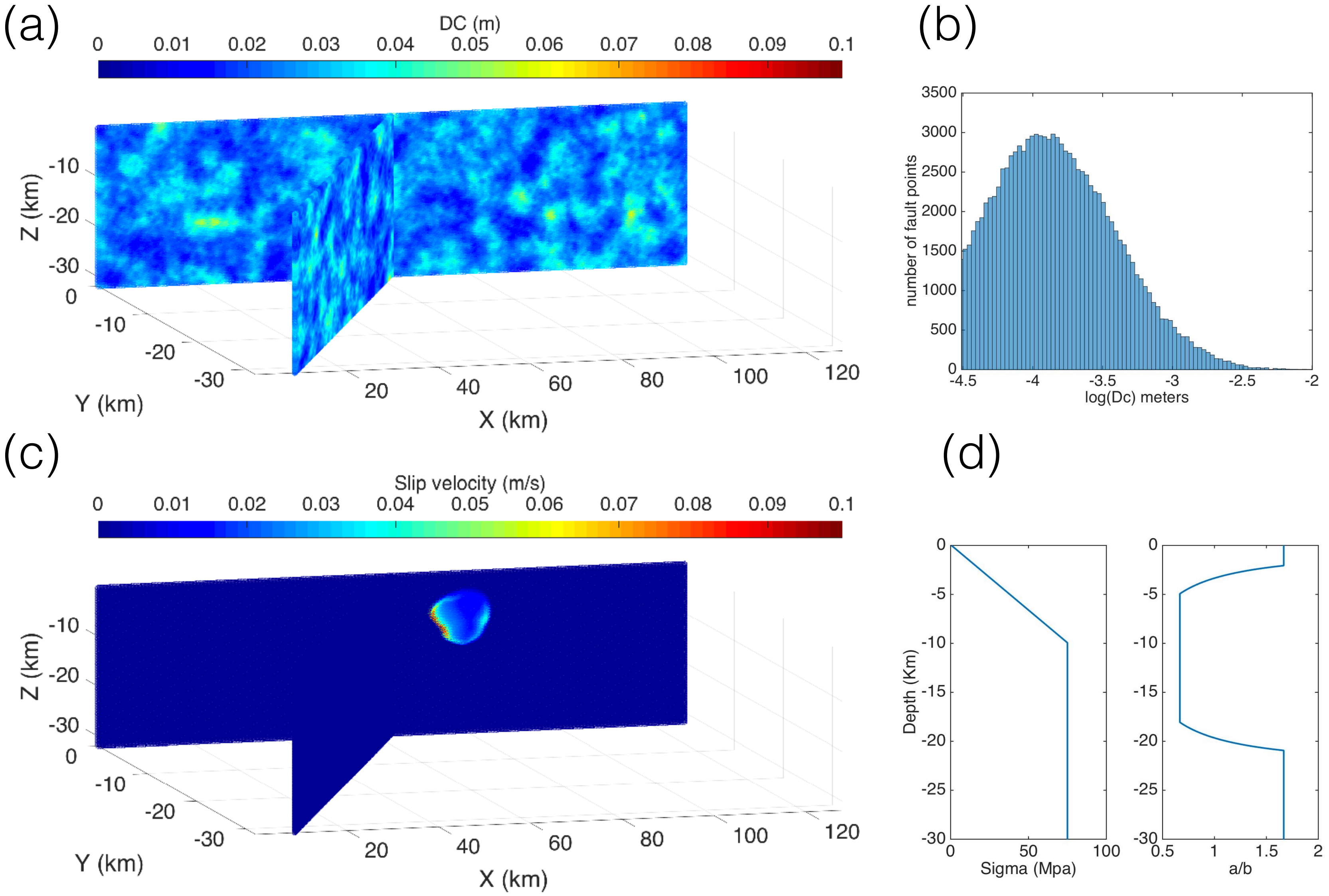
Simulation Approach

- SPECFEM3D (Galvez et. al., 2014, 2016)
- The fault geometry and the mesh for Hosgri-Shoreline fault is shown at right
- The rupture process is simulated by rate-and-state friction with aging law (Dietriech, 1979).
- To compute the initial parameters prior to one event we perform earthquake cycle modeling.
  - Quasi-dynamic solver
  - Import stresses, friction and state
  - Not prescribing initial conds

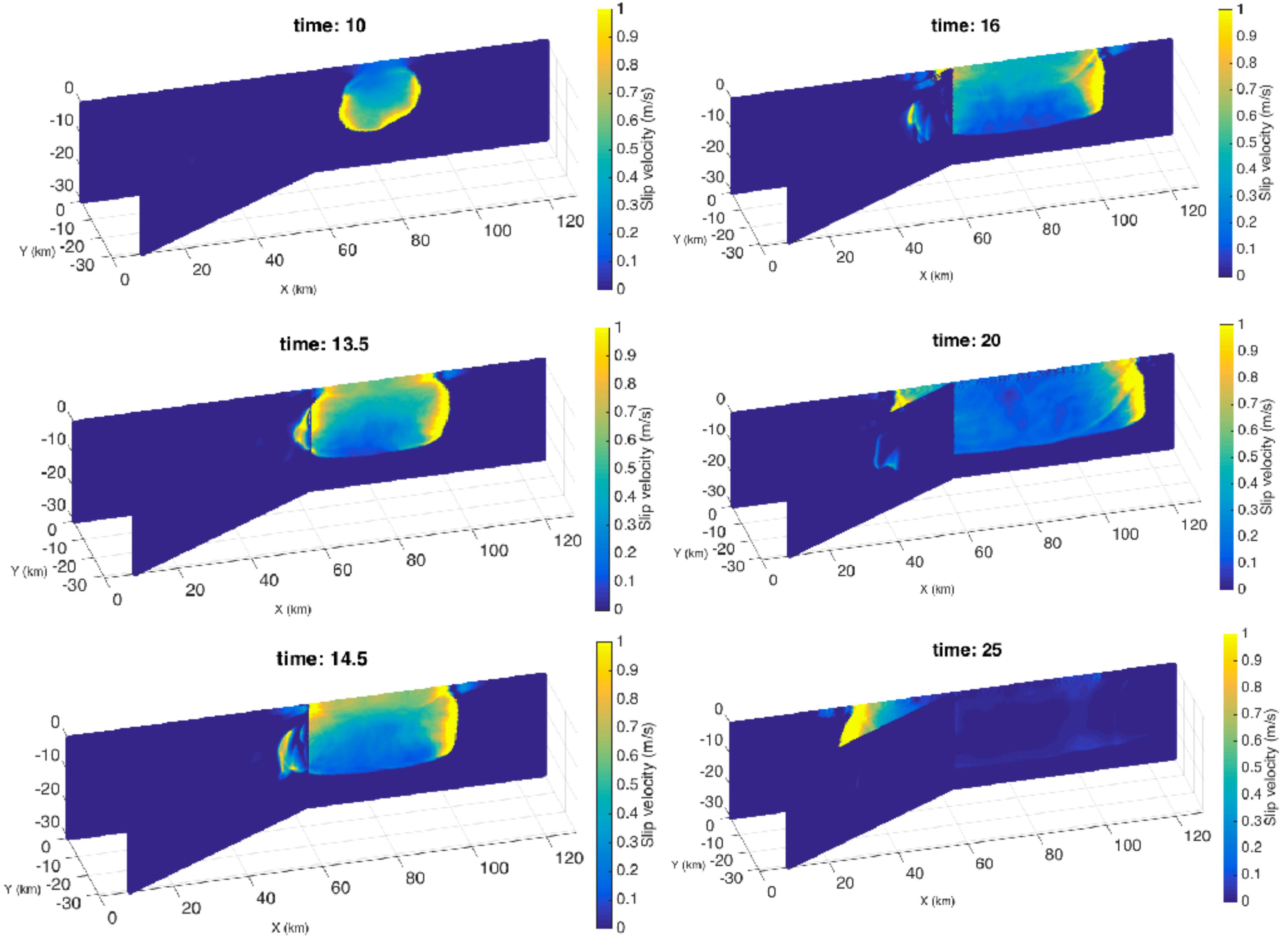


Hardebeck et al. (2013)

Setup for the eqk cycle modeling



Snapshots of Branch Faulting



Dynamic Fault Branching

- The rupture velocity on the branching rupture is between 0.8 and 0.9 times shear velocity (Vs). The fault mechanism is right-lateral strike slip.

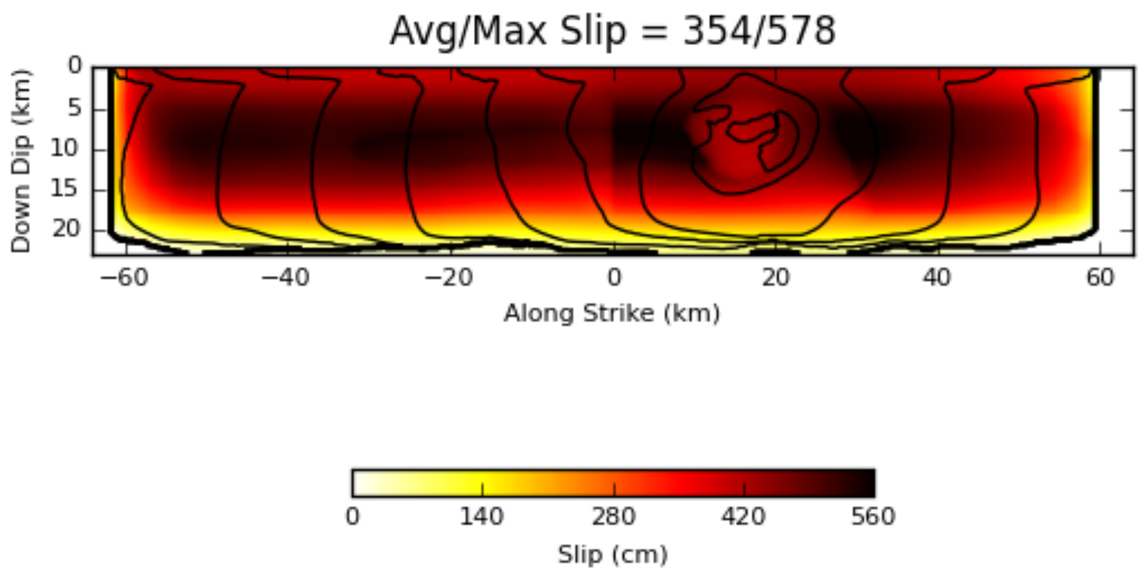
- The angle between the Hosgri and Shoreline faults is about 30 degrees and the event nucleates close to the junction.

- These conditions were found to be favorable for branching rupture where both the Hosgri and Shoreline faults break at the same time.

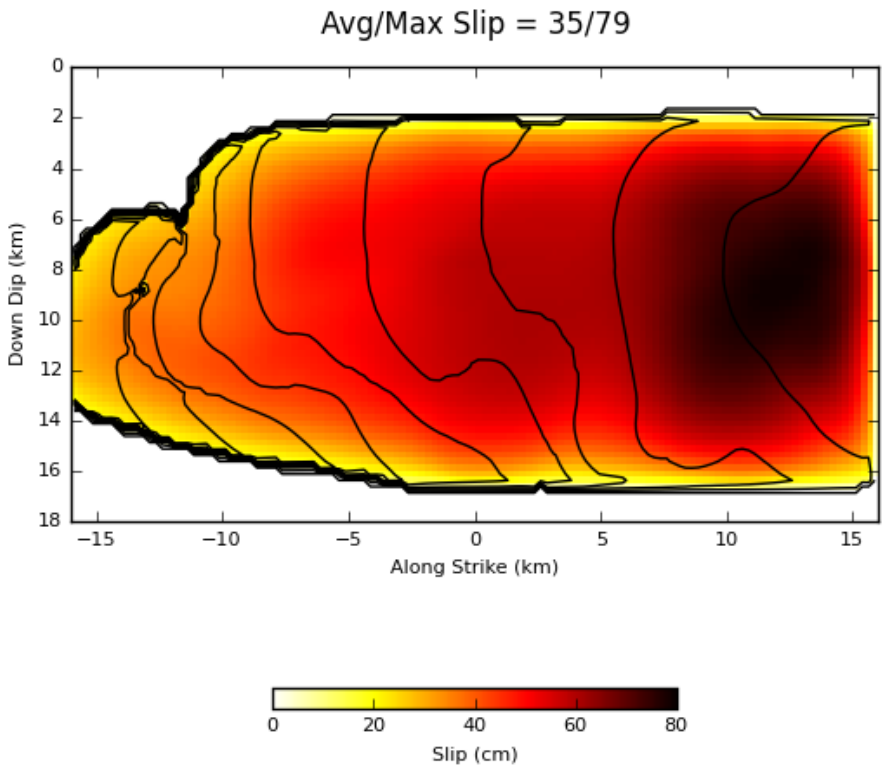
- Kame et al. (2003) predicts similar branching rupture under similar conditions where both the main and branch faults rupture at the same time.

Kinematic Slip Model

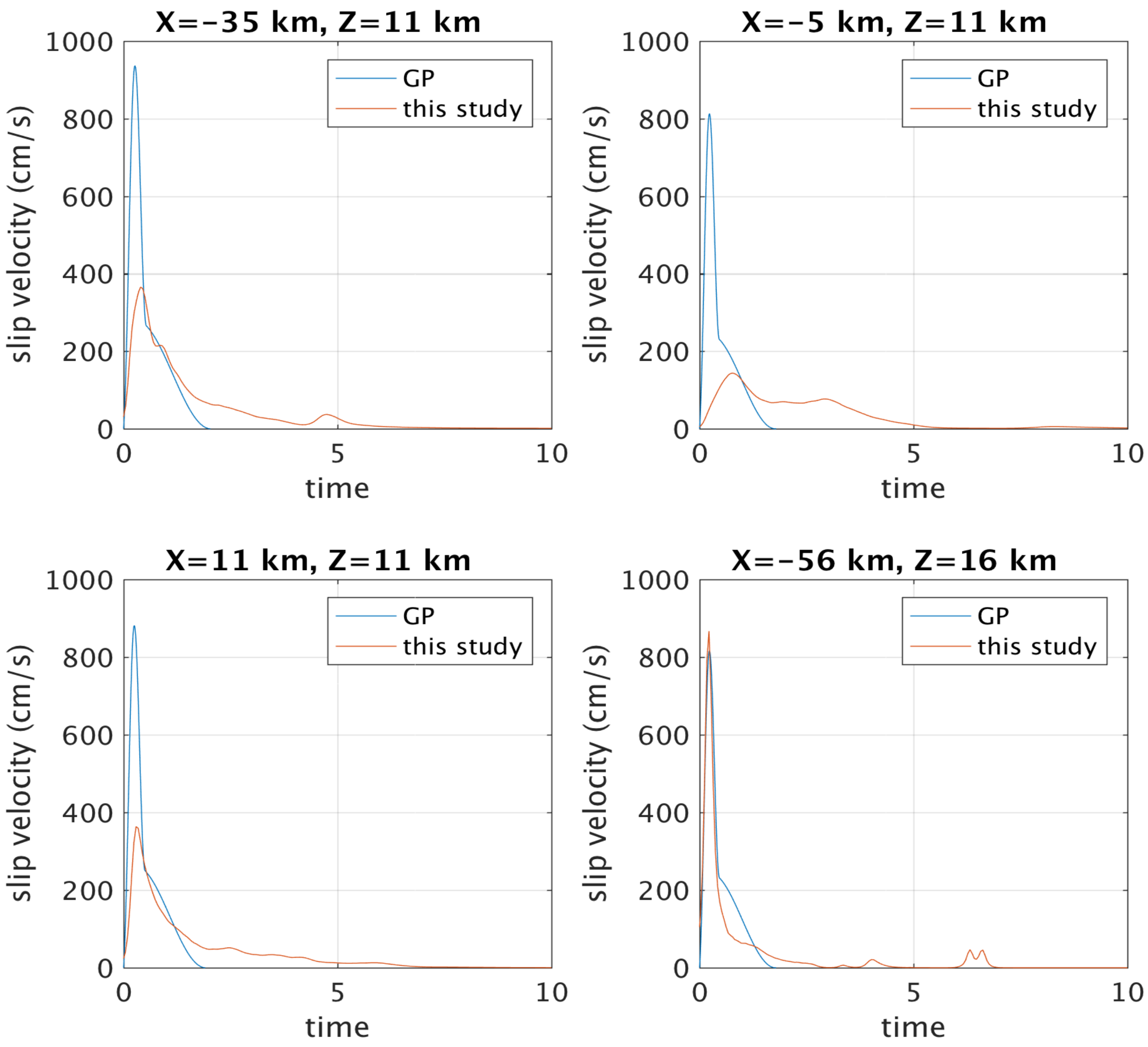
M7.6 **Hosgri**



M6.6 **Shoreline**



Comparison of Dynamic and Kinematic Slip Velocity Functions



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Results

- The kinematic simulations consisted of 2 methodologies:
  - In Trial A we used the fault dimensions, the final slip distributions, and the rupture initiation timing on both faults from the dynamic simulations in the kinematic simulation. The GP recipe is used for the scaling and shape of the slip rate functions on each subfault (which is a modified version of the Liu et al. (2006) slip rate function.)
  - Trial B used all of the above, as well as the full slip velocity time histories on each subfault from our dynamic simulations.

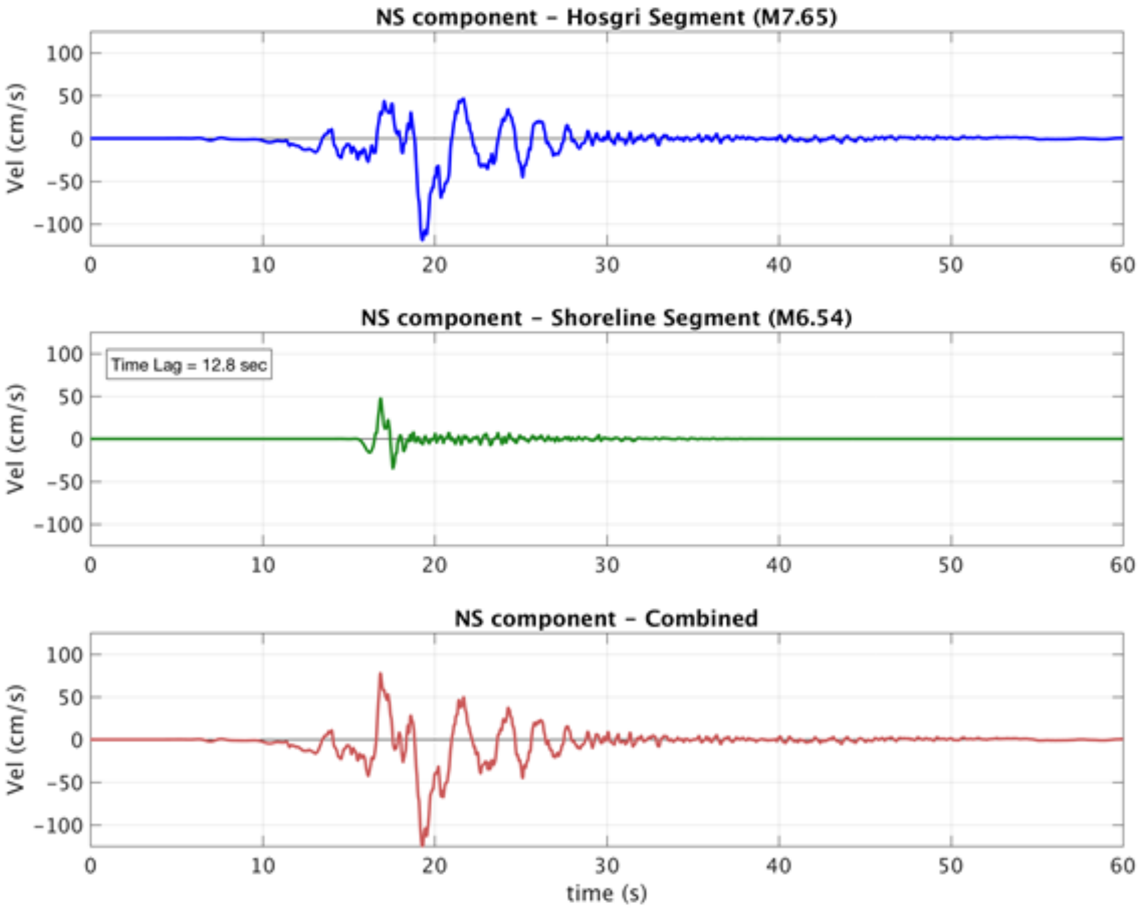
- At periods between 0.2 and 0.8 seconds, the contributions of the Hosgri and Shoreline faults to the combined ground motions are comparable, whereas the contributions from the Hosgri fault are larger at longer periods.

- Use of the full dynamic slip velocities instead of the kinematic slip velocities resulted in much lower ground motions at intermediate and long periods.

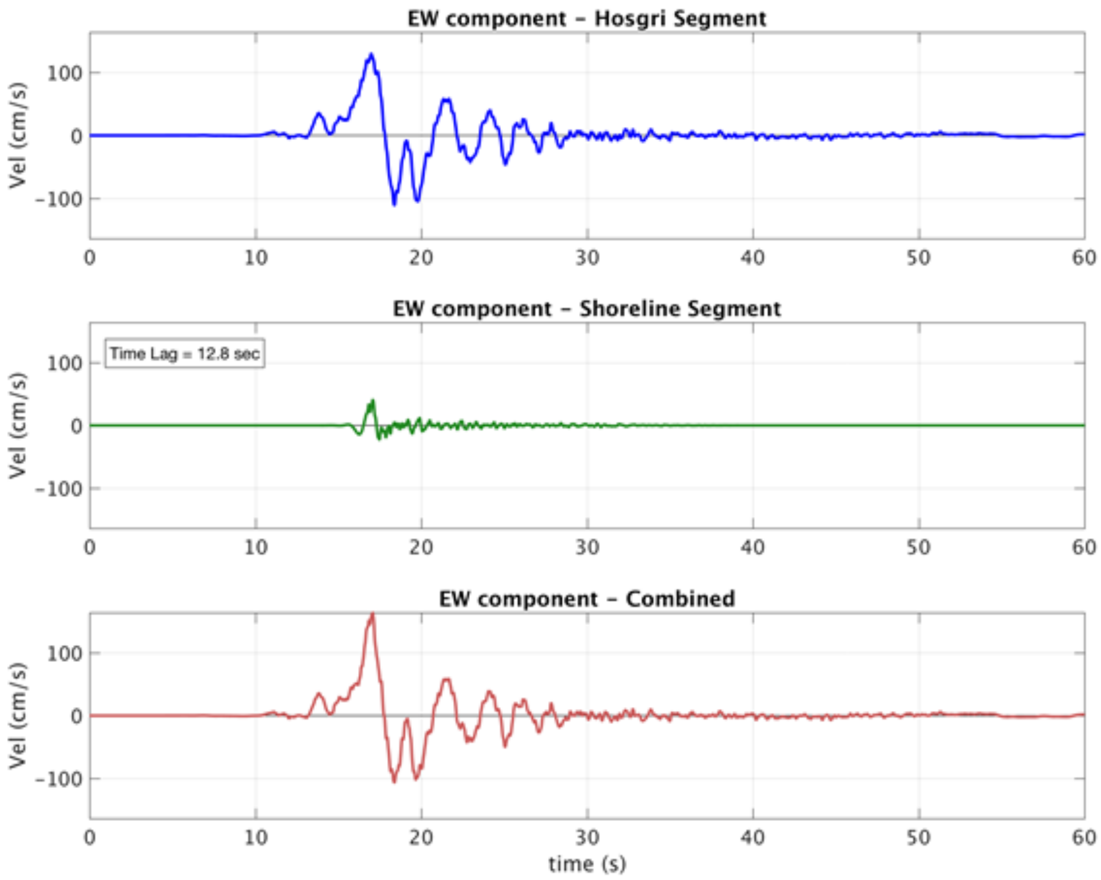
- The scenario as described was found to be favorable for branching rupture where both the Hosgri and Shoreline faults break at the same time.

Kinematic Simulations – Trial A

Trial A Simulations - NS



Trial A Simulations - EW



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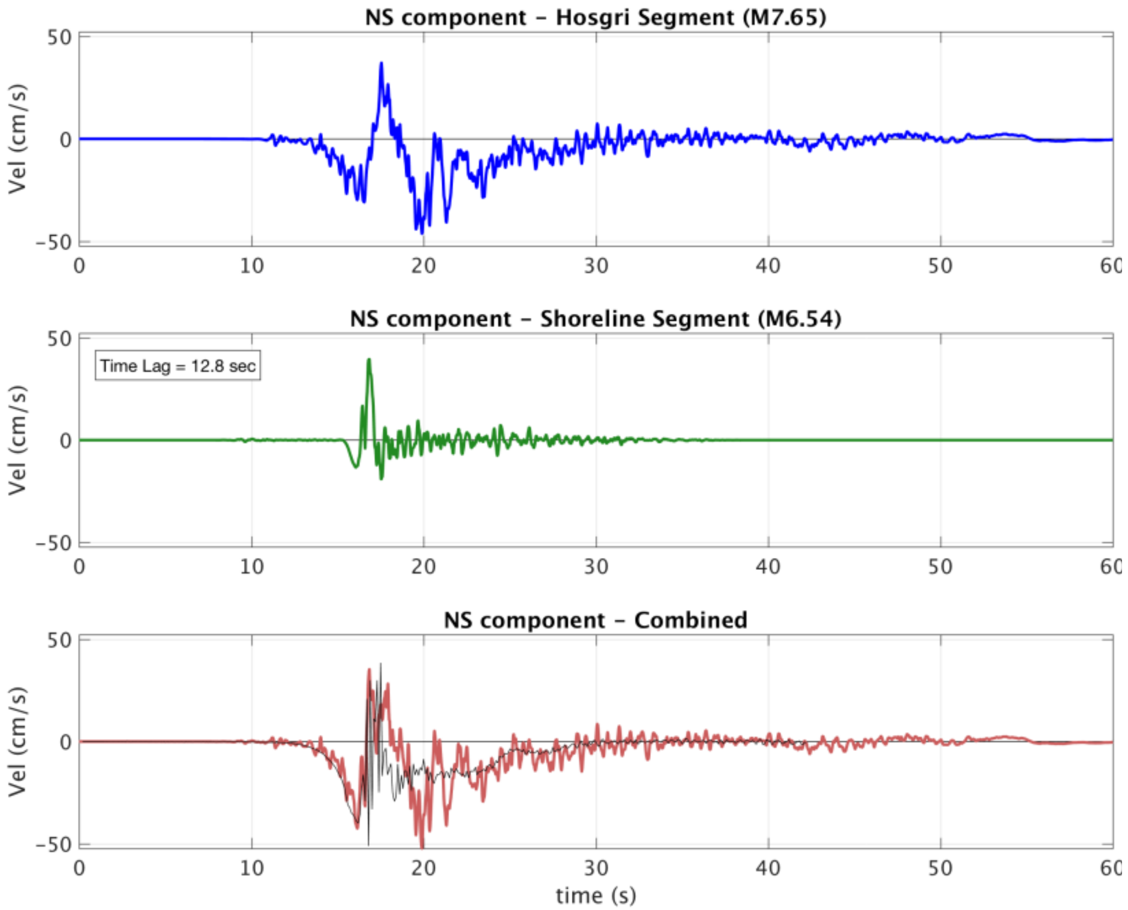
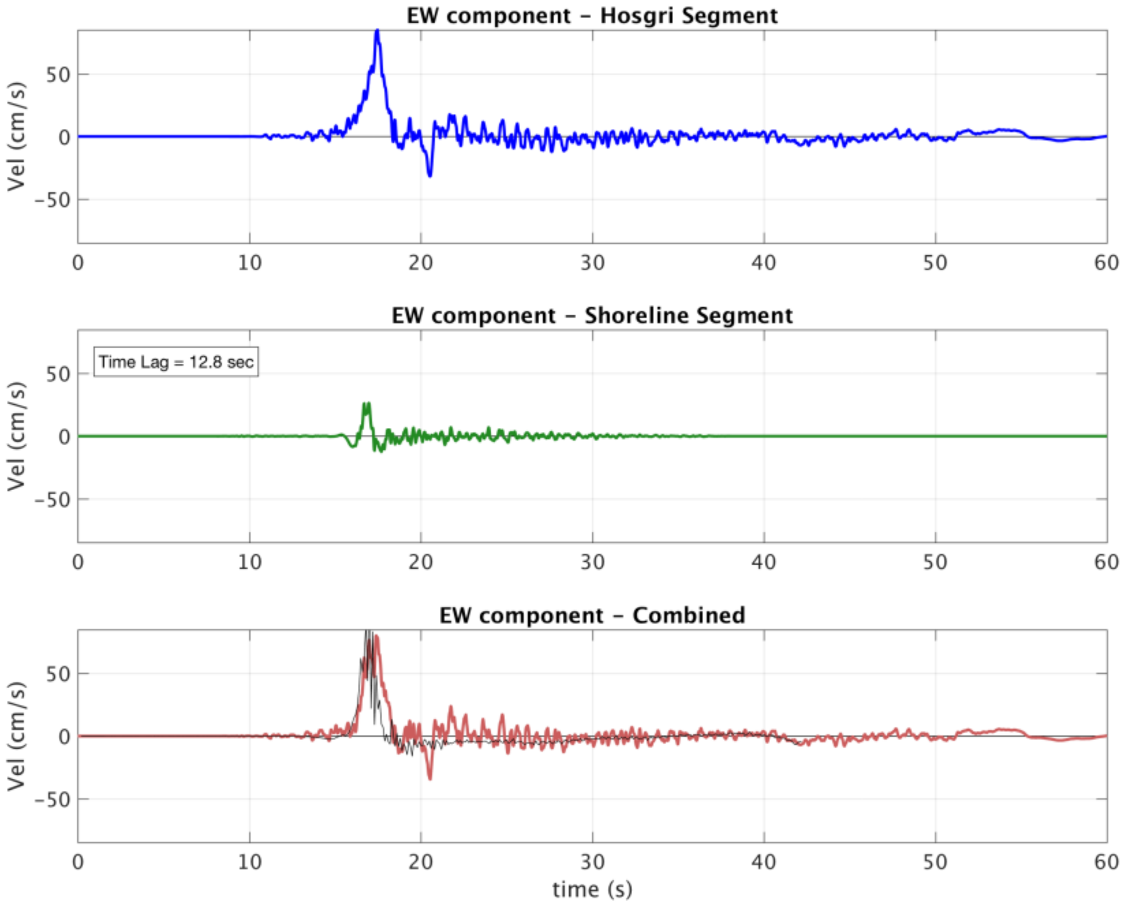
Kinematic Simulations – Trial B

NS



EW



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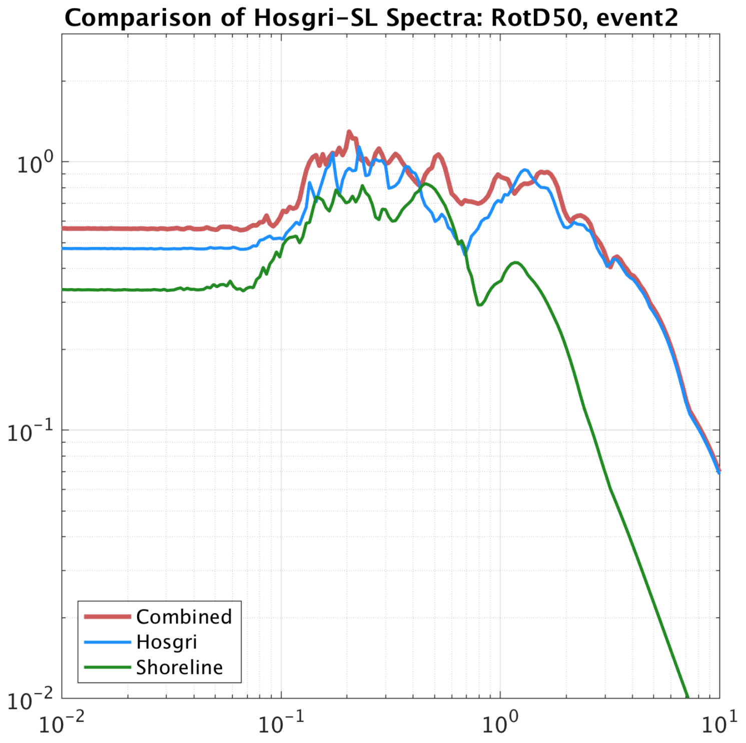
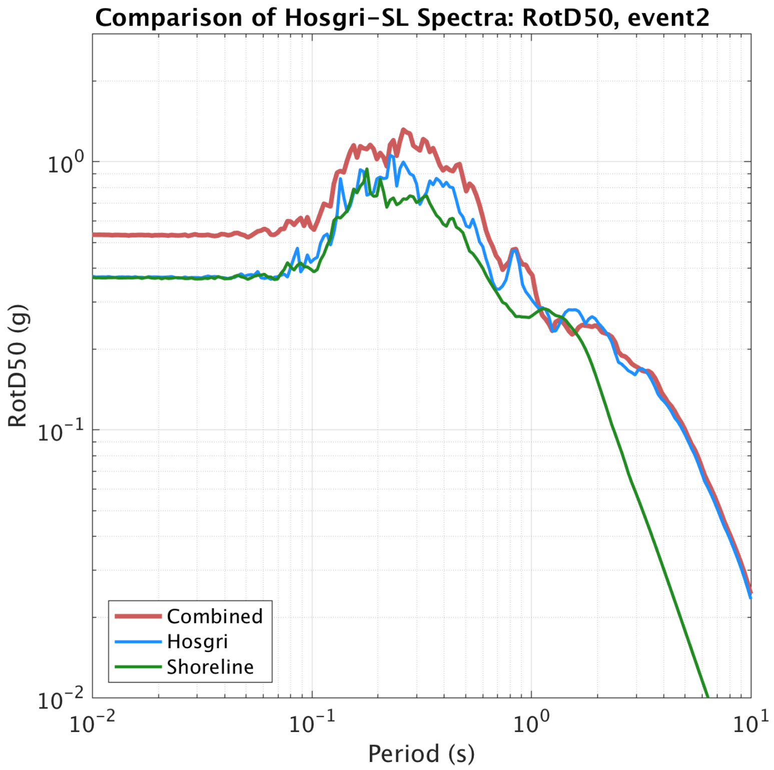
Response Spectra

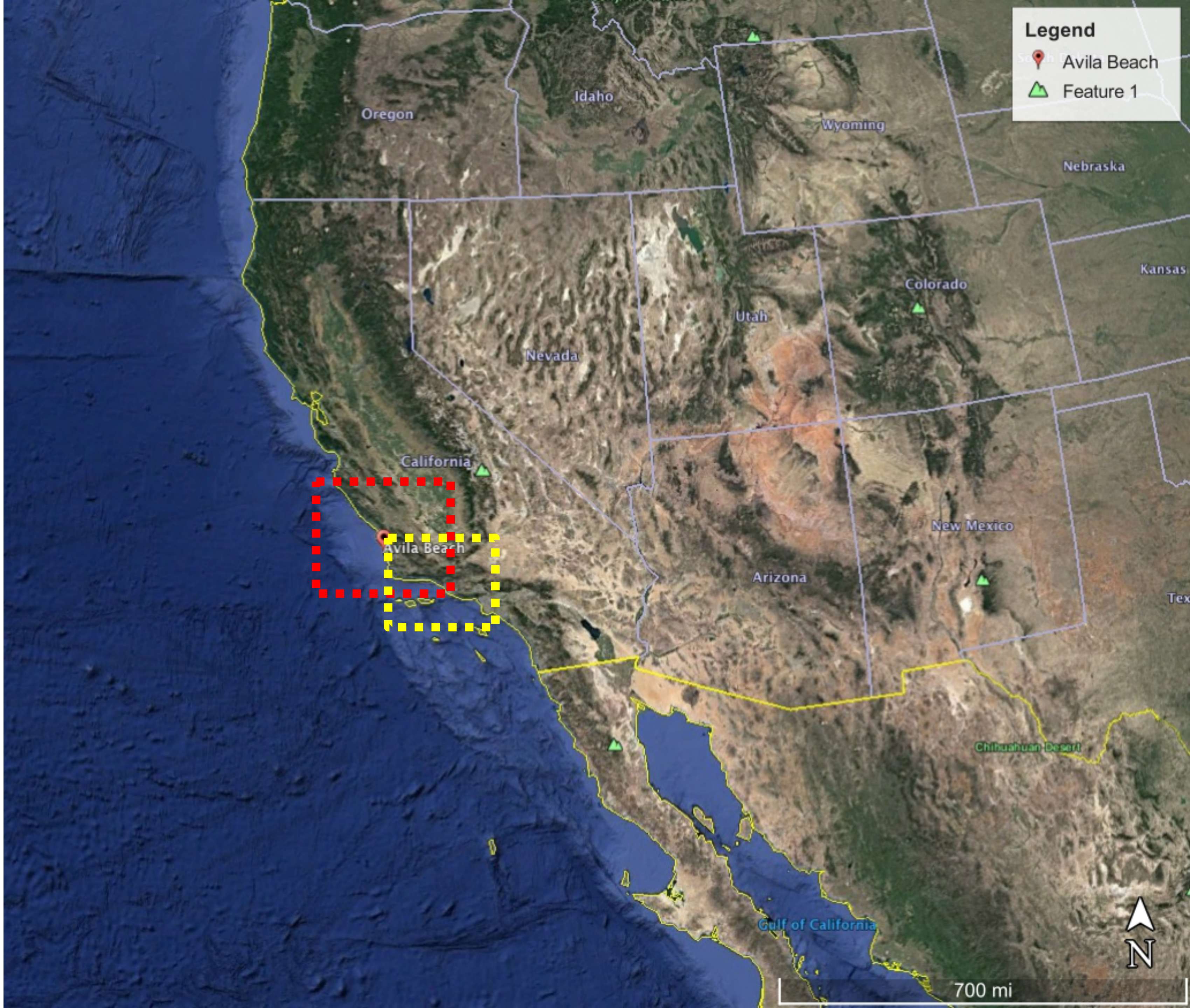
Trial A Response Spectra



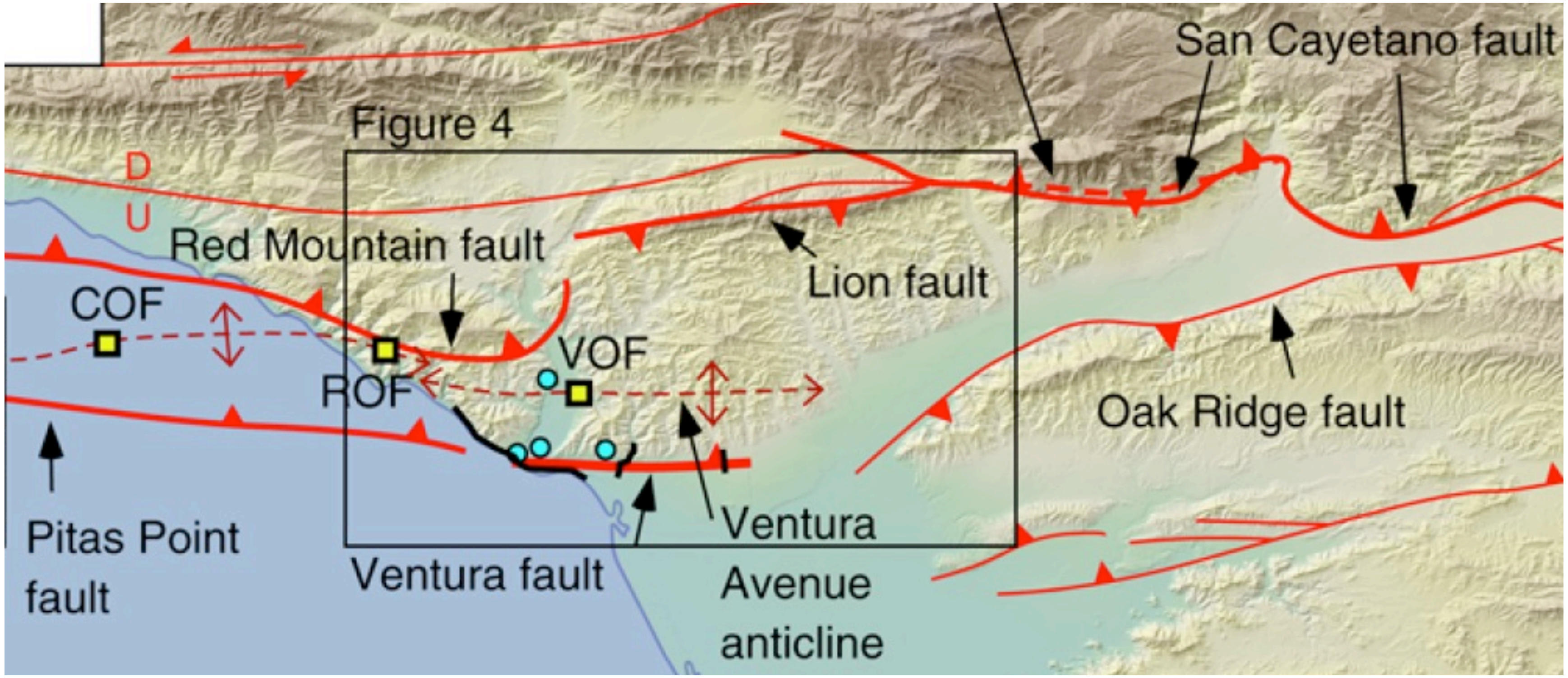
Trial B Response Spectra



Scenario 2: Ventura and Lion Branch Faulting



Scenario 2: Ventura and Lion Branch Faulting



Hubbard et al. (2015)

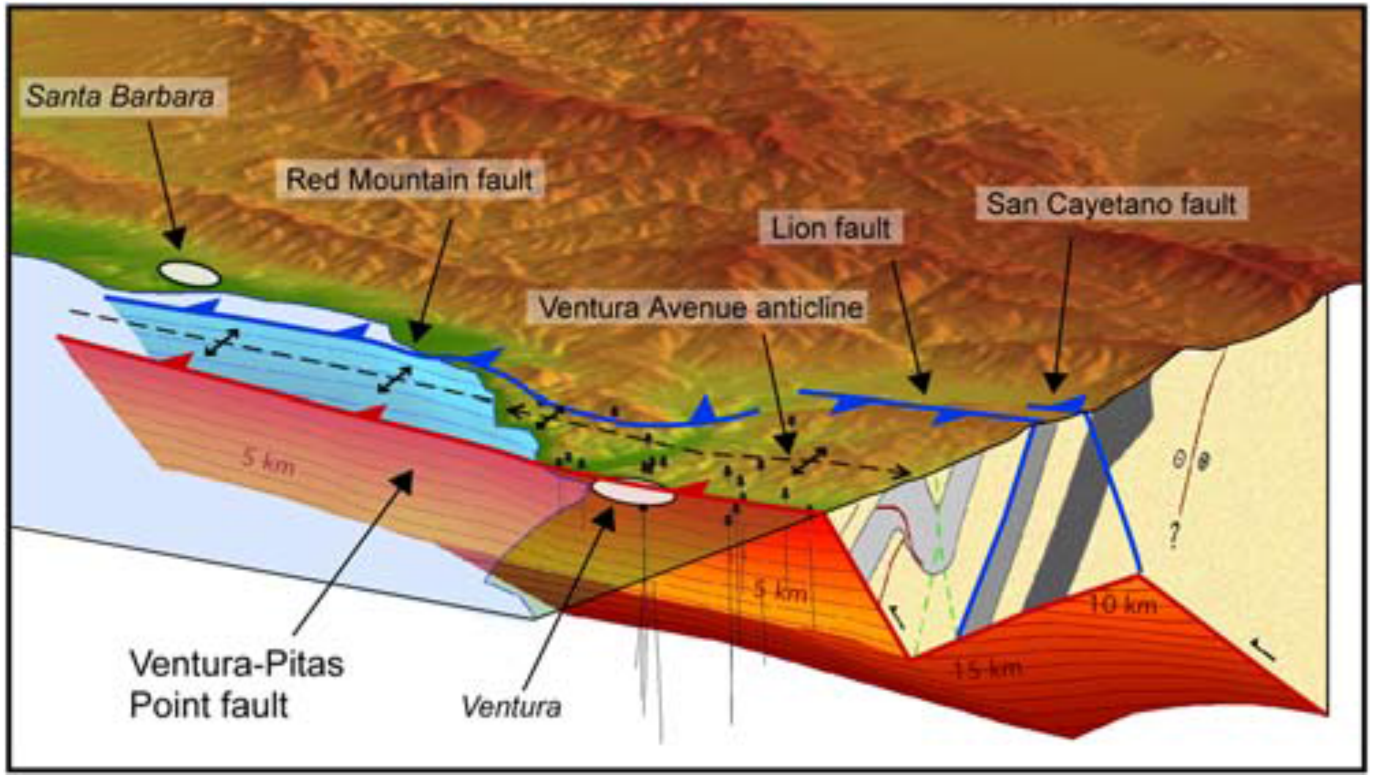
Fault Geometry

Hubbard et al. (2015) proposed two alternative interpretations of how the Ventura Anticline is growing:

In the first, the region below the Ventura Avenue anticline is highly fractured and close to failure.

In the second scenario, a pre-existing backthrust embedded in the faulted region below the Ventura anticline branches off the Ventura fault, as shown at right.

Xu et al (2015) performed dynamic rupture simulations and provide mechanisms of how backthrust faulting can be activated.
- How shallow will it go?

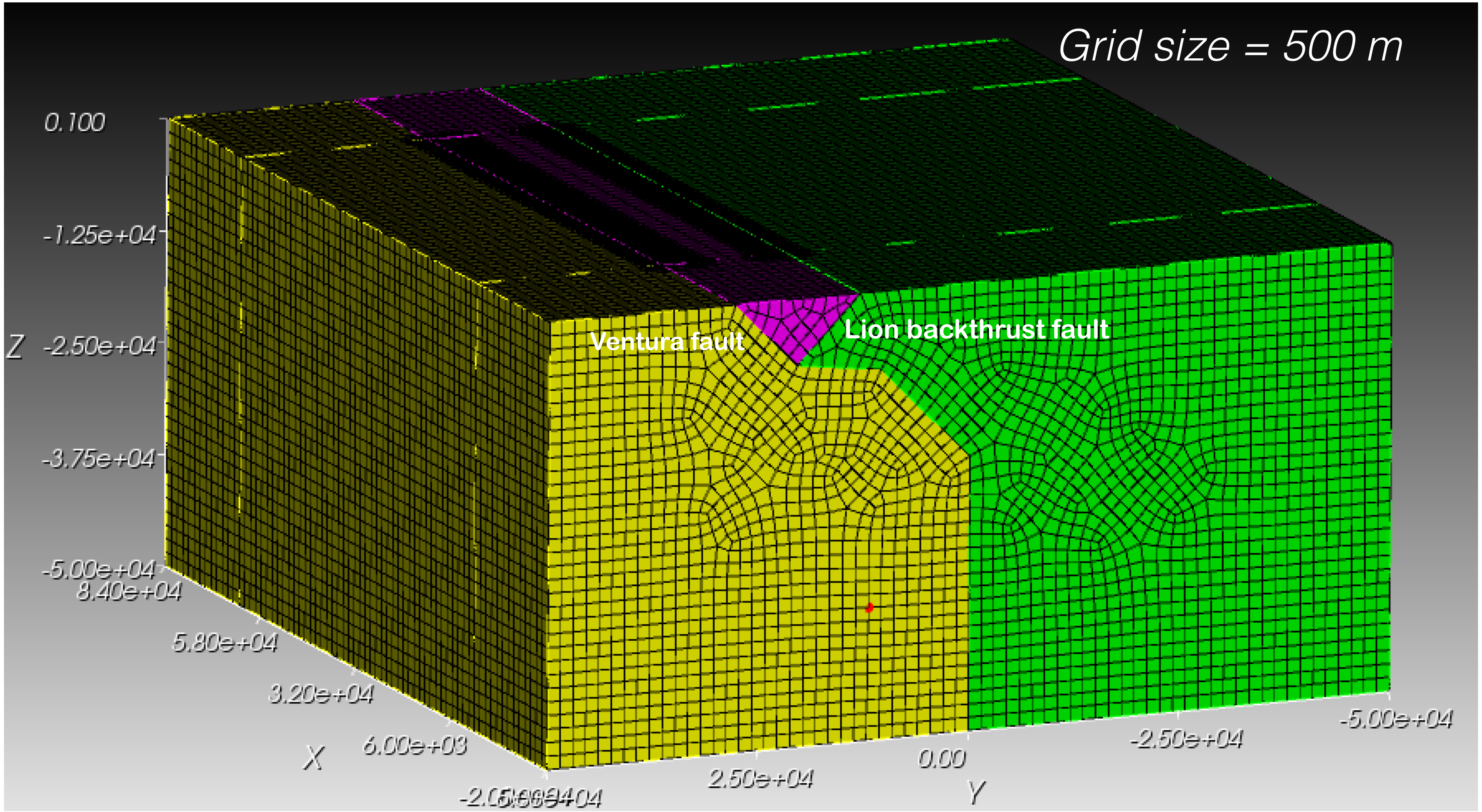


Hubbard et al. (2015)

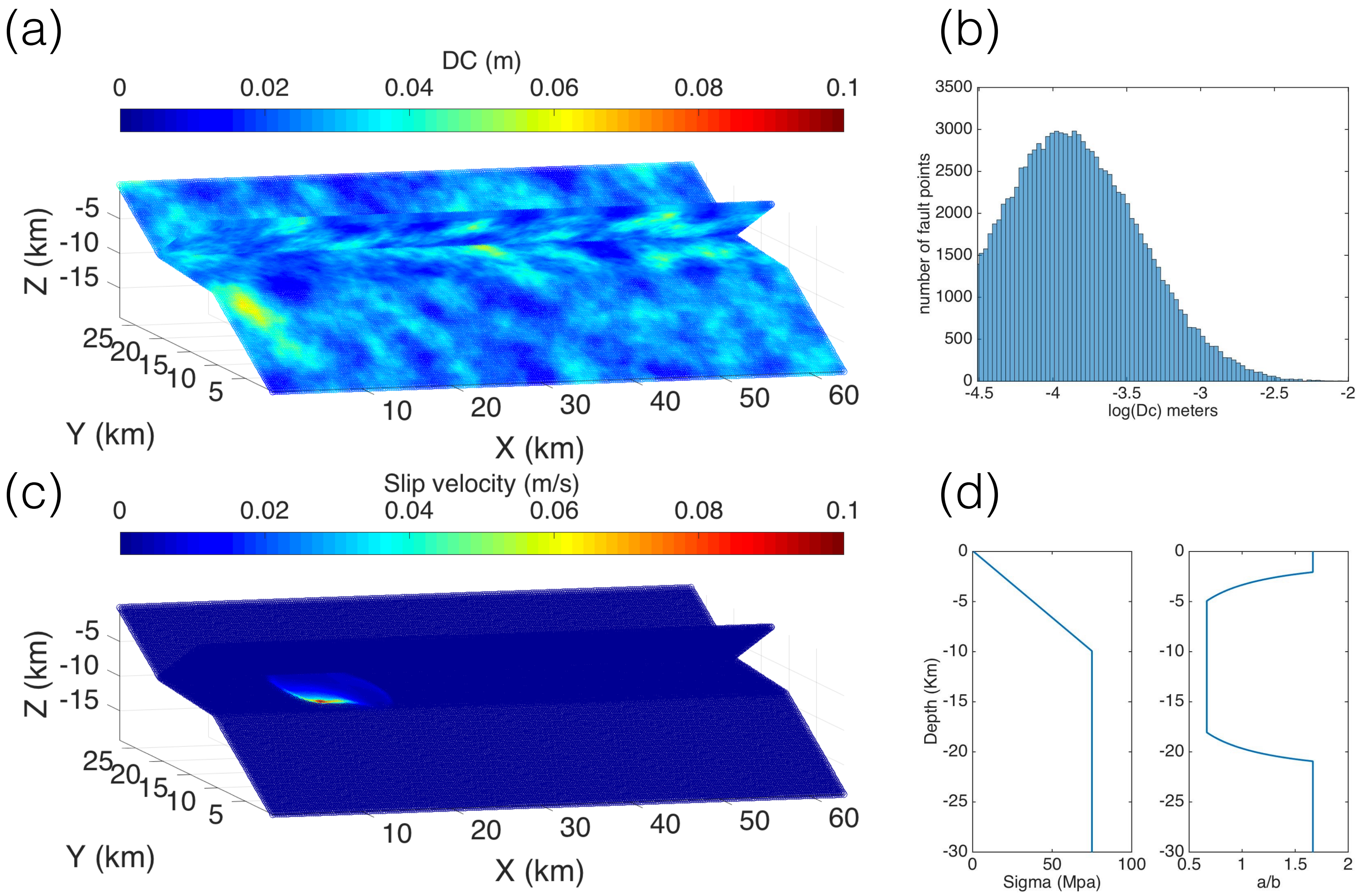
Objective

- Use dynamic rupture modeling to investigate the conditions under which conjugate backthrust faulting can occur, and to use kinematic ground motion simulations, guided by the dynamic modeling, in broadband simulations of conjugate backthrust faulting
- Use the rupture time, slip functions, and final slip to perform kinematic rupture modeling of the ground motions.

Fault Geometry and Fault Grid



Setup for the eqk cycle modeling



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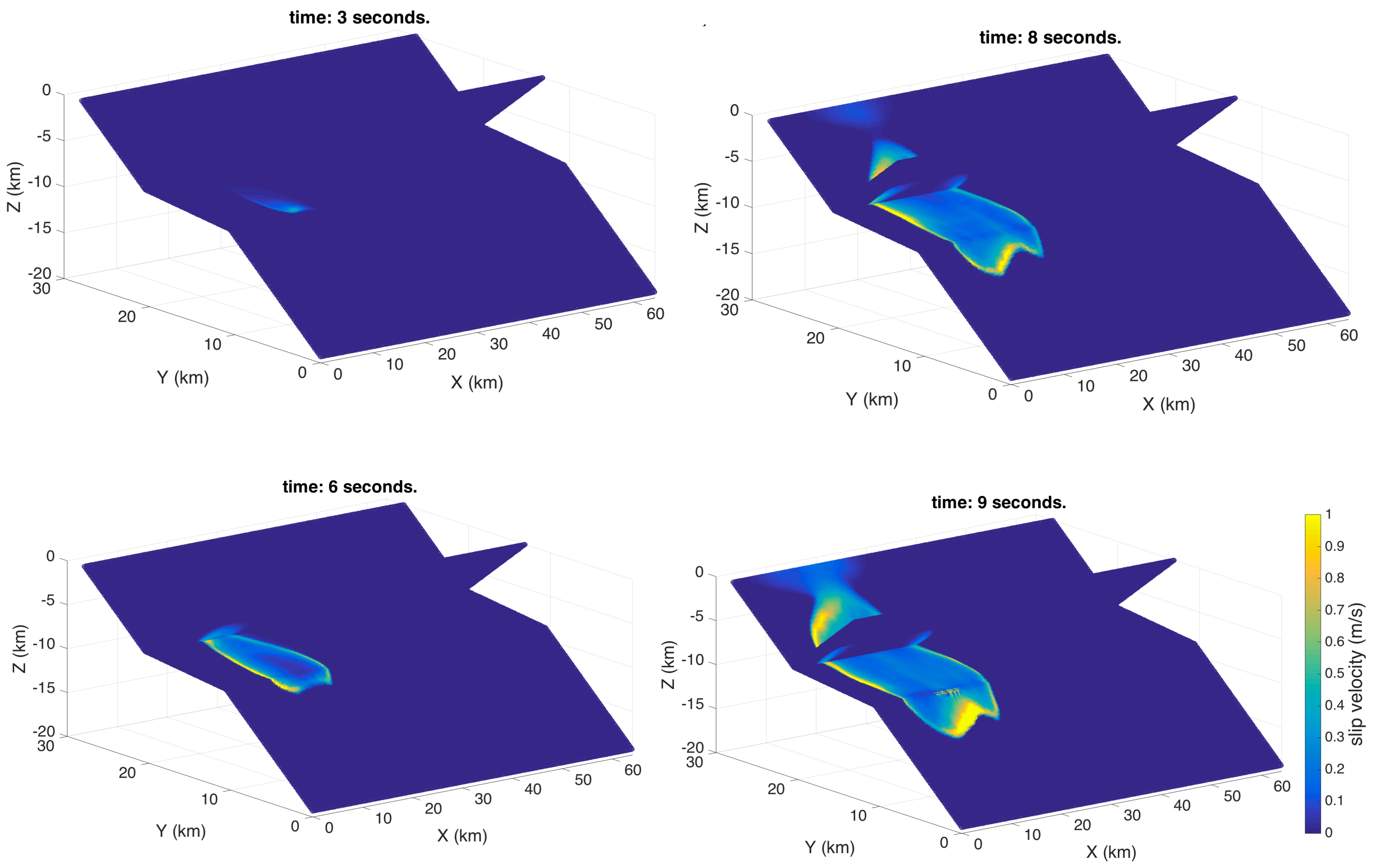
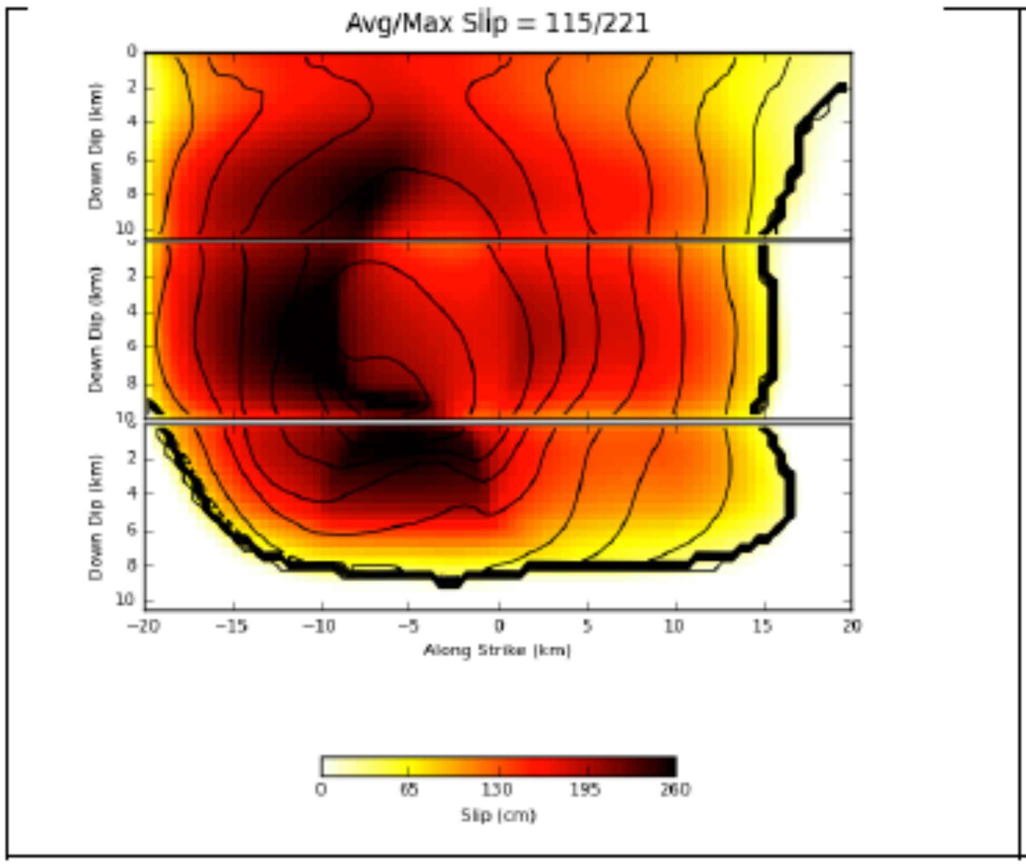
Snapshots of Branch Faulting



Kinematic Slip Model

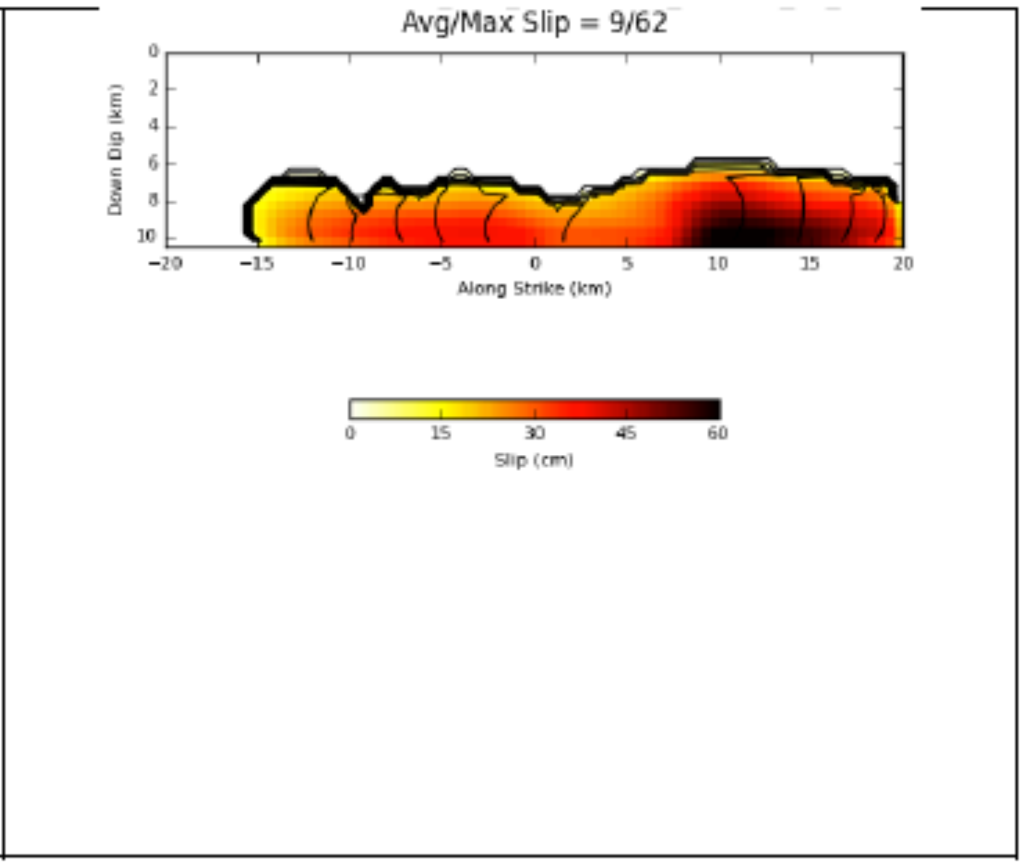
We used the rupture time, slip functions, and final slip to perform kinematic rupture modeling of the ground motions.

Ventura



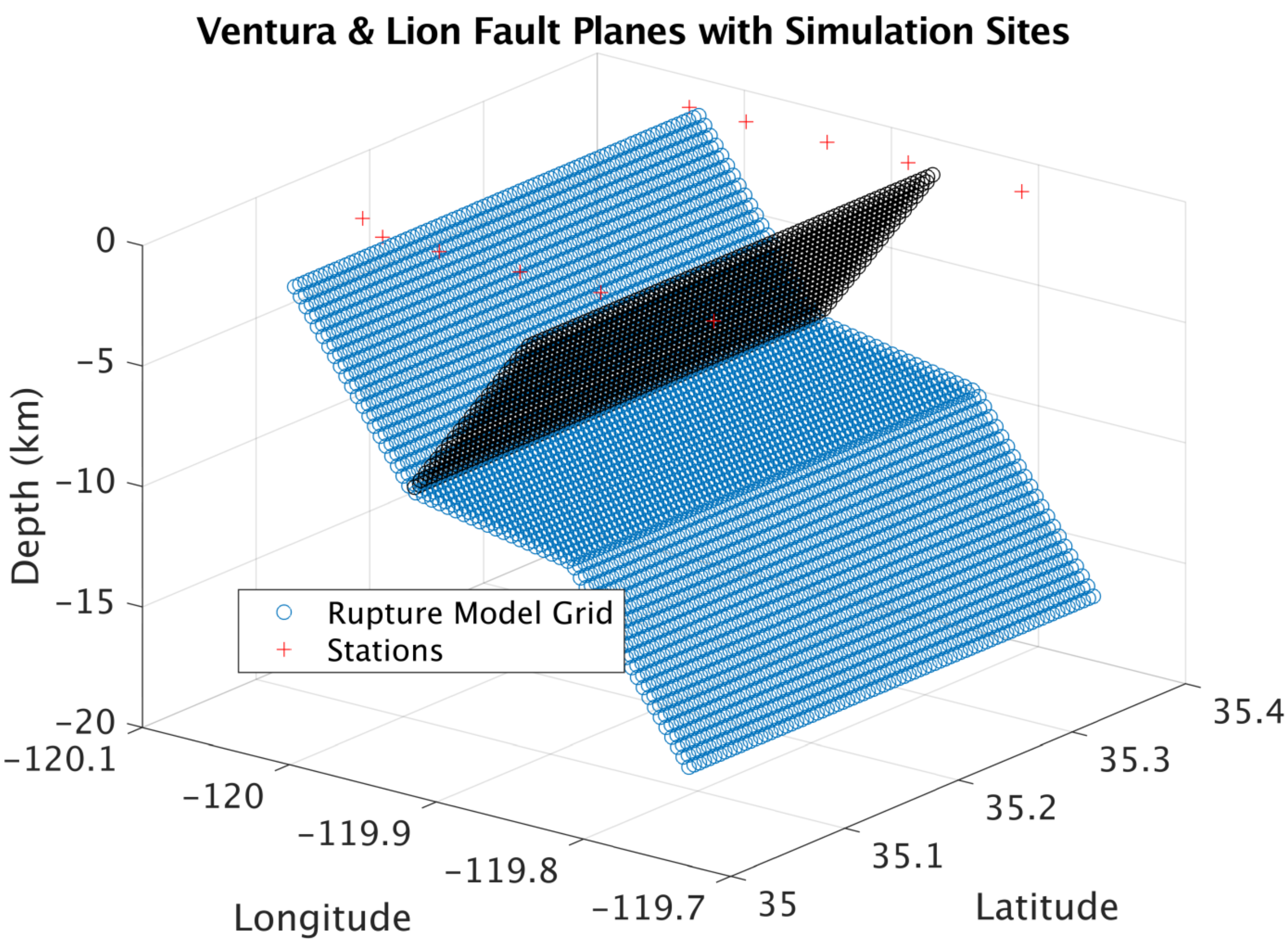
M7.0

Lion



M6.0

Kinematic Fault Geometry



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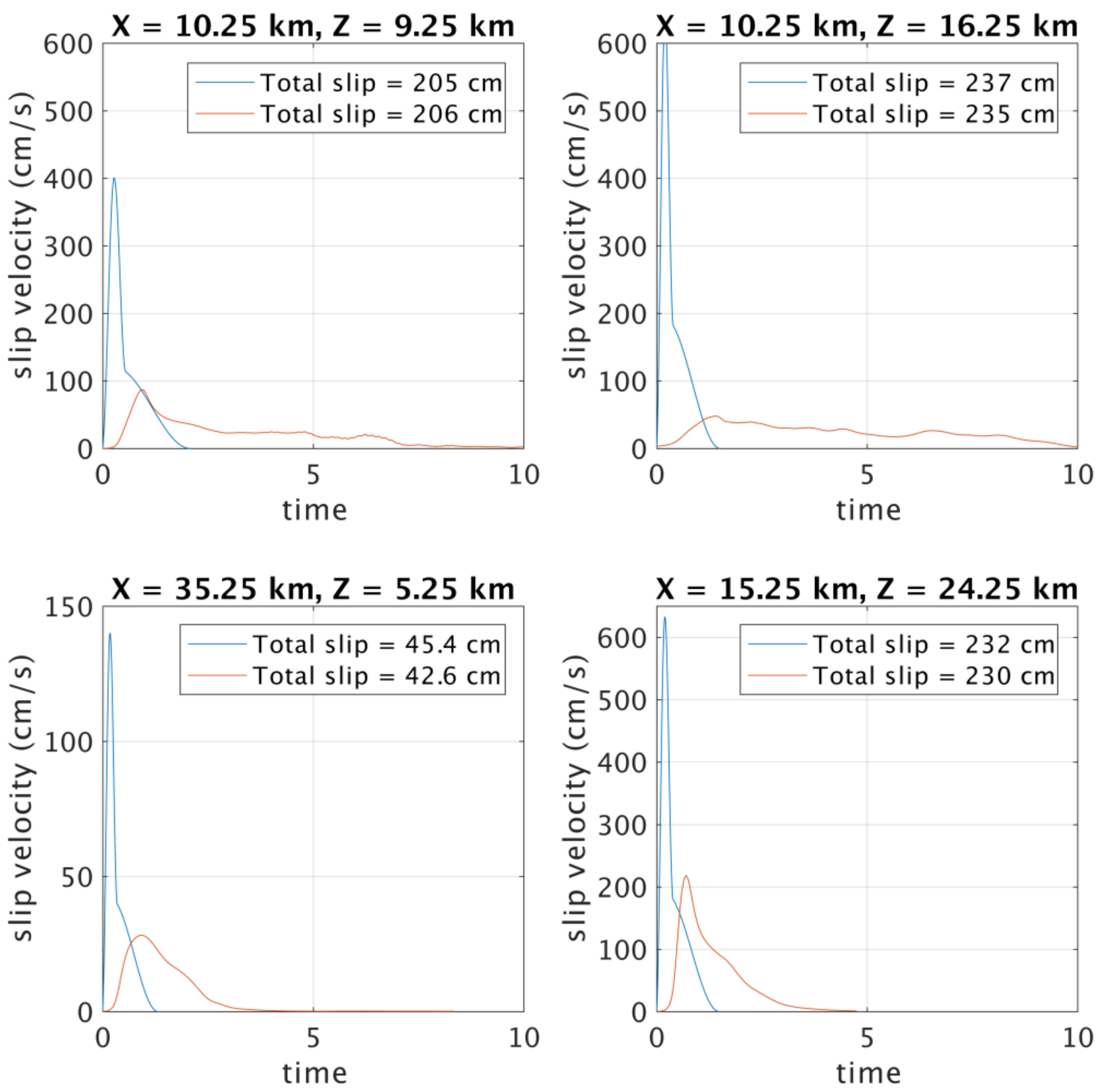
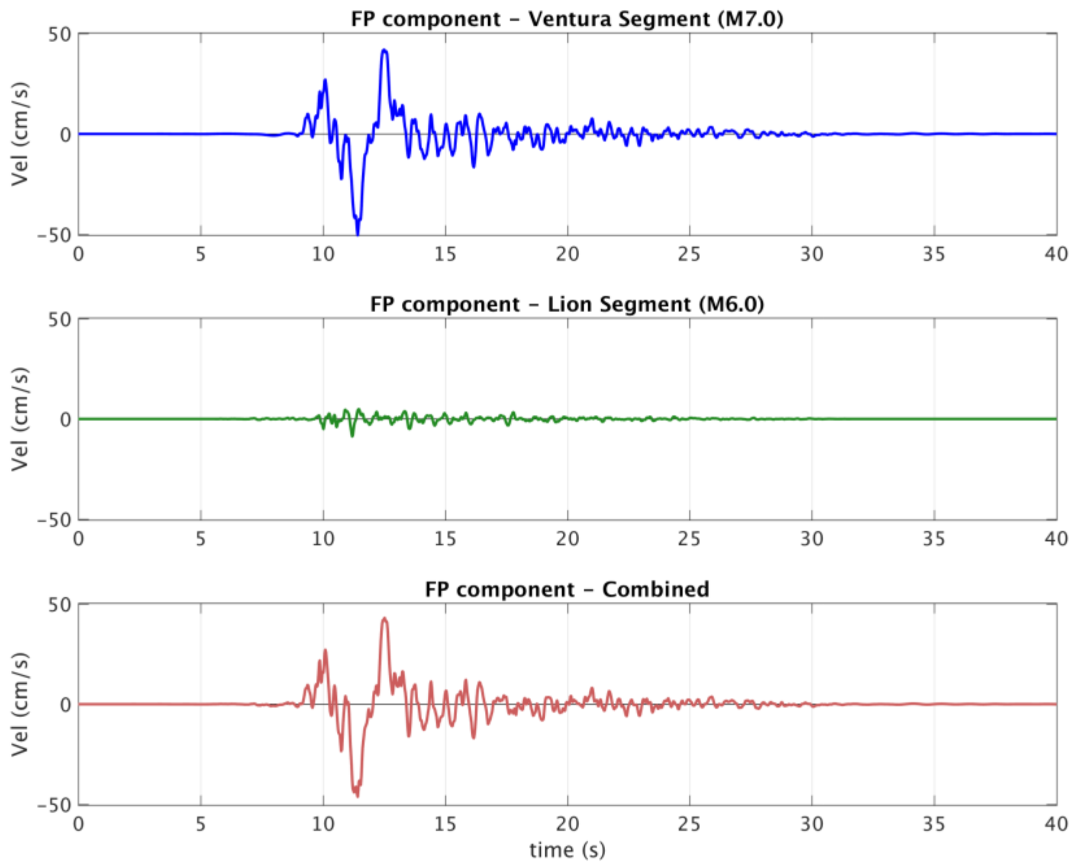
Comparison of Dynamic and Kinematic Slip Velocity Functions

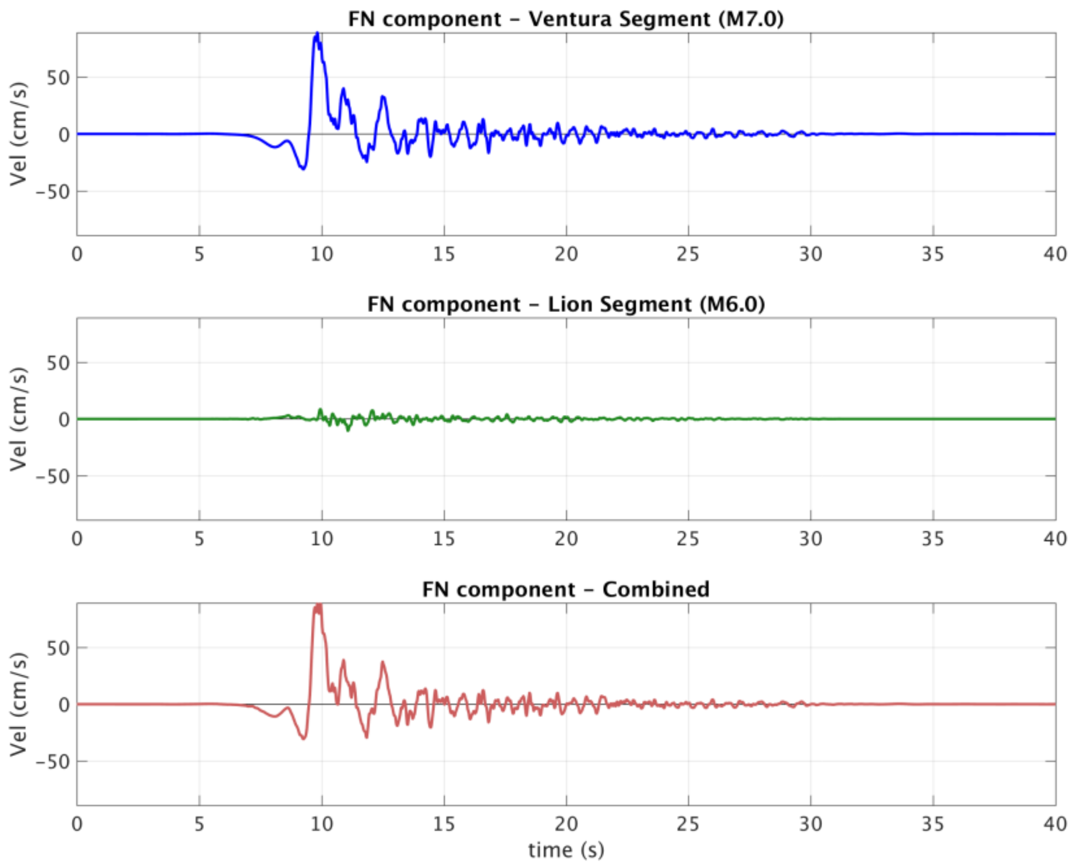


Kinematic Simulations – Trial A (Ventura Site)

NS



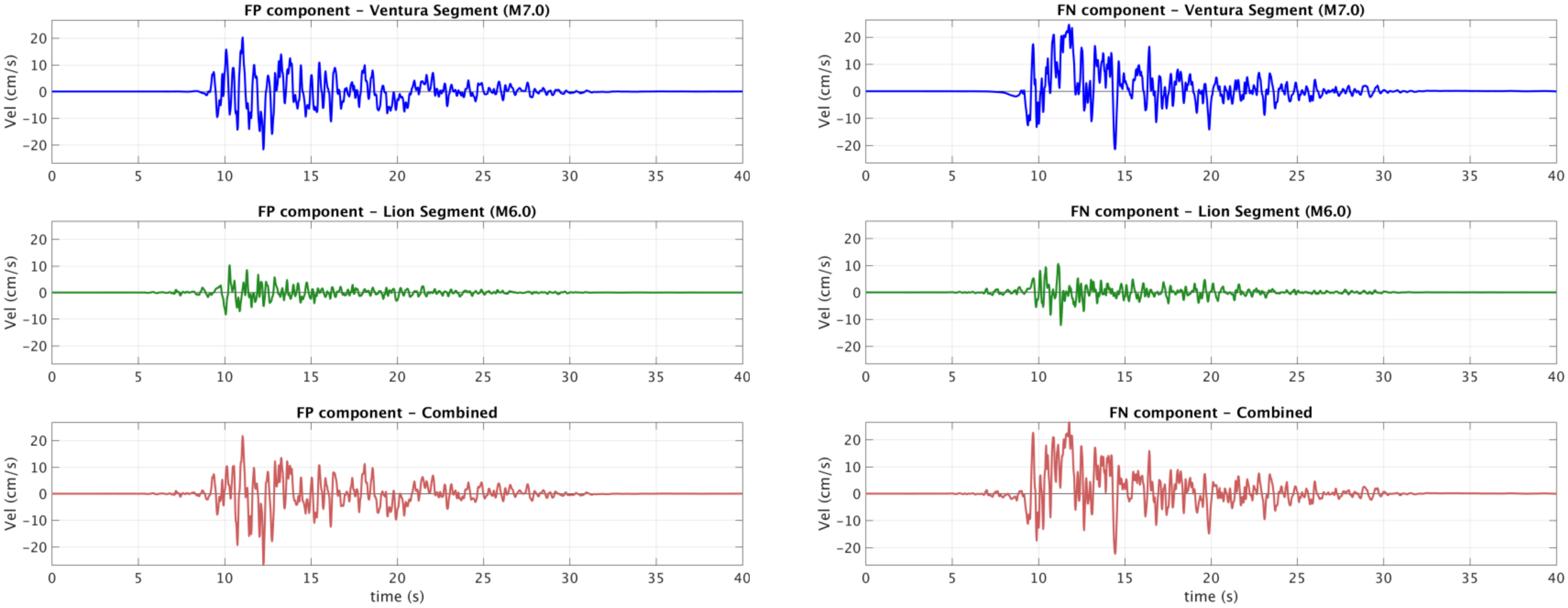
EW



Kinematic Simulations – Trial B (Ventura Site)

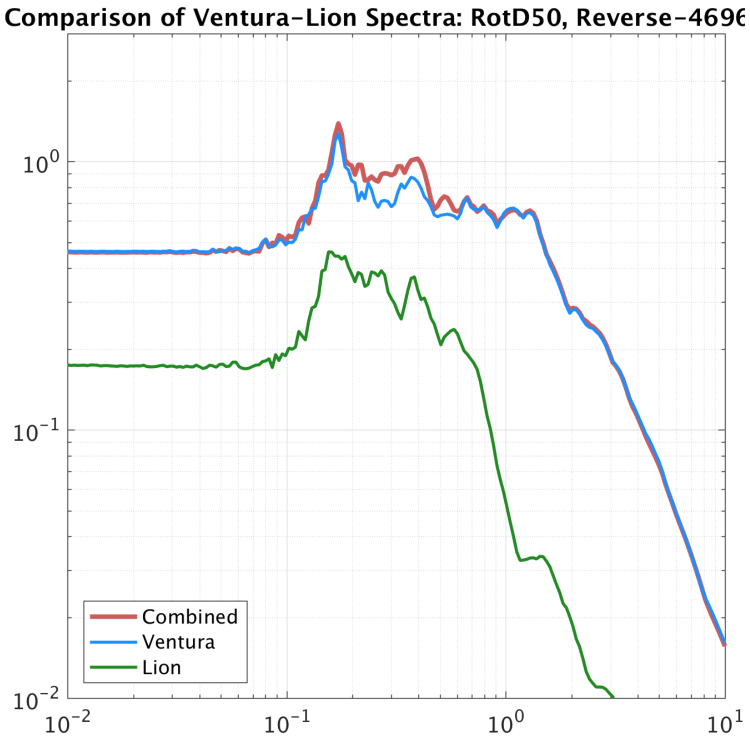
NS

EW

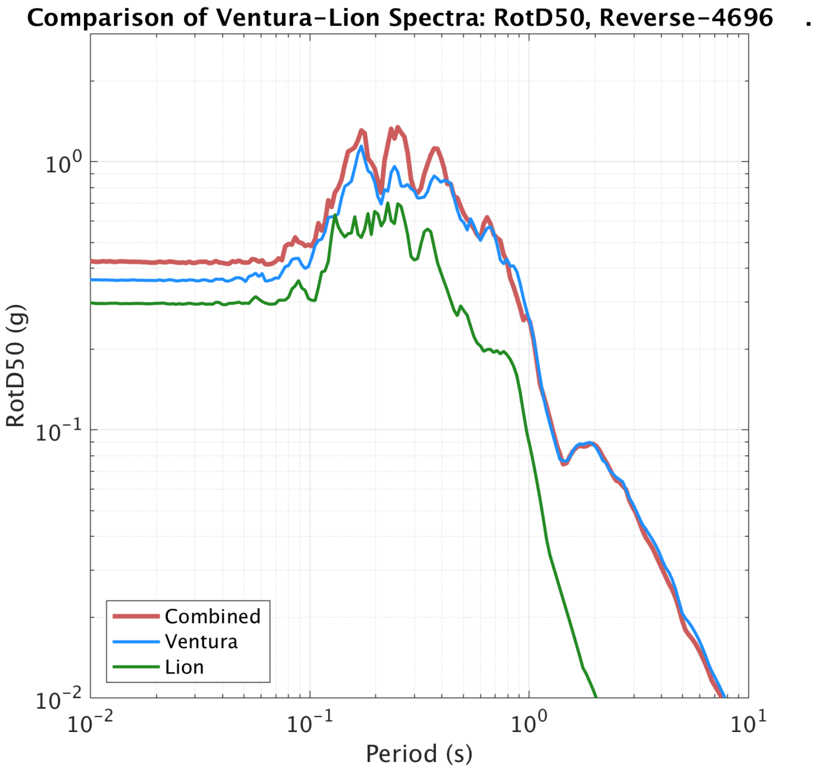


Response Spectra (Ventura Site)

Trial A Response Spectra



Trial B Response Spectra



Ground Motion Simulation Results

- Trial A used the fault dimensions, the final slip distributions, and the rupture initiation timing on both faults from the dynamic simulations in the kinematic simulation.

- Trial B used the full slip velocity time histories on each subfault from our dynamic simulations in the kinematic simulation.

- The contribution of the Lion backthrust fault to the combined ground motion is quite small.

- Use of the full dynamic slip velocities instead of the kinematic slip velocities results in much lower ground motions at intermediate and long periods, and increases the contribution of the Lion backthrust.

- In the Dynamic sims, the rupture front breaks the Lion backthrust fault and dies out after a few seconds, breaking only the deep section of the Lion fault. The second rupture on the Ventura fault continues and breaks the free surface.

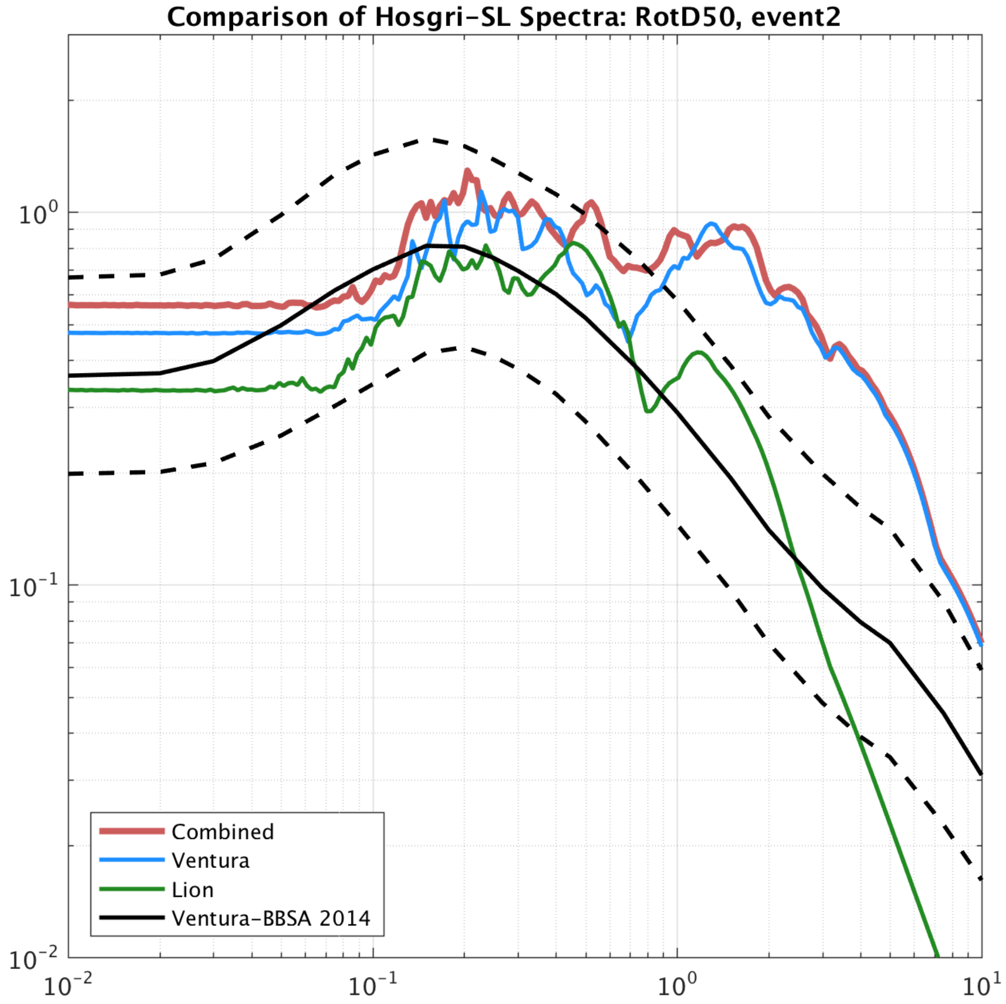
Thank you

Questions?

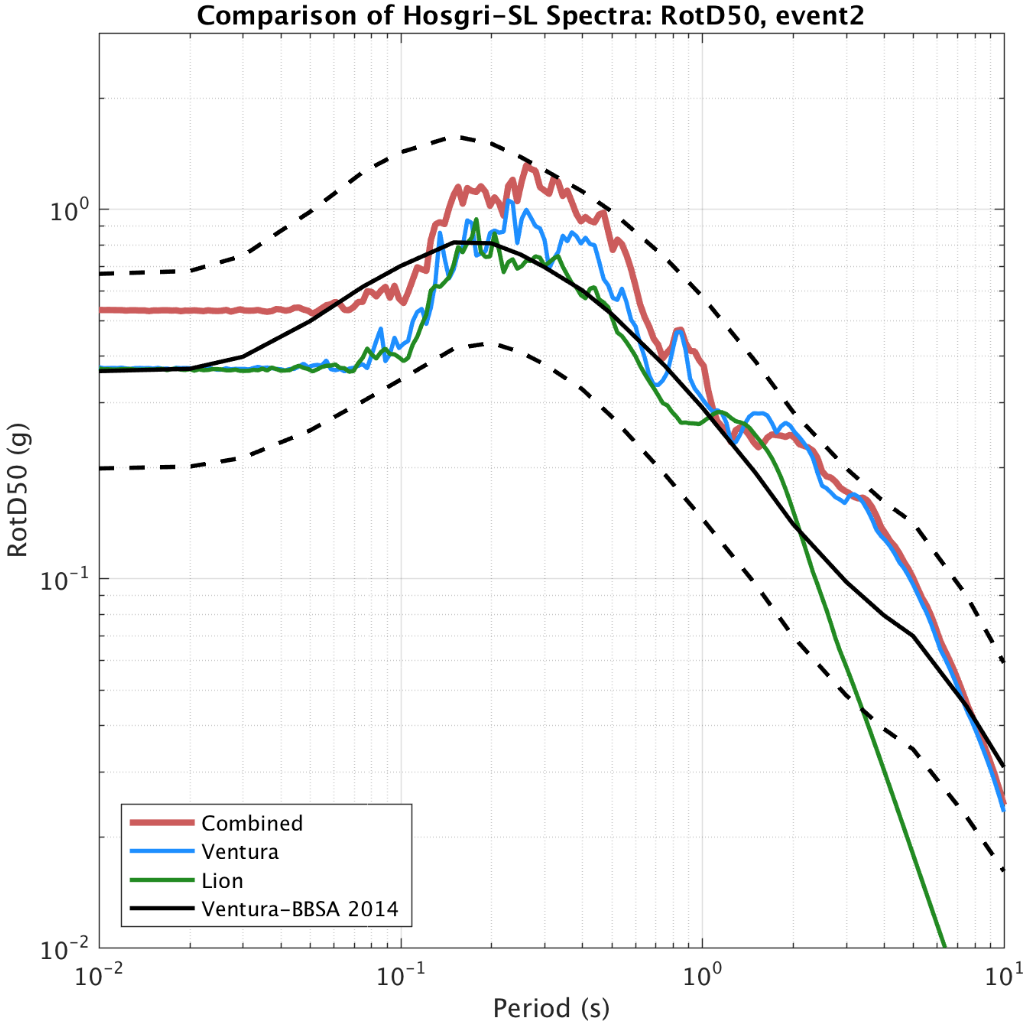
Hosgri-Shoreline

Same spectra as previously, with BSSA 2014 GMPE median +/- 1σ (M7.6 Hosgri scenario, Rjb=5km)

Trial A

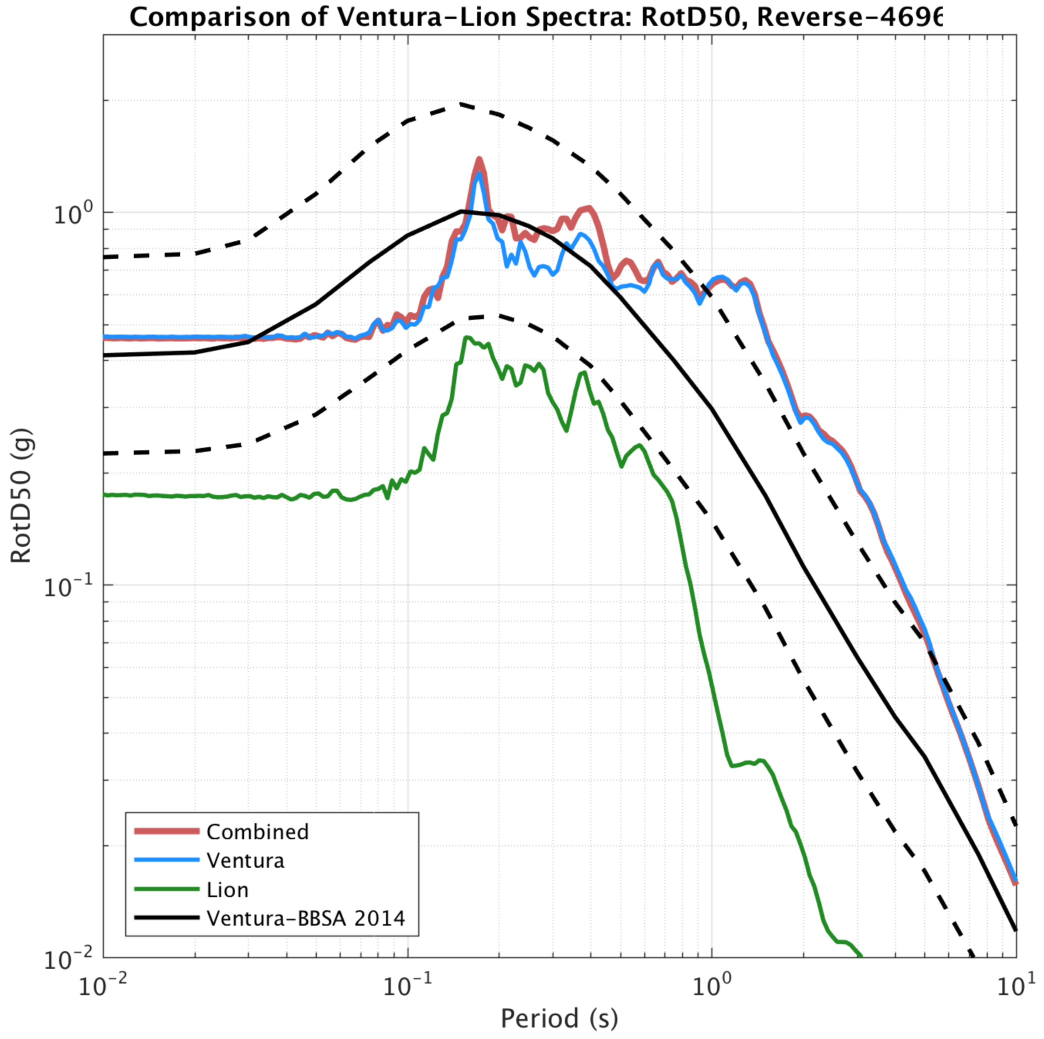


Trial B



Ventura-Lion
Same spectra as previously, with BSSA 2014 GMPE median +/- 1σ (M7.0 Ventura scenario, Rjb=0.5 km)

Trial A



Trial B