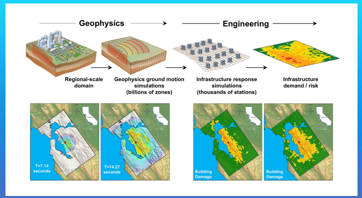


PEER International Pacific Rim Forum
June 16-17, 2021

Seismic Velocity Relations for SF Bay Quaternary Sediments and Simulation of Long Duration Shaking in the East Bay Plain

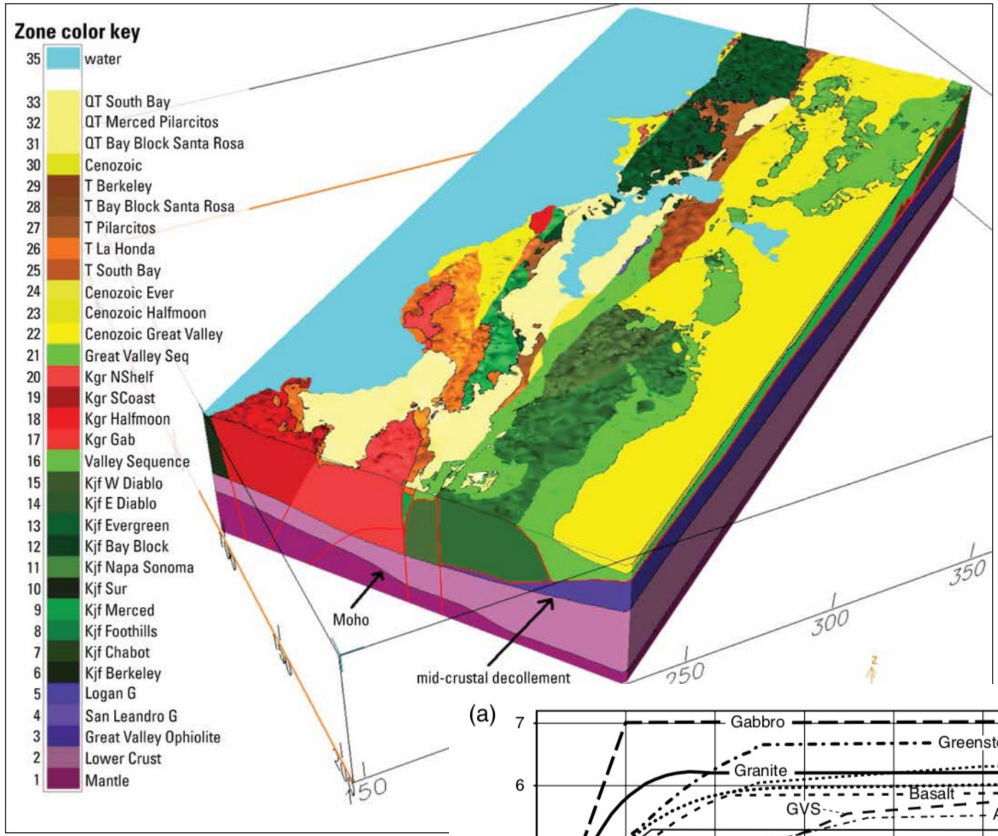
Evan Hirakawa
Brad Aagaard
US Geological Survey

June 16, 2021

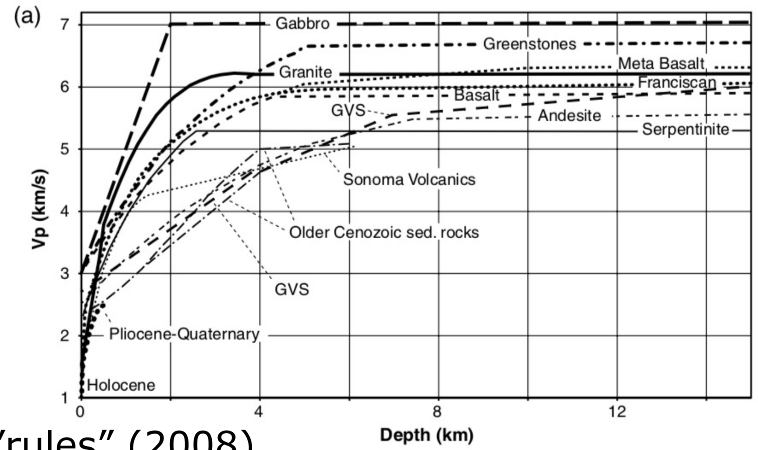
science for a changing world

PEER

USGS San Francisco Bay Region 3D Seismic Velocity Model (SF-CVM)

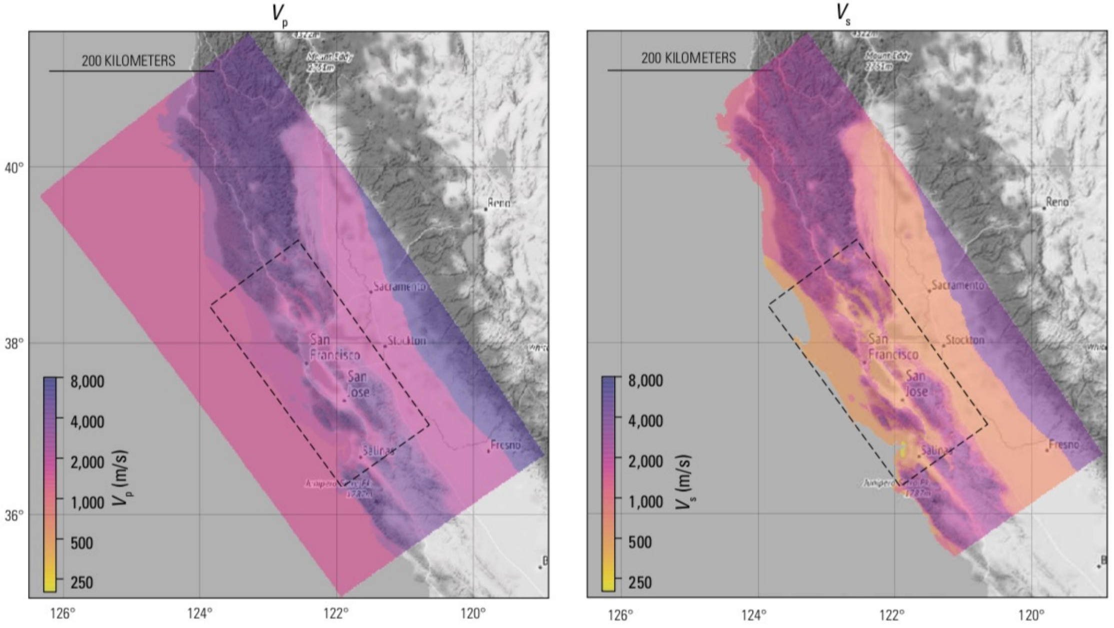


Geologic model
Jachens et al. 2006



Brocher "rules" (2008)

Seismic velocities at -100 m

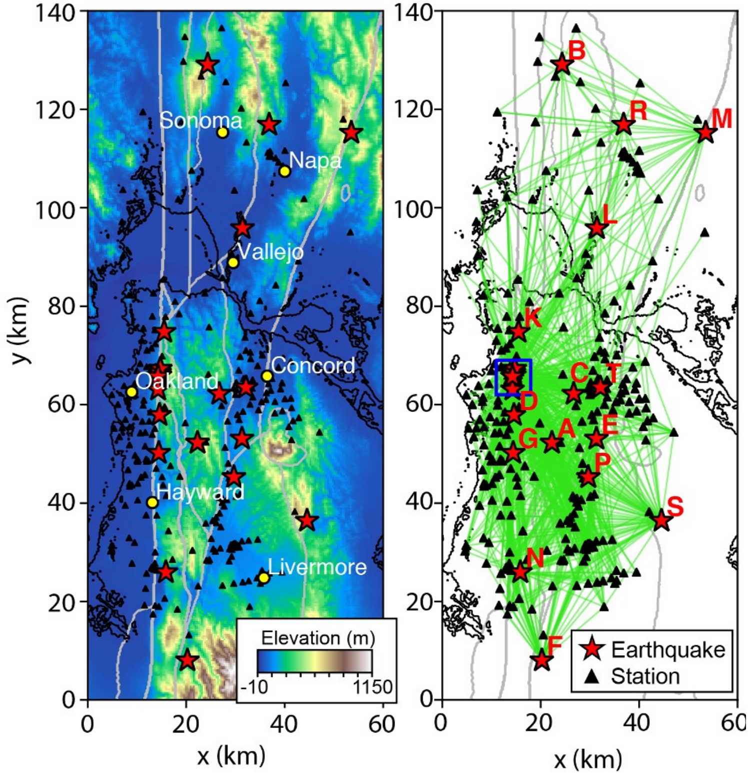


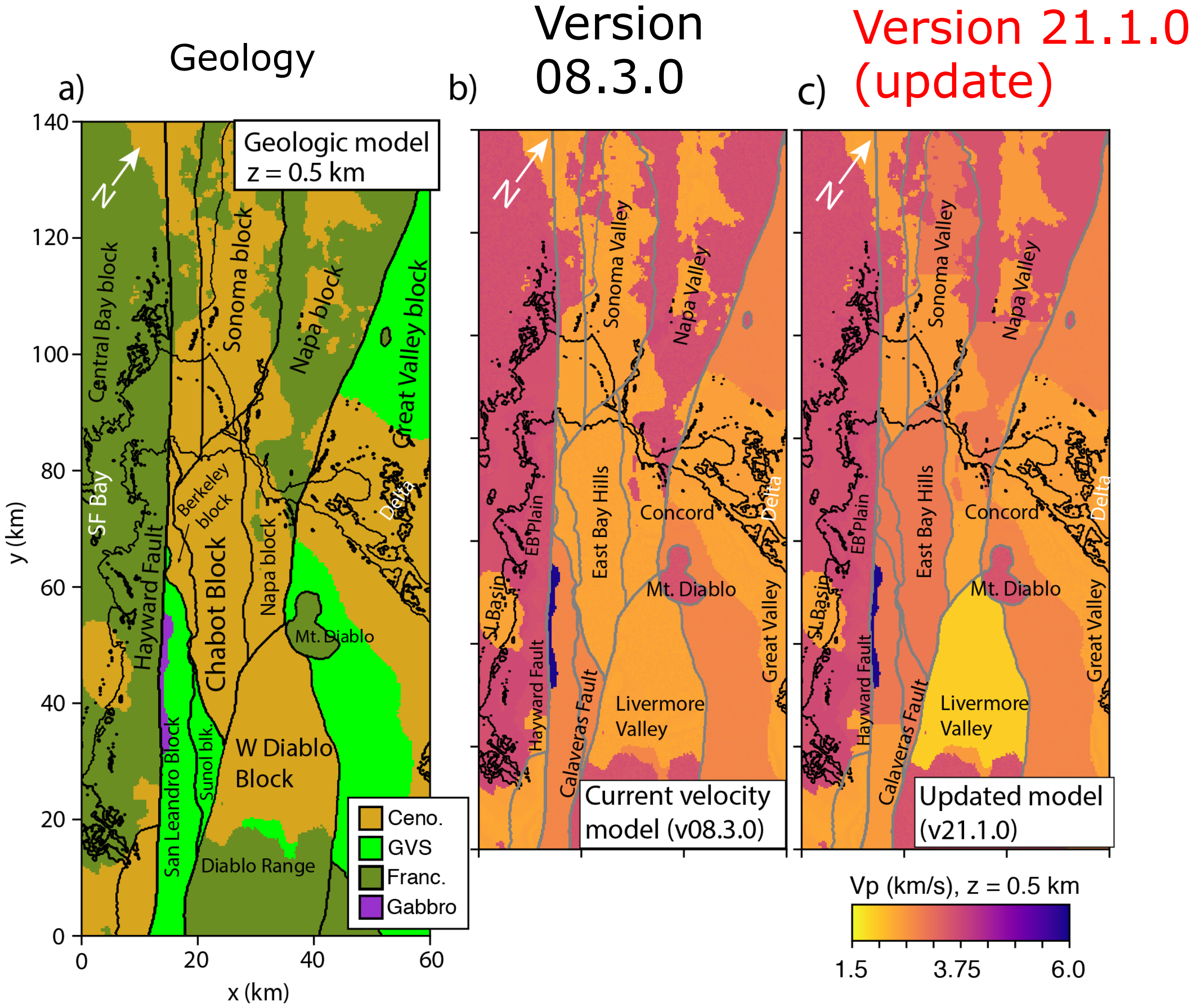
- The USGS SF-CVM is a seismic velocity model based on an underlying structural geology model (Jachens et al., 2006).
- Seismic velocity vs. depth "rules" assign seismic properties to geologic model (Brocher, 2005, 2008).

Evaluation and update for SF-CVM (Hirakawa and Aagaard, in review)

- We simulated 20 moderate (Mw 3.7-4.5) earthquakes in the East Bay, using SW4 (finite difference software, Petersson and Sjogreen, LLNL).

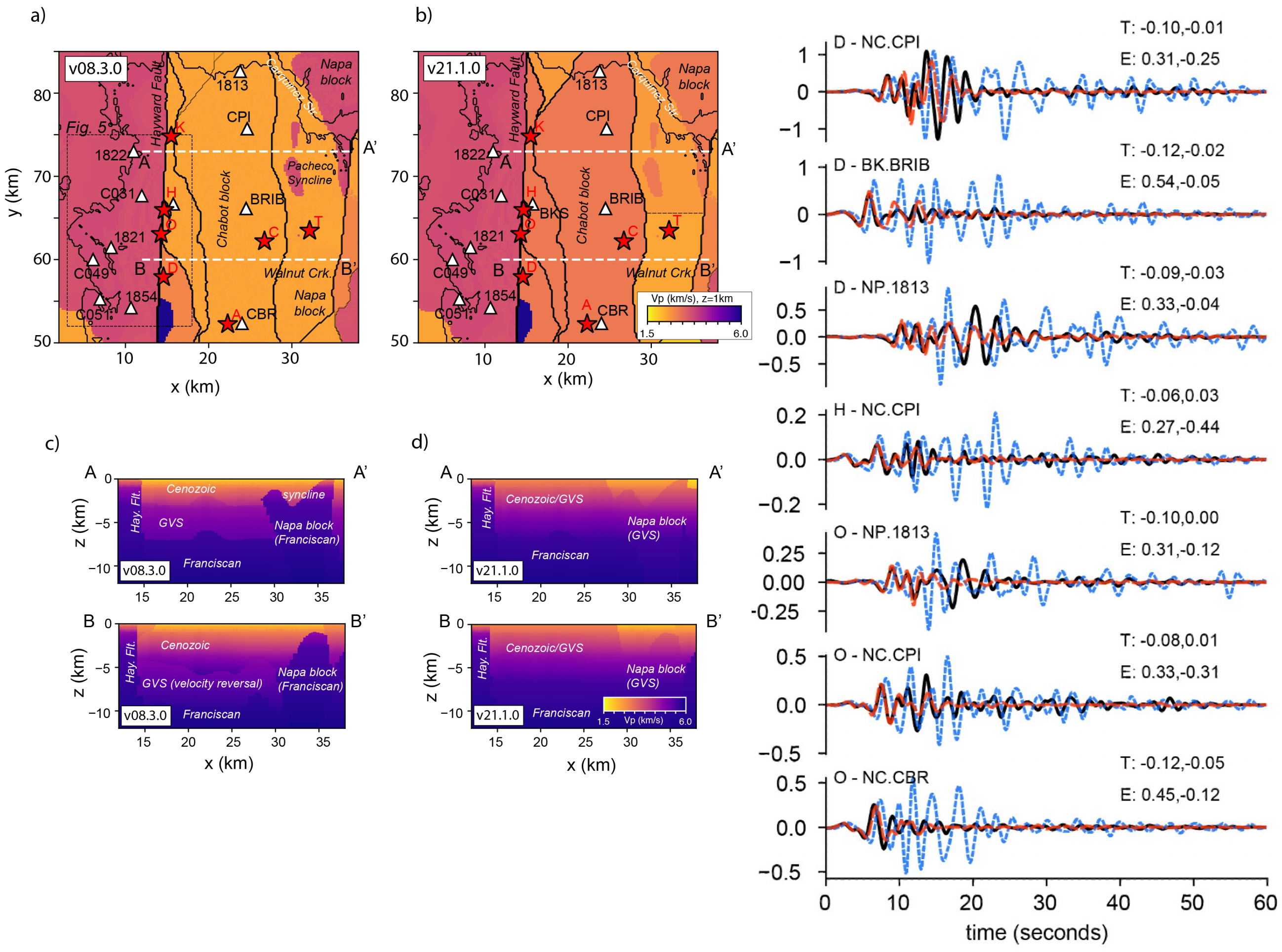
- We compared synthetic and observed waveforms using quantitative performance metrics, these comparisons drive the velocity model updates.



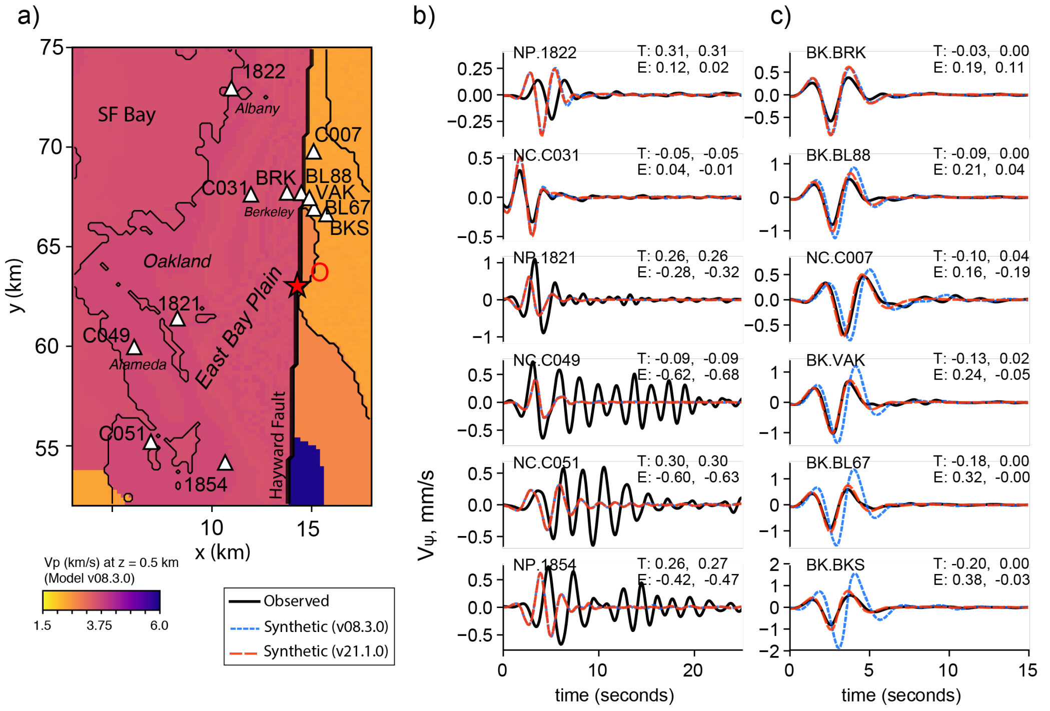


- Main changes are to the East of the Hayward Fault
- Velocity increase in East Bay Hills
- Velocity decrease in Livermore valley

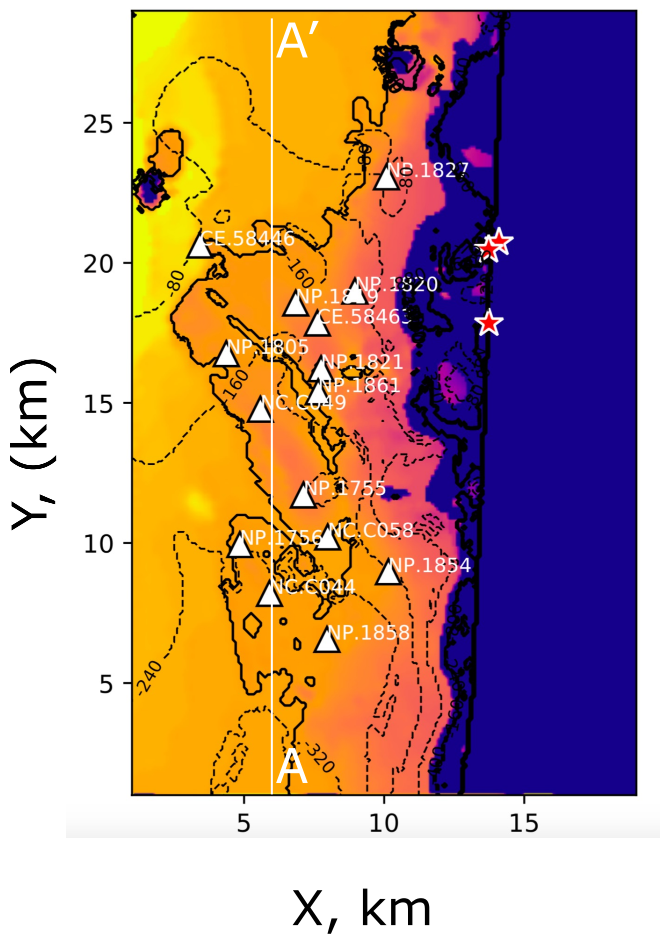
East of the Hayward Fault, the model update improves synthetic arrival time, peak ground velocity (PGV), and cumulative energy.

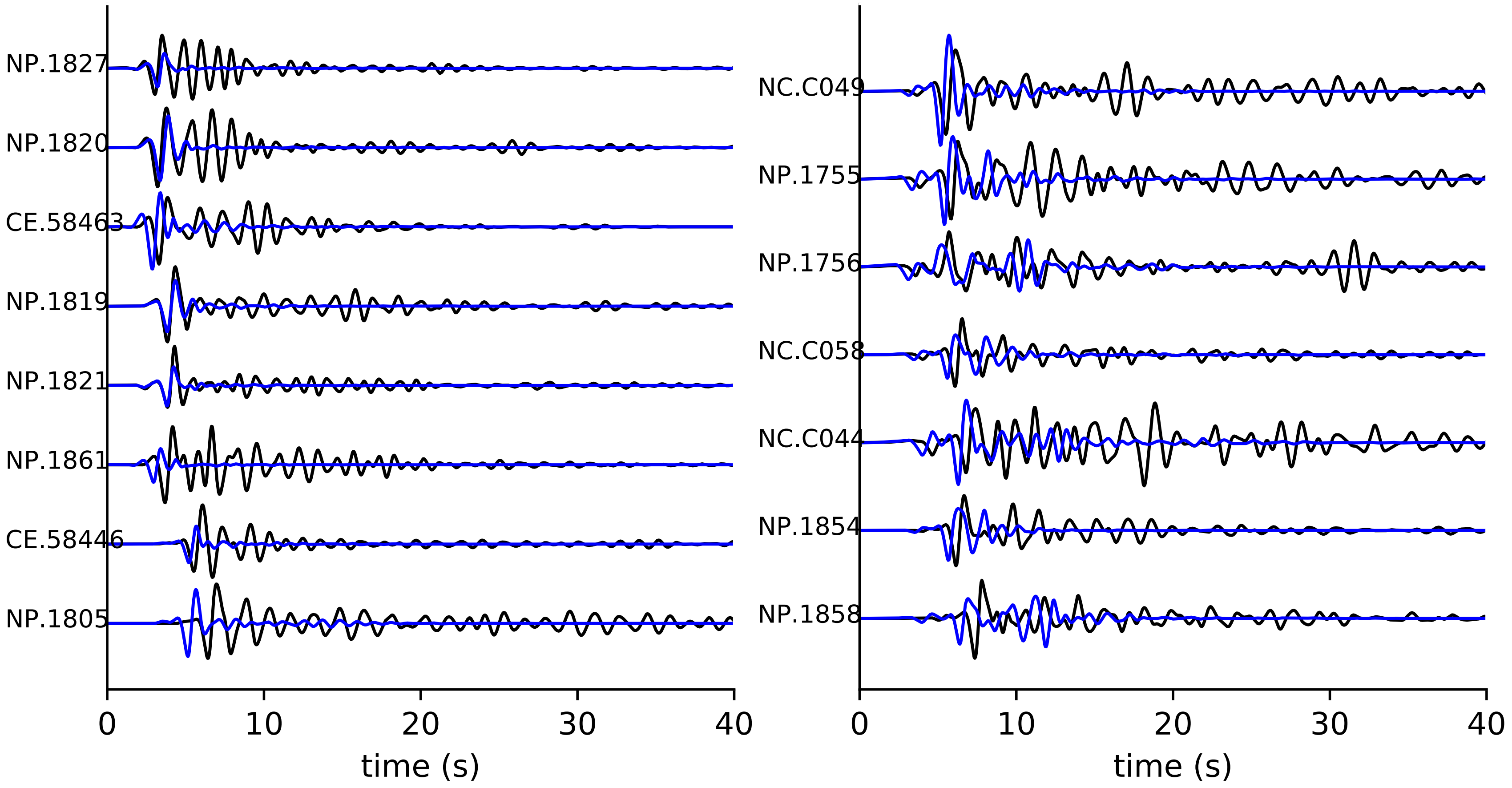


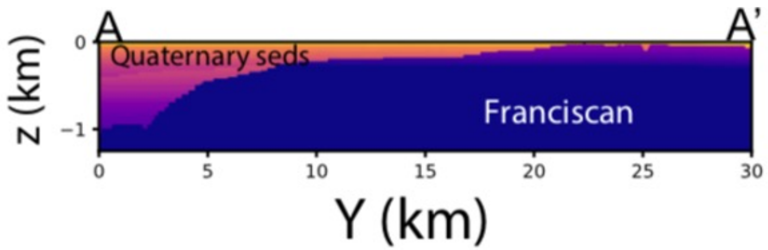
West of the Hayward Fault, long reverberations are recorded in real earthquakes that are not in the synthetics.

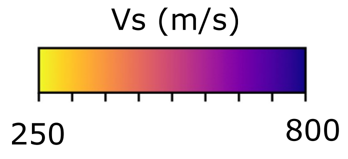


Intense shaking in the Oakland and Alameda, CA region







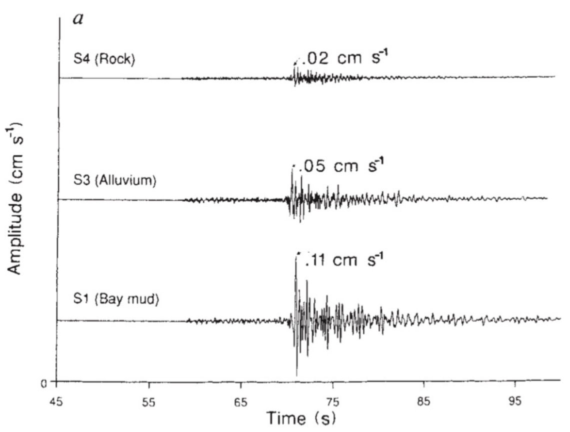


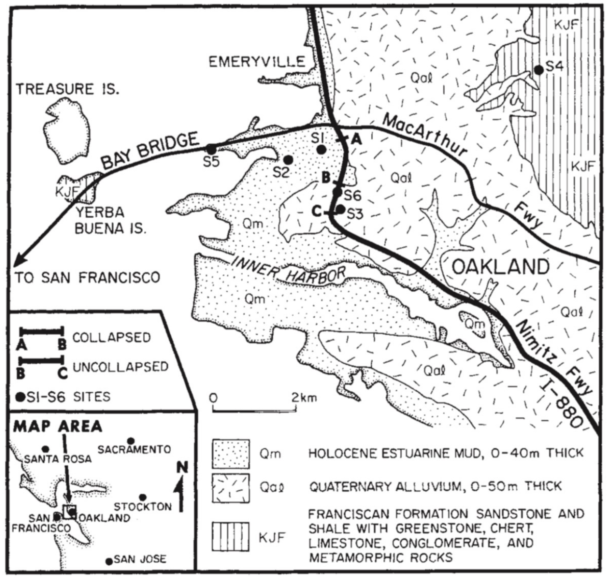
West of Hayward Fault, long reverberations are recorded in real earthquakes that are not in the synthetics

Historic shaking in this area:
1989 Mw 6.9 Loma Prieta Earthquake

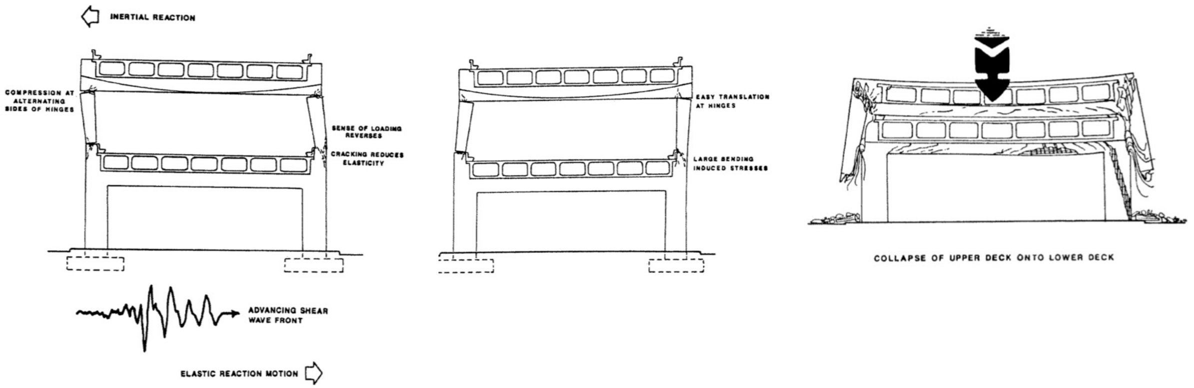
Sediment-induced amplification and the collapse of the Nimitz Freeway

S. E. Hough*, P. A. Friberg*, R. Busby*, E. F. Field*, K. H. Jacob* & R. D. Borcherdt†

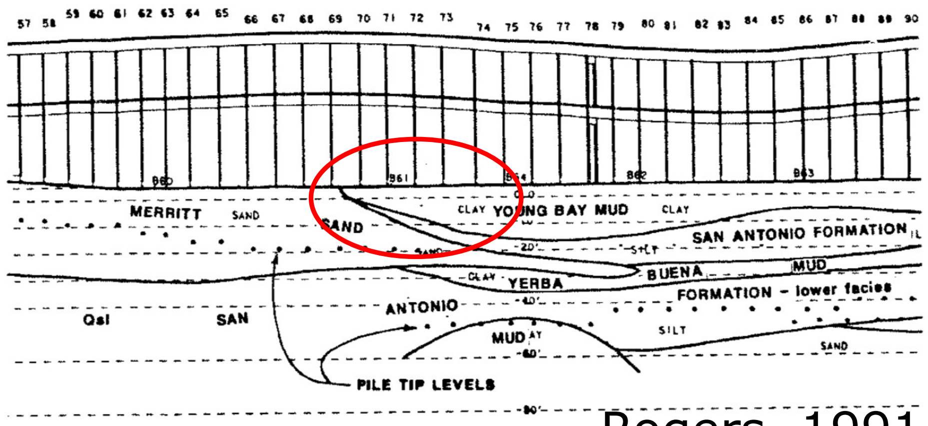




Cypress Viaduct collapse due to situation on soft bay mud



CYPRESS VIADUCT IN VICINITY OF BENT 72



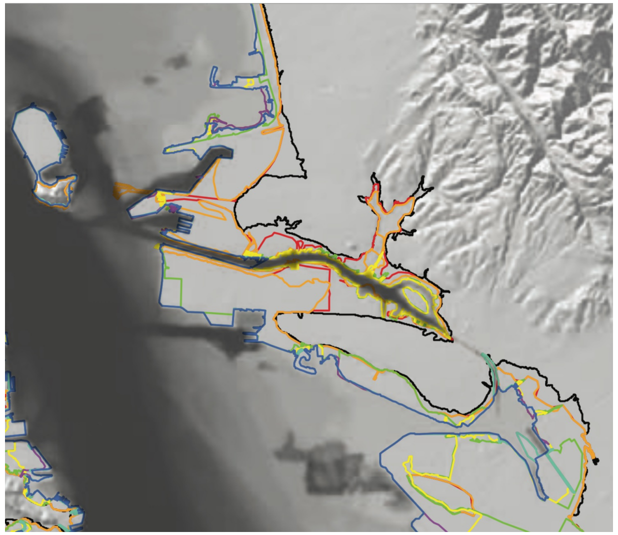
Rogers, 1991

From 1989 Loma Prieta aftershock studies, it was found that motions are amplified in Oakland bay mud relative to alluvium and rock

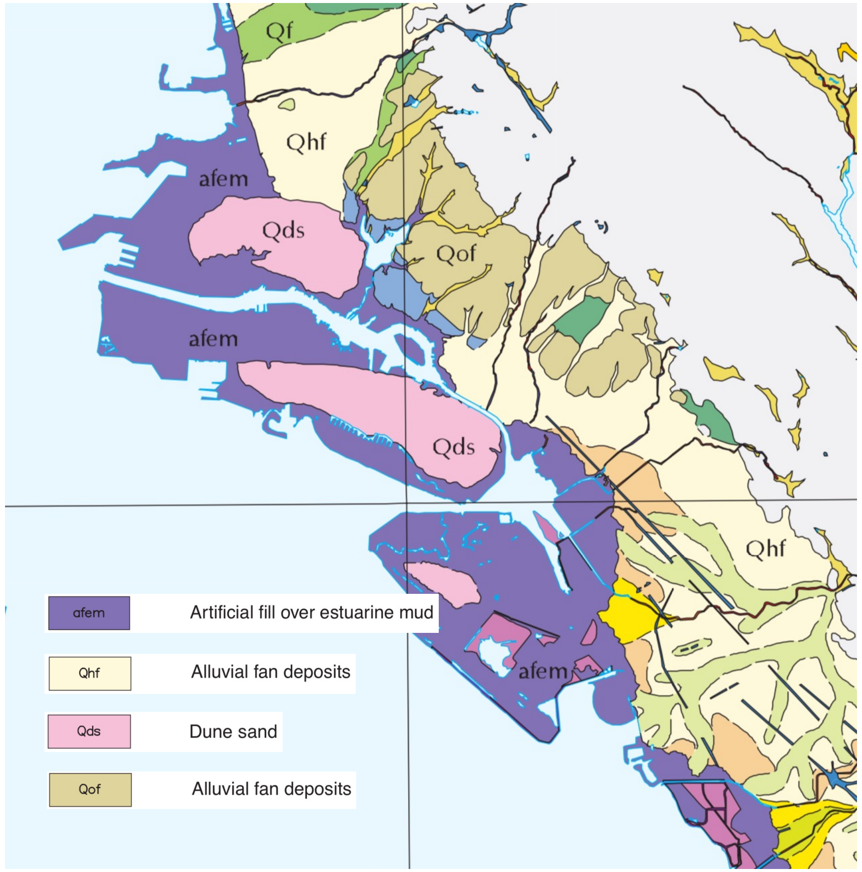
Much of this area is built on artificial fill over SF Bay mud and estuary deposits

Quaternary Geology

Oakland Area, 1857

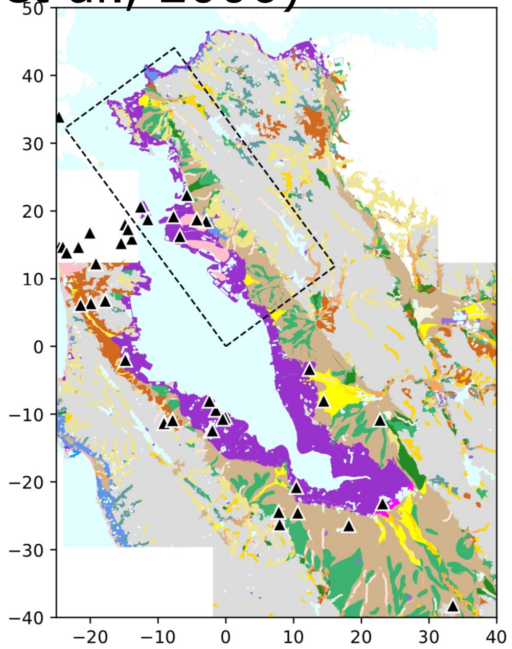


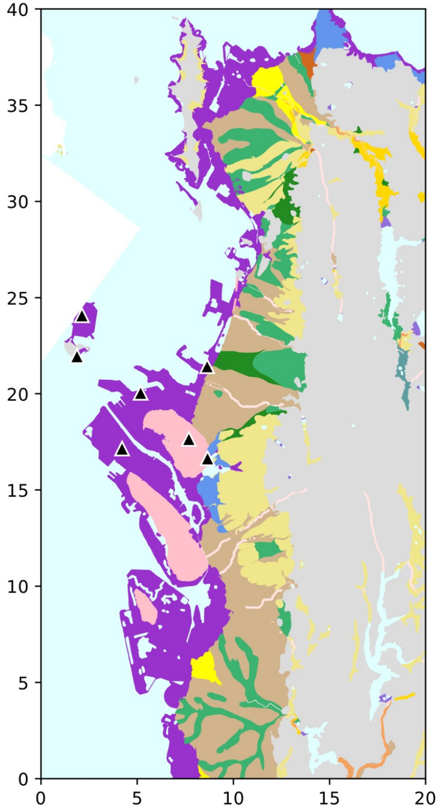
Hitchcock et al., 2008



Estuarine mud, dune sand, and alluvial fan deposits cover the area west of the Hayward Fault

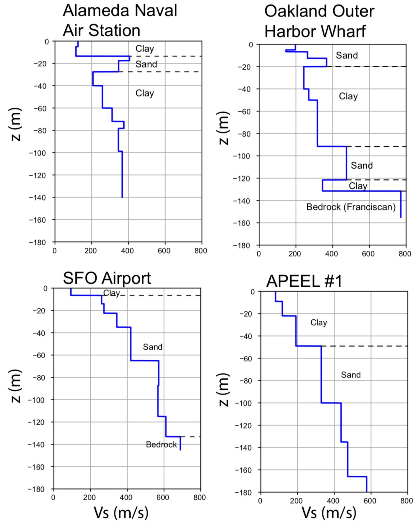
Map of Quaternary Deposits (Witter et al., 2006)



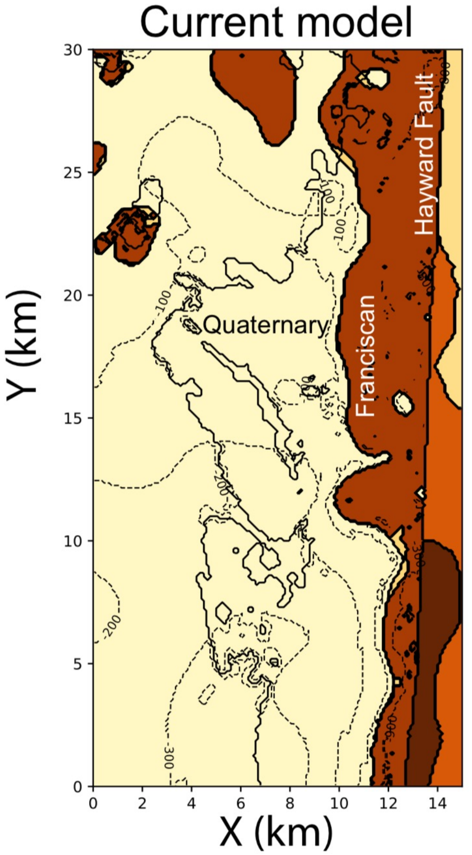


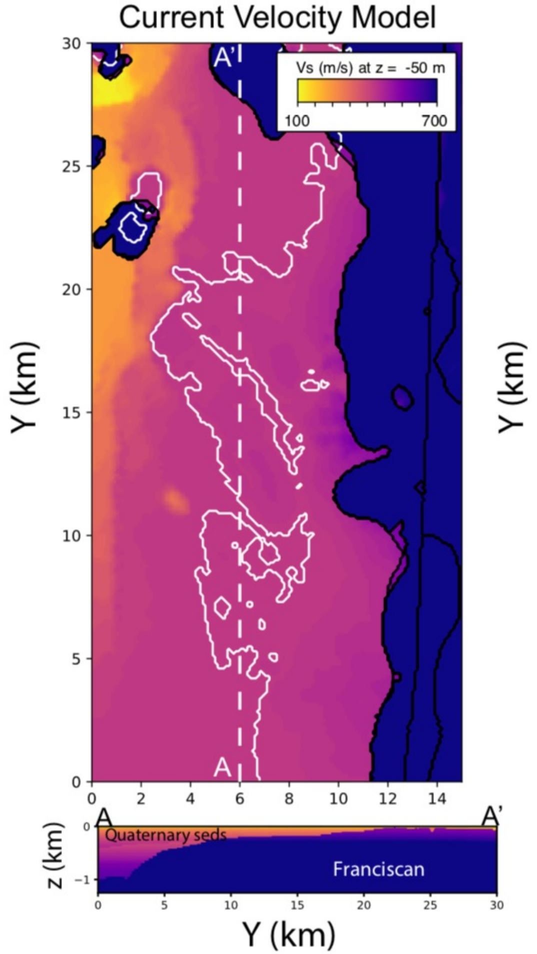
Map colors show quaternary sediment types from Witter et al (2006) Clay/mud: purple, dune sand: pink, alluvium: tan

Downhole velocity logs (black triangles on map above) (Gibbs, et al, 1992; Boore, 2003)

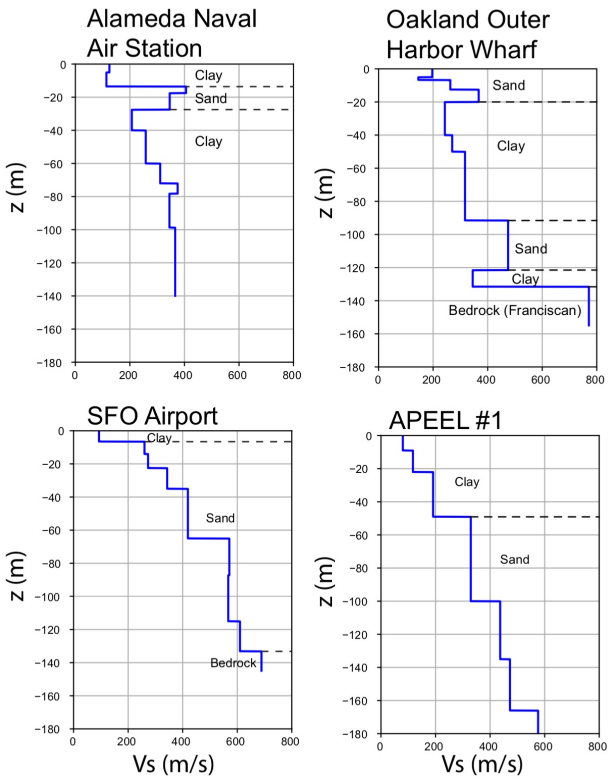


Incorporating outside data into SF-CVM to better represent SF Bay Quaternary sediments

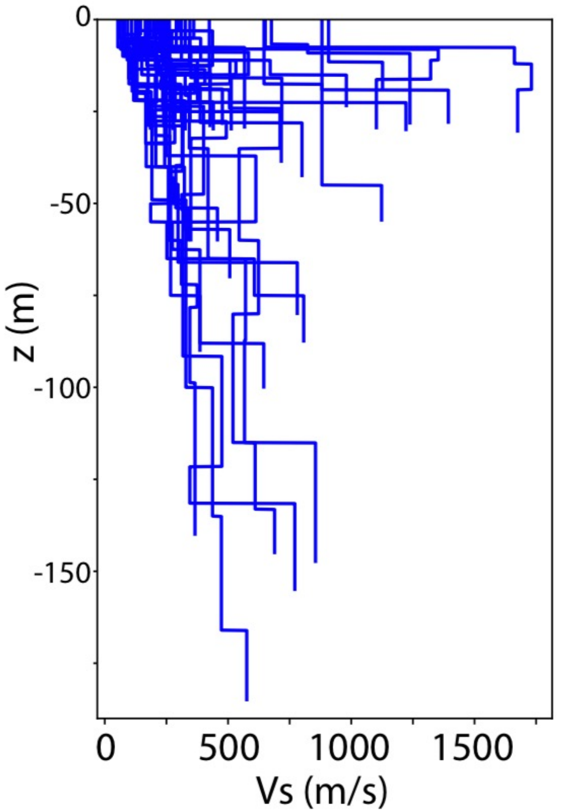




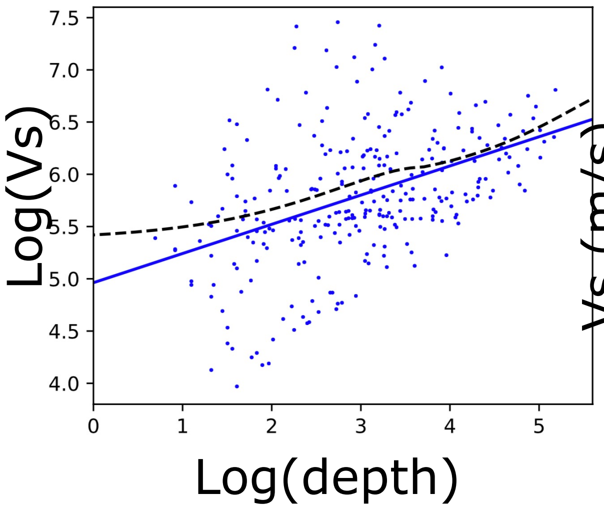
Fitting new rules with Boore (2003) 1D velocity models



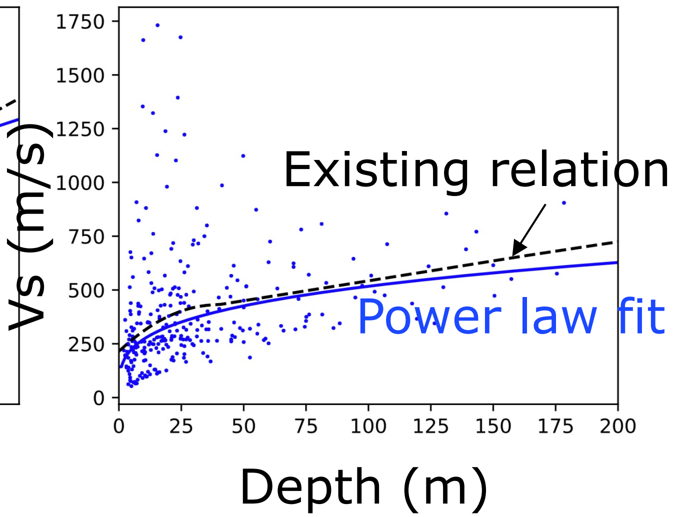
Gibbs et al, 1992



Compilation of all profiles in Central Bay Block, Boore 2003

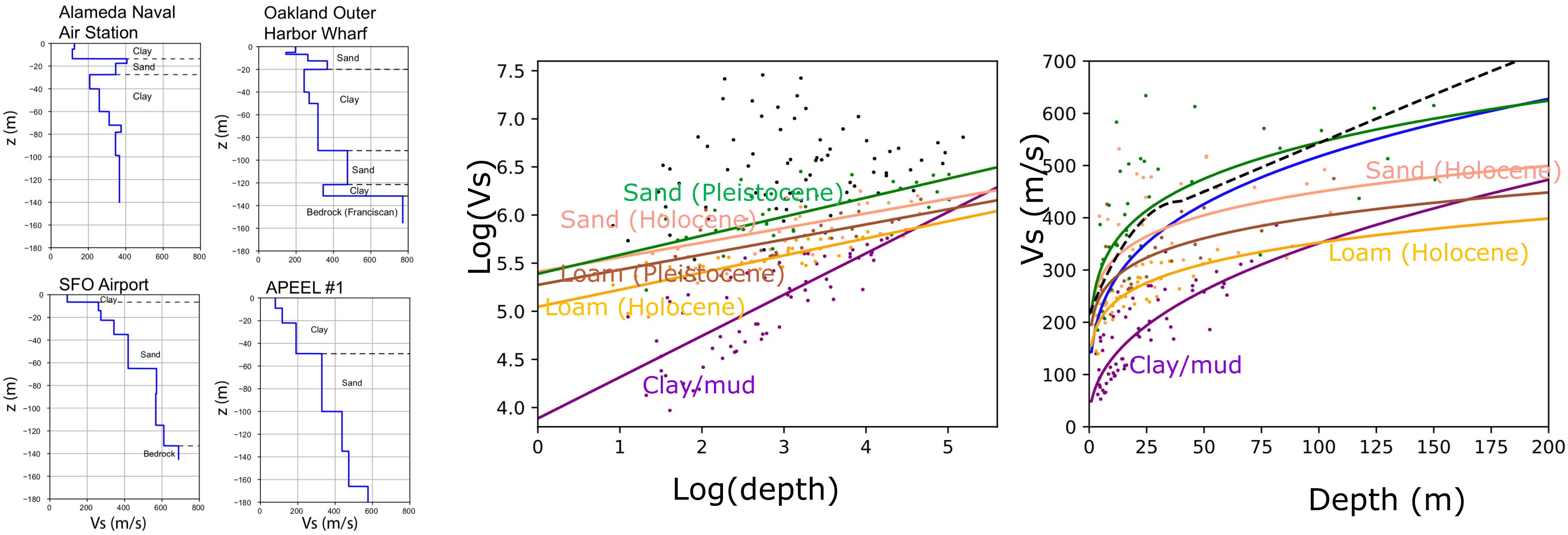


Consider each layer as a velocity-depth point and fit with power law (in log space)

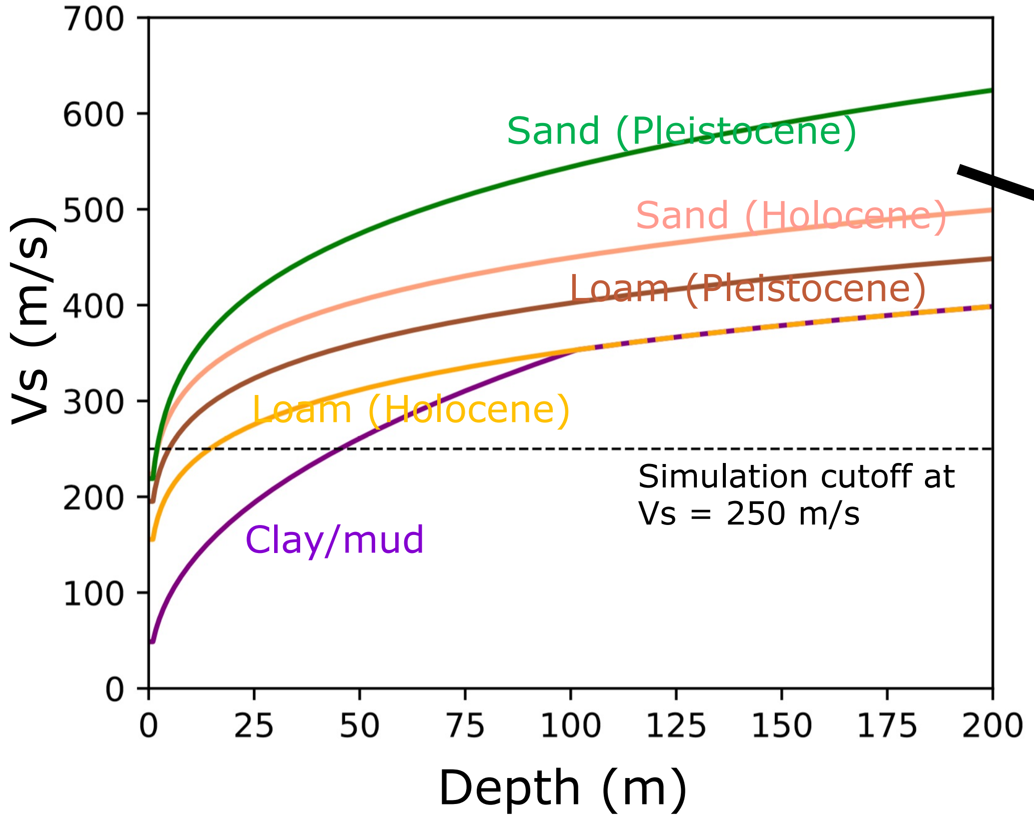


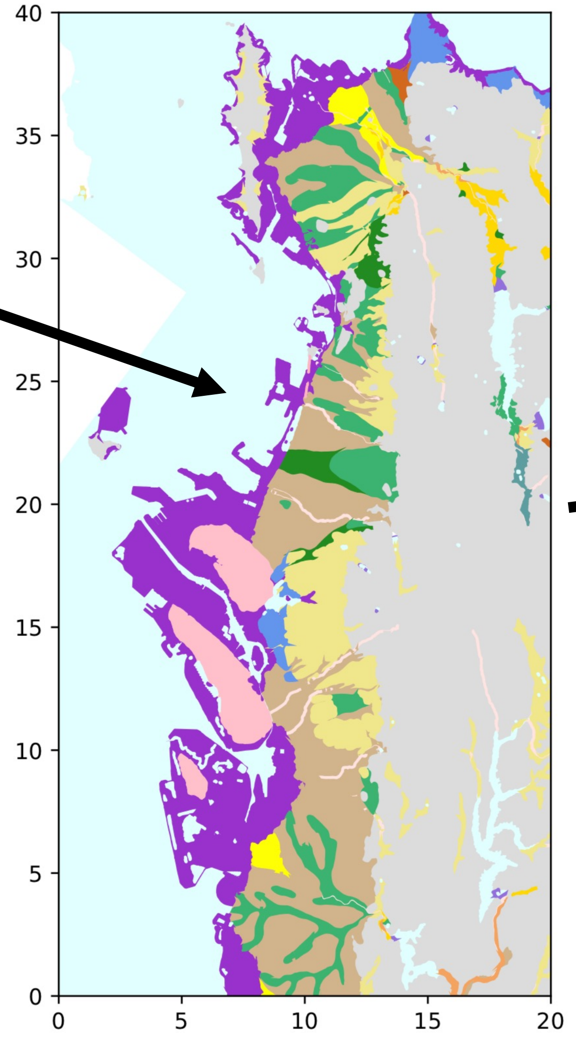
Resulting velocity-depth curve is too high for some SF Bay sediments.

Categorize and refit the 1D layer data points based on rock type



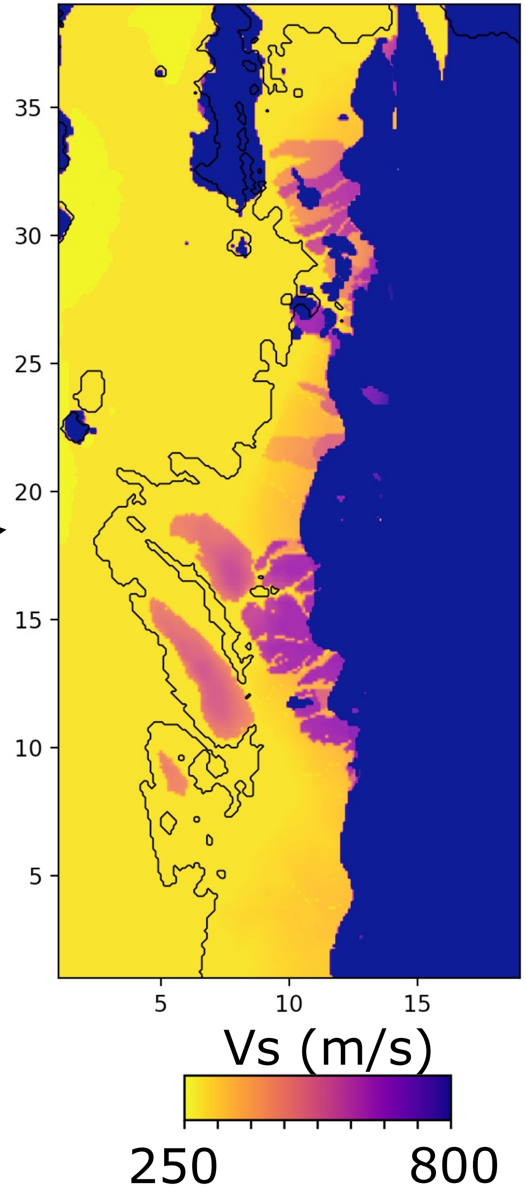
Assign new rules for Quaternary sediments to geologic units (only in Quaternary "zone" of SF-CVM)



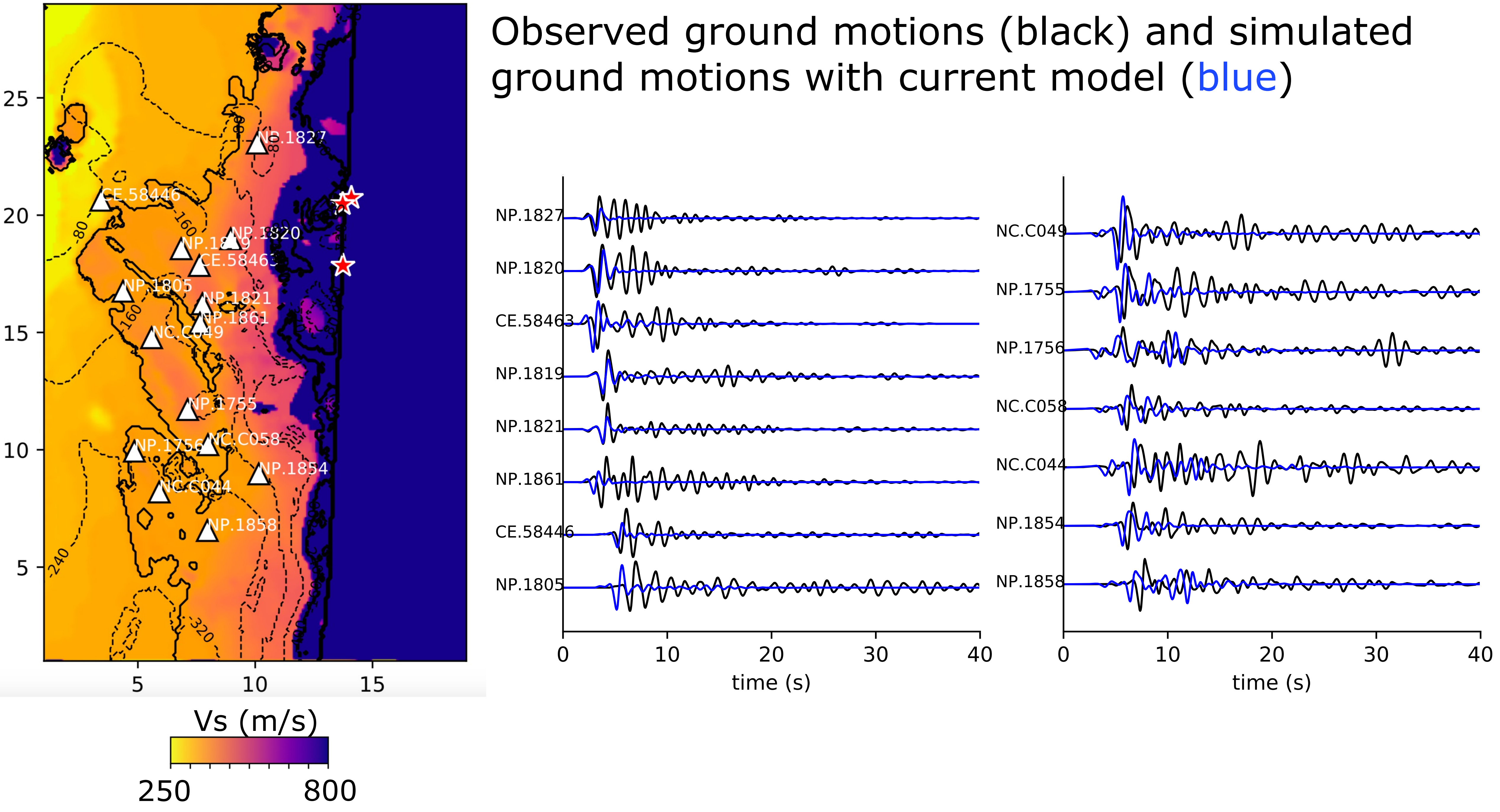


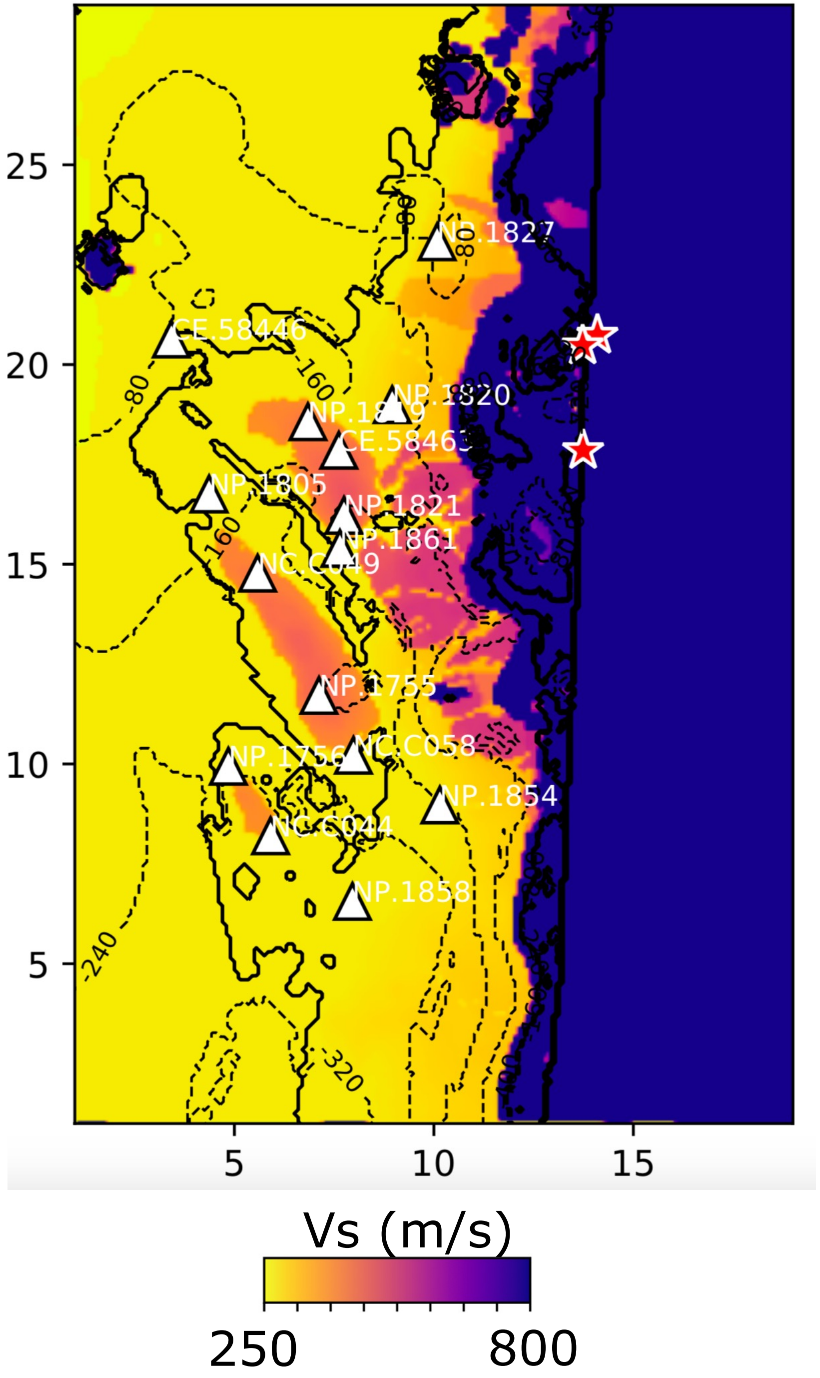
Clay/mud: purple, dune sand: pink, alluvium: tan

Resulting velocity model (@ z=20m)

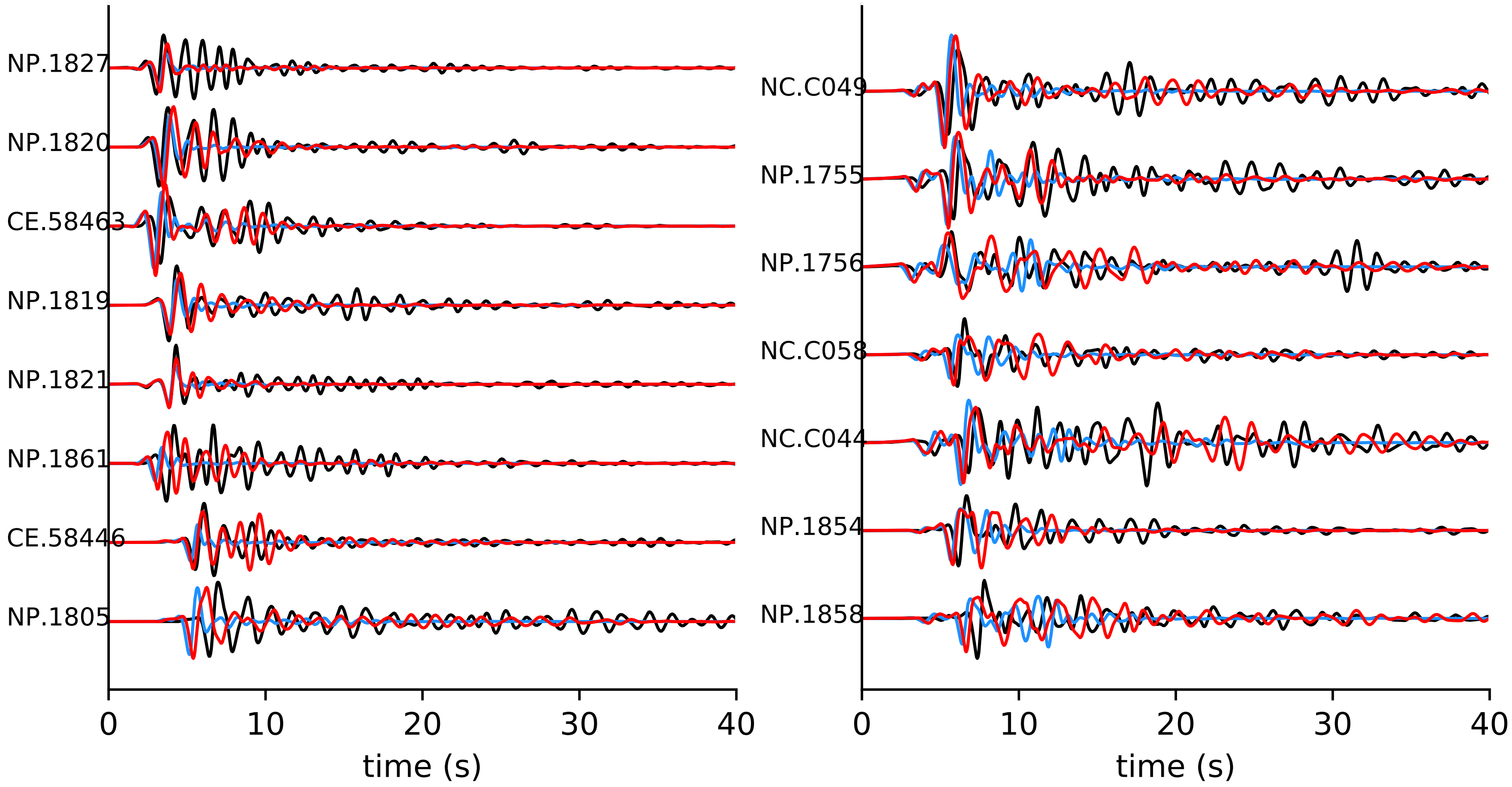


Observed ground motions (black) and simulated ground motions with current model (blue)

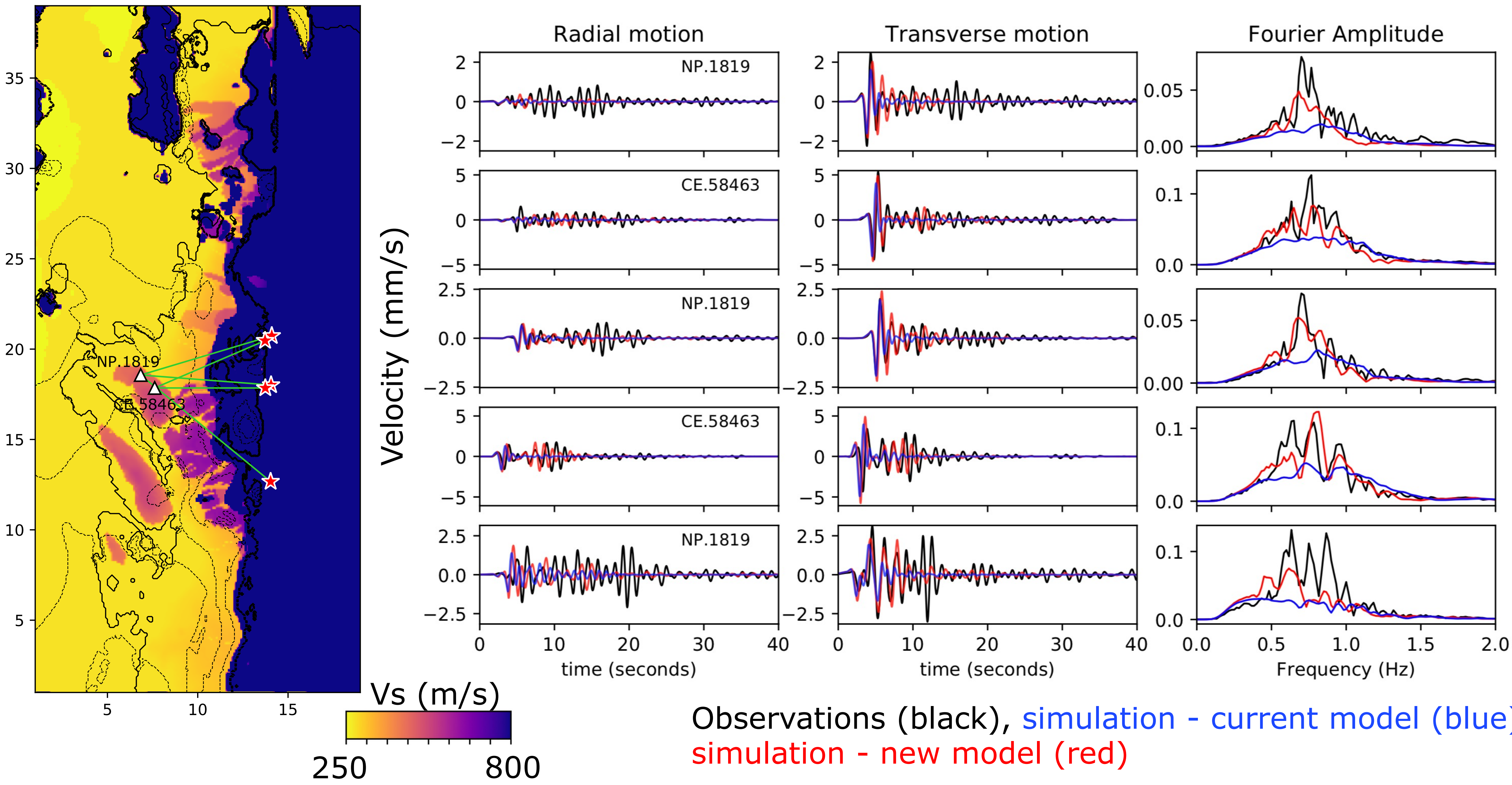




Observed ground motions (black) and simulated ground motions with new model (red) and current model (blue)

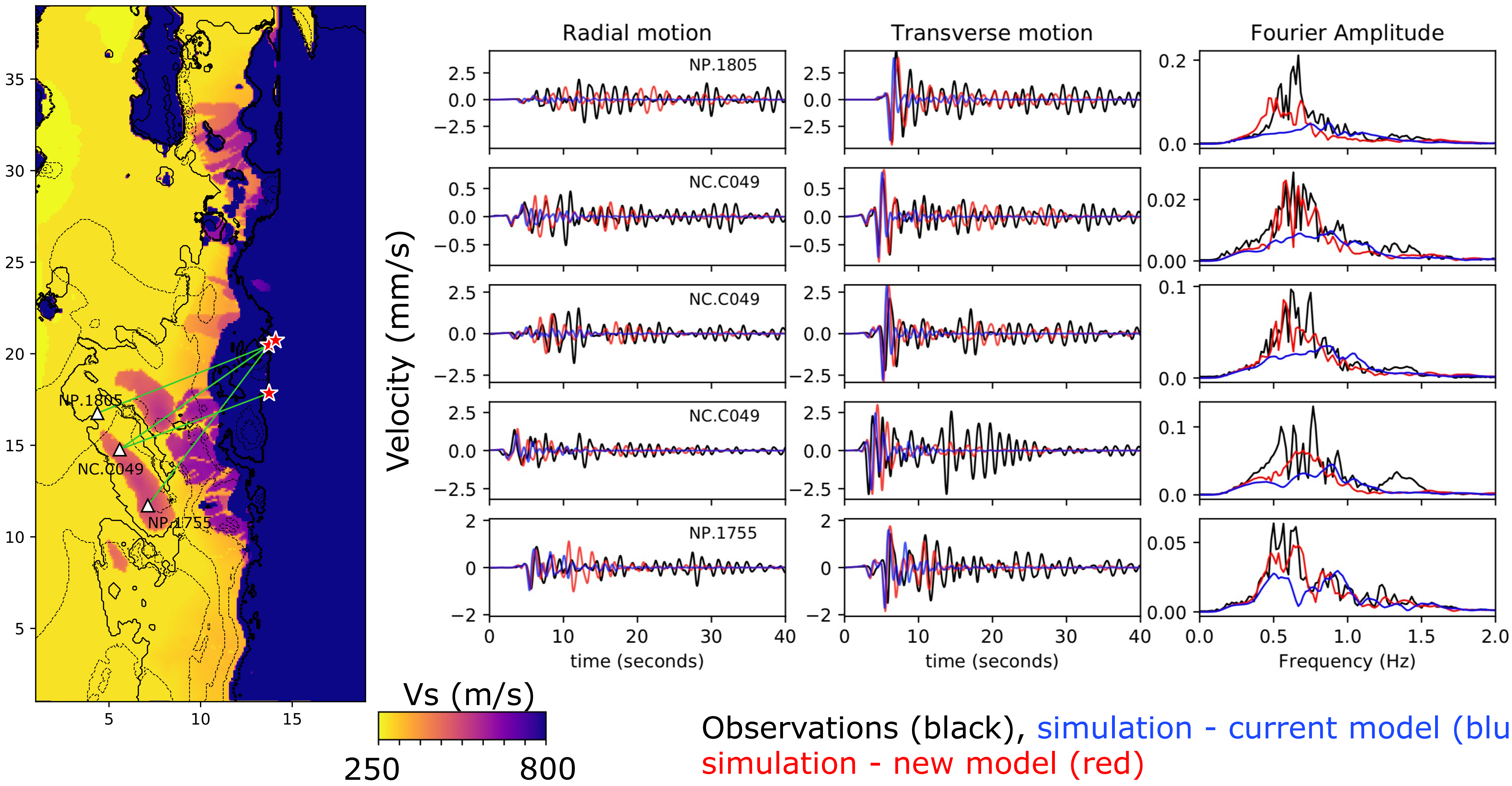


Ground motions in West/Downtown Oakland



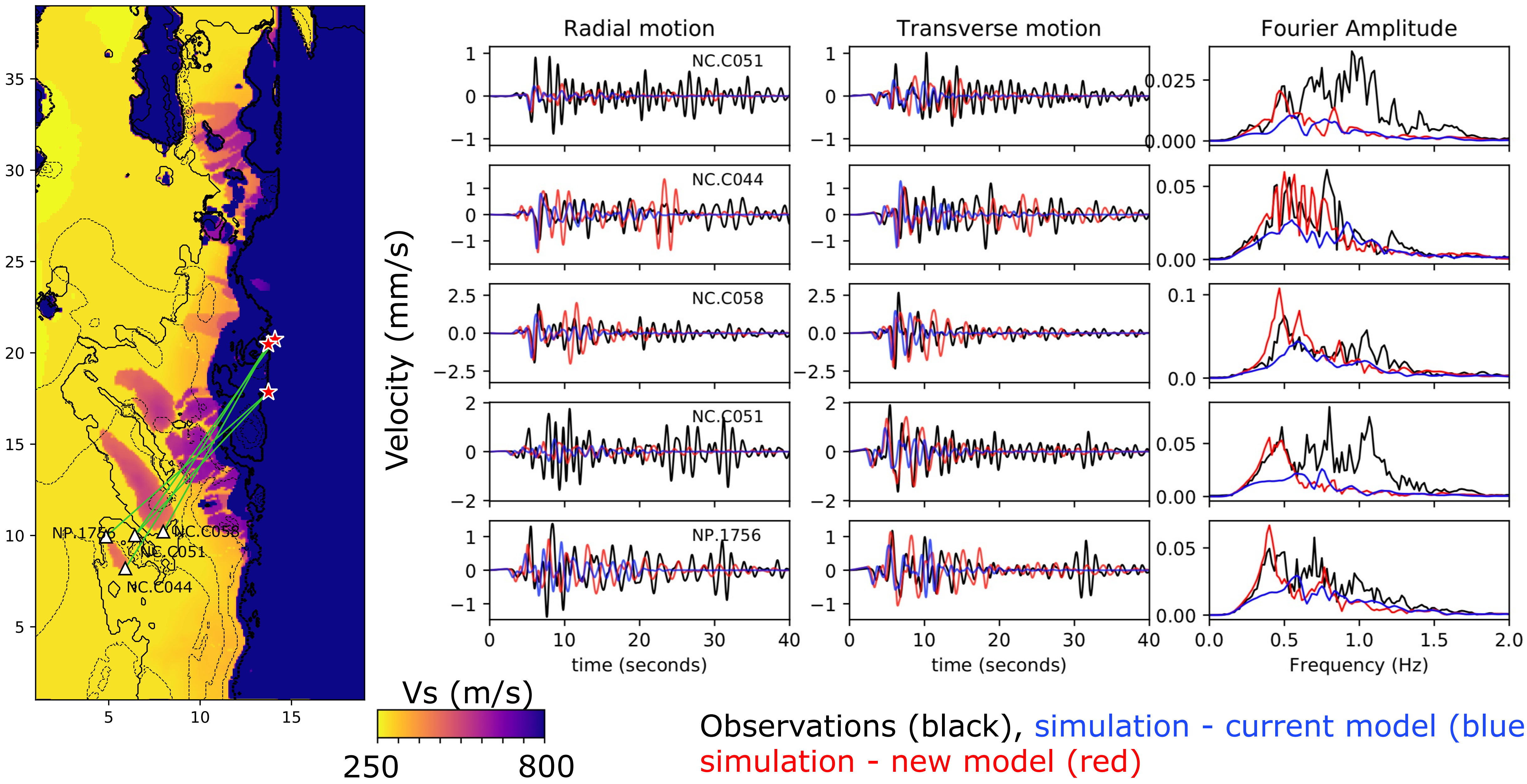
Observations (black), simulation - current model (blue), simulation - new model (red)

Ground motions in Alameda Island



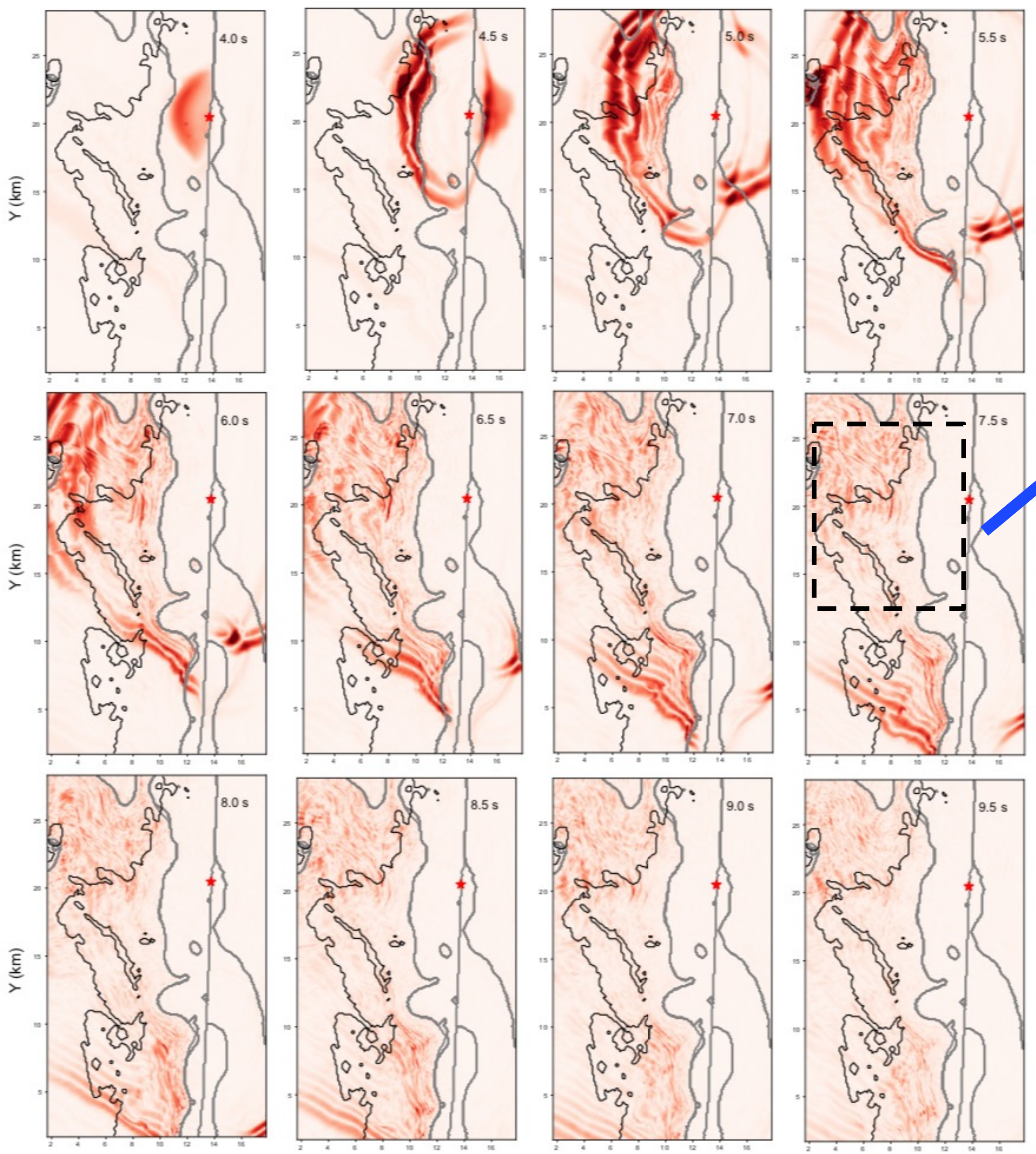
Observations (black), simulation - current model (blue), simulation - new model (red)

Ground motions on Bay Farm Island

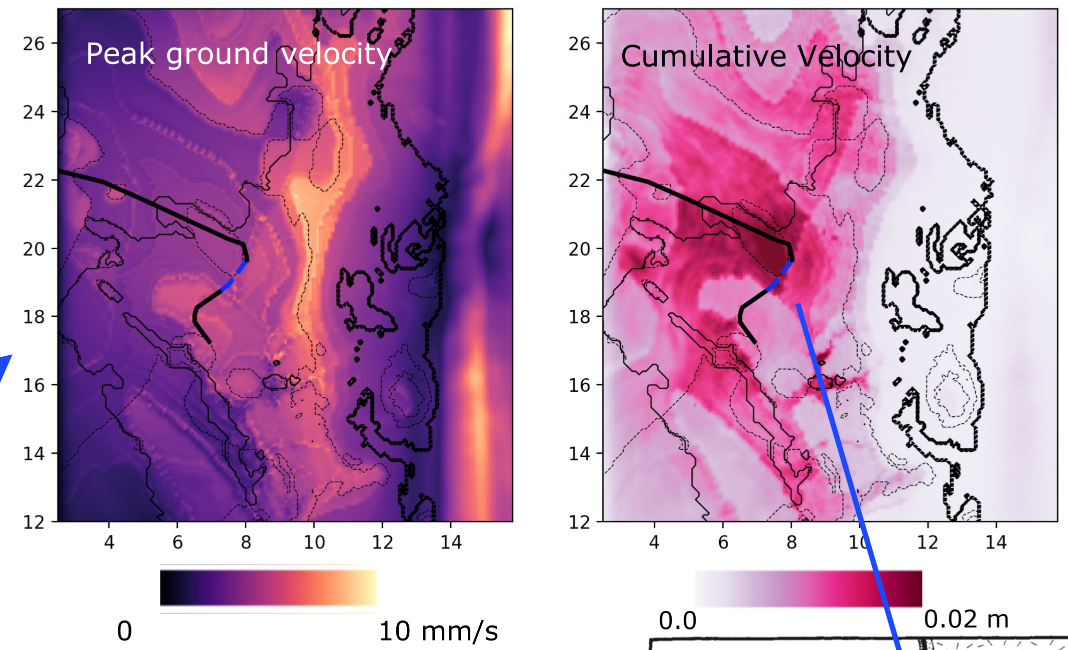


Observations (black), simulation - current model (blue), simulation - new model (red)

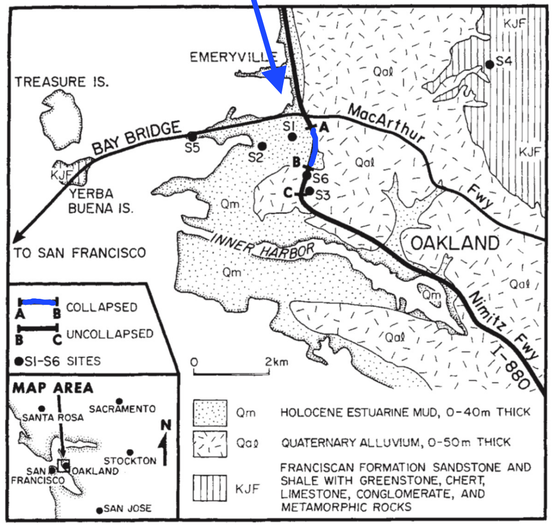
Ground Motion Snapshots



Simulated cumulative motions are high near boundary of sand/clay and in basin-like (concave bedrock surface) areas



High cumulative shaking near areas of extreme structural damage in 1989



Conclusion

- We incorporate additional surface data into the USGS SF Bay region 3D seismic velocity model; our updates lowered velocities in the quaternary sediments around the SF Bay and increases the cumulative seismic motion.

- Velocity-depth relations are fit for Bay Mud and sands around the SF Bay, and are combined with geologic distinctions from a Quaternary surface geology map to create the new model.

- The update allows more efficient trapping of seismic energy near the surface, but the cumulative motion is still too low compared to observations.