Further Validation of a Dynamic Earthquake Model to Produce Realistic Ground Motion: Some Preliminary Results

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Rupture Dynamics Code Validation and Comparing Simulations of Earthquake Sequences and Aseismic Slip Workshop

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The Heterogeneous Stress Model

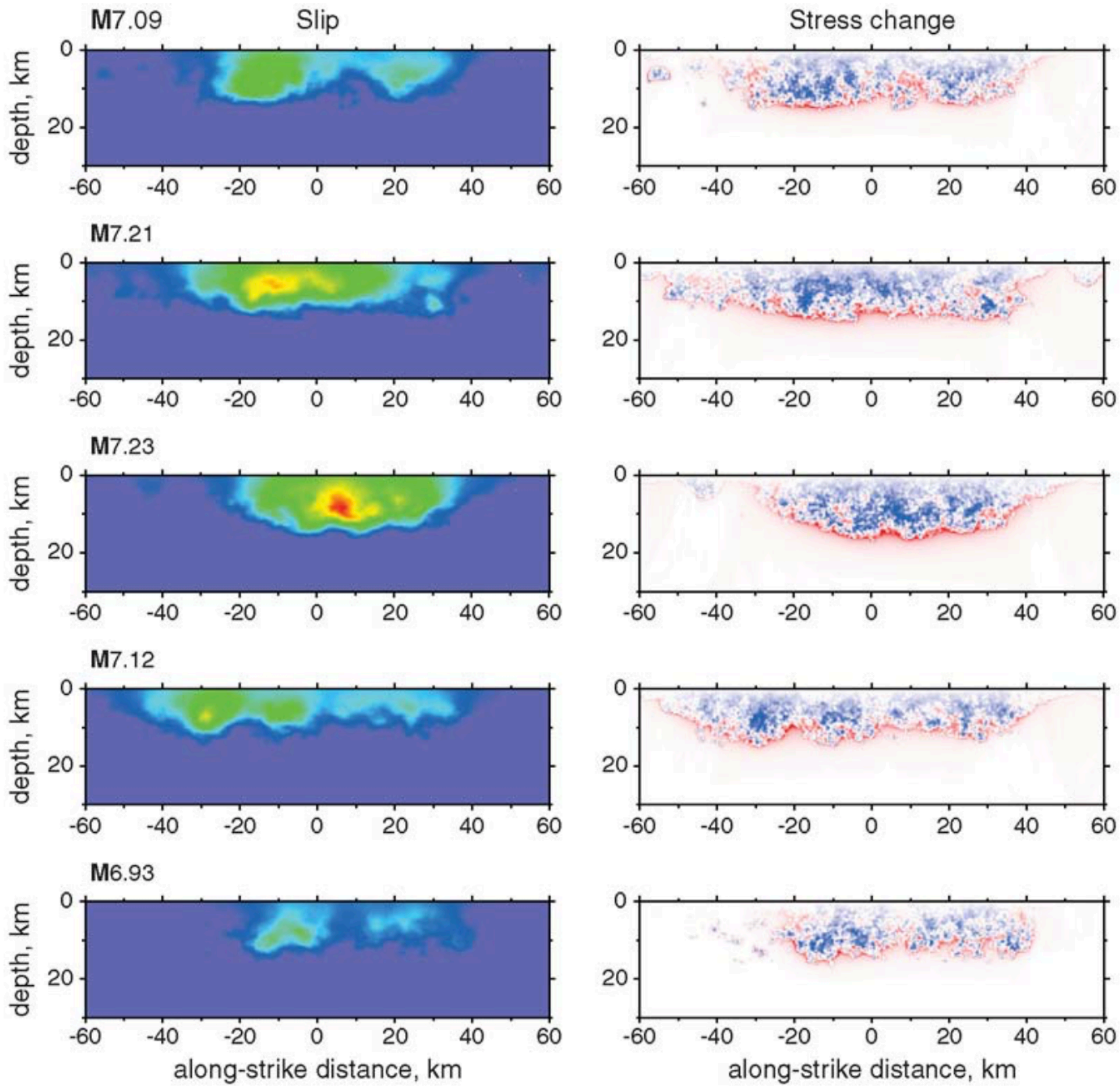
Initial stress that is random heterogeneous and self-similar, being statistically the same at different length scales can explain

1. The number-size distribution of earthquakes with b = 1.
2. The stress drop distribution being independent of magnitude.

Andrews and Barall (2011) and Andrews and Ma (2016) propose

1. The physics of slip on a rough fault (and all other complexities) can be subsumed into an emergent law of self-similar stress on a planar fault.
2. Rupture length is determined by long-wavelength stress variation that should be part of the same spectrum as the shorter wavelength heterogeneities.
3. Rupture stops naturally due to long-wavelength stress variation.

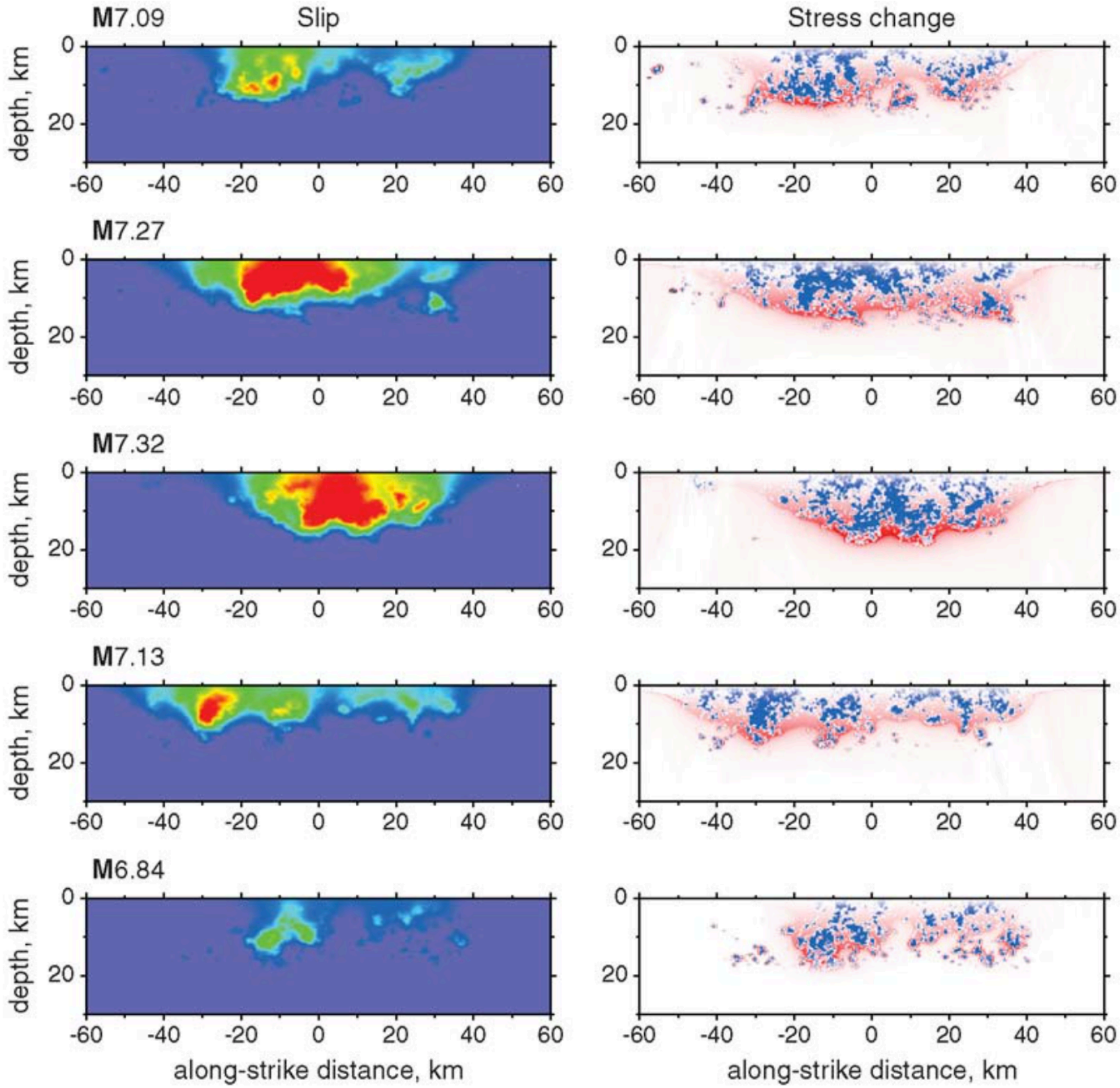
High sliding stress model without asperity



A Gaussian distribution is used for the 1-point statistics.

Andrews and Barall (2011)

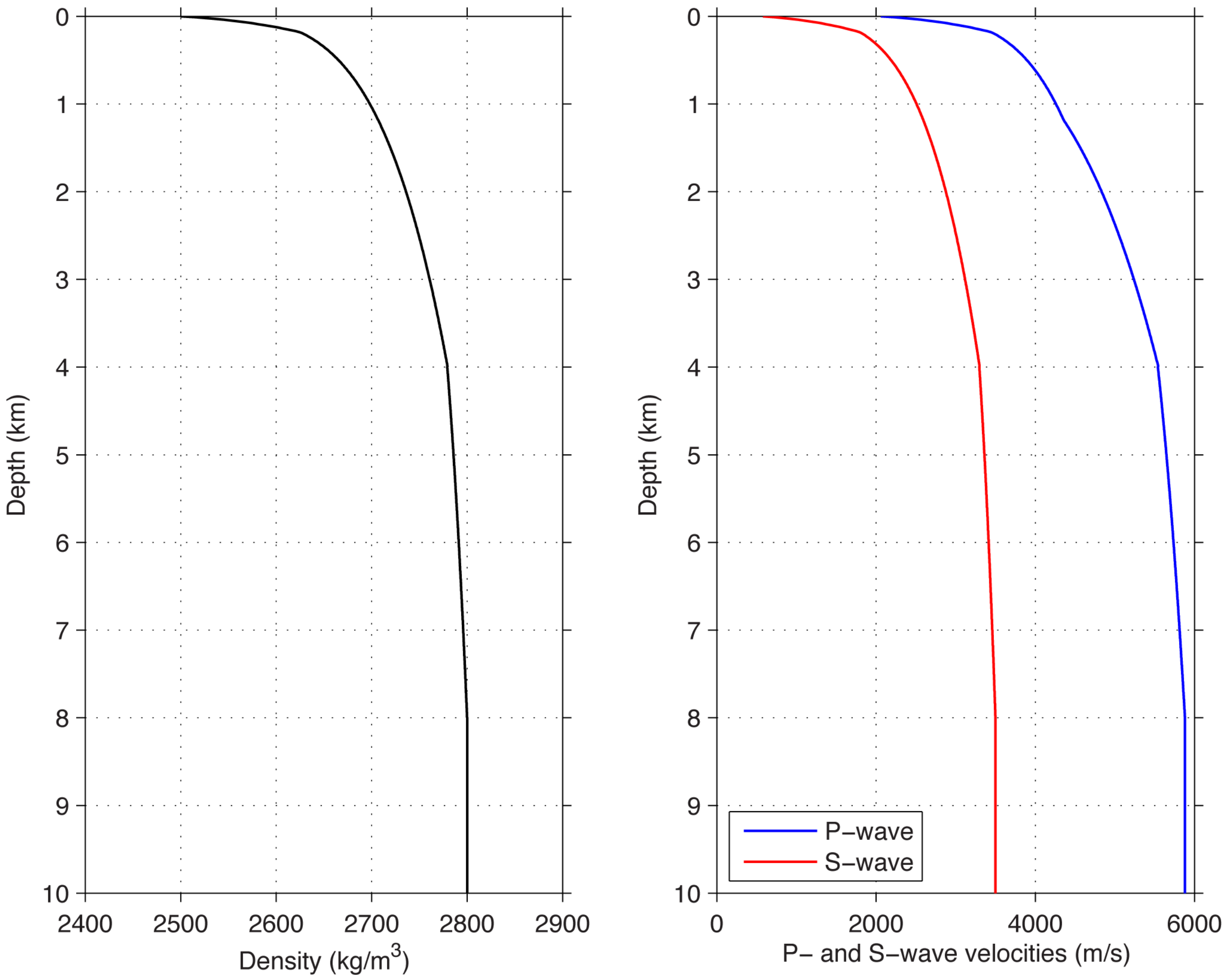
High stress asperity and low sliding stress model



A heavy-tailed (non-Gaussian) distribution is used.

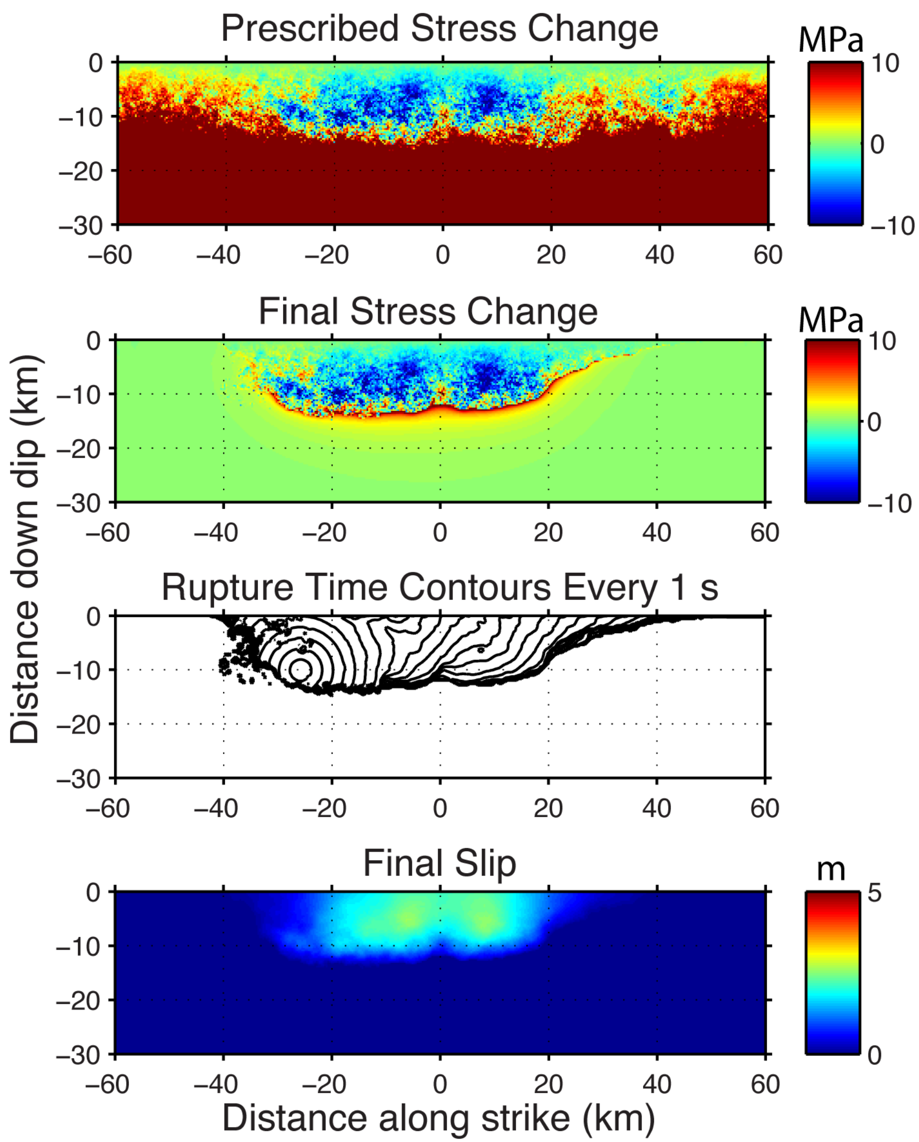
Andrews and Barall (2011)

1D Structure for a hard rock site, V_{S30} = 760 m/s



min Vs = 579.1 m/s

Andrews and Ma (2016)



Andrews and Ma (2016)

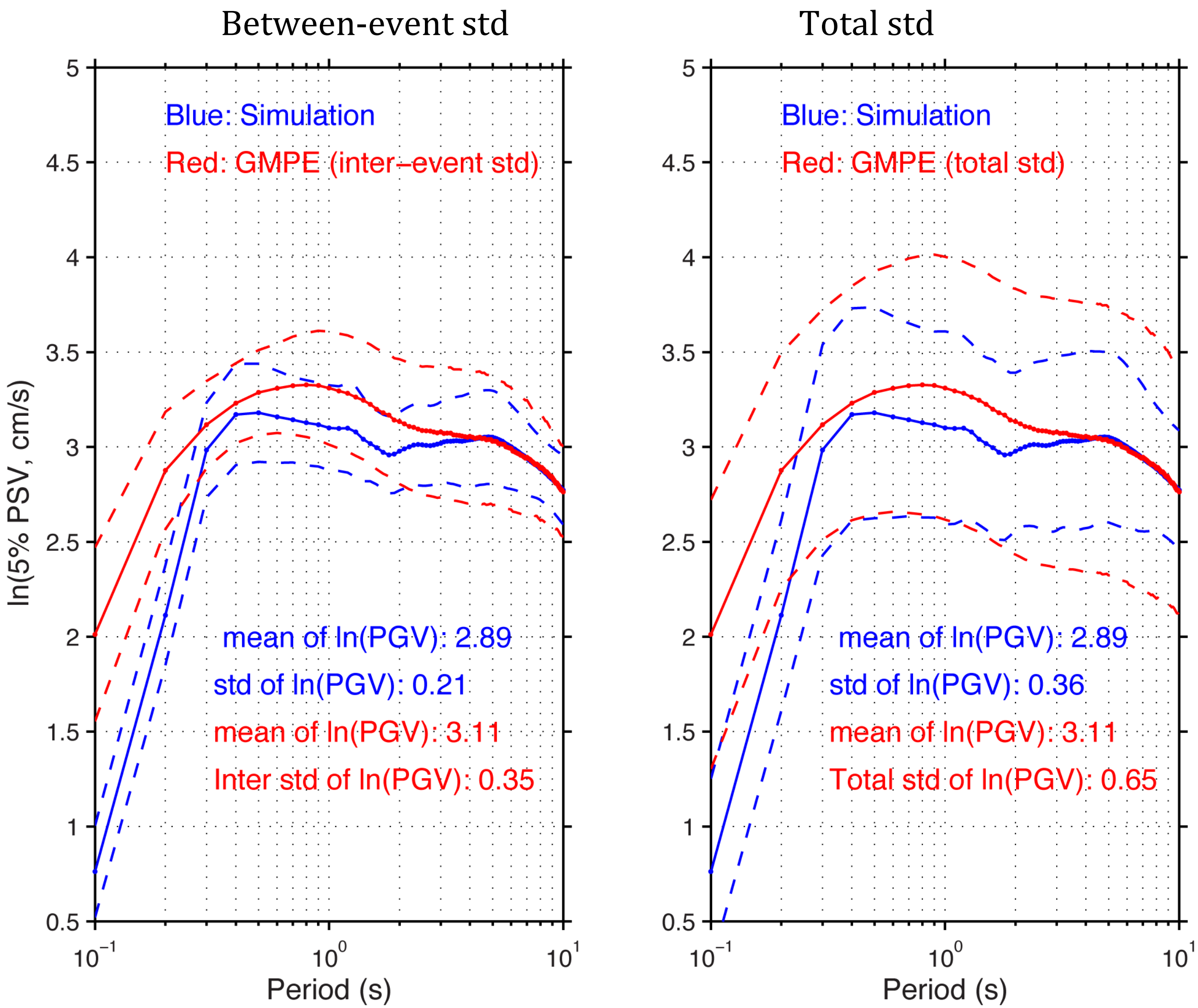
The random field is used to generate a fluctuating ratio of initial shear stress to normal stress on the fault.

The normal stress increases linearly with depth with conditioning at the base of seismogenic depth.

A time-weakening friction law to allow stress to drop as abruptly as possible.

A finite-element method with variable mesh sizes along depth is used. Simulation is accurate up to 3 Hz.

Mean Spectra and Standard Deviations (M7.0)



The fit depends on a correct match of the self-similar random stress spectrum to the specified 2D lowest mode of initial stress.

Other rupture parameters have a minor effect.

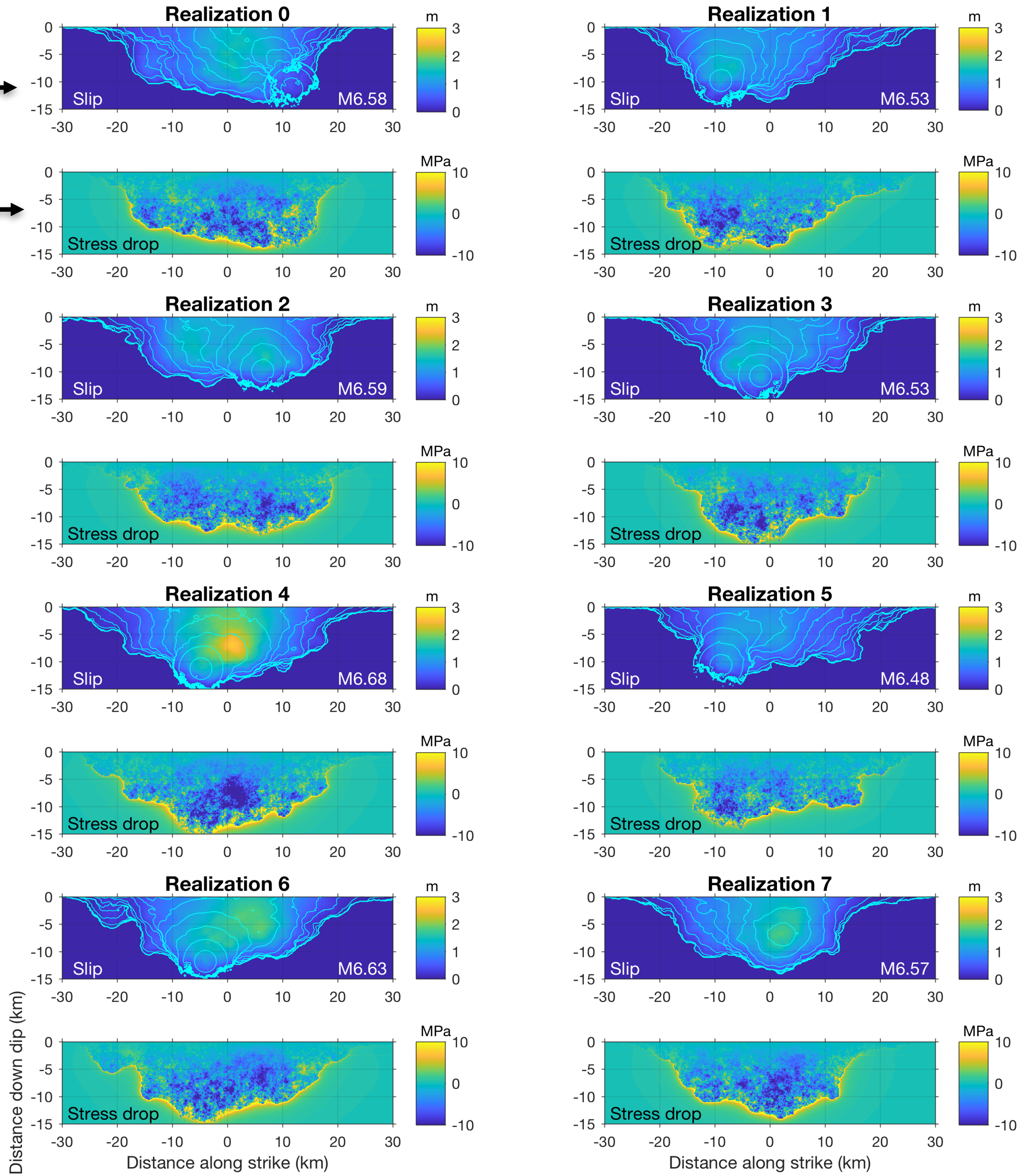
R_{JB} = 10 km

Andrews and Ma (2016)

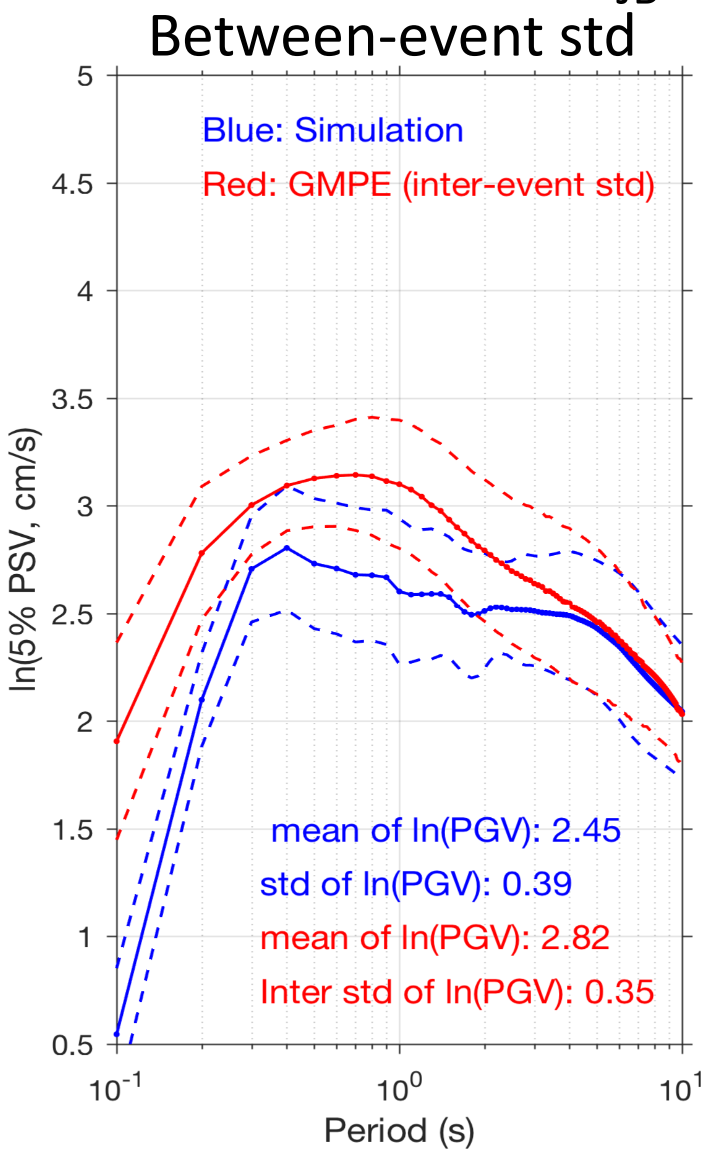
Slip →

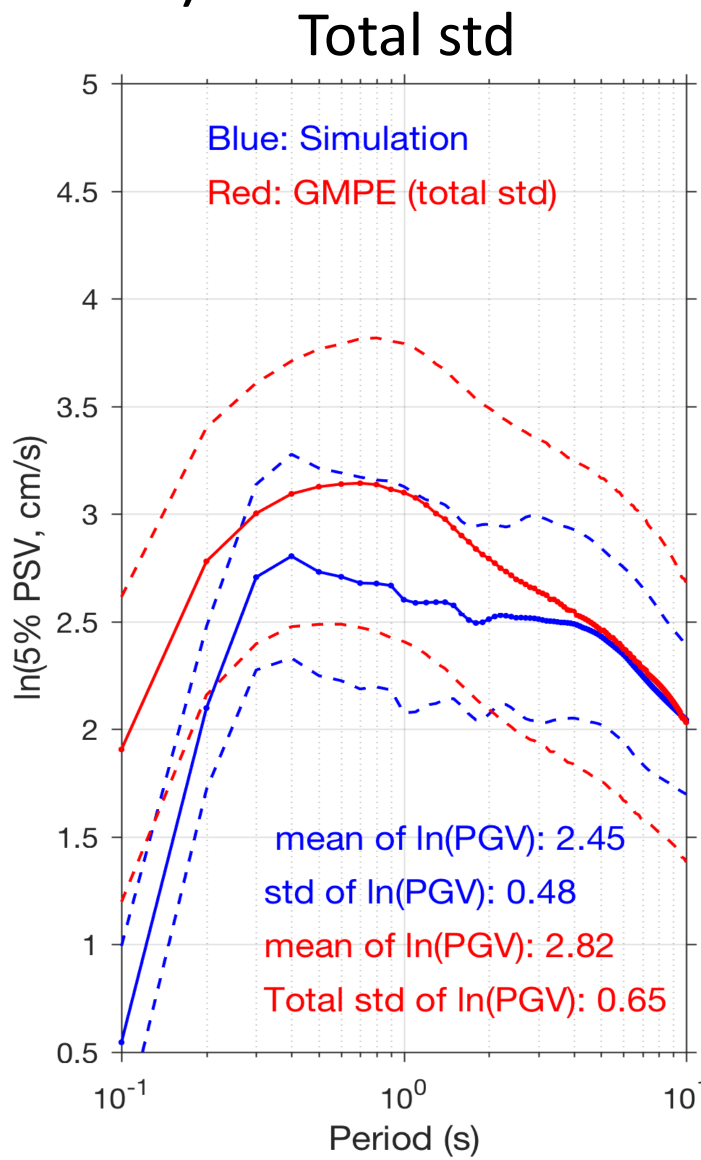
Stress drop →

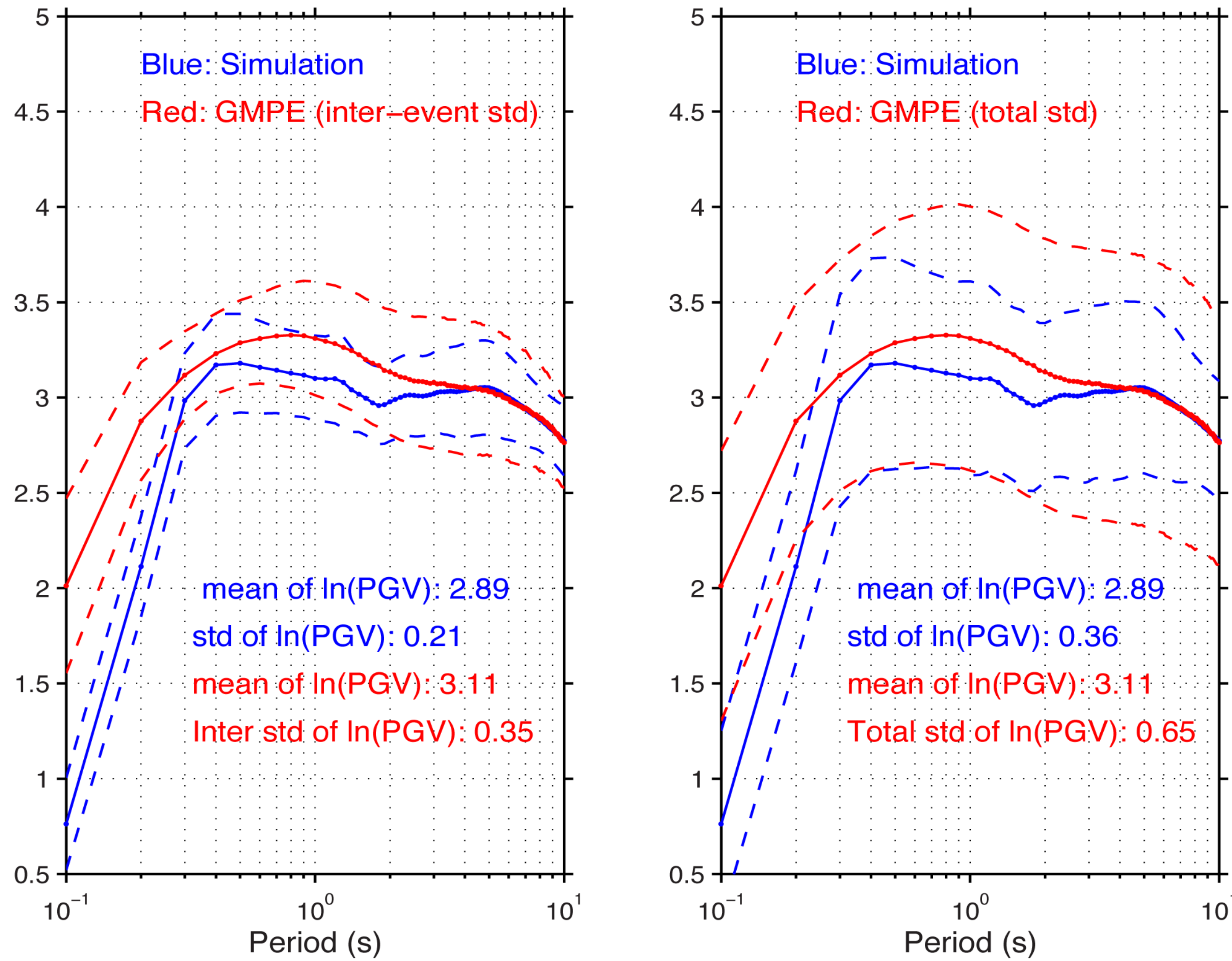
M6.5
8 Realizations



Mean Spectra and Standard Deviations (M6.5)
(R_{JB} = 10 km)





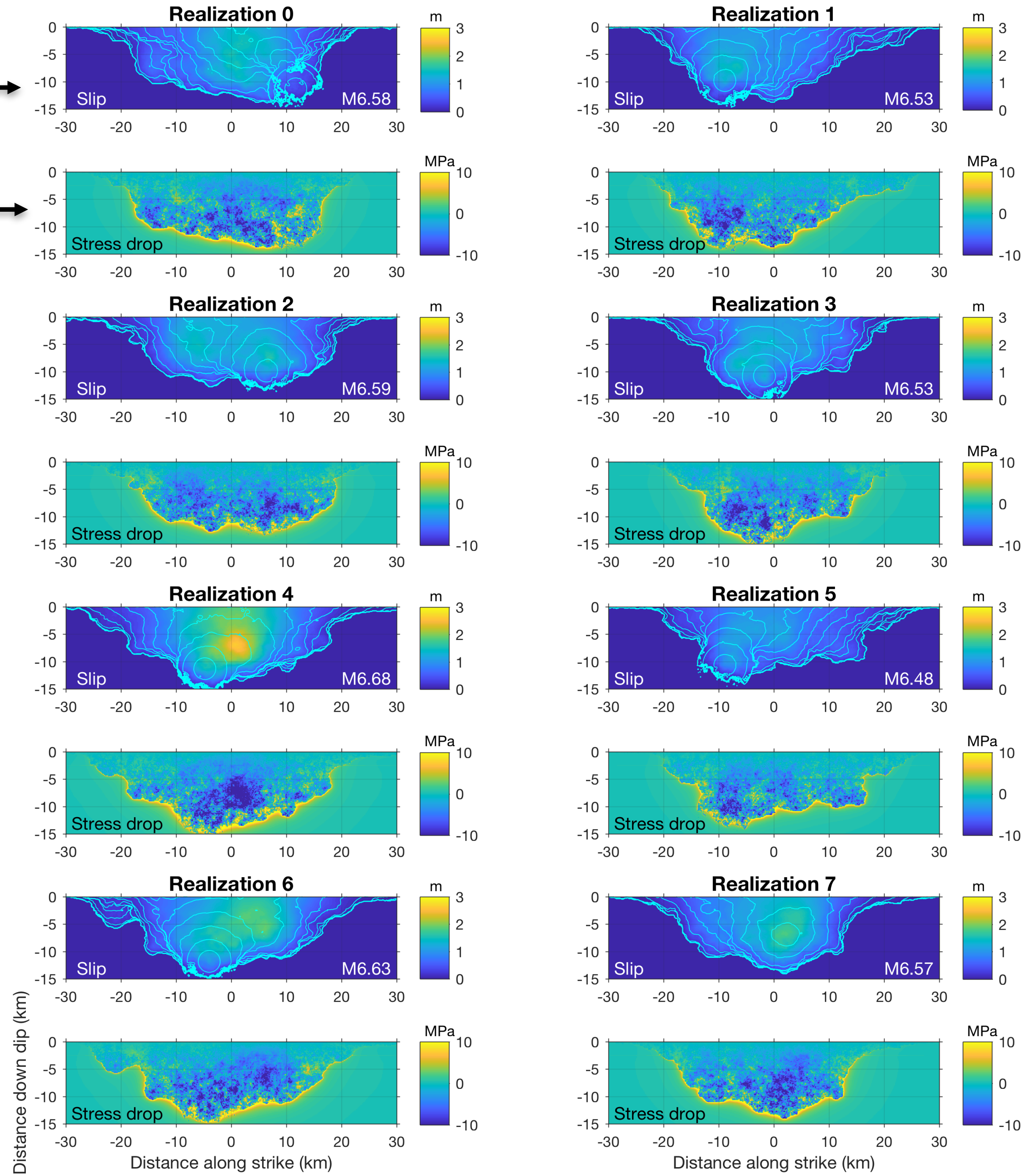


Blue: Simulation
Red: GMPE (inter−event std)
mean of ln(PGV): 2.89
std of ln(PGV): 0.21
mean of ln(PGV): 3.11
Inter std of ln(PGV): 0.35
Period (s)
Blue: Simulation
Red: GMPE (total std)
mean of ln(PGV): 2.89
std of ln(PGV): 0.36
mean of ln(PGV): 3.11
Total std of ln(PGV): 0.65
Period (s)

Slip

Stress drop

M6.5
8 Realizations



Ongoing Work

1. Reduce near-surface shallow slip and increase the stress drop at depth.

- *Ground motion is more sensitive to stress drop than moment.*

- *Near-surface rupture is less effective than deeper rupture in generating strong ground motion (Dalguer, et al., 2008; Pitarka et al., 2009)*

2. Use the asperity model of Andrews and Barall (2011).

Conclusions

Preliminary validation of ground motion at R_{JB} = 10 km for M6.5 earthquakes show good agreement in the between-event and total standard deviations with those of the GMPE. However, the ground motion measures at higher frequency are underestimated.

Ongoing work are focusing on reducing shallow slip and enhancing stress drop at depth, as well as testing the asperity model of Andrews and Barall (2011).

Stay tuned!