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Implementing inter-period correlations into SCEC Broadband Platform simulations

Poster #011

Introduction

The inter-period correlation of epsilon is a ground motion variability parameter which needs to be tested and validated in simulations, since it is related to spectral shape (widths of peaks and troughs in the spectra) and is an important feature for the response of MDOF structures (Bayless and Abrahamson, 2018). We explore methods to implement the inter-period correlation of EAS epsilon into two of the currently implemented SCEC BBP simulation methods: GP (Graves and Pitarka, 2014) and EXSIM (Atkinson and Assatourians, 2014). The approach for this implementation is unique for each simulation method as described below. Both implementations are under development.

(1) Background

In Bayless and Abrahamson (2018) we show that inter-period correlation of epsilon is an important component of ground motions for capturing the variability of structural response that is needed in seismic fragility and seismic risk studies. Without the adequate inter-period correlation of ground motions, variability in the structural response may be under-estimated. This leads to structural fragilities which are too steep (under-estimated dispersion parameter β) and propagates through to non-conservative estimates of seismic risk.

Bayless and Abrahamson (2018) also evaluated six finite-fault simulation methods for their inter-period correlation. None of them adequately captured the inter-period correlations over the entire frequency range evaluated, although several of the methods show promise, especially at low frequencies. This is the motivation for calibrating the inter-period correlation of the finite fault simulations.

(2) EXSIM

The procedure for the point source stochastic simulation method SMSIM is shown in Figure 1. Steps to incorporate correlated FAS epsilon into SMSIM are:

- Generate an array of zero-mean correlated random variables using a total correlation model for FAS. These are the correlated epsilons over the chosen frequency range.
- scale the ϵ by the desired standard deviation
- Insert the correlated ϵ into step d of the SMSIM procedure (Figure 1) and proceed as usual (shape to spectrum then inverse transform)

Figure 2 shows an example application of this procedure.

EXSIM is the the finite-fault extension of SMSIM. In theory, adding the empirical correlation should follow the same procedure for all sub-sources. We started modifying EXSIM by trying this, but found that the resulting correlation (of the FAS of the finite fault time series) was lower than desired, meaning there is destructive interference of the correlation between sub-sources. This should be studied further in the future.

Next, we implemented the correlation model into the SCEC BBP version of EXSIM (written in fortran) as a post-processing step on the final time series and re-ran simulations of the Dreger et al. (2014) validation events. This procedure correctly calibrates the correlation, but we found that on average, the ground motions increased relative to the unmodified version, which was unexpected (Figure 3). This may be a sign of an error in the implementation; we are currently reviewing this.

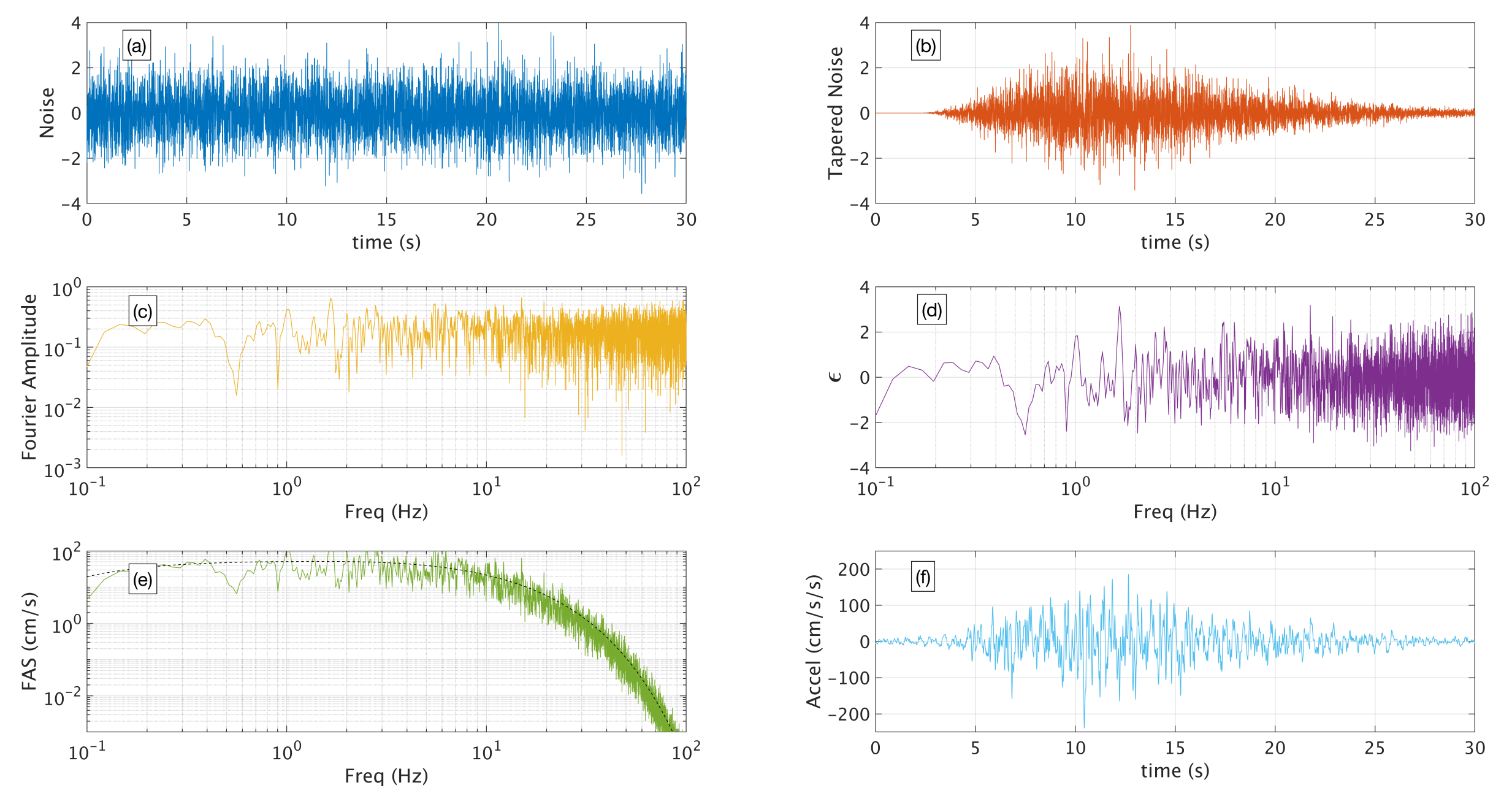

Figure 1: The SMSIM procedure steps

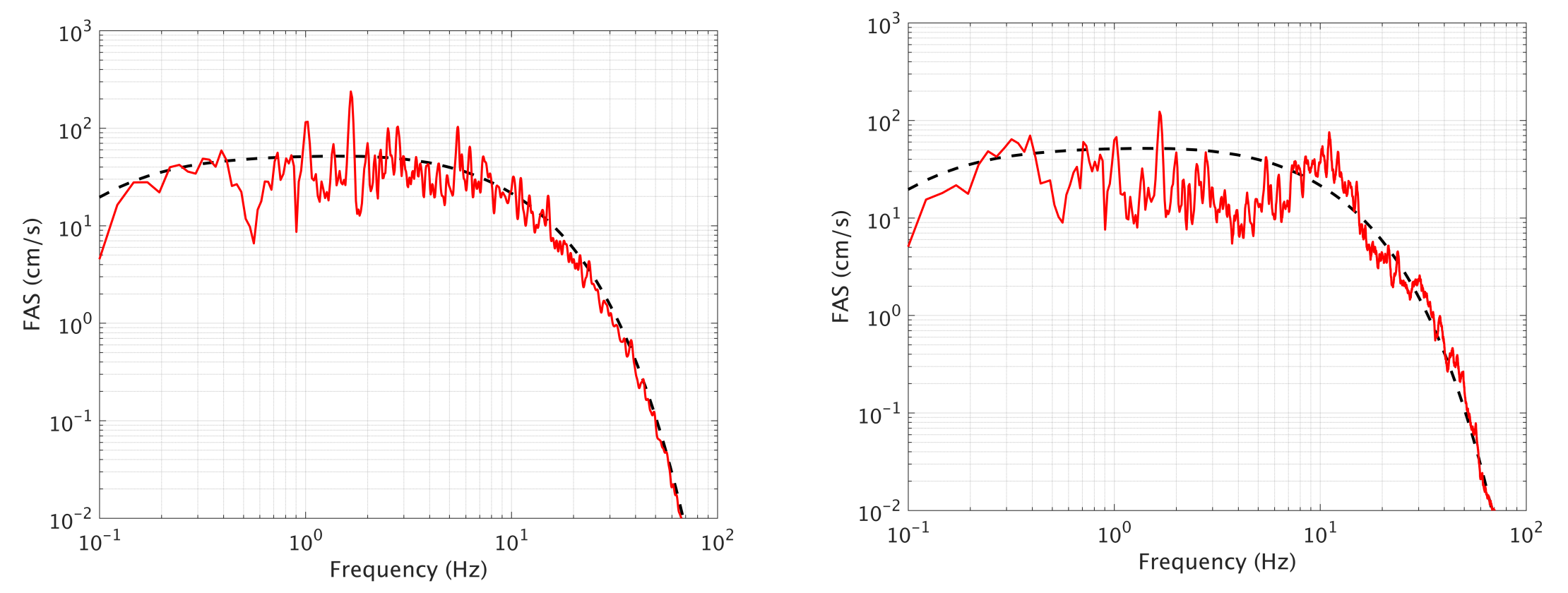

Figure 2: Example FAS. Left: unmodified SMSIM. Right: SMSIM with correlation

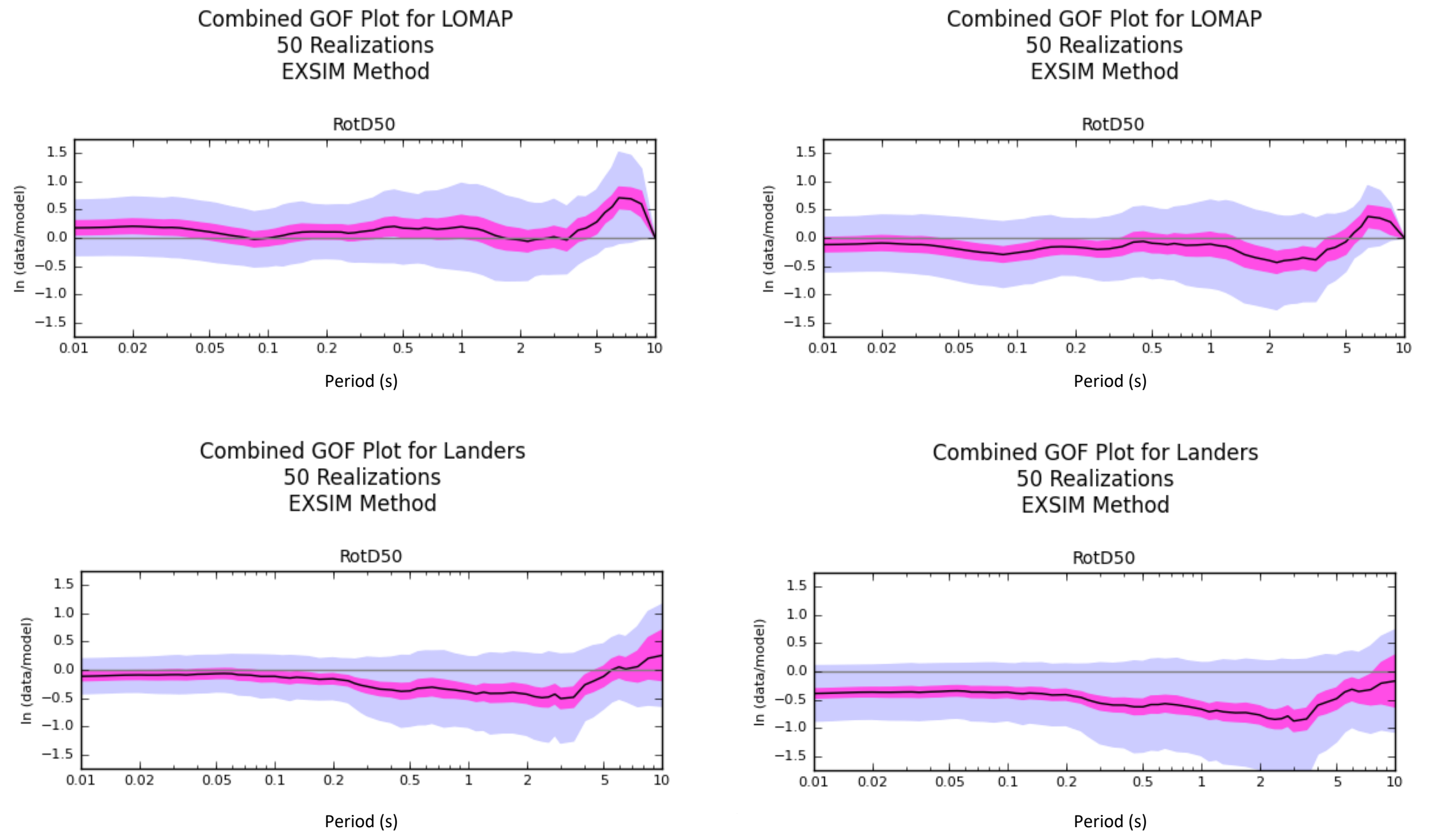

Figure 3: EXSIM Goodness of fit for the Loma Prieta (top) and Landers (bottom) events. Left: unmodified EXSIM. Right: EXSIM with correlation

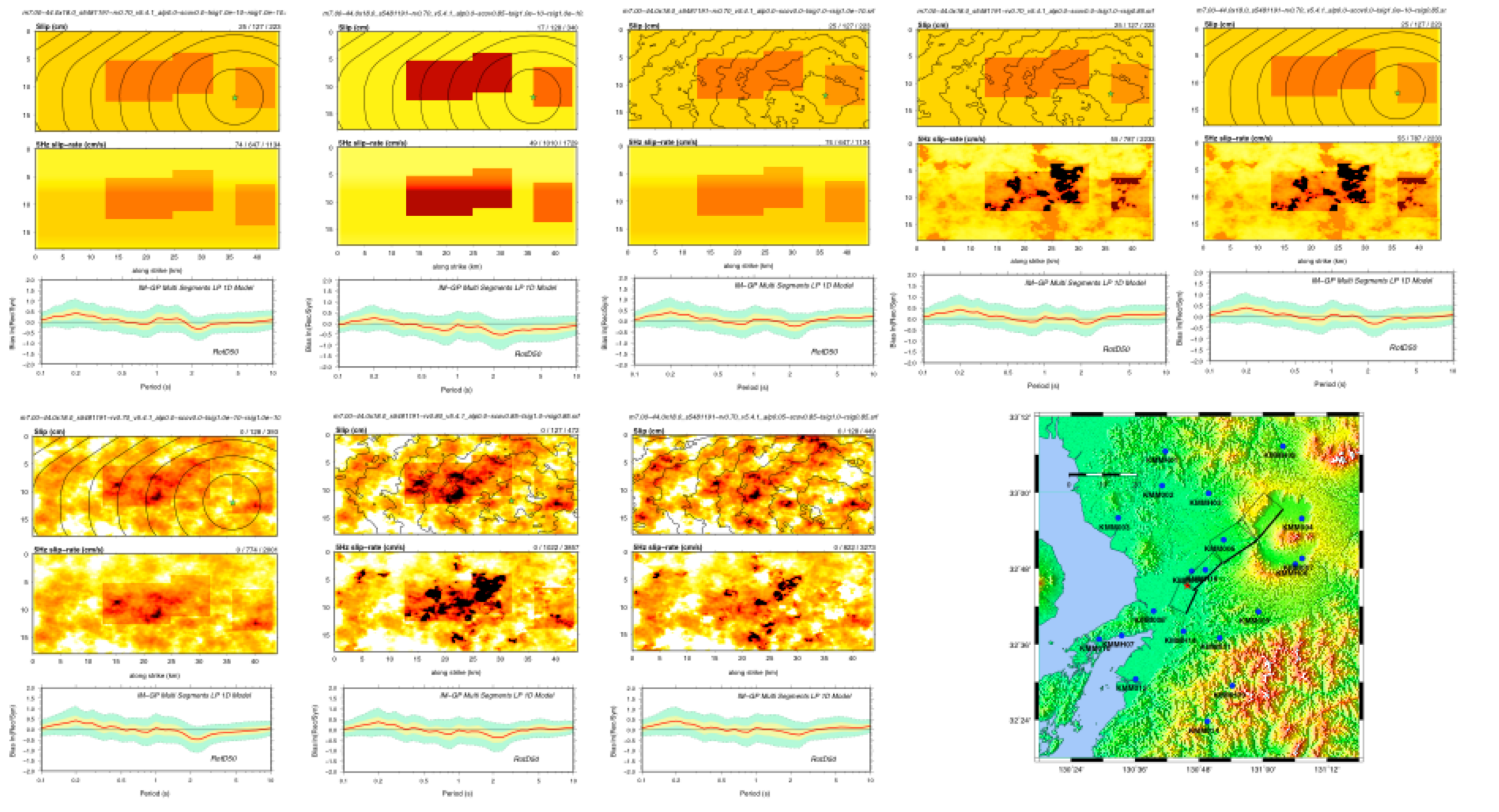

Figure 4: From Pitarka (2018), source realizations of the Kumamoto eqk used to evaluate correlation sensitivity

(3) GP

For the GP method, we have evaluated the long-period correlations and tested the sensitivity of the correlations to various source methods. This has been accomplished by performing simulations using three methods:

- unmodified GP
- SONG (2014) which uses GP wave propagation but with source parameters constrained by dynamic rupture modeling
- Pitarka (2018) which use an Irikura-type source along with GP wave propagation.

For each method, we evaluate the correlation of FAS and PSA. Since all three methods use the same wave propagation codes, the effects of the source on the correlations are isolated. The effect of spatial correlation in source slip and slip velocity on the inter-period correlations was explored using simulations from Arben Pitarka (Figure 4). Similarly, using SONG, the sensitivity to autocorrelation in space and correlation between kinematic parameters is identified.

We conclude that modifications to the source can have impactful effects on the between-event and within-site components of the correlation, especially at low frequencies. However, the between-site component of the correlation (which cannot be determined for simulations based on a 1-D velocity model) is significant in the data, and so modifications made to the source alone may not be sufficient to get the total correlation of the 1-D simulations up to the levels of the data.

(4) Next Steps

For now, we have applied the correlation modification as a post processing script to GP and EXSIM, rather than making modifications to the source or sub-sources. This approach is not preferable, but it achieves our short-term goal of being able to prescribe the full total correlation seen in the data on the BBP simulations (for other applications, e.g. structural risk).

Short-term future work includes:

1. Troubleshooting the EXSIM post-processing implementation
2. Re-running the BBP validation events using EXSIM and GP with the post-processing correlation

Long-term future work includes:

1. EXSIM sub-source implementation
2. Calibrating the correlations of GP kinematic parameters to approximate the between-event and within-site low frequency correlations observed in the data
3. Modifying the GP method at high frequencies
4. Calibration of other BBP methods
5. Upon successful calibration, performing validations (median PSA first, then standard deviation)