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Exploring the relation between backprojection images and earthquake source processes

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1-minute summary

1. **Backprojection (BP) is a powerful seismic-array processing tool that provides observational constraints on the evolution of the seismic radiation during large earthquakes. To better interpret the BP images in terms of earthquake dynamics, a careful relation between the BP images and the kinematics of the source is needed.**

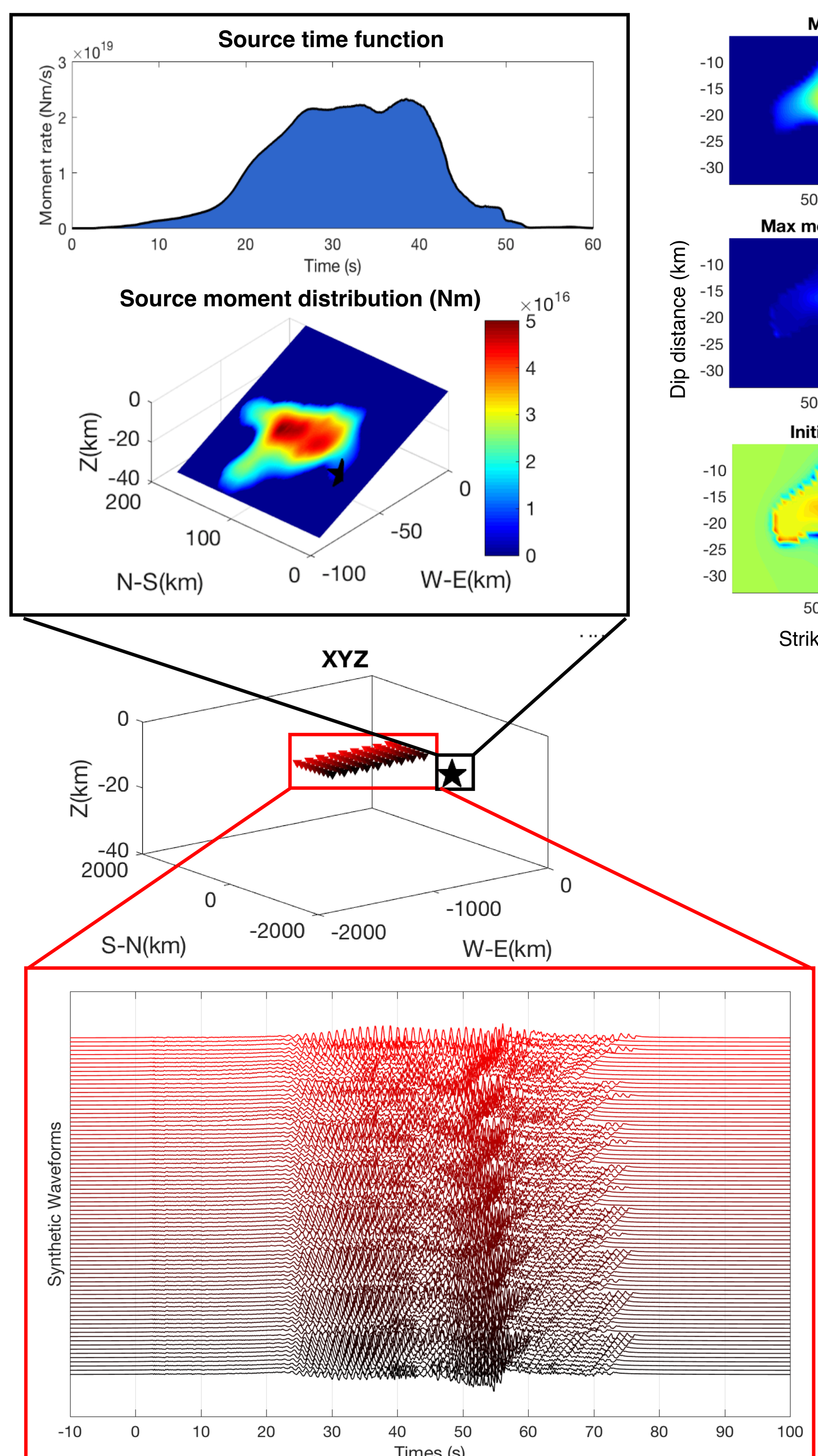
2. **We explore the relation between BP images and seismic radiation using synthetic waveforms from both kinematic and dynamic source models embedded in a pure elastic wholespace.**

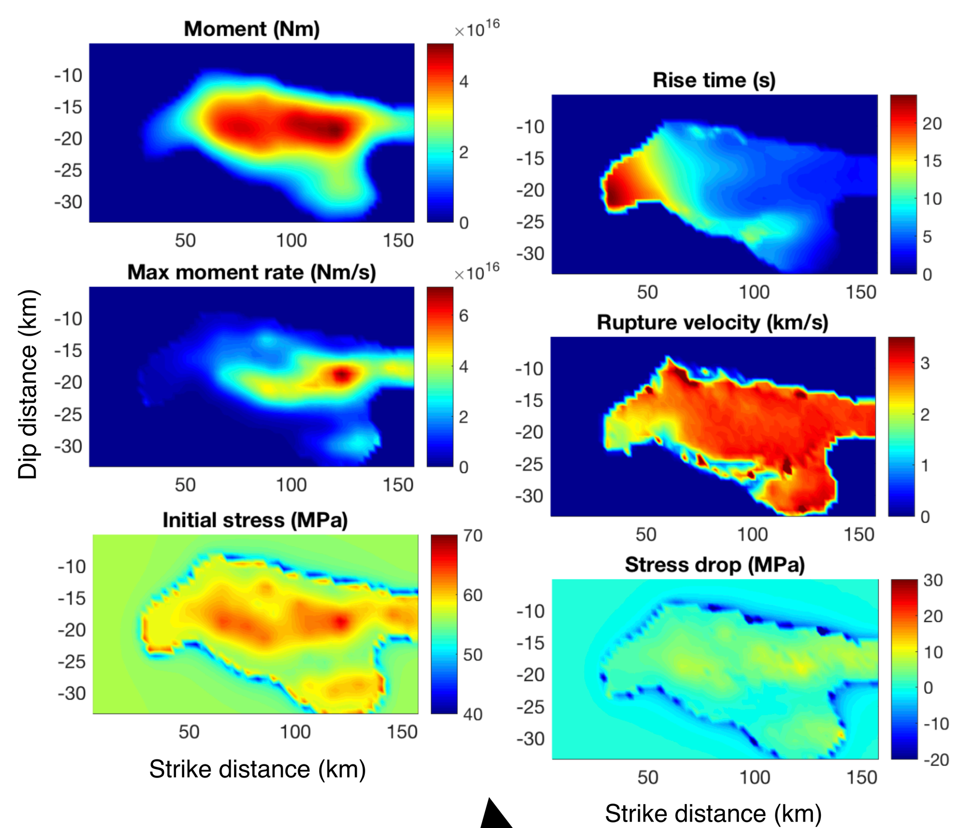
3. **Preliminary results show the BP image is mostly correlated to the distribution of peak slip/moment rate, for both kinematic and dynamic sources. However, it is also highly related to other factors thus should be carefully interpreted with coseismic observations.**

Methodology

1. Source models

- Kinematic source models are generated by **FFSP** (source generator developed by *Liu et al.* [2006] and *Crempien and Archuleta* [2014])
- Dynamic source model is from *Dr. Huihui Weng* for the 2015 Gorkha Mw 7.8 earthquake based on slip weakening with parameters constrained by near-field ground motion observations.

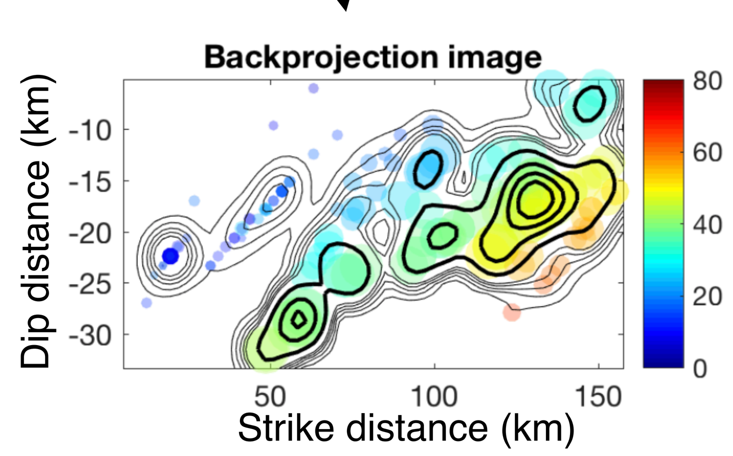




2. Synthetic waveforms:

Waveforms are derived from the slip histories of the source models in the homogeneous, elastic wholespace.

4. 2D Image correlation (quantified comparisons)



3. BP in frequency domain

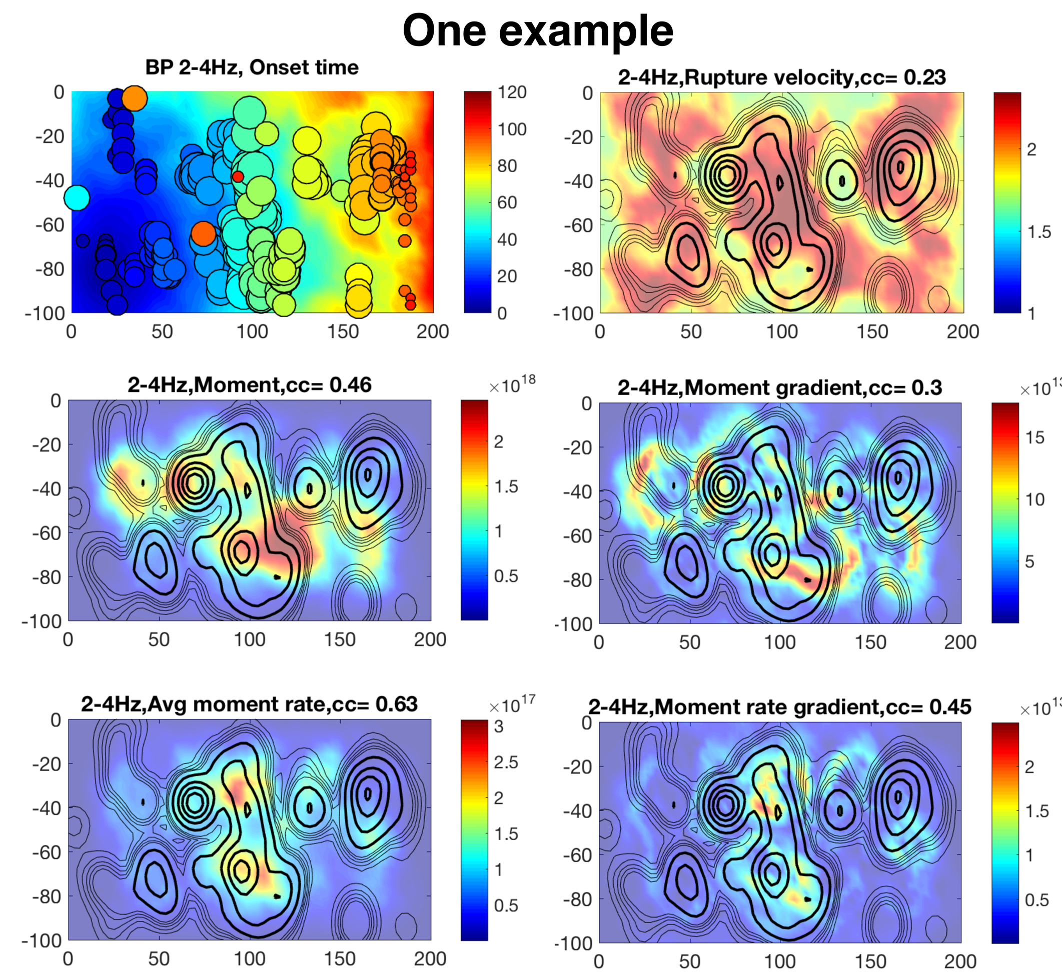
$$\mathbf{B}(f) = \mathbf{A}(f)\mathbf{X}(f)$$

$$\mathbf{X}(f) = \mathbf{A}^{H}(f)\mathbf{B}(f)/\mathrm{N}$$

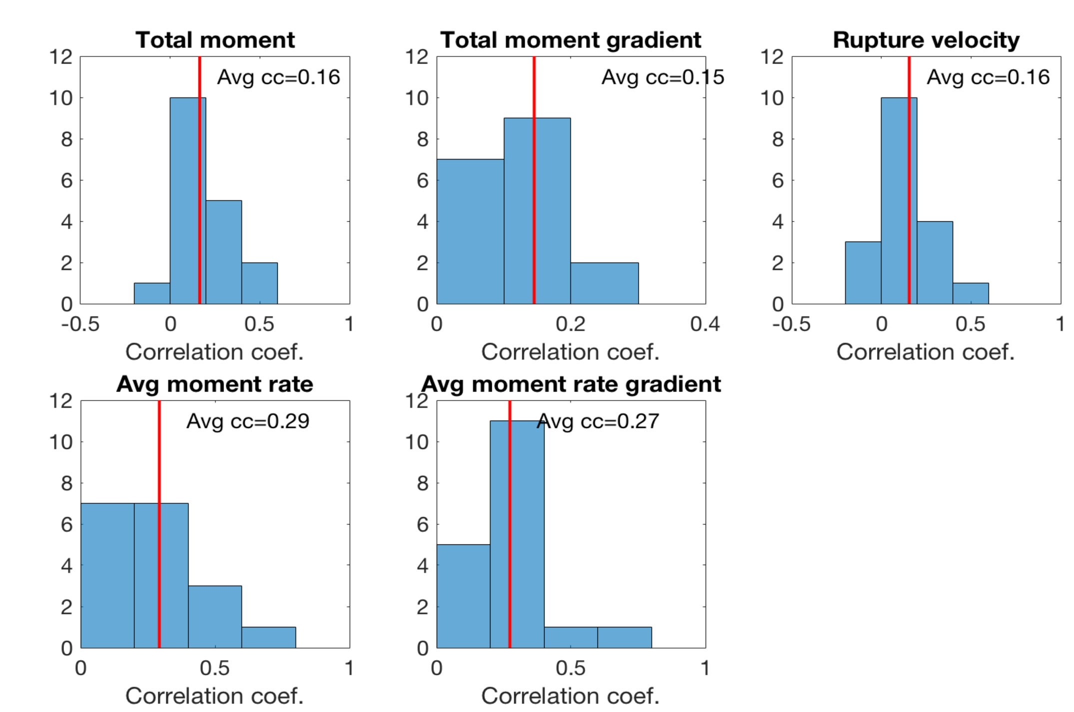
$\mathbf{B}(f)$: Velocity data in frequency domain
$\mathbf{A}(f)$: Propagation matrix (travel time shifting)
$\mathbf{X}(f)$: Distribution of BP power
H: Conjugate transpose N: Number of stations

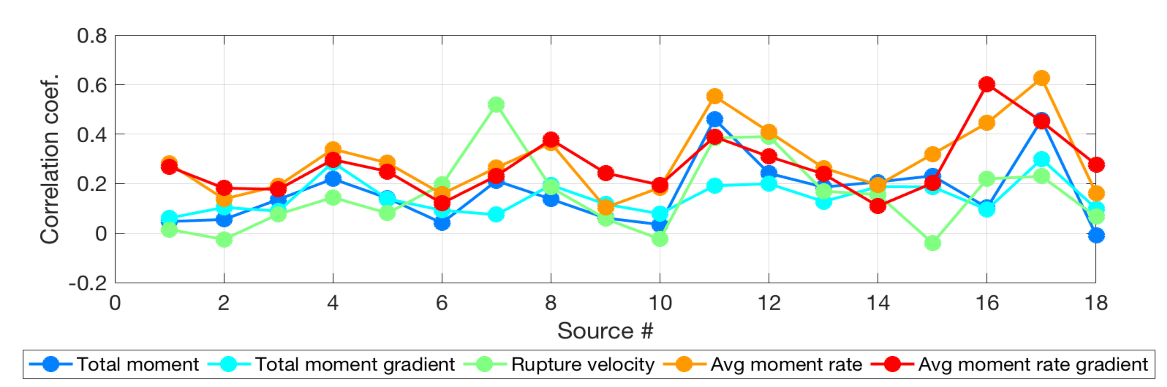
Results

1. BP image & Kinematic sources

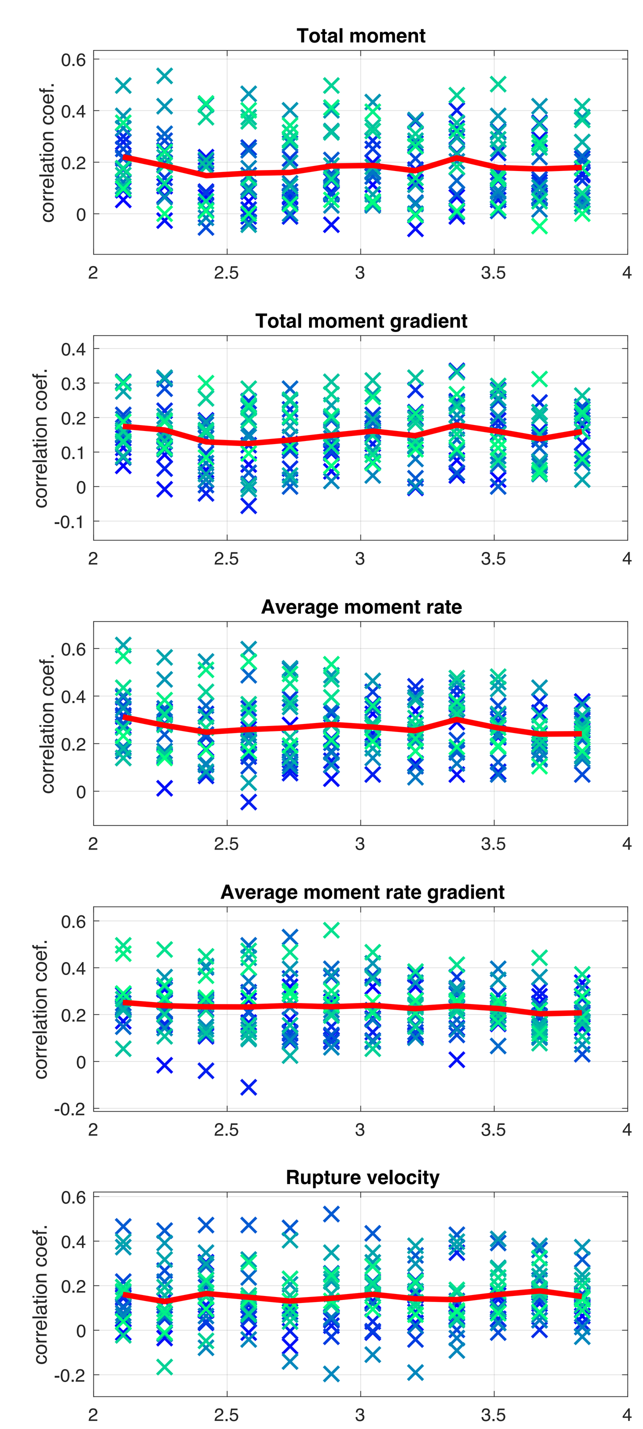


⬆ **2-4 Hz integrated BP image (black contours)** is most correlated to average moment rate, spatial gradient (strain/stress rate?) and rupture velocity variation.





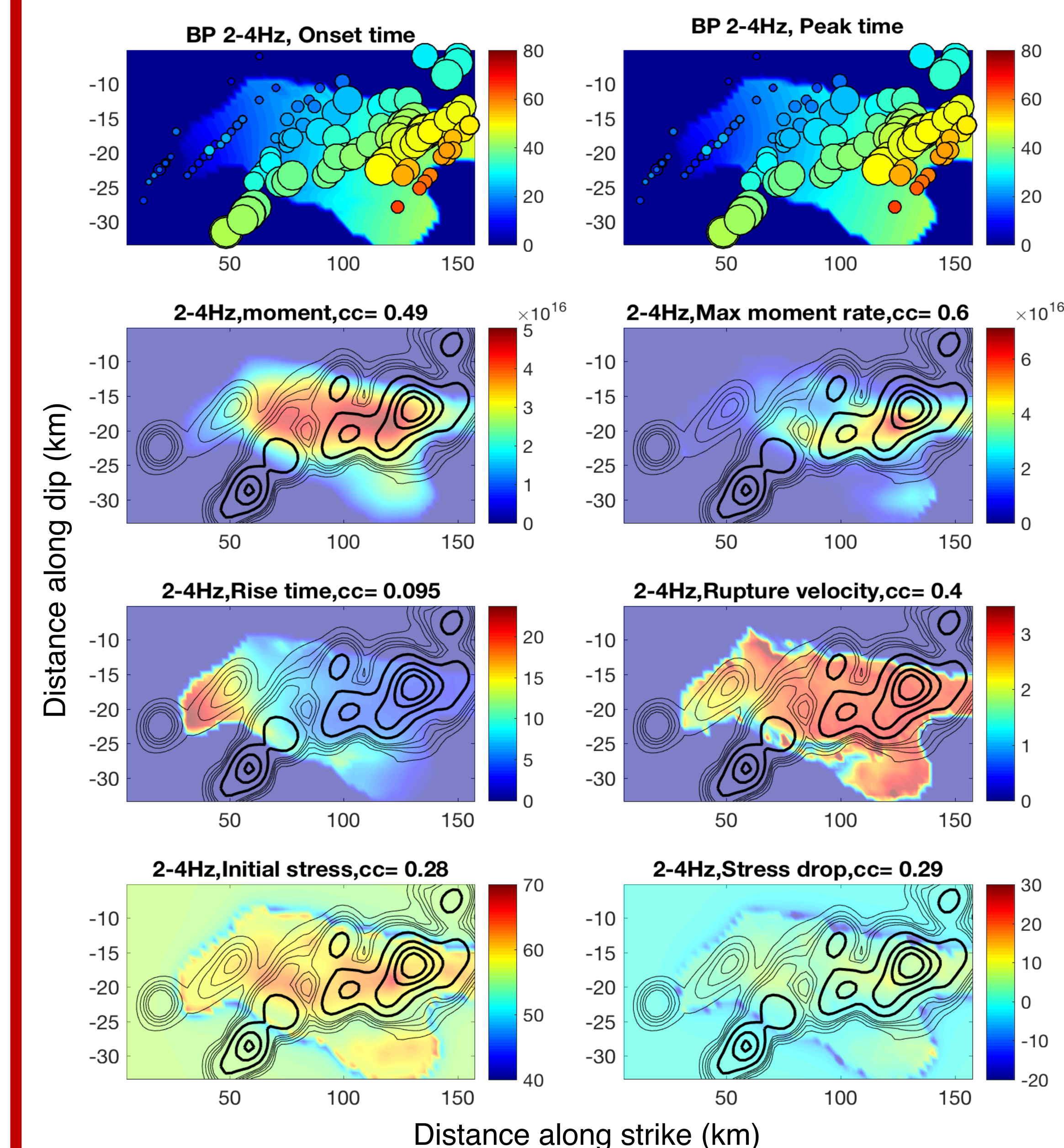
⬆ **Correlations with source parameters for all 18 generated kinematic sources in the integrated frequency band of 2-4Hz.**

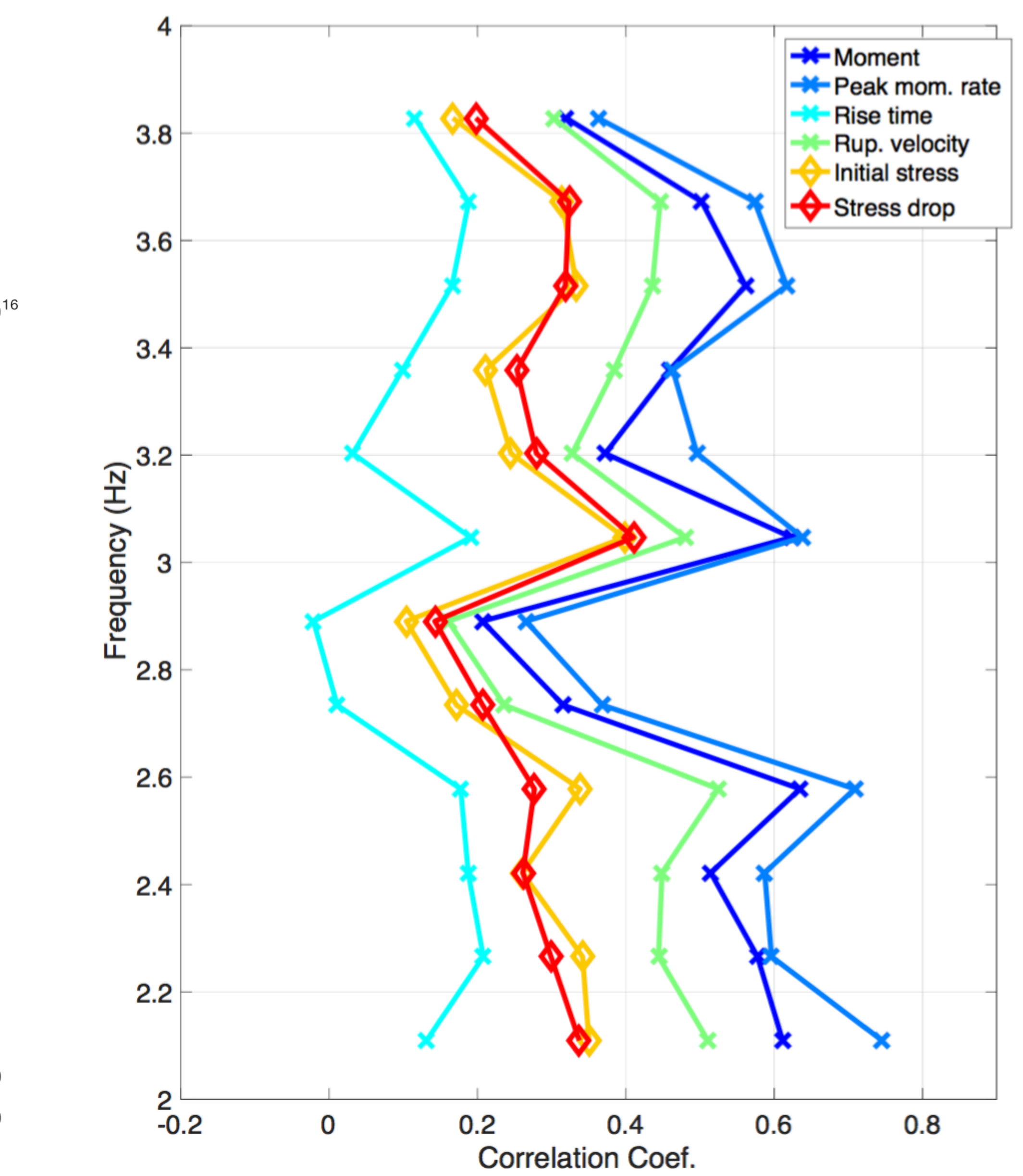


➡ **Correlations (crosses) with source parameters for all sources in each narrow frequency band.** Correlation coefficients vary for different sources and there is no systematic frequency dependence on the correlation coefficients of each source parameters.

➡ **Average correlation coefficients (red lines)** seem to be relatively stable, implying the general correlation between BP image and all these parameters.

2. BP image & Dynamic source model of 2015 Nepal Gorkha Mw 7.8 earthquake





⬆ **Correlation between BP image and dynamic model within 2-4Hz**
Peak moment rate > Moment > Rupture velocity (?) > Stress drop ≈ Initial stress > Rise time

⬈ **Correlations with source parameters from the dynamic source in each narrow frequency band.** Systematic frequency dependence on the correlation coefficients is unclear for this dynamic model, the valley around 2.8Hz is mostly due to swimming artifacts of conventional BP.

Conclusion and Discussion

- ❖ **Both kinematic and dynamic source models indicate correlations between BP image and distributions of slip, slip rate, slip gradient (strain), slip rate gradient (strain rate) and rupture velocity heterogeneities.**
- ❖ **No single parameter dominates the characteristics of BP images, but rather a combination of them (moment, moment rate).**
- ❖ **Our results show no systematic frequency-dependent correlation patterns, which implies that the differences reported in BP images with variable seismic frequencies probably stem from other factors such as fault geometry, roughness and/or frictional properties etc.**

Future work:

- **Apply to more diverse kinematic source models for better parametrization (i.e. varying asperity size and amplitude of heterogeneity)**
- **Use advanced BP methods to gain better BP image with less artifacts**

Acknowledgements:

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