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Towards Systematic Kinematic Source Models of Historically Large Earthquakes

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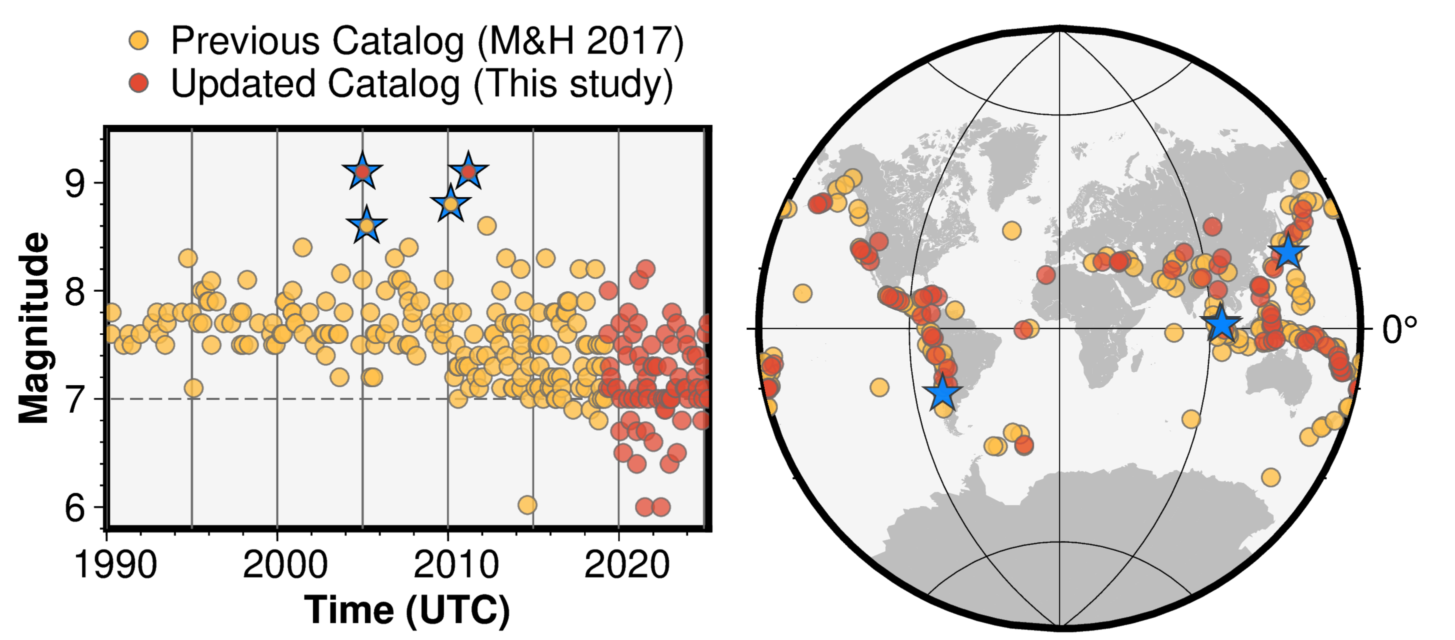
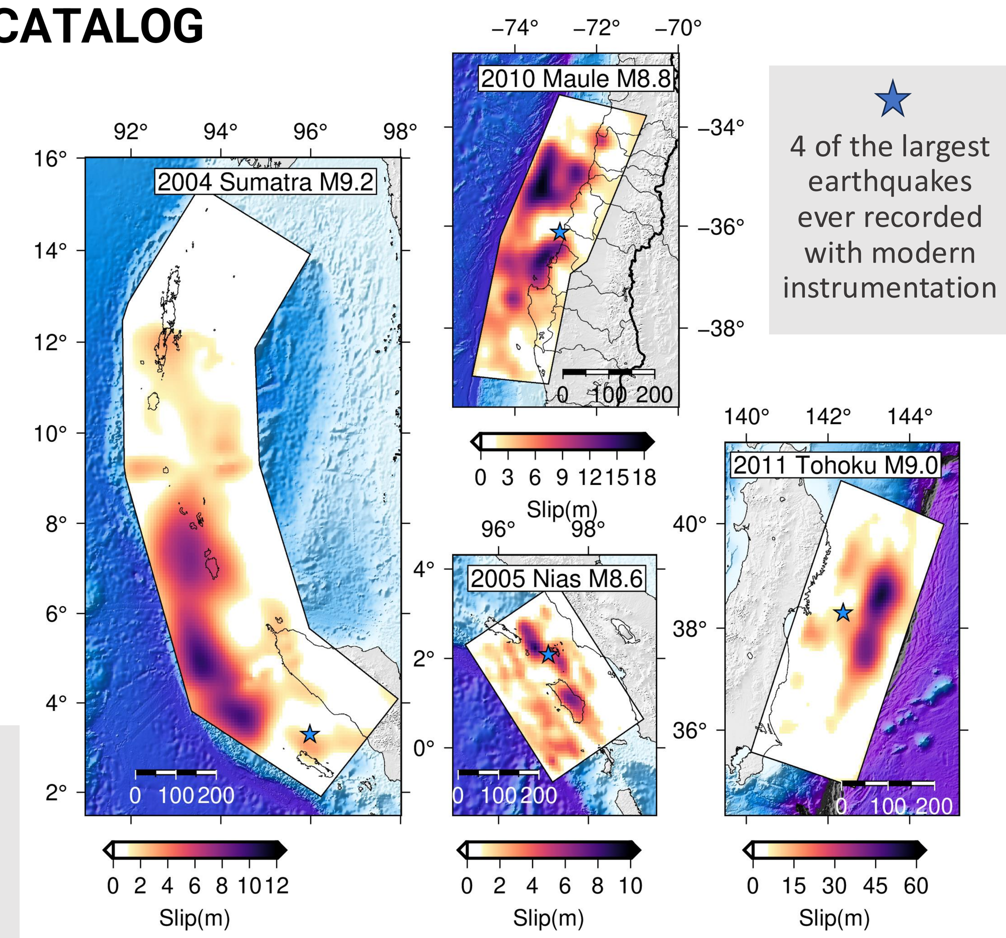
1.0 Developing a Systematic Workflow

1.1 U.S. GEOLOGICAL SURVEY (USGS) - NATIONAL EARTHQUAKE INFORMATION CENTER (NEIC) FINITE FAULT MODEL (FFM) CATALOG



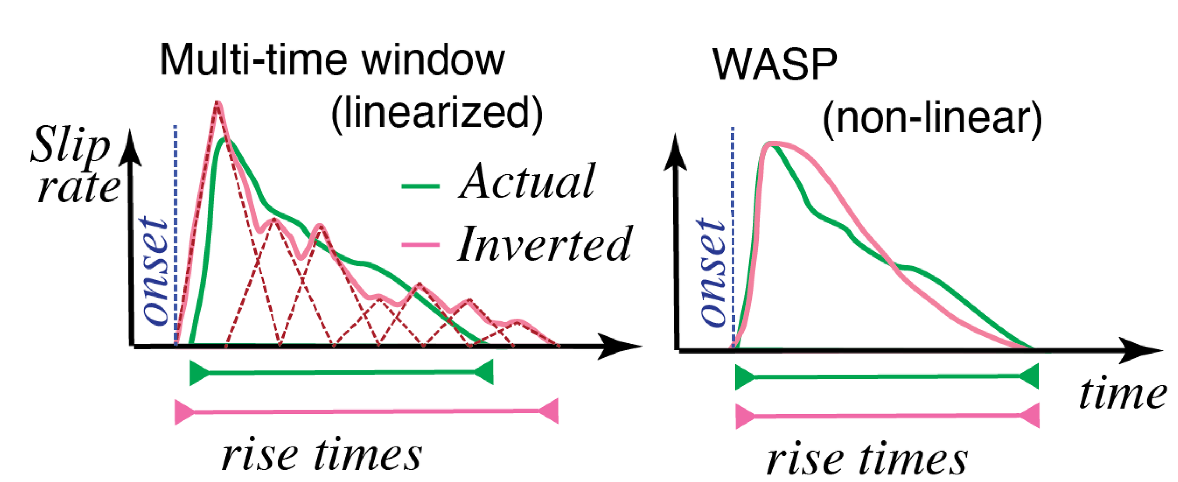


This USGS-NEIC FFM catalog includes 259 events — a ~46% increase from the 177 events since Melgar & Hayes (2017). Most models were generated using only teleseismic data, which limited the catalog to earthquakes of **M** ≥ 7 (Hayes, 2017). Since 2021, NEIC has routinely produced joint inversions that incorporate regional data (i.e., strong motion, GNSS, and InSAR data) with traditional teleseismic data (Goldberg et al., 2022).

1.2 NON-LINEAR INVERSION METHOD FOR FINITE-FAULT MODELING:

Wavelet and simulated Annealing SliP inversion (WASP; Koch, et al., 2019; Goldberg et. al., 2022)

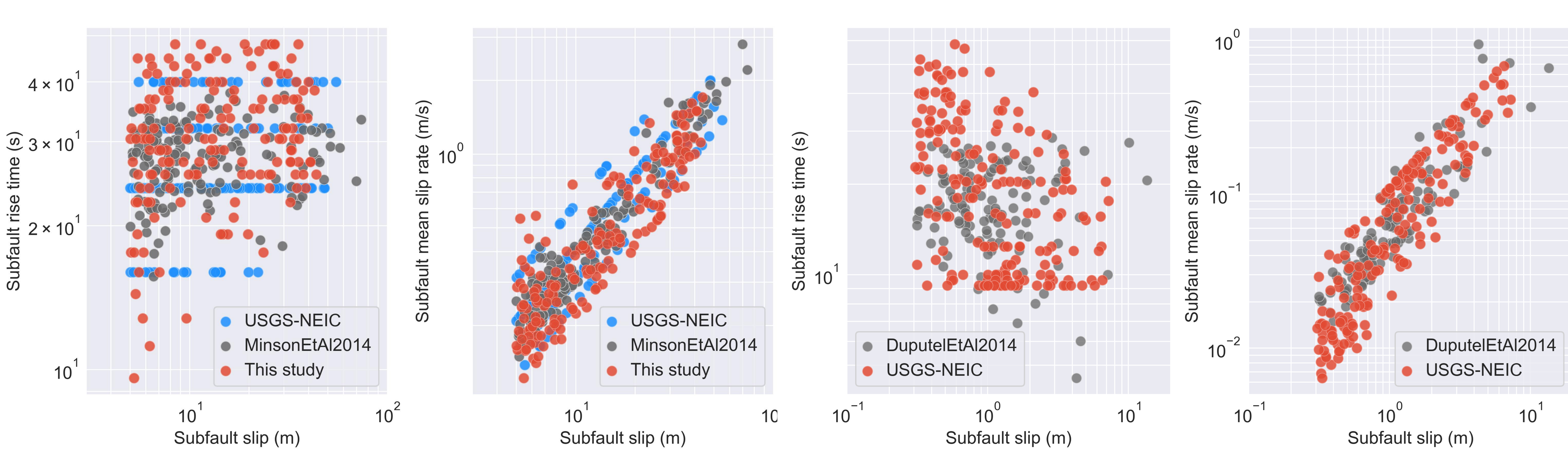
- Uses a nonlinear simulated annealing method to estimate slip amplitude, rake, rupture time, and rise time on a discretized fault plane, finding the solution that best fits the observations in the wavelet domain.
- Uses wavelet transforms to separate spatial and temporal components of slip.
- Integrates data from teleseismic broadband, regional strong motion, GNSS (static and high-rate), and InSAR* observations.
- Based on Ji et al. (2002) inversion framework; regional Green's functions follow Zhu & Rivera (2002).



*InSAR observations will be processed by JPL into ready-to-use products for both historical and future events, ensuring standardized input files.
Visit poster on-site [16216] this afternoon! Cole et al. (2025)

1.3 VALIDATION OF INVERSION METHOD

Comparison of the NEIC finite-fault modeling method with alternative and independent non-linear inversion methods to validate results and perform a sanity check.



2011 Tohoku , Japan (**M**9.1)

Comparison with Minson et al. (2014), which used a Bayesian approach to jointly invert for rise time, slip onset time, and slip. The method incorporates multiple datasets, including GNSS and tsunami observations, and uses a triangular slip velocity function. Here, we rerun the Tohoku inversion using WASP.

2014 Iquique, Chile (**M**8.2)

Comparison with Duputel et al. (2014), which, like Minson et al. (2014), directly solves for rise time using a Bayesian approach. It employs triangular slip-rate functions and incorporates all available regional data in the inversion. Here, we compare it to the original NEIC finite-fault product.

Research Motivations and Goals

How can we establish general behaviors of earthquake sources when FFMs are created using heterogeneous methodologies and datasets?

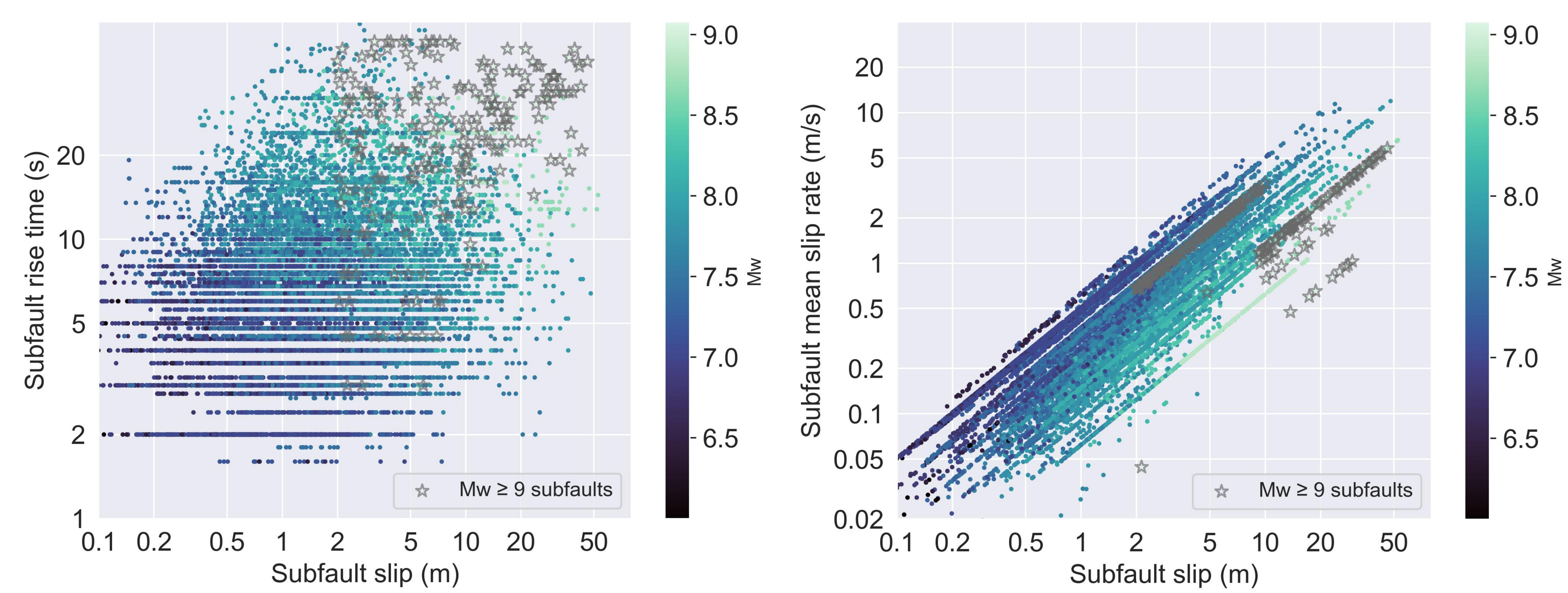
At the subfault scale, what correlations emerge between kinematic properties? Are these trends expected, or do they reveal new behaviors?

What do slip distributions reveal about the rupture process? Do ruptures tend to propagate as cracks or self-healing pulses?

How do regional geodetic datasets (GNSS, InSAR) improve rupture characterization and source parameter estimates?

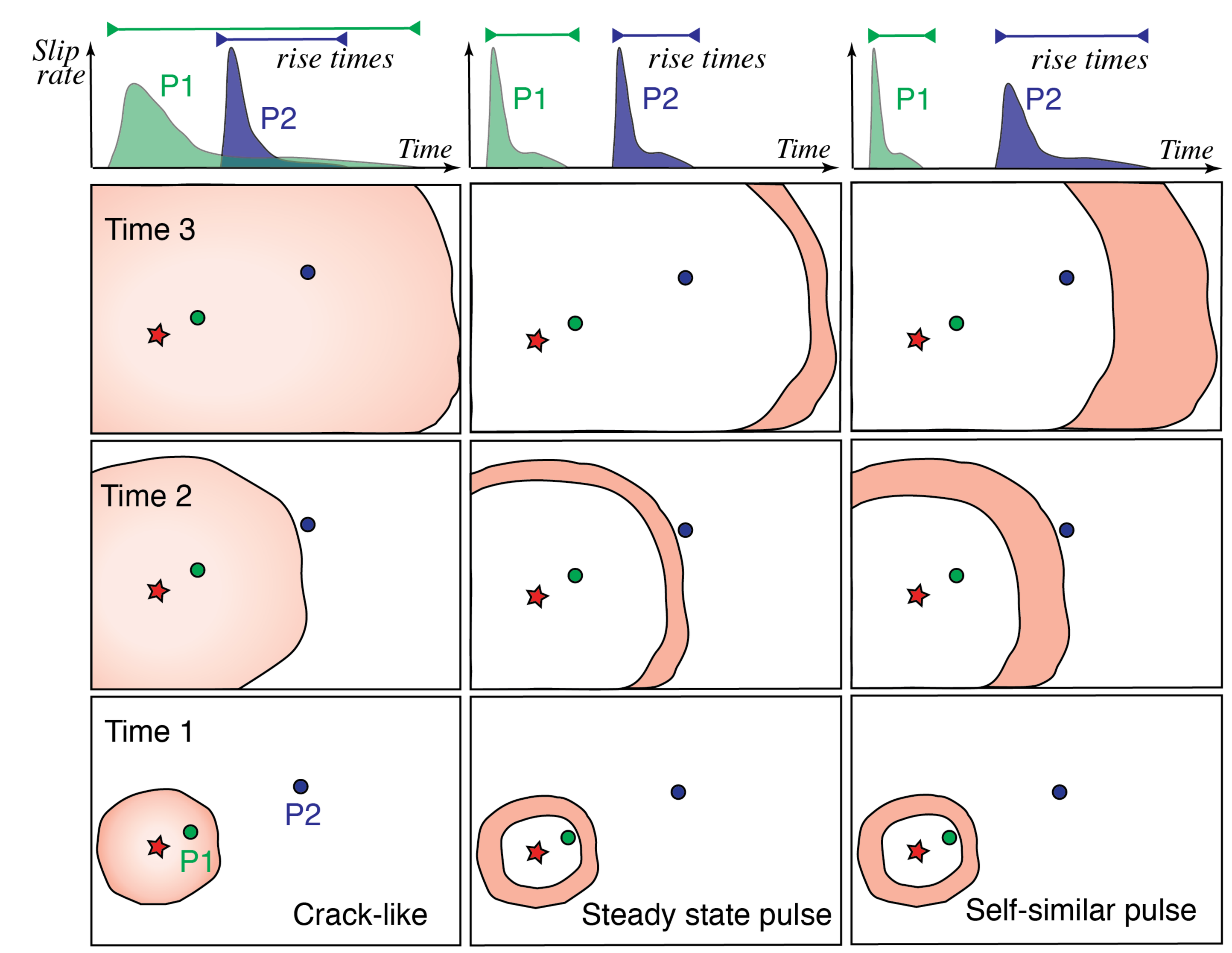
2.0 Exploring Source Properties in the NEIC FFM Catalog at the Subfault Scale

Dataset for all events at the subfault level – including only subfaults with more than 15% of the maximum slip from their parent earthquake.



(a) shows subfault time versus subfault slip **(b)** shows subfault slip rate versus subfault slip

- At the subfault level, slip rate shows a strong correlation with slip, whereas rise time exhibits no clear dependence. In contrast, when averaging over the entire fault, rise time scales with moment magnitude (Mw), while slip rate does not. Could this behavior be incorporated into the inversion?
- As moment magnitude (Mw) increases, rupture pulses become broader, leading to longer rise times. Within a given event, larger slip does not appear to be accommodated by a wider pulse, but rather by an increase in local slip rate while rise time remains approximately constant.
- Slip rates also appear to scale with magnitude beyond a certain slip threshold. This is consistent with a scenario where rise time is relatively stable within events but increases with overall event size—implying that, for the same slip, smaller events must release slip more rapidly.



Main takeaways messages

- **We investigate earthquake scaling properties using the USGS-NEIC finite-fault model catalog from the past 25 years.**
- **We present our workflow to systematize the inversion process by expanding the FFM database for comprehensive scaling studies of large earthquakes (M6+), validating nonlinear inversion method, and integrating regional datasets, particularly GNSS and InSAR, when available.**
- **Through retrospective analysis of slip distributions, we explore general rupture characteristics and aim to refine scaling laws for key source parameters (e.g., rise times, slip rates, rupture speeds) following methods from Melgar & Hayes (2017).**

EGU Abstract Info

Suggestion? Feedback? References?