Earthquake Dynamics: The Fast, The Slow, And The Rough

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The Fast

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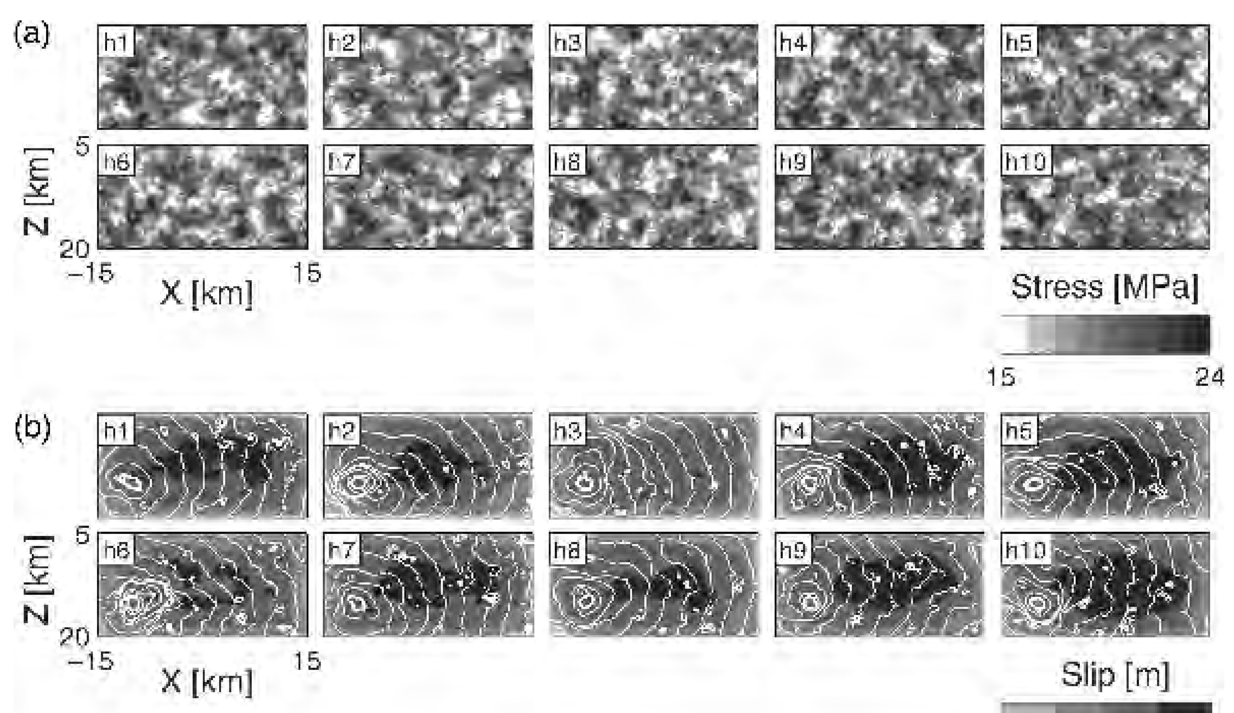
We study the effect of initial stress heterogeneities on the statistical properties of dynamic ruptures for ground motion prediction.

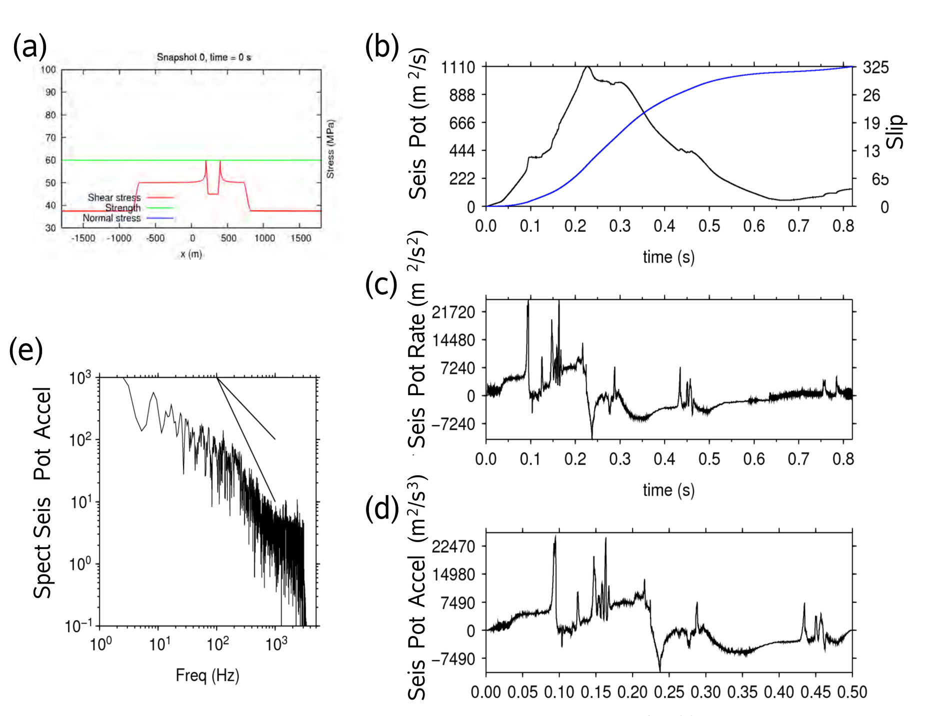
Seismic ground-motions in the vicinity of active faults are strongly controlled by the spatial-temporal details of the earthquake source rupture process. Unfortunately near-field recordings are scarce specially for large size magnitudes, and empirical approaches for ground motion prediction are insufficient. A complementary approach for ground motion prediction is the physics-based modeling of earthquake dynamic scenarios. Previous studies have been studying the effect on initial stress heterogeneities on the statistical properties of dynamic ruptures and the induced near-field ground motion (e.g. Ripperger et al., 2008).



(a) A set of stochastic initial stress realizations.
(b) Dynamic rupture fronts and final slip.
(Ripperger et al., 2008).

Our mid-term goal is to characterize the range of initial stress and strength heterogeneities and fault constitutive laws that can produce spontaneous dynamic ruptures that are statistically consistent with the current body of seismological observations. This involves quantifying the impact of several physical ingredients on those properties of dynamic rupture that are critical for ground motion prediction. The following ingredients are identified as our priority:

- Heterogeneous initial stress (probab. distribution, correlation length);
- ... and strength (fluctutations, scale dependent fracture energy);
- friction laws (velocity weakening, role of self healing).



(a) Initial shear stress heterogeneity for spontaneous dynamic rupture simulation. Results for seismic (b) potency, (c) potency rate, (d) potency acceleration and (e) Fourier spectral amplitude of seismic potency acceleration.

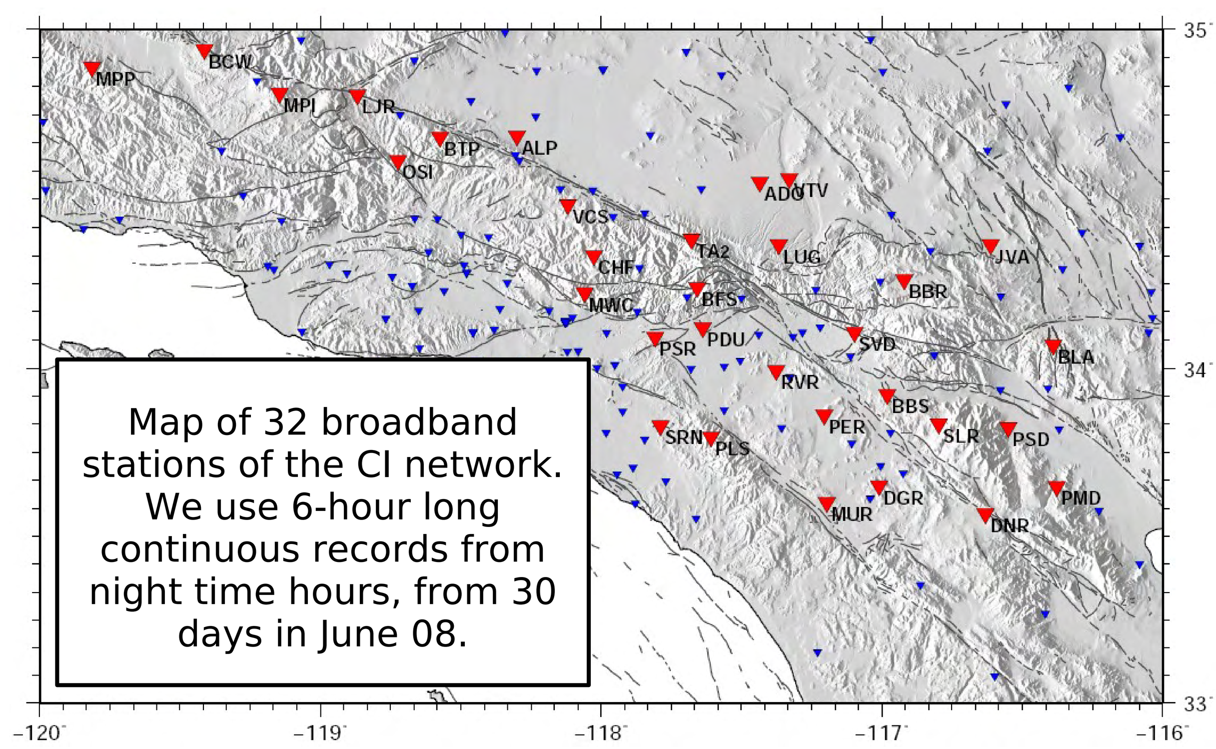
We are currently working on the effect of shear stress heterogeneities using 2D rupture models. The adjacent figure shows a very simple case using a stress discontinuity of a previous earthquake, and shows the result in term of seismic potency radiated by the source. Next is to introduce a physical description on the heterogeneities distribution on the fault.

The Slow

G. Hillers & J.-P. Ampuero

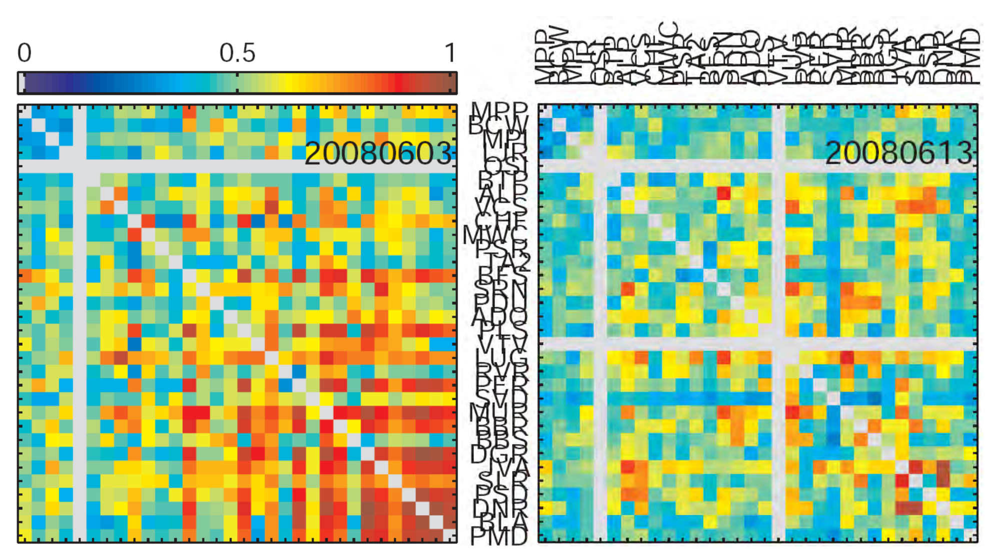
We work on the automatic detection and source modeling of slow and silent slip events and tremor.

Non-volcanic tremor signals and slow slip events are now frequently observed in subduction zones. Their physical origin remains speculative, however, fluids seem to play an important role. Intermittent tremor has also been observed over a 2 year period below the central section of the San Andreas Fault, and in several regions across California, triggered by surface waves from the 2002 Denali earthquake. We develop and test a systematic procedure for the detection of tremor signals, analyzing continuous data from the Southern California network.



Map of 32 broadband stations of the CI network. We use 6-hour long continuous records from night time hours, from 30 days in June 08.

We compute the envelopes of bandpass filtered 6-hour long continuous records, and determine an average value at a new, smaller sampling rate. Overlapping data sections (5-20 min.) from individual stations are cross-correlated with corresponding data sections from all other stations in the subnetwork. *We need to test the sensitivity of the cross correlation to algorithmic choices.*



Scaled CC coefficients highlight the maximum similarity of any two templates during the respective day. High CC values across a number of neighbored stations are an indicator of a potential tremor waveform.

Future work includes the

- removal of earthquake signals from the analysis;
- expansion to longer time periods, and the analysis of data from more sensitive borehole stations.

Once tremor signals can be detected in a consistent and reliable manner, our goal is to

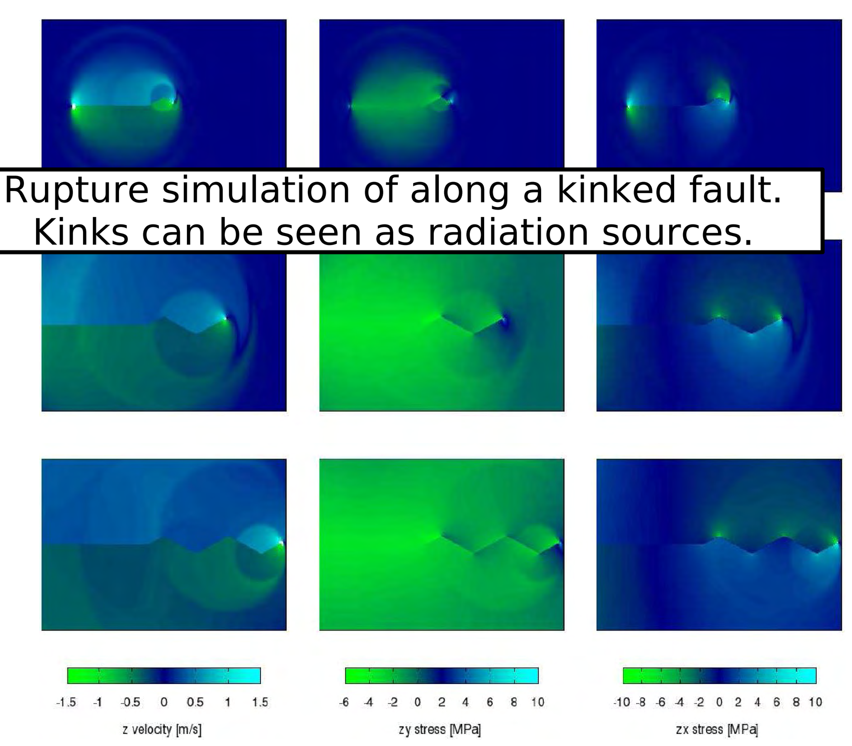
- investigate the source mechanisms;
- implement the technique to perform a regular near real time search for tremor;
- expand the method to other regions, e.g., to Southern Peru.

The Rough

J. Elkhoury & J.-P. Ampuero

We characterize fault roughness and study the evolution of numerical dynamic rupture propagations on rough faults.

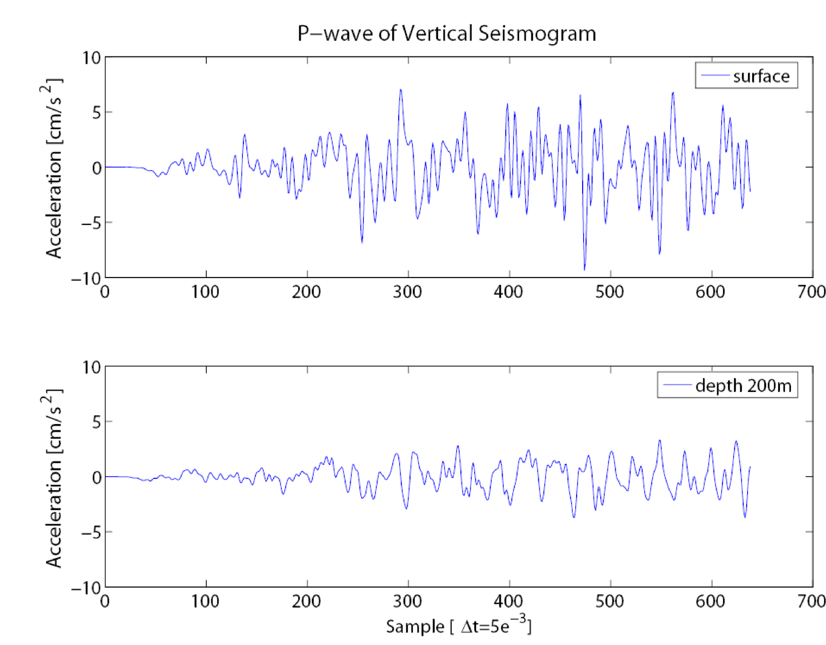
Fault roughness is responsible of the high frequency radiation bursts emitted by rupturing strong heterogeneities during earthquakes. A step towards the understanding of ruptures on non planar faults is taken in the study of the influence of jogs, steps, kinks and branches which represent primary sources for high energy radiation. However, natural faults show geometrical complexities over many length-scales which affect the dynamical evolution of ruptures and the seismic radiation of high-frequency energy. We are investigating the dynamics of rough faults beyond the simple non planar features mentioned above.

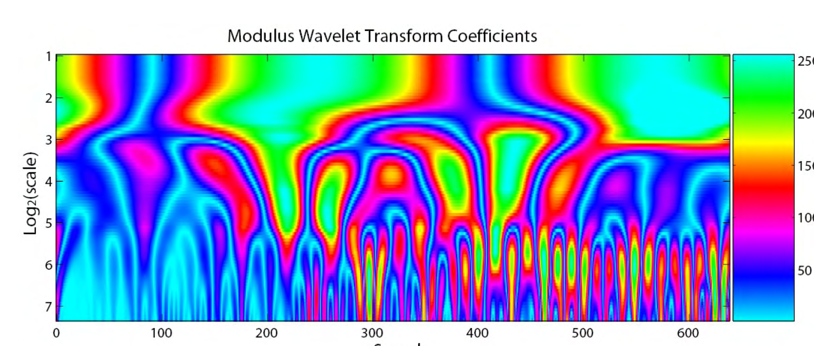


Rupture simulation of along a kinked fault. Kinks can be seen as radiation sources.

We use a multi-scale wavelet-based analysis to extract statistical information from strong motion records to infer heterogeneities of fault ruptures. In particular, we apply the Wavelet Transform Modulus Maxima in the estimation of regularity spectrum (Holder exponents) that can be used to constrain the imposed roughness in numerical dynamical models of rupture propagation.

Two vertical component seismograms showing the first 3 seconds of the P-wave part for the 2005/03/20, M7 earthquake in Japan at the surface and at a depth of 200 m. The station is about 36 km from the epicenter. Notice the clear difference in the amplitude and character of the signal.





Continuous wavelet transform for the seismogram at depth. Following changes of the wavelet coefficients along maxima lines provides an estimate of the irregularity (heterogeneities) of the signal.

Since we observe many maxima, the result is a multi-fractal spectrum that characterizes the heterogeneities. One of the major difficulties is the discrimination between the source and path signals. The figure shows that a difference of 200 m in depth results in a shift towards negative exponents.