4D Source Analysis of the 2015 Illapel, Chile Mw8.3 Earthquake

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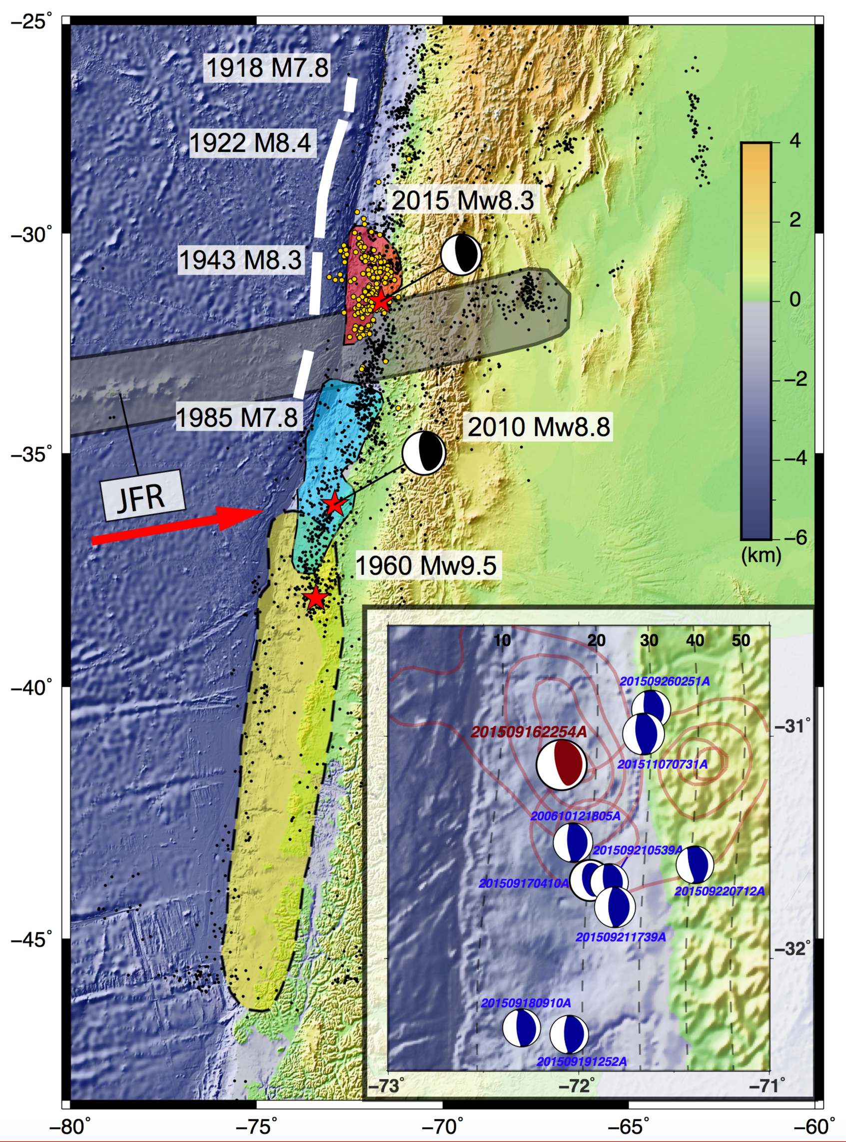
Abstract



- Combination of the time-domain and spectral-domain analysis to evaluate the temporal and spatial (4D) evolution of dynamic source parameters during the **2015 Illapel, Chile Mw8.3 earthquake**.
- **Compressive sensing backprojection** method to propose the spatial distribution of both low and high frequency energetic seismic waves.
- A **two-step spectral analysis** to construct the P-wave source spectrum both for the total event data as well as for the running time segments of data.
- Integration of both independent results to constrain the **duration**, **radiation**, **high frequency falloff rate**, **directivity** etc. during the dynamic rupture process.

Methodology

1. Compressive sensing backprojection: Spatial and temporal evolution of seismic energy bursts/excitation

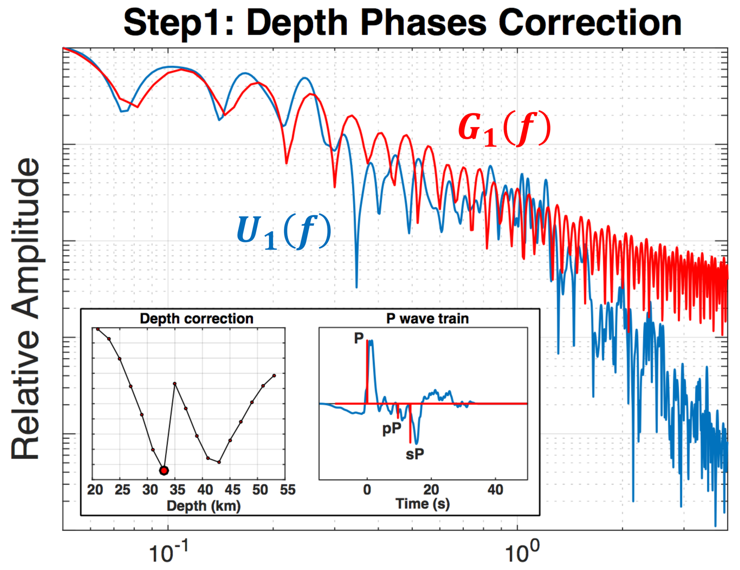
$$\text{minimize}(\|\mathbf{A}(f)\mathbf{X}(f)-\mathbf{B}(f)\|_1+\lambda\|\mathbf{X}\|_1)$$

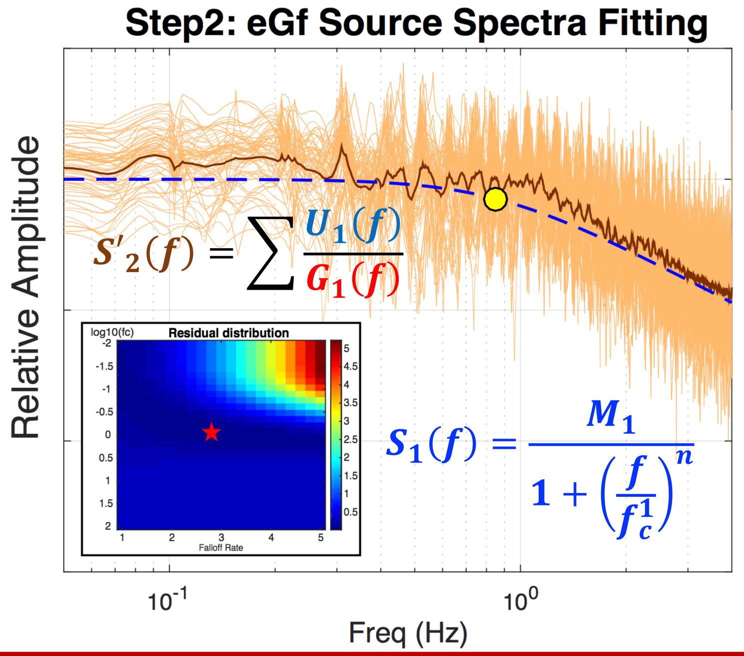
- $\mathbf{B}(f)$: Velocity data in frequency domain
- $\mathbf{A}(f)$: Propagation matrix
- $\mathbf{X}(f)$: Distribution of radiating power (Model)
- λ: Damping factor
- $\|\cdot\|_1$: L1 norm

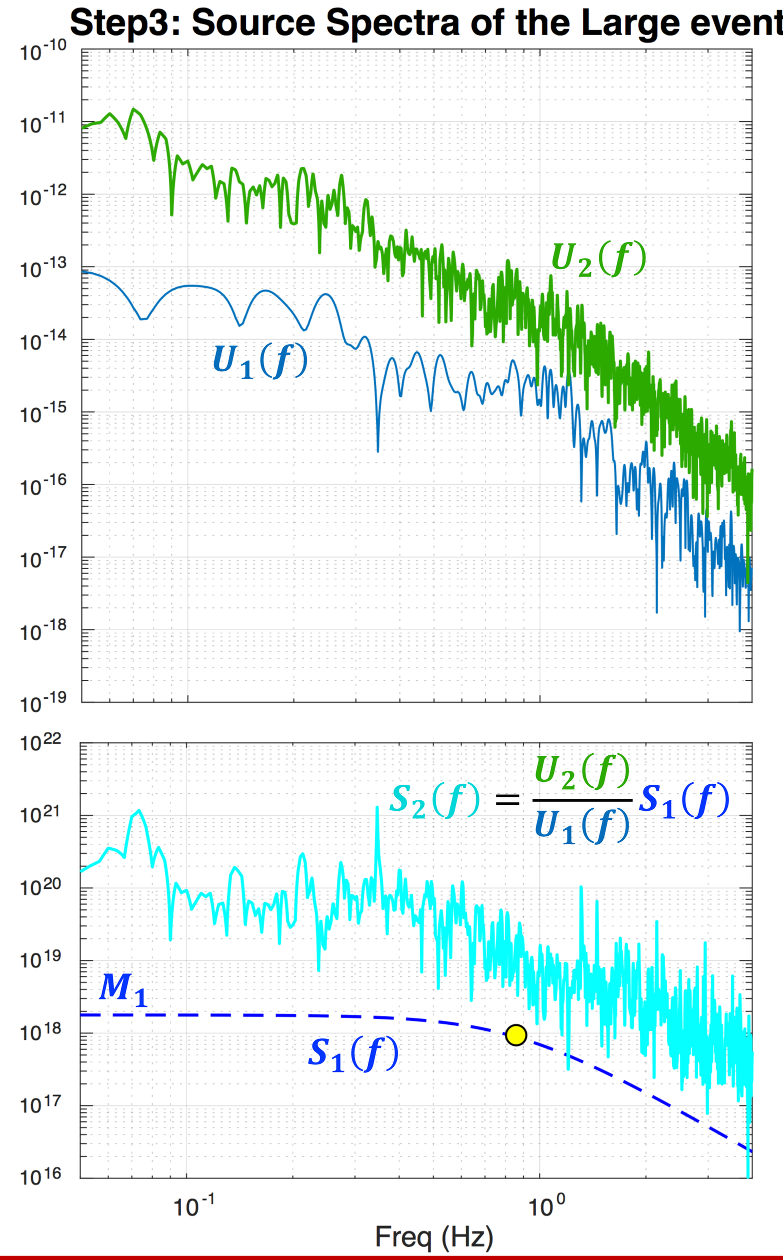
2. Source spectral analysis: Constraints on dynamics

$$U(f)=S(f)\times G(f)$$

- $U(f)$: Displacement Spectrum
- $S(f)$: Source spectrum
- $G(f)$: Small event: P wave train with depth phases + t*; Large event: Empirical Green's function (EGF)

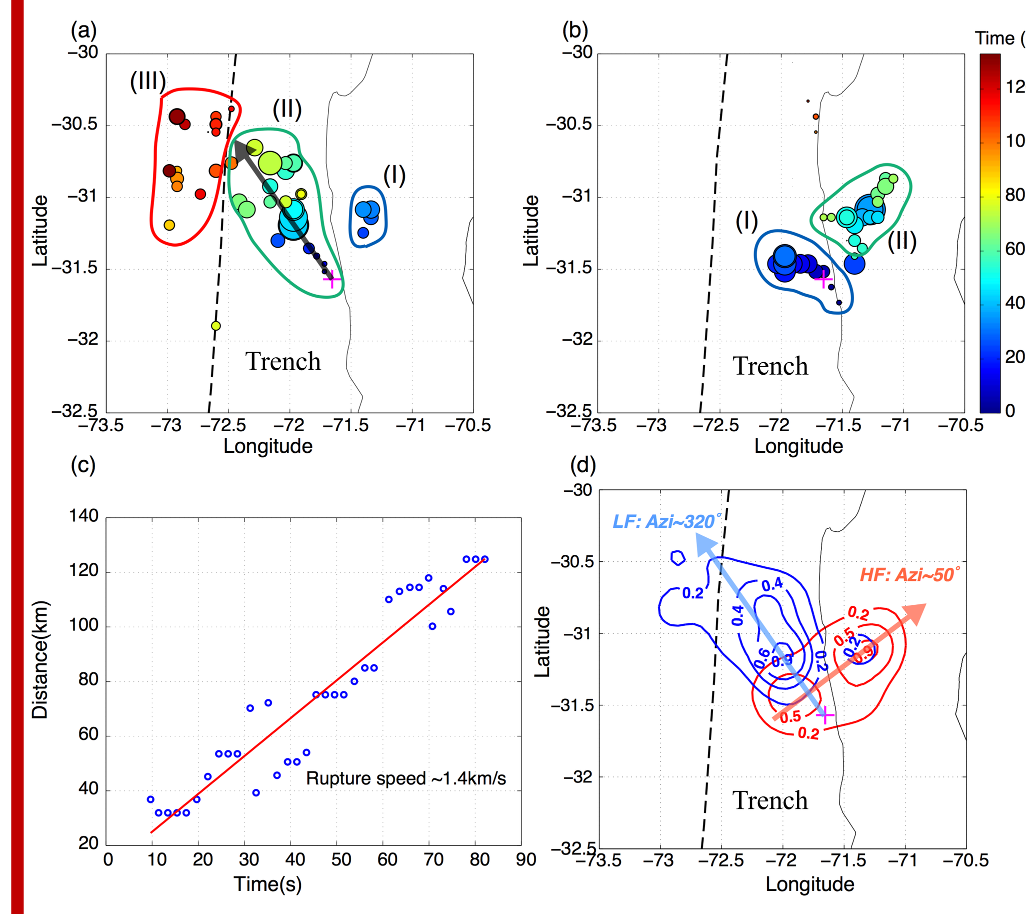






Results

1. Compressive sensing backprojection (Using TA array)



Low Frequency (LF: 0.08-0.5Hz):

- Updipward propagating: $Azimuth\approx 320°\pm15°$
- Three stages and two energy peaks in stage (II)
- Rupture speed ~ 1.4km/s
- Energy from outer-rise region

High Frequency (HF: 0.5-1Hz):

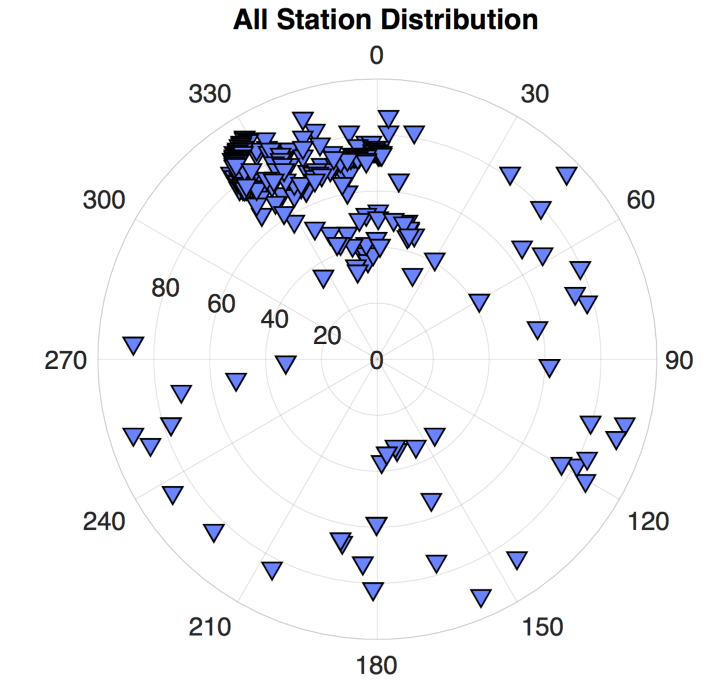
- Downdipward propagating: $Azimuth\approx 50°\pm15°$
- Two stages
- Clustering

Overall:

- Frequency-varying behaviors
- No southward propagation

2. Source spectral analysis

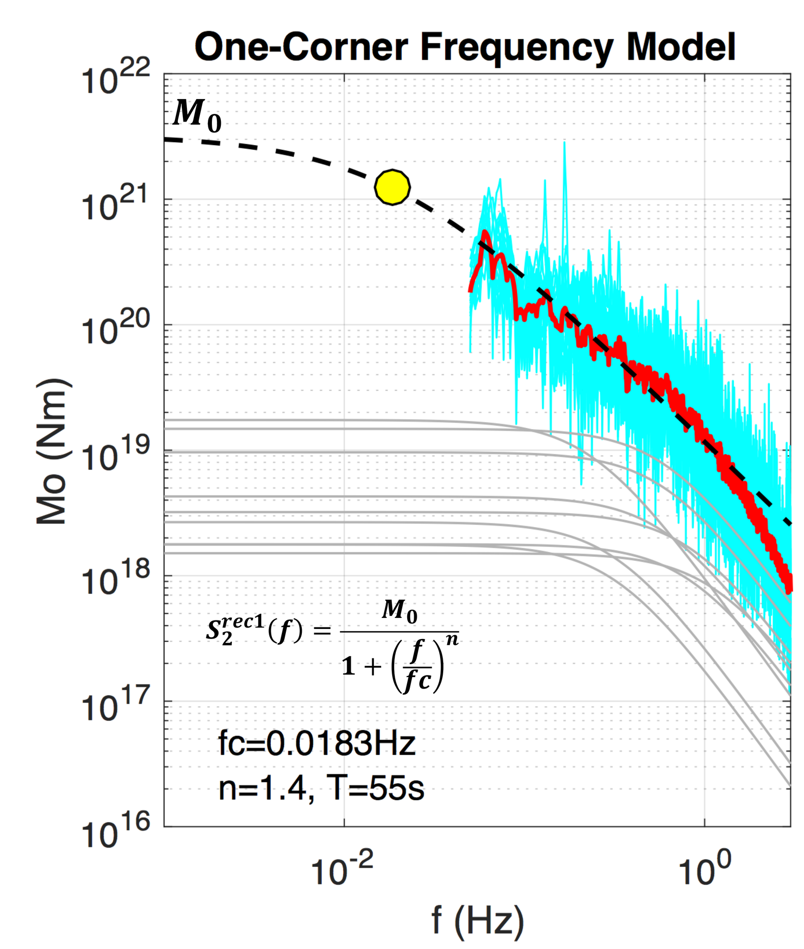
(1). Stations and Corrected depth for EGF events

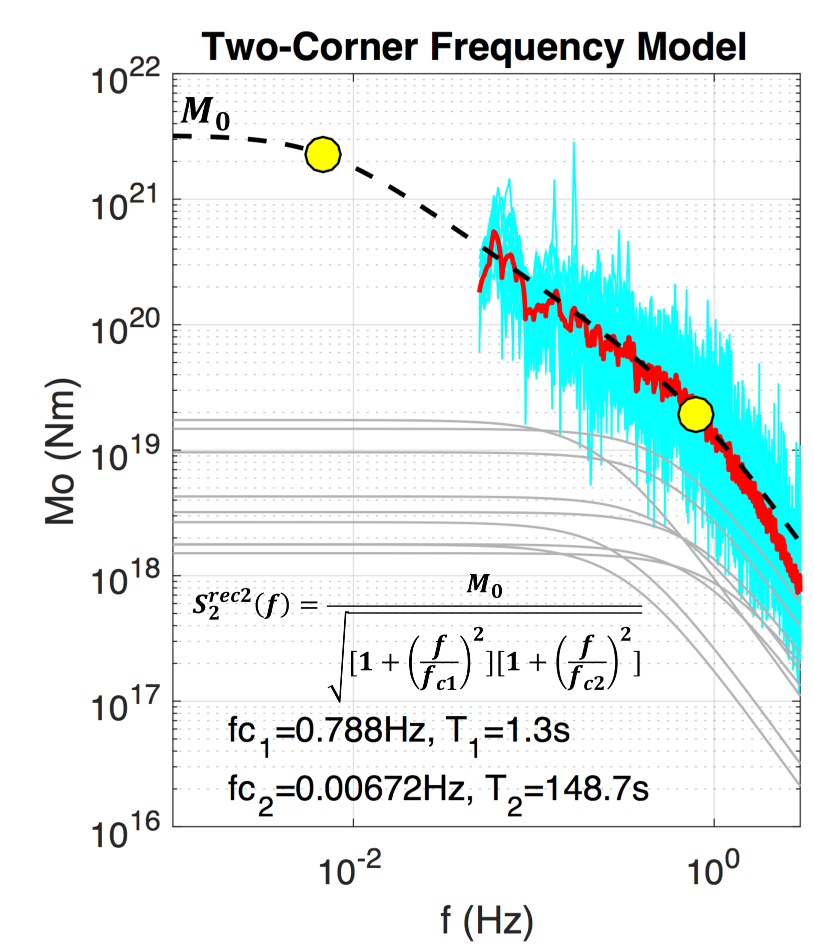


EGF event	Centroid depth (km)	Corrected depth (km)
200610121805AMw6.4	36.8	41
201509170410AMw6.8	36	36
201509180910AMw6.1	15	28
201509191252AMw6.2	20	34
201509210539AMw6.1	37	33
201509211739AMw6.6	39	33
201509220712AMw6.1	50	72
201509260251AMw6.3	46	59
201511070731AMw6.7	43.4	58

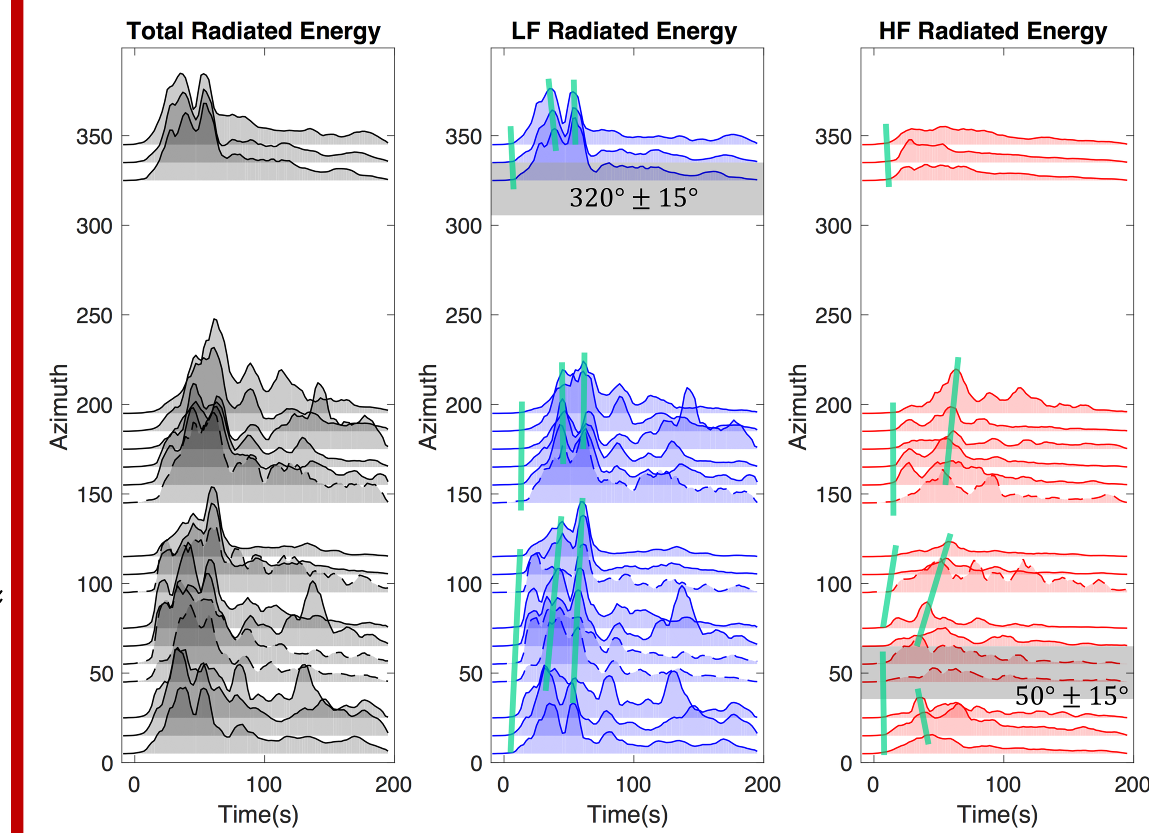
(2). Source spectra constructed for the total event data

- First stack the source spectra recovered from all the EGF events for each azimuth bin.
- Second stack the spectra for all azimuth bins.
- Two different source spectral models to fit the recovered source spectra data for the Mw8.3 event.

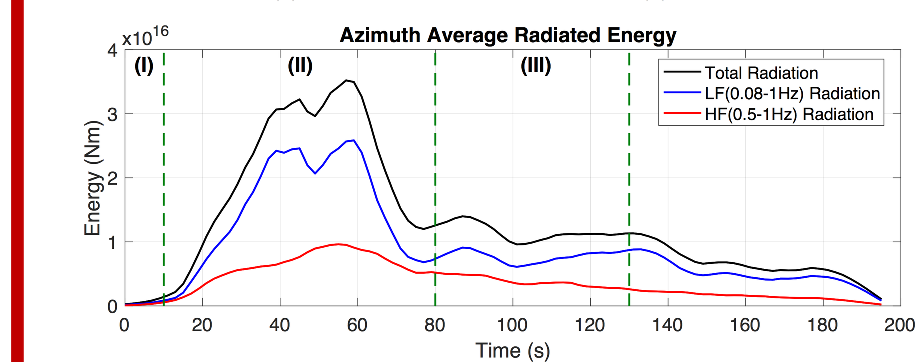


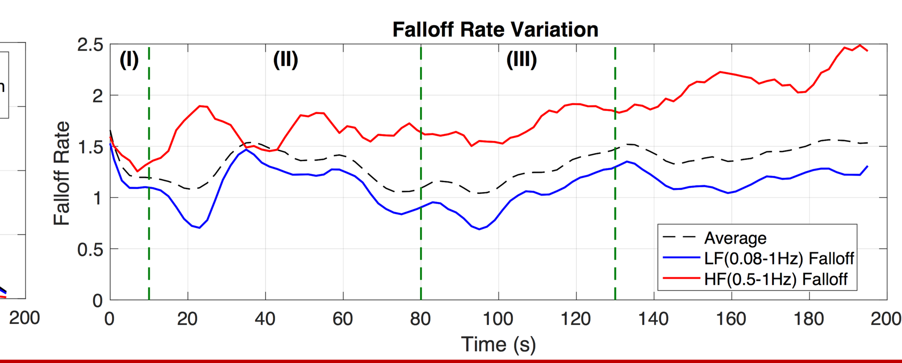


(3). Spectral analysis for running time windows in data



- Source spectra analysis for every 12s' waveform data (2s overlap)
- $E_R=\frac{2\pi M_0^2\langle R_P^2\rangle}{\rho\alpha^5}\int|fS(f)|^2\,df$
- Total radiated energy "**Rate**"
- Two peaks of radiated dominant in LF energy in stage (II)
- Frequency-varying behaviors
- Different directivities for LF and HF results
- Falloff rate varies with time (?)

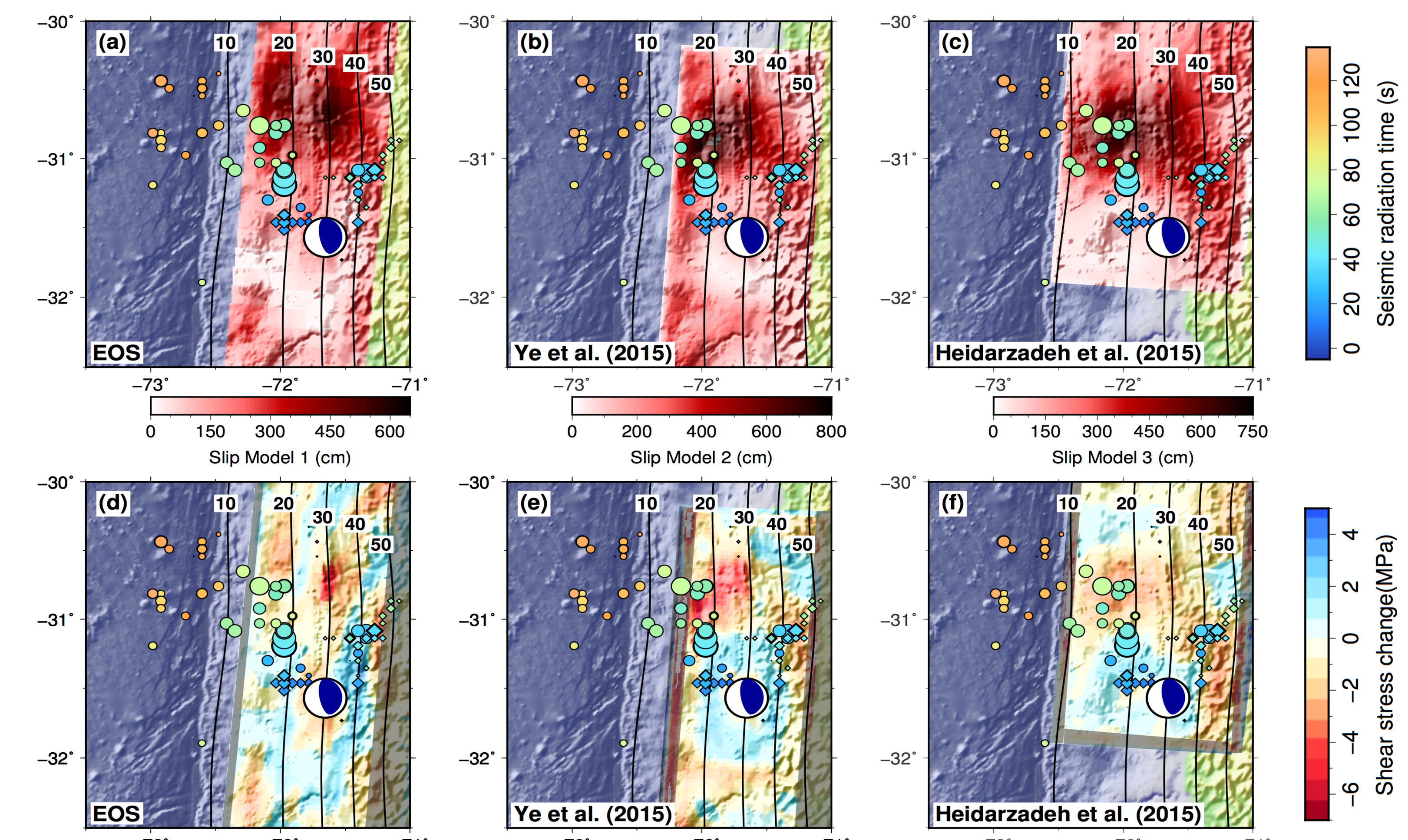




Discussion and future work

4D source analysis
- **Backprojection:** Spatiotemporal evolution of seismic energy bursts/excitation
- **Source spectral analysis:** More constraints on dynamics source parameters (corner frequency, duration, high-frequency falloff rate, radiated energy etc.); Temporal evolution of "true" radiated energy

Frequency-varying: Confirmed by both methods; Different locations, propagation and directivities; Related to rupture changes and coseismic stress changes on the subducting slab.



Future work:

- Apply to more events with better azimuth- and takeoff angle- coverage and try to recover the radiated energy distribution on the focal sphere.
- Dynamic models to figure out what corresponds to the falloff rate variation and frequency-varying radiation (geometry, friction or else?)