Characterizing earthquakes source physics with source scanning algorithms.

A better earthquake analysis

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Outline

1. Shift & stack approaches
2. Characteristic functions
3. Source mechanism preliminary analysis
4. Conclusion

Shift & stack approaches

Why?

- Quantify the earthquakes physical properties & uncertainties from continuous signals.

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  - Probabilistic earthquake nucleation understanding and hazard assessment.

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  - Probabilistic earthquake nucleation understanding and hazard assessment.
    - Earthquakes could be triggered by local stress perturbation from many sources, natural or not, with implications for the rupture characteristics.

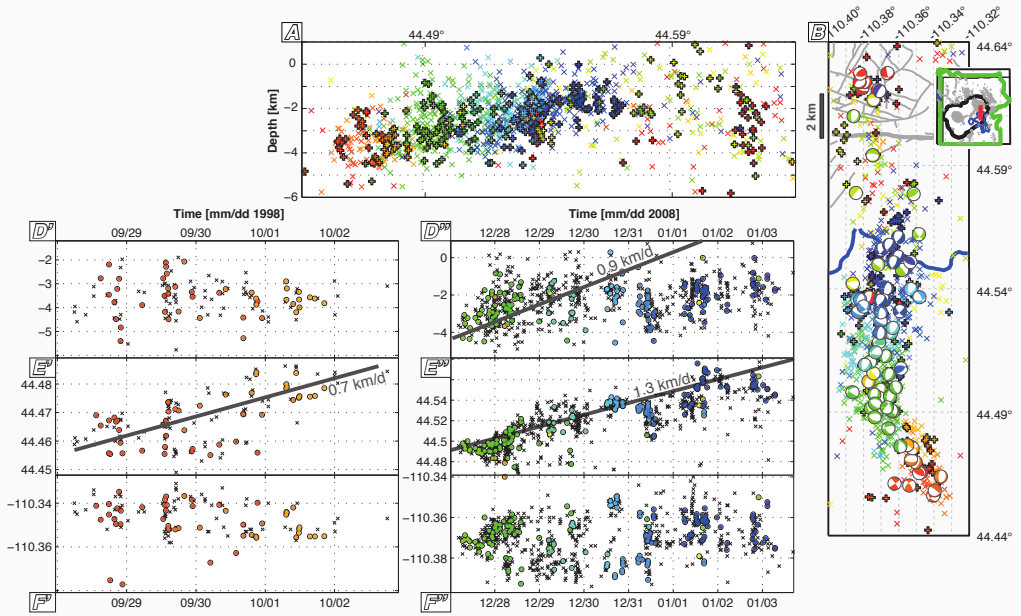

Figure 1: The 2008-9 Yellowstone Lake eq. swarm.

Conventional approach

- Arrival times (data reduced to minimum) => Hypocenter

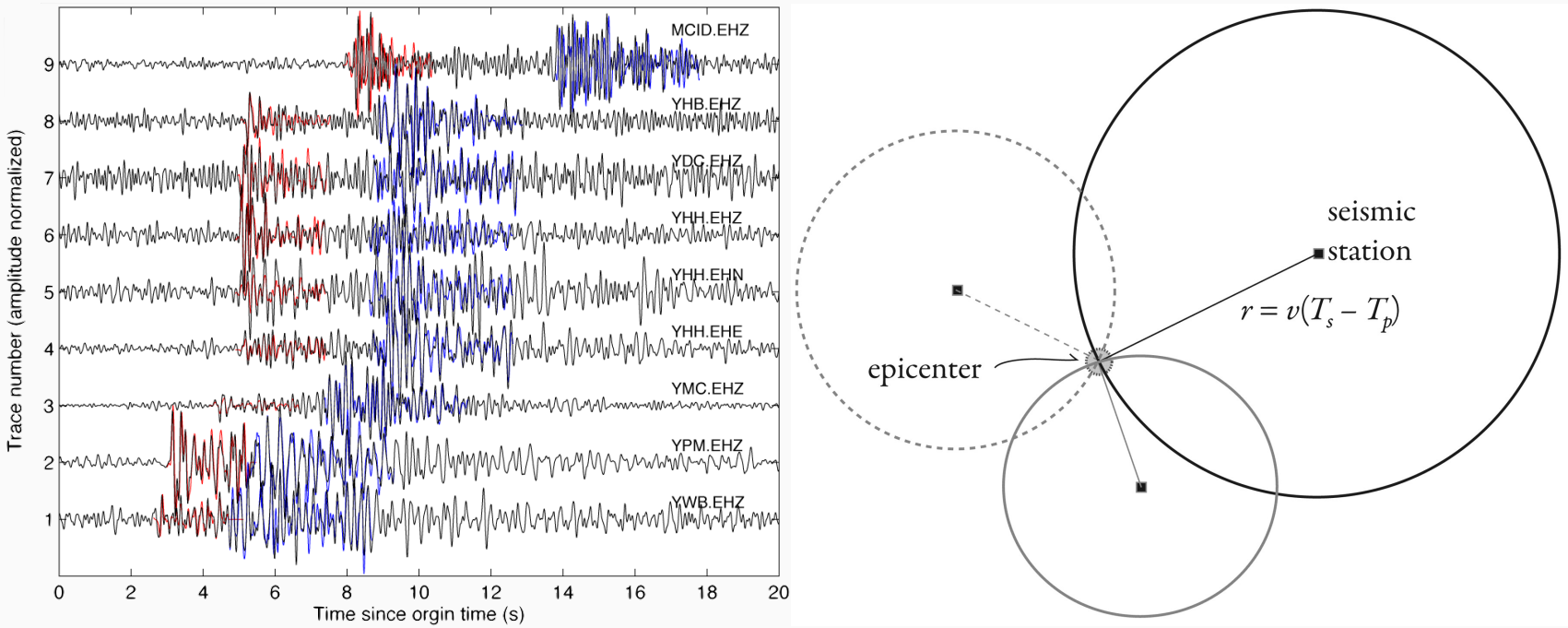

Figure 2: From picks to precise location [5].

Conventional approach

- Arrival times (data reduced to minimum) => Hypocenter
- Long period signals (filtered data) => Moment tensor

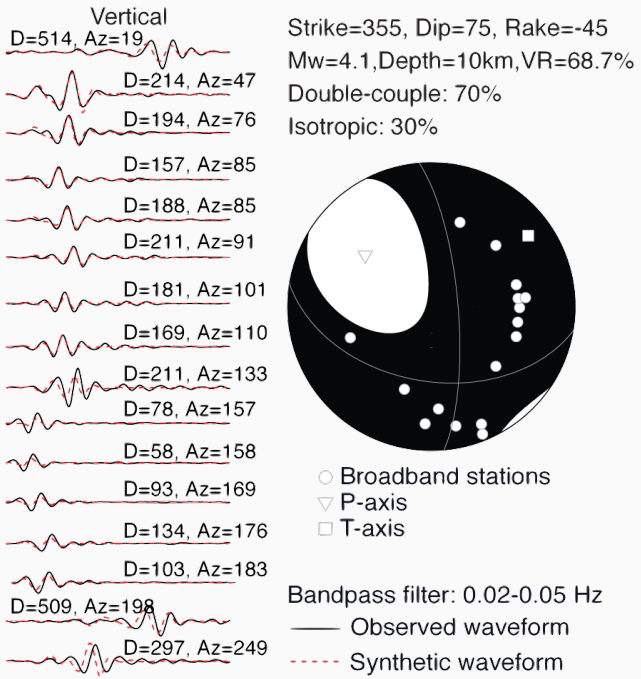

Figure 2: ... to moment tensor [2].

Conventional approach

- Arrival times (data reduced to minimum) => Hypocenter
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- Modeling of:
  - slip distribution,
  - stresses perturbation,
  - ground deformation.

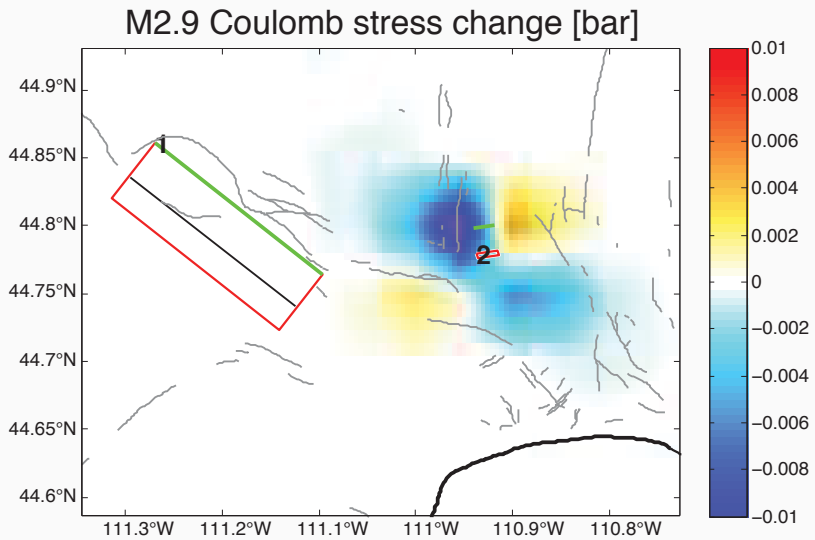

Figure 2: ... to stress change.

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How to use more data in source parameters analysis ? In a more direct way ?

Shift & stack approach (or source scanning or SSA)

Hypocenter scanning [3]

- Grid pre-calculation of travel time for trial source positions,

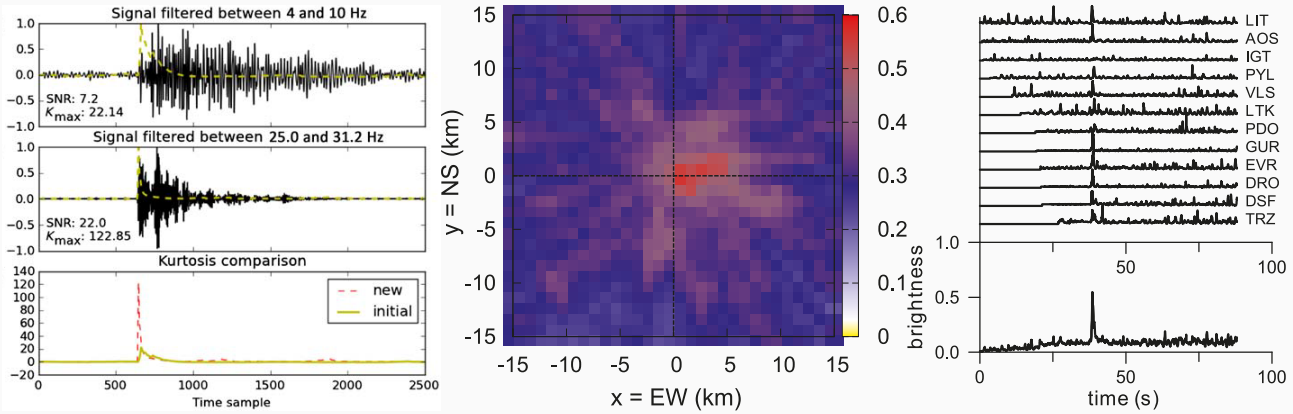
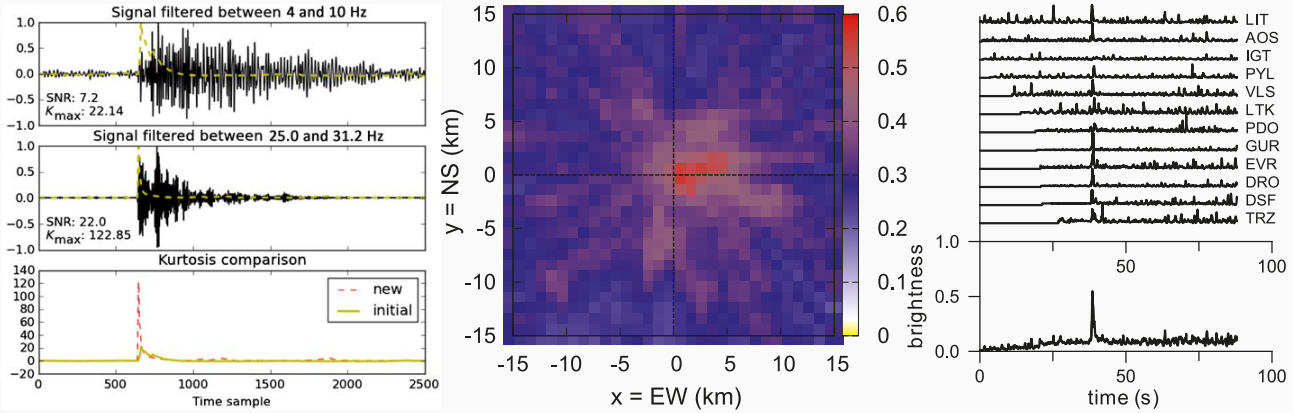


Figure 2: From signal to location

Shift & stack approach (or source scanning or SSA)

Hypocenter scanning [3]

- Grid pre-calculation of travel time for trial source positions,
- Signal pre-processing with body-wave characteristic functions,



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Shift & stack approach (or source scanning or SSA)

Hypocenter scanning [3]

- Grid pre-calculation of travel time for trial source positions,
- Signal pre-processing with body-wave characteristic functions,
- stacking using pre-defined travel times :
  - probability grid,
  - centroïd are defined with bayesian approach.

How to ***explore more spaces?***

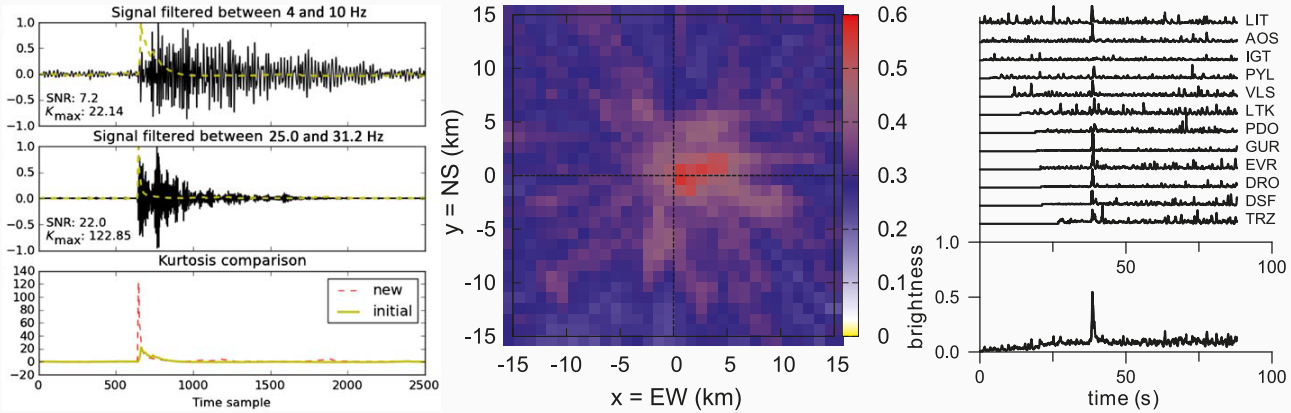

Figure 2: From signal to location

Shift & stack approach (or source scanning or SSA)

Hypocenter scanning [3]

- Grid pre-calculation of amplitudes for take off angles,
- Signal pre-processing with body-wave wavelets,
- stacking using pre-defined amplitudes:
  - probability sphere,
  - P-T axis are defined with bayesian approach.

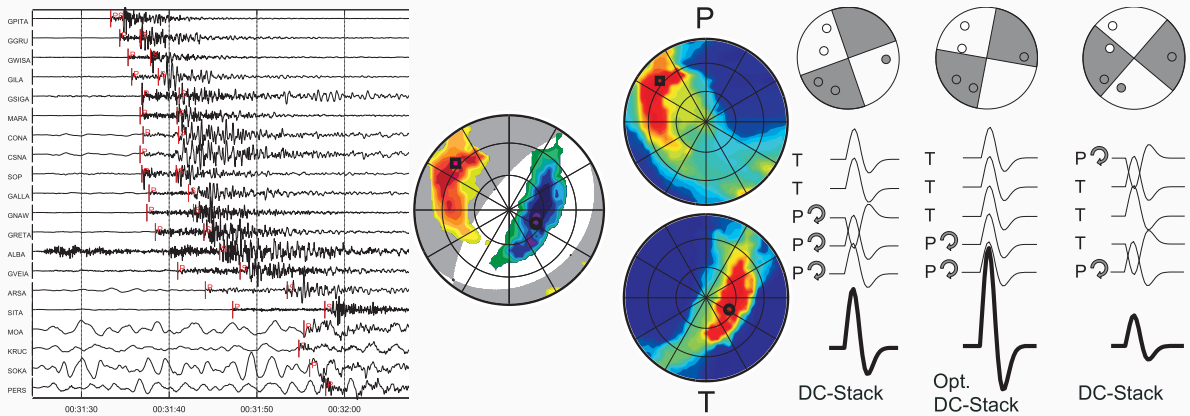

Figure 2: From signal to source mechanism

SSA advantages

System simplicity => Robust, stable & applicability.

- constant volume of computation,
- apparent lack of
  - optimization,
  - complex logic.

What do we need?

Characteristic functions

Existing CF

Body-waves arrival => Δ[Amplitude, Frequency].

- CF_A:
  - $\frac{Short Term Average}{Long TA}$
  - $\frac{Right Part A}{Left PA}$

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  - Multiscale (based on $\frac{STA}{LTA}$)
  - Kurtosis (based on $\frac{STA}{LTA}$, envelop ...)
  - Auto-regressive (based on any of the other)
  - Wenner filter <=> Match filter (based on any of the other).

Existing CF

Body-waves arrival => Δ[Amplitude, Frequency, Polarization].

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  - Auto-regressive (based on any of the other)
  - Wenner filter <=> Match filter (based on any of the other).
- CF_P:
  - Component Energy Correlation Method (CECM[4], based on RMS)

A better CF using CECM

Advantages:

- based on specific property of body-waves,
- scaled between 0 and 1

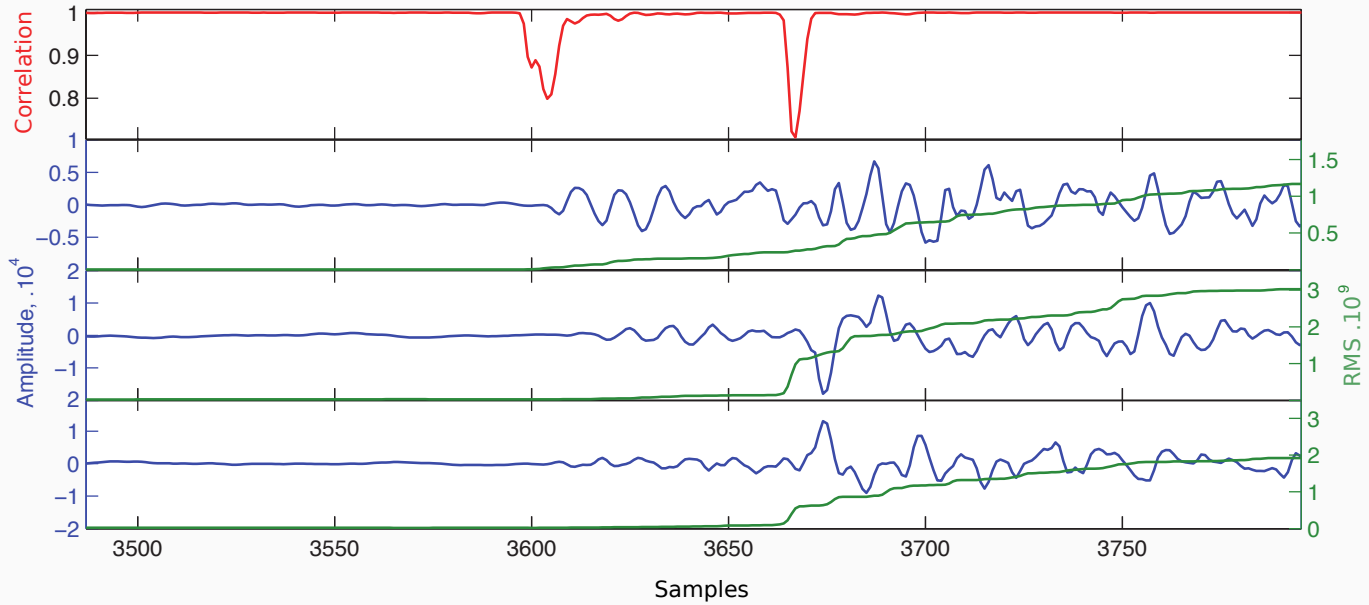


Figure 3: The $C_{omponent}E_{nergy}C_{orrelation}M_{ethod}$.

A better CF using CECM

Advantages:

- based on specific property of body-waves,
- scaled between 0 and 1,
- easy wave-type discrimination.

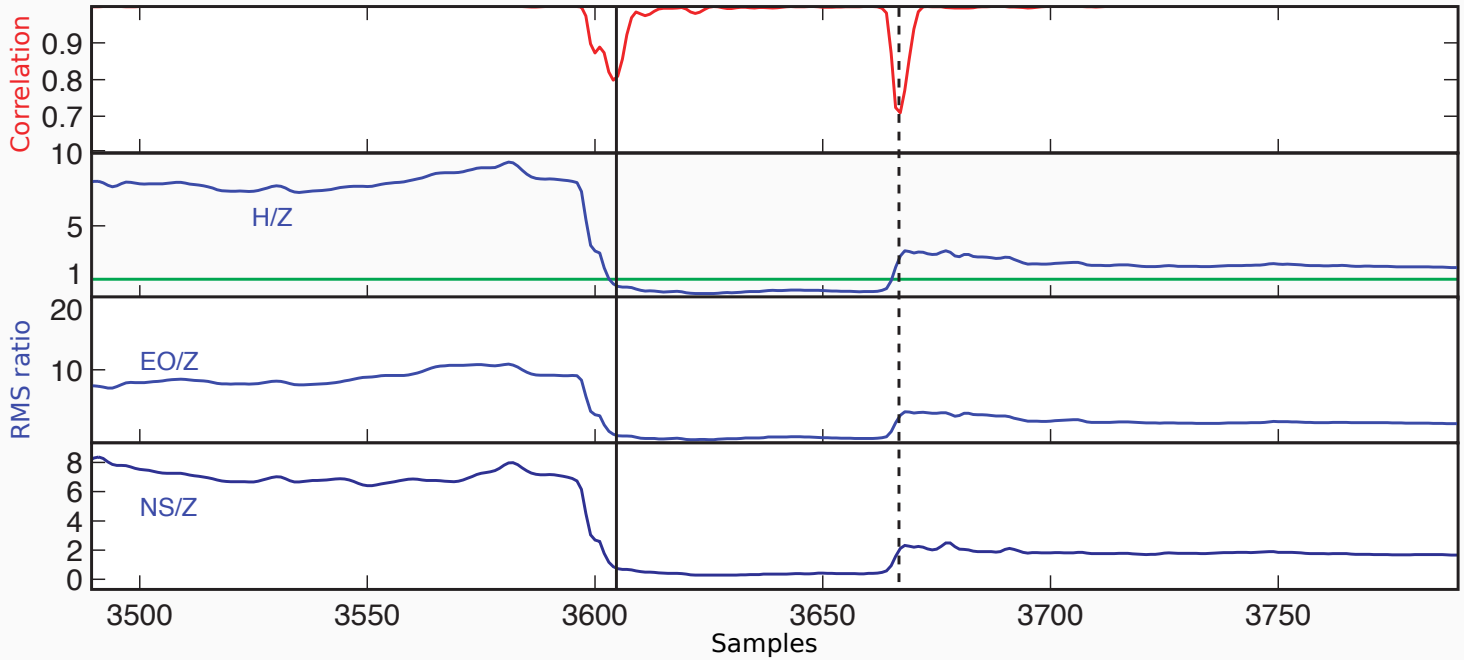


Figure 3: Wave type discrimination.

Examples

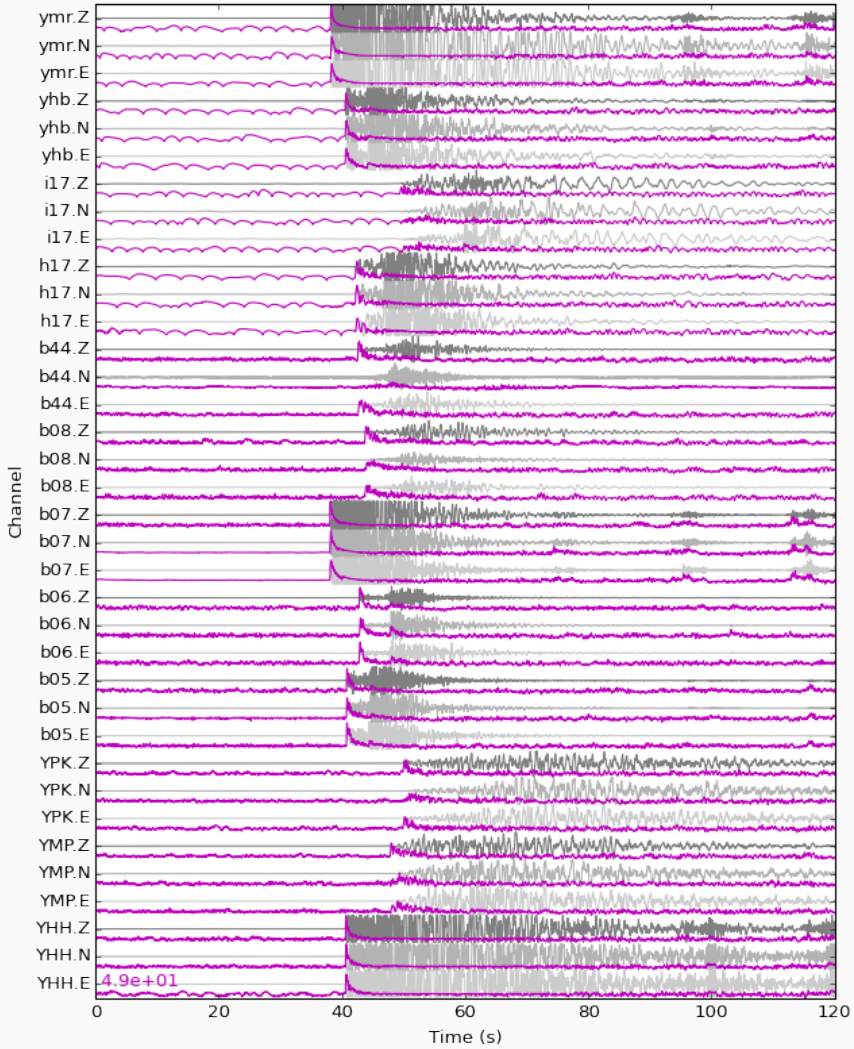
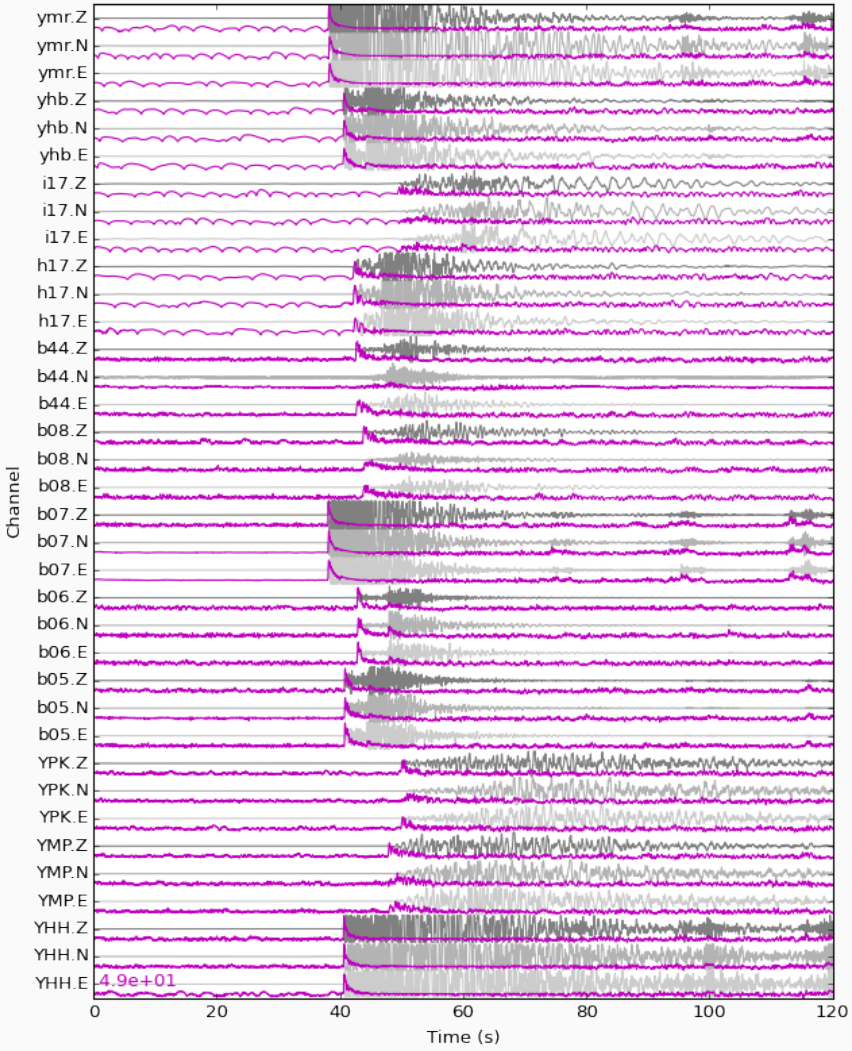


Figure 4: Data and $\frac{STA}{LTA}$.

Examples improvements with CECM



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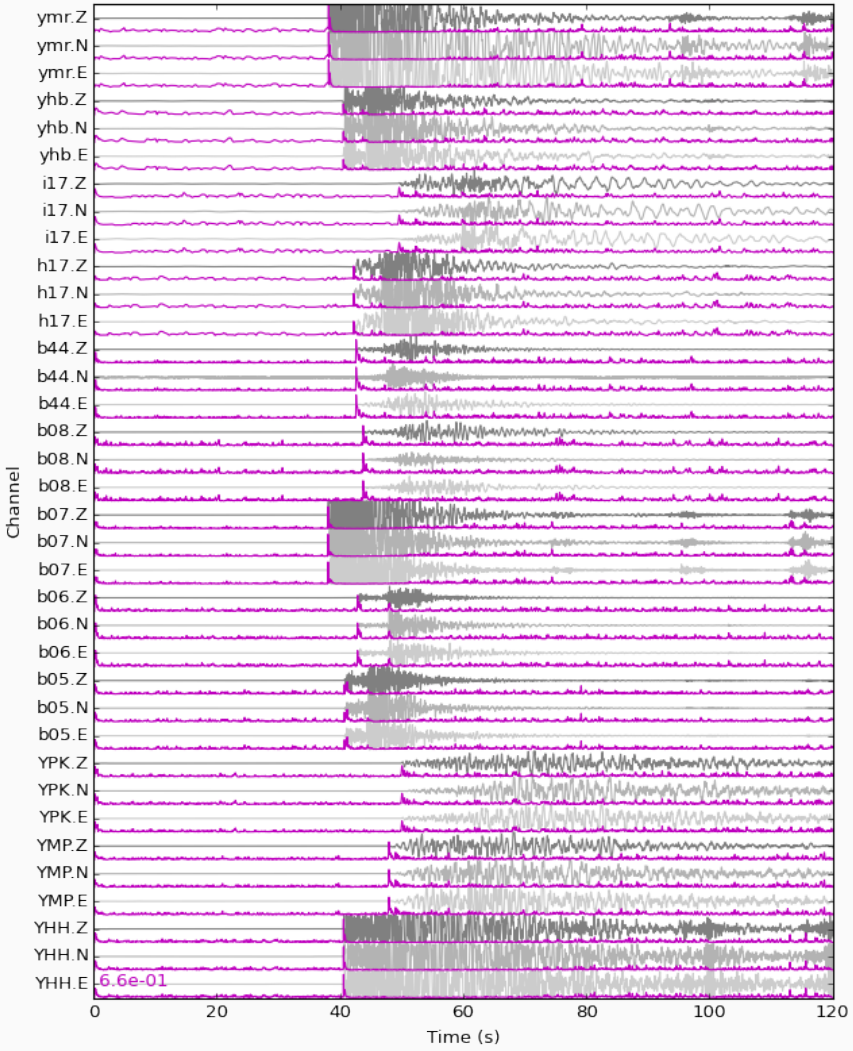

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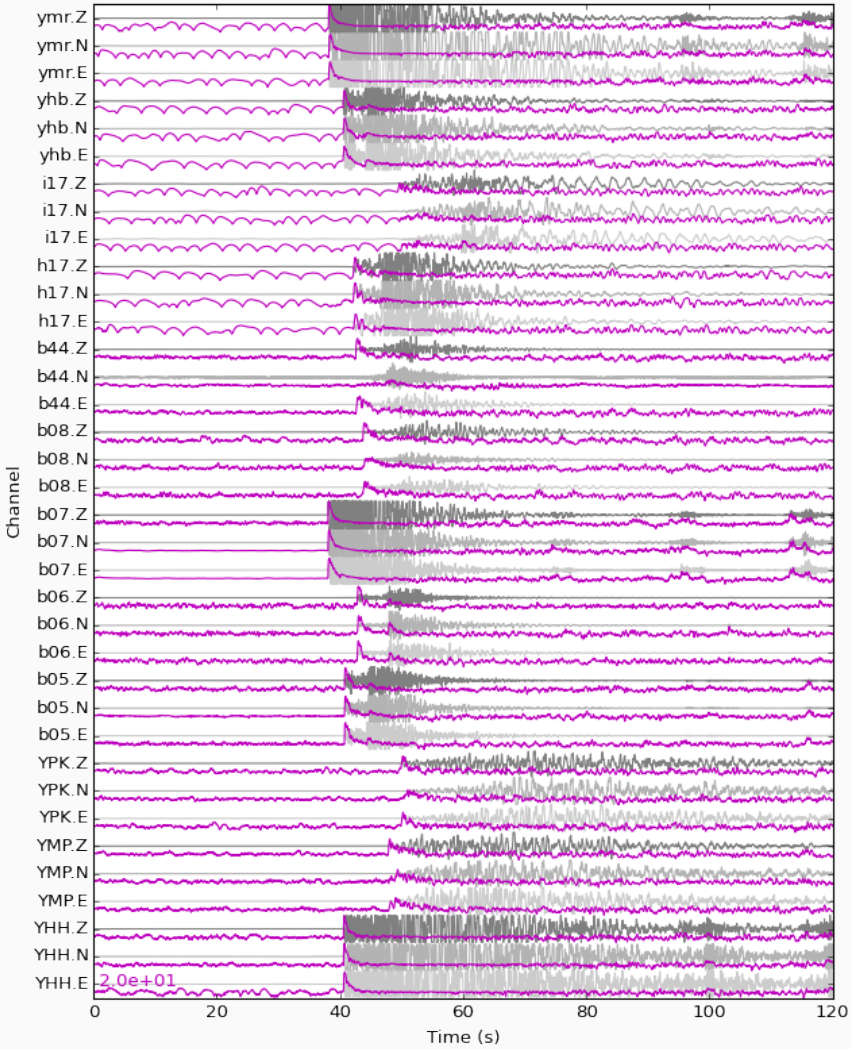
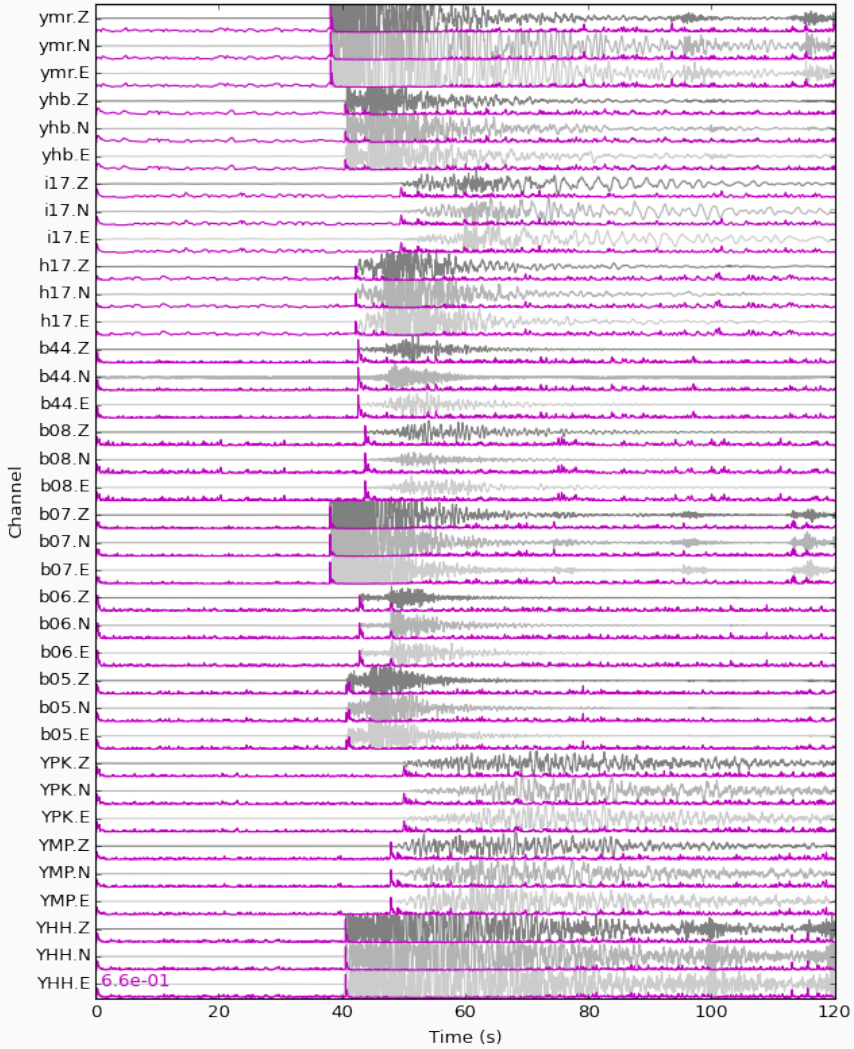


Figure 4: Data and $^{M}\frac{STA}{LTA}$.



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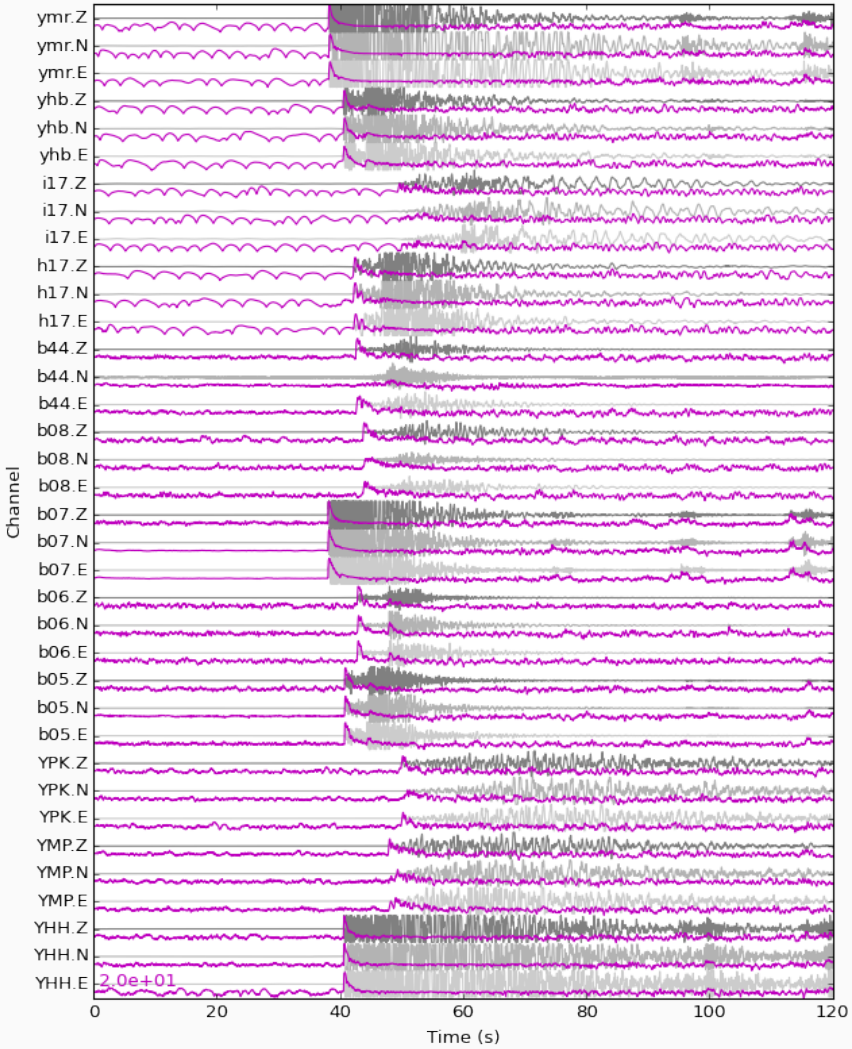
Examples improvements with CECM and multi-scaling



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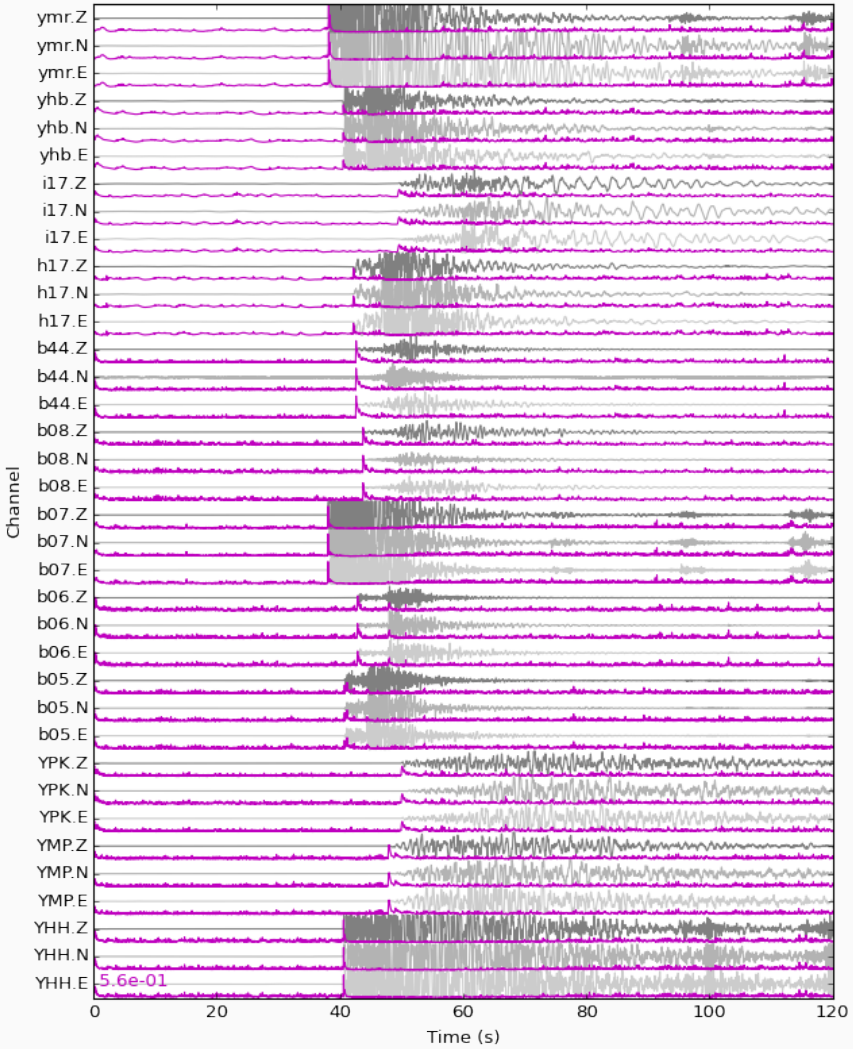


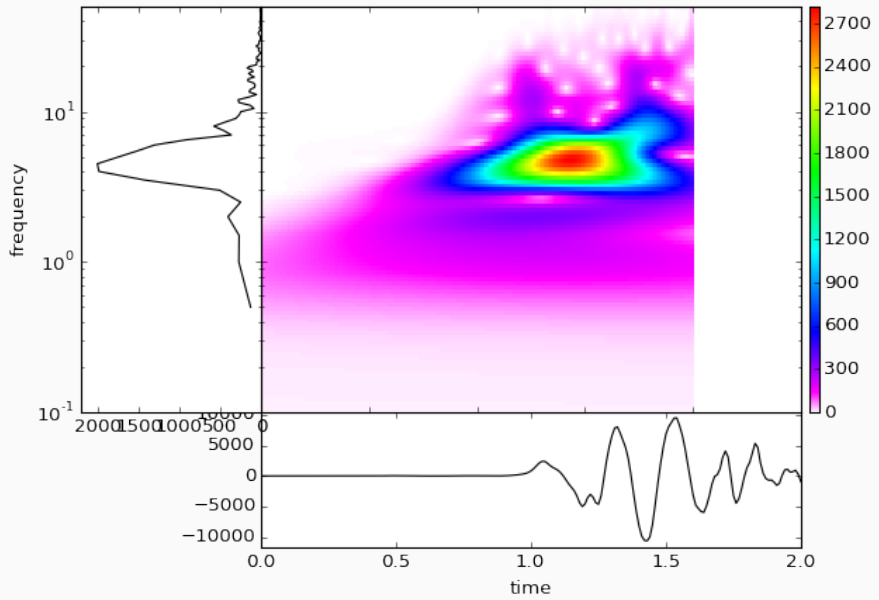
Figure 5: Data and ^{M}CECM.

Source mechanism preliminary analysis

Body-wave wavelets

The wavelet parameters:

- onset estimated by correlation based CF,
- length estimated by time-frequency analysis.



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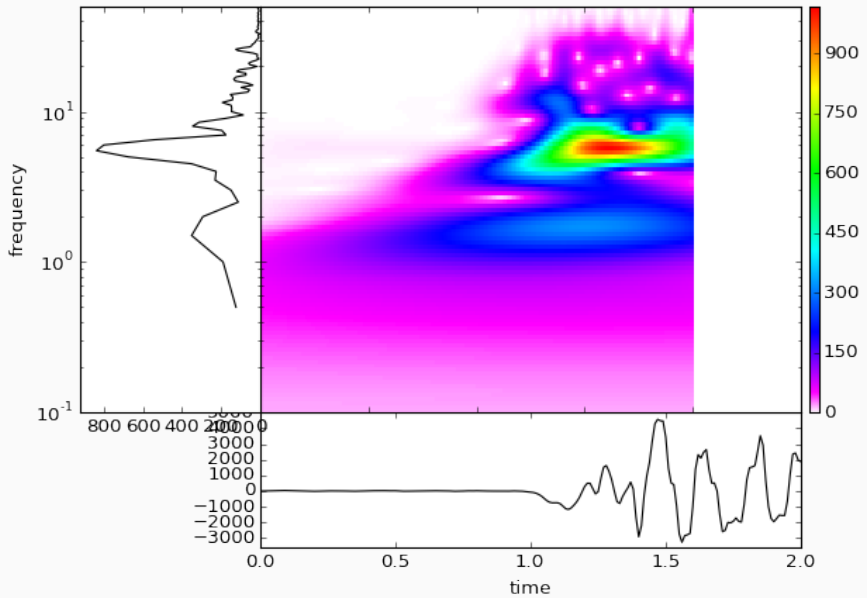

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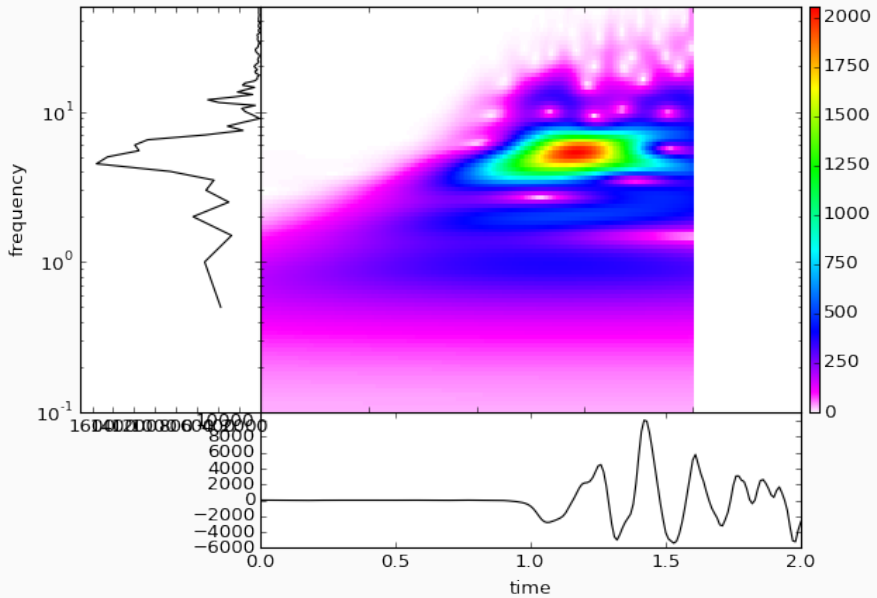

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Source models

The moment tensor components spaces:

- polarities of P, S_V, S_H => double-couple component,

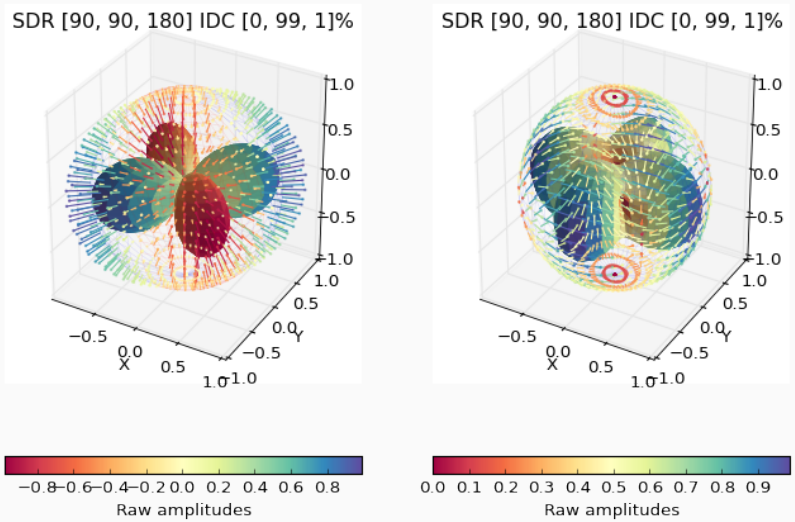

Figure 7: Source model, P & S waves displacements [1].

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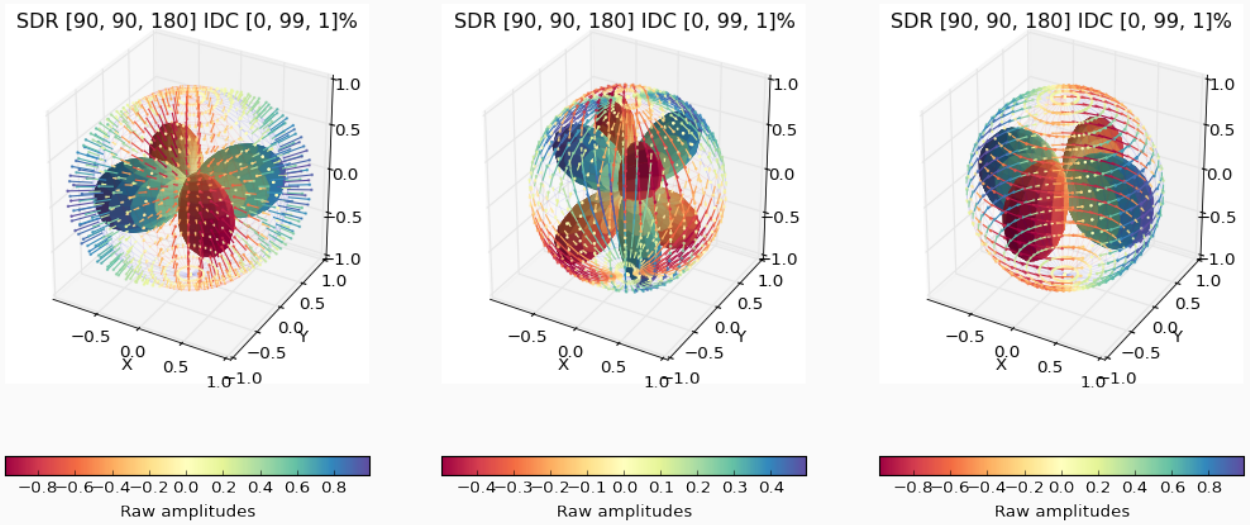

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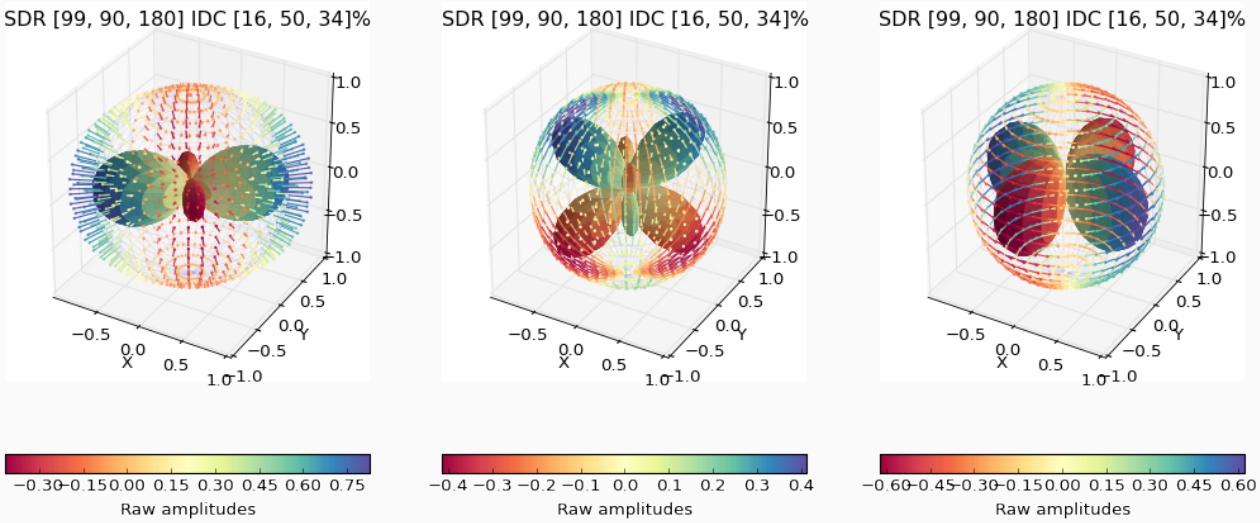

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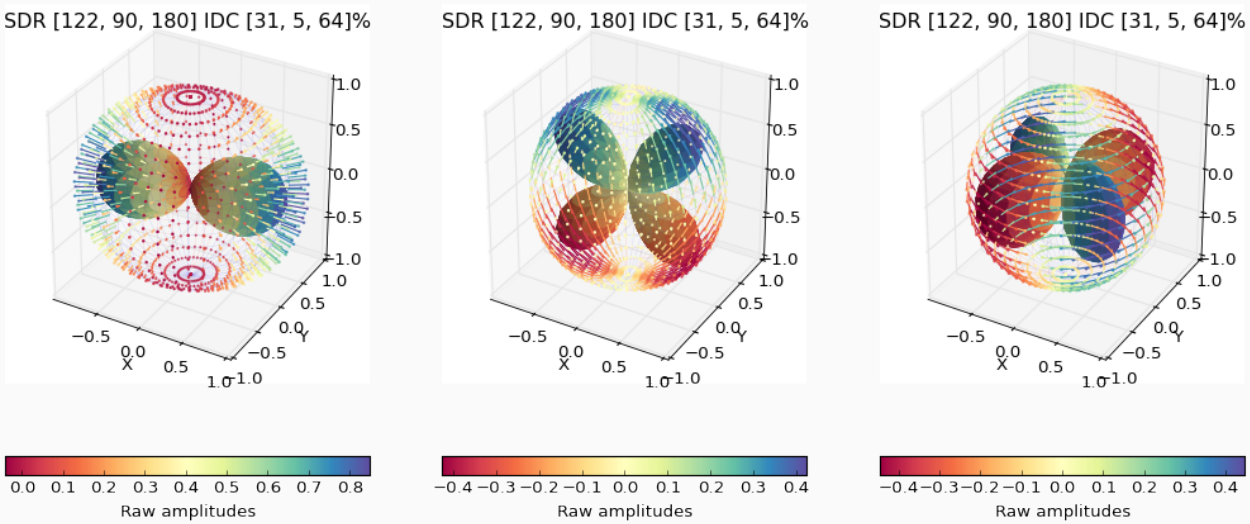

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Source models

The moment tensor components spaces:

- polarities of P, S_V, S_H => double-couple component,
- ratios of P, S_V, S_H => tensile component.

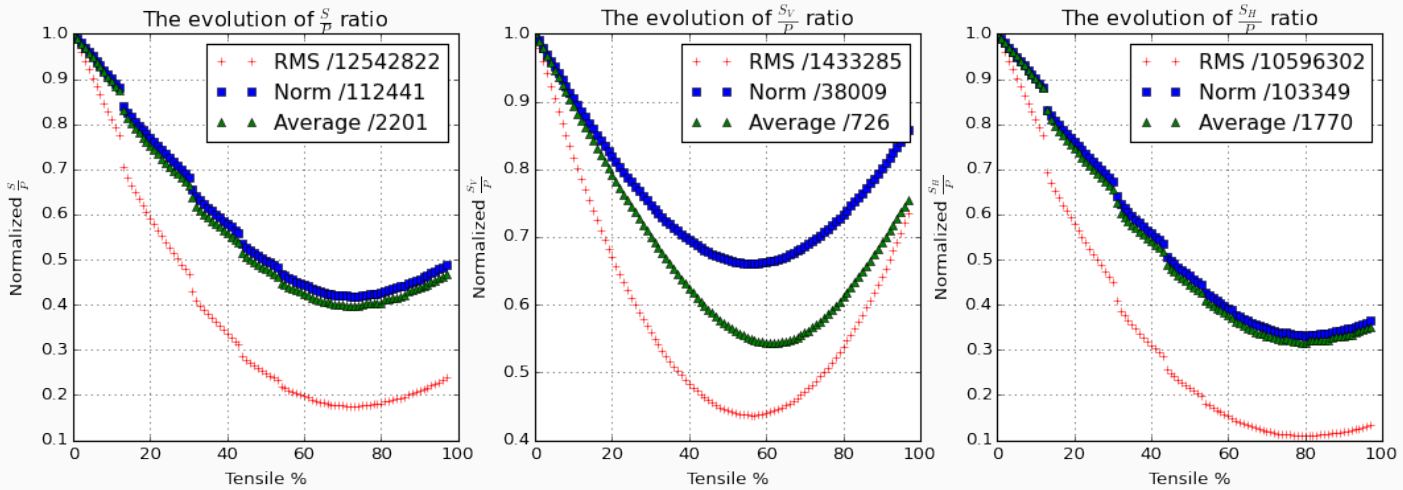

Figure 7: $\frac{S}{P}$, $\frac{S_V}{P}$ & $\frac{S_H}{P}$ from double couple to tensile source models.

Conclusion

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We are obtaining:

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We are aiming at:

- estimating applicability,
- interfacing SSA with the source mechanism scanner,
- a broader earthquake scanner approach.

Questions?

References I

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