

Characterizing earthquakes source physics with source scanning algorithms.

A better earthquake analysis

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February 19, 2016

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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.

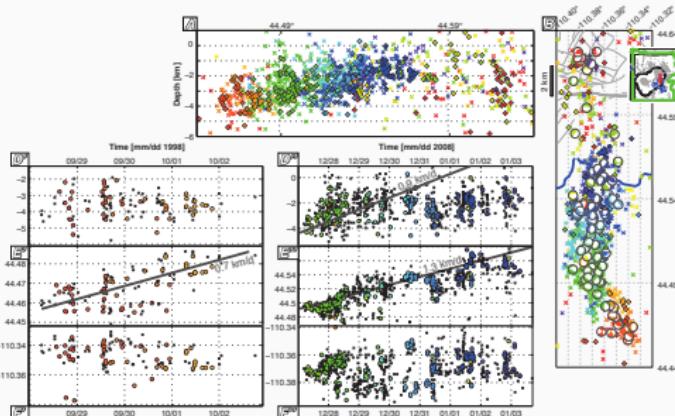


Figure 1: The 2008-9 Yellowstone Lake eq. swarm.

Conventional approach

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

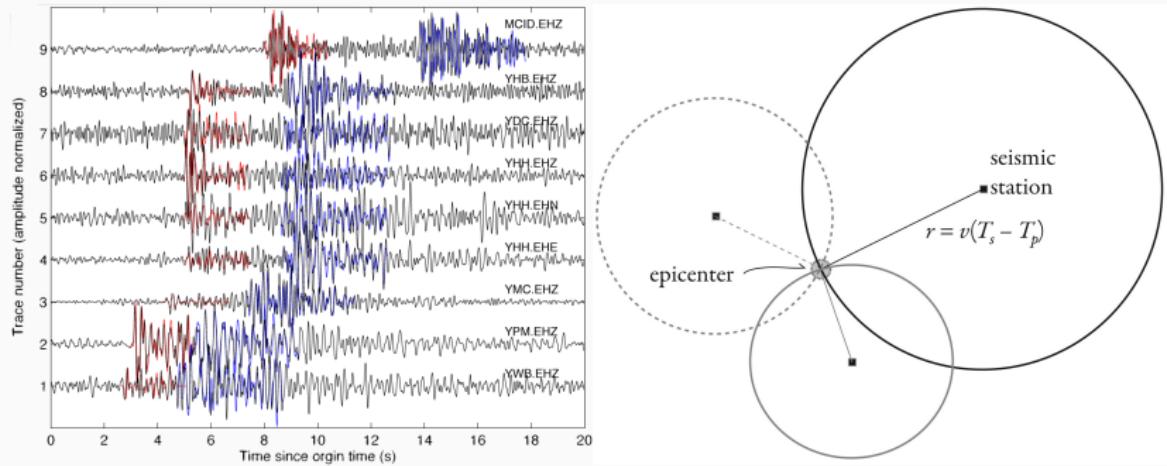


Figure 2: From picks to precise location [5].

Conventional approach

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

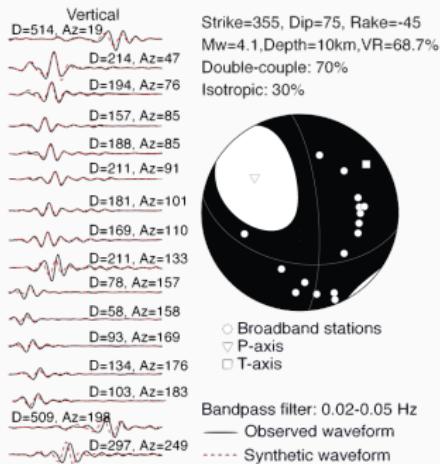


Figure 2: ... to moment tensor [2].

Conventional approach

- Arrival times (data reduced to minimum) => Hypocenter
- Long period signals (filtered data) => Moment tensor
- Modeling of:
 - slip distribution,
 - stresses perturbation,
 - ground deformation.

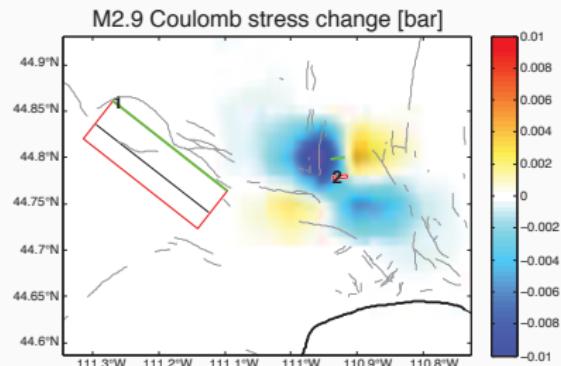


Figure 2: ... to stress change.

Conventional approach

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- Long period signals (filtered data) => Moment tensor
- Modeling of:
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 - stresses perturbation,
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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,

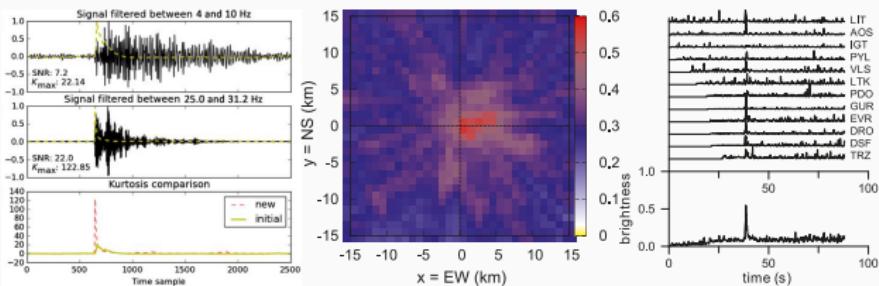


Figure 2: From signal to location

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,

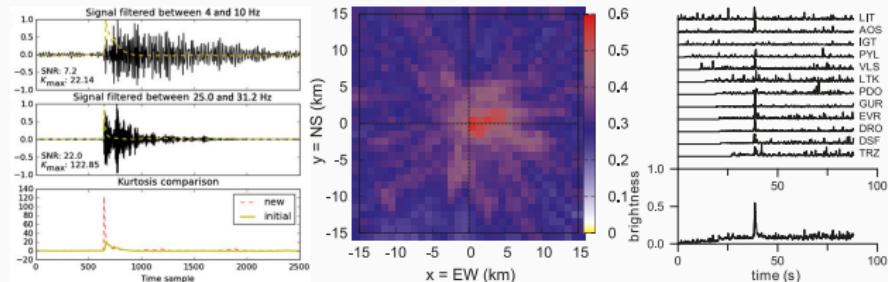


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Shift & stack approach (or source scanning or SSA)

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,
 - centroid are defined with bayesian approach.

How to *explore more spaces?*

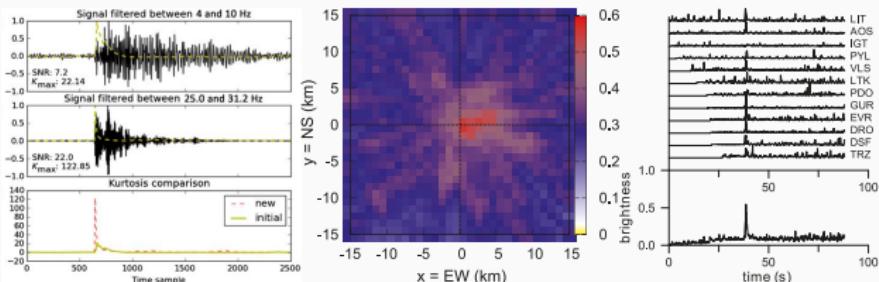


Figure 2: From signal to location

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.

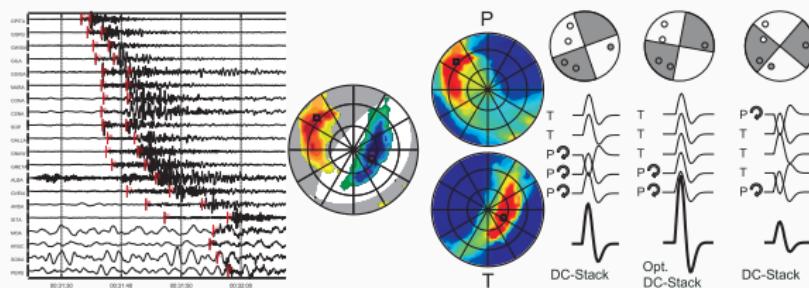


Figure 2: From signal to source mechanism

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:
 - $\frac{S_{hortTermAverage}}{L_{ongTA}}$
 - $\frac{R_{ightPartA}}{L_{eftPA}}$

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- CF_F:

- 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

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- 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

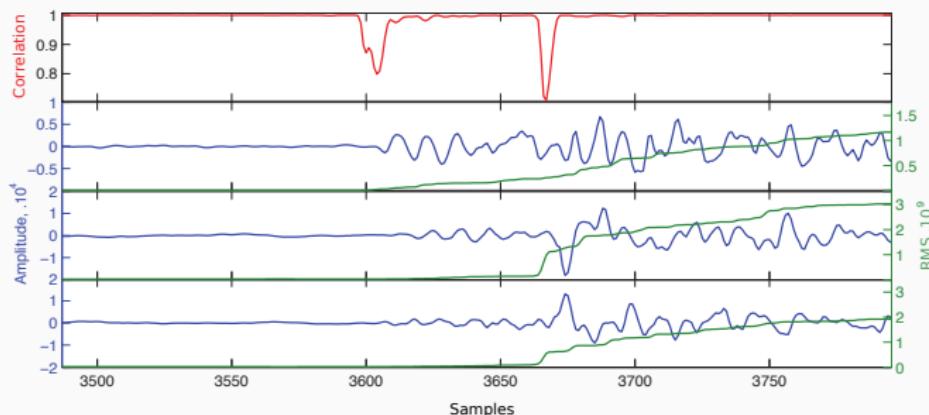


Figure 3: The $C_{\text{omponent}} E_{\text{nergy}} C_{\text{orrelation}} M_{\text{ethod}}$.

A better CF using CECM

Advantages:

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

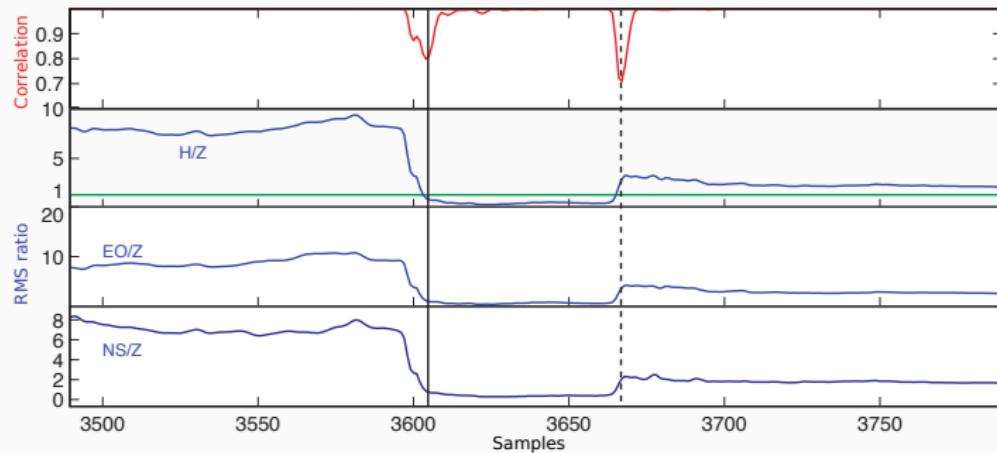


Figure 3: Wave type discrimination.

Examples

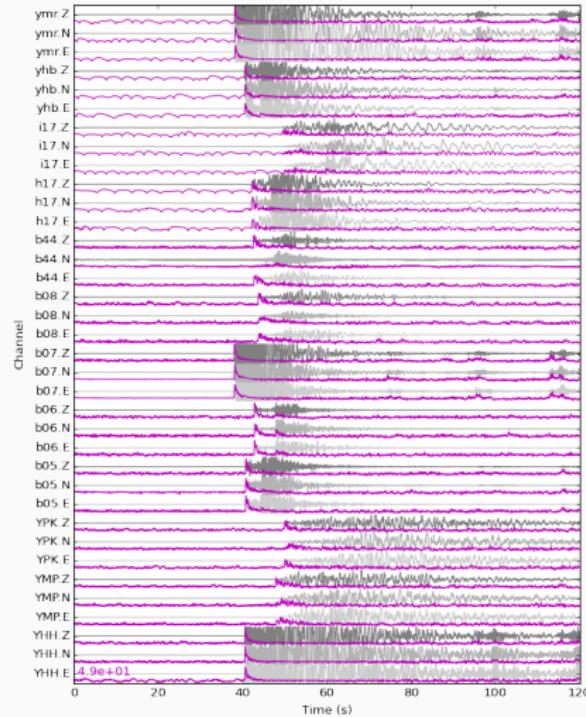


Figure 4: Data and $\frac{STA}{LTA}$.

Examples improvements with CECM

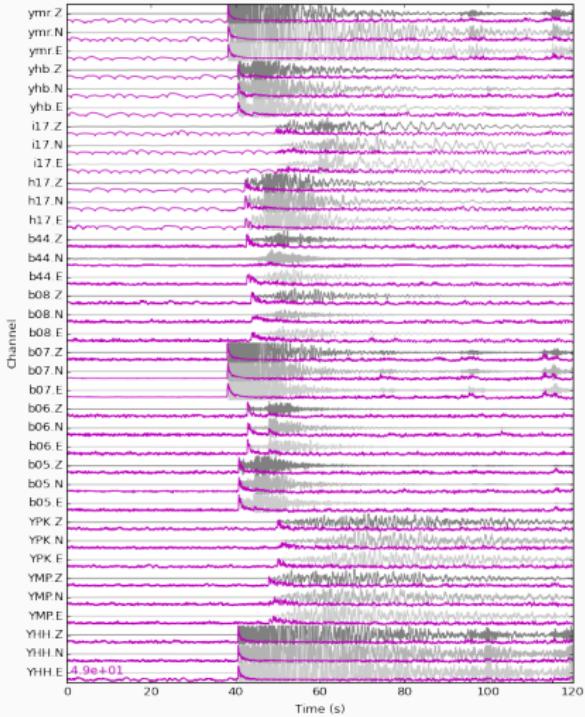


Figure 4: Data and $\frac{STA}{LTA}$.

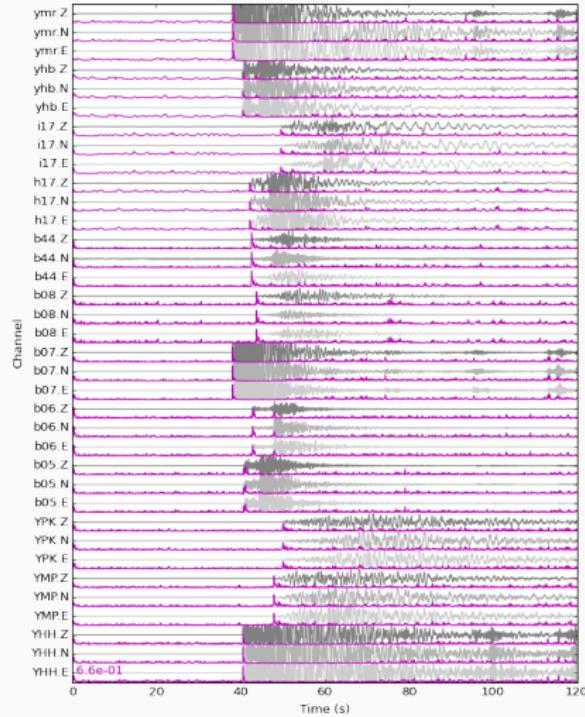


Figure 5: Data and CECM.

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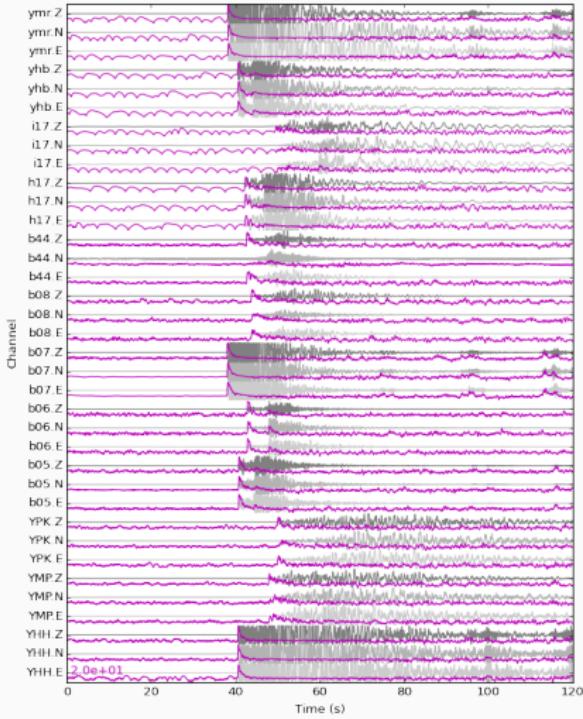


Figure 4: Data and M_{STA}

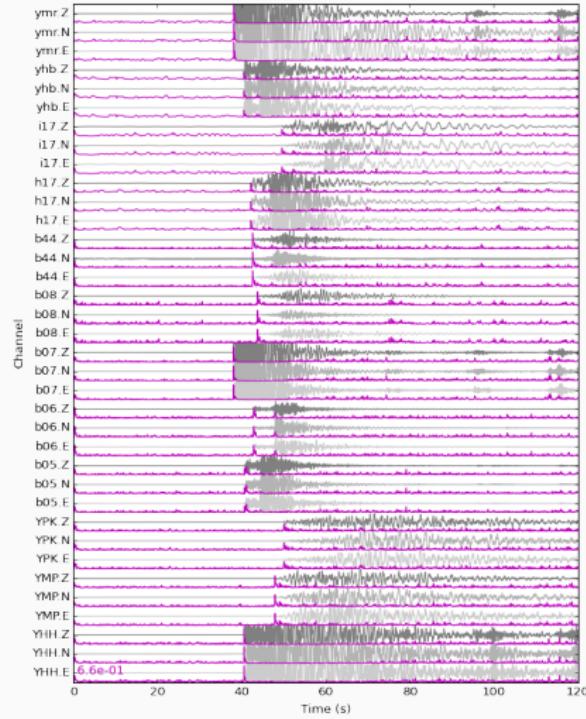


Figure 5: Data and CECM.

Examples improvements with CECM and multi-scaling

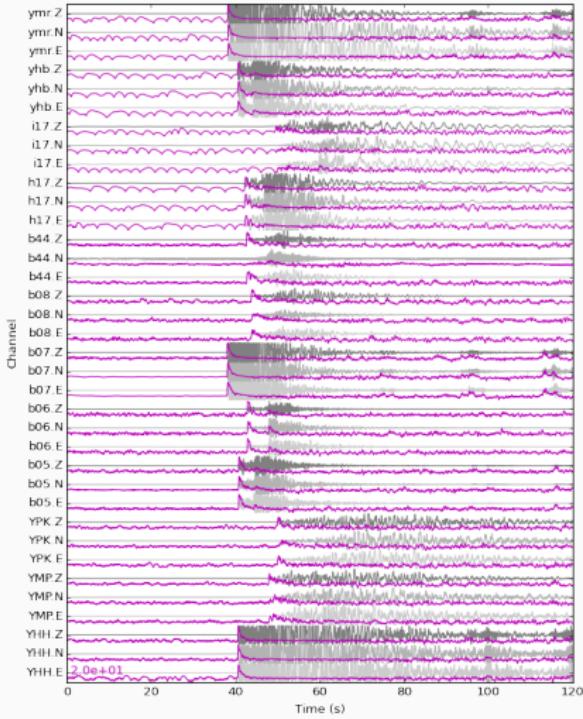


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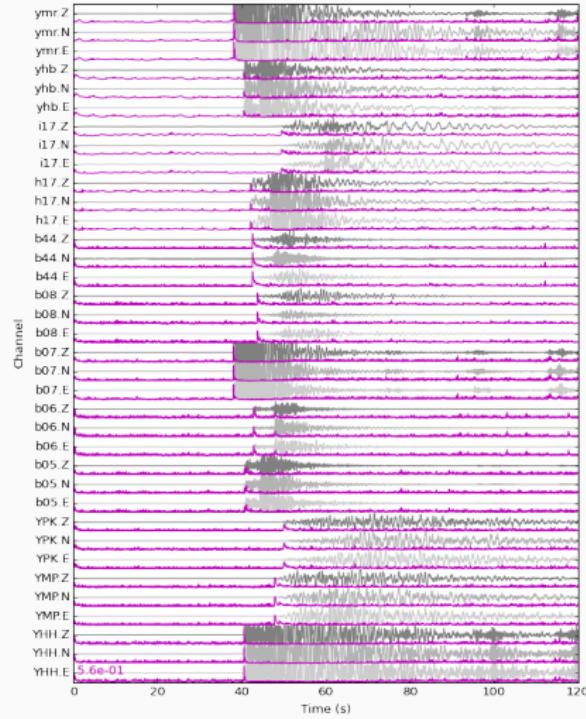


Figure 5: Data and M_{CECM} .

Source mechanism preliminary analysis

Body-wave wavelets

The wavelet parameters:

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

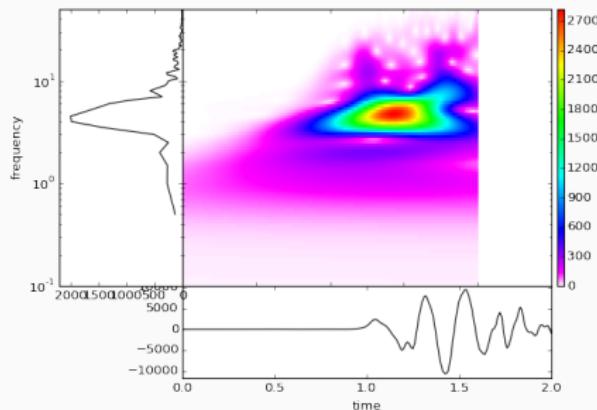


Figure 6: Data and frequency analysis, centered on arrival.

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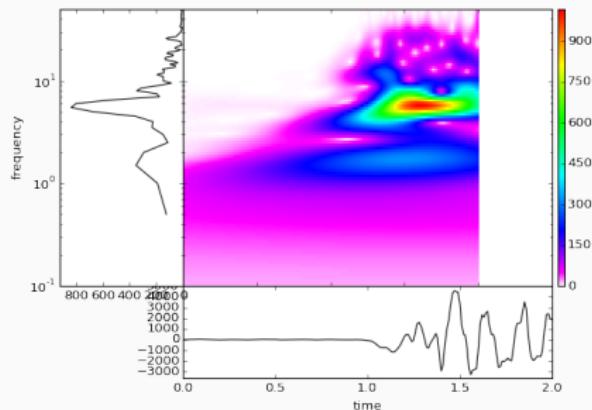


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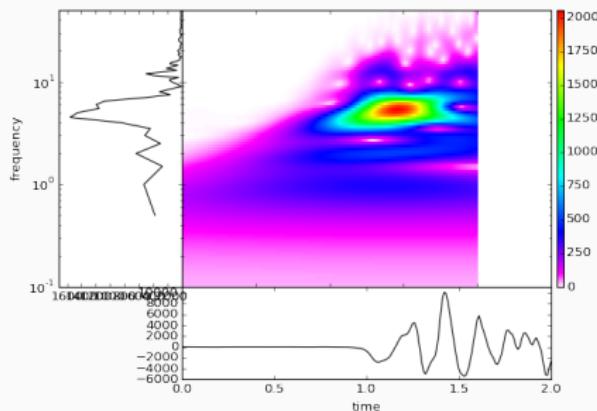


Figure 6: Data and frequency analysis, centered on arrival.

Source models

The moment tensor components spaces:

- polarities of P , S_V , $S_H \Rightarrow$ double-couple component,

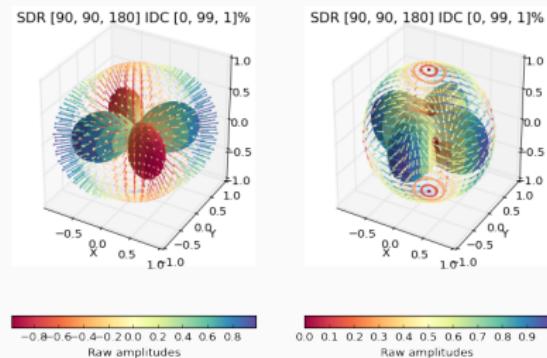


Figure 7: Source model, P & S waves displacements [1].

Source models

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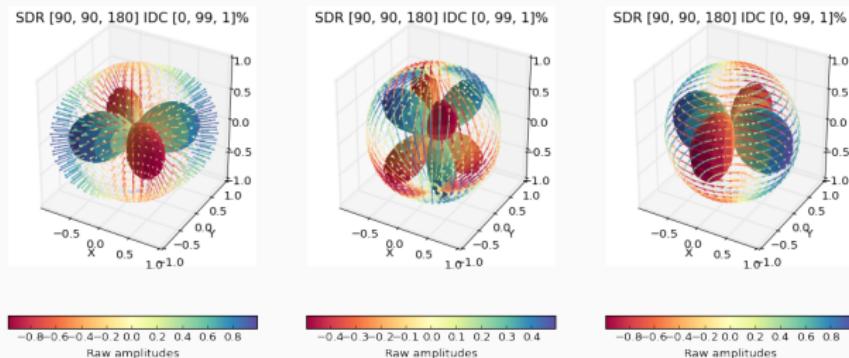


Figure 7: Source model, P , S_V & S_H waves displacements [1].

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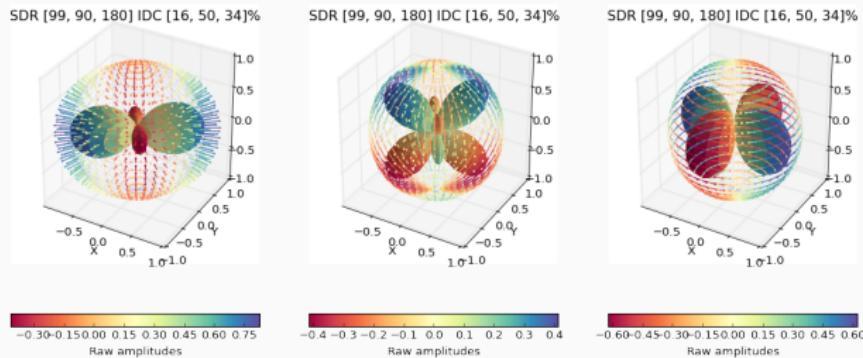


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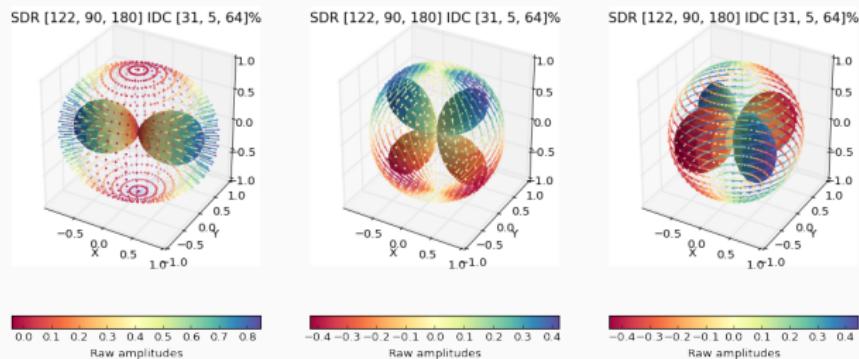


Figure 7: Source model, P , S_V & S_H waves displacements [1].

Source models

The moment tensor components spaces:

- polarities of P , S_V , $S_H \Rightarrow$ double-couple component,
- ratios of P , S_V , $S_H \Rightarrow$ tensile component.

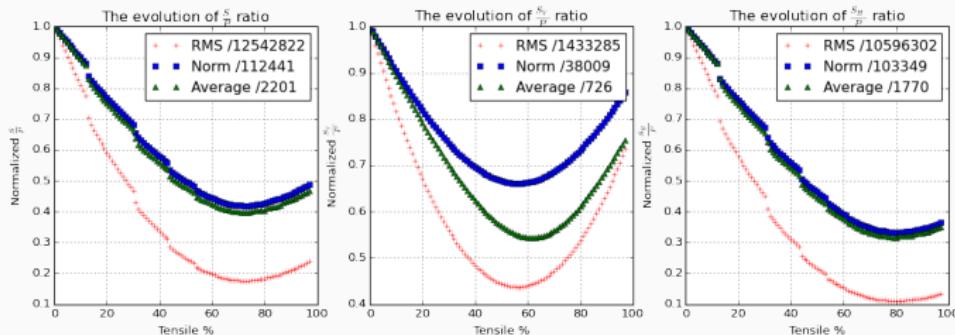


Figure 7: $\frac{S}{P}$, $\frac{S_V}{P}$ & $\frac{S_H}{P}$ from double couple to tensile source models.

Conclusion

Summary

We are obtaining:

- precise body-wave characteristic functions,
- automatic wavelets extractions,
- source mechanism scanning approach.

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We are obtaining:

- precise body-wave characteristic functions,
- automatic wavelets extractions,
- source mechanism scanning approach.

We are aiming at:

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

Questions?

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