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Source Inversion Validation: Forward problems

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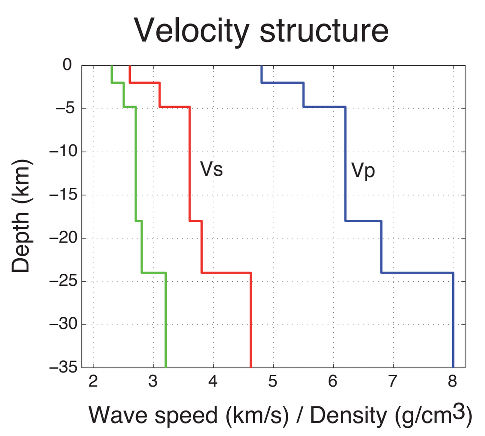
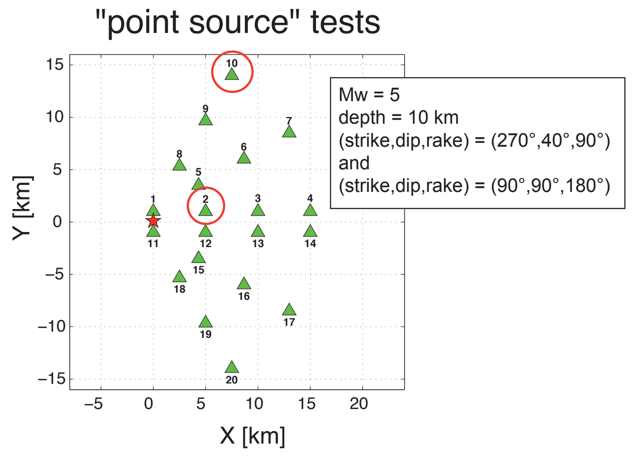
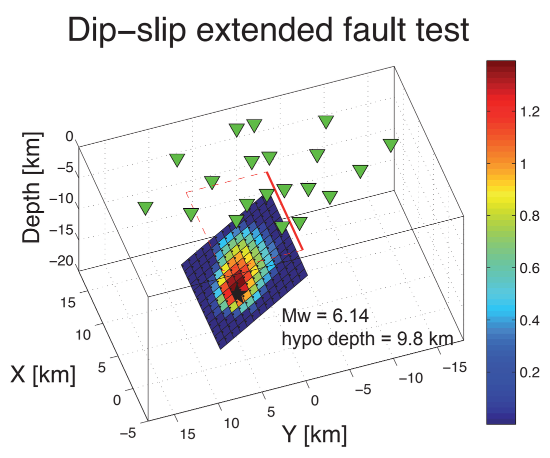
MOTIVATION

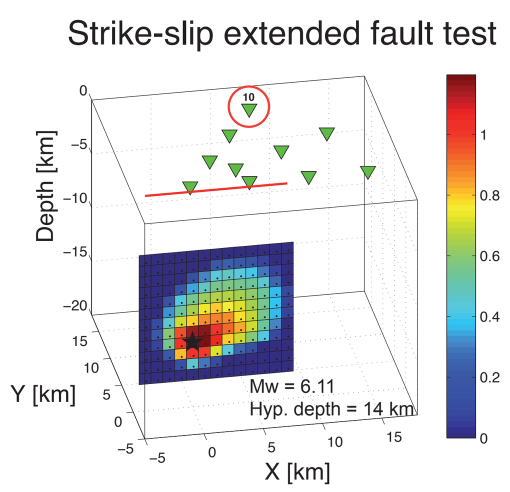
Source inversion techniques are routinely applied to retrieve features of the rupture process. However, kinematic inversions are affected by a number of epistemic uncertainties, leading to a large variety of potential source models for a single event (Mai et al. 2007). It is thus imperative to properly understand the origin of this variability to improve our understanding of the rupture process.

The very first step is to test the forward problem. As part of the Source Inversion Validation (SIV) project, **we carried out forward-modeling tests to compute synthetics at a set of stations**, for a specified velocity structure and different source scenarios: a simple point source and a "realistic" extended source, for strike-slip and dip-slip cases.









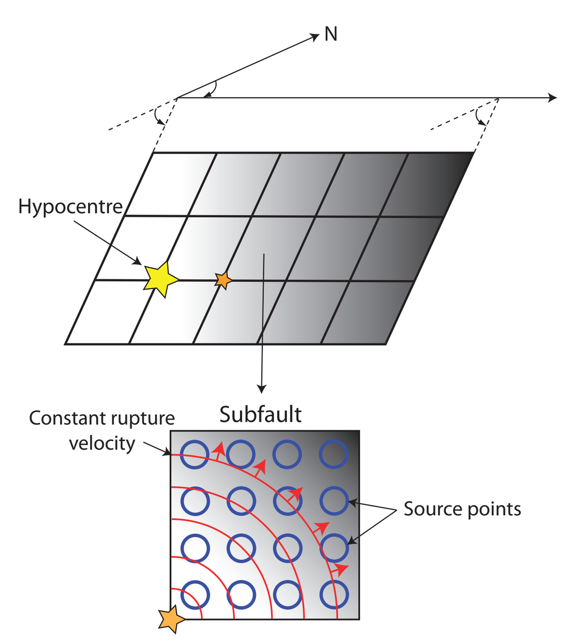
PARTICIPANTS AND METHODS

"Source point" exercise, 9 participants using:

- AXITRA **A1, A2, A3**
  Discrete wavenumber method, Bouchon (1981)
  Kennett (1979) propagator matrix technique
- Zhu and Riveira (2002) **Z1, Z2, Z3**
  Discrete wavenumber method
  Thompson-Haskell propagator matrix technique
- COMPSYN **C1, C2**
  Discrete wavenumber method
  Finite-element method (Olson et al. 1984)
- Discontinuous Galerkin (Martin Kaeser's code) **D1**
  Finite-element method combined with the explicit time integration method using arbitrary high-order derivatives

Extended fault exercise, 4 participants using:

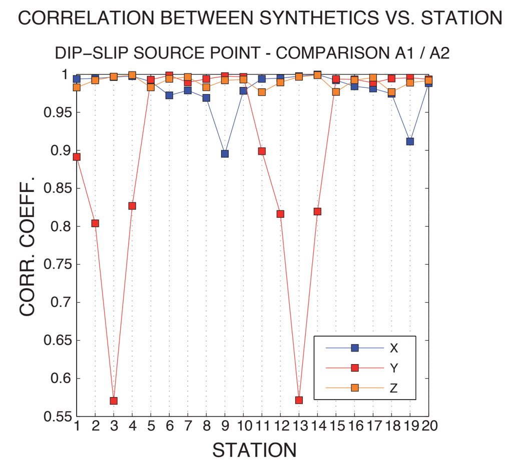
- AXITRA **A4, A5, A_{inv}**
  Note that **A_{inv} is commonly used for source inversion studies** (e.g. Cotton & Campillo 1995)
- COMPSYN **C3**



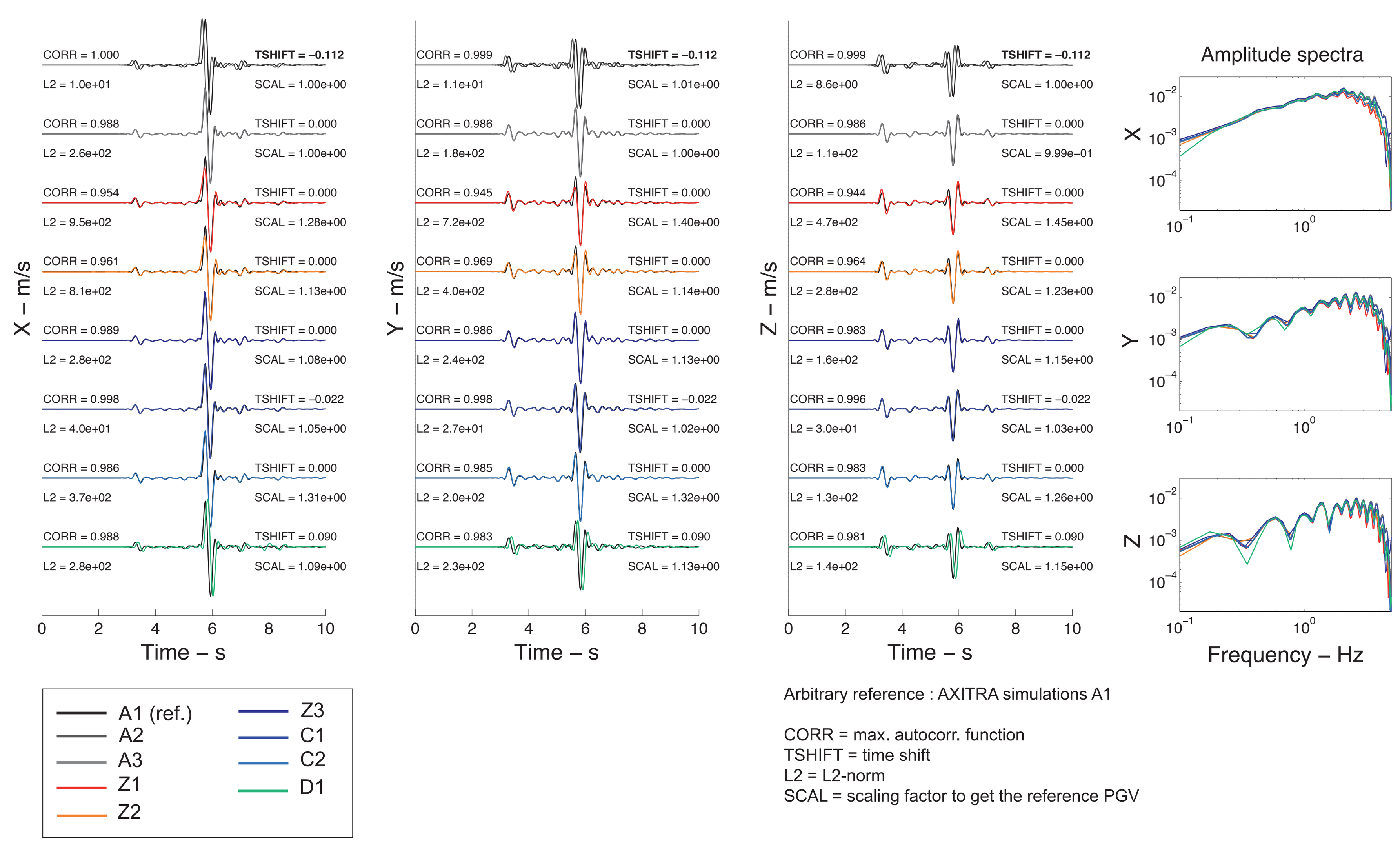
Principle of the forward problem computation in Cotton & Campillo (1995) inversion procedure (A_{inv} method)

RESULTS 1: "POINT SOURCE" TESTS

- In such simple cases, some discrepancies still appear, even between modelers using similar methods (time shifts, amplitude, frequency content)
- But basically, differences remain very small at low frequency (< 2 Hz)
- In the dip-slip case, for stations close to the source, some synthetics are affected by strong artefacts)



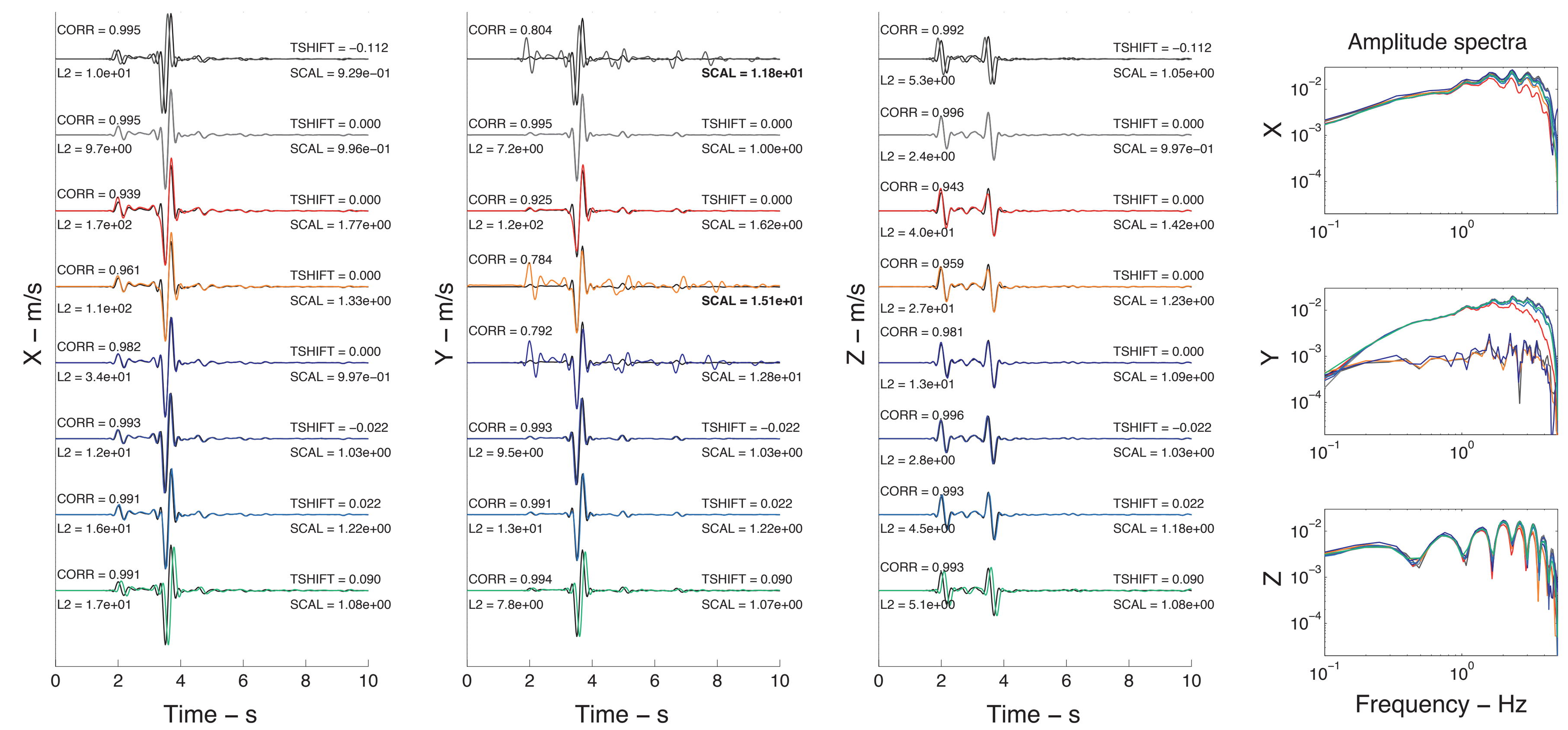
Waveform comparison for strike–slip point source at station 10 – [0 – 5Hz]



Arbitrary reference : AXITRA simulations A1

CORR = max. autocorr. function
TSHIFT = time shift
L2 = L2-norm
SCAL = scaling factor to get the reference PGV

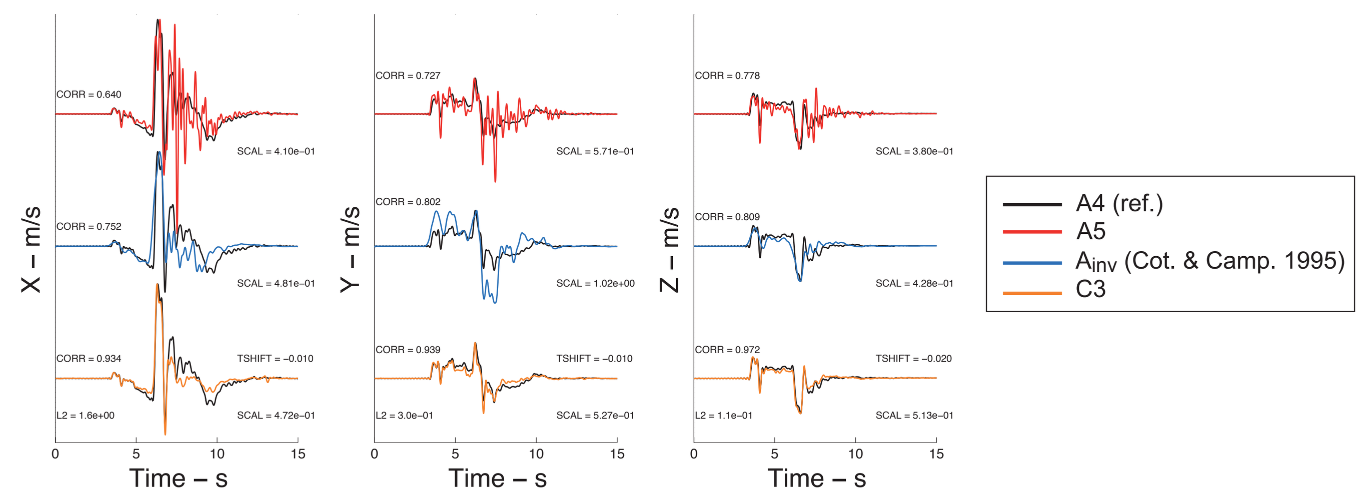
Waveform comparison for dip–slip point source at station 2 – [0 – 5Hz]



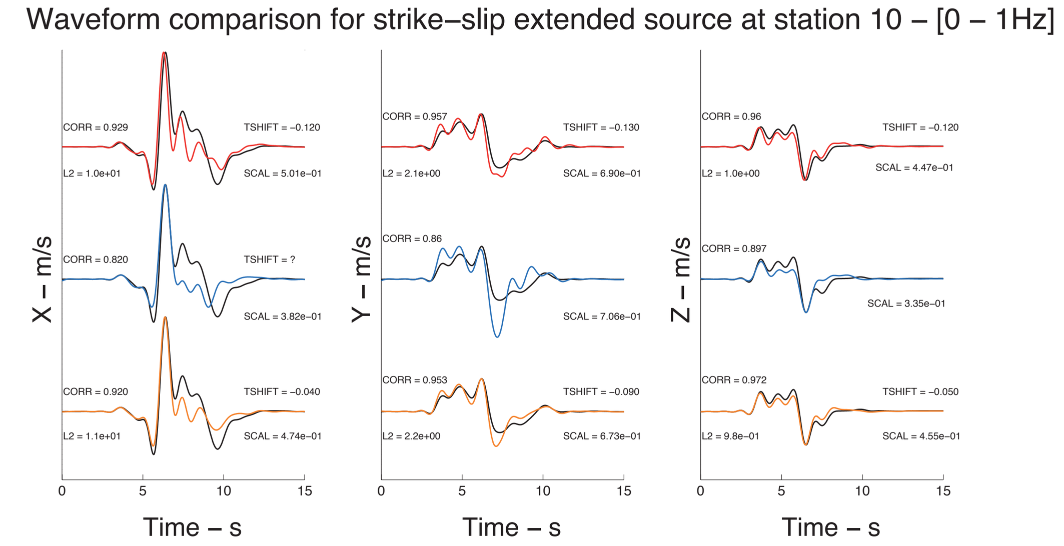
RESULTS 2: EXTENDED SOURCE TESTS

- Some significant differences appear in the whole frequency range (0 - 5 Hz)
- Discrepancies mainly arise from the various techniques used to interpolate the rupture parameters on the fault plane

Waveform comparison for strike–slip extended source at station 10 – [0 – 5Hz]

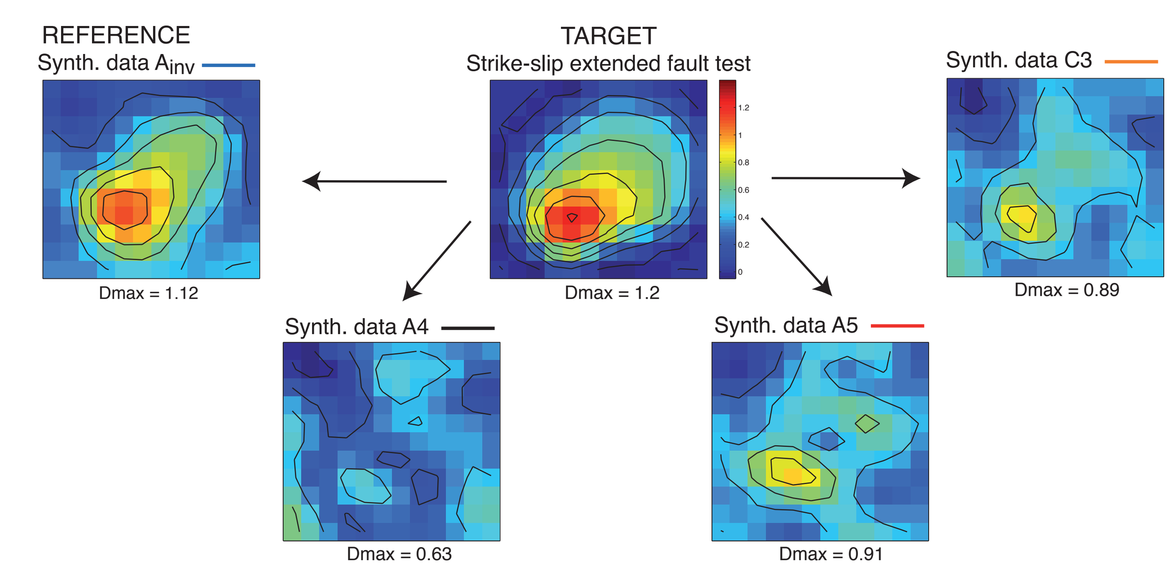


Waveform comparison for strike–slip extended source at station 10 – [0 – 1Hz]



EFFECTS ON INVERTED SLIP IMAGES

- We deploy a frequency-domain inversion technique (Cotton & Campillo 1995) to investigate the effects of these uncertainties on inferred slip distributions
- Forward problem is computed using A_{inv} technique (see figure bottom left) up to 1 Hz
  Inverted synthetic data are calculated using A_{inv} and A4, A5, C3
- Inversion results are strongly affected. Choosing adequate smoothing constraints is then crucial



CONCLUSION

- These simple tests reveal that modelers need a perfect understanding of the use, the definitions, and the corresponding input parameters of the codes deployed for forward computation
- There is a need to clearly understand the uncertainties arising from the rupture parameter interpolate procedure
- The observed uncertainties might have a strong impact on the inferred rupture process features