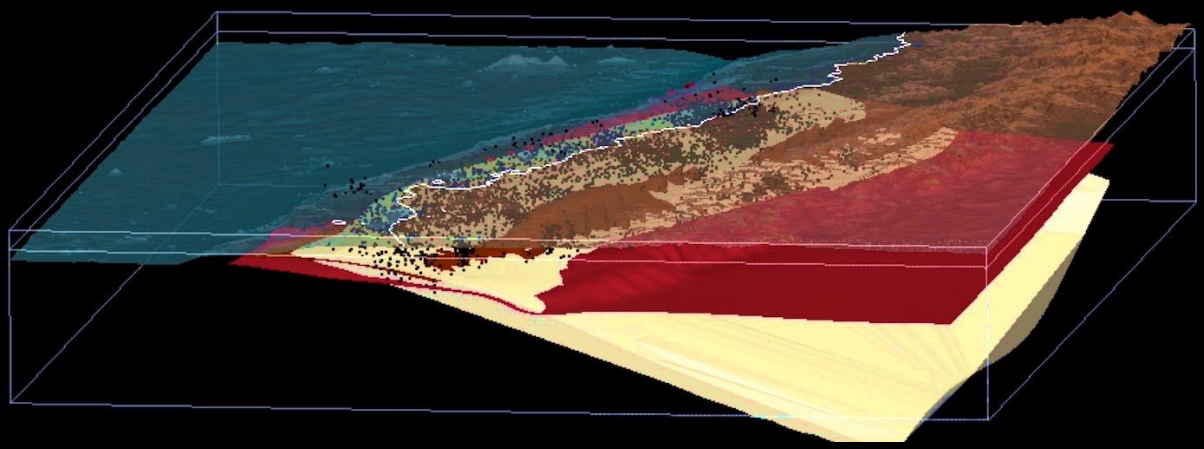
VERCE Summer School
Liverpool
July 1st-3rd

Andreas Rietbrock

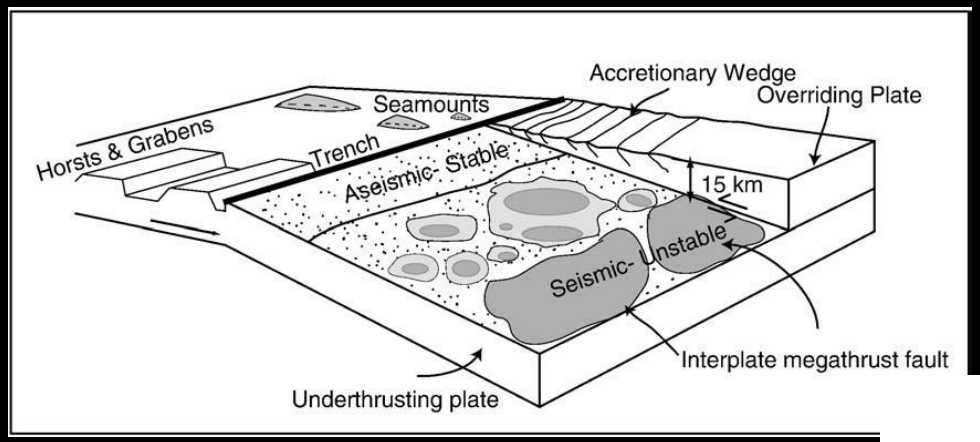
UNIVERSITY OF LIVERPOOL

LIVERPOOL EARTH OBSERVATORY

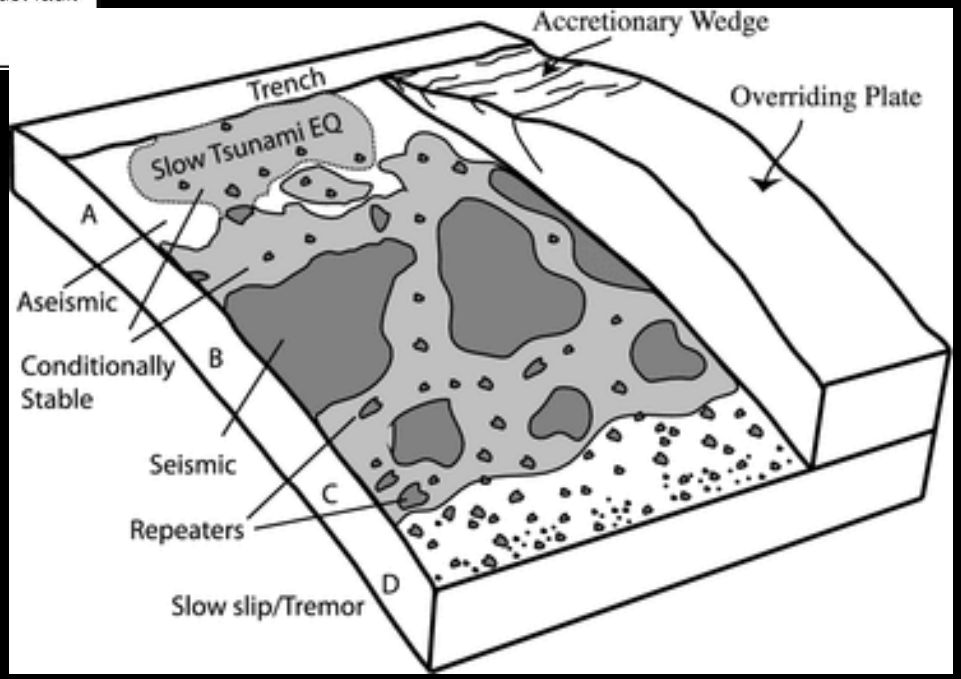
VERCE



Scale matters: The case for using full waveforms



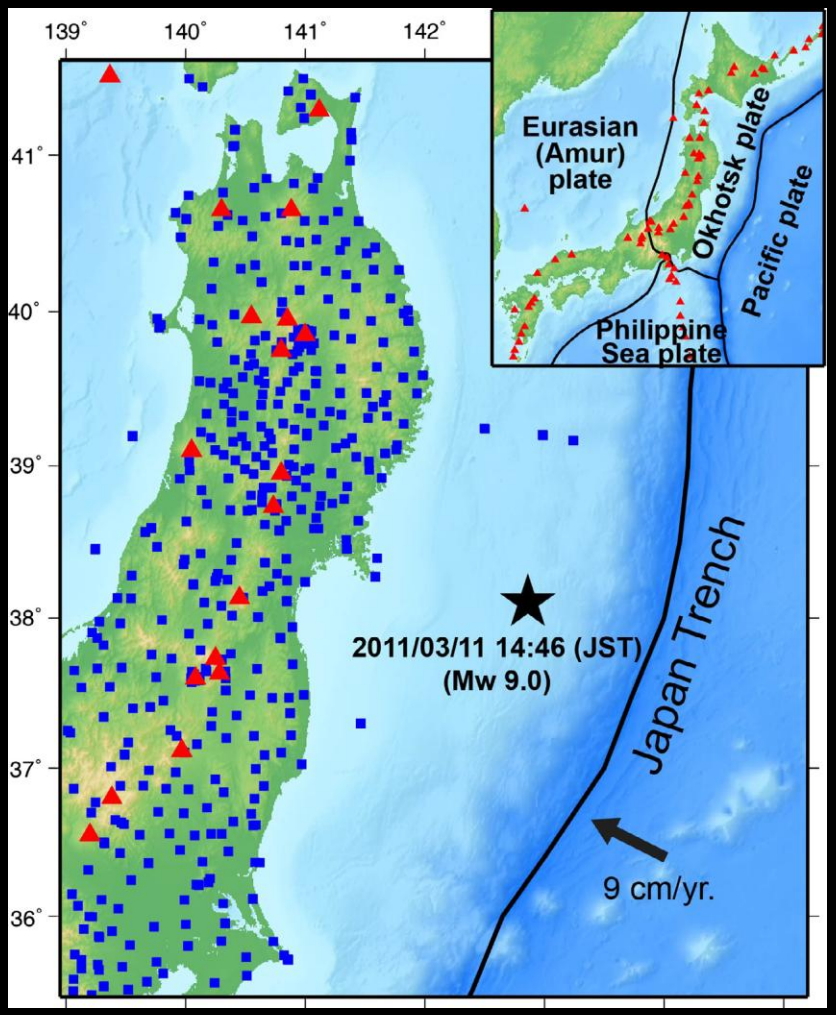
Bilek, 2009

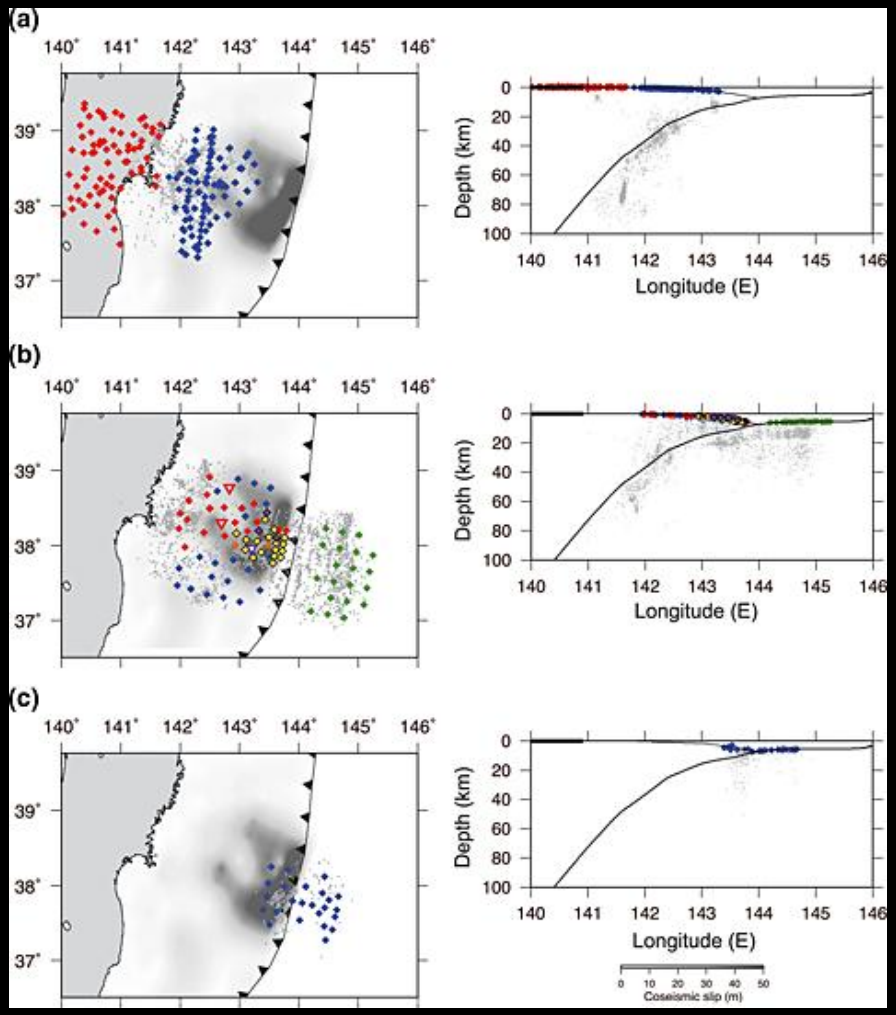


What are the physical properties of these 'patches' which have a distinctive seismic characteristic ?

Lay et al., 2012

The perfect example: Japan





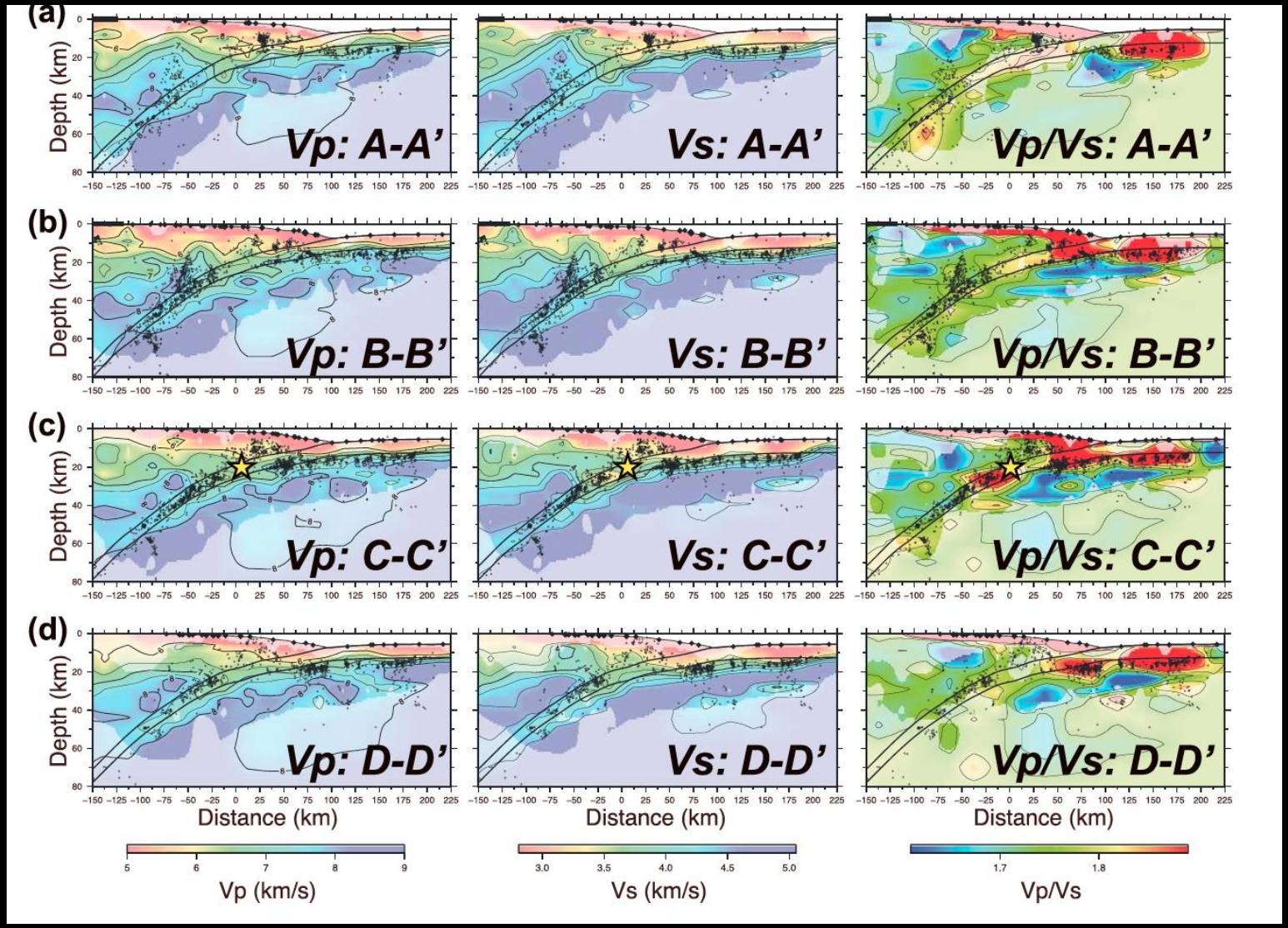
HighNet (e.g.: Huang&Zhao, 2013)

Temporary deployments (e.g. Yamamoto et al., 2014)

Travel time tomography results

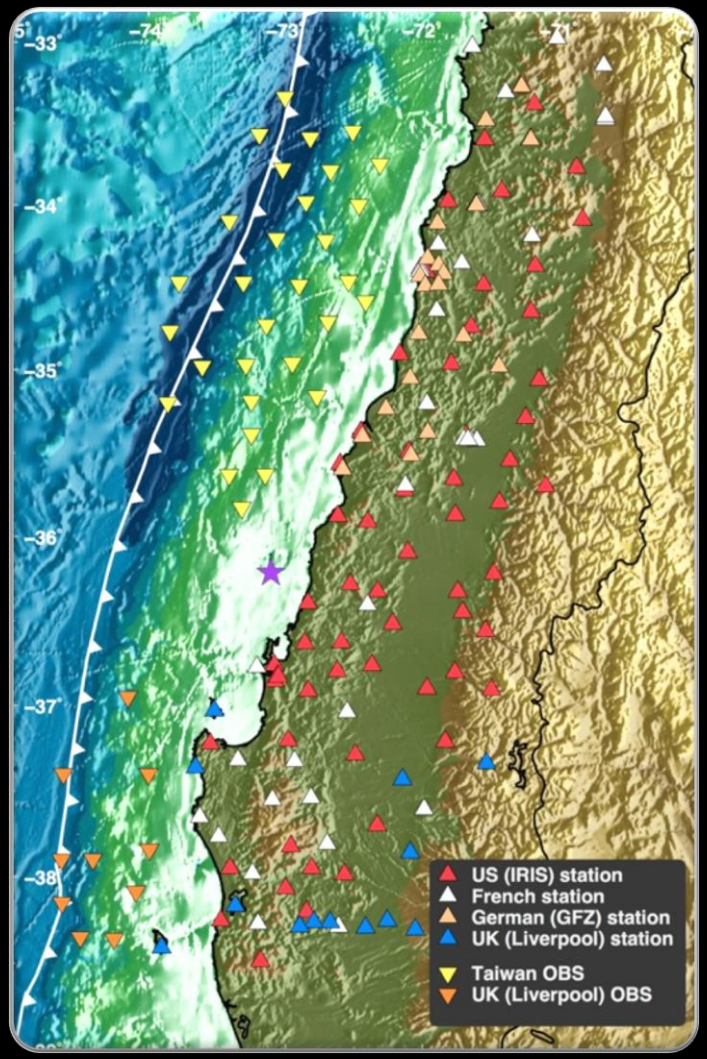
N

S



Yamamoto et al., 2014

Maule M_w 8.8 aftershock deployment (IMAD): pretty close to perfect



Unprecedented data set:

- International collaboration from the outset
- First stations in place in less than a week
- Open data policy from day one
- 200 stations (mainly broadband)
- 1TB of continuous high frequency data accessible through IRIS (or Liverpool)
- Onshore and offshore deployment covering the length of the rupture areas
- Travel time tomography data set:
  - 670 selected events for optimizing spatial and depth resolution
  - 38,000 P wave onset times
  - 14,000 S wave onset times

Rietbrock et al., 2013; Beck et al., 2014

Traveltime tomography results (3D)

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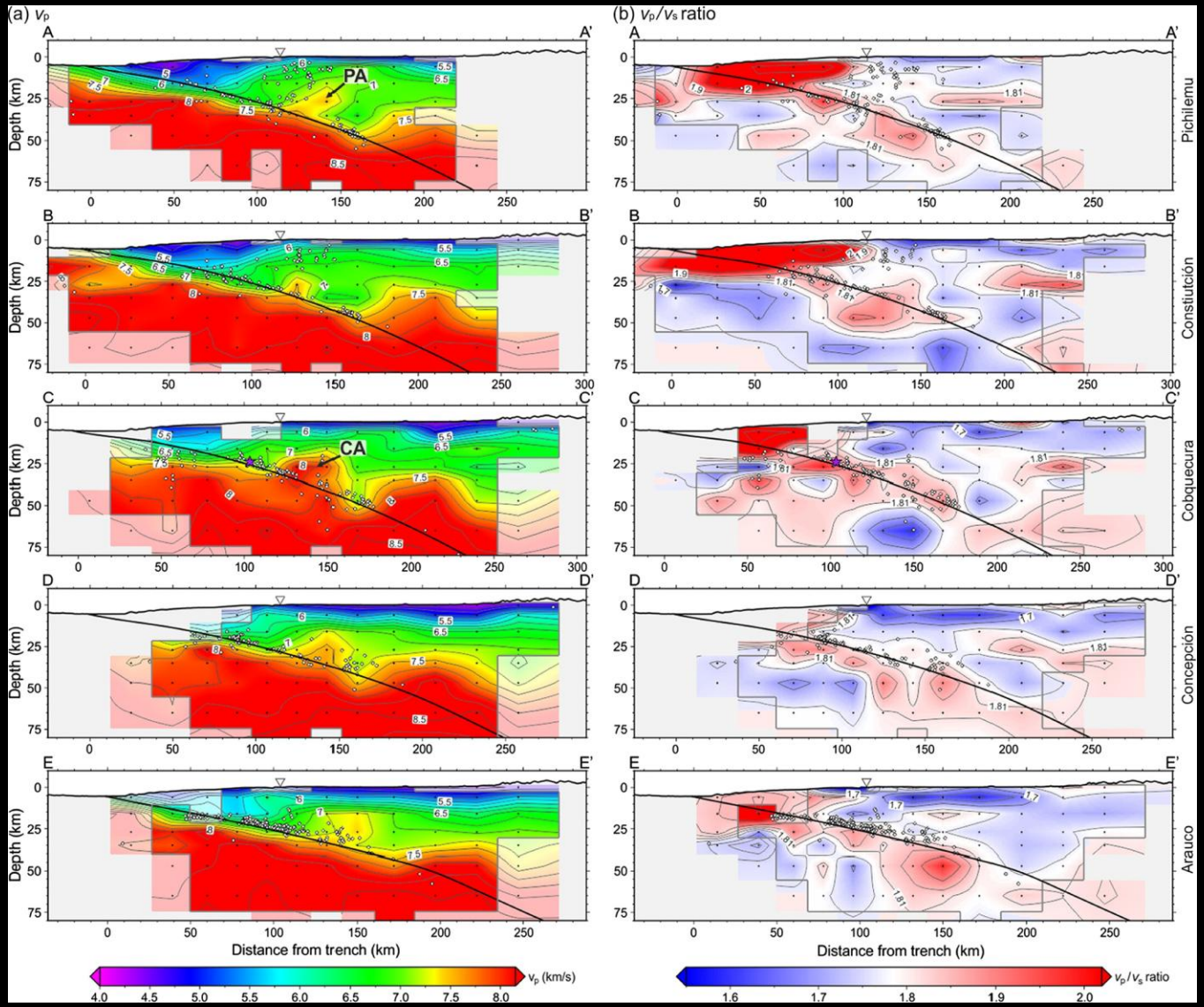
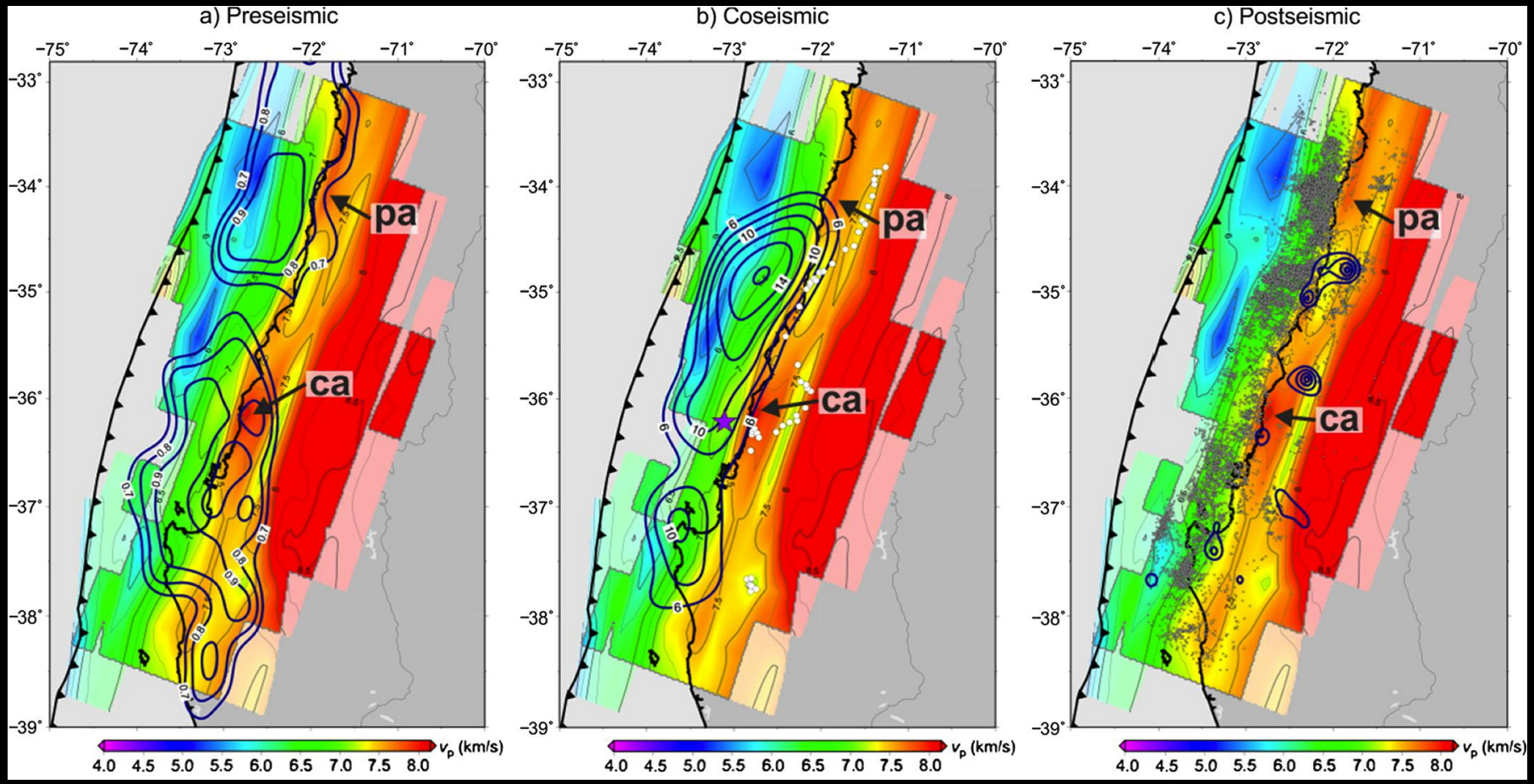


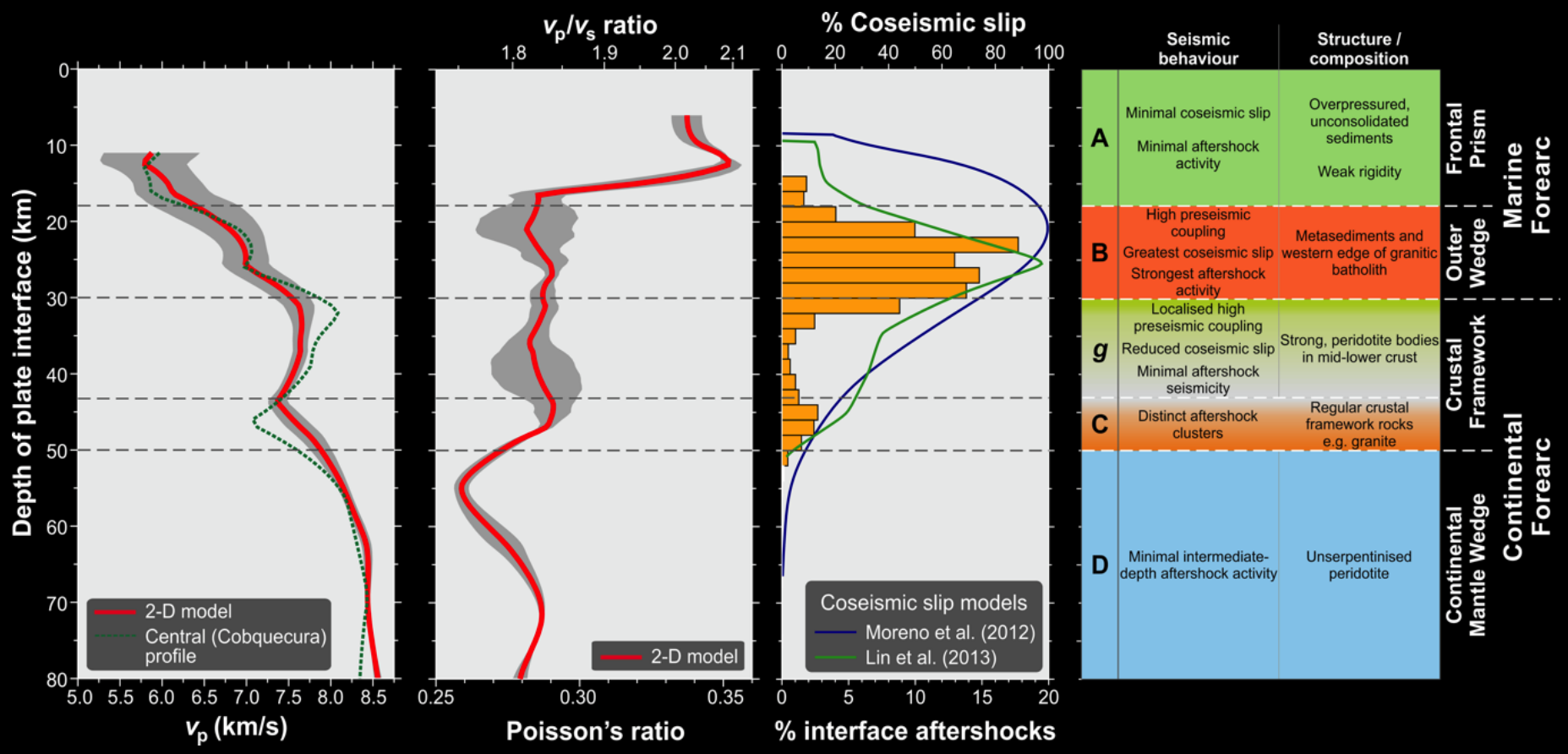
Hicks et al., 2014

Physical properties along the interface (P-wave velocity)



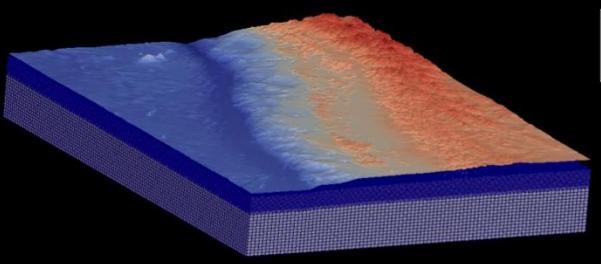
Hicks et al., 2014

Anatomy of the megathrust

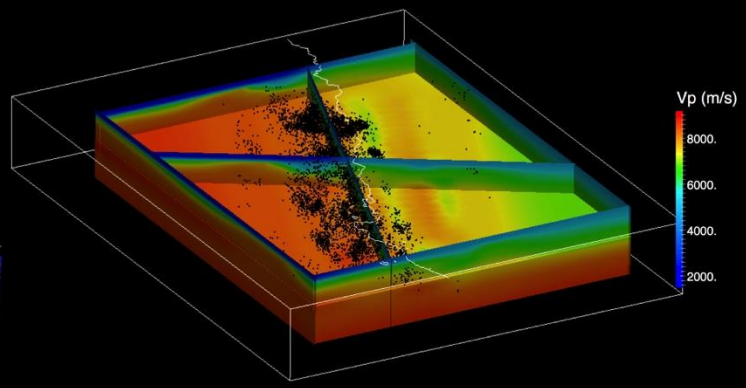


Hicks et al., 2014

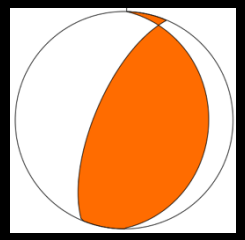
Towards Full Waveform Inversion (FWI)



3-D Mesh
Wave propagation effects due to topography

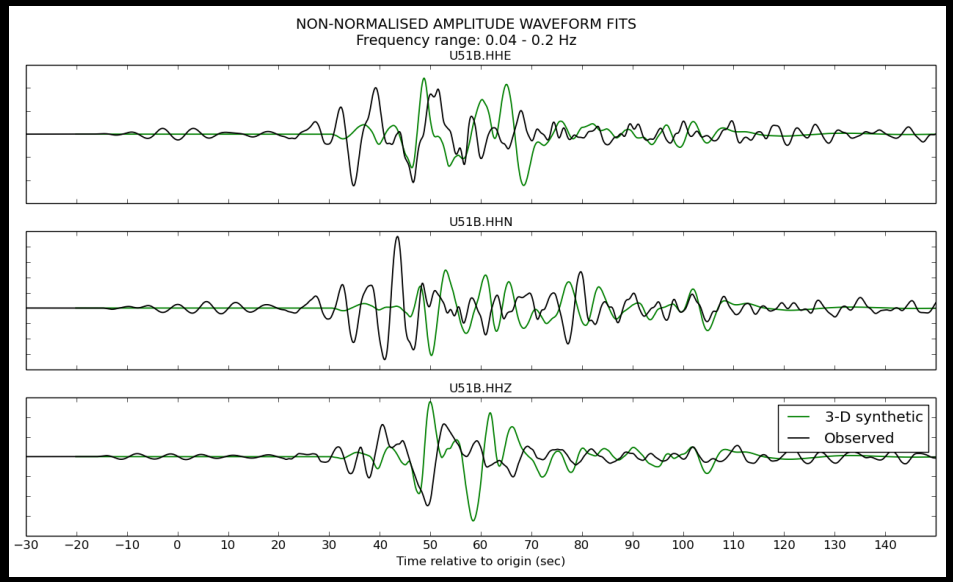


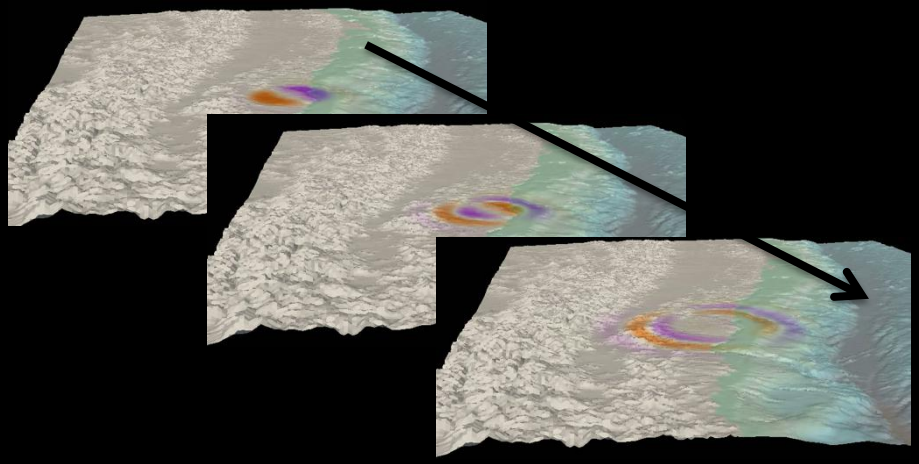
3-D Velocity Model
Detailed v_p and v_s structure (*Hicks et al., 2014, EPSL*)



Moment Tensors
1-D waveform inversion

Propagation Code
SPECFEM3D (*Komatitsch, 2011*)





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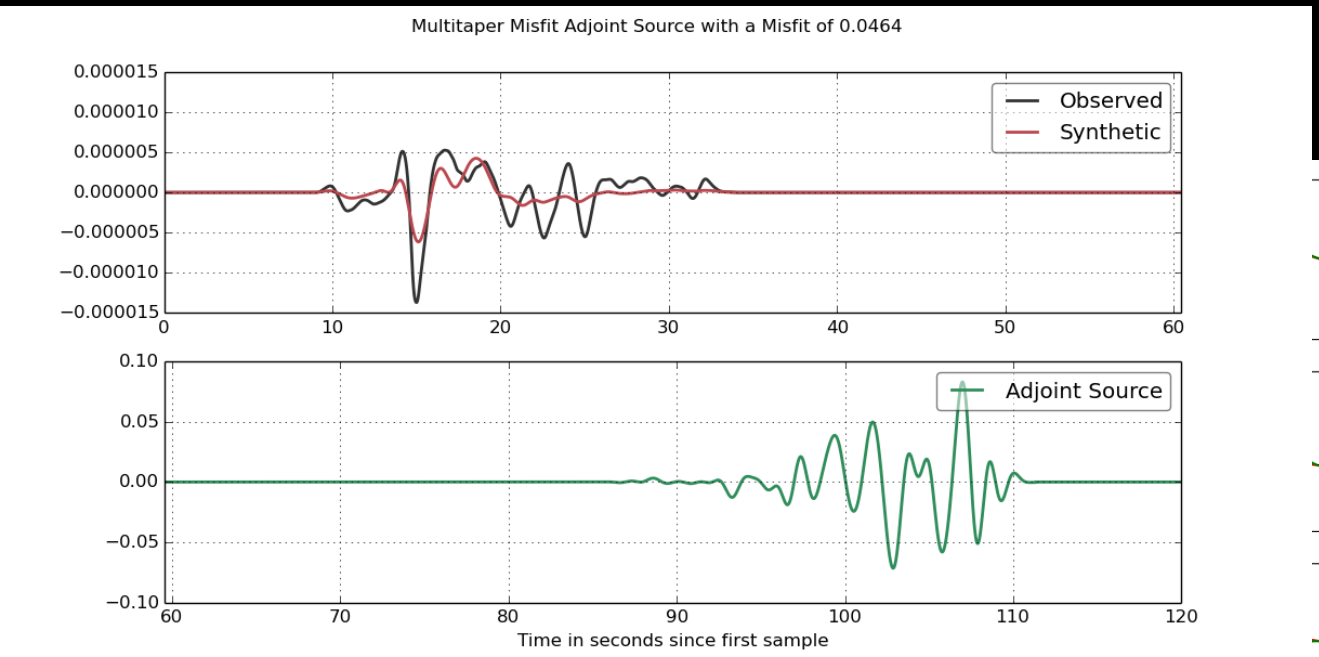
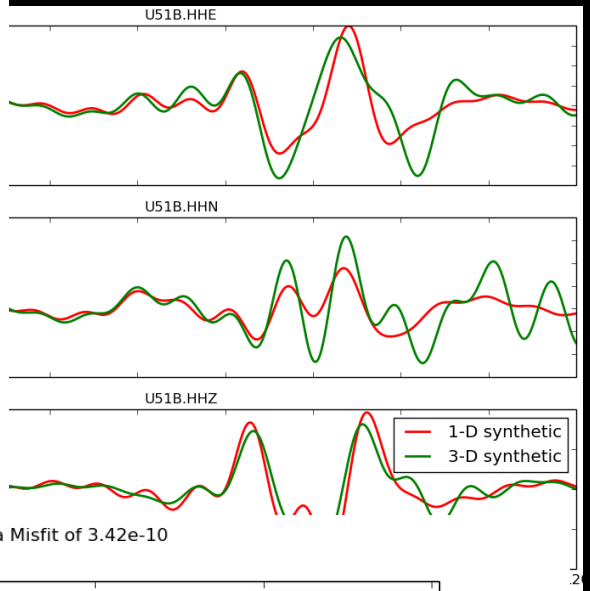
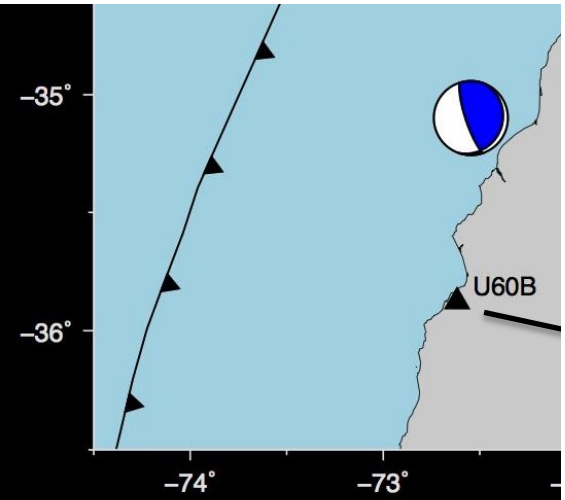
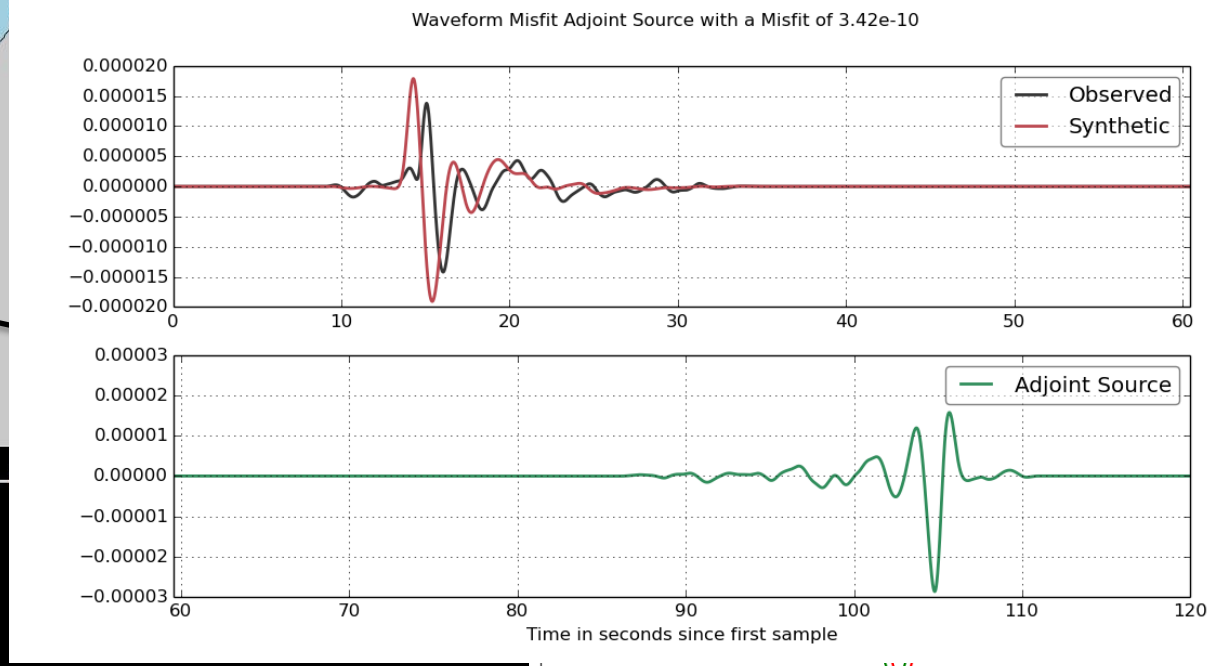
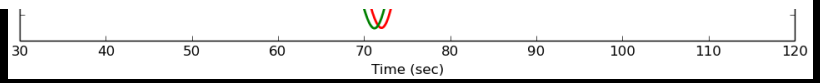
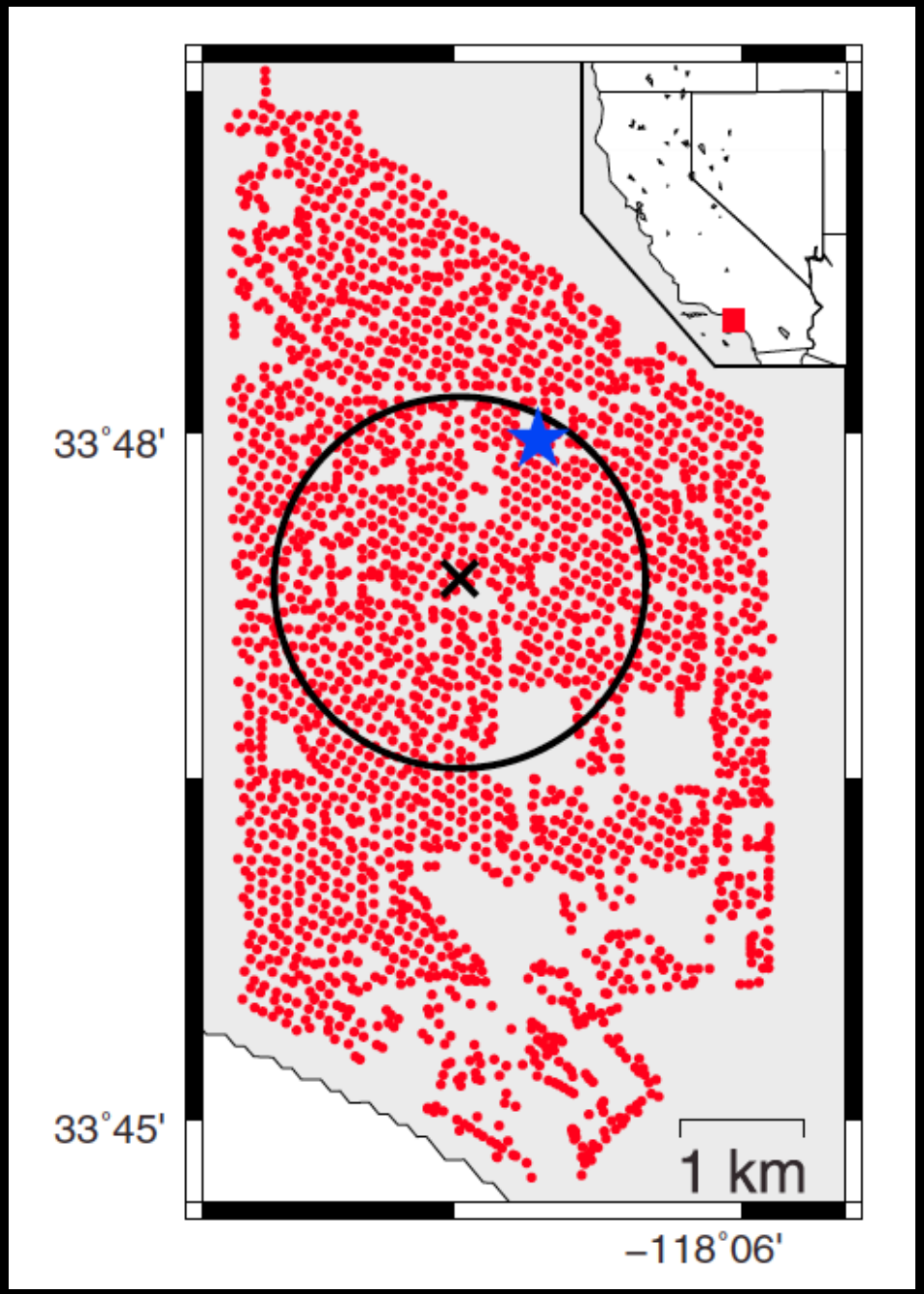

Multitaper Misfit Adjoint Source with a Misfit of 0.0464
Observed
Synthetic
Adjoint Source
Time in seconds since first sample


U51B.HHE
U51B.HHN
U51B.HHZ
1-D synthetic
3-D synthetic

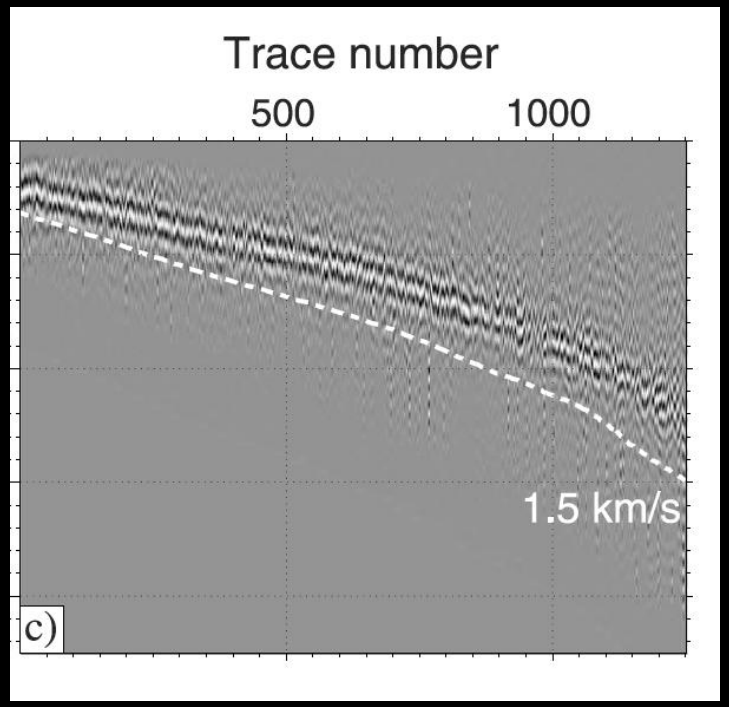

−35°
−36°
U60B
−74°
−73°


Waveform Misfit Adjoint Source with a Misfit of 3.42e-10
Observed
Synthetic
Adjoint Source
Time in seconds since first sample


Time (sec)



The future:
1000s of receivers



Outlook

- Advances and Challenges:
  - Geodesy and GPS have provided a revolution in the last decade (pre-, co-, and post-seismic)
  - What is the physical nature of variations in slip behavior?
- Future:
  - Utilizing FWI can give us the resolution required (especially for vs)
  - Dense wavefield observations (1000s of stations)
  - New lab measurements
  - IODP drilling program into the Megathrust (Japan, New Zealand, Costa Rica,…)