Rupture characteristics of the 2019 North Peru intraslab earthquake (Mw8.0)

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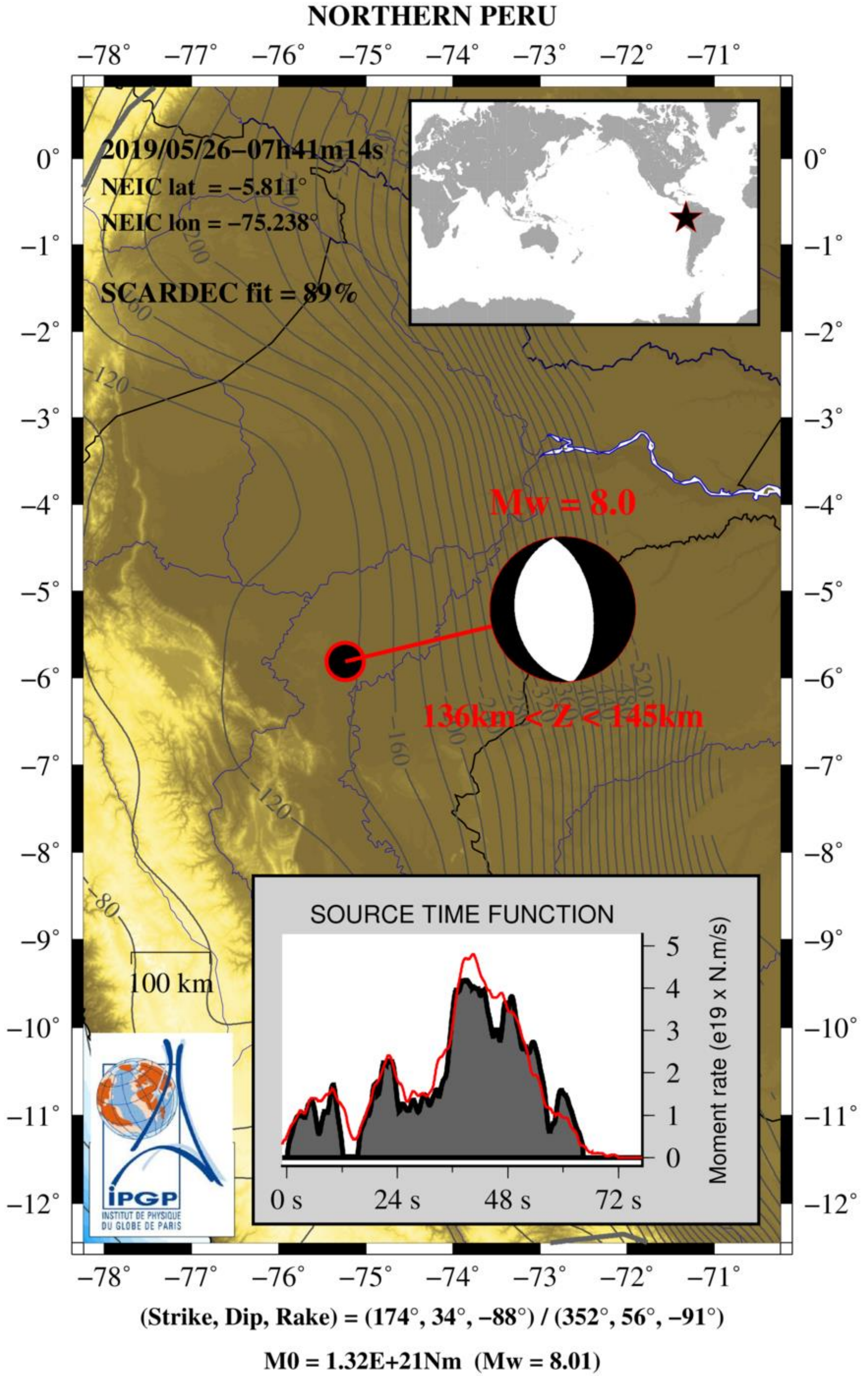
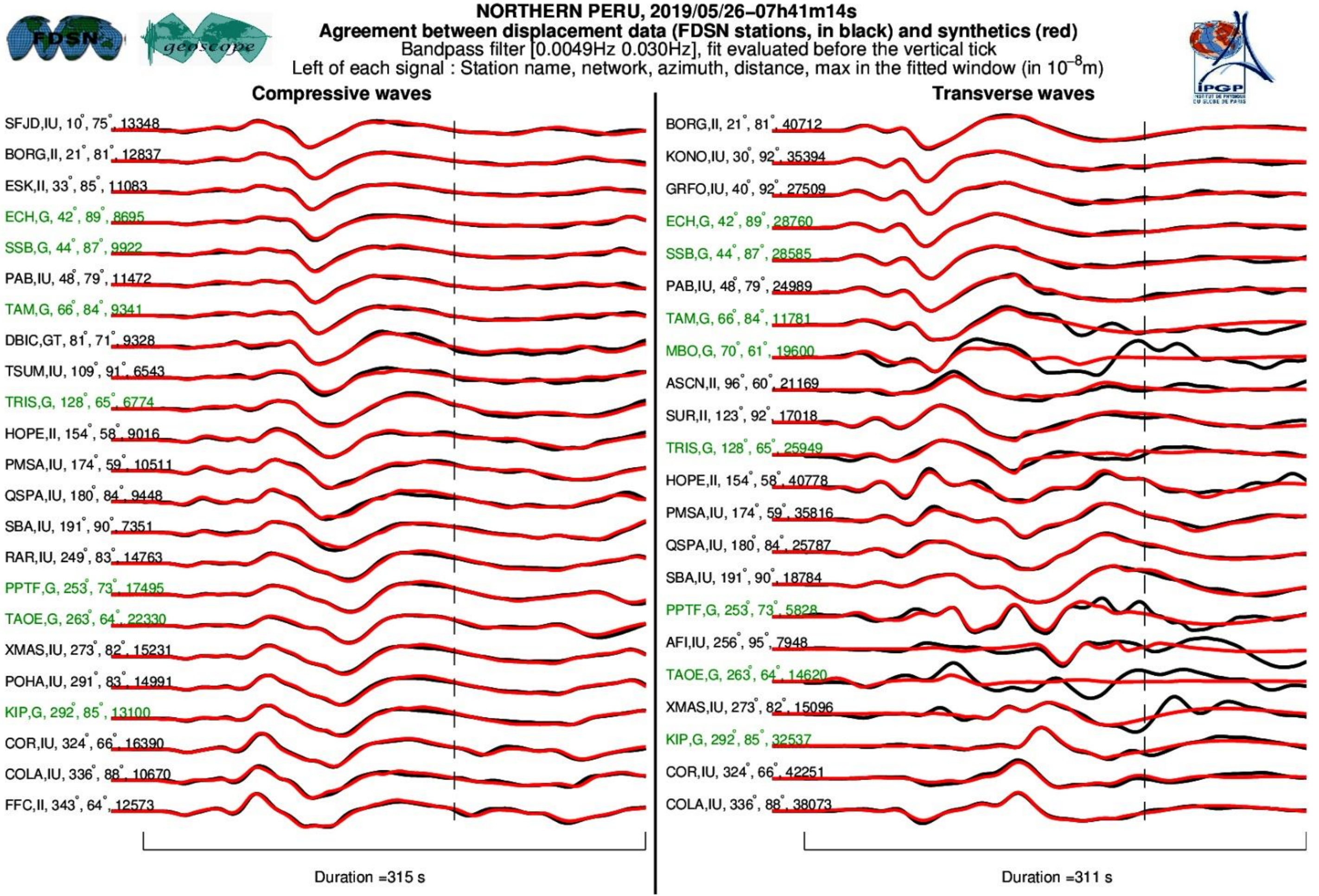
Context

- Largest earthquake since 1976 in the wide depth range between 70km and 550km (according to Global CMT)
- Well recorded with a variety of geodetic and seismic data
- Opens a window for the detailed analysis of an intermediate-depth intraslab earthquake; we usually only have limited resolution for such events



First-order source characteristics (SCARDEC method) :

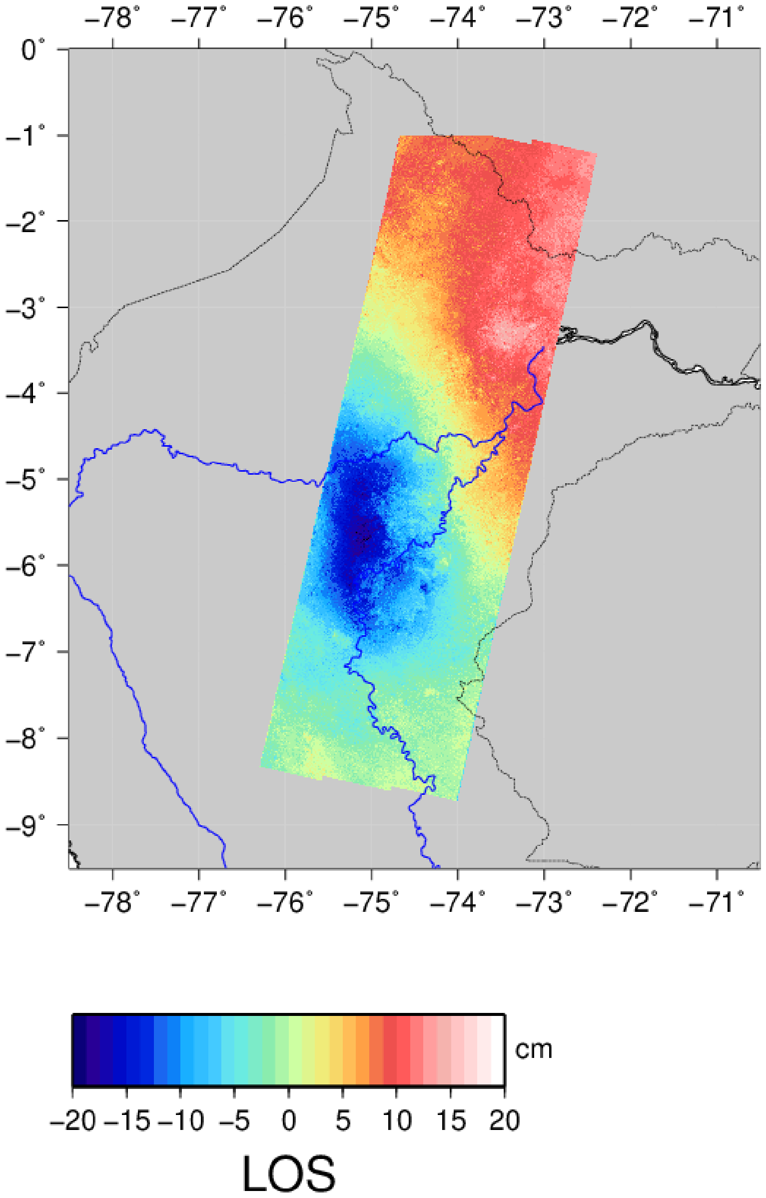
- **Mw=8 normal faulting event**
- **~140km depth**
- **Source duration ~60s**



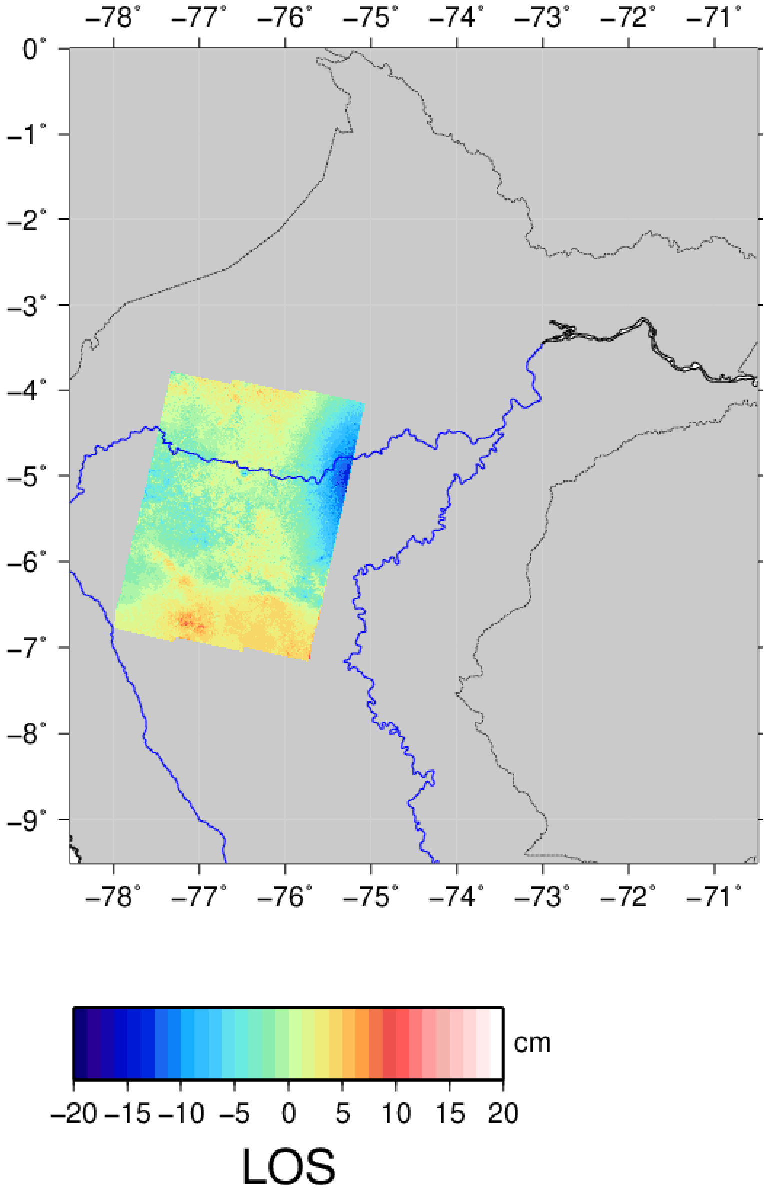
Data set

InSAR Data [Sentinel -1]

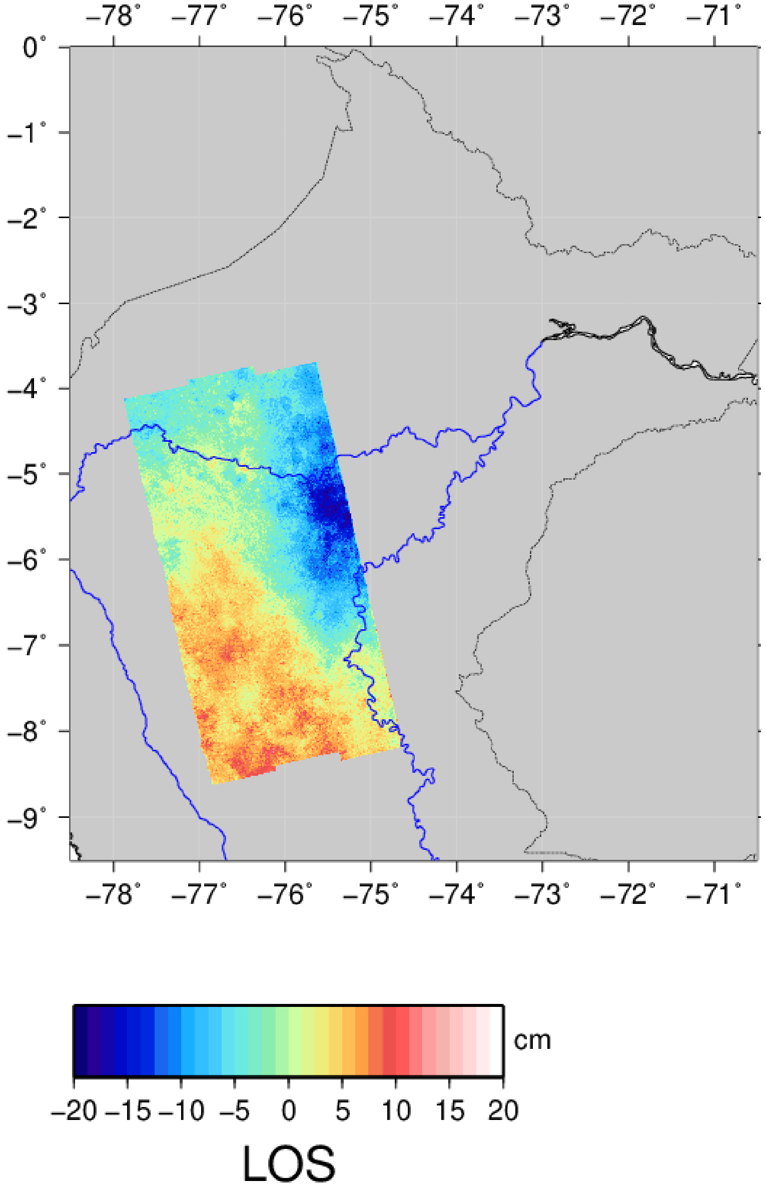
Descending



Descending

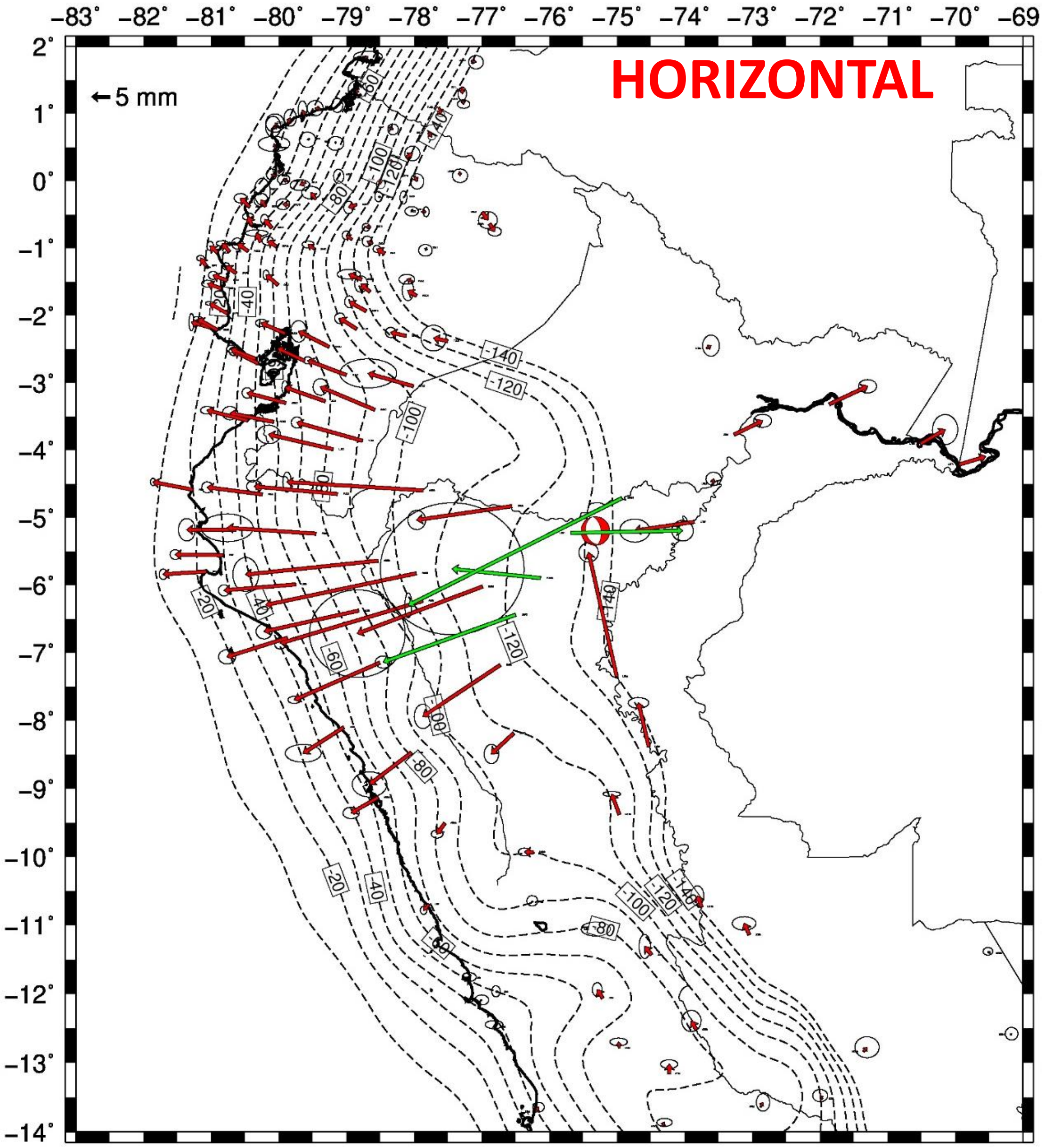


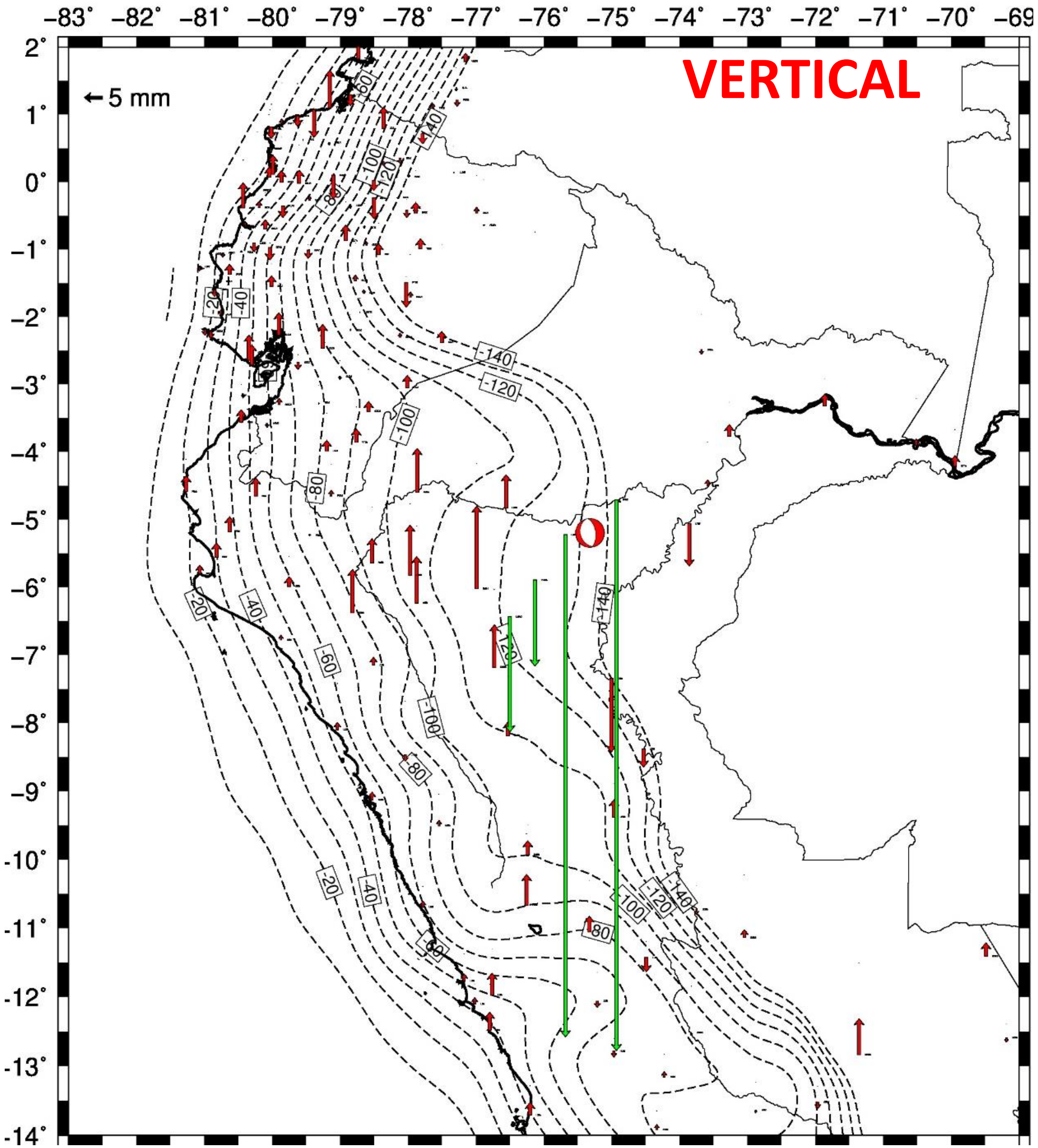
Ascending



GPS data

[IG Peru, IG-EPN Ecuador, IGN Peru, IGM Ecuador, Geoazur UCA-IRD-CNRS-OCA, IPGP]

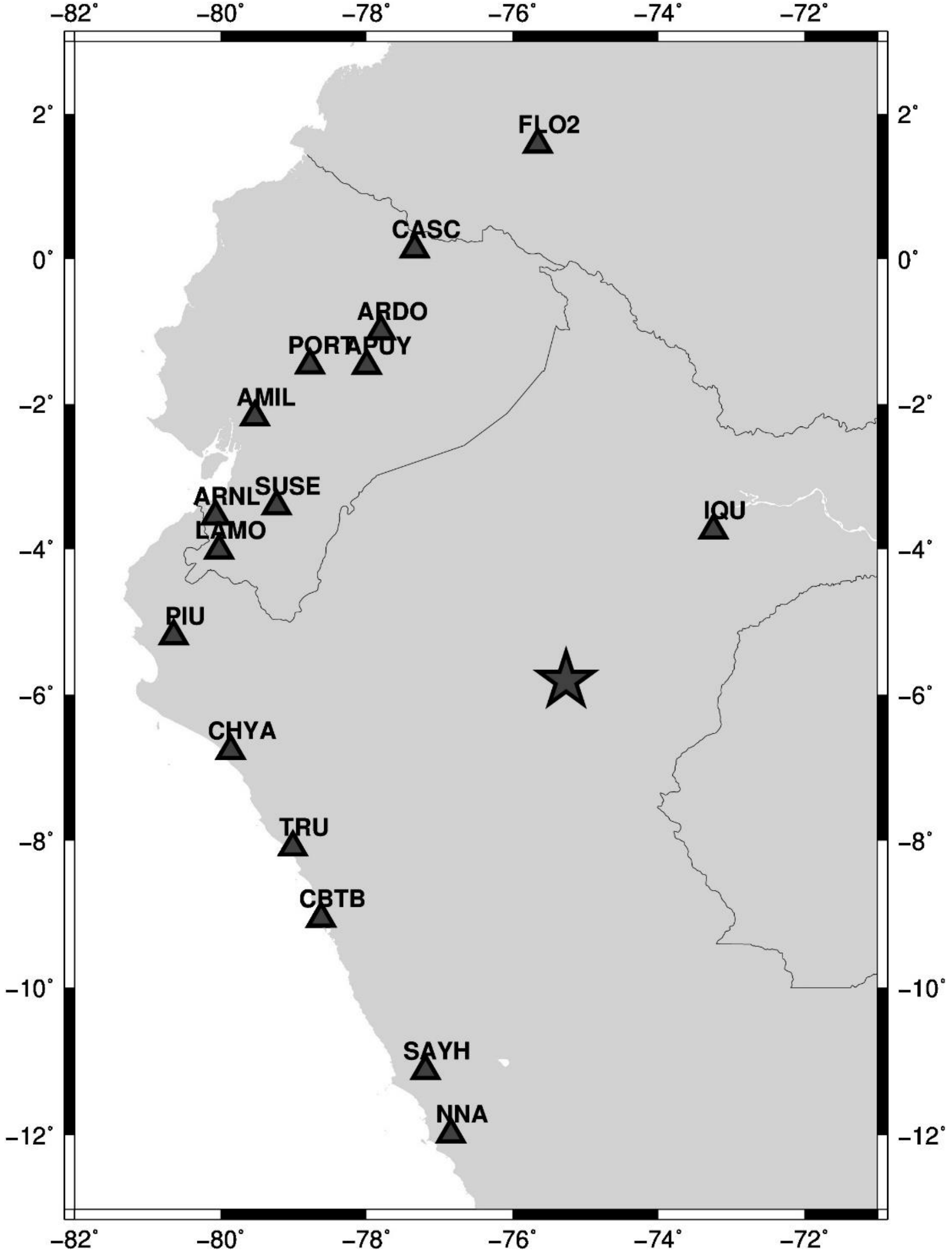


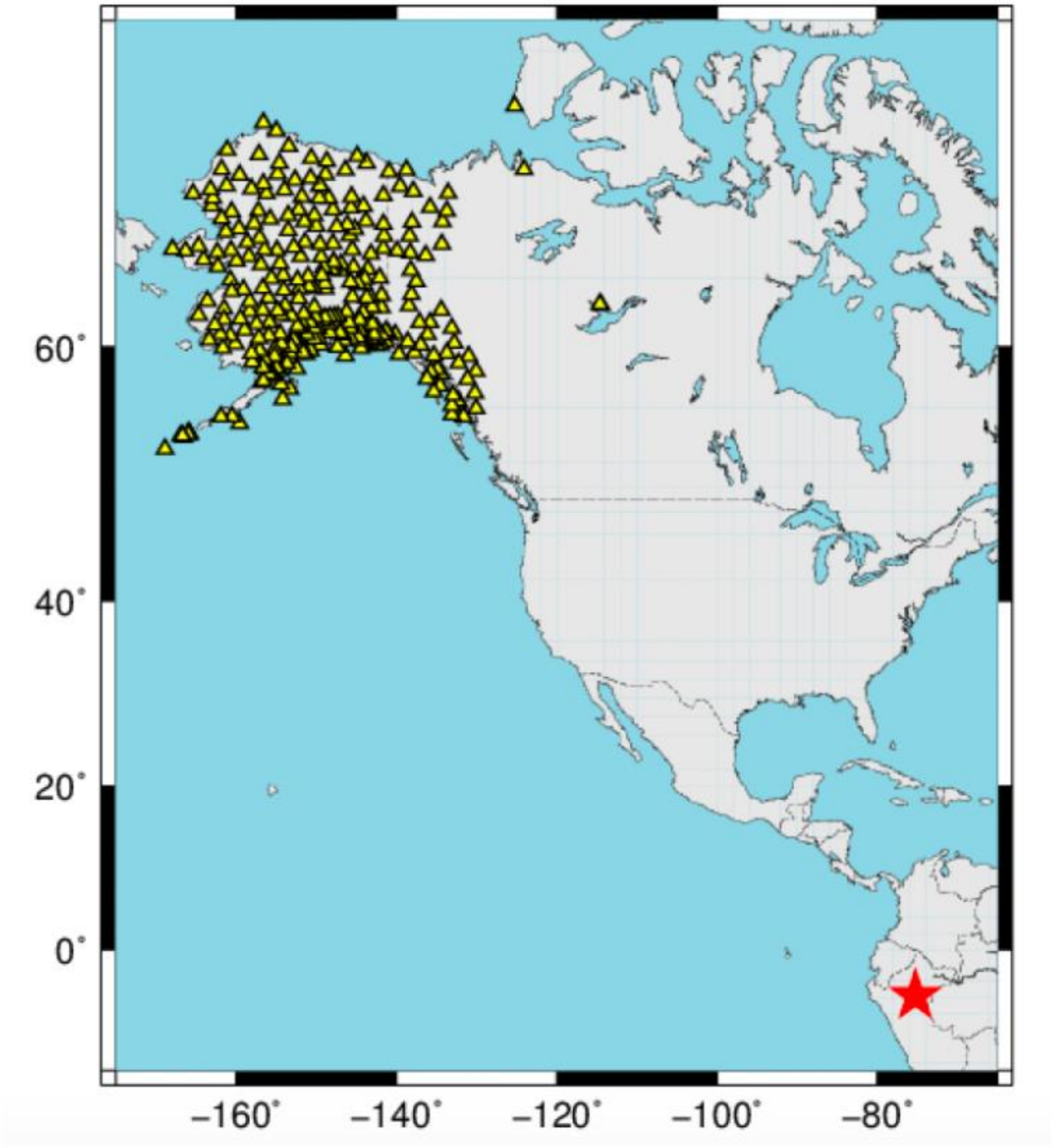


Broadband seismic data

- **Local and regional broadband and accelerometric networks**
  - IG-EPN (Ecuador) broadband and accelerometric network
  - IGP (Peru) accelerometric network
  - CISMID (Peru) accelerometric network
  - 1 broadband station from CM (Colombia) and II (GSN)

- **Teleseismic body waves (P and SH) from FDSN at the global scale**





Array data

- ➢ Data from the Alaska regional networks and USArray
- ➢ Data filtered around 1Hz or above to track high frequency emission

Strategy of analysis

1) Seismo-geodetic inversion

- Determination of the geographical coordinates of the fault, for the two possible planes, from geodesy alone (InSAR + GPS)
- Rupture process inversion (slip, onset time, rake) from InSAR + static GPS + regional waveform displacements [0.01-0.05Hz] + teleseismic body wave displacements [0.005-0.125Hz]

2) High frequency radiation

- Use of the Multitaper-MUSIC array processing technique
- Time window of 6 s, frequency band of 1-4 Hz.

3) Results comparison

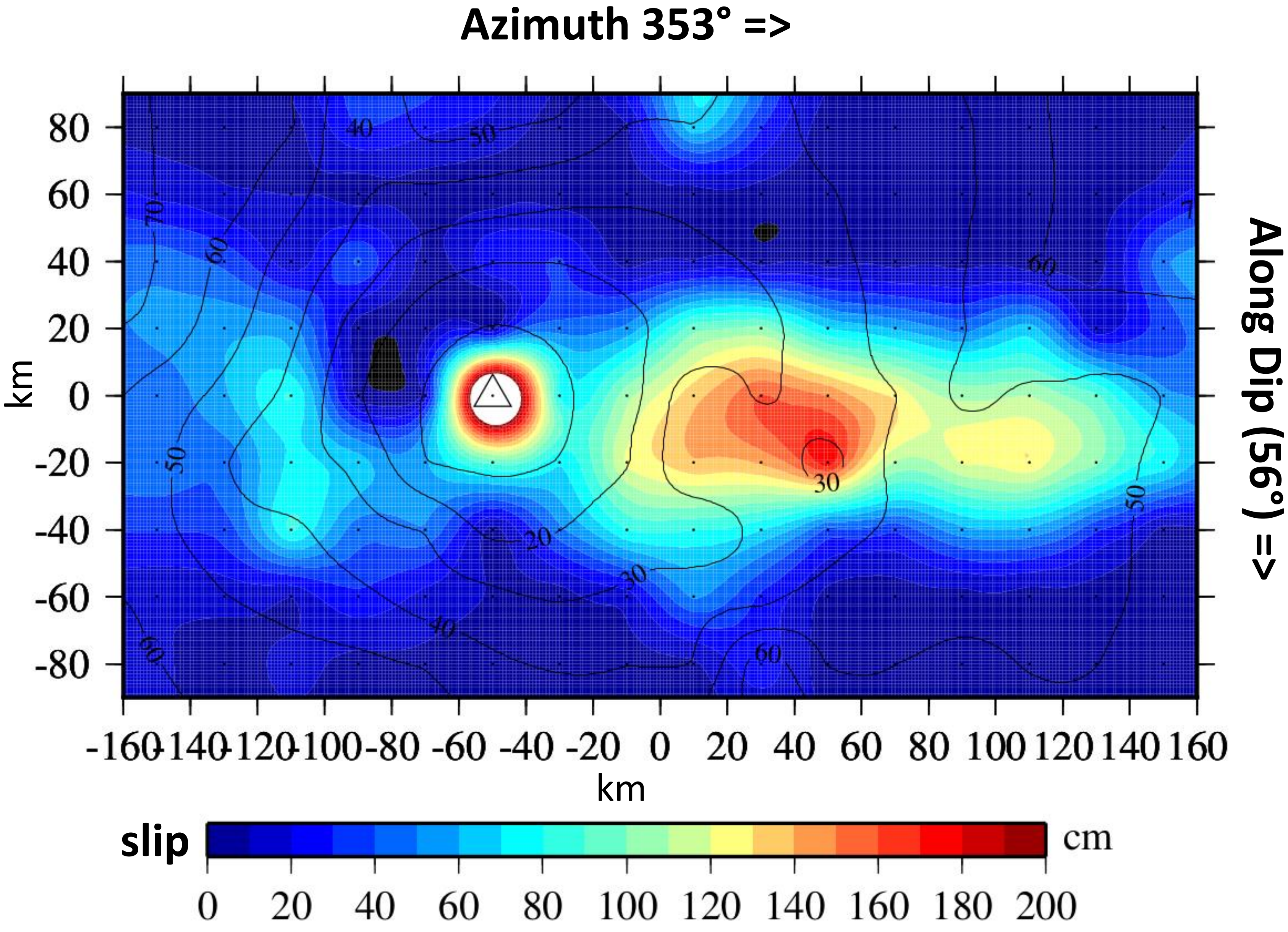
1) Seismo-geodetic inversion

- **Geodetic inversion** finds plane geometry explaining the data for **both** the steep (56°) Eastward dipping plane (**plane 1**) and the shallow (34°) Westward dipping plane (**plane 2**)

- **Seismo-geodetic inversion** also finds very **similar data agreement to GPS, InSAR and teleseismic** data for plane 1 and plane 2

- **Plane 1 is preferred by regional waveform displacements**

This difficulty of resolving the actual fault plane is due to the narrow along-dip extension of the rupture process

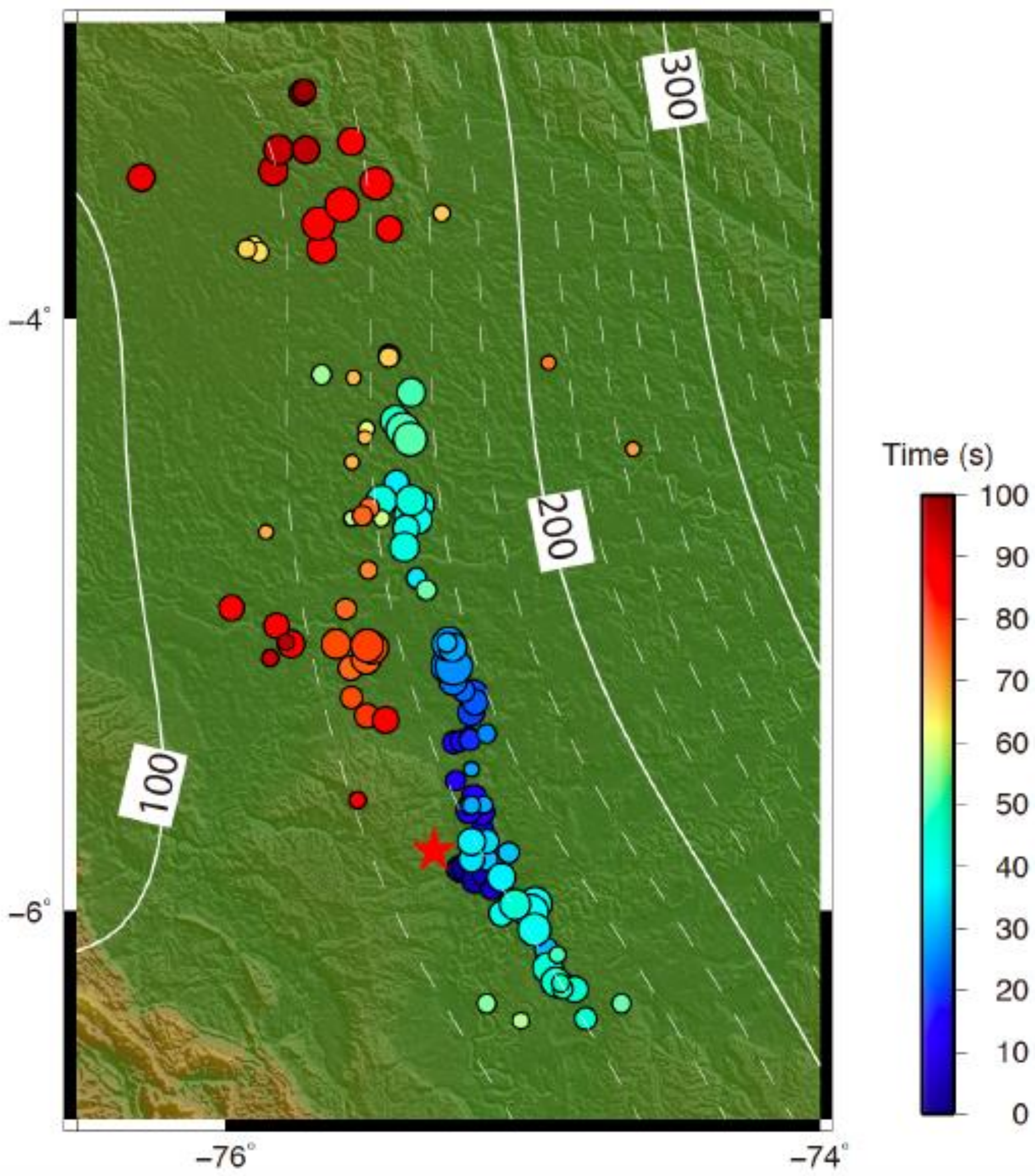


Triangle : hypocenter ; contour lines : rupture onset times

Typical model for Plane 1

- Rupture propagated over 200km toward North in ~60s
- Rupture velocity of 3-3.5km/s
- Narrow rupture aspect
- Typical slips of 1-2m
- Possibility of minor and slower (or delayed) rupture in the South direction

2) High frequency radiation from backpropagation

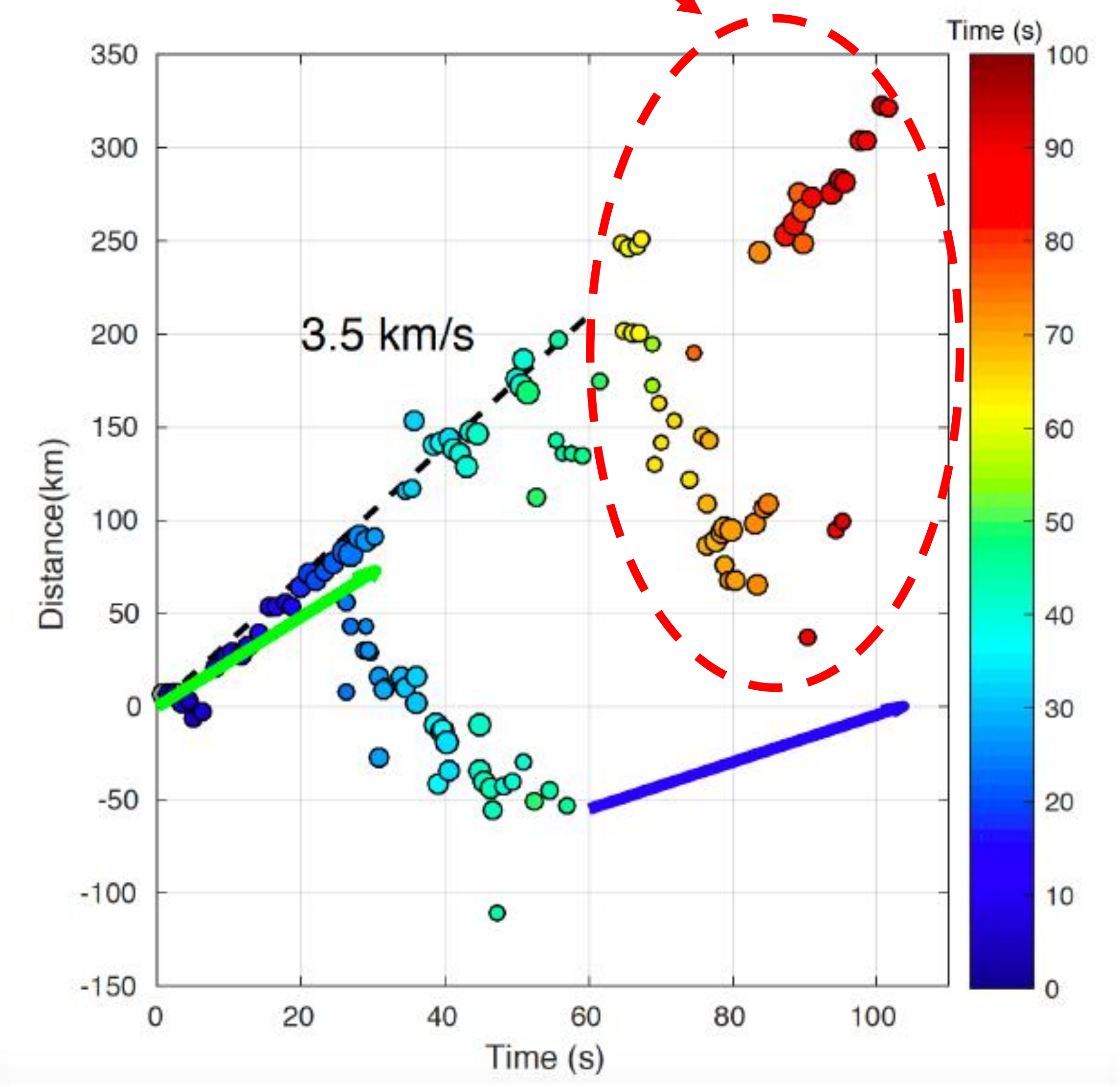


Map view of all HF emissions detected from origin time (OT) to (OT + 100s)

Emissions are detected if waveforms consistently stacks according to P-wave delays

Time distance diagram of high-frequency emissions

Depth phases detection

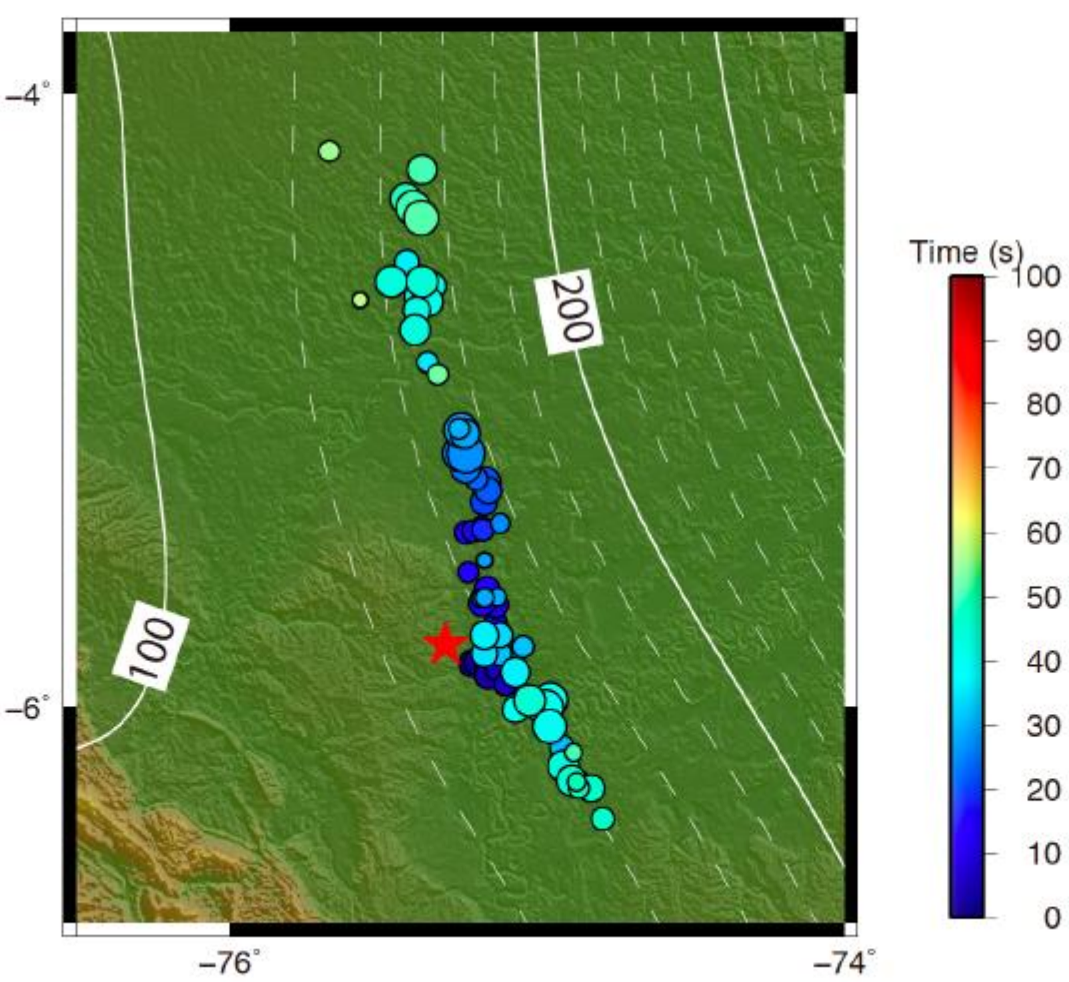


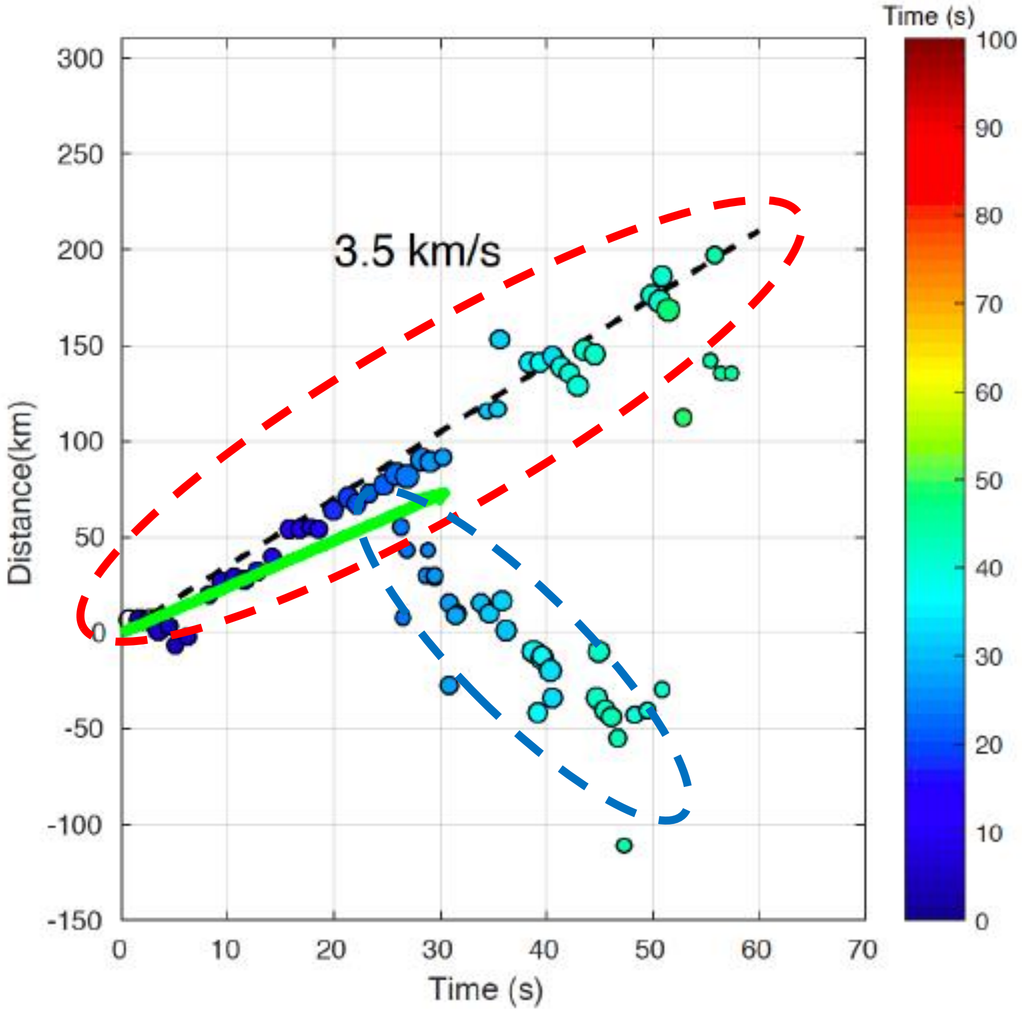
As expected, observation of rupture replication due to pP or sP depth phases.

Depth phases imaging is not only time-shifted but also space-shifted, as they do not have the same ray parameter as the P wave.

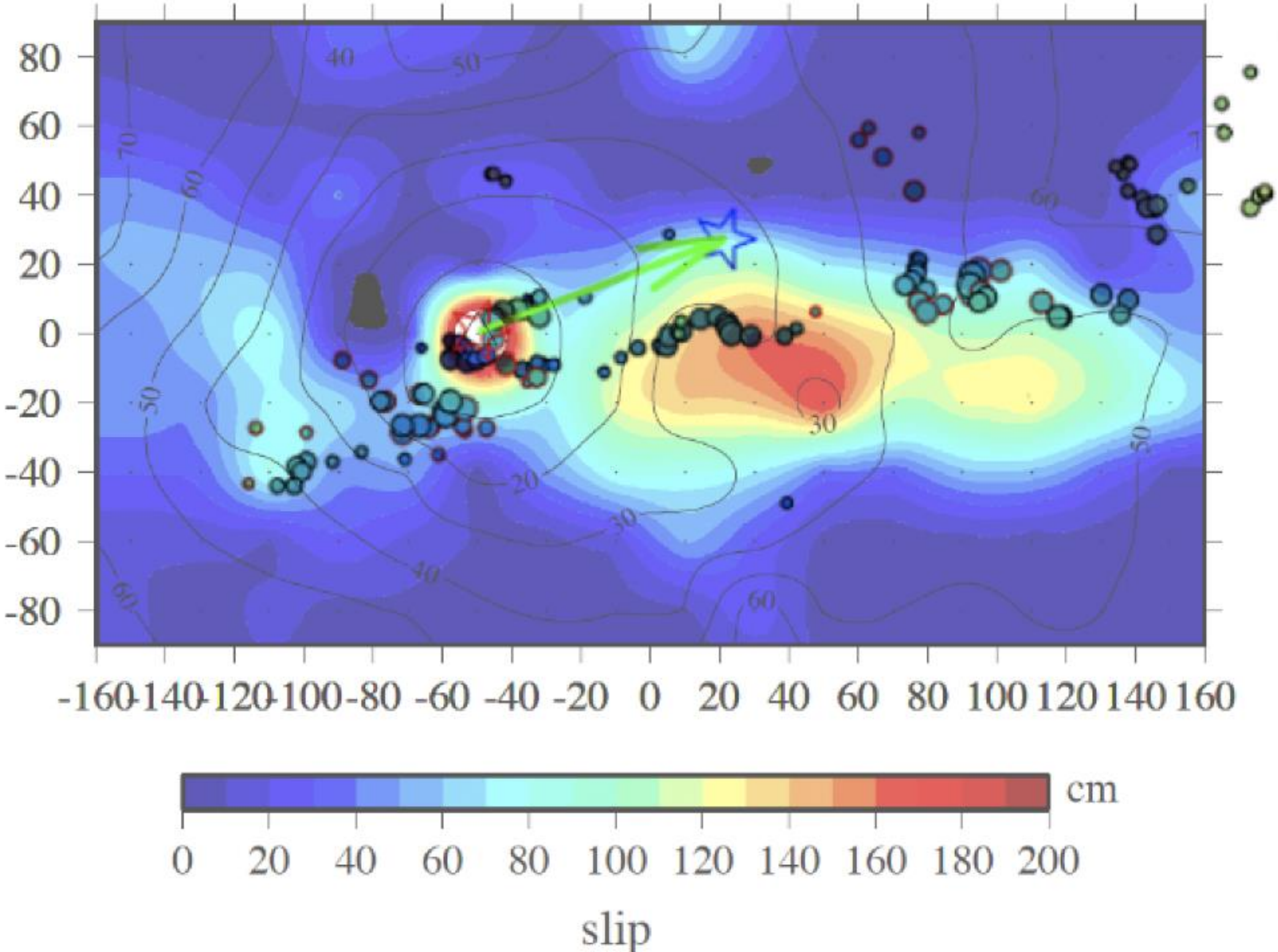
Green and blue arrows show the space-time offset expected for pP and sP, respectively.

Observations in the time window [OT OT+60s], most likely not affected by depth phases





- Primary front (red ellipse) traveling northward at 3.5km/s
- A secondary backward front (blue ellipse) appears to emerge after 30s



Slip model and high-frequency emissions

Good general agreement in terms of rupture dimensions, but the rupture timings South of hypocenter differ

Discussion

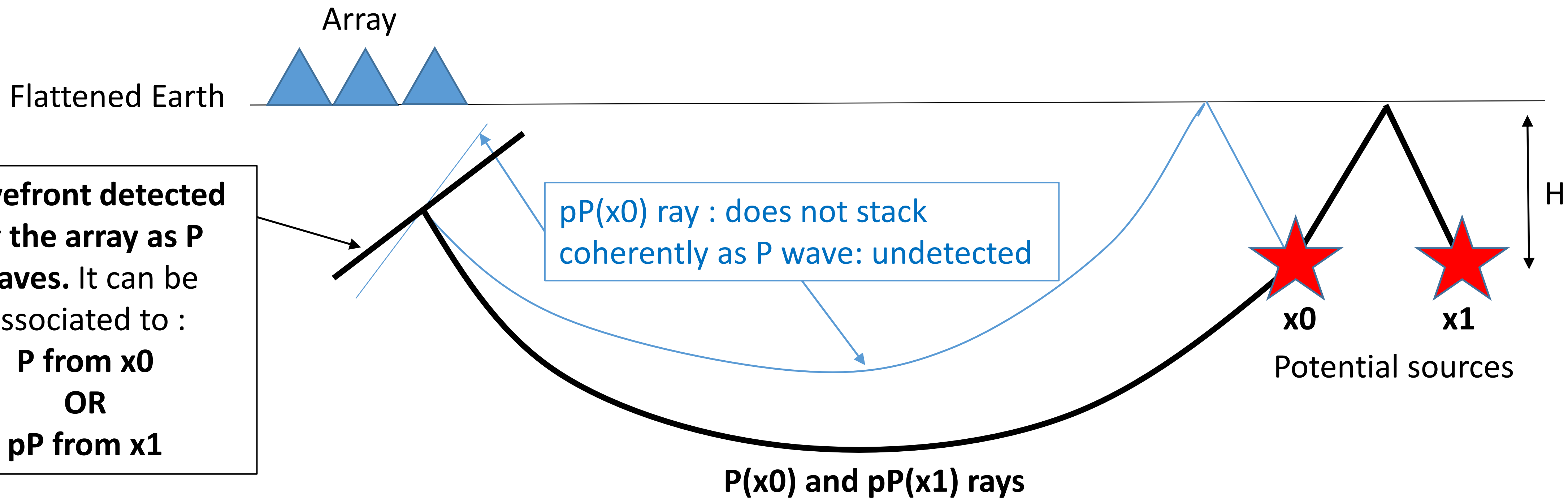
- **Well resolved characteristics** :
    - **Northward** propagation for **200km**, rupture velocity of **3-3.5km/s**
    - **Narrow along-dip** extension : this large earthquake has a **classical stress drop for an intermediate depth earthquake**, even if duration or corner frequency measurements would put it in a low stress drop category
    - Much larger earthquakes are unlikely at intermediate depth if they respect such one-dimensional rupture propagation

- **Steep eastward dipping plane is preferred**

- Strong clues of **backward rupture propagation**, that have to be further characterized

Additional slide

Origin of the spatial offset of depth phases imaging



wavefront detected by the array as P waves. It can be associated to :
P from x0
OR
pP from x1

pP(x0) ray : does not stack coherently as P wave: undetected

P(x0) and pP(x1) rays

All detections are assumed to be P waves; if it were in fact a pP wave, its source will be located too close from the array, by an amount of the order of ~2H* tan(i), where i is an average incidence angle between 0 and H