ISTerre
Institut des Sciences de la Terre

Influence of strong body waves in seismic noise on extraction of Green's function body waves from cross correlations

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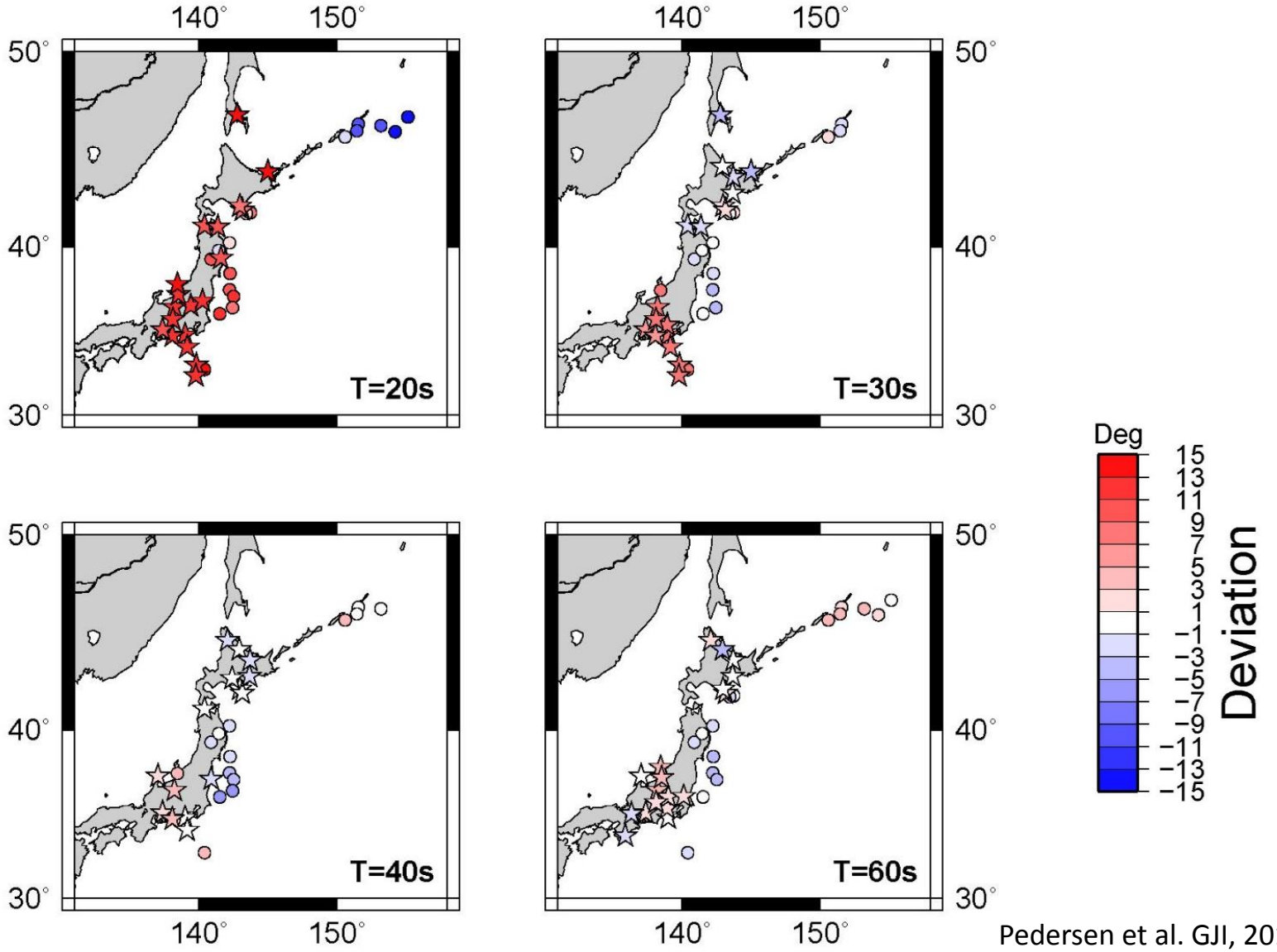
Extraction of body waves from seismic noise

Surface waves as observed in seismic noise correlations from seismic broadband stations

- Usually very robust, as demonstrated in abundant literature since 2004
- Influence from the distribution of noise sources: impacts mainly the relative amplitude between the waves at causal and acausal time
- The observations are sufficiently robust to allow for monitoring, using the surface wave coda
- The surface waves include also effects of lateral heterogeneities

-> In the case of seismic surface waves, (most of) the conditions are fulfilled for effective imaging

Example of surface waves great circle deviations observed in Finland



Pedersen et al. GJI, 2015

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Body waves as observed in seismic noise correlations from seismic broadband stations

- Still at its beginning (>2010)
- Spurious arrivals are known to exist, related to Earthquakes (-> talk by Piero Poli)
- Is the wave scattering sufficient to ensure a good Green's function retrieval in the frequency band where we have the most energy?
- Is the distribution of body wave sources sufficiently spread geographically?

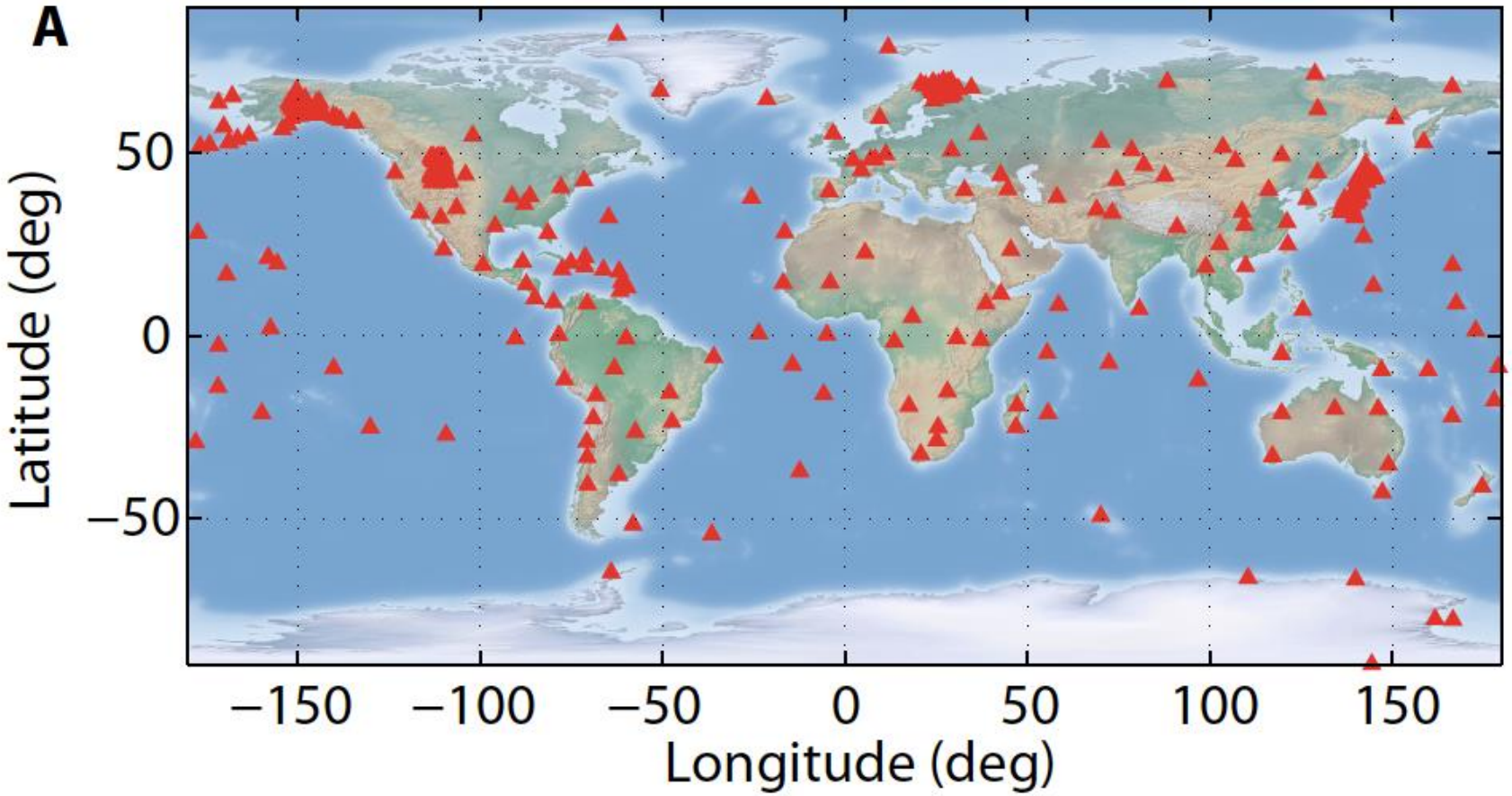
Scope of this talk:

- Demonstrate that in some cases (geographical location, array configuration) the distribution of noise sources is highly inadequate to obtain the body wave part of the Green's function

Body waves observed at global scale

339 stations, 57000 correlations, FB 0.01-0.5 Hz. Networks:
GEOSCOPE, GSN, K-NET, LAPNET, USARRAY, ALASKA SEIS. NET, ….

Thanks to all the data centers and network providers

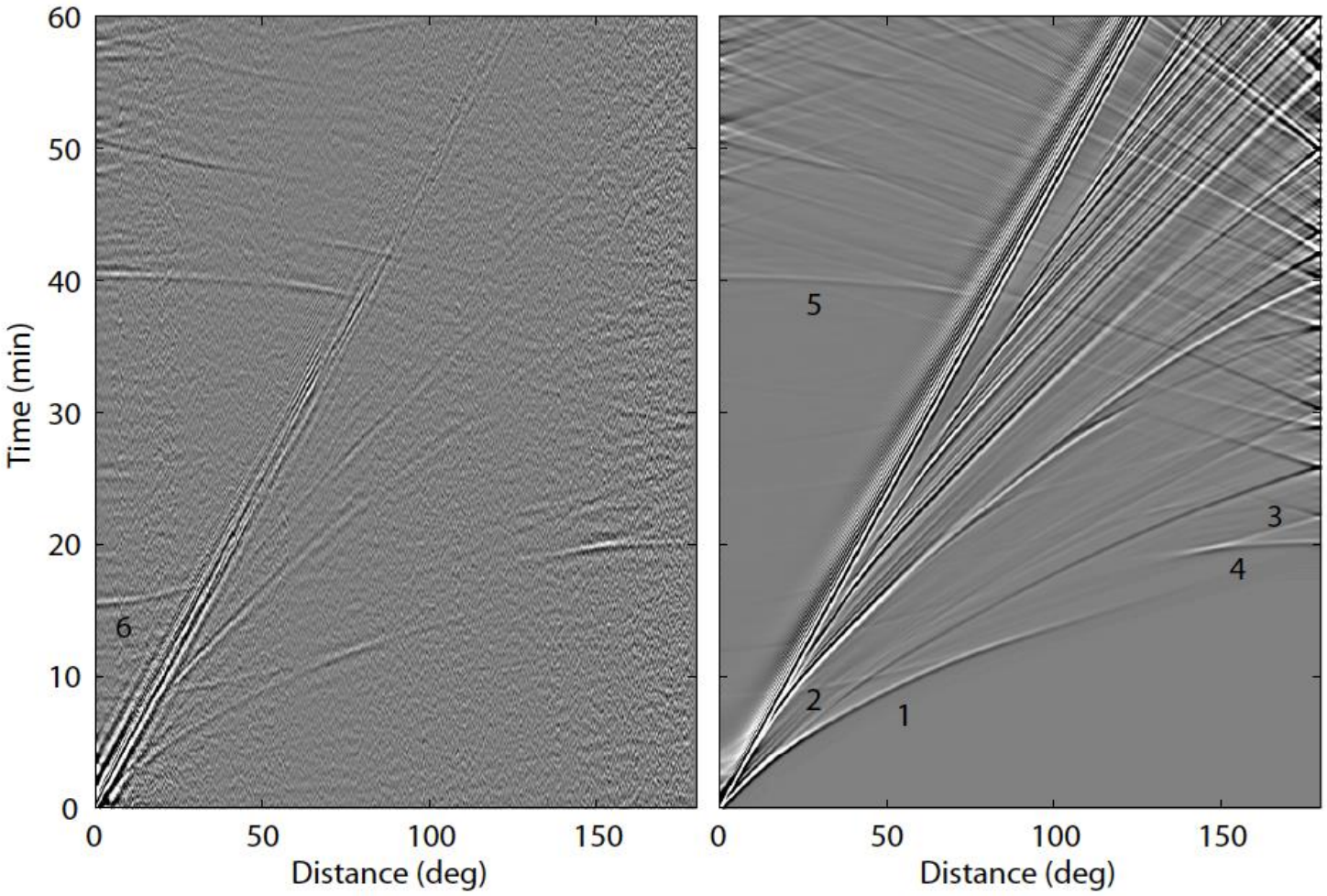


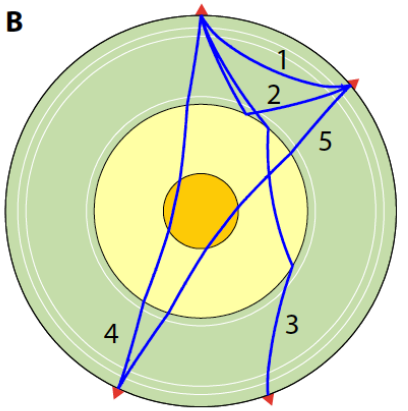
Boué et al. GJI, 2013

Body waves observed at global scale

Correlations

Synthetics



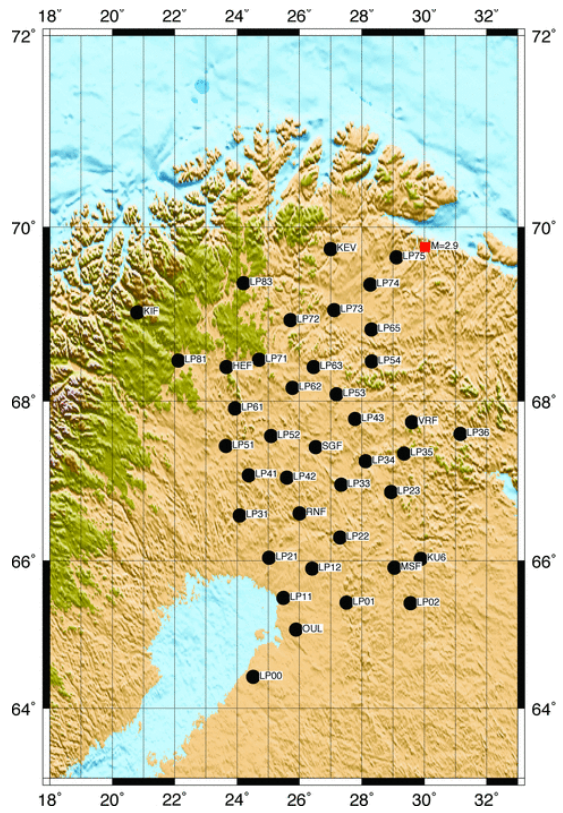


BIN SIZE 0.01°

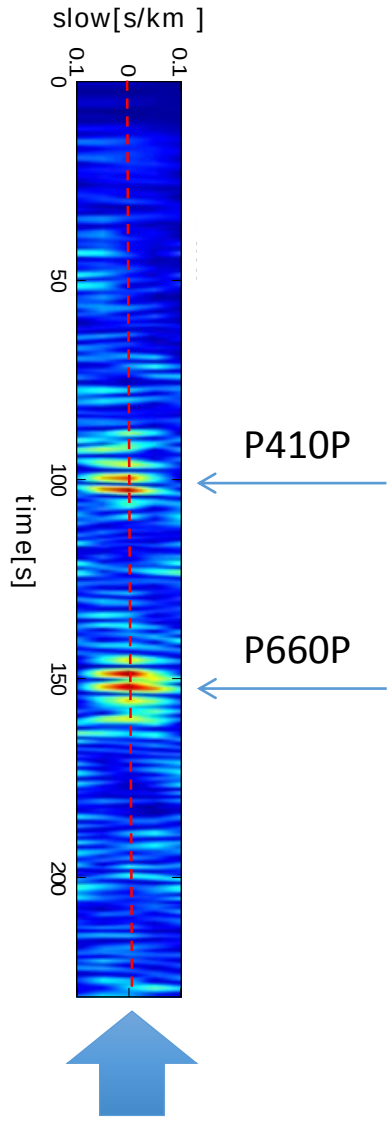
→ See talk by Piero Poli

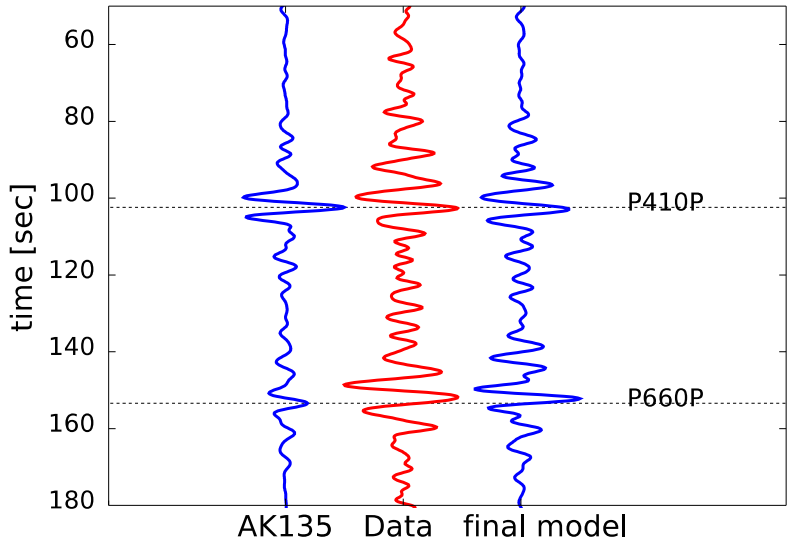
Boué et al. GJI, 2013

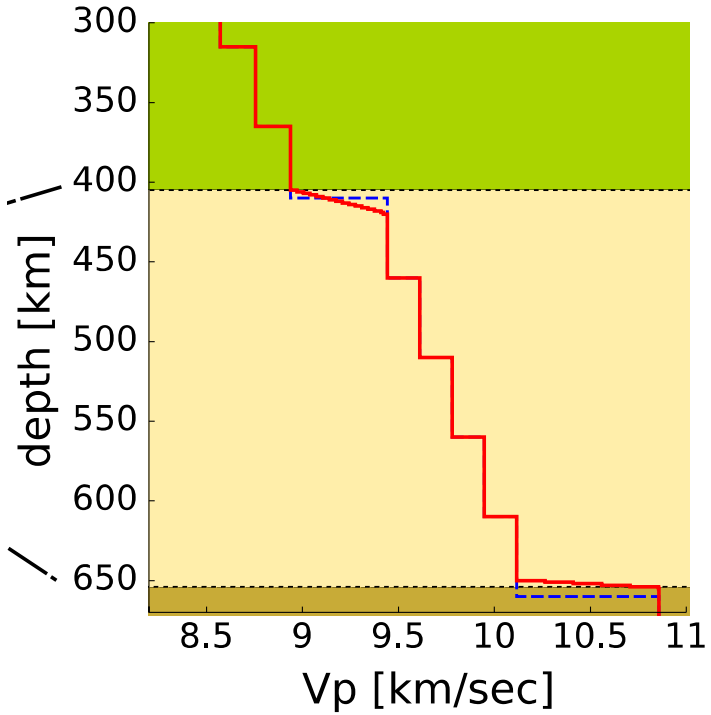
Previous observations of P410P and P660P



- 861 noise correlations
- ZZ component
- 0.1-0.5 Hz







Poli et al. Science, 2012

Data: Kozlovskaya et al., 2007, DOI: 10.15778/RESIF.XK2007)

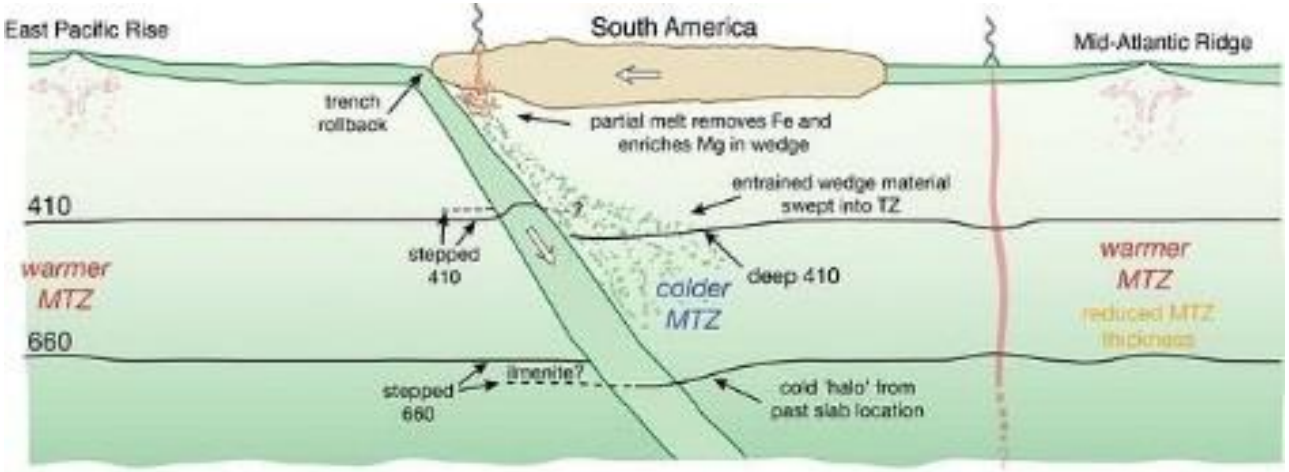
Parenthesis: citing seismic networks

Poli et al. Science, 2012

Data: Kozlovskaya et al., 2007,
DOI: 10.15778/RESIF.XK2007)

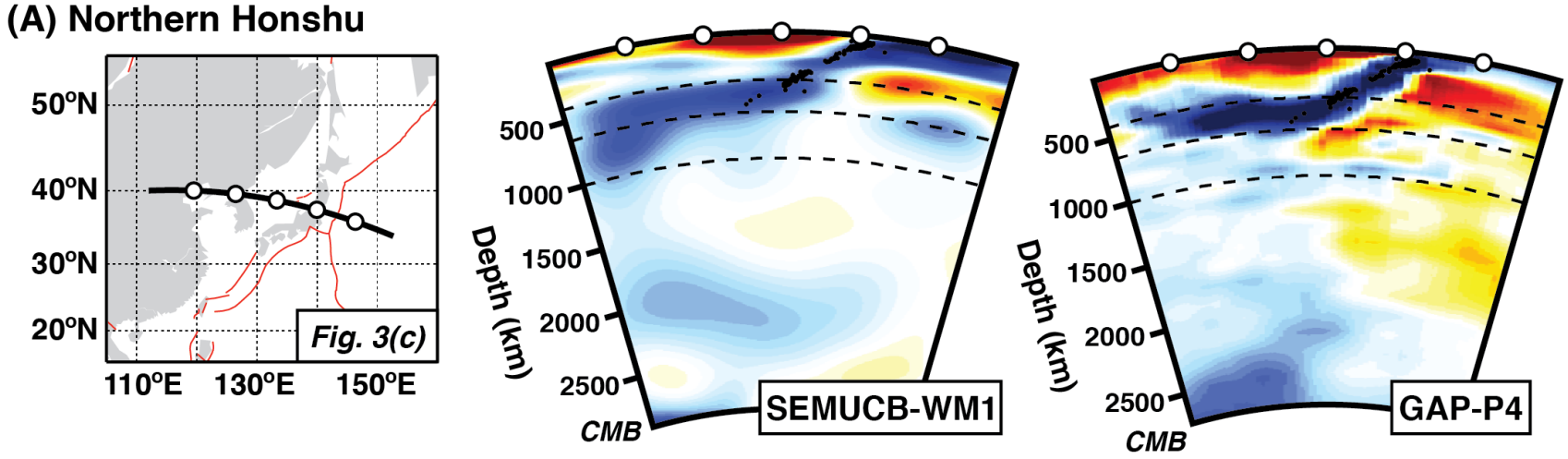
Why study the mantle transition zone?

Constraints on temperature and composition of the Earth's mantle



(Schmerr and Garnero, 2007)

Impact on mantle convection

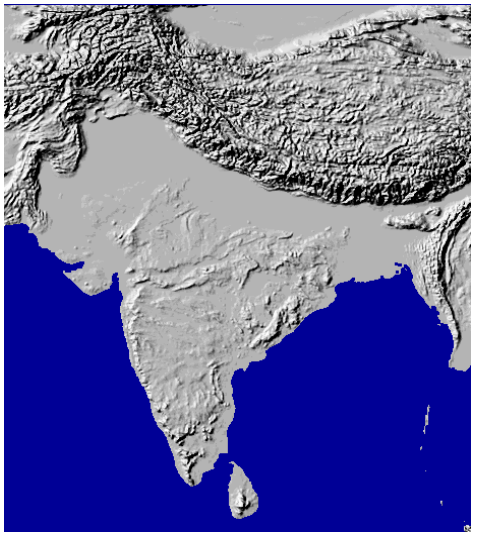


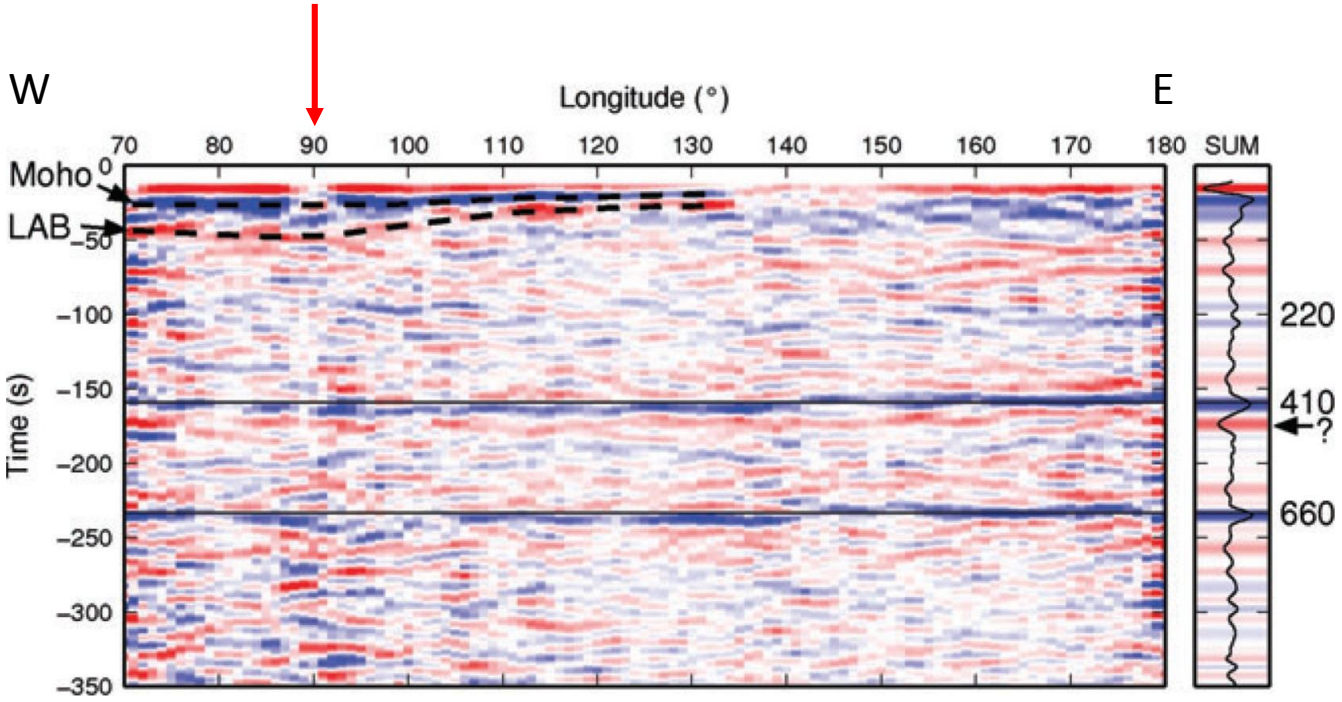
(French and Romanowicz, 2014)

Moving to Nepal-Tibet: HICLIMB Data

Why?
- Dense network
- Previous observations of 410 and 660 (SS precursors; Heit et al., 2010)
- Important geodynamic questions are still open

Why not?
- Complex crustal structure
- Linear array



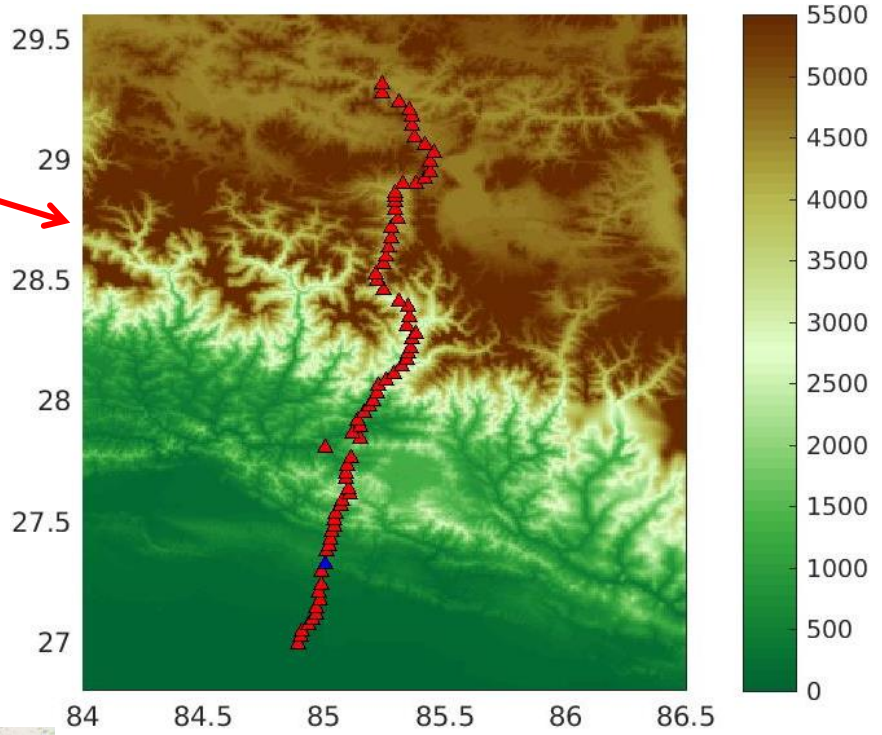


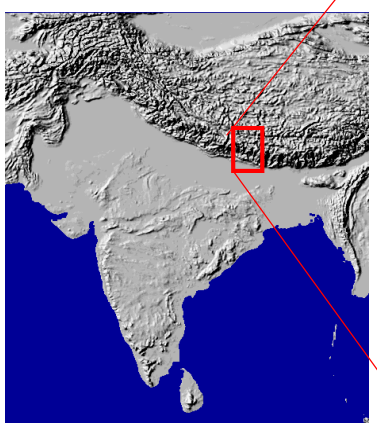
Seismic array

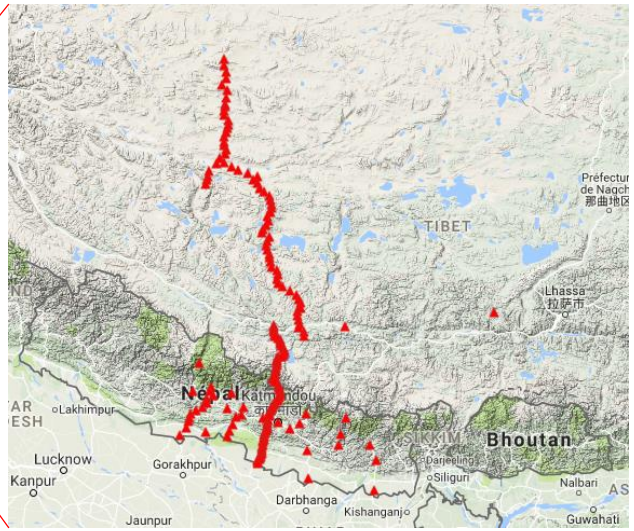
Southern part:
-76 BB with 4-5 km interstation spacing, running between Sept 2002 and June 2004

Northern part:
approx 90 stations, 10km interstation spacing, 1 year approx running time

Data: Nabelek et al., 2002.
doi: 10.7914/SN/XF_2002

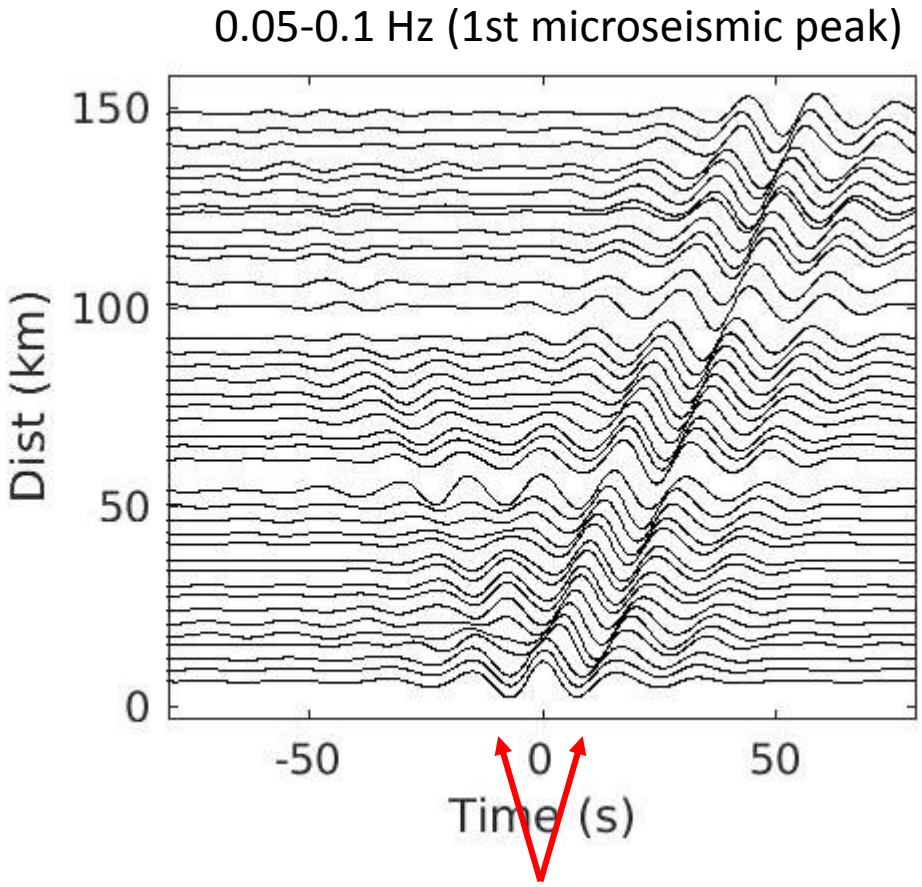






Noise correlations calculated with an method that minimises the impact of earthquakes and high amplitude storms

Correlations between station H0130 and all profile stations north of H0130



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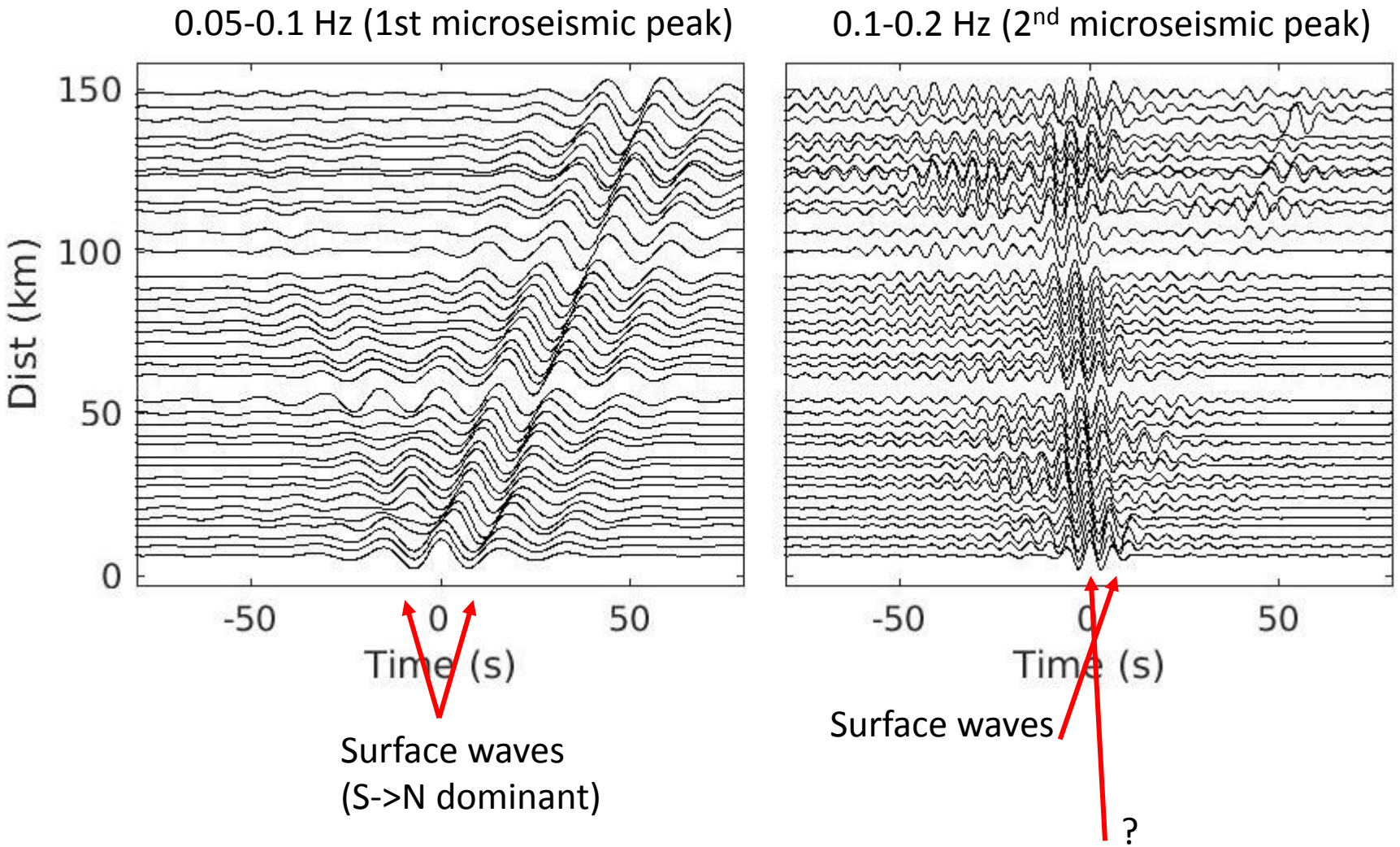
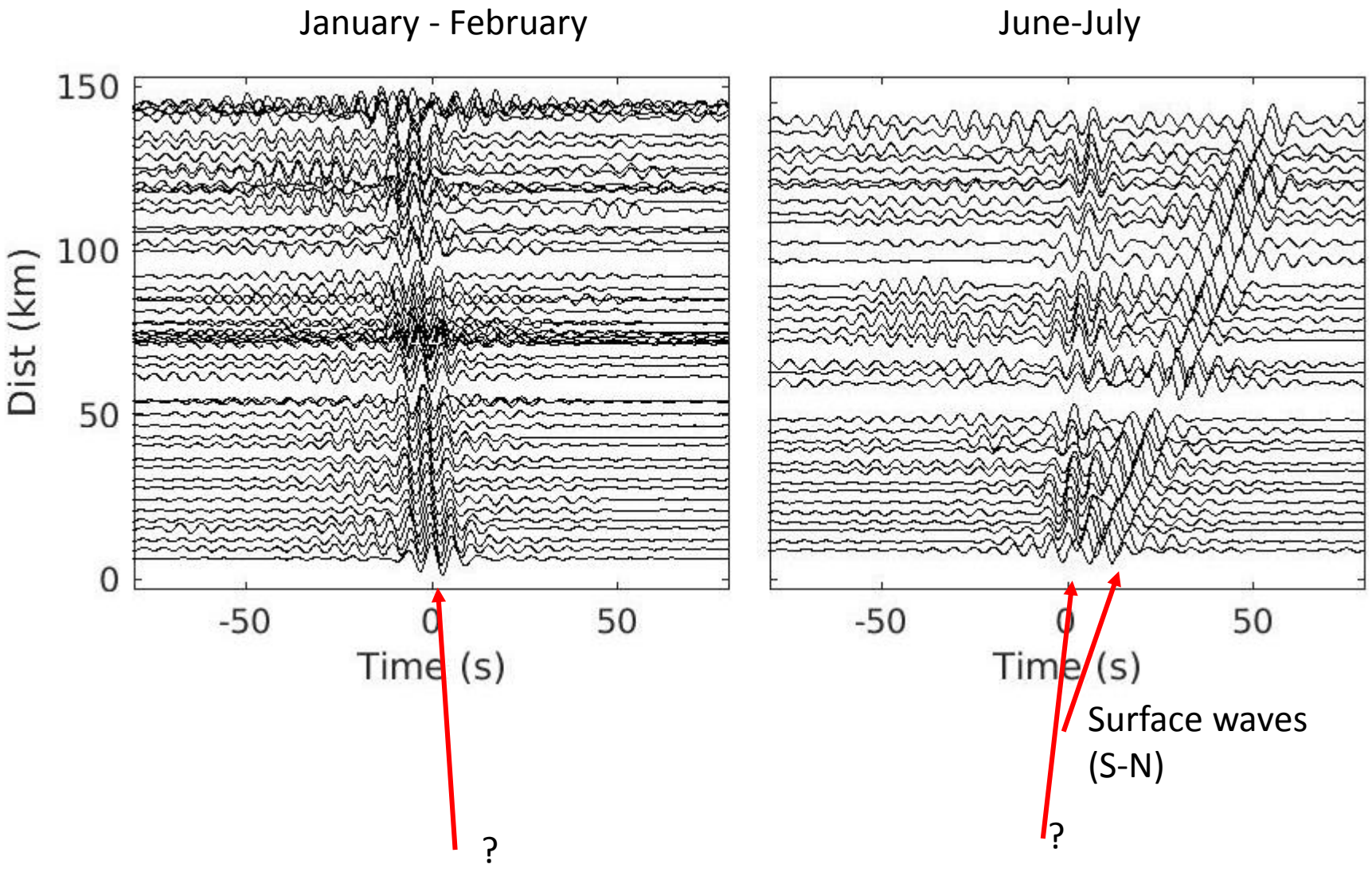
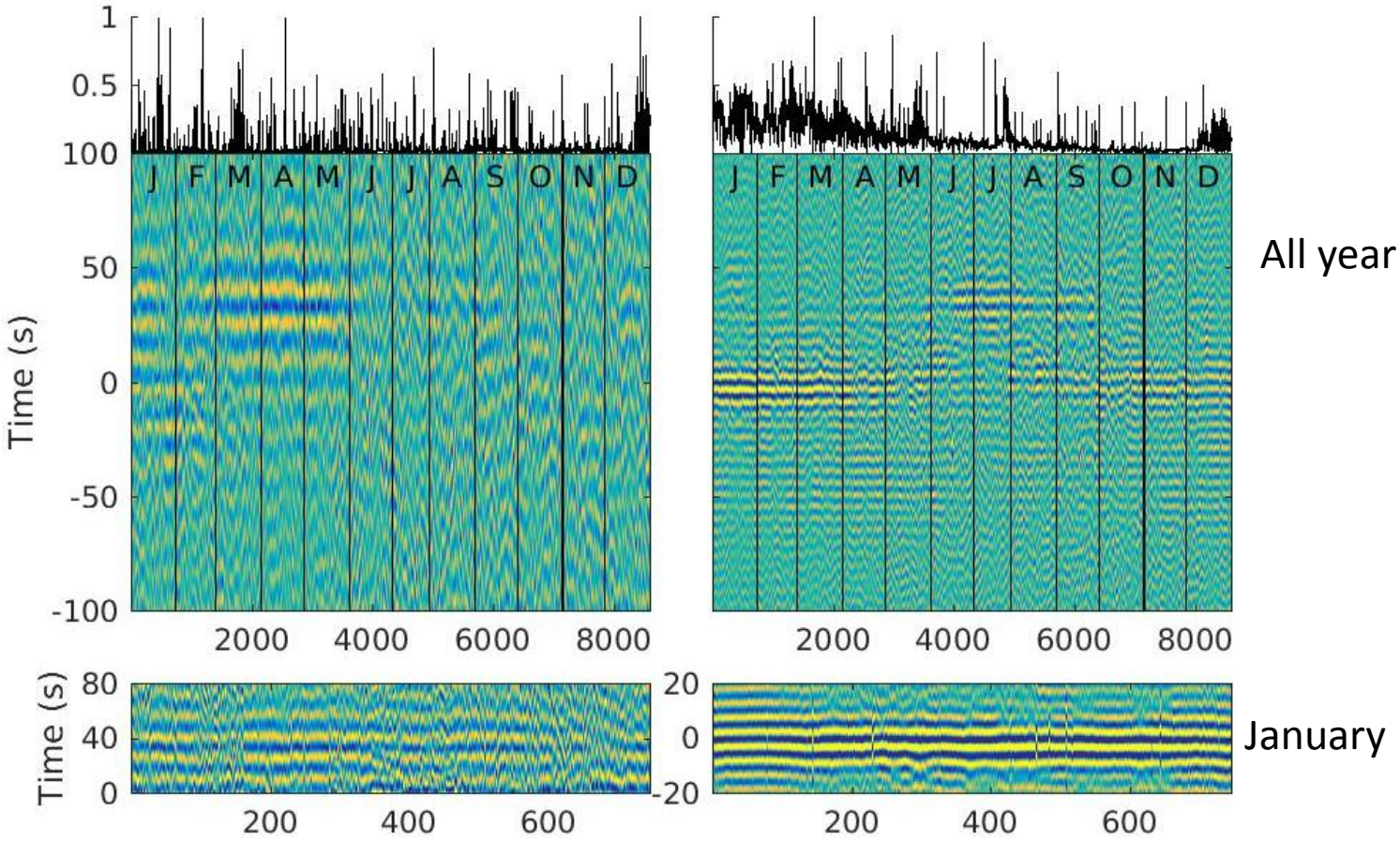


Variations over the year (0.1-0.2 Hz)



Variations over the year
Hourly correlations between two stations

0.05-0.1 Hz (1st microseismic peak) 0.1-0.2 Hz (2nd microseismic peak)



Single arrival dominant **in almost all hour** windows, for at least 8 months per year

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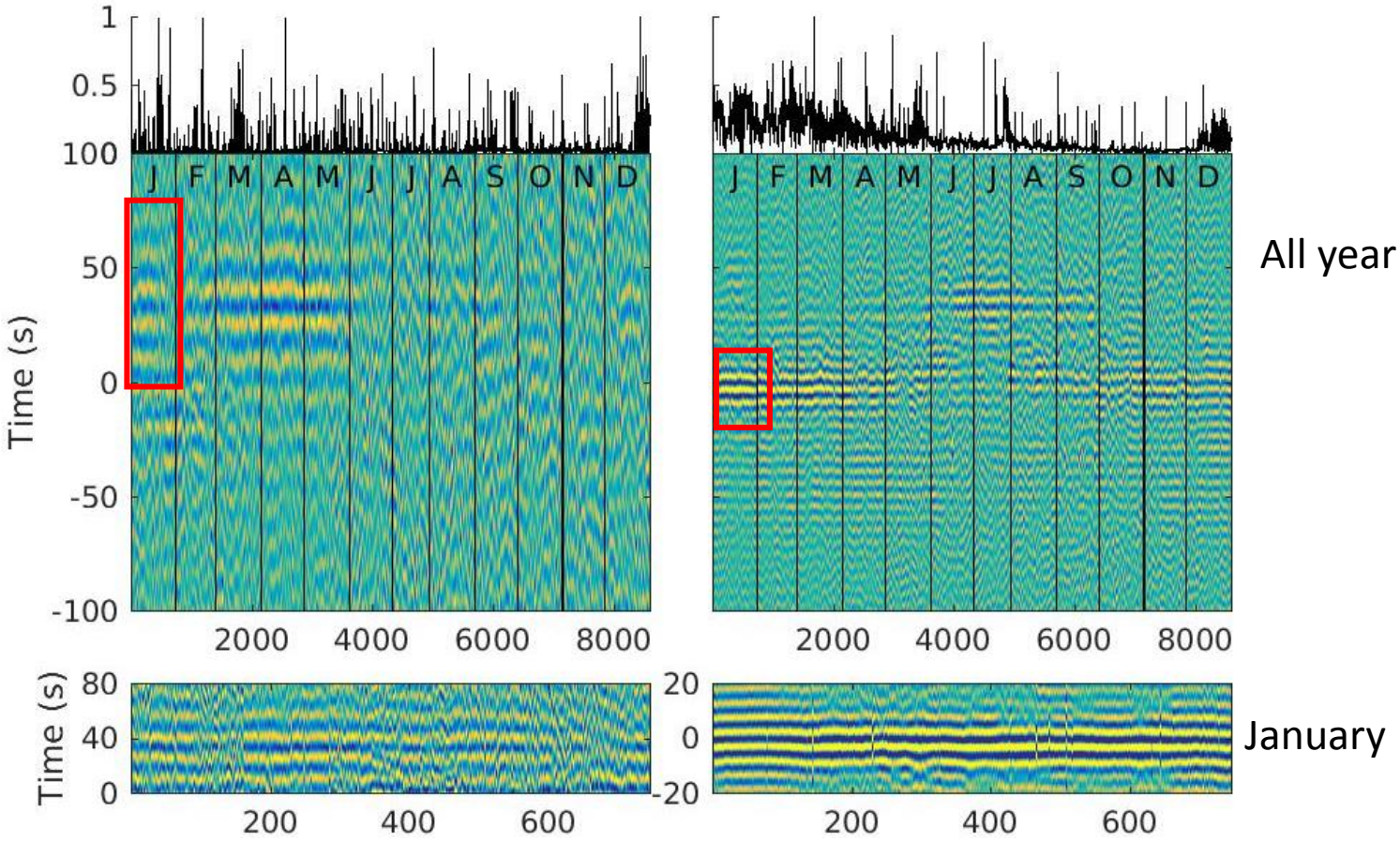
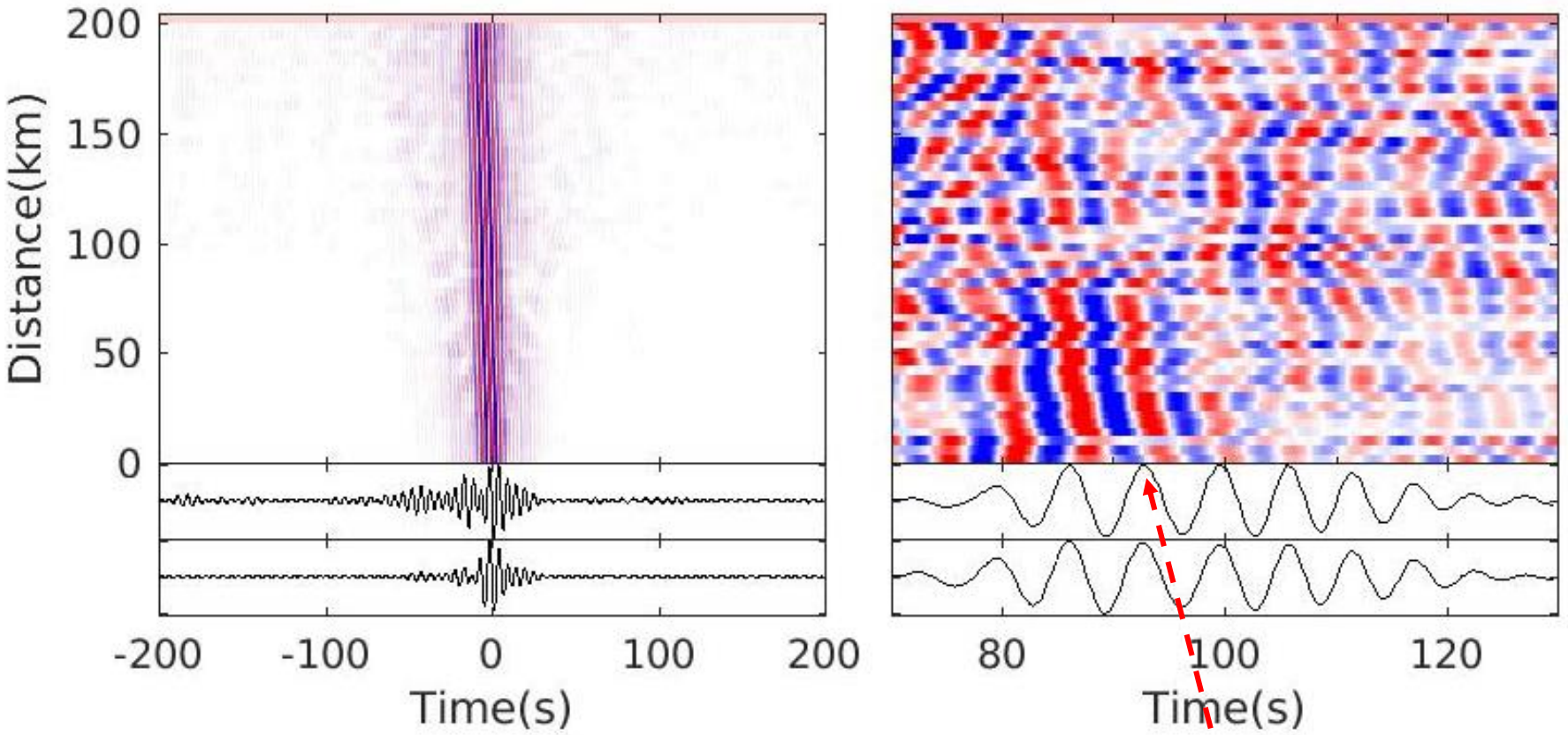


Single arrival dominant **in almost all hour** windows, for at least 8 months per year

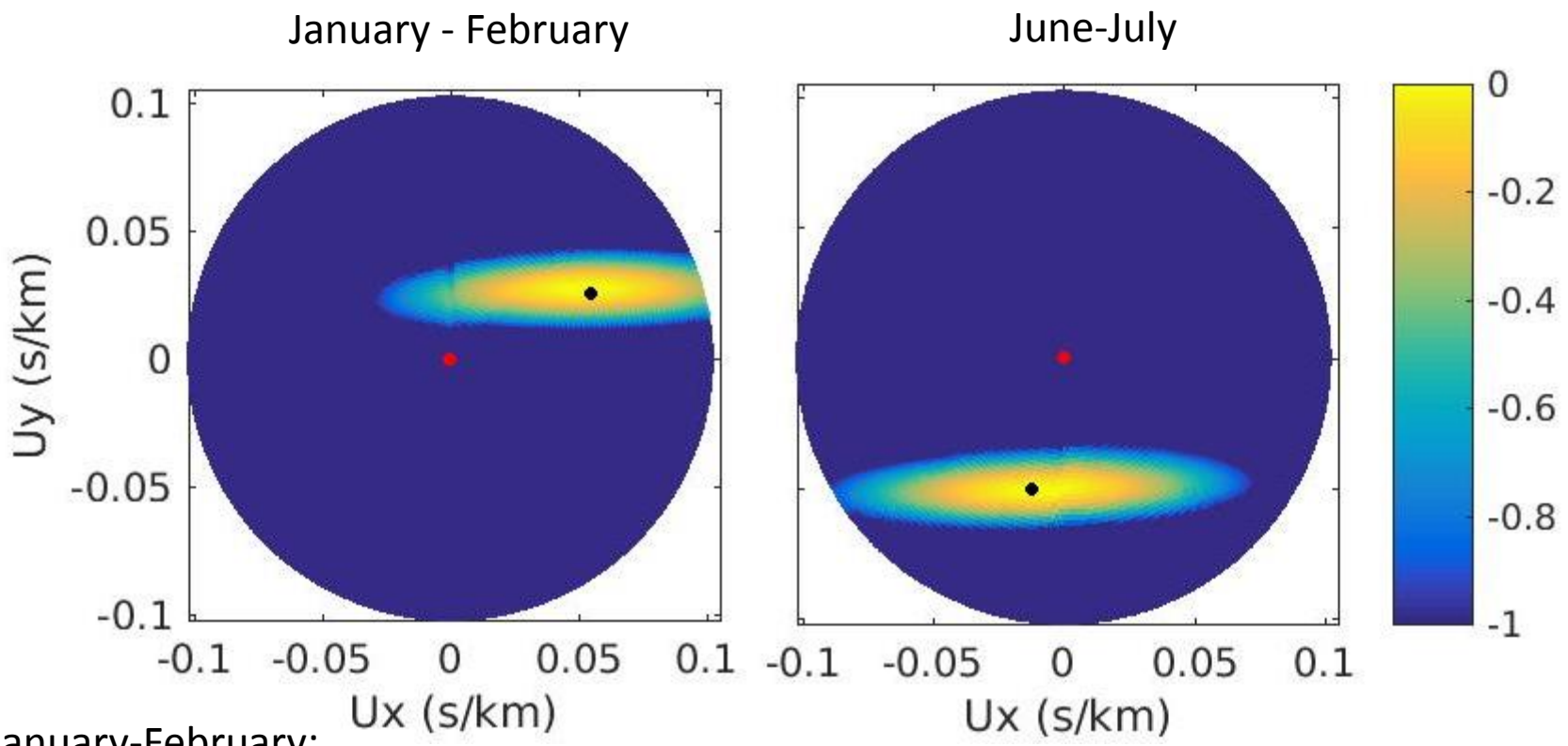
Looking more into the winter months

Stack of all southern pairs over the winter months (except stations <H0100)



Waves propagating in the ‘wrong’ direction

Beam-forming on small irregular part of array

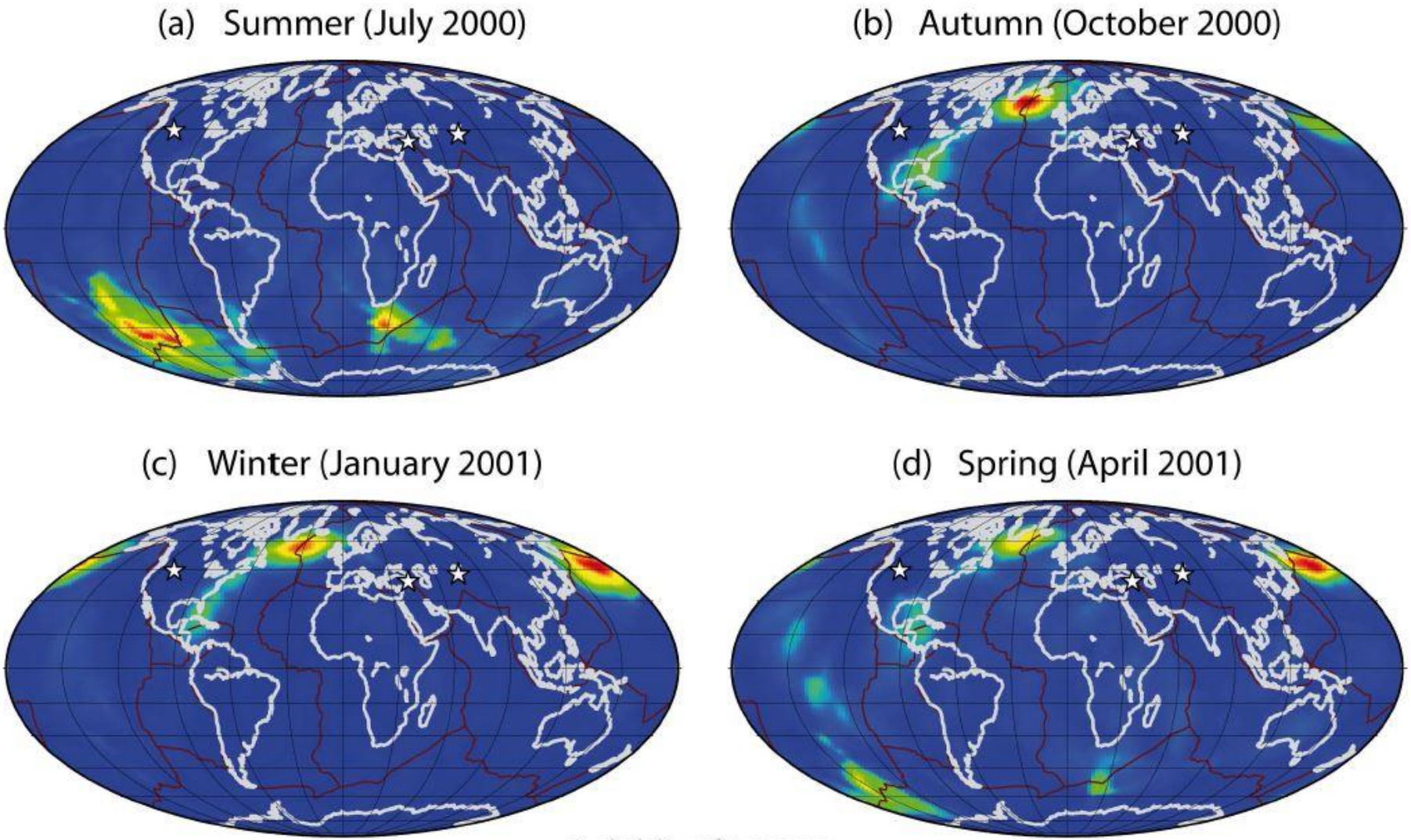


January-February:
Coherent with P wave from a source in the northern Pacific (~40°N ,~180°E)

Correlations are dominated by ballistic bodywaves from a specific source area (or more complex filtering effects, see Poli, Campillo, van der Hoop (in revision)

Known locations of P-wave seismic sources

(2nd microseismic peak)

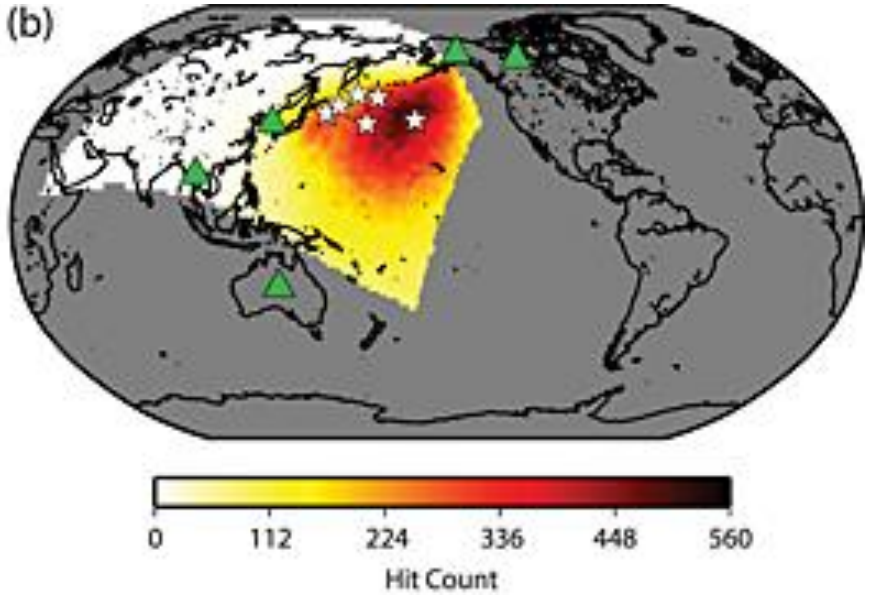


Landes et al., 2010

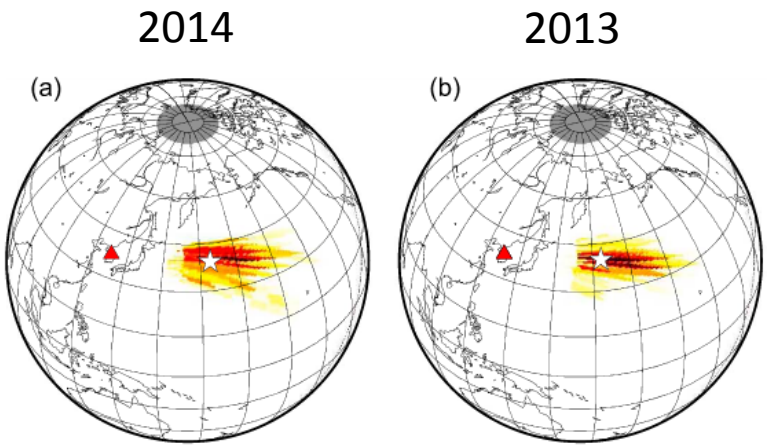
See also Obrebski et al., 2013; Sheen and Shin, 2016

Known locations of P-wave seismic sources (2nd microseismic peak)

Body wave noise sources (Pyle et al., 2015). White stars: Sources observed by Obrebski et al. 2013.

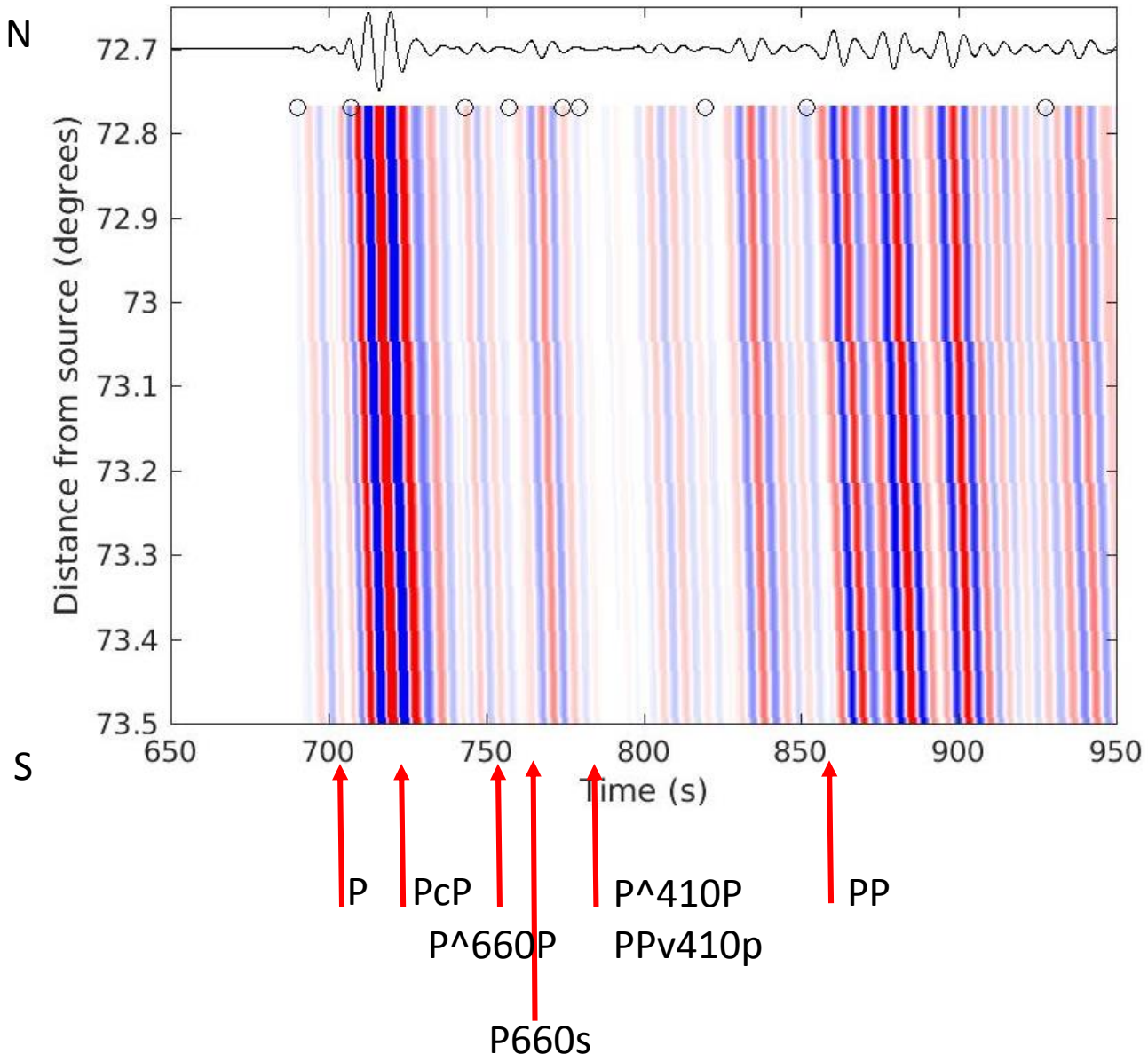


Body wave noise sources observed by Sheen and Shin (2016)



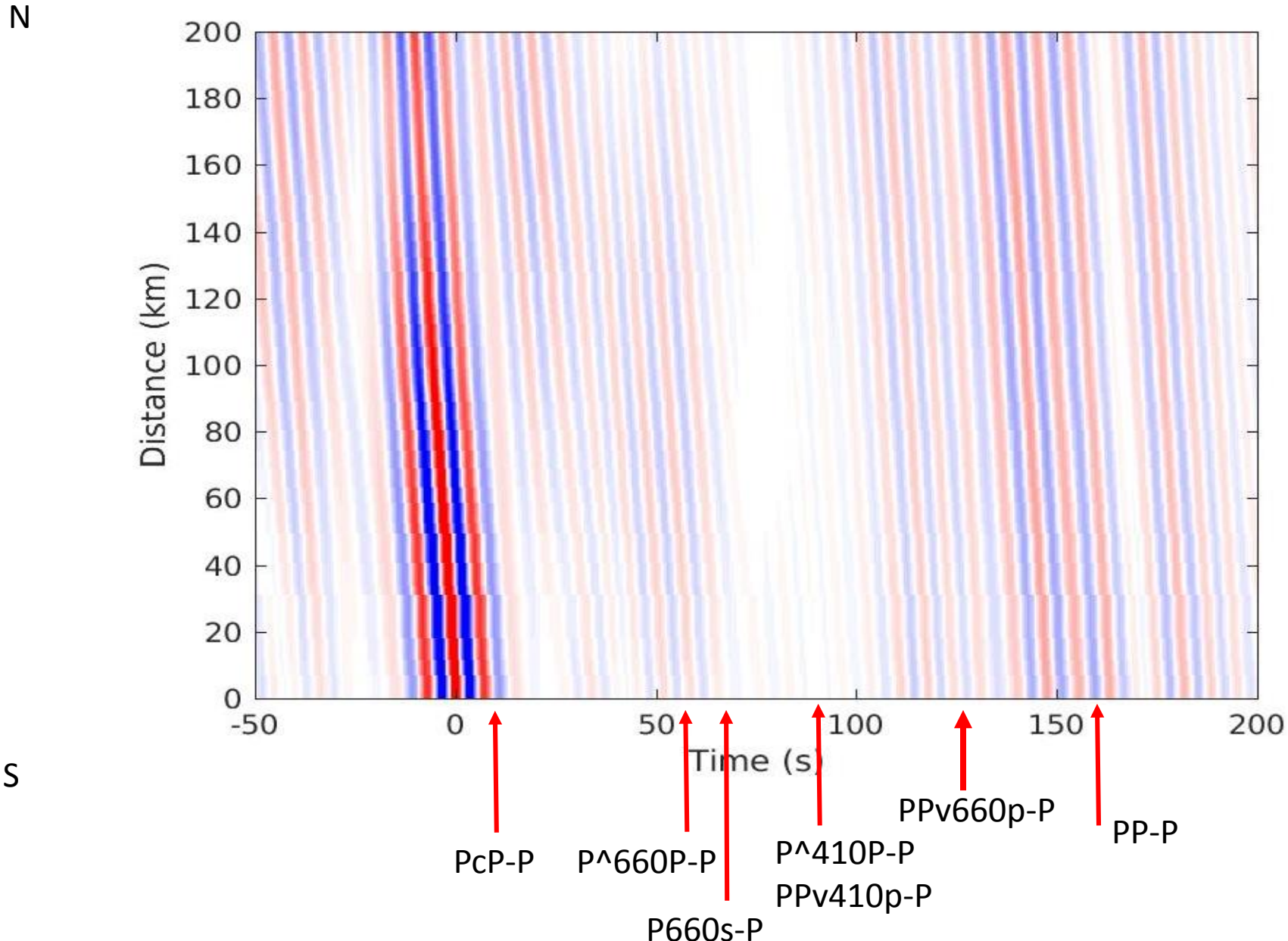
Synthetic Seismograms :

vertical point source at (~40°N ,~180°E)

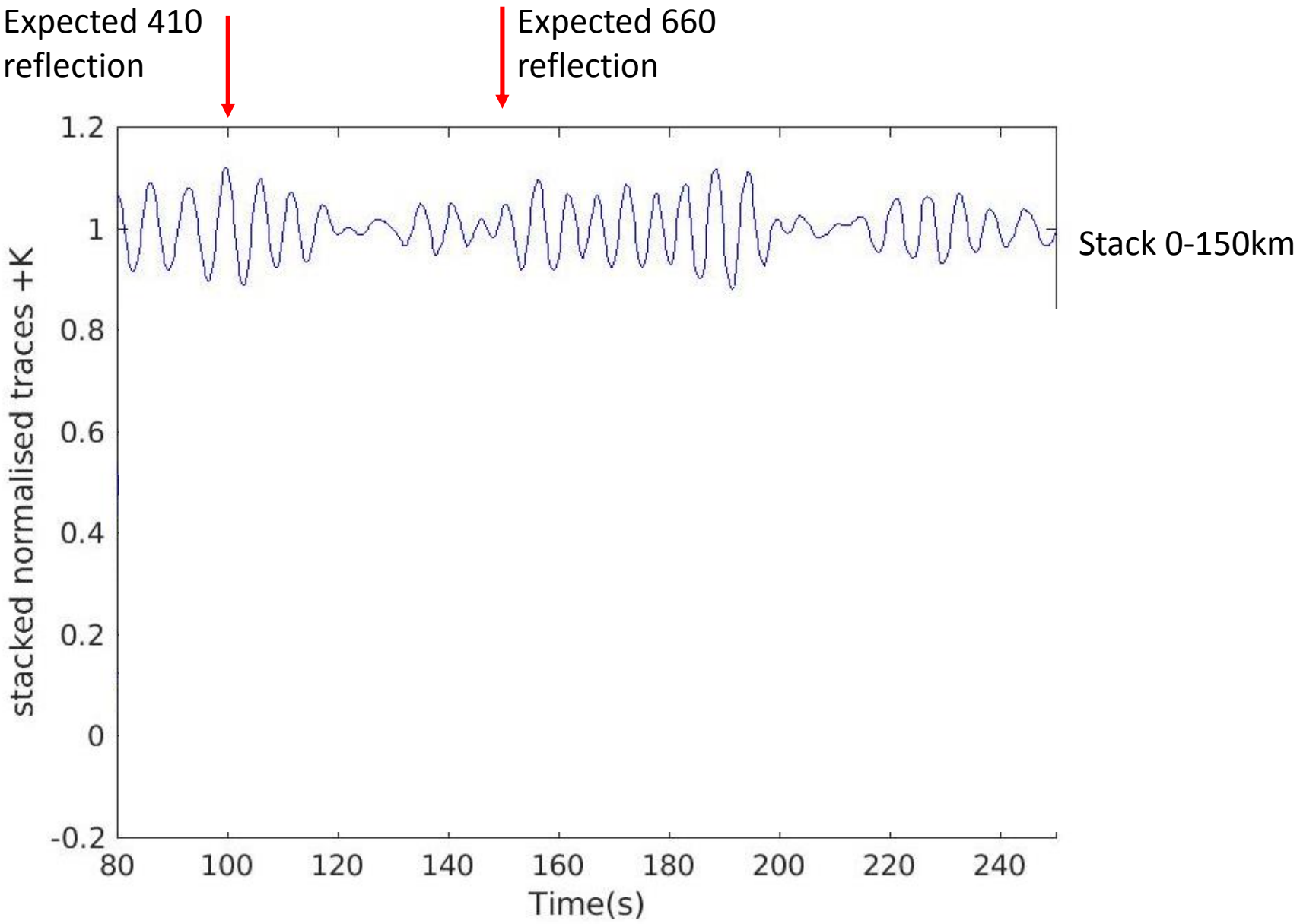


Correlations of synthetic seismograms

vertical point source at (~40°N ,~180°E)



Stacking the correlations (normalised for t>80s)



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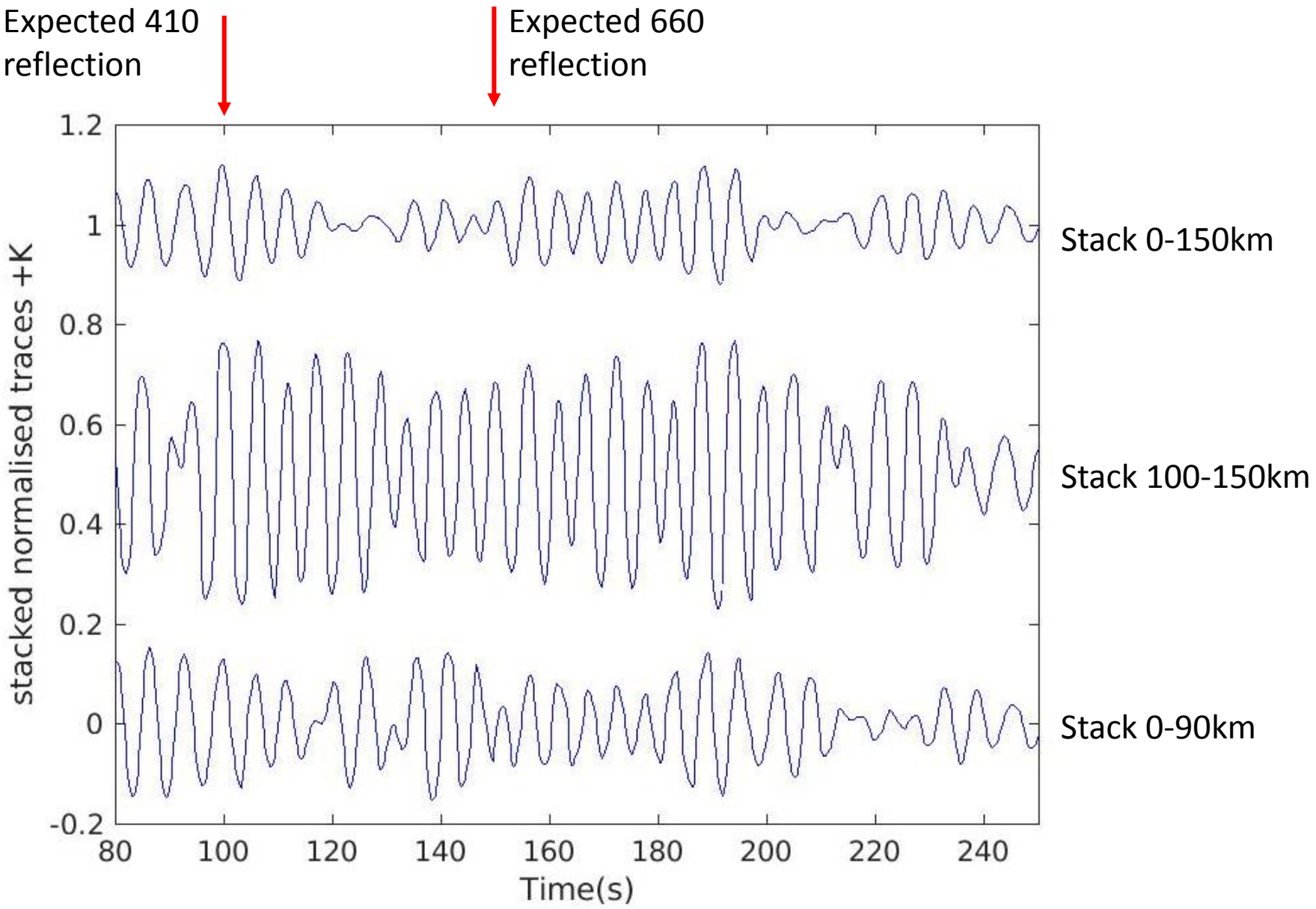

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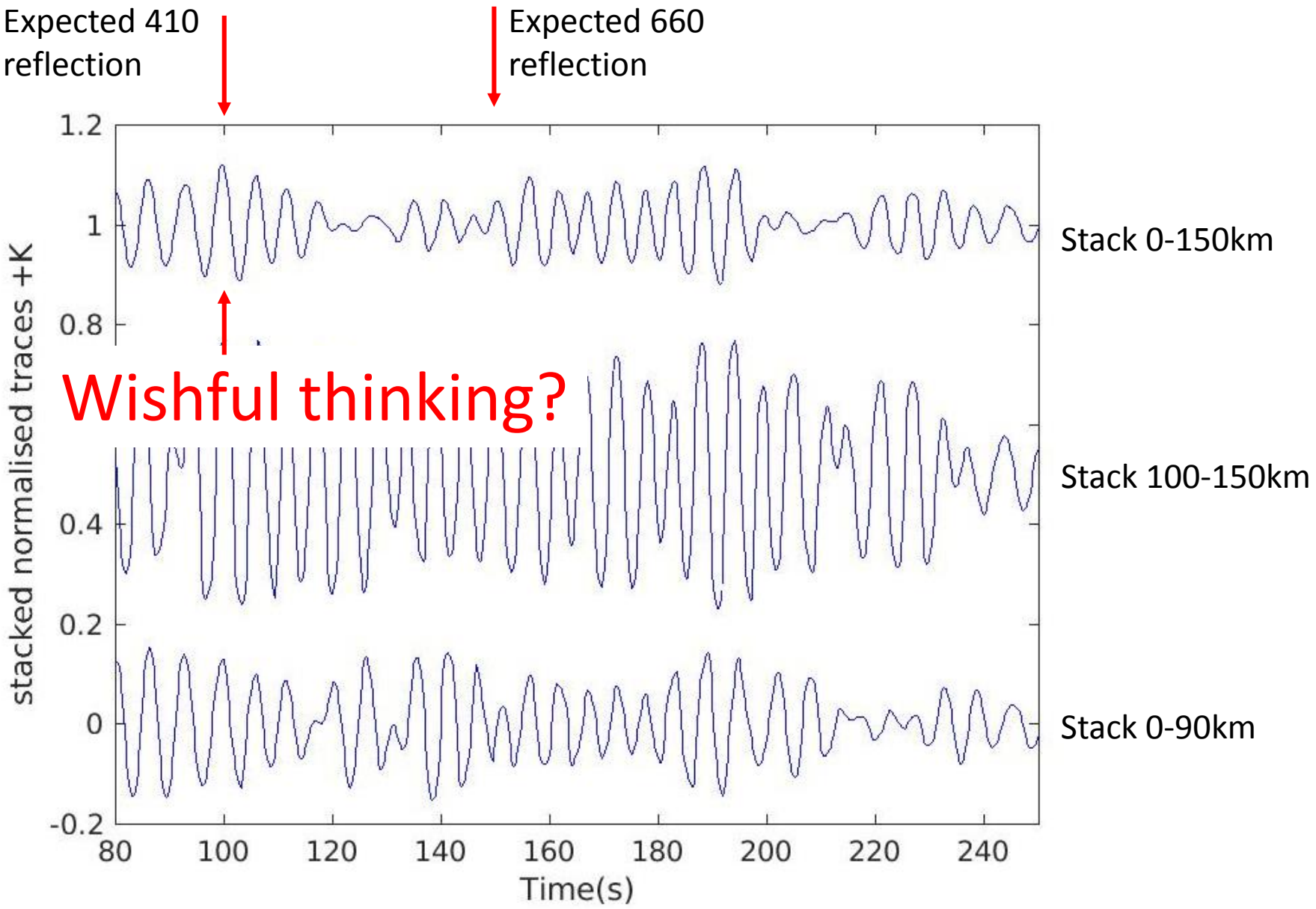
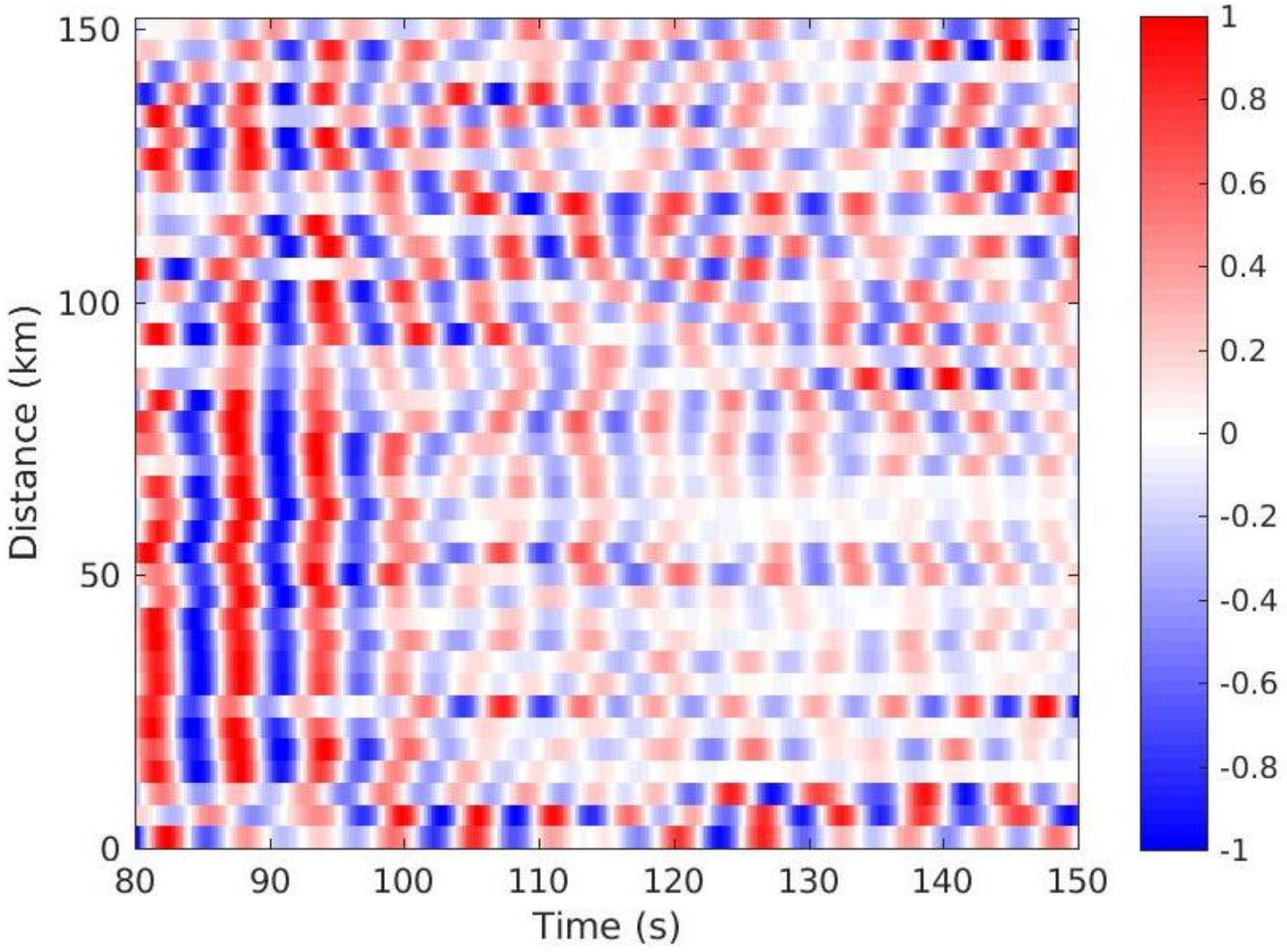
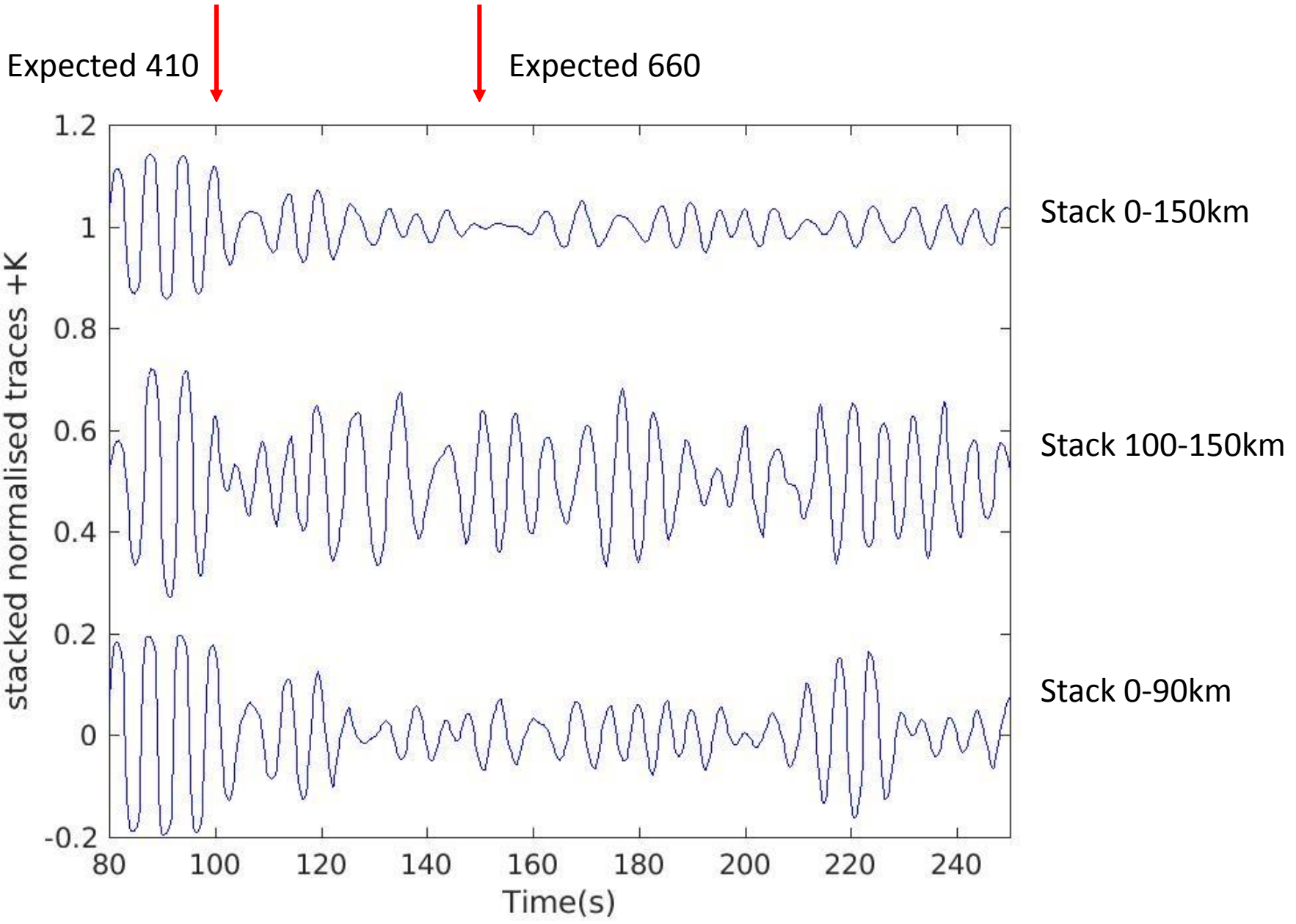


Shifting traces

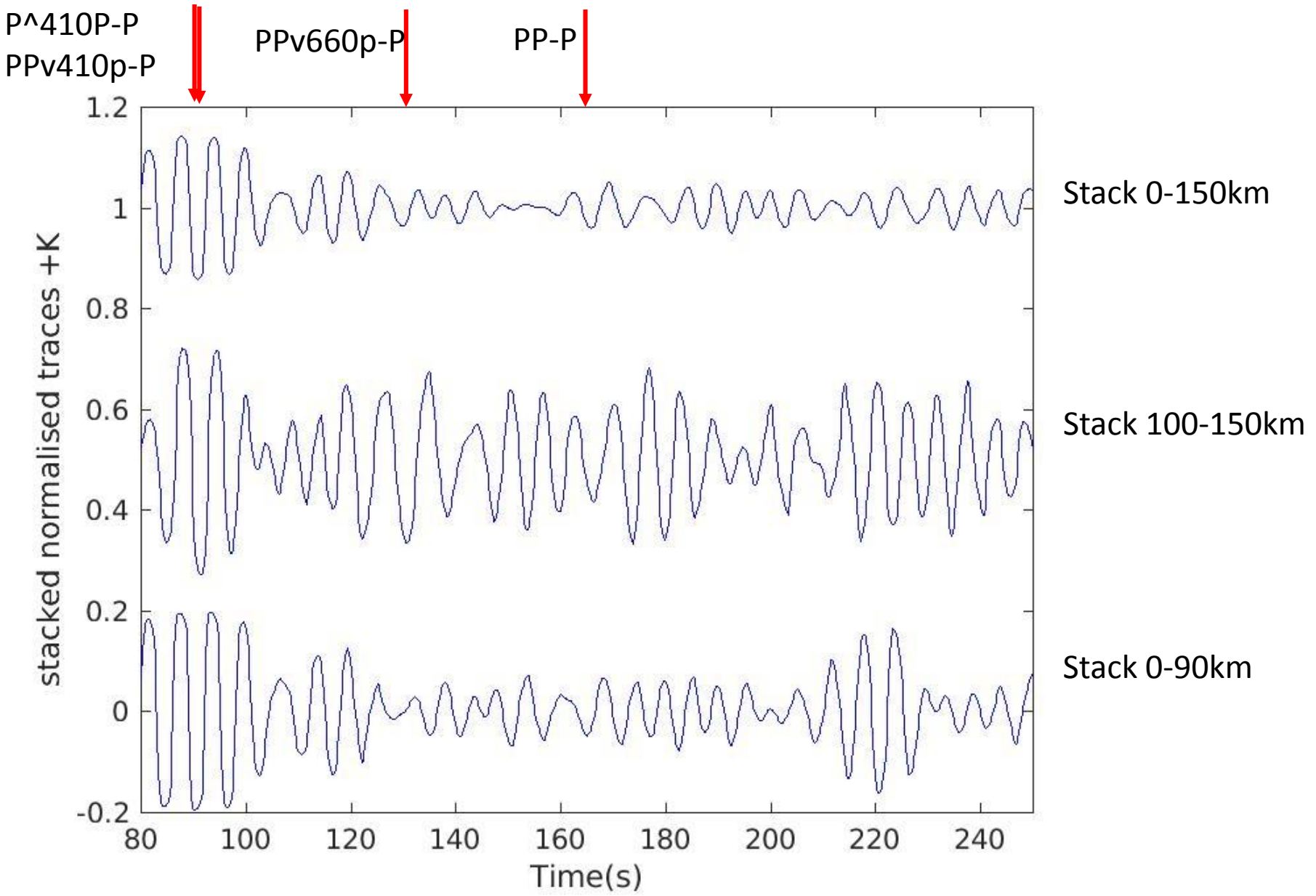
A: Traces shifted so max(trace) is at t=0s



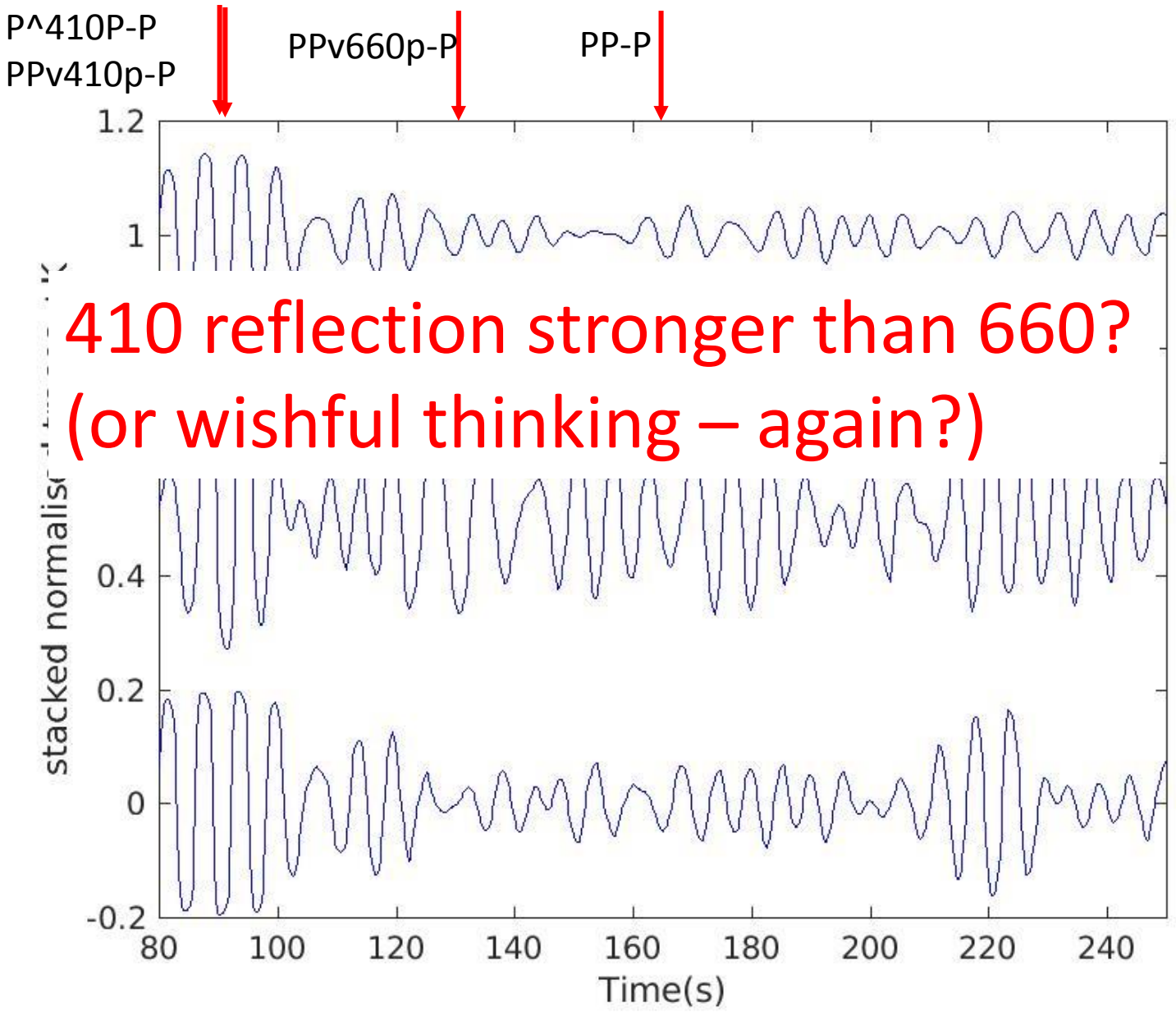
Stacking shifted traces (normalised for t>80s)



Stacking shifted traces (normalised for t>80s)



Subtracting main field by SVD



410 reflection stronger than 660?

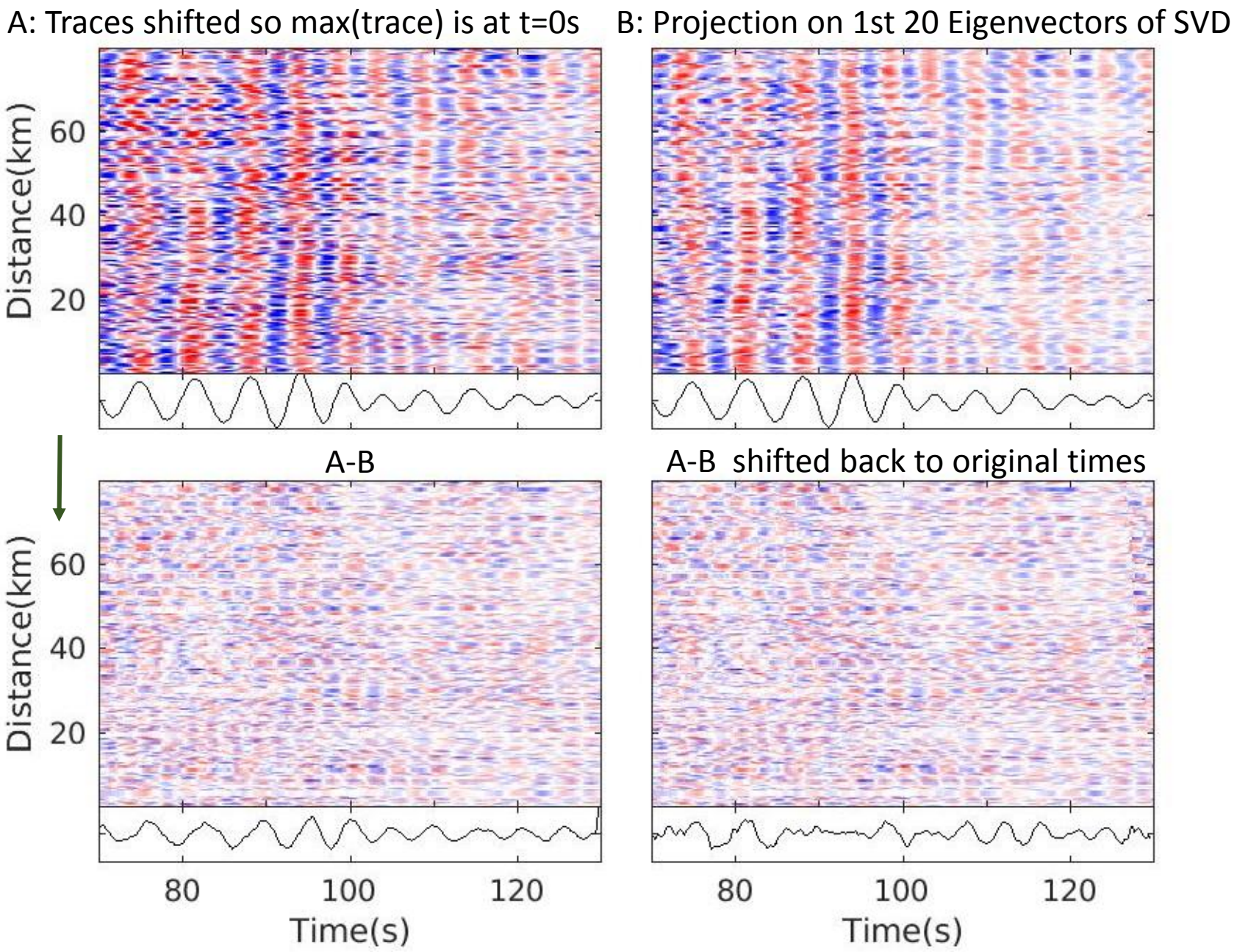
(or wishful thinking – again?)

Stack 0-150km

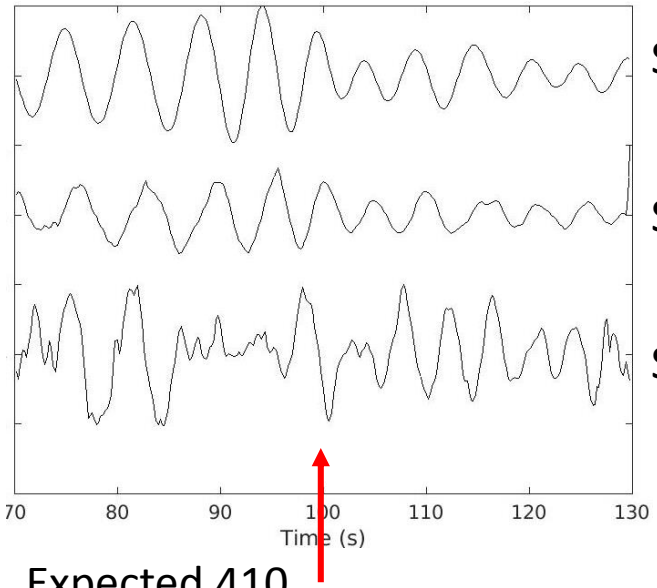
Stack 100-150km

Stack 0-90km

Subtraction of the ‘deterministic’ waves possible?



Stacks – and first conclusions



Stack of input to SVD x 1

Stack of extracted from SVD x 6.3

Stack of extracted from SVD and shifted back x 18.7

Expected 410

On HICLIMB data, second microseismic peak:

- The noise correlations are dominated by deterministic body waves almost all through the year
- The source of these body waves is likely to be located in the northern Pacific.
- These body waves are when stacked of ~20 times higher amplitudes than the stack of the remaining waves

- **Not possible to reliably extract reflections from mantle discontinuties beneath this location with the HICLIMB network geometry.**

Some general conclusions

- In some cases (location? array configuration, …) the noise correlations are dominated by deterministic body waves almost all through the year
- The spike at 't= ~0' in the second microseismic peak, observed (and muted) in many studies is not always a processing problem, but may indicate potential problems
- Large distances (Lapnet: ~ 400km) and spatial filtering (2D arrays) may be a minimum condition to respect to extract P410P and P660P
- Ultimate small distance: Autocorrelation - ???

Strong need of further diagnostic tools

And don't forget to properly cite the networks!