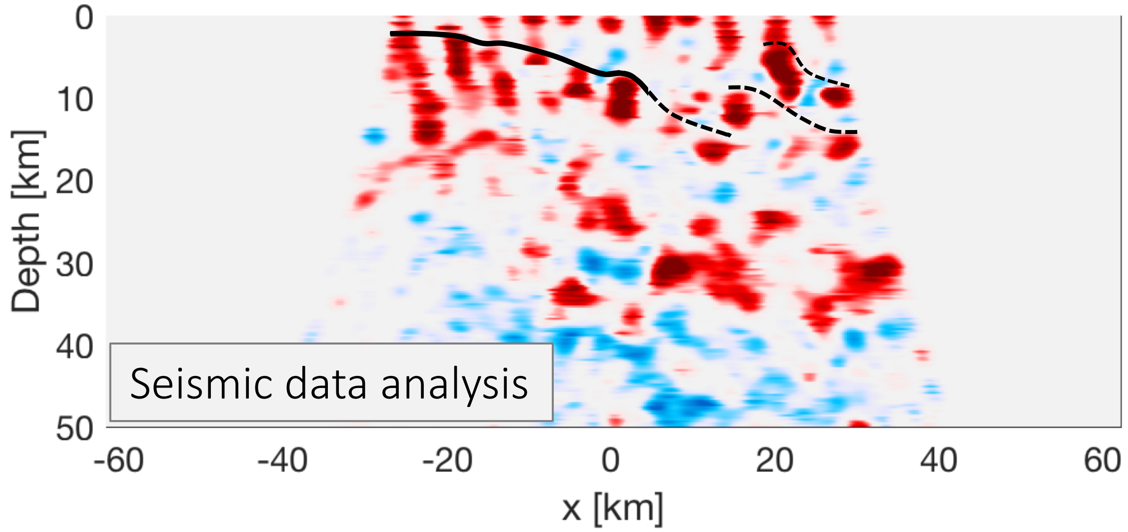
Contact: matteo.scarponi@unil.ch
Research Group: https://www.unil.ch/orog3ny/
EGU2020 08.05.2020

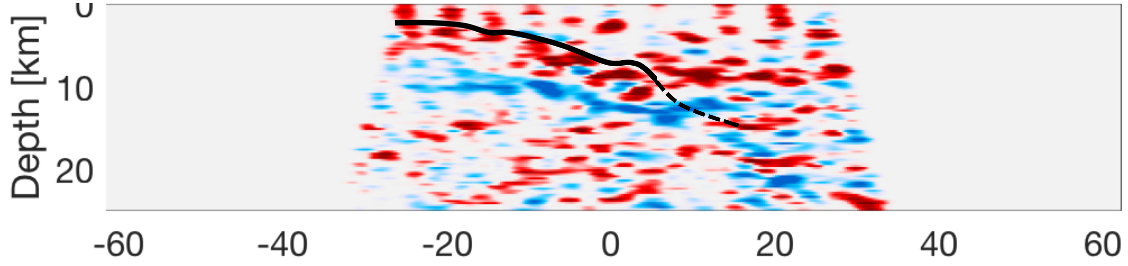
[1]University of Lausanne, Switzerland
[2]Czech Academy of Sciences, Prague
[3]INGV, Italy

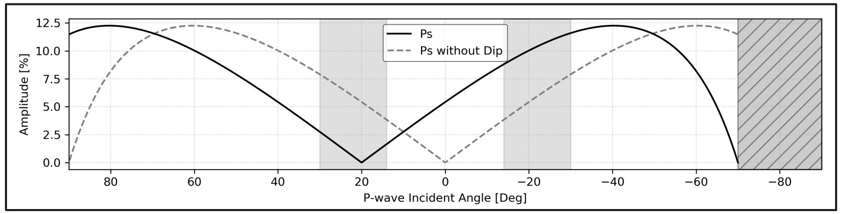
M Scarponi[1], G Hetényi[1], J Plomerová[2], S Solarino[3], L Baron[1]

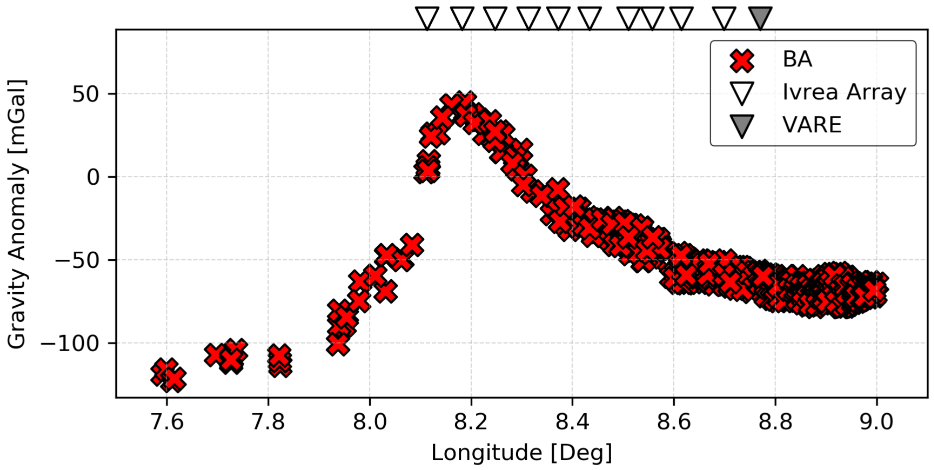
Towards receiver function analyses and joint inversion with gravity data

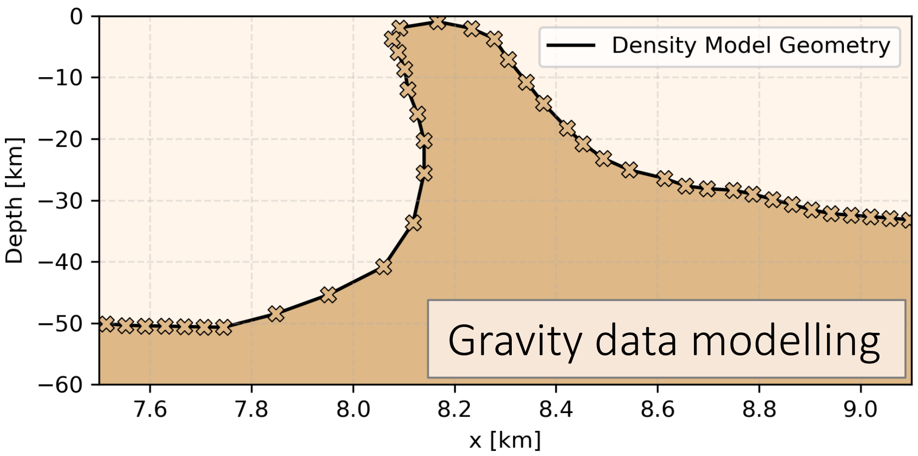
New constraints on the Ivrea geophysical body along a high-resolution profile











IvreaArray seismic network: https://doi.org/10.5281/zenodo.1038209

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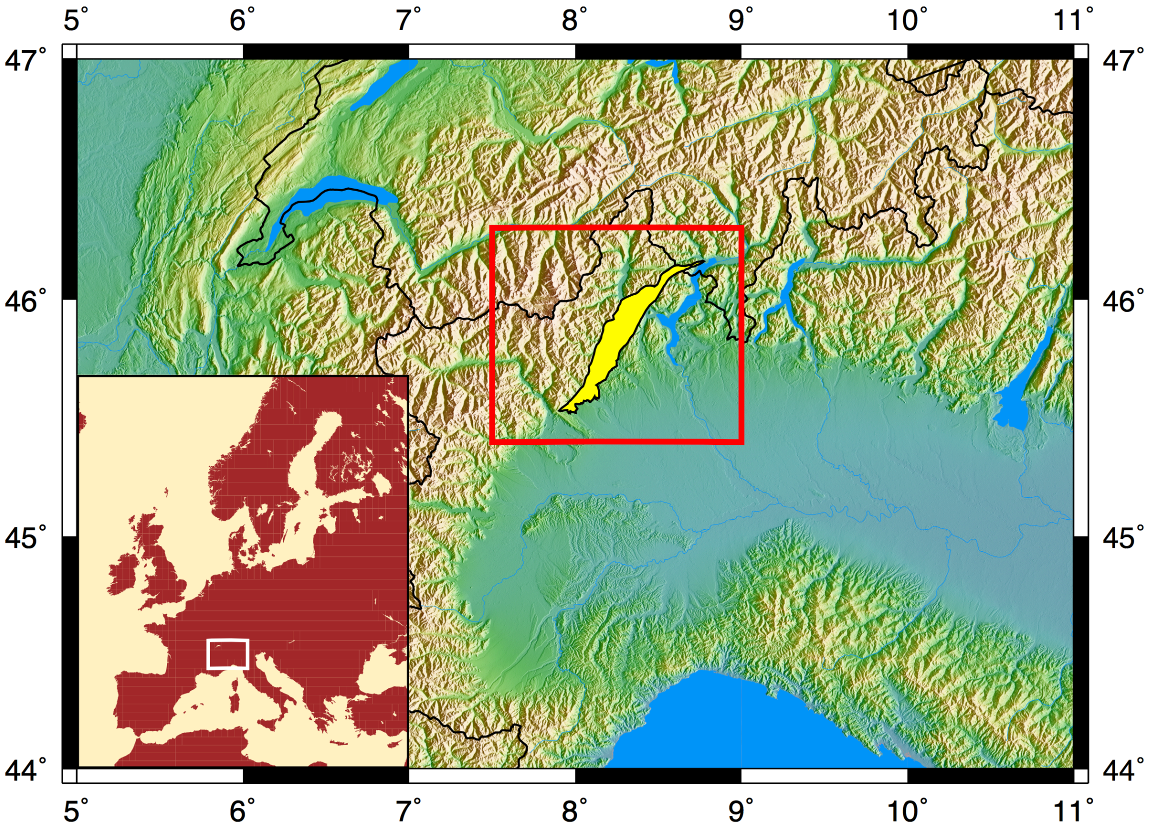
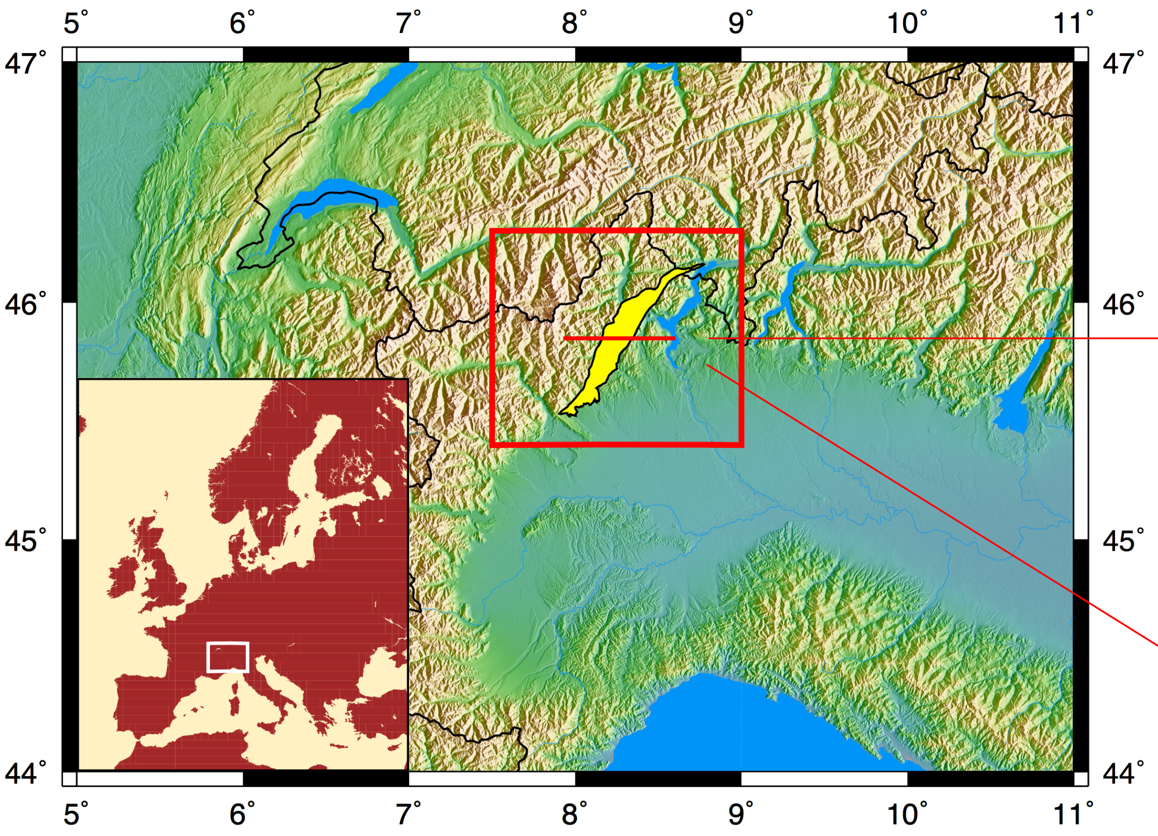
Thank you for taking the time for reading this presentation. Some comment boxes will guide the reader through the latest advances of this ongoing work.

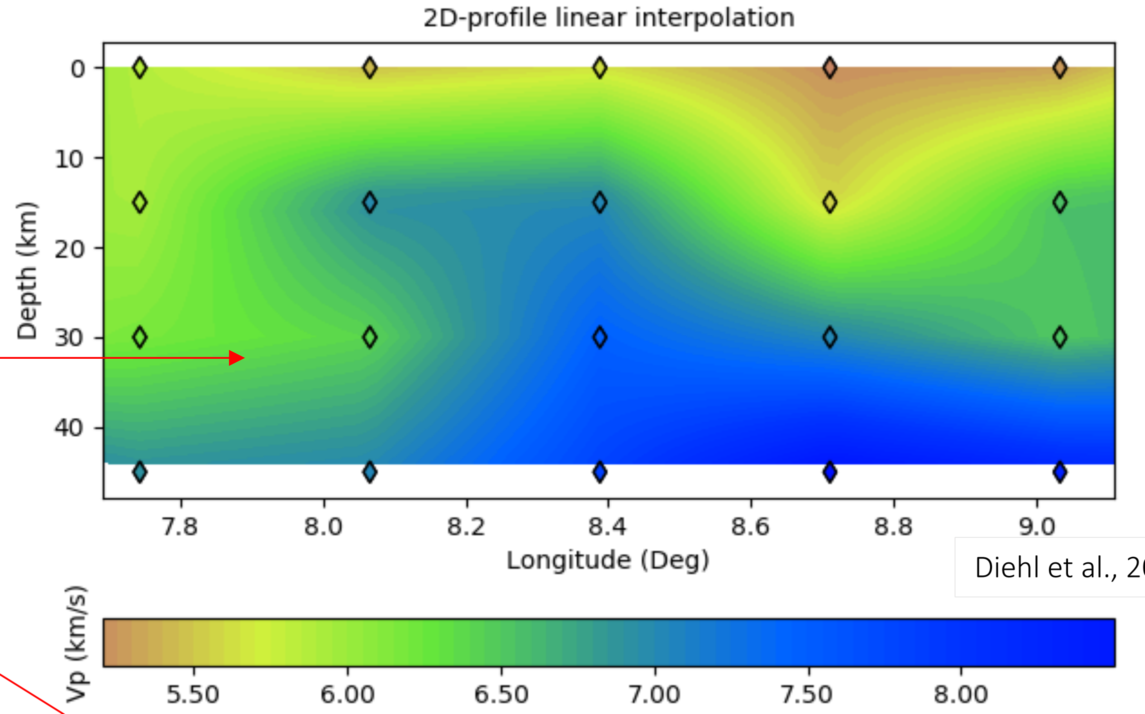
Study area



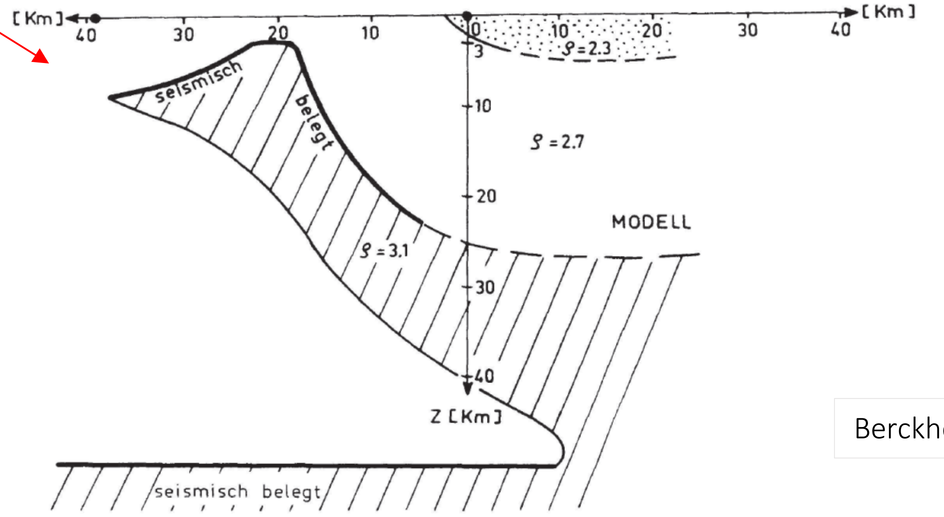
Our study area (red box) surrounds the so-called Ivrea-Verbano Zone (IVZ): a well-known geological complex that exposes an almost-complete crustal cross-section at the surface (e.g. Fountain et al. 1976), located at the boundary between the European and Adriatic plate (e.g. Schmid et al 2017).

Study area





Diehl et al., 2009



Berckhemer, 1968

As documented by many authors, the crustal roots of the IVZ host a pronounced seismic (e.g. Diehl et al. 2009) and positive gravity anomaly (e.g. Berckhemer 1968), to which we refer as **Ivrea Geophysical Body** (IGB).

Main Purpose and strategy

- Perform a higher-resolution imaging of the IGB
- Analyze its structure and composition with respect to the surrounding crust

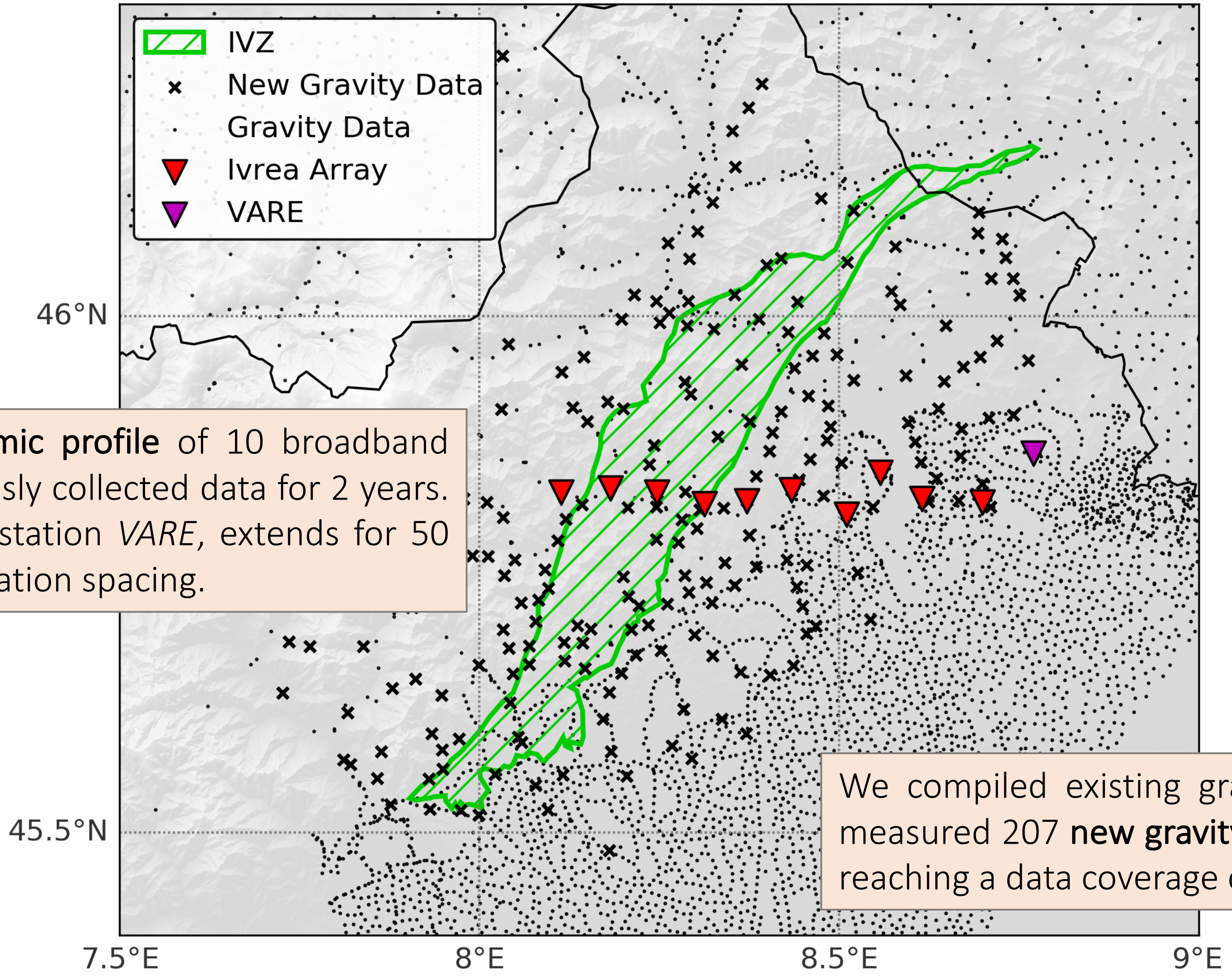
How:

1. New seismic data collected
    1. Receiver functions (RFs) computation
    2. RFs analyses and migration
    3. RFs inversion
    4. Velocity gradient analysis

2. New relative gravity data collected
    1. Bouguer gravity anomaly computation
    2. Density modelling

3. Seismic and gravity joint inversion

New seismic and gravity data



IvreaArray is a **West-East seismic profile** of 10 broadband seismic stations, that continuously collected data for 2 years. The profile, together with the station *VARE*, extends for 50 km and presents a 5 km inter-station spacing.

We compiled existing gravity data in the area and we measured 207 **new gravity data points** (crosses in figure), reaching a data coverage of ~ 0 to 9 pt/km^2.

What is a receiver function (RF) ?

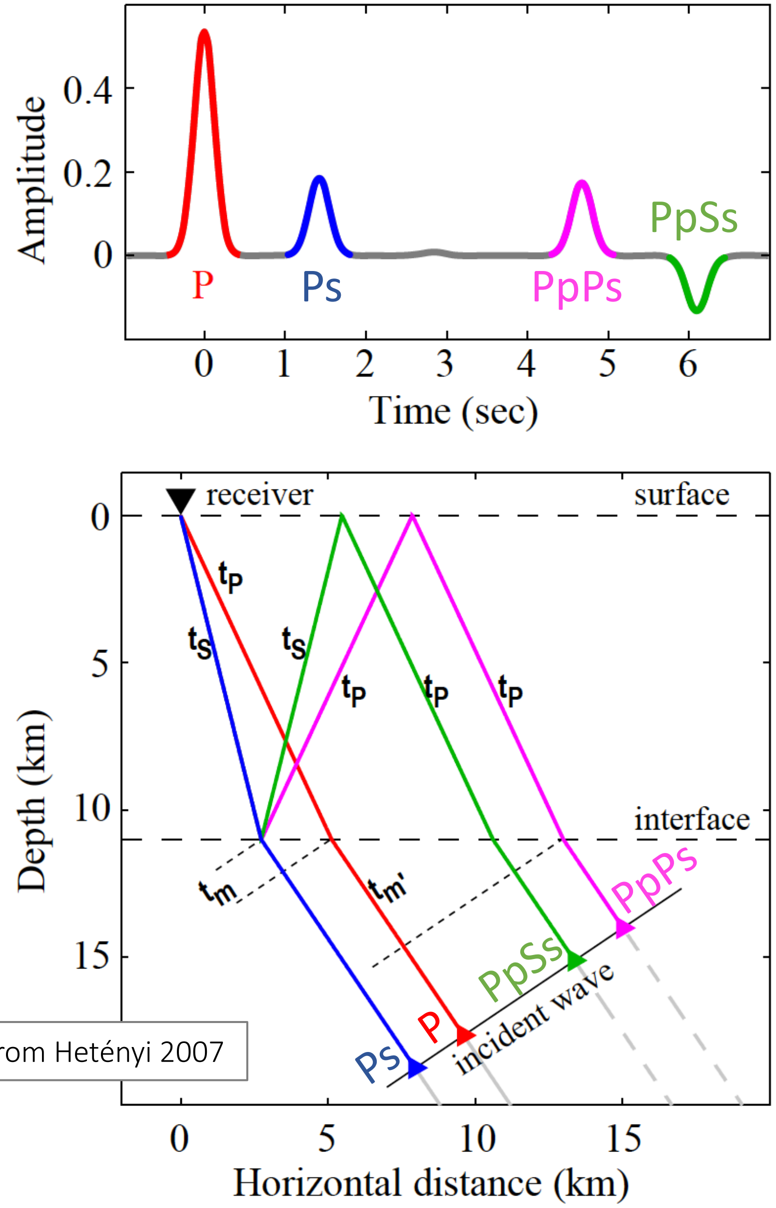


Image from Hetényi 2007

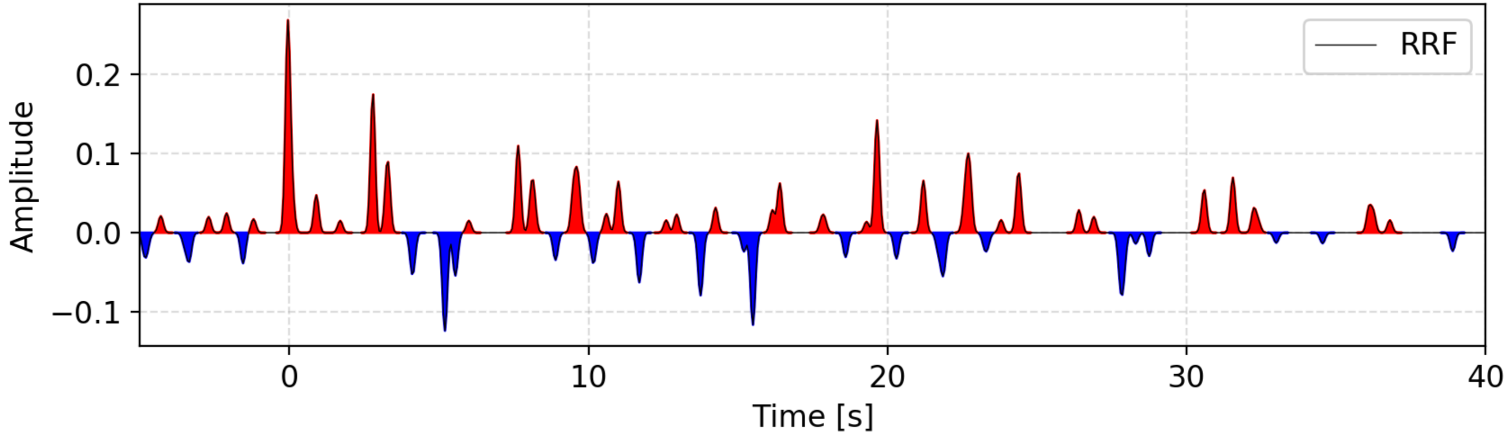
(**Top**) Example of a synthetic RF in case of a simple setting with a planar interface, representing a seismic discontinuity.

(**Bottom**) Example of teleseismic P-wave reaching a seismic discontinuity. Together with the P-wave, converted phases such as P-to-S (Ps) and their multiple reflections are produced when a P-wave is crossing the interface.

The slower converted phases are generated just after the P-wave arrival, producing the signals indicated in the top panel (Ps, PpPs and PpSs).

How are RFs migrated?

1) The RFs are computed through deconvolution of the radial component from the vertical component.

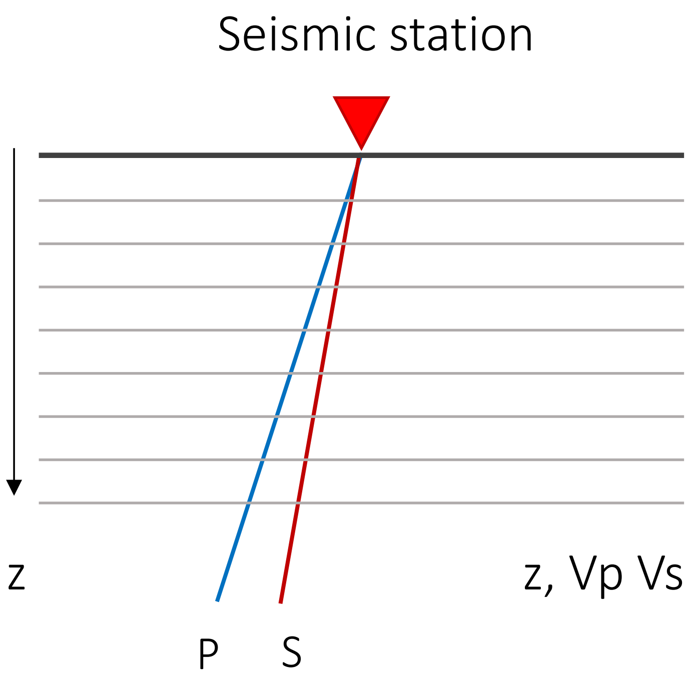


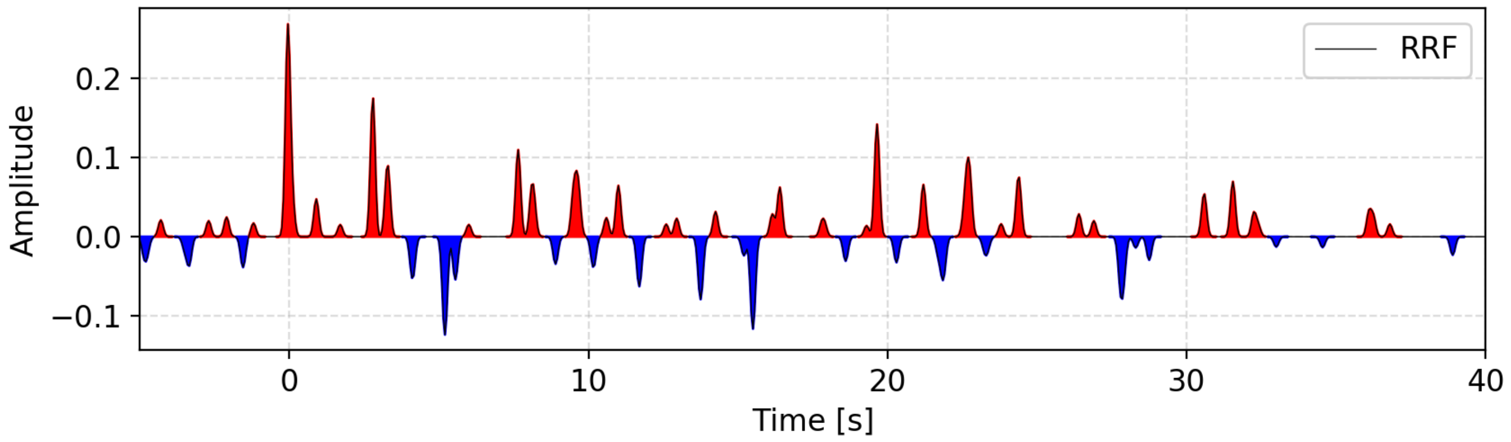
In this case, we used the time-domain iterative deconvolution technique from Ligorría and Ammon (1999).

How are RFs migrated?

1) The RFs are computed through deconvolution of the radial component from the vertical component.

2) Ray tracing is performed for each RF of the catalog, along a 1-D velocity model for Vp and Vs seismic velocities.





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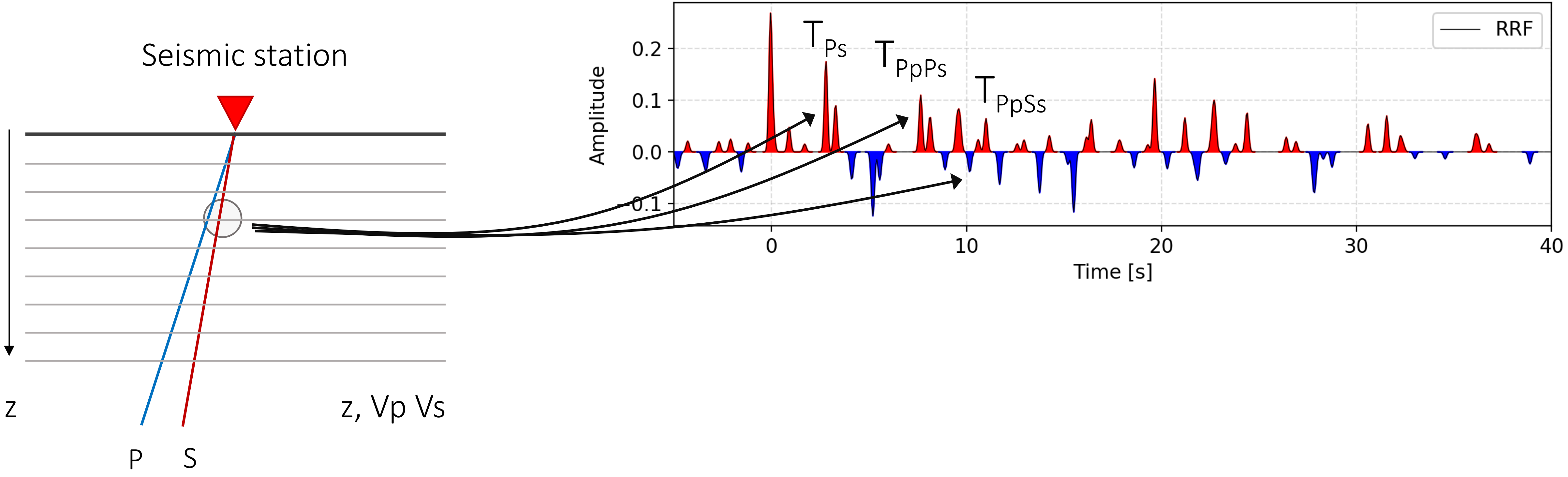
1) The RFs are computed through deconvolution of the radial component from the vertical component.
2) Ray tracing is performed for each RF of the catalog, along a 1-D velocity model for Vp and Vs seismic velocities.
3) Theoretical travel-times are computed for Ps- , PpPs- and PpSs-phases at each z along the ray path.



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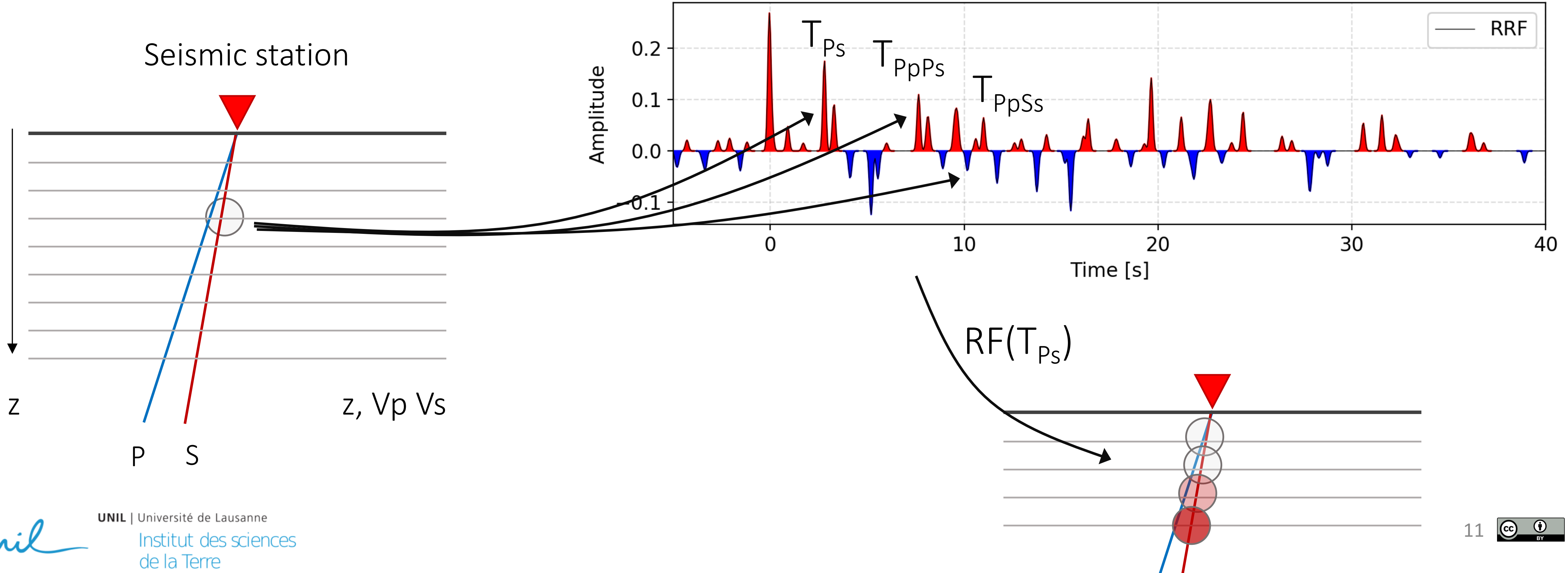
3) Theoretical travel-times are computed for Ps- , PpPs- and PpSs-phases at each z along the ray path.
4) Amplitudes from the observed RFs are stacked along the ray paths, high-lighting the best-fitting depths.



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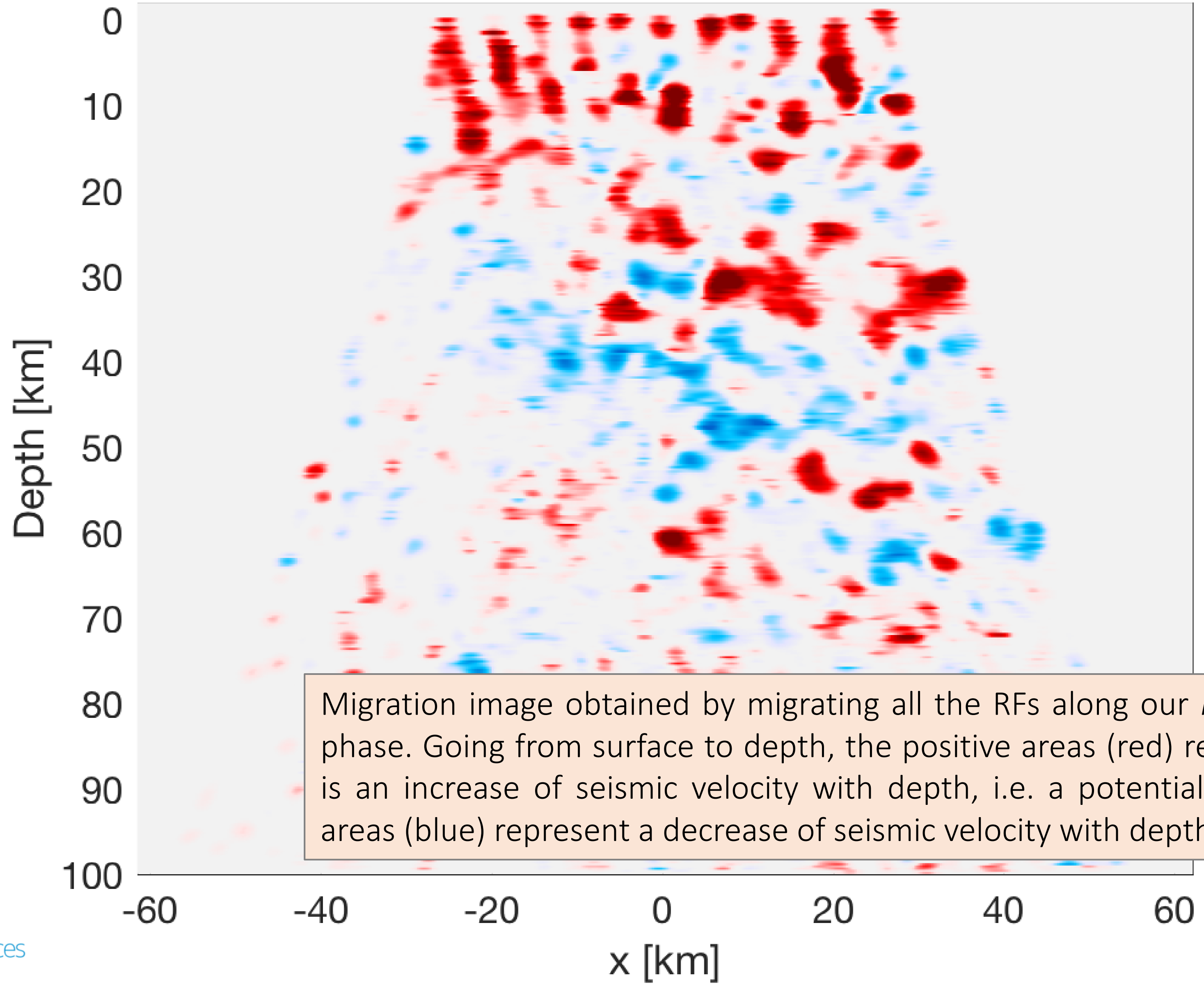
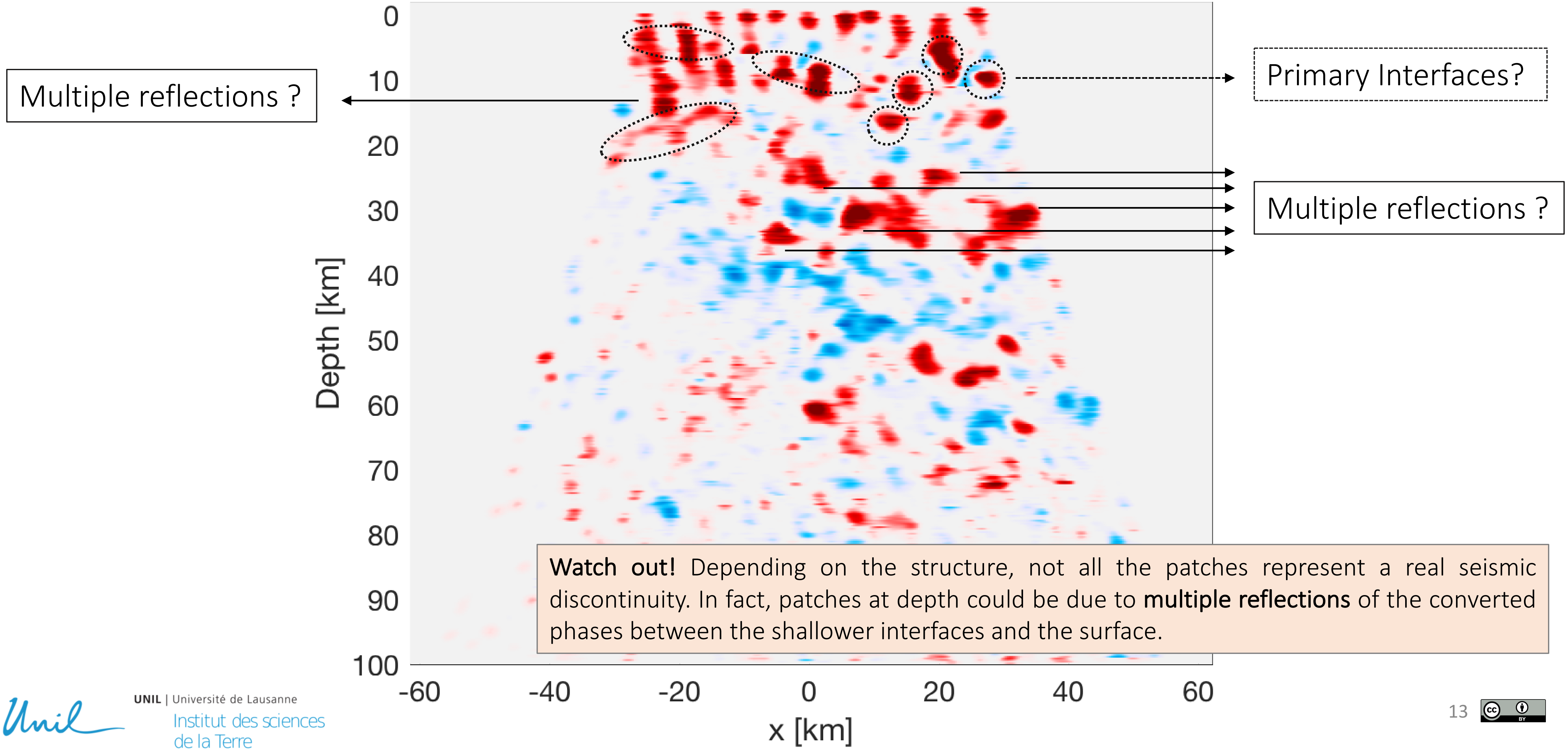
Ps-phase migration



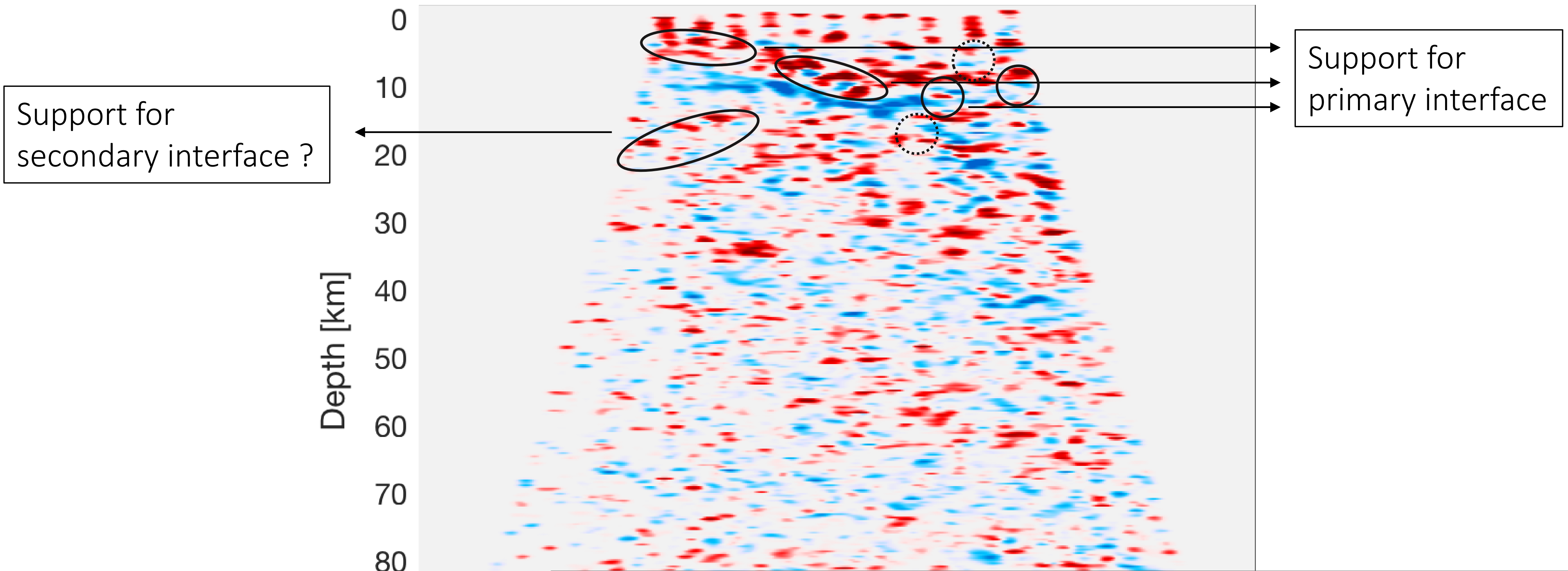
Migration image obtained by migrating all the RFs along our *IvreaArray* profile, for the Ps-phase. Going from surface to depth, the positive areas (red) represent areas in which there is an increase of seismic velocity with depth, i.e. a potential interface. Similarly, negative areas (blue) represent a decrease of seismic velocity with depth.

Ps-phase migration



Watch out! Depending on the structure, not all the patches represent a real seismic discontinuity. In fact, patches at depth could be due to **multiple reflections** of the converted phases between the shallower interfaces and the surface.

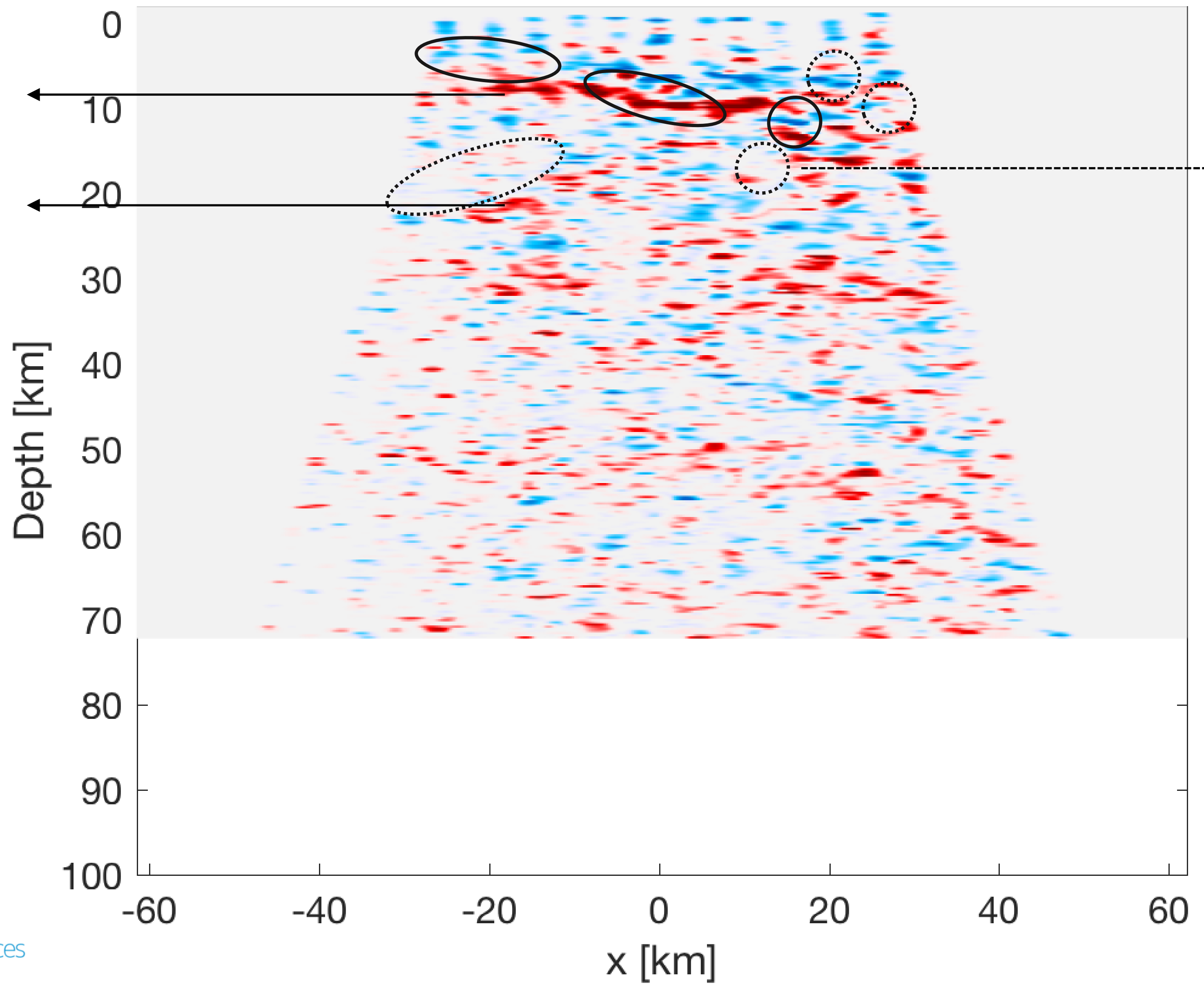
PpPs-phase migration



Migrating the converted-phases multiple reflections (*multiples*) can help looking for further support for the existence of a seismic discontinuity. When a signal is constructively stacked at the same depth among different phases, it supports the existence of a real interface.

PpSs-phase migration

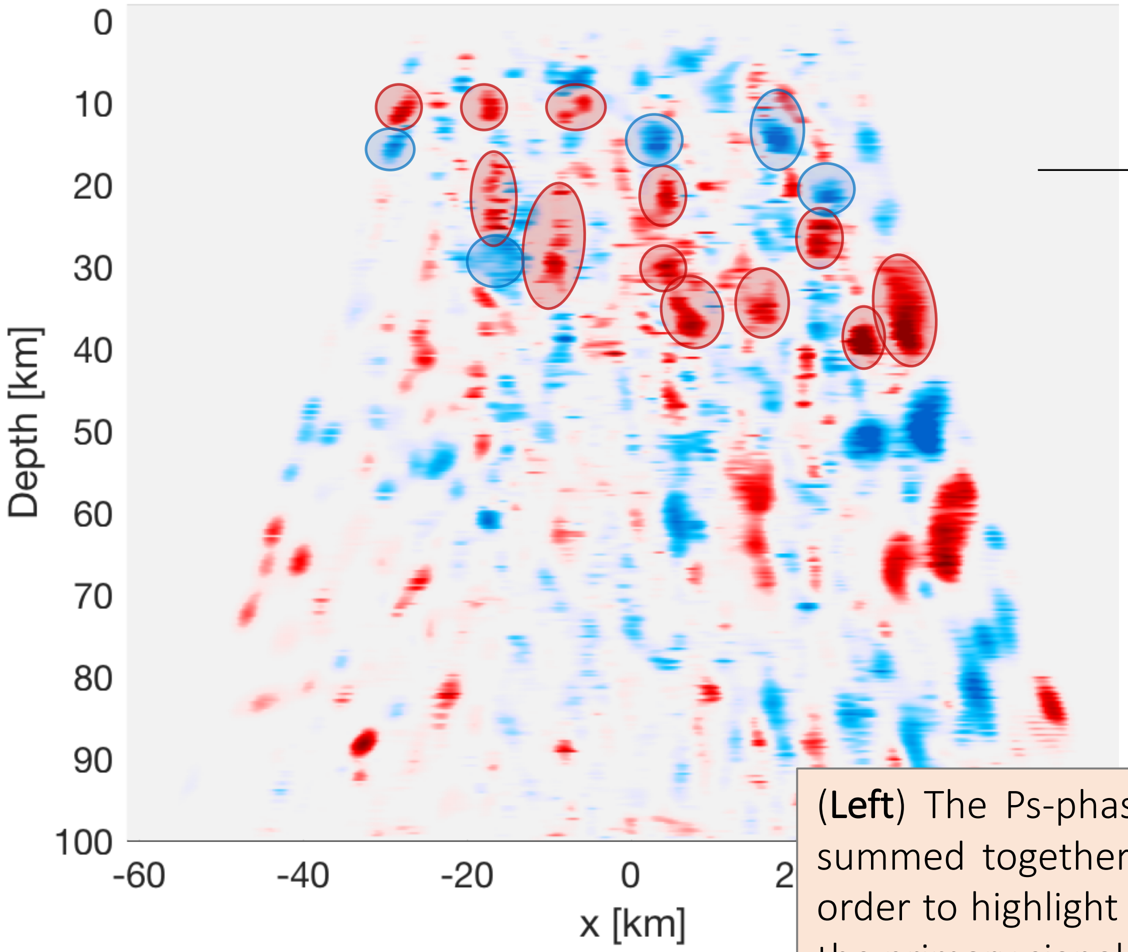
Here signal is visible, but shifted. May be due to the simplistic velocity model.



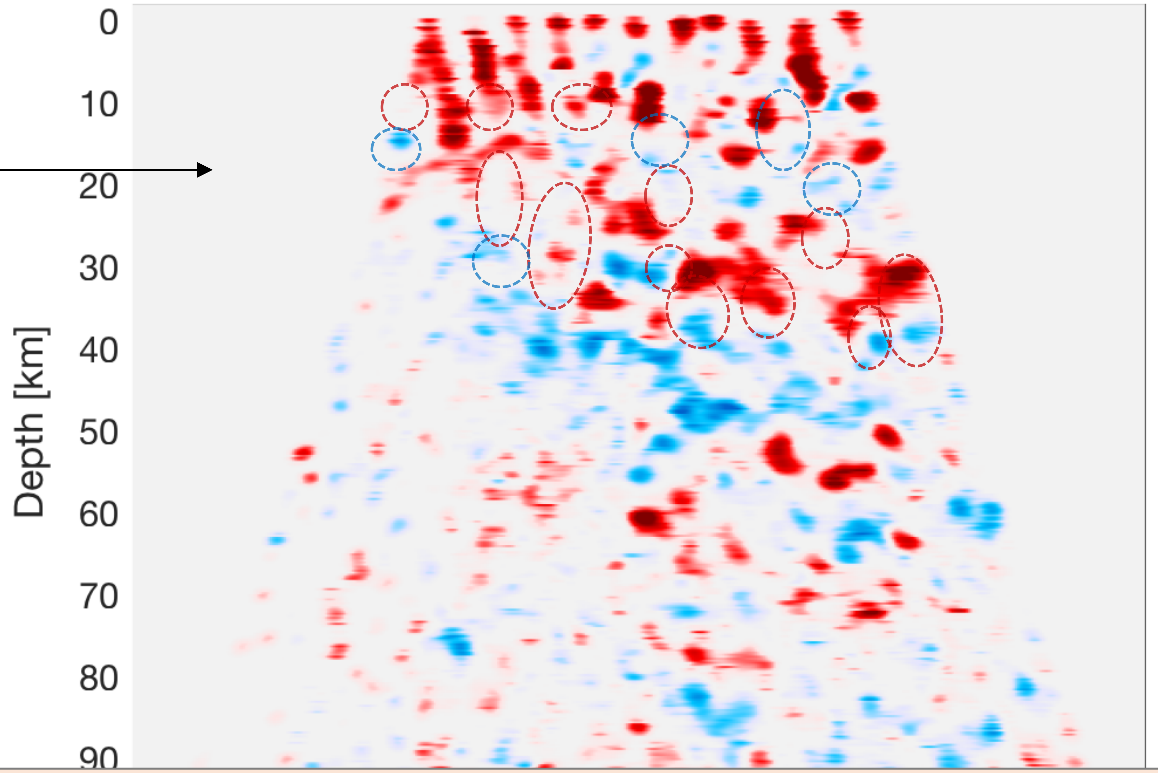
This provides no further support for a real interface.

Ps as PpPs+PpSs -phase migration

Ps as PpPs+PpSs

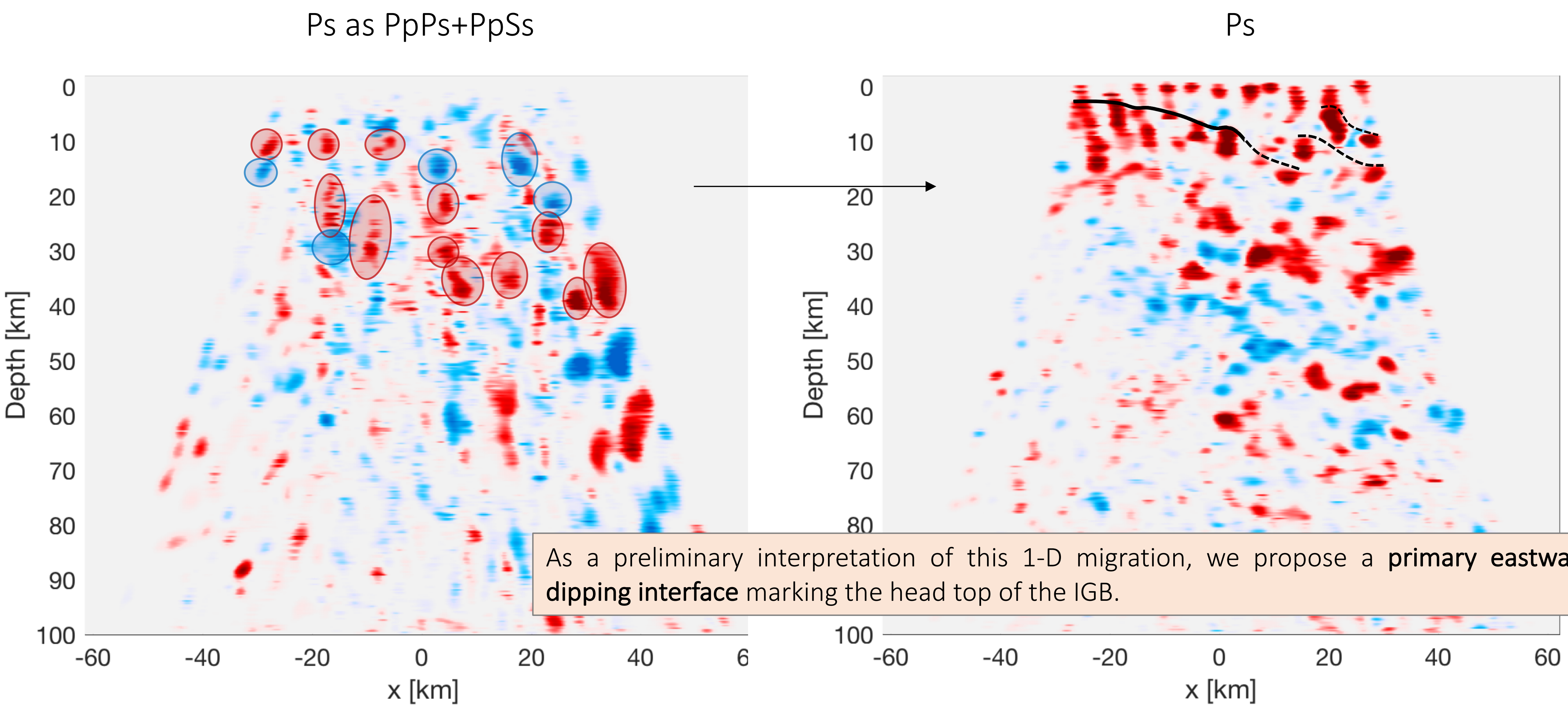


Ps



(**Left**) The Ps-phase is migrated as a PpPs- and as a PpSs-multiple respectively, and then summed together. In practice, this corresponds to a *stretching of* the Ps-phase image, in order to highlight the areas where the corresponding multiples could fall and interfere with the primary signal. (**Right**) Ps-phase migration.

Ps as PpPs+PpSs -phase migration



As a preliminary interpretation of this 1-D migration, we propose a **primary eastward-dipping interface** marking the head top of the IGB.

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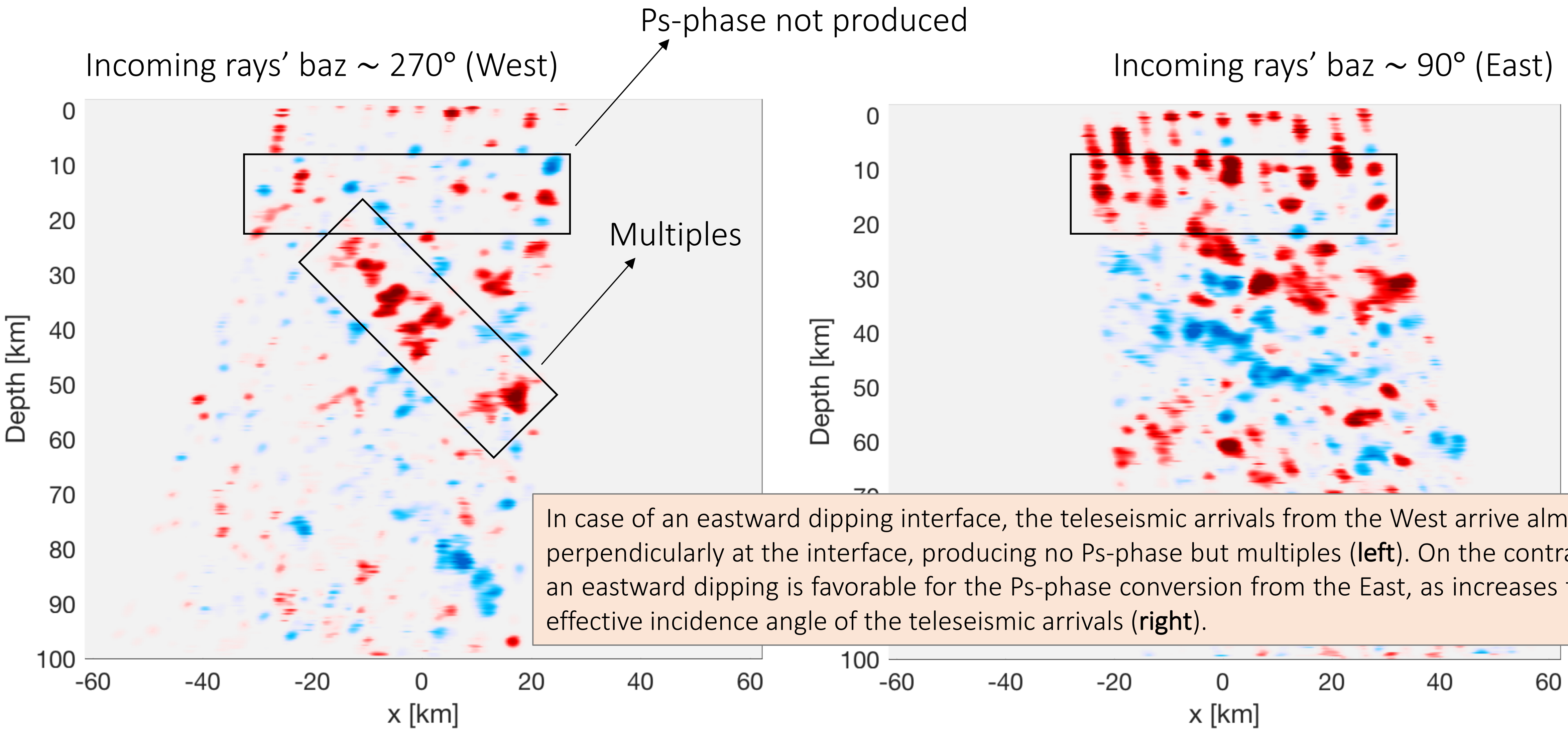
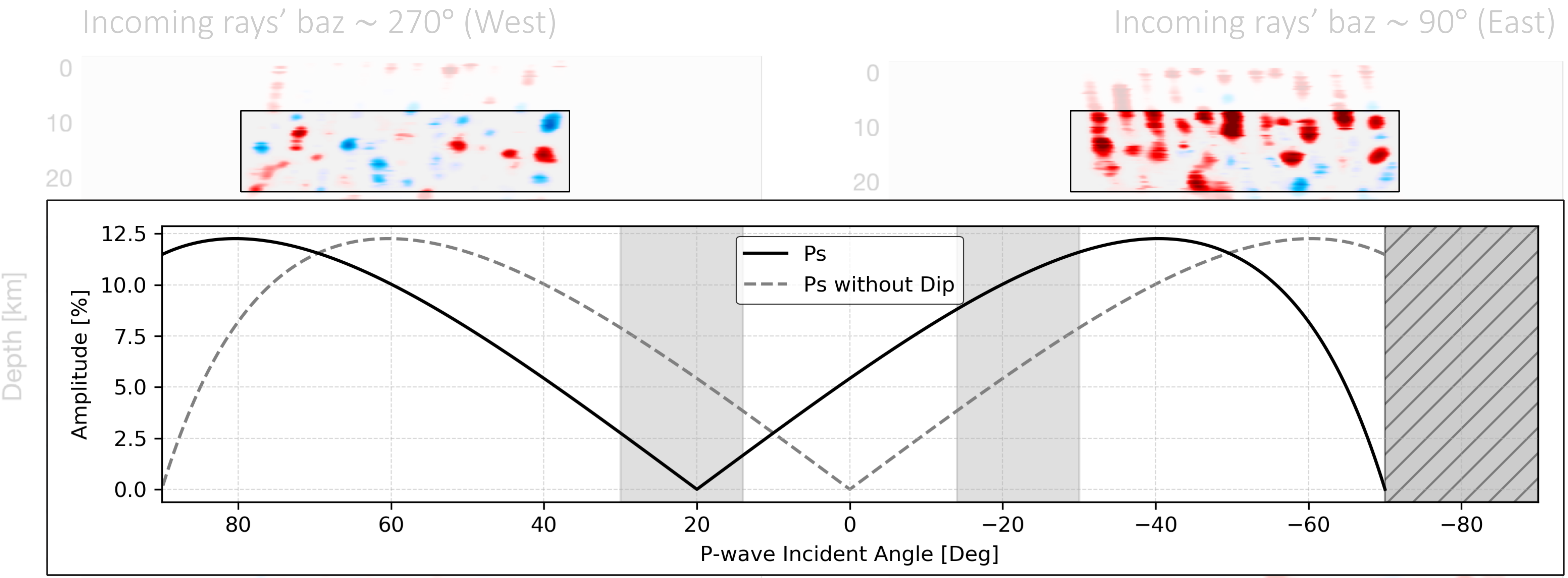
Ps-phase migration back-azimuthal dependence



In case of an eastward dipping interface, the teleseismic arrivals from the West arrive almost perpendicularly at the interface, producing no Ps-phase but multiples (**left**). On the contrary, an eastward dipping is favorable for the Ps-phase conversion from the East, as increases the effective incidence angle of the teleseismic arrivals (**right**).

Ps-phase migration back-azimuthal dependence



Expected Ps-phase amplitude with an eastward dipping interface, as a function of the incoming P-wave incident angle. The gray-shaded area indicates the range of the incident angles of teleseismic arrivals.

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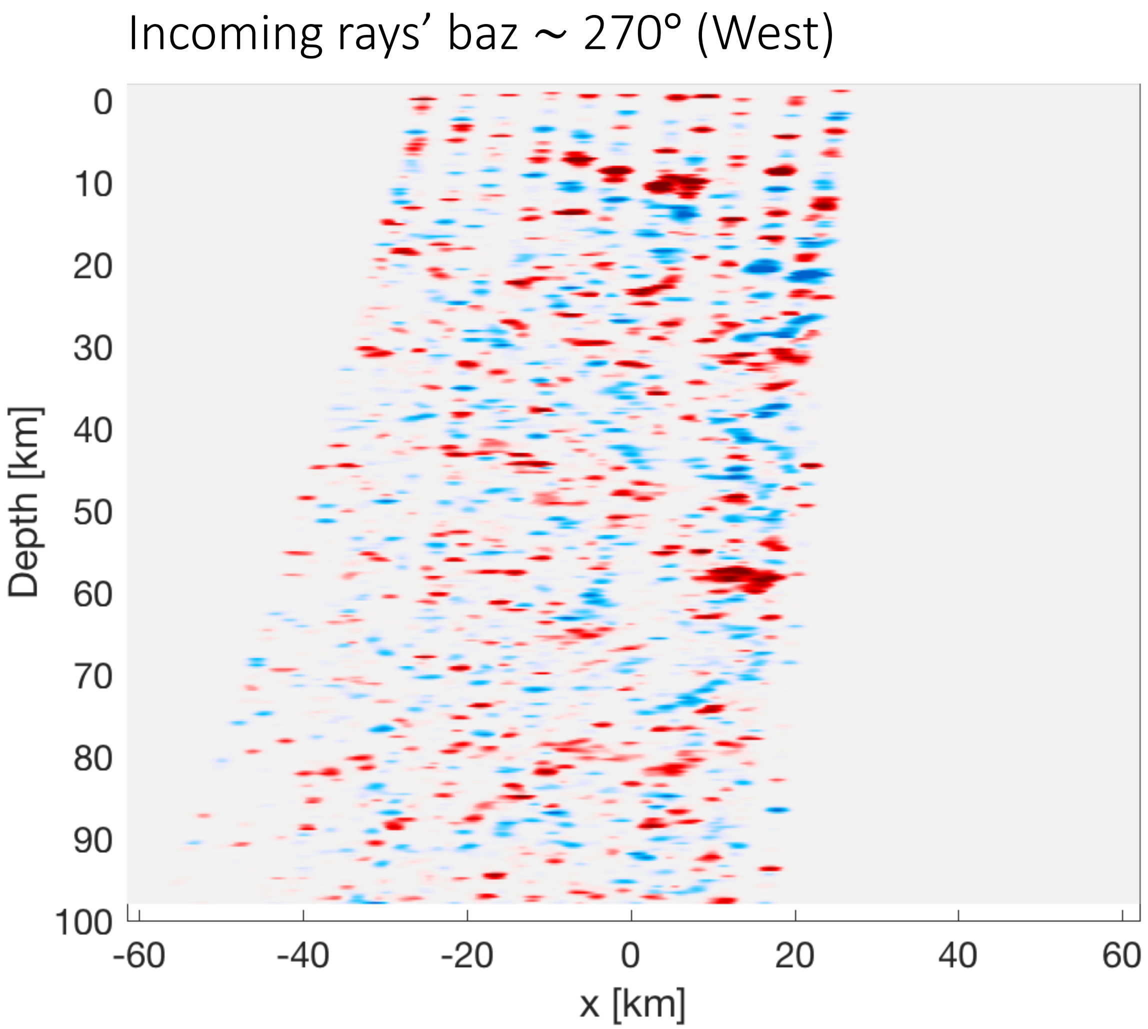
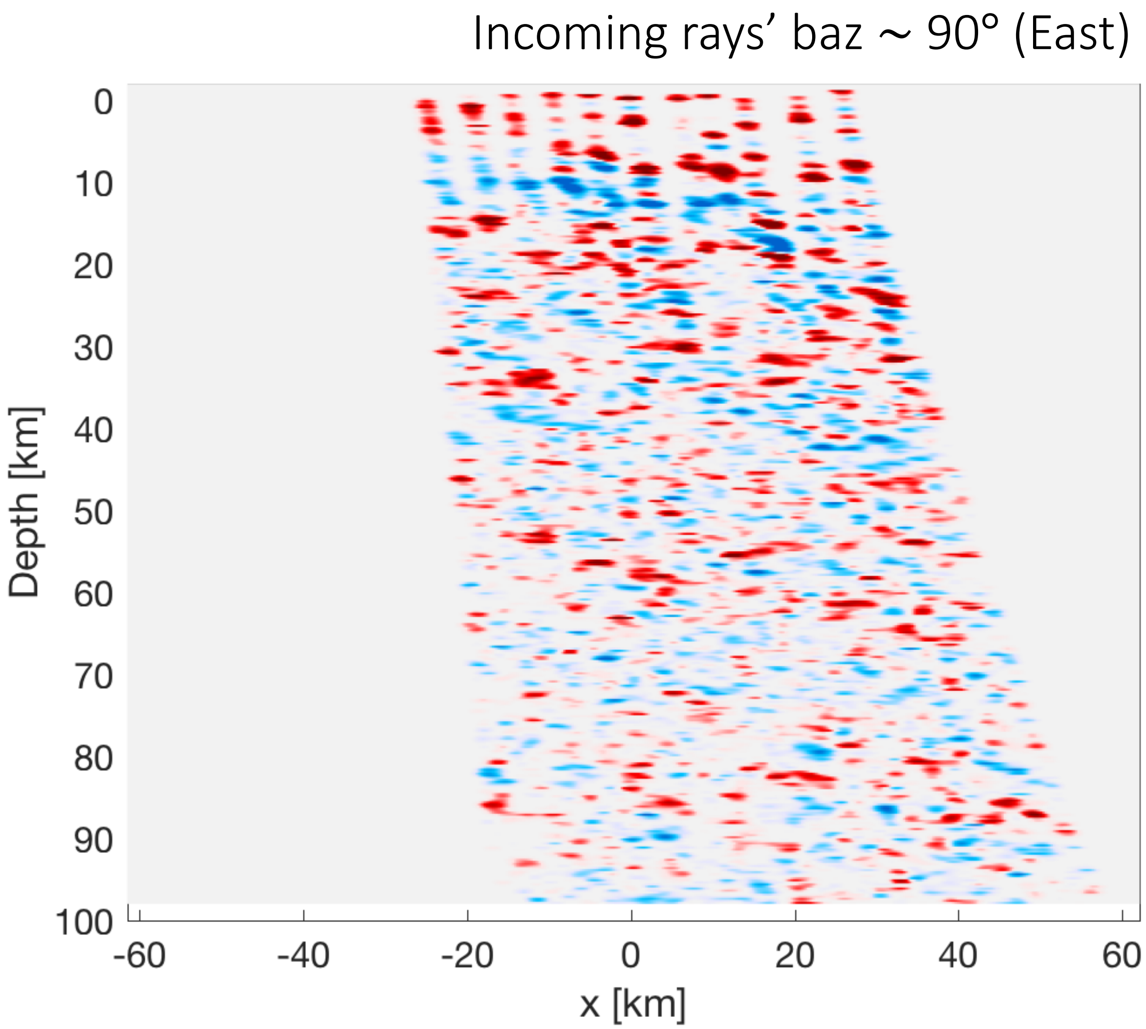
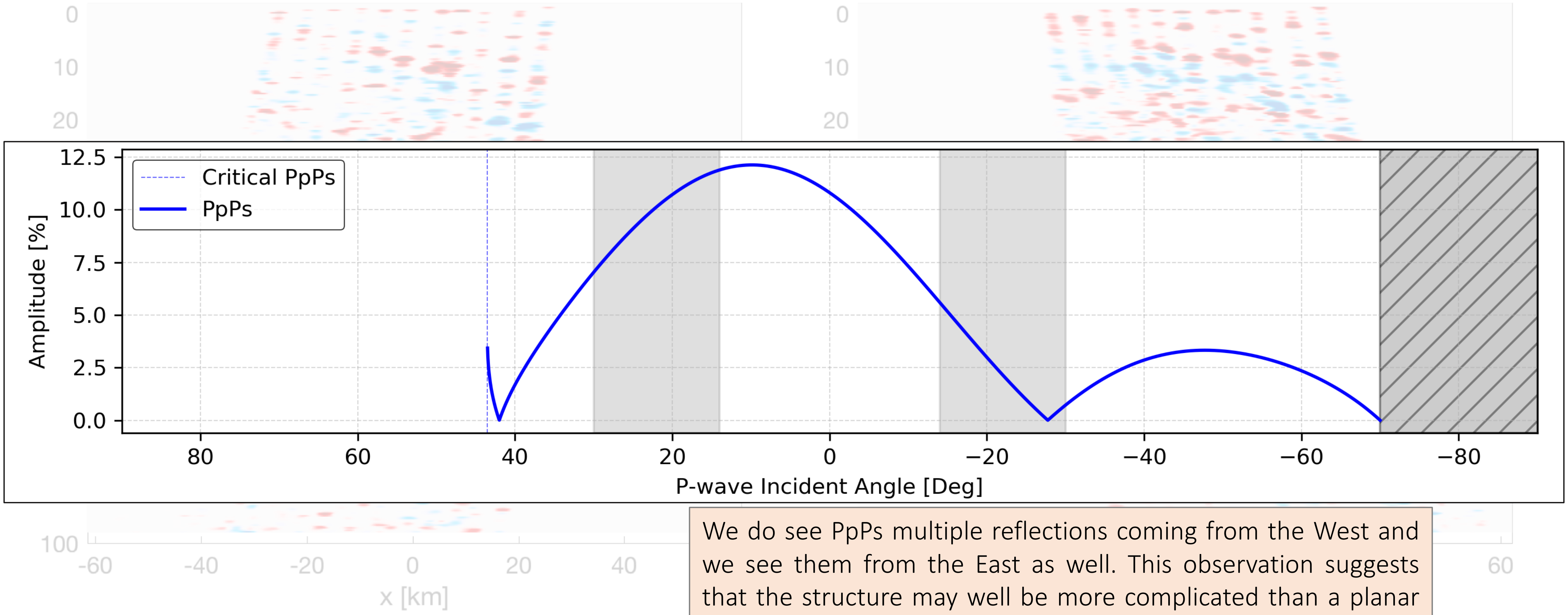
PpPs-phase migration back-azimuthal dependence





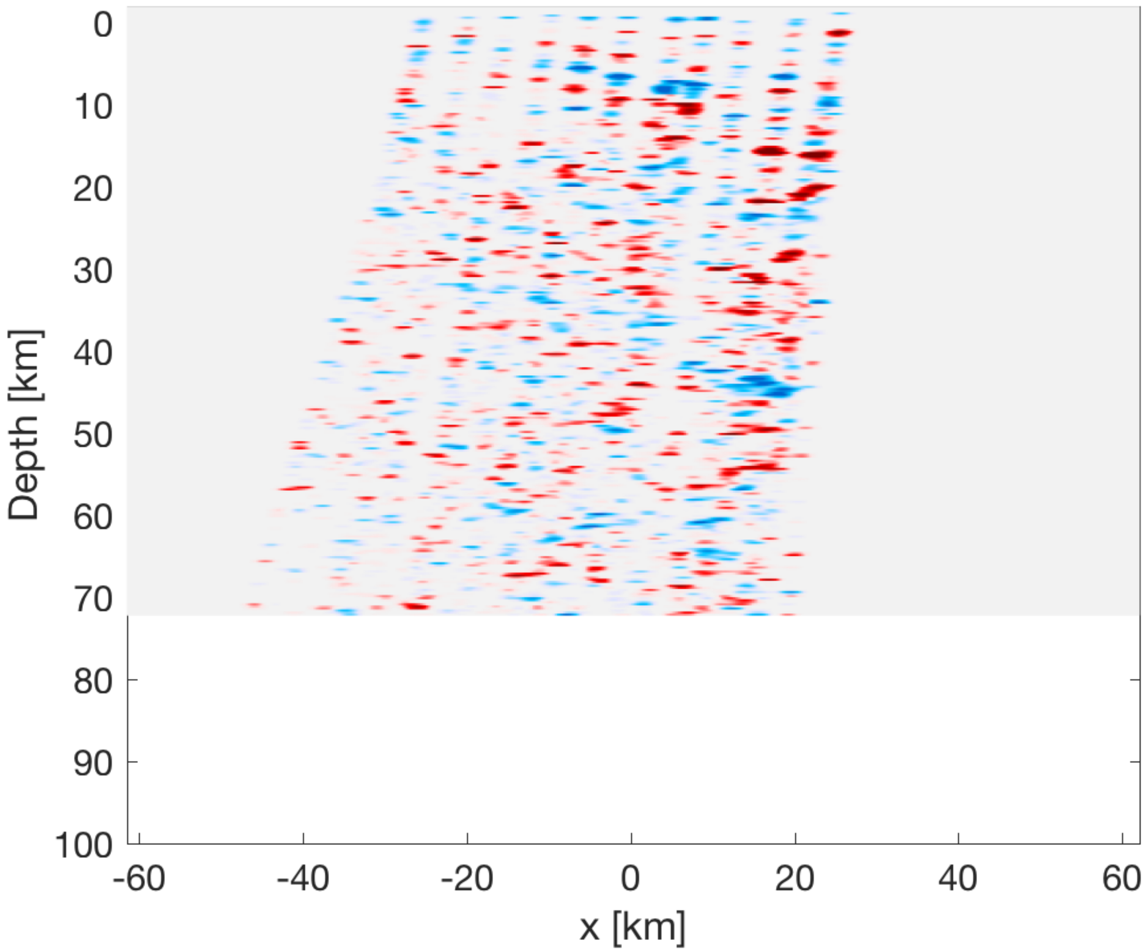
PpPs-phase migration back-azimuthal dependence



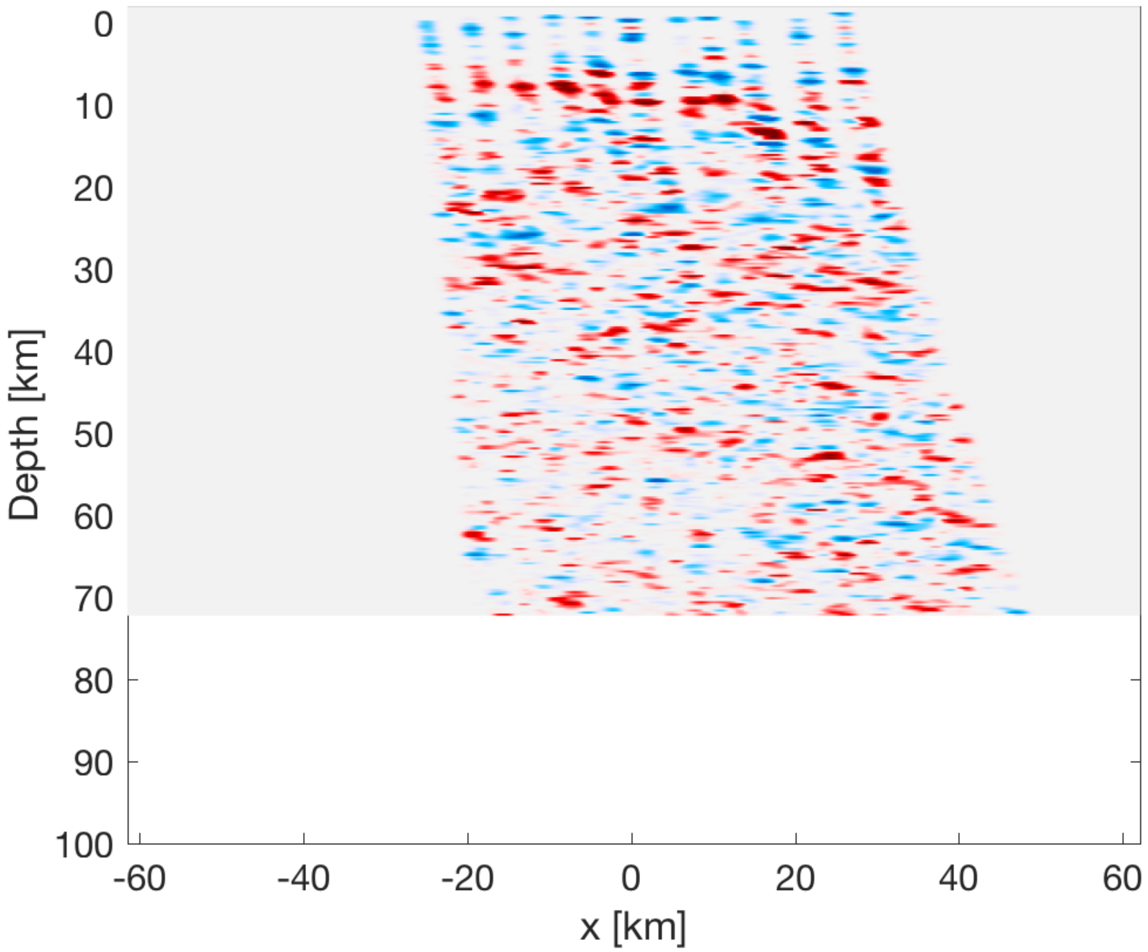
We do see PpPs multiple reflections coming from the West and we see them from the East as well. This observation suggests that the structure may well be more complicated than a planar dipping interface.

PpSs-phase migration back-azimuthal dependence

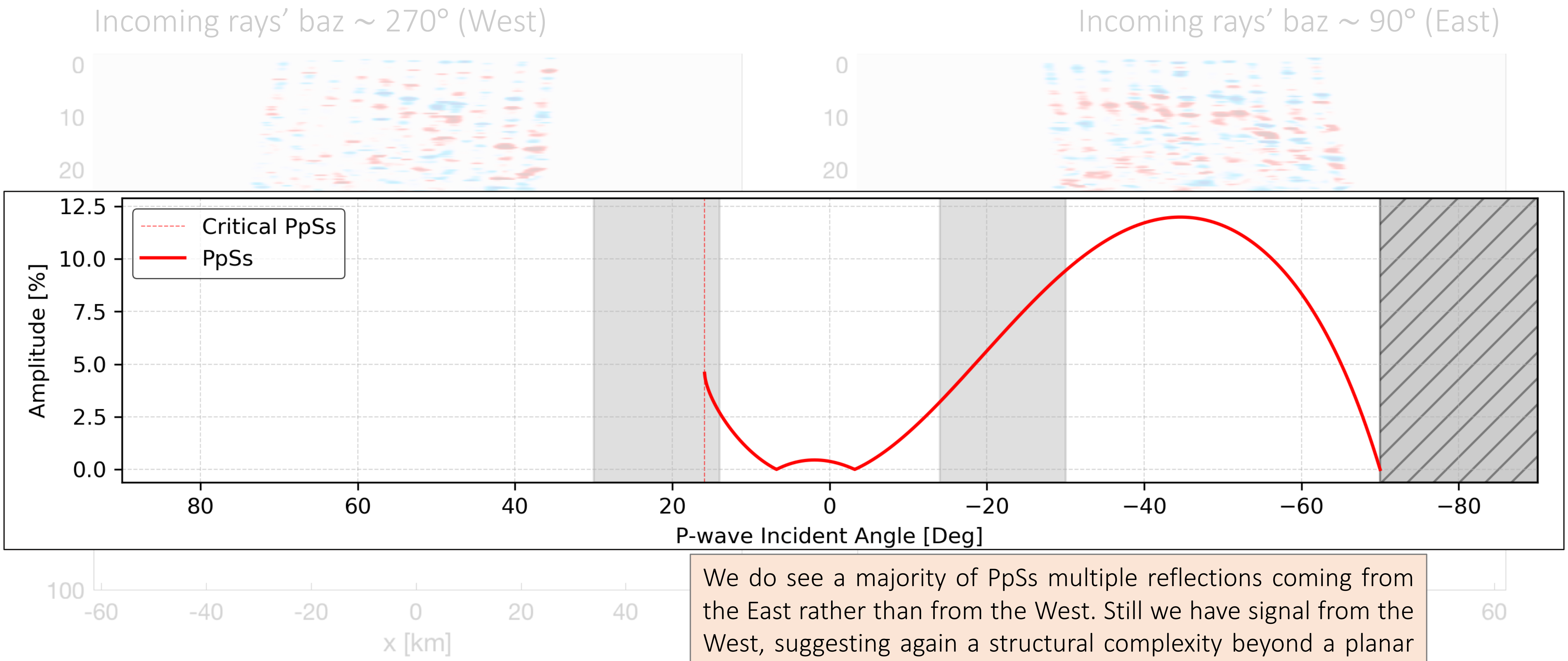
Incoming rays' baz ~ 270° (West)



Incoming rays' baz ~ 90° (East)



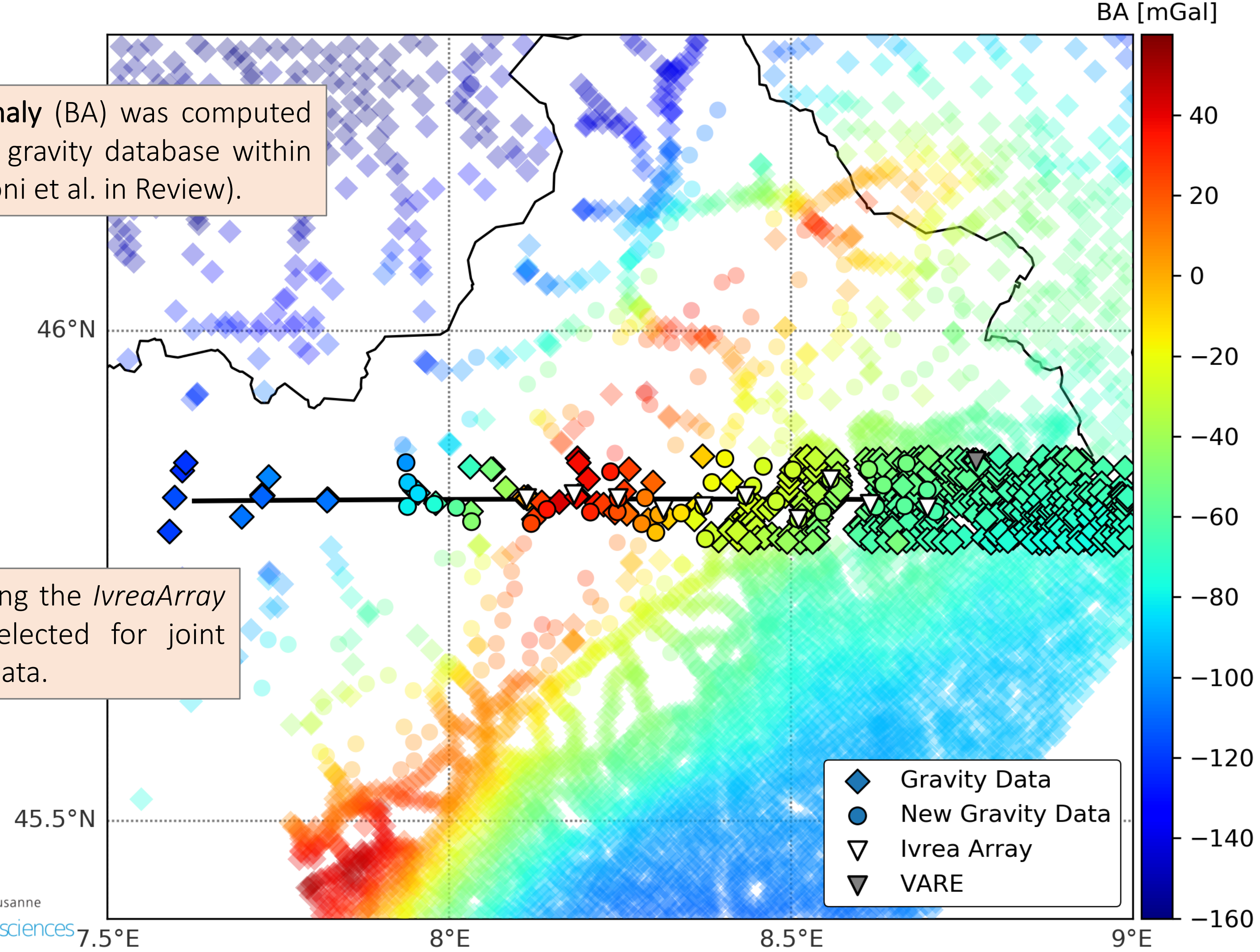
PpSs-phase migration by back-azimuth (baz)



We do see a majority of PpSs multiple reflections coming from the East rather than from the West. Still we have signal from the West, suggesting again a structural complexity beyond a planar interface.

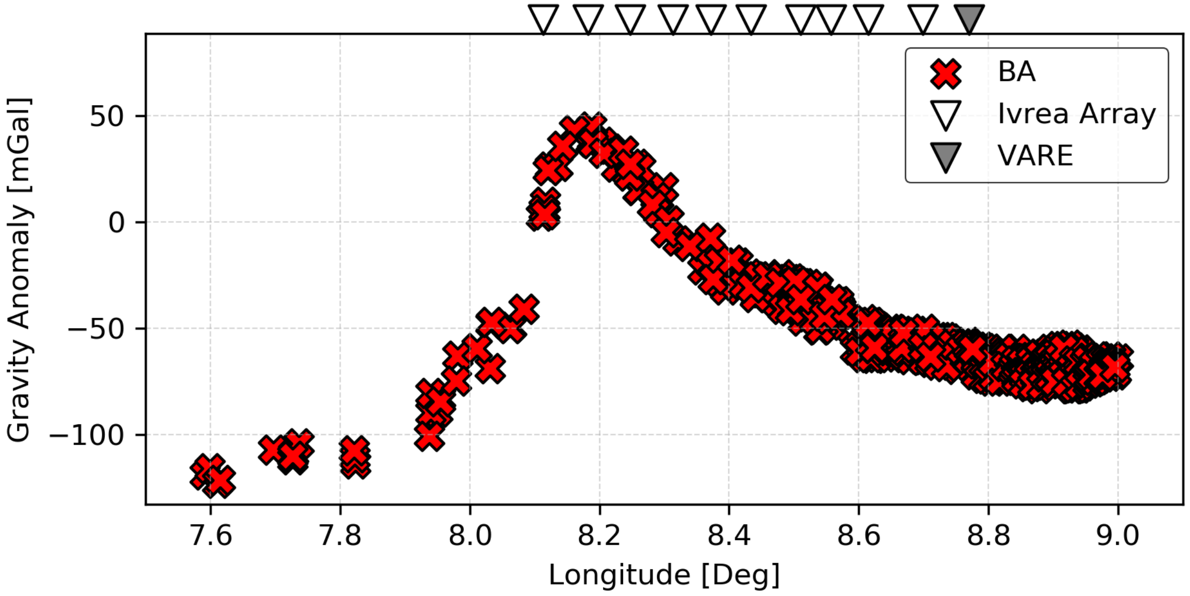
What about gravity data?

Bouguer gravity anomaly (BA) was computed for each point of our gravity database within our study area (Scarponi et al. in Review).

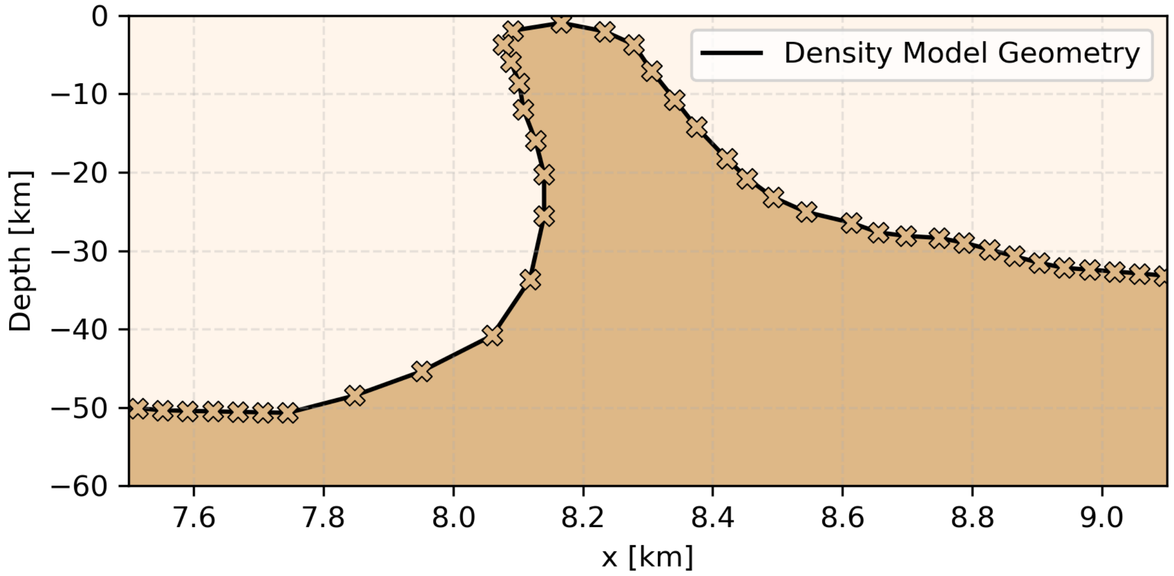


The gravity points along the *IvreaArray* profile have been selected for joint analysis with seismic data.

Density model



(Top) Bouguer gravity anomaly along the *IvreaArray* profile, together with seismic station locations.



(**Bottom**) A 3D crustal density model has been developed across the study area (Scarponi et al. in Review). Here is the model geometry along the *IvreaArray* profile.

Results and Next steps

- ✓ We have created a database of **Receiver Functions** from *IvreaArray;*
- ✓ RFs **migration** highlights new features on of the IGB structure;
  - ✓ **Shallow** interfaces are visible between surface and 10 km depth;
  - ✓ East-West differences suggest a primary **eastward dipping** interface;

- ❑ **RFs inversion** for the velocity structure along the profile;
- ❑ Improved velocity model (better than 1D iasp91) and investigation of the interface velocity gradient;
- ❑ RFs and Bouguer gravity anomaly **joint inversion** along the *IvreaArray* profile;
  - ❑ *Ad hoc* equations for Vp- , Vs-density relationships will be adopted;
  - ❑ RF analysis and gravity modelling will provide the initial model for the joint inversion

Thank you very much for your attention!

Please provide any feedback you would like to
- either in the chat
- or via email at matteo.scarponi@unil.ch

Acknowledgements

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