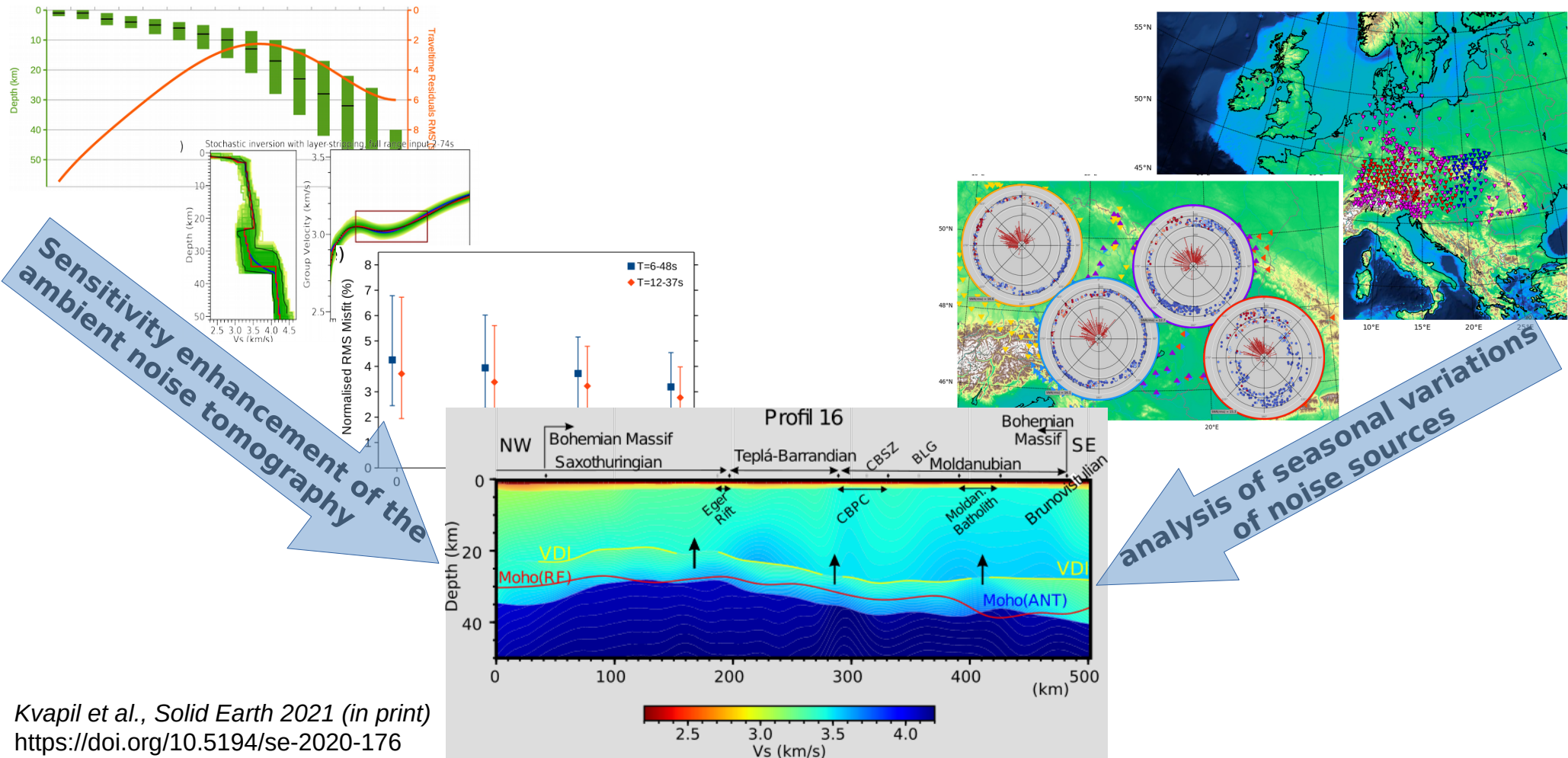




Sensitivity enhancement of the ambient noise tomography and analysis of seasonal variations of noise sources to refine velocities in the lower crust in central Europe

Jiří Kvapil, Jaroslava Plomerová, and AlpArray Working Group



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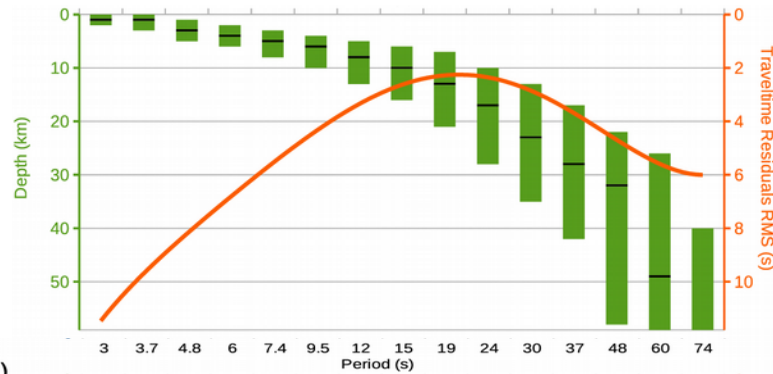
- Is the ambient noise tomography (ANT) able to resolve small scale velocity features in the lower part of the crust?

- Main limitations:

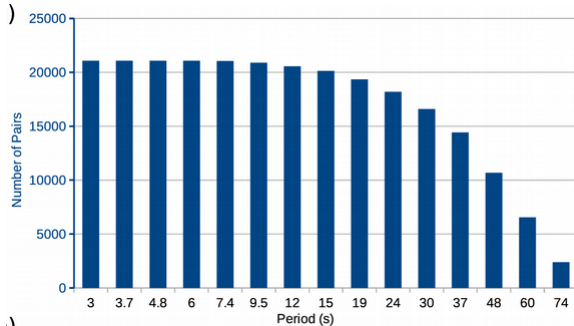
– Lower crust in central European area is imaged by period band 30-60s.

– Velocity measurements at these periods require separation of stations in pairs by more than 350km.

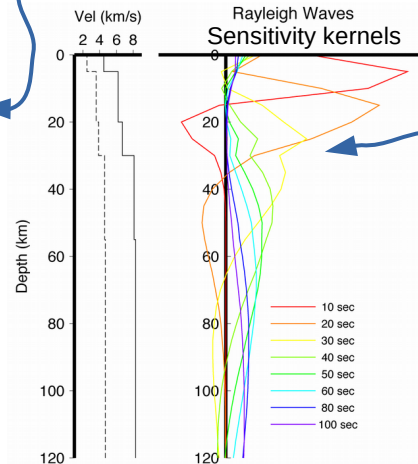
– There is significant decrease of sensitivity in this period band



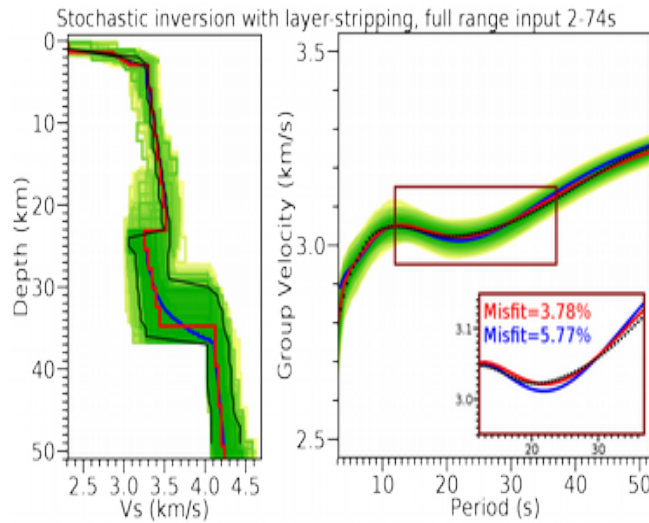
The average sensitivity kernels, calculated across cells in Central Europe, show the highest sensitivity to structures in the upper part of the crust (~3–20 km) for periods between 6–19 s. The lower part of the crust down to Moho is sampled with periods 30–60 s



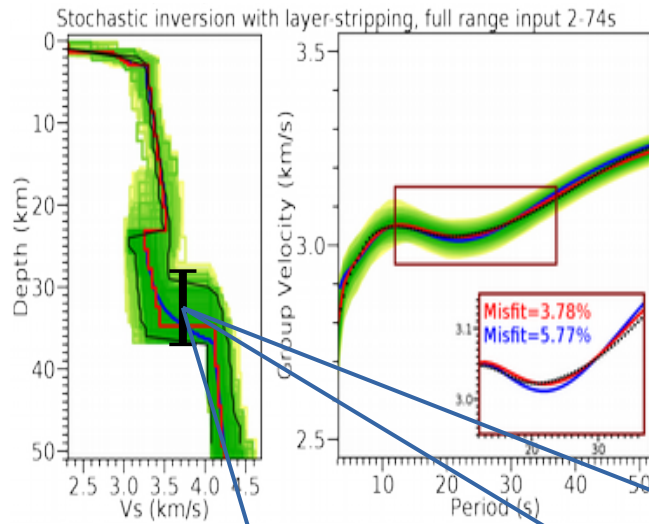
Decrease of station-pair count from 30s



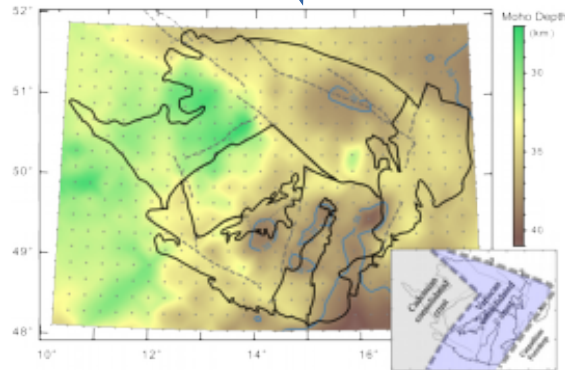
Pasyanos, 2013



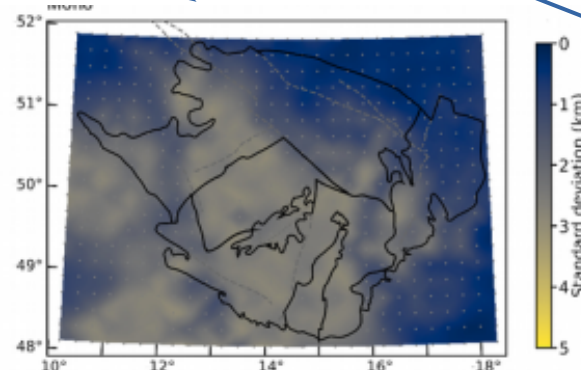
- Stochastic Inversion: 3-parameter model space control
 - The reliability of the NA solution depends mainly on the number of randomly generated starting models, number of iterations and the **model space**
 - The overall quality of the inversion results is assessed by misfit values, which indicate how each model fits the input dispersion curve by the normalised RMS error



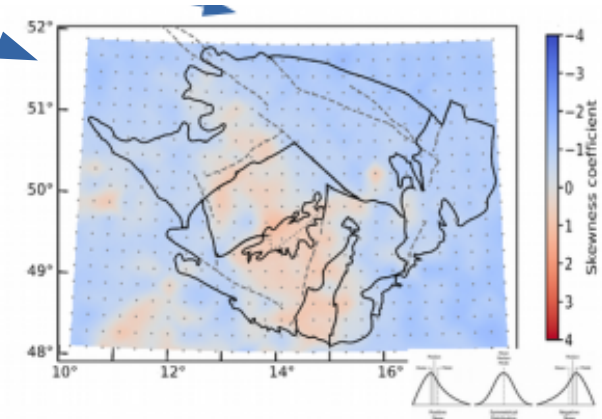
- Stochastic Inversion: 3-parameter model space control
 - We tune the NA parameters by evaluation of the **misfit** values, the **coefficient of skewness** and **standard deviations** of the group of best-fitting models with the aim of achieving the Gaussian distribution of group of best-fitting solutions without a bias of the NA search constraints.
 - These three measures provide confirmation that the model space in the stochastic inversion is fully explored and that the model space does not influence the outcome.



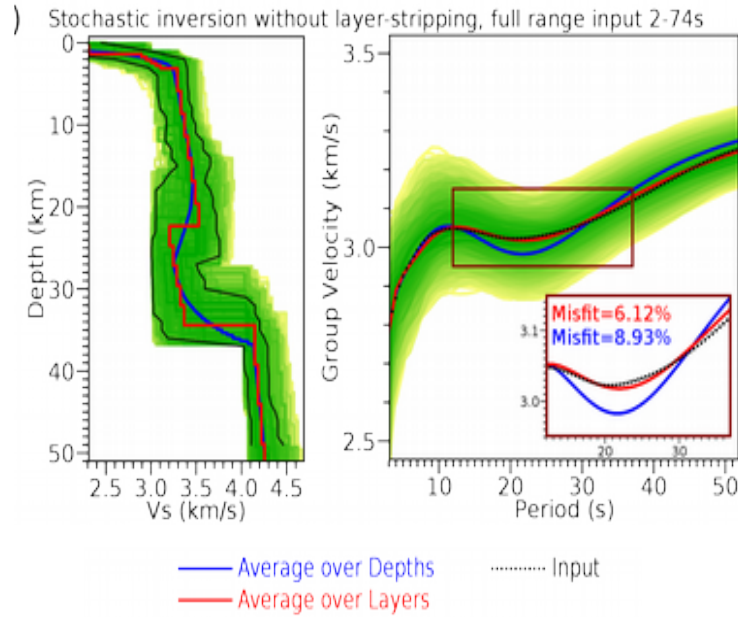
Depth



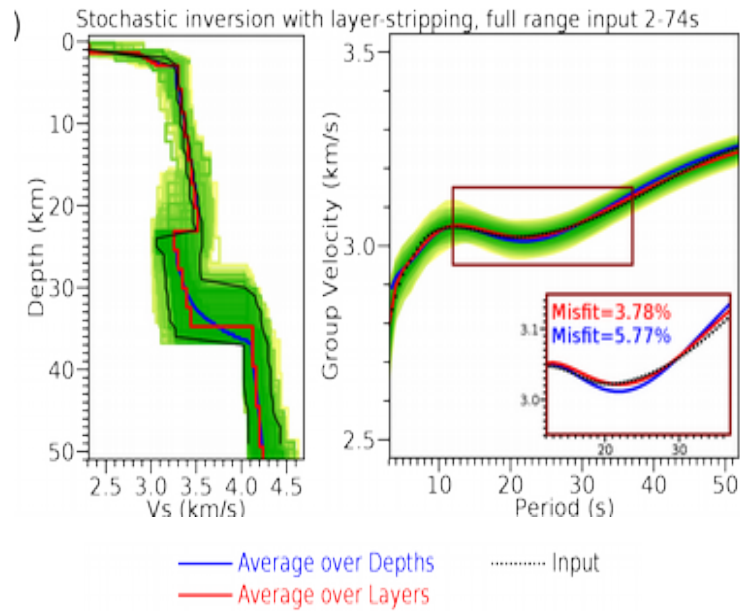
Standard deviation



Coefficient of skewness

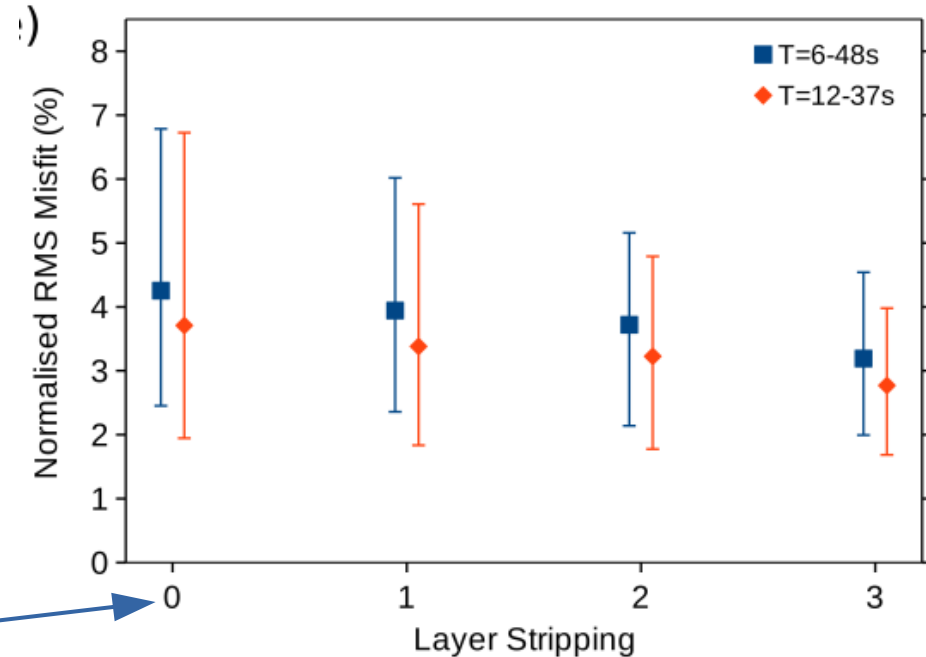


- Stochastic Inversion: Model Averaging
 - the conventional average v_s over the fixed depths results in a gradient-velocity model
 - the average over layer indexes (v_i, z_i) results in a layered-velocity model
 - the dispersion curve, calculated from the layered-velocity model, matches better the input dispersion curve. The misfit improves by almost 3%.

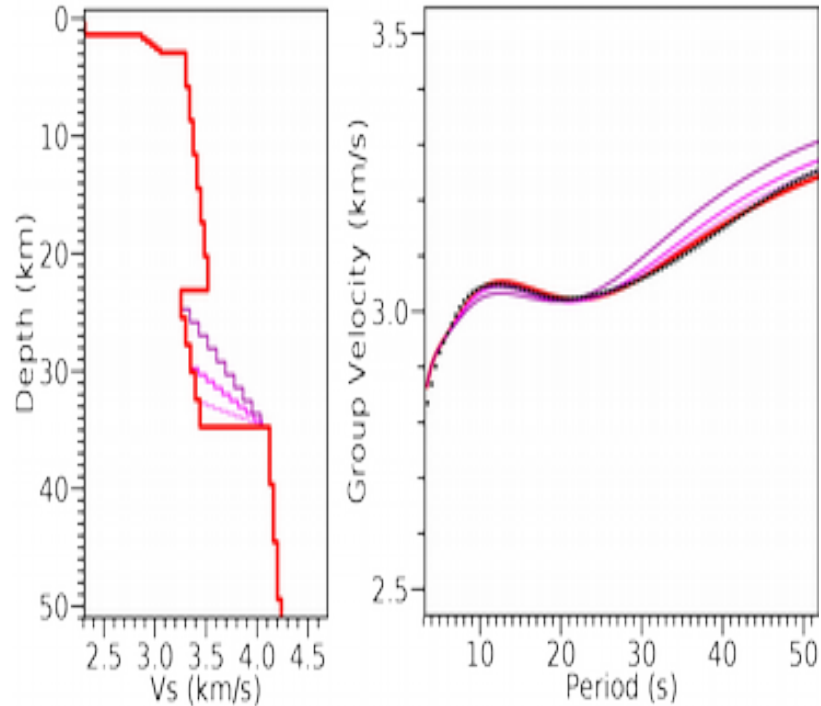


• Stochastic Inversion: Layer stripping technique

- The averaging over layer indexes leads to the straightforward implementation of a layer-stripping technique into the stochastic inversion.
- The layer stripping appears to be efficient tool to enhance the NA search in deeper layers of the model, where the solution suffers from the significant decrease of sensitivity kernels with depth
- The recursive stripping of the upper layers increases depth sensitivity and leads to better fit at long period range of the dispersion curves

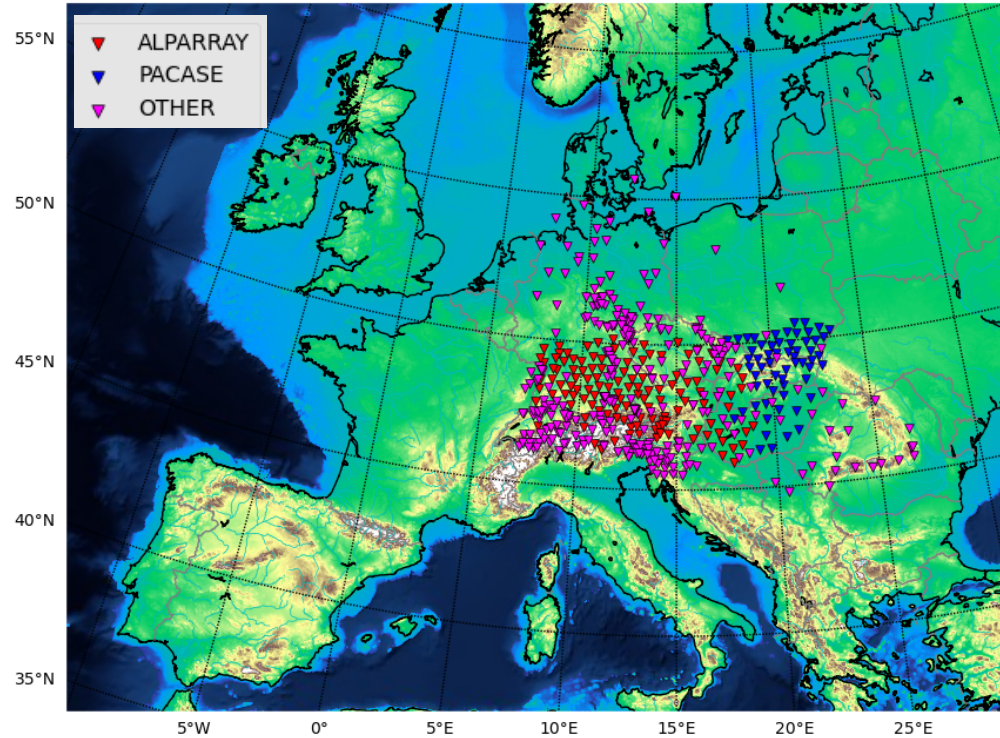


0 = standard approach (no layer stripping)

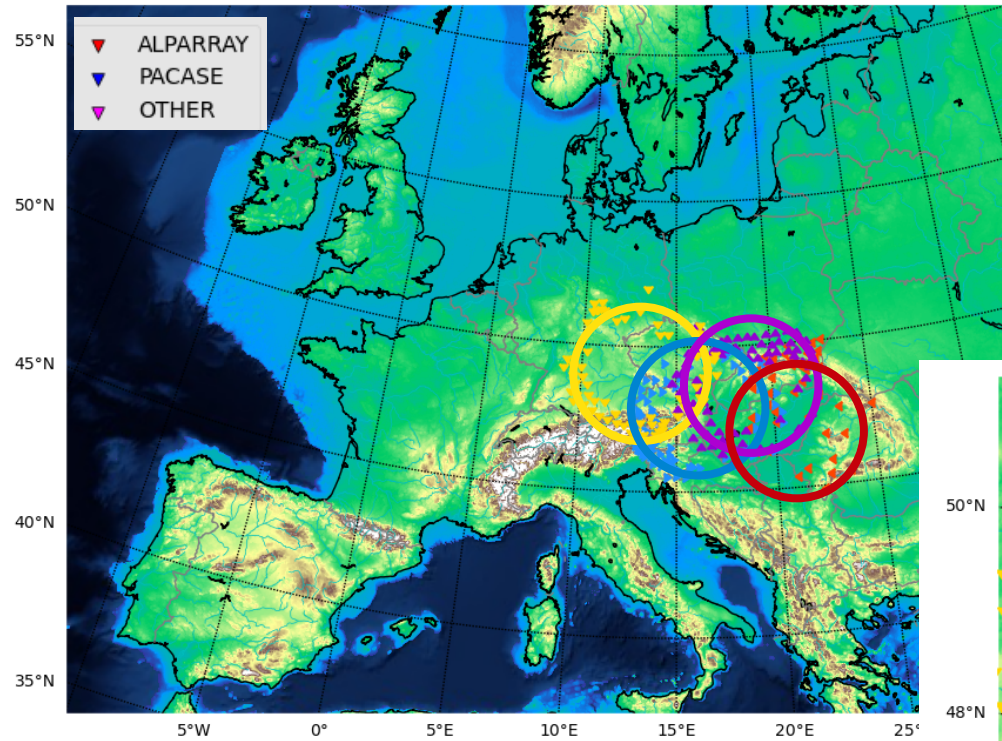


- Stochastic inversion: Sensitivity to gradational Moho:
 - We assess the sensitivity of our inversion approach to the sharpness of the Moho as an interface by adding an additional gradient layer into the final 1-D model
 - to mimic the gradational Moho, we insert the layer on top of the uppermost mantle layer and vary its thickness from 2 to 10 km
 - the test result shows that the thickness of the transitional layer (i.e. gradational Moho) does not exceed 2 km

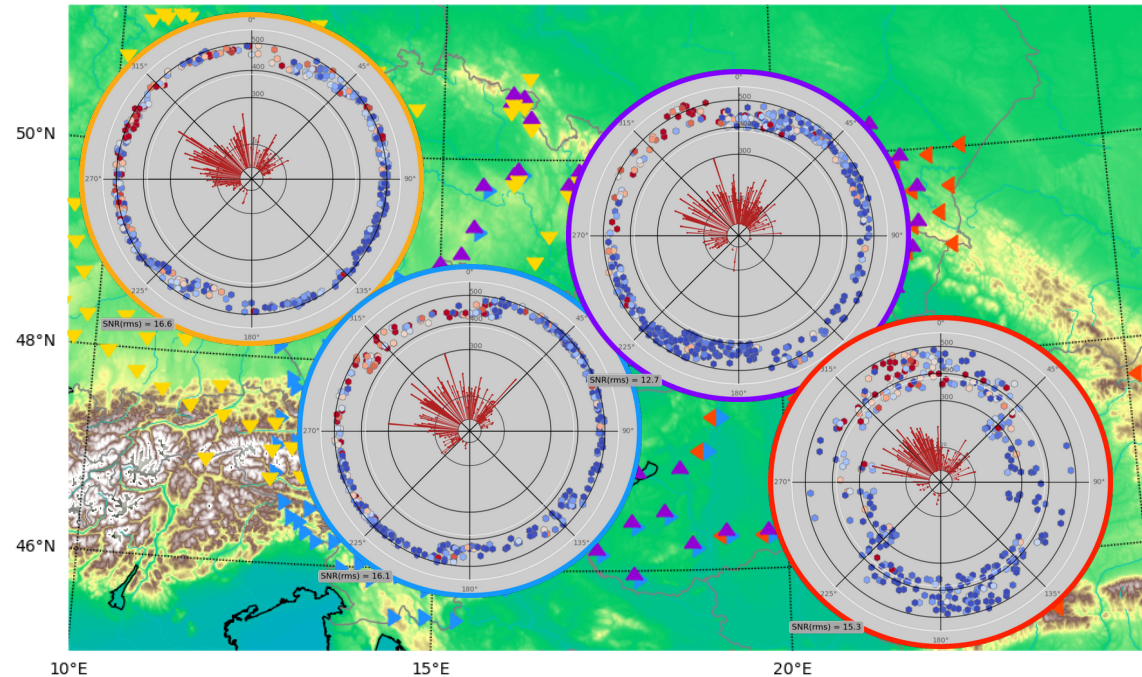
Sensitivity enhancement of the ambient noise tomography and analysis of seasonal variations of noise sources to refine velocities in the lower crust in central Europe

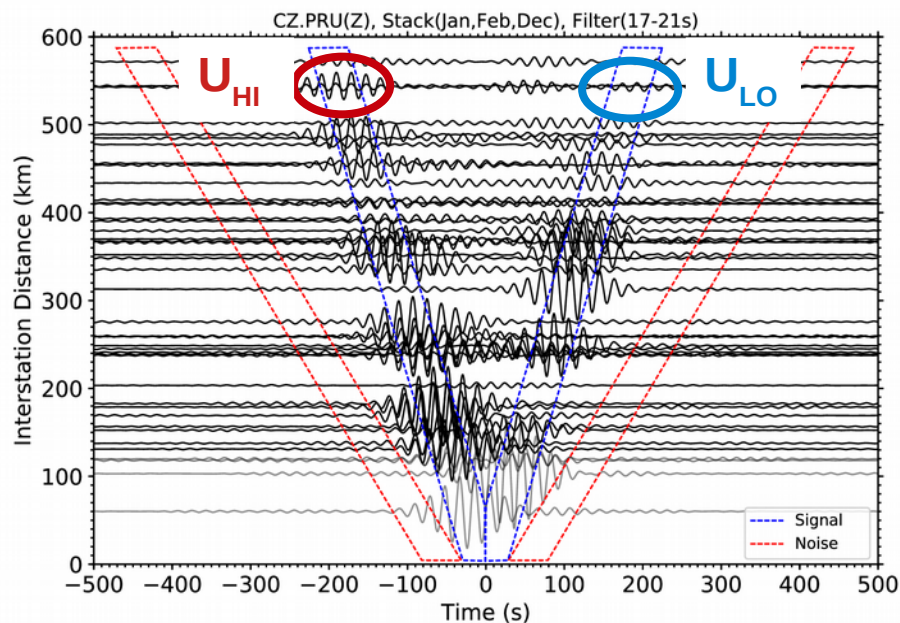


- How does the seasonal directionality of the ambient noise source field affect Rayleigh group velocities measured by FTAN technique?
 - We analyse ambient noise sources over the two 1-month stacks in February and June 2020.
 - We use data from
 - * permanent stations
 - * AlpArray passive experiment
 - * AlpArray complementary experiment PACASE



- We focus on central Europe
- We select stations in 4 areas with different tectonic settings
- In each area we analyse > 200 station-pairs with interstation-distance 400-500km (with exception of SE circle with lower station coverage, there we select 250-500km)



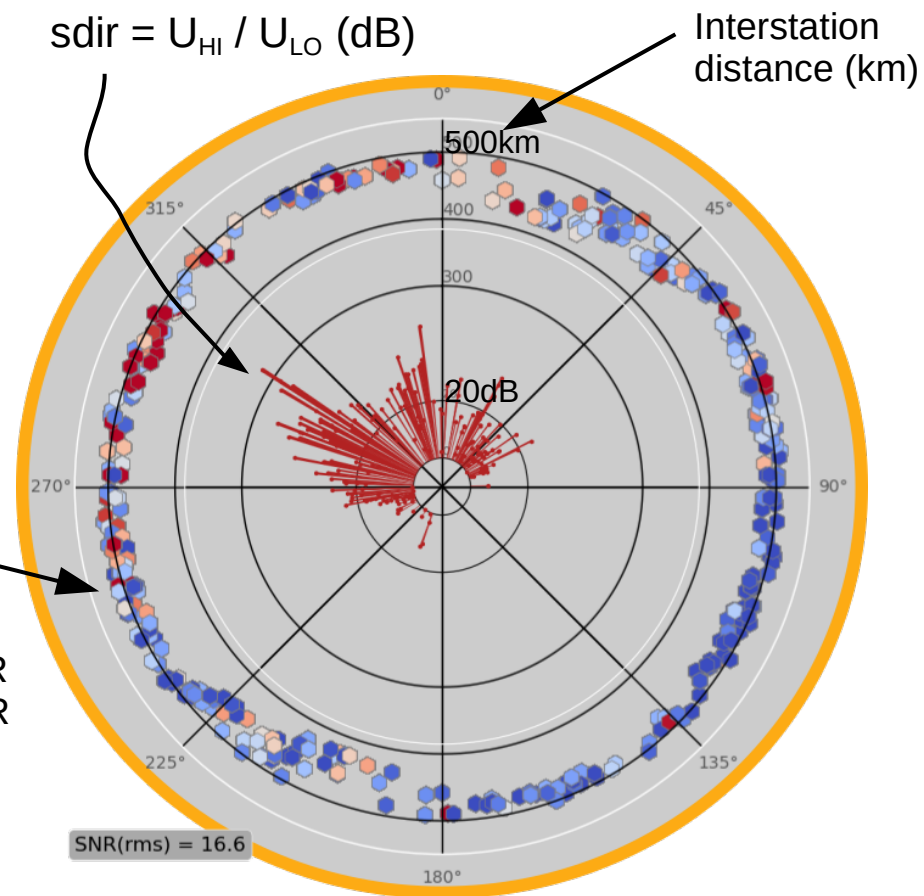


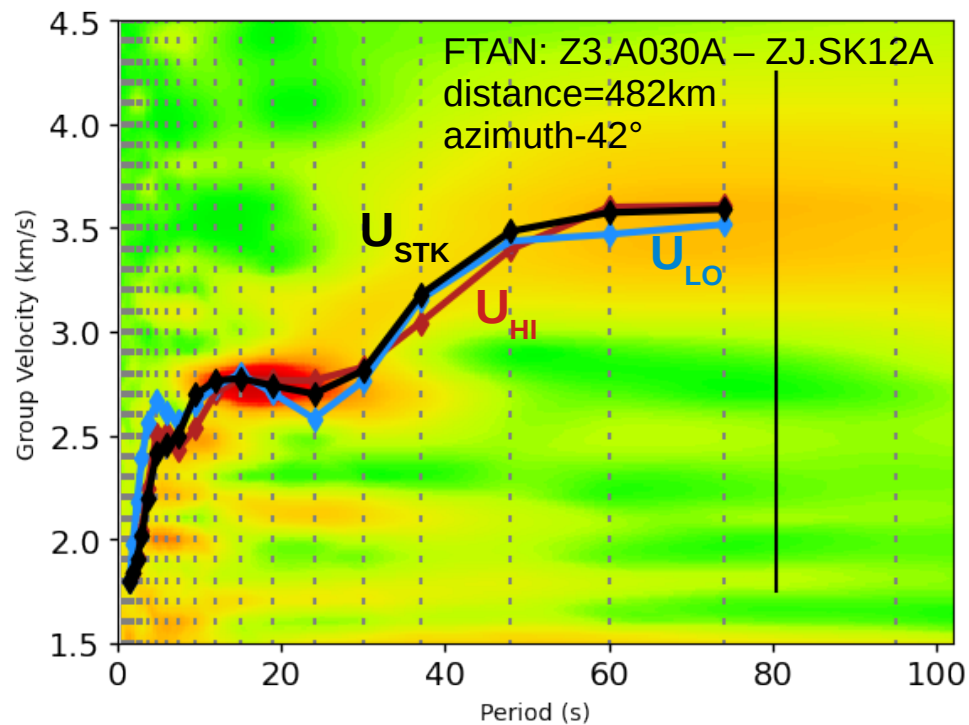
and signal-to-noise ratio, which is shown as a function of interstation-distance and azimuth

red=high SNR
blue=low SNR

- On each cross-correlation function (CCF) we measure amplitude ratio between the two sides of Rayleigh group

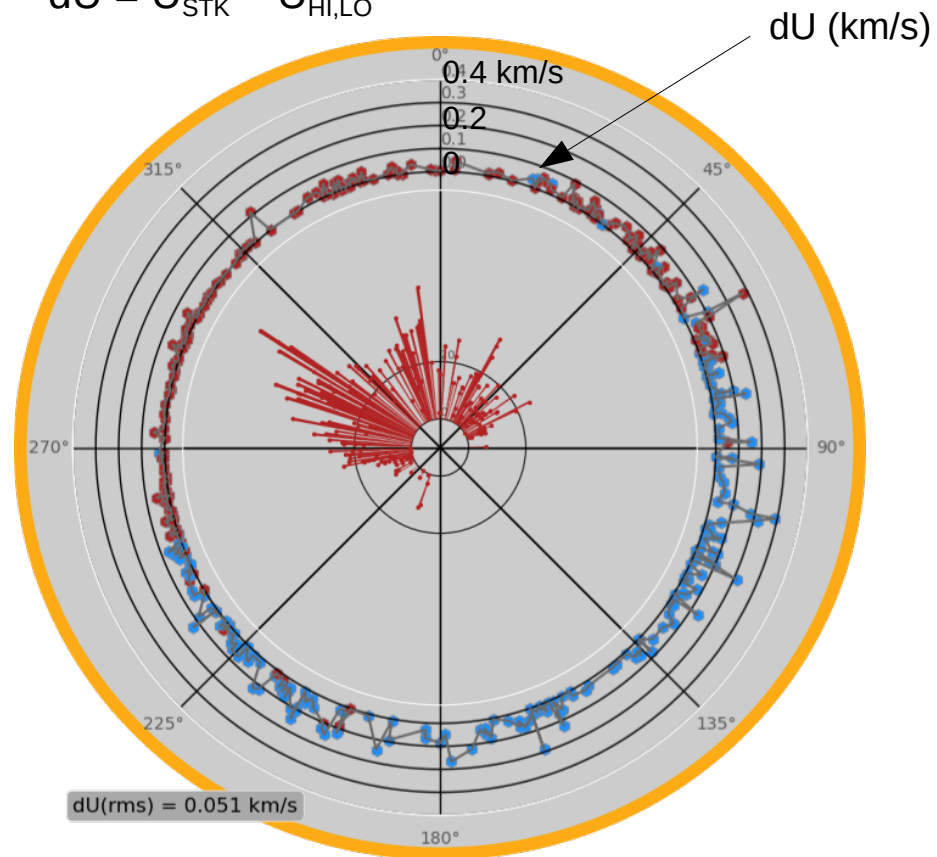
$$sdir = U_{HI} / U_{LO} \text{ (dB)}$$





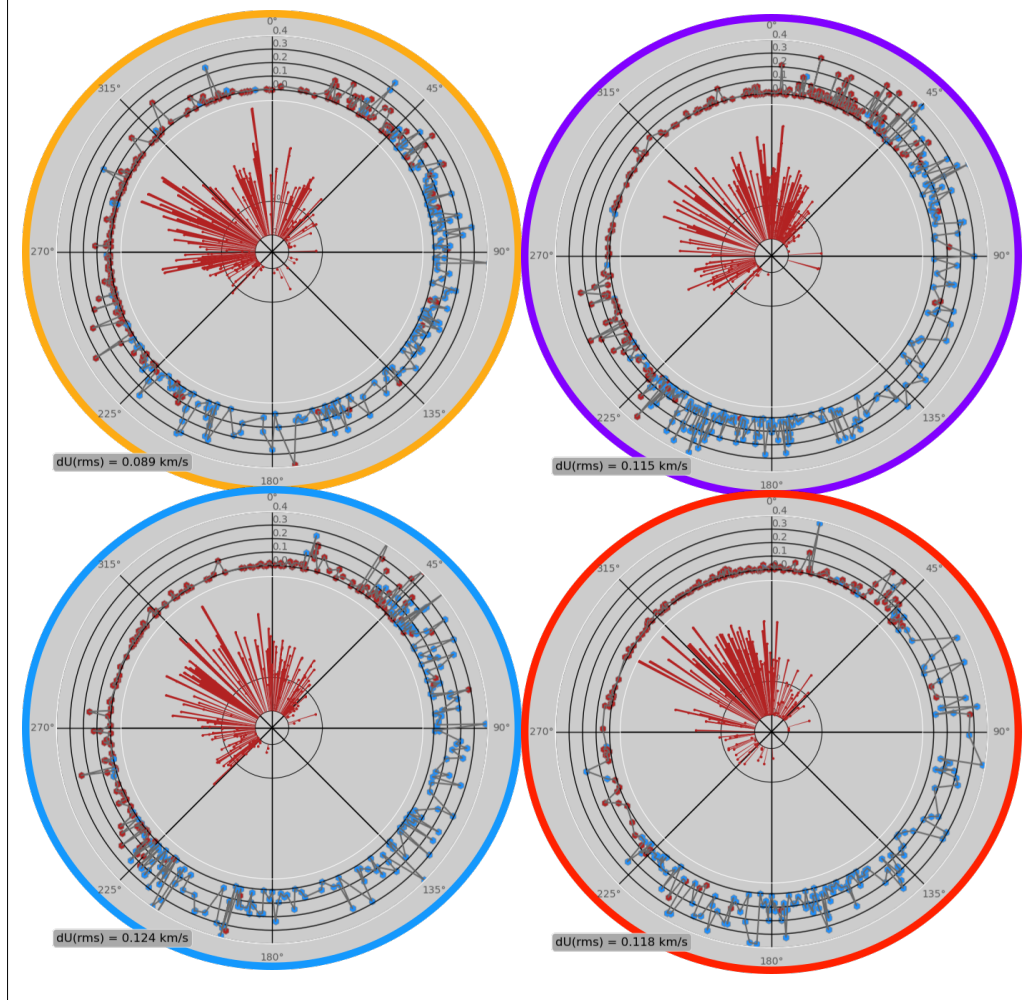
- Finally, we obtain difference between dispersion curves picked on stack of both sides and each side of the CCF

$$dU = U_{STK} - U_{HI,LO}$$

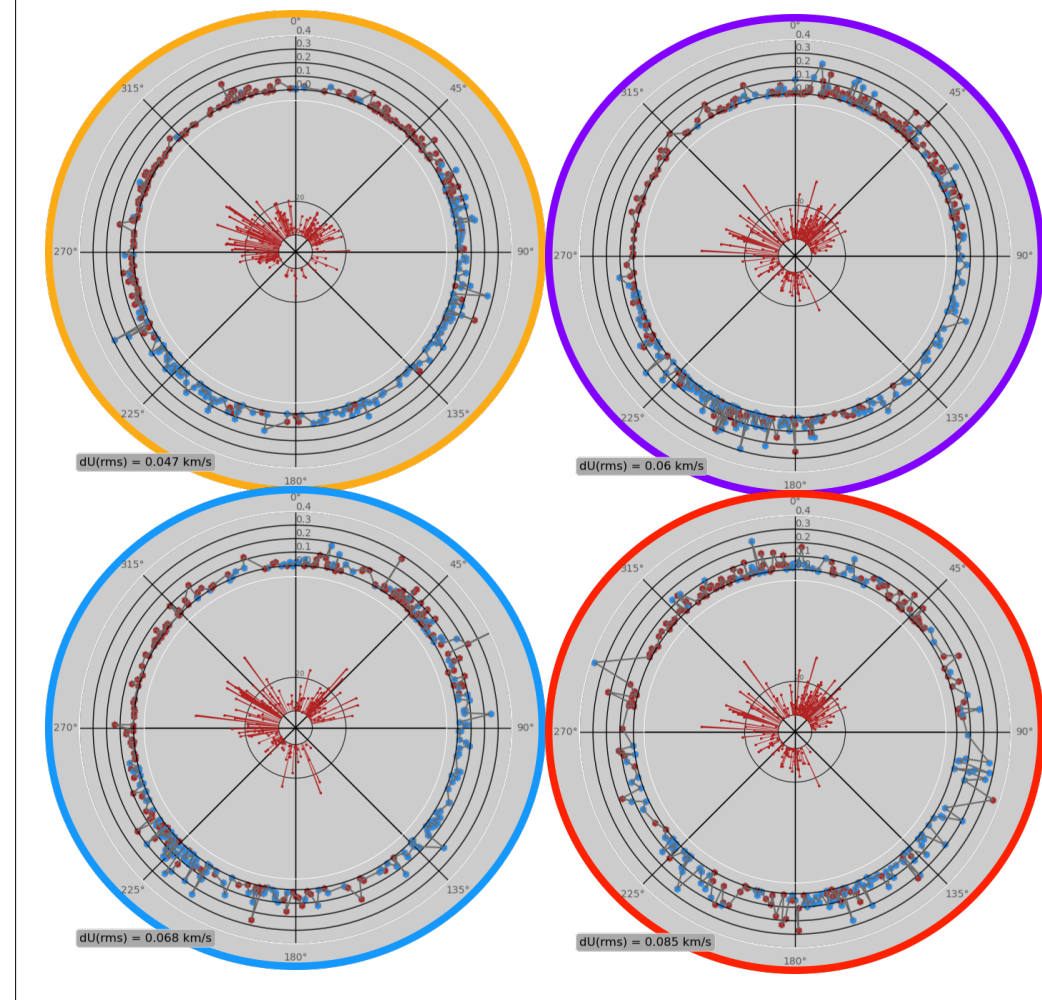


T=19s (primary microseism)

30-day stack, February 2020

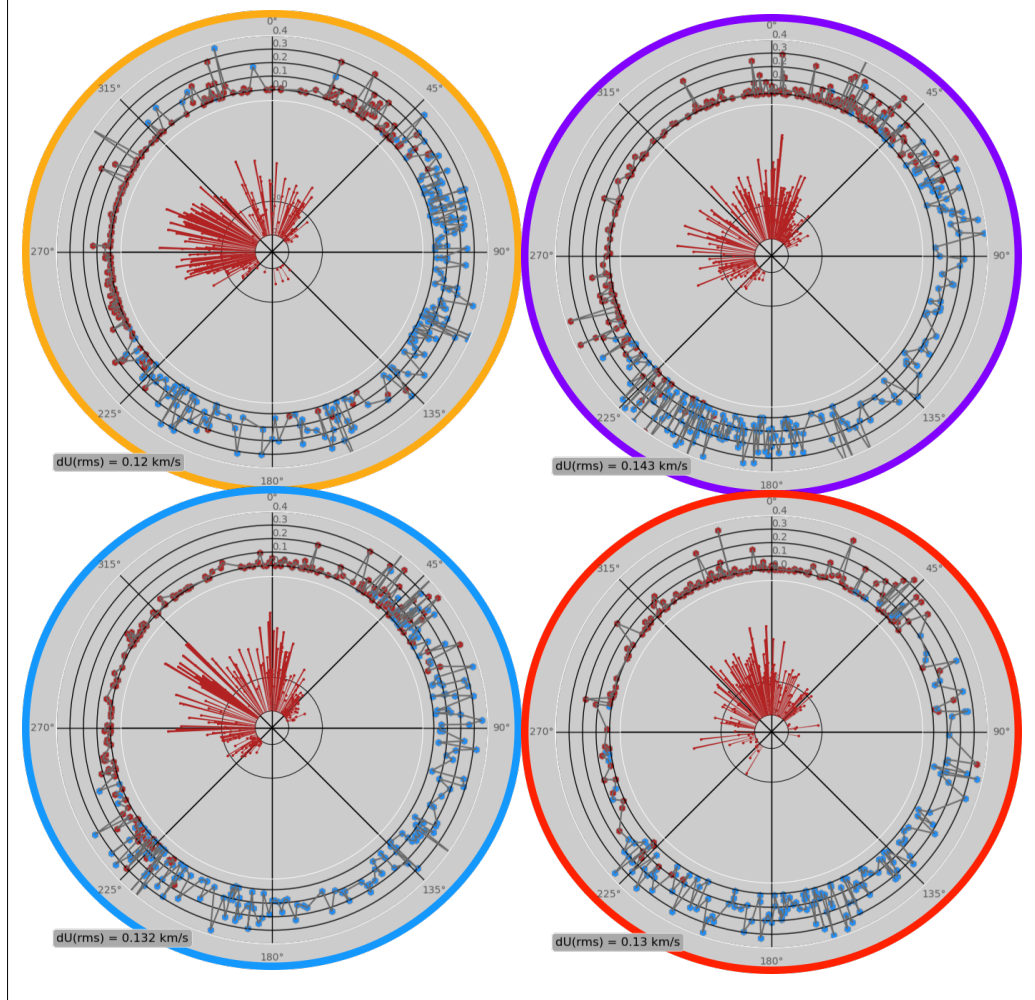


30-day stack, June 2020

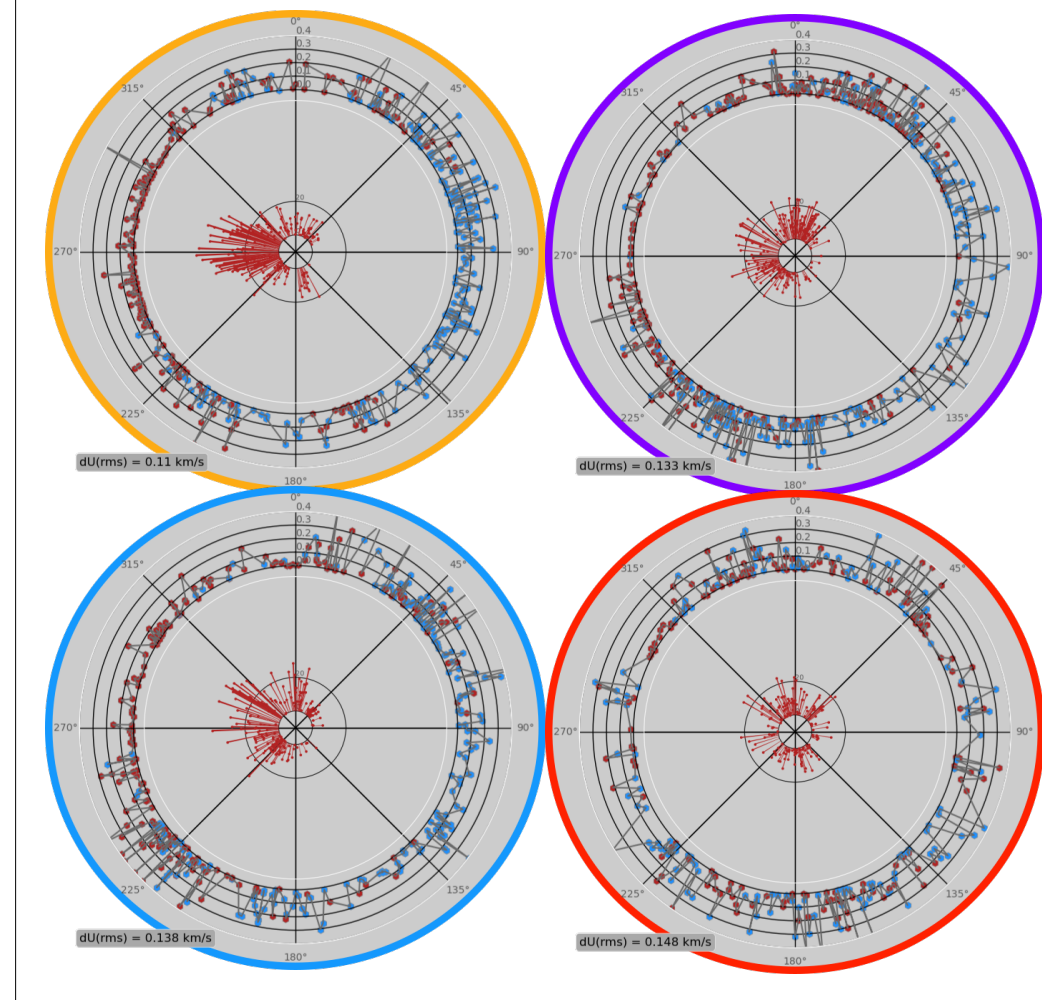


T=6s (secondary microseism)

30-day stack, February 2020

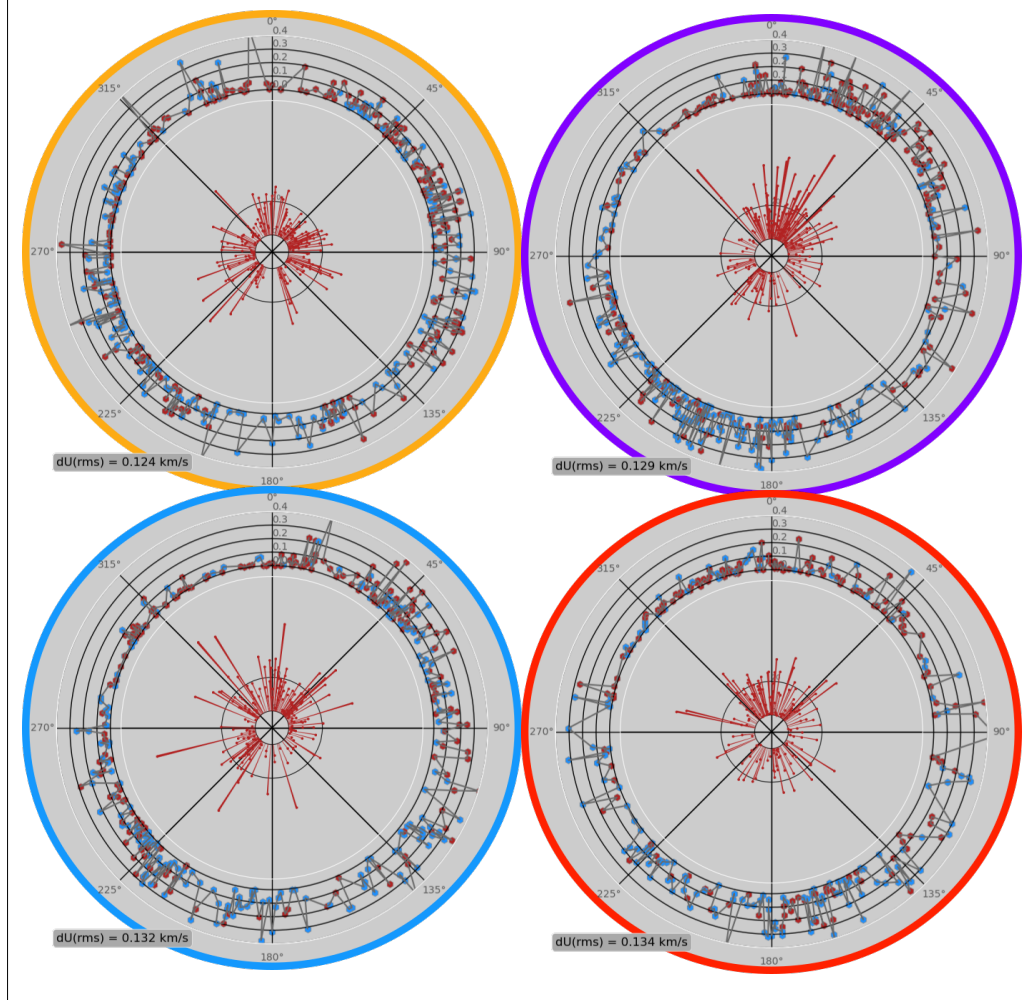


30-day stack, June 2020

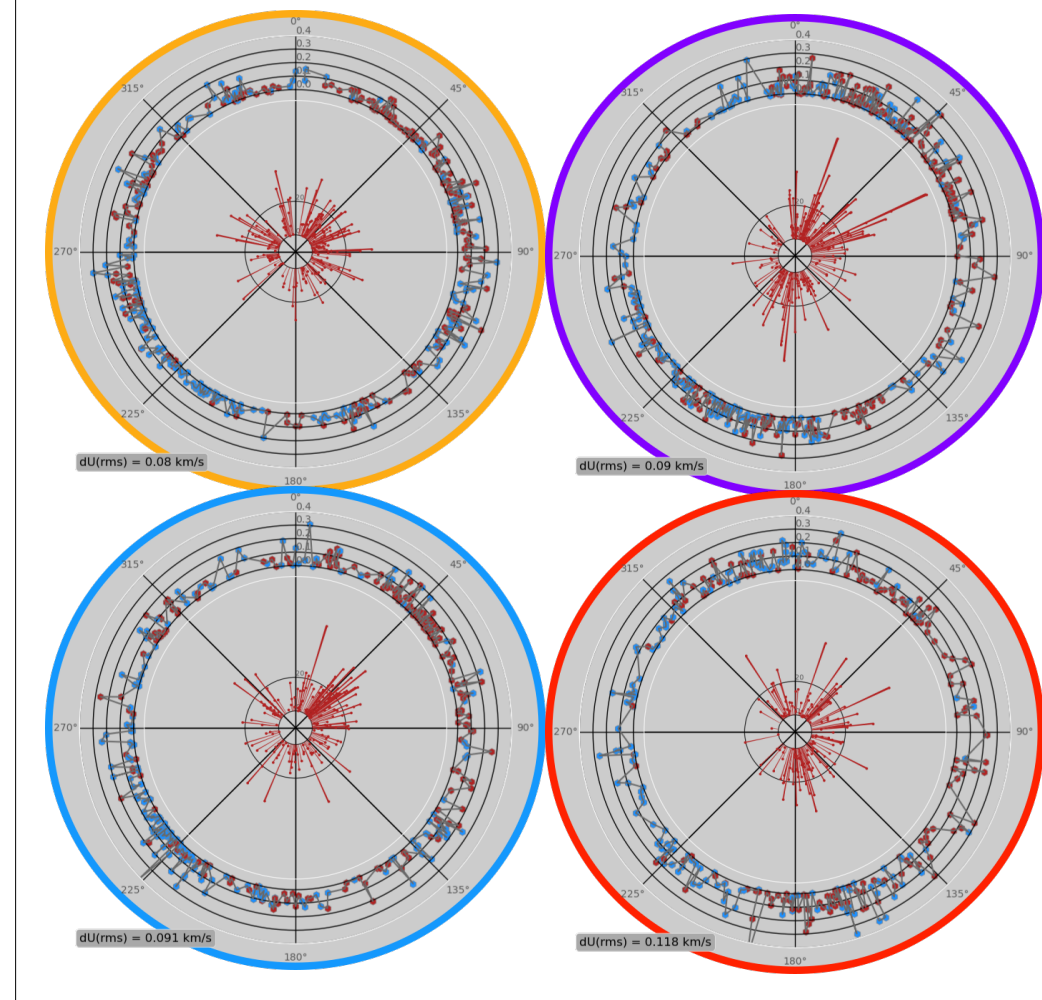


T=37s (low frequency seismic noise)

30-day stack, February 2020



30-day stack, June 2020



Conclusions

- Strong microseismic energy arriving from the North Atlantic Ocean, particularly in the winter, disturb the ambient noise wave field in central Europe and thus corrupt the fundamental assumptions of the method.
- With the summer season selection of data, the certainty of Rayleigh wave group dispersion measurements is mostly within 0.1 km/s.
- The sensitivity of ambient noise tomography to the velocity changes in the lower crust can be enhanced by layer stripping technique and by averaging of the best-fitting models over layers (instead of the commonly used averaging over fixed depth).