Receiver function analysis in the circum-Pannonian region: results and plans

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MOMENTUM OF INNOVATION

AdriaArray Workshop

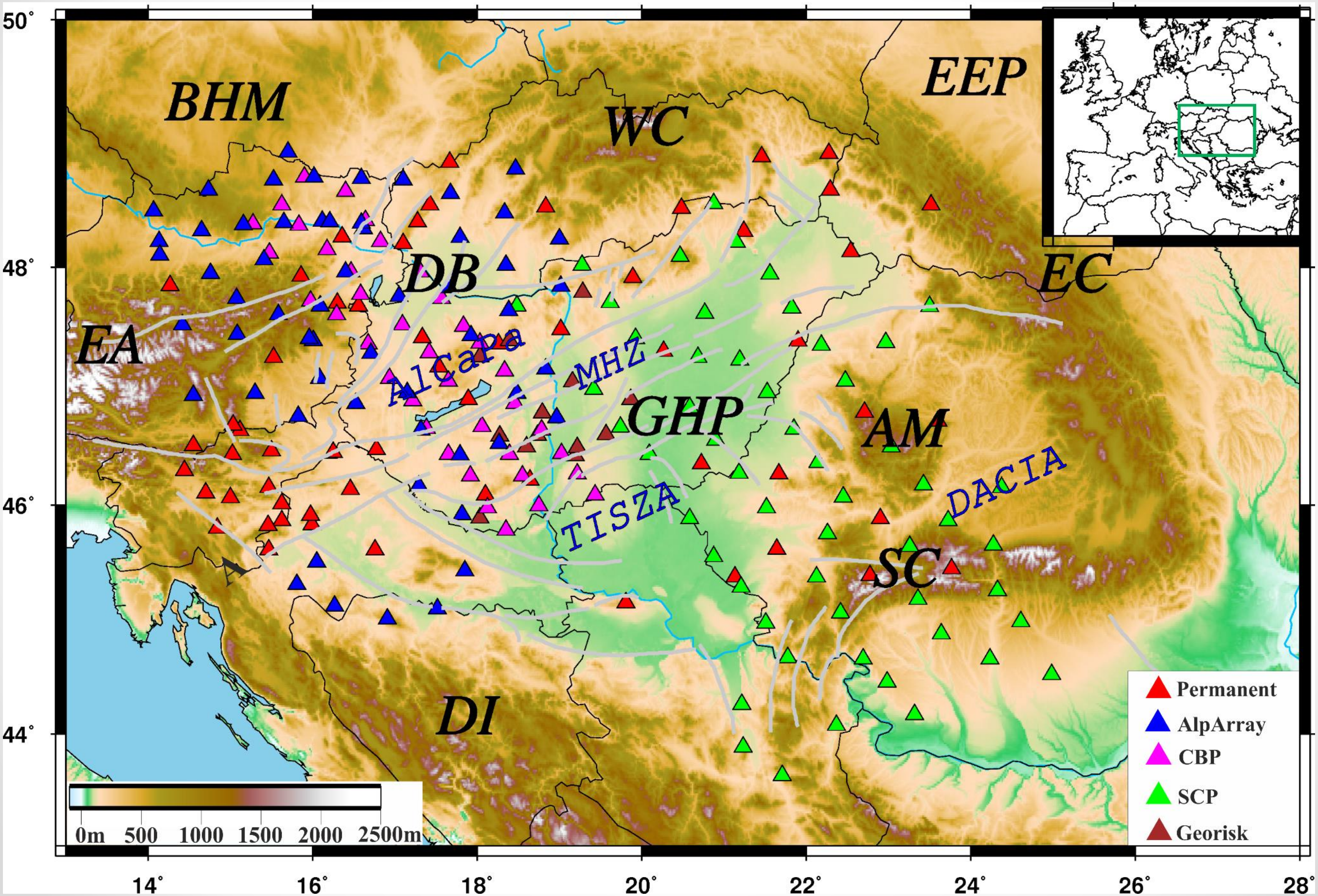
April 3-5, 2023
Dubrovnik, Croatia

Carried out research

P-to-S RF analysis	Steps	S-to-P RF analysis
Crustal structure	**Target**	LAB determination
221 permanent and temporary	**Stations**	389 permanent and temporary
28°≤Δ≥95°; M≥5.5; 01.01.2002-31.03.2019	**Events**	55°≤Δ≥85°; M≥5.5; 01.01.2002-31.01.2022
2 for the ZNE waveforms, 1 for the RFs	**Quality controls**	1 for the ZNE waveforms, 1 for the RFs
From ZNE to ZRT	**Rotation**	From ZNE to ZRT and LQT
Iterative Time Domain	**Deconvolution**	Iterative Time Domain
1, 1D H-K Grid Search 2, 2D CCP Migration 3, Neighbourhood Inversion, interpolation with NNCI algorithm	**Interpretation**	1, Migration with 1D model 2, 2D CCP Migration
Kernel Density Estimation	**Uncertainty estimation**	Bootstrapping method
Kalmár et al., 2021, JGR Solid Earth	**Papers**	Kalmár et al., 2023, submitted G-cube

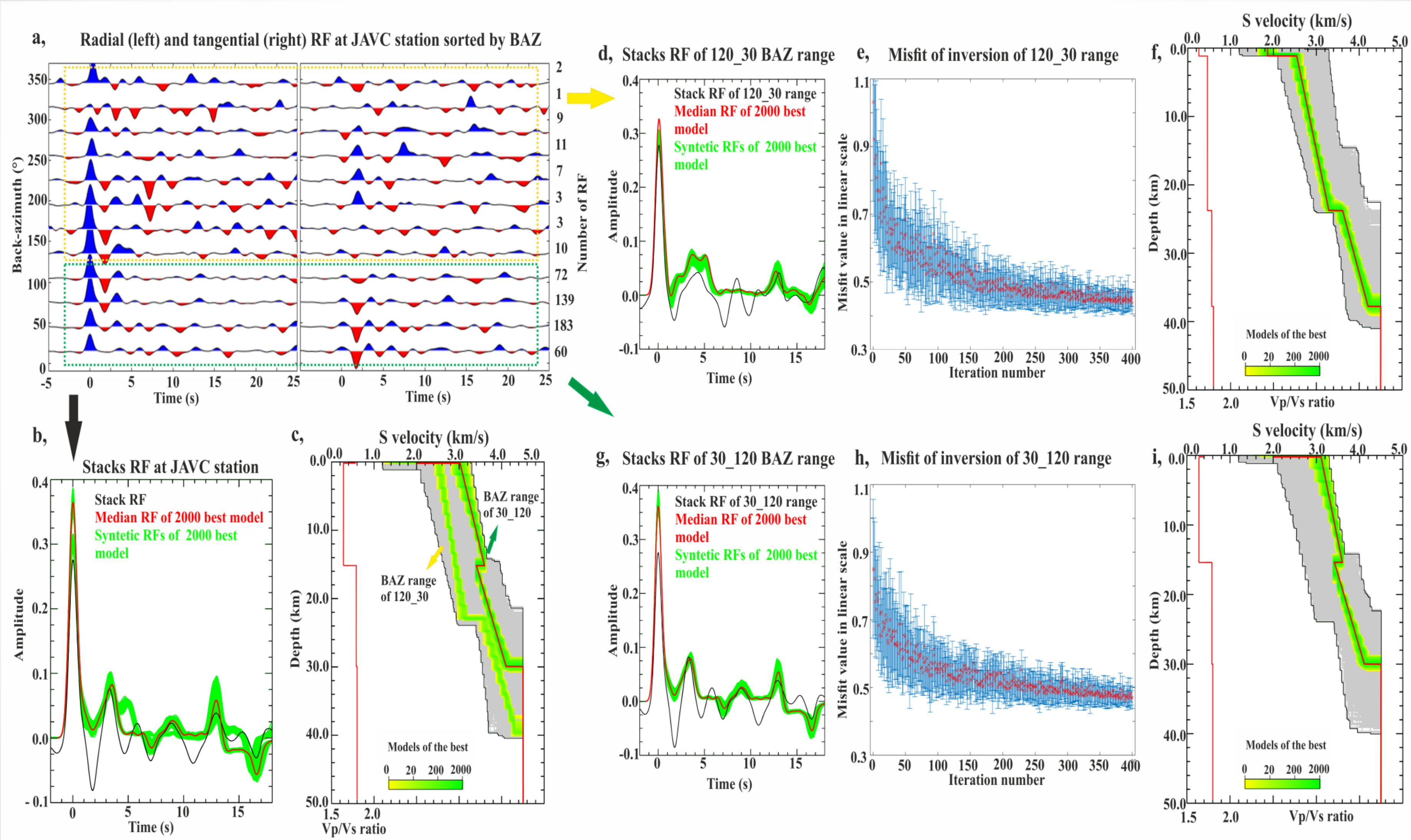
Study area and seismic stations in the P-to-S RF study

- We used altogether 221 (71 permanent and 150 temporary) seismological stations



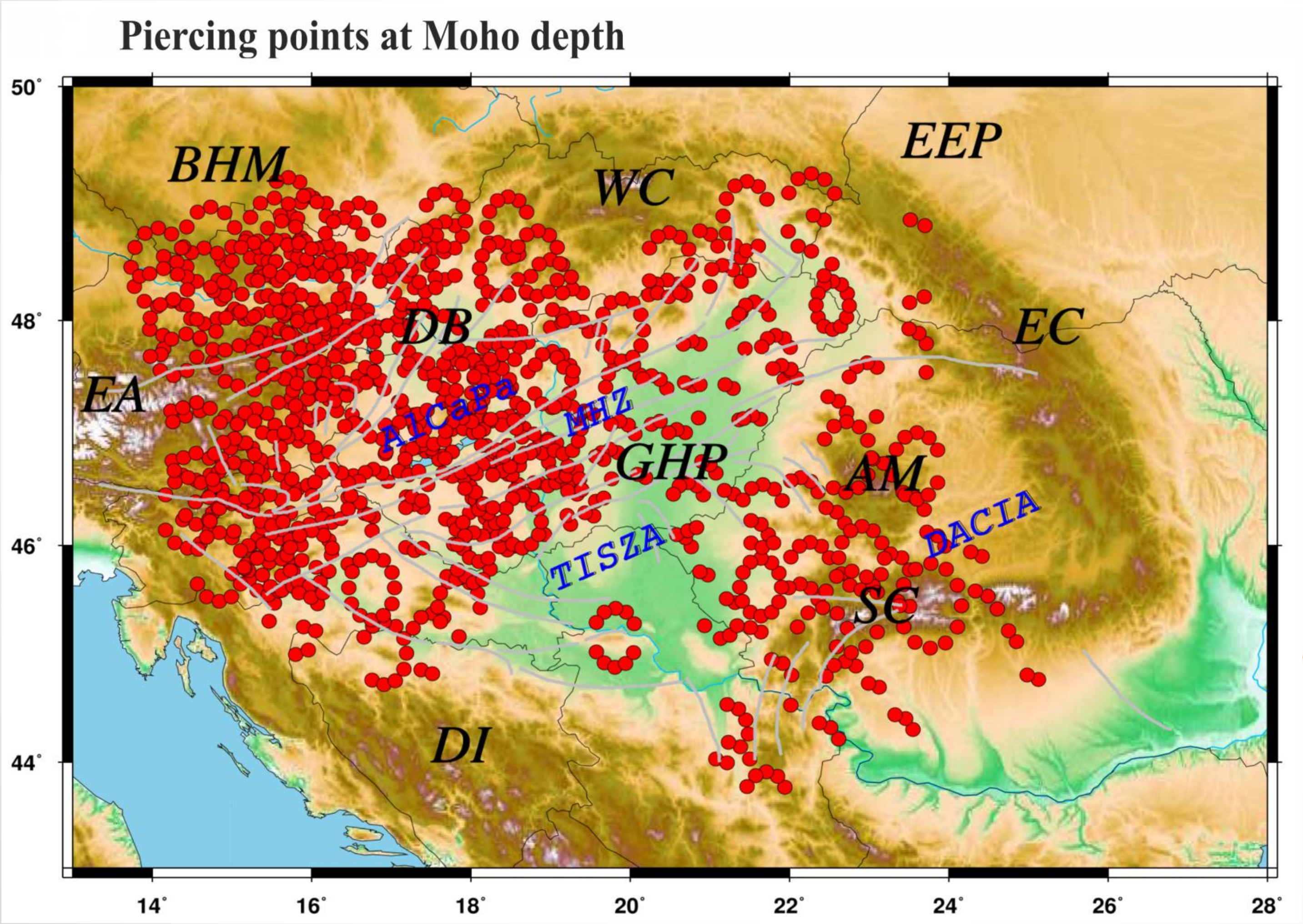
S-wave velocity inversion (grouped by back-azimuth)

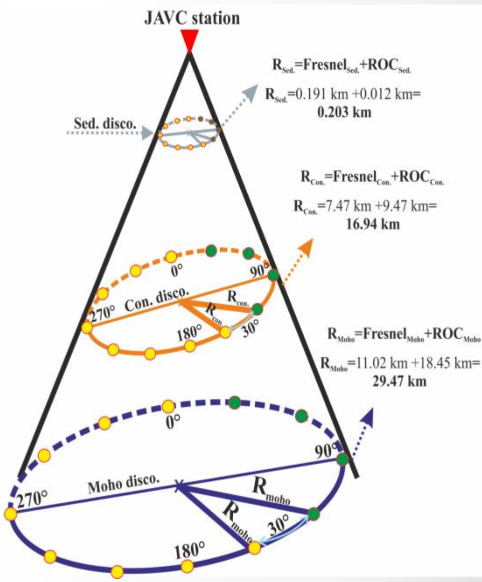
- We applied Neighborhood Algorithm method (Sambridge, 1999) that gives an ensemble of acceptable solutions. This was performed individually for each of the 221 stations
- Inversions have been run for 400 iterations with 50 models tested in each step. In the subsequent iteration step, the best 30 results defined the parameter space to be resampled.



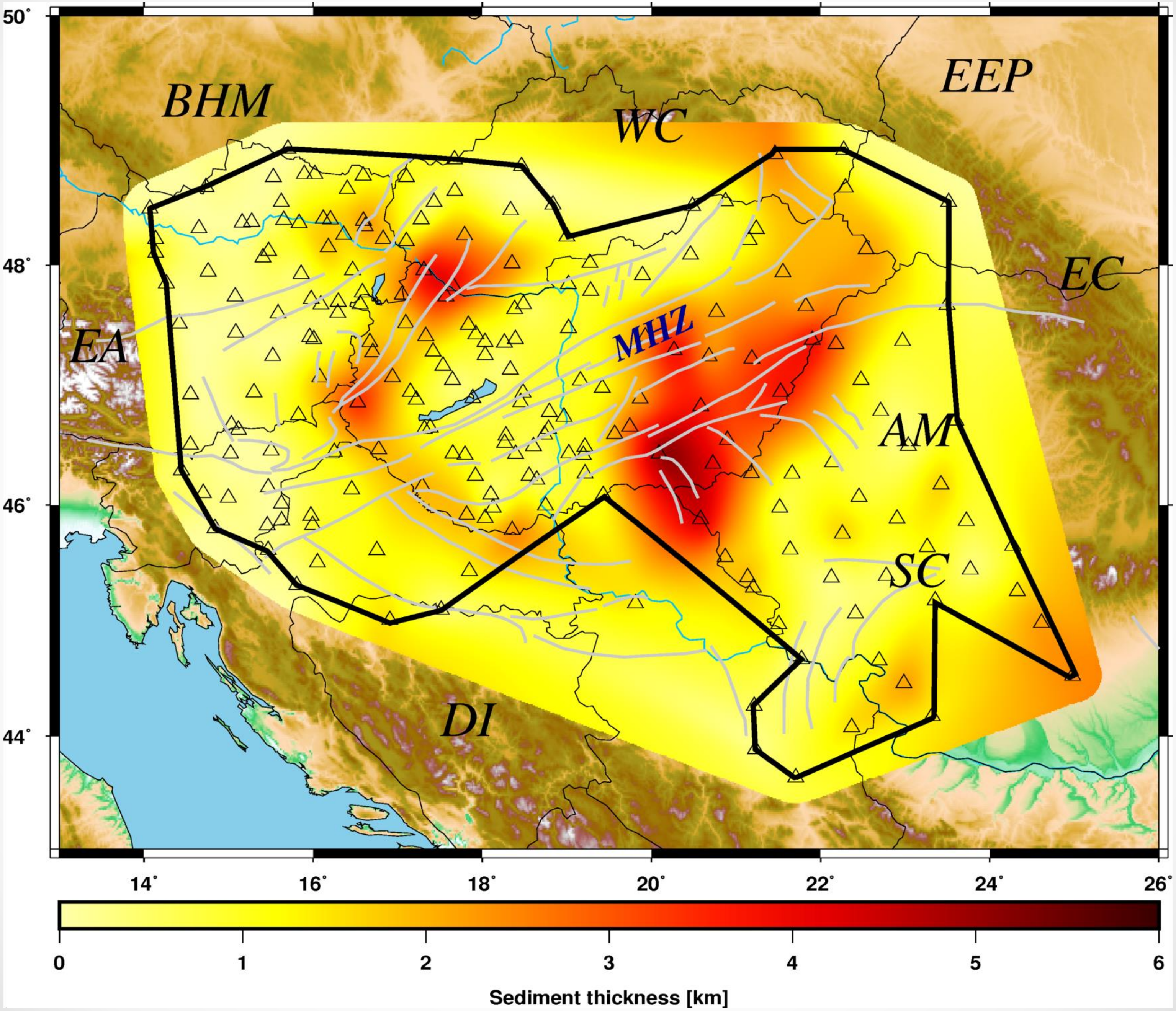
New visualization method (NNCI)

- Natural Neighbor Cone Interpolation (NNCI)
- This model is not directly 3D but is constructed by a much larger number of 1D models than classical interpolation of a single 1D model per station

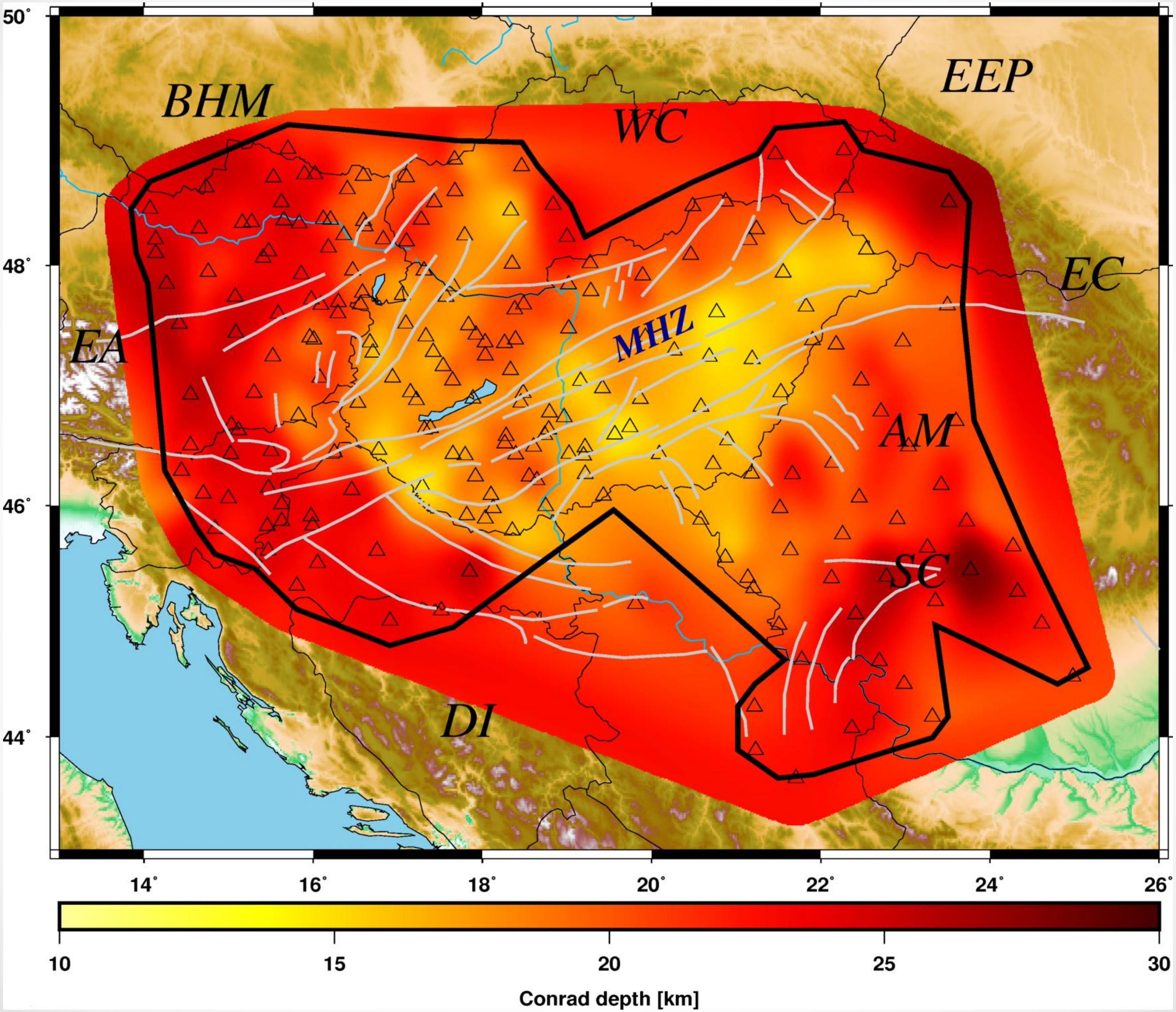




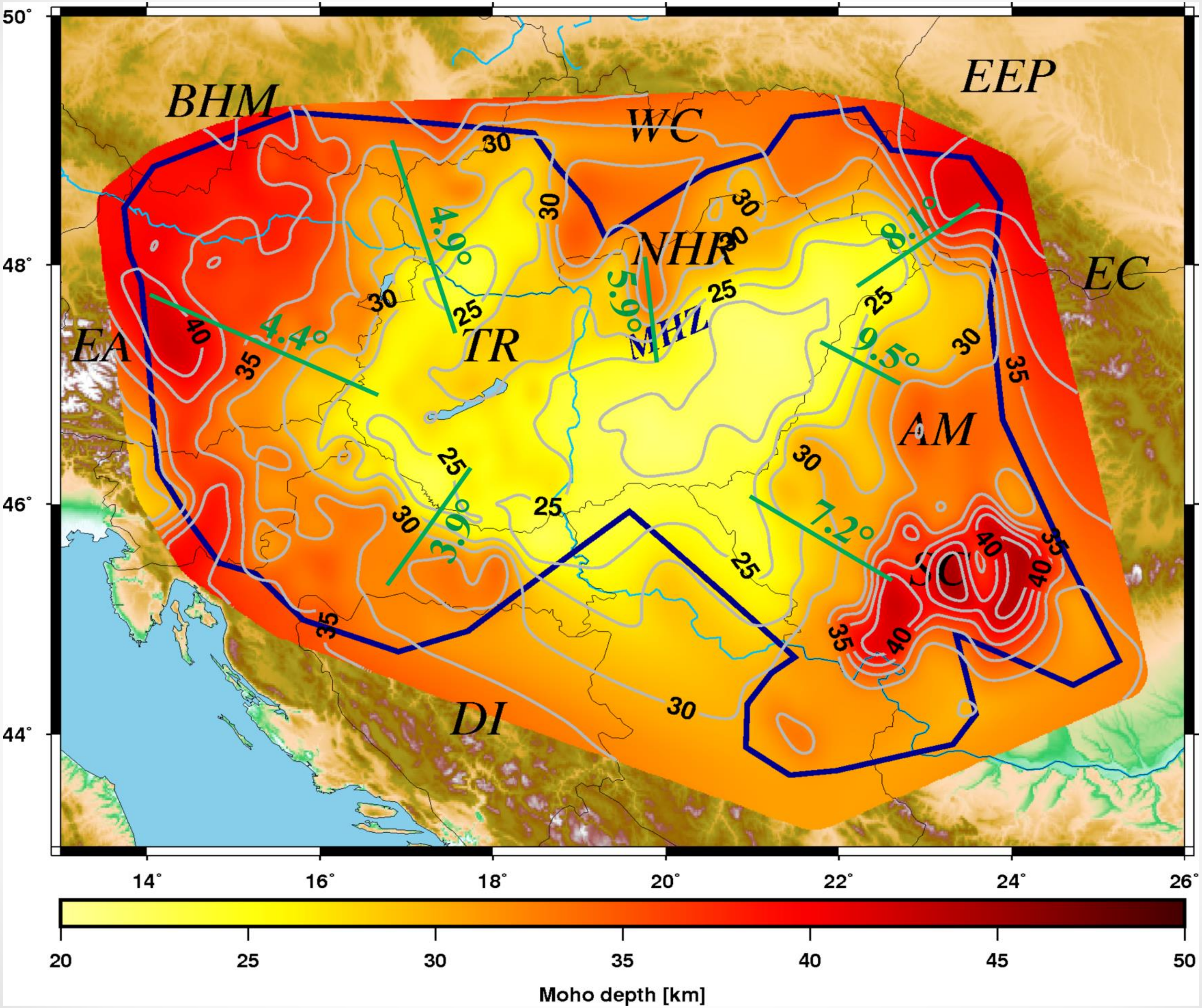
Basement map



Conrad discontinuity



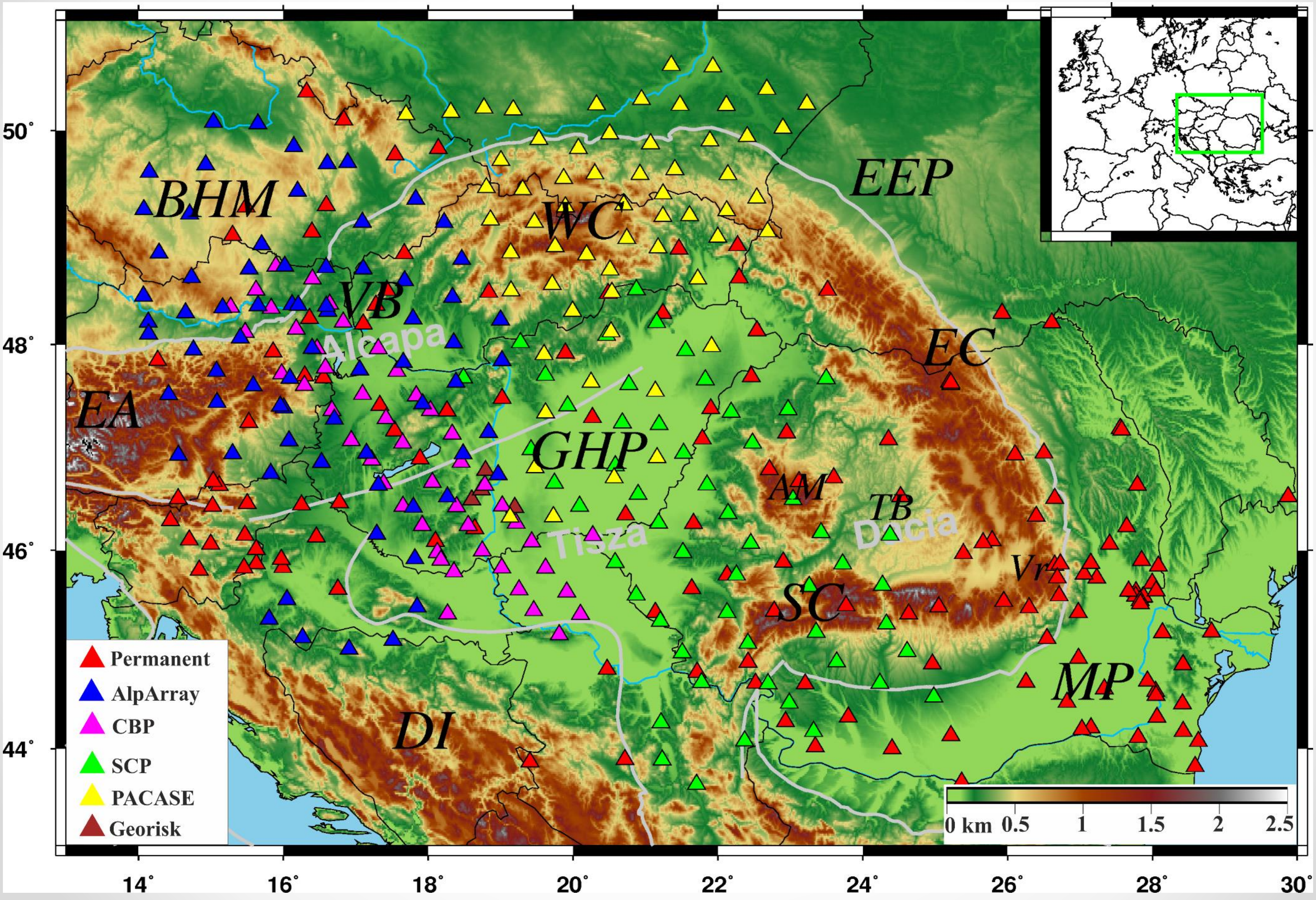
Moho depth



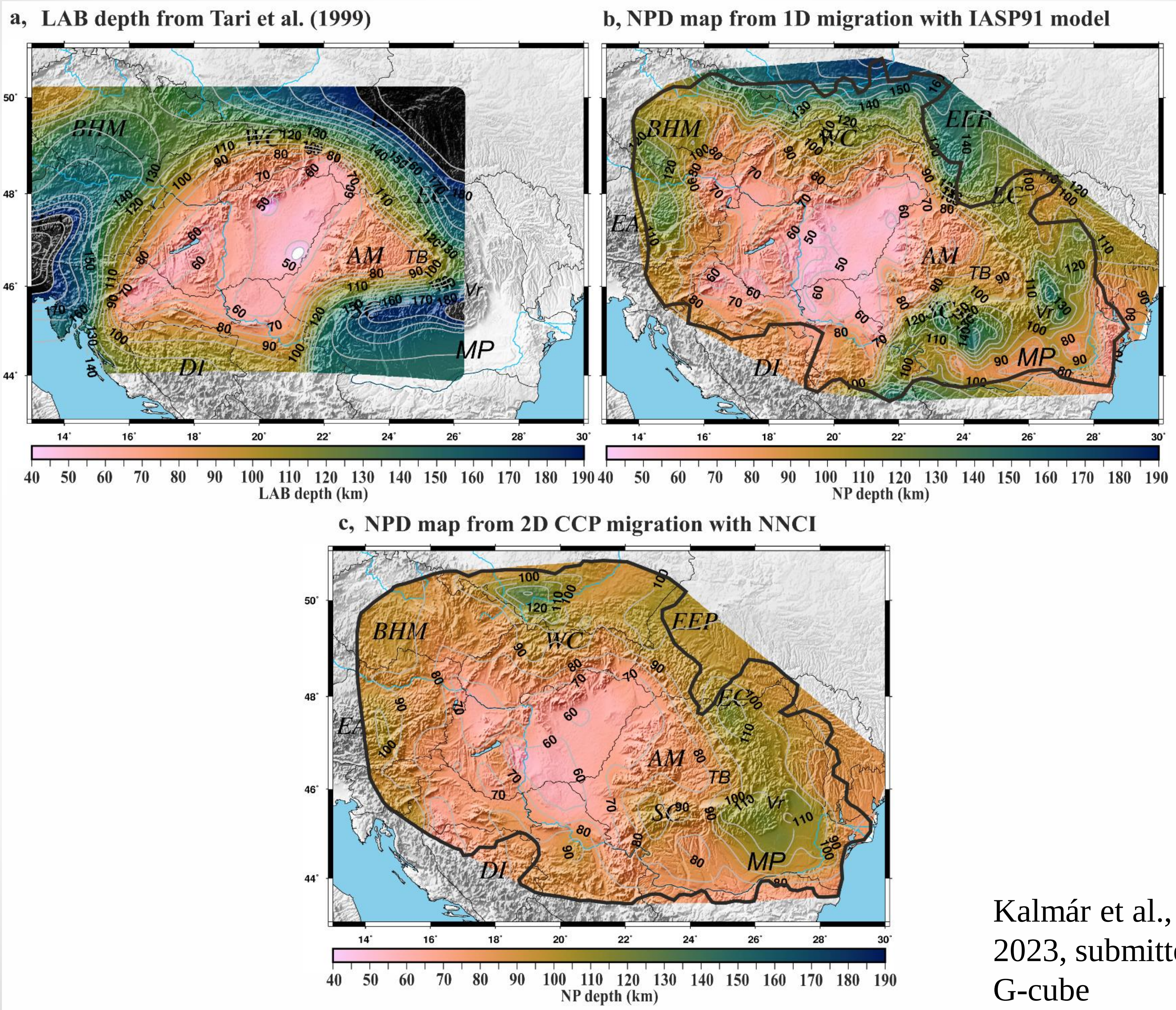
BHM
WC
EEP
NHR
EC
EA
TR
MHZ
AM
SC
DI
4.9°
5.9°
8.1°
4.4°
9.5°
3.9°
7.2°
50°
48°
46°
44°
14°
16°
18°
20°
22°
24°
26°
20
25
30
35
40
45
50
Moho depth [km]

Study area and seismic stations in the S-to-P RF study

- We used altogether 389 (155 permanent and 234 temporary) seismological stations

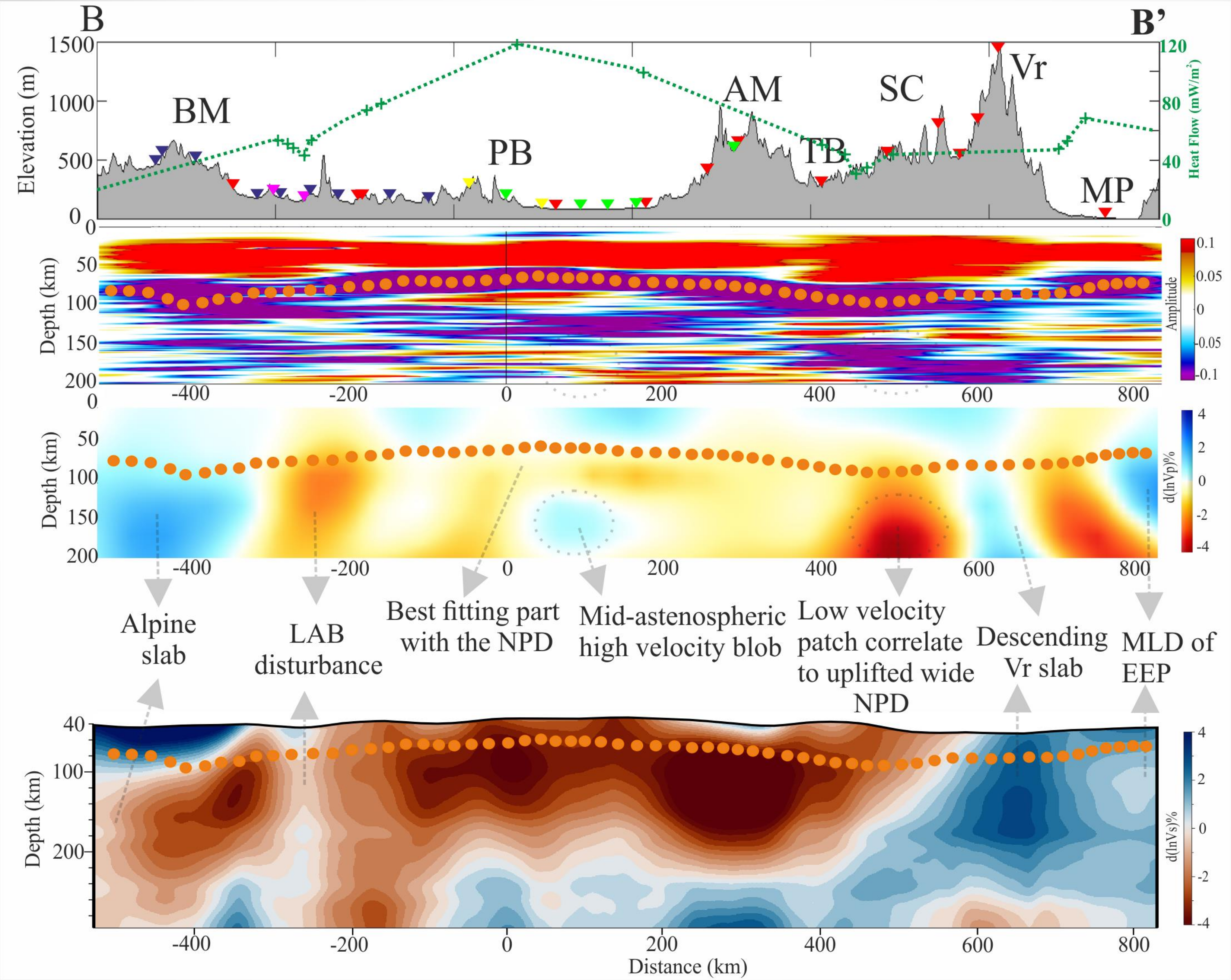


Maps from the S-to-P RF study



Kalmár et al., 2023, submitted G-cube

Results comparison of the S-to-P RF and other studies



Fuchs et al., 2021

Kalmár et al., 2023, submitted G-cube

Ren et al., 2012

Timkó et al., 2023, in prep.

Future work of my Post-Doc project

- Imaging the ~410 and ~660 km phase transition from P-to-S RF analysis with 3D velocity model and it is role in the region

- An updated geodynamic model, revision and extension in the Alpine-Carpathian-Pannonian region

Optional Future work

- New temporary stations (i.e., AdriaArray) are taken into account in determining the crustal structure, a significant improvement in resolution can be achieved in the eastern part of the Pannonian Basin and surroundings

- Anisotropy determination from RF dataset (e.g., harmonic analysis), it is currently completely untapped

- Joint inversion of the RFs data (i.e., P-to-S and/or S-to-P) and dispersion curve (i.e., ambient noise and/or surface wave). All input data is available for this/these.

- We welcome any other suggestions! ☺

Acknowledgments

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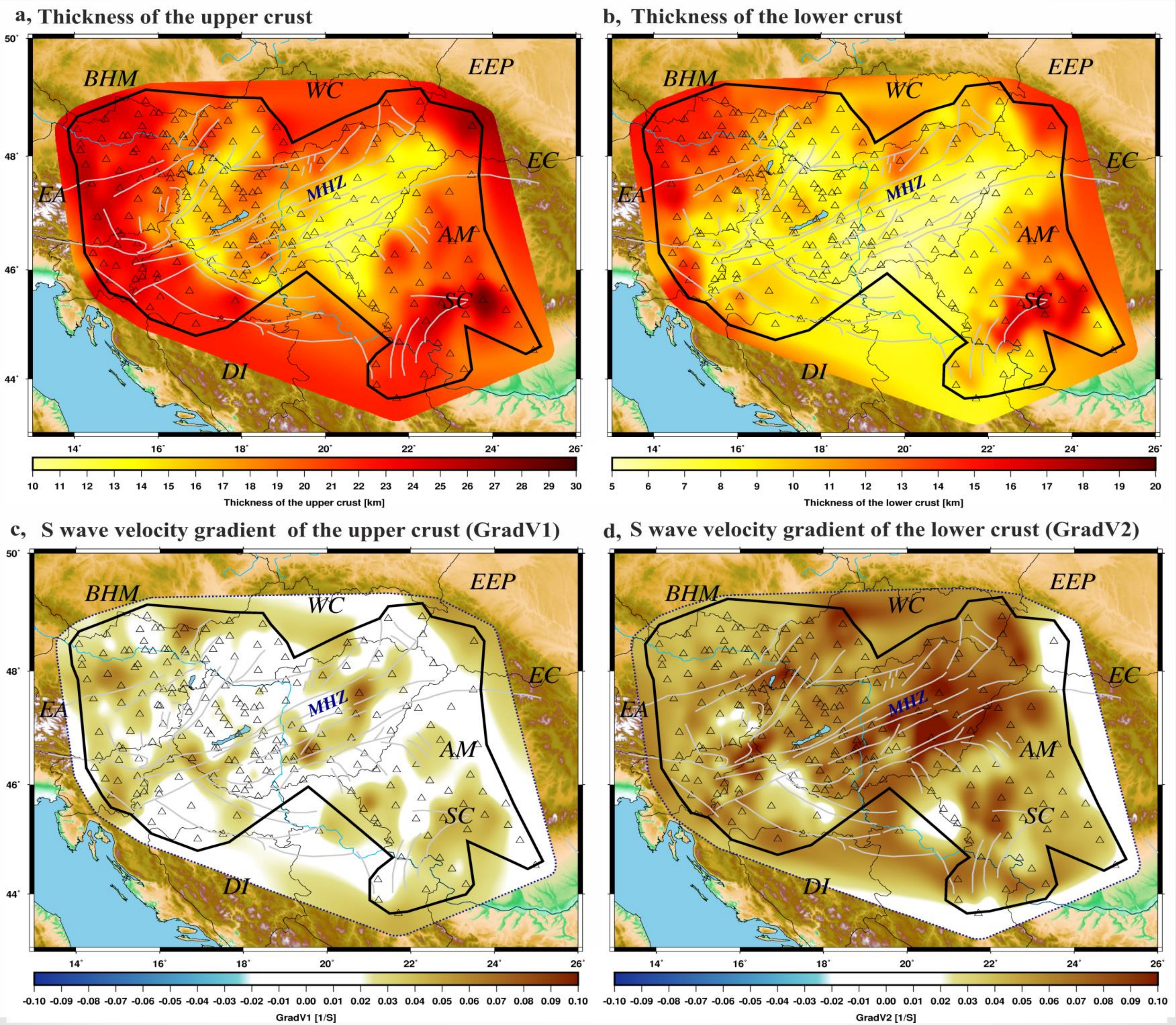
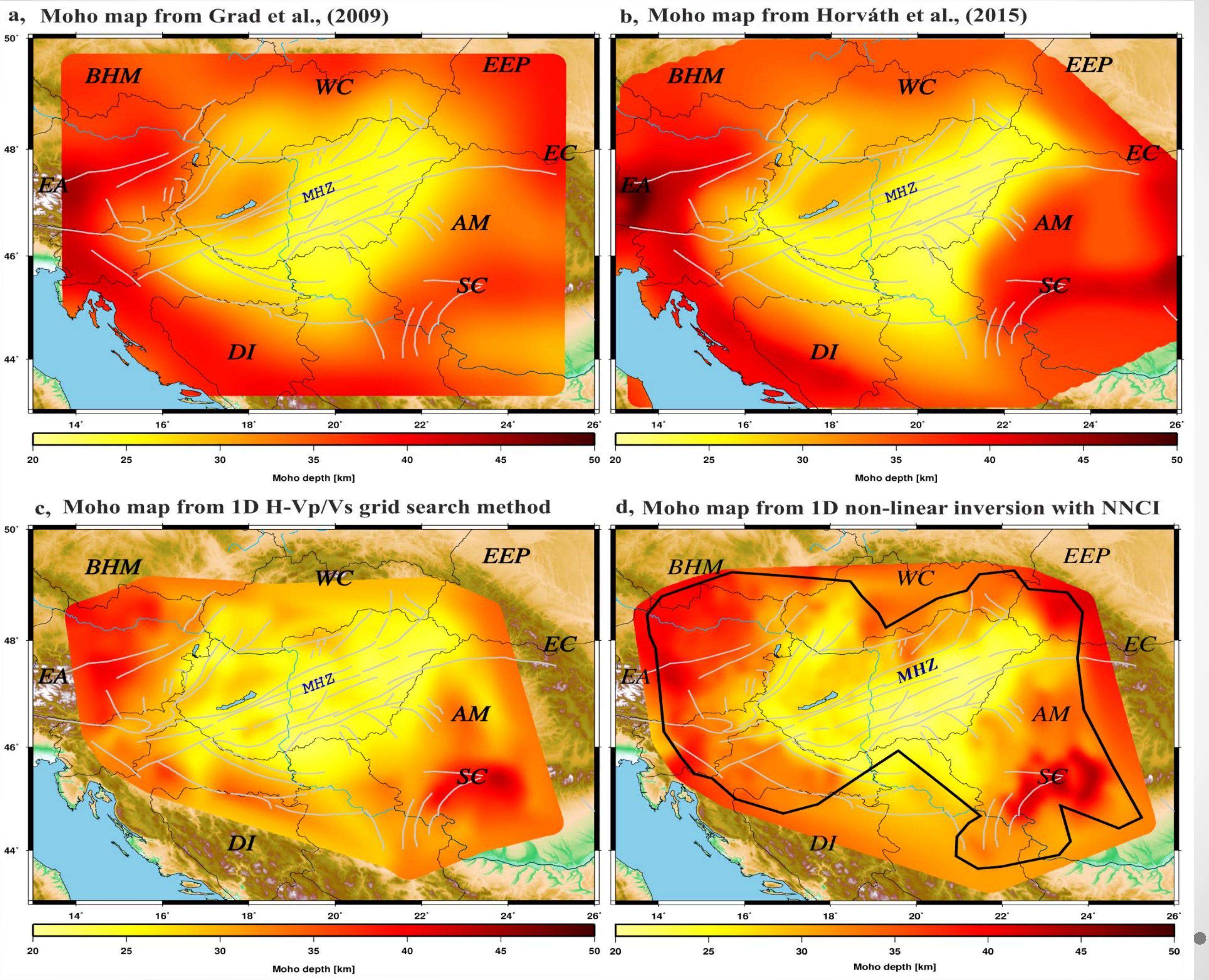
Thank you for your attention!

Extra Slides

First, data-driven upper and lower crust thickness maps

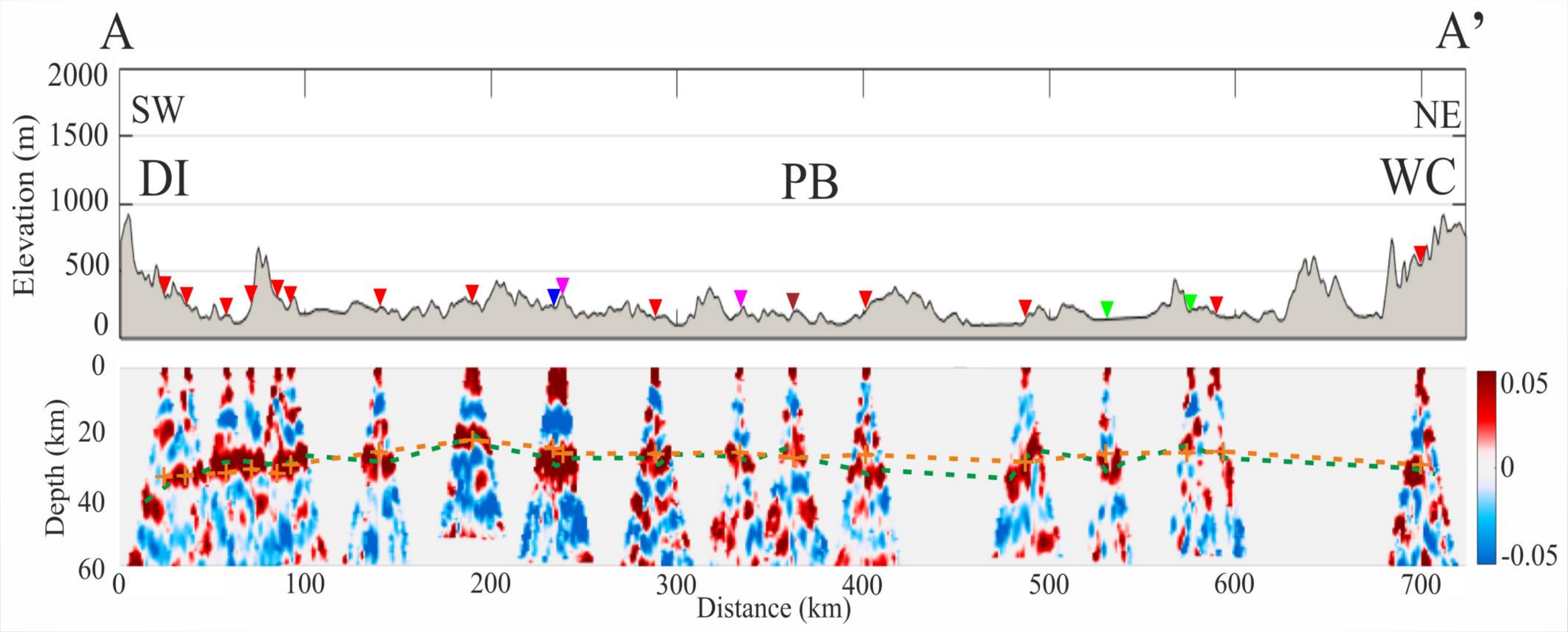


Moho depth comparison with previous studies

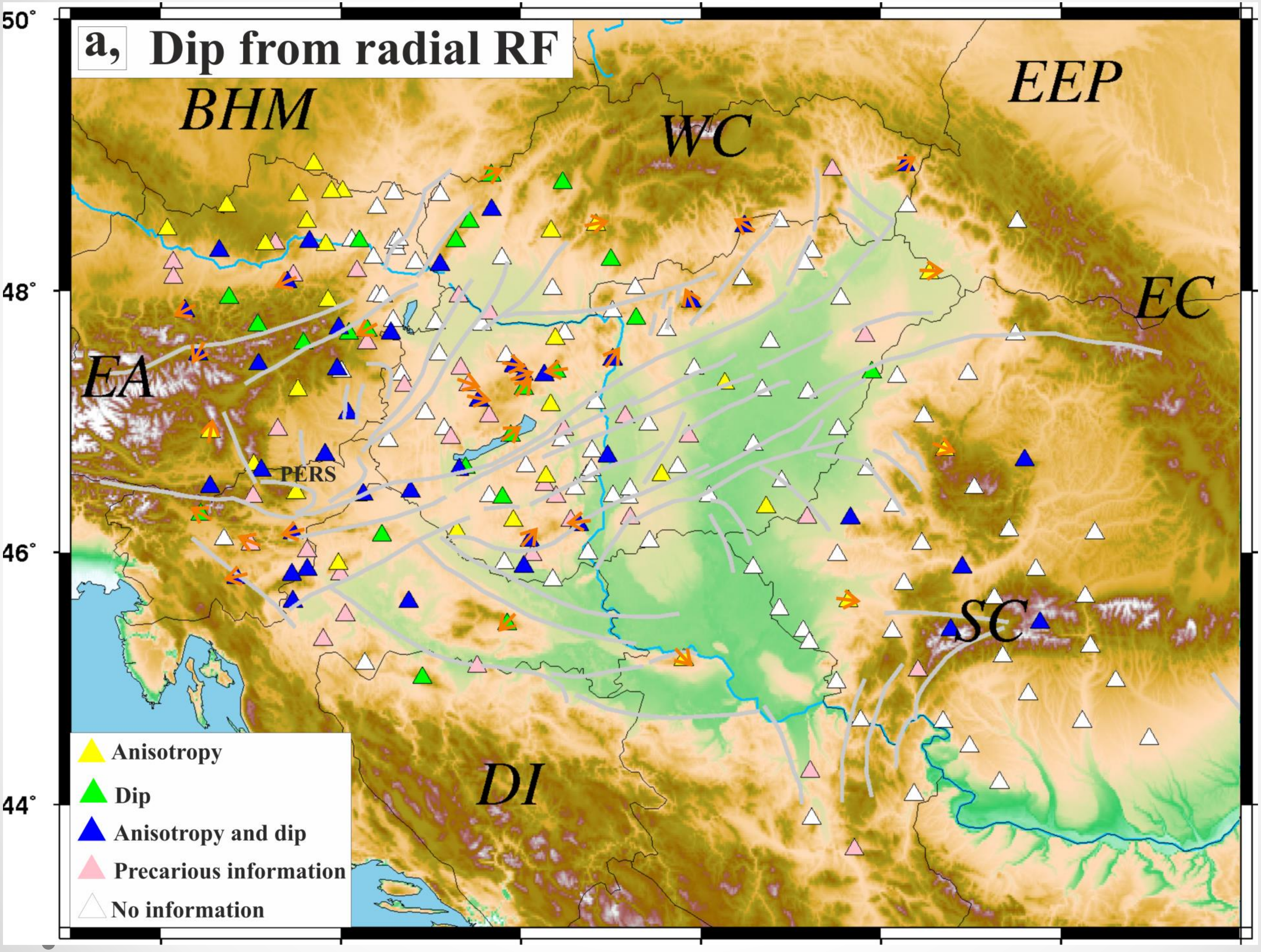


CCP migration in P-to-S RF

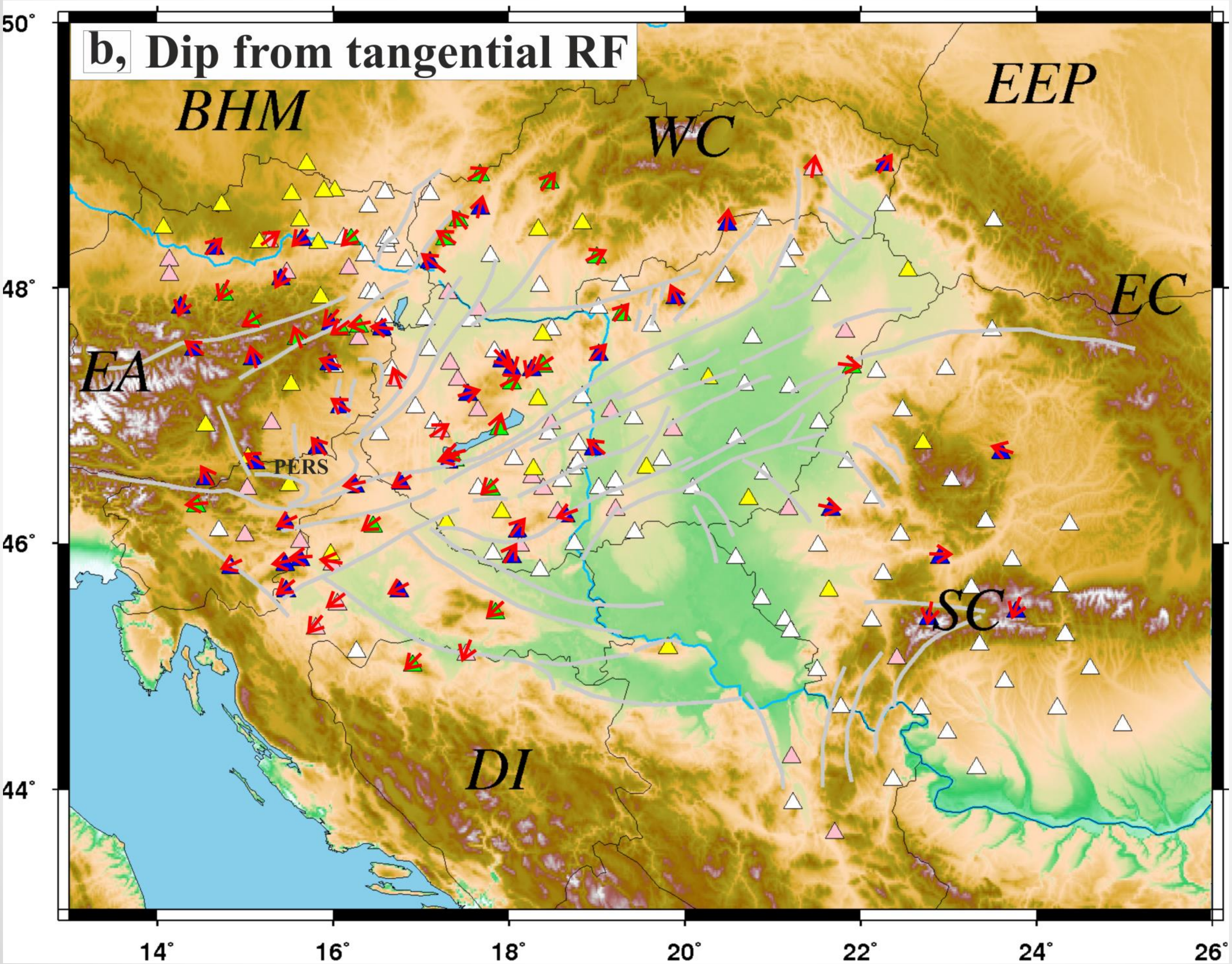
- We imaged the Moho discontinuity with CCP migration method (Zhu, 2000) using a recent 1D local velocity model (Gráczer & Wéber, 2012).
- The sedimentary basin depth correction, we used a Neogene basement depth map compiled recently from reflection seismic profiles and well data (Balázs et al., 2018).
- The pre-stack migration (1 km horizontal and 0.5 km vertical resolution of the bin size)
- The obtained Moho depth and Vp/Vs ratio from the H-Vp/Vs grid search and CCP migration serve as good starting parameter ranges of the receiver function inversion



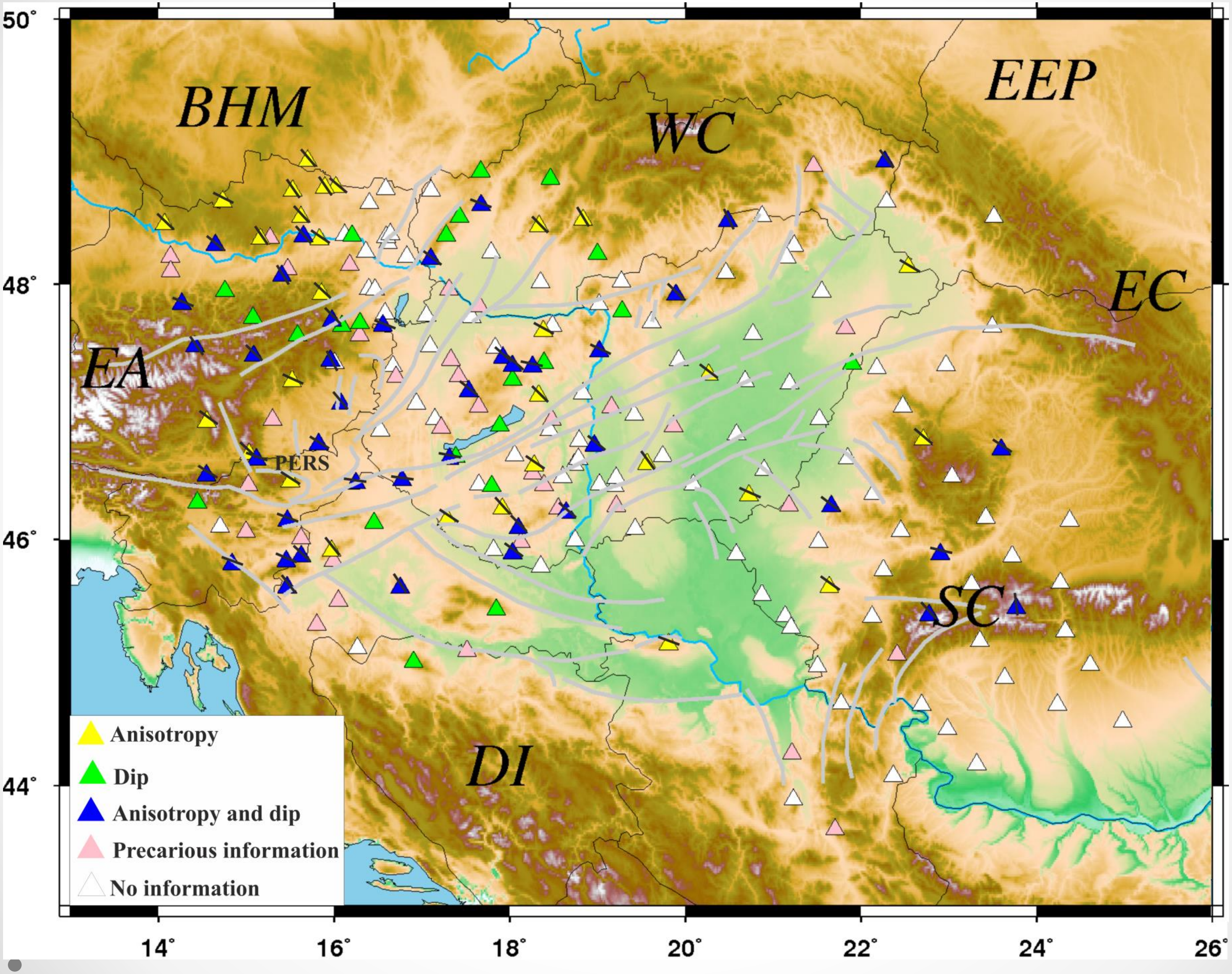
Dip from radial P-to-S RF



Dip from tangential P-to-S RF



Anisotropy from P-to-S RF



Conclusions of P-to-S RF

- We performed the first comprehensive receiver function analysis in the Pannonian Basin and surrounding regions using the most recent data set (221 stations) available.

- Our study is based on a relatively long time-span (2002–2019) of broadband waveforms with uniform automatic waveform processing and quality control procedures.

- We have developed a new interpolation and visualization algorithm (NNCI), in order to image seismic features (including dip estimates) as accurately as possible.

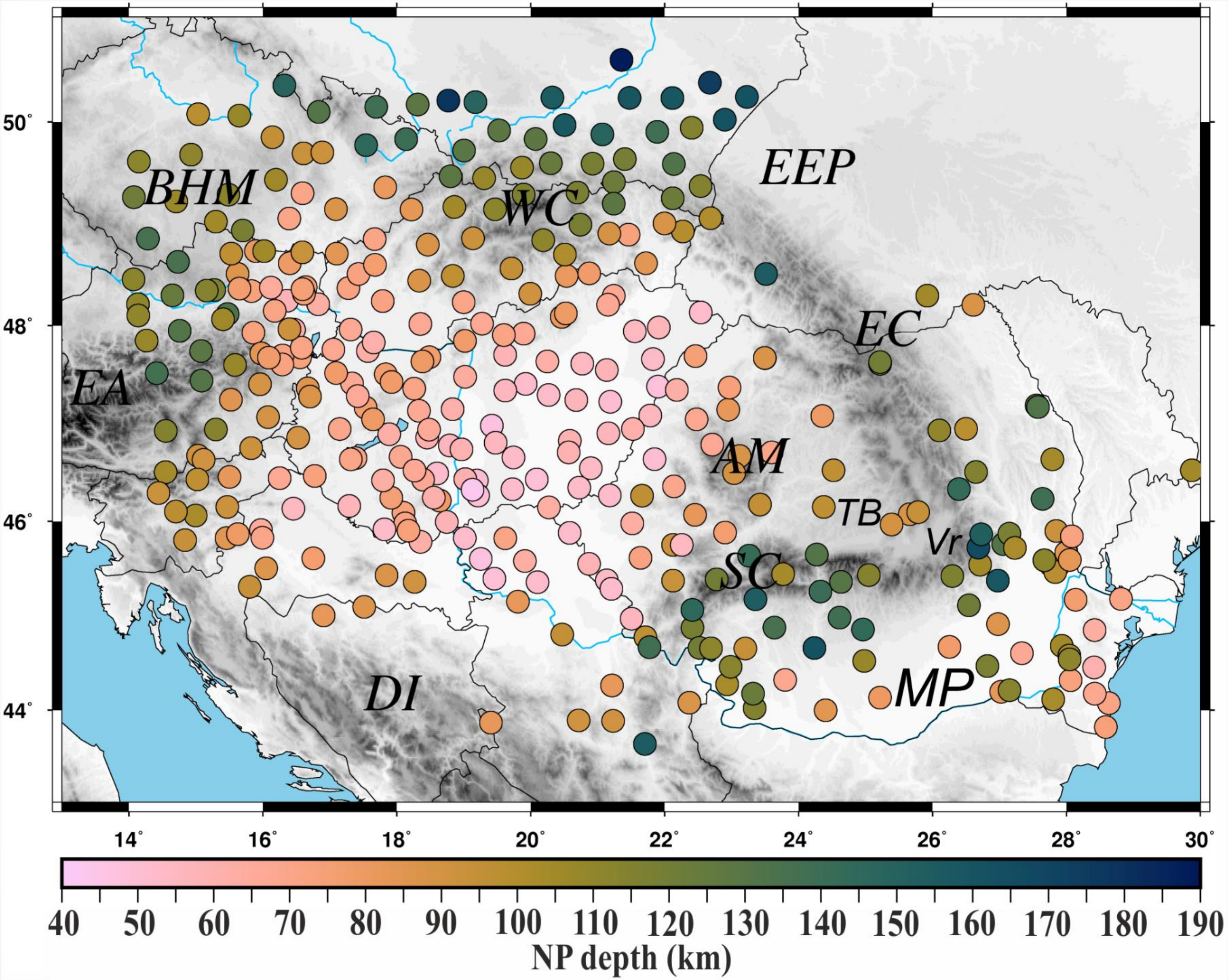
- We mapped the thickness of major crustal layers and determined their S-wave velocity and Vp/Vs ratios.

- The Conrad depth, upper crust, and lower crust thickness maps are the first for the Pannonian Basin region.

- The Moho depth map presents local variations with more finely and better resolved values than previous investigations.

- The dense seismic network with the large amount of quality-controlled data processed here allowed to infer a 3D structural and shear-wave velocity model of the region.

Migration results of S-to-P RF with 1D model



CCP Migration results and piercing points from S-to-P RF