European-Adria plate collision in teleseismic tomography of the Eastern Alps

J. Plomerová , H. Žlebčíková , G. Hetényi, L.Vecsey, V. Babuška and AlpArray Working Groups

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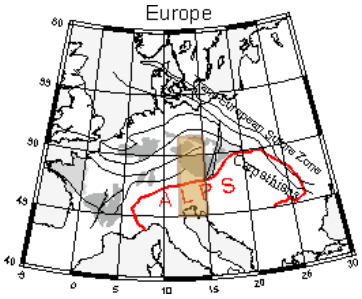
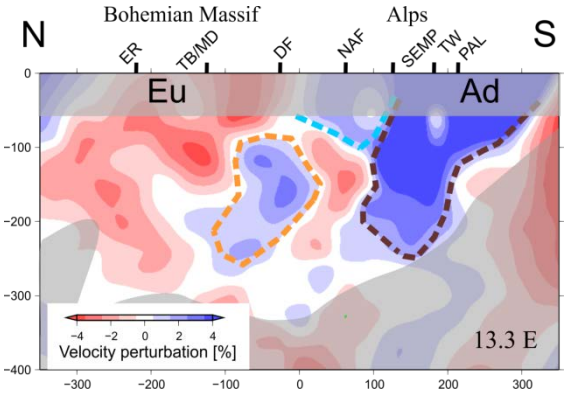
➢ from the **northern Bohemian Massif** across **the Eastern Alps** towards the **Adriatic see**



Data: Teleseismic P waves
AlpArray Seismic Network (AASN)
doi.org/10.12686 /alparray/z3_2015
AlpArray-EASI
doi.org/10.12686 /alparray/xt_2014

Cross-section through the EASI-AA model

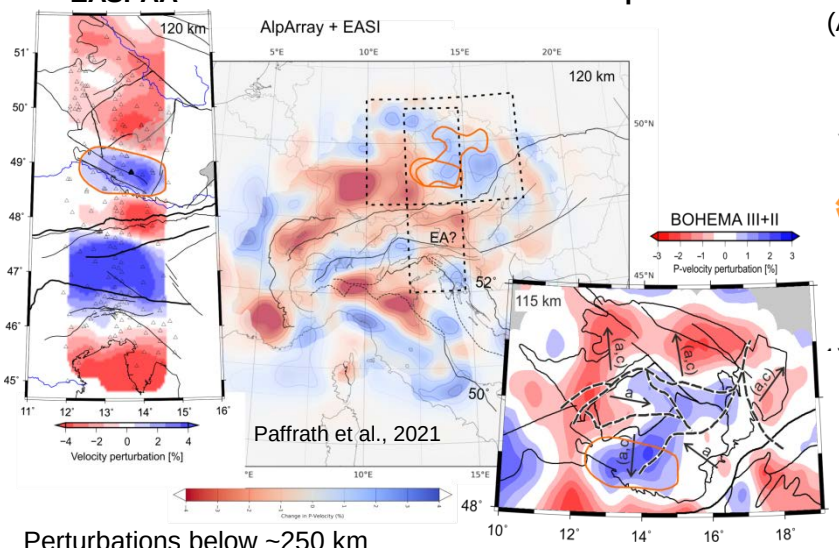


Isotropic mode of the AniTomo code (Munzarova et al., 2018)

- E. Alpine high-velocity perturbation - between the Periadriatic Lineament (PAL) and the Northern Alpine Front (NAF)
- Northward-dipping lithosphere keel - down to ~200-250 km depth, without signs of delamination - the Adriatic plate subduction
- High-velocity heterogeneity beneath the southern Bohemian Massif - at ~100-200km depth with SW-NE strike, parallel with the MD/BV mantle lithosphere boundary in the BM or with the westernmost part of the Carpathian front
- Interpretation:
  - (A) a remnant of the delaminated European plate
  - (B) a piece of continental-and-oceanic lithosphere mixture related to the building of the BM
  - (C) a fragment of a quite extended lithosphere immersing into the mantle in a preceding phase of the Adriatic plate subduction

EASI-AA

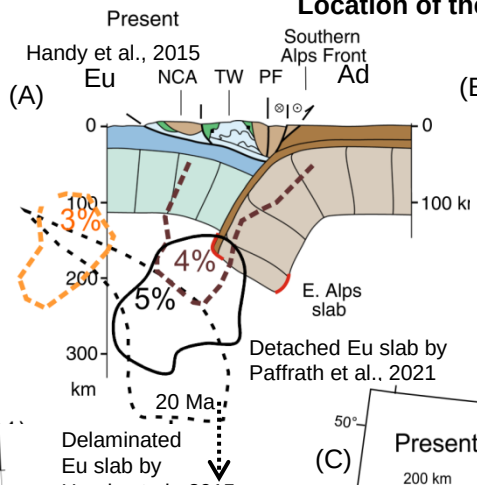
Horizontal slices at 120 km depth



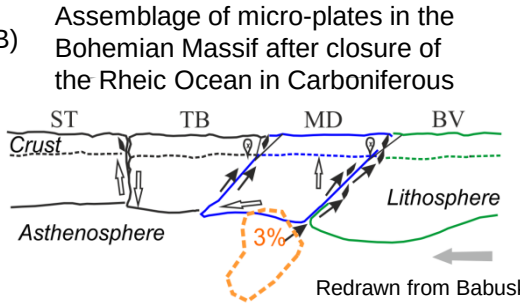
Perturbations below ~250 km depth are very weak in the EASI-AA model, without any significant clustering

Karousova et al., 2013

Location of the high-velocity heterogeneities

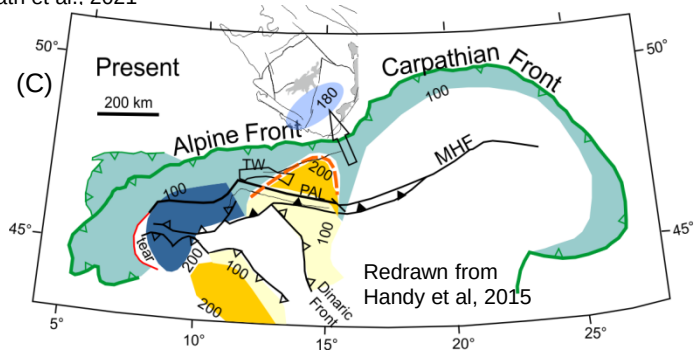


Detached Eu slab by Paffrath et al., 2021



Assemblage of micro-plates in the Bohemian Massif after closure of the Rheic Ocean in Carboniferous

Redrawn from Babuska and Plomerova, 2013



Redrawn from Handy et al, 2015

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J. Plomerová [1)], H. Žlebčíková [1)], G. Hetényi [2)] L.Vecsey [1)], V. Babuška [1)],
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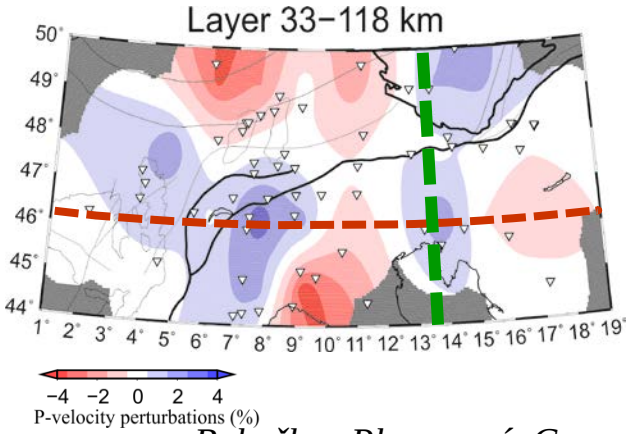
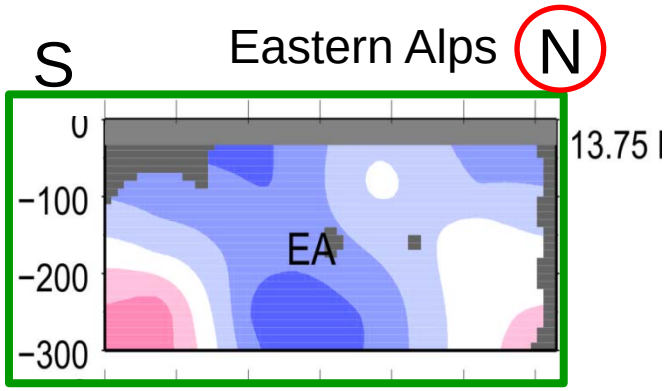
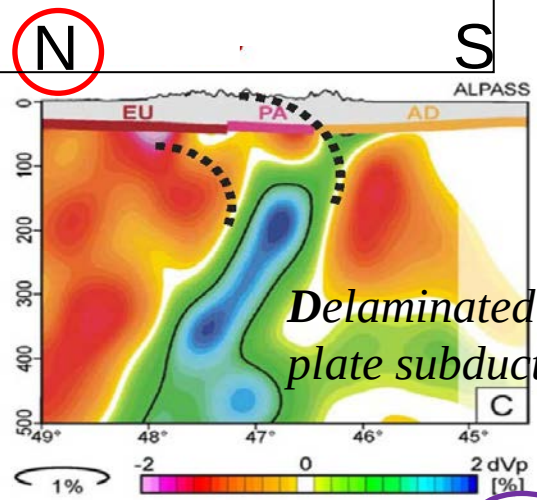
vEGU 2021 TS7.8 The Alps and neighbouring mountain belts …

Segmentation of the Alpine root and northward dip of subduction beneath the Eastern Alps in pre-AlpArray studies



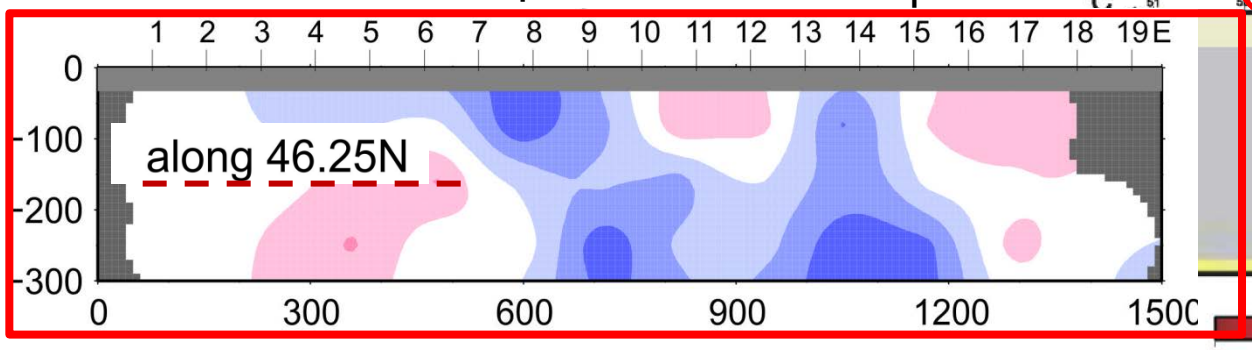
Babuška , Plomerová, Granet, Tectonophysics 1990

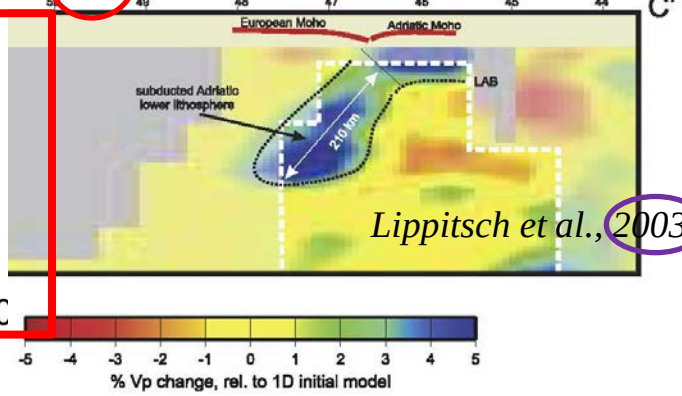




Delaminated E plate subductio

Mitterbauer et al., Tectonophysics 2011
Brückl et al., Tectonics 2011





Lippitsch et al., 2003

Two subductions –switched polarity and a gap in between the Western/Central and Eastern Alps lithosphere roots

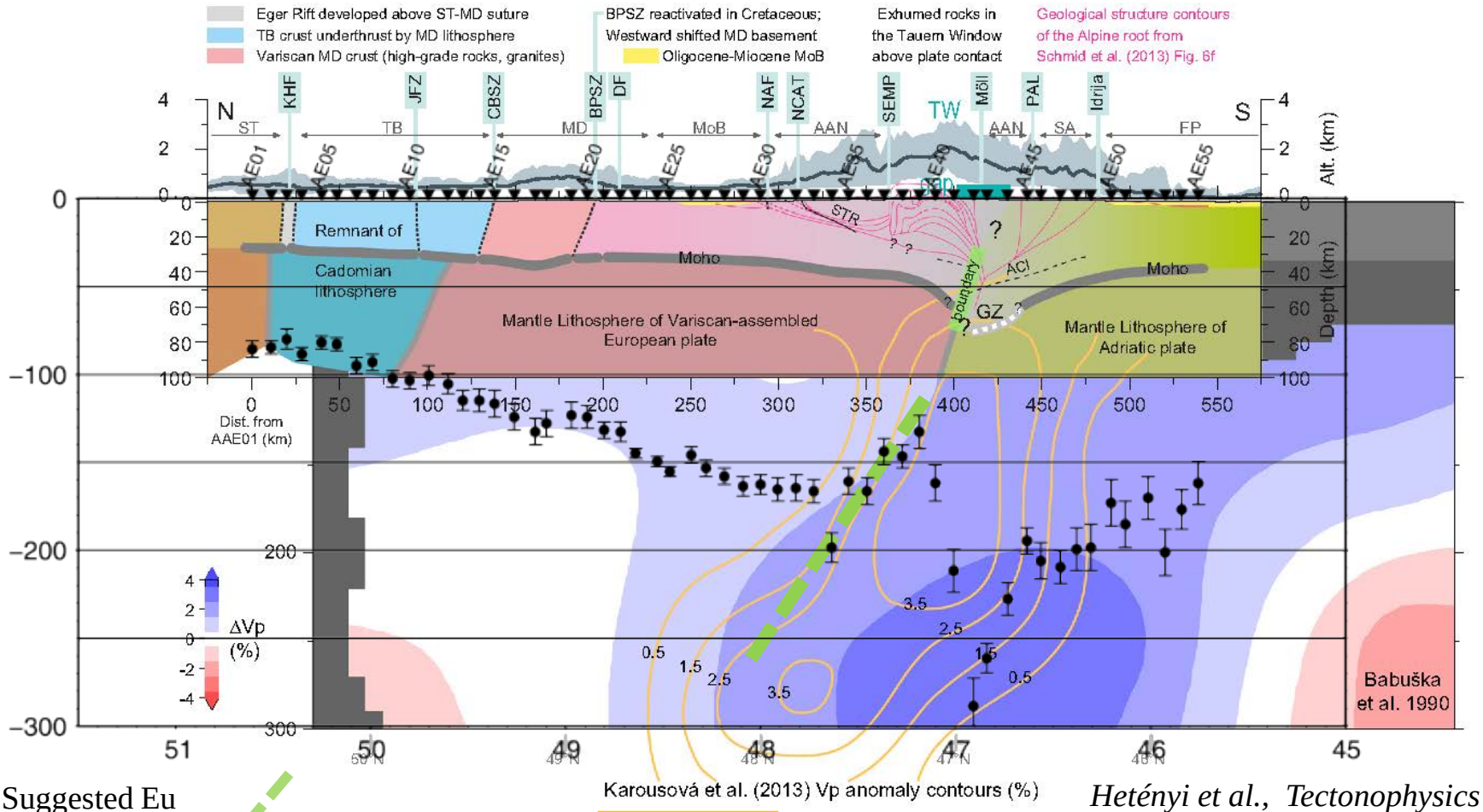
Western Alps - obliquely to the EAST

Eastern Alps- steeply to the North

- **different data sets and tomography codes**
- **consistent results**, but diff. interpretations

- *in touch in depth* or merged due to vertical *smearing*, or lower resolution in depth

Tomography images of the E. Alpine root along with the crust from the AlpArray-EASI receiver-functions and LAB estimate



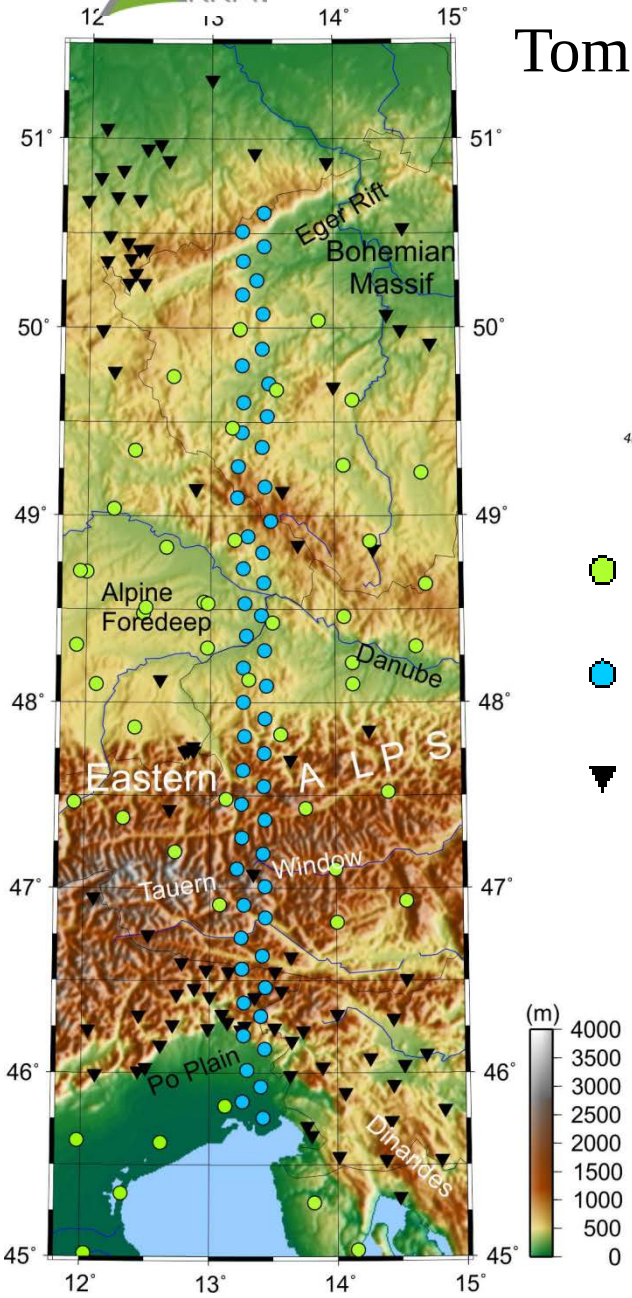
Hetényi et al., Tectonophysics 2018

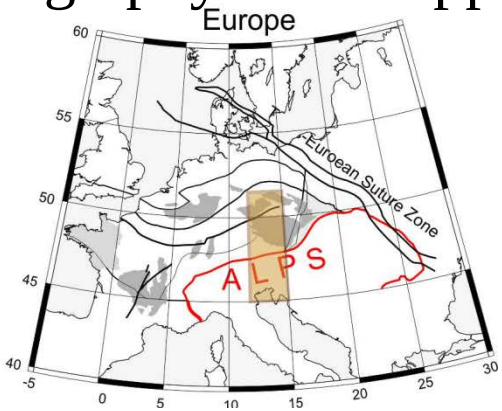
Suggested Eu and Adria plate boundary

Lab depths from static terms of relative travel time deviations of teleseismic P waves

Crust in superposition with tomography from sparse data from permanent observatories (1x1 deg lateral spacing) and 40x40 km grid from the BOHEMA III and the northern part of ALPASS experiments.

Tomography of the upper mantle along the EASI





- From the **northern Bohemian Massif** across **the Eastern Alps** toward the **Adriatic see**

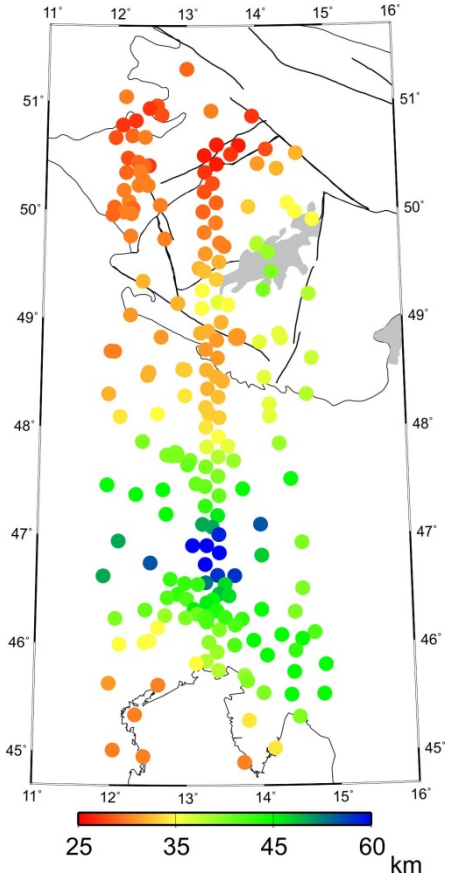
- AlpArray Seismic Network (AASN), doi: 10.12686/alparray/z3_2015
- AlpArray EASI , doi: 10.12686/alparray/xt_2014
- Permanent stations

Anitomo code
Munzarová et al., GJI 2018
Isotropic mode

0 km = 13.3 E 48.5 N
block size 30 x 30 km
Total number of stations: 240
Number of events: 201
Number of rays in the model: ~30 000

Data were carefully pre-processed and corrected for crustal effects

Moho depth



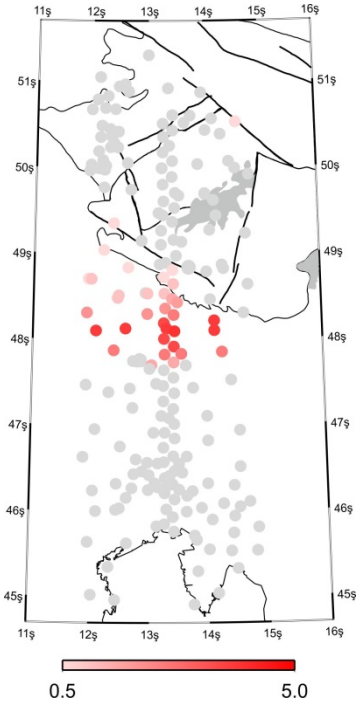
Crust corrections

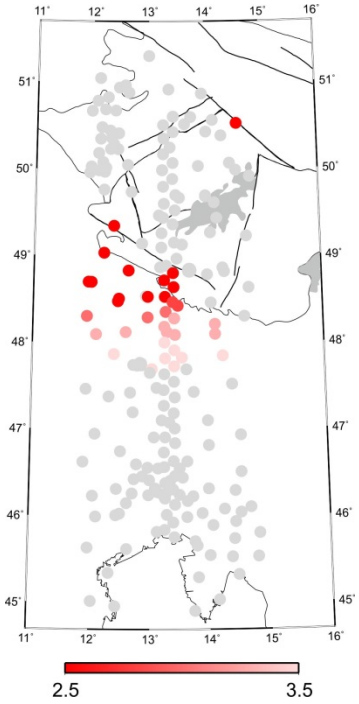
Compilation from different sources:

along EASI
Hetényi et al., 2018

in the BM
Karousová et al., 2012
south of BM, e.g.
Di Stefano et al., 2011
Hua et al., 2017
Tesauro et al., 2008

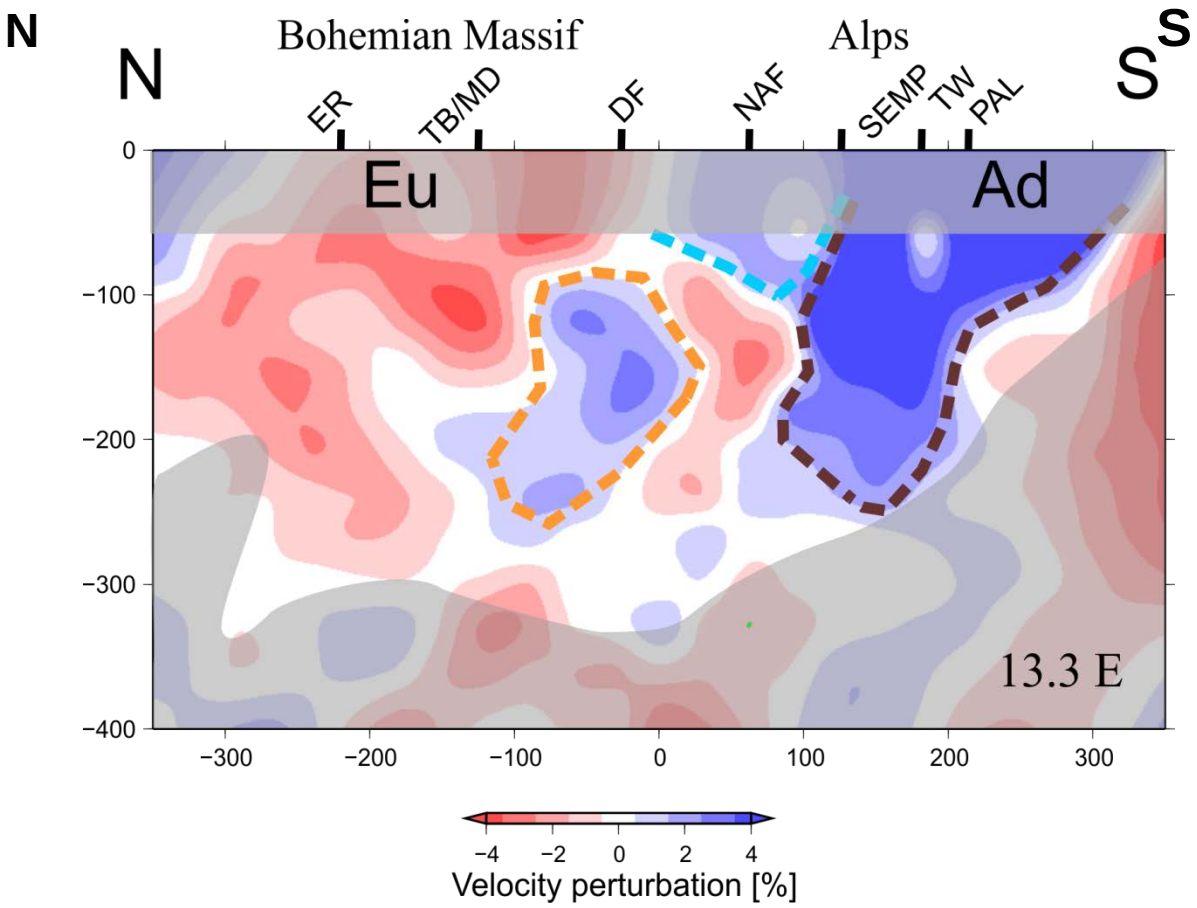
Corrections for sediment thickness and velocities





P-wave tomography for 200km wide band along the EASI

North dipping high-velocity heterogeneities

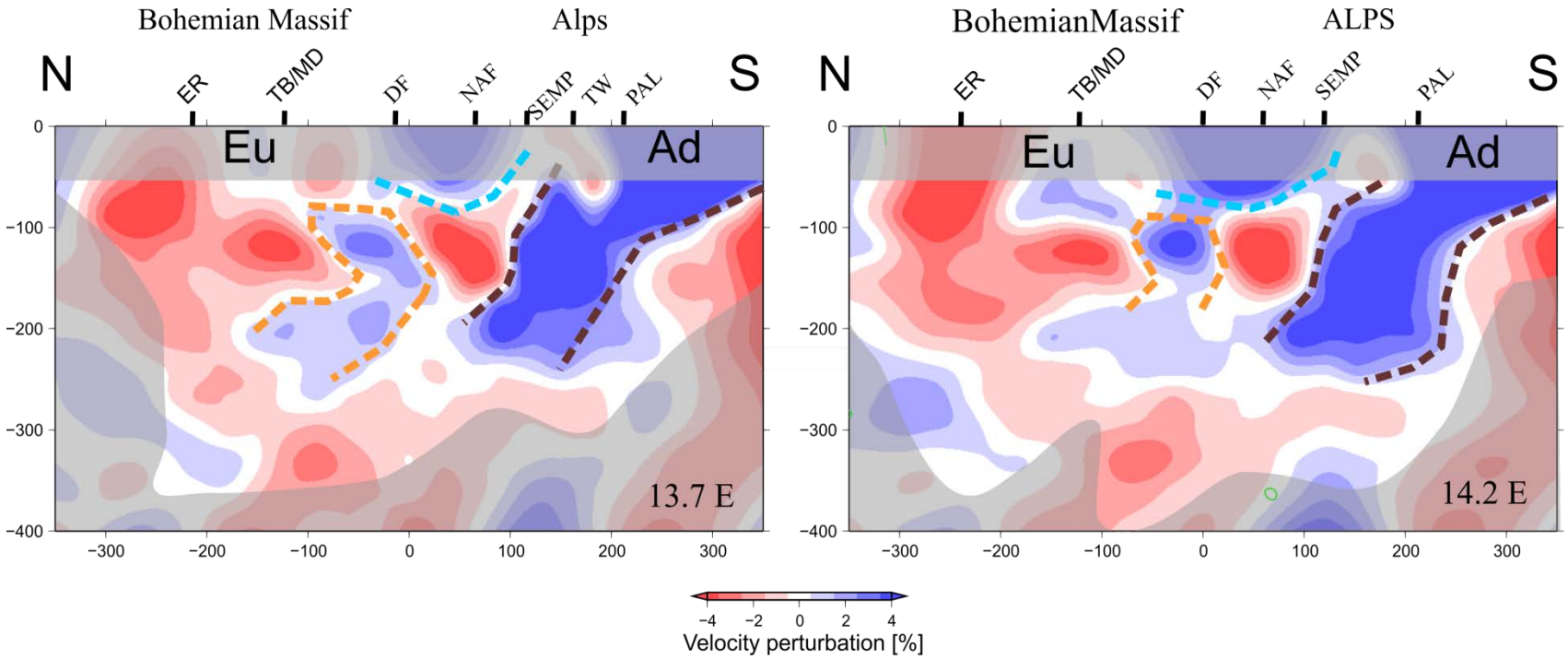


Extended data set: EASI + AASN

- rays in 60° bands from South and North along the EASI
- **Two sub-parallel** heterogeneities
- Southern one stronger (HV-EA)
- **Northern** one weaker (HV-BM), delaminated
- Slab thickness ~80-100 km

Lateral changes of mantle velocity structure

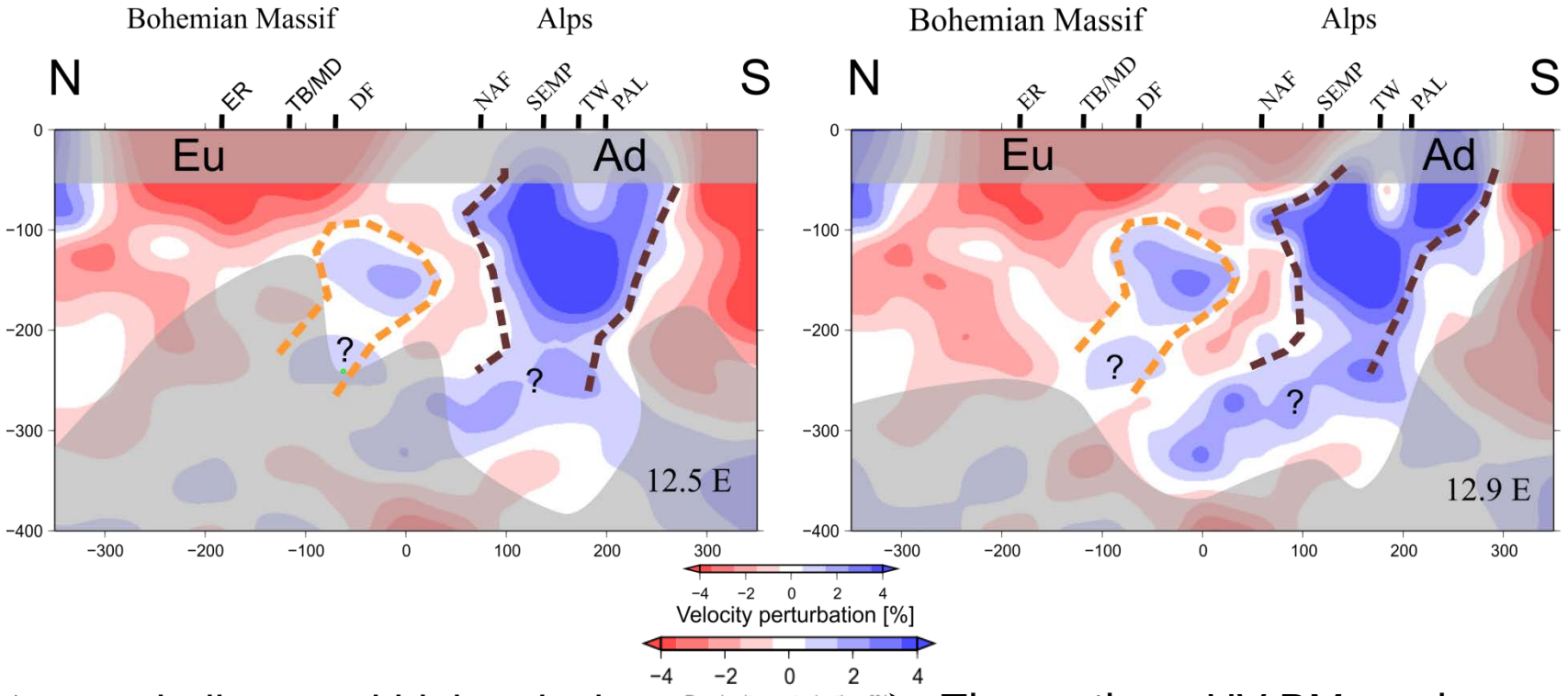
North-South vertical slices **east** of the EASI



- The weaker northern high-velocity heterogeneity HV-BM detached
- Two to the north dipping high-velocity heterogeneities
- Crust not resolved

Lateral changes of mantle velocity structure

North-South vertical slices **west** of the EASI



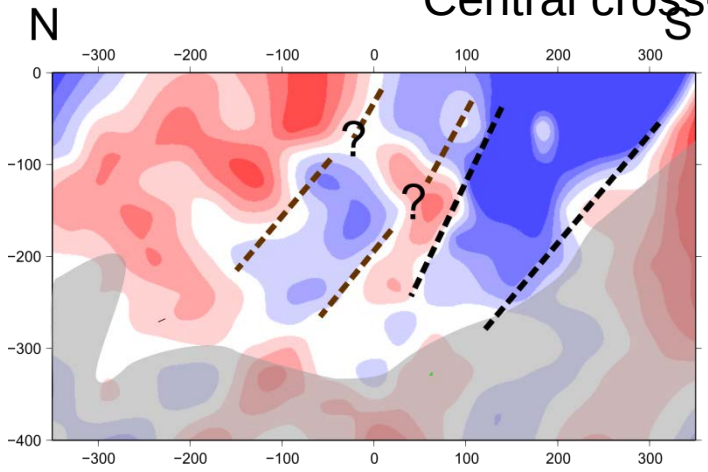
- Weak dispersed high-velocity perturbations below 200 km
- The northern HV-BM weakens
- No connection to shallower depths
  - Crust not resolved

Synthetic tests of tomography capability to resolve

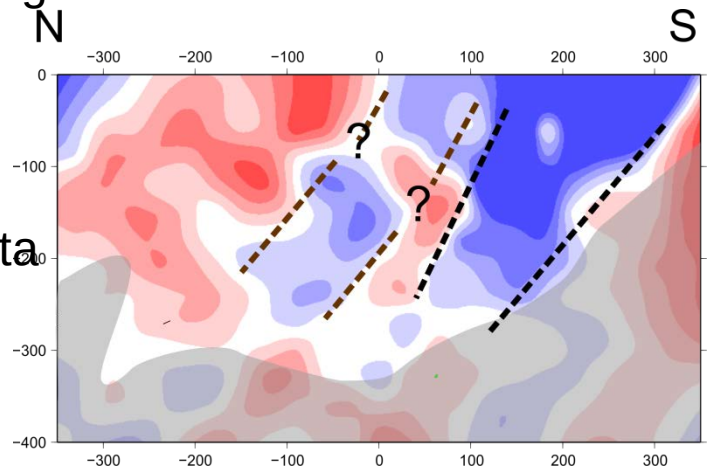
- One vs. two slabs
- Dipping direction of the slab(s)
  - to the North
    (change polarity relative to the central Alps)
  - to the South
  - two bi-vergent slabs
- detached slab beneath the E. Alps

Synthetic tests – 5% high-velocity heterogeneities

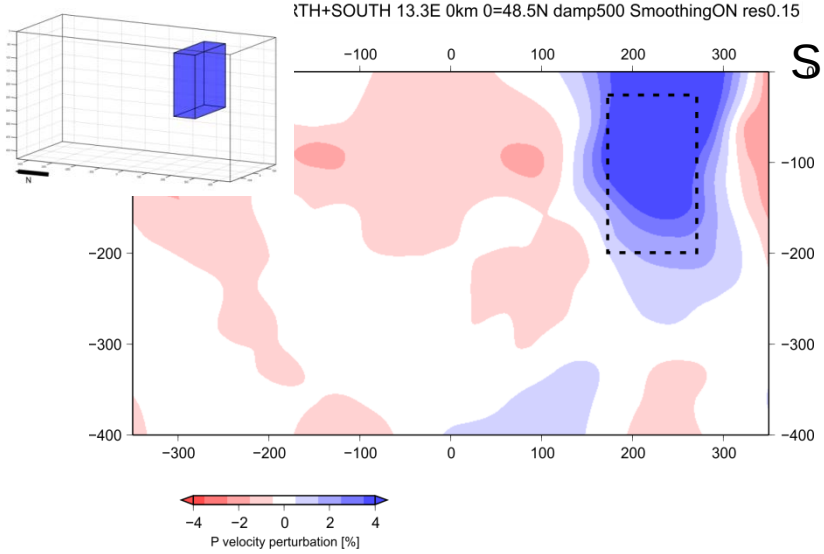
Central cross-section along 13.3E



Retrieved from AA data

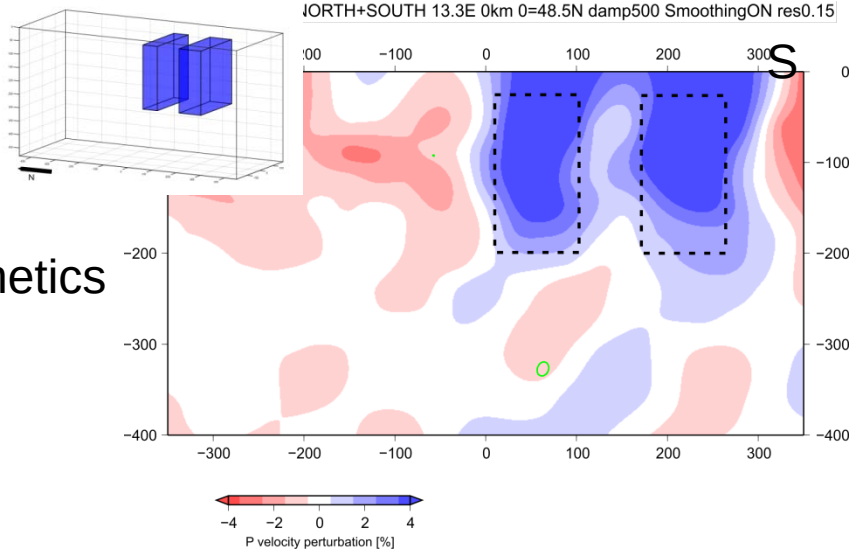


One vertical heterogeneity



Synthetics

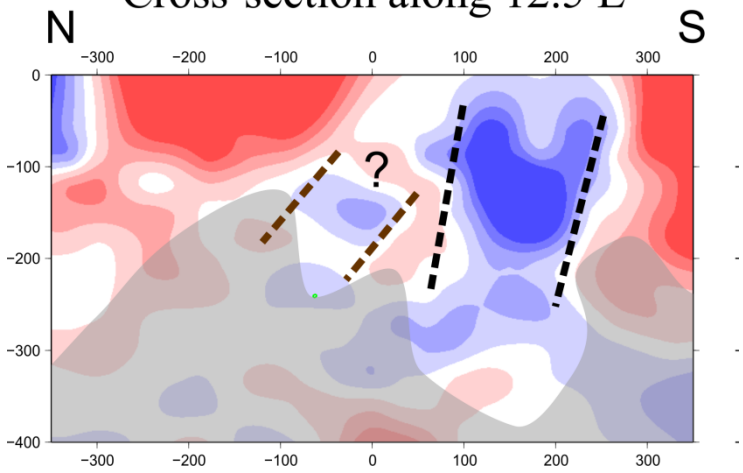
Two vertical heterogeneities



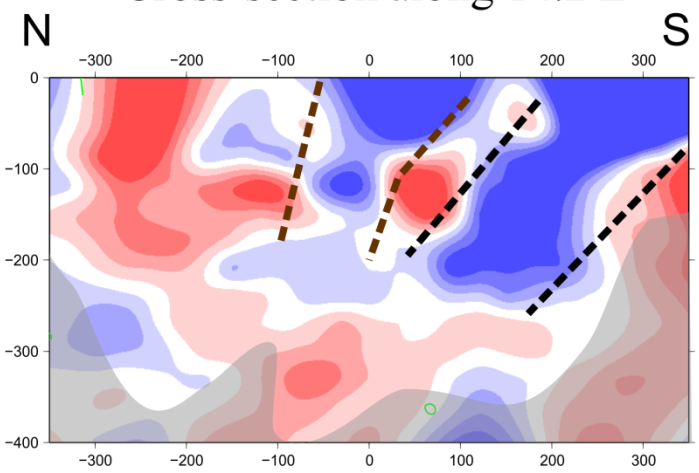
- No northward smearing due to ray geometry

Perturbations retrieved from **AA data**

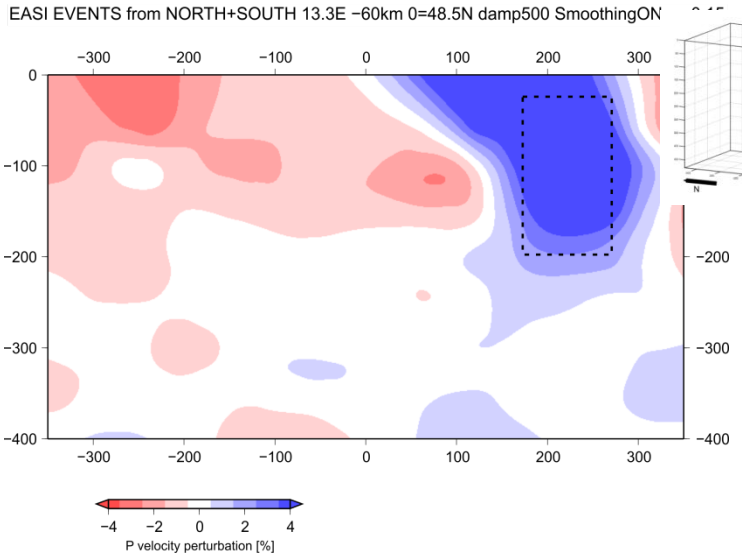
Westernmost
Cross-section along 12.5 E

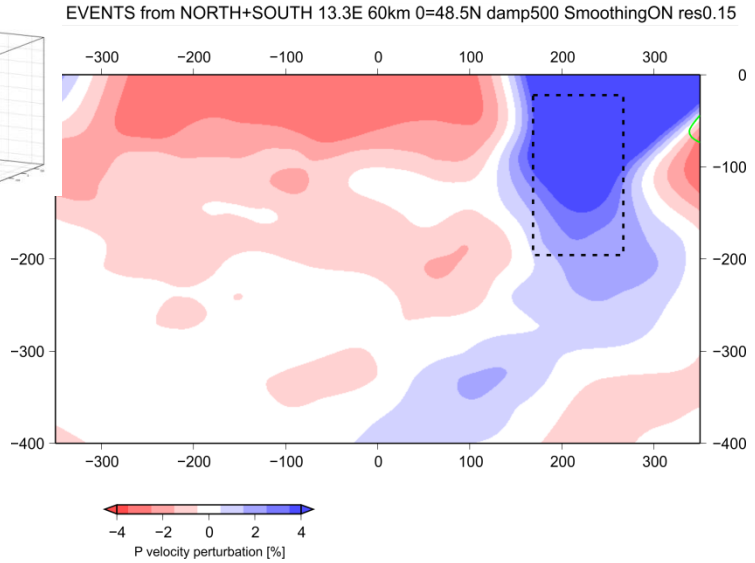


Easternmost
Cross-section along 14.2 E



Synthetics with one vertical heterogeneity

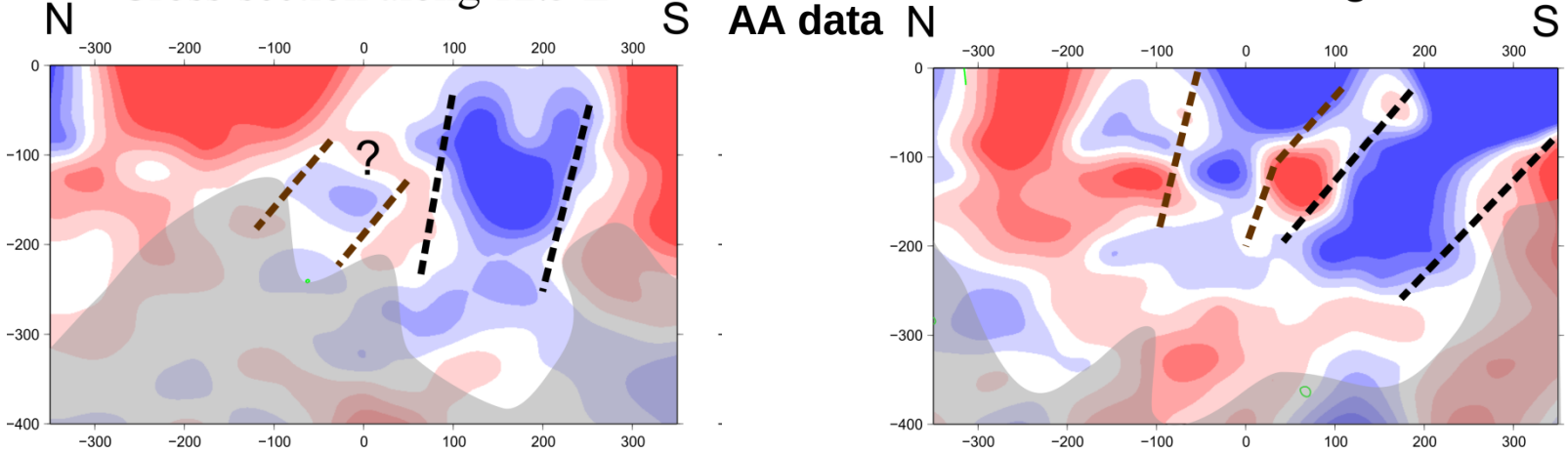




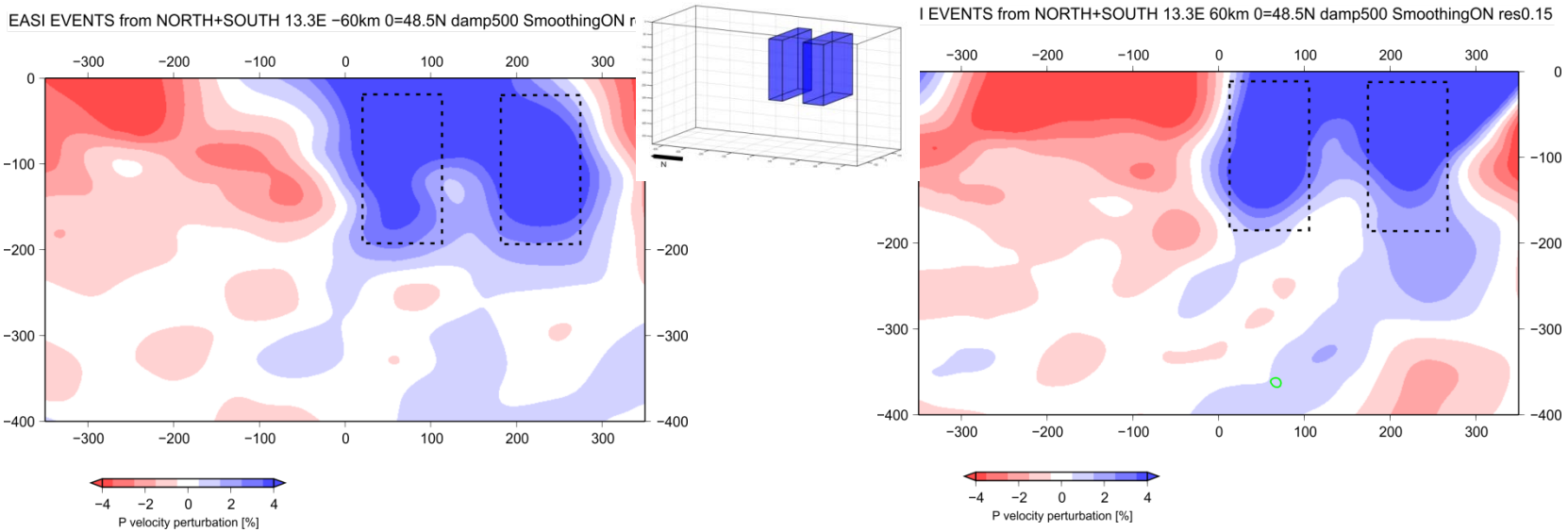
Westernmost Cross-section along 12.5 E

Perturbations retrieved from **AA data**

Easternmost Cross-section along 14.2 E

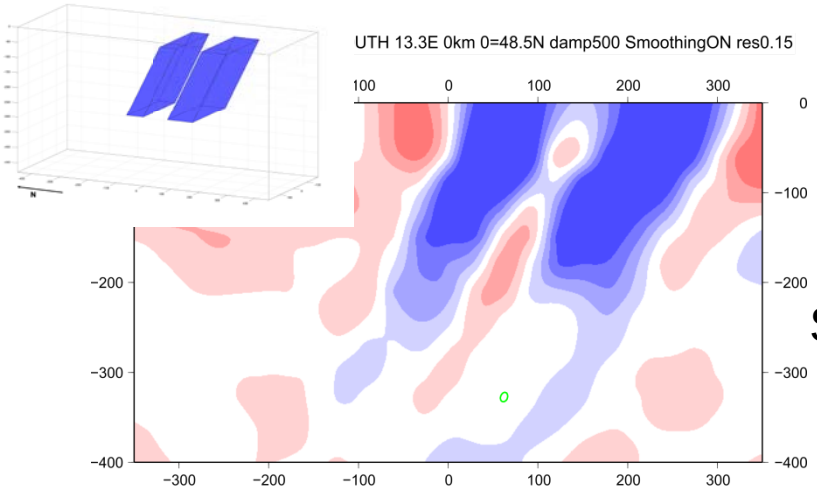


Synthetics with two vertical heterogeneities

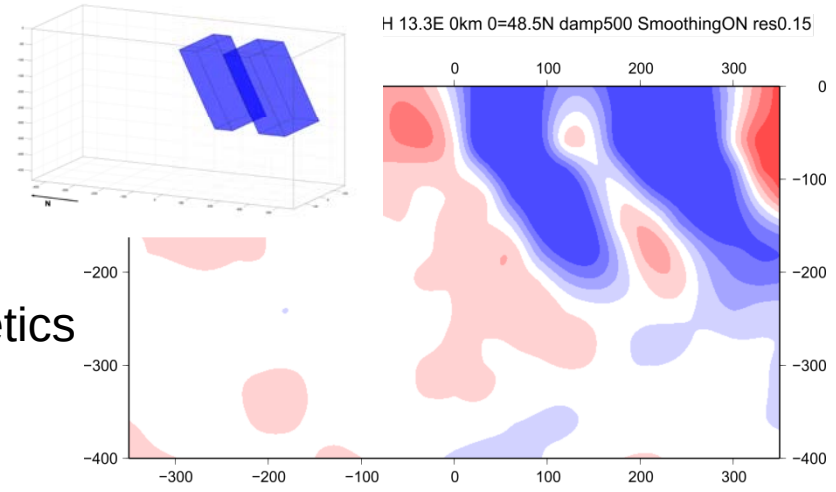


Synthetic tests of slab(s) inclination – 5% high-velocity heterogeneities

Two north-dipping heterogeneities

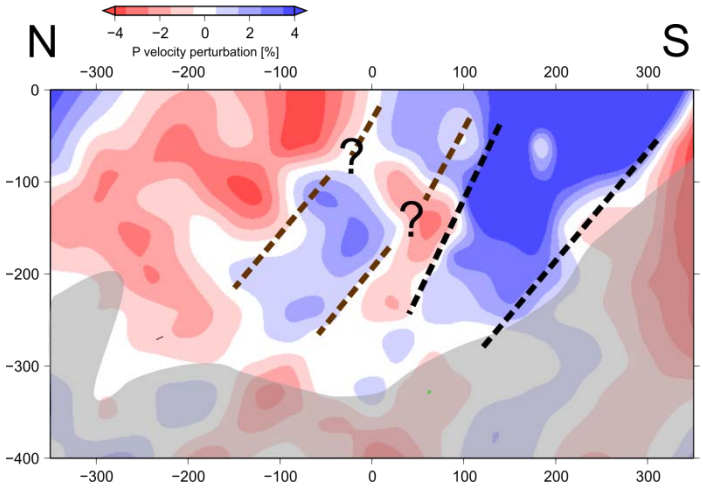


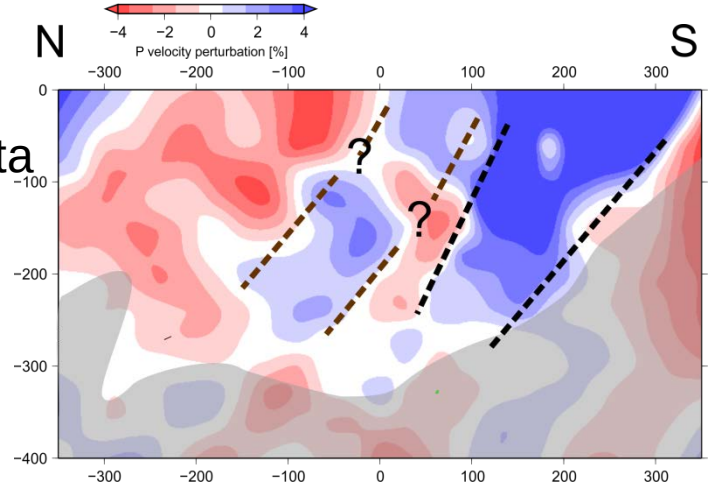
Two south-dipping heterogeneities



Synthetics

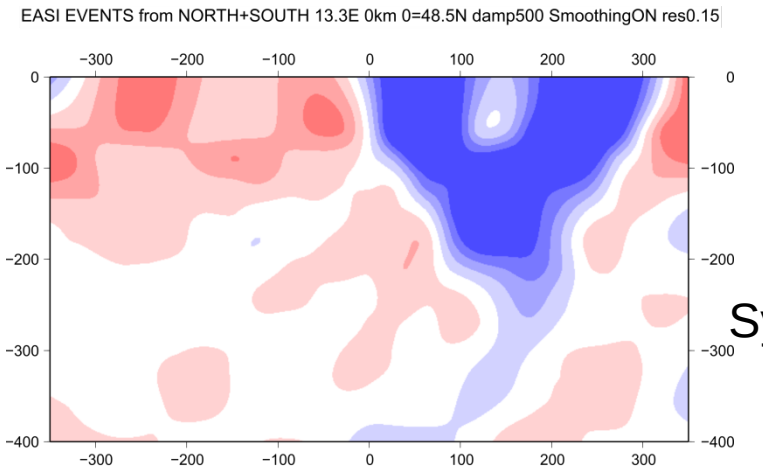
Retrieved from AA data

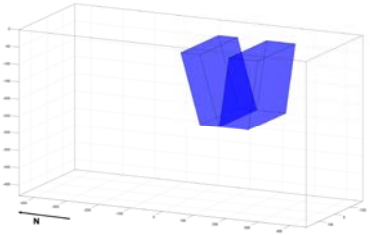




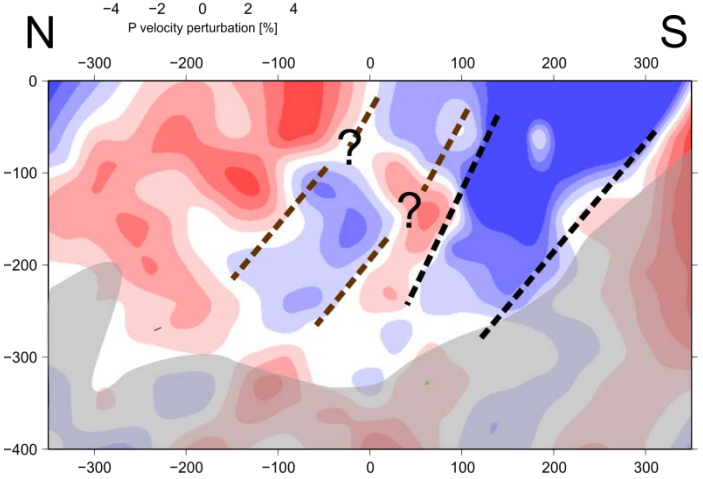
Synthetic tests of slab(s) inclination – 5% high-velocity heterogeneities

Two bi-vergent dipping heterogeneities





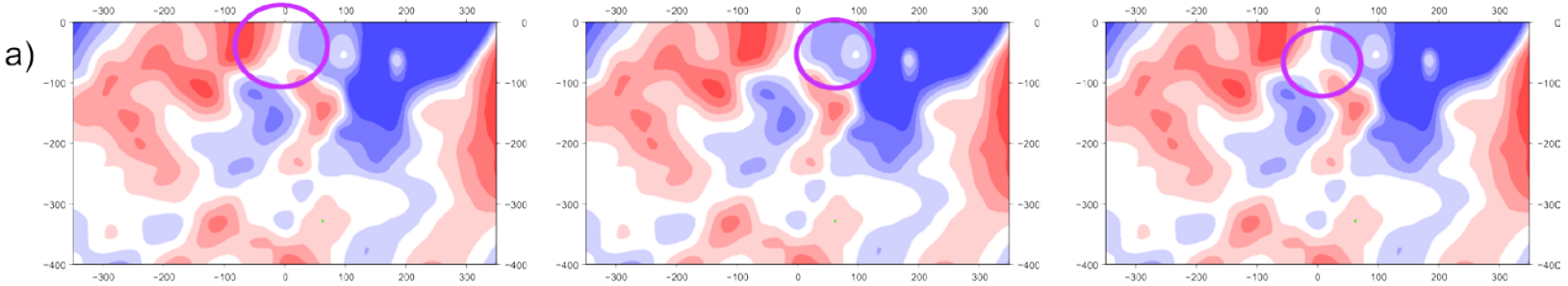
Synthetics



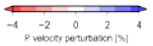
Retrieved from AA data

Synthetic test of the E. Alps slab detachment

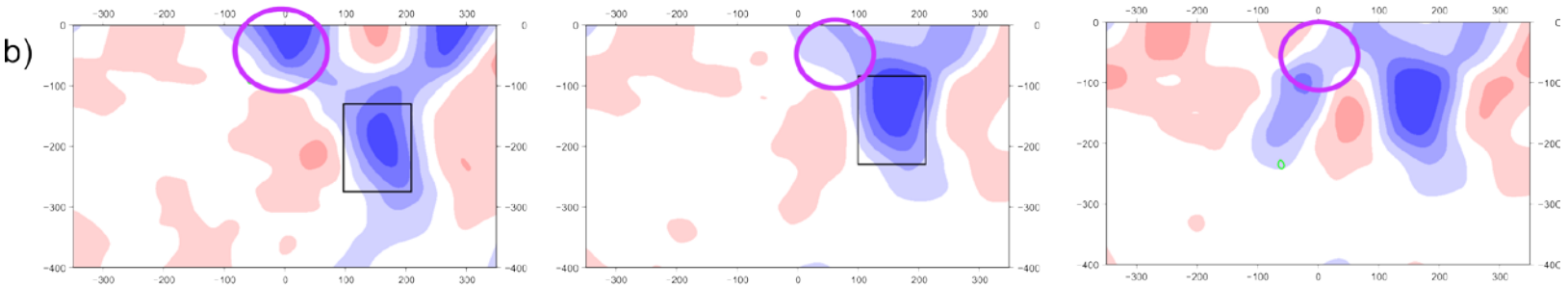
a)



Retrieved from AA data

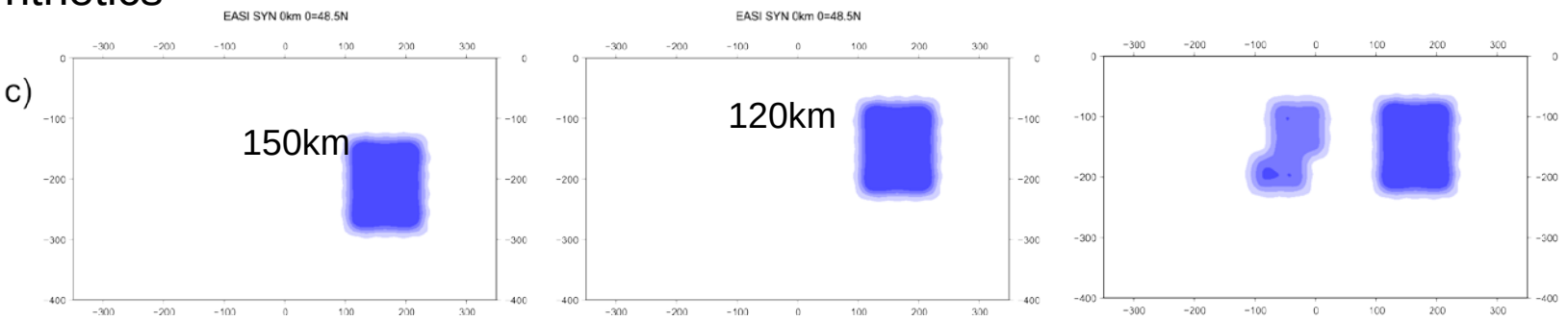


b)



Synthetics

c)

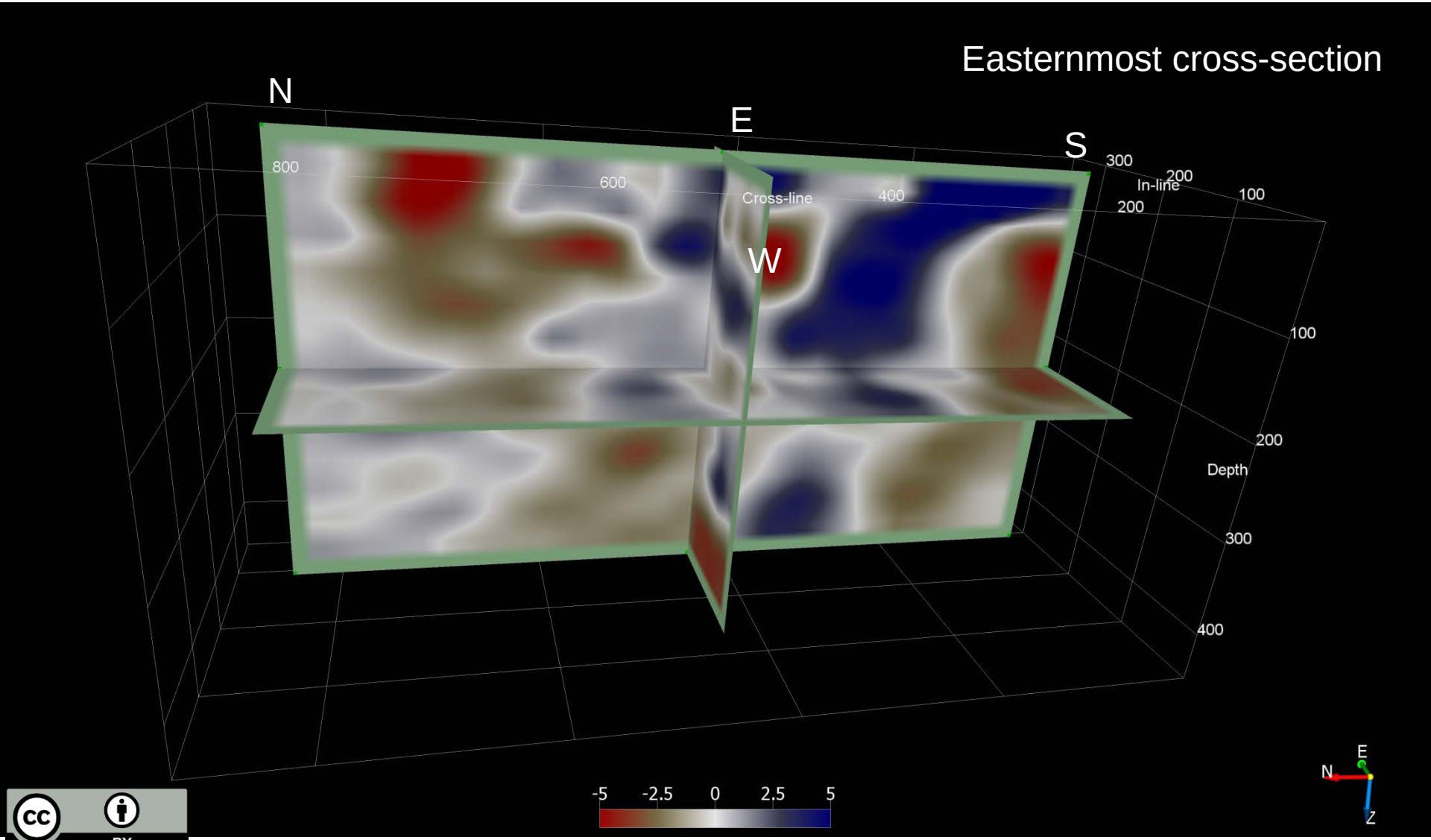


Simulation of detached HV-EA

HV-BM added

- Potential slab detachment would be revealed in or data.

3D images of **lateral variations of intensity and shape** of the two sub-parallel heterogeneities beneath the Eastern Alps



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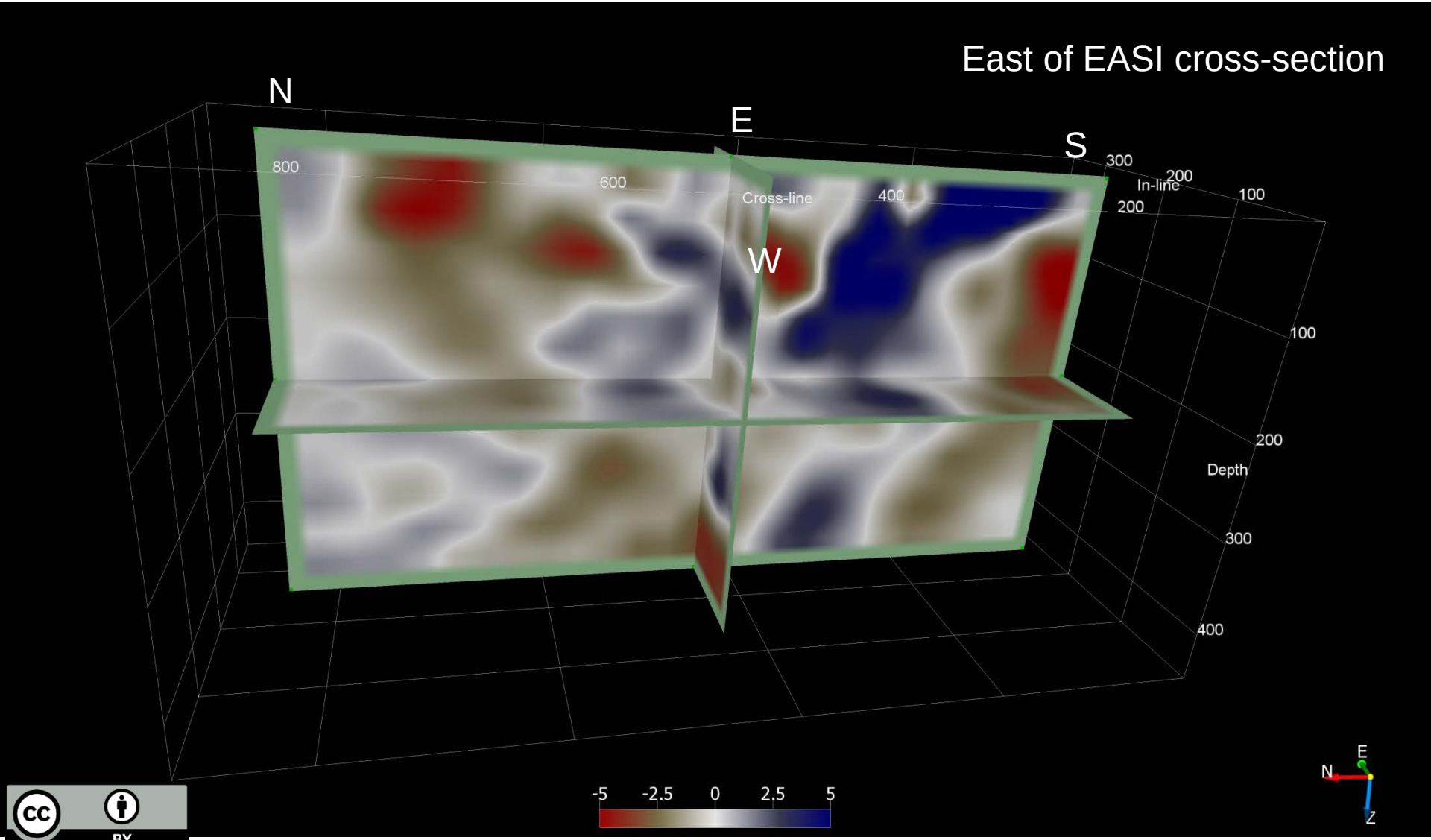
3D images of lateral variations of intensity and shape of the two sub-parallel heterogeneities beneath the Eastern Alps



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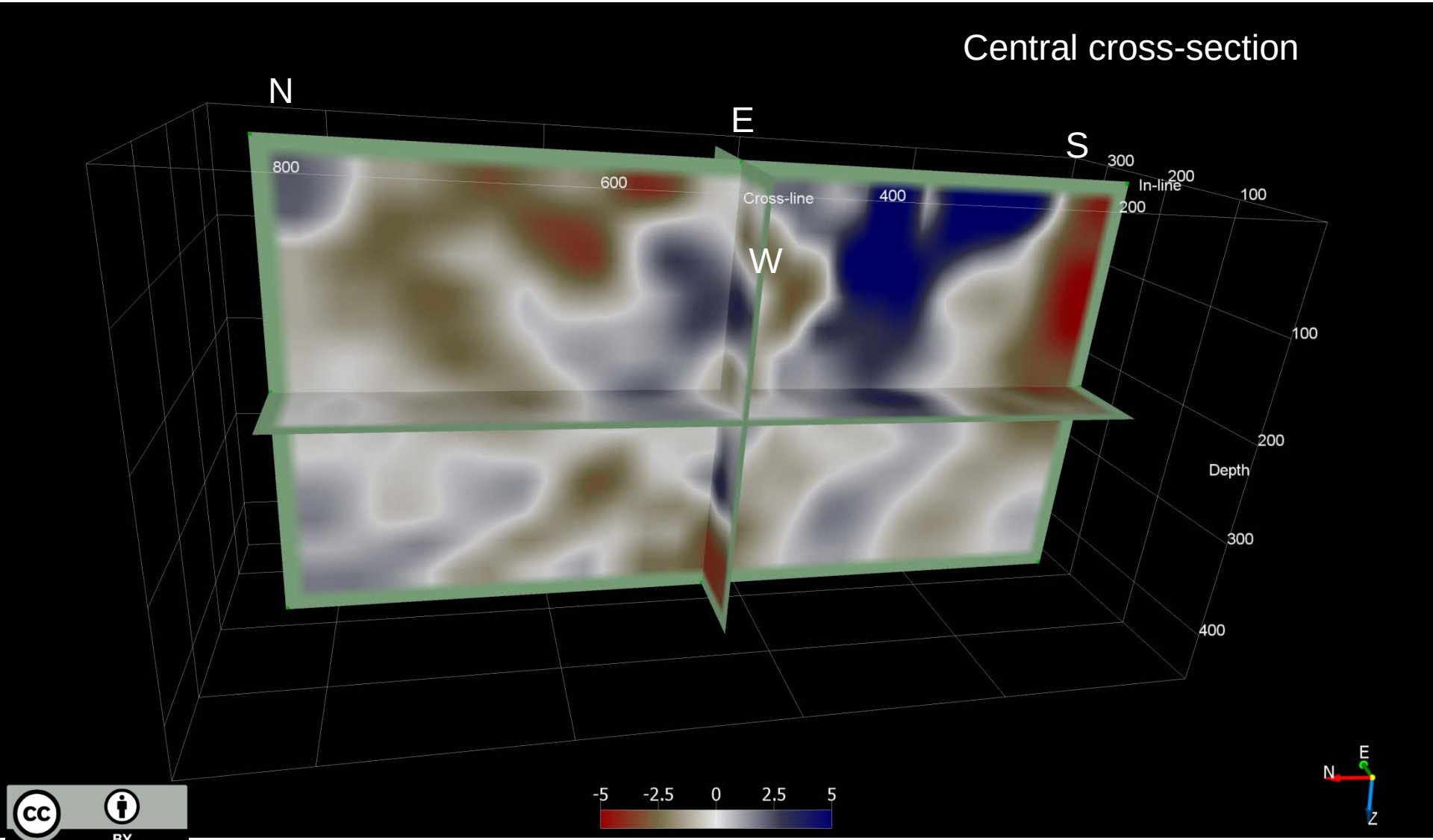

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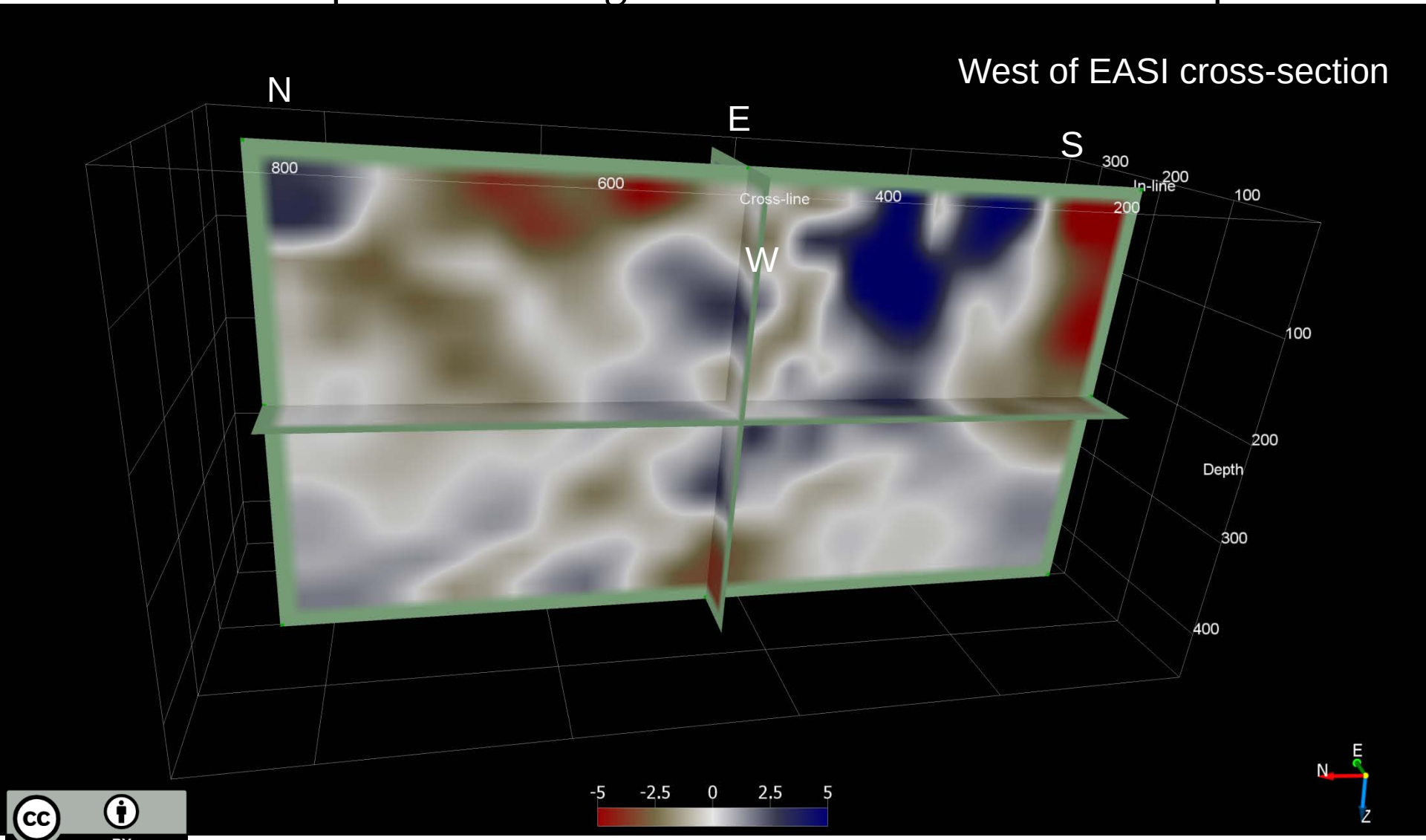

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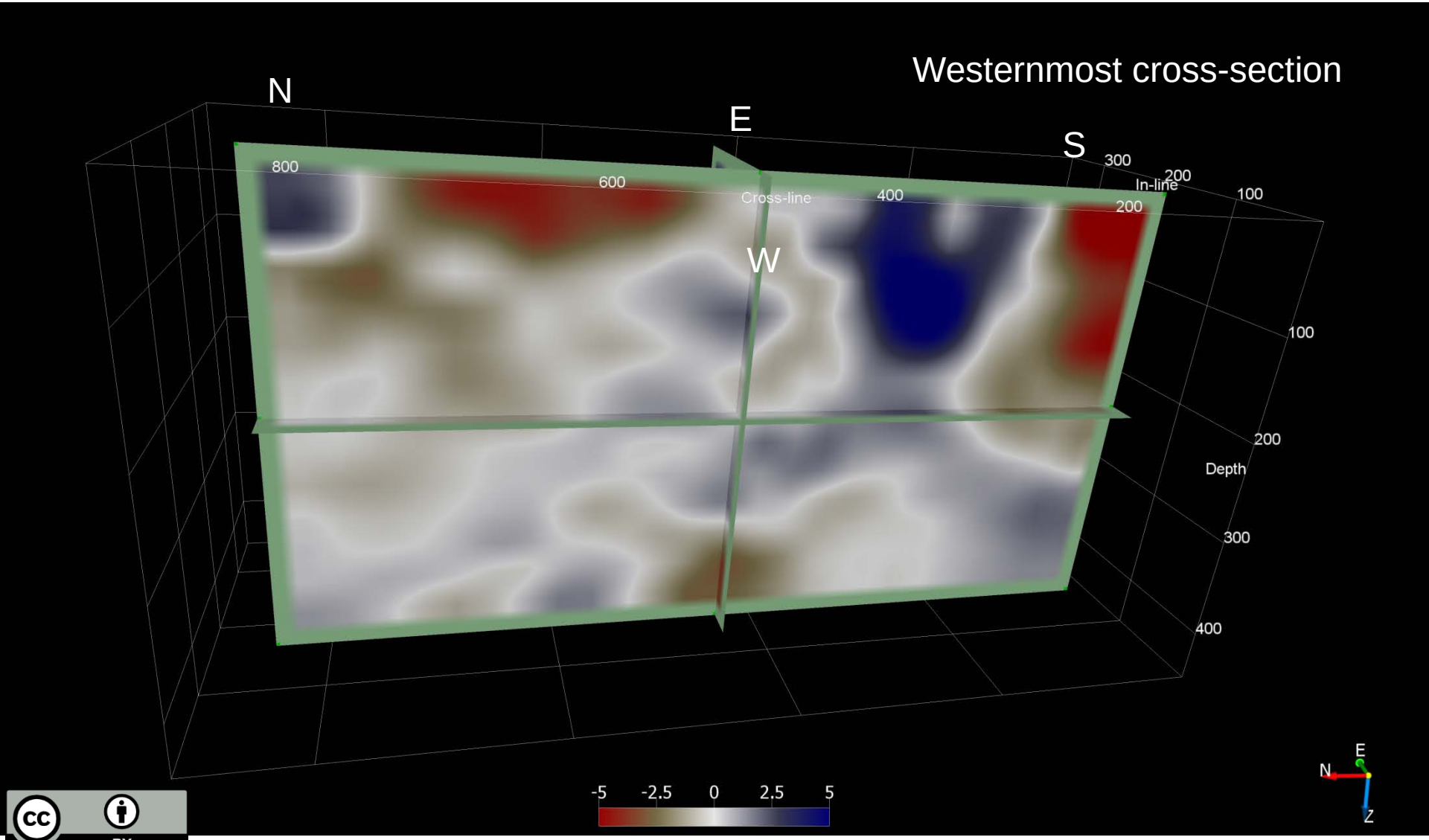
3D images of lateral variations of intensity and shape of the two sub-parallel heterogeneities beneath the Eastern Alps



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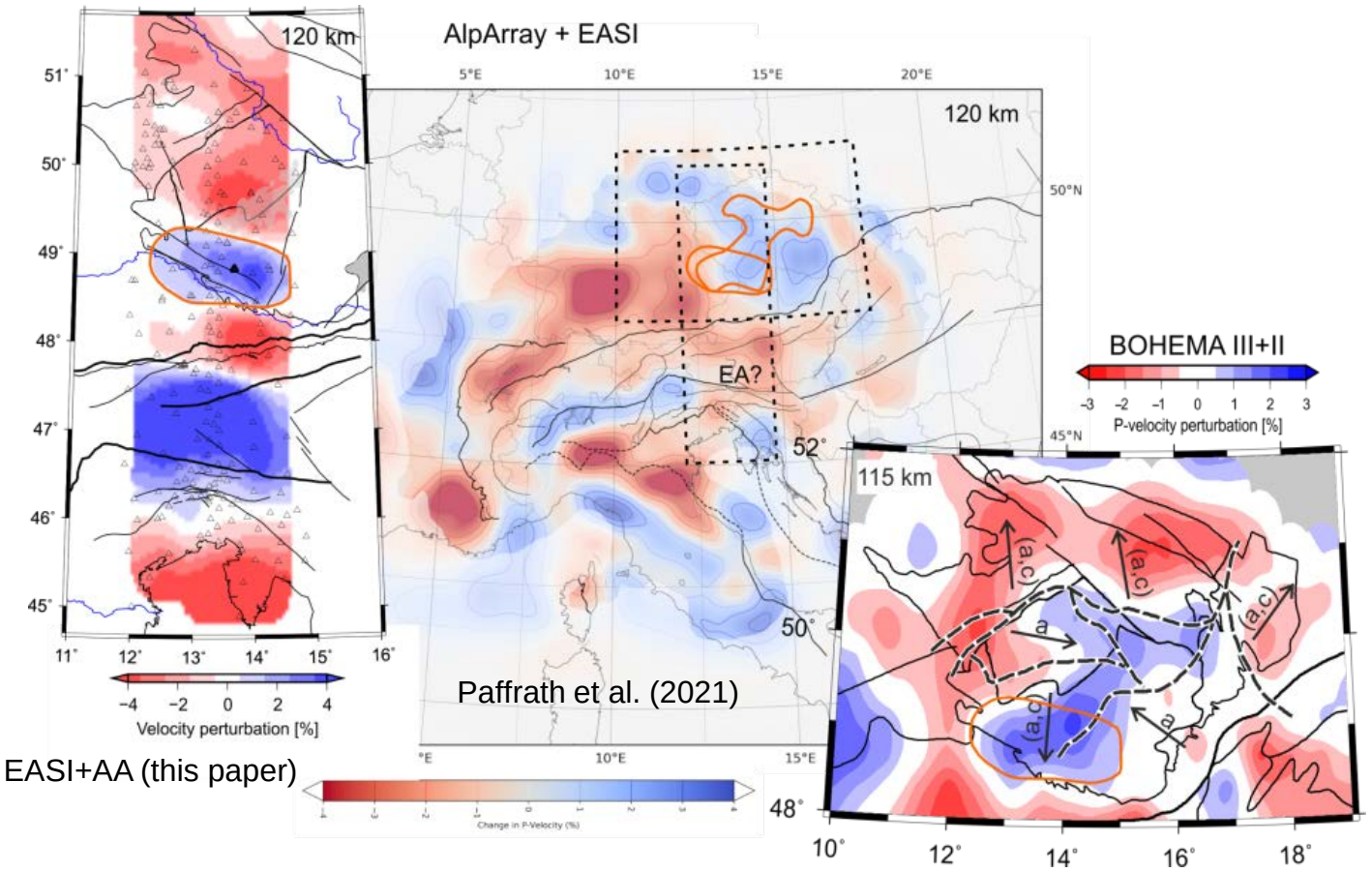
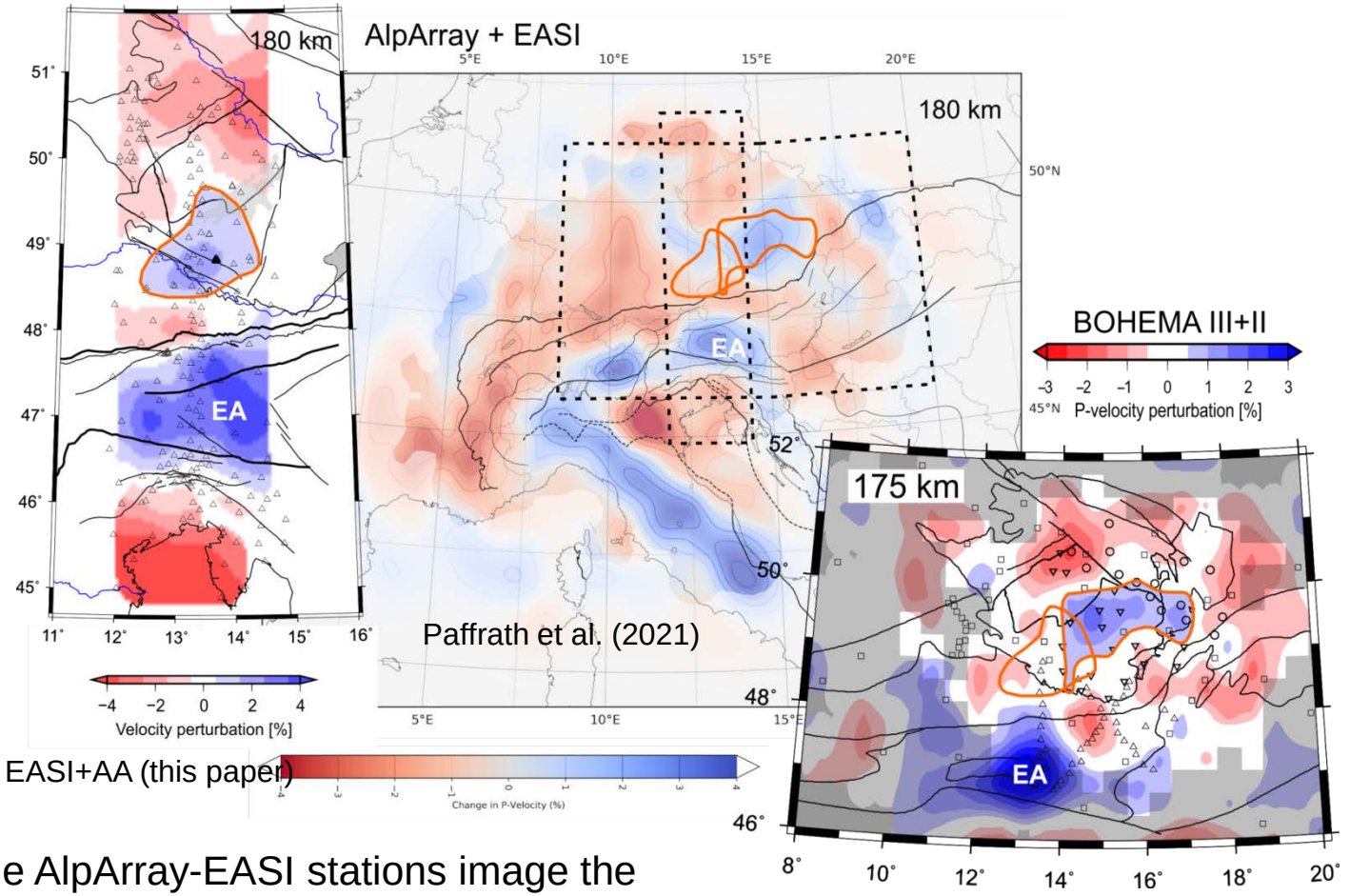
Horizontal slices at 120 km depth through three velocity-perturbation models of the Alps and Bohemian Massif

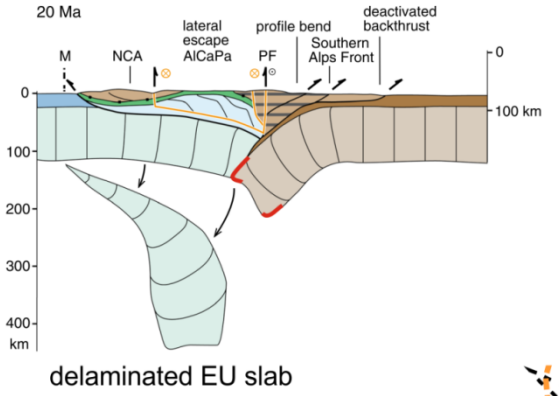


Horizontal slices at 180 km depth through three velocity-perturbation models of the Alps and Bohemian Massif

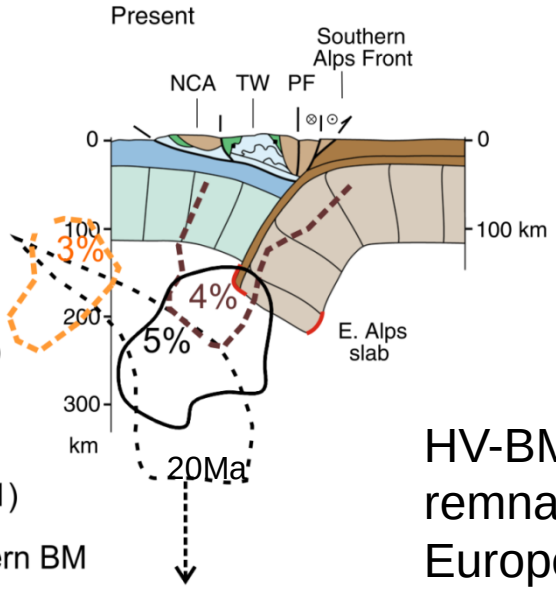


The AlpArray-EASI stations image the positive velocity perturbations beneath the southern BM farther to the SW.
The HV-BM is added as orange contour.

Eastern Alps slab interpretation (Adriatic vs. European) and potential scenarios of origin of the HV_BM heterogeneity .



Slab delamination at 20Ma redrawn from Handy et al. (2015)



Eurpean and Adriatic plate configuration at present complemented by location of the high-velocity heterogeneities from models EASI+AA (this paper) and Paffrath et al. (2021)

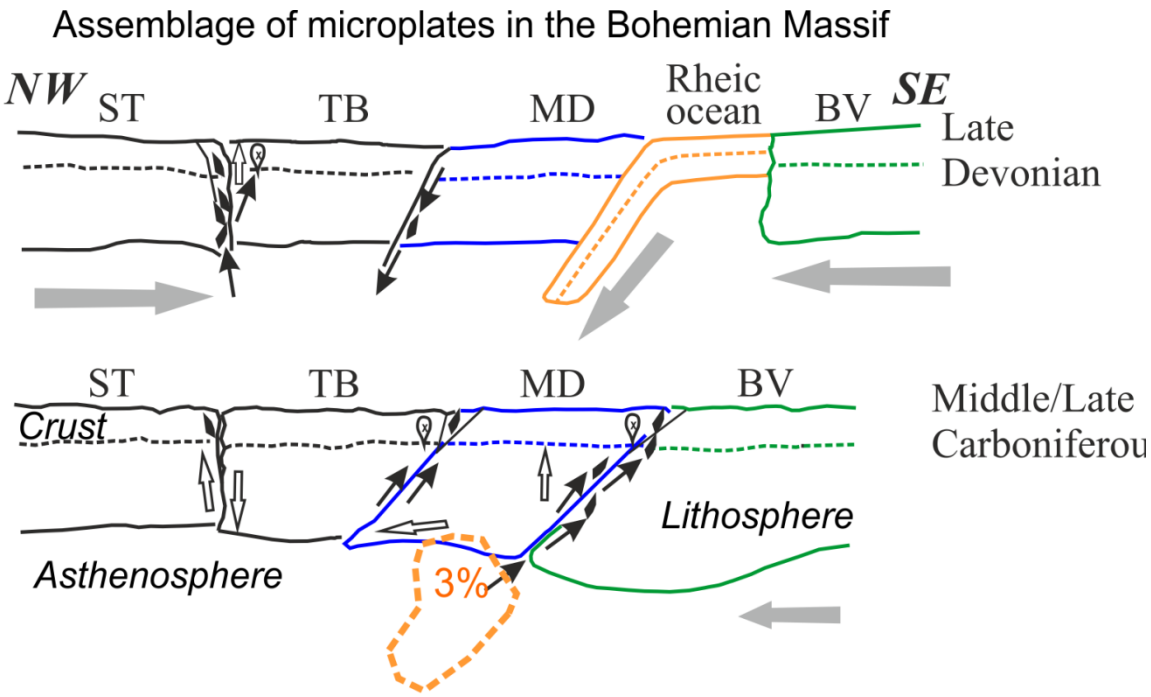
detached EU slab (Paffrath et al., 2021)

high-vel. heterogeneity beneath southern BM

high-vel. heterogeneity beneath the EA related to Adria

HV-BM (orange) as a remnant of the delaminated European plate

Eastern Alps slab interpretation (Adriatic vs. European) and potential scenarios of origin of the HV_BM heterogeneity

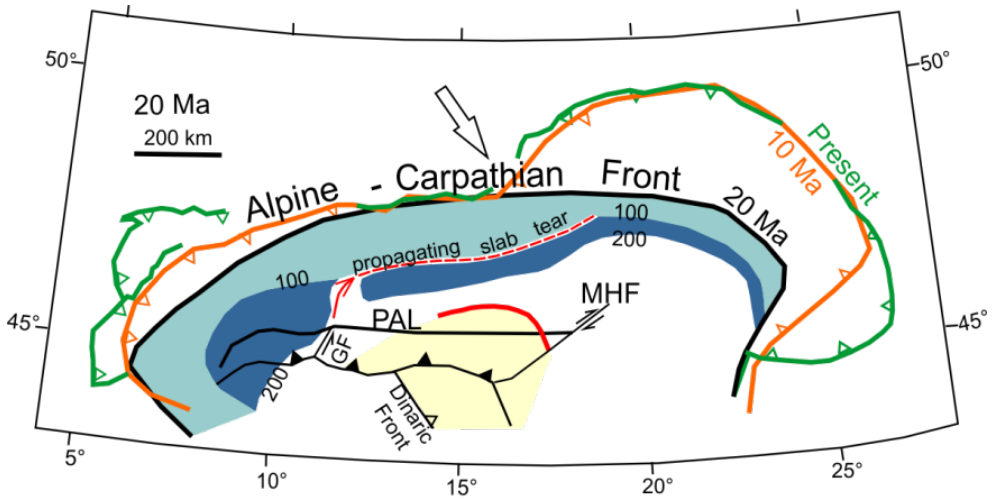


high-vel. heterogeneity beneath southern BM

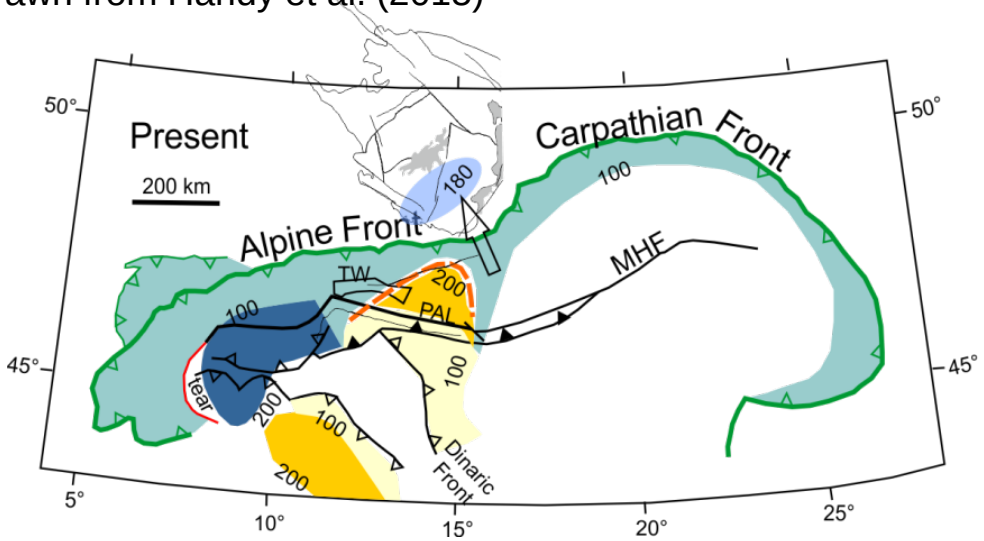
Scenario considering closure of the Rheic ocean and collision of the Brunovistulian (BV) and the Moldanubian (Mdin the south-eastern BM (Babuska and Plomerova, 2013)

HV-BM as a piece of continental-and-oceanic lithosphere mixture related to the building of the BM

Eastern Alps slab interpretation (Adriatic vs. European) and potential scenarios of origin of the HV_BM heterogeneity



redrawn from Handy et al. (2015)



Scenario related to fragmentation of the Alpine and Carpathian front

HV-BM as a fragment of a quite extended lithosphere immersing into the mantle in a preceding phase of the Adriatic plate subduction

Conclusions

- E. Alpine high-velocity perturbations - between the Periadriatic Lineament (PAL) and the Northern Alpine Front (NAF)

- Northward-dipping lithosphere keel - down to ~200-250 km depth, without signs of delamination – related to the Adriatic plate subduction

- High-velocity heterogeneity beneath the southern Bohemian Massif - at ~100-200km depth with SW-NE strike, parallel with the MD/BV mantle lithosphere boundary in the BM or with the westernmost part of the Carpathian front

- Interpretation of the HV-BM:
  - (A) a remnant of the delaminated European plate
  - (B) a piece of continental-and-oceanic lithosphere mixture related to the building of the BM
  - (C) a fragment of a quite extended lithosphere immersing into the mantle in a preceding phase of the Adriatic plate subduction