Radial anisotropy in Europe from surface waves ambient noise tomography and transdimensional hierarchical inversion

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and the AlpArray working group

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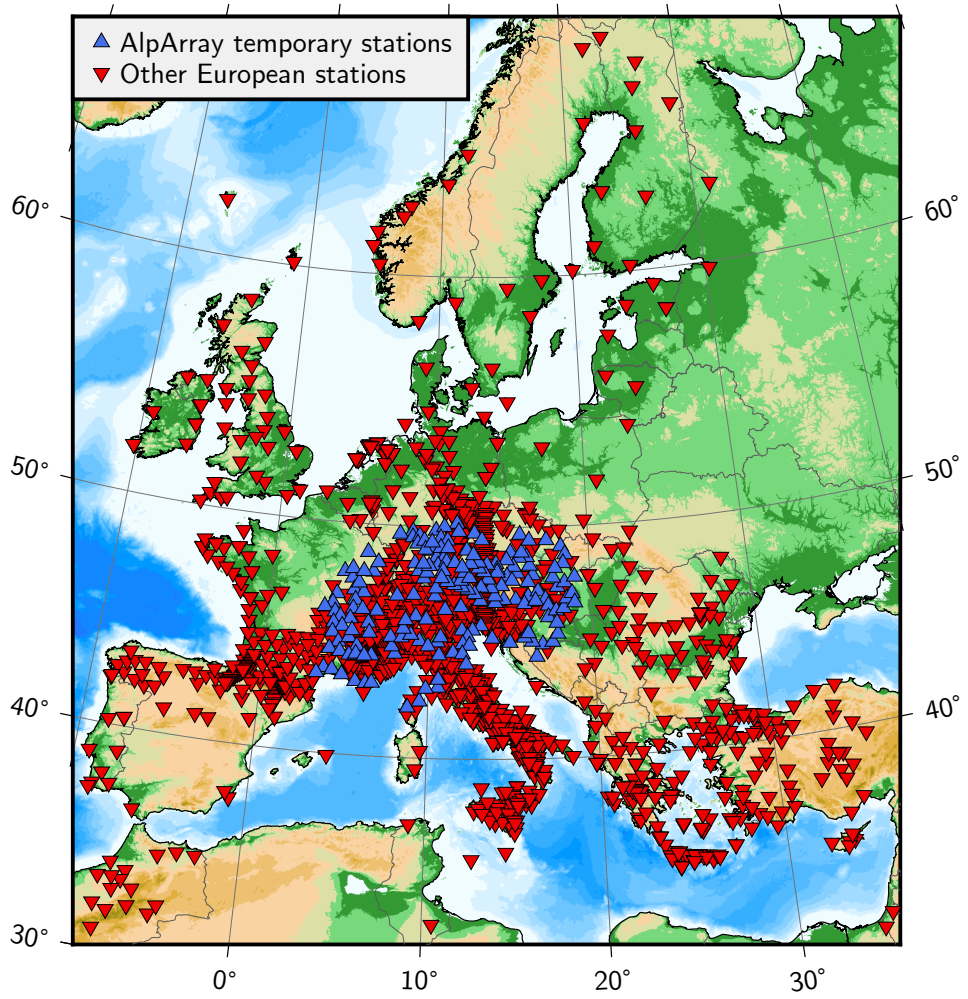
General idea

- **Goal**
  → image radial anisotropy ($\frac{V_{SH} - VSV}{V_{SV}}$) in Europe
  → deformation of the crust and uppermost mantle

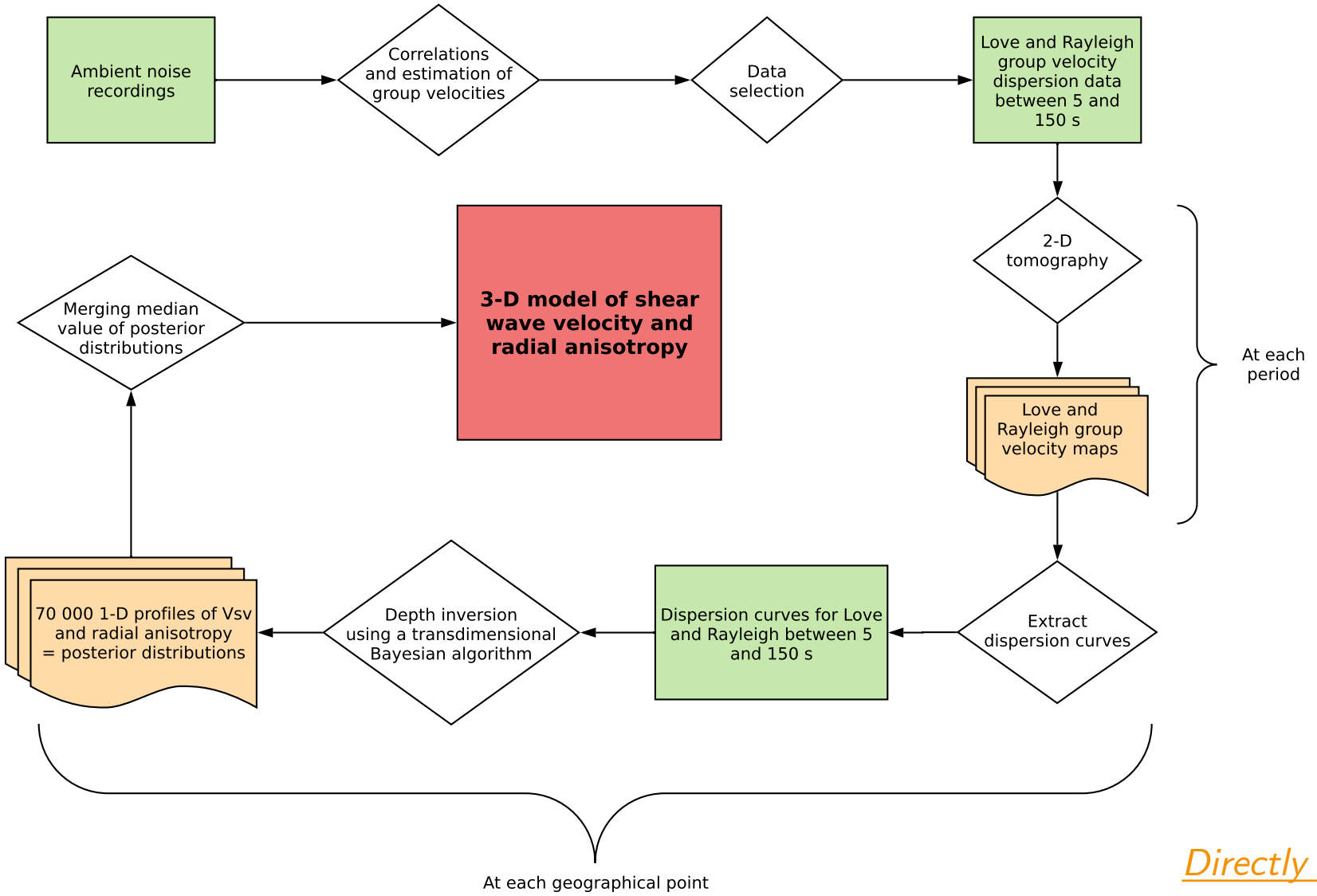
- **AlpArray deployment**
  → large and new dataset of Rayleigh and Love dispersion data from ambient noise correlations between 5 and 150 s
  → study all across Europe focusing on the Alps and Apennines

- **Inversion method at depth**
  → hierarchical transdimensional Bayesian inversion
  → probabilistic information taking into account the trade-off between layering and radial anisotropy



Stations used in this study
(Alder et al., in prep.)

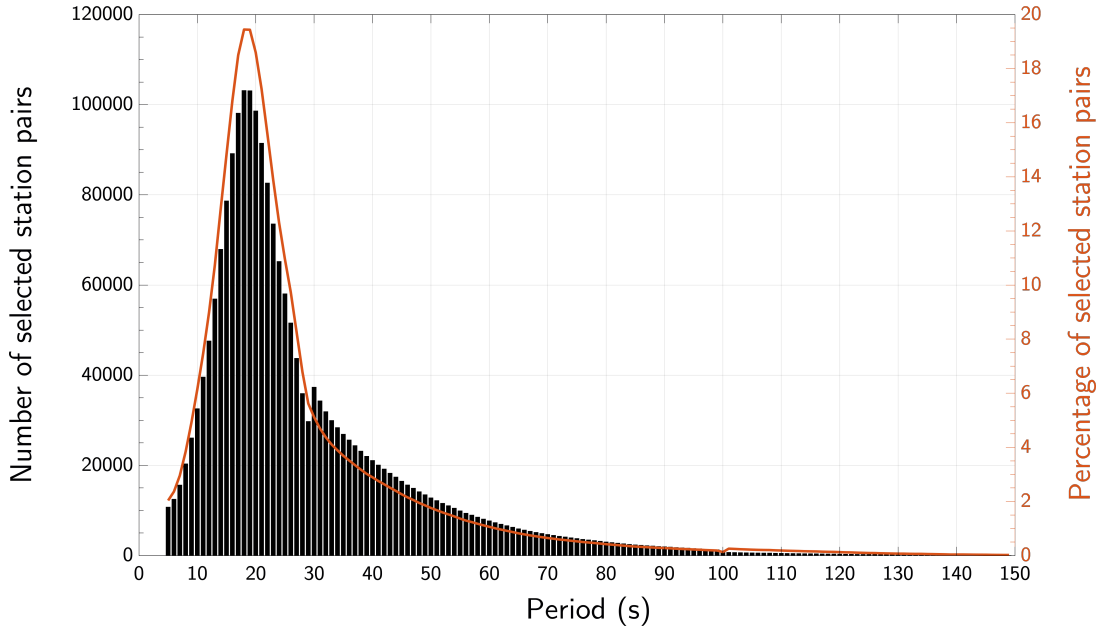
Workflow



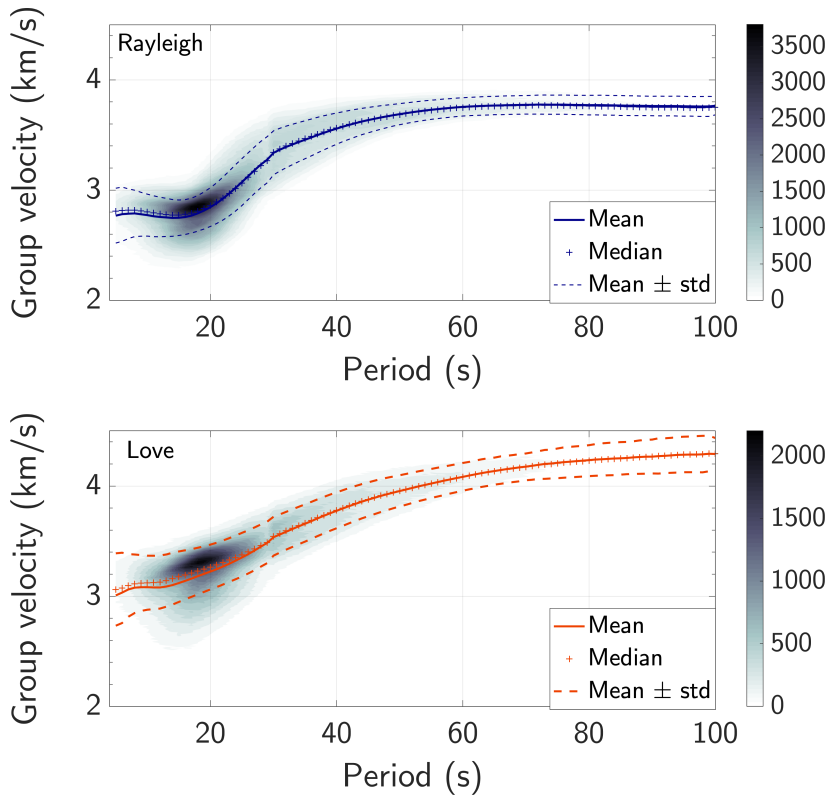
Directly skip to main results

Dataset and 2D tomography

- At each period: joint selection of Rayleigh and Love group velocity data
  - Same data coverage → same lateral resolution → no artefact in radial anisotropy due to a difference of lateral resolution between Love and Rayleigh data
- 2D surface waves tomography:
  - iterative least square inversion



Number of selected data per period



Ensemble of selected Rayleigh and Love dispersion measurements

(Alder et al., in prep.)

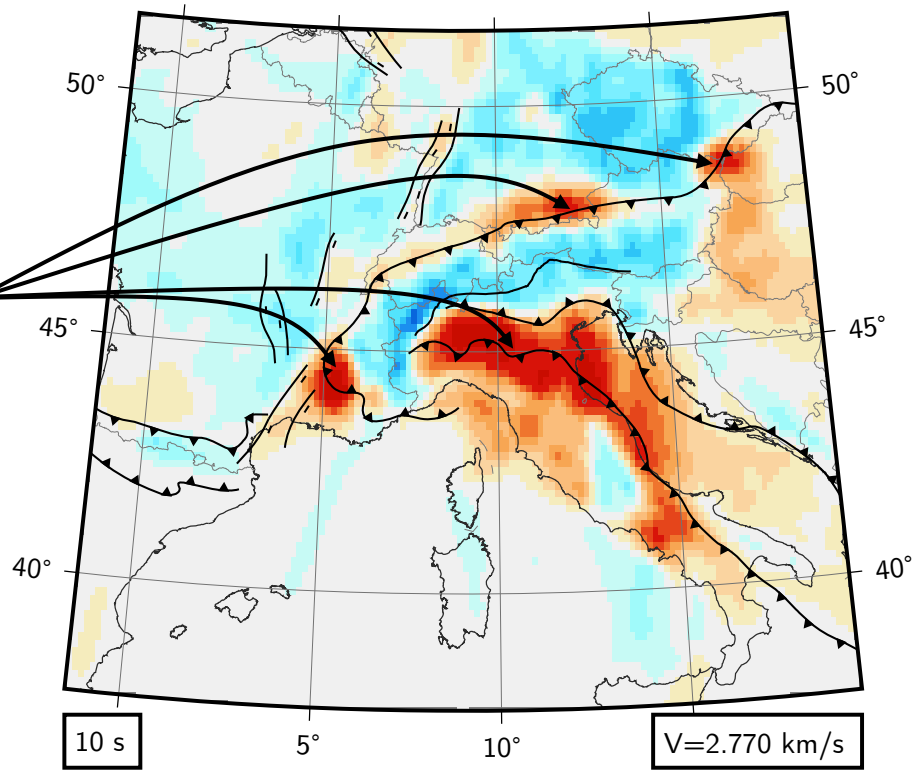
2D group velocity maps for Rayleigh and Love waves

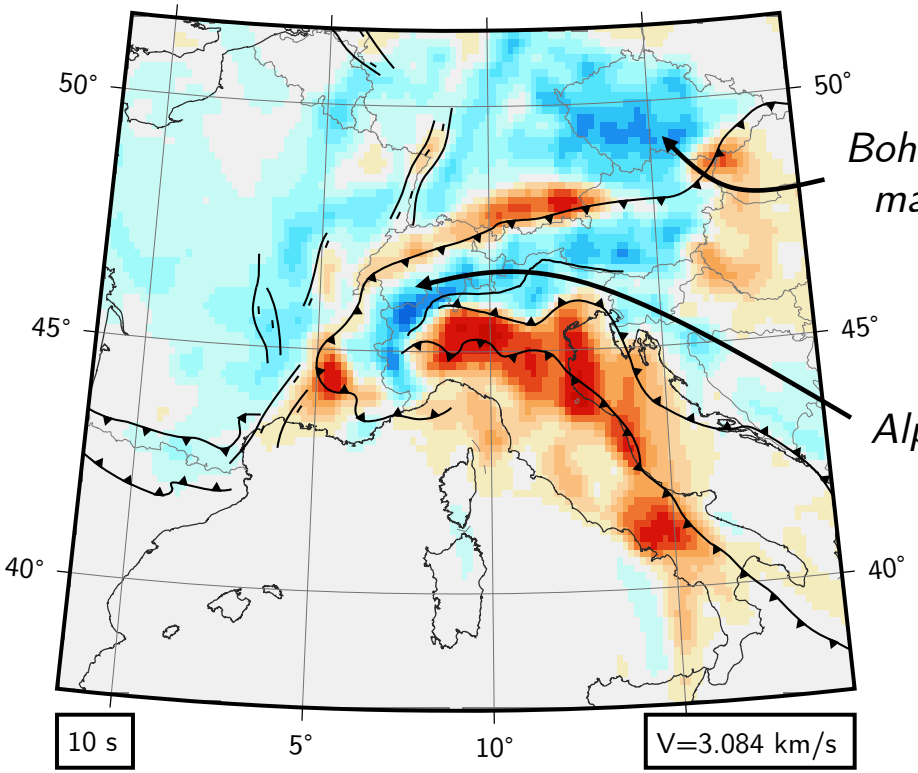
T = 10 s
(upper crust)

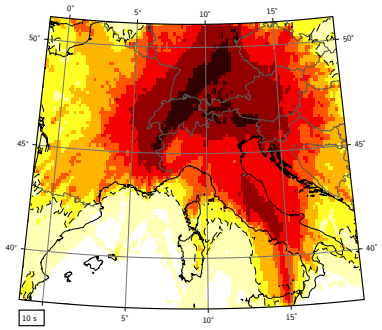
Sedimentary basins

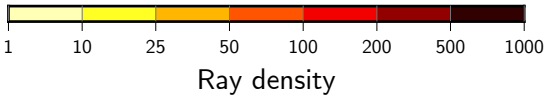
Bohemian massive

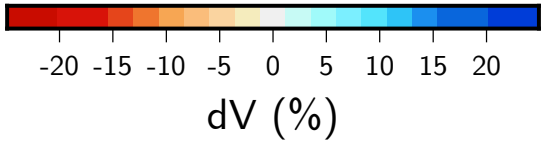
Alpine arc







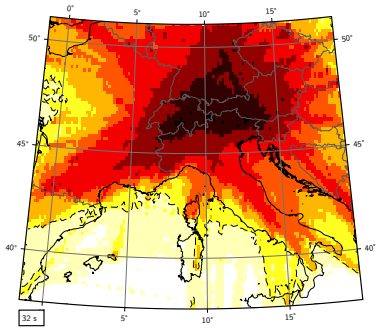




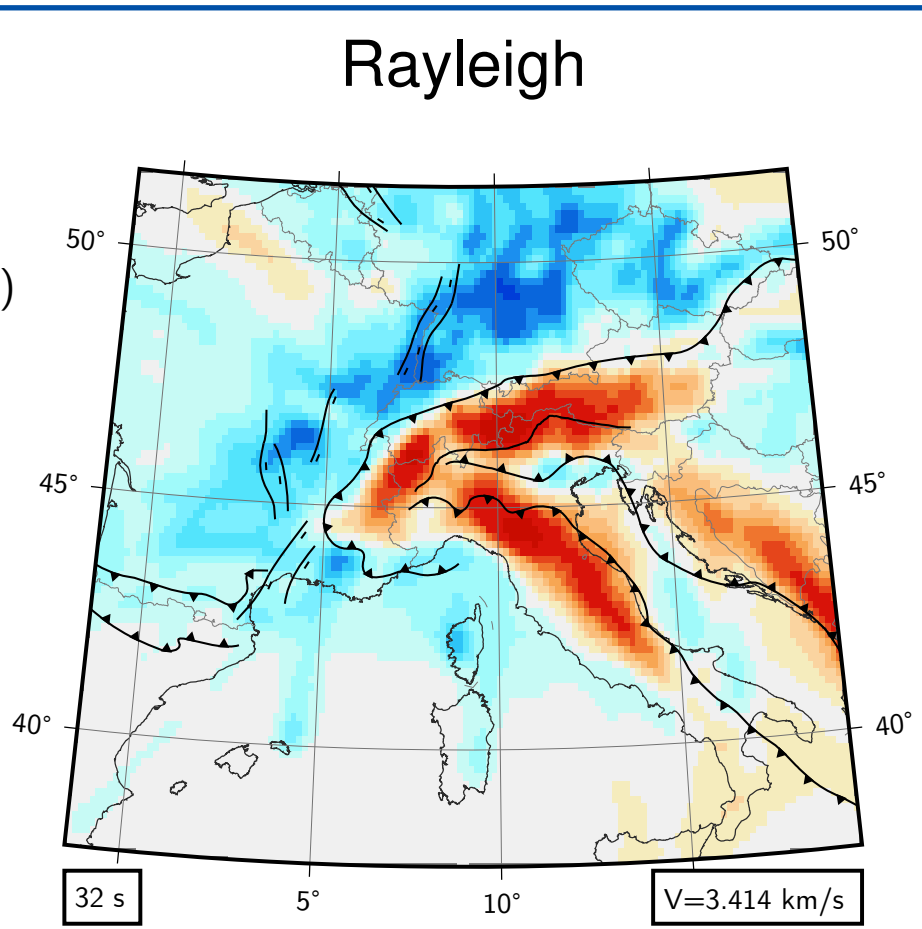
(Alder et al., in prep.)

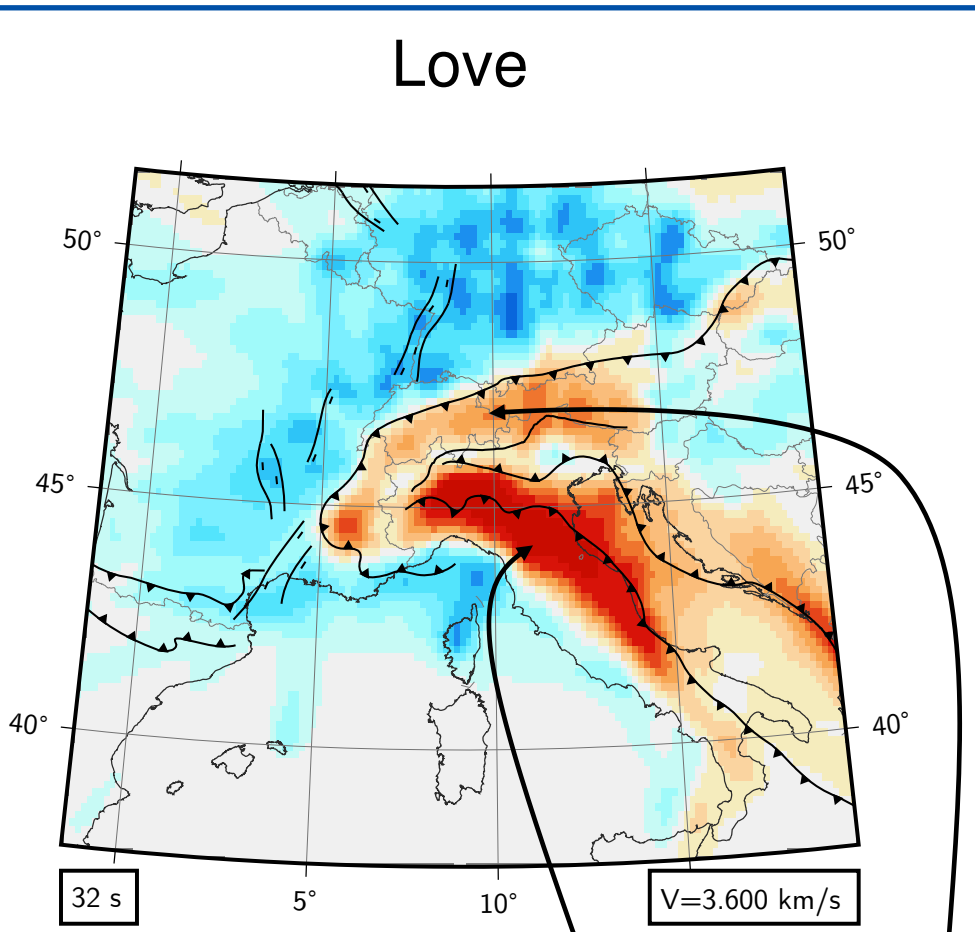
2D group velocity maps for Rayleigh and Love waves

T = 32 s
(lower crust, Moho depth)



1 10 25 50 100 200 500 1000
Ray density





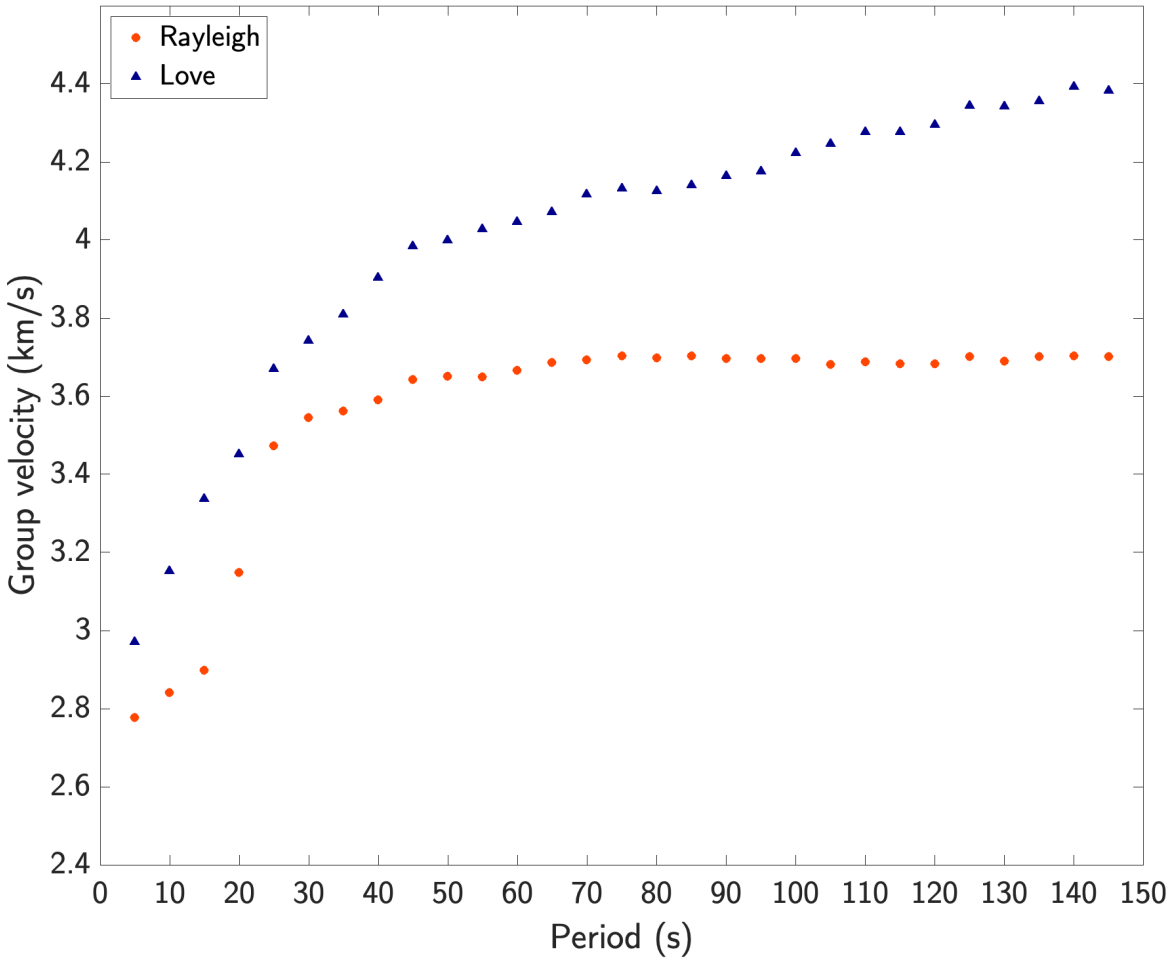
-10 -5 0 5 10
dV (%)

Alps crustal root

Apennines crustal root

(Alder et al., in prep.)

Extracting dispersion curves at each grid point



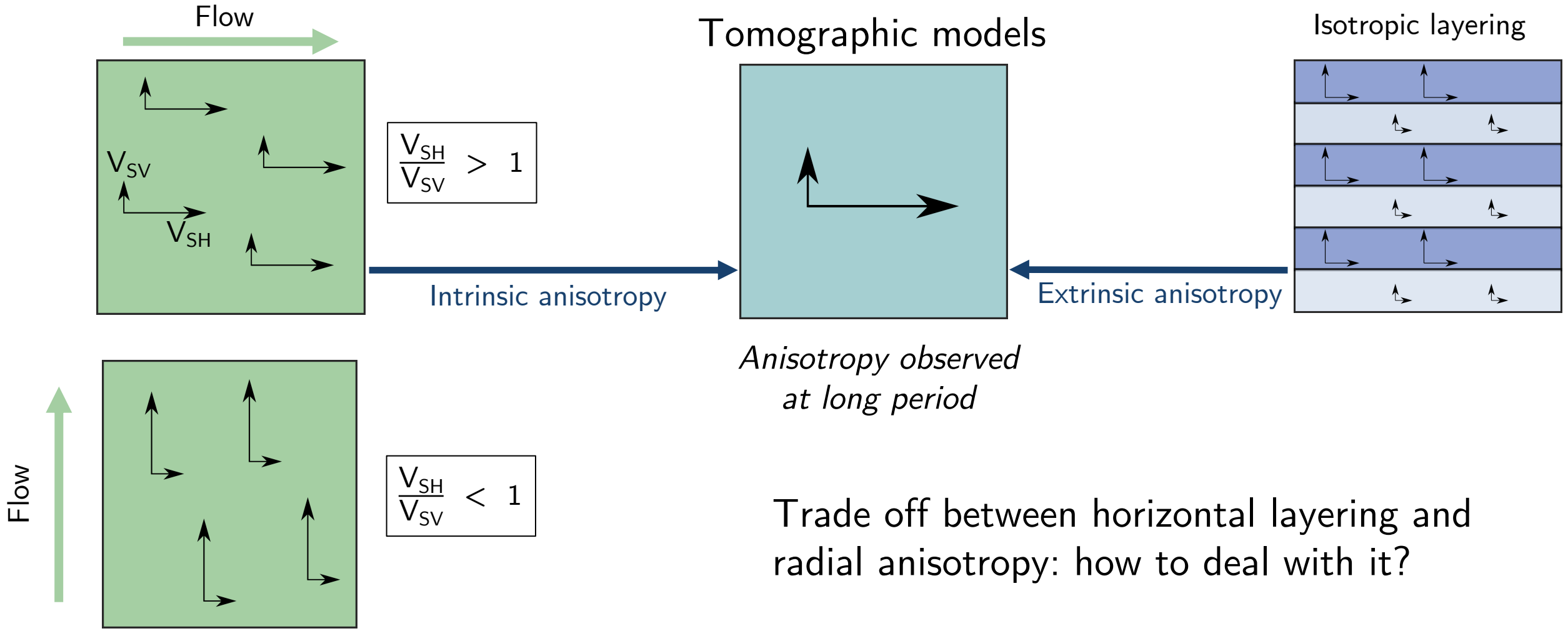
Example of extracted dispersion curves

- Get dispersion curves at each grid point (1 pixel = 0.15° x 0.15°)
  → **data for the Bayesian inversion**

- Jointly invert for Love and Rayleigh dispersion curves
  → 1D profiles of V_{SV}, radial anisotropy and V_P/V_{SV}

Imaging and interpreting radial anisotropy

Strain in the crust or the mantle (e.g. flow) → preferred orientation of minerals → intrinsic anisotropy



Trade off between horizontal layering and radial anisotropy: how to deal with it?

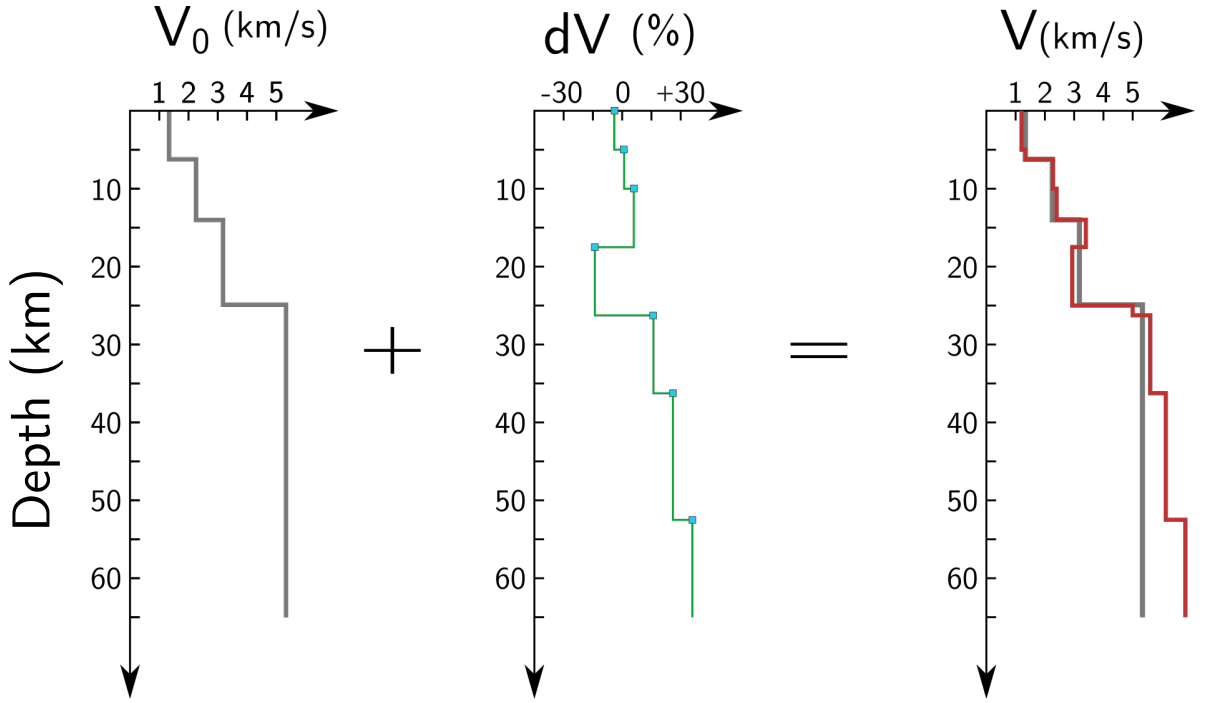
1D transdimensional hierarchical Bayesian inversion

- **Transdimensional:**
  number of model parameters = unknown
  - total number of layers
  - number of anisotropic layers
    → anisotropy added only if required by the data

- **Hierarchical:**
  noise on the data = unknown

- **Exploration of model space**:
  rj-McMC algorithm (e.g. Bodin et al. 2016)
  - 70 000 1D models at each point
    = posterior distribution

- **Surface waves**: no sensitivity to discontinuities
  - Layered referenced model:
    LSP_Eurcrust1.0 of Lu et al. 2018
  - Used to impose discontinuity depth



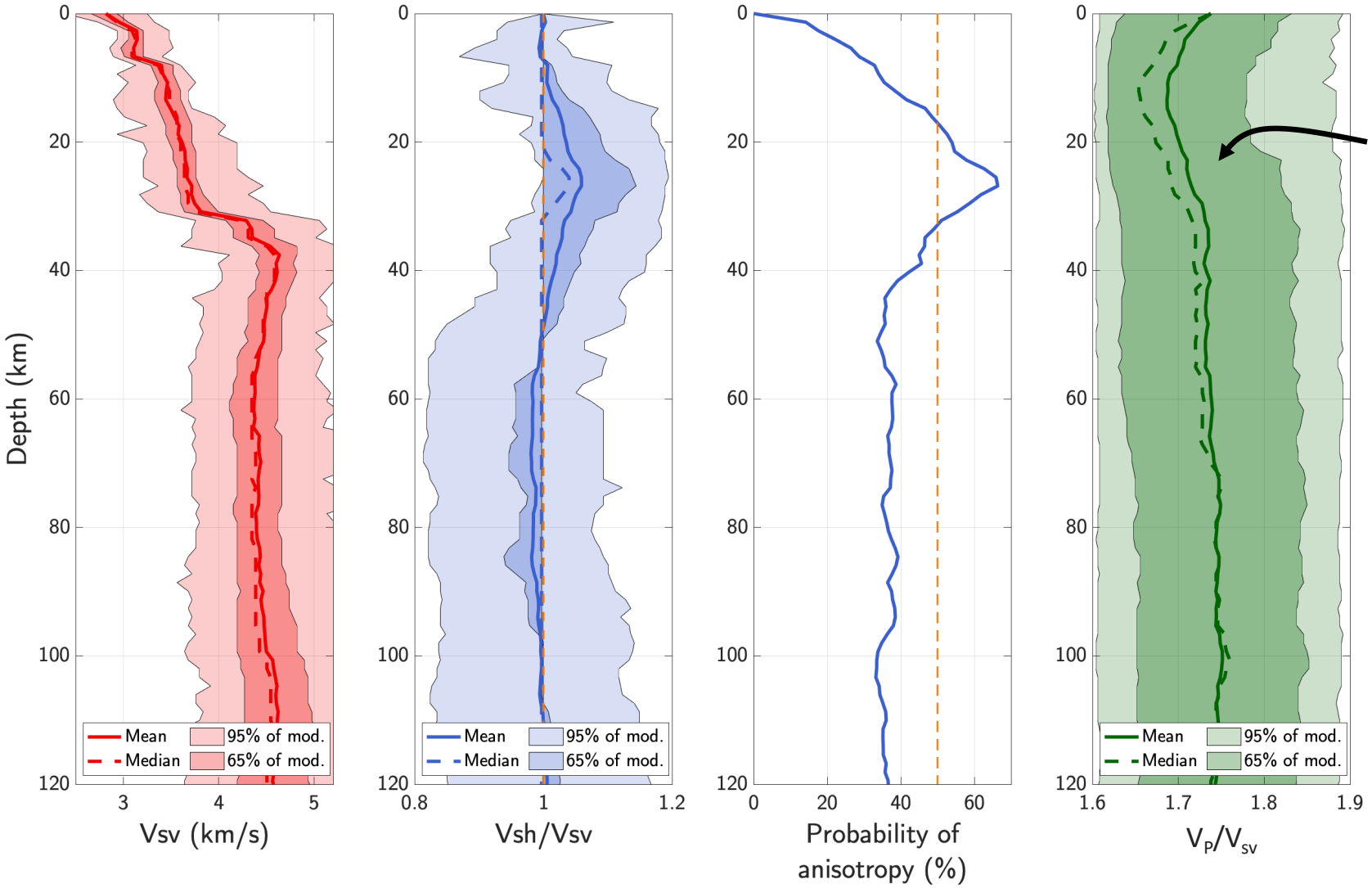
Parametrisation of the inverted model

(Alder et al., in prep.)

1D depth profiles

Posterior distributions
70 000 models

Median value of posterior distributions: used to build a 1D profile at each geographical point



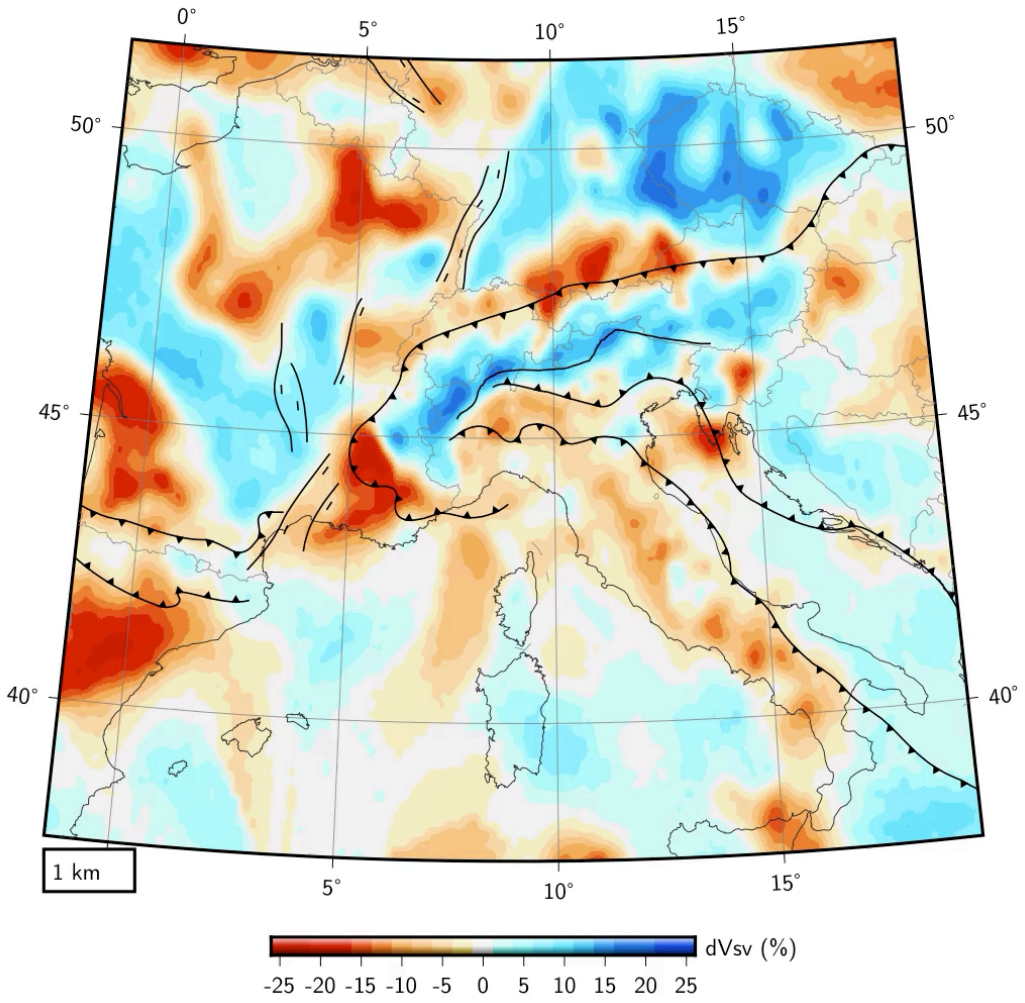
Not constrained by the data: not interpreted

(Alder et al., in prep.)

Probabilistic maps

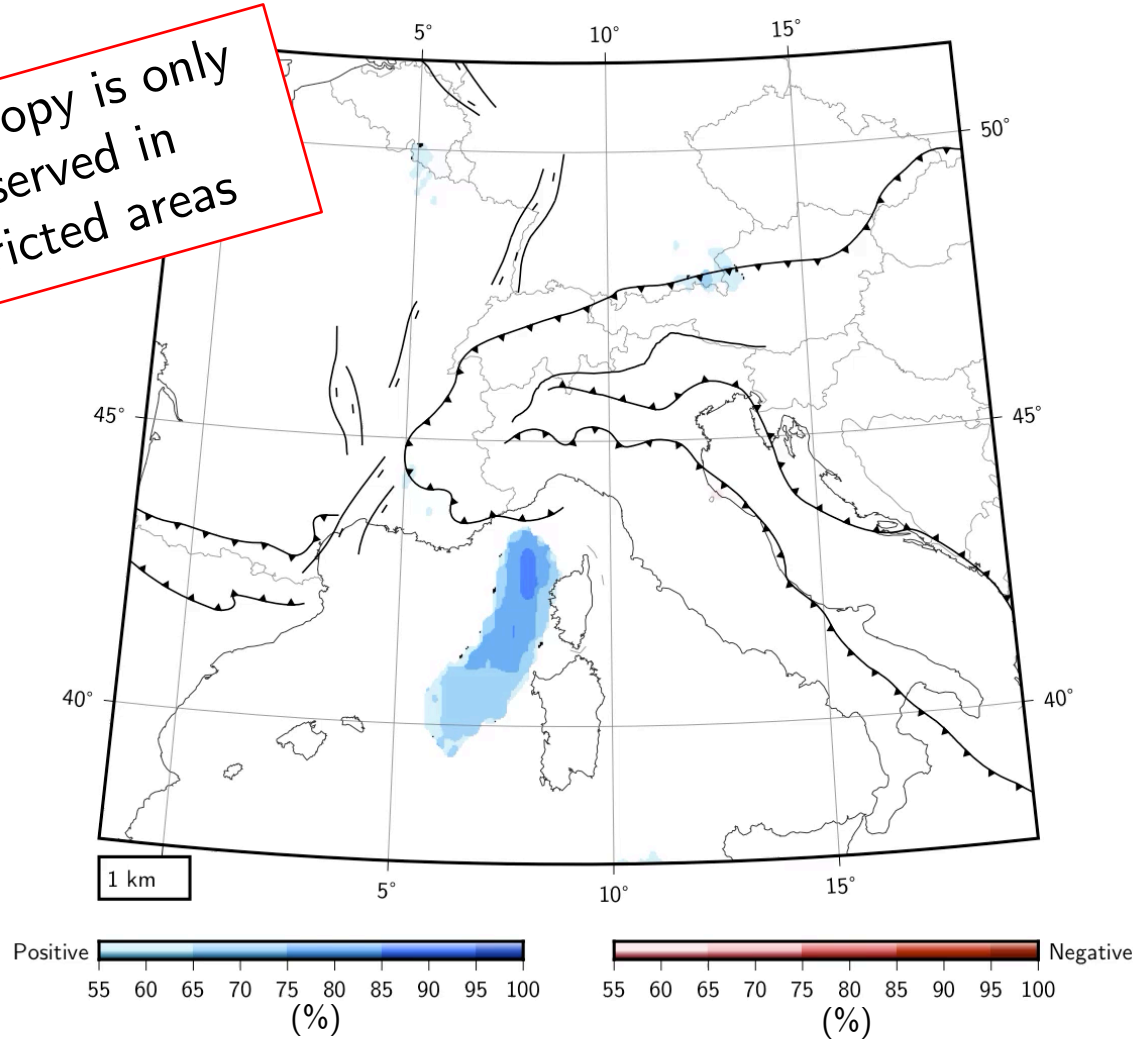
Movies: link to download files

dVsv



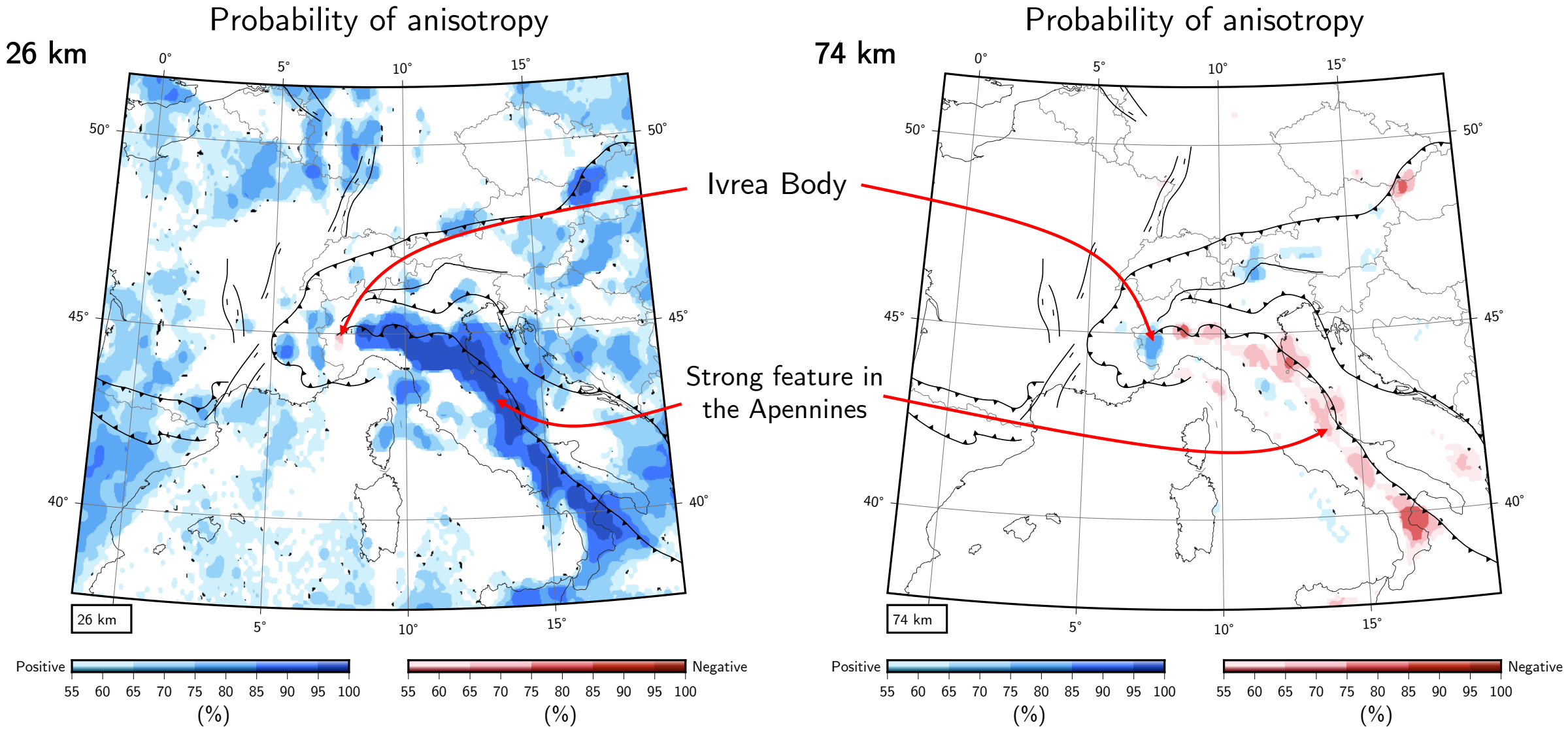
Probability of anisotropy

Anisotropy is only observed in restricted areas

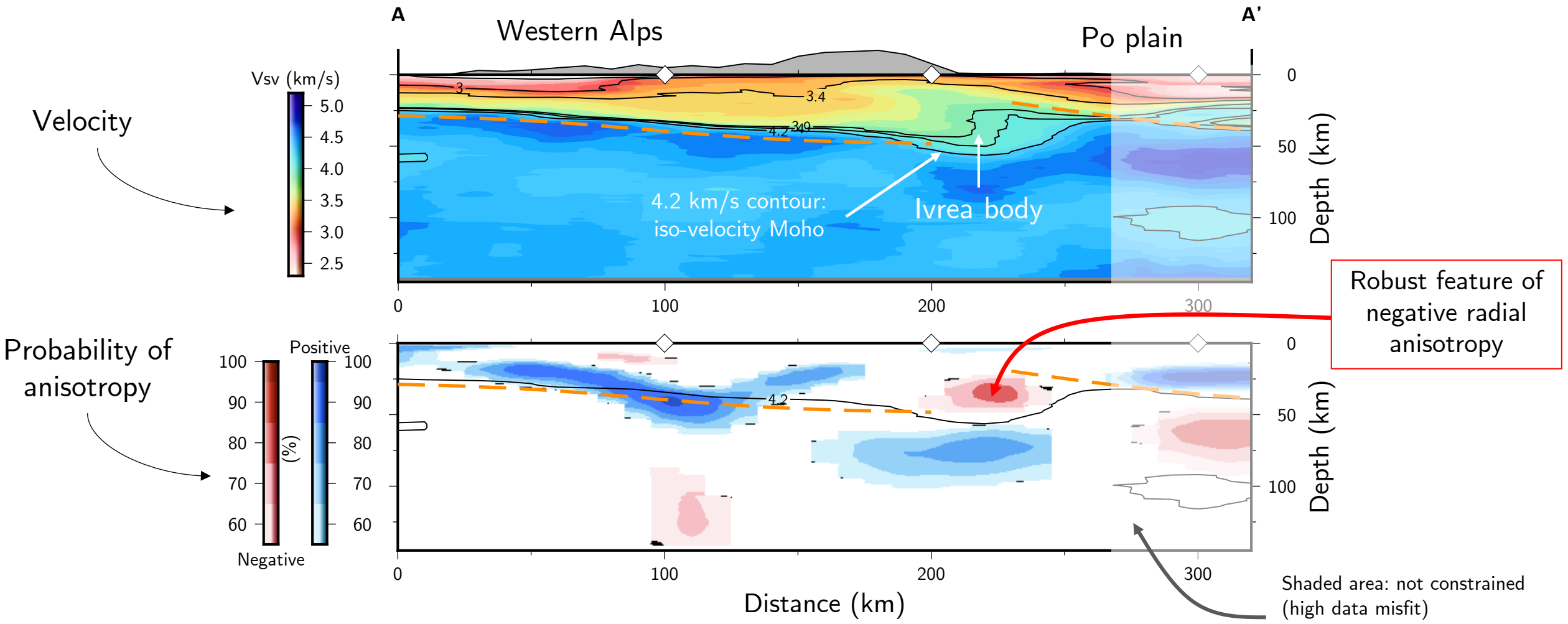


Probabilistic maps

(Alder et al., in prep.)

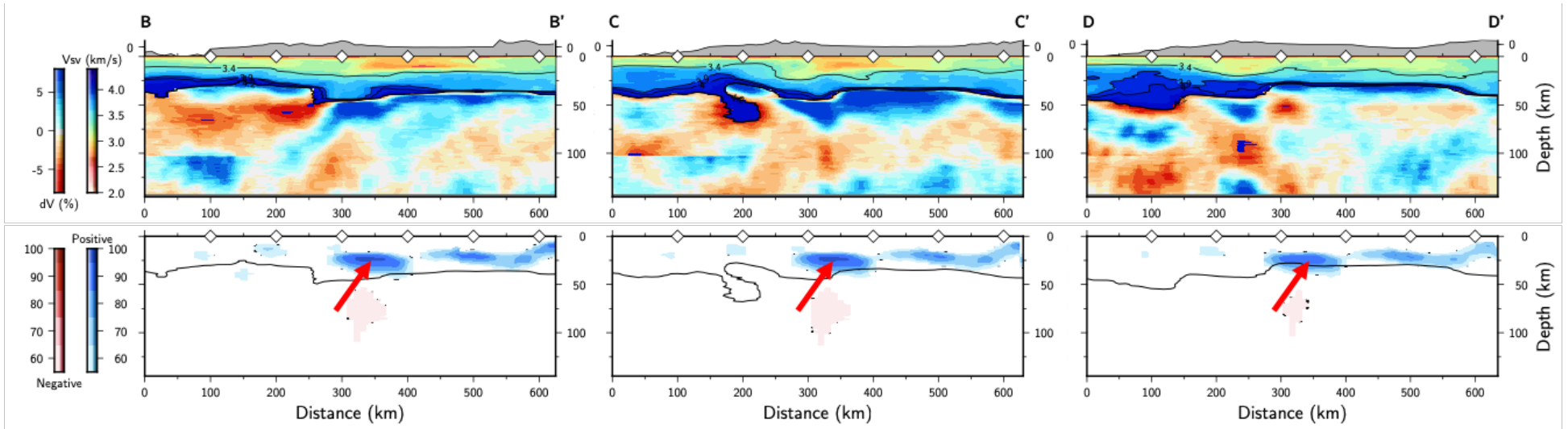


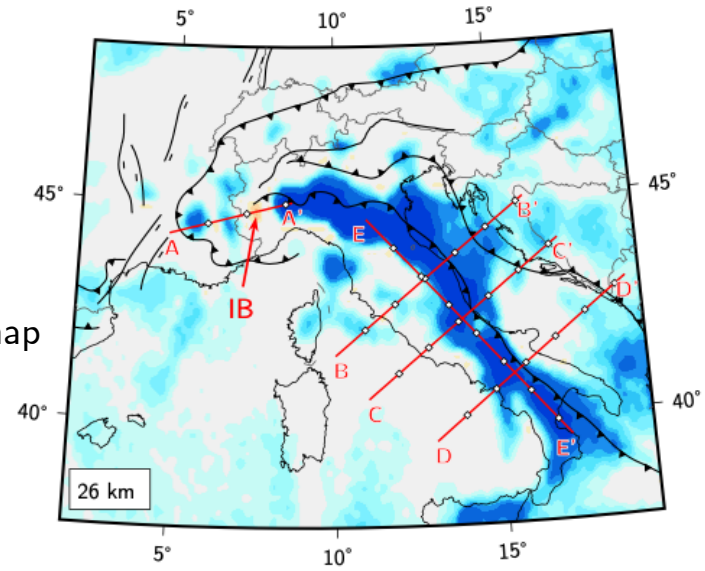
Cross-sections: CIFALPS profile



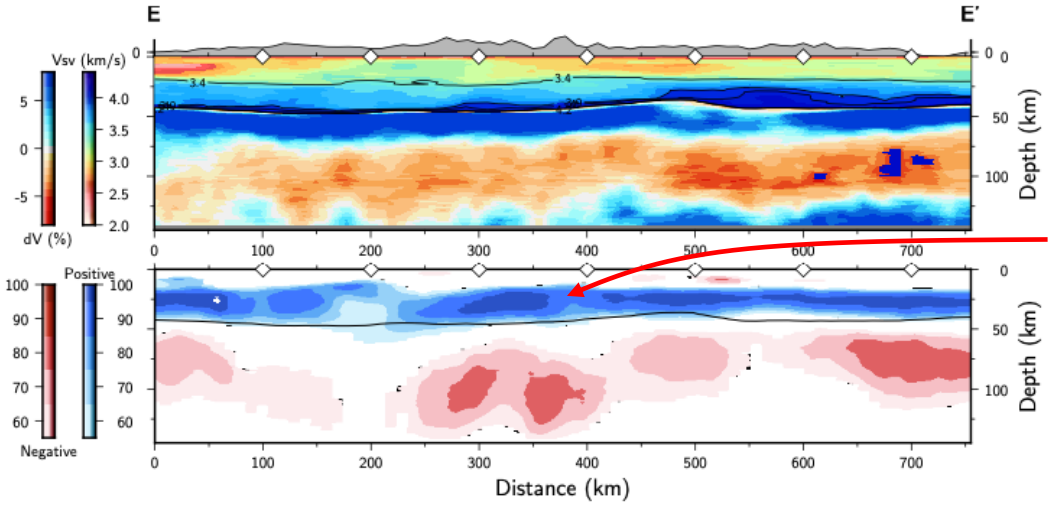
(Alder et al., in prep.)

Cross-sections: Apennines





Radial anisotropy map



Highly probable positive radial anisotropy in the lower crust

(Alder et al., in prep.)

Conclusions

- ✓ Large and new dataset of surface waves data thanks to AlpArray
- ✓ First radially anisotropic model of the crust and uppermost mantle at such depths
- ✓ Trade-off between layering and anisotropy is taken into account
- ✓ Radial anisotropy is not pervasive in the crust and uppermost mantle
- ✓ A robust signal of anisotropy is visible in the lower crust in the Apennines and could be related to the present day deformation
- ✓ Anisotropy indicates vertical flow in the Adriatic mantle in the Ivrea body