Slab Geometry and Upper Mantle Flow Patterns in the Central Mediterranean from 3D Anisotropic P-wave Tomography

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RESEARCH ARTICLE

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Key Points:

- *P*-wave tomography resolves three-dimensional (3D) isotropic and anisotropic structures in the Central Mediterranean
- A 3D reconstruction of the main slabs reveals their complex geometry resulting from pronounced tectonic deformation since the Oligocene
- Azimuth and dip of seismic anisotropy provide new constrains on mantle flow dynamics below the Central Mediterranean

Slab Geometry and Upper Mantle Flow Patterns in the Central Mediterranean From 3D Anisotropic *P*-Wave Tomography

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Abstract We present the first three-dimensional (3D) anisotropic teleseismic *P*-wave tomography model of the upper mantle covering the entire Central Mediterranean. Compared to isotropic tomography, it is found that including the magnitude, azimuth, and, importantly, dip of seismic anisotropy in our inversions simplifies isotropic heterogeneity by reducing the magnitude of slow anomalies while yielding anisotropy patterns that are consistent with regional tectonics. The isotropic component of our preferred tomography model is dominated by numerous fast anomalies associated with retreating, stagnant, and detached slab segments. In contrast,

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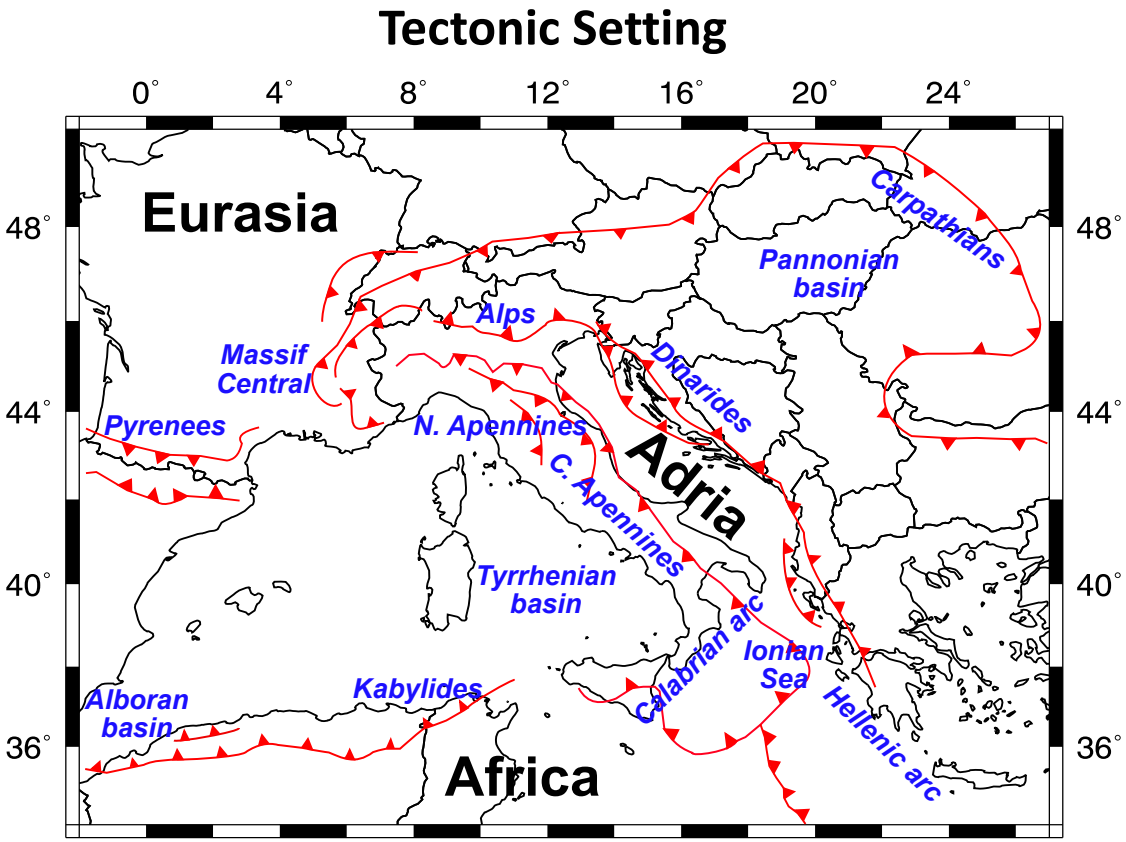
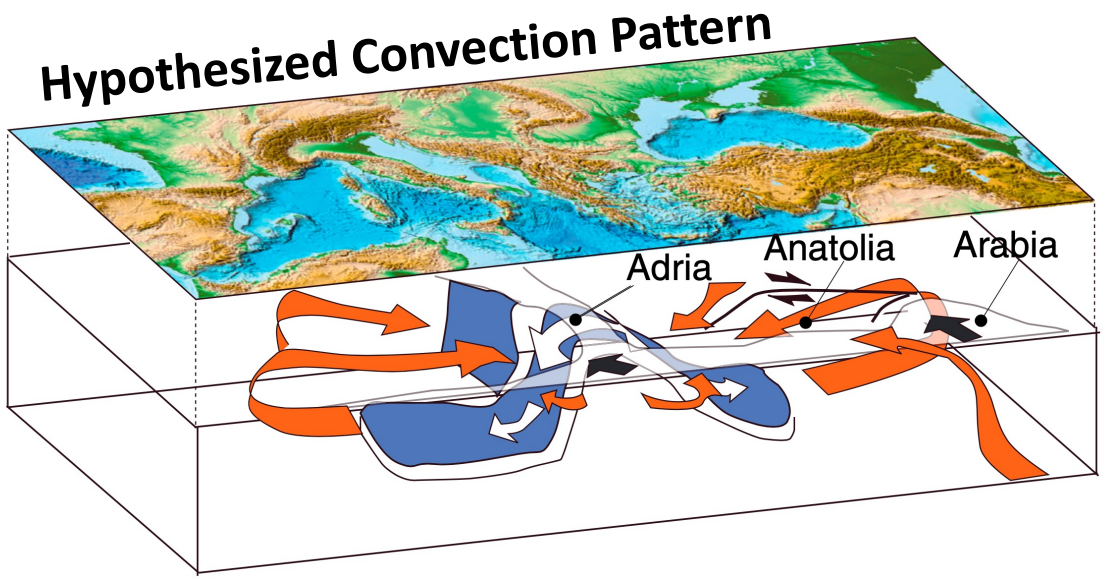
Study Area: Central Mediterranean



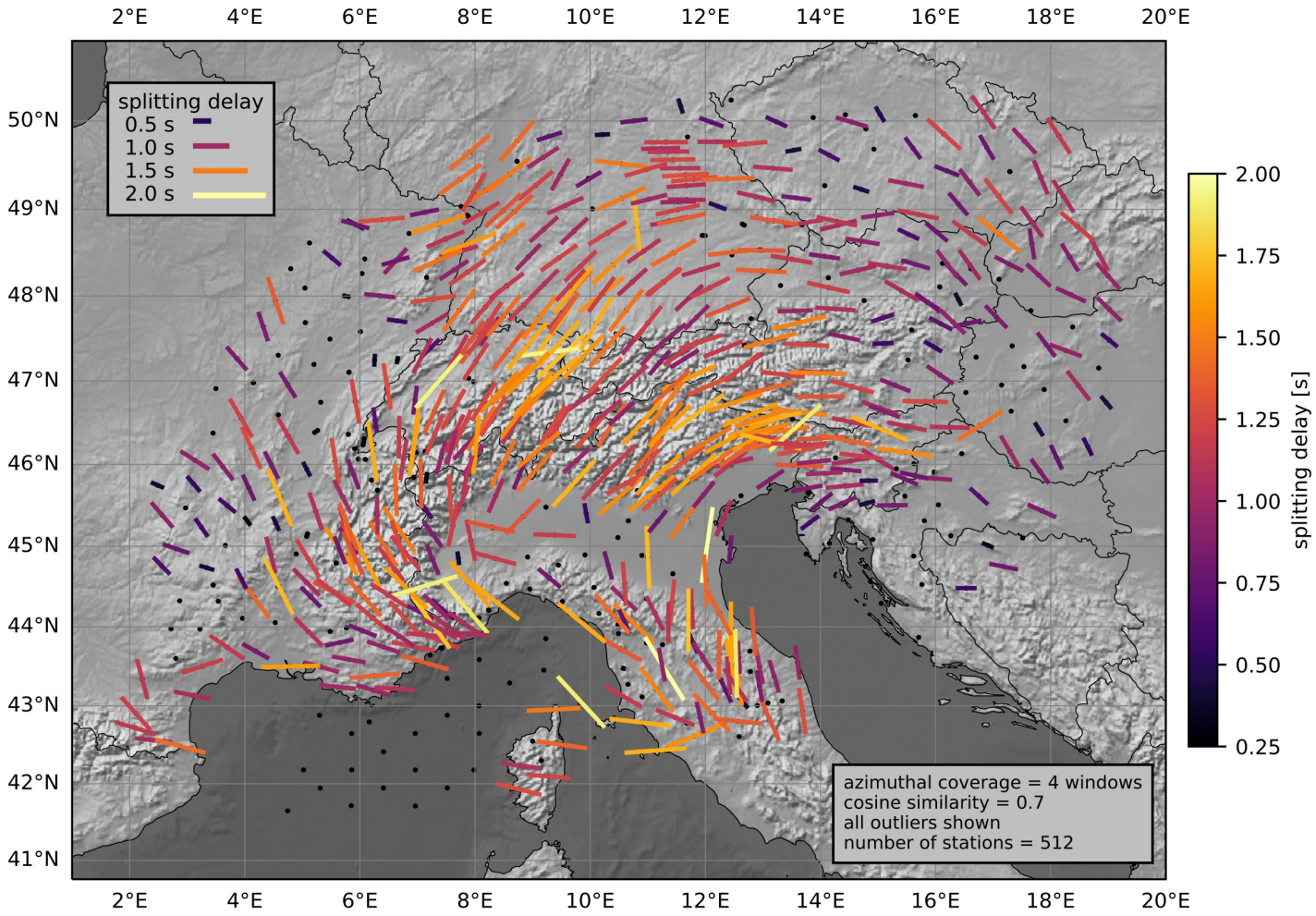
Rappisi et al. 2022

- Tectonically active area controlled by the convergence of Africa with Eurasia
- Multiple sinking slab fragments drive local convective mantle flow patterns



Faccenna et al. 2014

Study Area: Central Mediterranean



Hein et al. 2021

- Central Mediterranean characterized by strong seismic anisotropy
- Implies diverse patterns of lithospheric deformation and mantle flow
- Despite overwhelming evidence for mantle anisotropy, majority of body wave seismic imaging is isotropic
  - Some radial and azimuthally anisotropic tomography (e.g. Hua et al., 2017)

Motivation

Improve understanding of Mediterranean mantle dynamics via improved seismic imaging >> <u>Anisotropic P-wave Travel-time tomography</u>

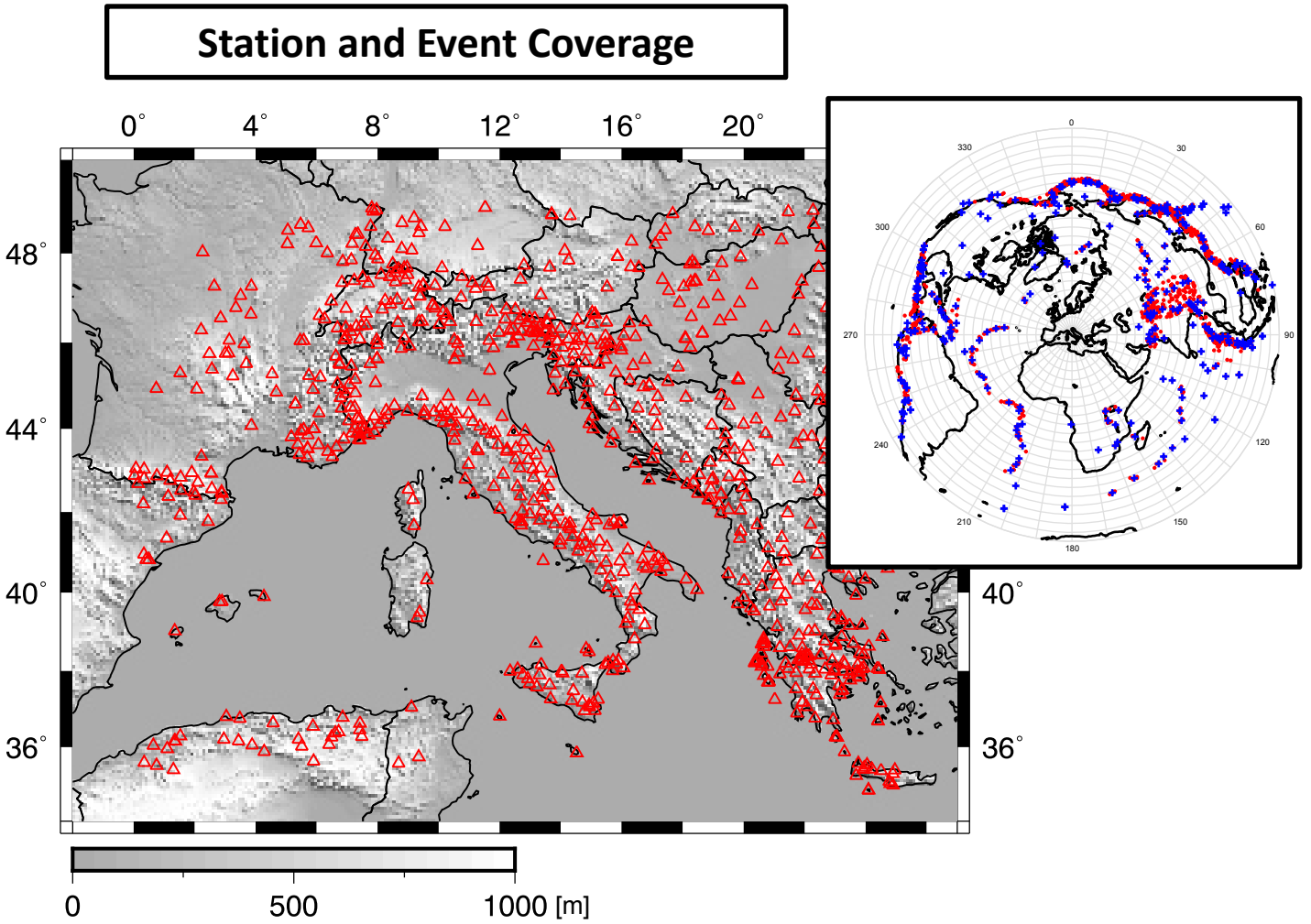
1) What is the nature of potential imaging artefacts introduced by neglecting anisotropic heterogeneity in teleseismic body wave tomography?
   - Neglecting anisotropy can result in significant isotropic imaging artefacts (Sobolev et al., 1999; Lloyde & van der Lee, 2008; Bezada et al., 2016; VanderBeek & Faccenda, 2021)
   - Especially true when neglecting dipping fabrics

2) What is the geometry of upper mantle flow beneath the central Mediterranean?

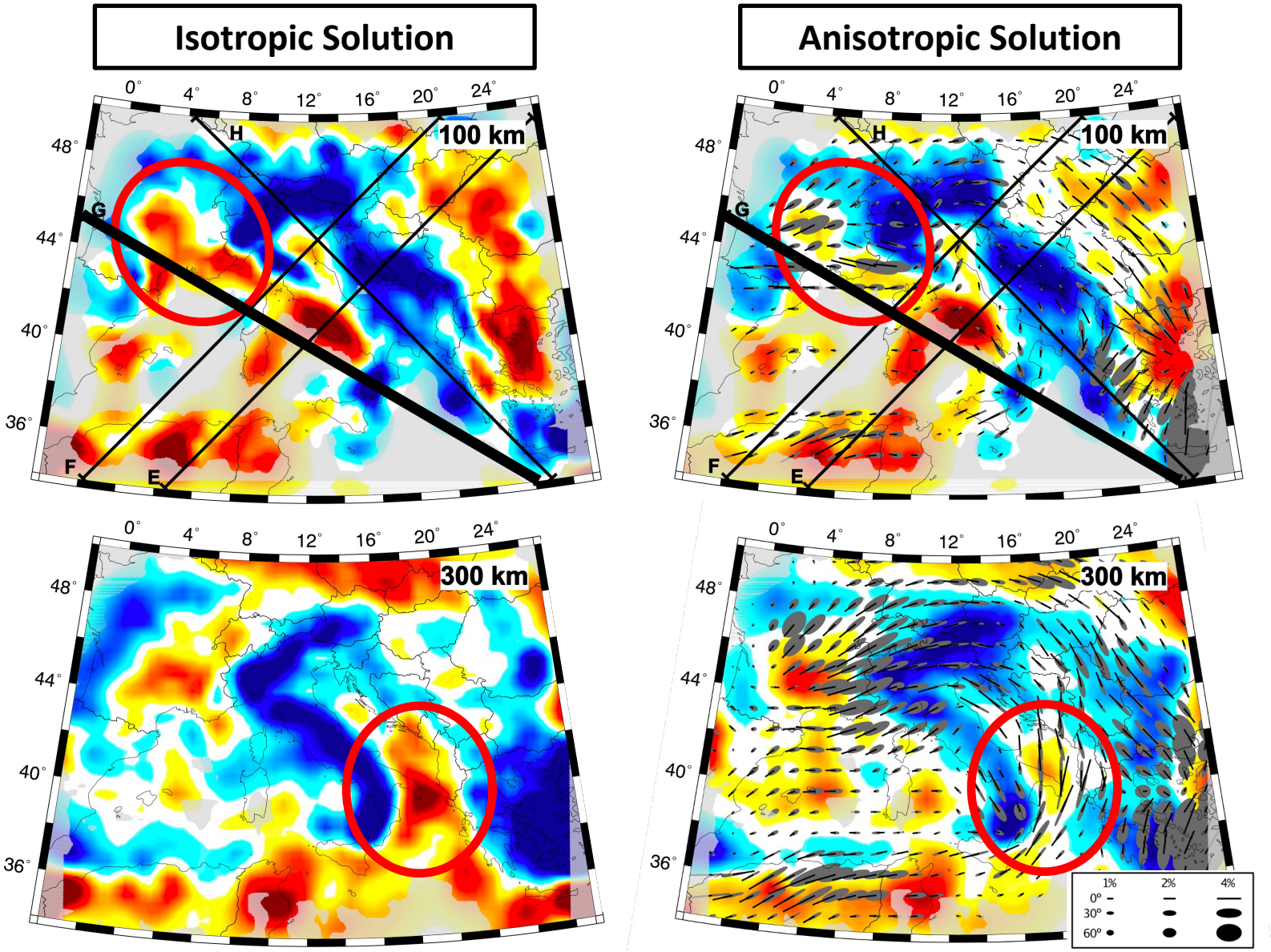
3) What is the present-day configuration of slabs beneath the central Mediterranean?

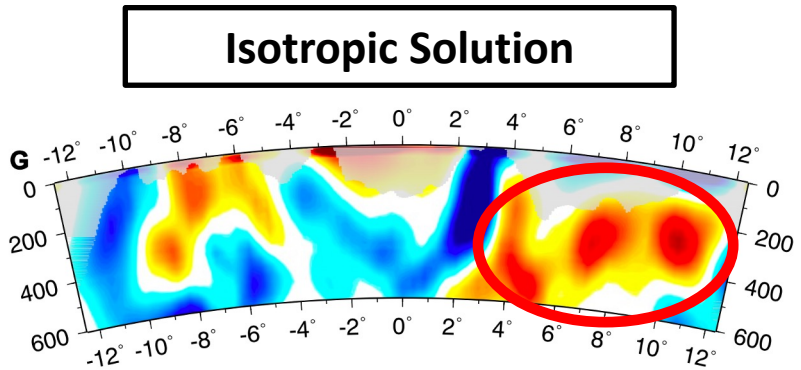
Data and Methods

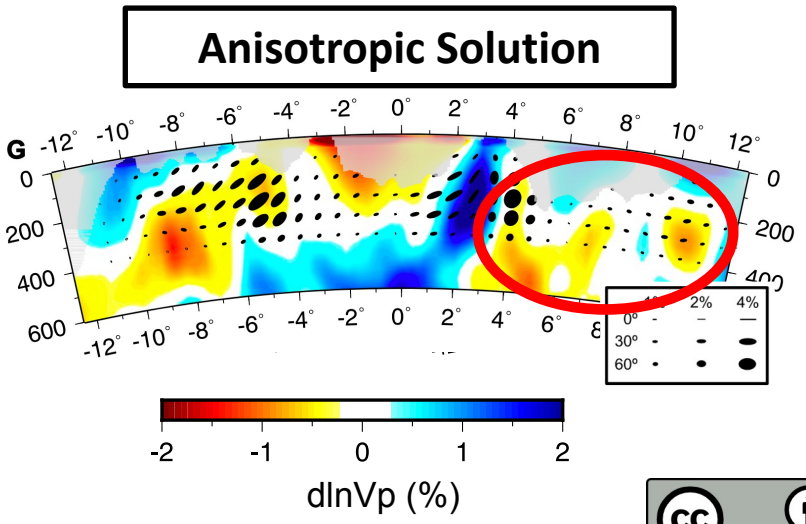
- Direct P-wave arrival times from the ISC-EHB identified between 2000 – 2018
- Good station coverage throughout Europe but poor in marine areas
- Good back-azimuthal event distribution
- Apply new imaging method that includes as parameters the magnitude, azimuth, and dip of an approximate hexagonally symmetric media (VanderBeek & Faccenda, 2021)



Anisotropic Inversion Reduces Low-Velocity Anomalies

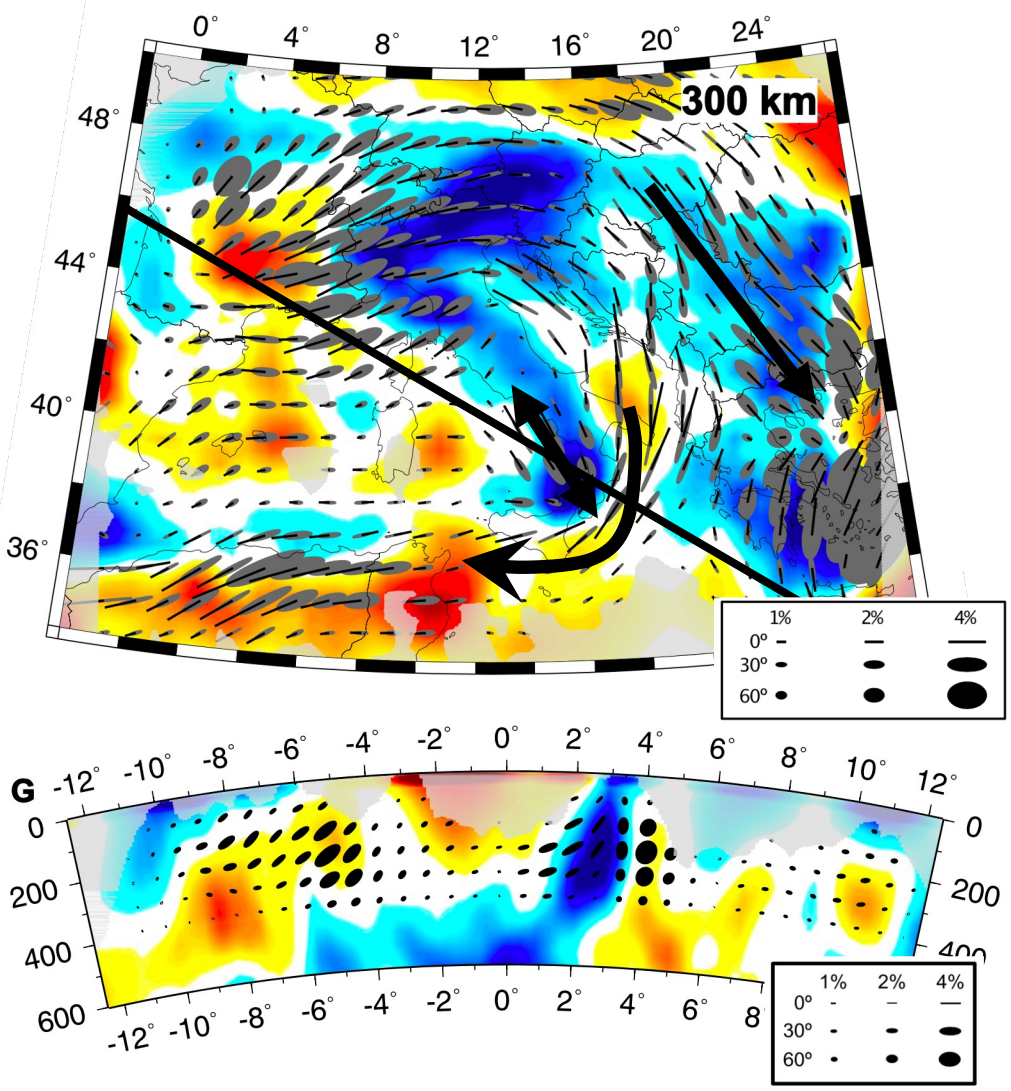






Horizontal and Vertical Mantle Flows

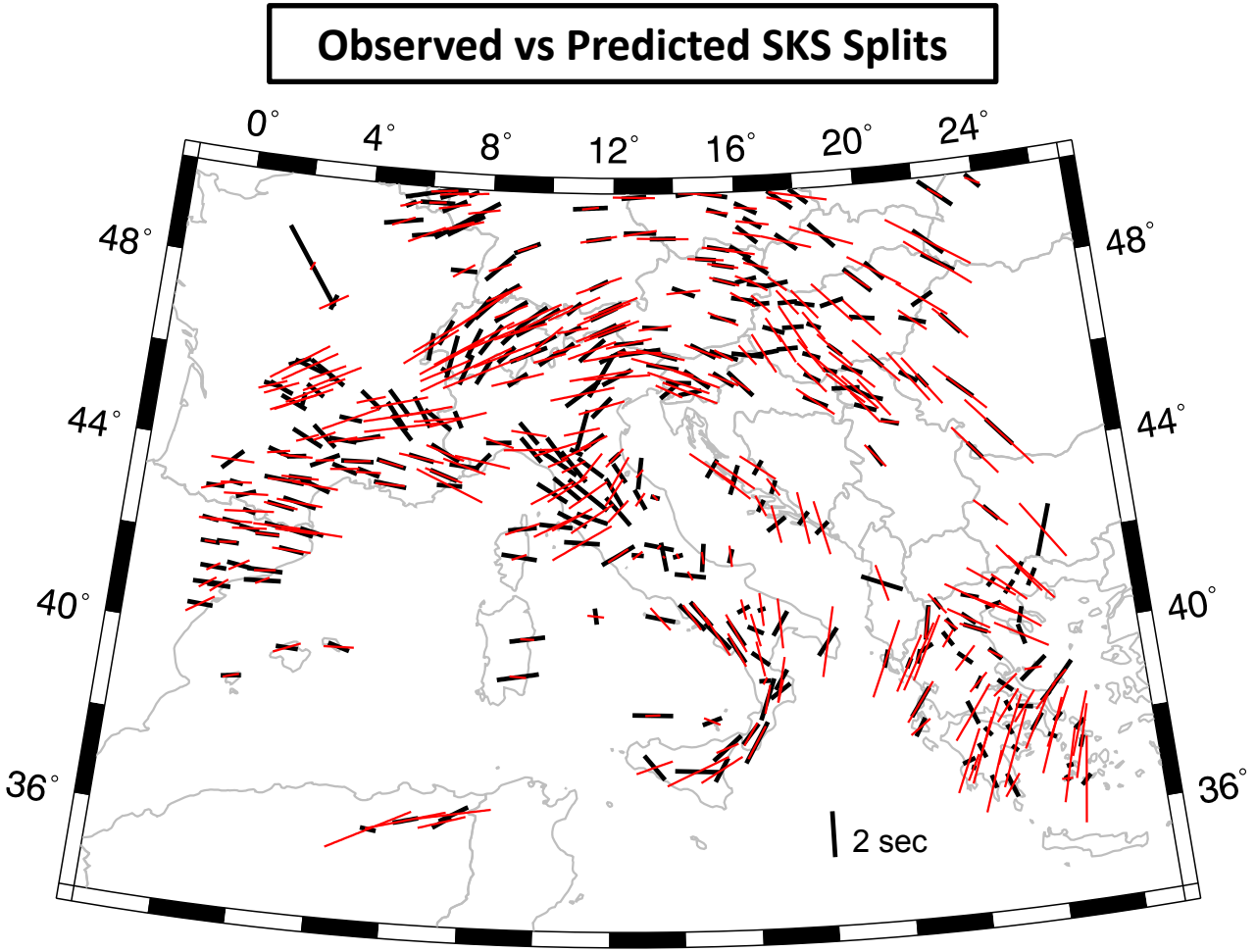
Isotropic and Anisotropic P-wave Heterogeneity



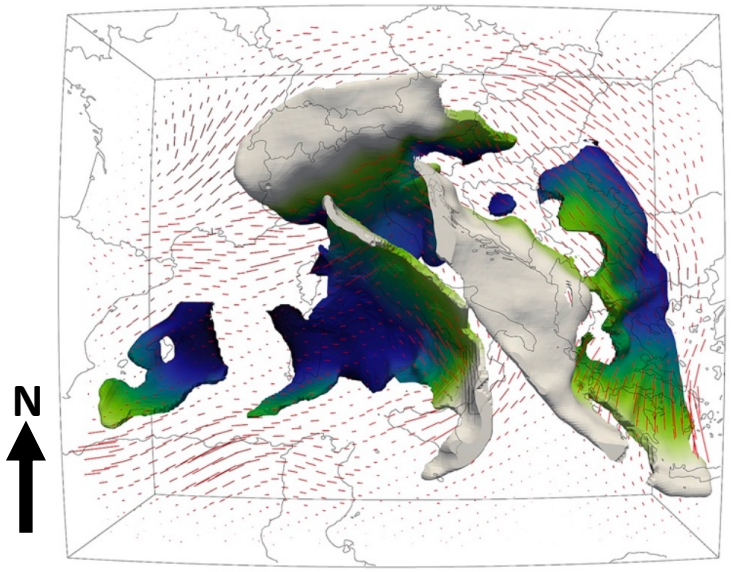
- Slab driven mantle flow
- Circular flow pattern around Italian peninsula and trench-perpendicular fabrics in Calabrian back-arc consistent with geodynamic predictions (e.g., Faccenda & Capitanio, 2013; Lo Bue et al., 2021)
- Strong retreat of Aegean trench draws material from the Alpine region
- Generally steeper dipping fabrics in vicinity of inferred subducting slabs consistent with entrained flow

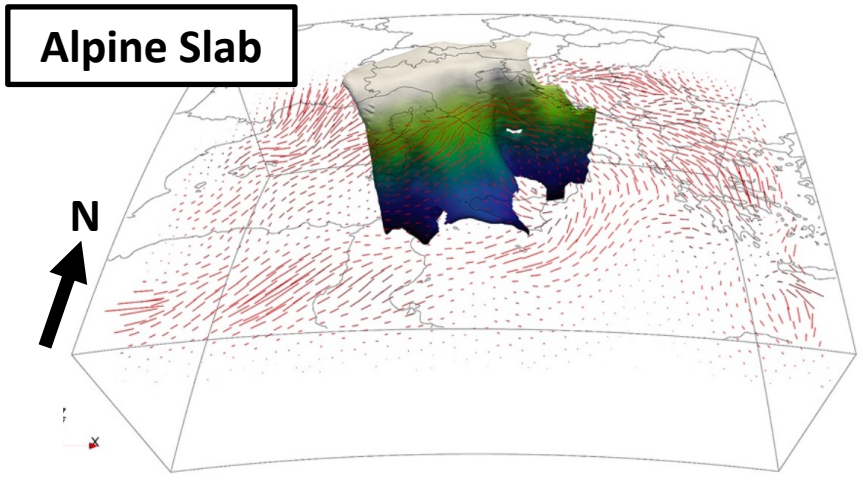
Comparison with SKS Splitting

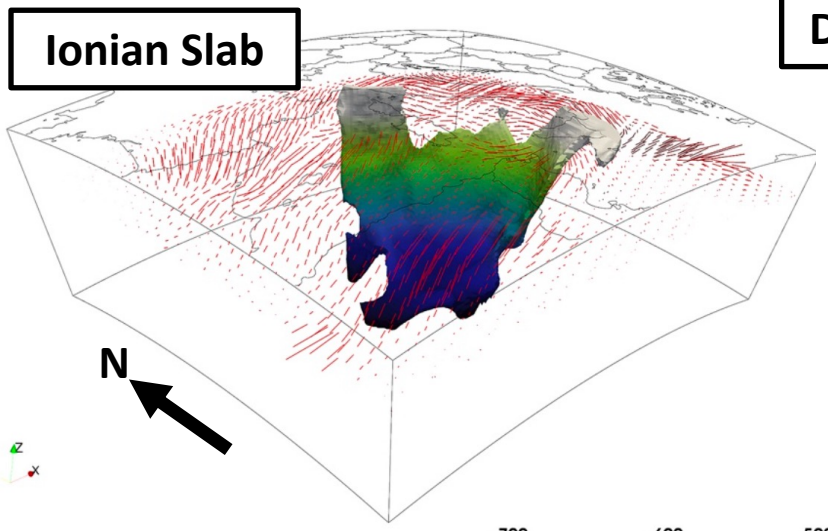
- Anisotropic model generally consistent with SKS splitting results
  - Azimuthal error < 20 deg. for 50% of observations
- Some noteable areas of disagreement such as the northern Appennines
- Teleseismic P-waves better illuminate anisotropic structure between stations

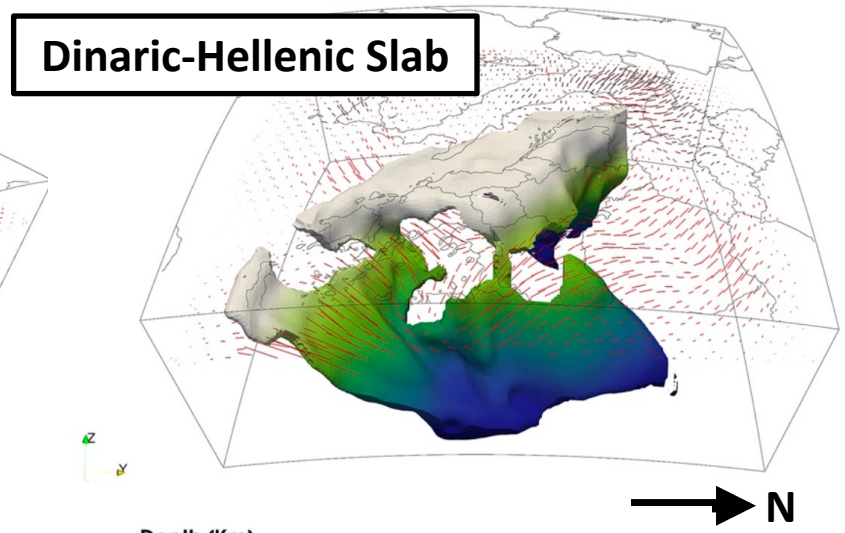


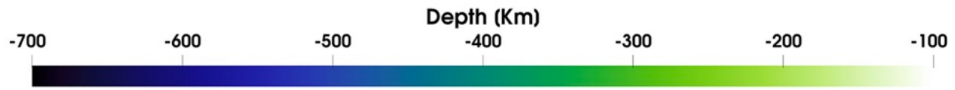
Geometry of Slabs in Central Mediterranean











- 3D slab reconstruction from fast anomalies following Portner and Hayes (2018)
- Segmented Alpine slab extends into transition zone
- Shallow slab gap (< 200 km) in Ionian slab through central Italy
- Fragmented Dinaric slab with possible dip reversal at northern end

Conclusions

1) Teleseismic P-waves constrain meaningful mantle anisotropic heterogeneity consistent with independent observations

2) Accounting for anisotropy reduces the magnitude of mantle low-velocity zones which may otherwise be interpreted as thermal and/or compositional anomalies
   - Largely the result of including dipping fabrics

3) Anisotropic heterogeneity consistent with slab-driven convective flow