Observations of dynamics in the lowermost mantle

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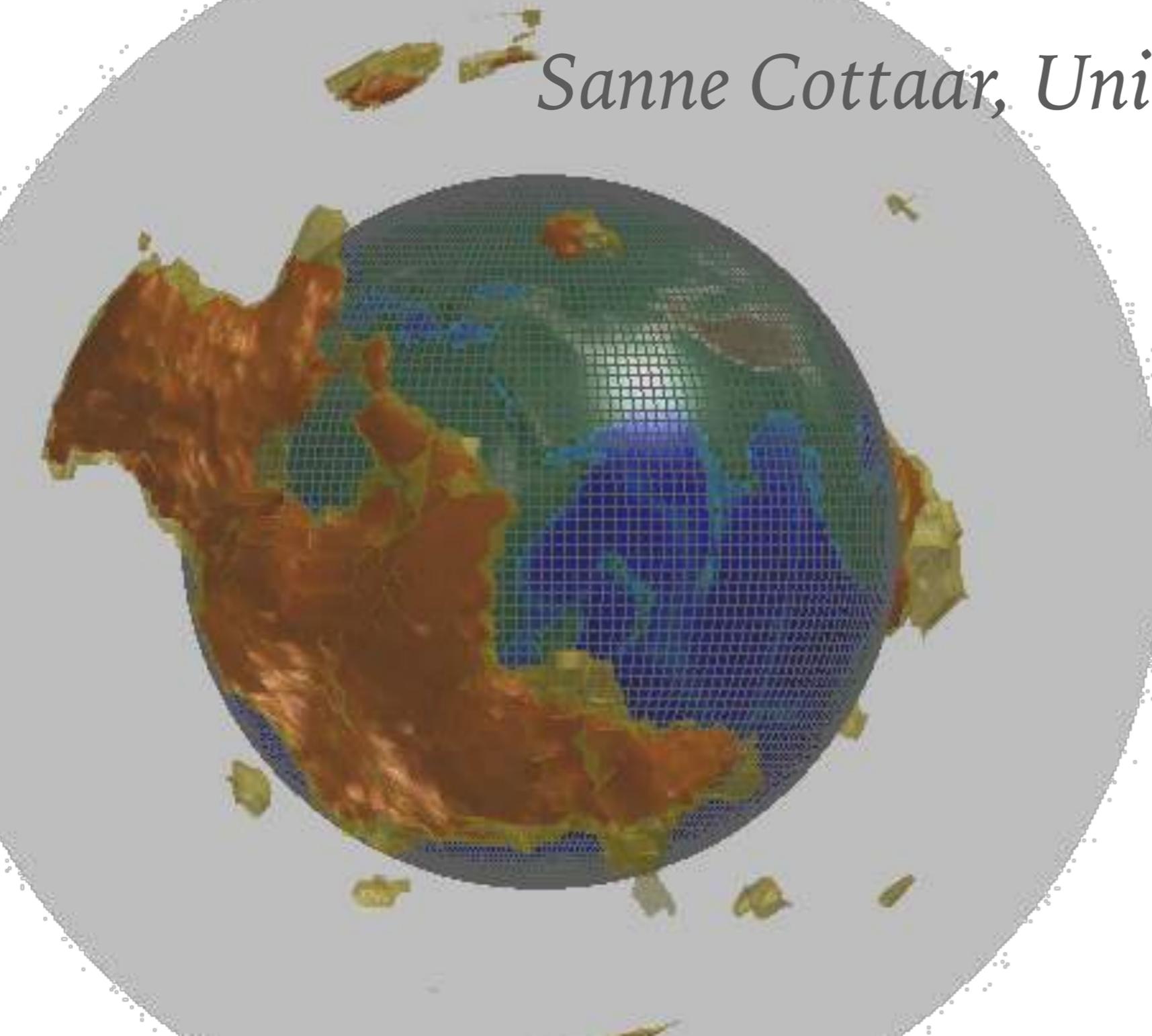
Collège de France
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OUTLINE

➤ Clustering analysis of seismic tomographic models in the lower mantle

      ➤ Agreement with regional higher-frequency waveform studies in the varied morphology of Large Low Shear Velocity Provinces (LLSVPs)

      ➤ Suggestions of mesoscale slow-velocity features

➤ Observations of anisotropy at LLSVP boundaries
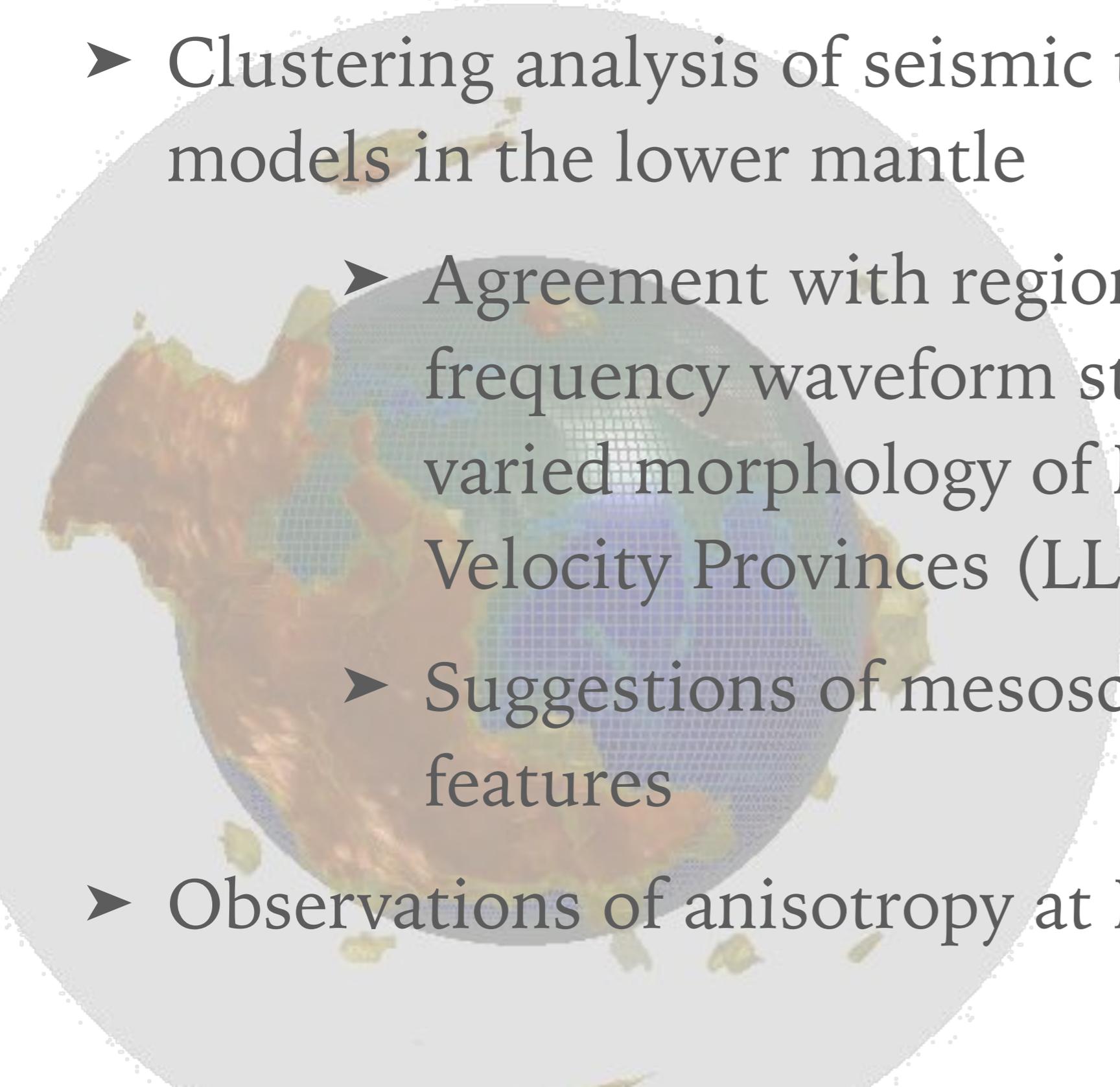
CLUSTERING ANALYSIS OF PROFILES, '2D'

➤ Clustering analysis in the upper mantle shows it distinguishes 'tectonic' regions.
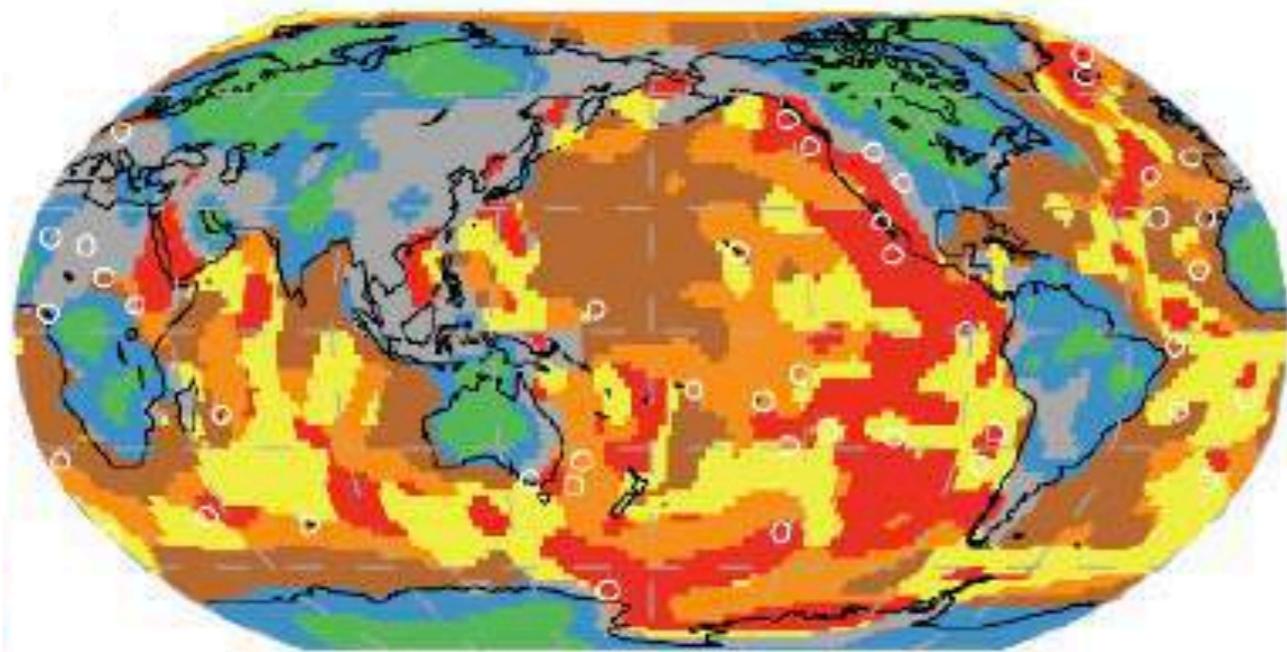
➤ Extend this method to map regions in the lower mantle

➤ Here information from five models is collated in a vote map.
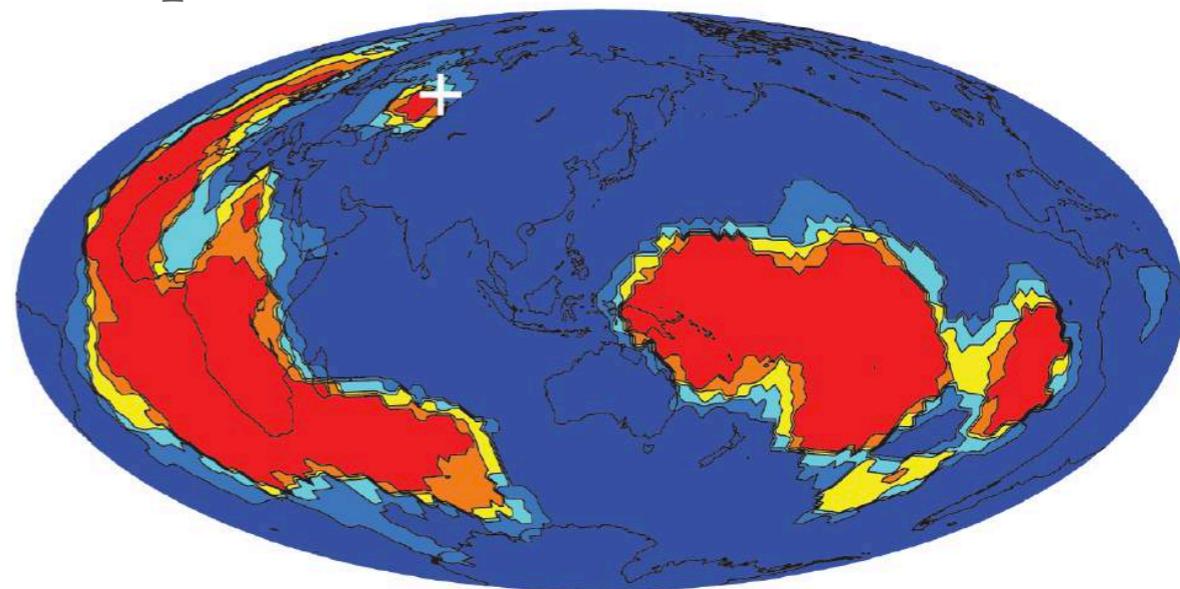
Lekic & Romanowicz 2011

5 4 3 2 1 0

Lekic et al. 2012

Kustowski et al., 2008; Ritsema et al., 2011; Mégnin and Romanowicz, 2000; Houser et al., 2008; Simmons et al., 2010

CLUSTERING ANALYSIS OF PROFILES, '2D'

➤ k- means clustering- set to two clusters

➤ 'distance' is L2-norm between lower mantle shear wave velocity profiles

mean velocity profiles for the two clusters
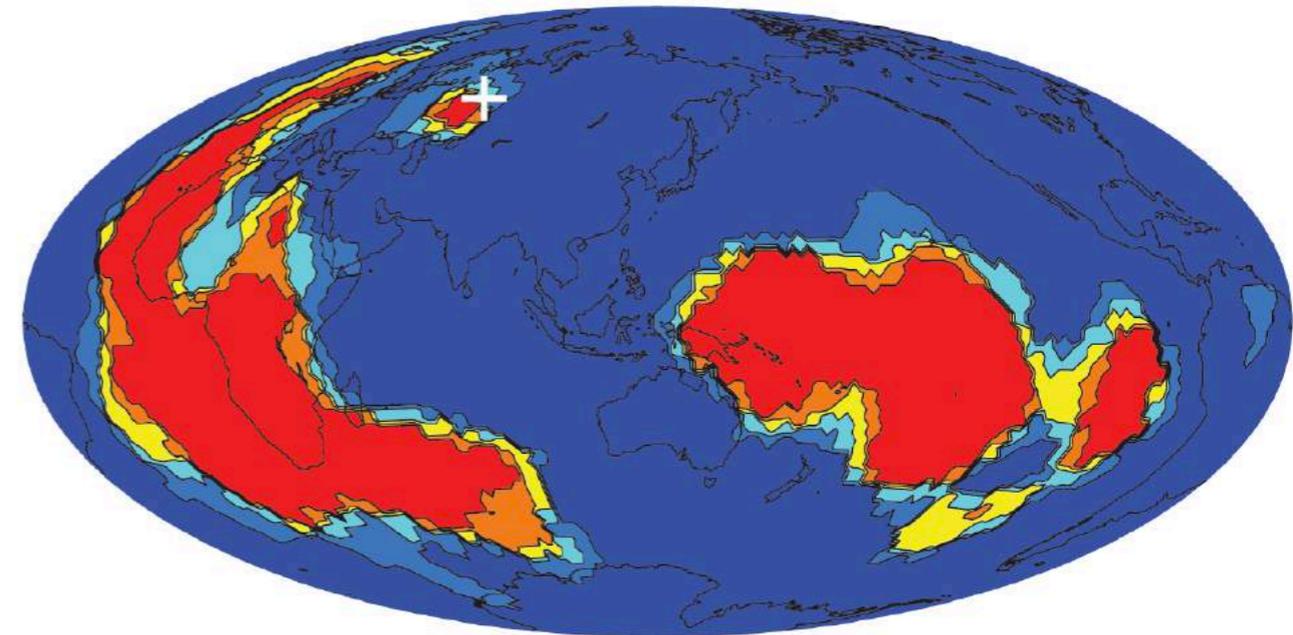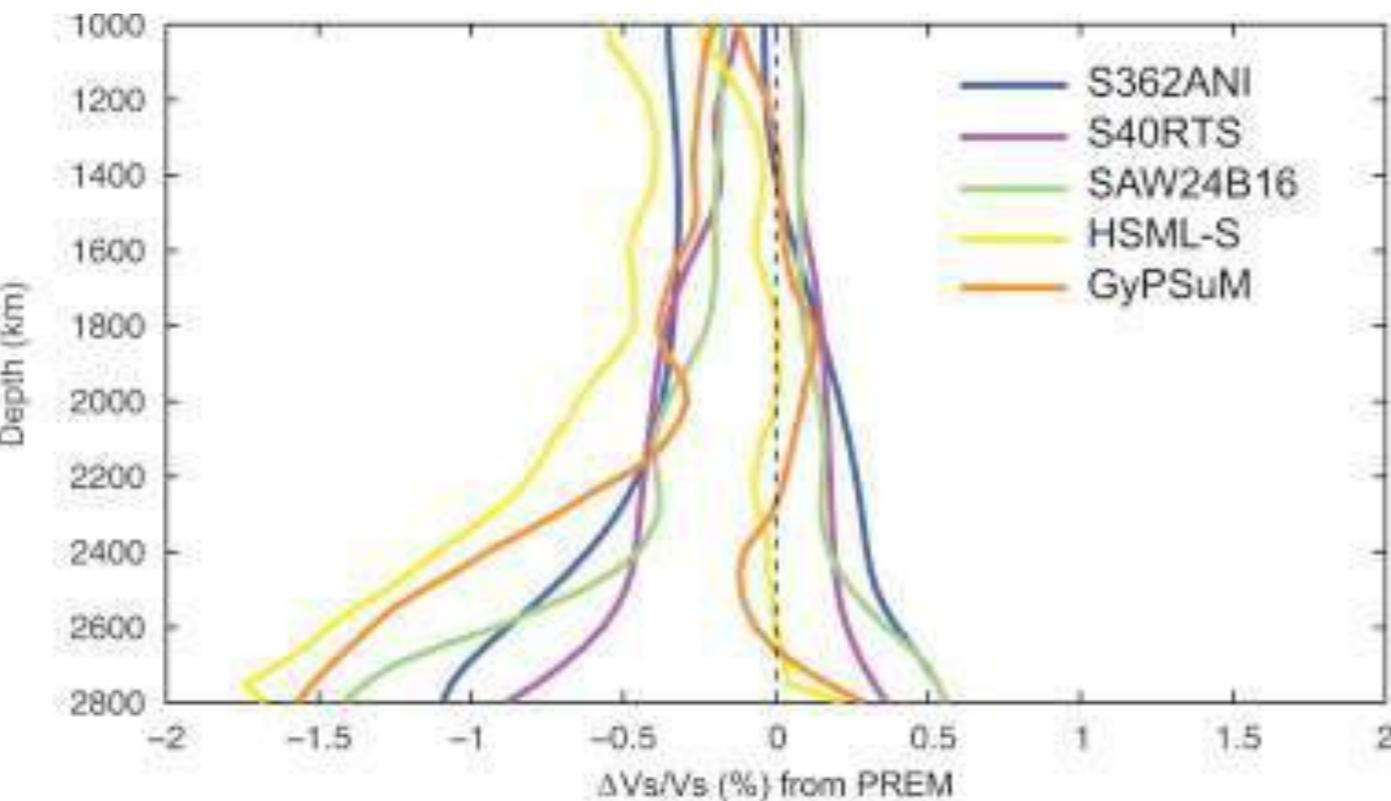
Lekic et al. 2012

Kustowski et al., 2008; Ritsema et al., 2011; Mégnin and Romanowicz, 2000; Houser et al., 2008; Simmons et al., 2010

CLUSTERING ANALYSIS FOR 3 CLUSTERS

➤ Lowermost mantle represents a dichotomy with strong gradients in between.

➤ The mid-lower mantle shows strong gradients around both fast and slow anomalies, suggesting a trichotomy.
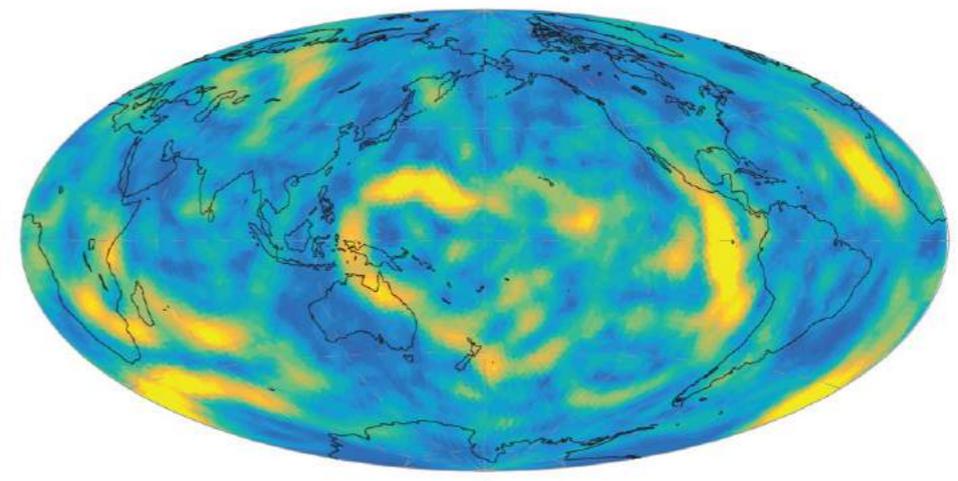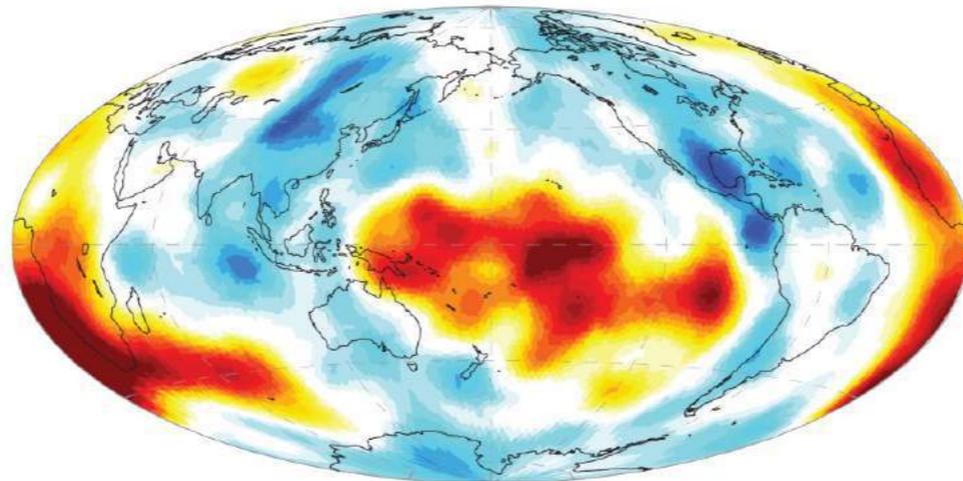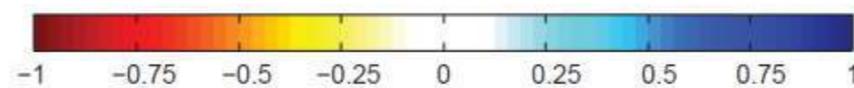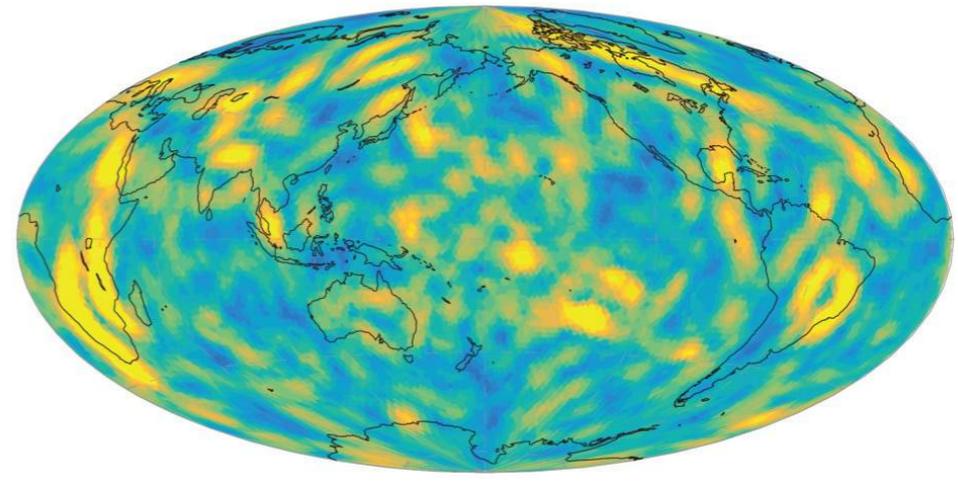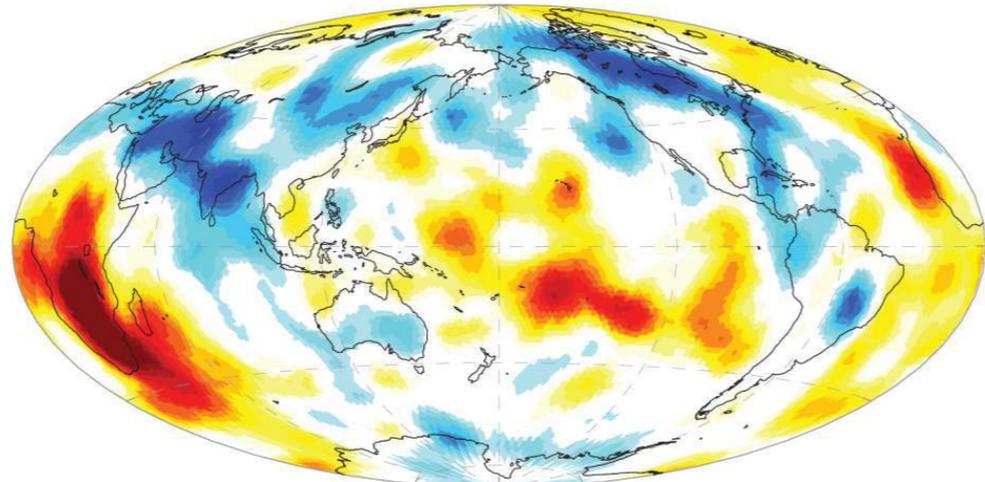
Median Vs (%)   Range of Vs (%)

➤ We clustered all Vs perturbation profiles using **300 km depth range every 50 km depth**
➤ Using **3 clusters.**
➤ Including the latest Vs tomographic models:

- HSML-S (Houser et al. 2008)
- GyPSuM (Simmons et al. 2010)
- TX2011 (Grand 2002)
- **S40RTS (Ritsema et al. 2011)**
- Savani (Auer et al. 2014)
- SEMUCBWM1 (French & Romanowicz 2014)
- SPani (Tesoniero et al. 2015)
- ME2016-S (Moulik & Ekstrom 2016)
- SP12RTS (Koelemeijer et al. 2016)
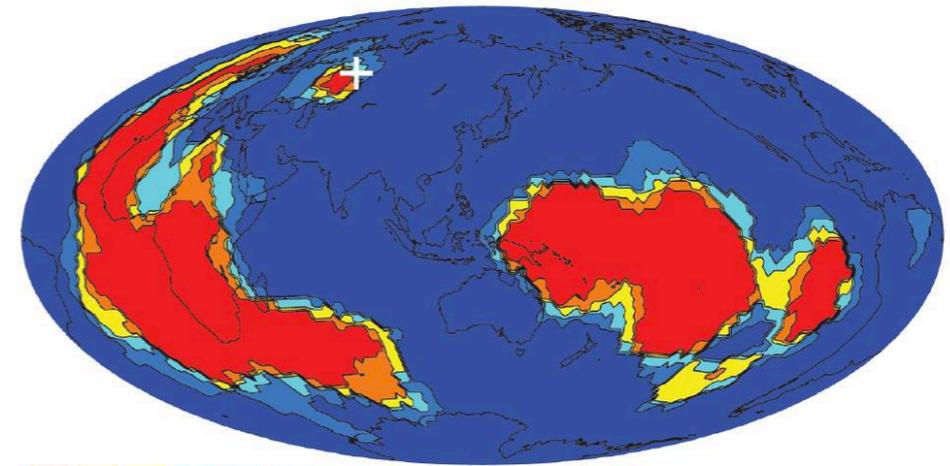
5 4 3 2 1 0
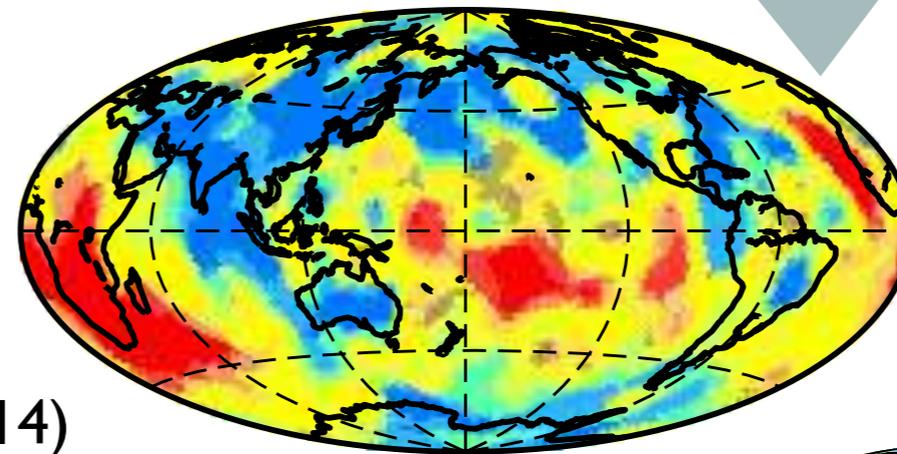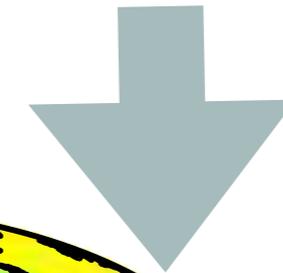
1750-2050 km

2550-2850 km

Cottaar & Lekic 2016

neutral

slow

fast

Cottaar & Lekic 2016
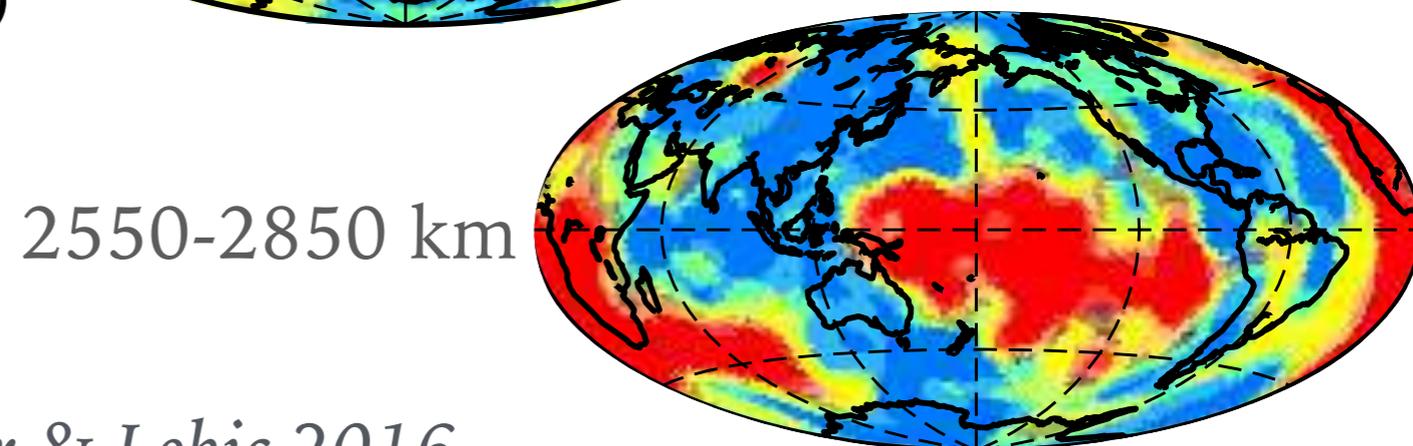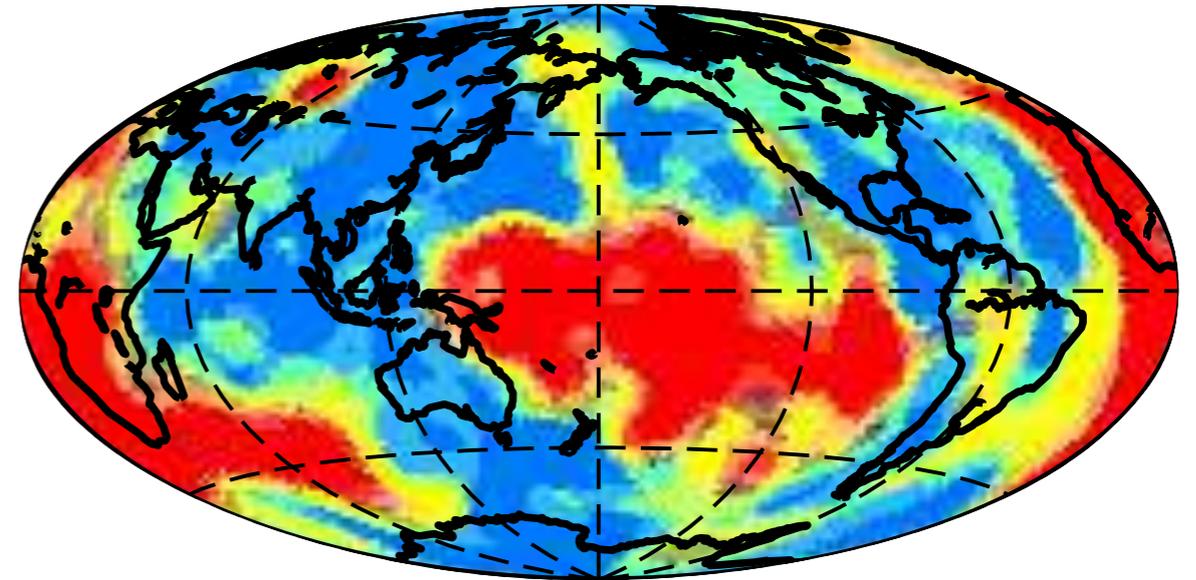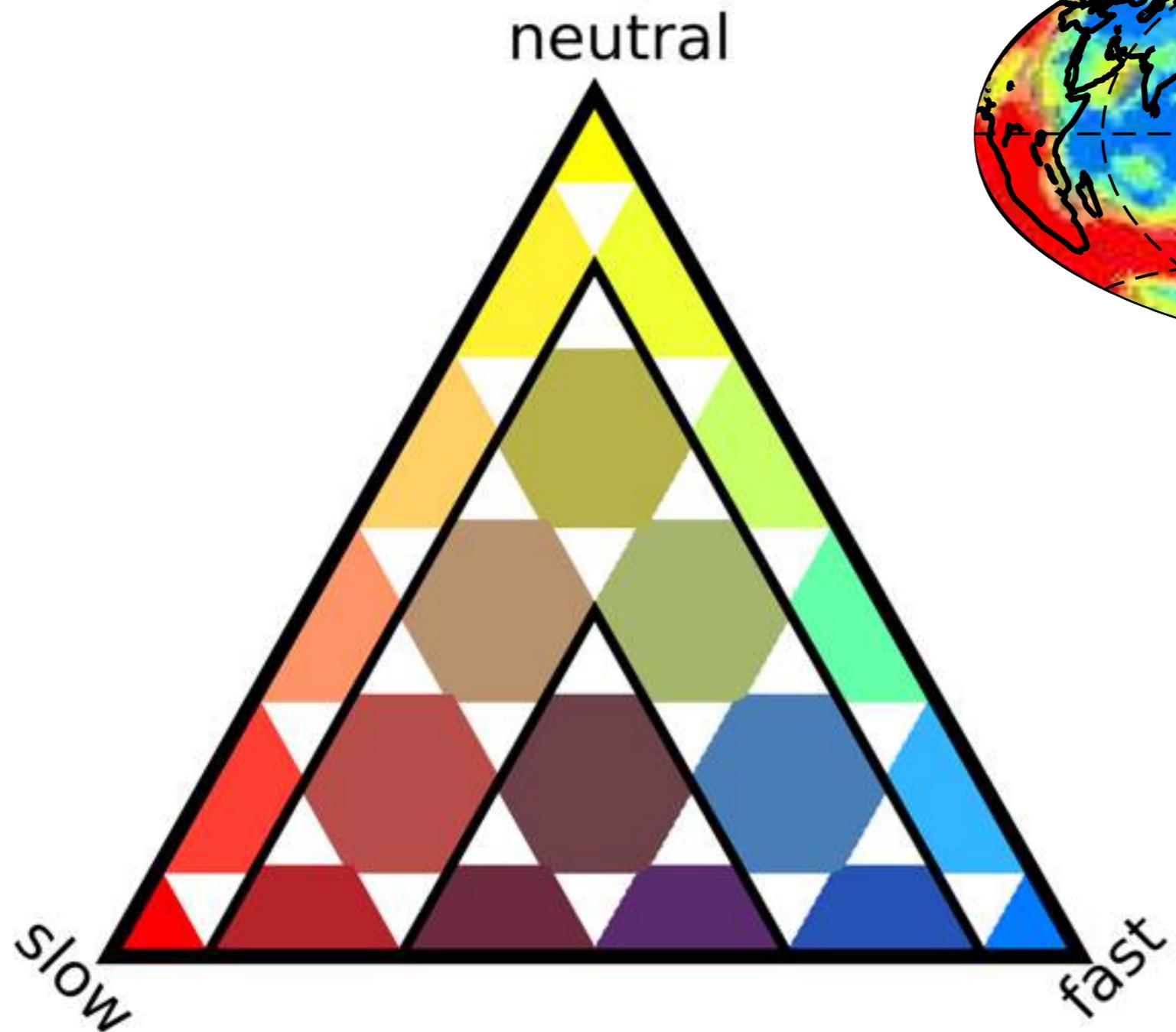
QUALITATIVE INTERPRETATION OF THE CLUSTERS

➤ The fast velocities in the lowermost mantle are readily interpreted as slabs, and thus associated with compositional variations.

➤ The slower velocities are more difficult to interpret:

  ➤ purely thermal variations

  ➤ the introduction/creation, survival, and destruction of chemical heterogeneity
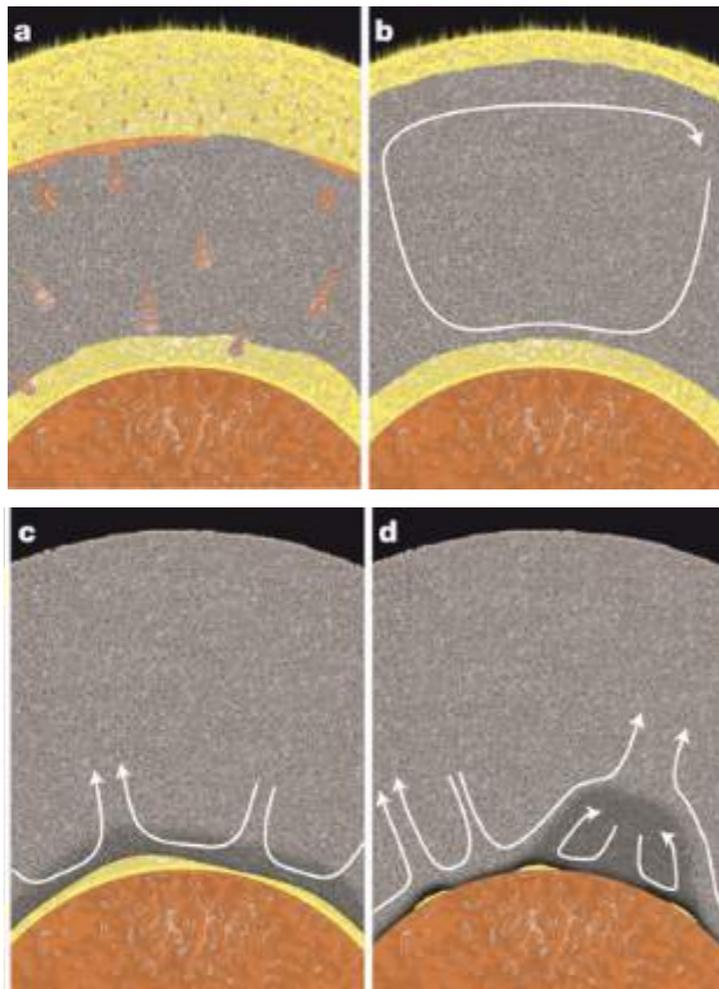
Labrosse et al. 2015
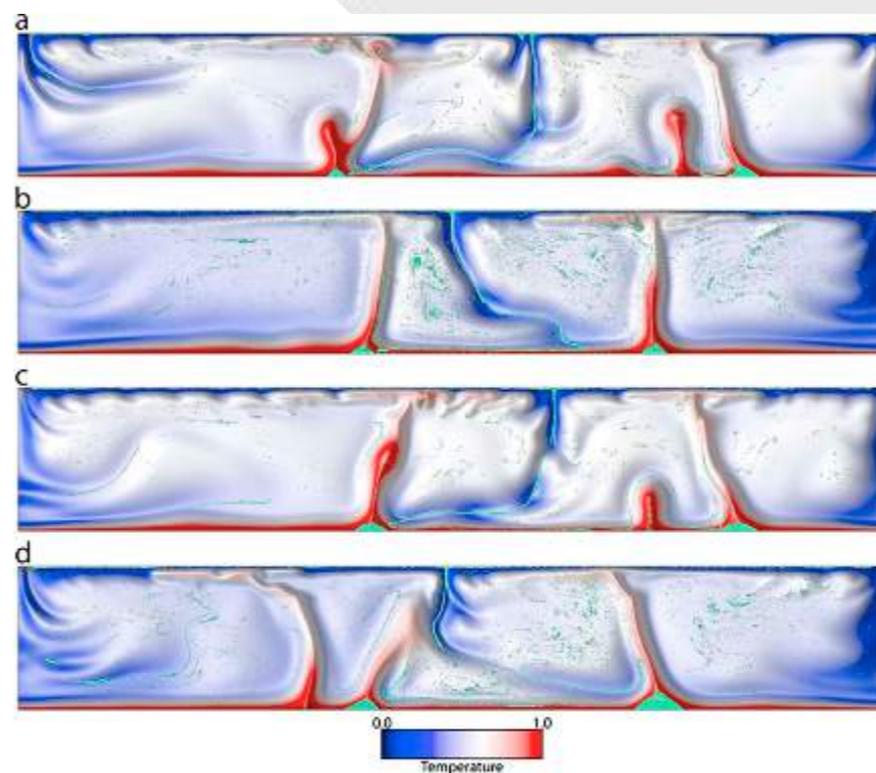
Li and McNamara 2013
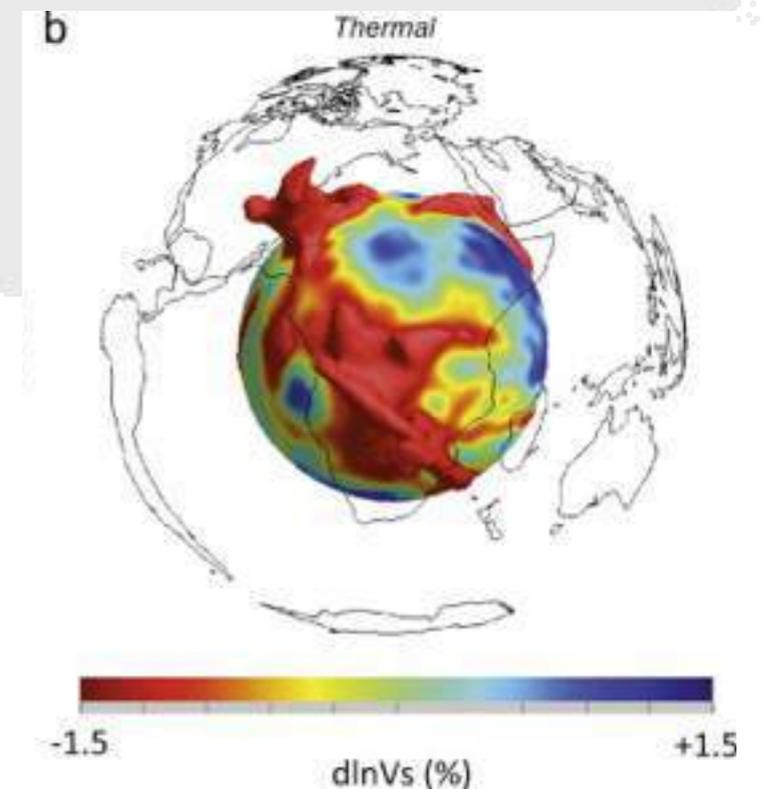
Davies et al. 2012

VOTE MAPS ACROSS

DIFFERENT DEPTHS

VOTE MAPS

V$_S$ vs. V$_P$

- HSML-P (Houser et al. 2008)
- GyPSuM (Simmons et al. 2010)
- LLNL_G3Dv3-P (Simmons et al. 2012)
- SPani (Tesoniero et al. 2015)
- ME2016-P (Moulik & Ekströ¨m 2016)

S velocity vote maps

P velocity vote maps
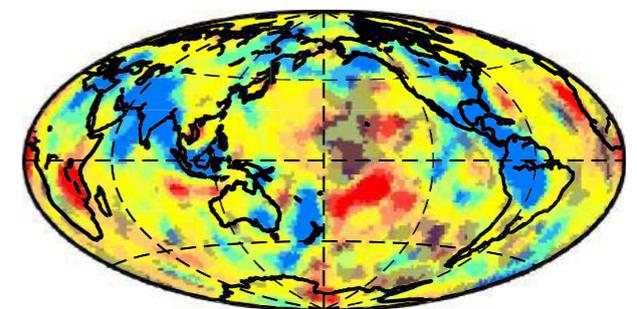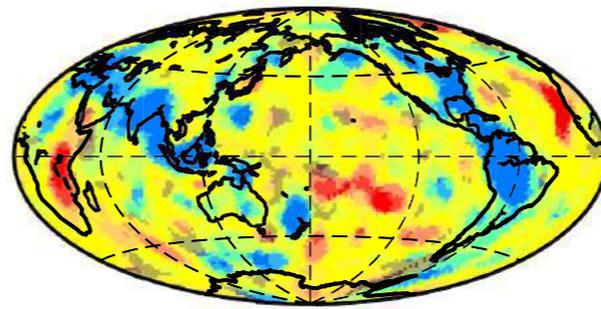
950 - 1250 km
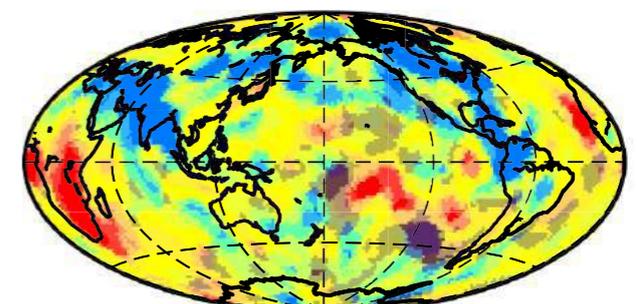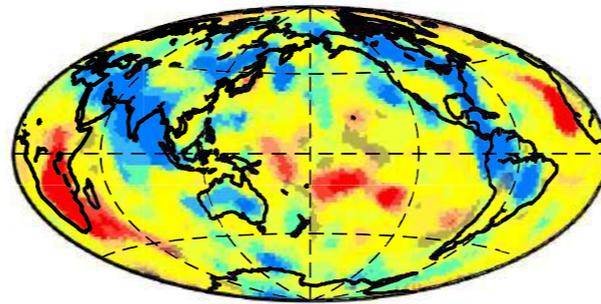
1350 - 1650 km
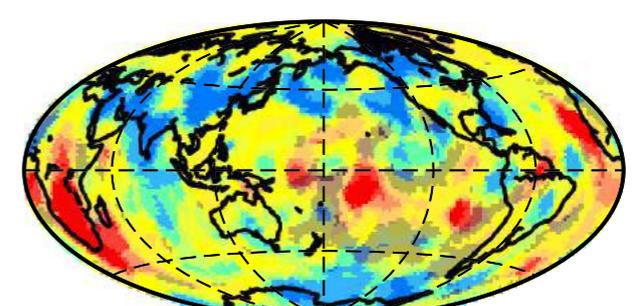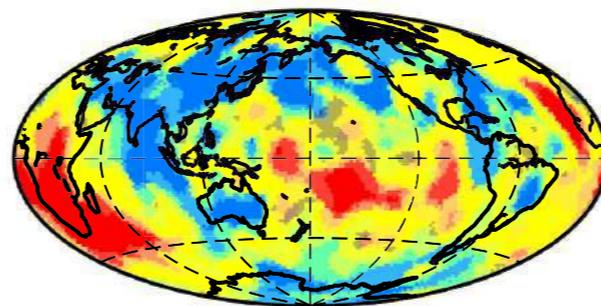
1750 - 2050 km
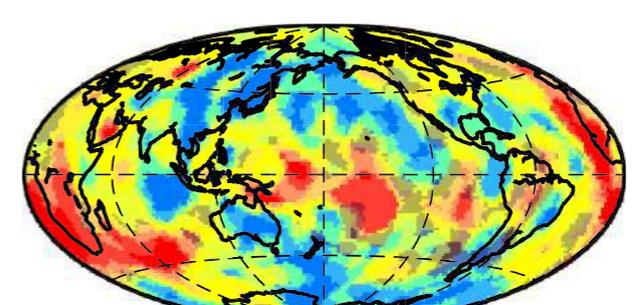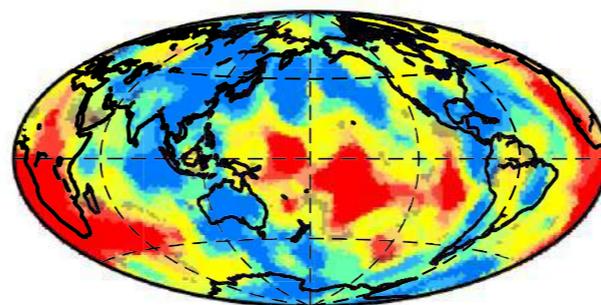
2150 - 2450 km
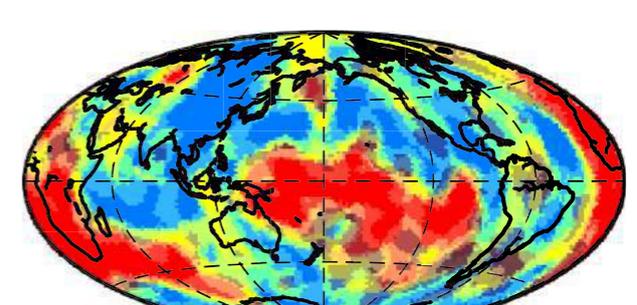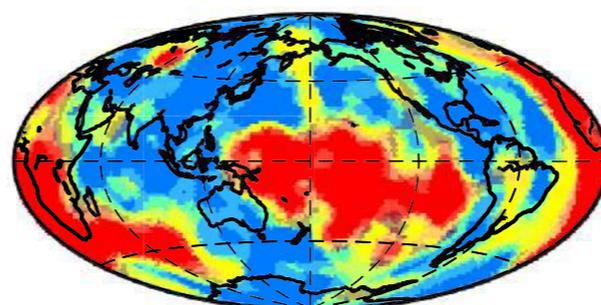
2550 - 2850 km
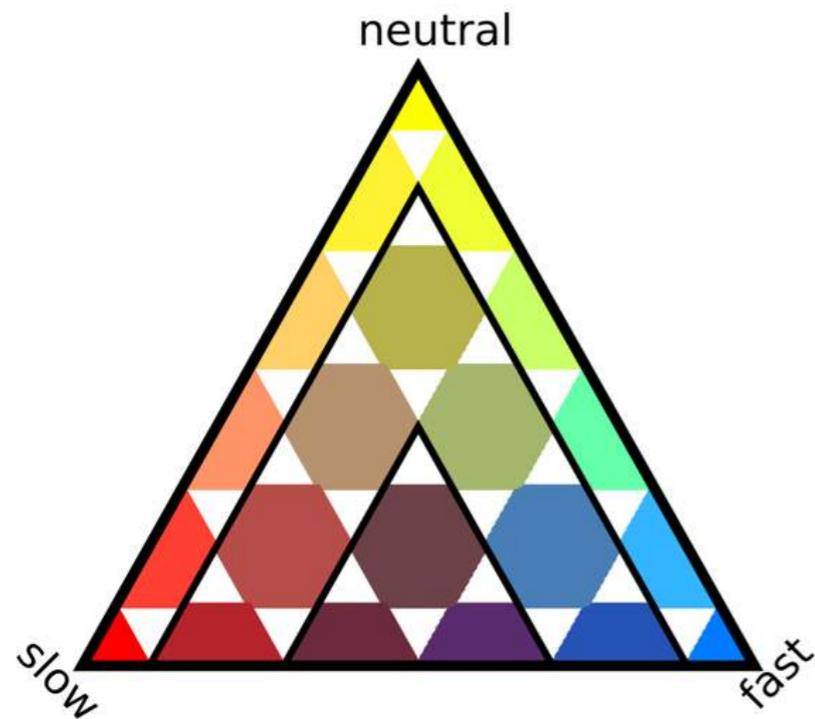
➤ Vote map shows variation in slope boundary
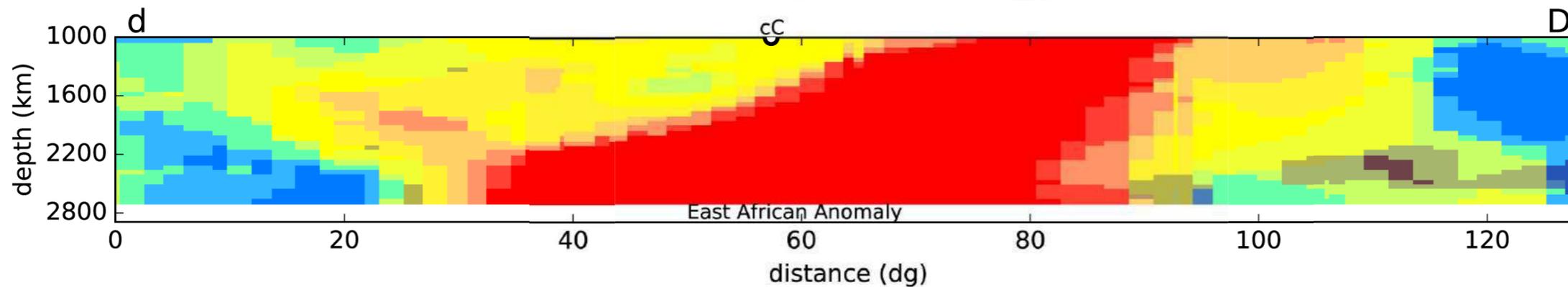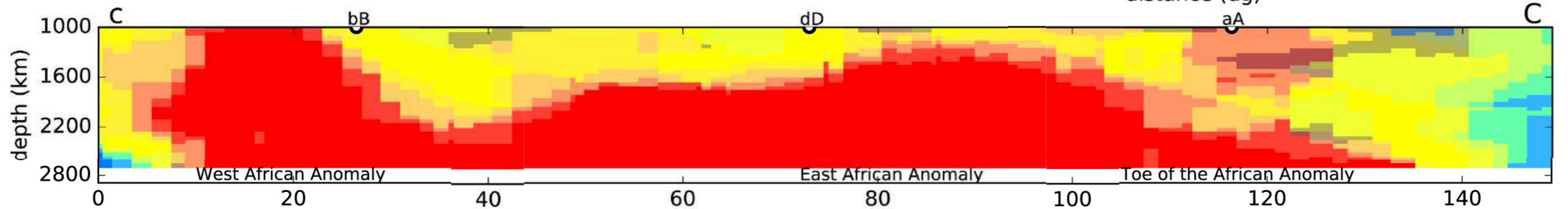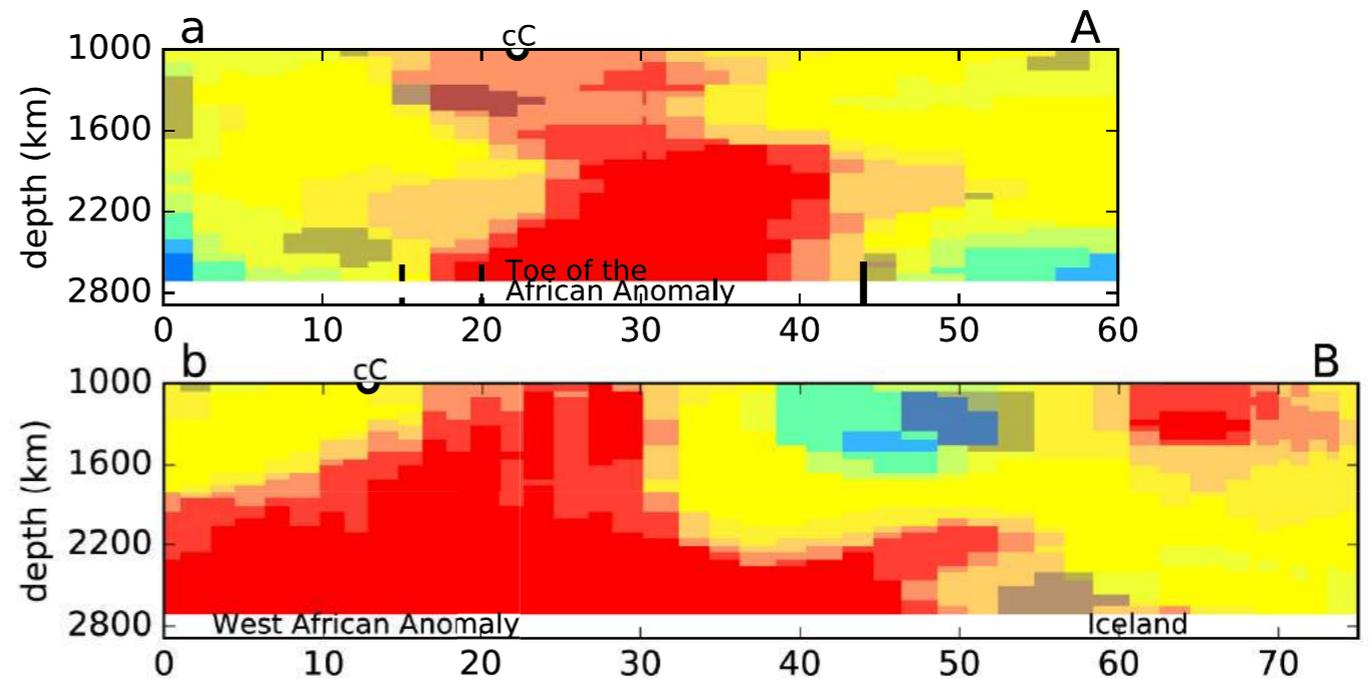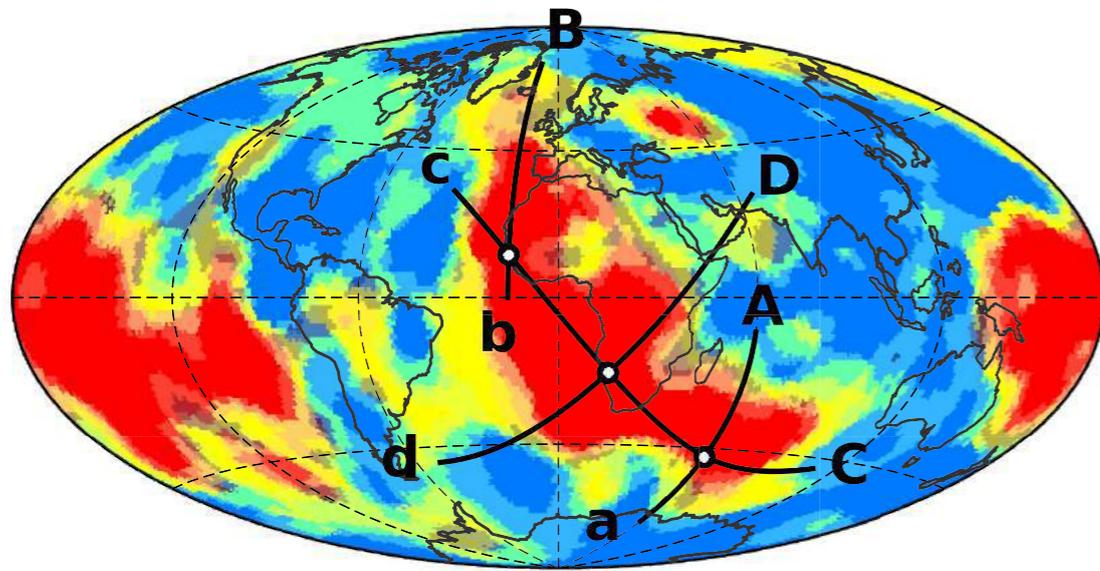
➤ Clusters are not uniform in their velocity
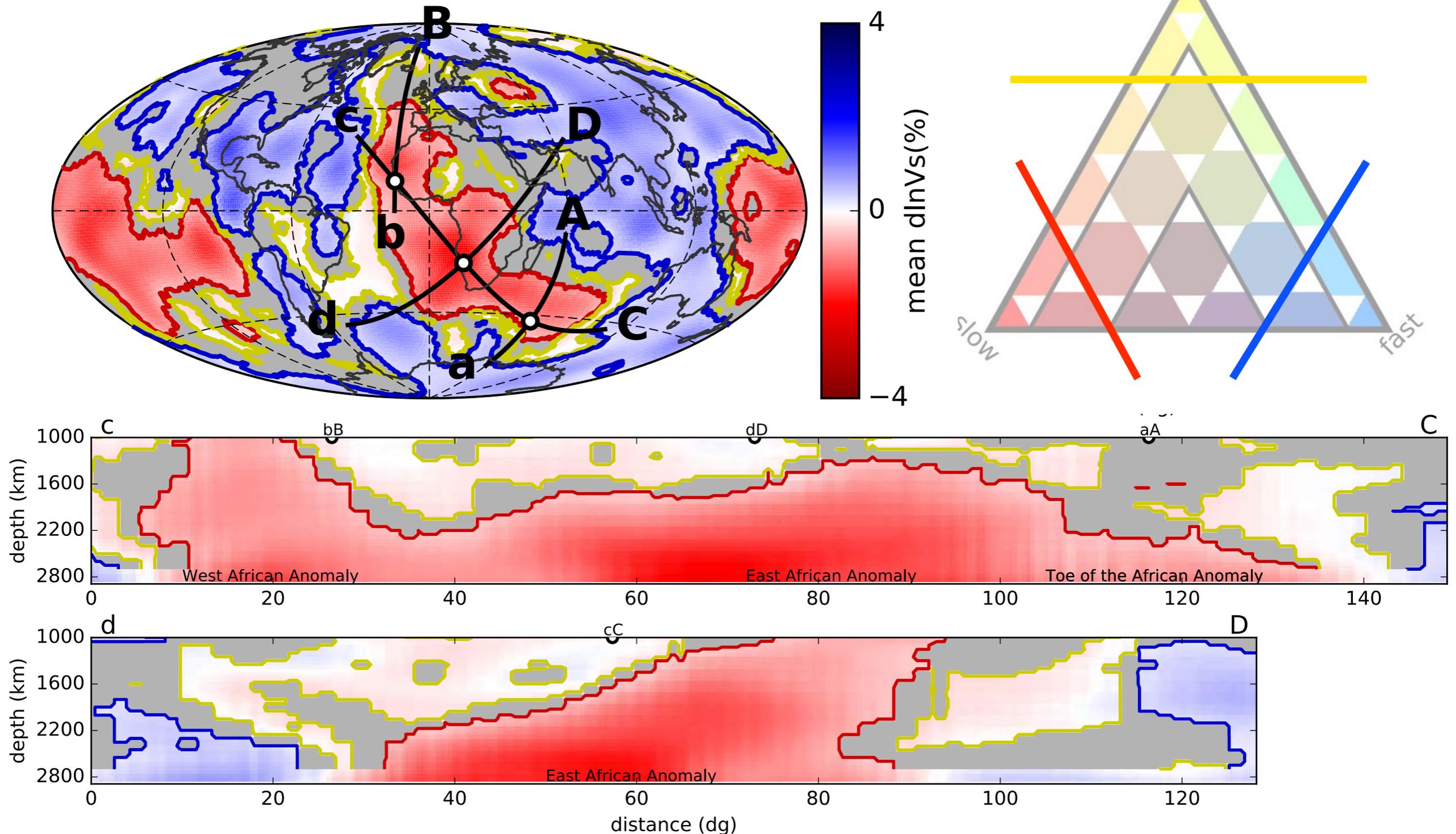
TILT OF THE EAST AFRICAN ANOMALY
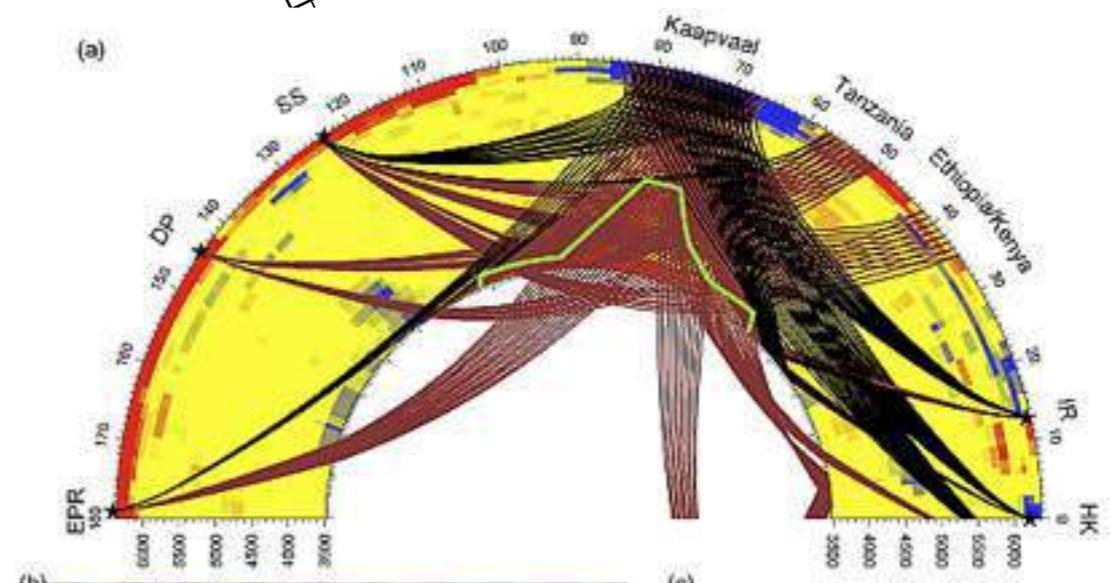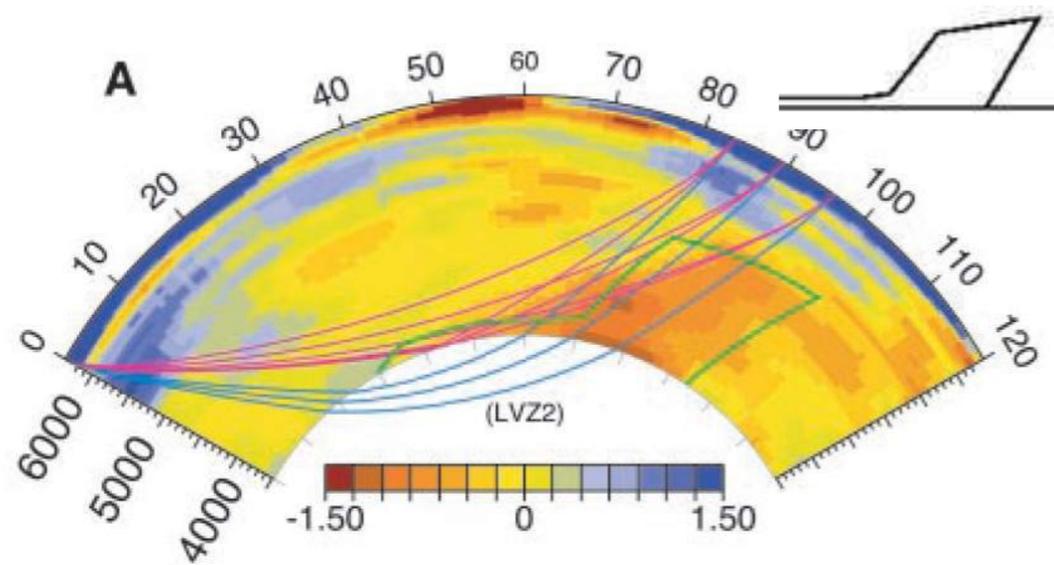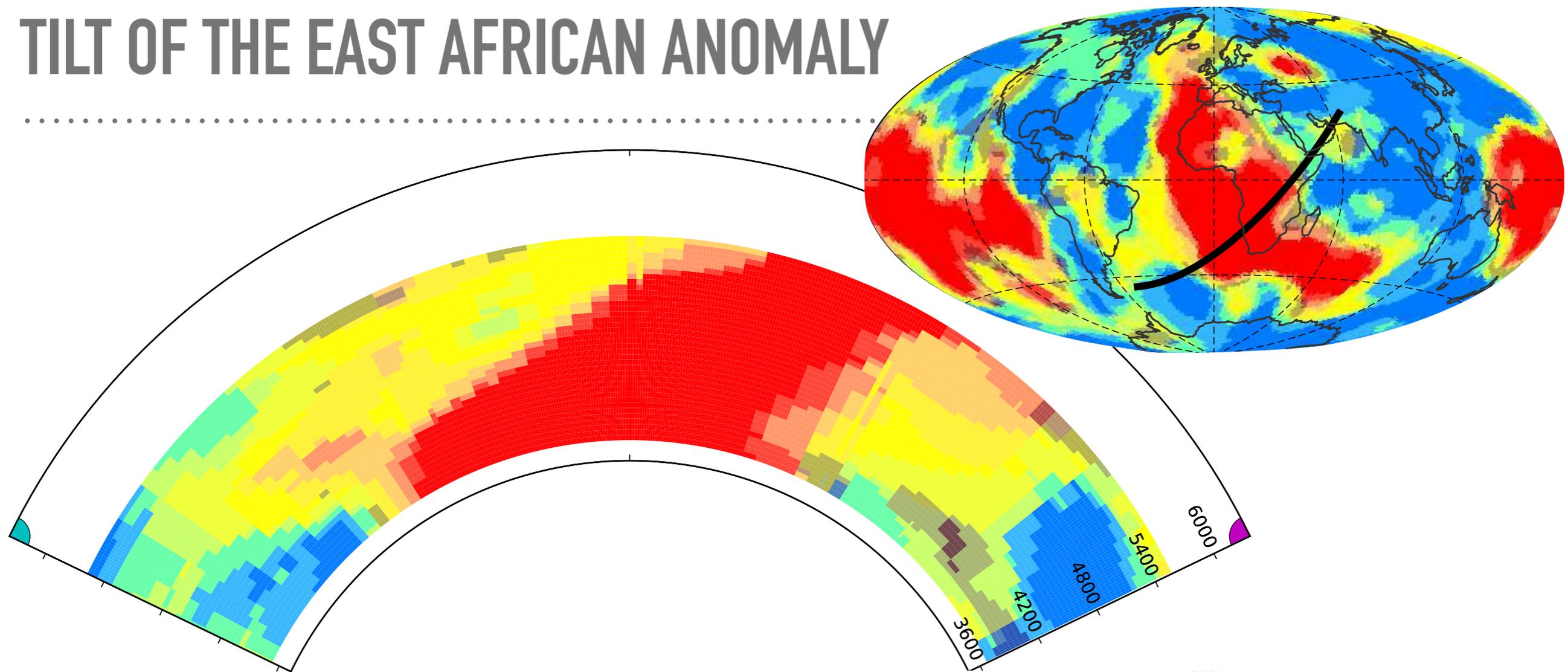
Ni et al. 2002 Ritsema et al. 1998

Wang & Wen 2007

PILES IN THE PACIFIC

He & Wen 2012
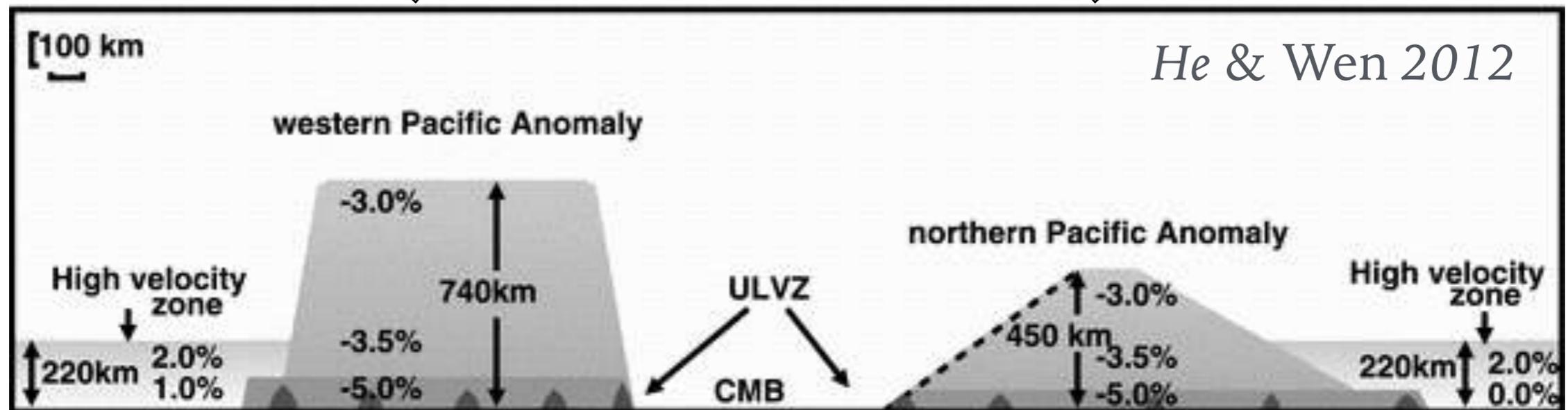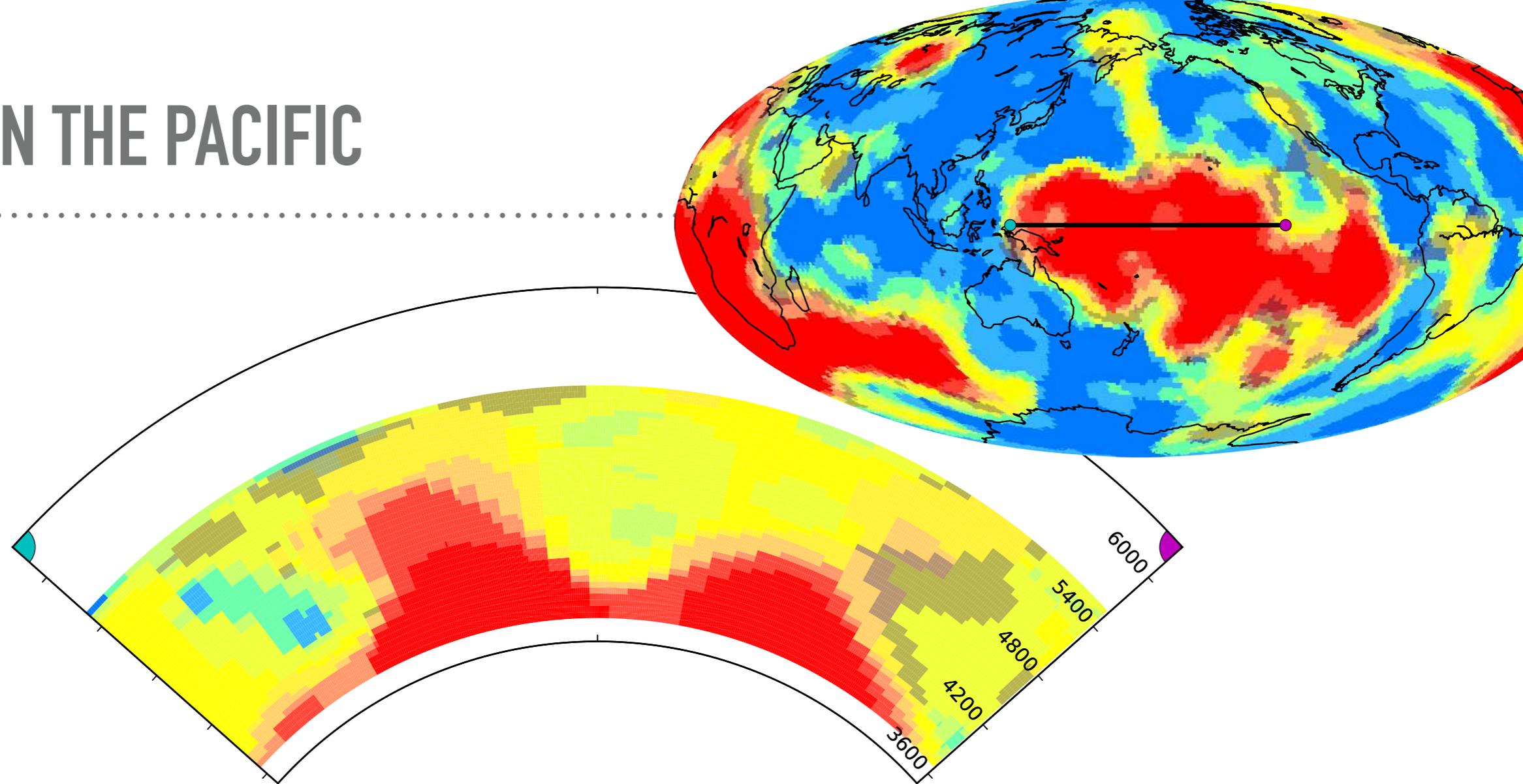
➤ Pacific anomaly consists of multiple smaller anomalies.

PILES IN THE PACIFIC

~1400 km

~900 km

6000
5400
4800
4200
3600

[100 km

He & Wen 2012

western Pacific Anomaly

-3.0%

High velocity zone

740km

-3.5%

220km 2.0%
1.0%

-5.0%

ULVZ

CMB

northern Pacific Anomaly

-3.0%

450 km
-3.5%

-5.0%

High velocity zone

220km 2.0%
0.0%

➤ Pacific anomaly consists of multiple smaller anomalies.
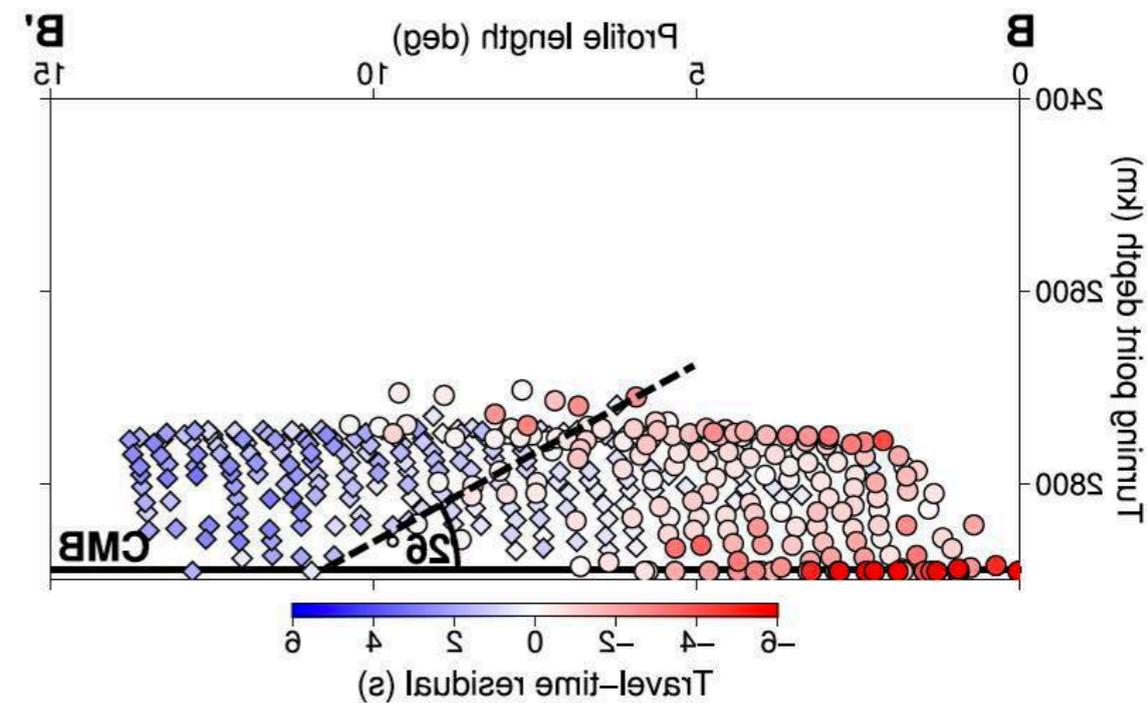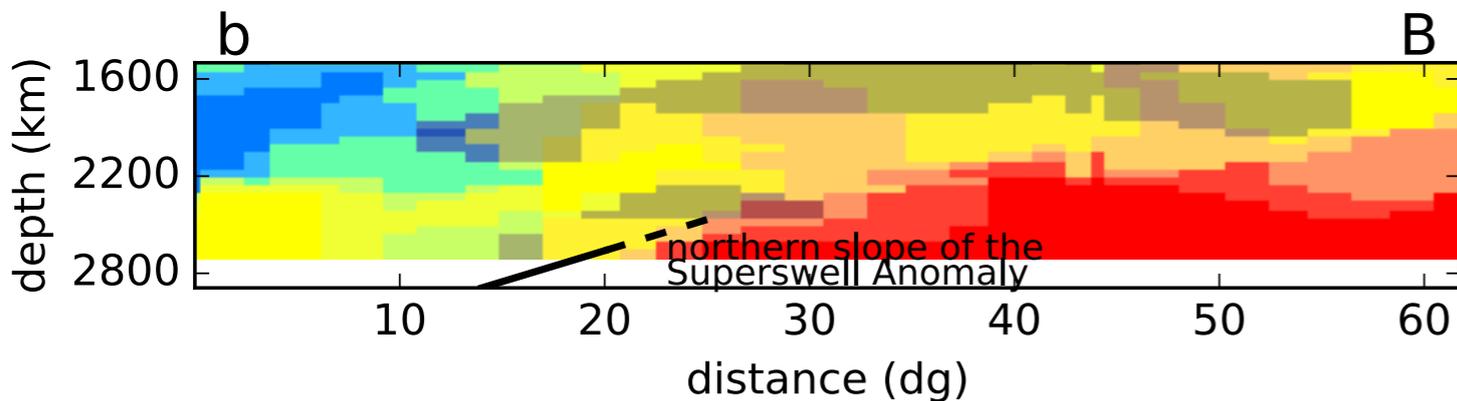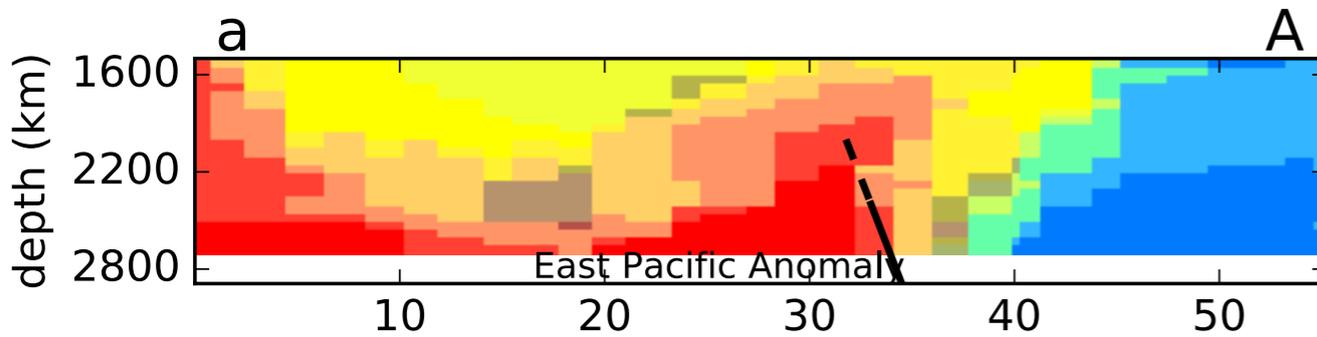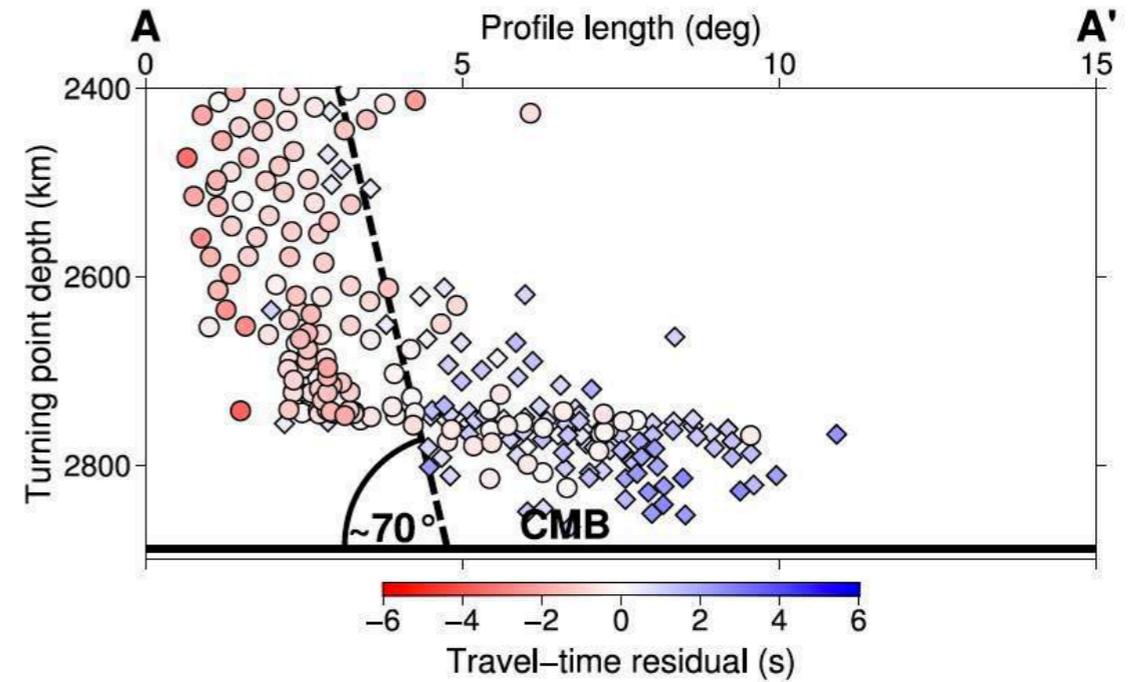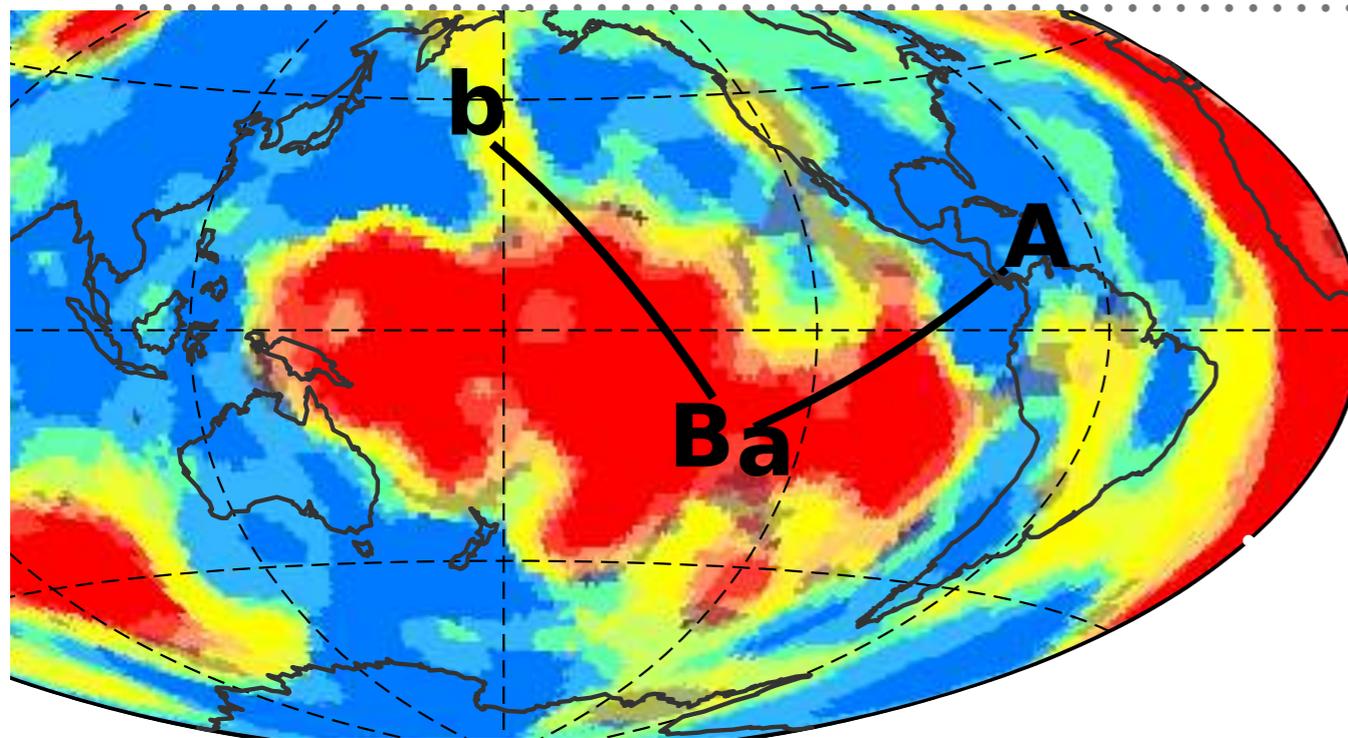
Frost & Rost 2014

➤ P wave travel times confirmation of the different suggested slopes.

3D COMPILATION SHOWING SUGGESTED LLSVP MORPHOLOGY

➤ Total volume of LLSVPs of 8-9 %. across models, and ~4% for consensus region.

➤ Previous estimates are only 1-2% (Wang & Wen 2004, Burke et al. 2008)

➤ The African LLSVP is roughly 30% larger than the Pacific LLSVP

3/5 votes

5/5 votes

Cottaar & Lekic 2016