Imaging the full extent of the Australian cratonic lithosphere using waveform tomography with massive datasets.

Supplementary Material

Full model *Aus*22, methods, validation tests & interpretation

Janneke I. de Laat[1,2], Sergei Lebedev[3], Nicolas L. Celli[1], Raffaele Bonadio[1], Bruna Chagas de Melo[1,2], Nicholas Rawlinson[3]

1) *Dublin Institute for Advanced Studies, Dublin, Ireland*
2) *Trinity College Dublin, Dublin, Ireland*
3) *Department of Earth Sciences, University of Cambridge, United Kingdom*

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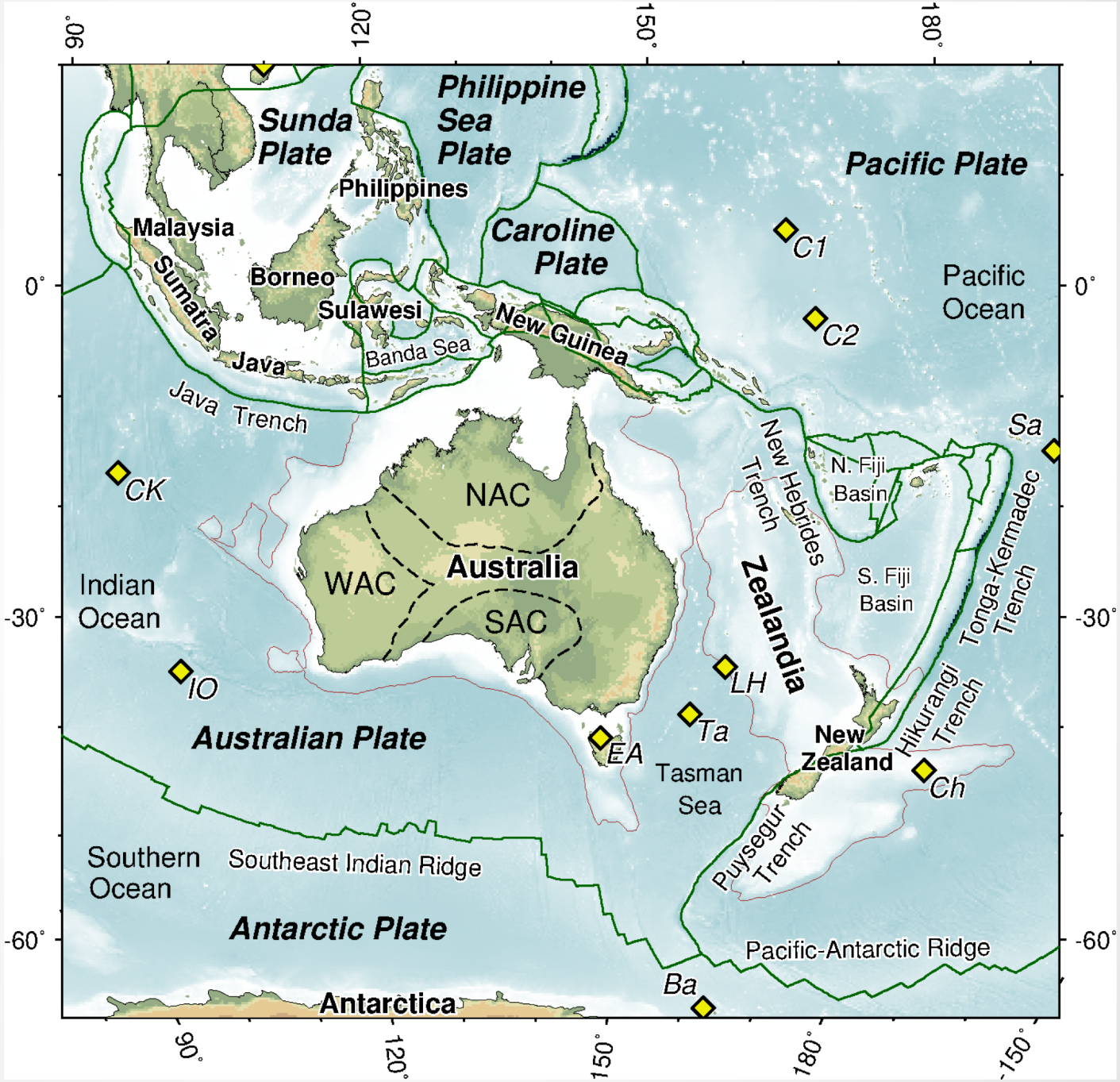
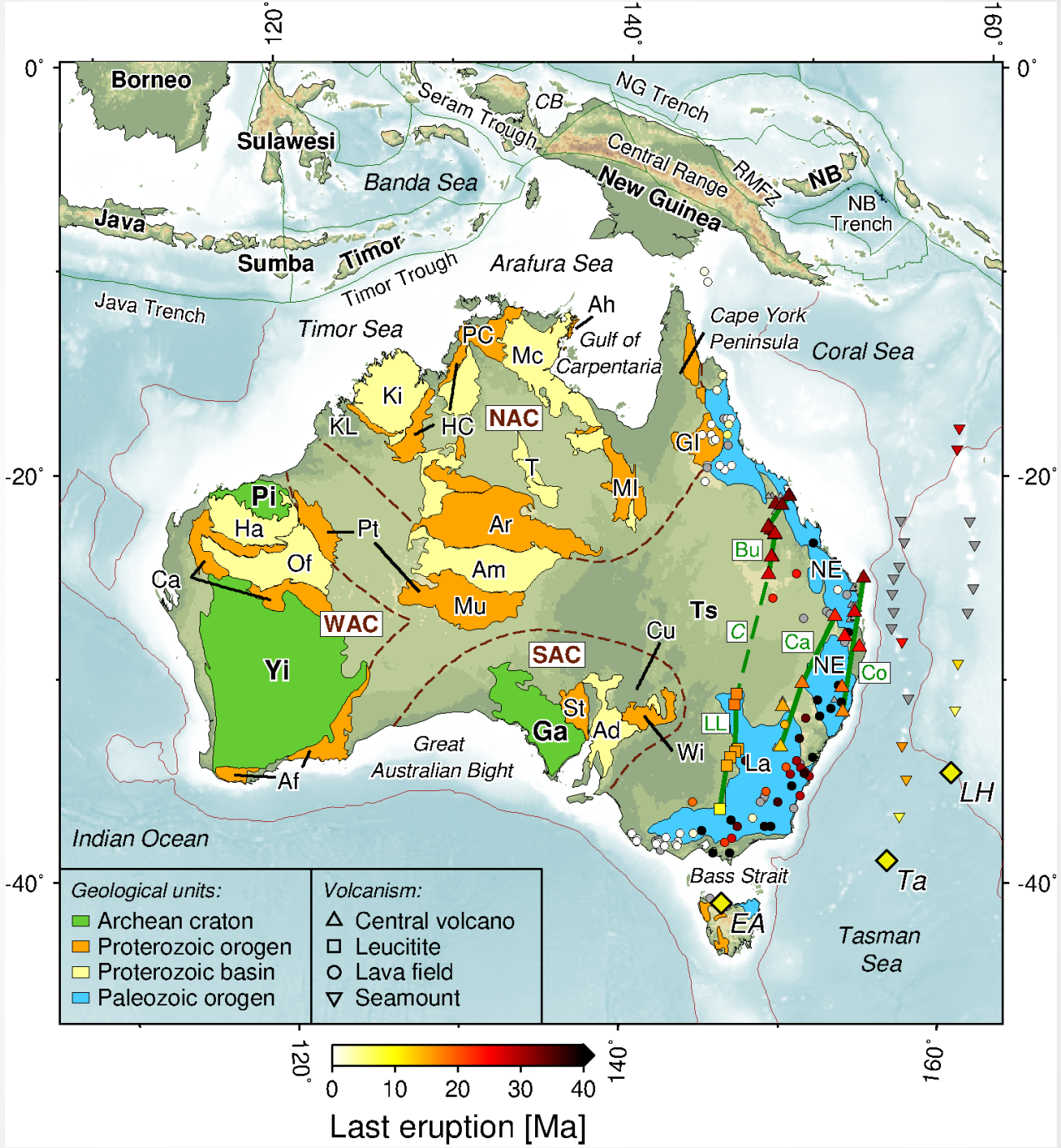
  - Northern boundary Australian Plate
  - Hotspots
- Conclusions.

Tectonic Setting



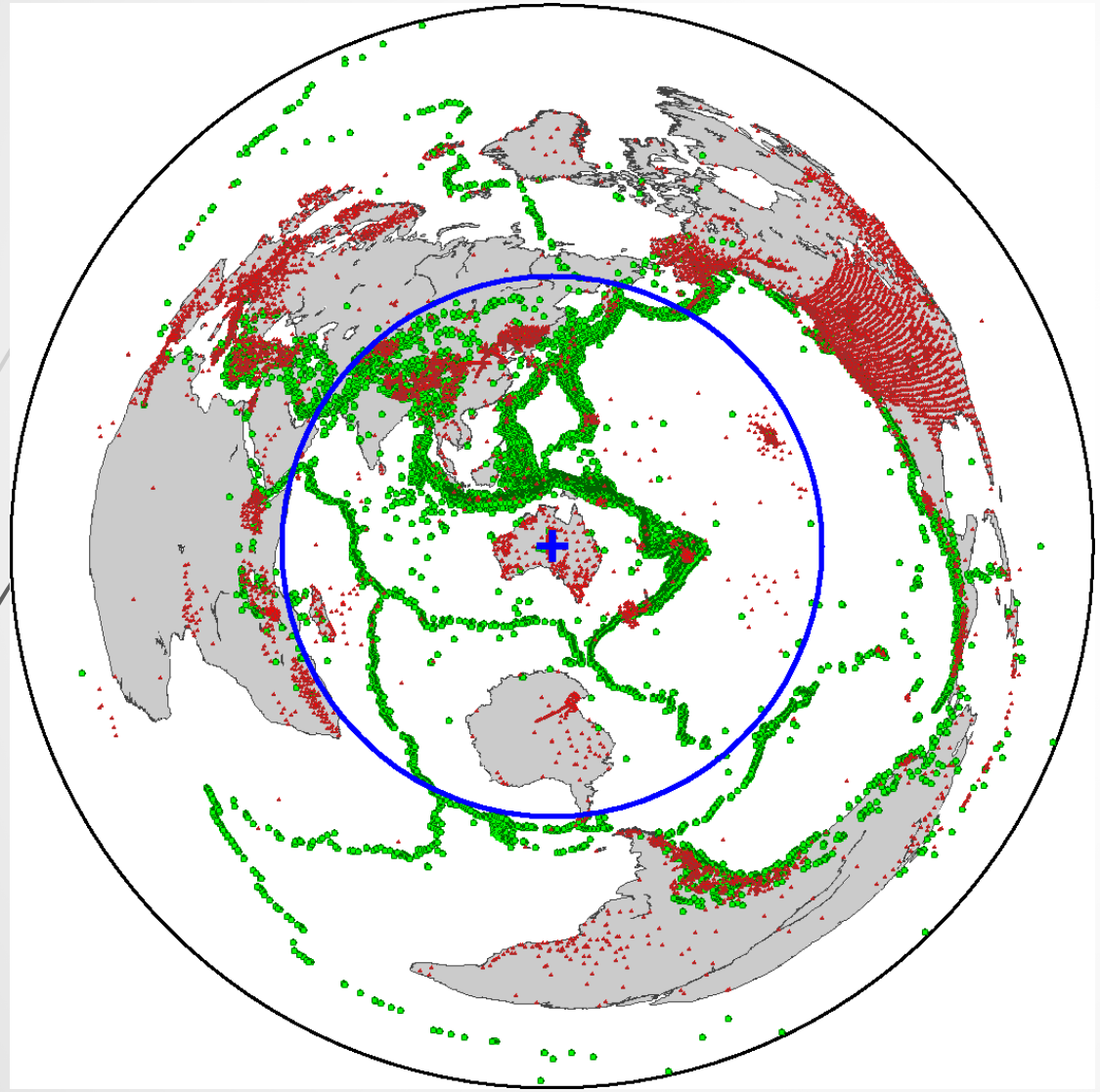
Tectonic Setting



Aim

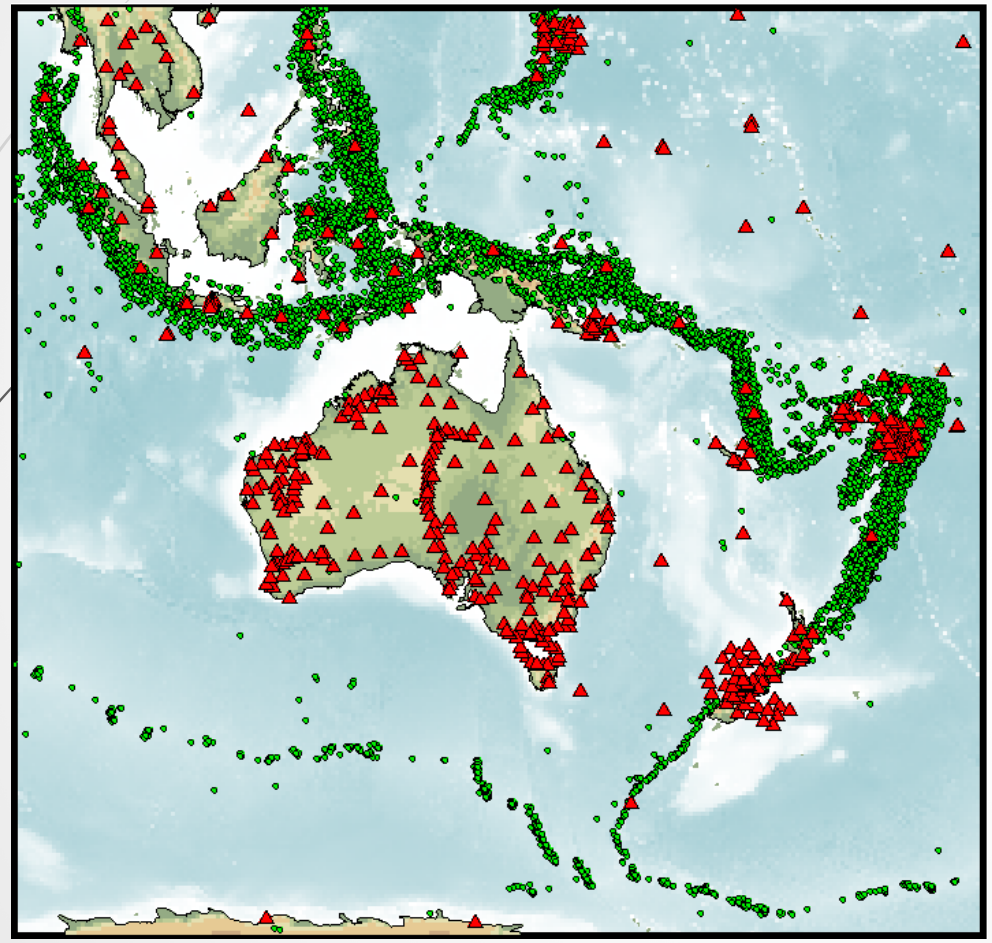
- To provide a detailed image of the upper mantle of the full Australian Plate and its boundaries,
- To gain better insight in the structure and evolution of the full Australian Plate.

Methods: dataset



- **Hemisphere model** generated using a dataset of almost **1 million waveforms**
  - 26 thousand teleseismic events,
  - 9 thousand broadband stations (eg NSN, ANU, SKIPPY, MOANA).

Methods: dataset



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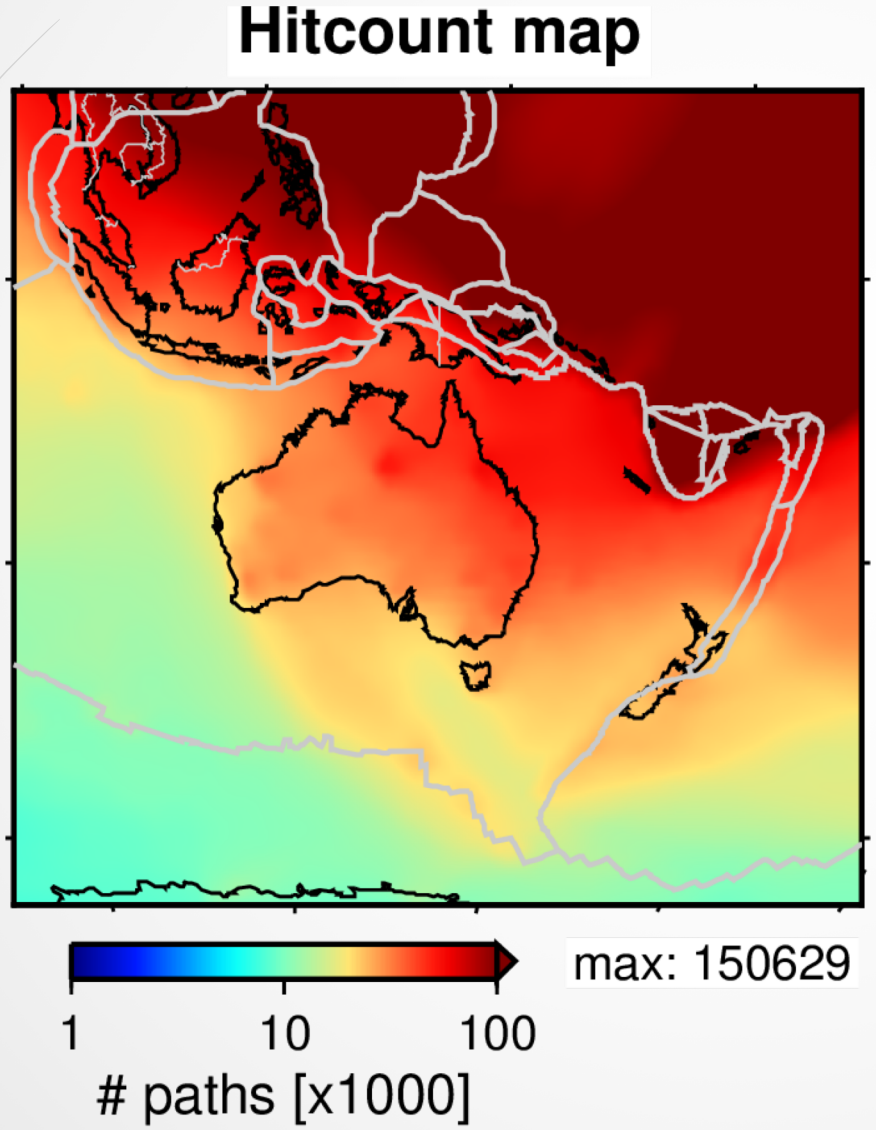


- **Highly uneven** coverage of the plate.
- Should be taken into account when **tuning** and **interpreting** the model.

Methods: Inversion Procedure

- **1. Automated Multimode waveform Inversion (AMI):**
  - fits surface, S- and multiple S-waves in the waveforms to computed synthetic waveforms.
  - Generates a set of independent linear equations that describe the 1D average perturbations in the P- and S- wave velocities within the sensitivity volume between the source and receiver.
  - Perturbations relative to a 3D reference model (3D crust and 1D mantle velocity profile).

- **2. 3D Tomographic inversion**:
  - Combines all the AMI equations into one large linear system,
  - Solves it for the 3D distributions of P- and S-wave velocities and the S-wave azimuthal anisotropy with SLQR.
  - Regularization is applied by lateral and vertical smoothing and gradient damping, tuned per depth knot (18 for S and 10 for P-waves).

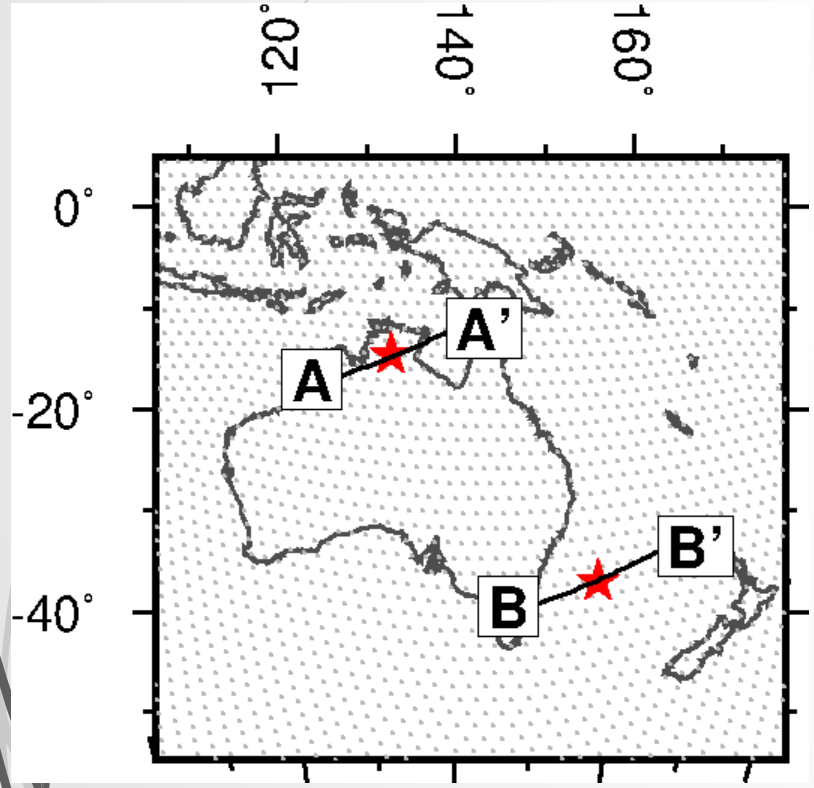
- **3. Outlier analysis**:
  - Selects the **most mutually consistent** data by automatically and manually removing outliers in the obtained tomographic model.
  - Rerun step 2 with reduced dataset. (Final dataset = **650 thousand** waveforms).

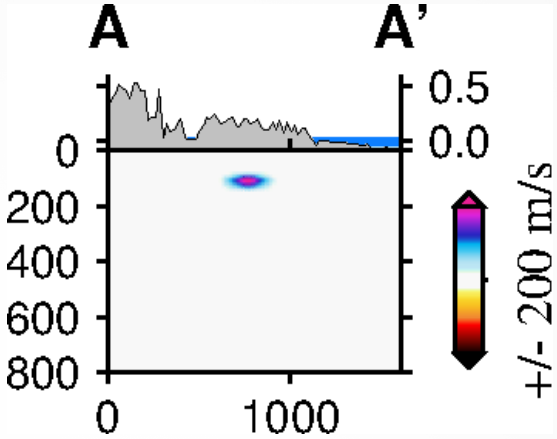
Methods: Note

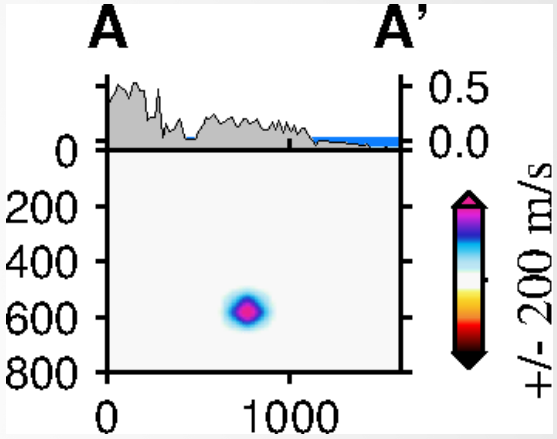
- Although the tomographic inversion in performed **globally**, the obtained model is **regional** as:
  - Only the waveforms that cross the hemisphere centered around the Australian continent are included,
  - Regularization is optimized for the Australian Plate,
  - Outlier analysis is focused on the Australian Plate.
    - Faulty stations/events outside the area might not be detected.

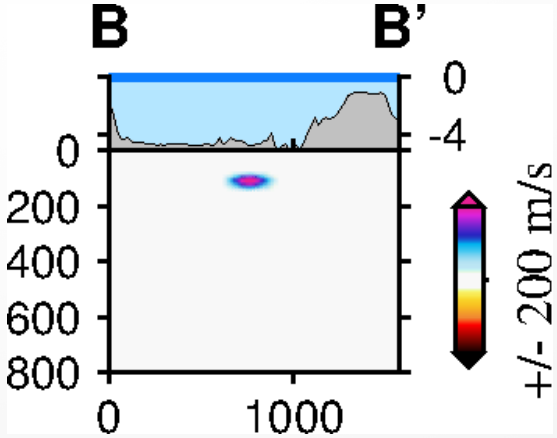
Validation: 1. Spike Tests

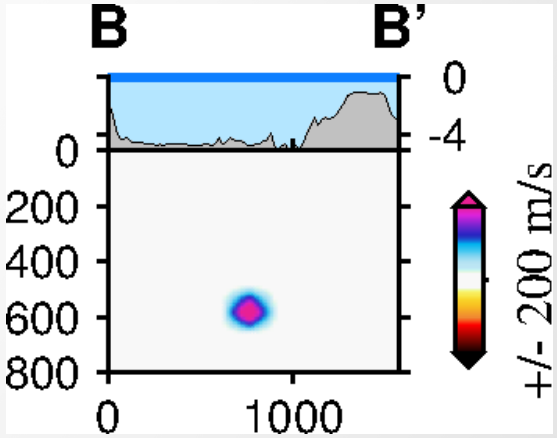
- Input





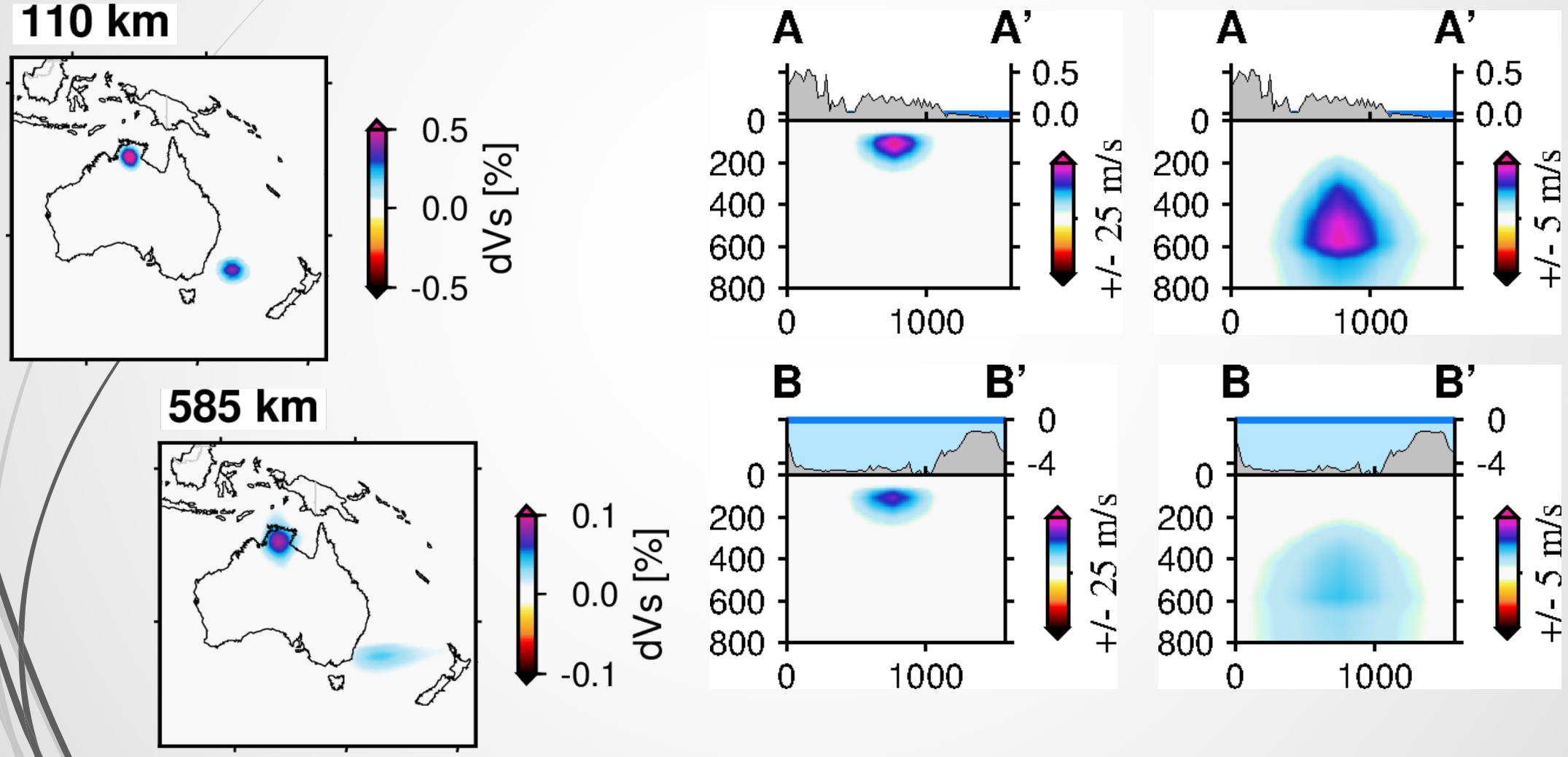






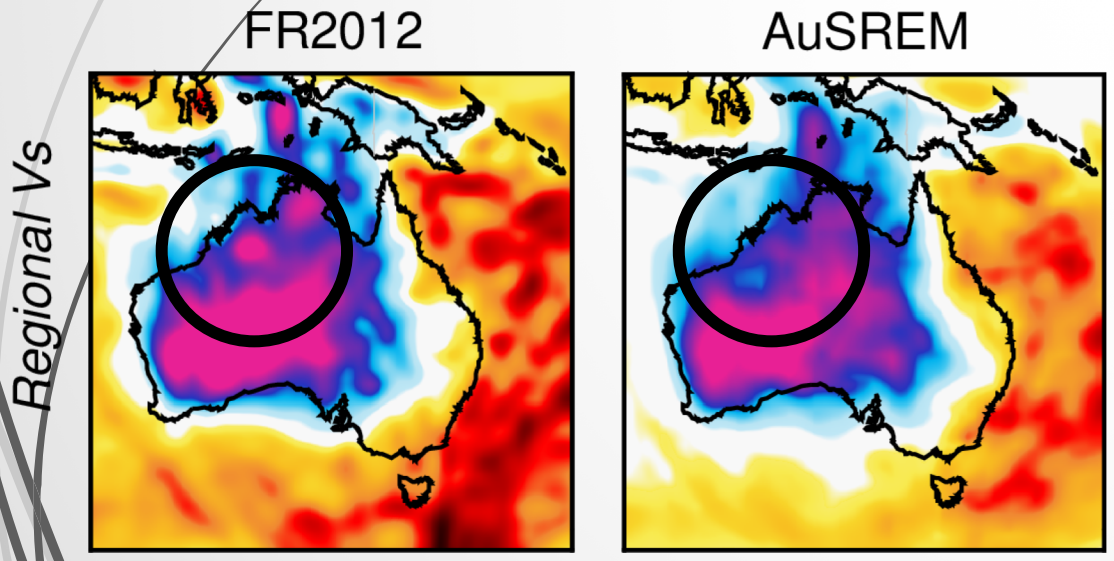
Validation: 1. Spike Tests

- Output

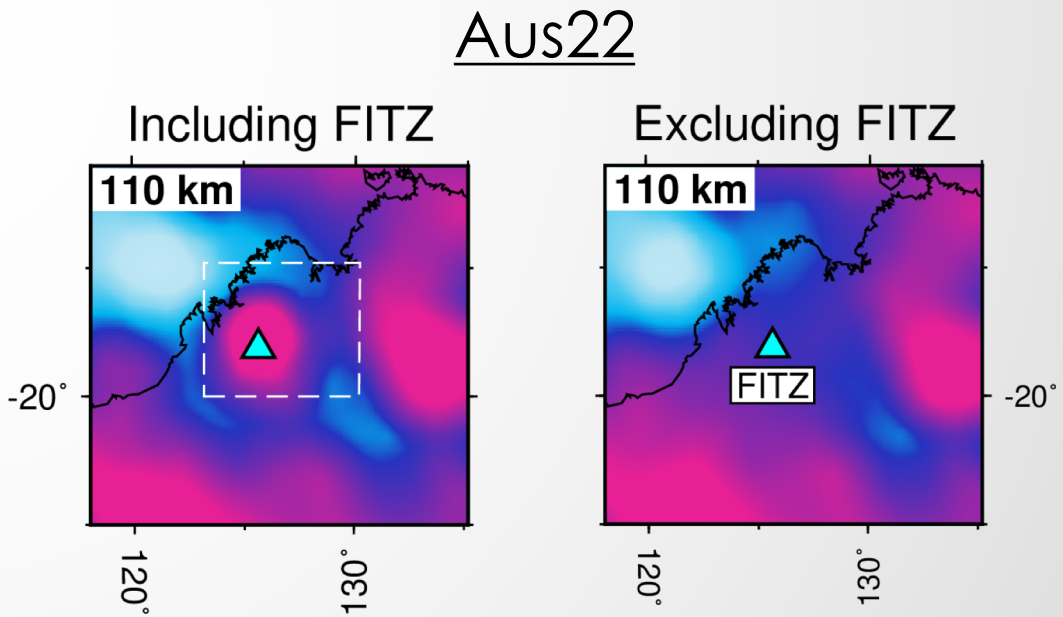


Validation: 2. Interstation method

- **Independent** method to define the **phase velocity curve** across an **array of stations**.
- Used to verify the tomography result in certain areas.
- I.e. around station FITZ:



Fishwick & Rawlinson (2012) *Kennett et al. (2013)*



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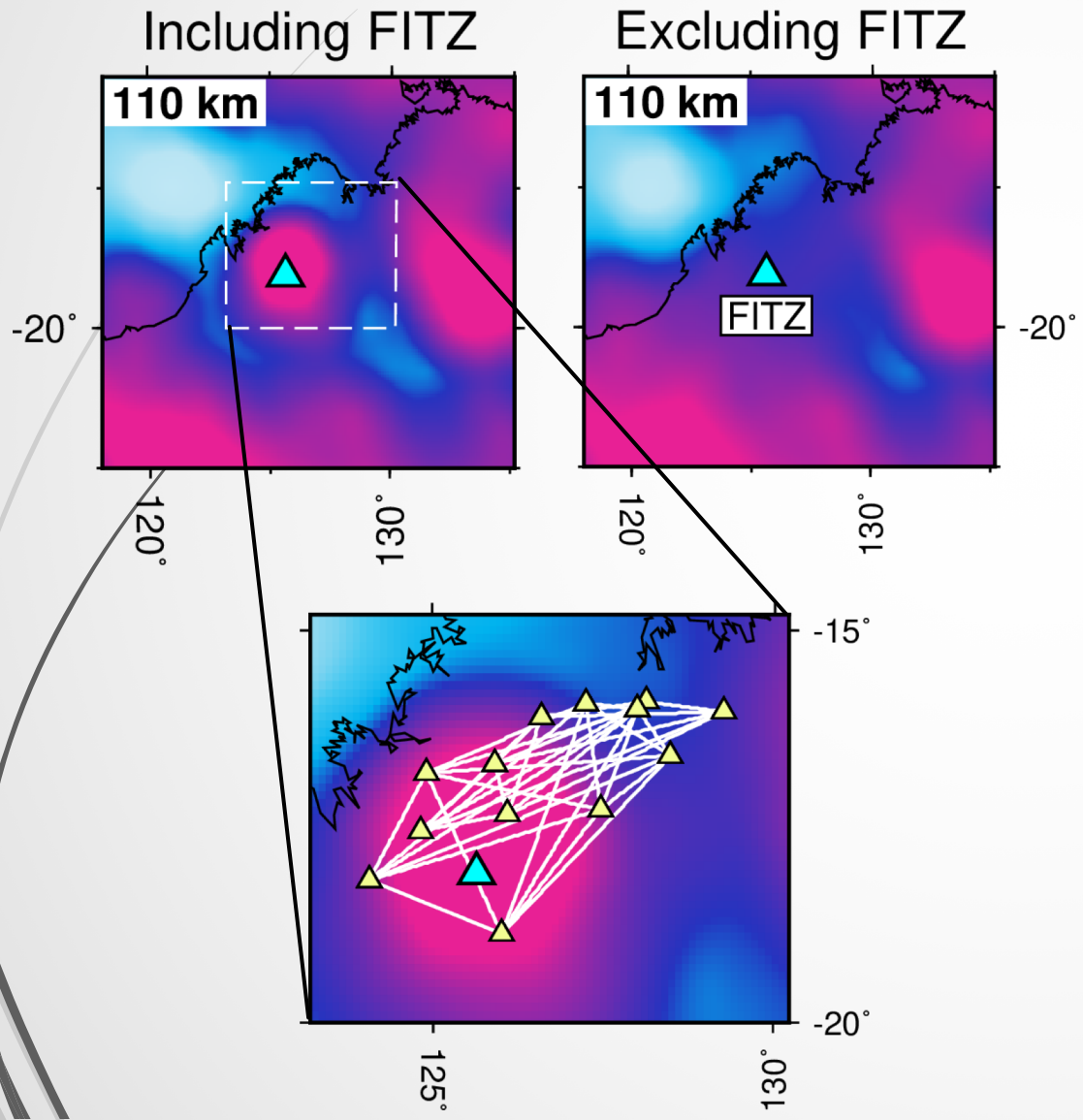
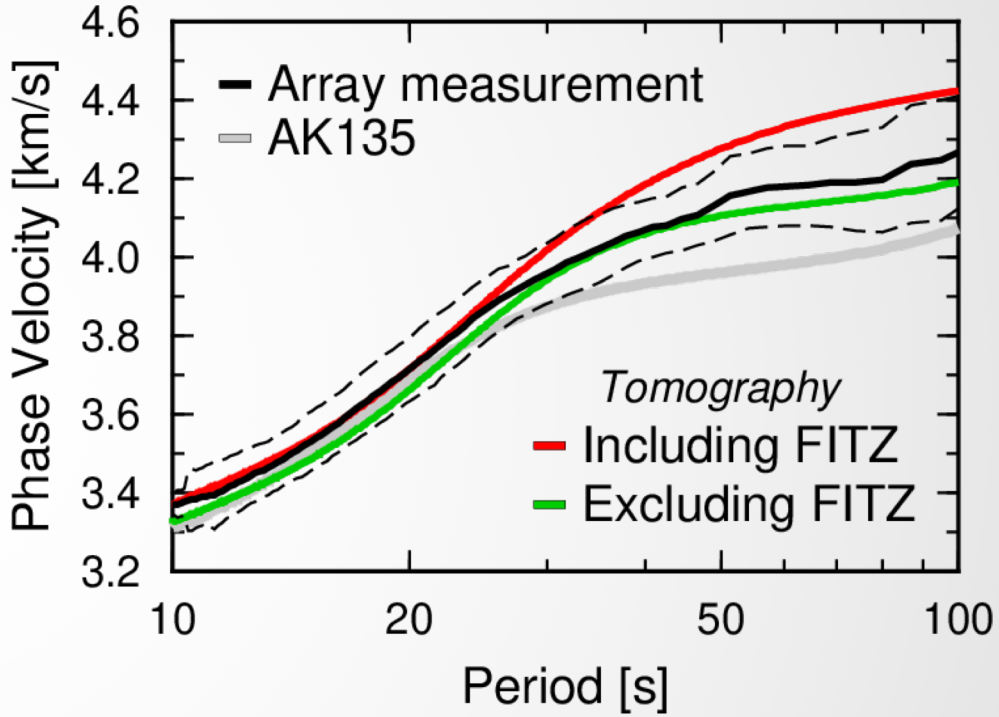
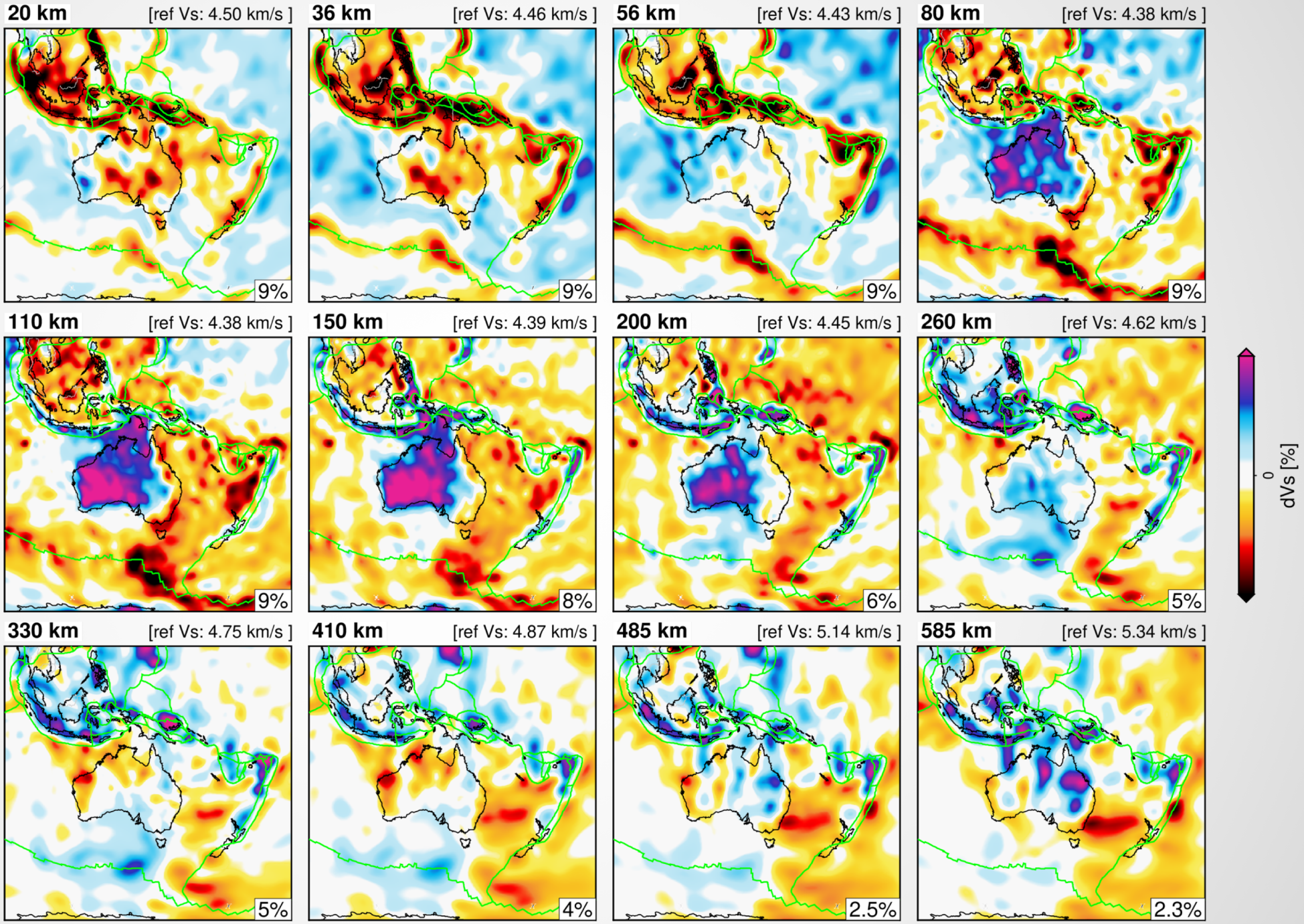




- Interstation phase velocity curve **correlates better** with tomography model **excluding** the data from station FITZ.

The Model: **Aus22** - dVs



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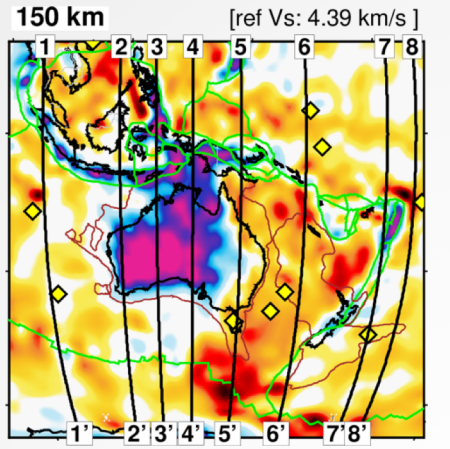
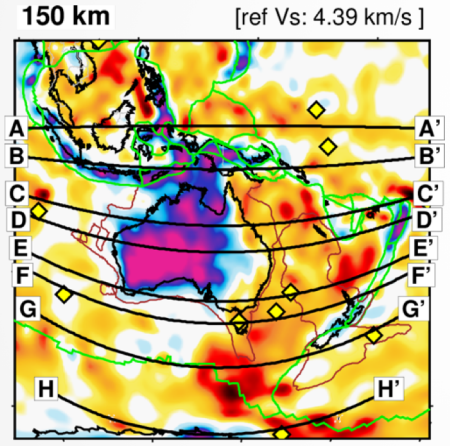
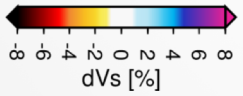
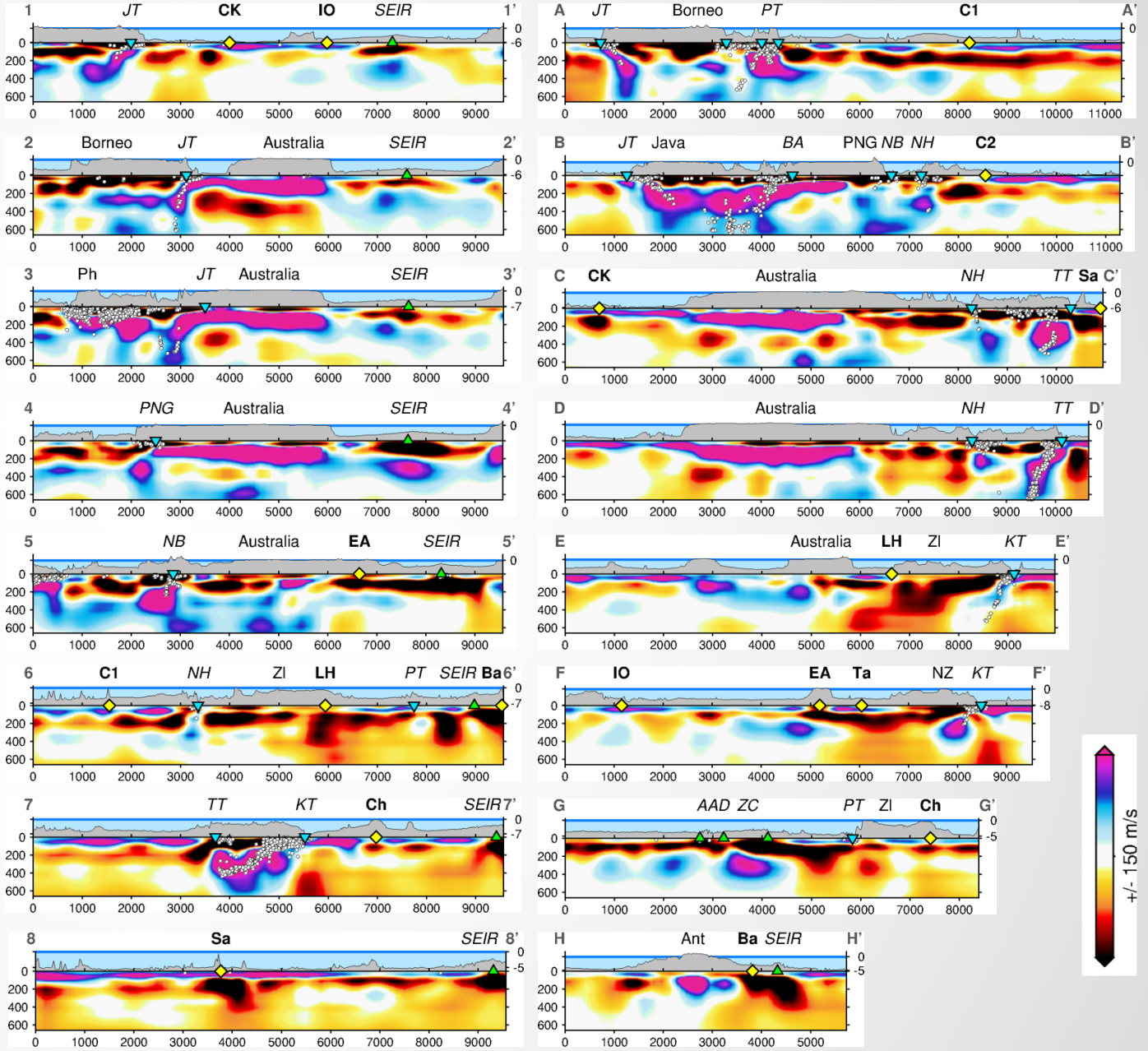
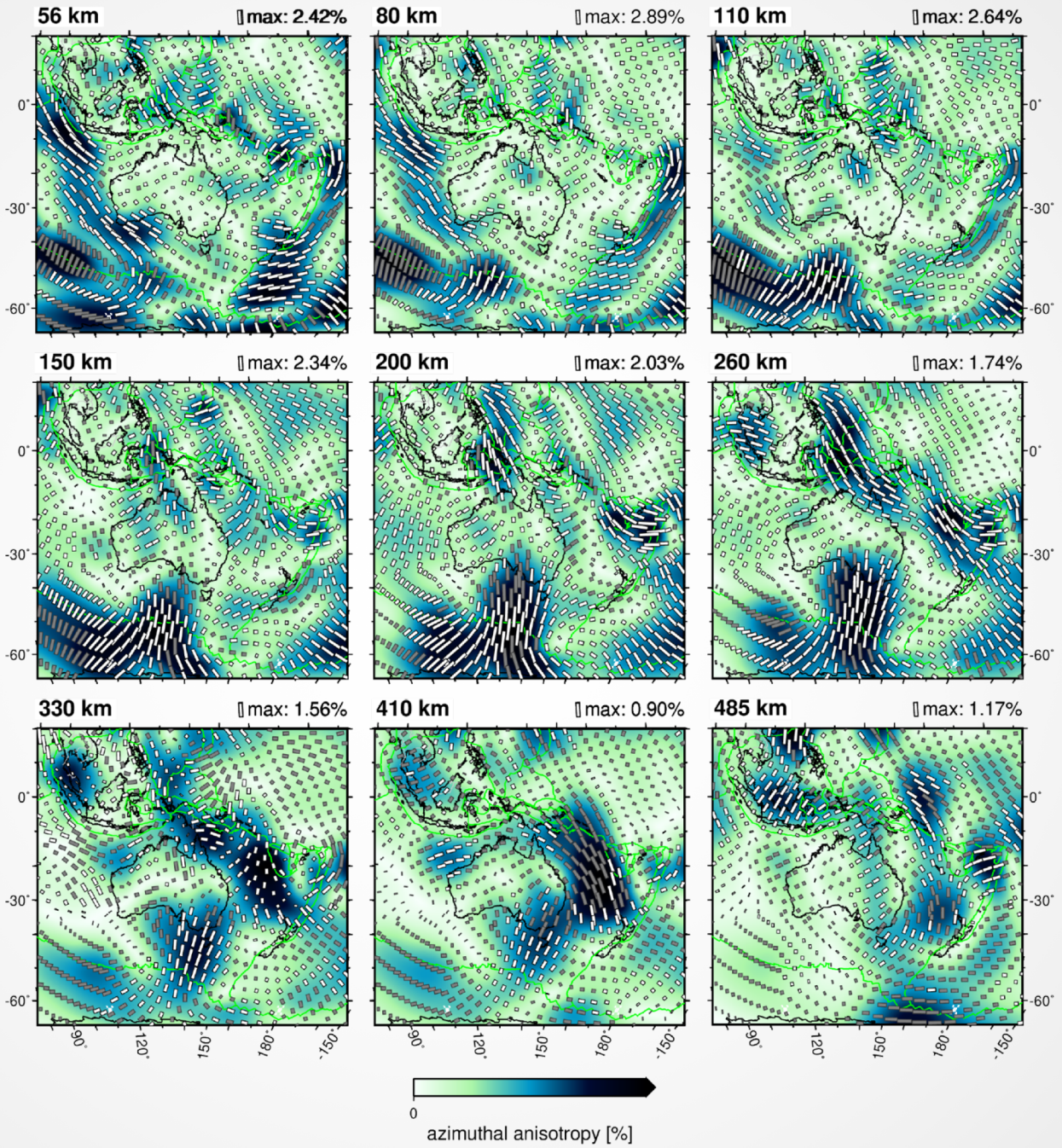






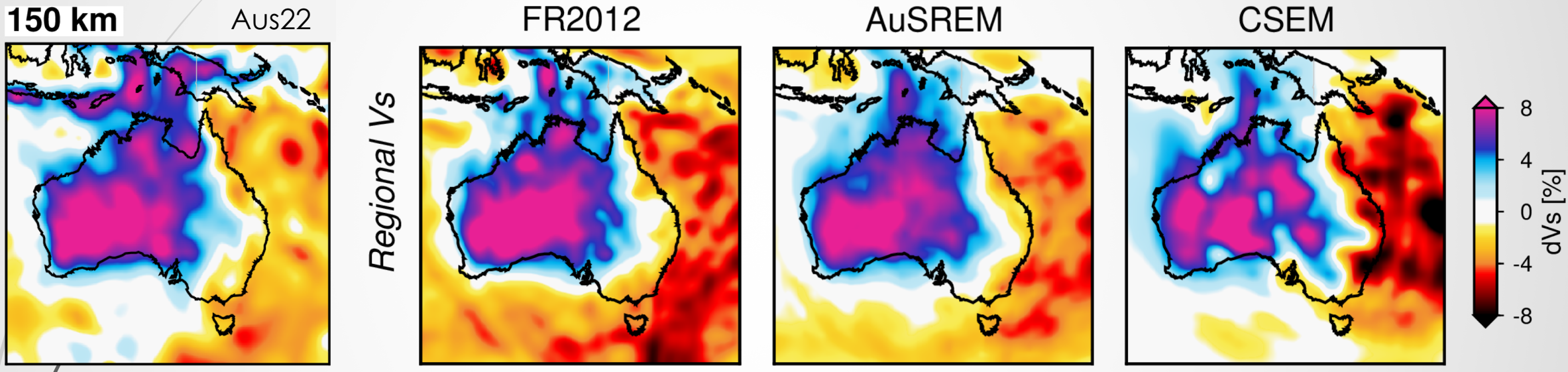


The Model: **Aus22** - Azimuthal Anisotropy



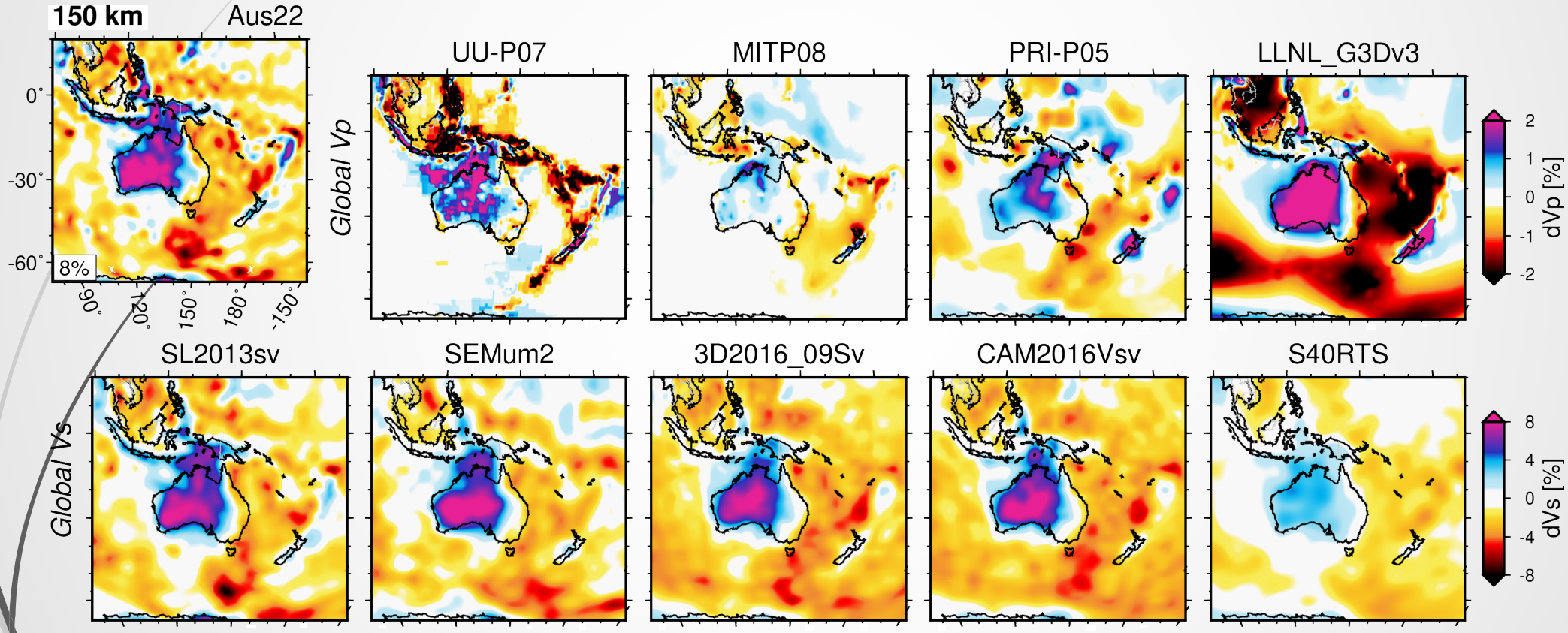
- White bars: passed anisotropy test
- Grey bars: did not pass anisotropy test

Comparison: Regional models

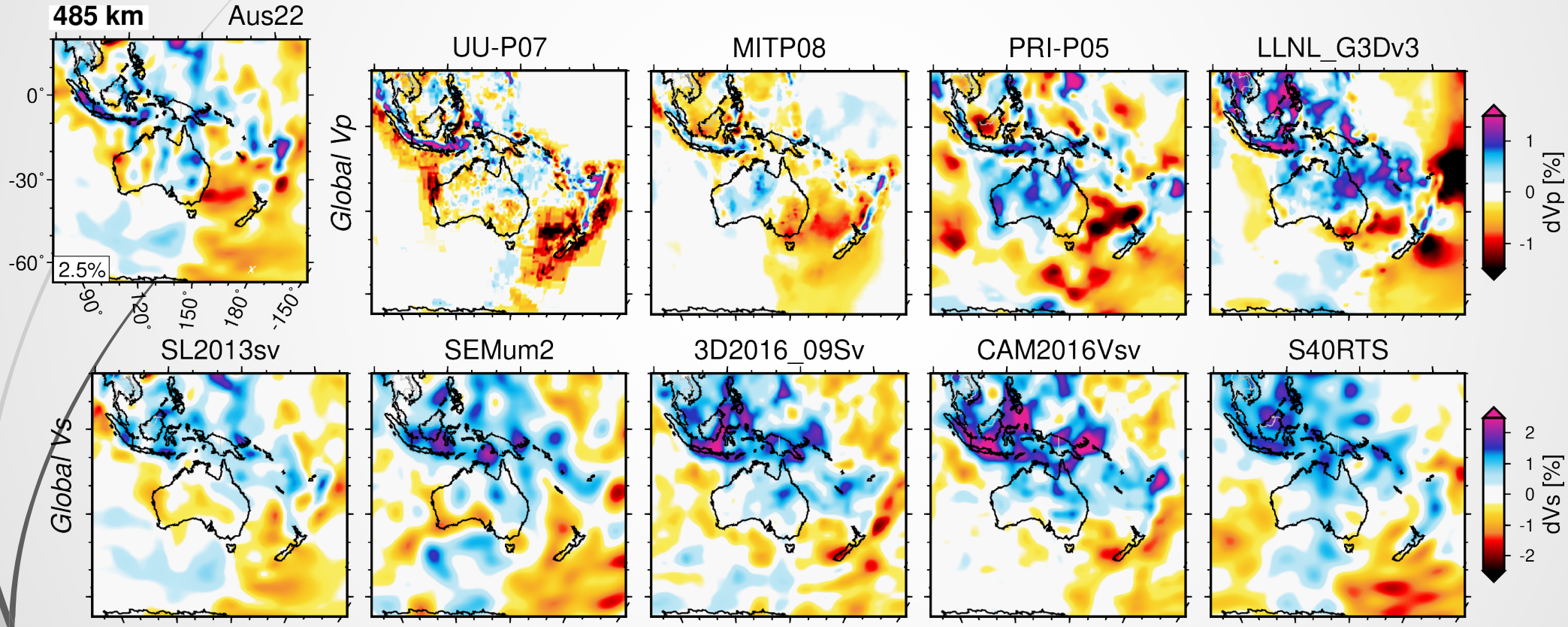


Fishwick & Rawlinson (2012) *Kennett et al. (2013)* *Fichtner et al. (2010)*

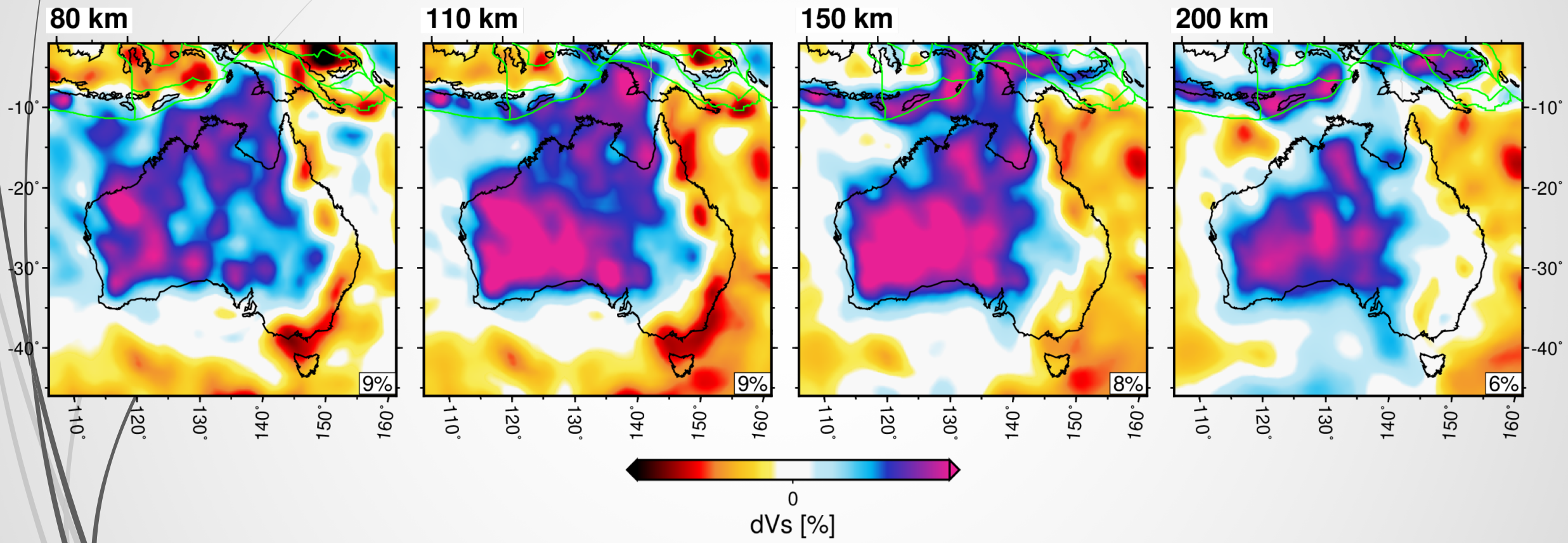
Comparison: Global models – 150 km depth



Comparison: Global models – 485 km depth



The Australian Lithosphere



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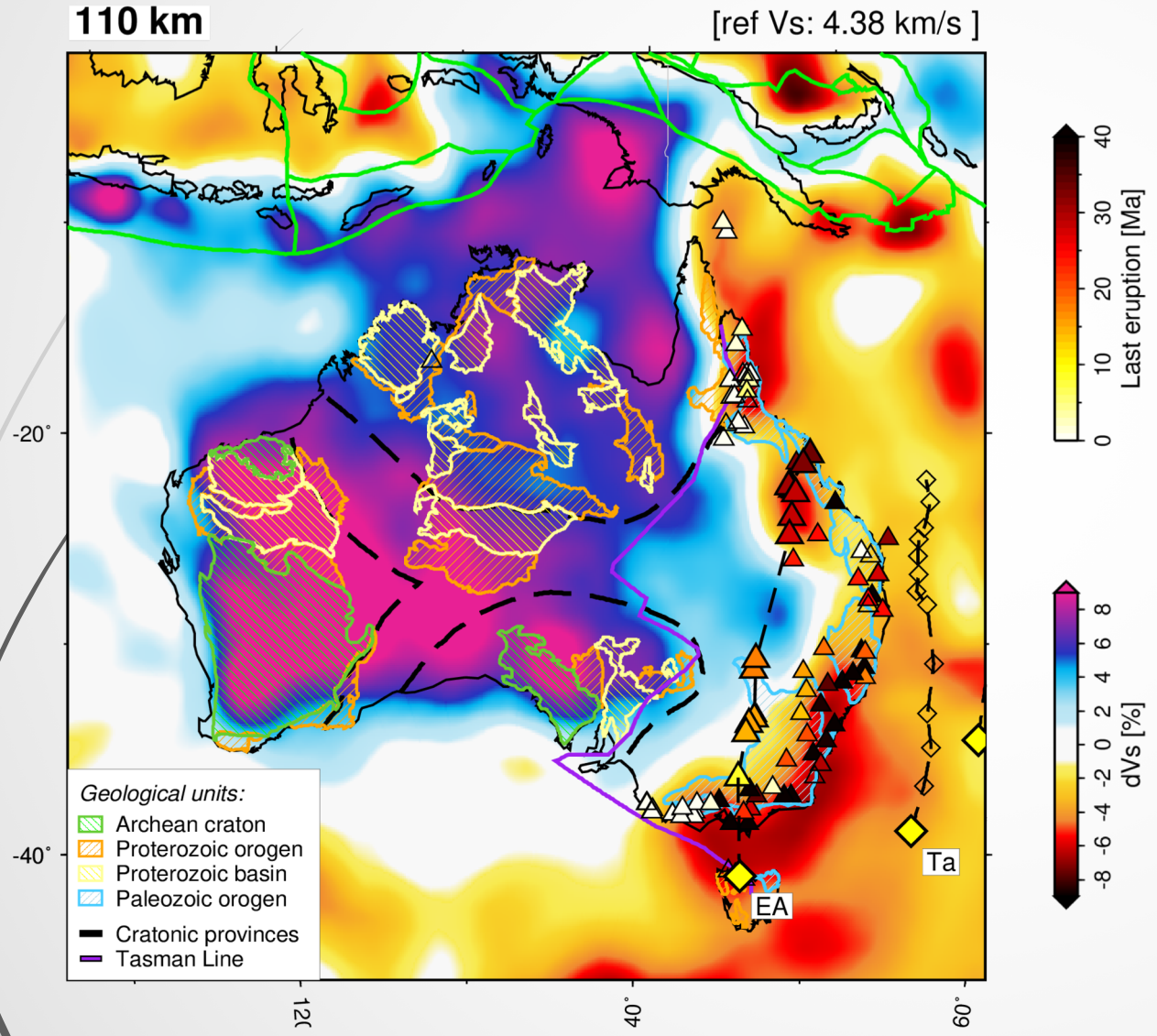
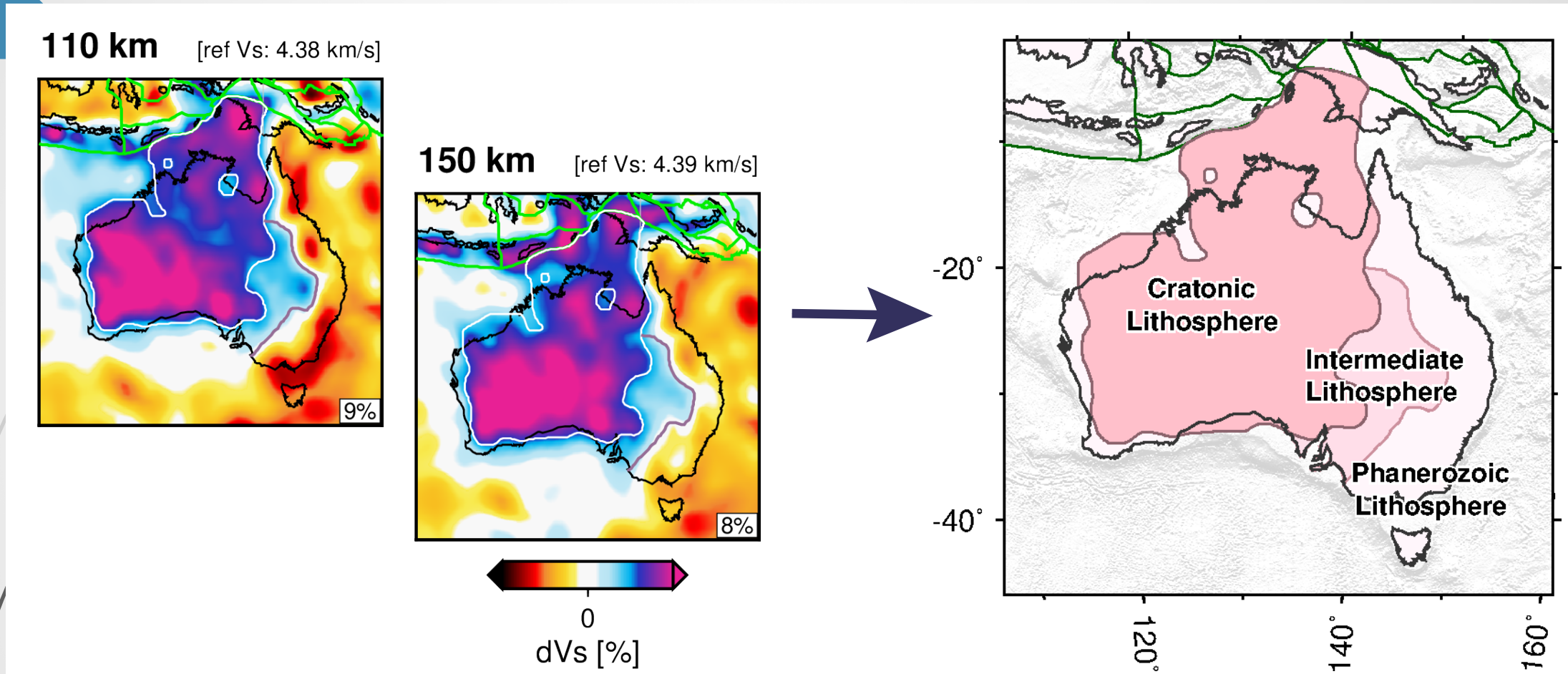


- Cratonic lithosphere **terminates** at N boundary Australian Plate.
- Almost all **Archean** and **Proterozoic outcrops** underlain by cratonic lithosphere.
- All Cenozoic **intraplate volcanism** underlain by **warm, thin** lithosphere.
- **Gap** in **Cosgrove Track** coincides with **thicker, colder** lithosphere.
- **Peak** in low velocity below **East Australian** hotspot.

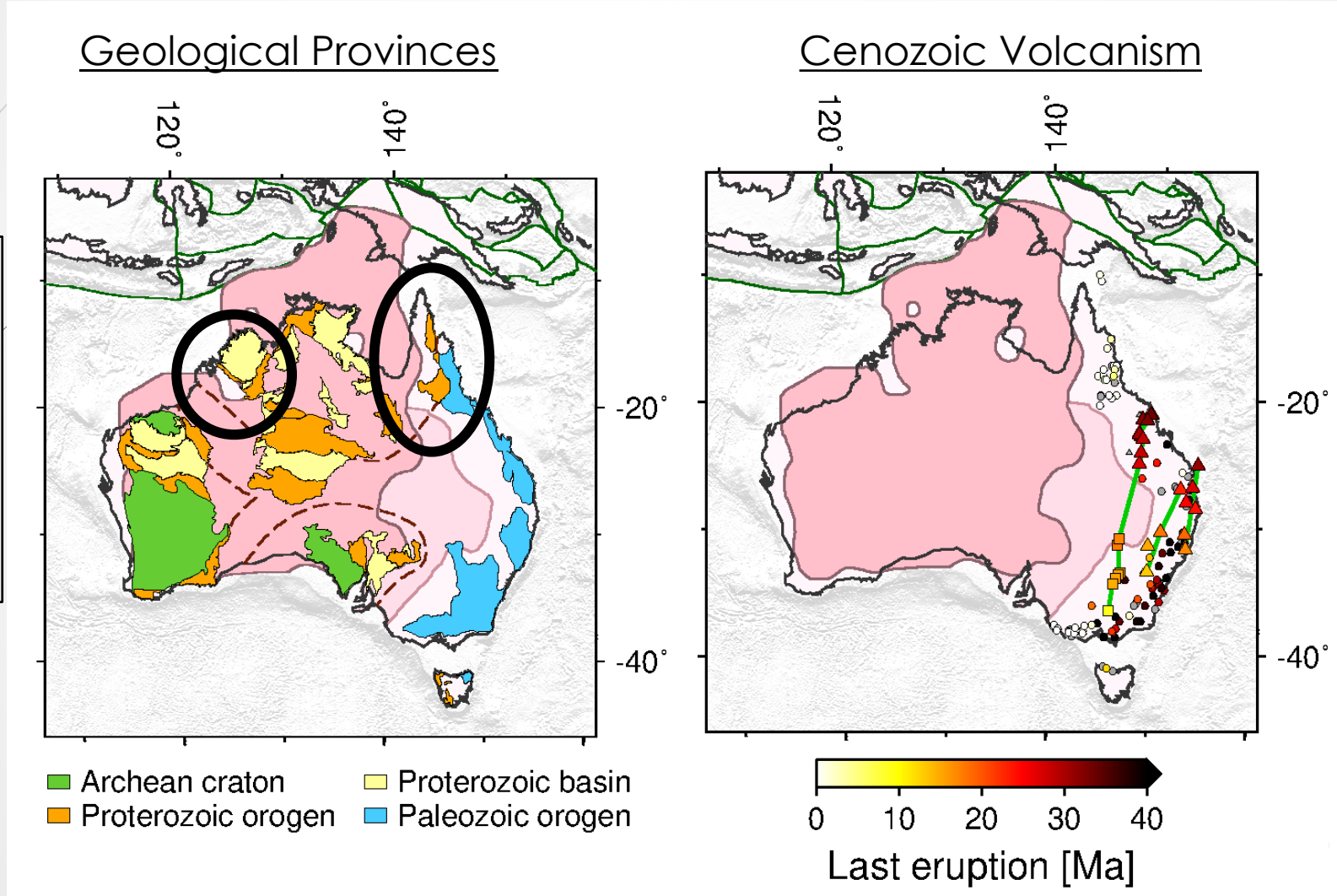
The Australian Lithosphere



- 1. Cratonic lithosphere: **dVs > 4.5%** at 110-150 km
- 2. Transitional lithosphere: **1% < dVs < 4.5%** at 110-150 km
- 3. Phanerozoic lithosphere: **dVs < 1%** at 110-150 km

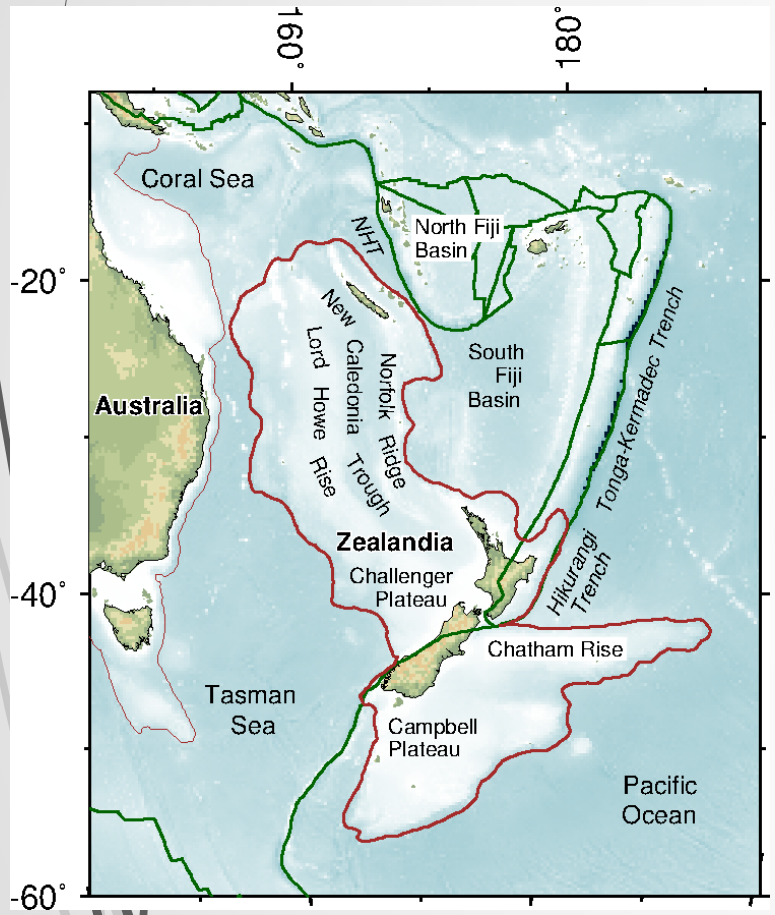
The Australian Lithosphere: Overlays

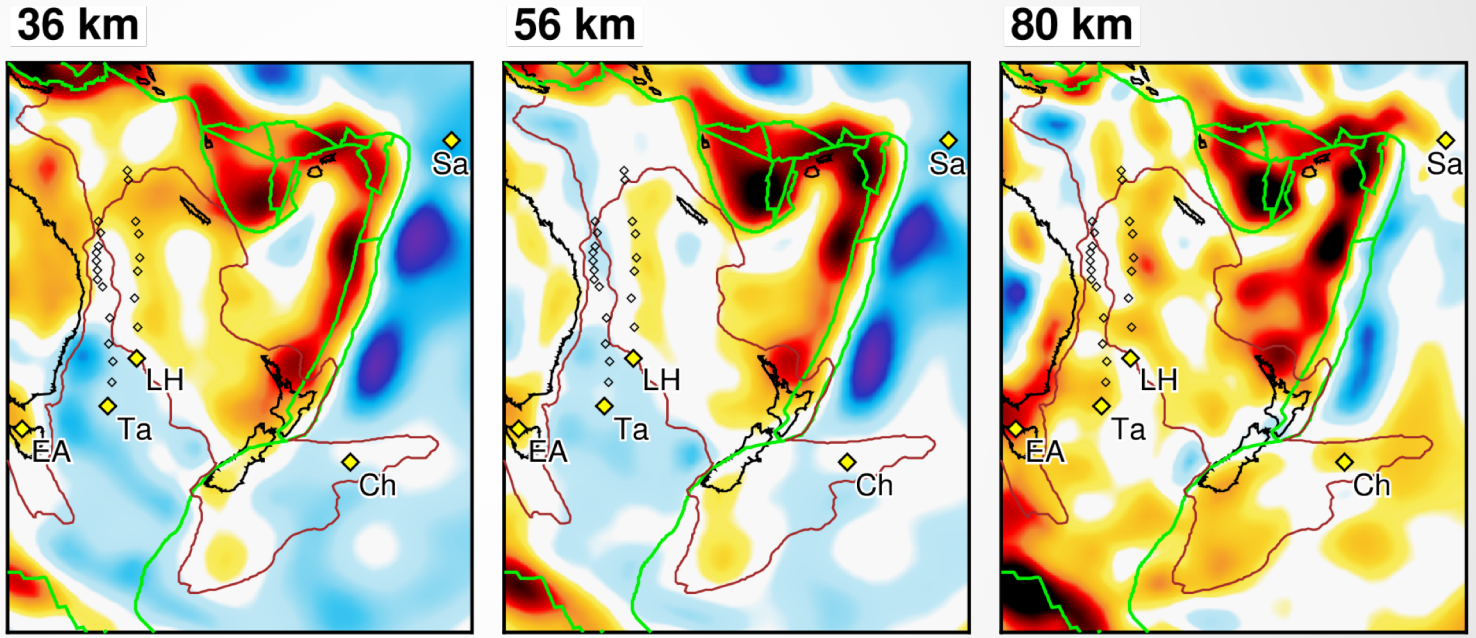
- **Georgetown** Inlier and **King Leopold** Orogen not underlain by cratonic lithosphere.



- **All** Cenozoic volcanism underlain by thin **Phanerozoic** lithosphere
- **Gap** in **Cosgrove** hotspot track underlain by **Transitional** lithosphere

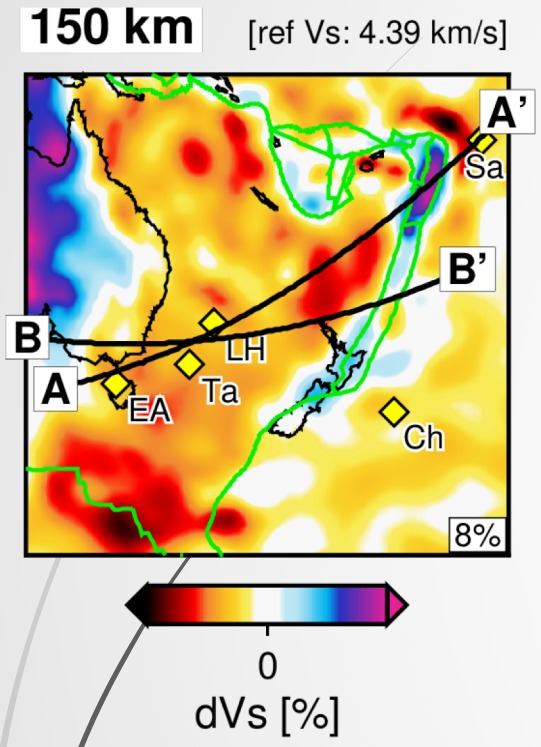
The Zealandian Lithosphere

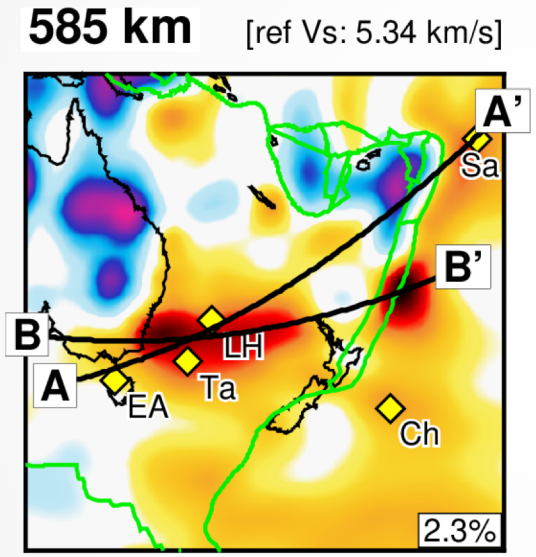


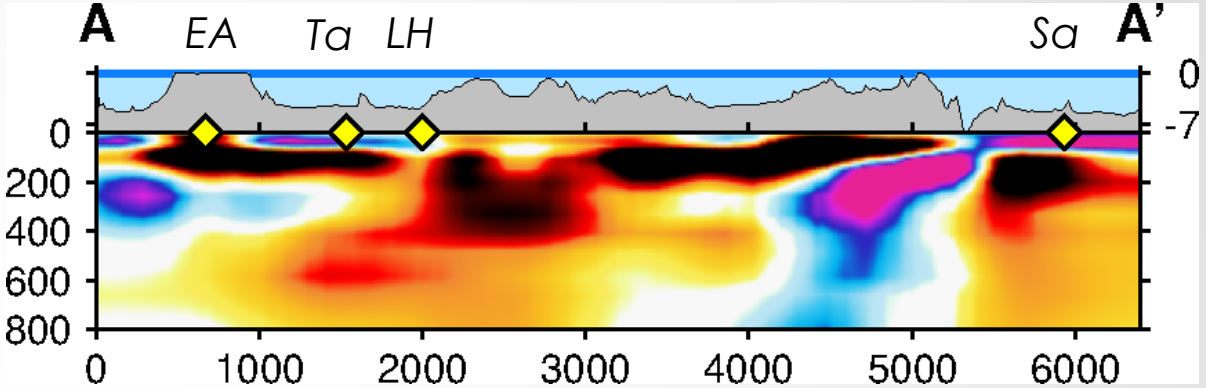


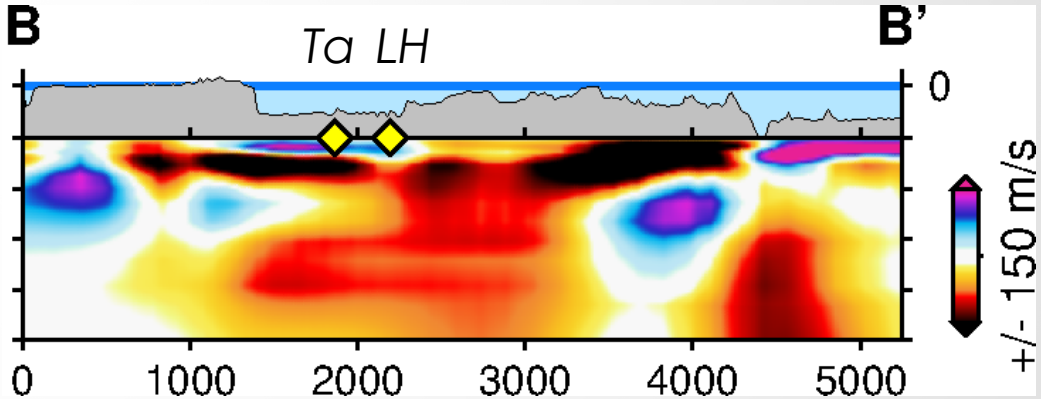
- Western Zealandia **distinguishes** from surrounding oceanic lithosphere.
- Underlain by **low velocity anomaly** down to the transition zone.

Hotspots









- **Tasmanid** & **Lord Howe originate** from **single plume head** in transition zone, waned at the surface, possibly also feeds the **East Australia** hotspot.
- **Curves** around northern tip **Tonga s**lab with depth, vanishes in transition zone.

Conclusions

- ***Aus22***: **New regional upper mantle model** of the full Australian Plate and its boundaries using massive datasets.
- Detailed lithospheric structure of the **Australian** and **Zealandian lithosphere** resolved, including the full extend of the **cratonic** lithosphere.
- Transition in northern boundary from oceanic to continental subduction at the Java trench to **slab delamination** and **underthrusting** below New Guinea.
- **Ancient slab remnants** visible in the transition zone below NE Australia, best correlated with the northward subduction 40-26 Ma – continental remnants?
- Lord Howe and Tasmanid hotspot source from **single plume source**, possibly also sourcing the East Australian hotspot, waned at the surface.
- **Samoa** plume curves around the Tonga slab and vanishes in transition zone. Another plume further south?

Thank you!

Any questions?

Contact me:

delaat@cp.dias.ie

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  - MOANA and STREWN (Zealandia),
  - L-SCAN_Active (Fiji), TODA (Tonga), Woodlark (Solomon Sea).
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- The FDSN Webservice, Obspy and the Global CMT Catalogue.

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