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Ambient Noise Studies in Australia and Indonesia

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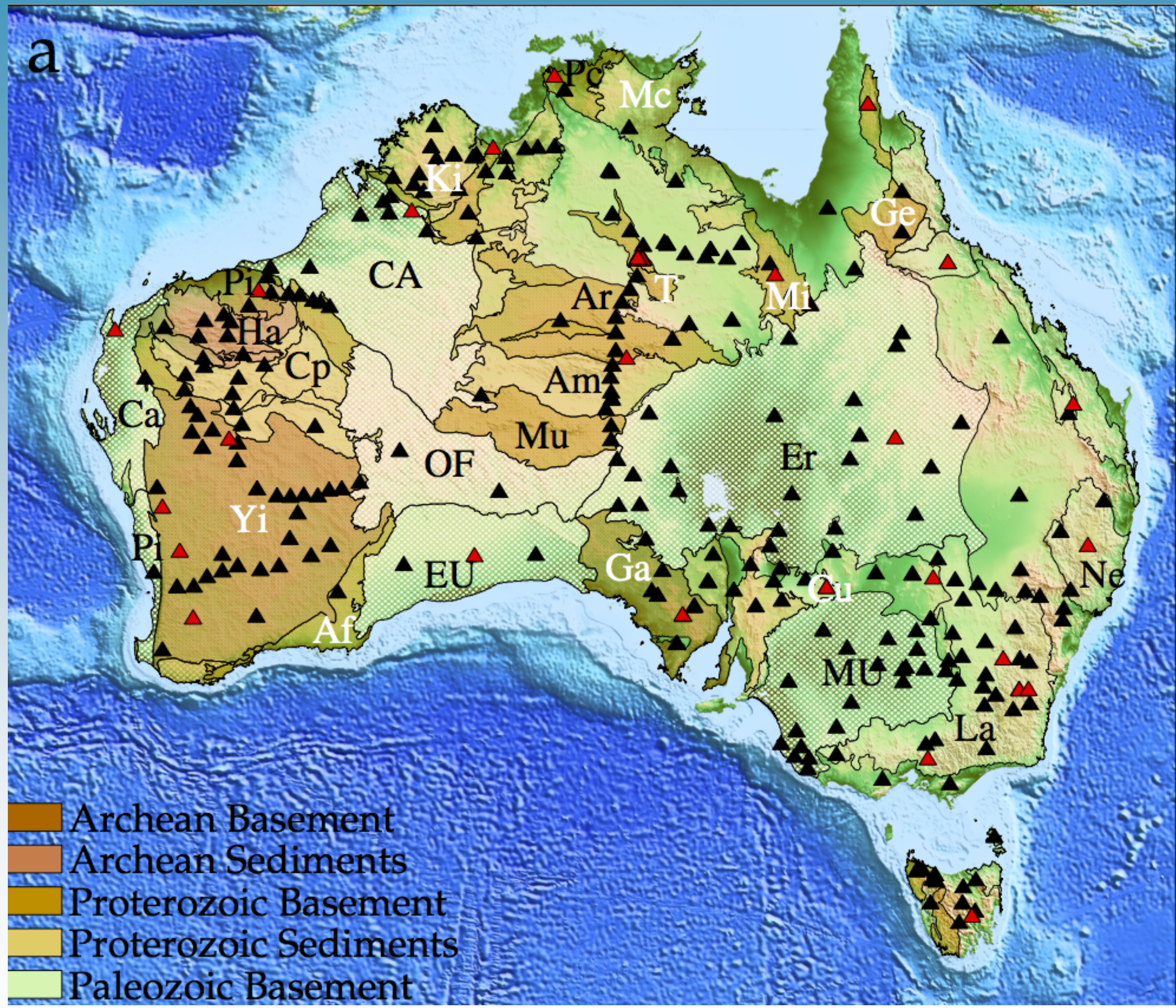
Ambient Noise - Australia I

- Exploits the extensive deployments of portable broad-band stations since 1992 (more than 200 stations), using permanent stations to link results from different temporary deployments.
- Continental coverage is improved by recent Geoscience Australia upgrades to the national network for tsunami warning.
- Up to 7500 paths are available for 4 s Rayleigh waves with dense coverage of the whole continent for Rayleigh waves and even 3800 paths for Love waves.
- Provides information on crustal seismic wavespeeds in the top 10 km and the presence of deep sedimentary basins in rather inaccessible places.

Tectonic features and stations

Portable broad-band stations – black

Permament stations – red



Green's function construction

Rather than using the conventional stacked cross-correlation between pairs of stations we have used stacked transfer functions. The phase response is the same, but with a broader frequency response.

In the frequency domain, for stations A and B we use a water-level deconvolution:

$$\Phi(\omega) = \frac{\mathbf{v}(\mathbf{x_A}, \omega)\mathbf{v}^*(\mathbf{x_B}, \omega)}{\varphi_{\mathbf{ss}}(\omega)}, \tag{1}$$

where

$$\varphi_{\mathbf{ss}}(\omega) = \max[\mathbf{v}(\mathbf{x_B}, \omega)\mathbf{v}^*(\mathbf{x_B}, \omega), \mathbf{c}\max[\mathbf{v}(\mathbf{x_B}, \omega)\mathbf{v}^*(\mathbf{x_B}, \omega)]],$$

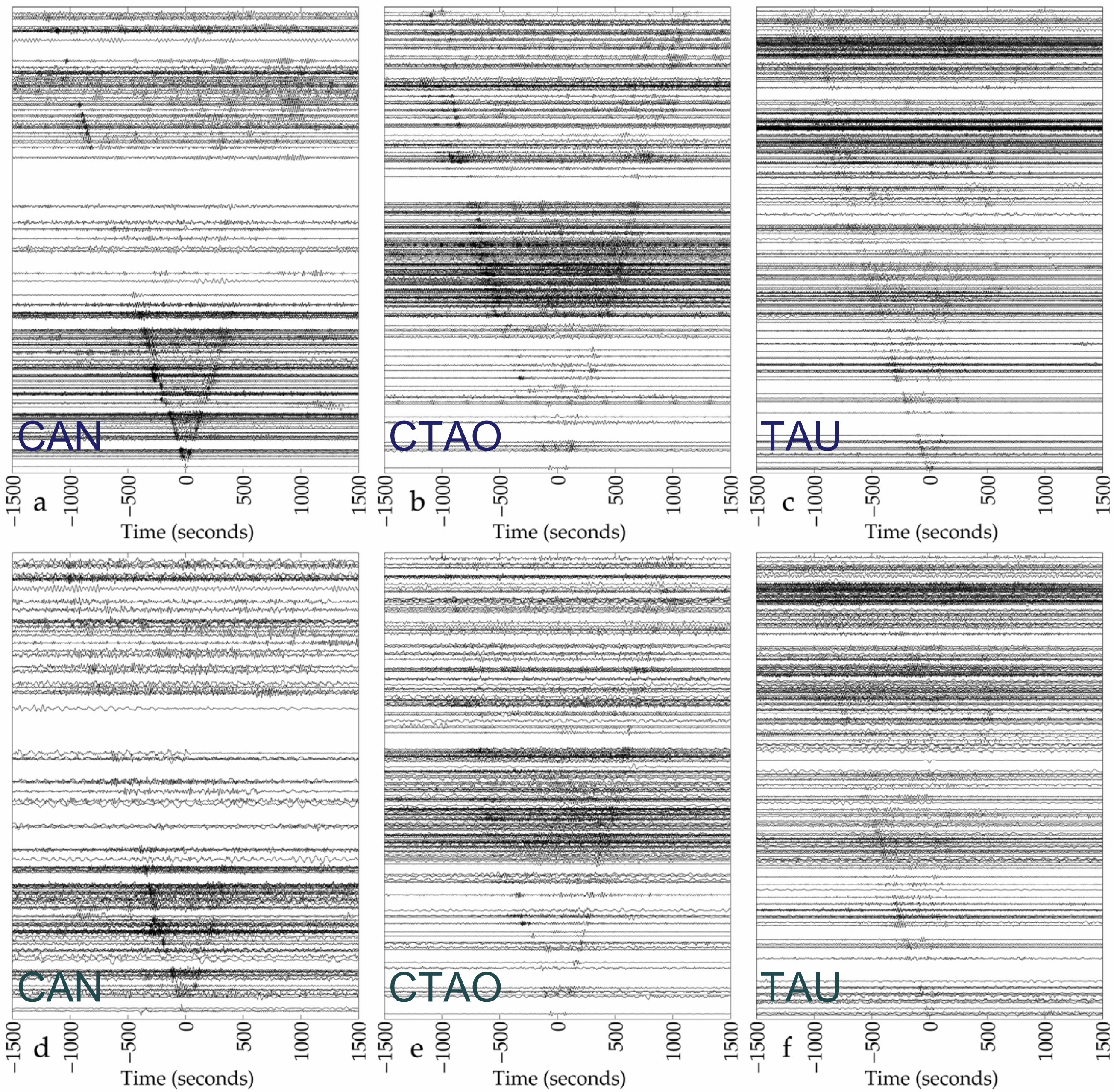
$*$ denotes complex conjugation.

Unlike the cross-correlation, the transfer function is not modulated by the squared spectrum of the ambient noise and hence has a much broader spectral response.

Empirical Green's Functions

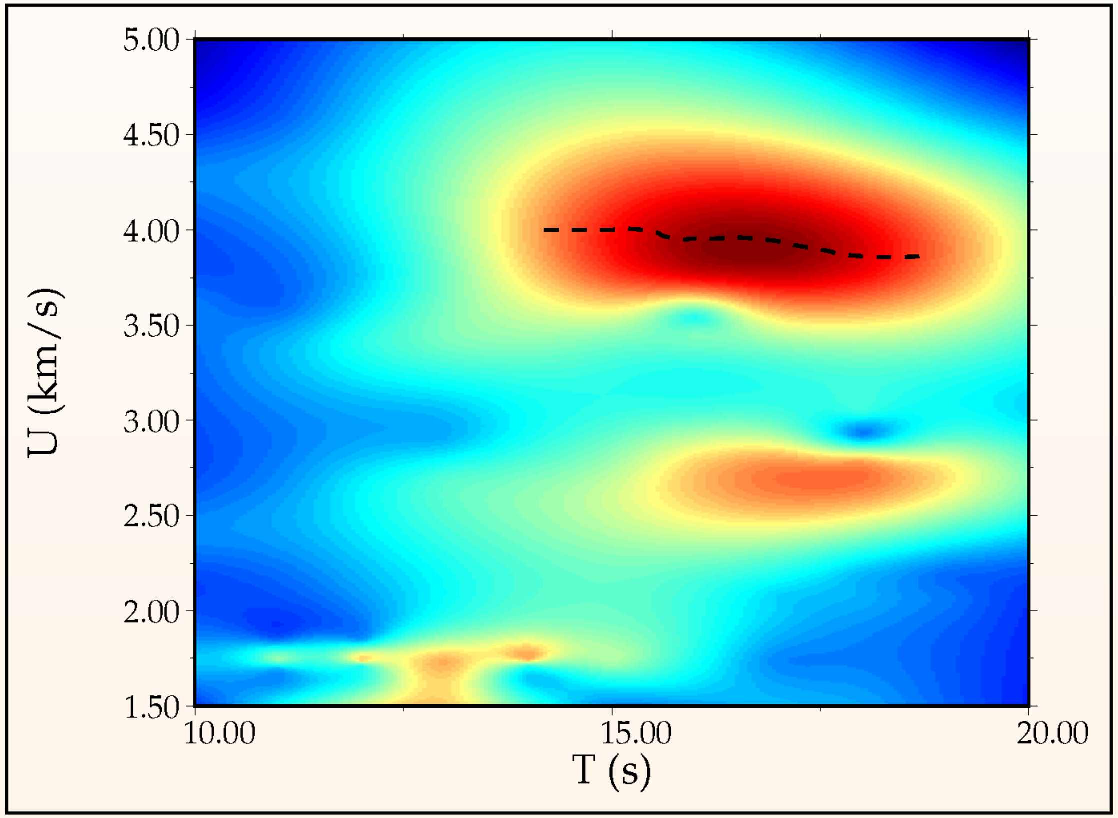
ZZ
Rayleigh

TT
Love



Extraction of group dispersion

Group velocity dispersion estimated by FTAN analysis for each pair of stations

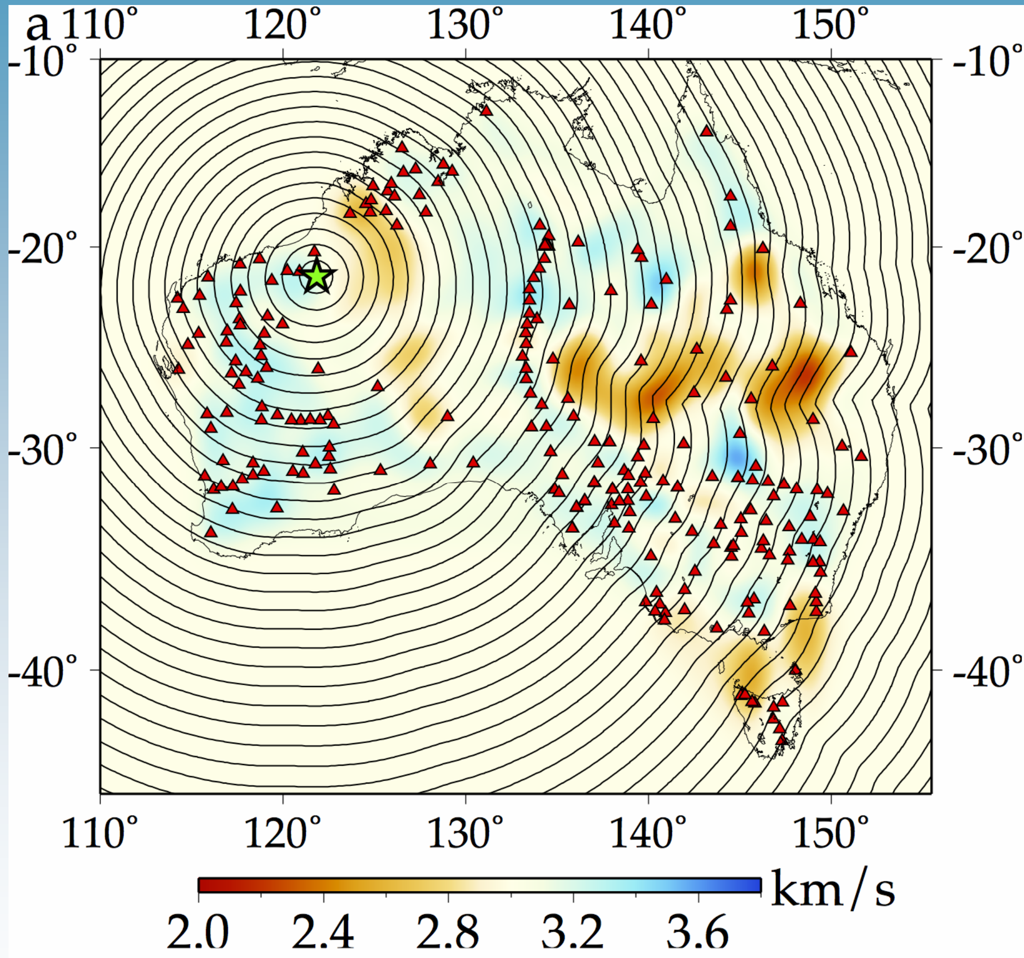


Group speed tomography I

Forward modelling using Fast Marching Method (FMM) suitable for strong heterogeneity

Wavefront tracking using group speed

Hierachical inversion using a subspace approach



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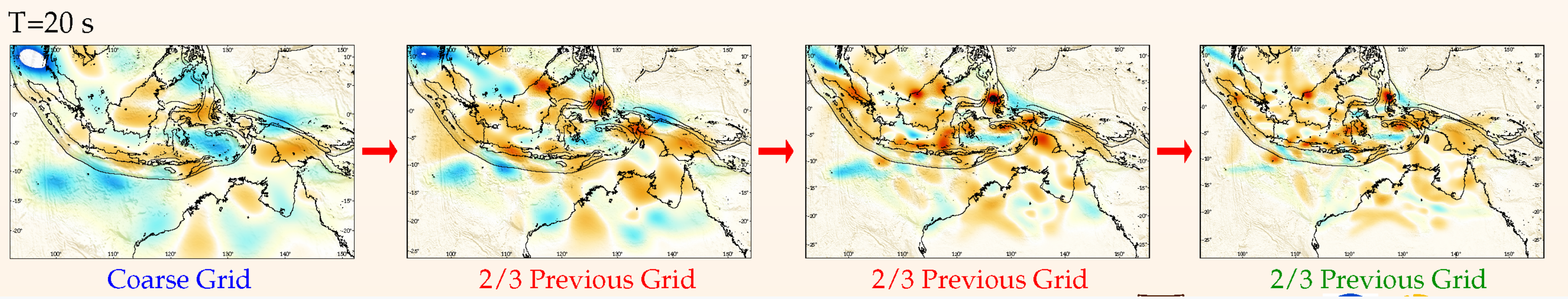
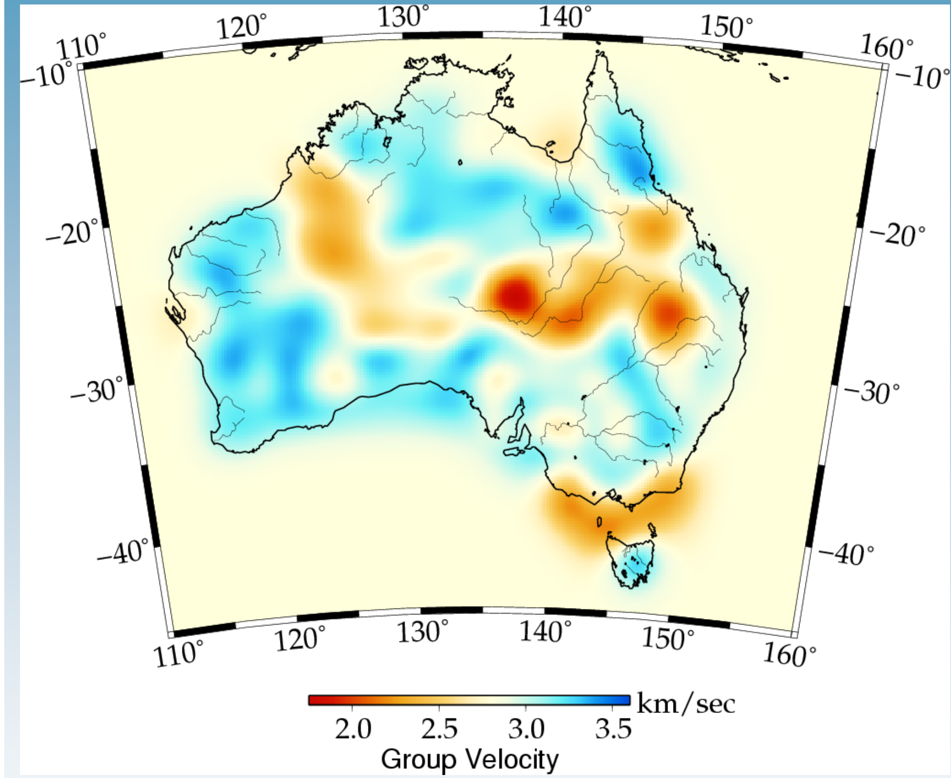
Group Speed Tomography 2

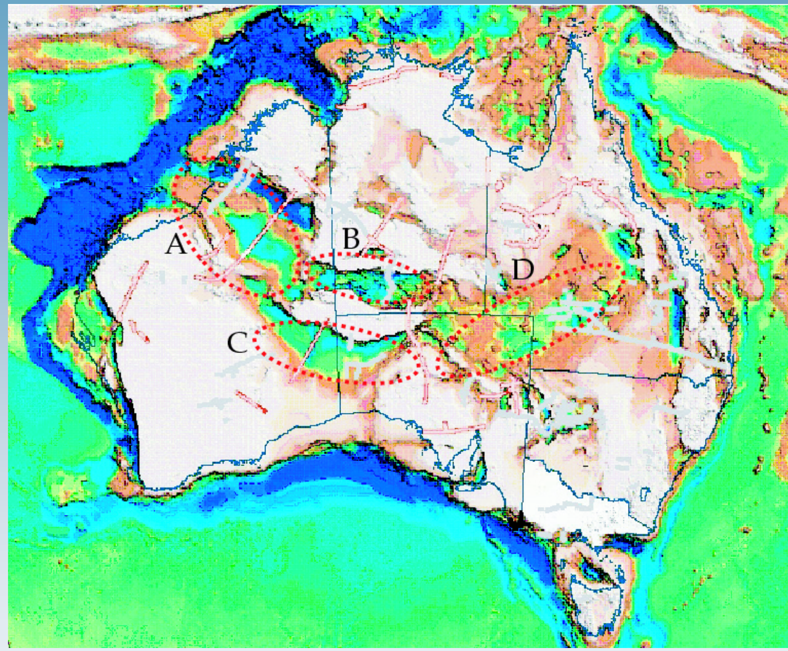
- Use a hierarchical approach to the inversion with subspace inversion of Kennett et al., (1988) as implemented by Rawlinson & Sambridge (2004).
- Tomographic inversion is conducted on a coarse grid
- Resample the current model with bilinear interpolation, and use it as input model for the next step.
- Continue till a satisfactory model is obtained.



Early results from ambient noise study 1



Map at 5s period – dominated by influence of sediments



Sedimentary thickness distribution from GA database

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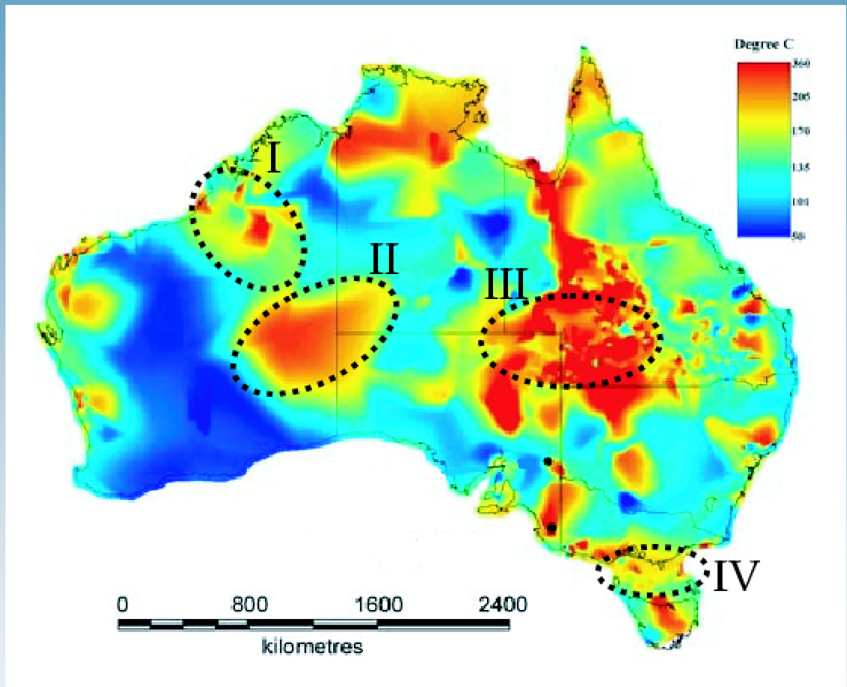
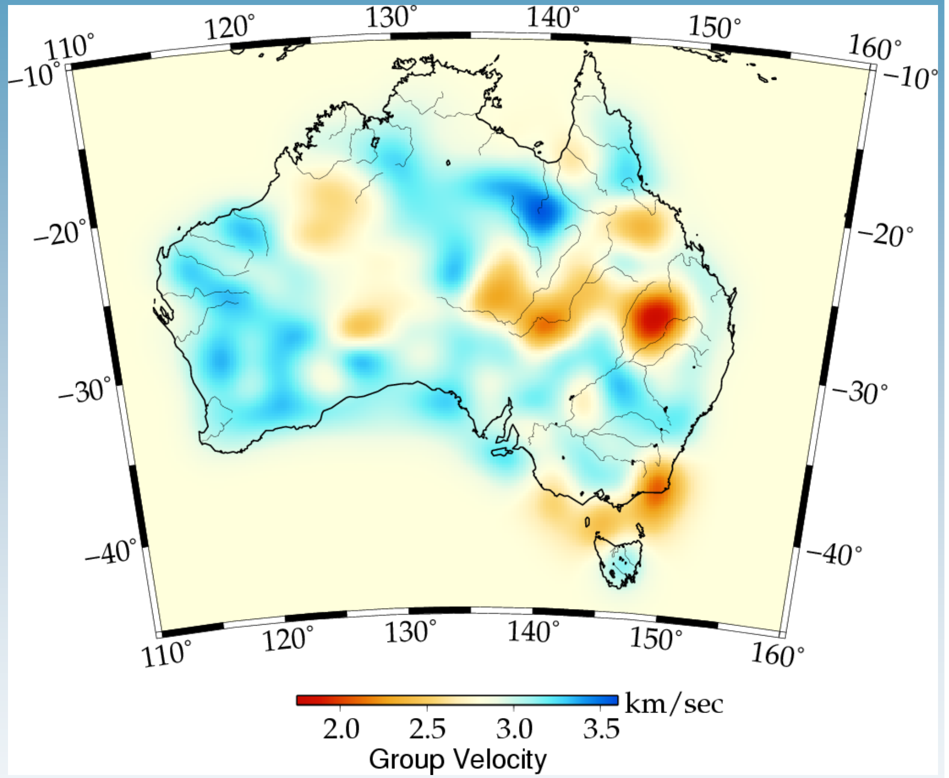
Early results from ambient noise study 2



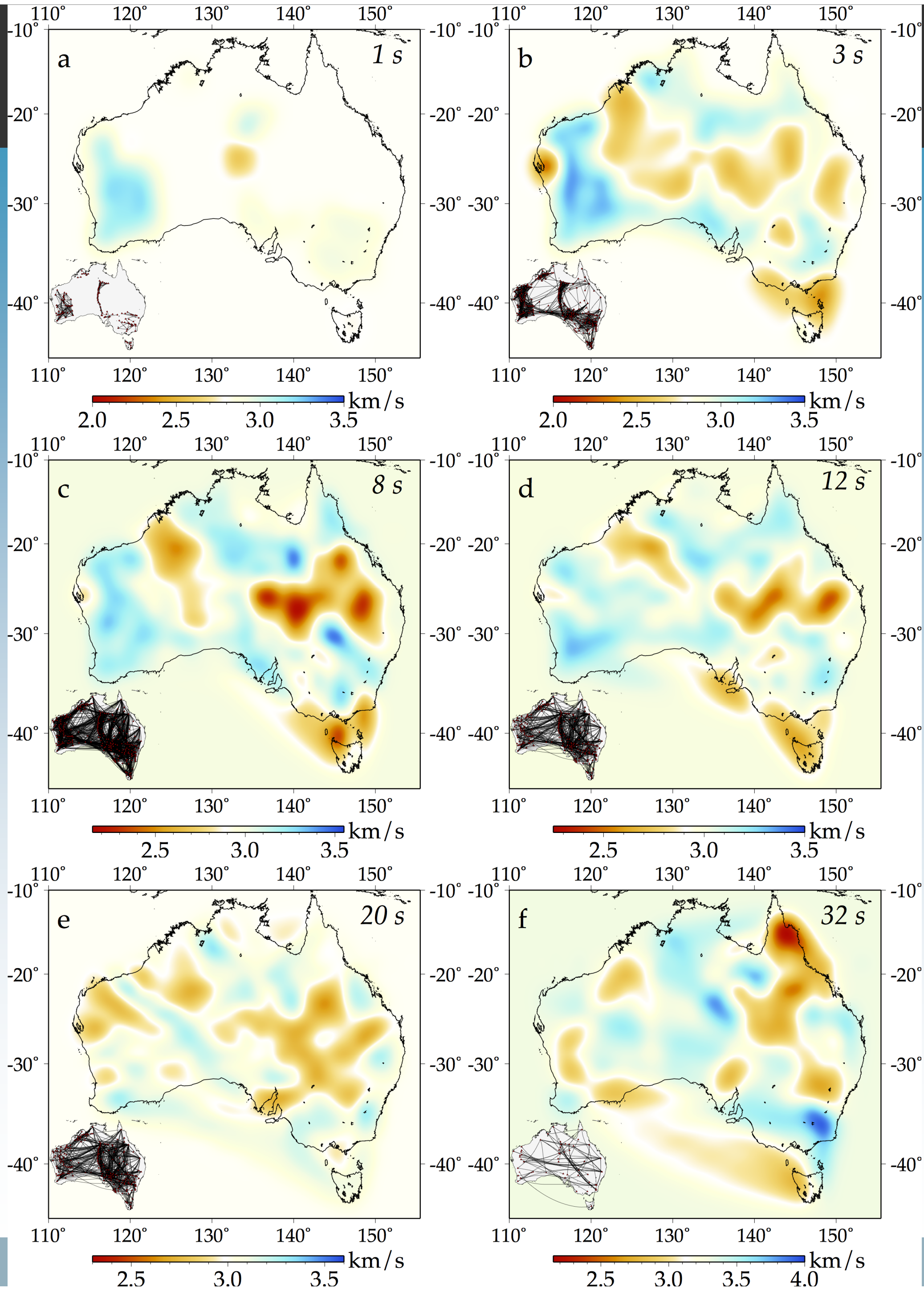


Estimated temperature at 5 km depth – elevated temperatures reduce seismic wavespeed

Map at 12.5s period – main influence from crustal variations such as temperature

Rayleigh

Group dispersion as a function of period



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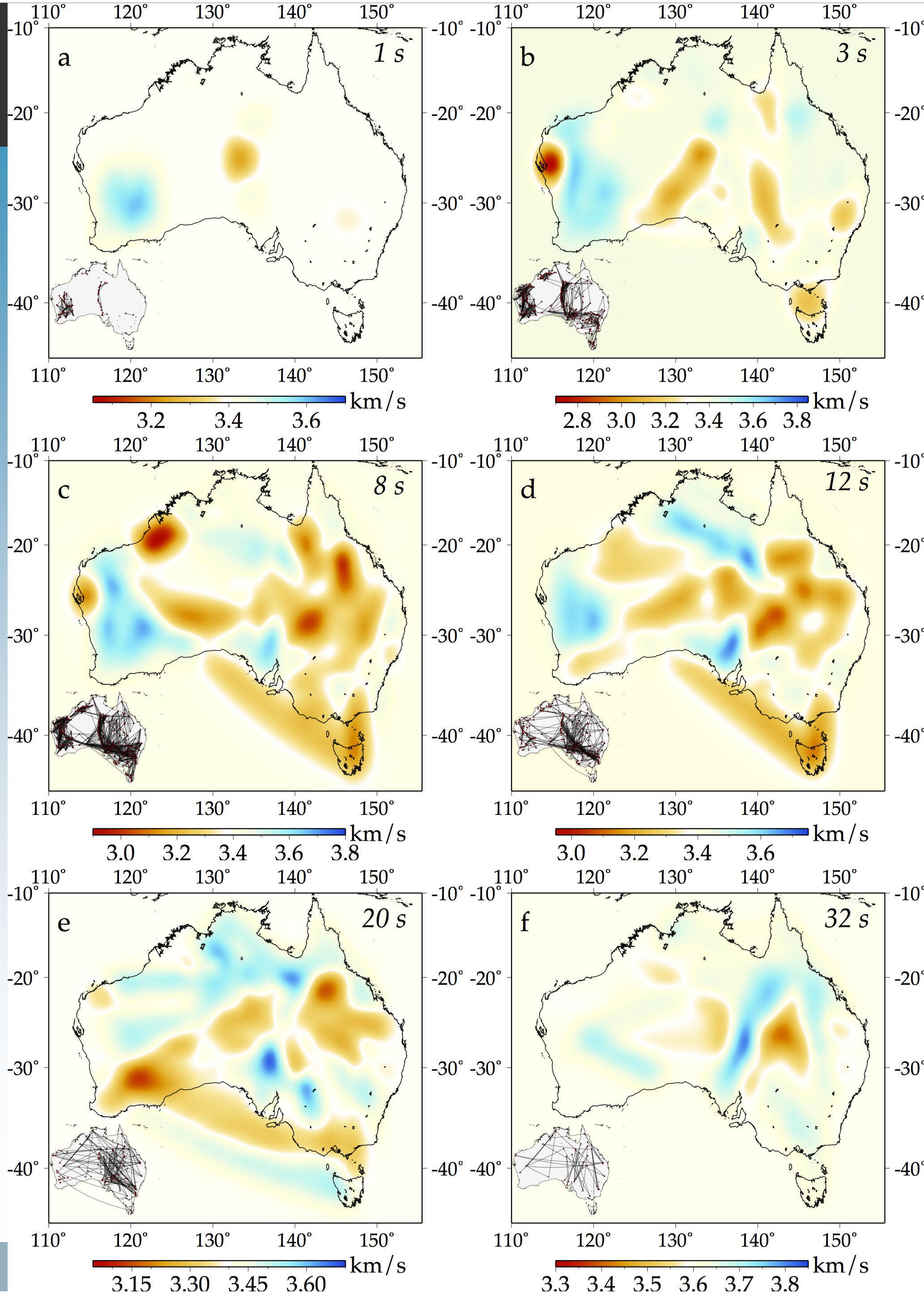
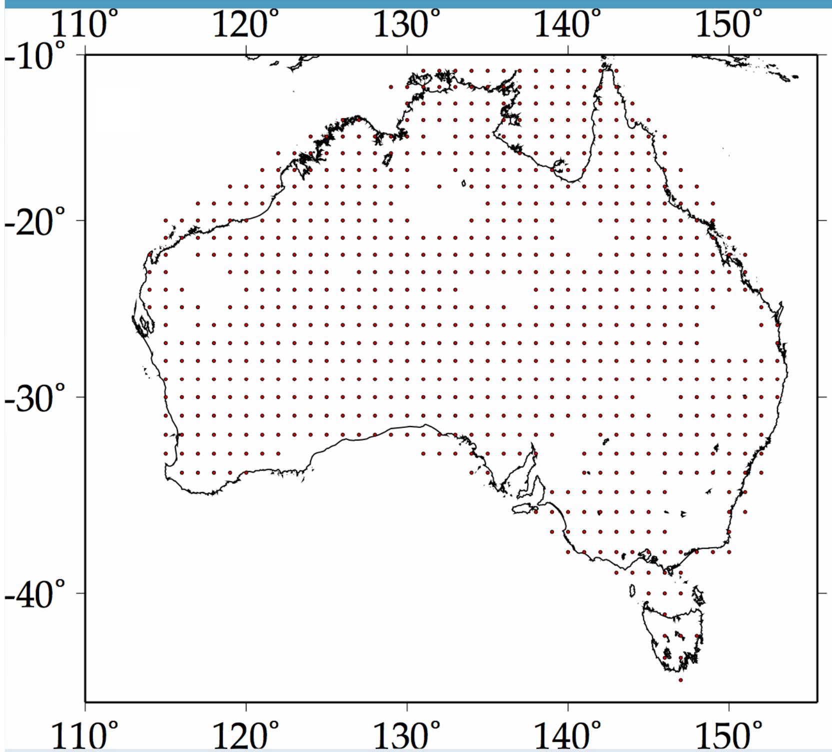
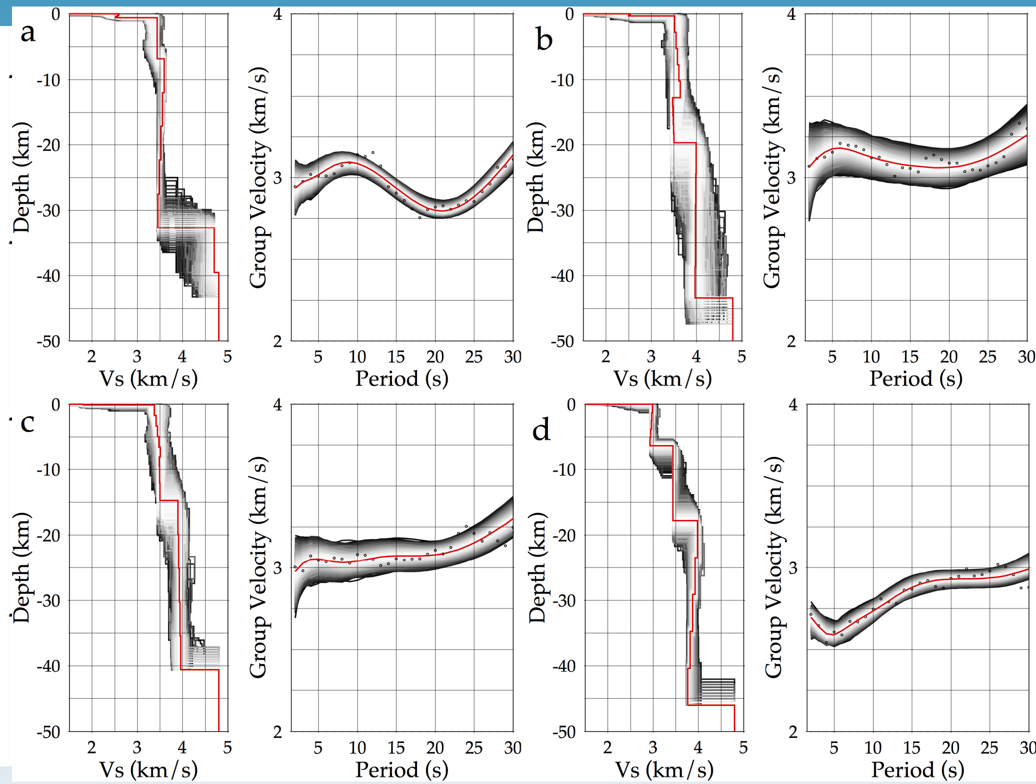
Love

Group dispersion as a function of period



Conversion to velocity model





NA inversion for local velocity model on 1 degree grid across continent

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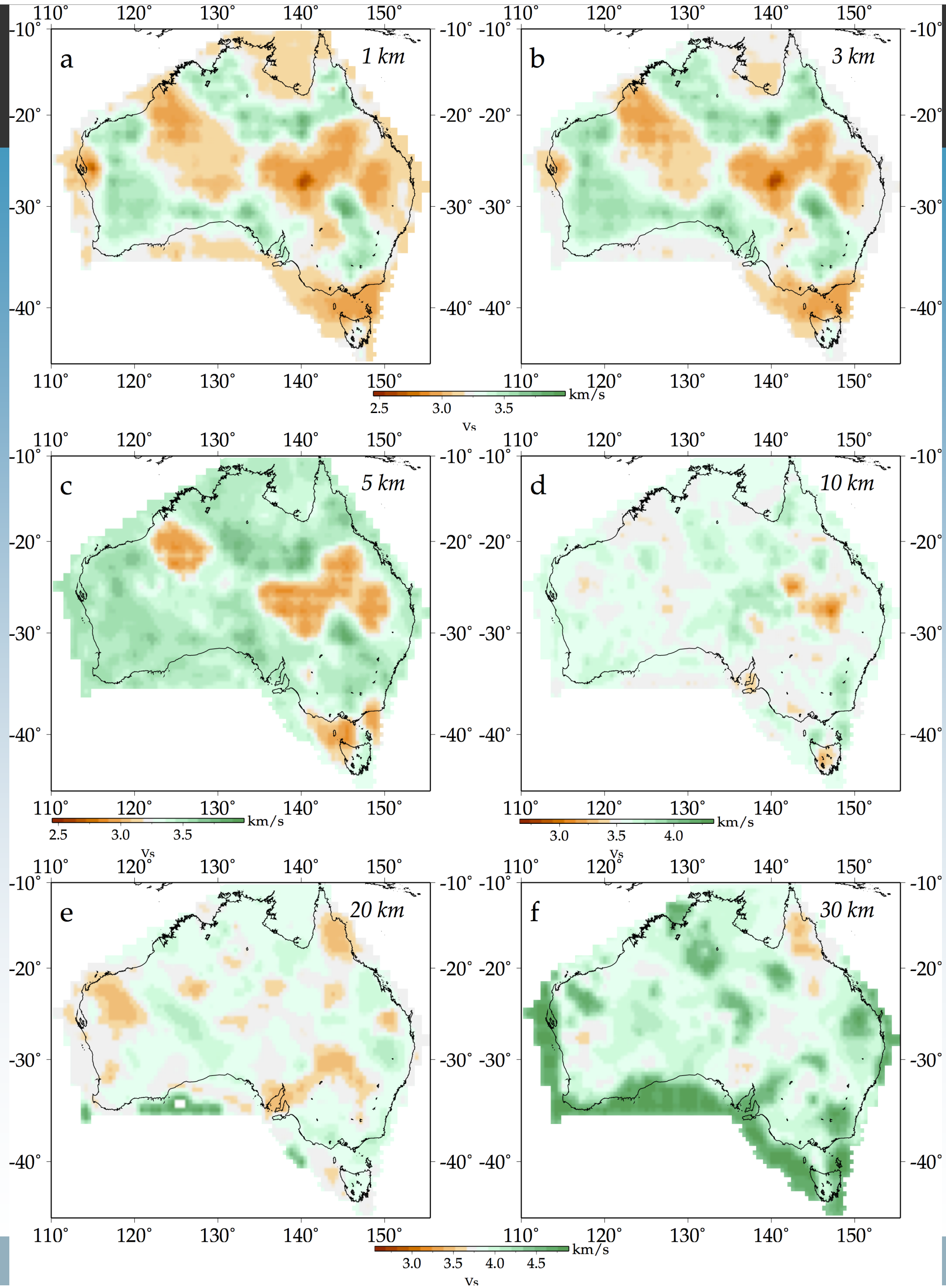
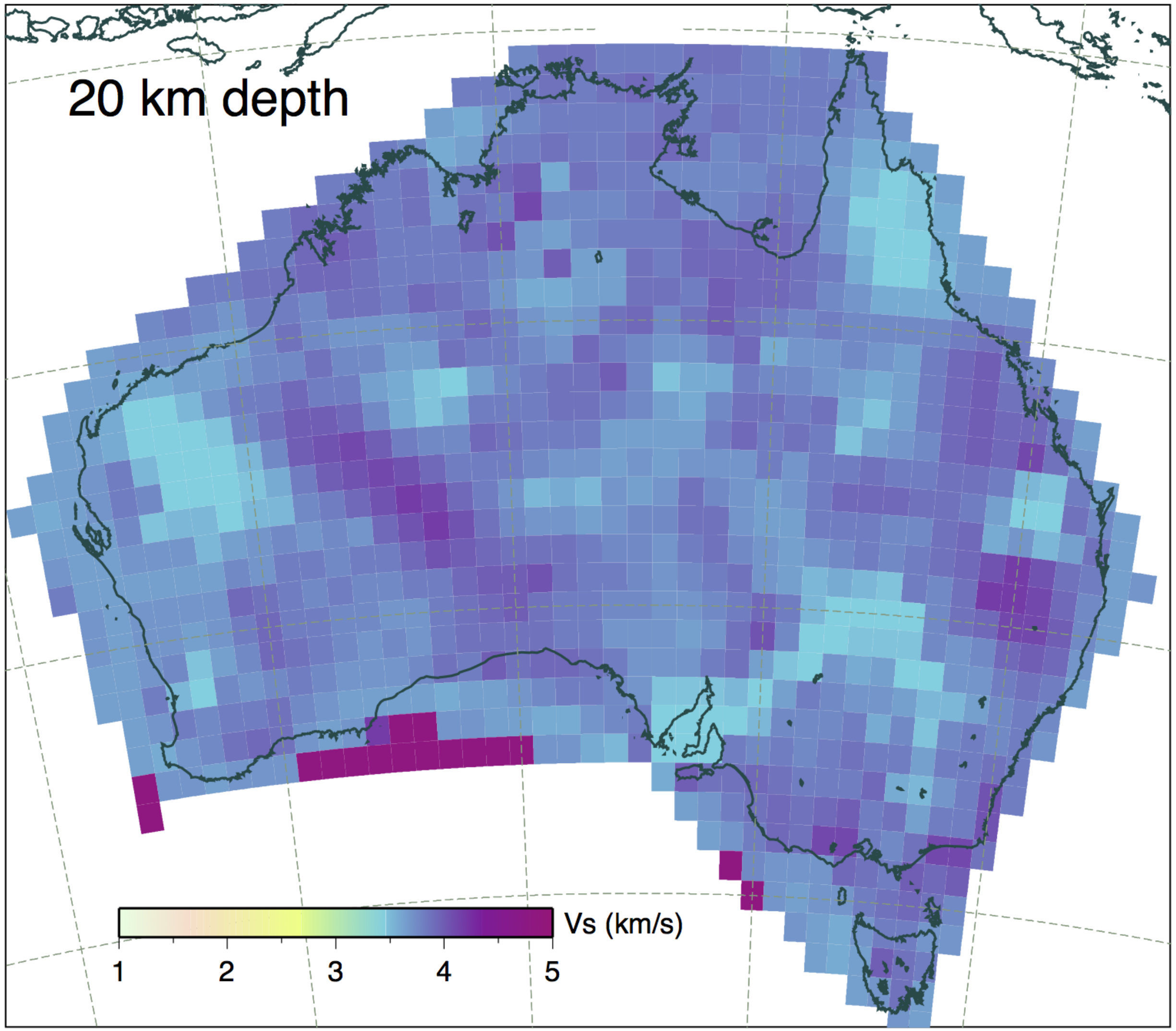
SV wavespeed model from local inversions with weak sediment and Moho constraints

All depths with same wavespeed scale

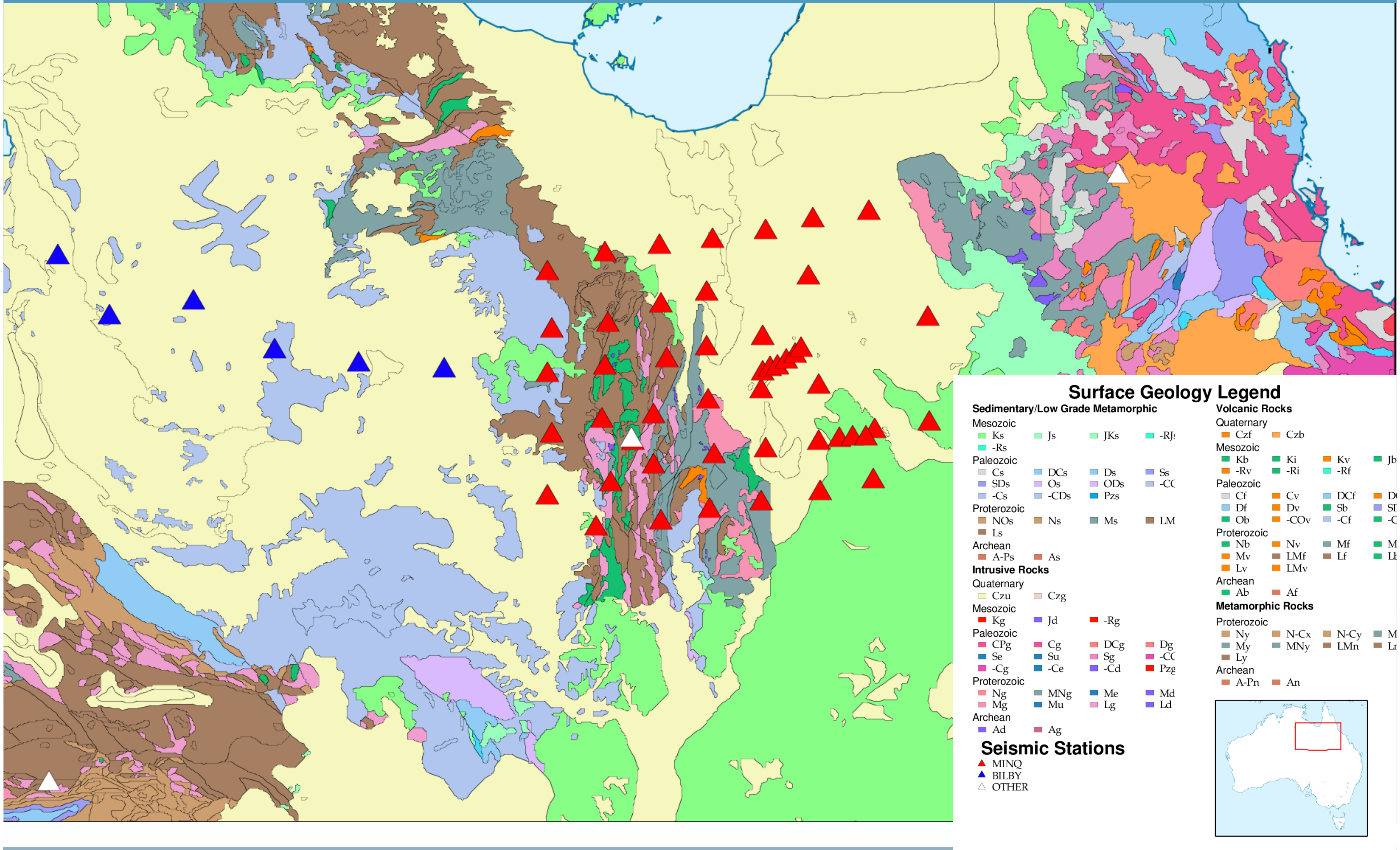


Australia - SV wavespeed model

SV model from ambient noise tomography provides crustal control in many areas where little prior information was available.



Detailed Study – Mt Isa, QLD



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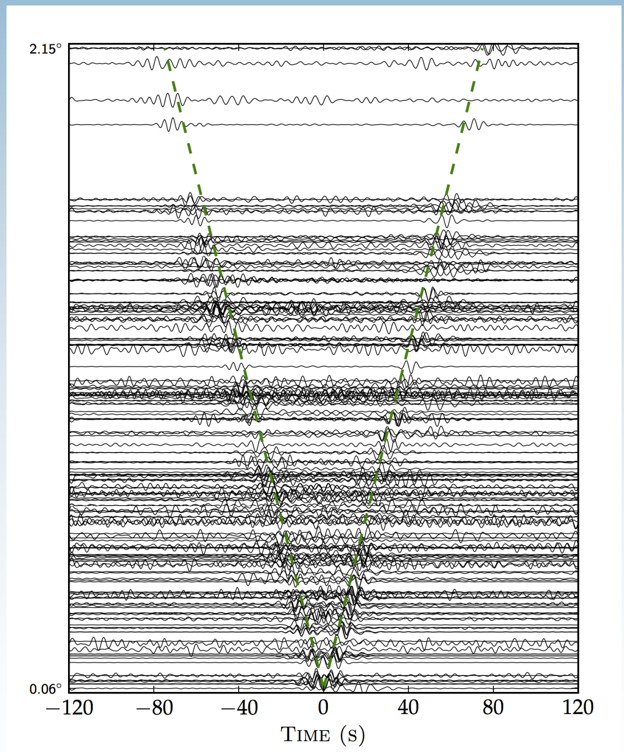
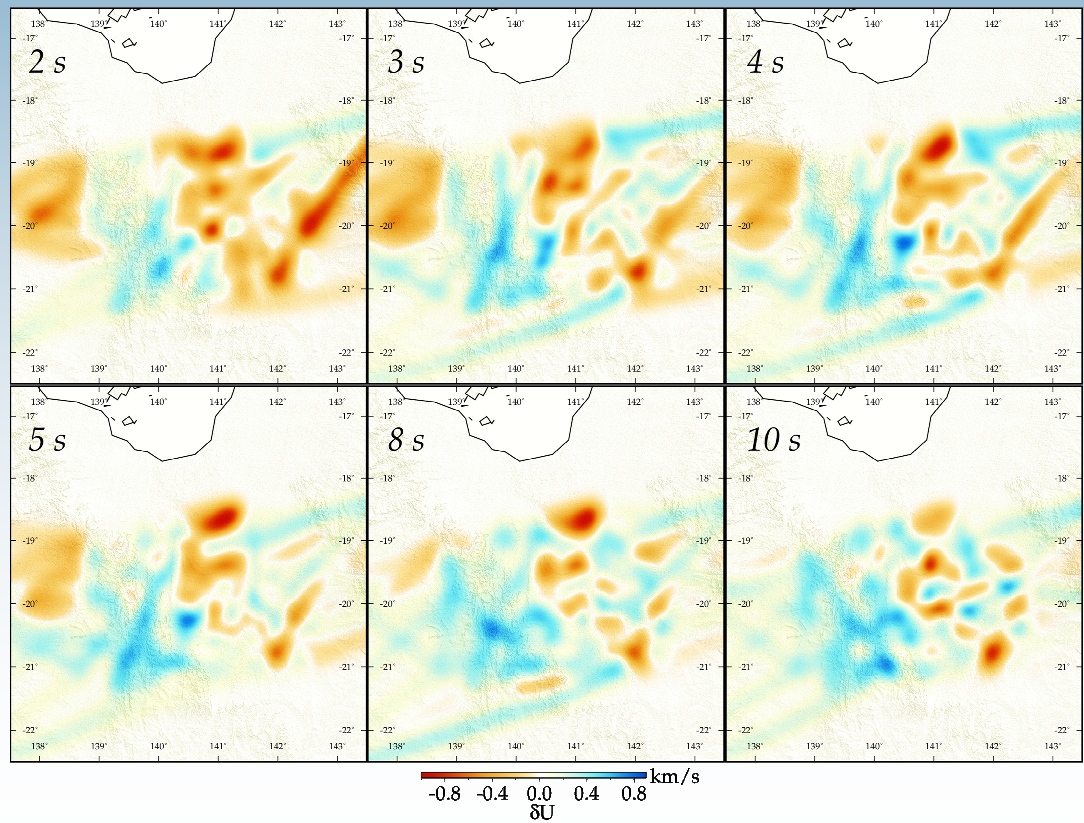
Mt Isa 2

- Region of complex geology with considerable regolith cover
- Exploit mixture of broad-band and shorter period stations
- Very strong contrasts in group speed





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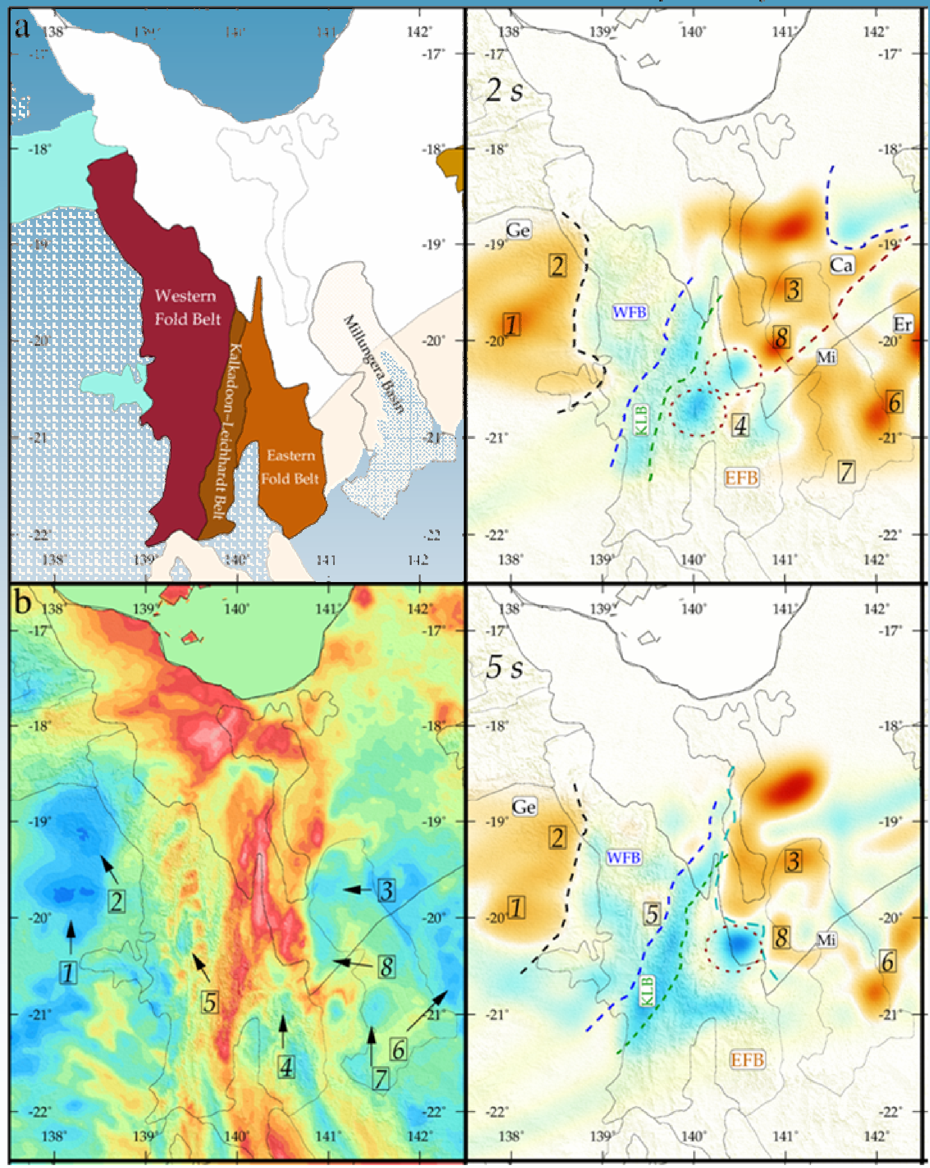
Mt Isa 3a

Group Velocity

Gravity



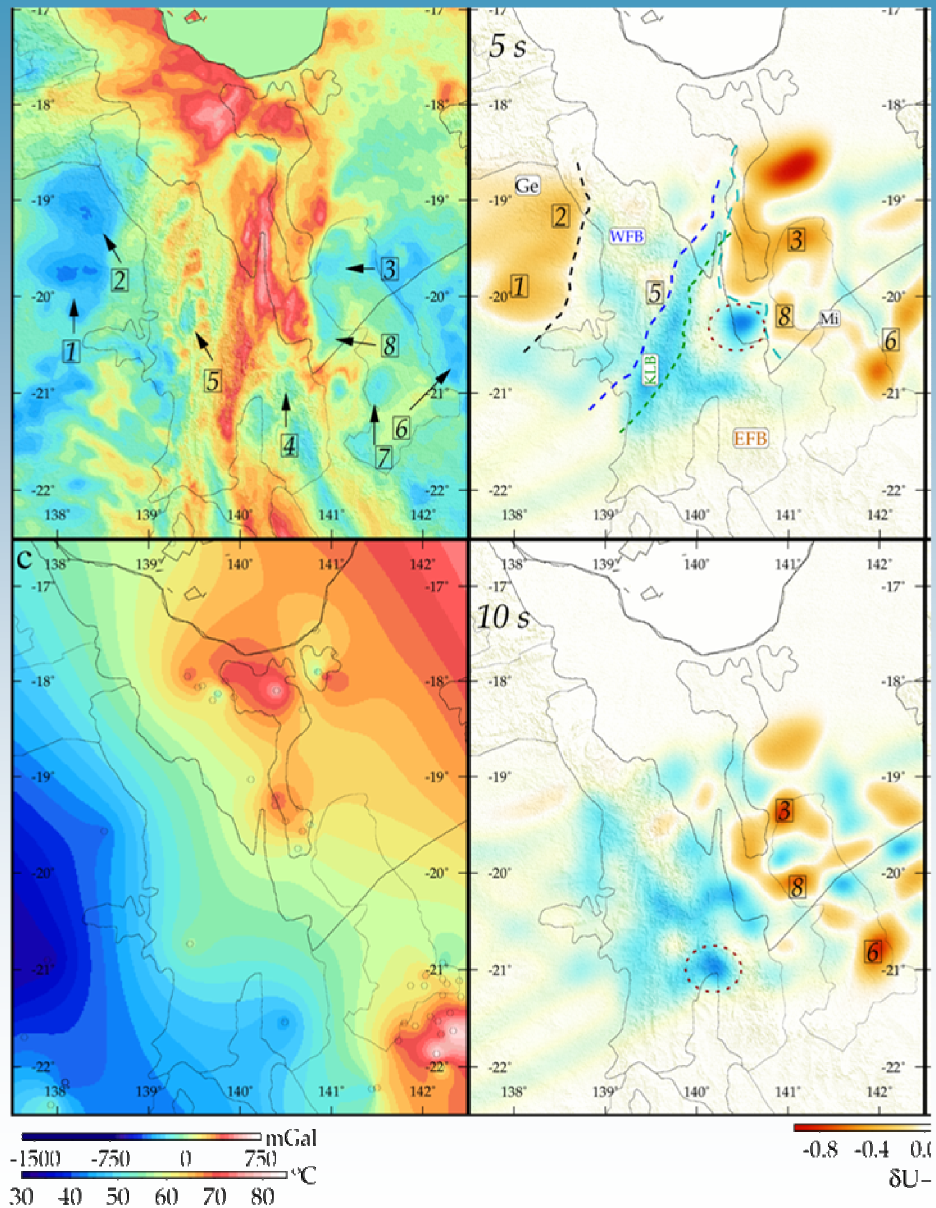
- Contrasts preclude interpretation via local 1-D structure yet still reveal geological boundaries

Mt Isa 3b

Gravity

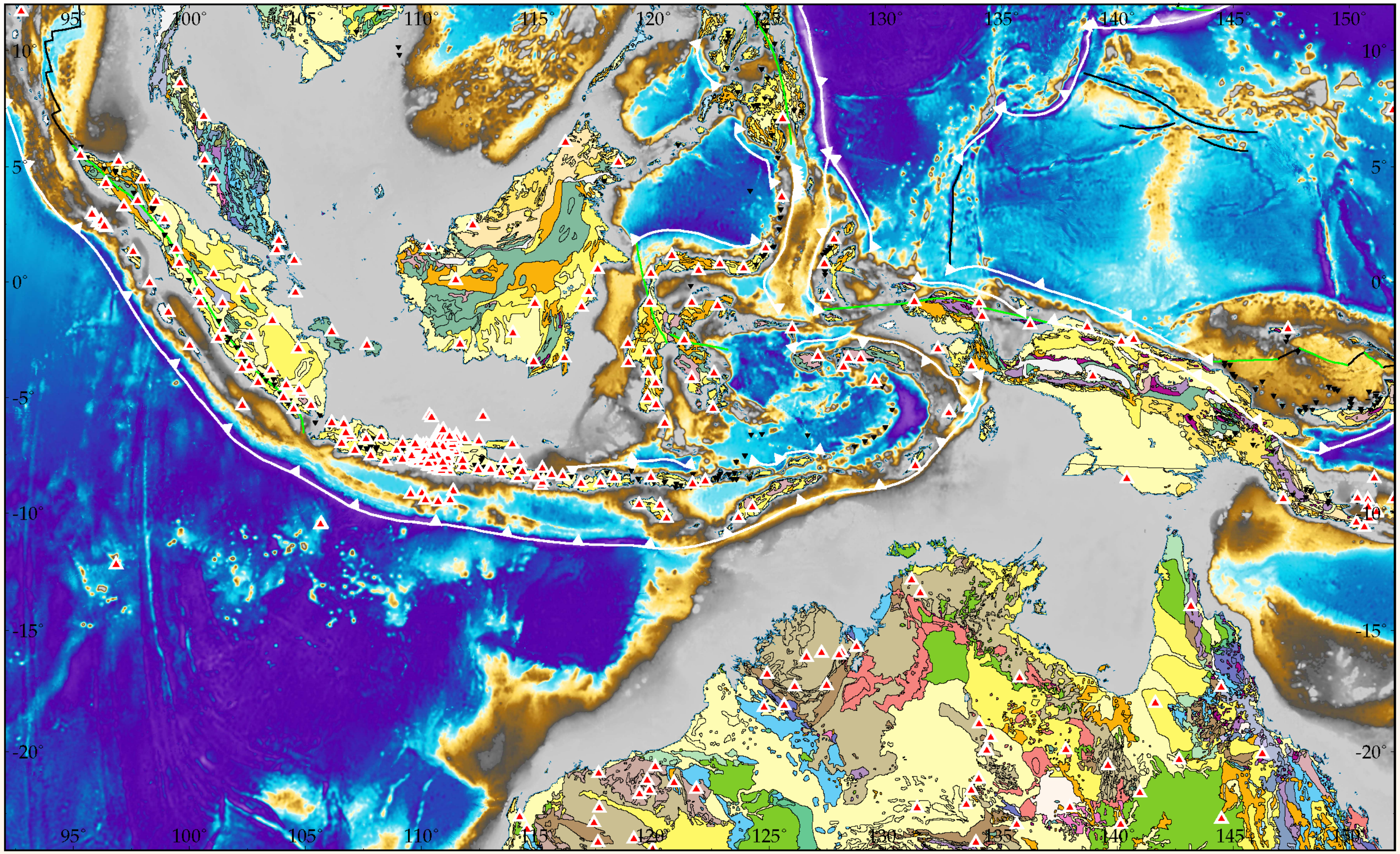
Temp at 5 km

limited data



- Possible mapping of temperature anomalies under thick sedimentary cover

Ambient Noise – Indonesia 1

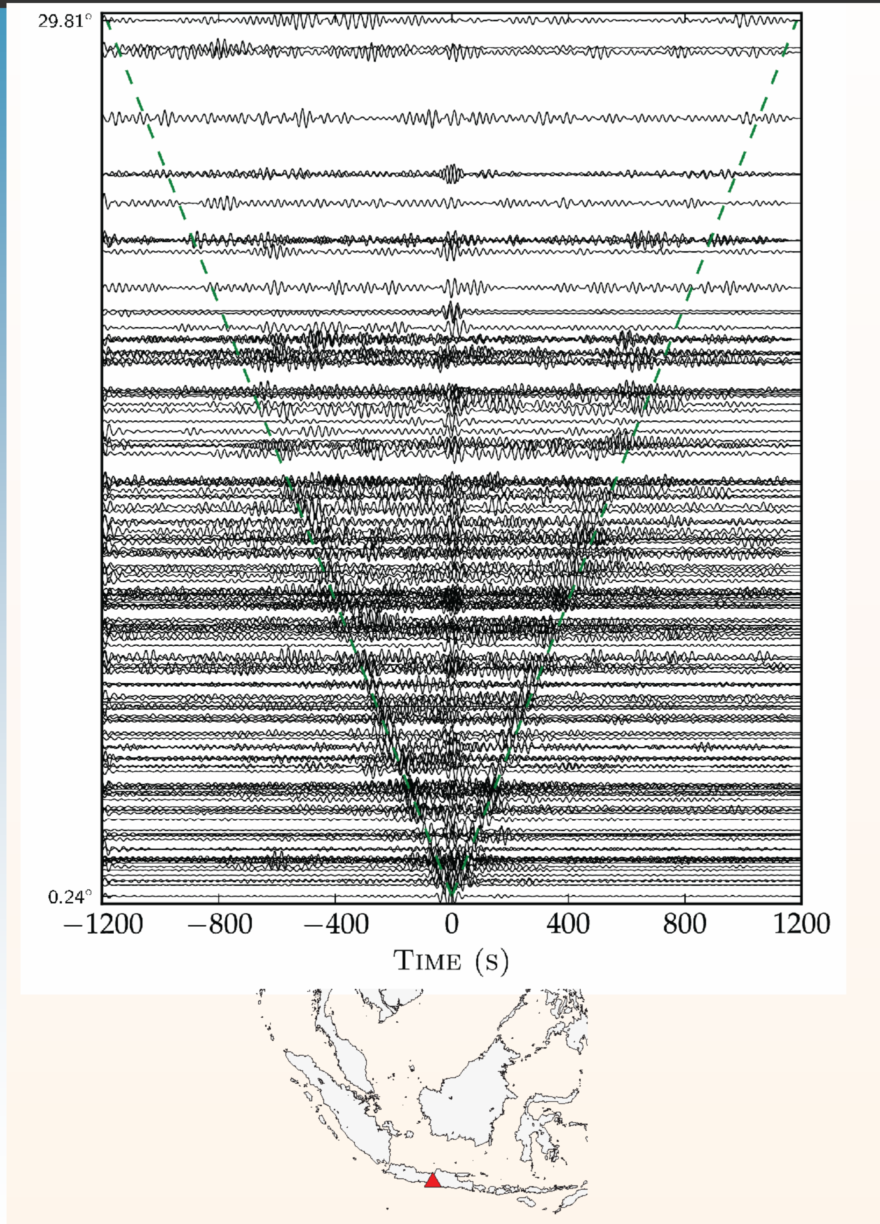


- Over **500** broadband and shortperiod stations from Indonesia, Australia and other networks.

Indonesia 2

Example of Green's Function estimation across Indonesia for distances out to 29 degrees

All paths from station in central Java



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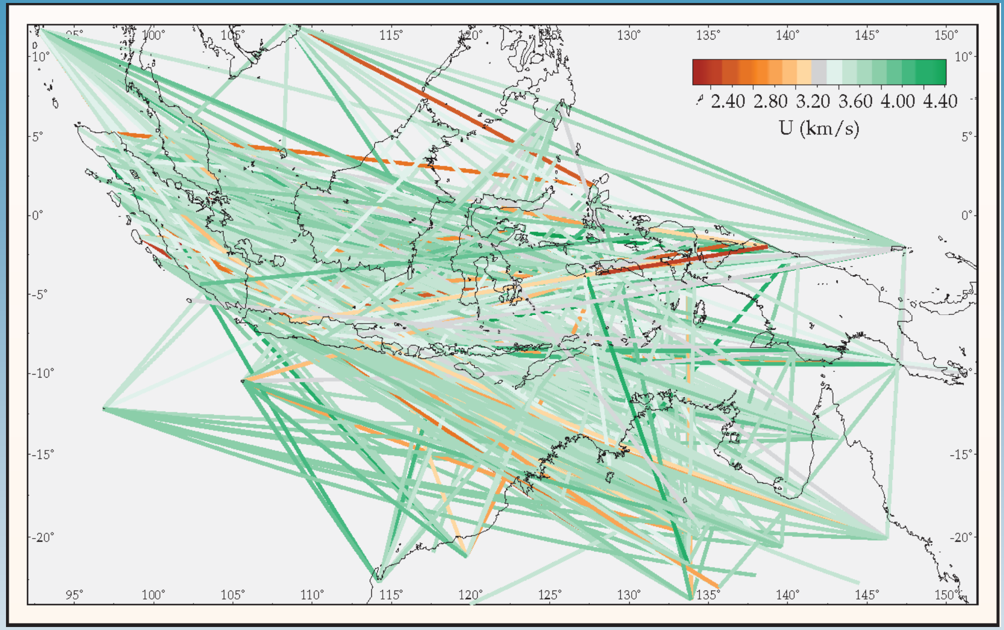
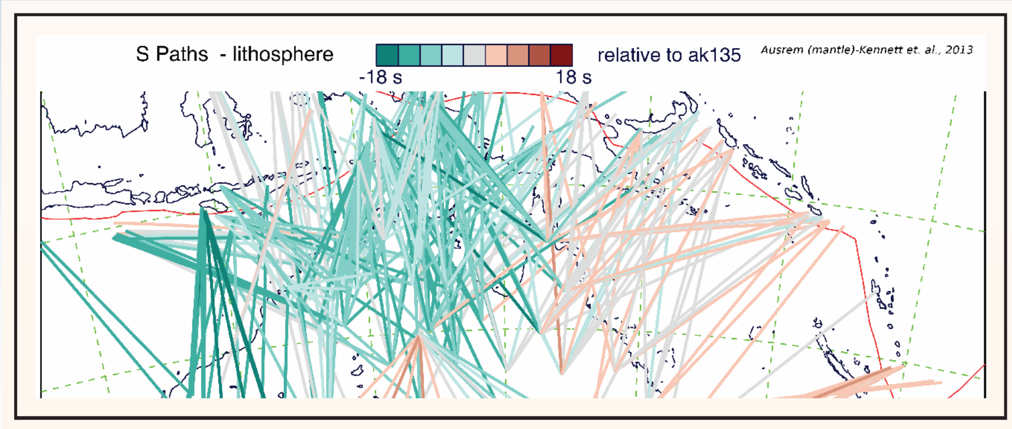
Indonesia 3

The group speed pattern at 48 s period shows considerable similarity with the AuSREM mantle velocities across the same region (Kennett et al., 2013)





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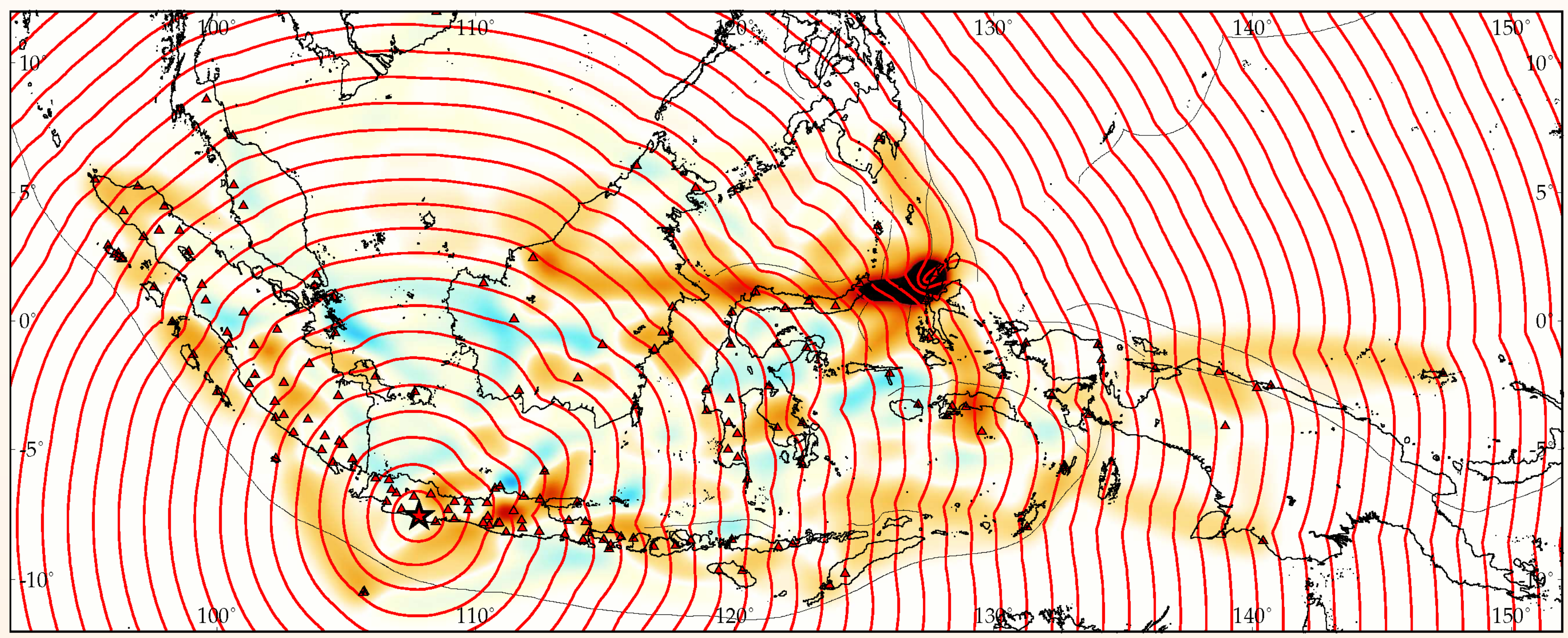
Indonesia 4

- Region with highly heterogeneous structure and very strong contrasts in group speed



Propagation for Rayleigh wave at 10 s period

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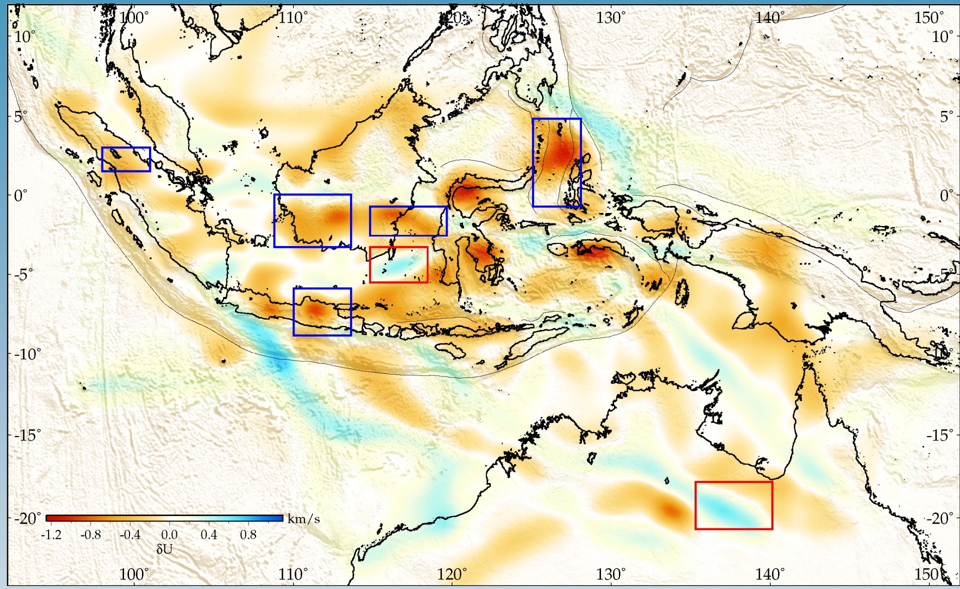
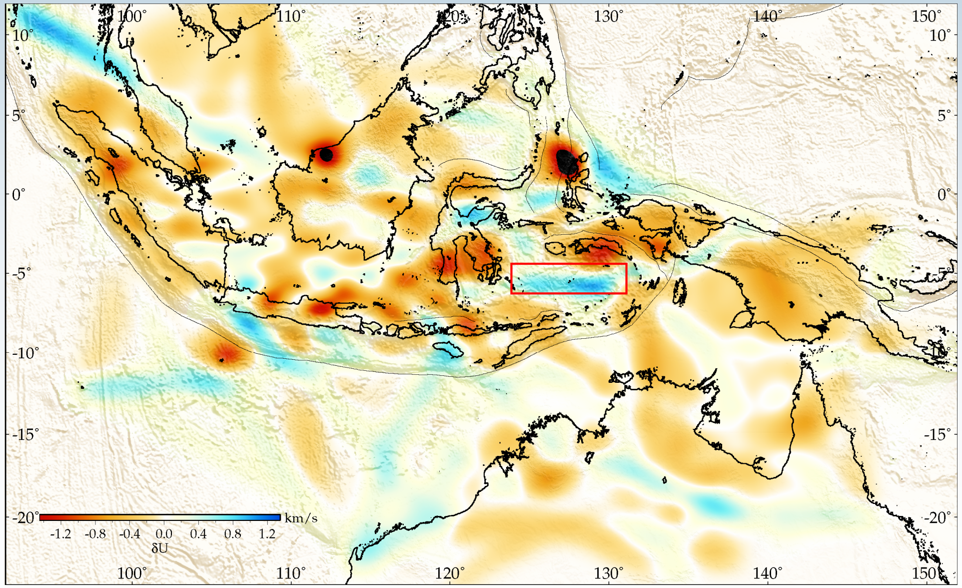
Indonesia – 12, 20 s period

12 s
Ref: 2.8 km/s



20 s
Ref: 3.0 km/s



Group speed perturbations from reference

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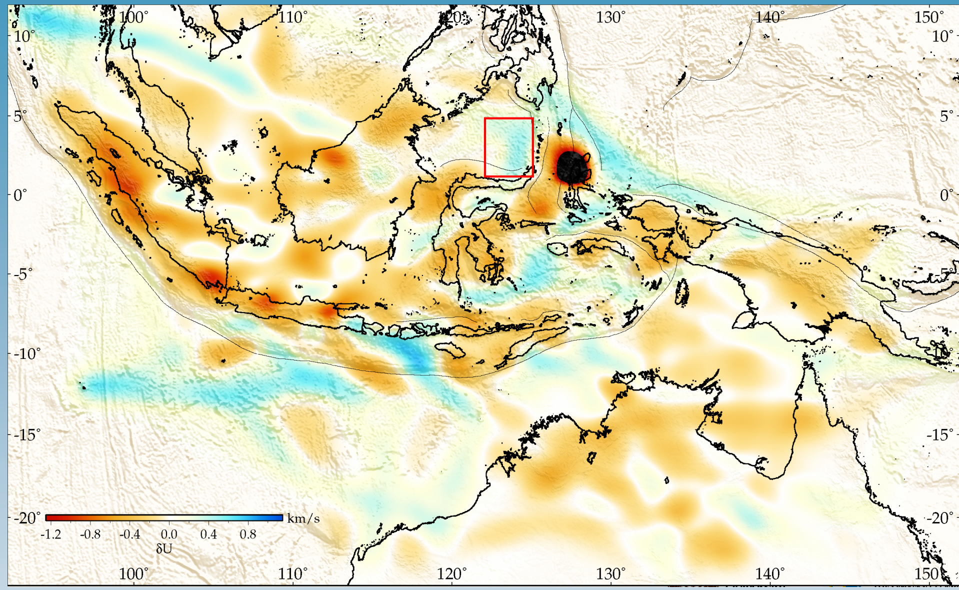
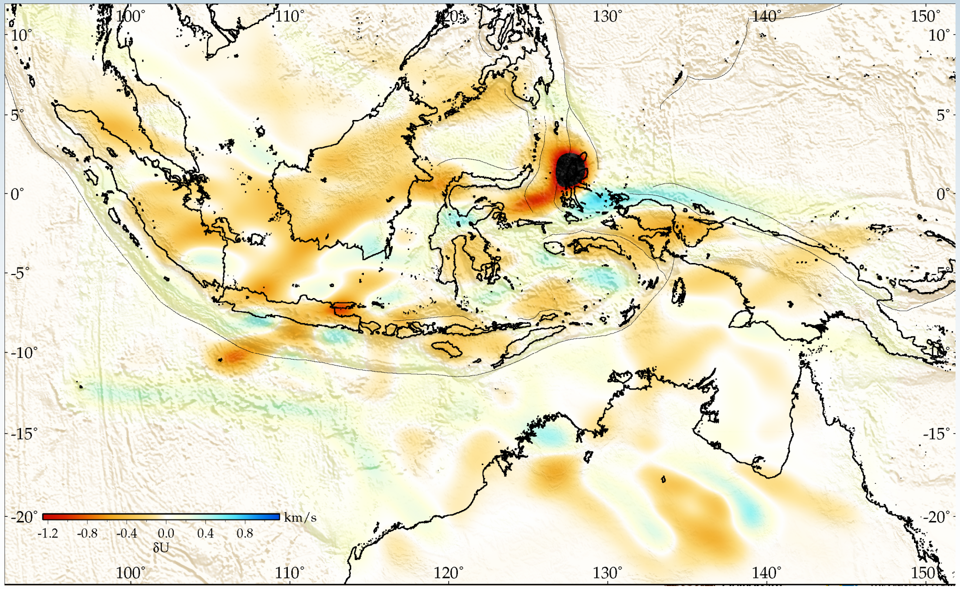
Indonesia – 30, 40 s period

30 s
Ref: 3.1 km/s



40 s
Ref: 3.4 km/s



Group
speed
perturbations
from
reference

Conclusions

- Stacked station transfer functions represent a useful strategy for enhancing bandwidth of empirical Green’s functions.
- Energy tracking via wavefronts in group speed model proves an effective imaging tool.
- Crustal contrasts are frequently too large and rapid to allow inversion of local dispersion for 1-D structure
- Need improved theoretical tools to tackle the case of large heterogeneity

QUEST in Australia