Can Teleseismic Travel-Times Constrain 3D Anisotropic Structure in Subduction Zones? Insights from Realistic Synthetic Experiments

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NEw Window InTO Earth's iNTerior

Summary

- Unmodeled anisotropic structure can generate significant artefacts in teleseismic body wave images (e.g. Bezada et al., 2016)
- We evaluate the ability of teleseismic P-wave travel-time tomography to recover realistic isotropic and anisotropic subduction zone structure
- Summary of main results:
  - Teleseismic P-waves can constrain lateral and depth variations in the azimuth and dip of mantle anisotropy
  - While anisotropic structure can be recovered, isotropic artefacts remain particularly if only azimuthal anisotropy is considered
  - SKS splitting intensity can be incorporated into P-wave inversions to better constrain azimuthal anisotropy patterns

Methods: Synthetic Data

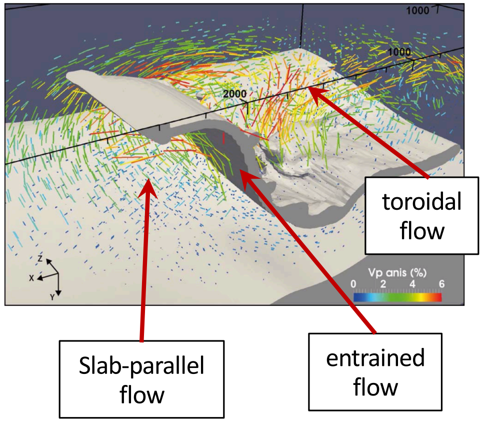
❖ Create anisotropic elastic model from geodynamic simulation of subduction (Faccenda, 2014)

❖ Model teleseismic wavefield through model using SPECFEM + AxiSEM
- 15 s double couple source

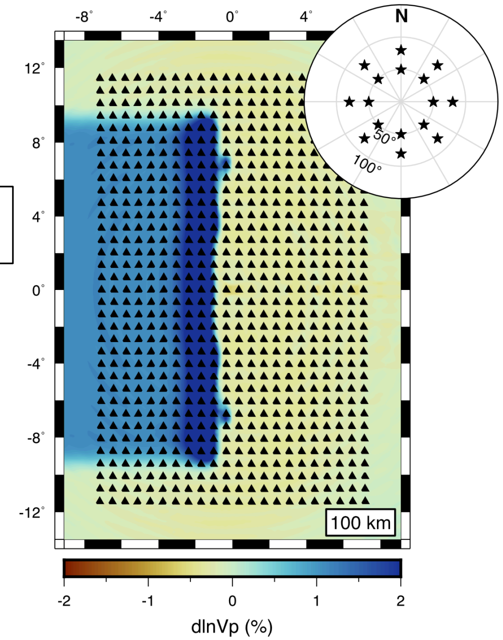
❖ 770 receivers spaced 75 km apart record the wavefield generated from 16 sources evenly distributed in back-azimuth and range
- P arrivals picked via cross-correlation (VandeCar and Crosson, 1990)

❖ Synthetic data is independent of inversion algorithm

Geodynamic Model: Slab + P-wave anisotropy



Synthetic Experiment Geometry



Methods: Tomography

- Use common sinusoidal approximation for hexagonal anisotropy:

$$v = v_i[1 + f(2[\cos(\theta)\cos(\gamma)\cos(\phi - \psi) + \sin(\theta)\sin(\gamma)]^2 - 1)]$$

- Simplified parameterization for SKS splitting intensity assuming azimuthal anisotropy and near vertical ray paths:

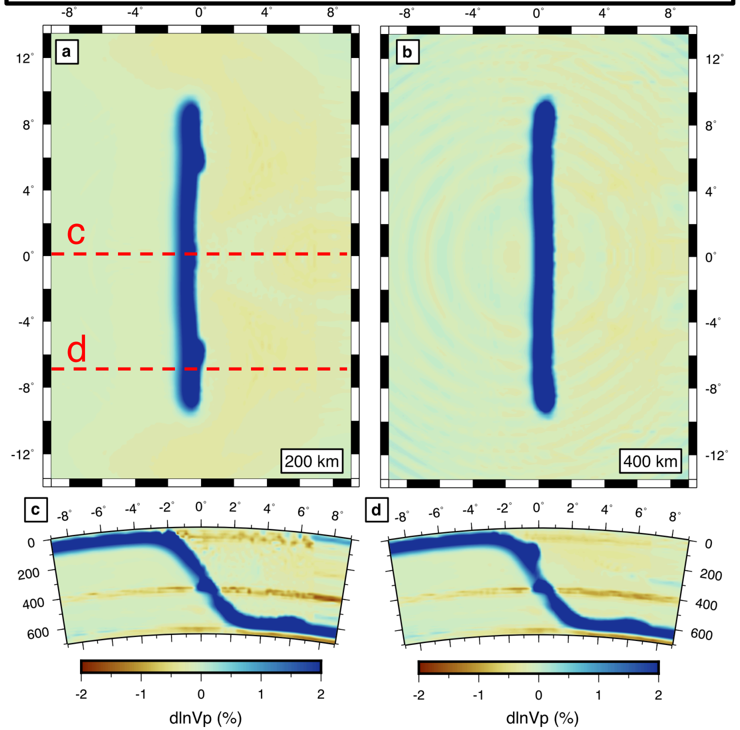
$$si = 2rLu_i[A\sin(2\lambda) + B\cos(2\lambda)]$$

- The *A* and *B* terms control anisotropy orientation and P-wave anisotropic magnitude; fixed ratio of P-to-S anisotropic fraction (*r*) is assumed
- Inversion includes approximate anisotropic finite-frequency kernels
- This presentation focuses on inversion results; method details will be presented in manuscript currently in preparation for *Geophys. J. Int.*

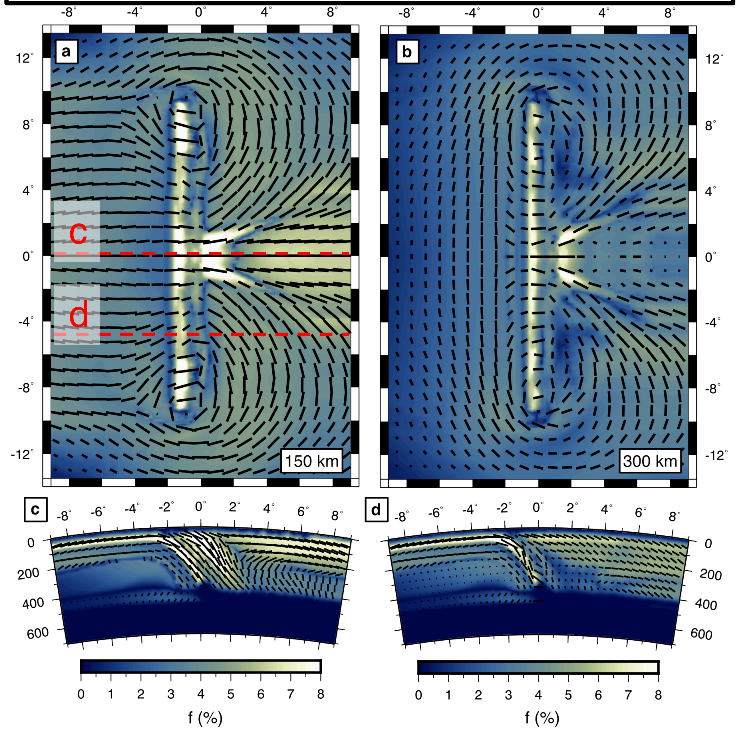
$v_i = $ *mean velocity*
$f = $ *anisotropic fraction*
$\psi = $ *symmetry axis azimuth*
$\gamma = $ *symmetry axis elevation*
$\phi = $ *ray azimuth*
$\theta = $ *ray elevation*
$\lambda = $ *polarization azimuth*
$L = $ *ray segment length*
$u_i = 1/v_i$

True Model

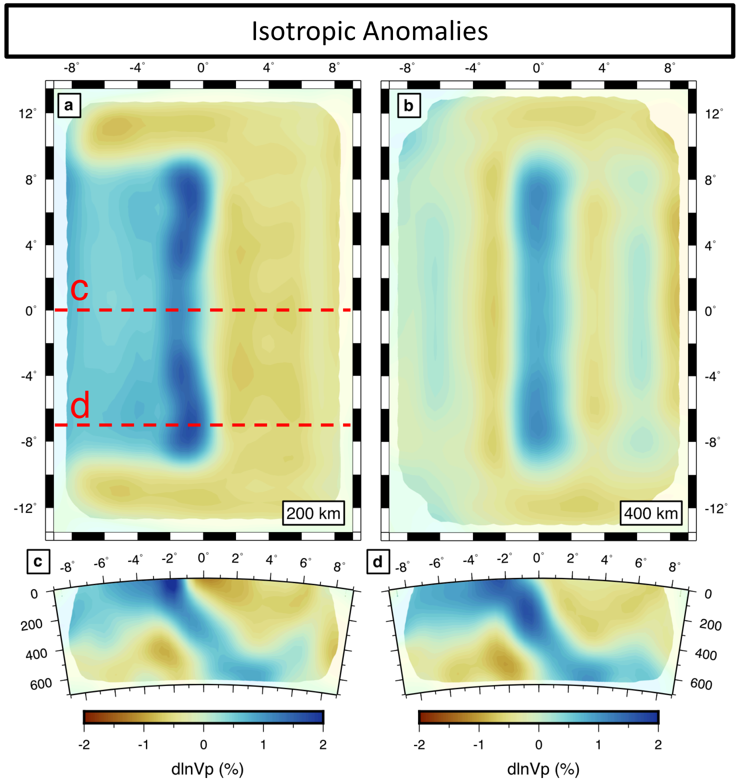
Isotropic Anomalies



Anisotropic Magnitude and Orientation

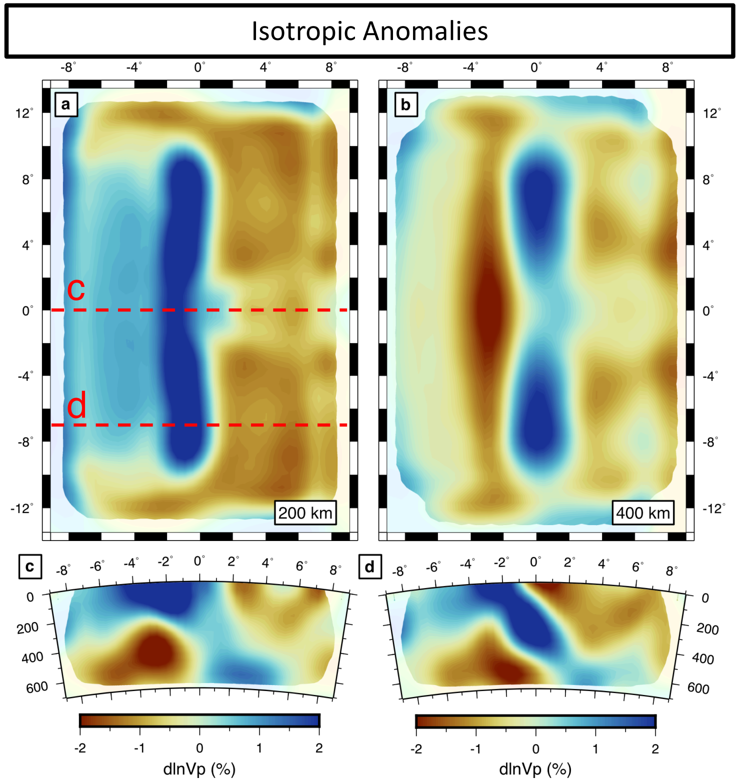


Isotropic Inversion of Isotropic Data



- In this case, inverting teleseismic data created with isotropic model
- Illustrates recovery of isotropic heterogeneity in absence of complications due to anisotropy
- Relative nature of teleseismic data requires that the fast slab be balanced by low velocity perturbations
- Low-velocity artefacts are small in amplitude and evenly distributed

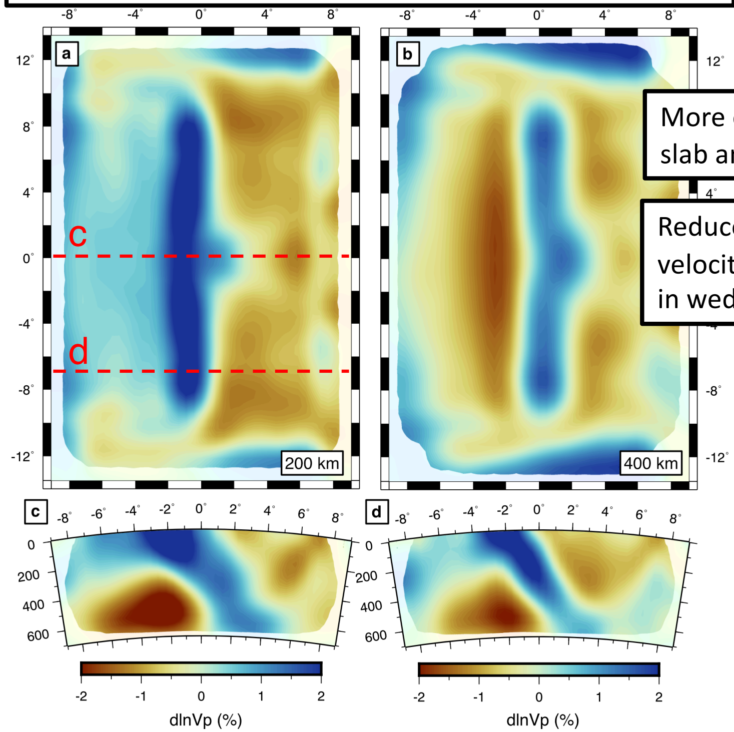
Isotropic Inversion of Anisotropic Data



- Significant distortion of slab geometry
- Significant increase in magnitude of low velocity artefacts
- Low velocity zones have stronger amplitude beneath the slab

Azimuthal Anisotropy Inversion

Isotropic Anomalies

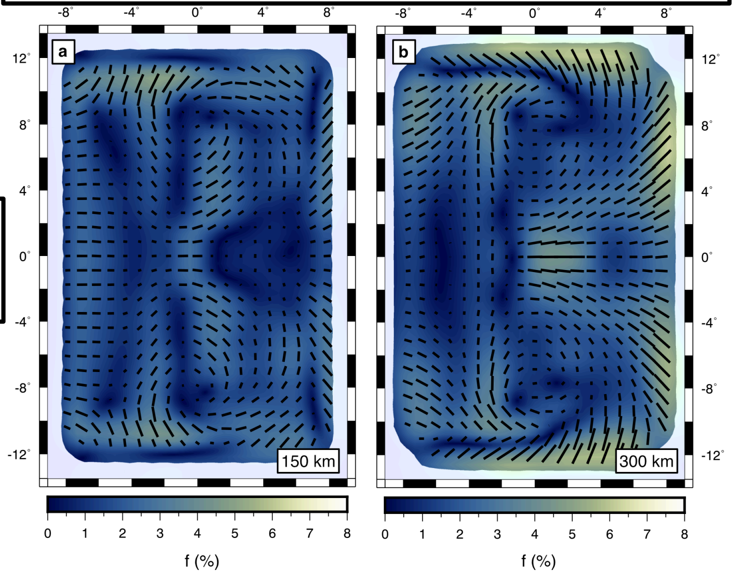


More continuous slab anomaly

Reduced low velocity artefacts in wedge

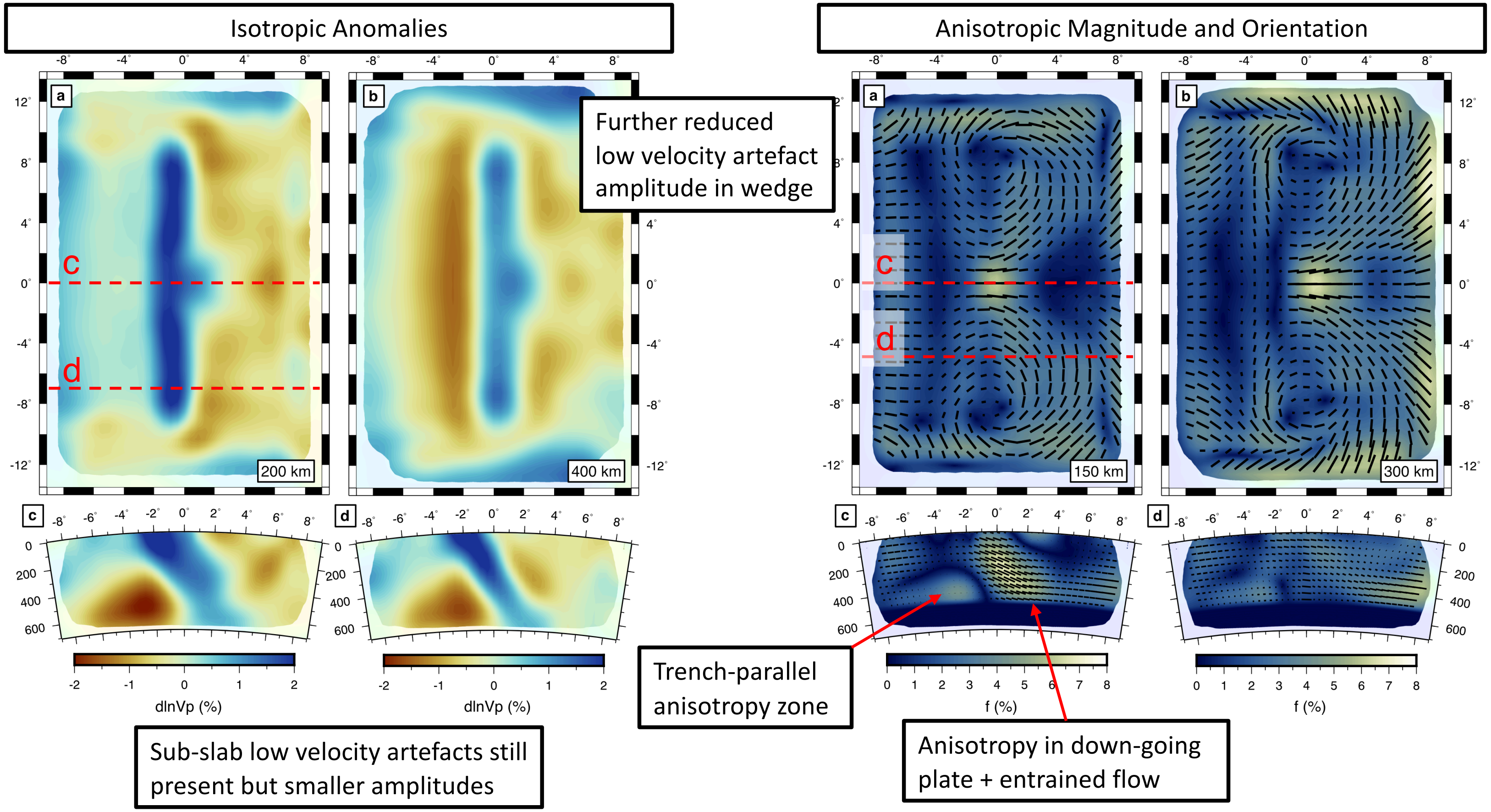
Sub-slab low velocity artefacts still present

Anisotropic Magnitude and Orientation

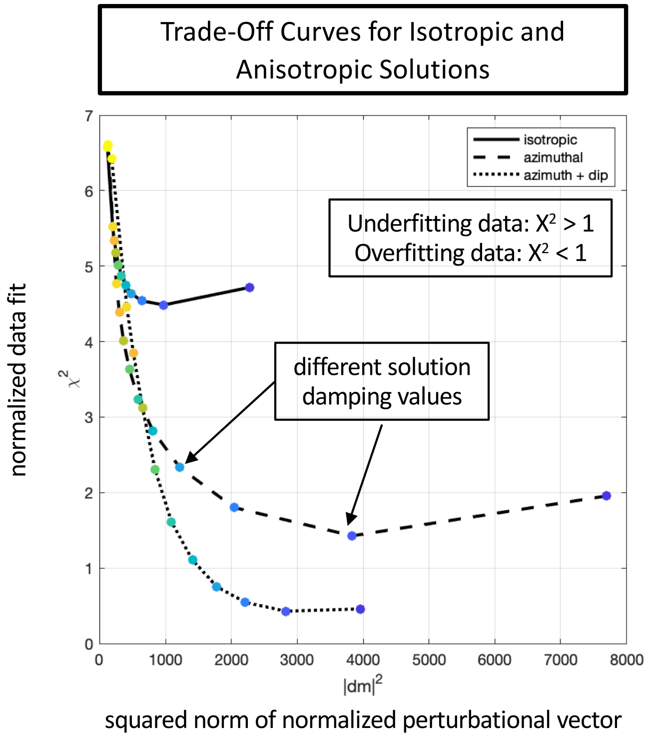


Toroidal flow pattern and transition from trench-normal to trench-parallel anisotropy imaged beneath down-going plate

3D Anisotropic Inversion

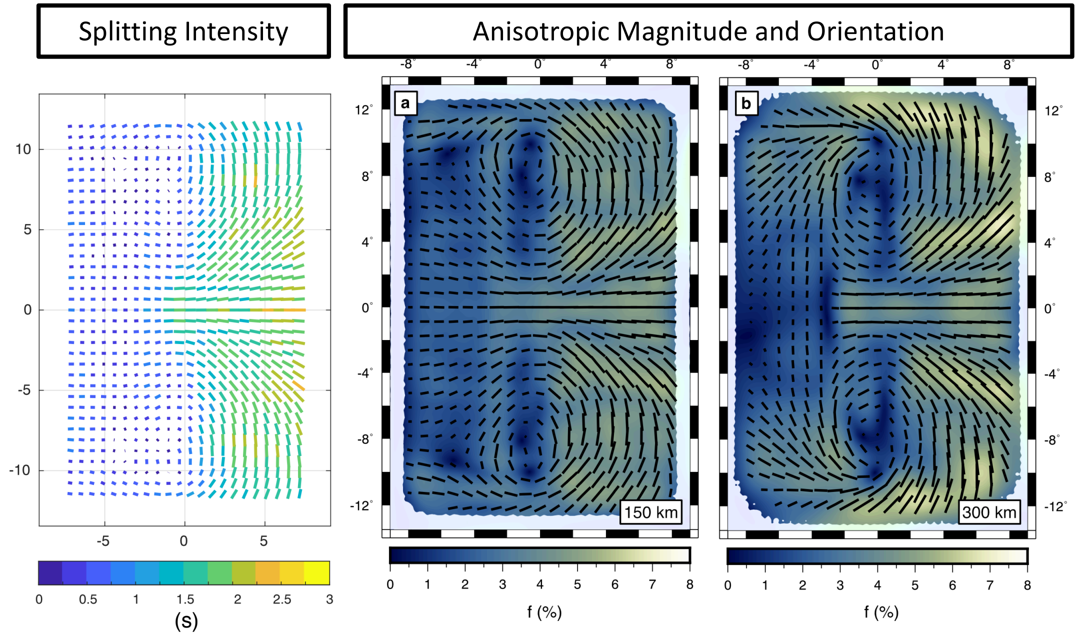


Data Fit



- ❖ Including anisotropy in inversion improves data fit
  - Expected since more model complexity is introduced
- ❖ For a given perturbational vector length, anisotropic solutions consistently yield better fit

P + SKS Joint Inversion for Azimuthal Anisotropy



- Inclusion of SKS splitting intensity measurements significantly improves recovery of azimuthal anisotropic structure
- Inversion uses additional 8 SKS events evenly distributed in back-azimuth at 120^o distance
- P Isotropic anomalies remain effectively identical to those previously shown (slide 8)

Conclusions

- Teleseismic P-waves can constrain 3D anisotropic structure but untangling anisotropic from isotropic structure remains a challenge
  - Low-velocity artefacts are persistent features
  - Reflect trade-off between symmetry axis dip and mean velocity
- SKS splitting intensity can be incorporated into P-wave azimuthal anisotropic inversions in a simple but effective manner
- Removing isotropic artefacts will require better starting models derived from prior geophysical or geodynamic constraints
- Caution should be exercised when inferring physical properties (e.g. temperature, melt) from subduction zone velocity anomalies derived from teleseismic delay times