Cooling of the oceanic lithosphere: new insights from 3D surface-wave tomography

[1]Latallerie F., [1]Koelemeijer P., [1]Walker A., [2]Maggi A., [2]Lambotte S., [2]Zaroli C.

[1]University of Oxford, [2]University of Strasbourg

Objectives

- To provide accurate images of the Pacific upper mantle with uncertainty and resolution in 3D;
- To draw inferences on the dynamics of the oceanic lithosphere-asthenosphere boundary;
- To image mantle upwellings in relation to hotspots.

Challenges

- Uneven data distribution and data errors lead to models with complex resolution and uncertainty;
- Classical 2-step approach treats lateral and vertical dimensions independently.

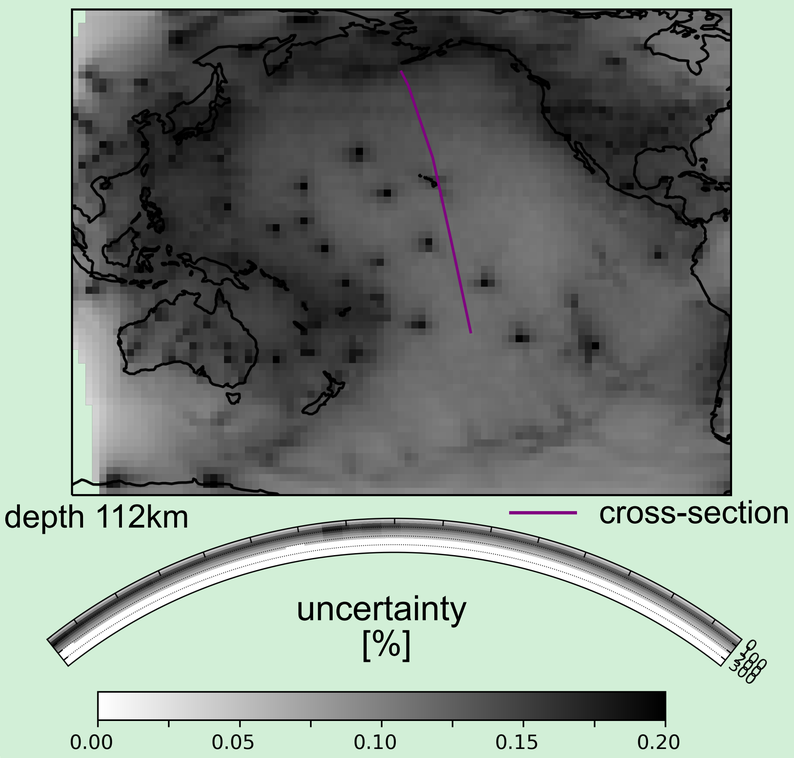
Approach

- Use Backus-Gilbert approach to control and produce resolution, uncertainty, and Vsv model;
- Use finite-frequency theory, for an accurate and fully 3D framework.

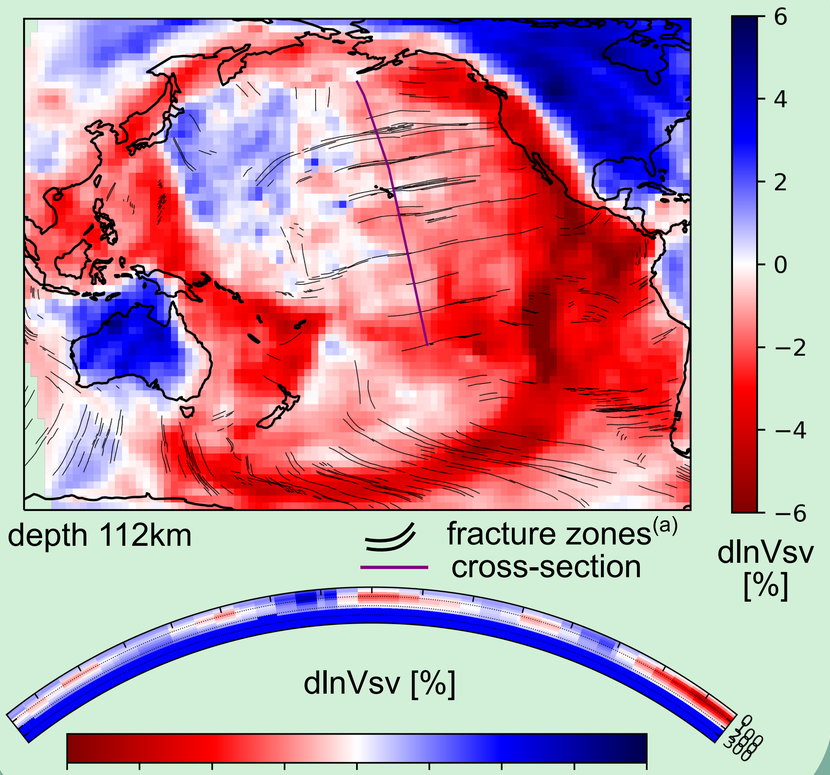
Key results

- Elongated anomalies align with fracture zones & age offsets;
- Significant slow anomalies correlate with hotspot locations;
- Strong resolution depth leakage.

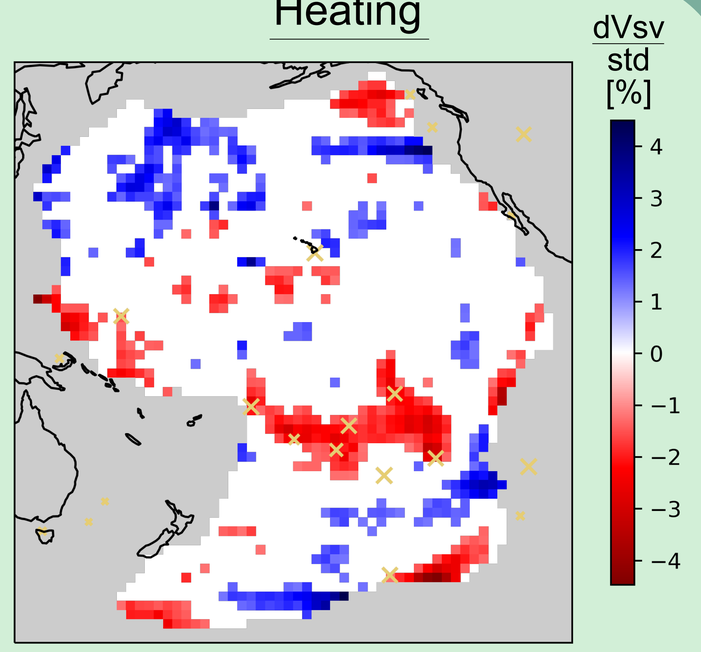
Uncertainty



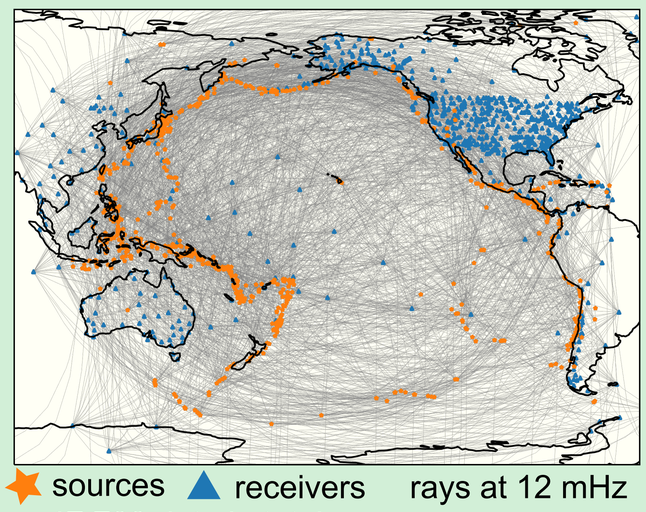
Cooling



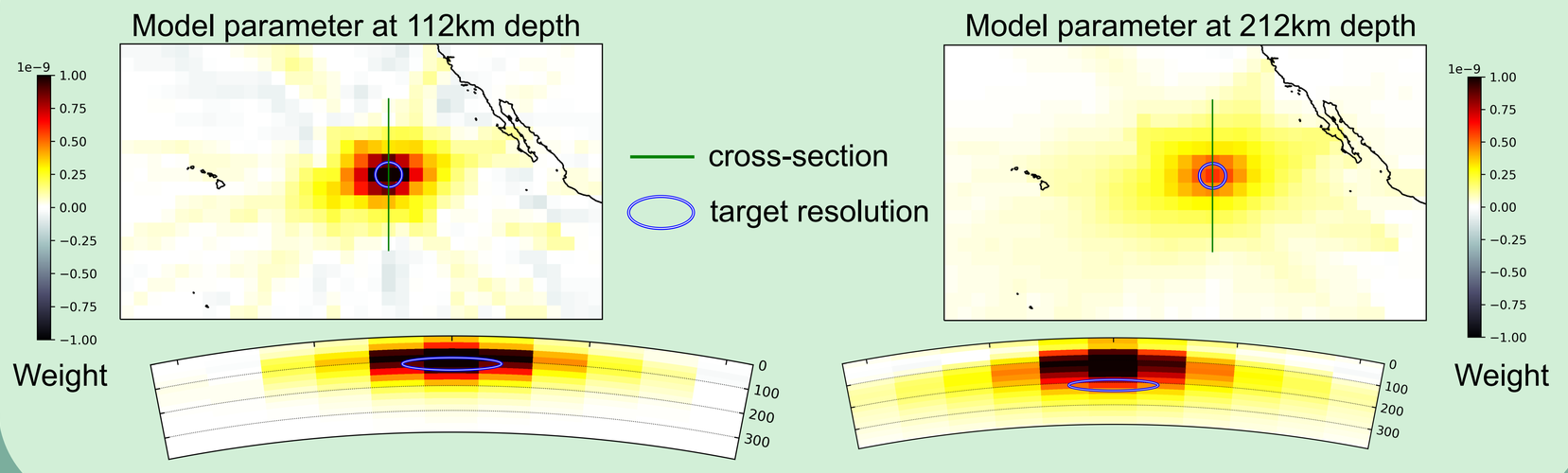
Heating



Data distribution



Resolution

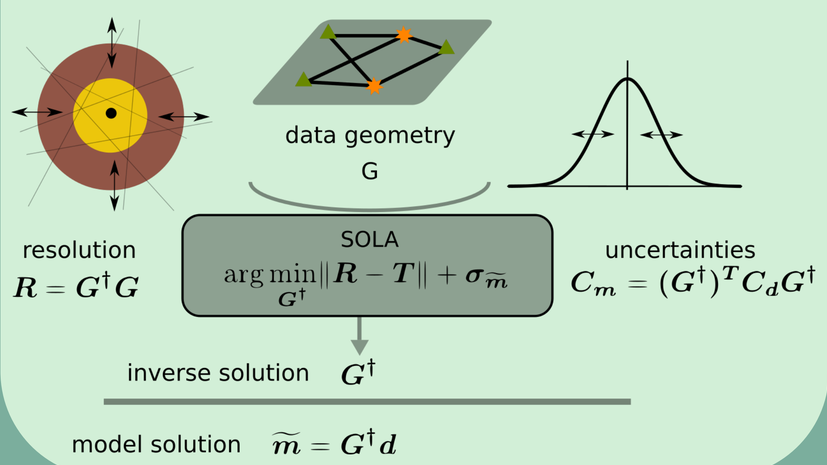


SOLA(c)

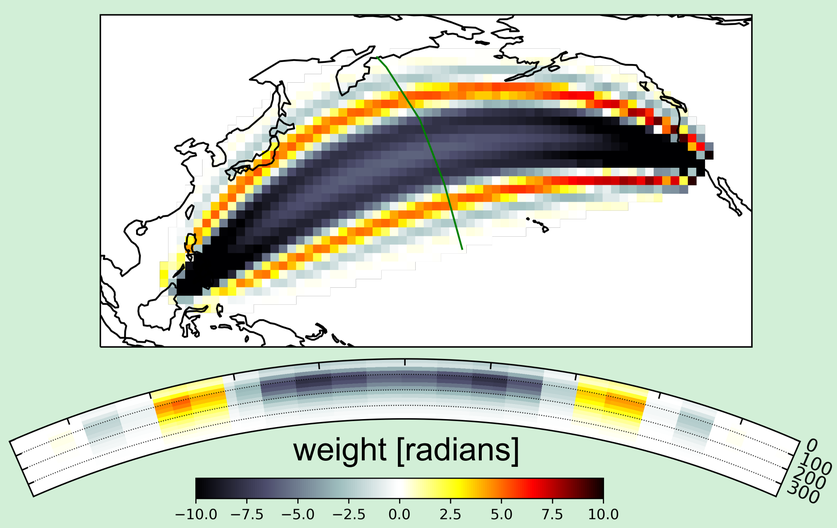
The data (d) are assumed to be linear combinations (G) of the true Vsv structure.

We look for linear combinations ($G^\dagger$) of data that can be interpreted as local averages ($\widetilde{m}$) of the true Vsv (m), and for which the propagation of data uncertainty (C_d) into model uncertainty (C_m) is low.

$$d = Gm \qquad \widetilde{m} = G^\dagger d \qquad G^\dagger \ ?$$



3D Finite-frequency(d)



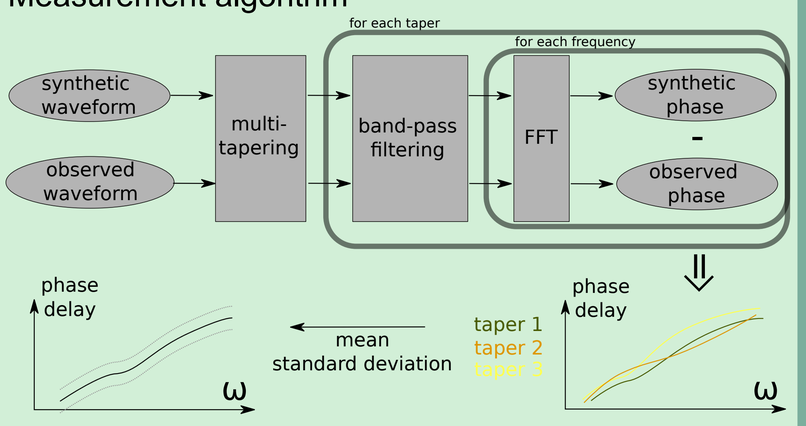
Example sensitivity kernel at 12 mHz, at 112km depth.

$$\delta\phi(\omega) = \iiint_{\oplus} K(\omega; \boldsymbol{x}) \delta V_{SV}(\boldsymbol{x}) d^3\boldsymbol{x}$$

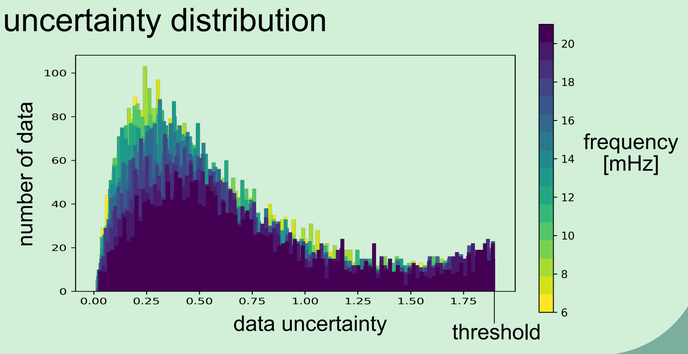
Volumetric sensitivity of fundamental-mode Rayleigh-wave phase-delays to Vsv (6, 7, .., 21 mHz).

Data & uncertainty

Measurement algorithm



Data uncertainty distribution



franck.latallerie@earth.ox.ac.uk

https://users.earth.ox.ac.uk/~eart0587/index.html

@flatallerie.bsky.social

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(b) Latallerie et al., in revision, https://doi.org/10.31223/X5FM79
(c) Zaroli, C, 2016, doi: 10.1093/gji/ggw315
(d) Zhou, Y., 2009, doi: 10.1111/j.1365-246X.2008.04010.x

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Seismic source solutions are obtained from www.globalcmt.org (Dziewonski et al., 1981; Ekstrom et al., 2012).
Waveforms and related metadata are obtained from the facilities of the EarthScope Consortium (National Science Foundation's Seismological Facility for the Advancement of Geoscience (SAGE) Award under Cooperative Agreement EAR-1724509).
Networks: 1P, 6E, 7A, 7C, 7D, AE, AI, AK, AR, AT, AU, AV, AZ, BK, C, C1, CB, CC, CI, CM, CN, CU, DK, G, GG, GS, GT, IC, II, IM, IU, JP, KS, LB, LD, MI, MM, MX, MY, N4, NA, NE, NM, NN, NR, NU, OO, PB, PE, PN, PR, PS, PY, RM, RV, S1, SC, SV, TA, TM, TW, TX, UO, US, UW, WI, XF, XV, XZ, Y6, YP, YU, Z7, ZL.
Reference waveforms in a 1D radial model are computed with MINEOS (G. Masters, et al., Mineos v1.0.2, https://geodynamics.org/cig, 2011)