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Thermal and Chemical Properties of the Mantle Transition Zone from Seismic Observations

Saskia Goes[1], Chunquan Yu[2], Ross Maguire[3], Elizabeth Day[1], Rob van der Hilst[4], Jeroen Ritsema[5], and Jing Jian[4],

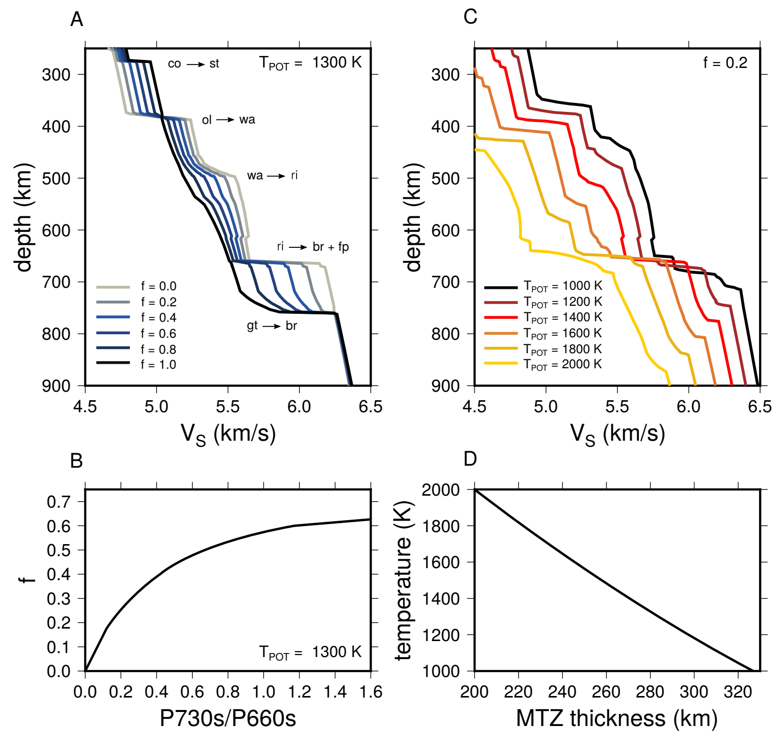
Background

- The mantle transition zone (MTZ), bounded by *410* and *660* discontinuities, is a key region to understand the thermal, chemical, and dynamical evolution of the mantle.
- Mantle dynamics is primarily thermally driven and the topography of *410* and *660* has been widely used to infer the temperature of the MTZ. However, in a number of recent studies we have found that properties of transition-zone discontinuities may also provide insight in the distribution of compositional heterogeneity.

Synthetic Velocity Profiles

Fig. 1

Systematic variations of discontinuity strengths and depths are expected as a function of composition (expressed as the fraction of basalt, *f*, in a mechanical mixture of basalt and harzburgite in A,B) and temperature (expressed as potential temperature of mantle adiabats, C,D) (from *Maguire et al.*, 2018)



SS and PP precursors

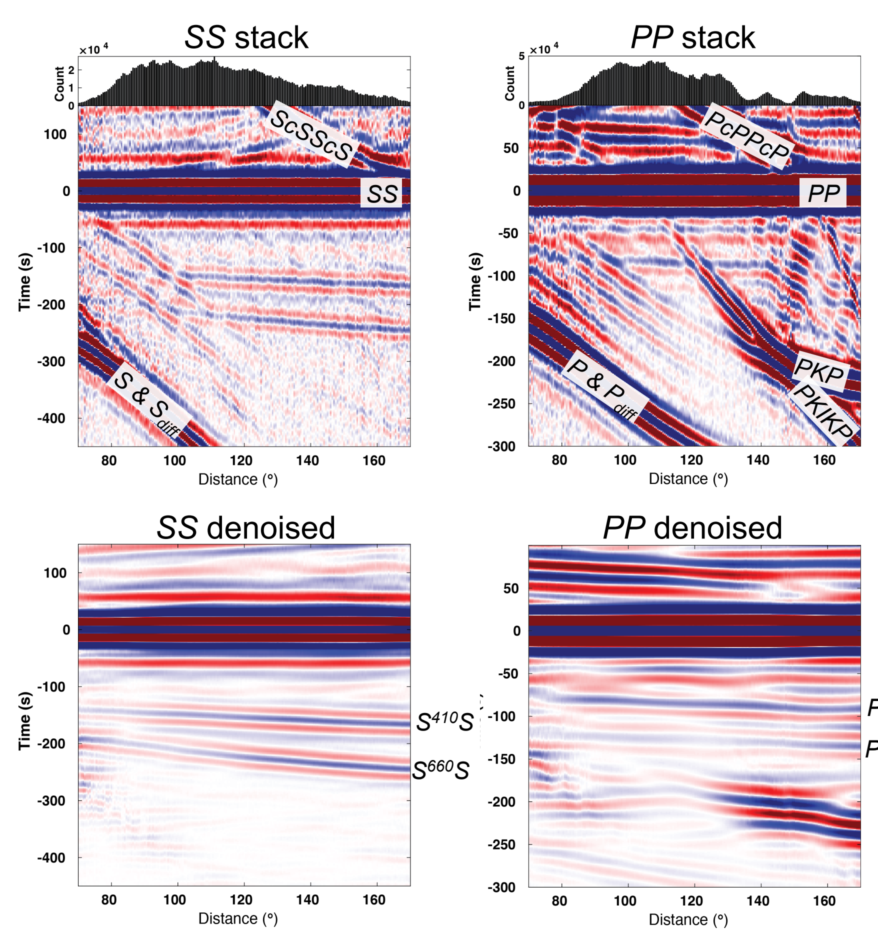


Fig. 2

Preliminary results from a global study of *PP* and *SS* precursors using a curvelet-based seismic array processing technique (*Yu et al.*, JGR 2018), where we successfully extract $P^{660}P$ signals.

Global Amplitude vs Offset

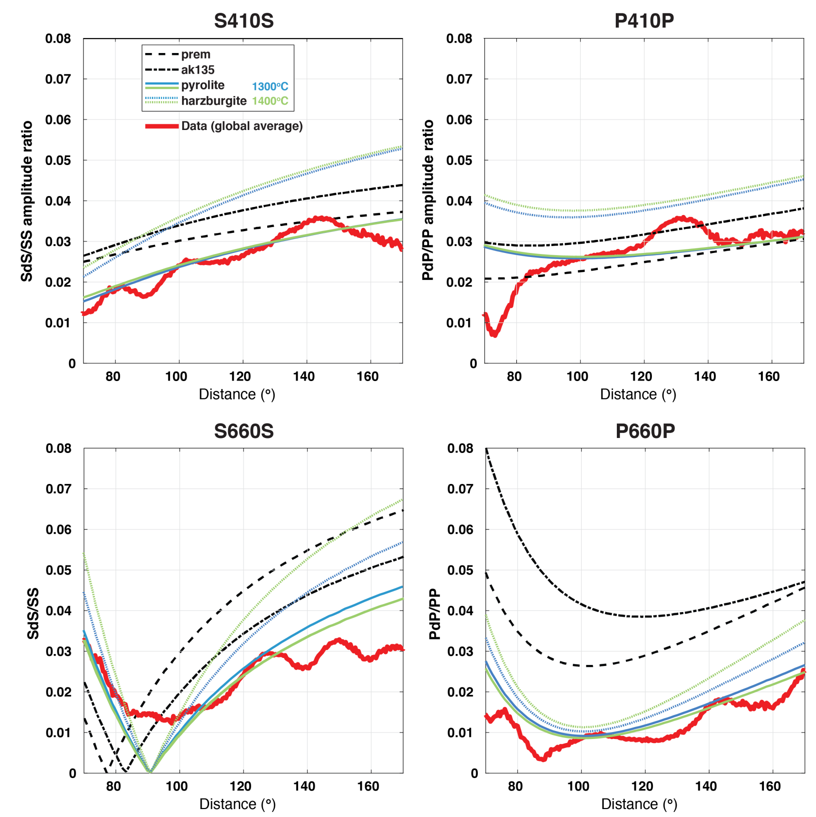
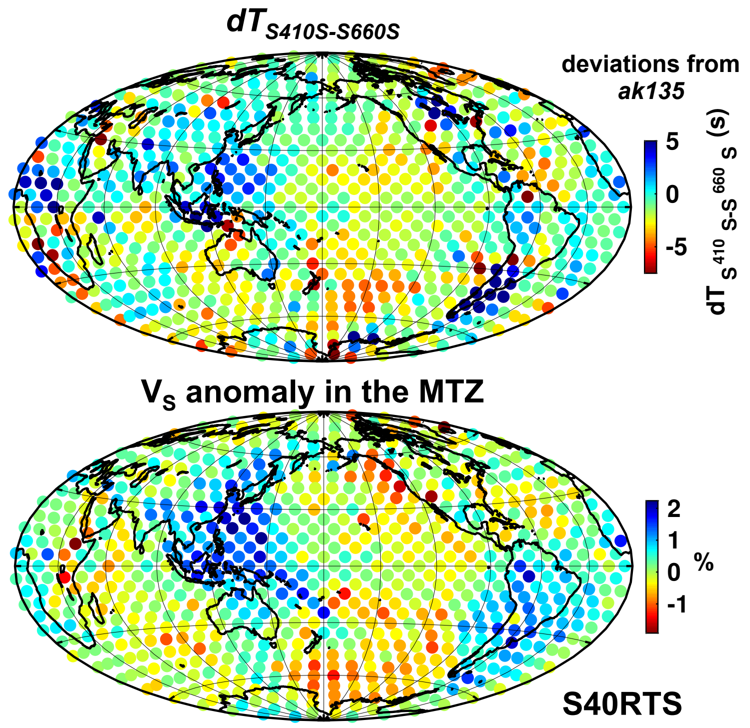


Fig. 3

Global trends of SdS/SS and PdP/PP amplitude ratios are consistent with predictions from a **pyrolitic mantle transition zone**. Effects of geometrical spreading, attenuation and incoherent stacking are not considered in these calculations. The results can not distinguish between cooler (1300°C) or hotter (1400°C) potential mantle temperature

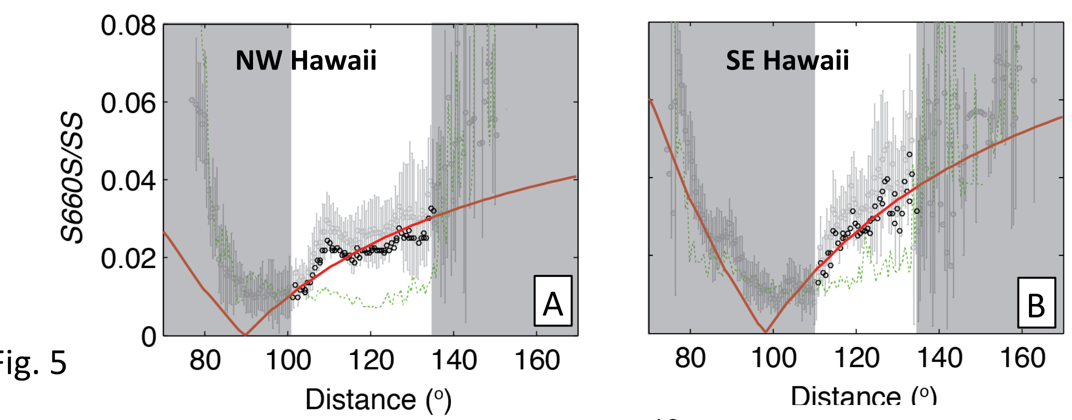
Fig. 4

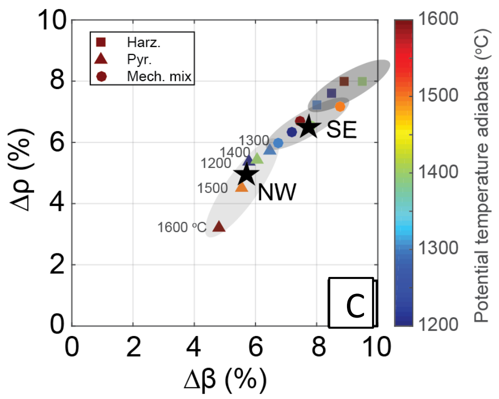
travel time difference across the MTZ (after moveout correction to 130°) is positively correlated with **velocity anomalies within the MTZ** (from S40RTS, *Ritsema et al.*, 2011). Both of them are likely **controlled by thermal anomalies**.
Mean: dT = -0.7s (relative to *ak135*) => MTZ thickness = 248 km => ~1350°C adiabat



Regional Evidence for Heterogeneity

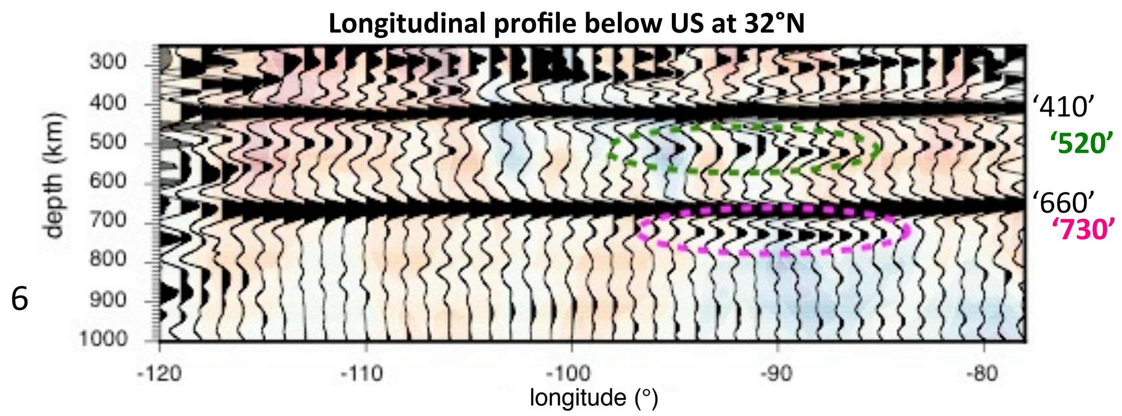
Fig. 5





S660S/SS amplitude ratios from **curvelet filtering**, after correction for geometric spreading, intrinsic attenuation and incoherent stacking for two regions with high data density, **NW** (A) and **SE** (b) **of Hawaii**. Red curves shows how predicted reflection coefficients for our best fitting models are clearly **different** for the two regions. Comparison with corresponding **density** and **velocity jump**s around **660 km** from models as in Fig. 1 are shown in panel C (*Yu et al.* 2018)

Fig. 6



Longitudinal cross section through **P-to-S receiver-function** CCP volume below the US. Background tomography from Schmandt and Lin (2014). Regional high-amplitude discontinuities around **520** and **730 km depth** could be due to **enhanced hydration** and concentrations of **basaltic materia**l, respectively. Both signatures might be a record of recent Farallon subduction (*Maguire et al.*, 2018).

Key Points

- Comparison of $P^{660}P$ amplitude-distance trends with thermodynamic models suggests that on a **global** scale, **amplitude trends of *SS* and *PP* precursor**s from both *410* and *660* are consistent with predictions from a **pyrolitic mantle transition zone**
- **Global variation in MTZ thicknes**s has a positive correlation with velocity anomalies within the MTZ, consistent with a control by **variable transition zone temperatures.**
- In an application of this method to data from **Hawaii**, we however found evidence of **compositional variations**, consistent with the analysis of tomographic images below a few other hotspots
- Further **compositional heterogeneity** linked to **recent subduction** has been found from a receiver-function study below the US
- Results thus indicate a quite **well mixed background mantle** with more **heterogeneity in areas of recent up-and downwelling**.

- R. Maguire, J. Ritsema, S. Goes, *Geophys. Res. Lett.*, *2017* doi:10.1002/2017GL073120;
- R. Maguire, J. Ritsema, S. Goes, *Geophys. Res. Lett.*, 2018: doi:10.1029/2018GL078378;
- C. Yu, E. Day, M. de Hoop, M. Campillo, S. Goes, R. Blythe, R. van der Hilst, *Nature Comms.,* 2018 . doi: 10.1038/s41467-018-03654-6.
- C. Yu, E. Day, M. de Hoop, M. Campillo, R. van der Hilst, *J. Geophys. Res.* 2018., doi: 10.1002/2017JB014327.

[1]Imperial College London UK, [2]Southern University of Science and Technology, Shenzhen, China, [3]University of New Mexico, USA, [4]Massachusetts Institute of Technology, USA, [5]University of Michigan, Ann Arbor, USA.