The upper-mantle structure beneath Alaska imaged by teleseismic S-wave reverberations

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Abstract

Alaska is a tectonically active region with a long history of subduction, but knowledge of its deep seismic structure is limited by a relatively sparse station distribution. By combining data from the EarthScope Transportable Array and other regional seismic networks, a high-resolution state-wide map of the Moho and upper-mantle discontinuities beneath Alaska is obtained using teleseismic SH-wave reverberations.

Crustal thickness is generally correlated with elevation with the Yakutat region having the deepest Moho, consistent with its more mafic composition and higher density. The crustal thickness in the Brooks Range is consistent with gravity measurements and predictions based on Airy isostasy theory, suggesting a state of isostatic equilibrium without the need to introduce density anomalies.

The 410- and 660-km discontinuities are also resolved in most regions, with a thickened mantle transition zone (MTZ) under central Alaska, suggesting that the slab may have entered the MTZ, and a thinned MTZ under the Alaska Peninsula region, suggesting a slab above the MTZ. The inferred varying depths of slab under Alaska is also supported by tomography and receiver-function studies.

Background, Method and Dataset

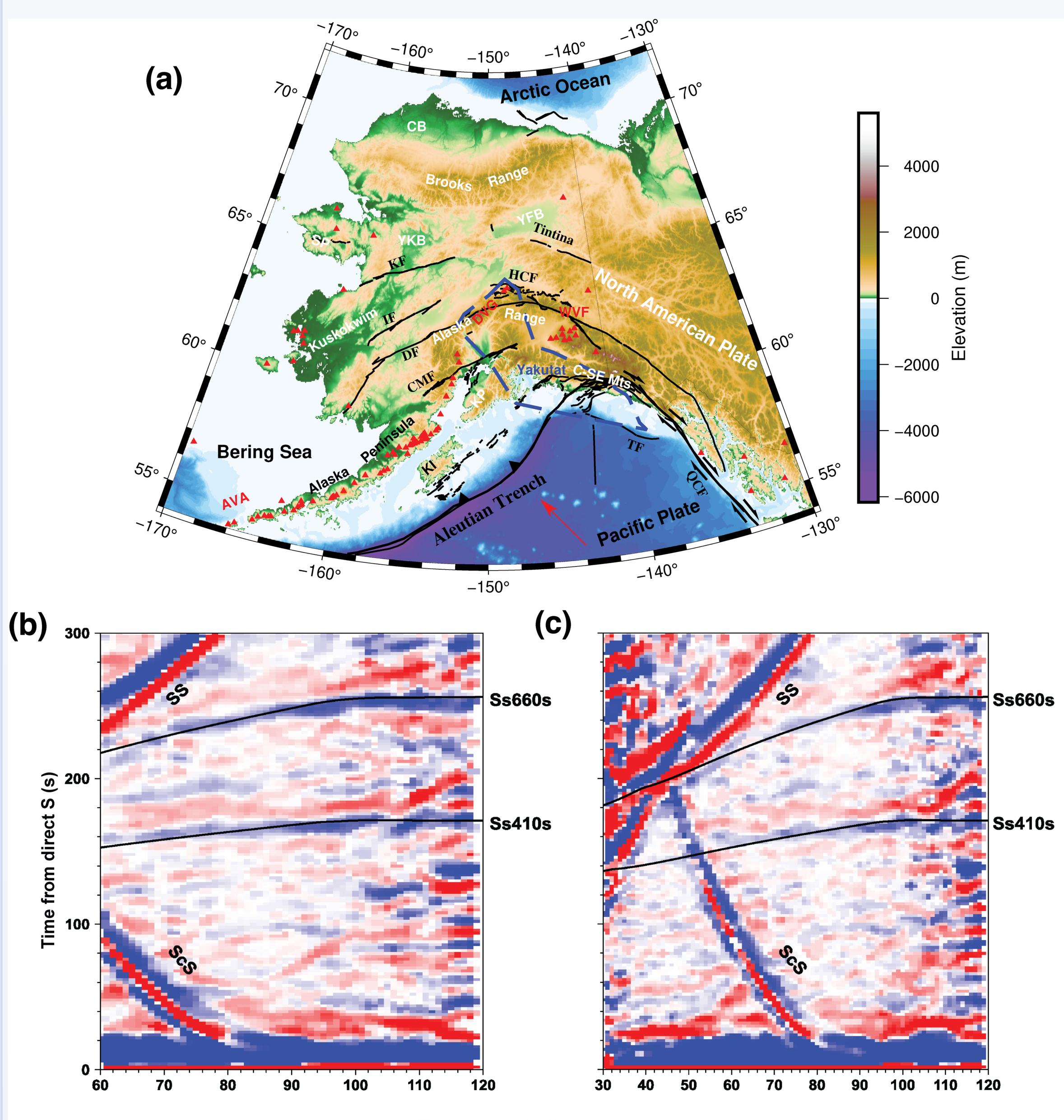

Fig.1 (a) Map of the research region. Tectonic features mentioned in this poster: AVA, Aleutian volcanic arc; Yakutat, Yakutat microplate. (b) and (c) are record section stacks of high-quality traces for the 10-s and 5-s lowpass datasets, respectively, aligned and normalized on direct S, with the black curves denoting the predicted topside S-reflections at 410- and 660-km depths based on the iasp91 model.

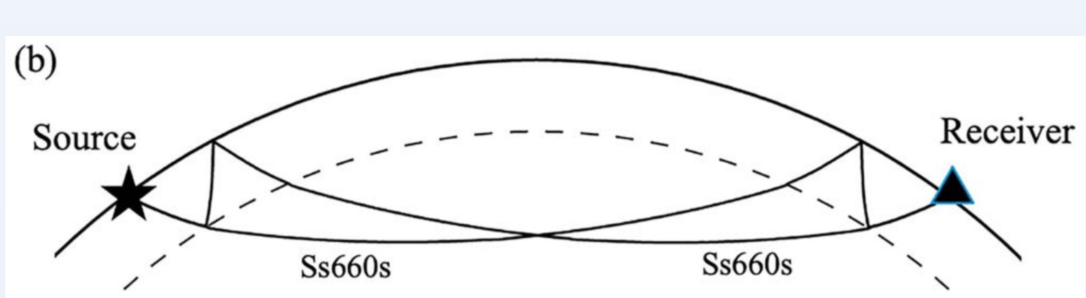

Fig. 2. Ss660s raypaths for both near-source and near-receiver reflections

Common-reflection-point method

- 120°~180° W, 50°~75° N, 4° (lon) ×2° (lat) cells with 2° and 1° overlaps
- Separate source and receiver-side contribution by inversion (Shearer and Buehler, 2019)
- 5-s lowpass for the crust, 10-s lowpass for the MTZ
- Only plot cells contributed by >100 bounce points

Crust

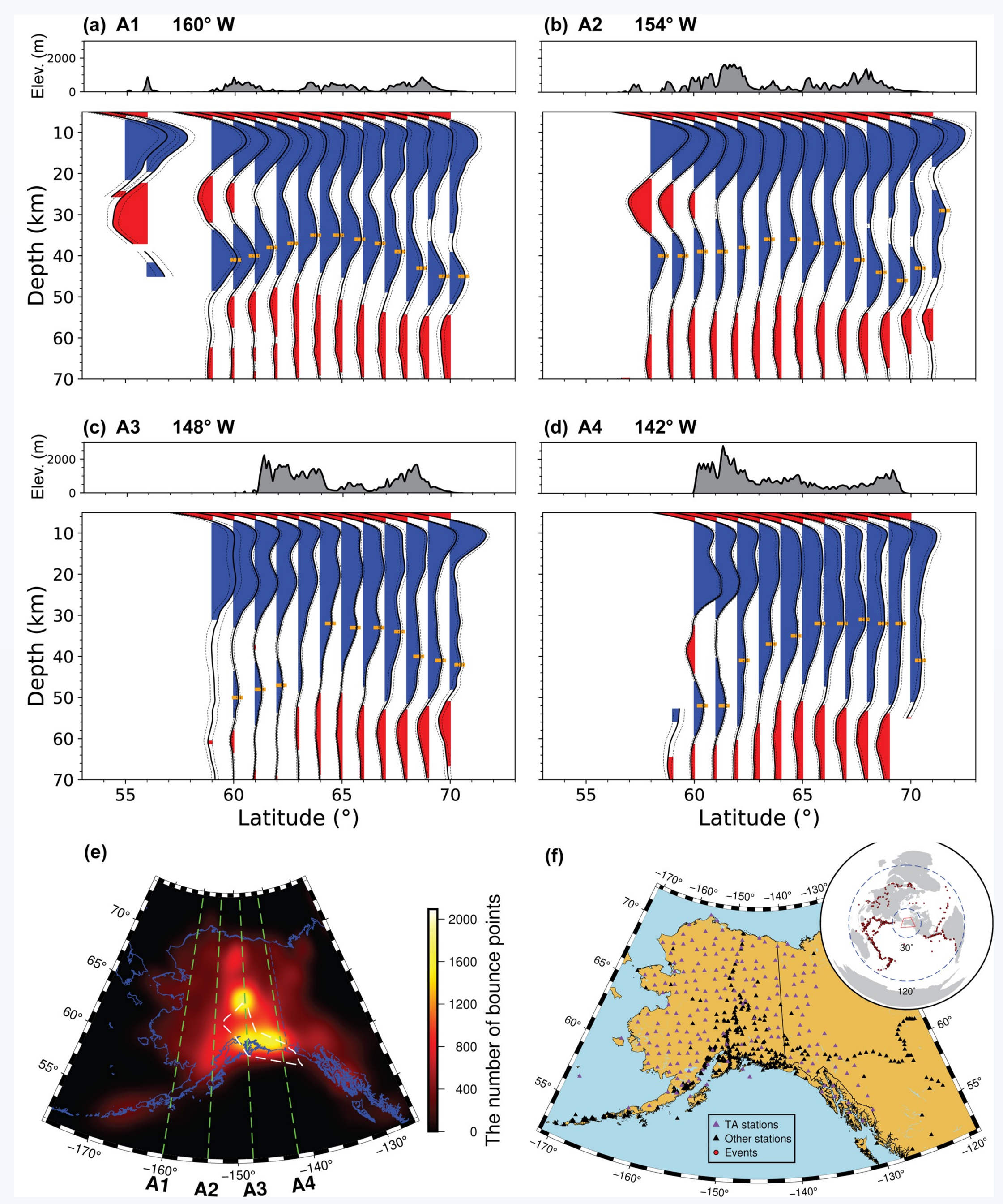

Fig. 3. Cross sections (a-d), bounce points (e) and stations and events (f). Corrected using CRUST 1.0 model (Laske et al., 2013).

- Crust: thick in northern and southern mountains and thin in central lowlands
- Negative pulses in the southwest: subparallel to the AVA & consistent with tomography → low-velocity layer
- Double peaks near Yakutat: shallower peak → top interface of Yakutat plate; deeper peak → Yakutat Moho

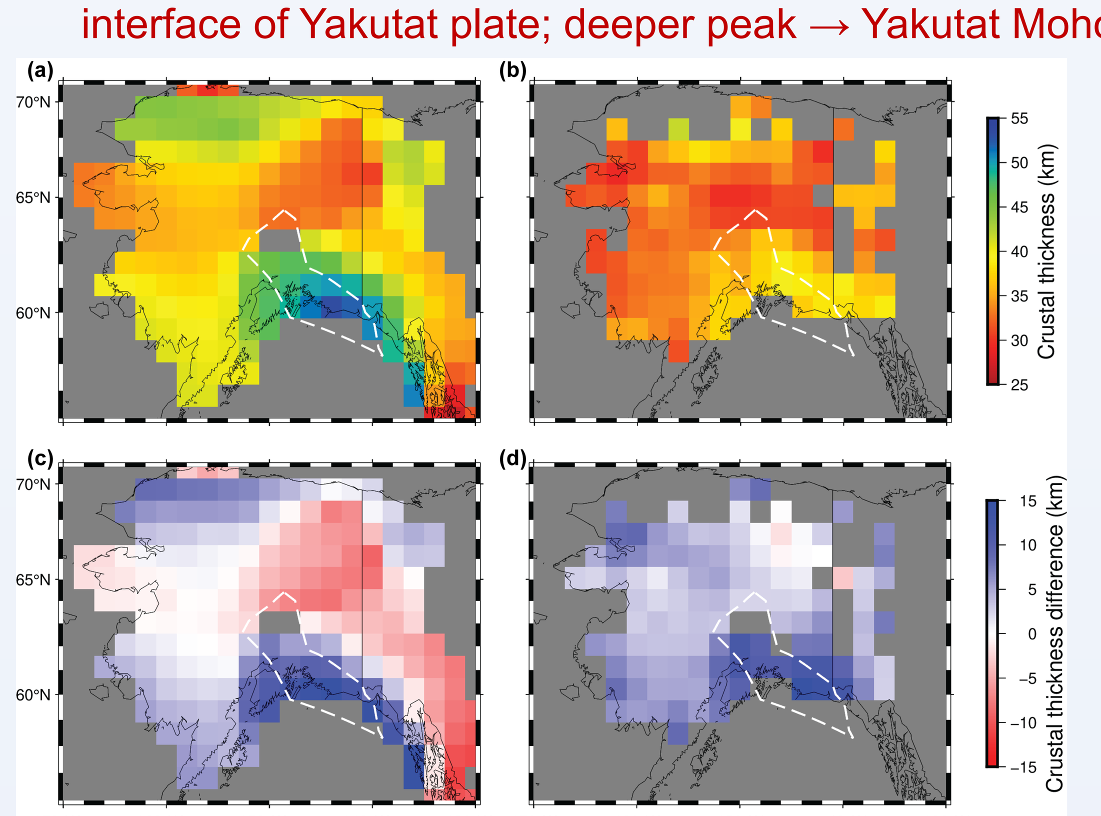

Fig. 4. Crustal thickness in our study (a) and Zhang et al. (2019) (b) Crustal thickness between ours and prediction based on isostasy theory (c), between ours and Zhang et al. (2019) (d).

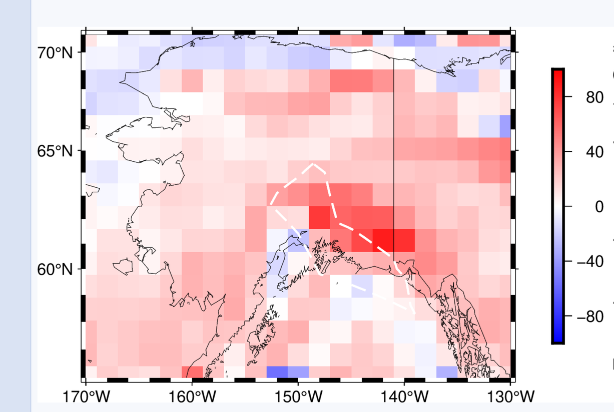

Fig. 5 Free-air gravity anomaly

- Yakutat (dashed line): Thicker crust than prediction & High free-air gravity anomaly → Higher density of the Yakutat plate
- Brooks Range: Weak crustal difference & Weak gravity anomaly → Isostatic equilibrium w/o introducing density anomaly

Mantle Transition Zone (MTZ)

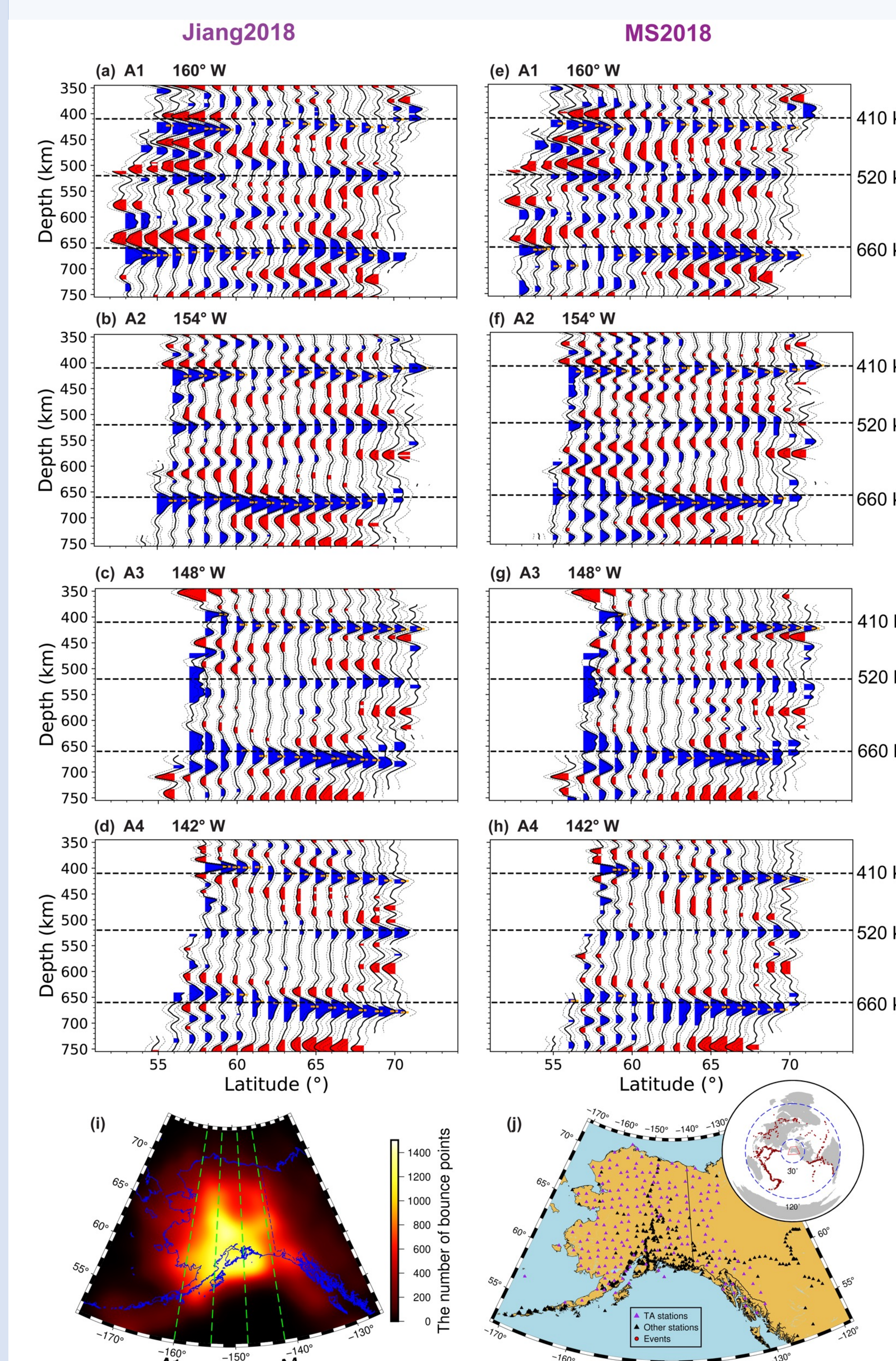

Fig. 6. Cross sections corrected using Jiang et al. (2018) (a-d) and Martin-Short et al. (2018) (e-h), bounce points (i), and stations and events (j)

- > 60° N: clearly resolved "410" and "660
- < 60° N: some ambiguous peaks near 410- or 660-km depths
- Significant effect of tomography models on the depth, stacking coherence, and amplitude
- Results based on Jiang et al. (2018) are more continuous at low latitudes and consistent with prior receiver-function and tomography results

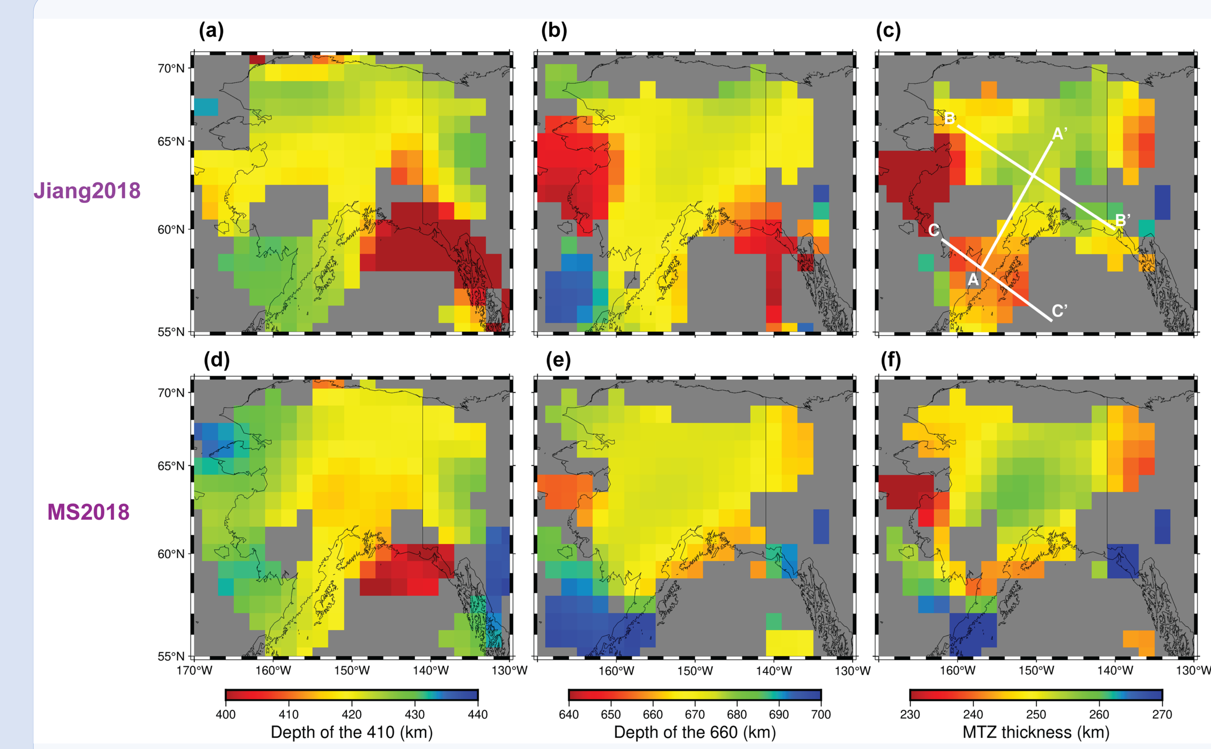

Fig. 7. Estimated "410" and "660" depths and the MTZ thickness corrected using Jiang et al. (2018) (a-c) and Martin-Short et al. (2018) (d-f)

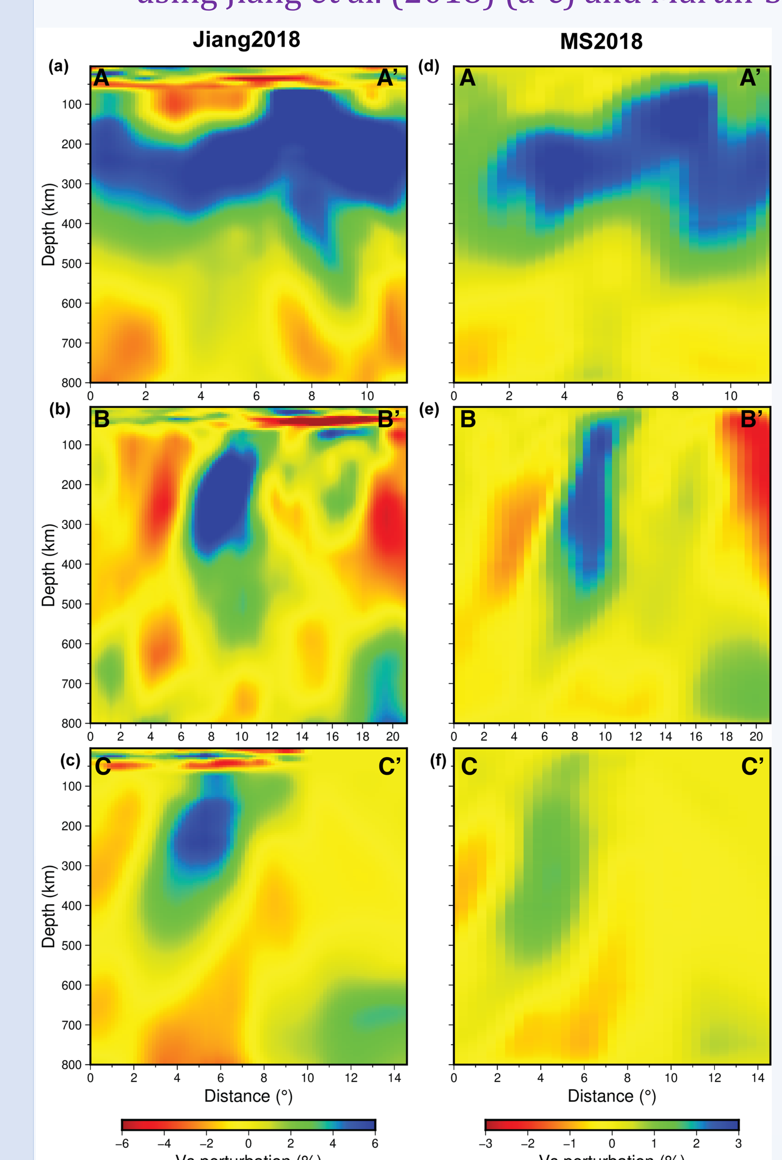

Fig. 8 Cross sections along AA', BB' and CC' (locations are marked in Fig. 7) using Jiang et al. (2018) (a-c) and Martin-Short et al. (2018) (d-f)

- Southeastern AK
  Thin MTZ (results based on Jiang et al. (2018))
  &
  Low velocity
  ↓
  Hot mantle upwelling
- Central AK
  Thick MTZ
  &
  High velocity deeper than 400 km
  ↓
  Slab in the MTZ
- Alaska Peninsula (SW Alaska)
  Thin MTZ
  &
  High velocity above 400 km
  ↓
  Slab above the MTZ

Reference

Jiang, C., Schmandt, B., Ward, K. M., Lin, F.-C., & Worthington, L. L. (2018). Upper mantle seismic structure of Alaska from Rayleigh and S wave tomography. Geophysical Research Letters, 45 (19), 10–350.

Laske, G., Masters, G., Ma, Z., & Pasyanos, M. (2013). Update on CRUST1. 0—A 1-degree global model of Earth's crust. In Geophysical research abstracts (Vol. 15, p. 2658).

Martin-Short, R., Allen, R., Bastow, I. D., Porritt, R. W., & Miller, M. S. (2018). Seismic imaging of the Alaska subduction zone: Implications for slab geometry and volcanism. Geochemistry, Geophysics, Geosystems, 19 (11), 4541–4560.

Shearer, P. M., & Buehler, J. (2019). Imaging upper-mantle structure under USArray using long-period reflection seismology. Journal of Geophysical Research: Solid Earth, 124 (9), 9638–9652.

Zhang, Y., Li, A., & Hu, H. (2019). Crustal structure in Alaska from receiver function analysis. Geophysical Research Letters, 46 (3), 1284–1292.

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