A Preliminary Crustal Shear Wave Velocity Model for the eastern China

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1. Introduction

The continental China recorded a crustal evolution history from the Archean core of the Sino-Korean platform to active continent-continent collision in Tibet. In the present study, we image the three-dimension (3D) structure of the crust and uppermost mantle beneath the continental eastern China by jointly using the Rayleigh wave phase velocity dispersion curve (PVD), the Rayleigh wave ZH ratio dispersion curve (ZHD) and the receiver function (RF).

2. Data coverage

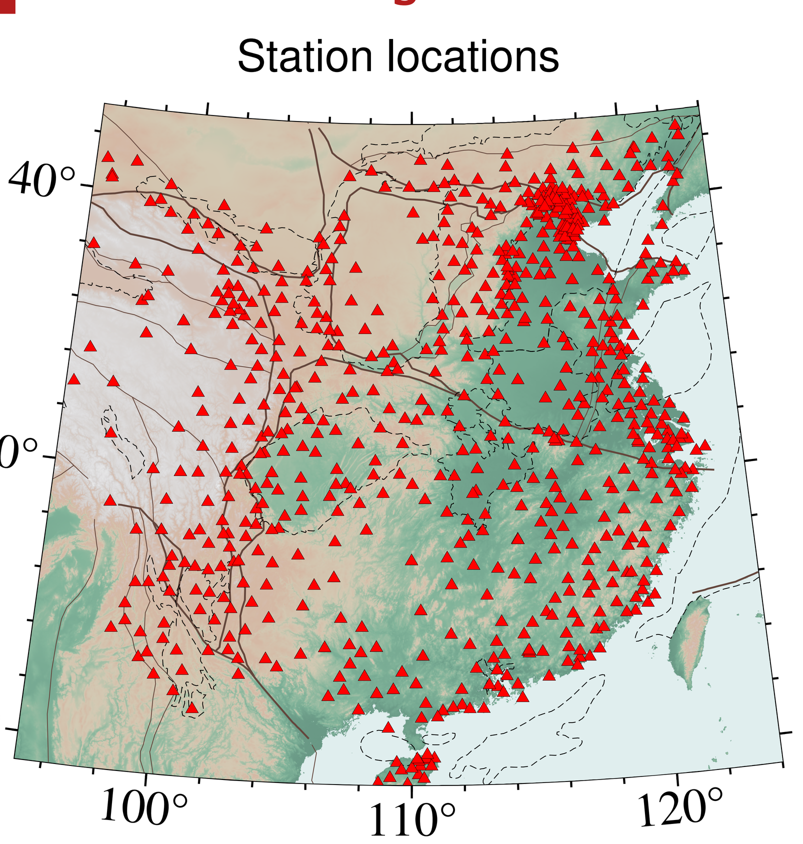

Figure 1: Locations of seismic stations. Seismic stations (red triangles), along with the boundaries of geological units (solid lines) and the major sedimentary basins (areas enclosed by dashed lines). Lines in all later maps represent same meanings with those in this figure.

In this study, we use continuous waveforms and waveforms of mid-large (M > 5.5) seismic events recorded by 705 three-component broadband seismometers in eastern China during 2015 to 2017 (**Figure 1**).

3.Observations

1. With a linearized ambient noise tomography method, we obtain two-dimension (2D) phase velocity maps in the period range of 8 – 38 s with a step of 2 s, where the PVDs under grids are extracted (**Figure 2**).
2. We measure ZH ratios in the period range of 20 – 80 s with a step of 4 s with Rayleigh waves from the mid-large seismic events on all seismic stations, and then interpolate these station-based measurements to obtain ZH ratio and uncertainty maps of each periods, where the ZHDs beneath grids are estimated (**Figure 3**).
3. We first correct travel times and amplitudes of the raw receiver functions based on CRUST 1.0. For each 0.5°× 0.5° grid, we then estimate the isotropic RF and associated uncertainty using all raw receiver functions with conversion points on the Moho locating in this grid with a harmonic stripping method (**Figure 4**).

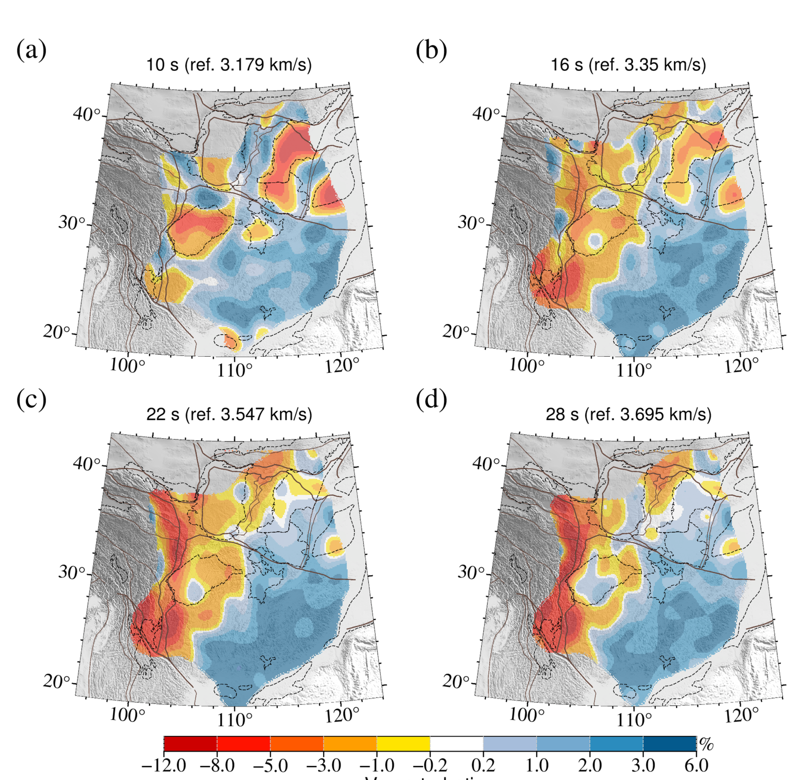

Figure 2. Rayleigh wave phase velocity perturbation maps of the 10s (a), 16s (b), 22s (c) and 28s (d). (a)-(d) The period and corresponding refence phase velocity are labeled on the title of each panel.

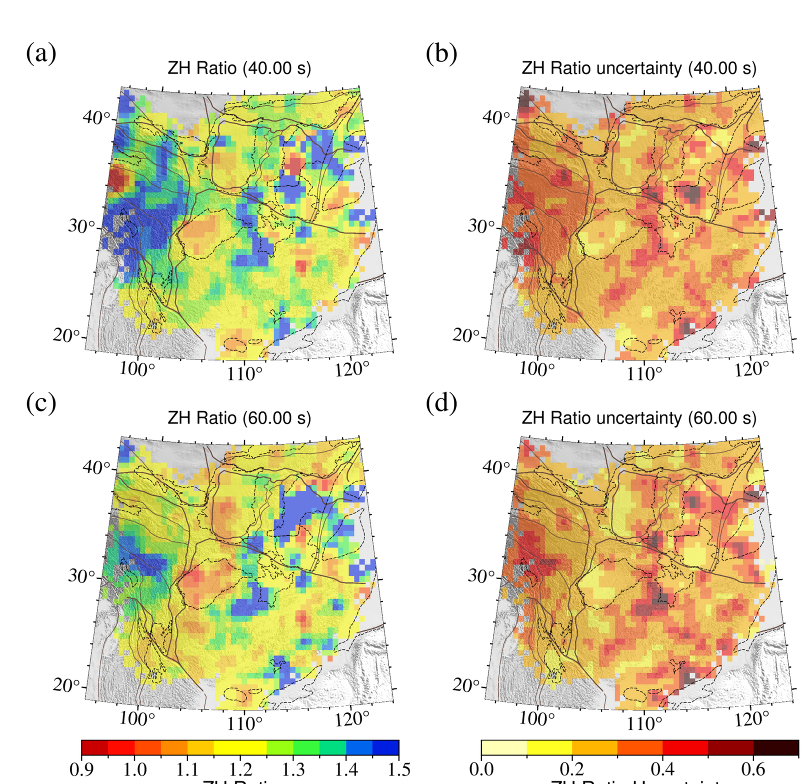

Figure 3. Maps of interpolated Rayleigh wave ZH ratio (a/c) and associated uncertainties (b/d). (a)/(b) corresponds to a period of 40 s while (c)/(d) for 60 s.

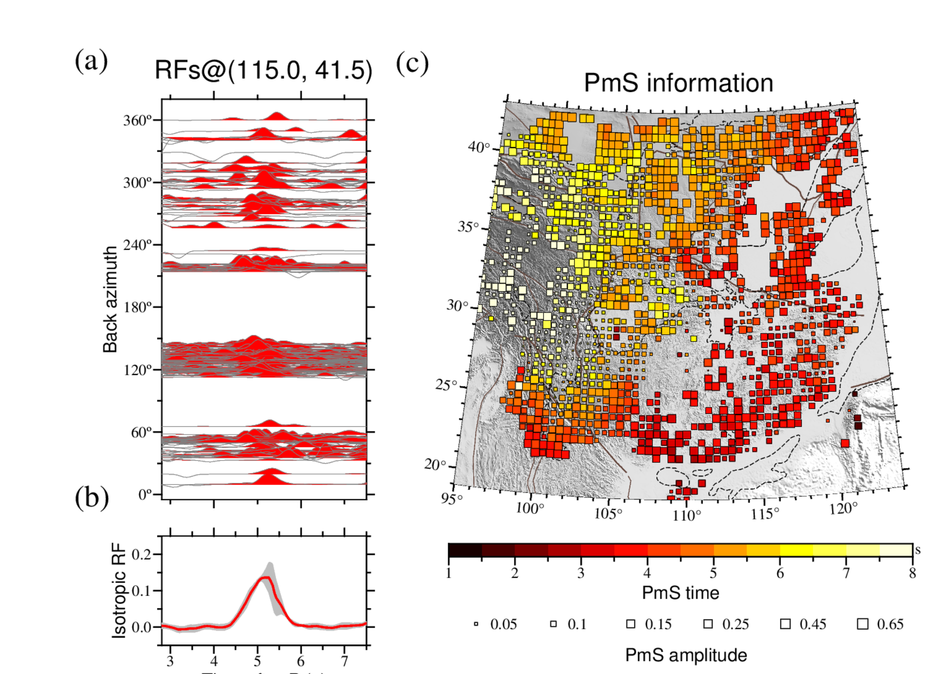

Figure 4. RF processing procedure for a demo grid and integrated PmS information over the eastern China. (a) Raw RFs in a 0.5°× 0.5° grid centered with specific grid point (115°, 41.5°) in the North China Craton. (b) Isotropic PmS phase and associated uncertainty, estimated with RFs in (a) utilizing a harmonic stripping method. (c) Map of the PmS information. Grids colors indicates PmS travel time while the sizes of squares show PmS amplitude.

4. 1D Joint inversion of phase velocity dispersion curve, ZH ratio and RF

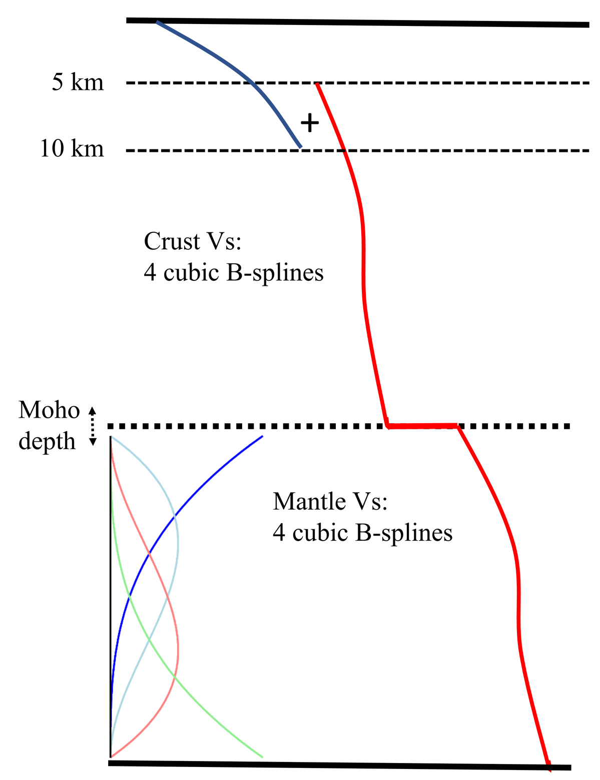

Figure 5: Model parameterization illustration. The one-dimension (1D) Vs model, composed of a shallow layer (fixed from surface to 10 km in depth), a crustal layer and a mantle layer. It totally contains 9 independent parameters, including thicknesses of the crustal layer, 4 cubic B-spline coefficients for Vs in the crustal layer and another 4 coefficients for Vs in the mantle layer. Four colored curves at the bottom left corner demonstrate shapes of the B-spline basis functions.

- In each 0.5°× 0.5° grid point, we collect the phase velocity dispersion curve (PVD), ZH Ratio dispersion curve (ZHD) and receiver function (RF) and associated uncertainties for 1D joint inversion.
- The 1D seismic shear wave velocity (V_s) model beneath each grid point composes of a fixed shallow layer (from surface to 10 km with V_s from previous model) (Xiao et al, 2018, AGU abstract), a crustal layer (from 5 km to Moho) and a mantle layer. V_s in the overlap depth range (5 km to 10 km) are weighted average of those in the shallow layer and the crustal layer (**Figure 5**).
- The cost function of 1D joint inversion contains four terms: 1) average uncertainty-damped data misfit of the observed PVD, 2) average uncertainty-damped data misfit of the observed ZHD, 3) average uncertainty-damped data misfit of the observed RF, and 4) degree-one smoothness of Vs in the mantle layer. Each term includes a variable weight parameter.
- To optimize the cost function, we use a Markov Chain Monte Carlo (MCMC) method to randomly sample the given model space with a Metropolis-Hastings rule, defined by the cost function. We then accept a series of sampled models constituting a model cluster, where the final model and associated uncertainty are estimated (**Figure 6, Figure 7, Figure 8**).
- We finally interpolate all inverted 1D models to obtain a 3D Vs model under the eastern China.

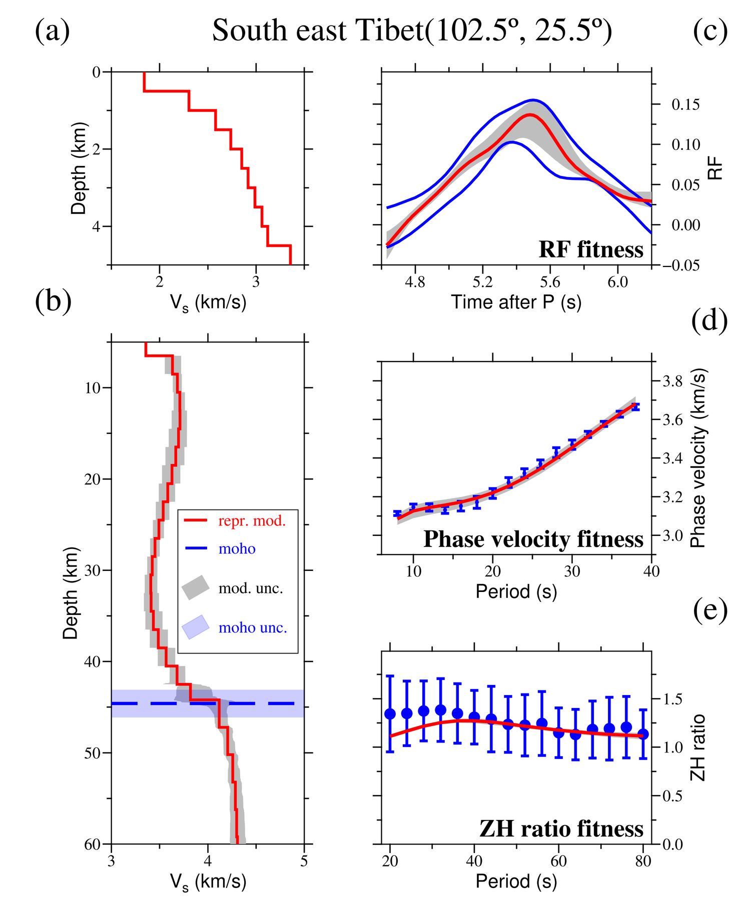

Figure 6: One-dimension joint inversion result for a grid point in the south-eastern Tibet. (a) The fixed Vs profile in the shallowest 5 km of the representative model, the sampled model that is nearest to mean of the accepted model cluster (red line). (b) Representative model in the crust and mantle, along with model uncertainty, quantified by the two-fold standard deviation (s.d) of accepted models. Mean depth of the Moho (blue dashed line) and its uncertainty range (blue area), quantified by two-fold s.d of Moho depth of accepted models. (c) The observed RF with uncertainty (blue lines), along with RF predicted by the representative model (red line) and two-fold s.d width of RFs modeled with the accepted models (grey area). (d) The observed PVD with uncertainty (blue dots with error bars), along with PVD predicted by the representative model (red line) and two-fold s.d width of PVDs modeled with the accepted models (grey area). (e) is the same as (d), but for the ZHD fitness.

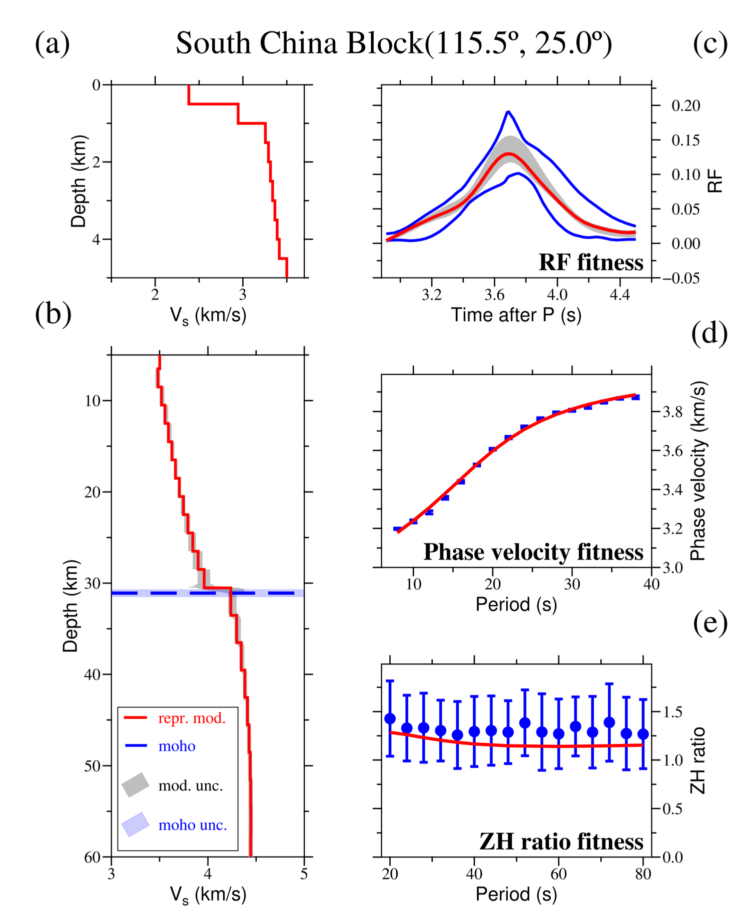

Figure 7: The same as Figure 6, but for a grid point in the South China Block.

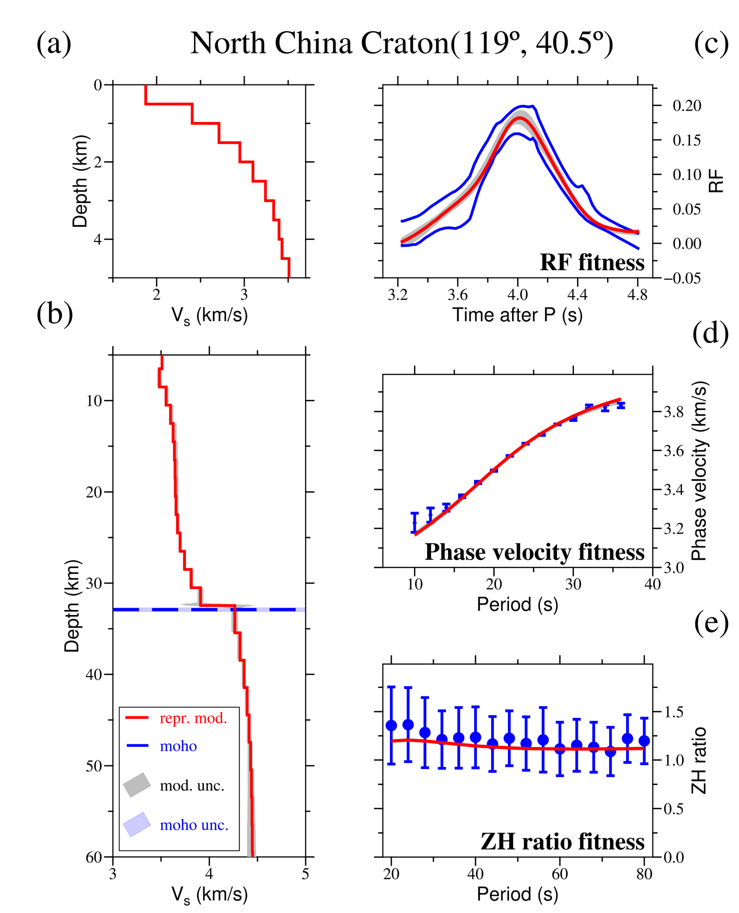

Figure 8: The same as Figure 6, but for a grid point in the North China Craton.

6. 3D Vs model under the eastern China

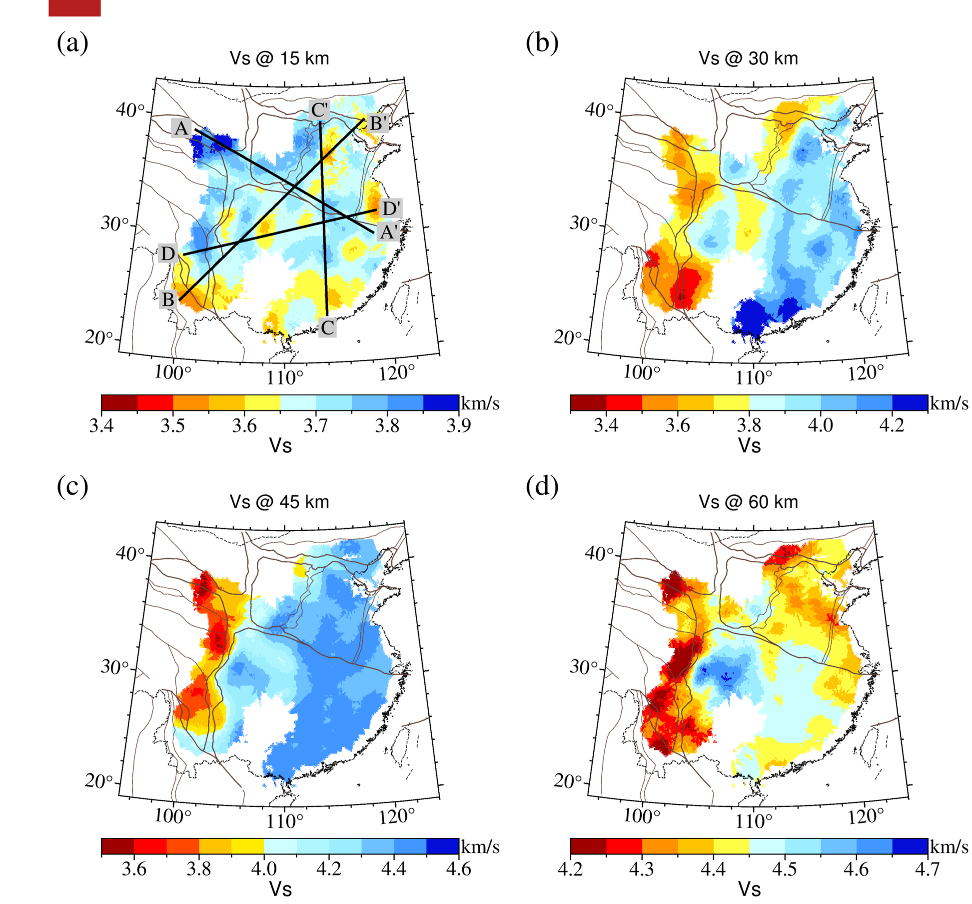

Figure 9: Horizontal slices of the interpolated 3D Vs model at four depths: (a) 15 km, (b) 30 km, (c) 45 km and (d) 60 km. Locations of the profiles AA', BB', $CC'$and DD'(black thick lines), in Figure 11.

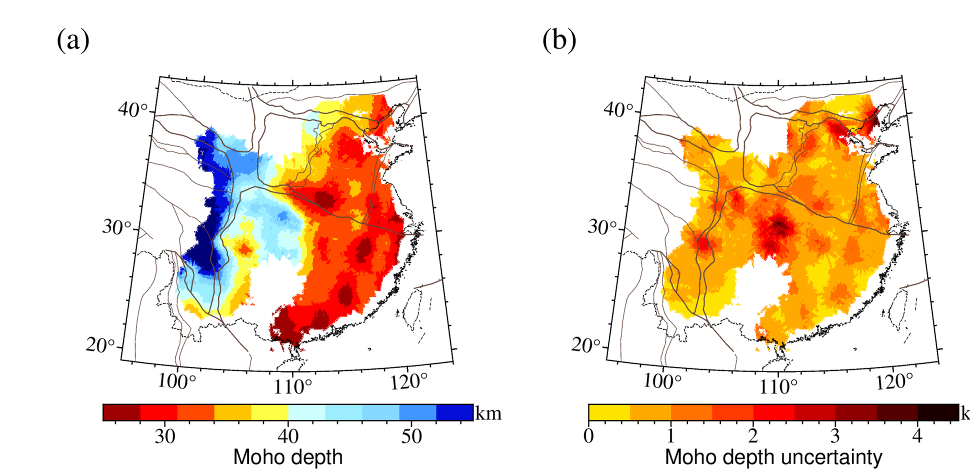

Figure 10: Maps of the interpolated Moho depth (a) and associated uncertainty (b). Moho depth in 1D inversion is mean Moho depth of the accepted models while its uncertainty is quantified by two-fold s.d width.

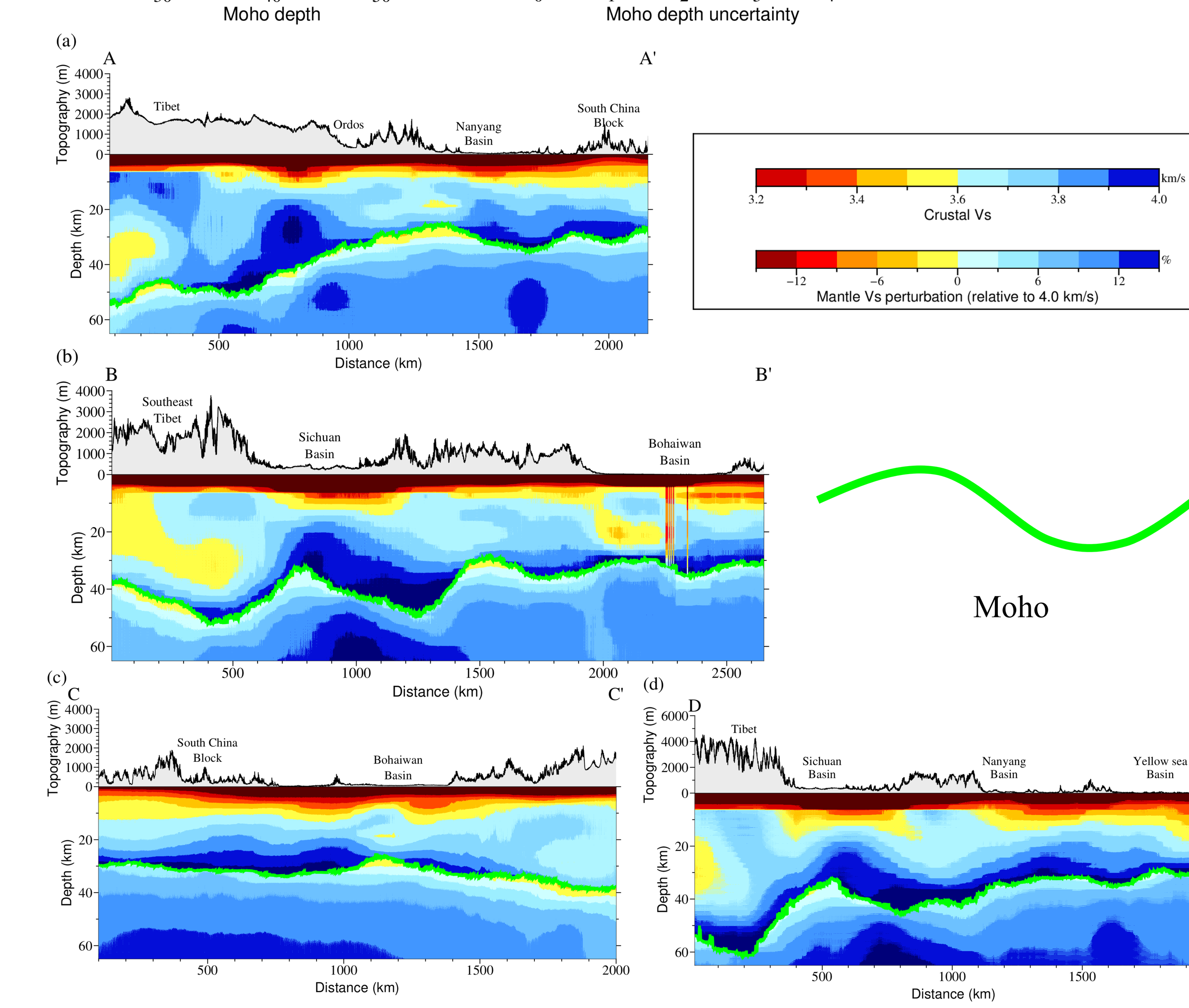

Figure 11: Cross-sectional views of (Bottom) Vs structure (colored background), estimated Moho depth (bold green lines) and surface topography. The locations of the cross-sections are shown in Figure 9 with the same labeling of AA', BB', $CC'$and DD'. Major geological units are labeled at the top of the cross-sections. Note the disproportional scales in horizontal distance, depth and elevation and different colors bars for Vs in the Mantle and Crust.

7. Conclusions

- We construct a preliminary 0.5°×0.5° three-dimension crustal Vs model under the eastern China with Rayleigh wave phase velocity dispersion curve, ZH ratio and receiver function.
- Our 3D Vs model reveals a highly variable crustal structure under the eastern China and is well correlated with major geological units.