Global seismic tomography and its CIDER applications

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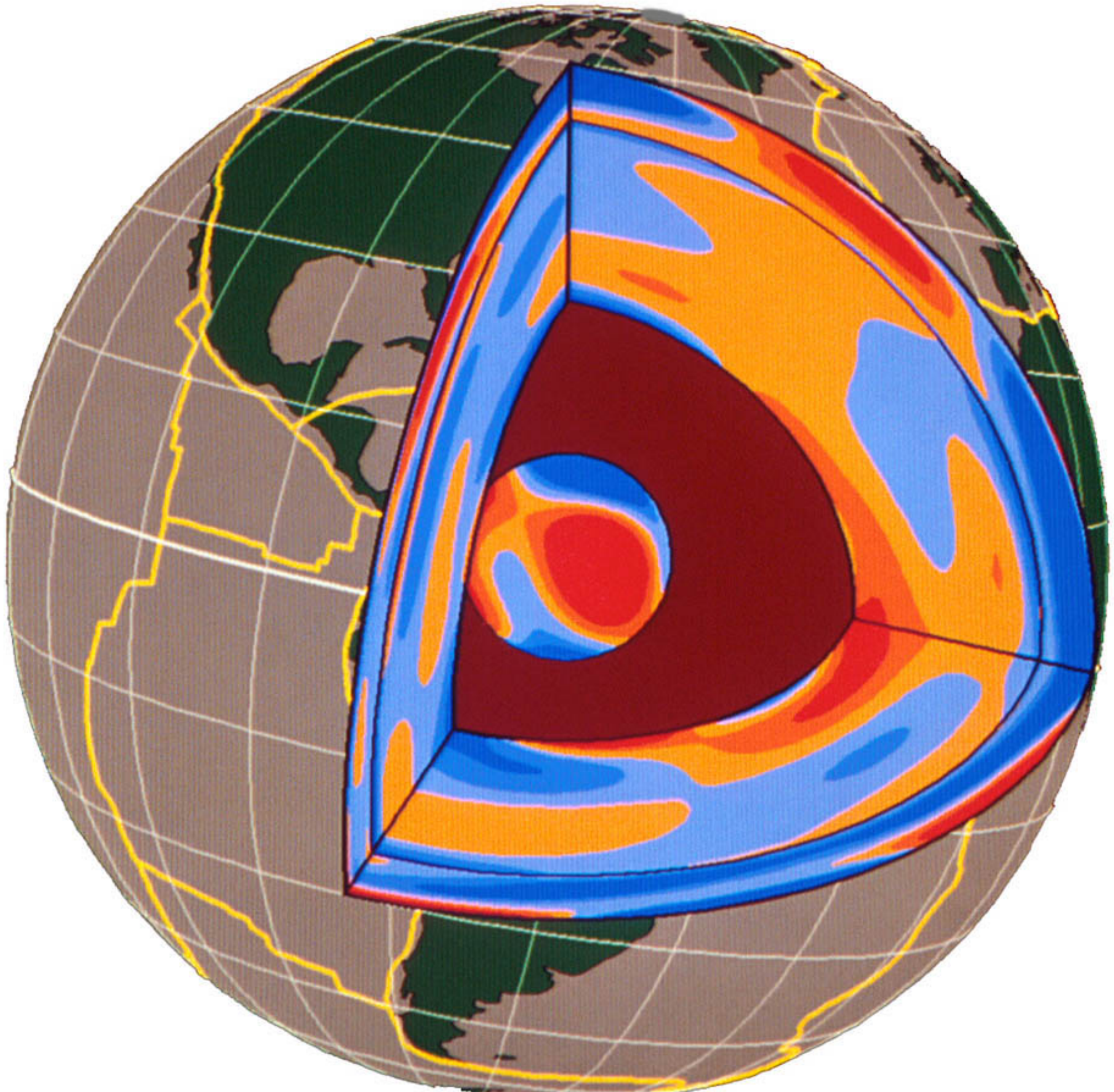
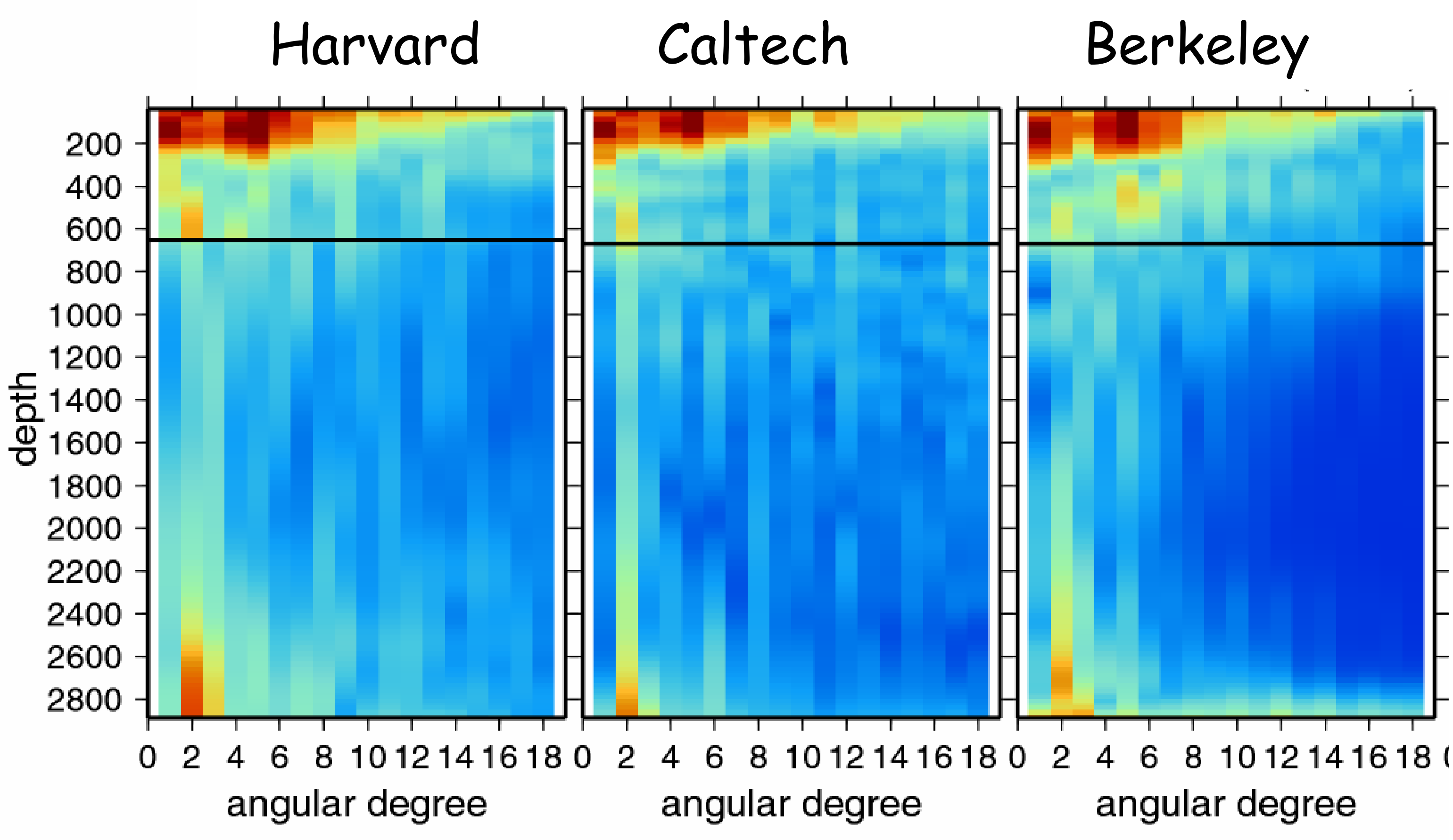
KITP, July 14, 2008

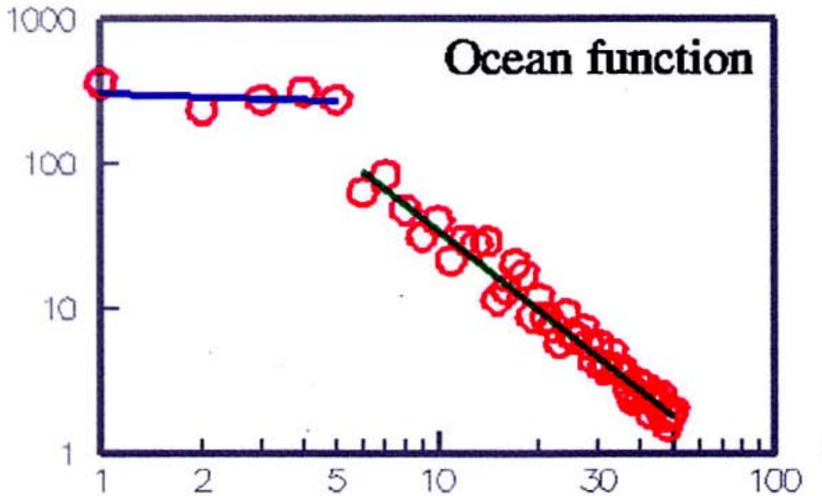
Earth's boundary layers



Power spectra of three models

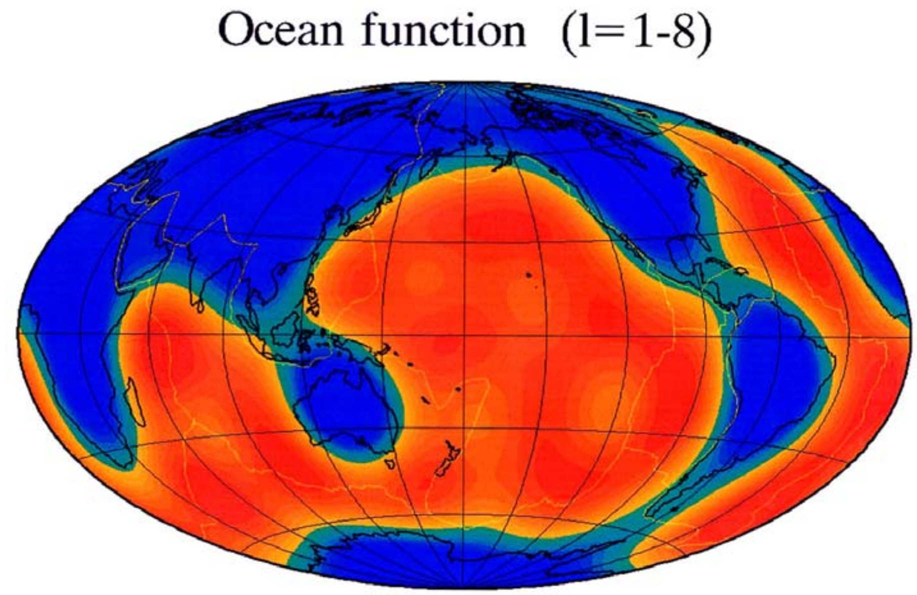


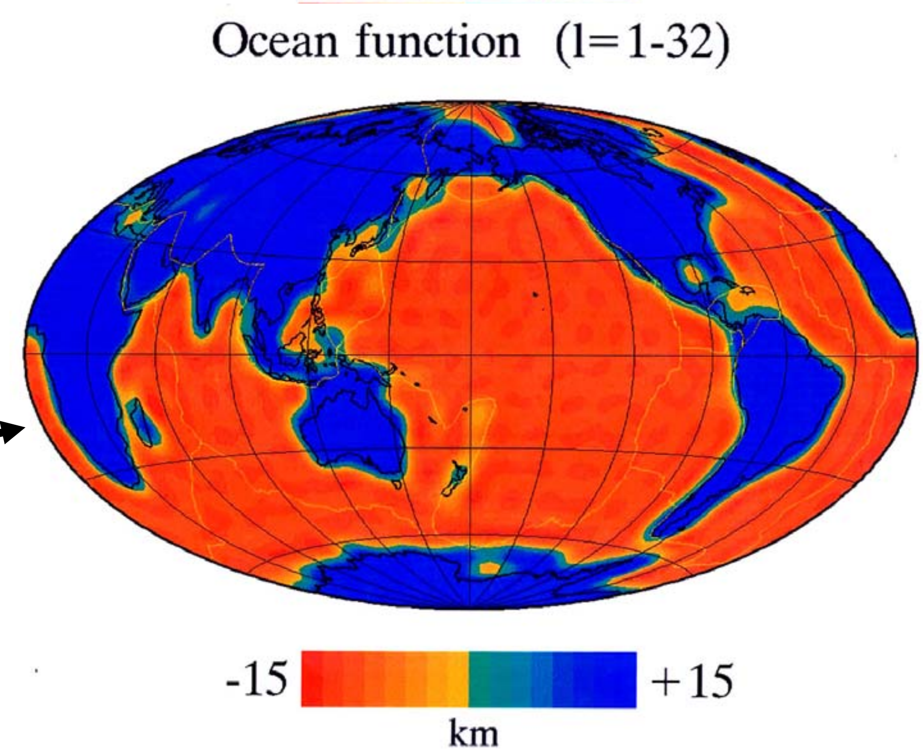
The properties of a “super-red” spectrum



harmonic order

15 times more coefficients



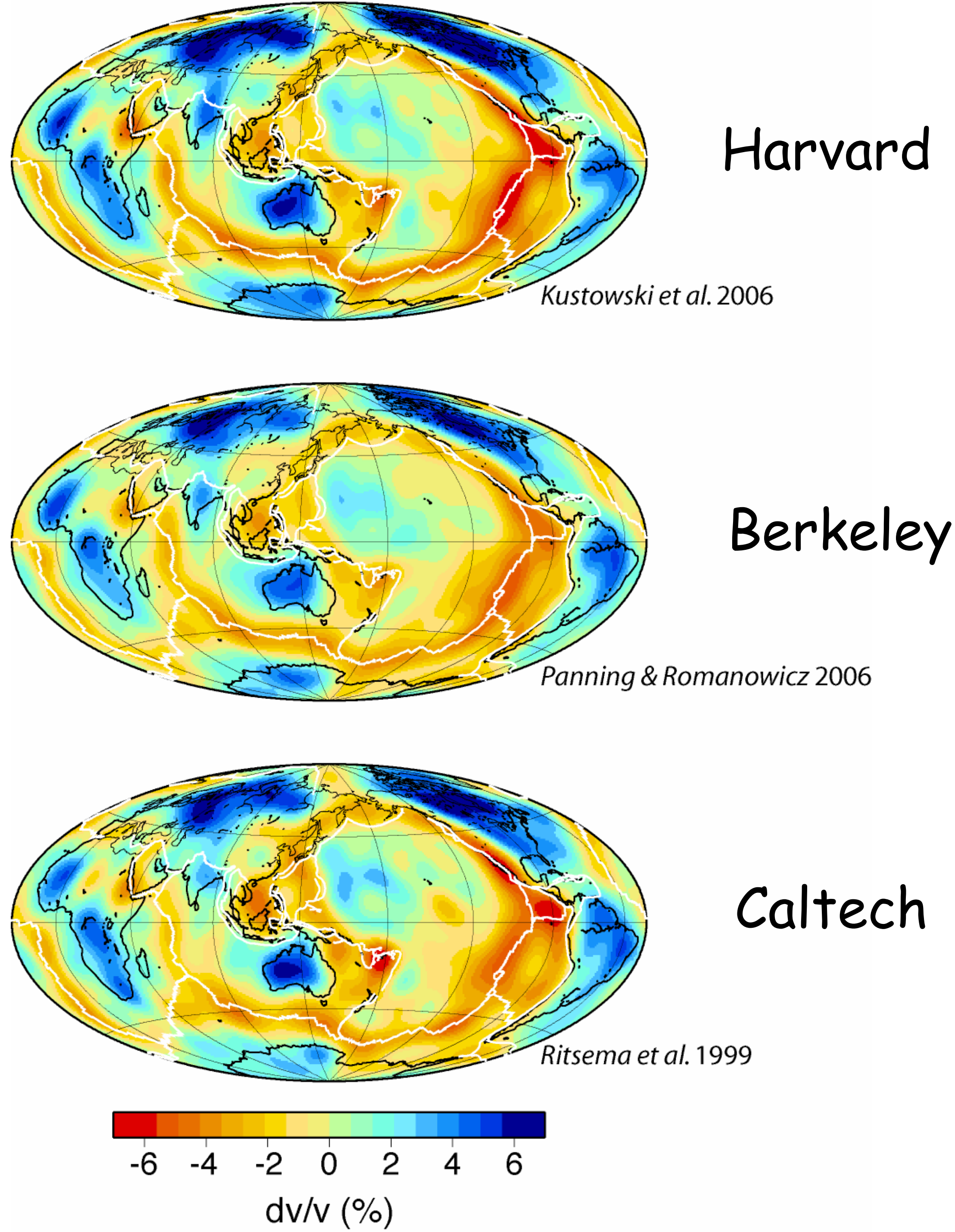


Current Issues:

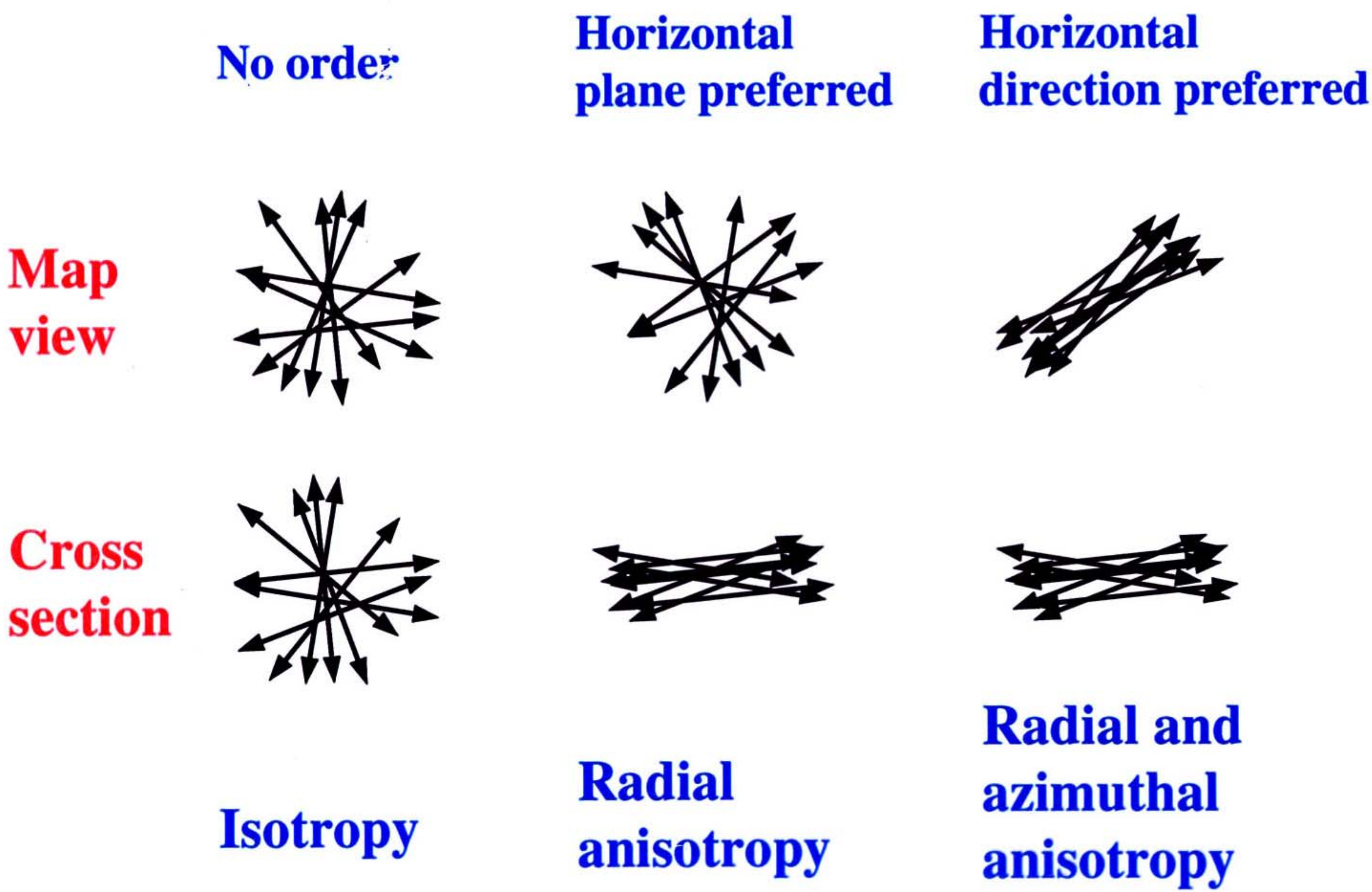
1. Anisotropy in the lithosphere-asthenosphere system
2. Transition zone and the fate of the subducted slabs.
3. Large scale structures in the lower mantle.
4. Stable layers in the outer core

Surface boundary layer

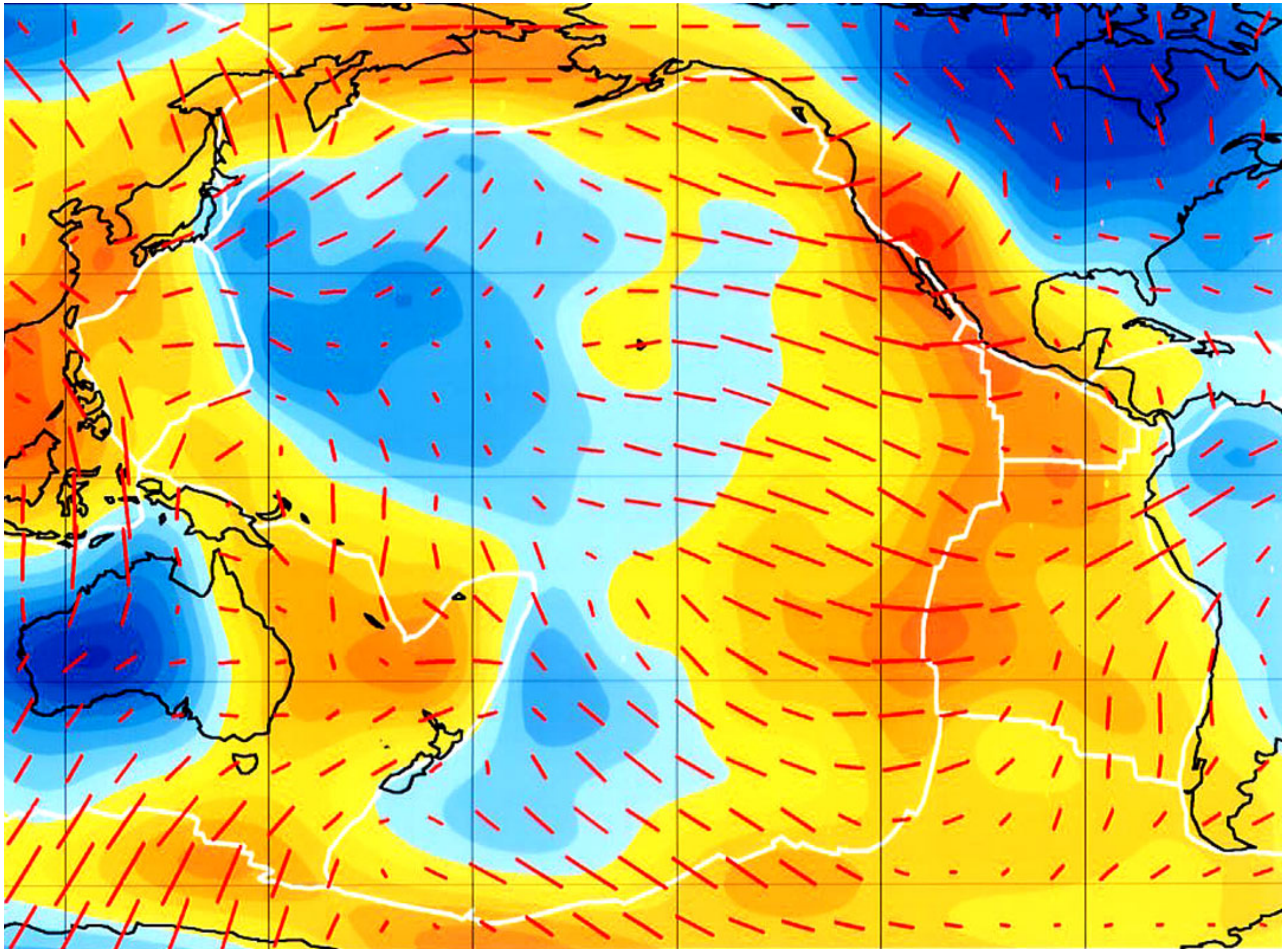
Isotropic shear velocity anomalies at 100 km depth; nearly perfect agreement among different models



Anisotropy and Ordering



Phase velocities in the Pacific



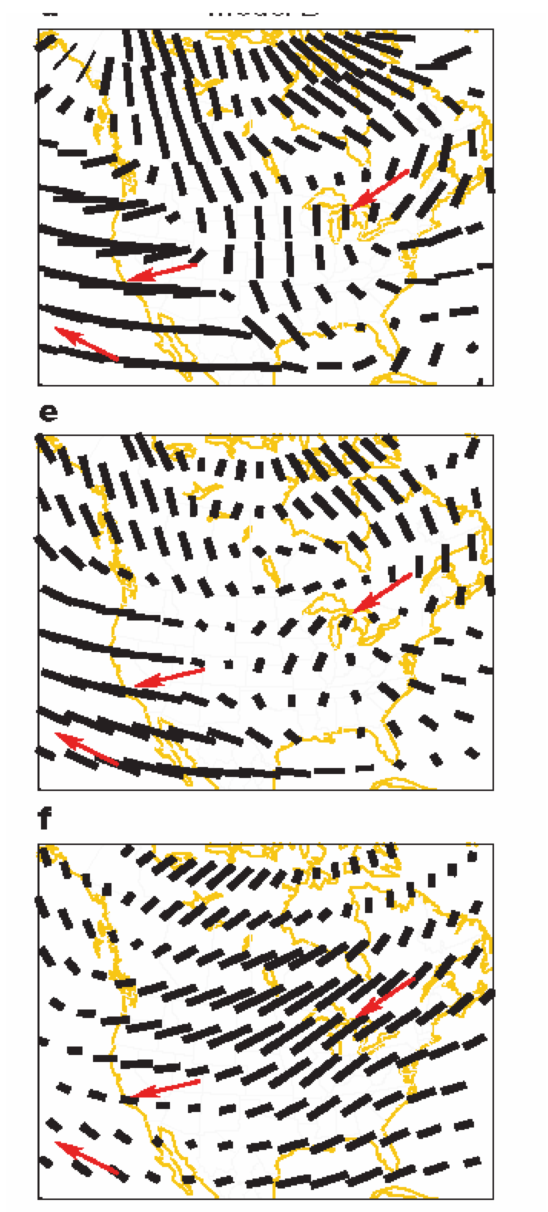
Dispersion of Rayleigh waves with 60 second period. Orange is slow, blue is fast. Red lines show the fast axis of anisotropy.

Azimuthal anisotropy under N. America

100 km

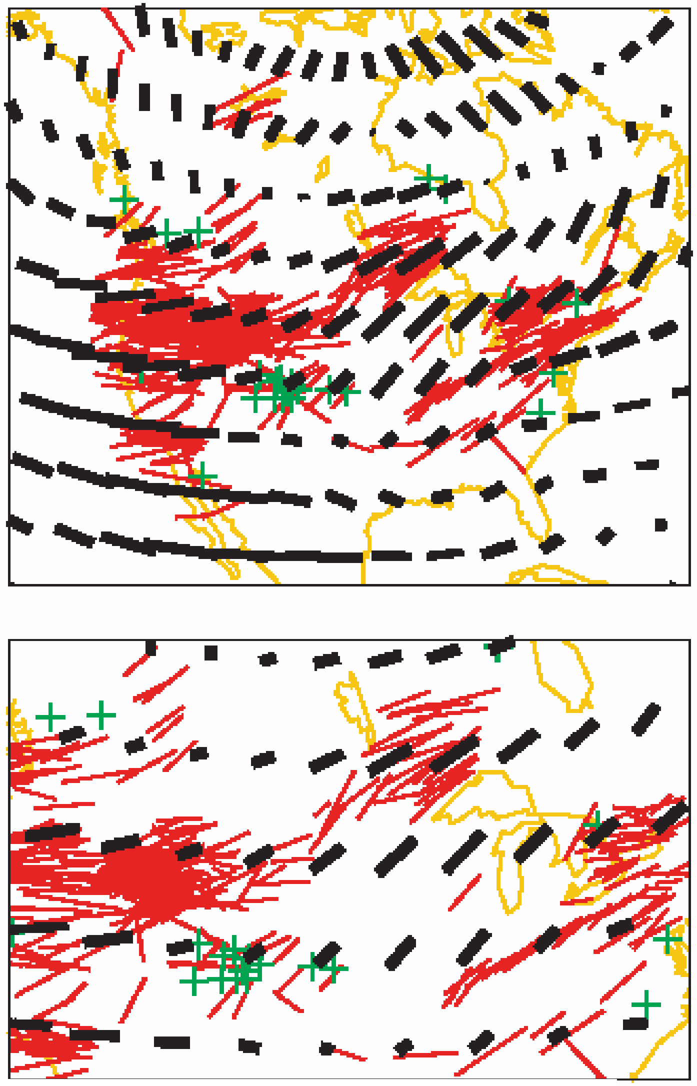
200 km

300 km



after Marone and Romanowicz, 2007

Observed and predicted SKS splitting measurements

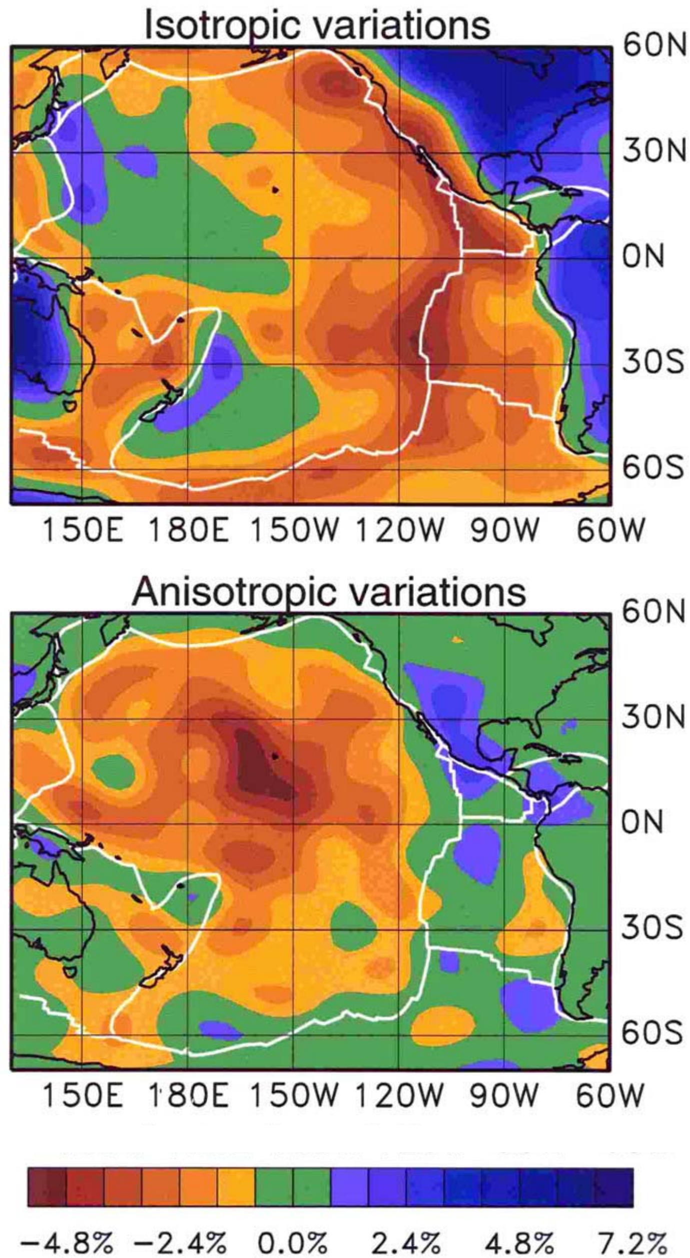


after Marone and Romanowicz, 2007

Pacific anisotropy

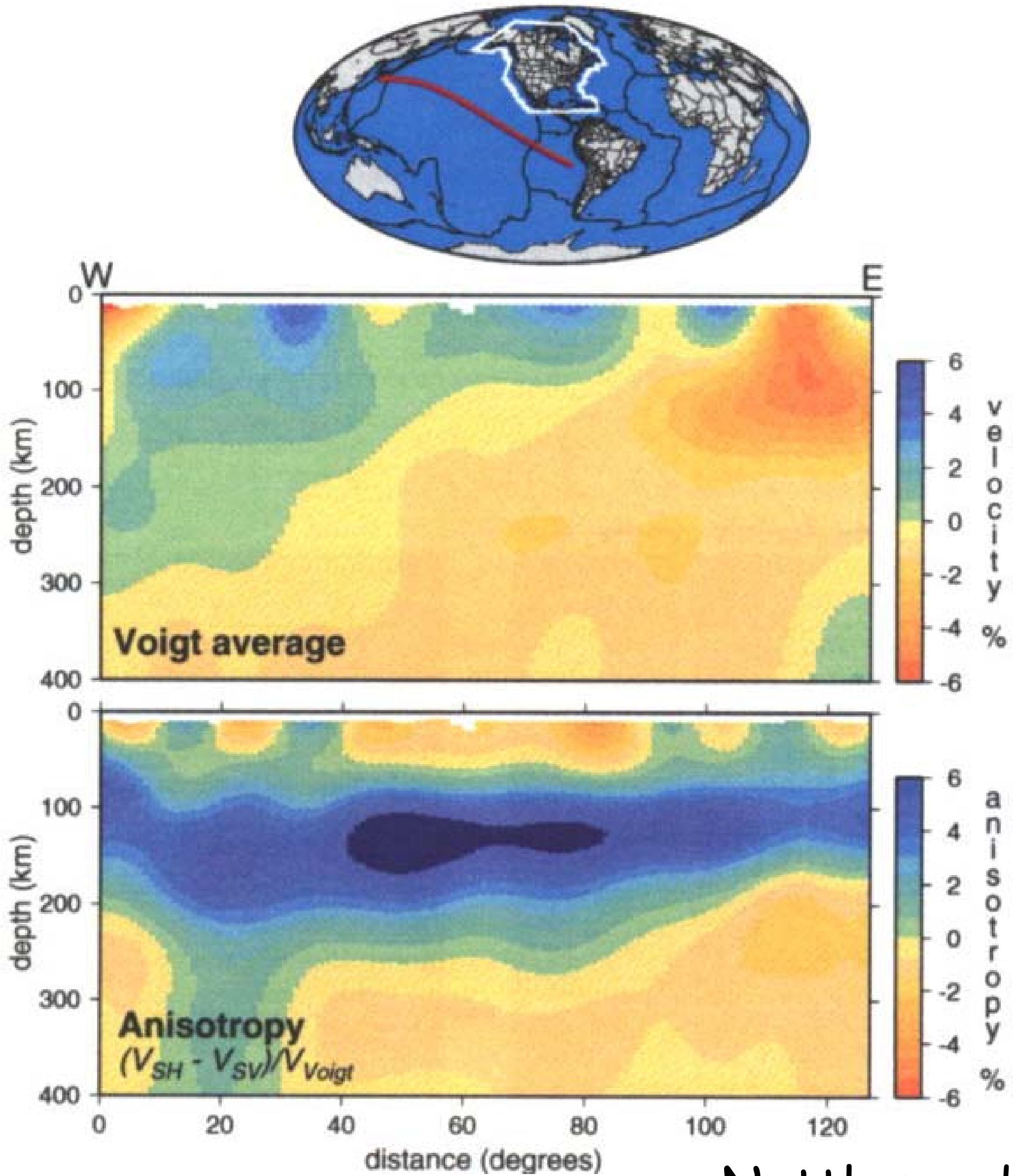
The isotropic variations (top; Voigt average) agree with the pattern of the plate cooling model, even though thermal models predict constant temperature at 150 km depth.

The difference between the SV and SH (bottom) velocities at this depth shows no correlation with plate tectonics.



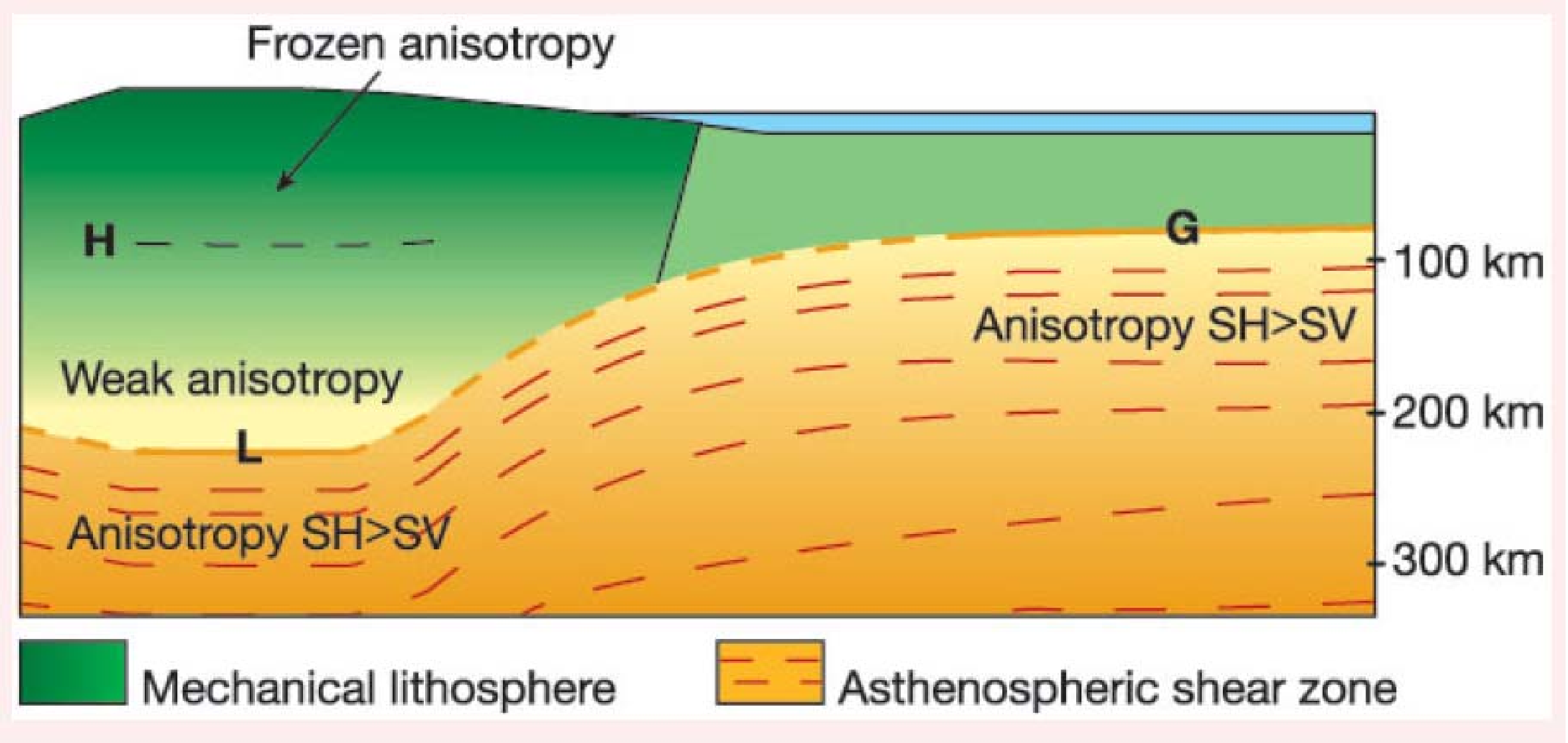
from Ekström & Dziewonski, 1998

Pacific cross-section



Nettles and Dziewonski, 2008

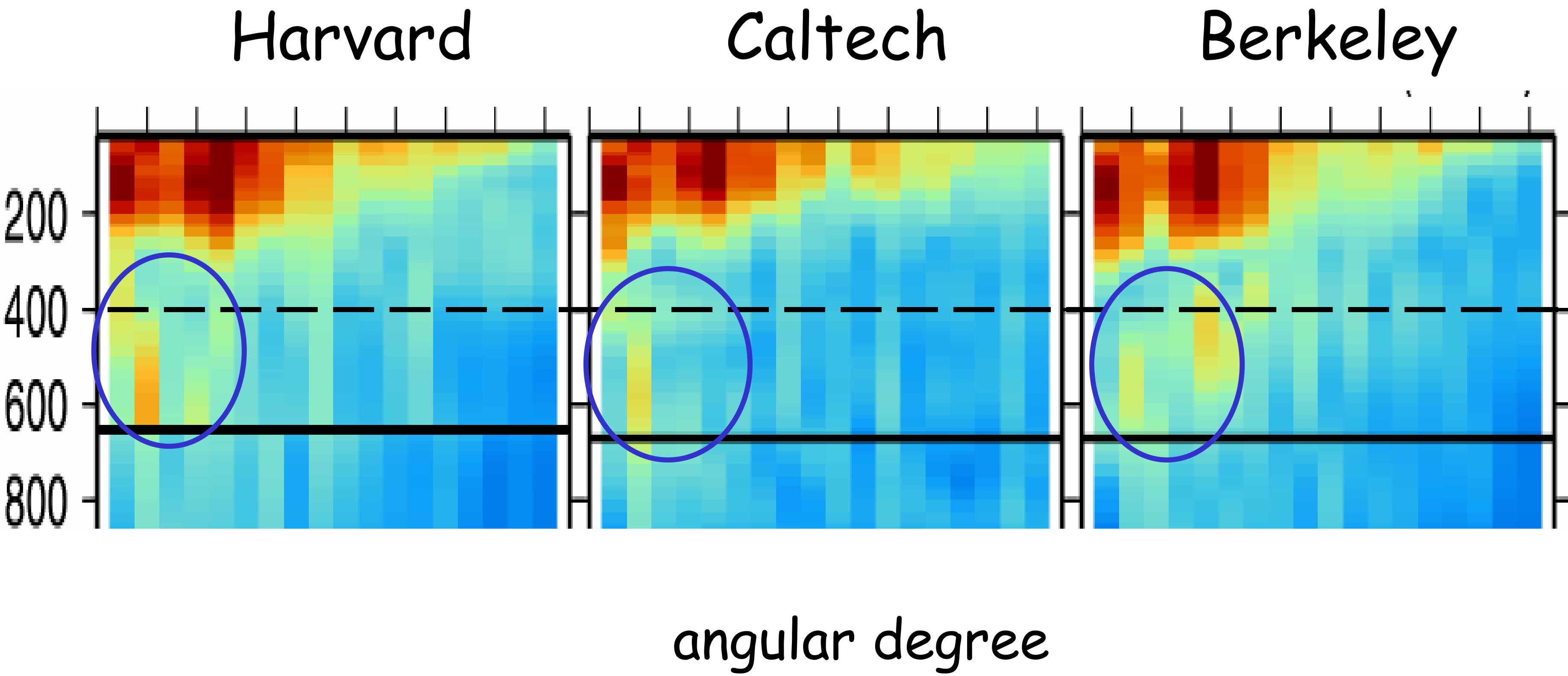
Radial anisotropy under continents and oceans



From Gung et al., 2003

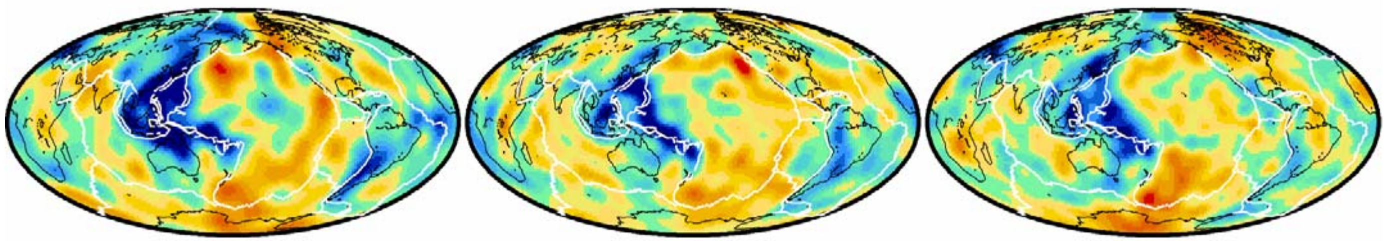
Transition zone boundary layer

Power spectra of the three models; a closer look at the transition zone

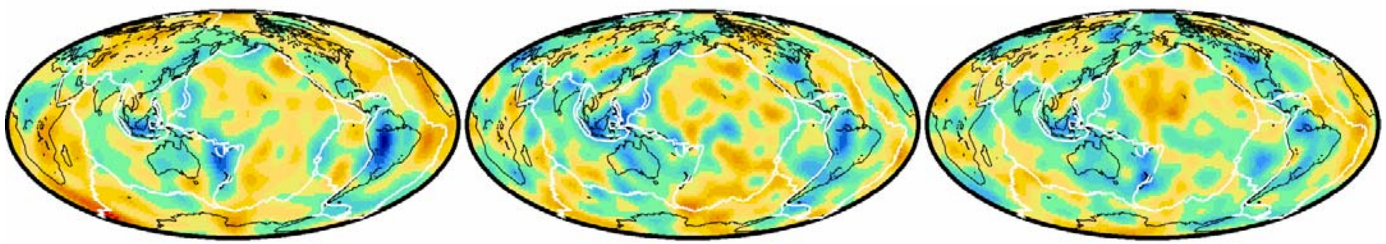


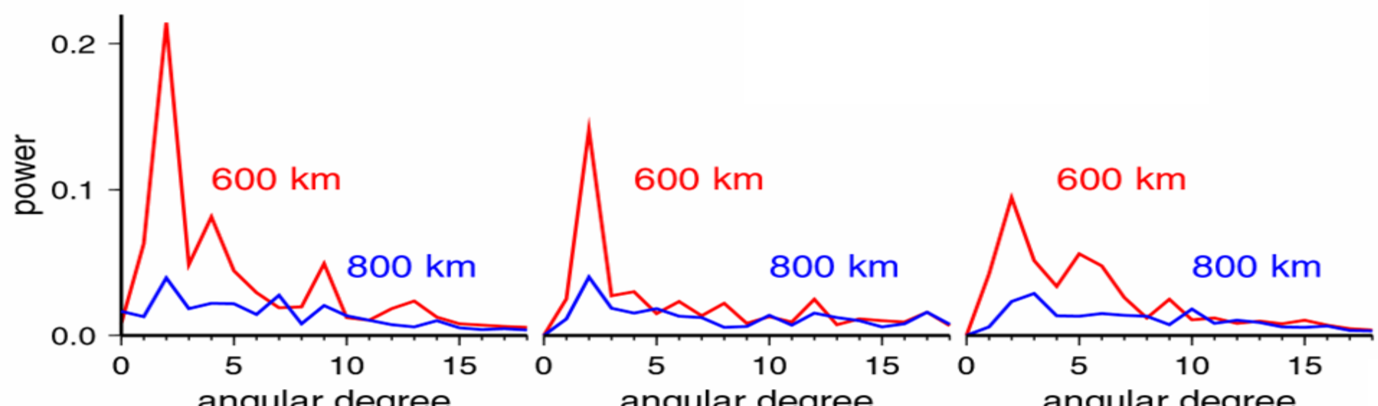
Harvard Caltech Berkeley

600 km depth

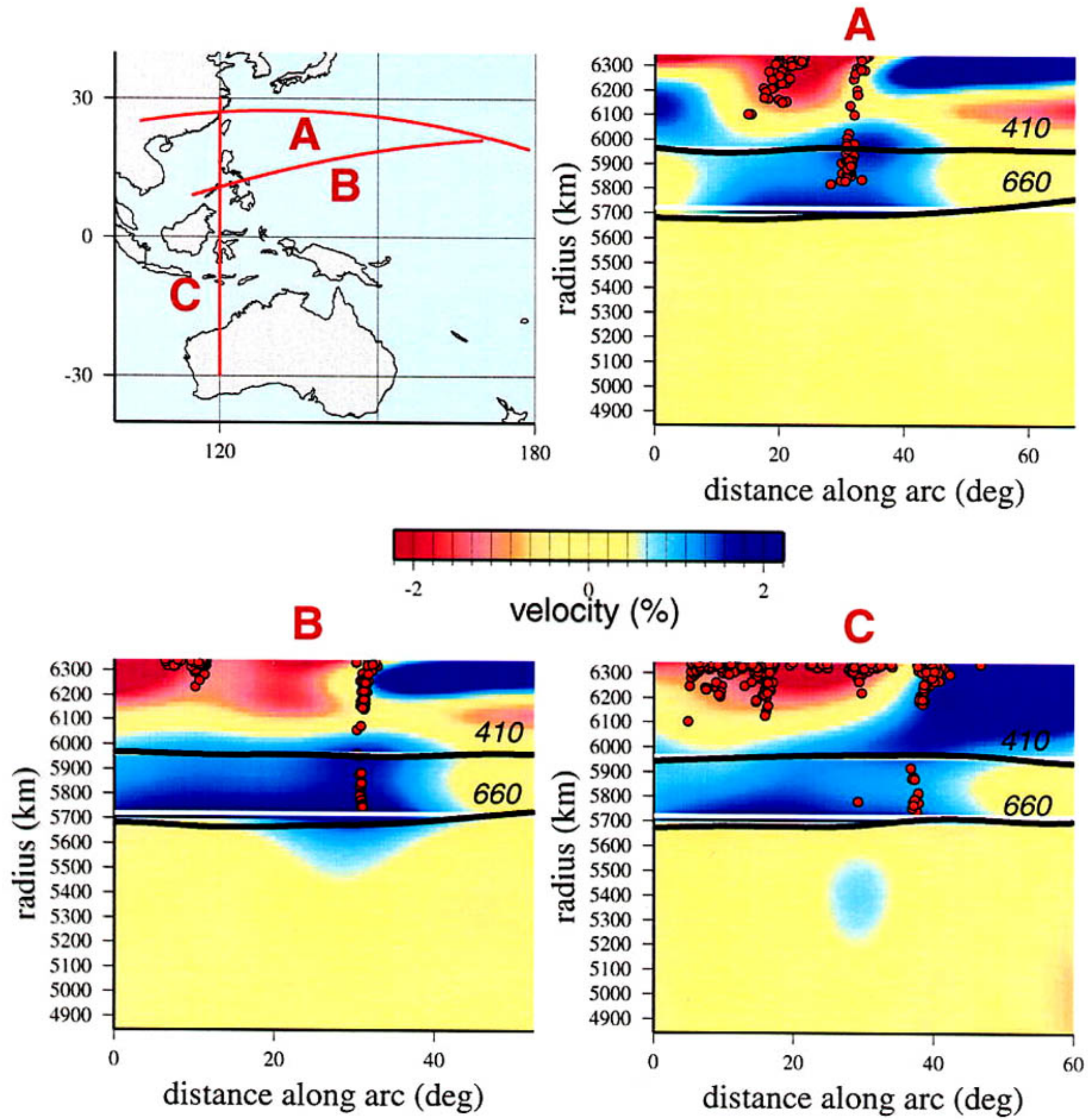


800 km depth



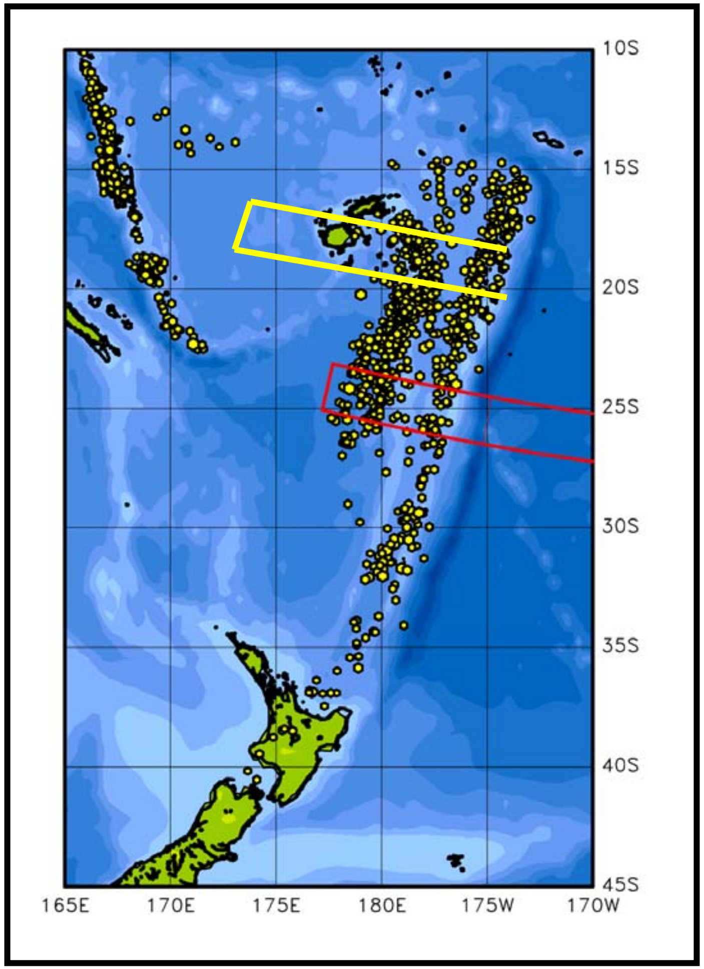


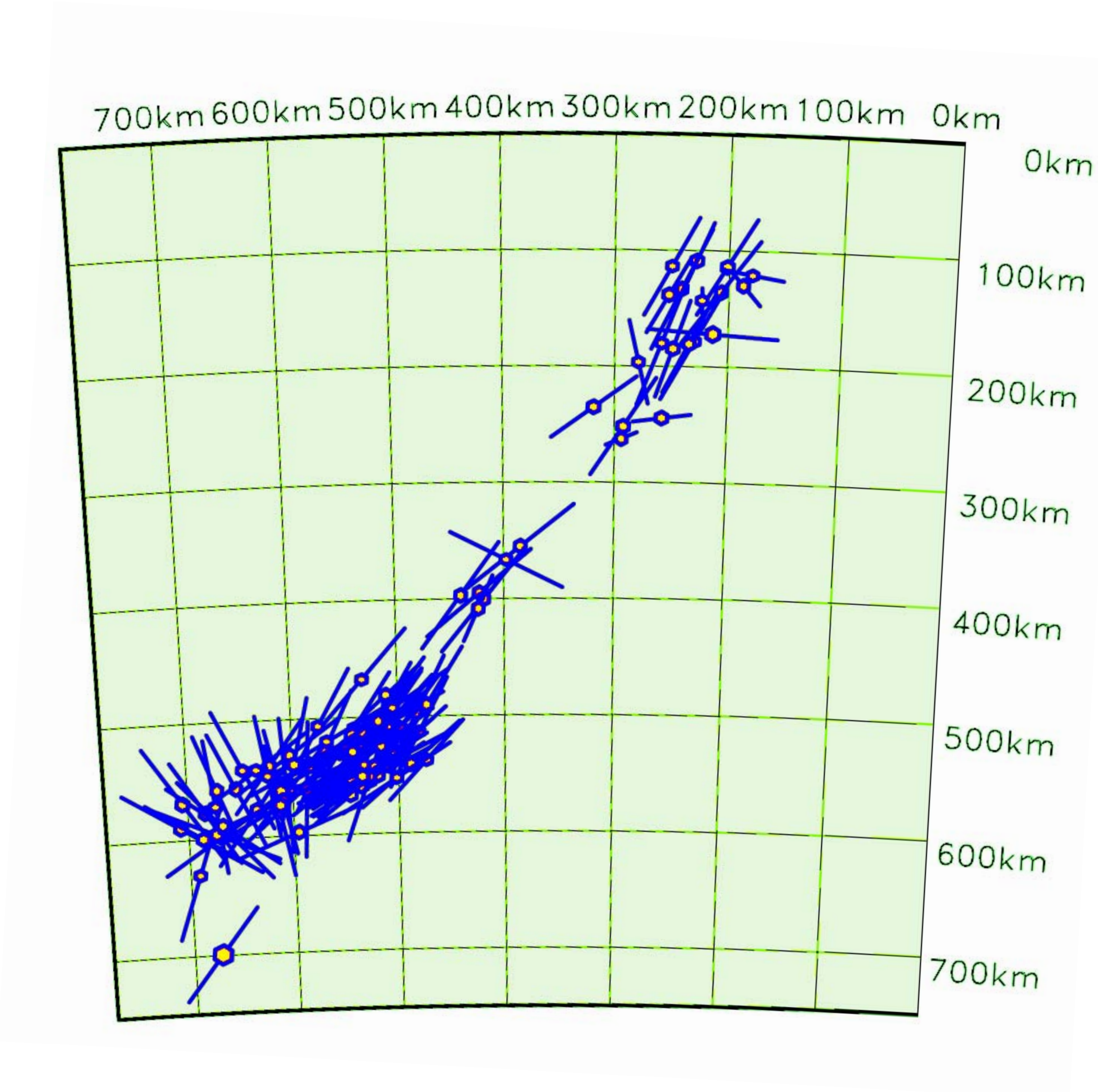
Cross-sections through model TOPO362



from Gu et al., 2003

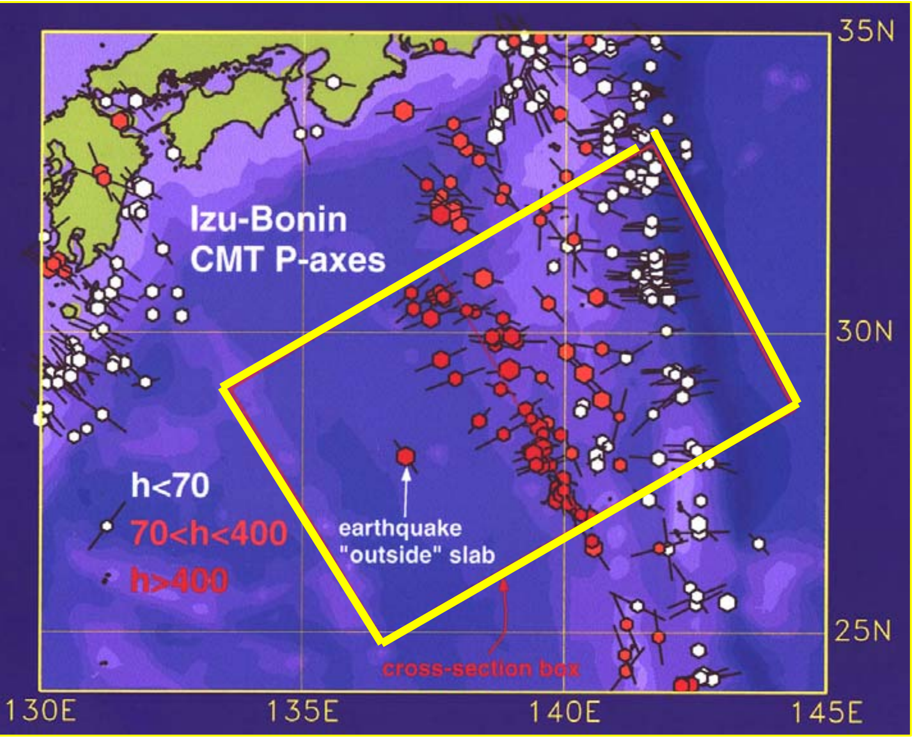
Change in the stress pattern near the 650 km discontinuity

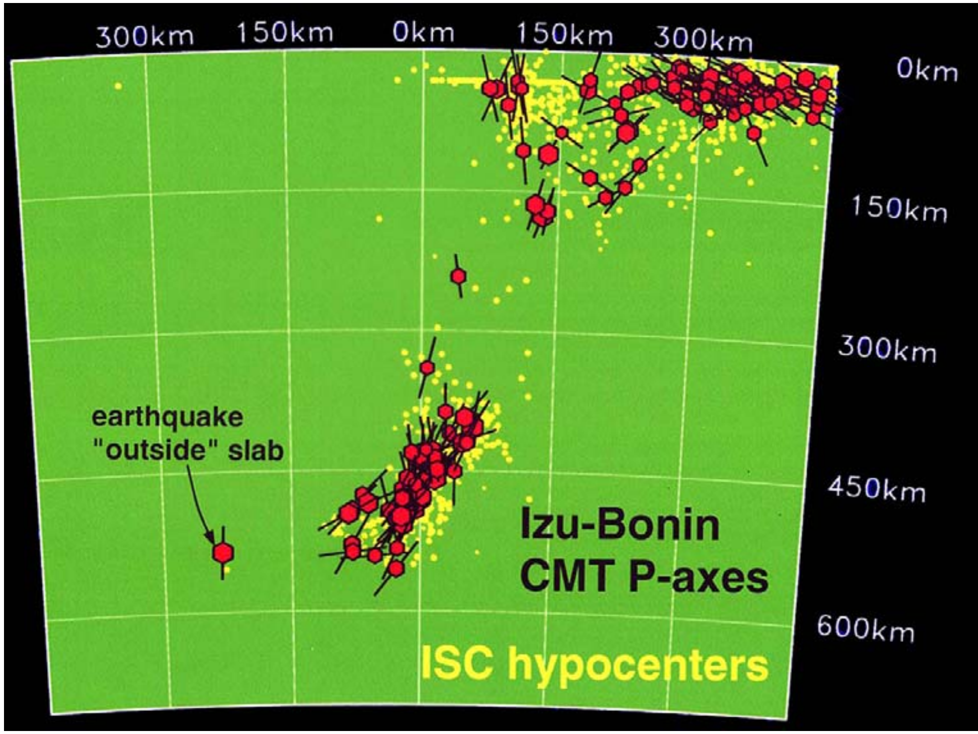




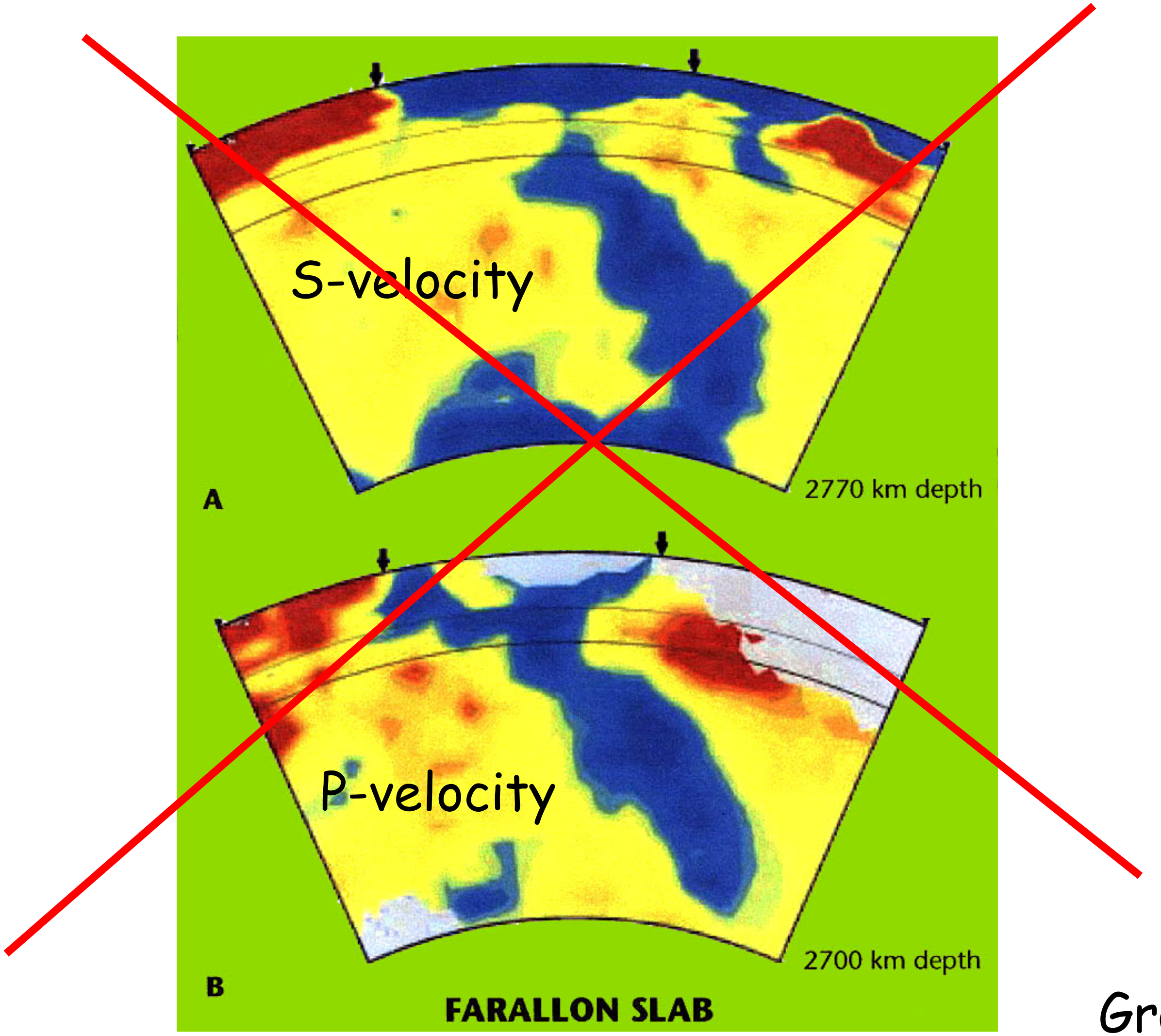
Izu-Bonin slab

Stress pattern changes at 500 km depth; is the transition zone full of slabs?



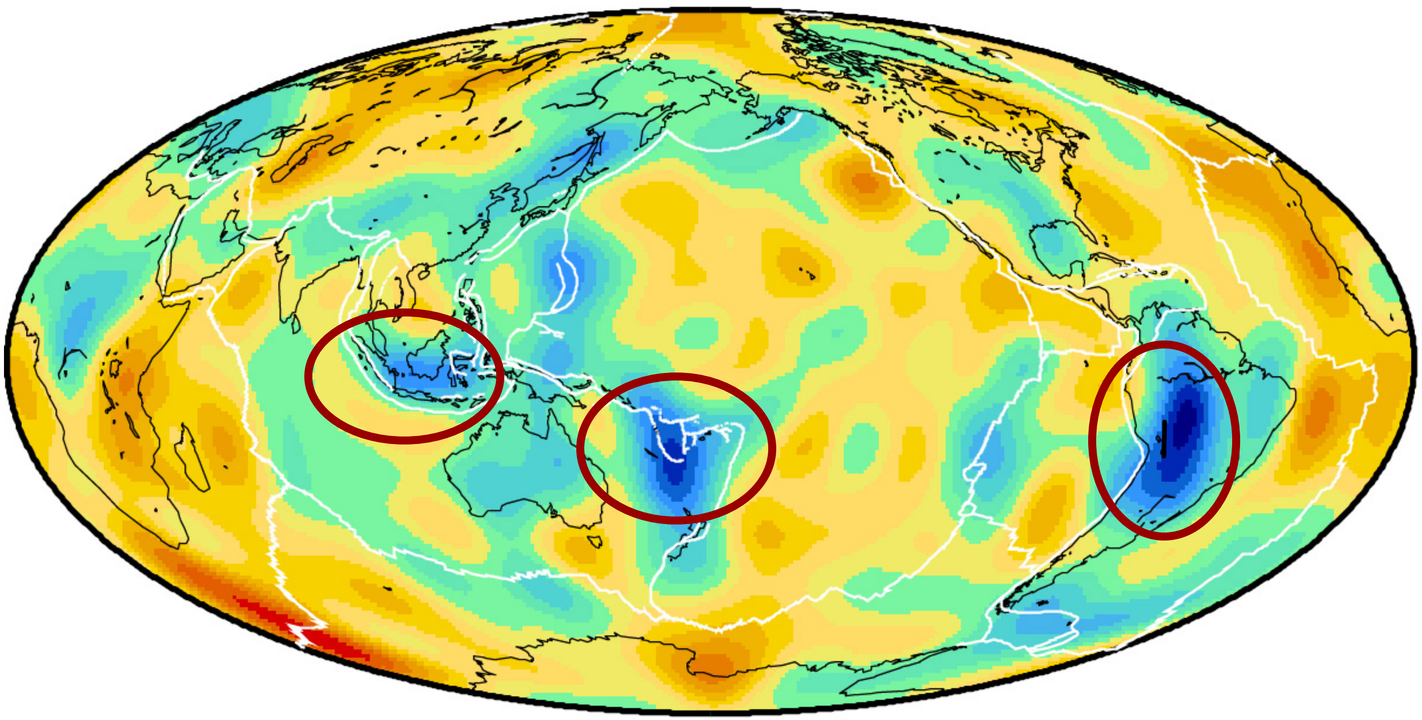


It cannot be this simple; even if it were true, it is not representative of the global behavior



Grand et al., 1997

Model S362ANI
Depth 750 km

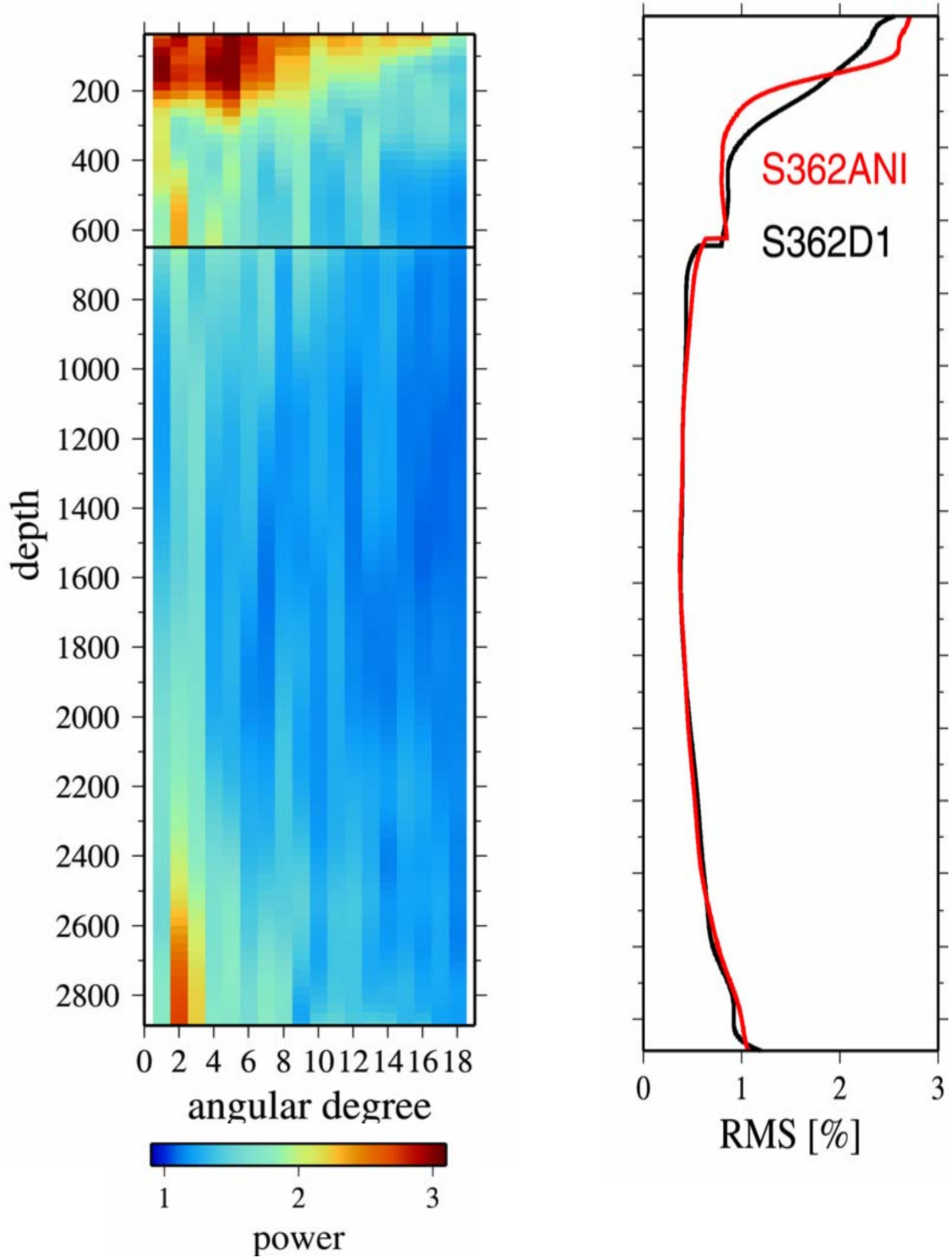


Strong, but spatially limited fast anomalies in the lower mantle may represent regions of limited penetration of subducted material accumulated in the transition zones

Questions:

- Why is global topography of the 410 km and 650 km discontinuities de-correlated?
- How do the slabs interact with the 650 km discontinuity?
- What happens to the slab material after it stagnates in the transition zone?
- Why is there such an abrupt change in the spectral power across the 650 km discontinuity?

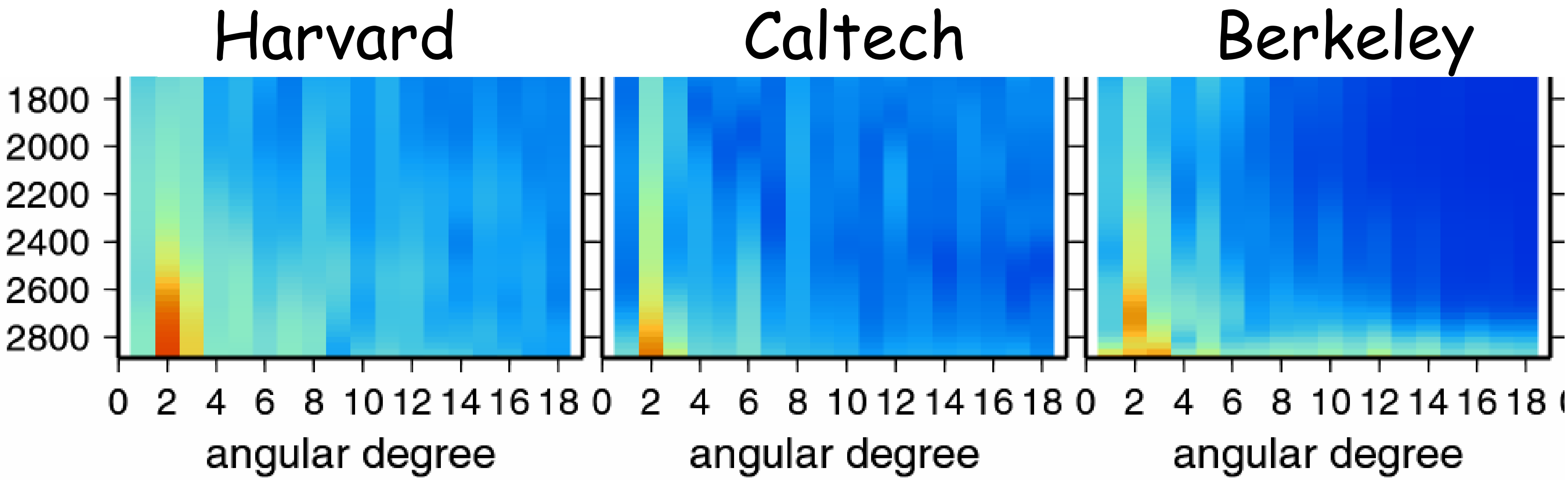
Core-mantle boundary layer



Power spectra and RMS of models S362ANI and S362D1

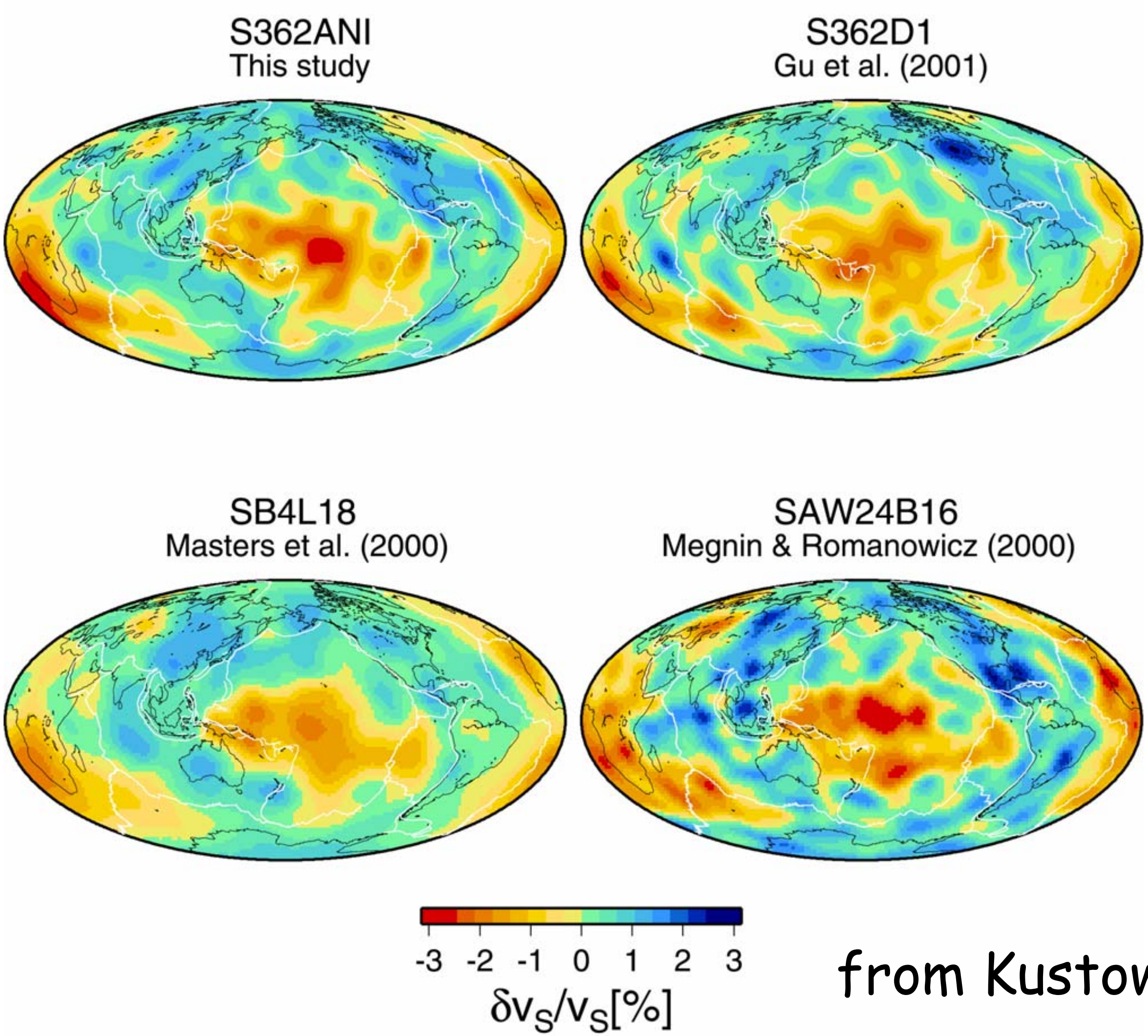
After Kustowski et al. (2008)

Power spectra of the three models near the CMB



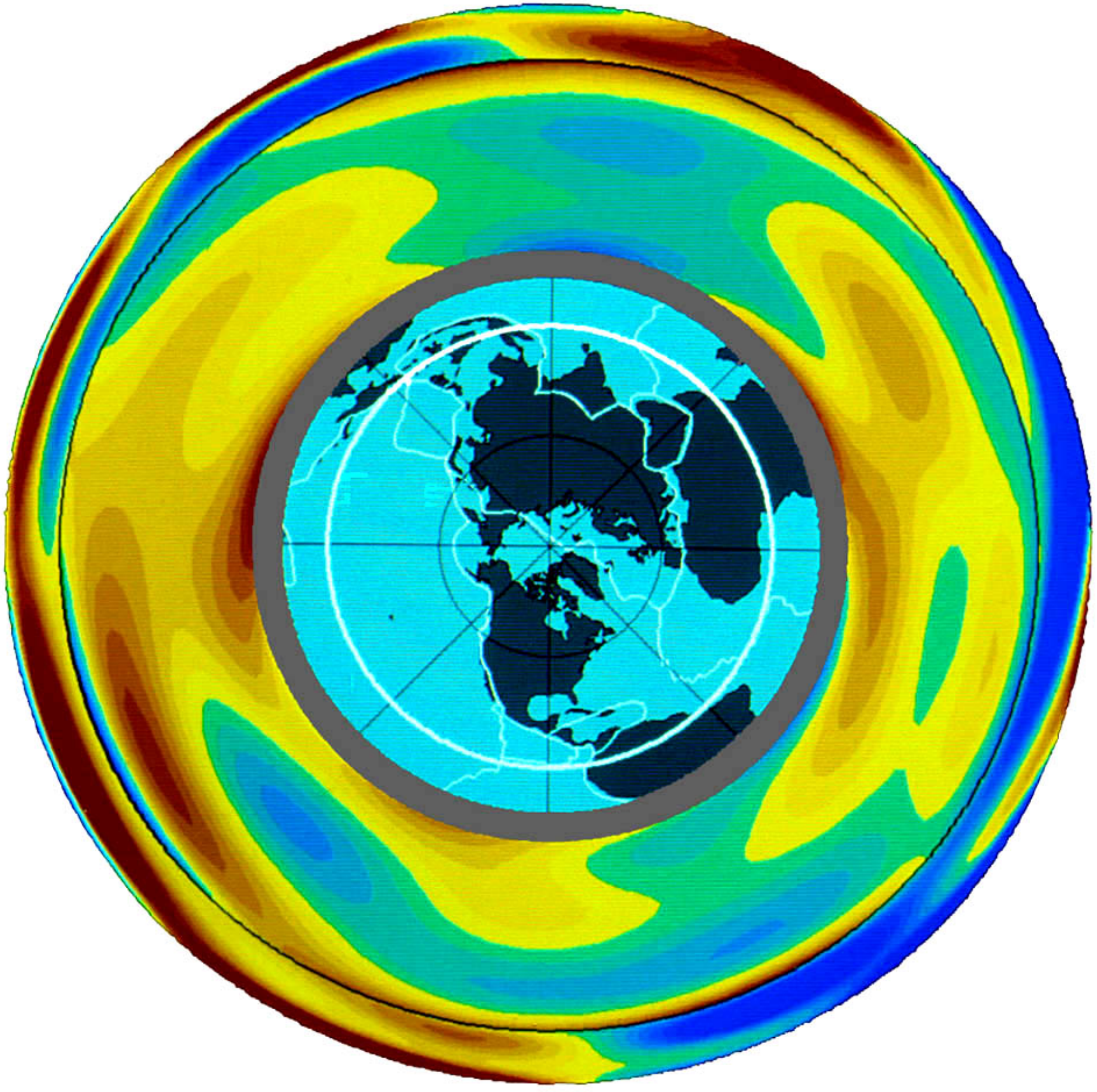
Kustowski et al. (2008)

2800 km depth



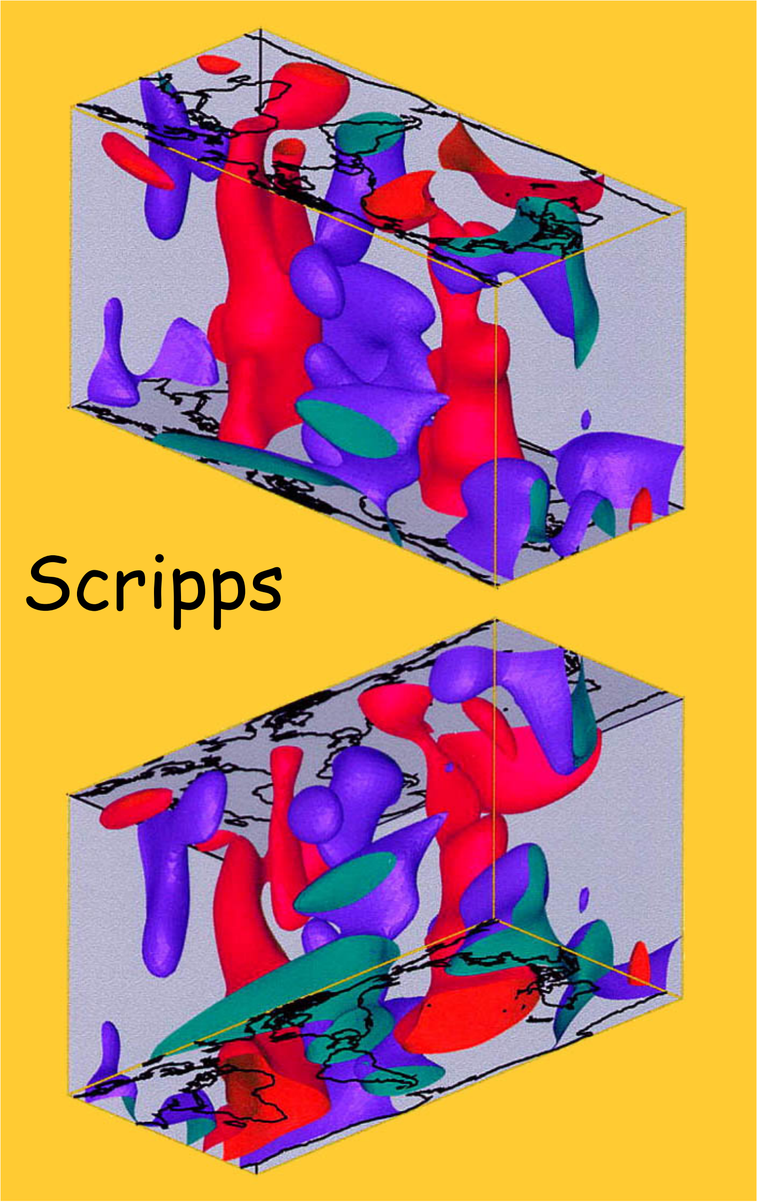
from Kustowski, 2006

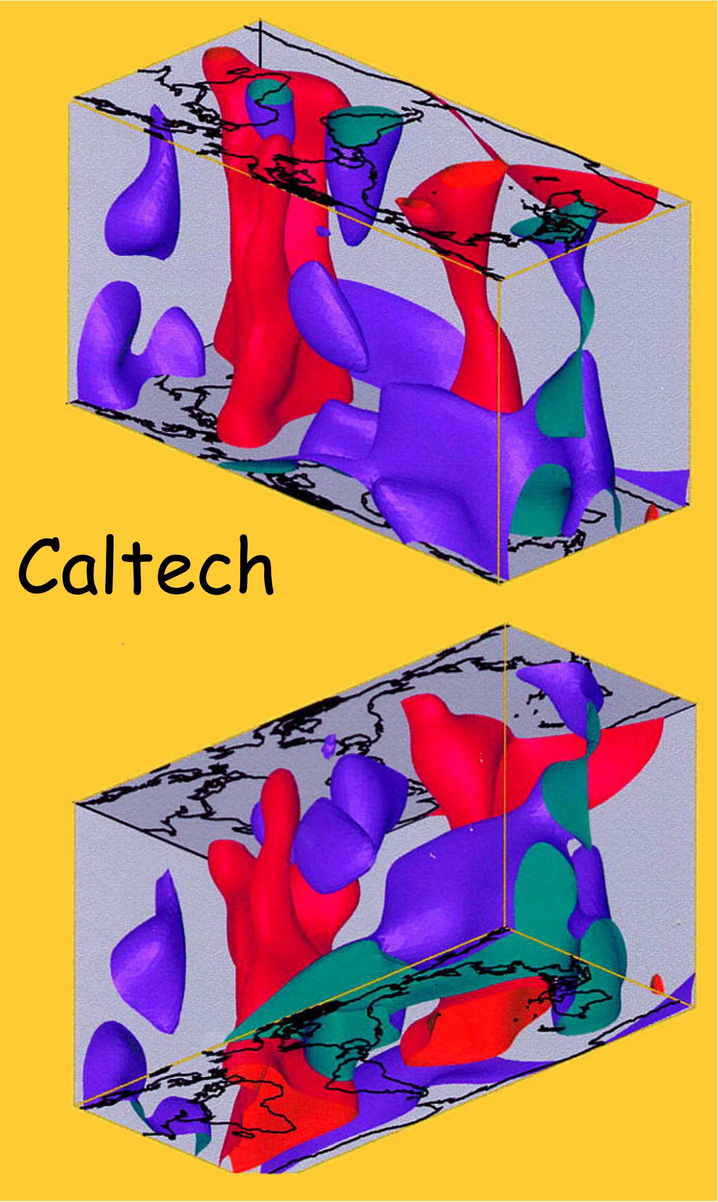
Equatorial cross-section



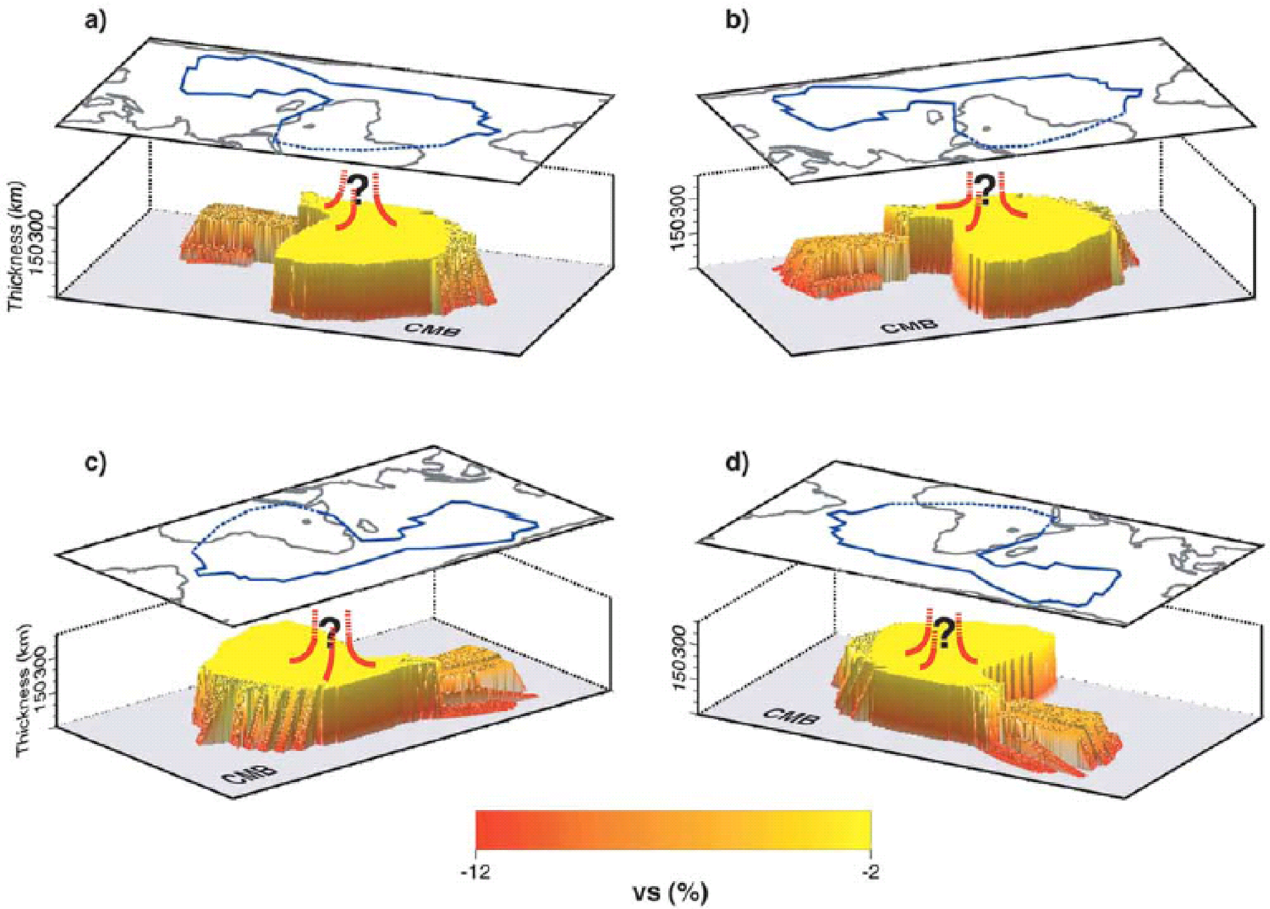
Dziewonski (1984) and Woodhouse and Dziewonski (1984)

Super-plumes





The shape of the African superplume



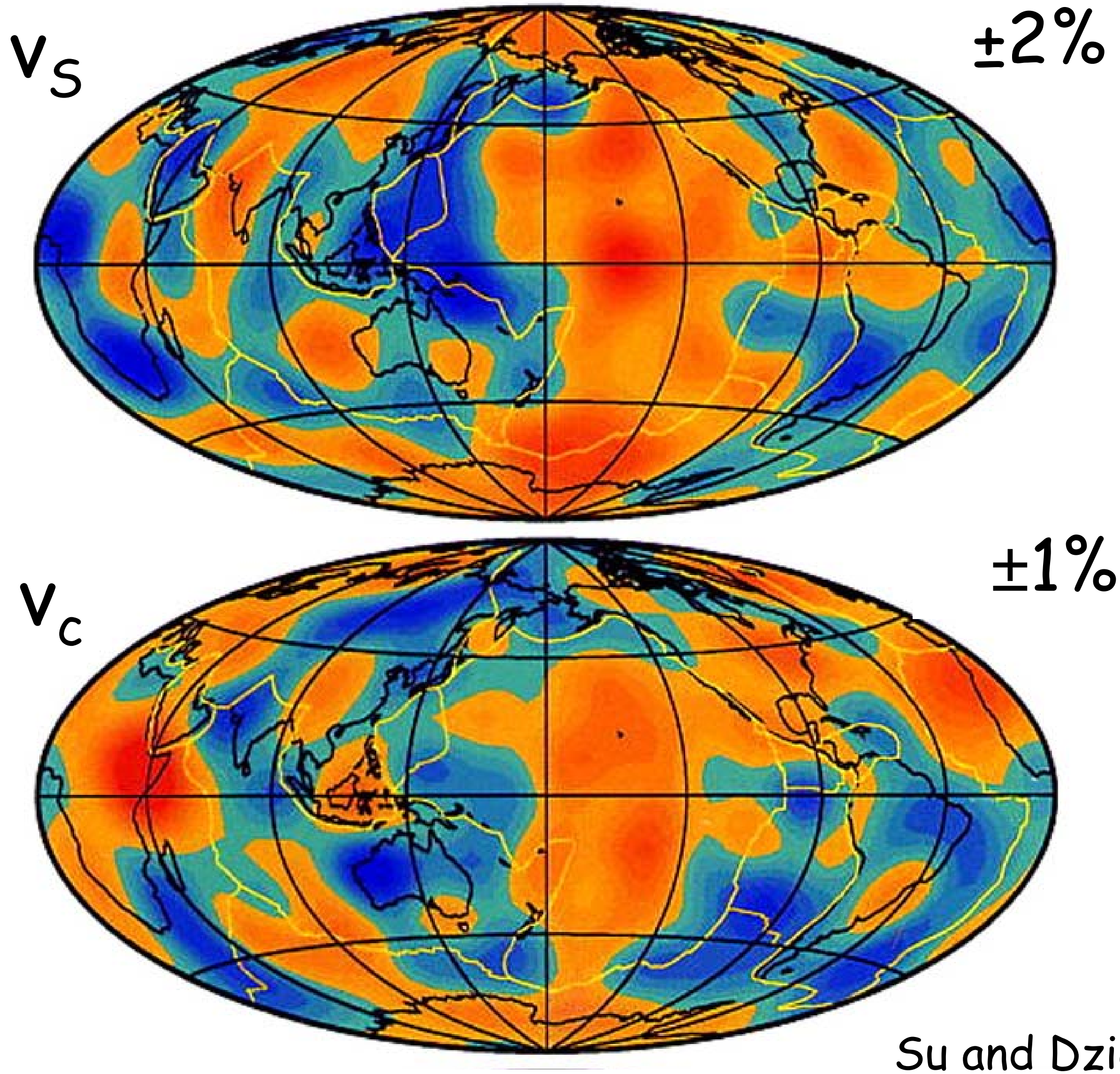
The vertical extent of the two superplumes is much greater than 300 km but velocity anomalies are less than -12%

from Wang and Wen (2004)

Trying to understand the super-plumes

Generally, models of the shear and compressional velocity are obtained independently. In 1994, Su & Dziewonski obtained P- and S-velocity models by inverting simultaneously a large data set. However, P-velocity depends both on shear modulus and bulk modulus. To isolate this interdependence, Su & Dziewonski (1997) formulated the inverse problem for a joint data set sensitive to P- and S-velocities and derived 3-D perturbations of **bulk sound velocity** and **shear velocity**.

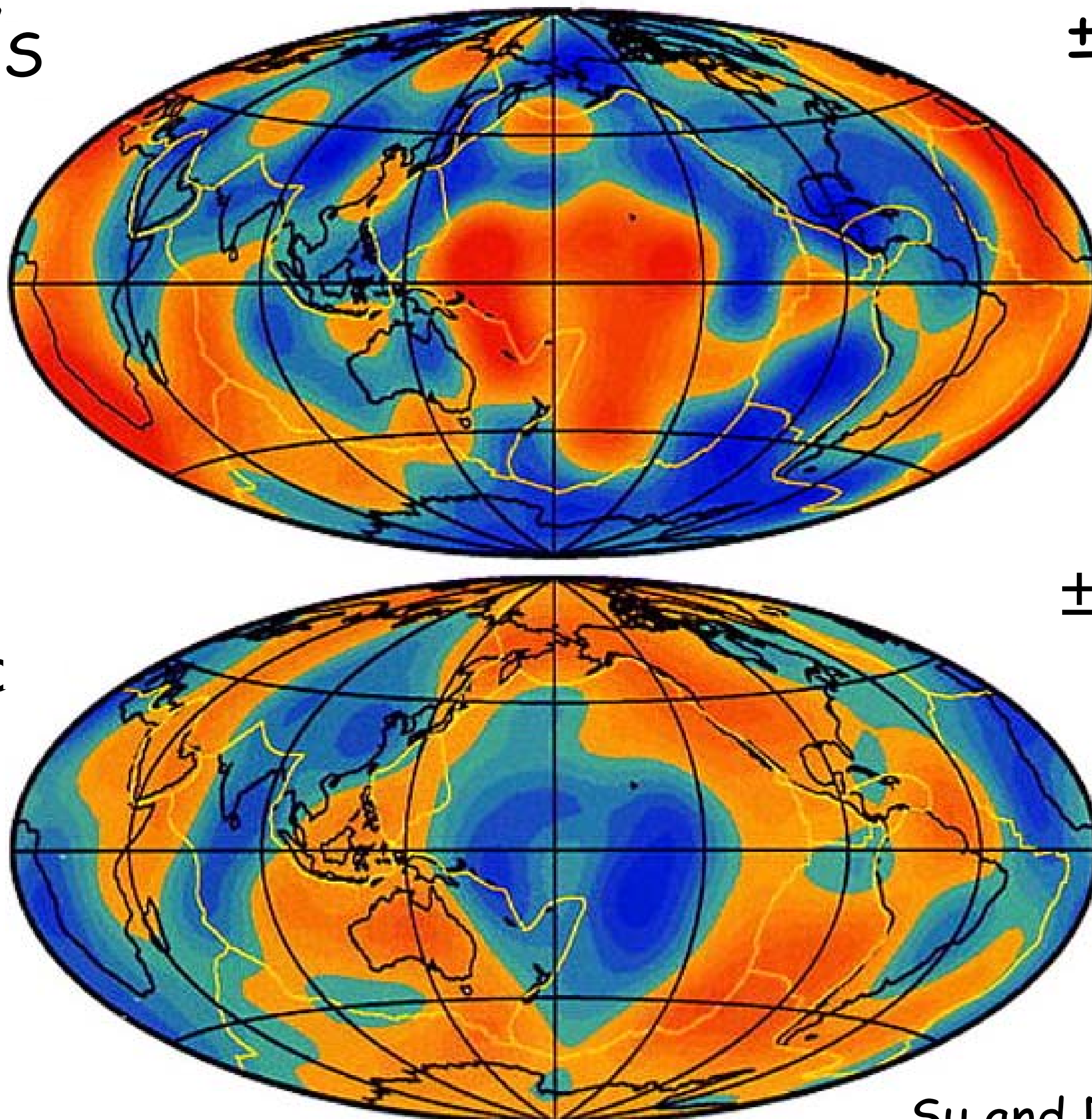
Shear and bulk velocity at 550 km



Su and Dziewonski, 1997

Shear and bulk velocity at 2800 km

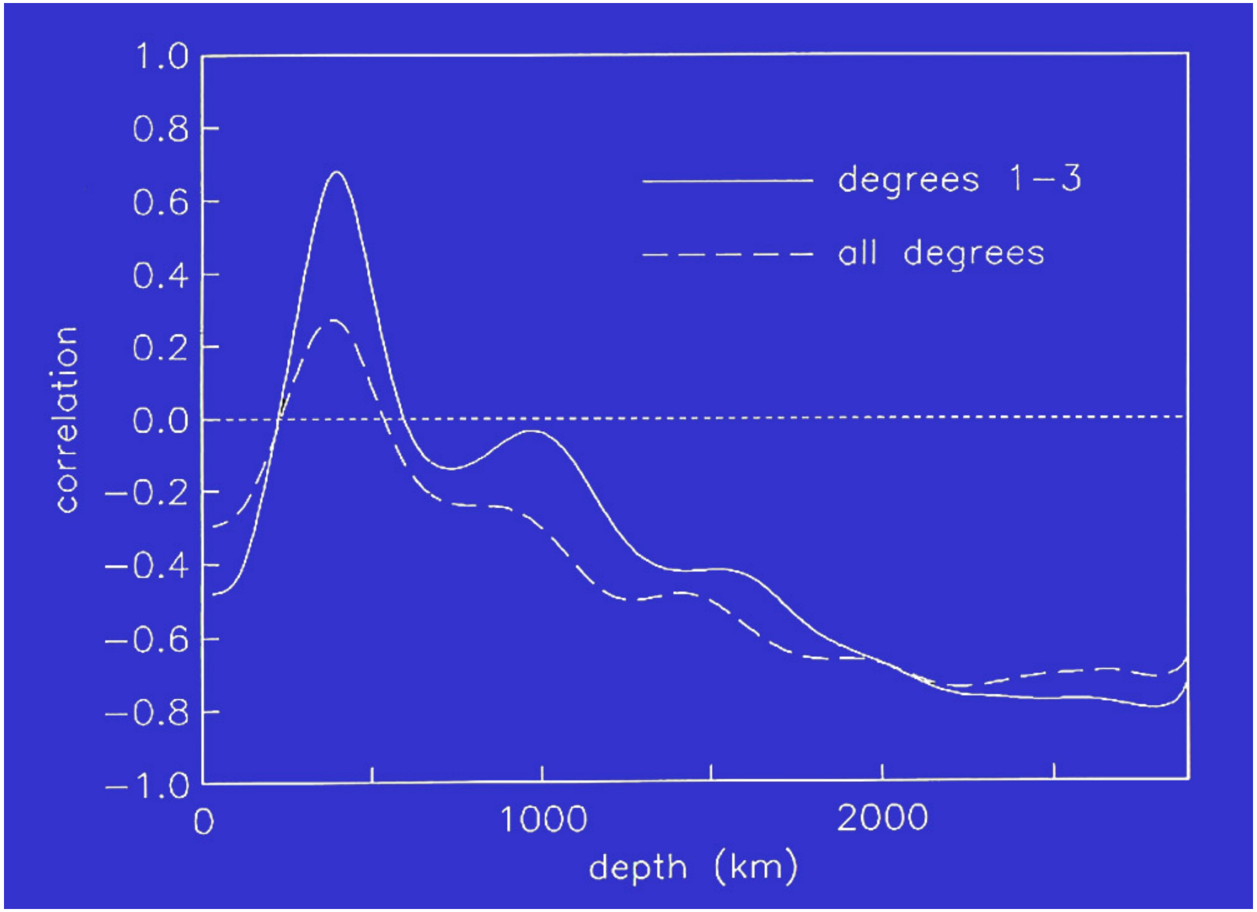
v_S ±2%



v_c ±1%

Su and Dziewonski, 1997

Bulk Sound and Shear Velocity Anomalies



Correlation between the bulk sound and shear velocity anomalies changes from +0.7 in the transition zone to -0.8. From Su and Dziewonski, 1997.

CMB questions:

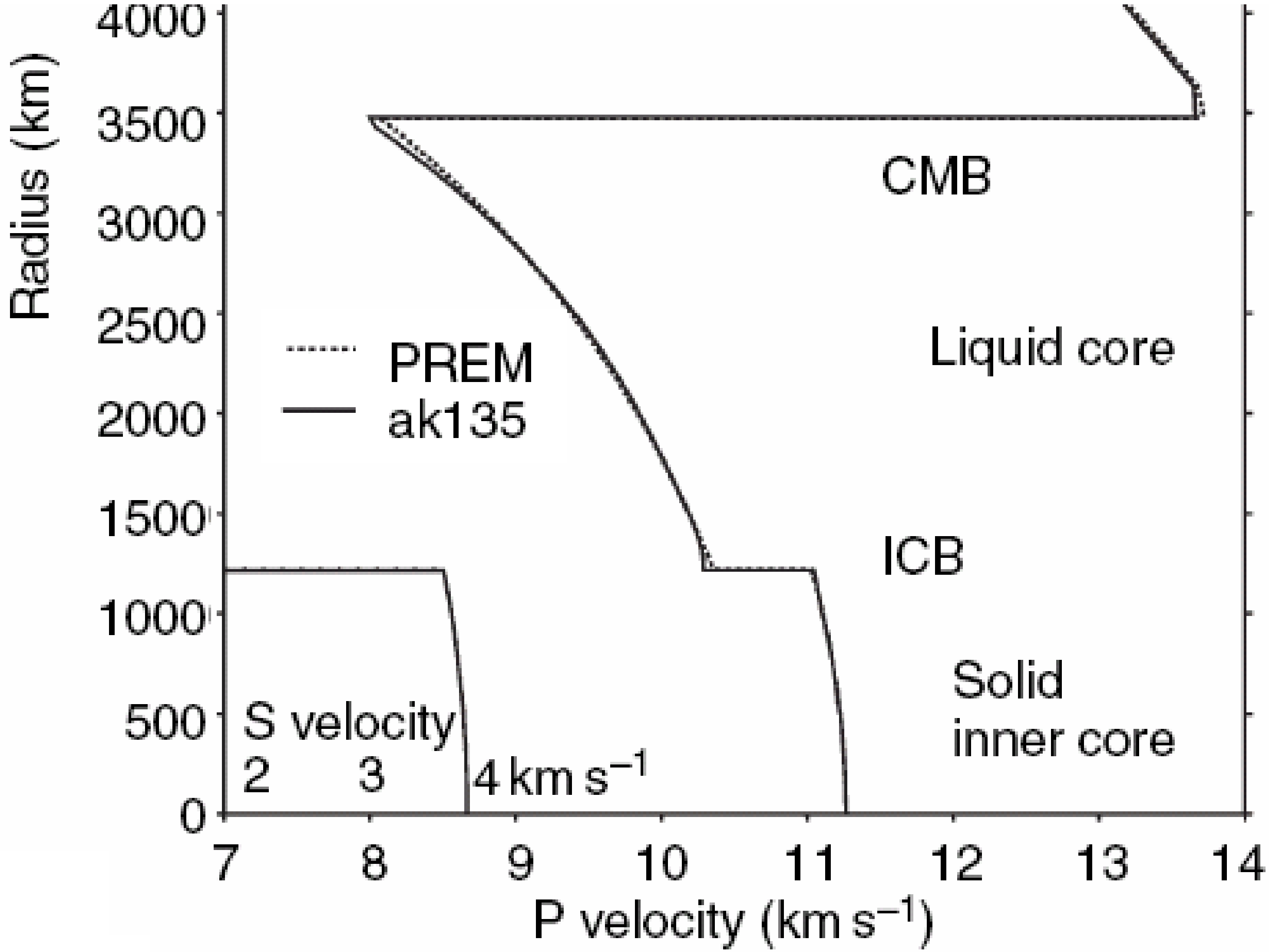
- How have the super-plumes formed?
- What part of the anomalies is caused by compositional rather than thermal variations?
- Why do the super-plumes continue above the D" without an apparent abrupt change in the amplitude of the anomaly?

Outer core boundary layers

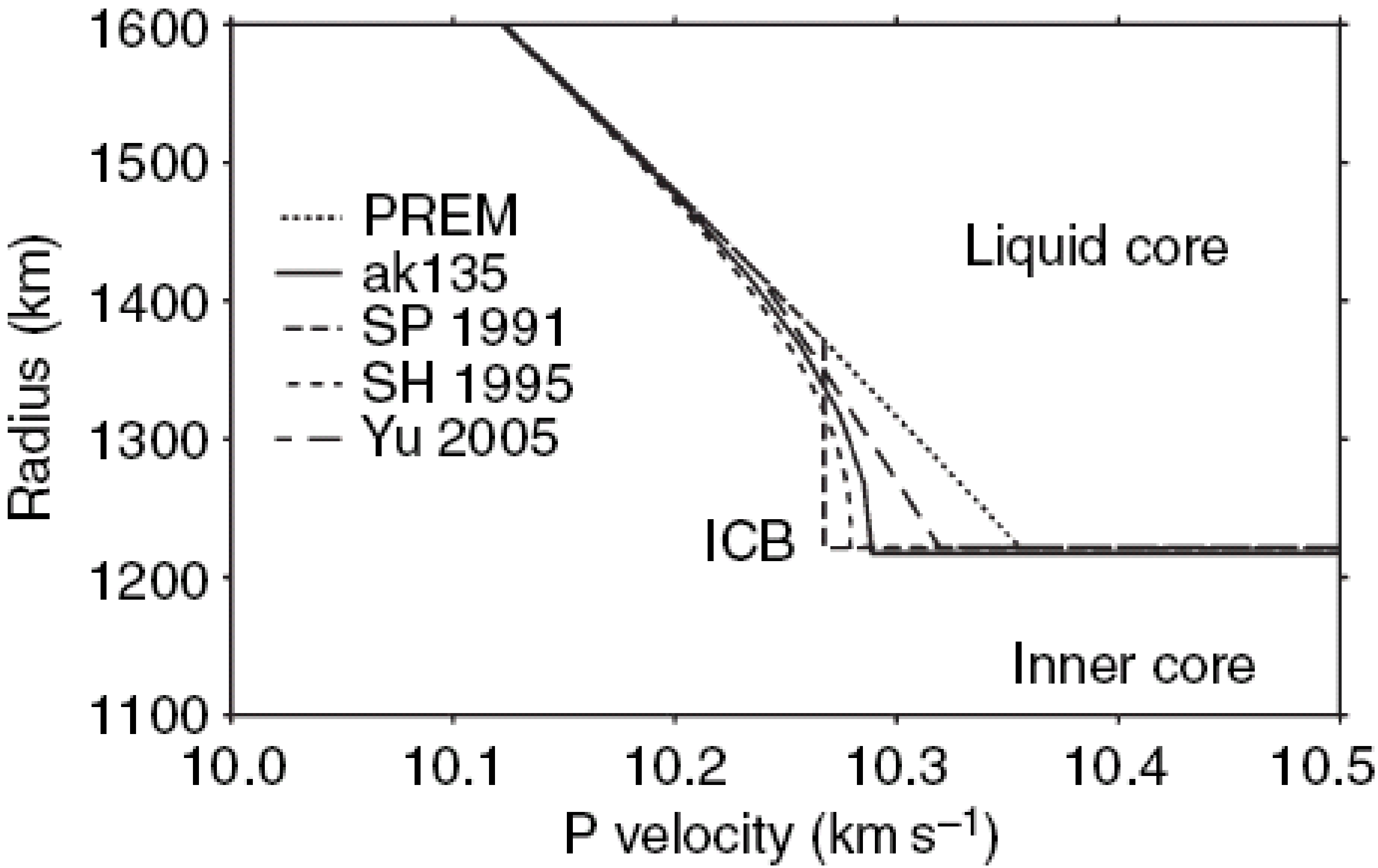
Stable layers in the outer core?

Generally, the outer core is expected to be well mixed. However, in some 1-D models compressional velocity the gradients at the top and the bottom of the outer core are anomalous, leading to inference that either one or both of these layers are stable.

P-velocity gradient in the outer core



P-velocity gradient near the ICB



Core questions

- Are there stable layers at the top and bottom of the outer core?
- How large is the density contrast between the inner and outer core?
- How the properties of the inner core vary with depth?
- What is the cause of inner core anisotropy?

Inner-most Inner Core?

PKIKP residuals in the distance range from 173 to 180 degrees show anomalous behavior as a function of the ray angle, indicating that anisotropy within 300 - 400 km of the Earth's center is different from the bulk of the inner core.