The Earth is Red;

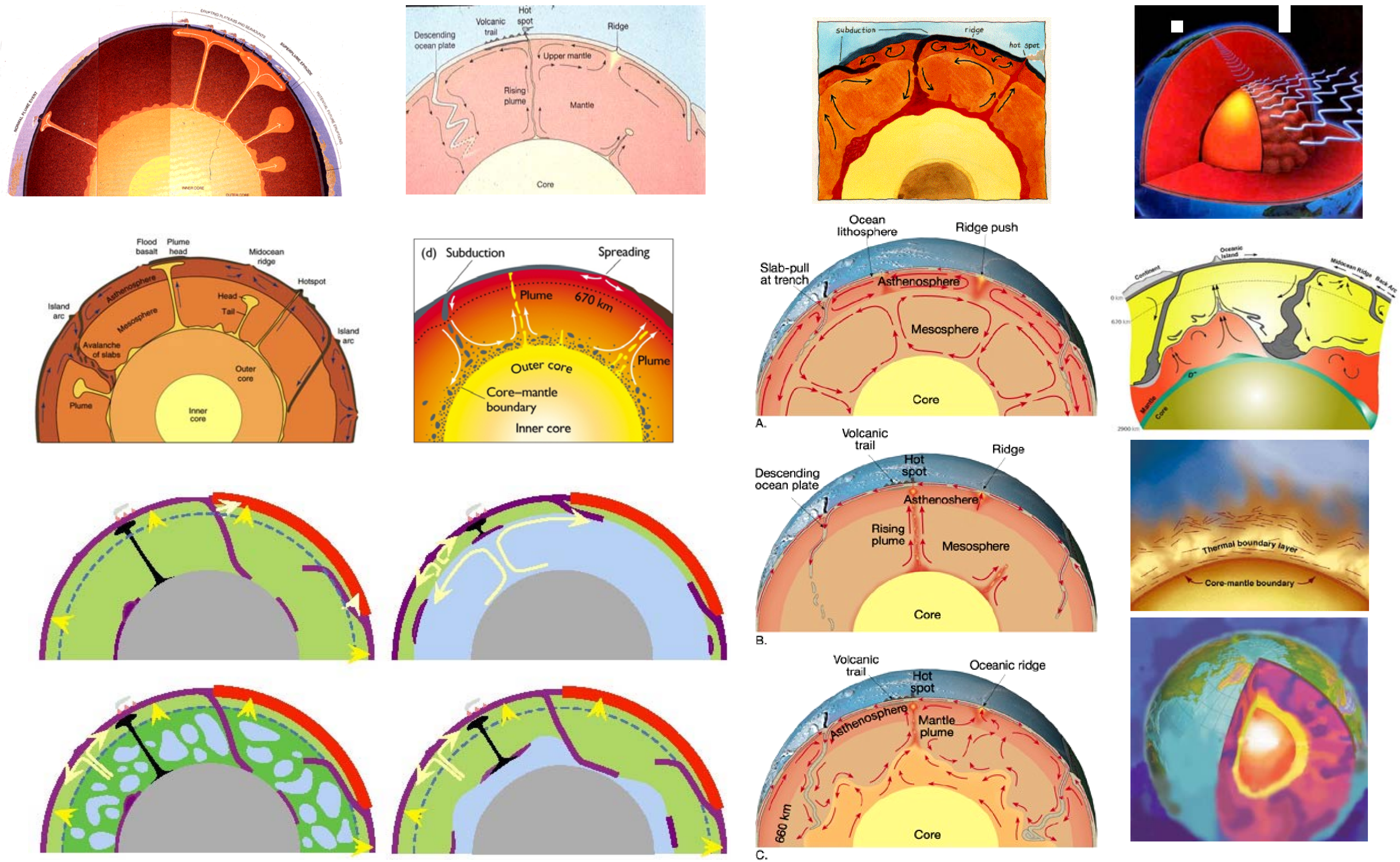
Dominance of large wavelength features in mantle boundary layers

Adam M. Dziewonski

KITP, EARTH08, July 2, 2008

Kircher, 1665

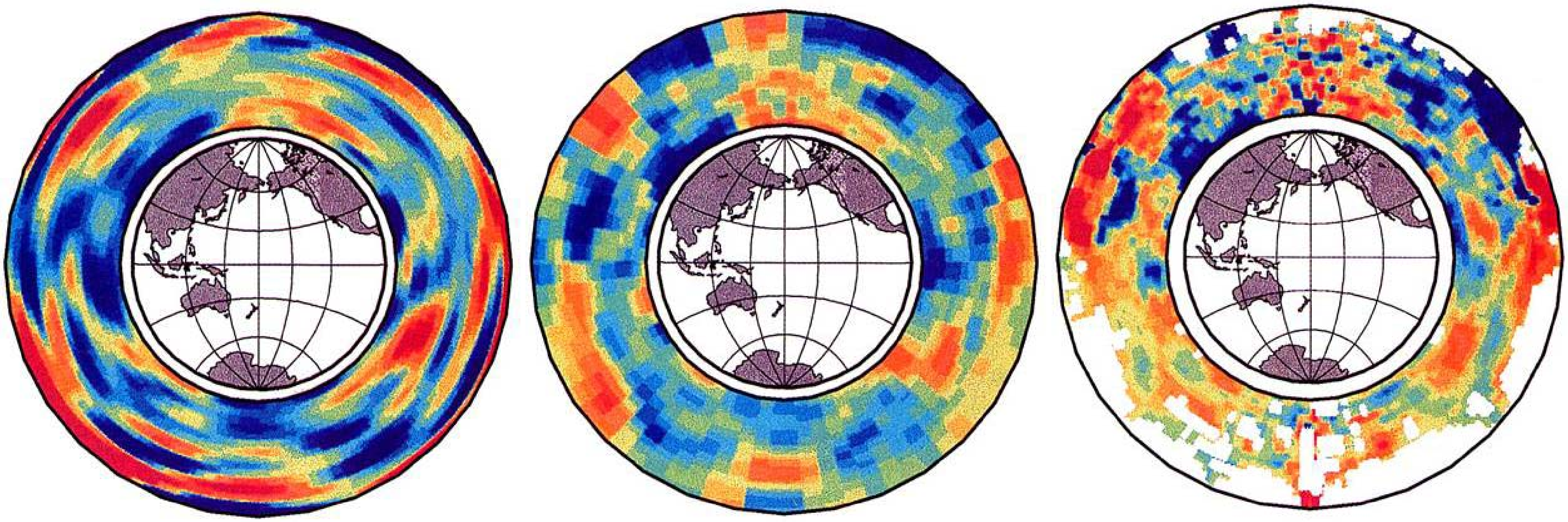
ca. 2005



from E. Garnero's files

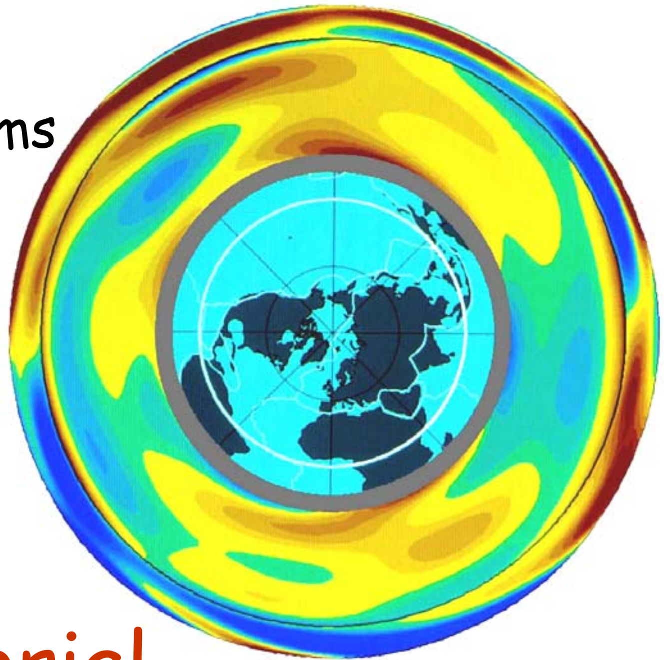
Same data, three models

deg. 12 sph. har.	5 deg. X 5 deg.	2 deg x 2 deg

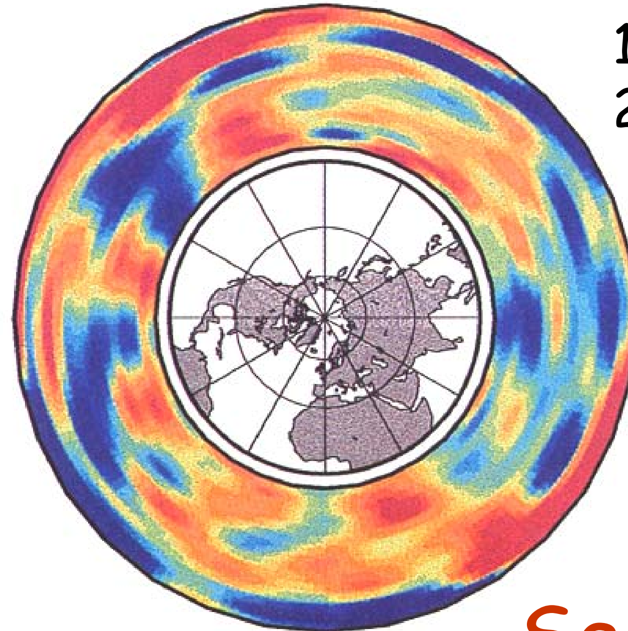


Su & Dziewonski, 1997	Boschi & Dziewonski, 1999	Van der Hilst et al., 1997

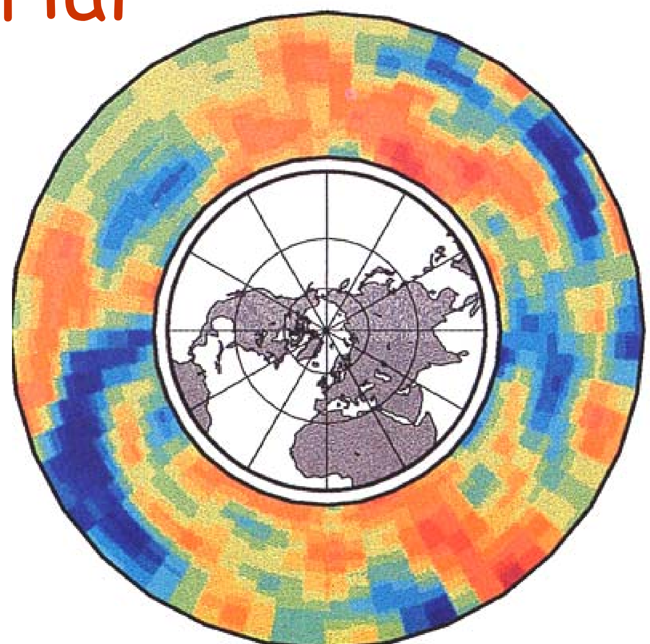
1984
245 parms



1997
2,500 parms

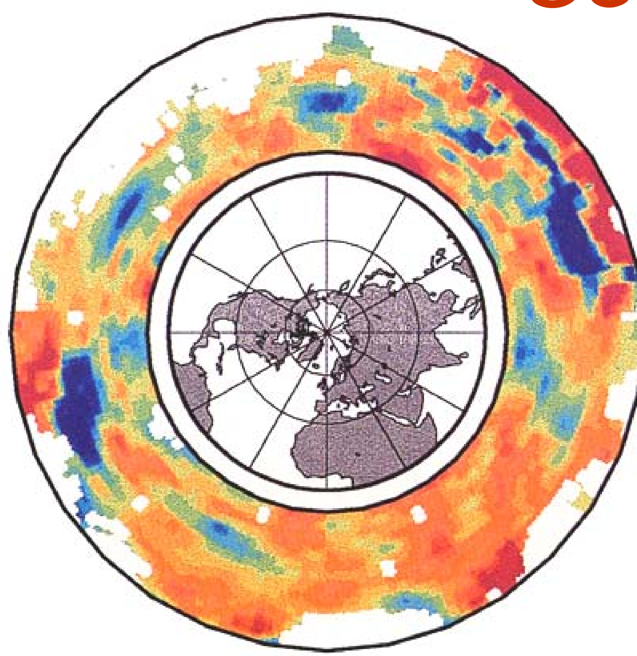


Equatorial Sections



1999

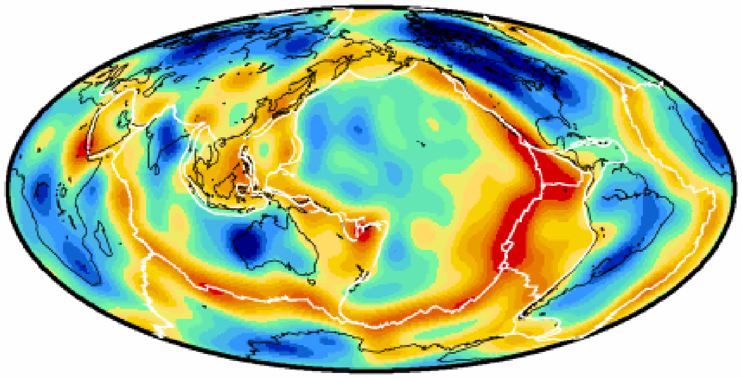
25,000 parms



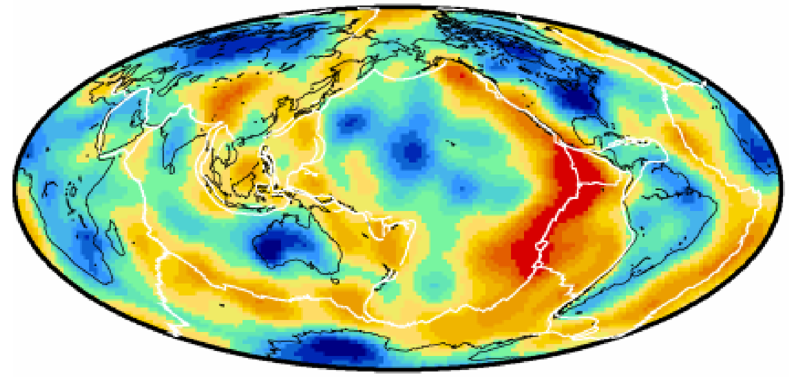
1997
250,000
parms

70 km depth

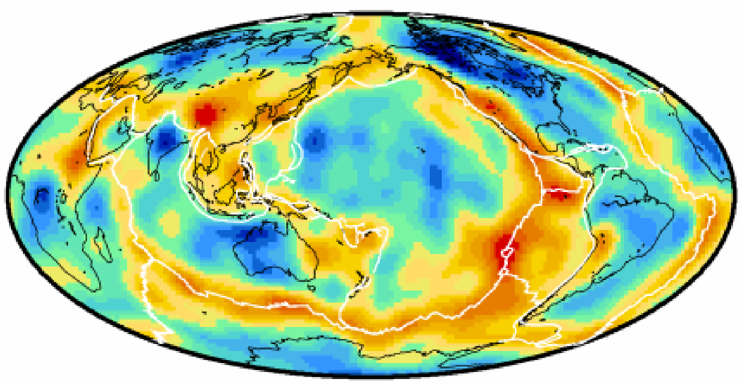
S362ANI
This study



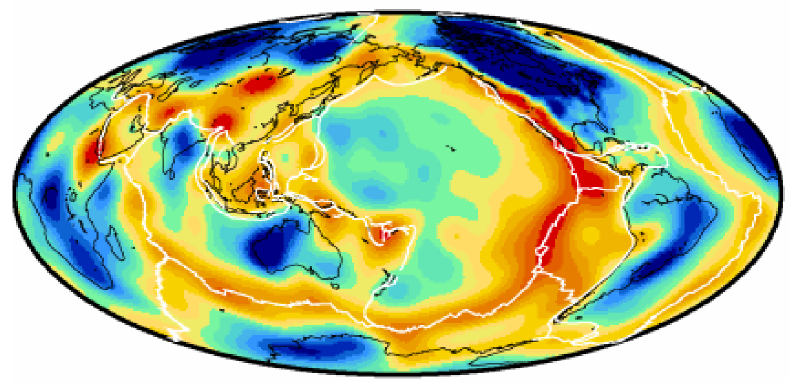
SB4L18
Masters et al. (2000)



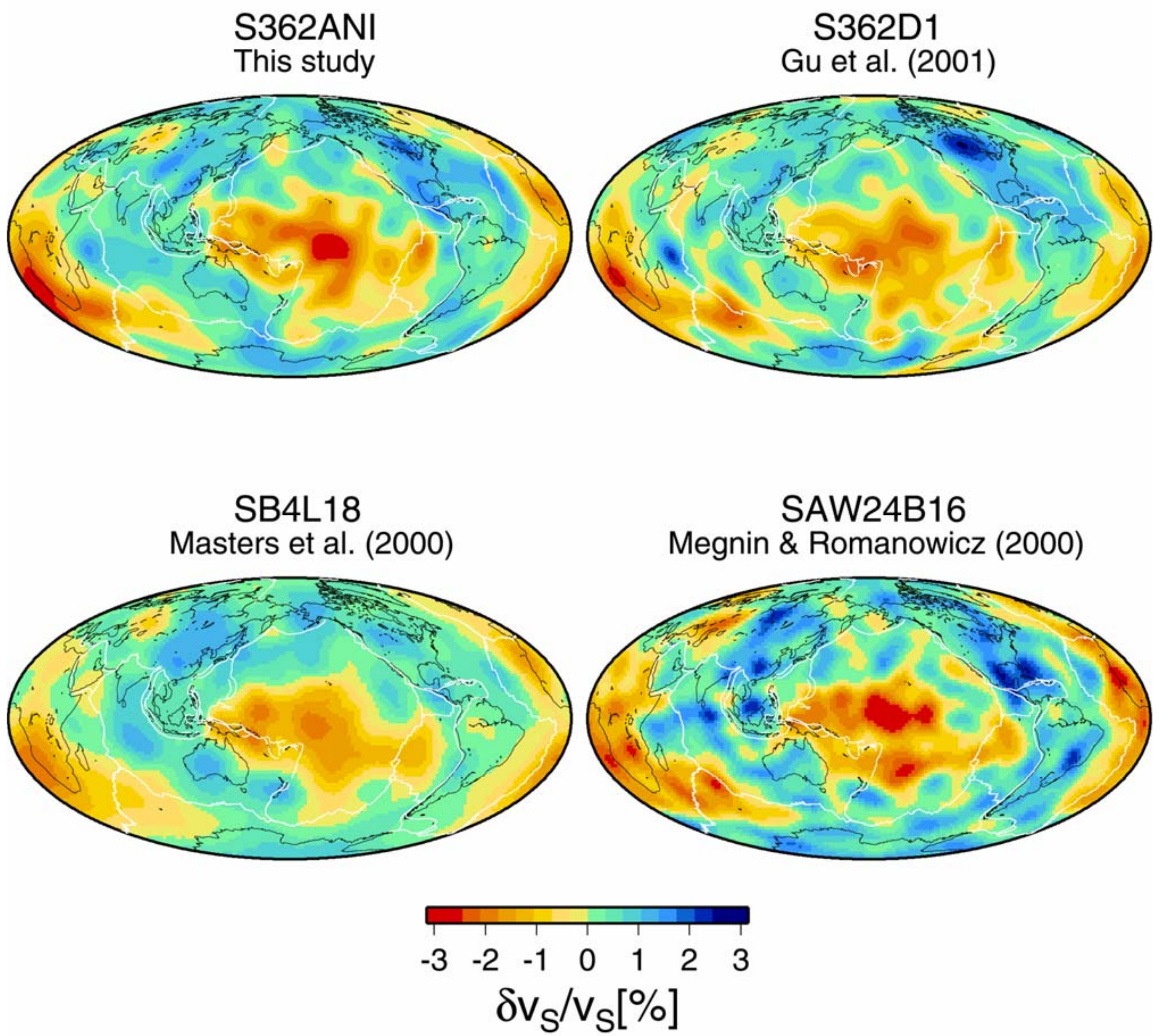
SAW24B16
Megnin & Romanowicz (2000)



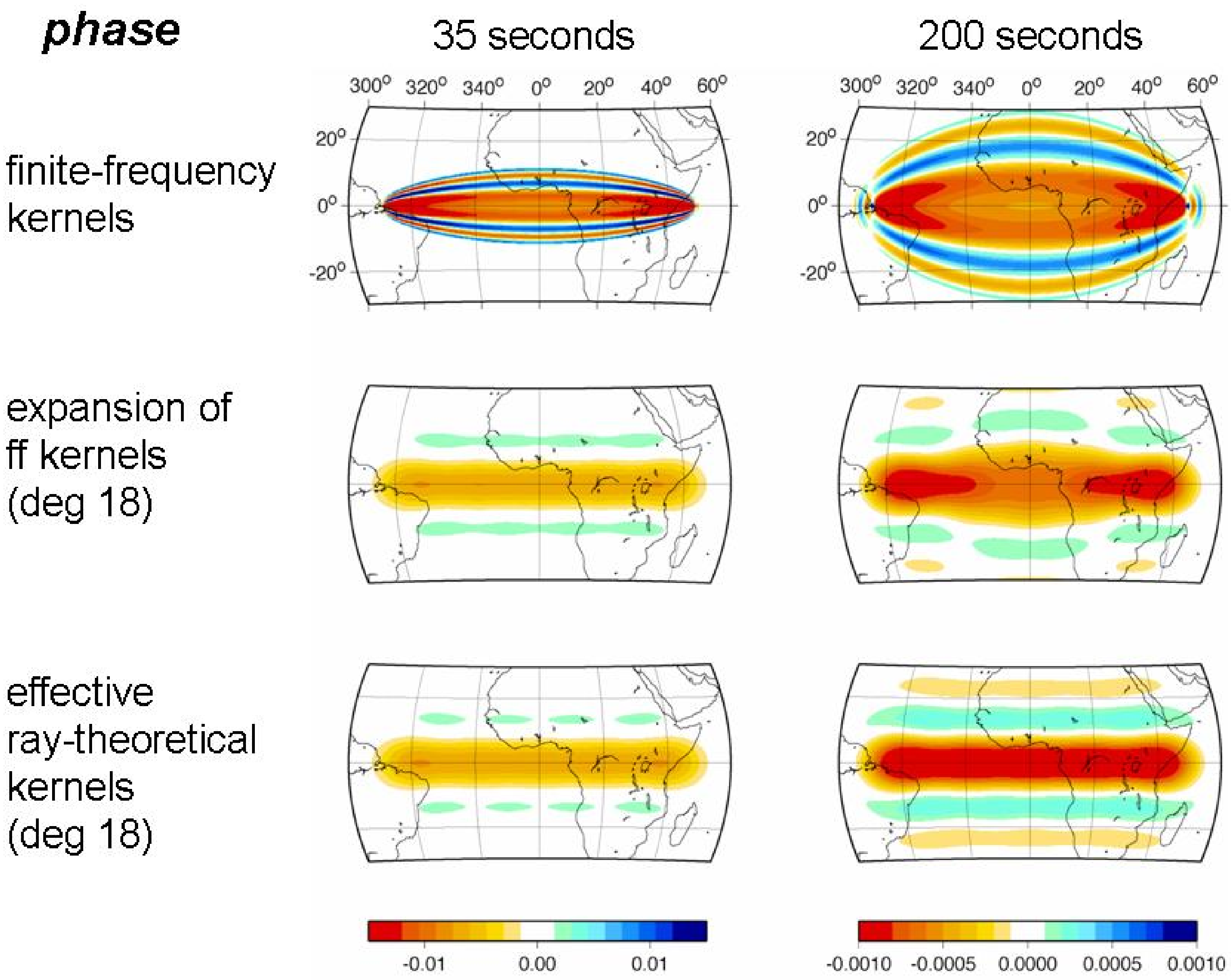
Nettles (2005)



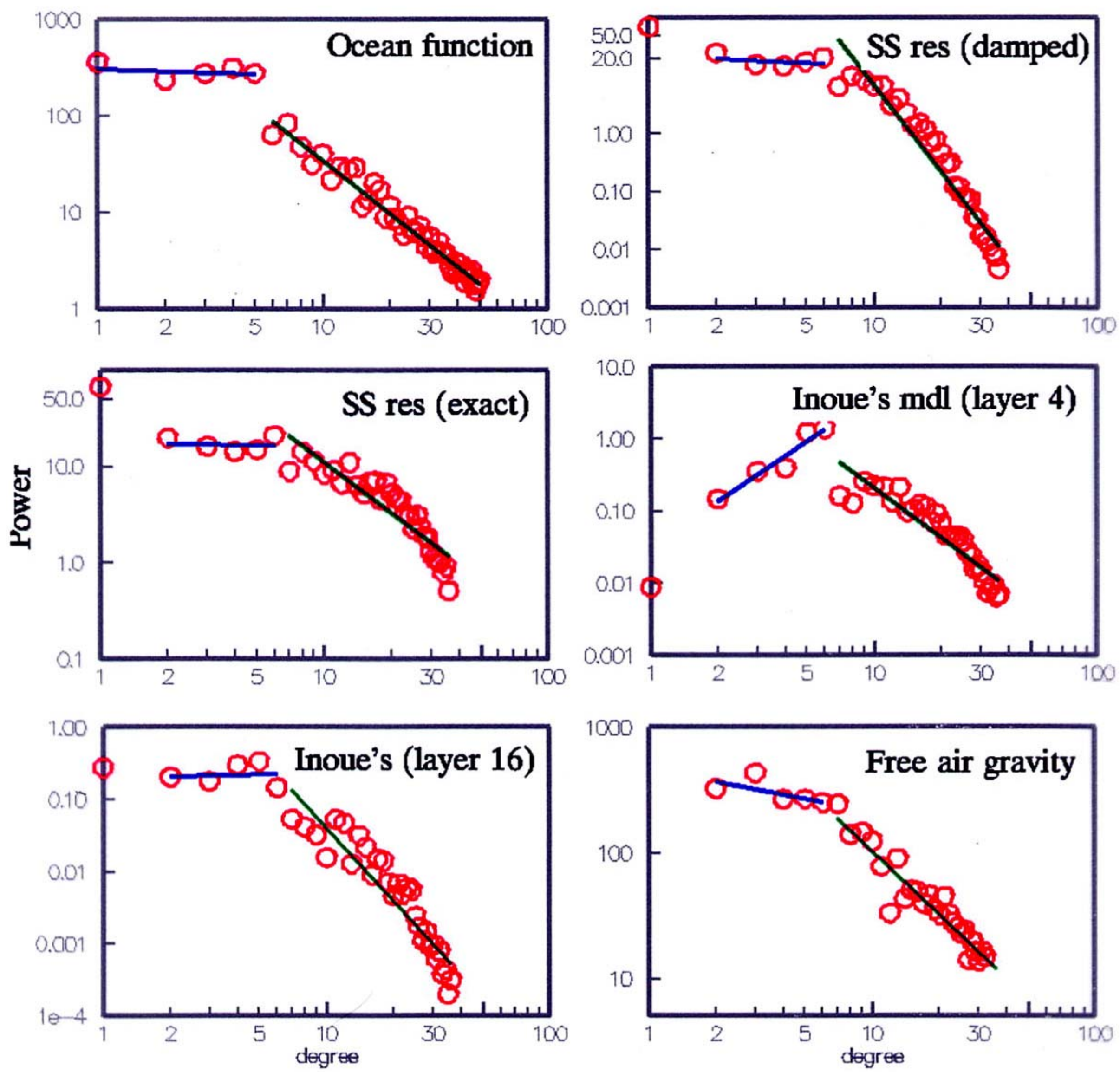
2800 km depth



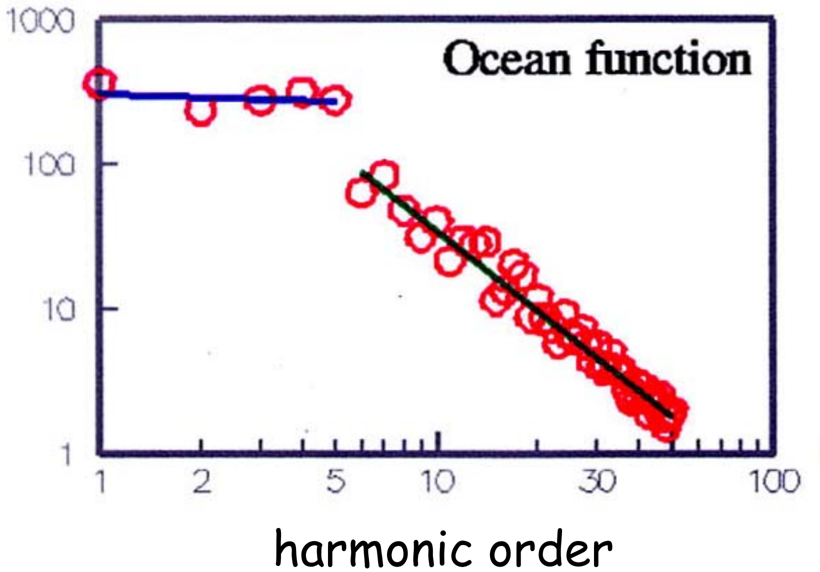
Finite frequency vs. ray theory



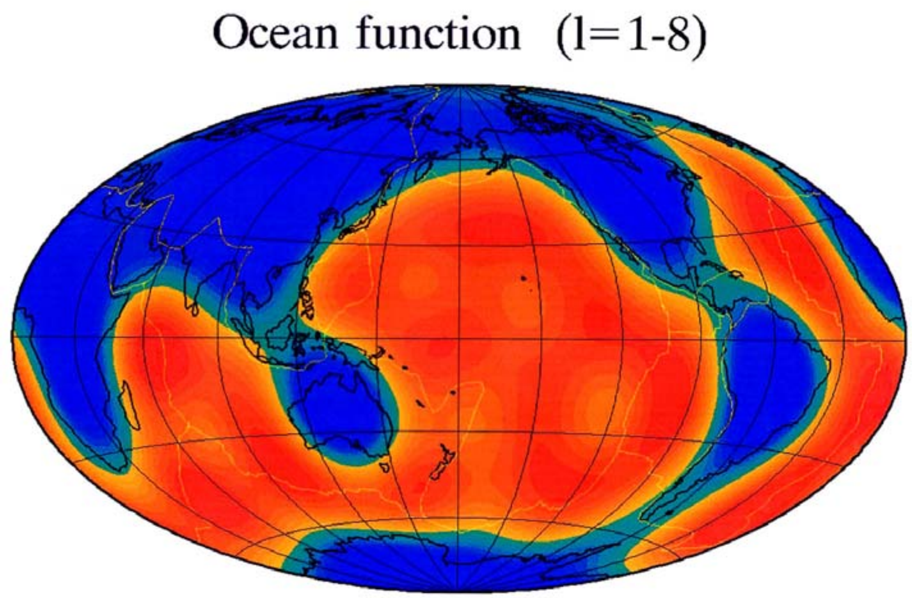
Power spectra of S. H. expansion of several terrestrial functions

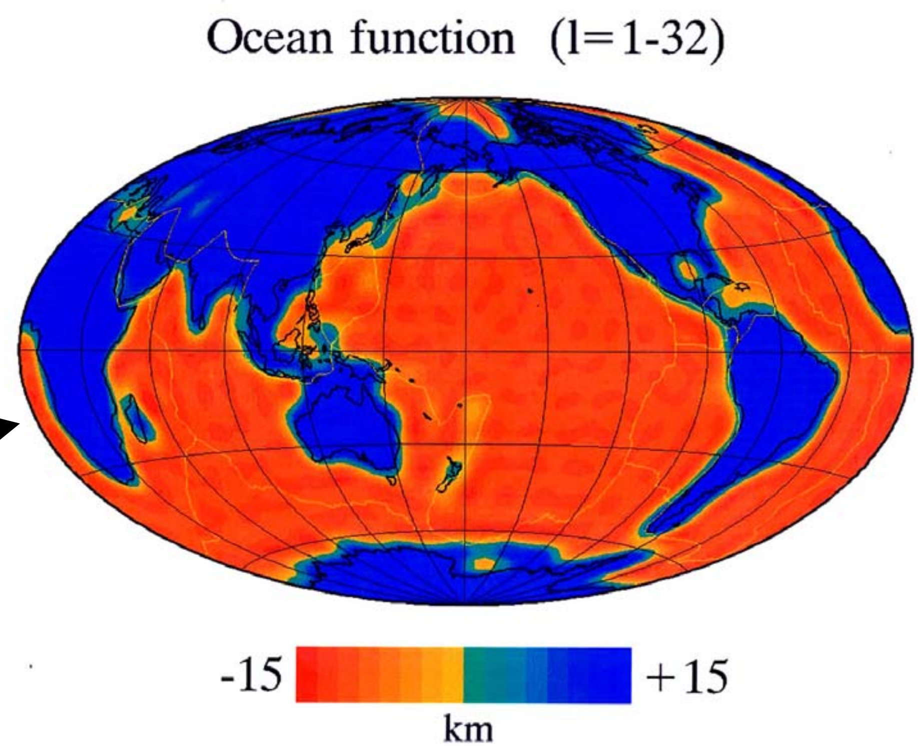


The properties of a “super-red” spectrum



15 times more coefficients →



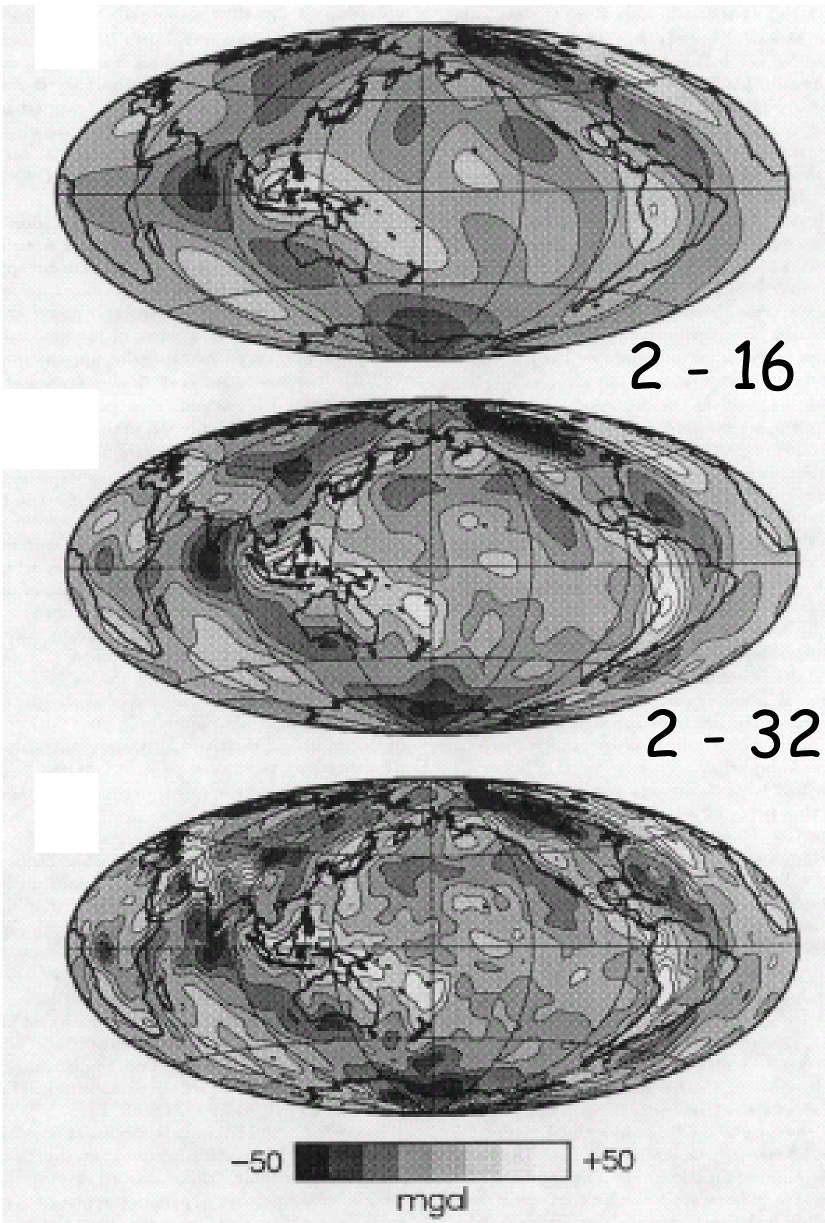


Synthesizing the free air gravity

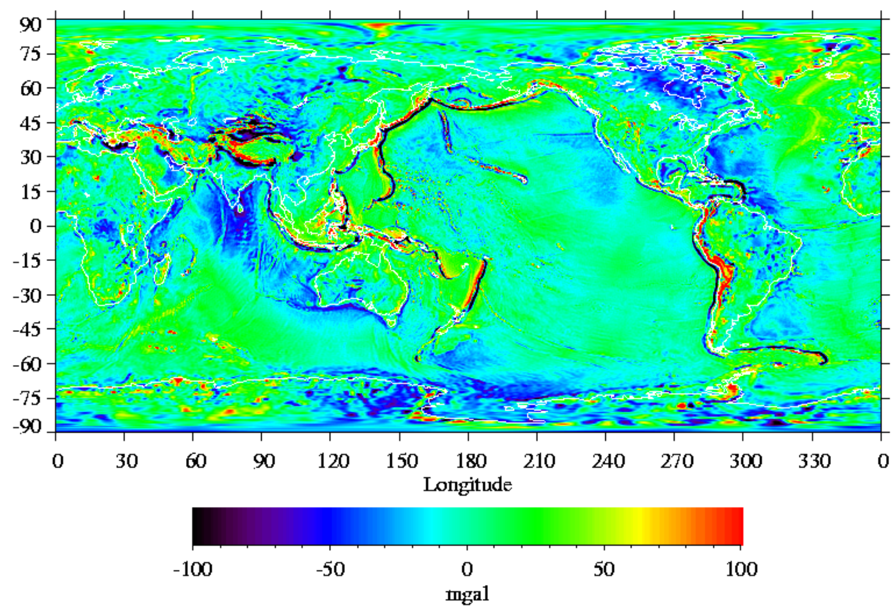
2 - 8

2 - 16

2 - 32

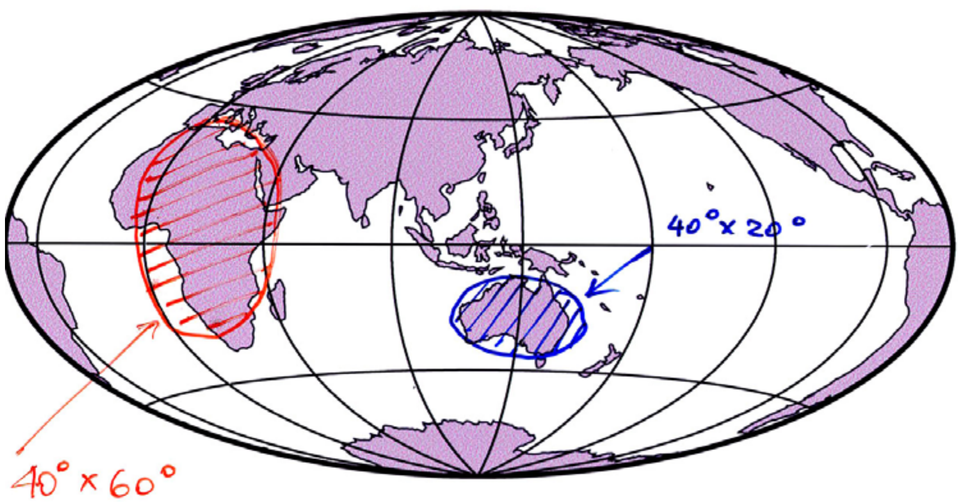


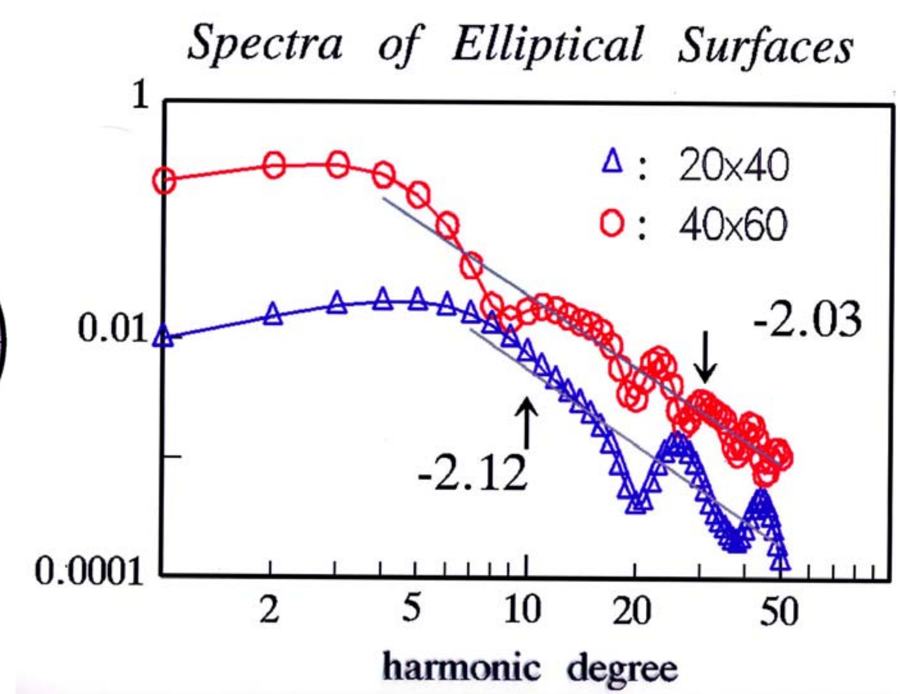
2 - 360



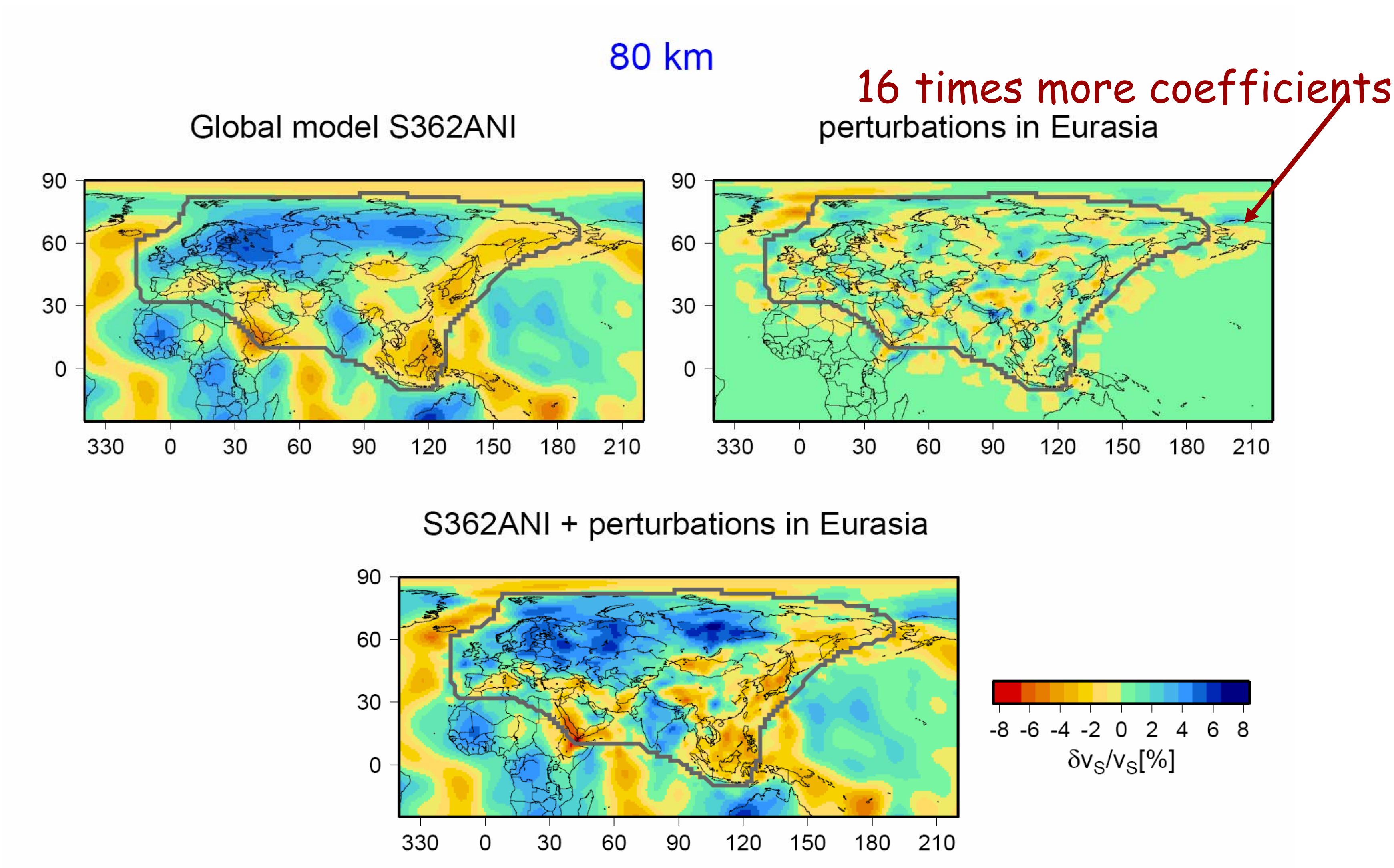
Where do these flat- steep spectra come from?

Two elliptical surfaces of different dimensions





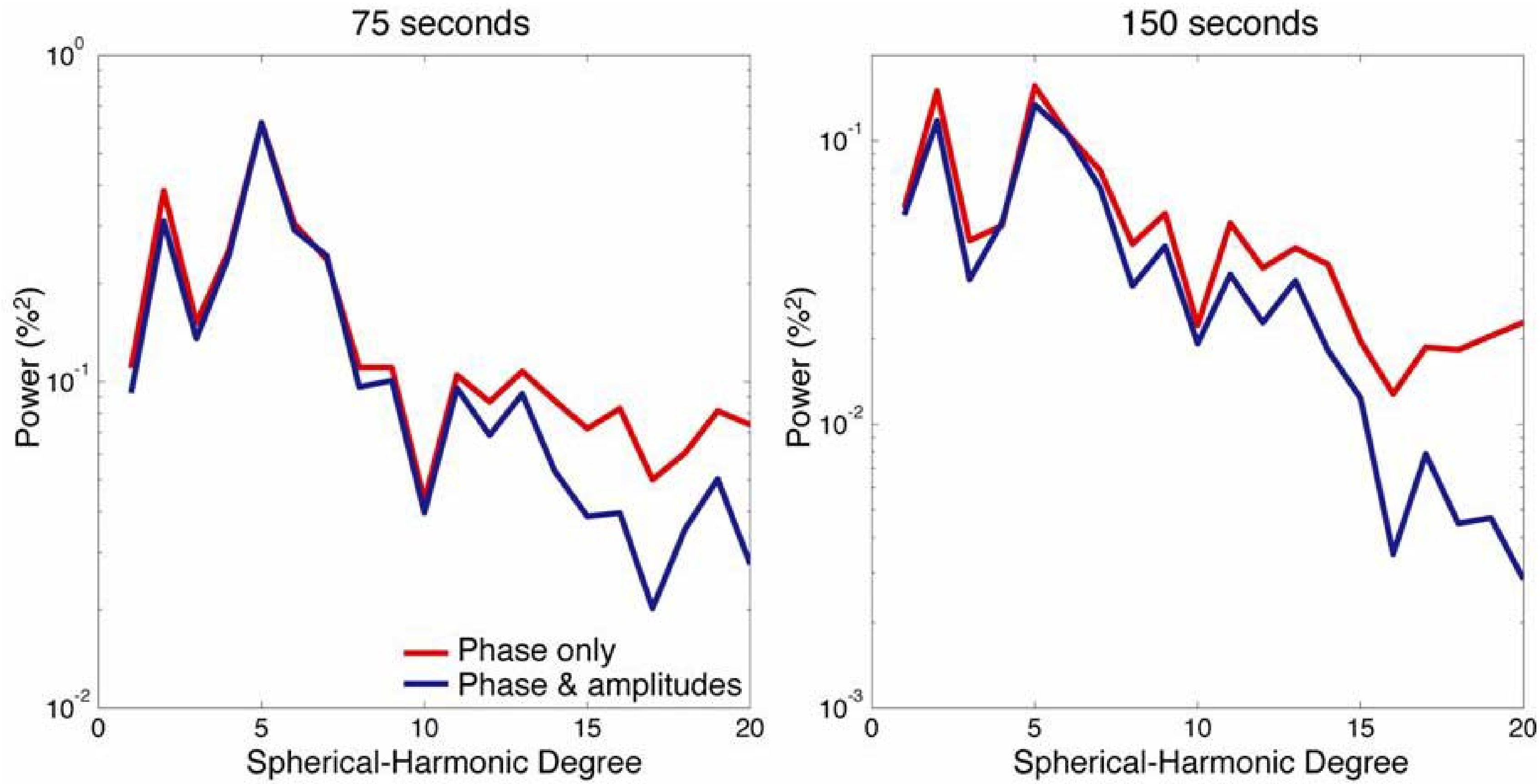
Relative contribution of the long- and short-wavelength anomalies



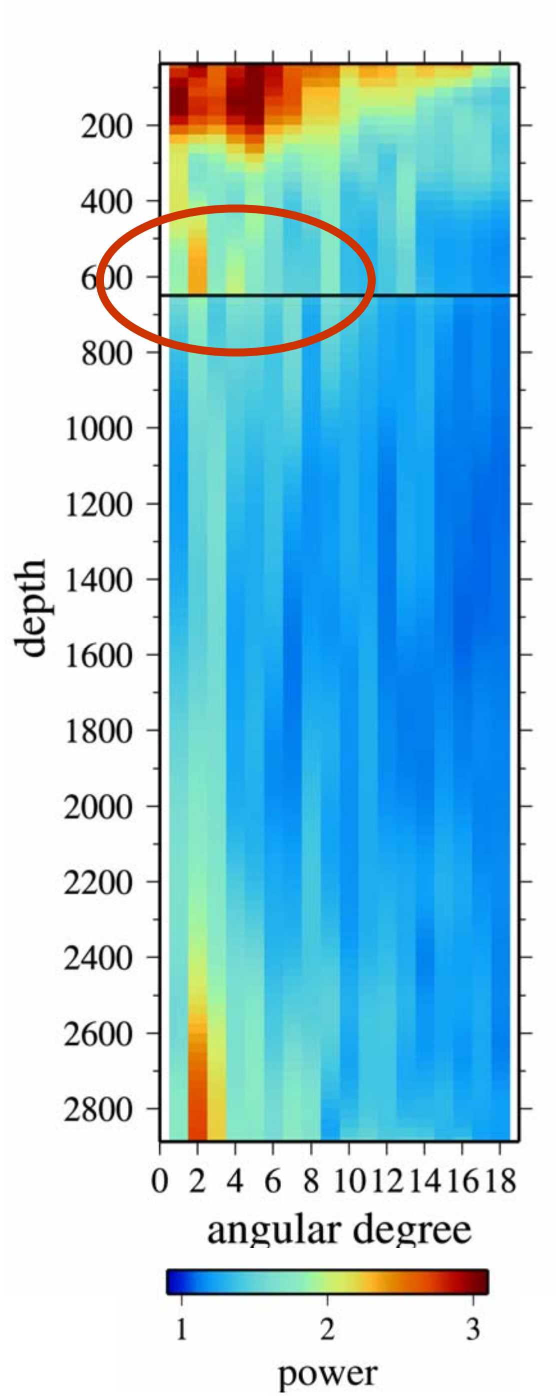
From Kustowski et al., 2008

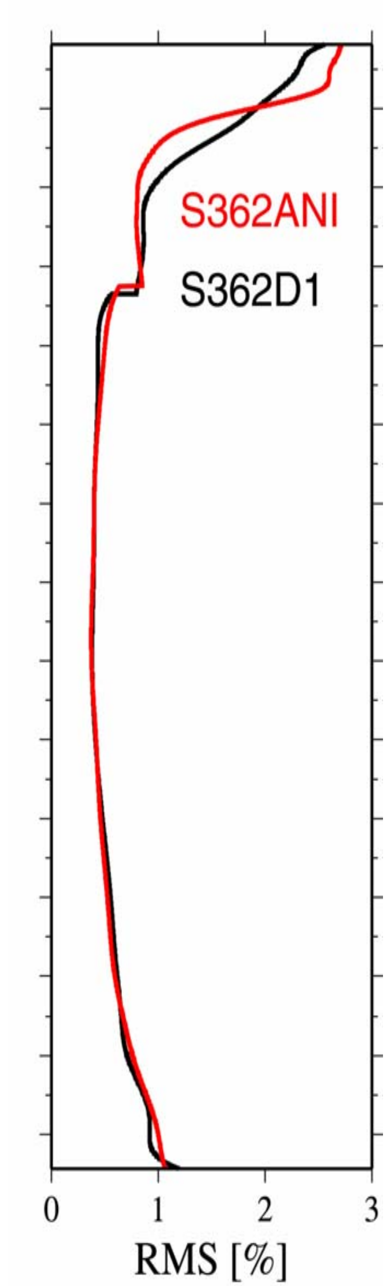
Power in phase velocity maps;

the indication is that, if anything, we overestimate power at higher degrees



Dalton & Ekström JGR 2006

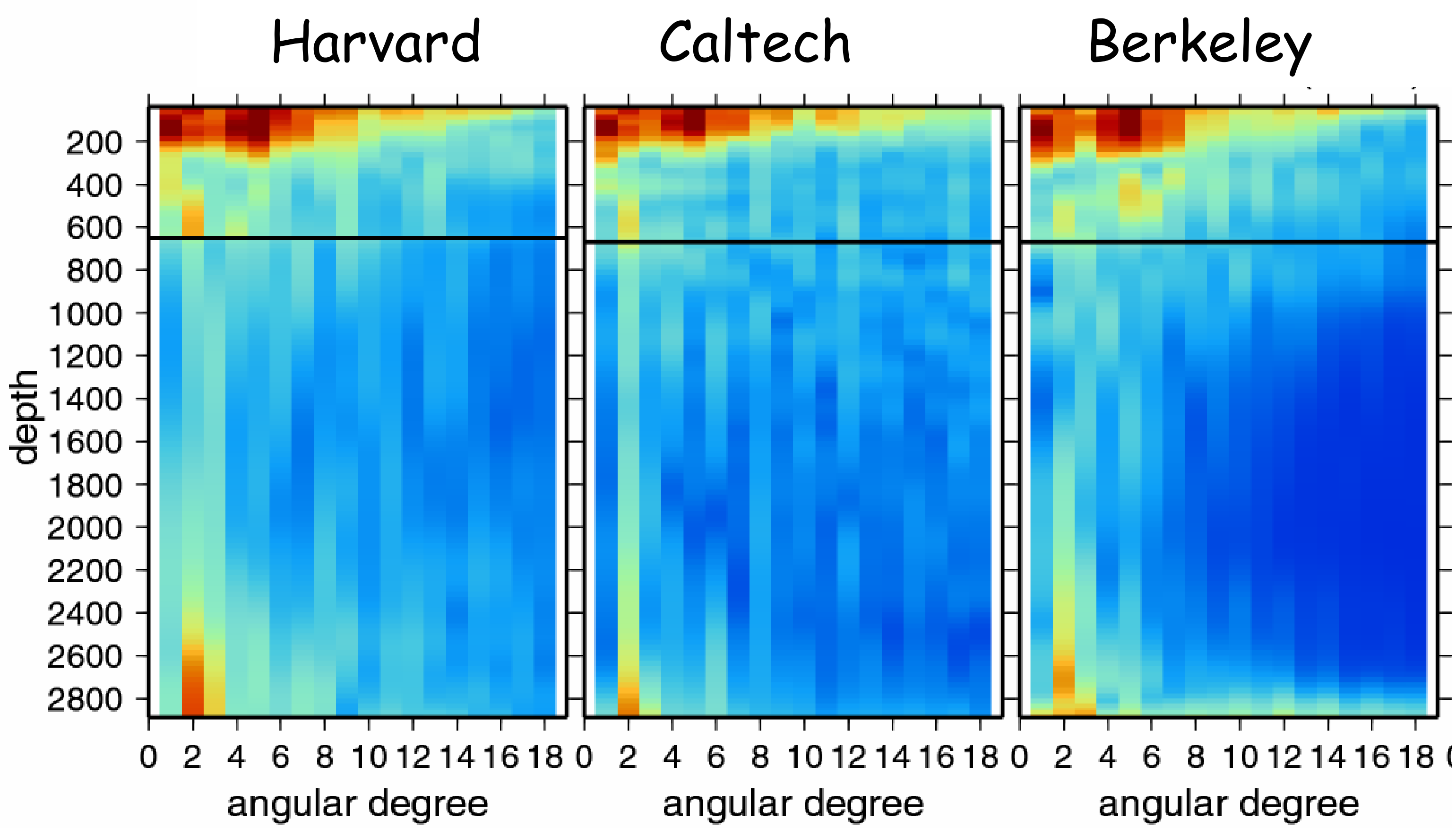




Power spectra and RMS of models S362ANI and S362D1

After Kustowski et al. (2006)

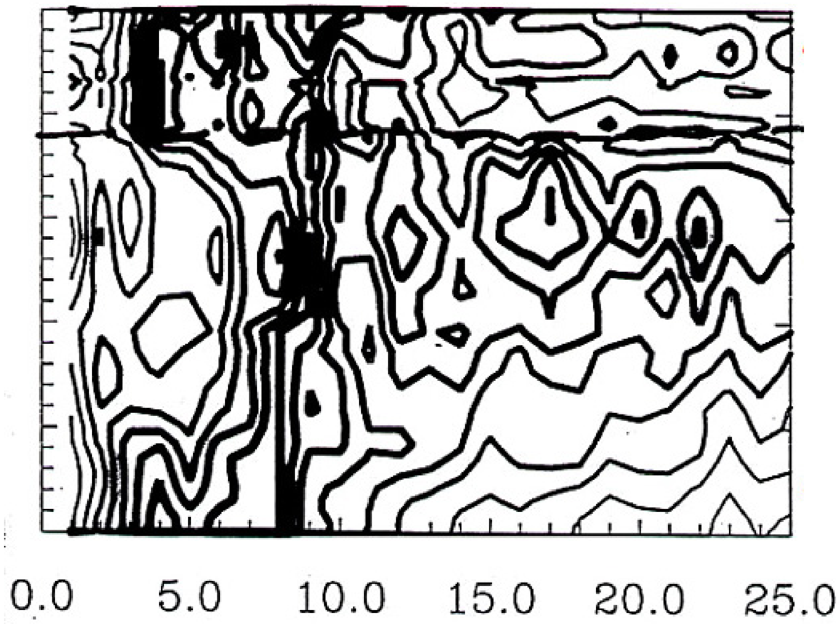
Power spectra of three models with good depth resolution



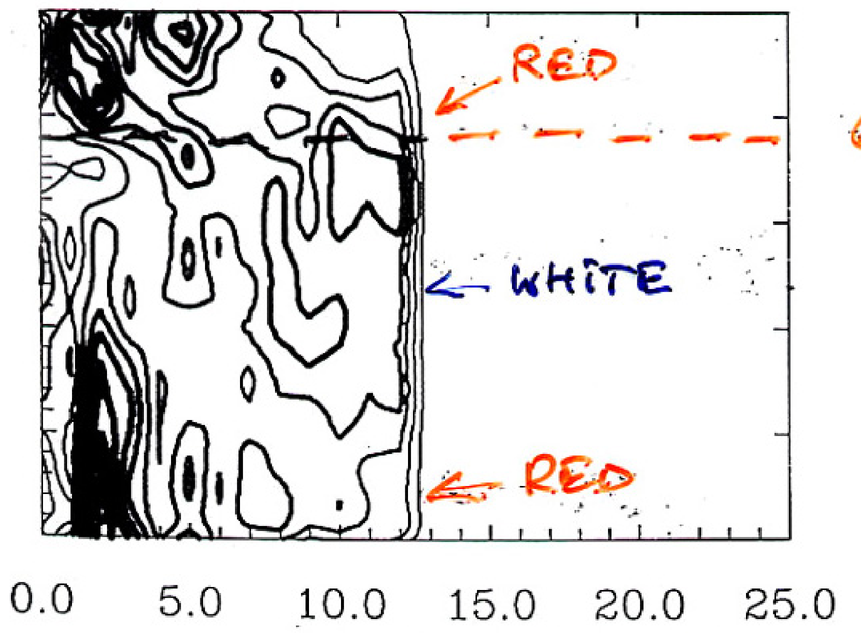
Kustowski et al. (2008)

Behavior of the power spectra as a function of depth for a simulated mantle convection with a phase change boundary and a tomographic model (Su et al., 1994) is very similar.

Mantle convection



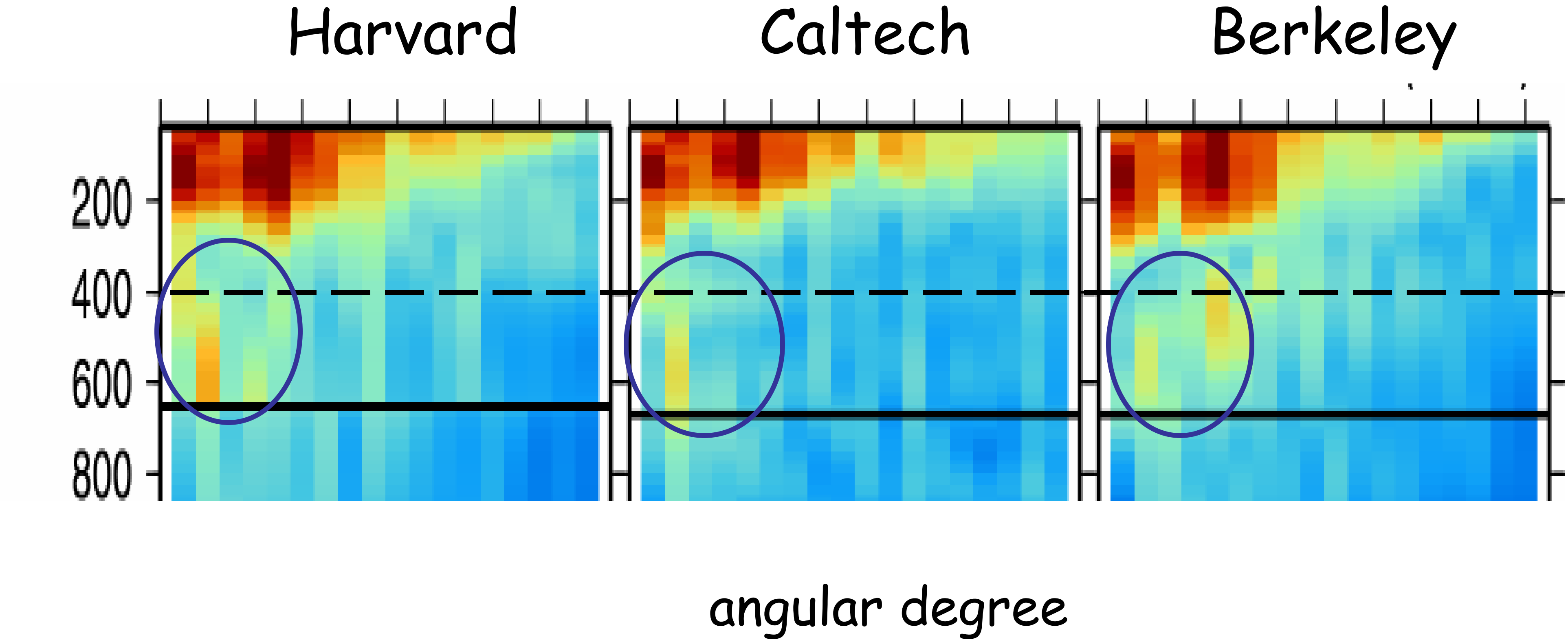
Seismic tomography



From Tackley et al., 1994

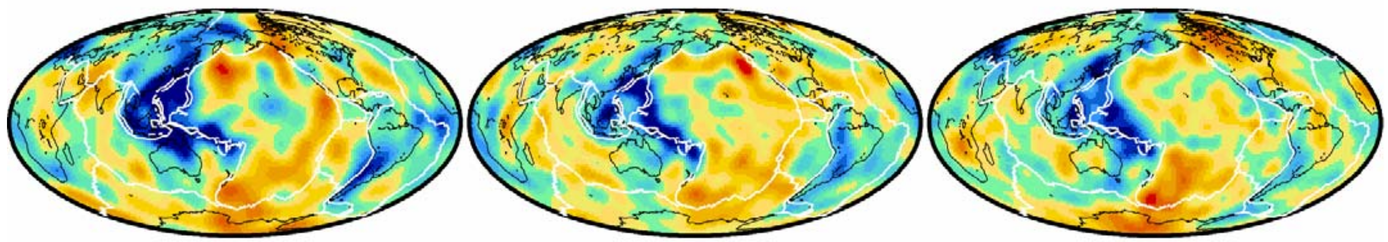
Transition Zone

Power spectra of the three models; a closer look

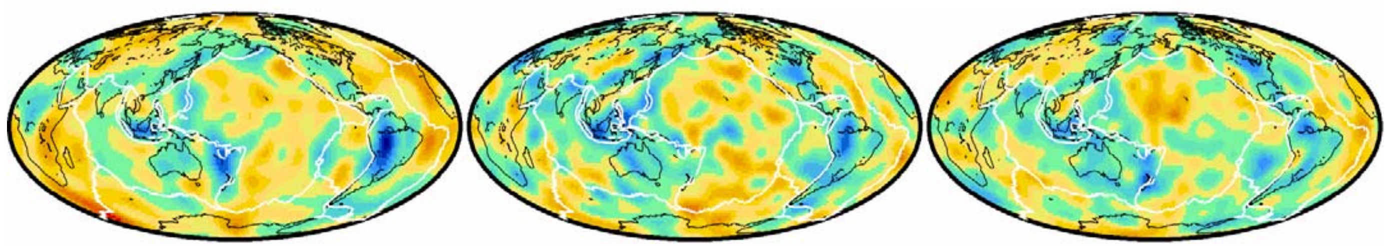


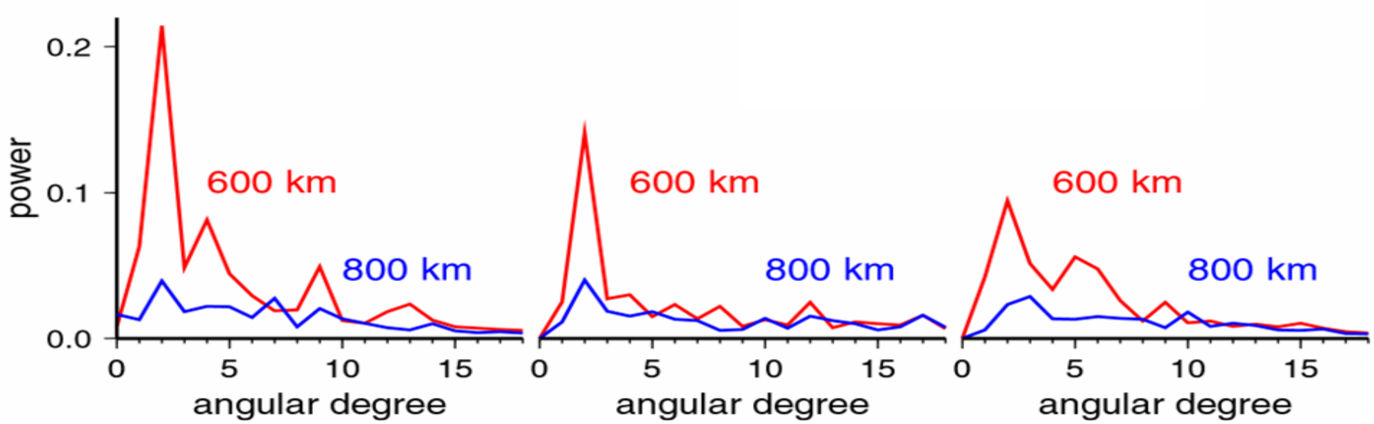
Harvard Caltech Berkeley

600 km depth

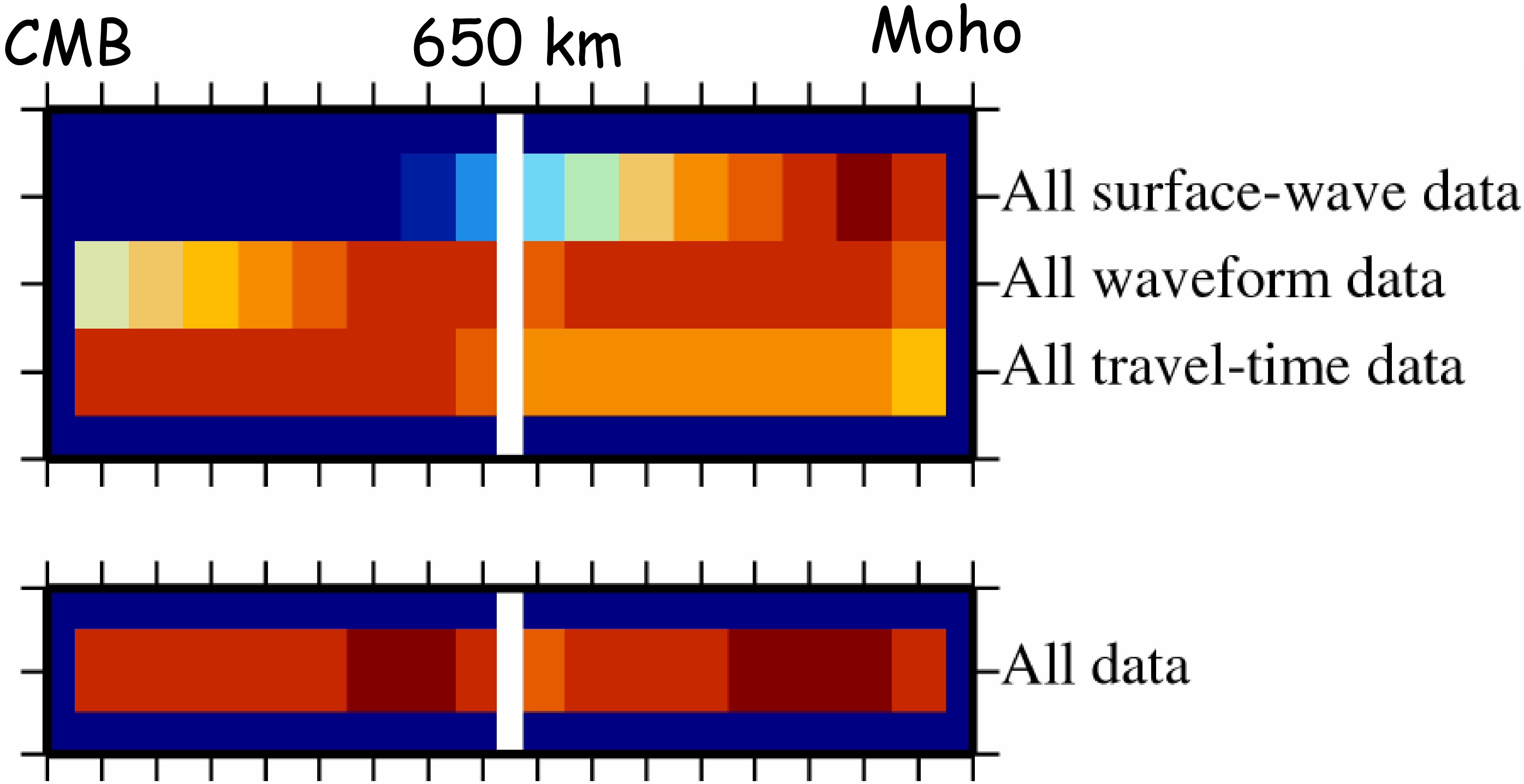


800 km depth



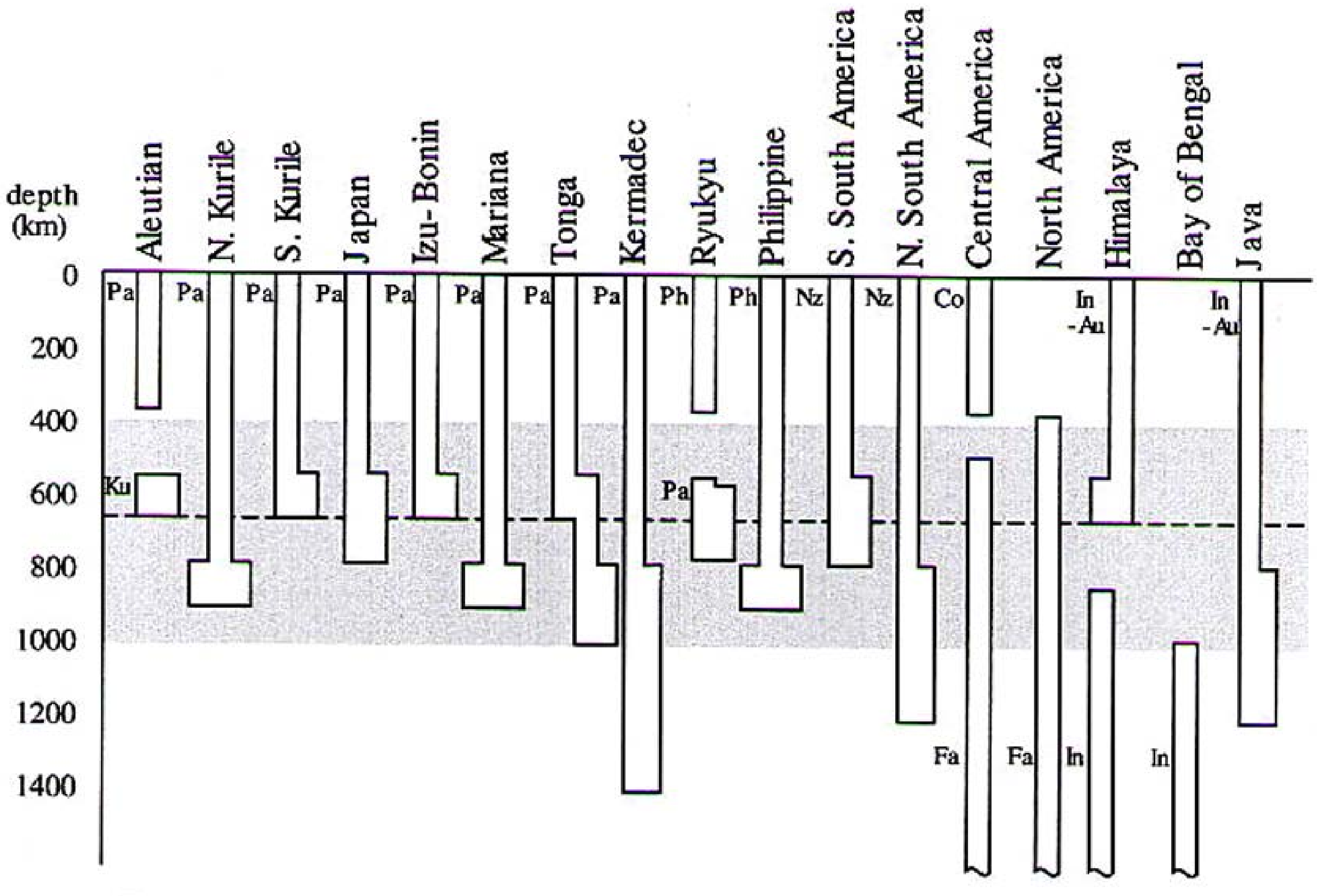


Depth resolution of different data subsets

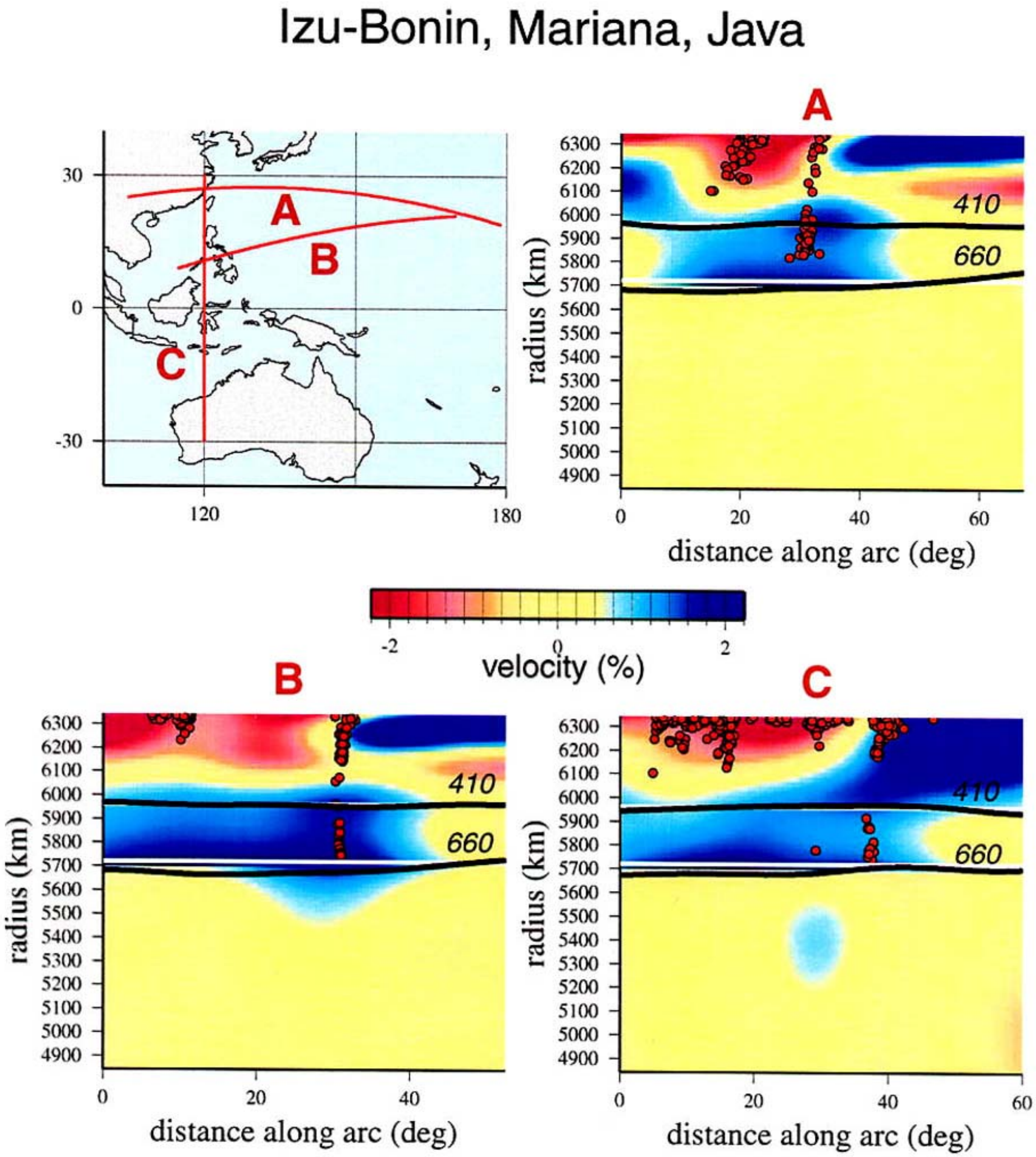


Modified from Kustowski et al., 2006

Stagnant slabs are common

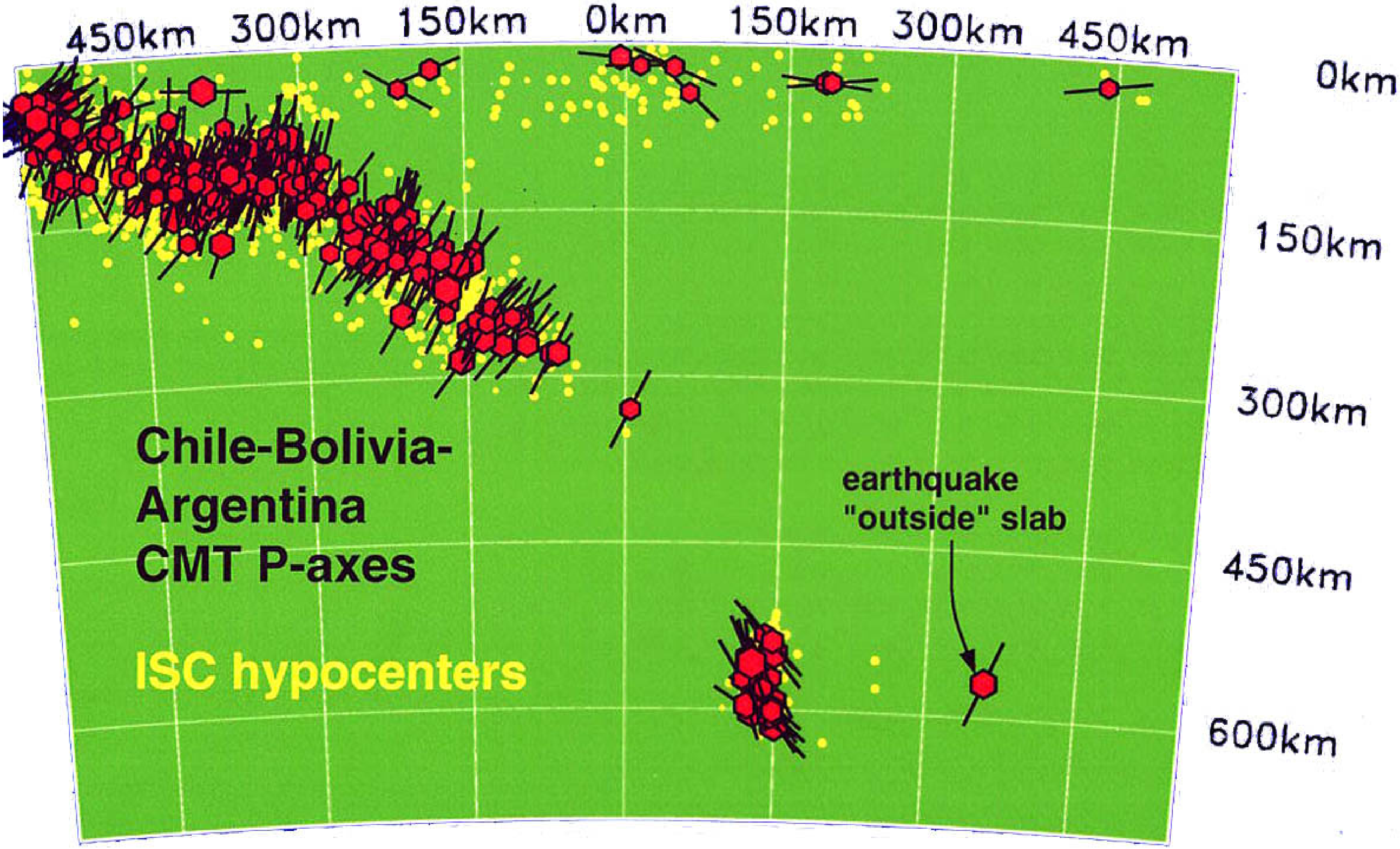


from Fukao et al. (2001)

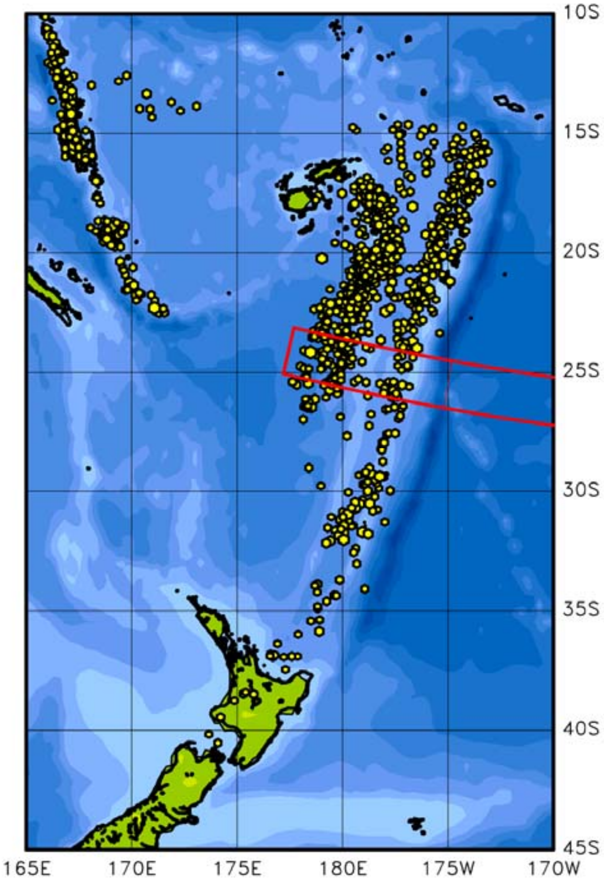


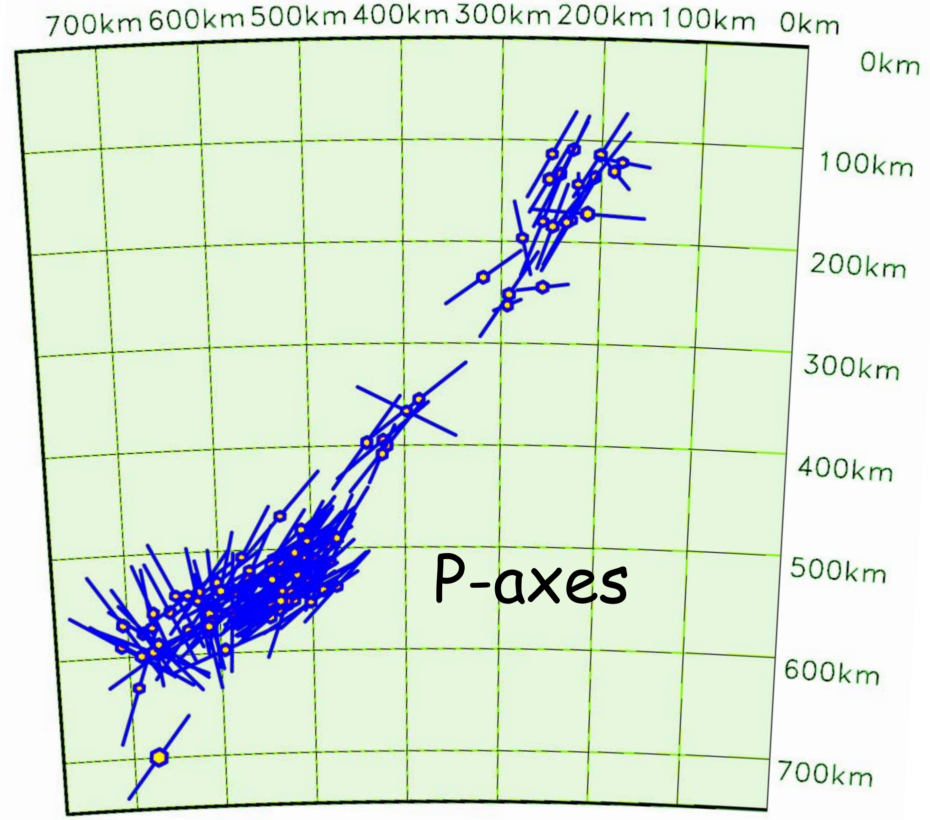
white line ----> global average of discontinuity depth
black line ----> regional discontinuity depth

Cross-sections through the velocity model TOPO362 and the boundary topography (exaggerated)


450km
300km
150km
0km
150km
300km
450km
0km
150km
300km
450km
600km
Chile-Bolivia-
Argentina
CMT P-axes
ISC hypocenters
earthquake
"outside" slab

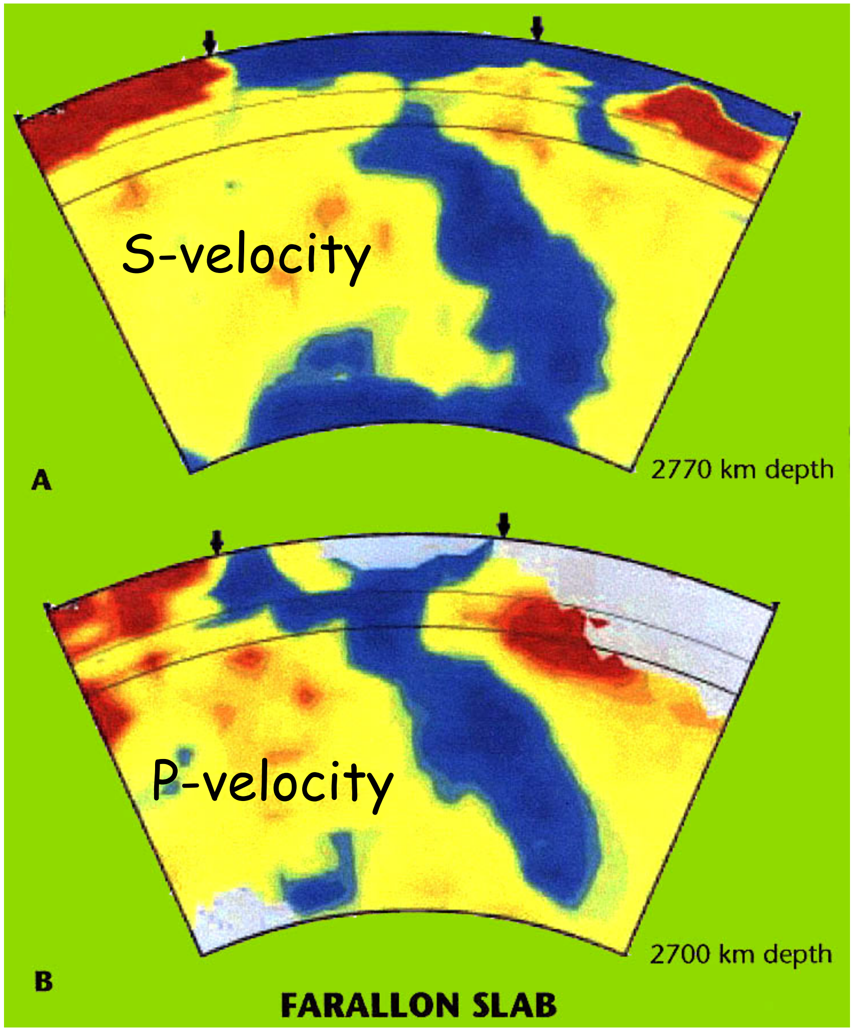
Additional evidence





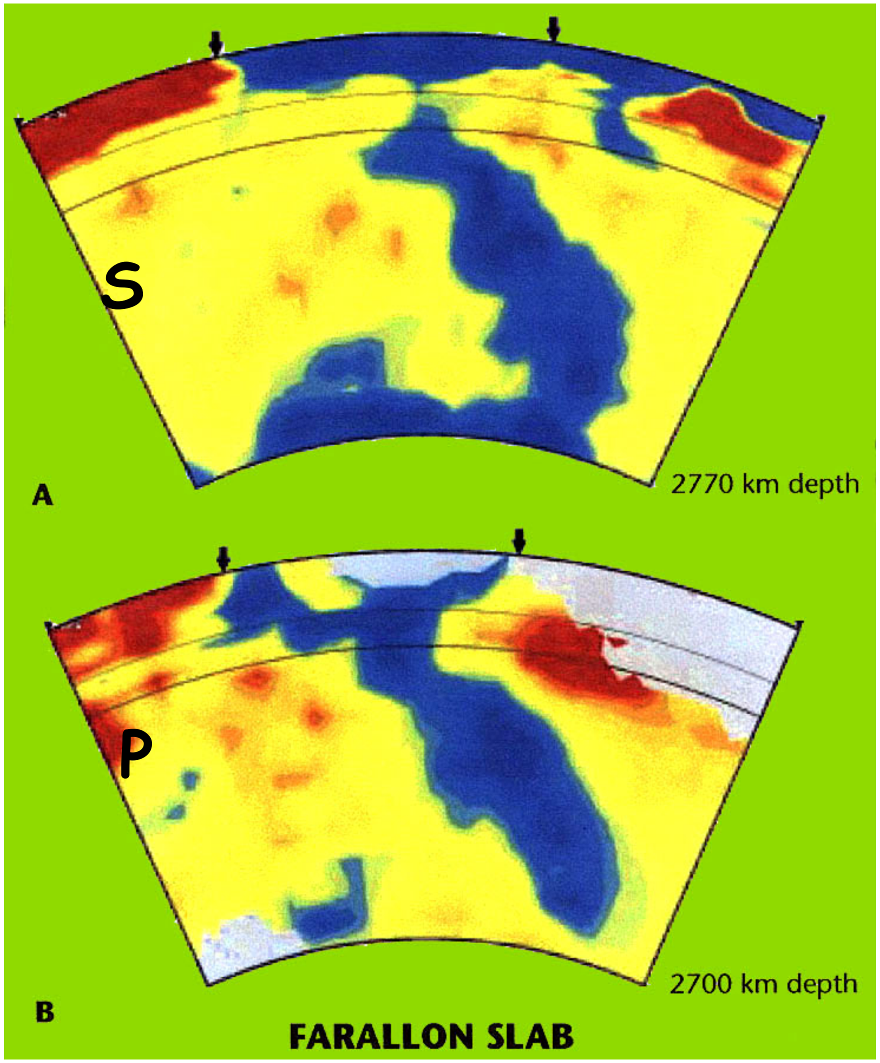
Change in the stress pattern near the 650 km discontinuity

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

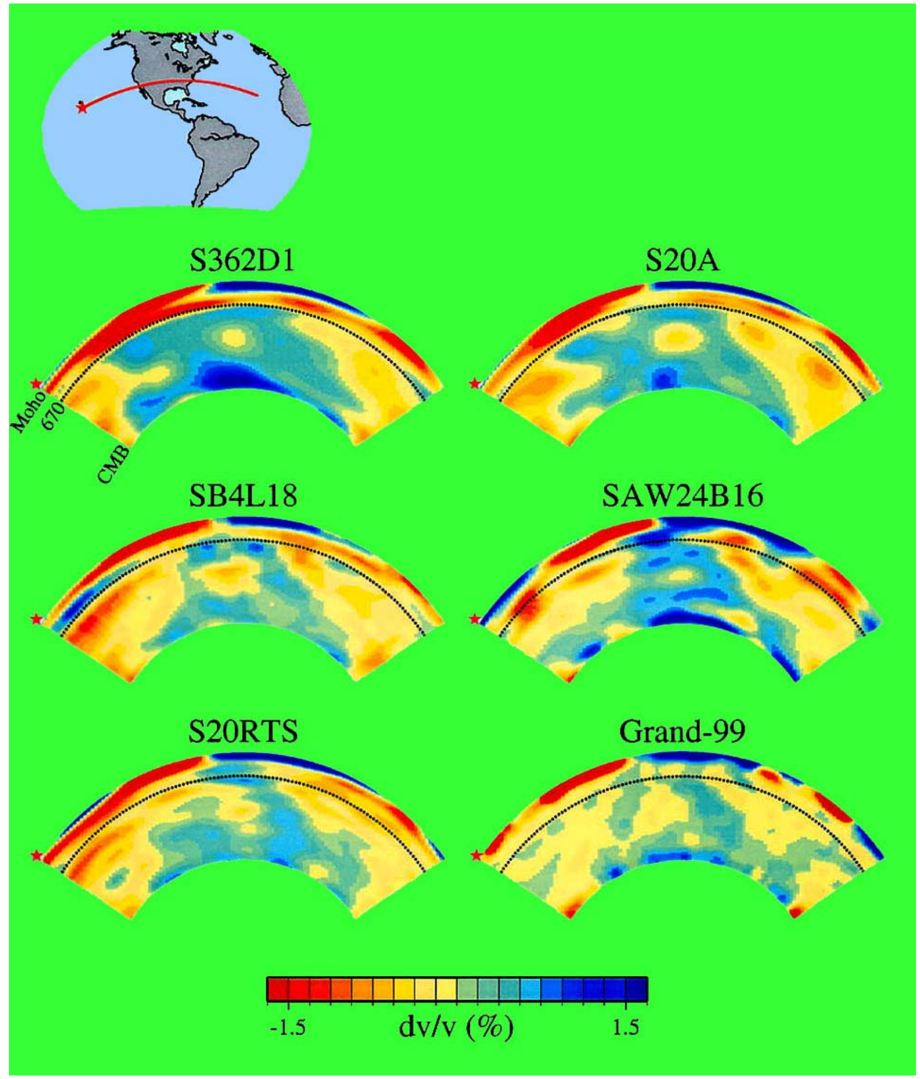


Grand et al., 1997

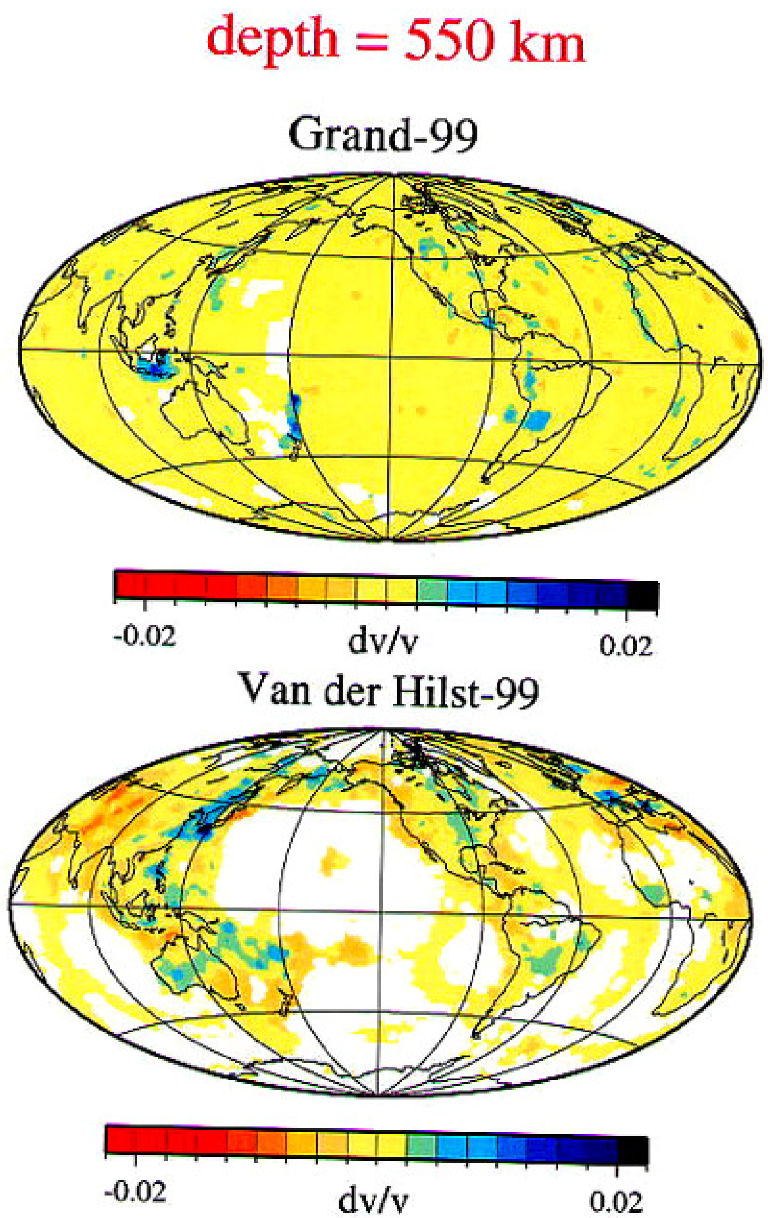
Cross-sections on the right show more complex images than the famous picture on the left.



Grand et al., 1977

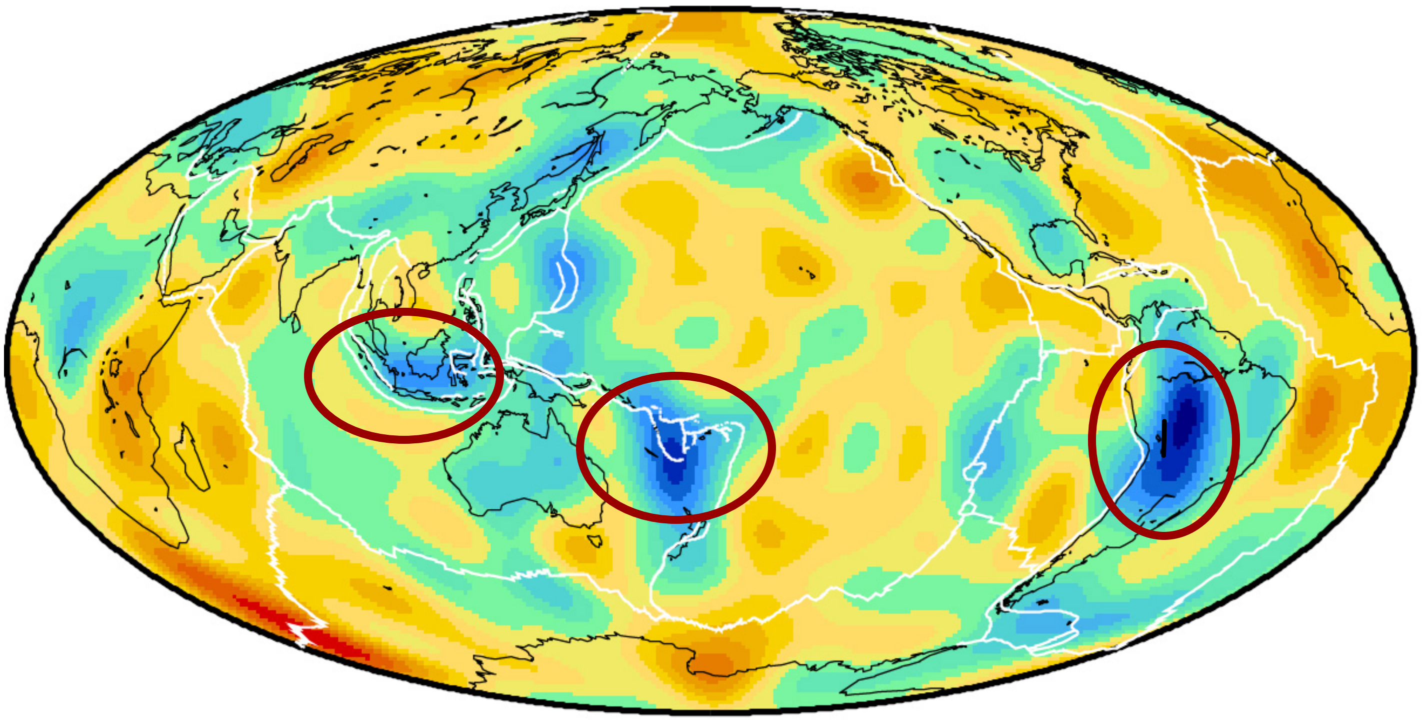


Gu et al., 2001



Travel-time based models do not show structure in the transition zone

Model S362ANI
Depth 750 km



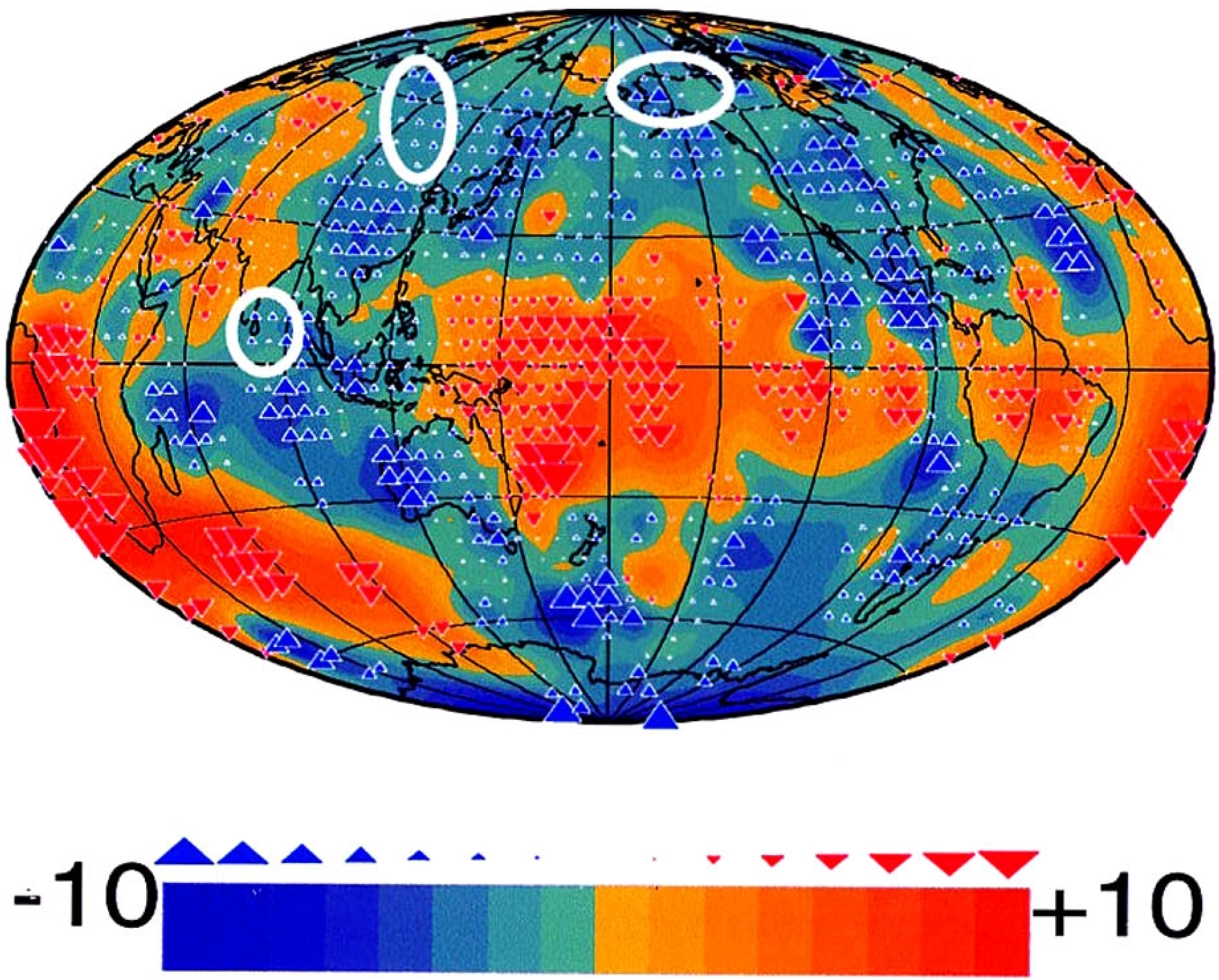
Strong, but spatially limited fast anomalies in the lower mantle may represent regions of limited penetration of subducted material accumulated in the transition zones

Transition Zone Conclusions

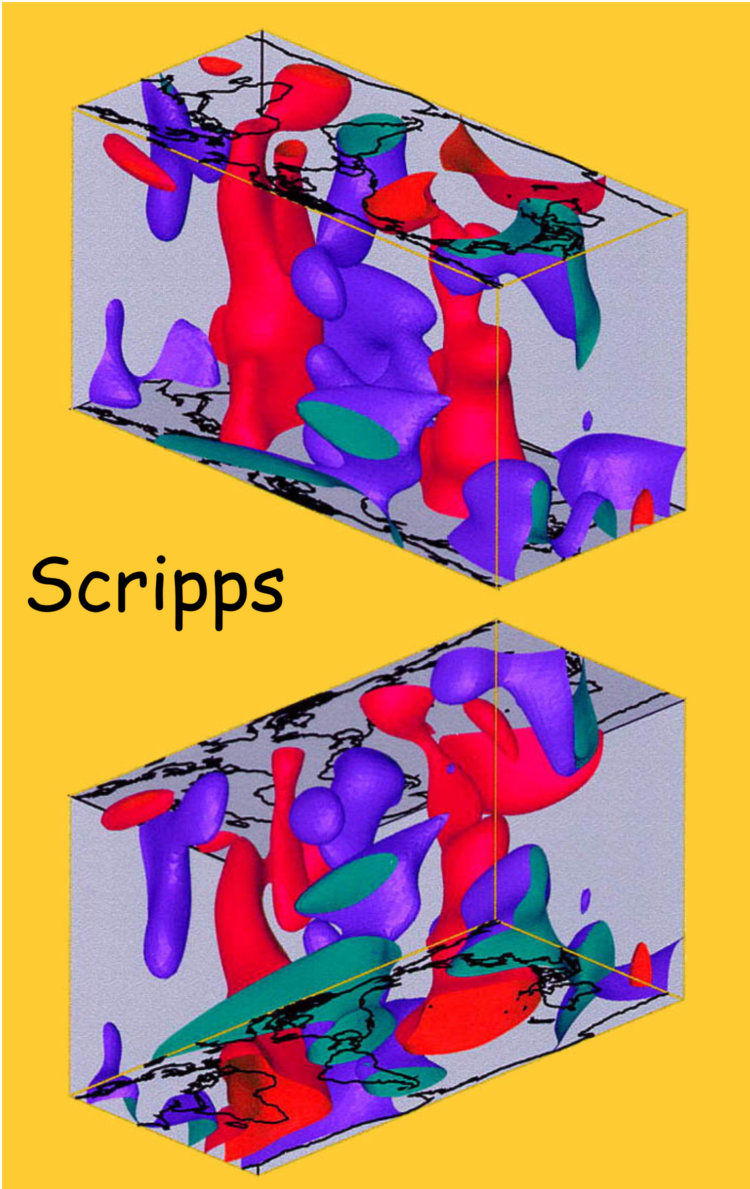
- Overtone/waveform data are critical for resolution of the transition zone structure.
- The change in the spectrum across the discontinuity is as sharp as can be resolved at the present time.
- We conclude that the transition zone is a boundary layer that could be penetrated by episodic events, but does not permit steady state circulation across the 650 km discontinuity.

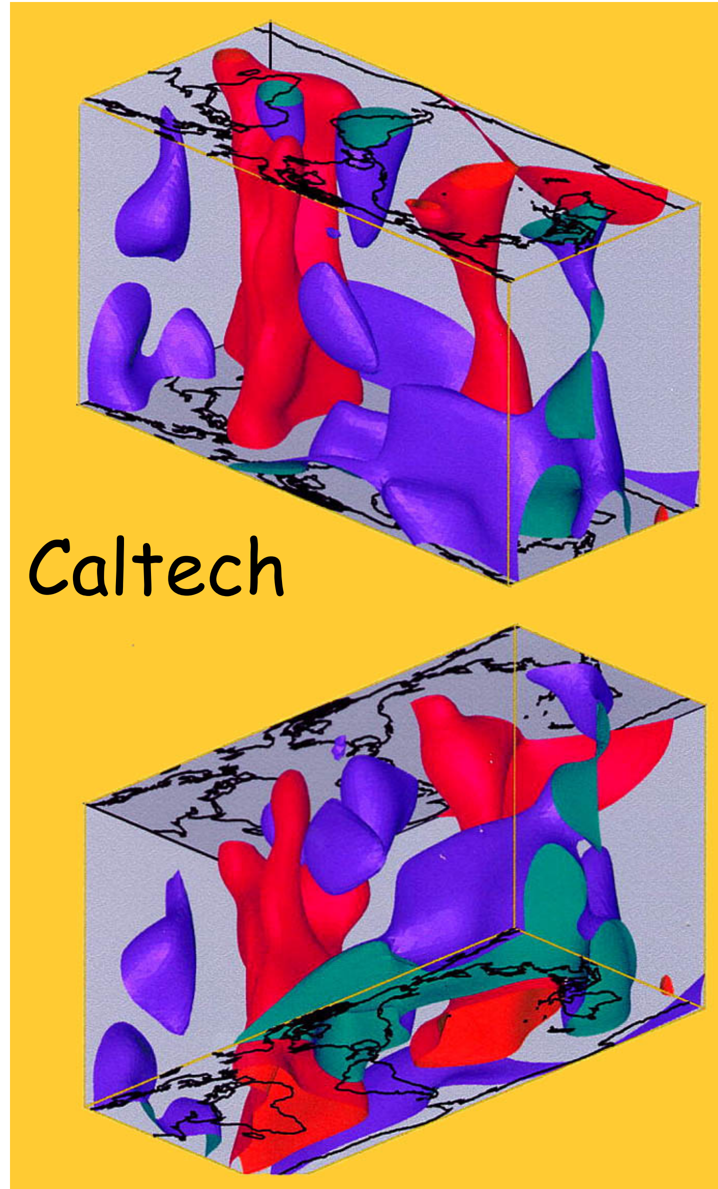
Lower Mantle

ScS – S affair;
the need for global approach

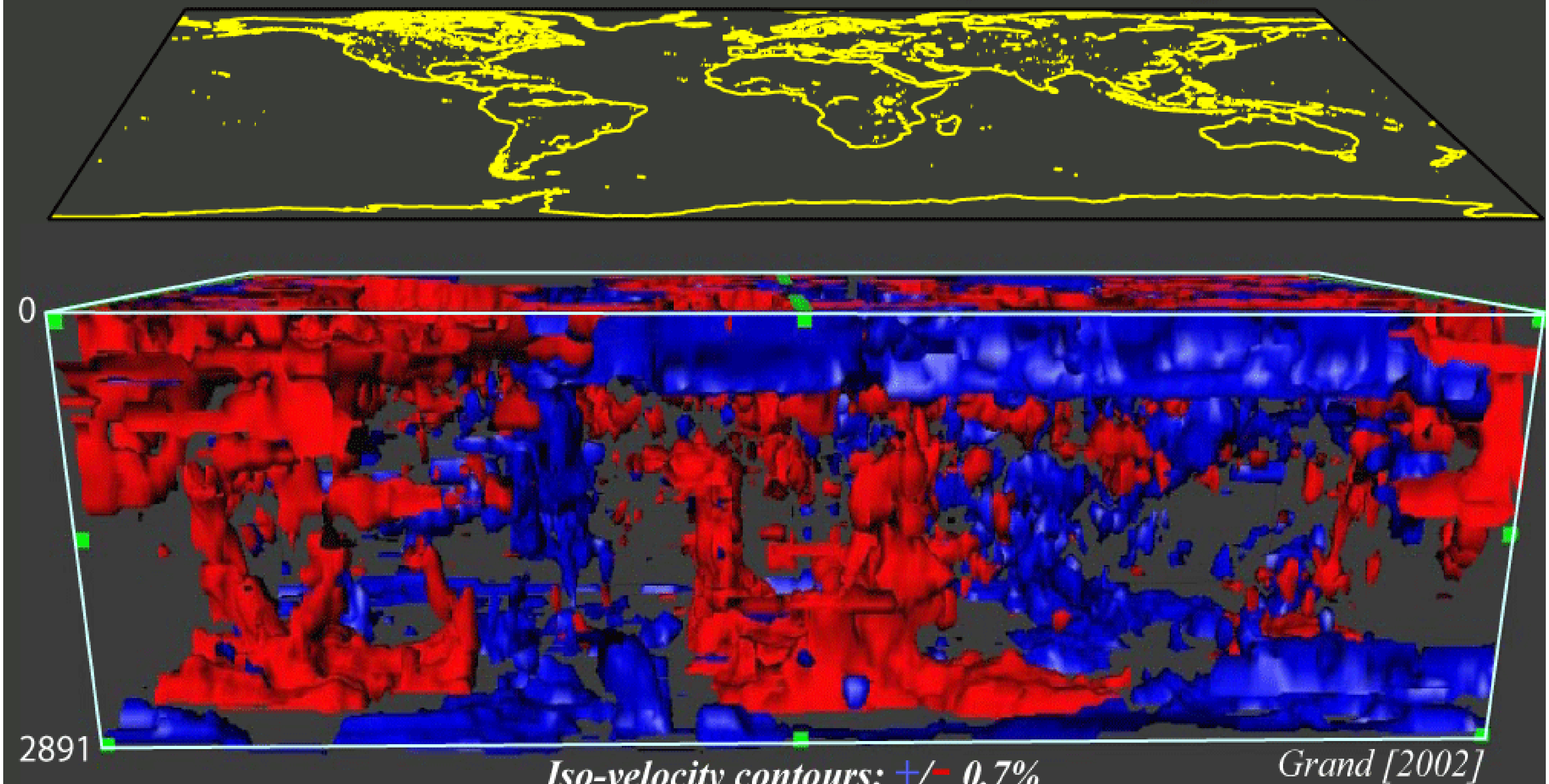


Mega-plumes





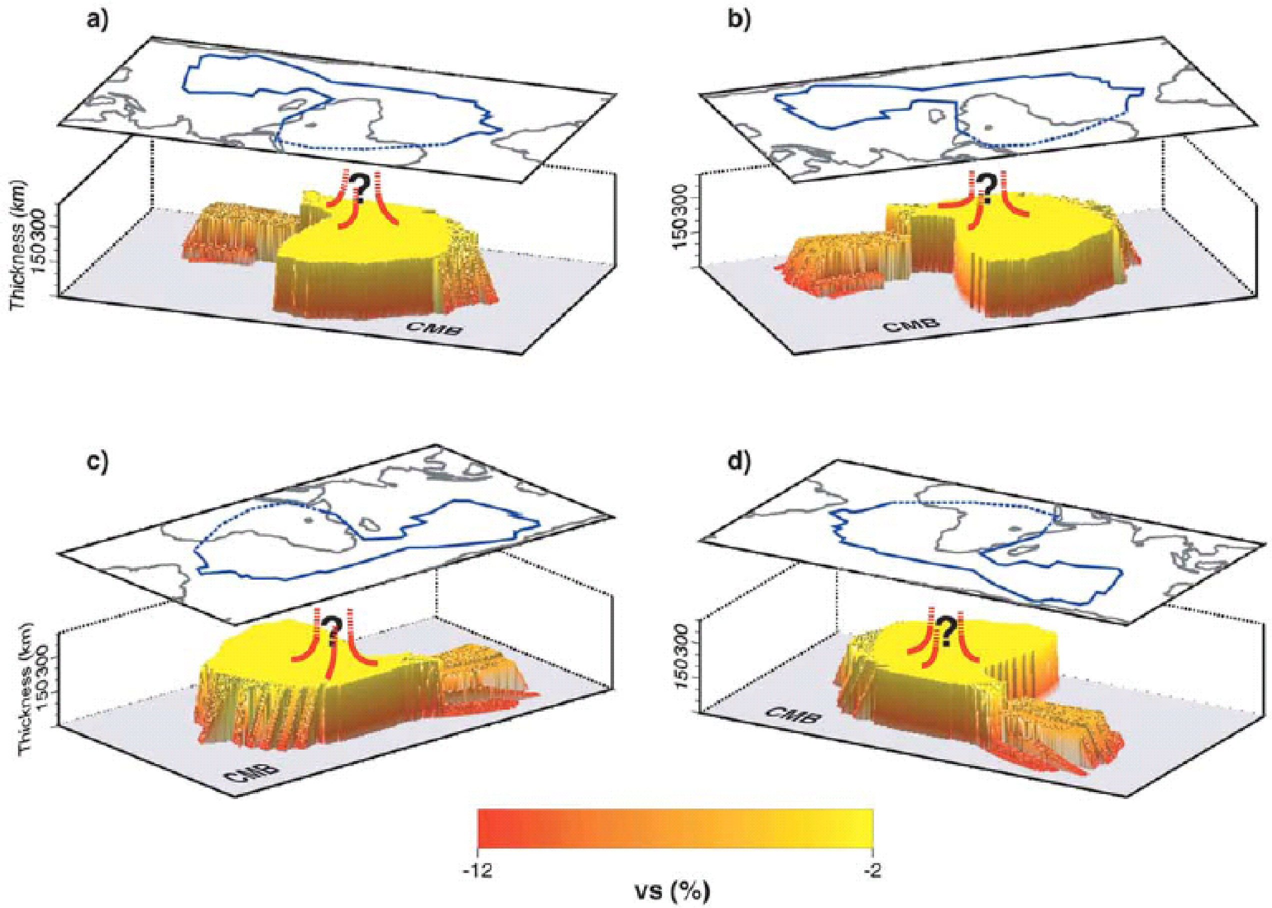
Whole mantle shear velocity heterogeneity



Iso-velocity contours: +/- 0.7%

from E. Garnero's website

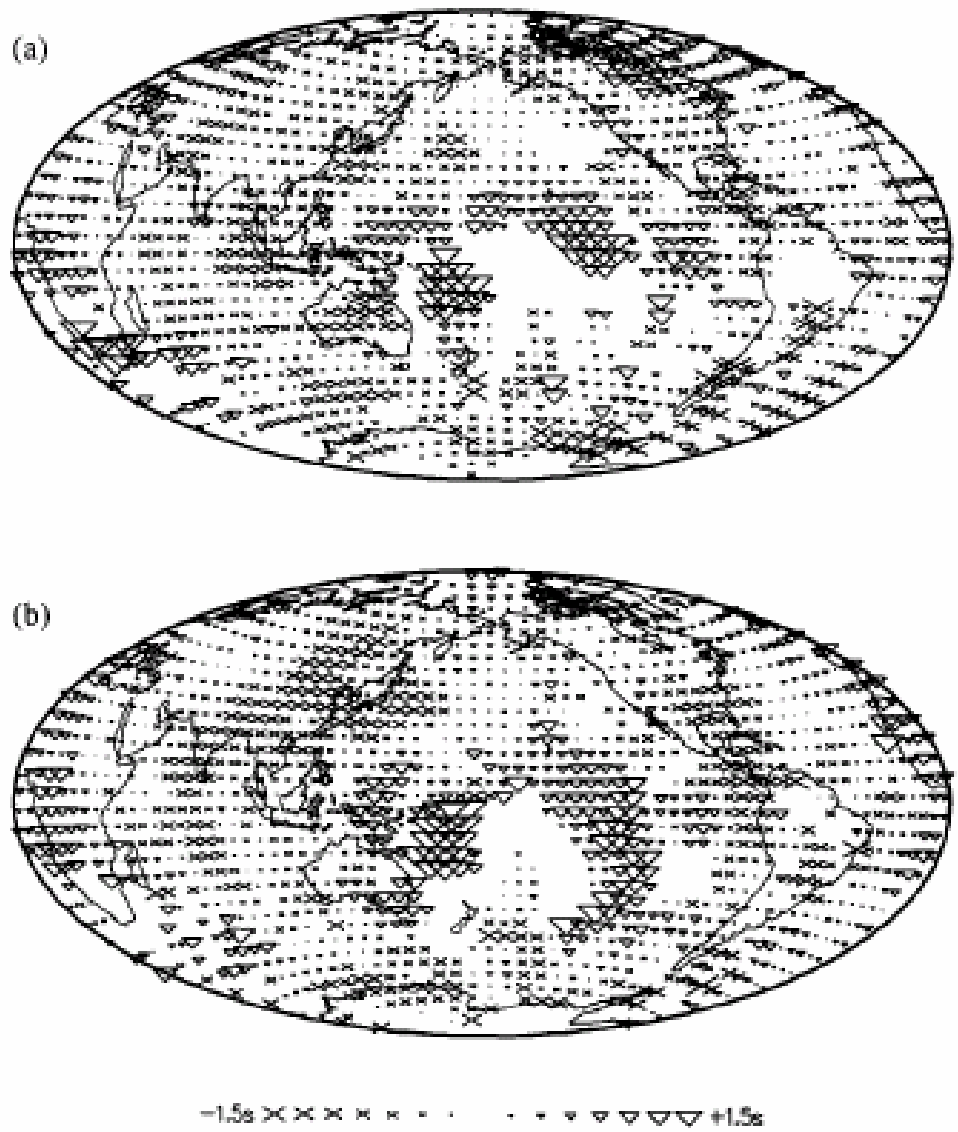
The shape of the African superplume



The vertical extent of the two superplumes is much greater than 300 km

from Wang and Wen (2004)

Super-plume signal well above the CMB; P-wave travel time residuals

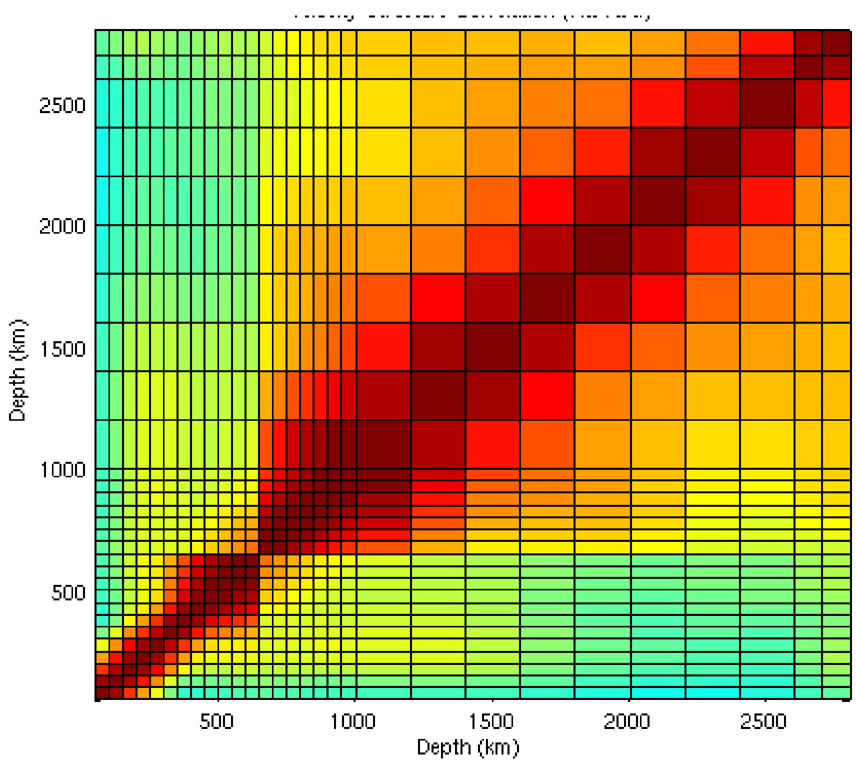


2390 - 2570 km

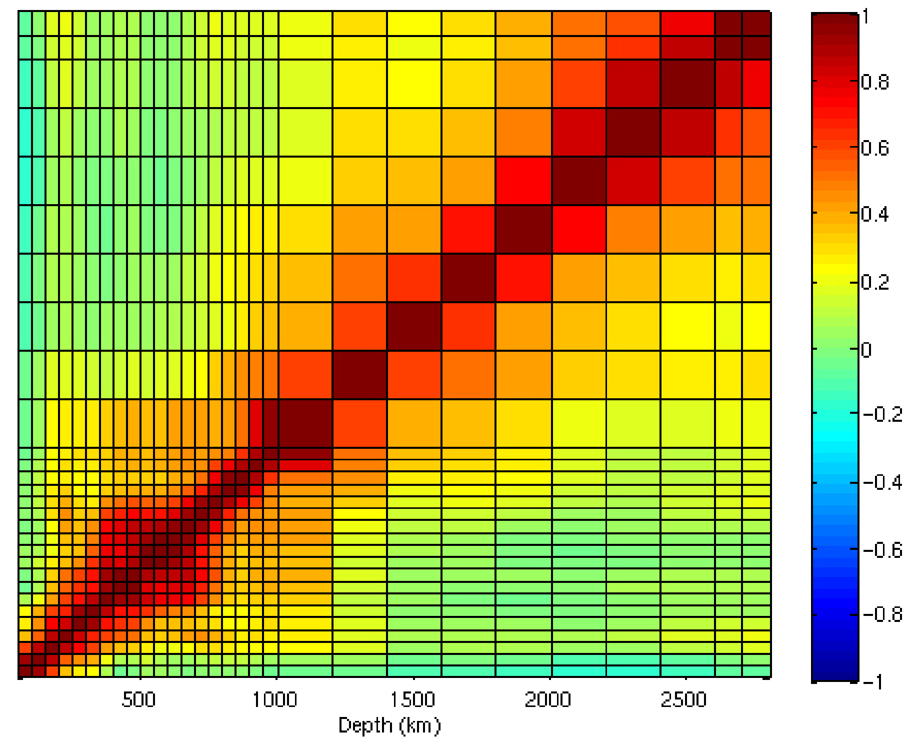
2740 km - CMB

Radial correlation functions

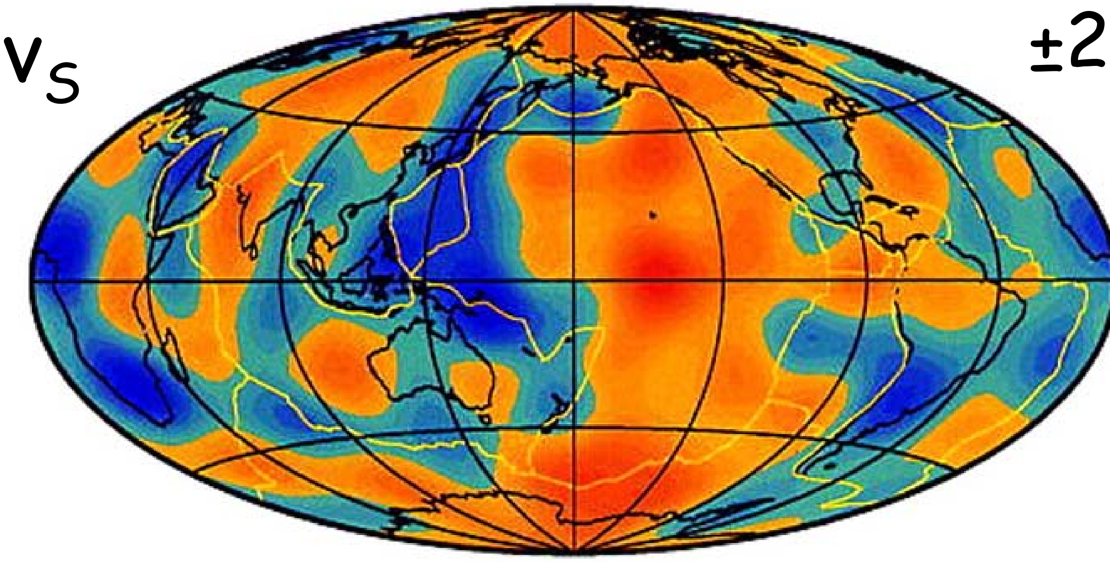
Harvard

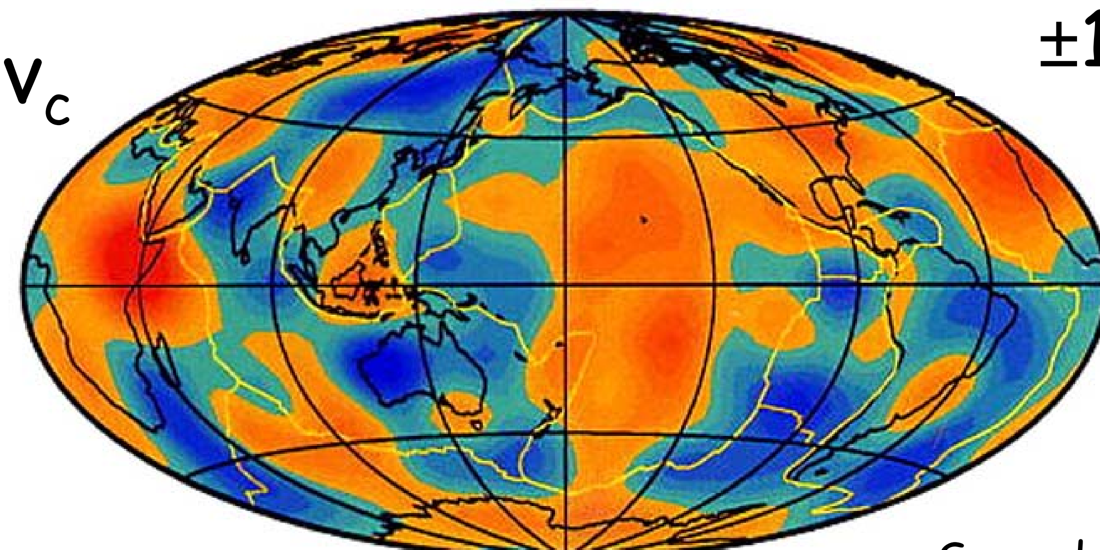


Caltech



Shear and bulk velocity at 550 km



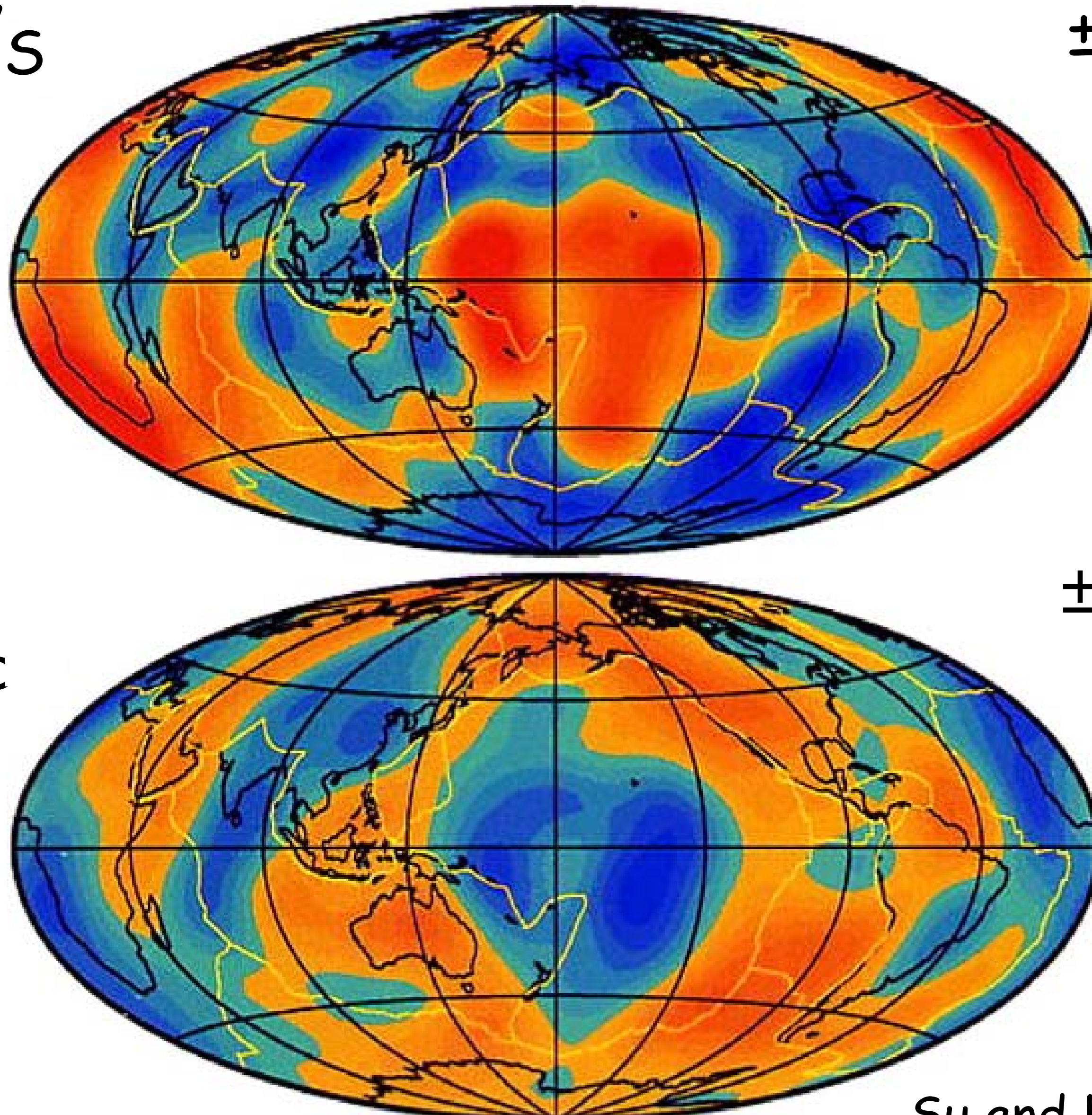


Su and Dziewonski, 1997

Shear and bulk velocity at 2800 km

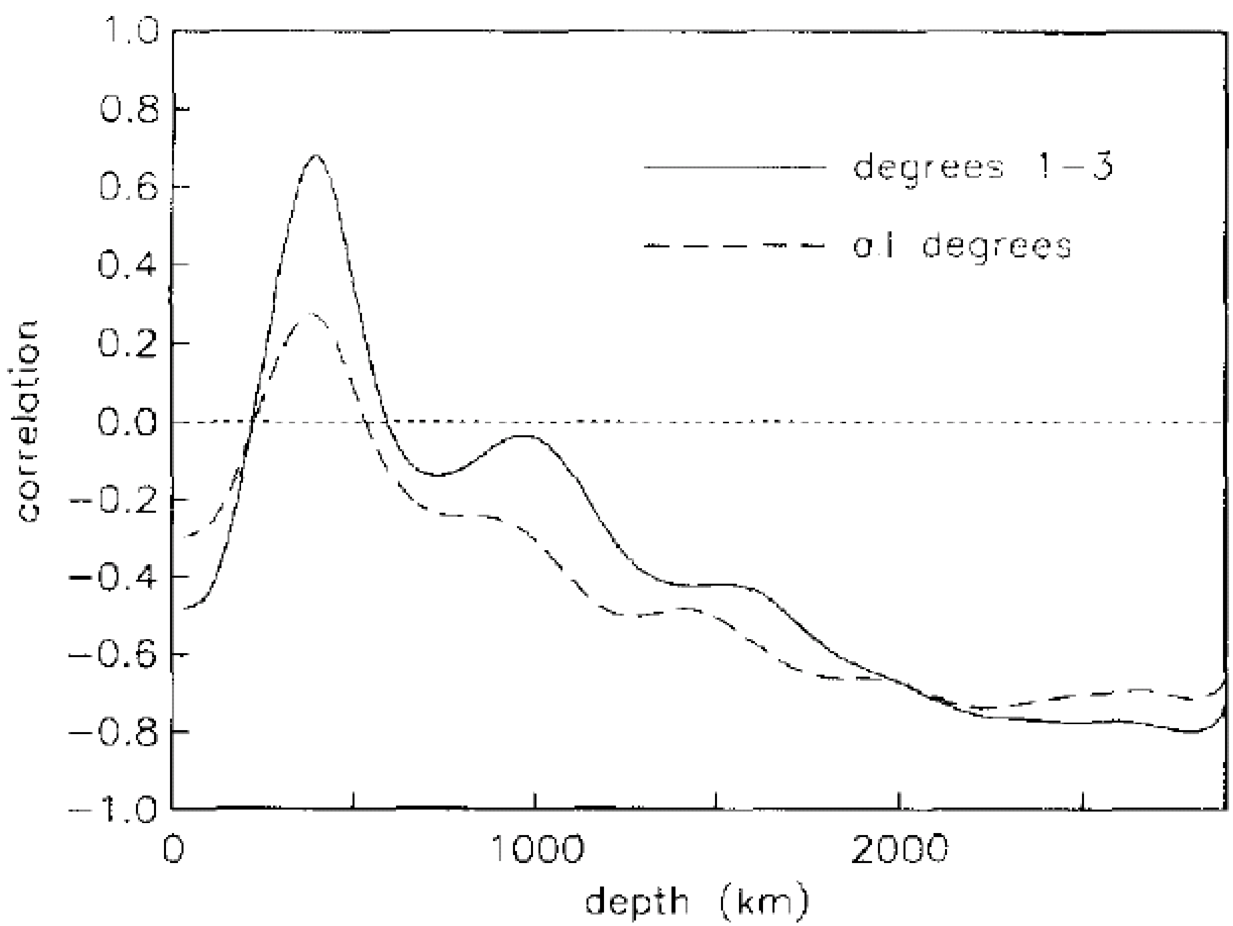
V_S ±2%

V_C ±1%



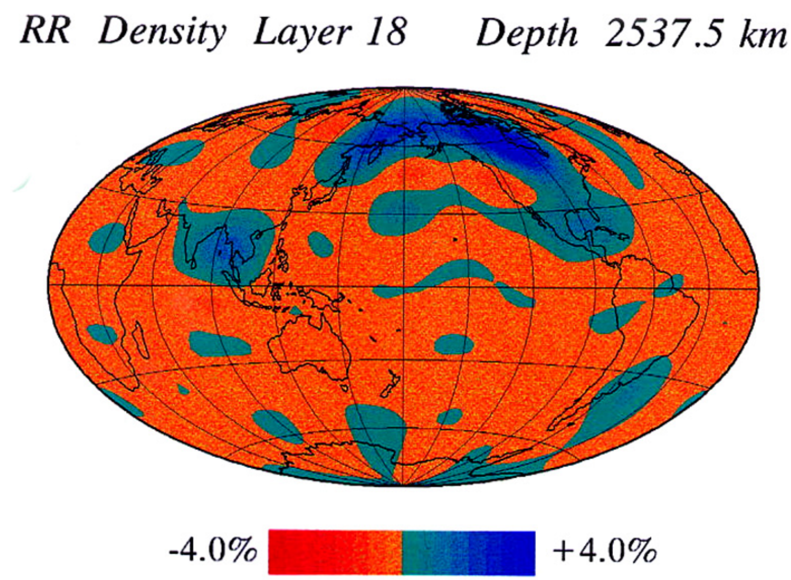
Su and Dziewonski, 1997

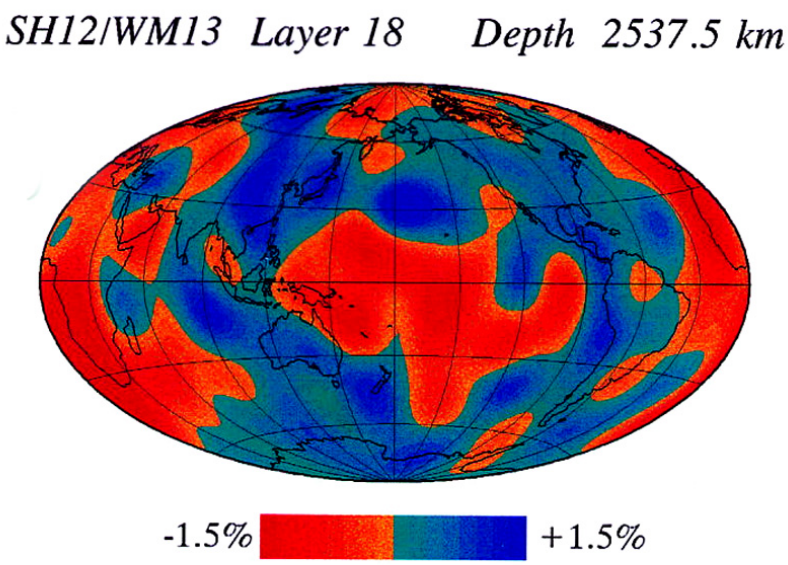
Correlation of bulk sound and S-velocity in model KM12WM13



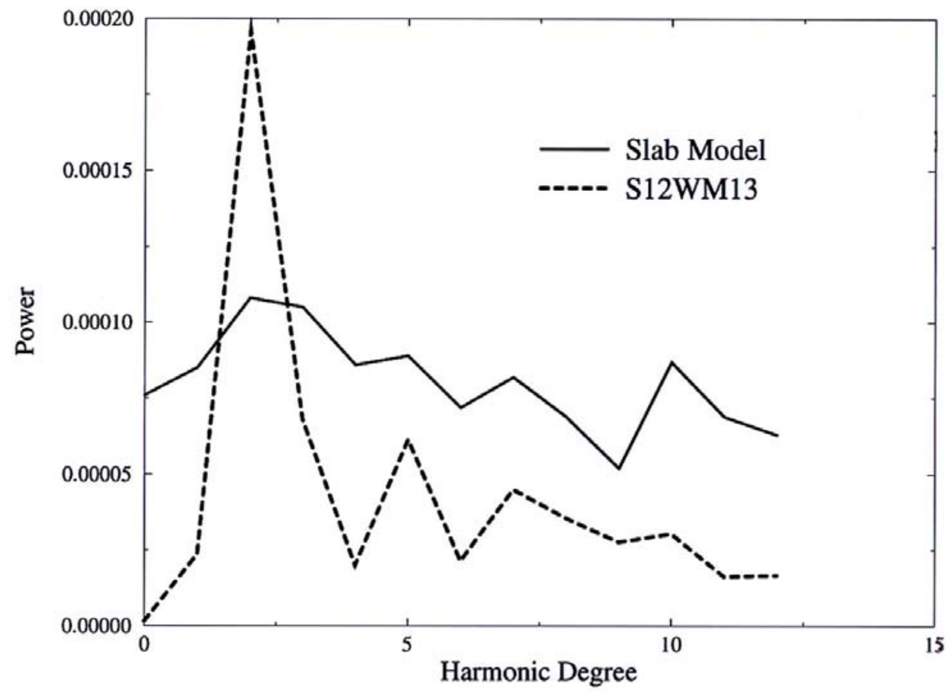
Su & Dziewonski, 1997

Slabs and seismic velocities; Degrees 1-12

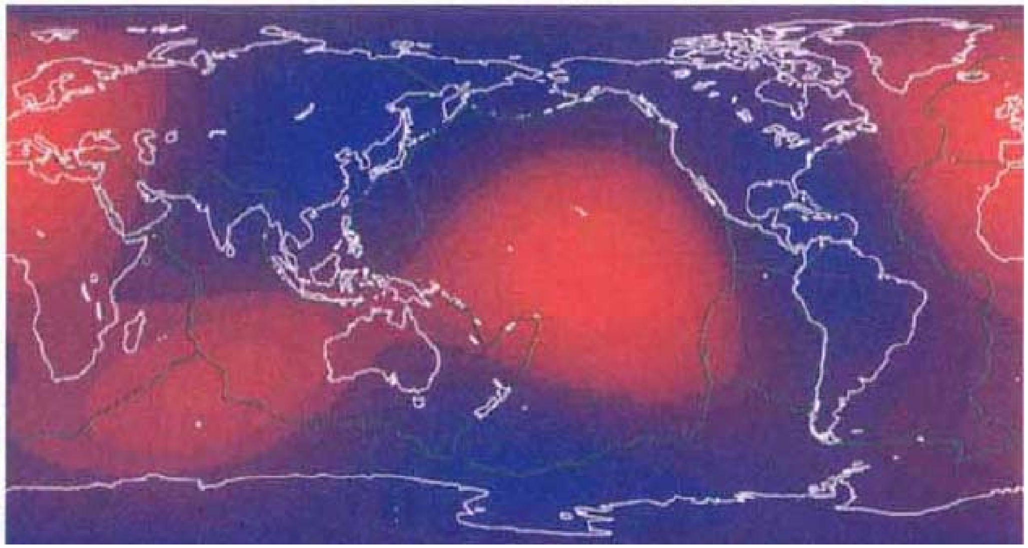


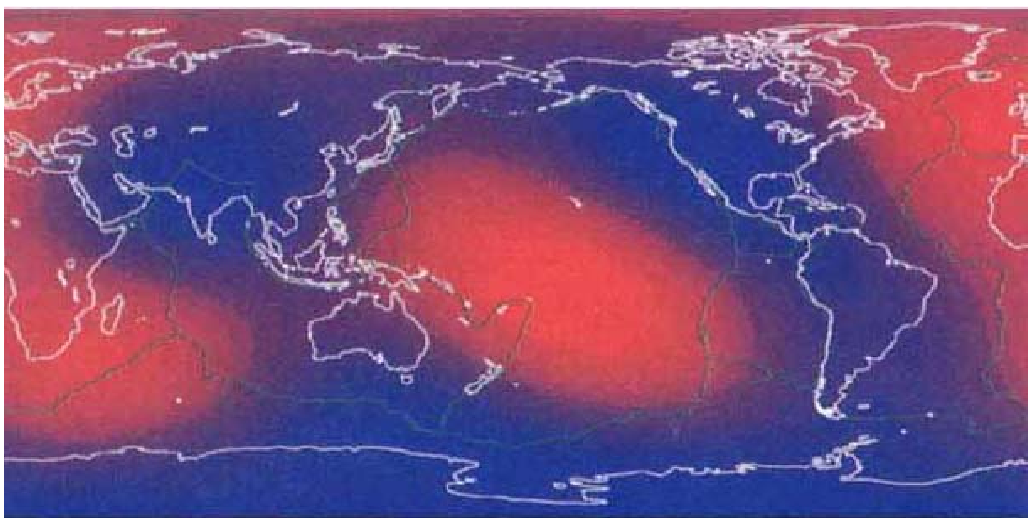


Power spectra



Slabs and seismic velocities; degrees 2 and 3



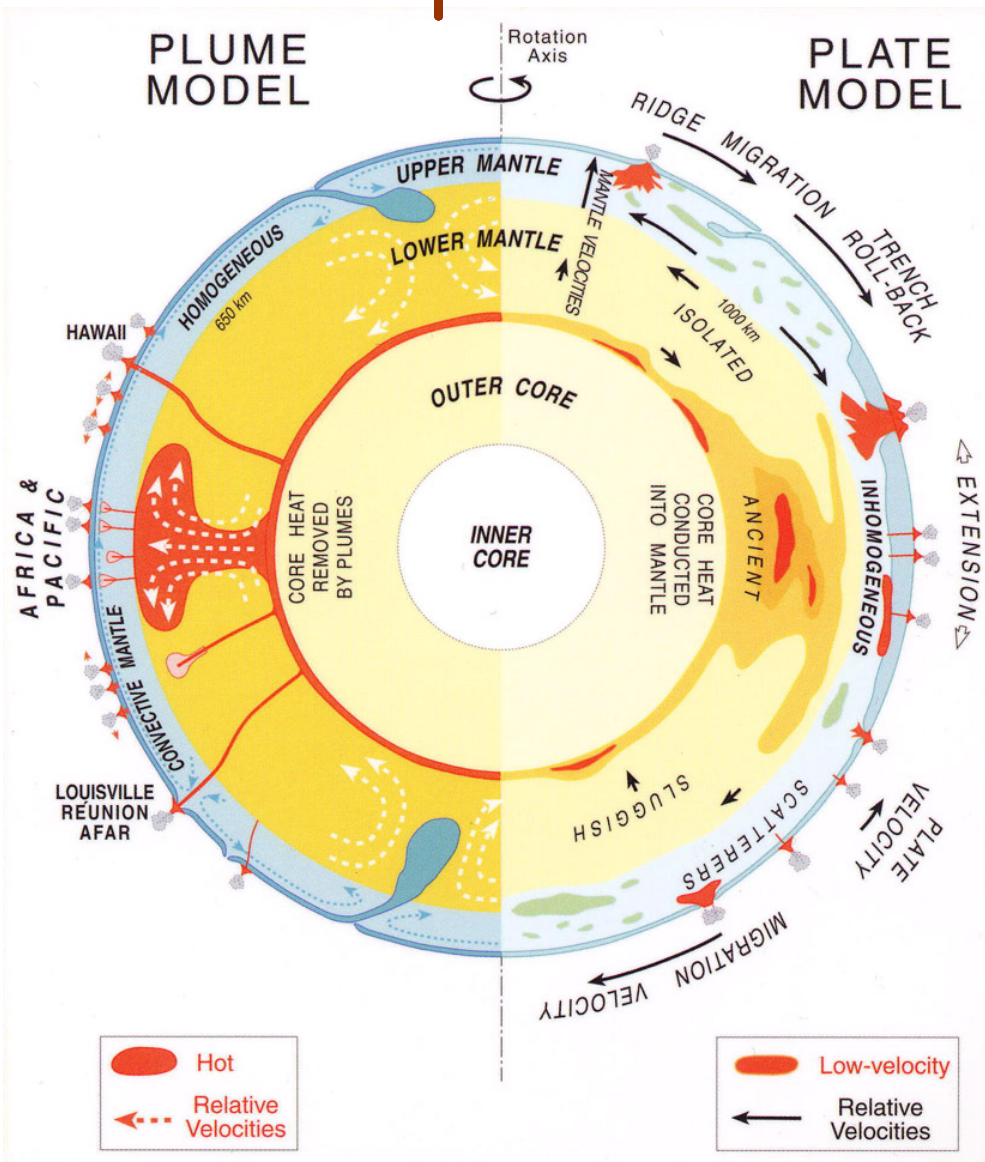


from Richards and Engebretson (1992)

A speculation

It appears that the integrated slab signal is highly correlated with the velocity anomalies in the lower mantle, but only at degrees 2 and 3. This poses a question whether the slab distribution at the surface is not influenced by the properties and behavior of the lowermost mantle. It should be remembered that the degree-2 signals in the transition zone and the lowermost mantle are nearly in phase

Same information, totally different interpretation.



The cover of "The Plumes, Plates and Paradigms"