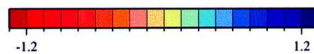
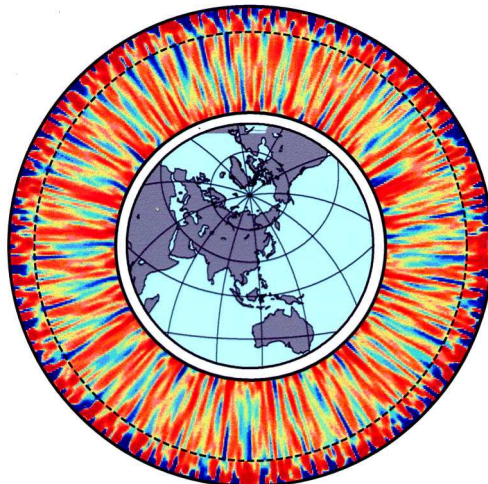


Mantle Heterogeneity; Seismological Perspective

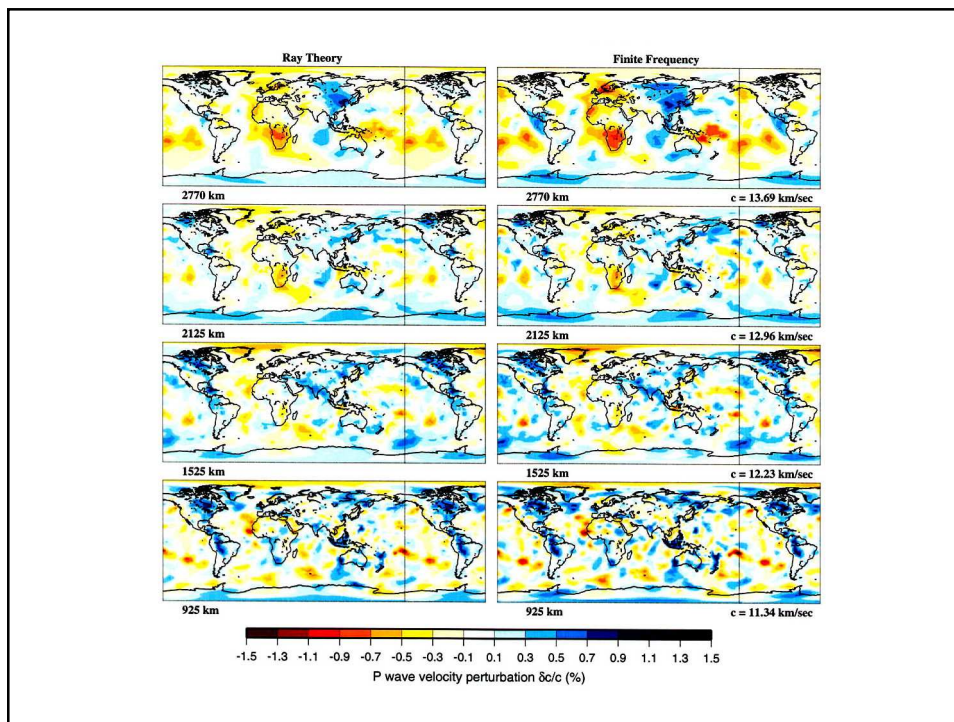
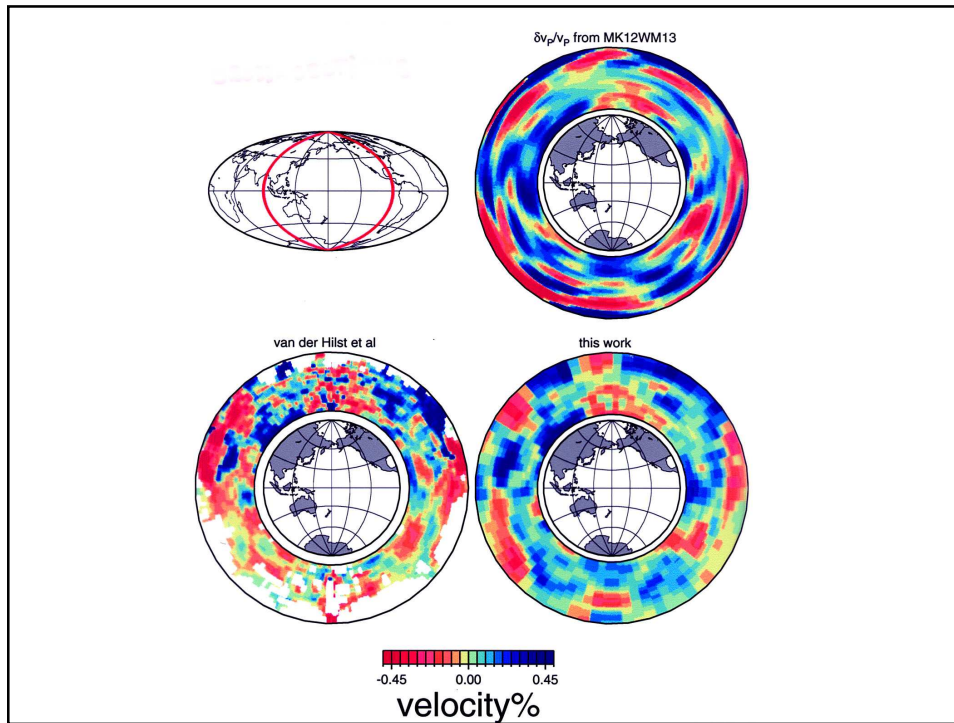
Adam M. Dziewonski

July 26, 2004

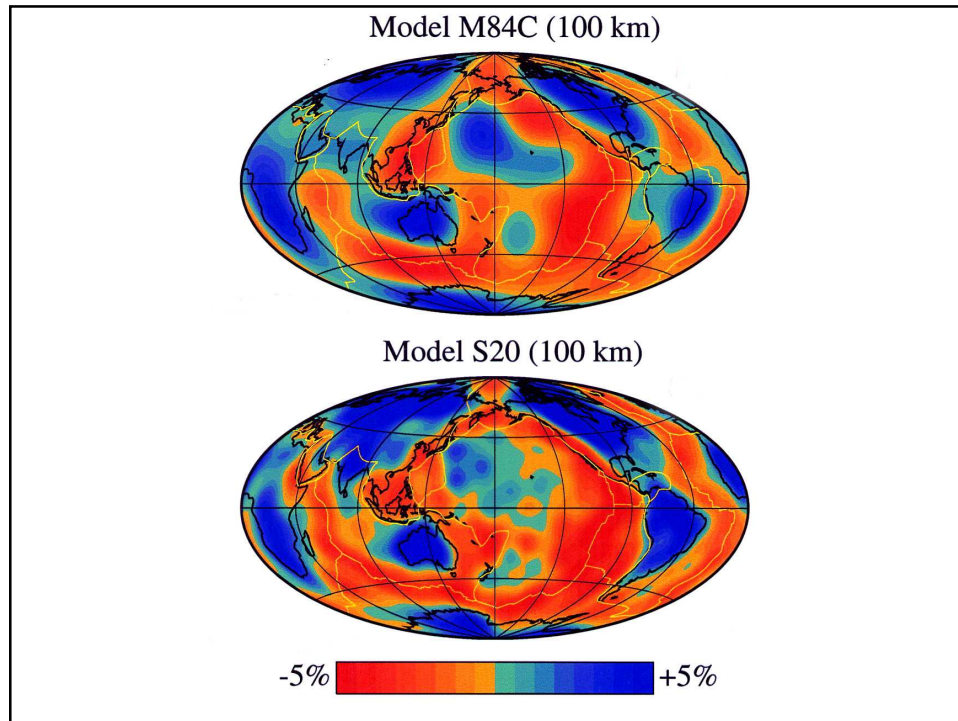
High Resolution



Scales of lateral heterogeneity: Seismology



Scales of lateral heterogeneity: Seismology



Linear Inverse Problem

Solve

$$\mathbf{A} \cdot \mathbf{x} = \mathbf{d};$$

subject to the least squares condition:

$$\|\mathbf{A} \cdot \mathbf{x} - \mathbf{d}\|_2 = \min$$

and one or more regularization constraints:

$$\|\mathbf{x}\|_2 = \min$$

$$\|\nabla \mathbf{x}\|_2 = \min$$

$$\|\nabla^2 \mathbf{x}\|_2 = \min$$

These can be combined:

$$\|\mathbf{A} \cdot \mathbf{x} - \mathbf{d}\|_2 + \eta_0^2 \|\mathbf{x}\|_2 + \eta_1^2 \|\nabla \mathbf{x}\|_2 + \eta_2^2 \|\nabla^2 \mathbf{x}\|_2 = \min$$

By selecting the size of the coefficients η_0 , η_1 or η_2 the influence of the regularization with respect to the rms of the model, its integrated gradient or the laplacian can be controlled.

Scales of lateral heterogeneity: Seismology

Parameterization

We represent a function on a surface of a sphere by superposition of basis functions:

$$f(\vartheta, \varphi) = \sum_i c_i \cdot g_i(\vartheta, \varphi).$$

The basis function may be **local** (splines), such that they vanish at some distance from point i . A frequently used form of a local basis function is the block representation:

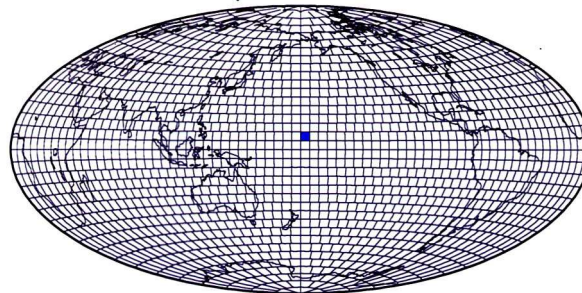
$$g_i(\vartheta, \varphi) = \begin{cases} 1 & \text{if } \vartheta_i^- \leq \vartheta \leq \vartheta_i^+ \text{ and } \varphi_i^- \leq \varphi \leq \varphi_i^+ \\ 0 & \text{otherwise} \end{cases}$$

A common form of representation of **global** basis functions are spherical harmonics, which are orthogonal on the surface of the sphere:

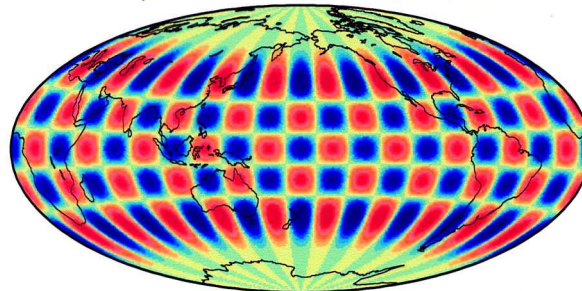
$$g_i(\vartheta, \varphi) = \begin{cases} p_l^m(\vartheta) \cos m\varphi & \text{or} \\ p_l^m(\vartheta) \sin m\varphi. \end{cases}$$

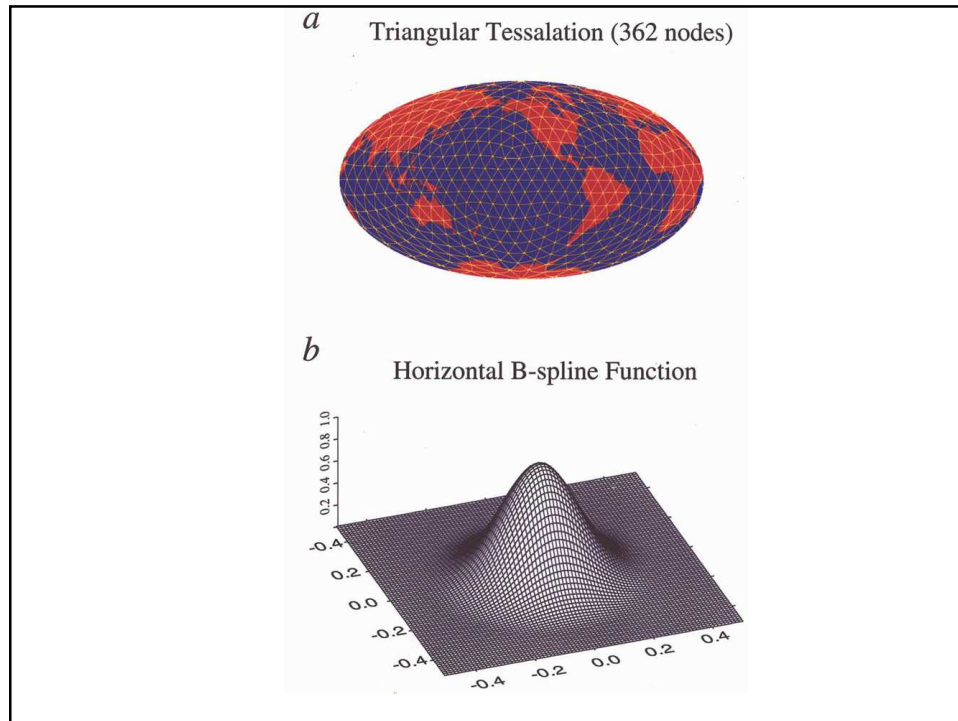
In the first example, the representation is simple in the **space domain**, in the other, it is equally simple in the **wavenumber domain**. The choice depends on the kind of observations that are interpreted and on the kind of information that we want to obtain.

equal area blocks



real spherical harmonic function, $l=14, m=10$





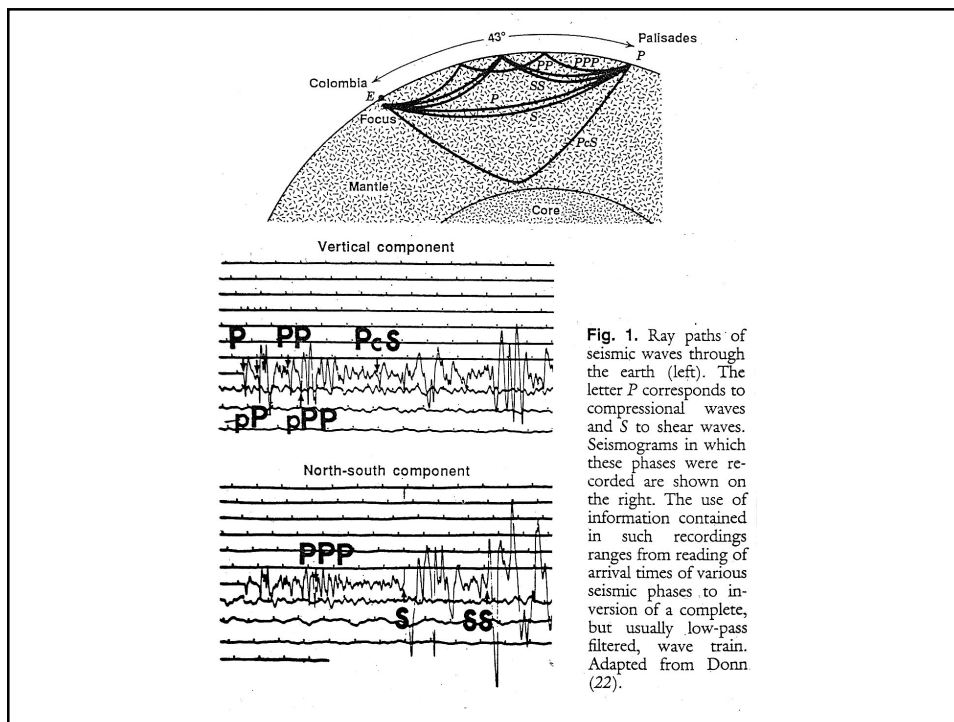
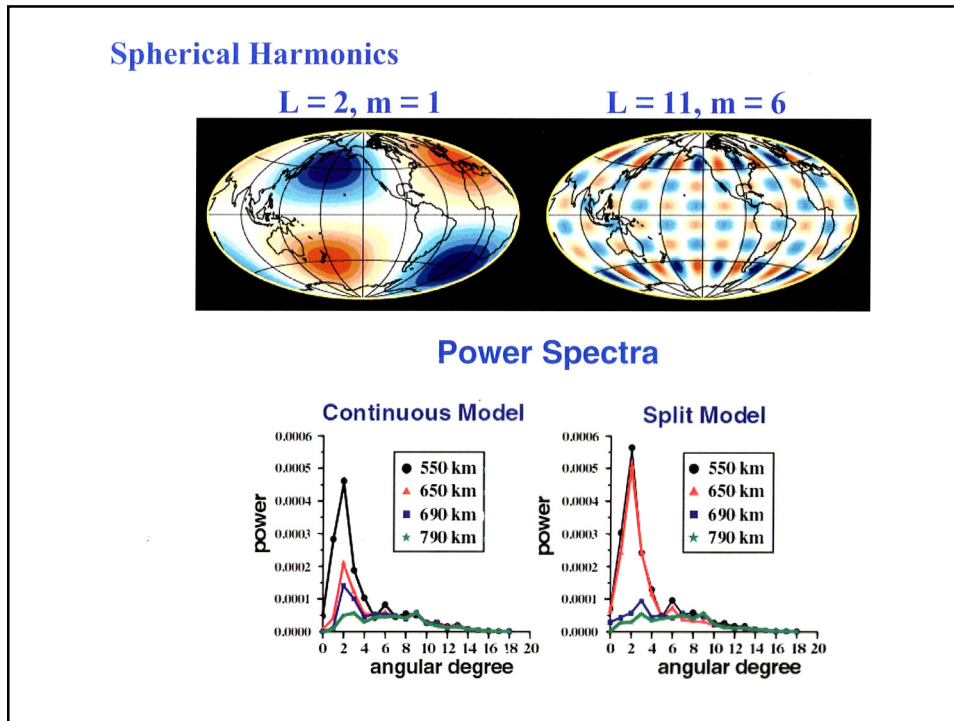
Power Spectrum

With a function $f(\vartheta, \varphi)$ described on a spherical surface by:

$$f(\vartheta, \varphi) = \sum_{\ell=0}^{\infty} \sum_{m=0}^{\ell} (A_{\ell}^m \cos m\varphi + B_{\ell}^m \sin m\varphi) p_{\ell m}(\cos \vartheta);$$

the *power spectrum* is defined for a harmonic degree ℓ as:

$$G_{\ell} = (A_{\ell}^0)^2 + \frac{1}{2} \sum_{m=1}^{\ell} (A_{\ell}^m)^2 + (B_{\ell}^m)^2.$$

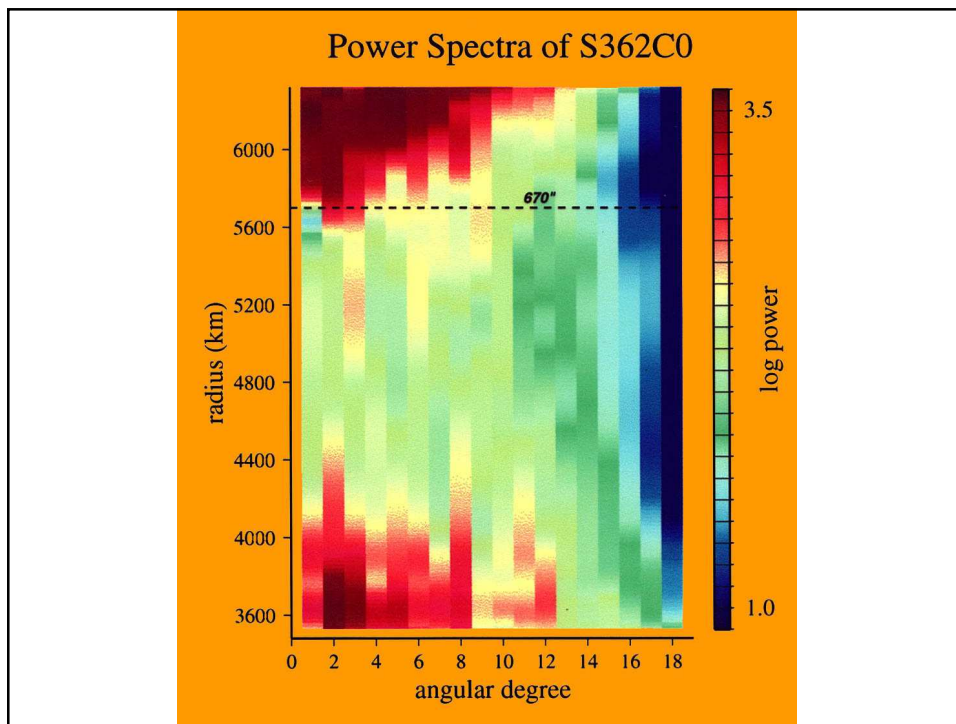
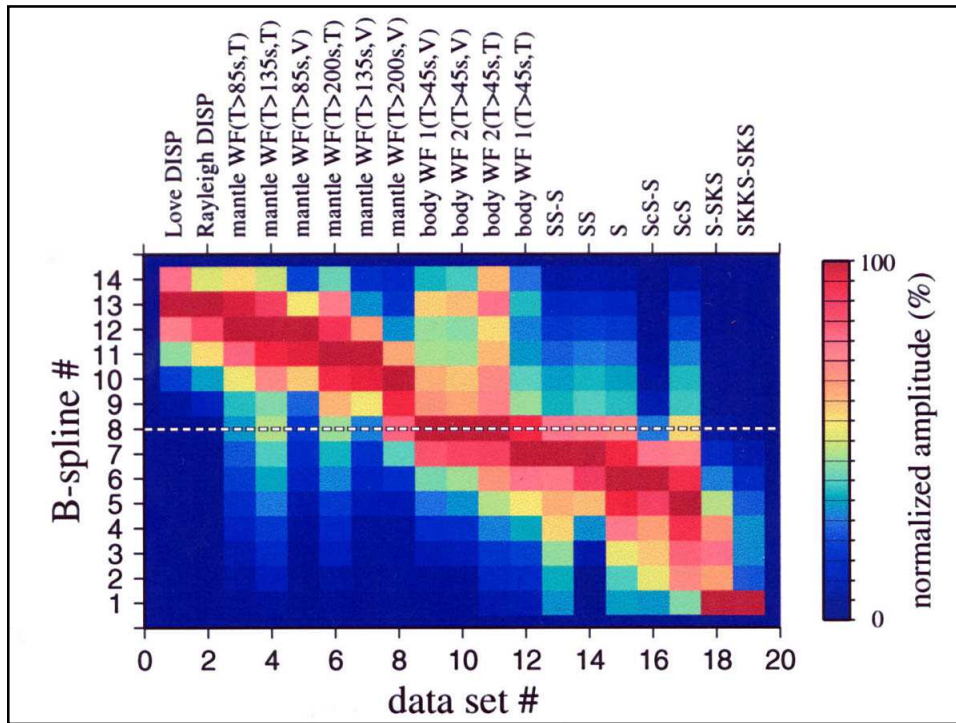


Scales of lateral heterogeneity: Seismology

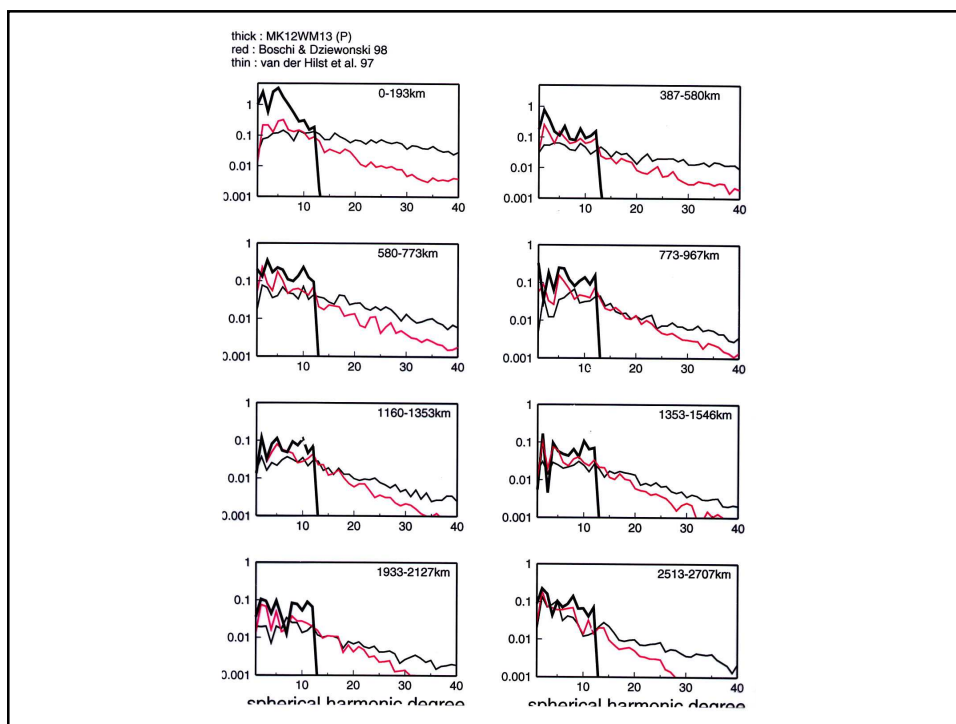
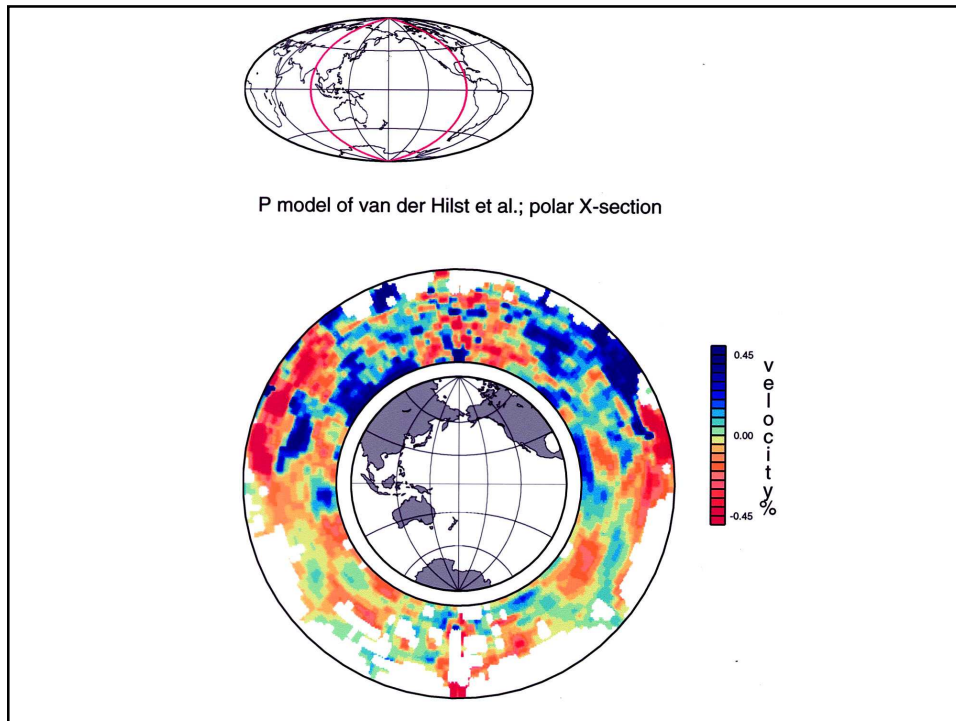
Data Type	Observations
Absolute travel time	
S	24,462
SS	11,410
ScS	4,269
Differential travel time	
SS-S	5,124
ScS-S	3,550
S-SKS	3,567
SKKS-SKS	2,232

Data Type	Observations
Waveforms	
body waves (T > 45s Z T)	13,997
body waves (T > 85s Z T)	8,462
mantle waves (T > 85s Z)	2,760
mantle waves (T > 85s T)	2,665
mantle waves (T > 135s Z)	2,211
mantle waves (T > 135s T)	1,720
mantle waves (T > 200s Z)	2,989
mantle waves (T > 200s T)	1,853
Dispersion measurements	
Love wave (35-150s)	15,473-23,228
Rayleigh wave (35-150s)	28,457-37,739

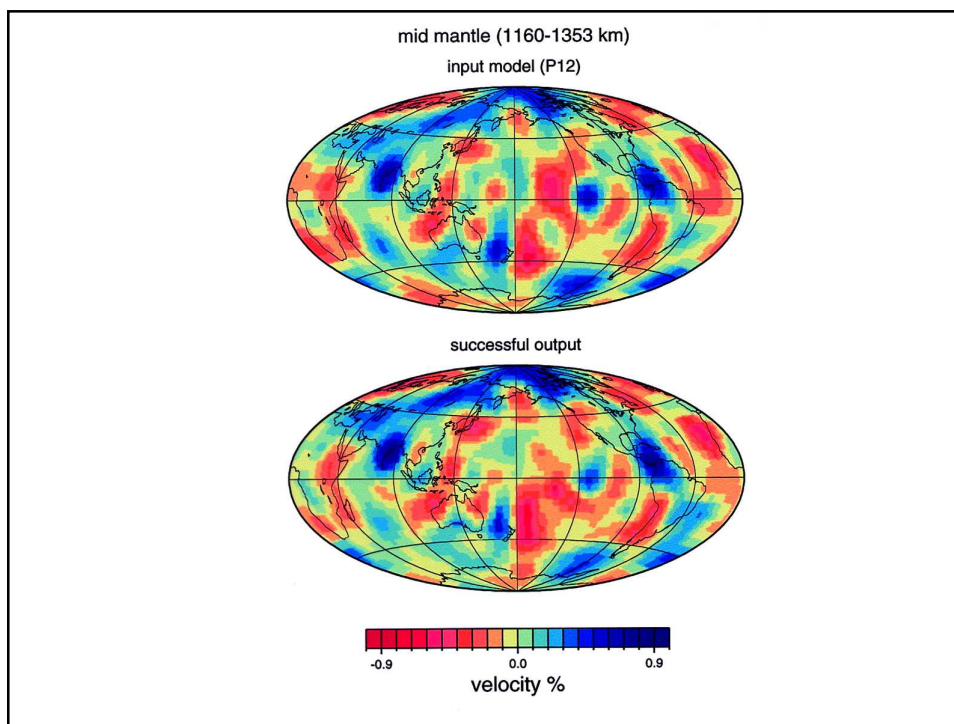
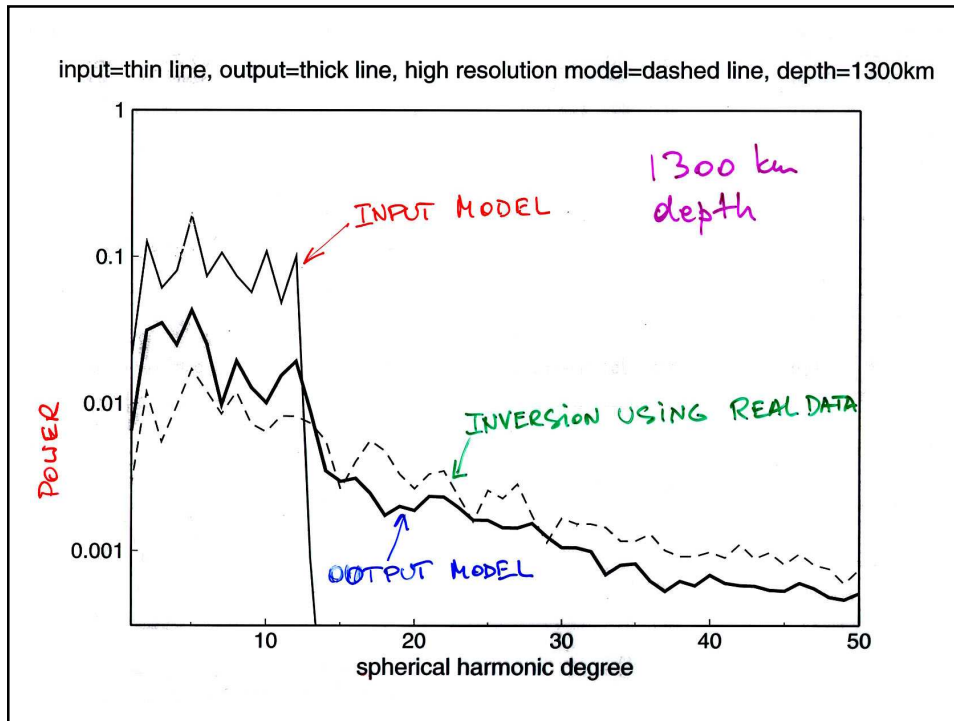
Scales of lateral heterogeneity: Seismology



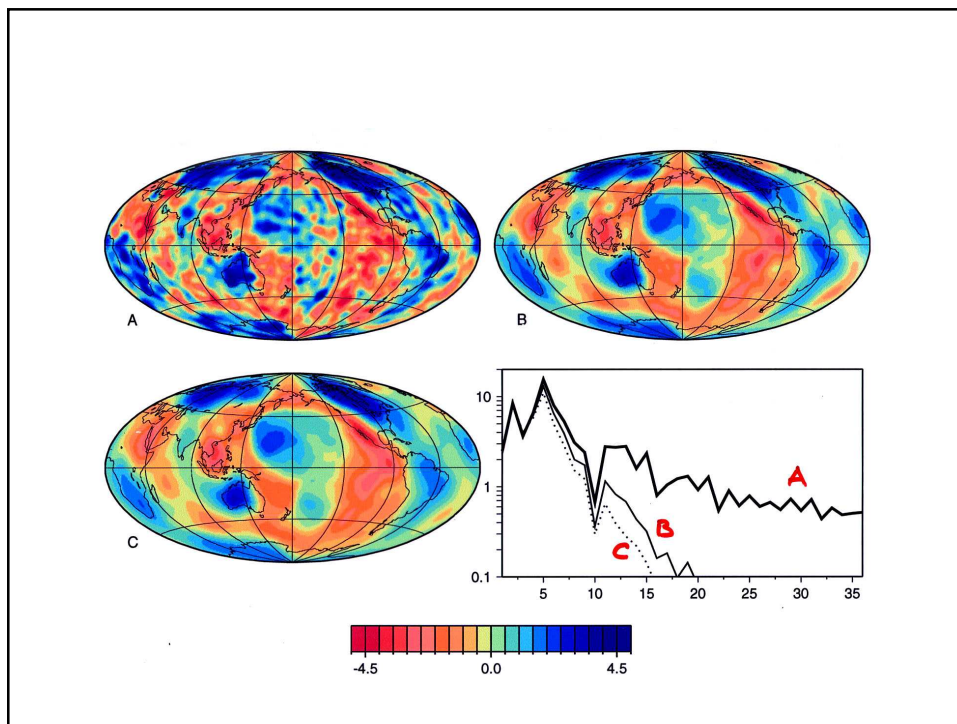
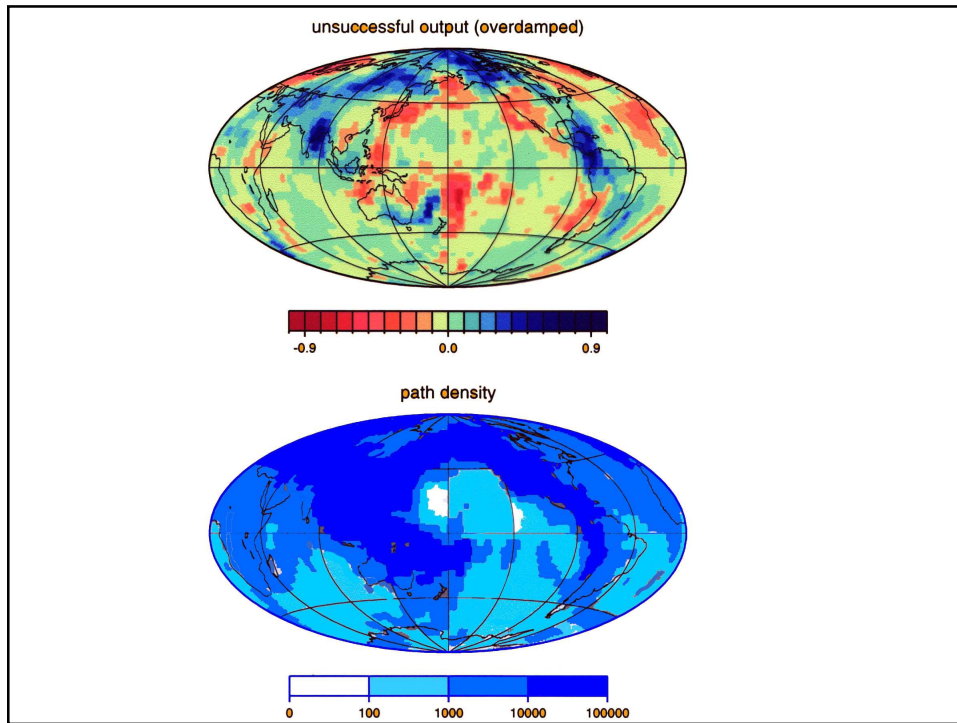
Scales of lateral heterogeneity: Seismology



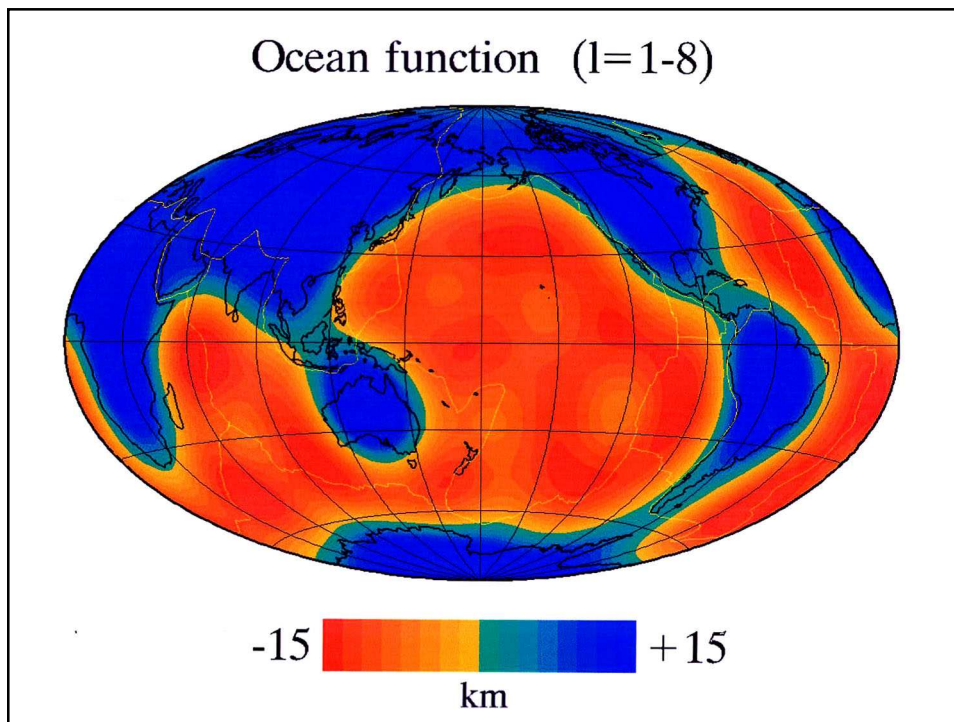
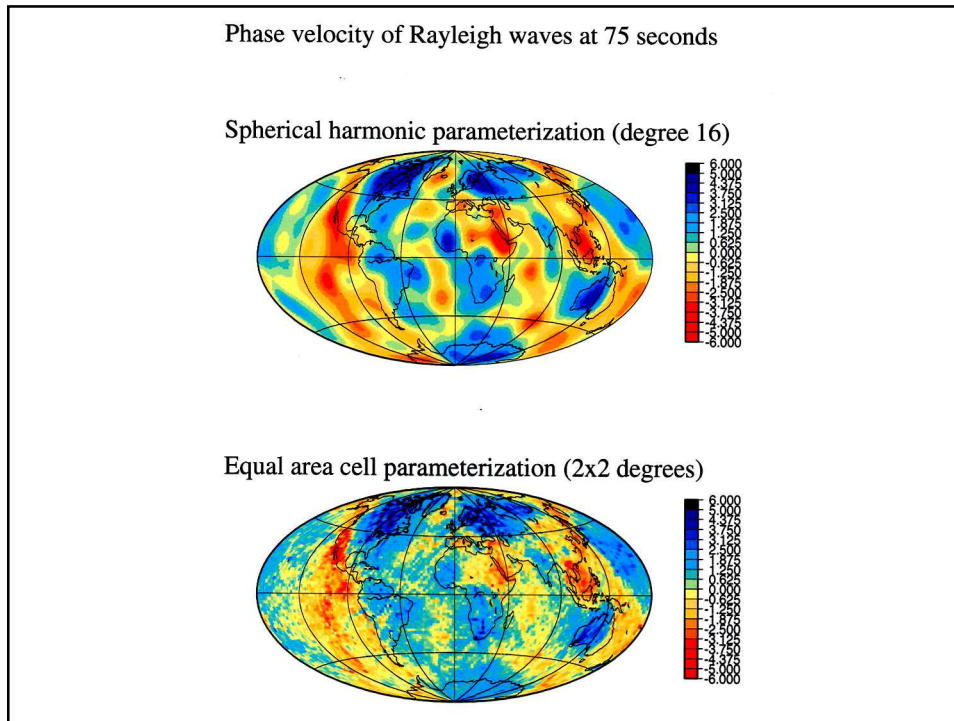
Scales of lateral heterogeneity: Seismology



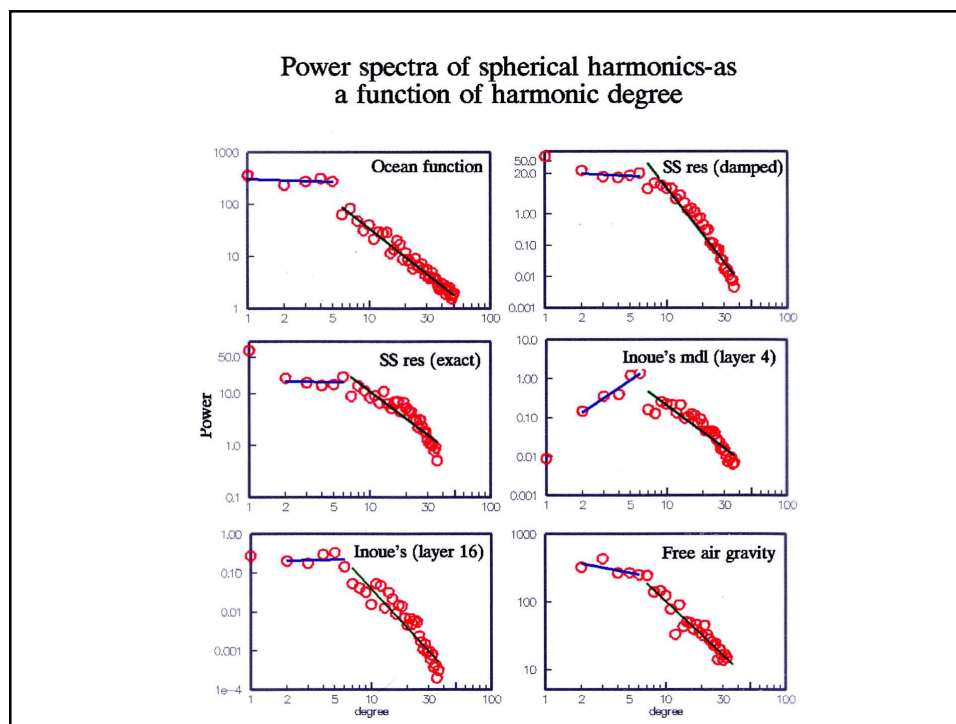
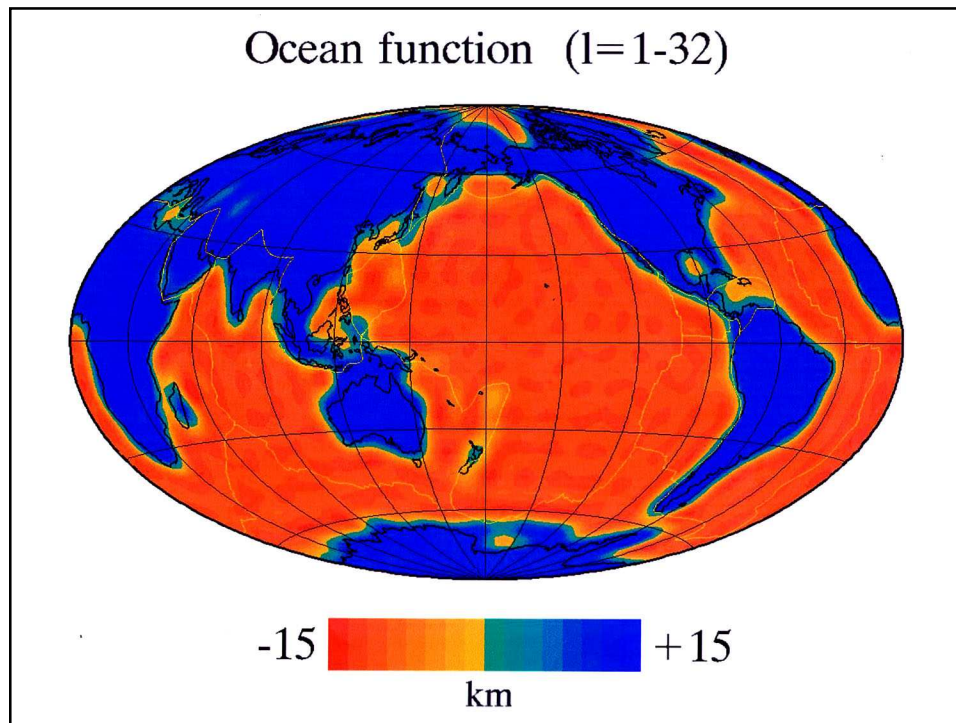
Scales of lateral heterogeneity: Seismology



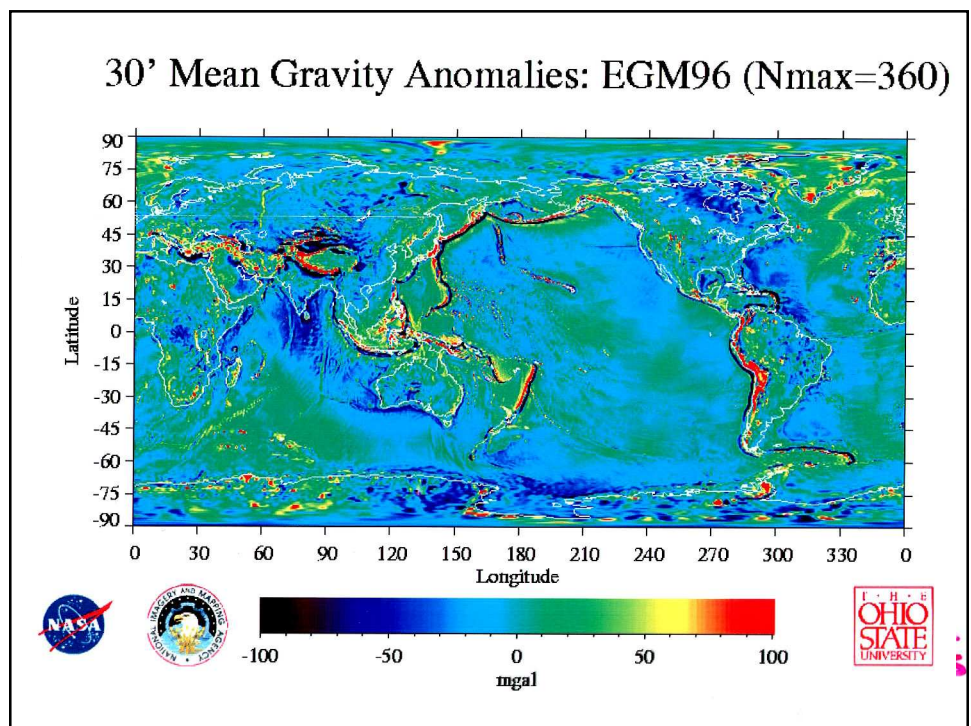
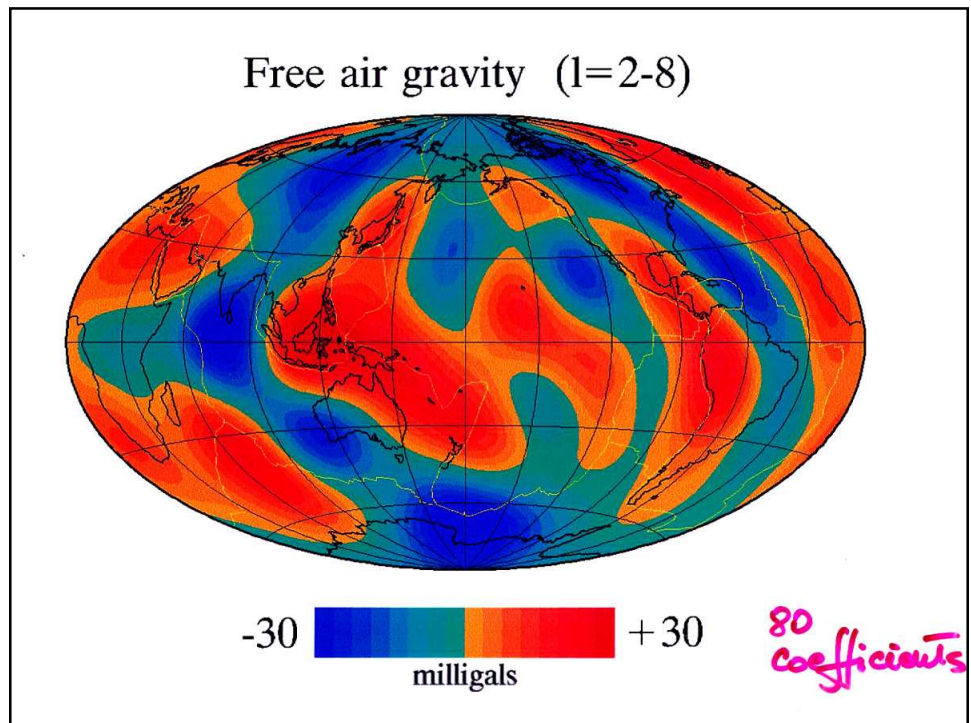
Scales of lateral heterogeneity: Seismology



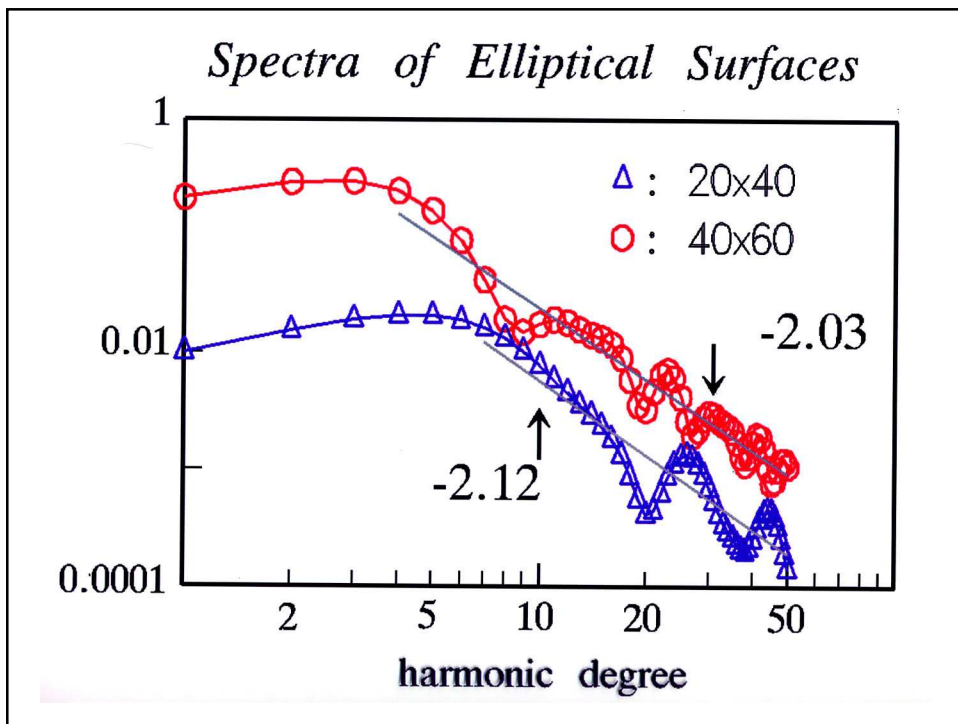
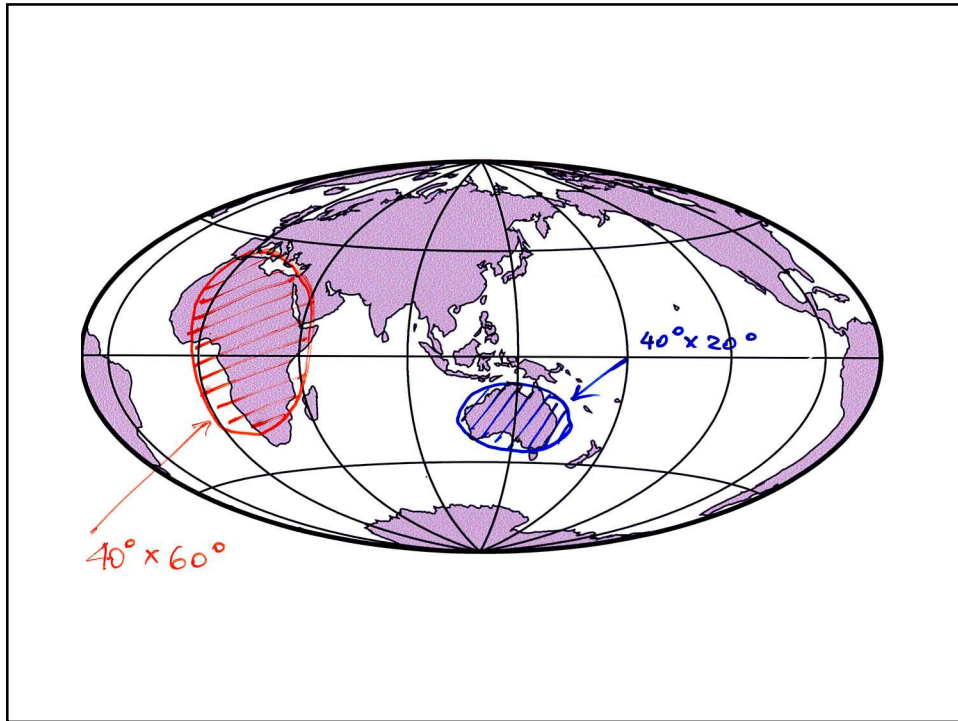
Scales of lateral heterogeneity: Seismology



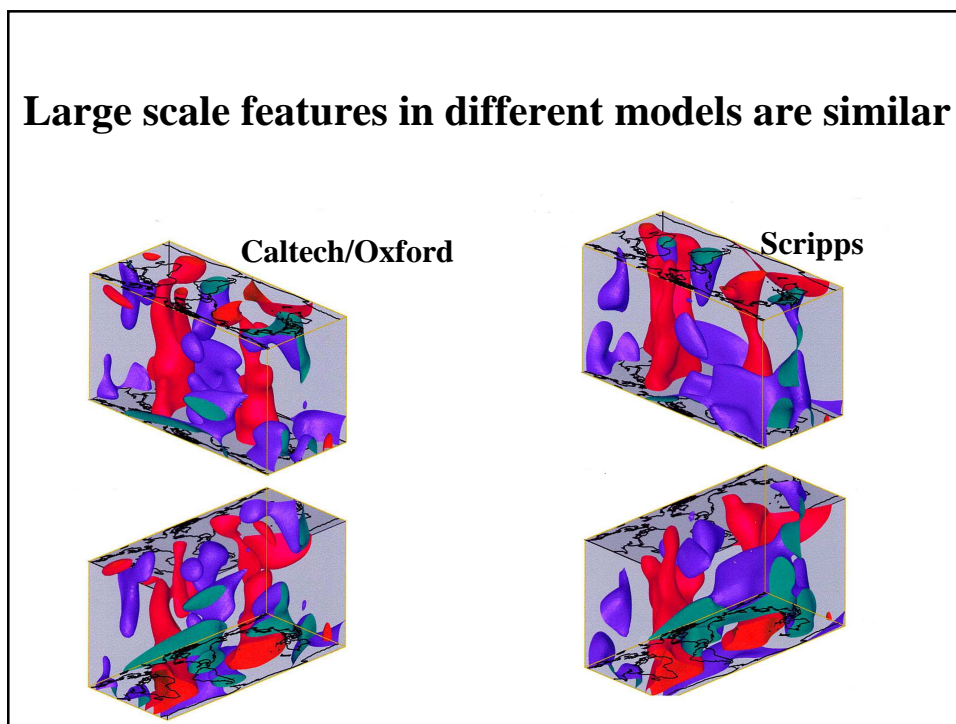
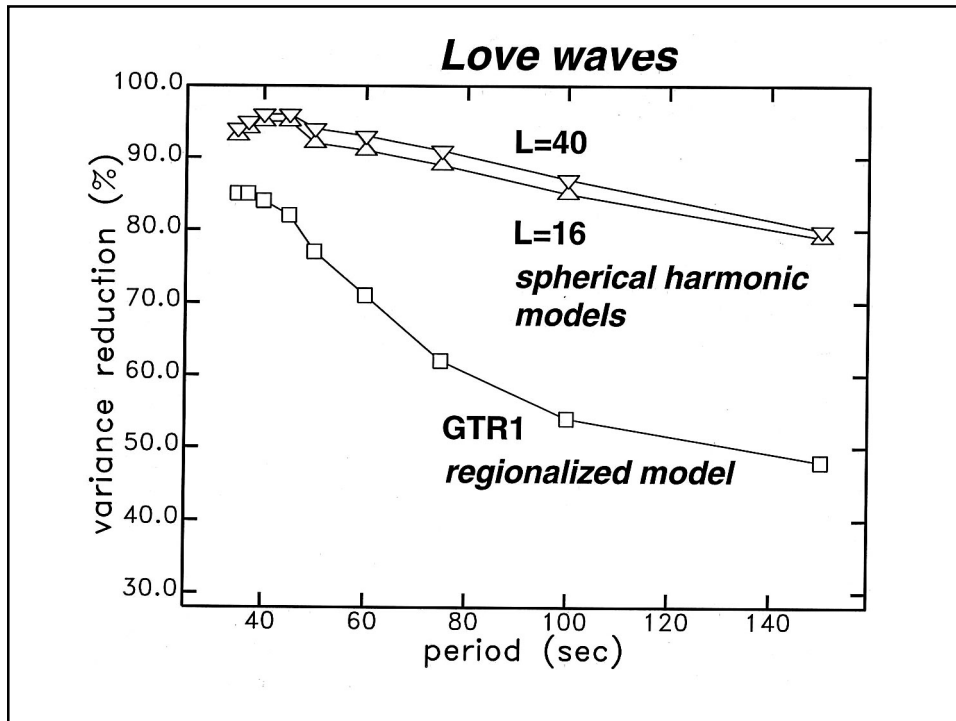
Scales of lateral heterogeneity: Seismology



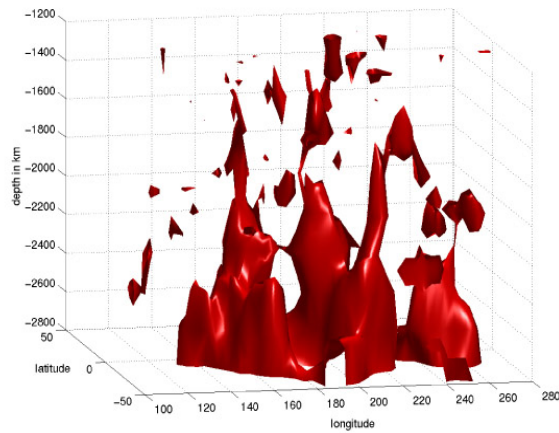
Scales of lateral heterogeneity: Seismology



Scales of lateral heterogeneity: Seismology

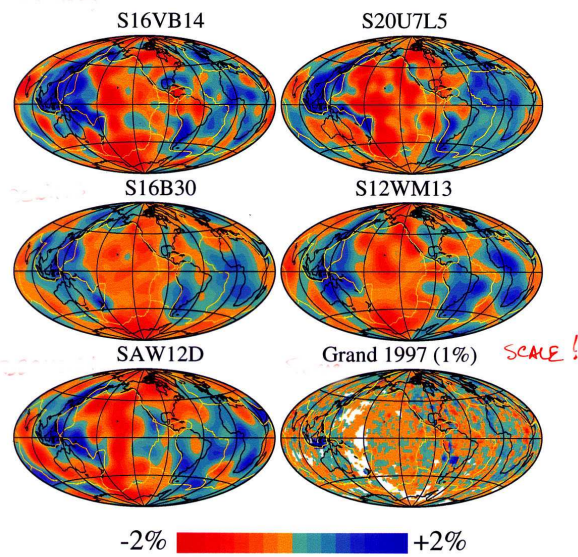


Equatorial Pacific Plume Group



The Pacific super-plume shows structure in this 3-D expansion of the -1% iso-surface of a recent Scripps model of shear velocity anomalies.

Depth = 550 km



Scales of lateral heterogeneity: Seismology

