Seismic wave Propagation and Imaging in Complex media: a European network

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Early Stage Researcher

Host Institution: University of Oxford
Place of Origin: Birr, Ireland
Appointment Time: February 2005

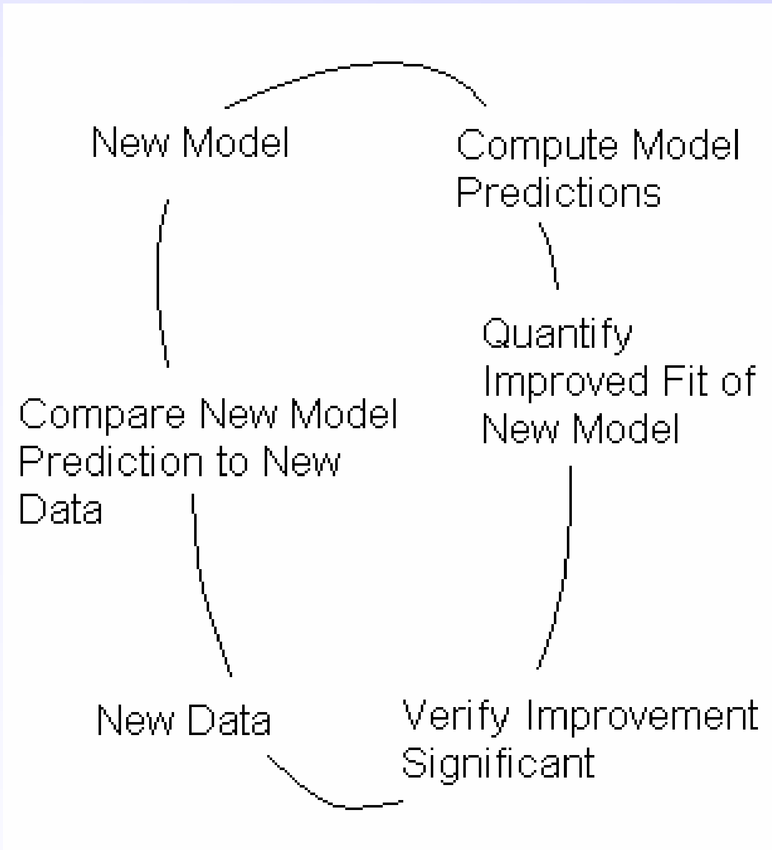
Project: Applications of numerical wavefield calculations in seismic tomography.

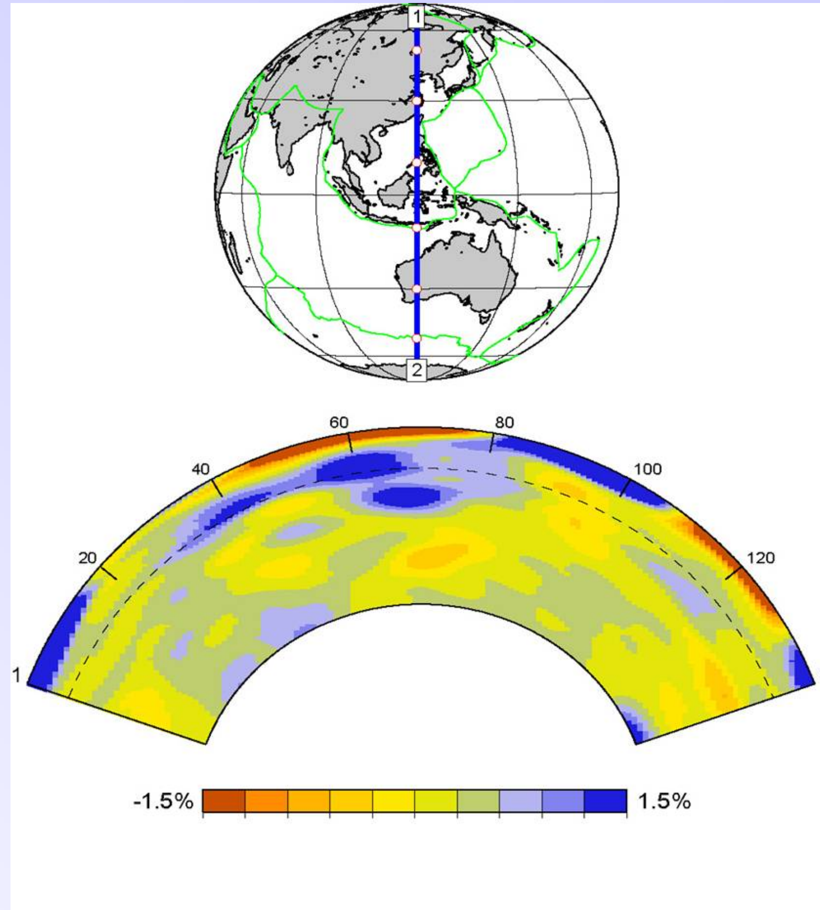
Task Groups: TG Planetary Scale

Cooperation: University of Utrecht

Project Scope

Global Tomographic Problem



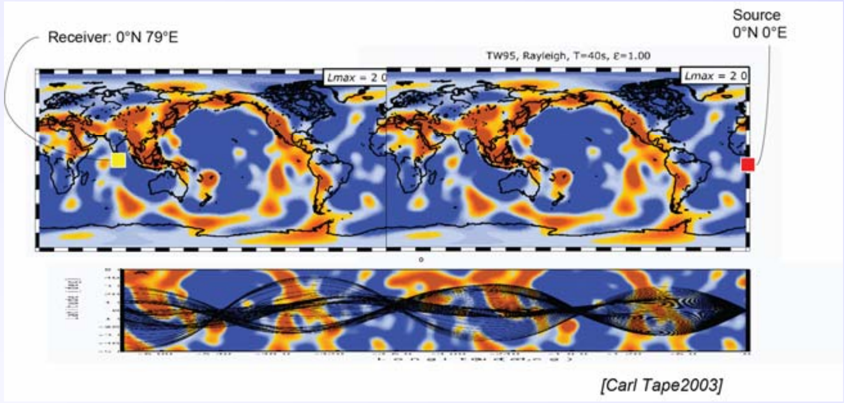


S20RTS
Ritsema, Van Heijst, and Woodhouse [1999]

Forward Modelling

It is desirable to use various different methods of forward modelling to minimise the effect of each methods limitations on the derived earth model.

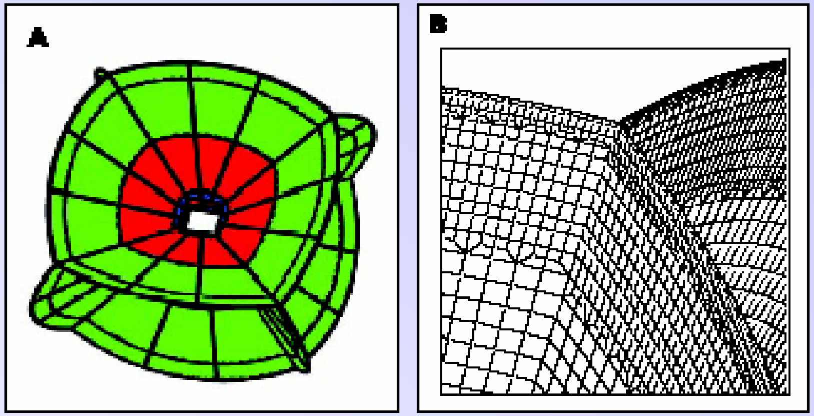
Ray Theory



[Carl Tape2003]

The validity of Ray theory is constrained by the requirement that the variations in wave speeds to be smooth. Rays are computed representing the full range of possible paths from a source point to a receiver point.

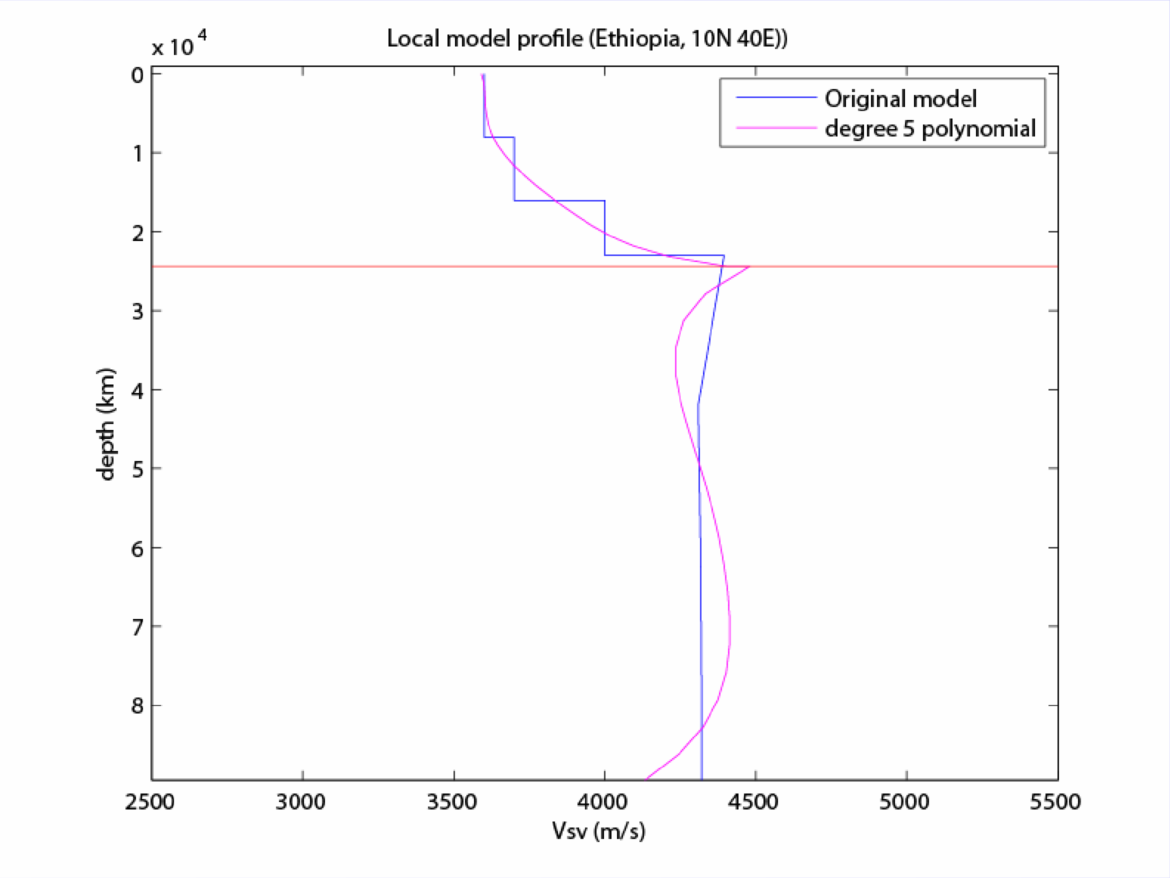
Spectral-Element Method



Komatitsch, Ritsema and Tromp, The spectral element method, beowulf computing and global seismology, *Science* Vol.298, 29 Nov 2002, Pg.1737

The Spectral-element method is based upon generalised Galerkin finite-element methods, with the accuracy of any solution constrained by the discretisation of the solution space.

Model comparison



V_{sv} comparison of model smoothing in continental crust (Ethiopia)

Method

Aim: A Method for simplifying crustal structure for the purposes of of three dimensional numerical wave field modelling.

Technique concerns the matching of the statistical moments of functions representing the parameters of the model in question, to those of new, smooth, m^{th} degree polynomial functions.

$$\int_a^b f(x)\, x^n \, dx = \int_a^b \left(\sum_{i=0}^{m} g_i x^i \right) x^n \, dx$$

In the simple case where f(x) is some constant value v in each of k layers over the interval [b,a], by elementary integration, the problem reduces to solving the simple linear system of n equations, $b_n = A_{ni} g_i$,

$$\sum_k v_k \left| \frac{x^{n+1}}{n+1} \right|_{x_k}^{x_{k+1}} = \sum_{i=0}^{m} \left| \frac{x^{i+n+1}}{i+n+1} \right|_a^b g_i$$

Method

Moment matching carried out using

A: the model's functions of the elastic parameters and density.

B: the'Backus parameters'.

$$A = \langle a - f^2 c^{-1} \rangle + \langle c^{-1} \rangle^{-1} \langle f c^{-1} \rangle^2$$

$$C = \langle c^{-1} \rangle^{-1}$$

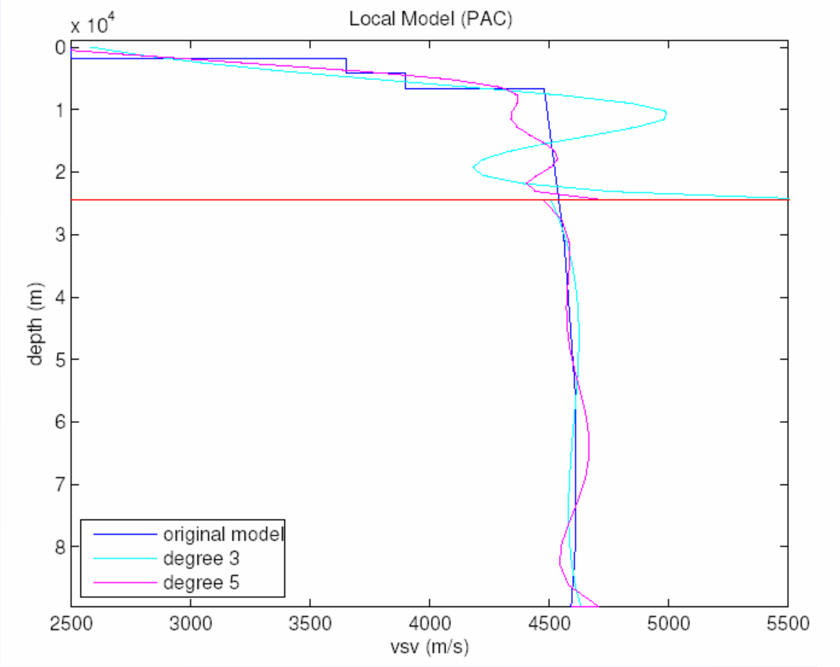
$$F = \langle c^{-1} \rangle^{-1} \langle f c^{-1} \rangle$$

$$L = \langle l^{-1} \rangle^{-1}$$

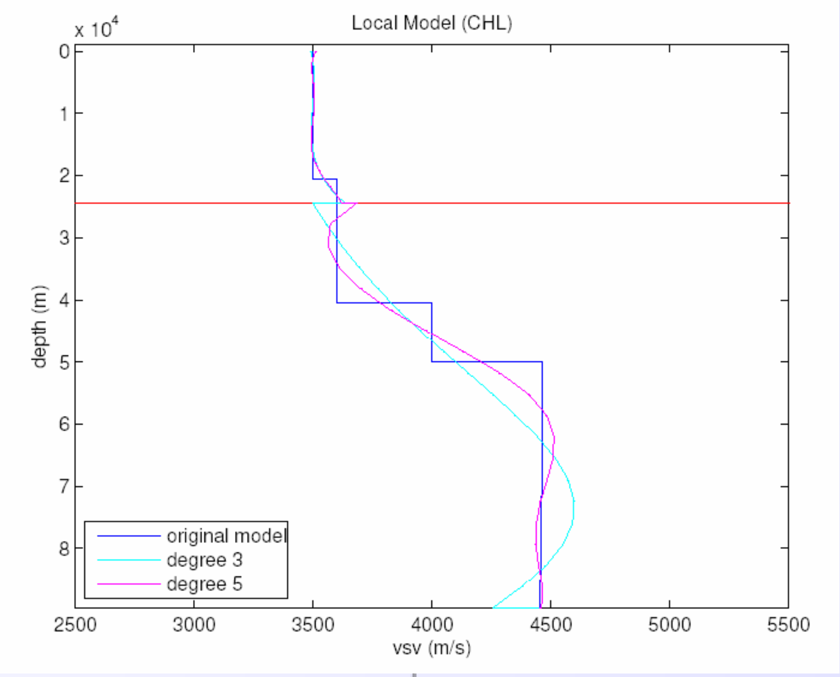
$$N = \langle n \rangle$$

A, C, L, N and F represent the effective elastic moduli of the averaged, long wave equivalent media to the original

Model comparison



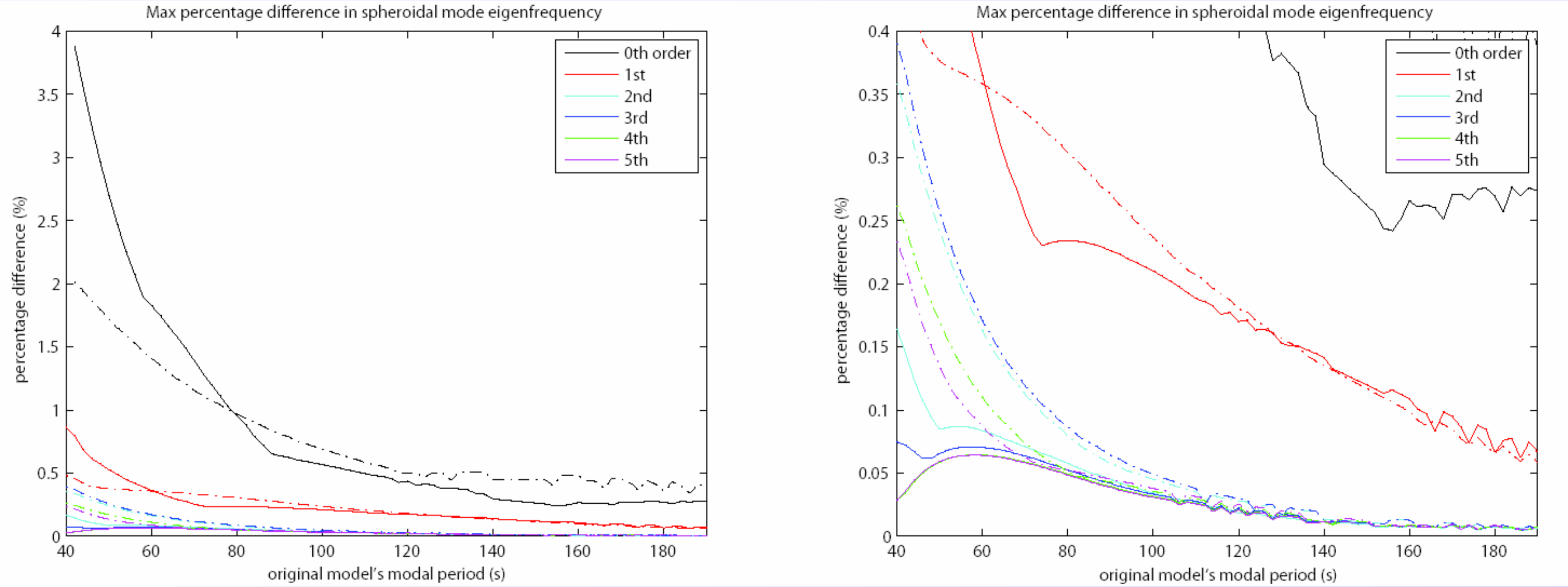
V_{sv} comparison of model smoothing in oceanic crust (mid Pacific ocean)



V_{sv} comparison of model smoothing in thick continental crust (Chilean Andes)

Results: Rayleigh waves

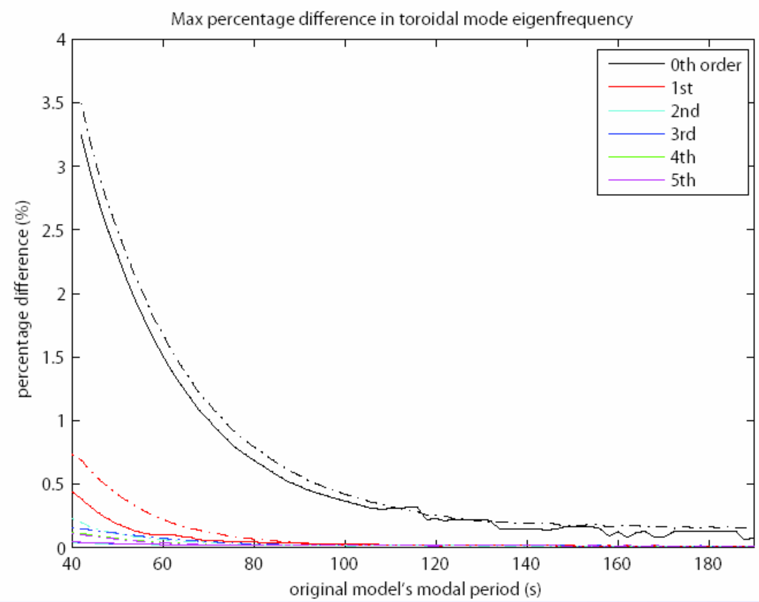
Maximum percentage differences in eigenfrequency across entire globe between layered medium and smoothed medium.

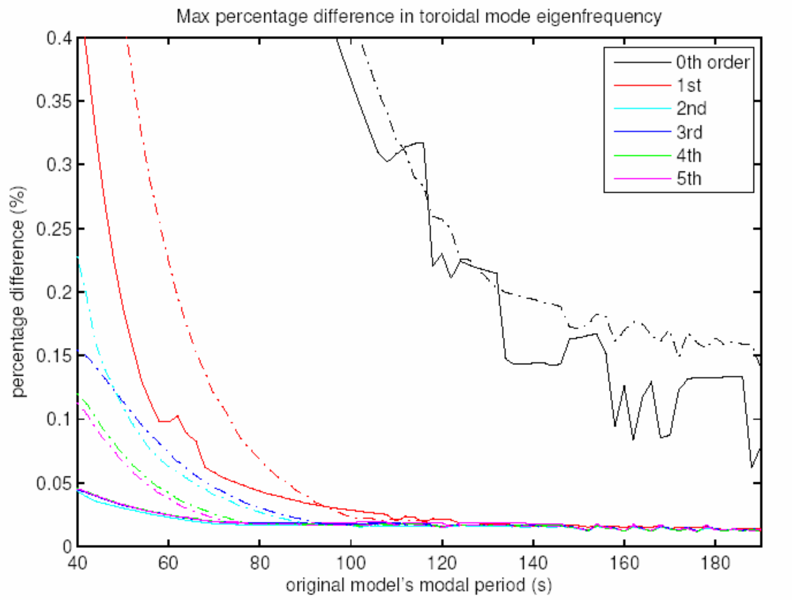


Solid lines:- Backus parameters
Dash-dotted lines:- elastic moduli

Results: Love waves

Maximum percentage differences in eigenfrequency across entire globe between layered medium and smoothed medium.

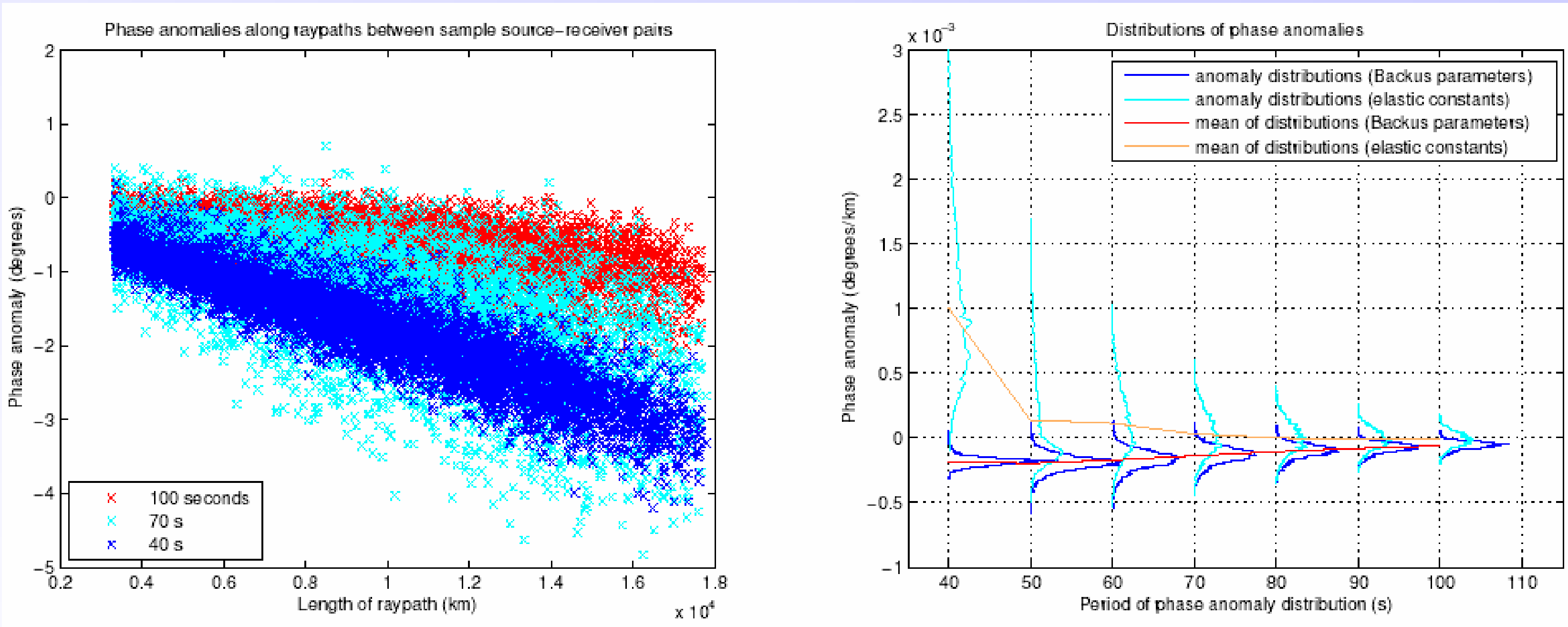




Solid lines:- Backus parameters
Dash-dotted lines:- elastic moduli

Results: Rayleigh waves

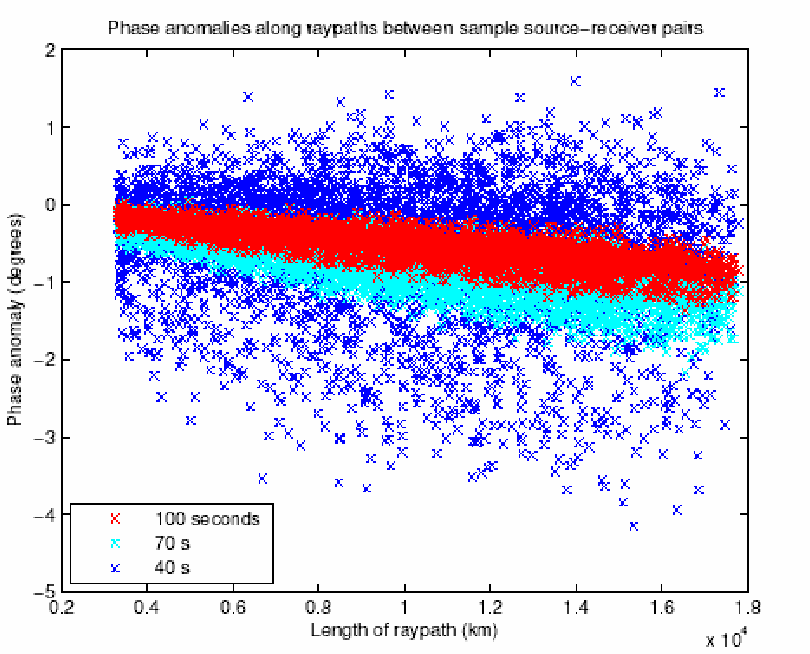
Phase anomalies introduced by smoothing of the medium.

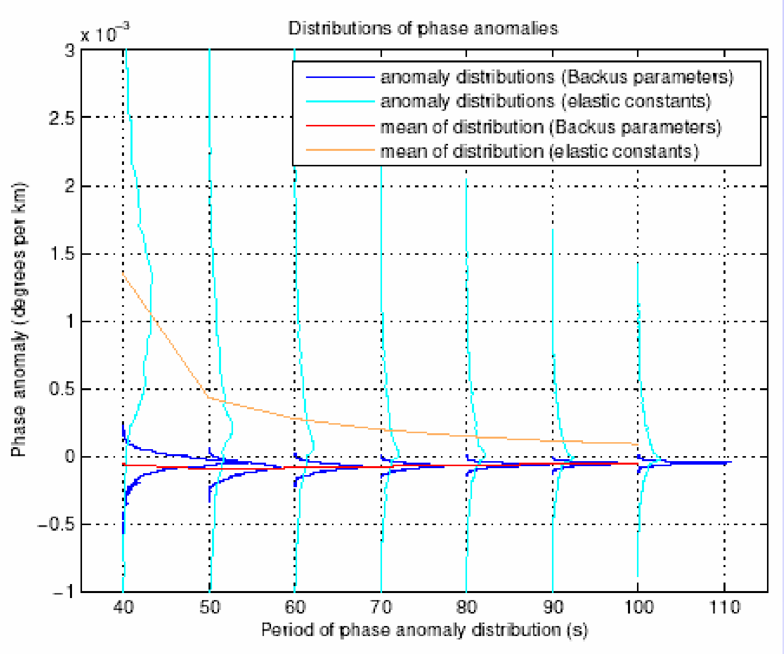


- 5123 sample raypaths
- Phase anomalies computed using great circle approximation

Results: Love waves

Phase anomalies introduced by smoothing of the medium.





- •5123 sample raypaths
- •Phase anomalies computed using great circle approximation

Conclusions

•Moment matching to the Backus parameters provides a significant improvement over matching merely to the elastic moduli.

•Matching to degree 4 polynomials provides the best solution with no clear improvement when matching to degree 5.

•Differences of no more than 0.065% in the modal eigenfrequencies in the period range of greater than 40 seconds.

•Average phase anomaly of no more than 10^{-4} degrees per kilometer.

Outlook:

•Incorporate the smoothed crustal structure into the implementation of the Spectral Element Method of Komatitsch & Tromp (2002).

•Compare with full ray theory (Ferreira & Woodhouse, 2007).

References

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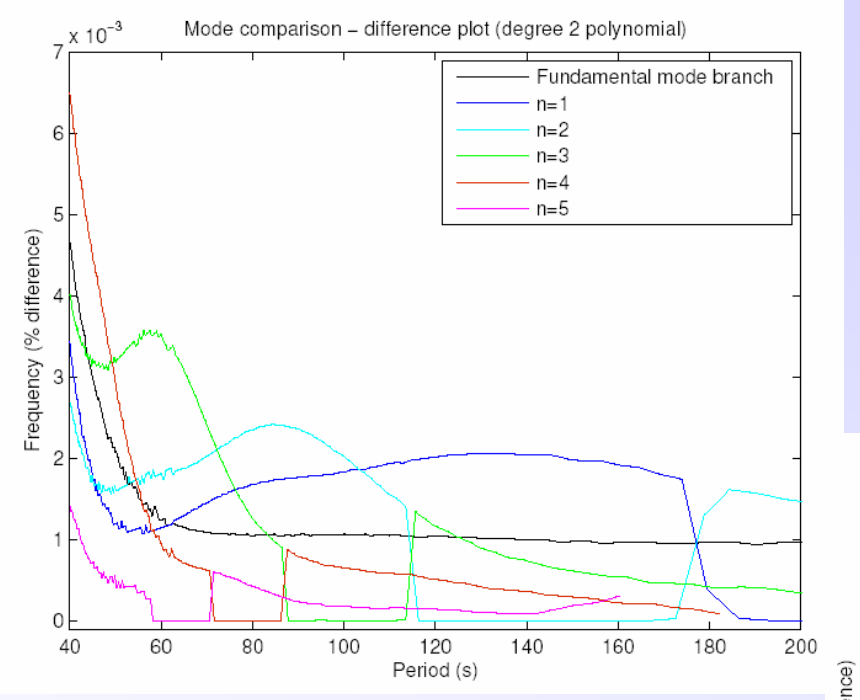
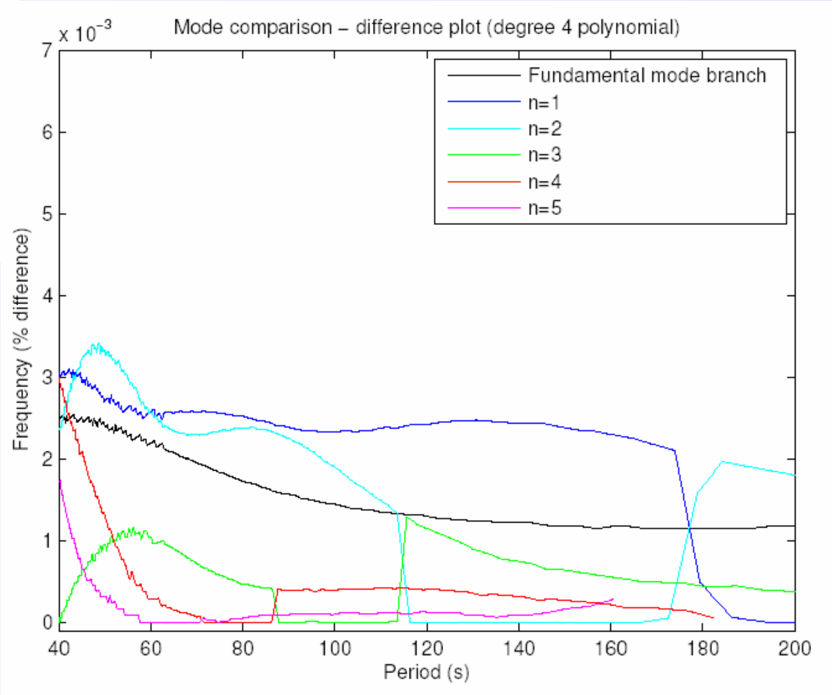
Results



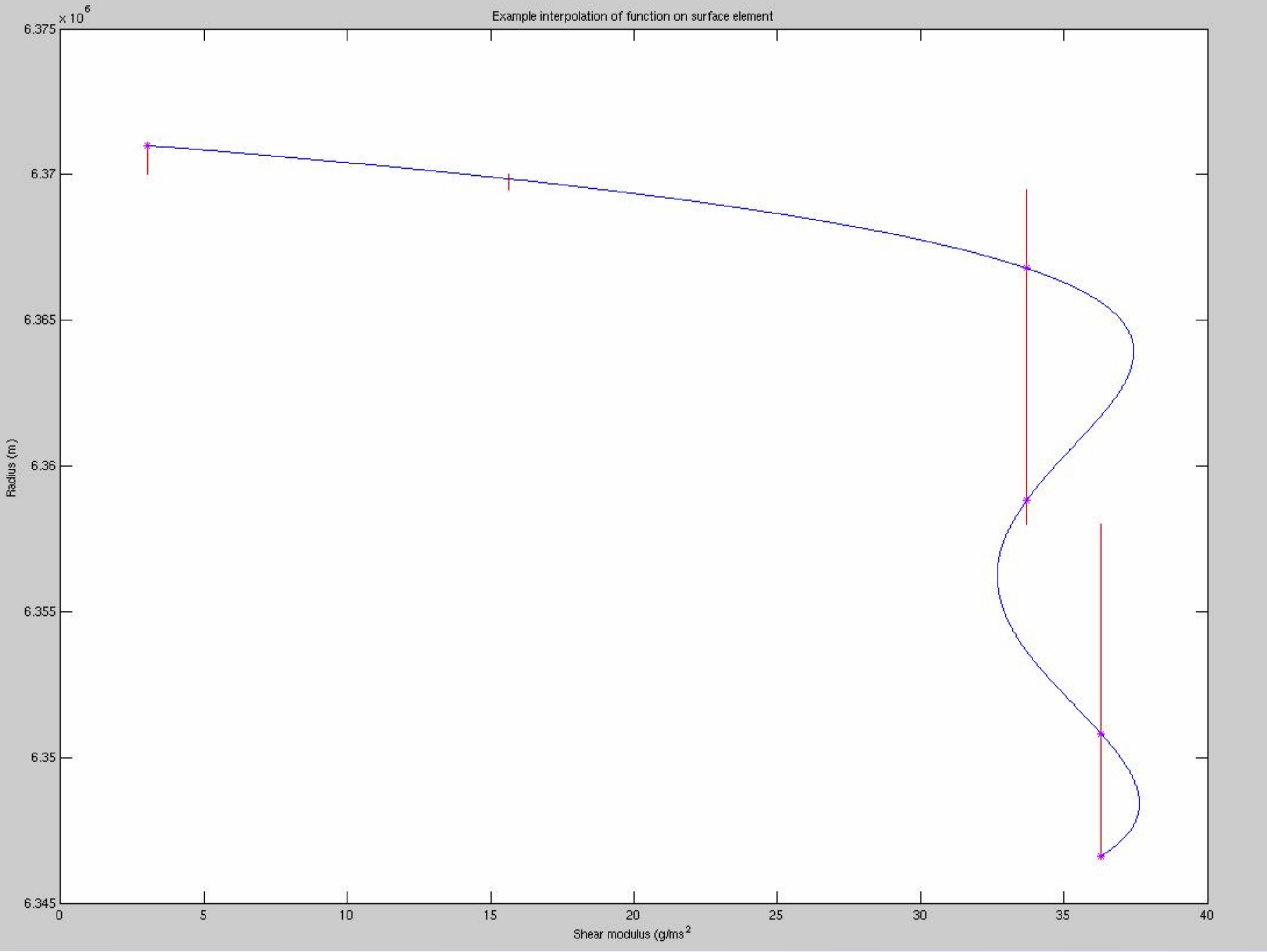
Percentage difference of eigenvalues computed for original model vs. model derived by polynomial moment matching to Backus parameters.

Left: Degree 2 polynomial

Right: Degree 4 polynomial



Model comparison



Shear Modulus comparison: *Red - Discontinuous crustal structure*

Blue - Interpolated 4th order polynomial