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ANALYTIC TOMOGRAPHY OF THE MANTLE FOR A SPHERICALLY SYMMETRIC P VELOCITY MODEL

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To date, numerous studies use the arrival times of seismic waves to explore the Earth structure. Seismic arrival times have provided a fundamental constraint on the radial and lateral velocity structure of our planet. In this task, reference models (such as PREM, IASP91 and SP6) constitute the common basis for all the different studies and constitute the starting point for a number of applications, including seismic tomography and synthetic seismogram calculations. In this sense, any effort to improve the available reference models will benefit on the current seismological knowledge, especially those concerning local deviations in boundary interfaces in the Earth's interior. In this paper we focuse our attention on the tomography of the Mantle, usind and developing a non-linear inversion technique based on the analytic solution of the elliptic integrals involved in the hamiltonian ray theory. The use of analytic functions to derive a model that globally reproduces the observed traveltimes by acting locally on a multilayer and spherical Mantle does not prescribe the physical meaning of the proposed model. Indeed, it results in an improved understanding of some particular areas, for example the D'' layer at the CMB.

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ANALYTIC TOMOGRAPHY OF THE MANTLE

FOR A SPHERICALLY SYMMETRIC P VELOCITY MODEL

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Overview

- Properties of the technique
- Computational requirements
- Hypotheses
- Some equations
- Modus operandi
- The MZY model
- Conclusions and future work

Properties of the technique

- Novelty (?)
- Easiness
- Accuracy
- Functionality
- Inexpensive!

Computational requirements

- One computer
- Standard math software
  - MathCad, Matlab, etc.
  - MuPad is free!

Other requirements:

- Travel times for one or various phases (P, PcP, S, PcS, etc.)
- Coffee and cookies

Hypotheses

- The Mantle is described as a collection of layers with (*a priori*) unknown thickness.
- A unique *common* trial function to describe the velocity variation in depth:

$$v(r) = r \cdot (B_i - A_i \ln r)$$

  - B_i y A_i to be determined
  - Smoothness imposed

The function v(r) has some interesting properties.

Some equations…

- For the epicentral distance:

$$\Delta = \frac{2}{p} \cdot \left(\sum_i \frac{\cos(I_i) - \cos(I'_i)}{A_i} + \frac{\cos(I_k)}{A_k} \right)$$

- For the travel time:

$$T = 2 \cdot \left[\sum_i \frac{1}{A_i} \cdot \ln \left[\frac{tg\left(\frac{I'_i}{2}\right)}{tg\left(\frac{I_i}{2}\right)} \right] - \frac{1}{A_k} \cdot \ln \left(tg\left(\frac{I_k}{2}\right) \right) \right]$$

These expressions are calculated analytically using v(r)

Modus operandi

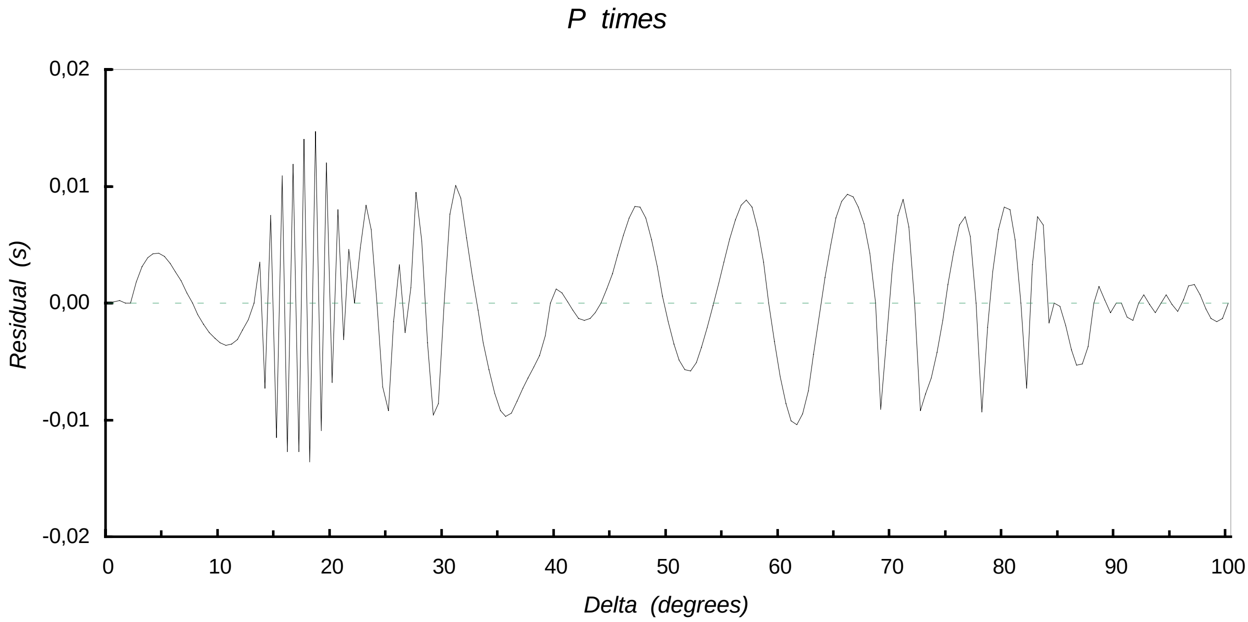
- Posing a **non linear** system of equations with the expressions for (Δ, T) and the ray parameter *p*.
  - One boundary condition **(Δ_o,T_o)** for discontinuities of the 2nd kind.
  - Three boundary conditions **(Δ_o,T_o)** for discontinuities of the 1st kind.
- Performance of your preferred software to obtain (**B_i, A_i**).

Results (I)

- Tomography of the Mantle, using 34 observed travel times (**T_o**) for the P phase, and 2 observed travel times for the PcP phase.
- The travel times correspond to observed times of P and PcP from Herrin et al. (1968).
- We have detected 29 layers in the Mantle.

Results (II)

P residuals: $r = (T_o - T_c)$

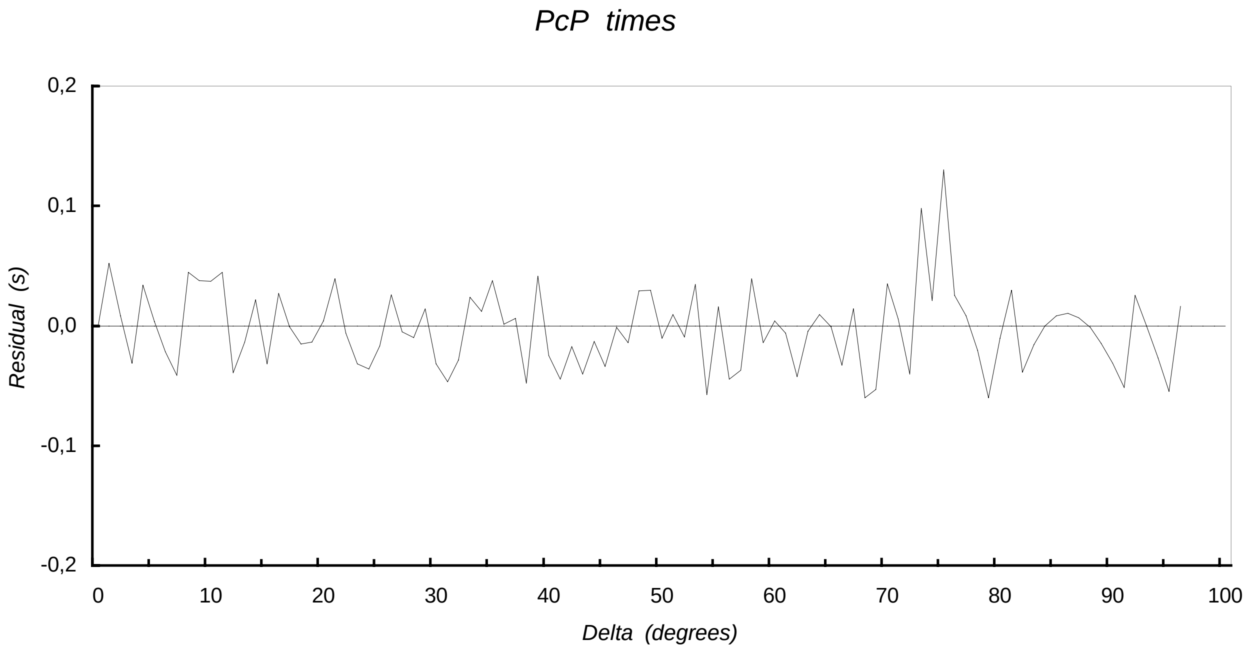


Δ: 0 – 100° every 0.5°

r_{max} = 0,015 s. at Δ=18,5°

Results (III)

PcP residuals: $r = (T_o - T_c)$



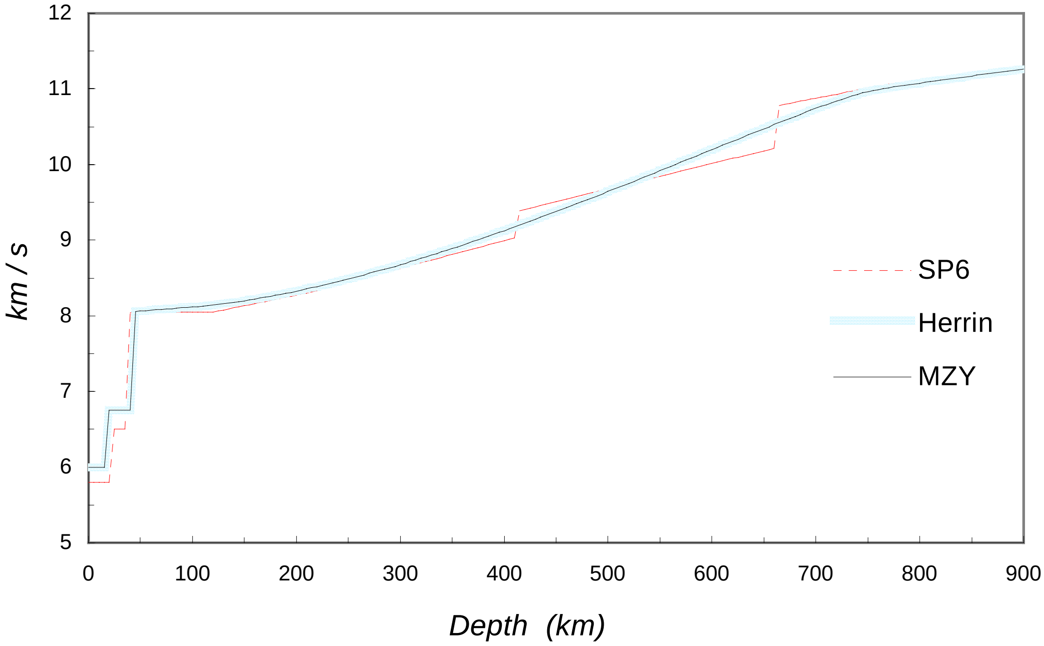
Δ: 0 – 96° every 1°

r_{max} = 0,13 s. at Δ = 75°

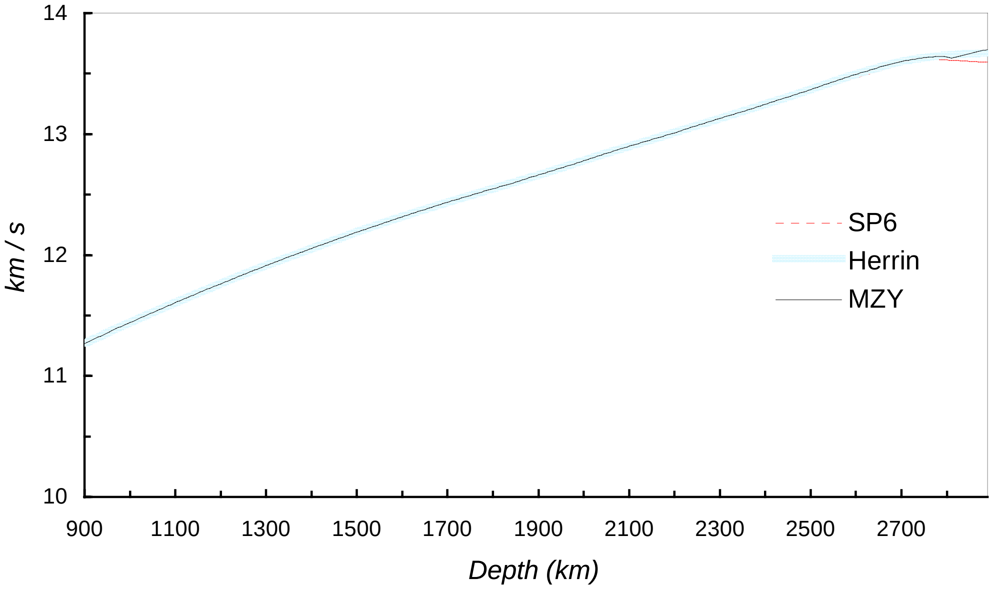
$Depth_{Outer\ Core}$: 2893.9 km

MZY model:

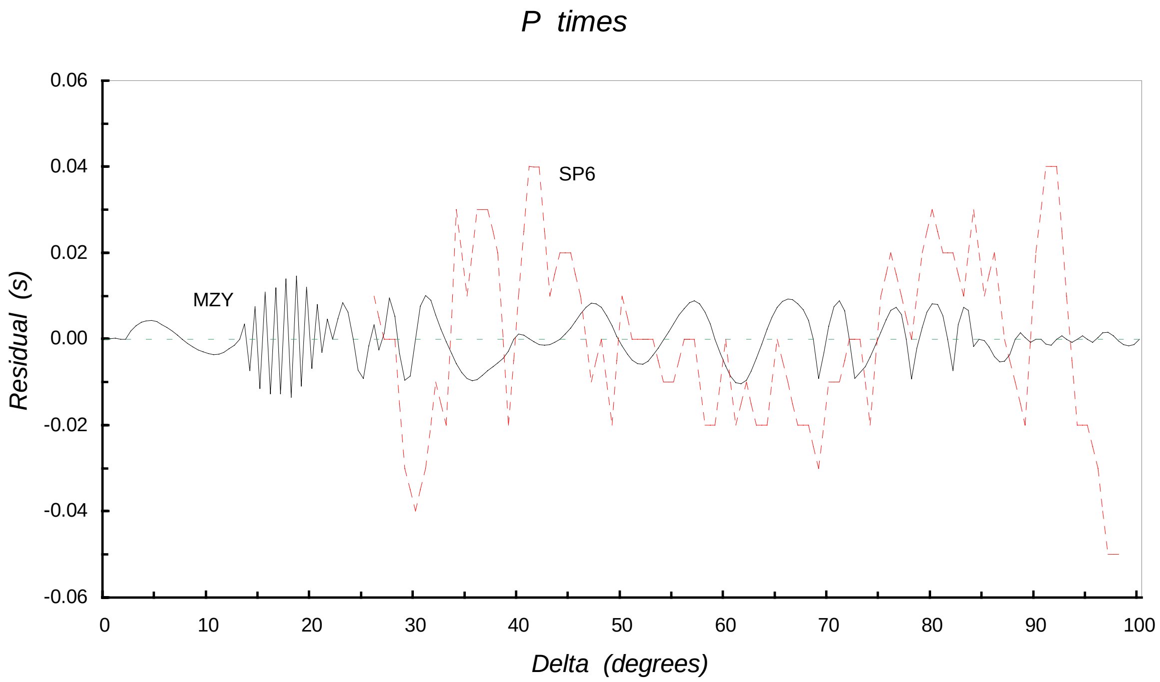
P - wave velocity (upper mantle)

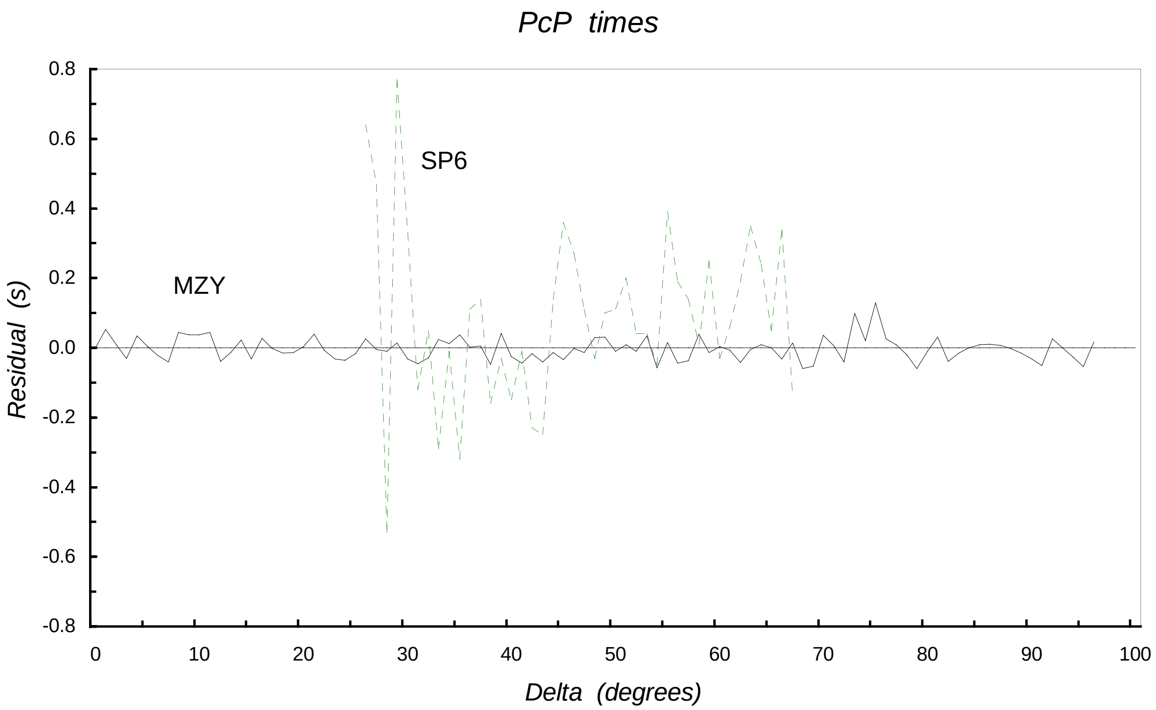


P - wave velocity (lower mantle)

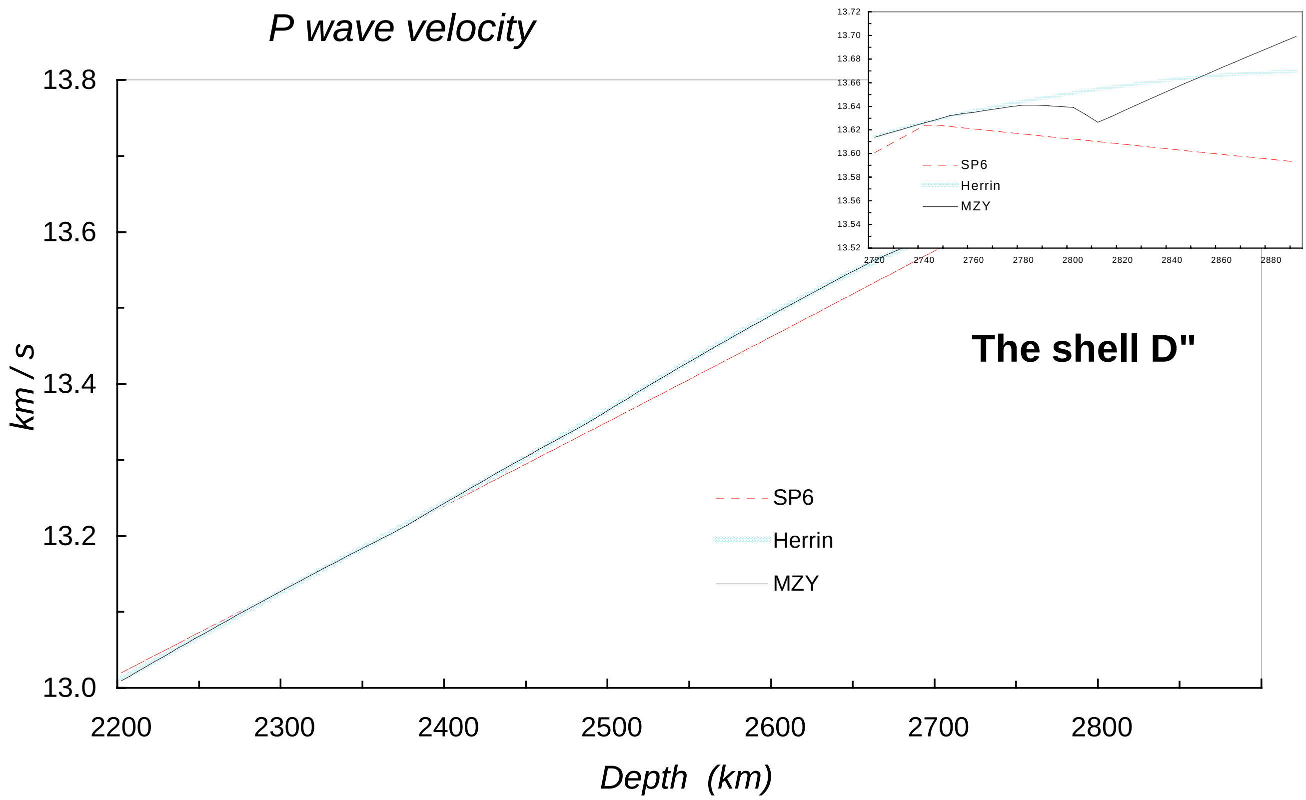


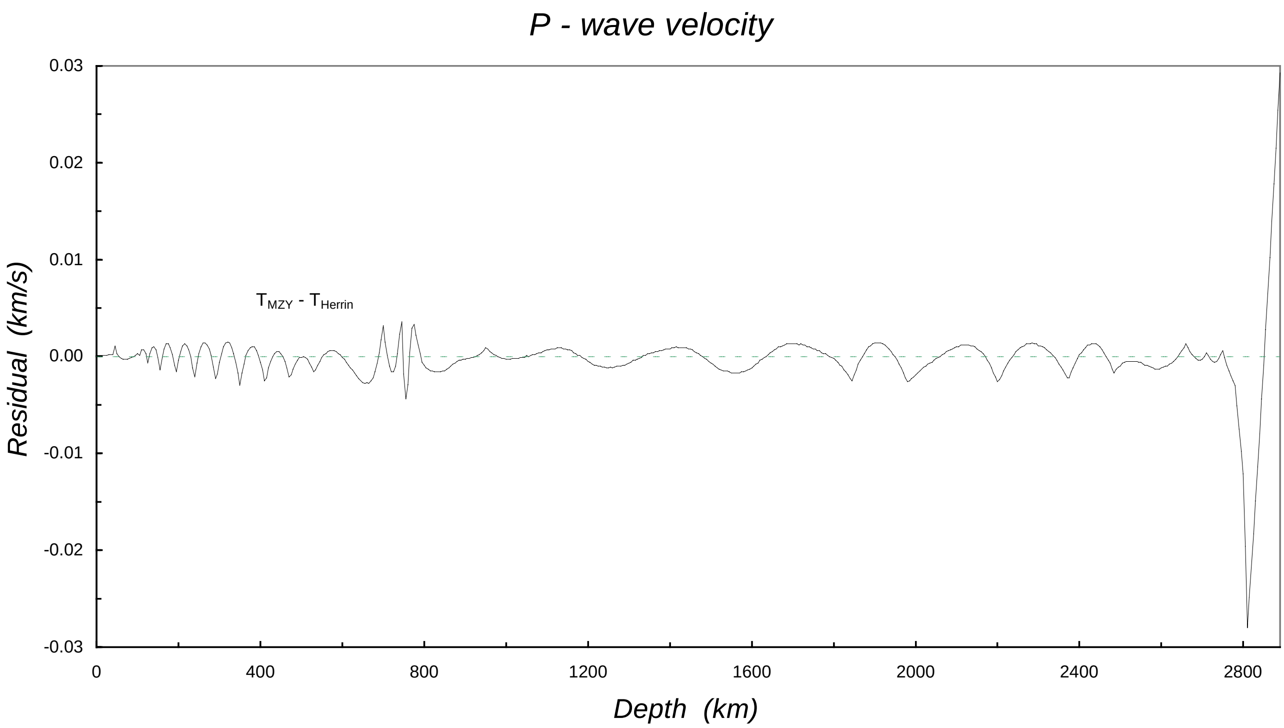
MZY versus SP6:





MZY model: D'' shell





Conclusions:

- Herrin (1968) says: "With this distribution, our computed times are lower than the observed times from 91.5°, with a maximum residual of 0.3 s at 100°"
- Morelli & Dziewonski (SP6 model) obtain better residuals (maximum of 0.05 s at 98°) introducing a linear decreasing of the velocity in the D'' shell.
- The MZY model proposes a brief decreasing in the velocity profile, followed by a gradual increasing. With this profile, the maximum residual is 0,002 s at 99°.

Future work:

- Tomography of the Core, thus completing the Earth's distribution of velocities.
- Tomography with *real* travel times, thus validating this technique and obtaining objective results.
- Joint tomography (velocity + density), thus providing a full description of the Earth's interior.
- Synthetics: the MZY model is a very powerful tool in global traveltime tomography, reducing the computing time required by forward simulations.