Synthetic travel-time tomography: resolution tests for models with regular and irregular parameterisation

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We perform tomographic inversion of synthetic data in order to study the ability of seismic tomography to reveal structures created by mantle dynamic processes (Bunge and Davies, 2001). The synthetic input velocity model is based on the density heterogeneities obtained from 3D model of thermal convection, P and pP arrival-times are used in the inversion. We assess the sensitivity of the inverse problem to parameterisation, explicit regularisation (damping) and data error.

We use both irregular cell parameterisation (based on Spakman and Bijwaard, 2001) and regular cell parameterisation (equi-surface area). Due to uneven distribution of sources and receivers, we found substantial differences between inversion output for models with regular and irregular cells. For the irregular parameterisation, the cold-downwellings are resolved quite well. However the resolving power decreases with increasing depth. In the areas, where upwellings occur, the distribution of rays is very sparse and the parameterisation cells are big there. Therefore the upwellings can not be resolved due to high parameterisation error. The explicit regularisation is not necessary, if data errors are not included. For the regular parameterisation on the other hand, the inverse problem is very unstable and oscillation occur, hence the explicit regularisation is necessary.

Further, we compare the power spectra of input seismic velocity anomalies and inversion output for both regular and irregular parameterisations. In case of irregular parameterisation, the spectra of input model and inversion output are rather similar except for the layer above the core-mantle boundary, where the spectrum of input is steeper than spectrum of output. This effect is probably caused by lack of resolution near core-mantle boundary. This problem can be solved by including other seismic phases. Output of inversion with regular parameterisation produces much flatter spectra (high degree oscillations) and damping is needed to produce reasonable power on higher degrees. The anomalous layer above the core-mantle boundary is even more clear than in the case of irregular parameterisation.

We also investigate decrease (slope) of log-log power spectra for degree 20-40. The decrease of input model spectra is stronger than decrease of output model for both regular and irregular parameterisation. For regular parameterisation without damping (or with small value of damping coefficient), the spectrum can even increase, especially in the top layer of mantle with very uneven distribution of rays is the largest. Including the data error causes further flattening of spectra.

References:

Bunge H.P. and J.H. Davies. Tomographic Images of a Mantle Circulation Model. Geophysical Research Letters, 28, 78–80, 2001.
Spakman W. and H. Bijwaard. Optimization of Cell Parameterization for Tomographic Inverse Problems. Pure and Applied Geophysics, 158, 1401–1423, 2001.