Geophysical Research Abstracts
Vol. 21, EGU2019-16341, 2019
EGU General Assembly 2019

Unbiased Tomographic Filtering and Robust Model Estimates – Including uncertainties in linking geodynamic models to seismic observations

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Over the past two decades, a number of strategies to link geodynamic models and global seismic tomography have been developed, as both are individually not able to reveal the structure, composition and dynamic evolution of Earth's mantle unequivocally. In this project, we develop a novel approach aimed at quantitatively testing geodynamic scenarios against whole-mantle tomographic images. Technically speaking, we analyse geodynamic models through fully unbiased SOLA (Backus-Gilbert) tomographic lenses, while taking into account the amount of data noise (i.e., uncertainty) that propagates into the tomographic solution.

As a point of reference, we study the effects of the tomographic filter from the SOLA inversion of Zaroli (2016) on a recently published mantle circulation model (MCM). To this end, we convert the temperature field of the MCM to seismic heterogeneity using a thermodynamic model of mantle mineralogy and then perform the tomographic filtering with the resolution operator R_{SOLA}. The resulting filtered model can either be compared to results using alternative resolution operators to understand the effects of different inversion strategies, or to the SOLA tomographic model for geodynamic interpretation. Since we are interested in additionally taking into account the effect of propagated seismic data noise, we introduce a new method for computing filtered model solutions that we call *Robust Model Estimates* (RME). To this end, we apply the generalized inverse $G^\dagger$ of the SOLA tomographic inversion to a synthetic data set of ray-theoretical S-wave traveltime variations calculated in the geodynamic model. By adding a particular amount of synthetic noise, we are able to systematically investigate the effects of uncertainties in seismic data on the inverted model in a quantitative manner and how the noise gets projected into the model space. We illustrate with some examples that the often assumed "Gaussian" noise affects different regions of the mantle in different ways owing to the data coverage and resolving power of the SOLA tomographic inversion. Furthermore, we explore the effects of biased (i.e., non-Gaussian) noise, such as that expected from uncertainties on crustal structure. The biased noise results in changes of the mean model, which, in contrast, is unaffected by the random noise contribution. RMEs represent an important improvement to plain tomographic filtering and are thus a promising tool for future studies that use seismic observations as constraint on geodynamic models.