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Interpreting seismic tomographic images in terms of marble cake geodynamically plausible models

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Geodynamical models and tomographic images often propose views of the mantle at separate scales. On the one hand, geodynamical models are able to simulate the chemical and rheological evolution of the mantle and to track sharp chemical boundaries. On the other hand, tomographic images produced from long-period observations (surface waves) are not able to resolve these sharp gradients, and only depict a continuous smooth anisotropic earth. In this way, tomographic images do not represent a realistic Earth, but rather an effective, apparent, or equivalent model that provides a similar long-wavelength data fit. This poses a major challenge to interpret tomographic images in terms of plausible geological and geodynamical structures.

We study the case of marble-cake like mantle models where chemical heterogeneities are stirred in the convective mantle. These models contain heterogeneities at all scales and are self-similar or scale-invariant. The long-wavelength equivalents to these models are computed using upscaling relations that link properties of an elastic medium to properties of the apparent medium that would be observed by tomography. We thus show that a non-negligible part of the observed anisotropy in tomographic models may be the result of unmapped fine chemical layering in the mantle.

Finding the fine scale, discontinuous marble-like Earth models that are compatible with a smooth and anisotropic tomographic image can be formulated as an inverse problem, which we designate as ‘downscaling’. For this, we propose to use a multipoint statistical framework, which allows to model spatial fields displaying a wide range of complex structures.