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Box Tomography: An efficient tomographic method for imaging localized structures in the deep Earth

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The accurate imaging of localized geological structures inside the deep Earth is key to understand our planet and its history. Since the introduction of the Preliminary Reference Earth Model, many generations of global tomographic models have been developed and give us access to the 3D structure of the Earth's interior. The latest generation of global tomographic models has emerged with the development of accurate numerical wavefield computations in a 3D earth combined with access to enhanced HPC capabilities. These models have sharpened up mantle images and unveiled relatively small scale structures that were blurred out in previous generation models. Fingerlike structures have been found at the base of the oceanic asthenosphere, and vertically oriented broad low velocity plume conduits [1] extend throughout the lower mantle beneath those major hotspots that are located within the perimeter of the deep mantle large low shear velocity provinces (LLSVPs). While providing new insights into our understanding of mantle dynamics, the detailed morphology of these features requires further efforts to obtain higher resolution images.

In recent years, we developed a theoretical framework [2][3] for the tomographic imaging of localised geological structures buried inside the Earth, where no seismic sources nor receivers are necessarily present. We call this ”box tomography” [4]. The essential difference between box-tomography and standard tomographic methods is that the numerical modeling (i.e. the raytracing in travel time tomography and the wave propagation in waveform tomography or full waveform inversion) is completely confined within the small box-region imaged. Thus, box tomography is a lot more efficient than global tomography (i.e. where we invert for the velocity in the larger volume that encompasses all the sources and receivers), for imaging localised objects. We present 2D and 3D examples showing that box tomography can be employed for imaging structures present within the D” region at the base of the mantle. Further, we show that box-tomography performs well even in the difficult situation where the velocity distribution in the mantle above the target structure is not known a-priori.

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