Seismic tomography of plume-like upwellings in the French Polynesian region using Backus-Gilbert inversion.

Context and state of the art:

Seismic imaging of small-scale structure within the Earth's mantle provides fundamental constraints within which to frame and answer major questions on present-day mantle dynamics. We know that mantle cooling operates through thermal convection: cold and dense oceanic lithosphere becomes gravitationally unstable and sinks, while mantle plumes carry mass and heat from the core-mantle boundary to the surface.

Almost fifty years after their appearance as a concept in the literature, the nature and characteristics of mantle plumes remain hotly debated in the Earth sciences. Today's seismic images of plumes are smeared by a combination of poor regional data coverage and biases that traditional (least-squares based) tomographic methods may produce when applied with poor data coverage. When used for solving large-scale (linear) tomographic problems, traditional least-squares inversion methods prevent us from interpreting tomographic images quantitatively (i.e. obtaining complete resolution information), because of prohibitive computational costs.

PhD project:

To produce better seismic images of these structures, we need to leverage state-of-the art developments in tomographic inversions and apply them to a high volume of seismic data that are sensitive to the region being imaged.

The PhD student will produce un-biased, high-resolution, whole-mantle S-wave velocity tomographic images of plume-like upwellings in the French Polynesian region. He/she will collate a new dataset of finite-frequency S-wave and surface-wave measurements on data recorded by all permanent seismic stations and previous temporary deployments in the region (both publicly available and non-public data). The student will then apply the new SOLA Backus-Gilbert tomography technique, recently developed by C. Zaroli, that drives the inversion from the model resolution standpoint instead of from the more usual data misfit standpoint.

The Backus-Gilbert tomographic scheme, whose computational cost is lower than for traditional methods, incorporates both finite-frequency data sensitivity kernels and data-adaptive model parameterizations and is guaranteed to produce bias-free seismic images, accompanied by model resolution and uncertainty information. The latter are required to interpret the images quantitatively, for example to determine whether a plume-like feature is or is not resolved given the geographical distribution of data and their associated errors. This PhD project will be one of the first to benefit from this major paradigm shift in seismic tomography.

Expected results:

We expect this PhD project and those of our partners will influence the broader scientific community's understanding of the structure and dynamics of mantle plumes. By producing high-resolution, whole-mantle S-wave velocity tomographic images of upwellings in the French Polynesian region, and by assessing their robustness, uniqueness, resolution and uncertainty, we will start to have the information required to interpret them correctly in a geodynamic context.

Supervision:

The student will be supervised by Alessia Maggi (alessia.maggi@unistra.fr), Christophe Zaroli (christophe.zaroli@unistra.fr), and Sophie Lambotte (sophie.lambotte@unistra.fr).