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Global thermochemical imaging of the lithosphere using satellite and terrestrial observations

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Conventional methods of seismic tomography, topography, gravity and electromagnetic data analysis and geodynamic modelling constrain distributions of seismic velocity, density, electrical conductivity, and viscosity at depth, all depending on temperature and composition of the rocks within the Earth. However, modelling and interpretation of multiple data sets provide a multifaceted image of the true thermochemical structure of the Earth that needs to be appropriately and consistently integrated. A simple combination of gravity, electromagnetic, geodynamics, petrological and seismic models alone is insufficient due to the non-uniqueness and different sensitivities of these models, and the internal consistency relationships that must connect all the intermediate parameters describing the Earth involved.
Thermodynamic and petrological links between seismic velocities, density, electrical conductivity, viscosity, melt, water, temperature, pressure and composition within the Earth can now be modelled accurately using new methods of computational petrology and data from laboratory experiments. The growth of very large terrestrial and satellite (e.g., Swarm and GOCE ESA missions) geophysical data sets over the last few years, together with the advancement of petrological and geophysical modelling techniques, now present an opportunity for global, thermochemical and deformation 3D imaging of the lithosphere and underlying upper mantle with unprecedented resolution.

This project combines state-of-the-art seismic waveform tomography (using both surface and body waves), newly available global gravity satellite data (geoid and gravity anomalies and new gradiometric measurements from ESA's GOCE mission) and surface heat flow and elevation within a self-consistent thermodynamic framework. The aim is to develop a method for detailed and robust global thermochemical image of the lithosphere and underlying upper mantle. In a preliminary study, we convert a state-of-the-art global waveform tomography velocity model into a mantle density model based on thermodynamic considerations and compute its 3D synthetic gravity response to compare with satellite data. As part of work in progress we present a lithospheric model based on integrated geophysical-petrological inversion of surface wave dispersion curves (Rayleigh and Love), topography, lithospheric geoid and surface heat flow. Broadband Rayleigh and Love fundamental mode phase velocity dispersion curves come from global phase velocity maps, computed in a broad period range using a large global dataset of phase velocity measurements, obtained using waveform inversion. The inversion is a non-linear gradient search combining steepest descent and local quadratic algorithms (Lavenberg-Marquardt) including dumping to a reference model and regularization for smoothness. The parameter space includes crustal structure (three layers with constant density, seismic velocities, heat production and thickness), mantle structure (Lithosphere-Asthenosphere boundary depth and temperature, composition and temperature distribution within the sublithosphere) and seismic radial anisotropy.