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Geodynamic modelling the thermochemical structure of the Earth's mantle using integrated geophysical and petrological inversion of surface wave and satellite gravity data

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The lateral and vertical thermochemical heterogeneity in the mantle is a long-standing question in geodynamics. The forces that control mantle flow and therefore Plate Tectonics arise from the density and viscosity lateral and vertical variations. Satellite gravity data are a unique source of information on the density structure of the Earth due to its global and relatively uniform coverage, which complements gravimetric terrestrial measurements. Gravity data (geoid, gravity, gravity gradients) sense subsurface mass anomalies have proven to be helpful in determining the Earth's thermochemical field in virtue of density's relatively stronger dependence on rock composition compared to seismic velocities. However, the inversion of gravity data alone for the density distribution within the Earth is an ill-posed problem with a highly non-unique solution that requires regularization and smoothing, implying additional and independent constraints. A common approach to estimate the density field for geodynamical purposes is to simply convert seismic tomography anomalies sometimes assuming constraints from mineral physics. Such converted density field does not match in general with the observed gravity field, typically predicting anomalies the amplitudes of which are too large. Furthermore, a complete description of the Earth's gravity field must include the internal density distribution and must satisfy the requirement of mechanical equilibrium as well. Therefore, the deformation of the density contrast interfaces (surface of the Earth and Core Mantle Boundary-CMB, primarily) must be consistent with the 3D mass distribution for a given rheological structure of the Earth. With the current resolution of modern tomography models and integrated geophysical-petrological modelling it is possible to consistently predict the topography of the mineral phase transitions across the transition zone (i.e., olivine à wadsleyite, and ringwoodite+majorite à perovskite+ ferropericlase) based on a temperature and chemical description of the Earth. However, for a consistent representation of the gravity field such thermochemical (i.e., density) 3D models must be compatible with the mantle flow arising from the equilibrium equations that explains both the surface topography (dynamic + isostatic-lithospheric components) and the CMB topography. Here

we present a new inversion scheme to image the global thermochemical structure of the whole mantle constrained by state-of-the-art seismic waveform inversion, satellite gravity (geoid and gravity anomalies and gradiometric measurements from ESA's GOCE mission) and surface heat flow data, plus surface and CMB dynamic topography (Stokes flow). The model is based upon an integrated geophysical-petrological approach where mantle seismic velocities and density are computed within a thermodynamically self-consistent framework, allowing for a direct parameterization in terms of the temperature and composition variables.