Geophysical Research Abstracts, Vol. 7, 02045, 2005
SRef-ID: 1607-7962/gra/EGU05-A-02045

Lower mantle thermo-chemical structure: seismological evidence and comparison with thermo-chemical convection

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We combine recent progress in seismic tomography and numerical modelling of thermo-chemical convection to infer robust features on mantle structure and dynamics. First, we use appropriate lateral variations of temperature and composition to separate the thermal and compositional contributions to the observed density anomalies. Thermo-chemical maps were previously computed following a new approach that combines independent constraints on density and seismic velocities from probabilistic tomography, a careful equation of state modelling of the lower mantle, and a Monte-Carlo search to account for uncertainties in the mantle reference state and thermo-elastic properties. The density signal is dominated by its chemical contribution, particularly in the lower mantle ($\leq$2000 km) where we report iron excess up to 2% beneath Africa and the Pacific. Unlike what is usually inferred, these regions appear to be non-buoyant. We then test models of thermo-chemical convection against the thermal and chemical contributions to the observed density. We compute synthetic anomalies of thermal and compositional density from models of thermo-chemical convection obtained with the anelastic approximation. These synthetic distributions are filtered to make meaningful comparisons against the observed density anomalies. Comparisons between the power spectrum of the synthetic and observed density anomalies suggest that a stable and ubiquitous layer of dense material is unlikely to be present at the bottom of the mantle. Models of piles entrained upwards explain the observation significantly better, but discrepancies remain at the top of the lower mantle. These discrepancies could be linked to the deflection of slabs around 1000 km, or to the phase transformation at 670 km, not included yet in the thermo-chemical calculations.