3D Spherical models of coupled mantle thermo-chemical evolution, plate tectonics, magmatism and core evolution incorporating self-consistently calculated mineralogy

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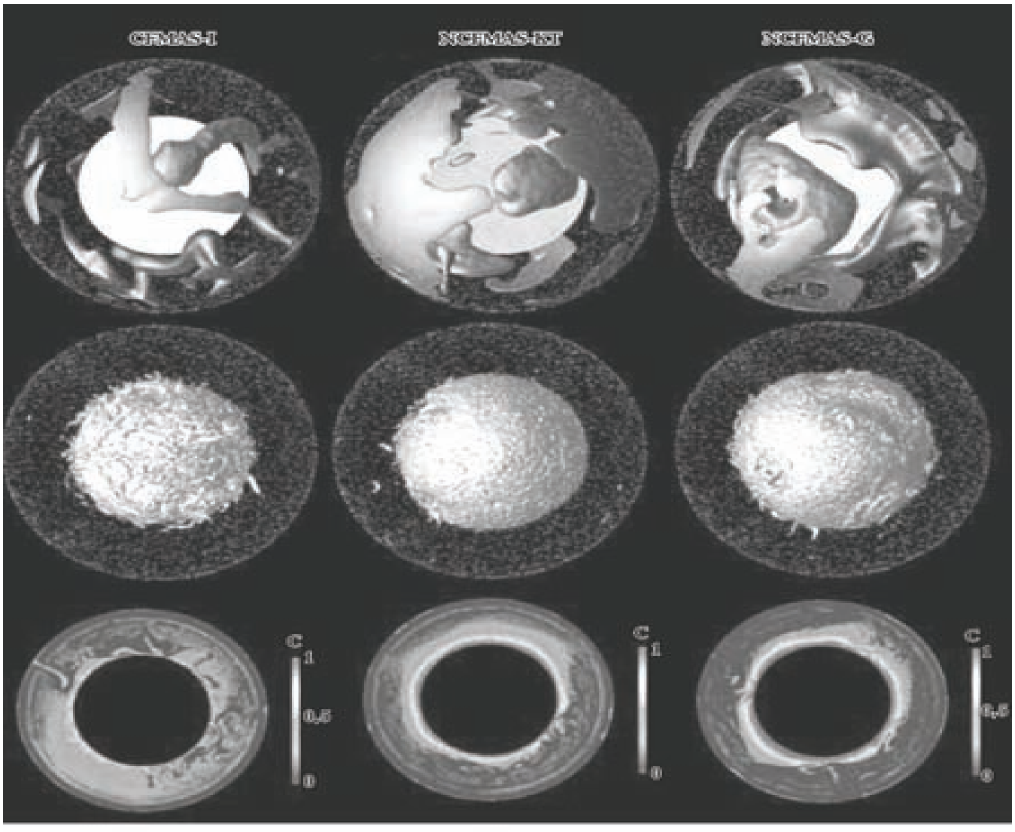
High pressure and temperature experiments and calculations of the properties of mantle minerals show that many different mineral phases exist as a function of pressure, temperature and composition (e. g., [Irifune, Ringwood, 1987]), and that these have a first-order influence on properties such as density, which has a large effect on the dynamics, and elastic moduli, which influence seismic velocity. Numerical models of thermo-chemical mantle convection have typically used a simple approximation to treat these complex variations in material properties, such as the extended Boussinesq approximation. Some numerical models have attempted to implement multiple, composition-dependent phases into thermo-chemical mantle convection (e. g., [Tackley, Xie, 2004]) and to calculate seismic anomalies from mantle convection simulations based on polynominal fitting for temperature, composition and mineral phase [Nakagawa, Tackley, 2006]. However, their linearised treatments are still approximations and may not adequately represent properties including effect of composition on phase transitions. In order to get closer to a realistic mineralogy, we calculate composition-dependent mineral assemblages and their physical properties using the code PERPLEX, which minimizes free energy for a given combination of oxides as a function of temperature and pressure [Connolly, 2005], and use this in a numerical model of thermo-chemical mantle convection in a three-dimensional spherical



Simulation results using three different compositions for basalt and harzburgite, showing (red isosurfaces) hot upwellings (blue isosurfaces) cold downwellings, (green isosurfaces) subducted crust, (bottom row) slices of compositoin. For full details see [Nakagawa et al., 2010].

shell, to calculate three-dimensionally-varying physical properties. In this presentation we compare the results obtained with this new, self-consistently-calculated treatment, with results using the old, approximate treatment, focusing particularly on thermo-chemical-phase structures and seismic anomalies in the CMB region and the transition zone [Nakagawa et al., 2009; 2010]. The numerical models treat the evolution of a planet over billions of years, including self-consistent plate tectonics arising from plastic yielding, melting-induced differentiation, and a parameterised model of core evolution based on heat extracted by mantle convection. Results indicate while the behaviour is broadly similar between the self-consistent treatment and the parameterised treatment, details of the behaviour depend quite sensitively on exact compositions, particularly in the contents of Al and Na [Nakagawa et al., 2010]. This approach is also being used to study Mars, Venus, Mercury and super-Earths (Figure).

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