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Using an integrated petrological-geodynamical approach to model the thermo-chemical evolution of terrestrial planetary mantle, crust and core in 3-D spherical geometry

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The latest generation of the global 3-D spherical convection model yinyang-Stag3D allows the direct computation of a planet's thermo-chemical evolution, including self-consistent lithospheric behavior (e.g., rigid lid, plate tectonics, or episodic plate tectonics), chemical differentiation induced by melting, large viscosity variations, a parameterized core heat balance, and a realistic treatment of phase diagrams and material properties. The latter has recently been added using free energy minimization to compute stable phases as a function of temperature, pressure, and composition as expressed by ratios of the five main oxides, and thus avoids the need for increasingly complicated and ad hoc parameterizations of phase transitions. Global models allow the computation of planetary secular cooling, including prediction of how the core heat flux varies with time hence the evolution of the geodynamo, and possible transitions in plate tectonic mode. Modern supercomputers and clusters allow increasingly higher resolution, with up to 1.2 billion unknowns possible on only 32 dual-processor nodes of an opteron cluster. In ongoing research, this tool is being applied to understand the evolution of Earth, Mars, Venus, Mercury and Io.

For Earth, results from such integrated modelling are compared to a wide range of seis-

mological observations ranging from statistical comparisons with global tomographic inversions (standard and probabilistic), and comparisons with regional models, for example of D'' structure and heterogeneity. For Mars and Venus, the focus is on the evolution of crustal structure for comparison with observations, for example Mars' crustal dichotomy and the lengthscales and character of crustal features on Venus. For Mercury, our focus is on whether a long-term heterogeneneous surface temperature can influence processes in the mantle and core, and for Io the focus is on the relative roles of melt migration and solid circulation in determining the influence of internal tidal dissipation on surface features.