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Searching for models of thermo-chemical convection that fit probabilistic tomography

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Recent seismological observations indicate that strong lateral density anomalies, likely due to compositional anomalies, are present in the deep mantle. We aim to identify models of thermo-chemical convection that can generate strong thermo-chemical density anomalies. For this, we explore the model space of thermo-chemical convection, determine the thermal and chemical density distributions predicted by these models, and compare their power spectra against those from probabilistic tomography. We conducted 3D-Cartesian numerical experiments using STAG3D, in which we varied compositional (buoyancy ratio, fraction of dense material), physical (Clapeyron slope of the phase change at 660 km, internal heating), and viscosity (thermal, radial, and compositional viscosity contrasts) parameters, and identified five important ingredients for a successful (in the sense that it fits seismological observations well) model of thermo-chemical convection. (1) A reasonable buoyancy ratio, between 0.15 and 0.25 (corresponding to chemical density contrasts in the range 60-100 kg/m^3). Larger density contrasts induce stable layering for long period of time, rather than the strong topography required by seismic observations. (2) A moderate (typically in the range 0.1-10), chemical viscosity contrast. Small chemical viscosity contrasts induce rapid mixing, whereas large chemical viscosity contrasts lead to stable layering. (3) A large ($\geq 10^4$), thermal viscosity contrast. Temperarure-dependent viscosity creates and maintains pools of dense material with large topography at the bottom of the mantle. (4) A 660-km viscosity contrast around 30. (5) And a Clapeyron slope of the phase transition at 660-km around 1.5-3.0 MPa/K. These two last ingredients help to maintain dense material in the lower mantle. Interestingly, they strongly inhibit thermal plumes, but still allow the penetration of downwellings in the lower mantle. Finally,

we test models that include various combinations of the previous ingredients.