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Heat flow scaling laws for thermal convection in spherical geometry

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Recently, with the help of massive computational resources, significant progresses were achieved in the numerical modeling of planetary mantles convection. Models with a high degree of complexity (including realistic viscosity laws, mixed mode of heating, spherical geometry, thermo-chemical convection, . . .) are now available. Among the parameters that recently became accessible, spherical geometry is a key ingredient because it affects the relative strength of the top and bottom thermal boundary layers. Despite these progresses, many details of planetary mantles convection remain unclear. For instance, no model of Earth's mantle convection fits all available geophysical, geochemical, and geological constraints. Less data are available for other bodies of the Solar System (e.g., Mars, Venus, and the icy moons of giant planets), but still no consensus could be reached concerning their internal dynamics. An alternative approach, which we employ in the present study, is to carry out parameter studies in order to build scaling relationships between relevant parameters and variables. Such an approach allows identification of important ingredients. Furthermore, the derived scaling laws can easily be used to model the thermal evolution of planetary mantles. Here, we conducted numerical experiments of thermal convection in spherical geometry for an incompressible fluid with infinite Prandtl number, using a spherical (Yin-Yang grid) version of STAG3D. We performed several series of experiments, in which we varied the Rayleigh number, the core radius, and the amplitude of viscosity variations with temperature. We then derived scaling laws for heat flux and mean temperature.