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Three-dimensional thermal convection in a spherical shell with a free surface

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Simple symmetric modes of convection of the Earth's mantle can be used to validate numerical codes and predict global dynamics patterns. We use an incompressible and isoviscous Rayleigh-Bénard thermal convection benchmark at infinite Prandtl number in a spherical shell to compare the state-of-the-art finite element code ASPECT with the previously benchmarked numerical code CitcomS. Thermal convection in the spherical shell is initiated by various perturbations of the conductive geotherm given by the sum of 2 spherical harmonics of different amplitude. We explore the sensitivity of the initial and steady-state root mean square velocity, average temperature and Nusselt number measured at both inner and outer boundaries to resolution for a range of Rayleigh numbers. Although the original benchmark is formulated with free slip boundary conditions, we explore for the first time the effect of a free surface on such calculations and compare the measured topography to dynamic topography measurements.
We find that using a free surface top boundary, the convection pattern is altered and more sensitive to model resolution. For free-slip and free surface, we will report the geoid values as measured using the current ASPECT pluggin which is based on spherical harmonic expansion.