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High Rayleigh Number 3-D Spherical Mantle Convection with Radial Basis Functions

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In the last quarter of a century many numerical methods, such as finite-differences, finite-volume, their yin-yang variants, finite-elements and pseudo-spectral methods have been used to study the problem of 3-D spherical convection. All have their respective strengths but also serious weaknesses, such as low-order and can involve high algorithmic complexity, as in triangular elements. Spectrally accurate methods do not practically allow for local mesh refinement and often involve cumbersome algebra. We have recently
introduced a new grid/mesh-free approach, using radial basis functions (RBFs). It has the advantage of being spectrally accurate for arbitrary node layouts in multi-dimensions with extreme algorithmic simplicity, and allows naturally node-refinement. One virtue of the RBF scheme is the ability to use a simple Cartesian geometry while implementing the required boundary conditions for the temperature, velocity and stresses on a spherical surface of both the outer(planetary surface) and inner shell (core-mantle boundary). The velocity and stress components are expressed in terms of the scalar potential approach and the other remaining variable is the perturbed temperature field. We have studied the problem from the weakly onlinear
to a moderately nonlinear regime involving a Rayleigh number, about 1000 times super-critical. Both purely basal and partially internal–heating cases have been considered.