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Choosing an adequate FEM grid for global mantle convection modelling

Cedric Thieulot
Utrecht University, Dept. of Earth Sciences, Utrecht, Netherlands (c.thieulot@uu.nl)

Global numerical models of mantle convection are typically run on a grid which represents a hollow sphere. In the context of using the Finite Element method, there are many ways to discretise a hollow sphere by means of cuboids in a regular fashion (adaptive mesh refinement is here not considered). I will here focus on the following two: the cubed sphere [1], which is a quasi-uniform mapping of a cube to a sphere (considering both equidistant and equiangular projections), and the 12-block grid used for instance in CITCOM [2]. By means of simple experiments, I will show that at comparable resolutions (and all other things being equal), the 12-block grid is surprisingly vastly superior to the cubed-sphere grid, when used in combination with trilinear velocity - constant pressure elements, while being more difficult to build/implement.

[1] C. Ronchi, R. Iacono, and P. S. Paolucci, The "Cubed Sphere": A New Method for the Solution of Partial Differential Equations in Spherical Geometry, Journal of Computational Physics, 124, p93–114 (1996).

[2] S. Zhong and M.T. Zuber and L.N. Moresi and M. Gurnis, Role of temperature-dependent viscosity and surface plates in spherical shell models of mantle convection, Journal of Geophysical Research, 105 (B5), p 11,063-11,082 (2000).