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A high-order mimetic finite element method for the shallow-water equations on the cubed sphere

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A mimetic finite element method for the shallow-water equations on the cubed sphere is presented. The weak form of the equations of motion is derived from their Hamiltonian formulation, ensuring exact conservation of energy. Compatible spaces are used for vorticity, velocity and mass, ensuring mimetic properties such as div.curl=0 and curl.div=0, as well as conservation of potential vorticity following Cotter & Shipton (2012).

Specific finite element spaces are constructed on the cubed sphere as the image of local polynomial interpolation/reconstruction operators. This construction ensures good dispersion properties by insisting that there is exactly one degree of freedom for mass and two for velocity per quadrangular element. Furthermore the scheme is easy to couple to finite volume advection schemes for transported species.

Numerical experiments confirm the mimetic properties and formal order of accuracy of individual building blocks of the method. Third-order convergence is achieved when simulating a solid-body rotation in geostrophic balance. Other standard test cases show a convergence rate between 2 and 3.