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A high-order spatial filter for a cubed-sphere spectral element model

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A high-order spatial filter is developed for the spectral-element-method dynamical core on the cubed-sphere grid which employs the Gauss-Lobatto Lagrange interpolating polynomials (GLLIP) as orthogonal basis functions. The filter equation is the high-order Helmholtz equation which corresponds to the implicit time-differencing of a diffusion equation employing the high-order Laplacian. The Laplacian operator is discretized within a cell which is a building block of the cubed sphere grid and consists of the Gauss-Lobatto grid. When discretizing a high-order Laplacian, due to the requirement of C0 continuity along the cell boundaries the grid-points in neighboring cells should be used for the target cell: The number of neighboring cells is nearly quadratically proportional to the filter order. Discrete Helmholtz equation yields a huge-sized and highly sparse matrix equation whose size is N*N with N the number of total grid points on the globe. The number of nonzero entries is also almost in quadratic proportion to the filter order. Filtering is accomplished by solving the huge-matrix equation. While requiring a significant computing time, the solution of global matrix provides the filtered field free of discontinuity along the cell boundaries. To achieve the computational efficiency and the accuracy at the same time, the solution of the matrix equation was obtained by only accounting for the finite number of adjacent cells. This is called as a local-domain filter. It was shown that to remove the numerical noise near the grid-scale, inclusion of 5*5 cells for the local-domain filter was found sufficient, giving the same accuracy as that obtained by global domain solution while reducing the computing time to a considerably lower level. The high-order filter was evaluated using the standard test cases including the baroclinic instability of the zonal flow. Results indicated that the filter performs better on the removal of grid-scale numerical noises than the explicit high-order viscosity. It was also presented that the filter can be easily implemented on the distributed-memory parallel computers with a desirable scalability.