

A nestable, multigrid-friendly grid on a sphere for global spectral models based on Clenshaw-Curtis quadrature

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A new grid system on a sphere is proposed that allows for straightforward implementation of both spherical-harmonics-based spectral methods and gridpoint-based multigrid methods. The latitudinal gridpoints in the new grid are equidistant and spectral transforms in the latitudinal direction are performed using Clenshaw-Curtis quadrature. The spectral transforms with this new grid and quadrature are shown to be exact within the machine precision provided that the grid truncation is such that there are at least $2N + 1$ latitudinal gridpoints for the total truncation wavenumber of N . The new grid and quadrature is implemented and tested on a shallow-water equations model and the hydrostatic dry dynamical core of the global NWP model JMA-GSM. The integration results obtained with the new quadrature (Figure b) are shown to be almost identical (Figure c) to those obtained with the conventional Gaussian quadrature on Gaussian grid (Figure a). Only little coding is required to adapt any Gaussian-based spectral models to employ the proposed quadrature.

The nestable nature of the proposed grid will allow for a straightforward implementation of a pseudo-spectral multigrid method without any complicated off-grid interpolation in solving the non-constant Helmholtz equation that results from semi-implicit time stepping. The proposed grid can be further adapted to take a structured form, such as the icositetrahedral (24-face polyhedral) grid (Figure d), by adjusting the number of longitudinal gridpoints and the longitude of the first gridpoint of each latitude circle. We postulate that employing the pseudo-spectral multigrid method will foster smooth and gradual transition from spectral modelling to grid-based (or grid/spectral hybrid) modelling since the grid-space representation of the horizontal derivatives evaluated by the pseudo-spectral method can be readily replaced by local horizontal derivatives evaluated by some grid-based scheme such as finite difference, finite volume, or finite/spectral element method. Given that grid-based elliptic solvers tend to be less efficient at larger scale, a grid/spectral hybrid approach, where a grid-based multigrid method with shallow layers is combined with a spectral elliptic solver used only at the coarsest grid with moderate resolution, seems a reasonable strategy that compromises the need to avoid global inter-node communications and to maintain acceptable accuracy and fast convergence rate.

Keywords: Numerical Weather Prediction, global spectral model, multigrid method

Galewsky et al. (2004) barotropic jet test
relative vorticity at 144hr integration

