Atmospheric modelling on the equal-area cubed-sphere

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Abstract

The Conformal-Cubic Atmospheric Model (CCAM) was the first atmospheric global model to be formulated on a cubed-sphere grid. CCAM employs semi-Lagrangian, semi-implicit dynamics (McGregor, 2005a), which handles the finer resolution near the vertices without a time step penalty. It also uses reversible staggering in the horizontal (McGregor, 2005b) to achieve good dispersion properties and good kinetic energy spectra.

The CCAM code has recently been generalized to provide a version on the Uniform Jacobian (UJ) arrangement of the cubed-sphere grid. This grid was modified from the conformal-cubic grid to provide equal area for every grid cell (Purser and Rancis, 2011); a similar grid was derived by Tsugawa et al. (2008),. Since the grid lines are no longer orthogonal, covariant and contravariant velocity components are required. Despite the complications of the non-orthogonality, most of the CCAM semi-Lagrangian approach may be used, including reversible staggering of the contravariant velocity components to switch between values at cell centres and cell edges. The solver for the Helmholtz equation is a little more complicated than for CCAM, but is well handled by the multigrid approach.

Both of these versions of CCAM include the Miller and White (1984) non-hydrostatic formulation, which provides extremely economical solutions in the context of semi-Lagrangian time differencing.

A second dynamical core has also been developed on the UJ grid. This version employs the primitive equations in conservative form, providing extra appeal for climate studies and for modelling trace gases and chemistry. Split-explicit time stepping is used, with small time steps for the fast gravity waves processes and longer time steps for the slow

advective processes and for the physical parameterizations. Flux-corrected-transport is employed to better preserve any sharp gradients in the advected fields. It also employs the reversible staggering technique for the contravariant wind components

Both new dynamical cores produce very acceptable climatologies. Results from the various dynamical cores will be shown, and their relative advantages and disadvantages discussed.

References:

McGregor, J. L.: C-CAM: Geometric aspects and dynamical formulation. CSIRO Atmospheric Research Tech. Paper No. 70, 43 pp. https://publications.csiro.au/rpr/pub?list=BRO&pid=procite:eb33ff33-c6d6-4779-8b82-867b2ca6e112, 2005a.

McGregor, J. L.: Geostrophic adjustment for reversibly staggered grids. *Mon. Wea. Rev.*, **133**, 1119-1128, 2005b.

Miller, M. J. and A. A. White: On the non-hydrostatic equations in pressure and sigma coordinates. *Q. J. R. Meteor. Soc.,*, **110**, 515-533, 1984.

Purser, R. J. and M. Rancic: A standardized procedure for the derivation of smooth and partially overset grids on the sphere, associated with polyhedra that admit regular griddings of their surfaces. Part I: Mathematical principles of classification and construction. *NOAA/NCEP Office Note 407*, 58 pp., 2011.

Tsugawa, M., Y. Tanaka and T. Matsuno: An ocean general circulation model on a quasi-homogeneous cubic grid. *Ocean Modelling*, **22**, 66-86, 2008.