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Continuous Dynamic Grid Adaptation in a Global Atmospheric Model

We have developed a global atmospheric model with continuous dynamic grid adaptation (CDGA) capability. The nonhydrostatic model is based upon an anelastic approximation for deep moist convection [2]; and uses nonoscillatory, forward-in-time (NFT) numerical schemes [4]. Options for moist thermodynamics use the cloud microphysical parameterization of [1].

The capability for CDGA derives from a generalized coordinate system used to formulate the model [4]. The generalized coordinates represent a transformed space that is homeomorphic with a specified physical space (e.g., spherical or Cartesian). In particular, the transformation can be any sufficiently continuous mapping that preserves the topology of the physical system. The horizontal and vertical coordinates are treated separately, with the latter transformed as a time and altitude variable generalization of terrain following coordinates. This allows the model to adapt to surface topography; and to have nonuniform vertical increments (in particular, it could be used to approximate sigma or isentropic coordinates). The transformed horizontal coordinates keep vertical columns vertical - following the basic hydrostatic character of the atmosphere.

A significant benefit of our model formulation is an elliptic pressure equation for the pressure perturbation field based upon a solenoidal form of continuity. Generally, the incompressible like character is lost in the continuity equation — even with the anelastic approximation — if the domain geometry is a function of time [3]. Another benefit is provided by the NFT numerics, which provide a device to advect a moving grid smoothly even if it has very sharp gradients (i.e, rapidly changing metric coefficients).

CDGA results for an idealized Held-Suarez climate on the sphere show that meridional grid stretching that moves points away from the poles substantially reduces the condition number of the elliptic operator, leading to faster execution times. This is in direct contrast to the common understanding in the computational community that use of CDGA methods always increase CPU time over that of a uniform grid of the same computational complexity. Global grids with reduced polar resolution are of high interest for numerous studies in the tropics and mid-latitudes. Results are also presented showing an innovative new procedure for advecting grid points. In this case, the model is applied to a regional Cartesian domain to simulate the propagation of a gravity wave packet generated by a traveling deformation in the tropopause. The advected grid simulates a "nested grid" which is characterized by discontinuous metric terms as the grid suddenly changes resolution. This grid generation problem is equivalent to a propagating shock wave problem

and represents an extreme test of the robustness of the CDGA machinery. We solve it using the NFT algorithm that is integral to our model. This automatically guarantees a sharp propagation without significant dissipation of the discontinuities or generation of dispersive waves.

References

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