**Uniform-Jacobian Cubic Grid for Efficient Global Modeling**

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## 1. Implications of the massive-parallelism of modern super-computers

In order to satisfy the demand for ever faster rates of computation in numerical weather prediction and similarly computationally-intensive tasks, the last two decades have seen the emergence of massively-parallel architectures as the dominant computational paradigm for these activities. Many traditional approaches to weather modeling, proven to be efficient for the older monolithic computer architectures (such as spectral and semi-implicit methods, that required long-range or global communication among the discretized variables of the model every time-step) are now placed at a severe disadvantage in the new massively-parallel context compared to alternative numerical methods designed to avoid all immediate long-range interactions. Not only do these considerations tend more to favor grid-point models over spectral, and explicit dynamics over semi-implicit, but, among grid frameworks, favor those grid configurations possessing a high degree of spatial uniformity that minimize the amount of necessary additional filtering demanded by the requirements of stability and the maintenance of approximate spatial homogeneity.

## 2. Polyhedral grids

Grids based upon the various ways one can map the surface of a regular griddable polyhedron (e.g., a cube or icosahedron) to the surface of the sphere, have therefore become increasingly popular within the numerical weather modeling community; these grids automatically avoid the strong polar singularity, as well as the need for extensive zonal filtering, associated with the otherwise attractive latitude-longitude computational grid framework. While it is topologically impossible to avoid having localized coordinate singularities at the corners of a continuous polyhedral grid, Rančić et al. (1996), Purser and Rančić (1998) and Tomita et al. (2001) described various techniques by which at least the "edge" singularities of a polyhedral grid are eliminated while elsewhere the smoothness of the grid, except only at the corner singularities, can be guaranteed. Generally, in designing a smooth polyhedral grid, a compromise is made between the degree of local grid distortion, including non-orthogonality, on the one hand, and smooth homogeneity of resolution, on the other, and this compromise can be made explicit in a variational formulation of the problem, as was done in Purser and Rančić (1998). If we opt for the extreme limiting choice of perfect uniformity of (areal) resolution in this context, the result is a polyhedral grid (see figure) with the least distortion possible subject to the overriding constraint of a uniform mapping jacobian; it is this choice of grid that we refer to as the "Uniform-Jacobian cubic" (UJ-cubic) grid when the polyhedron in question is the cube.

## 3. Putting the NMMB model on the UJ-cube

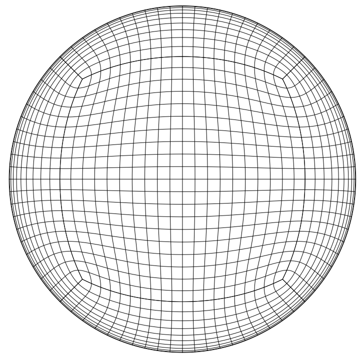

Figure 1. A coarse gridding of the Uniform-Jacobian cube.

We have developed a procedure, described in Purser and Rančić (2011), by which a satisfactory approximation to the UJ-cubic ideal grid can be numerically generated and have adapted a version of the NMMB three-dimensional explicit Eulerian nonhydrostatic forecasting model described in Janjić and Gall (2012) to take advantage of this grid framework. The dynamical core run on the new cubic grid exhibits a significant computational performance advantage compared with the version run on the latitude-longitude grid framework at a similar resolution. This advantage owes to two factors: firstly, the distribution of the horizontal grid points is more uniform over the surface of the sphere; and secondly, there is now no need to run a zonal Fourier filter at high latitudes needed by the latitude-longitude grid model to remove unwanted scales in order to prevent the violation of the CFL stability criterion. While some special numerical procedures are still evidently needed to prevent minor spurious numerical effects from occurring at the eight corners, these potential effects are narrowly confined to the immediate vicinity of each corner and their remedies (localized filtering and modifications to the numerical differencing stencils) are not of a kind that significantly impact the model performance.

## References


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