Weather Prediction and computational aspects of High Resolution Icosahedral-Hexagonal Gridpoint Model GME

H. S. Chaudhari*, K. M. Lee , and J. H. Oh

Department of Environmental and Atmospheric Sciences
Pukyoung National University
599-1 Daeyeon3-dong, Nam-gu, Busan 608-737, Republic of Korea
E-mail: hemant@climate.pknu.ac.kr

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ABSTRACT

A new approach to weather prediction uses geodesic grids generated from an icosahedron. For the modeling of high-resolution atmospheric general circulation, an icosahedral grid has several advantages: the homogenous and isotropic distribution of grid-points, the treatment of grid-point data as two-dimensional structured data in program code, the easy parallelization on massively parallel computer with distributed memory and so on. A major advantage of the icosahedral뻡exagonal grid is the avoidance of the so-called pole problem that exists in conventional latitude뾧ongitude grids. The grid-point approach also avoids the large amount of global communication required by spectral transform techniques as well as the large number of arithmetic operations normally associated with Legendre transforms at high spatial resolution. Icosahedral grid-point model is more competitive at higher resolution than at lower resolution [1]. Tomita and Satoh [2] has demonstrated that the grid-point method using a quasi-uniform grid system (e.g. Nonhydrostatic Icosahedral Atmospheric Model) has computational advantages over the spectral model at higher resolution (scale of which corresponds to 40km).

In this study, a new version of global numerical weather prediction model GME (40km/ 40L) of Deutscher Wetterdienst (DWD) has been adopted. GME employs a gridpoint approach with an almost uniform icosahedral뻡exagonal grid. Prognostic equations for wind components, temperature, surface pressure are solved by the semi-implicit Eulerian method. Only the two prognostic moisture equations (specific water vapor content and specific cloud liquid water content) use semi-Lagrangian advection in the horizontal direction to ensure monotonicity and positive definiteness [3]. GME constructs geodesic grid by starting with an ordinary icosahedron inscribed inside a unit sphere. The icosahedron has 12 vertices. As a first step in the construction of a spherical geodesic grid, each face of the icosahedron is subdivided into four new faces by bisecting the edges. This recursive bisecting process may be repeated until a grid of the desired resolution is obtained [3]. Such grids are quasi-homogeneous in the sense that the area of the largest cell is only a few percent greater than the area of the smallest cell. For example ni=192 has 40km resolution with 40 layers and it has 368,642 total number of grid points per layer. By combining the areas of pairs of the original adjacent icosahedral triangles, the global grid can logically also be viewed as comprising 10 rhombuses or diamonds, each of which has ni x ni unique grid points, where ni is the number of equal intervals into which each side of the original icosahedral triangles is divided. To facilitate the use of the model on parallel computer a diamond-wise domain decomposition is performed. For the 2-D domain decomposition the $(ni+1)^2$ grid points of each diamond are distributed to n1 x n2 processors [3]. Thus each processor computes the forecast for a sub-domain of each of the 10 diamonds. This is a simple yet effective strategy to achieve a good load balancing between processors.

Model has attributes of numerical weather prediction model and its high resolution can provide details on regional scale. Severe weather phenomena provide testing ground for models. South Korea experienced most of the damage, which was mainly caused by Typhoons. To evaluate this aspect, Typhoon simulation case has been studied. The initial state for the model run is based on ECMWF analysis and DWD analysis. Model computational performance has been evaluated on KISTI (Korea Institute of Science and Technology Information) HAMEL cluster with Intel Xeon 2.8 GHz, 2 CPUs/node, 3GB memory/node and 32 bit REALs. Performance of GME for the 24-h forecast has been evaluated on 512 processors of 256 nodes. Model run has been performed using full physics with time step of 133s. For computational efficiency, some of the parameterization schemes (convection, turbulent fluxes, sub-grid scale orographic effects) are called only every fifth time step of the model. Full radiation step has been performed every 2 hours. Between 126 to 208 processors, an almost linear speedup is obtained. Model obtains its optimum performance between 324 to 360 processors. For the use of 360 to 512 processors, increase in number of processors does not yield efficient parallelization. The communication on system becomes too slow to support simultaneous processing of more than 360 processors. As number of processors increases, number of sub-domains also increases. And it need large amount of data to be exchanged. For more than 360 processors, post-processing real time also increases. As a result model run time increases.

In prediction viewpoint, hindcast experiment of GME was performed by specifying observed SSTs every day based on ECMWF Re-analysis (ERA) dataset. In brief GME incorporates many of the positive features of spectral models and finite difference models into a single framework. GME generally employs the same methods and procedures applied in other NWP grid schemes. However, the uniformity of the GME grid avoids unnecessary physics calculations in over resolved high-latitude zones that commonly occur in grids with polar singularities. Implementation of model on high performance computer based on Linux clusters can provide added advantage. High resolution of GME can play key role in the study of server weather phenomenon such as heavy rainfall, snowfall and typhoon cases. We strongly believe that geodesic grids based on icosahedron hold a great deal of promise for the future of the atmospheric general circulation modeling.

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