Development of a Global Grid Model for Hyper-Parallel Computing in JMA

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1. Introduction

Computational efficiency in hyper-parallel computing environments is important for the future operation of a higher-resolution NWP model. Japan Meteorological Agency (JMA) started development of a global grid model in 2009. Since the global spectral model JMA currently uses requires global communication among computational nodes, feasibility of global grid models has been examined. The shallow-water test using the Yin-Yang grid configuration proposed by Kageyama and Sato (2004) are presented here.

2. Discretization method and grid configuration

The finite volume method (FVM) is used because of its advantages not only in computational efficiency for parallel computing but also in the conservation of mass. The flux calculation method adopted in this study is very similar to the one developed for ASUCA (Ishida et al. 2010) in which the up-wind method with a flux limiter proposed by Koren (1993) is used. With this scheme, global communication among nodes is unnecessary except for treatment of the output. The third-order Runge-Kutta scheme of ASUCA is also used as the time integration method.

As for the global grid configuration, the Yin-Yang grid shown in Figure 1 (a) is used. To prevent instability around the grid system border, the over-set length is set to be more than three grid points according the results of Baba et al. (2010). This configuration does not force the use of numerical diffusion or viscosity to stabilize time integration even with grid sizes of less than 1 degree. For parallel computation among distributed memories, the two-dimensional domain decomposition method is used. Figure 1 (b) shows the distributions of domains in the latitude-longitude projection covered by each calculation node when 8, 16, and 32 calculation nodes are used. The size of the area including the overset region for each grid is the same, and communication partners are easy to find using the coordinate transformation by Kageyama and Sato (2004).

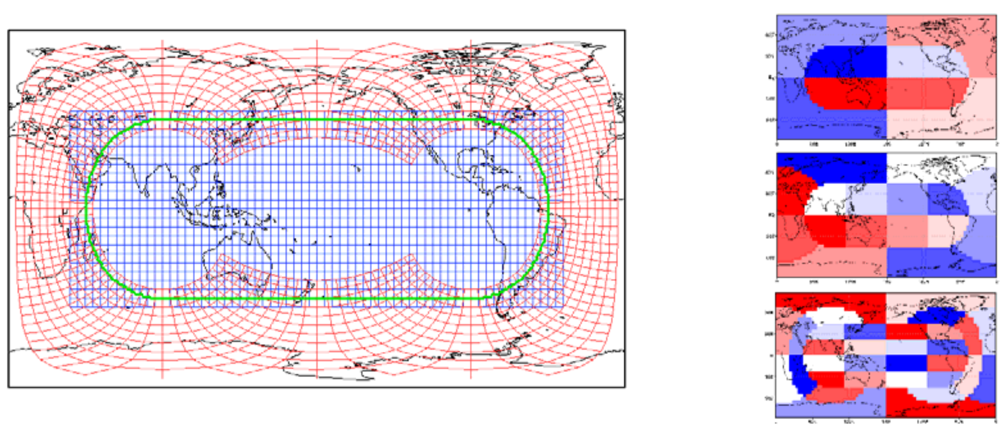

Figure 1. Configuration of the Yin-Yang grid in the lat.-long. map projection (a: left panel) and the domains covered by individual calculation nodes in two-dimensional domain decomposition (b: right panel). In panel (a), the bold green line indicates the yin-yang grid system borderline; the blue cells belong to the Yin grid, and the red ones are for the Yang grid. In (b), the domains are shown for cases in which 8 (top), 16 (middle), and 32 (bottom) calculation nodes are used.

3. Shallow water test

The zonal geostrophic flow test proposed by Williamson et al. (1992) was examined under various resolutions and with the different numbers of nodes used in the calculations. Figure 2 shows the results of five-day forecasts when α (the inclination angle of speed) is equal to zero. As shown in the figures, the level of error remains quite small. Figure 3 shows time series of the standard norms proposed by Williamson et al. (1992). The results indicate a reasonable level of accuracy in relation to those of other shallow water studies.

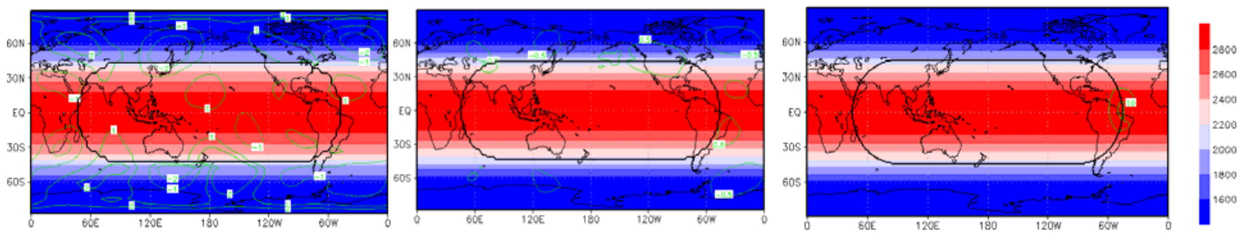

Figure 2. Results of five-day forecast for the zonal geostrophic flow test with spatial resolutions of 4.5 degrees (left: a), 2.25 degrees (center: b) and 1.125 degrees (right: c). The shading indicates the free surface height (m), and the green contours represent the level of error (m) from the theoretical truth. The time-step lengths are (a) 10 min., (b) 3 min. and (c) 1 min.

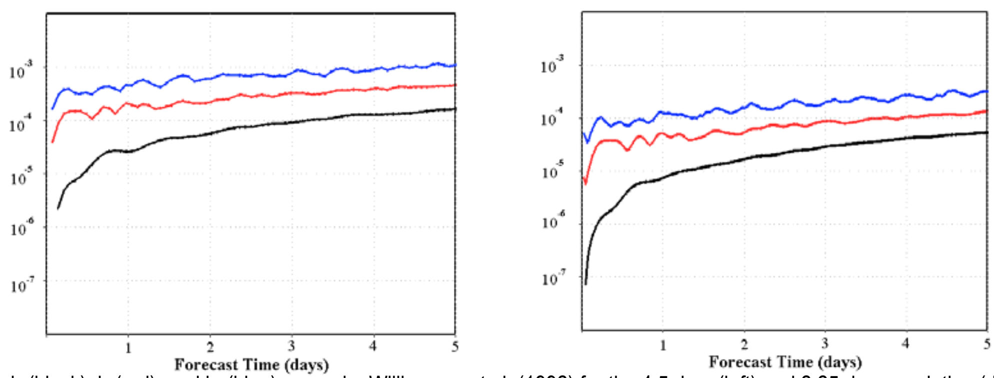

Figure 3. The l_1 (black), l_2 (red), and l_∞ (blue) norms by Williamson et al. (1992) for the 4.5 deg. (left) and 2.25 deg. resolution (right)

4. Summary

Zonal geostrophic flow test was performed using the FVM and the Yin-Yang grid. The discretization method and the grid configuration demonstrated effectiveness in the development of a global grid model for hyper-parallel computing. So far, shallow water test results have been successful even without the use of numerical diffusion or viscosity.

References

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