§63. Benchmark Test Using New Reduced Grid

Sugimura, T. (Grad. Sci., Nagoya Univ.)
Horiuchi, R.
Watanabe, K. (Earth Simulator Center)

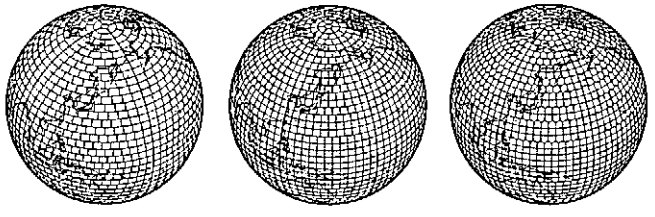
We have been developed a non-hydrostatic atmospheric global circulation simulation code by using our advanced reduced grid system (Fig.1(c)). Original Reduced grida (Kurihara 1965) was well known as a grid system (Fig.1(a)), called Kurihara grid, which longitudal grids points decreases gradually toward the poles. In order to reduce computational errors in derivatives of the approximate solution, grid aspect ratio is required to be 1.0 for any objective region. In the Kurihara grid system, there are only 4 grid points in the polar region, therefore, grid aspect ratio is $\frac{2\pi}{4} \simeq 1.5$ there.

In this study, we introduce a new grid system which is divided into 6 regions, and longitudal grids points change each longitude. Thus, in this advanced Reduced grid, grid aspect ratio near the pole region becomes $\frac{2\pi}{6} \simeq 1.045$.

Because this grid system is un-structured grid, we have to have the list array and search the reference points (Fig.2(a)). However, list representation make calculation efficiency reduce. Then, we have used a 2-dimensional array in order to use no list. But the 2-dimensional array have waste area, which is white squares in Fig.2(b) and is 36.3% of whole area. To reduce the area, we use Fig.2(c) array image. This changes reduce the waste area 3.0 % of whole area.

To meet the necessity of a good benchmark to test new grid system for solving the 2-dimensional shallow-water equations, Williamson *et al* (1992) developed a test set, containing the seven different test cases of increasing complexity. Fig.4 shows results of test case 1, which is called *Advection of Cosine Bell over the Pole.* This case tests the advective component in isolation. α is parameter of advection direction. We tests $\alpha = 0$ (along-equator flow), and $\alpha = 90$ (cross-pole flow) advection using finite volume method(FVM).

$$u_\lambda = -u_0 \sin\lambda \sin\phi, \quad u_\phi = -u_0 \cos\lambda$$

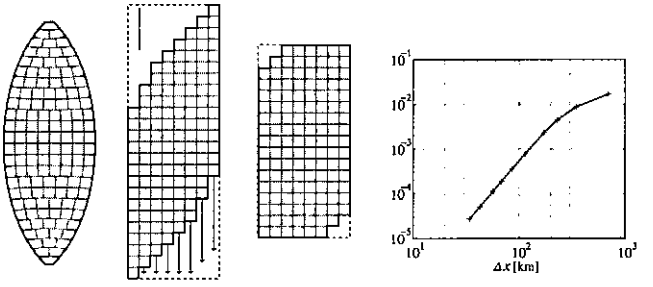


(a).Kurihara grid (b).lat-lon Reduced grid (c).advanced Reduced grid

Fig. 1. Reduced grid.

Fig.4 shows results of this case's l_2 norm using a grid system of Fig.1(b) (the lat-lon Reduced grid) and (c) (the advanced Reduced grid). Cell interface of lat-lon Reduced grid differs from its of the advanced Reduced grid system. Initial Reduced grid coincide with latitudal and longitudal line, on the other side, the advanced Reduced grid doesn't coincide(Fig.1).

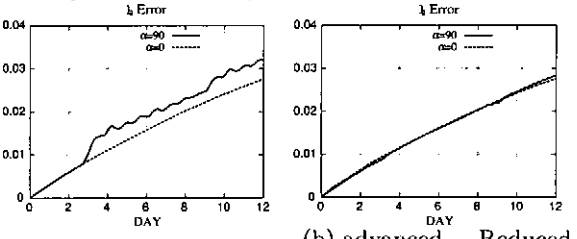
In this test case, since the field is analytical nondivergent, the initial divergence pattern computed on the grid system will be a mesure of the accuracy of the difference approximations and the grid. The cross-polar flow is a particularly suitable experimnts to validate the truncation error at high latitudes, because its strongest flow goes directly across the Pole. The height field after 1 step integration is presented in Fig.5. The divergence of the advanced Reduced grid is 3 order smaller than that of the lat-lon Reduced grid. Finally, Fig.3 shows that this FVM scheme can keep second-order accuracy.



(a).real space array (b).2-dimensional array (c).array image

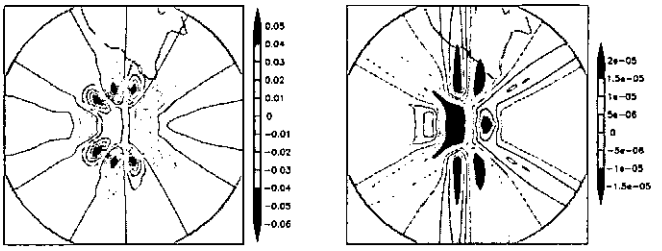
Fig. 2. array image.

Fig. 3. scheme accuracy.



(a).lat-lon Reduced grid (b).advanced Reduced grid

Fig. 4. l_2 norm.



(a).lat-lon Reduced grid (b). advanced Reduced grid

Fig. 5. $\nabla \cdot v$ flow pattern.

References
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2) D.L.Williamson et al., J.Comp.Phys., 102(1992)211
3) C.H.Dey., Mon.Weth.Rev., 97(1969)597