Introduction of the Reduced Gaussian Grid into the Operational Global NWP Model at JMA

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1. Introduction

JMA (Japan Meteorological Agency) plans to upgrade the spatial resolution of the operational global spectral NWP model from T_L319 to T_L959. In order to realize this, we are going to introduce the reduced Gaussian grid into the model. On the standard Gaussian grid, when the latitude is higher, the longitudinal interval between two grid points is smaller. However, especially in the polar region, all of grid points are not so necessary. Therefore, we wish to reduce the redundant grid points, in order to save the computational throughput. This article describes the determination of the necessary number of longitudinal grid points at each latitude and the sustained accuracy of the model with the reduced Gaussian grid system.

2. Reduction Strategy of the Number of Grid Points

In order to determine the necessary number of longitudinal grid points at each latitude, we adopt the reduced spectral transformation introduced in Juang (2004). Since our global atmospheric model is a spectral model, some calculations are processed in grid space and the others are processed in wavenumber space. The variables in the model experience a wave-to-grid transformation and a grid-to-wave transformation in each time step. In the standard spectral transformation which is used in the model with the standard Gaussian grid system, the Legendre transformations use all of wavenumber components corresponding to the higher left half of the upper three squares in Figure 1. However the values in the purple region are negligibly small compared with those in the red region. The lower three squares in Figure 1 concern the reduced spectral transformation which is used in the model we are now developing. In the reduced spectral transformation, the Legendre transformations only use the wavenumber components for which the associated Legendre function has significant value (grater than the machine epsilon). Obviously, we can define the maximum longitudinal wavenumber for each latitude. Resting on this maximum longitudinal wavenumber, we evaluate the necessary number of longitudinal grid points for each latitude. The total number of grid points can be curtailed by about 30% in the case of $T_{LR}959$ (Figure 2).

3. Performance in the Shallow Water Experiment

A simplified experiment is performed to examine the accuracy of the reduced spectral transformation. The shallow water equation in advective form is integrated for 14 days on the core of the T639 reduced quadratic Gaussian grid (T_R639) with an Eulerian advection scheme. The initial condition is a zonal flow with the corresponding surface height field (one of steady state solutions to the non-linear shallow water equation; same as in the second test case by Williamson et al., 1992). In Figure 3, we are not able to distinguish the initial state and the state after 14-day integration, concerning with the surface height and the zonal velocity. Regarding the meridional velocity, the difference is discernible. Since the true meridional velocity is always zero, the red plot shows the distribution of the error. However, because the scale of the ordinate is 10^{-11} times smaller than that of the zonal velocity, we are able to recognize that the steady state could be kept during 14-day integration and the reduced spectral transformation which we adopt has enough accuracy for practical daily weather forecasts.

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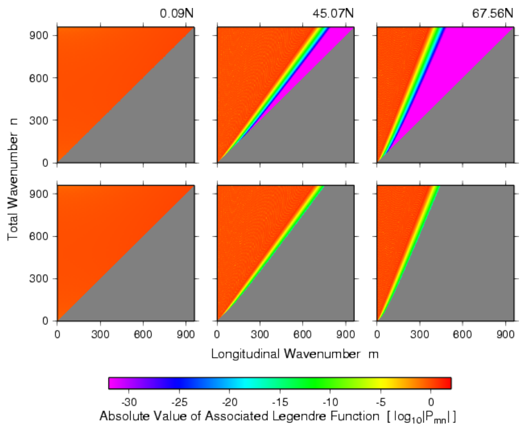

Figure 1: The absolute values of the associated Legendre function on three latitudes, near the Equator, in the middle latitudes, and in the high latitudes. The upper (lower) three squares concern the standard (reduced) spectral transformation. The abscissa (ordinate) is the longitudinal (total) wavenumber. There are not any values in the gray hatched lower right half of each square.

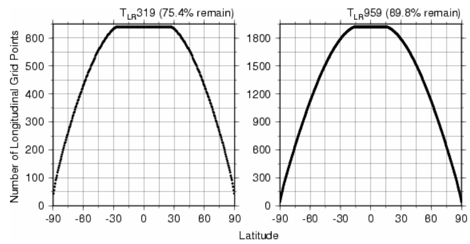

Figure 2: The necessary number of longitudinal grid points for each latitude. JMA plans to use $T_{LR}319$ (left panel) for the inner model of the 4D-Var data assimilation system and $T_{LR}959$ (right panel) for the forecast model.

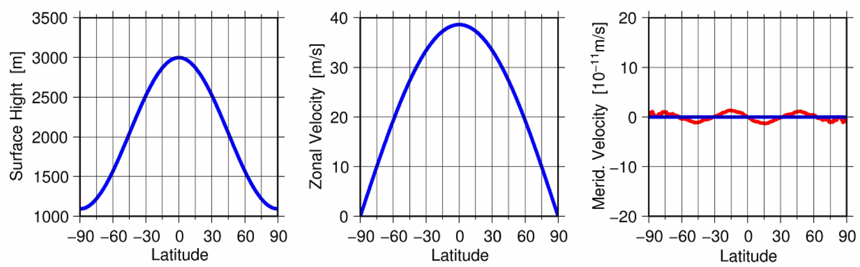

Figure 3: The Latitudinal distributions of the surface height (left), the zonal velocity (middle), and the meridional velocity (right) at Greenwich meridian in a simplified experiment performed with a shallow water model of T_R639. The blue plots show the initial values on each field. The red plots show the values after 14-day integration.