Introduction of Vertical Normal Mode Incremental Initialization for a High Resolution Global Model

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1 Introduction

The Japan Meteorological Agency (JMA), the Meteorological Research Institute (MRI) and the Advanced Earth Science and Technology Organization (AESTO) cooperate to develop a global climate model, which is called "JMA-MRI Unified Global Model"(Katayama, *et al.*, 2003). Because the model is utilized to investigate the effect of global warming on typhoons through time-slice numerical experiments, balanced initial condition is needed. The JMA also plans to use this model operationally in high resolution with a four-dimensional variational assimilation (4DVAR) system in the future. Even though analysis will be consistent with the model dynamics, it will still contain spurious high-frequency noise if the minimization of cost function in the 4DVAR is performed at lower resolution than the forecast model because model topography is different. Therefore, initialization will still be necessary for high resolution model.

Originally, the JMA-MRI Unified Global Model had a module of nonlinear normal mode initialization (conventional NNMI) (Daley, 1991). However, there was a problem that the computational costs of horizontal structure separation became much higher as a model resolution becomes higher. The time-slice numerical experiments are planned to be conducted with a 20km mesh resolution model. If the conventional NNMI method were used for initialization in such a high resolution, total memory for eigenvalues and eigenvectors becomes several giga bytes. Since it is impractical to carry out the conventional NNMI for high resolution model, a new initialization method is needed.

In order to carry out initialization in the high resolution model, we introduce a vertical normal mode initialization scheme(Bourke and McGregor, 1983) which doesn't require horizontal structure separation. To achieve such a simplified method, incremental nonlinear normal mode initialization(INCNMI) (Ballish, *et al.*, 1992) is also introduced.

2 Incremental normal mode initialization

The INCNMI uses most of the procedures of the conventional NNMI. In the conventional NNMI, the tendencies of the model fields are calculated from analysis. However, in the INCNMI, the tendencies of the model fields are first calculated from the analysis first guess (i.e., the 6-h forecast). And the tendencies of the analysis first guess are then stored in the computer. Next the model tendencies due to the analysis are also calculated. Then, the guess tendency is subtracted from the analysis tendency, which is called "increment". And the increment is passed to the same normal-mode initialization code. After modification, the increment is added to the guess. We introduce the INCNMI into the JMA-MRI Unified Global Model to achieve the following vertical mode initialization.

3 Vertical mode initialization

When primitive equations are linearized by deriving perturbation from basic state, the linearized equations after vertical separation become

$$\frac{\partial \zeta}{\partial t} = -fD - \beta V + N_\zeta,$$

$$\frac{\partial D}{\partial t} = -\nabla^2 \Phi + f\zeta - \beta U + N_D,$$

$$\frac{\partial \Phi}{\partial t} = -\xi^2 D + N_\Phi,$$

where ζ is the vorticity, D is the divergence, Φ is the geopotential, U and V are wind velocities, f is the Coriolis parameter, β is the latitudinal derivative of Coriolis parameter, ξ is the term of equivalent depth of shallow water equation, N mean the non-linear terms.(Bourke and McGregor, 1983)

In the conventional NNMI, these equations are applied to horizontal structure separation for normal mode initialization(Daley, 1991). Bourke(Bourke and McGregor, 1983) proposed an applied initialization scheme for limited area, in which the initialization is implemented in the vertical modes on the assumption that the β can be neglected by the f-plane approximation. As a result, those equations treat only gravitational waves. This suggests high-frequent gravitational waves can be modified without huge matrix calculations of horizontal structure separation.

We apply the above simplification into the JMA-MRI Unified Global Model on the assumption that the neglect of β is allowed because the analysis first guess maintains Coriolis part by introducing the INCNMI.

4 Result

The results to be discussed here is to investigate whether the new initialization can suppress spurious gravity wave oscillations in a low resolution model (T213L40). Data assimilation and forecast experiments were conducted to test the impact of the new initialization.

Figure 1 displays surface pressure variations for the first 24 hours at one grid point. It denotes that without initialization (thin solid curve), there are oscillations with amplitudes of two hPa with periods of only a few hours. Dashed curve denotes the conventional NNMI and bold solid curve denotes the vertical mode initialization with INCNMI (new initialization). With both cases, the spurious waves seem to be well removed. It indicates that spurious gravity waves are suppressed well with the new initialization.

Two data assimilation experiments using the conventional NNMI and the new initialization were conducted for the period of 1-31 July 2002 and 1-31 January 2003. Nine days forecasts were performed for 22 cases from 12UTC 1 July to 22 July 2001 and 15 cases from 8 January to 22 January 2003. The model resolution is T106L40 and assimilation method is 3DVAR. Figure 2 shows the mean forecast error of 500 hPa geopotential height over the global (90°S-90°N) averaged for the each cases with respect to the forecast time. This indicates the impact of new initialization for forecast skill is neutral in both July 2002 and January 2003.

The JMA plans to change the conventional NNMI to the new initialization at the same time of operational introduction of semi-Lagrangian integration schemes in October 2004.

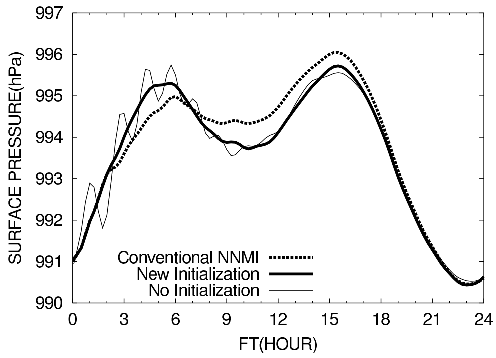

Fig.1 Surface pressures in hPa for a grid point of the foot of Tibet (90°E,25°N). Thin solid curve is uninitialized starting analysis. Dashed curve is the conventional NNMI. Bold solid curve is the new initialization.

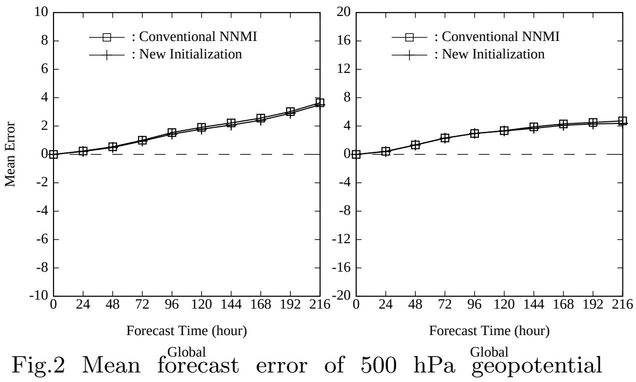

Fig.2 Mean forecast error of 500 hPa geopotential height(m) over the global (90°S-90°N). Left: Averaged 22 cases in July 2002. Right: Averaged 15 cases in January 2003. Square curve is the conventional NNMI. Cross curve is the new initialization.

References

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