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THE APPLICATION OF TIDAL SIGNAL EXCLUSION SCHEME FROM INITIALIZATION IN A GENERAL CIRCULATION MODEL

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ABSTRACT: In this paper, some corrections was made to the assumption that the forcing is quasi-static, which is the basis of the nonlinear diabatic initialization scheme adopted by a global model $T_{106}L_{19}$. Thus the tidal signal is expressed and excluded from the initialization scheme. It shows that the new scheme captures the semi-diurnal pressure variation and is much closer to the uninitialized field. Compared with the standard initialization scheme, both the anomaly correlation coefficients and RMS of 500 hPa geopotential height simulated under the new scheme have improved significantly.

Key words: initialization; tidal signals; semidiurnal pressure variation

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1 INTRODUCTION

Since the 1980's, nonlinear diabatic initialization schemes have been widely used in major numerical forecasting models in the world. Its inclusion reduces the weakening of tropical divergence circulation that occurs due to the use of adiabatic initialization scheme and improves to some extent both medium and short term model forecasts. The nonlinear diabatic initialization scheme[1, 2] used in the medium-range numerical model, $T_{106}L_{19}$[3], at the National Meteorological Center, has achieved good results in controlling high-frequency gravity-wave oscillations and improving the model forecasts. It should be noted, however, that such schemes are based on the discovery that large-scale external modes and inertia gravity interior modes (with the exception of tidal effects) are quasi-static. As what is found in operational forecast by the European Center for Medium Range Weather Forecasts (ECMWF), its analysis scheme has a large correction of the first-guess field but the initialization process eliminates most of the correction. Consequently, an analysis with initialization does not necessarily get closer to the first guess than the one without, which suggests some defects in the design of initialization schemes. Similar problems were also found by the Japan Meteorological Agency in its operational models. These are related to inaccurate representation of tidal trends in the initialization schemes, which degrades the analysis quality of surface pressure in data assimilation. In other words, there is a deviation between the analysis field and first-guess field as far as mean sea surface pressure is concerned.

To solve the problem, much work has been done abroad. Daley[4] (1987) proposes a normalized initialization technique that uses variance and enables correction of the analysis field, though it modifies the Rossby mode as well as the coefficient of the gravity mode. Temperton[5] (1984) gives a similar scheme for the ECMWF baroclinic model. Restricting the modification of initialization, the schemes do not significantly improve forecasts that come subsequently. In view of it, the current study probes the cause of systematic rejection by initialization schemes and

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modifies the assumption that exterior forcing is quasi-static. It is achieved by explicitly expressing tidal signals in the conditions of initialization and removes them from the initialization schemes.

The work is presented in four parts. The first part is the introduction, the second introduces the scheme that removes tidal signals form the initialization conditions, the third gives the comparison and verification results of model forecast and analysis, the fourth describes the stability test of the system and semi-diurnal variation of pressure and the final part summarizes and discusses the work.

2 THE SCHEME FOR REMOVING TIDAL SIGNALS FROM INITIALIZATION

2.1 *Scheme of standard initialization*

For a standard scheme of normal mode initialization, the atmosphere is required to be in stationary state and which is expressed by

$$Y_j^{l+1} - Y_j^{l} = i\frac{\frac{1}{\Delta t}[Y_j^{l}(\Delta t) - Y_j^{l}(0)]_a + \bar{q}_j}{2\Omega\gamma_j} \tag{1}$$

Specifically, q_j is a normalized projection of all non-linear tendencies with j vertical modes, Y_j is the coefficient of gravity mode, Ω is the rotational angular velocity of the earth, γ_j is the frequency of wave, l is the times of iteration and subscript a is the diabatic tendency. Independent of the iteration times l, q_j is includes tendencies in the computation of physical parameterization: vertical diffusion, radiation, deep and shallow convection, and large-scale condensation.

2.2 *Scheme of standard initialization*

Based on the fact that radiation processes in the model simulate diurnal variations of the sun and daily observations also contain tidal movement of the atmosphere, it is inferred that there are transient tidal components in model tendencies. In other words, the assumption in original initialization schemes of stationary atmospheric condition distorted tidal components in the atmosphere. The projection of gravity modes of the tidal signals should be conducted allowing their westward propagation, rather than stationary, with the solar movement. Principally expressed by zonal wavenumbers 1 and 2, the atmospheric tides are intrigued mainly by absorption of solar radiation heat in ozone and moisture. In the current work, the original initialization scheme is modified by expressing the temporal tendencies of tidal signals in the initialization conditions.

Assuming that $\dot{Y}_t$ is the tidal component of the temporal tendency. When it is subtracted from the original standard initialization conditions, the effects of tidal components on the model can then be adequately reduced. The initialization conditions from which tidal signals are removed can be written as:

$$Y_j^{l+1} - Y_j^{l} = \frac{\frac{i}{\Delta t}\left[Y_j^{l}(\Delta t) - Y_j^{l}(0)\right]_a + \bar{q}_j - \dot{Y}_t}{2\Omega\nu_j} \tag{2}$$

in which $\dot{Y}_t$ is assumed to be independent of the physical tendency $\bar{q}_j$ or iteration times l.

According to Chapman and Lindzen[6] (1970), most of the pressure waves with 1-day period and 1 zonal wavenumber are truncated while the semidiurnal waves, which are the main components of the atmospheric tides, propagate vertically. Other harmonic waves, such as semidiurnal waves with wavenumber 3, fluctuate with moderate amplitudes. It is then clear that semidiurnal waves dominate the surface pressure field. In the new scheme, $\dot{Y}_j$ is used to express the time series of gravity mode tendency on the date *J* when real analyses end and the tidal component at the *J* moment is estimated using a simple and steady time series of

$$\dot{Y}_{t_J} = \frac{1}{J}\sum_{j=1}^{J}\dot{Y}_j e^{\mathrm{i}\frac{\pi m}{2}j} \tag{3}$$

in which the time interval is 6 hours and *m* is the wavenumber. For the zonal wavenumber 1, westward-propagating waves at the period of 1 day are isolated; for the zonal wavenumber 2, however, corresponding periods are 12 hours. The two waves are main components of atmospheric tides. A 10-day time series is adopted in the model to obtain tidal components of the gravity tendency. As it is a spectral model, the initialization scheme is applied in spectral space and variables to be predicted can be expressed as functions of meridional and zonal wavenumbers. It is then natural to remove waves with wavenumbers 1 and 2 based on the frequency of modes in wavenumber cycles.

3 VERIFICATIONS OF MODEL FORECAST AND ANALYSIS

To verify the result of the new scheme, the $T_{106}L_{19}$ model is used to conduct an experiment comparing two initialization schemes with and without tidal signal correction. The experiment is conducted at a period of 84 days and has a valid time 7 days. Coefficients of anomalous correlation and root-mean-square errors are verified against model analysis fields in the tropics (20°N – 20°S), boreal low latitudes (0°N – 30°N), austral low latitudes (15°S – 30°S) and boreal mid- and high- latitudes (20°N – 90°N). Fig.1 gives the results of comparing coefficients of

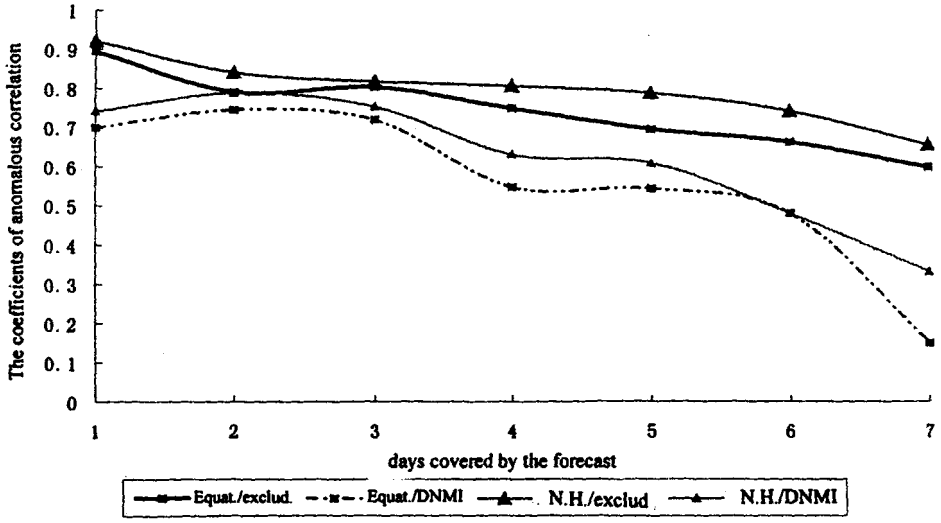

Fig.1 A verification that compares coefficients of anomalous correlation between 500-hPa geopotential fields and corresponding analysis fields in the equatorial and Northern Hemisphere regions.

anomalous correlation between 500-hPa geopotential fields and corresponding analysis fields in the equatorial and Northern Hemisphere regions.

It can be seen that the coefficients of anomalous correlation of the scheme without tidal signals have improved greatly over the original one, with the coefficient increasing by at least 4%. The results of root-mean-square errors are similarly consistent. Conclusions for other regions and levels are generally similar to those for the equatorial and Northern Hemisphere regions, which will not be discussed one by one.

4 STABILITY VERIFICATION OF THE INITIALIZATION SYSTEM AND SEMIDIURNAL VARIATIONS OF PRESSURE

4.1 *Stability verification of the system*

To verify the stability of the modified initialization system that has been incorporated with the 3-D Spectral Statistical Interpolation (SSI)[7], the SSI analysis field for 12 UTC on July 26, 2001 is used to conduct a 30-day forecast experiment. Fig.2 (a & b) gives the temporal evolution of global divergence and kinetic energy over the period. It shows that the variation is smooth and free from substantial increase, suggesting stable and reliable workings of the system.

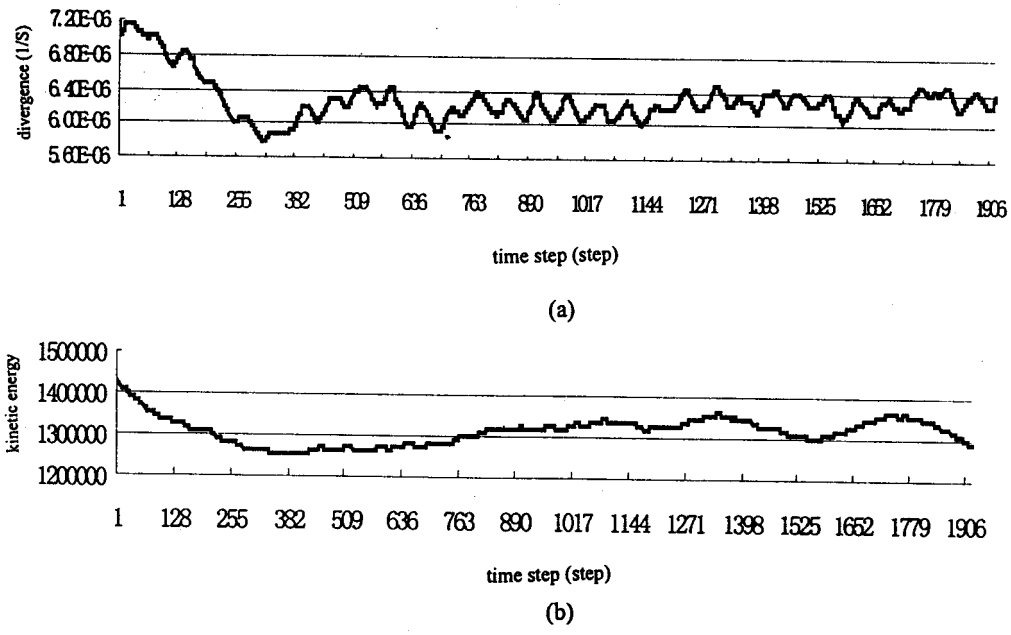

Fig.2 Temporal evolution of divergence (a) and kinetic energy (b) in 30-day model integration. The abscissa is the time step and 1 day is equivalent to 64 steps.

4.2 *Semidiurnal variations of pressure*

As a modified initialization scheme with tidal signal exclusion should reflect semidiurnal variations of pressure, a 12-day assimilation experiment is conducted. Initial fields available with SSI are used to conduct experiments, standard diabatic initialization schemes, schemes that exclude tidal signals. Fig.3 gives the evolution of 20-h surface pressure forecasts starting from

analyses that have not been initialized (the fine and solid line, i.e. no nmi), initialization (the dotted and dashed line, nmi) and treated with tidal signals removal (the circular and dotted line, tidal). The point selected in Fig.3a is at 10°N, 130°E in the Pacific Ocean and the one in Fig.3b is somewhere in the Rocky Mountains. It can then be seen that the new scheme is closer to the uninitialized analysis and better captures the semidiurnal pressure variations than normal mode initialization scheme. In terms of noise control, additionally, the new schemes have the same effect. It should be noted that analysis fields without initialization treatment are seemingly the results of various data at respective times but reflect the real state of the atmosphere in the forecast/assimilation system.

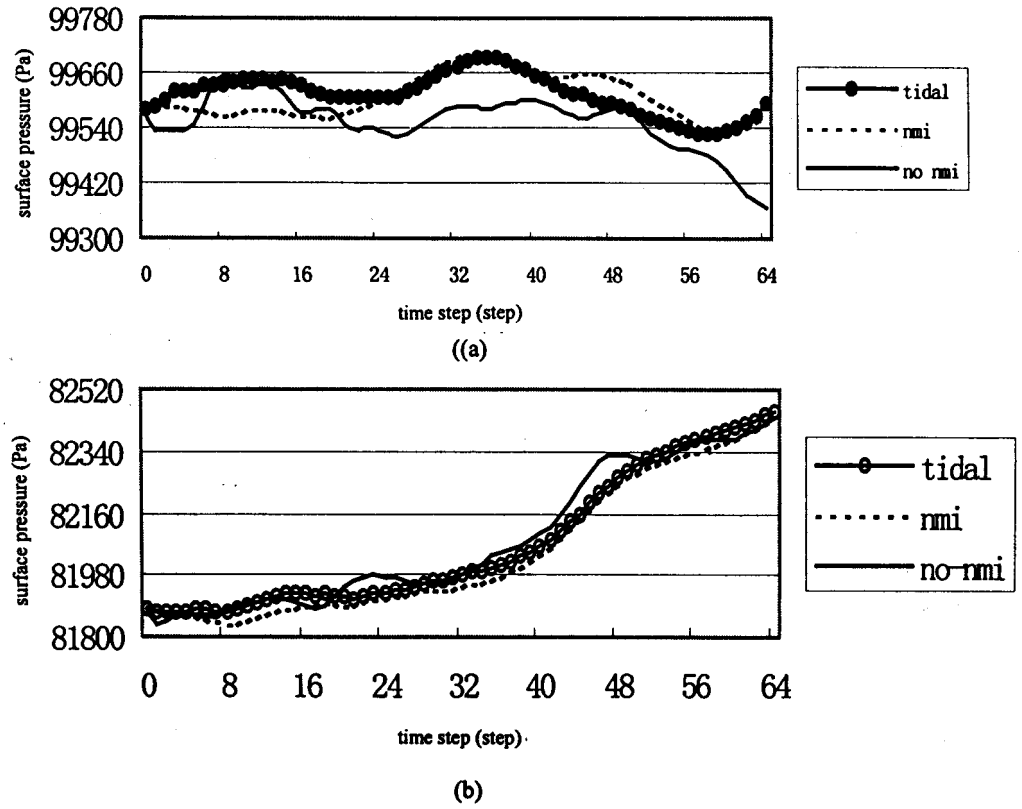

Fig.3 Temporal evolution of 24-h surface pressure forecasts at a point in the Pacific Ocean (a) and another in the Rocky Mountains. The abscissa is the time step and 1 day is equivalent to 64 steps, with one graduate mark for 3 h.

5 CONCLUSIONS AND DISCUSSIONS

As the radiation processes in the model simulate the diurnal solar variation and observations contain atmospheric tidal movement, the requirement in the old initialization scheme that the atmosphere is quasi-stationary has misrepresented the tidal components in the atmosphere. In view of the problem, the current work modifies the nonlinear diabatic initialization scheme of $T_{106}L_{19}$, a global model at the National Meteorological Center, by correcting the representation of tidal signals in the initialization condition.

From our verification that aims at comparing the forecast and analysis fields, it can be seen

that the new scheme with removal of tidal signals improves significantly over the old scheme both in the correlation coefficients of the anomalies and root-mean-square errors in the analysis. As shown in the evolution of surface pressure, the initialization scheme with the treatment of tides is closer to the analysis and better captures the semidiurnal variations than normal mode initialization. As far as removing the noise of the analysis field is concerned, the schemes with normal initialization and removal of tidal signals have the same effect.

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