STUDY ON EFFECTS OF REFERENCE ATMOSPHERE ON CPTEC SPECTRAL MODEL

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ABSTRACT

The reference atmosphere is applied in CPTEC spectral model in order to reduce spectral truncation errors and improve medium-range forecasts. The variables temperature and geopotential height are replaced by their deviations from the reference atmosphere. The pressure-gradient terms are rewritten to remove much of the cancellation between them, and so are the temperature advection terms. A series of experiments has been performed in order to assess the impacts of the reference atmosphere on forecasts. The results reveal that the reference atmosphere introduced in CPTEC model has generally beneficial impacts on forecast quality, especially on that in Southern Hemisphere.

1 - INTRODUCTION

The sigma coordinate, pressure normalized by its surface value, has become widely used in numerical weather forecast models as a way of conveniently incorporating variations in the height of Earth's surface. The upper and lower boundary conditions become more simple, but the use of this vertical coordinate is not without problems. One that has been discussed most by many meteorological scientists is that of the calculation of pressure gradients comprised by two terms. Over steeply sloping orography, the two terms tend to be large with opposite signs. This leads, however, to some problems in numerical computation. The second is about the computation of advection of temperature. It consists of two terms (both horizontal and vertical advections) too, which nearly cancel over the steeplysloping orography. Third, in the spectral representation of orography, Gibbs waves occur in the neighbourhood of narrow transition zones with steep slopes between mountains and oceans. Though these Gibbs waves tend to be small, they can trigger noticeable biases in the patterns of precipitation. And finally, it is usual in spectral models to use the natural logarithm of surface pressure, $\ln P_s$, rather than surface pressure, P_s, as one of the prognostic variables. This is computationally convenient in sigma-coordinate models, but it violates the mass-conservation, and can give rise to problems in long-term integrations of spectral models. However, use of P_s as a prognostic variable does introduce a much more substantial aliasing errors in the calculations of the pressure gradient.

2 - METODOLOGY

The roughness of Earth's surfaces and very slow convergence rate of expansions of orography in spherical harmonic analysis of the grid points are responsible for the above mentioned problems. In order to improve the convergence rate, a reference atmosphere, which is a function of pressure alone, is intruduced in spectal model.The concept of the reference atmosphere is first proposed by Zeng(1963) and Phillips(1974), and introduced in spectral model by Chen et al. (1987), Chen and Simmons (1989) and Chen and Jingjun (1994)

The main idea for introducing reference atmosphere in spectral modelis based upon the following concept. Consider an arbitrary function $f(x)$ and its expansion in Fourier series and the sum of its first n terms, $f_n(x)$, the truncation errors are readily found as follows

$$\| f(x)-f_n(x) \| \leq \frac{\ln (n+0.5)}{(n+0.5)} \max [\| f'_x(x) \|]$$

It is evident from the last inequality that the truncation errors depend on truncation wavenumber $\boldsymbol{n}$, and maximum derivative $f'_x(x)$ as well. As decreasing the maximum derivative $f'_x(x)$, the spectral truncation errors will be reduced.

In fact, we can introduce an auxiliary function $\overline{f(x)}$, which has nearly the same derivative as that of the function ***f(x)***. Comparing with derivative of f(x),the difference

$$f'(x) = f(x) - \overline{f(x)}$$

has a small derivative, and hence a small truncation errors. In this case, a reference atmosphere, which is a function of pressure ***p*** alone, is introduced as the auxiliary function.

3 - RESULTS

The reference atmosphere is introduced in CPTEC spectral model, and a variable, temperature, is replaced by the deviation of temperature from a reference atmosphere temperature which is a particular analytic function of pressure. The new prognostic variable exhibits less variation along the sigma coordinate surfaces of the model than does temperature, and the pressure-gradient terms are rewritten to remove much of the cancellation between them. The sensitivity is tested for different forms of thermal-dynamical equation to the reference atmosphere. We found that the form of thermal-dynamical equation with vertical finite-differencing scheme keeping total enthalpy conservation (RPL2) was not sensitive to reference atmosphere, but more sensitive that with vertical finite-differencing scheme keeping total energy conservation (RPL4).

Forecast experiments were initially carried out using a version with introducing reference atmosphere (called RPL-scheme) and CPTEC model (called control-scheme). Experiment was also done without the large scale precipitation adjustment and the minimum amount of convective precipitation multiplied by 10 (lrg10). A set of 12 cases was run for 8-day forecast using the 9-level sigma vertical resolution and horizontal resolution triangular truncation on zonal wave 21 (T21). Anomaly correlations for geopotential height on 500 hPa were computed for every case (figures 1 to 15). The experiments show a clear beneficial impact of RPL-scheme (introducing reference atmosphere) in the Southern Hemisphere and Tropical areas. And little impact of RPL-scheme is found in Northern Hemisphere.

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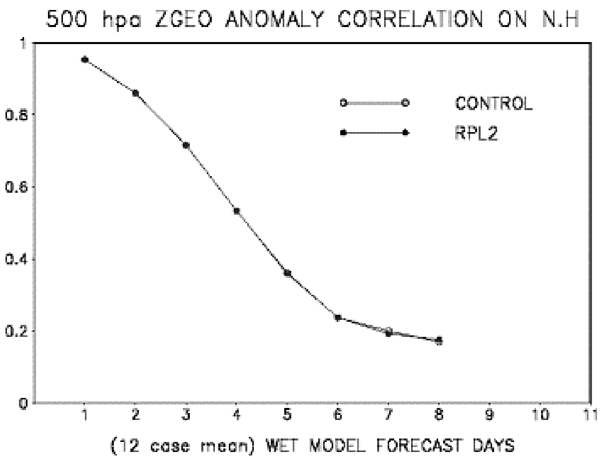

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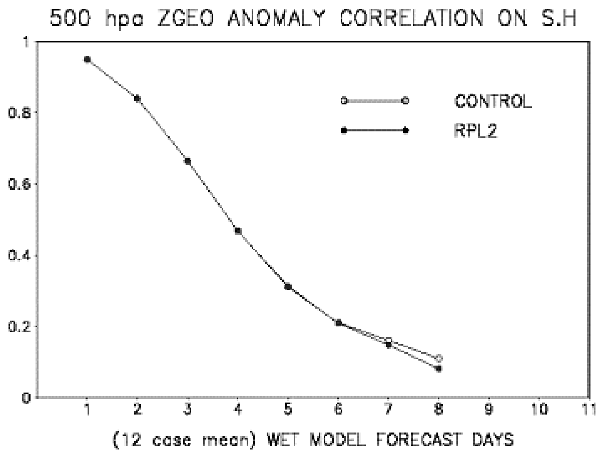

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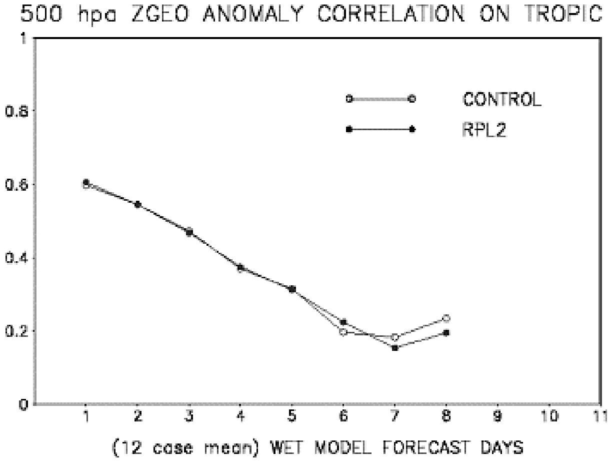

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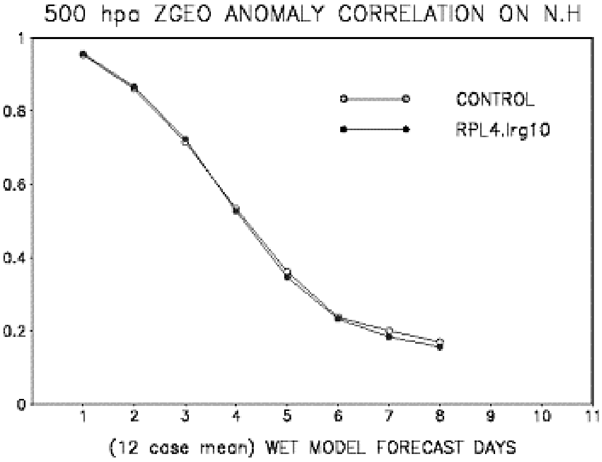

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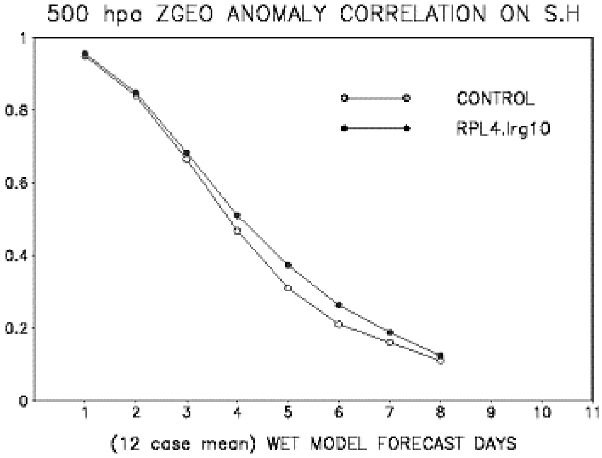

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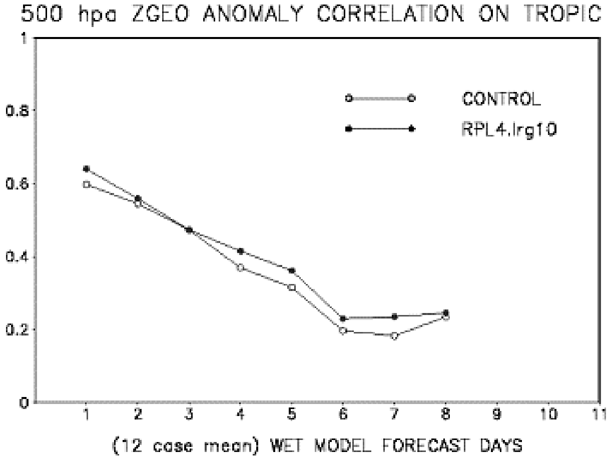

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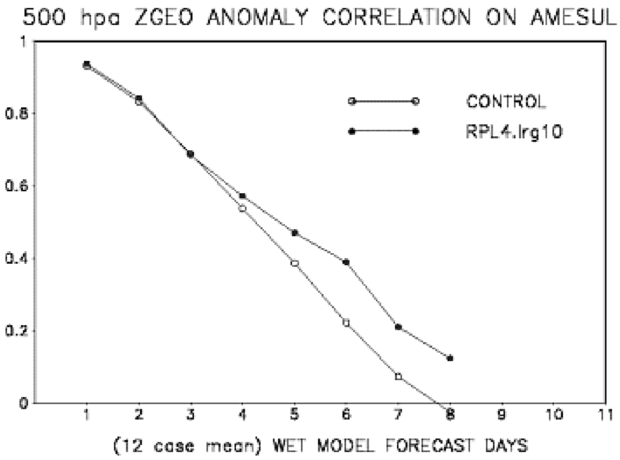

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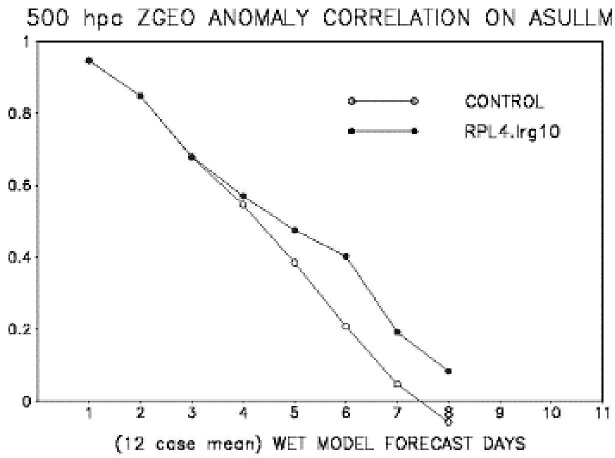

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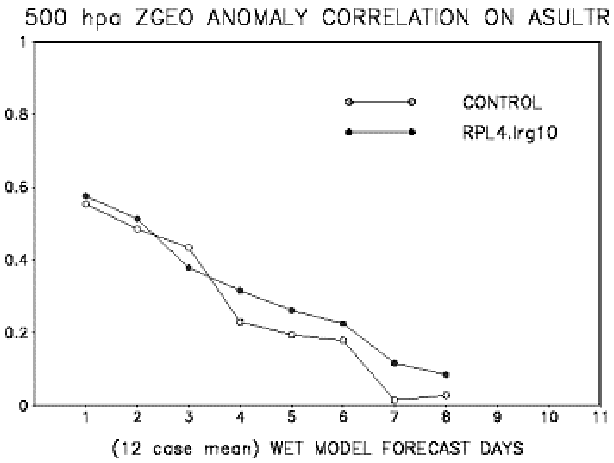

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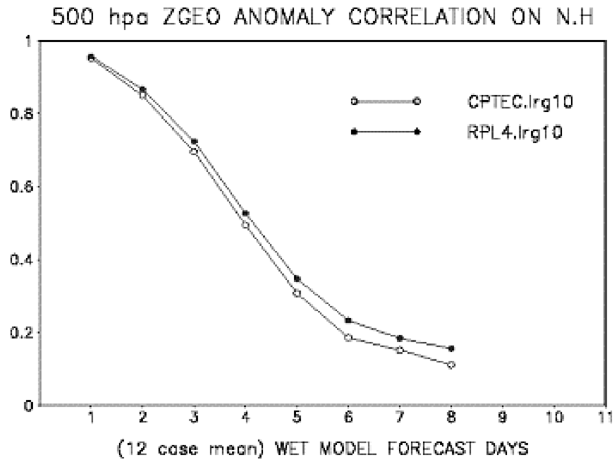

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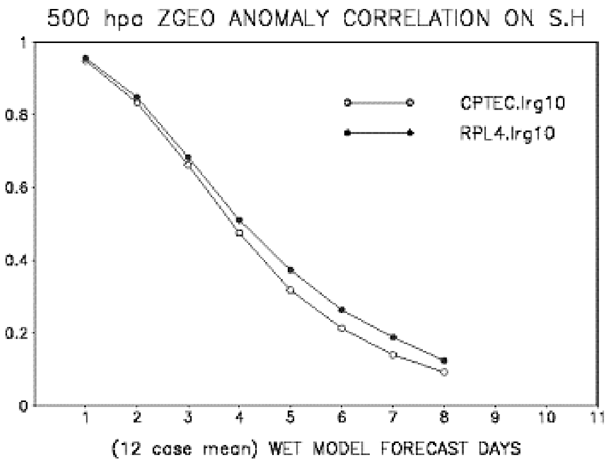

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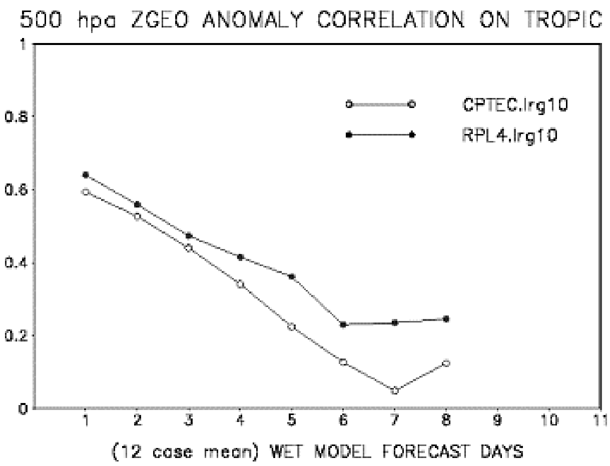

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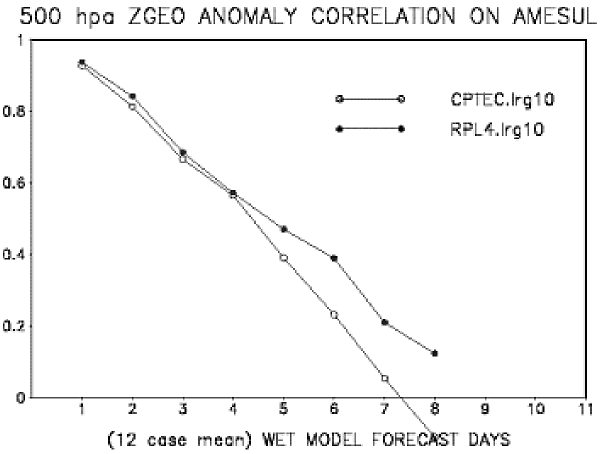

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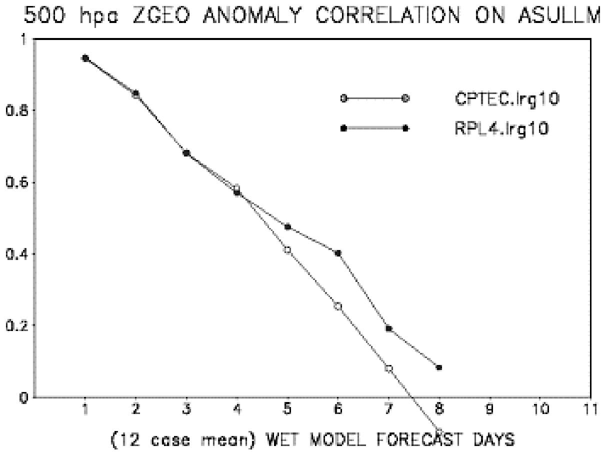

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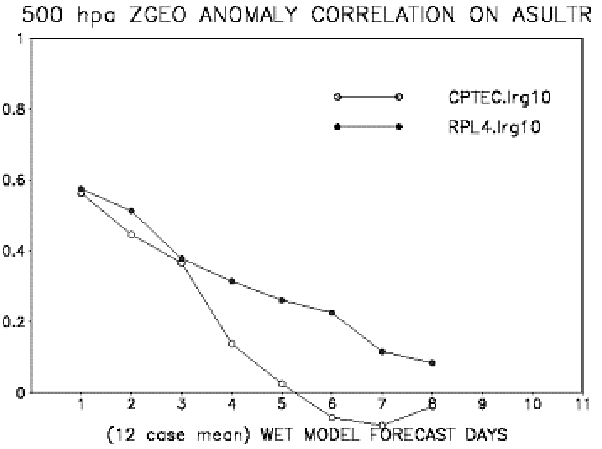

Figure 15