Use of Reanalyses to Examine Climate Model Errors via NWP type Forecasts

David L. Williamson

National Center for Atmospheric Research, Boulder, CO. USA
Correspondence: wmson@ucar.edu

INTRODUCTION

NWP type forecasts made with climate models initialized from reanalyses have proven to be an effective method to diagnose parameterization errors (Phillips et al. 2006, Boyle et al. 2005, Williamson et al. 2005, Williamson and Olson 2007). This approach is most powerful when paired with field campaign observations of parameterized variables. However the approach can also be applied to examine errors and to test hypotheses associated with those errors by using the reanalyses for verification as well initial conditions. There is an advantage in using several reanalyses for the initial conditions. The reanalyses are good enough in many regions, but not necessarily all. Model parameterizations still dominate the analyses in some regions for some phenomena. If the forecasts exhibit the same errors when initialized from and verified against different reanalyses we have more confidence that we are looking at a model error, rather than the difference between the model and an analysis model.

POLAR TROPOPAUSE COLD BIAS

We apply this forecast approach to the Community Atmosphere Model, CAM3 (Collins et al. 2006), to examine the polar tropopause cold bias (Figure 7, Collins et al. 2006), a persistent bias present in almost all global atmospheric general circulation models. We perform forecasts with the T42, 26 level standard version of CAM3 initialized from the JRA-25 and ERA40 for 24 days in June/July 1997. We plot the vertical column representing the zonal average, meridional average from 70N to 90N, and ensemble average of the 24 forecasts. Figure 1 (left) shows the June/July 1997 model temperature error from an AMIP simulation computed against ERA40. Figure 1 (center and right) shows the evolution of the temperature error for 30 day forecasts initialized from and verified against ERA40 and JRA-25, respectively. The polar tropopause temperature error forms immediately in the forecasts and grows steadily through the 30 days. It grows slightly faster initially from the JRA-25 initial conditions, which are about 2K warmer than ERA40 at the tropopause, but the overall growth pattern is the same for the two sets of forecasts.

Several hypotheses have been advanced concerning the cause of the cooling and were presented in the talk. Here we illustrate three of them with forecasts initialized from the ERA40: 1) increased radiative cooling due to increased water vapor at the polar tropopause caused by

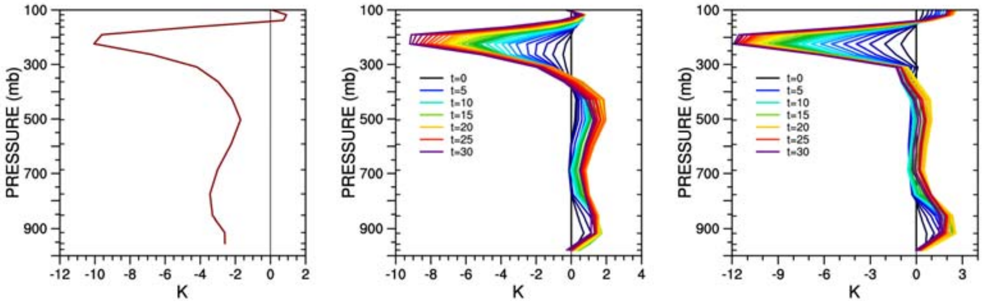

Figure 1. (left) June/July 1997 model climatological temperature error from an AMIP simulation computed against ERA40; (center and right) evolution of temperature error for 30 day forecasts initialized from and verified against ERA40 and JRA-25, respectively.

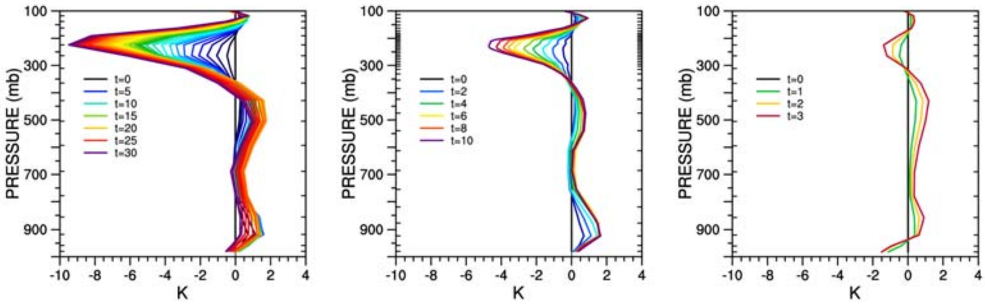

Figure 2. (left) temperature error when the water vapor seen by the longwave radiation is from the ERA40 rather than the predicted water vapor; (center) temperature error from 10-day forecasts with 48 levels, inner ticks indicate model levels; (right) temperature error from 3-day forecasts with T170 truncation.

dynamical errors; 2) inadequate vertical resolution in the region of the tropopause; and 3) truncation errors due to horizontal resolution. Figure 2 (left) shows the temperature error when the water vapor seen by the longwave radiation is from the ERA40 rather than the predicted water vapor. The initial error growth is the same as in the regular model (Figure 1, center) and the first hypothesis can be rejected. There is, however, a secondary affect associated with the water vapor seen at the model level above 200 mb where the model cools less with the ERA40 water vapor. Figure 2 (center) shows the temperature error from 10-day forecasts with 48 levels. The inner ticks in the plots indicate the model levels. The extra levels are placed between 350 and 150 mb, decreasing the grid interval there by around a factor of three. The initial growth is unaffected by the increased vertical resolution. Figure 2 (right) shows the temperature error from 3-day forecasts with T170 truncation. Once again the initial growth is unaffected. In the talk we showed that the initial growth of the polar tropopause cold bias was insensitive to vertical resolution in the vicinity of the tropopause, the water vapor (ERA40 versus CAM3 predicted), a small, systematic error in the radiation parameterization of order of 0.1K/day, the particular dynamical core (Eulerian spectral transform, semi-Lagrangian spectral transform, and finite volume), and horizontal resolution. The cause of the cold bias remains a mystery at this time.

.COMMENTS

This forecast approach is a relatively inexpensive method to examine fast, primary model errors before climate balancing occurs. It allows experiments that might not survive long climate runs, such as the specified water vapor experiment above, or the increased vertical resolution which might adversely affect the parameterizations in longer runs. It is useful for sensitivity studies compared to reanalyses alone. However, it is most effective when coupled with field campaign observational estimates of some terms in the budgets. Without such extra observations it is difficult to establish cause and effect.

The use of several different reanalyses for the initial conditions and verification data provides an indication of the robustness of the model error signal. This, of course, assumes the reanalyses are considered to be of similar quality. Thus here we use both JRA-25 and ERA-40 data. We emphasize that in order to be able to interpolate the best initial conditions for the climate model, the reanalyses must be made available on the analysis native model/analysis grid. In that case the interpolation to the climate model grid can maintain structures that might be important to the parameterizations. Such structures can be lost by interpolation to specified pressure levels.

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