The impact of aerosols on medium range weather forecasts

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I. Introduction

Aerosols affect the radiation budget both directly (via scattering and absorption) and indirectly (through cloud-radiation interaction). In addition, the dust-laden Saharan air layer is found to reduce occurrences of deep convection and suppress tropical cyclone activity in the North Atlantic and Caribbean [Dunion and Velden, 2004].

The NOAA National Centers for Environmental Prediction (NCEP) Global Forecast System/Global Data Analysis System (GFS/GDAS) is the decision support system used by NOAA for medium-range numerical weather predictions. The effects of aerosols on radiation, clouds, and convection, however, are poorly represented in the GFS as its aerosol distributions are currently derived from climatology. Furthermore, the effects of aerosol attenuation on radiance assimilation are yet to be quantified in the GDAS, as background aerosol conditions are currently assumed in the radiative transfer scheme.

NOAA NCEP recently initializes the efforts to develop global aerosol forecasting and assimilation capability in GFS/GDAS via the NCEP-GSFC-Howard University collaborations. Main tasks of this collaborative project include the adoption of GSFC aerosol module (GOCART, Chin et al. 2000) in GFS and the utilization of satellite aerosol measurements (e.g., MODIS, OMI, CALIPSO) in GDAS. Global aerosol products generated in this project will provide an improved estimate of aerosol distributions and variations within the GFS/GDAS system, which in turn will improve the accuracy of weather forecasts issued by NOAA to protect life and property.

In this study, GDAS experiments are conducted to assess the impact of aerosols on GFS medium range weather forecasts. Section II gives a brief model description. The experiment configuration is discussed in Section III. Model results are given at Section IV, followed by the conclusions (Section V).

II. Model Description

The GFS/GDAS system is the decision support tool used by NOAA for medium-range numerical weather prediction. The forecast model, GFS, is a global spectral model with the state-of-the-science physical parameterizations [Moorthi et al., 2001]. Key model physics and dynamics include: sigma-pressure hybrid coordinate, non-local vertical diffusion, simplified Arakawa-Schubert convection scheme, RRTM long wave radiation scheme, GSFC MD Chou short wave radiation scheme, explicit cloud microphysics and Noah land surface model. Initial conditions for both atmosphere and land states are taken from NCEP GDAS analyses.

The Gridpoint Statistical Interpolation (GSI) [Wu et al., 2002] is NCEP 3D VAR assimilation system. It was implemented for replacement of the Spectral Statistical Interpolation (SSI) [Parrish and Derber, 1992] in the GFS system in May 2007. Key scientific advances for GSI include grid point definition of background errors, the inclusion of new types of data (e.g., COSMIC GFS, AIRS radiance), advanced data assimilation techniques (e.g., improved balance constraints), and the addition of new analysis variables (e.g., SST).

III. Experiment Setup

Two T126 L64 GDAS experiments covering the period from 2006-06-01 to 2006-09-07 are conducted. The experiments are initialized from 2006-06-01 00Z GDAS analysis. The two GDAS experiments are identical expect for aerosol scheme configuration. The control experiment is based on the OPAC climatological scheme (5° x 5° monthly mean [Hess et al., 1998]), as in the operational applications. The experimental run carries aerosols as passive tracers, updated every 6 hour from GEOS4-GOCART simulations (1° x 1.25°).

The former experiment is referred to as PRC (climatology) and the latter experiment is referred to as PRG (time varying aerosols) throughout the text. Note the experimental aerosol treatment only impacts the model results via its direct effect on the radiative forcing of the atmosphere.

IV. Results

Figure 1 shows the time series of anomaly correlation for 5-day forecasts of Northern hemisphere 500 mb heights, verified against its own analysis, during the 14-week period. The PRG run shows a neutral impact on the daily score. The same results are found for southern hemisphere height field (not shown here). The time series of RMS vector wind errors for 3-day forecasts in the tropics are shown in Figure 2. Mixed results are found, as a reduction in RMS errors is found at 850 mb while the degradation in tropical wind forecasts is found at higher level (200 mb).

As noted earlier, change in model forecasts arises from the direct radiative effects. The effect of variable tropospheric aerosols on surface UV radiation is examined. Figure 3 shows the comparisons between GDAS downward solar radiation fluxes and in situ observations at Desert Rock, NV site. A small reduction in the flux bias is found. Similar reduction is also found at other SURFRAD sites (not shown here). A positive bias in solar insolation is a long standing problem for GDAS, and the small improvement resulting from improved aerosol treatment is encouraging.

The effect of aerosols on temperature field is examined by comparing with radiosonde observations. Figure 4 show extensive warm bias in North American at 850 mb level in the PRC experiment. A slightly reduced bias is found in the PRG experiment, resulting from the adoption of time varying aerosol loading. Figure 5 shows vertical profiles of temperature biases in North America region, verified against radiosonde observations, averaged over the 2006-06-04 to 2006-09-07 period. Approximately 10% reduction in temperature biases is found in lower troposphere (up to 750 mb) for both 24-hour and 48-hour forecasts.

V. Conclusions

Results of GDAS experiments with different aerosol loading for the 2006 summer period are presented. Change in model forecasts arises from the direct radiative effects. Forecasts are verified against analysis and observations. Overall, the adoption of time varying aerosol fields appears to be a neutral to slight improvement.

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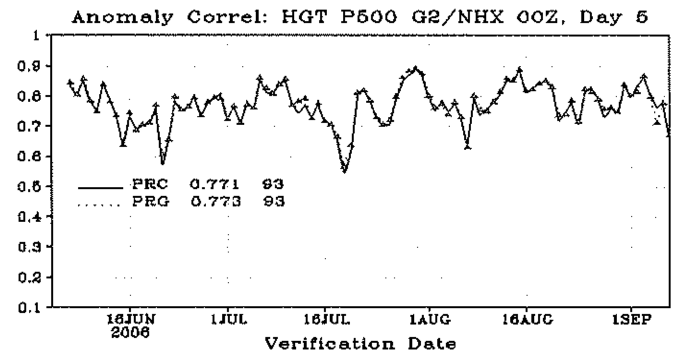

Figure 1. Time series of anomaly correlation for 5-day forecasts of Northern hemisphere 500 mb heights, verified against its own analysis, for PRC experiment (black solid line) and PRG experiment (red dotted line).

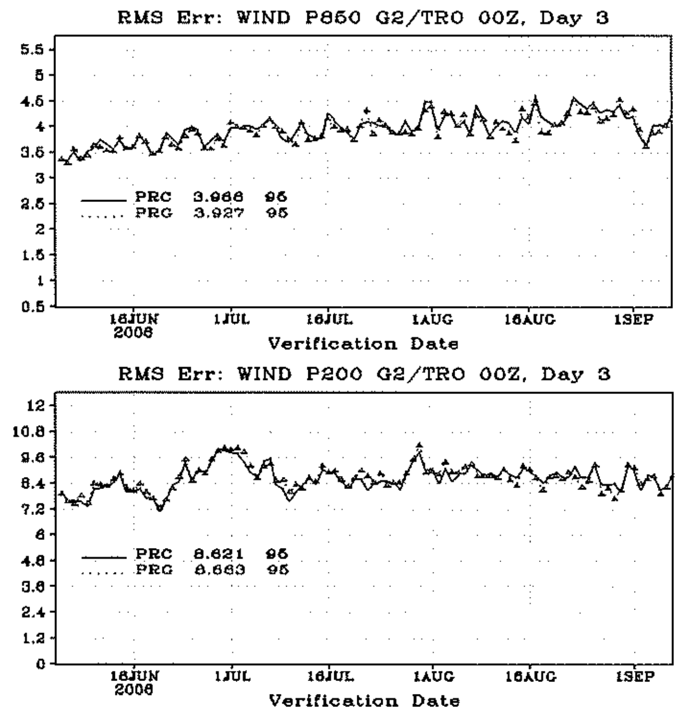

Figure 2. Time series of RMS vector wind errors for 3-day forecasts in the tropics at 850 mb (upper panel) and at 200 mb (lower panel), verified against its own analysis, for PRC experiment (black solid line) and PRG experiment (red dotted line).

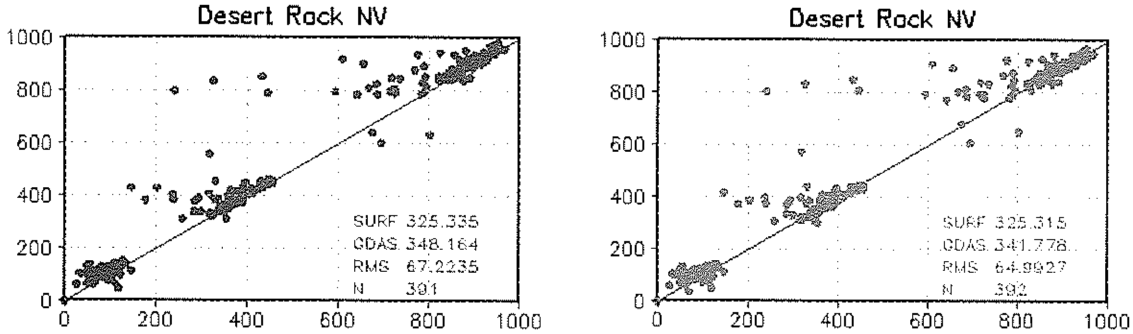

Figure 3. Comparisons of downward solar radiation flux (in W/m2) at Desert Rock, NV between GDAS (y-axis) and in situ observations (x-axis) for the PRC experiment (left panel) and PRG experiment (right panel).

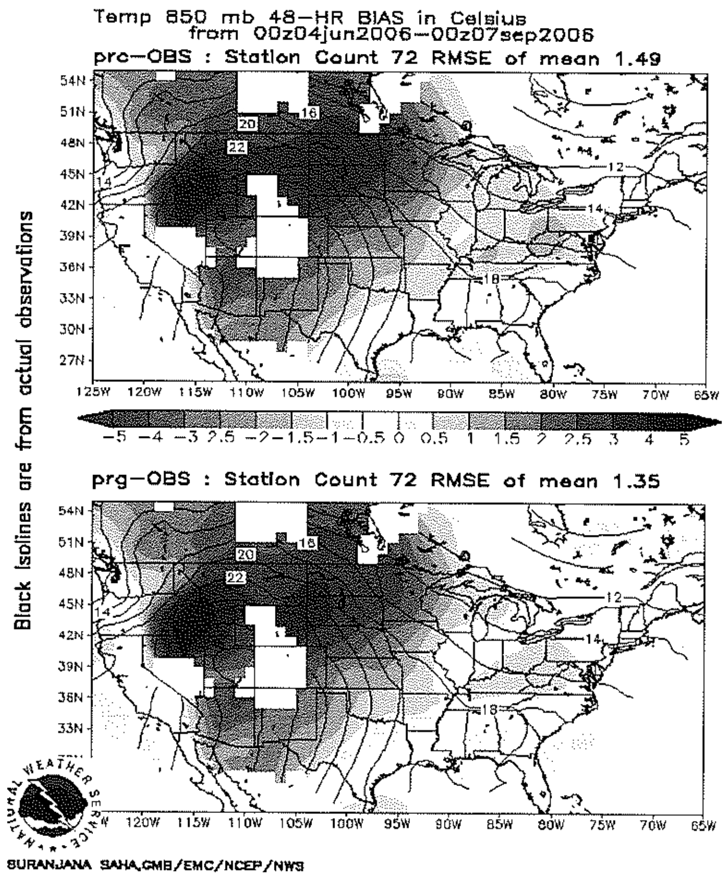

Figure 4. Spatial pattern of North America temperature biases at 850 mb, verified against radiosonde observations, for PRC experiment (upper panel) and PRG experiment (lower panel), averaged over the 2006-06-04 to 2006-09-07 period.

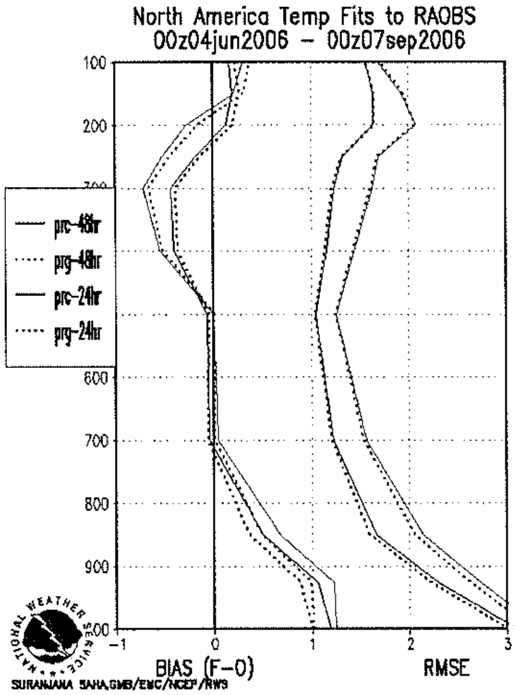

Figure 5. Vertical profile of North America temperature biases, verified against radiosonde observations, for PRC experiment (solid line) and PRG experiment (dotted line) for 24-hour forecasts (black color) and 48-hour forecasts (red color).