Assessing the impact of aerosols on climate using NCEP CFS

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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) Climate Forecast System (CFS) is a fully coupled atmosphere-land-ocean model. It was developed by NCEP Environmental Modeling Center (EMC) and became operational for seasonal forecasts in August 2004. The effects of aerosols on radiation, clouds, and convection, however, are poorly represented in the CFS as its aerosol distributions are currently prescribed from climatology. .

In this study, CFS experiments are conducted to assess the impact of different aerosol loading on climate. Section II describes the CFS model system and experiment configuration. Model results are given at Section III, followed by the conclusions (Section IV).

II. Model Description and Experiment Configuration

The NCEP CFS is a fully coupled model representing the interaction among the Earth's ocean, land and atmosphere. A description of the CFS is given in Saha et al. [2006]. The atmospheric model is NCEP Global Forecast System (GFS) and the ocean model is GFDL's Modular Ocean Model Version 3 (MOMv3). The CFS became operational at NCEP in August 2004. There are four members per day with the atmospheric initial conditions obtained from NCEP Reanalysis-2 and the ocean initial conditions from NCEP Global Ocean Data Assimilation (GODAS).

In this study, CFS experiments are conducted under the Climate Test Bed (CTB). In specific, two sets of CMIP (with resolution T126 L64) experiments are conducted for the 2000-2006 period when the stratospheric volcanic aerosols are close to the background level. The two CFS experiments are identical expect for aerosol scheme configuration. The control experiment (CTR) is based on the OPAC climatological scheme (5° x 5° monthly mean [Hess et al., 1998]), as in the operational applications. The experimental run (EXP) uses the monthly-mean data from GEOS3-GOCART integration. Note aerosols only impact the model results via its direct effect on the radiative forcing of the atmosphere.

For each CMIP set, there are 5 members initialized from GDAS and GODAS on early Jan 2000 (with one day apart). The atmosphere and ocean is coupled every hour, and the output is dumped every 6 hour.

IV. Results

Figure 1 shows the differences in aerosol optical depth (AOD) between CTR and EXP runs on Feb., May, Aug. and Oct. 2006. The GOCART data set (based on more updated emission inventory) leads to elevated AOD over Asia (corresponding to more anthropogenic pollution) and Africa (enhanced dust emissions and biomass burning).

Figure 2 shows the corresponding monthly mean near surface temperature differences. The differences between the CTR and EXP runs are caused by different aerosol background (direct effect only). Large differences (up to 10 deg) are found in high latitude area where the differences in aerosol optical depth (AOD) are not always large. This illustrates the complexity of the interaction among aerosol, radiation, and general circulations.

Aerosol optical properties (e.g., extinction coefficients, asymmetric factor and single scatter albedo) differ among different aerosol species. The response of atmosphere to different aerosol loading, consequently, depends on the physical and chemical properties of aerosol mixture. The complexity is illustrated by the CFS results over Africa. Figure 3, 4, and 5 shows the Jul-Aug averaged AOD, atmospheric column short-wave absorption, and near surface temperature, respectively. The CTR has lower AOD than EXP in West Africa and tropical Africa areas. The elevated aerosol loading in EXP can be attributed to higher dust emissions in West Africa and biomass burning activities in tropical Africa, respectively. The atmospheric column short-wave absorption is reduced in West Africa and enhanced in tropical Africa in the EXP run. The near surface temperature in West Africa and tropical Africa is lower and about the same in the EXP run, respectively.

Figure 6 shows the cross-section of zonal wind at 10°W. The intensity and location of African Easterly Jet are affected by background aerosol loading. The results shown here imply the possible role aerosols play in affecting the tropical storm formation and evolution.

V. Conclusions

Results of CFS experiments with different aerosol loading are presented. The global impact and regional differences due to aerosol fields are discussed. Change in model forecasts arises from the direct radiative effects.

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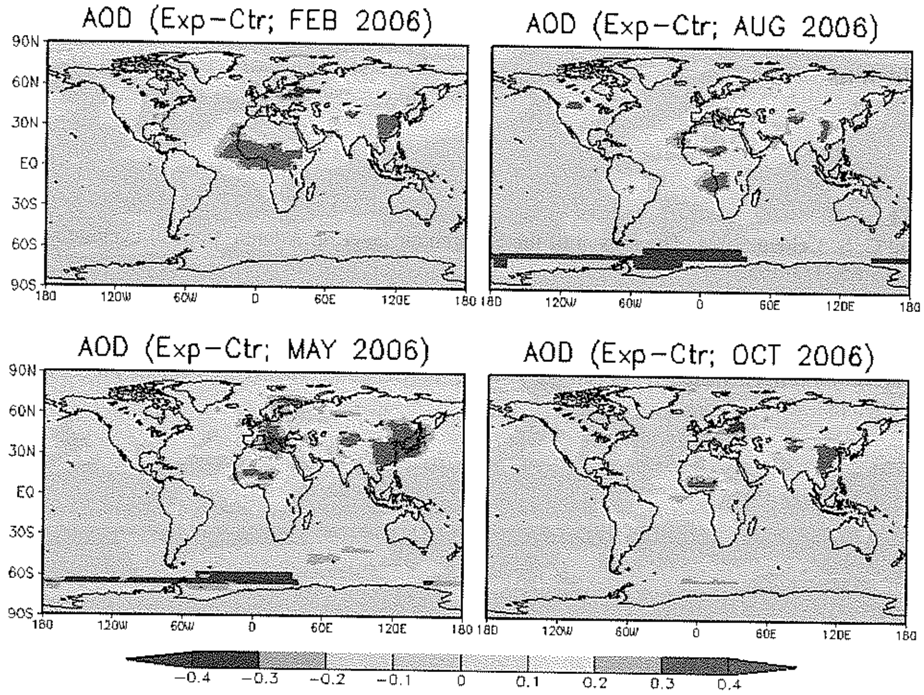

Figure 1. The differences in aerosol optical depth (AOD) between CTR and EXP runs on Feb. (upper-left panel), May (lower left panel), Aug. (upper right panel) and Oct. (lower right panel) 2006

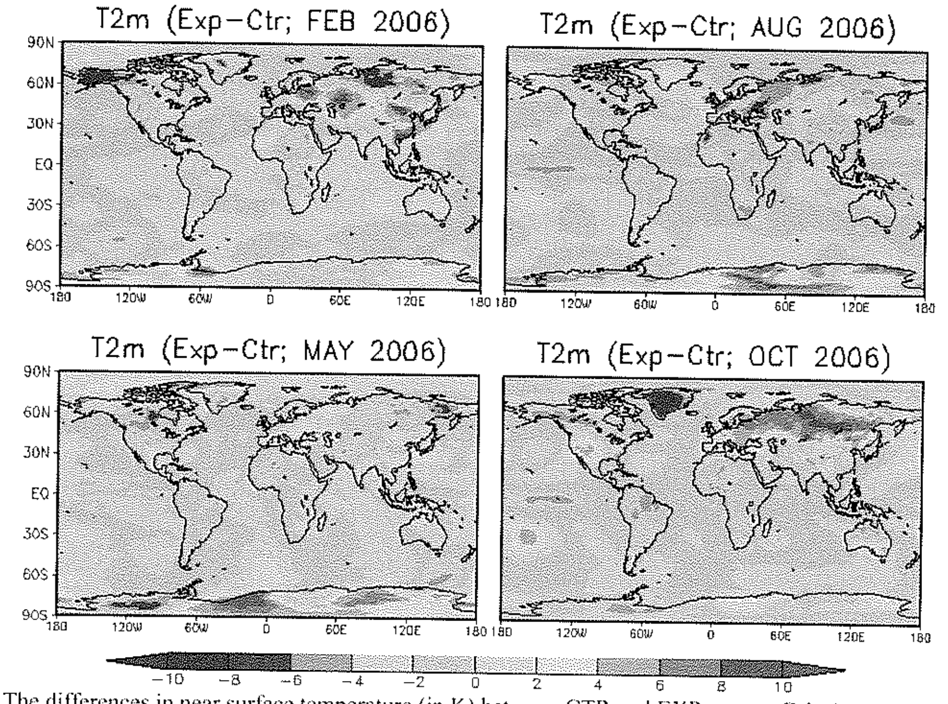

Figure 2. The differences in near surface temperature (in K) between CTR and EXP runs on Feb. (upper-left panel), May (lower left panel), Aug. (upper right panel) and Oct. (lower right panel) 2006.

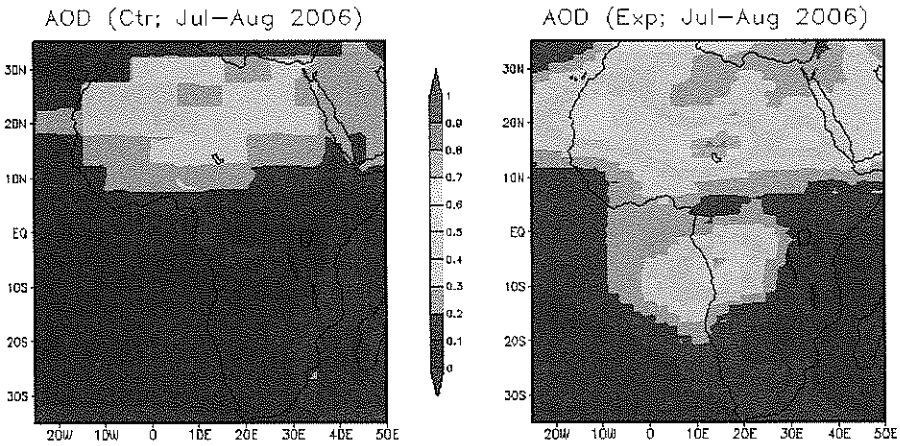

Figure 3. The Jul-Aug averaged AOD for CTR (left) and EXP (right) in Africa.

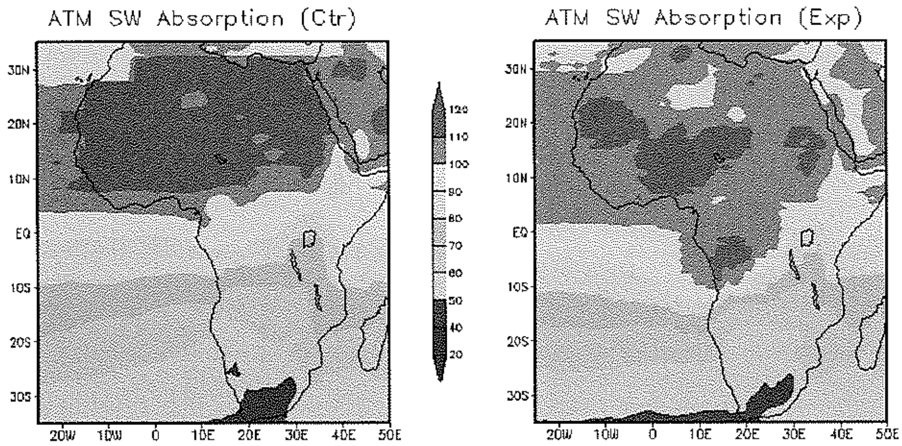

Figure 4. The Jul-Aug averaged atmospheric column short-wave absorption (in W/m^2) for CTR (left) and EXP (right).

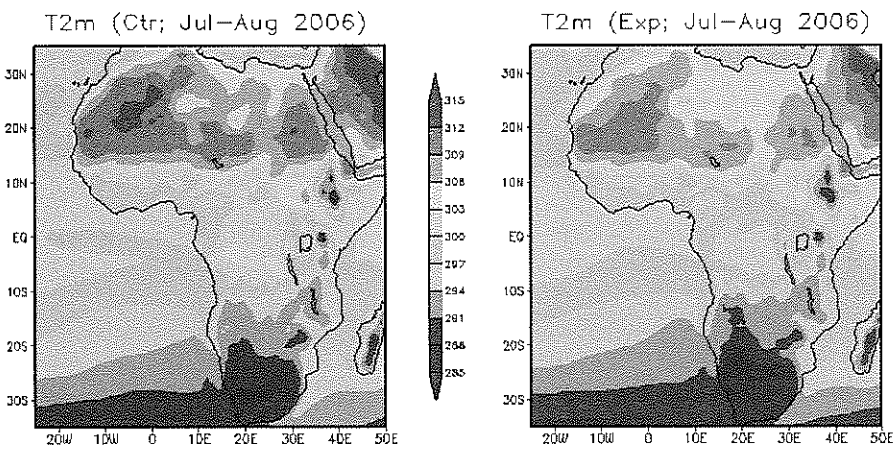

Figure 5. The Jul-Aug averaged near surface temperature (in K) for CTR (left) and EXP (right).

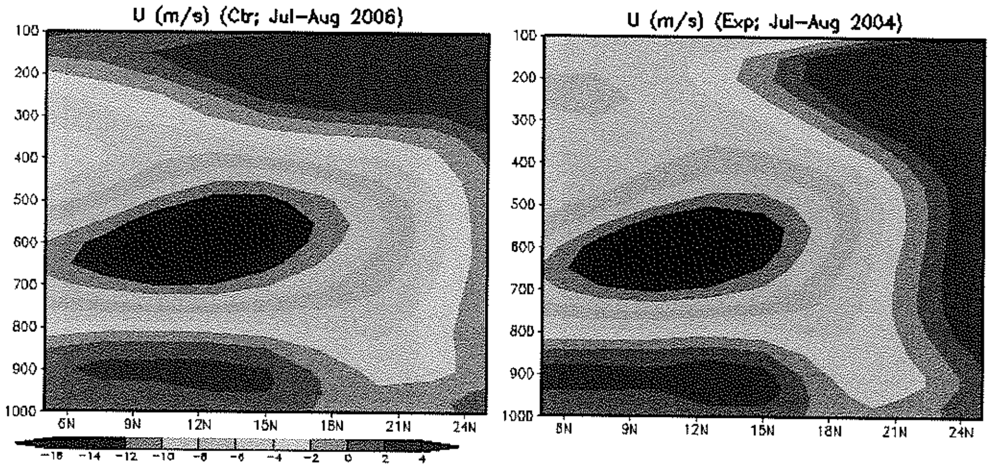

Figure 6. The Jul-Aug averaged zonal wind cross section (in m/sec) at 10°W for CTR (left) and EXP (right).