Assimilation of Satellite-derived Aerosol Optical Thickness in a Mesoscale Model: Online Integration of Aerosol Radiative Effects

Jun Wang, Udaysankar Nair, Sundar A. Christopher
Department of Atmospheric Sciences, University of Alabama in Huntsville, Huntsville, AL
wangjun@nsstc.uah.edu

Introduction

Dust aerosols affect visibility, perturb the radiative energy balance of the earth-atmosphere system, and also cause serious ecological effects. Numerical simulations of dust aerosols have large uncertainties due to poor characterization of dust emission fluxes and inadequate observations. Most current atmospheric models are driven externally by meteorological fields that come from a mesoscale model in which aerosol effects are not explicitly considered. This leads to further uncertainties in the modified meteorological fields, which in turn cause errors in the modeling of aerosol distributions and impacts.

On the other hand, satellite measurements are one of the best tools to monitor dust events, and could improve numerical simulations. However, several satellite measurements and retrievals usually provide only column quantities and have limited forecast capabilities.

Through a case study, we show that assimilation of satellite aerosol optical thickness (AOT) into a mesoscale model with the online integration of aerosol radiative effects model greatly improves the aerosol forecast capability.

Data and Model

- California State University Regional Atmospheric Modeling System (CSU RAMS)
- Four-stream radiative transfer
- Dust aerosol optical model developed for PRIDE
- Dust aerosol optical model with consideration of hygroscopic effect using sea salt size distribution in RAMS with appropriate radiative transfer
- AOT inferred from GOES during Puerto Rico Dust Experiment (PRIDE), July 19 – July 22, 2003
- Downward shortwave and longwave flux data measured from the suite of Surface Measurements for Atmospheric Radiative Transfer (SMART)
- AOT compared with Sunphotometer and aircraft measurements in PRIDE
- NCEP reanalysis data (every 6 hours)
- Sunphotometer and aircraft measurements

Methodology

- Two types of aerosols, sea salt and dust are modeled. The concentration of sea salt is diagnosed as a function of sea wind speed at the ocean surface. The mass concentration of dust is initialized from GOES8 AOT using aerosol profile measured from aircraft.
- AOT is assimilated into CSU RAMS by adding dry deposition term.
- GOES8 AOT was assimilated into the RAMS twice a day using the nudging method.

Dust Radiative Effects and Their Feedbacks

- Dust aerosol optical model produced a large difference in surface energy budget and the 2m air temperature. Feedback, explicitly considering aerosol radiative effect, in the four-stream radiative transfer model produces the best match with the observations.

Summary

- Comparisons of aerosol forecasts show that direct online integration of aerosol radiative effects produces more realistic surface energy budgets.
- Numerical simulations show that the dust loading considered in this study (AOT = 0.45 at 0.67µm), if the dust radiative effects are not properly represented, the uncertainty in the modeled AOT is about ±5%. If AOT is overestimated by 30% in the surface energy budget is overestimated by 30 to 40Wm-2 during the day and underestimated by 10Wm-2 during the night, and the bias in 2m air temperatures near the surface could be up to ±0.5°C, though these biases also depend on local time, AOT values and surface properties.
- The results from this study demonstrate that the assimilation of satellite aerosol retrievals not only improves the aerosol forecasts but also has the potential to reduce the uncertainties in modeling the surface energy budget and other associated atmospheric processes.

References