Impact of Aerosols on the Simulation of Brightness Temperature in the NASA Goddard Earth Observing System Atmospheric Data Assimilation System

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Motivation
The Goddard Earth Observing System (GEOS) general circulation model has been using aerosols from the Global Ozone Chemistry Aerosol Radiation and Transport (GOCART) to interact with its radiation physics component (Colarco et al. 2010). The application of the two-dimensional physical-space aerosol optical depth (AOD) assimilation method for the MODIS observations of the AQUA and TERRA satellites has allowed real-time, three-hourly, improved GOCART aerosol fields. However, the fifteen GOCART aerosol tracers are not felt by the underlying Grid-point Statistical Analysis (GSI; Kleist et al. 2010) of the GEOS atmospheric data assimilation (ADAS) system. In our study, we enabled GSI to feel the impact of aerosols when applying the Community Radiative Transfer Model (CRTM; Kleespies et al. 2004) as part of its observation operator. A set of the GEOS ADAS 3DVAR experiments were carried to evaluate the influence of aerosol fields on its observation operator algorithms. The experiment result shows that noticeable aerosol-cooling effect on brightness temperature calculation is triggered in aerosol active area.

GEOS ADAS Experiments for Accessing Aerosol effect
- GEOS ADAS 3DVAR system
  - Combines the Cubed-Sphere GEOS AGCM with GSI
  - Schematic of GEOS ADAS 3DVAR cycle with incremental analysis update
- Experiments for the assessment of aerosol-affected radiance
  - Control experiment (C20)
  - Aerosol experiment (aer)
    - Aerosol fully interactive in GEOS AGCM
    - Based on assimilated AOD field
    - Standard GSI global analysis with 6-hour cycle
    - GEOS ADAS 3DVAR of August, 2016
   - Model resolution: horizontal 0.25 degree and vertical 12 levels
   - CRTM Aerosol transfer routine is turned on for all tracers: stratus, AER, SMS, HHS, ChL, AERHR, and GCMHR
   - Start GEOS ADAS 3DVAR analysis for the month of August (12:00 UTC), 2016
   - GGI/CRTM observation operator
     -5 GEOS GOCART aerosol species: radius and SO concentration fields
     - gmi calculated optical parameter table is applied in CRTM

Global Aerosol Distribution
- TOTAL AOT, Dust Fraction, and Dust Vertical Mass Field for August 2016
  - Comparison of computed Tb with Observation: IASI/Metop-a (channel 210, wavelength of 10.38µm), August 29 (12:00 UTC), 2016

Impact of Aerosols on Brightness Temperature Simulation
- Computed brightness temperature difference (Tb): Aer – Ctl
  - Monthly mean for August (12:00 UTC), 2016
  - Monthly mean and histogram plots of OMF for IASI/Metop-a
  - Monthly mean and histogram plots of OMF for Cris/NPP

Impact on Observation Innovations and Analysis Fields
- Statistics of observation-minus-forecast (OMF): August (12:00 UTC), 2016
  - Monthly mean and histogram plots of OMF for Cris/NPP
  - Comparison of computed Tb with Observation: IASI/Metop-a (channel 210, wavelength of 10.38µm), August 29 (12:00 UTC), 2016
  - Monthly mean analysis surface temperature difference (Tb): Aer – Ctl: the buoy data points

Summary
Aerosol-affected radiances have been enabled in the GSI/CRTM atmospheric analysis step of the GEOS ADAS system. When compared with the aerosol-blind radiative transfer calculations, the aerosol experiment triggers a considerable aerosol cooling effect on computed brightness temperature. Especially in the dust dominant region, the cooling effect is about 1.0~1.5 ˚K for the IR atmospheric window channels of the wavelength between 9 and 11 µm. This leads to an improved brightness temperature calculation compared with observation data. In addition, we also observed that slightly increased analysis surface temperature field at tropical Atlantic ocean (off west Africa) is produced by the aerosol cooling effect on the brightness temperature computation. The comparison with the drifting buoy data shows that the aerosol experiment allows a slightly improved analysis outcome (about 0.2˚K) of the surface temperature field.

References