The Fate of a Saharan Dust Event During the NASA TC-4 Campaign

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Introduction

During the NASA TC-4 field campaign (San Jose, Costa Rica, July-August, 2007), Saharan dust was observed over the Caribbean and Central America. Satellite and airborne observations suggest a barrier to dust transport across Central America and into the Pacific.

Here, we introduce the NASA GEOS-5 atmospheric general circulation model and assimilation system and use it to help understand how Saharan dust interacts with the Caribbean environment during transport. We first evaluate our model by comparing it to monthly mean observations of aerosol optical thickness (AOT) from the MOderate Resolution Imaging Spectroradiometer (MODIS) and the Multi-angle Imaging Radiometer (MISR-Terra) satellites, as well as sun photometers as part of the ground based AErosol RObotic NETwork (AERONET).

We then utilize observations provided by the Cloud Aerosol Lidar with Orthogonal Polarization (CALIOP) spaceborne sensor and the Cloud Physics Lidar (CPL) while flying on the NASA ER-2 aircraft during TC-4 to evaluate our simulated vertical horizontal dust distributions during transport. Additionally, in an effort to understand how the Caribbean environment influences transported Saharan dust, we perform sensitivity tests by turning off cloud scavenging and washout processes to determine the influence of wet removal on our simulated dust distributions.

NASA GEOS-5 General Circulation Model

GEOS-5 is the latest version of the Goddard Earth Observing System modeling initiative and builds upon previous versions by offering radiative interactions between aerosols and the atmosphere and improved model resolution with capabilities to run with horizontal resolution as high as $0.25^o x 0.33^o$ and up to 72 hybrid-eta vertical levels. For this study, we ran GEOS-5 for the TC-4 time period based with the following configuration:

- $0.5^o x 0.66^o$ spatial resolution on 72 vertical hybrid-eta levels driven with meteorology from a previous NASA Global Modeling and Assimilation Office (GMAO) analysis.
- Aerosols are treated by a version of the Goddard Chemistry Aerosol and Radiation Model (GOCART) that has been implemented for the GEOS modeling system [Chin et al., 2002; Colarco et al., 2009]. Dust aerosols are simulated with 5 non-interacting radius bins spanning 0.1-10µm.

Evaluation of Dust Transport in GEOS-5

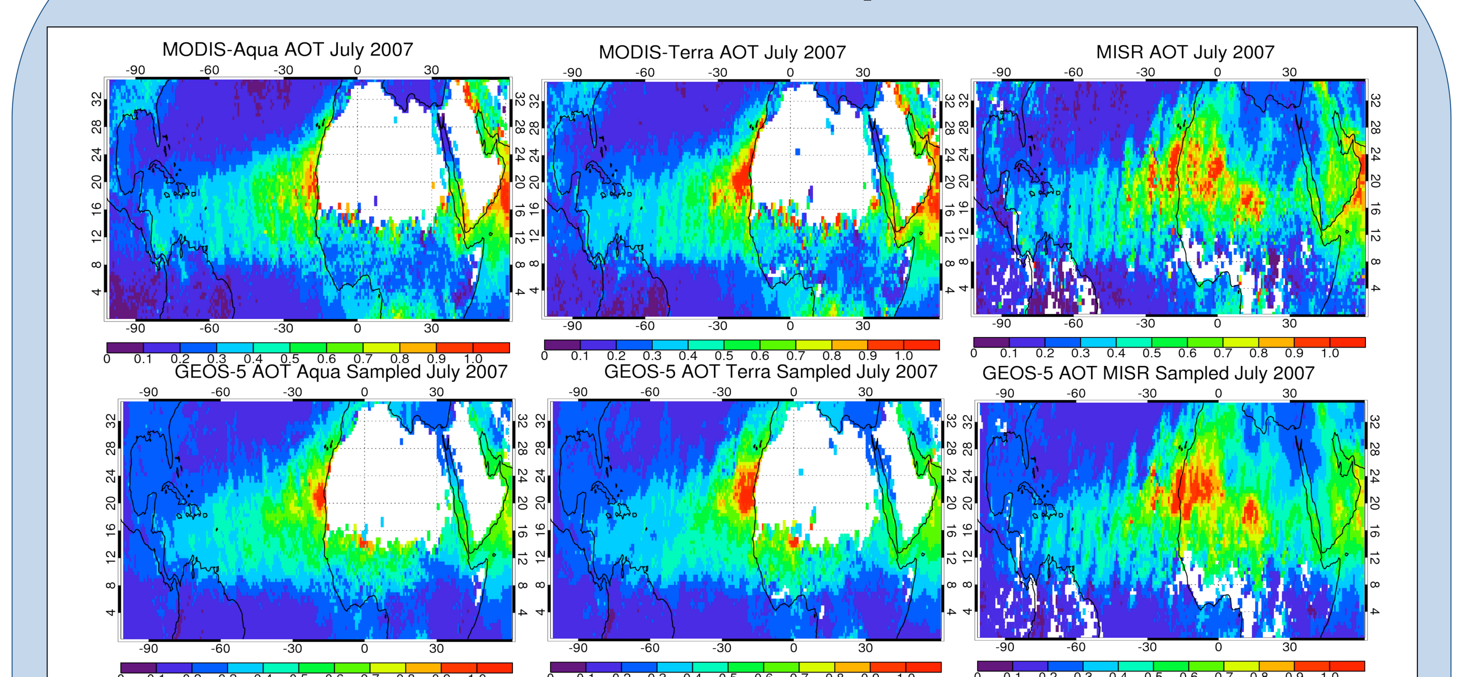

Figure 1. MODIS-Aqua (top left), MODIS-Terra (top center), MISR (top right) and corresponding GEOS-5 (bottom) July 2007 mean AOT that have been sampled at the location and nearest synoptic time for each satellite retrieval. MODIS and GEOS-5 MODIS sampled AOT are weighted using MODIS Quality Assurance flags.

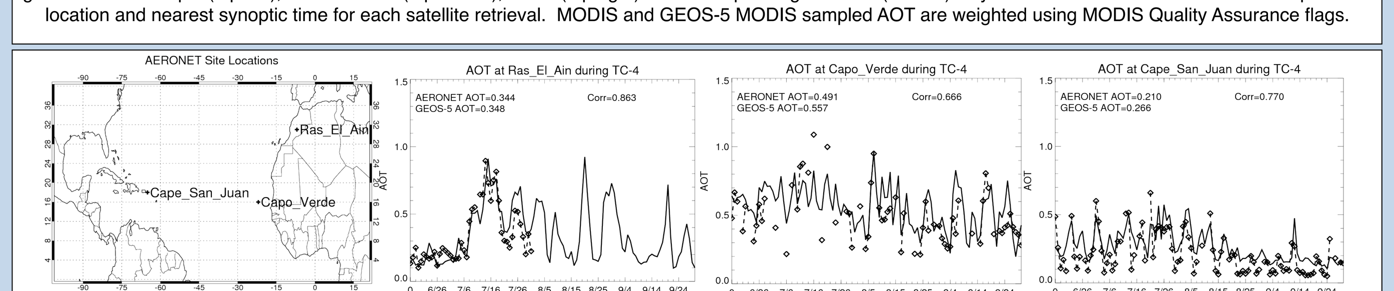

Figure 2. Daily AERONET (dashed-circle) and GEOS-5 (solid) AOT time series for the duration of our simulation. Mean AOT values and correlations (R^2) are displayed on each plot.

Comparisons to observations show that GEOS-5 has excellent agreement with observed dust plume magnitude, extent, and event timing.

Transported Dust Event on 7/19/2007

On 7/19, the CPL observed Saharan dust that had been transported across the Atlantic Ocean to the Caribbean. Figure 3 shows the spatial distribution of AOT from MODIS-Terra and GEOS-5 at 18Z with the ER-2 track overlaid. The model matches the AOT location observed by MODIS-Terra, but is lower in magnitude. Additionally, Figure 3 shows the CPL profile of total attenuated backscatter and GEOS-5 extinction profile sampled along the ER-2 track. Qualitatively,GEOS-5 produces similar horizontal and vertical distributions of dust. Both CPL and GEOS-5 show a dust transport barrier at the coastline of Costa Rica (9°N, 84°W, marked by a mountain), suggesting a strong dust removal process due to deposition or a change in transport direction controlled by atmospheric dynamics.

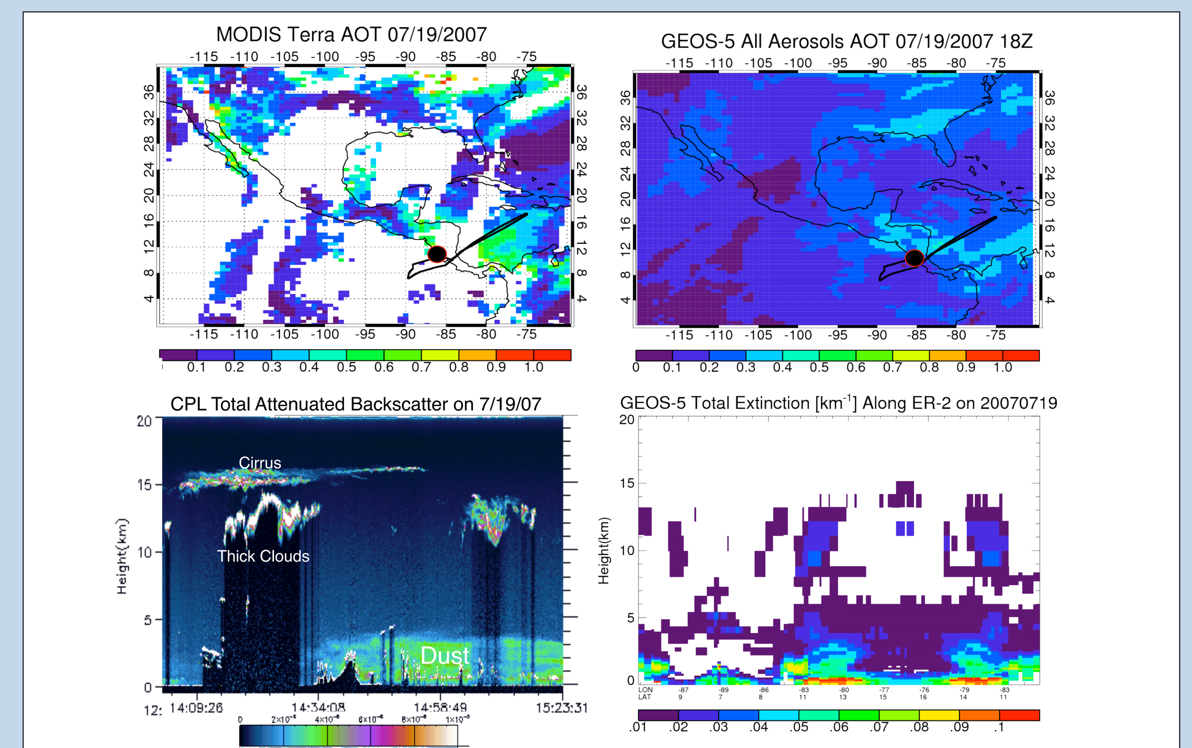

Figure 3. MODIS Terra AOT (top, left), GEOS-5 AOT at 18Z (top right), CPL total attenuated backscatter (bottom, left), and GEOS-5 extinction from all aerosols (bottom, right. The ER-2 flight track is overlaid on the top plots and the beginning is marked by the black circle.

Dust Event Transport Evaluation Using CALIOP

To evaluate the ability of GEOS-5 to transport a dust event from the Sahara to the Caribbean, we sampled our model along CALIPSO tracks over the Tropical North Atlantic Ocean for days prior to 7/19. Shown in figure 4 are the CALIPSO track, CALIOP total attenuated backscatter, CALIOP layer product [Vaughan et al., 2005], and GEOS-5 extinction from all aerosols sampled along the CALIPSO track. On most days, GEOS-5 matches the horizontal and vertical extent of observed dust plumes. However, GEOS-5 has difficulty simulating elevated dust layers, as seen in the CALIOP layer product. CALIOP data was unavailable on 7/12 & 7/13.

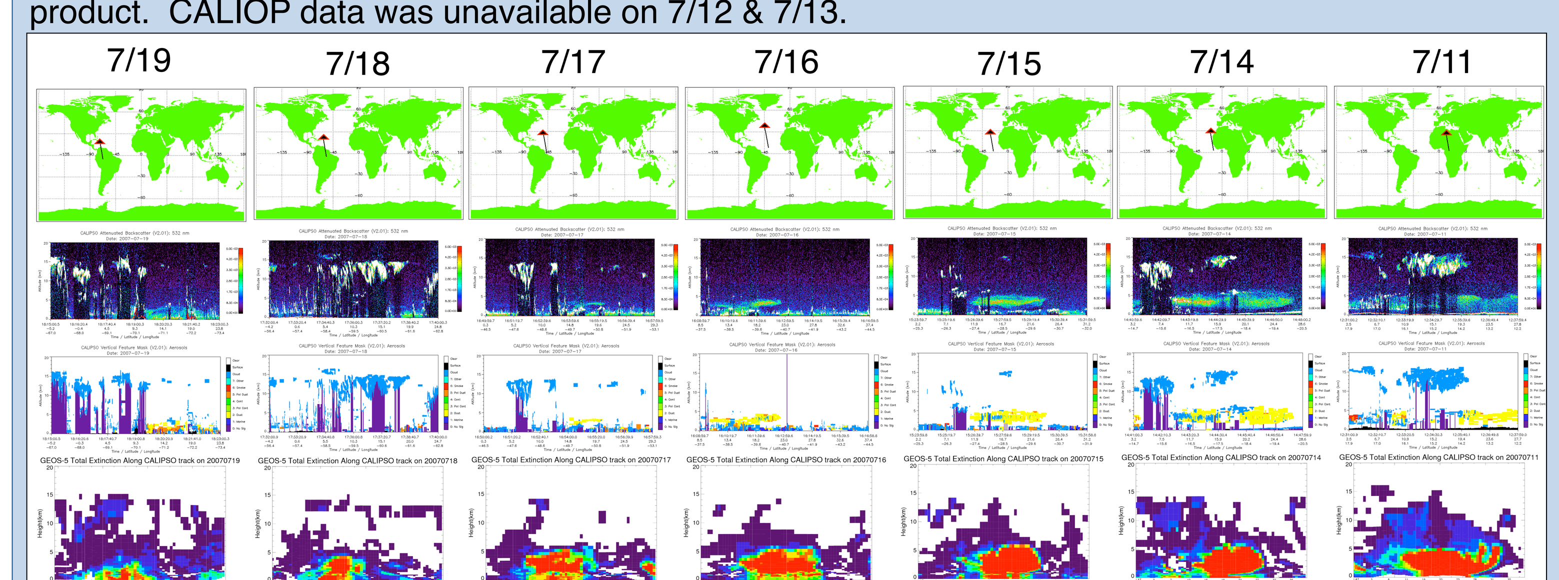

Figure 4. CALIPSO track (first row), CALIOP total attenuated backscatter (second row), CALIOP layer product (third row), and GEOS-5 extinction [km^{-1}] from aerosols sampled along the CALIPSO track (bottom row) tracked from the Caribbean (7/19) to the Sahara (7/11). CALIOP data was unavailable on 7/12 & 7/13.

Role of Wet Removal on Transported Dust

In an effort to understand how the Caribbean environment influences transported Saharan dust, we performed two additional simulations where cloud scavenging and all wet removal (cloud and convective scavenging) processes were not simulated. Shown in Figure 5 are GEOS-5 dust extinction profiles sampled along the ER-2 track on 7/19 for our baseline (left), no cloud scavenging (center), and no wet removal (right) cases. Both sensitivity tests show dust being transported over Costa Rica, suggesting that wet removal processes have a strong influence on Caribbean dust distributions.

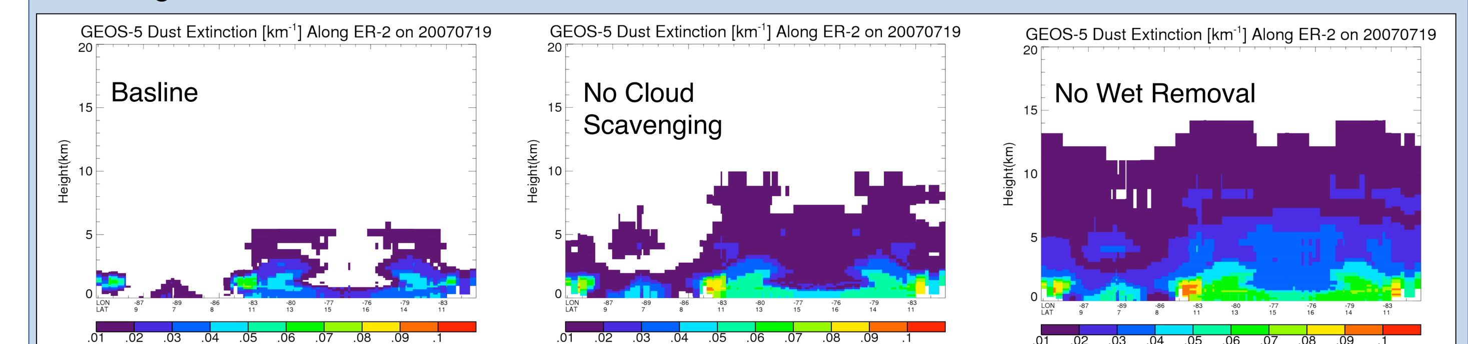

Figure 5. GEOS-5 dust extinction[km^{-1}] profiles sampled along the ER-2 track on 7/19 for our baseline (left), no scavenging (center), and no wet removal (right) cases.

Shown in Figure 6 is the averaged July dust AOT from our baseline simulation and differences between our sensitivity tests and baseline run. Turning off all wet removal processes creates a large increase in AOT over Costa Rica, whereas turning off only cloud scavenging has a constant influence from Sahara to the Caribbean. This suggests that dust removal by convective scavenging is more significant than cloud scavenging in the Caribbean.

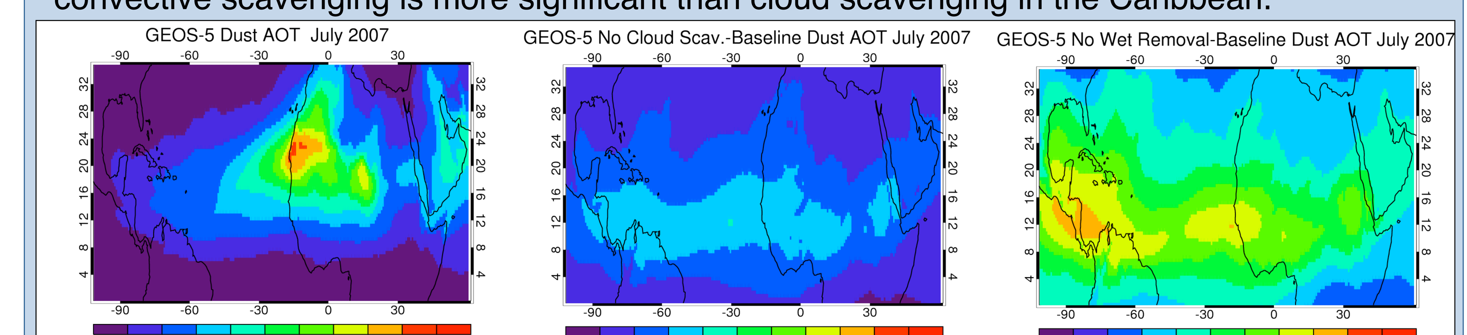

Figure 6. GEOS-5 July dust AOT from our baseline simulation (left) and differences for our no scavenging (center) and no wet removal (right) sensitivity tests.

Summary

- GEOS-5 dust distributions have excellent agreement with MODIS and AERONET observations during the NASA TC-4 field campaign timeframe.
- GEOS-5 captured the horizontal and vertical extent of a transported dust event, but has difficulty simulating elevated dust layers when compared to CALIOP.
- Wet removal of dust aerosols in the Caribbean environment is significant and is likely responsible for for the dust transport barrier seen on 7/19.
- Of the wet removal processes, washout by convective scavenging has a greater influence on the AOT than cloud scavenging over the Caribbean.

References

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