Assessing the Radiative Impact of a Dust Storm using Satellite Remote Sensing and Radiative Transfer Calculations

Poster No. 371

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Objective

Use CALIPSO and Cloudsat observations as inputs into a 4-stream RTM [*Fu and Liou*, 1992] to assess the detailed vertical structure of an intense dust storm on June 21, 2007 (Figure 1) where low-level water clouds resided beneath the dust making it an impossible case to study using passive satellites alone.

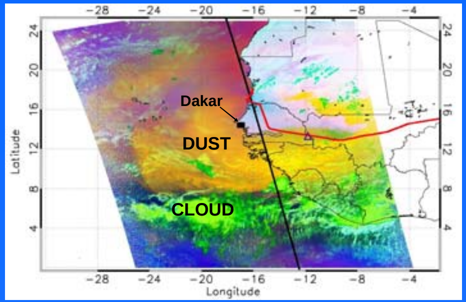

Figure 1. MODIS red-green-blue (RGB) composite image at about 1430 UTC on June 21, 2007. The black line is the CALIPSO transect occurring near the same time with the black square denoting the AERONET Dakar station and red line showing FAAM BAE-146 aircraft path.

Data

- CALIPSO Level 1B total attenuated backscatter profiles (Figure 2) and Level 2 cloud and aerosol top and base heights.
- Cloudsat cloud top and base heights (Figure 3), cloud optical depth (COD), and cloud effective radius.
- Aerosol effective radius, single scatter albedo (ω_0), and asymmetry parameter (*g*) retrieved by AERONET Dakar station.
- FAAM BAE-146 aircraft 550 nm AOD.
- Spectral albedo from MODIS MCD43C1 product.

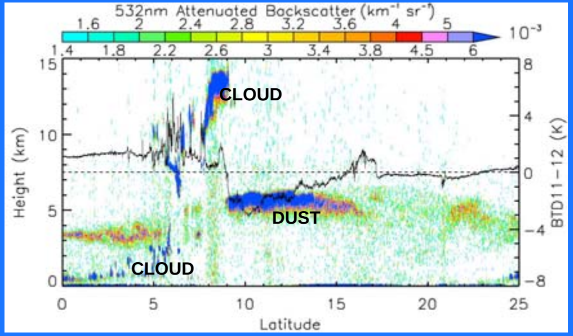

Figure 2. CALIPSO Level 1B attenuated backscatter profiles along transect shown in Figure 1. MODIS brightness temperature difference (BTD) between the 11 and 12 μm channels is shown by black curve where the thick dust leads to negative values.

Methodology

CALIPSO attenuated backscatter profiles and cloud and aerosol top and base heights are used to derive extinction coefficient profiles for the RTM along transect from 10-14°N in Figure 1.

Cloud top and bottom heights, COD, and cloud effective radius from Cloudsat were input directly into RTM.

Dakar station retrieved aerosol effective radius near 1.1 μm, therefore, we choose the 1.0 μm mineral dust type in the RTM.

We computed ω_0 of 0.95 and 0.98 and *g* of 0.76 and 0.74 for the RTM bands 1 (0.2-0.7 μm) and 2 (0.7-1.3 μm).

BAE-146 aircraft measured 550 nm AOD of 1.67 for the dust storm which we varied along the transect based on the derived 532 nm extinction (Figure 3).

Results

$SWARE_{dust} = F_{cloud+dust} - F_{cloud}$ where SWARE is shortwave aerosol radiative effect and F is radiative flux.

$SWARE_{dust}$ is shown in Figure 3.

Dust has a strong cooling effect over cloud-free water regions (i.e. 10-10.3°N).

Dust has a strong warming effect over water with low-level water clouds due to the increased background reflectance of the clouds.

A significant amount of solar radiation is absorbed in the atmosphere due to dust with even higher SWARE values in low cloud profiles.

The solar radiation reaching the surface is substantially reduced by dust due to its absorption and scattering effects.

Low clouds somewhat mask the impact of dust on solar radiation reaching the surface.

The TOA SWARE changes from negative to positive as the albedo increases to greater than 30% which suggests a critical albedo of 30%.

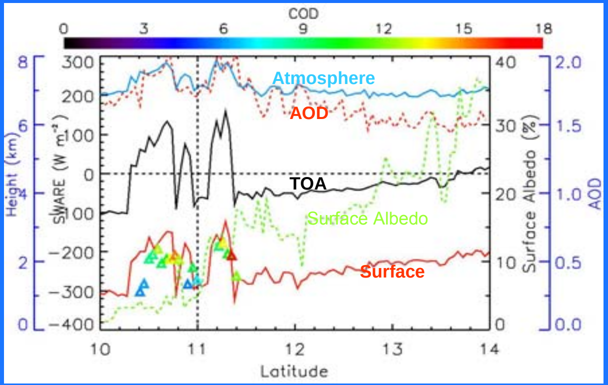

Figure 3. Cloudsat cloud top heights (triangles, outer left axis) and COD (scale at top) along with derived AOD (dashed red line, outer right axis) along transect in Figure 1. Also, TOA (black line), in atmosphere (blue), and surface (red) SWARE (inner left axis) and broadband SW albedo (dashed green line, inner right axis). South of dashed vertical black line at 11°N is primarily ocean while north is all land.

More Results

A large area of SW heating rates > 2 K/ day are simulated which indicates the warming effect of dust in the atmosphere (Figure 4).

The largest SW heating rates occur when low clouds are present as the increased background reflectance leads to more radiation received at the dust level.

Up to 8 K/day SW heating rates are simulated within the dust above the low clouds.

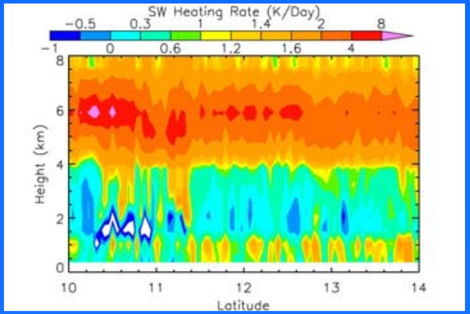

Figure 4. SW heating rates along transect in Figure 1.

What's next…

Additional case studies involving low clouds beneath dust must be studied as this study shows the impact of low clouds may be substantial.

We are currently investigating the impact of dust on tropical cyclone formation.

Does the presence of low cloud beneath dust impact mesoscale circulation patterns and consequently convection and precipitation over western Africa and eastern Atlantic?

Is there a significant dust aerosol semi-direct effect?

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5th Symposium on Aerosol-Cloud-Climate Interactions