P1.28 USING A-TRAIN TO ESTABLISH THE EFFECTS OF SAHARAN DUST ON THE DEVELOPMENT AND INTENSITY OF TROPICAL CYCLONES

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1. INTRODUCTION

Tropical cyclones often develop from tropical easterly waves off the coast of Africa. Some of the most notable hurricanes in the past four years (Ivan, Katrina, etc.) formed from tropical waves off the coast of Africa. These waves and incipient tropical cyclones are often enveloped in wind-blown dust from the Saharan Desert. The resulting Saharan Aerosol Layer (SAL) plays an important role during the initiation and intensification of tropical cyclones in the entire tropical North Atlantic Ocean basin [Lau and Kim, 2007; Evan et al., 2006; Wong and Dessler, 2005; Dunion and Velden, 2004; Rothman et al., 2004]. In fact, the persistence of dust in the 2006 hurricane season is cited as a primary reason for the decreased tropical cyclone activity in the North Atlantic Ocean in the 2006 season and may have directly caused Tropical Storms Chris and Debby to dissipate despite forecasts that they would intensify [Klotzbach and Gray, 2006].

The SAL has a number of characteristics that affects the development and intensification of tropical cyclones. First, it originates from an area known to produce a deep layer of hot and dry conditions. Second, the SAL contains a large amount of dust aerosol, which is known to absorb solar radiation. The absorption of solar radiation keeps the temperature high and the relative humidity low as the layer transports over the North Atlantic Ocean. These characteristics have several possible effects on tropical cyclone development and intensification, including stabilization of the tropical storm environment [Evan et al., 2006; Dunion and Velden, 2004], reduced latent heating, increased vertical wind shear, and the formation of baroclinic instability [Rothman et al., 2004].

2. METHODOLOGY

This paper uses Moderate Resolution Imaging Spectroradiometer (MODIS), CloudSat, and the Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) lidar data, all from the A-train constellation of satellites to further study these effects. These data will provide the first simultaneous measurements of the vertical distribution of cloud water and aerosol particles within a tropical cyclone. The MODIS instrument on-board the Aqua and Terra satellites provide cloud top temperature and aerosol optical depth to correlate the presence of aerosols with the intensity of convection within a tropical cyclone. The CALIPSO lidar provides measurements of aerosol optical properties such as aerosol extinction and backscatter at wavelengths of 0.532 µm and 1.064 µm in a vertical column of the atmosphere [Winker et al., 2003]. CloudSat consists mainly of a 94 GHz cloud profiling radar that provides vertically resolved radar reflectivity. The radar obtains data at 2 km horizontal resolution and 500 m vertical resolution and a calibration accuracy of 2.0 dBZ [Stephens et al., 2002]. CloudSat will be able to observe vertical cloud structure deeper into the tropical system where the CALIPSO lidar beam is unable to penetrate. The combination of these data will allow a direct relationship to be established between the horizontal and vertical distribution of these aerosols in the tropical cyclone environment and the convective clouds that make up the tropical cyclone.

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3. DISCUSSION

On 2 August 2006, Tropical Storm Chris, a circularly-symmetric mass of clouds, observed in the MODIS cloud-top temperature product, approaches a thick aerosol layer, observed in the MODIS aerosol product, to the west of the storm (Fig. 1). The vertical detail of the elevated aerosol layer entering Tropical Storm Chris is observed in the CALIPSO backscatter image in Fig. 2. The elevated layer of aerosols is observed approximately 500 km to the west of Tropical Storm Chris in Fig. 2 and enters the front left quadrant of the west-northwest moving storm (Fig. 1). Aerosol optical depths are between 0.25 and 0.5 and are concentrated 3-4 km above sea level. The storm quickly dissipated within the next 24 hours.

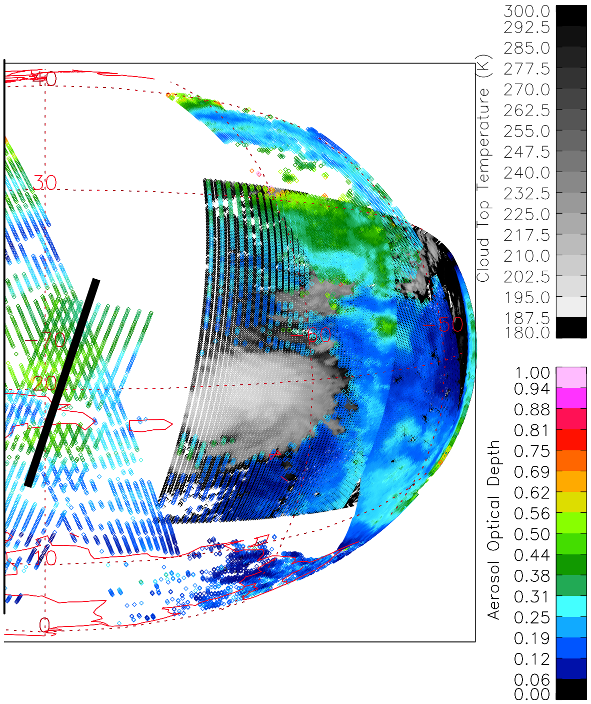

Figure 1. MODIS cloud top temperature (gray-scale) on 2 August 2006 at 1450 UTC plotted on top of MODIS aerosol optical depth (color-scale) in the area around Tropical Storm Chris near its peak intensity. The thick solid black line is the location of the CALIPSO observations shown in Fig. 2.

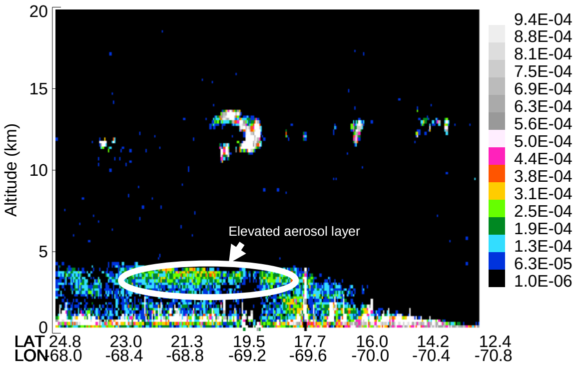

Figure 2. CALIPSO observed 0.532 µm attenuated backscatter (km^{-1} sr^{-1}) on 2 August 2006 at 620 UTC. The highest attenuated backscatter in the image exceeds 1 x 10^{-3} km^{-1} sr^{-1}.

CloudSat cloud radar reflectivity and CALIPSO backscatter are plotted in Fig. 3 on 1 August 2006 as Tropical Storm Chris was intensifying. Tropical Storm Chris shows evidence of convective bursts that pushed clouds above 15 km near the center of the storm. This intense convection is identified as part of the mechanism for intensifying tropical cyclones [Montgomery et al., 2006] and was observed in Hurricanes Dennis (2005) and Emily (2005) during NASA's Tropical Cloud Systems and Processes Experiment [Halverson et al., 2007]. Cloud radar reflectivity can be converted into liquid water content and backscatter can be converted into aerosol mass for ingestion into mesoscale models. The data within figures 1-3 provide enough data to model the interaction of Tropical Storm Chris with the elevated aerosol layer. MODIS cloud top temperature on subsequent days provides validation data for the simulation. Unfortunately, CALIPSO and MODIS aerosols are only observed where there is little or no cloud cover.

Similar interactions are seen in Tropical Storm Debby (2006) and Hurricane Claudette (2003). All storms went through considerable increases in their central pressure within a 24 hour period after a large area of aerosol optical depths greater than 0.35 were observed within 600 km of the storm (Fig. 4).

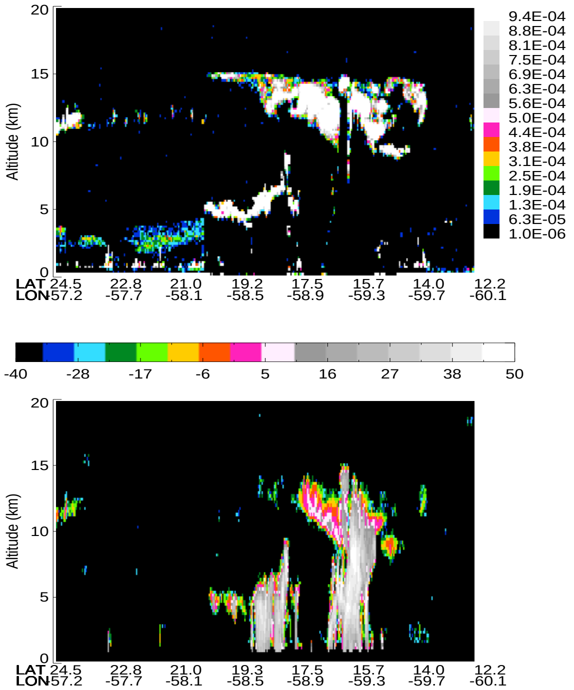

Figure 3. CALIPSO observed 0.532 µm attenuated backscatter (km^{-1} sr^{-1}) on 1 August 2006 at 415 UTC (top) and CloudSat observed radar reflectivity (dBZ) on 1 August 2006 at 420 UTC (bottom).

4. FUTURE WORK

This study will be expanded to all tropical cyclones within all tropical cyclone seasons when MODIS AQUA and Terra were functioning (starting in 2002). Correlations will be calculated between a number of variables associated with tropical cyclone intensity and aerosol optical depth in different areas relative to tropical cyclone center and motion. A number of other parameters affect tropical cyclone intensity and these too will be measured. However, many of these factors are associated with the Saharan aerosol layer and may not be able to be separated. Also, the vertical cross-sections of aerosols and cloud water can provide input data into cloud scale and mesoscale models to further study and understand this interaction.

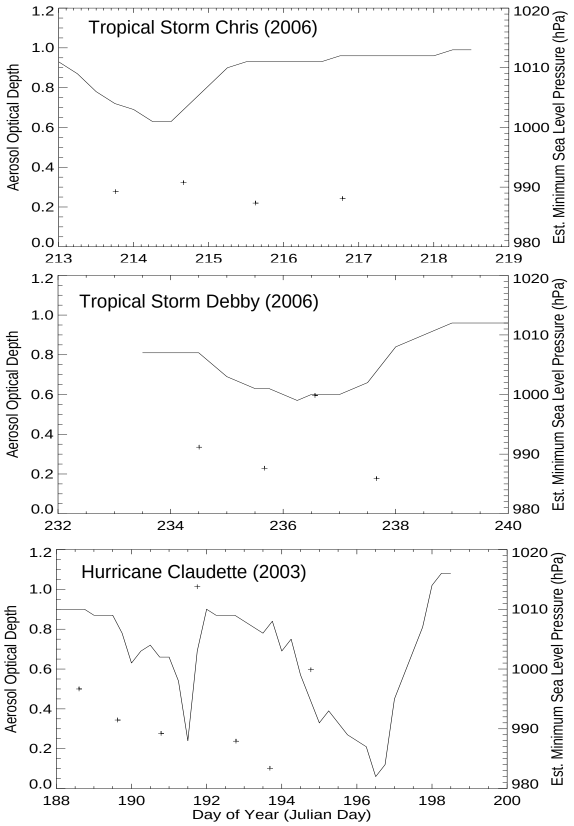

Figure 4. Aerosol Optical Depth (+) from MODIS and Estimated Sea Level Pressure (solid line, hPa) from the National Hurricane Center for Tropical Storm Chris (top), Tropical Storm Debby (middle), and Hurricane Claudette (bottom)

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