Authors: Kathryn Sauter, Tristan L'Ecuyer

Title: The Impact of Convection on the Transport and Redistribution of Dust Aerosols

Type of Presentation: Oral

Short Abstract:

The distribution of mineral dust aerosols that originate from the Saharan Desert and sweep across the tropical Atlantic Ocean can significantly impact climate processes in the region. The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) mission was launched in April 2006 as a part of the A-Train constellation in order to gain a better understanding of the role that aerosols and clouds play in the complex climate system [*Winker et al.*, 2006, 2007]. The ability to assess the vertical and spatial transportation of dust across the Atlantic Ocean using CALIPSO aerosol retrievals provides valuable insight into the effects of dust aerosols on the Earth's climate system. This study couples in-situ observations of dust storm events with aerosol optical depth from the polar orbiting CALIPSO ground track and the GOES East Pathfinder Atmospheres Extended (PATMOS-x) geostationary cloud dataset to constrain the processing, transport and redistribution of dust aerosols over the tropical Atlantic Ocean before and after the passage of convection. Cloud top temperature, cloud optical thickness, and cloud top size are further used to quantify the sensitivity of wet deposition to the intensity of tropical convection. Identifying the removal impacts from convection on the dust aerosols will allow for the interpretation and understanding of processes that transport and redistribute the dust. It is conjecture that when there are more convective clouds present, more dust will be removed from the atmosphere. Preliminary results provide evidence that convection both reduces downstream dust optical depths and occasionally transports dust to higher altitudes than the main Saharan dust layer. These redistribution and scavenging effects have implications for direct and indirect impacts of dust on radiation balance both locally and downstream of the convection. Further analysis of these complementary datasets may offer new revelations into aerosol-cloud climate interactions.

THE EFFECT OF CONVECTION ON THE TRANSPORT AND DISTRIBUTION OF DUST AEROSOLS

Kate Sauter & Tristan L'Ecuyer • University of Wisconsin

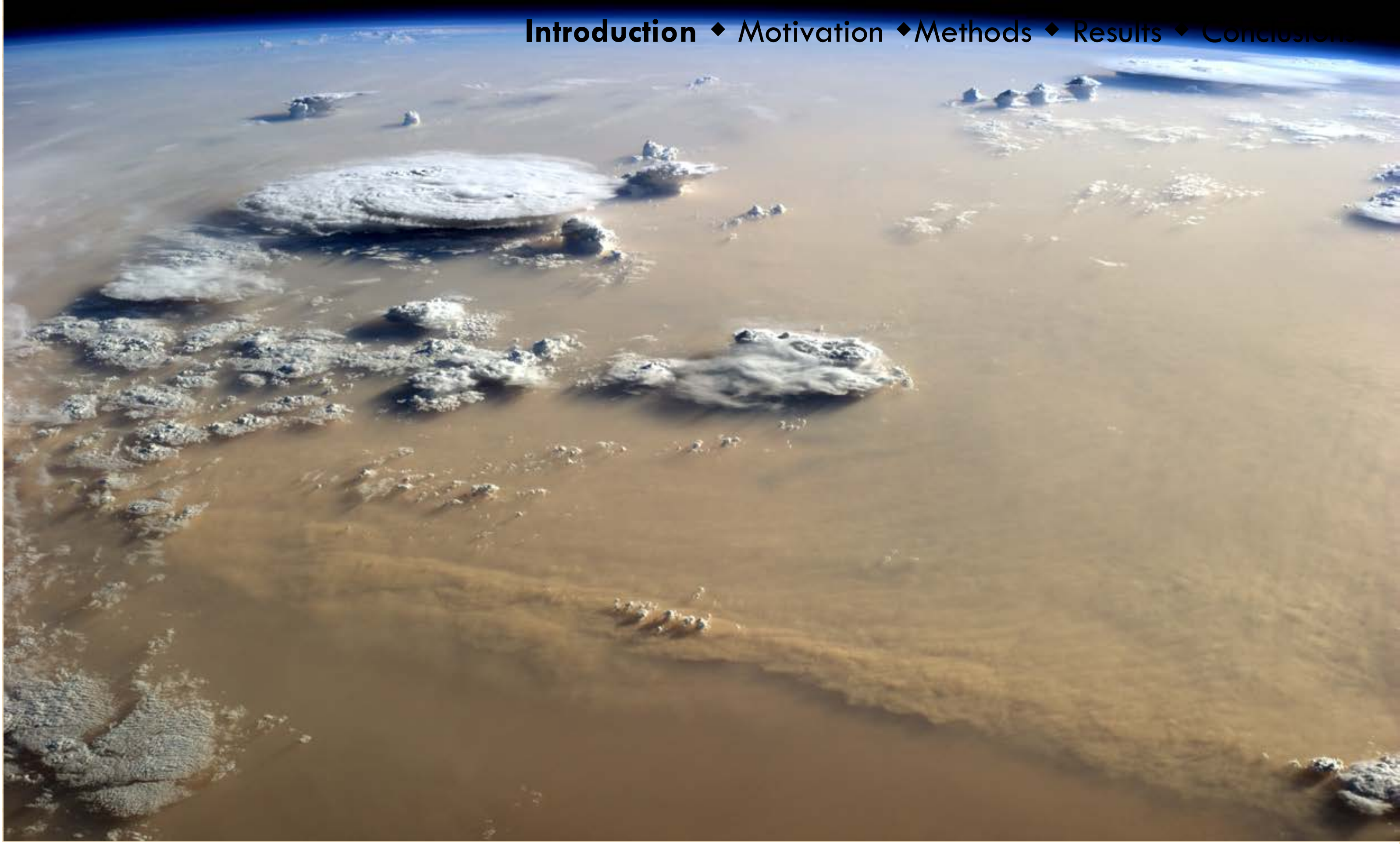
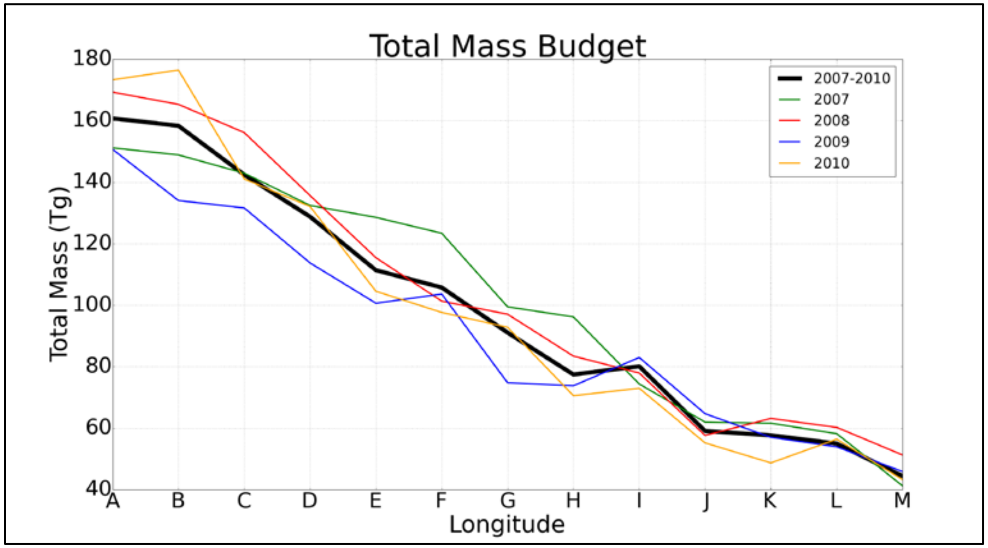


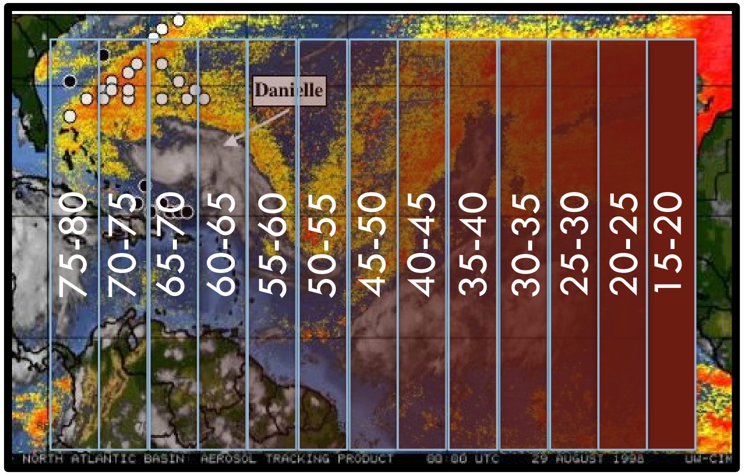
Image from NASA's Earth Observatory taken from the International Space Station of the African landscape

Why Dust Aerosols?

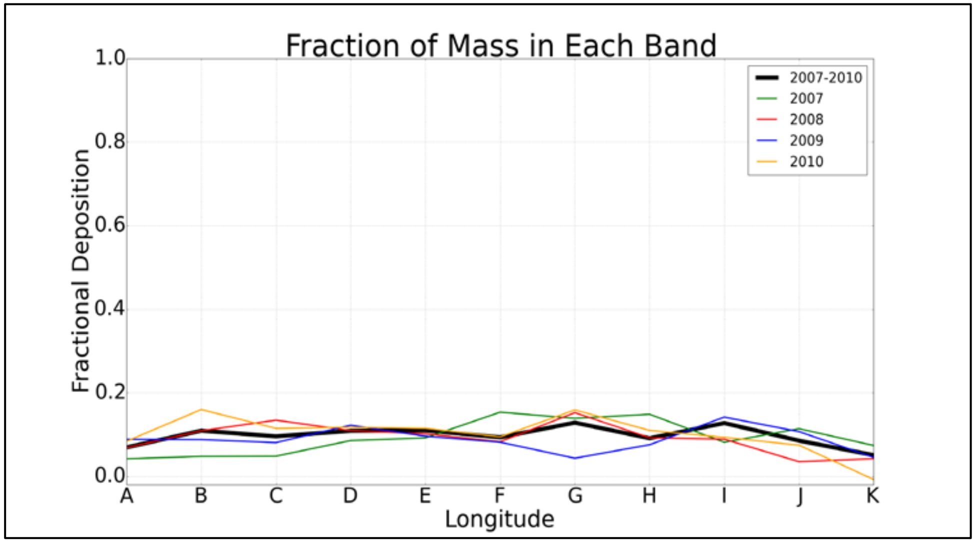
- Dust aerosols from the Saharan Desert account for 60-70% of global dust emissions.
- Significant climate impacts:
  - Act as CCN, or IN, altering cloud microphysical properties.
  - Impact radiation budget through scattering and absorption.
  - Connected to marine biogeochemical processes.

Tropical Atlantic Dust Budget



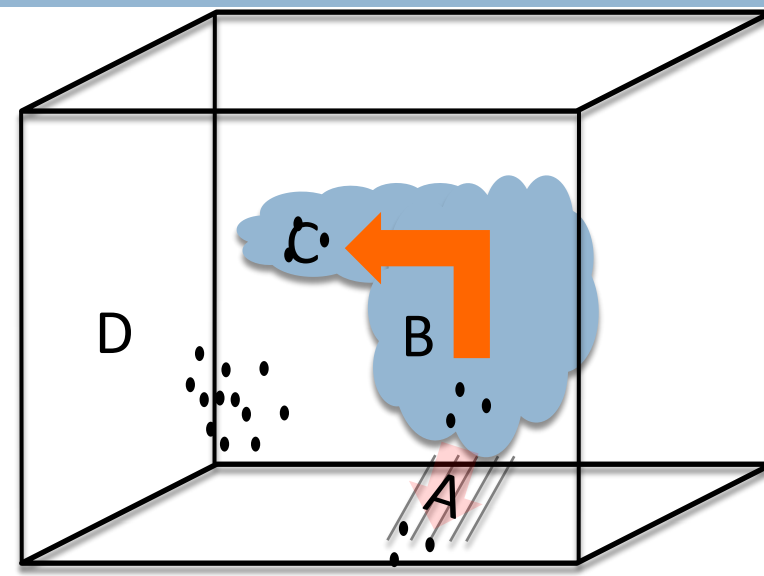


A: 15W-20W B: 20W-25W
C: 25W-30W D: 30W-35W
E: 35W-40W F: 40W-45W
G: 45W-50W H: 50W-55W
I: 55W-60W J: 60W-65W
K: 65W-70W L: 70W-75W
M: 75W-80W



Science Questions

- How does convection impact the dust layer?
- How much dust is removed from the atmosphere due to precipitating storms?
- Where do the convective storms redistribute the dust in the atmosphere and how does the vertical distribution of dust change?



A: Precipitation, wet and dry deposition.
B: Dust in hydrometeors.
C: Dust returned following evaporation and sublimation.
D: Horizontal Advection

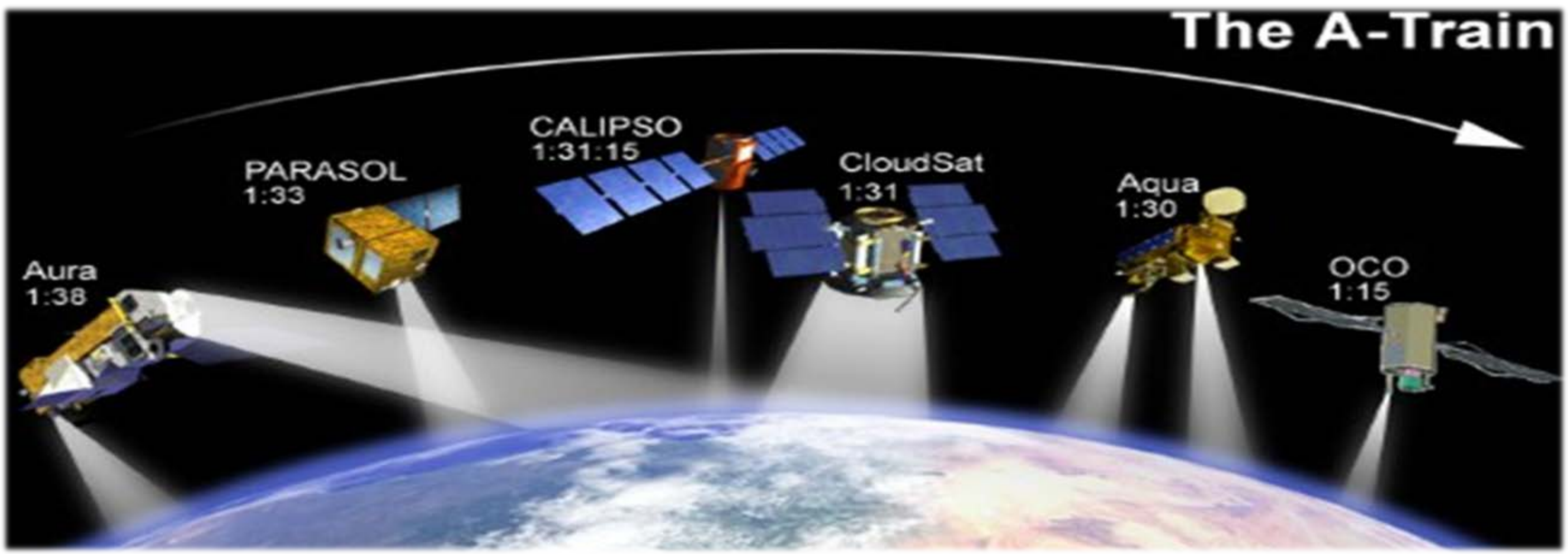
HYPOTHESIS: More dust will be removed when convective clouds are present.

Outline

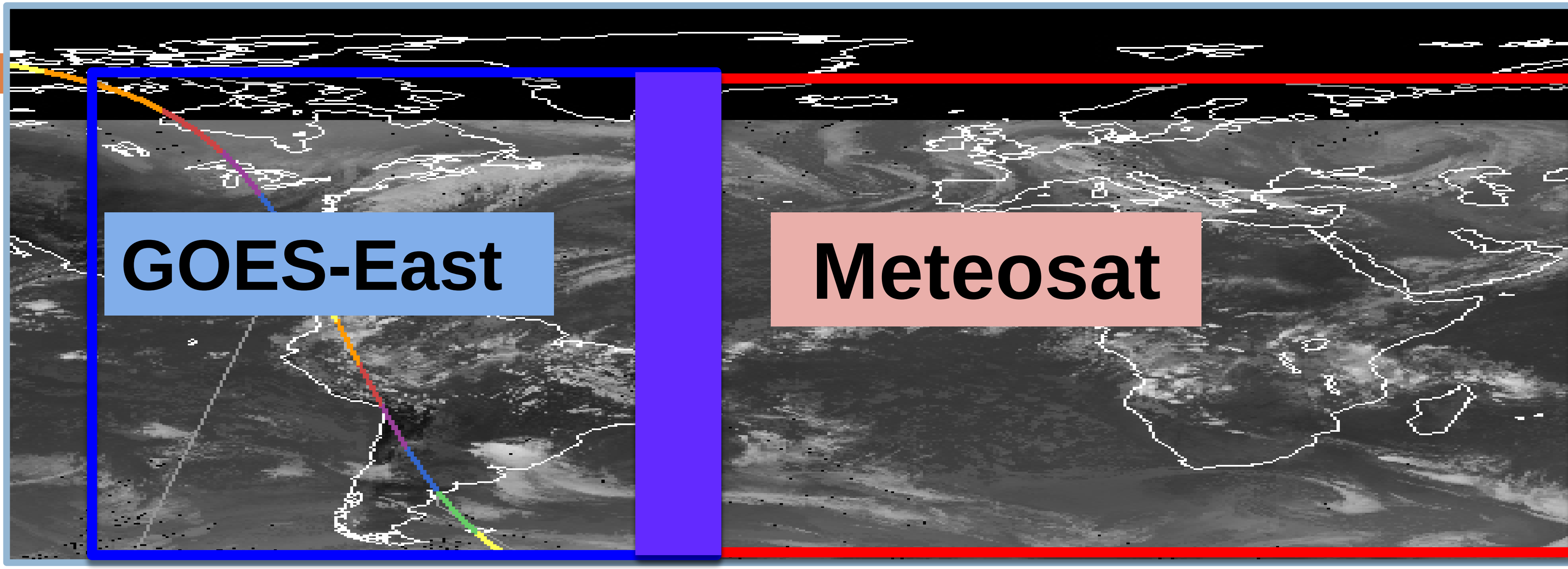
- Datasets
- Collocation
- Tropical Storm Debby Case Study
- Composite Analysis
- Conclusions

Datasets

- Pathfinder Atmospheres Extended (PATMOS-x)
- CloudSat
- Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)



PATMOS-x



- Suite of cloud products derived from Advanced Very High Resolution Radiometer (AVHRR) sensors.
- Processes level 1b data from satellites to obtain cloud products including cloud and aerosol information.
- On NOAA instruments since 1978.
- Cloud detection using a naïve Bayesian cloud mask algorithm.
- Hourly Data

Variables Used:

- Cloud Top Temperature
- Cloud Optical Depth
- Cloud Top Height

CloudSat and CALIPSO

CloudSat

- Cloud Profiling Radar (CPR)
  - 94 GHz
  - Minimum detectable sensitivity of ~29dBz.
- Detects vertical distribution of clouds.

CALIPSO

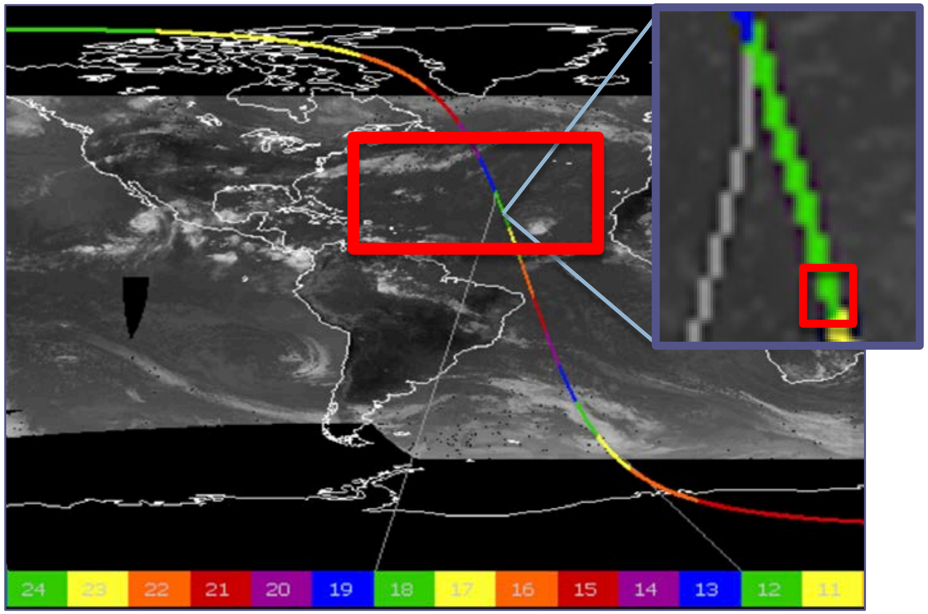
- Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP)
  - Two orthogonal polarization components – 532nm and 1064nm
- Detects vertical distribution of aerosols.

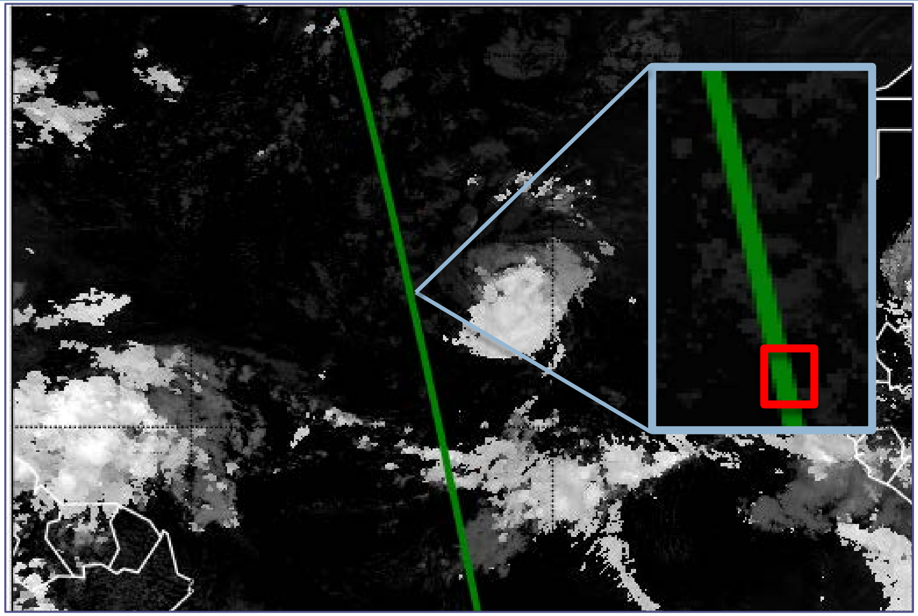
- January 2007-December 2010
- 1:30 and 13:30 equatorial crossing time
- 16 day repeating cycle

PRODUCTS USED:

- 2b-FLXHR-LIDAR-AUX
- 2c-PRECIP-COLUMN
- 2b-GEOPROF-LIDAR

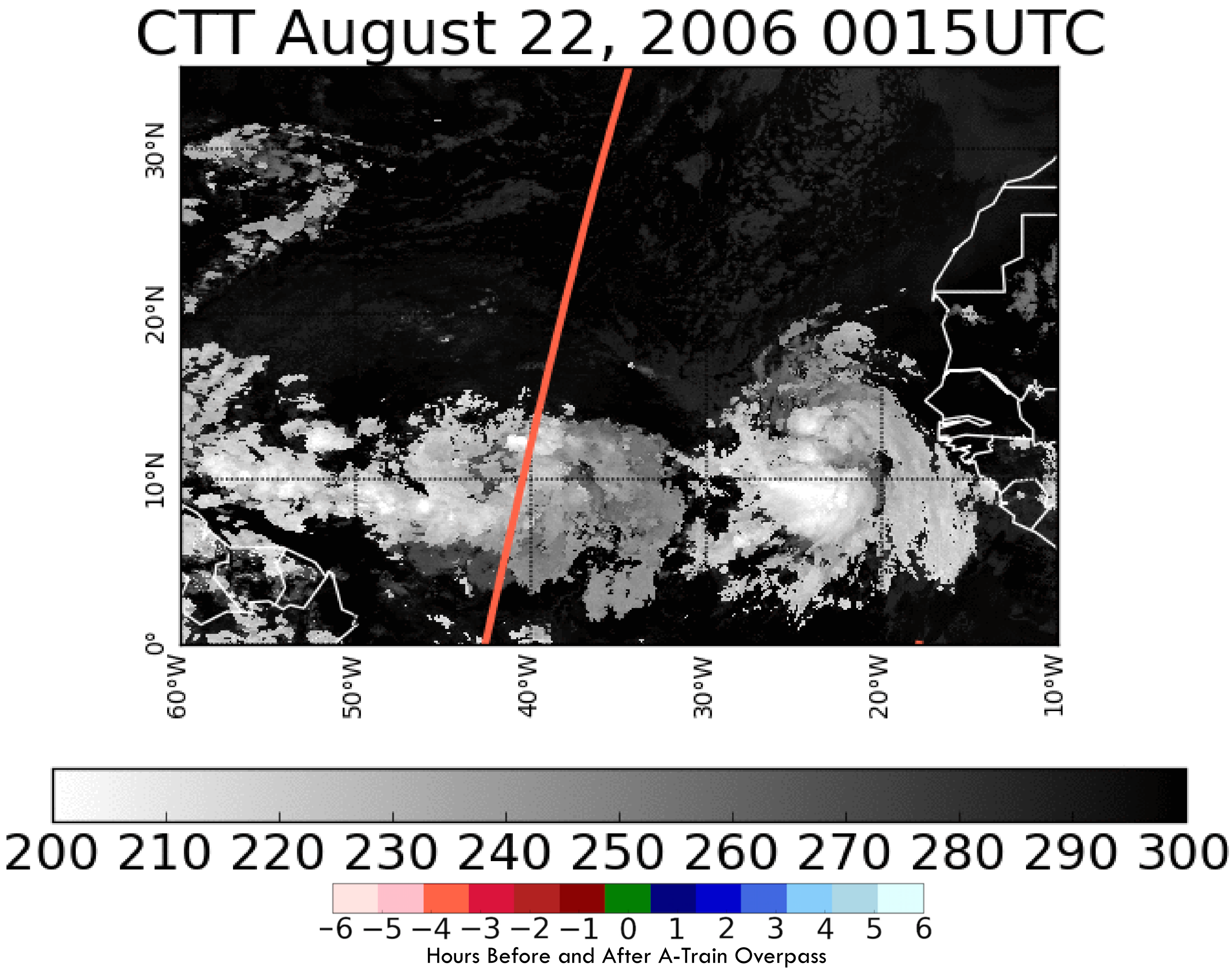
Matching GOES-East/Meteosat to CloudSat



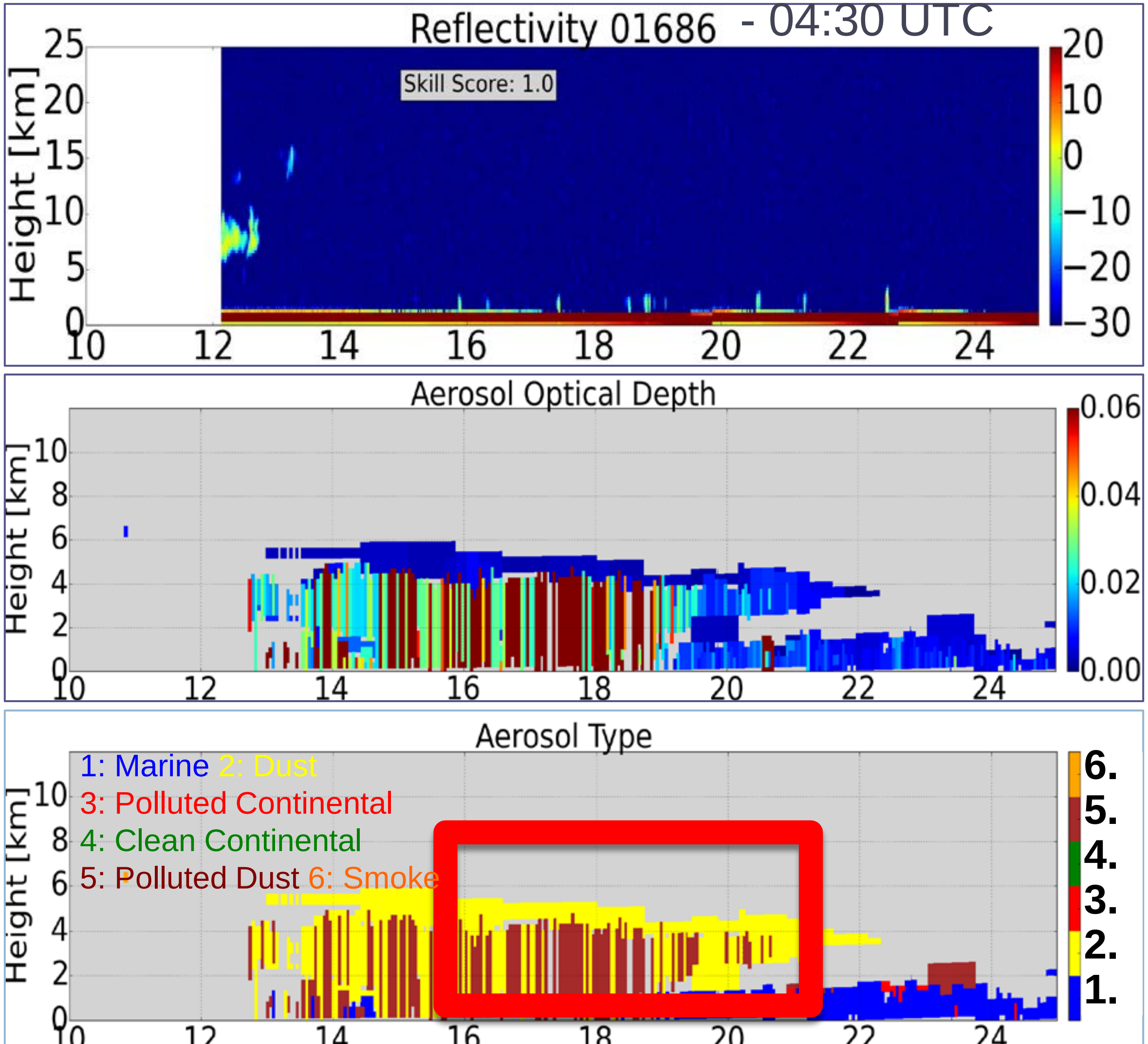


- Determine day and time of CloudSat overpass.
- Find GOES-East/ Meteosat pixel closest to CloudSat.
- Retrieve cloud top temperature, cloud top height, cloud optical depth from PATMOS-x.

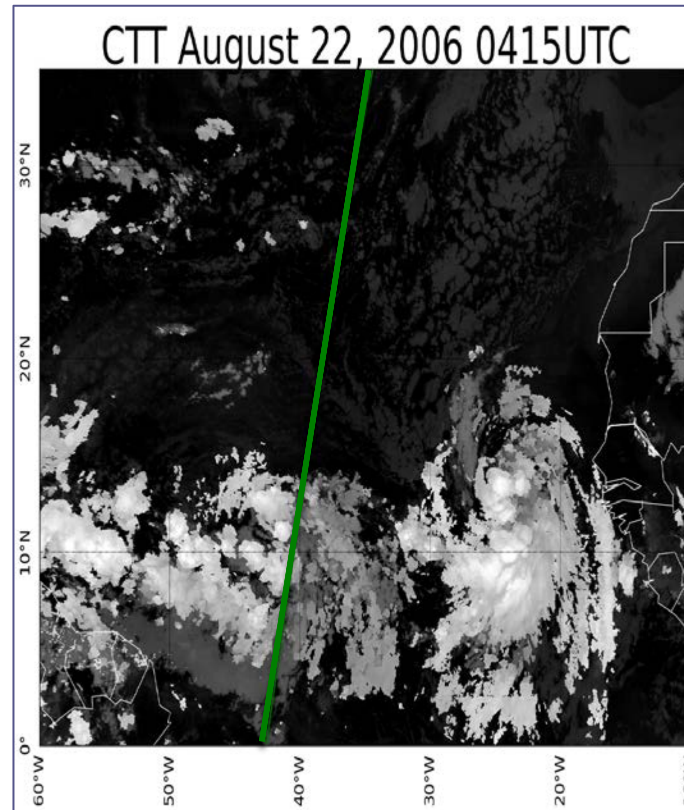
Tropical Storm Debby Case Study


CTT August 22, 2006 0015UTC
30°N
20°N
10°N
0°
60°W
50°W
40°W
30°W
20°W
10°W
200 210 220 230 240 250 260 270 280 290 300
−6 −5 −4 −3 −2 −1 0 1 2 3 4 5 6
Hours Before and After A-Train Overpass

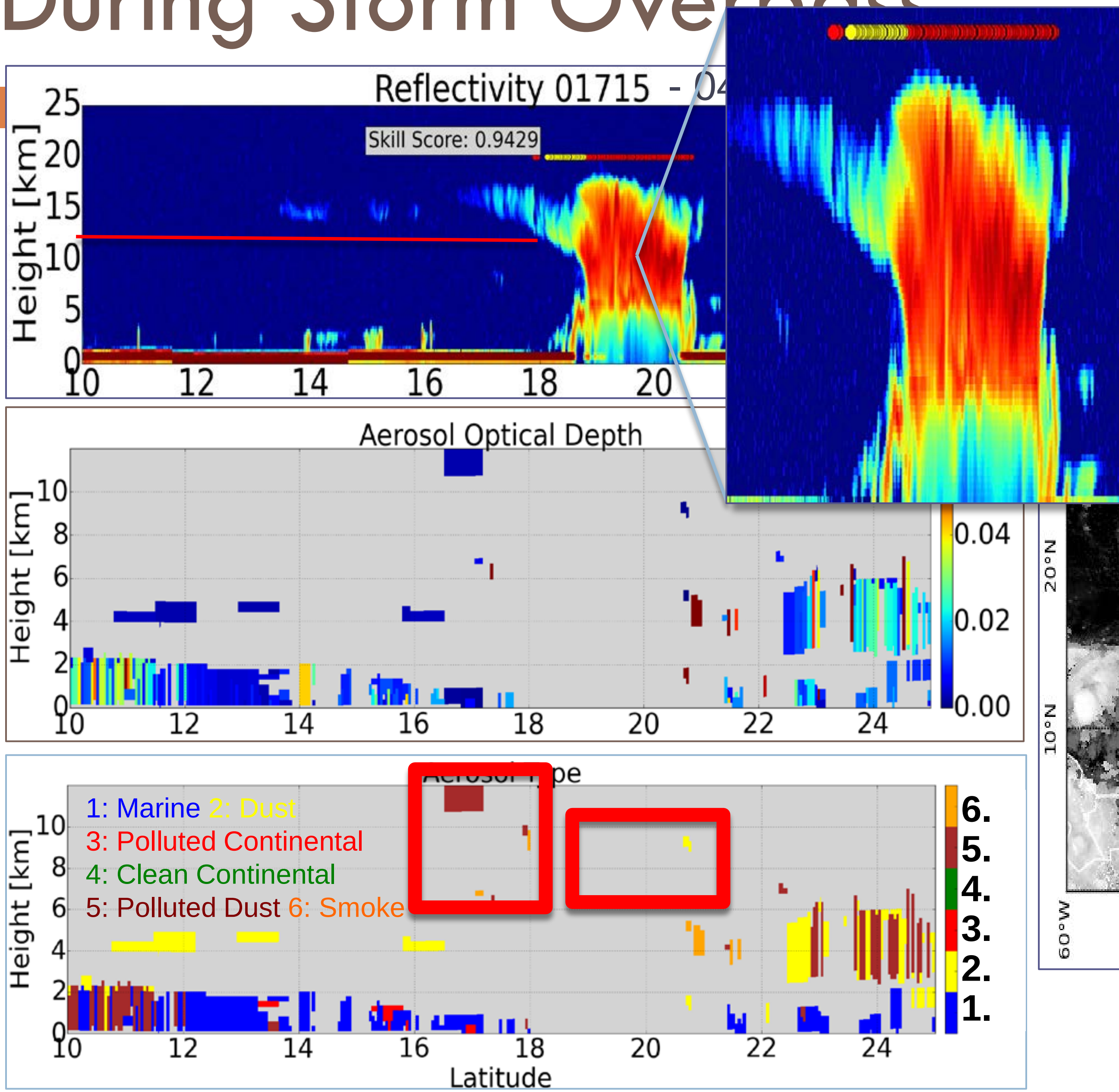
Before Storm Overpass



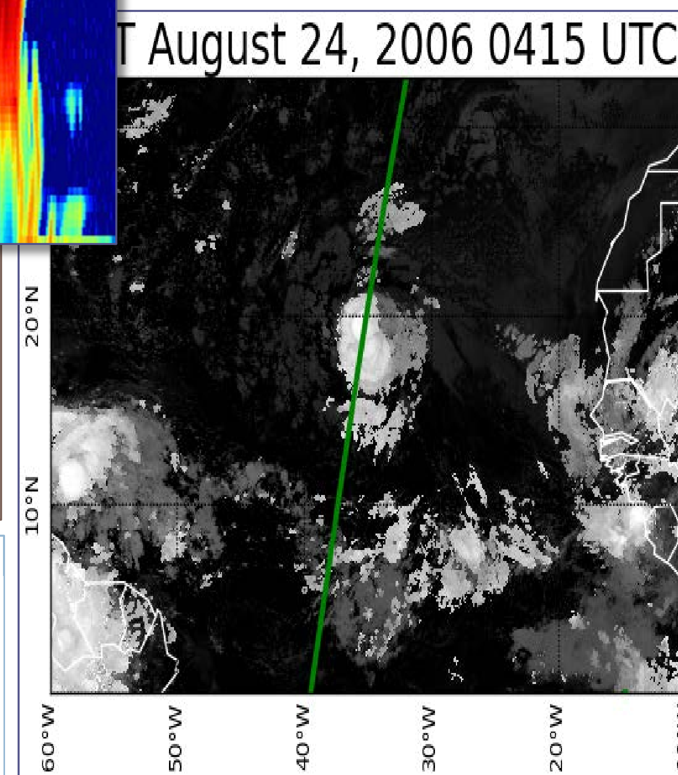
August 22, 2006
04:15 UTC



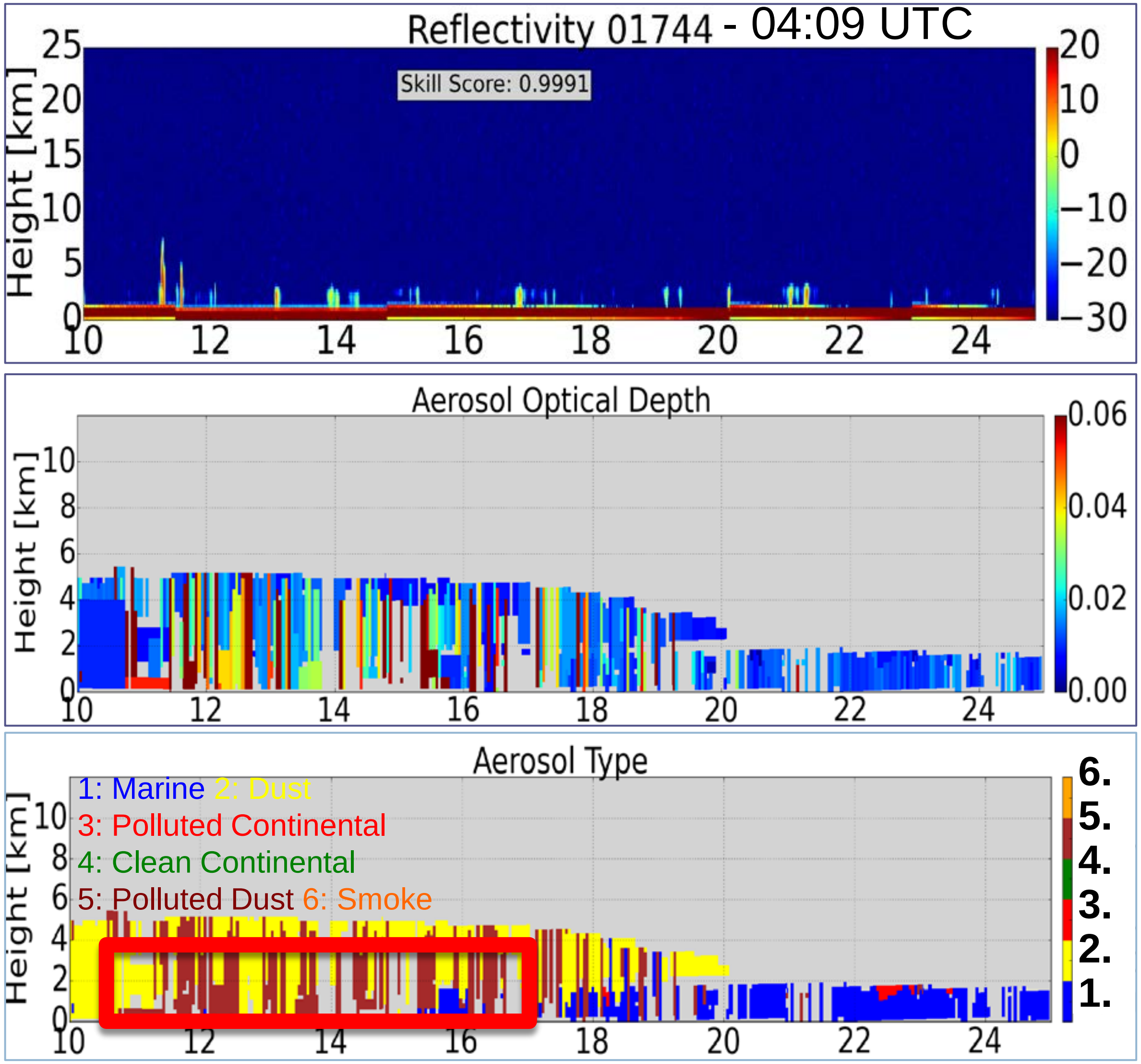
During Storm Overpass



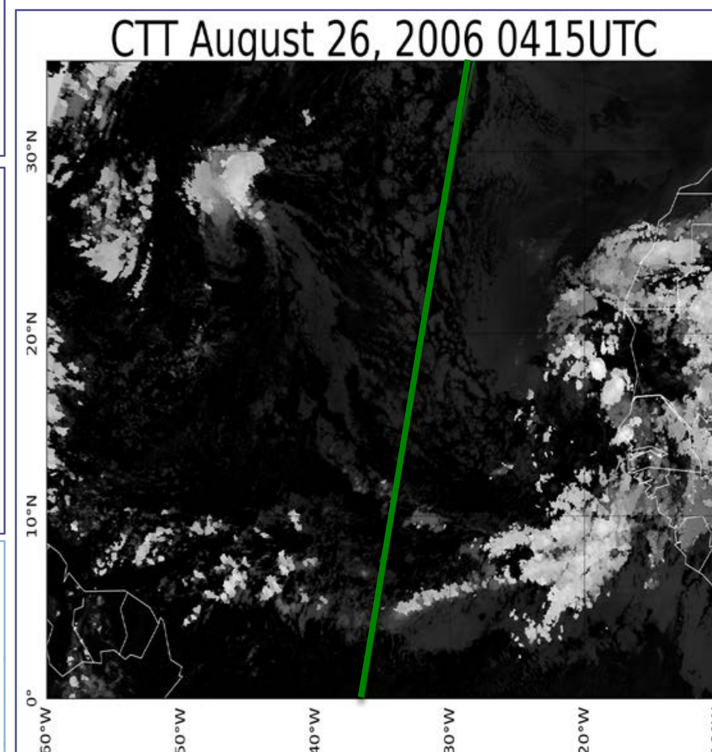
August 24, 2006
04:15 UTC



After Storm Overpass



August 26, 2006
04:15 UTC



Dust Budget Analysis

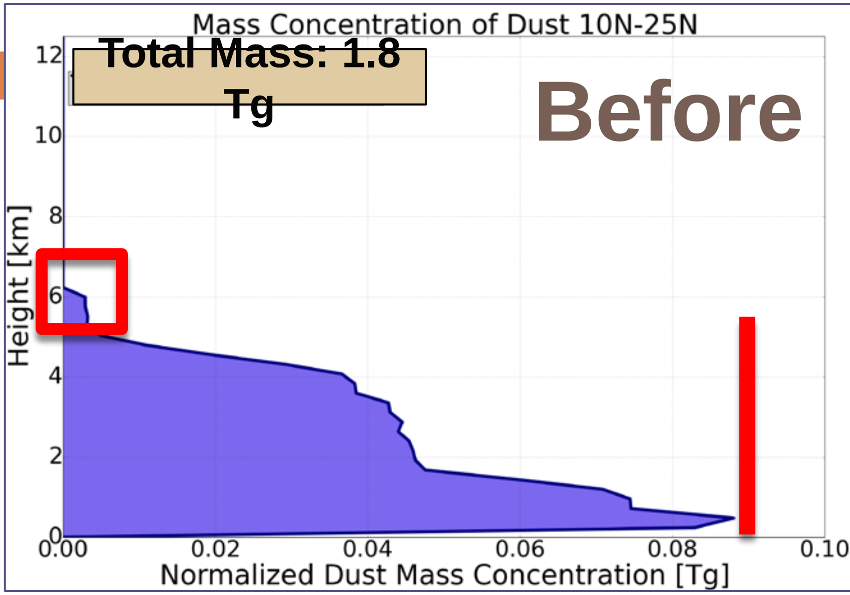
- Using the AOD from CloudSat and CALIPSO, the mass column concentration of dust can be found.

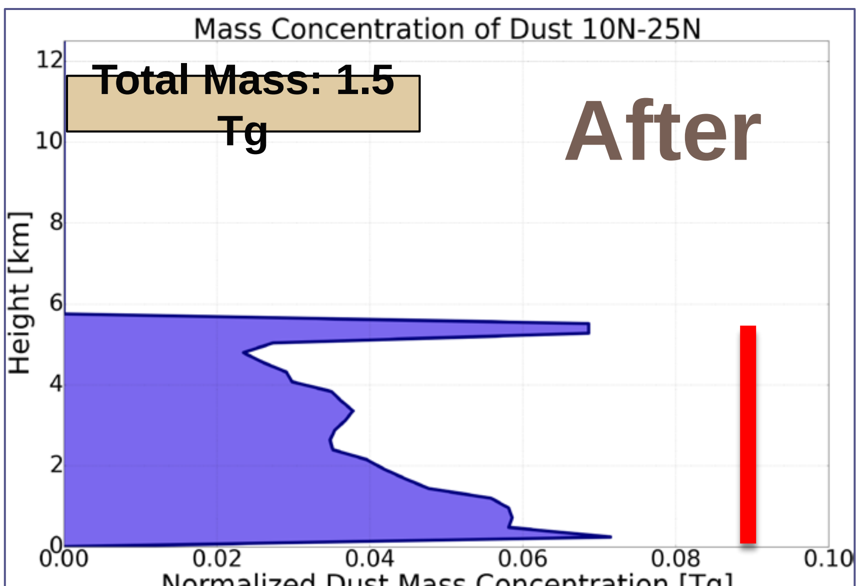
$$\boxed{\mathbf{M_{du} = (2.7\ g/m^2) * \tau * Area}}$$

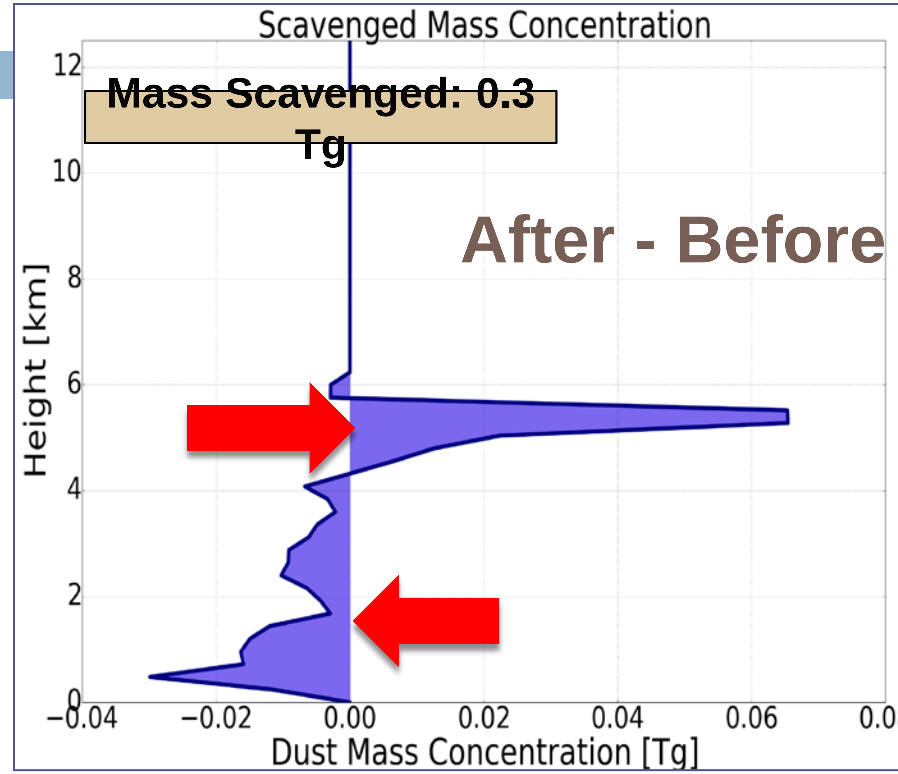
- Comparing the mass concentration of dust before convection and after convection indicates amount of dust scavenged by the storm.

Kaufman et al., GRL, 2005

TS Debby Budget Analysis







- Negative values indicate higher dust concentration before storm passes.
- Positive values show higher dust concentrations after storm passes

Conclusions

- Dust aerosols are lofted and redistributed to upper and middle levels of the atmosphere due to evaporation and sublimation, particularly around anvil regions of the storm.

- With respect to large, individual, convective storm systems, dust aerosol concentration decreases and is redistributed to higher levels in the atmosphere, relative to pre-storm amounts.

Ongoing and Future Work

- A composite analysis has been started by splitting Atlantic Ocean into 5° longitude bands from 10°W to 80°W.
  - Convection is identified, an all CloudSat/CALIPSO overpasses in the same location are found.
  - Reconstruct the composite evolution of dust AOD over a typical convective lifecycle.
- Combine these results with CSU RAMS model runs and NAMMA aircraft data.
- Use a cluster analysis for identifying convection.
- Indirect and direct radiative impacts.
- Ocean Fertilization.

Acknowledgements

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Questions?

References

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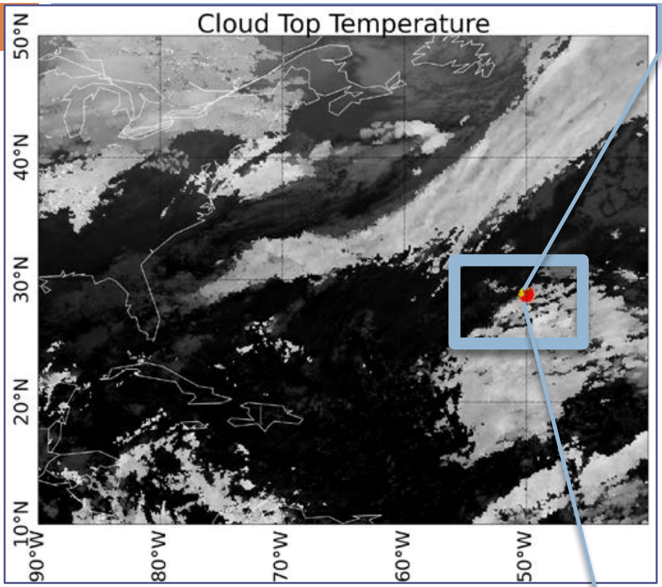
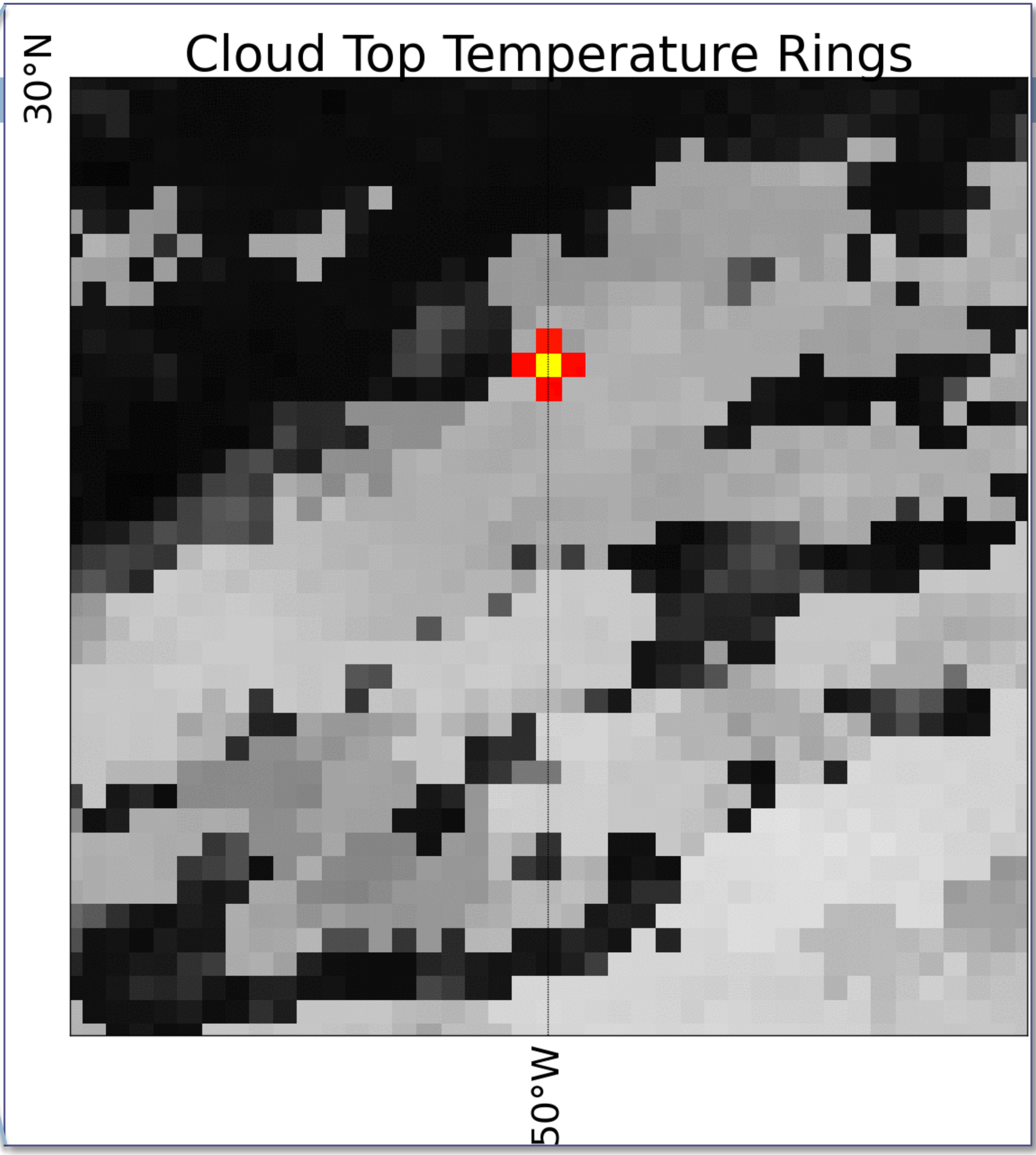
Supplemental Slides

Area Footprints



Footprint	Area (km^2)	Avg. CTT (K)
1	729 km^2	240.54K
2	1773 km^2	239.63K
3	3393 km^2	241.60K
4	5517 km^2	242.86K
5	10161 km^2	243.64K
6	13653 km^2	246.15K
7	19089 km^2	248.51K



Identifying Convection

Footprint Size (FS)	Area
1	729 km^2
2	1773 km^2
3	3393 km^2
4	5517 km^2
5	10161 km^2
6	13653 km^2
7	19089 km^2

Convection

↓

COD FS 1 >= 5

↓

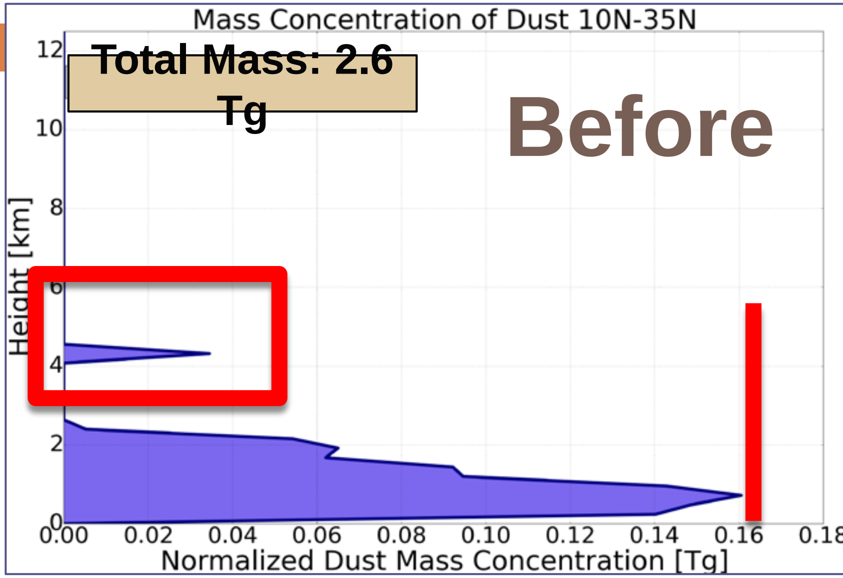
CTT FS (7/1) >FS(2/1)

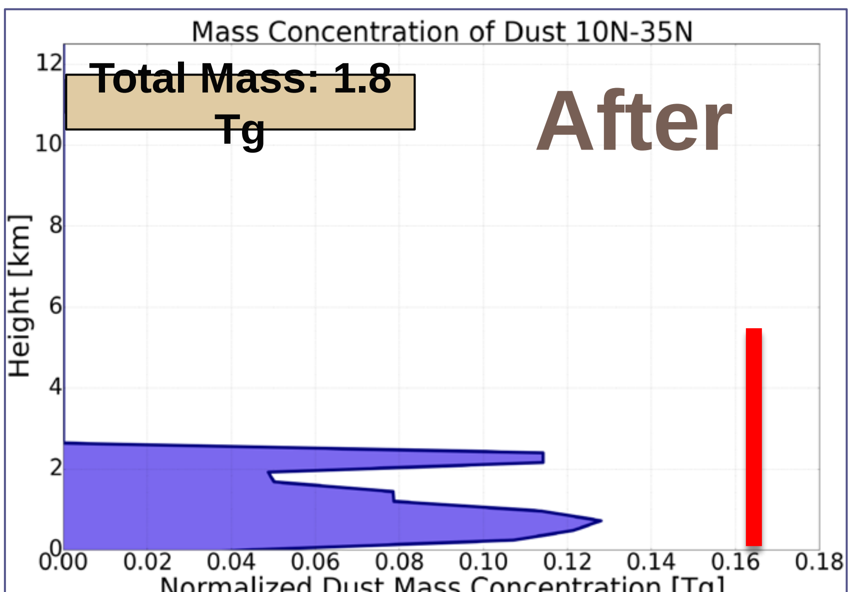
↓

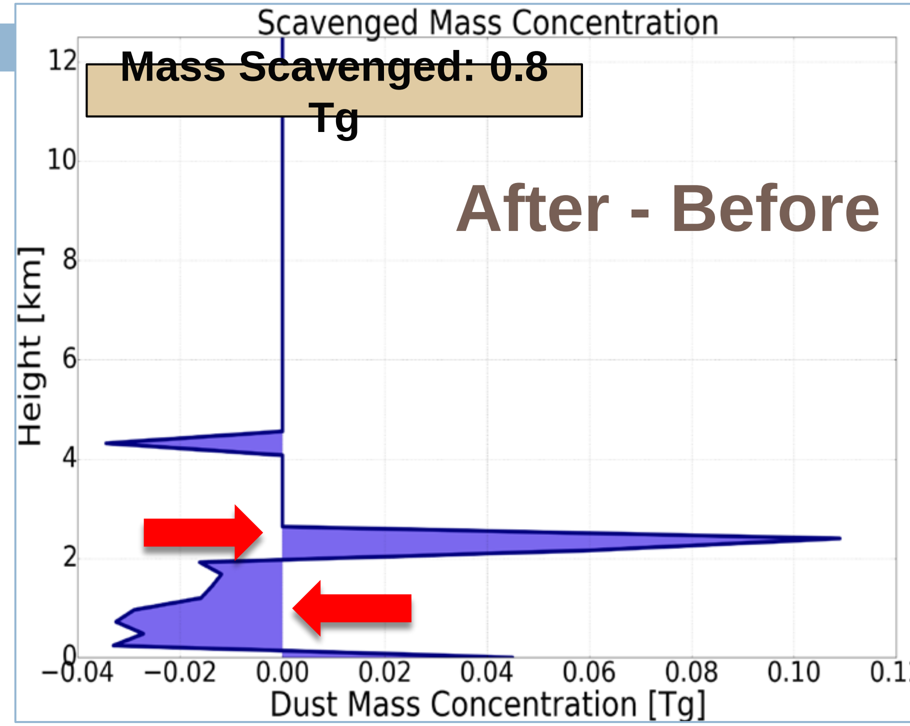
CTT FS Increasing and FS 1 <= 225K

Mature Convection

Hurricane Helene Budget Analysis

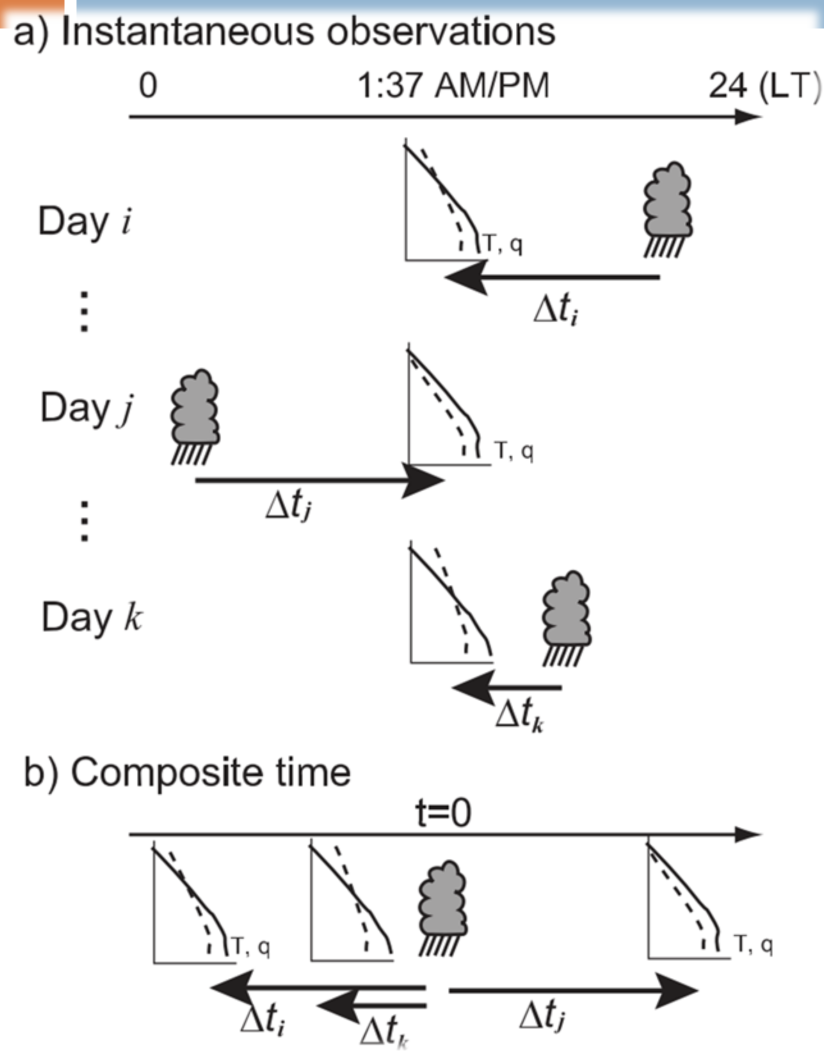






- Dust scavenged out after storm
- Negative values indicate higher dust concentration before the storm passes.

Time Dimension to Composite Analysis



Masunaga, JAS, 2012

- Use Masunaga composite approach
- Find profiles of AOD from CloudSat/CALIPSO when convection is flagged from PATMOS-x data.
- Reconstruct the composite evolution of dust AOD over a typical convective lifecycle.