Coupling Satellite Observations and Models to Study Atmospheric Processes

How Tropical Convection Influences the Saharan Dust Layer

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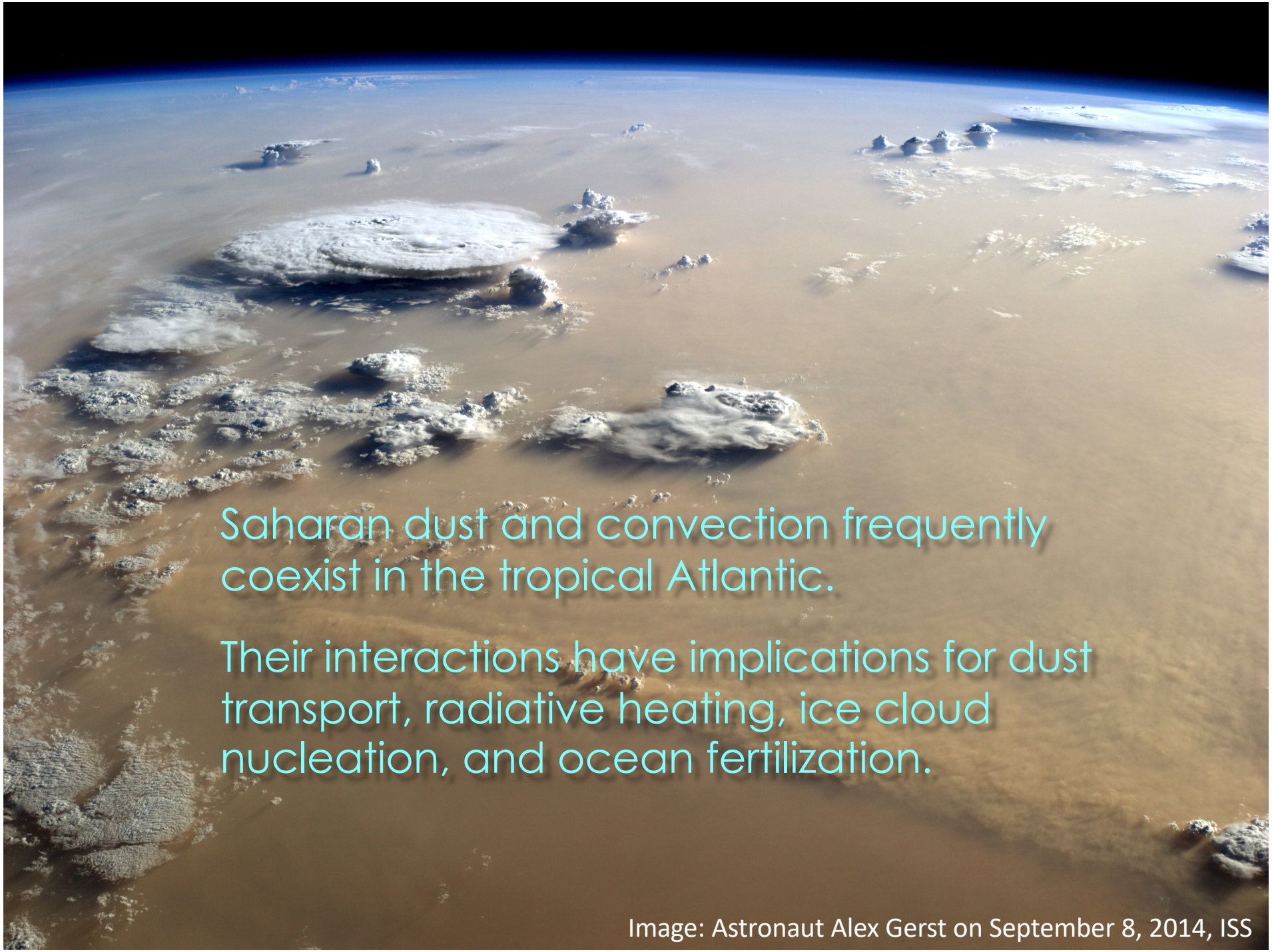
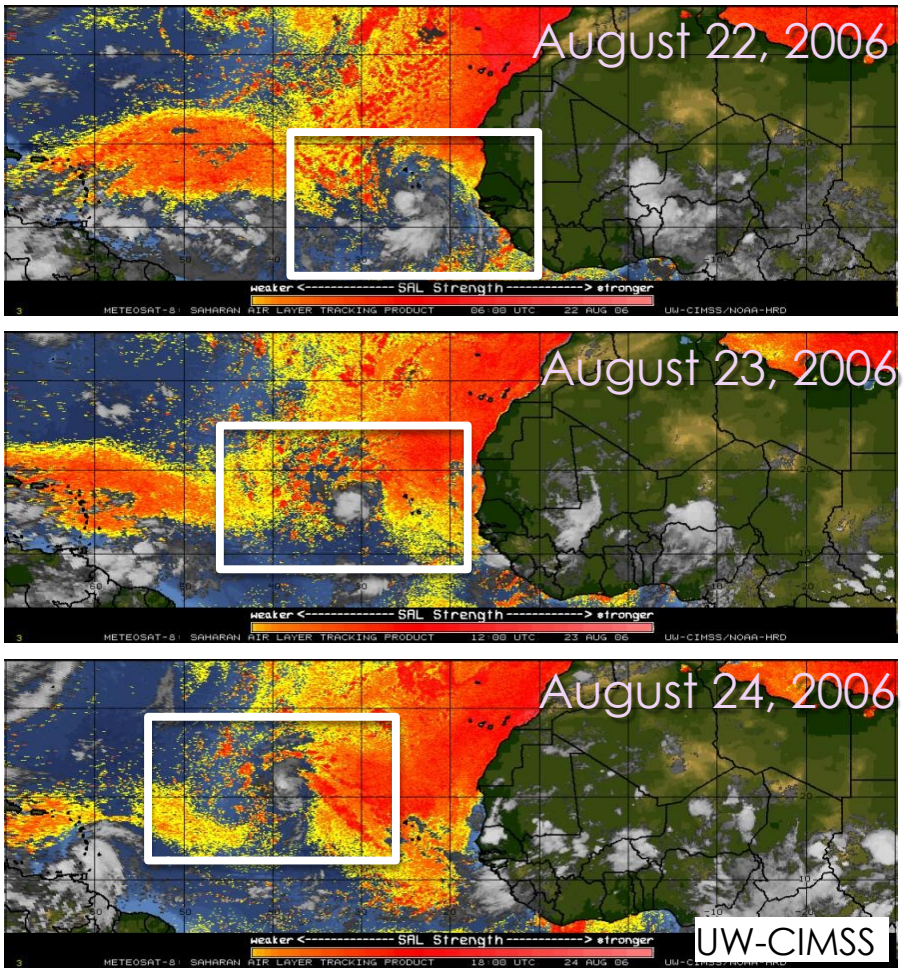

Saharan dust and convection frequently coexist in the tropical Atlantic.
Their interactions have implications for dust transport, radiative heating, ice cloud nucleation, and ocean fertilization.
Image: Astronaut Alex Gerst on September 8, 2014, ISS

Tropical Storm Debby (2006)

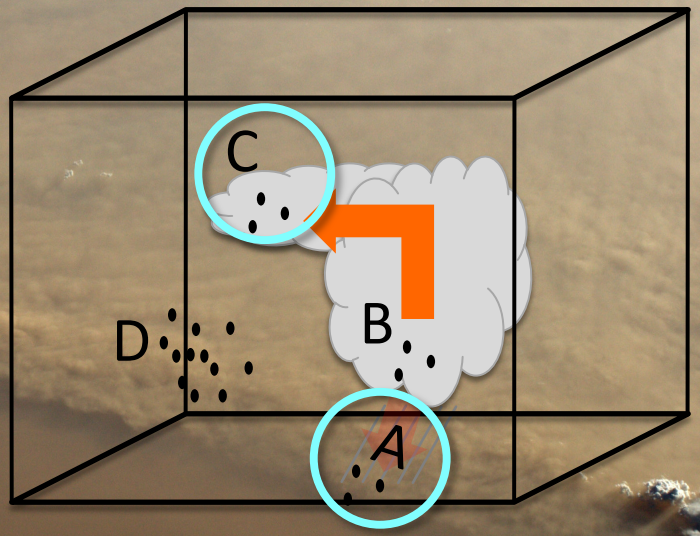


- Oberved during NAMMA in 2006
- Storm traversed and interacted with the Saharan Air Layer (SAL) for multiple days
- Mutual impacts
  - SAL can suppress cyclone development
  - Convection redistributes dust and modifies thermodynamic structure of SAL

Zipser et al, *BAMS* (2009)

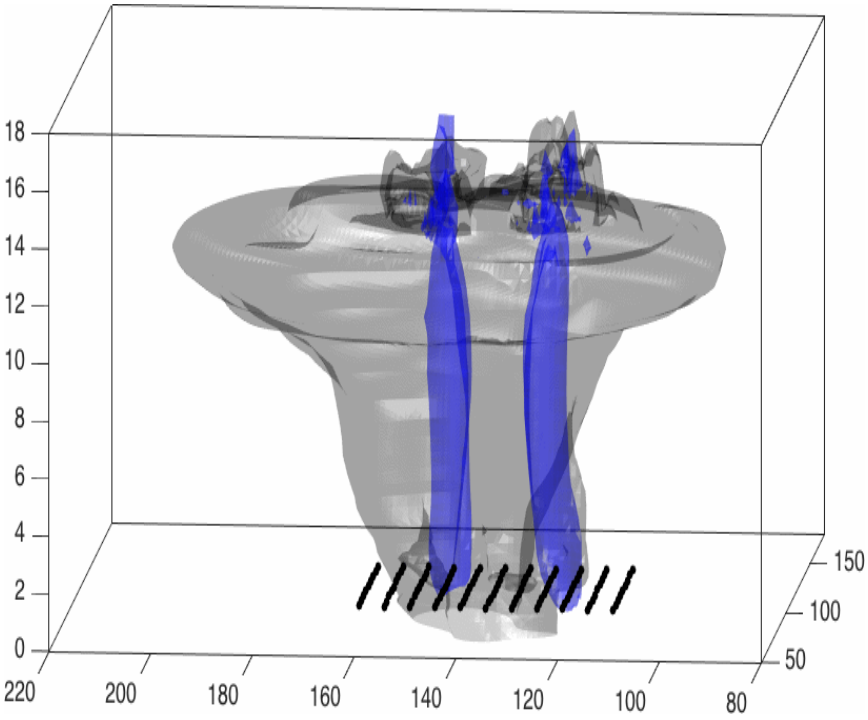
Specific Questions

- How much dust does tropical convection remove from the atmosphere?
- How much dust is lofted convection by tropical convection?



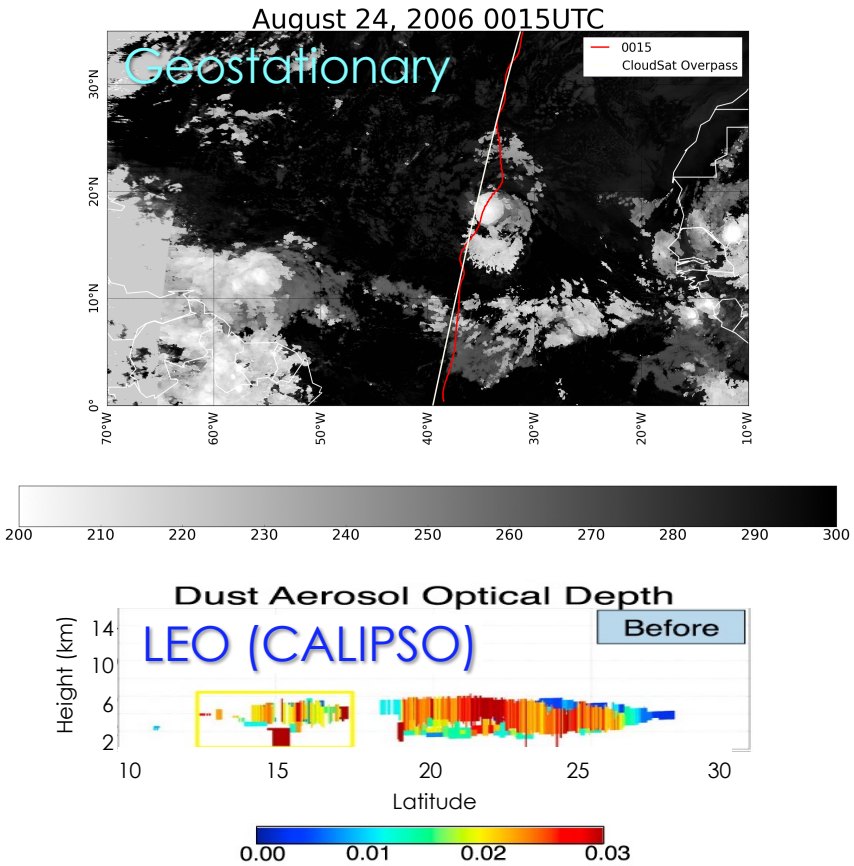
Complementary Perspectives

Cloud Resolving Model



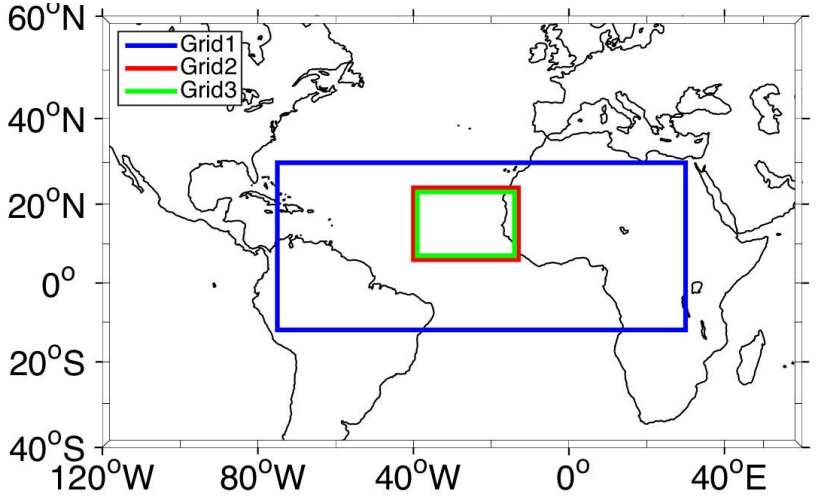
Courtesy Adele Igel

Satellite



Model Setup

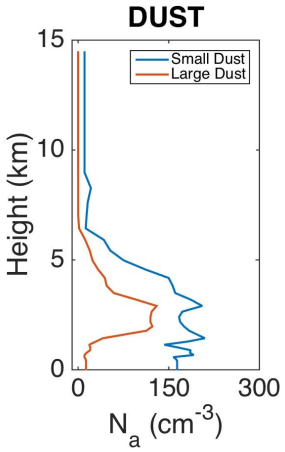
- RAMS model (Cotton et al, 2003)
- 2 moment bin-emulating bulk microphysics (Saleeby and Cotton, 2004)
- Triple nested grid: 30 km, 15 km, 3km
- GFS environmental conditions
  - Warm, dry mid-level air layer

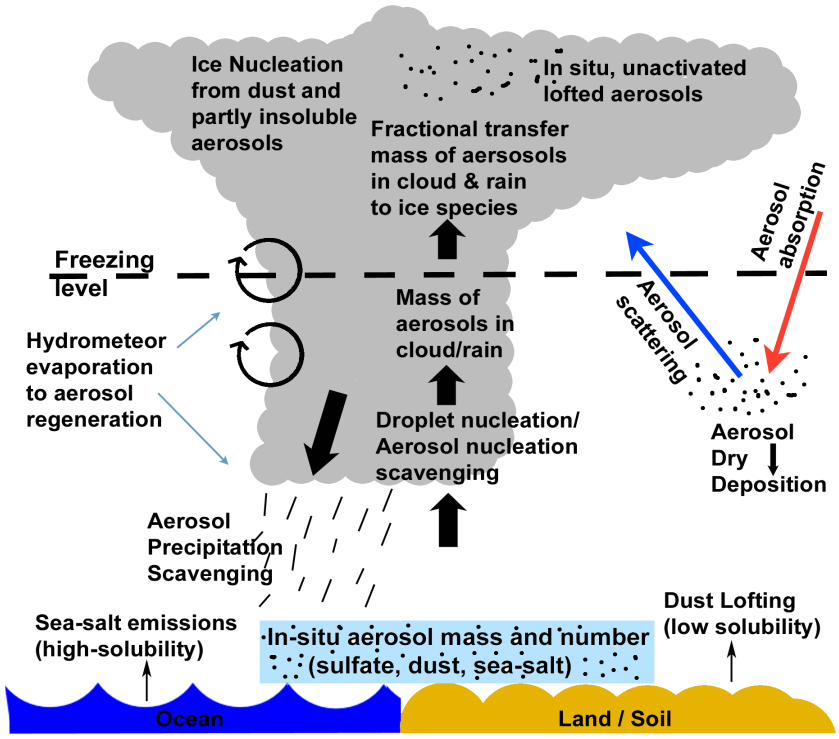


RAMS is open source: *http://vandenheever.atmos.colostate.edu/vdhpage/rams.php*

Aerosol Initialization and Processes

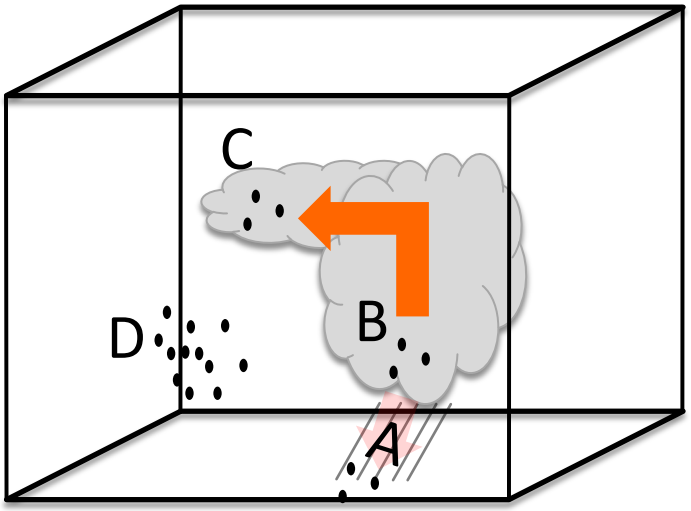
- Prognostic aerosol scheme => activation, advection, diffusion, wet and dry deposition, regeneration
- Initialized with NAMMA dust profile measurements
  - Median diameters: 0.1 and 1.0μm
  - Mildly hygroscopic => act as CCN and INP
- Background sulfates
- Sea salt emissions





Saleeby and van den Heever, *JAMC* (2013)
Herbener et al, *GRL* (2016)

Dust Transport Processes over 48 Hours of TS Debby



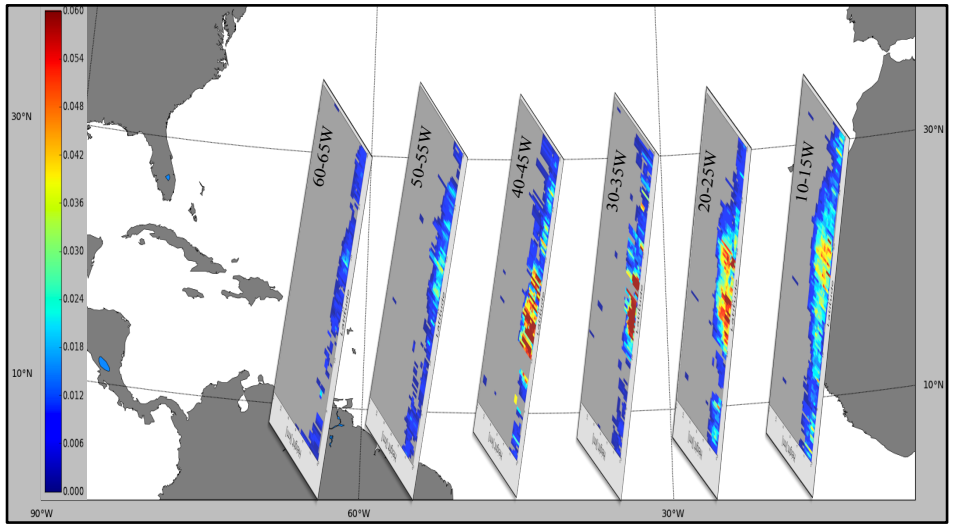
Can these processes be quantified using satellite observations?

Dust Transport Process	Teragrams (Tg)
Precipitation, wet and dry deposition (A)	0.1 Tg
Dust in Hydrometeors (B)	0.00001 Tg
Detrained Dust (C)	0.001 Tg
Advection (D)	1.0 Tg

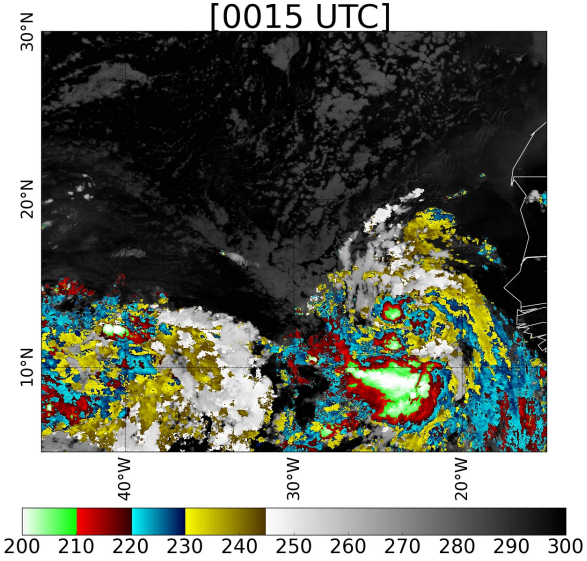
Herbener et al, *Geophys. Res. Letters* (2016)

The Observational Perspective

CALIPSO Conditional Mean AOD (one month)



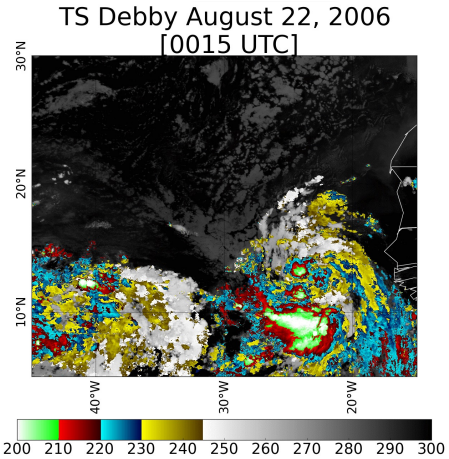
TS Debby August 22, 2006
[0015 UTC]

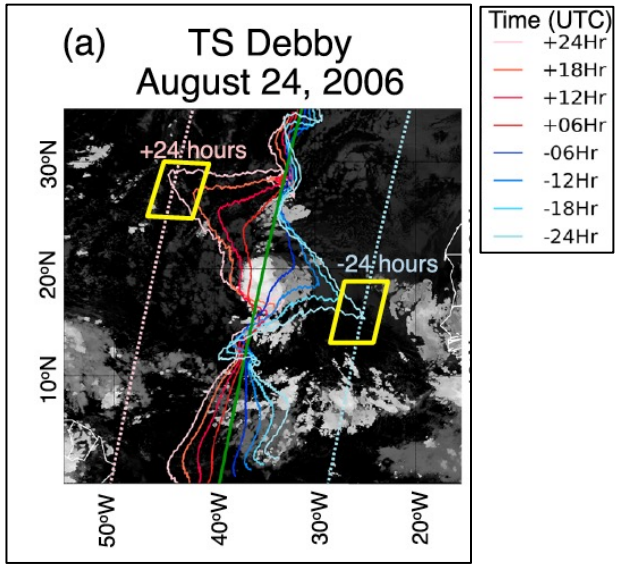


CALIPSO offers a unique multi-year data record of global aerosol vertical structure.

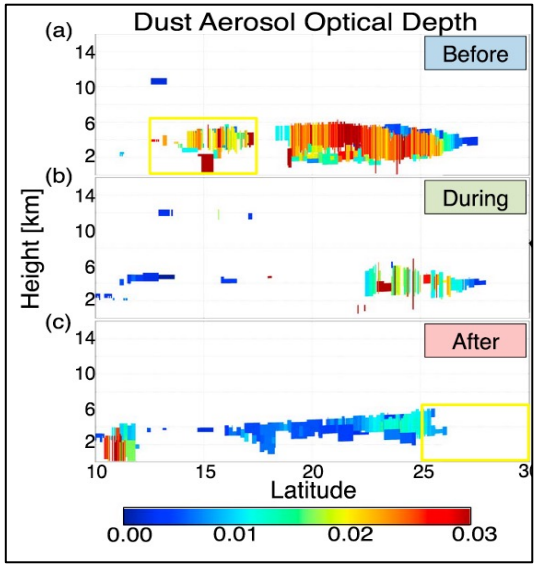
Geostationary satellites offer near-global time-resolved observations of global.

TS Debby

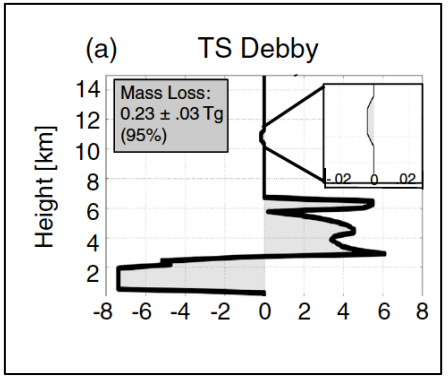




95% Scavenged



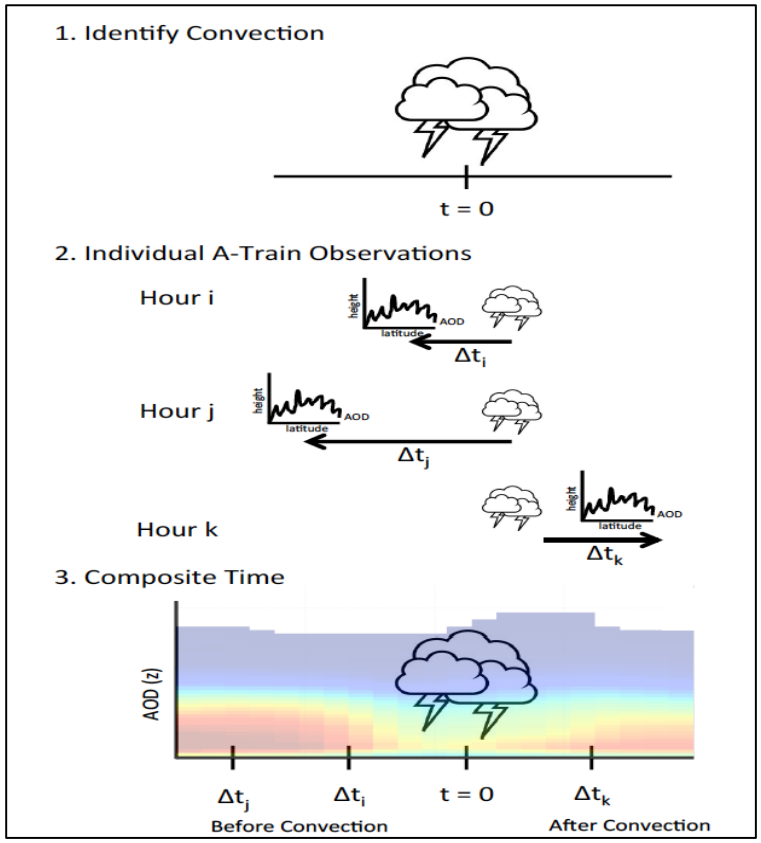
2% Lofted



Sauter and L'Ecuyer, *Geophys. Res. Letters* (2017)

Tropical Storm Debby reduced the optical depth of the dust layer by 95% and lofted 2% to mid-levels (6-9km) consistent with model findings.

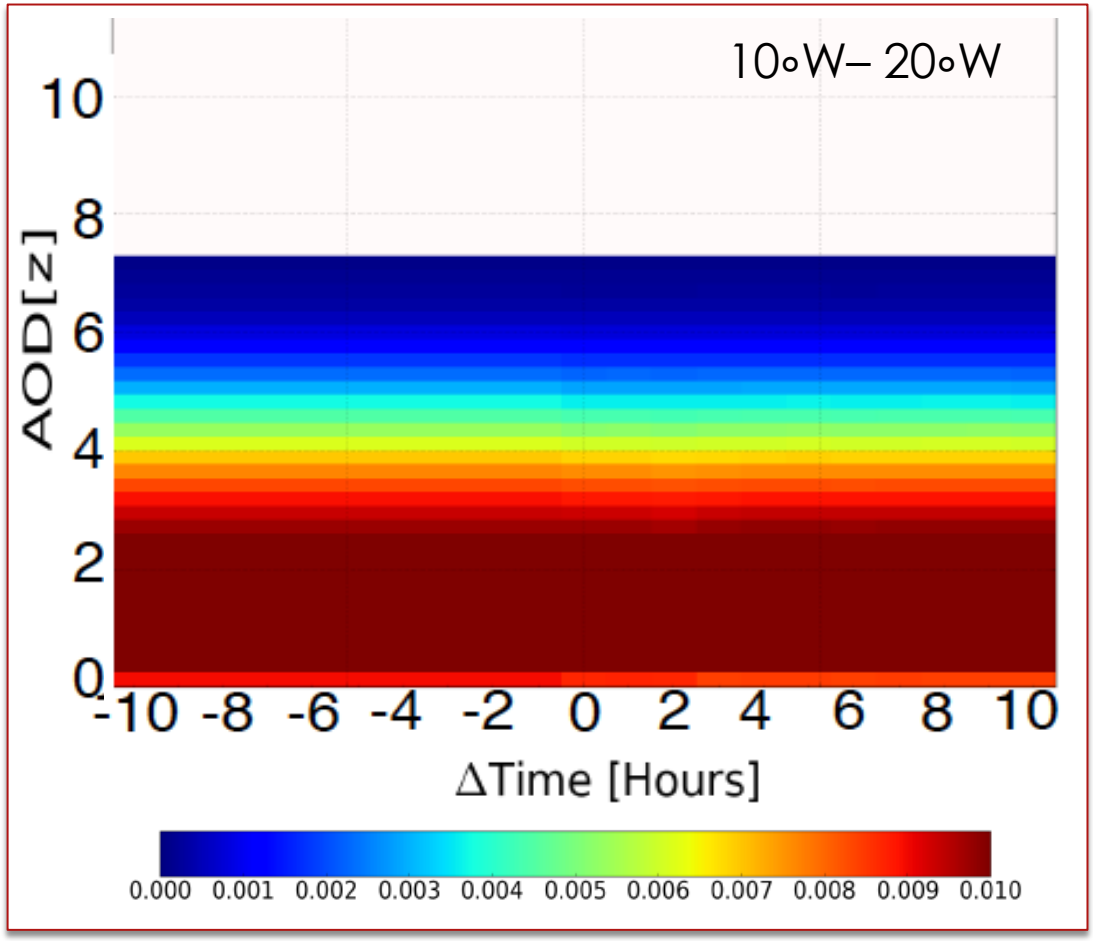
Composite Lifecycle Analysis



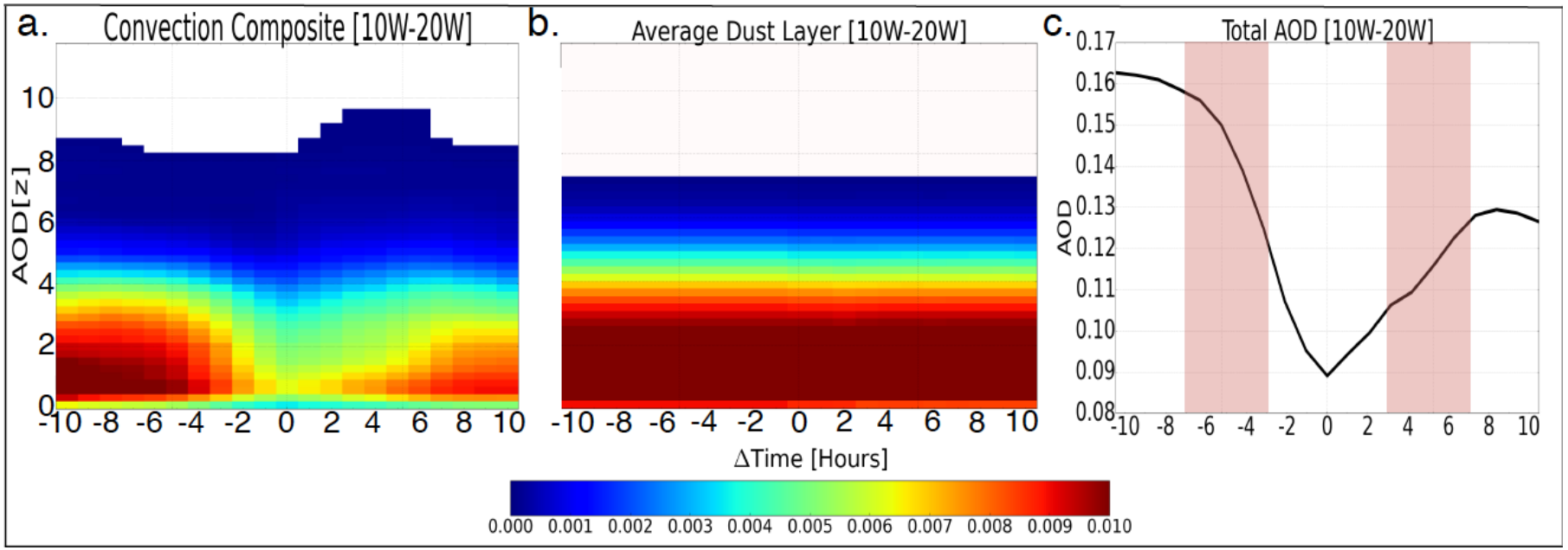
- Temporal compositing adapted from Masunaga, *J. Atmos. Sci.* (2012)
- Match IR-based convection to AOD profiles from advected CALIPSO/CloudSat track
- Use time difference between CALIPSO and nearest convection (in time) to reconstruct the composite evolution of dust AOD over a typical convective lifecycle.

Sauter el al, *J. Geophys. Res.* (2019)

All Observations (2007-2010)



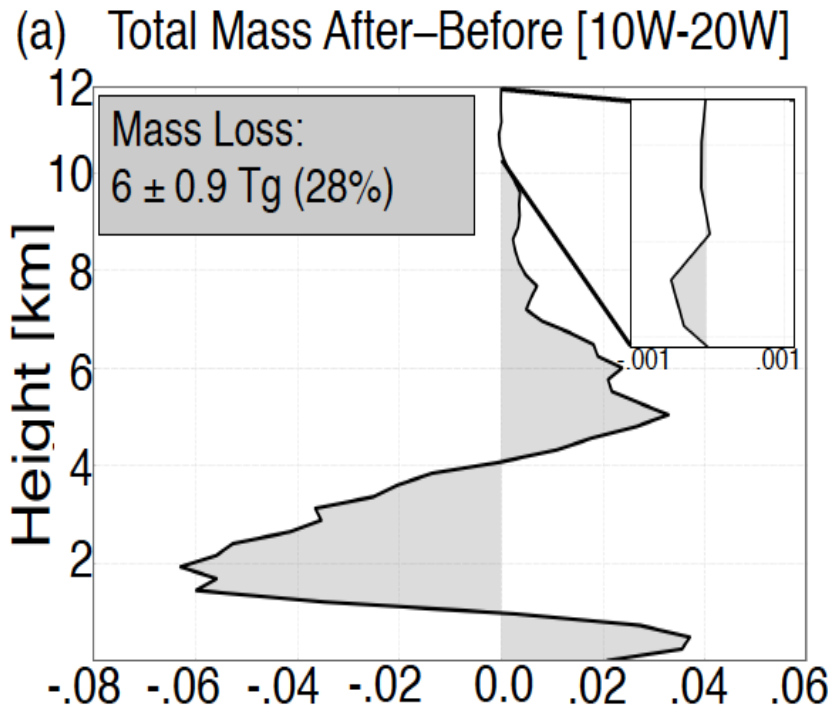
Influence of Convection

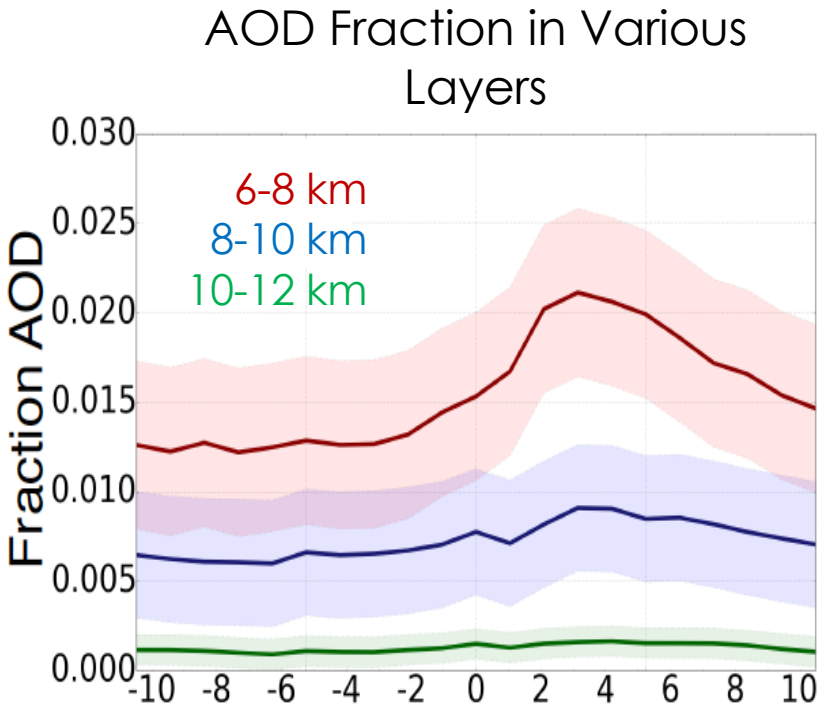


Sauter et al, *J. Geophys. Res.* (2019)

Convection is responsible for removing 18 ± 6 Tg between 15◦W and 80◦W or 15% of the total deposition inferred from budget analyses

Vertical Redistribution





Sauter et al, *J. Geophys. Res.* (2019)

Convection also elevates dust to higher altitudes, primarily 6-10 km.

Summary

- The new paradigm of studing atmospheric processes using LEO satellites coupled to process models can be realized by rethinking the way active active sensor observations are analyzed in the context of the geostationary program of record.
- RAMS simulations and time-differenced CALIPSO observations reveal that the passage of Tropical Storm Debby reduced dust mass in the SAL by more than 95% and lofted 2% to altitudes greater than 10 km.
- Temporal composites of CALIPSO observations in the context of geostationary convective objects indicates that tropical convection accounts for 15% ± 7% of dust deposition across the Atlantic and lofts 1.5% ± 0.6% of to altitudes greater than 6 km.

Herbener et al, *Geophys. Res. Letters* (2016)
Sauter and L'Ecuyer, *Geophys. Res. Letters* (2017)
Sauter et al, *J. Geophys. Res.* (2019)

Datasets

- Geostationary Data
  - GOES East Pathfinder Atmospheres Extended (PATMOS-x)
  - Meteosat Second Generation (MSG) 8 and 9
- Polar Orbiting Data
  - CloudSat
  - Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)