Effects of Aerosols on Deep Convective Clouds

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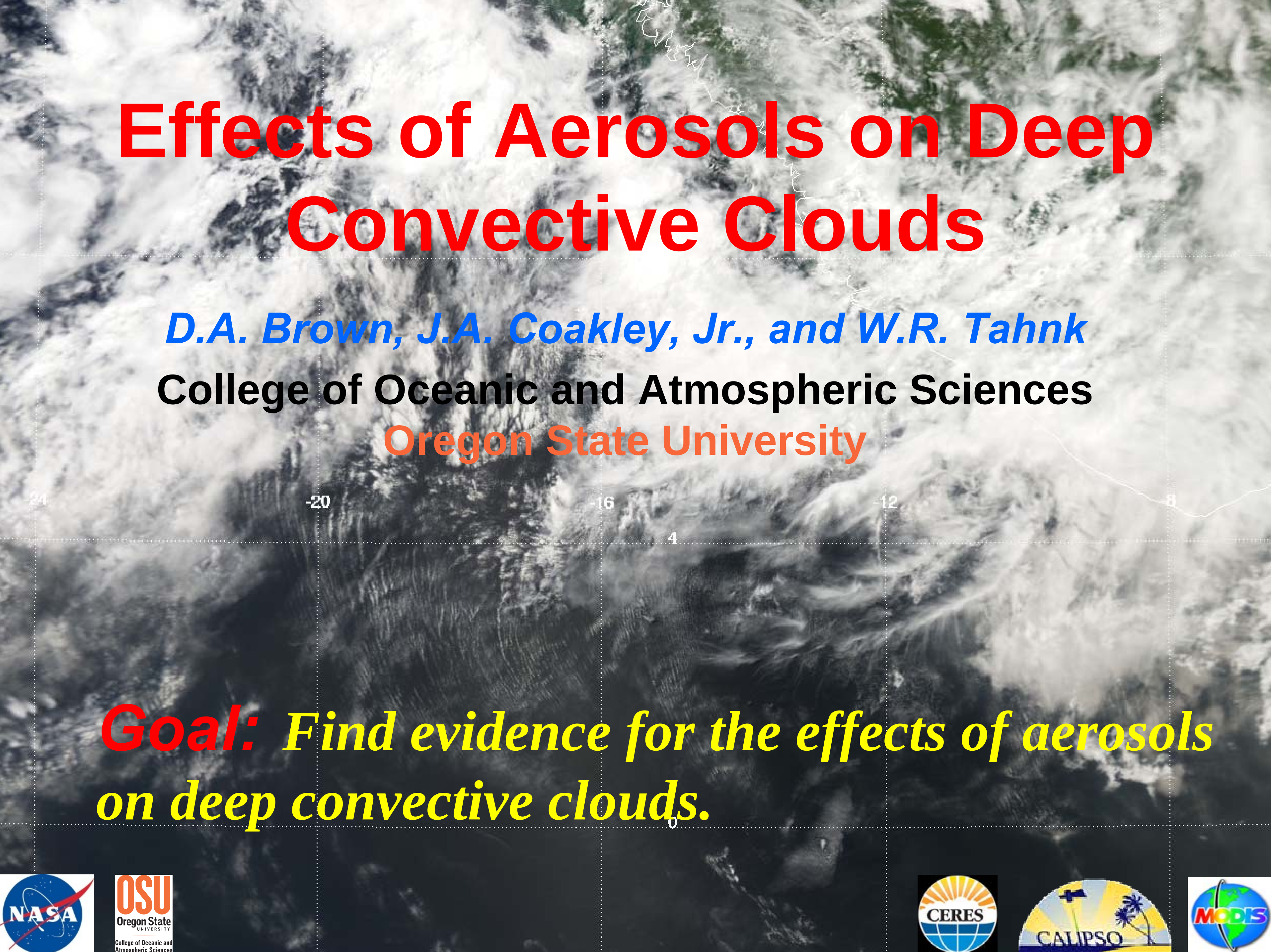
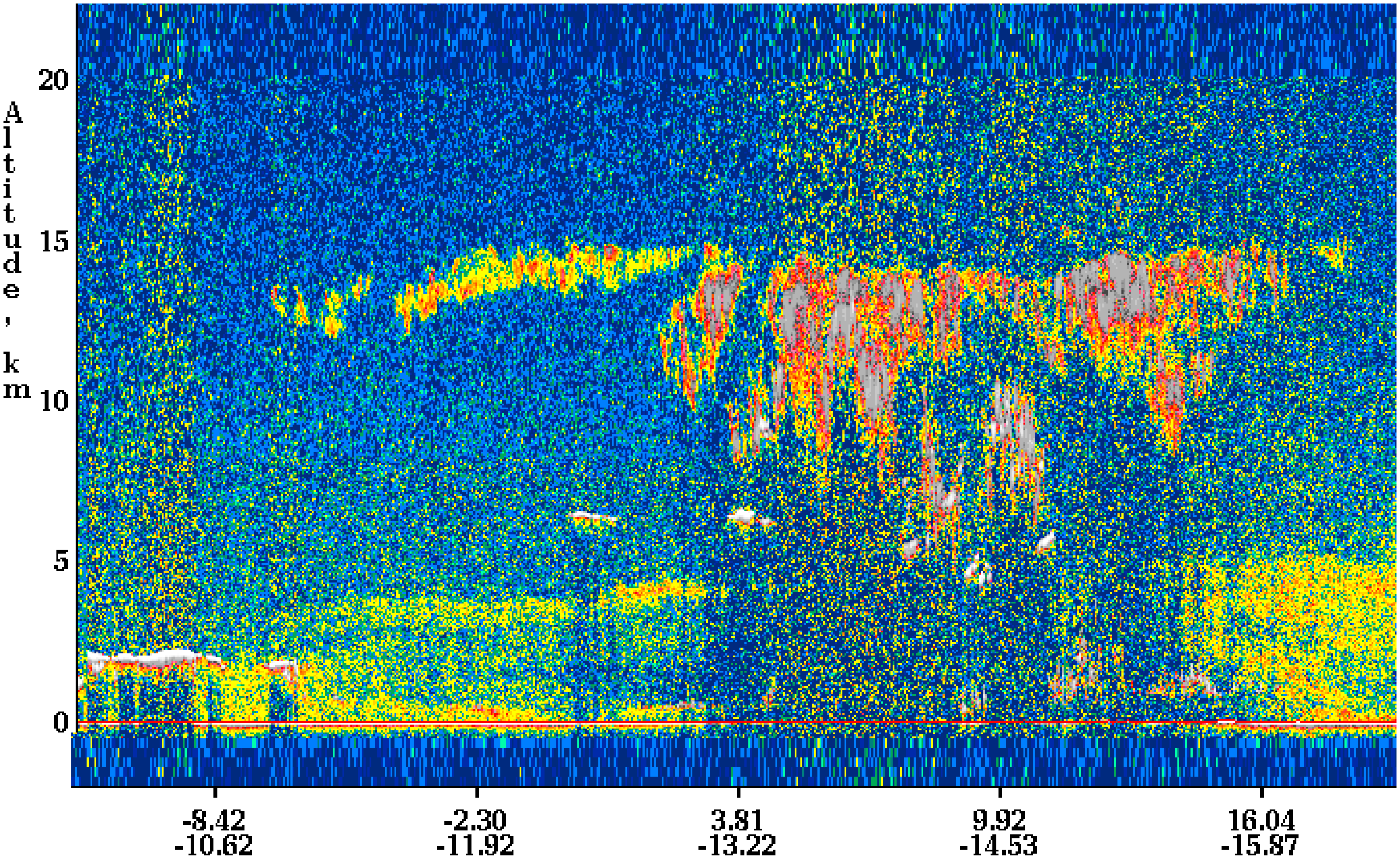


Goal: ***Find evidence for the effects of aerosols on deep convective clouds.***

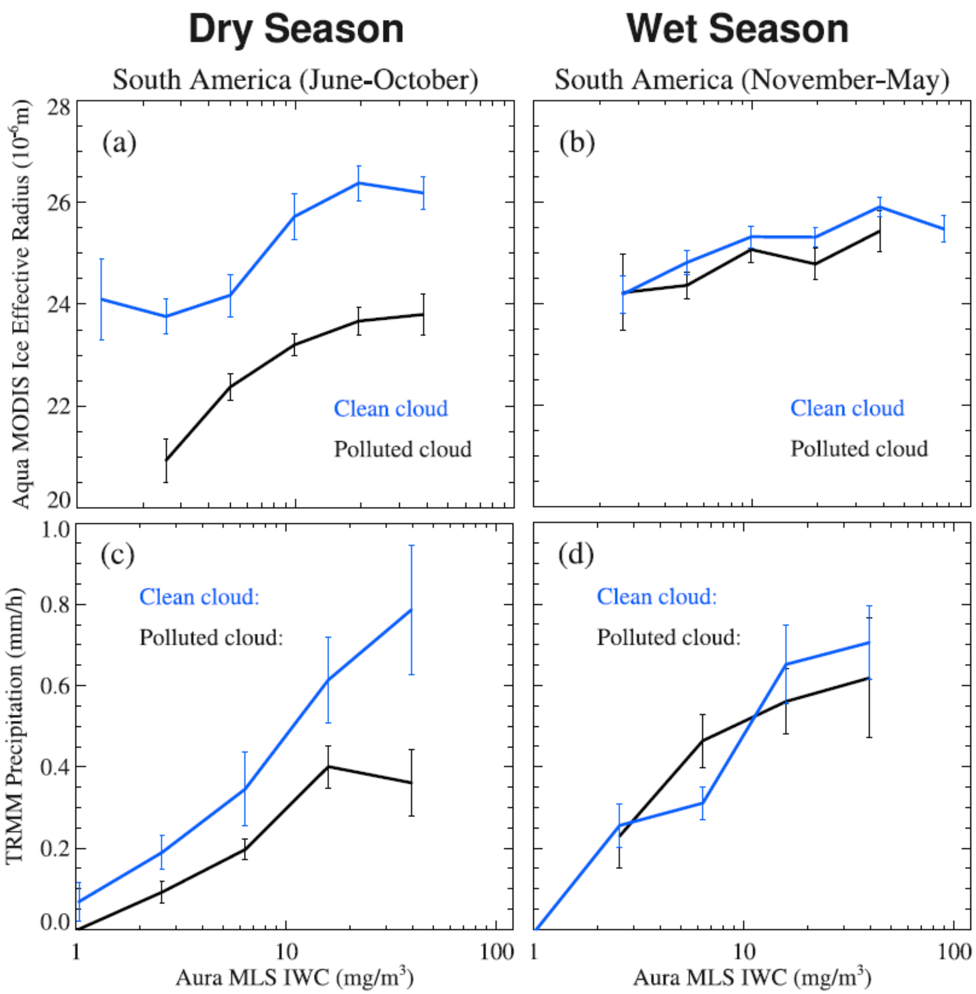
NASA
OSU Oregon State University College of Oceanic and Atmospheric Sciences
CERES
CALIPSO
MODIS

Deep convective clouds frequently occur with heavy aerosol burdens off the west coast of Africa during the season of biomass burning.

CALIPSO 532-nm attenuated backscatter, 13 August 2009 1430 UTC



Aerosols are associated with smaller ice crystals and smaller precipitation rates during the dry season in South America.



- Jiang et al. (2008) used CO concentrations as a proxy for aerosol burdens.
- In the wet season, polluted and unpolluted clouds have similar ice crystal sizes and seem to be associated with the similar precipitation rates.
- Sherwood (2002) also noted decreases in monthly mean ice particle size with increasing monthly mean TOMS aerosol index in the South American region.

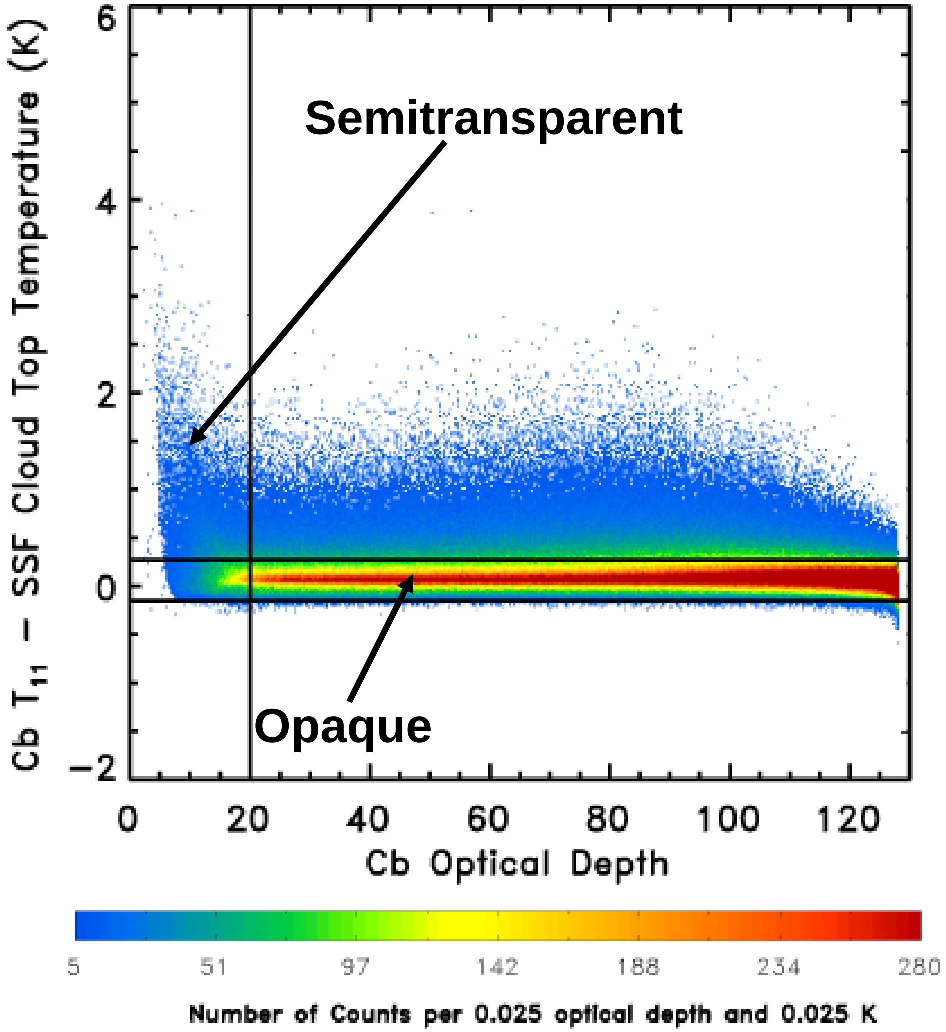
Source: Jiang et al. (2008)

Three years of CERES SSF from Terra used to obtain the properties of deep convective clouds collocated with large aerosol burdens.

***CERES**: Clouds and Earth's Radiant Energy System*
***SSF**: Single Satellite Footprint*

- **The SSF combines retrievals of aerosol and cloud properties based on MODIS radiances with radiative fluxes derived from the CERES broadband radiometers.**
- **Each CERES footprint is ~20 km resolution at the Earth's surface.**

Deep convective clouds taken to be undergoing intense convection when cold and opaque in the infrared.



CERES FOVs taken to contain deep convective clouds if:

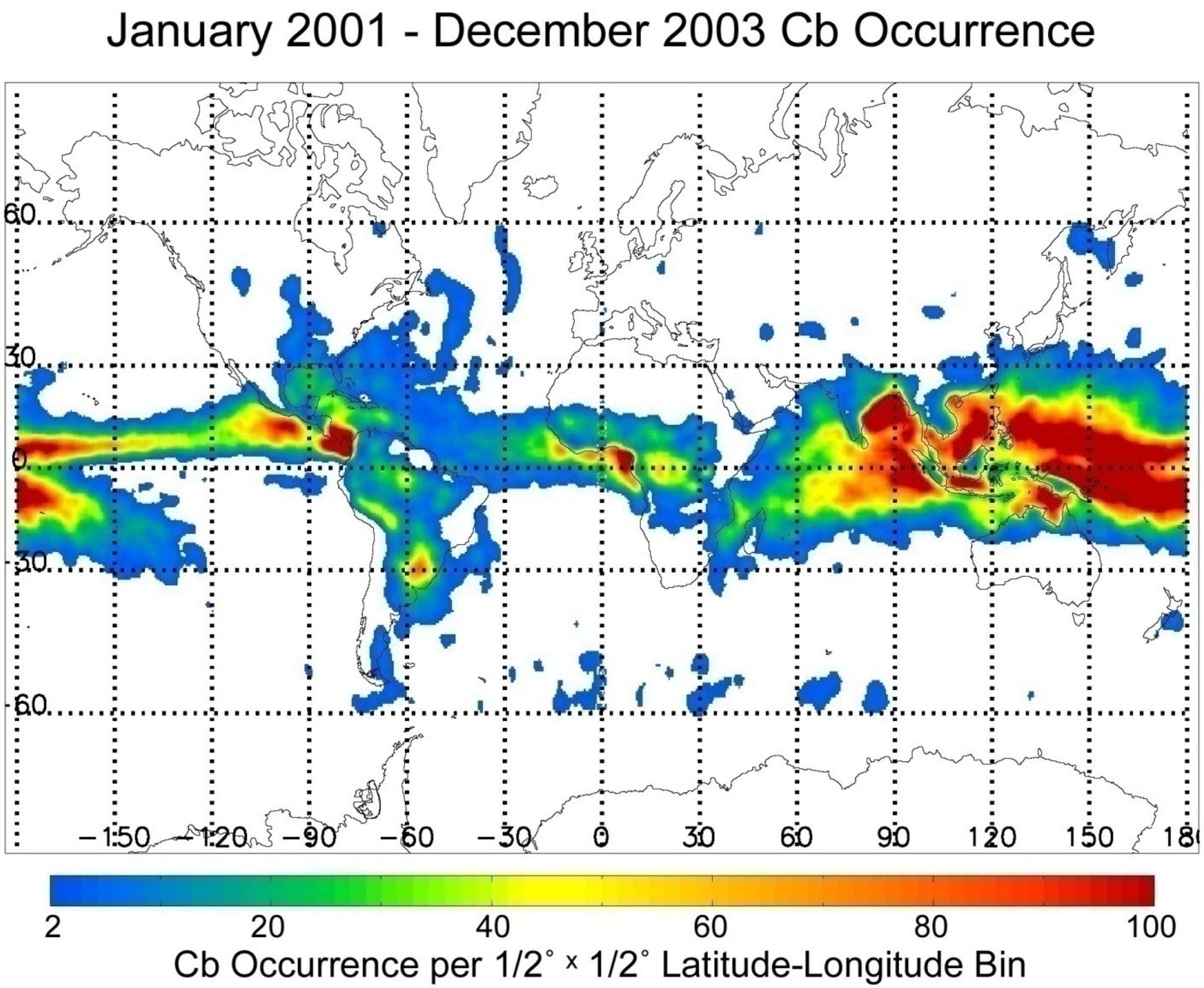
1) ***the associated 11-μm brightness temperature is less than 210 K,***

2) ***the brightness temperature is the same as the retrieved cloud top temperature, and***

3) ***the visible optical depth is greater than 20.***

Approximately 75% of CERES FOVs that have brightness temperatures less than 210 K are opaque at 11 μm.

Deep convective clouds frequent the Pacific Warm Pool, the North Indian Ocean, the west coast of Africa, and South America.



Deep convective systems were sought between 60° S to 60° N.

Sherwood (2002) and Jiang et al. (2008) reported finding effects of aerosols on deep convective clouds over South America.

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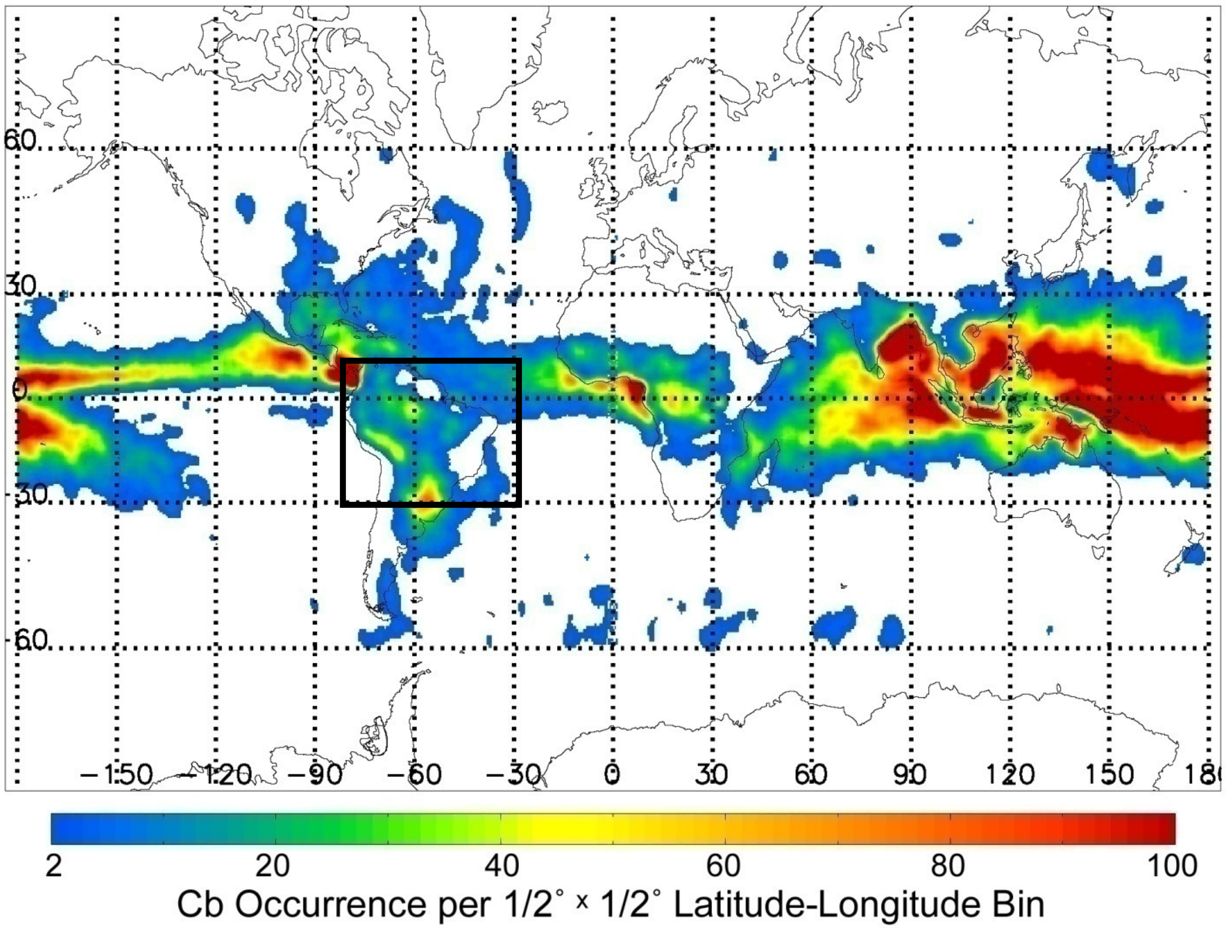
January 2001 - December 2003 Cb Occurrence



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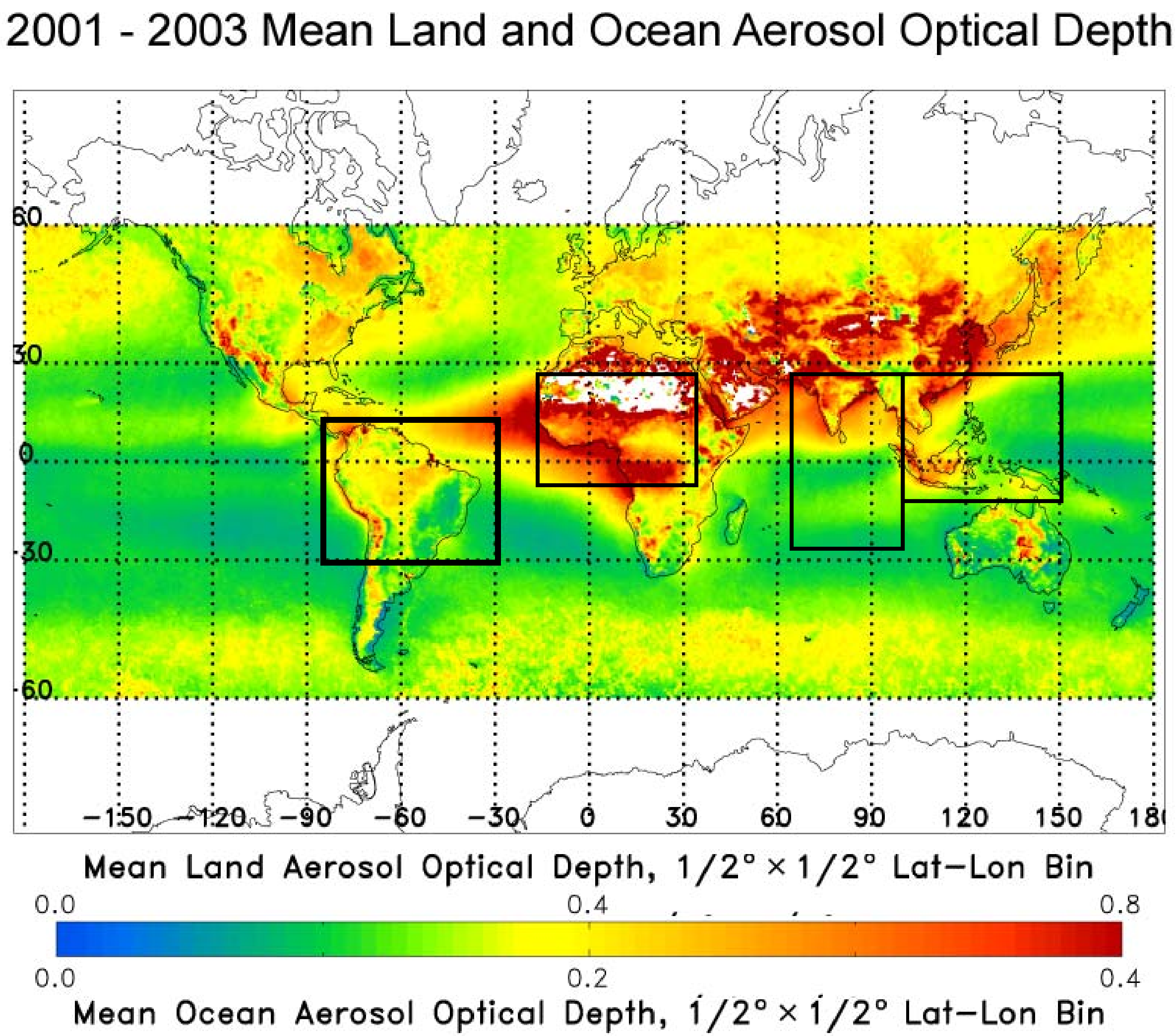
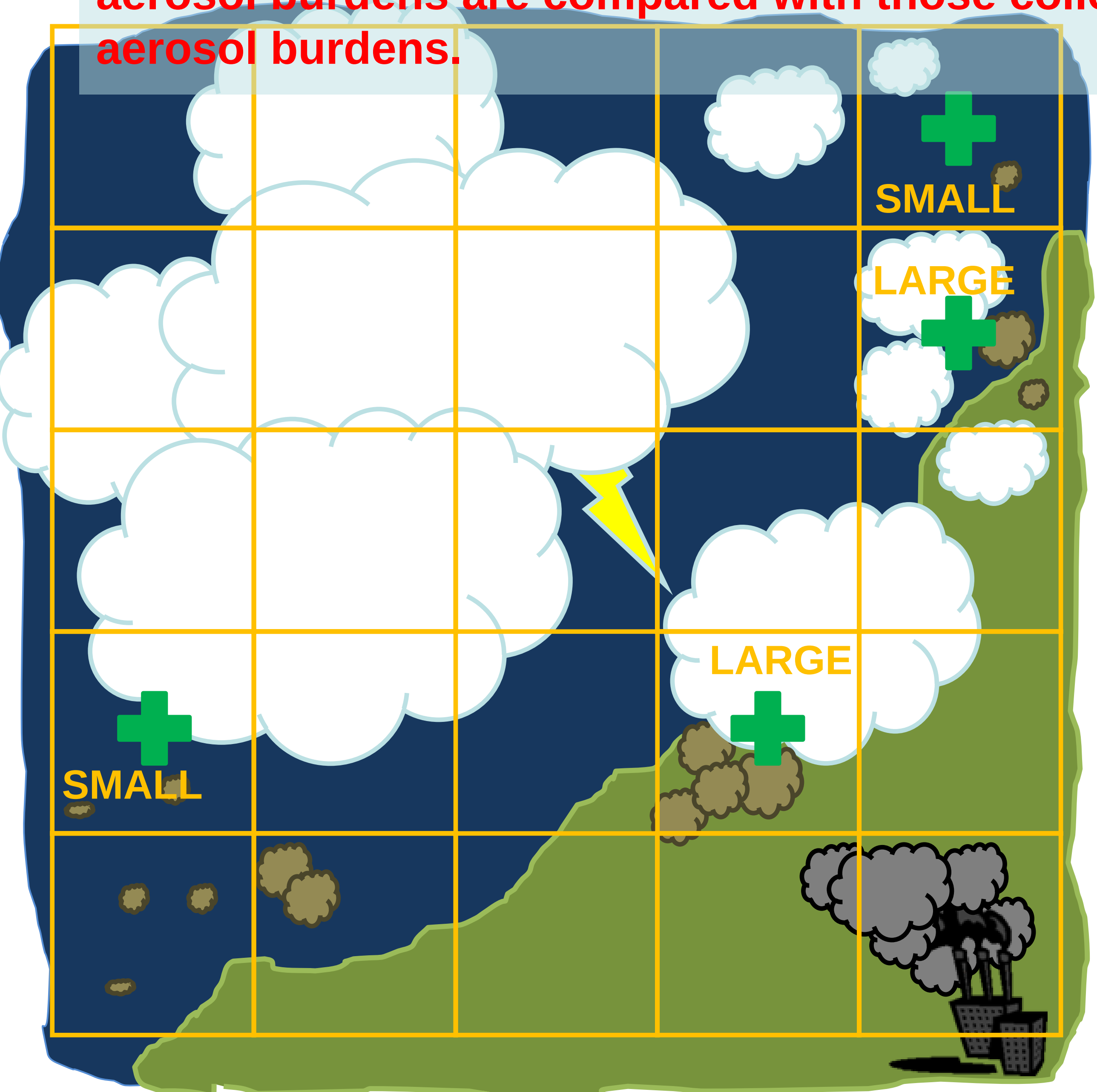
Deep convective clouds and heavy aerosol burdens occur primarily in the Northern Indian Ocean, Africa, and South America.



Properties of deep convective clouds collocated with large aerosol burdens are compared with those collocated with small aerosol burdens.

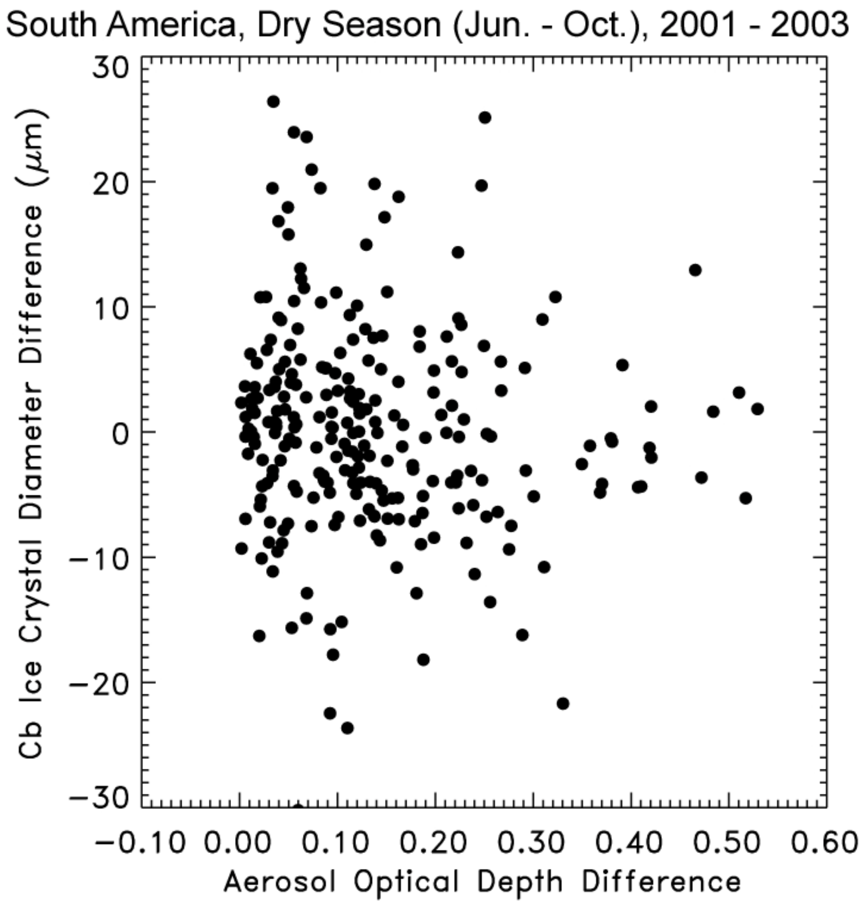


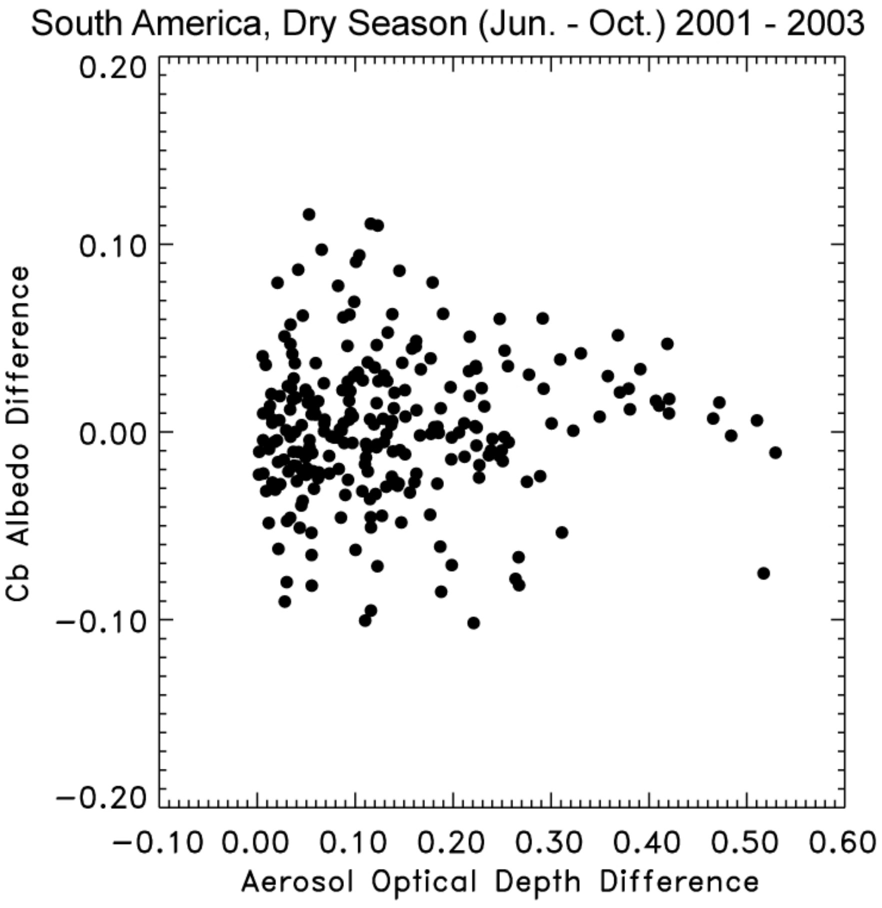
Following Loeb and Schuster (2008), for each day obtain mean properties of deep convective clouds and mean aerosol burdens in each 2°× 2° lat.-lon. region.

Divide the 2°× 2° regions within a 10°× 10° region into those with mean aerosol optical depths greater than the mean for the 10° region and those with optical depths less than the mean.

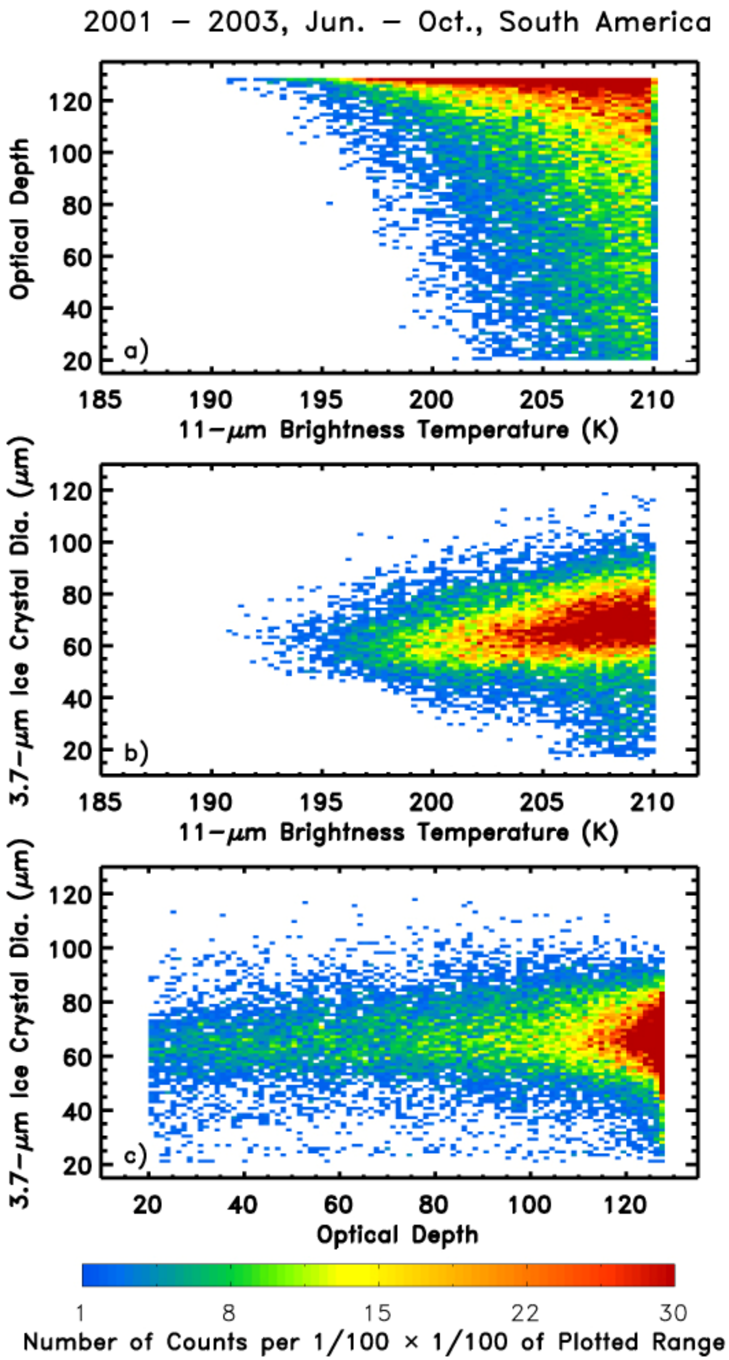
Correlate differences in cloud properties with differences in aerosol optical depths.

Deep convective clouds show no changes with increased aerosol burdens.

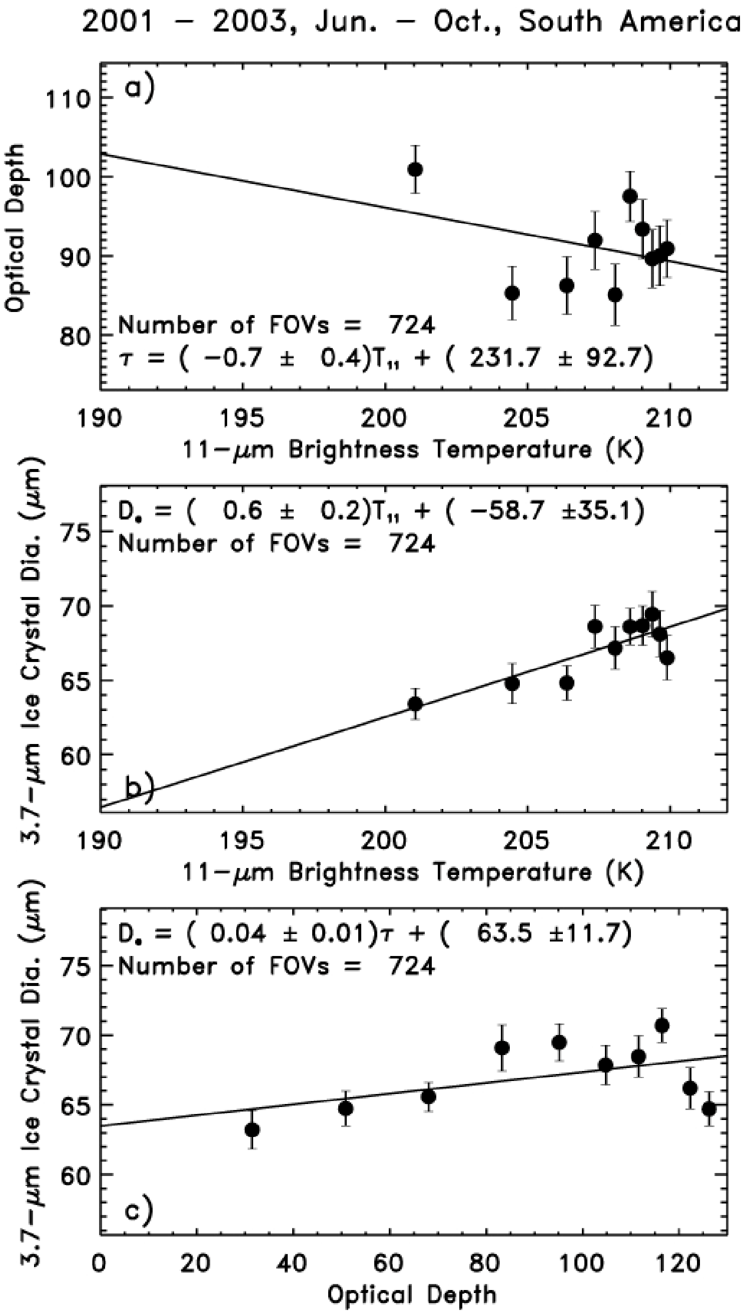




Difference = Large – Small



Ice crystal diameter and cloud optical depth increase with decreasing cloud temperature.



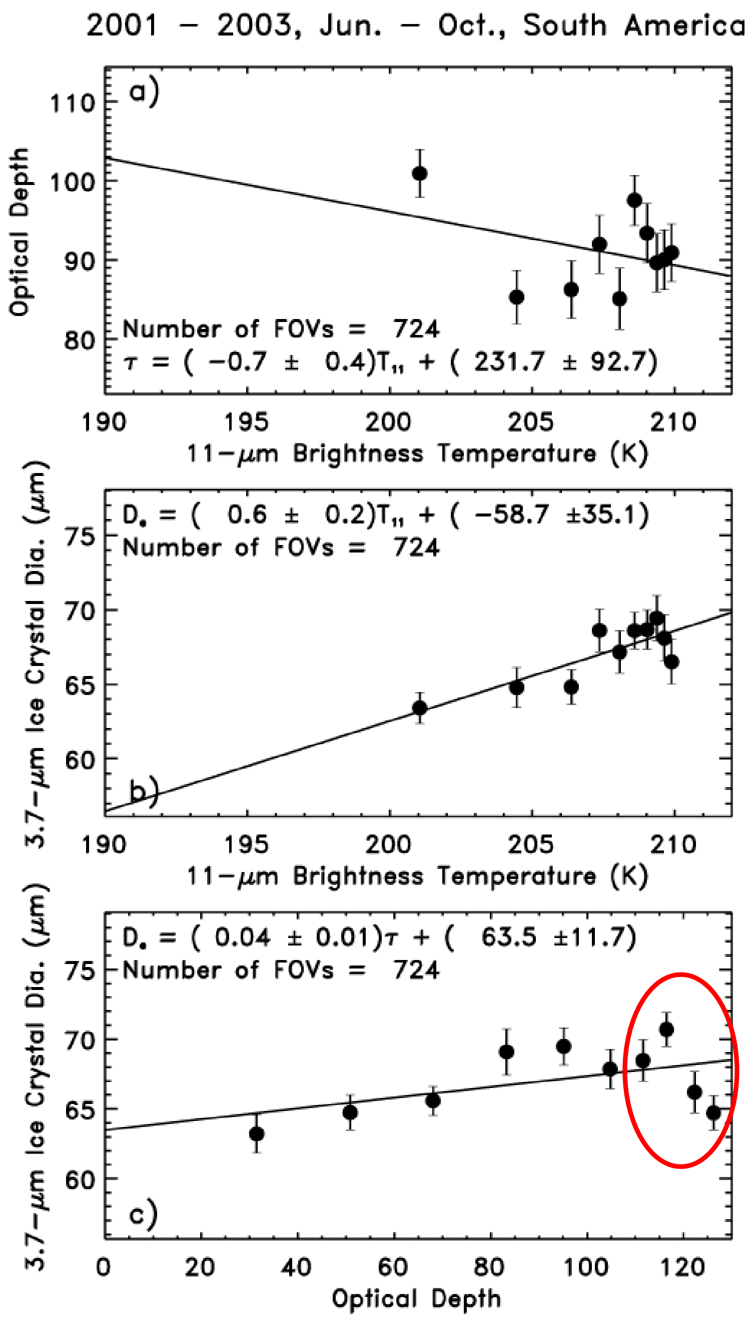
Deep convective clouds exhibit relationships among their properties.

The least-squares fits were calculated using statistically independent FOVs.

The means and standard errors were obtained for equal populations (10th percentiles) of the cloud optical depth and 11-μm brightness temperature.

The coldest bin consistently had the largest optical depths and the smallest ice crystal diameters in all regions and all seasons.

The largest optical depth bins consistently showed a decrease in ice crystal diameter with increasing cloud optical depth.



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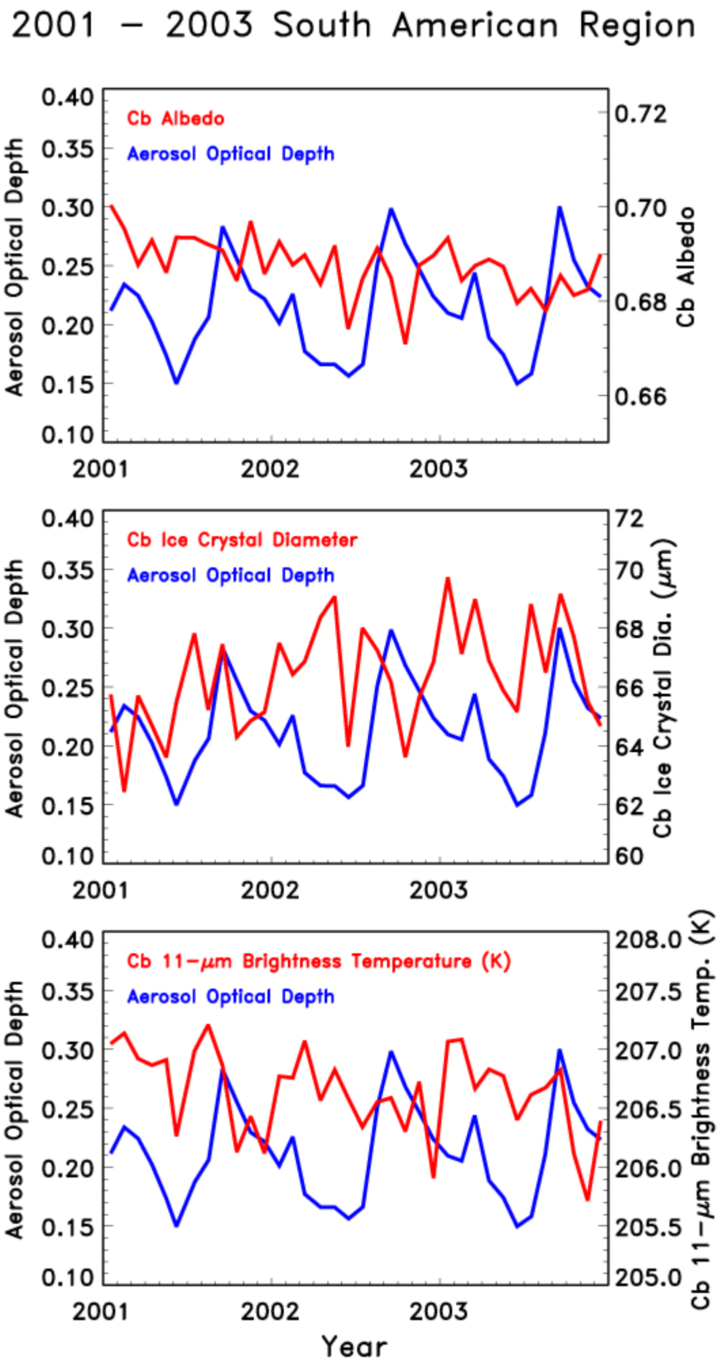
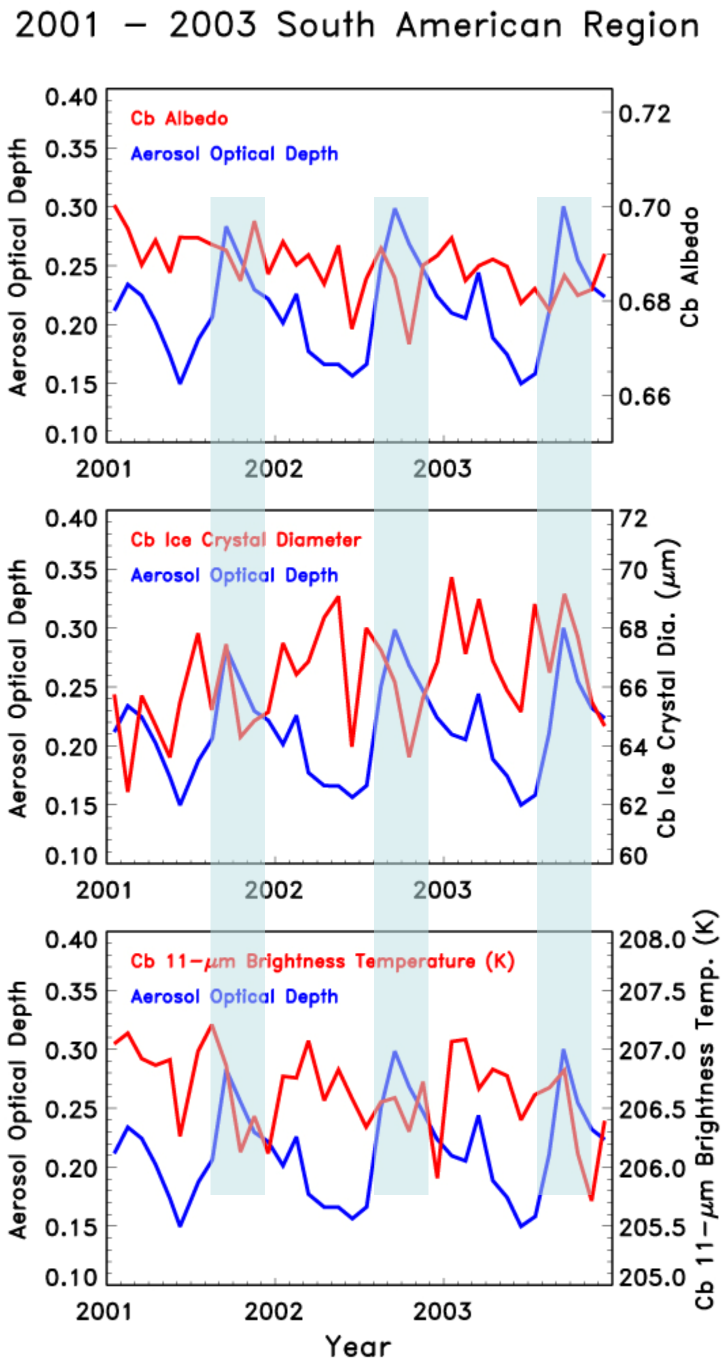


Monthly mean ice particle diameters appear to decrease with increasing monthly mean aerosol burdens.

The changes in ice particle diameters are also consistent with the lower temperatures observed during the season with increased aerosol loading.

Sherwood (2002) also found lower cloud top temperatures linked to smaller ice crystal sizes.

Perhaps previous studies claiming aerosol effects were observing the increase in small ice crystals with decreasing temperatures.



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Summary

Deep convective clouds appear to be unaffected by collocated elevated burdens of aerosols in regions where deep convective clouds and large aerosol burdens occur frequently: South America and western Africa during biomass burning and the Northern Indian Ocean during the winter and summer monsoons.

Ice crystal diameter and cloud optical depth appear to increase with decreasing cloud temperature presumably due to large numbers of supercooled cloud droplets being lofted above the freezing level by strong updrafts in deep convective clouds (e.g. Garrett et al. 2003 and Garrett et al. 2007, and Heymsfield et al. 2009).

Previous studies claiming evidence for the effect of aerosols on clouds (Sherwood 2002; Jiang et al. 2008, and Jiang et al. 2009) focused on South America where clouds have lower cloud top temperatures and smaller ice crystals during the season of biomass burning.

Perhaps, the effect of aerosols is to suppress warm cloud precipitation thereby facilitating deeper convection forming clouds with lower temperatures and smaller ice crystals (Andrae et al. 2004).