Effects of Aerosols on Deep Convective Clouds

REVISITED

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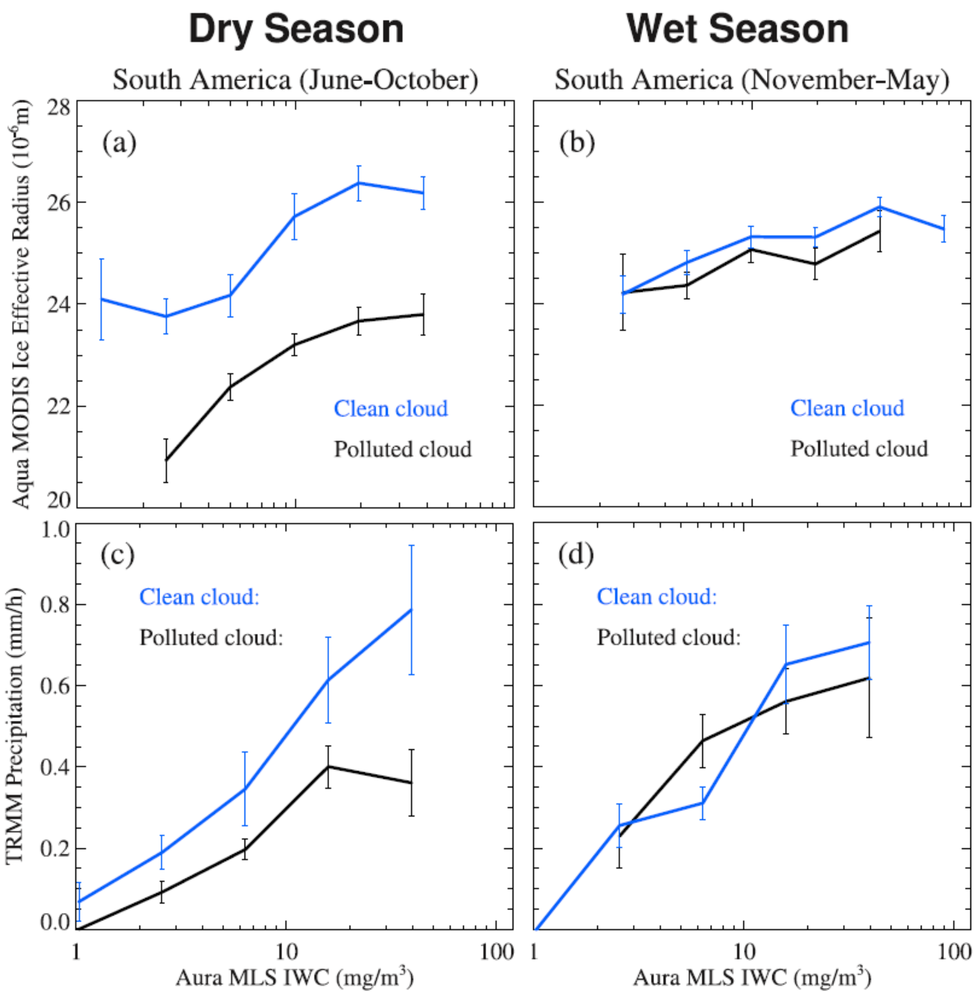
Goal: ***Find evidence for the effects of aerosols on deep convective clouds.***

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 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)

Why re-examine results of previous studies?

- **Sherwood (2002) used monthly means for 5° latitude × 10° longitude.**
- **Jiang et al. (2008) used upper-level CO as a proxy for aerosol burdens and MLS ice water concentrations as a proxy for deep convective cloud occurrence in regions of order 3° latitude × 1° longitude in 3 km altitude range.**

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

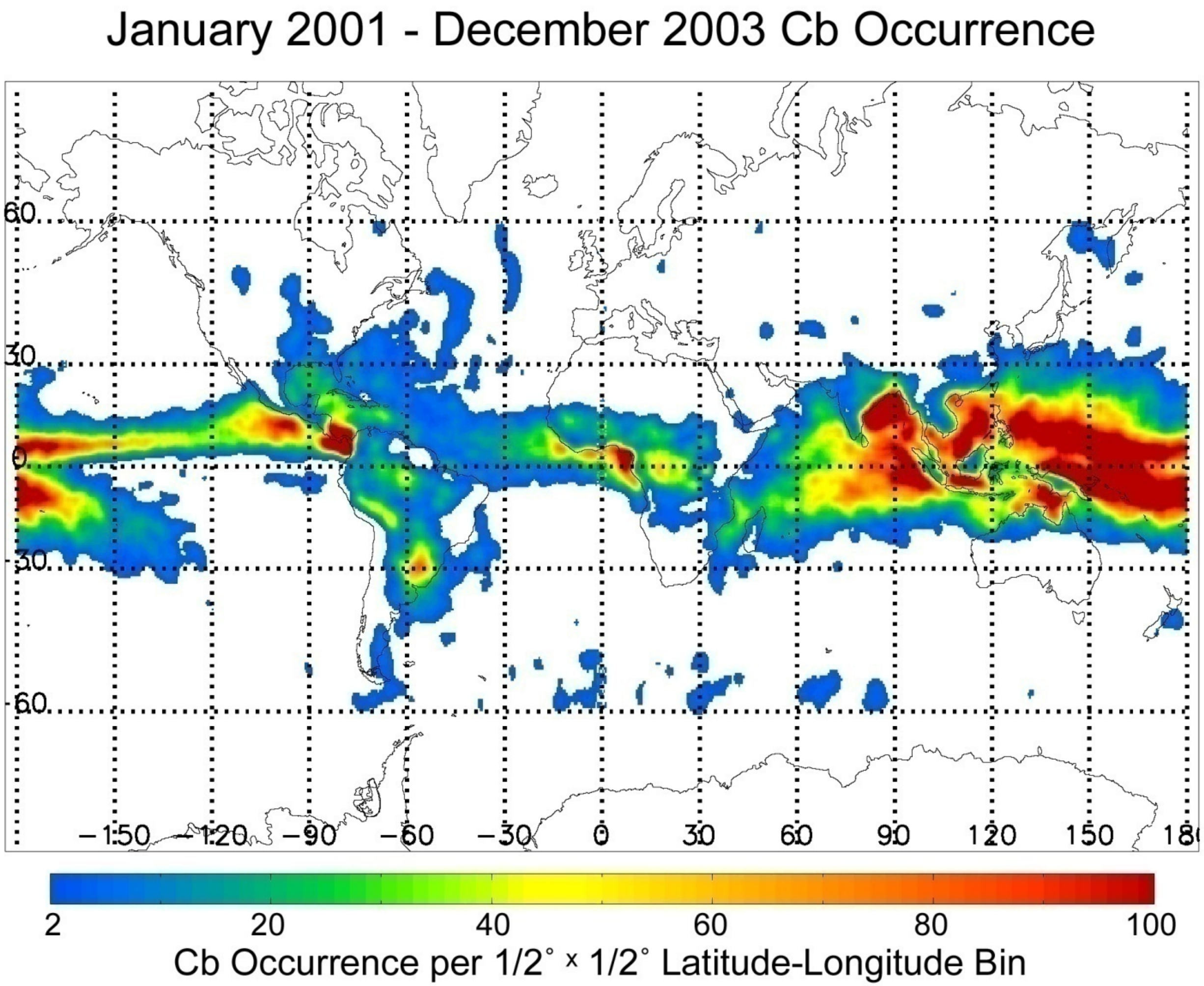
***CERES*: Clouds and Earth's Radiant Energy System**
***SSF*: Single Satellite Footprint**

- **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 in CERES FOV:

1) **11 μm brightness temperature < 210 K**
2) **Opaque at 11 μm**
3) **Visible Optical depth > 20**

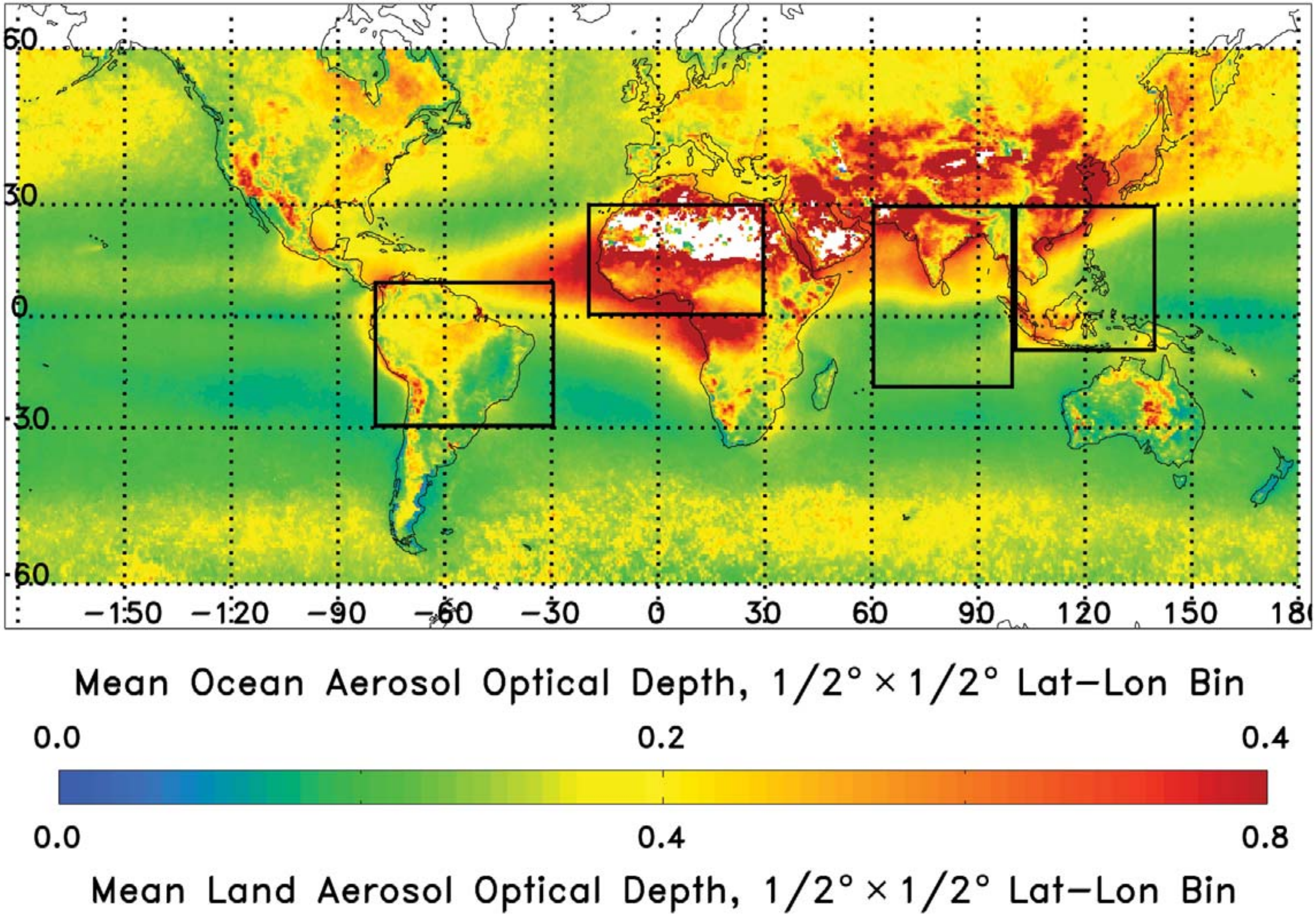
Deep convective clouds frequent the Pacific Warm Pool, the North Indian Ocean, the west coast of Africa, and South America.

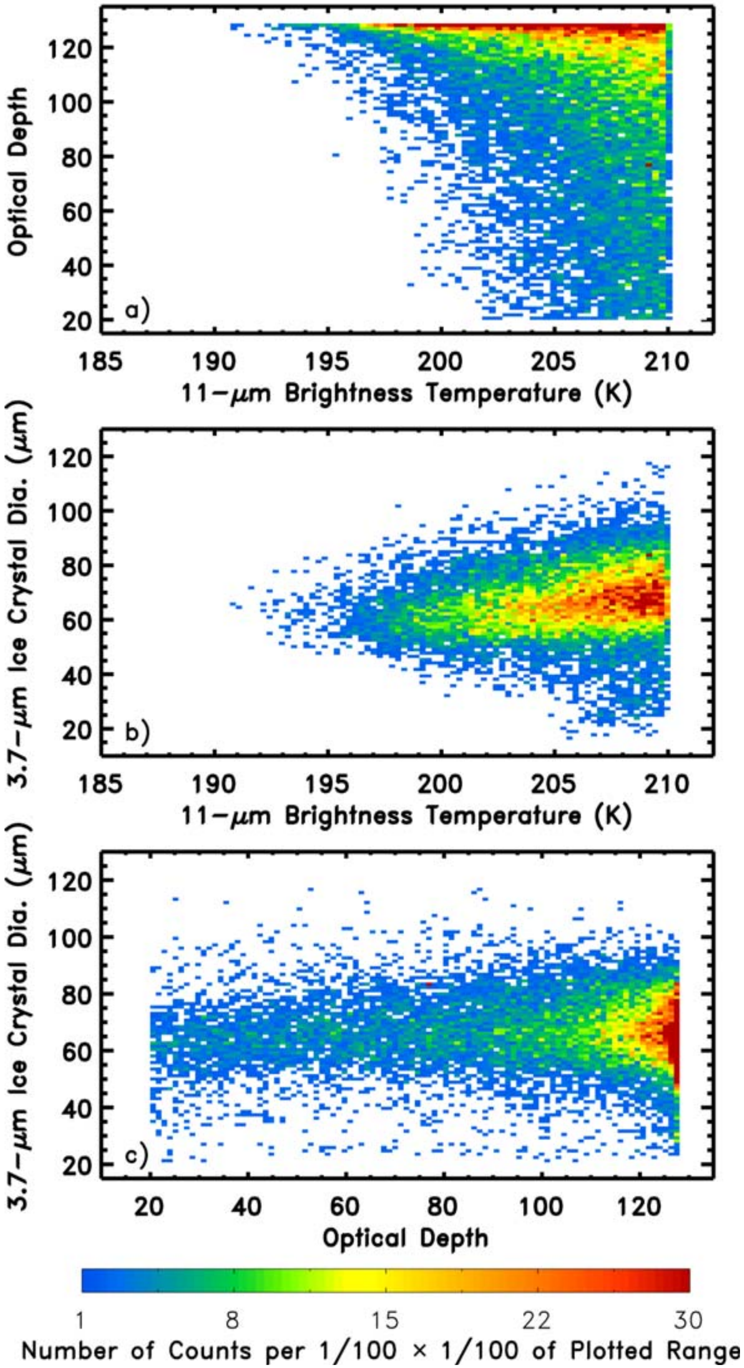


Deep convective systems were sought between 60° S to 60° N.

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

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





For deep convective clouds, ice crystal diameter decreases and visible optical depth increases as cloud top temperature decreases.

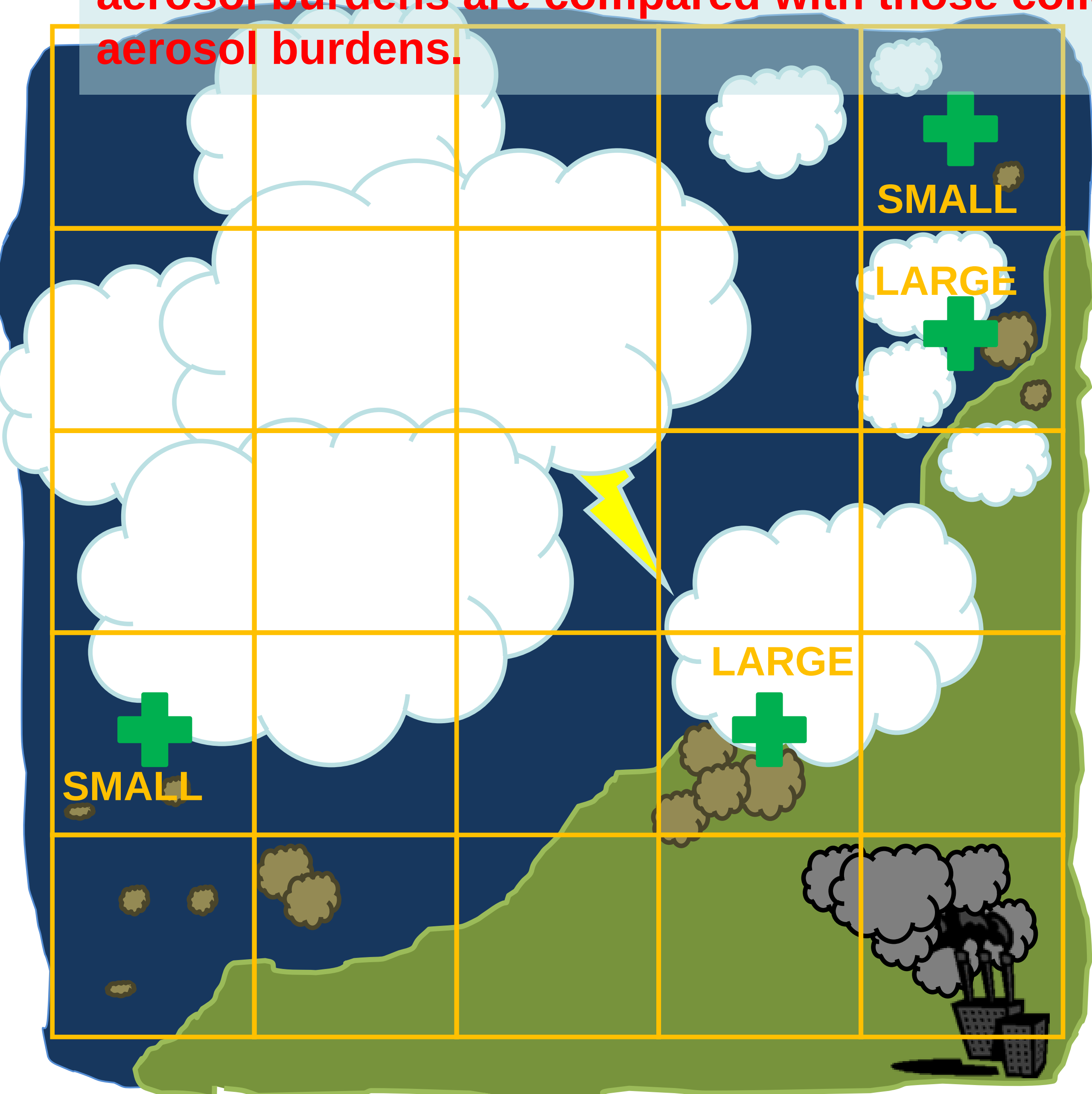
South American region during June–October dry season.

Decrease in ice crystal diameter and increase in visible optical depth with decreasing temperature occurs in all regions and all seasons.

Part of the decrease in ice crystal diameter attributed by by Jiang et al. (2008) as caused by increased aerosol burdens was probably caused by decreased cloud top temperature.

Sherwood (2002) also noted the decrease in ice crystal diameter with decreasing cloud top temperature.

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



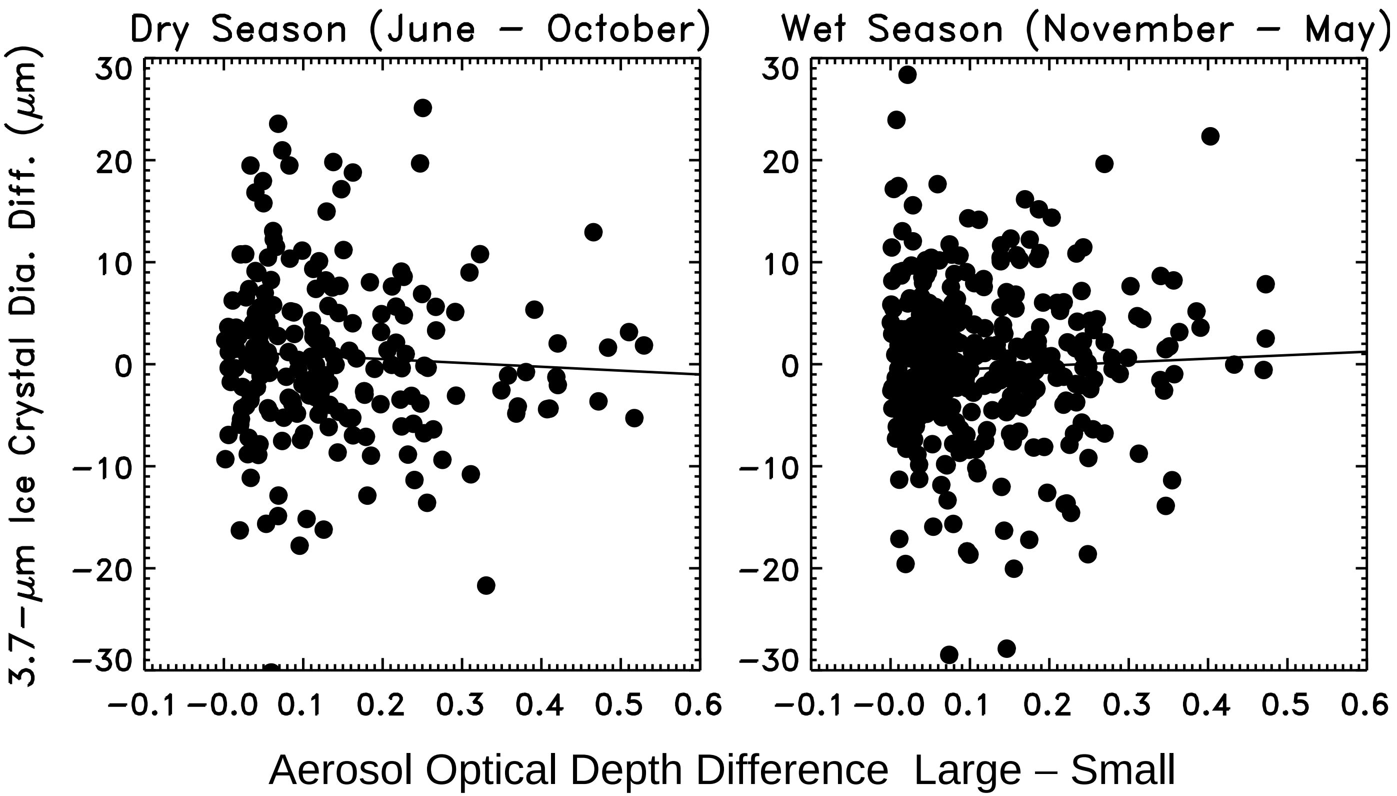
Following Loeb and Schuster (2008), for each day obtain mean properties of deep convective clouds and mean aerosol burdens in each 2°× 2° lat.-lon. region.

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.

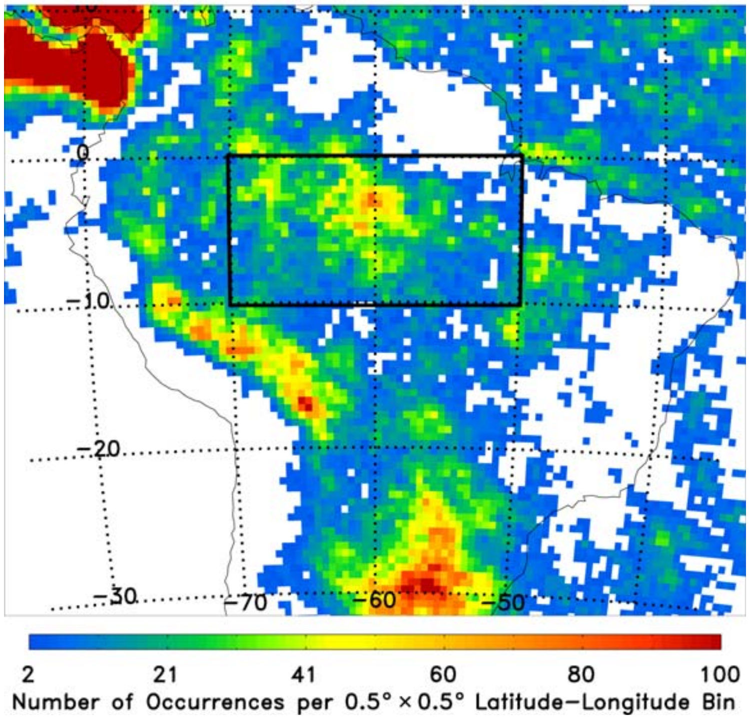
South America



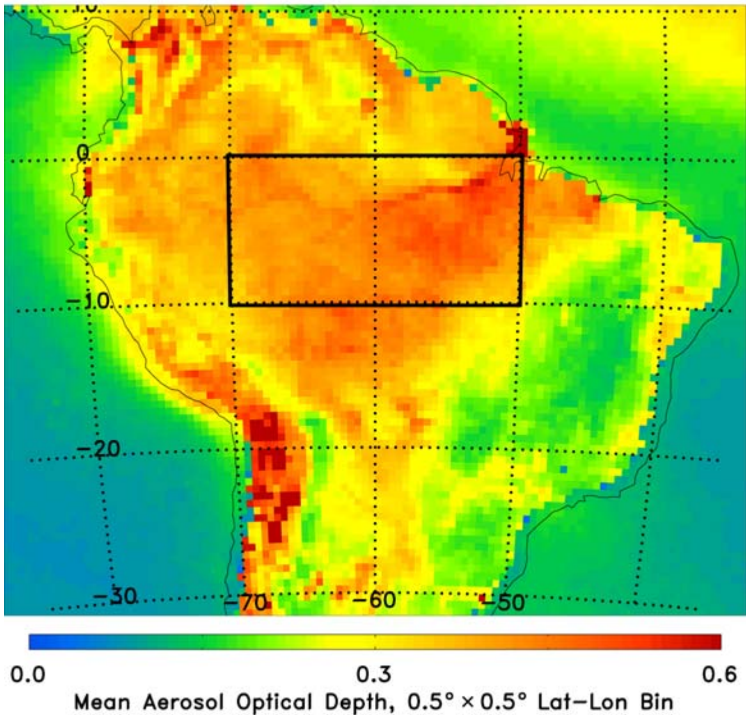
Regardless of region and season, deep convective clouds appear to be insensitive to nearby aerosol burdens.

Sensitivity of deep convective clouds to aerosol burdens re-examined for Amazon Basin.

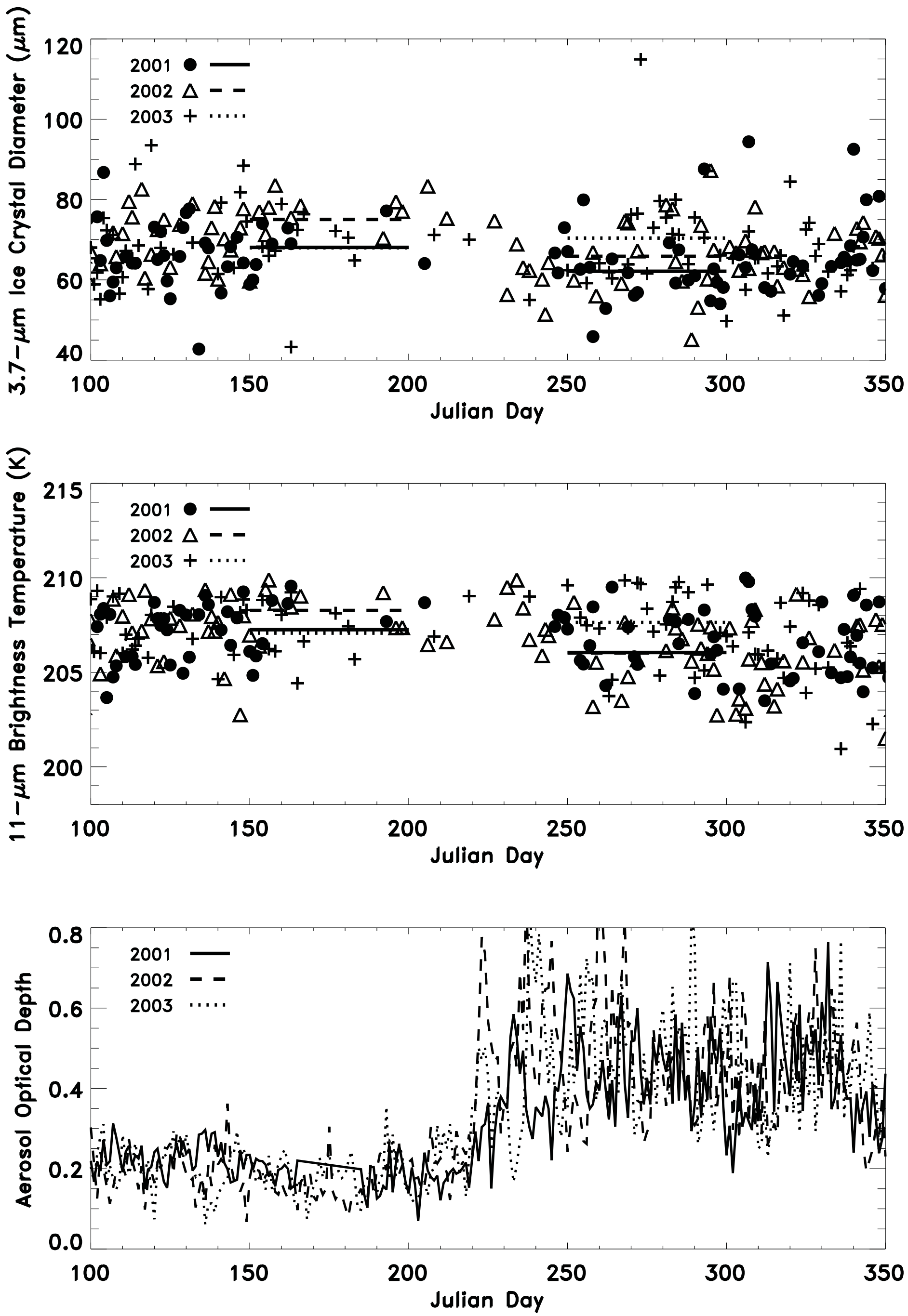
Occurrence of deep convective clouds



0.55 μm aerosol optical depth



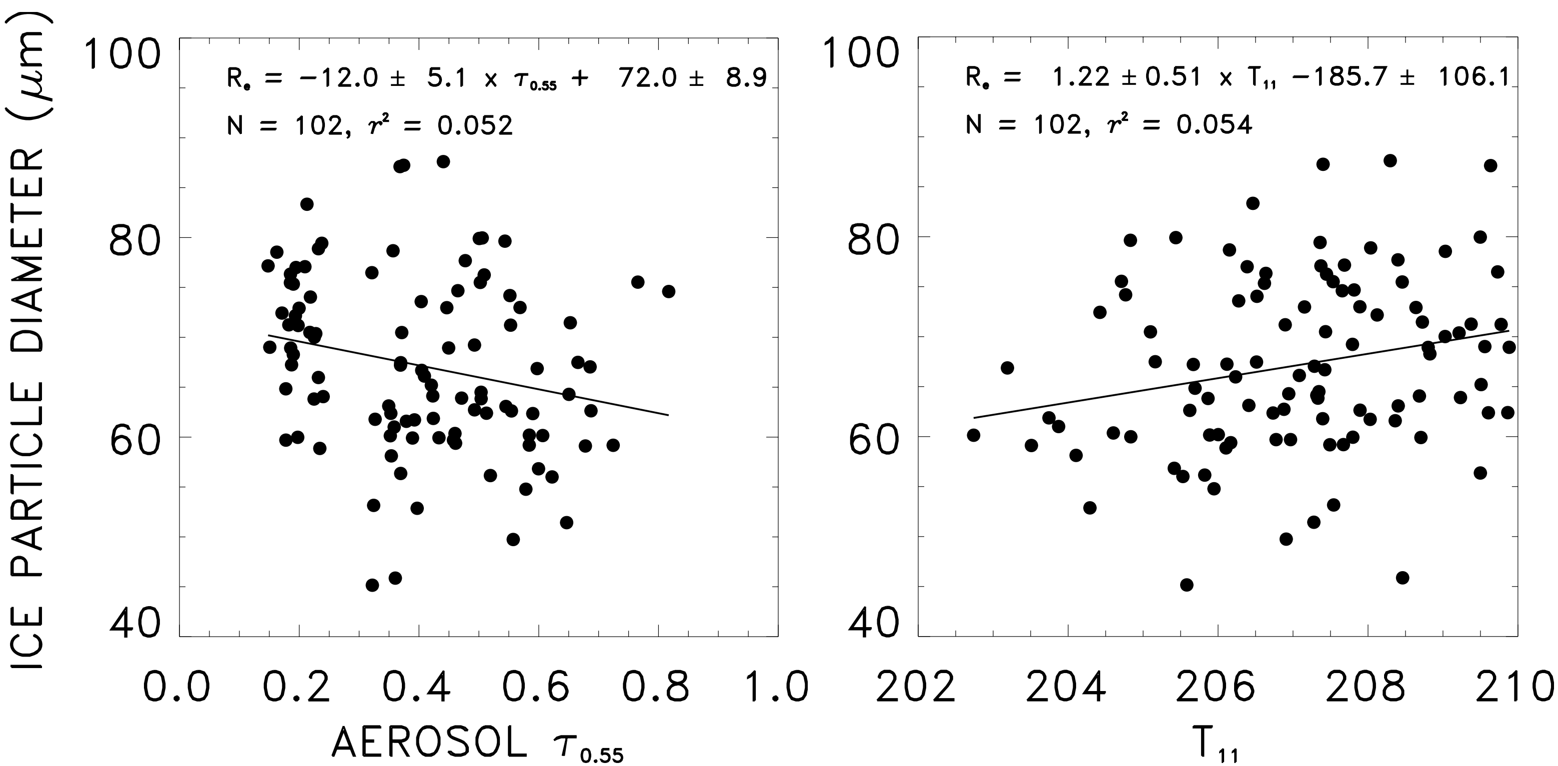
Daily average aerosol optical depths and properties of deep convective clouds composited within the 10° × 20°.



Aerosol burdens peak and cloud top temperatures generally lower during second half of the dry season.

- **Occurrences of deep convective clouds sparse during the first half of the dry.**
- **Aerosol optical depths are small and vary little during the first half of the dry season.**
- **Interestingly, in 2003 ice crystal diameter larger during the first half of the dry season when cloud temperature is lowest.**

For the Amazon Basin during the dry season, approximately half the reduction in ice crystal diameter is due to aerosol loading and half due to decreasing temperature.



Sensitivity of ice crystal diameter to aerosol loading and cloud temperature about the same as that found by Sherwood (2002).

Conclusions

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

The decreases in ice crystal diameters for deep convective clouds as a response to increases in aerosol burdens as reported by Jiang et al. (2008) were probably due in part to decreases in cloud temperatures.

For the Amazon Basin, decreases in daily average ice crystal diameters for deep convective clouds associated with increases in average aerosol burdens and decreases in average temperatures for the clouds mimic the findings reported by Sherwood (2002) based on multiyear patterns in monthly mean aerosol burdens and cloud properties.

Clearly, determining the effects of aerosols on deep convective clouds will prove difficult given the similarity of the effects on ice crystal diameters and temperatures that evidently result from the vagaries of convective processes.