Dynamical and Thermodynamic Controls on Smoke-Cloud Interactions over the Amazon

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Observational Evidence of Smoke-Cloud Interactions over Amazon

- Smoke particles act as CCN, resulting in highly concentrated but narrowly distributed cloud droplet spectra (larger reflectivity)
- Warm rain processes are suppressed, promoting vertical transport of water and pollutants ("smoking clouds") and modifying circulations
- Smoke absorption both cools the surface and heats the atmosphere, changing the thermodynamics and likely reducing cloud cover ("cloud burning")

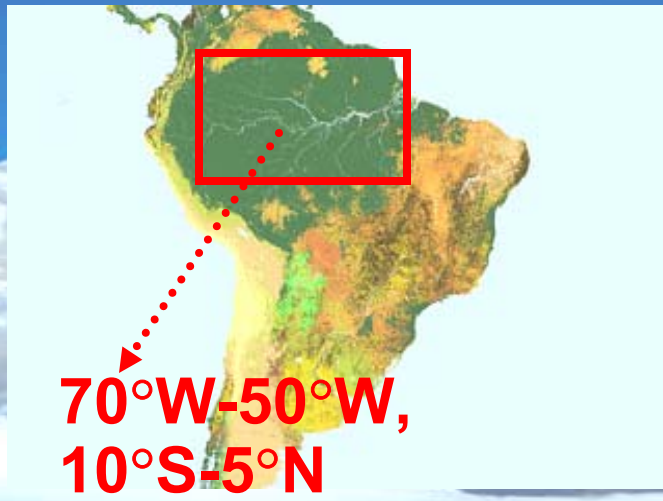
Objectives:

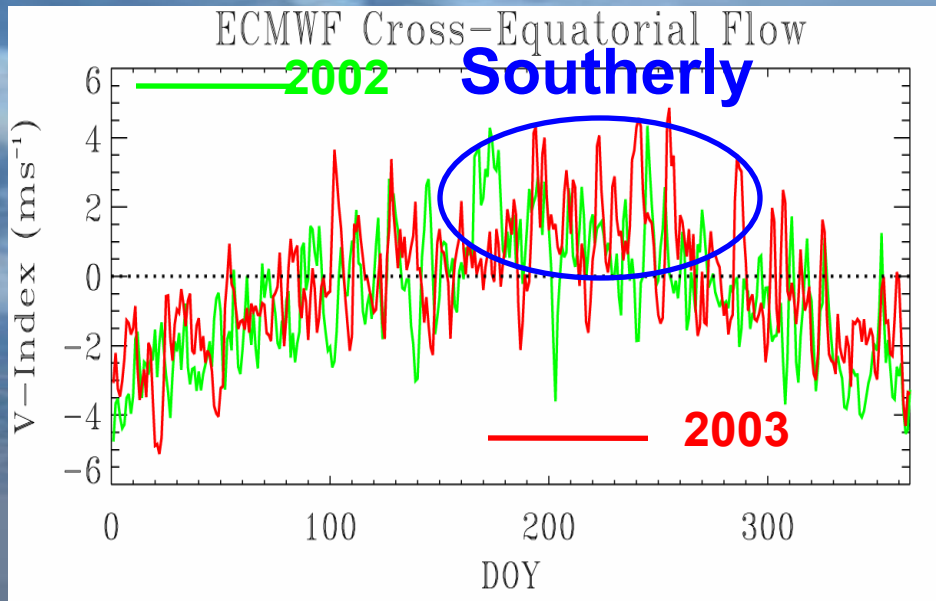
- To demonstrate the complexity of smoke-cloud interactions using MODIS data

- To explore
  - whether or not these complex interactions vary with the interannual changes of large-scale background;
  - what processes might control how changes of aerosol influence warm clouds.

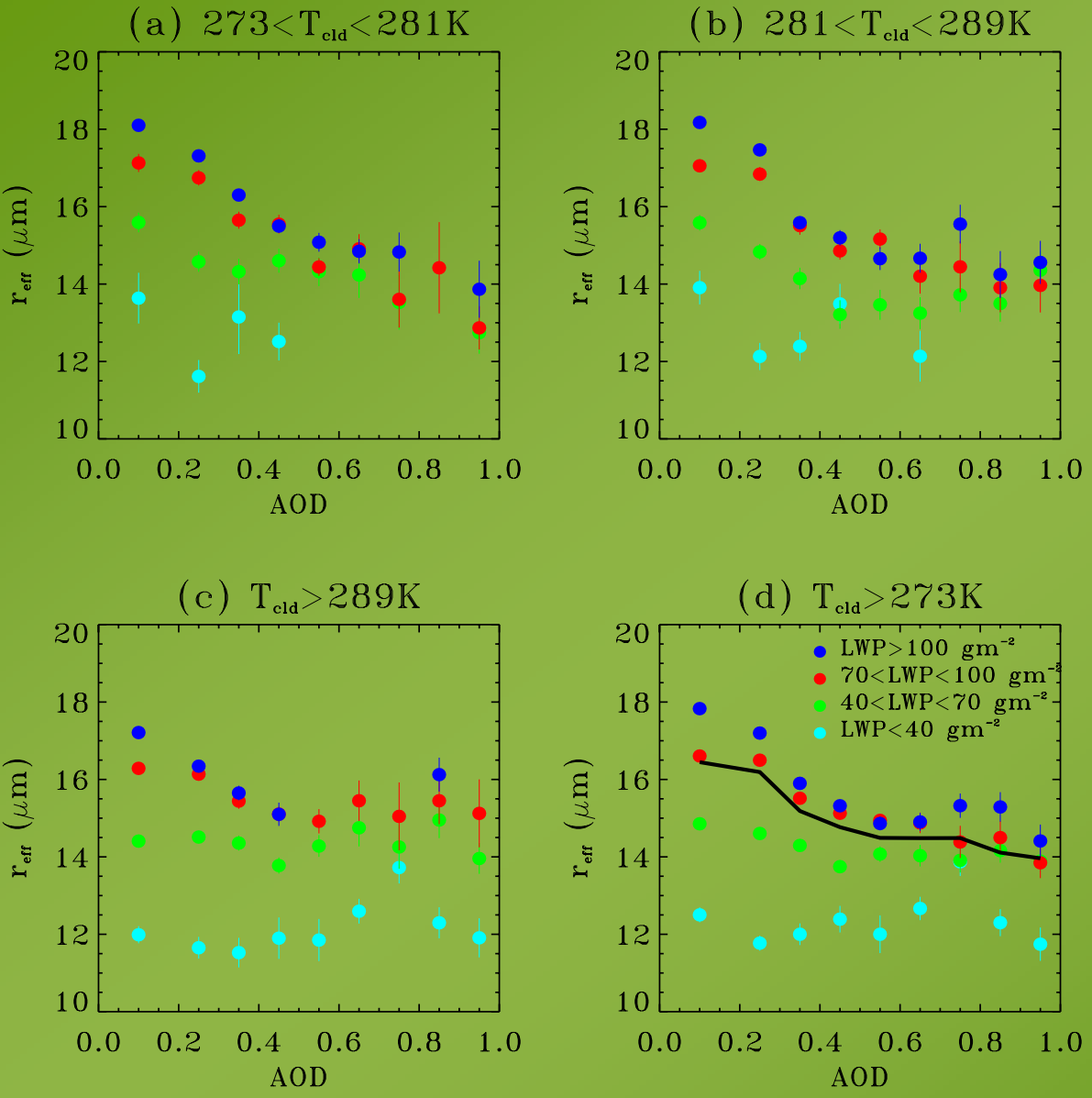
MODIS Analysis

- MODIS/Aqua daily 1°x1°
- ECMWF, radiosondes
- Dry-to-wet transition *(Aug-Oct)*, tropical Amazon
- 2003 *(normal)* vs 2002 *(El Nino)*
- Warm clouds only
- Southerly cross-equatorial flow





2003: Normal Year

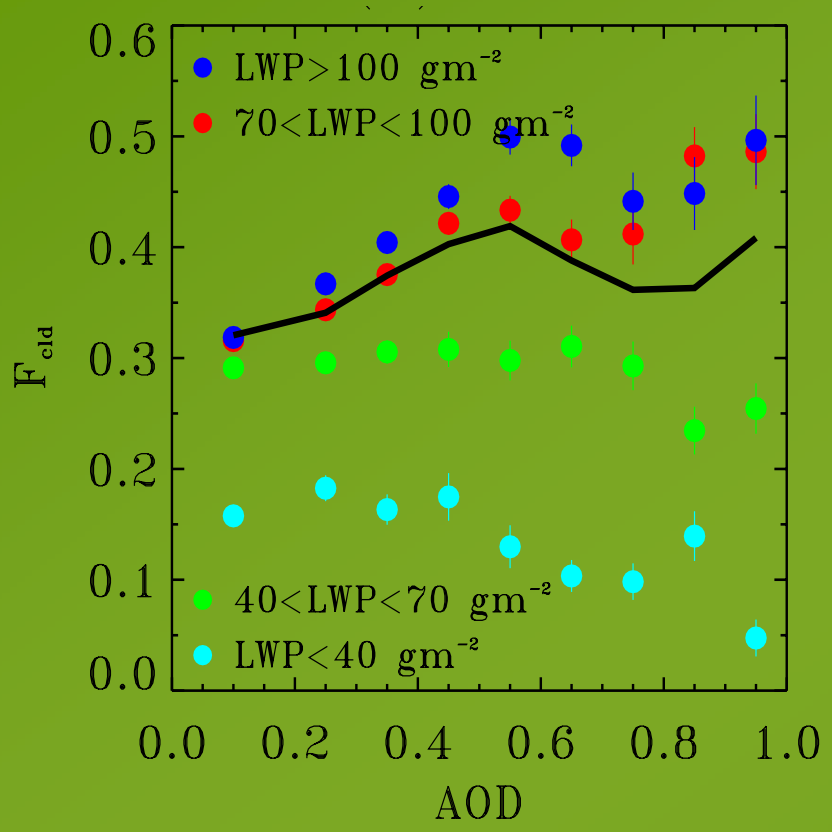


Twomey effect for AOD<0.6;

More significant at high LWP than at low LWP;

Droplet size levels off at a high AOD.

2003: normal year



For LWP>70g/m2, cloud fraction increases with AOD (<0.6)

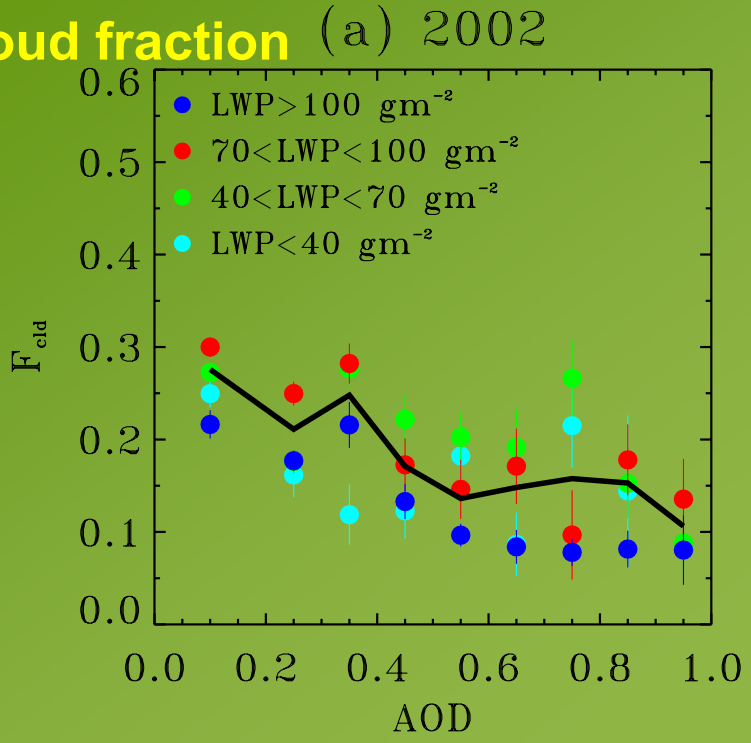
Thin clouds:

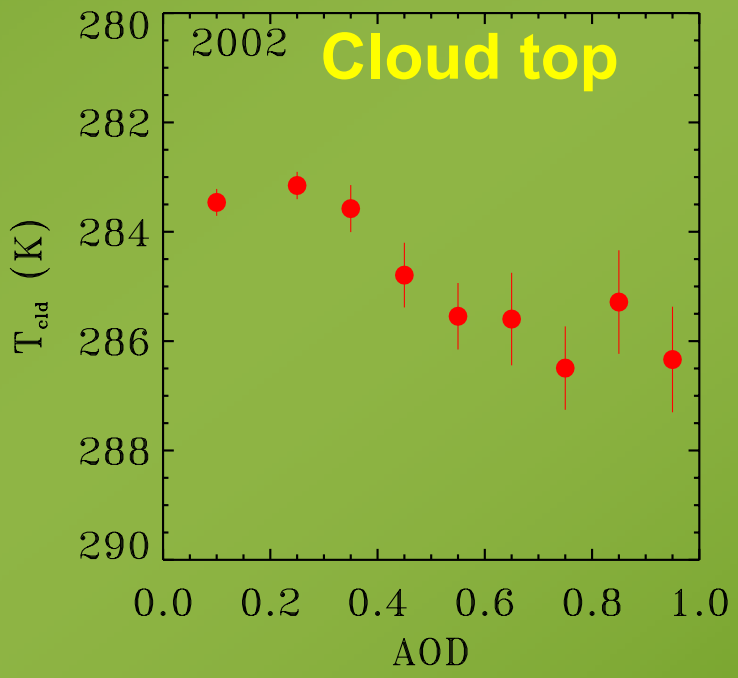
more or less constant fractions for AOD<0.6

decrease for higher AOD conditions. (indication of cloud-burning effect)

2002 ---- El Nino year

Cloud fraction



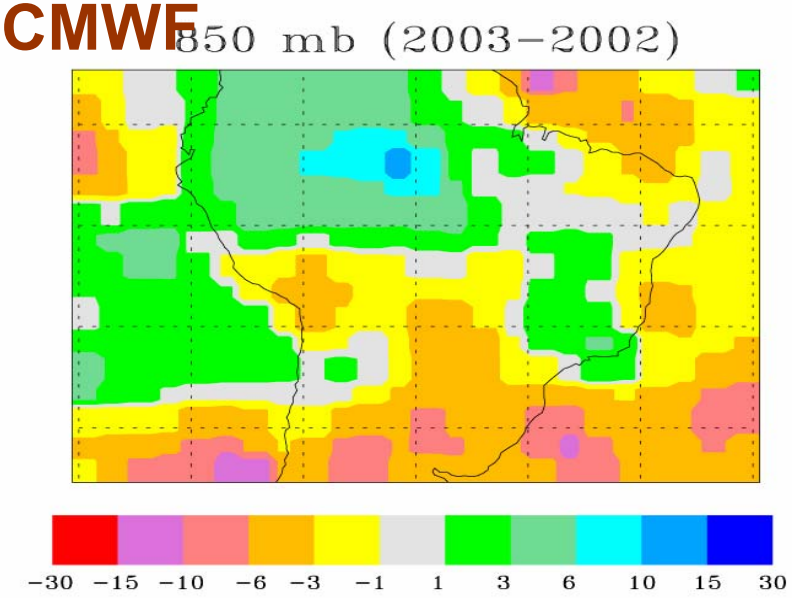


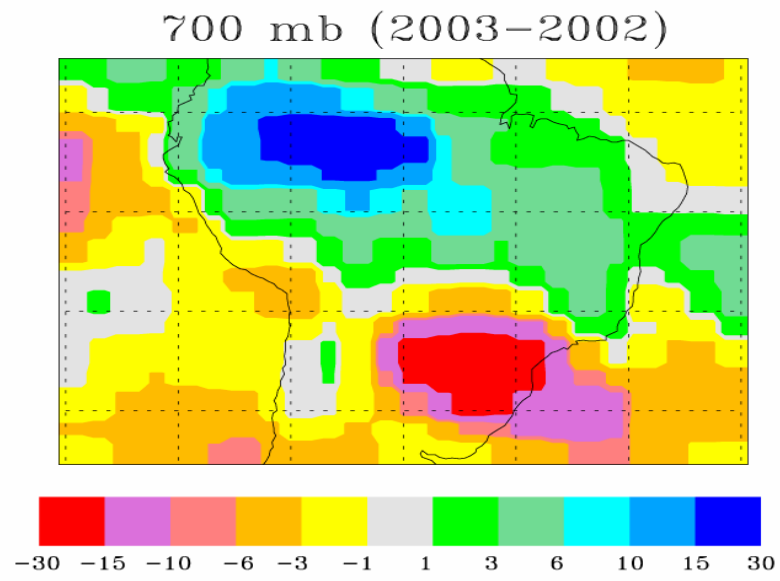
- Cloud fraction decreases with AOD, with greatest reduction for thicker and higher clouds. ***(semi-direct effect)***

- The tops of warm clouds are apparently lowered by smoke
  - stabilization of ABL
  - enhanced capping inversion by smoke absorption

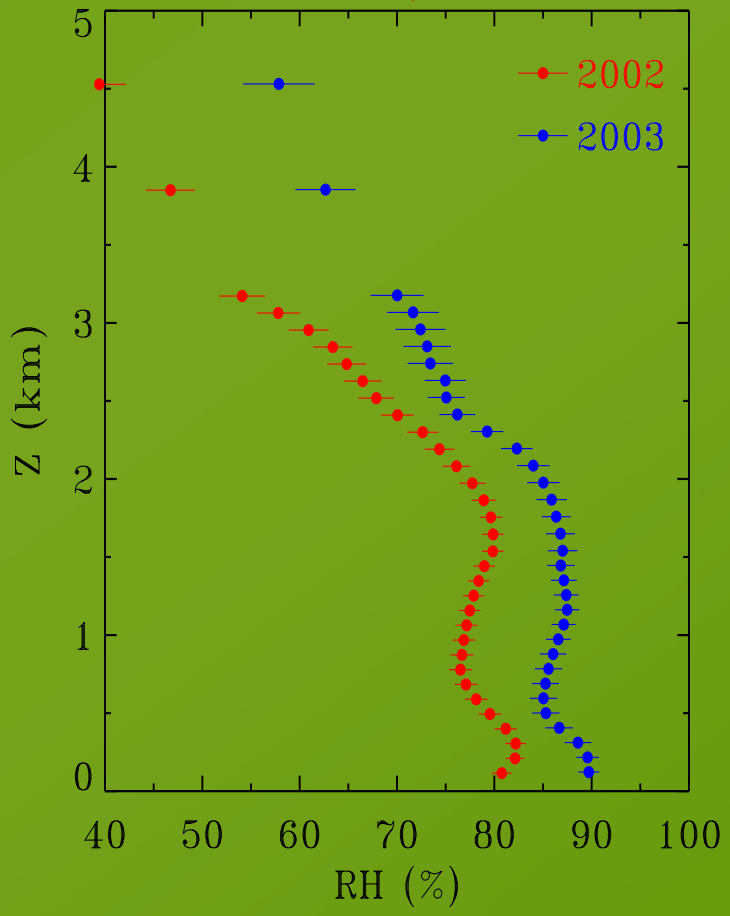
2003 was wetter than 2002

ECMWF



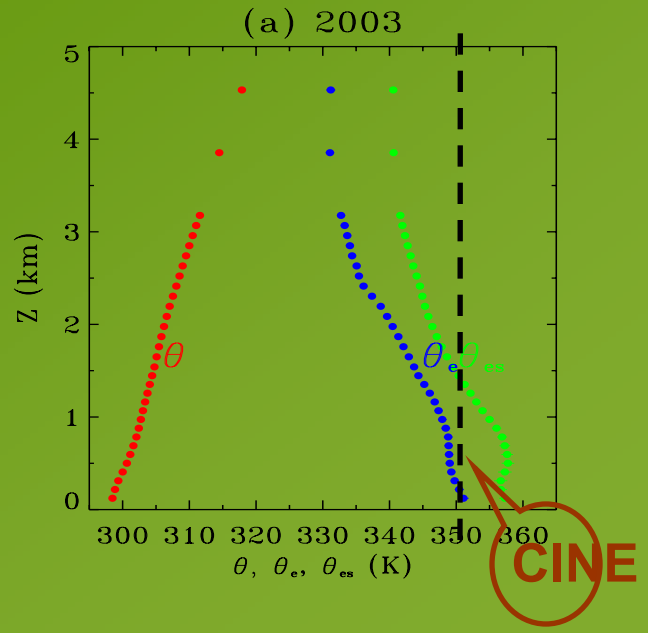


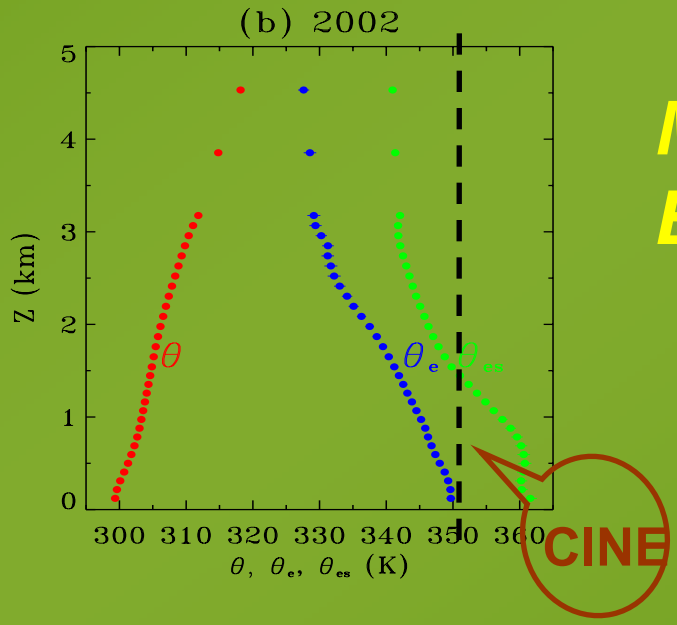
Manaus, Brazil



Radiosonde measurements

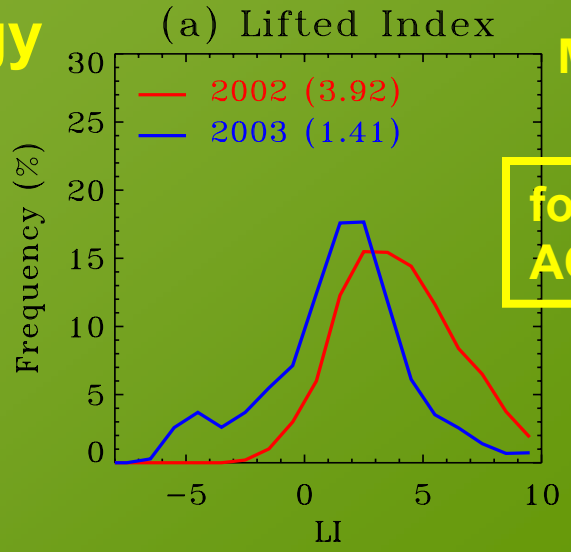
2003 was more unstable than 2002





Manaus, Brazil

Convective Inhibiting Negative Energy (CINE): 2003 < 2002

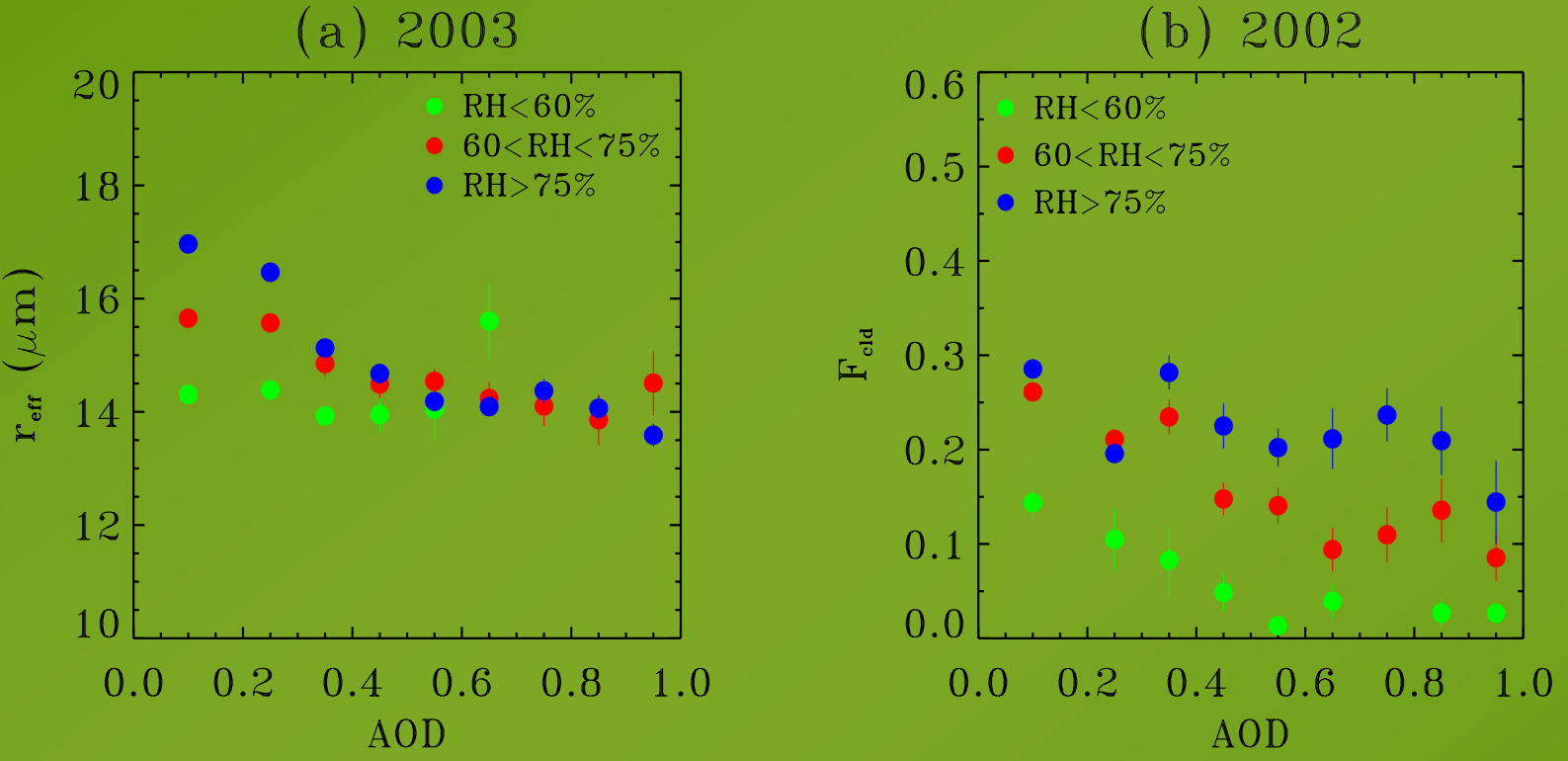


MODIS

for AOD<0.2

also corroborated by MODIS Lifted Index (LI). A larger LI means more stable atmosphere.

Dependence on RH (@850mb)

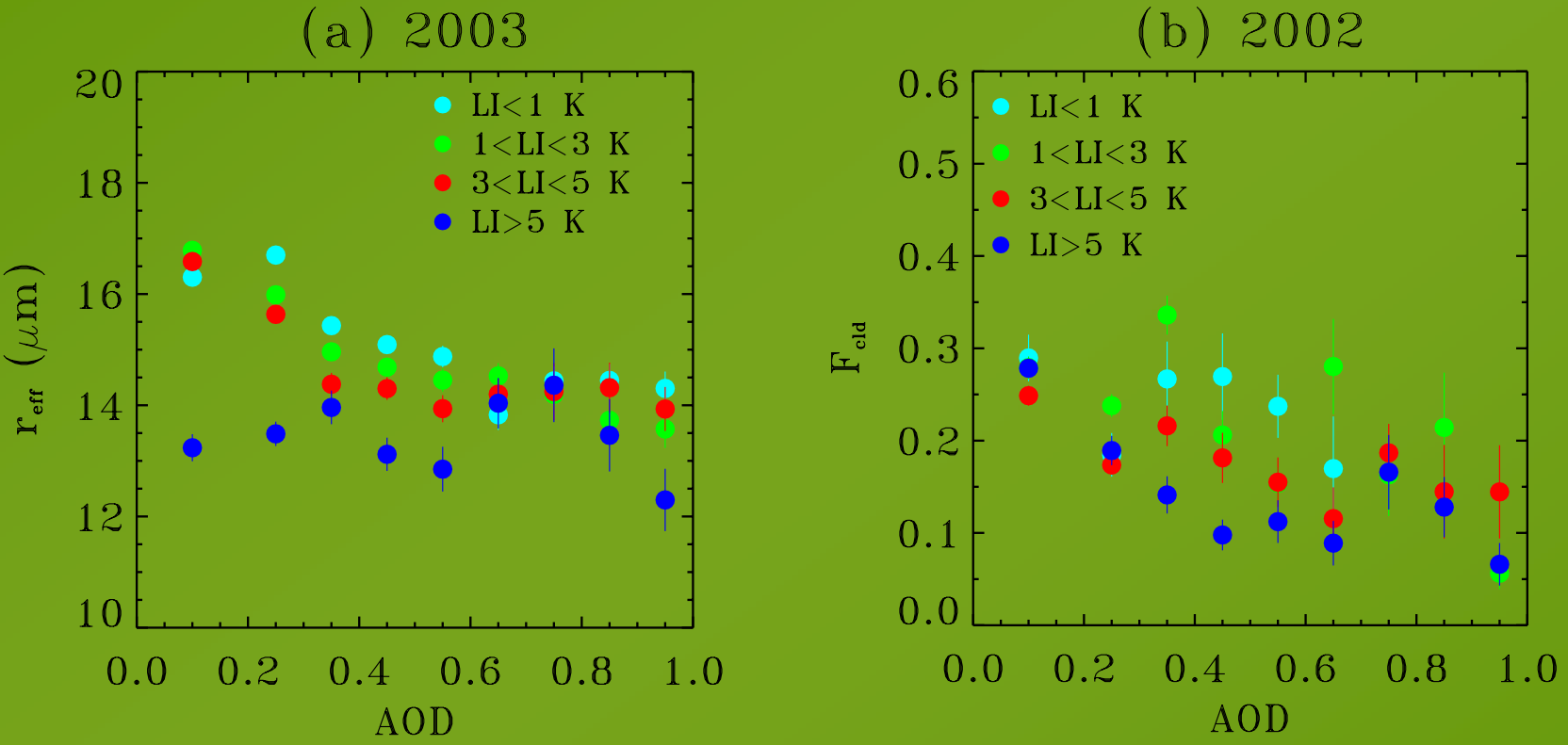


2003: more rapid decrease of droplet size at higher RH.

2002: more rapid reduction of cloud cover at lower RH.

Dependence on Lifted Index (LI)

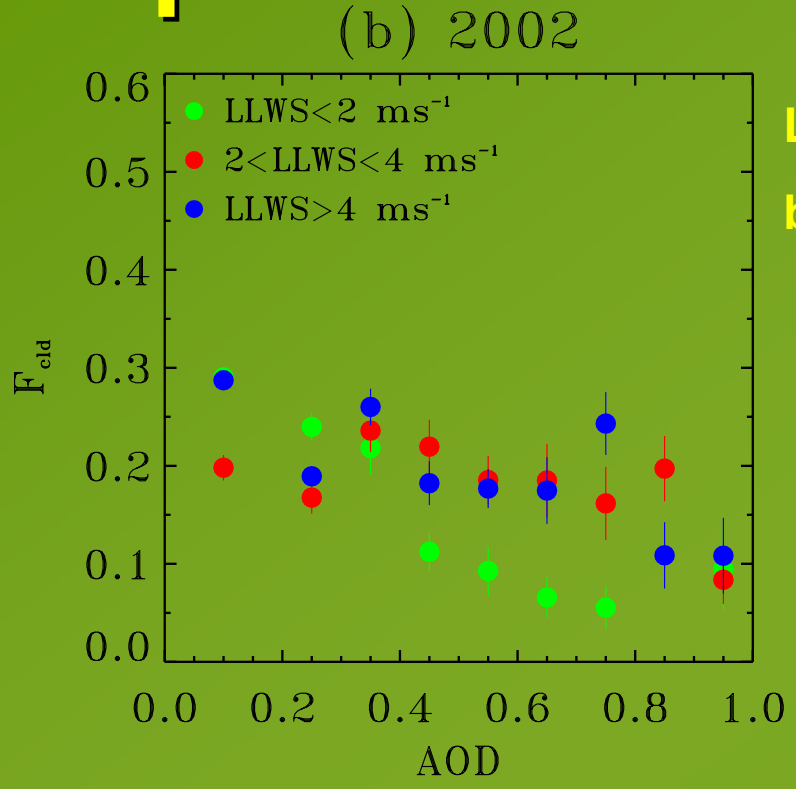
LI < 0 unstable; **LI > 0 stable**



In 2003, Twomey effect is larger at smaller LI (unstable);

In 2002, the reduction of cloud fraction appears to be greater for larger LI (stable)

Dependence on Wind-Shear



LLWS: from radiosonde measurements between 925-700 mb level

*** Cloud burning is more significant under weaker wind-shear, presumably because**

– turbulence/convection are largely determined by surface fluxes for smaller wind-shear; and these can be significantly reduced by smoke absorption.

What have we learned from this study?

- Smoke influences clouds significantly but differently between a normal 2003 (indirect effects) and an ENSO 2002 (semi-direct effect).

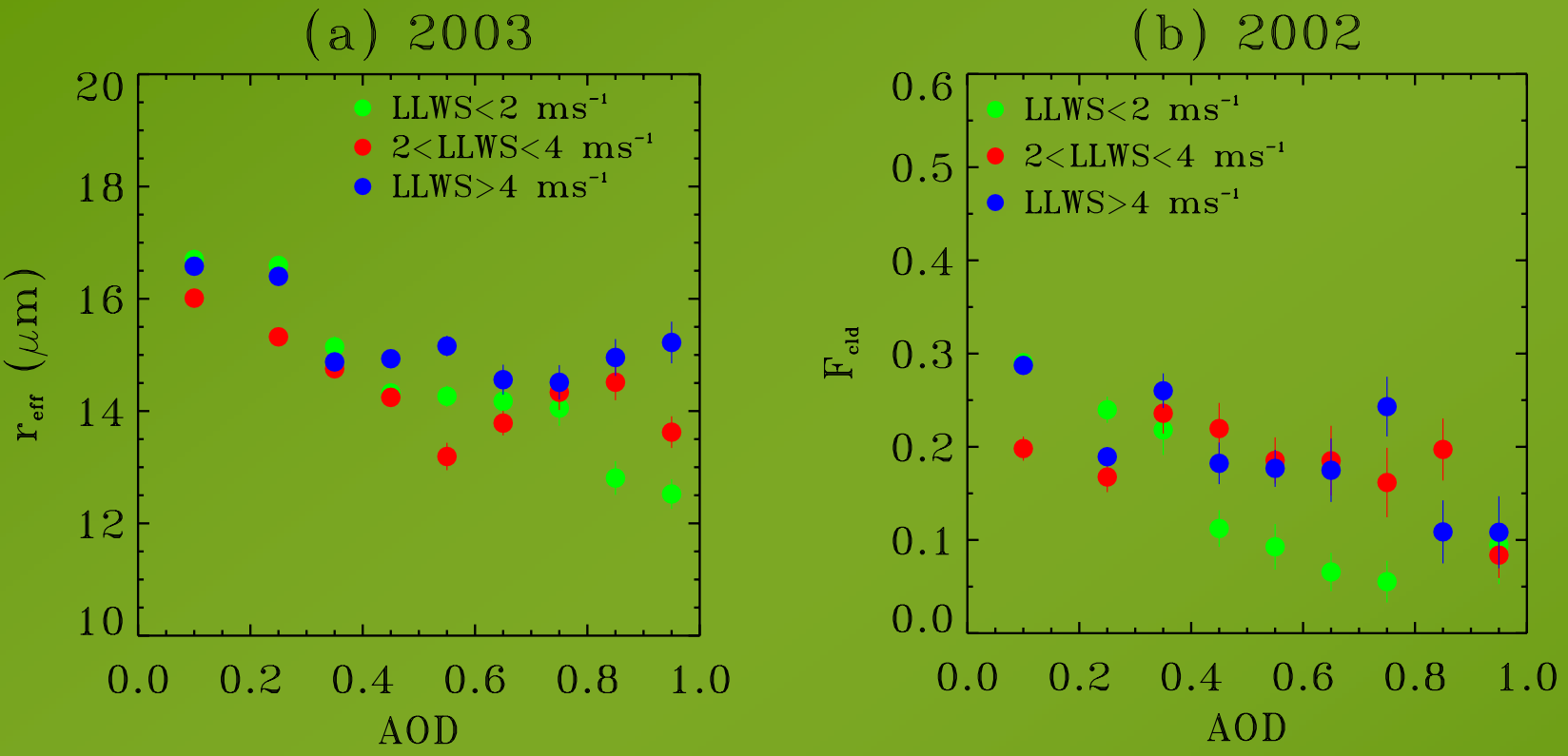
- Such differences correlate with differences in atmos. dynamics/thermodynamics:
  - 2003 was wetter and more unstable, favorable for activation of CN to CCN;
  - 2002 had a relatively dry ABL and less extensive clouds, presumably more susceptible to smoke absorption

- Atmospheric dynamics & thermodynamics play a complex role in regulating the influences of aerosols on clouds. Findings at a specific time & location are not easily extrapolated to other times & places.

END

THANKS!

Dependence on Wind-Shear



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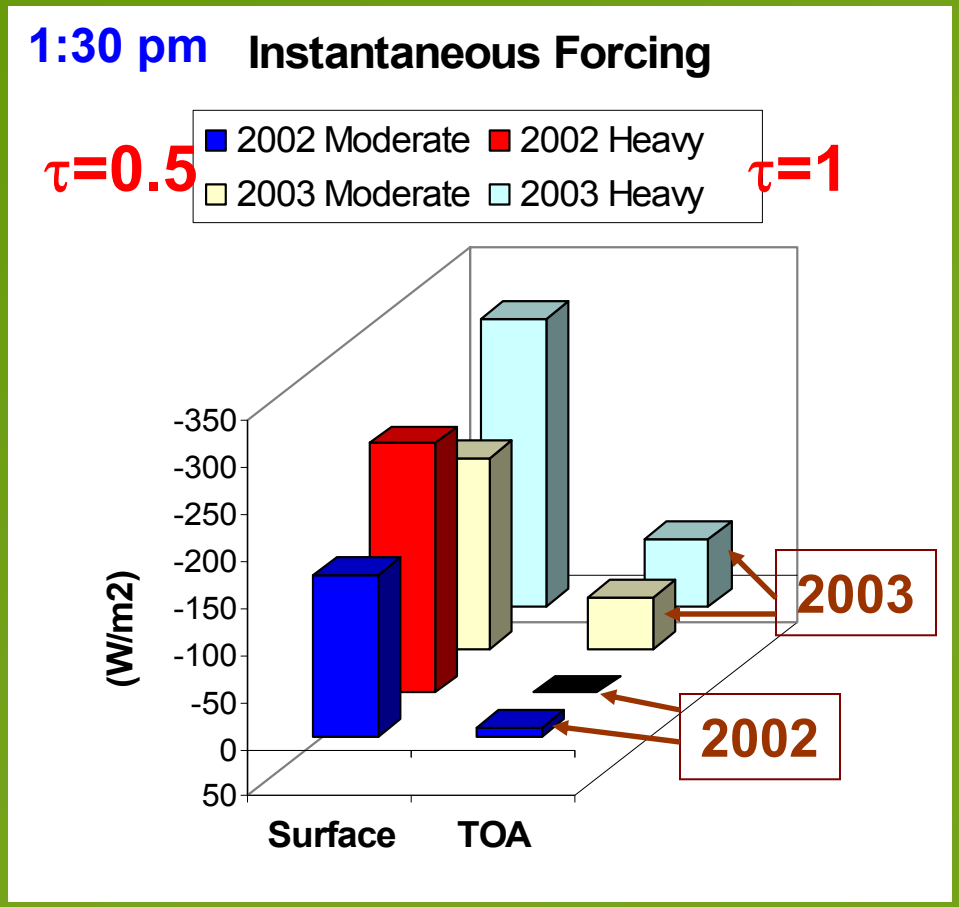
- Cloud burning in 2002 is more significant under weaker wind-shear

  – presumably, turbulence/convection are largely determined by surface fluxes for smaller wind-shear; and these can be significantly reduced by smoke absorption.

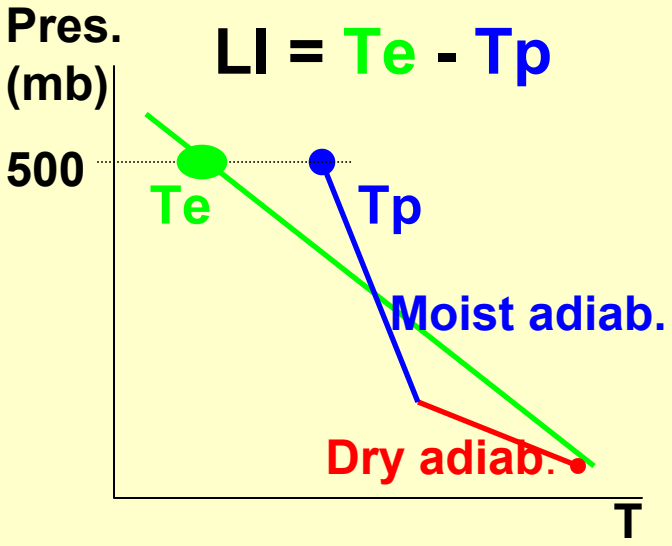
Different smoke-cloud interactions result in interannual variations of aerosol forcing



- TOA cooling in 2003, but nearly zero in 2002
- Surface flux reduces by 20~30% (moderate smoke) and 35~45% (heavy smoke) (2003 more than 2002)
- Atmos. heating increases by 50-60% (moderate) and 80-90% (heavy).

- *Possible influences on wet season onset (influenced by surface fluxes, thermodynamics)*

MODIS Lifted Index (LI) for AOD < 0.2

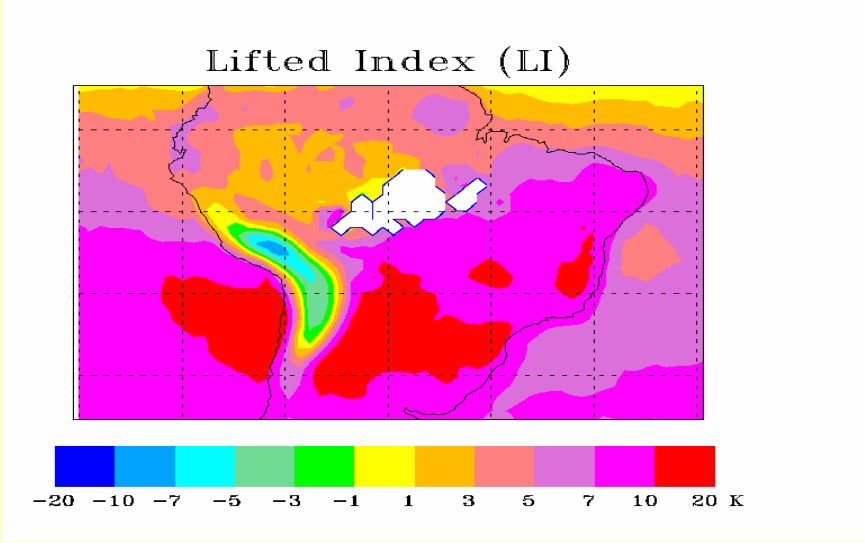


Tropics:

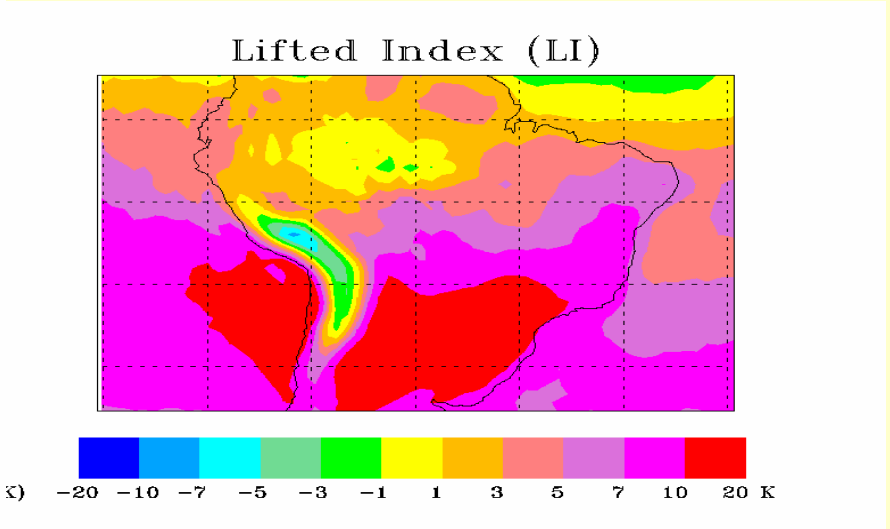
Smaller LI, less stable atmosphere in 2003;

Stronger updrafts in 2003 could activate CN to CCN more efficiently.

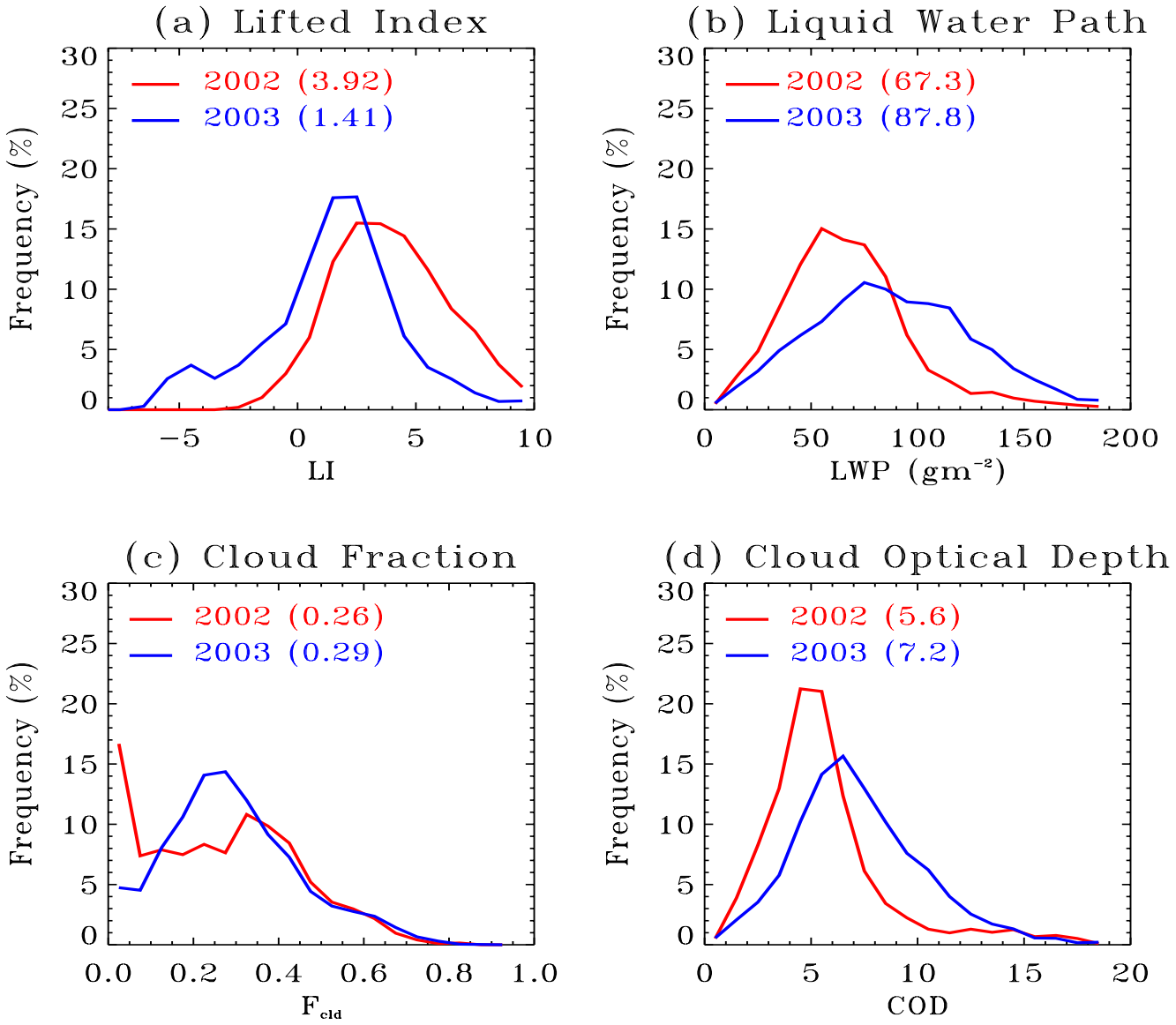
2002



2003

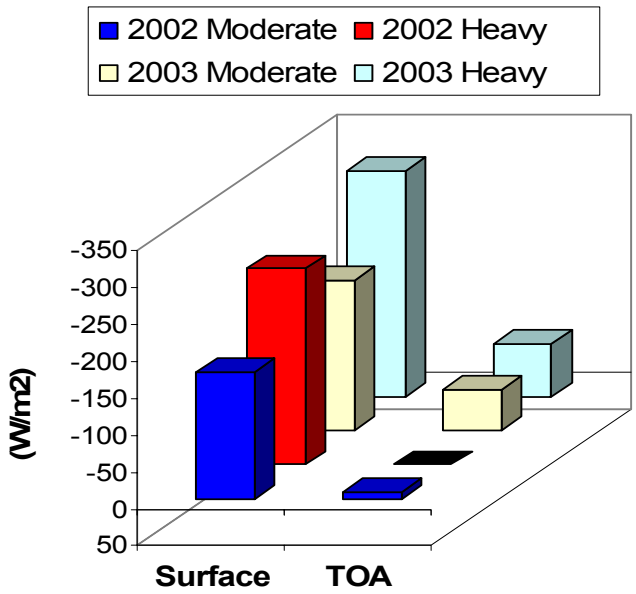


MODIS Observed PDFs
---- for AOD < 0.2

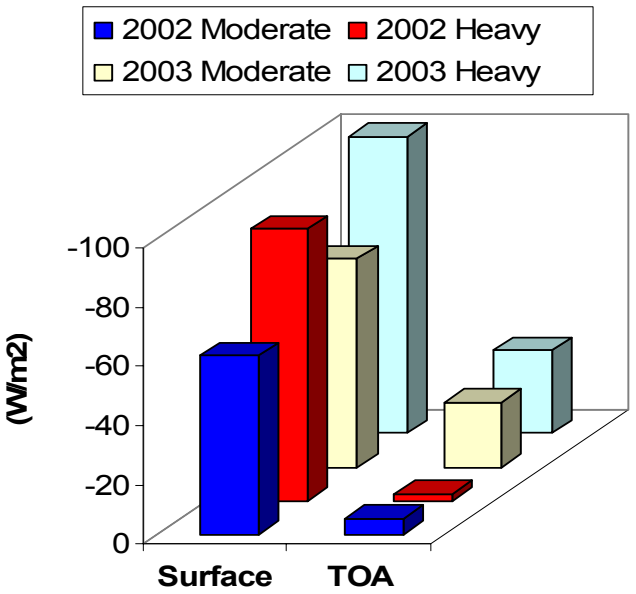


Different smoke-cloud interactions result in interannual variations of aerosol forcing

1:30 pm Instantaneous Forcing



24-h Average Forcing



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