CALIPSO and MODIS Observations of Changes in Aerosols near Clouds

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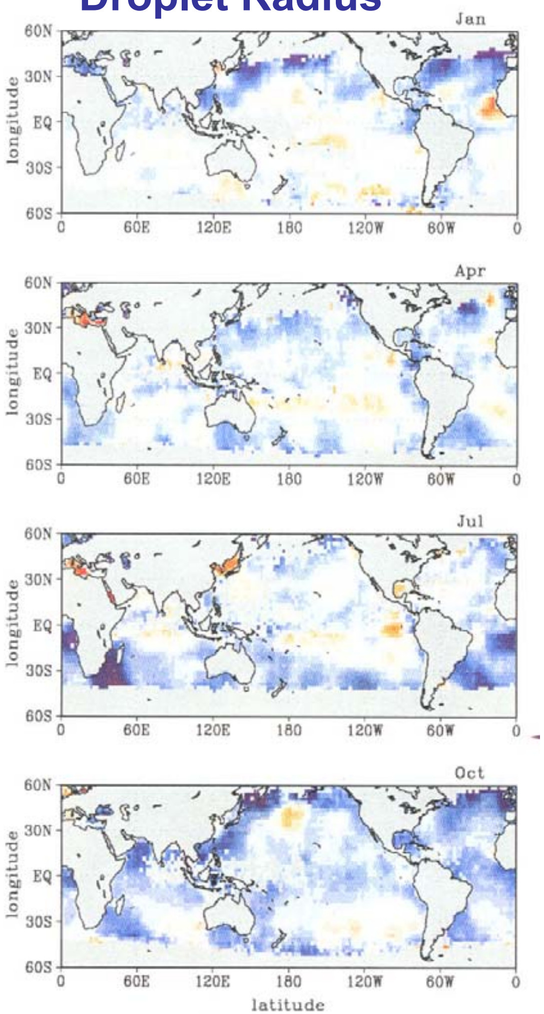
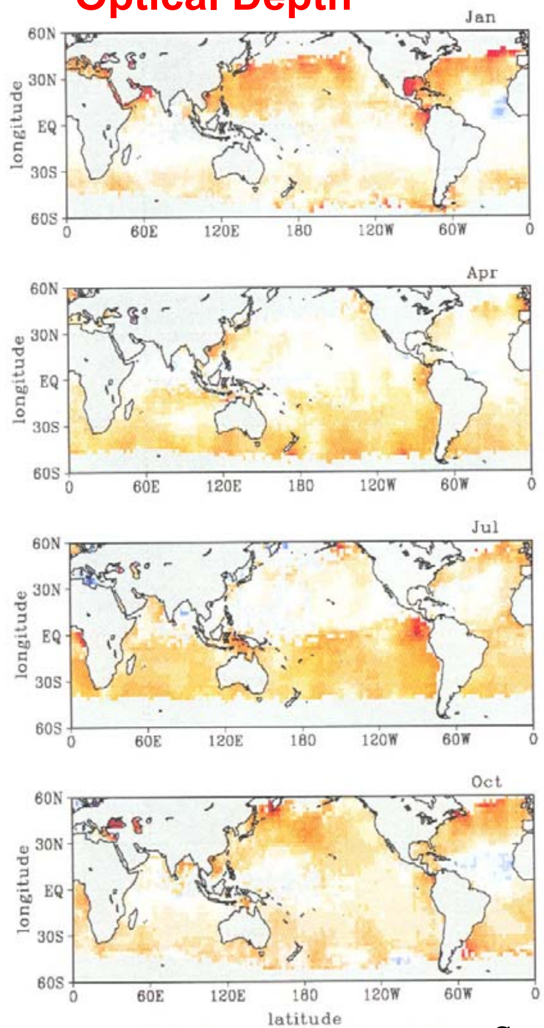
GOAL: **Appraise the fidelity of the CALIPSO optical depth retrievals with the intent of using daytime and nighttime retrievals to characterize changes in aerosol properties near clouds.**

Aerosol Indirect Radiative Forcing: Cloud Droplet Radius, Optical Depth, and Aerosol Column Number

Droplet Radius



Optical Depth

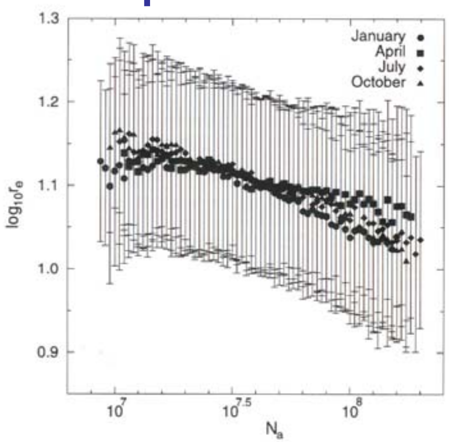


- **4-km AVHRR data for 1990.**
- **Correlations shown for month of daily average values composited for 17.5° × 17.5° latitude-longitude regions.**
- ***Blues*** **indicate negative and** ***Reds*** **positive correlations.**

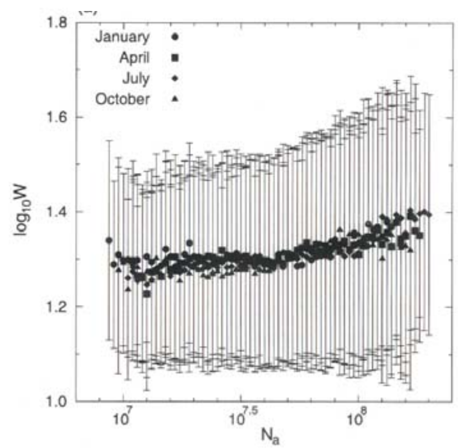
Source: Sekiguchi et al. (2003)

Global Composites: Aerosol Number, Cloud Droplet Radius, Optical Depth, Liquid Water Path, and Fractional Cloud Cover

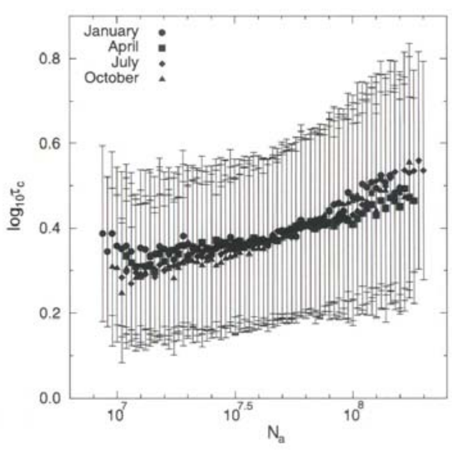
Droplet Radius



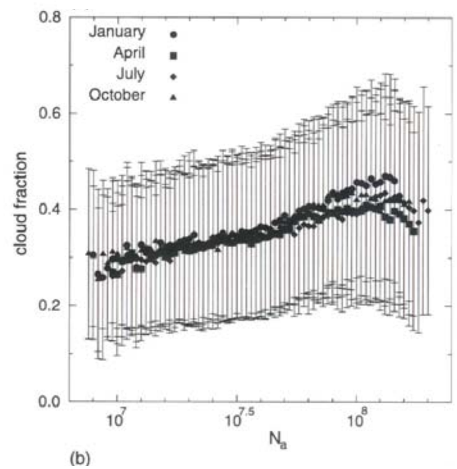
Liquid Water



Optical Depth



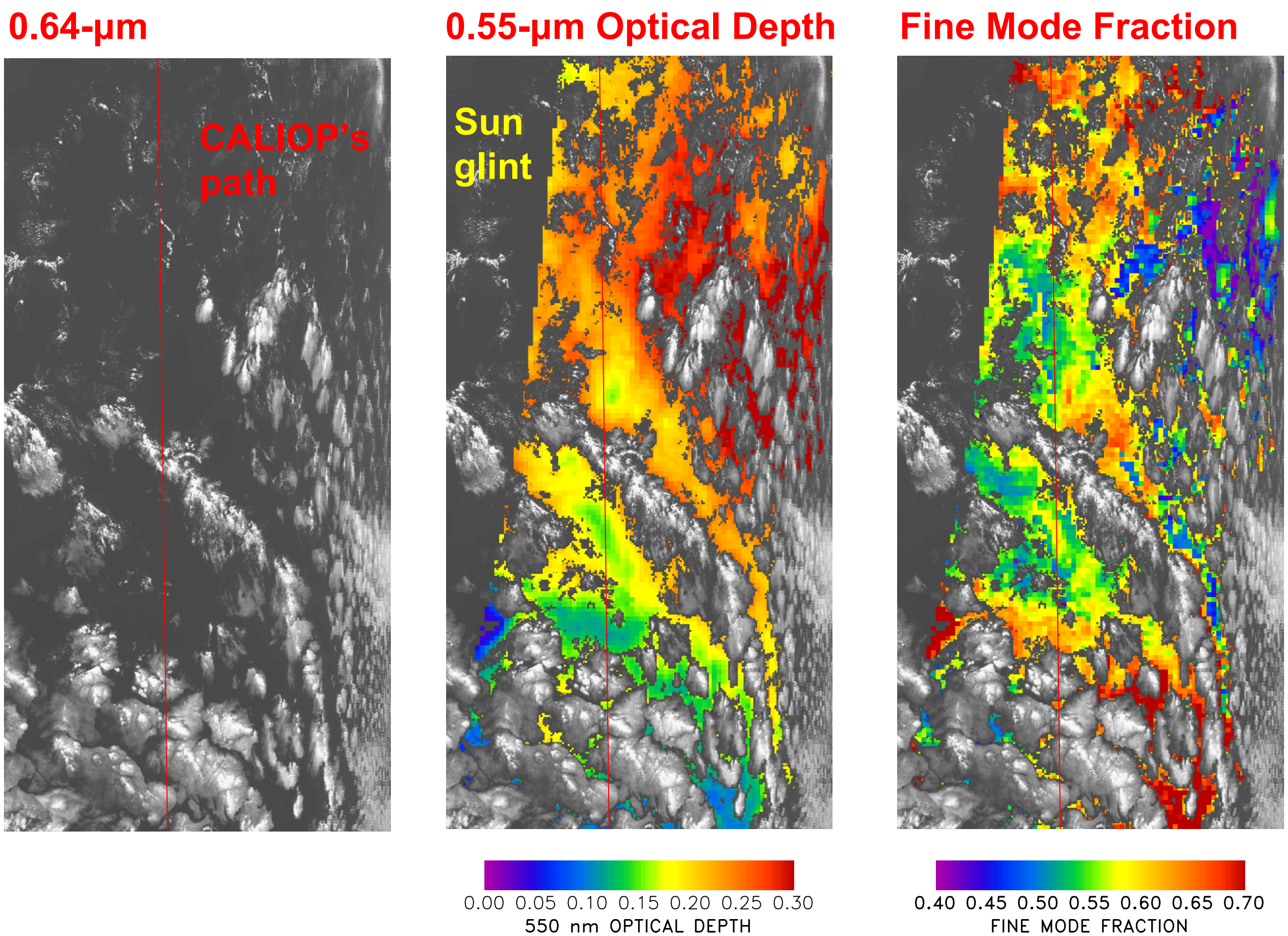
Cloud Cover



- **Daily averages for 2.5° × 2.5° latitude-longitude regions composited for the indicated month and for the entire Earth.**
- **Droplet radius *decreases* while optical depth, column liquid water, and fractional coverage *increase* with *increasing* aerosol column number.**
- **Assuming a 30% increase in aerosol optical depth since the industrial revolution, the direct forcing is –0.4, the indirect forcing, assuming fixed cloud liquid water is –0.6 and the total is between –1.0 and –1.8 Wm^{-2}.**

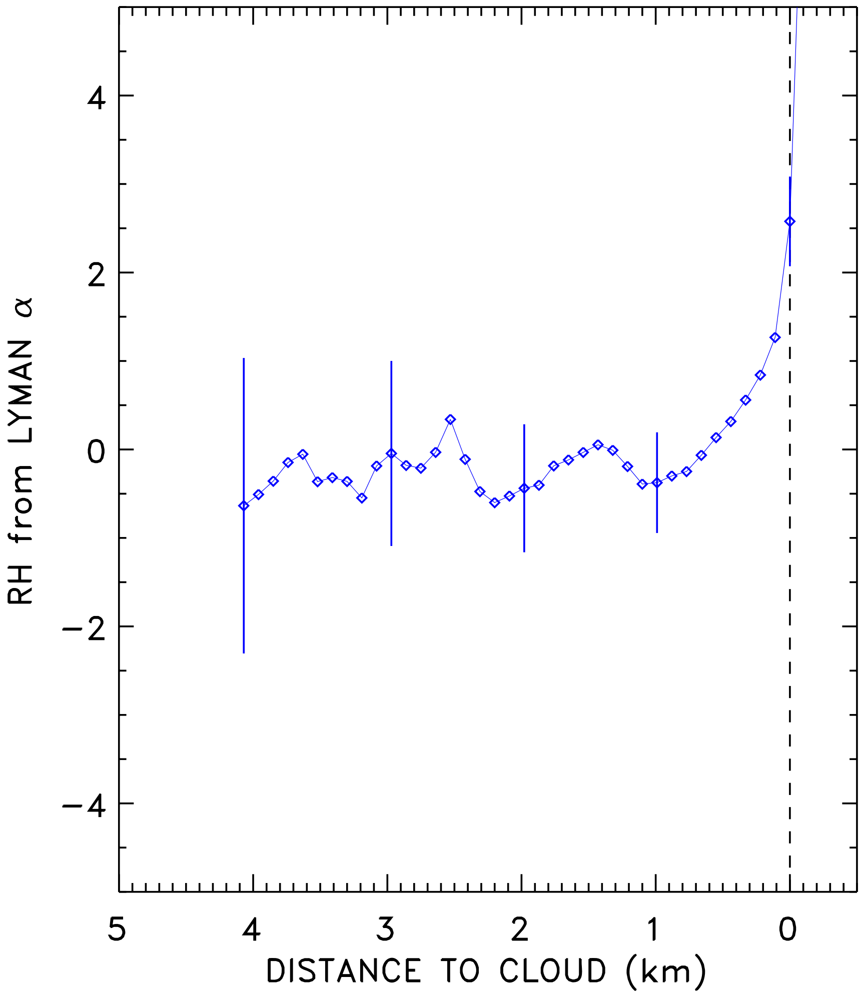
Source: Sekiguchi et al. (2003)

Aerosol Optical Depths over Oceans: *The MODIS View*



MODIS aerosol optical depths and fine mode fractions generally increase in the neighborhood of low-level marine stratocumulus.

Relative Humidity Changes near Clouds



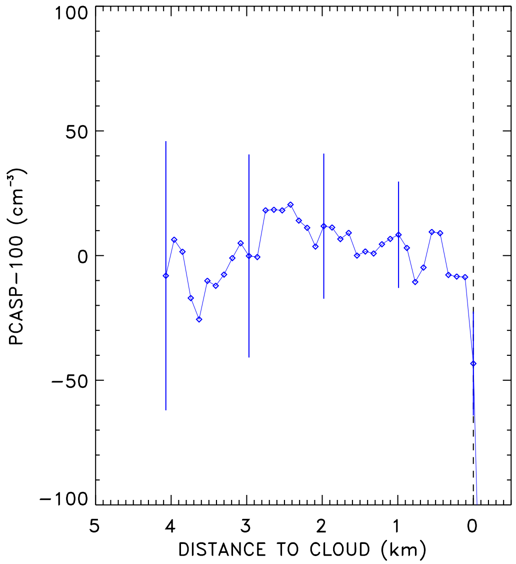
Departures from means of cloud entering and leaving flight legs composited from nine INDOEX flights.

Clouds identified by LWC > 0.03 g m^{-3} and FSSP-100 > 10 cm^{-3} for more than 3 sec.

3% rise in RH (from 89-90%) within 1 km of clouds.

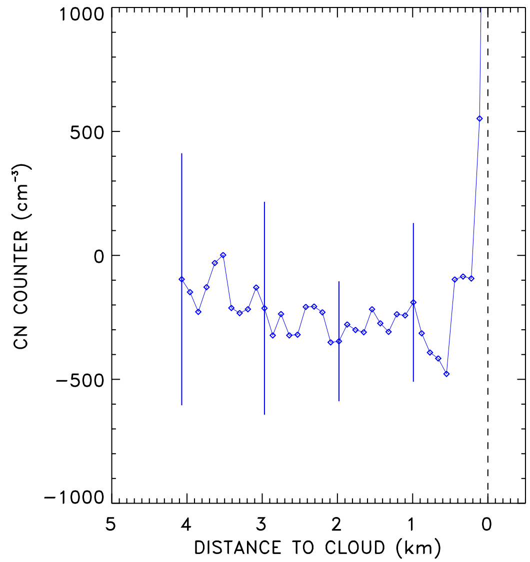
Particle Concentration Changes near Clouds

PCASP



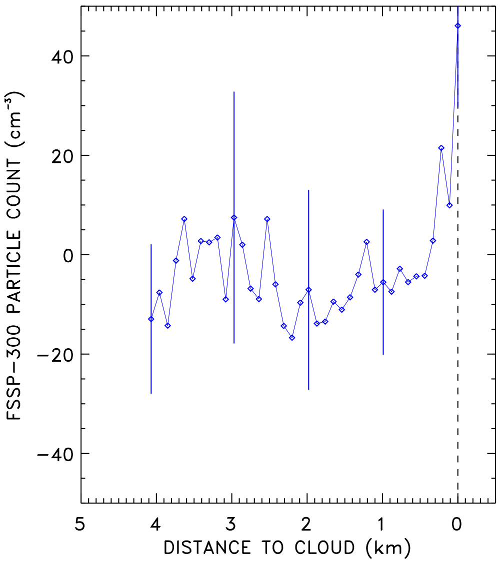
Change from 900 cm^{-3}

CN



Change from 2500 cm^{-3}

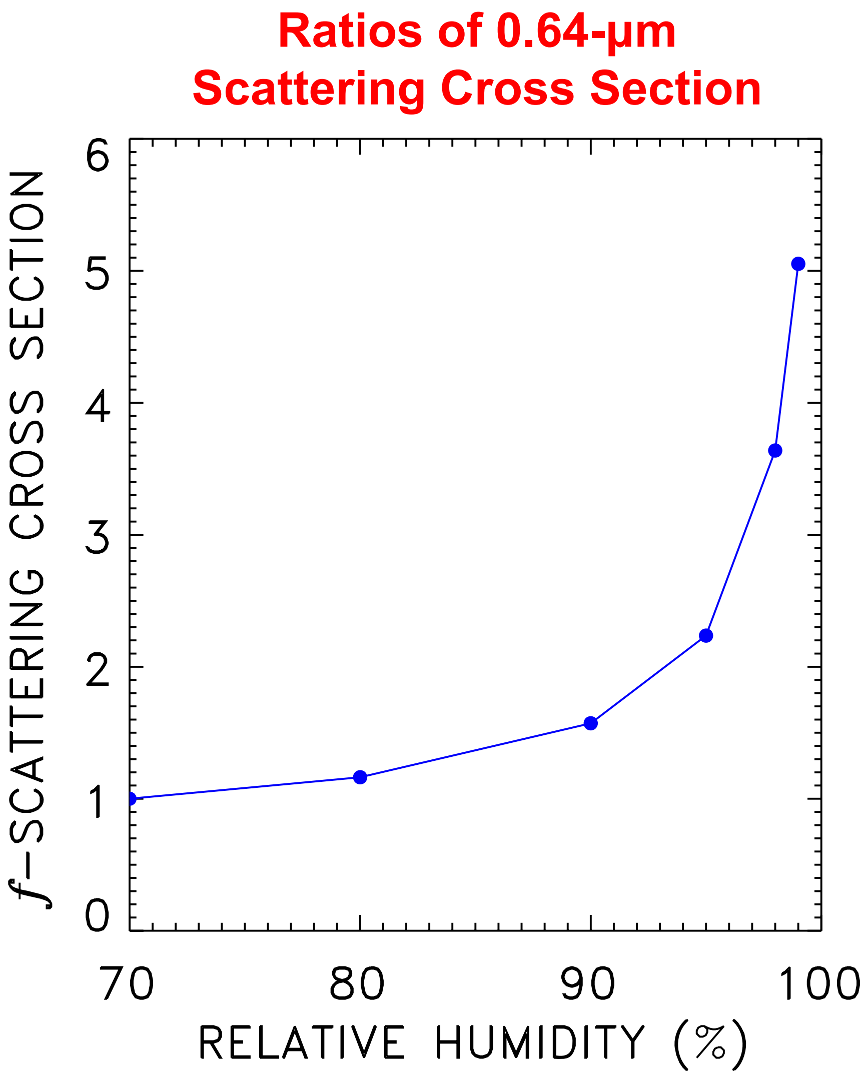
FSSP-300



Change from 30-40 cm^{-3}

Aside from a possible increase in FSSP-300 particle counts 200 m from clouds, there is no indication that particle concentrations increase as the clouds are approached.

Scattering Cross Section and Relative Humidity



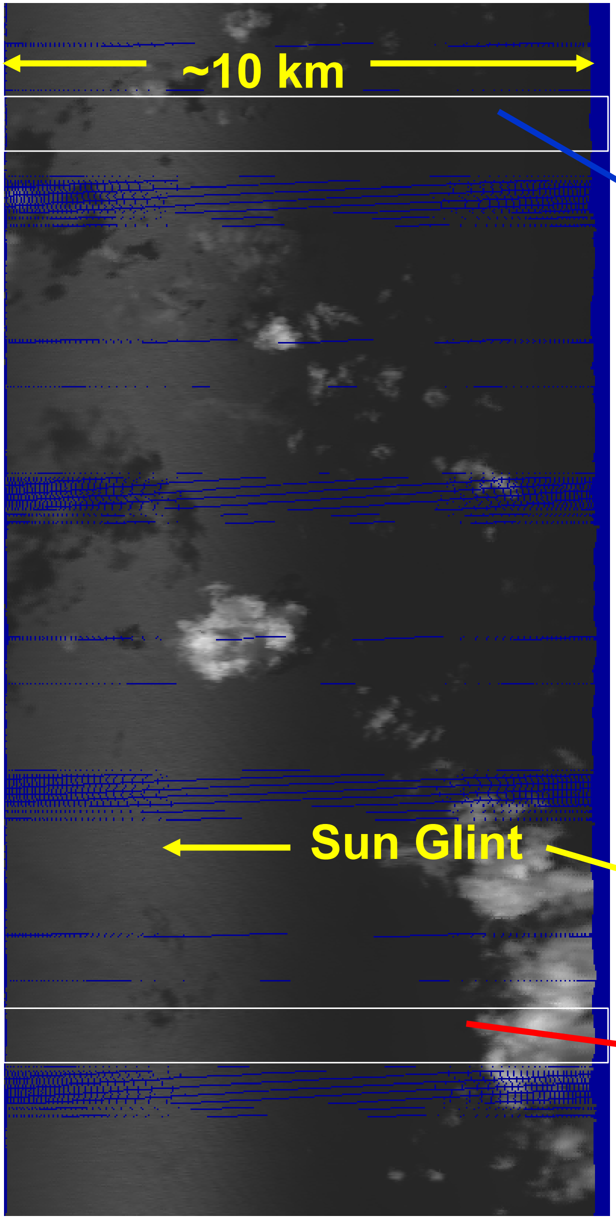
Reflected radiances observed by satellites are proportional to the scattering cross section.

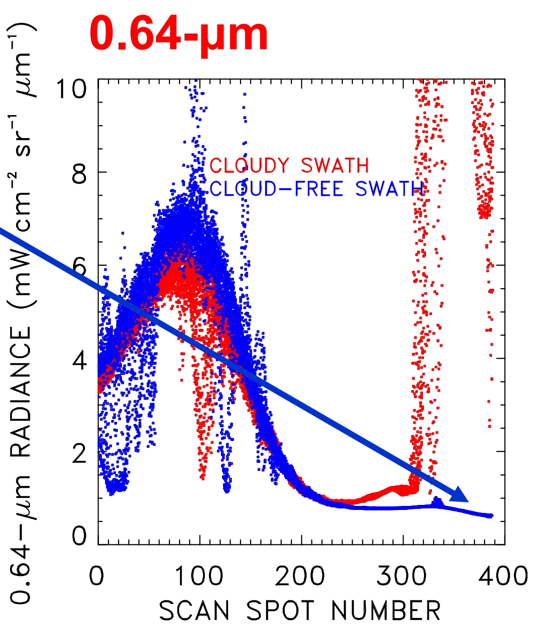
3% rise in RH from 90% is equivalent to a 30% enhancement in scattering cross section for the "INDOEX Aerosol."

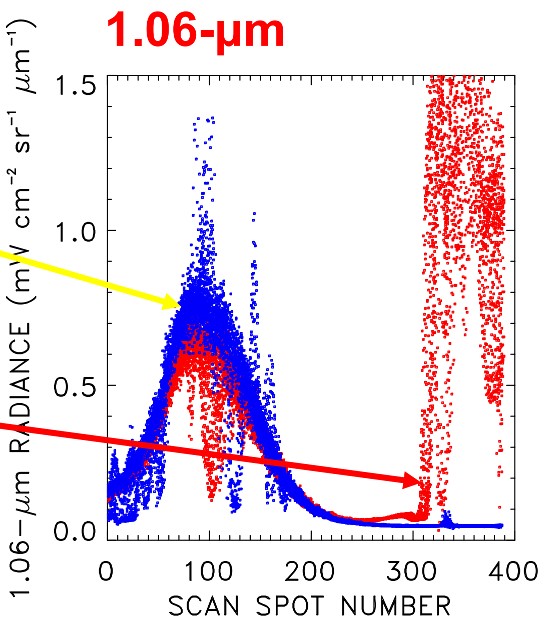
Calculations based on chemical composition described in Ramanathan et al. (2001) and methodology described in Sateesh et al. (1999).

Clean

Southern Hemisphere







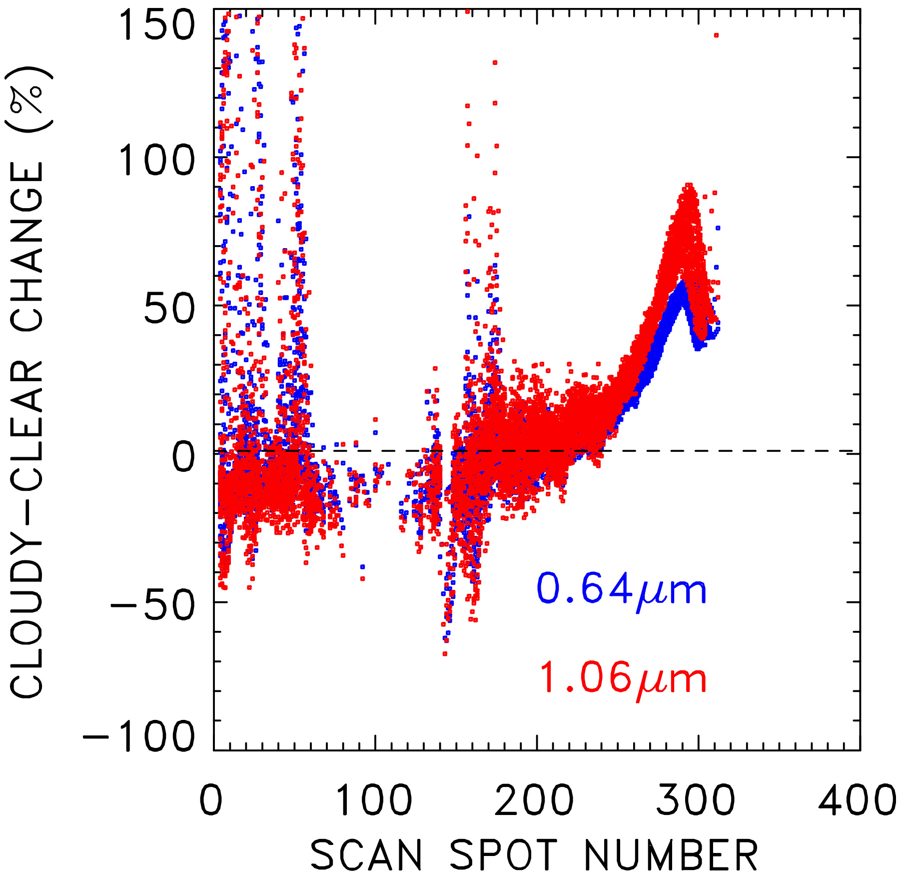
MCR Imagery from INDOEX

30-m imagery at 0.64, and 1.06 μm from ~5-km altitude along C-130 flight path.

0.64 and 1.06-μm radiances enhanced ~50% within 1-km of cloud, roughly consistent ~30% enhancement in scattering cross sections with particle growth.

Enhanced illumination of the cloud-free column has not been accounted for in these observations.

Percentage Enhancement and Distance from Cloud Edge

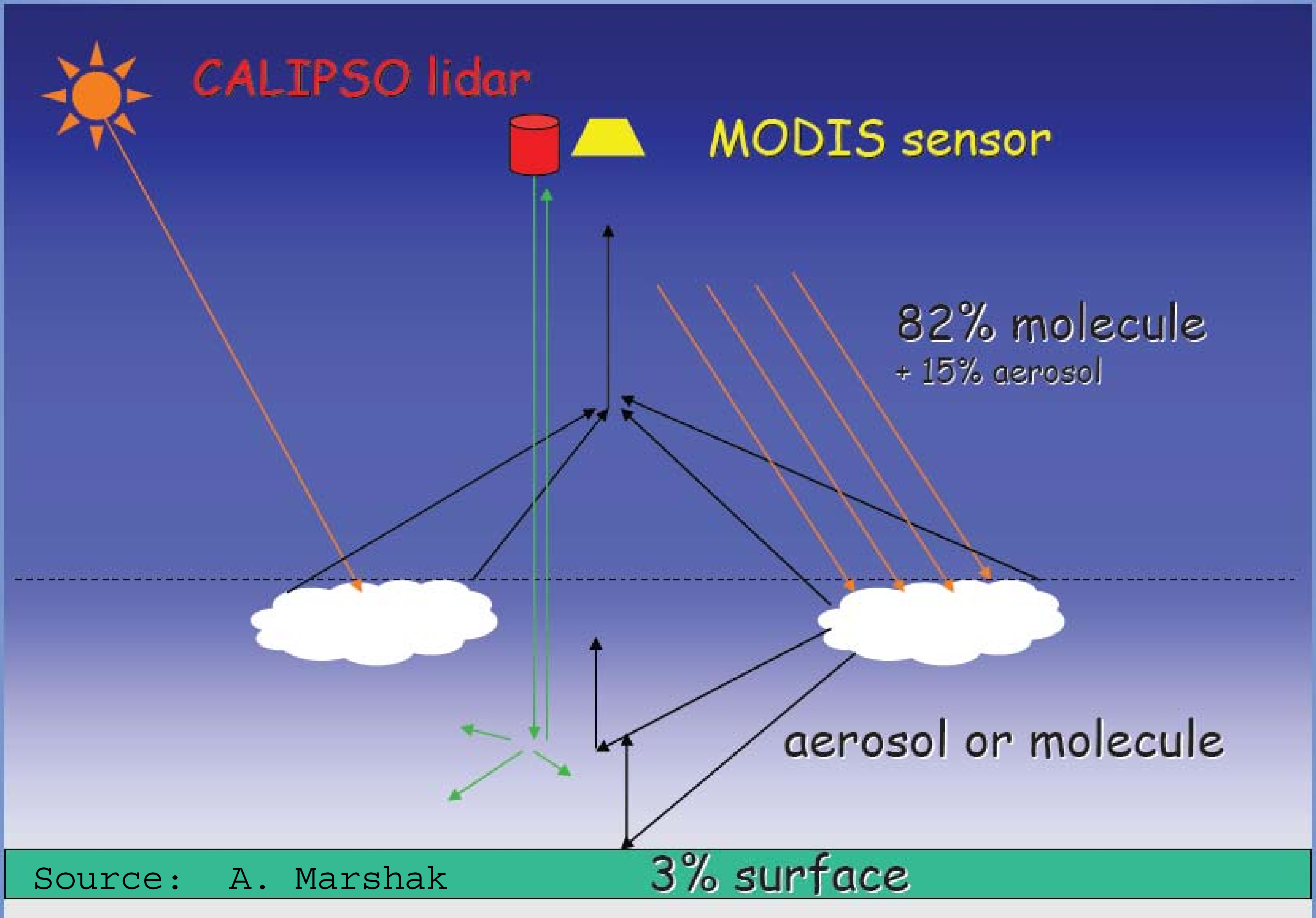


$$I_D = \frac{I'_S - I_S}{I_S}$$

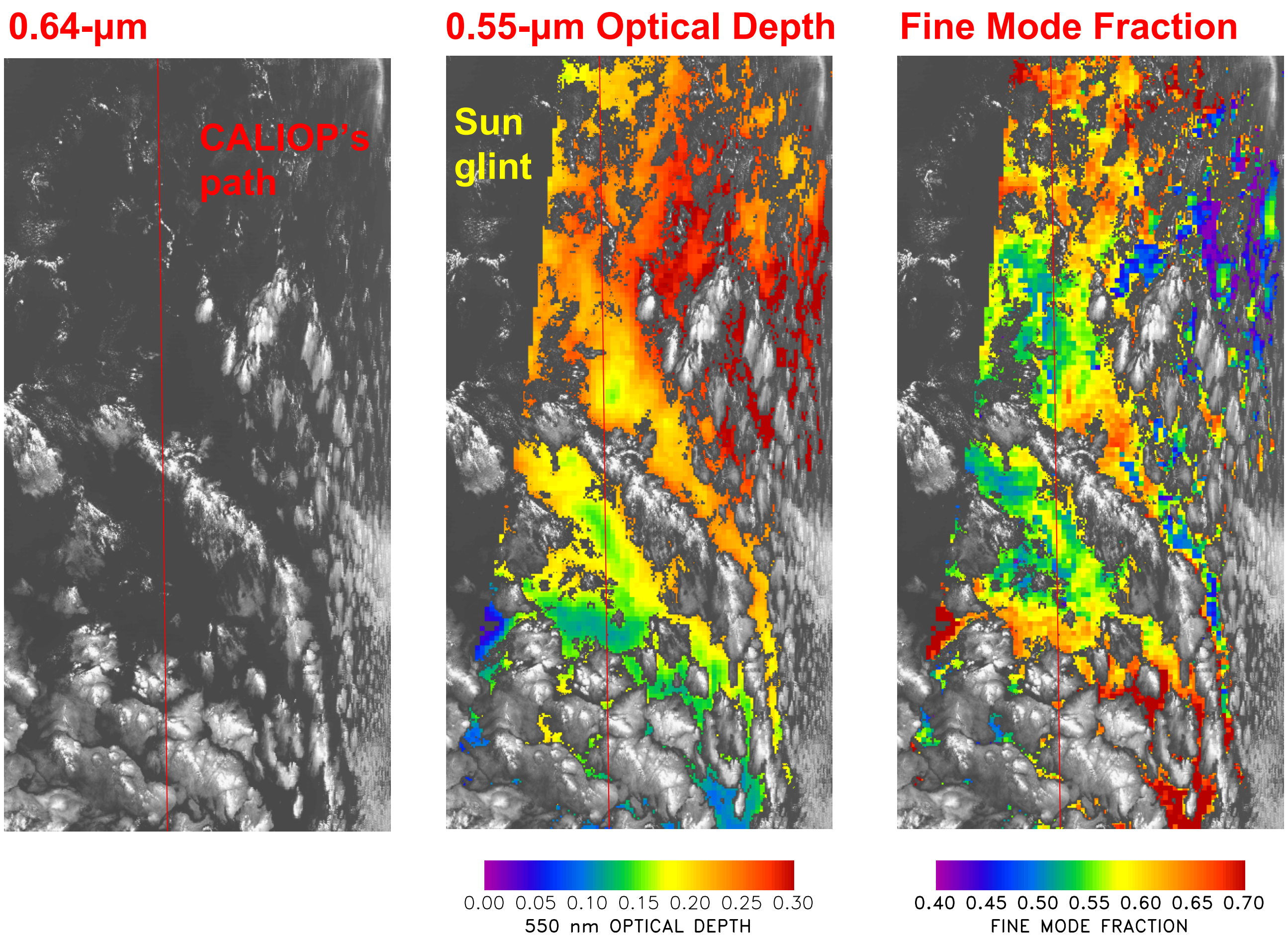
Percentage enhancement for cloud-free radiances only.

Enhancement in reflected radiance ~50% at cloud edge and begins to ramp upwards about 1.5-2 km prior to cloud edge.

Conceptual model to account for 3D cloud effects



Aerosol Optical Depths over Oceans: *The MODIS View*



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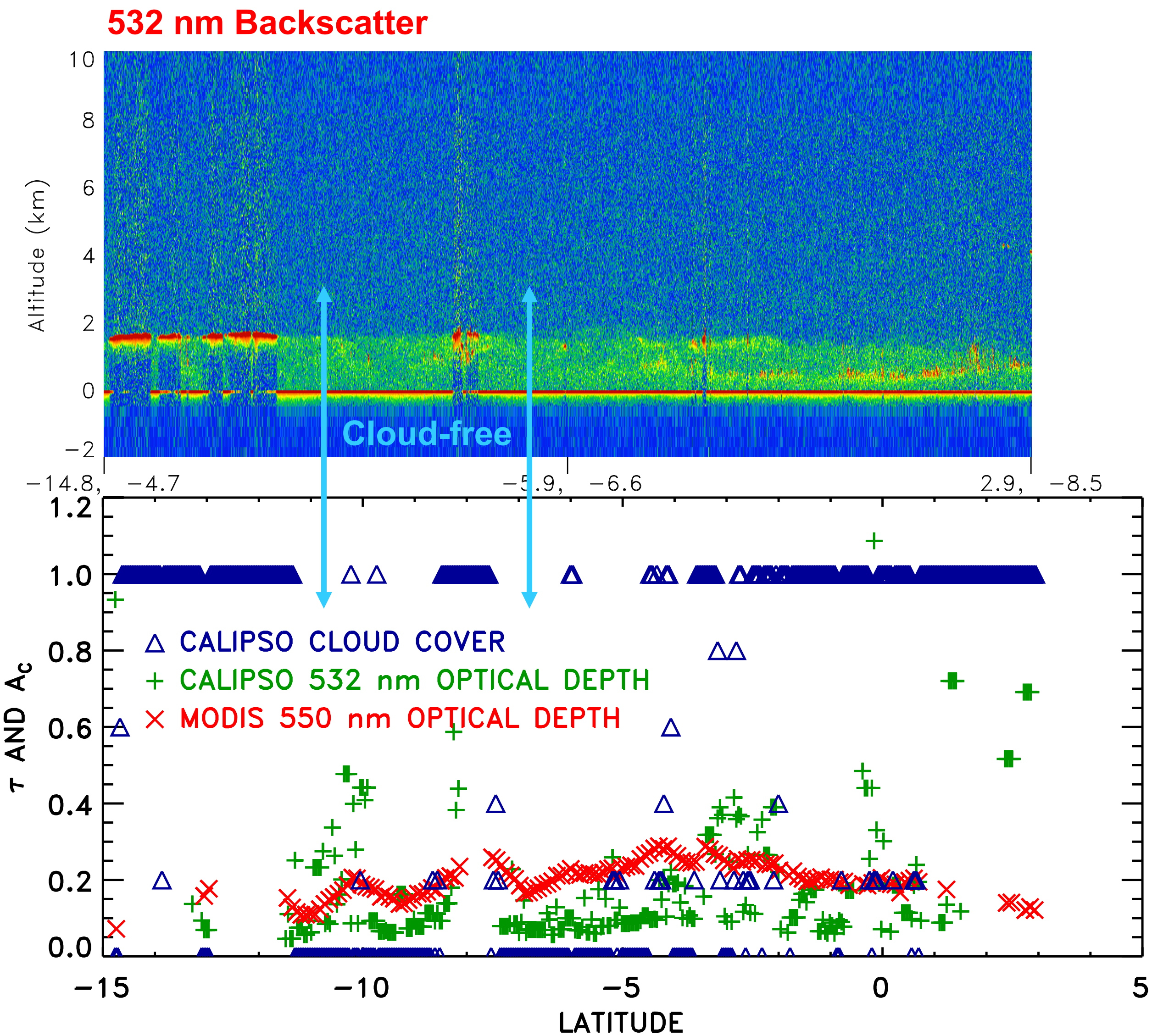
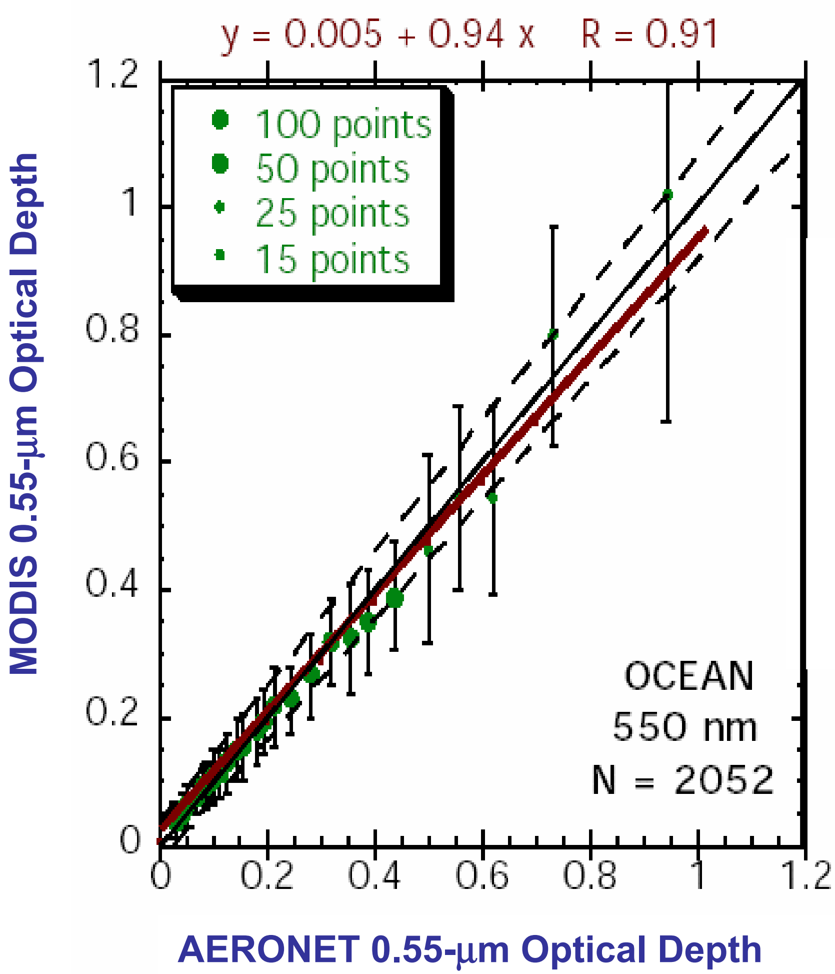
Aerosol Optical Depths over Oceans: *The CALIOP View*



Comparisons of MODIS and AERONET Optical Depths



AERONET observations within ± 30 min of the MODIS overpass.

MODIS observations nearest 5 × 5 array of 10 km optical depth retrievals of the AERONET site.

MODIS retrievals underestimate optical depths at 550 nm by 6% for large optical depths.

Some of the underestimate is compensated by overestimates for the range of optical depths < 0.2, i.e., where most of the optical depths over oceans occur.

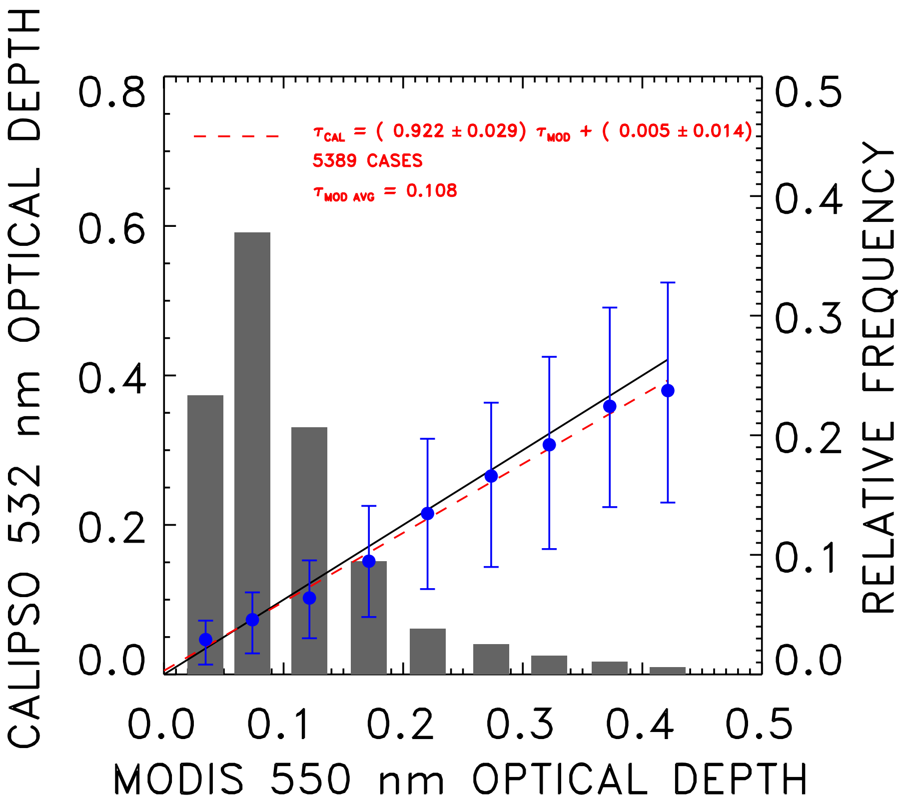
Since MODIS optical depths show good correspondence with actual optical depths, use MODIS as a proxy for the actual optical depths.

Source: Remer et al. (2005)

Analysis Strategy

- Collocate MODIS and CALIPSO aerosol retrievals for 50-km scale, cloud-free ocean regions with nonzero aerosol optical depths (not clear sky) as identified by CALIPSO lidar returns.
- Compare *averages* of the CALIPSO aerosol products with those of the nearest 10-km MODIS MOD04 product in each 50-km region.
- Consecutive 50-km cloud-free ocean regions separated by at least 200 km within an orbital pass to increase the likelihood that each 50-km matchup is statistically independent.
- 15 months of analysis completed (January 2007 - March 2008) for global oceans from 60°S to 60°N.

532 nm CALIPSO and 550 nm MODIS Aerosol Optical Depths

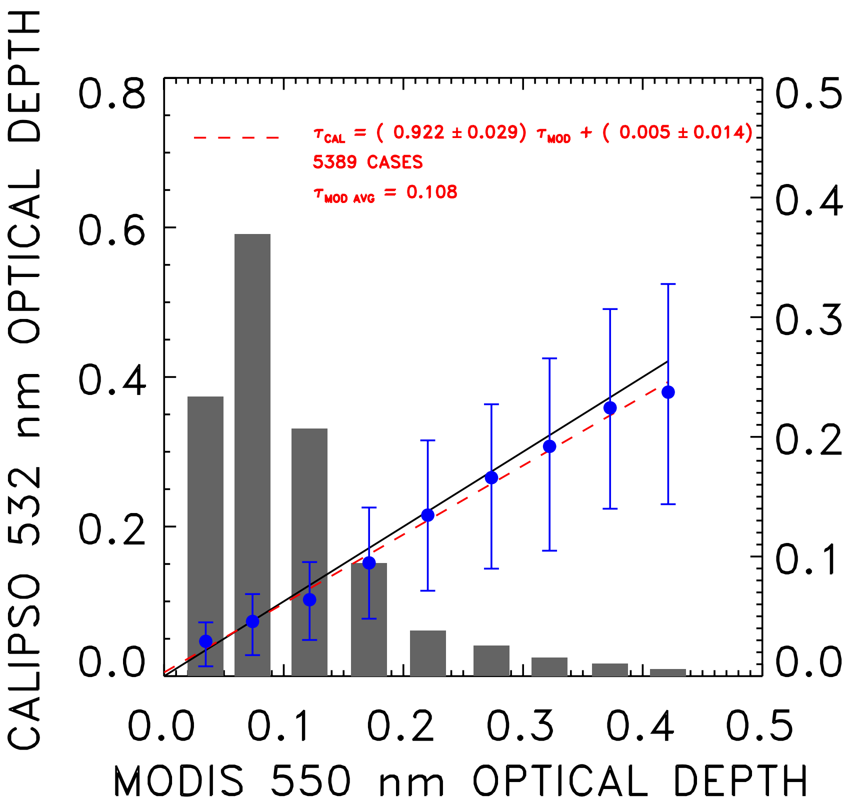


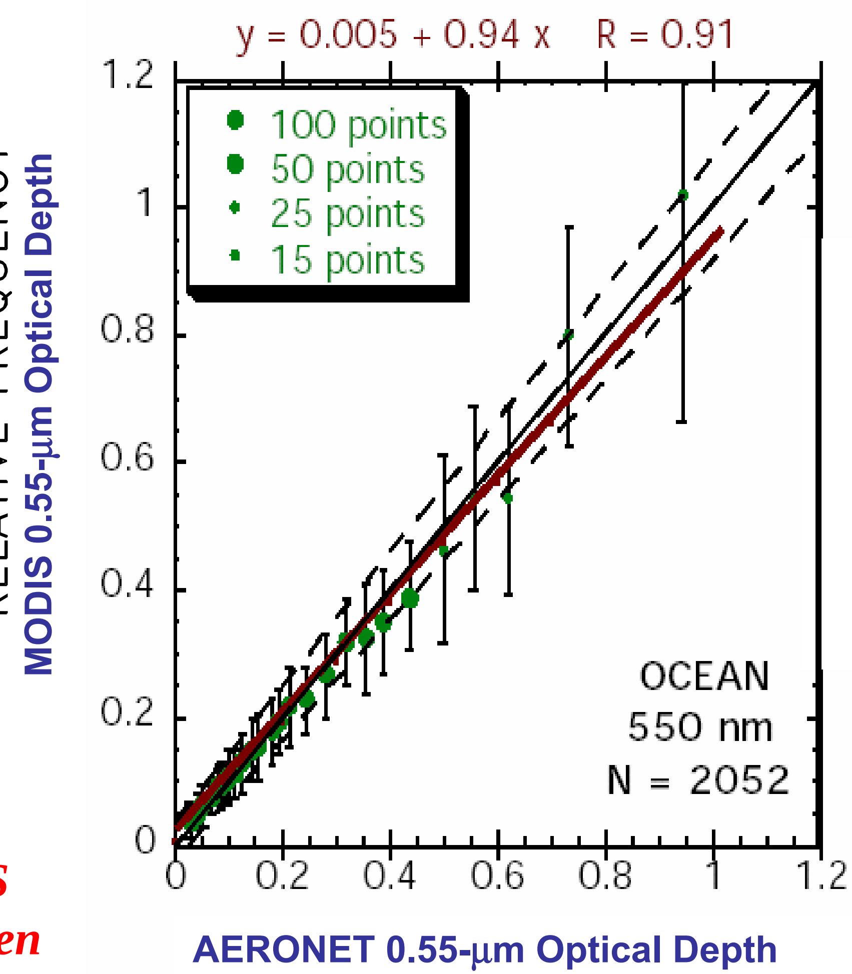
Results composited for each 0.05 interval of the MODIS optical depth and means and 15th to 85th percentiles (error bars) shown for the CALIPSO optical depths.

The results are for just over 5000 collocated 50-km scale cloud-free, ocean regions.

CALIPSO optical depths underestimate the MODIS optical depths implying that the CALIPSO optical depths would fall about 14% below the AERONET measurements for large optical depths.

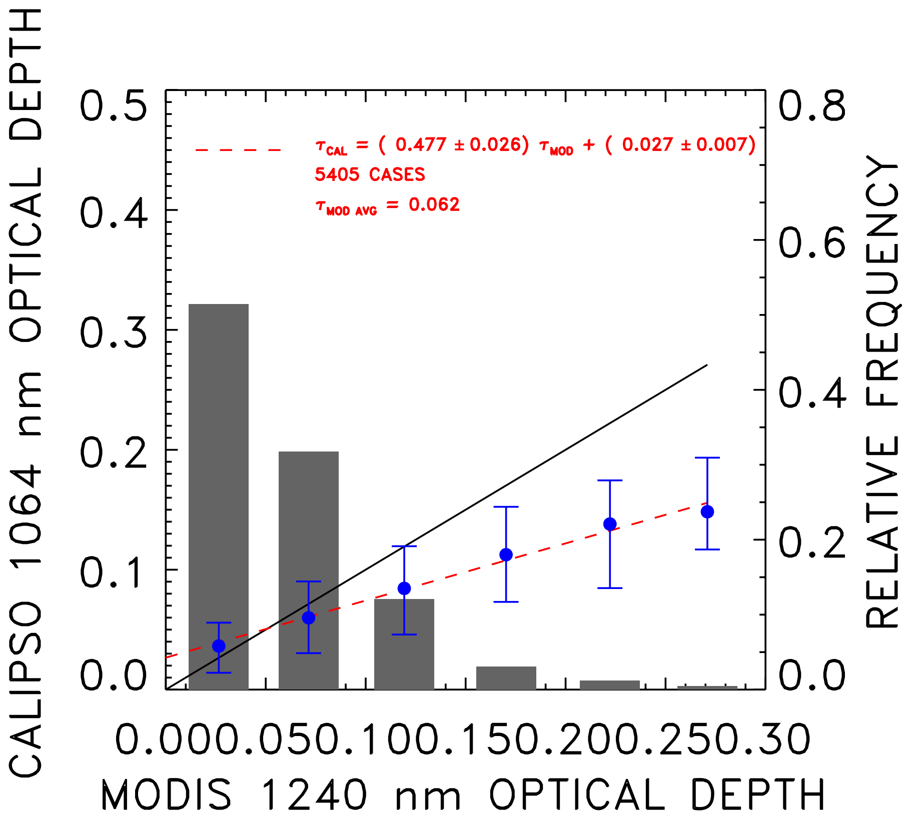
532 nm CALIPSO and 550 nm MODIS Aerosol Optical Depths





Agreement between CALIPSO and MODIS aerosol optical depths similar to that between MODIS and AERONET.

1064 nm CALIPSO and 1240 nm MODIS Aerosol Optical Depths

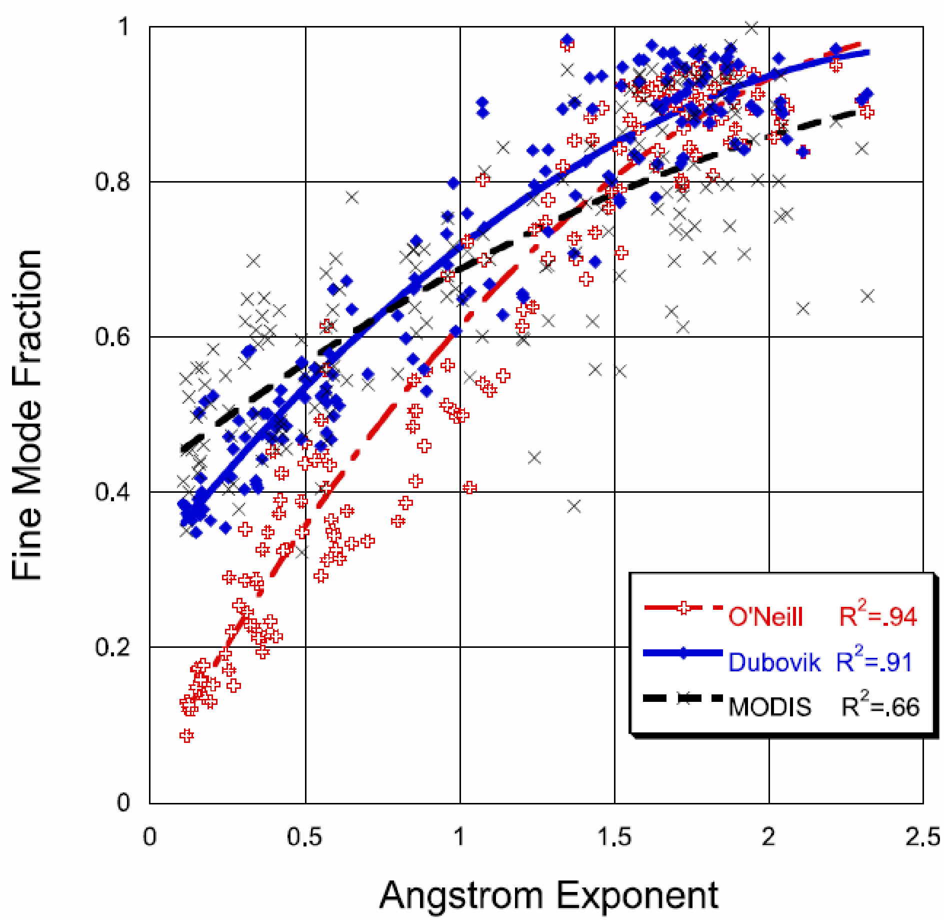


CALIPSO optical depths at 1064 nm are approximately half the MODIS 1240 nm optical depths.

AERONET observations at 1020 nm have not been compared with the MODIS 1240 nm optical depths(?).

CALIPSO calibration at 1064 nm is preliminary.

AERONET and MODIS Fine Mode Fractions and Ångström Exponents



MODIS and AERONET exponents are based on wavelength dependence of extinction between 470 and 870 nm.

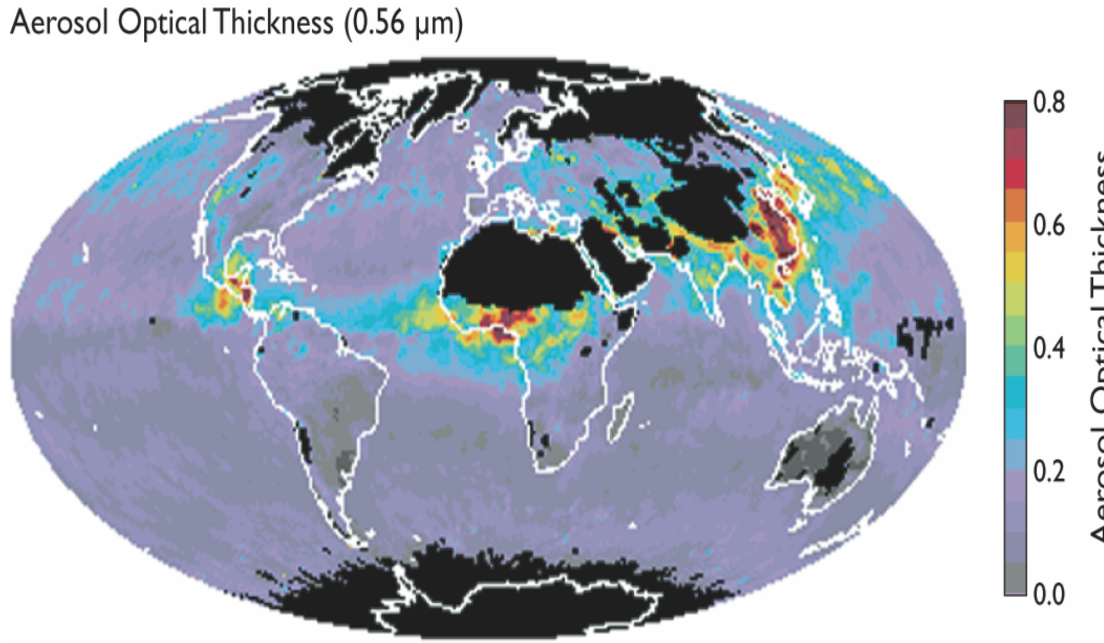
Relative to other measures, MODIS Ångström exponents show similar trends, but with considerable scatter.

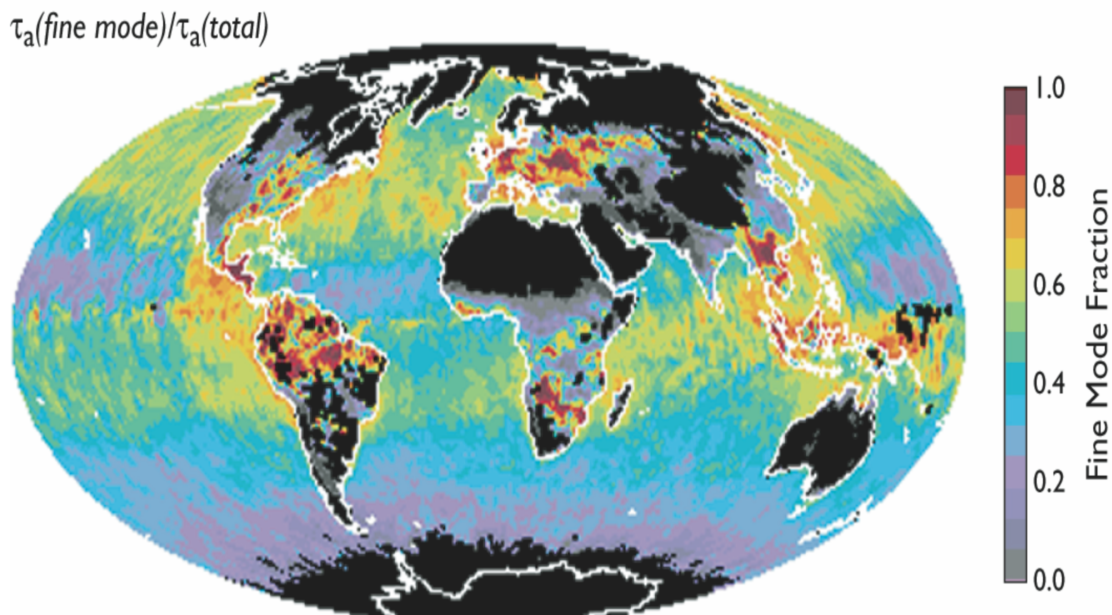
Source: Kleidman et al. (2005)

Monthly Mean Aerosol Optical Properties

(L. A. Remer, Y. J. Kaufman, and D. Tanré et al. – GSFC, U. Lille)

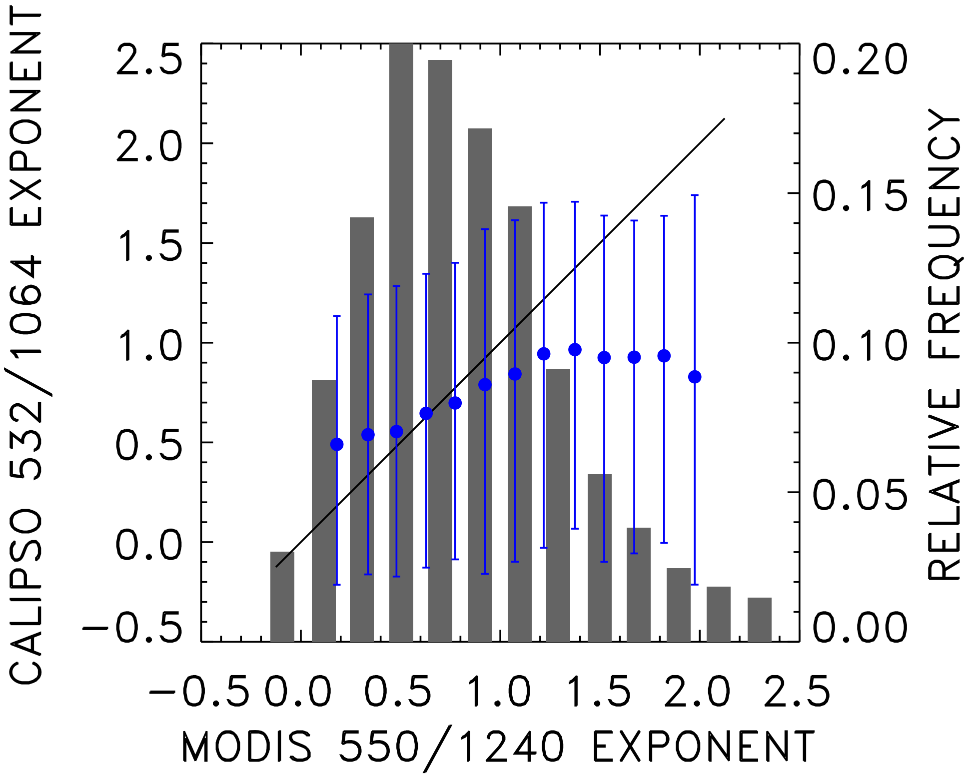
April 2005
(Collection 5)
Aqua





Source: King (2006)

CALIPSO 532 nm/1064 nm and MODIS 550 nm/1240 nm Ångström Exponent

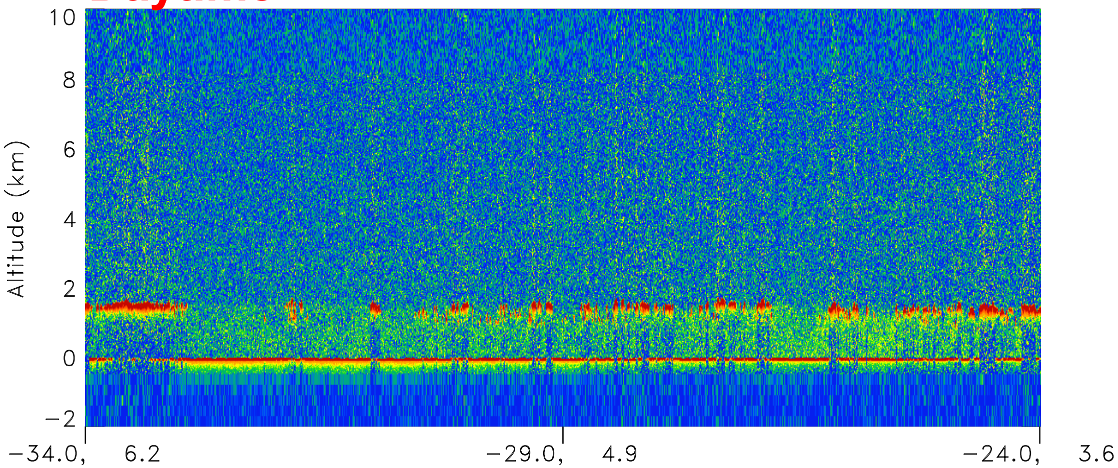


Ångström exponents averaged within 50-km regions and then composited in bins associated with the average MODIS exponent.

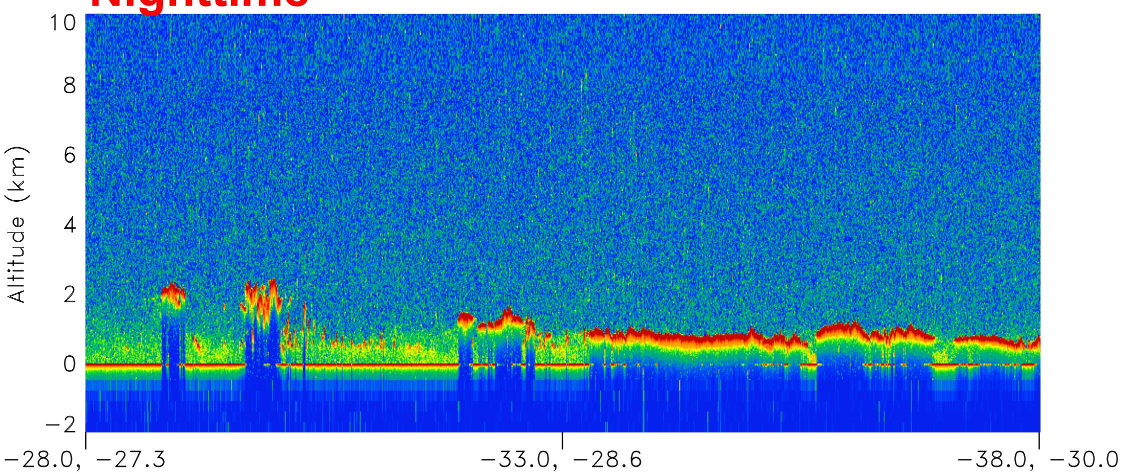
CALIPSO and MODIS show similar trend for 0.5 $\leq \alpha \leq$ 1.5, but the exponents are poorly correlated.

Use of Daytime and Nighttime Observations

Daytime



Nighttime



Compare statistics of daytime and nighttime aerosol properties for large, cloud-free ocean regions.

Use nighttime observations to determine changes in aerosol properties as clouds are approached.