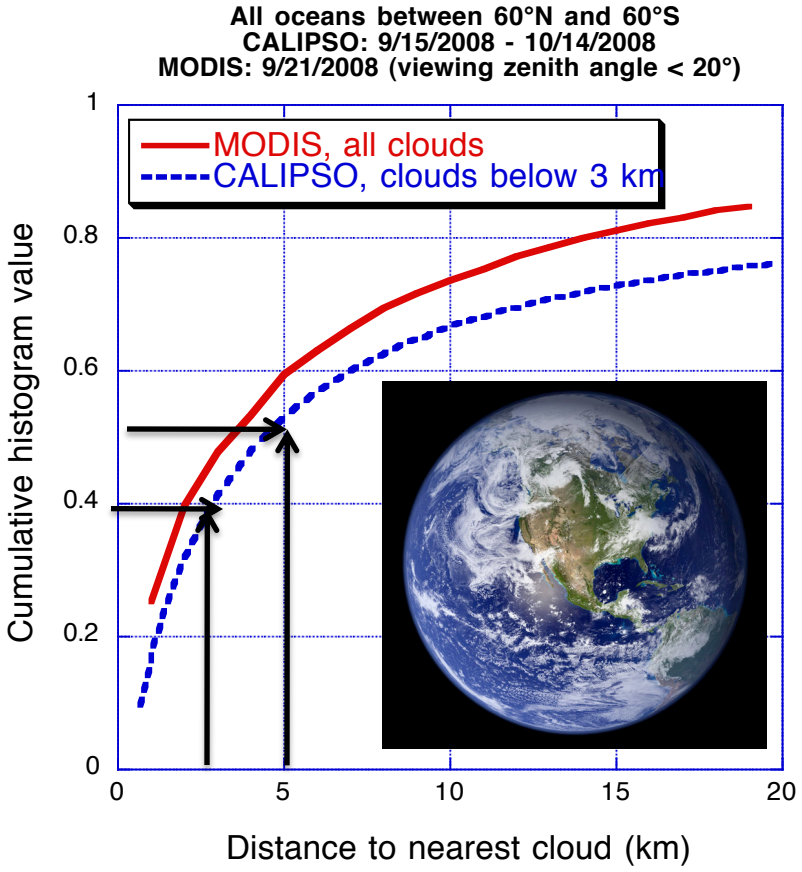
Motivation

- Climate studies demand a precise separation of clear and cloudy air;

- Remote sensing retrieval of aerosol properties near clouds is challenging;

- Excluding aerosols retrieved near clouds biases aerosol radiative forcing.

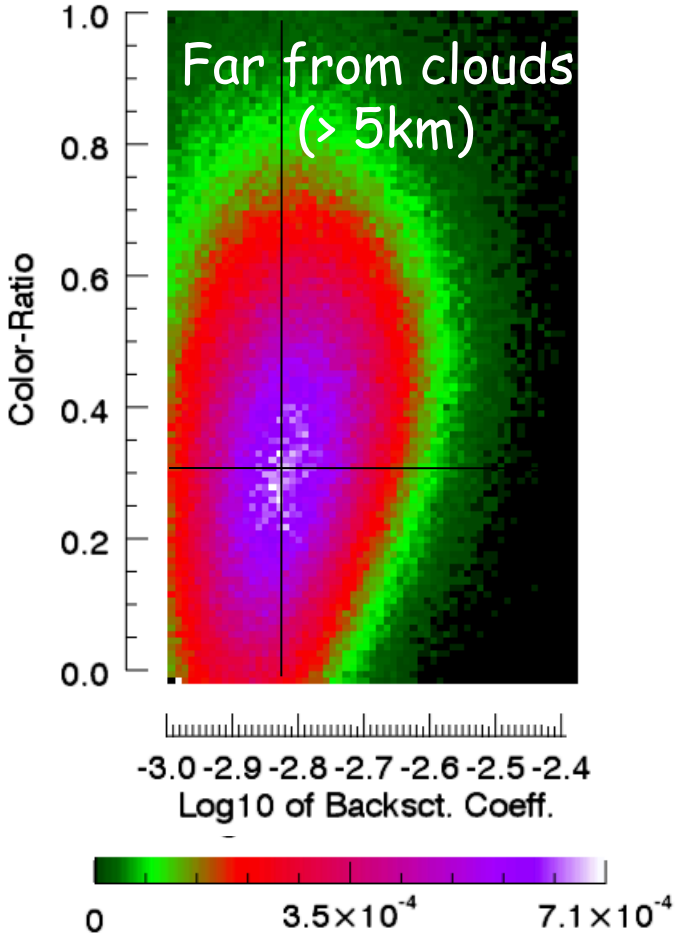


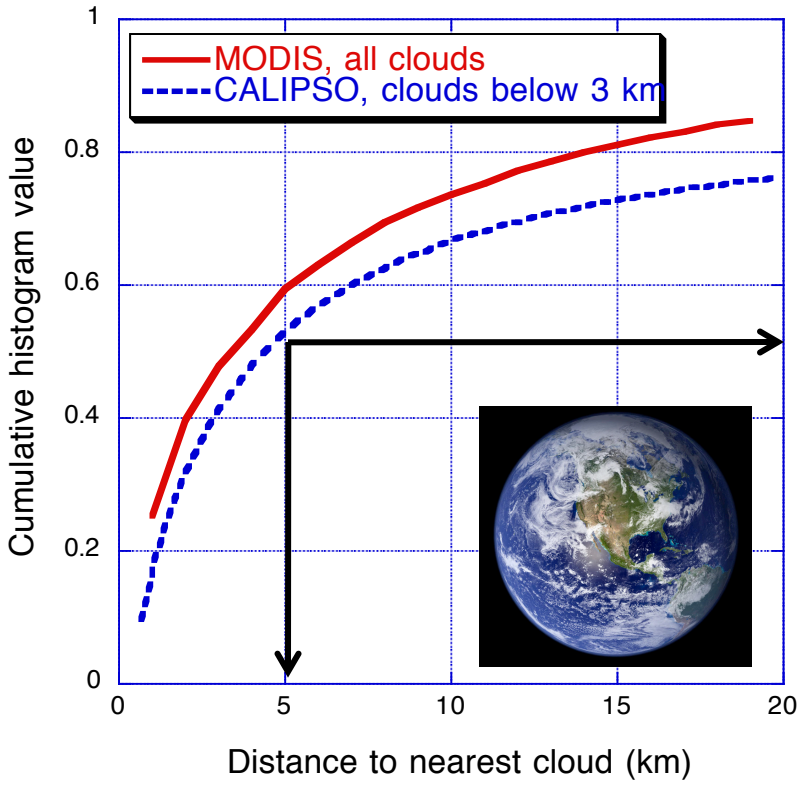
from **MODIS**: 60% of all clear sky pixels are located 5 km or less from all clouds
from **CALIPSO**: 50% of all clear sky pixels are located 5 km or less from low clouds
(e.g., Twohy et al., 2009)

CALIPSO

(ColorRatio vs. Backscat close to and far from clouds)

Global night data over ocean



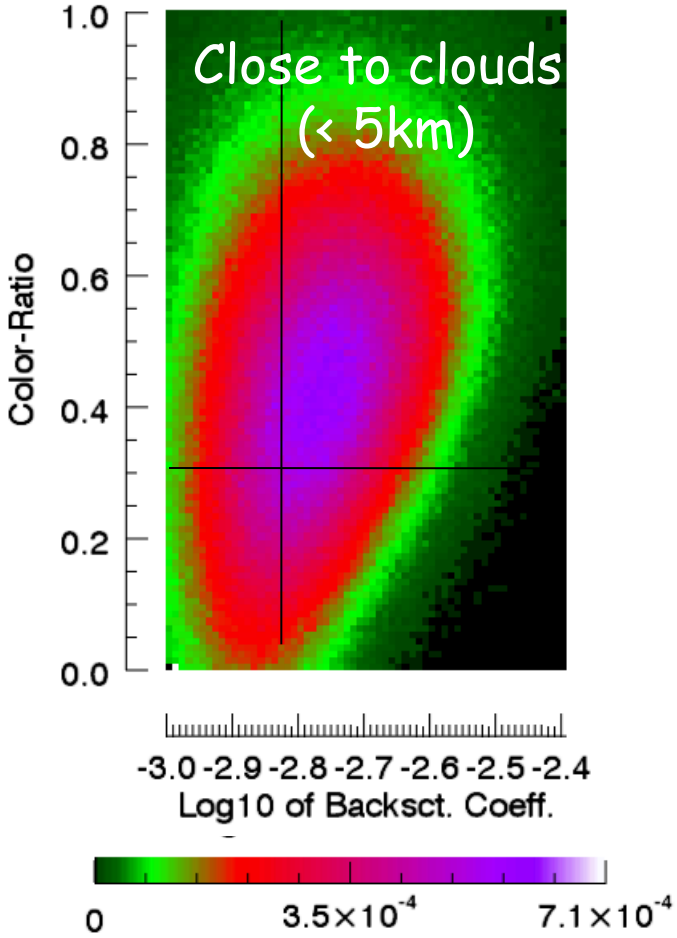


Fraction of cloud-free vertical profiles

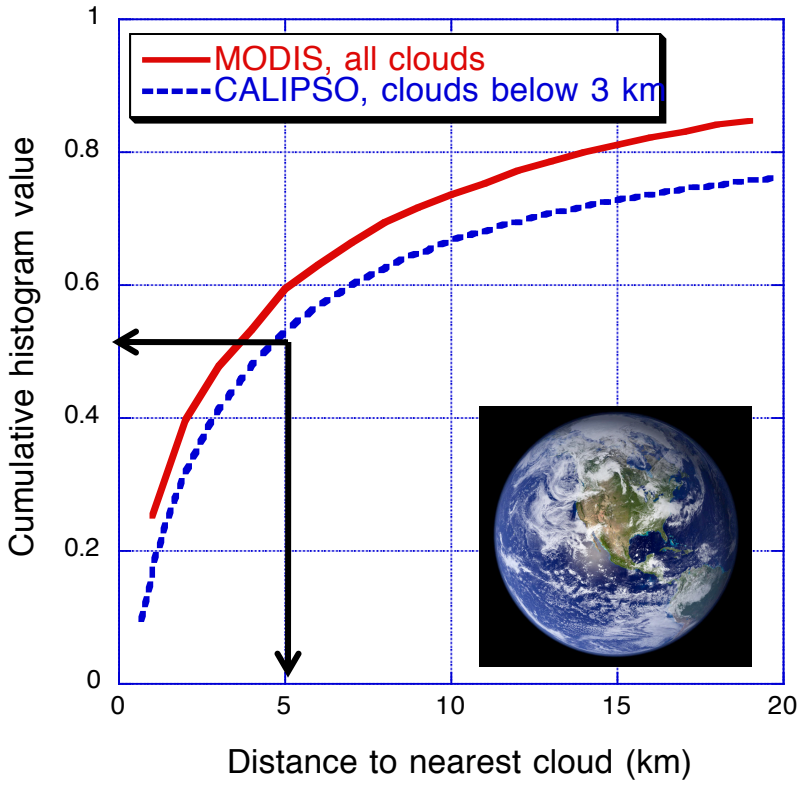
CALIPSO

(ColorRatio vs. Backscat close to and far from clouds)

Global night data over ocean



Fraction of cloud-free vertical profiles



Aerosol optical properties and size change systematically

Transition (twilight) zones near clouds include (Koren et al., 2009)

- Particles at various stages of their uptake of water vapor;

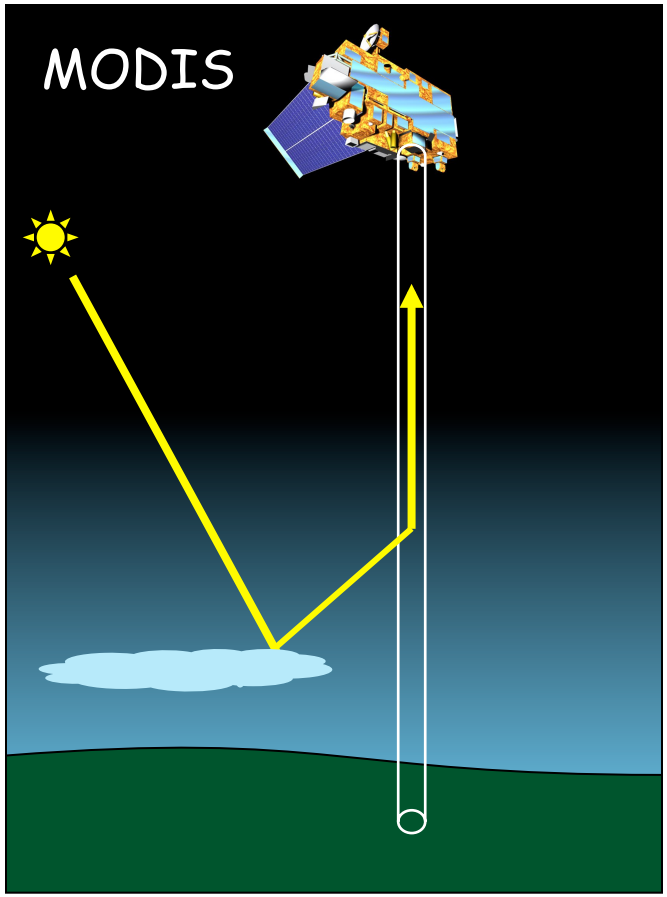
- Cloud fragments that have sheared off from adjacent clouds and that are at various stages of evaporation;

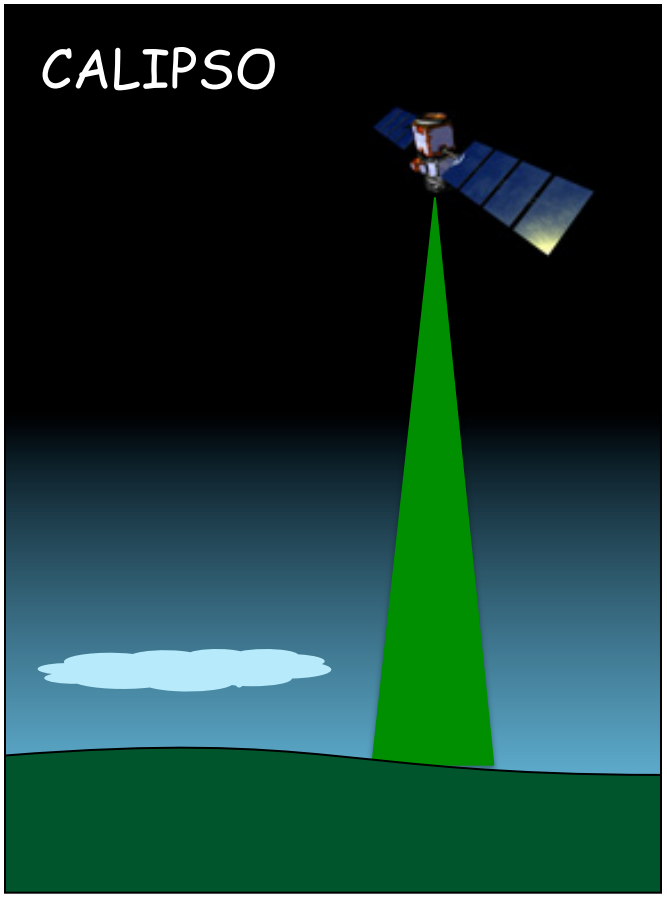
- Clouds that are forming but do not yet exist as stable entities;

- Clouds that are disappearing into the environment that spawned them;

- Pockets of high humidity that oscillate near saturation.

Synergy of MODIS and CALIPSO

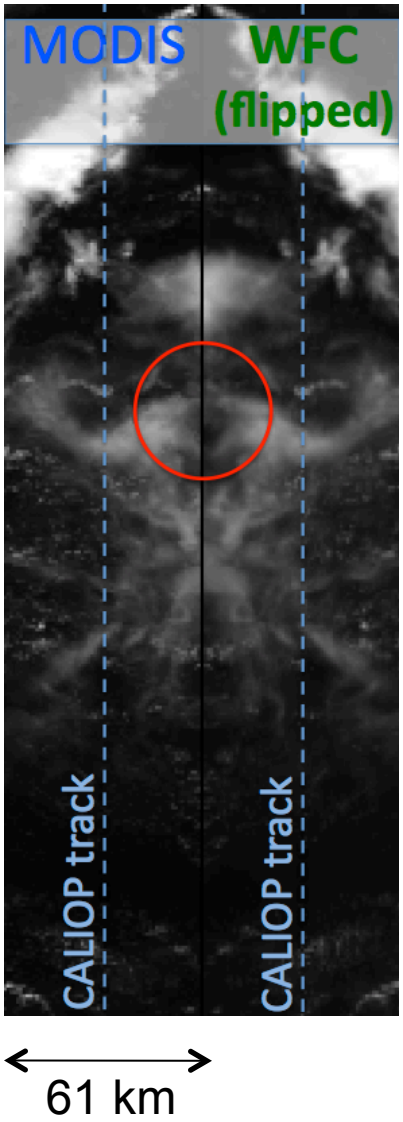




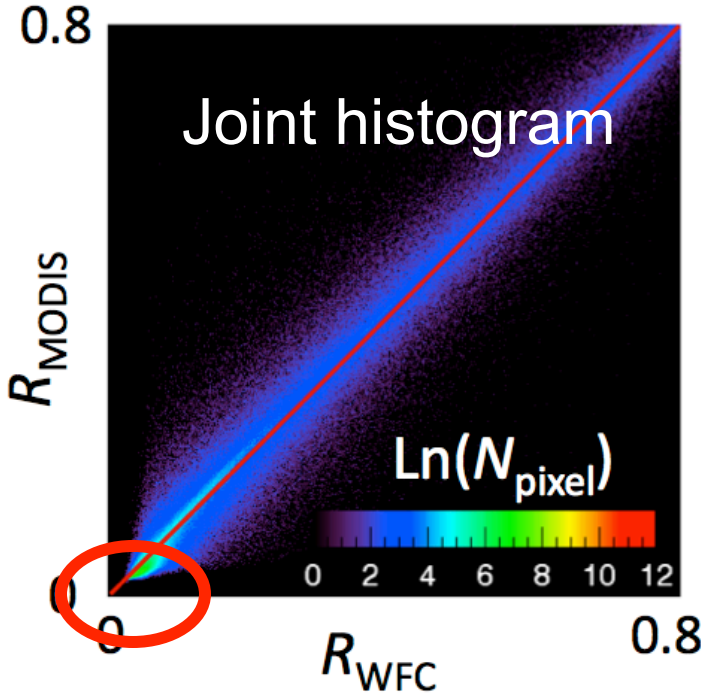
Synergy of MODIS and CALIPSO

Wide Field Camera (WFC)

Spectral range: 620-670 nm
IFOV: 125 m
Swath: 61 km



MODIS/Aqua is 72 sec ahead of CALIPSO



MODIS & WFC reflectances are very similar; some differences are due to clouds drifting with the wind: the drift exceeds 1 km for < than 10% of scenes containing clouds below 3 km

Synergy of MODIS and CALIPSO

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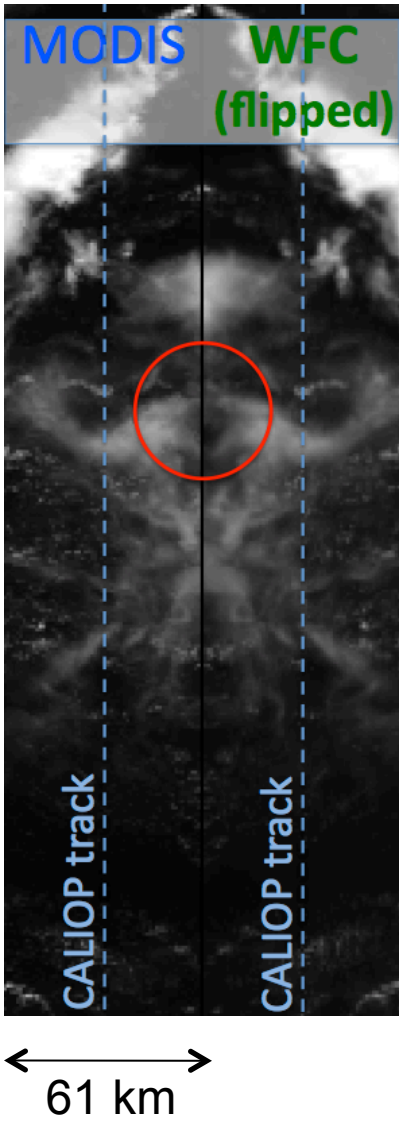

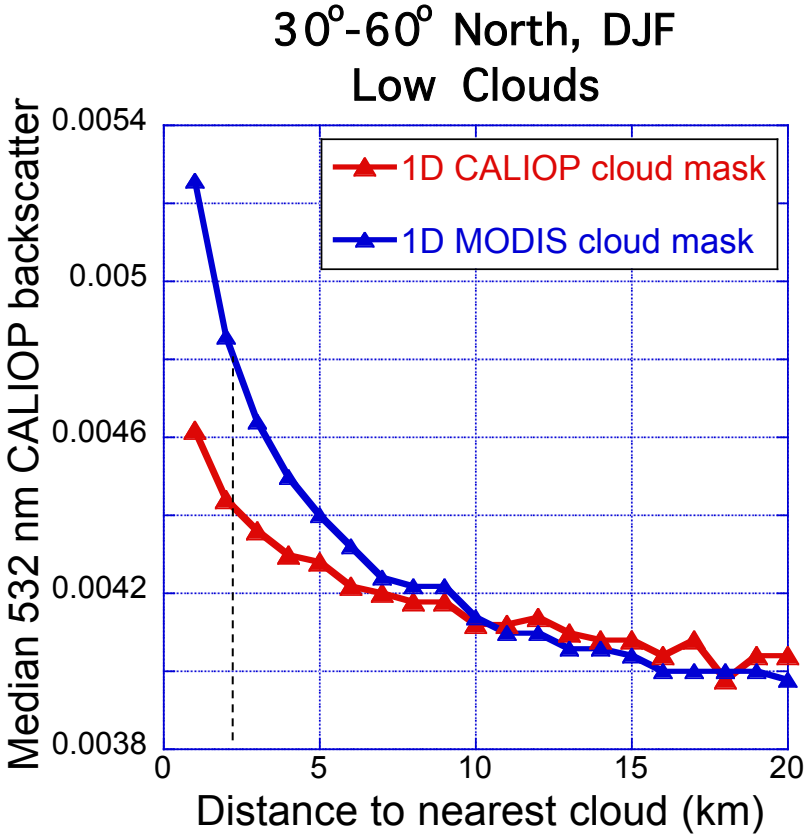

CALIOP 532 nm backscatter integrated up to 3 km altitude using MODIS and CALIPSO cloud masks

Synergy of MODIS and CALIPSO

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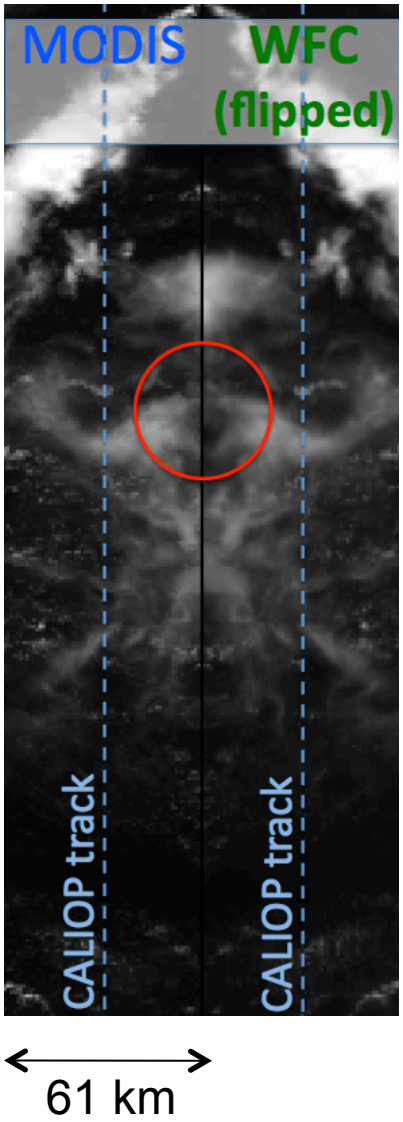
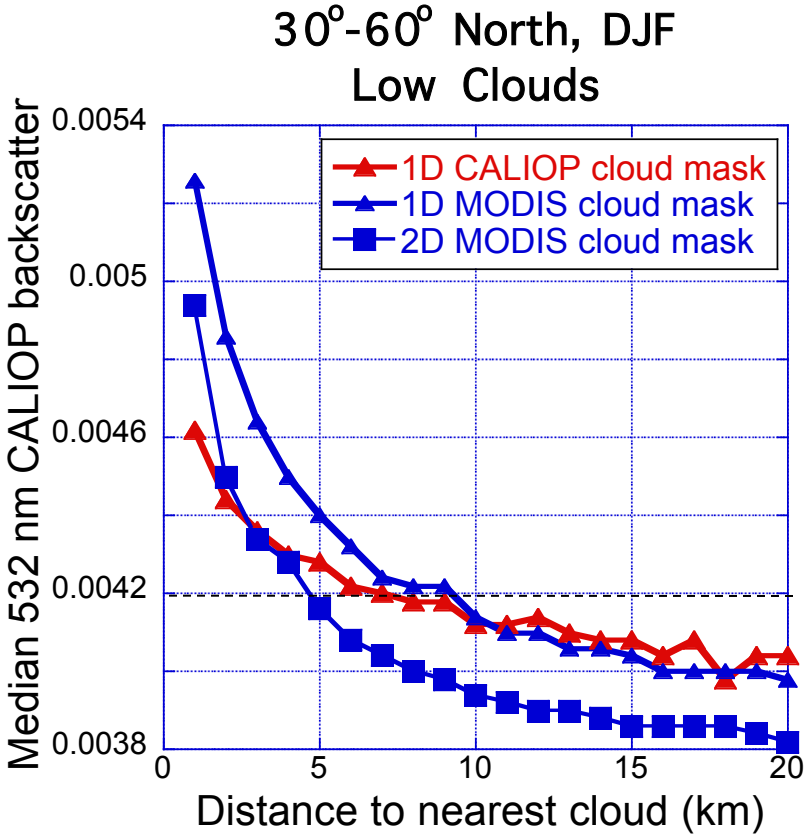
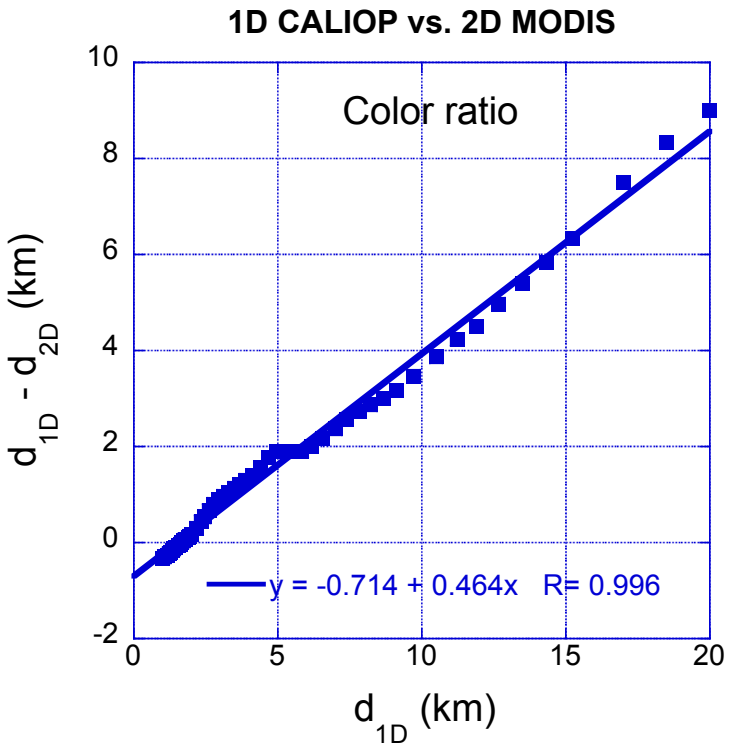
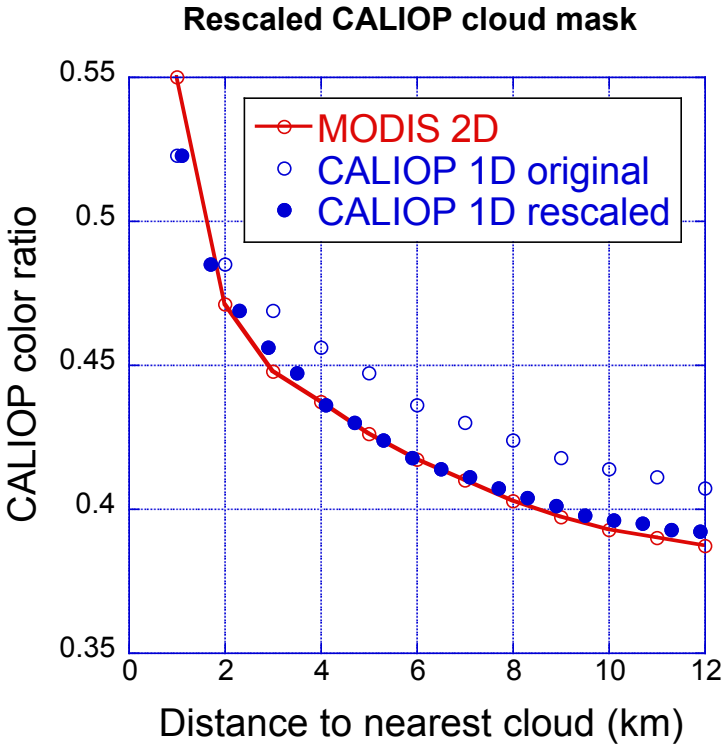




CALIOP 532 nm backscatter integrated up to 3 km altitude using MODIS and CALIPSO cloud masks

1D vs 2D cloud mask



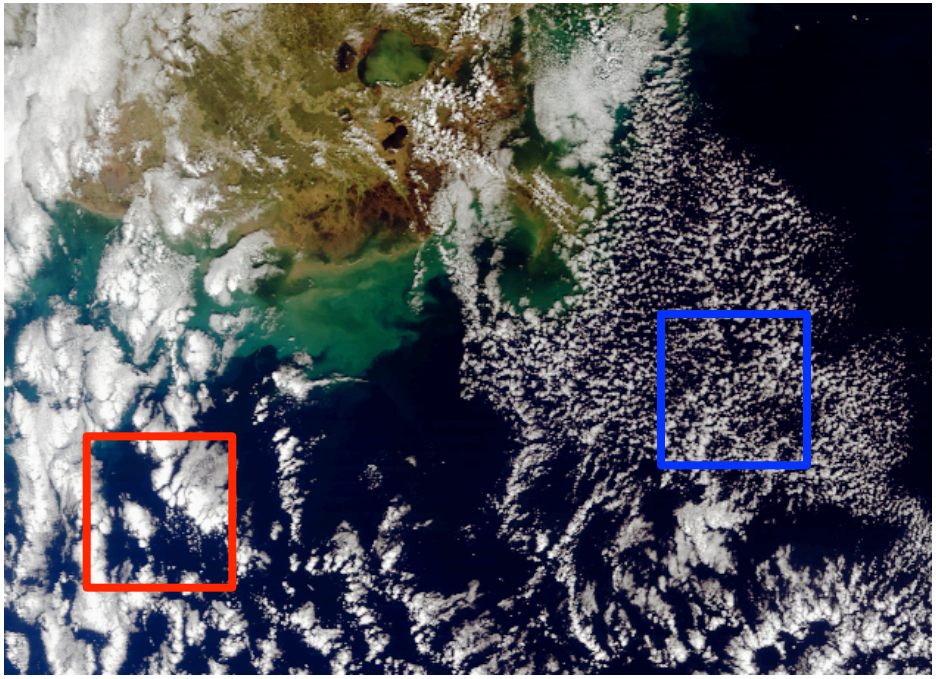


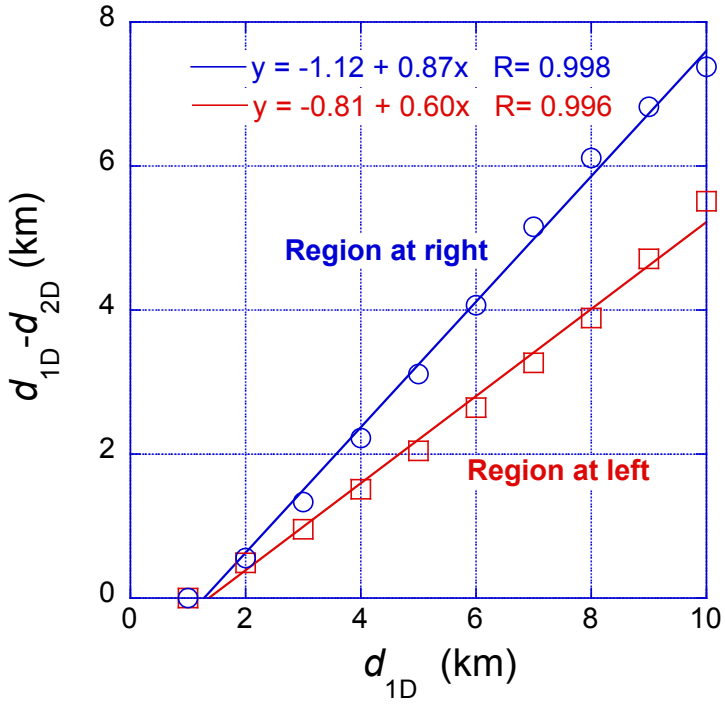
d_{1D} and d_{2D} are the average distances from a clear-sky pixel to the nearest cloudy pixel in 1D or 2D, resp.

-The impact of clouds lying off the CALIOP track can be accounted

- The aerosol properties based on the 1D CALIOP cloud mask can be rescaled.

1D vs 2D cloud mask



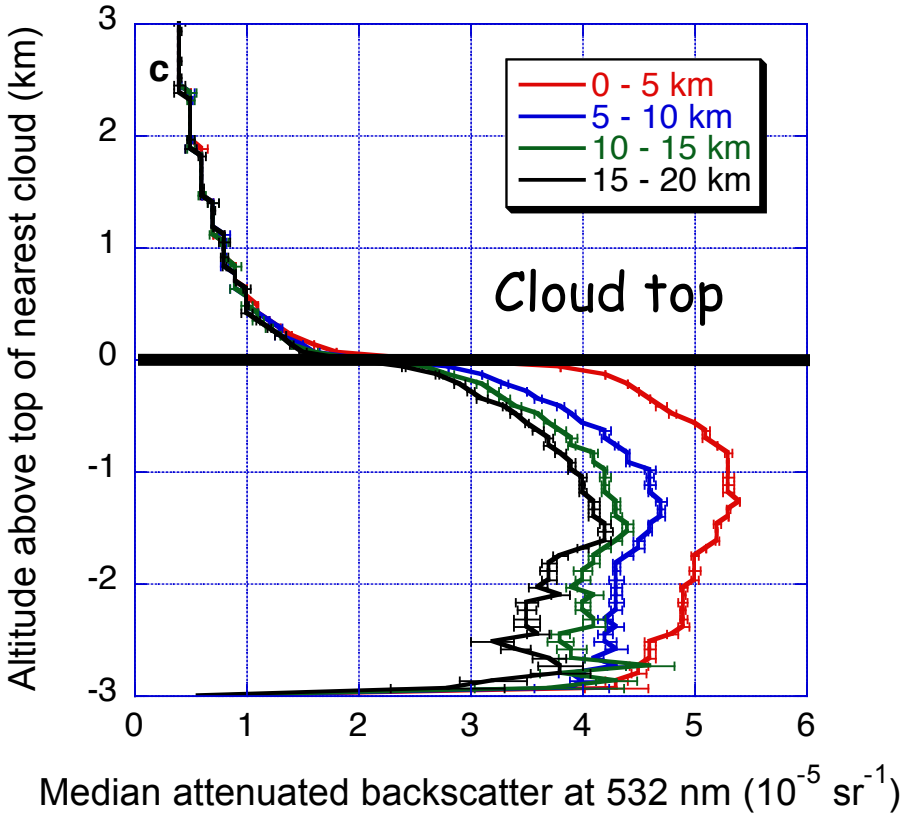


d_{1D} and d_{2D} are the average distances from a clear-sky pixel to the nearest cloudy pixel in 1D or 2D, resp.

Slopes d_{1D}-d_{2D} vs d_{1D} characterizes cloud (and clear sky) horizontal structure

CALIPSO

Following Tackett and Di Giloramo (2009), we studied global night data over ocean Sep 15 – Oct 14, 2008



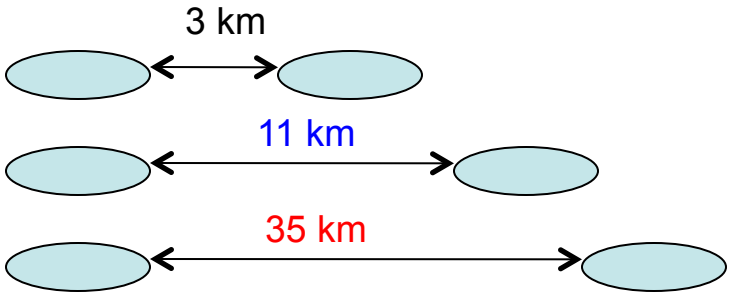
Increases occur below cloud top

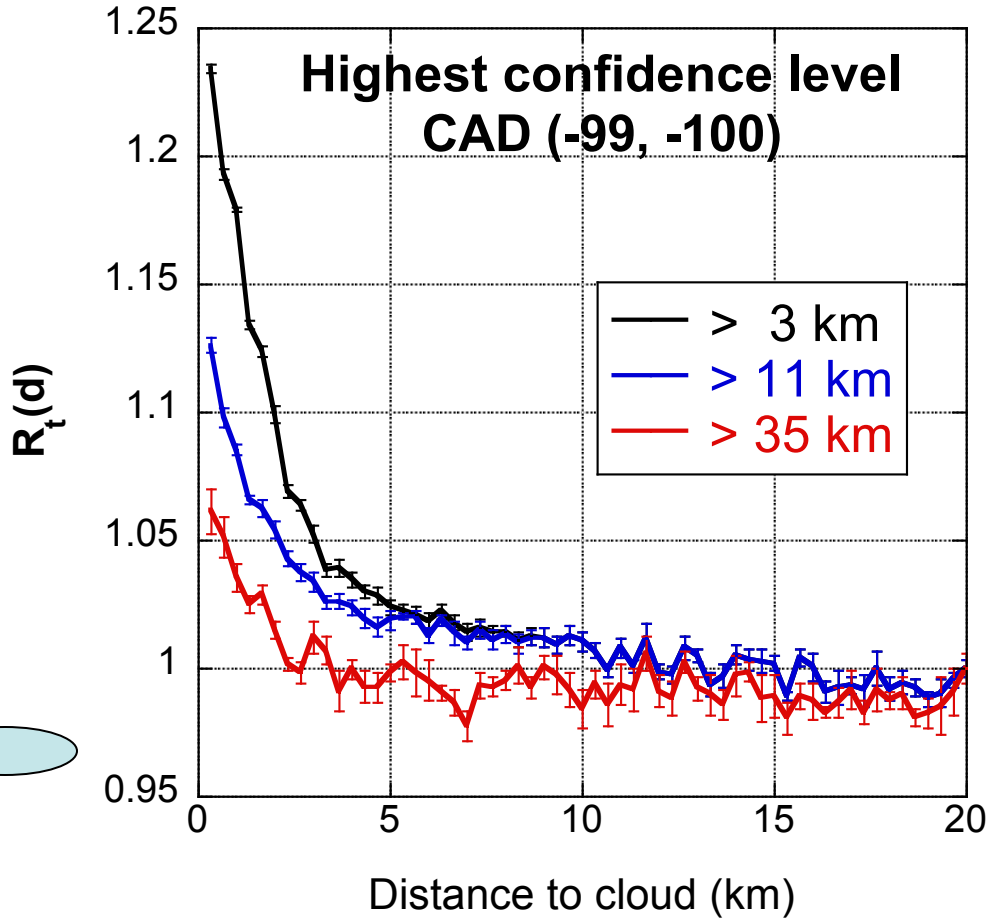
CALIPSO

Effect of the distance between clouds

Normalized backscatter

$$R_t(d) = \frac{\beta_{532}(d)}{\beta_{532}(20\ \text{km})}$$



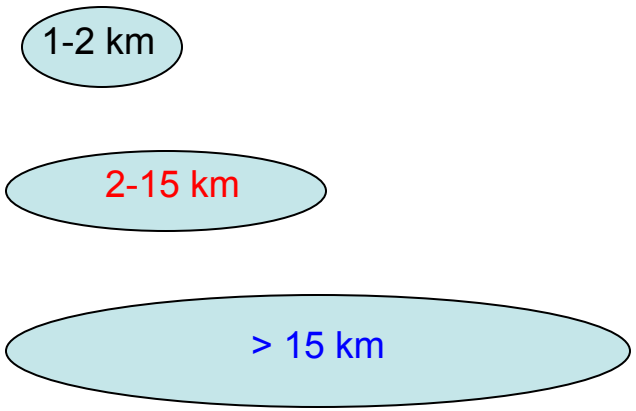


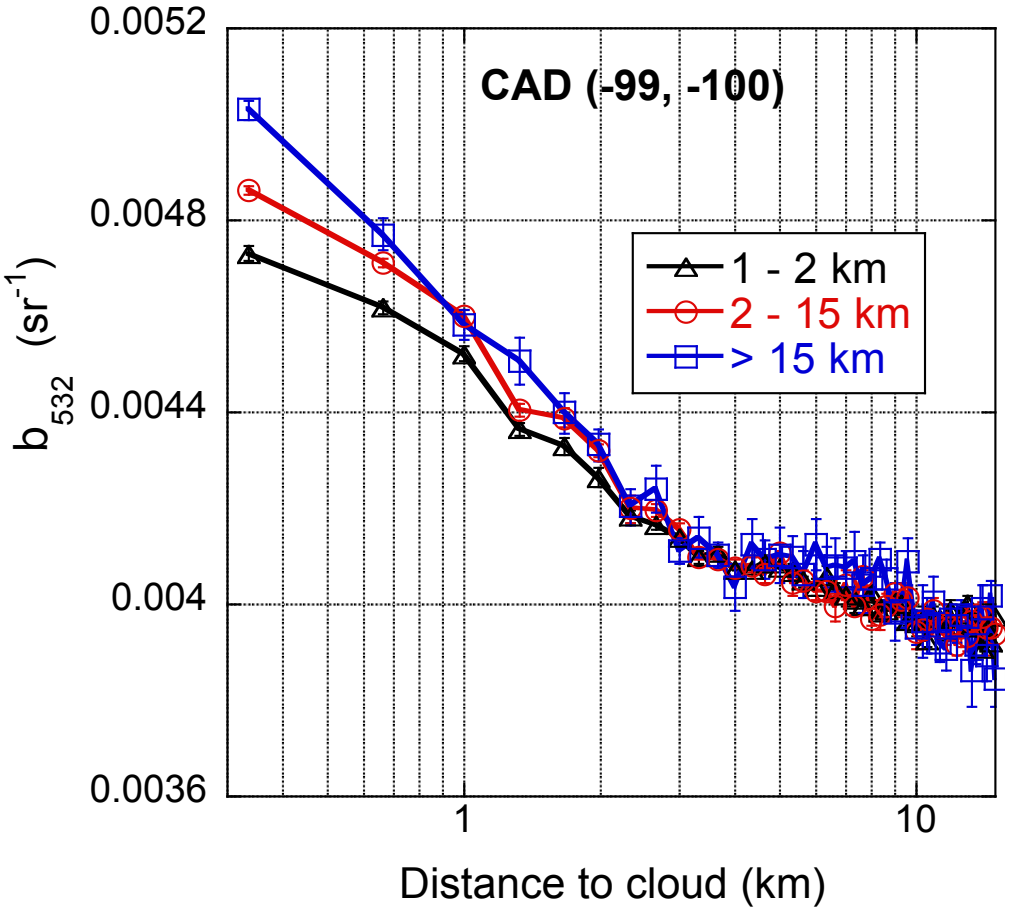
The transition zone is shorter for
(a) for high confidence level data, and (b) relatively dry air

CALIPSO

Effect of cloud size

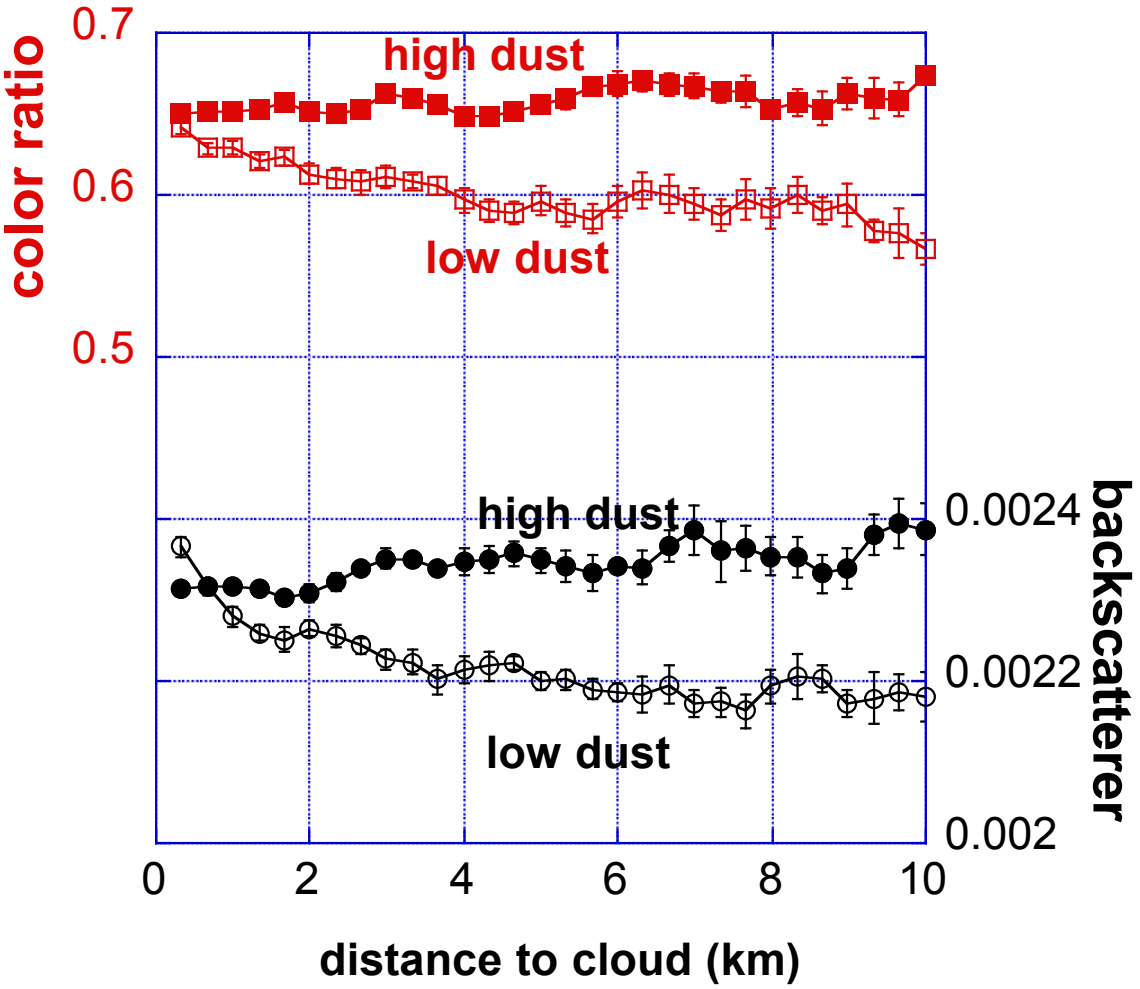
Attenuated backscatter





The transition zone depends on cloud size only weakly (closer than 0.5 km to clouds). Horizontally larger clouds tend to have slightly stronger impacts on aerosols near clouds.

Low and High Dust vs. Distance to Clouds



Low dust increases near clouds while high dust does not

Summary

- Clouds are surrounded by a wide transition zone of *enhanced* particle size and light scattering. Enhancement is strongest at low altitudes, slightly below the top of the nearest clouds.

- Transition zones need to be considered in studies of aerosols and aerosol-cloud interactions.

- Synergy of passive and active remote sensing helps to better interpretation of aerosol properties near clouds.