Combining 'apples' and 'oranges' in near cloud observations

A. Marshak (NASA GSFC),
T. Varnai (JCET), W. Yang, P. McBride (GESTAR),

Twohy et al. (2009)

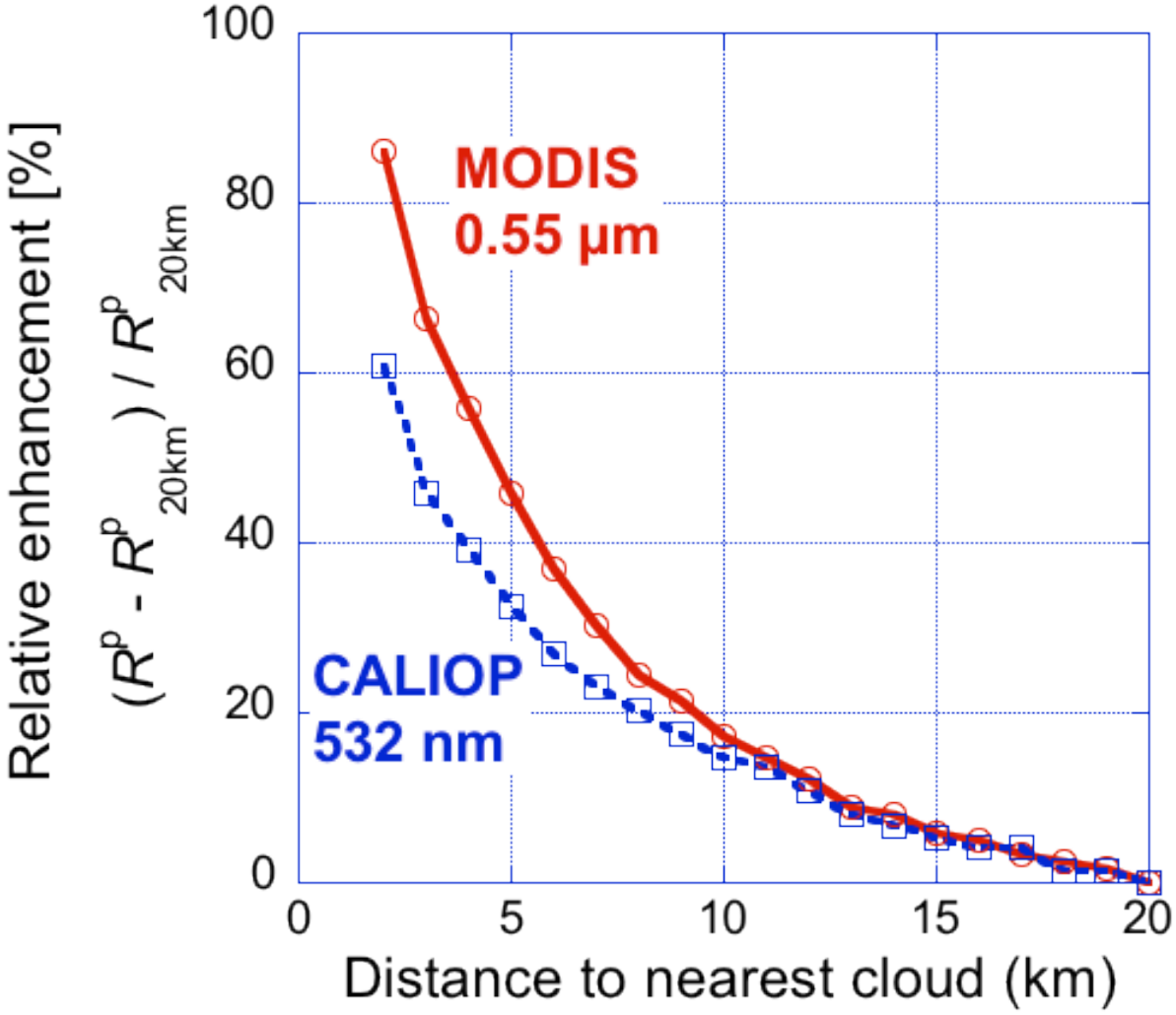
estimated that "*the aerosol direct radiative effect as derived from satellite observations of cloud-free oceans to be 35–65% larger than that inferred for large (>20 km) cloud-free ocean regions.*"

Chand et al. (2012)

found a 25% enhancement in AOT between CF 0.1-0.2 and CF 0.8-0.9. This *"enhancement is consistent with aerosol hygroscopic growth in the humid environment surrounding clouds."*

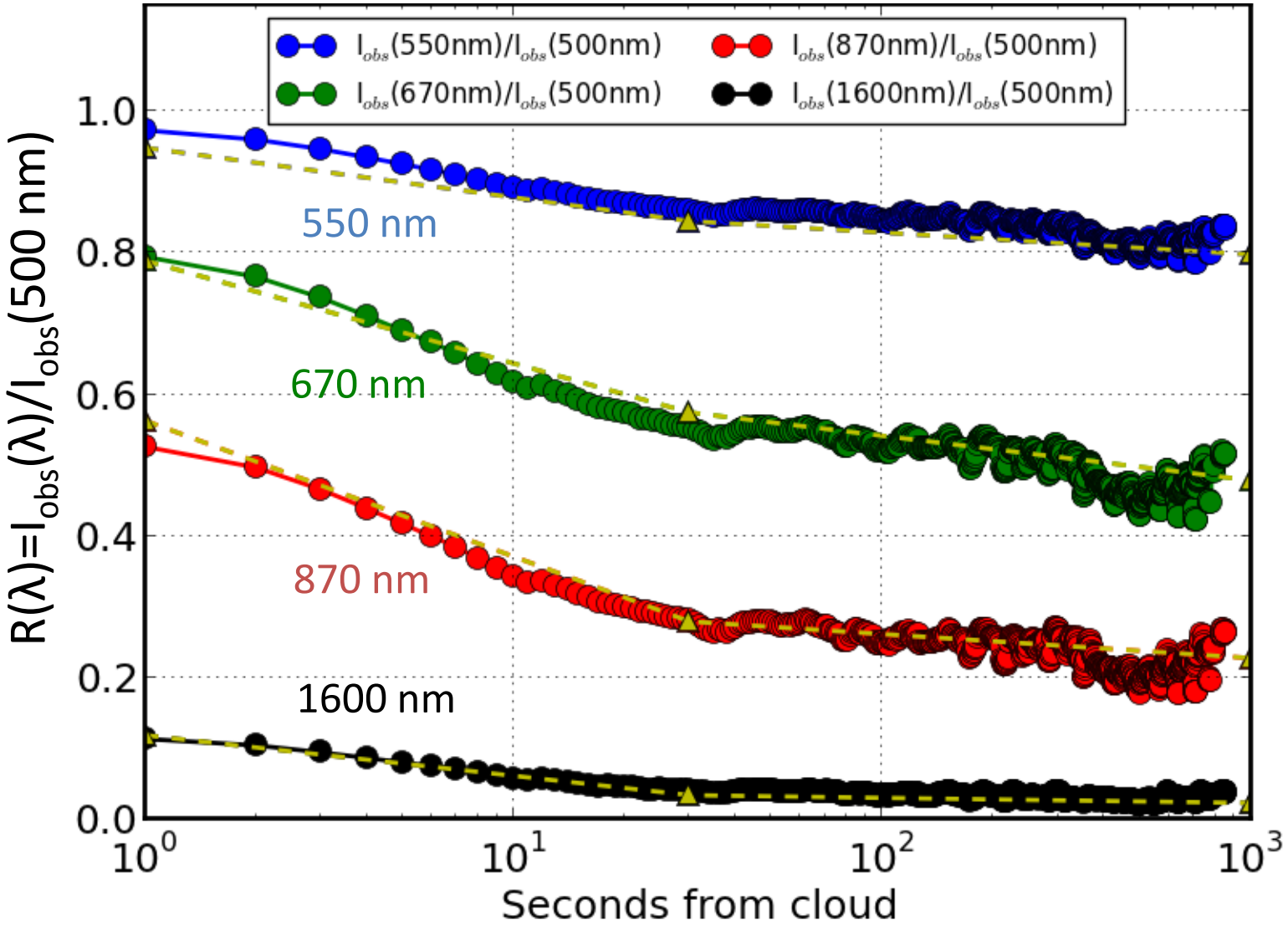
Relative enhancement

Varnai et al., 2013



The same MODIS cloud mask has been used

ARM SWS



Measured radiance ratios from 7 months and 208 cases; μ_0=0.6-0.7.

The enhancement of observed radiation near clouds is mainly due to

- Humidification of aerosols near clouds;
- Small cloud contamination;
- 3D RT effects
- What's about sampling issues due to different large-scale meteorological conditions???

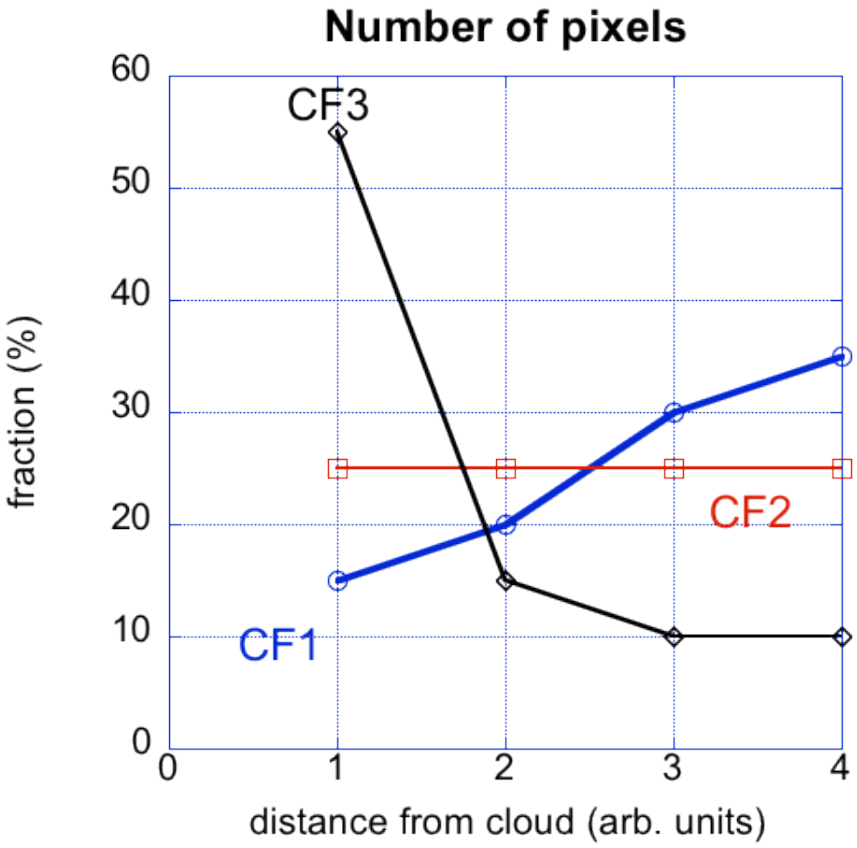
Large-scale meteorology

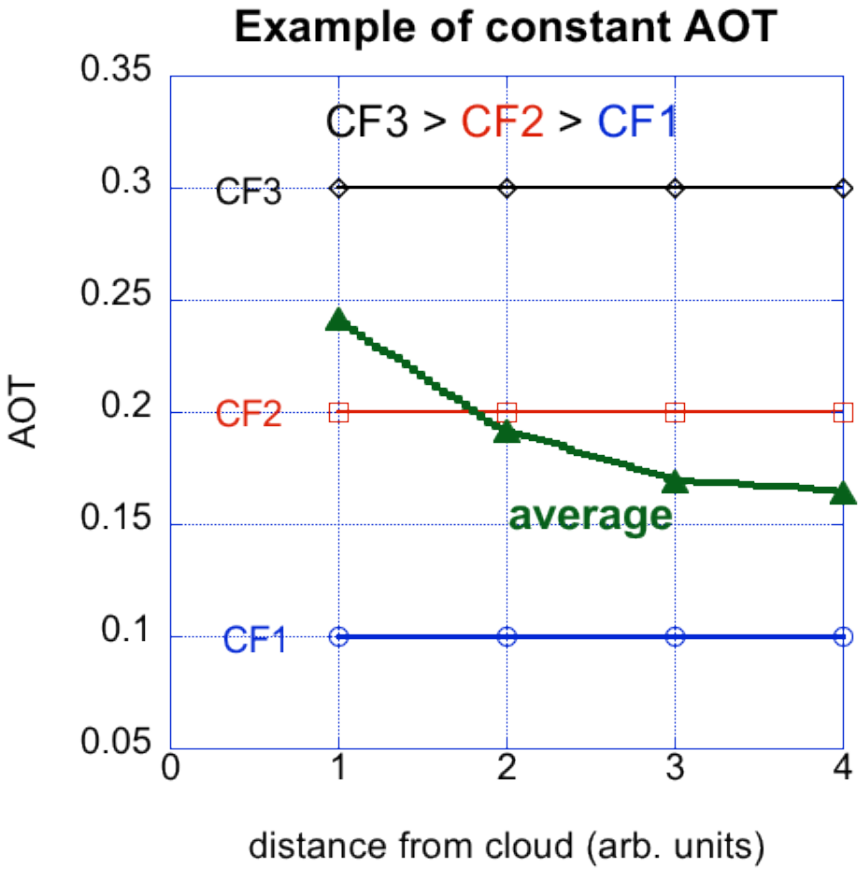
The clear pixels within a few km of clouds are under partly cloudy conditions, while the clear pixels 10-20 km away from clouds are under large-scale high pressure conditions.

The weather patterns and circulations for these two cases can be very different and the AOT and size can be different.

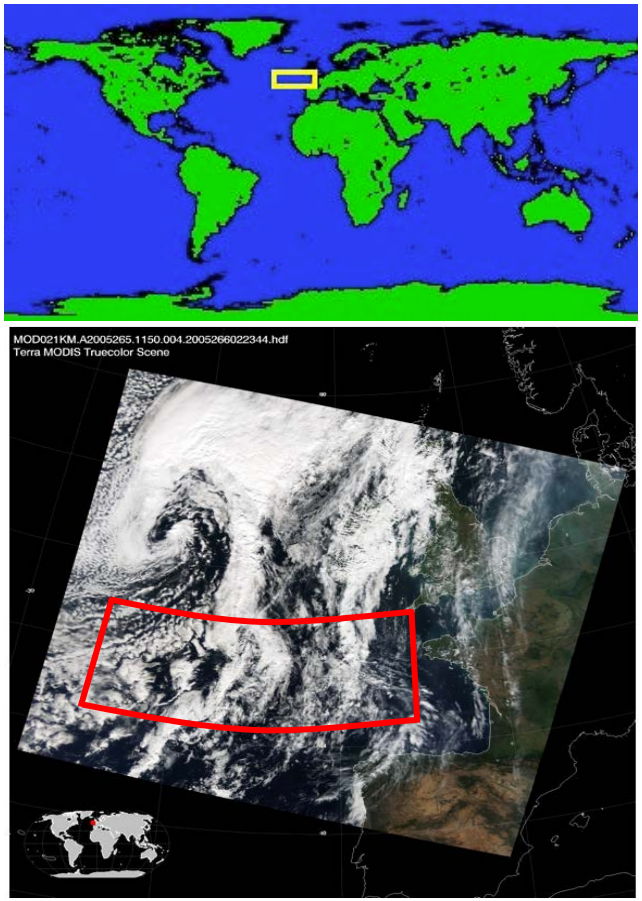
Relative humidity under these two cases is also different: higher under partly cloudy conditions than under large-scale clear conditions.

What's about 'apples' and 'oranges' or a sampling issue?



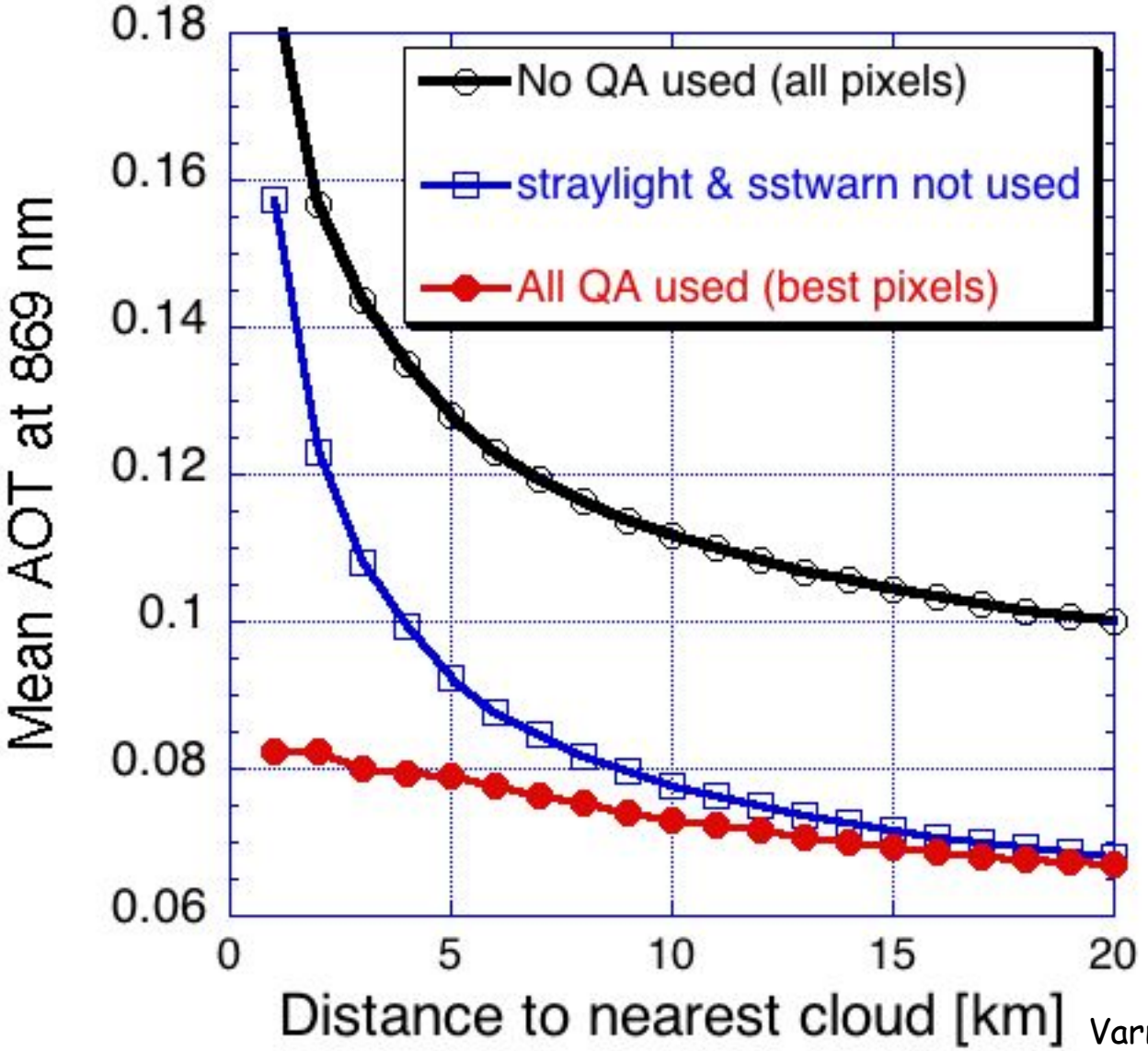


MODIS
Ocean Color Aerosol Product



2 Sep. weeks for 10 years (2002-2011) of MODIS obs.: southwest of UK

MODIS Ocean Color Product: AOT @ 869 nm



Varnai and Marshak, 2014

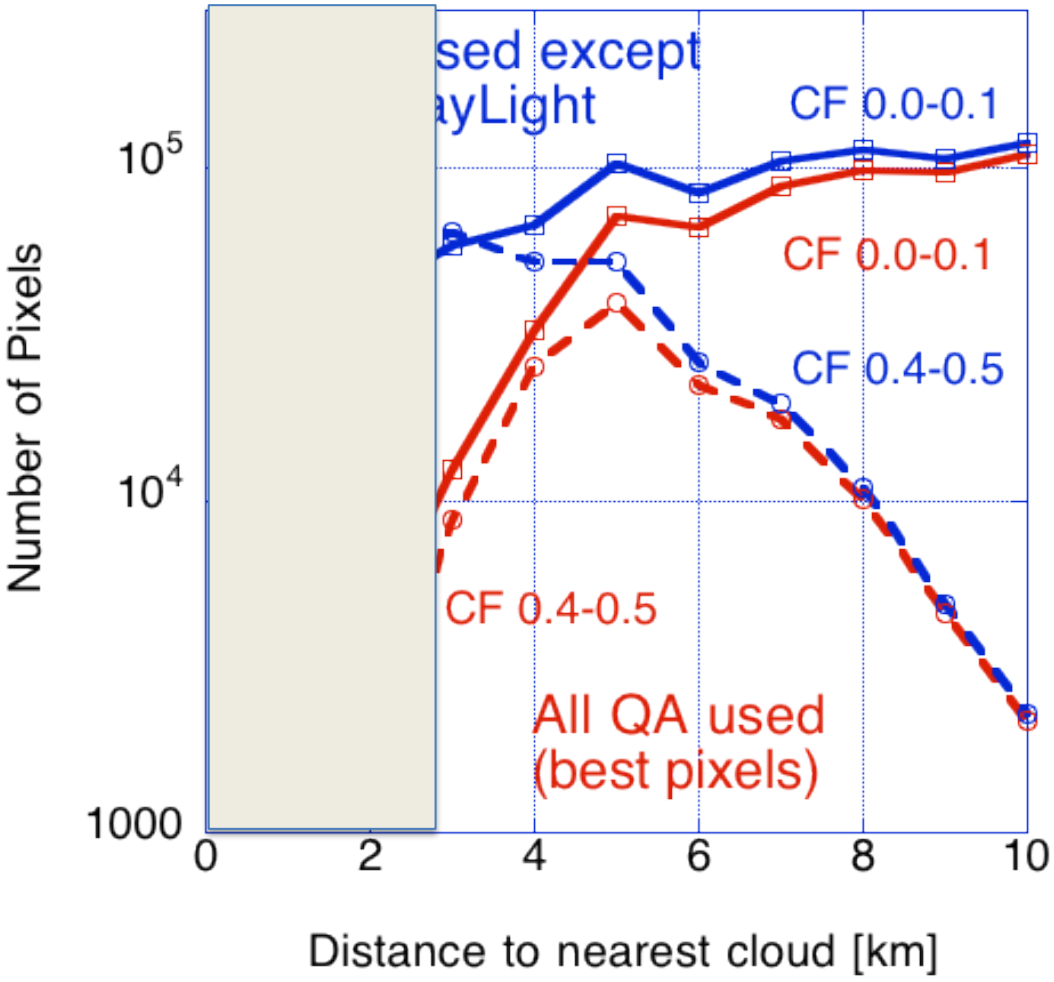
STRAYLIGHT flag

Stray light from adjacent, bright sources such as cloud edges is known to contribute to error in SeaWiFS and MODIS ocean color retrievals. In MODIS/Aqua Reprocessing 1.1 (2005), ***pixels within a 7x5-pixel region around bright pixels were flagged as straylight and masked in Level-3.***

This decision was based on the point-spread function as described in Meister et al. (2008) coupled with the lack of an adequate straylight correction capability for MODIS. …

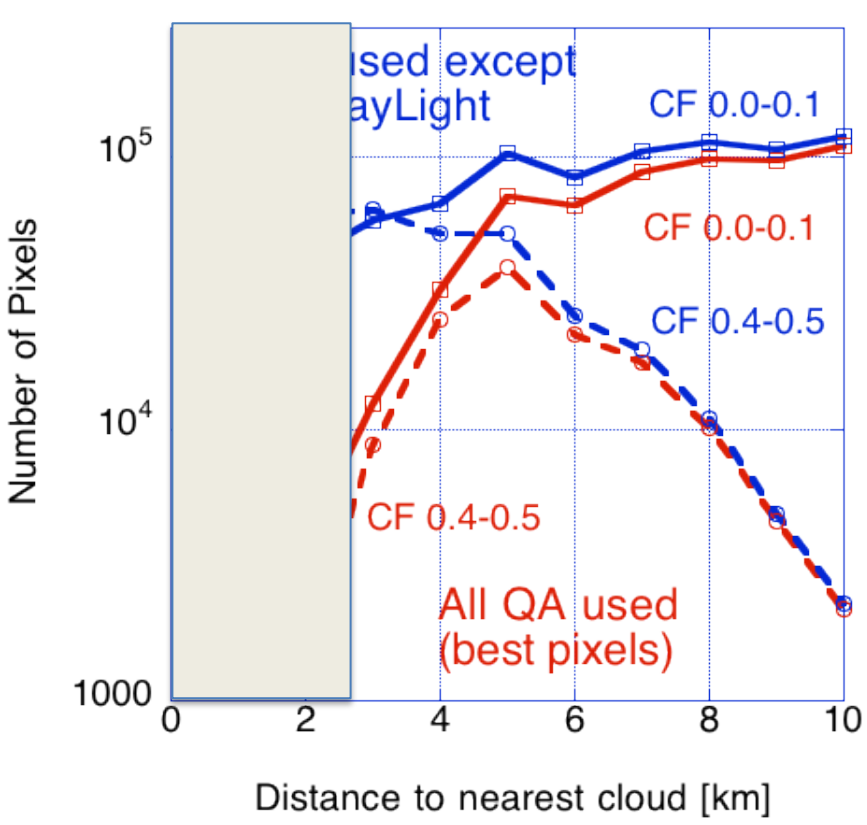
It should be emphasized that the ***straylight-contaminated pixels are flagged at Level-2 and masked at Level-3, so there is no impact to Level-2 coverage.***

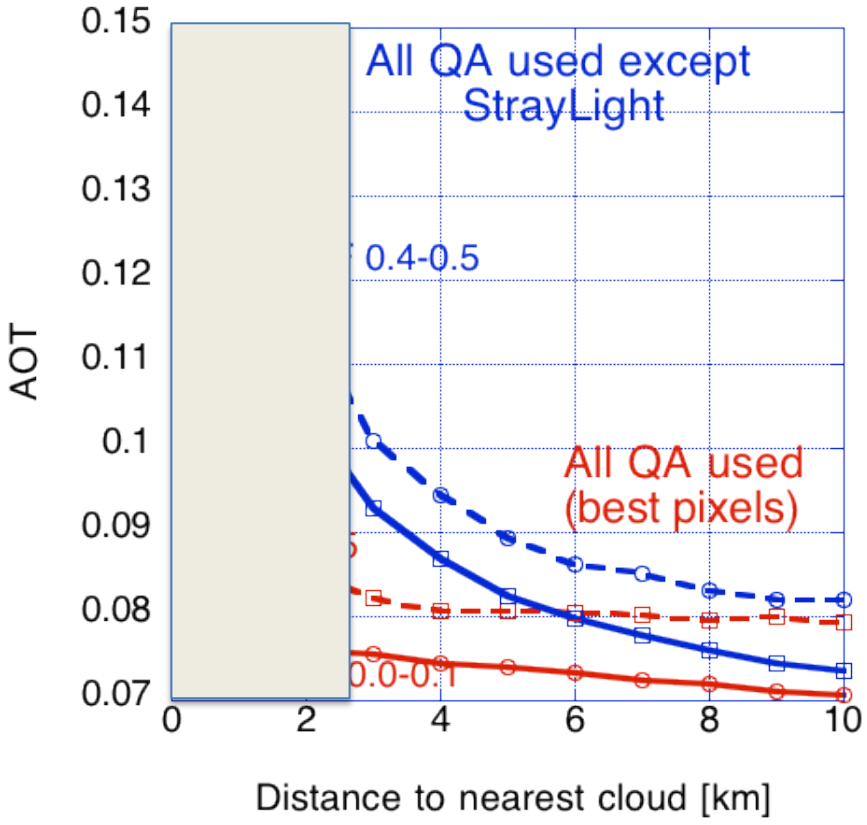
MODIS Ocean Color Product: AOT @ 869 nm
41 km x 41 km boxes; the same CF

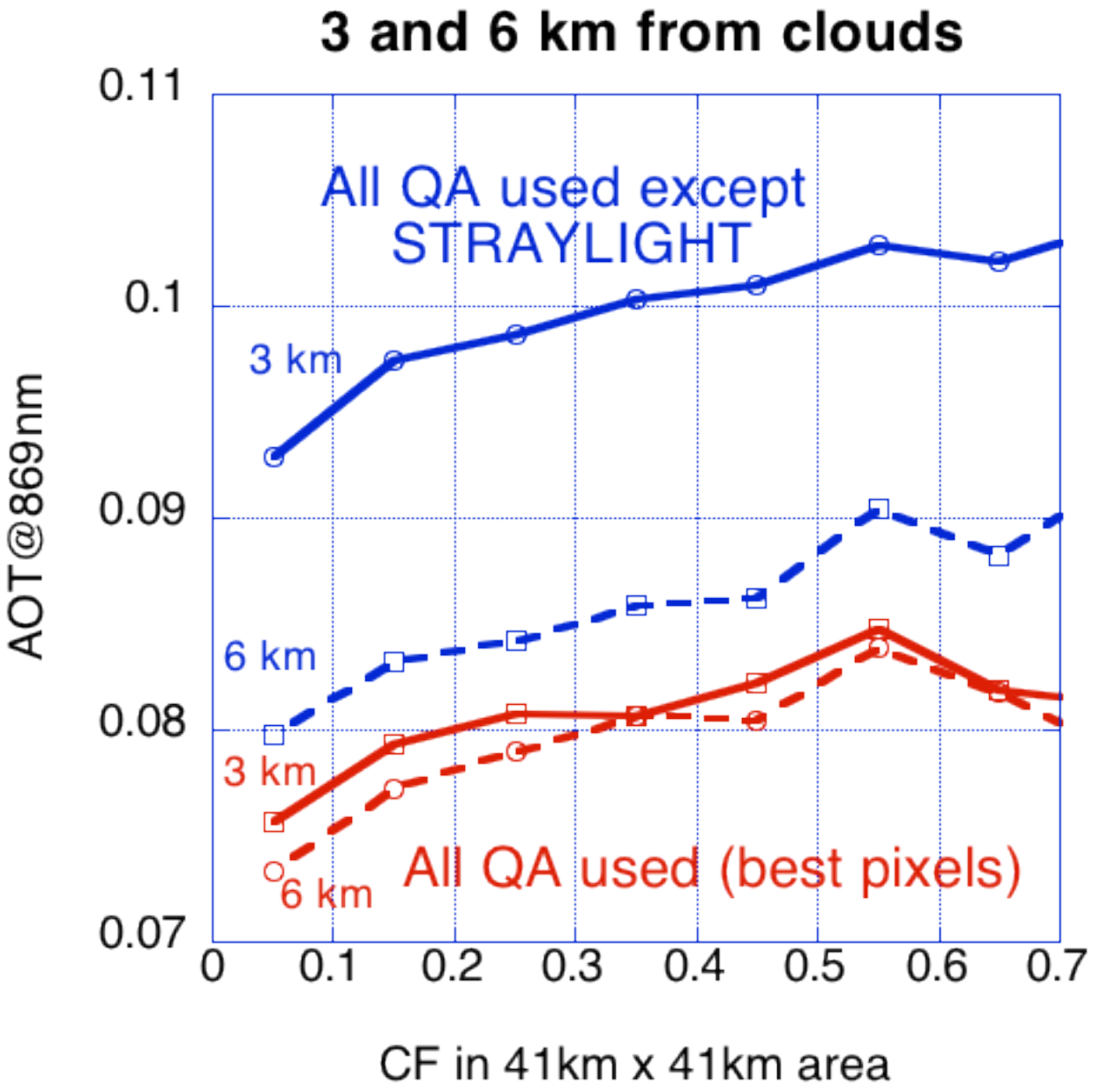


MODIS Ocean Color Product: AOT @ 869 nm
41 km x 41 km boxes; the same CF

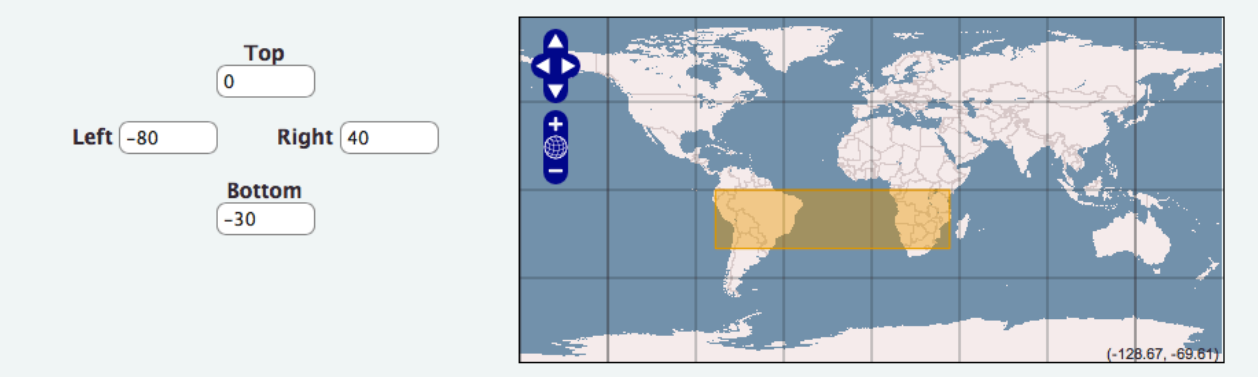
Effect of a STRAYLIGHT flag






3 and 6 km from clouds
All QA used except STRAYLIGHT
3 km
6 km
3 km
6 km
All QA used (best pixels)
AOT@869nm
CF in 41km x 41km area
0.11
0.1
0.09
0.08
0.07
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

CALIPSO



3 years

From 2006-09-01 to 2006-12-01

CALIPSO

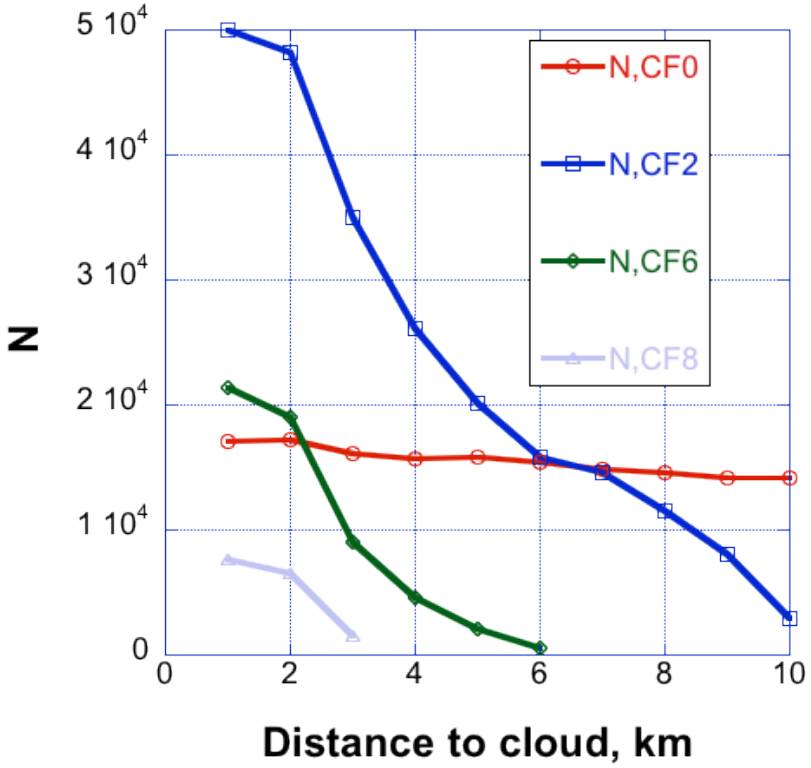
Cloud Fraction

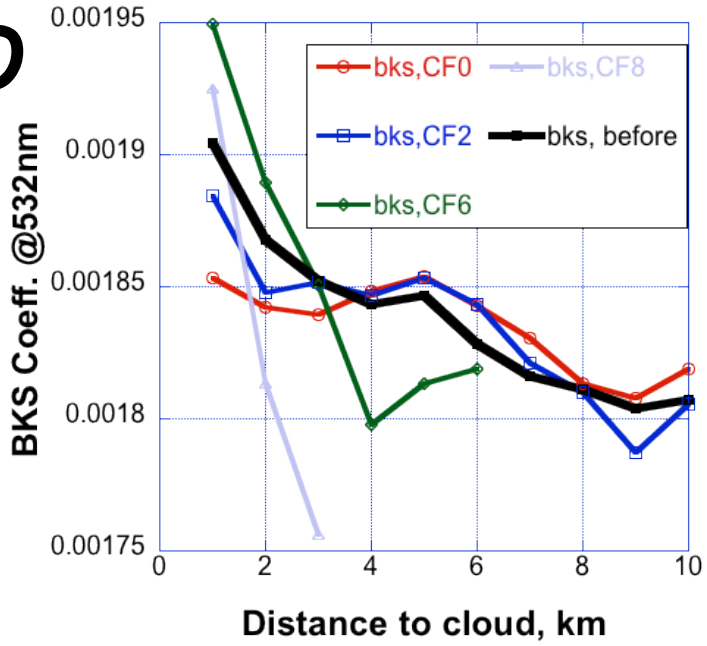
0.0-0.1

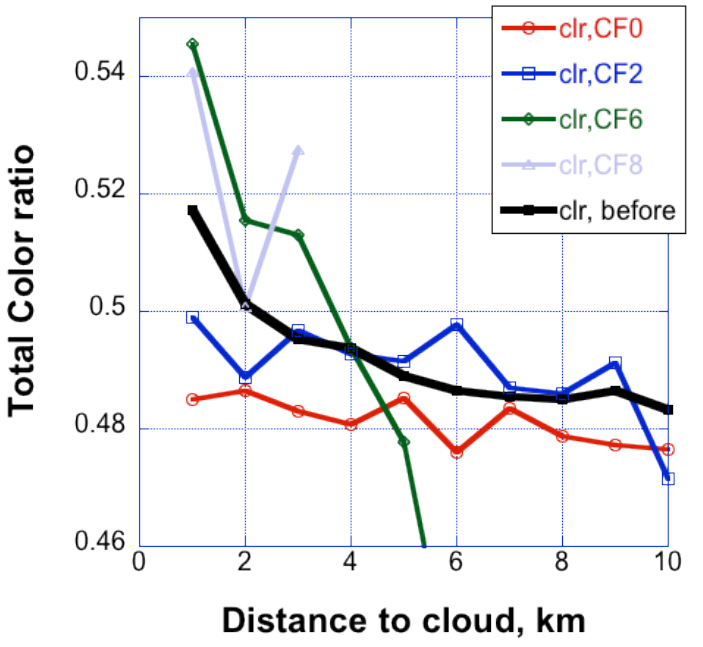
0.2-0.3

0.6-0.7

0.8-0.9

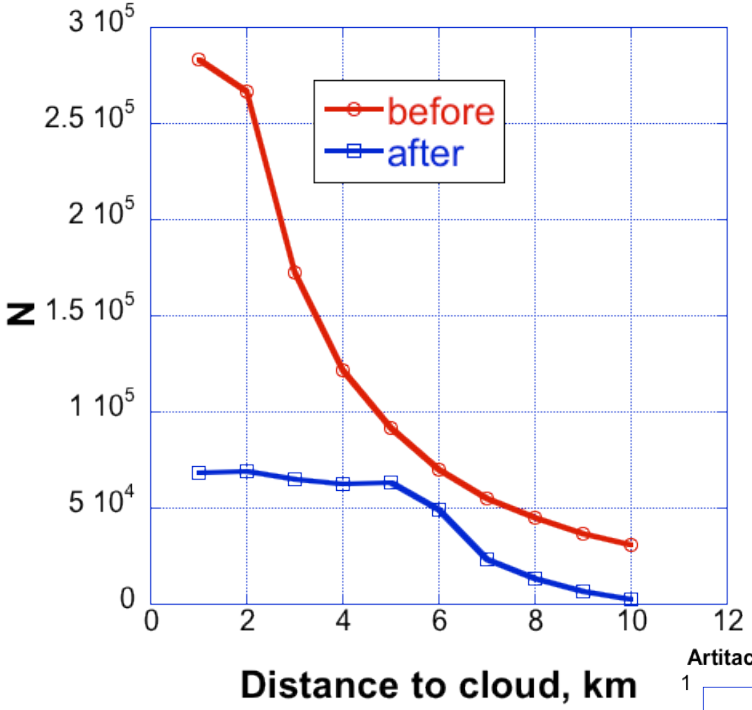




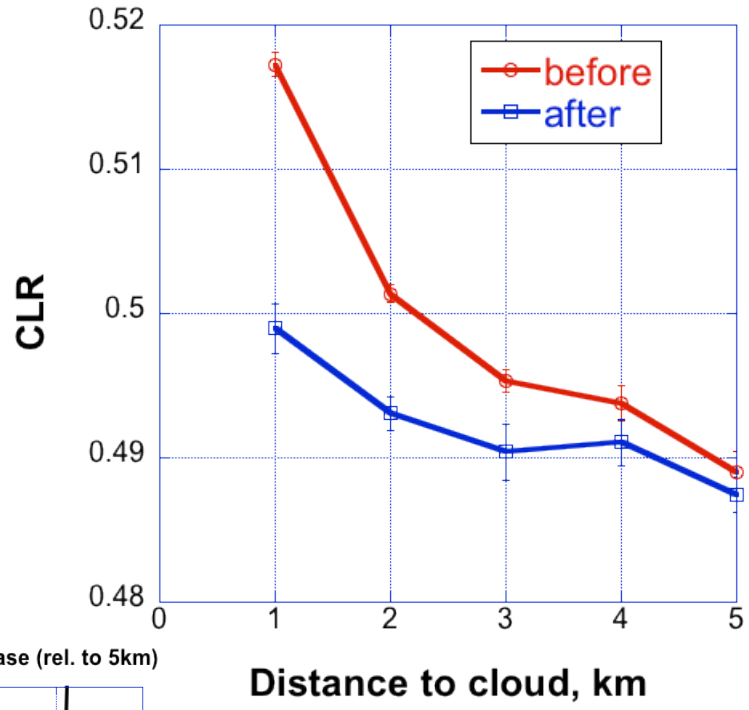


CALIPSO

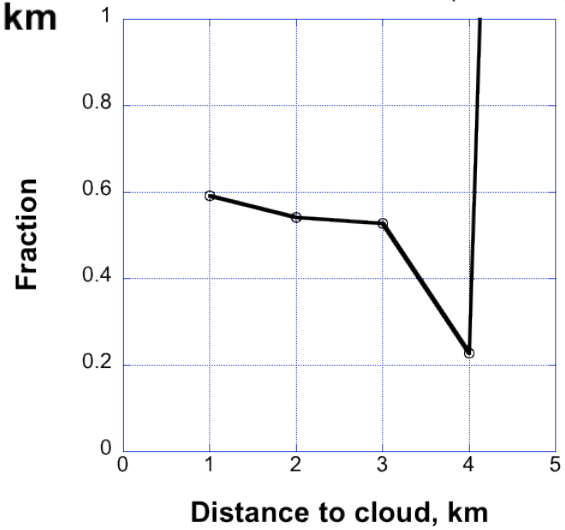
of pixels



Color ratio



Artitact Fraction in CLR increase (rel. to 5km)



Take home message

- Both passive and active measurements show that radiation is bigger near clouds. But radiation is not identical to AOD. There are other effects that increase *apparent* AOD near clouds, e.g., cloud fragments detrained from a nearby cloud or 3D radiative effects.

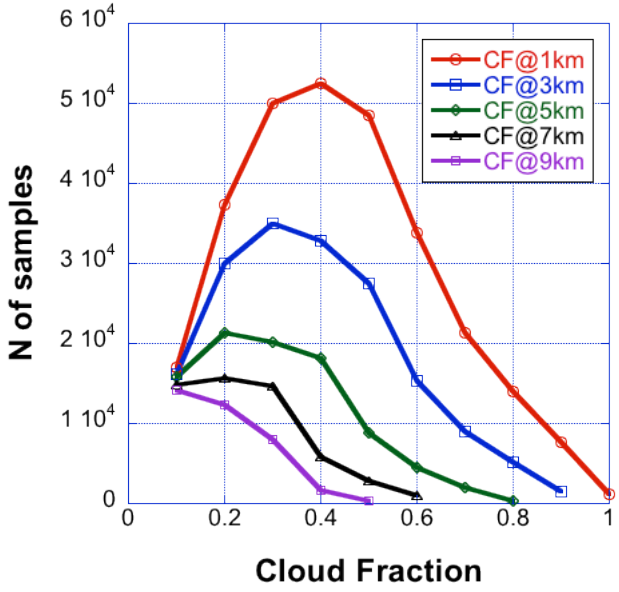
- There is also a sampling issue: pixels from different large-scale meteorological conditions are mixed together resulting to more higher humidity samples near clouds.

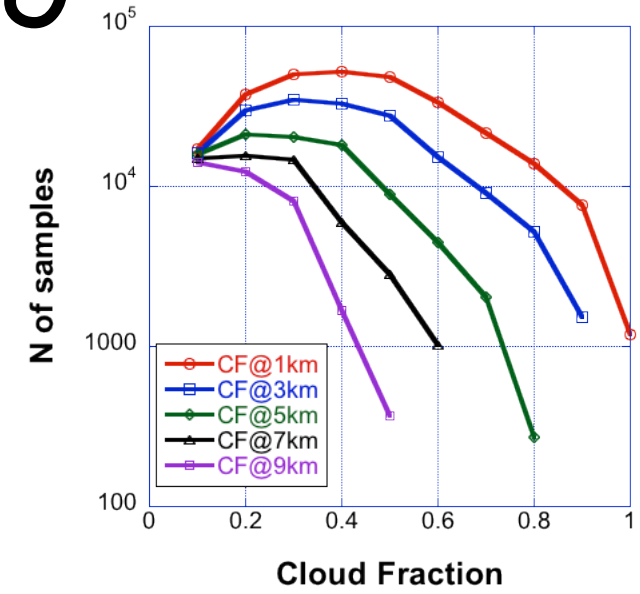
- This effect can be substantial; by our estimates its contribution is between 30% to 70%.

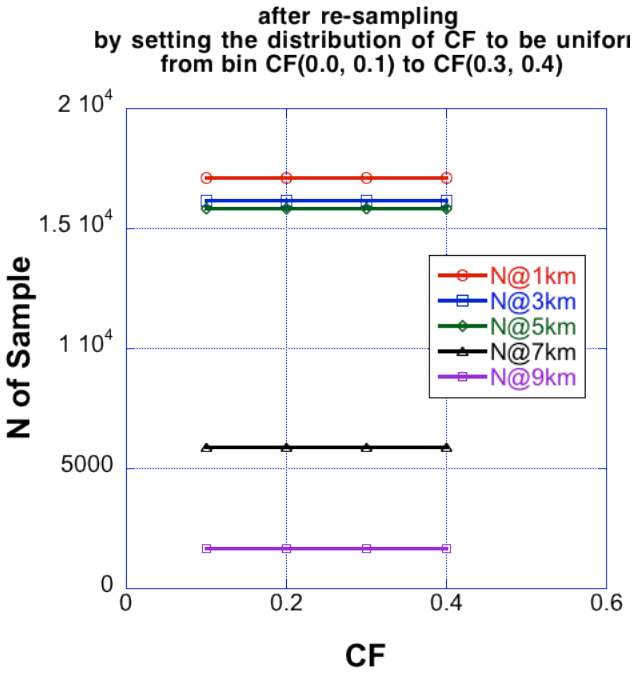
- Removing the statistical effect of sampling (comparing 'apples' and 'apples') reduces the difference between near and far from cloud AOD by factor of 1.5-3.

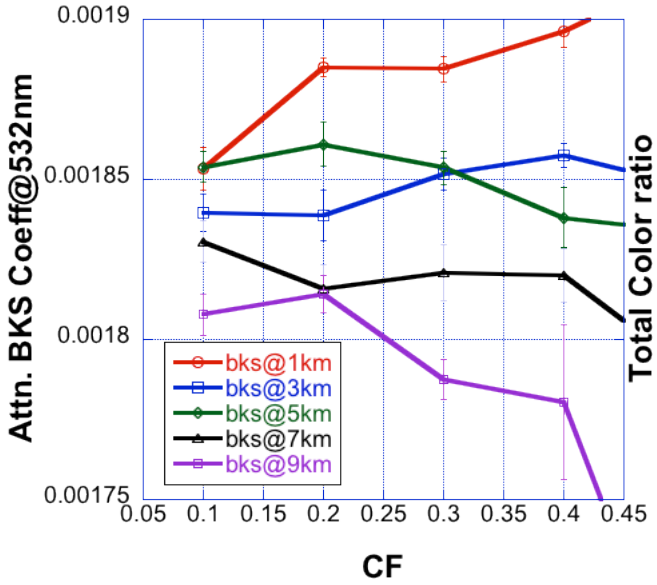
- As estimated earlier, for MODIS AOT, unaccounted 3D effects are responsible for 20-25% of the enhanced near cloud radiance. Now with an improved sampling strategy, it contribution is much bigger: between 30-75%. The rest are the small cloud elements and near-cloud changes in aerosol properties. The separation between these two factors is yet an open problem.

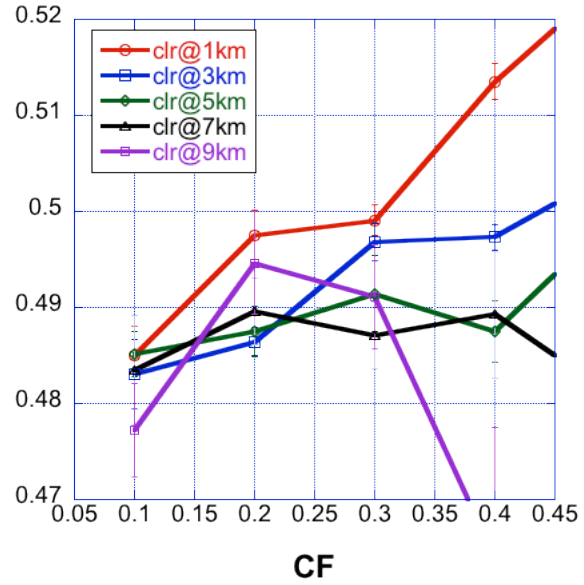
CALIPSO


N of samples
Cloud Fraction
CF@1km
CF@3km
CF@5km
CF@7km
CF@9km


N of samples
Cloud Fraction
CF@1km
CF@3km
CF@5km
CF@7km
CF@9km

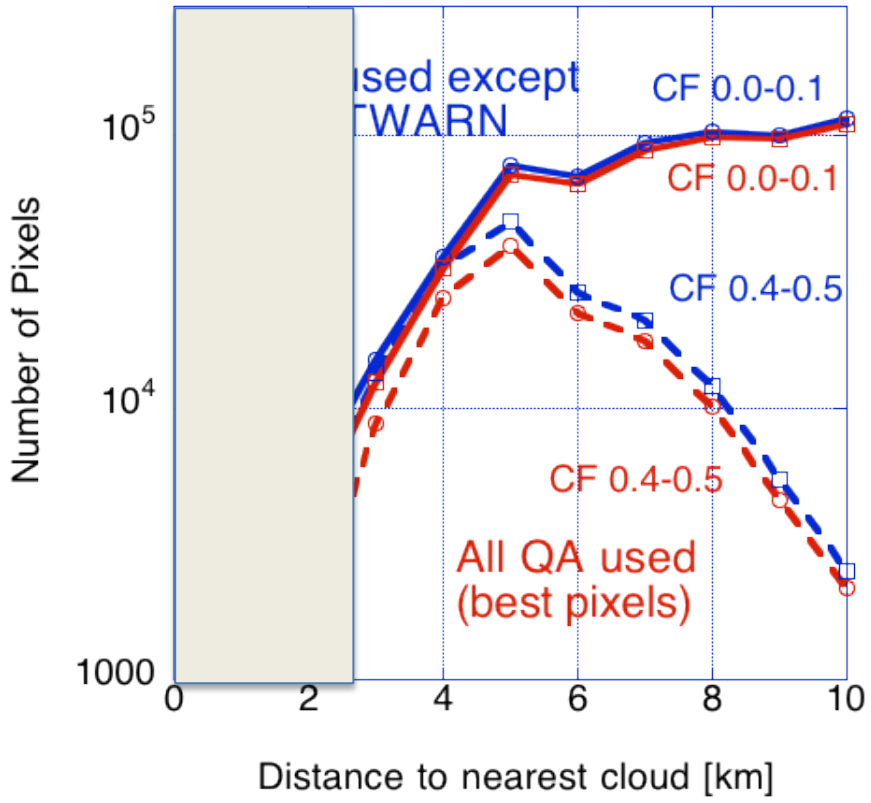

after re-sampling
by setting the distribution of CF to be uniform
from bin CF(0.0, 0.1) to CF(0.3, 0.4)
N of Sample
CF
N@1km
N@3km
N@5km
N@7km
N@9km

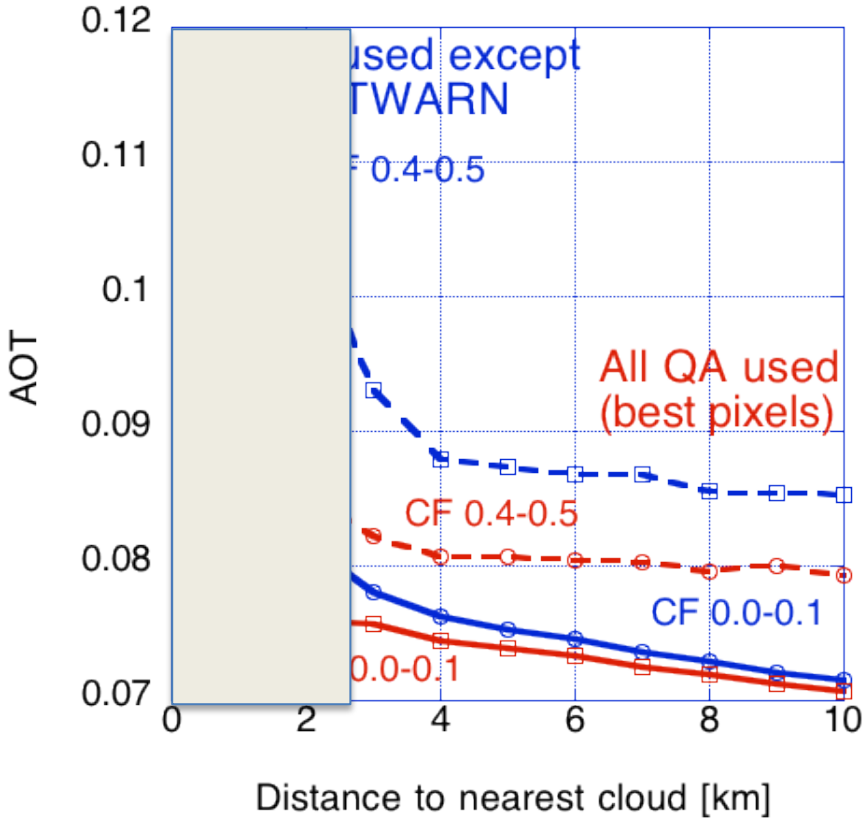

Attn. BKS Coeff@532nm
CF
bks@1km
bks@3km
bks@5km
bks@7km
bks@9km


Total Color ratio
CF
clr@1km
clr@3km
clr@5km
clr@7km
clr@9km

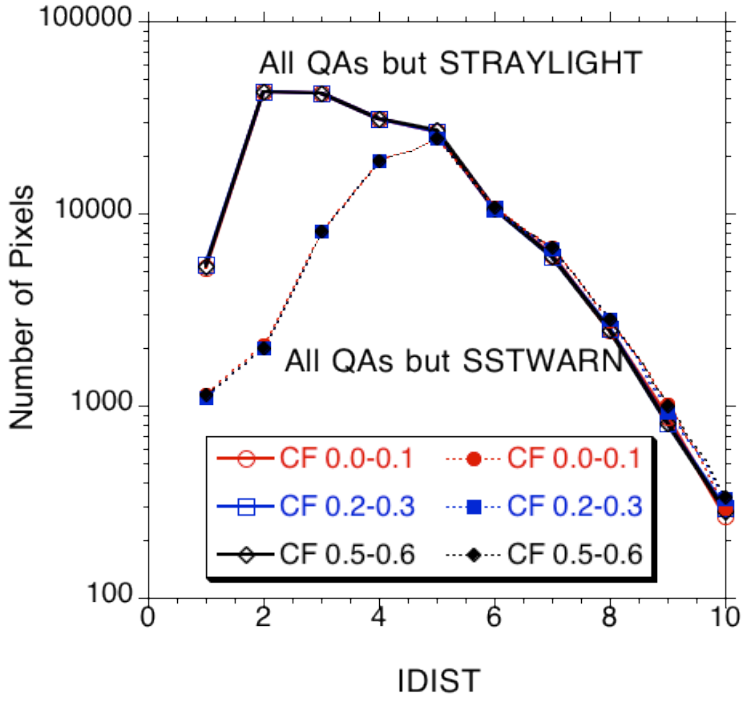
MODIS Ocean Color Product: AOT @ 869 nm
41 km x 41 km boxes; the same CF

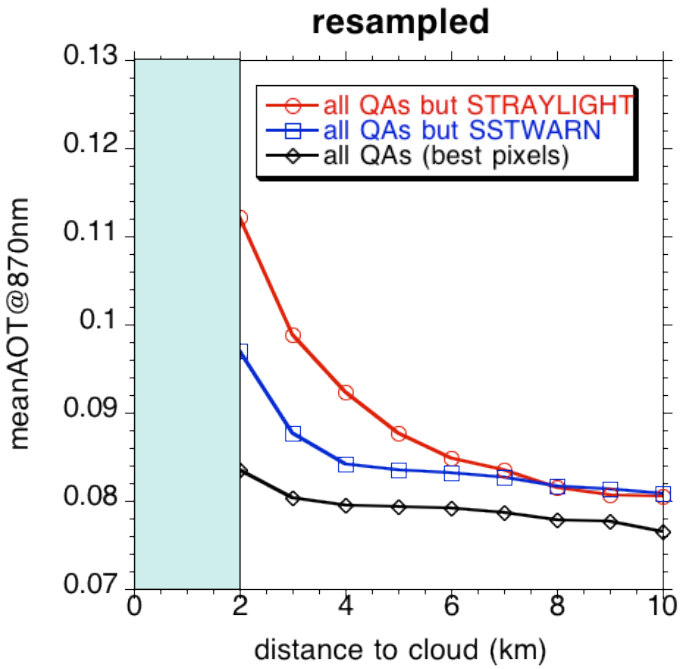
Effect of a SSTWARN flag

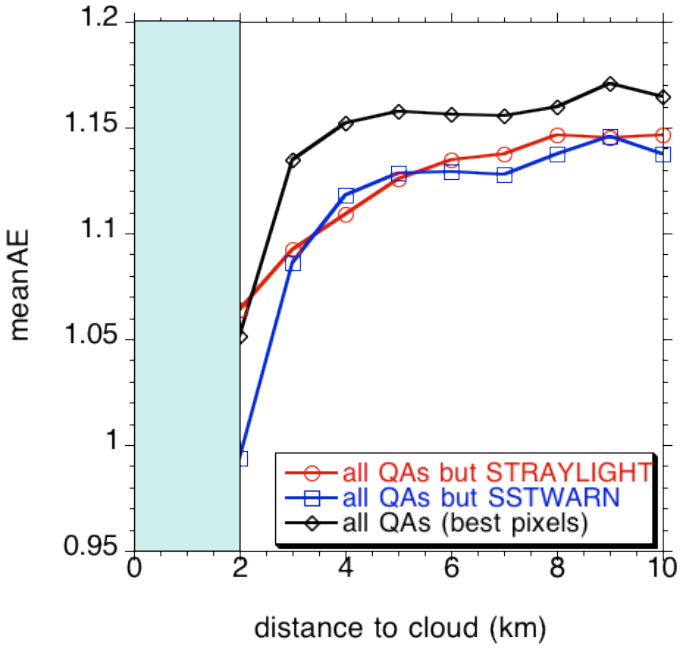




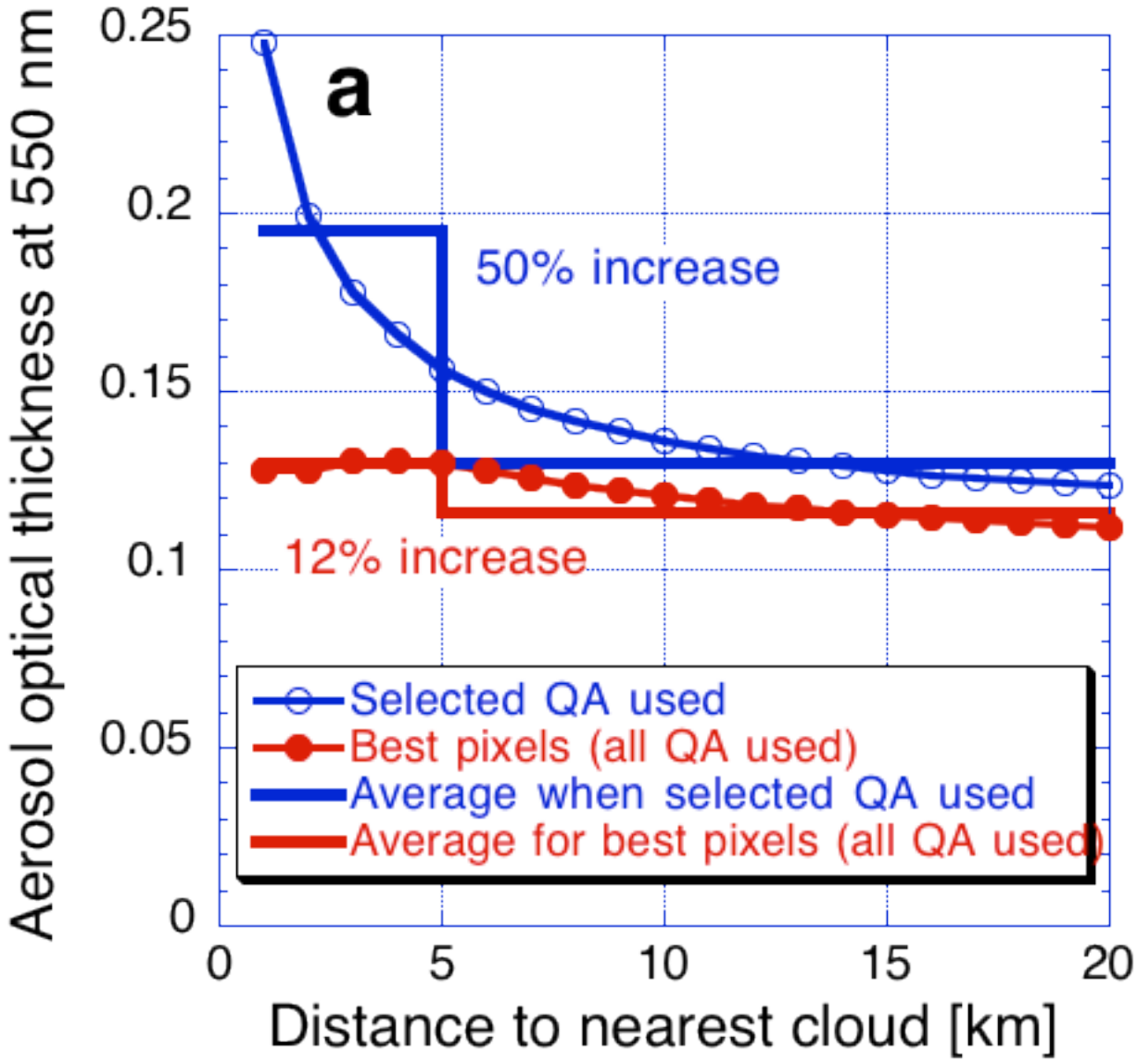
Re-sampling: equal number of pixels for each CF

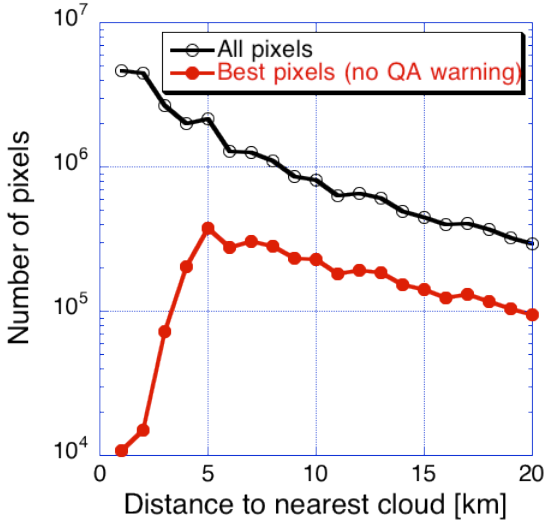






MODIS Ocean AOD @ 550 nm





excluding aerosols data near clouds will dramatically reduce the database

Chand et al. (2012) found a 25% enhancement in AOT between CF 0.1-0.2 and CF 0.8-0.9 which was *"consistent with aerosol hygroscopic growth in the humid environment surrounding clouds."*