Aerosol Properties in Partly Cloudy Regions

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1: NASA GSFC, 2: UMBC JCET, 3: Morgan State Univ., 4: USRA

Aerosols are sometimes near clouds

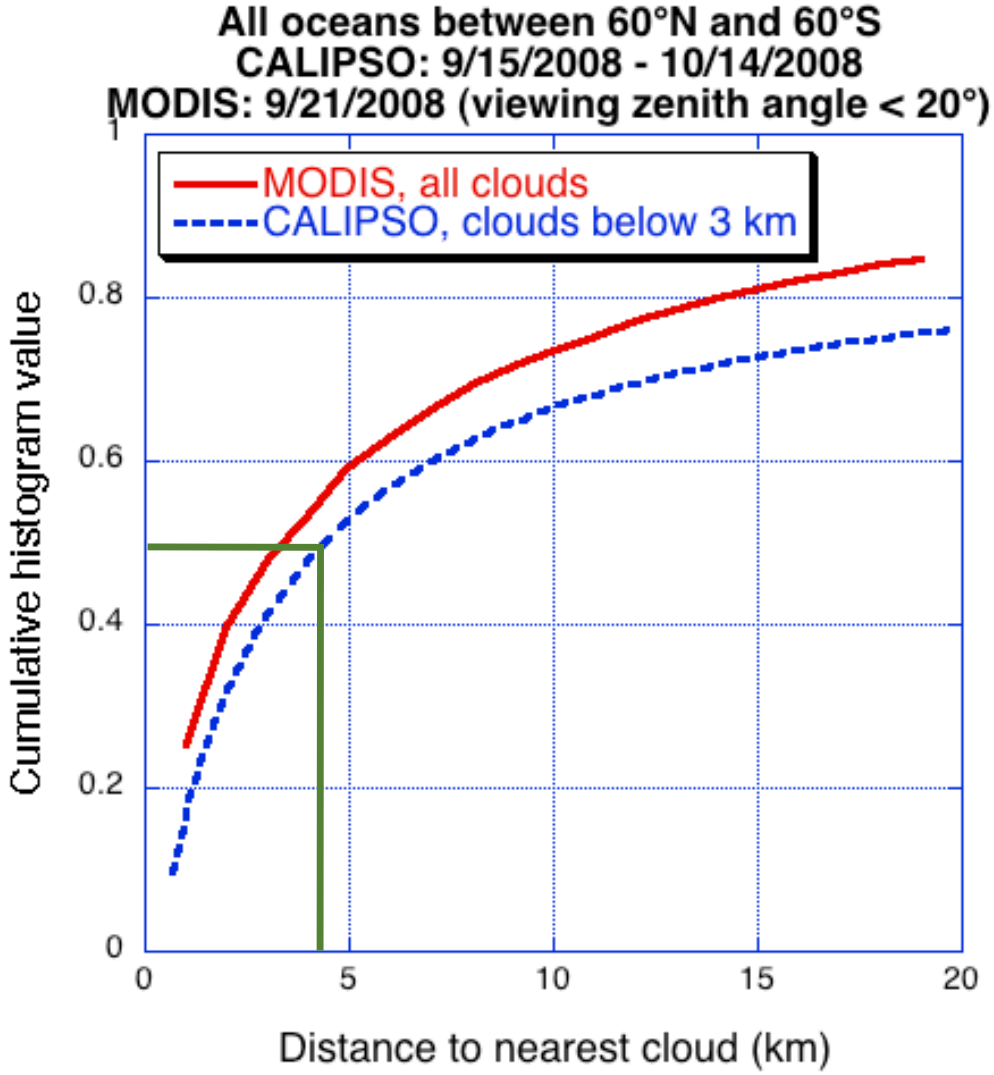
Arctic haze

Saharan dust & clouds

View from DC-8; A. Wisthaler, NOAA

View from G-IV, J. Dunion, NOAA

Most clear areas are not too far from clouds



DSCOVR spacecraft, EPIC imager, February 1, 2018

Aerosols are different near clouds

"… aerosol measured in the vicinity of clouds is significantly different than it would be were the cloud field, and its proximate cause (high humidity), not present".

IPCC AR5, Chapter 7

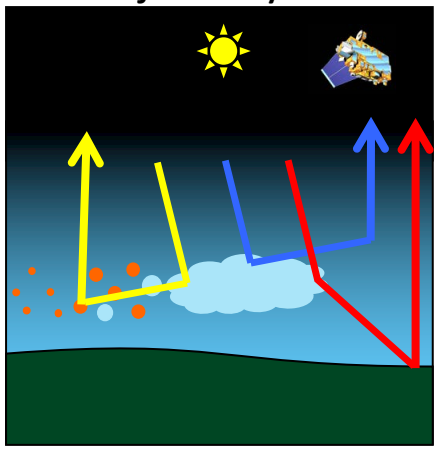
Aerosols are different near clouds due to:

- Aerosol swelling
- Cloud processing of aerosols
- New particle formation

Remote sensing issues can exaggerate the differences:

- Undetected cloud droplets
- 3D cloud adjacency effect
- Instrument blurring

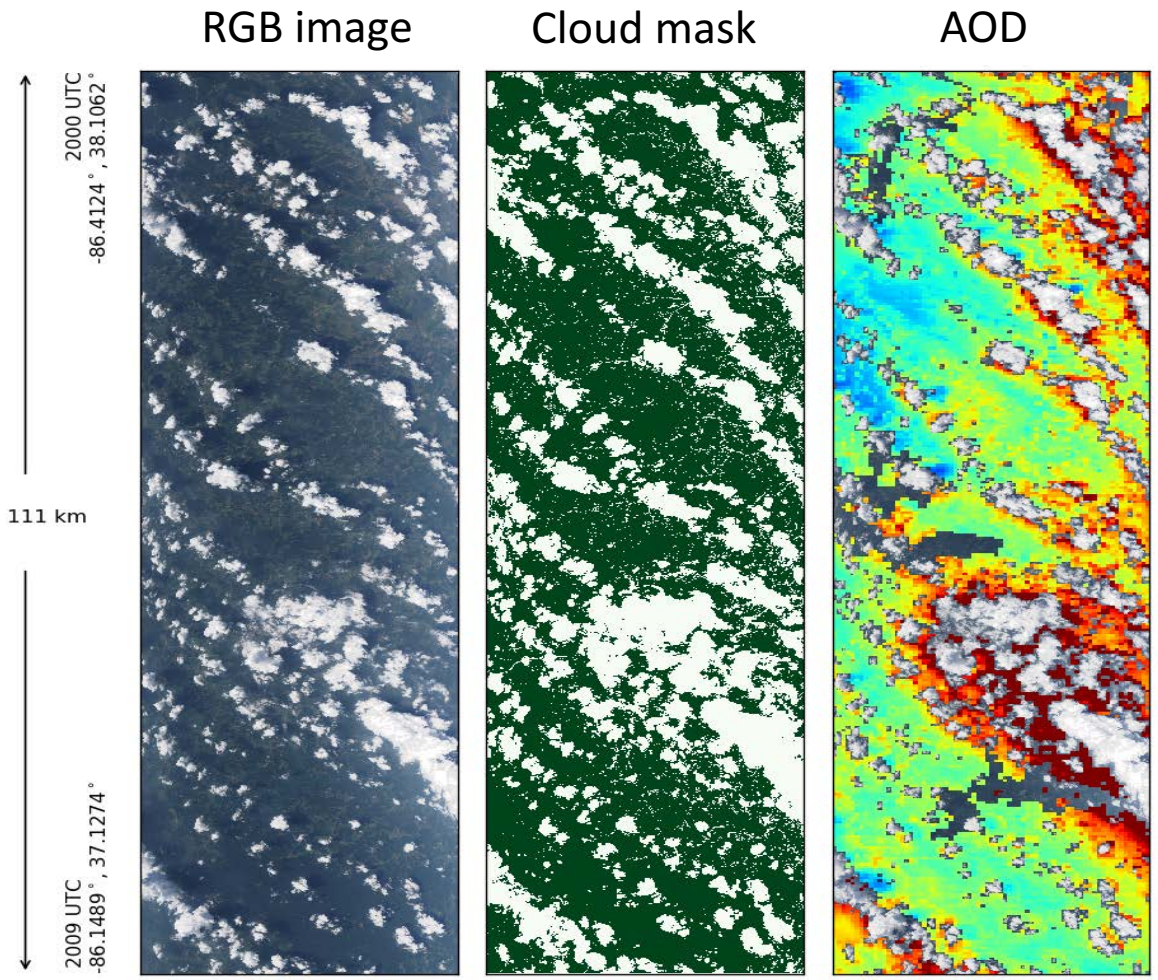
3D adjacency effect

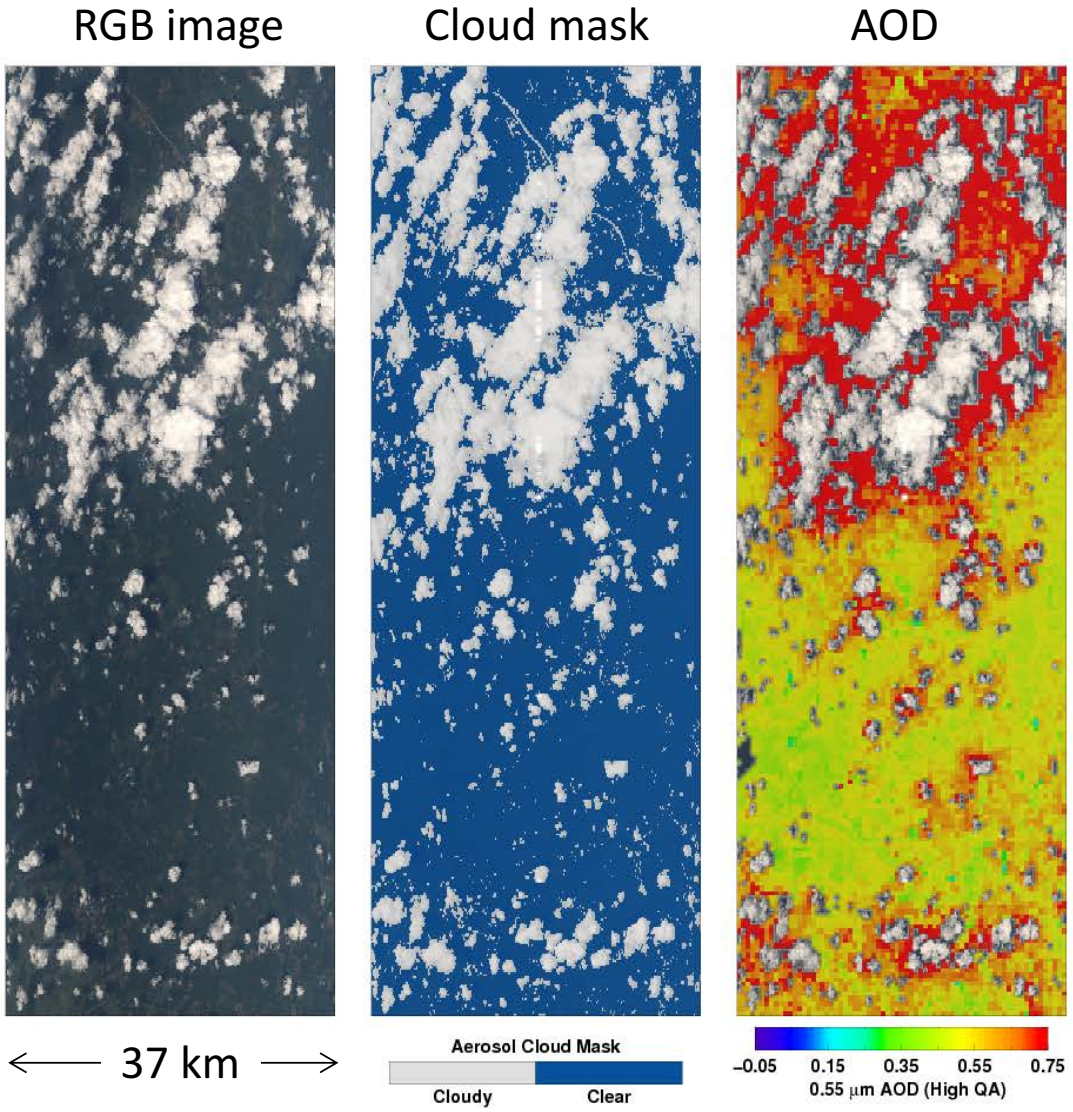


Project goals:

- Advance our understanding on the effect of clouds and cloud-related processes on aerosol properties and aerosol radiative forcing.
- Improve the interpretation of MODIS and VIIRS aerosol observations near clouds through a correction model accounting for the adjacency effect of clouds.

eMAS data often show near-cloud aerosol enhancements

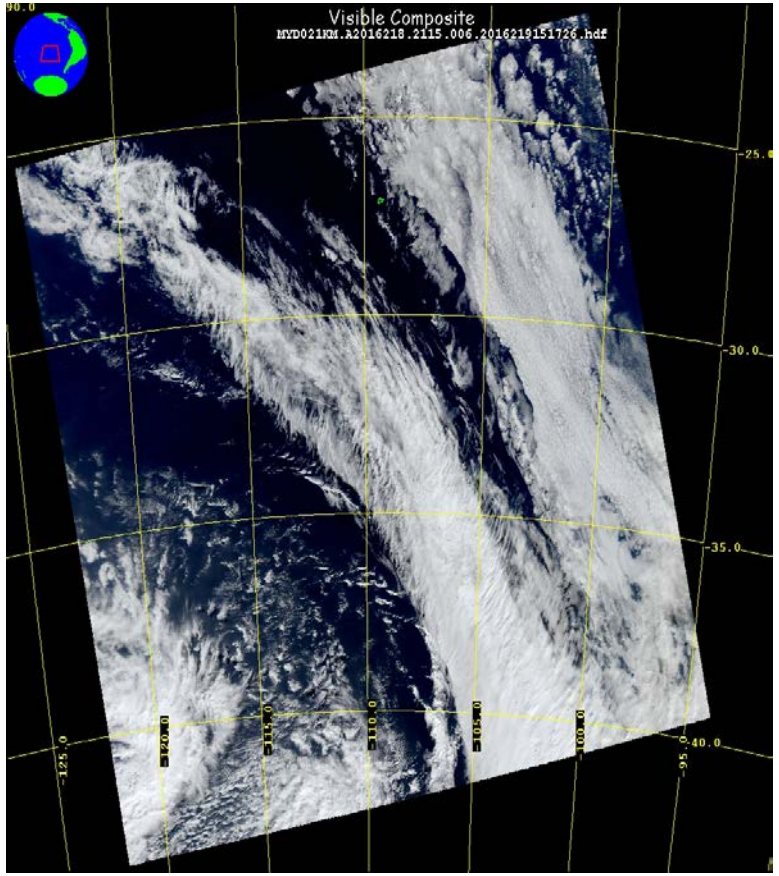




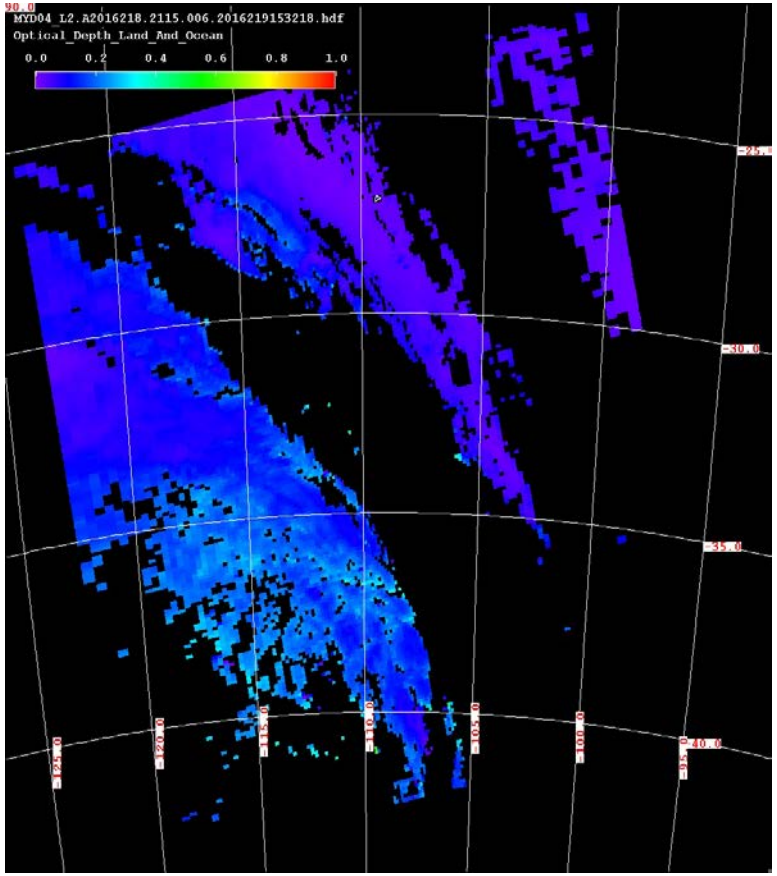
NASA ER-2 eMAS, SEAC4RS, Kentucky & Alabama, August 30, 2013

Satellite images also show near-cloud enhancement

MODIS image



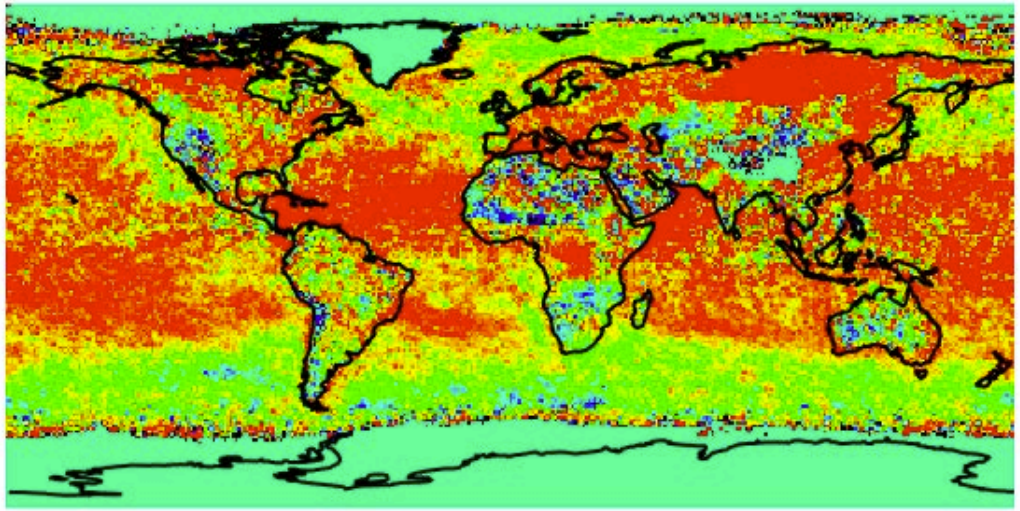
AOD



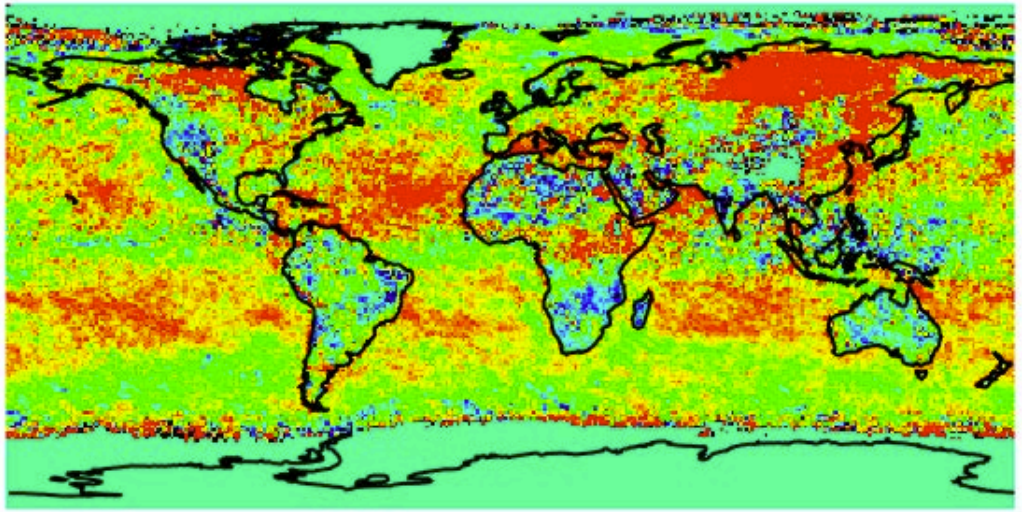
Aqua MODIS, August 5, 2016

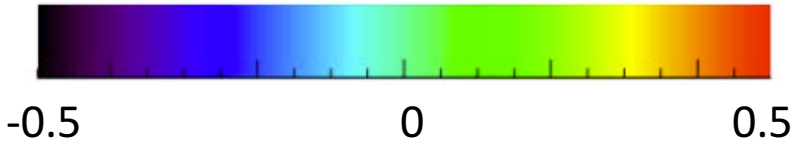
CF-AOD correlation is positive throughout the globe

MODIS



MERRA-2

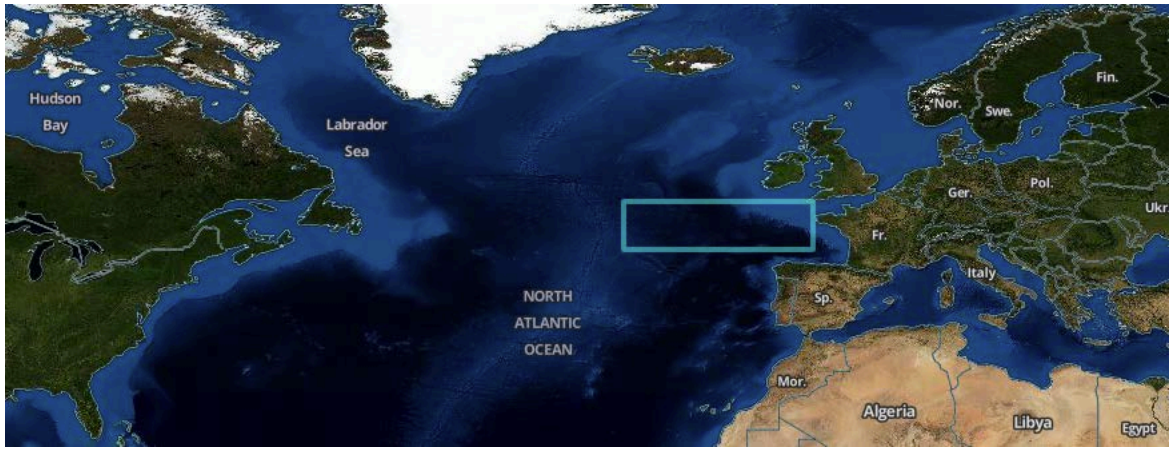


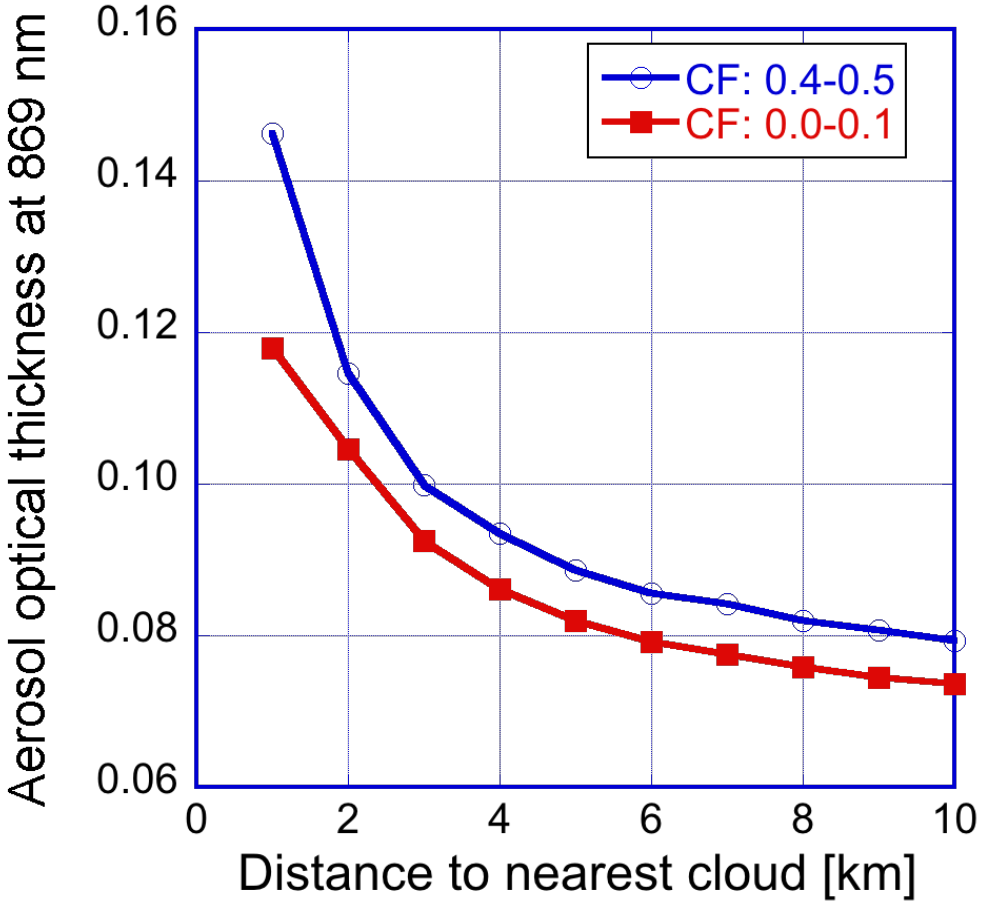


June-July-August, 2012-2014

Similar behavior for other models (e.g.,Quaas et al., ACP, 2010)

AOD increases with both CF and proximity to clouds



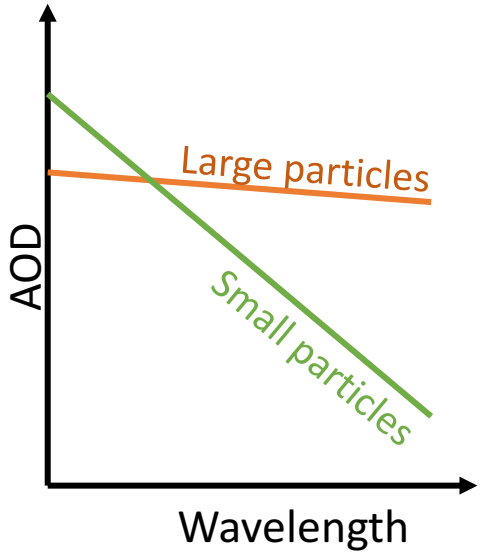


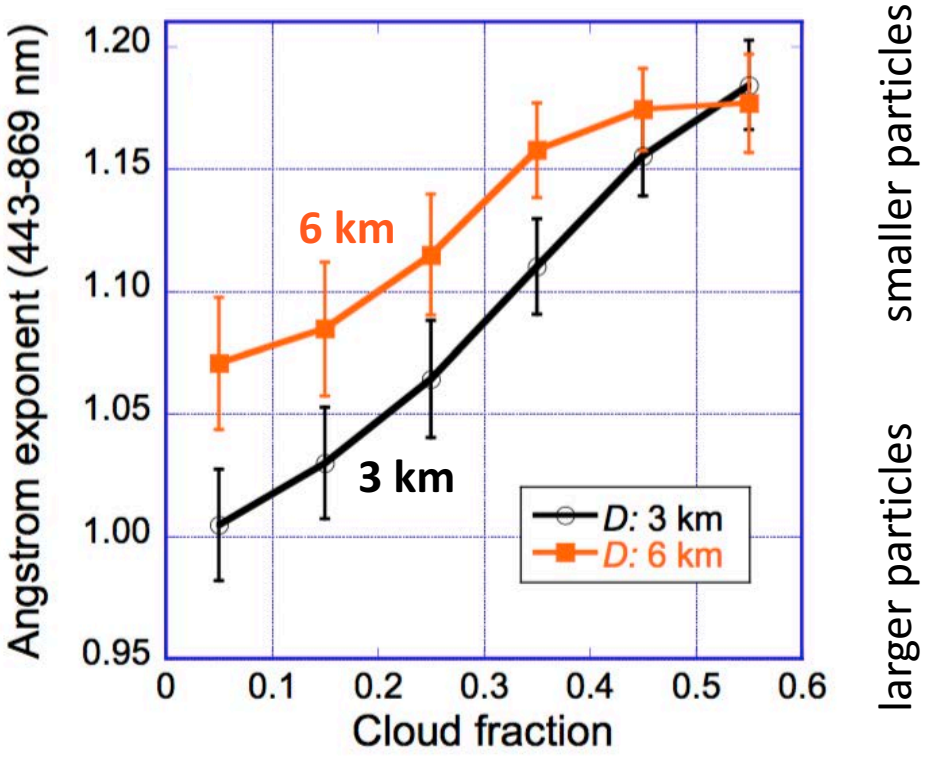
Retrieved 0.55 µm AOD is 50% higher in the half of data that is closer to clouds

Sept. 14-29, 2002-2011

AE decreases near clouds even if it increases with CF

Angstrom exponent:
"steepness" of spectral slope



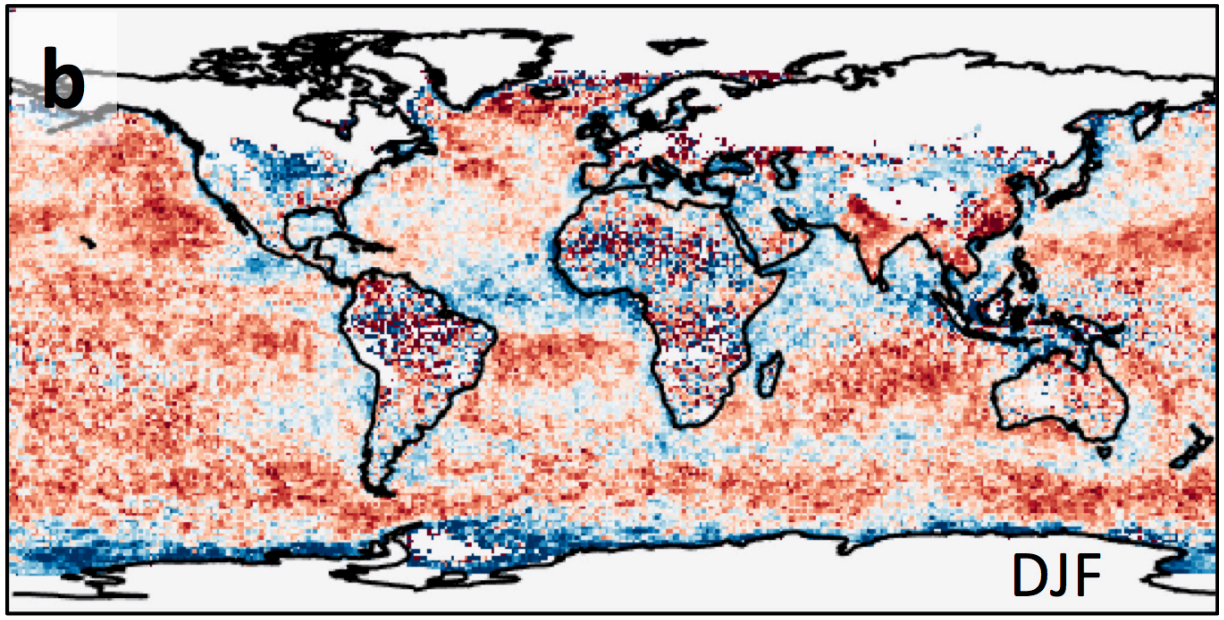


CF: large-scale environment

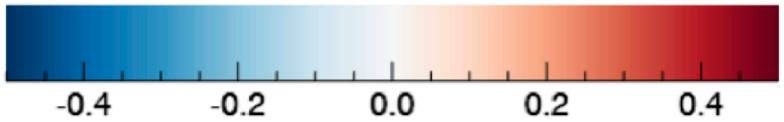
D: effect of individual clouds

Sept. 14-29, 2002-2011

When CF increases, in many areas the aerosol population shifts toward smaller sizes



Shift to larger size



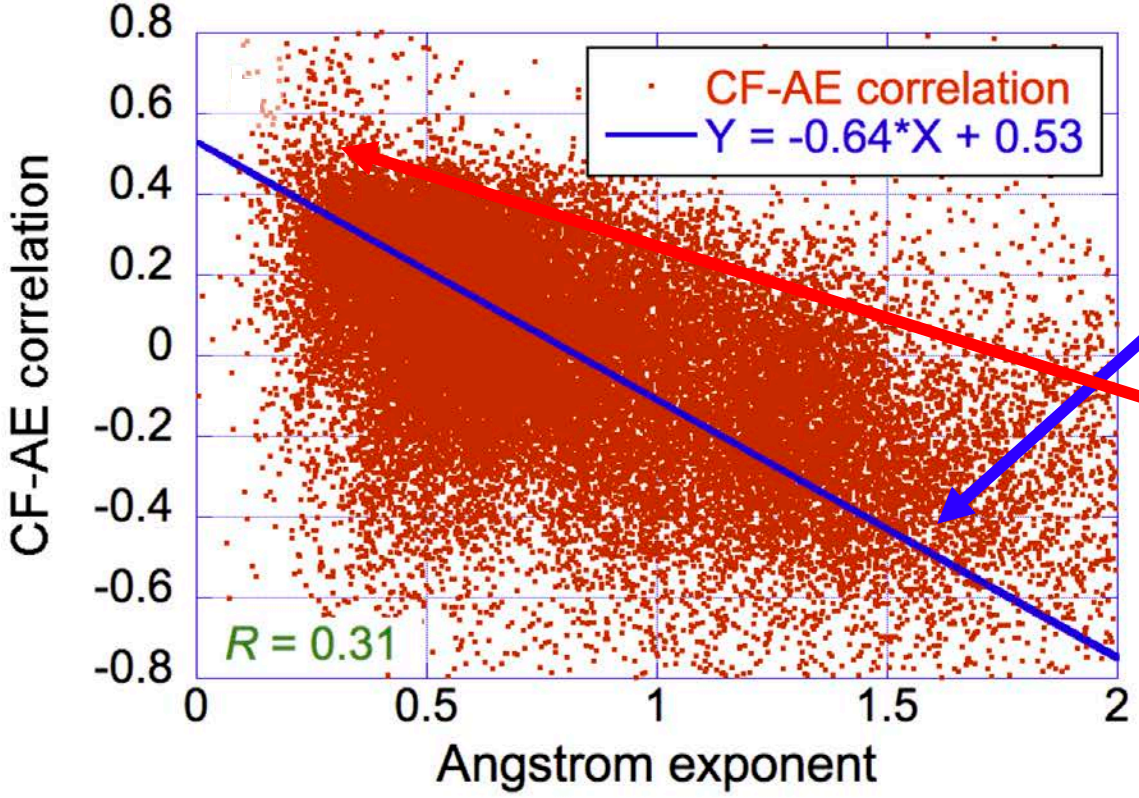
Shift to smaller size

Correlation of CF & AE

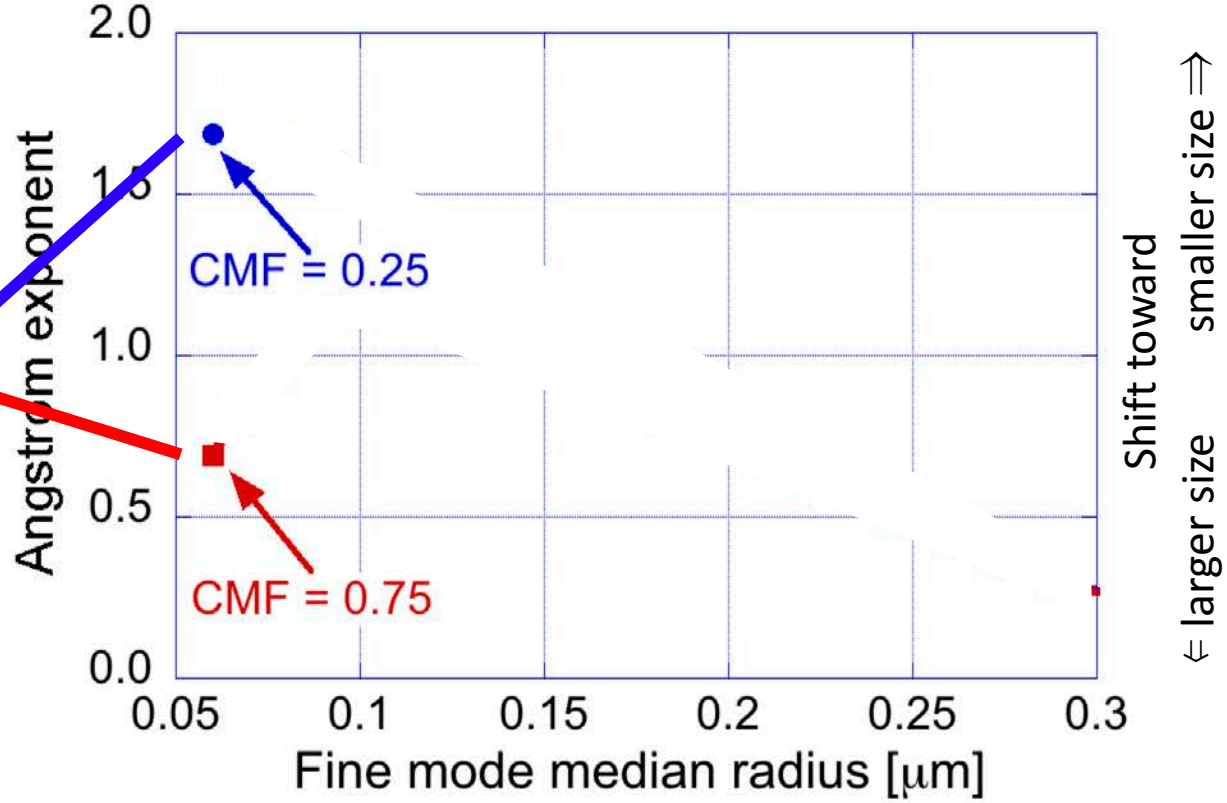
MODIS Aqua, DJF 2012-2014

AE can increase with CF due to small mode swelling

MODIS observation

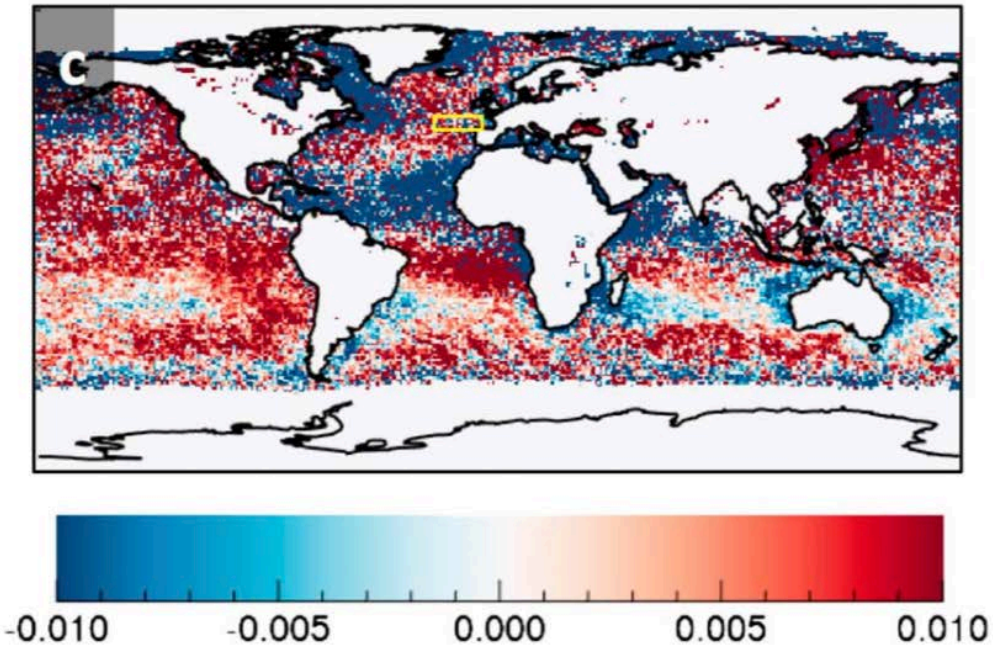


Simulation of small mode swelling



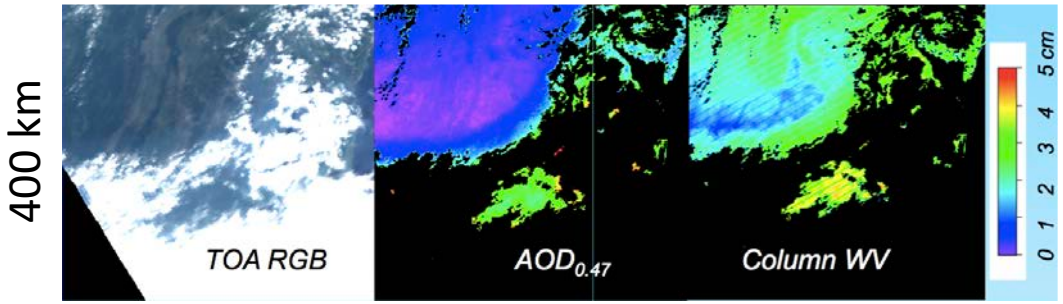
MODIS Aqua, JJA 2012-2014

AOD often increases with CF more for small mode



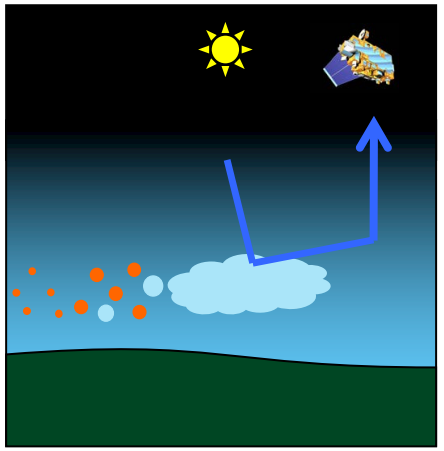
AOD increases more with CF for

Coarse mode Small mode



MAIAC, MODIS Aqua, July 31, 2011, Baltimore region

3D adjacency effect

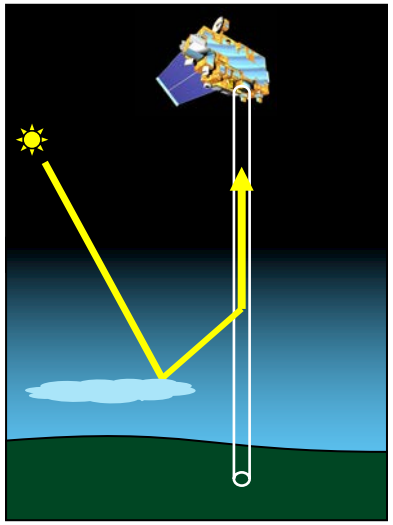


- cloud contamination is not dominant (MAIAC, VIIRS 375 m TIR)
- small mode swells more (MAIAC, MERRA-2, CALIOP)
- cloud processing creates small aerosols (MERRA-2)
- 3D adjacency effect

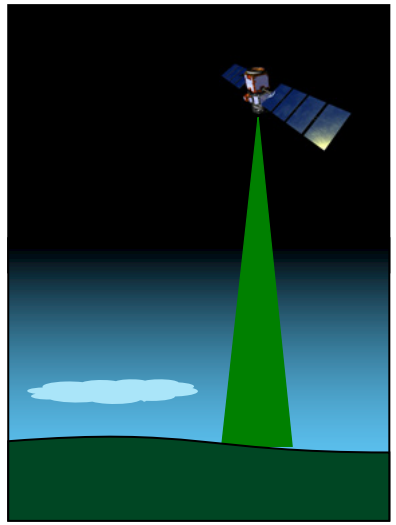
MODIS Aqua, JJA 2012-2014

3D causes significant part of near-cloud enhancements

MODIS



CALIOP

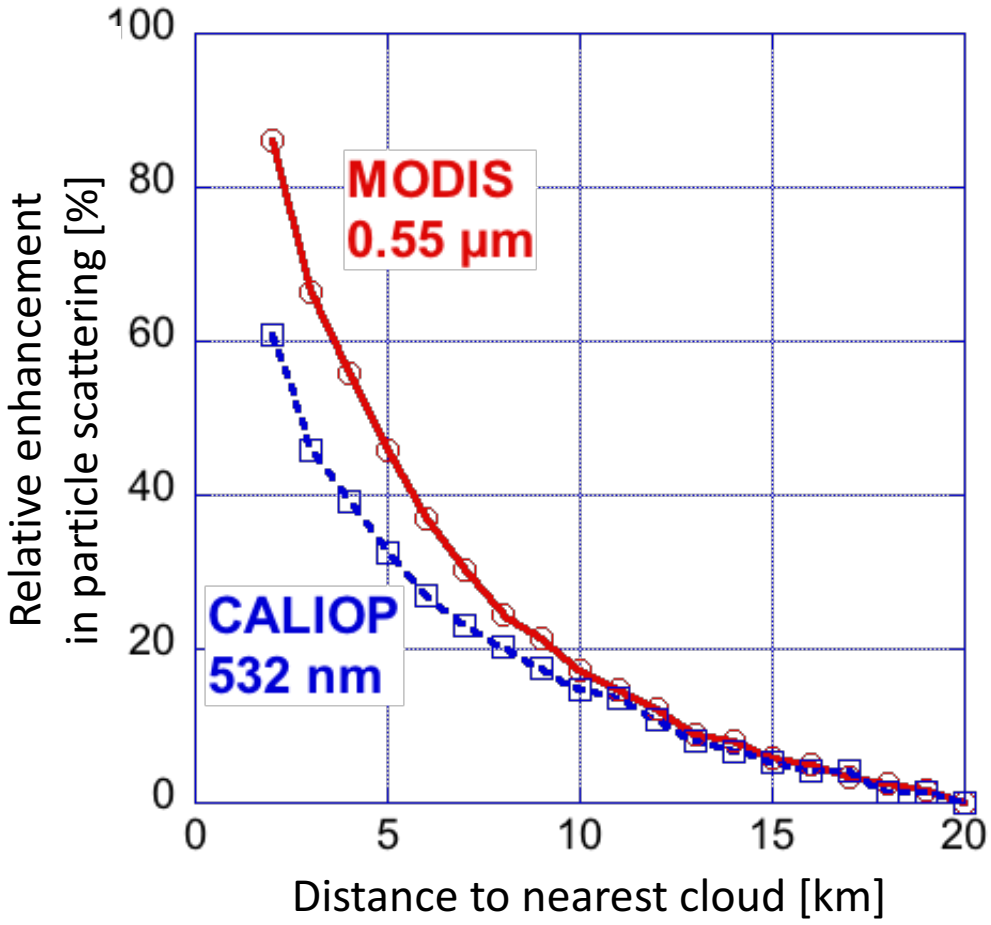


CALIOP can observe enhancements from:

- Aerosol swelling
- Cloud contamination
- Cloud processing

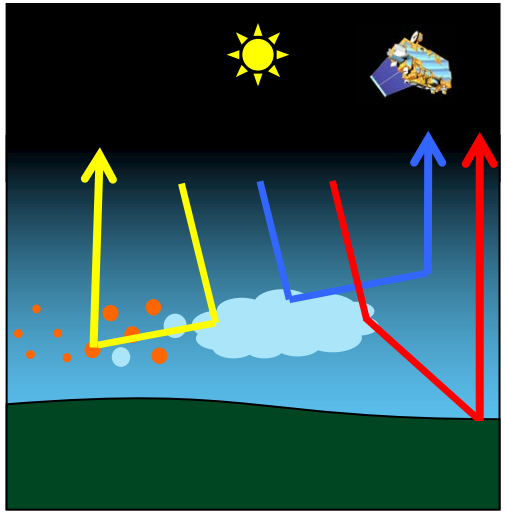
It is not affected by:

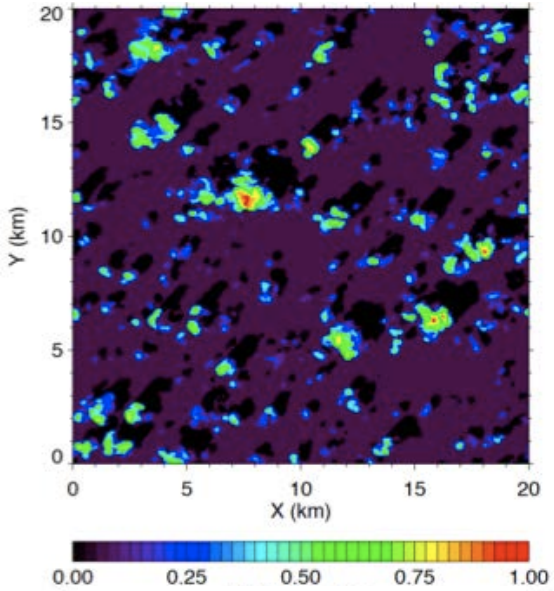
- 3D enhancement
- Instrument blurring



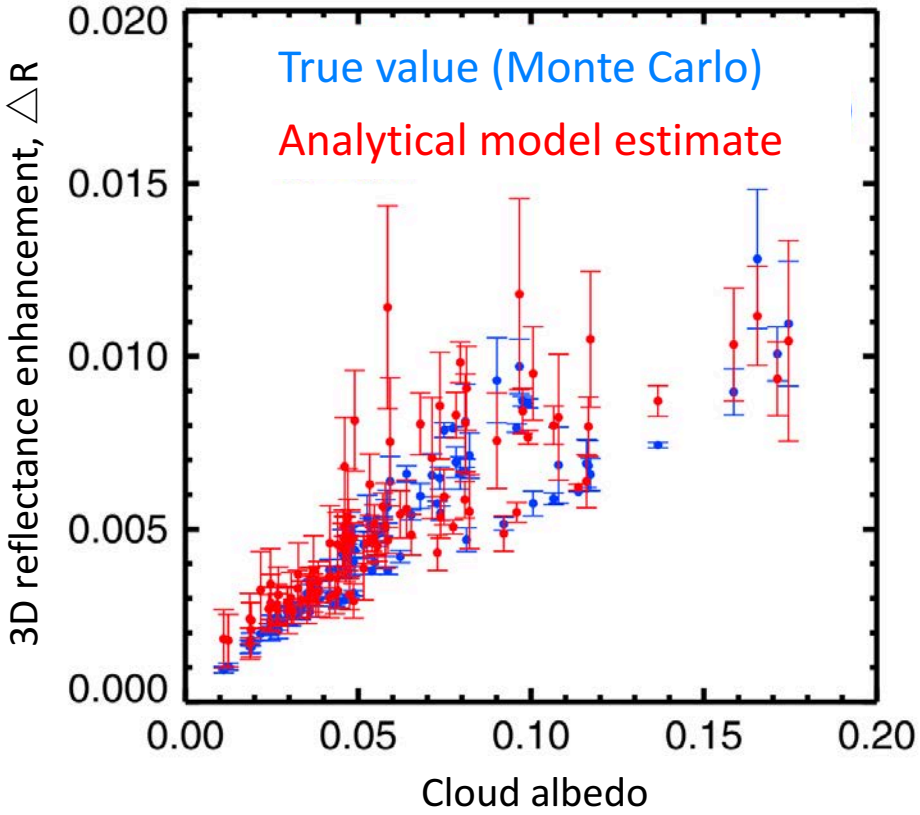
Global oceans, 60°N – 60°S, Nov. 2006 - Oct. 2007

Analytical model is tested for removing 3D enhancements

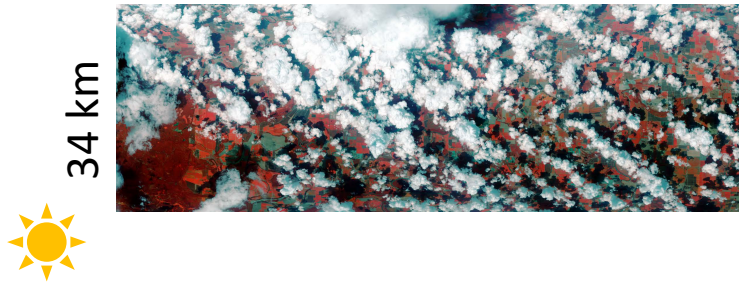


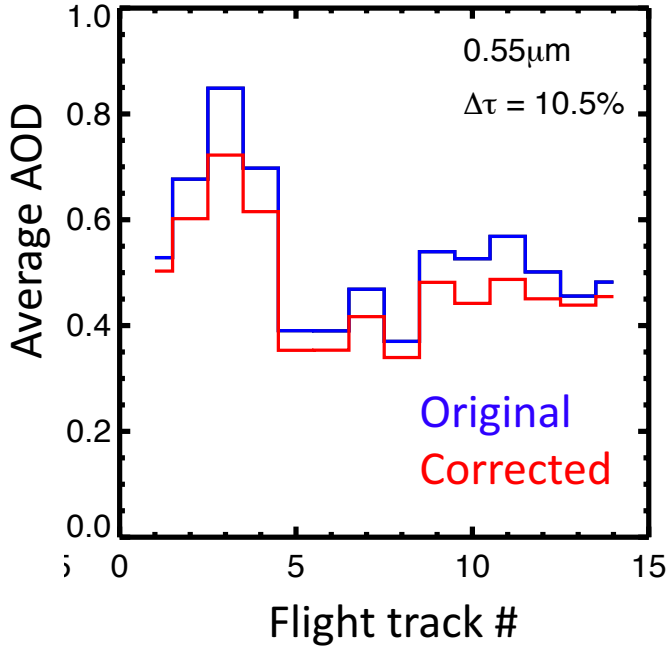


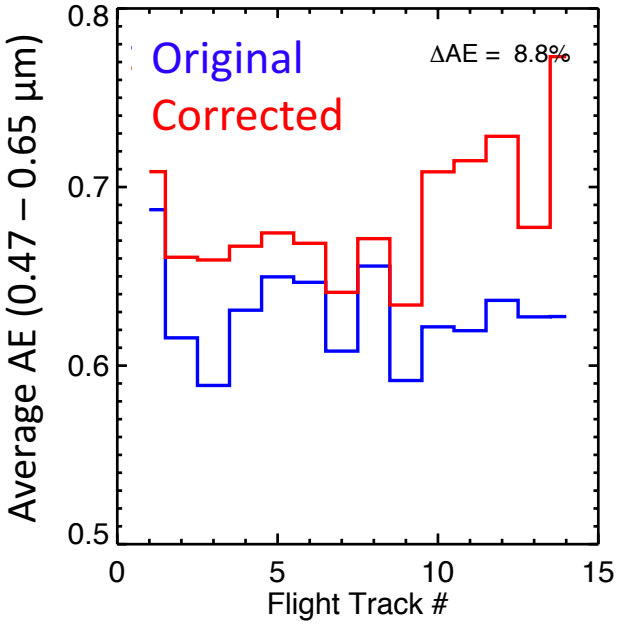
0.55 µm reflectance

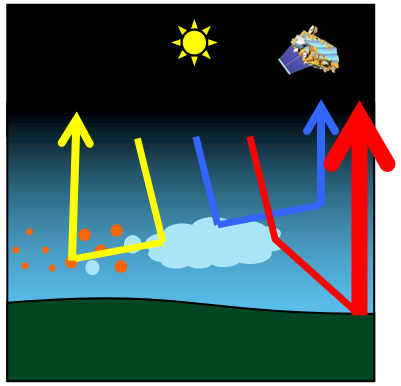


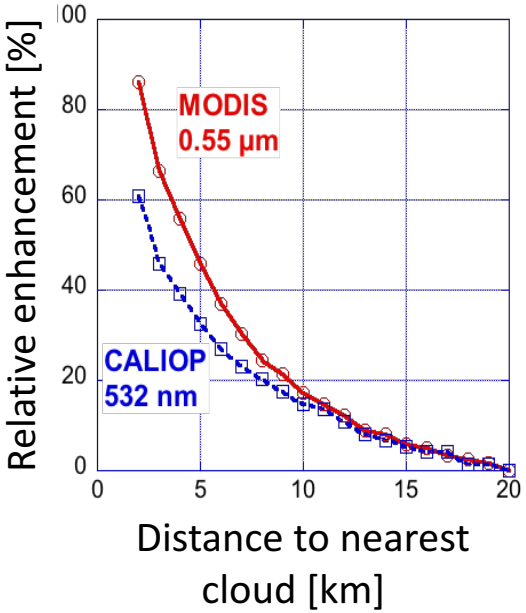
3D correction over land reduces retrieved AOD-s and increases Angstrom exponents









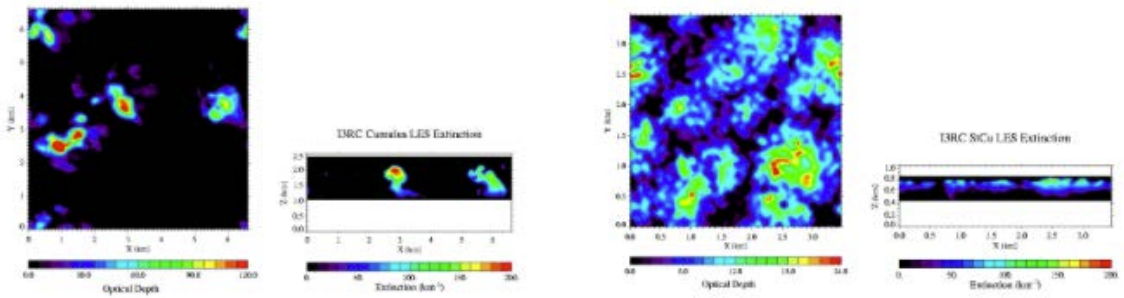


15 eMAS flight segments over South-Central US during SEAC4RS (2013)

Online 3D radiative transfer simulator is available

- Quick 1D & 3D Monte Carlo simulations through web interface (15 sec - 4 min)
- Reflectance at 5 MODIS wavelengths: 0.47, 0.55, 0.65, 0.86, 2.13 µm
- Goal: help initial exploration of ideas, class projects
- Part of the Intercomparison of 3D Radiation Codes (I3RC) project: i3rcsimulator.umbc.edu

Sample input LES fields



Summary

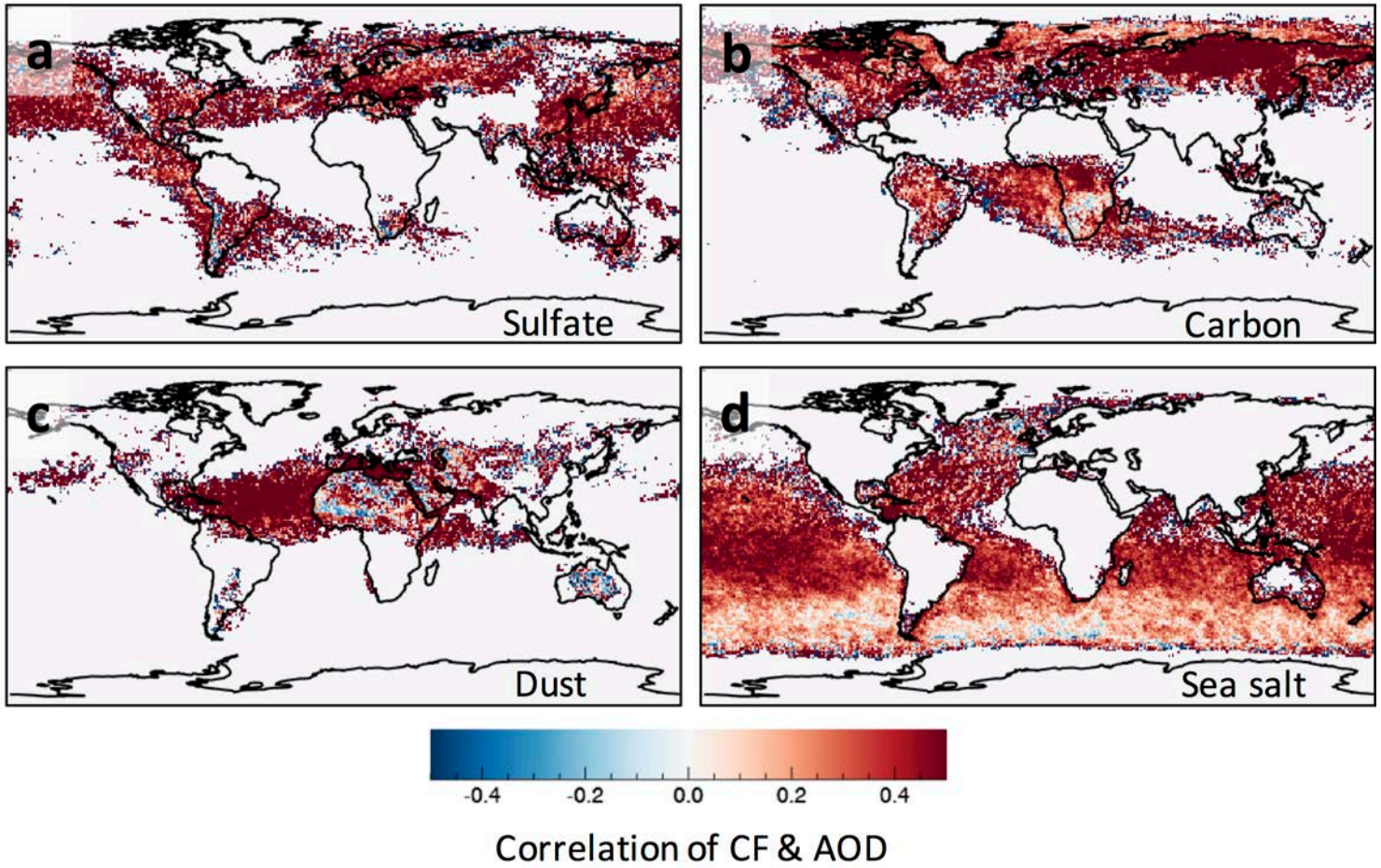
- Cloud fraction and AOD are positively correlated through most the globe and for all aerosol types. Correlation is stronger for MODIS than MERRA-2.

- In many areas, aerosol size distributions shift toward smaller sizes as CF increases, but it always shifts toward larger size near clouds.

- 3D radiative effects have a significant impact on satellite radiances near clouds, where a large portion of clear-sky columns occur.

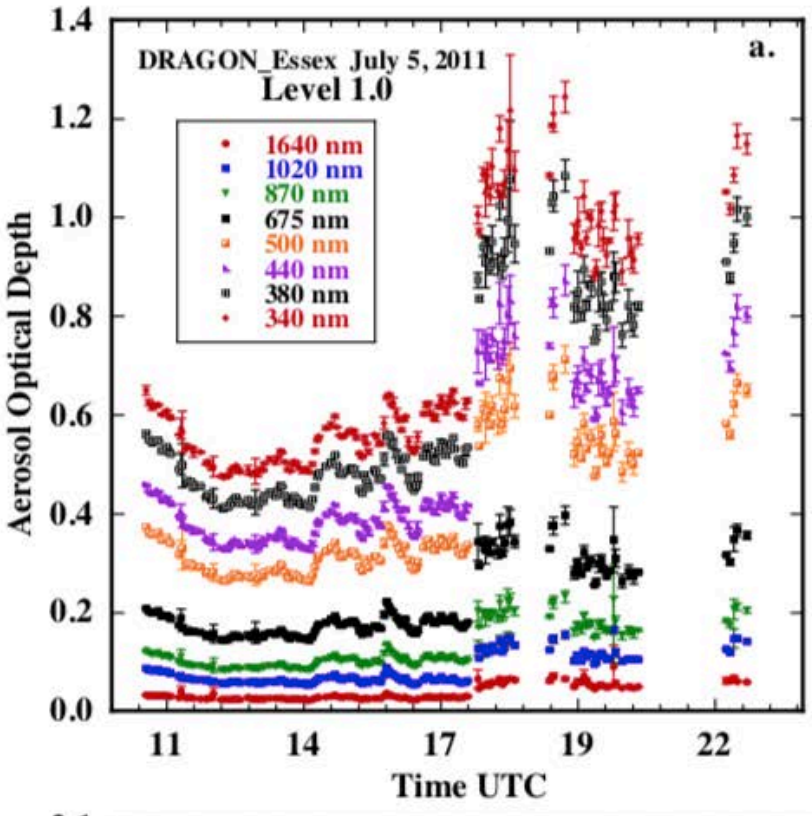
- An analytical model is being developed to help aerosol retrievals by estimating 3D reflectance enhancements.

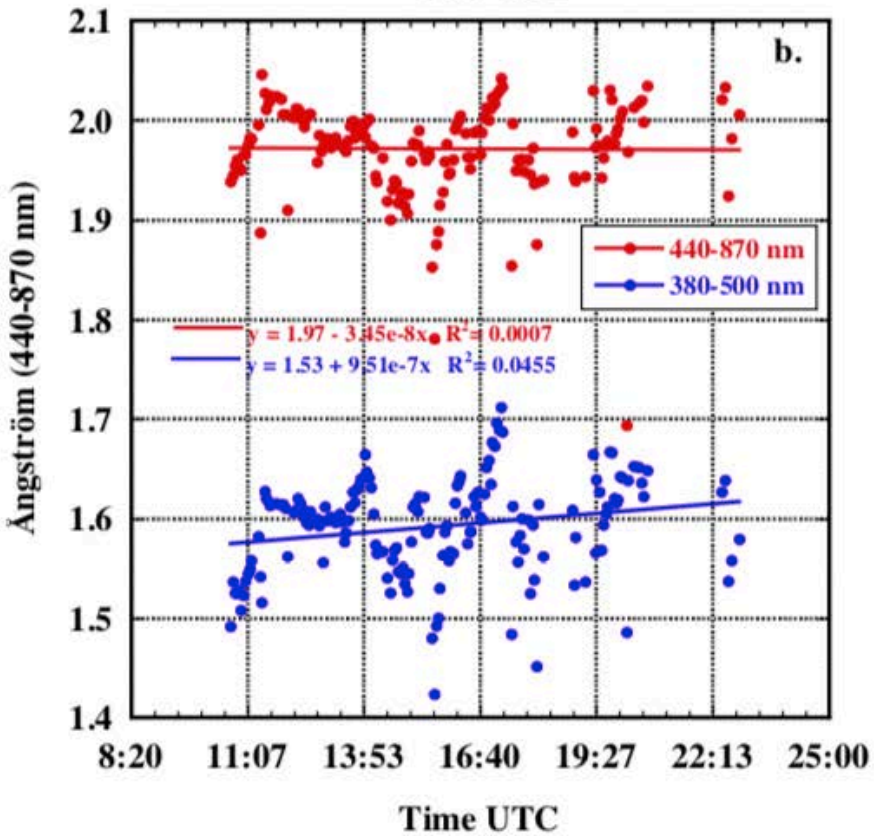
MODIS CF & AOD well-correlated for all MERRA-2 aerosol types



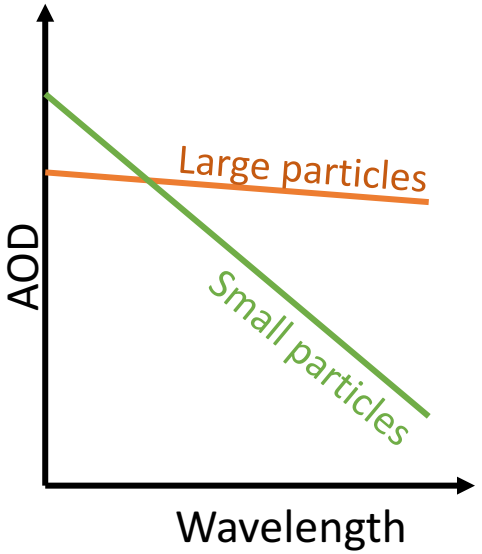
MODIS Aqua, JJA 2012-2014

Aeronet: AOD jumps when clouds appear, but aerosol size distribution does not change





Angstrom exponent:
"steepness" of spectral slope



Eck et al. (2014), DISCOVER-AQ

Impact of 3D effect varies with retrieval algorithm

3D effects vary with

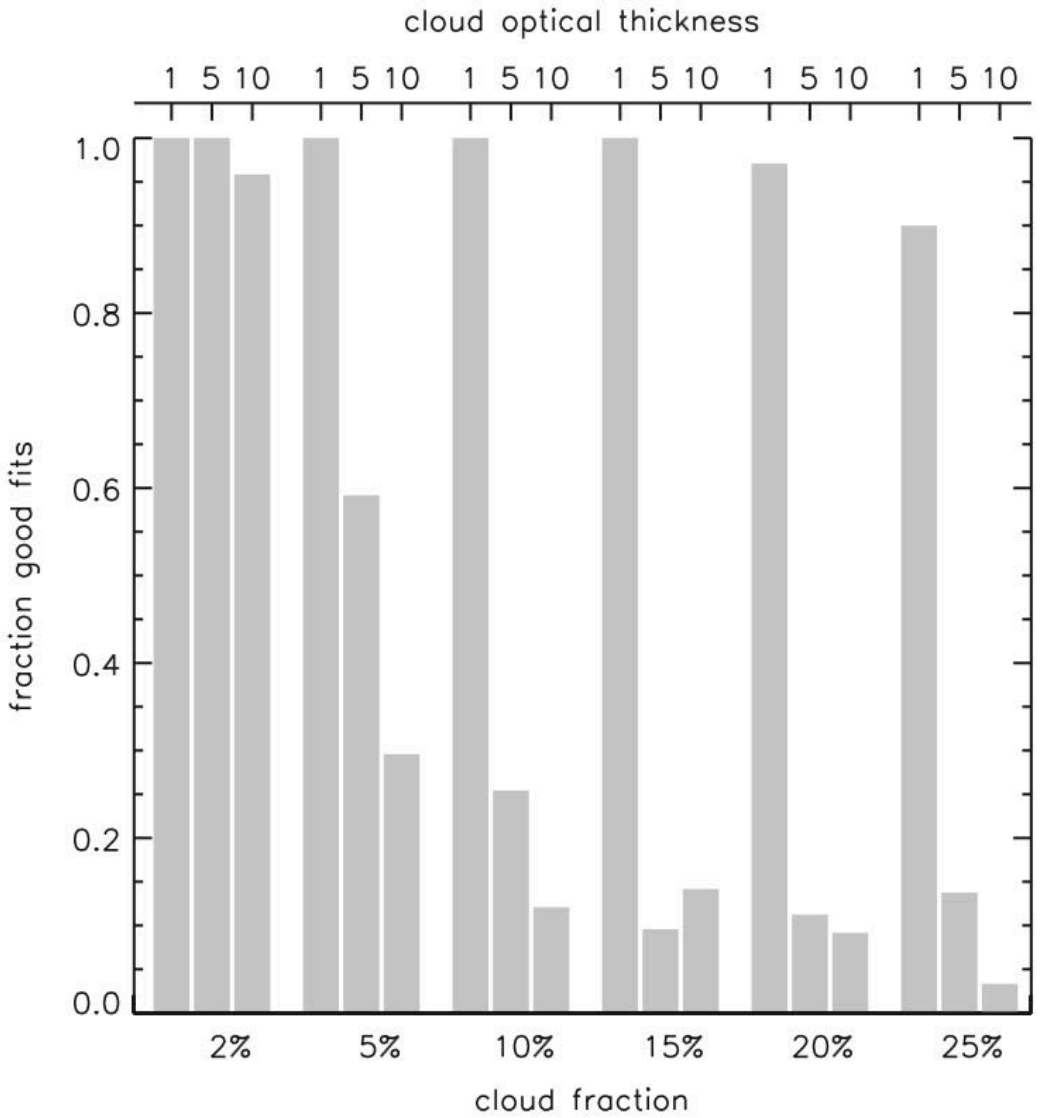
- Wavelength (deep blue vs. dark target)
- Polarization (POLDER vs. MODIS)
- View directions (MISR vs. MODIS)

POLDER: 3D effects do not cause problems if

CF < 5% or $\tau_{cloud} < 5$

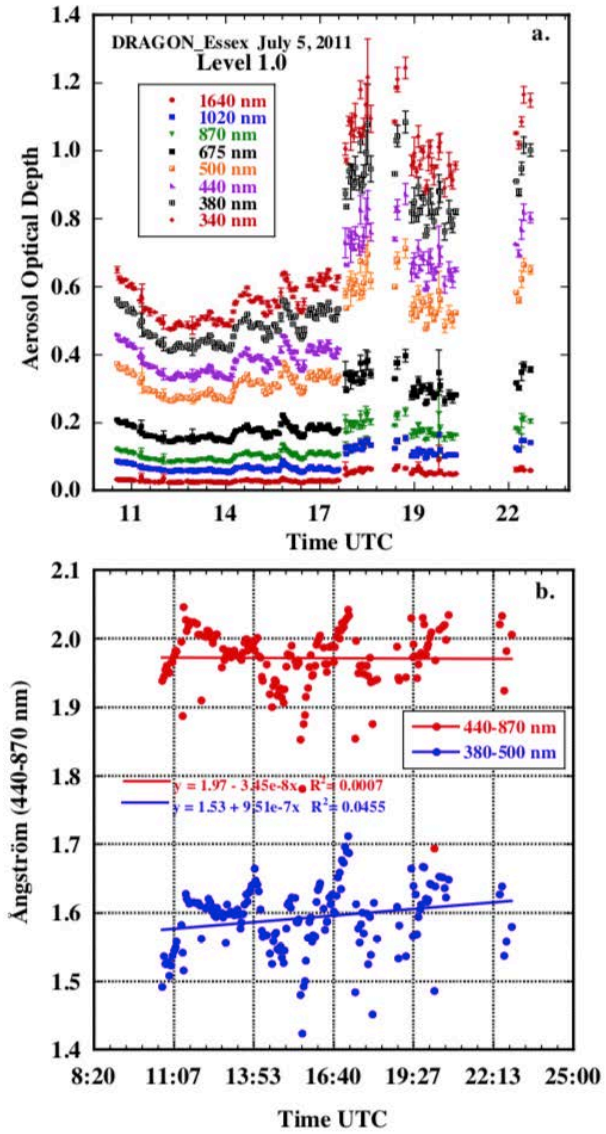
For CF = 25% and $\tau_{cloud} = 10$:

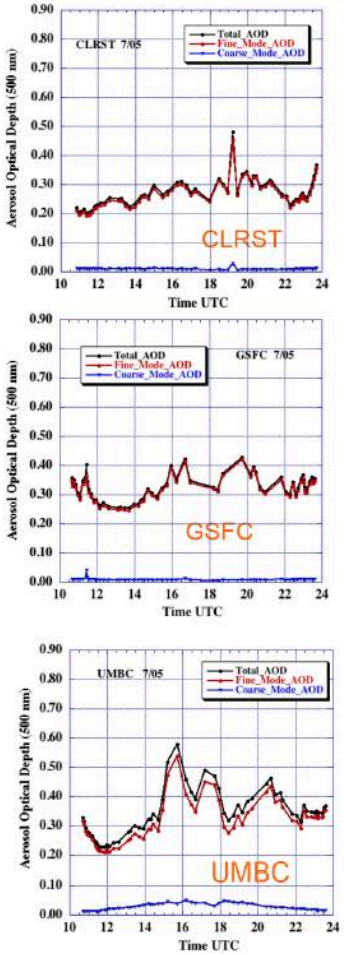
ΔAOD = 0.12 (≈25%), ΔSSA = 0.09

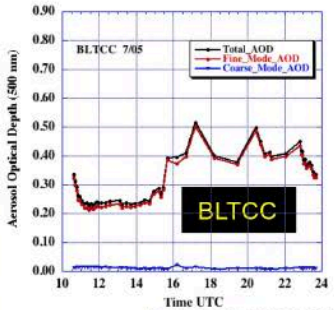


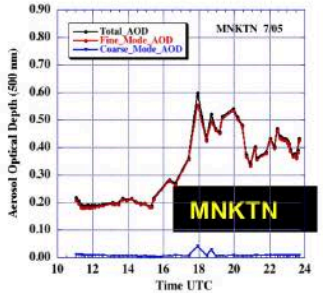
Stap et al. (JQSRT, 2016):

Aeronet: small mode increases near clouds

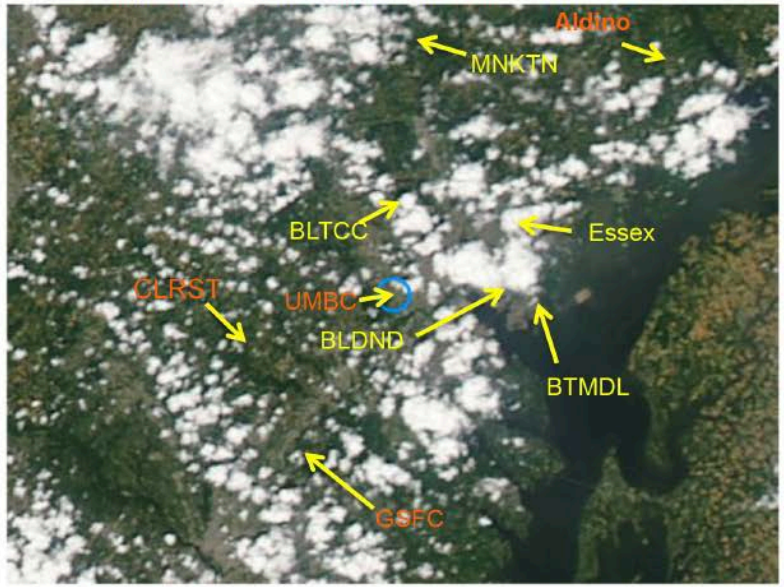






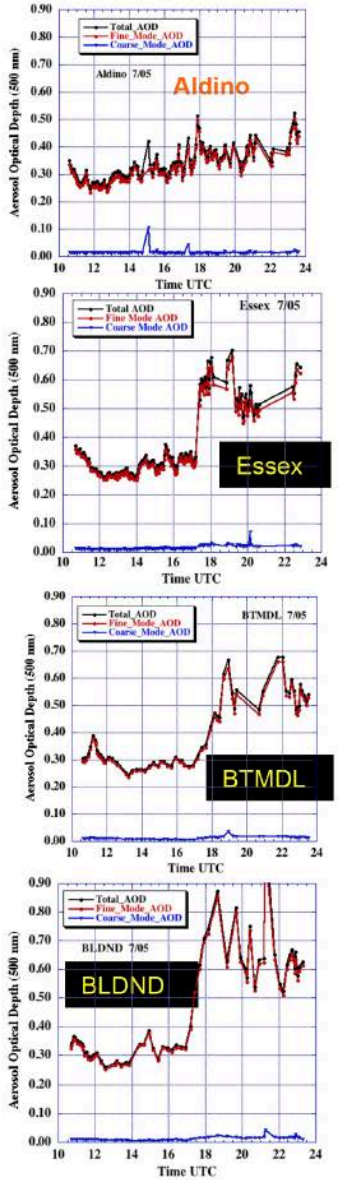


Composite AQUA-MODIS Image on JUL 5 of 2011; Centered on UMBC



MODIS Images: 2000m 1000m 500m 250m

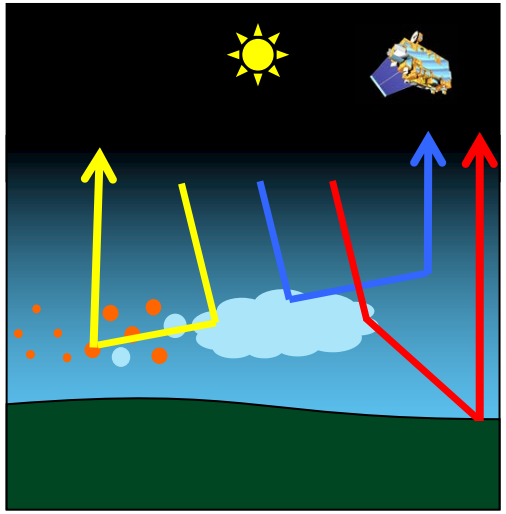
AQUA-MODIS Granule Overpass Times:
16:50, 18:30 UTC

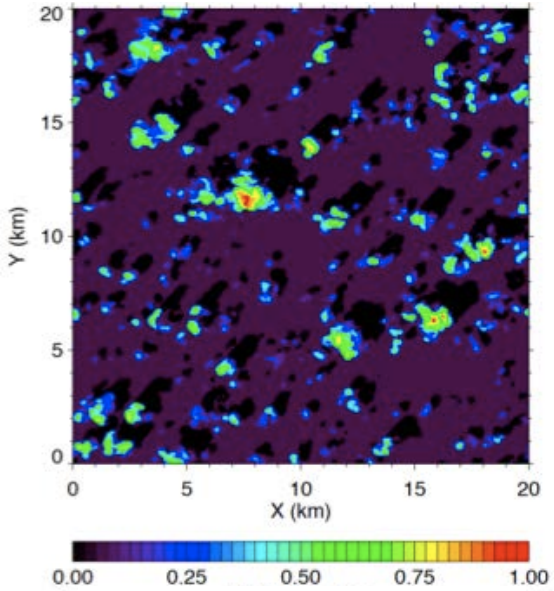


Large increases in AOD are associated with sites that are in close proximity to larger Cu clouds

Eck et al. (2014)

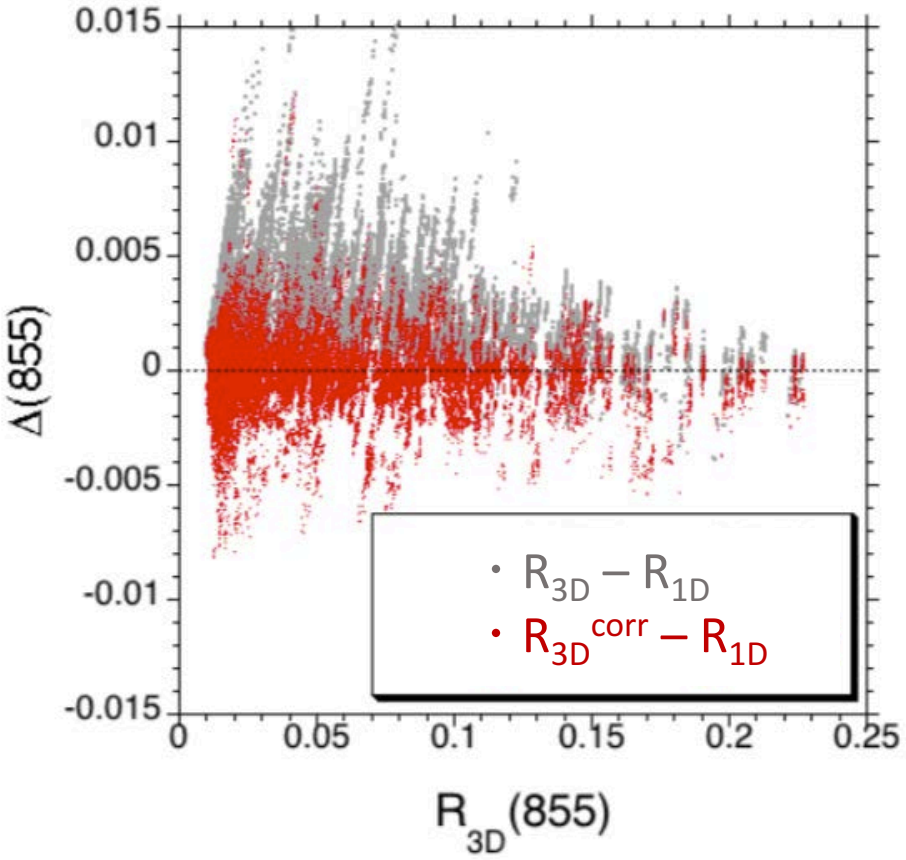
Analytical model is tested for removing 3D enhancements



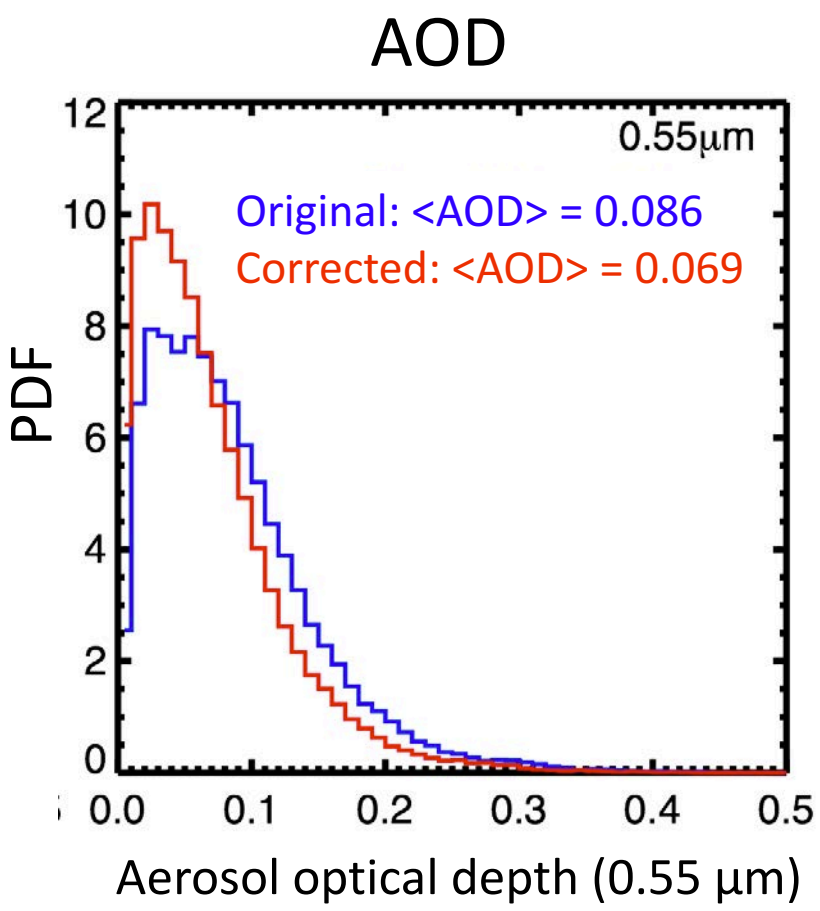


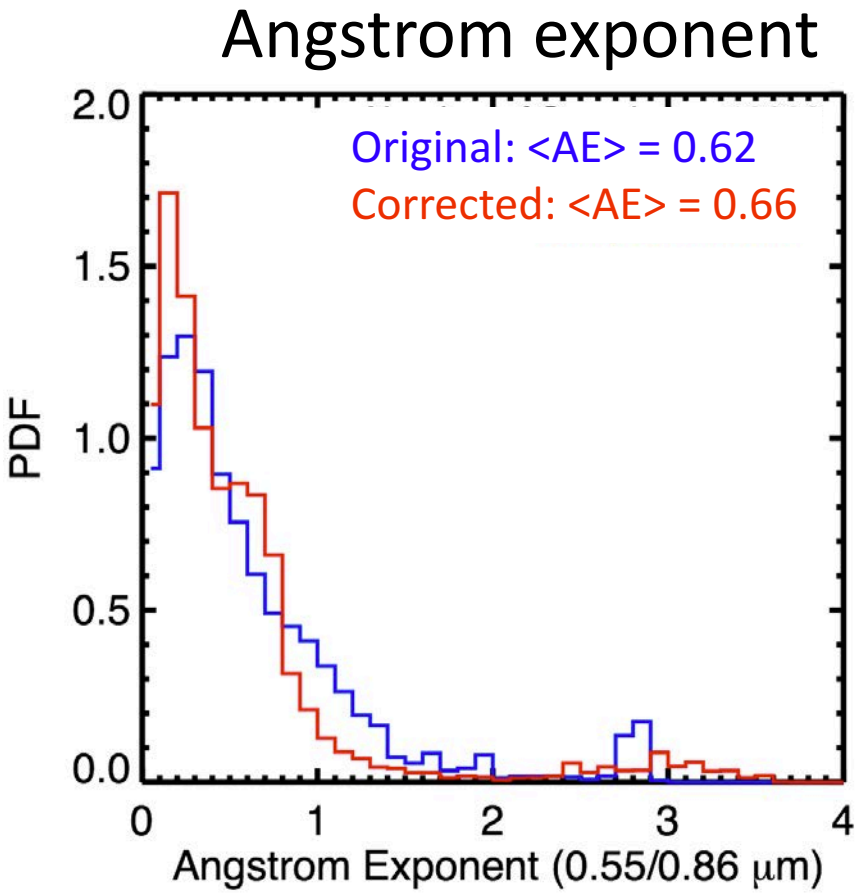
0.55 µm reflectance

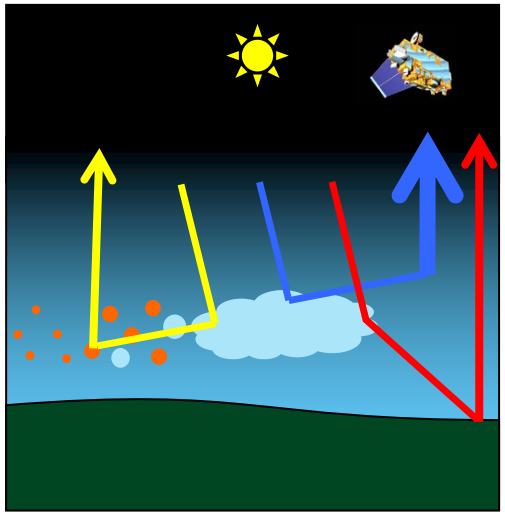
80 LES-based scenes (Frank Evans)



3D correction over ocean reduces retrieved AOD-s and can change Angstrom exponents either way

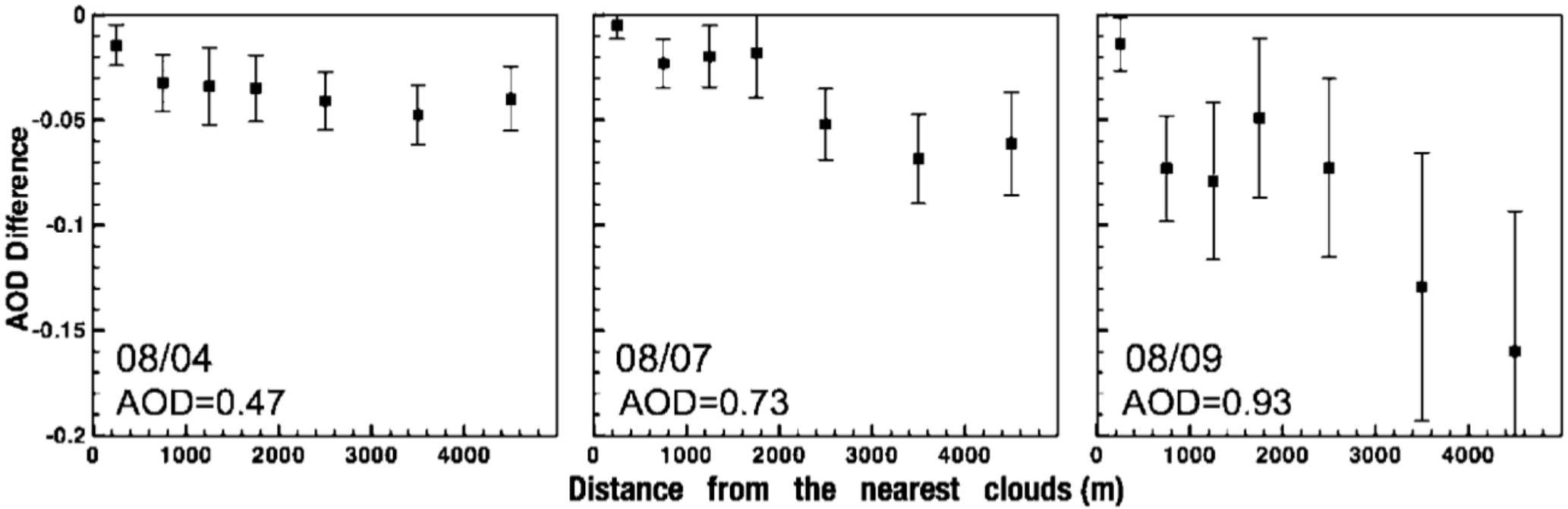






31 MODIS granules off the West coast of North & South America, August 1-8, 2013

Airborne HSRL: aerosol optical depth (AOD) can be larger near clouds, but not always



Su et al. (2008)