Separating Real Aerosol Effects from Artifacts Using Space-borne, Air-borne and Ground Measurements and Understanding Physical Processes Using a CRM

Zhanqing Li
University of Maryland

Contributors
T. Yuan, M.-J. Jeong, R. Zhang and J. Fan

Objectives

- Evaluate various effects on remote sensing products from satellite and ground sensors.
- Separate artifacts from the real effects.
- Eventually, generate "clean" products for studying aerosol direct and indirect effect.
- Presented are some preliminary findings toward these goals.

Candidate Factors Causing the Apparent Correlation between the AOT and Cloud Parameters

Real Effects

- Aerosol humidification effect
- Convergence of aerosols
- Aerosol production (Cloud-processed particles/New particle genesis) associated with cloud

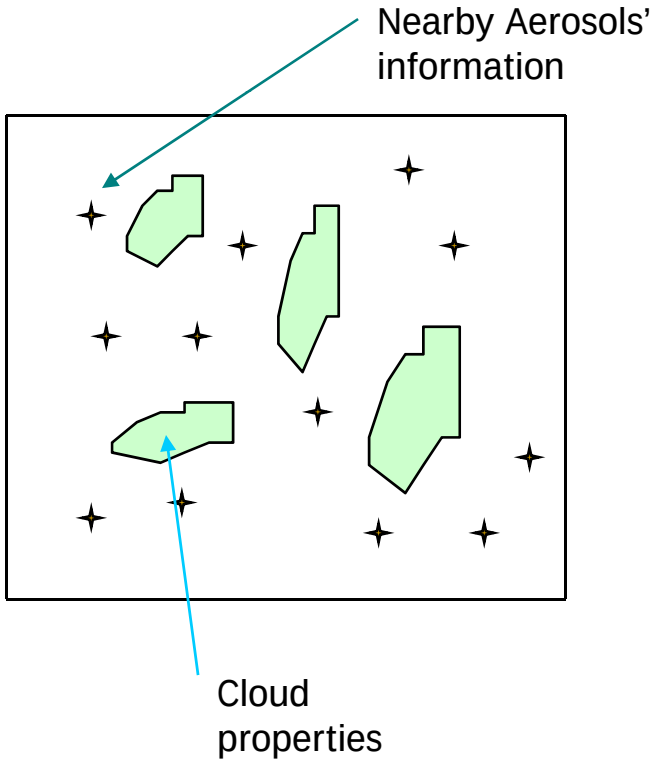
Artifacts

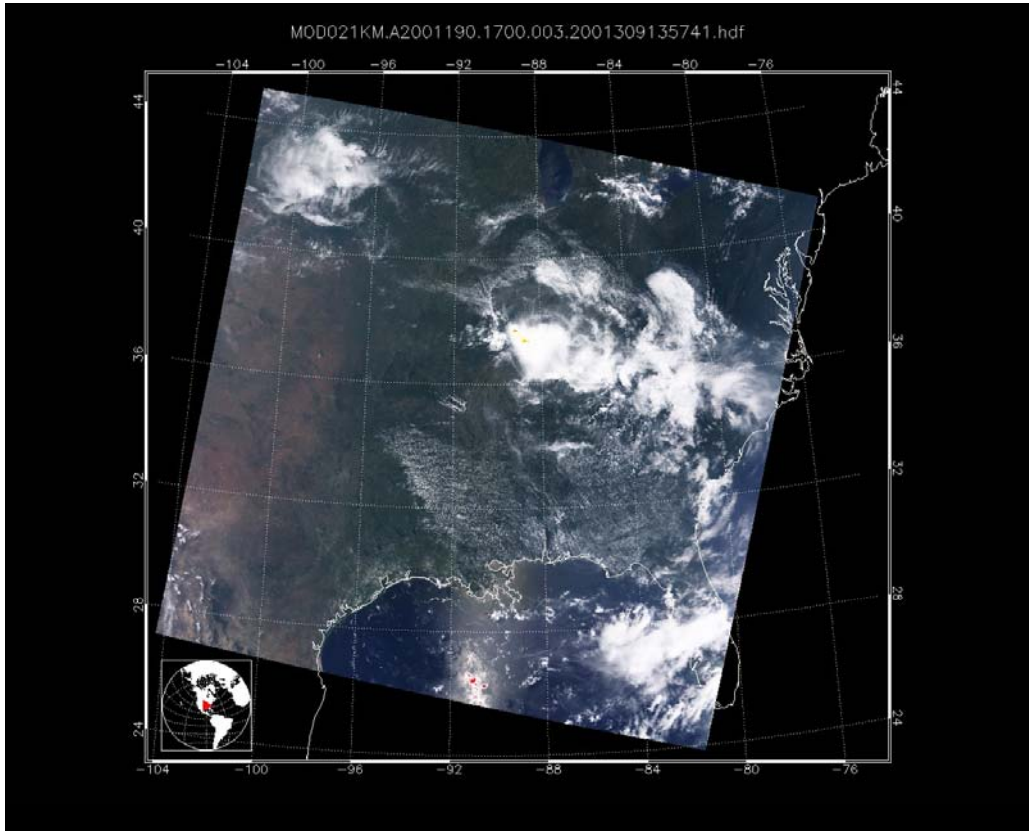
- Cloud contamination
- Erroneous cloud cover estimation associated with aerosol
- Enhanced diffuse radiation due to clouds

Methods

- Analyses of satellite data to examine the issues in perspective: scene-by-scene selection, automated ensemble analysis
- Analysis of in-situ/ground data to evaluate various effects
- Use of cloud resolving model to understand the physical processes

Cumulus clouds and aerosols: the most challenging problem, but essential for AIE studies



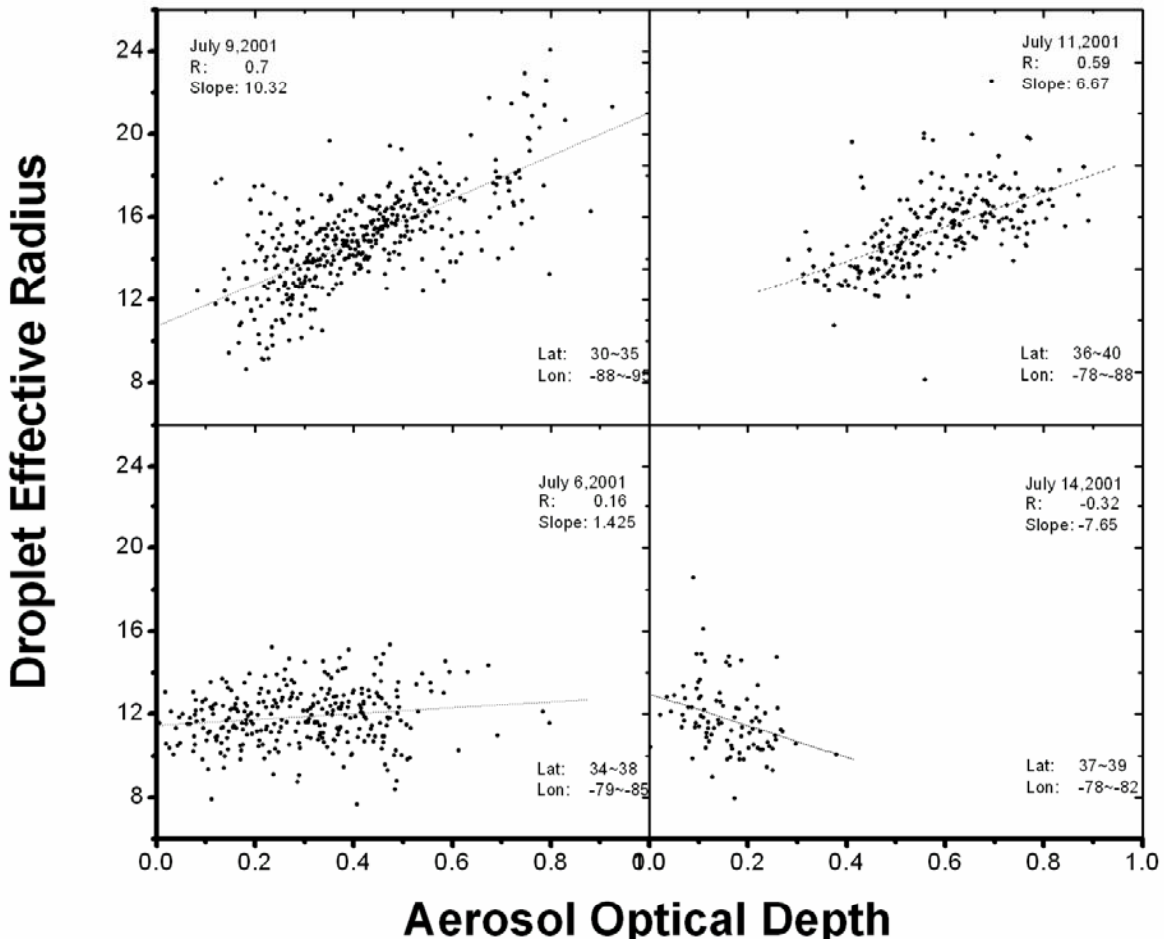


Global analysis

Region	Latitude range	Longitude range	Dominant Aerosol/Cloud Types	Period	AIE efficiency	Sample size
North Atlantic	10-20N	20-40 W	Dust, Stratocumulus	June-August, 2002	Negative	99,978
South Atlantic	5-20S	5E-20W	Smoke, Stratocumulus	June-August,2002	Negative	100,377
Southern Pacific	5-25S	75-105W	Sea salt, sulfate and pollution, Stratocumulus	August-October,2002	Negative	74,216
Indian Ocean	12-20N	60-70E	Dust with pollution, Trade cumulus	June-August, 2002	Negative	94,023
India	13-24N	70-85E	Mixture of sulfate, dust, sea salt and smoke, cumulus	June-August,2002	Neutral	53,888
Amazonia	8S-12N	44-76W	Mainly smoke	August-October, 2002	Negative	672,421
Southeastern China	23-43N	100-120E	Mixture, cumulus	June-August,2002	Positive	179,533

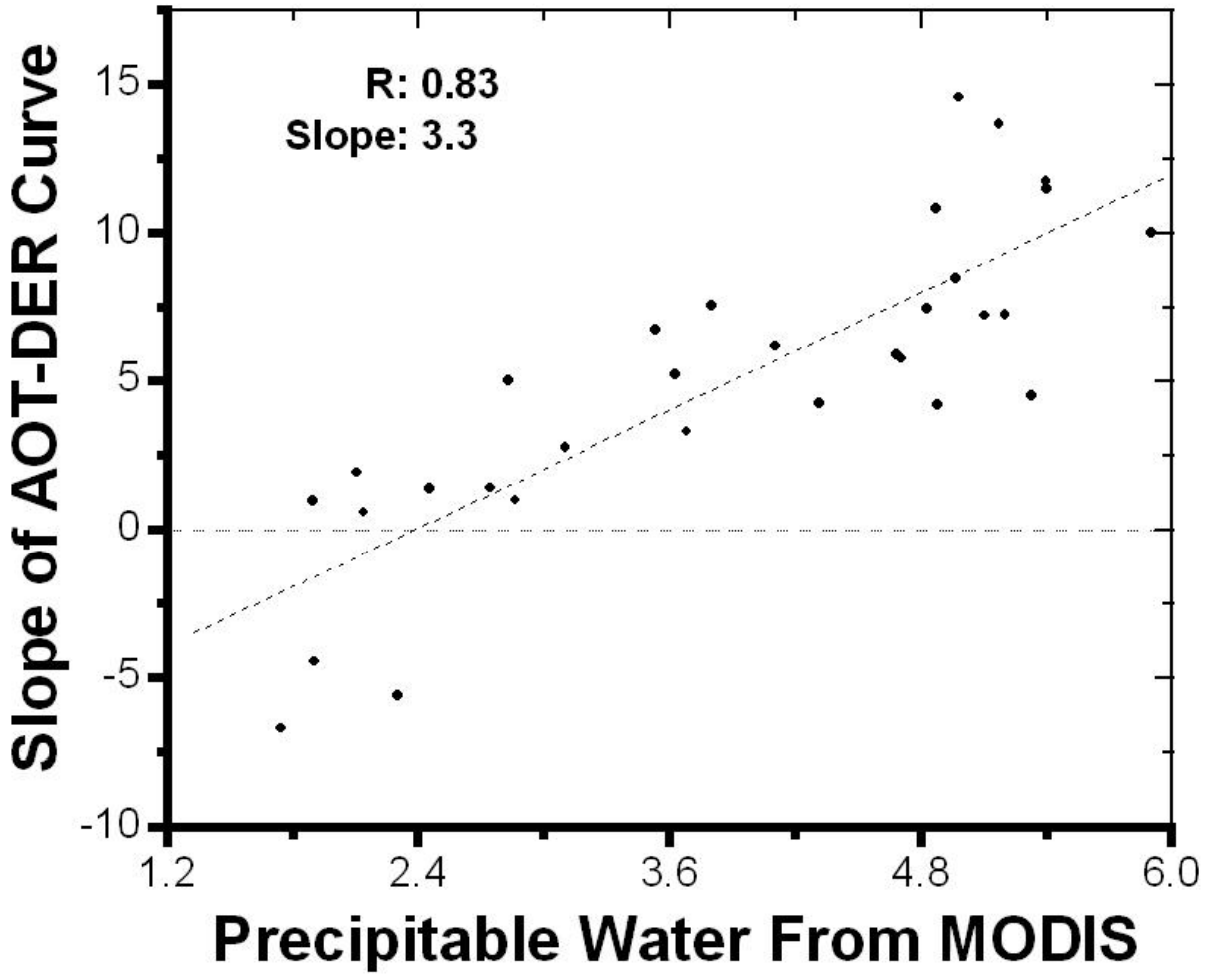
Student-t test indicates except India the difference among different loading of aerosols are statistically significant at least at the 95% level

DER-AOD relationship



AIE efficiency:
the slope of
the correlation.

AIE efficiency determining factor



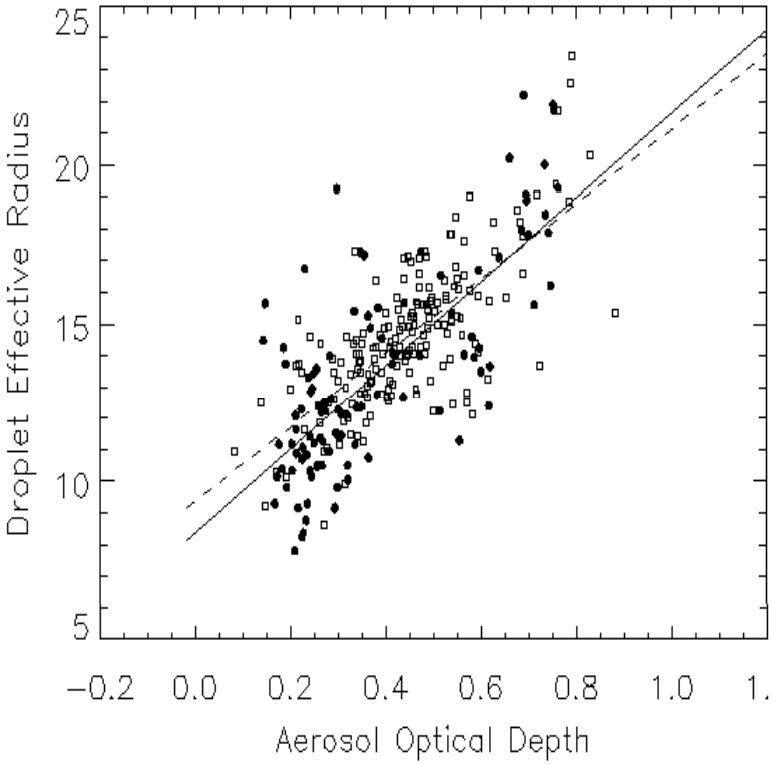
Analysis of possible third factors

- Partially cloudy pixels
- Aerosol hygroscopic growth
- Cloud 3-D effect
- Cloud dynamics effect
- Surface effect

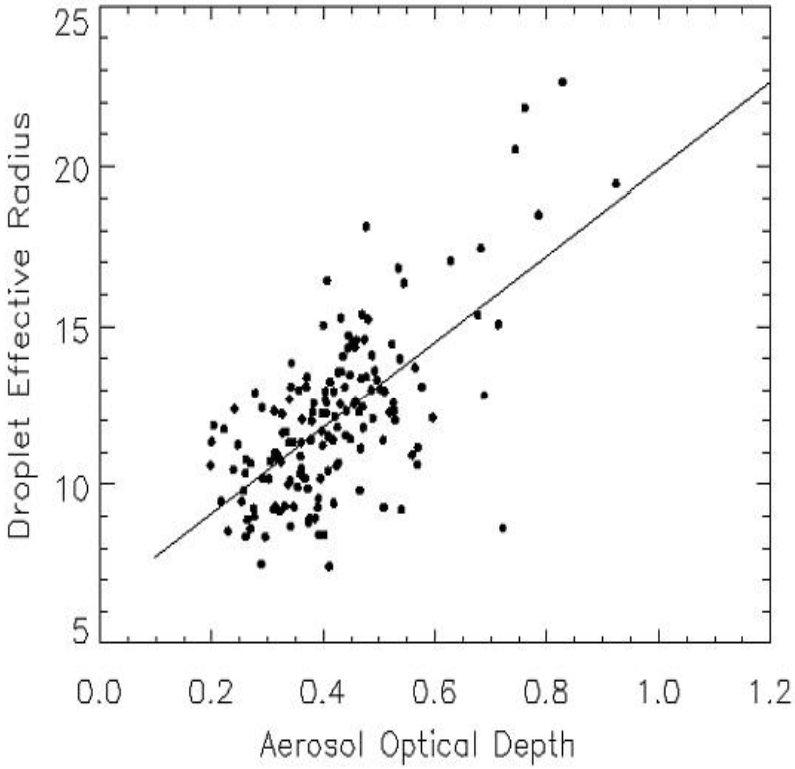
Filtering out optically thin clouds largely alleviates all possible artifacts

The Effect of Cloud Fraction

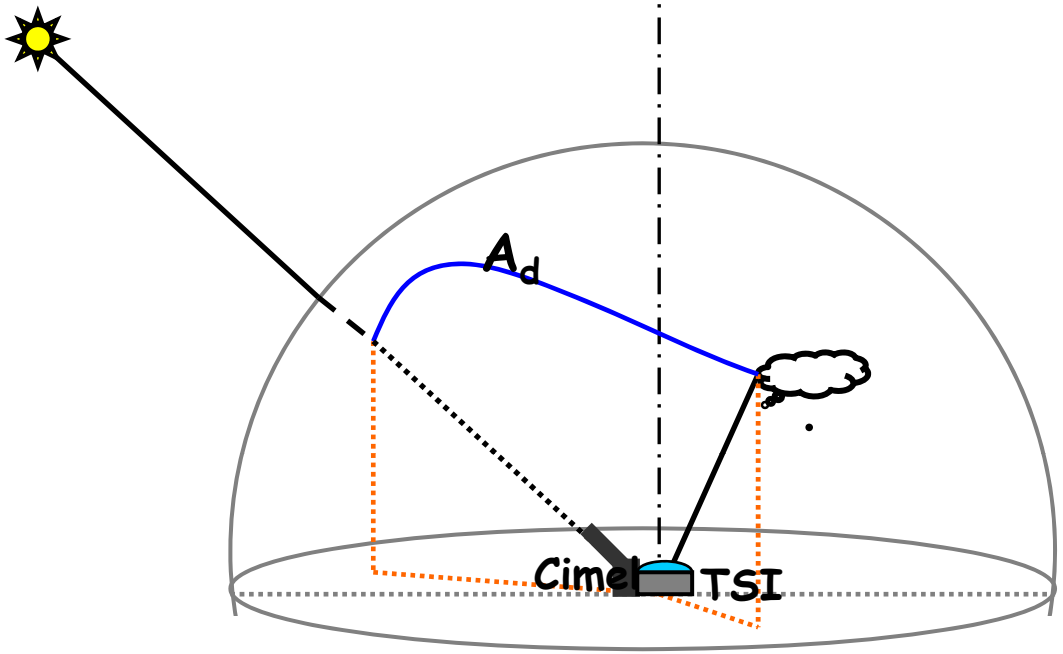
Comparison of high and low cloud connectivity

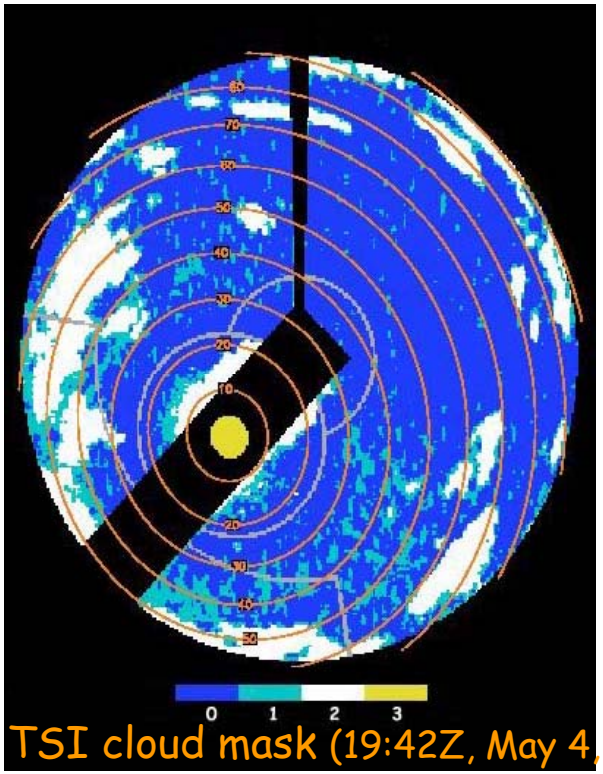


Connectivity = 8



Cloud Contamination?
Erroneous Cloud Cover Estimation?



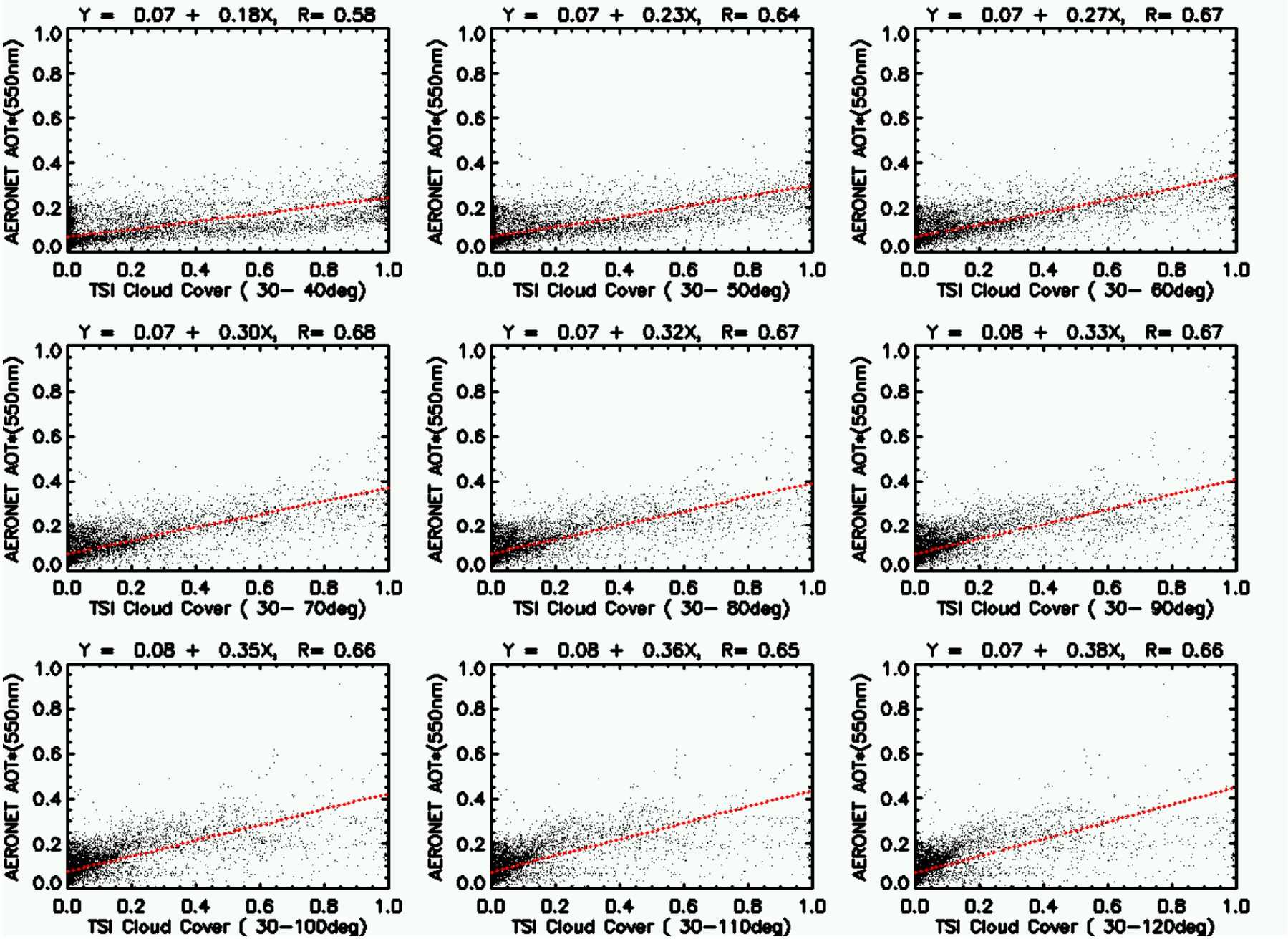


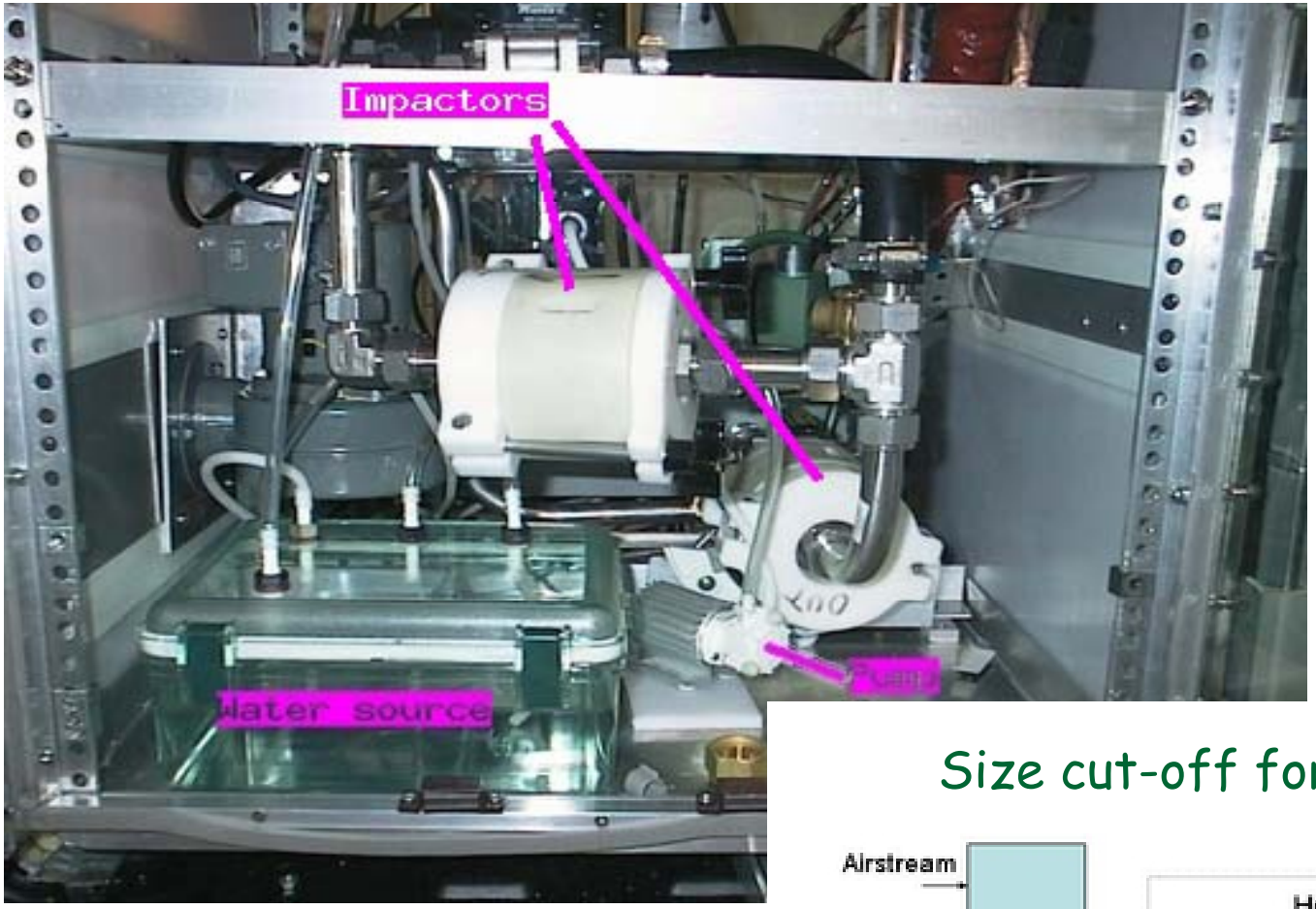
TSI cloud mask (19:42Z, May 4, 2003)

TSI Cloud cover was acquired for circumsolar areas with increasing angular distance from the sun (w/ 10-deg. increment). Then, it was examined if there is any correlation between the AOT and cloud cover.

0: clear sky; 1: thin cloud;
2: opaque cloud; 3: location of the sun

AERONET AOT v.s. Cloud Cover for Various Circum-Solar Areas

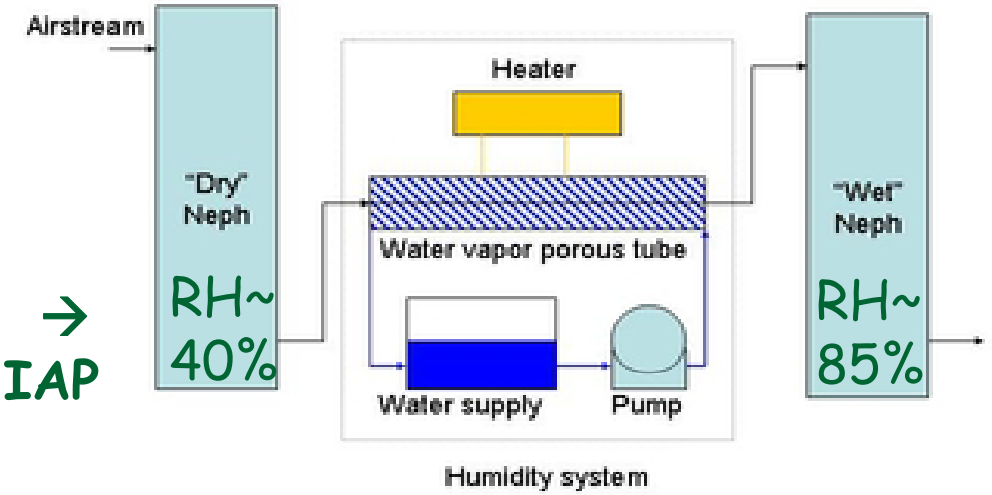




← Nephelometer for the In-Situ Aerosol Profiling (IAP) flights

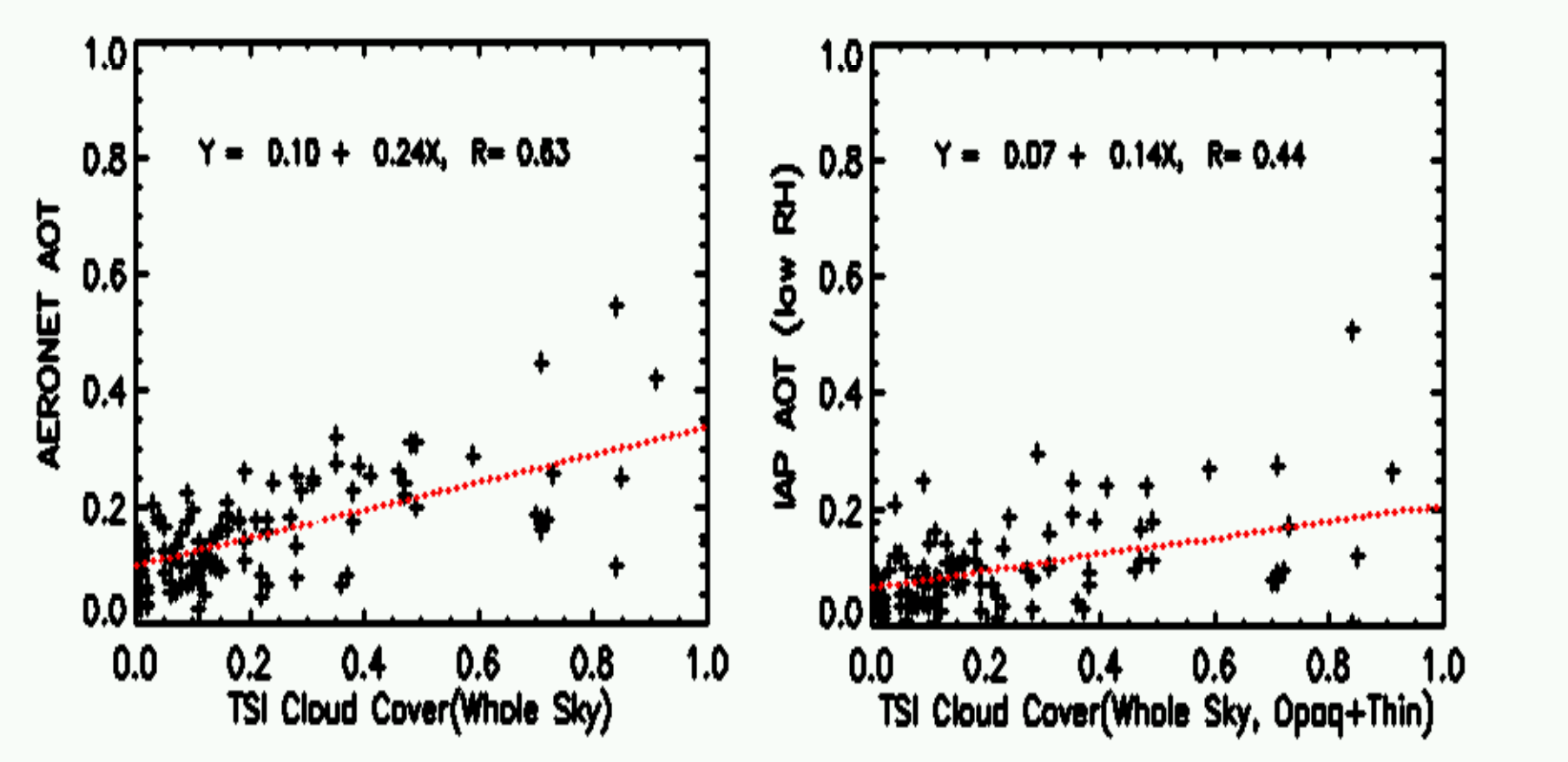
Size cut-off for IAP/Neph → 1um

→ A flow schematic for the IAP



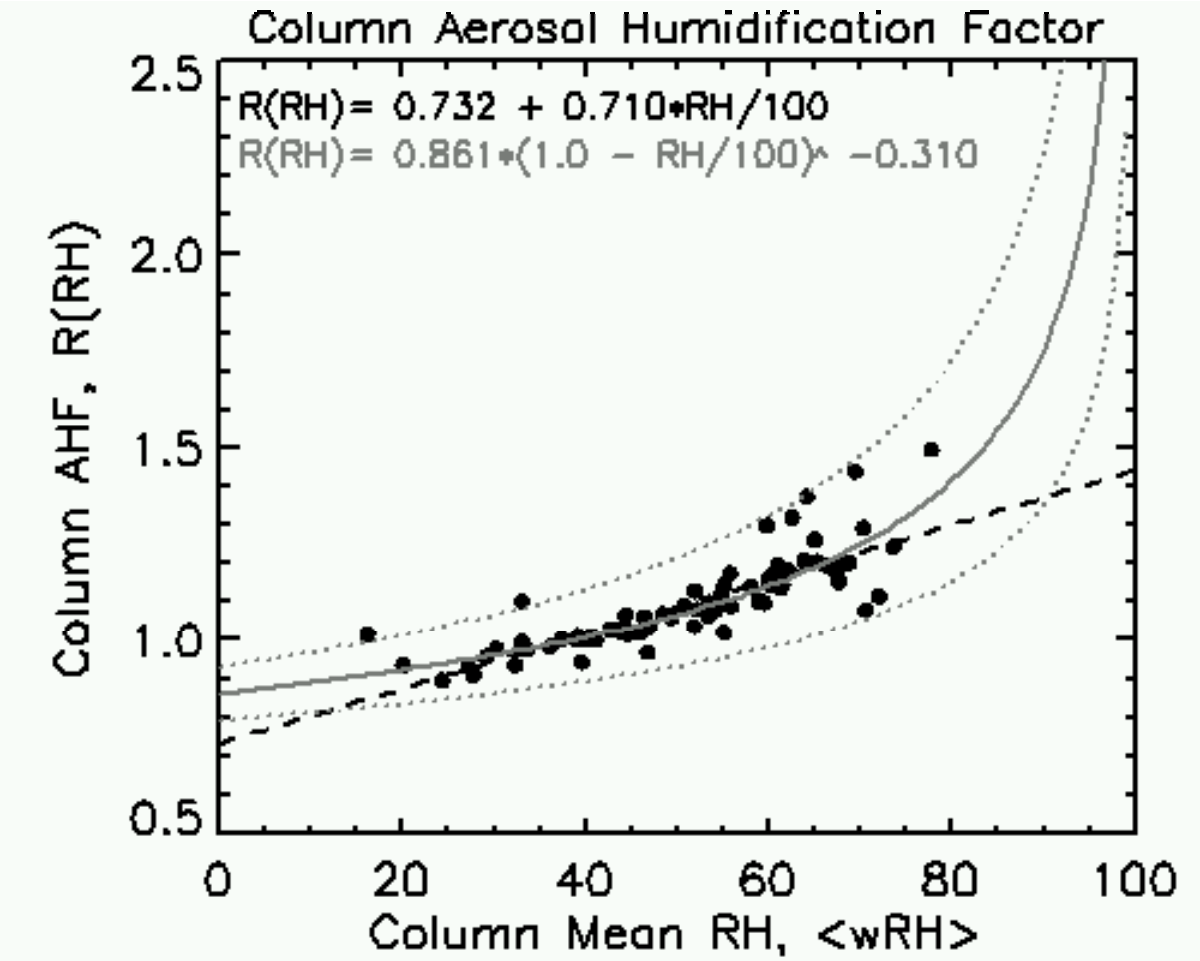
Ex

IAP AOT v.s. TSI Cloud Cover

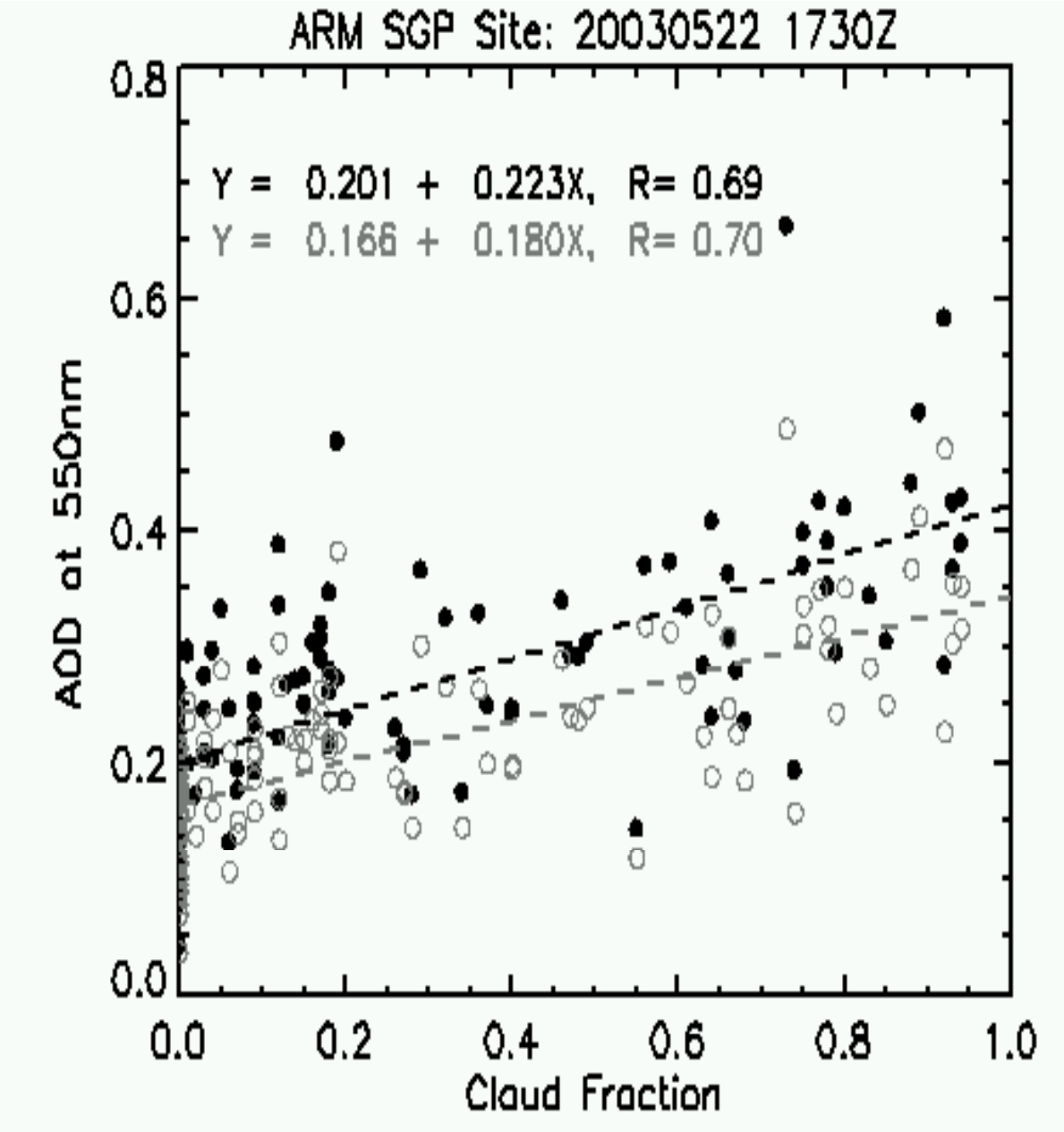


Column Aerosol Humidification Factor at the SGP Site

(Apr. 2003-Jun. 2004)



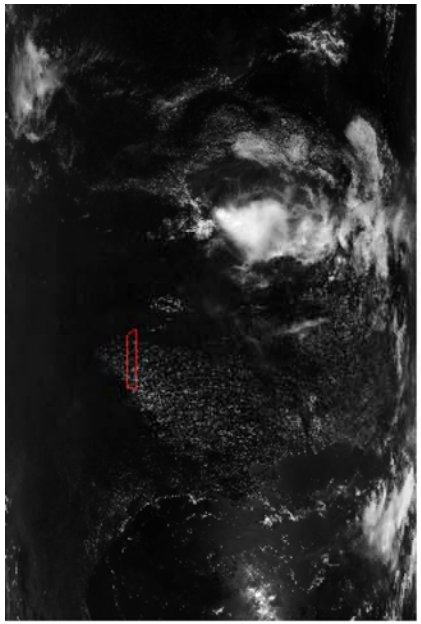
Column AHF: $R(RH) = a \cdot \left(1 - \frac{< wRH >}{100}\right)^{-b}$ → Compute the AHE

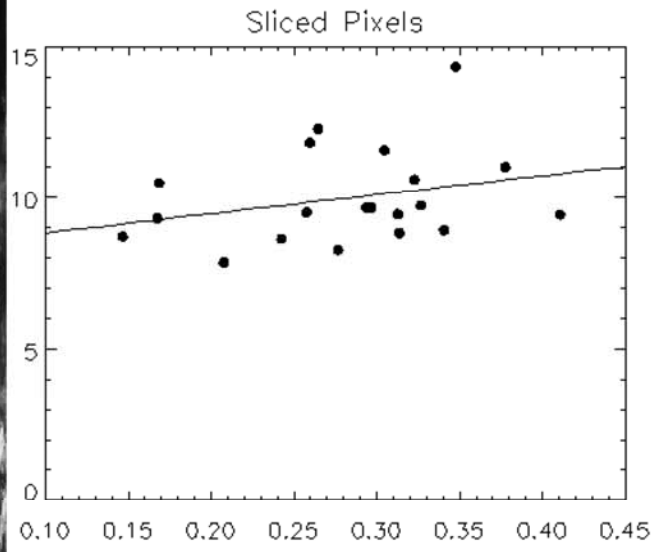


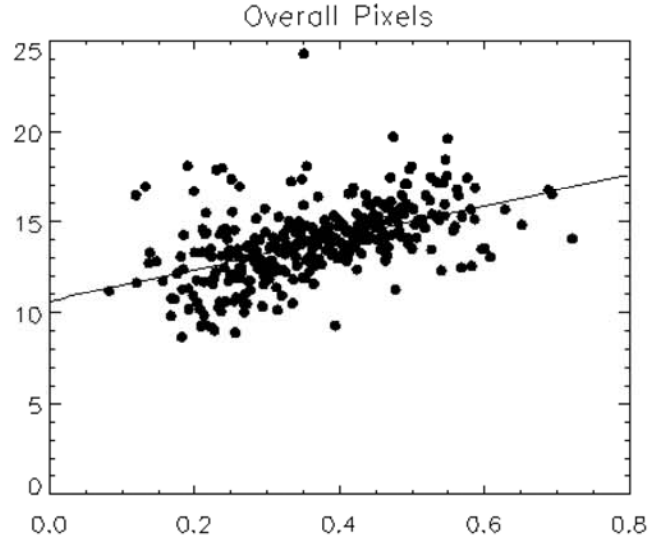
After the AHE is taken out, there remain a correlation.

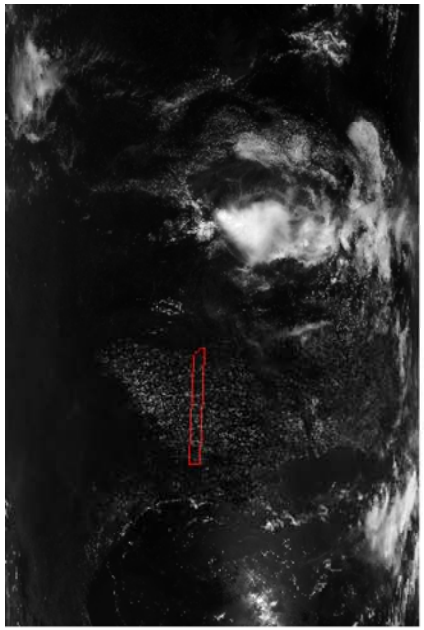
SZA~20°
VZA~13°
Θ_{sca}~150°

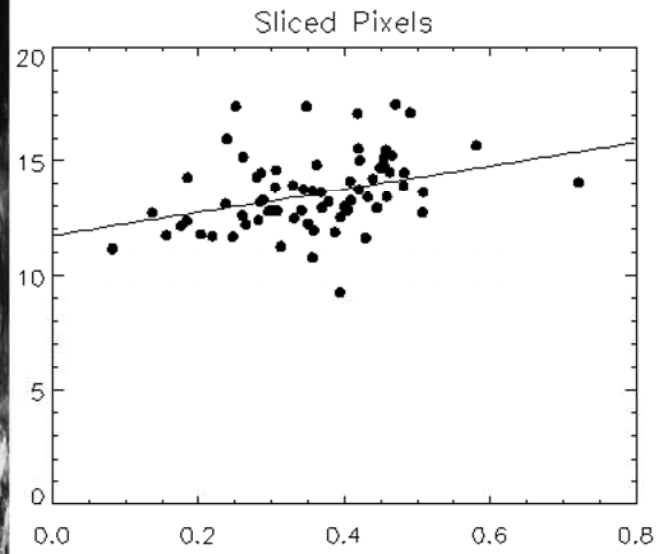
3-D Effects ?

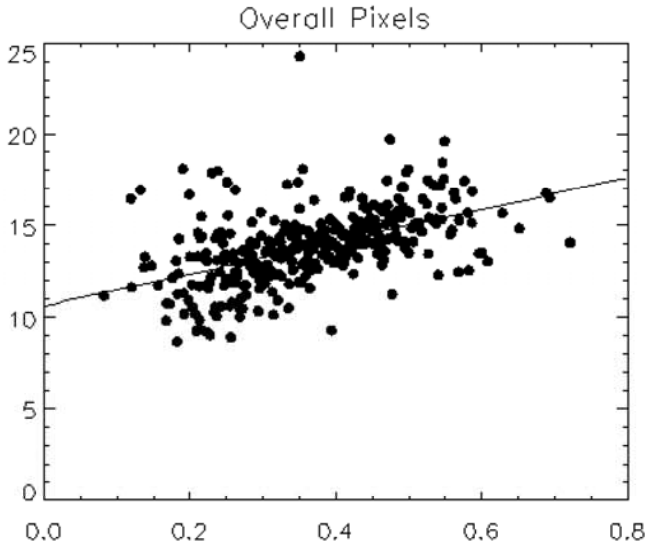



Sliced Pixels
15
10
5
0
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45


Overall Pixels
25
20
15
10
5
0
0.0
0.2
0.4
0.6
0.8



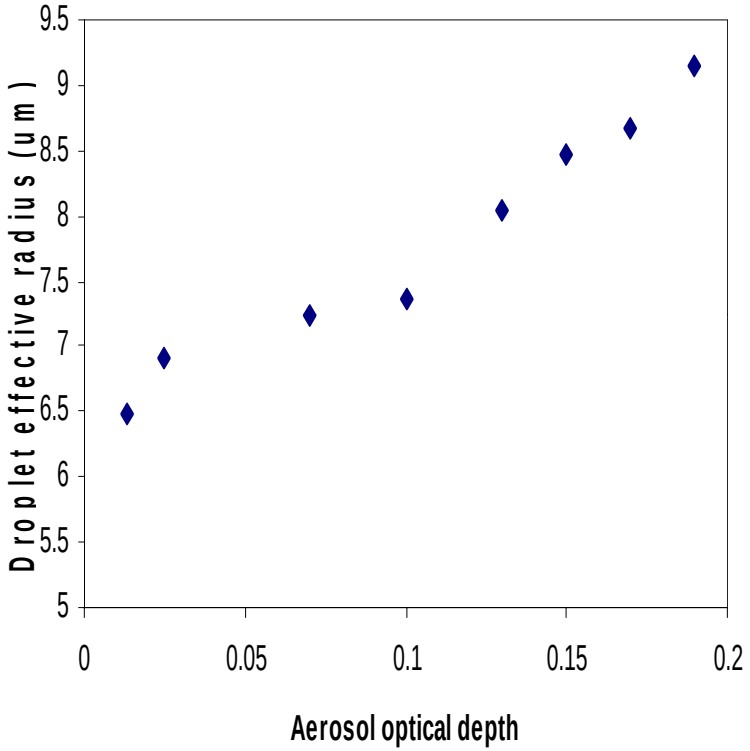

Sliced Pixels
20
15
10
5
0
0.0
0.2
0.4
0.6
0.8

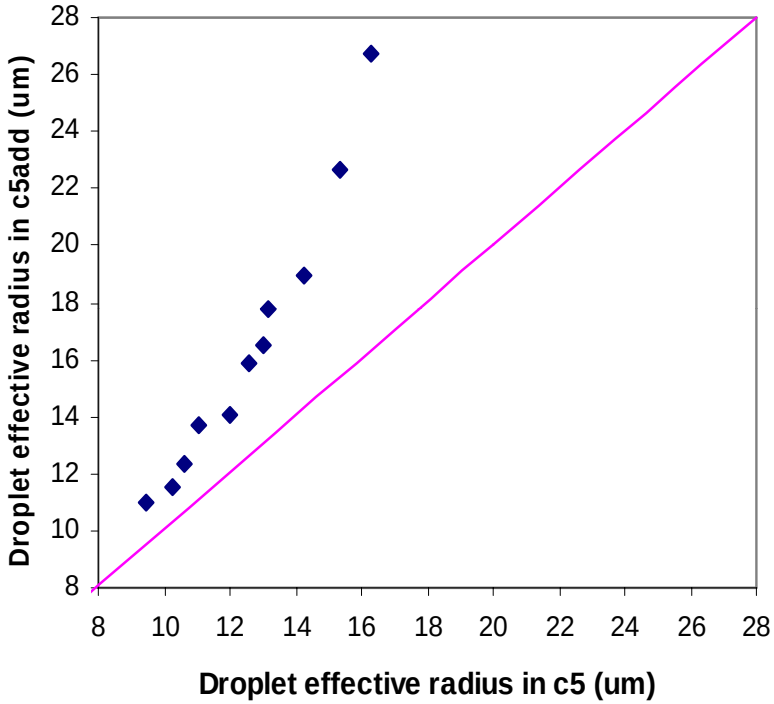

Overall Pixels
25
20
15
10
5
0
0.0
0.2
0.4
0.6
0.8

A Modeling Study

- NASA GSFC Cloud Ensemble (GCE) cloud resolving model
- Modified Kohler's theory by Fan et al. (2007)
- Detailed bin-microphysics
- The model is able to calculate the CCN activation spectrum and the subsequent growth of cloud droplets that are resolved in 33 size bins [*Fan et al.*, 2007].

Modeling results





Effects of SSO

Effects of Giant Particles

c

Note that these results can only be simulated if the air mass is moisture enough

Take home messages

- Care must be exercised in using satellite data to study AIE
- Real effects and artifacts may be separated by combined use of satellite, in-situ and ground observations.
- For fair-weather Cu AIE efficiency may be either positive or negative based on the satellite analysis
- Different environmental factors like aerosol type and air humidity may affect AIE
- A lot more in-depth studies are required to further sort of various issues