Parameterization of Cloud Microphysics and Aerosol Indirect Effects

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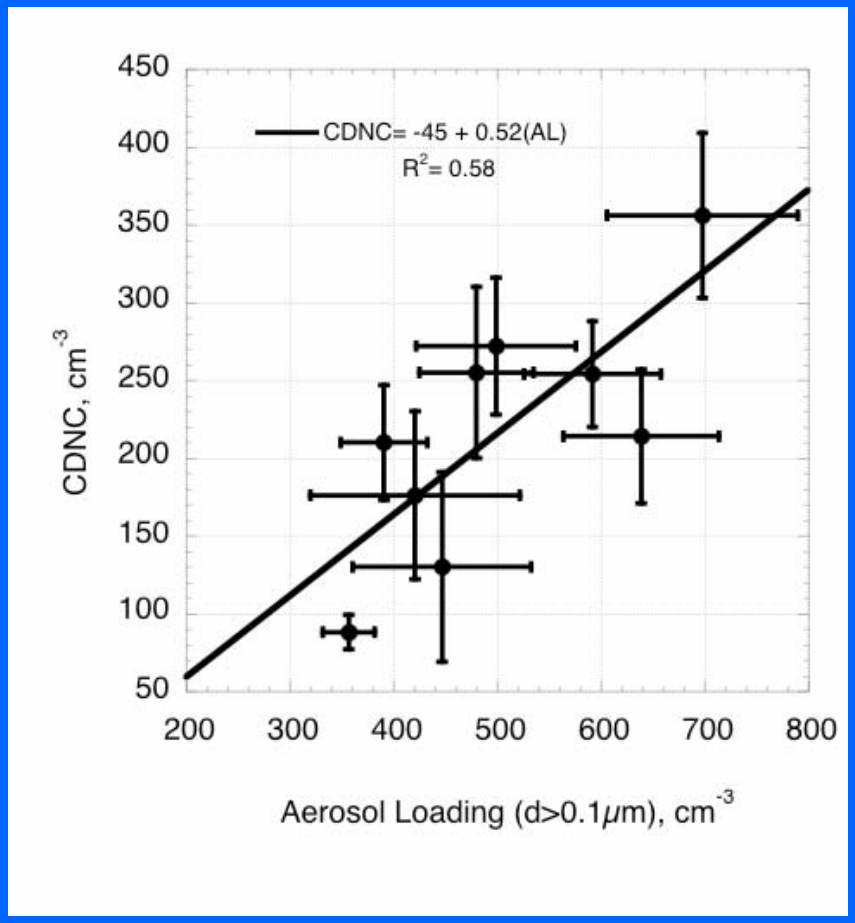
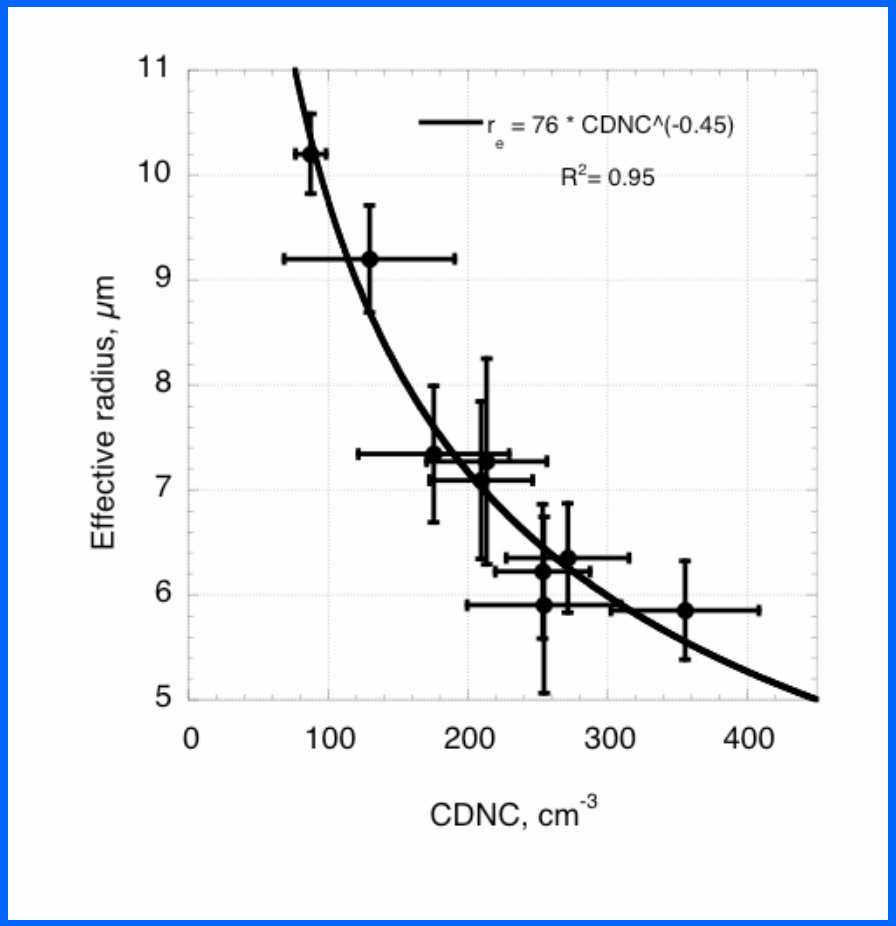
Aerosol Indirect Effect Studies

1. Observations MASE-MASRAD, NSA, and SGP

2. Theory and Modeling

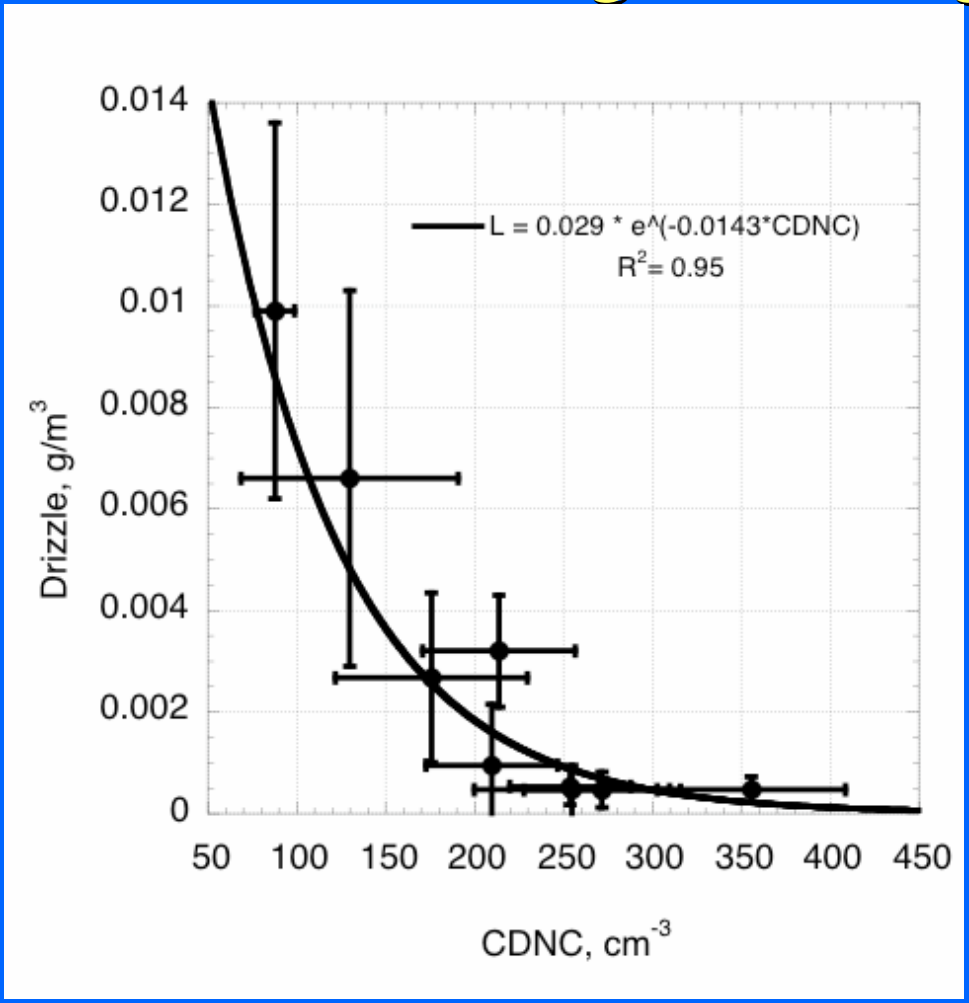
Results from G-1 Flights During MASE





Increasing aerosol concentrations are associated with an increase in the droplet concentration and a decrease in the effective radius- consistent with the first aerosol indirect effect (P. Daum).

Results from G-1 Flights During MASE

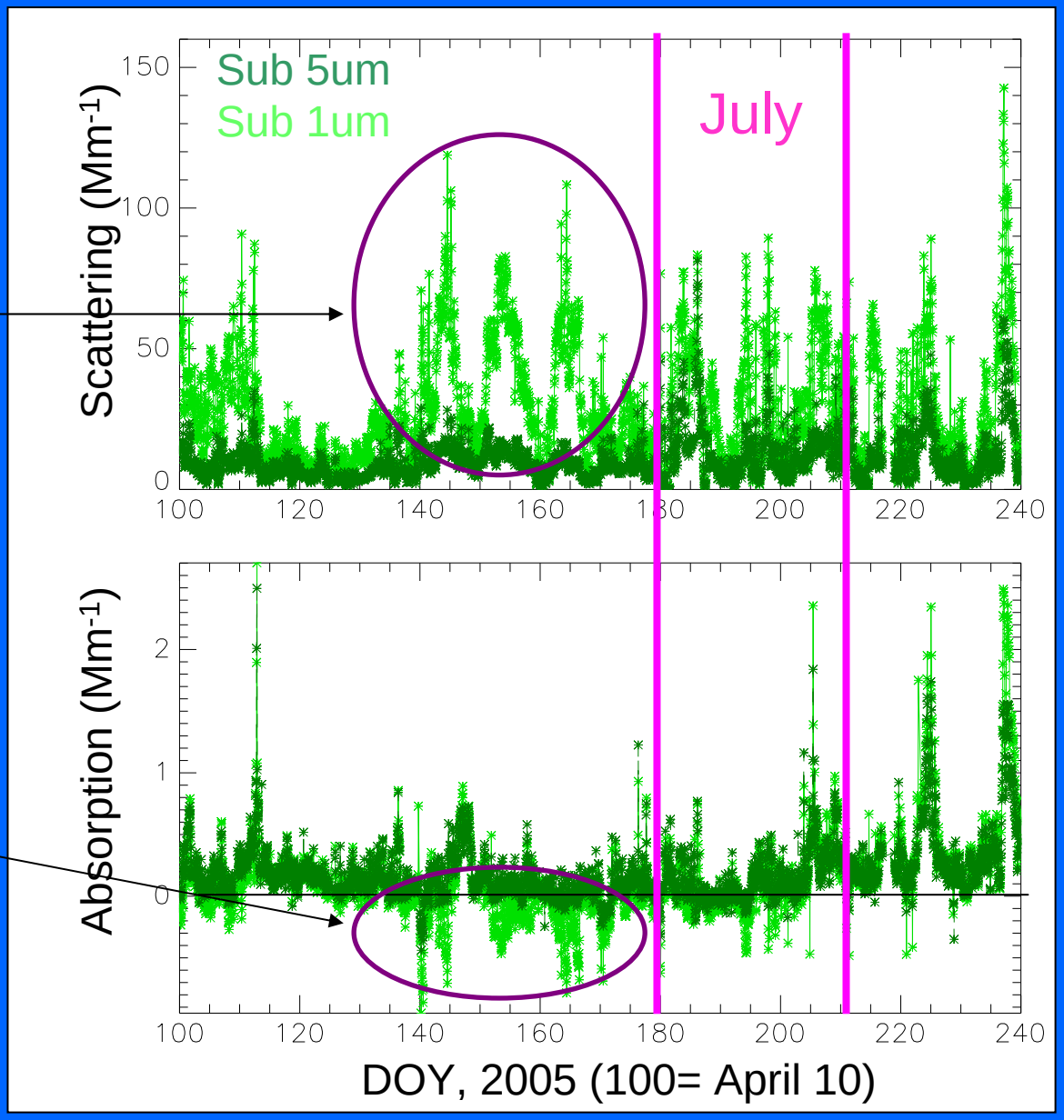


Increasing cloud droplet concentrations cause a decrease in the drizzle concentration- consistent with the second aerosol indirect effect (P. Daum).

What'd we see? Aerosol scattering and absorption

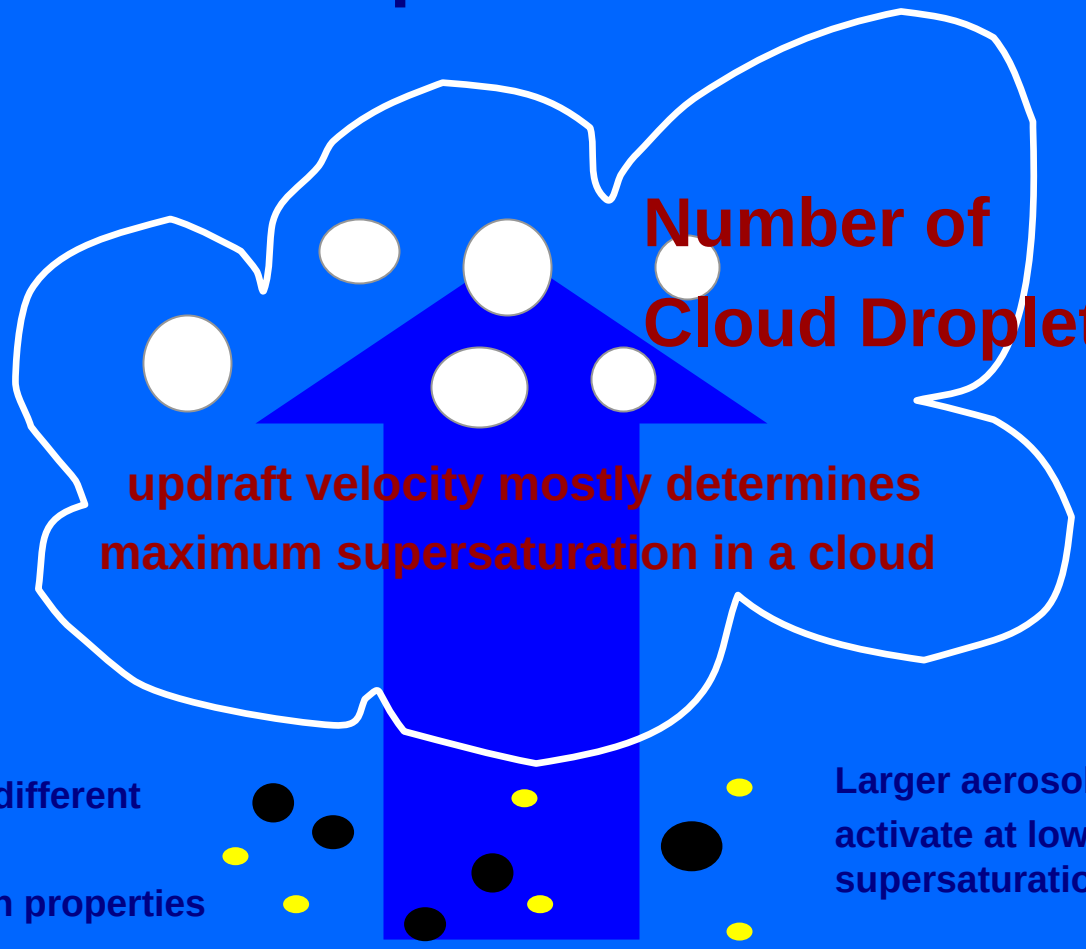
The large difference in scattering between sub5-um and sub1-um aerosol is likely due to sea salt.

Bond et al., 1999 standard correction for scattering may be too large for sea salt dominated aerosol.



Courtesy of E. Andrews and J. Ogren

Cloud Droplet Nucleation



Aerosols have different

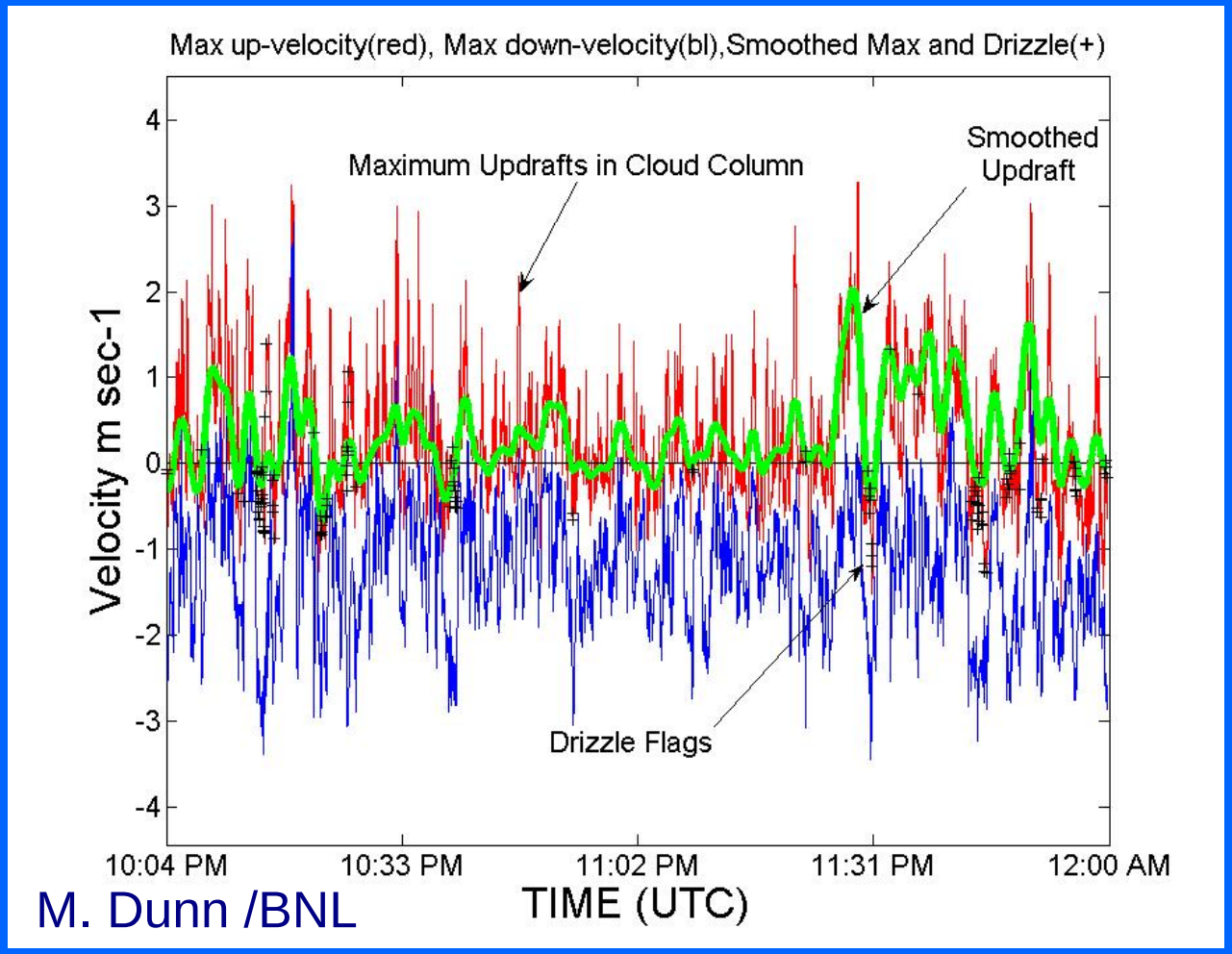
1. Sizes
2. Nucleation properties

Larger aerosol particles activate at lower supersaturation

Cloud Condensation Nuclei (CCN) Activation Spectrum

–Number CCN activated as a function of supersaturation

In-cloud Vertical Velocity



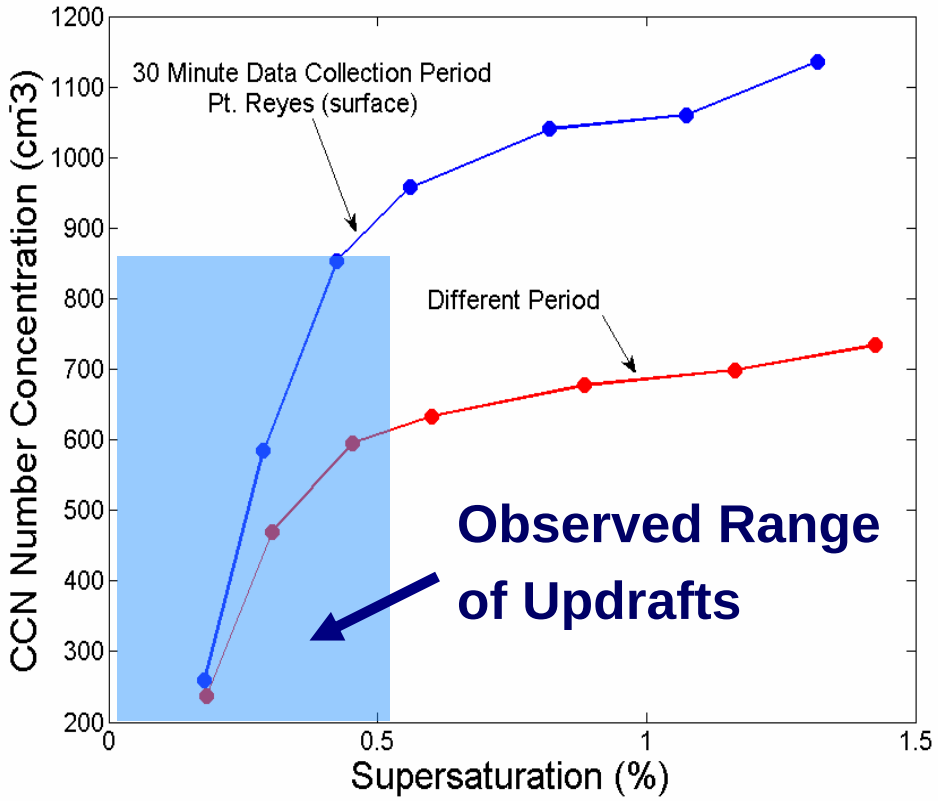
M. Dunn /BNL

Cloud Droplet Nucleation

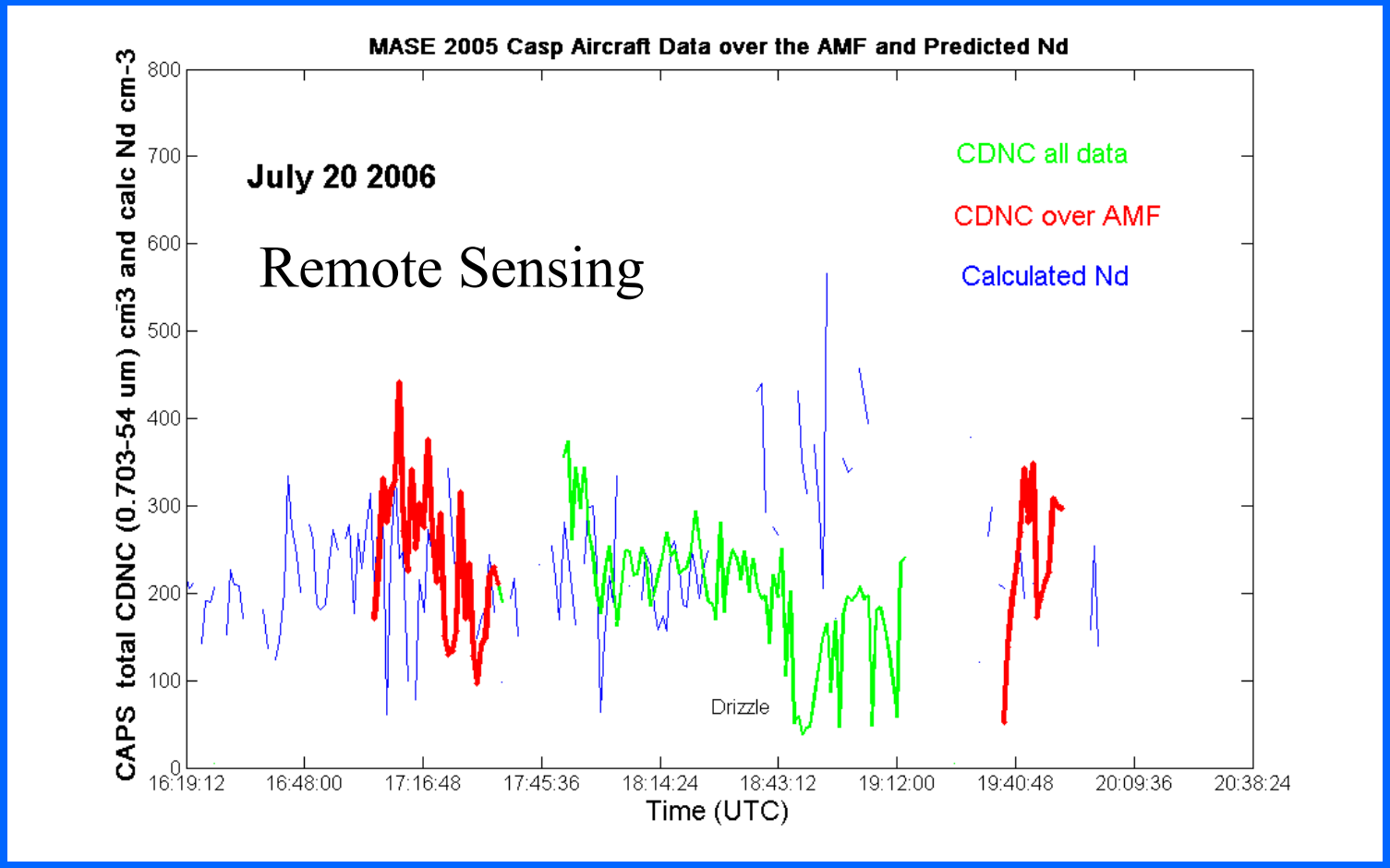
- Cloud Condensation Nuclei (CCN) activity spectrum measured continuously
- Explicitly determine the C and k values for power-law fit (Twomey)

$$S_{\max} = f(U, parameters)$$

$$N_d = f(S_{\max}, parameters)$$

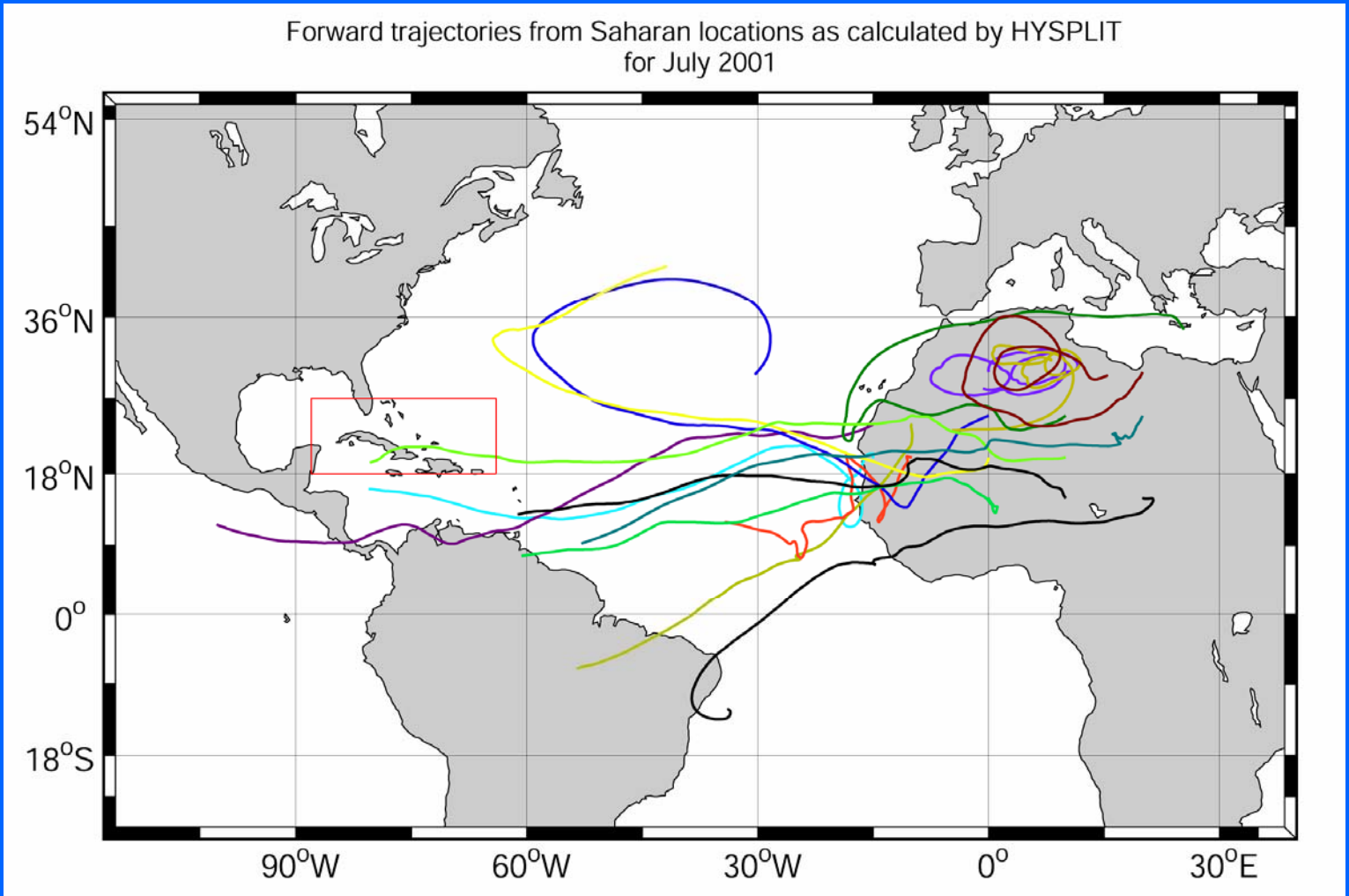


Aerosol Indirect Effects during MASRAD

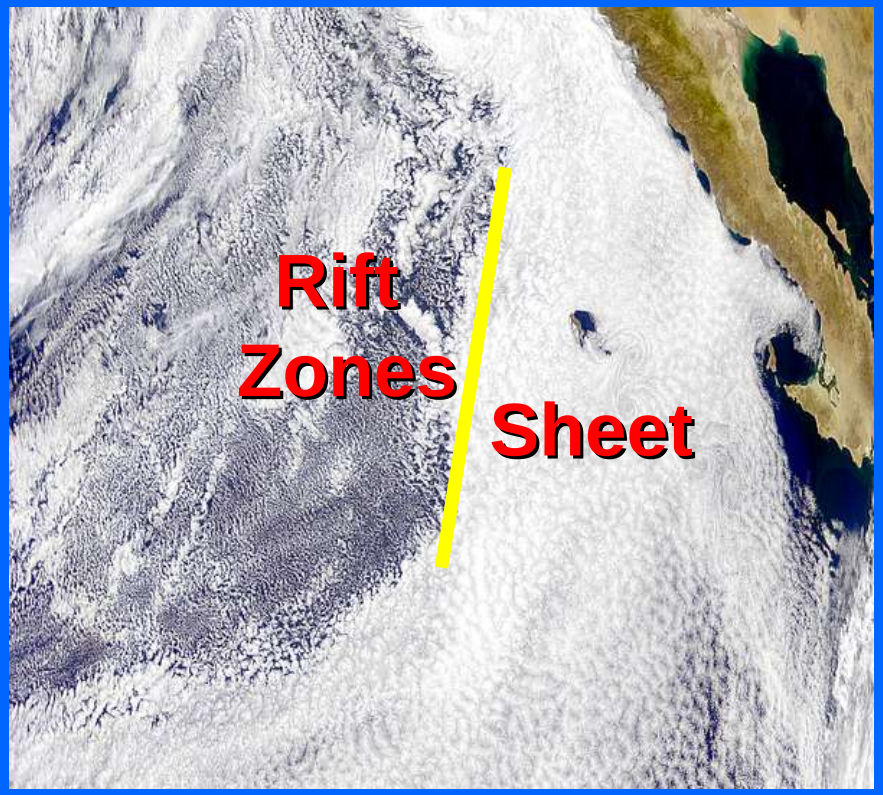


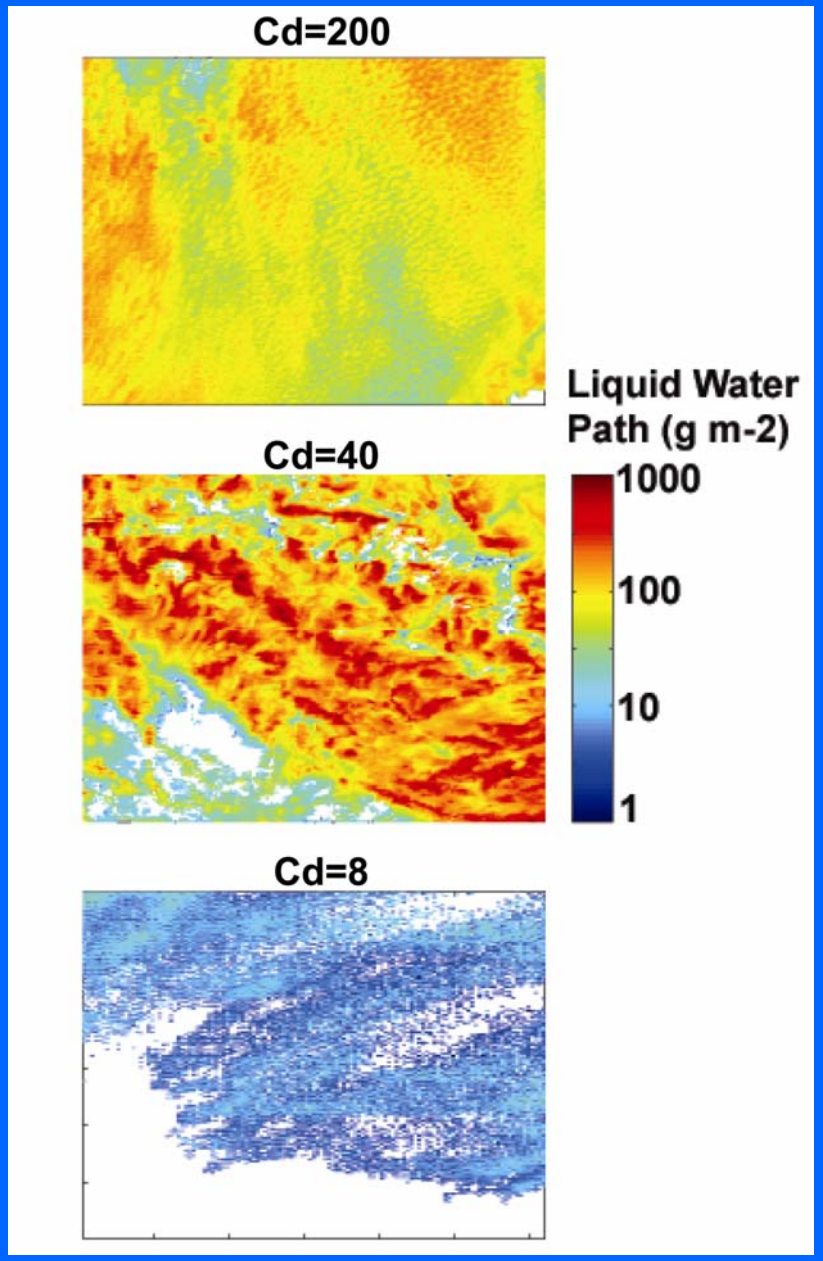
Miller, Dunn, Kollias, Daum, Andrews

Airmass Context: Backtrajectory Analyses

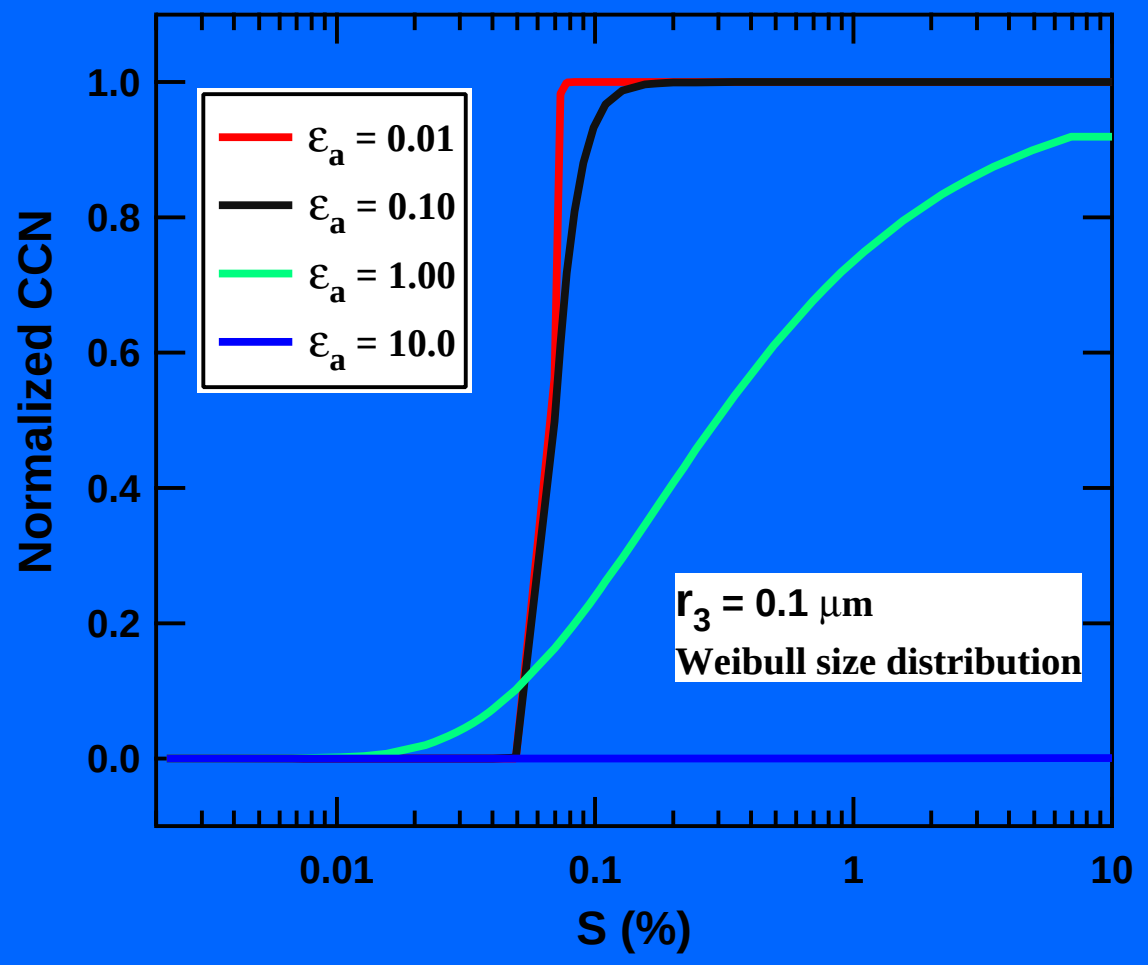


MODIS Analyses: Effective cloud diameter





Parameterization of Droplet Activation/CCN

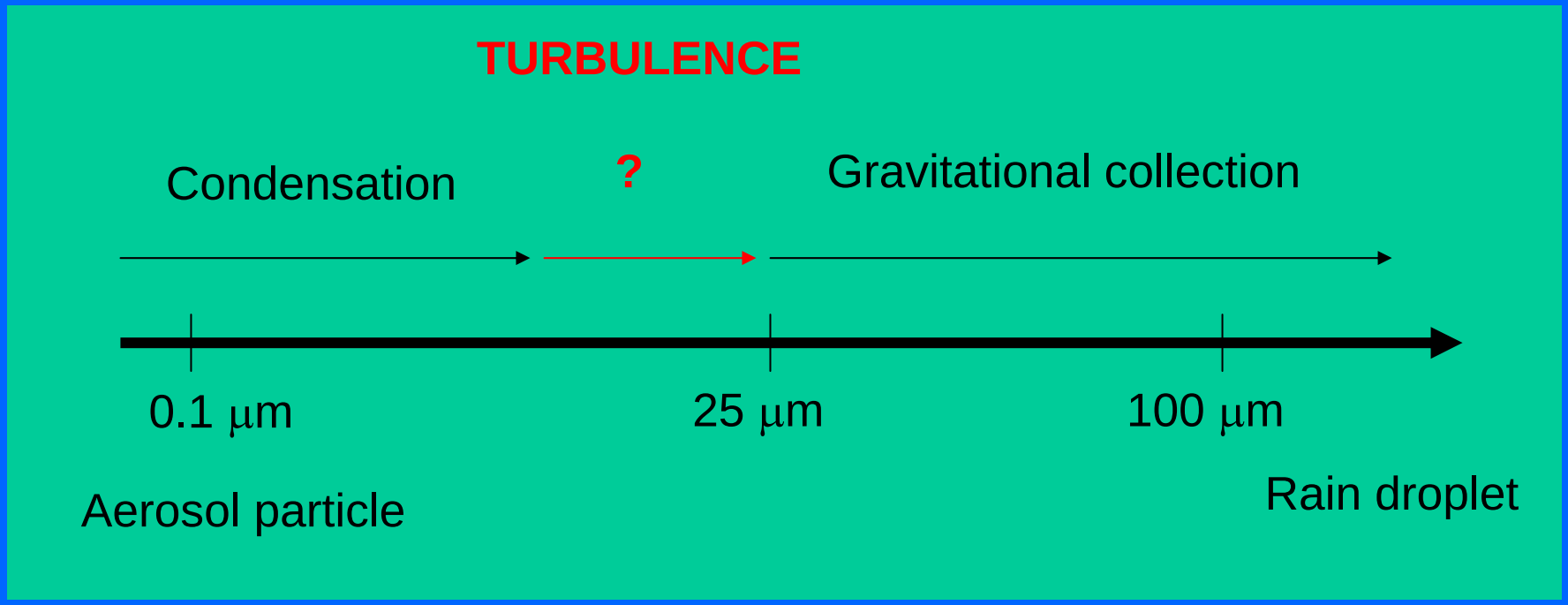


ε_a = relative dispersion of aerosol population
r_3 = volume mean radius of aerosol population, a function of mass loading and number concentration.

Droplet activation needs to be parameterized as a function of aerosol mass loading, aerosol number concentration and relative dispersion of aerosol size distributions.

Turbulence Enhancement of Droplet Growth in Atmospheric Clouds

Collaboration with Nicole Riemer, ITPA, Stony Brook University



We are using cloud parcel model simulations with explicit bin-microphysics to investigate the role of turbulence for cloud droplet growth due to coagulation.

Turbulence enhancement of droplet growth in atmospheric clouds

We are using MASRAD/MASE data to

- obtain realistic input data to initialize the model simulations;
- compare our predictions quantitatively with respect to the droplet size evolution;
- determine how to constrain the model, and how to derive key model parameters.

Cloud System Resolving Modeling

Dr. Wei Kuo Tao
NASA Goddard Space Flight Center

NASA Goddard Cumulus Ensemble model

Multiple bulk microphysics parameterizations

Two explicit spectral-bin models

- Explicitly treats turbulence effects on the collision and coalescence processes (Khain)
- Explicitly accounts for aerosol chemistry (Chen-Lamb)

Runs at various grid sizes (resolution from 10–2000 m)

- LES mode to CSRM mode

LES w/ explicit bin models can examine aerosol-cloud interactions in exceptional detail

CSRM Objectives

- Incorporate new microphysical parameterizations developed at BNL
- Evaluate them through comparison with existing parameterizations and observations
- Validate bulk microphysical parameterizations to facilitate developments from a model perspective

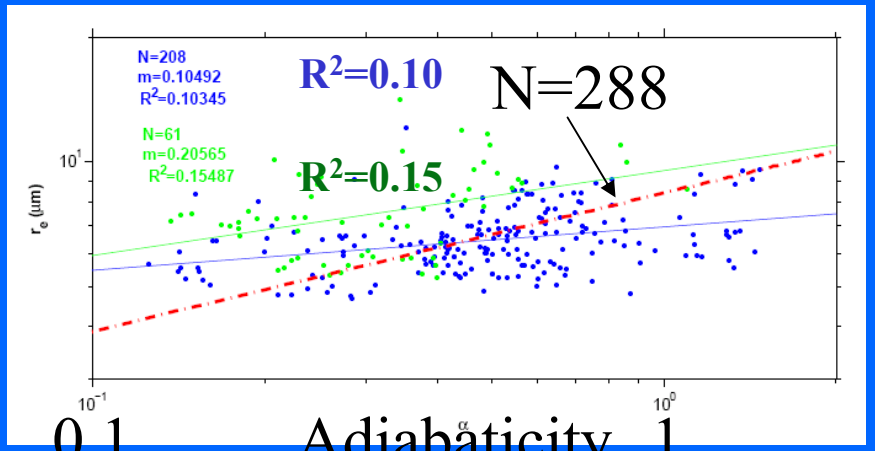
Impacts of Cloud Dynamics on Cloud Microphysics

Adiabaticity, α
α = 1: adiabatic
α < 1: sub-adiabatic

Bins of Cloud Thickness

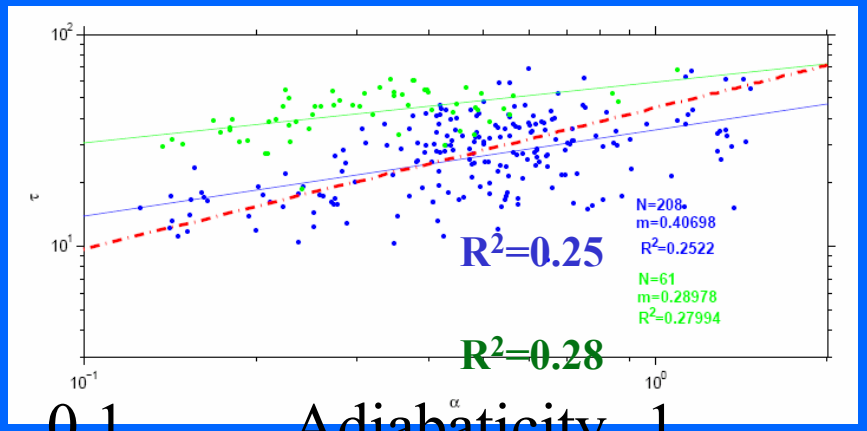
Blue: 50-600m
Green: 600-1000m

r_e



0.1 Adiabaticity 1

τ



0.1 Adiabaticity 1

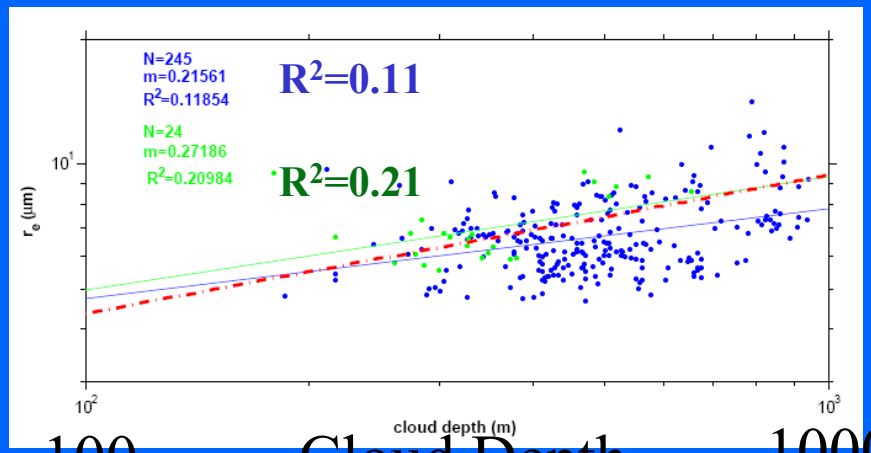
Collaborators: B.G. Kim, Steve Schwartz

Impacts of Cloud Dynamics on Cloud Microphysics

Bins of Adiabaticity

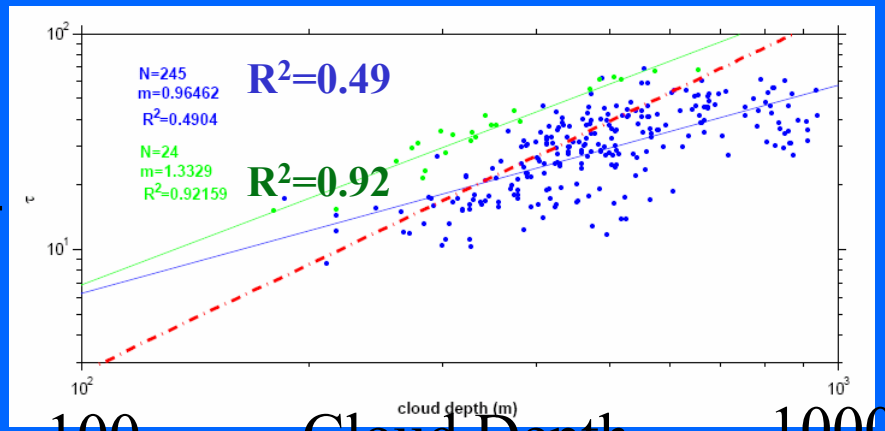
Blue: 0.1-0.9
Green: 0.9-1.5

r_e



100 Cloud Depth 1000

τ

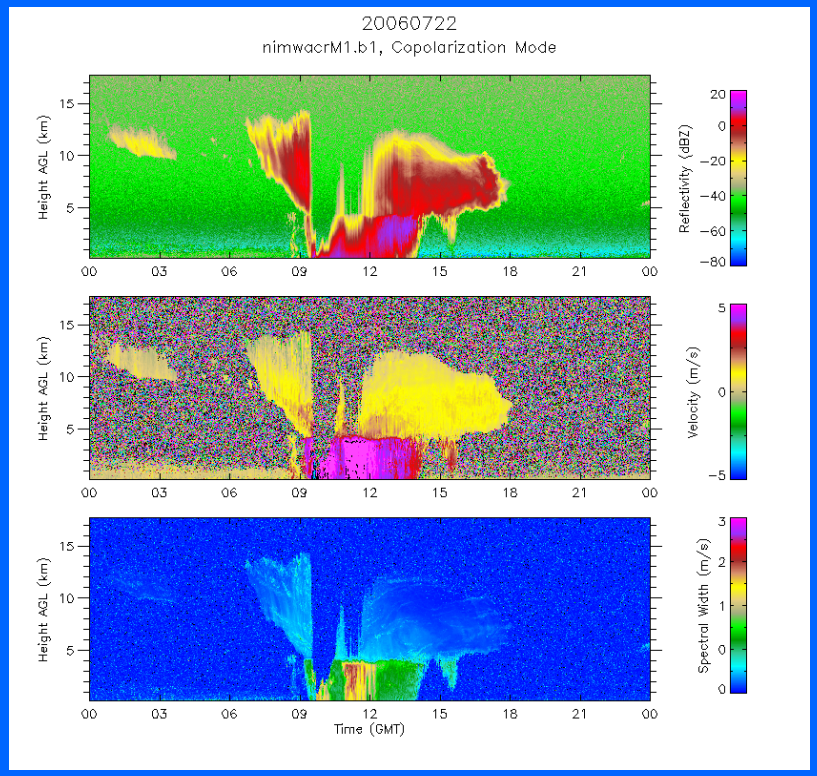


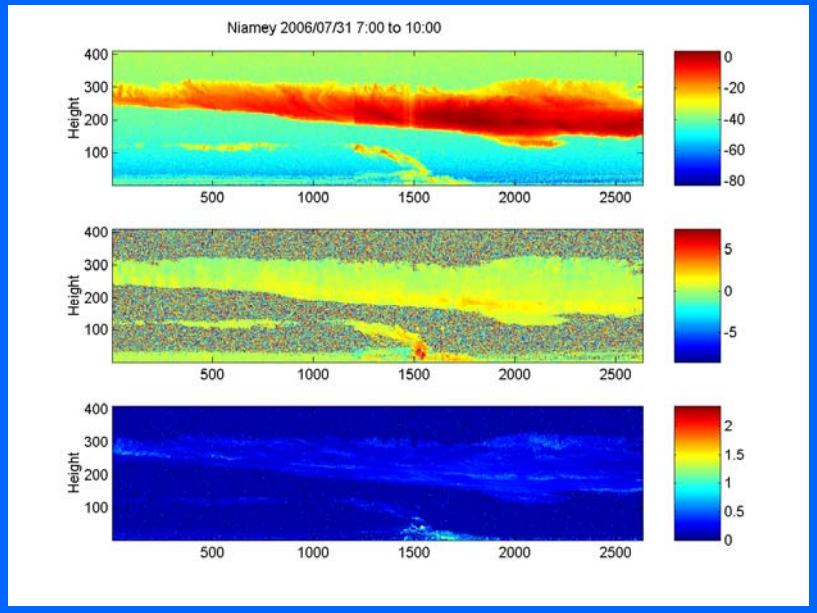
100 Cloud Depth 1000

Transmission in these clouds dominated by LWP [Sengupta et al. 2003 Kim et al. 2003]

Collaborators: B.G. Kim, Steve Schwartz

The Niamey, Niger, Africa Data Set!





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