Warm Rain Detection & Aerosol Impact on Cloud and Rain

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Topics

- Use of CloudSat, TRMM, Ground-based radars to investigate if MODIS can
  - help detect drizzles
  - estimate rain rate

- Use of ground-based (ARM) and space-borne (A-Train) measurements to investigate
  - if aerosols have discernible long-term effects on
    - cloud height
    - cloud particle size
    - rainfall frequency

Topic I

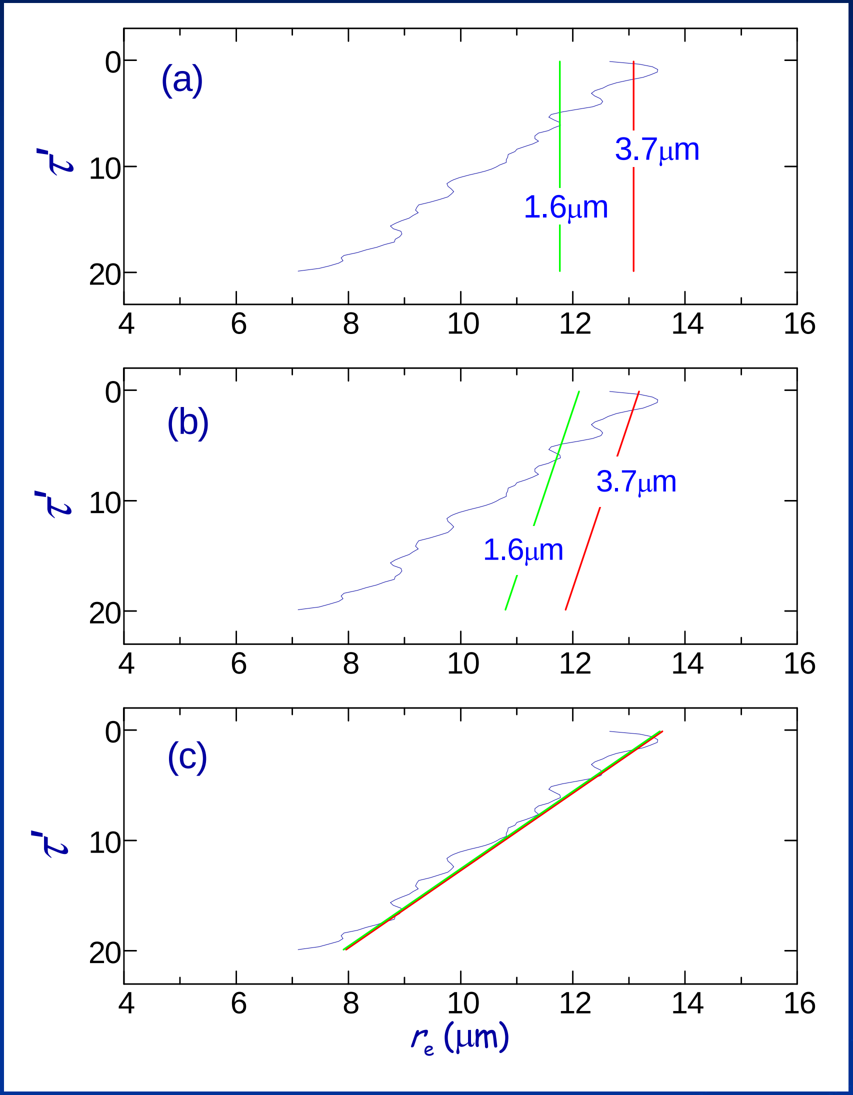
- Chen, R., R. Wood, Z. Li, R. Ferraro, F.-L. Chang, 2008, Studying the vertical variation of cloud droplets effective radius using ship and space-borne remote sensing data, *J. Geophy. Res.*, 113, doi: 10.1029/2007/JD009596.

- Chen, R., F. Chang, Z. Li, R. Ferraro and F. Weng, 2008: Impact of the Vertical Variation of Cloud Droplet Size on the Estimation of Cloud Liquid Water Path and Rain Detection. *J. Atmos. Sci.* 64, 3843-3853.

- Chang, F.-L., Z. Li, 2003, Retrieving the vertical profiles of water-cloud droplet effective radius: Algorithm modification and preliminary application, J. Geophy. Res., 108, D(24), 4763, 10.1029/2003JD003906.

- Chang, F.-L., Z. Li, 2002, Estimating the vertical variation of cloud droplet effective radius using multispectral near-infrared satellite measurements, J. Geophy. Res., 107.

Schematic Illustration of a Bispectral Retrieval Procedure



(a) Conventional r_e retrievals by assuming $dr_e/d\tau = 0$.

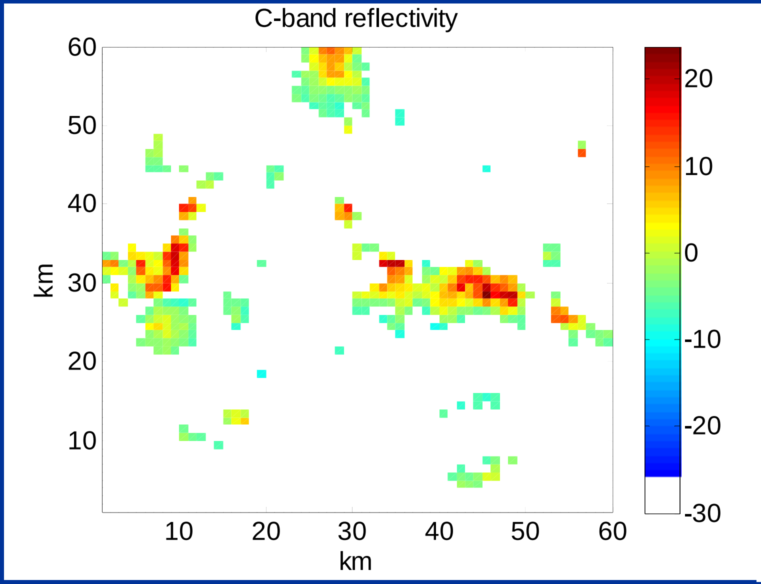
(b) The linear-r_e retrievals with $dr_e/d\tau = \Delta r_e/\tau_{total}$, where Δr_e = 13.1–11.8 μm as obtained from the 3.7- (red) and 1.6-μm (green) retrieved r_e values shown in Figure (a).

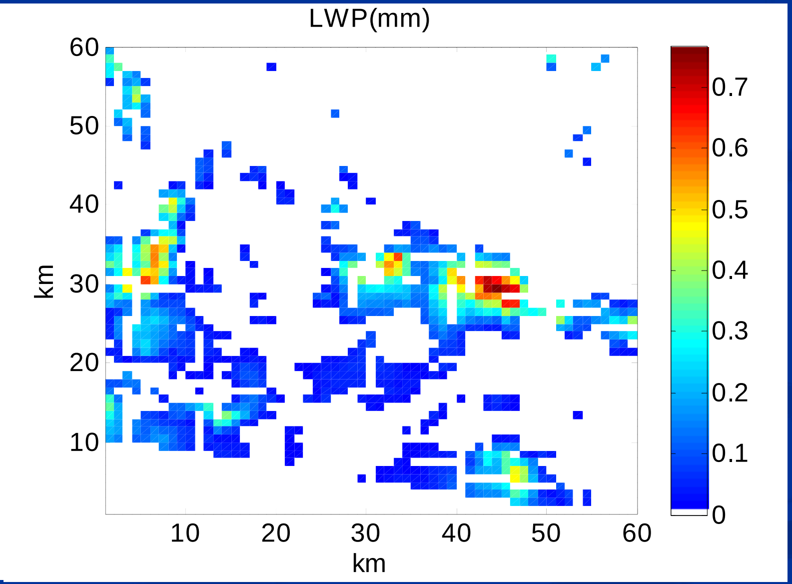
(c) The optimal linear-r_e retrieval for the two channels.

Chang and Li (JGR. 2002, 2003)

Validation with Ship-borne Radar

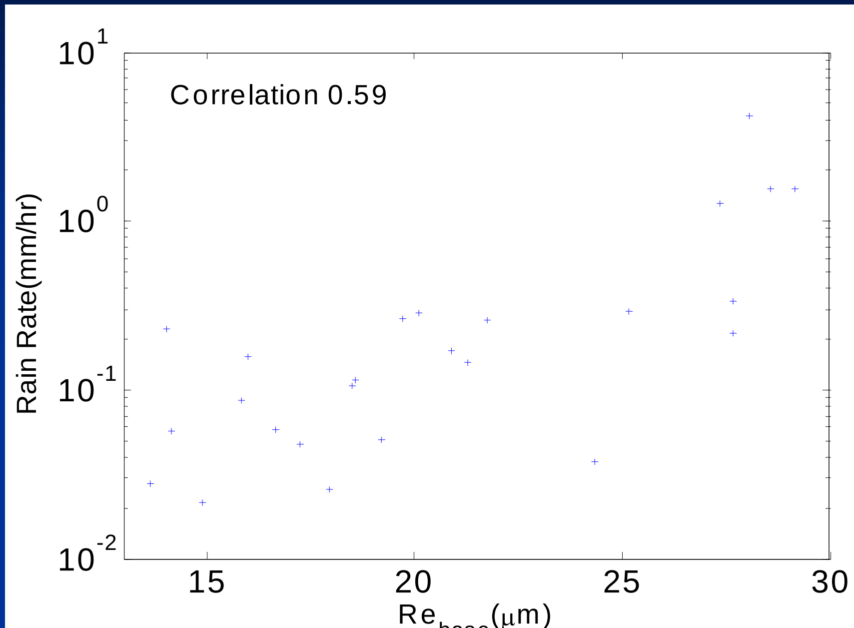
- Estimation of cloud DER, DER profile, LWP from MODIS measurements, 1x1 km, instantaneous.
- Rain estimation at cloud base from C-band ship-based radar during EPIC 2001, 0.5x0.5 km, 5-min averaged

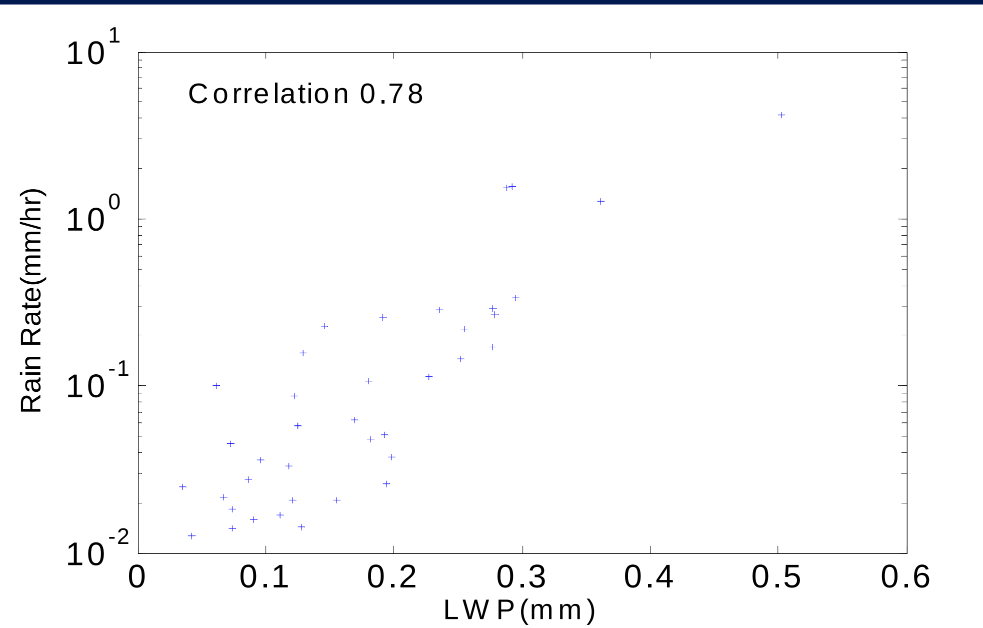


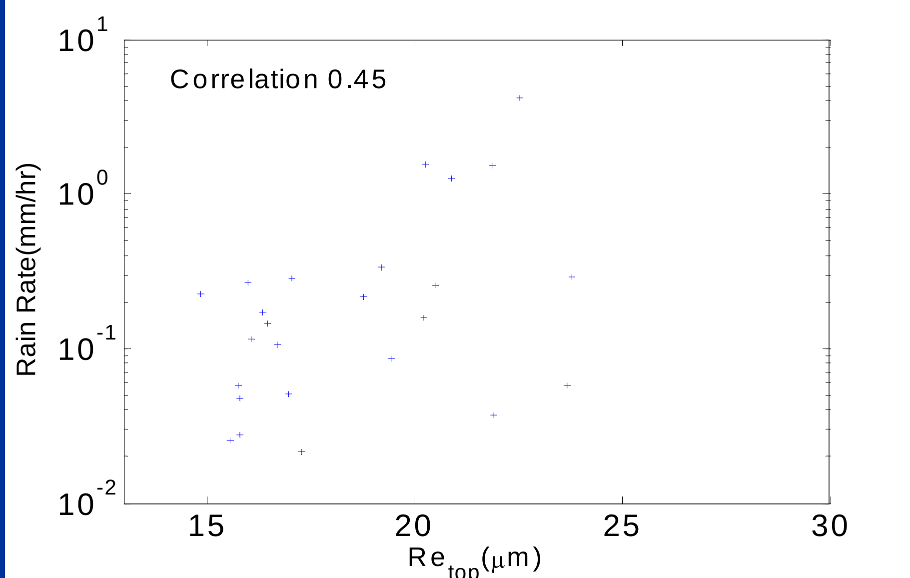


Chen et al. (2008a)

Rain rate and Cloud Microphysics



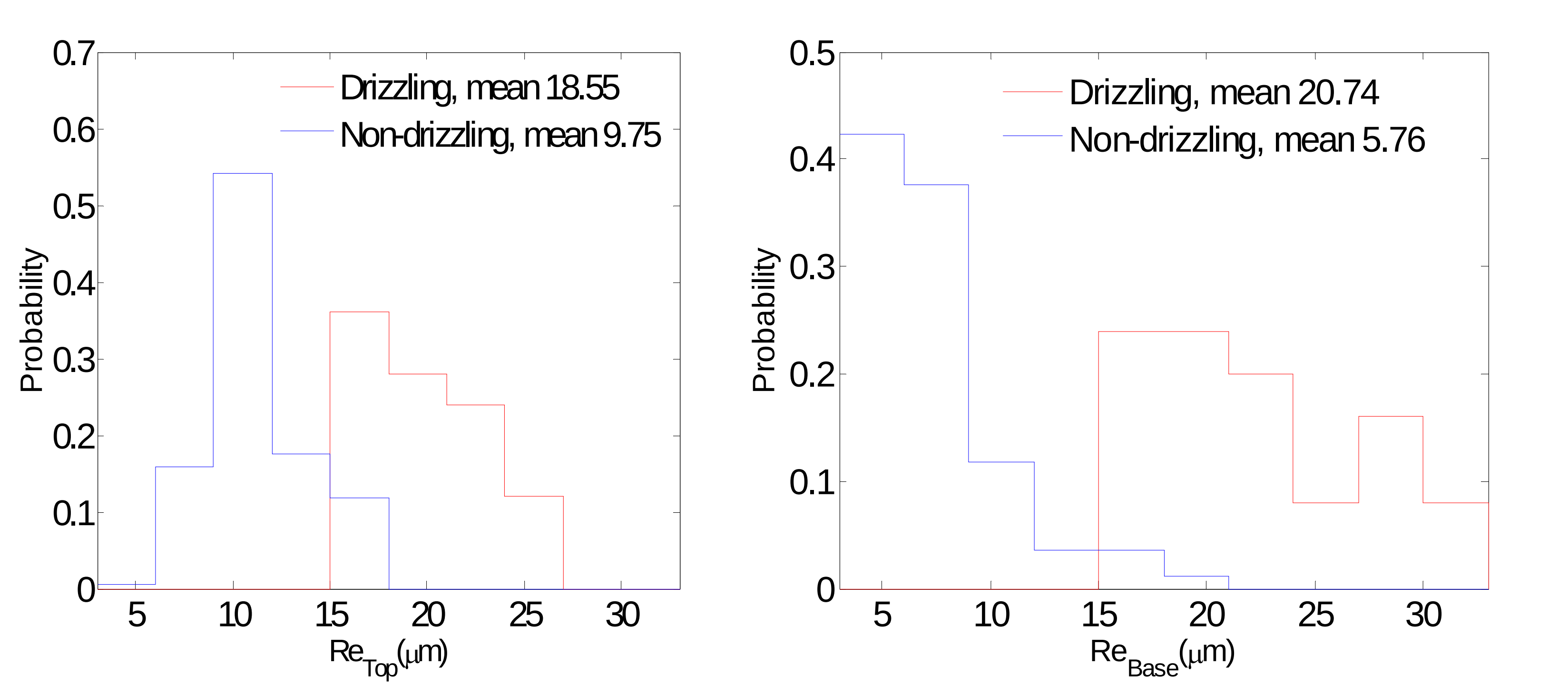




- DER at cloud base are correlated more closely with rain rate than DER at cloud top

Chen et al. (2008b)

DER and Drizzling

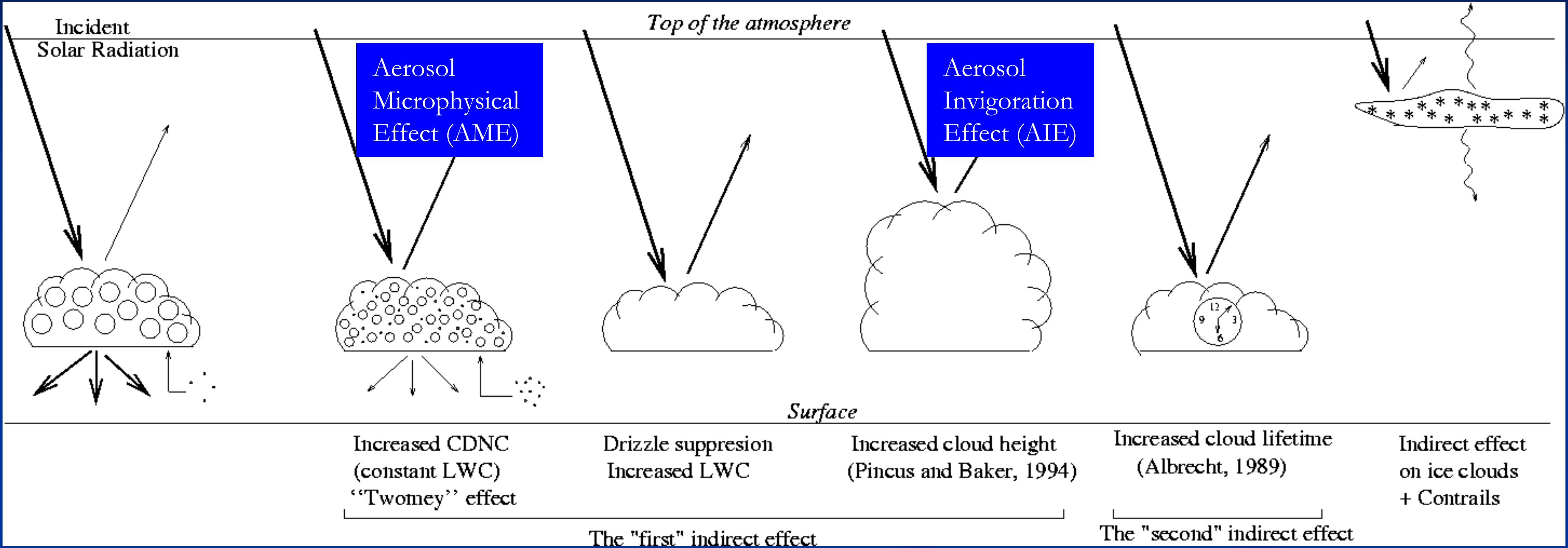


- Drizzling increases DER at cloud base by 14.98, increases DER at cloud top by 8.8

Topic II
Aerosol Impact on Rain Frequency, Cloud Thickness & Particle Size Using Long-term Ground and Global Satellite Data

Indirect Effects

Haywood and Boucher *Revs. Geophys.* **2000**



1) Increased CCN - reduces r_{eff}

2) Drizzle suppression - increases LWC

3) Increased cloud height

4) Increased cloud lifetime

'First' indirect effect (AME)

'Second' indirect effect (AIE)

A lot of studies on aerosol effects on precipitation with opposite findings

Aerosols (not including GCCN) **inhibit** precipitation:

Kaufman and Nakajima 1993;

Borys et al, 1998; 2000;

Rosenfeld and Lensky 1998;

Rosenfeld 1999, 2000;

Givati and Rosenfeld 2004

Tao et al (1995), Ferrier et al (1996)

Khain et al, 2001;

Khain and Pokrovsky (2004);

Khain et al (2004a,b)

Axel et al (2004); Tao et al (2004)

Teller and Levin(2006)

Margaritz et al (2006)

Lynn et al (2006)
Jirak and Cotton (2006)

Aerosols can **increase** precipitation:

Ohashi and Kida 2002
Shepherd and Burian 2003
Amiranashvili et al 2004

Filho et al (2004)

Khain et al (2004a,b)

Khain et al (2005-QJRMS)

Axel et al (2004);

Axel and Beheng (2004)

Tao et al (2004)

Van den Heever et al (2004)

Lynn et al (2005a,b)

Lynn et al (2006)

Khain et al (2005, 2006)

Khain and Pokrovsky (2006)

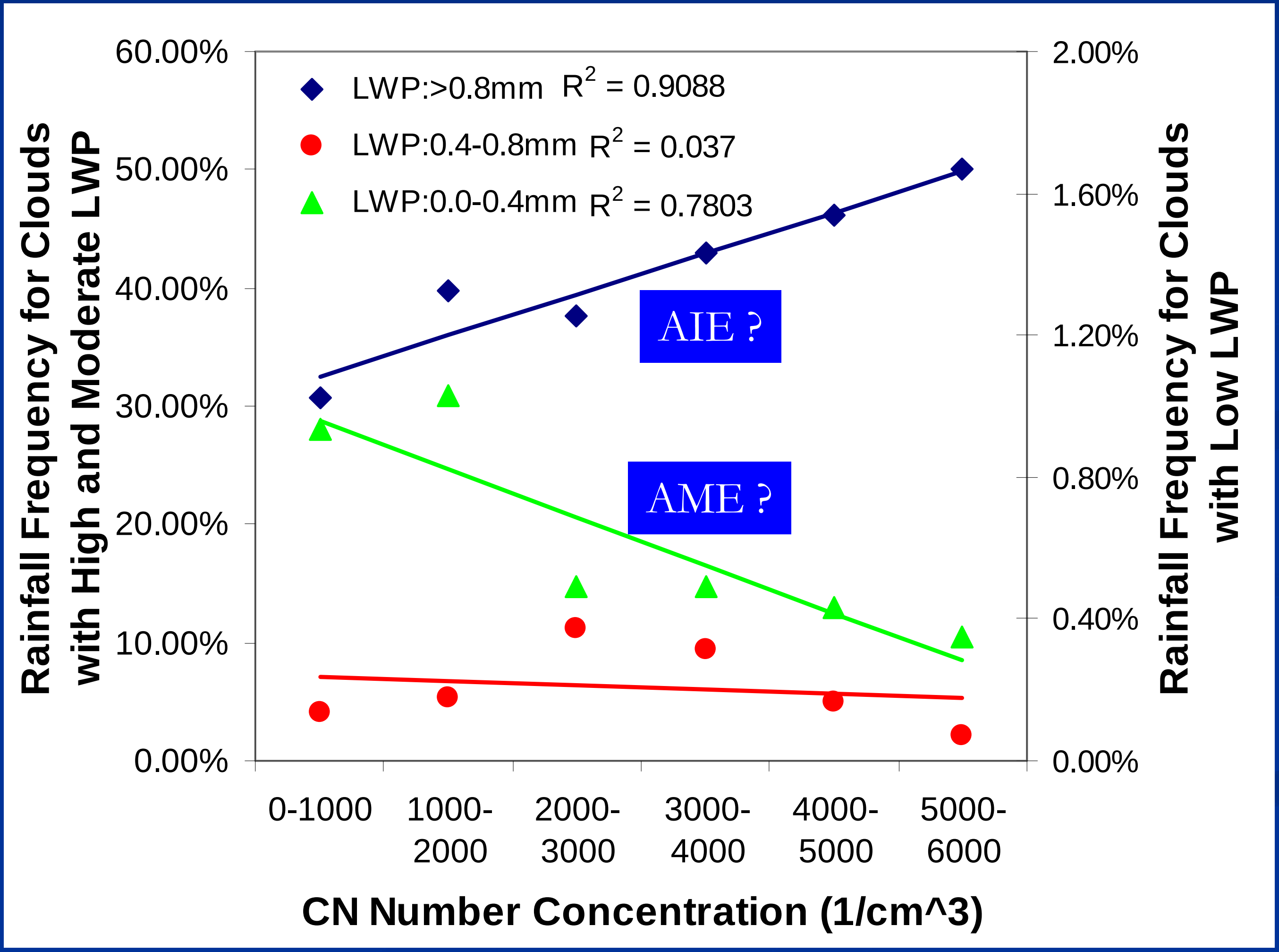
But little has been done for rain frequency!

While rain amount and frequency change in harmony in general, the impact of aerosol on initiation of rain is likely to be more significant than rain amount, as the latter is dictated more by dynamics and abundance of available water

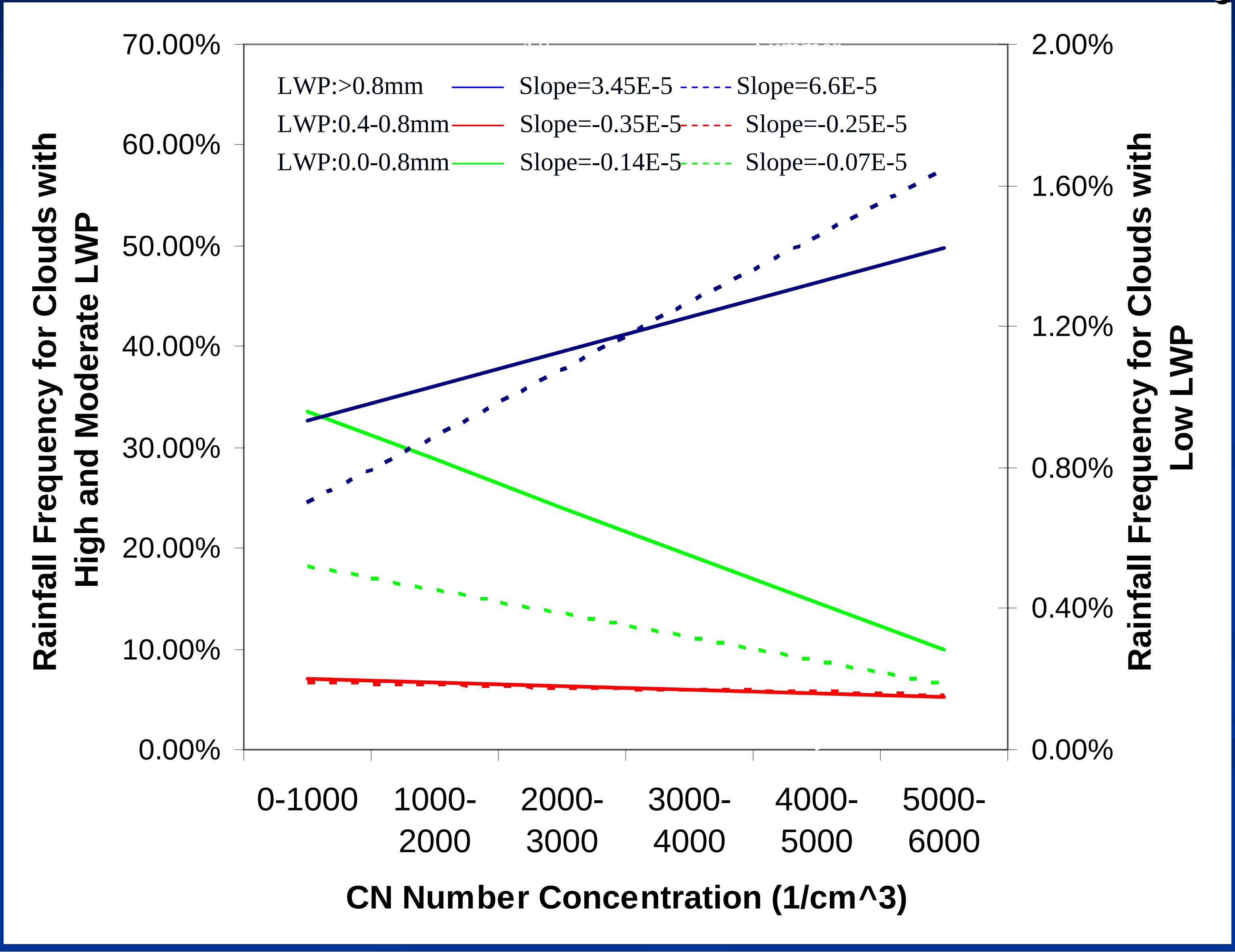
Datasets Used

- Daily ARM SGP data 2003-2008 (~20000 data samples)
- Most complete and highest quality measurements of aerosol, cloud, atmospheric state
- Key variables used:
  - Aerosol CN number concentration on the ground
  - Tipping bucket rain gauge
  - LWP from microwave radiometer
  - Cloud bottom and top heights from cloud radar & lidar
  - NOAA/NCAR Reanalysis
  - MODIS cloud particle size

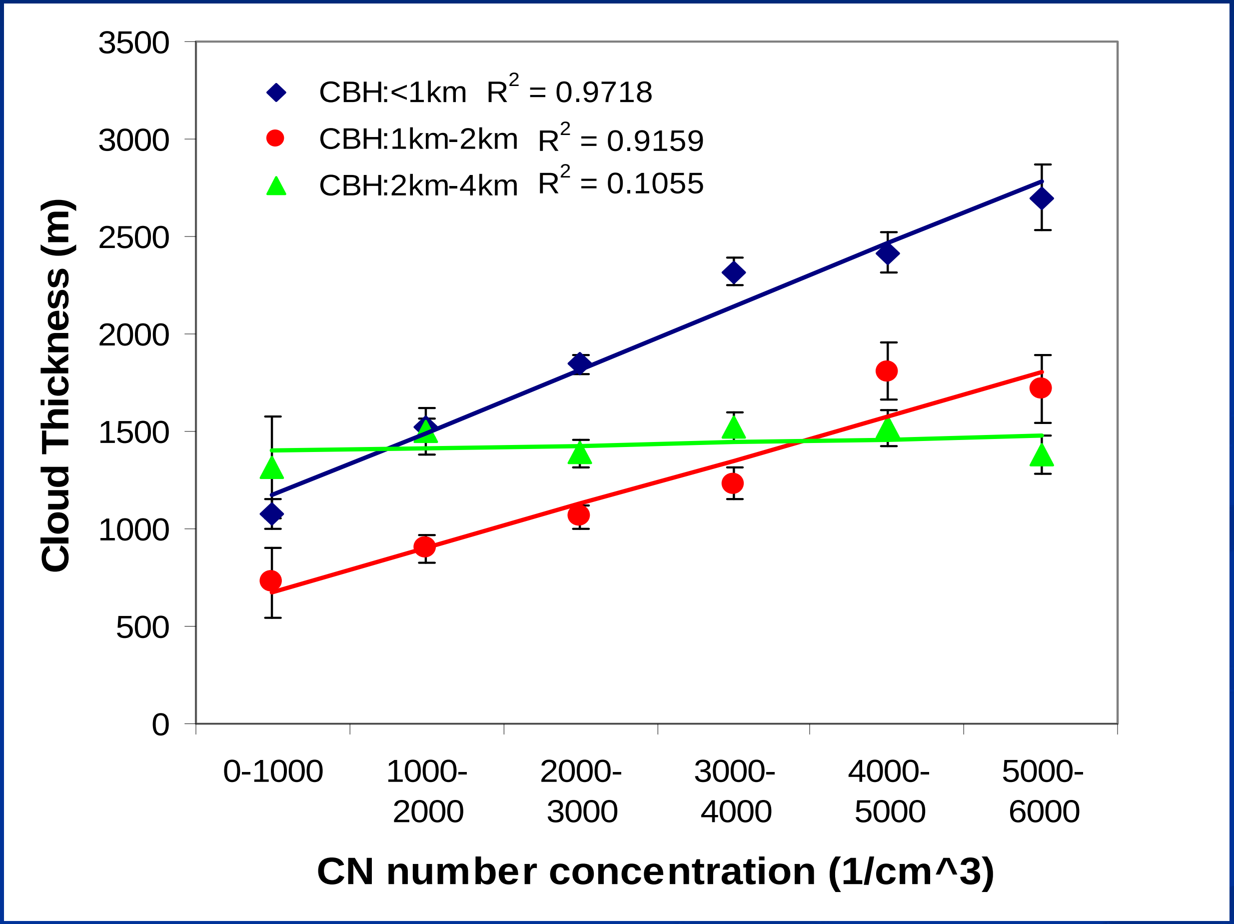
Rainfall Frequency for clouds with different liquid water path at SGP (All-Season Data)



Comparison of the Results Obtained in All Seasons and in Summer Only

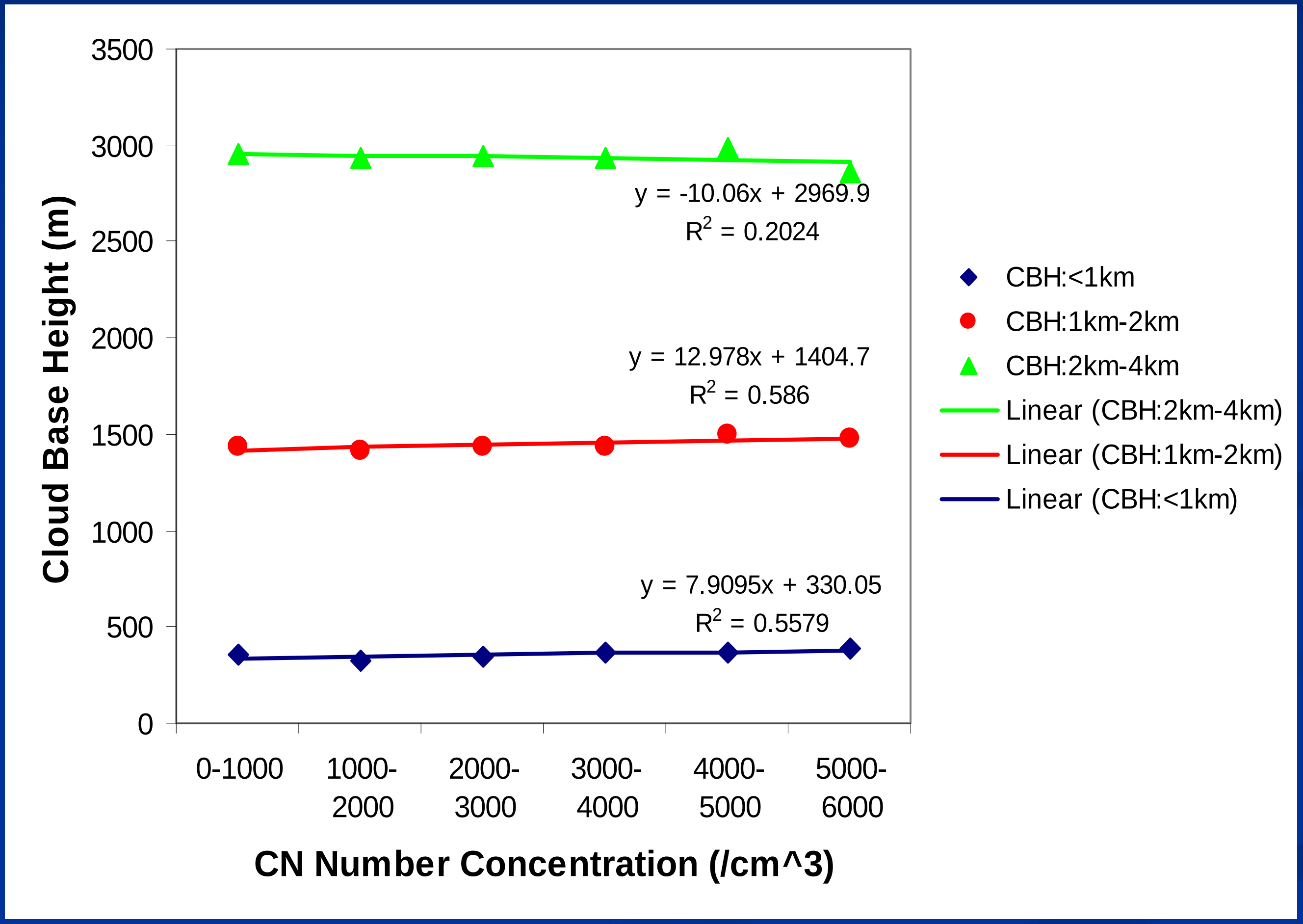


Cloud Thickness for clouds with different cloud base heights



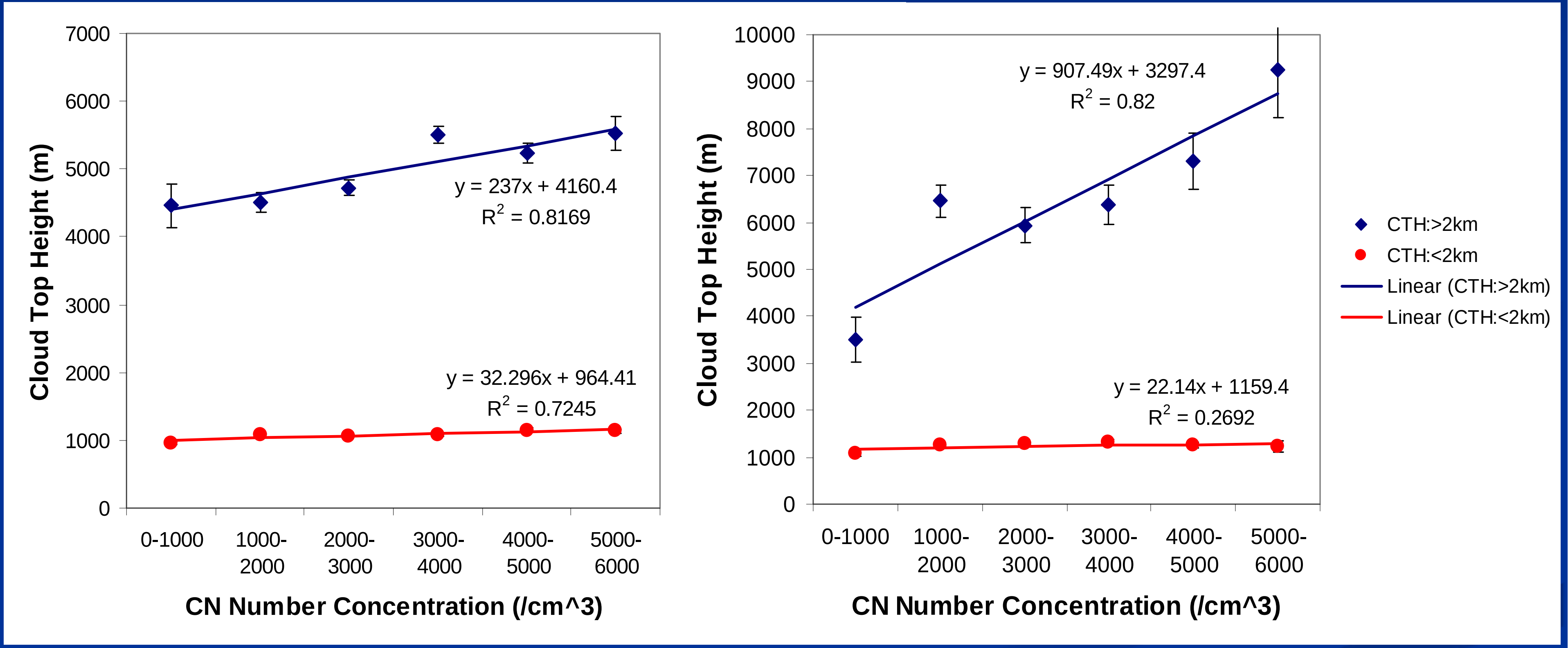
Most Direct Evidence of the Invigoration Effect !

Cloud Base Heights



Cloud Top Heights (for clouds of cloud base <1km)

All Seasons — Summer Only



For clouds with CBH<1km, clouds are classified into two categories with cloud top heights greater (blue) and less than (red) 2km.

Data

- Aqua/MODIS:
  Level 3 daily aerosol product: AOD, Angstrom exponent

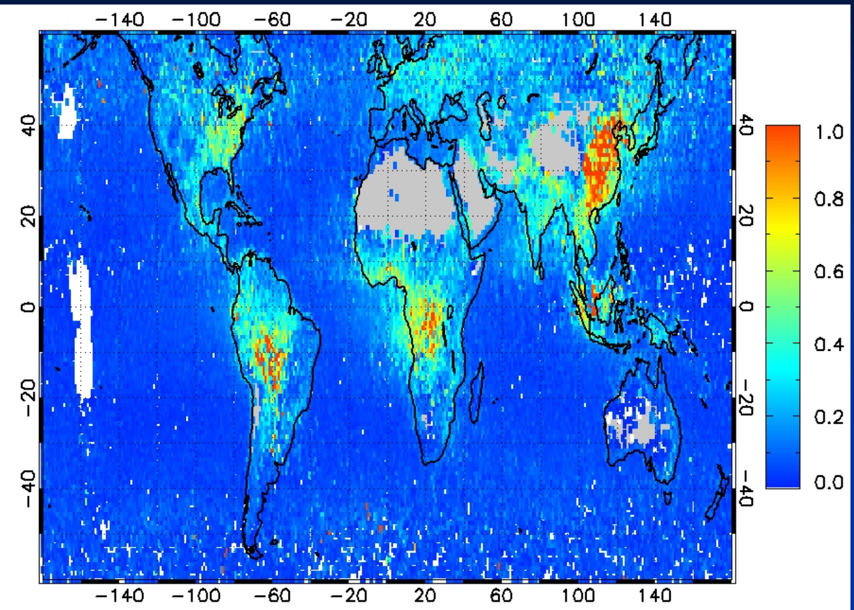
- Cloudsat: Level 2 daily products
  2C-PRECIP-COLUMN product version 000: Precip_rate
  2B-TAU product version 008: COD, mean Re
  2B-GEOPROF-LIDAR product version 003: layer height
  2B-CWC-RO product version 008: LWP, IWP

- Available DATA:
  collected during Aug 2006~Aug. 2007
  more will be downloading

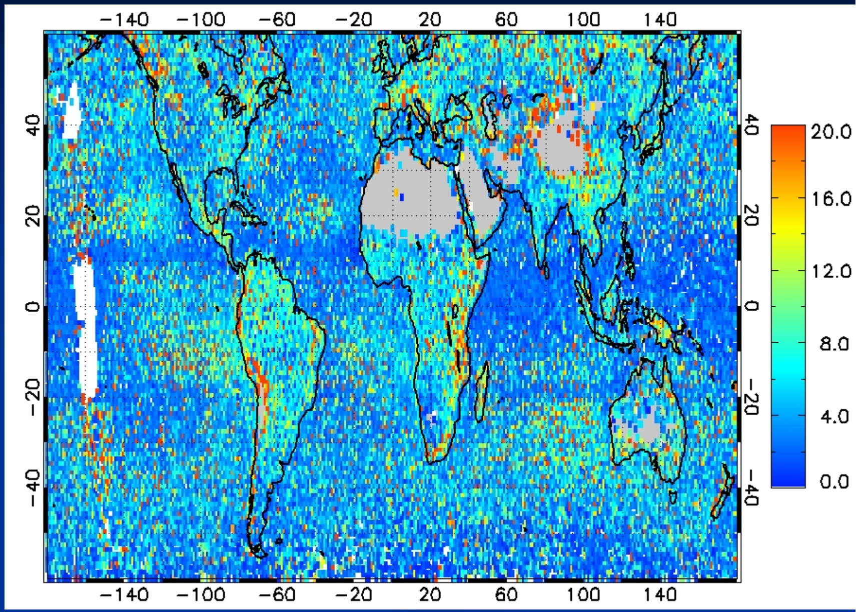
- Outputs:
  Scatter plots for cloud properties vs. Aerosol Index (daily observation)
  Annual mean AI, COD, Re distribution maps (coincident only)

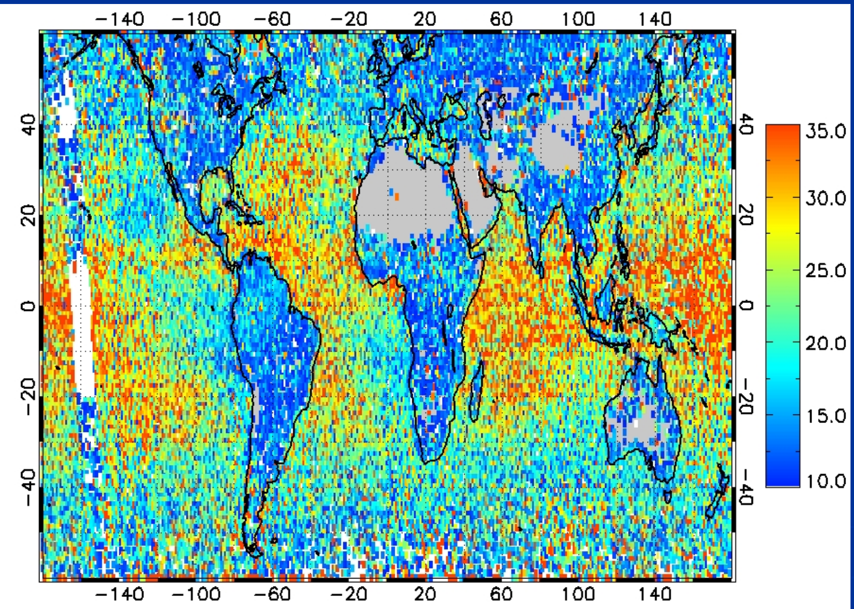
Global Non-Precipitable Clouds

MODIS AI



Cloudsat COD



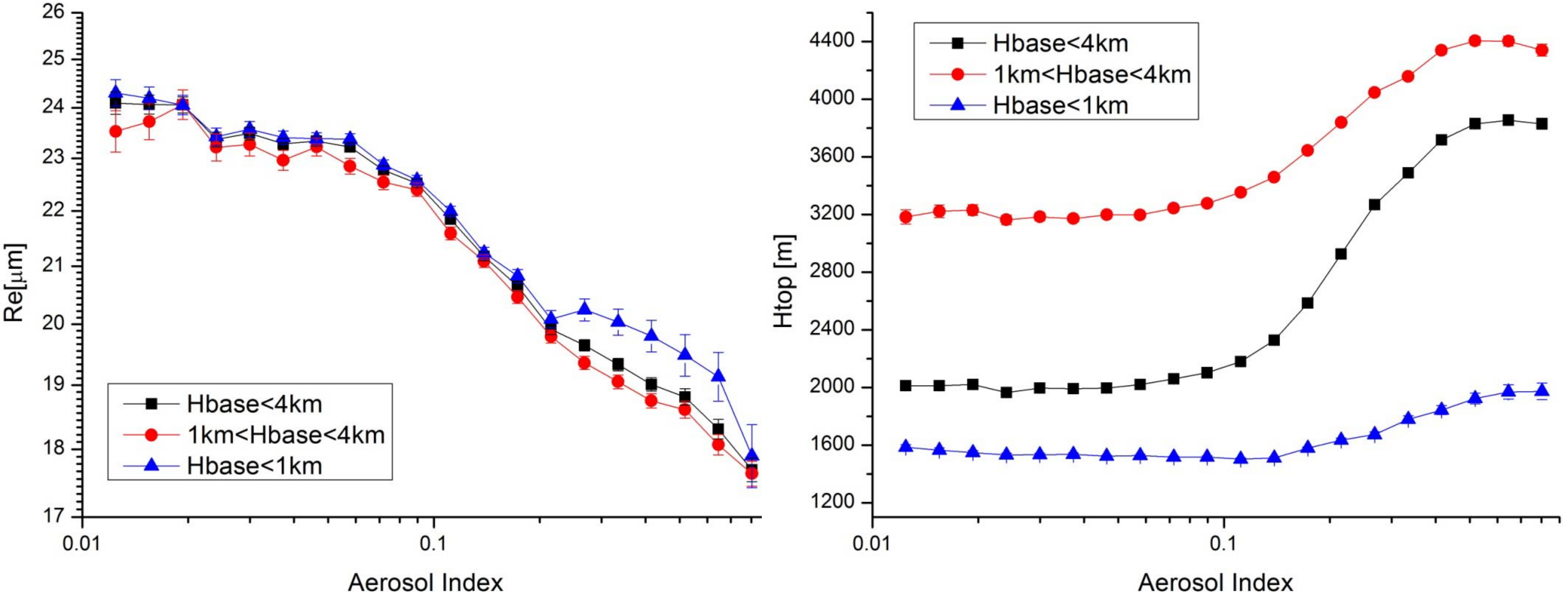


Cloudsat Re

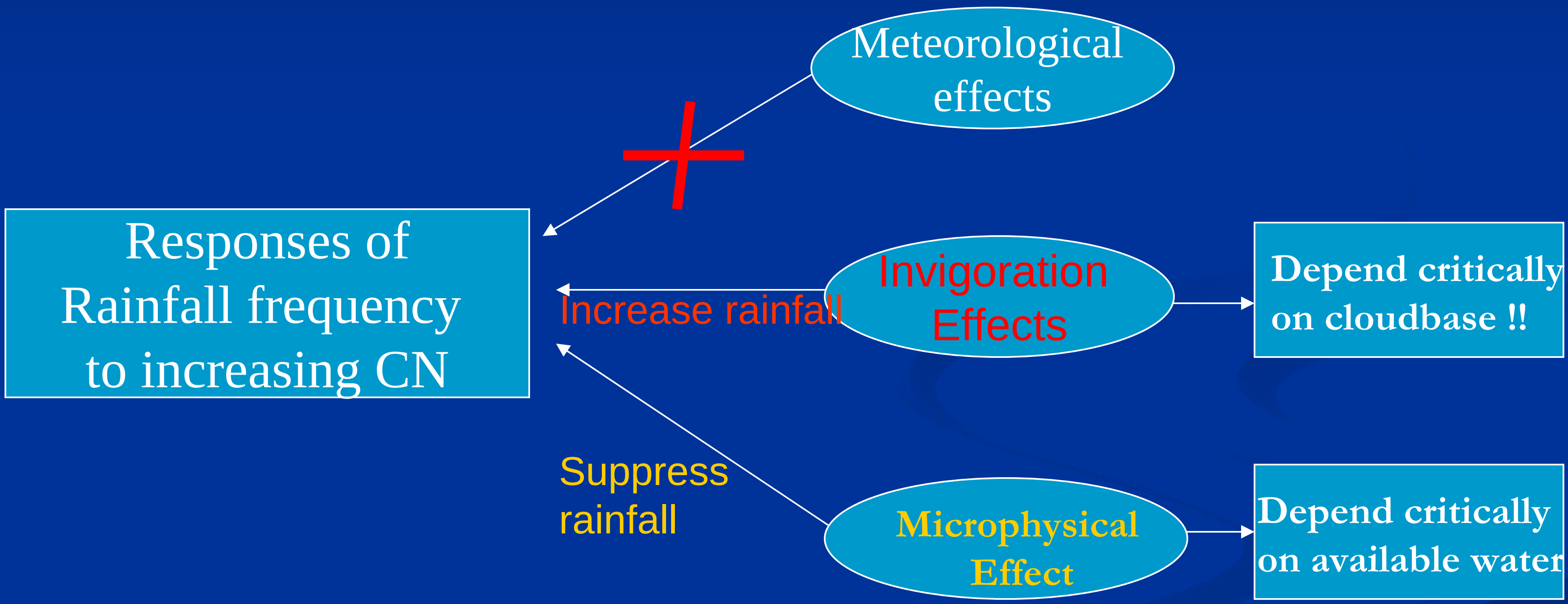
MODIS pixels were chosen where Cloudsat COD exists.

AI=AODxAngstrom [Nakajima et al., 2001]

Global Mean Aerosol Indirect Effect From CloudSat and MODIS



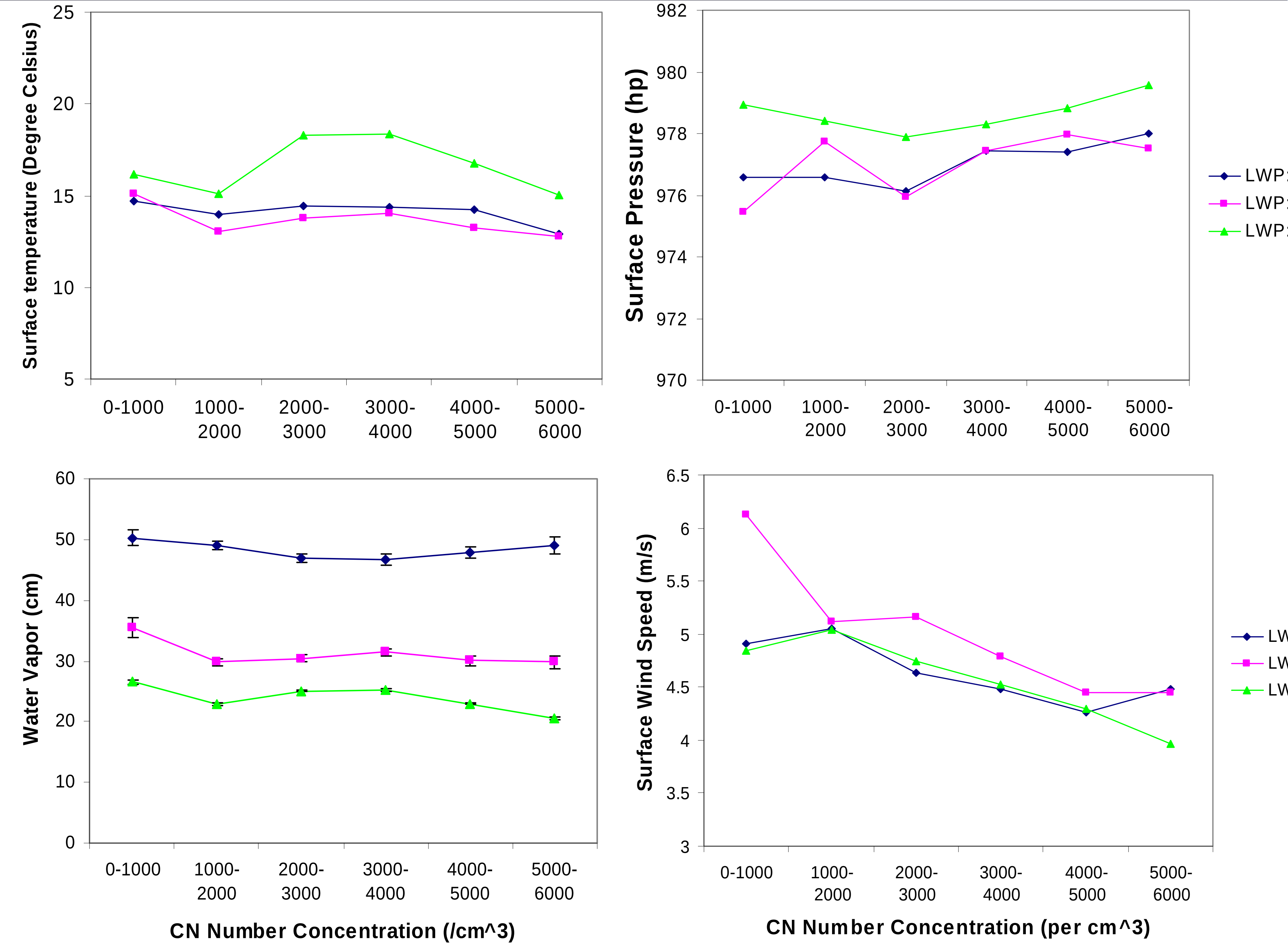
Competition of two opposite effects



Future Studies

Use of GLOBAL CloudSat-Calipso-MODIS-AMSR-E together with LONG-TERM ground measurements to address the following questions

- *What are the NET effects of aerosols on cloud (coverage, hydrometeor amount, height, etc.) and precipitation on long-term and large scales?*
- *Under what conditions, the aerosol's microphysical effect (AME) is dominant over the thermodynamic effect (AIE), and vice versa; and what is the determinant factor?*
- *How do the AME and AIE depend on aerosol properties, weather condition and cloud regimes?*



Surface temperature (Degree Celsius)
Surface Pressure (hp)
Water Vapor (cm)
Surface Wind Speed (m/s)
0-1000
1000-2000
2000-3000
3000-4000
4000-5000
5000-6000
CN Number Concentration (/cm^3)
CN Number Concentration (per cm^3)