Ground-based remote sensing of the first aerosol indirect effect

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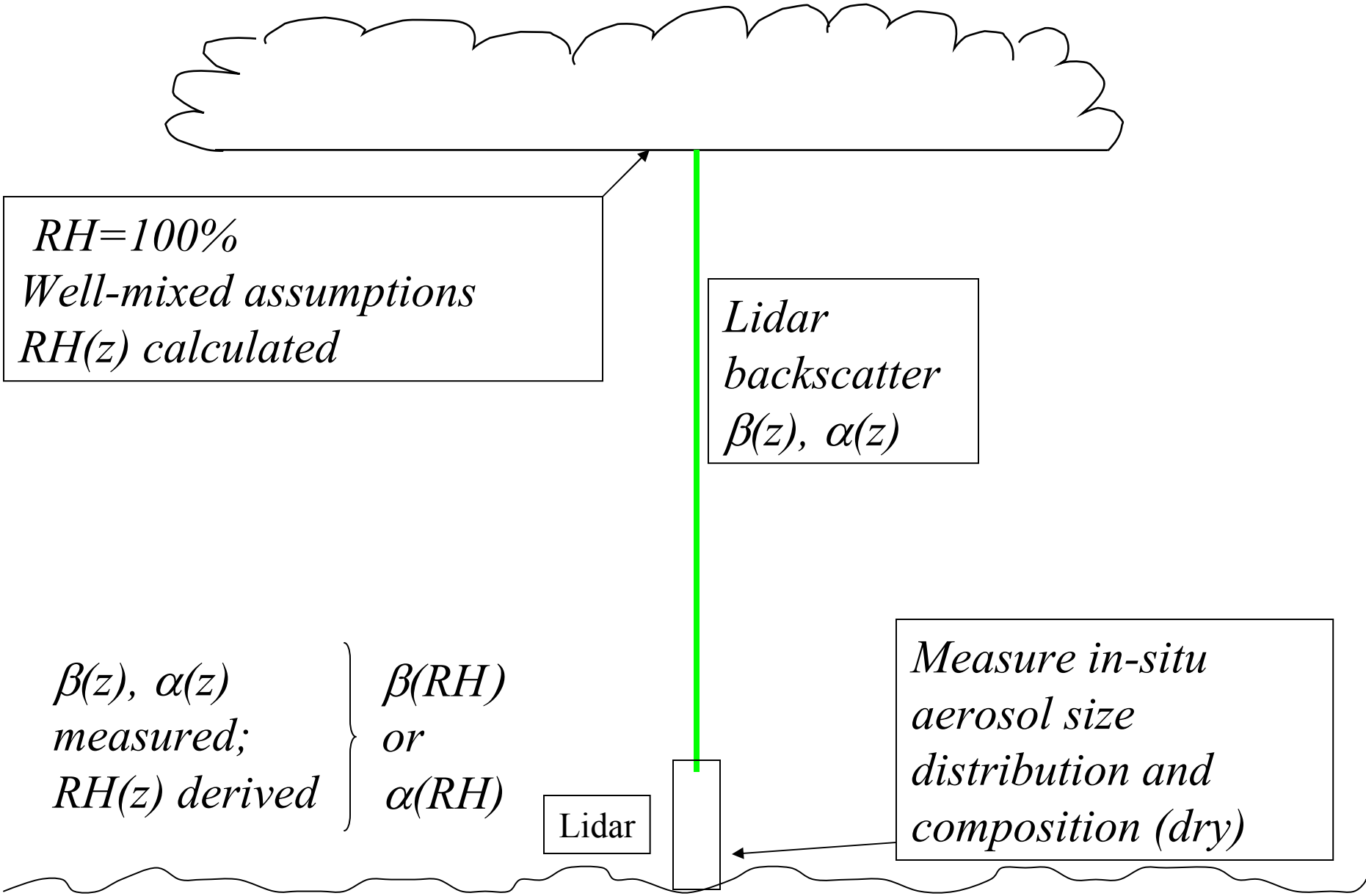
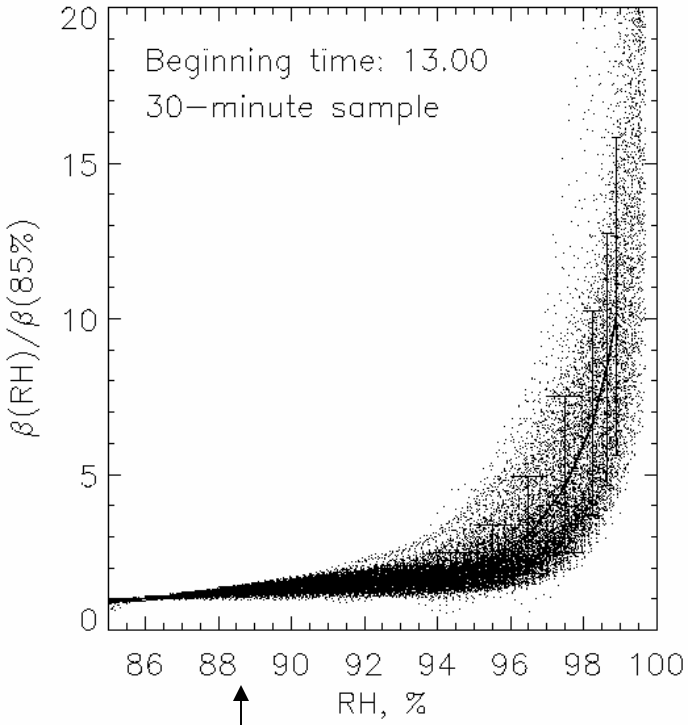
Two distinct but related topics

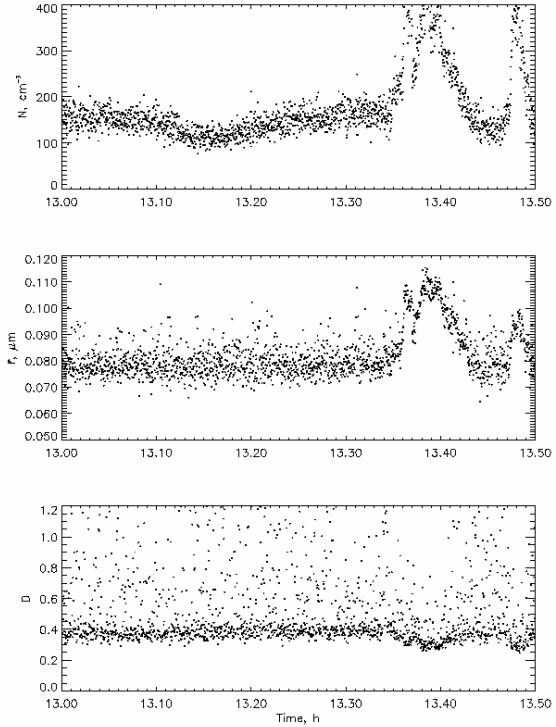
1) Quantification of lidar-derived hygroscopic growth factors *f*(RH)

2) Ground-based remote sensing of the Twomey effect

f (RH): **Well-mixed boundary layers**

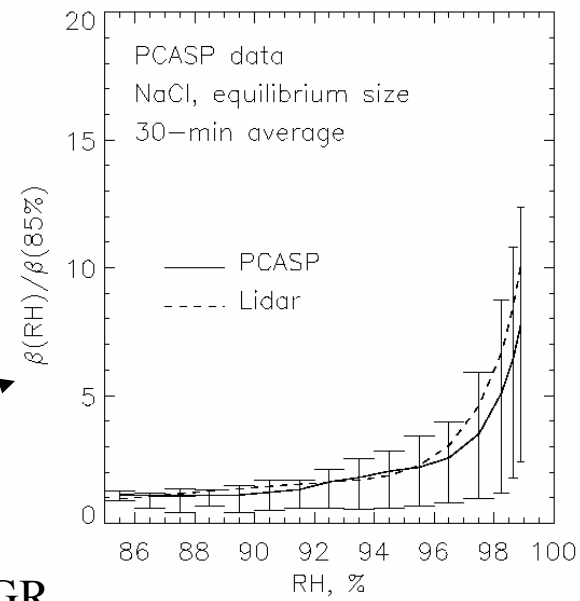






Lidar-derived β-equivalent f(RH)

In-situ PCASP



Comparison

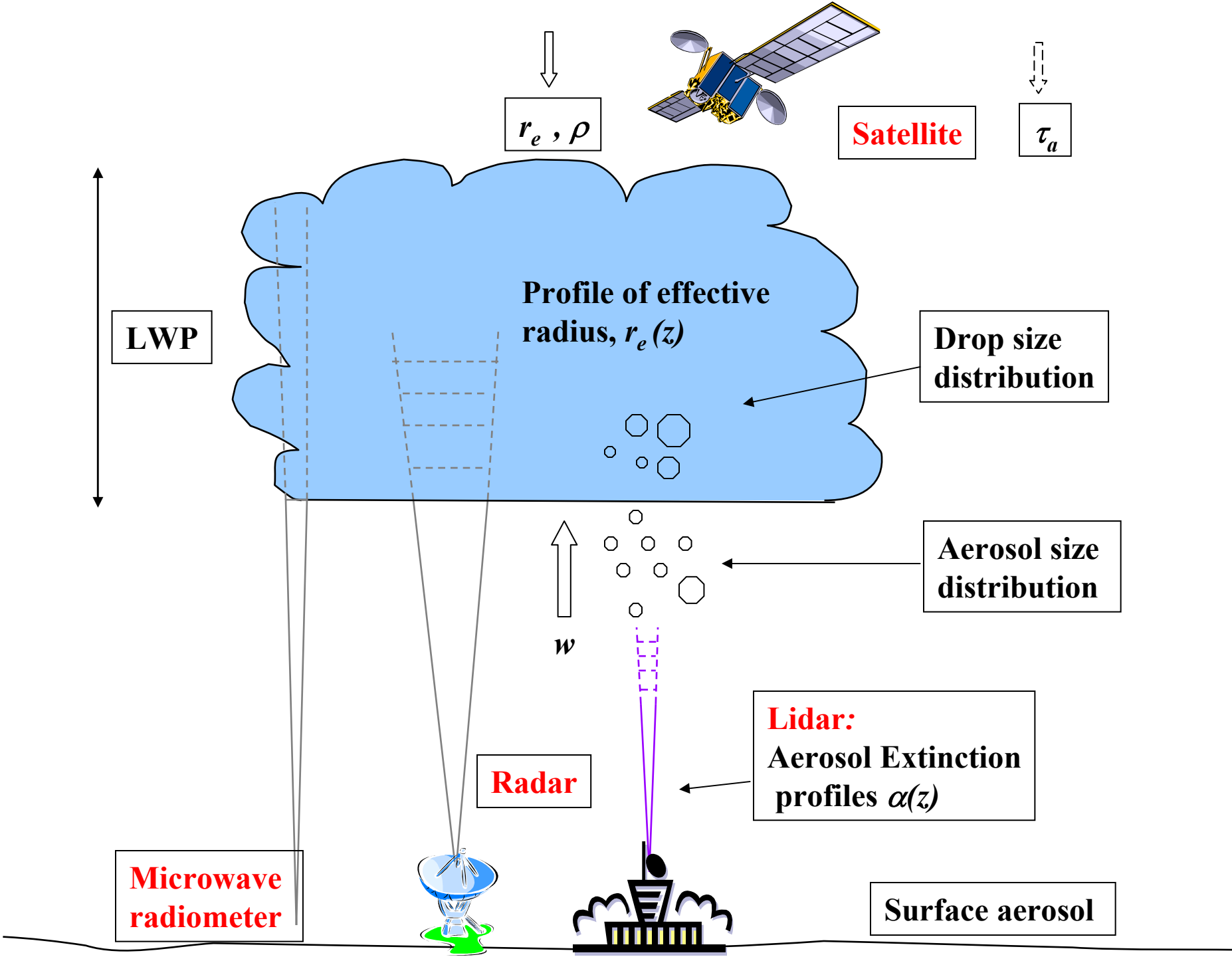
DYCOMS-II SABL 0.532 nm Airborne, low level

Feingold and Morley, 2003, to appear, JGR

Topic #2

1) Quantification of lidar-derived hygroscopic growth factors *f*(RH)

2) Ground-based remote sensing of the Twomey effect


r_e , ρ
Satellite
τ_a
LWP
Profile of effective radius, $r_e(z)$
Drop size distribution
Aerosol size distribution
w
Lidar:
Aerosol Extinction profiles $\alpha(z)$
Radar
Microwave radiometer
Surface aerosol

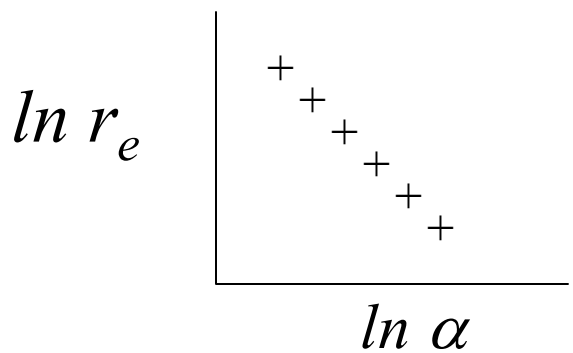
Southern Great Plains

- MMCR K-band 8-mm cloud radar
- Microwave radiometer
  - LWP
- CARL Raman Lidar
  - aerosol extinction, α

r_e, α, LWP

r_e from Frisch et al. 2002

At constant LWP



$$\mathbf{IE} = -\frac{d \ln r_e}{d \ln \alpha}$$

Theory

Twomey:

- $N_d \sim N_a^{a1}$ (drop number – aerosol number)
- $\tau_d \sim N_d^{1/3}$ (cloud optical depth – drop number)
- $r_e \sim \tau_a^{-a1/3}$ (effective radius – aerosol optical depth)

- $$\boxed{\mathbf{IE} = -\frac{d \ln r_e}{d \ln \alpha} = \frac{a_1}{3}}$$

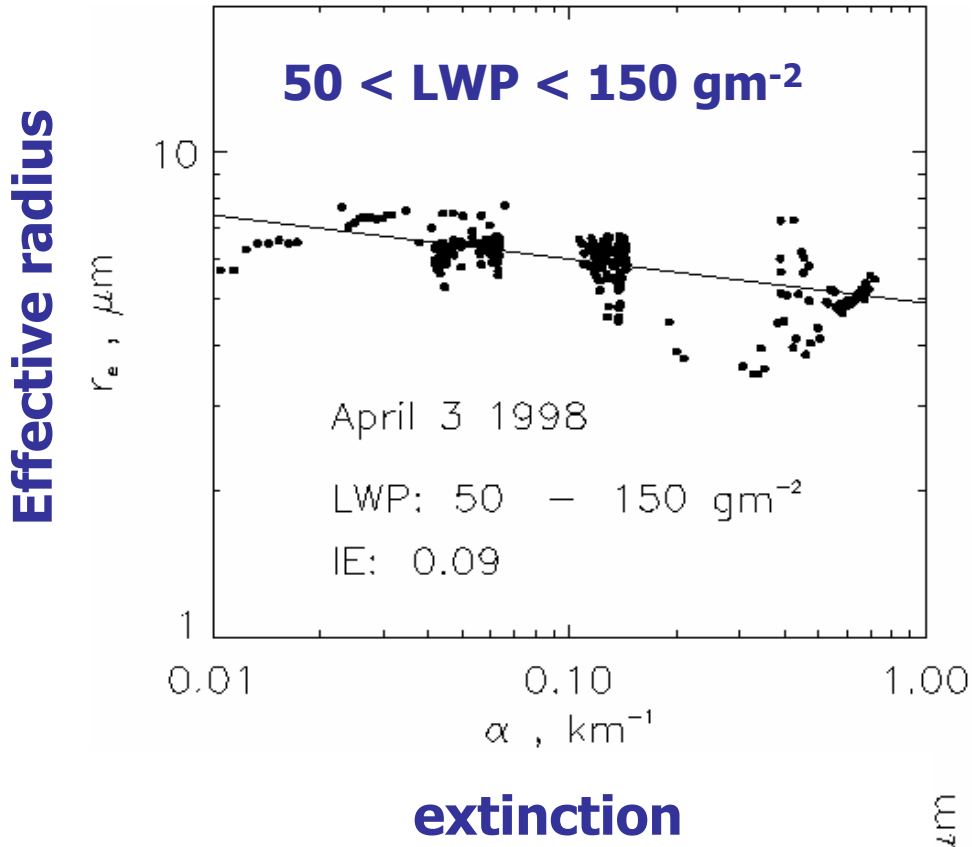
$a_1 < 1$ => IE<0.33

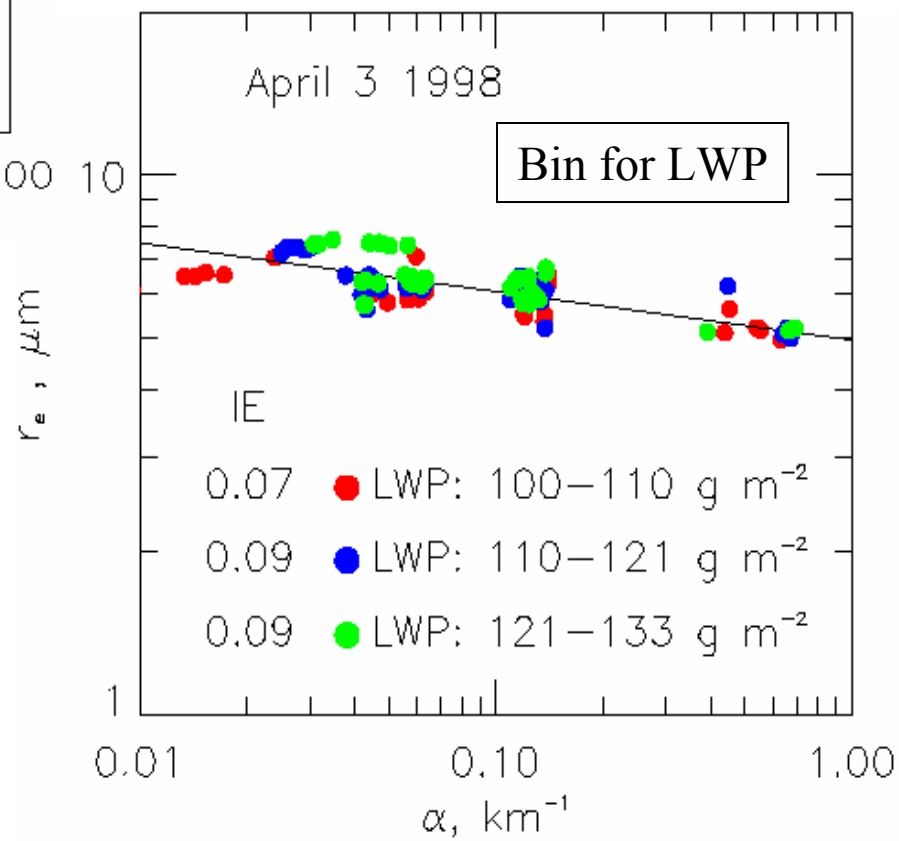
$$\boxed{N_d \sim N_a^{a_1}}$$

Slope is related to

- *aerosol composition*
- *Size distribution*

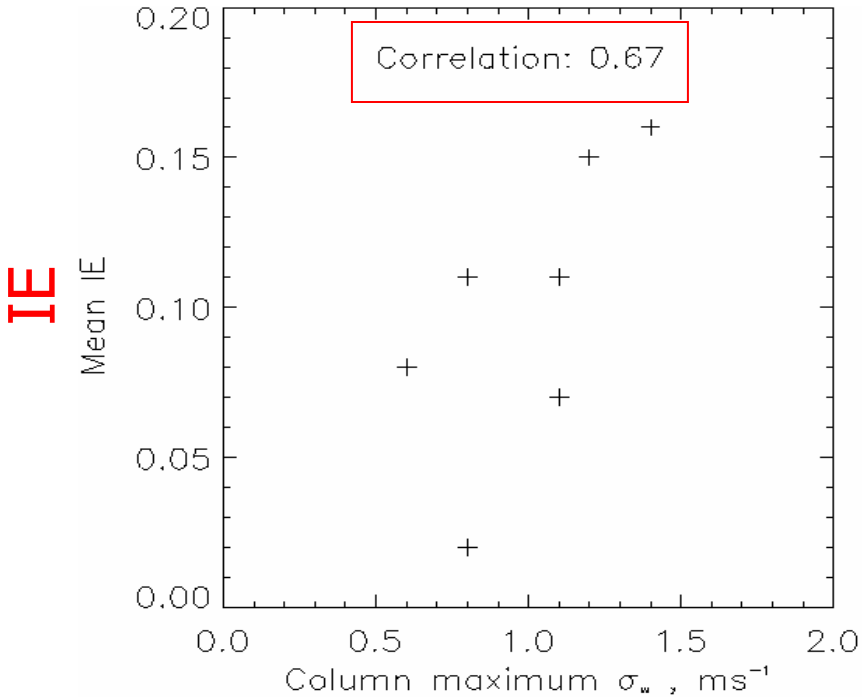
E.g., Feingold, et al., JGR, 2001, 106, 22907-22922





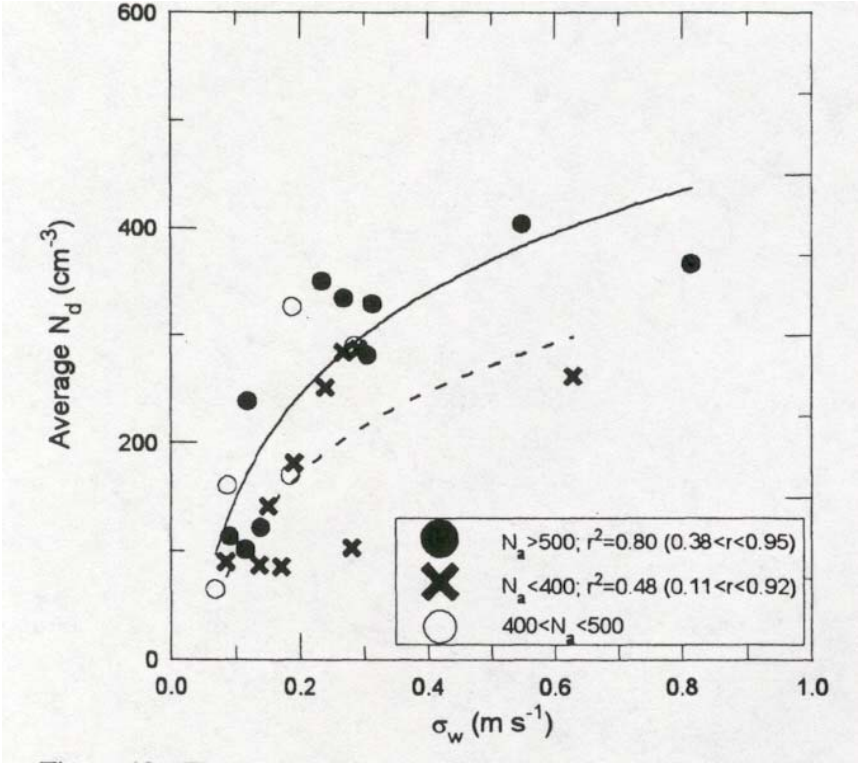
Updrafts only
Z_{max} < -17 dBZ
Ice free, nonprecipitating clouds
Aerosol extinction at z=350m
(avoid high RH)

Relationship between IE and cloud turbulence for 7 cases



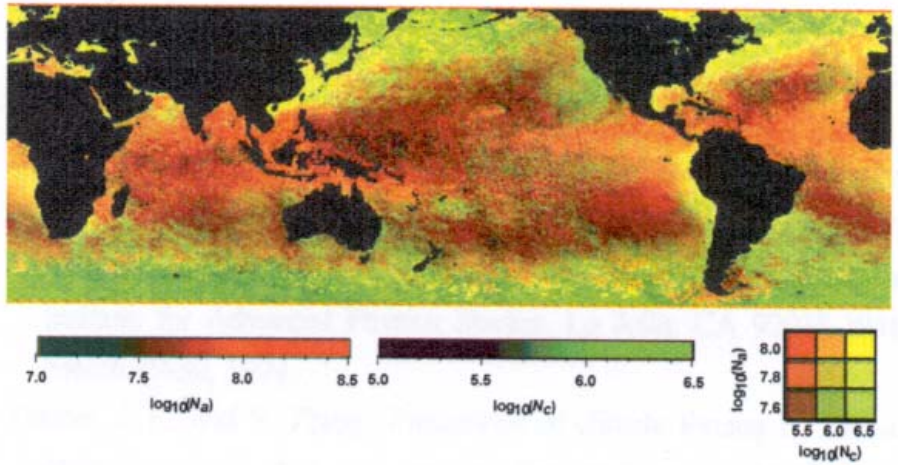
σ_w = Standard deviation of updraft w

Leaitch et al 1996

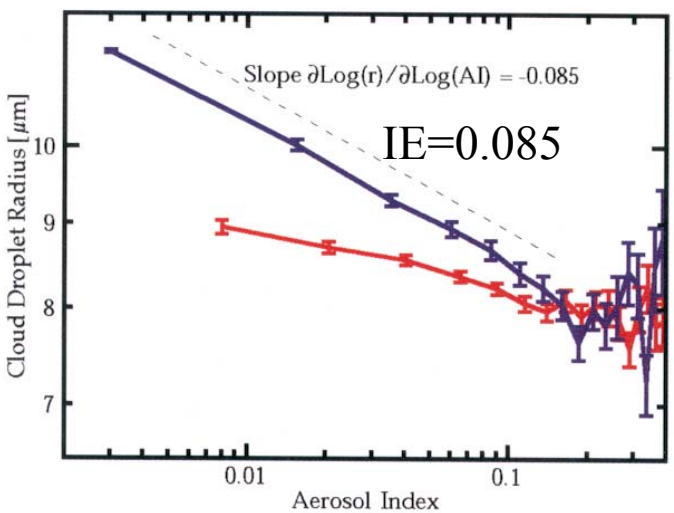


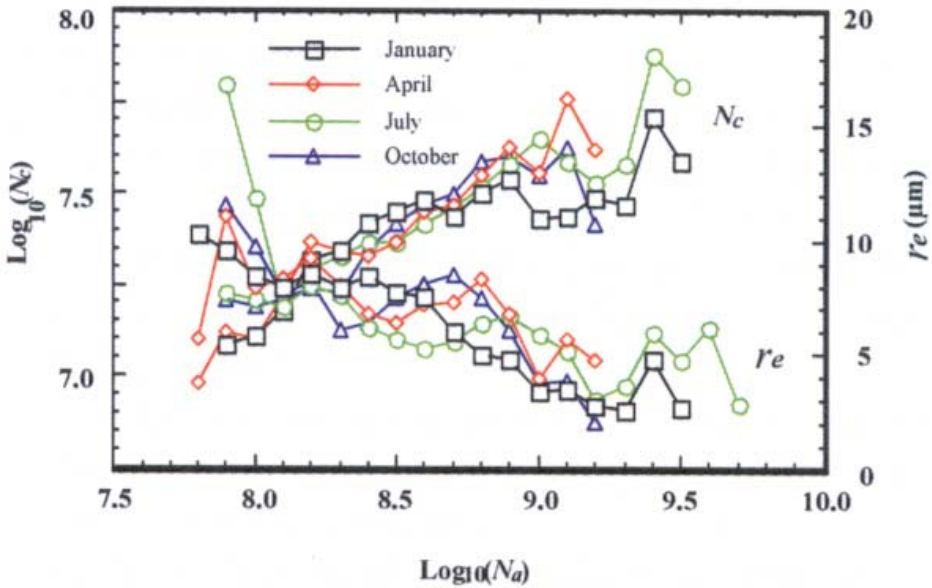
Comparison with other work

- *Nakajima et al.* 2000
  - Globally, over oceans: IE=0.17



- *Breon* et al. 2001
  Globally, IE = 0.04 - 0.085





Modeling

Application of

- Cloud parcel models (water vapor uptake, activation theory)
- Large Eddy simulations with size resolved aerosol and cloud microphysics