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Investigations of aerosol-cloud-precipitation processes in observations and models at The University of Arizona

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COMPARISON OF CLOUD PROPERTIES IN SATELLITE AND SHIP MEASUREMENTS TO CAM SIMULATIONS

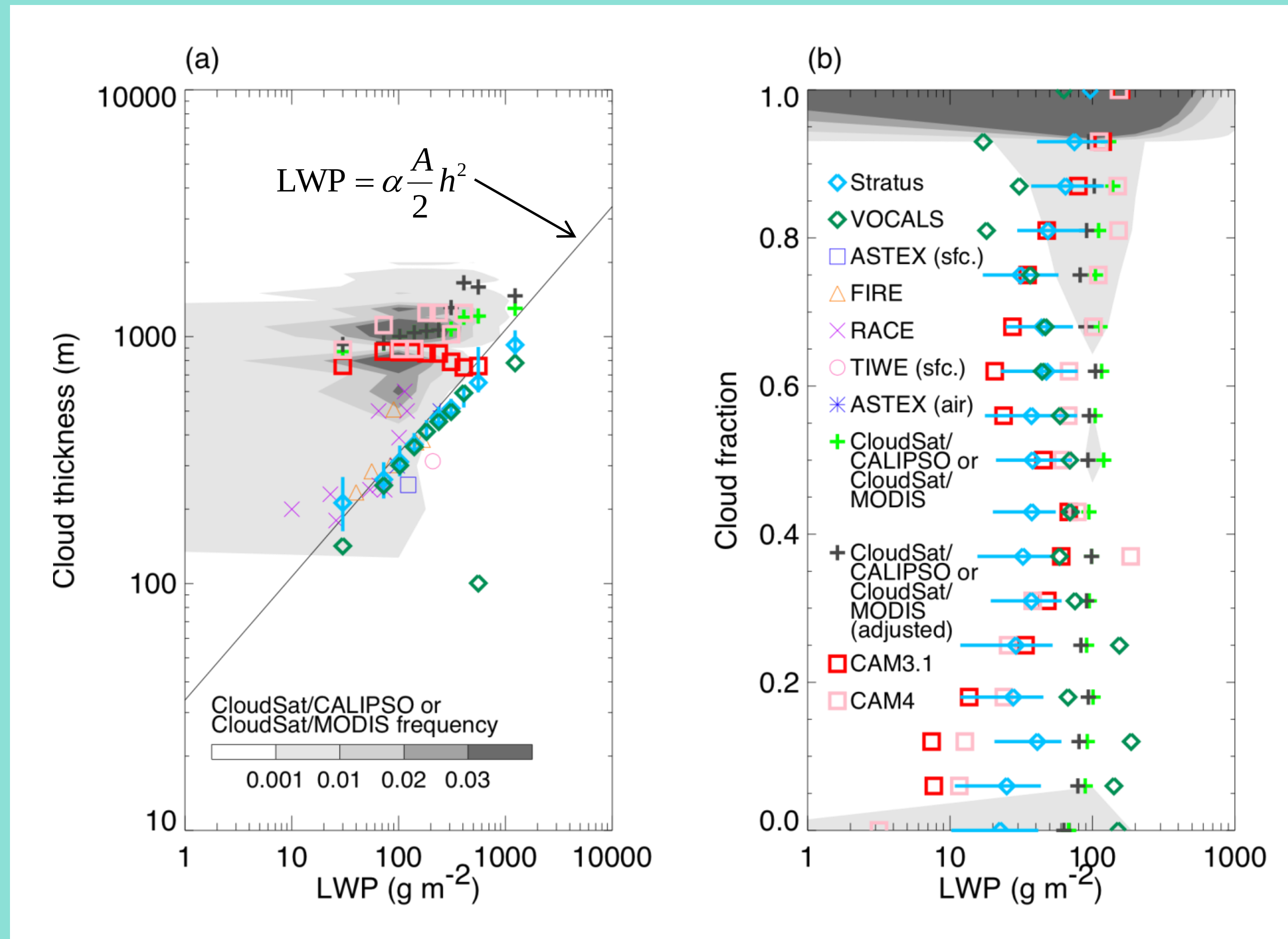
Brunke, de Szoeke, Zuidema, and Zeng

(2010, *ACP*, 10, 6527-6536)

Website: http://www.atmo.arizona.edu/~brunke/VOCALS

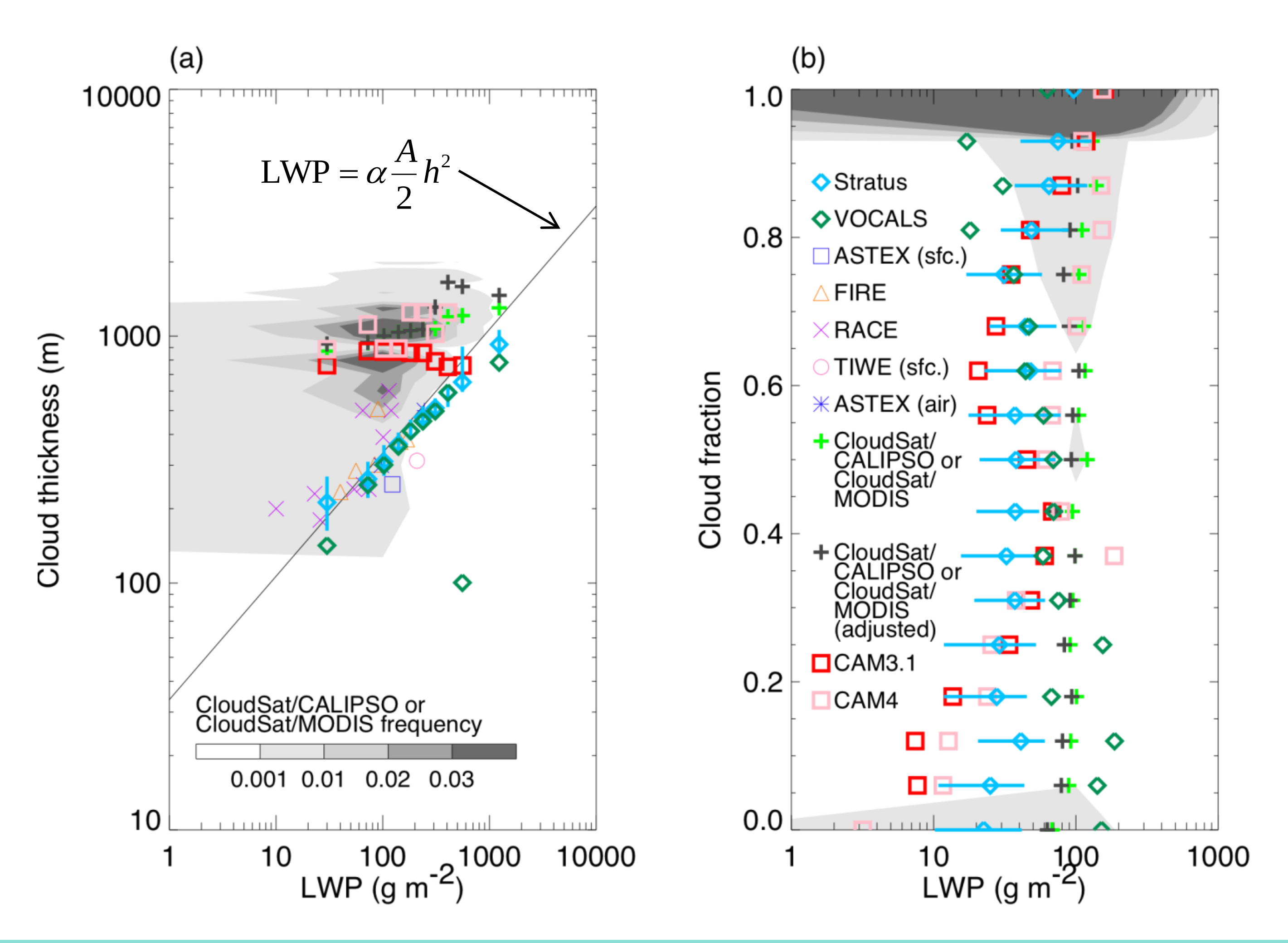
CLOUD PROPERTY COMPARISON

- Cruise data falls along adiabatic relationship.
- Cloudsat team products: account for precip., use adiabatic relationship for cloud base.



CLOUD PROPERTY COMPARISON

- Model LWP good but clouds too thick, low.
  - Very different LWP/thickness relationship.
  - LWP/CF relationship consistent w/ Stratus cruises.



UA-VOCALS
The VAMOS Ocean Cloud Atmosphere Land Study at The University of Arizona

VAMOS Ocean Cloud Atmosphere Land Study VOCALS

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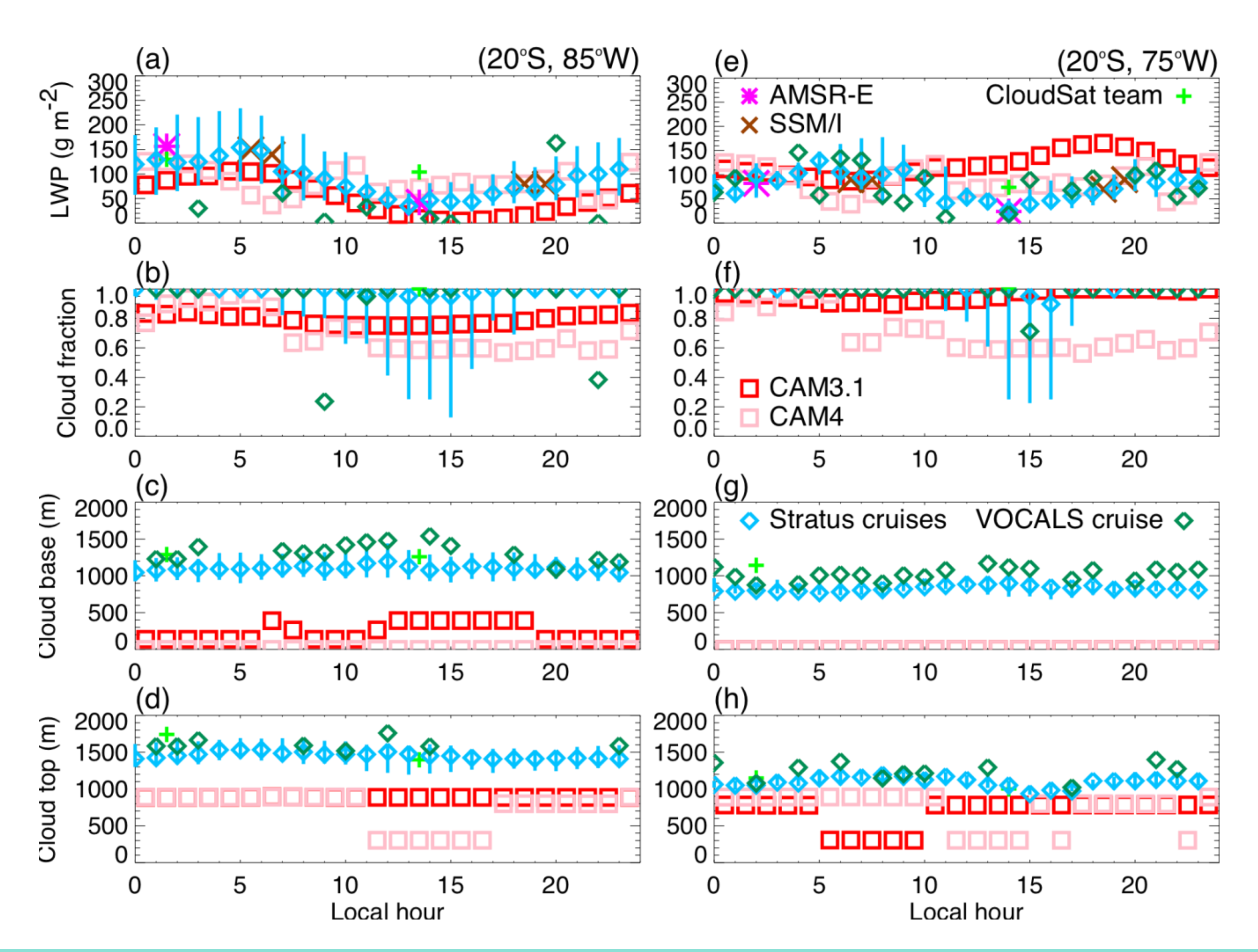
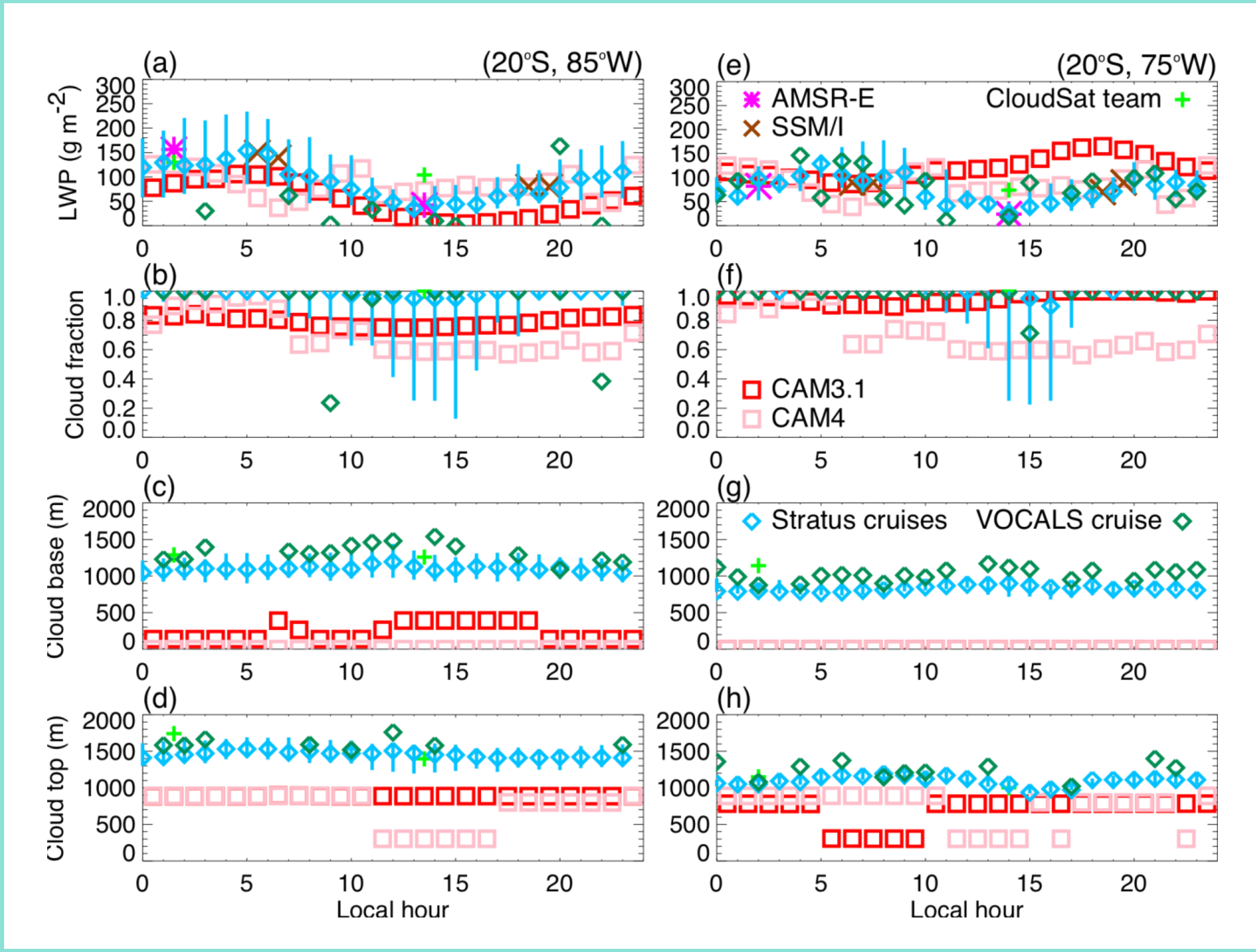
CLOUD PROPERTY COMPARISON

- VOCALS diurnal cycle compares to the Stratus cruises well, especially to the E.
- Adjusted CloudSat team data compares w/ AMSR-E, SSM/I, Stratus cruise data.



CLOUD PROPERTY COMPARISON

- Model diurnal cycle in LWP and CF good at WHOI buoy, opposite at SHOA (better in CAM4).



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AEROSOL-CLOUD-PRECIPITATION INTERACTIONS IN OBSERVATIONS AND MODELS

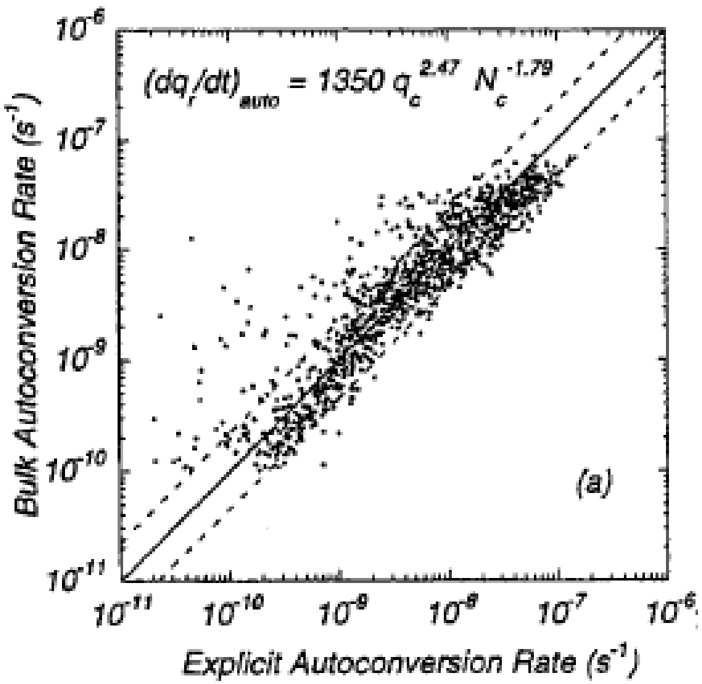
- Aerosol effects on clouds
- Cloud effects on aerosols

Aerosol-rain Interactive Term in Climate Models

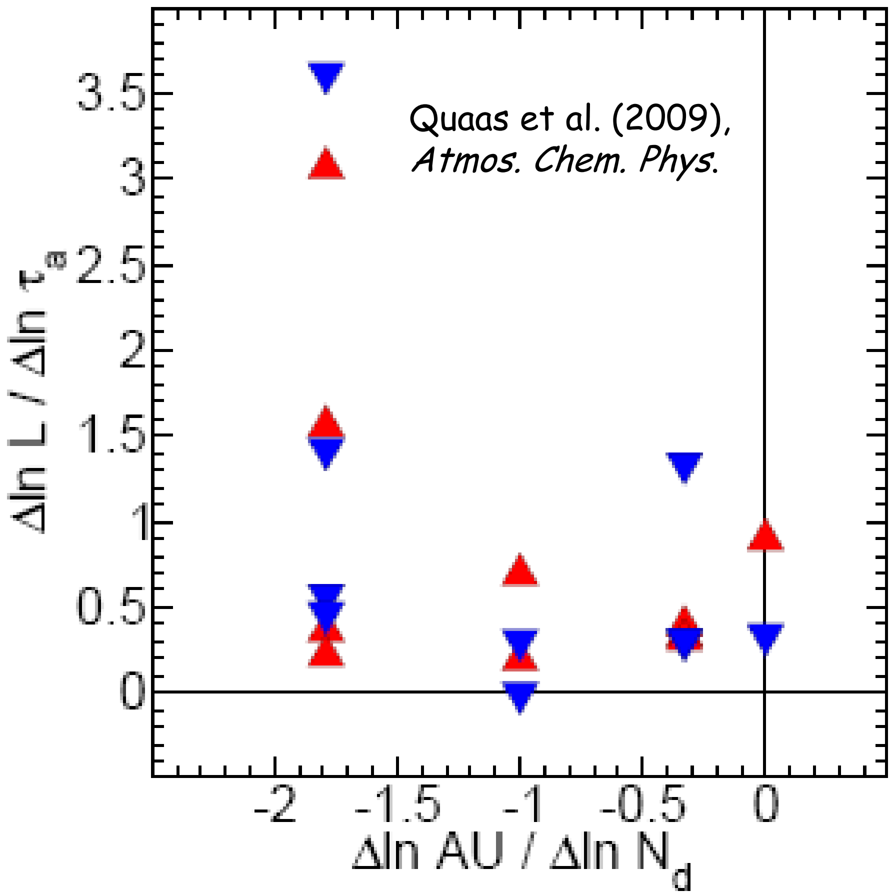
Autoconversion parameterization: $R \sim LWP^{x_1} N_d^{x_2}$

A typical value of x_2 is ~ -1.8

Values commonly prescribed in global climate models result in widely varying second aerosol indirect effect responses



Khairoutdinov and Kogan (2000), *Mon. Weather Rev.*

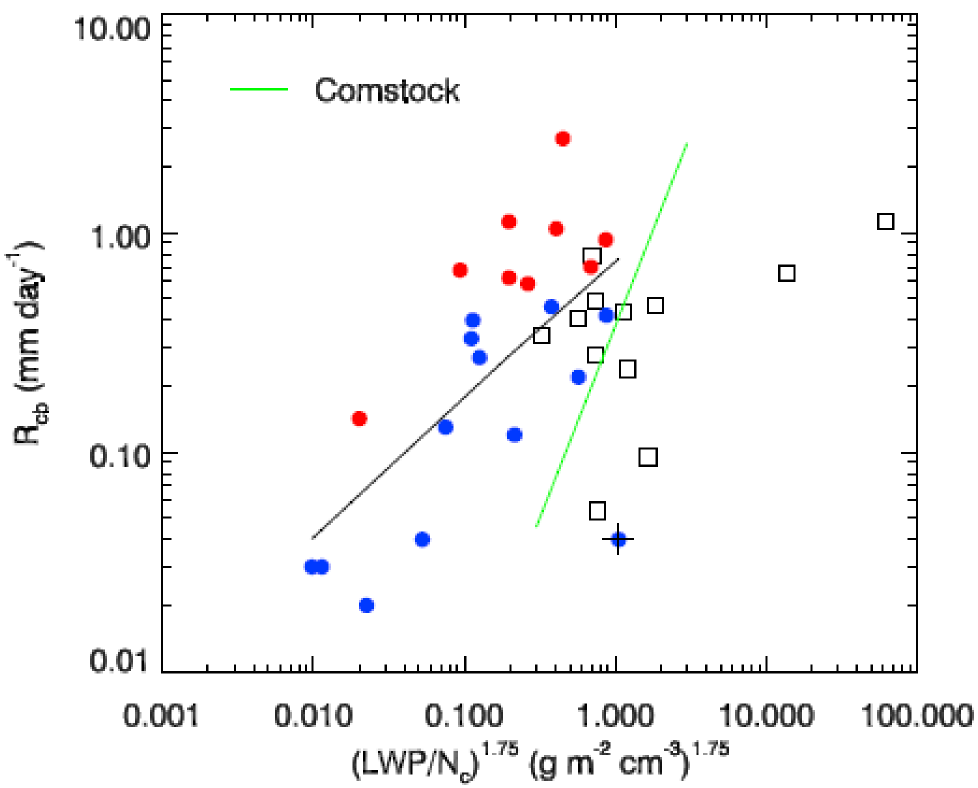


Need to improve understanding of aerosol effects on warm rain as a function of cloud type with attention to data analysis methodology

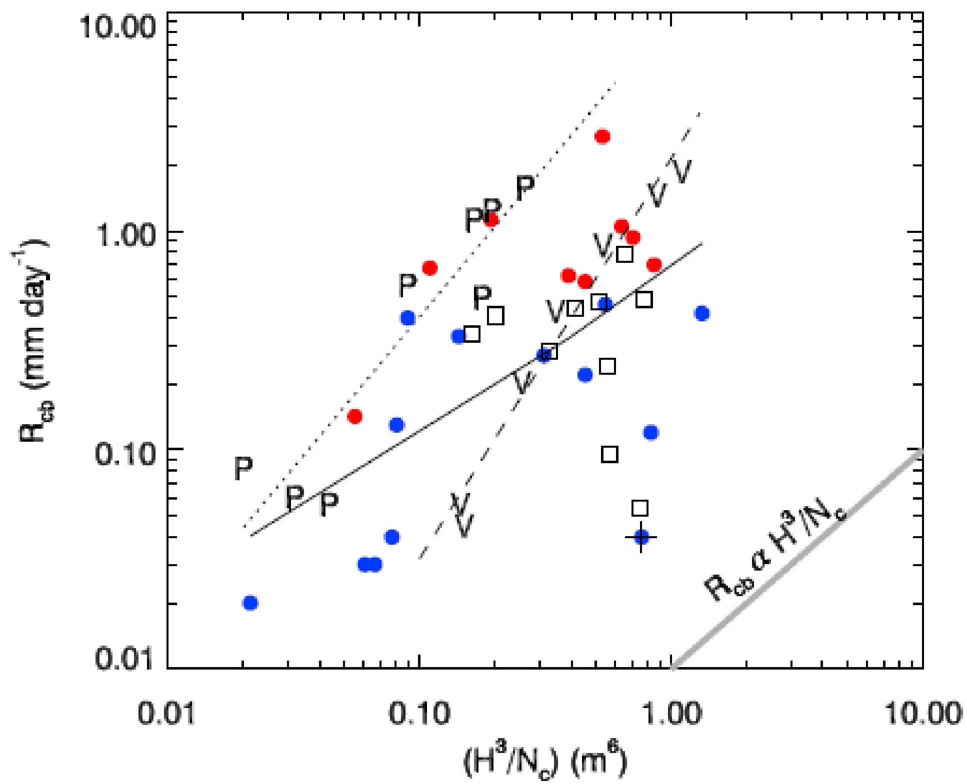
Aircraft Measurements: Aerosol-Drizzle Relationships

Cloud base drizzle rate typically expressed in terms of LWP (or cloud depth, *H*) and drop concentration

$$R \sim LWP^{x_1} N_d^{x_2}$$



$$R \sim H^{x_1} N_d^{x_2}$$



Figures adopted from Lu et al. (2009), *J. Geophys. Res.*

Pawloska and Brenguier (2003), *J. Geophys. Res.* P

Comstock et al. (2004), *Q. J. R. Meteorol. Soc.*

vanZanten et al. (2005), *J. Atmos. Sci.* V

Wood (2005), *J. Atmos. Sci.* □

Recent aircraft-based measurements suggest a wide range of values for SCu clouds (x_2 ~ -0.8 to -1.75)

Recent Work: Improve the evidence for, and quantification of aerosol effects on precipitation using observational data

ACI relates aerosol perturbations to drop size

$$ACI_r = \frac{\partial \ln r_e}{\partial \ln \alpha}$$

$$-\frac{\partial \ln r_e}{\partial \ln N_d} \sim 0.33$$

Feingold et al. (2001), *J. Geophys. Res.*

R = precipitation rate
r_e = drop effective radius
N_d = drop concentration
α = sub-cloud CCN proxy (e.g. AOD or AI)

$$\chi_r = \frac{\partial \ln R}{\partial \ln r_e}$$

Precipitation susceptibility

$$S_o = -\frac{d \ln R}{d \ln \alpha} = \text{ACI} \times \chi$$

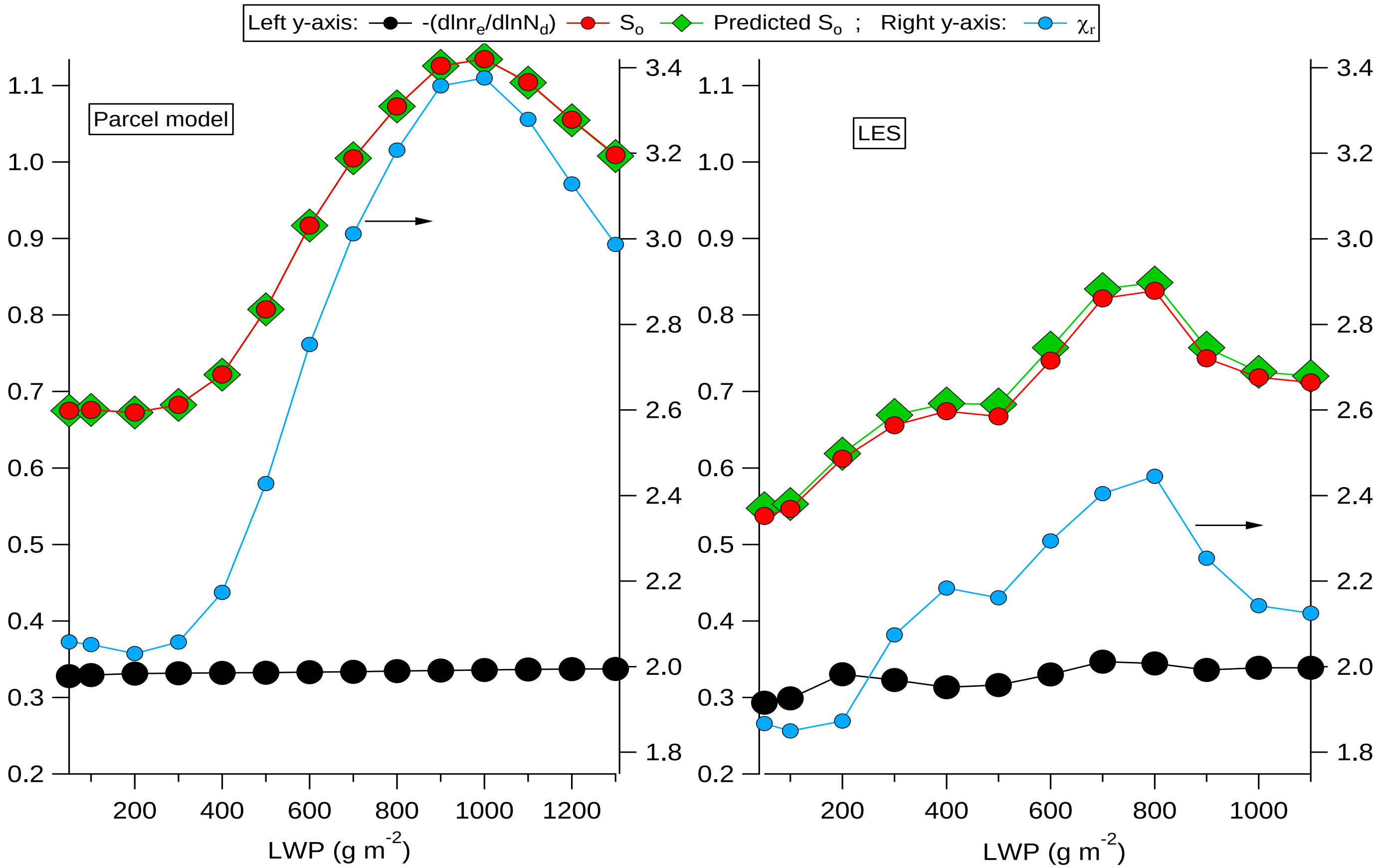
S_o is equivalent to $-x_2$ ($R \sim LWP^{x_1} N_d^{x_2}$) at fixed LWP:

$$S_o = -\frac{d \ln R}{d \ln N_d} = -x_1 \frac{d \ln LWP}{d \ln N_d} - x_2$$

Sorooshian et al. (2010), *J. Geophys. Res.*

Recent Work

Satellite observations and parcel model/LES data show similar qualitative behavior for S_o – LWP, and χ-LWP relationships in shallow cumulus cloud (Jiang et al., 2010; Sorooshian et al., 2009/2010)



Uncertainties in absolute values of S_o and χ (or similar metrics) and LWP dependence of such metrics remain between studies (e.g. Wood et al., 2009; Jiang/Sorooshian et al., 2010)

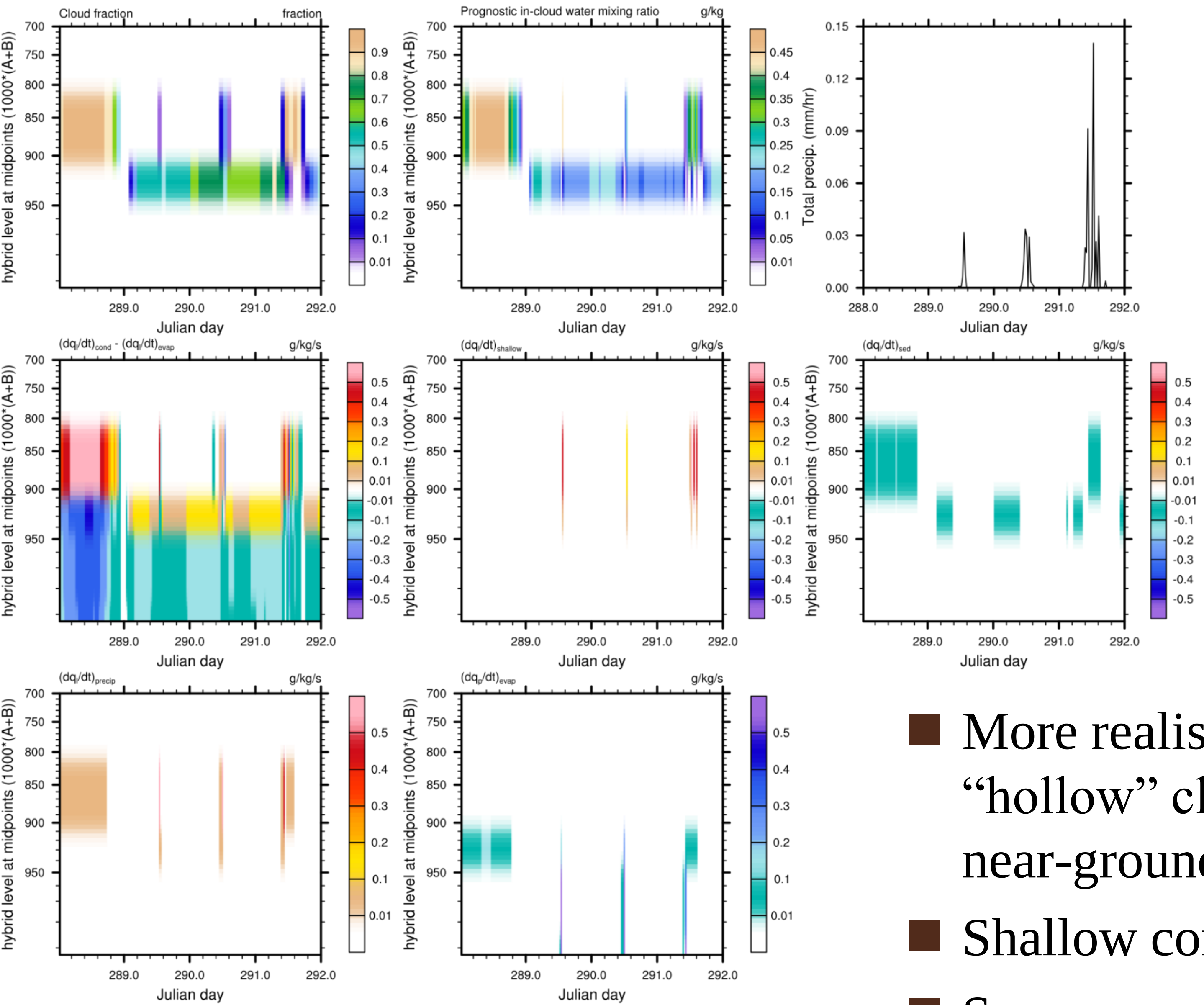
Critical to pay attention to factors such as data analysis methodology, aerosol retrieval biases, and cloud types studied. --- (Duong, Sorooshian, and Feingold, 2011, Atmos. Chem. Phys. Disc.)

PRELIMINARY CLOUD WATER BUDGET ANALYSIS IN CAM5

Process study

$$\frac{\partial q_l}{\partial t} = \sum_i \left(\frac{\partial q_l}{\partial t} \right)_i$$

BUDGET ANALYSIS

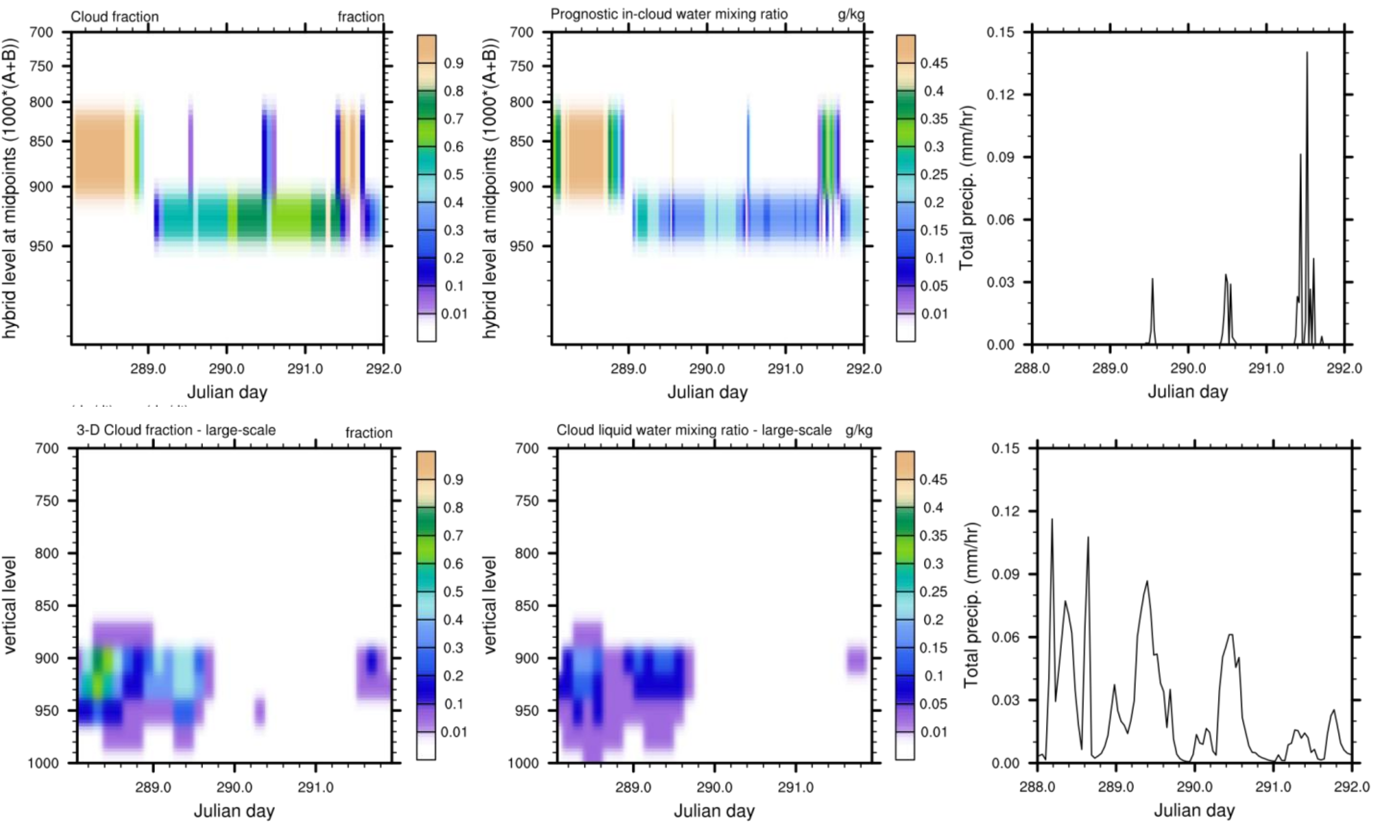


October 15-18, 2006

20° S, 85° W

- More realistic clouds: no more "hollow" clouds, clouds no longer near-ground.
- Shallow convection detrainment.
- Some conversion of cloud water to precip., most evaporated.

BUDGET ANALYSIS



CAM5

MERRA

- MERRA clouds lower, disappears for 1½ days.
- Much higher, persistent precip.
- How do these results compare w/ observations?
- How do aerosols affect the CAM5 simulations of cloud/precip. properties?