Interactions Between Water and Biomass Burning Aerosol Particles

Armin Sorooshian

Chemical & Environmental Engineering

Atmospheric Sciences

University of Arizona

NCAR JFF

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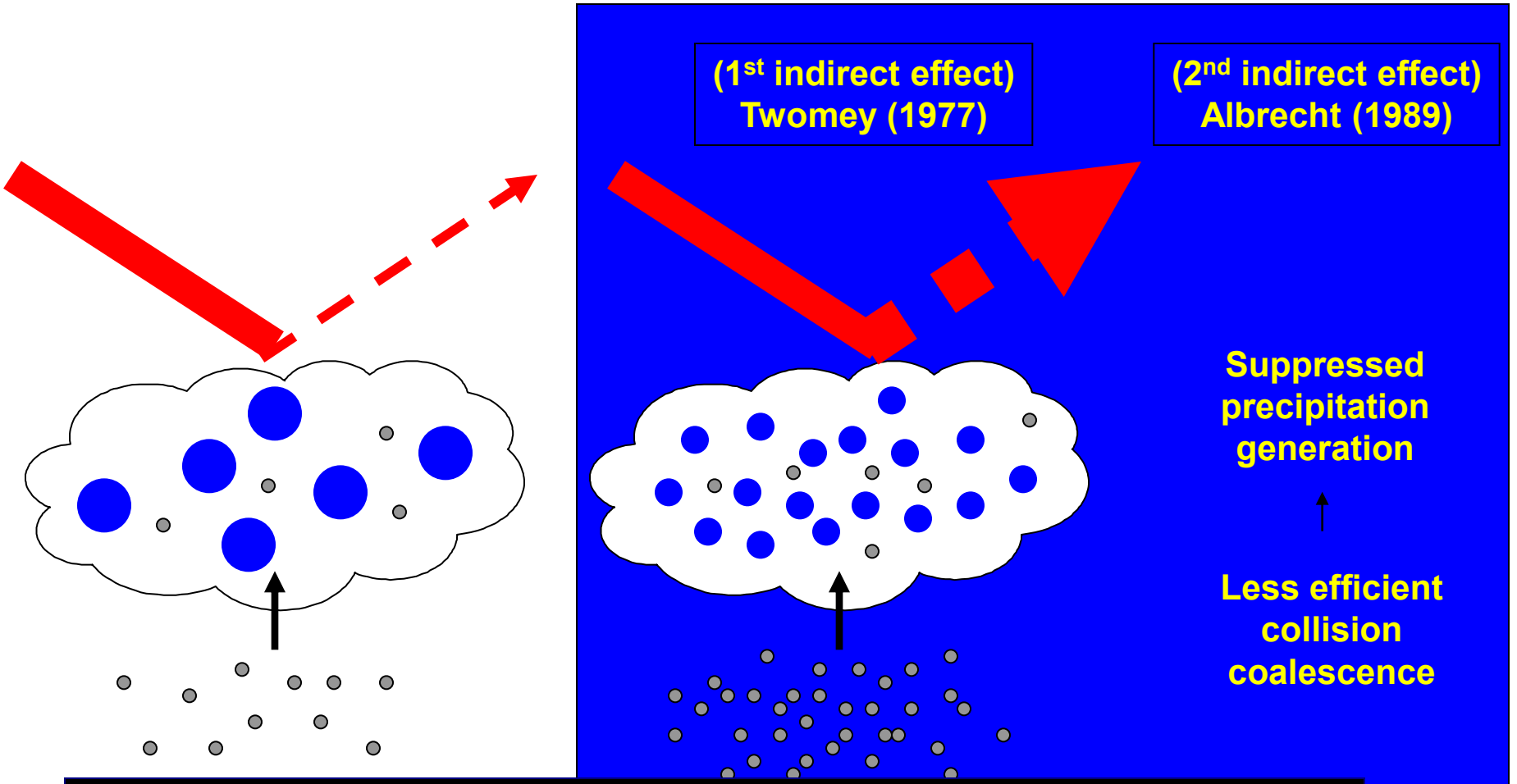
The Physical Basis for Aerosol Particle Effects on Clouds

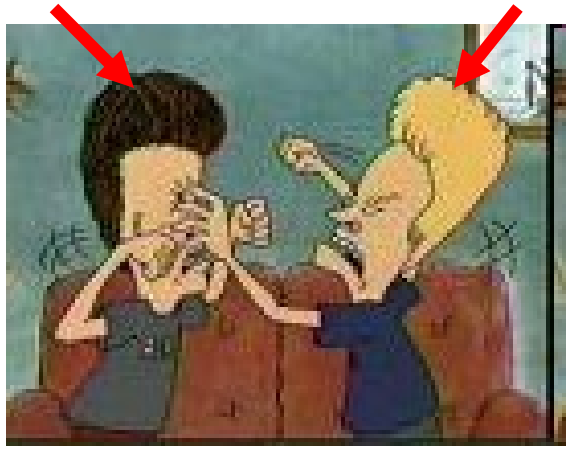


Smoke aerosol particles can invigorate convection, transporting water to supercooled temperatures where ice nucleation occurs.

Measurement Challenges

- Isolating a particle effect
- Correlation vs. causality
- Limited data sets

Scientist A Scientist B



"It would be surprising if the microphysics of a cloud played no part in determining its rainfall, but we must await further results if this is to be adequately demonstrated" - Warner, 1971

- Aircraft and ground-based studies
  - Limited spatial/temporal range
  - Aerosol variability limitations
- Satellite studies
  - Snapshots
  - Co-location issues

Precipitation Susceptibility (S_o)

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

"Precipitation susceptibility" relates a change in precipitation rate to perturbations in drop concentration

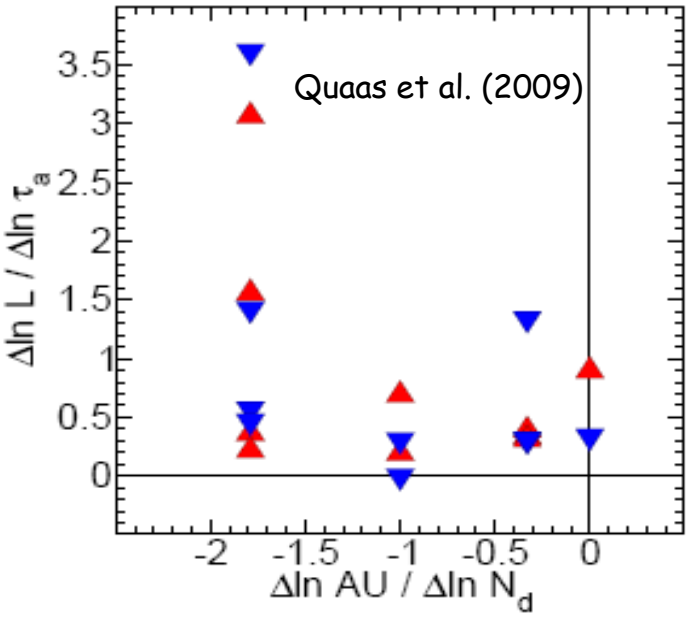
R = rain rate *N_d = Drop concentration*

Sorooshian et al. (2009)

How Does S_o Relate to Climate Models?

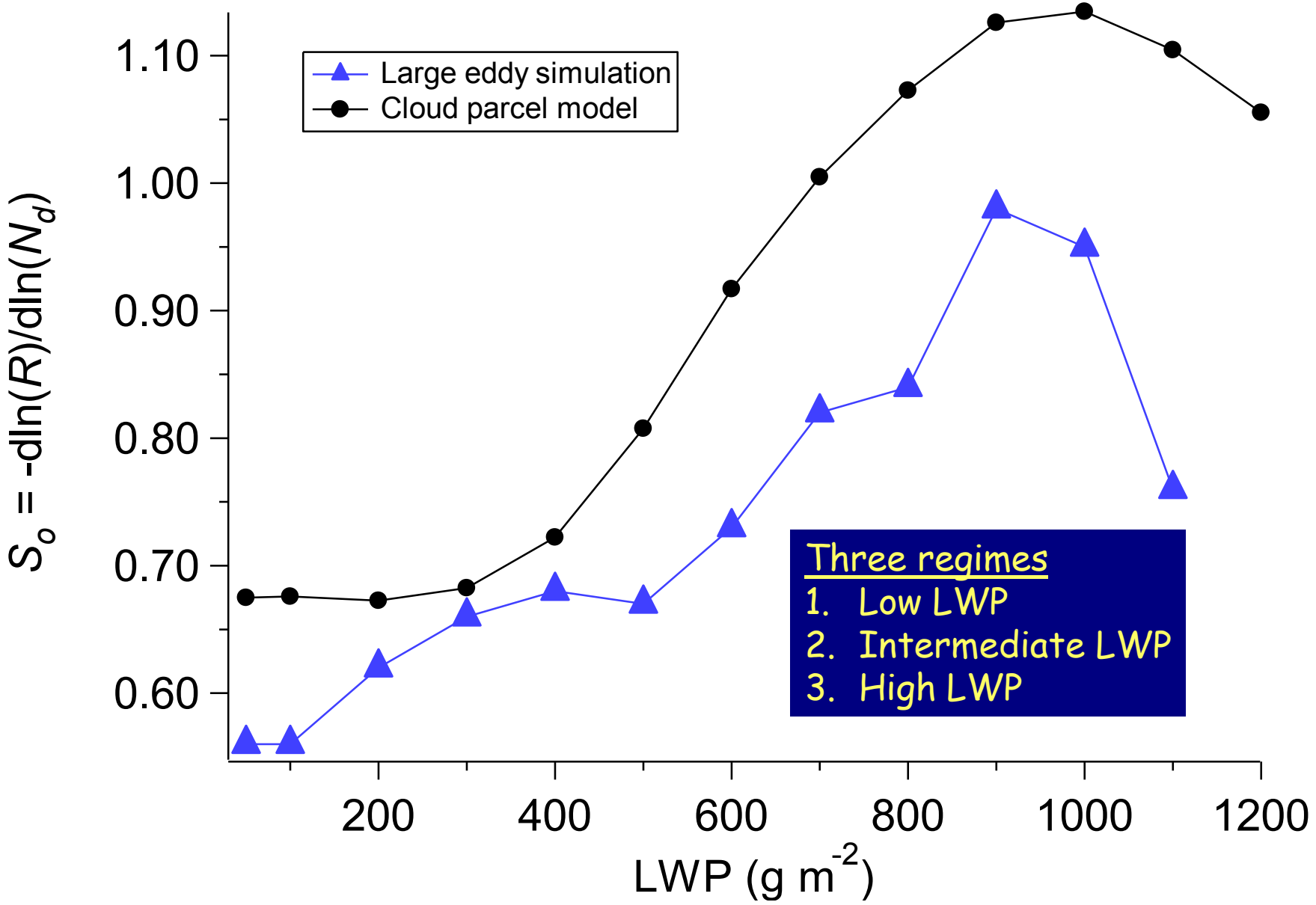
Autoconversion parameterization: $R \sim LWP^{x_1} N_d^{x_2}$

S_o is equivalent to "-x_2" at fixed LWP: $S_o = - \frac{d \ln R}{d \ln N_d} = - x_1 \frac{d \ln LWP}{d \ln N_d} - x_2$

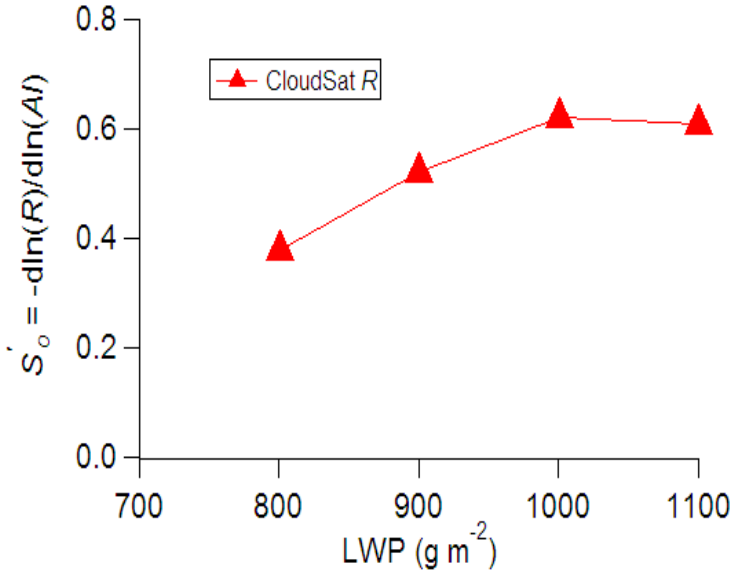


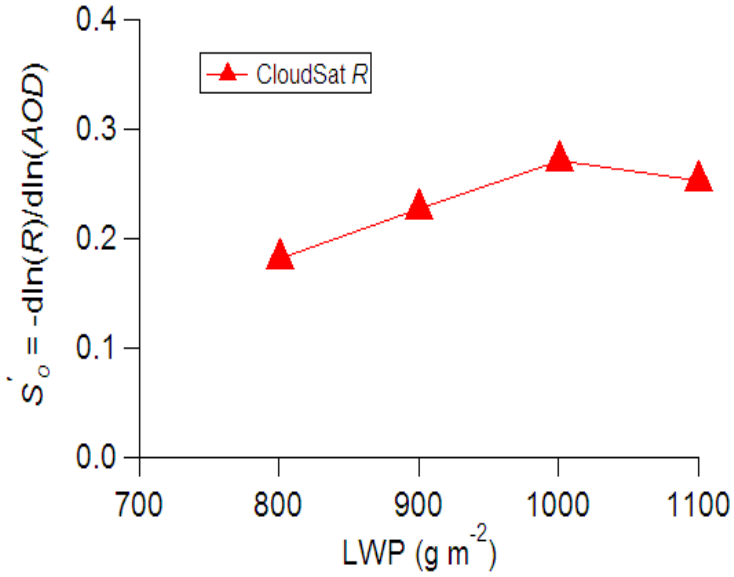
Values commonly prescribed in global climate models result in widely varying second aerosol indirect effect responses

Models of Varying Complexity Reveal Qualitatively Similar S_o Behavior



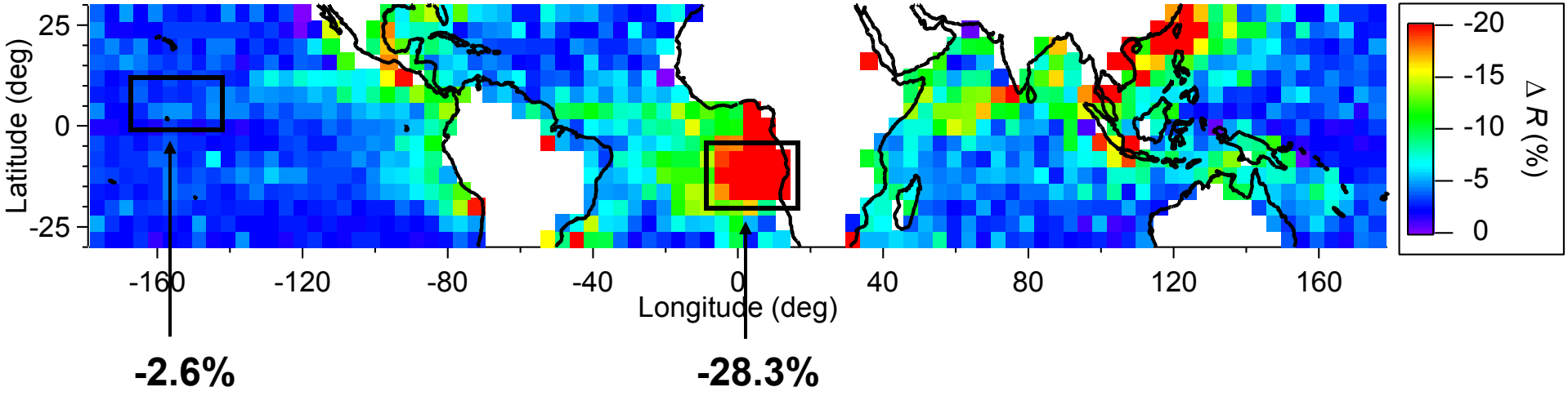
A-Train Results: Shallow Cumulus Clouds



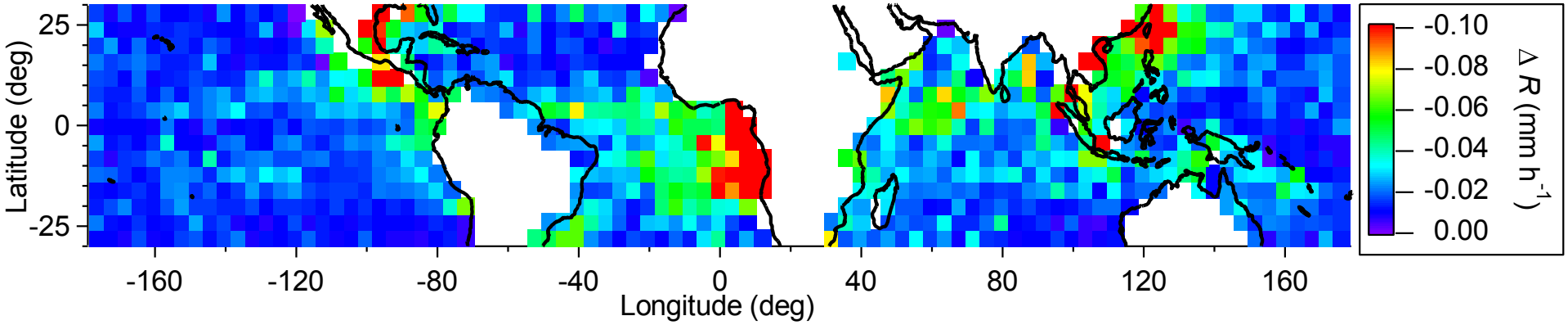


Similar qualitative behavior as compared to models for shallow warm clouds

Simplified Look at Potential "Relative Reduction" in Rain Owing to Aerosol Particle Perturbations

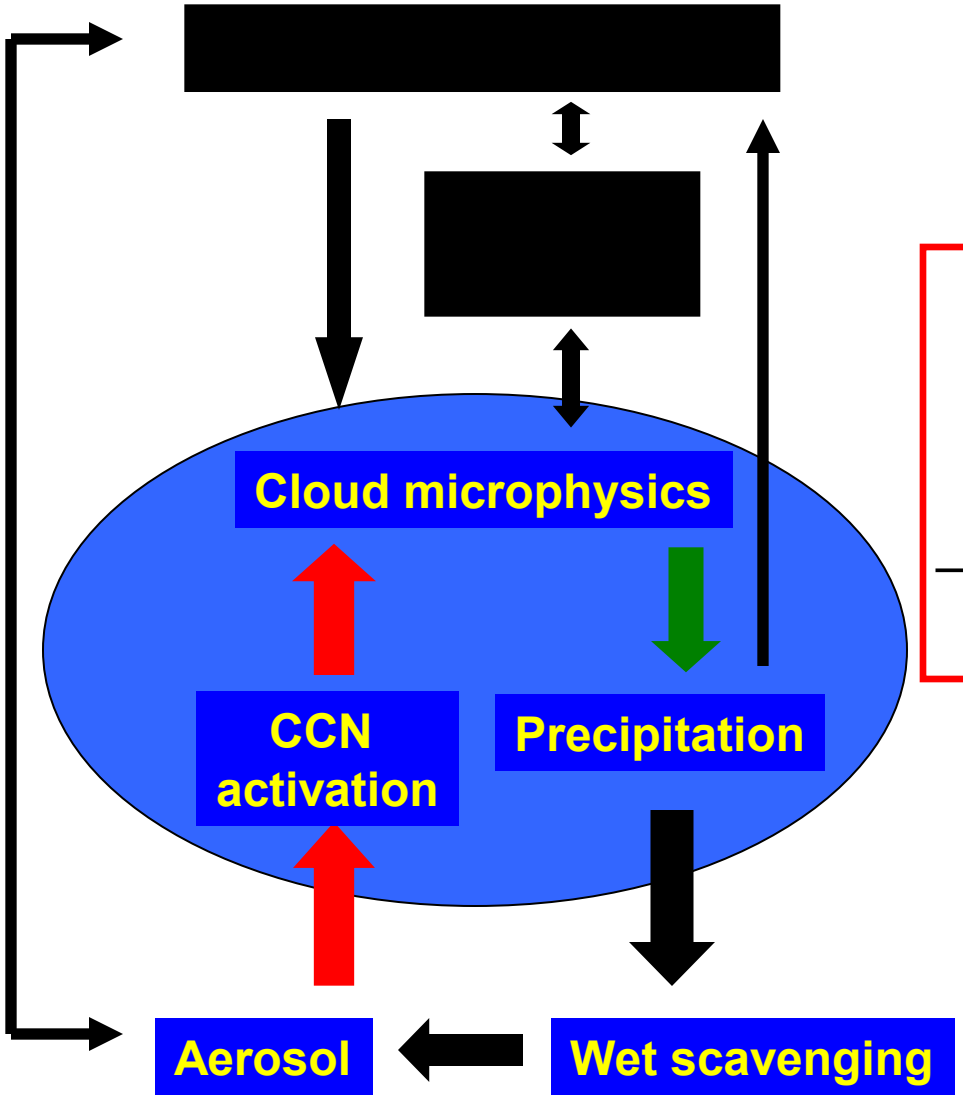


Regions most susceptible in a RELATIVE sense may not always coincide with those most susceptible in an ABSOLUTE sense



Deconstruction of S_o

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



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

$$\text{ACI}_r = -\frac{\partial \ln r_e}{\partial \ln \alpha}$$

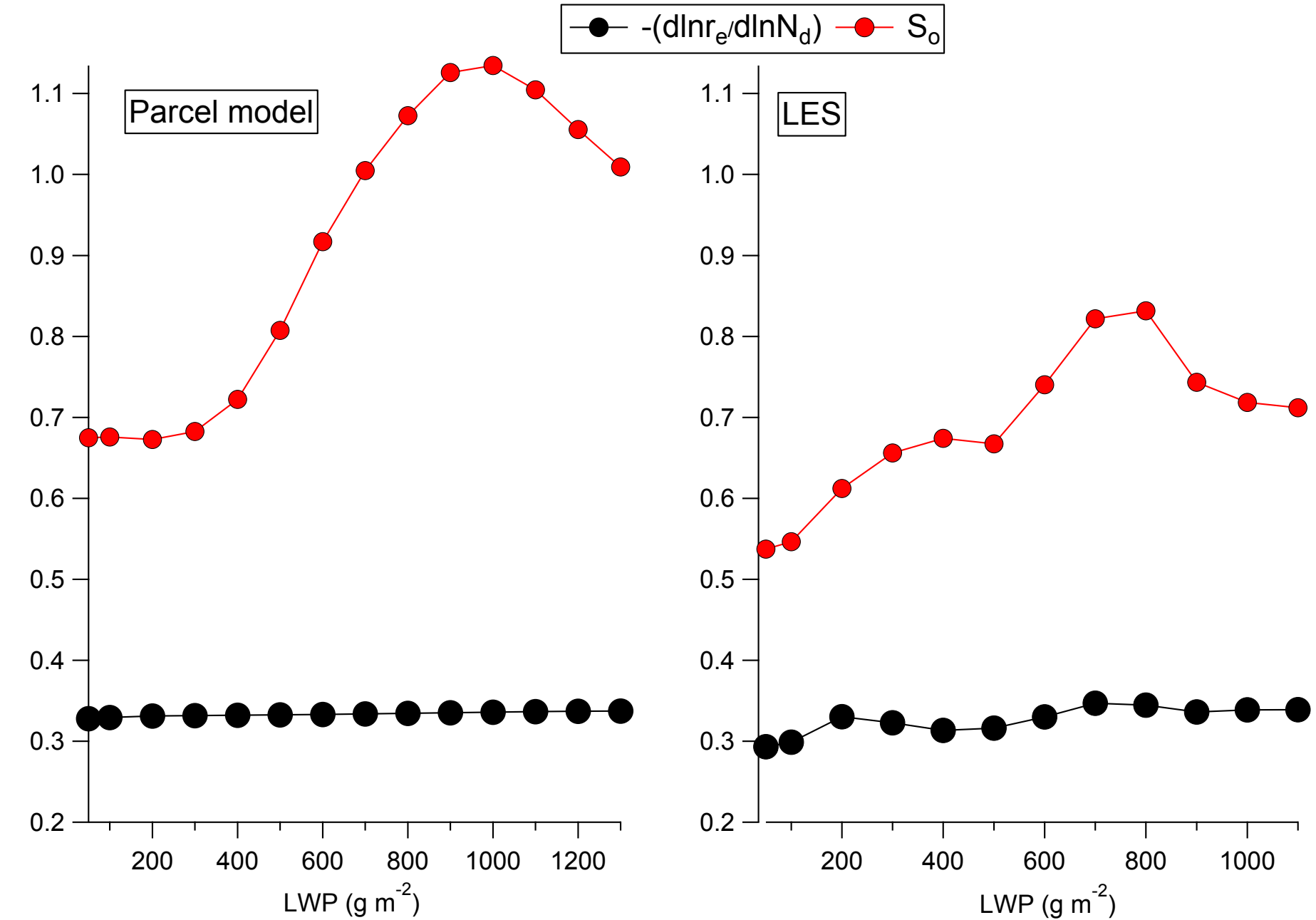
$$-\frac{\partial \ln r_e}{\partial \ln N_d} \sim 0.33$$

Feingold et al. (2001)

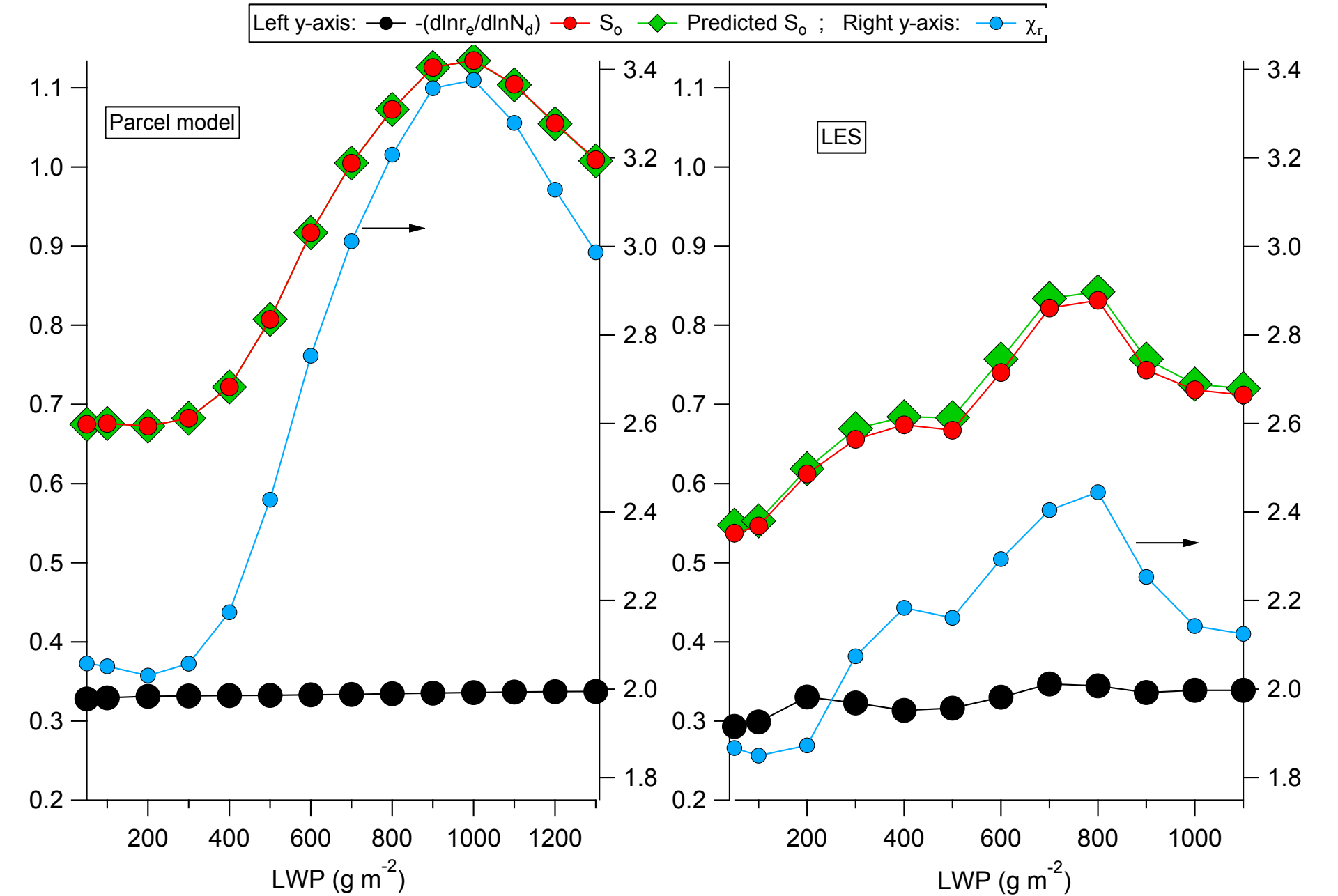
$$\chi = \frac{\partial \ln R}{\partial \ln r_e}$$

Sorooshian et al. (2010)

Deconstructing S_o with Models



Deconstructing S_o with Models



Deconstructing S_o with Aircraft Data

$$-\frac{\partial \ln r_e}{\partial \ln N_d} = 0.35$$

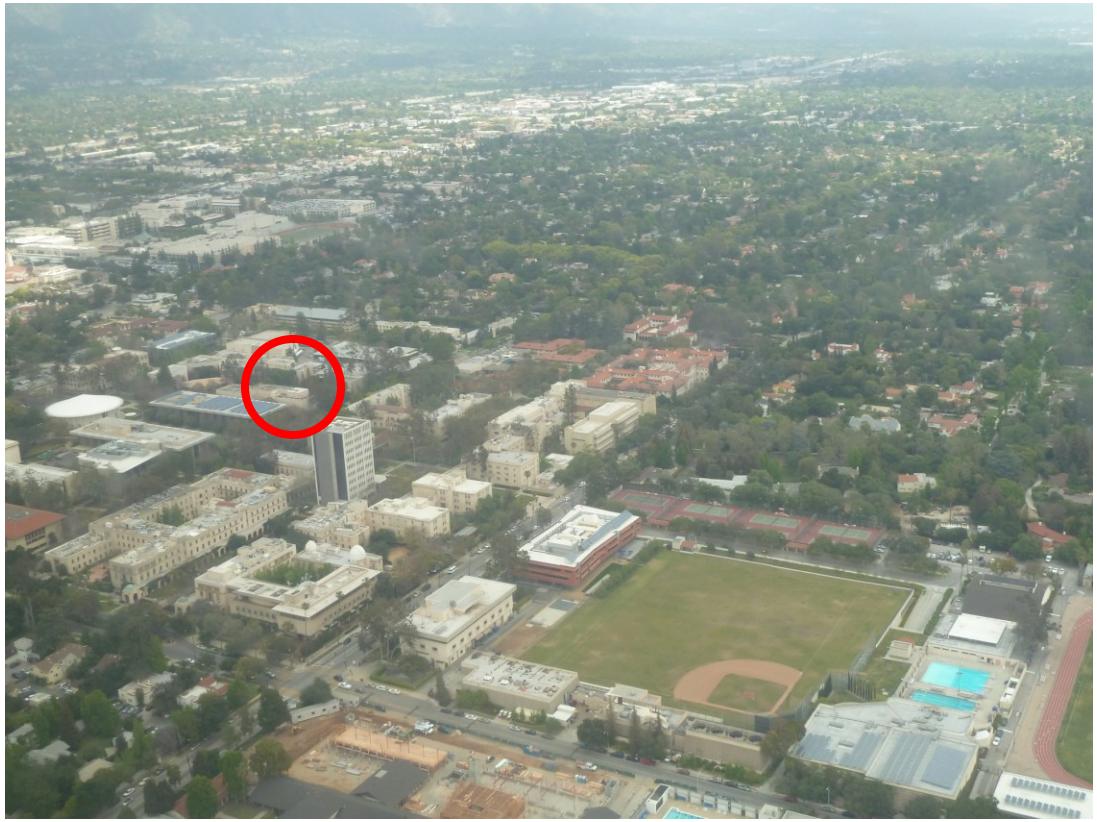
$$\chi = \frac{\partial \ln R}{\partial \ln r_e} = 3.52$$

Predicted S_o = 0.35 x 3.52 = 1.23

Directly-quantified S_o = 1.29

Next Step: Effect of Aerosol Type on S_o

Pasadena Aerosol Characterization Observatory (PACO 2009)



	Instrument	Measurement
Composition	c-ToF-AMS	Non-refractory composition
	PILS	Water-soluble composition
	Filters	OC/EC, overall composition
Hygroscopicity	DASH-SP	Multi-RH hygroscopicity
Particle distribution	DMA	Aerosol size distribution

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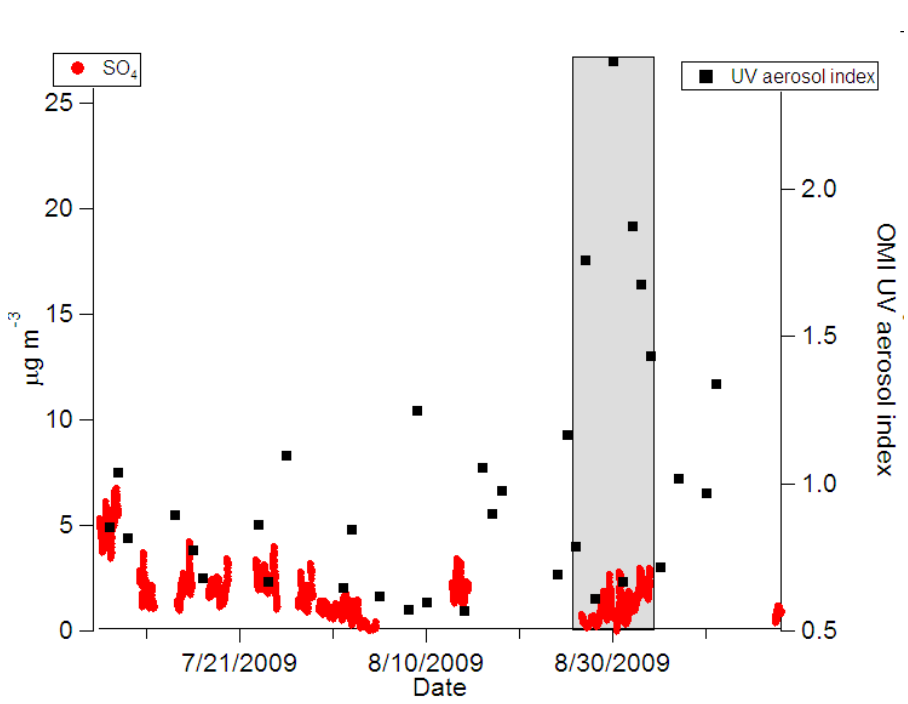
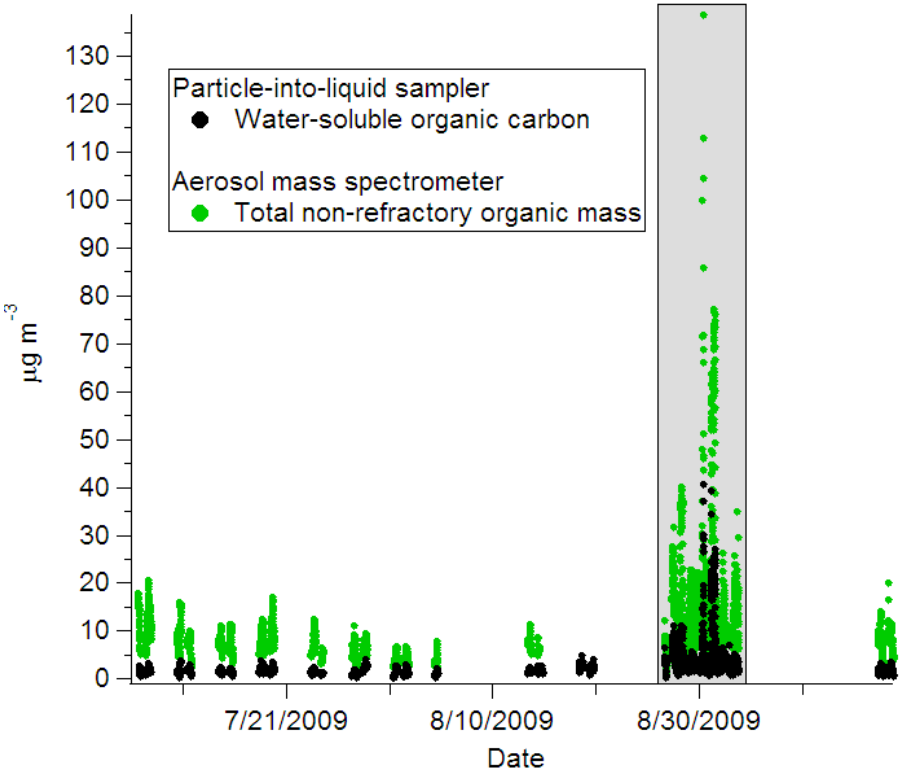




Prelim Results: Water-soluble organics accounted for up to more than 80% of the non-refractory organic mass during the Station Fire

Ongoing: In-depth aerosol physicochemical characterization (Hygroscopicity-composition closure studies, organic speciation, …)

Final Thoughts

- Potential Needs?...
  - Coordination of research efforts between modelers, field/lab scientists, and satellite experts
  - More opportunities for early-career scientists in instrument development and field measurements

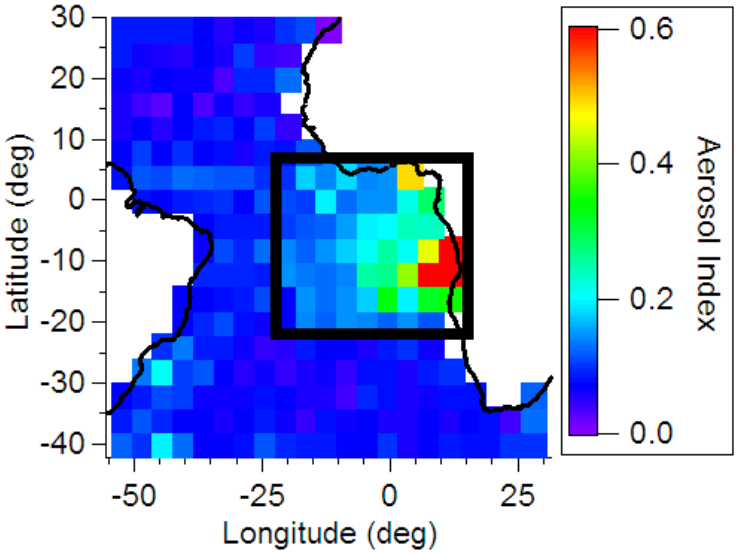
Thank You. Questions?

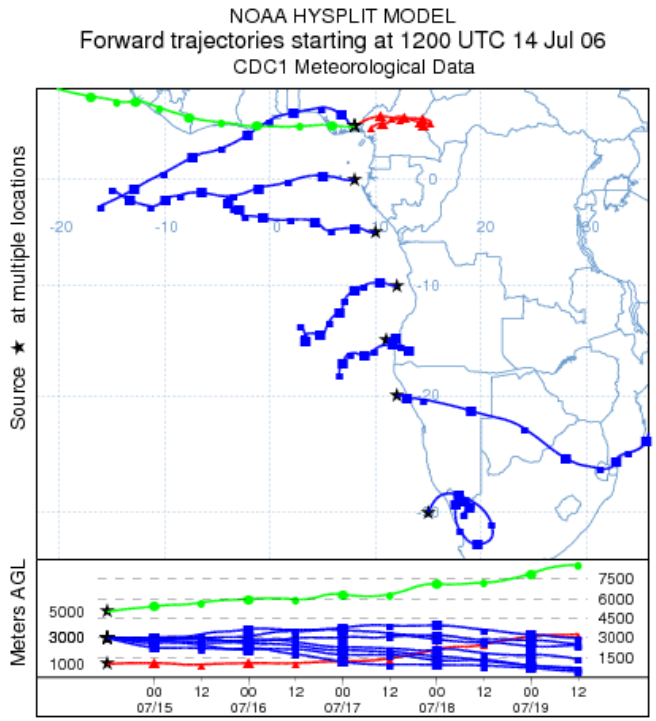
How do Above-Cloud Layers Bias ACI, χ, and S_o?

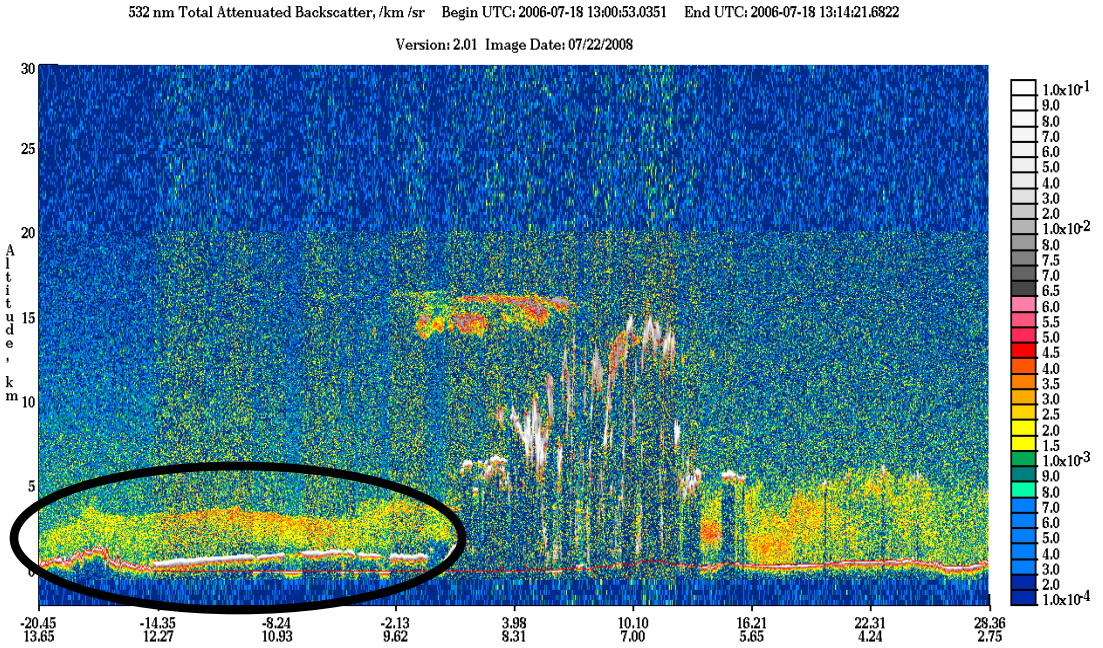
Case Study: June-October 2006 in boxed region

Identify cases of above-cloud plumes using CALIPSO and air-mass back/forward trajectory analysis

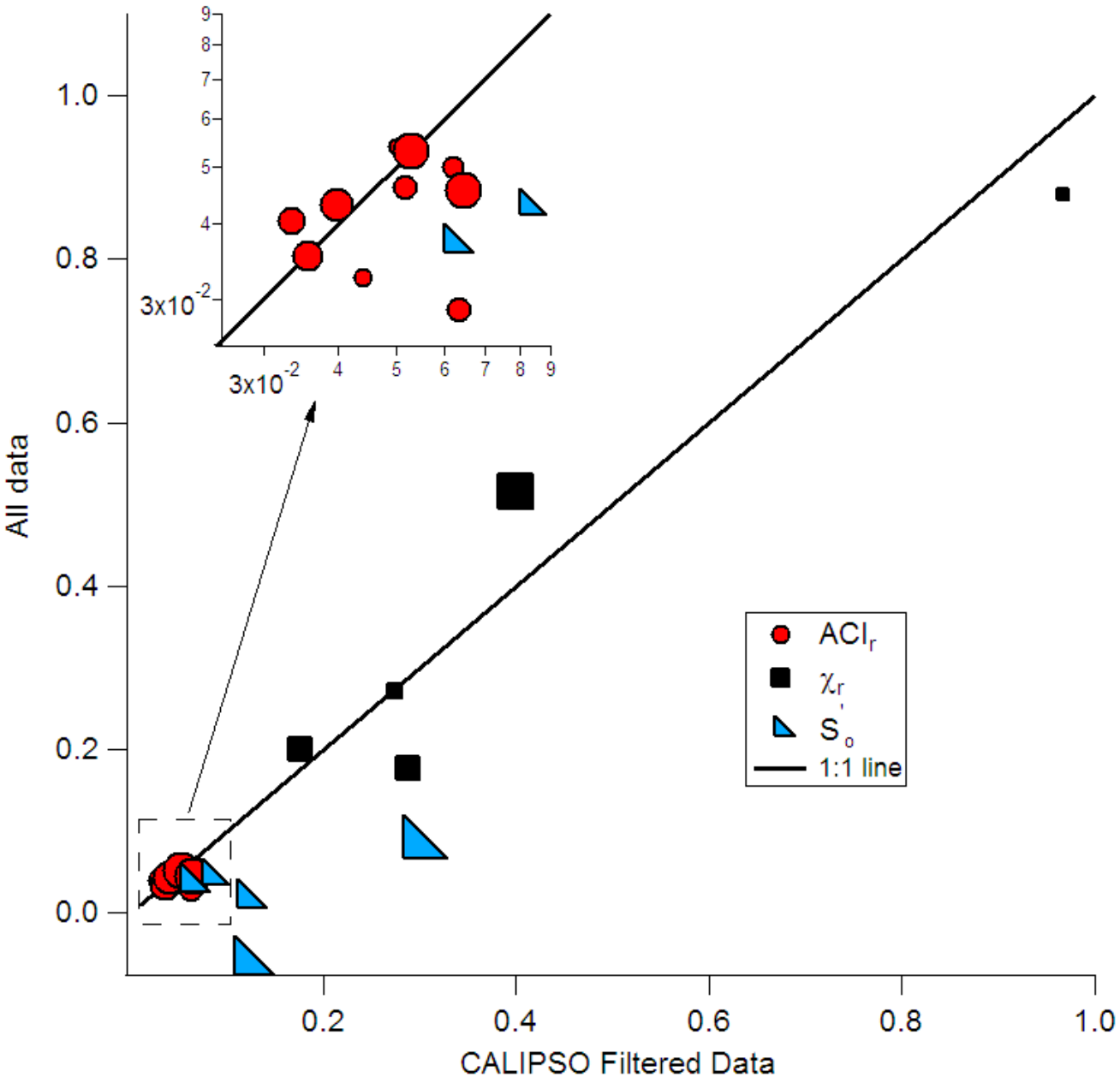
Compare values of ACI, χ, and S_o with/without data filtering







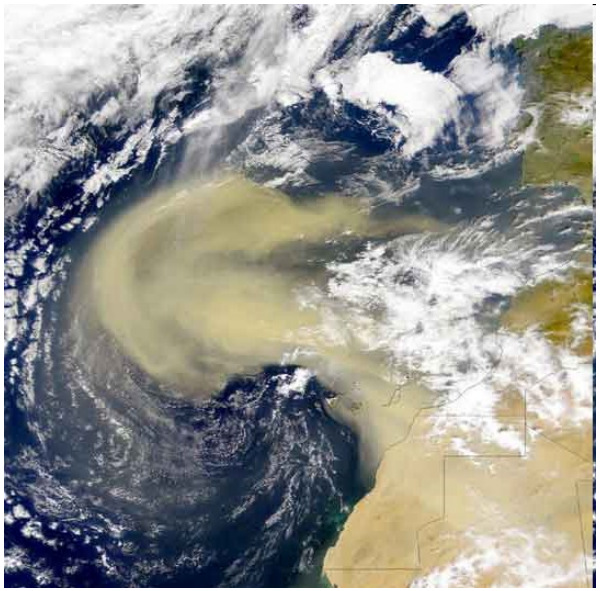
How do Such Layers Bias ACI, χ, and S_o?



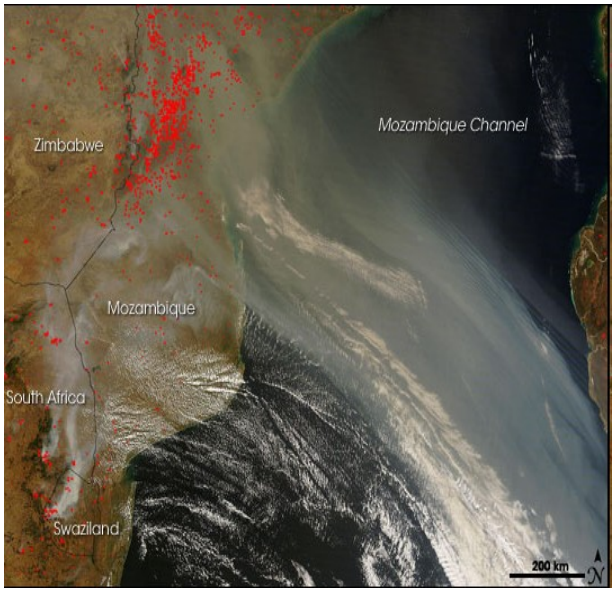
ACI and S_o tend to be enhanced without the layers.

Reduction in desired signal when unrealistic aerosol concentrations are used to represent CCN.

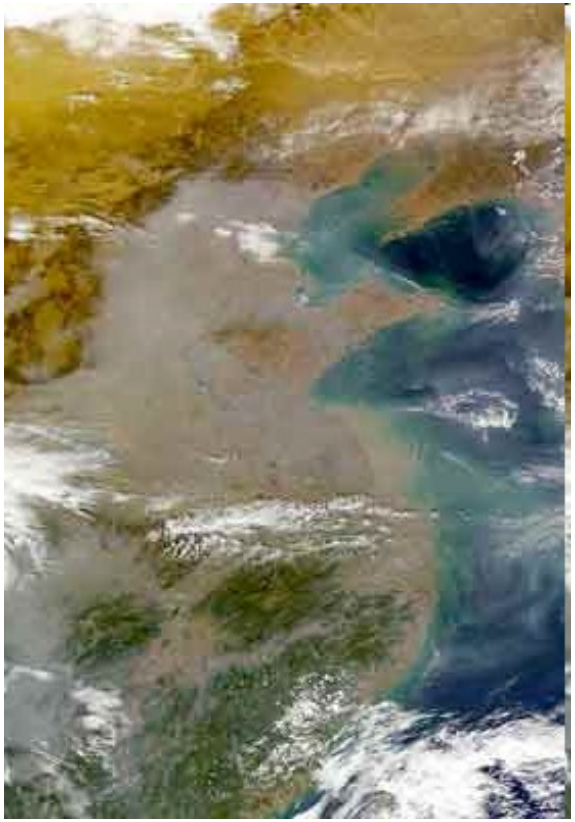
How do different aerosol types influence S_o?



DUST



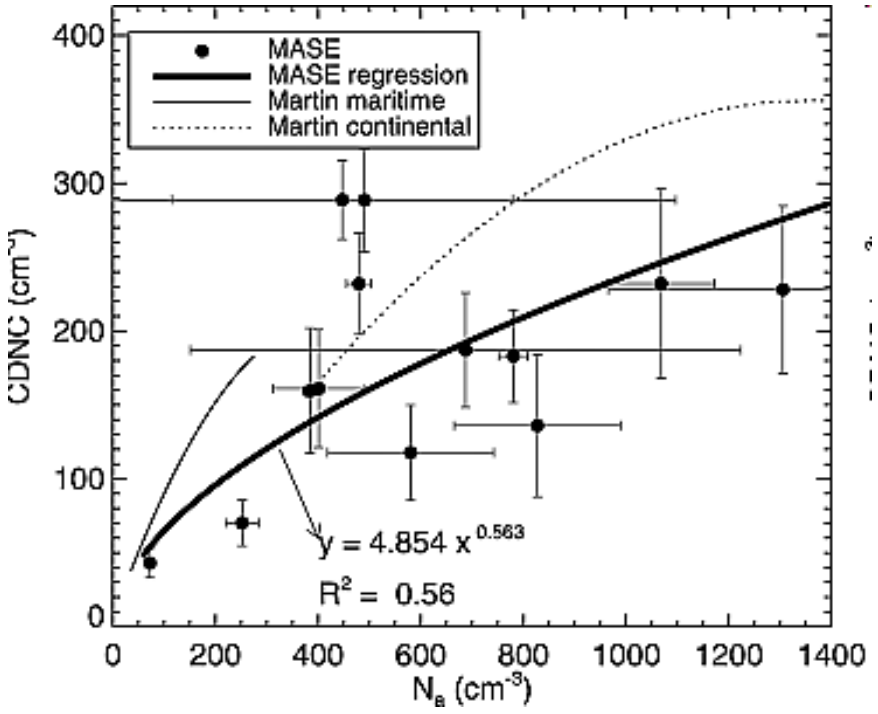
BIOMASS BURNING

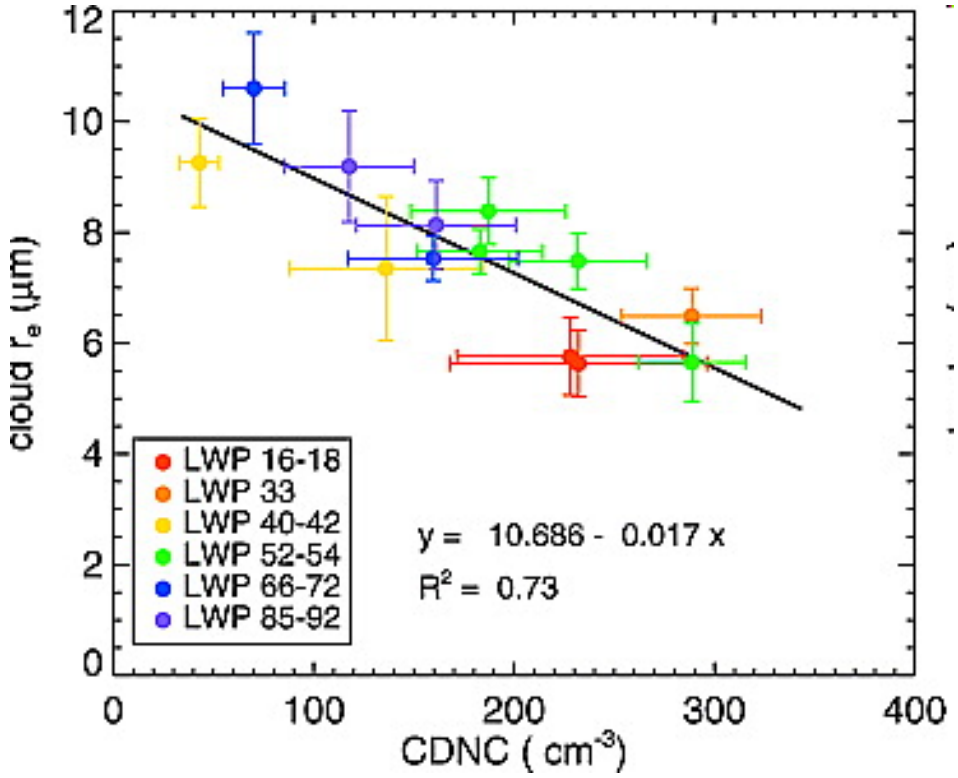


INDUSTRIAL POLLUTION

Also: Sea salt &
Primary Biological Aerosol Particles

Aerosol-Cloud Interactions: In-situ Measurements





Lu et al. (2007)