LASSO: Perspective and Results

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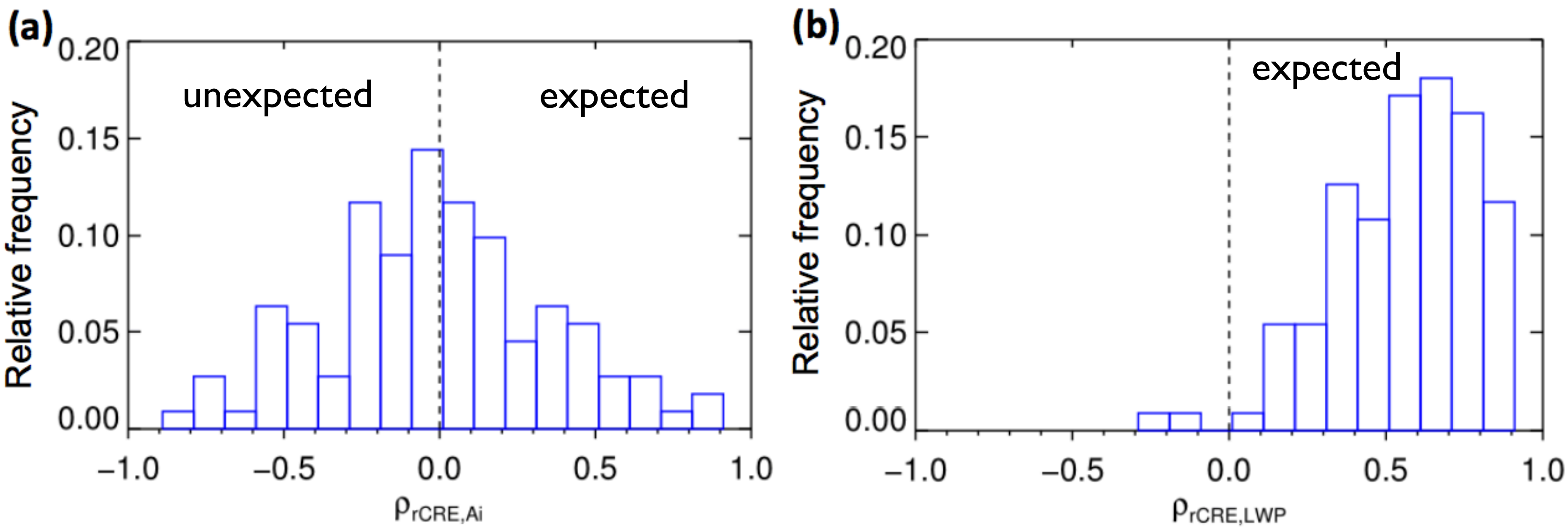
Observations: 14 years of warm clouds at SGP Continental US

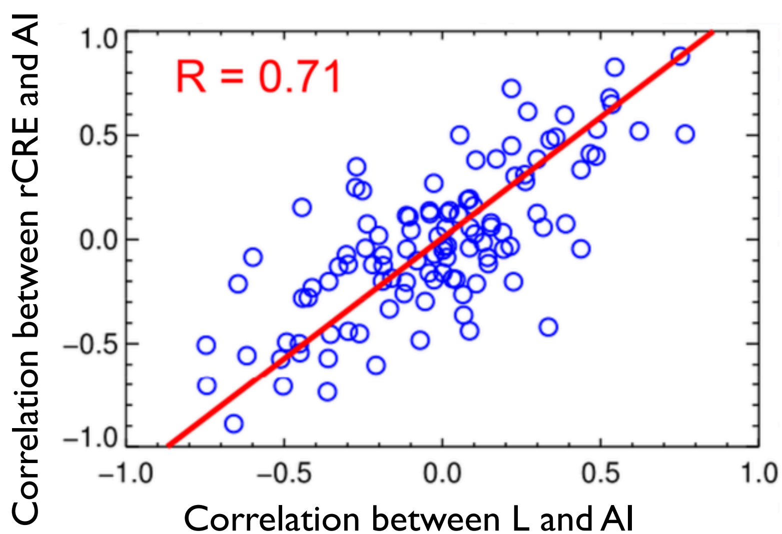


Correlation between rCRE and Aerosol Index

Correlation between rCRE and L

$$\mathrm{rCRE} = 1 - \frac{F_{sw,all}}{F_{sw,clr}}$$

F_{sw} = downwelling shortwave flux



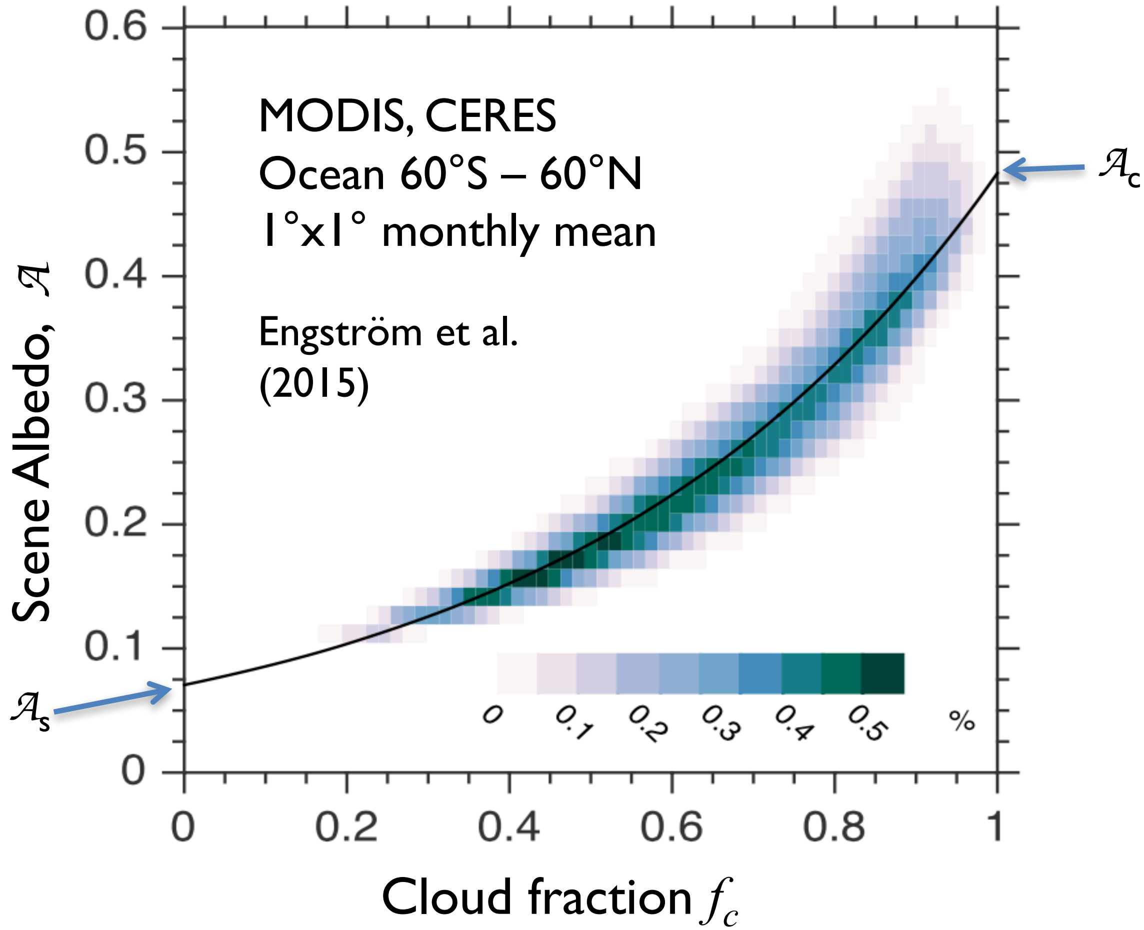
Importance of understanding co-variability between aerosol and meteorology/L

Sena et al., 2016

Approaches to quantifying Aerosol-Cloud Radiative Effect

Top-down

$$\mathcal{A} = f_c\ \mathcal{A}_c + (1 - f_c)\mathcal{A}_s$$



Cloud field Properties

Cloud fraction, f_c

Liquid water path, L

Cloud optical depth, τ_c

Cloud albedo, $\mathcal{A}_c$

Top-down

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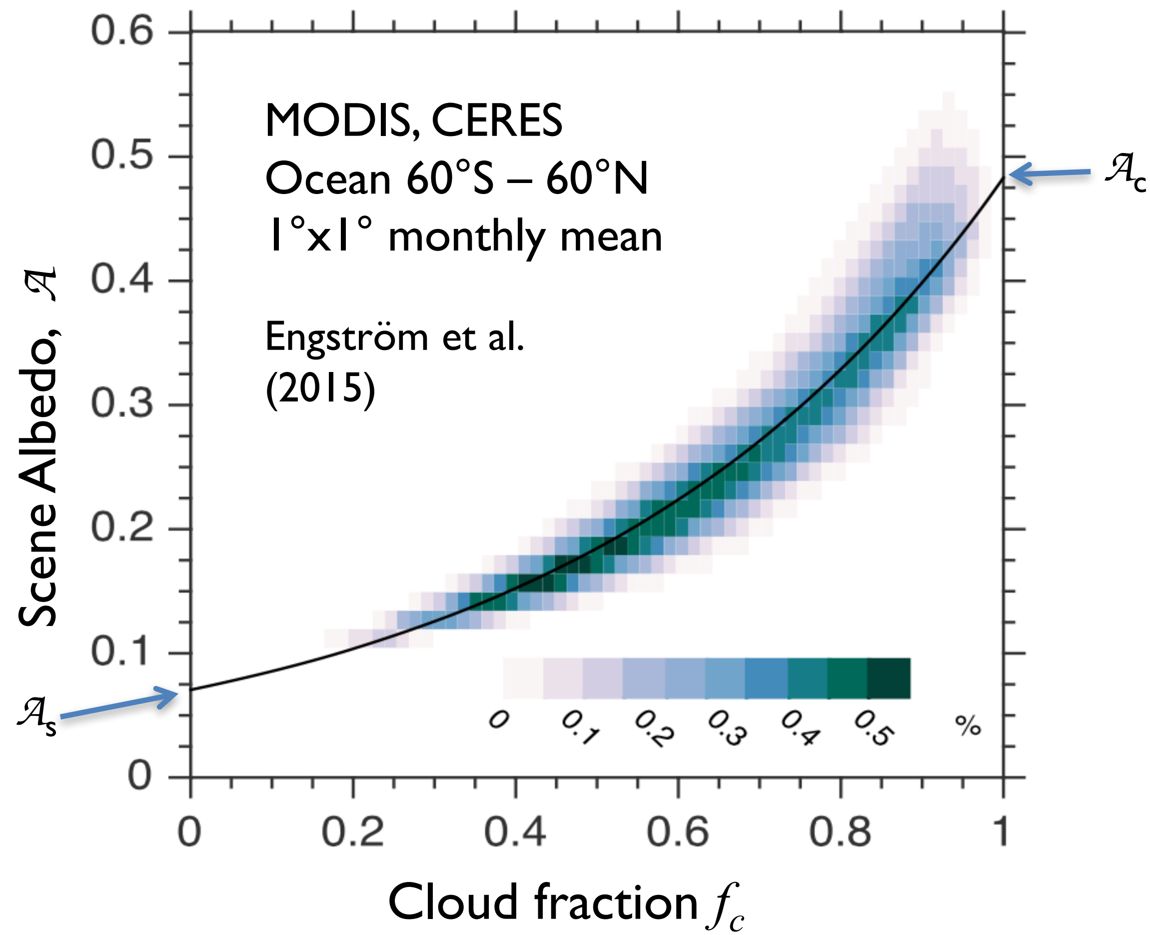
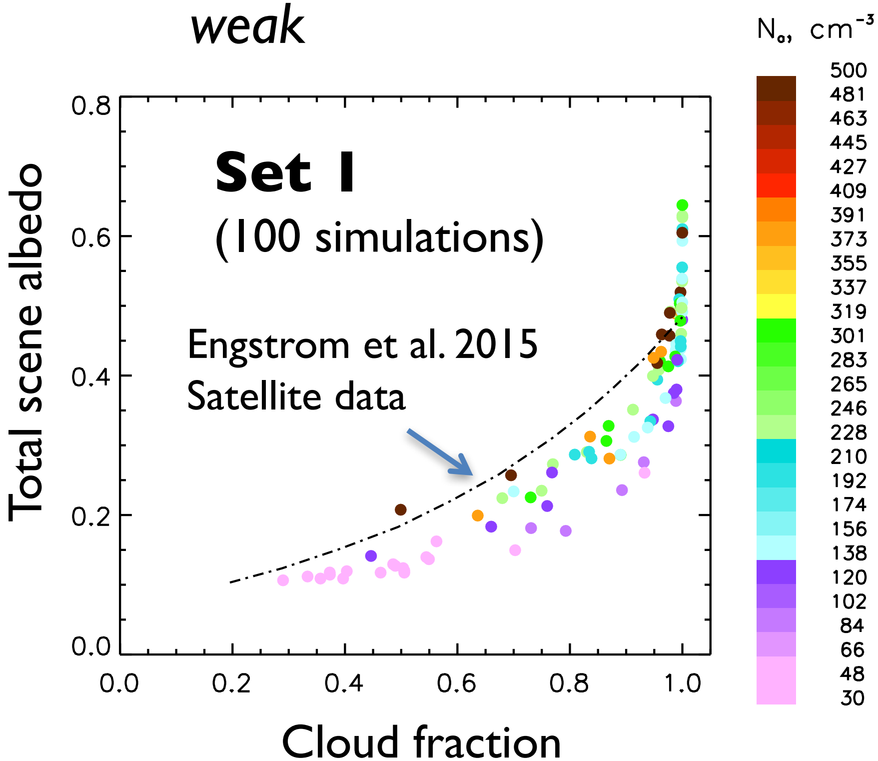


How do aerosol cloud interactions manifest themselves in this kind of framework?

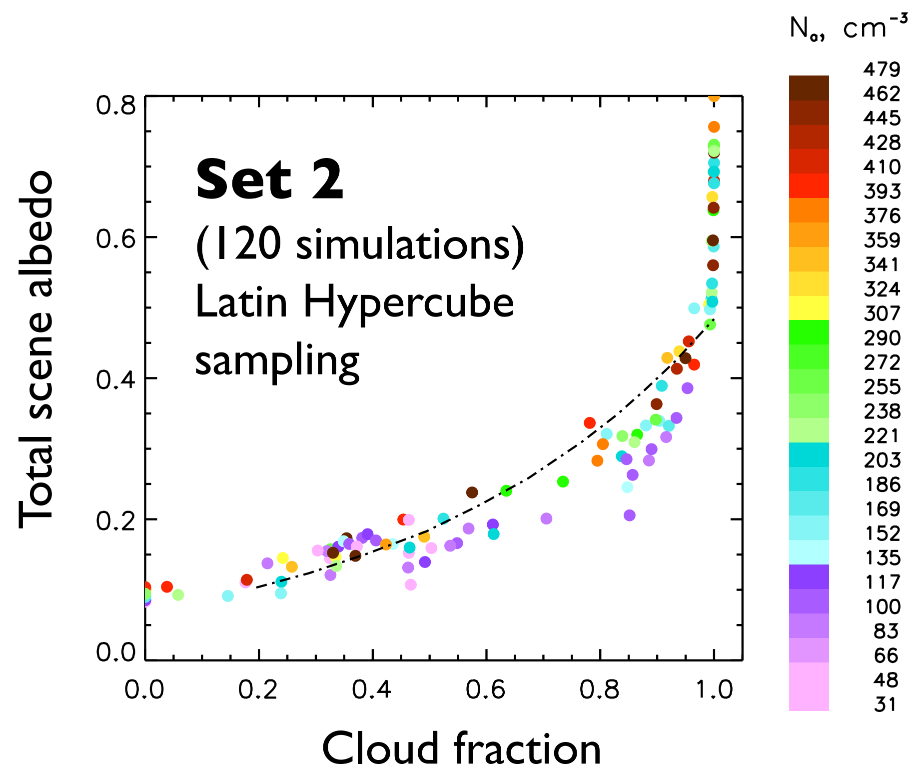
Two sets of model simulations, differing only in the co-variability of aerosol and meteorology

Co-variability of inputs influences detectability of aerosol effects!

Aerosol influence is detectable but relatively weak



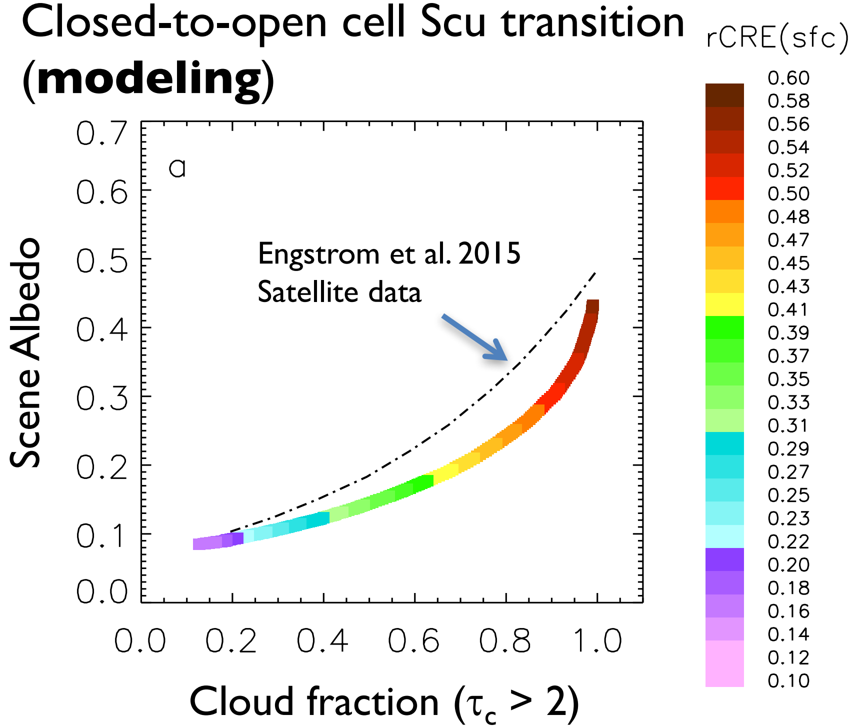
Aerosol effect is imperceptible



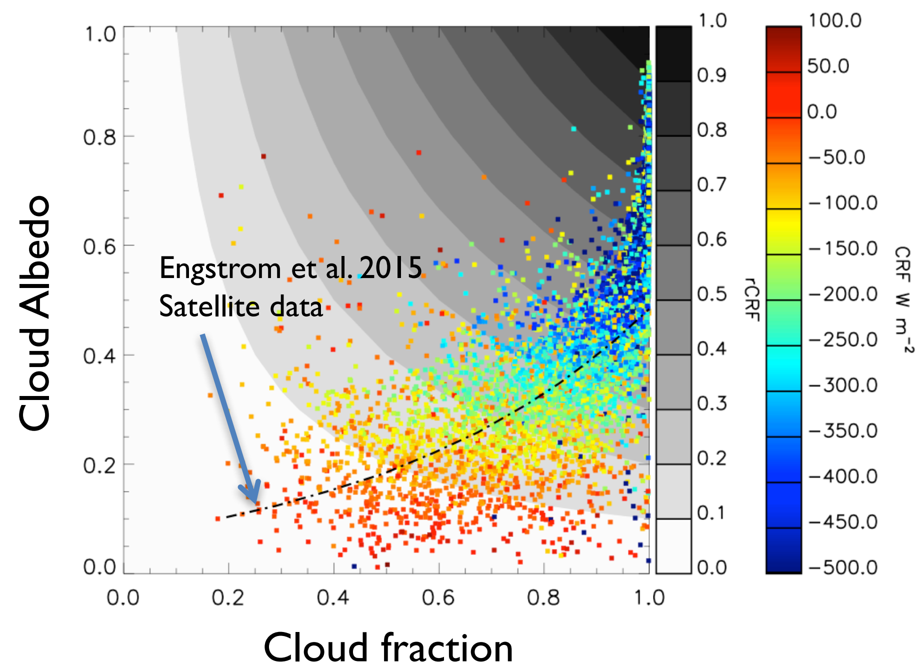
Feingold et al., 2016, PNAS

Relative Cloud Radiative Effect

Closed-to-open cell Scu transition (**modeling**)



SGP observations



SGP, 1999-2010
- shallow clouds (300-3000 m)
- single layer, non-precipitating
- Each point is a daily average

Relative Cloud Radiative Effect

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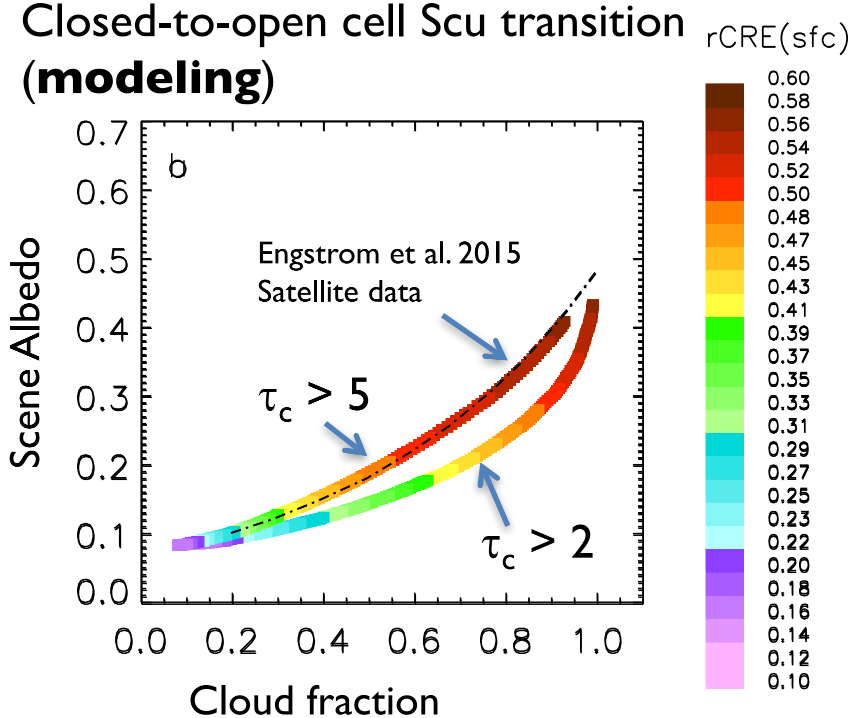
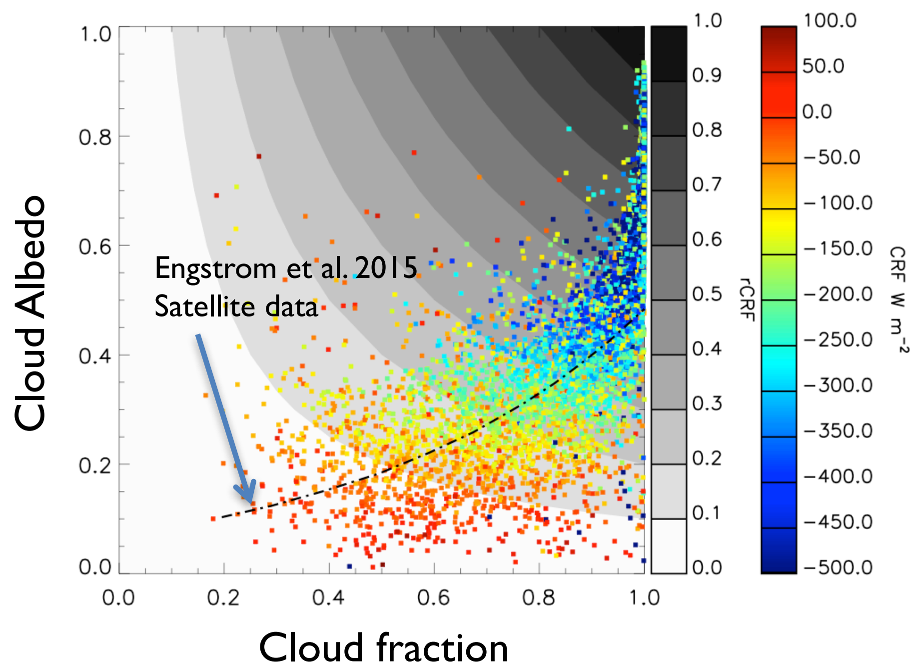


SGP observations

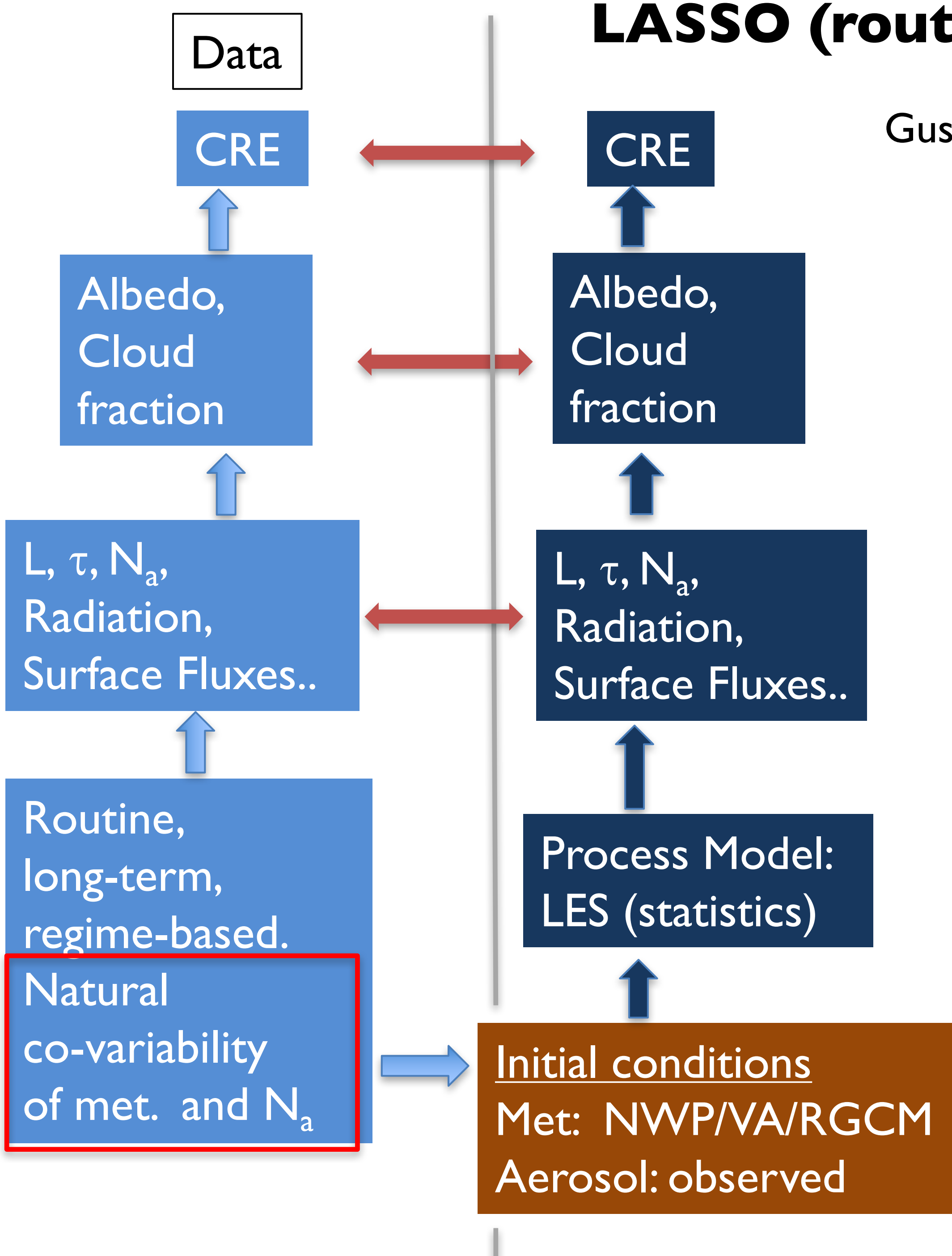


SGP, 1999-2010
- shallow clouds (300-3000 m)
- single layer, non-precipitating
- Each point is a daily average

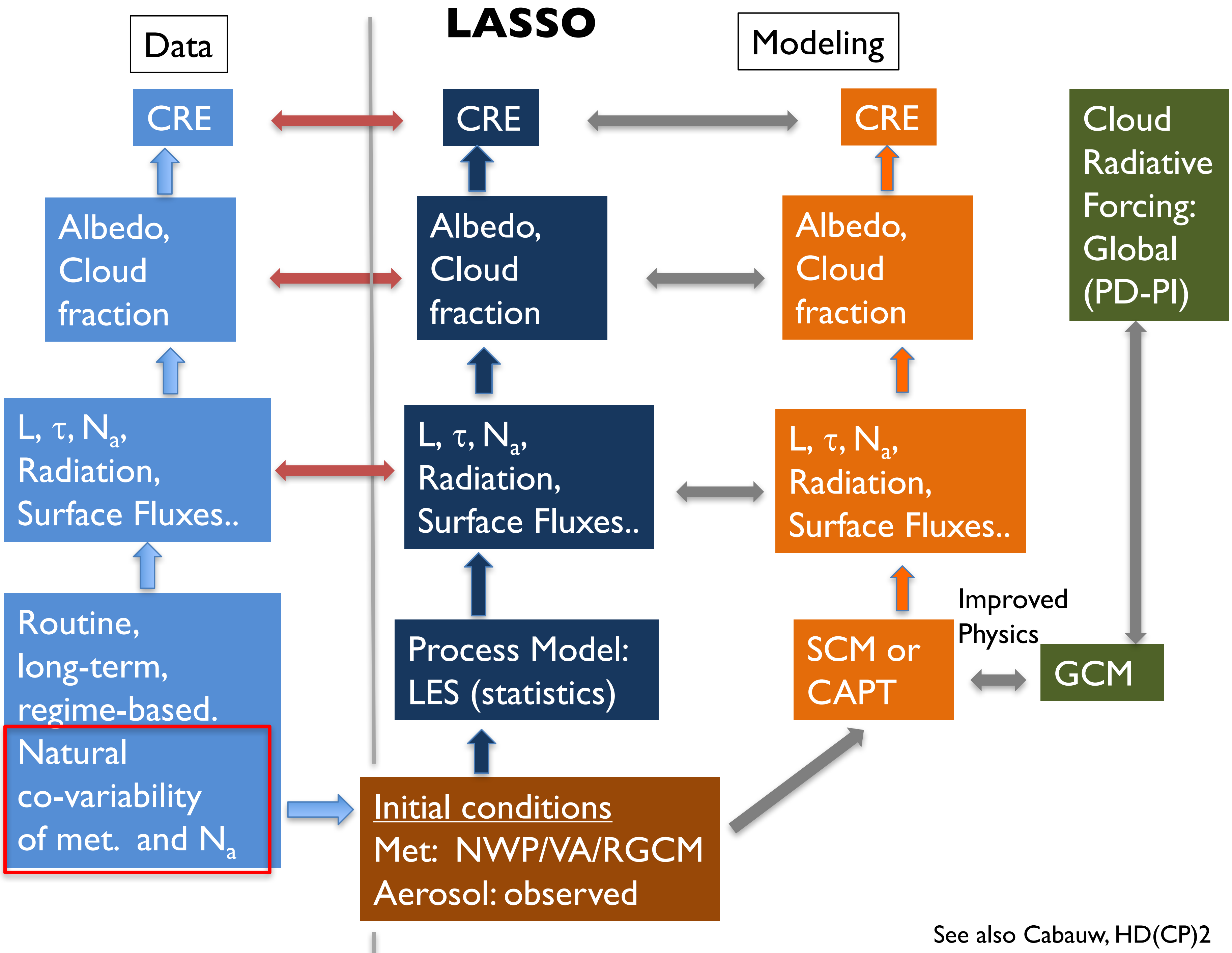
Cloud fraction requires careful definition!

LASSO (routine LES at SGP)

Gustafson and Vogelmann



See also Cabauw, HD(CP)2

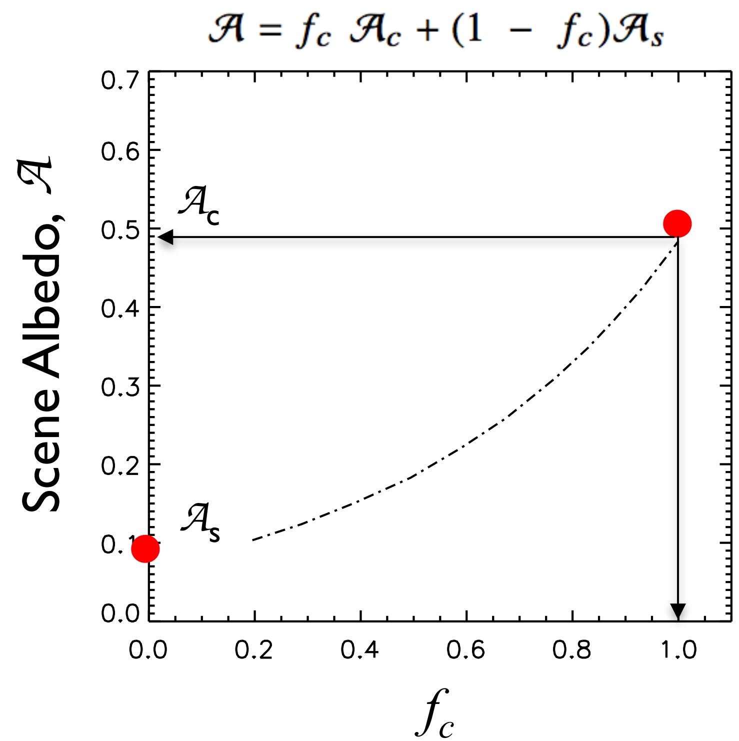

LASSO
Data
Modeling
CRE
CRE
CRE
Cloud Radiative Forcing: Global (PD-PI)
Albedo, Cloud fraction
Albedo, Cloud fraction
Albedo, Cloud fraction
L, τ, N_a, Radiation, Surface Fluxes..
L, τ, N_a, Radiation, Surface Fluxes..
L, τ, N_a, Radiation, Surface Fluxes..
Routine, long-term, regime-based.
Natural co-variability of met. and N_a
Process Model: LES (statistics)
SCM or CAPT
Improved Physics
GCM
Initial conditions
Met: NWP/VA/RGCM
Aerosol: observed
See also Cabauw, HD(CP)2

But what controls the shape of these A vs. f_c curves?

Connect cloud processes to shape of A; f_c curves

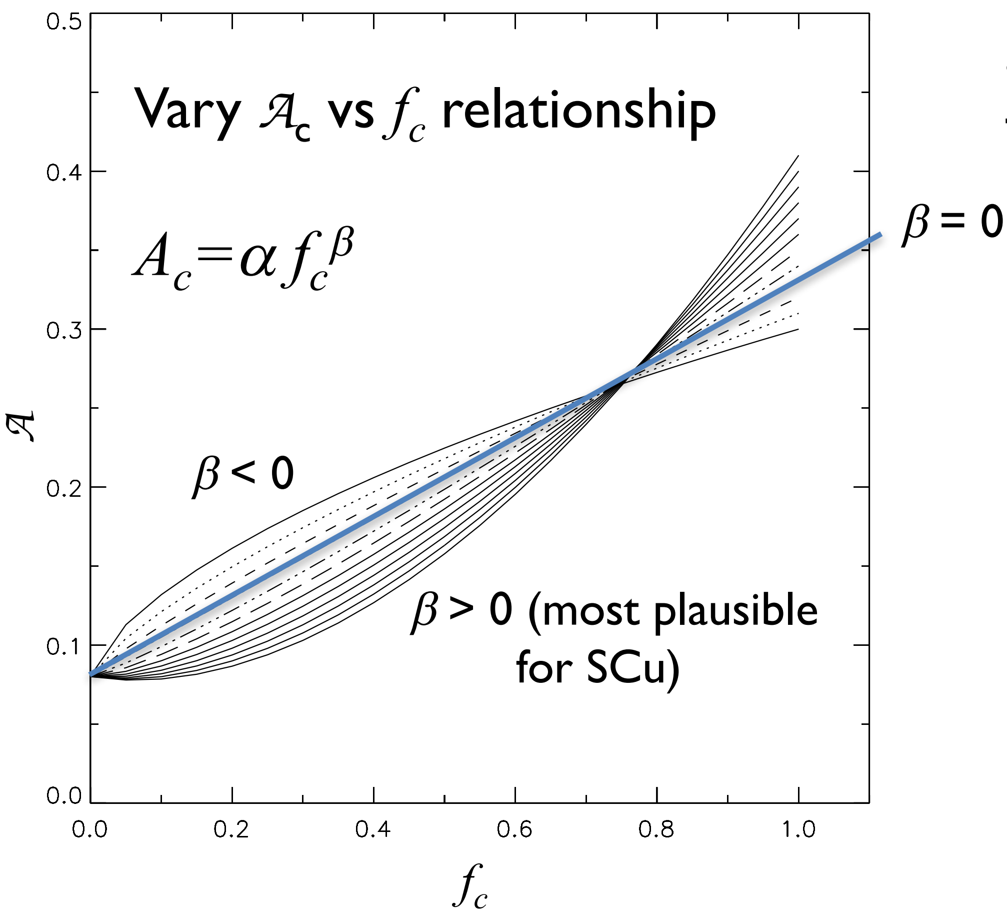
Simple models:

1. Stratocumulus
2. Cumulus



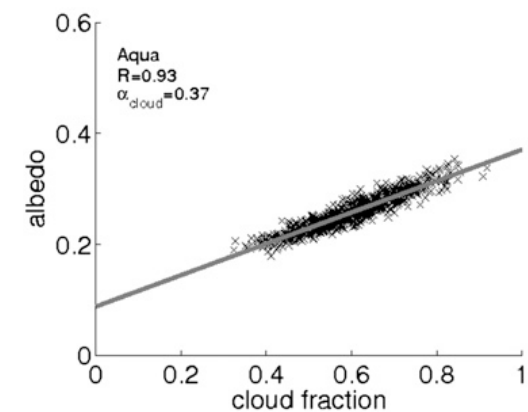
Feingold et al. (2017)

Simple Stratocumulus Cloud Model (Considine 1997)



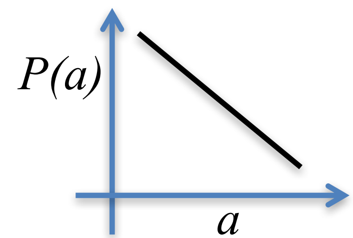
Considine model 1997

Curvature indicates that cloud albedo increases with cloud fraction



Bender et al. 2011
Peruvian SCu

Simple <u>Cumulus</u> Cloud Model (Feingold et al., 2017)



a = cloud area

Assumptions:

- Cloud size distribution is a negative power law

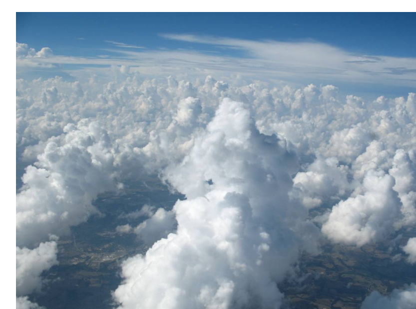
  $$P(a) = A\ a^{-b}$$

- Power law relationship between cloud depth and area (cloud top varies)

  $$z = \alpha\ a^{\beta}$$

  z = cloud depth $\beta \sim 0.3$

- Cloud base is constant



Simple <u>Cumulus</u> Cloud Model (Feingold et al., 2017)

Adiabatic: $L = \frac{c_w z^2}{2}$

$$\bar{L} = \frac{\int LP(L)dL}{\int P(L)dL} = \frac{(b'/2)}{(b'/2+1)} \frac{[L_{max}^{b'/2+1} - L_{min}^{b'/2+1}]}{[L_{max}^{b'/2} - L_{min}^{b'/2}]}; \qquad b' = (1-b)/\beta$$

Subadiabatic: $L = -\frac{p\ z^3}{3} + \frac{c_w\ z^2}{2}$ integrate numerically

$$\tau_c = \mathrm{C}N^{1/3} \int (-pz^2 + qz)^{2/3} dz = \mathrm{C}N^{1/3} \left[\frac{0.6z(qz(1-pz/q))^{2/3}\ {}_2F_1(-2/3,\ 5/3;\ 8/3;\ pz/q)}{(1-pz/q)^{2/3}} \right]$$

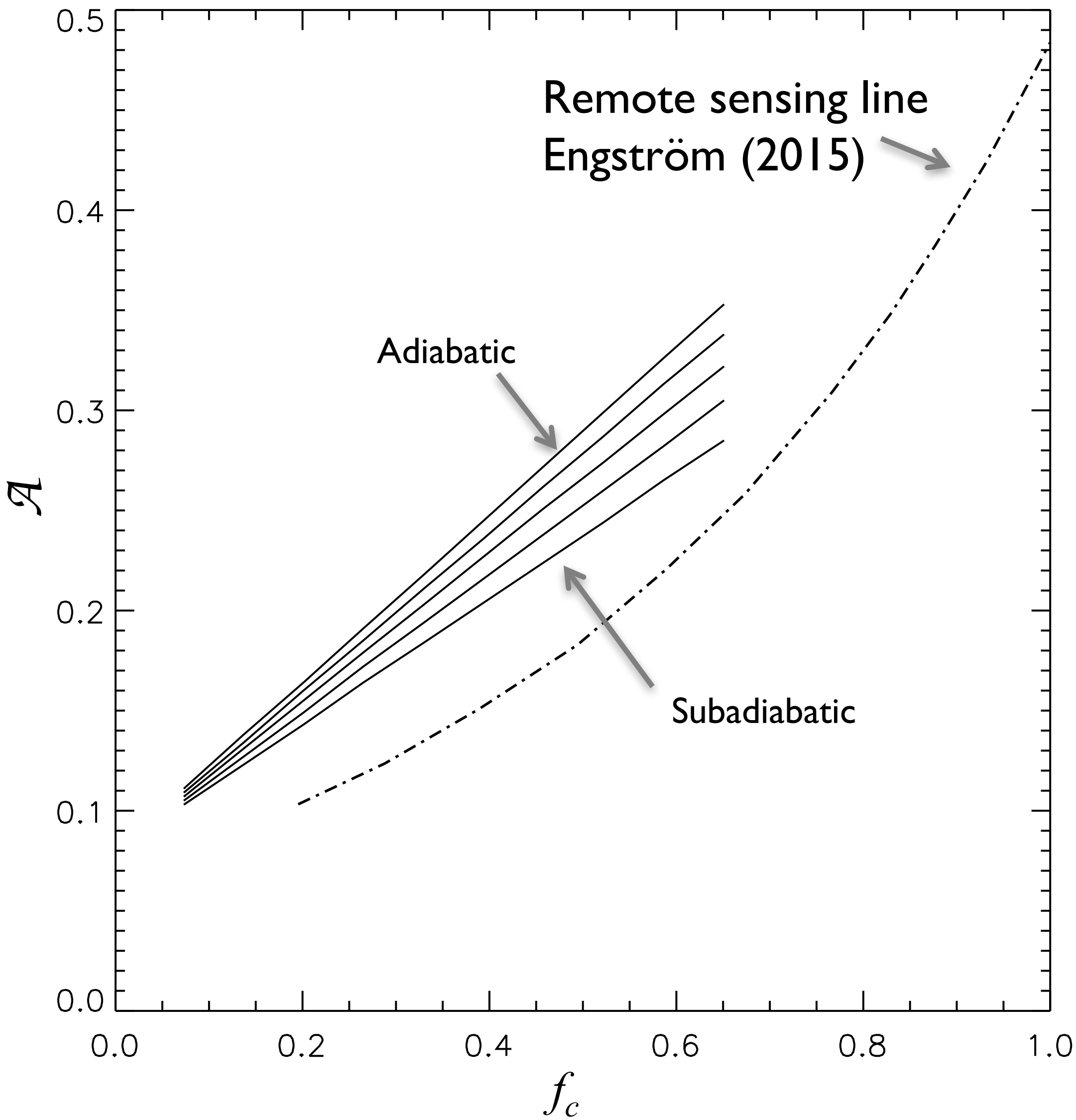
cloud optical depth

$$\mathcal{A}_c = \frac{(1-g)\tau_c}{2+(1-g)\tau_c}$$ cloud albedo

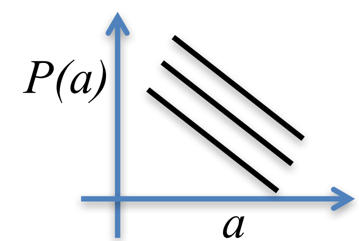
$$f_c = \frac{\int_{a_{min}}^{a_{max}} aP(a)da}{L_x L_y} = \frac{A}{(2-b)} \frac{\left[a_{max}^{(2-b)} - a_{min}^{(2-b)}\right]}{L_x L_y}$$ cloud fraction

$$\mathcal{A} = f_c\ \mathcal{A}_c + (1 - f_c)\mathcal{A}_s$$ scene albedo

Simple Cumulus Model: Sub-adiabatic Clouds



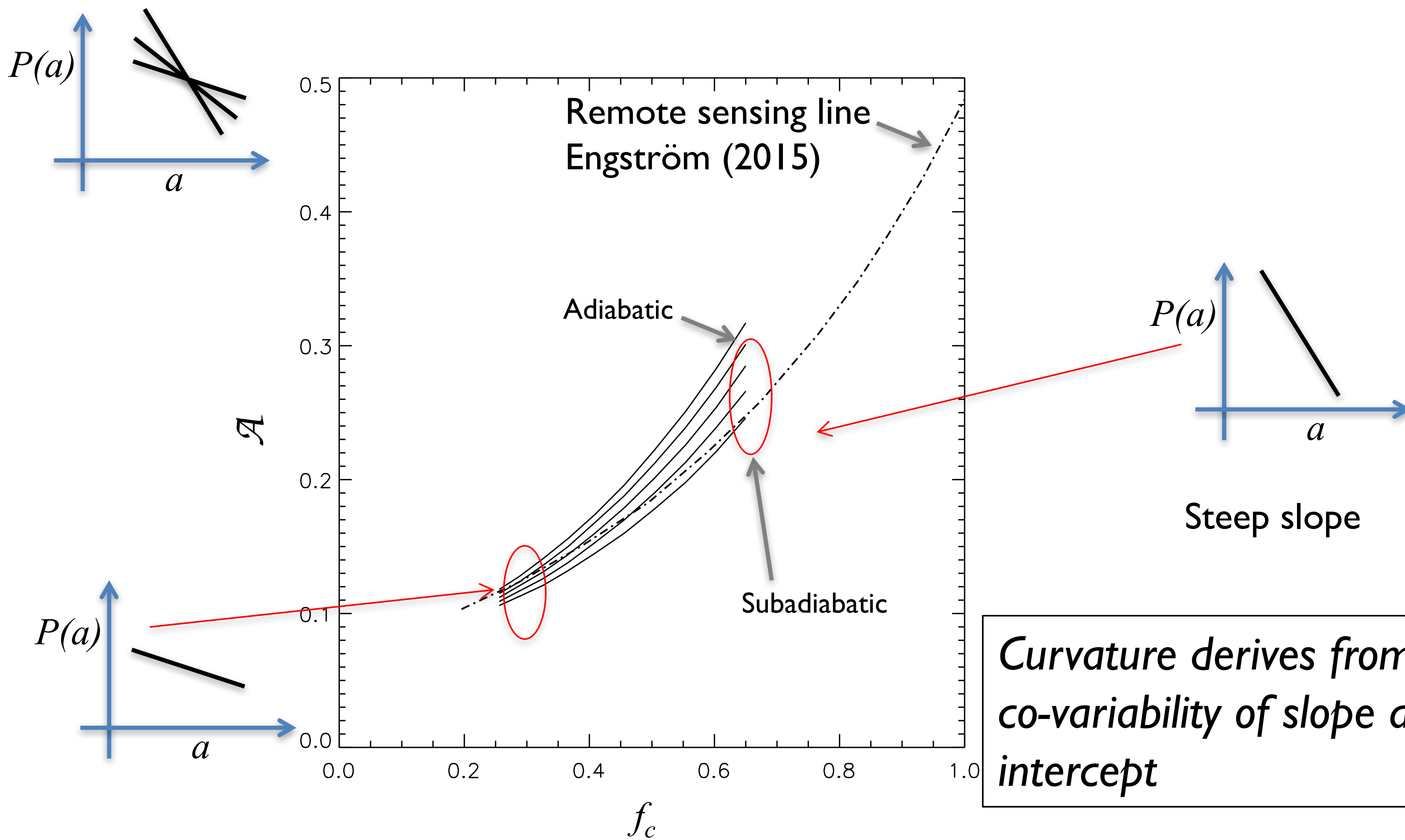
Linear $\mathcal{A}$ vs. f_c when intercept varies and slope is constant



Change intercept (slope is constant)

Feingold et al. (2017)

Simple Cumulus Model: Sub-adiabatic Clouds



Curvature derives from co-variability of slope and intercept

Feingold et al. (2017)

Summary Points

- (Scene) Albedo vs. cloud fraction framework for understanding cloud field responses to perturbations

- Co-variability in meteorology and aerosol influences detectability of aerosol-cloud interactions; **LASSO**

- Link shape of rCRE, Albedo, f_c plots to:
  - Micro/macrophysical processes, scale, regime

- Simple models to understand shape of $\mathcal{A}$ - f_c curves and its relationship to convective processes