

Detection of Aerosol-Cloud Interactions in Shallow Cumulus during LASSO



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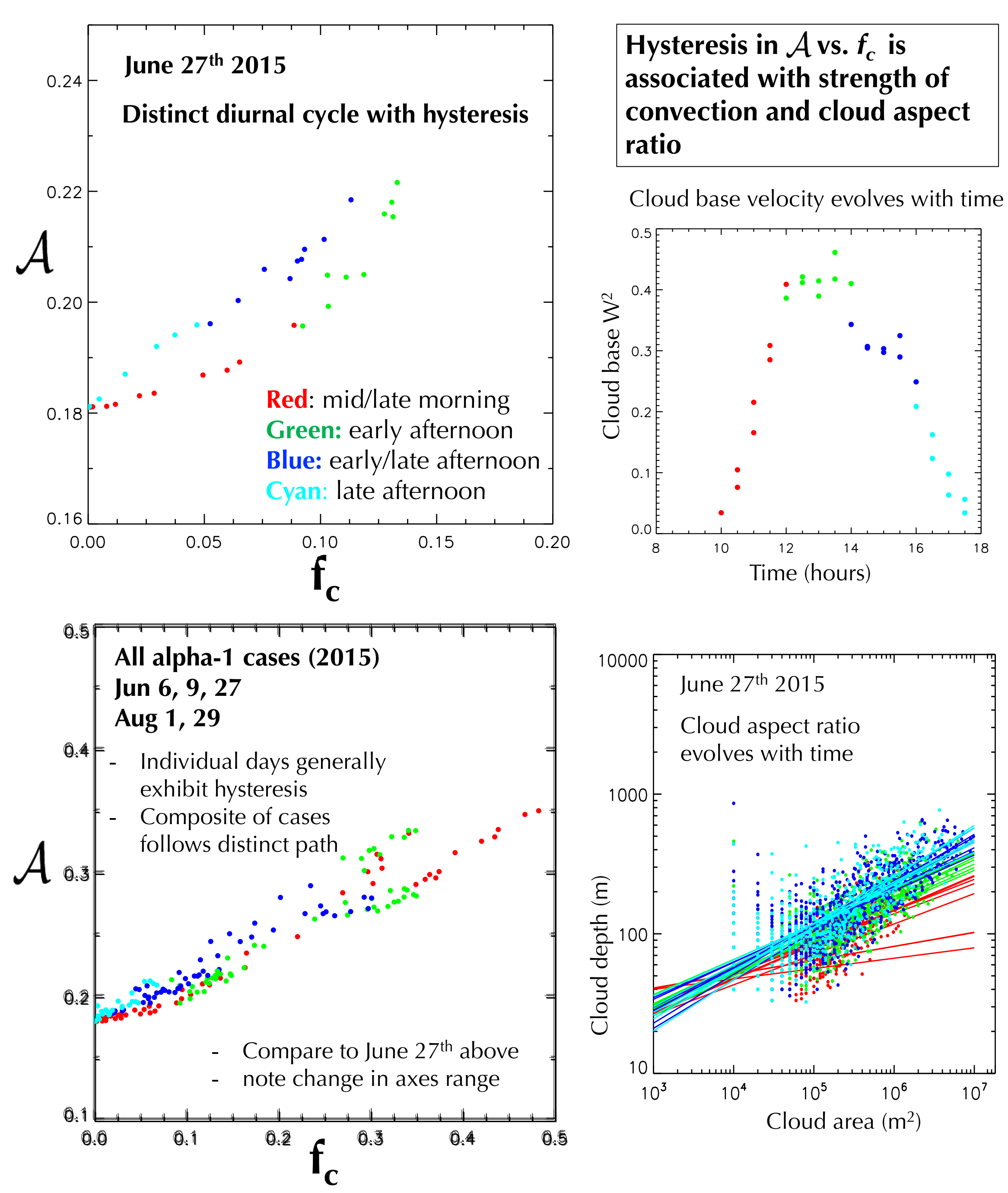
Background and Motivation

Aerosol influences on shallow cumulus:

- hard to quantify with observations
- hard to resolve in climate models

Here we use LES ARM Symbiotic Simulation and Observation (LASSO) model output to evaluate the effect of aerosol on the brightness of clouds at ARM's SGP site

Scene Albedo vs f_c : fixed aerosol



Theoretical considerations

Cloud optical depth: τ_c

Adiabatic clouds: $\tau_c \propto N^{1/3} H^{5/3}$

τ_c is 5x more sensitive to H than to N (relatively)

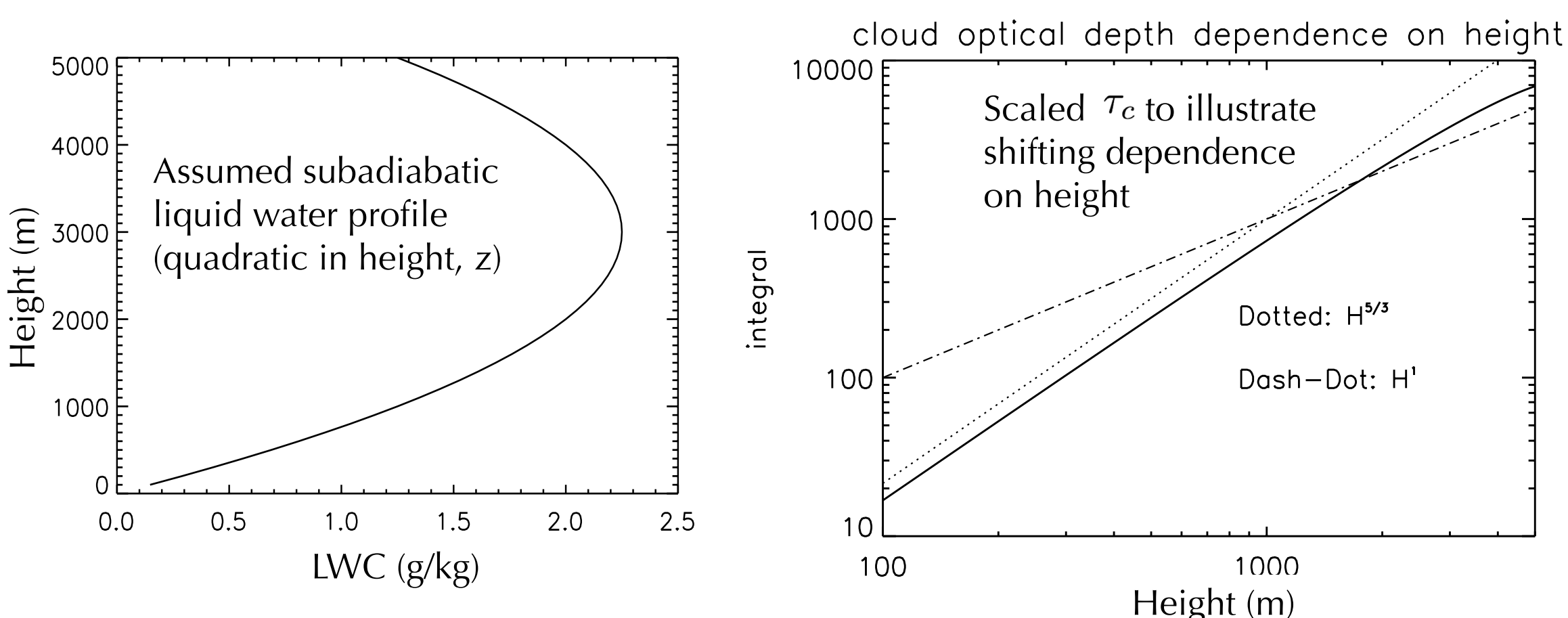
Subadiabatic clouds:

$$\tau_c = CN^{1/3} \int (-pz^2 + qz)^{2/3} dz$$

$$= CN^{1/3} \left[\frac{0.6z(qz(1-pz/q))^{2/3} {}_2F_1(-2/3, 5/3; 8/3; pz/q)}{(1-pz/q)^{2/3}} \right],$$

(Feingold et al. 2017)

τ_c dependence shifts from $H^{5/3}$ to H in the example below.
Still more strongly dependent on H than N .

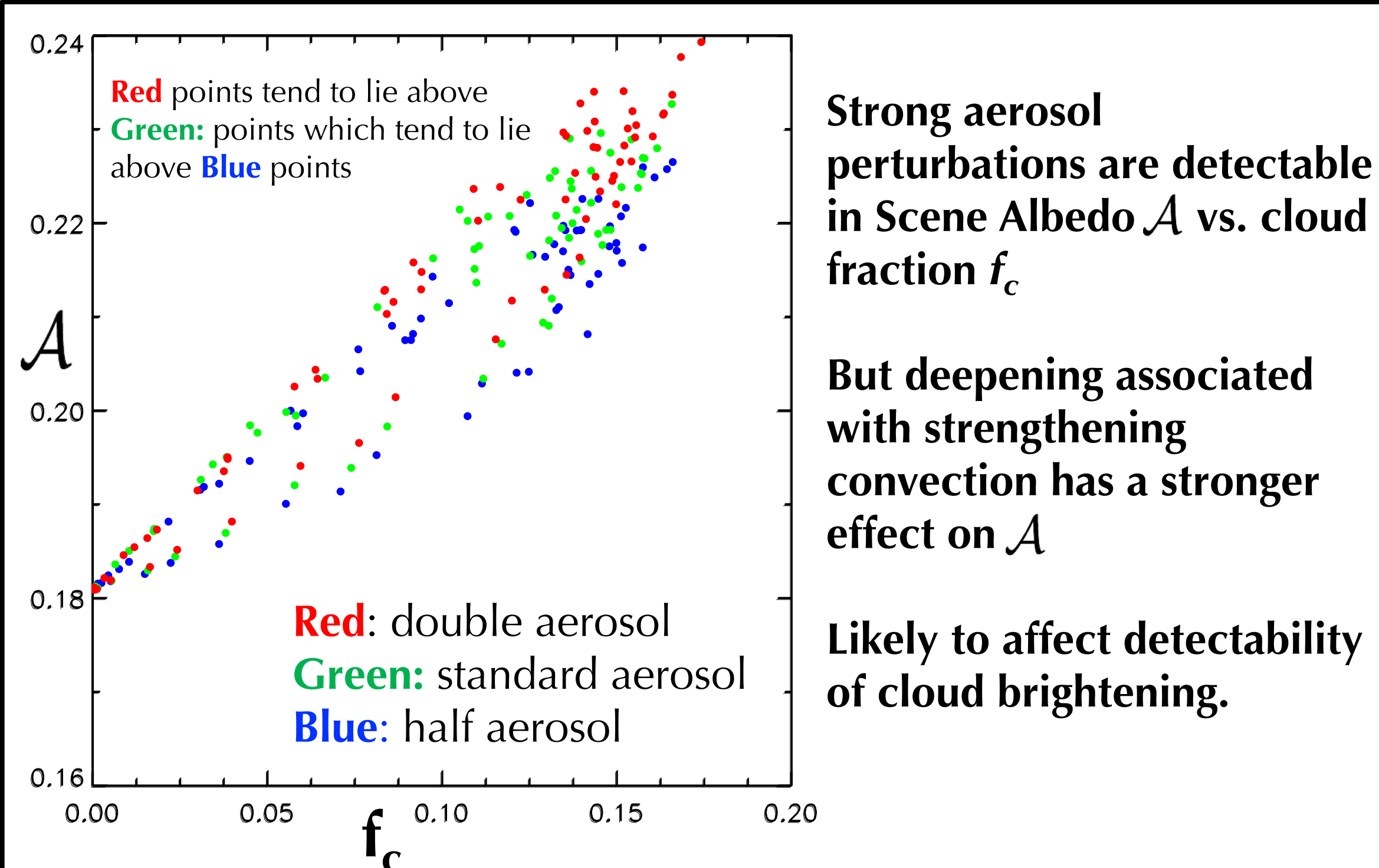


References:

Feingold, G., J. Balsells, F. Glassmeier, T. Yamaguchi, J. Kazil, and A. McComiskey, 2017: Analysis of Albedo vs. Cloud Fraction Relationships using Heuristic models and Large Eddy Simulation. *J. Geophys. Res.*, 122, doi:10.1002/2017JD026467.

Sena, E. T., A. McComiskey, and G. Feingold, 2016: A long-term study of aerosol-cloud interactions and their radiative effect at the Southern Great Plains using ground-based measurements. *Atmos. Chem. Phys.*, 16, 11301-11318, doi:10.5194/acp-16-11301-2016.

Scene Albedo vs f_c : variable aerosol



Key Points

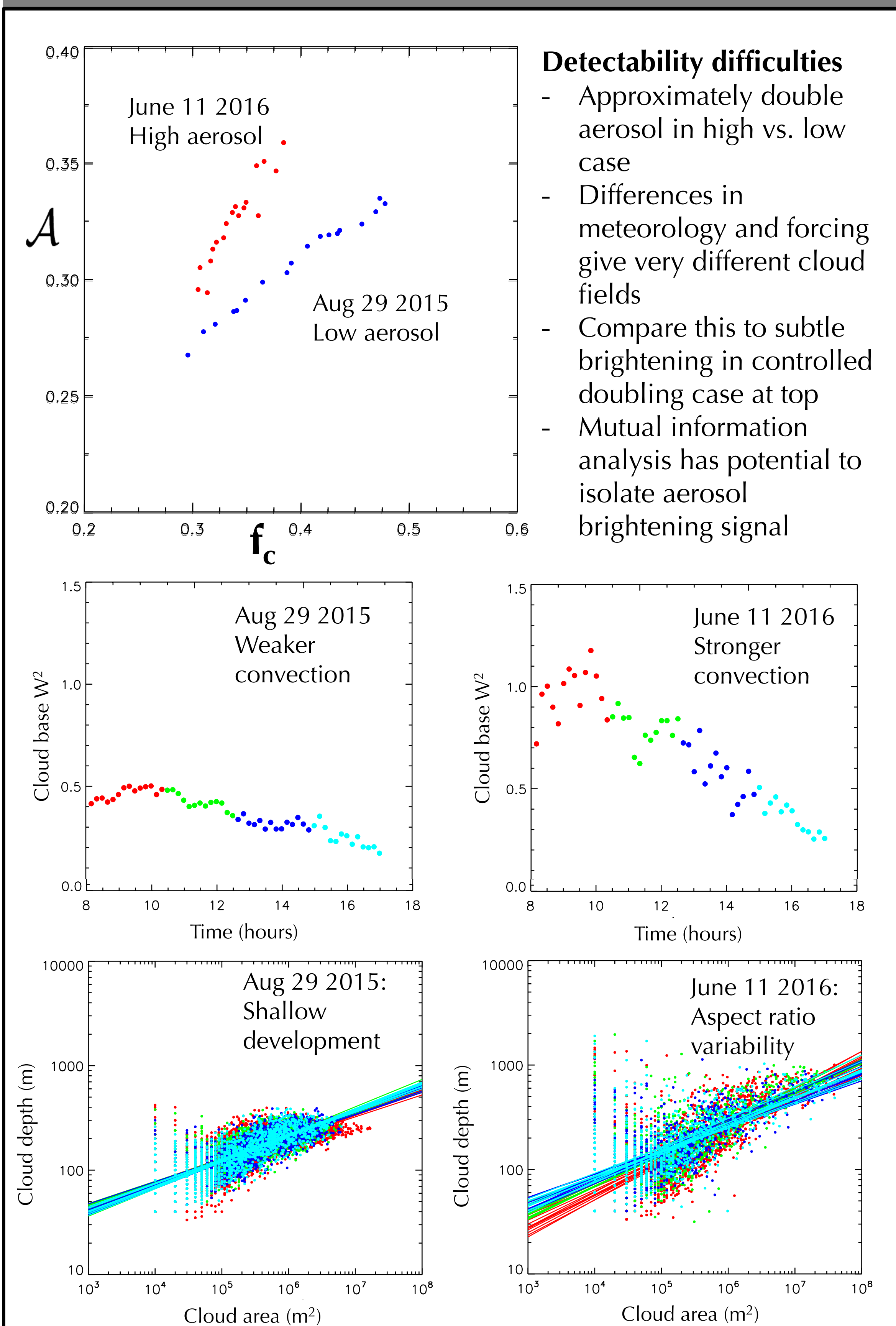
Scene Albedo A vs. Cloud Fraction f_c relationships:

- Useful way to detect aerosol related cloud brightening
- Exhibit diurnal cycle hysteresis related to cloud aspect ratio (depth vs. area)
- Detectability of aerosol effects studied with *ad hoc* and observed perturbations (derived from CCN spectra)

Aerosol/meteorology co-variability analysis for 14 years of ARM data at SGP:

- Shannon mutual information is applied to identify and quantify meteorological states affecting detectability

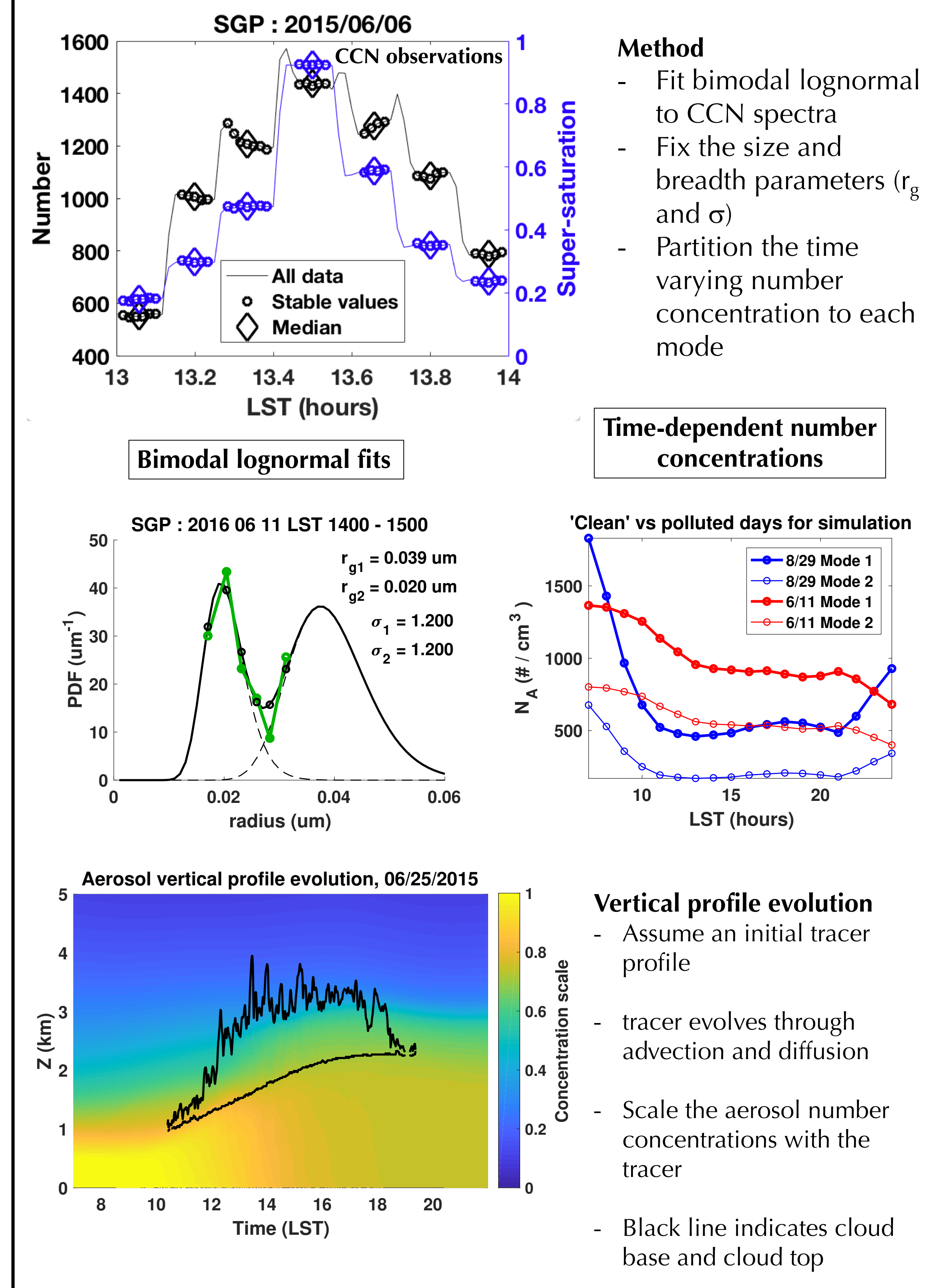
LASSO cases with aerosol variability



Observed aerosol input to model

Aerosol variability

- Based on observed CCN spectra
- Microphysics scheme altered to allow temporal and spatial variability



Aerosol-Radiation Mutual Information

