# CAPI Updates

Steve Ghan, Rob Wood, the CAPI Team

The Sackler Colloquium:

# *Improving Our Fundamental Understanding of the Role of Aerosol-Cloud Interactions in the Climate System*

June 23-24, 2015; Irvine, CA
Organized by John Seinfeld, Kim Prather, Ian Kraucunas, Alex Guenther and Ed Dunlea
*www.nasonline.org/programs/sackler-colloquia/completed_colloquia/Role_of_Aerosol_Cloud_Interactions.html*

Ten DOE-funded researchers gave presentations:

**Chris Bretherton, Paul DeMott, Graham Feingold, Steve Ghan, Sonia Kreidenweis, Joyce Penner, Phil Rasch, Danny Rosenfeld, John Seinfeld, Robert Wood**

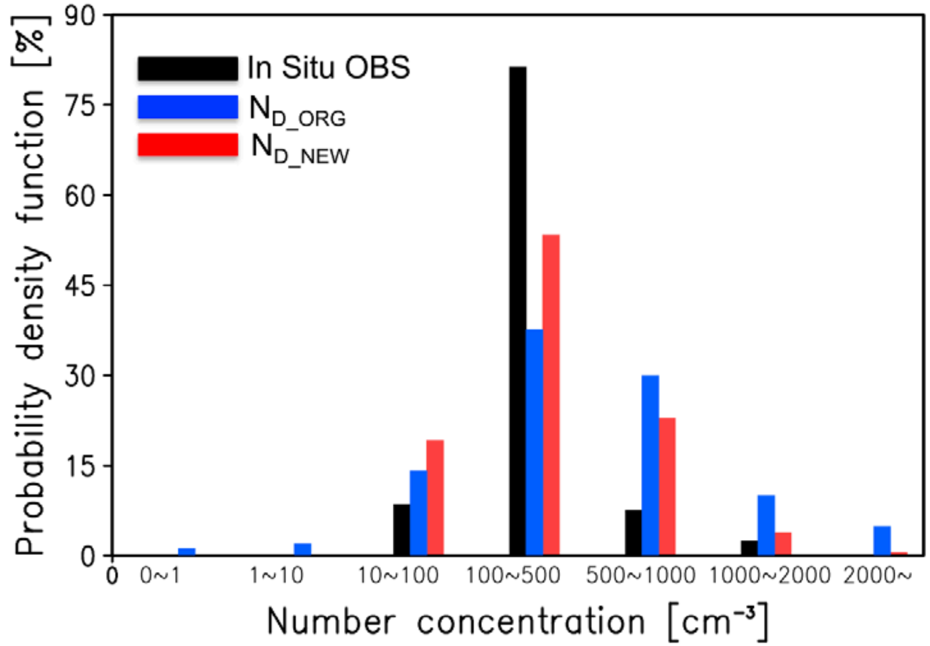
VIDEO of PRESENTATIONS AVAILABLE ONLINE

PNAS Special issue papers are being published and are available online

# A new operational retrieval of cloud droplet number concentration from surface remote sensors

## Objective

- Develop a new operational retrieval of cloud droplet number concentration (ND) at cloud base using measurements from surface remote sensors at the ARM Southern Great Plains site
- Evaluate ND and the relationship between ND and cloud droplet effective radius (RE) using available in situ aircraft measurements




## Approach

- Eliminate the adiabatic assumption
- Retrieve ND and collect the in-situ aircraft data for the evaluation

## Impact

- High bias in retrieved ND is reduced by eliminating the adiabatic assumption and by using liquid water path diagnosed from multi-filter rotating shadow-band radiometer
- The inverse relationship between ND and RE seen in the in situ data is captured well by the retrieved ND and RE

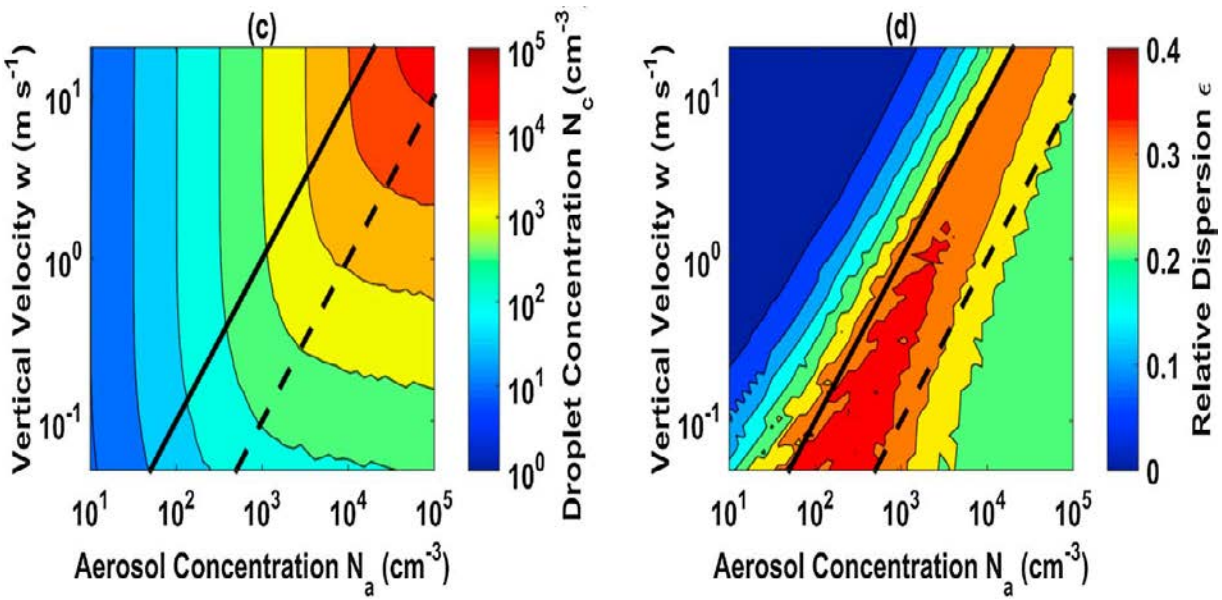
Lim, K.-S. S., L. Riihimaki, J. M. Comstock, B. Schmid, C. Sivaraman, Y. Shi, and G. M. McFarquhar (2016), Evaluation of long-term surface-retrieved cloud droplet number concentration with in situ aircraft observations, J. Geophys. Res. Atmos., 121, 2318–2331, doi:10.1002/ 2015JD024082.

# Cloud Droplet Spectral Shape Sheds New Light on Aerosol-Cloud-Interaction Regimes and AIE

- **Motivation:** Address regime dependence and dispersion effect together, both related to large AIE uncertainty but understudied.
- **Approach:** Parcel model simulations with updraft velocities and aerosols that likely occur in ambient clouds.
- **Main Results:**

-- Relative dispersion has non-monotonic regime dependence on aerosol concentration and updraft velocity: When aerosols increase, dispersion first increases in aerosol-limited regime, peaks in transitional regime, and decreases in updraft-limited regime.

-- The finding reconciles contrasting observations in literature, and highlights the compensating role of dispersion effect in AIE.




- Relative dispersion ε = standard deviation/mean radius
- Effective radius thus cloud albedo increases when dispersion increases

$$r_e \sim \beta(\varepsilon)\left(\frac{L}{N_c}\right)^{1/3}$$

**(More in Y. Liu's talk in CAPI warm cloud breakout Thur AM)**

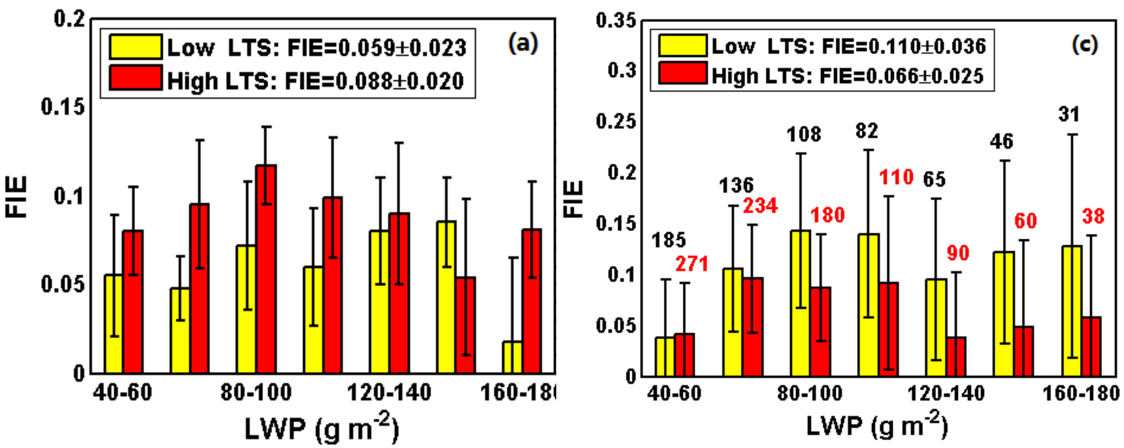
Chen J, Y Liu, M Zhang, and Y Peng. 2016. New understanding and quantification of the regime dependence of aerosol-cloud interaction for studying aerosol indirect effects. GRL.

# The influence of stability on aerosol-cloud interaction depends on platform used to retrieve cloud properties.

First (Twomey) Aerosol Indirect Effect

ARM surface aerosol and cloud properties

MODIS satellite aerosol and cloud properties




## Scientific Objective

To determine how meteorological parameters affect the diversity in the sensitivity of non-precipitation marine boundary layer (MBL) clouds to aerosol perturbations and the magnitude of the aerosol first indirect effect (FIE).

## Approach

•Aerosol and non-precipitation MBL cloud properties retrieved from ground measurements and MODIS over Azores during AMF-Azores campaign are used to examine the relationship between aerosol and cloud, and estimate the FIE .

•The influence of vertical velocity and atmospheric stability (Lower tropospheric stability  (LTS) ) on aerosol-cloud relationship and magnitude of FIE are studied..

## Key Accomplishment

Positive relationship between FIE and atmospheric stability is observed by using surface retrieved cloud properties, while satellite measurements of cloud properties give the opposite relationship.

## Publication

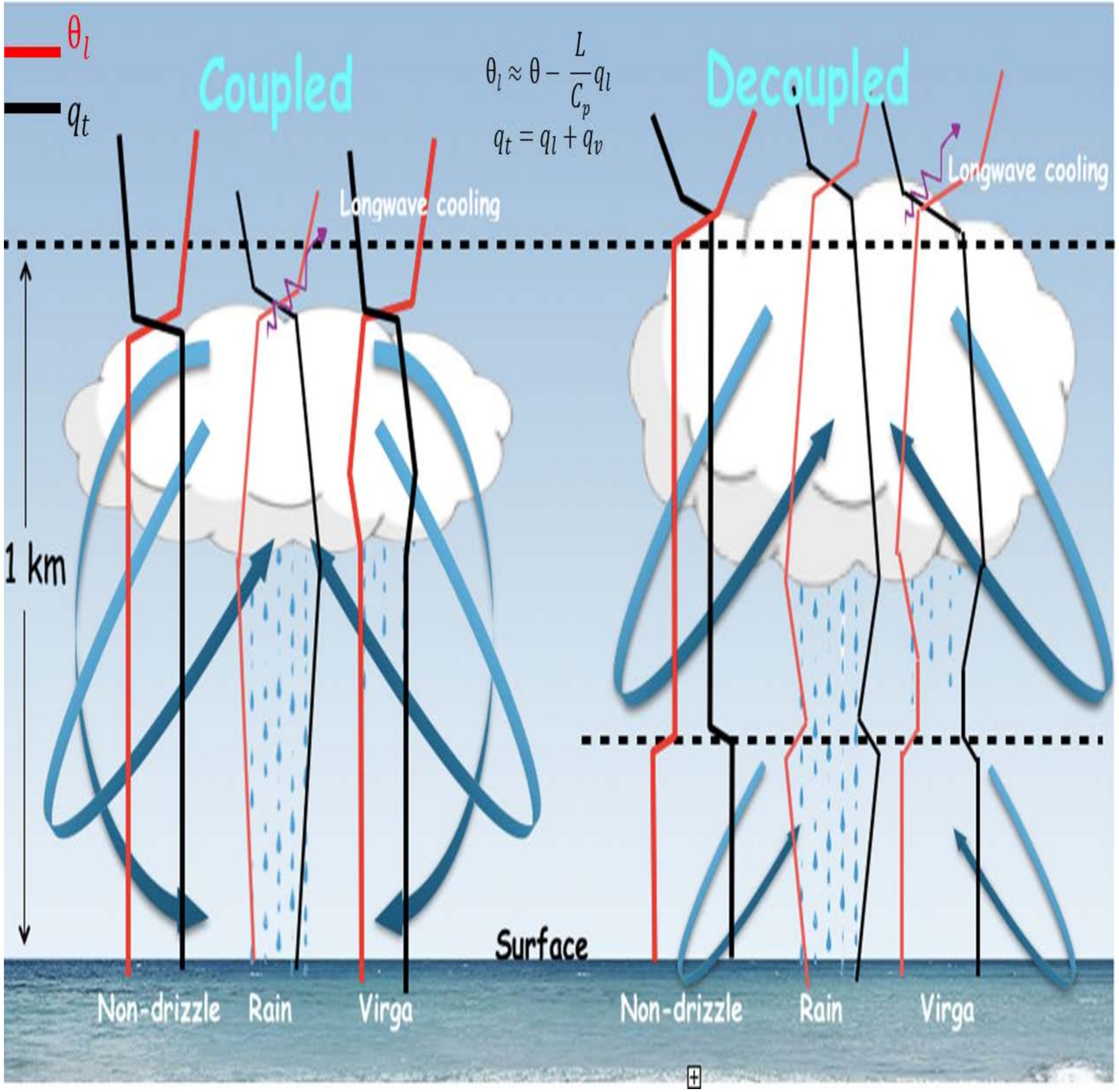

Liu, J., Z. Li, and M. Cribb (2016), Response of Marine Boundary Layer Cloud Properties to Aerosol Perturbations Associated with Meteorological Conditions from the 19-month AMF-Azores Campaign, Journal of the Atmospheric Sciences, revision submitted.

# MBL Cloud and CCN Properties under Coupled and Decoupled Conditions

**Xiquan Dong , University of North Dakota**

Vertical structure of thermodynamics (**θ**$_L$, $q_t$), circulation, drizzle, and aerosol are very different for coupled and uncoupled stratocumulus topped boundary layer.

Coupled stratocumulus topped boundary layer depths are shallow (<1 km), while decoupled are thicker (1 km).




Dong, X. A. C. Schwants, B. Xi, and P. Wu, 2015: Investigation of the Marine Boundary Layer Cloud Properties under the Coupled and Decoupled conditions over the Azores. JGR. 120, 6179-6191.

# Aerosol indirect effects over the NE Pacific during MAGIC


## David Painemal[1,2] and Patrick Minnis[2] ([1]SSAI, [2]NASA Langley)


### Aerosol indirect effect quantification and boundary layer modulation

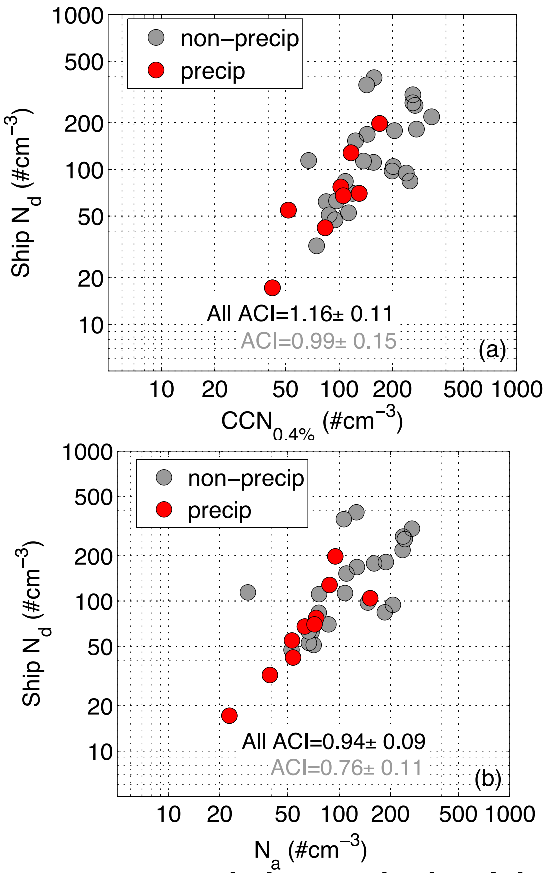



*Figure 1: Scatterplot between ship-based cloud droplet number conc. ($N_d$) and a) CCN, b) accumulation mode aerosols. ACI corresponds to the slope (log scale).*

### Synoptic variability of cloud droplet number concentration ($N_d$)

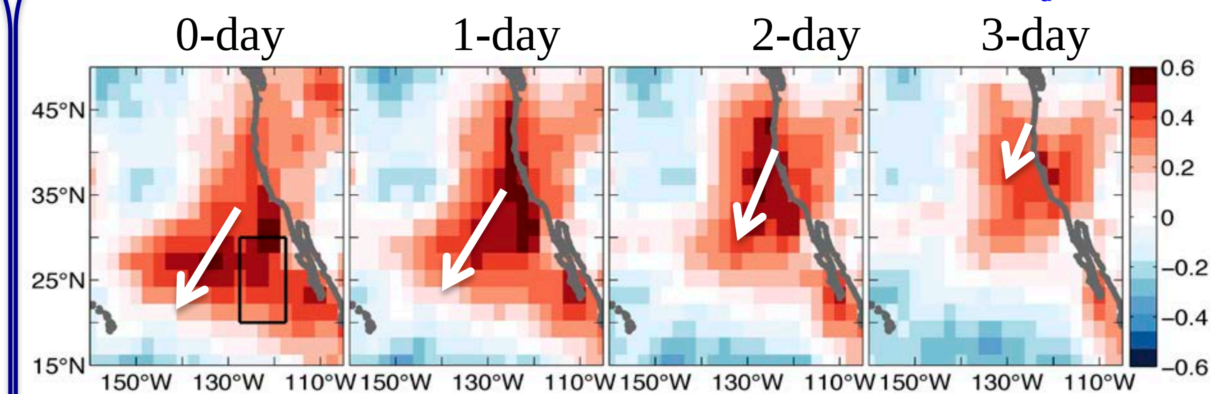


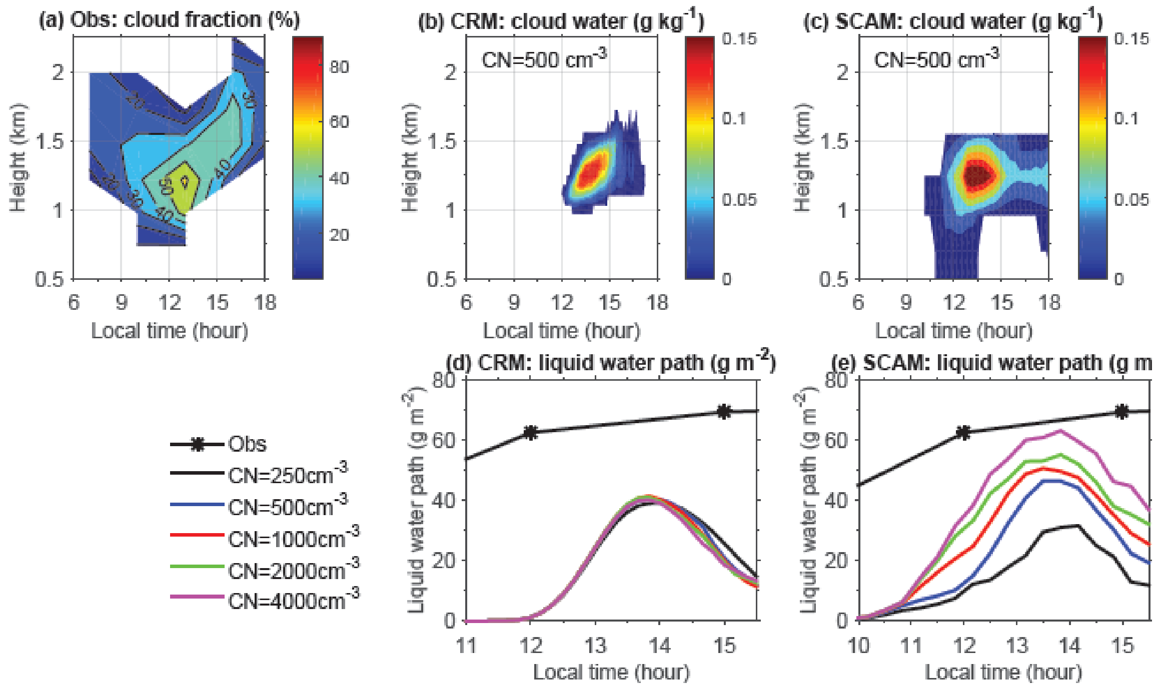

*Figure 2: One-point correlation map between coastal MODIS $N_d$ time series (black box) and mass concentration of organic carbon simulated by GEOS-Chem. Aerosol field precedes $N_d$ in 0, 1, 2, and 3 days. A propagating pattern from the coast is apparent.*

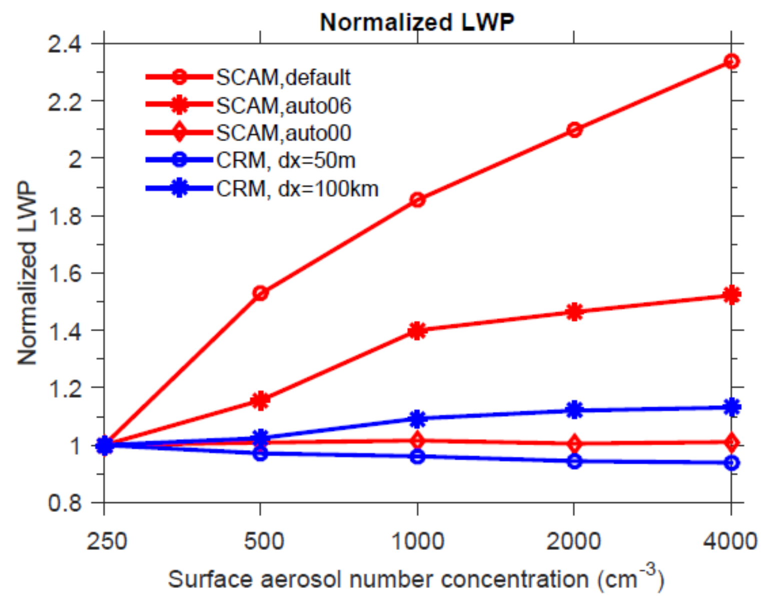
### Summary:

- Strong aerosol-cloud interactions consistent with aircraft observations in other marine low clouds regimes.
- Information about the aerosol vertical structure is essential in deep (decoupled) boundary layers.
- Coastal low level jet plays a primary role in modulating $N_d$ synoptic variability.
- Annual changes in cloud microphysics co-vary with boundary layer aerosols.

# Why do GCMs overestimate the aerosol cloud lifetime effect? A comparison of CAM5 and a CRM

**Cheng Zhou and Joyce Penner**
**University of Michigan**




1. Shallow warm clouds on 05/27/2011 at the DOE ARM SGP site were simulated with CAM5 and GCE-CRM.
2. The LWP simulated by CAM increases substantially with aerosol loading while that in GCE does not.
3. In GCE the effect from increased evaporation of cloud droplets, especially at the cloud top, offsets or even outweighs the effects from the reduced autoconversion rate and the increased condensation rate.

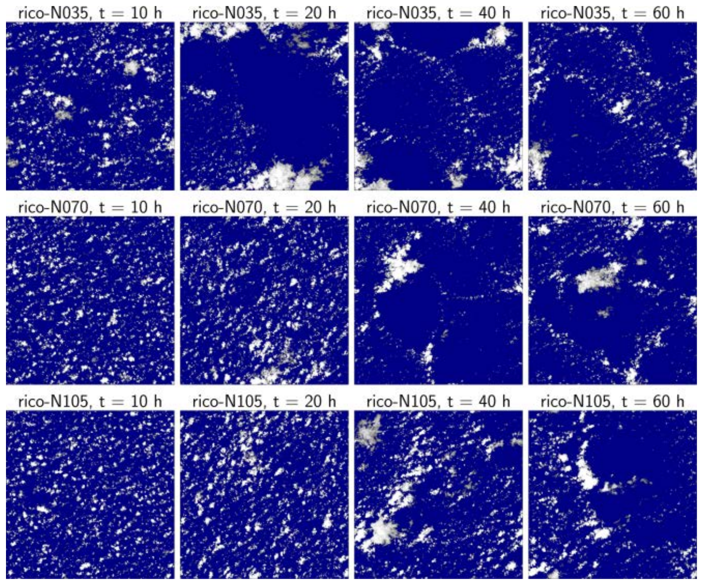
SCAM: The increase of LWP in CAM can be reduced or eliminated when the dependence of the autoconversion rate on cloud droplet number is reduced.

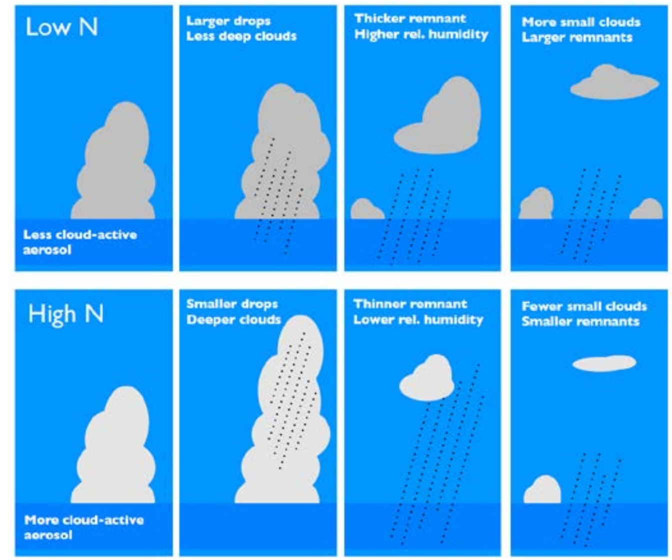
CRM: The LWP decreases with aerosol loading for dx=50m but increases slightly for dx=100km when the vertical velocities inside the clouds and the cloud top growth are limited.

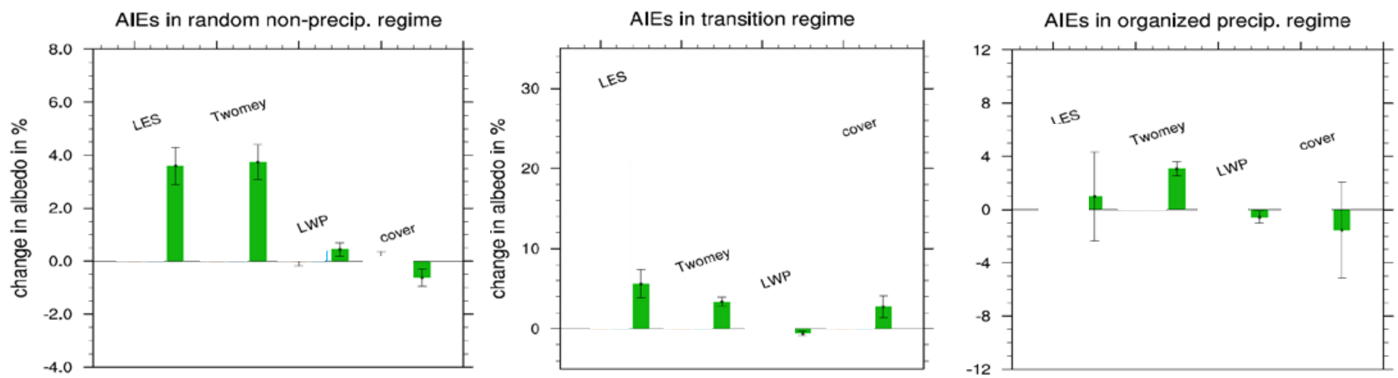
# Cloud cover decreases with increased Nd in large-domain trade Cu simulations

Idealized RICO sims.
50x50 km domain

- Twomey effect has largest effect on albedo
- As clouds start to precipitate and organize, cloud cover becomes slightly *smaller* (dryer atmos.) and opposes Twomey effect



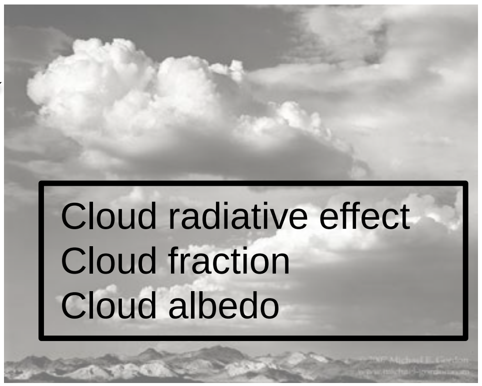

**Seifert, A. T. Heus, R. Pincus, B. Stevens. Large-eddy simulation of the transient and near-equilibrium behavior of precipitating shallow convection. JAMES, 2015.**

# Top Down vs. Bottom-up Approaches to Quantifying Aerosol-Cloud Interactions

Graham Feingold, Allison McComiskey, and Tak Yamaguchi

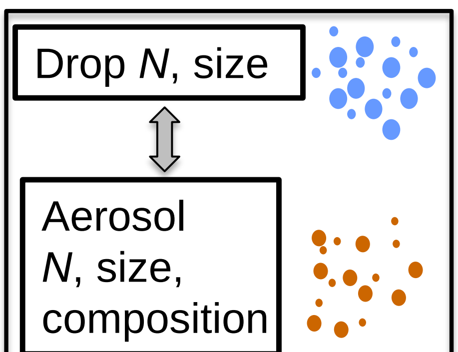
**Top-down**

$$A = A_c f_c + A_s(1 - f_c)$$




**Co-variability between aerosol and meteorology determines detectability of cloud radiative effect**

**Need quantification of both microphysical and macrophysical**

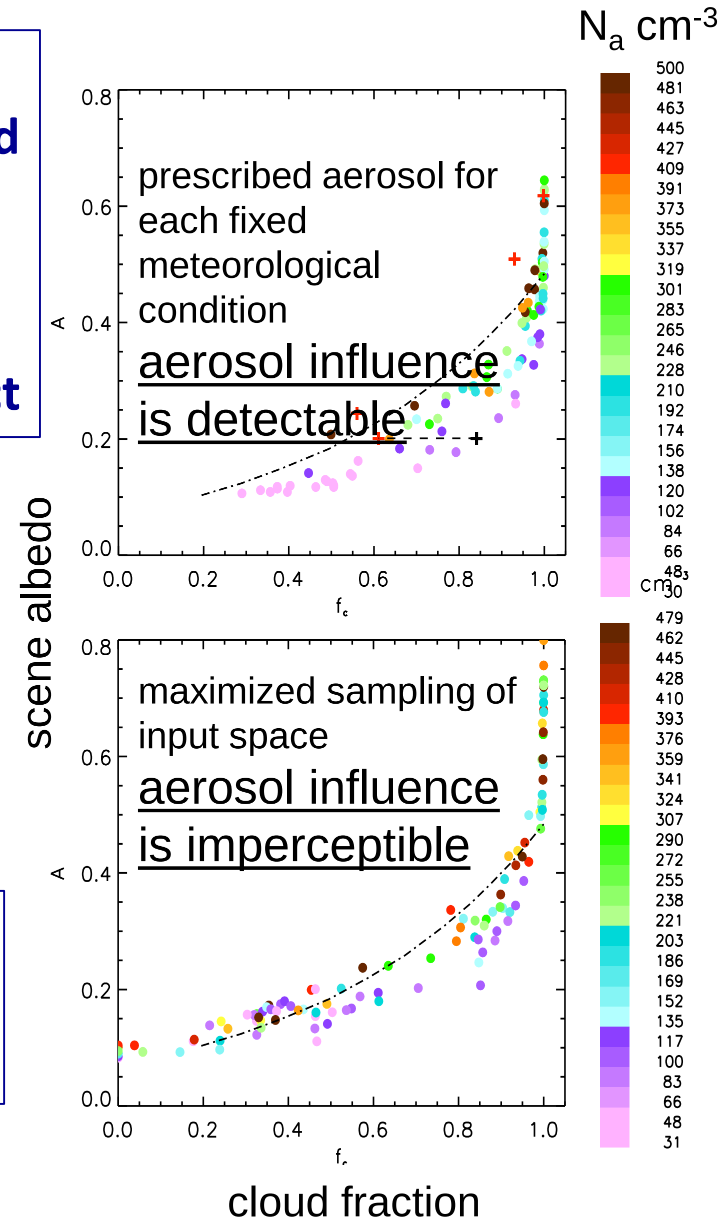



$$\mathrm{ACI} = -\left.\frac{\partial r_e}{\partial N_a}\right|_L$$

**Bottom-up**

**Strengthens case for routine LES (LASSO)**

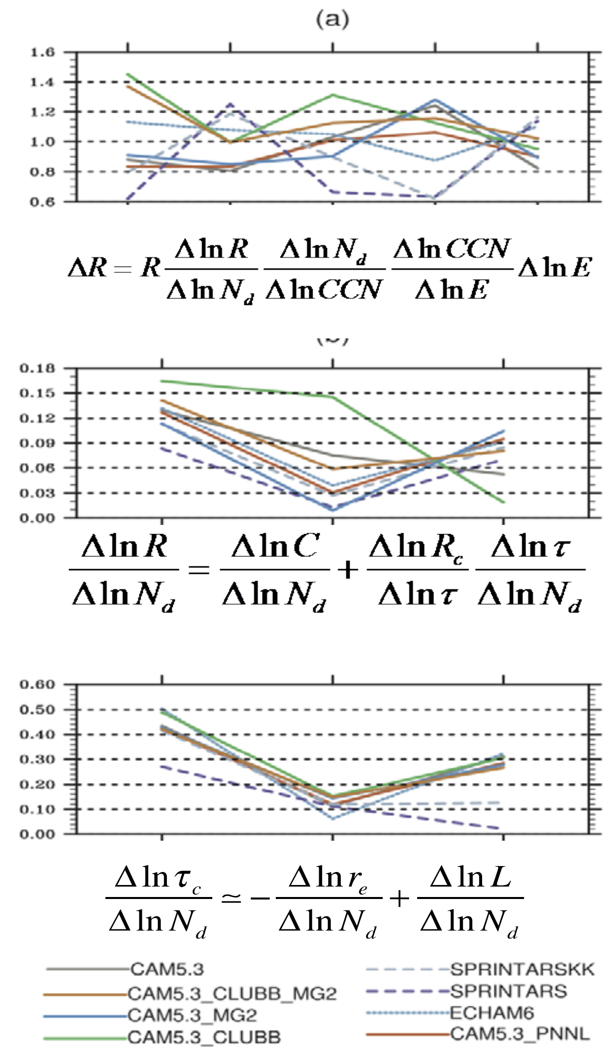
*Feingold et al. 2016, PNAS*



# Constraining estimates of aerosol effects on warm cloud radiative forcing

Ghan et al. PNAS (2016)

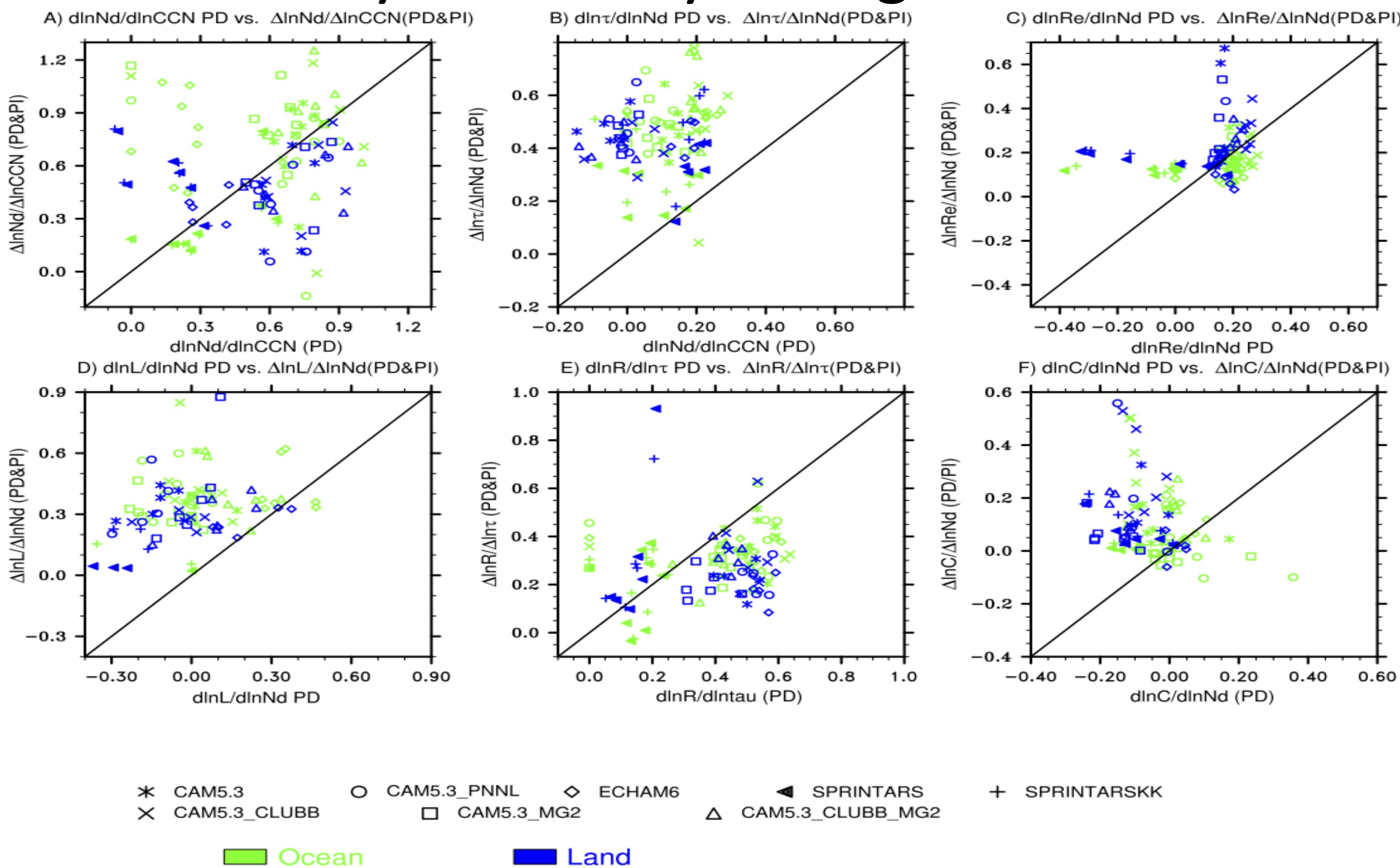
- Each factor contributes to model diversity in estimates of forcing
- Observational constraints are needed



# Constraining estimates of aerosol effects on warm cloud radiative forcing

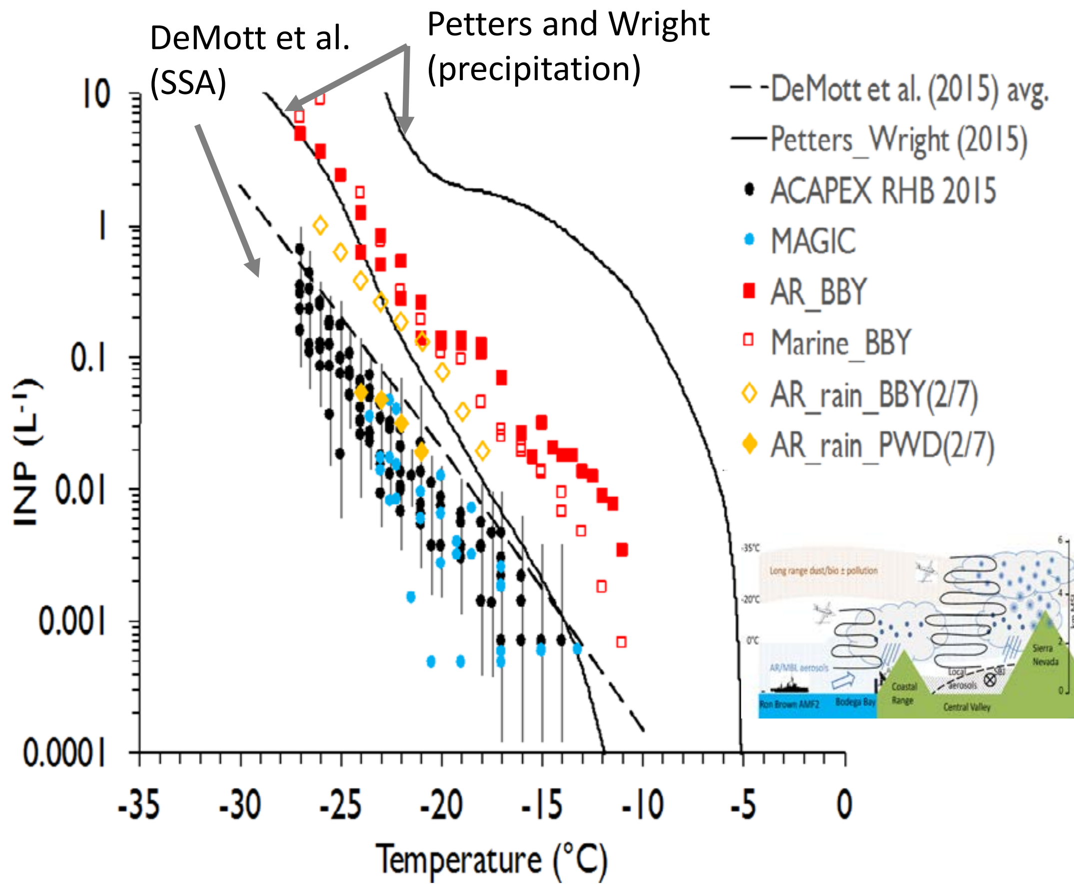
Ghan et al. PNAS (2016)

- Present day variability in might be insufficient



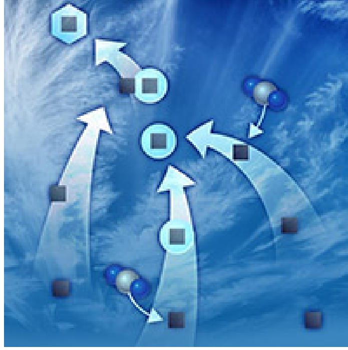
# ACAPEX ice nucleating particle (INP) measurements: Variability of MBL INPs and impact on precipitation

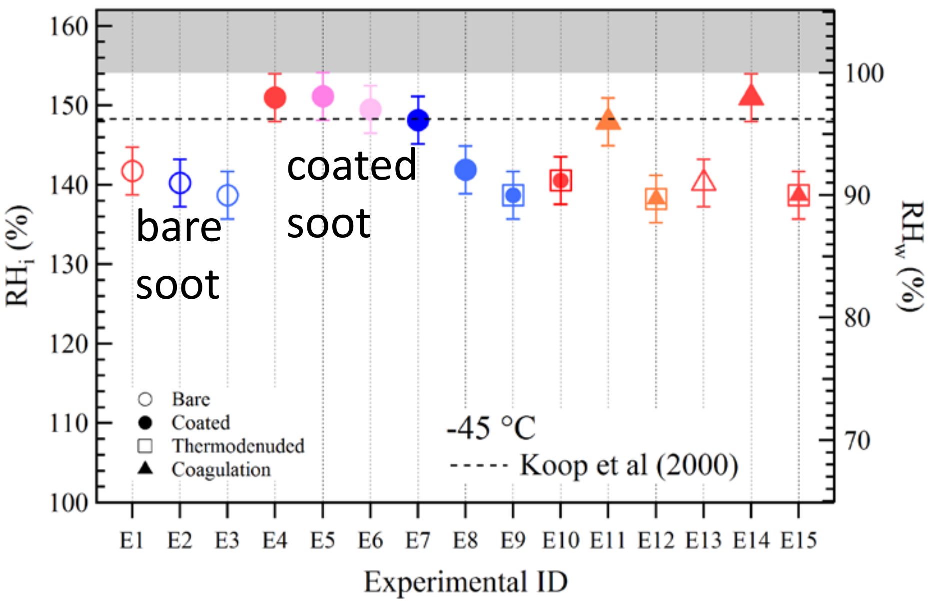
- Ice nucleation data from air and from precipitation during atmospheric river (AR) event (Feb. 2015)
- INPs from marine air are toward the lower bound of those attributed to sea spray aerosols (SSA) in previous work
- INP conc. AR (winter) ~ MAGIC (summer)
- Elevated INPs at coast (waves, land influence?)
- INPs in precipitation (converted from volume rain to per volume air for 0.4 g $m^{-3}$ cloud water content) span range of open ocean and coastal values
- Precipitation INP content falls at or below lower bound of published values
- Parameterizations will be developed for numerical modeling of AR case studies




**See DeMott poster**

# Influence of morphology and aerosol mixing state on ice nucleation






**Main Conclusions**

a. Humidification improves INP efficiency.

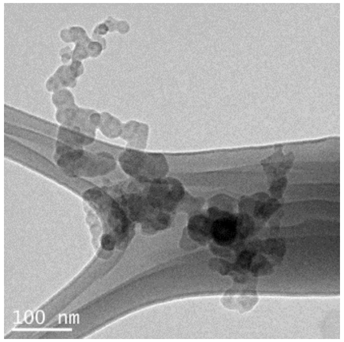
b. Coating at dry RH makes particles poor INP.

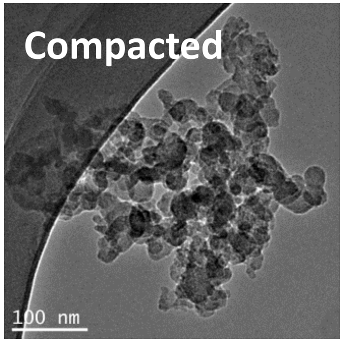
c. Coating at high RH restores INP efficiency.

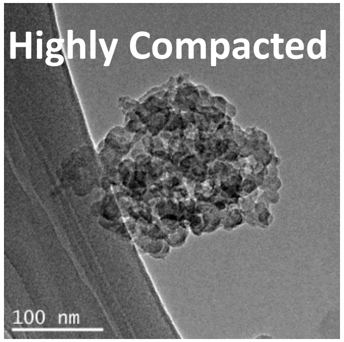
*d. Cold cloud processing* affects soot morphology

**SAAS-PNNL study**: Diesel soot particles were chemically and thermally treated to mimic the atmospheric aging and mixing state.

**Implications**: Soot IN efficiency depends on atmospheric aging and mixing state.




***Kulkarni et al.,*** (2016) Ice nucleation activity of diesel soot particles at Cirrus relevant temperature conditions: Effects of hydration, secondary organics coating, soot morphology, and coagulation. GRL.

***China et al***., (2015) Effect of ice nucleation of soot morphology and optical properties, Environ. Res. Lett.

# Improving predictability of ice/mixed-phase clouds and aerosol interactions in CESM-CAM5 with ARM measurements

Xiaohong Liu, Zhien Wang, Chenglai Wu, Minghui Diao, Meng Zhang, and Jing Yang

## Objective

- Test and improve the performance of ice microphysics in CAM5 with the ARM data using SCM, aircraft sampler and CAPT approaches
- Develop a long-term multi-sensor mixed-phase cloud dataset.
- Understand cloud microphysics-aerosol-dynamics-radiation interactions in ice/mixed-phase clouds

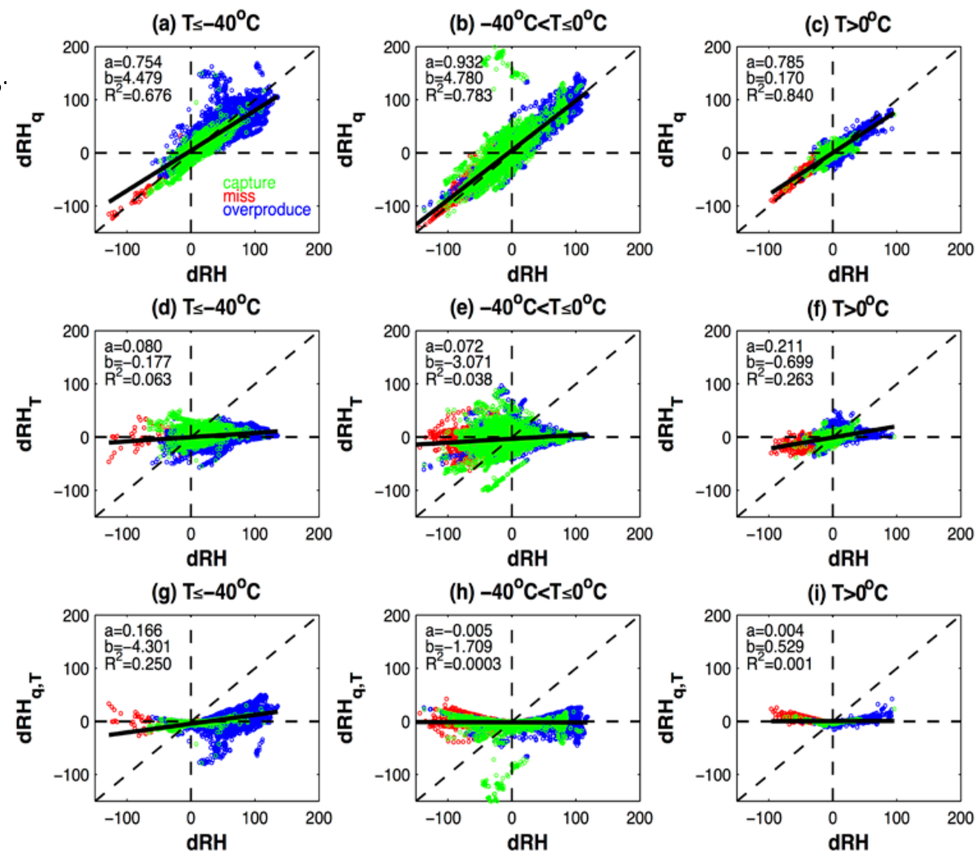
## Approach and Results

- Use the "***aircraft sampler***" approach to sample the CAM5 simulation along the aircraft flight tracks.
- Compare CAM5 results with ***HIPPO*** (2009-2011) and ***SPARTICUS*** (2010) observations.
- Errors in CAM5 simulated cloud occurrence is mainly due to RH errors, ascribed mostly to the errors in water vapor, not T. CAM5 cannot capture strong subgrid variability of water vapor observed by HIPPO.

**Contribution of errors in T and $H_2O$ to RH errors**

(*d*: model - observation; *o*: HIPPO observation

$$dRH = de \cdot \frac{1}{e_{s,o}} + e_o \cdot d(\frac{1}{e_s}) + de \cdot d(\frac{1}{e_s}) = dRH_q + dRH_T + dRH_{T,q}$$

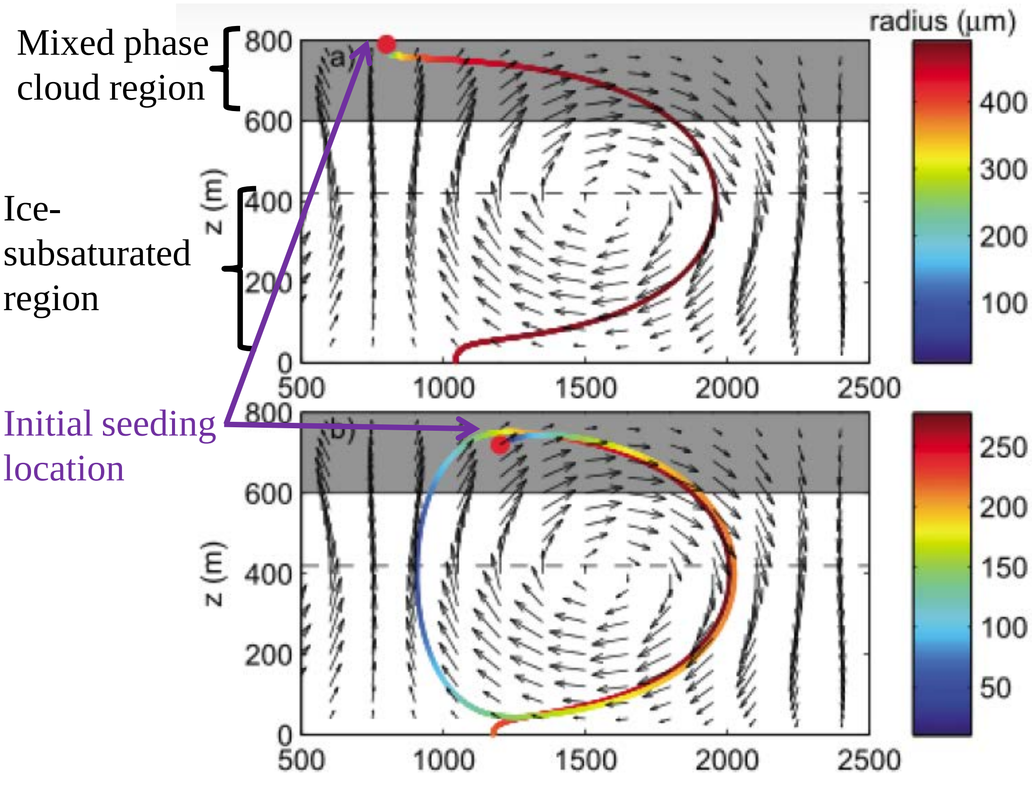


# Lagrangian ice particle tracking in mixed-phase stratiform clouds

Fan Yang[1] Mikhail Ovchinnikov[2] Raymond Shaw[1]

[1]Atmospheric Science Program, Physics Department, Michigan Technological University, Houghton, Michigan

[2]Pacific Northwest National Laboratory, Richland, Washington




Trajectories of two types of ice particles in 2-D idealized field: a) quasi-steady b) recycling. Color bar represents the radius of the ice particle.

## *Two ways to grow largest ice crystals*

**a. Quasi-steady growth:**

Ice particles are suspended in an updraft region for a long time.

**b. Recycling growth:**

Ice particles are trapped in the large eddy structures and slowly grow as they are recycled. Whether ice particles grow or sublimate depends on large eddy velocity field and the humidity profile within the trapping region.

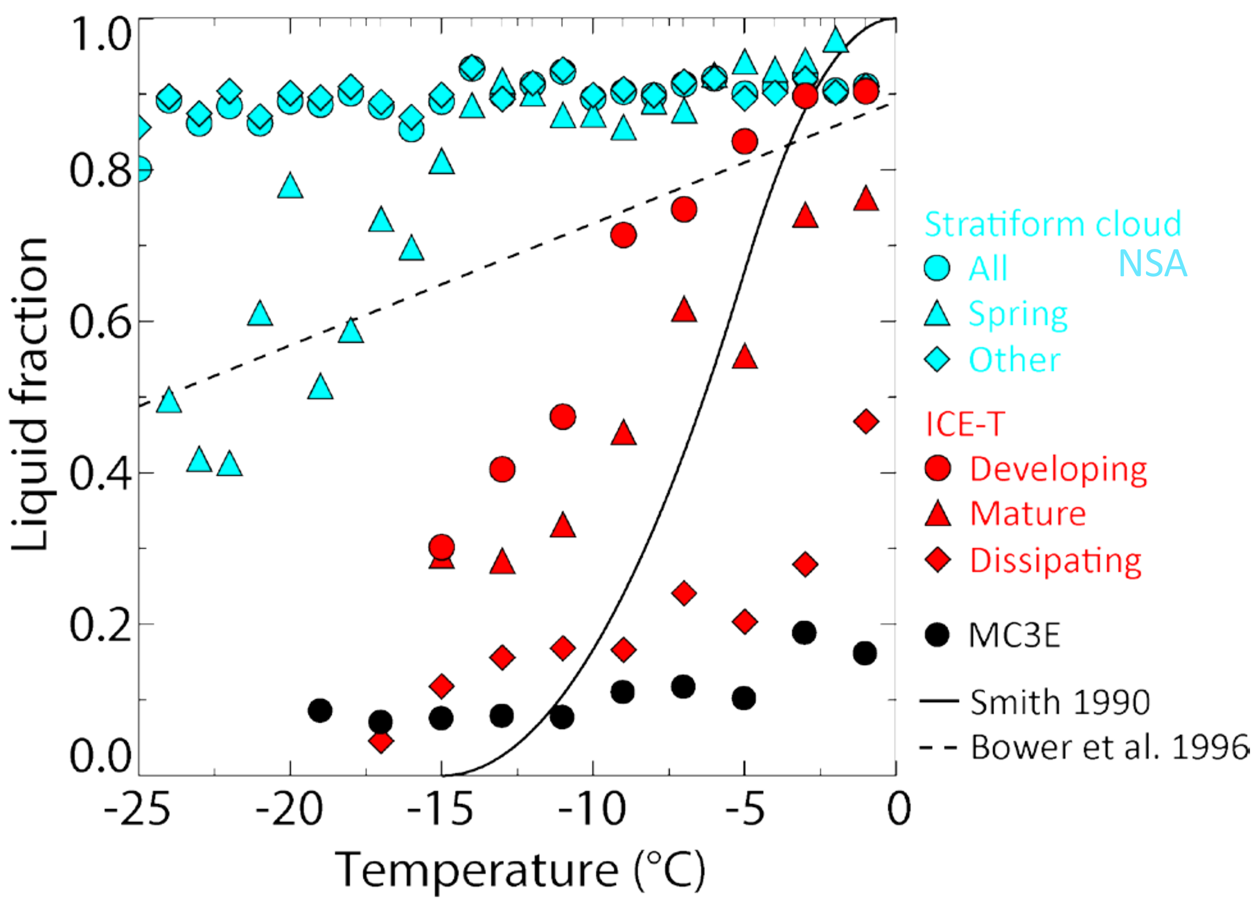
# Aerosol, Cloud Type, Lifecycle Dependent Liquid-Ice Mass Partition

**Liquid Fraction**= liquid mass/total mass

Seasonal variations in stratiform mixed-phase cloud highlight the importance of aerosols.

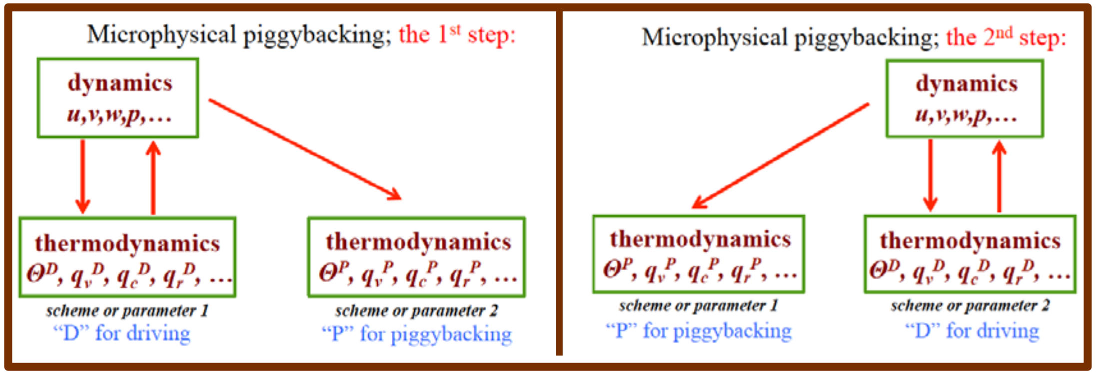
The partition in convective clouds evolves with cloud life stages.

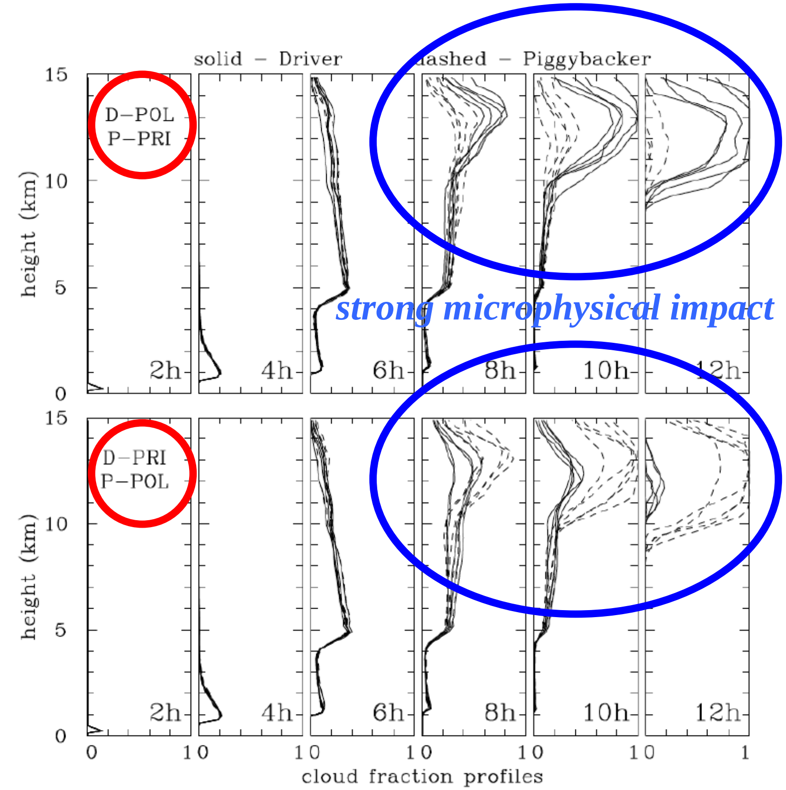
Systematic differences exist between stratiform and convective from mixed-phase clouds.




From Zhien Wang, Jing Yang and Damao Zhang, University of Wyoming

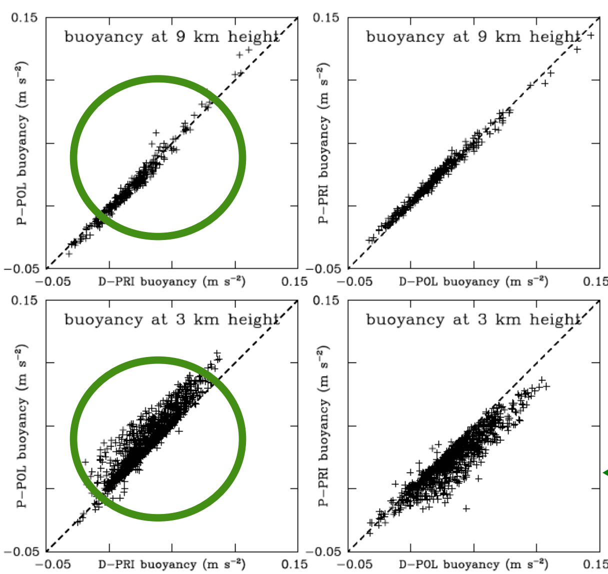
# *Weak dynamical and strong microphysical impacts of CCN on deep convection in a cloud model with 2-moment microphysics and microphysical piggybacking*




Piggybacking simulations consider diurnal cycle of deep convection and contrast clouds developing in pristine (PRI, 100 per cc of CCN) and polluted (POL, 1,000 per cc of CCN) conditions.

*weak dynamical impact at 3 km,*
*no impact at 9 km*




Strong microphysical impact: cloud fractions of the upper-tropospheric anvils in the second half of the day are significantly larger in POL than in PRI because of higher concentrations and slower sedimentation of ice particles regardless which set drives the simulation.

Weak dynamical impact: buoyancy is practically the same in PRI and POL at 9 km (-27 degC); buoyancy is larger in POL at 3 km (9 degC) because of the lower supersaturations.

Grabowski W. W., and H. Morrison, 2016: Untangling microphysical impacts on deep convection applying a novel modeling methodology: Part II: Double-moment microphysics. *J. Atmos. Sci*. (in review).