Cloud-Aerosol-Precipitation Interactions Working Group Updates

Rob Wood and Steve Ghan

ASR

CAPI Science Questions

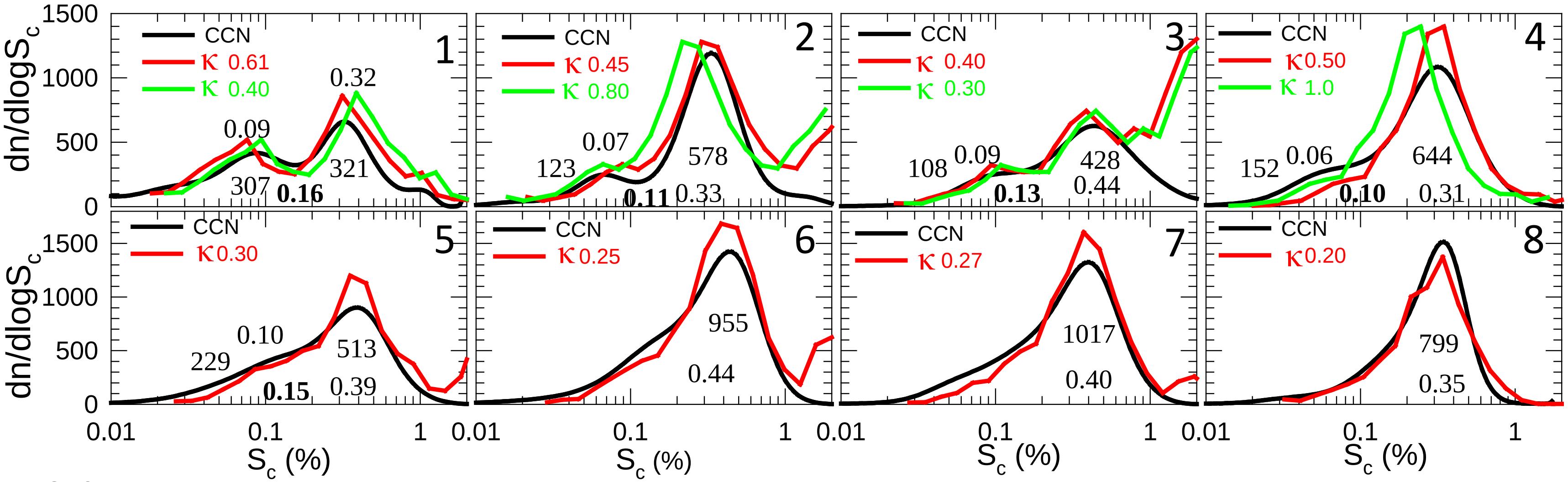
- **What processes control diversity in the sensitivity of warm low clouds to aerosol perturbations, and why do GCMs seem to overestimate the sensitivity?**
- **What aerosol-related processes control deep convective cloud properties relevant to climate?**
- **What processes control ice nucleation and its impact on ice-containing clouds?**

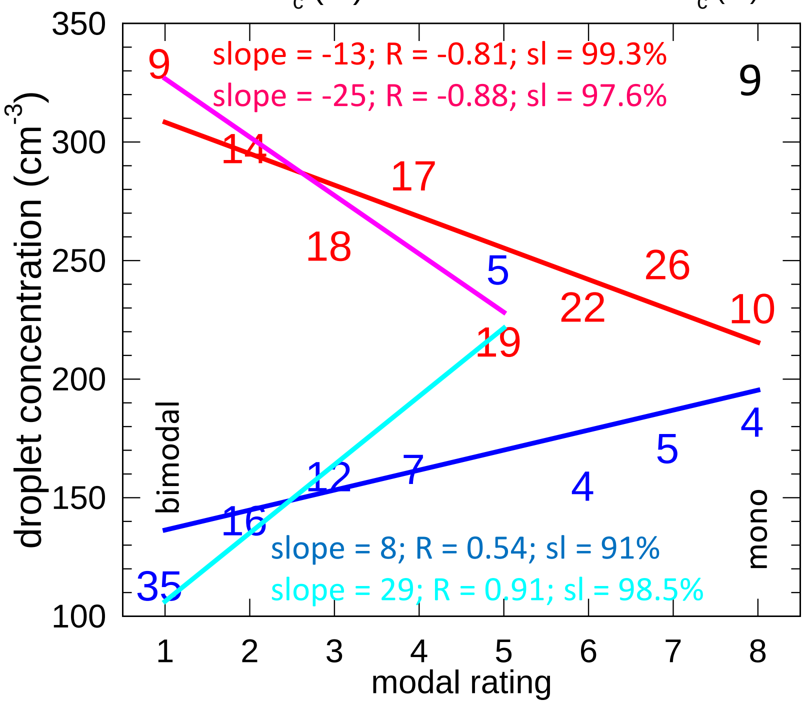
ASR

Low, warm clouds

- **What processes control diversity in the sensitivity of warm low clouds to aerosol perturbations, and why do GCMs seem to overestimate the sensitivity?**
- What aerosol-related processes control deep convective cloud properties relevant to climate?
- What processes control ice nucleation and its impact on ice-containing clouds?

CCN Bimodality and Cloud Microphysics by Hudson and Noble, DRI





Panels 1-8. MASE examples of simultaneous CCN (black) and DMA (red and green) distributions for each of the 8 modal ratings. 1 is most bimodal, 8 is strictly monomodal. DMA hygroscopicity (κ) are shown in legend. CCN concentrations (cm^{-3}) within each mode and modal critical supersaturations (S_c) in percent are shown as well as the Hoppel minima S_c (bold).

Panel 9. Mean cloud droplet concentrations against modal rating for MASE (red and pink; polluted California stratus) and ICE-T (blue and cyan; Caribbean cumuli). Cyan and pink regressions consider only modes 1-5; which have Hoppel minima. Data points are plotted as numbers of cases. Correlation coefficients, R, and significance levels of linear regressions are shown. Positive relationships in ICE-T indicate predominance of coalescence, which reduces concentrations. Negative relationships in MASE indicate chemical processing and Brownian scavenging, both of which make better CCN (lower S_c) that more readily produce cloud droplets.

Validation of surface retrieved cloud properties using in-situ aircraft observations at the Atmospheric Radiation Measurement Program (ARM) Southern Great Plains site

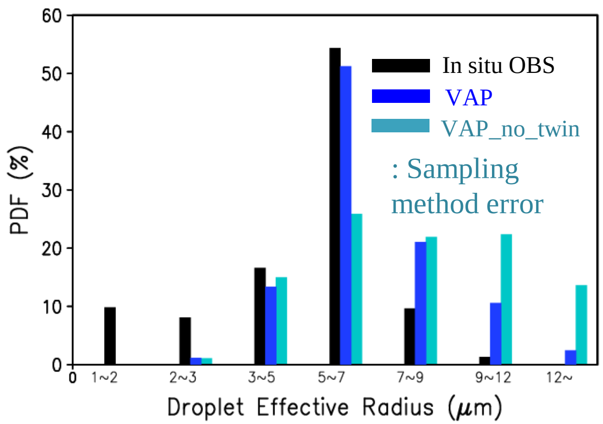
K. Sunny Lim, Laura Riihimaki, Jennifer M. Comstock, Beat Schmid, Chitra Sivaraman, and Yan Shi (PNNL)

❑ Evaluation of the cloud droplet effective radius (Re) and number concentration (Nd) from ARM Value-Added Products (VAPs) with in situ observations during RACORO campaign (5 five months of 2009)

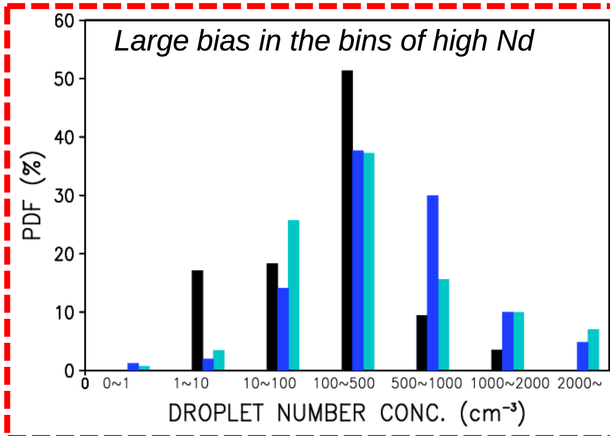
Revised VAP of Nd

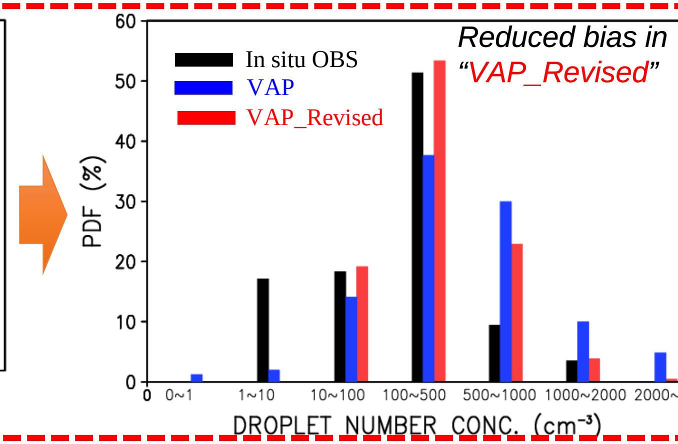
: Input of the VAP, liquid water path (LWP), is revised using the calculated LWP from the existing VAPs of cloud optical depth and effective radius of cloud, instead of LWP from microwave radiometer.

- PDF of Re

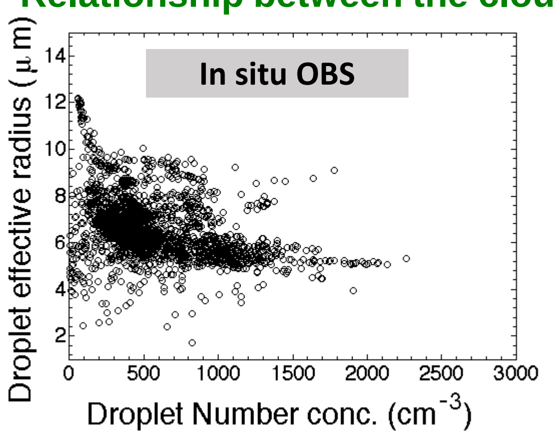


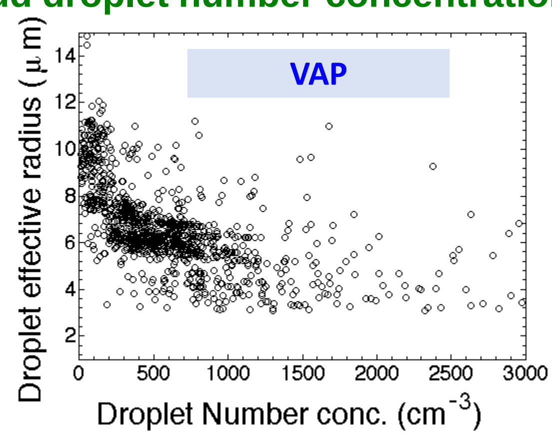
- PDF of Nd

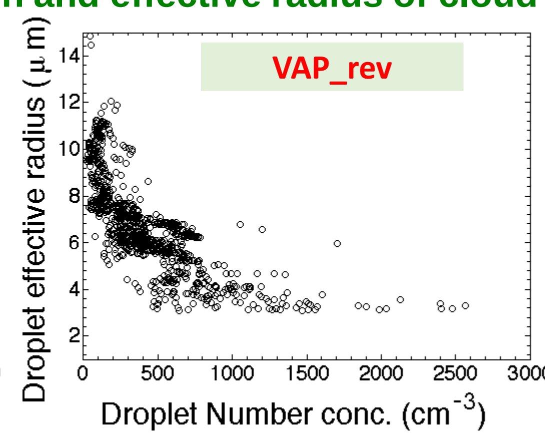




❑ Relationship between the cloud droplet number concentration and effective radius of cloud







Inverse relationship between the cloud droplet number concentration and effective radius of cloud is stronger in VAPs compared to that from in situ observations.

Analysis of shortwave spectrometry of cloudy atmospheres during MAGIC

A. Marshak (GSFC), W. Yang (USRA), P. McBride (ASTRA), C. Flynn (PNNL), S. Schmidt (U. Colorado), C. Chiu (U. Reading), and E. Lewis (BNL)

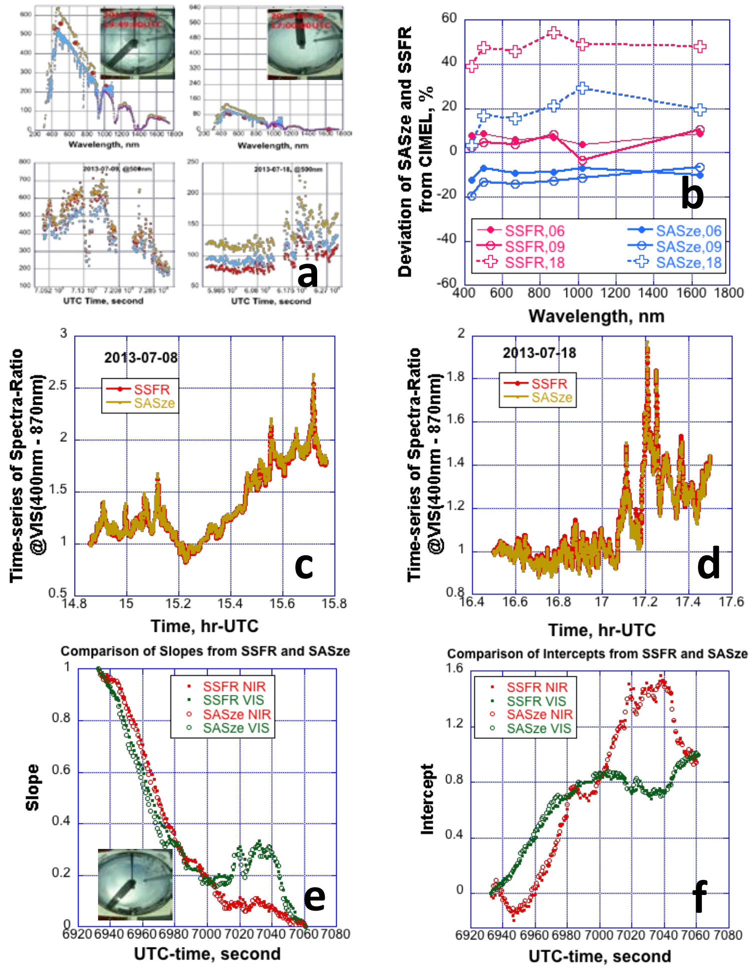
Measurements from SAS-Ze, SSFR and CIMEL can be significantly different (**Fig. a**). Analysis shows that the SSFR meas'ts are typically larger than the CIMEL by 10% while the SAS meas'ts are less than the CIMEL by 10-20%. (In some cases the deviations from CIMEL are as big as ~50%). However, the deviations have weak spectral dependence (**Fig. b**). Thus SSFR and SAS are in better agreement if self-normalized [e.g. $R(\lambda,t)/R(\lambda,t_0)$] (**Figs. c-d**).

Normalization to clear sky spectrum can be applied to analyze cloud properties in the transition zone between clear and cloudy air [e.g., Chiu et al., 2010]. Slope a and intercept b in the linear approximation

$$R_{transition}(t,\lambda)\,/\,R_{clear}(\lambda) = a(t)\; R_{cloudy}(\lambda)\,/\,R_{clear}(\lambda) + b(t)$$

contain info on cloud optical depth and droplet size. Our analysis of the transition zone shows that the slopes and intercepts from SAS and SSFR are very similar (**Figs. e-f**).

These results show that, despite large discrepancies in the rad. meas'ts between SAS and SSFR, retrievals/analyses of cloud properties using the spectral-ratio approach are robust.



(a) SSFR, SASze and CIMEL meas'ts.: spectral and time-series at 500 nm; **(b)** Deviation of SSFR and SAS from CIMEL at different wvls; **(c-d)** Temporal evolutions of self-normalized radiances from SSFR and SAS on 2013-07-08 (c) and 2013-07-18 (d); **(e-f)** slopes (e) and intercepts (f) derived from SSFR and SASze for visible and NIR bands.

A New Methodology for Separating Cloud and Drizzle Signatures from ARM Radar Observations

Cuong Nguyen and V. Chandrasekar

Colorado State University, Fort Collins, CO 80523

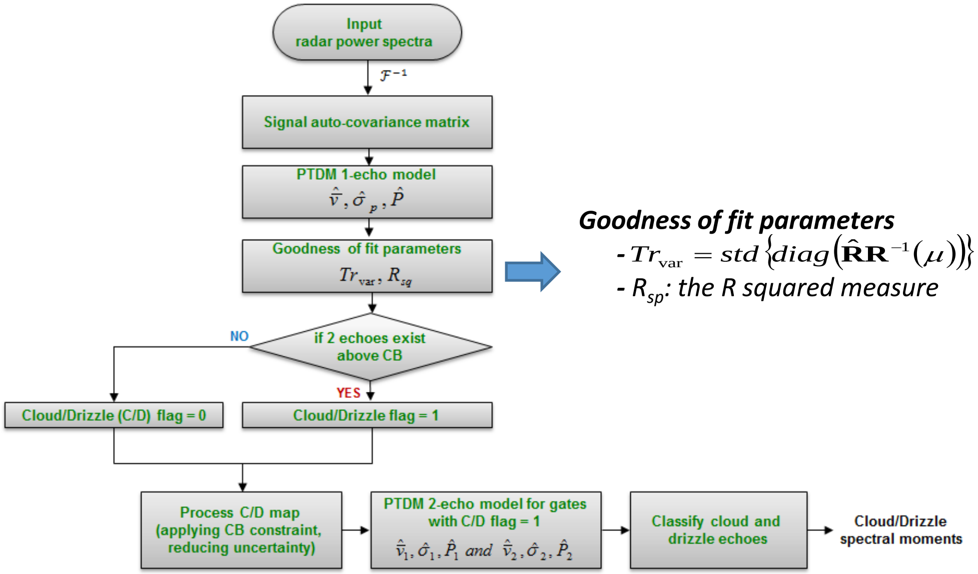


Fig. 1: Cloud/Drizzle separation procedure diagram.

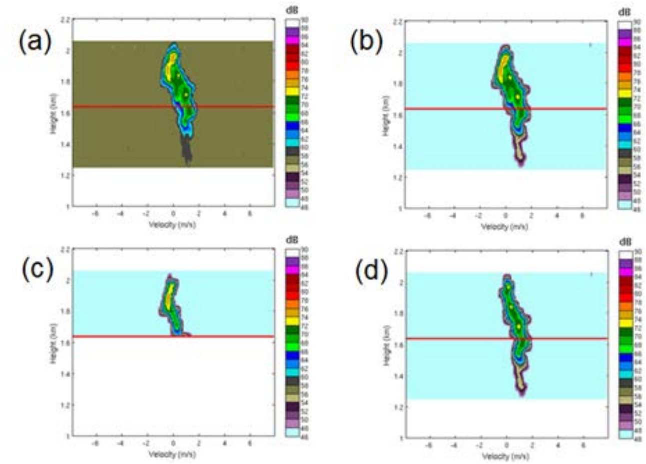


Fig. 2: Radar Doppler spectrogram collected at 10:23:04 UTC on 27 July, 2010 by the ARM WACR in the Azores. (a) measured spectrogram, (b) re-constructed spectrogram using PTDM and estimated cloud (c) and drizzle (d) spectrograms The red line is the cloud base.

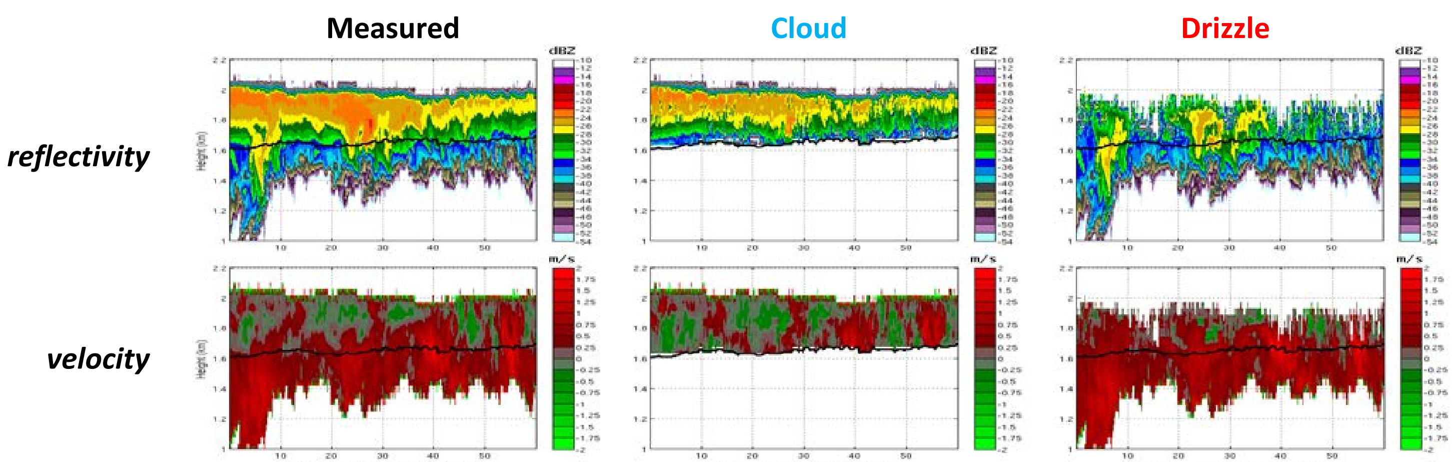
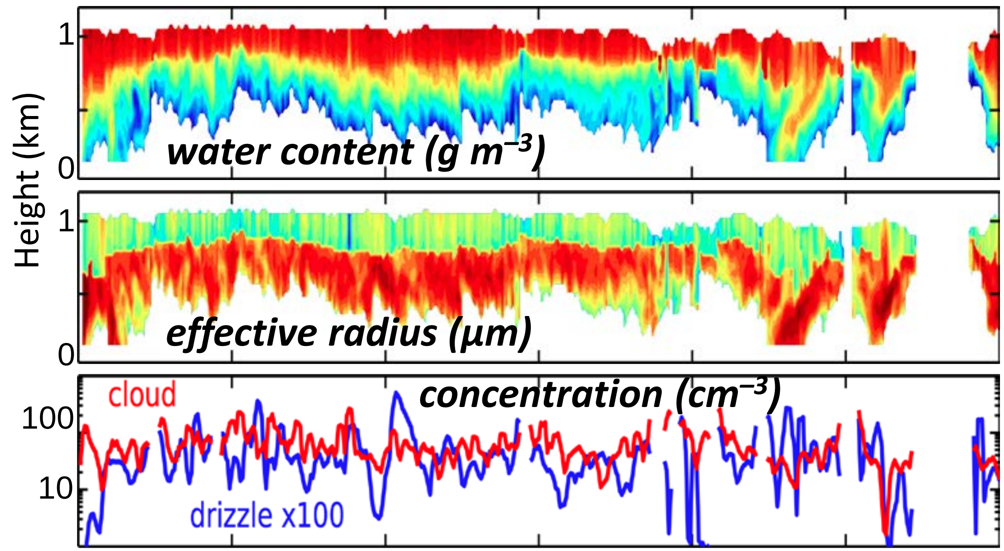


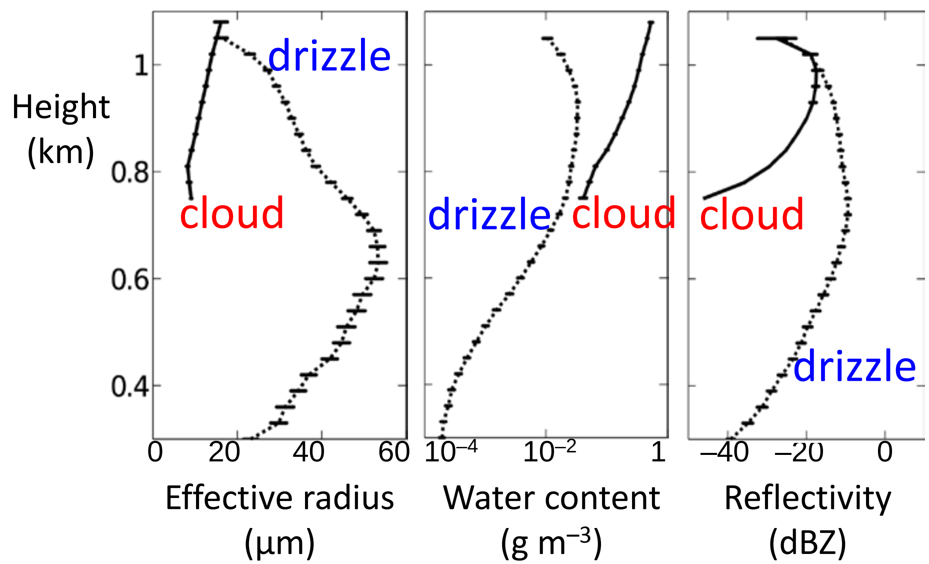
Fig. 3: Data collected by ARM WACR on 27 July 2010 from 10:00:04 UTC to 11:00:01 UTC in the Azores. Measured reflectivity and velocity (left column), retrieved reflectivity and velocity for cloud (middle column) and for drizzle (right column). The black line is the cloud base.

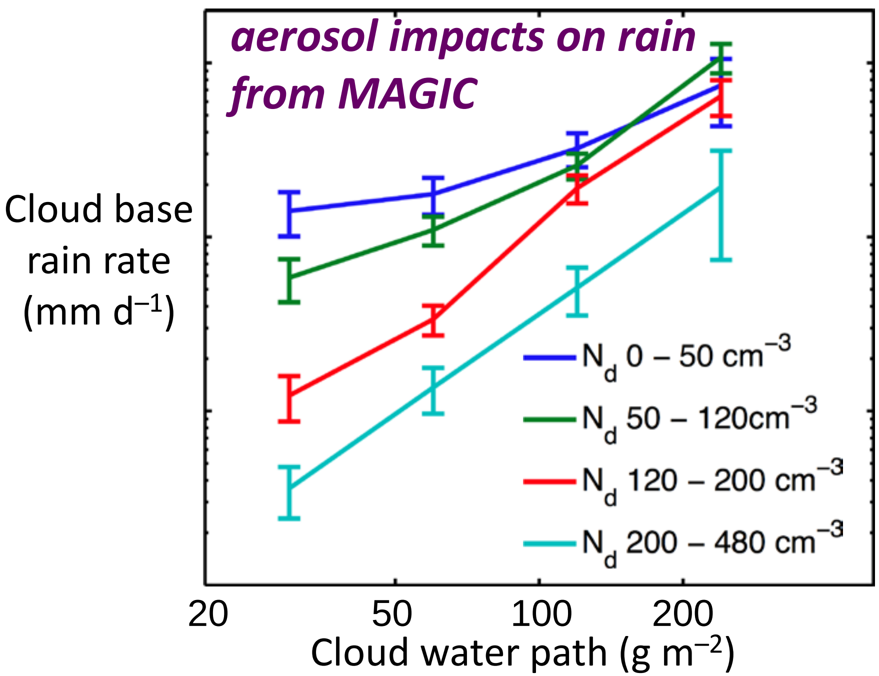
Simultaneous cloud/drizzle properties from MAGIC

- With a synergy between radar, lidar and cloud mode observations, we provide vertically-resolved cloud and drizzle properties with full error statistics.
- Help reveal aerosol effects on drizzle and the formation of precipitation within cloud; help parameterise sub-grid variability of cloud/precipitation.

Fielding, Chiu, Hogan, et al. (2015, AMTD)







Occu

Low Cloudiness over the Eastern North Atlantic as a Function of Synoptic Regime

David Mechem et al.

Retrievals in Entraining Stratocumulus Clouds

Simon de Szoeke et al.

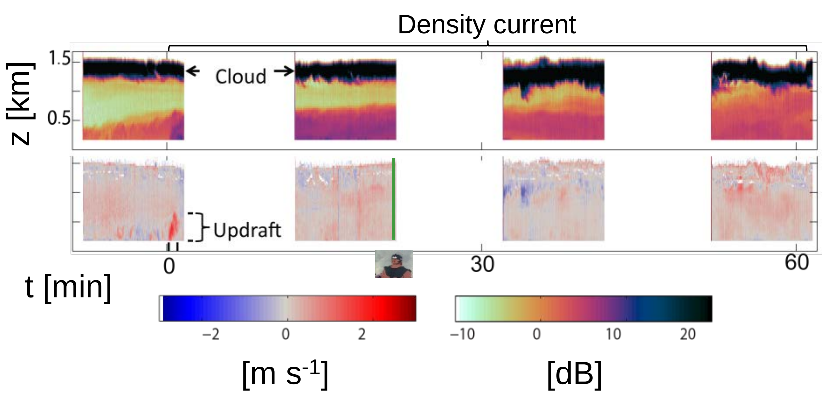
ASR Atmospheric System Research

Near-surface density currents observed in the stratocumulus-topped marine boundary layer

Matt Wilbanks and Sandra Yuter / North Carolina State University

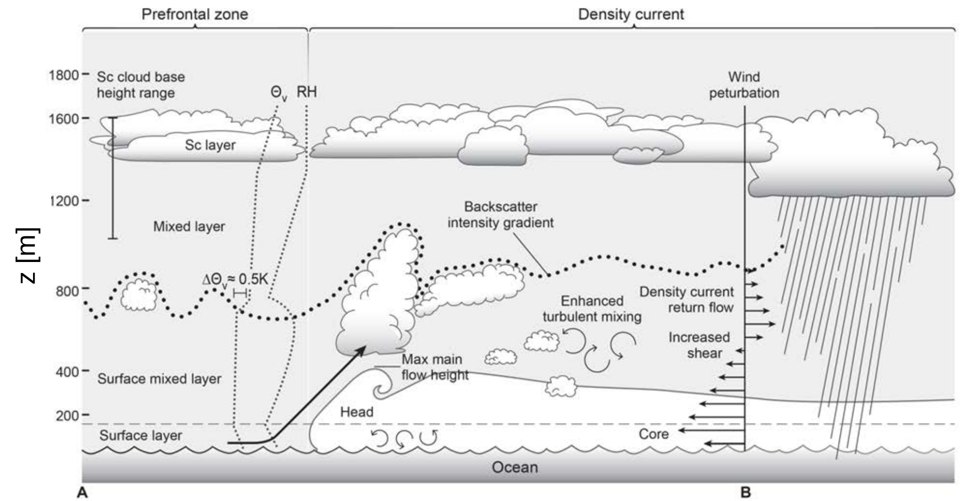
Motivating Questions

What are bulk characteristics of density currents (i.e. cold pools or drizzle outflows) beneath marine stratocumulus? What is their relationship to mesoscale cloud organization and boundary layer conditions? Do these density currents routinely initiate new drizzle cell convection?



Method

- Analysis of ship-based meteorological time series, upper air soundings, scanning Doppler lidar, scanning C-band radar, satellite data.
- 71 density currents objectively identified using air density from met data at the ship



Key Findings

- About 5-10 times thinner (330 m) and weaker (0.8 K) than continental thunderstorm cold pools.
- Prefrontal updrafts (0.91 m s^{-1}) accompanied nearly every density current up to an average of 800 m.
- Shelf clouds capped many updrafts, but did not often extend up to the overlying stratocumulus deck.
- Density currents preferentially occurred within a region of predominately open cells, but also occurred beneath closed cells.
- Density currents peak after sunrise. Daytime subcloud stability and drying may act in concert with enhanced local rain rates to form density currents.

Publication

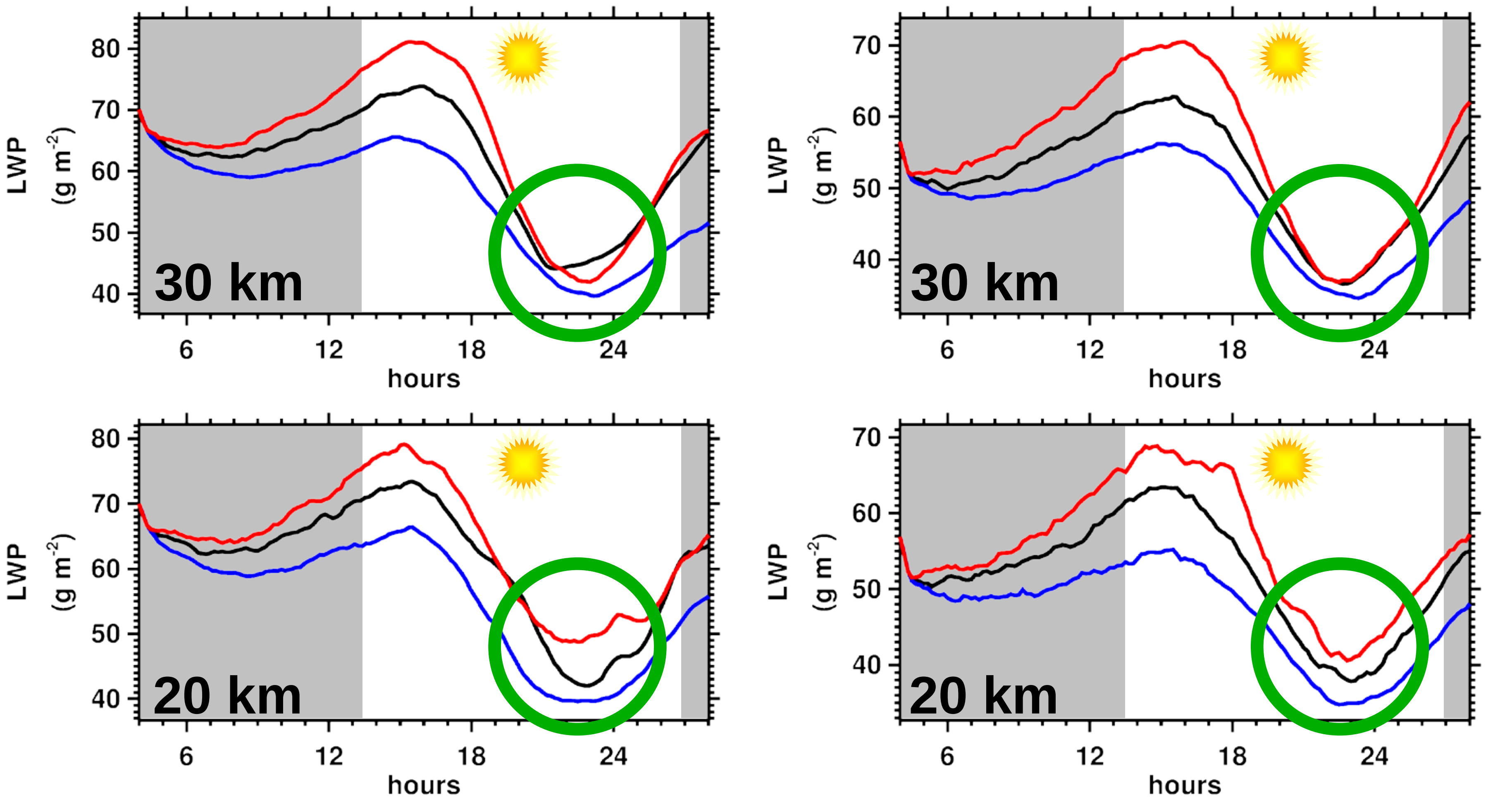
Wilbanks et al., 2015: Near-surface density currents observed in the southeast Pacific stratocumulus-topped marine boundary layer. *Mon. Wea. Rev.*, revision submitted.

Cloud-climate feedbacks, wind speed, LWP, decoupling

Kazil, Feingold, Yamaguchi

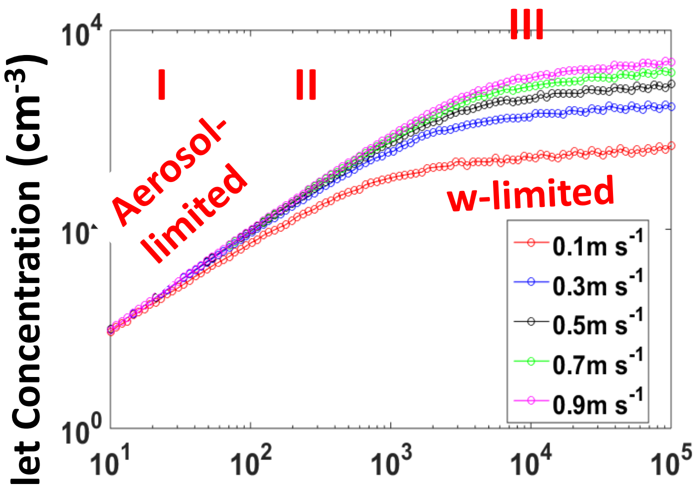
Wind speed: - 20 % — DYCOMS II RF 01 — + 20 %

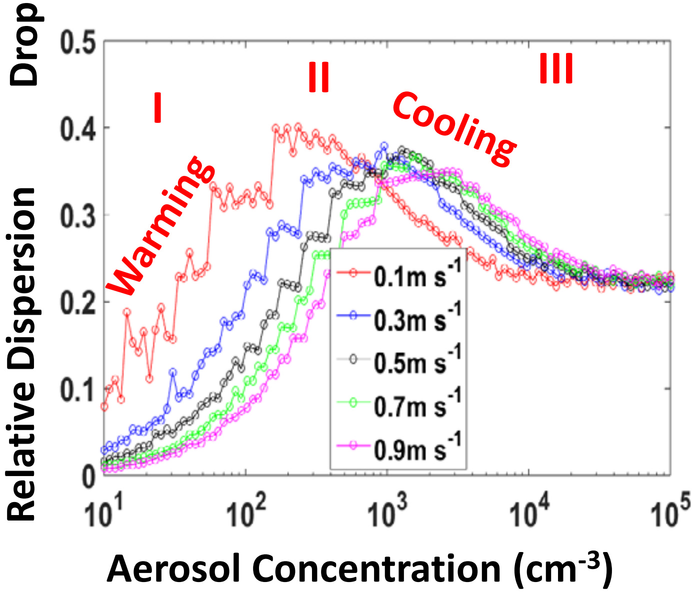
dx = dy = 75 m, dz = 7.5 m, dt = 0.75 s | **dx = dy = 150 m, dz = 15 m, dt = 1.5 s**

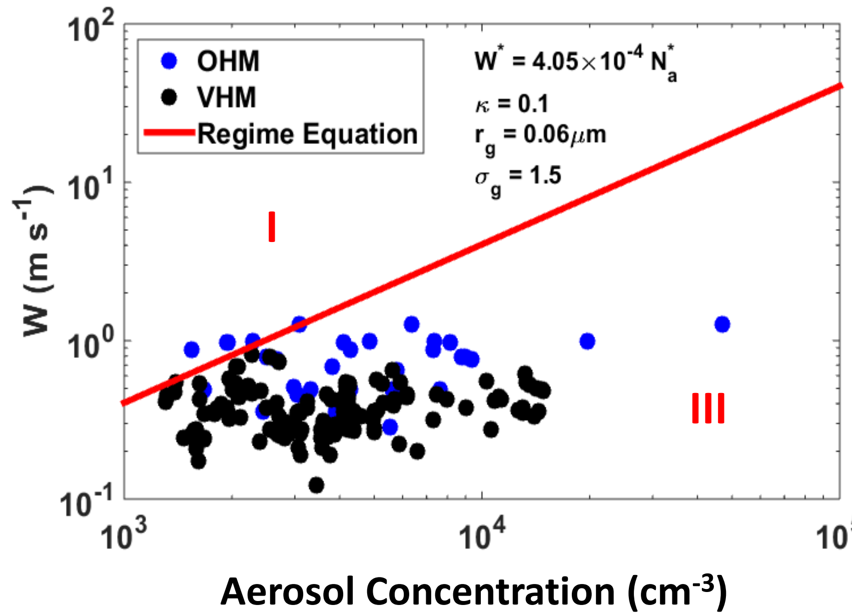


A sufficiently large domain (rather than higher resolution) required to simulate the response of LWP to wind speed

New Equation To Quantify AIE Regime







- Dispersion peak at certain pair of (Na*, w*)
- **Regime equation: w* = a Na***
- w* = 4.5 x 10^{-4} Na for RACORO aerosols
- RACORO cumuli belong to w-limited regime
- Ignoring dispersion effect underestimates AIE cooling at SGP, if the RACORO results can be generalized to SGP (work in progress).

The regime equation deriving from relative dispersion as a function of aerosol concentration (Na) and updraft velocity (w) allows for a more quantitative AIE regime classification.

(See Yangang Liu Poster)

Comparison of NASA GCE-CRM and SCM-CAM5 (SCAM) with ARM data: Examined 2 days 5/13/2011 and 5/27/2011

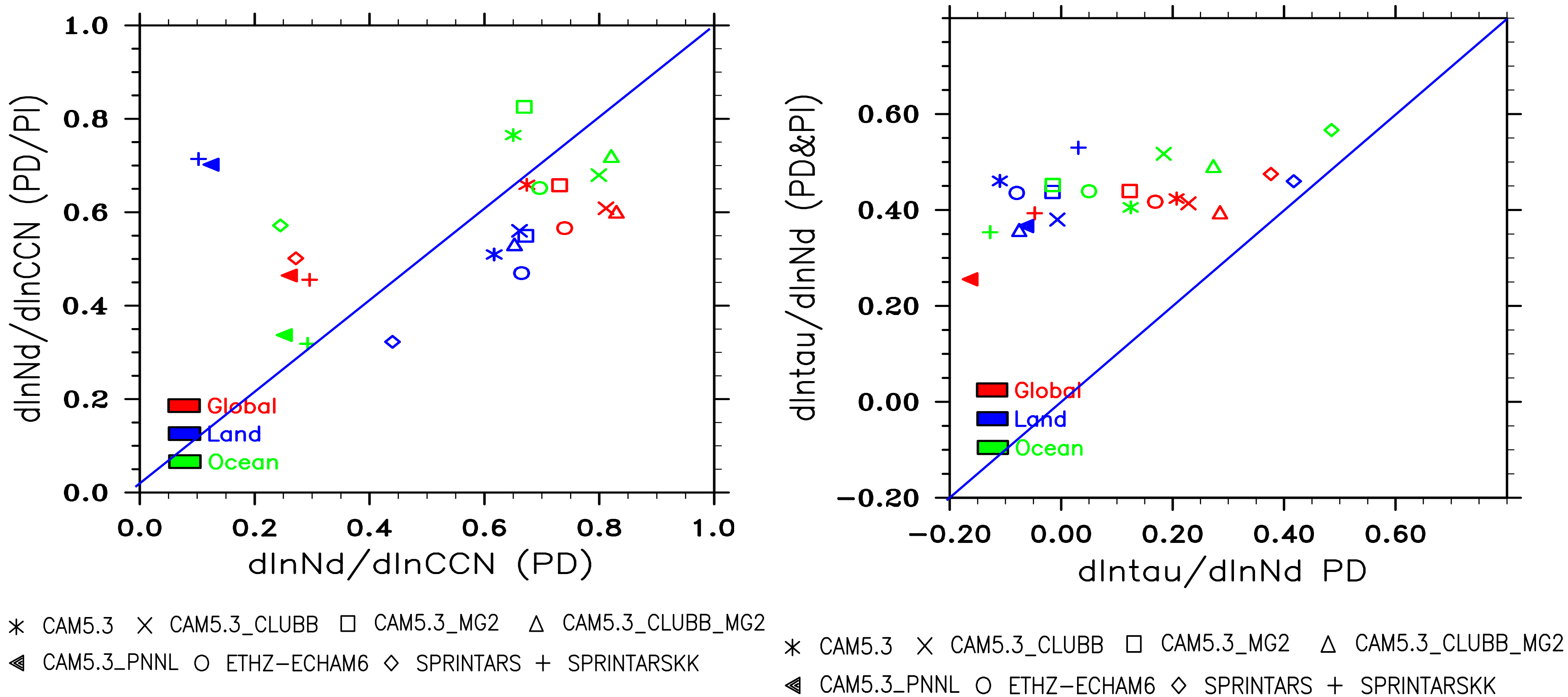
Cheng Zhou and Joyce E Penner

05/13/2011: small aerosol load	CRM	SCAM	
$\lambda = \frac{dln(LWP)}{dln(Na)}$	+0.10	+0.20	LWP increases with Na, but SCAM is more sensitive
$s = -\frac{dln(Precip)}{dln(Nd)}$	-0.24	+1.0	Opposite suspectibility of precipitation rate to aerosol increases
05/27/2011: high aerosol load			
$\lambda = \frac{dln(LWP)}{dln(Na)}$	-0.20	+0.02	Opposite responses
$s = -\frac{dln(Precip)}{dln(Nd)}$	<0	N/A	CRM has increased precipitation rate.

Constraining Aerosol-Cloud Interactions

Steve Ghan and Minghuai Wang

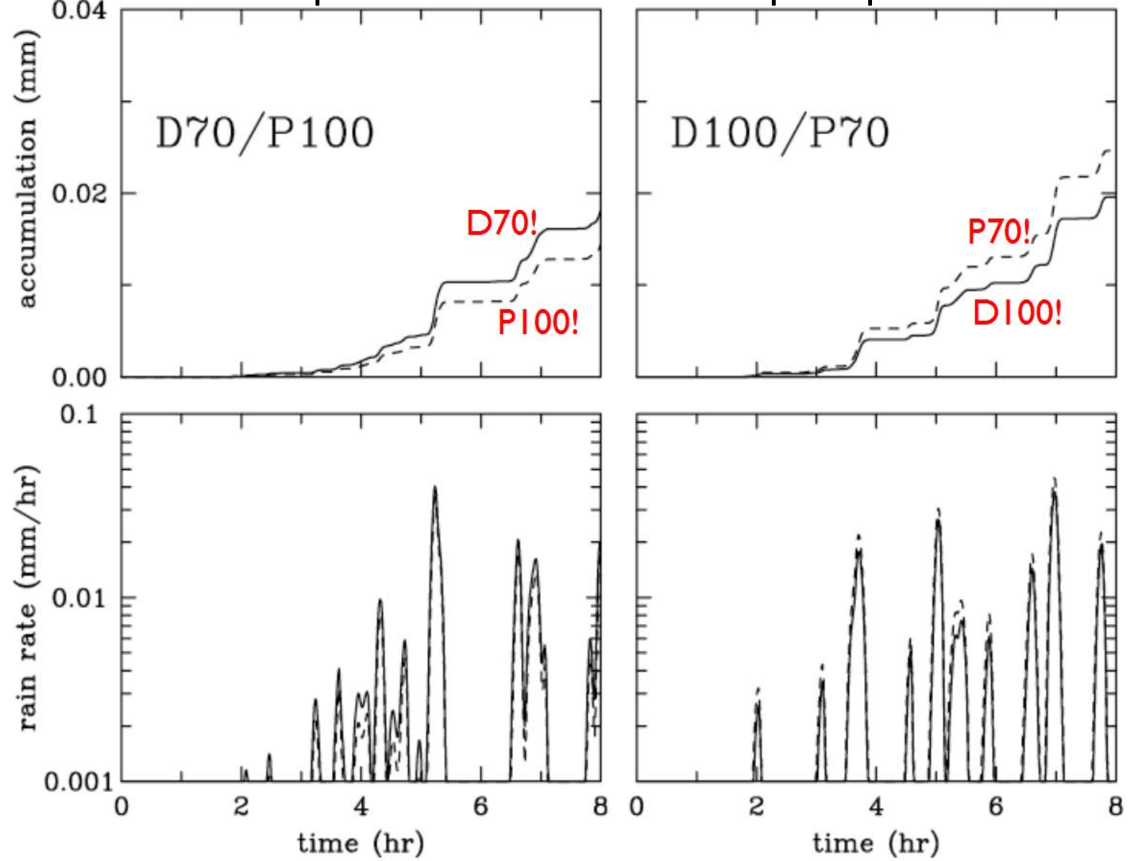
$$\Delta R = R\frac{d\ln R}{d\ln\tau}\frac{d\ln\tau}{d\ln N_d}\frac{d\ln N_d}{d\ln CCN}\frac{d\ln CCN}{d\ln E}\Delta\ln E$$

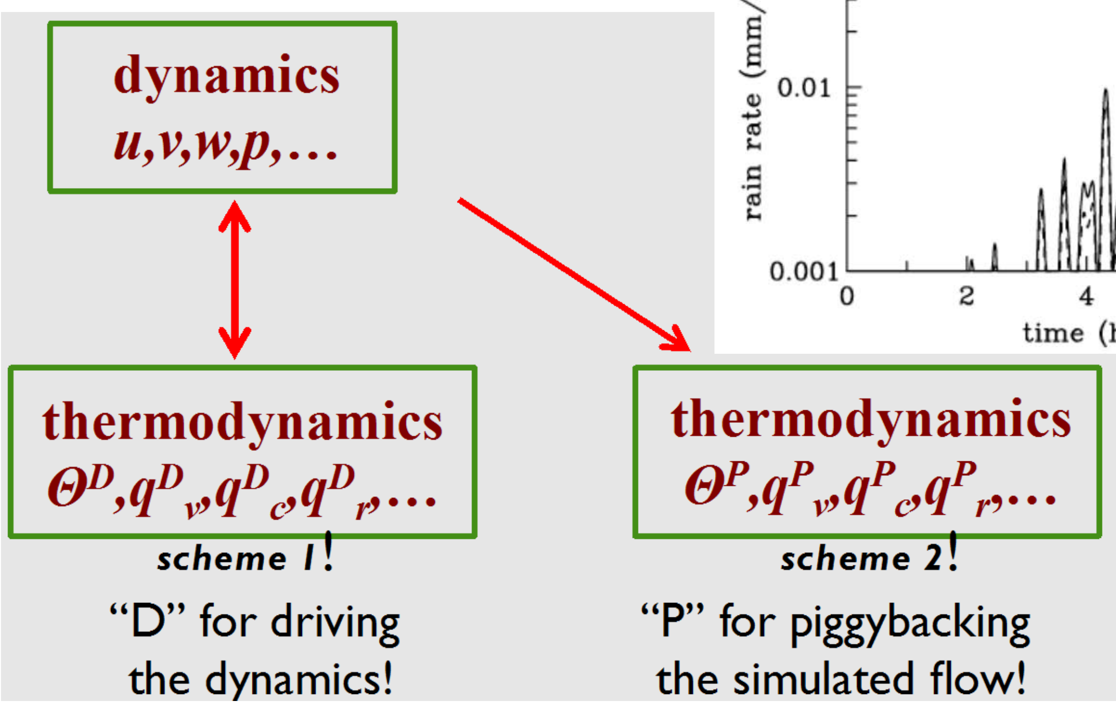


Isolating Microphysical Effects from Dynamics

Wojciech Grabowski

Droplet number effects on precipitation



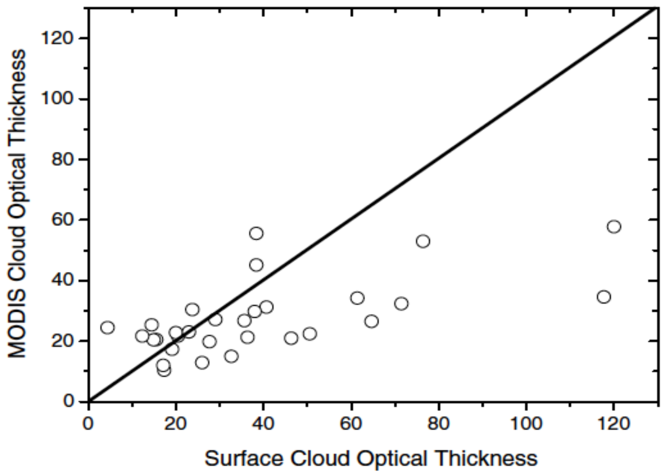


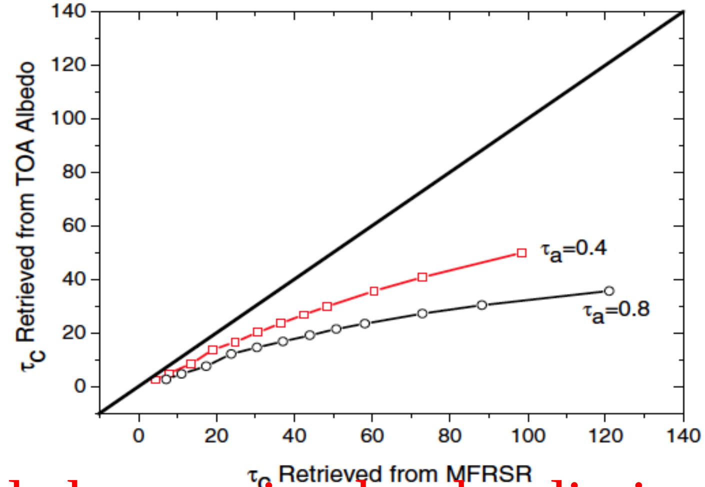
Grabowski, J. Atmos. Sci., (2014, 2015)

Deep convective clouds

- **What processes control diversity in the sensitivity of warm low clouds to aerosol perturbations, and why do GCMs seem to overestimate the sensitivity?**
- **What aerosol-related processes control deep convective cloud properties relevant to climate?**
- **What processes control ice nucleation and its impact on ice-containing clouds?**

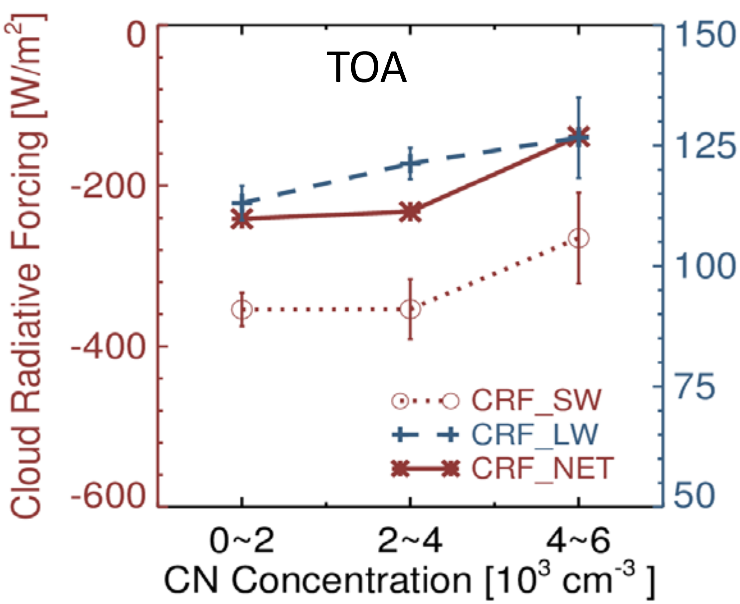
Systematic Bias in Cloud Optical Depth Due to Absorbing Aerosol

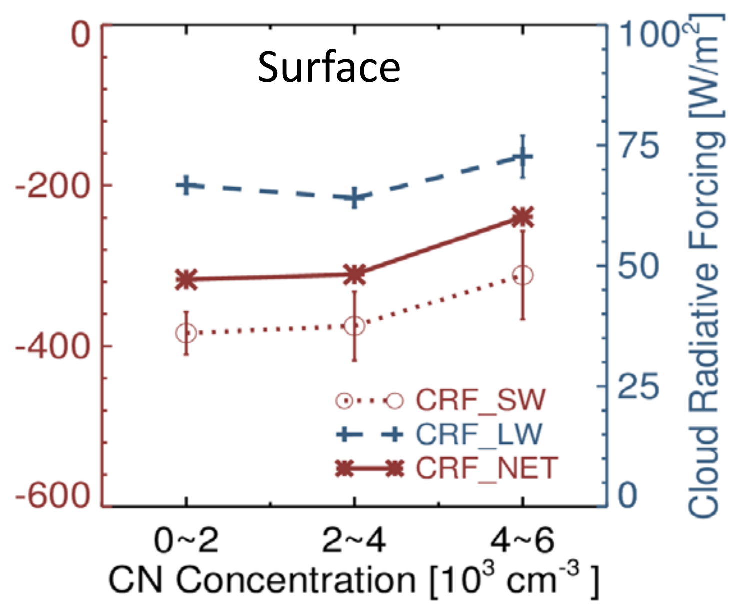




Li et al. (2014, JGR)

Long-term mean aerosol-induced changes in cloud radiative forcing for all deep clouds at SGP in 10-years: 0.45 Wm^{-2}

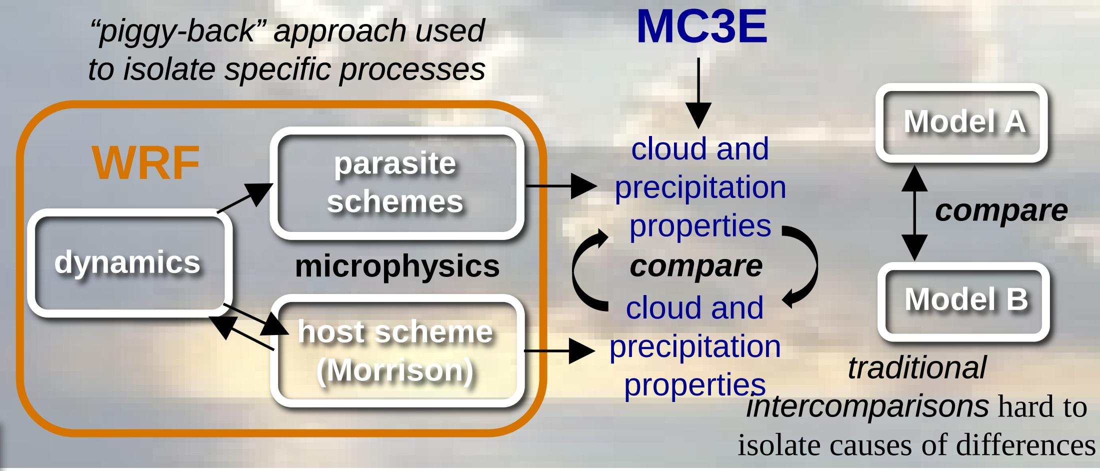




Yan et al. (2014, ACP)

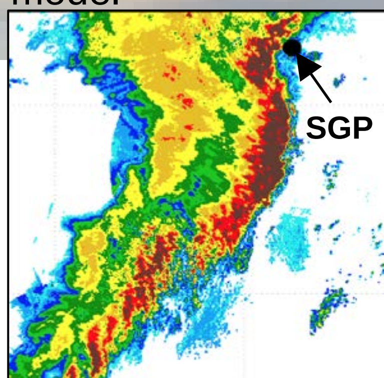
CRM Intercomparison Study on Deep Convection and Aerosol Effects

J. Fan, B. Han, H. Morrison, A. Varble, S. Collis, X. Dong, P. Kollias, E. Mansell, J. Millbrandt



Goals are to 1) identify major processes and factors leading to the large spread of CRM convection simulations of deep convection and 2) identify important aerosol-cloud feedback processes that need to be improved in climate model parameterizations.

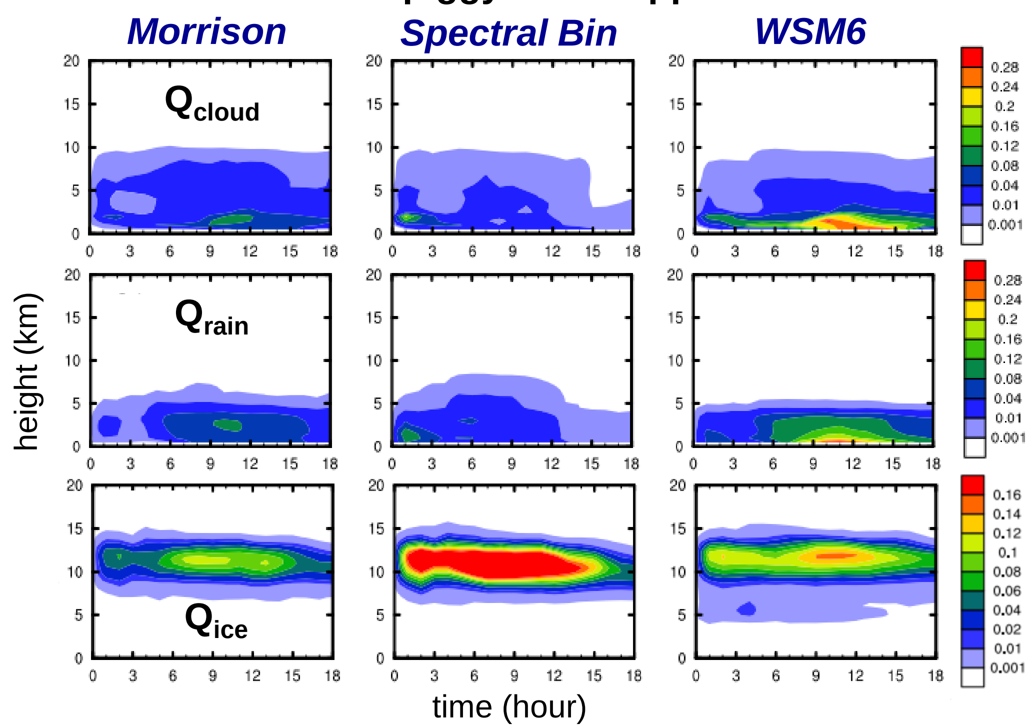
Squally line case from MC3E used to assess specific microphysical treatments



Preliminary Findings

- Differences in Q_{cloud}, Q_{rain}, Q_{ice} from several microphysics schemes under the same dynamical fields are large
- Differing treatments of condensation and riming processes are the major factors contributing to model differences

Example Differences in Microphysical Quantities with the "piggy-back" approach



Deep convection updraft properties during MC3E

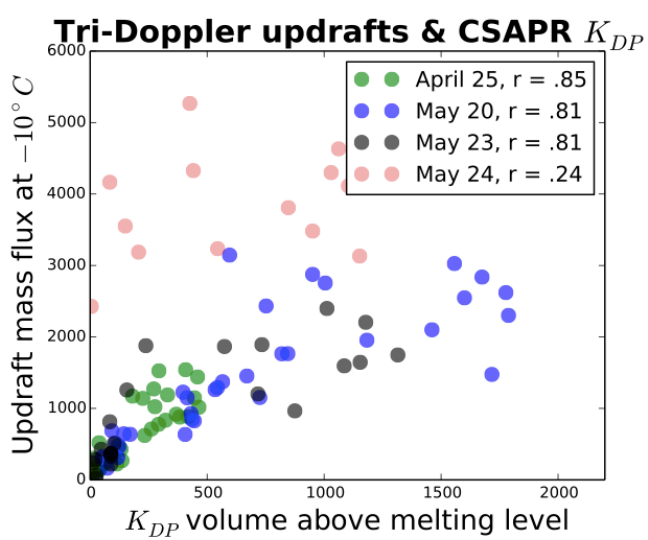
PI Ann Fridlind / NASA GISS

Science Question

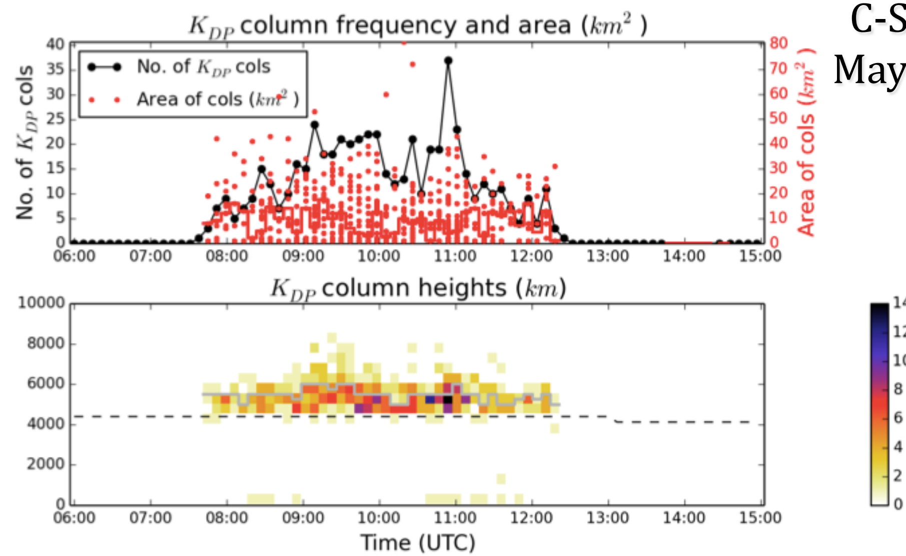
Are WRF simulations with bin or two-moment microphysics and observationally constrained interactive aerosol fields accurately simulating the fundamental characteristics of deep convection updrafts over a range of MC3E storm conditions?

Approach

- Identify the statistical properties of updraft features in C-SAPR and NEXRAD K_{DP} fields
- Statistically correlate objectively identified K_{DP} updraft features with C-SAPR rain rate retrievals, Lightning Mapping Array flash rates, and X-X-C-SAPR vertical wind speed retrievals



C-SAPR
May 20th



Key Conclusions

Across four observed storm events of varying strength and properties, K_{DP} volume above the melting level is found to be variable in a manner that is strongly correlated with observed updraft mass flux, lightning flash activity, and intense rainfall. C-SAPR is found to offer significantly finer resolution of K_{DP} features compared with NEXRAD. Robust results motivate development of algorithms to constrain simulations.

Publication

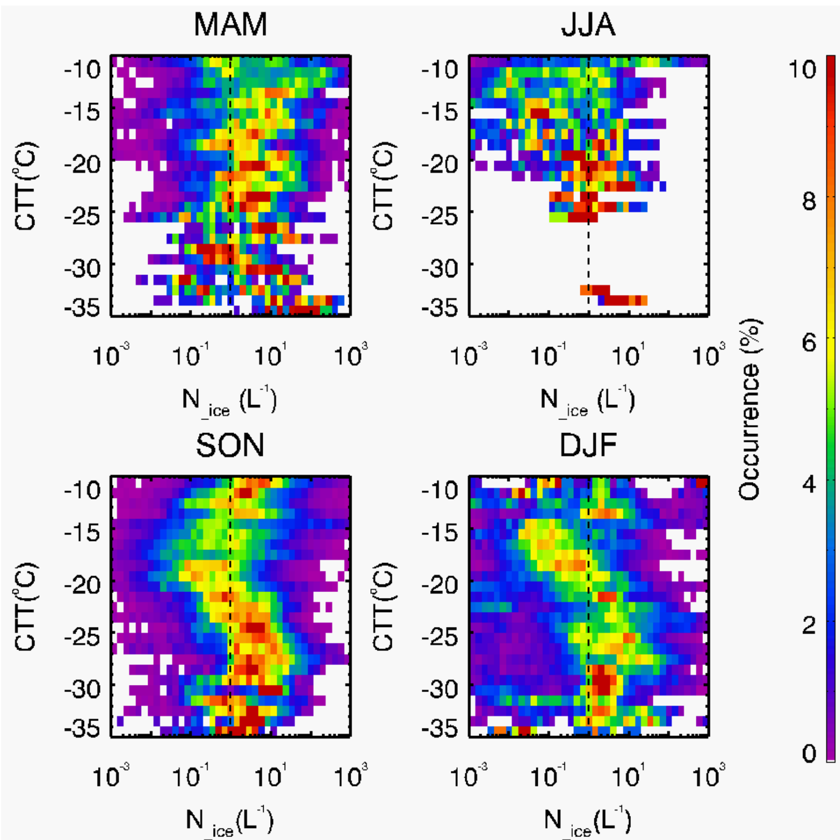
M. van Lier-Walqui, A. Fridlind, A. Ackerman, S. Collis, J. Helmus, D. MacGorman, K. North, P. Kollias, and D. Posselt, Polarimetric radar signatures of deep convection: Characteristics of KDP columns observed during MC3E, *Mon. Weath. Rev.*, submitted

Ice nucleation

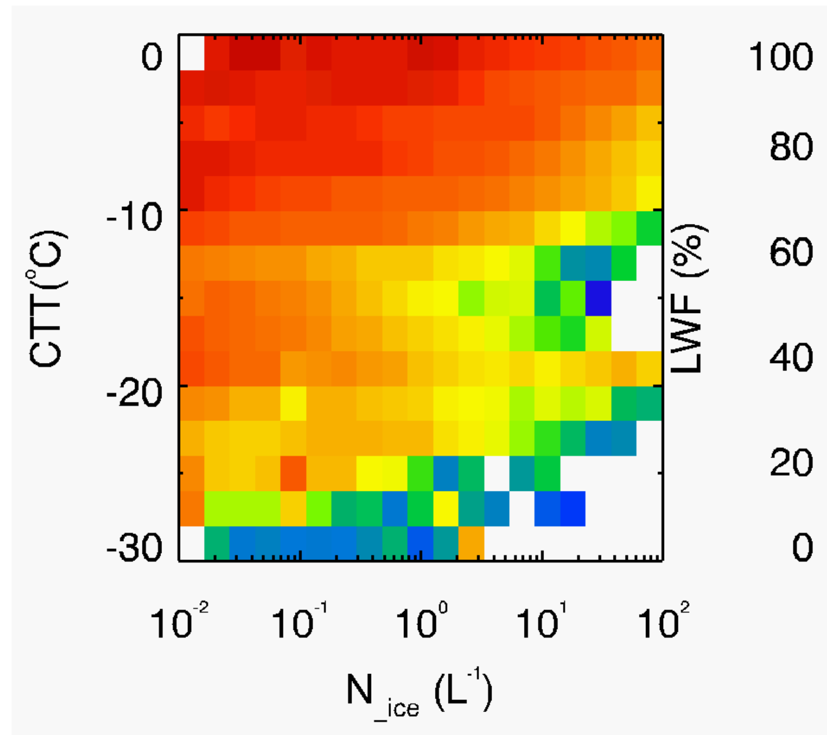
- **What processes control diversity in the sensitivity of warm low clouds to aerosol perturbations, and why do GCMs seem to overestimate the sensitivity?**
- **What aerosol-related processes control deep convective cloud properties relevant to climate?**
- **What processes control ice nucleation and its impact on ice-containing clouds?**

Seasonal Variations of Ice Concentrations in Arctic Stratiform Clouds and Their Controls on Liquid-Ice Mass Partition

Zhien Wang and Damao Zhang, Univ. of Wyoming



MAM have higher ice concentration than other seasons.



Ice concentration together with cloud top temperature (CTT) controls liquid water fraction (LWF) in Arctic mixed-phase clouds.

Based on MMCR measurements Oct, 2006 – Nov, 2010

Zhang et al. 2014: *J. Atmos. Sci.*, **71**, 3613–3635.

Dependence of homogeneous ice nucleation on season and latitude

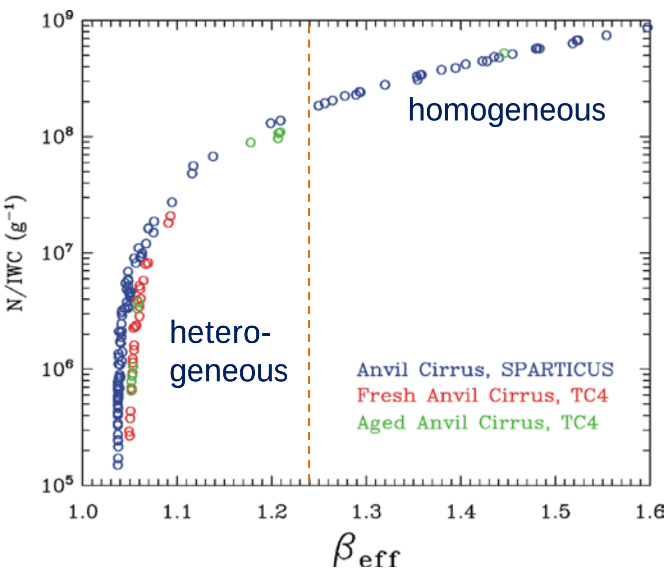
David Mitchell / Desert Research Institute & U. Nevada, Reno
Anne Garnier / Laboratoire Atmosphères, Milieux, Observations Spatiales, UPMC-UVSQ-CNRS, Paris, France
Melody Avery / NASA Langley Research Center, Hampton, Virginia

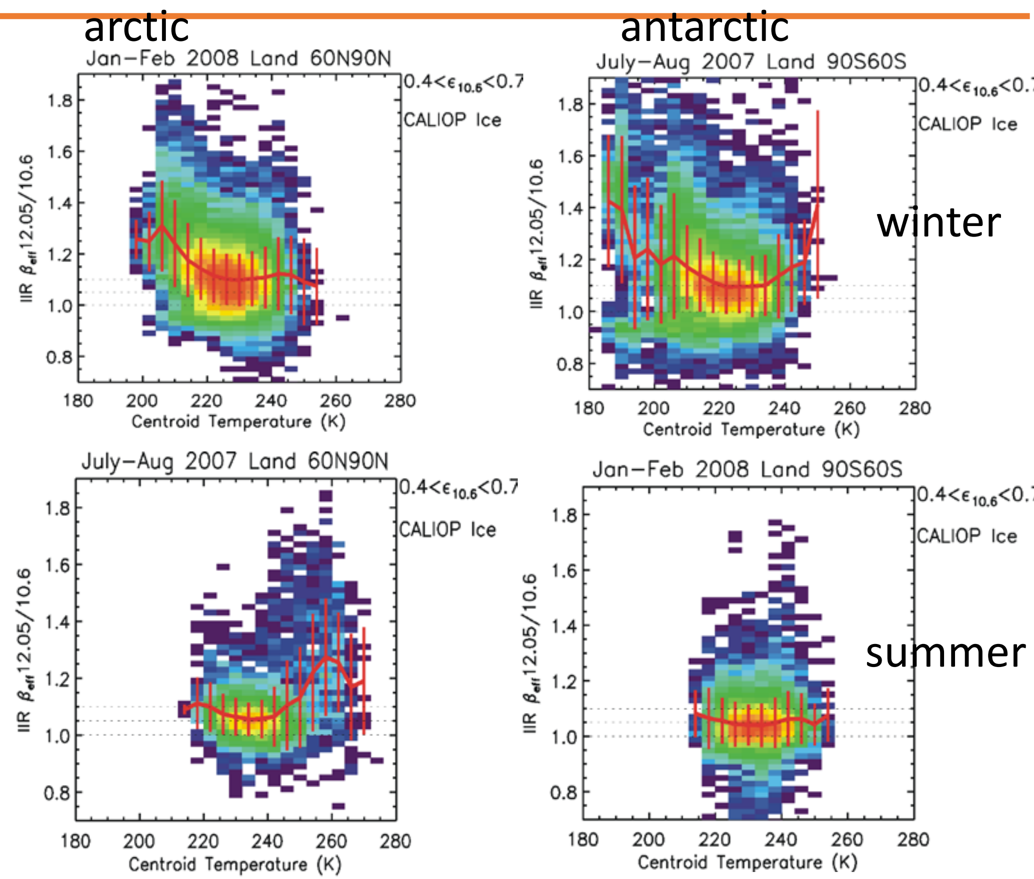
Science Question

What is the dependence of homogeneous ice nucleation on season and latitude?

Approach

- Found that the CALIPSO 12/10.6 μm effective absorption optical depth ratio, β_{eff}, is tightly related to the N/IWC ratio, where N = ice particle number concentration & IWC = ice water content.



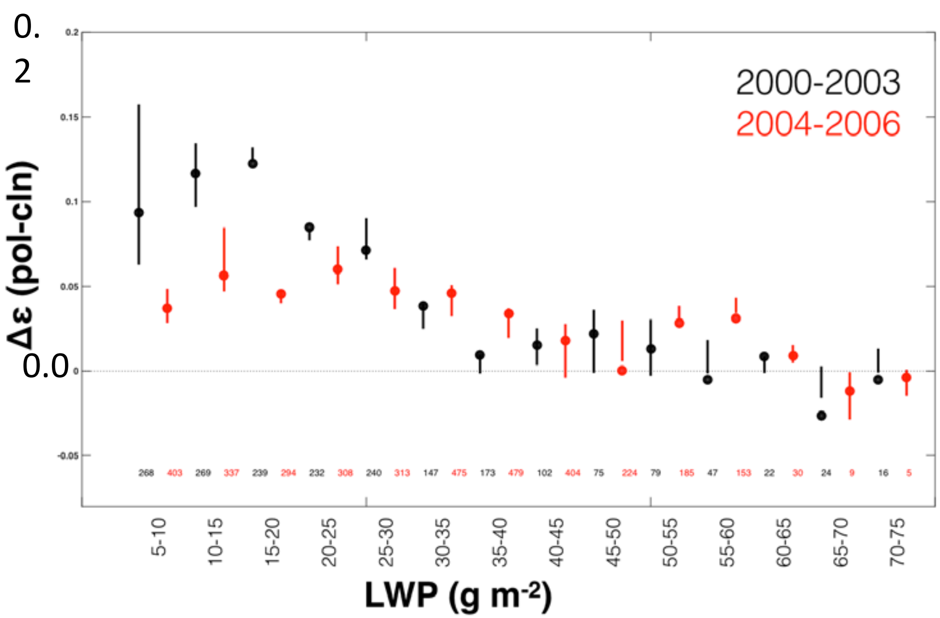


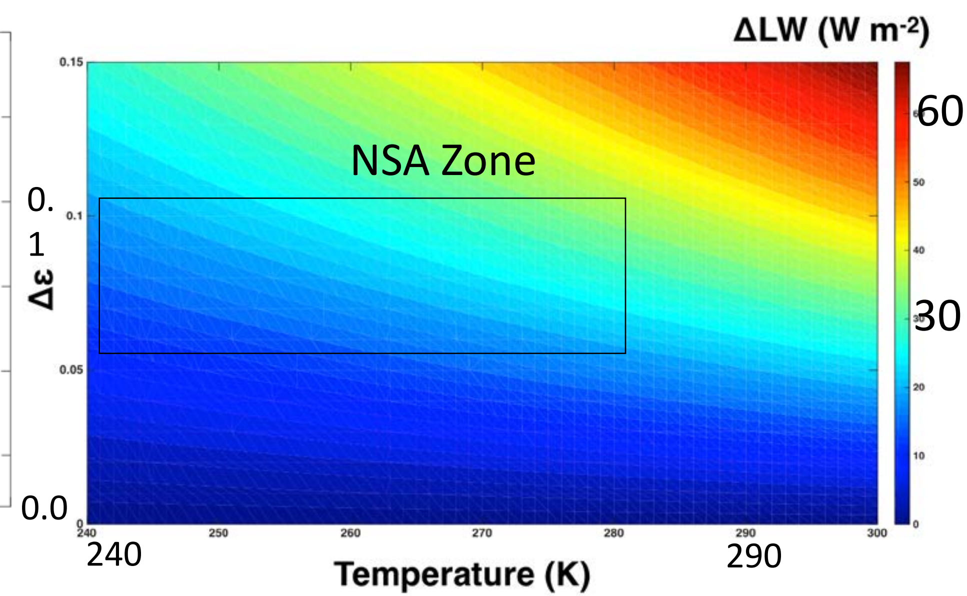
Conclusion: Homogeneous ice nucleation appears important during polar winters when cirrus cloud coverage is highest. During other seasons, CAM5 predicts higher concentrations of mineral dust.

Aerosol influence on thin, liquid-containing cloud emissivity

Gijs de Boer, Matthew Shupe, David Turner, Chuanfeng Zhao, Tim Garrett

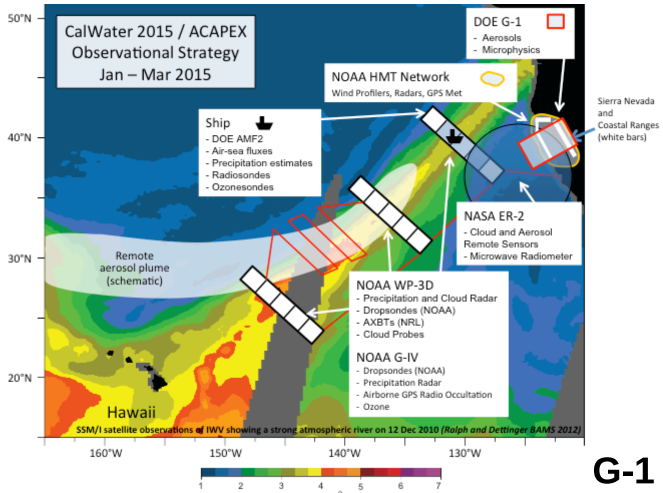
Barrow NSA





CalWater 2 – ARM Cloud Aerosol Precipitation Experiment (ACAPEX) (Jan 15 – Mar 8, 2015)

- Improve understanding and modeling of atmospheric rivers and aerosol-cloud-precipitation interactions **(See poster by LR Leung)**



urtesy of F. M. Ralph, NOAA Earth System Research Laboratory

DOE AMF2 on NOAA RV Ron Brown

G-1 flew a total of 28 flights:

- 8 flights in atmospheric rivers (over the ocean, along the coast, and in Sierra Nevada)
- 6 flights in coastal stratus and stratocumulus
- 4 flights in frontal orographic clouds
- 10 flights to characterize aerosols, CCN, INP from local sources and long range transport
- Of the 28 flights, 6 were coordinated with NASA ER-2, of which 2 were also coordinated with NOAA G-IV and P-3 for comprehensive moisture, cloud, and aerosol measurements

AMF2 on Ron Brown:

- Deployed from Jan 15 – Feb 9 from Honolulu to San Francisco; measured atmosphere, aerosols/clouds, and surface fluxes in 3 atmospheric rivers

NOAA G-IV and P-3:

- Sampled atmospheric moisture budget for 12 atmospheric rivers in the Pacific Ocean
- Cloud measurements by various radars and cloud probes

NASA ER-2:

- Measured aerosols, clouds and water vapor with radar, lidar and radiometer