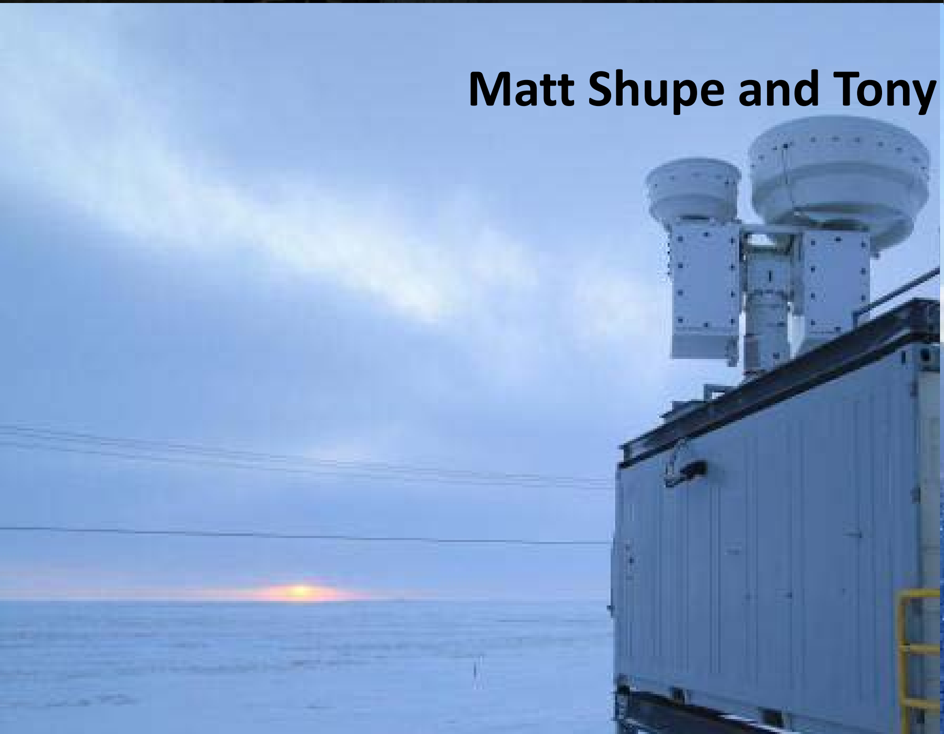
Cloud Life Cycle Working Group Activities


Matt Shupe and Tony Del Genio, 3/17/15




- Thematic interest/focus groups:
  - Warm low clouds
  - Cloud phase partitioning/mixed-phase
  - Ice physical and radiative properties
  - Mesoscale convective organization/cold pools
  - Vertical Velocity
  - QUICR – no longer a separate FG but embodied in what all the interest groups do

+ other breakouts too numerous to mention

Cloud Lifecycle Working Group

Warm Low Cloud Science Thematic Group

Spring 2015
ASR PI Meeting

Mark A. Miller
Rutgers University
m.miller@envsci.rutgers.edu

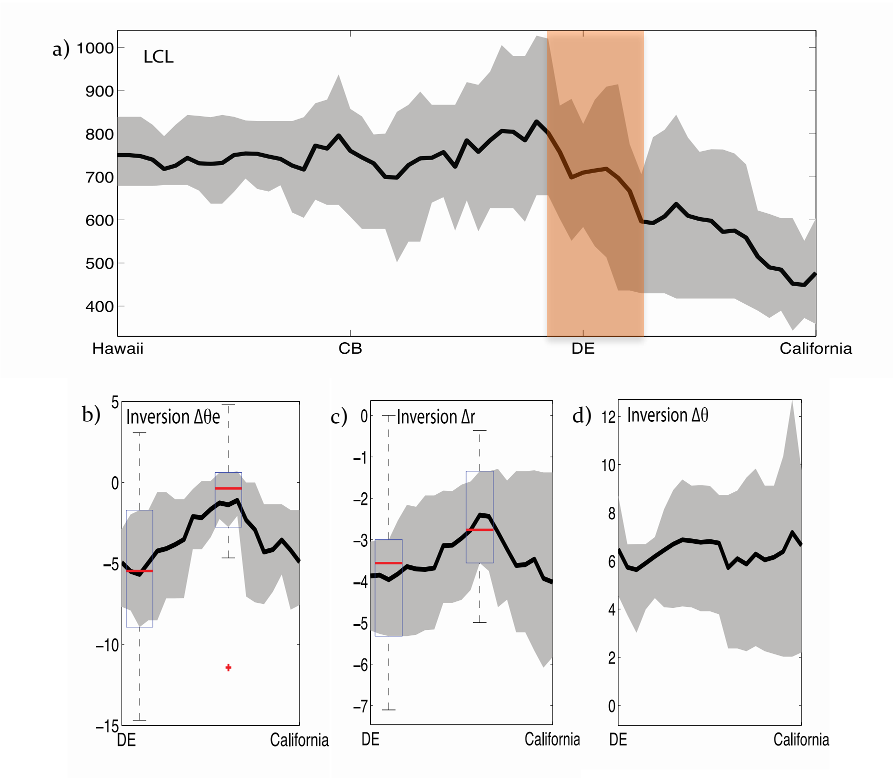
Minghua Zhang
SUNY at Stony Brook
minghua.zhang@stonybrook.edu

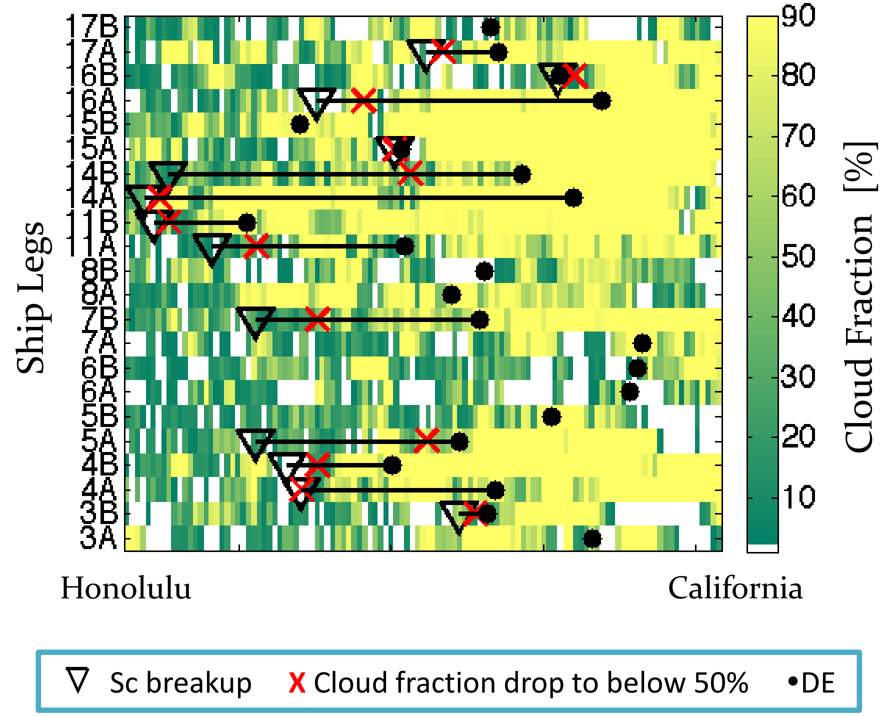
Group Mailing List

lowcloud@arm.gov

Warm Low Clouds Fall Working Group Summary

- Currently organized around three case studies
  - Additional case studies suggested
    - closed-cell MCC case during CAP-MBL when the AERI was operating
    - Analysis of shallow cumulus data from Darwin that included the Raman and Doppler Lidars
    - more precipitation-centric cases
  - Mass flux was noted as one observed quantity that could be a focus for the LES and observation comparisons
- Needs
  - ensemble forcing for our case studies
  - list of observables (in progress)





MBL decoupling:

Continuous and systematic

Strong moisture gradient ($q_v \geq 1.5$g/kg)

Triggered by entrainment of warm, dry air from free troposphere

Increase of surface latent heat flux not a trigger, but helps maintain decoupling

Sc break up:

Abrupt rather than gradual

Results from synoptic interaction

Clouds, Precipitation and Marine Boundary Layer Structure during the MAGIC Field Campaign, X. Zhou, P. Kollias, and E. R. Lewis *J. Climate*, doi:10.1175/JCLI-D-13-00320.1, 2015

The Interdependence of Cloud Properties Derived from Unexploited Signals in Lidar Measurements

Christine Chiu, James Holmes, Robin Hogan, Ewan O'Connor

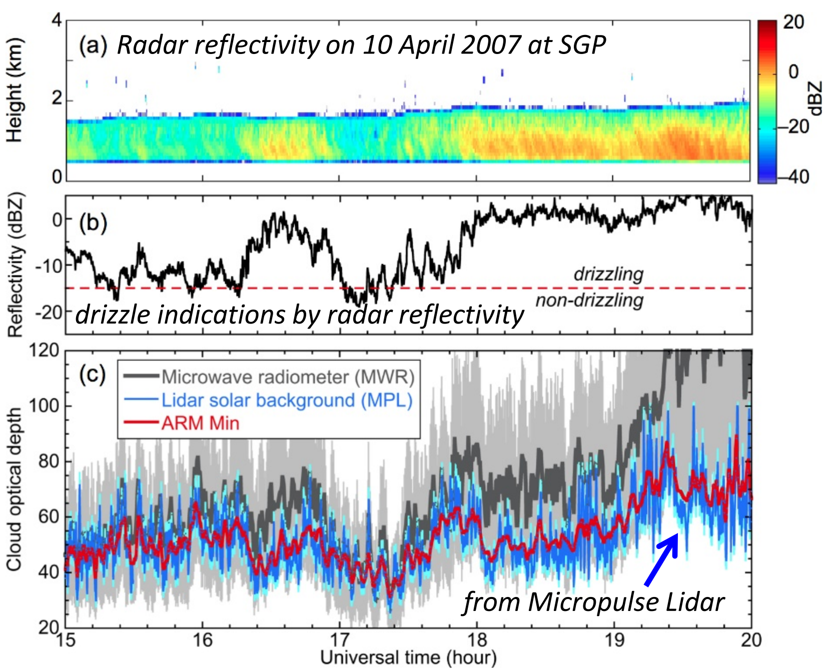
University of Reading

Science Question

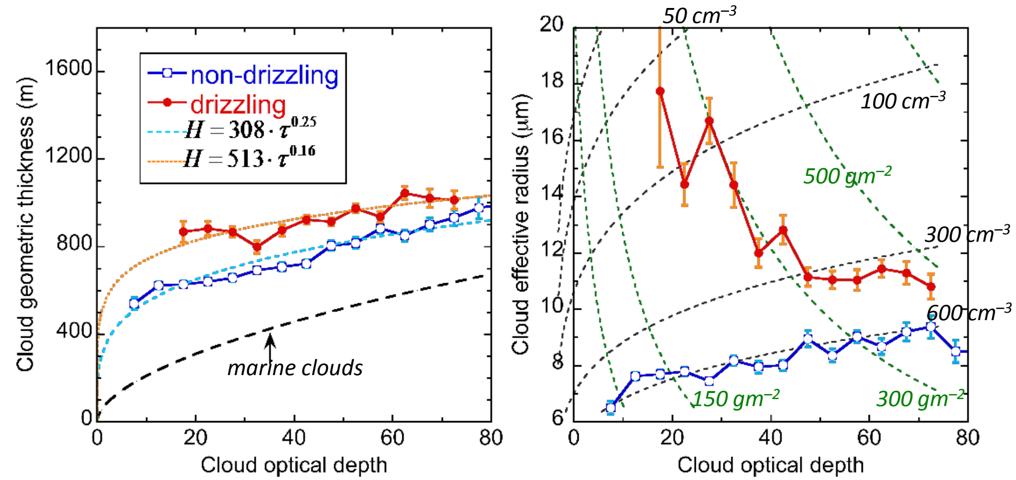
What is the relationship between cloud optical depth and droplet size in continental warm clouds , which is strongly linked to the development stage of cloud/precipitation?

Approach

- Exploit solar background signals previously treated as noise and removed in lidar obs.
- A new way to enhance ground-based cloud observations using existing lidar networks



Warm cloud properties at SGP during 2005–2007



Key Results

•Cloud droplet effective radius has a negative correlation with optical depth in drizzling clouds and a positive correlation in non-drizzling clouds, where, for large optical depths, it asymptotes to 10 μm.

•Having lower cloud droplet concentrations will help overcome the lack of liquid water to produce drizzling clouds with low optical depth.

Chiu., J. C., et al., 2014: The interdependence of continental warm cloud properties derived from unexploited solar background signals in ground-based lidar, *Atmos. Chem. Phys.*, 14, 8389-8401, doi:10.5194/acpd-14-8389-2014.

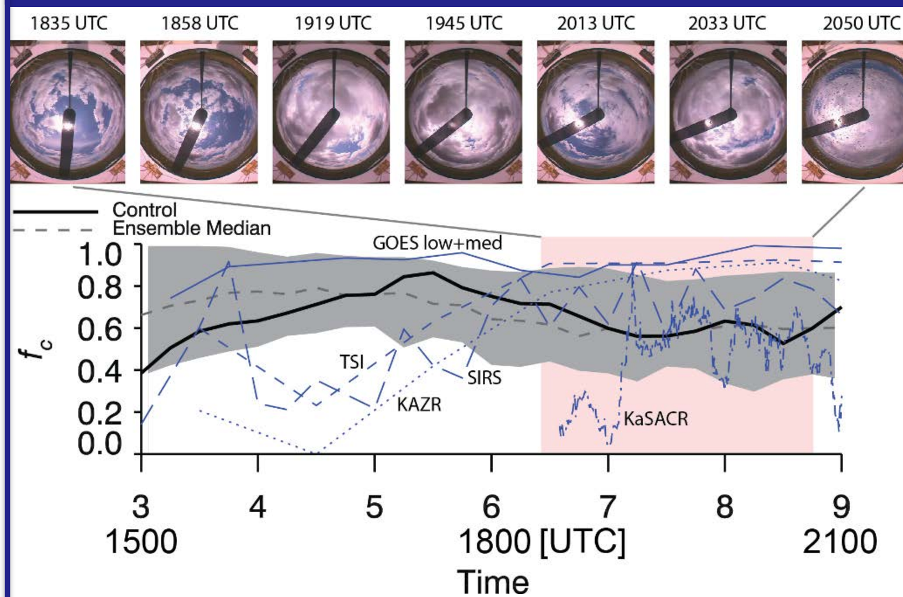
Modeling and Observational Evaluation of a Precipitating Continental Cumulus Event Observed During the MC3E Field Campaign

David B. Mechem, Scott E. Giangrande, Carly S. Wittman,
Paloma Borque, Tami Toto, and Pavlos Kollias

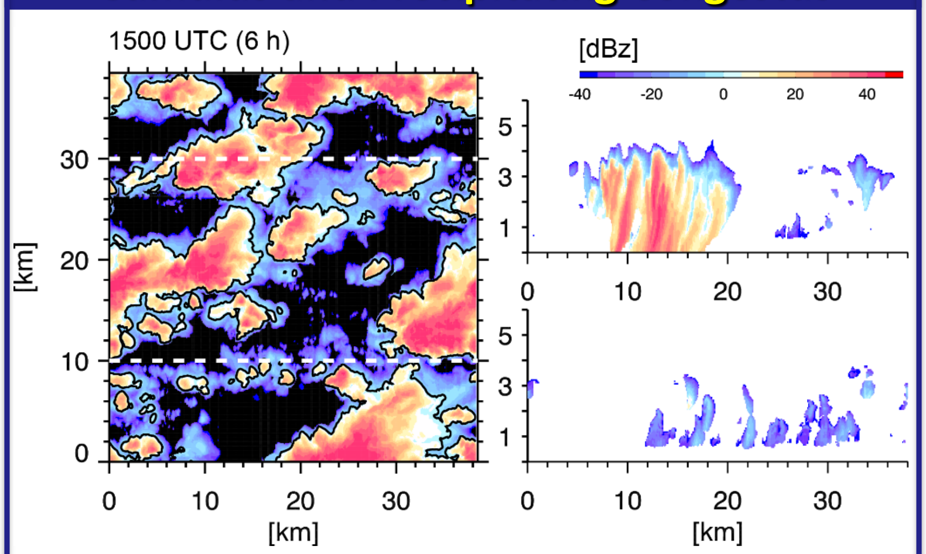
Science Questions:

- How sensitive is cloud evolutionary behavior to details in meteorological forcing?
- What are the best paths to compare macroscale cloud properties between models and observations?

Imagery from TSI (top) and Cloud Fraction from LES and a Range of Observational Estimates



Model Reflectivity Fields of Shallow Cumulus and Precipitating Congestus



Key Accomplishment:

Multi-dimensional cloud measurements from ARM radars demonstrate several advantages for simulations using time-varying forcing.

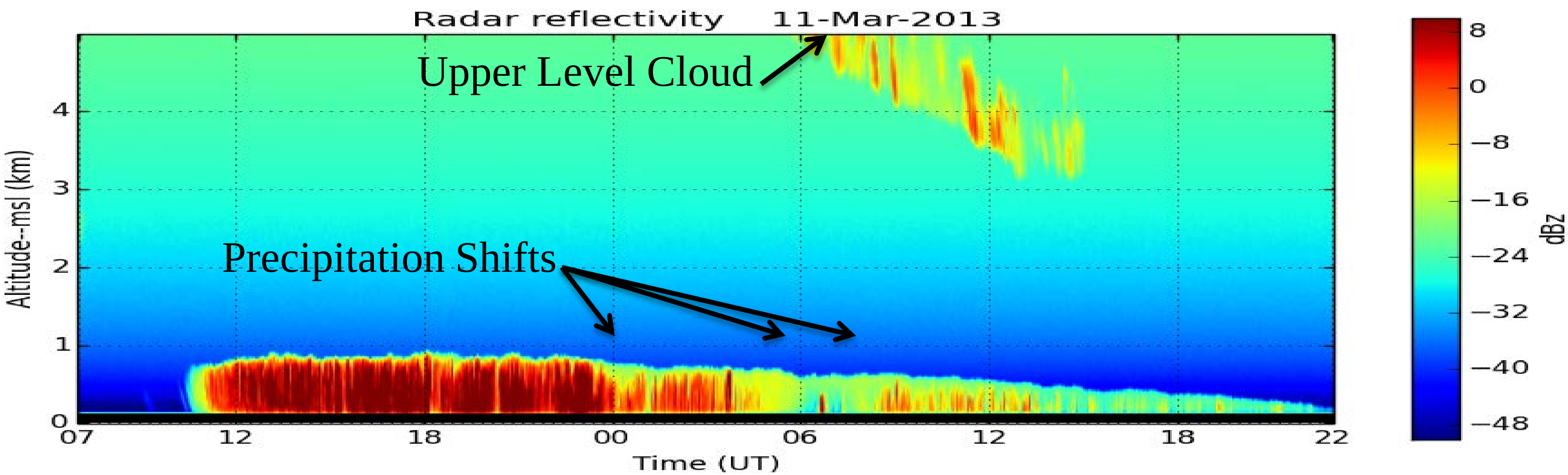
Mechem, D. B., et al., 2015: Insights from modeling and observational evaluation of a precipitating continental cumulus event observed during the MC3E field campaign. *J. Geophys. Res.*, doi:10.1002/2014JD022255.

Cloud Phase Focus Group Update

Gijs de Boer, Jerry Harrington

Two central points of discussion at the Fall Meeting:

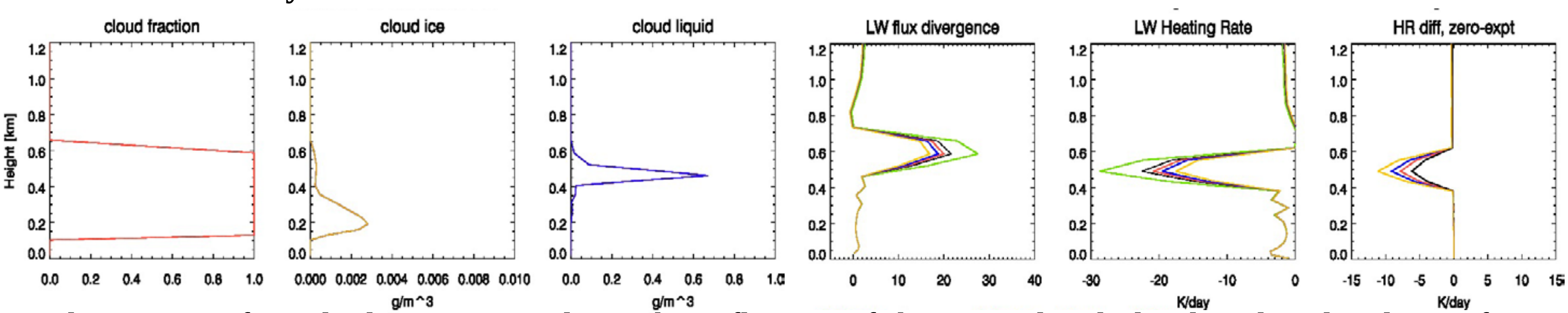
- **Phase partitioning in convective clouds**
  - Good 30-minute discussion – Group is currently trying to identify main observational needs
- **Ongoing case study (March 11-12, 2013 @ NSA)**
  - Active participants: Kalesse, Solomon, Ahlgrimm, de Boer, Shupe, Luke, Kneifel, Turner, Oue
  - Main points of interest:
    - Influence of the upper level cloud on lower cloud dynamics
    - Influence of aerosols on precipitation intensity
    - Shifts in precipitation observed in the stratiform cloud



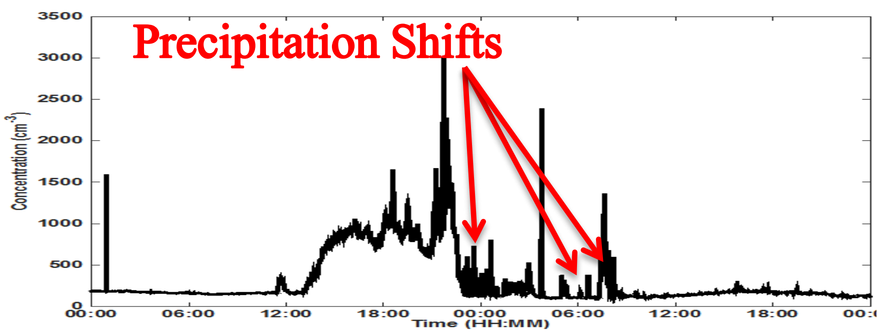
March 11/12 case, as seen by NSA KAZR (figure from U. Wisconsin Lidar Group Website)

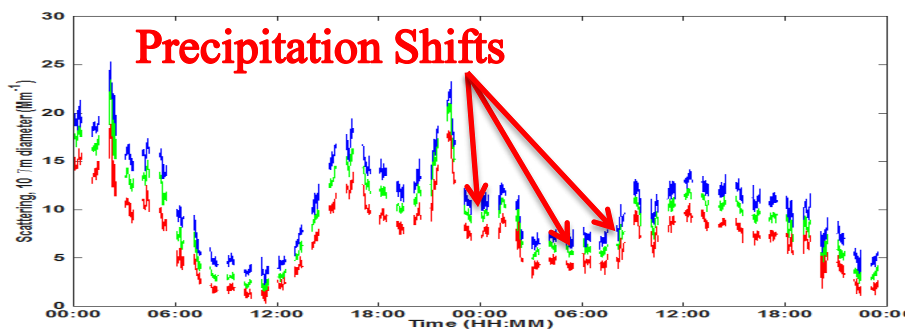
Cloud Phase Focus Group Update

March Case Study

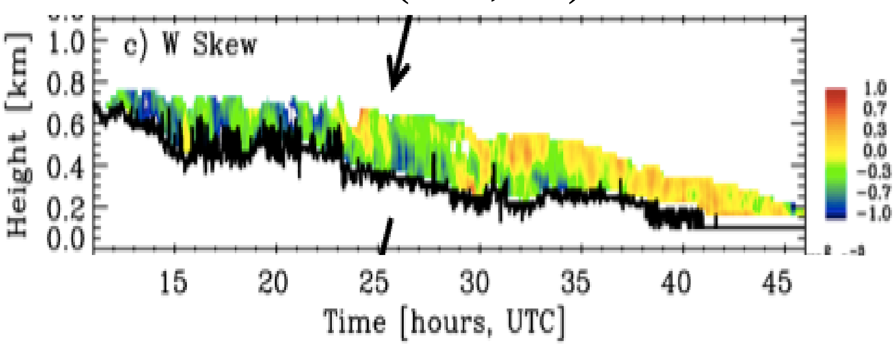


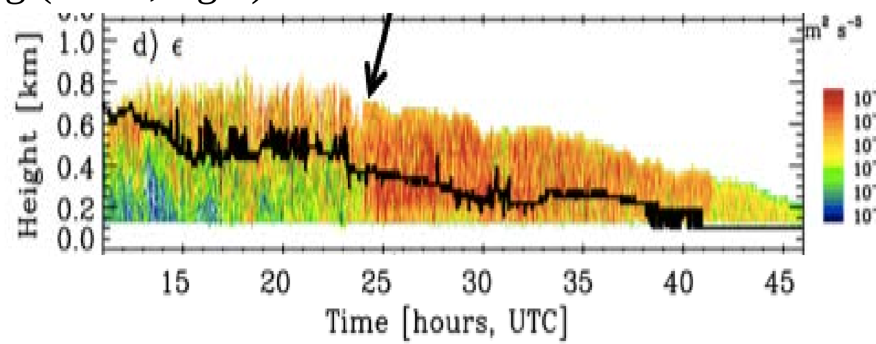
Radiative transfer calculations to evaluate the influence of the upper level cloud on low-level stratiform dynamics, based on microphysical retrievals from ARM sensors





Aerosol concentration (CPC, left) and aerosol scattering (PSAP, right)





Radar-derived small scale dynamical properties (skewness, left; turbulence dissipation rate, right)

Comparison of Liquid/Ice Mass Partitions between Arctic Stratiform Mixed-phase Clouds and Tropical Maritime Convective Clouds

Zhien Wang, Jing Yang, Damao Zhang, and Ming Zhao
University of Wyoming

Data Sources

For Arctic Stratiform Mixed-phase Clouds:

- Liquid fraction = LWP/(LWP+IWP), excluding ice below the mixed-phase layer.
- Based on multi-year multi-sensor retrievals at the Barrow site.
- There are high dust occurrence during spring.

For tropical maritime convective clouds:

- Liquid fraction = LWC/TWC
- In situ data from seven C-130 research flights during the ICE-T project conducted in July 2011 near St. Croix.
- Convective cloud life stages (developing, mature, and dissipating) are identified based on Wyoming Cloud Radar measurements.

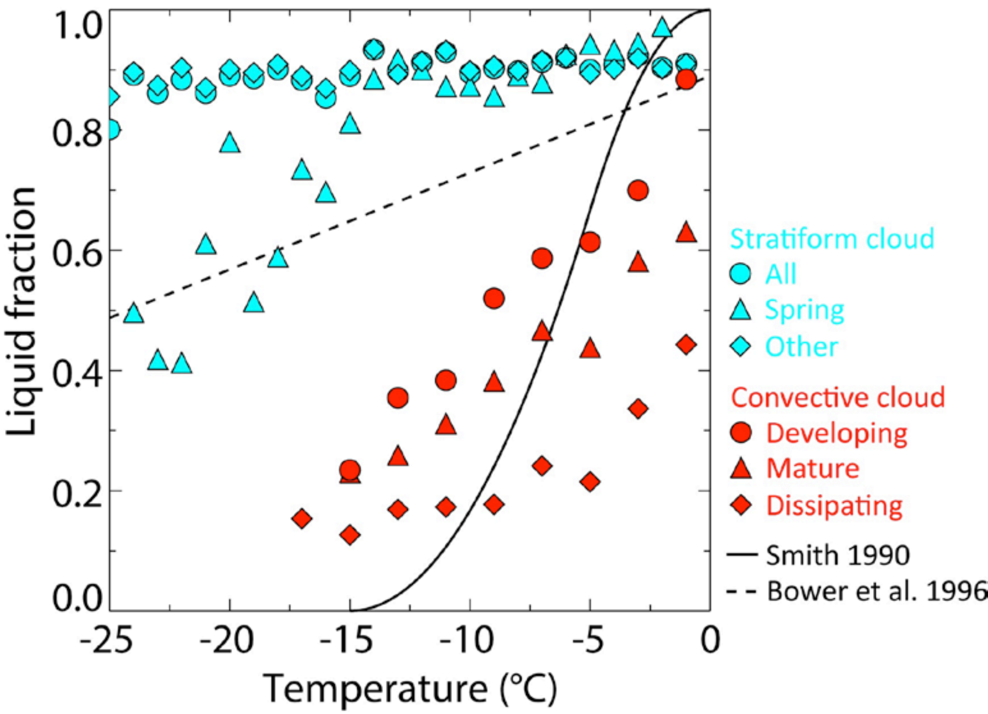


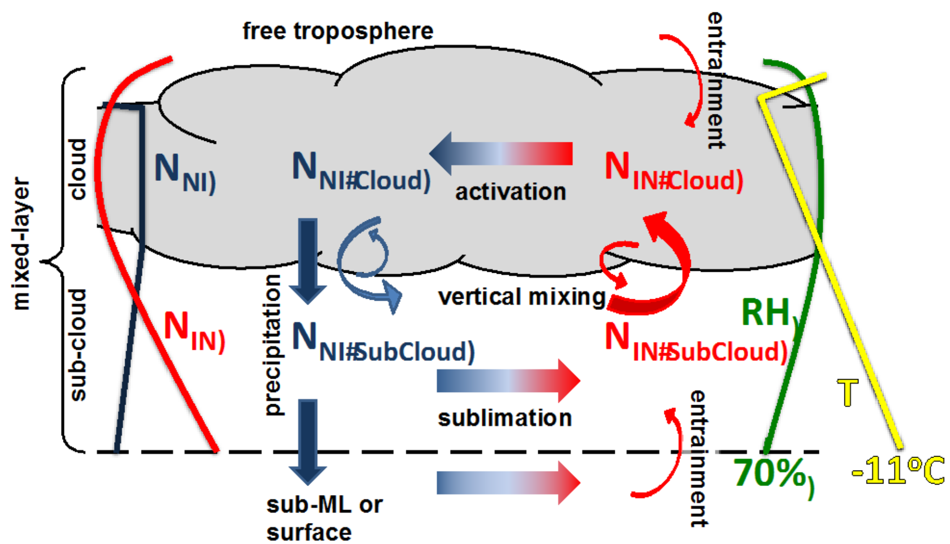
Fig. 1: Comparison of temperature-dependent liquid fractions between observations from arctic stratiform mixed-phase clouds and tropical maritime convective clouds.

Key Points

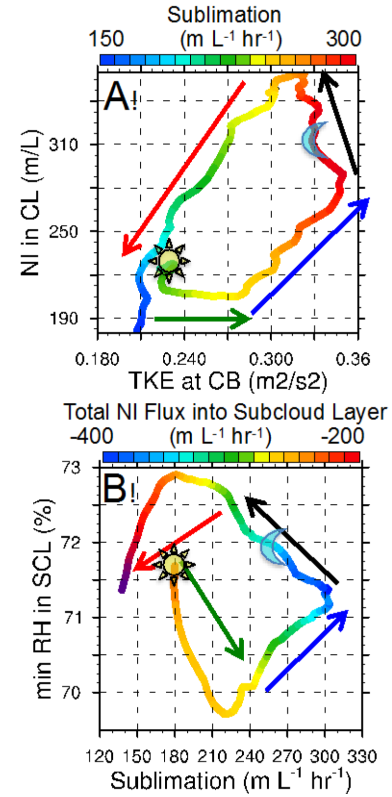
- There are systematic differences between stratiform and convective mixed-phase clouds.
- Ice generation is the controlling factor for liquid/ice mass partitions.
- Liquid/ice mass partition in convective clouds is strongly depend on convective cloud life cycles.

The Role of Ice Nuclei Recycling in the Maintenance of Cloud Ice in Arctic Mixed-Phase Stratocumulus

Amy Solomon[1,2], Graham Feingold[2], and Matthew D. Shupe[1,2]
(1) Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, Colorado, USA
(2) Earth System Research Laboratory, National Oceanic and Atmospheric Administration, Boulder, Colorado, USA
Atmospheric Chemistry and Physics, acp-2015-177, in review

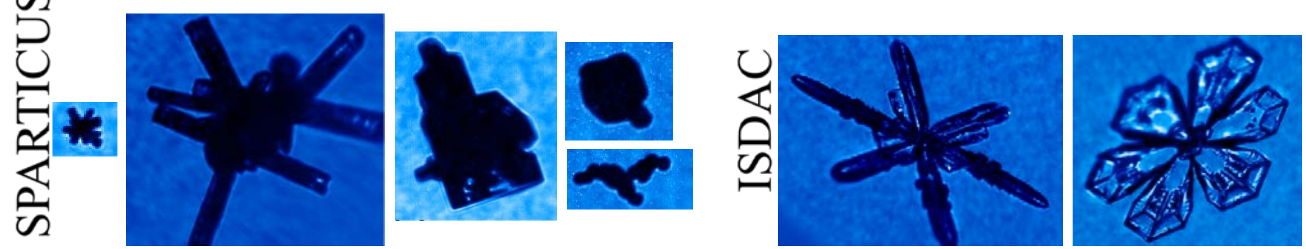


Schematic of feedback loops that maintain ice production and the phase-partitioning between cloud liquid and ice in AMPS when recycling is allowed. Red colors denote number concentration of ice nuclei (N_{IN}). Blue colors denote number concentration of ice crystals (N_{NI}). Vertical profiles of N_{NI}, N_{IN}, relative humidity, and temperature shown with thin blue, red, green, and yellow lines, respectively.

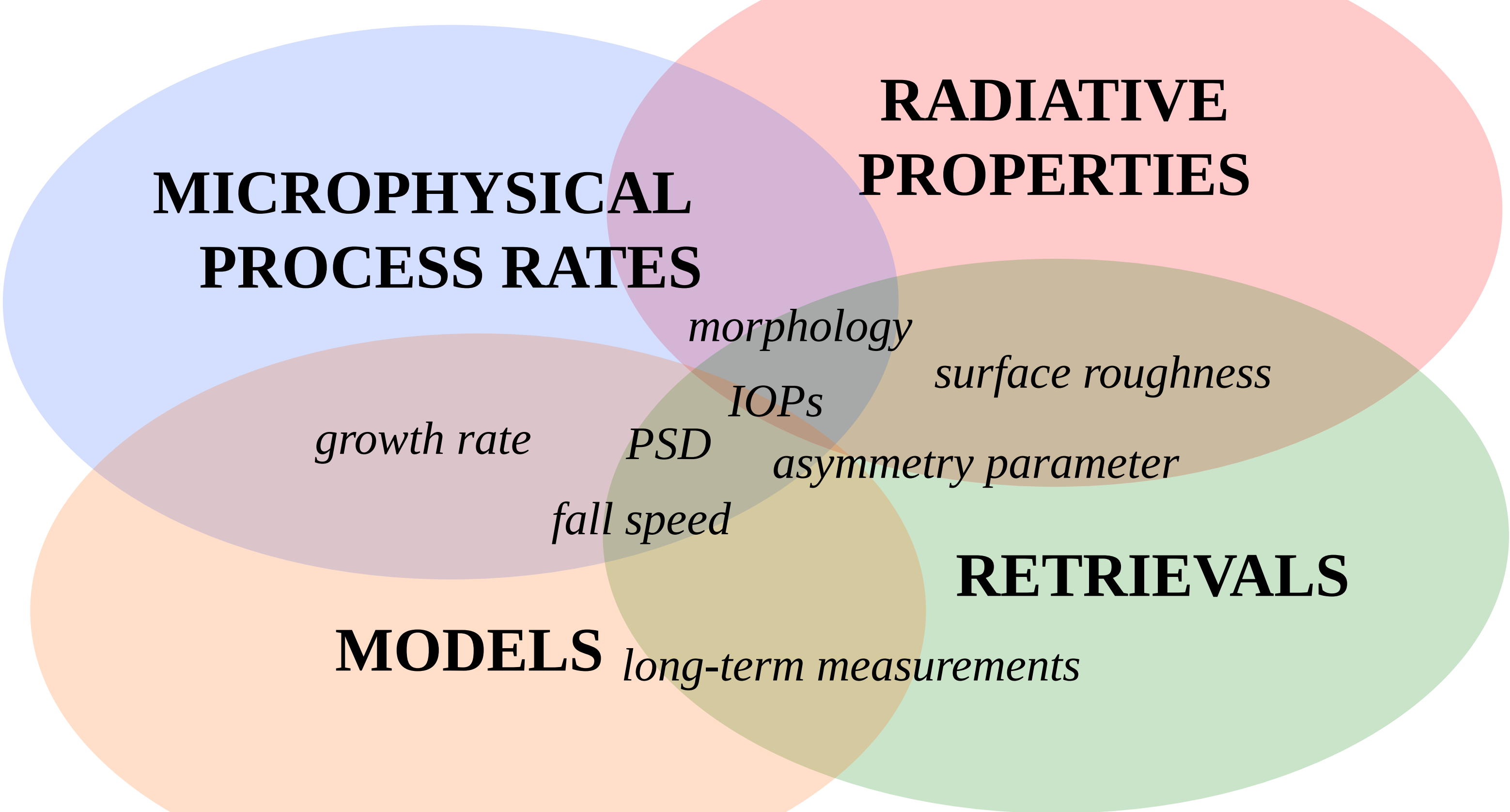


A) Phase diagram of TKE at cloud base vs. number of ice crystals (NI) in the cloud layer starting at peak shortwave hour 40, in units of m L^{-1} and m L^{-1} hr^{-1}, respectively. Colors show sublimation in units of m L^{-1} hr^{-1}. B) 24-hour phase diagrams of sublimation vs. minimum relative humidity in the subcloud layer starting at peak shortwave hour 40, in units of m L^{-1} hr^{-1} and %, respectively. Colors show total N_{NI} flux at cloud base, m L^{-1} hr^{-1}. Hours 42-47, 47-50, 50-56, and 57-62 indicated with green, blue, black, red arrows, respectively. Minimum shortwave indicated with the moon symbol. Maximum shortwave indicated with the sun symbol.

IcePro



- Objectives
  - develop and apply comprehensive representations of ice properties
  - establish uncertainties and requirements



Ann Fridlind, Greg McFarquhar, David Mitchell

http://asr.science.energy.gov/science/working-groups/clc/ice

- Multi-PI collaborations D1–D12
  - extension and use of single-particle databases, model schemes ✔
  - ISDAC radiative closure study underway (instrument obstacles at SGP) ✔
  - next foci: framework for evaluating uncertainties, identifying gaps

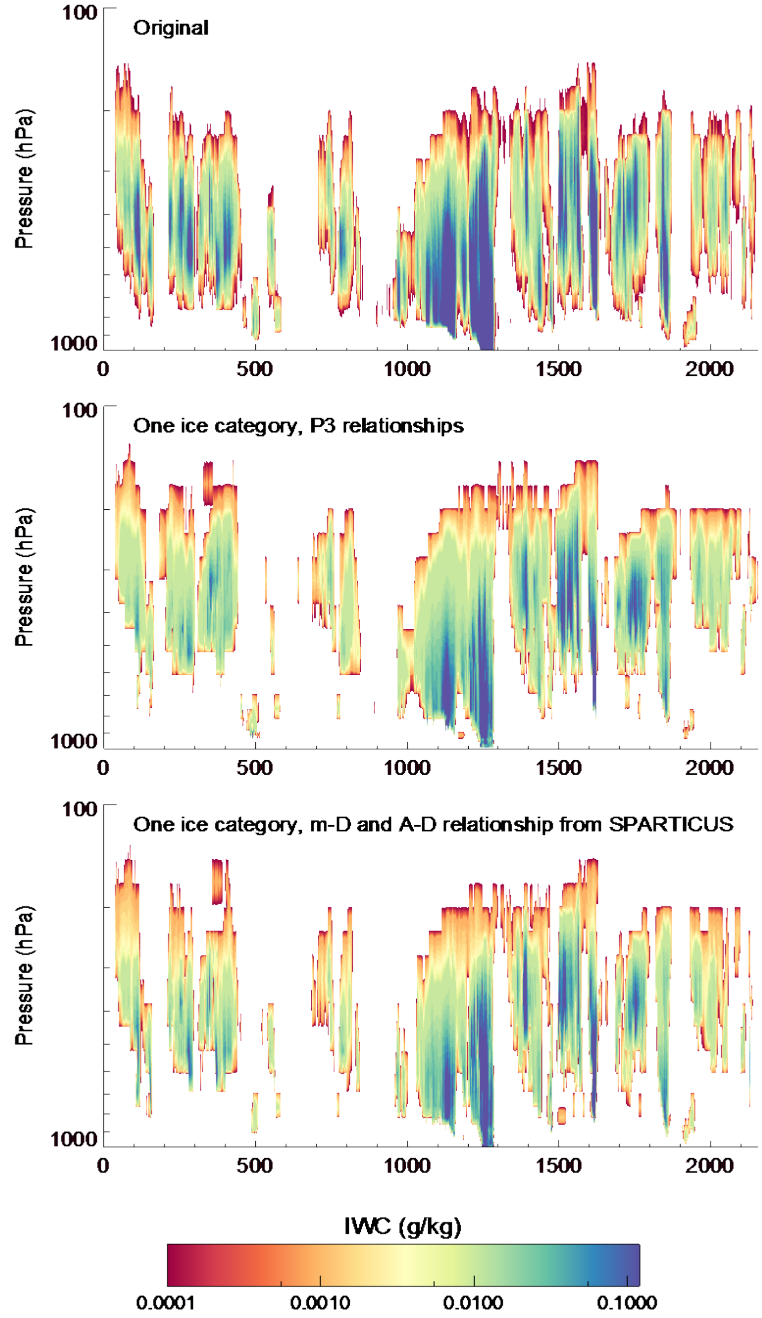
#	Deliverable	Contact(s)	Publication(s)
D1	Development of single-particle databases from in-situ data	Greg McFarquhar	1
D2	Characterization of ice property dependence on environmental conditions	David Mitchell	1
D3	Radiative closure studies from ISDAC	Dan Lubin	
D4	Radiative closure studies using data from SGP	Eli Mlawer	
D5	Impact of improved ice properties on retrievals	Xiquan Dong	
D6	Ground-based remote sensing techniques to infer ice habit information	Xiquan Dong	
D7	Upgrade CAM5 microphysics to make it self-consistent	Hugh Morrison	1 2
D8	Evaluate high-resolution simulations of MC3E systems	Ann Fridlind	
D9	Modeling impact of new ice property parameterizations	Jerry Harrington	1 2 3
D10	Framework for evaluating ice property uncertainties in models	Ann Fridlind	1
D11	Linking ice optical properties with microphysics observations	David Mitchell, Greg McFarquhar	
D12	Determine gaps in existing ice microphysics databases	David Mitchell, Greg McFarquhar	

Upgrade CAM5 microphysics to make cloud ice properties self-consistent

Trude Eidhammer, Hugh Morrison, David Mitchell, Ehsan Erfani

Upgrades to the MG2 microphysics scheme in CAM5:

- Cloud ice and snow are combined into a single category, removing the need for "autoconversion" of cloud ice to snow which has a limited physical basis
- For consistency, use the same mass- and area-dimension (m-D and A-D) relationships for all ice processes (e.g. mass weighted fall velocity, effective radius etc.). Updated relationships from SPARTICUS observations (Mitchell et al.)
- Currently in the process of implementing the m-D and A-D relationships as a function of temperature into MG2



Development & use of single-particle database from in-situ data

Junshik Um, Greg McFarquhar, Ann Fridlind and Bastiaan van Diedenhoven

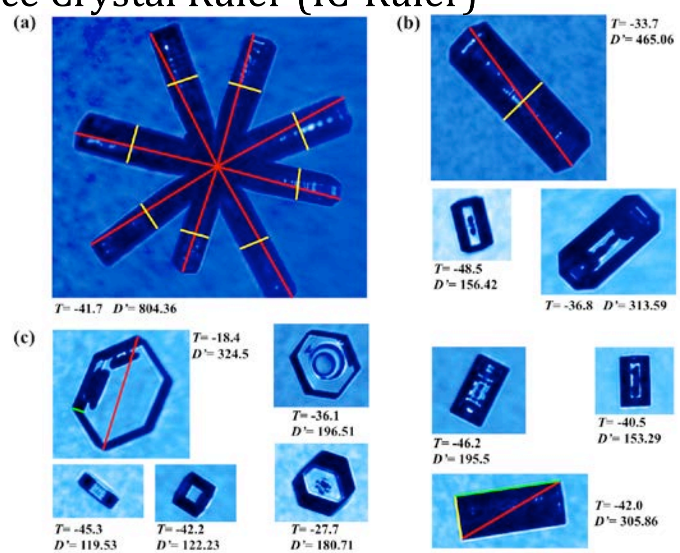
Science Question

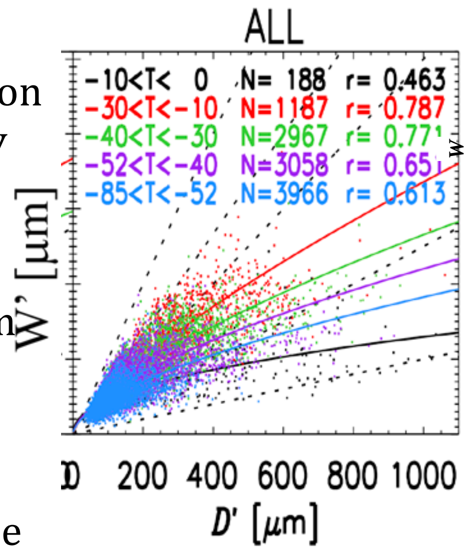
How microphysical properties (e.g., dimension aspect ratio, area, mass) of ice crystals vary with temperature (T), habit, & location?

Approach

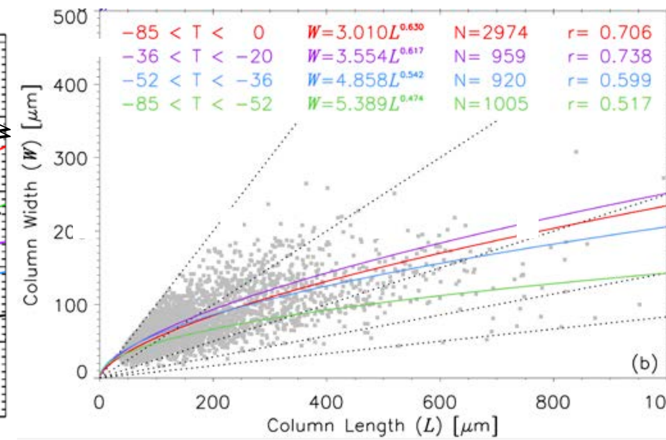
- Use high resolution images of crystals from state-of-the-art cloud probes acquired during TWP-ICE, ISDAC, and SPARTICUS

- Determine dimensions & aspect ratios of crystals using newly developed software, the Ice Crystal Ruler (IC-Ruler)





Length (L) – Width (W) relation for column crystals



L–W relations from previous studies (left) & determined (right) using current data (gray dots)

Progress:

- L-W relations from large set of data consistently analyzed largely within range of past studies.
- All dimensions & L-W relations depend heavily on T, but aspect ratio depends weakly on T.
- Database currently being used to compare against results of models predicting single-particle properties, and against remote sensing retrievals

Mesoscale Convective Organization (MCO)

Courtney Schumcaher, Adam Varble

Research Priorities

1. Determining and understanding mesoscale organizational modes, scales, and lifetimes as a function of environment
2. Linking vertical velocity and microphysics through the MCS life cycle
3. Creation of GCM parameterizations for mesoscale organization

Primary Activities

1. Trello webpages for connecting researchers working on mesoscale convective case studies from field campaigns (TWP-ICE, MC3E, AMIE)
2. Supporting the Cold Pool Interest Group

Recommendations

1. Find ways to extend radar retrievals of cloud and precipitation properties (especially vertical velocity) beyond case studies to routine products
2. Better connect observations and high-resolution modeling to design of GCM mesoscale organization parameterizations
3. Move deep convection work not related to mesoscale organization to a joint CAPI/CLWG Deep Convection group so that MCO is more focused

Mesoscale Convective Organization (MCO) – Cold Pool Interest Group

Angela Rowe, Zhe Feng

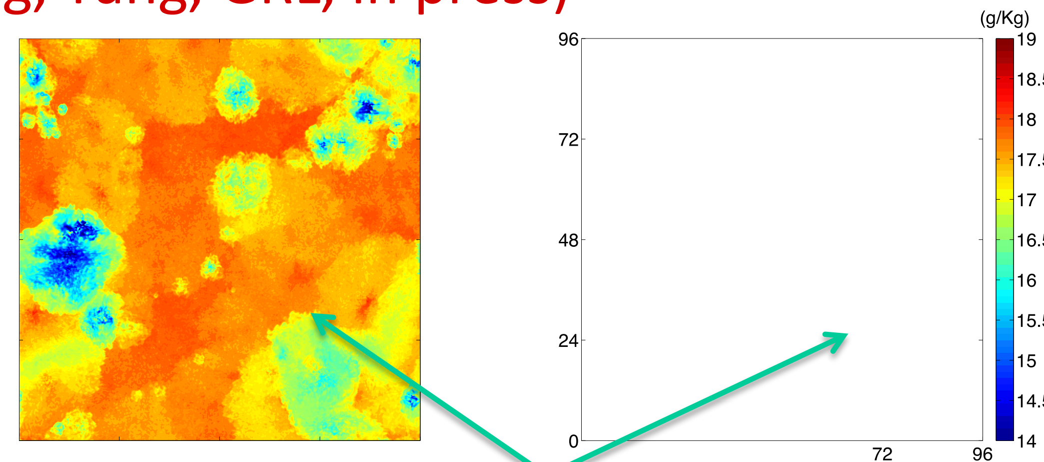
- **First breakout session during STM 2014**
  - Action item: Address disconnect between observations and high-resolution models
  - Need for low-level observations (e.g., rain rates, DSD, T, q)
- **Fall Meeting 2014**
  - Focus: Integrating observational datasets and models
    - Need to know when and where cold pools exist in a bulk sense, what large-scale conditions (that GCMs can produce) lead to these cold pools
    - **Ensemble cold pool characteristics**
  - Highlight available data products
    - AERI and Doppler lidars: Fill in gaps at low-levels
    - Polarimetric radar data: Precipitation/downdrafts and cold pool relationships
    - **Action item: A need for an IOP to address the crucial need for high-resolution, spatially representative moisture measurements**
  - A need for robust **automated cold pool detection algorithms**
    - Obtain statistics from large observational datasets
    - Apply to high-resolution model output

Cold pool forcing mechanisms

(Torri, Kuang, Yang, GRL, in press)

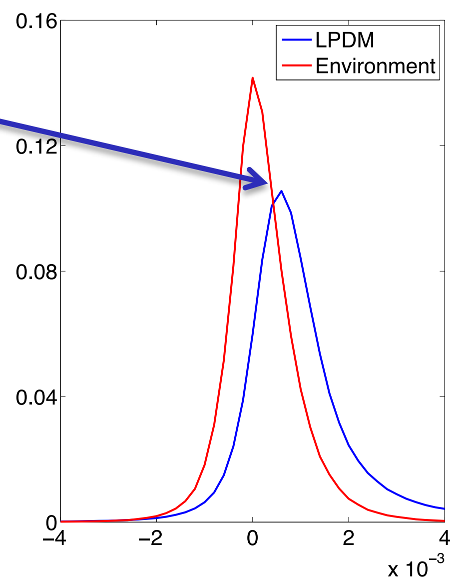
Triggering results from **cooperation** of forcings:

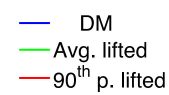
- *Mechanical forcing* lifts parcels from the surface;
- *Thermodynamic forcing* helps overcome convective inhibition.



Thermodynamic effect: negative T anomaly, positive MSE anomaly

Gust front lifting over the bottom 300m





The CIN is greatly reduced for air from edges of the cold pool (blue) compared to ambient boundary layer air (green)

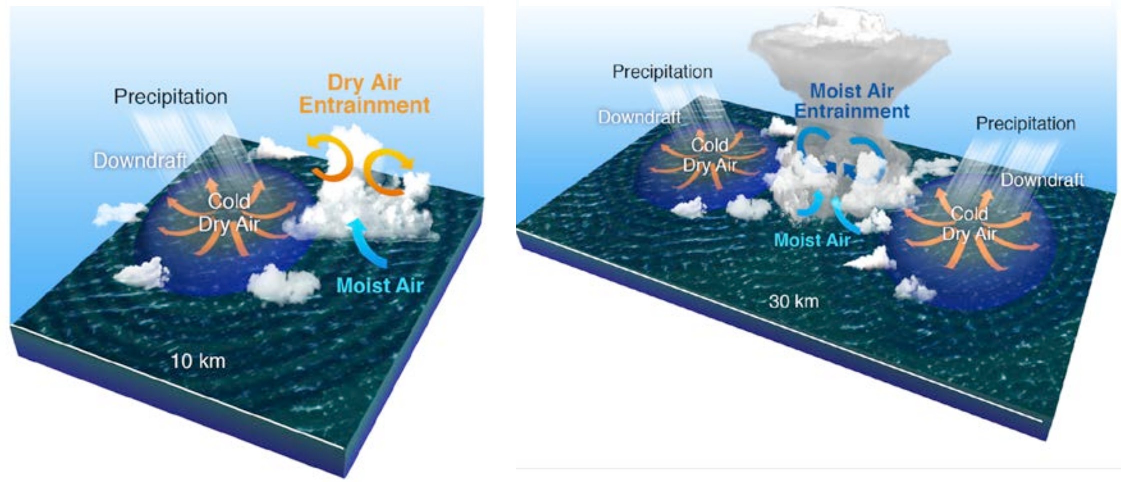
Large values of buoyancy cancelled by buoyancy pressure gradients

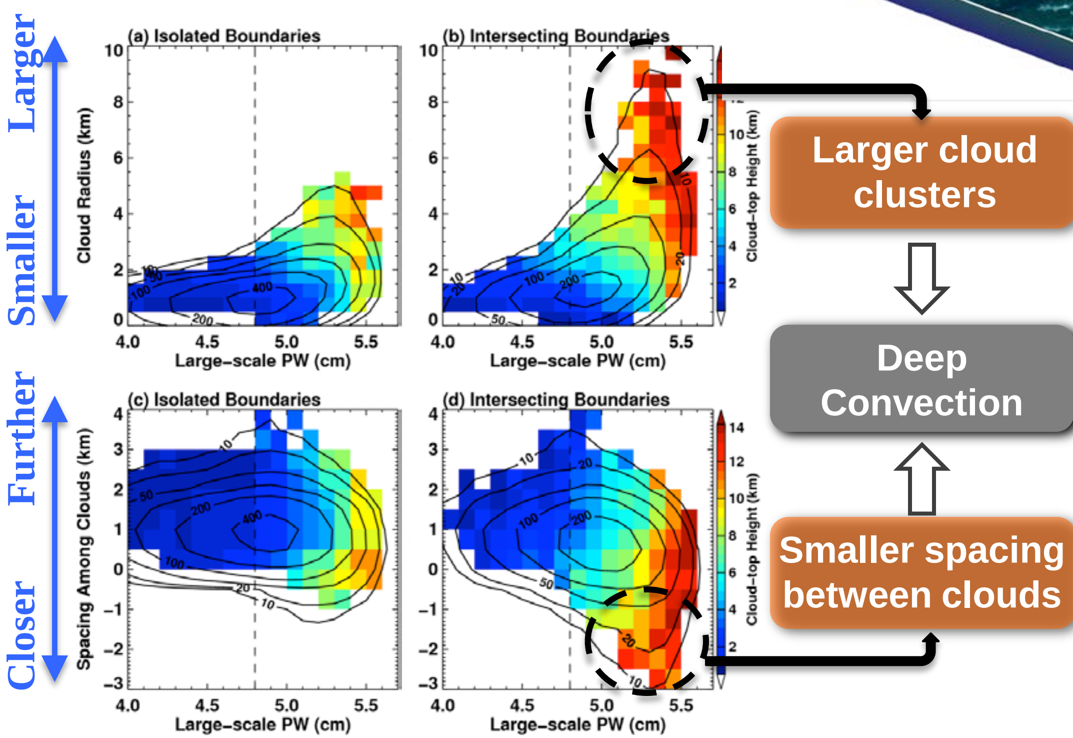
Mechanisms of Convective Cloud Organization by Cold Pools over Tropical Ocean

Feng et al. 2015. *J. Adv. Model. Earth Syst.*

Precipitation-driven cold pools in deep convective cloud development is a sub-grid scale process not represented in climate models, so our goal is to better understand the how cold pools affect organization of convection over the warm tropical Ocean

Isolated Cold Pools | **Intersecting Cold Pools**





- Intersecting cold pools trigger 73% more convection than isolated ones due to stronger secondary updraft velocities
- Deep convection preferentially develop at intersecting cold pool boundaries because of **closer spacing between clouds** and **larger cloud clusters**, **reducing entrainment drying**
- Findings represent new approach to parameterize cold pool effects on organized convection

matt shupe