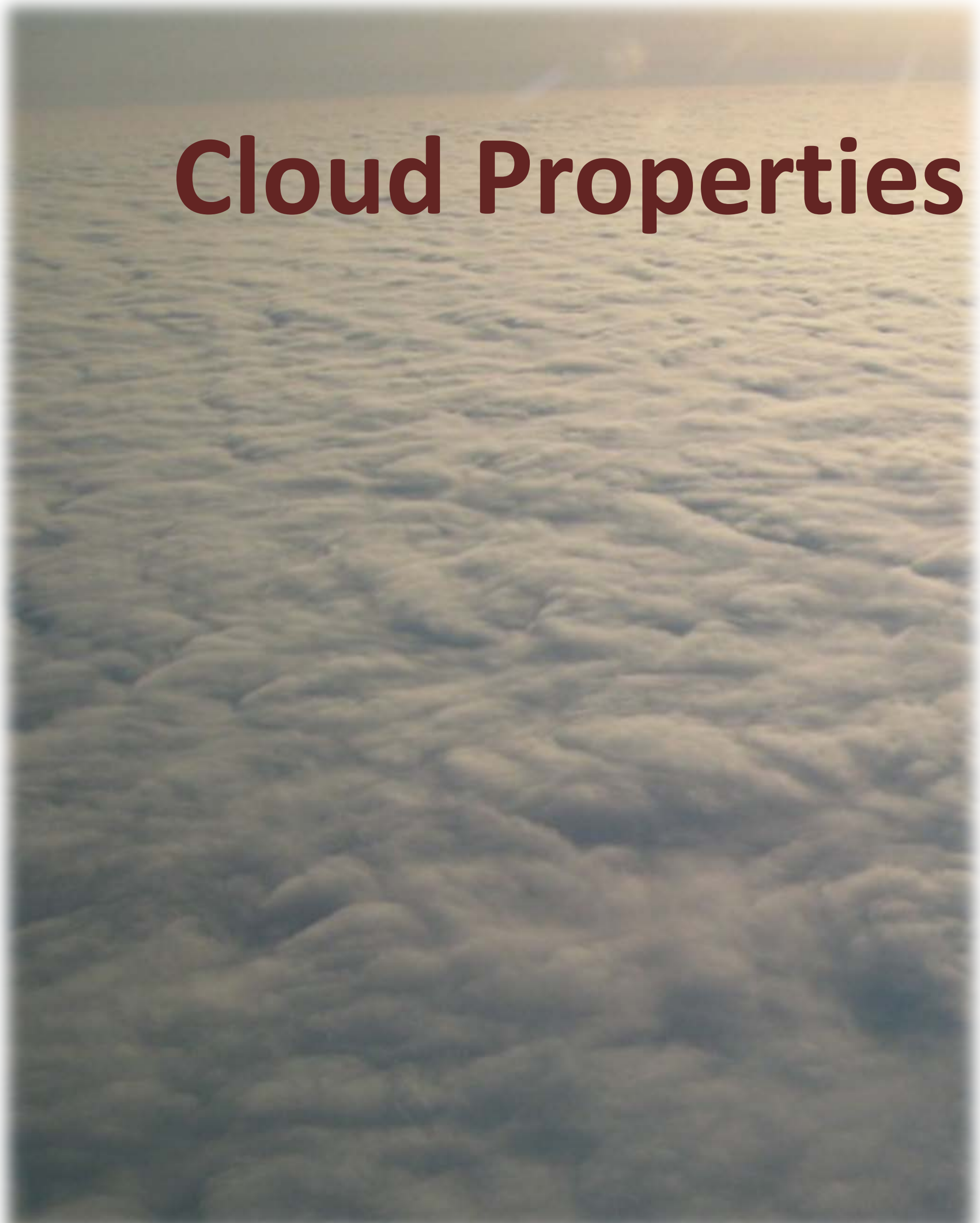
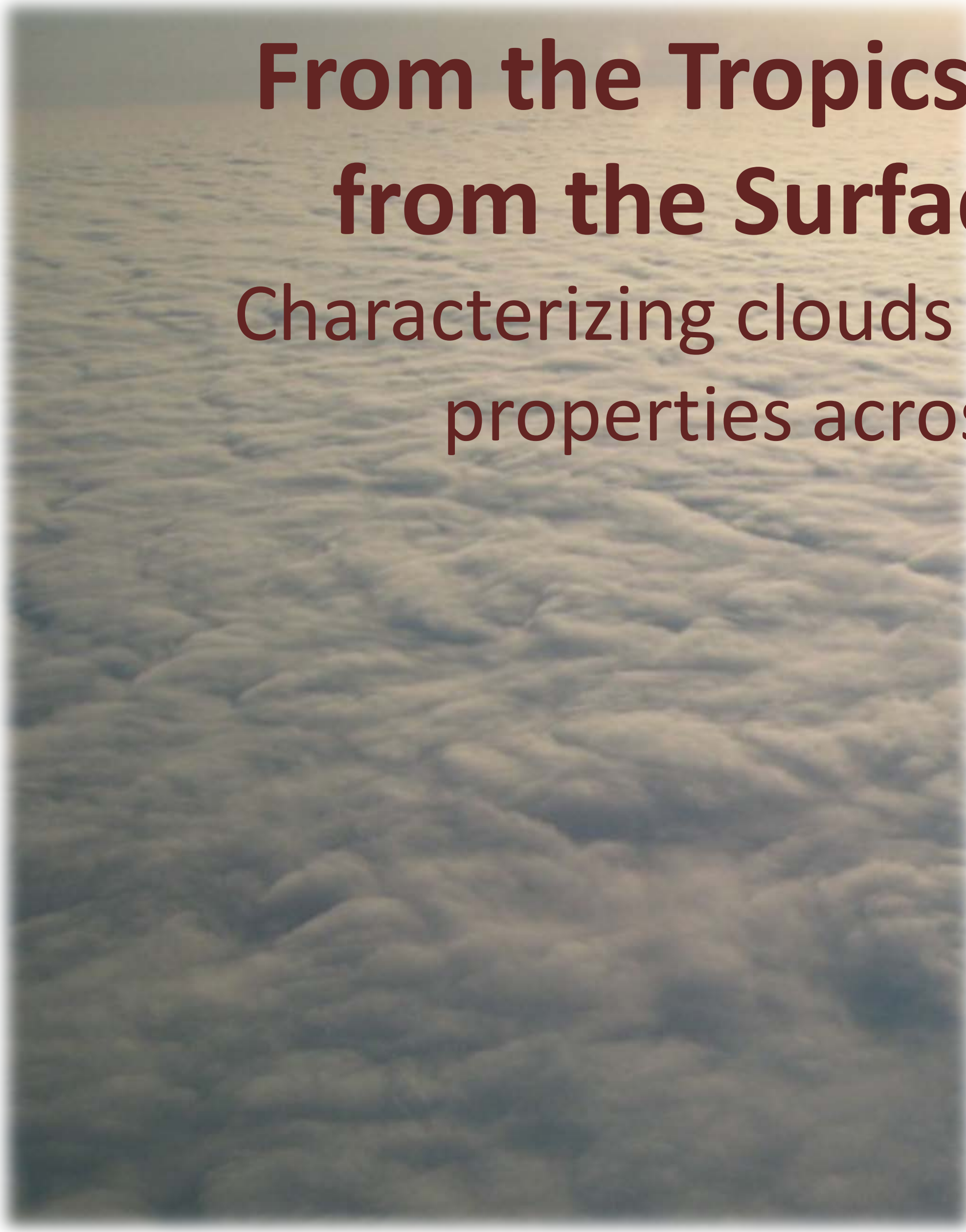


Cloud Properties Working Group Overview

Matthew Shupe
CPWG Chair

2009 ARM Science Team Meeting
March 31, 2009   Louisville, KY



From the Tropics to the Arctic, from the Surface to Space:

Characterizing clouds and cloud-related properties across the globe

<u>Outline</u>

Highlight exciting PI research results

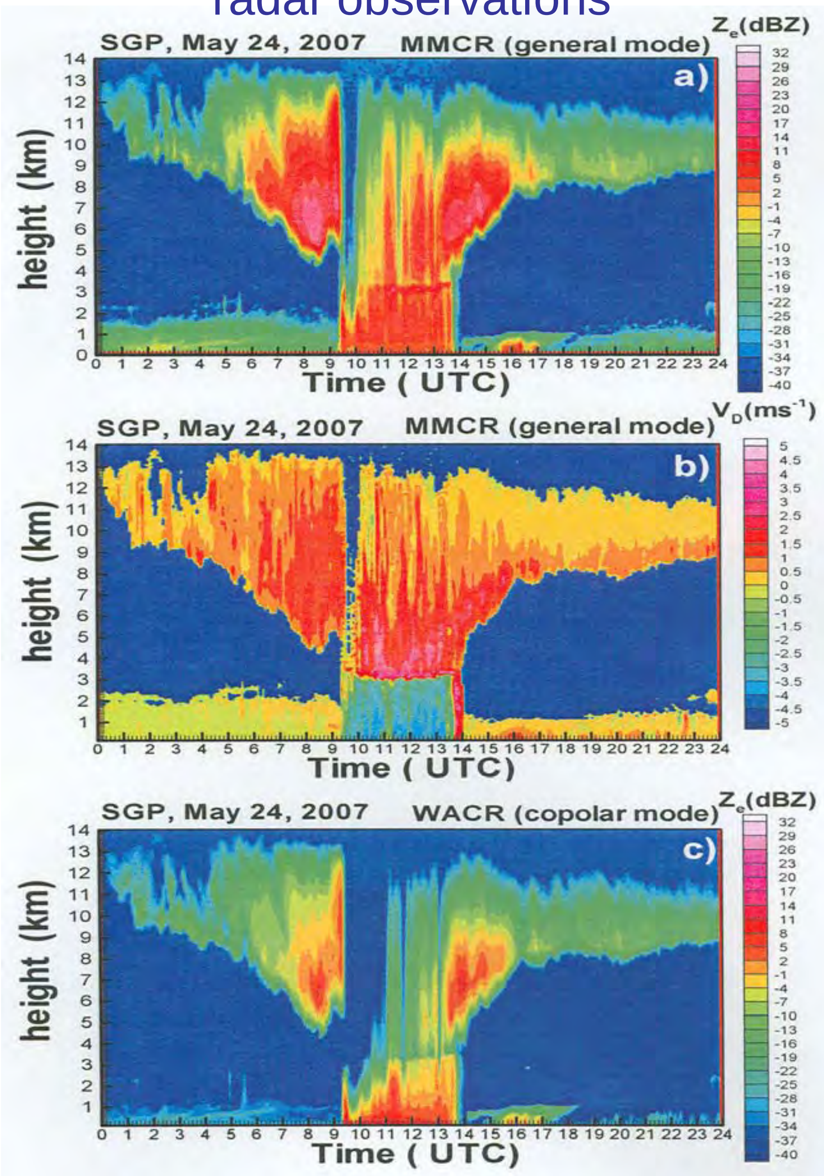
Touch on recent and upcoming IOPs

Three individual talks on current research

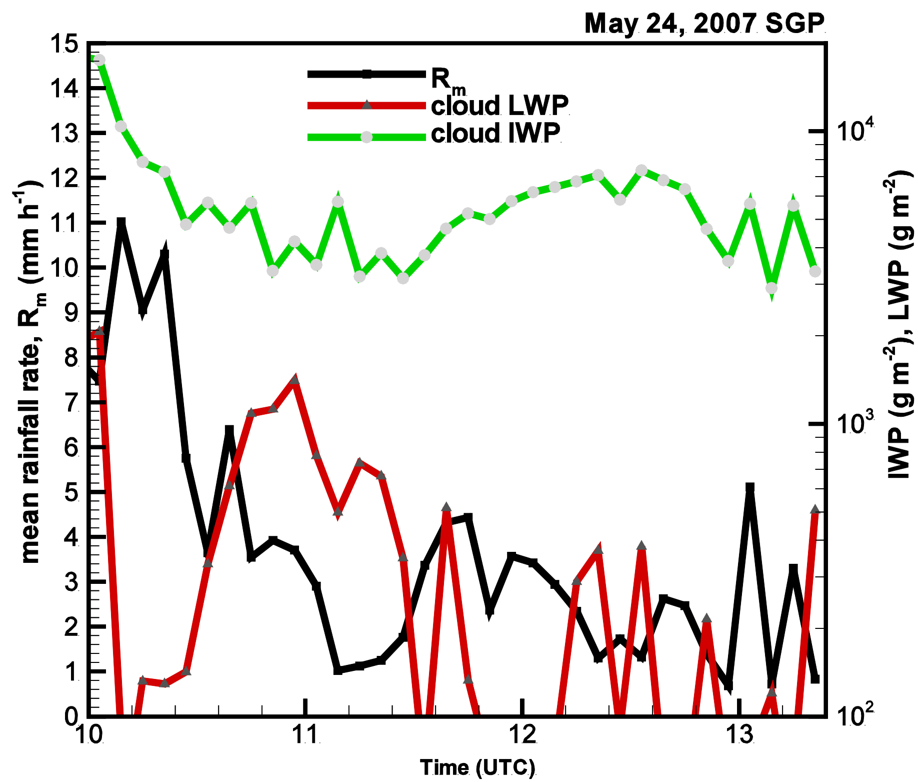
Retrievals of LWP, IWP and mean rain rate R_m in the vertical column above the SGP

Sergey Matrosov

radar observations



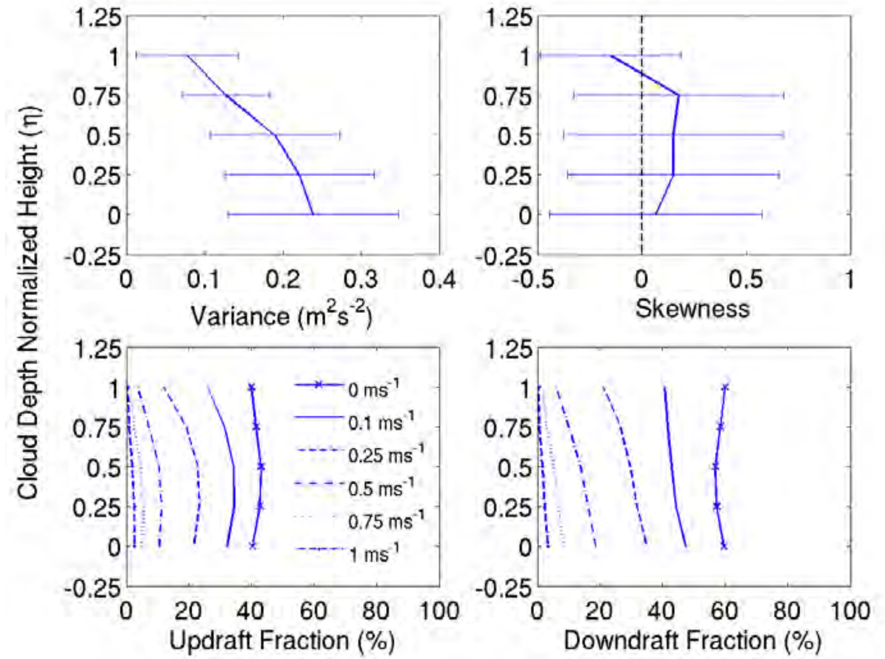
- *Rainfall and LWP derived from attenuation*
- *IWP derived from corrected reflectivity*
- *Method applicable in stratiform rain (0.5-15 mm/hr), May-Sept at SGP*
- *2007 retrieval results are now available*

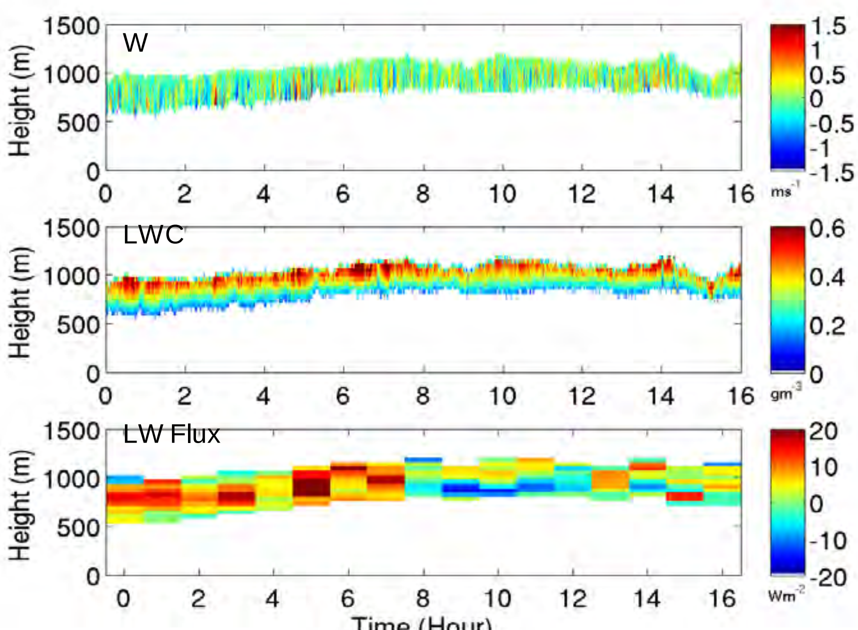


Vertical Velocities and Liquid Water Fluxes in Continental Stratocumulus Clouds

Virendra P. Ghate, Bruce A. Albrecht, Pavlos Kollias
(MPO/RSMAS, Univ. of Miami and McGill University)

Doppler MMCR observations from SGP (2005-2007) provide in-cloud vertical velocity statistics for 11 stratocumulus decks (141 half-hour periods)





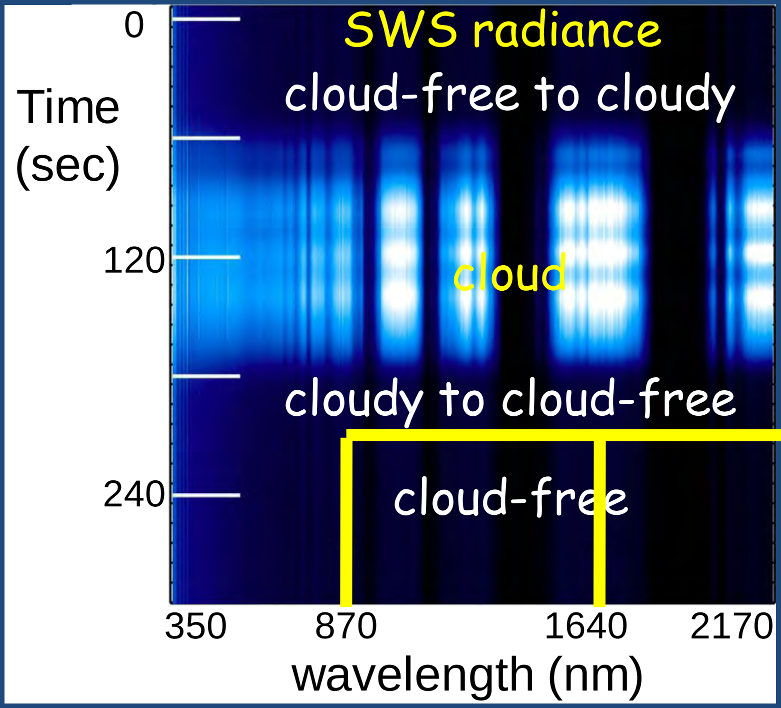
Liquid water fluxes calculated for a stratocumulus case using vertical velocity from MMCR and liquid water retrievals from radar reflectivity and liquid water path.

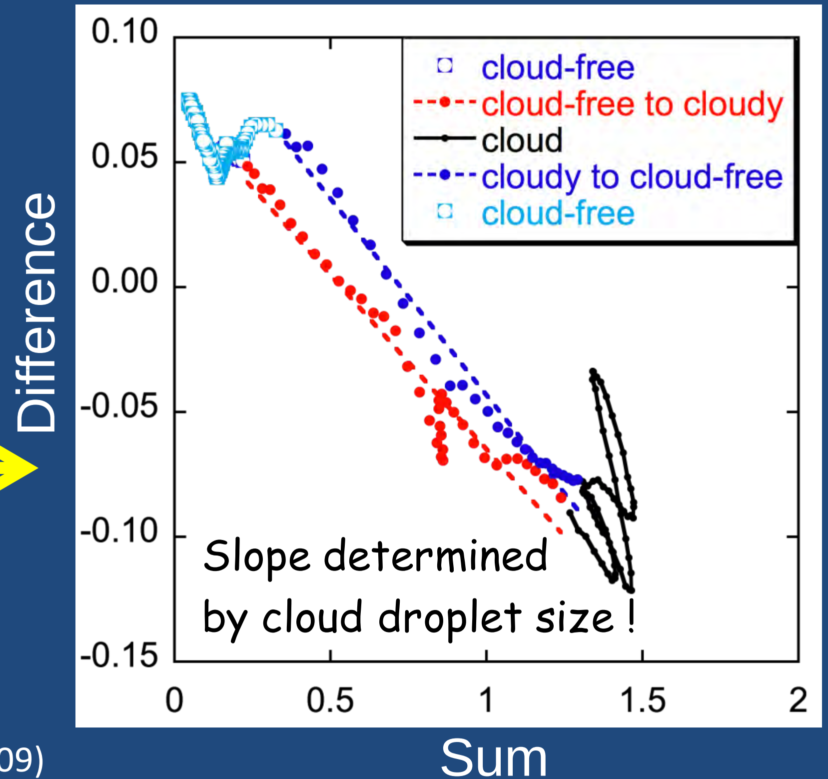
ARM shortwave spectrometer (SWS) is used to analyze the transition between cloud-free and cloudy regions, which has considerable bearing on the aerosol indirect effect

Chiu, Marshak et al.

TSI

In the transition zone, there is a remarkable linear relationship, allowing us to separate radiative signatures of aerosols and clouds

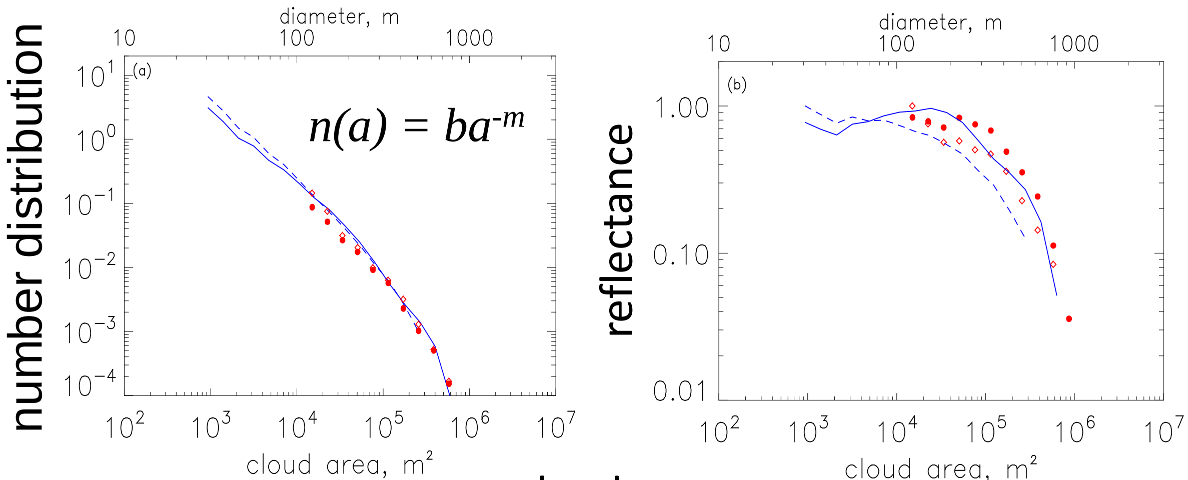




Chiu et al. (ACP, 2009)

The Importance of Small Cumulus Clouds

Feingold et al.



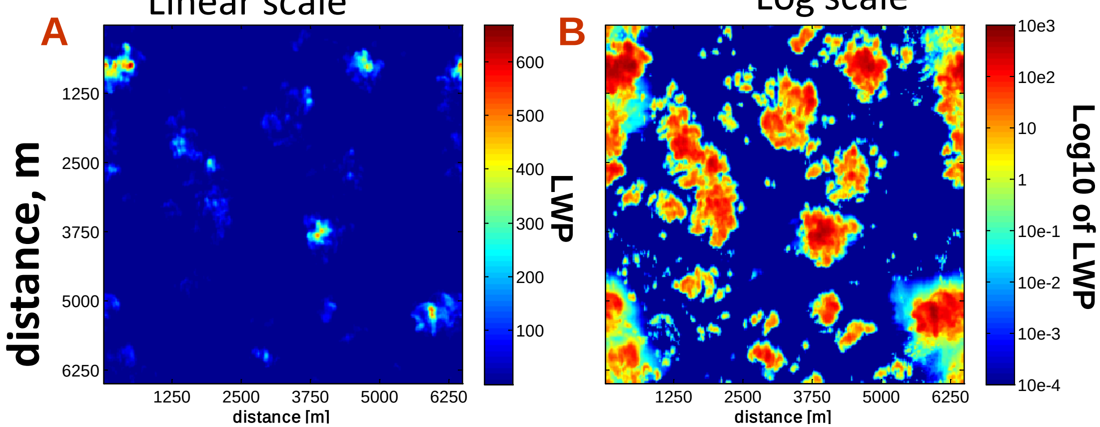
cloud area

Jiang et al. (2009)

LWP contours

Linear scale

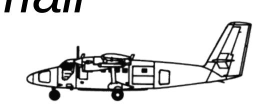
Log scale



distance, m

Koren, Feingold, Jiang (2009)

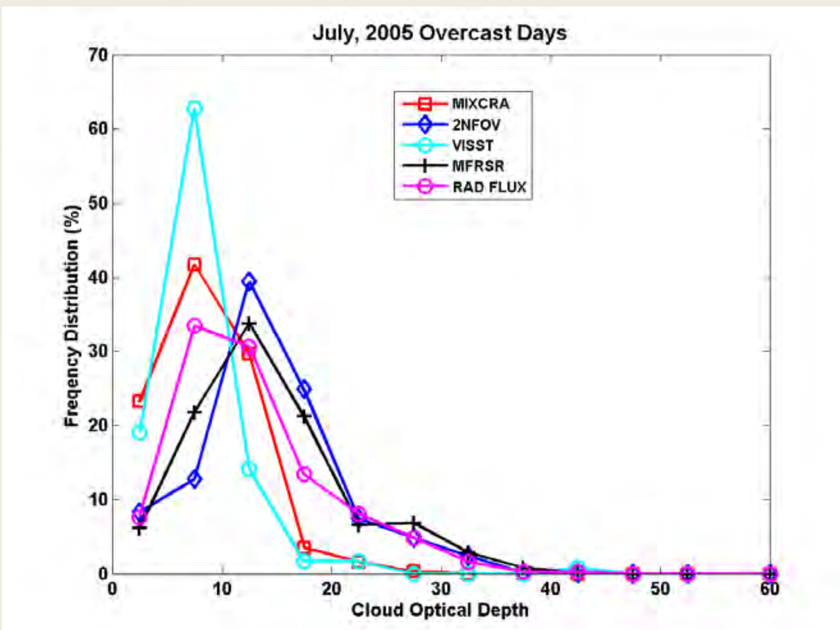
- *Small cumulus contribute significantly to number, cloud fraction and reflectance*
- *The regions between clouds are not cloud-free and contribute significantly to reflectance*
- *CHAPS, RACORO field experiments to characterize these small clouds*



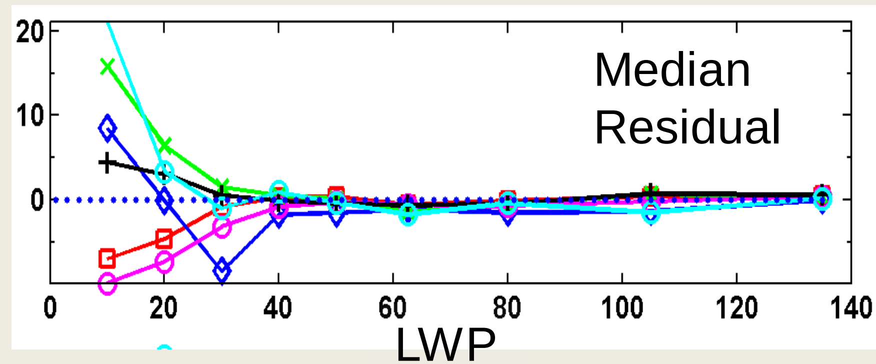
Clouds with Low Optical Water Depths (CLOWD)

Pt. Reyes Retrieval Algorithm Intercomparison Using the BBHRP Framework

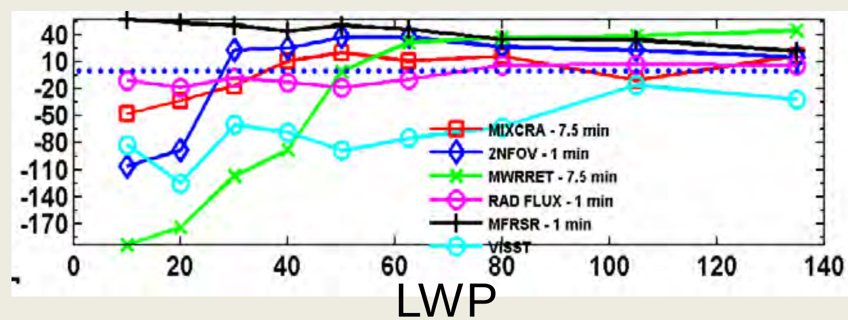
Cloud Optical Depth



LW Flux Closure for Overcast Skies



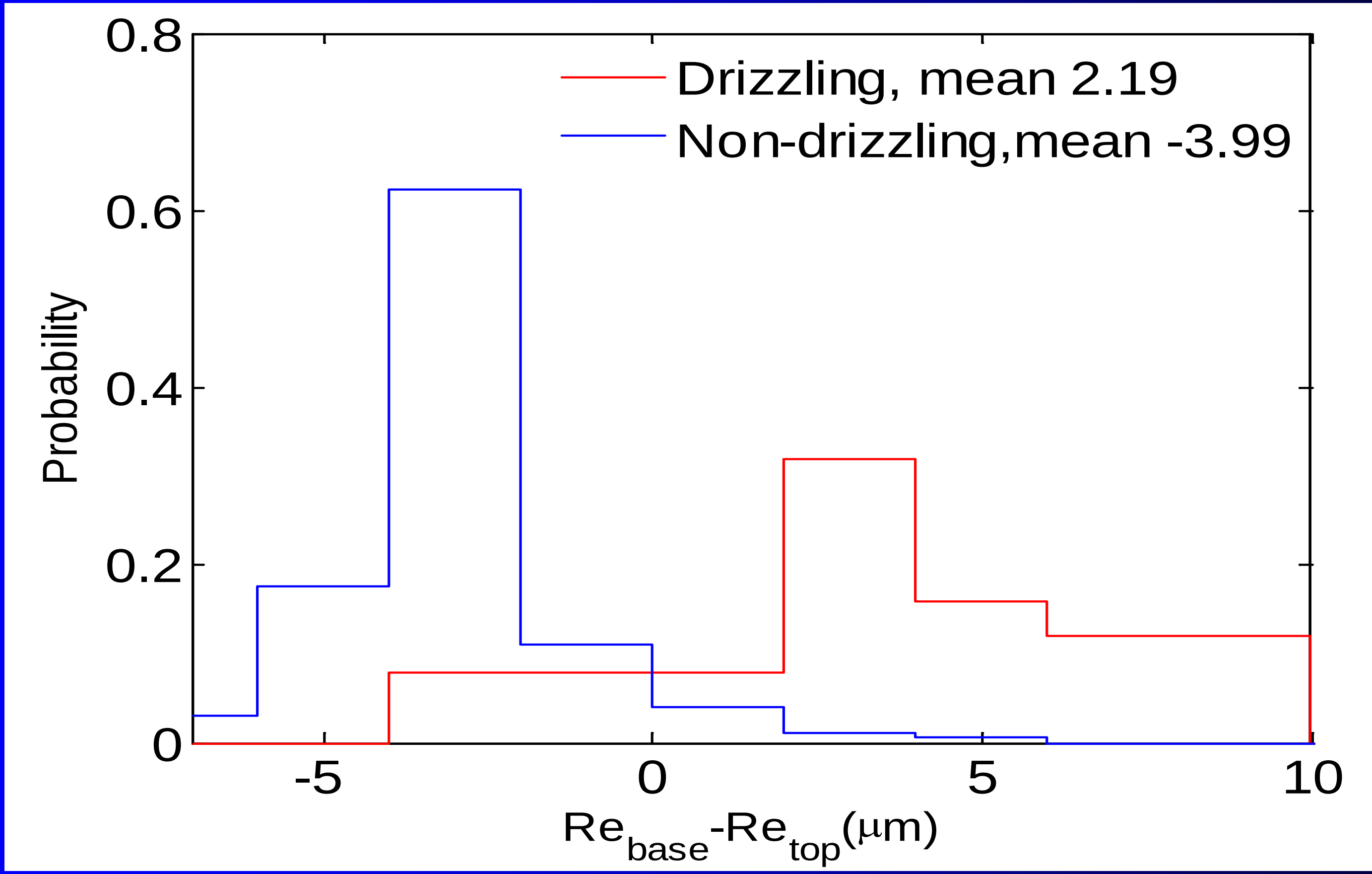
SW Flux Closure for Overcast Skies



Want to learn more? Attend the RACORO/CLOWD breakout Tues. at 3:30 pm or check out our poster by Lo, Comstock et al.

Contact Jennifer Comstock, Andy Vogelmann, or Dave Turner for more info.

Use of Re profile for Drizzle Detection

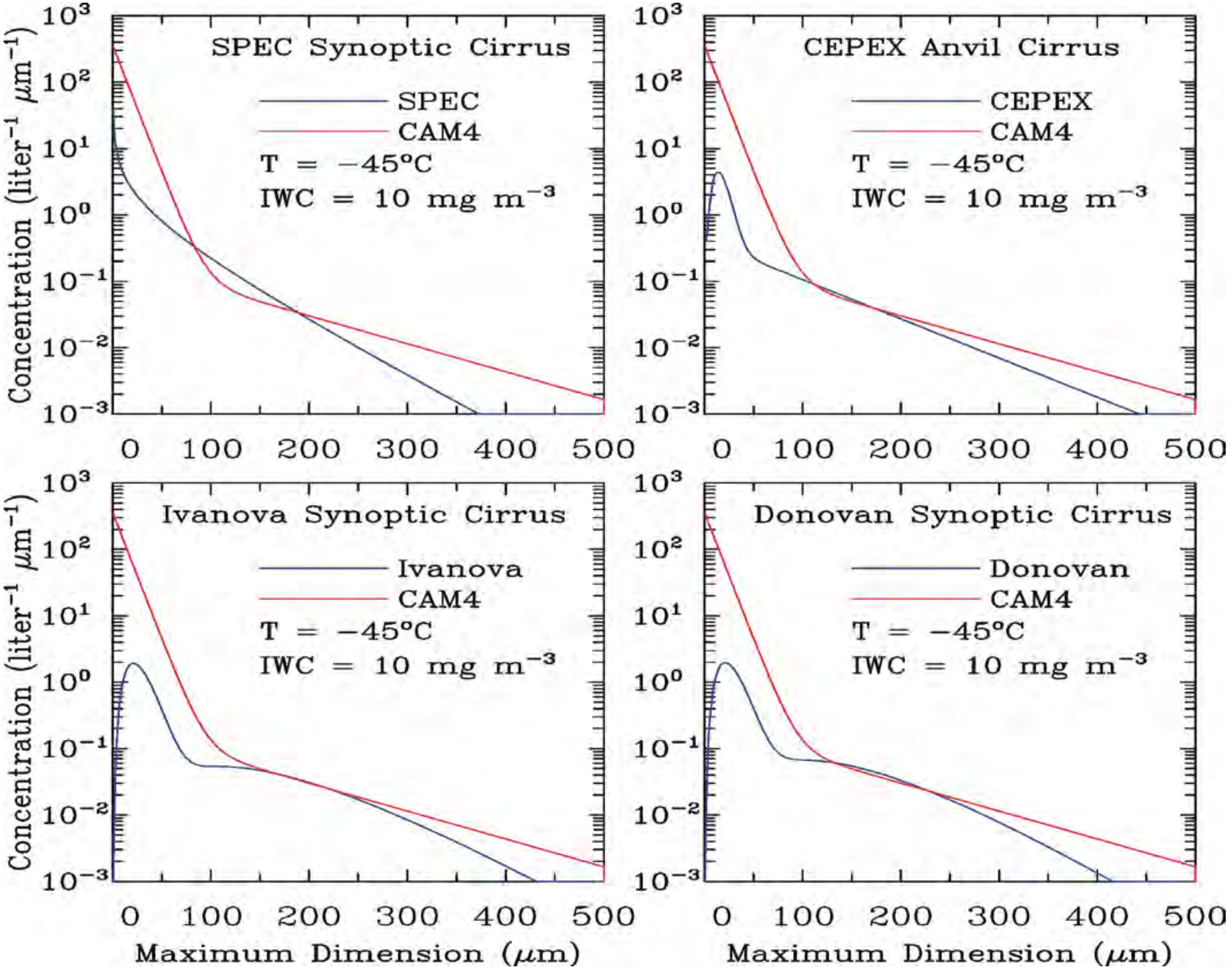


Re derived at multiple depths in the cloud from different MODIS channels. Independent drizzle identification w/ C-band radar.

Chen et al. (2008, JGR)

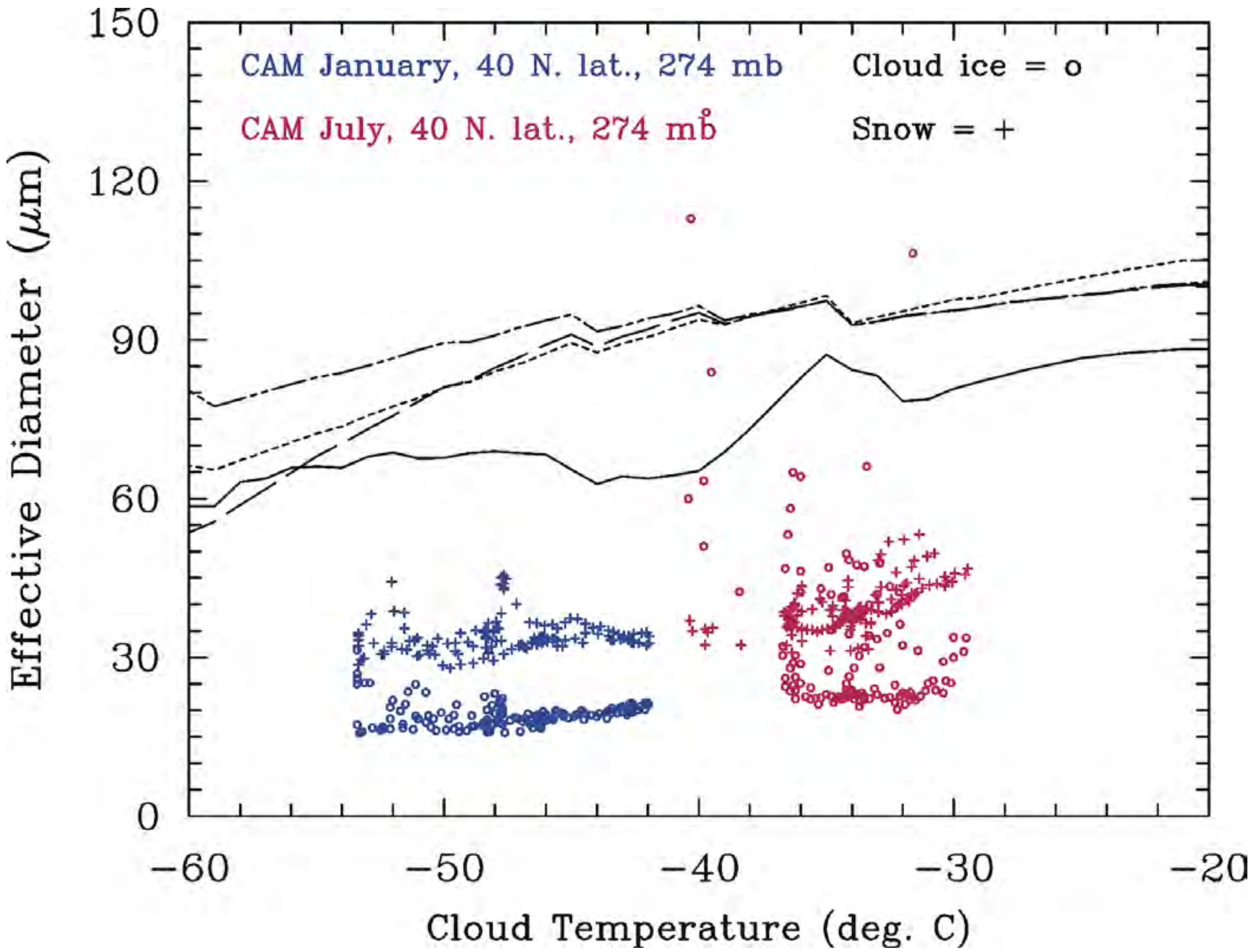
Comparison of CAM PSD (development version) with PSD schemes derived from in situ and remote sensing measurements; T = - 45 °C

Mitchell and Lawson, JAS 2009



PSD schemes have been adjusted to be consistent with thermal radiances measured by satellites (this corrects small particle concentrations).

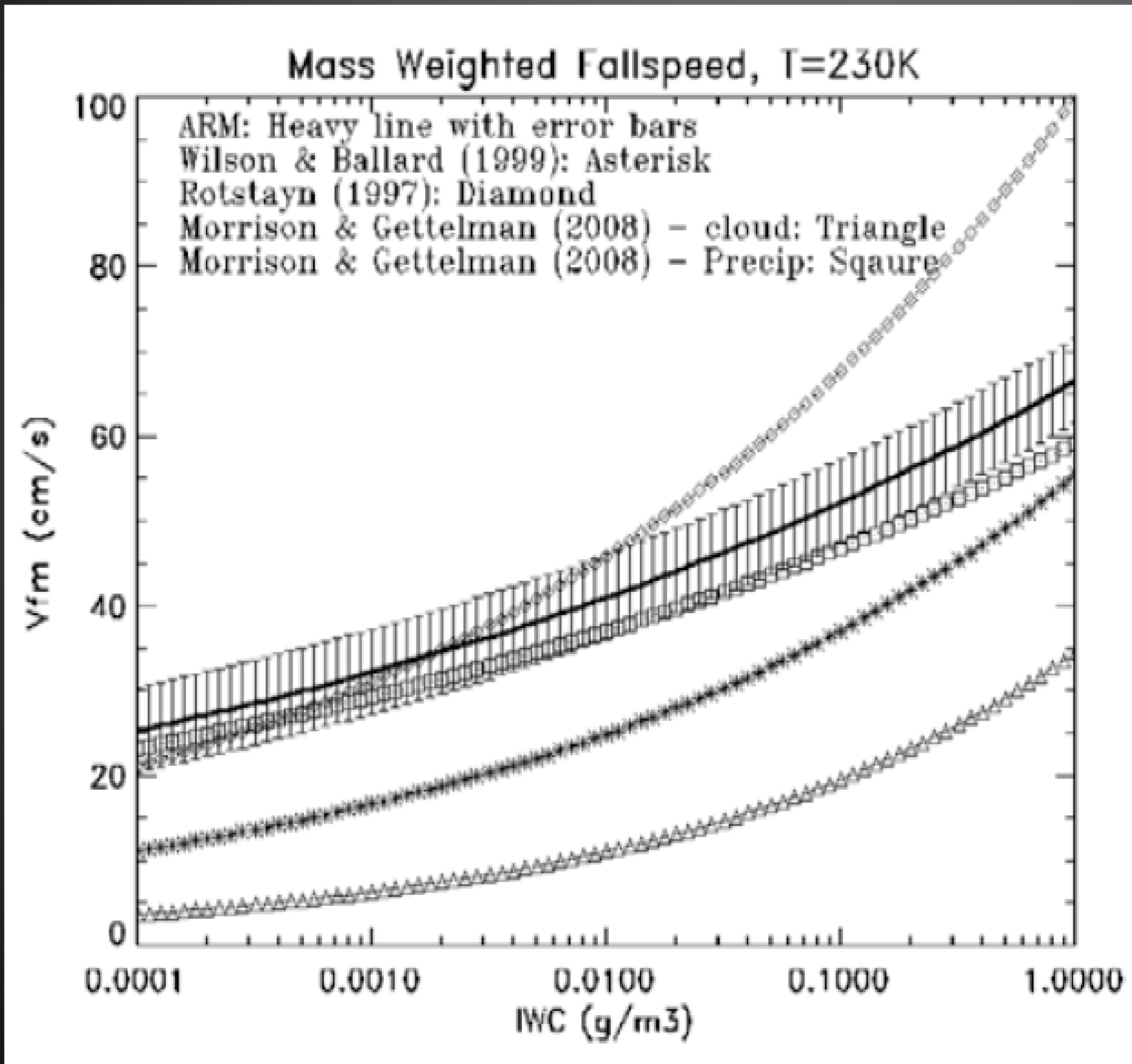
Comparison of CAM (development version) effective diameters with those from PSD schemes based on in situ and remote sensing measurements



Differences are due to 1) discrepancies between small crystal concentrations, and 2) different assumed mass-dimension relationships.

Comparison of Ice Sedimentation Rate Derived from ARM data Compared with GCM Parameterizations.

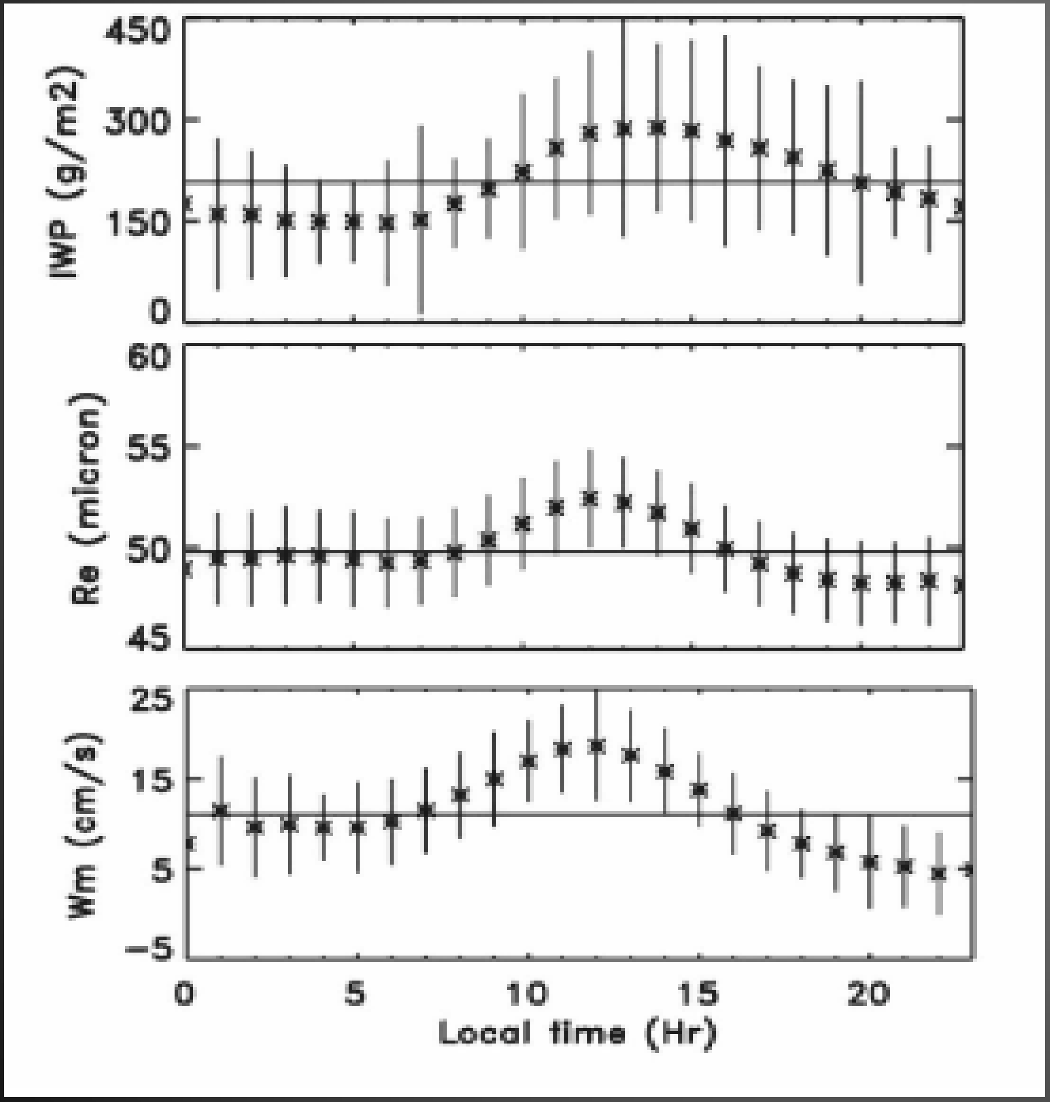
From Deng and Mace, GRL, 2008



- Morrison and Gettelman (2008) ice precipitation parameterization agrees within uncertainty with ARM results.
- Other GCM parameterizations are in stark disagreement with ARM results.
- Calls into question the ice mass and energy balance of the simulated upper troposphere in many GCMs.

The Diurnal Cycle of Cirrus Properties at Manus Derived from 5 years of ARM Data

Deng and Mace, JAMC, 2008



Water Path, Particle Size, Air Motion demonstrate a diurnal cycle that is 4-5 hours out of phase with peaks in convection.

Water Path and Particle Size maxima lag increases in Air Motion by 1-2 hours.

Understanding Factors Controlling Ice Supersaturation and Cirrus Properties

Jennifer Comstock (PNNL), Ruei-Fong Lin (UMBC/GSFC),
David Starr (GSFC), Ping Yang (Texas A&M)

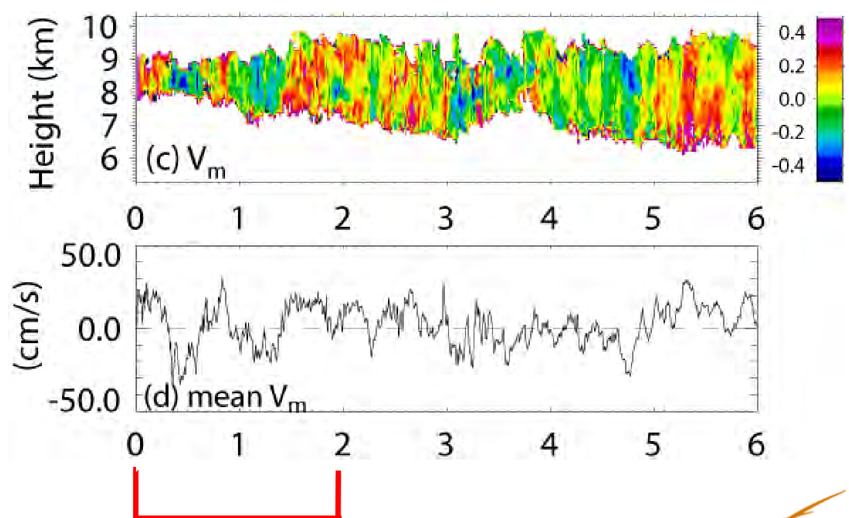
Science Question:

▶ What factors control the variability of ice supersaturation and cirrus microphysical properties on the scale of a GCM grid box?

Approach

- Size-resolved cloud model with explicit microphysical processes used to simulate cirrus formation and evolution.
- Cloud-scale vertical motion derived from MMCR Doppler velocity used to dynamically force the model.
- Model evaluation: Lidar extinction and radar reflectivity "instrument simulator"

Radar Derived Vertical Velocity

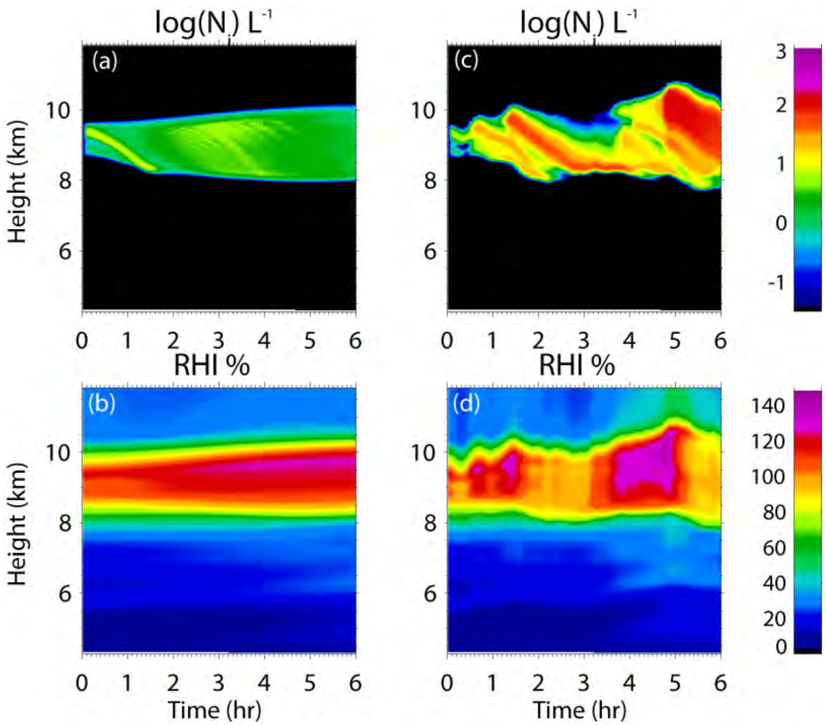


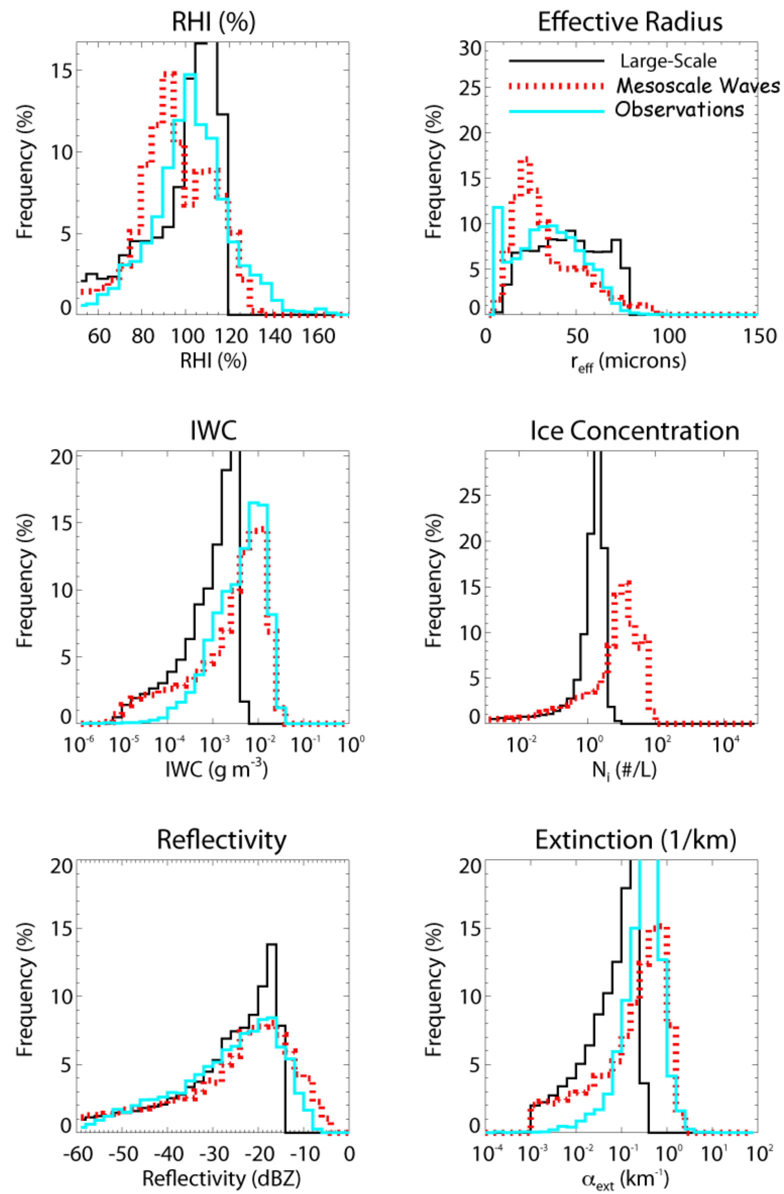
GCM Grid Box

Comstock, et al. JGR, 2008

Pacific Northwest NATIONAL LABORATORY

Understanding Factors Controlling Ice Supersaturation and Cirrus Properties

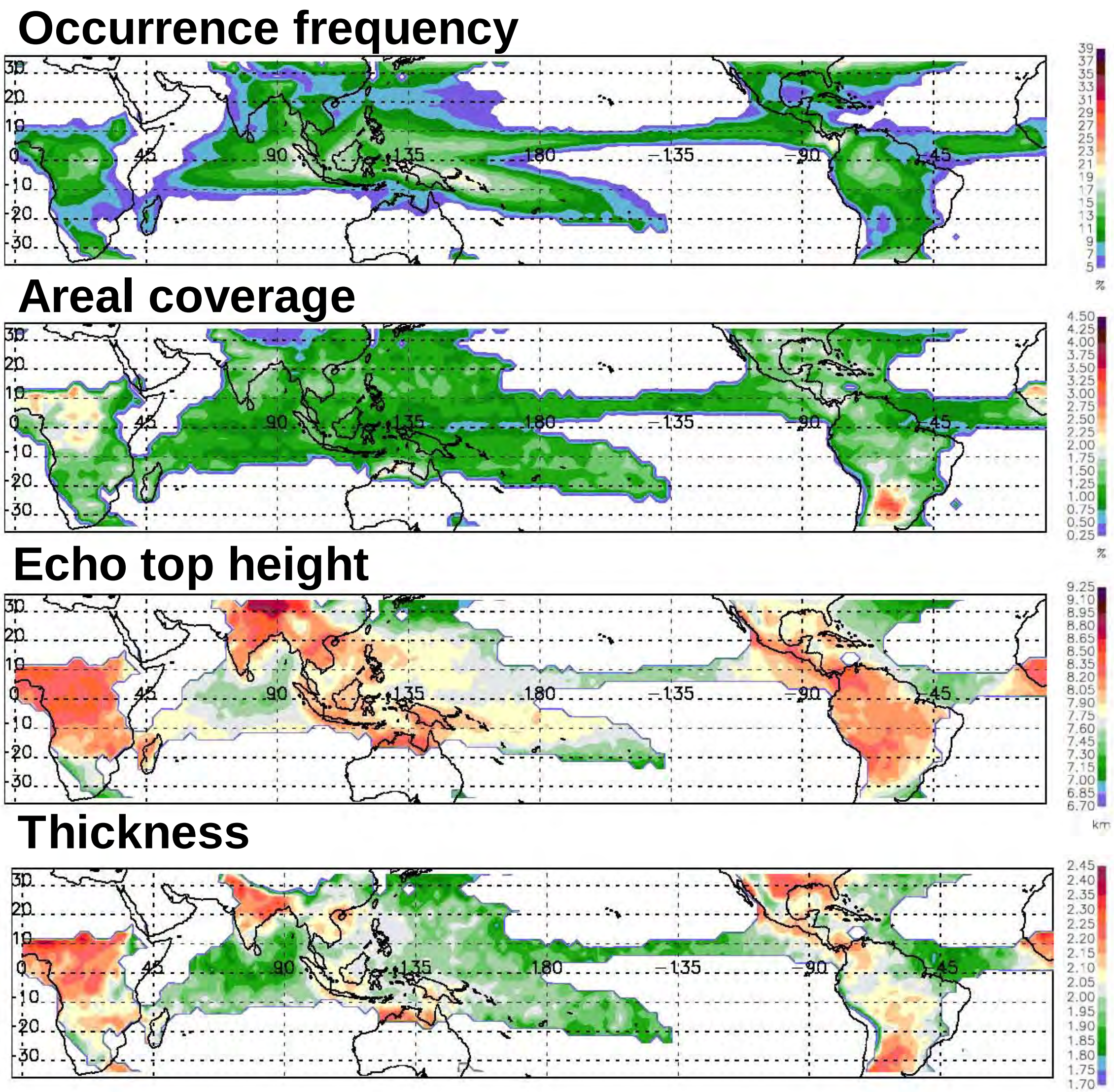




Key Findings:

- Primary mechanism: Mesoscale velocity variability
- Secondary mechanism: Ice Nucleation
- Ice crystal concentrations ~10-100 L^{-1}, much smaller than some aircraft obs.

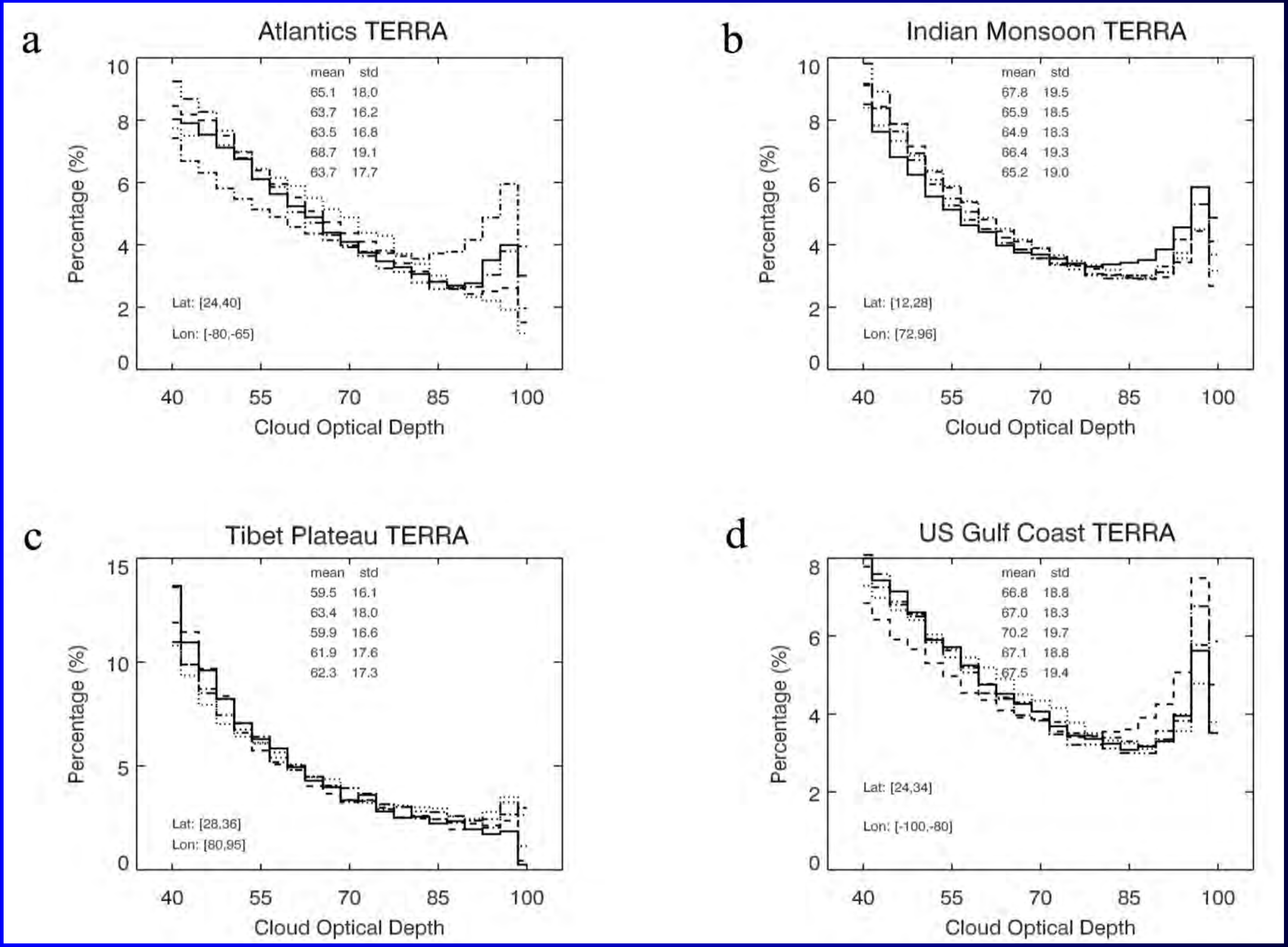
TRMM PR Thick Anvil Climatology (1998-2007)



- Anvil occurs most frequently over the Maritime Continent and West Pacific, but covers the largest area over tropical Africa.
- Anvil over land is higher and thicker than over ocean.
- Anvil also exhibits a strong ENSO signal (not shown).

Wei Li and Courtney Schumacher

COD Histogram of Deep Convective Clouds

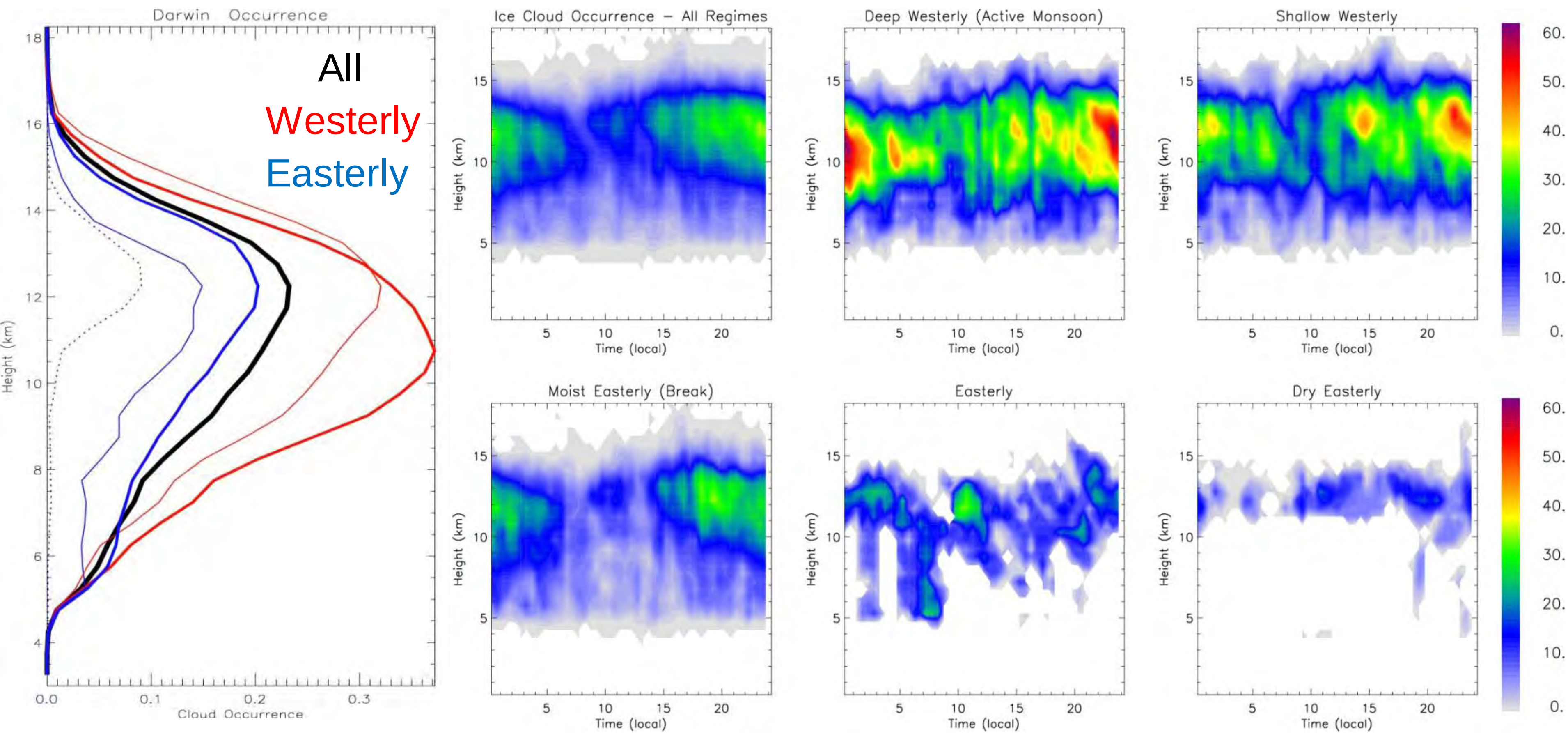


Interannual variability at a given location is small, but geographic variation is somewhat larger

Yuan and Li (2009)

Variability of ice clouds as a function of Darwin large-scale regimes

(Protat, Pope, May, Jakob, Reeder)

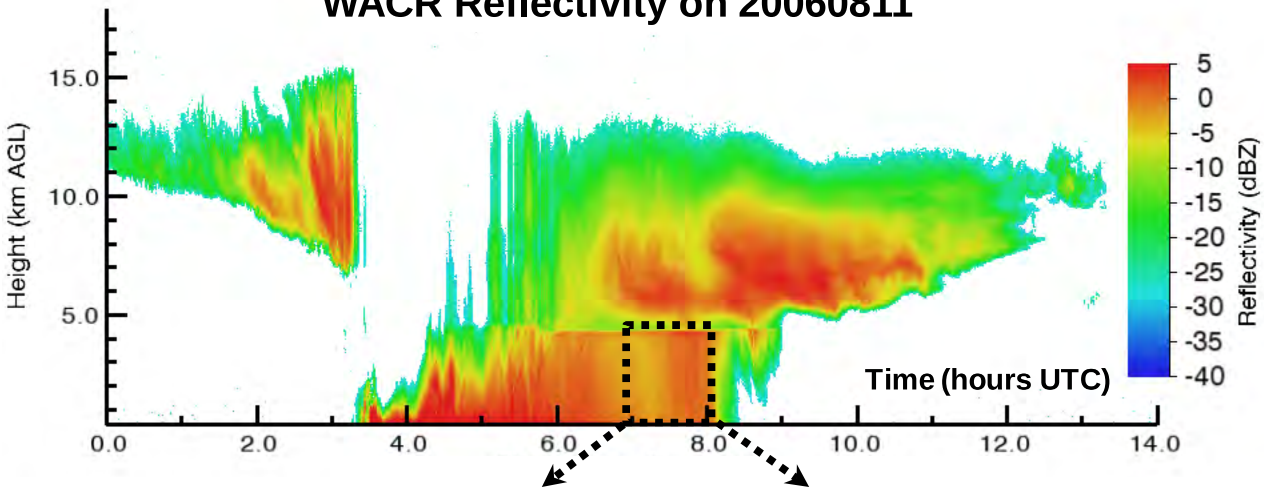


A large variability is observed as a function of the large-scale regimes
More seasons needed for robust statistics!

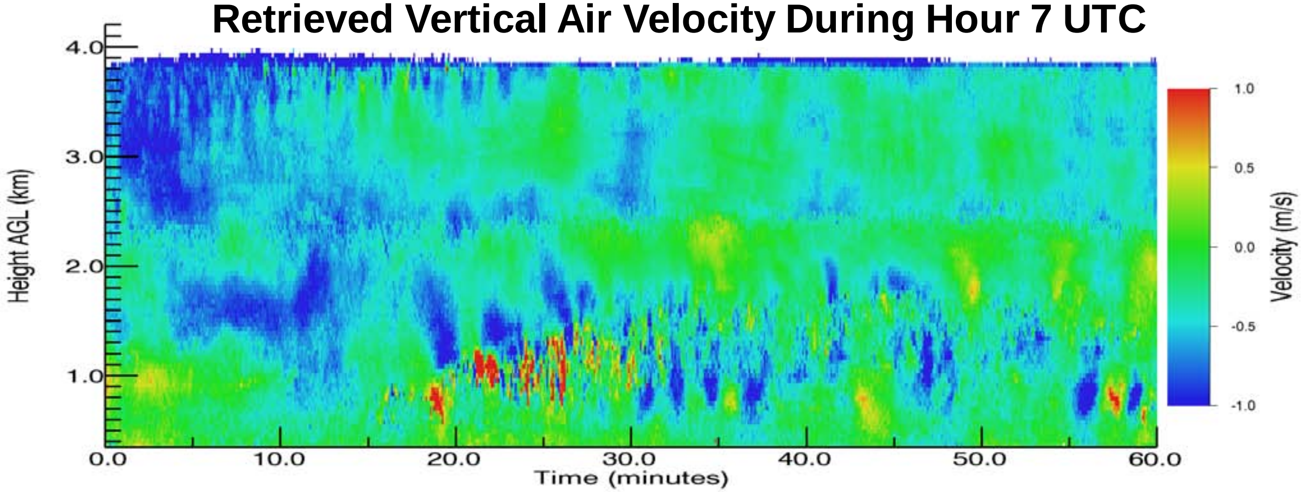
Vertical velocities in Niamey

Giangrande, Luke, Kollias

WACR Reflectivity on 20060811

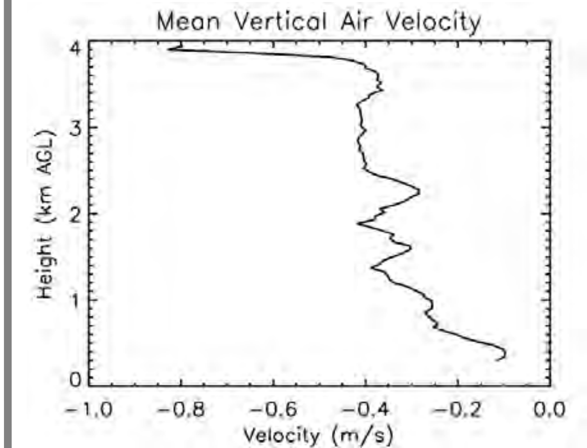


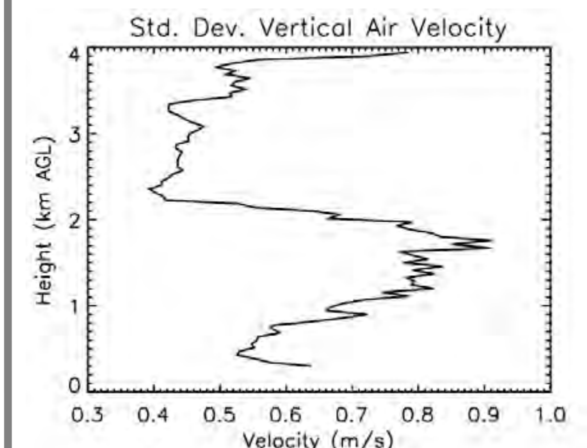
Retrieved Vertical Air Velocity During Hour 7 UTC



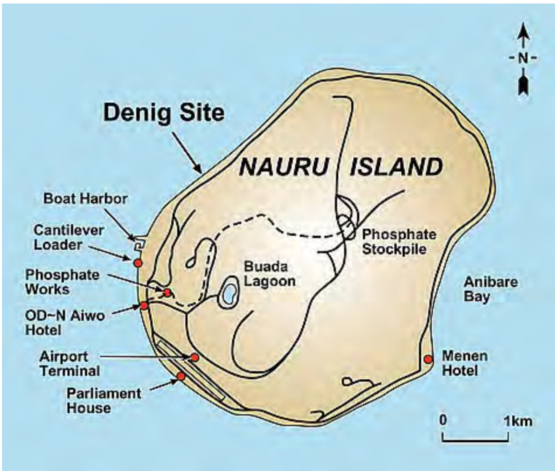
Vertical air velocity derived from non-Rayleigh signature in 94-GHz radar Doppler spectra.

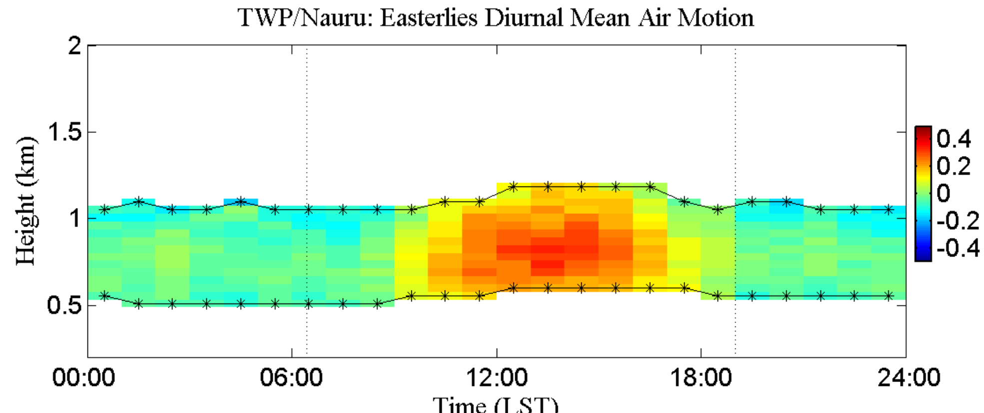
Vertical air velocity mean and standard deviation for full precipitation event.

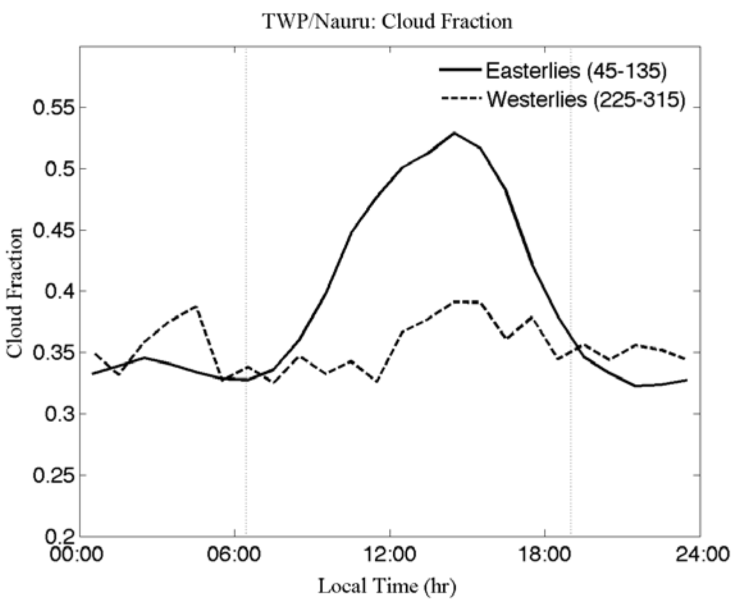


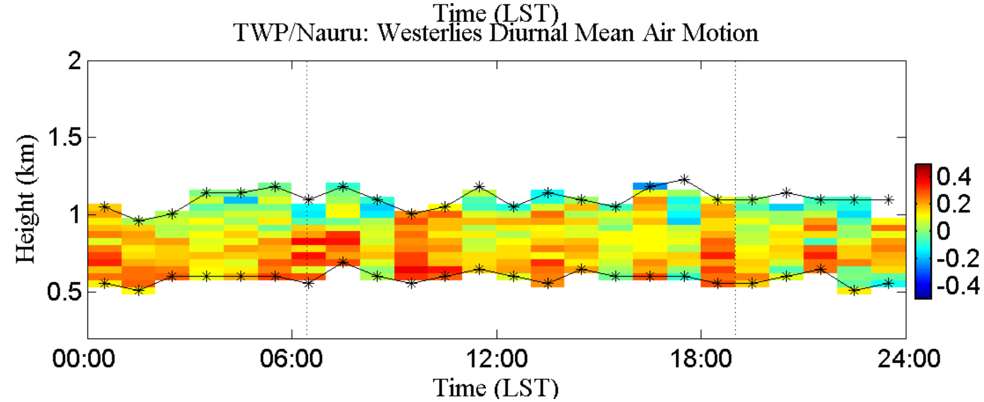


Vertical Velocity Statistics in Fair Weather Cumuli at the ARM TWP Nauru Climate Research Facility









Diurnal cycle of the hourly-averaged vertical air motion profile during a) easterlies and b) westerlies. Positive velocities indicate updrafts. (Kollias and Albrecht, 2009)

A FOCUS ON MIXED-PHASE CLOUDS

The Status of Ground-Based Observational Methods

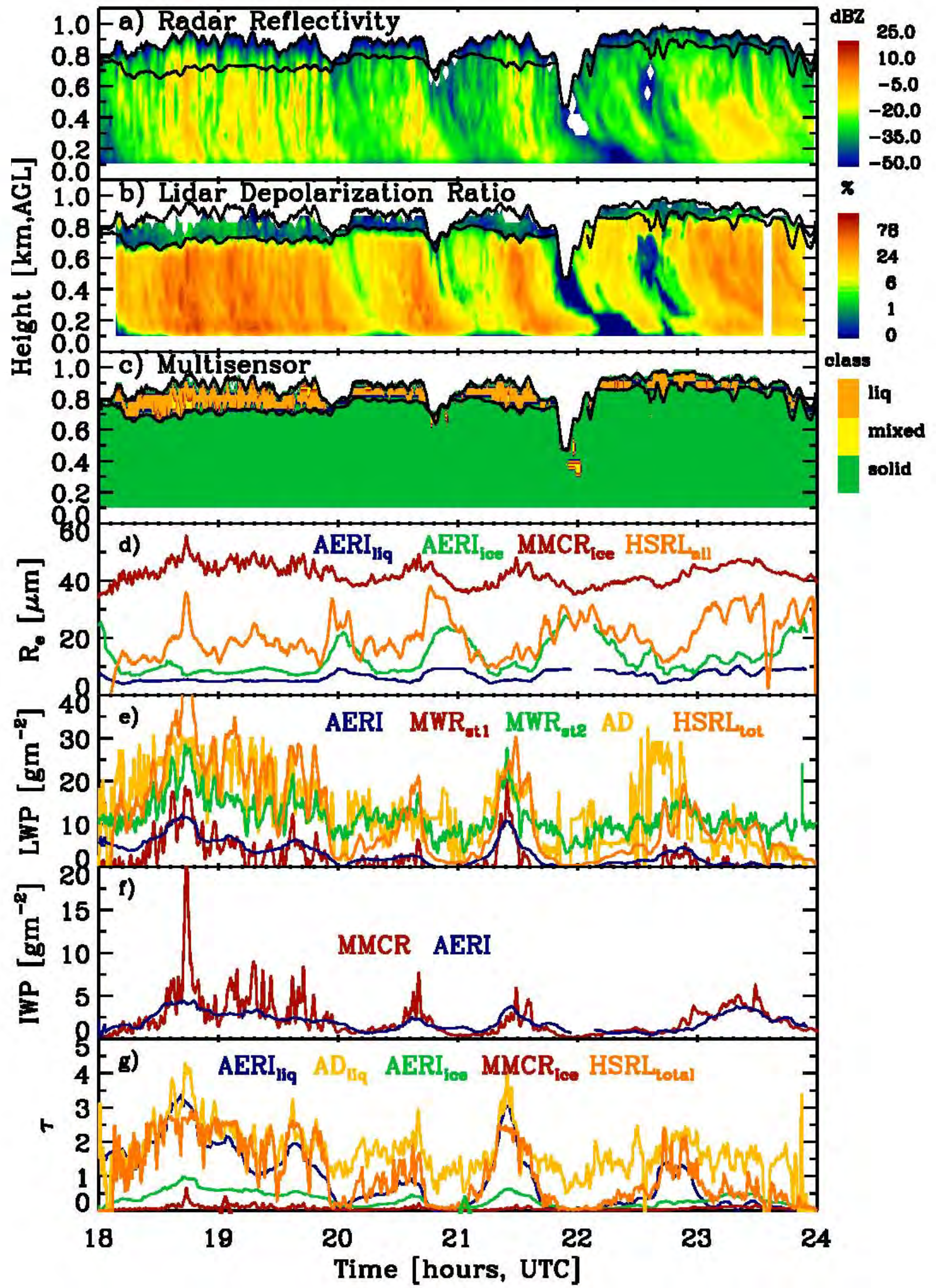
BY MATTHEW D. SHUPE, JOHN S. DANIEL, GIJS DE BOER, EDWIN W. ELORANTA, PAVLOS KOLLIAS, CHARLES N. LONG, EDWARD P. LUKE, DAVID D. TURNER, AND JOHANNES VERLINDE

Mixed-Phase Clouds Need More Attention!

- Need better characterization of liquid vertical profiles in all conditions.

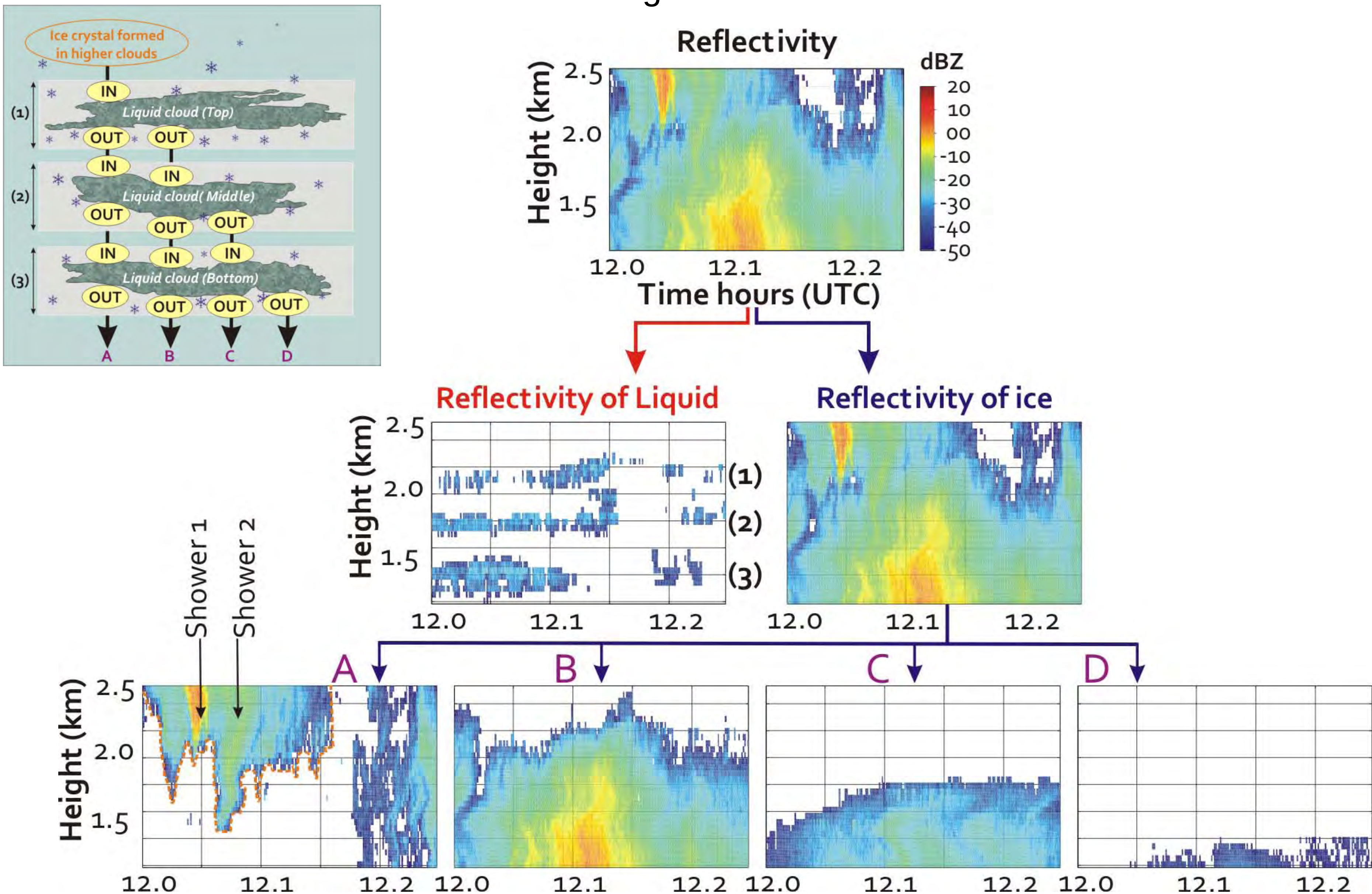
- Need more (routine) microphysics validation data

- Need better understanding of roles that IN, CCN, T, and vertical velocity play in phase partitioning



Morphology of Multilayer Mixed Phase Clouds

Rambukkange and Verlinde

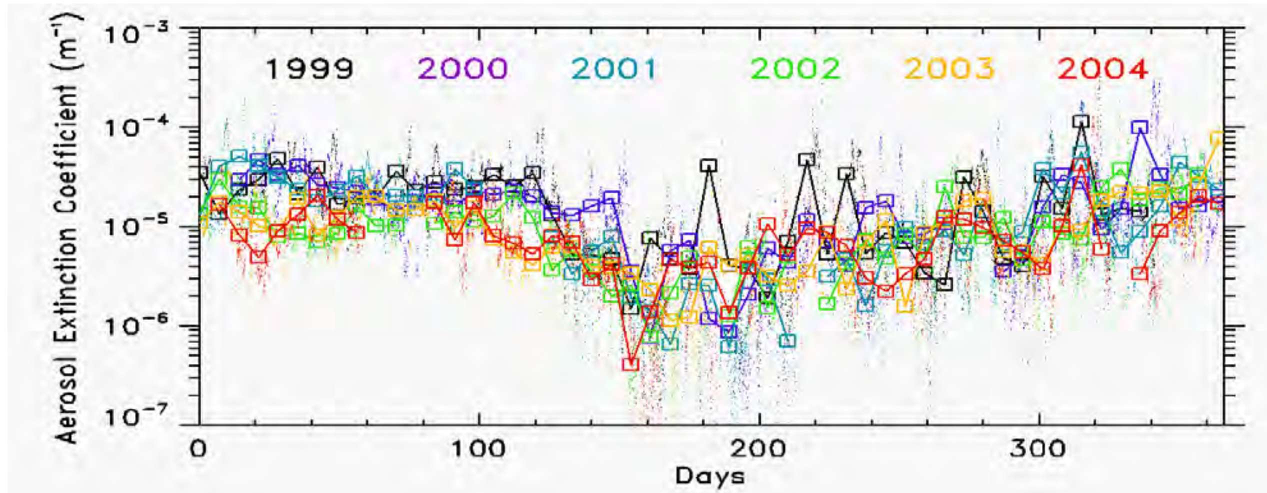


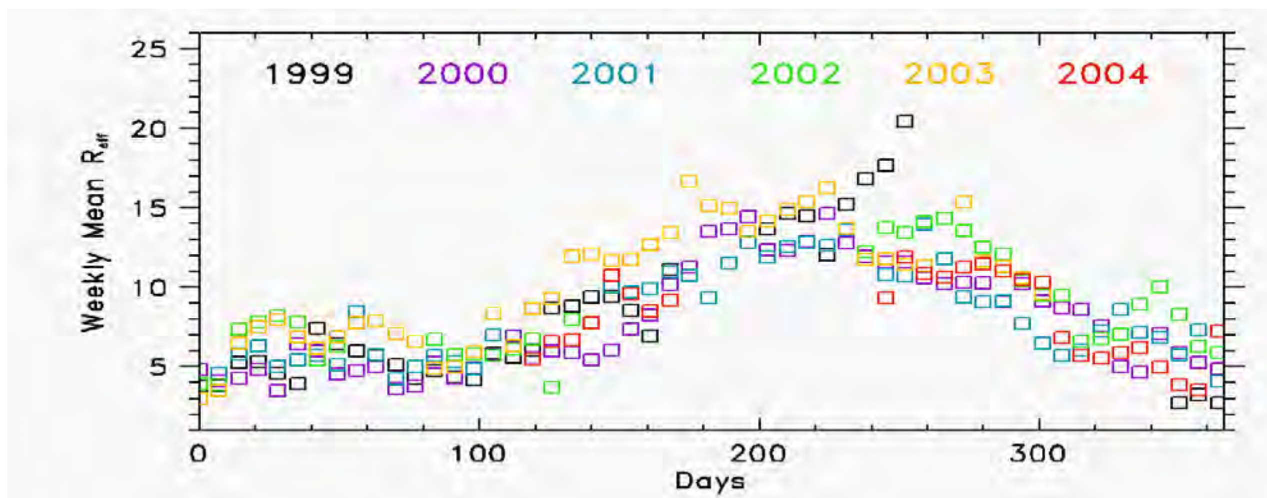
Multi-year mixed-phase cloud microphysical property dataset at the NSA site

Zhien Wang

Algorithm

- Inputs:
  - MPL
  - MMCR
  - MWR
- Outputs
  - LWP and R_{eff} for water
  - IWC and D_{ge} profile for ice
- Capable for all range of LWP

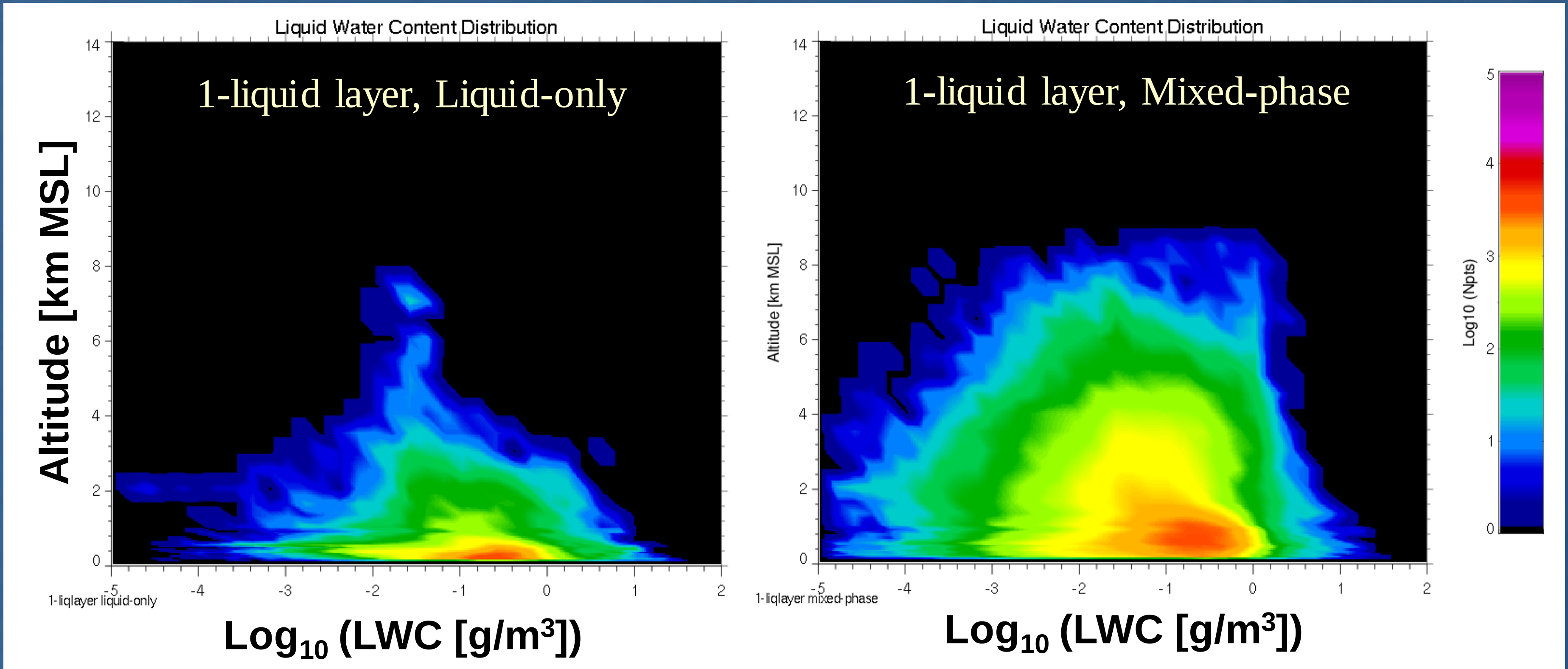




Annual cycles of water effective radius and aerosol extinction coefficient

Cloud Properties and Radiative Heating Rate Profiles in the Arctic

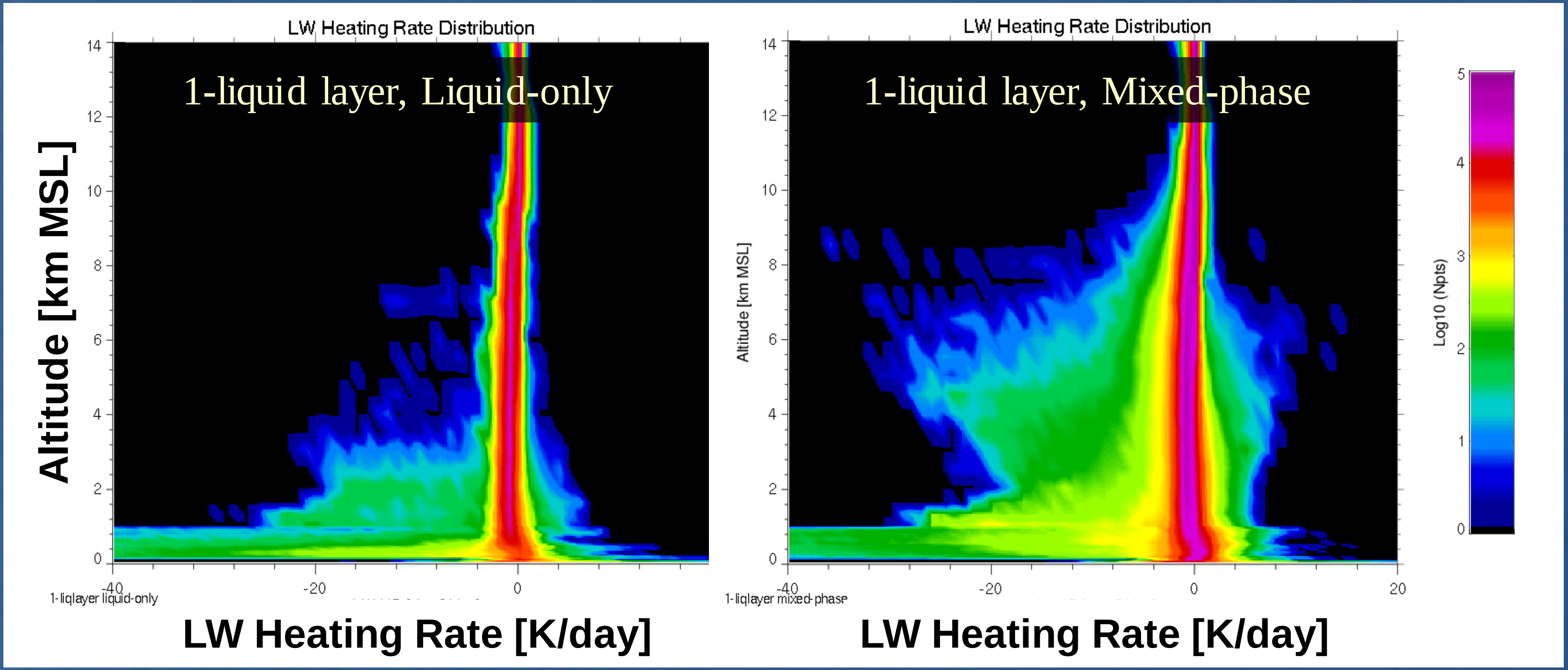
Liquid Water Content Distributions



Liquid water exists much higher in the troposphere in mixed-phase clouds than in liquid-only clouds…

Cloud Properties and Radiative Heating Rate Profiles in the Arctic

LW Heating Rate Distributions



…which has a large impact on the mid-tropospheric longwave heating rate profile (warming *AND* cooling).

Across the Globe,
We are addressing model needs

- Vertical velocities
- Ice PSDs and fall speed
- Mixed-phase characterization
- Precipitation & clouds together
- Cloud effects on radiation
- Results at a variety of scales

and many others….

Cloud and Land Surface Interaction Campaign (CLASIC)

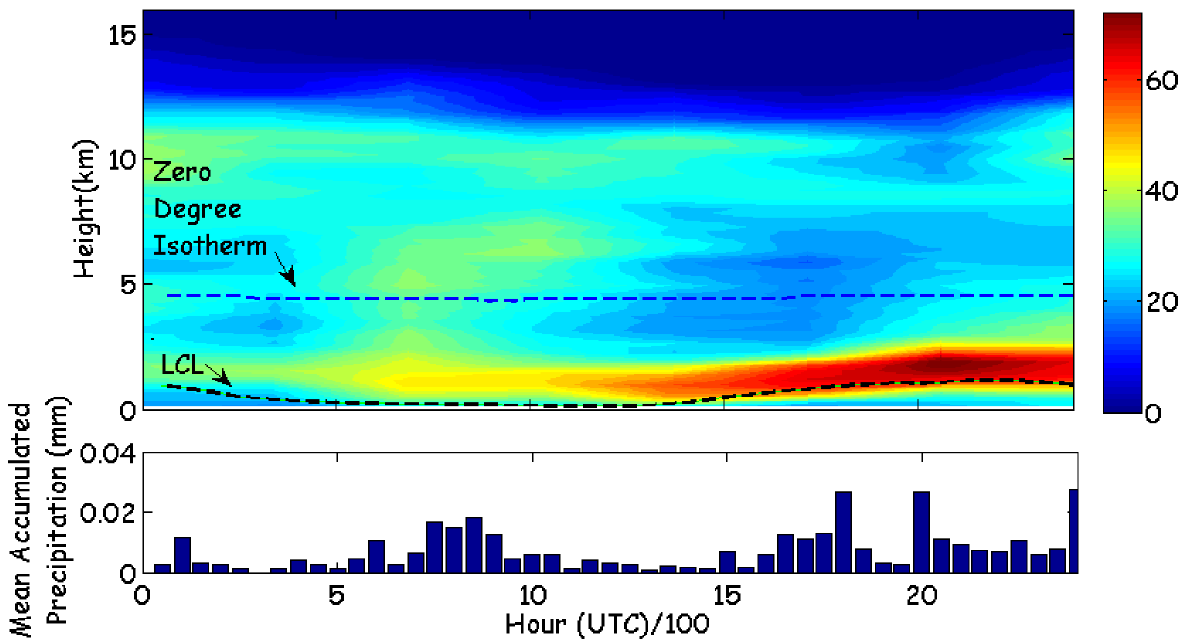
- ARM SGP: June 8-July 2, 2007
- PI: Mark Miller
- Nine aircraft
- ~100 participants
- Multiple Surface Super Sites
  - Measuring fluxes, met, soil moisture, vegetation characteristics, albedo
- Local *in situ* characterization of
  - Land surface, boundary layer, cloud microphysics and aerosols
- Regional characterization of large scale (synoptic) forcing
- Regional remote sensing of land surface, clouds, and aerosols

ARM Climate Research Facility

NASA

Cloud and Land Surface Interaction Campaign (CLASIC)

- Experiment was a success
  - Golden days: June 12, 19, 28, 2007
- BAMS article approved and under construction—June 1 submission target
- See poster (Miller, Lamb, DiPretore, Johnson, and Troyan)



Diurnal Cloud Fraction Profile June 2007
Shows nocturnal convection and a deepening of the BL as clouds clear aloft

Tropical Warm Pool International Cloud Experiment (TWP-ICE): A successful campaign, capturing the evolution between different regimes including monsoon, shallow convection, coastal convection, and cirrus outflow.

We'll hear more from Jennifer Comstock on this subject…..

Model breakout : Tues 3:30-5

Another ARM BAMS article

May, P.T., J.H. Mather, G. Vaughan, C. Jakob, G.M. McFarquhar, K.N. Bower and G.G. Mace, 2008: The Tropical Warm Pool International Cloud Experiment (TWPICE), *Bull. Amer. Meteor. Soc.*, **89**, 629-645.

Indirect and SemiDirect Aerosol Campaign (ISDAC)
Another success: Excellent measurements in Arctic mixed-phase clouds for studying cloud processes and aerosol-cloud interactions. Nice complement to MPACE.

We'll hear more from Greg McFarquhar on this subject…….

ISDAC breakout: Tues 1-3 pm


"Golden days" are great!
But we need more routine measurements as well!

RACORO

PI: Andy Vogelmann

Breakout Session: Tuesday 4:00-5:00
Poster 13.H: RACORO

- Systematic flights over SGP in boundary layer, liquid-water clouds
  - **5-Month study 22 Jan – 30 June**
  - **First-time, long-term aircraft sampling of cloud properties**
  - **Different operating paradigm**
- Obtain cloud, aerosol & radiative properties to
  - **Validate ACRF Remotely-Sensed Cloud Properties**
  - **Investigate Aerosol-Cloud Interactions**
  - **Improve Cloud Simulations in Climate Models**

Cloud tomography field campaign, May 15-June 15, 2009, SGP site PI: Dong Huang

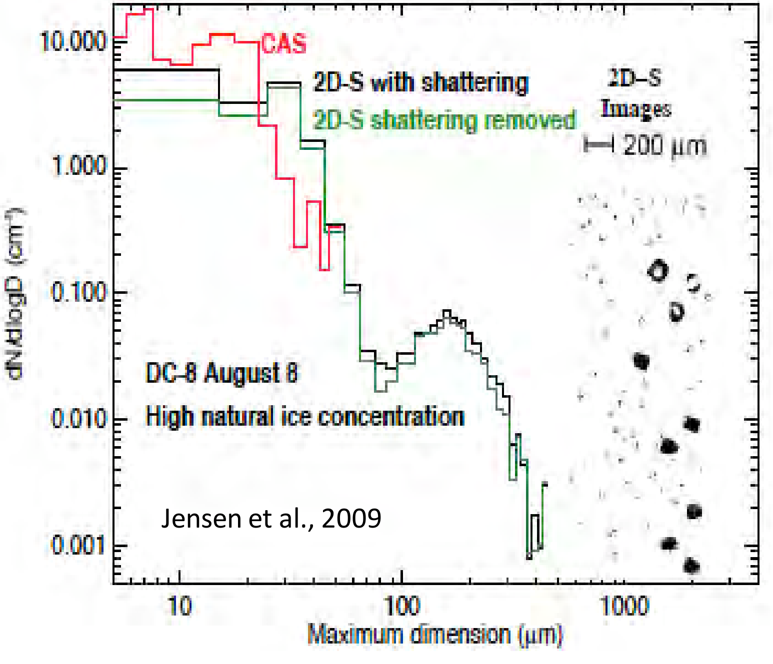
Five scanning microwave radiometers, scanning WACR, MMCR

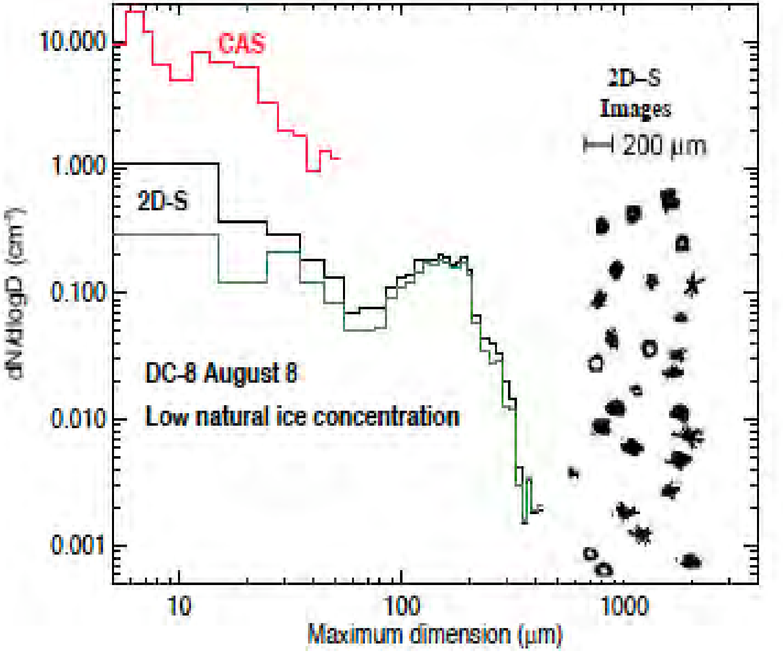
Objective: ***Evaluate the viability of this technique for monitoring 3D cloud properties.***

The Small Particles In Cirrus (SPartICus)
ARM Aerial Facility Mission

- What: Routine *in situ* cirrus mission over SGP (> 150 hours) with SPEC Lear 35
- When: Fall-Spring 2009/10

Breakout: Tuesday 1-5

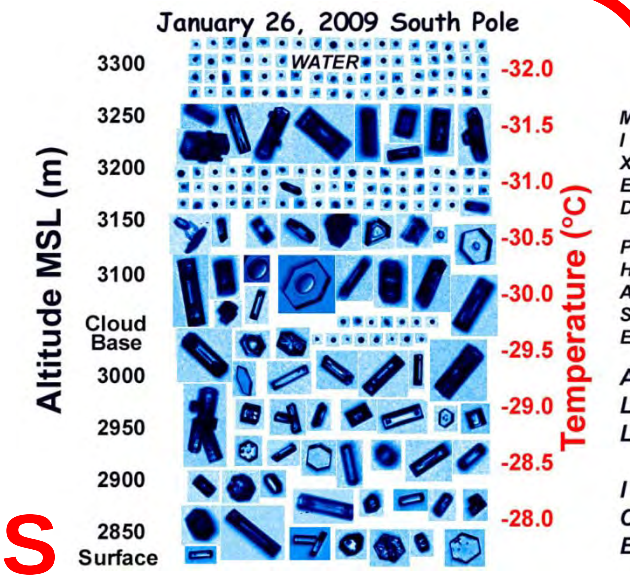




Science Team: Jay Mace, Eric Jensen, Greg McFarquhar, Jennifer Comstock, Tim Garrett, David Mitchell, Xiaohong Liu, Tom Ackerman, Paul Lawson, Beat Schmidt, Jason Tomlinson

Arctic Lower-Troposphere Observed Structure

- Tether Balloon
  - Atmospheric State
  - LWC/IWC
  - Ice habit distributions
  - CCN
- Surface
  - Radiation
  - MWR
  - (MMCR,MPL)
  - (Complete mphys/precip)



ALTOS

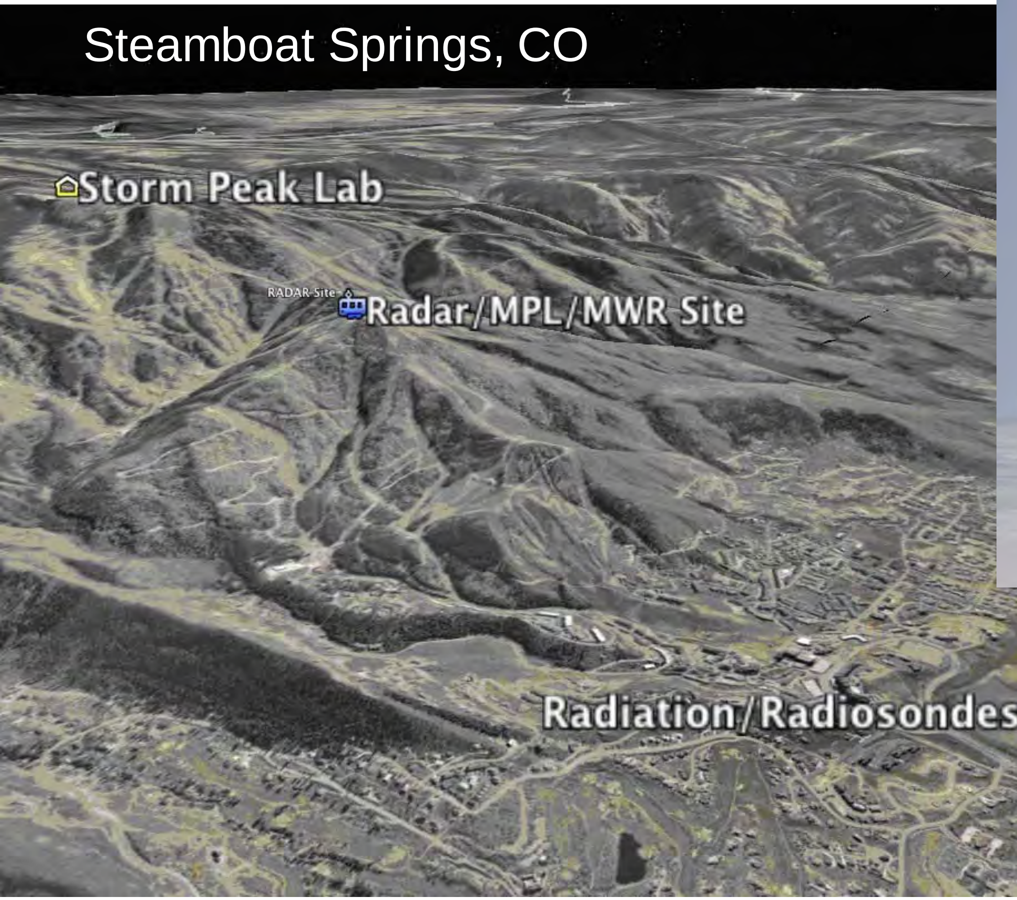
Science Objectives

- Statistics of microphysics
  - Environmental influences
  - Aerosol impacts
- Horizontal variability
  - Interaction with waves
- Retrieval verification
- Ice shattering

PI: Hans Verlinde   Breakout session: Tues. 3:30-5:00

The Storm Peak Lab Cloud Property Validation Experiment (StormVEx)

AMF2 Maiden Deployment



Project Team:

- **Jay Mace (PI), U. of Utah**
- **Sergey Matrosov, U. of Colorado and NOAA/ESRL**
- **Matthew Shupe, U. of Colorado and NOAA/ESRL**
- **Paul Lawson, Stratton Park Engineering Corp.**
- **Gannet Hallar, Desert Research Institute**
- **Ian McCubbin, Desert Research Institute**
- **Roger Marchand, U. of Washington**

Breakout Session: Thursday 3-5 pm

Directions and Objectives

•Define/improve methods for objective product evaluation. This will lead to better products, and hopefully improve our production rate.

•Strengthen the link between model "needs" and observations. Now is a great time to expand our capabilities around the model needs.

Proposal: Model-obs coordination "focus group"

•Renewed emphasis on observational advancement. ARM has an unmatched observational facility.