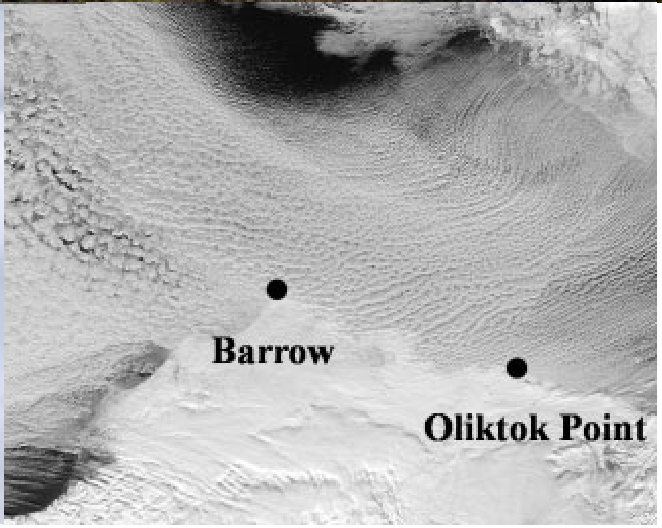
State of the Cloud Lifecycle Working Group Address



Tony Del Genio
and Matthew
Shupe

ASR Spring Meeting
3/11/14

Current organized activities within CLWG:

- Focus Groups: Vertical Velocity, QUICR
- Thematic interest groups:
  - Ice Properties (FG white paper submitted)
  - Cloud phase partitioning
  - Warm low clouds
  - Mesoscale convective organization/ cold pools
- Possible new groups: Madden-Julian Oscillation, Entrainment

Vertical Velocity Focus Group

- Group has total 57 participants
  - Group email -- vvfg@arm.gov; website http://asr.science.energy.gov/science/working-groups/focus-groups/vvfg
  - 34 articles published since the group's formation (2008)
- Data products available for all cloud types
  - Total of six data products available in the ARM archive – two are on the way.
- Current focus group activities have two goals
  - Development of a vertical velocity best estimate data product
    - Talk and discussion during the breakout session
  - Quantification of uncertainty in the retrieval techniques.
- Breakout session – Thursday 10:30 to 12:00 pm

Update on QUICR - Quantification Uncertainty in Cloud Retrievals

Shaocheng Xie (LLNL), Alain Protat (BOM), Jay Mace (U. Utah)

Infrastructure Support of QUICR

•Making BBHRP a retrieval evaluation framework (*Riihimaki/Shippert, PNNL*)

- BBHRP set up to run by users, user guide created
- Can be run with RRTMG – O(10) faster
- Working on RIPBE for running BBHRP for all sites

•Implementing UQ tools for uncertainty analysis (*Xie/Tang/Chen, LLNL*)

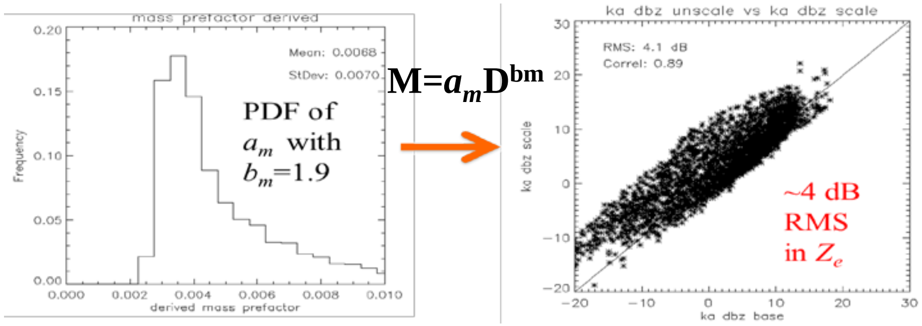
- PSUDAE implemented into MICROBASE for perturbed runs and uncertainty analysis
- Making MICROBASE suitable for parallel runs

Major community activities

- QUICR session at 2013 AGU Fall meeting
- EU-DOE meeting on cloud retrievals, May 2013, Germany
- Invited talk at the AOGS 2014 meeting

Quantify Uncertainty Introduced by Key Assumptions in Ice Cloud Retrievals

(*Hammonds, Mace, Matrosov, 2014, in review*)



PDF of a_m with b_m=1.9

$M=a_mD^{bm}$

~4 dB RMS in Z_e

Identified Key Issues

- Fully defined prior data sets and well understood forward model errors
- Common guideline for instrument calibration
- Measurement simulators to provide uncertainties when comparing to measurements due to unknown physical parameters and forward model error
- Develop an in-situ case library with improved data quality

Proposing a major field campaign

Targeted, comprehensive airborne campaign to build a library of mass- and area-dimensional relationships of ice crystals and other properties that are important and normally assumed in retrievals

Ice Properties & Processes (ICEPRO) Overview

Greg McFarquhar, David Mitchell

Purpose: To better characterize ice physical properties & uncertainties in CRMs & climate models using in-situ data from ARM field programs. This will also improve cloud retrievals containing *a priori* assumptions of ice physical properties

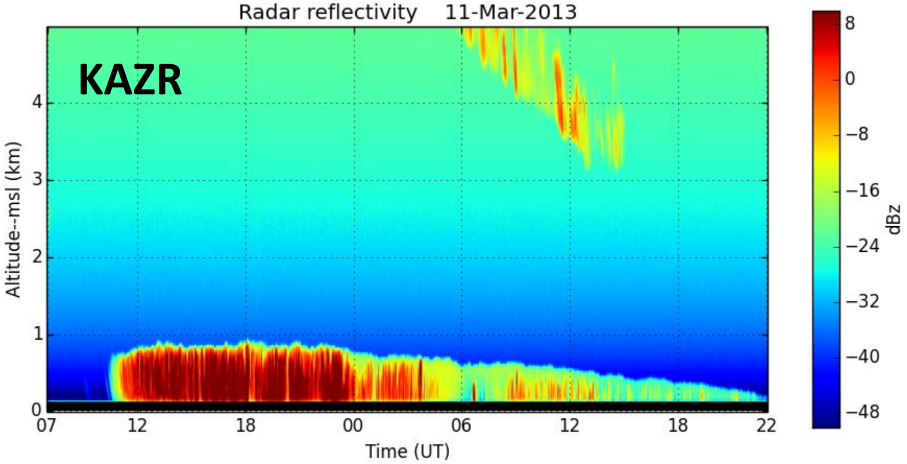
Objectives: (1) Develop **ice property databases** and parameterizations; (2) Develop a framework for determining **acceptable uncertainty** levels for ice particle and optical properties; (3) **Evaluate model** improvements resulting from improved ice physical and optical properties.

Current and planned high level activities:

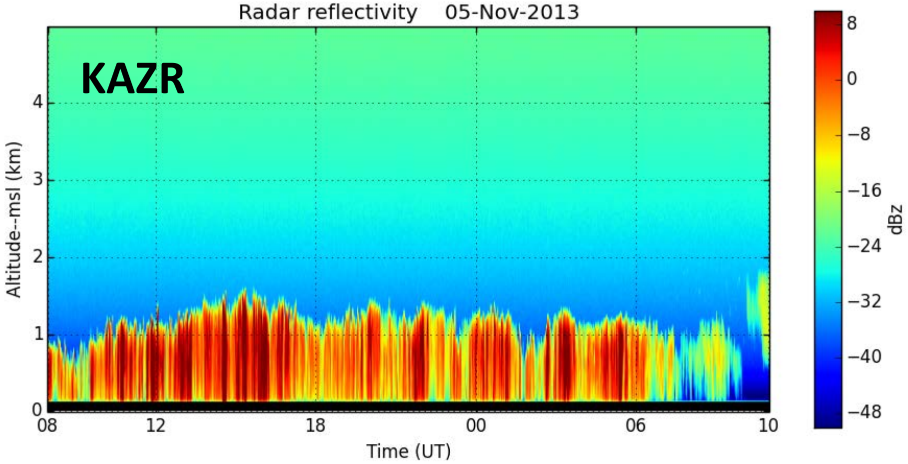
1. Develop single-particle databases from in-situ data, and characterize dependence of ice crystal properties on environmental conditions
2. Incorporate improved ice particle properties into CRMs and CAM5 and evaluate their impact
3. SGP and ISDAC radiative closure studies using remote sensing, in situ cloud microphysical and/or surface shortwave irradiance measurements
4. Demonstrate impact of improved ice properties on retrievals
5. Develop framework to translate ice property uncertainties into model output uncertainties.
6. Link ice optical properties computed from scattering models with observed microphysical properties like size distributions

Cloud Phase Research Area (Gijs de Boer, Jerry Harrington)

11 March 2013



05 November 2013



<u>Ongoing Activities:</u>

- **Selection of case study period:** We have narrowed the search down to two recent cases from NSA featuring single-layer mixed phase clouds (potential cases shown above).
- **Observational Efforts:** Remote sensor-derived estimates of precipitation mass flux from cloud base along with estimates of microphysical quantities. *We are focusing on recent periods to encourage the use of new instrumentation (e.g. scanning radars, HSRL) and techniques (e.g. analysis of spectra, multi-sensor approaches).*
- **Modeling Efforts:** The selected case will become a model comparison period, with a focus on precipitation mass flux. This quantity integrates several areas where models historically disagree, including ice nucleation, ice depositional growth, and crystal fall speeds.
- **Integrated Evaluation:** Based on observational and modeling results, scaling relationships between variables will be derived, evaluated and tested.

Warm Low Clouds Thematic Group

Mark Miller (m.miller@envsci.rutgers.edu)
Minghua Zhang (minghua.zhang@stonybrook.edu)
Group Mailing list: lowcloud@arm.gov

- 57 members
- Organized around three case studies
  - CASE 1: TROPICAL SHALLOW CONVECTION
    - AMIE/Gan and Manus Case Studies
    - ~8 active participants
    - Contact: Chidong Zhang (czhang@rsmas.miami.edu)
  - CASE 2: MARINE and COASTAL STRATOCUMULUS
    - CAP-MBL (Azores) and TCAP (Cape Cod) Case Studies
    - ~14 active participants
    - Contact: Mark Miller: (m.miller@envsci.rutgers.edu)
  - CASE 3: CONTINENTAL LOW CLOUDS
    - RACORO-FASTER Case Studies
    - ~3 active participants
    - Contact: Minghua Zhang (minghua.zhang@stonybrook.edu)

Mesoscale Convective Organization

Courtney Schumacher and Adam Varble

Objectives

Link vertical velocity and microphysics through the MCS life cycle

Understand production of cold pools, relation to MCS properties, and ways to parameterize this process

Activities

Cold pool interest group (Angela Rowe and Zhe Feng)

MCS database (observations and model output) – MC3E, AMIE, and TWP-ICE to start

PI presentations (Wednesday AM)

(free 1-day AMF deployment of your choice for all who attend)

- 8:30 – 8:45 Review of TWP Research Highlights – *Chuck Long*
- 8:45 – 9:00 Shallow cloud structure and organization under suppressed conditions in AMIE/DYNAMO – *Angela Rowe*
- 9:00 – 9:15 On the role of cold pool in organization of convection over tropical Indian Ocean during DYNAMO – *Zhe Feng*
- 9:15 – 9:30 Prove It! ARM's Progress Towards a Suite of Verified Precipitating Cloud System Retrievals – *Scott Collis*
- 11:00 – 11:15 The relationship between cirrus ice microphysical properties and meteorological conditions observed during SPARTICUS – *Robert Jackson*
- 11:15 – 11:30 CAPT analysis of land-atmosphere interactions manifested in ARM observations at the US SGP site – *Tom Phillips*
- 11:30 – 11:45 Cloud transitions between high-coverage stratocumulus and low-coverage cumulus over the Eastern Pacific Ocean during MAGIC – *Xiaoli Zhou*
- 12:00 – 12:15 Statistical analysis of turbulence induced fluctuations in in-cloud saturation ratio and rates of cloud droplet growth – *Bob McGraw*

ARM Cloud Forcing Data Set For the MMCR Era Available On PI Archive

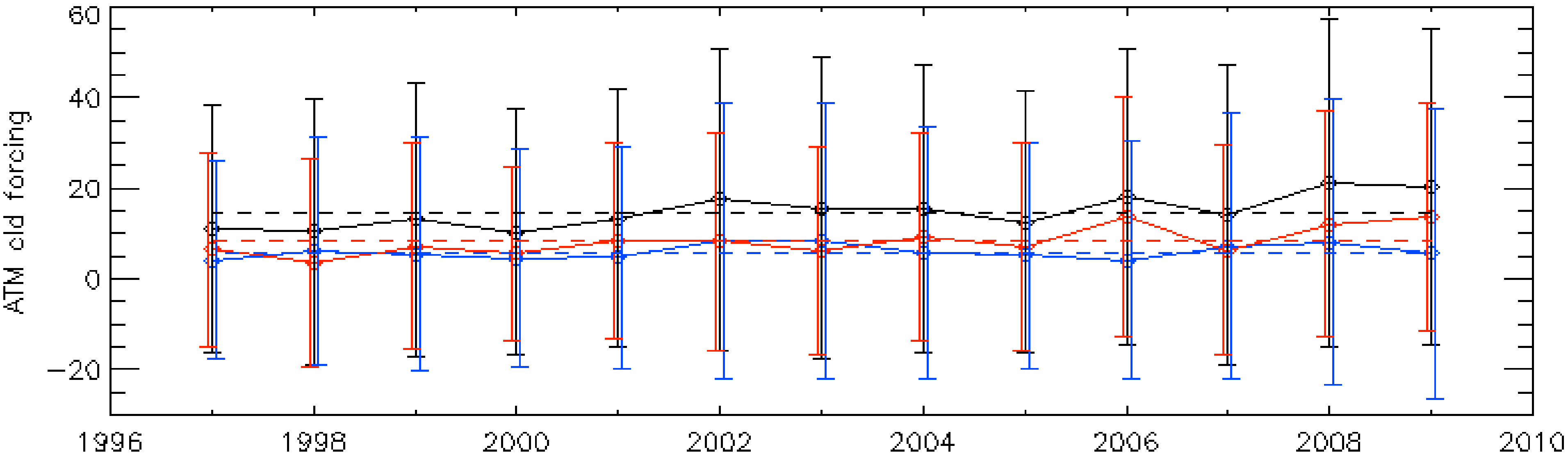
Using the methodology of Mace et al., (2006a,b) and Mace and Benson (2008) (with numerous updates and bug fixes) we have submitted the following to the PI Archive:

SGP: 1997-2009	13 years
NSA: 2000-2004, 2008-2010	7 years
TWPC1:1999-2000,2003-2007	7 years
TWPC2:1999-2006	8 years
TWPC3:Jan 2003,Nov-Dec 2005,2006-2008	3 years

38 Years of Cloud Forcing Data!

Data includes (5 min resolution): Soundings, masked MMCR, microphysics, fluxes, forcing, …

SGP Annual Atmosphere Cloud Forcing (W/m^2). Solar, IR, Net (Dashed 13-year Mean)

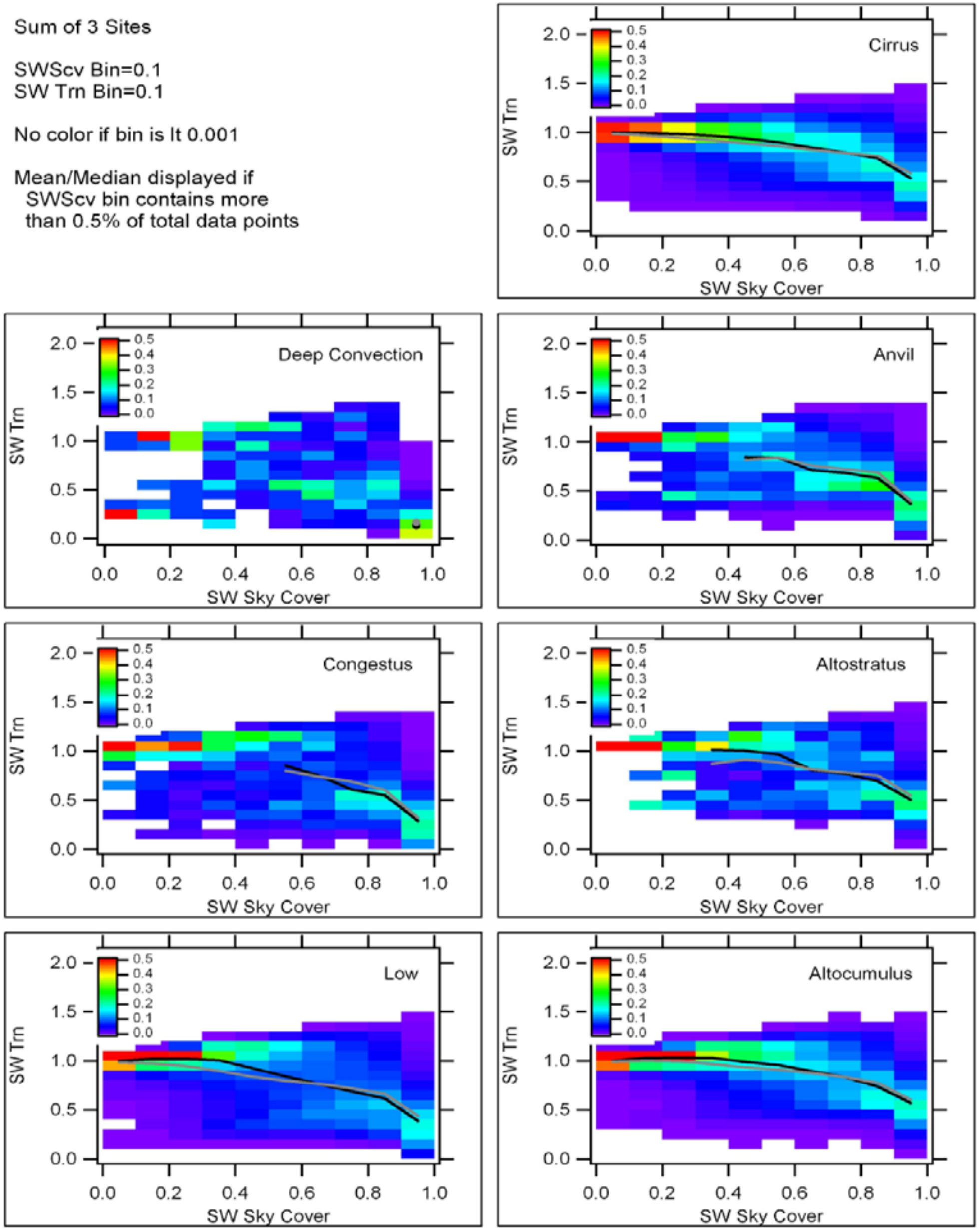


Note upward trend in IR Forcing over the 13-year period

Climatology of TWP Clouds and Radiation

Chuck Long, Julia Flaherty, Jennifer Comstock, Casey Burleyson

- Includes:
  - Analyses by ENSO phase for Manus and Nauru, wet/dry seasons for Darwin
  - Also using a radar/lidar based cloud classification
    - Frequency of occurrence of cloud types
    - Radiative effects by cloud type
- Currently investigating diurnal analyses for ENSO or Wet/Dry, and diurnal cloud type frequencies and cloud effects



Sum of 3 Sites

SWScv Bin=0.1
SW Trn Bin=0.1

No color if bin is lt 0.001

Mean/Median displayed if
SWScv bin contains more
than 0.5% of total data points

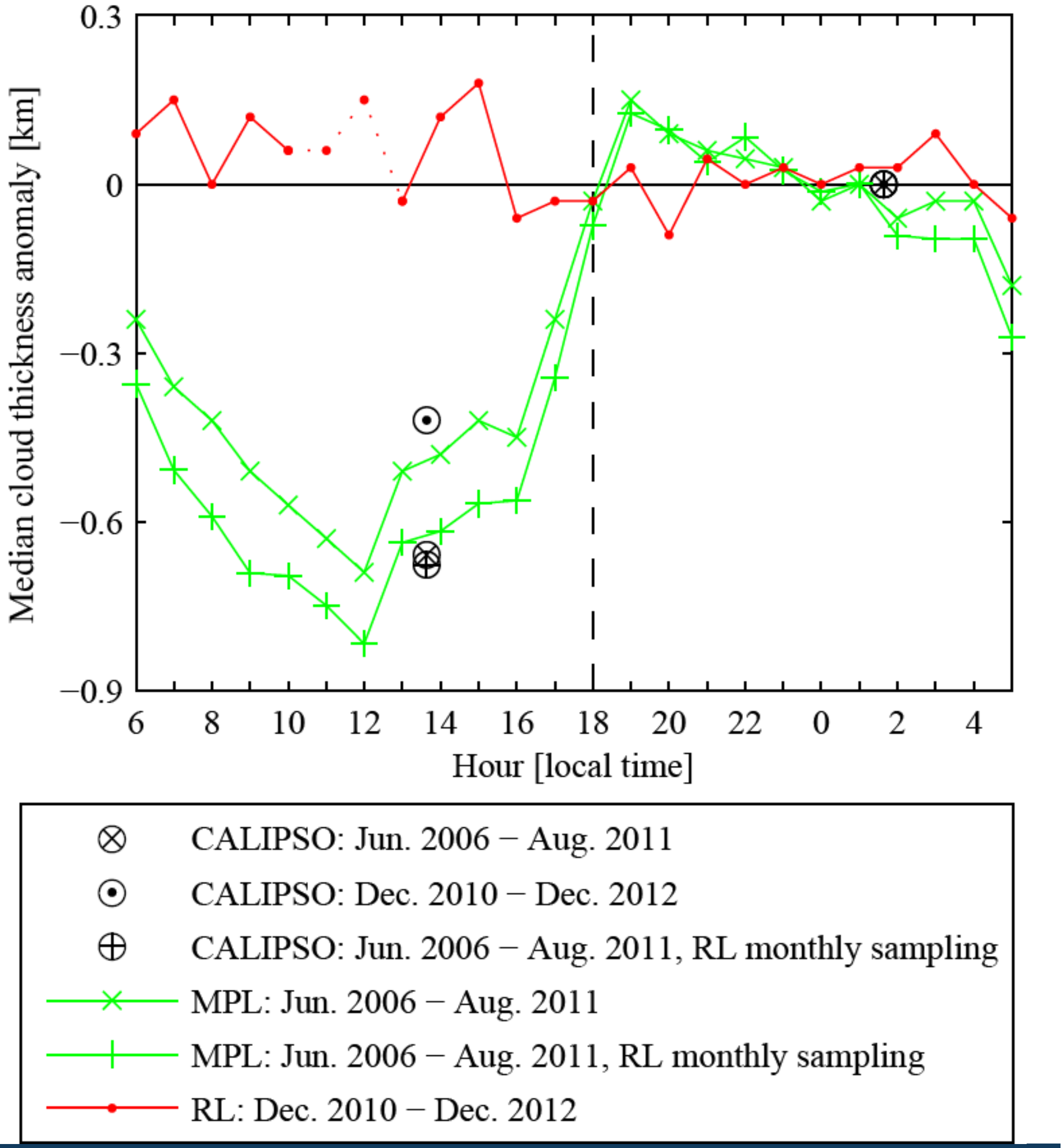
McFarlane, SA, CN Long, J Flaherty, 2013: A Climatology of Surface Cloud Radiative Effects at the ARM Tropical Western Pacific Sites. J. Appl. Meteor. Climatol., 52, 996-1013. doi: http://dx.doi.org/10.1175/JAMC-D-12-0189.1

Diurnal variation of cirrus cloud thickness at Darwin:

CALIPSO, MPL and Raman lidar

- CALIPSO and the MPL have a diurnal cycle in cirrus cloud thickness that is correlated with the amount of background noise.

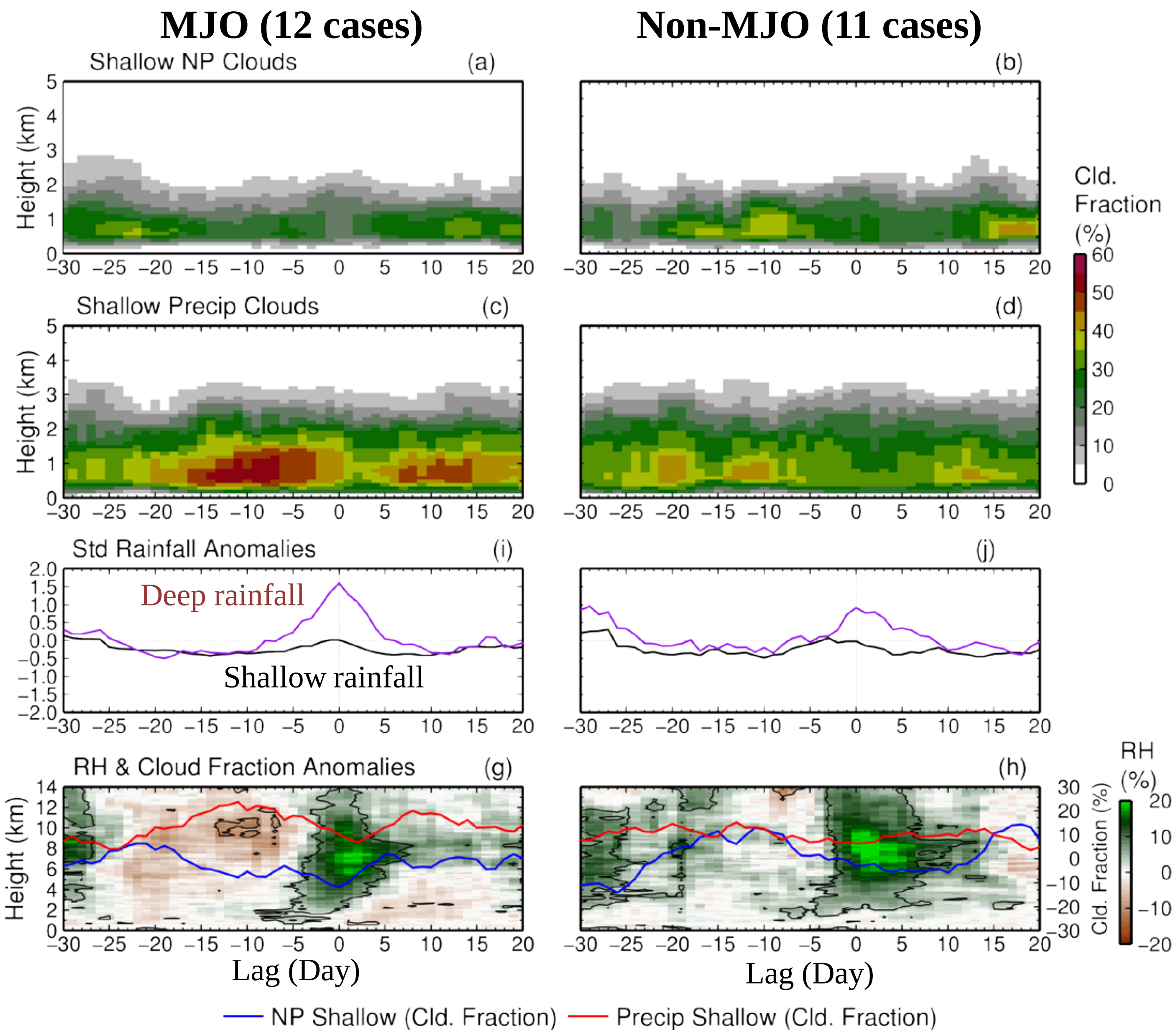
- The low solar background in the Raman lidar elastic channel allows for unbiased cirrus observations across the diurnal cycle.



Thorsen, T. J., Q. Fu, J. M. Comstock, C. Sivaraman, M. A. Vaughan, D. M. Winker, and D. D. Turner; JGR, 2013.

On the Role of Shallow Clouds during the pre-onset of MJO over Manus

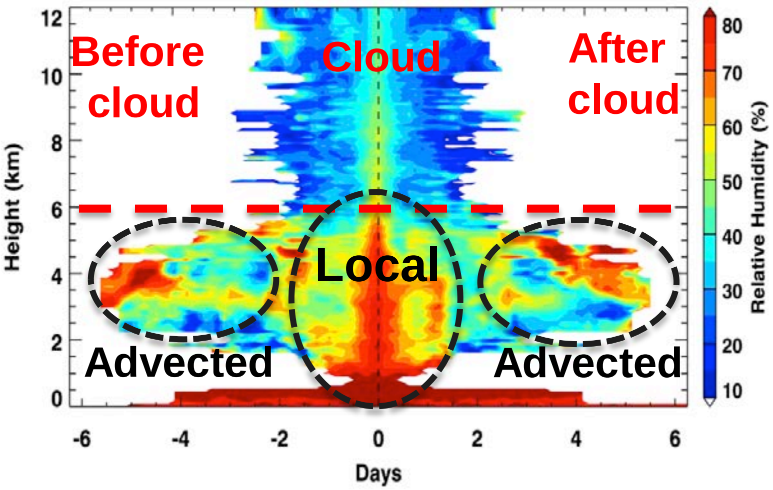
David Zermeno and Chidong Zhang, RSMAS, University of Miami, Miami FL
Pavlos Kollias and Heike Kalesse, McGill University



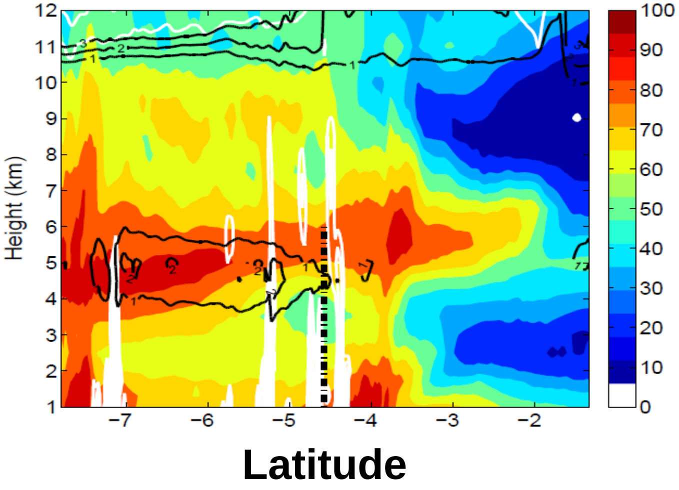
Mechanisms of Moistening in MJO

Samson Hagos, Zhe Feng, Kiran Landu and Chuck Long

Observed RH (DYNAMO/AMIE)



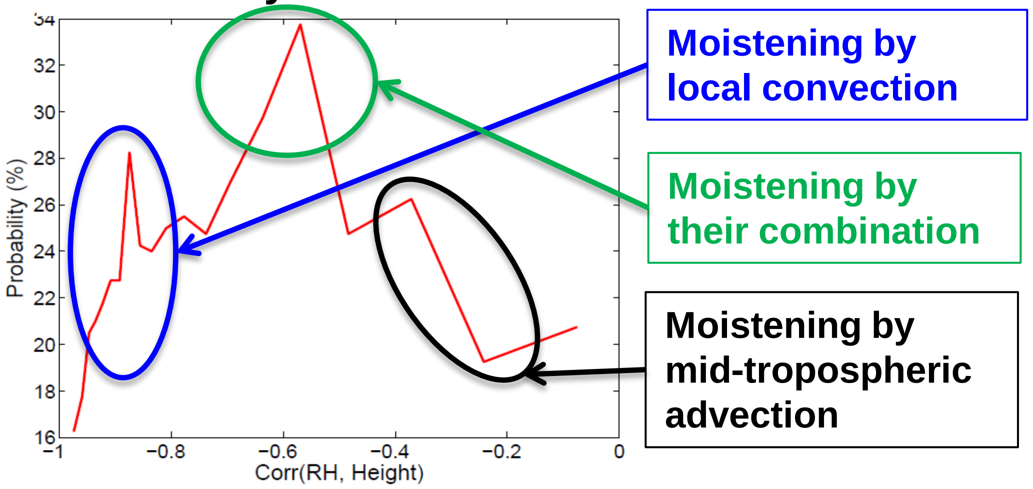
WRF model simulated



Meridional cross-section of RH (shaded) , cloud (white contour) and meridional wind (black contours). Deep convection will take place at the location of the dashed line after 6 hours.

- The large-scale shallow-to-deep convection transition associated with MJO initiation are accelerated by mid-tropospheric advection of moisture detrained from previous deep convection.

Probability of Transition

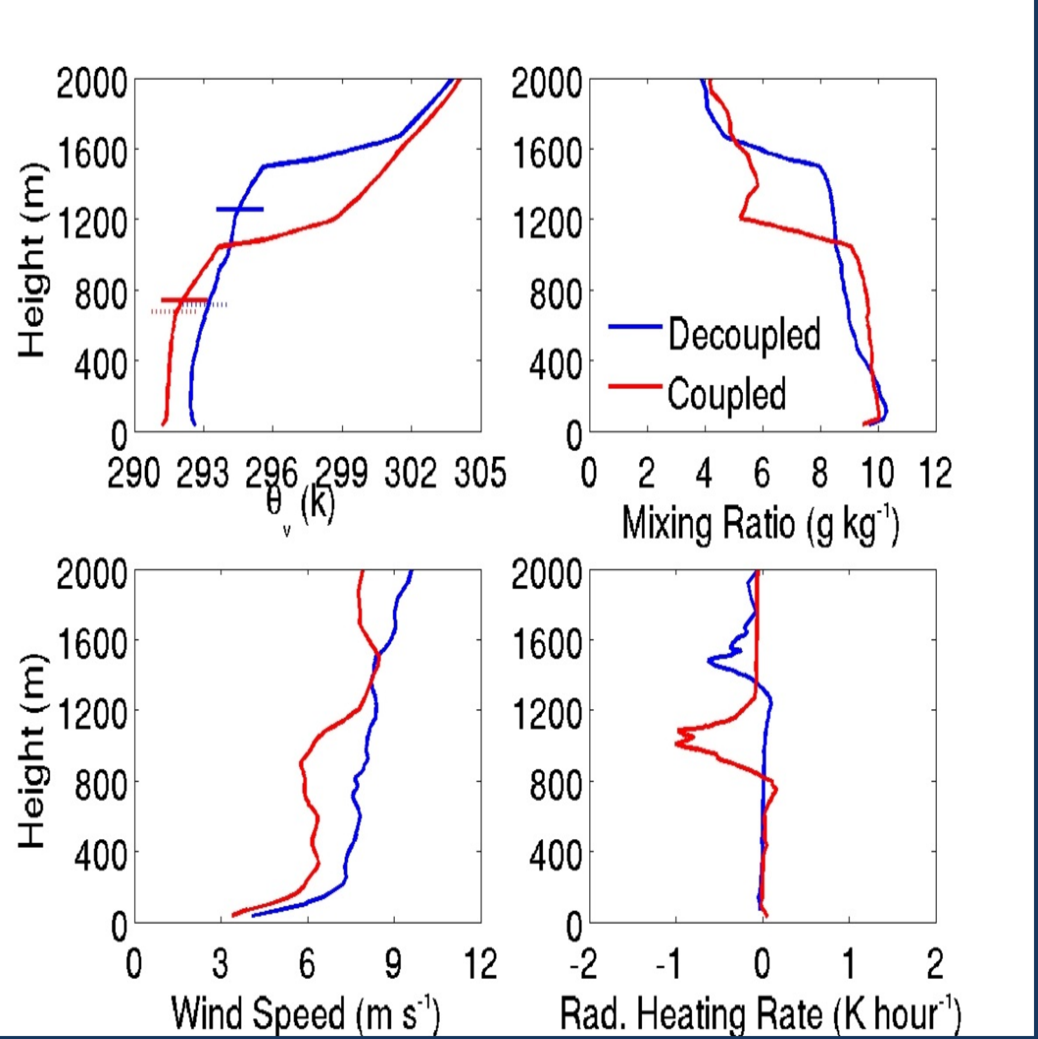


Moistening by local convection

Moistening by their combination

Moistening by mid-tropospheric advection

Decoupling in Stratocumulus Topped Marine Boundary Layers



- Used soundings launched during AMF-1 deployment at GRW
- Decoupled BL were deeper with thicker clouds and had higher surface fluxes and lower radiative cooling compared to coupled BL.
- Consistent with the view of deepening and warming leading to decoupling.

Virendra P. Ghate, Mark A. Miller, Bruce A. Albrecht and Chris W. Fairall

Detection, variations and intercomparison of the PBL depth from radiosonde, lidar, and IR spectrometer

Virginia Sawyer and Zhanqing Li / University of Maryland

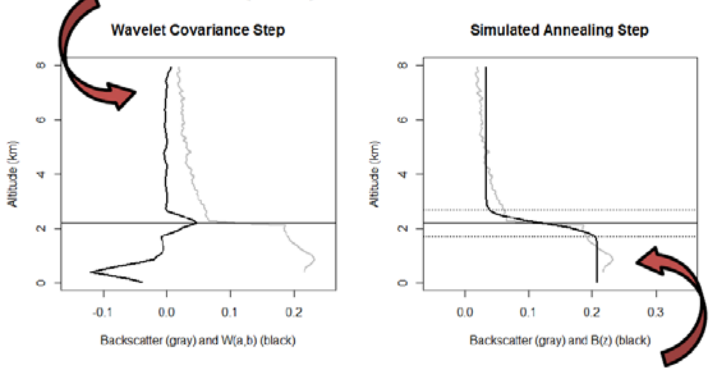
Objective

Develop automated PBL detection algorithm for lidar and IR spectrometer

Develop PBL climatology at the ARM sites

Approach

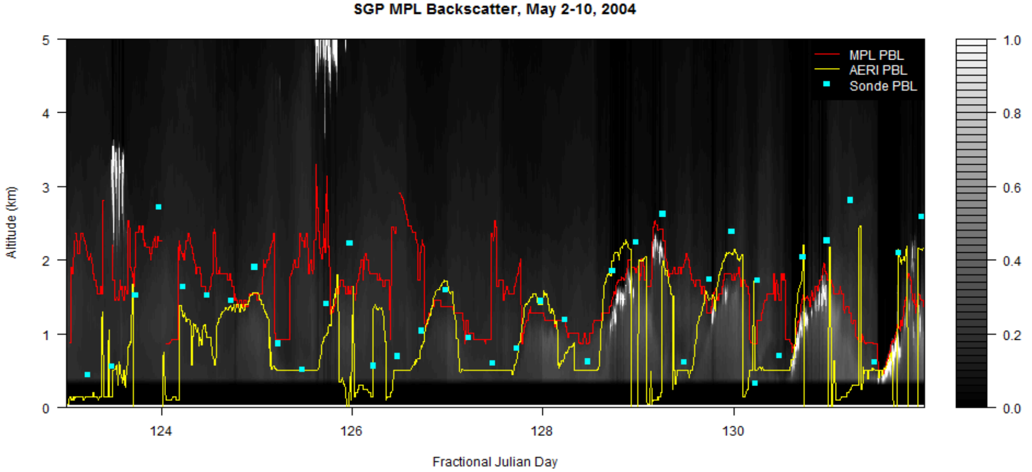
$$W_f(a,b)=\frac{1}{a}\int_{z_b}^{z_t} f(z)\,h\left(\frac{z-b}{a}\right)dz$$



$$B(z)=\frac{(B_m+B_u)}{2}-\frac{(B_m-B_u)}{2}\mathrm{erf}\left(\frac{z-z_m}{s}\right)$$

- Combine two established PBL detection algorithms with complementary strengths
- Compare PBL results among three instruments for same site and time period
- Determine how PBL detection accuracy changes with diurnal and seasonal cycles

PBL results for MPL, AERI, and radiosonde



Key Accomplishment

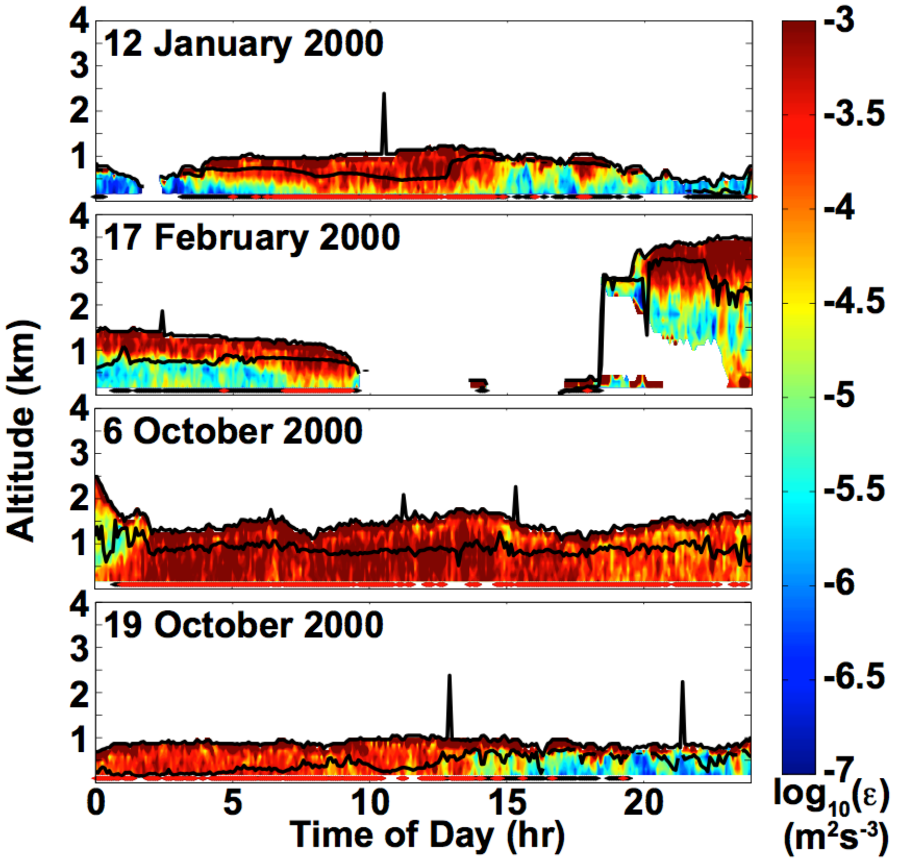
MPL and AERI-derived PBL depths comparable to radiosonde, but at high temporal resolution.

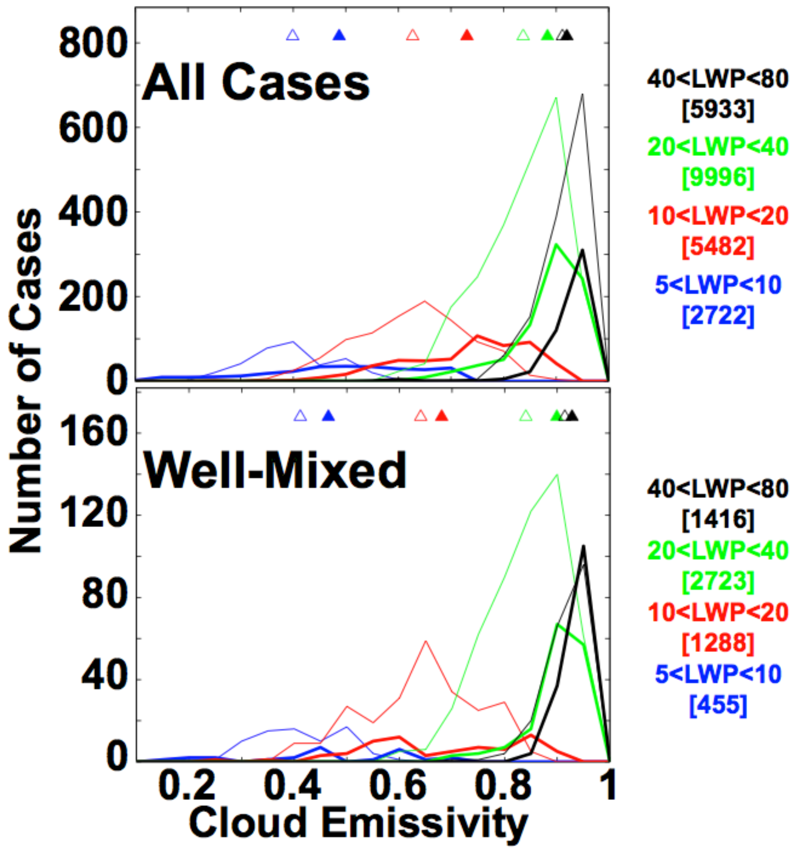
PI Product for SGP: PBL from AERI and MPL,
http://www.arm.gov/data/pi/84
MPL 5-min. resolution, 1996-2004
AERI 8-min. resolution, 1996-2011

Sawyer, V., and Z. Li, 2013: Detection, variations and intercomparison of the planetary boundary layer depth from radiosonde, lidar, and infrared spectrometer, *Atmos. Environ.*, 79, 518-528.

Evaluating Aerosol Effects in Thin, Liquid-Containing Arctic Clouds

Gijs de Boer, Matthew Shupe, Timothy Garrett, Chuanfeng Zhao





- Use MMCR and other instruments to derive turbulent dissipation rate (left figure, Shupe et al., 2013 [ACP]), and use it as an indicator of lower atmospheric mixing for 2000-2003 at NSA.
- Combine estimates of lower atmospheric mixing state with estimates of cloud emissivity from AERI and other instruments (Garrett and Zhao, 2013 [AMT])
- Evaluate whether mixing state impacts estimation of longwave AIE for these clouds (right figure) when using ground-based aerosol measurements (surprising preliminary answer, not really!)

ASR Atmospheric System Research

Developing and Bounding Area- and Mass-dimension Expressions

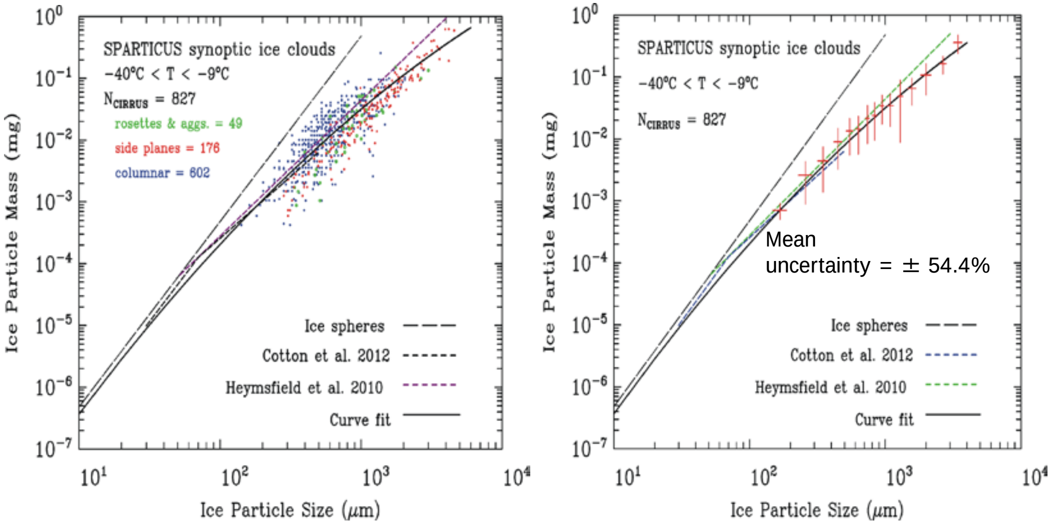
David Mitchell and Ehsan Erfani / Desert Research Institute

Science Question

Much uncertainty in modeling ice cloud microphysics and in retrievals of ice cloud properties due to uncertainties in the ice particle mass-, area-dimension power laws. How can these uncertainties be decreased?

Approach

- Develop temperature and cloud type dependent m-D and A-D expressions from SPARTICUS 2DS probe data, using 2nd order polynomial fits. Reduces uncertainty associated with linear approximation, like $m = \alpha D^{\beta}$.
- Test against 827 m-D measurements of single ice particle shapes in cirrus, compare to m-D power laws developed from recent cirrus field campaigns
- Calculate m-D and A-D power laws from polynomial fits, estimate uncertainties for prefactors and exponents. Mean uncertainty for β ≤ ±8%, for α ≤ ±54%.



An m-D curve fit is compared against the masses of ice particle shapes found in cirrus clouds and m-D power laws developed from recent studies/field campaigns.

Key Accomplishment

New approach for relating ice particle mass & area to size can also be formulated in terms of m-D and A-D power laws, with most uncertainty in prefactor. Expressions for cirrus clouds are consistent with observations with less uncertainty than other studies have shown.

Publication

Mitchell, D., et al., 2014: Developing and bounding ice particle mass- and area-dimension expressions for use in atmospheric models and remote sensing. Submitted *JGR.*

ASR Atmospheric System Research

Aspect Ratios of natural crystals in ice clouds

Greg McFarquhar and Junshik Um, University of Illinois

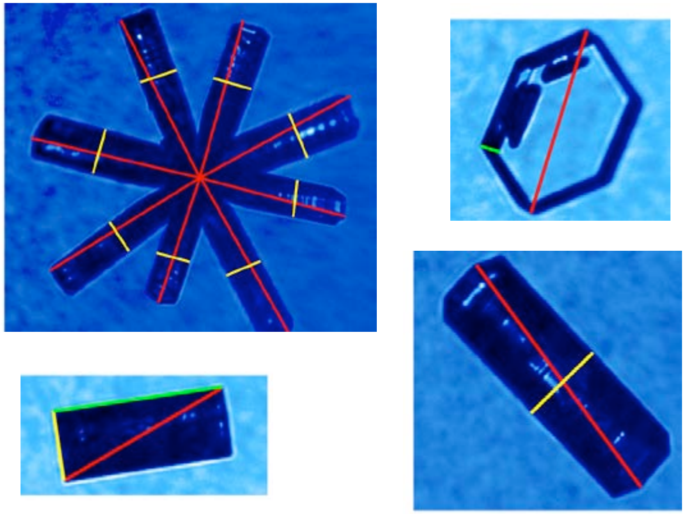
Science Question

Ice single-scattering properties and sedimentation depend on aspect ratios,, but how do aspect ratios depend on cloud and environmental parameters?

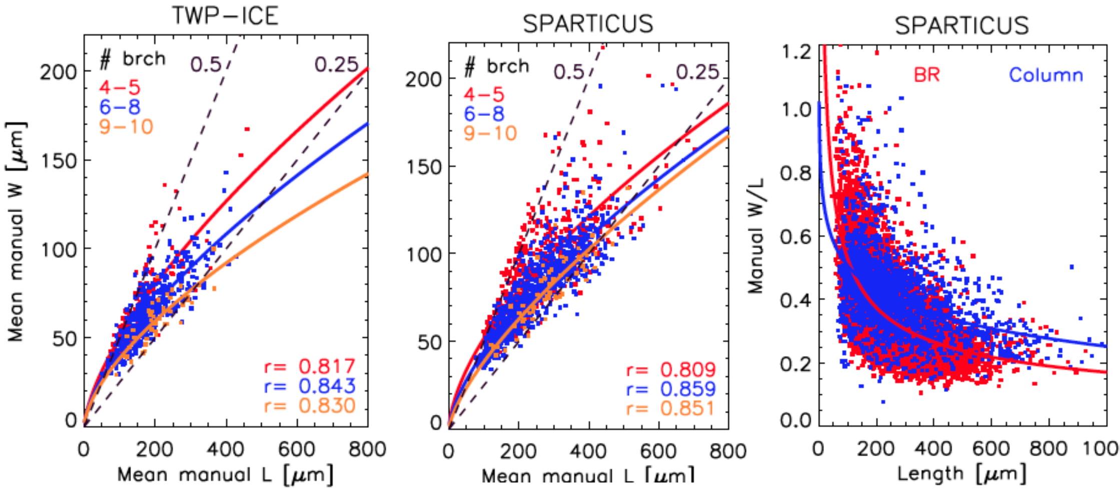
Approach

- Apply UI' s new software *Ice Crystal Ruler* to high-resolution (2.3 μm) images of plates, columns & bullet rosettes (BRs) from Tropics (TWP-ICE), Arctic (ISDAC) and mid-latitudes (SPARTICUS) to measure length (*L*), width (*W*), maximum dimension (*D*)
- Examine how L/W relations depend on temperature, relative humidity, location

IC-Ruler Application to determine *L*, *W*, **D**



E.g., of relationships between L/W in different locations



Key Results

- **aspect ratio smaller when more rosettes, smaller for columns than bullet rosettes**
- **No significant dependence on temperature**

Key Accomplishment

Database of single-particle properties for developing new models predicting ice particle properties and in remote sensing retrievals

Publication

Um, J., et al., 2014: Aspect ratios of natural ice crystals from in-situ observations, *Atmos. Chem. & Phys*., In preparation.

Aircraft in situ measurements during MC3E

Xiquan Dong / University of North Dakota

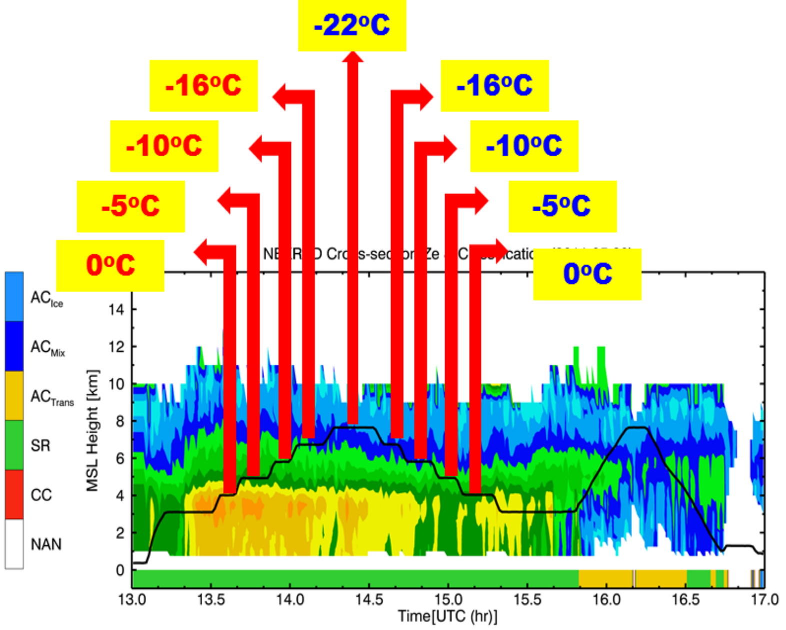
Science Question

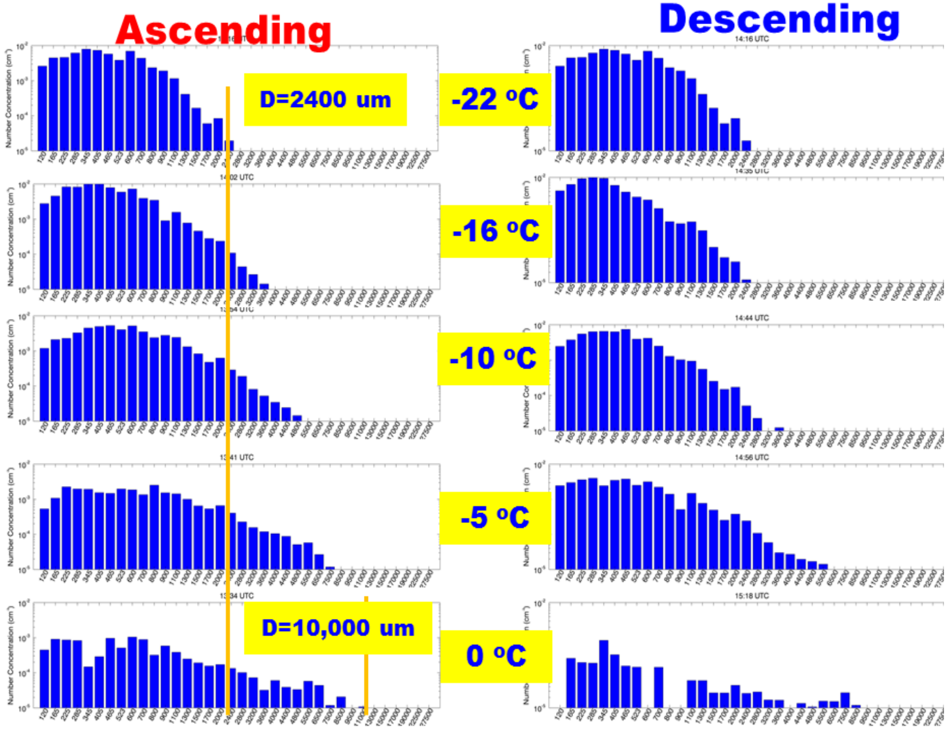
How can we accurately estimate the microphysical properties of Deep Convective System using aircraft in situ measurements?

Key Accomplishment

Cloud Particle Size Distribution (PSD) is narrow and concentration (Nd) is high at upper layer (~ 8 km, -22 °C), and PSD becomes broader and Nd is low at bottom part (~ 4 km, 0°C).

Aircraft flew cloud through five steps during ascending and descending with temperatures of 0, -5, -10, -16, and -22 °C





Max Diameters range from 2400 to 10,000 um when T increases from -22 to 0°C.

Publication

- Wang, J., **X. Dong**, and B. Xi, 2014: Investigation of Microphysical Properties of DCS using Aircraft in-Situ Measurements: Part I: the Ice-Phase Layer of DCS. Submitted to JGR.

Evaluation of double-moment and single moment microphysical schemes with radar data and high-resolution numerical simulations of MC3E mesoscale deep convective systems

Zhaoxia Pu and **Chao Lin**, *University of Utah*, **Xiqun Dong**, *University of North Dakota*
(Contact: Dr. Zhaoxia Pu, Zhaoxia.Pu@utah.edu)

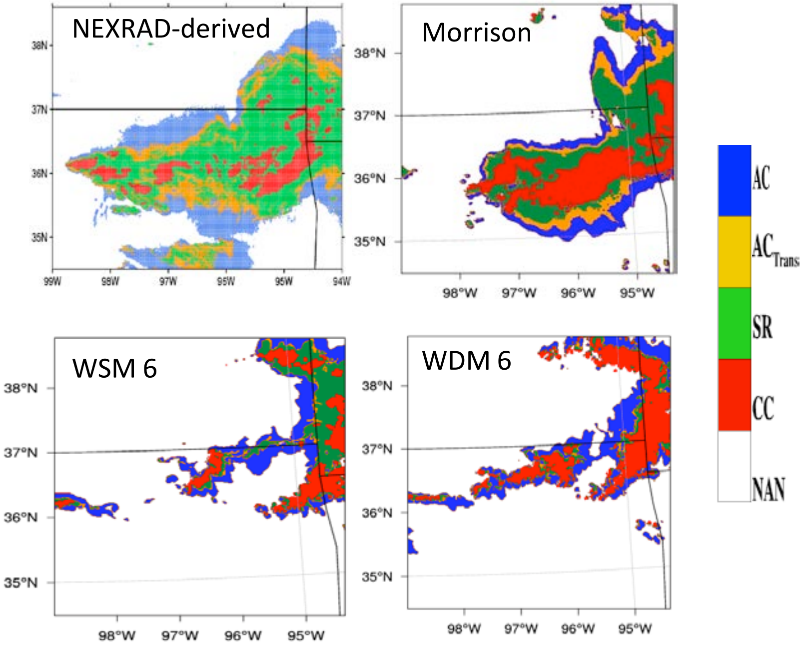


Figure 1. Cloud classification from a) NEXRAD-derived data product, compared with WRF model simulations with Morrison double-moment scheme, WSM 6 single moment scheme and and WDM 6 double moment scheme at 0100 UTC 24 May 2011. The WRF simulations with WSM6 and WDM6 both produce too many convective clouds and fewer transitional anvils, whereas the simulation with Morrison scheme generates more reasonable results.

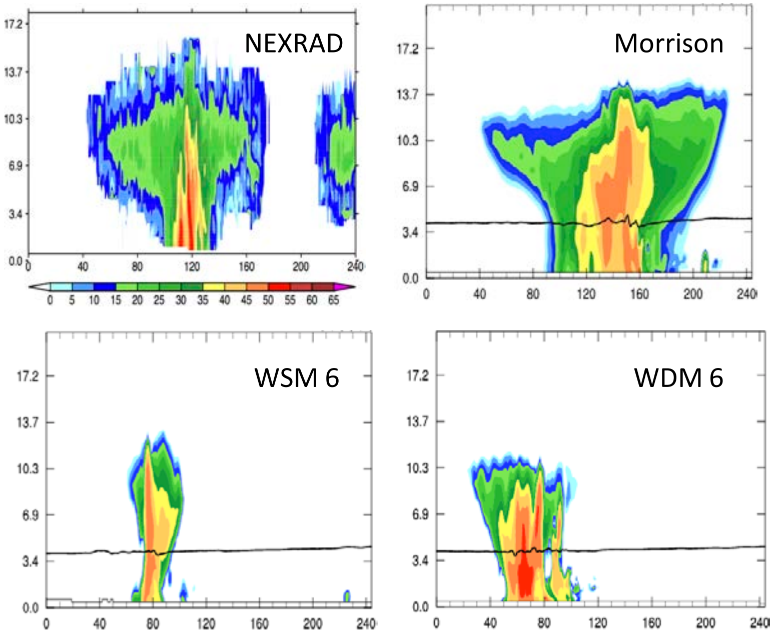


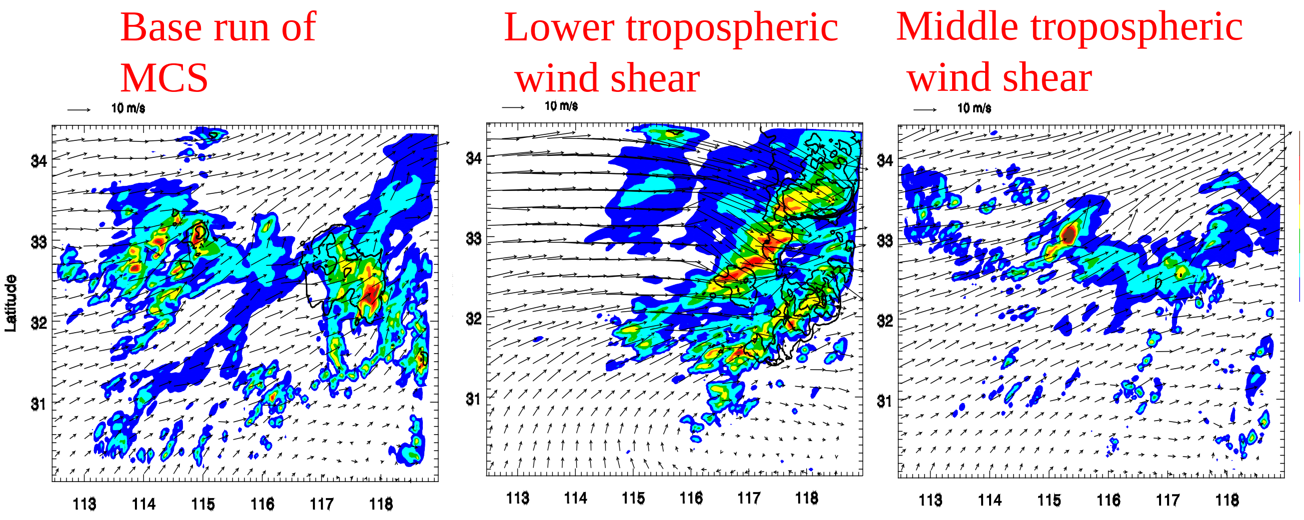
Figure 2. The cross-sections of radar reflectivity along 96.5W from 37.5N to 34.5N at 0100UTC 24 May 2011. NEXRAD data product is compared with WRF model simulations with Morrison double-moment scheme, WSM 6 single moment scheme and and WDM 6 double moment scheme. The simulation with Morrison scheme produces more ice-phase hydrometeors (ice, snow, and graupel), which bring the 3-D radar reflectivity structures closer to observations

Roles of Vertical Wind Shear in Cloud System Organization

Jiwen Fan/ Pacific Northwest National Laboratory

Objectives

- Improve understanding of how vertical wind shear at different vertical levels impacts cloud system organization and properties


Base run of MCS

Lower tropospheric wind shear

Middle tropospheric wind shear

Spatial distribution of precipitation; arrows denote wind field.

Approach

- Cloud-resolving model simulations with detailed bin cloud microphysics
- Impose wind shear to the lower, middle, and upper troposphere and examine how cloud system is changed

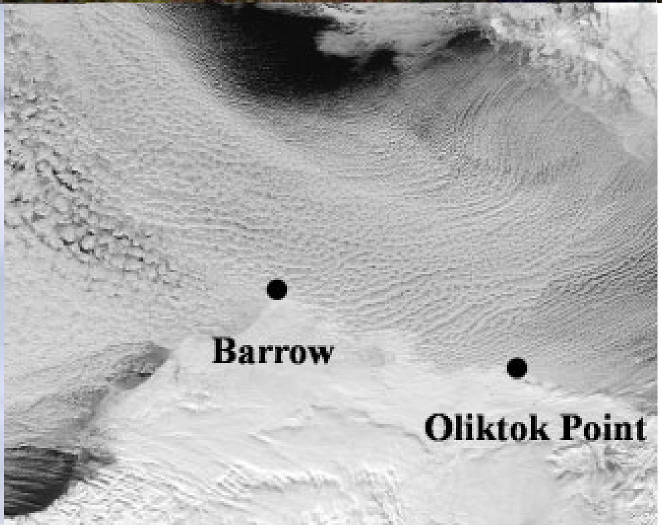
Key results

- Increasing wind shear at the lower-troposphere is favorable for a more organized quasi-line system.
- Strong wind shear in the middle troposphere produces a strong super-cell with much reduced precipitation area.
- Increasing wind shear at any vertical levels reduces precipitation.

Reference

Chen, Q., J. Fan, S. Hagos, Roles of Wind Shear at Different Vertical Levels, Part I: Cloud System Organization and Properties, J. Geophys. Res., in review.

State of the Cloud Lifecycle Working Group Address



Thanks!