Overview of QUICR FG Activities

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QUICR: Quantification of Uncertainties In Cloud Retrievals

Lawrence Livermore National Laboratory

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Mission Statement

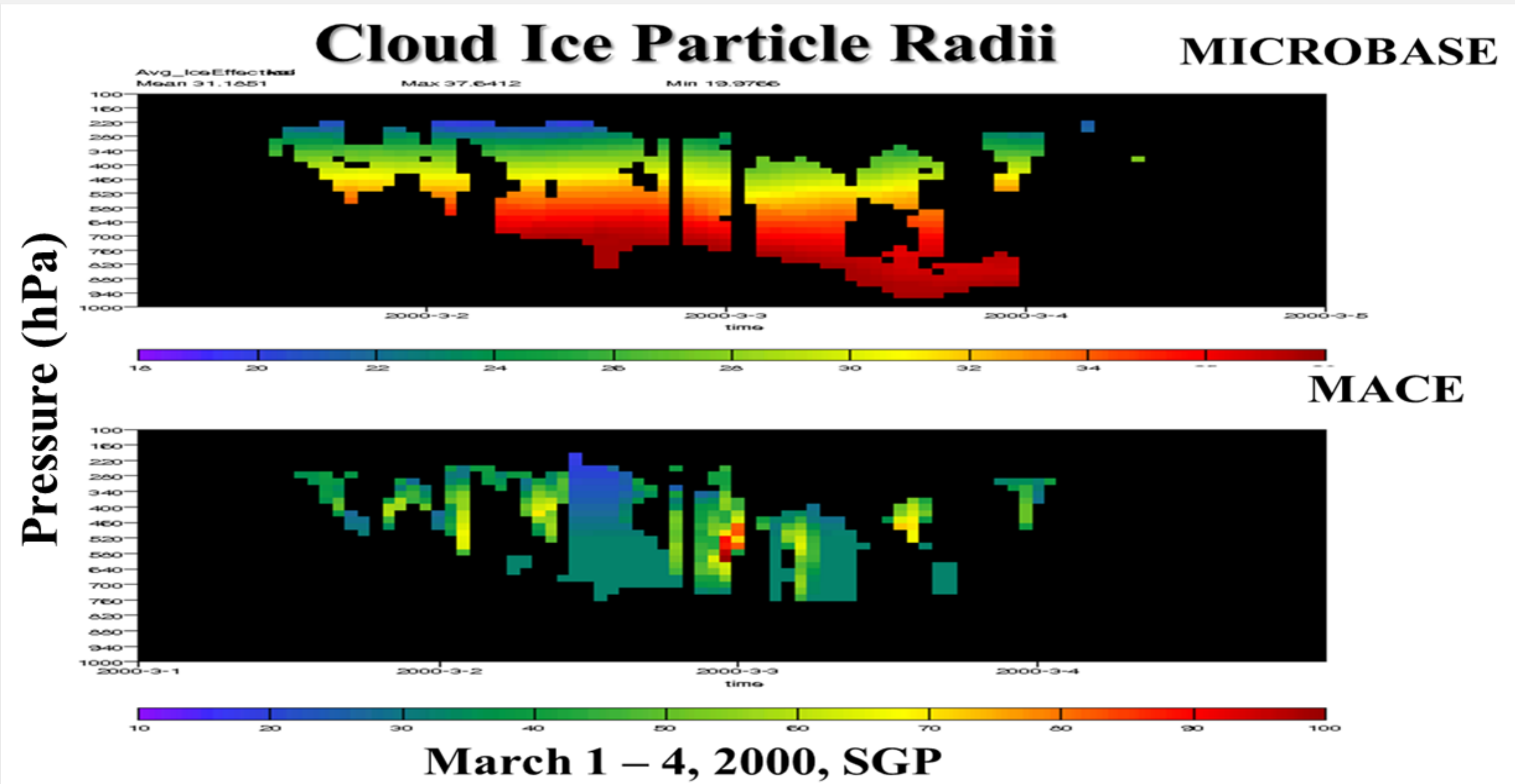
“to develop a methodology for characterizing and quantifying uncertainties in current and future ARM cloud retrievals, separately for different cloud regimes, in support of both retrieval algorithm improvement and cloud modeling study”

Outline

- Motivation
- Science Goals
- Recent Activities
- Future Plans

A little background ……

Large uncertainties exist in current retrieval products



Efforts toward Understanding The Differences

Previous intercomparison studies – limited cases

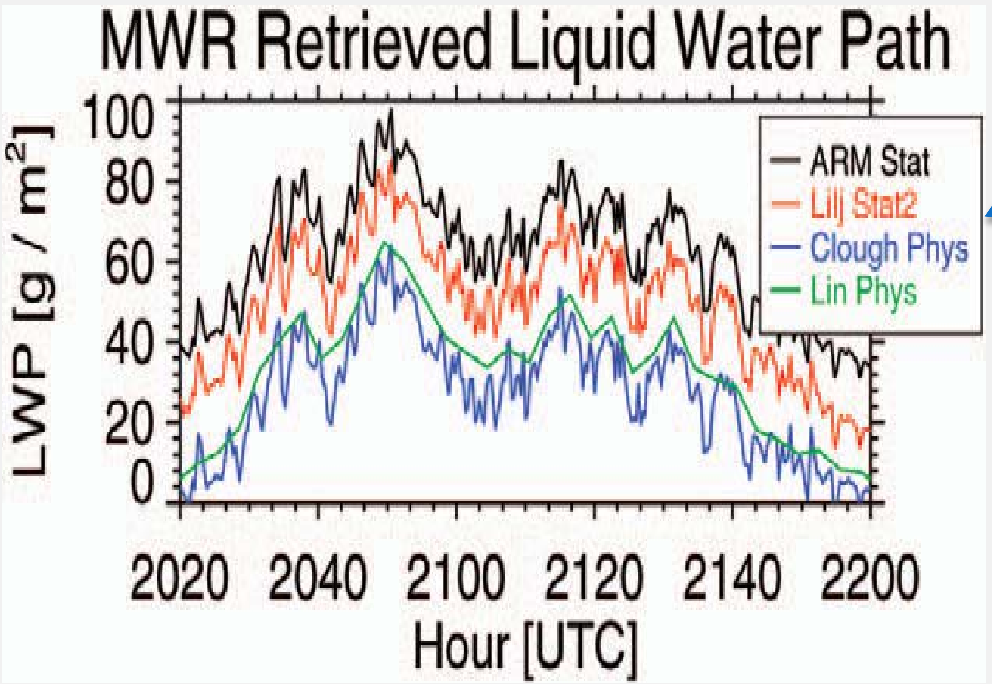
- Comstock et al. (2007): High level ice clouds (16 algorithms, SGP- March 2000 IOP).
- Turner et al. (2007): Optically thin liquid clouds (18 algorithms, SGP-March 2000 IOP).
- Shupe et al. (2008): Mixed-phase clouds (~8 algorithms, NSA-MPACE).

Major Conclusions

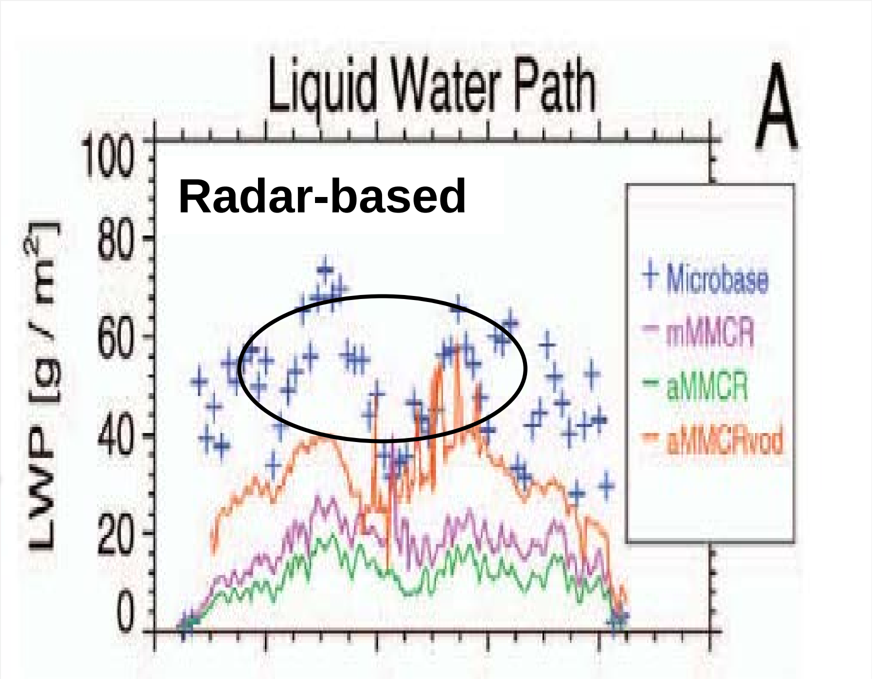
- Limitations of instruments and uncertainties in the measurements and assumptions used in the algorithms account for a significant portion of the differences
- The accuracy varies greatly with instrument, analysis method, and cloud type
- No single retrieval method can work properly for all instruments and all cloud conditions

Example – Optically Thin Liquid Clouds

Turner et al. (2007)



Even LWPs retrieved from MWR show large disagreement



LWPs from radar is significantly different from those retrieved from MWR without constraint

Importance to the Program

- Characterizing the uncertainty in cloud properties is highly desired by cloud modelers. It is critical to improve cloud representations in GCMs, and reduce the associated uncertainties in climate simulations, which is the ultimate goal of the ASR CLWG.
- Quantifying the uncertainty in cloud properties also helps quantify the uncertainty in cloud radiative forcing and aerosol indirect effort.

QUICR was created to continue these group efforts, particularly with the goal to address cloud modelers' needs, in additional to retrieval algorithm improvement.

What are Modelers' needs?

- **Ideally, cloud modelers want a best estimate of cloud retrievals with error bars for multiple years under all cloud conditions**
- **Multiple retrievals are better than a single retrieval**
- **Uncertainties with each retrievals**
- **Long-term continuous data**
- **Flags to identify periods where algorithm or instrument work the best**
- **Documentations to address potential issues with the data**

Objectives

- Systematically analyze differences in current widely accepted cloud retrievals algorithms and their products
- Understand potential uncertainties in each of the selected algorithms
- Evaluate the accuracy of the assumptions made in these cloud retrievals with observations and observation system simulation experiment (OSSE) datasets
- Apply advanced statistical methods to quantify uncertainties in these cloud retrievals for different cloud regimes

What have we done so far and what are we working on?

Assembled 11 Retrievals on A Common Grid - ACRED

Multiple retrievals are better than a single one!

Use of ARM Cloud Retrieval Ensemble Dataset (ACRED)

- Provide a rough estimate of uncertainties in current cloud retrievals
- Facilitate use of various cloud retrieval products by the modeling community
- Facilitate cloud retrieval intercomparison studies

ACRED Used to Systematically Explore Differences among Current Available Retrievals

Toward understanding of differences in current cloud retrievals of ARM ground-based measurements

Zhao et al (2012), JGR

Chuanfeng Zhao,[1] Shaocheng Xie,[1] Stephen A. Klein,[1] Alain Protat,[2,3] Matthew D. Shupe,[4,5] Sally A. McFarlane,[6] Jennifer M. Comstock,[6] Julien Delanoë,[2] Min Deng,[7] Maureen Dunn,[8] Robin J. Hogan,[9] Dong Huang,[8] Michael P. Jensen,[8] Gerald G. Mace,[10] Renata McCoy,[1] Ewan J. O'Connor,[9,11] David D. Turner,[12] and Zhien Wang[7]

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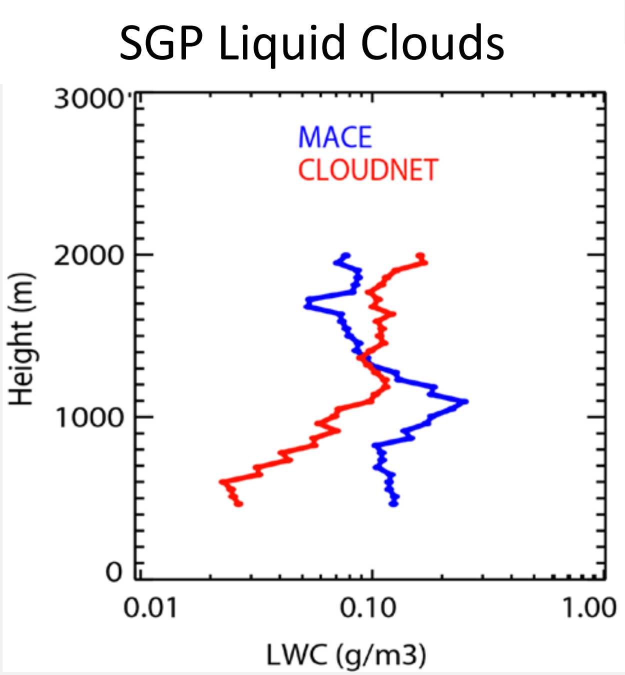
- Emphasize on BL overcast clouds and high level ice clouds
- Attempt to understand potential causes from the way they are retrieved
- Explore potential issues that need to be addressed in the future
- Setup a baseline for further studies

Similar to earlier studies, Zhao et al (2012) found:

- Most of the differences can be explained by the differences in retrieval basis, parameters, and underlying assumptions, as well as input and constraint parameters

Example: Difference in Vertical Structure Caused by Retrieval Theory



- MACE - Radar Reflectivity Basis

  $LWC \sim Z^{1/2}$

  - LWC generally decreases with height

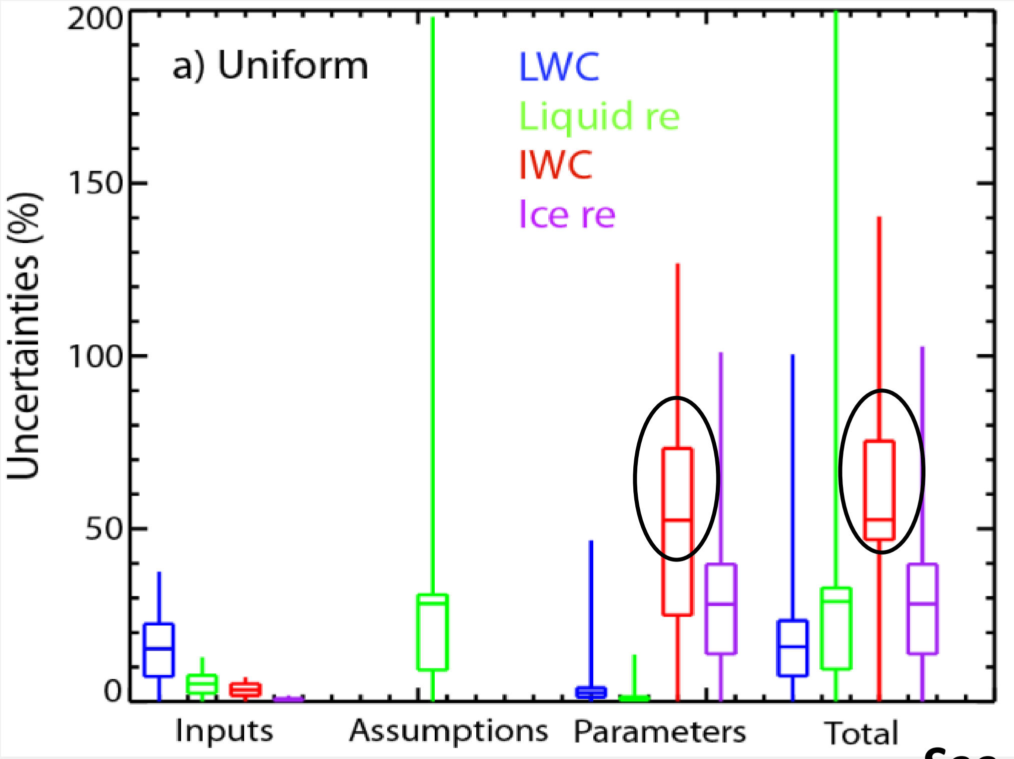
- CLOUDNET - Adiabatic Estimate

  - LWC generally increase with height

Uncertainties in Each Retrieval Are Being Analyzed

- **Perturb key parameters and/or change key assumptions used in several selected algorithms (MICROBASE; MACE; VARCLOUD)**

MICROBASE ***(Work with the BNL team)***



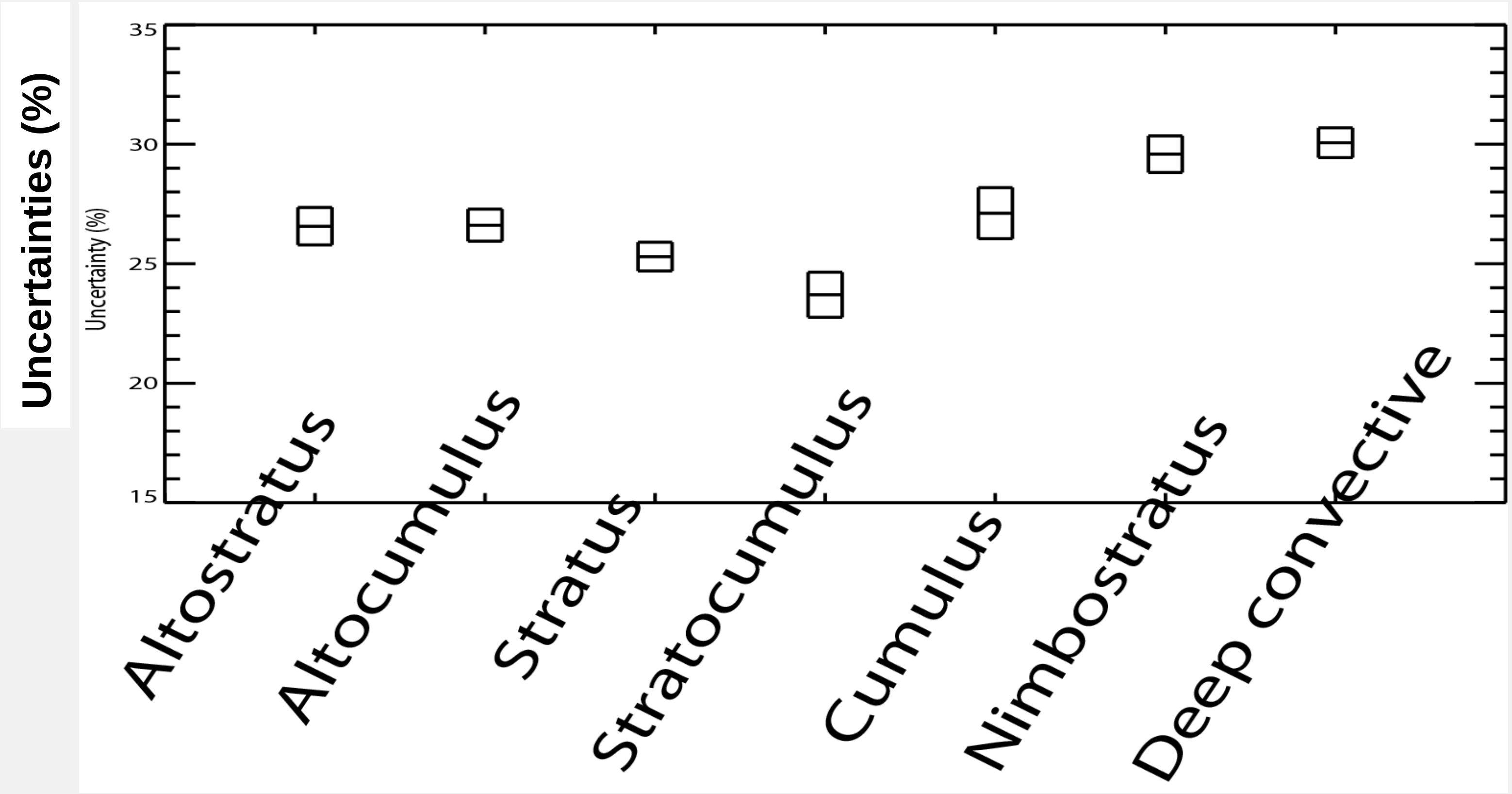
Dominant factors are different for different quantities

e.g., LWC-Input

IWC shows the largest uncertainty related to empirical regressions (20-80%)

See Zhao et al (2013) poster

Uncertainties in LWC Vary with Cloud Types

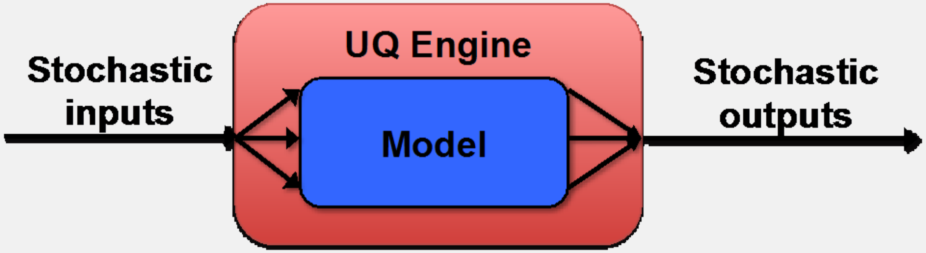


- **Larger uncertainties for deep convective clouds**

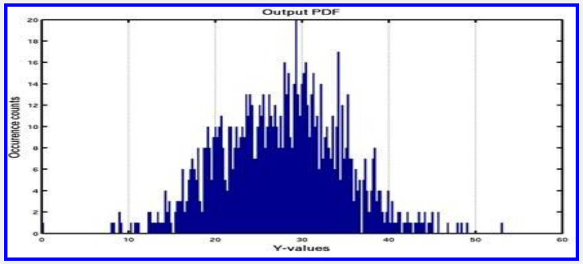
See Zhao et al (2013) poster

Utilizing PSUADE in Uncertainty Analysis

PSUADE- a powerful tool for UQ analysis



Many deterministic simulations

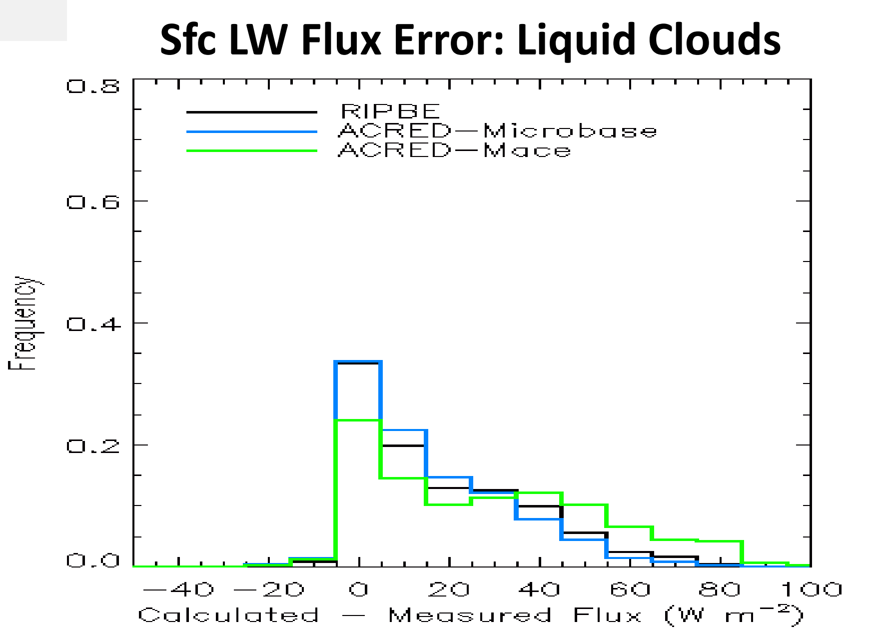


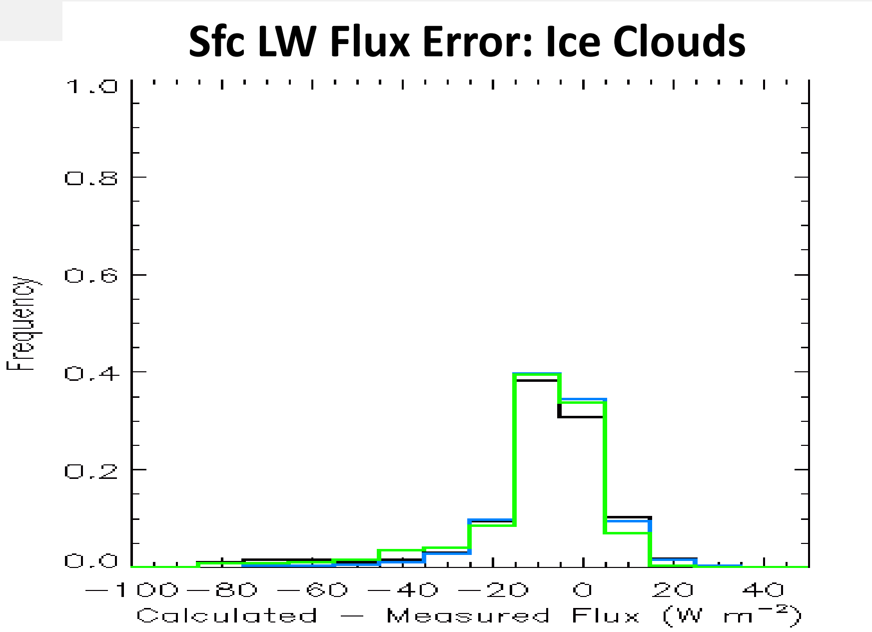
Courtesy of Xiao Chen, LLNL

- Modify ranges and distributions for parameters
- Response surface analysis (MARS, Gaussian process, etc.)
- Moment analysis (mean, standard deviations, etc.)
- Hypothesis testing and correlation analysis
- Main effect (first order sensitivity) analysis with or without input inequality constraints
- Group and total sensitivity analysis
- Bayesian inference and numerical optimization

Integrating ACRED and RIPBE for BBHRP (work with the ARM infrastructure team at PNNL)

- Created a high-resolution ACRED consistent with RIPBE to facilitate the use of BBHRP in evaluating various cloud retrievals
- Will define cases for intercomparison studies
- Important pilot study for QUICR – other retrieval PIs could follow the same path to use BBHRP



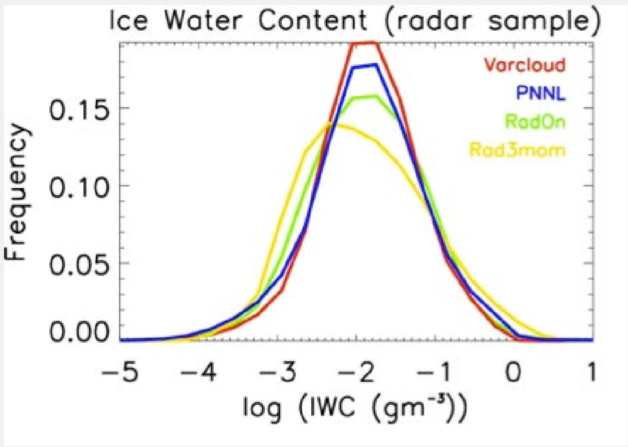


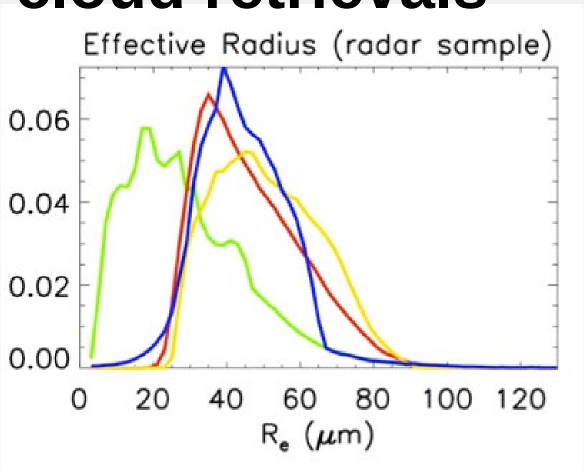
Courtesy of Sally McFarlane

Investigating impact on Cloud-Radiative Effect and Heating Rates

Comstock et al. (2012)

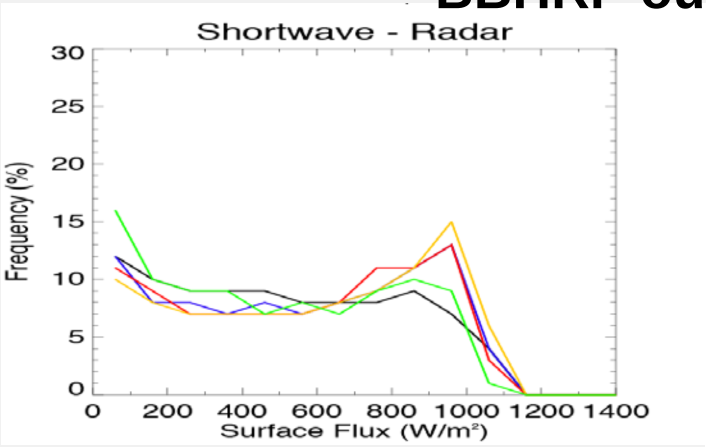
Difference in Ice cloud retrievals

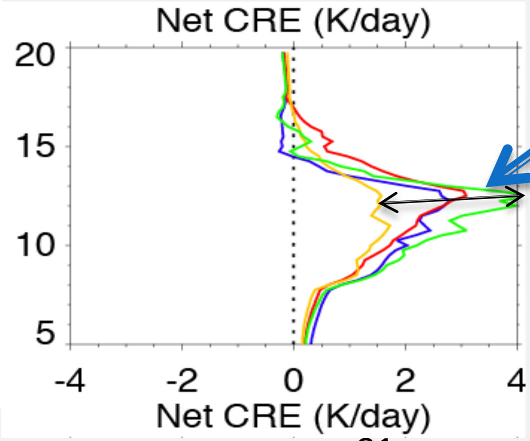




3-yr data at Darwin

BBHRP outputs





Diff. between green and yellow ~ 3K/day

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Build-up a Cloud Retrieval Test Case Library (led by Alain Protat)

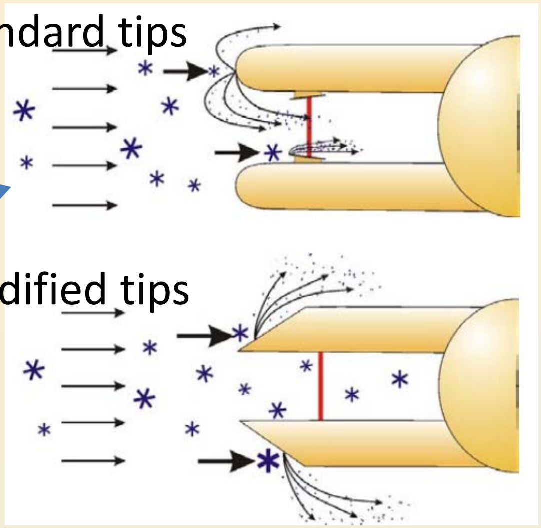
- **Build up a cloud retrieval test case library that will include radar, lidar, radiometer measurements colocated with reference in-situ microphysical parameters**
- **Uniform input data files for running different algorithms**
- **In-situ data from both ARM and non-ARM field campaigns and radiative fluxes for evaluation and validation – *need to closely collaborate with PIs to understand the in-situ data and their uncertainties***
- ***Some funding supports are needed!***

Collaborating with IcePro to Understand Uncertainty in In-situ Data

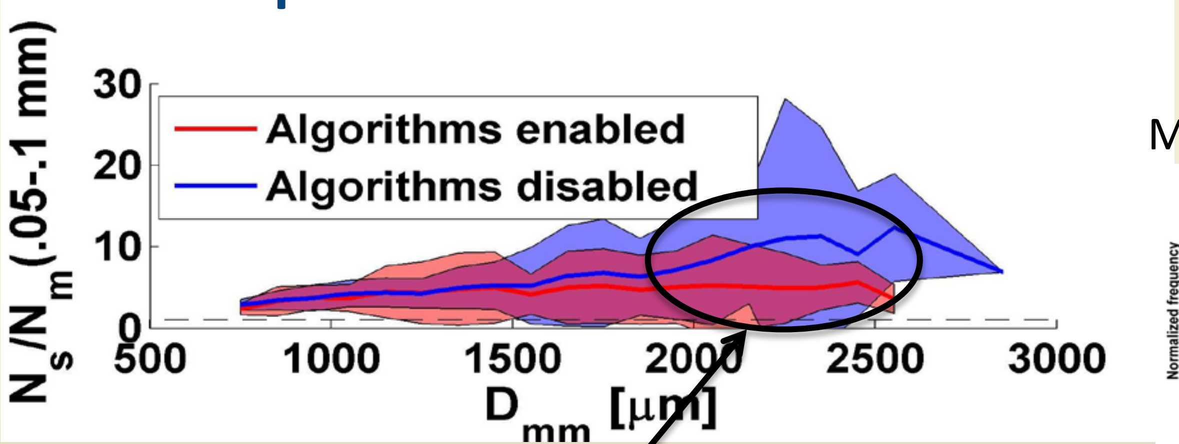
Shattering Issue: shattering of large ice crystals on inlets & tips can artificially generate small ice crystals - PSD

Standard tips

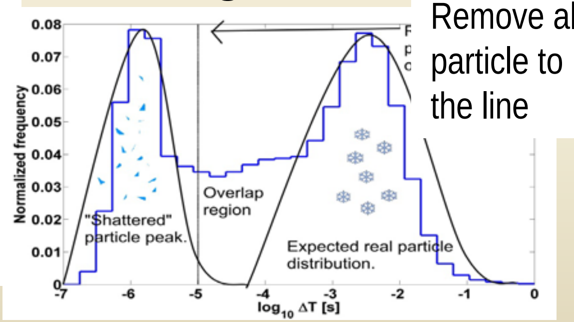
Modified tips



Compare Standard & Modified 2DC



Modified algorithm



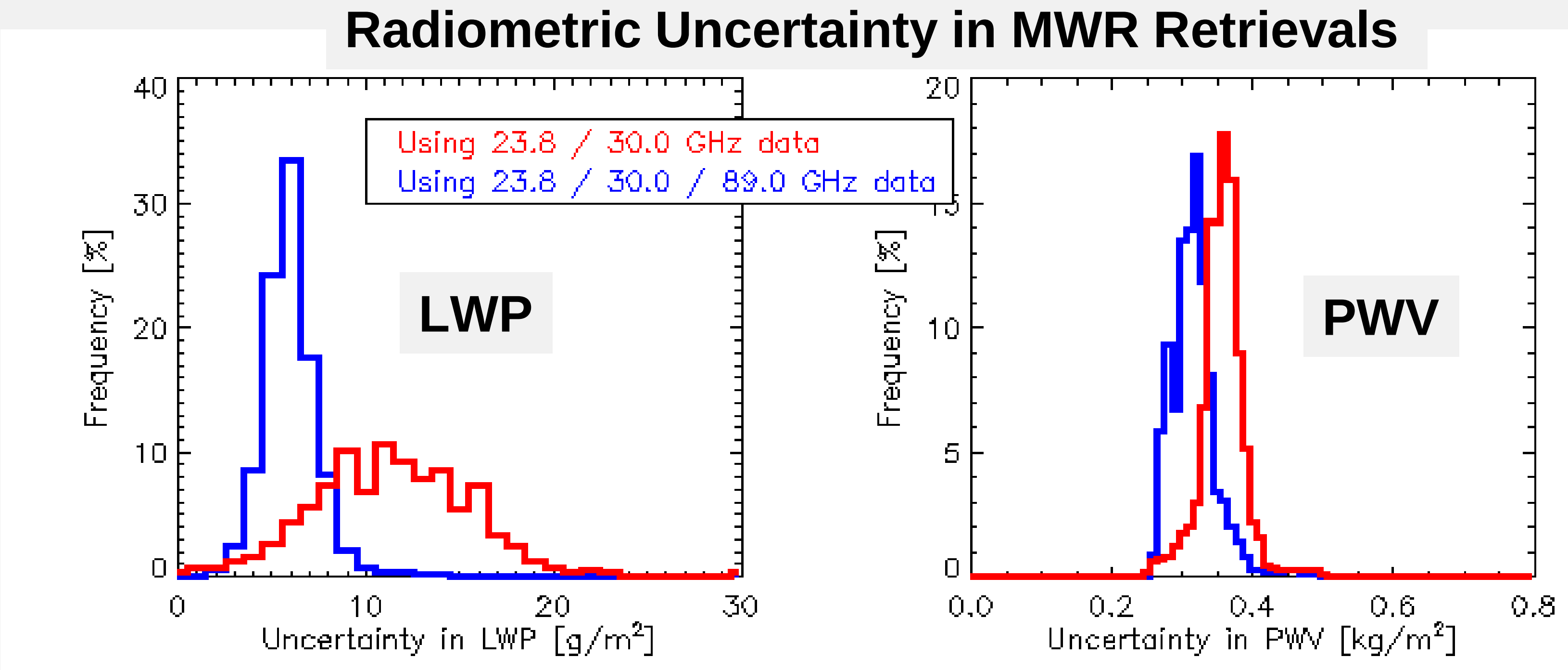
Remove all particle to left of the line

Fewer shattered particles with algorithms enabled

Ratio of Ns/Nm increases with median mass diameter Dmm

Courtesy of Greg McFarquhar, Univ. of Illinois

Advanced Instrument Helps Improve The Accuracy of Retrievals



Courtesy of Laura Riihimaki and Dave Turner

New 3 channel retrievals give lower random errors than 2-channel retrievals in retrievals of LWP and PWV.

Future Plans (1)

- Develop the methodology for quantifying uncertainties with individual retrieval method for different cloud regimes.
  - On-going pilot study with MICROBASE, but more retrieval groups need to participate in.
- Select in-situ cases for test case library
  - Need to interact with in-situ people and some funding support is needed
- Need to make the use of BBHRP easier to run with different retrieval techniques (ongoing pilot study : integrate ACRED in RIPBE)
- Utilize new instruments in quantifying uncertainties in current retrievals

Future Plans (2)

- Collaboration with the IcePro Interest Group (Co-Chaired by Greg McFarquhar and David Mitchell)
  - Identified important 2-ways synergies with the IcePro group (in-situ work from IcePro → QUICR & QUICR-validated retrievals will serve IcePro objectives)
- Collaboration with other science communities (European groups)
  - A joint US ARM/ASR-EU workshop on cloud retrieval algorithms and uncertainties in May 2013 in Cologne will help identify the areas that both communities could work together
  - Potential areas include identifying common algorithm frameworks, common algorithm evaluation approaches, and geophysical variables to be retrieved and shared.

Thank You