Update on Recent QUICR Activities

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QUICR: Quantification of Uncertainties In Cloud Retrievals

Lawrence Livermore National Laboratory

LLNL-PRES-571334

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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”

Recent Activities

EU / DOE Ground-based Cloud and Precipitation Retrieval Workshop

13-14 May 2013, University of Cologne, Germany

- Workshop Objective: *To advance algorithm development and uncertainty quantification for retrieving cloud and precipitation properties from ground-based remote sensors through international scientific collaboration and data sharing.*
- 20 Attendees from Europe (12) and U.S. (8).
- Discussion Topics: Retrieval algorithm frameworks, forward models, instrument issues, prior datasets, evaluation approaches etc.

Courtesy of Jennifer Comstock

EU / DOE Ground-based Cloud and Precipitation Retrieval Workshop

13-14 May 2013, University of Cologne, Germany

- Primary Outcomes & Actions
  - Submitted BAMS manuscript provides general overview of retrieval algorithms, uncertainty sources and path forward for improvement (Turner et al.)
  - Build on EU-led experiment using synthetic datasets to evaluate retrieval algorithms
  - Build a set of real-atmosphere datasets for algorithm development and evaluation (i.e. ARM/EU COPS)
  - Create common guidelines for calibrating and characterizing uncertainty in ground-based instruments
  - DOE/ARM Data Portal (http://useu.ornl.gov/cap/) to share data, codes, forward models etc.
  - Characterize uncertainty of forward models
  - Develop common optimal estimation framework

Courtesy of Jennifer Comstock

Making BBHRP a retrieval evaluation framework

Laura Riihimaki, Tim Shippert

RIPBE

Radiatively Important Parameters Best Estimate

Puts needed inputs for radiative transfer calculations into common format

BBHRP

Broadband Heating Rate Profile

Calculates LW and SW heating rates and fluxes from RIPBE input files

Phase 1: Adjust BBHRP to be user-run

- ☑ Create user-configurable run script and documentation
- ☐ Port to appropriate computing system *in progress*
- ☐ Use RRTMG instead of RRTM *being tested*

- *Plan to have initial setup ready for beta testing by Science Team Meeting*
- *The bulk of effort is adjusting so it is practical to run many sensitivity tests.*

Making BBHRP a retrieval evaluation framework

Laura Riihimaki, Tim Shippert

Phase 2: Support QUICR beta testers

- ☐ Adjust RRTM for new ice crystal assumptions
- ☐ Prepare RIPBE input files at additional sites
- ☐ Develop additional documentation/procedures as needed

- *Start with one beta test with well-defined tasks for user and infrastructure before opening up to a broader community*
- *Bulk of development effort is in creating RIPBE input files at new sites because not all info currently available beyond SGP.*

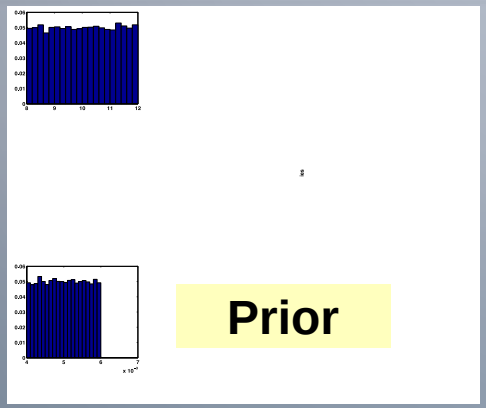
A Suggested Framework for QUICR

Qi Tang, Xiao Chen, and Shaocheng Xie (LLNL)

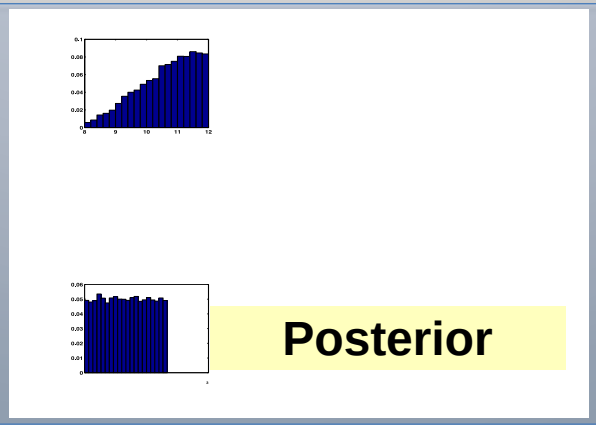
Cloud retrieval → Radiation Transport → Model outputs

(I) Aleatory variability	(II) Epistemic uncertainties	ONLY Aleatory variability	NO Epistemic uncertainties
• ARM measurements • Parameters	• Theoretical bases • Assumptions	• Parameters	• Model is treated as accurate

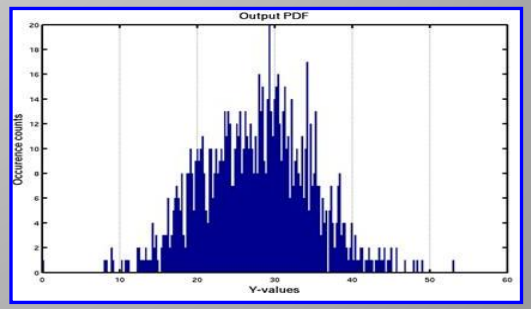
Observable measurements



Prior

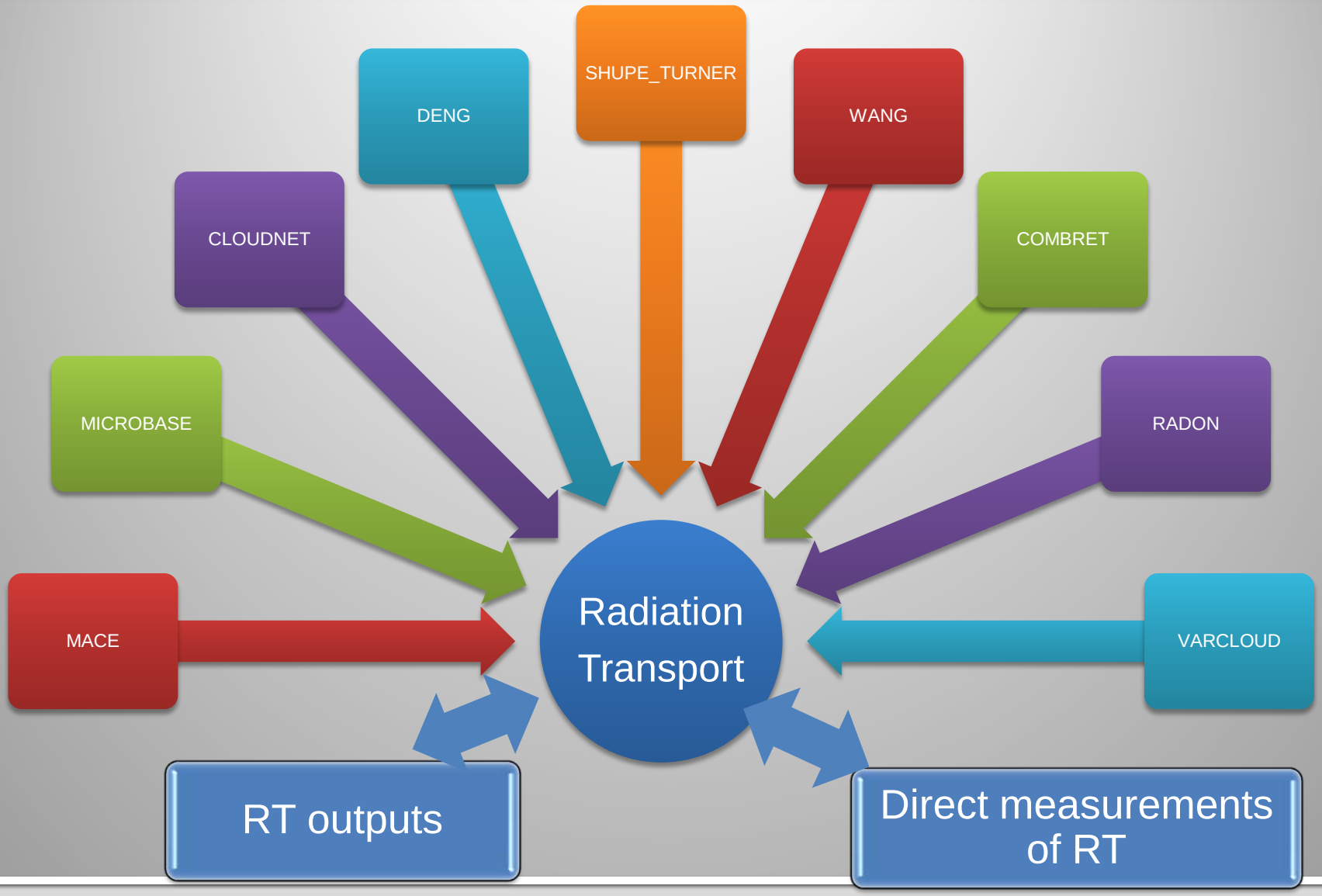


Posterior



Combine Retrievals to Optimize Data

Qi Tang, Xiao Chen, and Shaocheng Xie (LLNL)



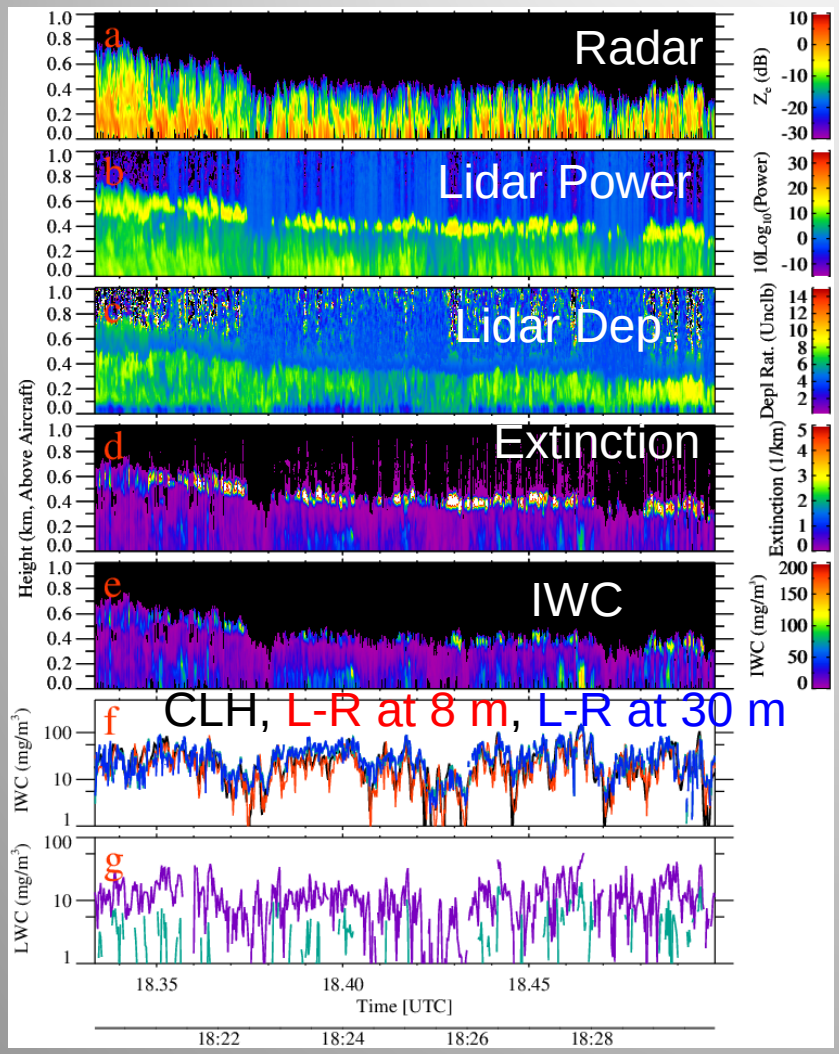
Build-up a Cloud Retrieval Test Case Library (led by Alain Protat)

- **Build up a cloud retrieval test case library that will include radar, lidar, radiometer measurements colocated with reference in-situ microphysical parameters**
- **The current identified cases include the ARM/EU Convective and Orographic Precipitation Study (COPS) and several selected cases at SGP and TWP-DARWIN**
- **Uniform input data files for running different algorithms**

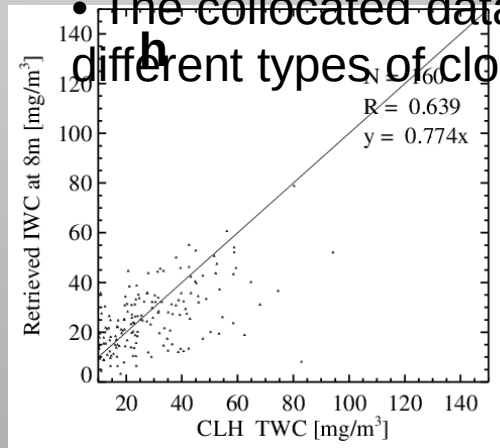
Validate lidar-radar IWC retrievals with collocated airborne in situ and remote sensing measurements

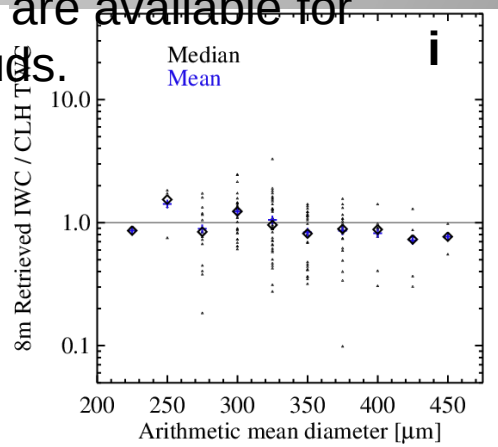
Zhien Wang (U. of Wyoming)

STORMVEx/CAMPS 02/17/2011



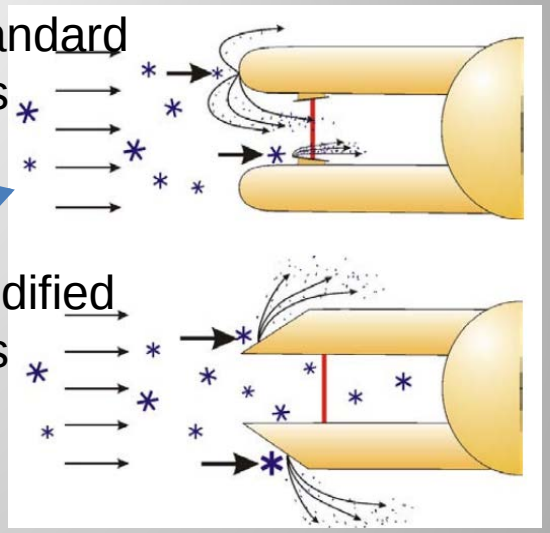
- The collocated airborne measurements minimize the impact of cloud inhomogeneity on retrieval evaluation.
- In situ microphysical properties can be used to assess algorithm assumption errors.
- A case study
  - Total water measurement—CLH (University of Colorado laser hygrometer)
  - Airborne lidar and radar
  - 2D-C and others for size distribution
- The collocated data are available for different types of clouds.



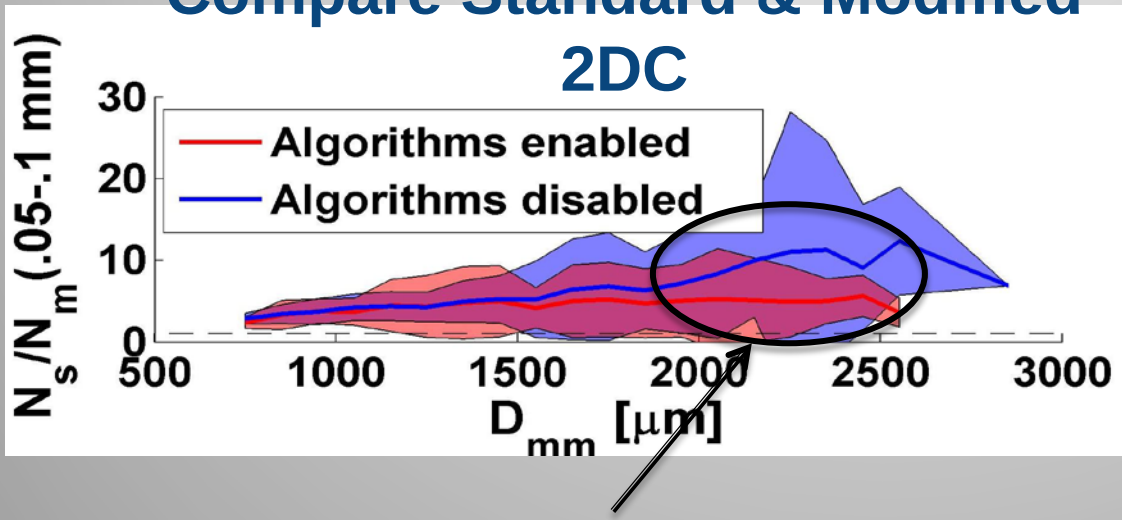


Collaborating with IcePro to Understand Uncertainty in In-situ Data

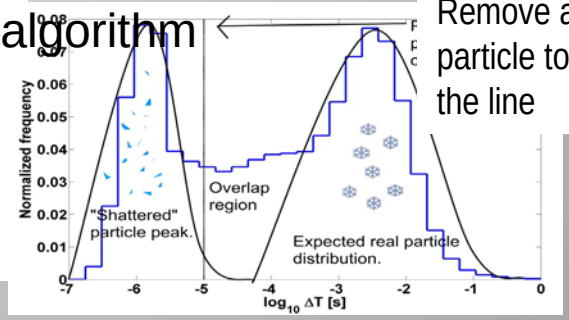
Shattering Issue: shattering of large ice crystals on inlets & tips can artificially generate small ice crystals - PSD



Compare Standard & Modified 2DC



Modified algorithm



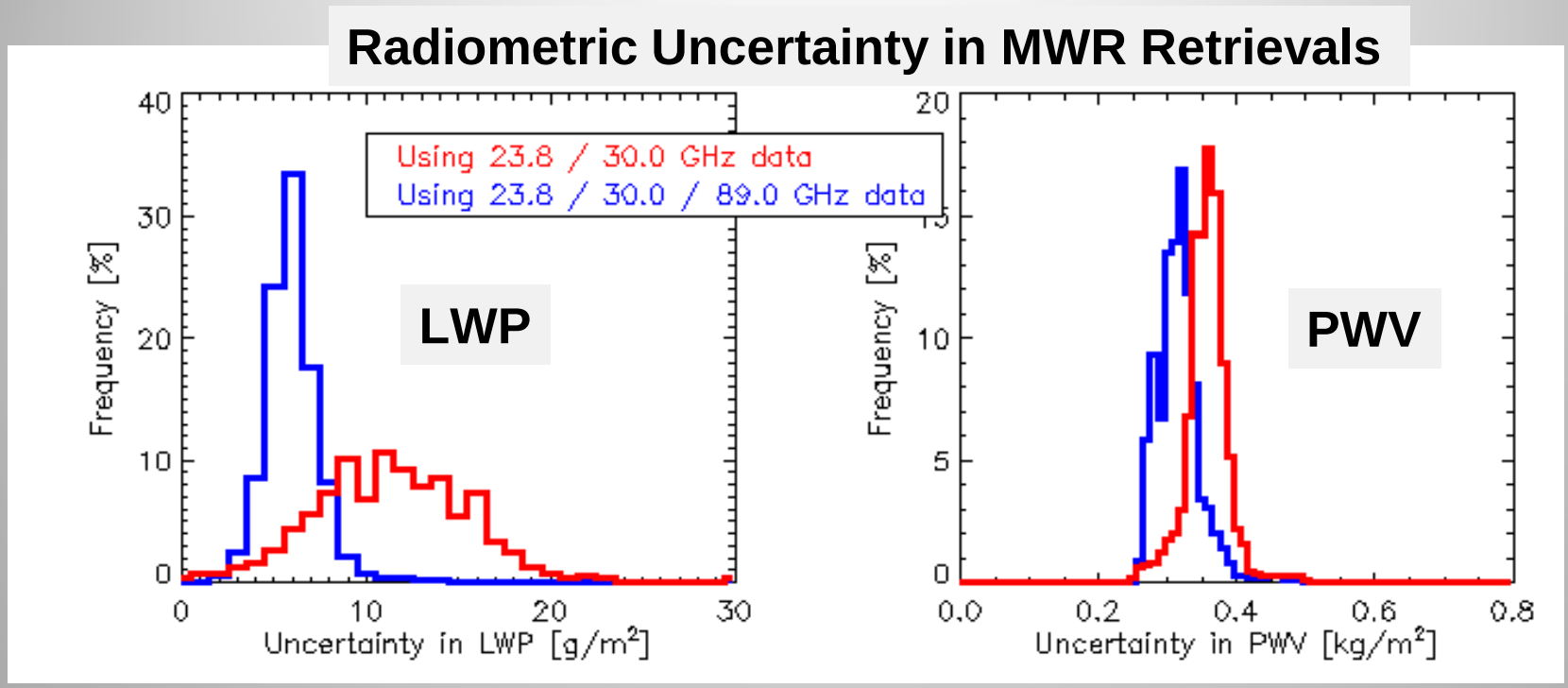
Remove all particle to left of the line

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

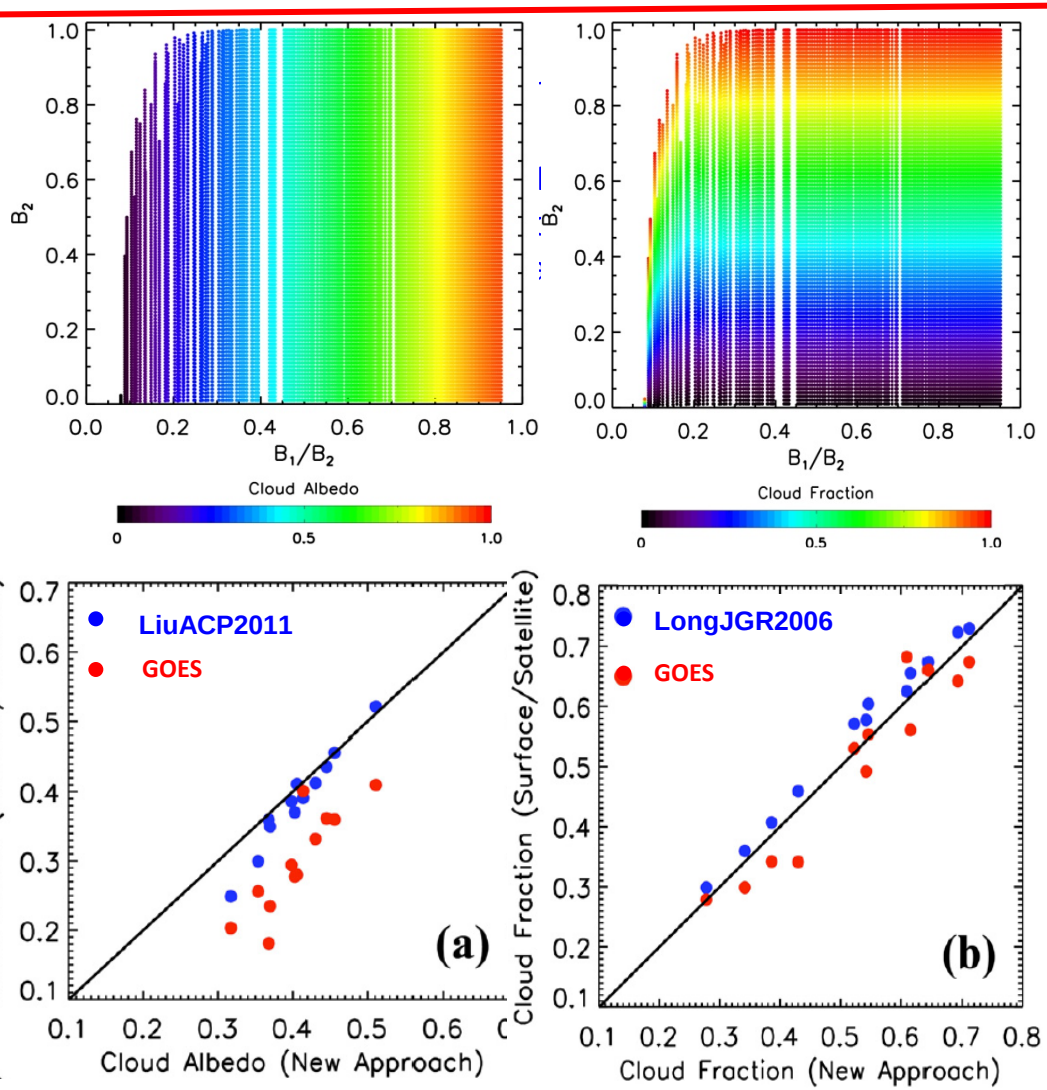


Courtesy of Laura Riihimaki and Dave Turner

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

A new approach for simultaneous retrievals of cloud albedo and cloud fraction from shortwave radiation measurements

- **C**loses equations for cloud albedo and cloud fraction using the partitions of total into direct and diffuse radiative fluxes.
- Cloud fraction is primarily determined by the relative cloud radiative forcing for the direct radiation (B2); cloud albedo is essentially determined by the ratio of the relative cloud radiative forcing for total radiation (B1) and that for direct radiation.
- Simultaneous retrievals of cloud fraction and albedo minimizes mutual contaminations.
- Use of B1, B2 and their ratio minimizes
- influences from other "secondary" factors.
- The new retrievals compare with "old" methods well; GOES overestimates cloud albedo compared to surface-based methods
- More detailed comparison and UQ is underway.



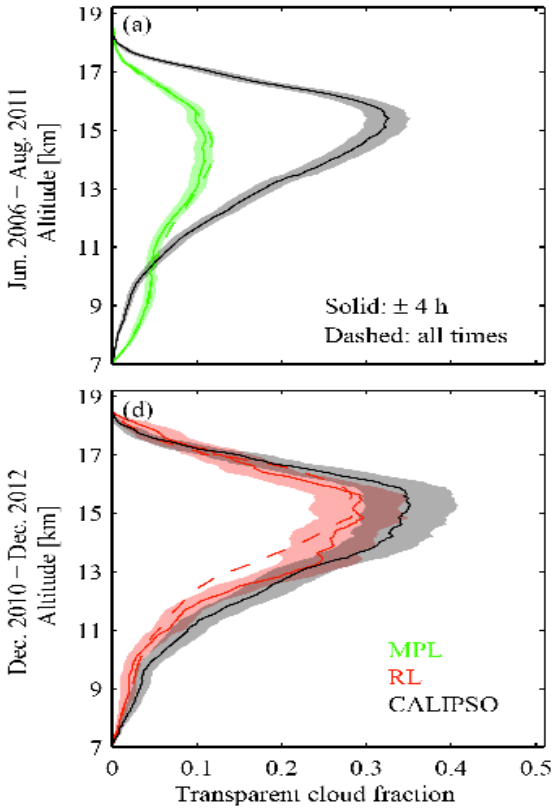
(Xie, Y. and Y. Liu, 2013: Environ. Res. Lett., 8, 044023, doi:10.1088/1748-9326/8/4/044023)

Automated detection of particulate layers from the ARM Raman lidar – Thorsen et al. 2013

Raman lidar (RL) feature mask

- The RL is far more sensitive than ARM's primary lidar the MPL.
- But the capabilities of the RL are under utilized in the current ARM VAPs:
  - Don't use the full set of measurements available.
  - Many clouds go undetected.
  - Identify features using arbitrary thresholds.

This work: Development of a context-sensitive threshold detection algorithm to objectively identify clouds and aerosols.



[Thorsen et al., *JGR*, 2013]

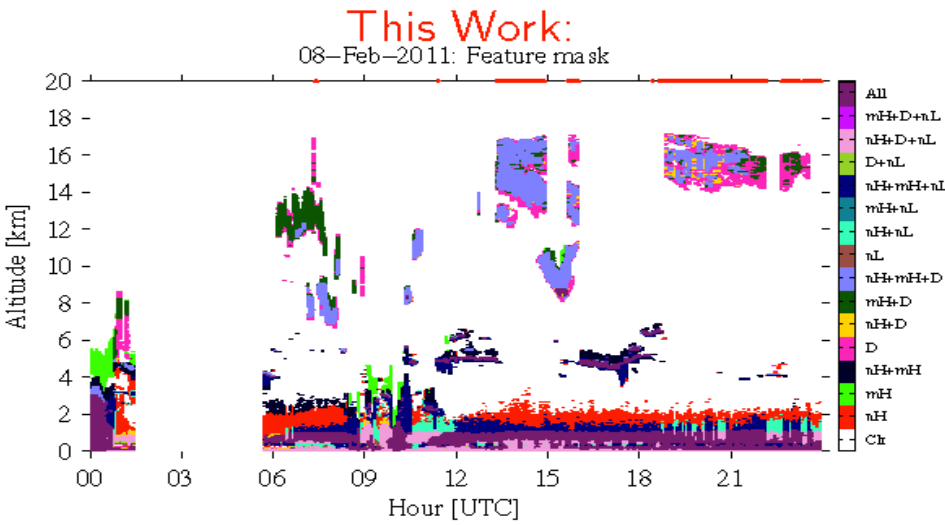
Automated detection of particulate layers from the ARM Raman lidar – Thorsen et al. 2013

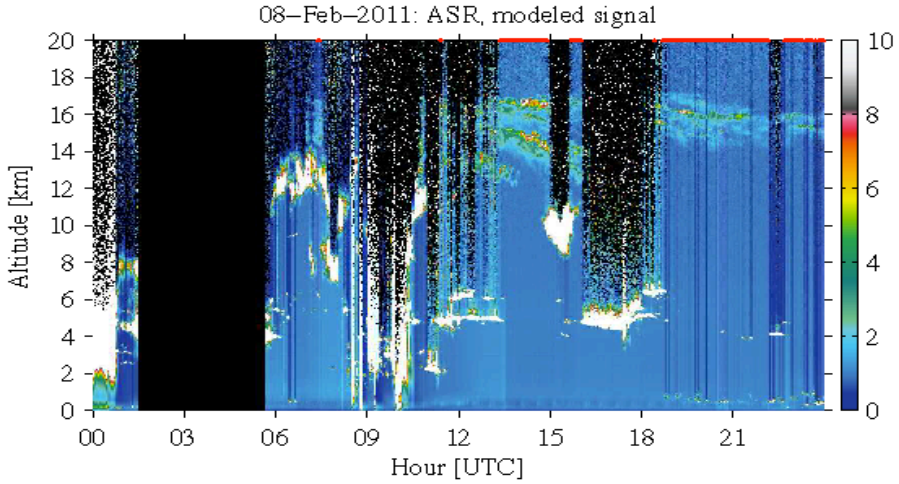
Four different quantities measured by the RL are examined independently for features to create a comprehensive mask:

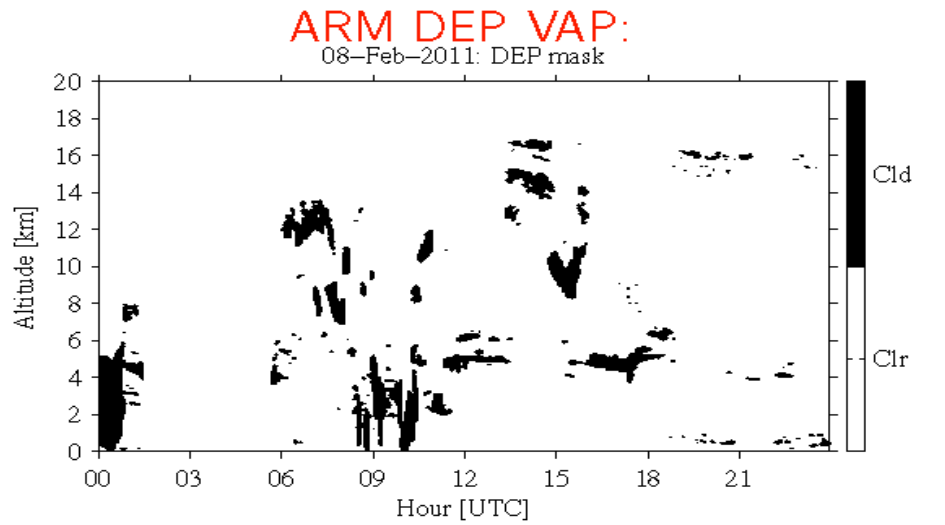
❶ / ❷ Scattering ratio using the high/low nitrogen channel.

❸ Scattering ratio using a modeled signal (high channel).

❹ Depolarization ratio.



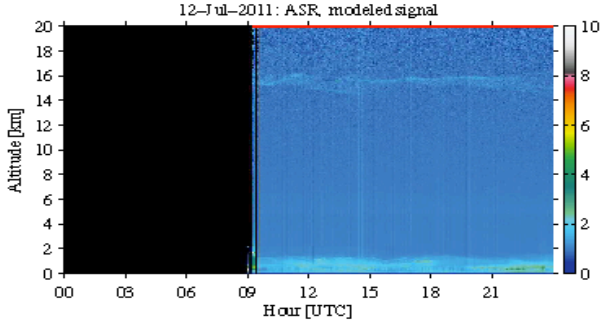




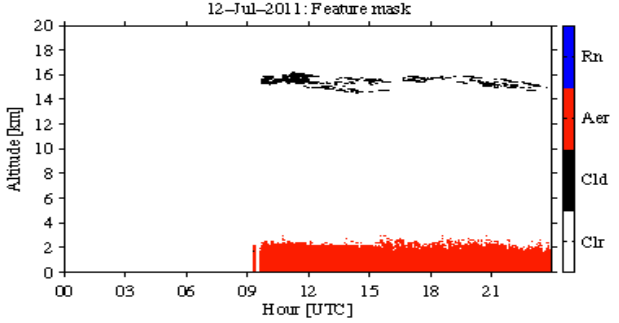
Automated detection of particulate layers from the ARM Raman lidar – Thorsen et al. 2013

Large improvement in cirrus detection:

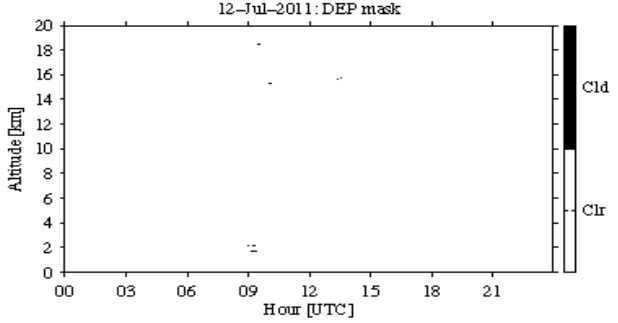
Scattering Ratio:

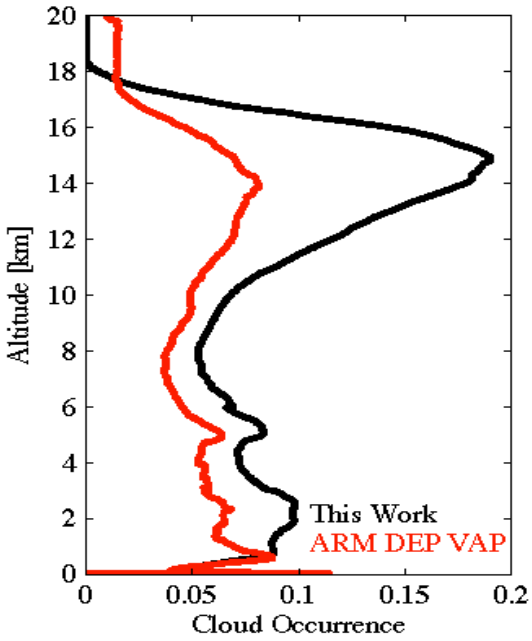


This Work:



ARM DEP VAP:





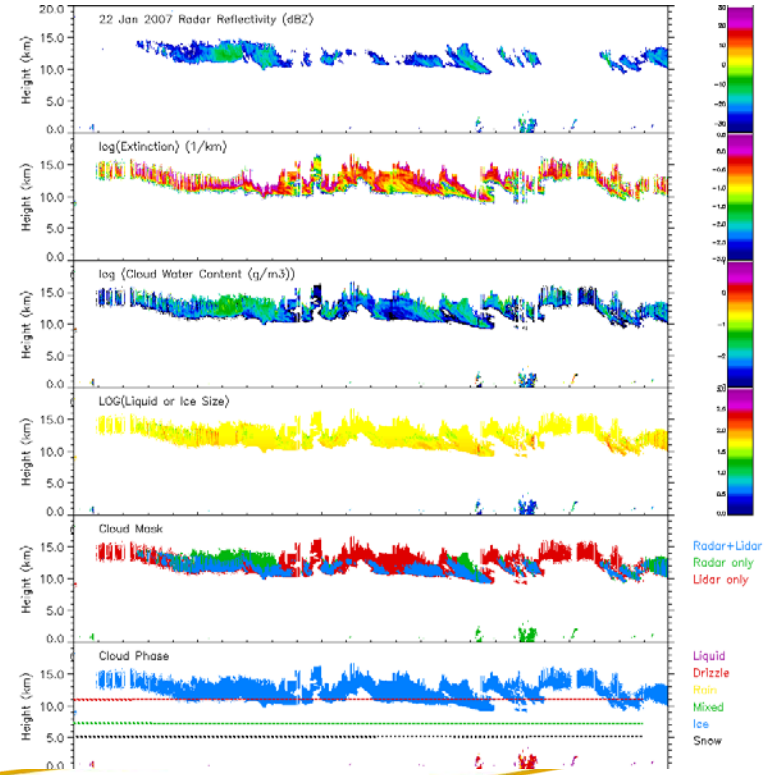
- This work improves the identification of clouds— a basic uncertainty for cloud retrievals.

Delivered more data to the ARM archive

10-yr of Cloud Properties and Radiative Heating Rates Dataset in the Tropical Western Pacific

submitted by Jennifer Comstock and Sally McFarlane

- Manus, Nauru, and Darwin
- All available data between 2002-2012
- Combined lidar-radar algorithm (CombRet)
- Profiles of cloud occurrence, cloud water/ice content, effective size, phase, drizzle/rain rate and water content.
- Comstock et al. JGR 2013



Other activities

- **Dave Turner gave an online lecture on variational (Bayesian) methods to ARM infrastructure teams. This helps understand some key basics about cloud retrievals and potential sources causing uncertainties in the retrieved solution.**
- **A QUICR session is planned for the upcoming AGU meeting (C. Zhao, A. Protat, X. Dong, and E. Clothiaux)**
- **A couple of papers that highlighted issues in cloud properties and their impact on cloud radiative effects have been either published or accepted by peer-reviewed journals (e.g., Comstock, Protat, et al. 2013; Protat et al. 2013).**

Thank You

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. Some preliminary results have been summarized in a paper submitted to JGR (*Zhao et al. 2013*)
- 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.

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

QUICR Was Created to Address 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