CLOWD Overview

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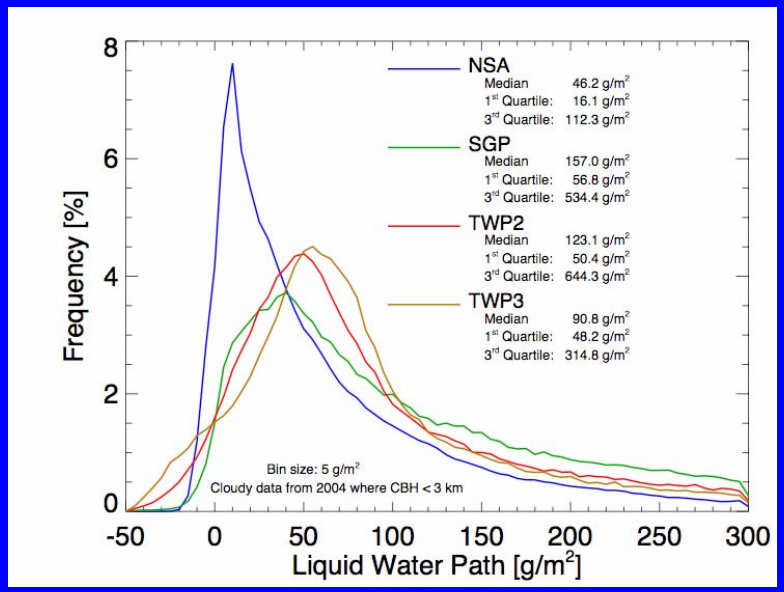
& Lots of Contributors

“What we can expect from liquid water cloud remote sensing in terms of accuracy within the next year or two?”

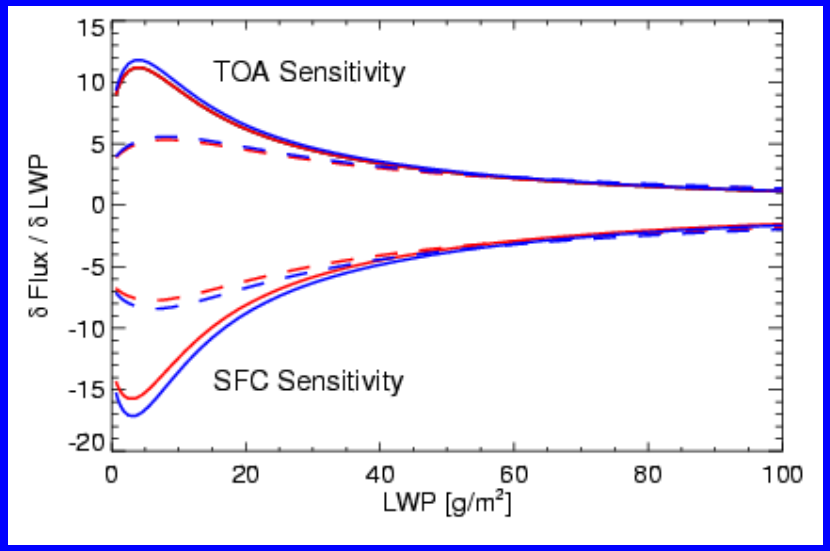
CPWG Co-Chair Eugene Clothiaux

1. **Brief Introduction**
2. **Where we stand**
3. **“Sticky” Points**
4. **Paths forward**
5. **Conclusion/Summary**

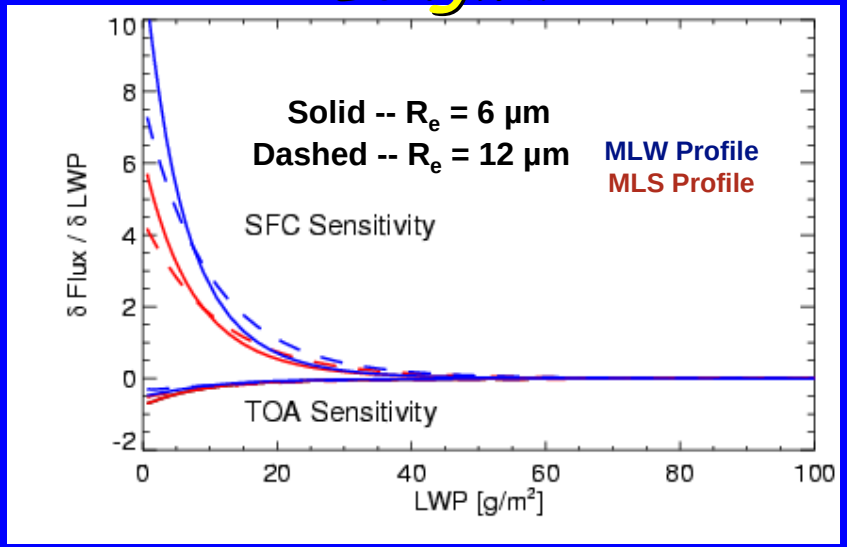
Radiative Importance of "Thin" Liquid Water Clouds



Shortwave



Longwave



- Thin clouds occur very frequently in Arctic, mid-latitudes, and tropics
- Radiative fluxes very sensitive to small changes in liquid water path (LWP) when LWP <100 g/m²

Turner et al., BAMS, 2006 (accepted), Sengupta et al., J Climate, 2003

CLOWD Strategy

Goal:

Accurate retrievals of low τ, LWP (Reff) at ARM sites 24/7 (VAP).

1) Develop and characterize retrievals

a) Identify algorithm gaps
b) Identify instrument needs

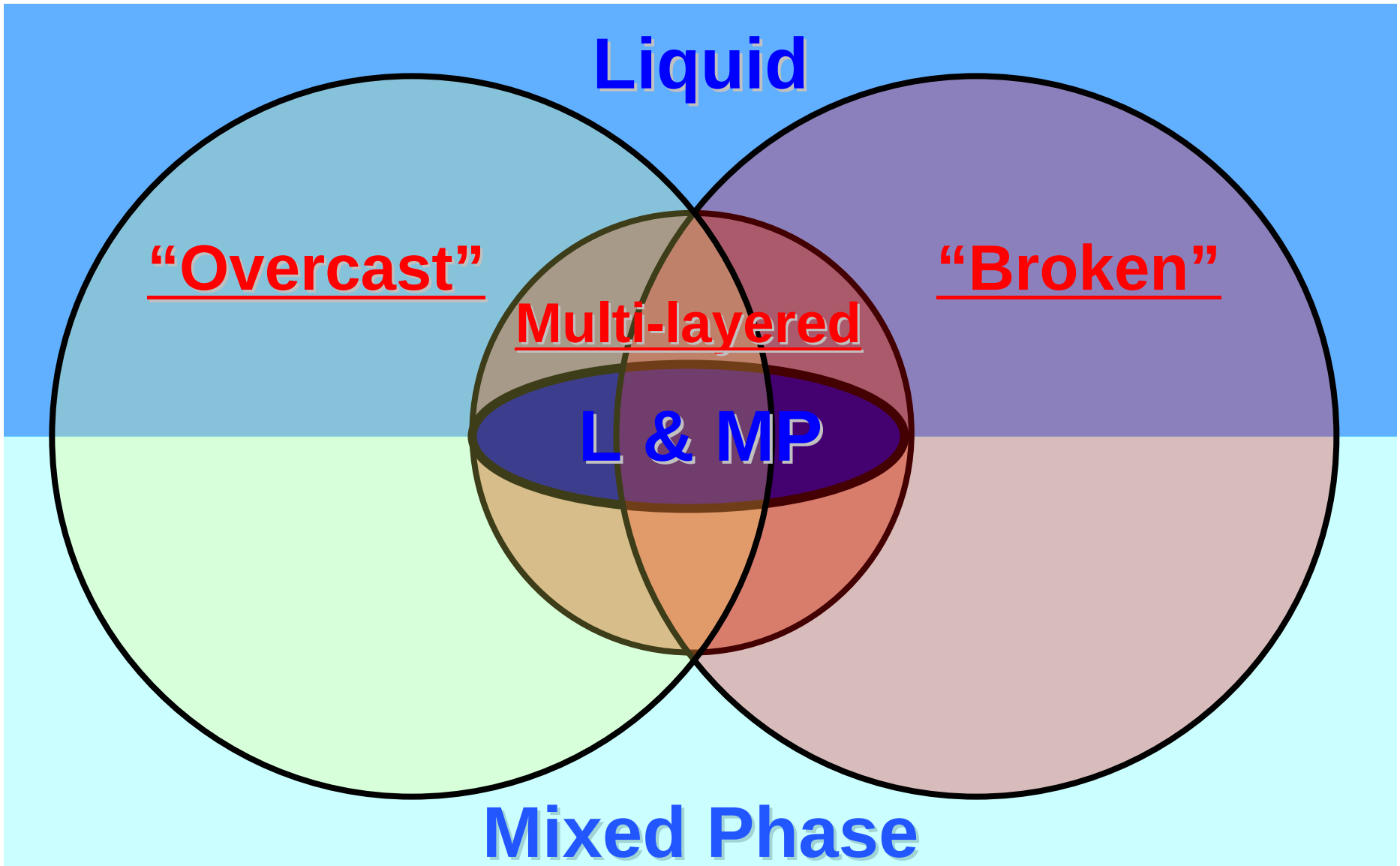
2) Synthesize (multiple) methods into single, BE product

a) Truth it (IOP)
b) →Entrain modelers (get feedback)

3) Operational mode

a) Battery test it
b) Extend to other sites
c) Extend to other types of CLOWD clouds

CLOWD Clouds



Where We Stand

Single-layered, liquid-phase clouds

MWR-based approaches (LWP)

- **Instrument improvements**
  - WACR, GVR (183 GHz), 90/150 GHz
- **Field studies**
  - MWR IOP (SGP), & GVR (Cadeddu)
- **Algorithm developments**
  - MWRRet VAP
  - Refined MWR retrievals (Wang)
  - Combined AERI+MWR retrievals (Turner)

Complementary approaches (τ, Reff)

MFRSR diffuse flux VAP (Min)

Flux analy. retrs for thin cloud ODs (Long & Barnard)

2-NFOV & SWS (Chiu et al.)

Lidar solar bkgrnd for opt. thick clouds (Marshak et al.)

MWRRET
(Microwave Radiometer Retrievals)

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4 The Pennsylvania State University
5 Pacific Northwest National Laboratory

MWRRET Overview

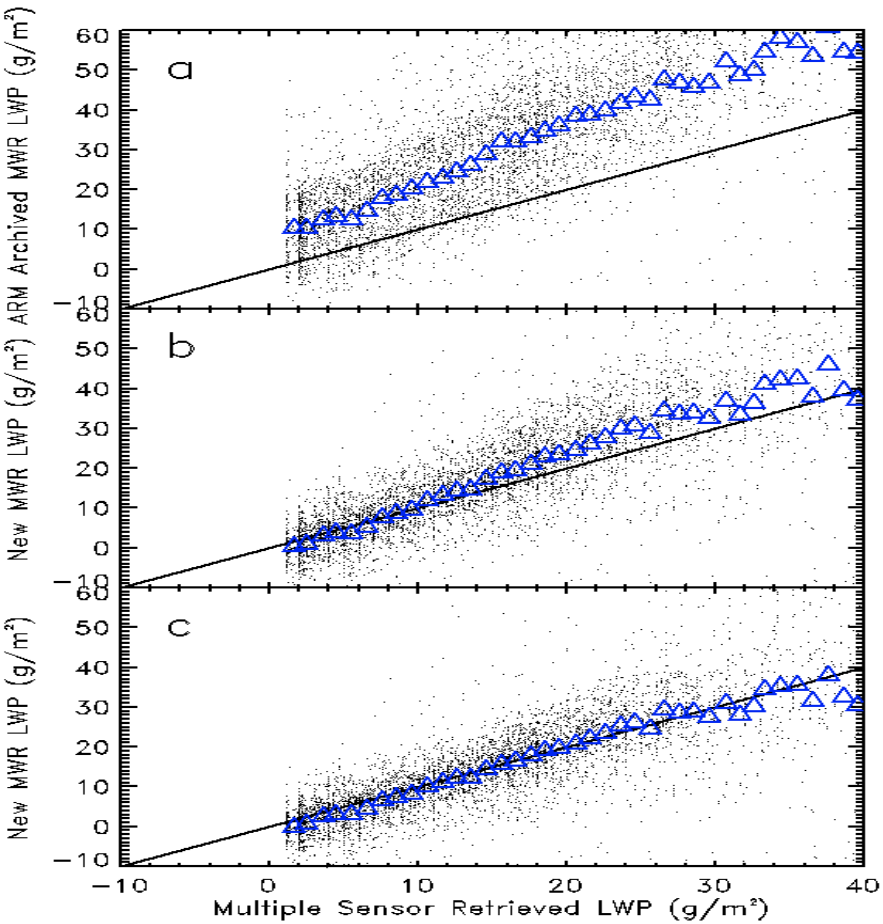
- A new VAP for ARM; will be released in next few months
- Provides improved retrievals of PWV and LWP from ARM's 2-channel MWRs
  - Forward model is AER's monoRTM
  - Provides both physical retrievals and statistical retrievals (latter method uses surface PTU data as additional constraints)
  - Radiometric uncertainty propagated to retrieved quantities
  - Cloud temperature is accounted for by both retrieval methods
  - Uses dynamic 'brightness temperature offsets' to reduce errors in LWP due to calibration uncertainties (drift)
- Beta datasets are available; M. Jensen is working to place these data in the ARM archive
- Manuscript in preparation; will be submitted within the month

Zhien Wang

Using clear sky observations as a reference to improve MWR LWP retrieval at the NSA site

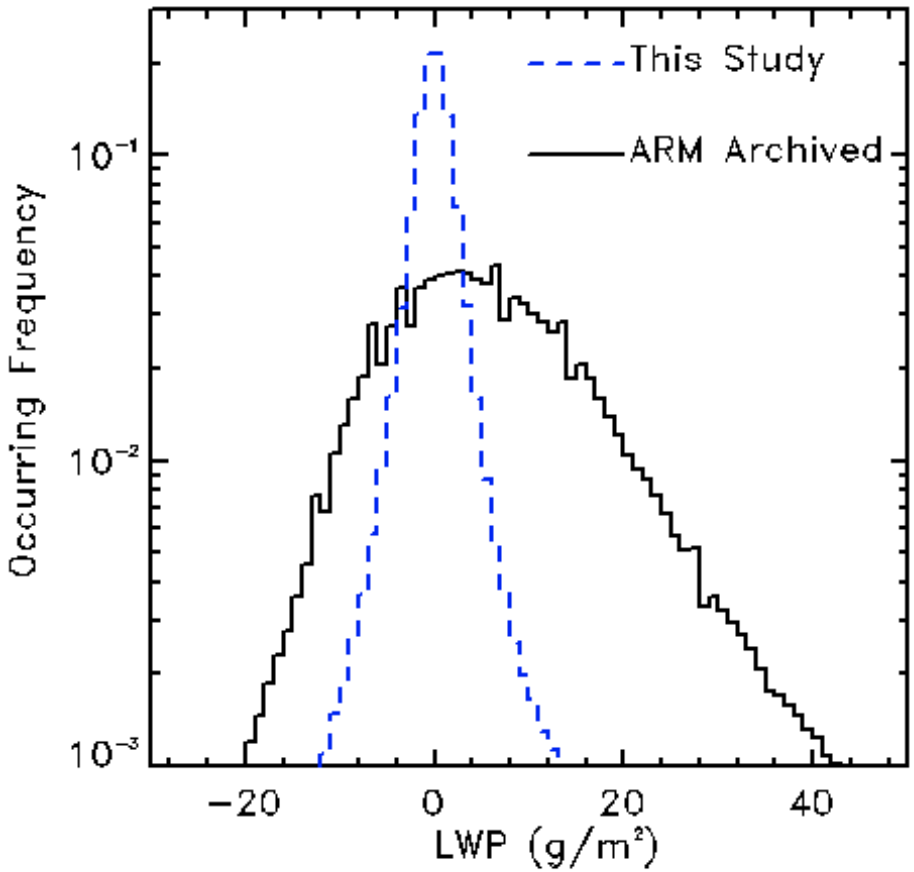
LWP Comparison

MWR vs. multiple sensor

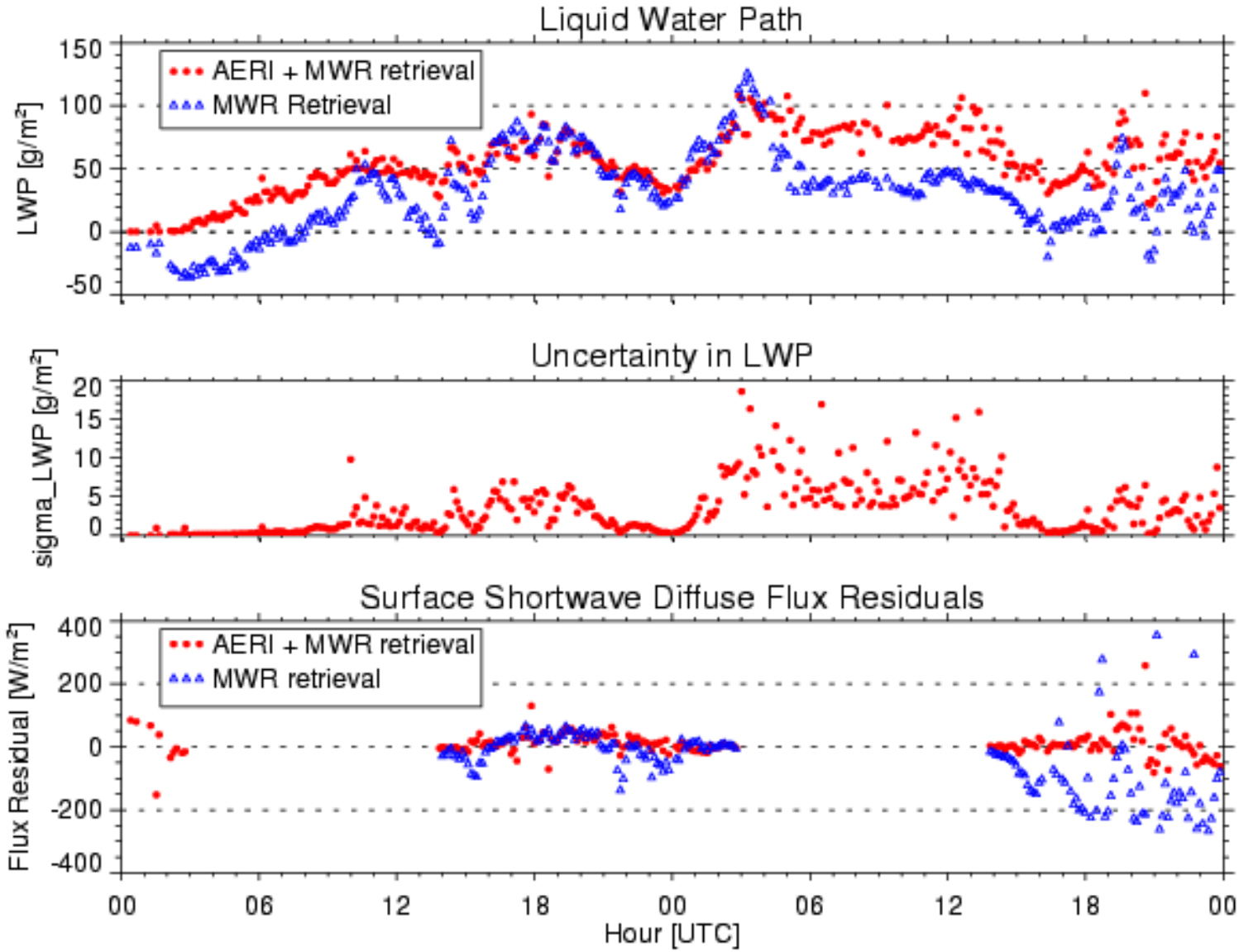


Clear Sky LWP Distribution

New approach vs. ARM archived



Dave Turner
AERI+MWR Method



Field Work - Cadeddu

GVR activity

1. GVR returned to Barrow and started to collect data on September 8
2. Data ingest completed. Data soon to be archived.
3. TGARS paper accepted (GVR instrument + PWV-LWP retrieval)

MWR/MWRP activity

1. MWR IOP under way at the SGP
2. NSA/MWRP new SW installed for fast scan boundary layer profiling improvement
3. Improvement of Monortm oxygen modeling and reduction of LWP bias (TGARS paper accepted)

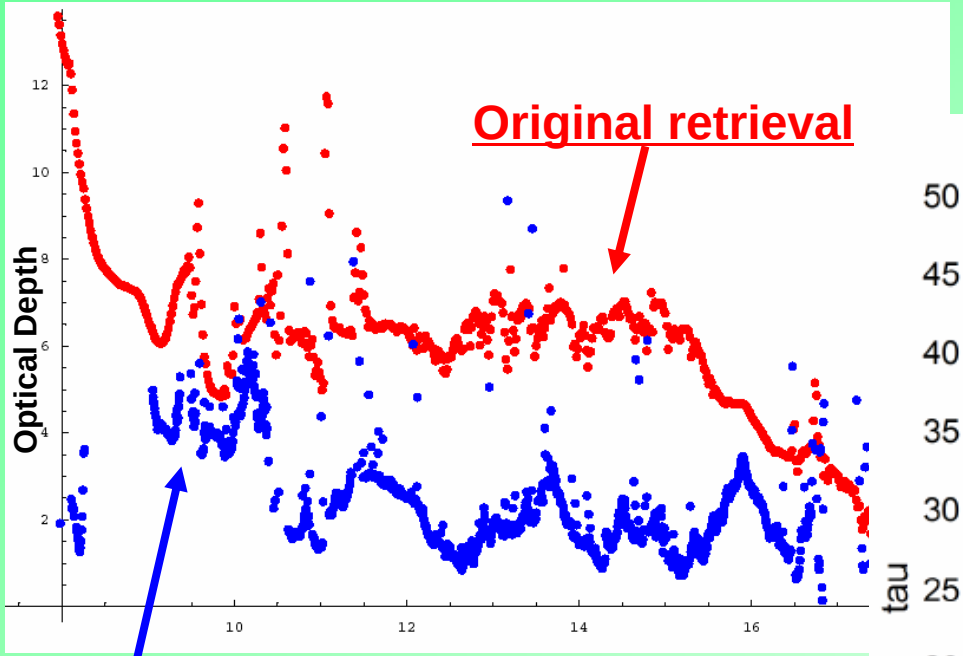
Improvement in Flux Analysis Retrievals for Thin Cloud Optical Depths

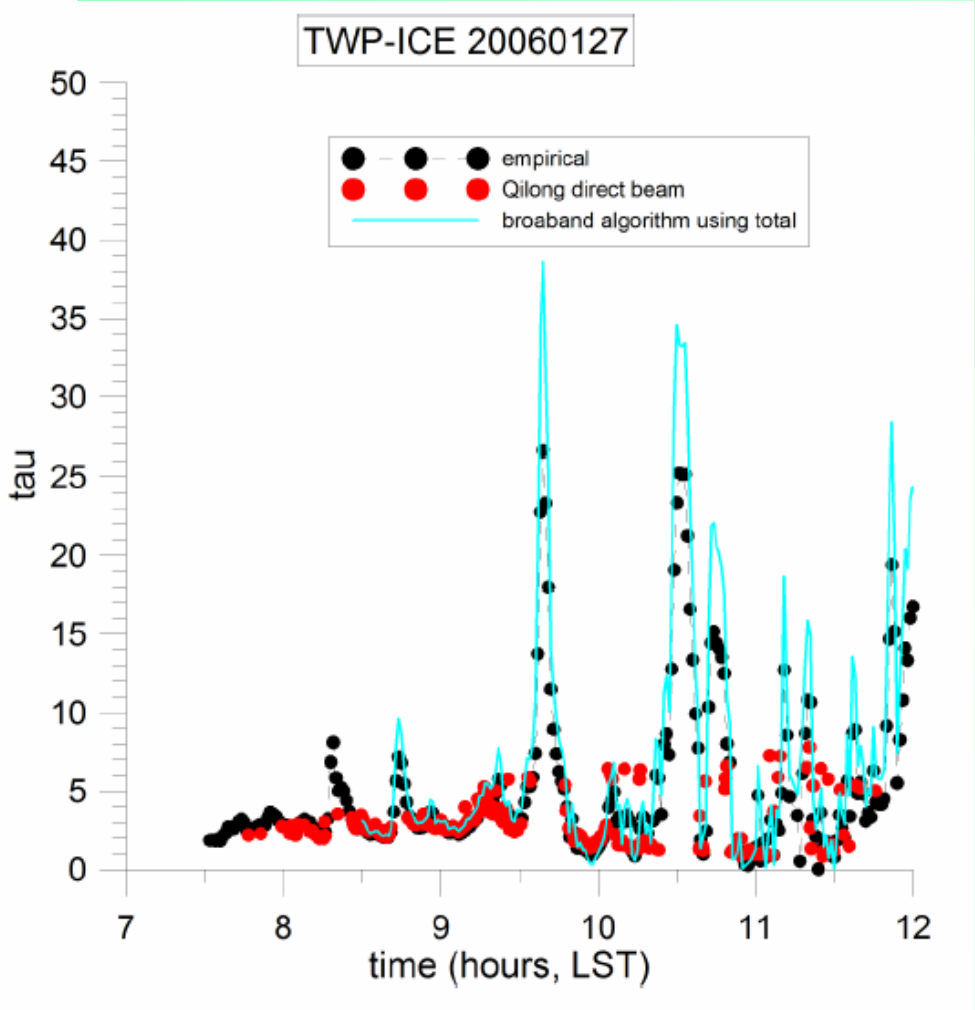
Chuck Long and Jim Barnard

PNNL

TWP-ICE, Jan. 27, 2006

- Thin overcast cirrus case over Darwin





New formula matches MFRSR direct beam retrievals well.

Also well matches SW model calculations using Jennifer Comstock and Evgueni Kassianov ice microphysics retrievals.

No discontinuity/limit in retrievable range.

Marshak et al.

Raman lidar

Lidar solar background for retrievals of cloud optical depth

MPL

Idea:
To use a lidar as a *very*-narrow-field-of-view one-channel radiometer with *calibrated* solar background "noise" as measured zenith radiance.

Technique:
A double-value "zenith radiance vs. cloud optical depth" relationship
plus
a binary information from the same lidar on whether cloud is "thick" or "thin."

Advantage:
- New use of freely available information
- Both cloud and aerosol properties can be retrieved using a single lidar.

Limitations:
- Cloud brokenness may cause serious problems;
- Optical depth between 4 and 12 is hard to discriminate.

Reference:
Chiu J.C., A. Marshak, W. J. Wiscombe, E. J. Welton, and S. C. Valencia, 2006. Cloud optical depth retrievals from solar background "signal" of micropulse lidars. *Geosci. Remote Sens. Lett.,* (in press).

Chiu et al.

2NFOV radiometer for retrievals of cloud optical depth

Idea and Technique :
To use zenith radiance at two wavelengths (0.67 and 0.87 μm), where cloud optical properties are similar but the vegetated surface albedos are different, to retrieve cloud optical depth and effective cloud fraction.

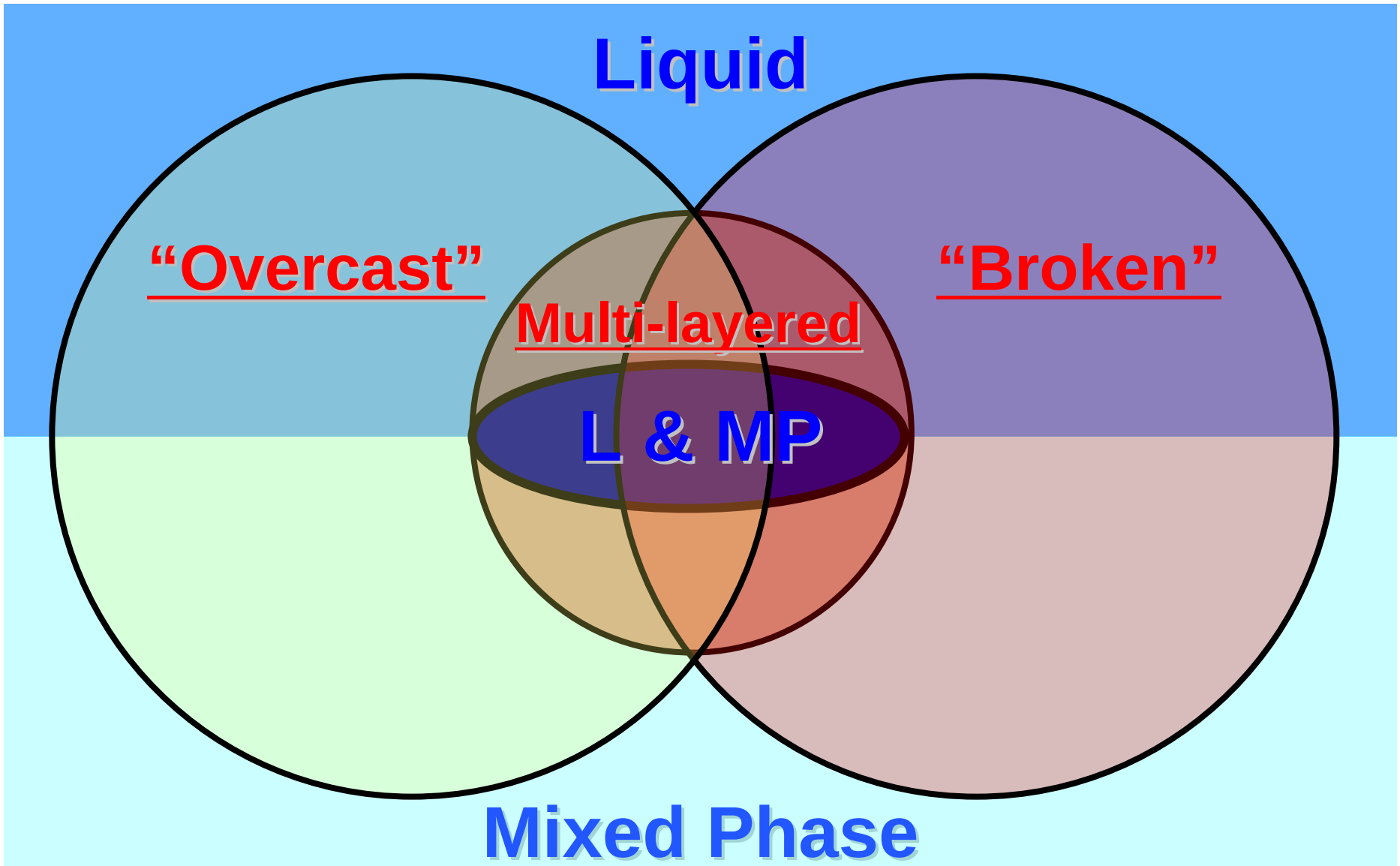
Advantage:
- Can work in fully 3D situations;
- In addition to cloud optical depth provides effective cloud fraction.

Limitations:
- Requires vegetation with NDVI > 0.4.

Main references:
Marshak, A., Knyazikhin, Yu., Evans, K.D., and Wiscombe, W.J., 2004. The "RED versus NIR" plane to retrieve broken-cloud optical depth from ground-based measurements. *J. Atmos. Sci.*, 61, 1911-1925.

Chiu, J. C., A. Marshak, Y. Knyazikhin, W. J. Wiscombe, H. W. Barker, J. C. Barnard, Y. Luo, 2006. Remote sensing of cloud properties using ground-based measurements of zenith radiance. *J. Geophys. Res.*, 111, D16201, doi:10.1029/2005JD006843.

CLOWD Clouds



“Sticky” Points

Many things fine for typical applications, but CLOWD pushes the limits

- e.g., If only want 10% accuracy → 0.1x50 gm^{-2} = 5 gm^{-2} !

MWRs

- More recent evidence of some sort of sub-daily fluctuation in the signal? (Turner, Cadeddu)

Operation/calibration of new/important instruments

- NFOV/SWS (w/ 1.6 μm channel)
- MPL background calibration (very new)

(cont.)

“Scale babble”

Time and/or spatial (FOV) sampling mismatch

- ‘Inconvenient' for intercomparisons
- Wreaks havoc on multi-sensor retrievals (Turner)

Validation via a (future) CLOWD IOP

- CLOWD clouds are tenuous
- Tricky to get suitable in situ sampling

Paths forward – A lot of work in progress

1. Instruments

WACR
GVR
90/150
TC-RSR (proposed)

2. Retrieval methods

MFRSR diffuse flux VAP (Min)
Flux analy. retrs for thin cloud ODs (Long & Barnard)
2-NFOV & SWS (Chiu et al.)
Lidar solar bkgrnd for opt. thick clouds (Marshak et al.)
New MWR (Wang, Turner)
AERI (Turner)
AERI+MWR+MFRSR (Turner)

(cont.)

3. Field Studies & IOPs

a) Past/current

- Pt Reyes is a CLOWD gold mine
- SGP MWR IOP (Cadeddu)
- GVR work (Cadeddu)

b) Coming up

- RHUBC-1
- CLASIC
- COPS (CLOWD?)
- ISDAC

Optimistic will resolve the issues

Project a 2009 CLOWD IOP to test/validate

“What we can expect from liquid water cloud remote sensing in terms of accuracy within the next year or two?”

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Single-layered, liquid-phase clouds

- MWR uncertainties (SGP, COPS)
- New MWRs (GVR, 90/150)
- Overcast
  - Merged AERI+MWR+MFRSR (Turner)

Move to more complicated CLOWD Cases

- Broken clouds (NFOV)
- Mixed phase
- Multi-layered systems

Operational?