CLOWD Progress & Plans

ARM Science Team Meeting
Norfolk, Virginia, March 2008

Andy Vogelmann, Dave Turner
& Jennifer Comstock

Plus

CLOWD PI Contributors

Warren Wiscombe, Christine Chiu, Sasha Marshak, Maria Cadeddu, Qilong Min, Susanne Crewell, Ulrich Löhnert, Mandy M. Khaiyer, Greg McFarquhar , Chuck Long, Bill O'Hirok, Bin Lin, Connor Flynn, Eli Mlawer, Graham Feingold, Jim Barnard, Jim Liljegren, John Ogren, Karen Cady-Pereira, Karen Johnson, Mark Miller, Mary Jane Bartholomew, Matt Shupe , Mike Reynolds, Pat Minnis, Ray Edwards, Richard Austin, S. Y. Matrosov, Sally McFarlane, Scott Smith, Tim Shippert, Tony Clough, Zhien Wang

OUTLINE

1. Background
2. Recent Highlights
3. Validation & Vetting -- Need “truth”
4. Build modeler interface

Background

"CLOWD"

- **Clouds with Low Optical Water Depth**
- **Defined LWP ≤ 100 gm^{-2} ($\tau \approx 12$ to 25)**
- **MWR's uncertainty is 20-30 g m^{-2} (i.e., errors of 20% to over 100%)**

Why?

- **Optical depth most basic cloud optical property**
- **CLOWDs common globally**
- **Radiation *very* sensitive to perturbations at low optical depths**

Cloud LWP Frequencies

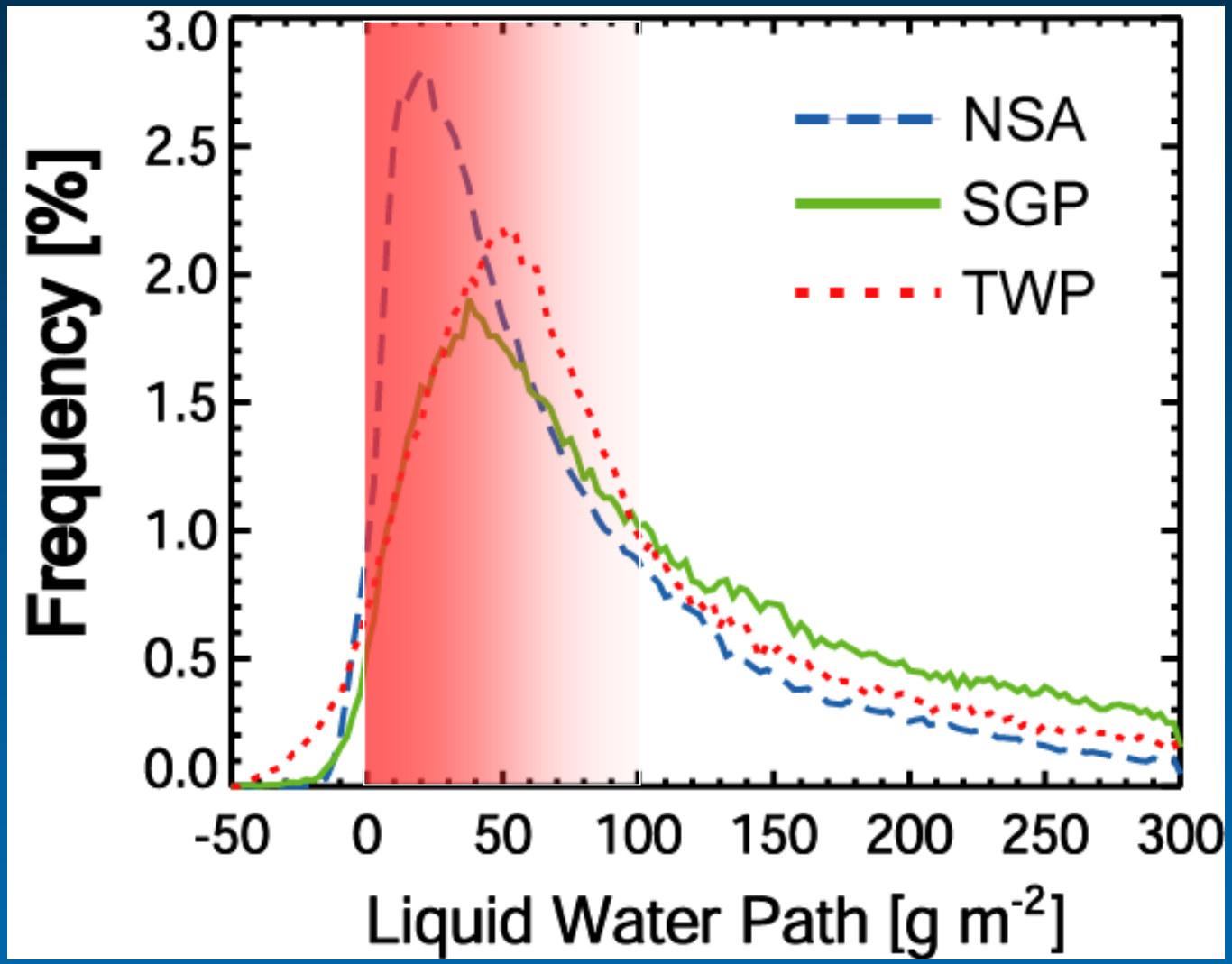


Figure adapted from Turner et al. (*TGARS*, 2007)

Research Areas Effected

Modeling continental boundary layer clouds

- Poor agreement w/ observations (Lenderink et al., 2004)
- Subgrid scale to boot!

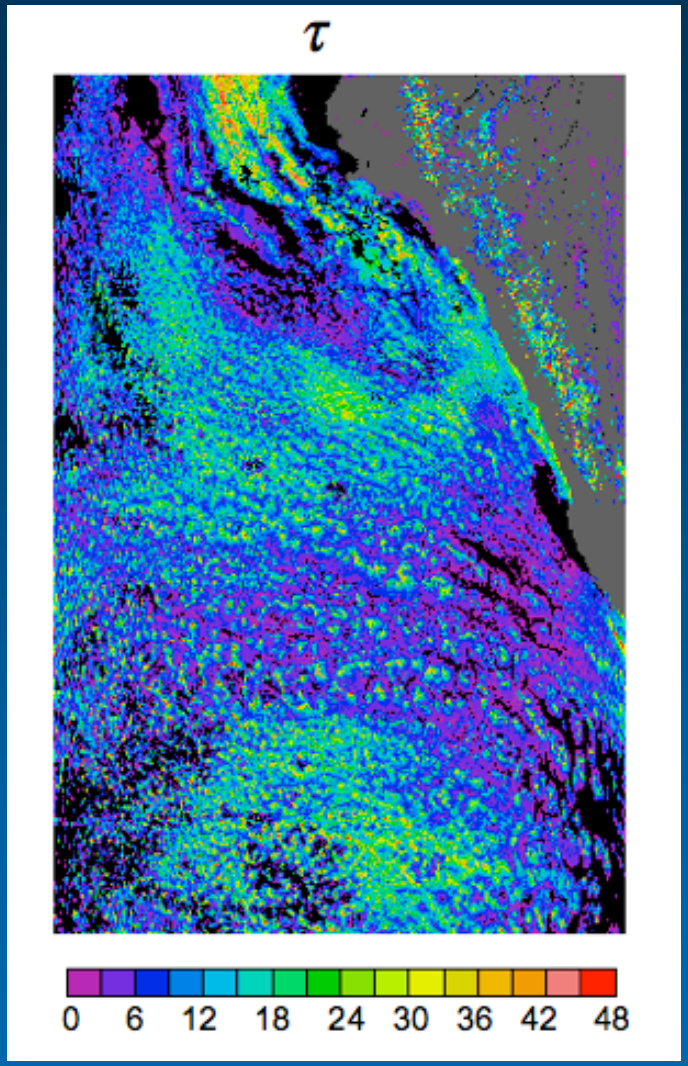
Marine boundary layer (MBL) clouds

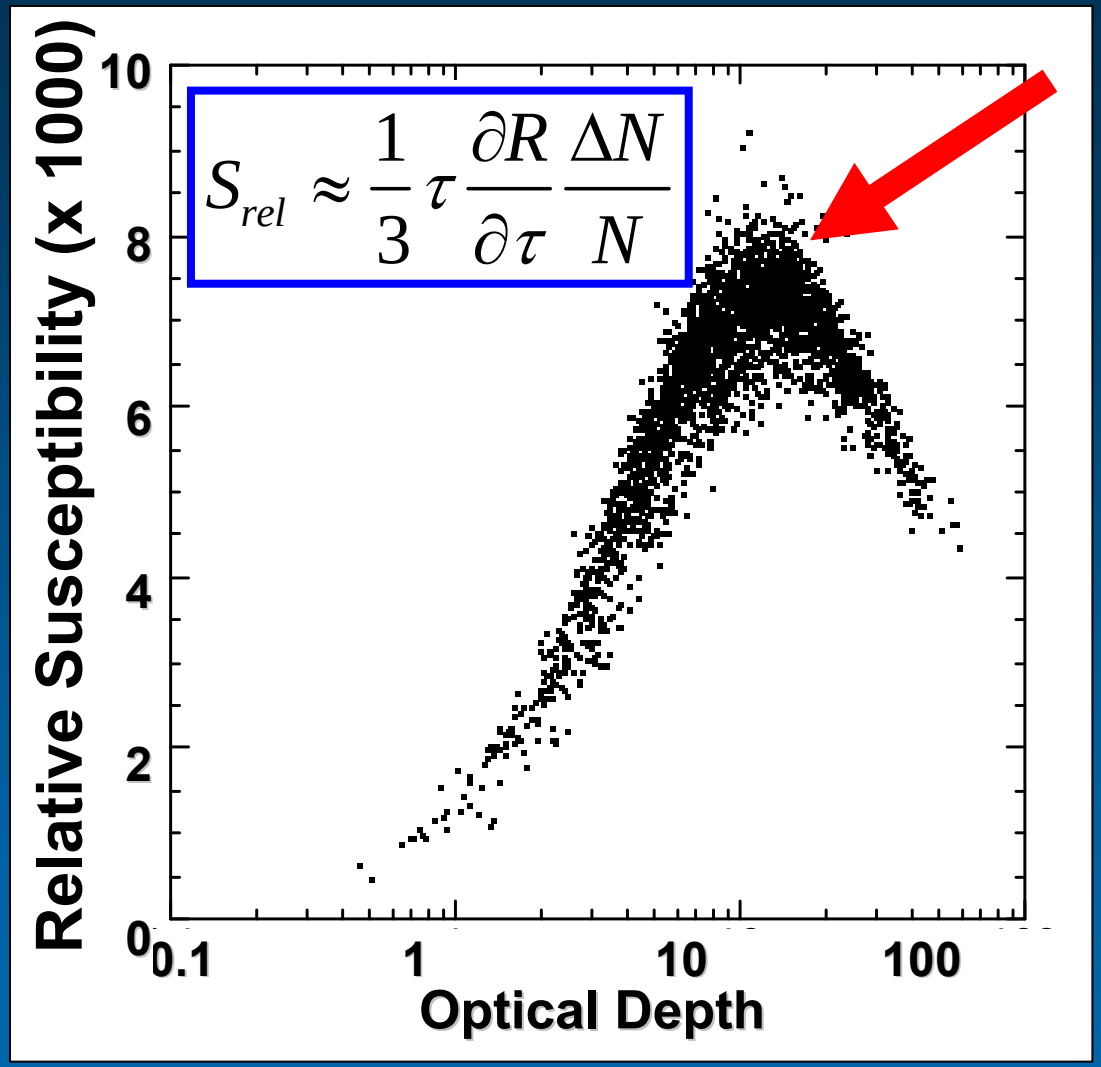
- MBL cloud albedos poorly simulated (Zhang et al., 2005; Bender et al., 2006; Zhu et al., 2005)
- Main source of uncertainty in GCM tropical cloud feedbacks (Bony and Dufresne, 2005)

Aerosol Indirect Effects (AIE)

- AIE has greatest uncertainty range (IPCC, 2001)
- AIE least saturated for thin and developing cloud

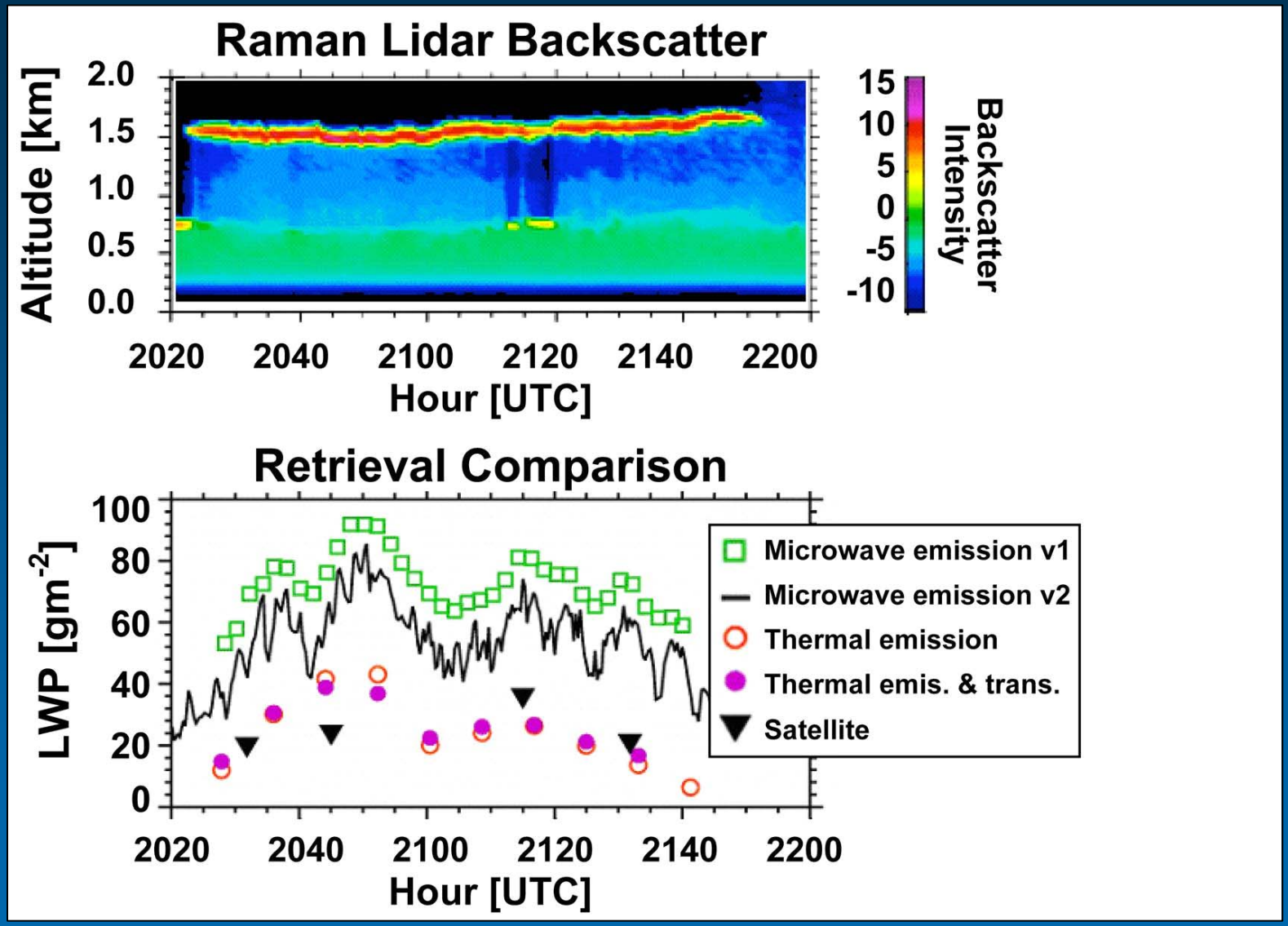
Cloud Relative Susceptibility





Platnick and Oreopoulos (*JGR*, Submitted)

CLOWD BAMS Paper



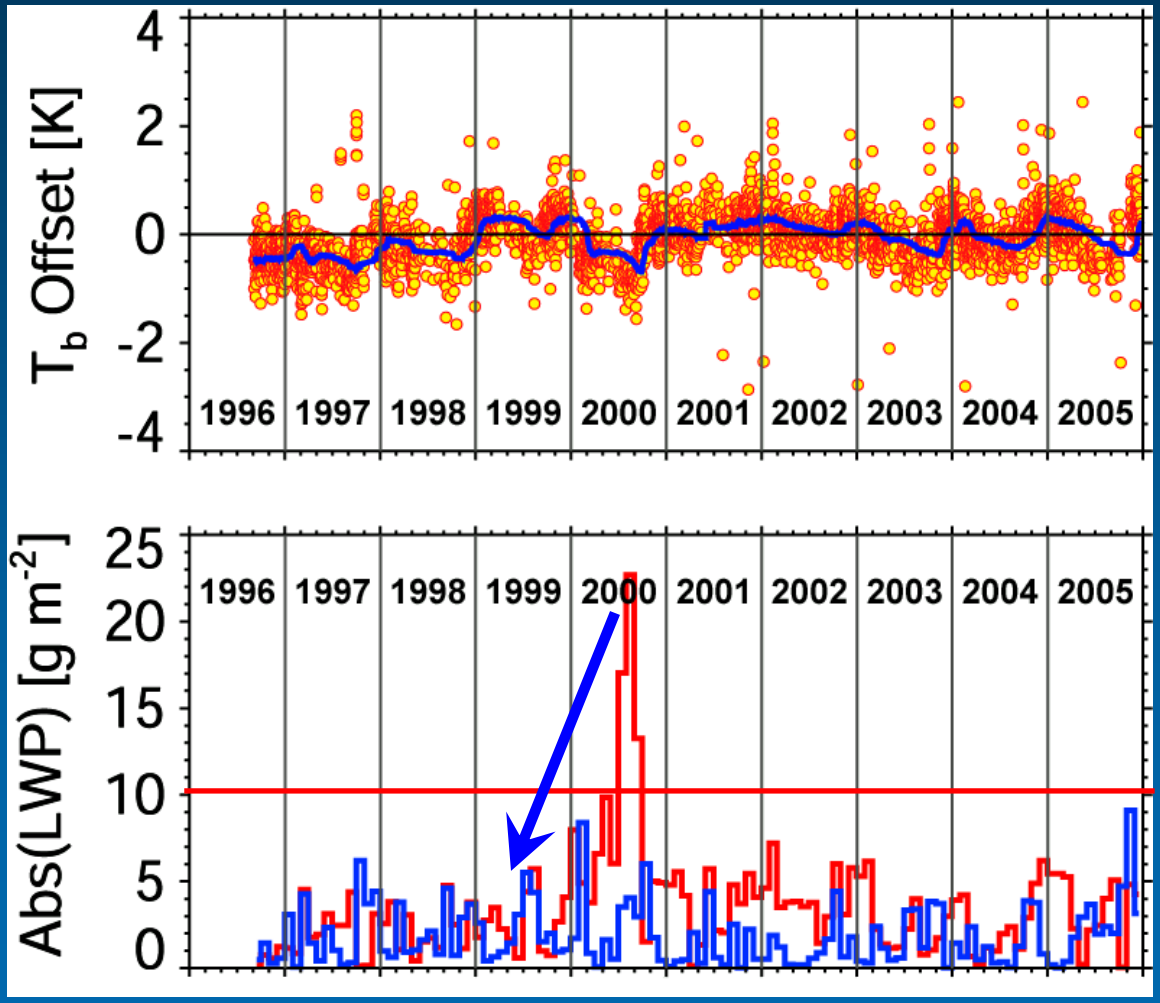
Turner and 21 Co-Authors (BAMS, 2007)

Instruments

- **Microwave Radiometers**
  - 183 GHz (GVR) [NSA]
  - 90/150 GHz microwave radiometer [SGP & AMF/COPS]
  - 3-channel MWR to be deployed
    - 23, 31, and 90 GHz, with an option to add 4th at 183 GHz
- **Longwave Radiometers**
  - AERIs made "fast-scanning"
- **Shortwave Radiometers**
  - 2-Channel NFOV & Cimel in "cloud" mode
  - Shortwave Spectroradiometer (SWS)
  - Thin-Cloud Rotating Shadowband Radiometer (TC-RSR)
- **Raman Lidar**
  - Liquid-water profile retrievals

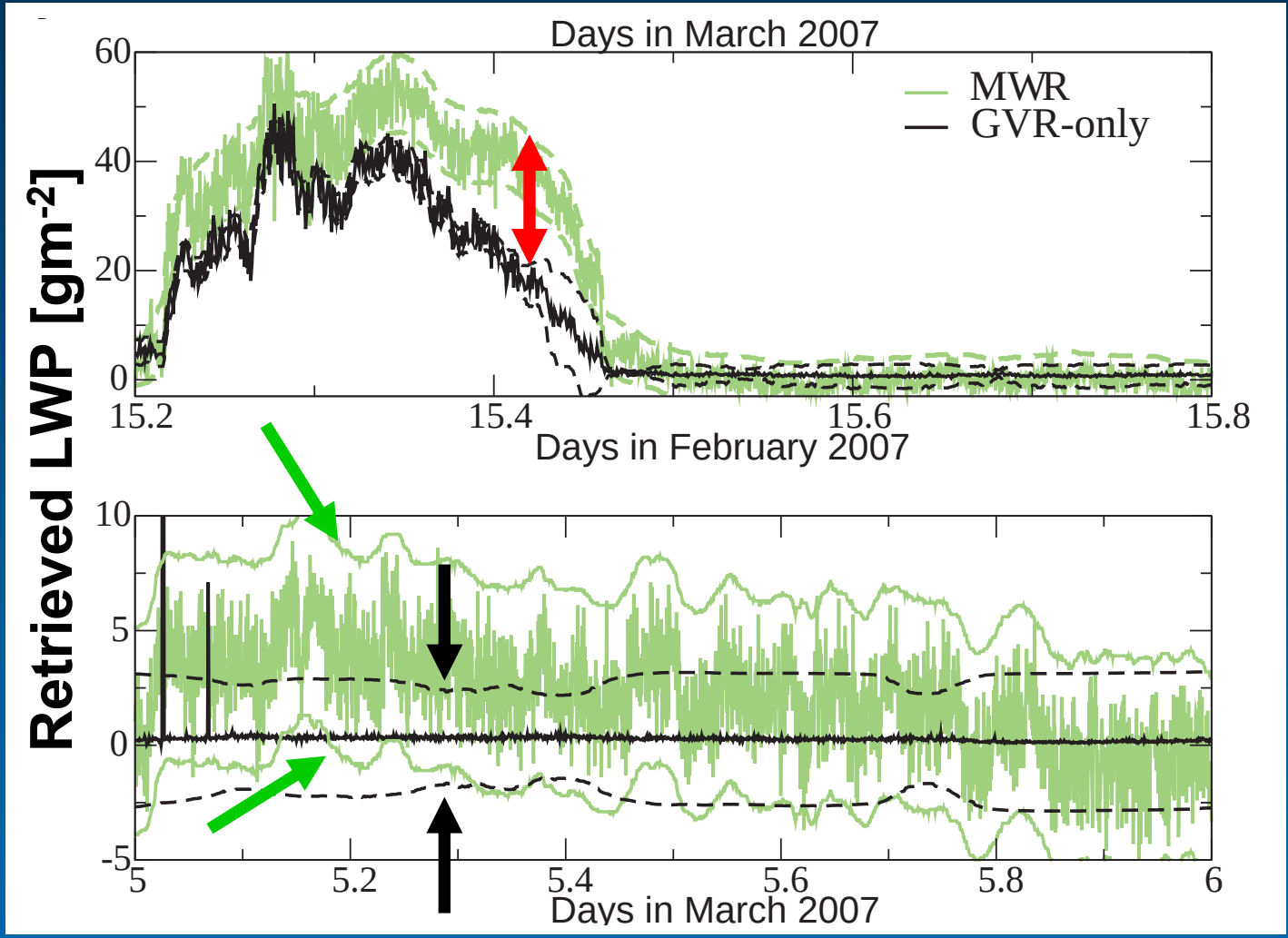
MWRRet -- A new VAP

Improving Standard ARM Microwave Radiometer Retrievals of PWV and LWP



Turner et al. (*TGARS*, 2007)

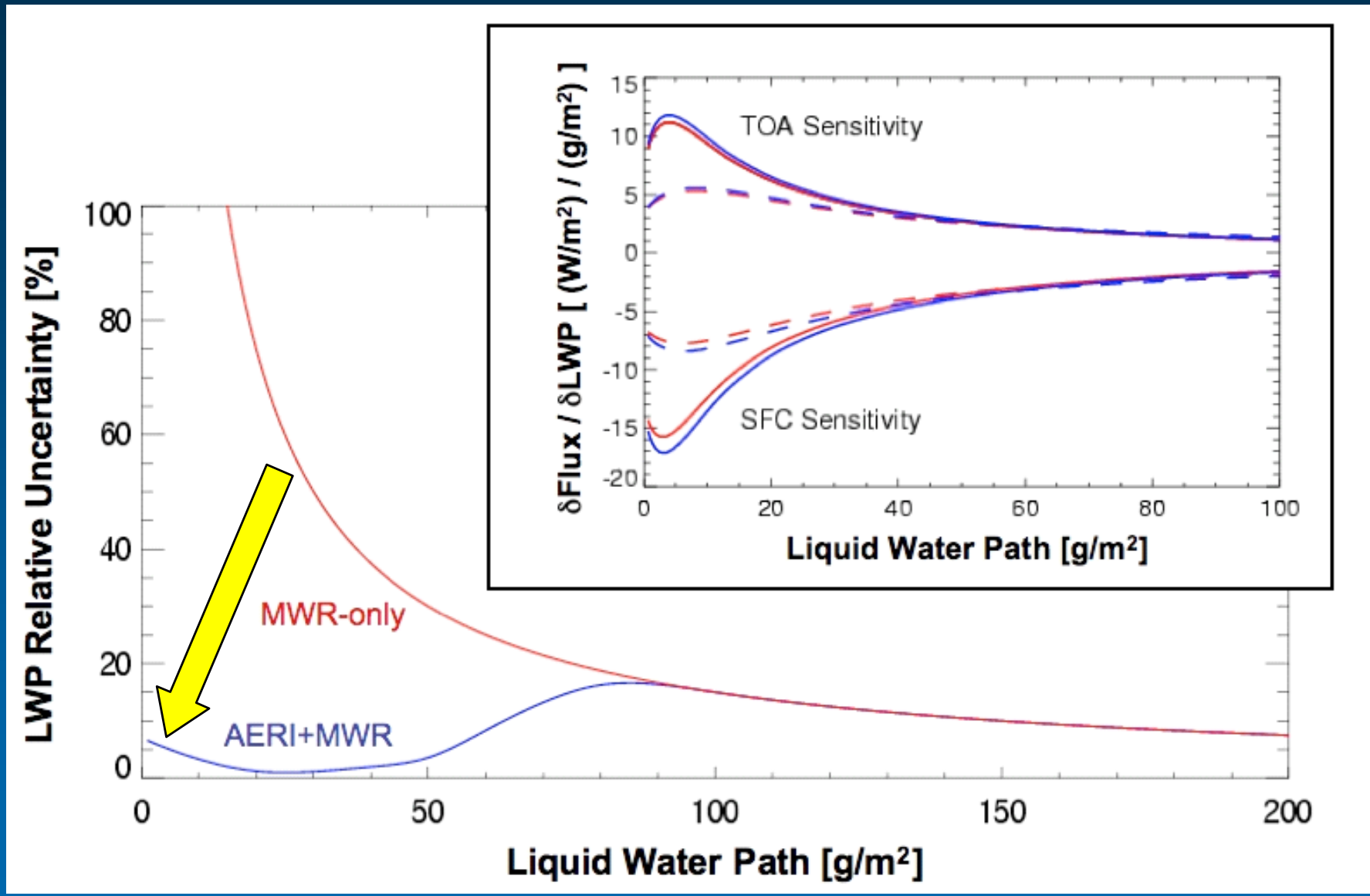
Neural Network Retrievals of PWV & LWP from 183 GHz Observations



Cadeddu et al. (*TGARS*, 2007)

Cadeddu et al. (*TGARS*, Submitted)

Joint MWR-AERI Retrievals

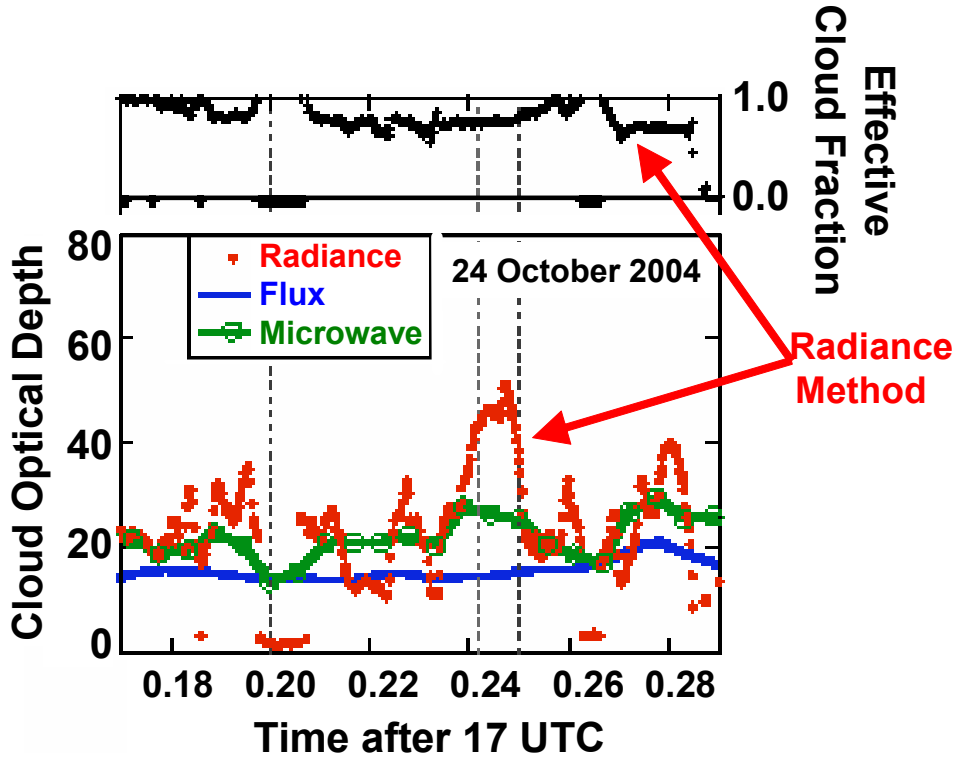


Turner (*JGR*, 2007)

Broken Cloud Retrievals

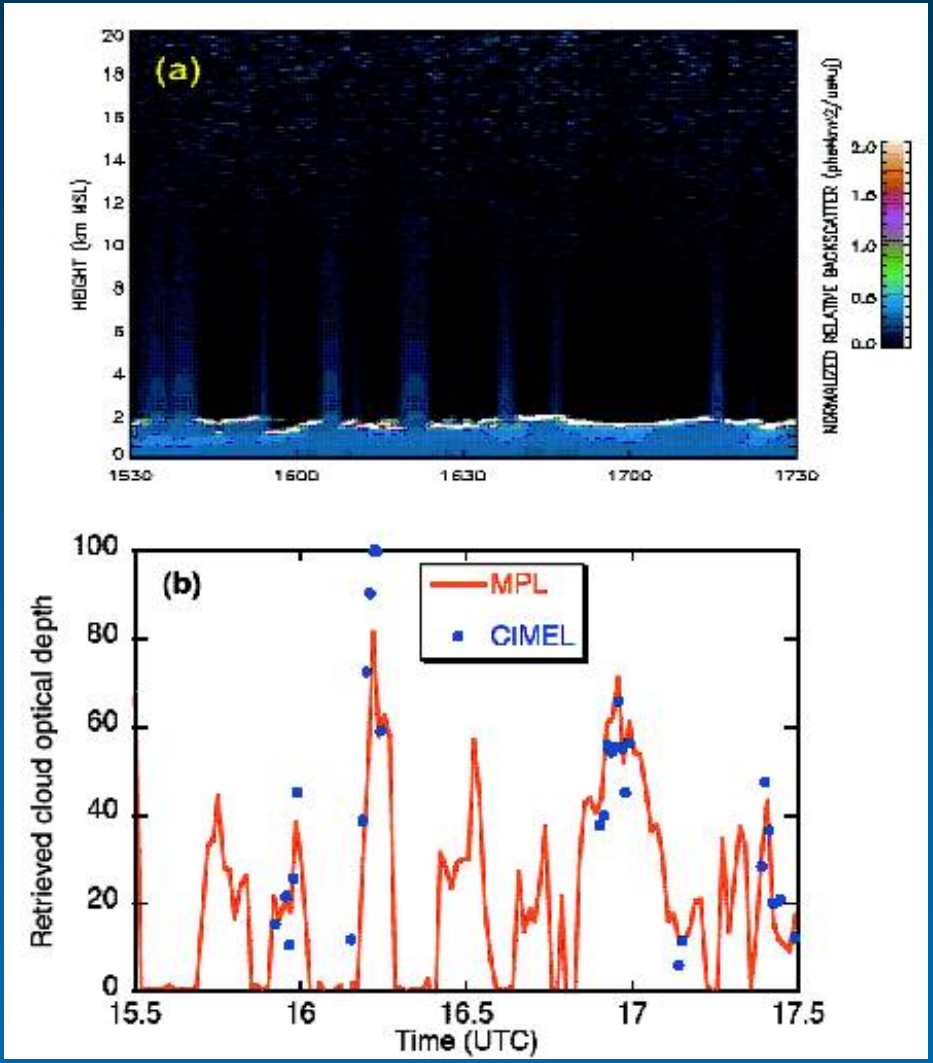
Remote Sensing of Cloud Properties Using Surface Measurements of Zenith Radiance

Retrievals of Cloud Optical Depth & Effective Cloud Fraction



Chiu et al. (*JGR*, 2006)

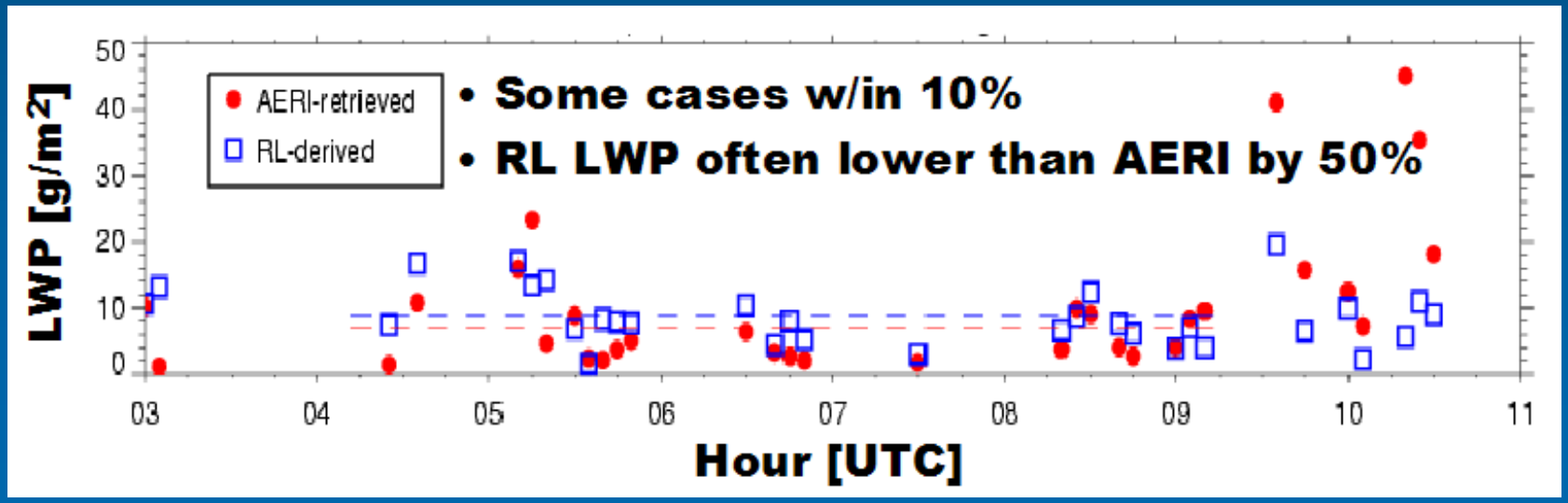
Lidar THICK Cloud Retrievals Using the Solar Background Signal



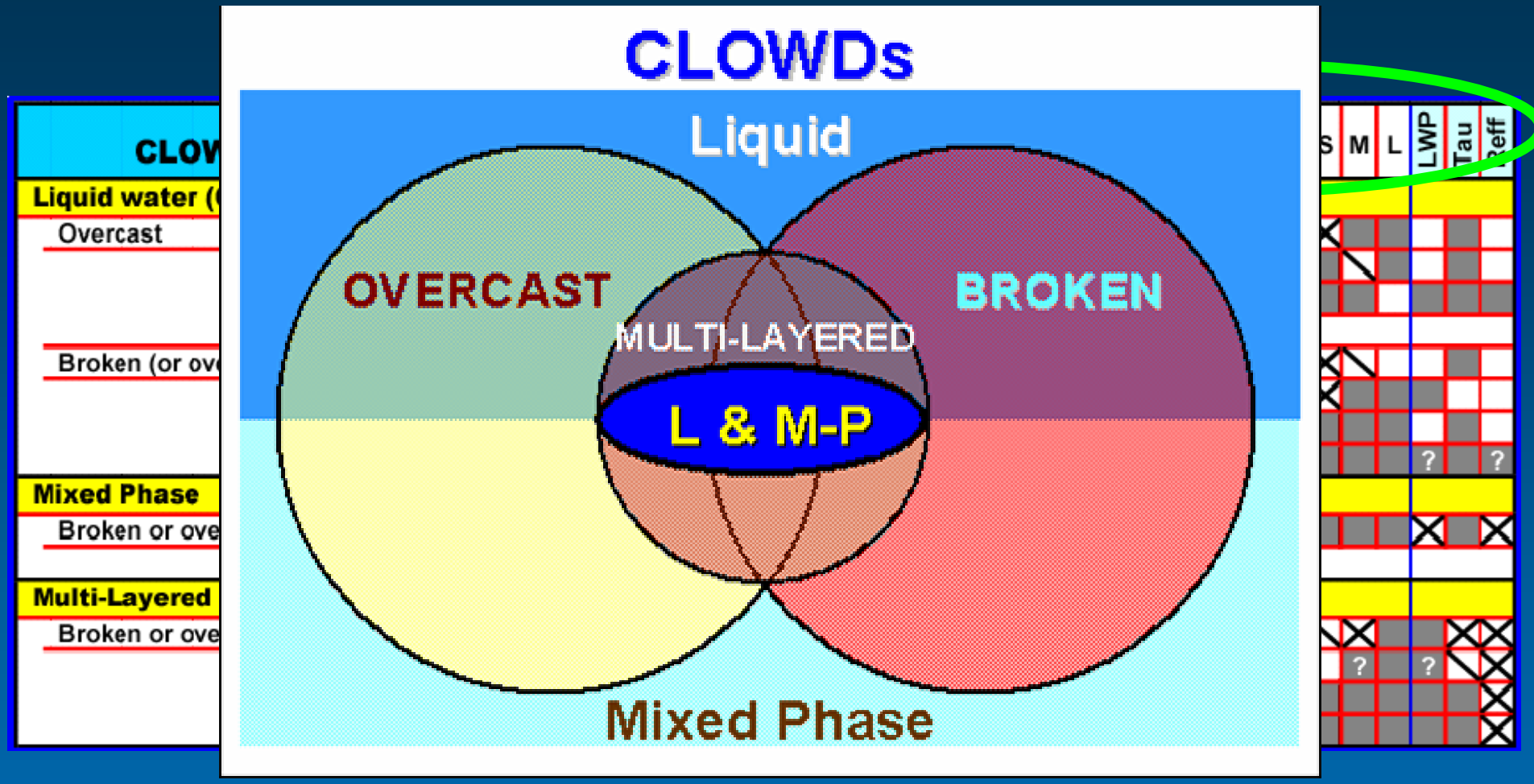
Chiu et al. (*Geosci. Remote Sens. Lett.*, 2007)

SGP Raman Lidar Liquid Water Profiles

- **Modified Raman Lidar in Sep 2005**
  - Profile liquid water and (by extension) Reff
- **Due to weak signal**
  - Only nighttime LWC profiling
  - Thin ($\tau < 3$) clouds (15 to 25 gm^{-2})
- **LWC profile calibrated w/ a 1st-principles approach**
- **Evaluated via a comparison with AERI-retrievals**



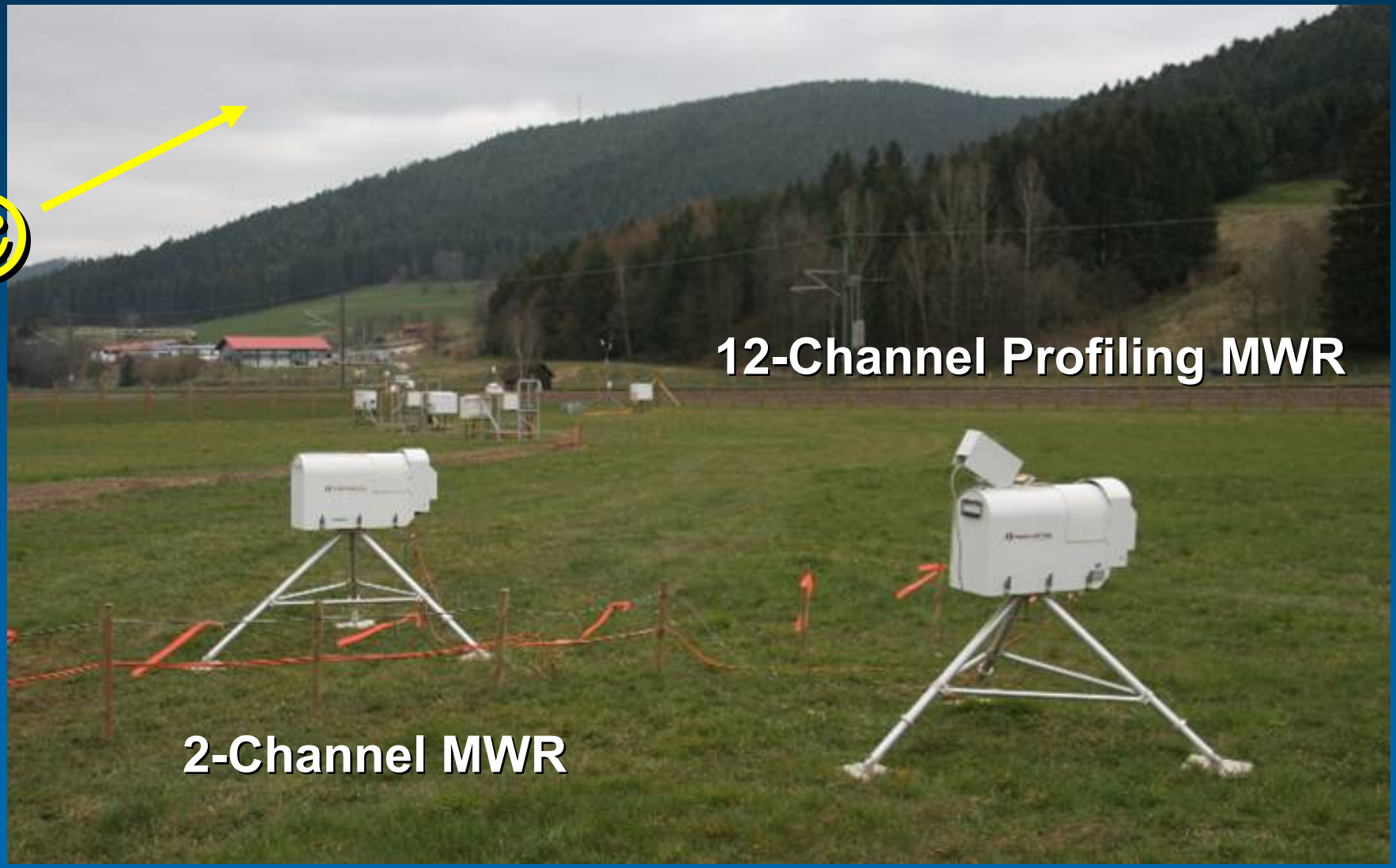
Russo, Whiteman, Turner, Demoz, and Hoff (JTech, Submitted)


CLOWDs
Liquid
OVERCAST
BROKEN
MULTI-LAYERED
L & M-P
Mixed Phase
CLOW
Liquid water (
Overcast
Broken (or ov
Mixed Phase
Broken or ove
Multi-Layered
Broken or ove
S
M
L
LWP
Tau
Reff

Validation needs “Truth”

- Cloud MW Dielectric Properties
  - **COPS CLOWD 90/150 Experiment ’08**
- Vet Retrievals for Operational Use
  - **Flux Closure via BBHRP-CLOWD**
- Microphysics “Referee”
  - **RACORO ‘09**

Cloud Microwave Validation Experiment in Support of CLOWD -- *90/150 MWR at COPS*



AMF/COPS Site -- Heselbach, Germany

CLOWD-BBHRP
(Broadband Heating Rate Profiles)

Jen Comstock, Eli Mlawer, Tim Shippert,
Dave Turner, and Andy Vogelmann

Objectives

1. Use BBHRP to evaluate CLOWD retrievals
   - Use residuals for statistics per CLOWD type

2. BBHRP calculations for CMWG CLOWD simulations
   - Need periods where variational analyses exist

CLOWD Cases

• Overcast, single-layered warm cloud	AMF/Pt Reyes
• Broken, single-layered warm cloud	AMF/COPS, SGP
• Mixed-phase cloud, single-layered	NSA
• Broken M-P cloud & Multi-level clouds	SGP

RACORO

Routine
Aerial Vehicle Program (AVP)
Clouds with Low Optical Water Depths (CLOWD)
Optical
Radiative
Observations

Steering Committee

Andy Vogelmann, Greg McFarquhar, Dave Turner, Jennifer Comstock, Graham Feingold, Chuck Long and John Ogren

RACORO Overview

- **Conduct long-term, routine flights in the boundary layer, liquid-water clouds at SGP**
  - **Microphysical properties**
  - **Optical properties and radiative fluxes, and**
  - **Associated aerosol properties & atmos. state**
- **Long-term statistics needed because these clouds are thin and/or broken, which make retrievals highly uncertain**
  - **Help develop & evaluate cloud retrievals**
  - **Improve our understanding of how boundary layer clouds interact with aerosols & radiative fluxes**

Summary

- **BAMS paper defined the problem**
- **Focused research efforts to improve**
  - **Instrumental aspects**
  - **Retrieval approaches/theory**
- **Vetting & Integration ➡ Best Estimate**
  - **MWR cloud prop., Flux closure, Microphysics**

CLOWD Science Team Menu

PI Posters!!

BBHRP-CLOWD	Comstock, McFarlane	Tues, 1:00-3:00
AMF/COPS 90/150	Cadeddu, Crewell	Wed., 7:30-9:00
RACORO	RACORO Team	Thurs, 1:00-3:00