Recent Activities of the ARM Radiative Processes Working Group

Dave Turner

RPWG Chair

Space Science and Engineering Center

University of Wisconsin - Madison

2008 CERES Science Team Meeting
NASA GISS
New York City
28 October 2008

ARM Program Objectives

- Relate observed radiative energy (spectrally and temporally resolved) to temperature and composition of the atmosphere

- Develop and test parameterizations of the radiative properties and processes of water vapor, clouds, and aerosols, and incorporate these parameterizations in GCMs

ARM Science Plan
October 2004

Working Groups within ARM

Working Groups within ARM

- Radiative Processes
- Aerosol
- Cloud Properties
- Cloud Modeling

Working Groups within ARM

- Radiative Processes
- Aerosol
- Cloud Properties
- Cloud Modeling

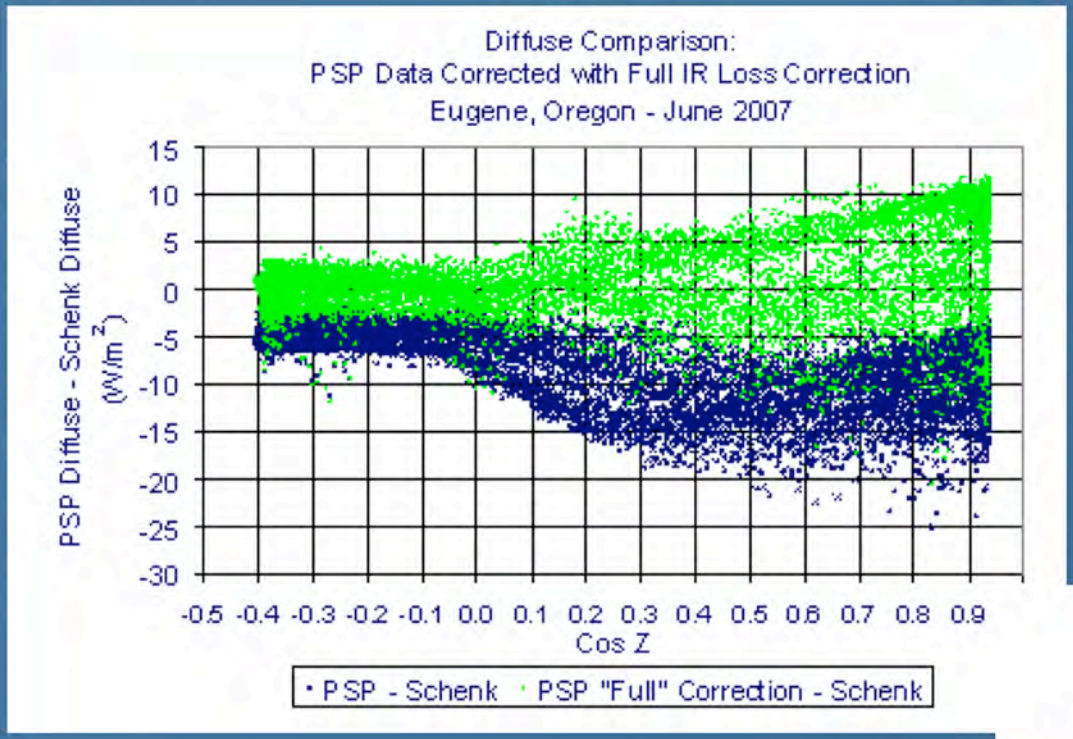
- Several “focus groups”
  - *CLOWD* (clouds with low liquid water path)
  - Vertical velocity
  - *BBHRP*
  - Several instrument focus groups

RPWG Steering Group

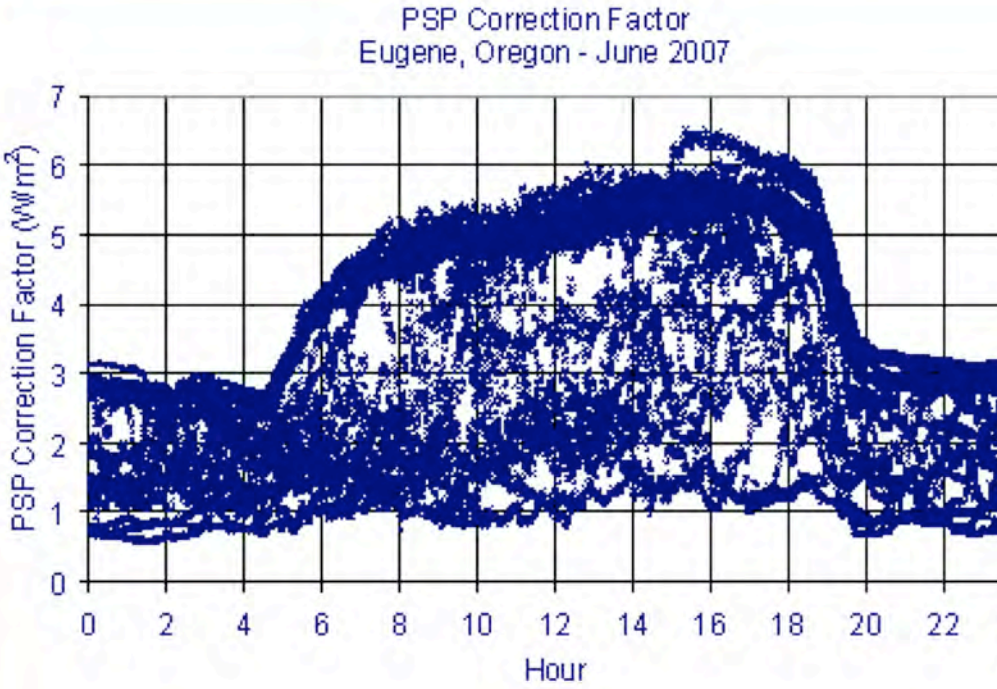
- Bob Ellingson, FSU
- Chuck Long, PNNL
- Sally McFarlane , PNNL
- Andy Vogelmann, BNL

Represent about 40 RPWG members

Correcting IR loss in pyranometers



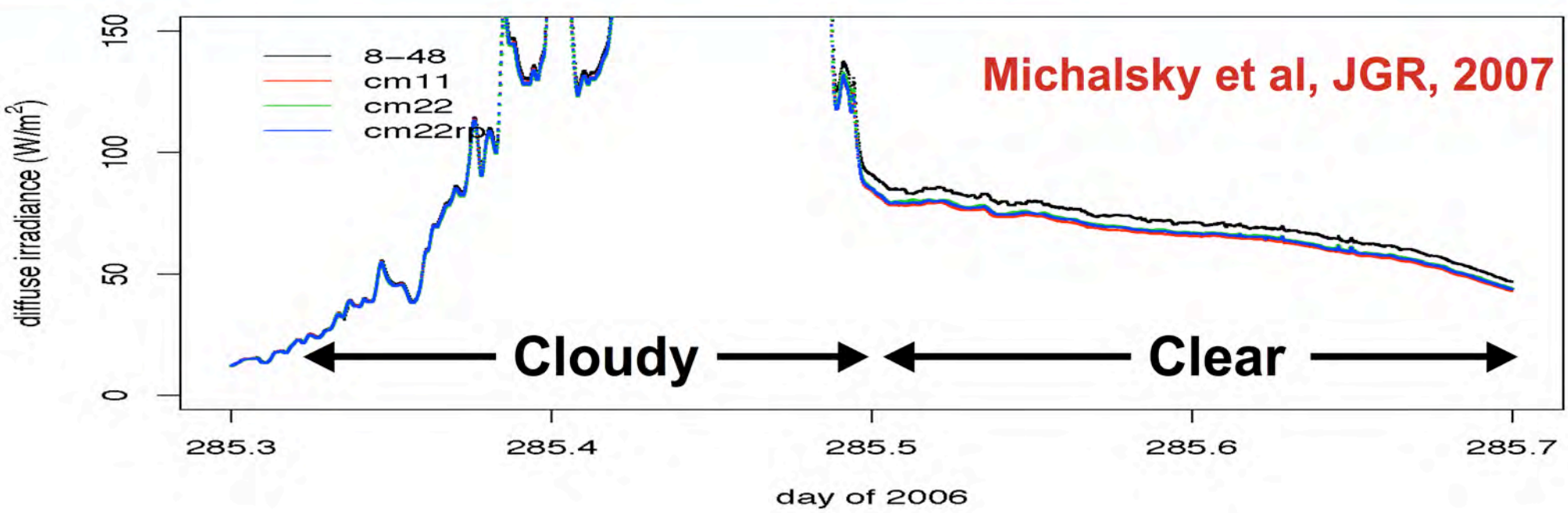
Alternate methods of correcting for IR loss are investigated for use when collocated pyrgeometer information is not available (left). Study confirms that IR loss is greate during daylight hours than at night (below).



Vignola, Long, and Reda, OMMSES, 2007.

SW Diffuse Radiation 'Standard'

- Carefully characterized 4 diffuse pyranometers
- Shade/unshaded calibration performed during Diffuse IOP at SGP site
- Excellent agreement in cloudy scenes, only the '8-48' diverges slightly in clear skies

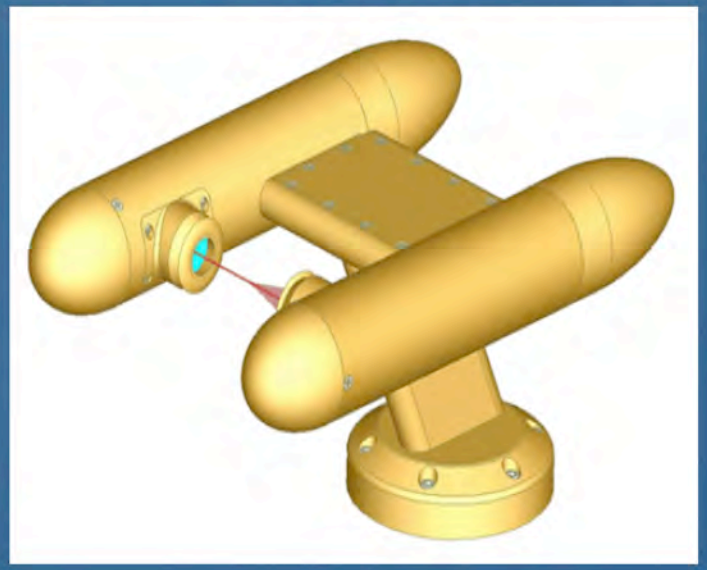


Measurements of Small Ice Crystals (D < 50 μm)

Cloud and Aerosol Spectrometer

Shroud Inlet

Cloud Droplet Probe

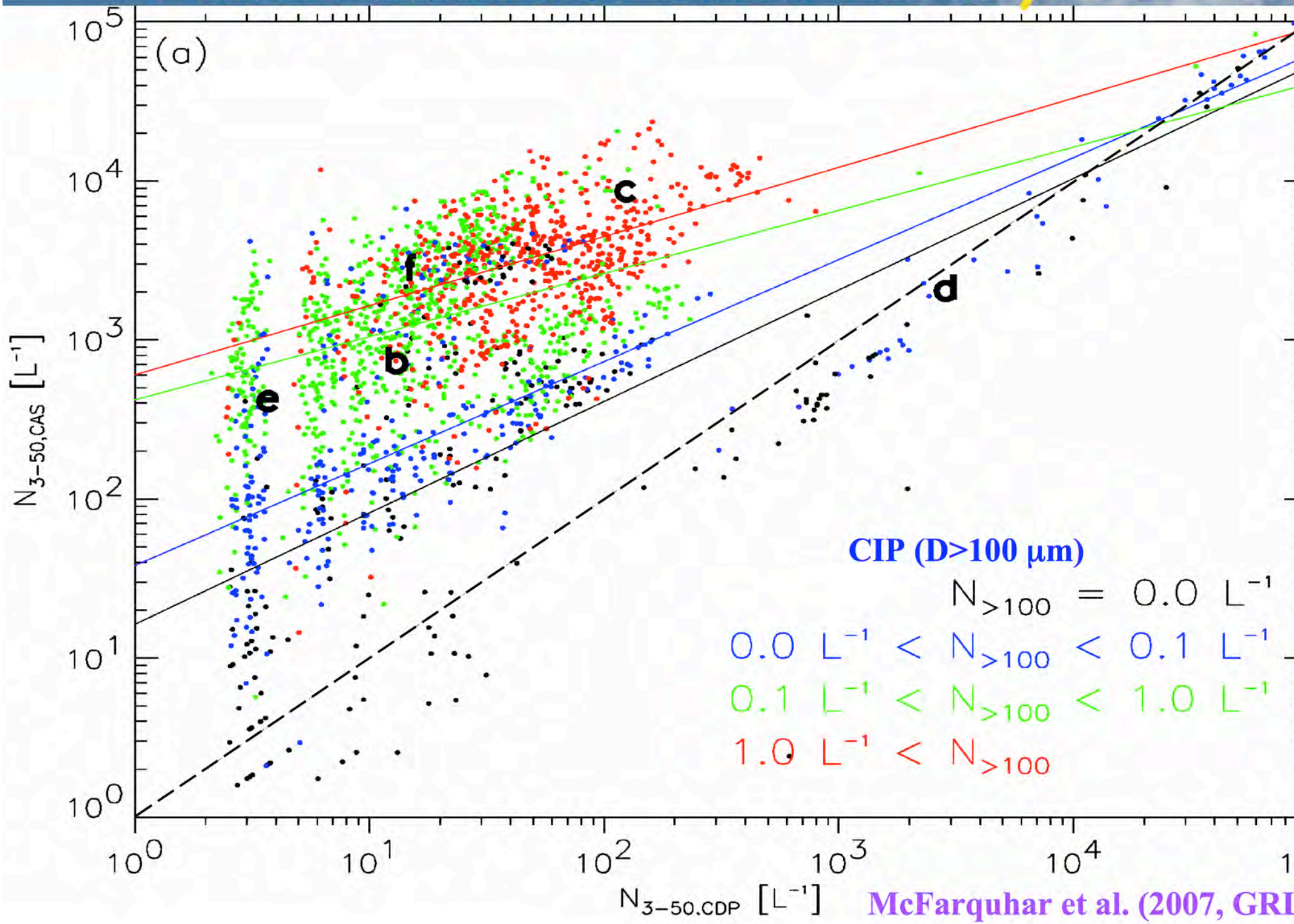


- Open path
- Neither inlet nor shroud

- The same working principle and look-up table
- Do large crystals shatter on inlet or shroud of CAS?

McFarquhar et al. (2007, GRL

Measurements of Small Ice Crystals



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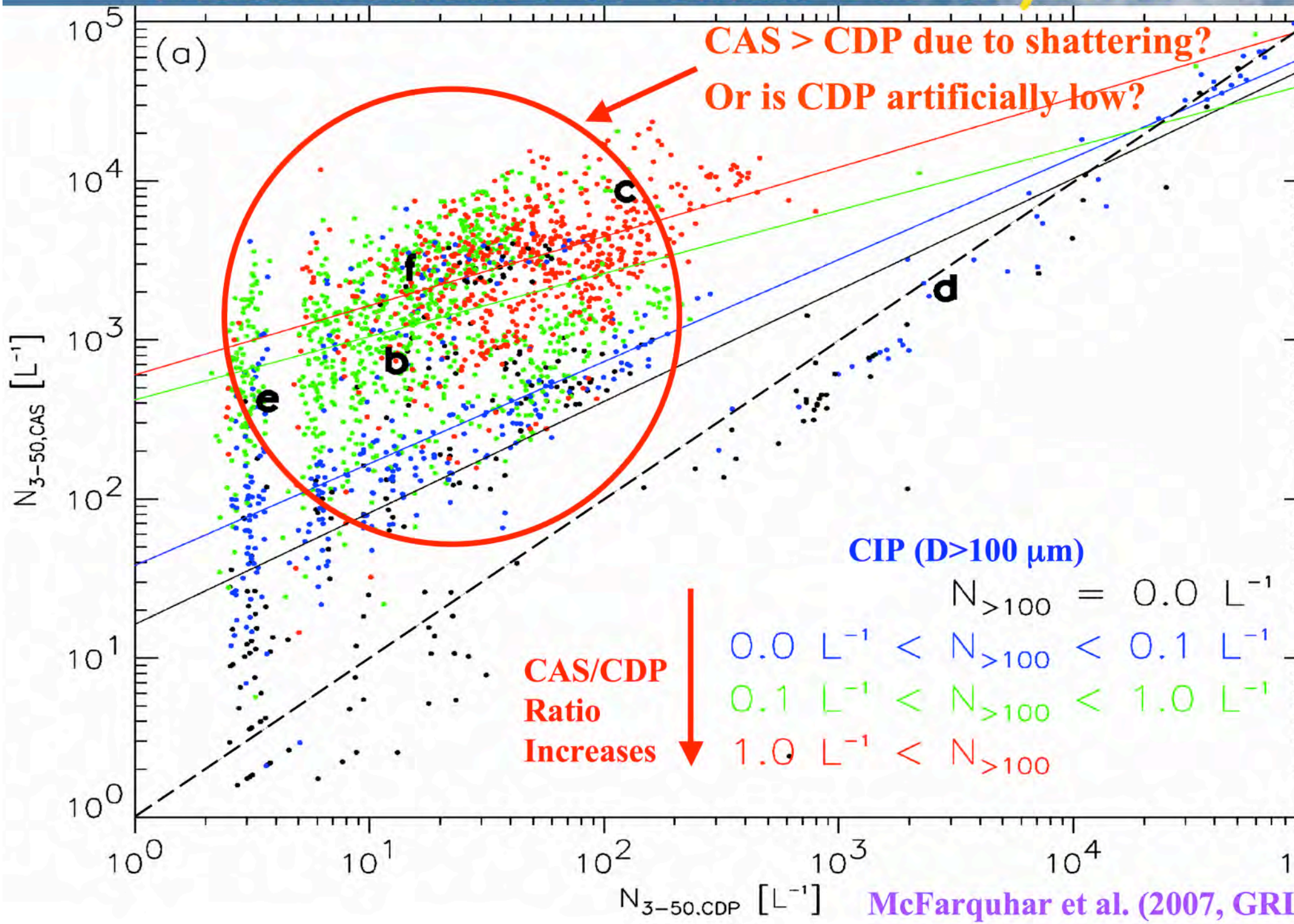

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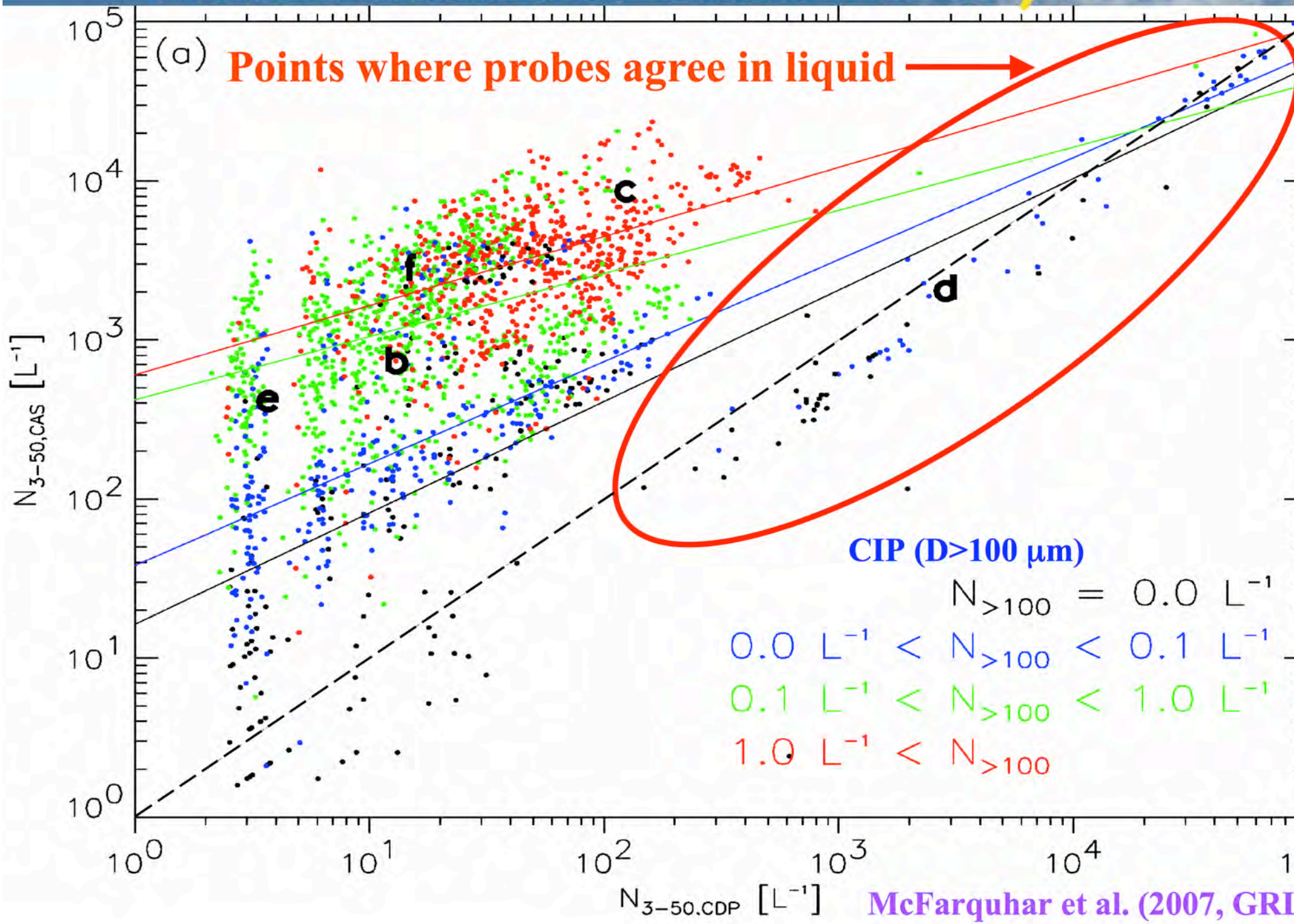

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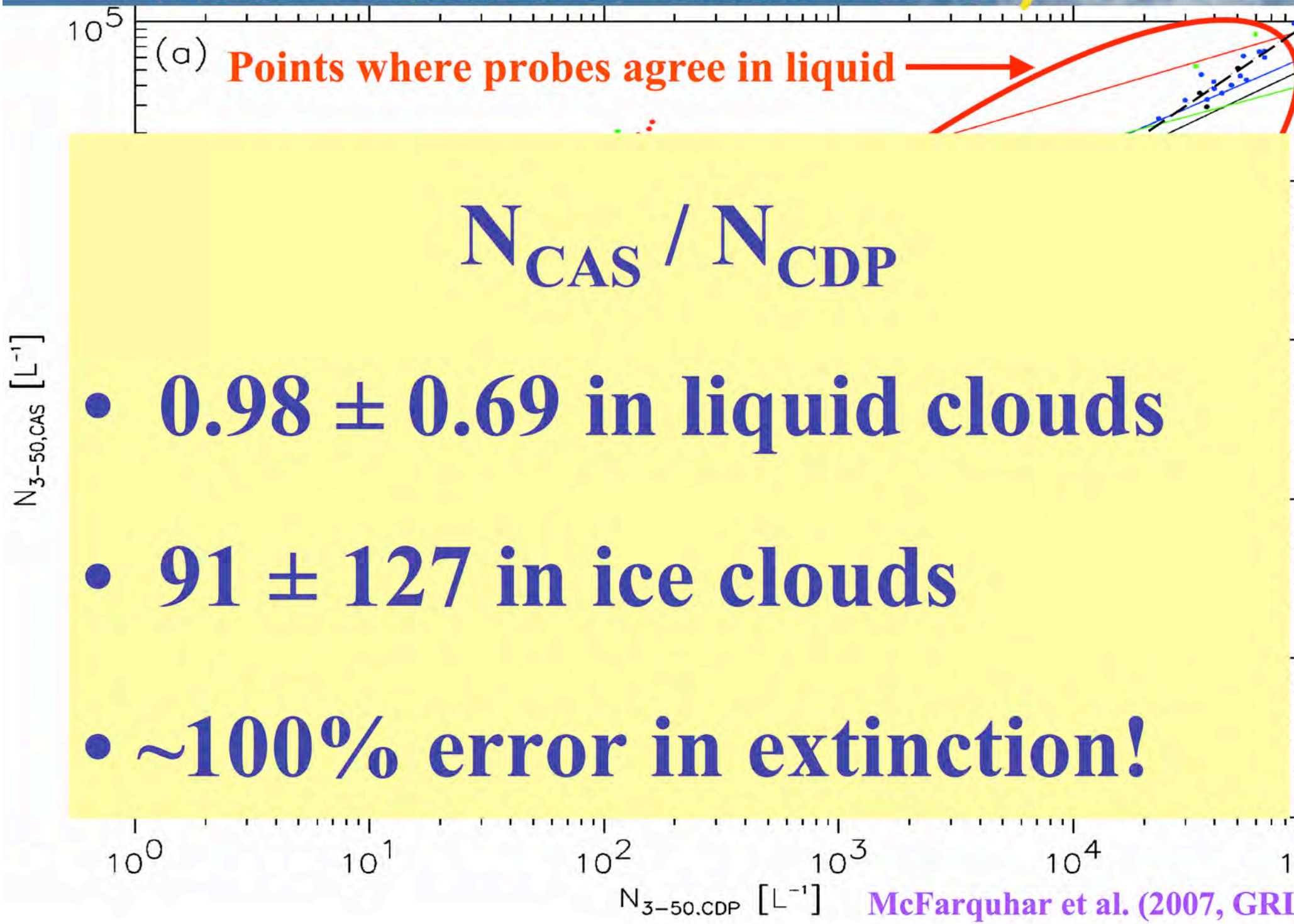
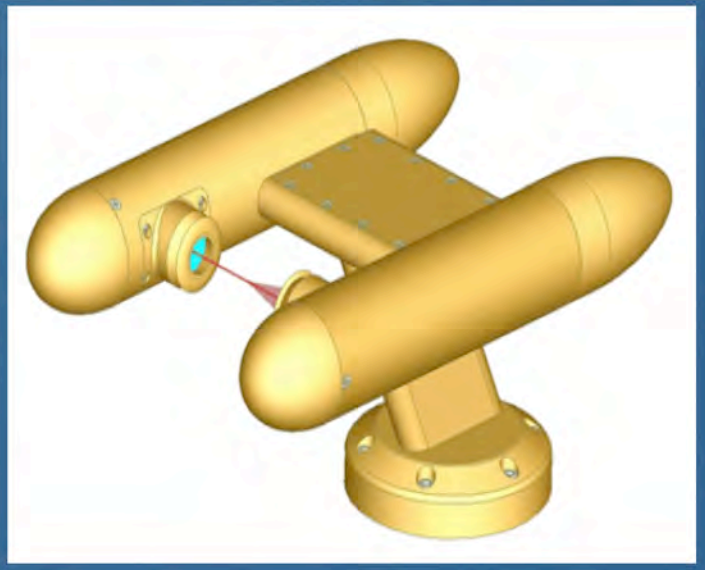


McFarquhar et al. (2007, GRL

Measurements of Small Ice Crystals (D < 50 μm)

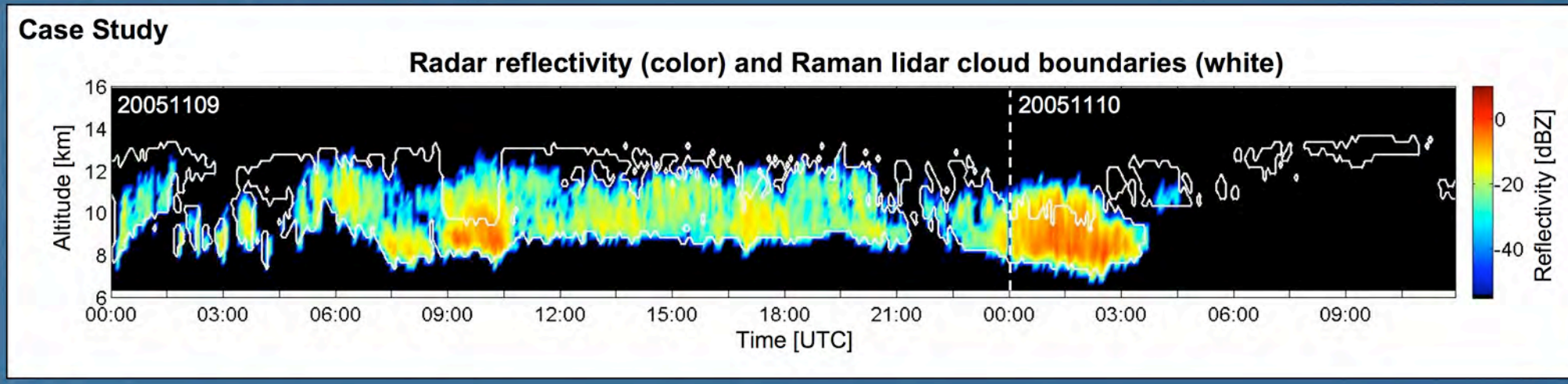
- Latest results from ISDAC also show sensitivity to shape of the leading edge of the CDP
- Wind tunnel tests being used to evaluate different designs
- Alexei Korolev and colleagues really leading this effort

Cloud Droplet Probe



Improving Cirrus Cloud Characterization with Raman Lidar Measurements at SGP

- Algorithm to derive extinction profiles developed for RL
- Lidar extinction profiles used with MMCR to improve cirrus characterization



Borg, Revercomb, et al

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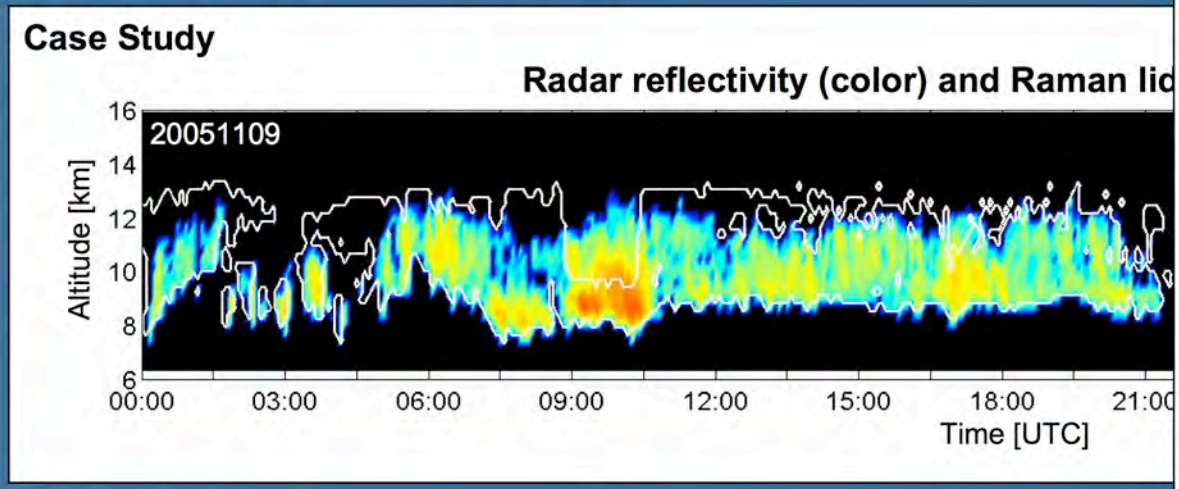
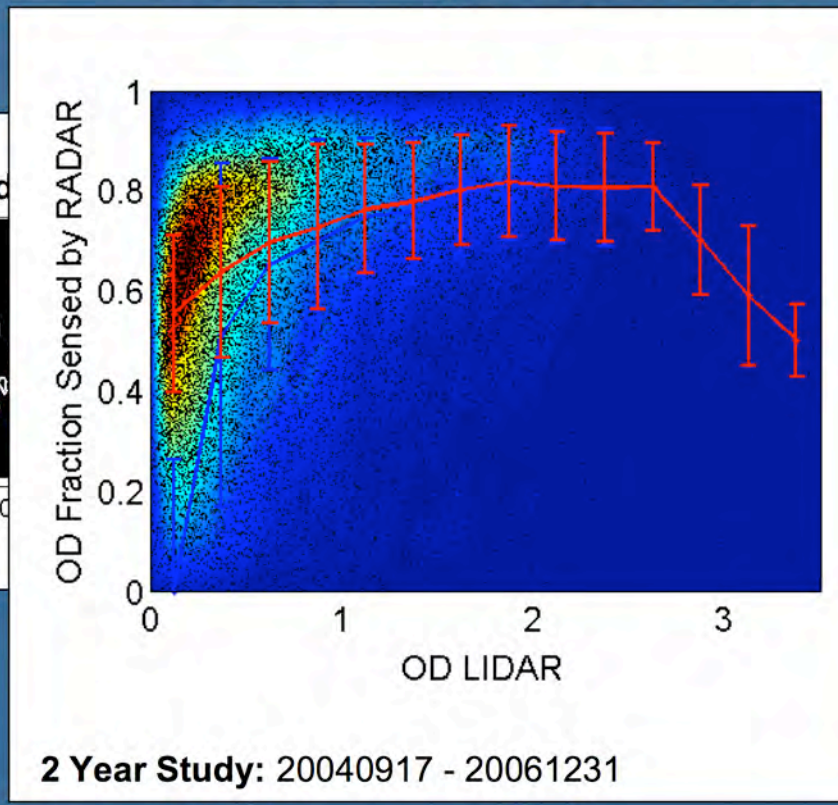




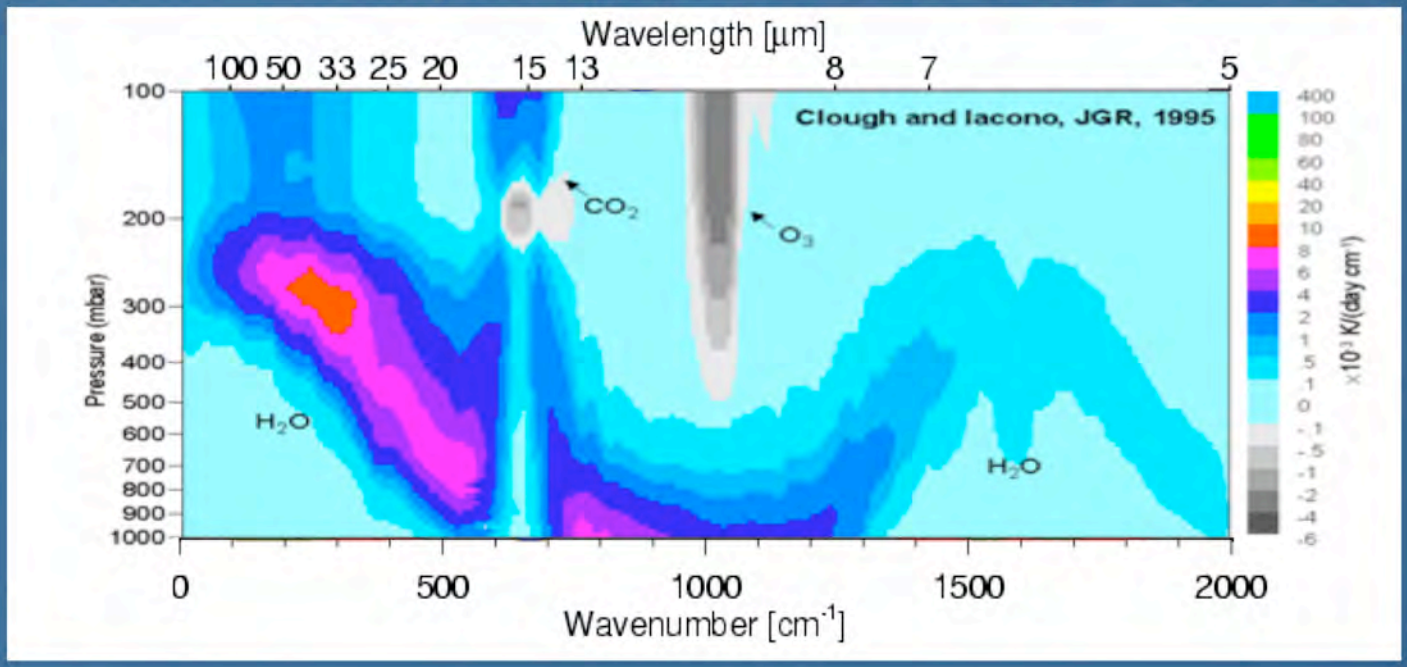
2 Year Study: 20040917 - 20061231

Conclusions:

- The MMCR misses significant upper level cirrus; also many cases where lidar is attenuated before top of cirrus.
- Radar does not detect upper portion of cirrus (approximately 20-30% of the total optical depth)

Borg, Revercomb, et al

Radiative Heating in Underexplored Bands Campaign (RHUBC)



- Emission from far-IR is ~40% of OLR
- Accurate RT modeling needed for computing mid-to-upper tropospheric radiative heating rates
- New observational capabilities recently available
- Evaluate RT models wrt water vapor and ice crystals

PIs: Turner and Mlawe

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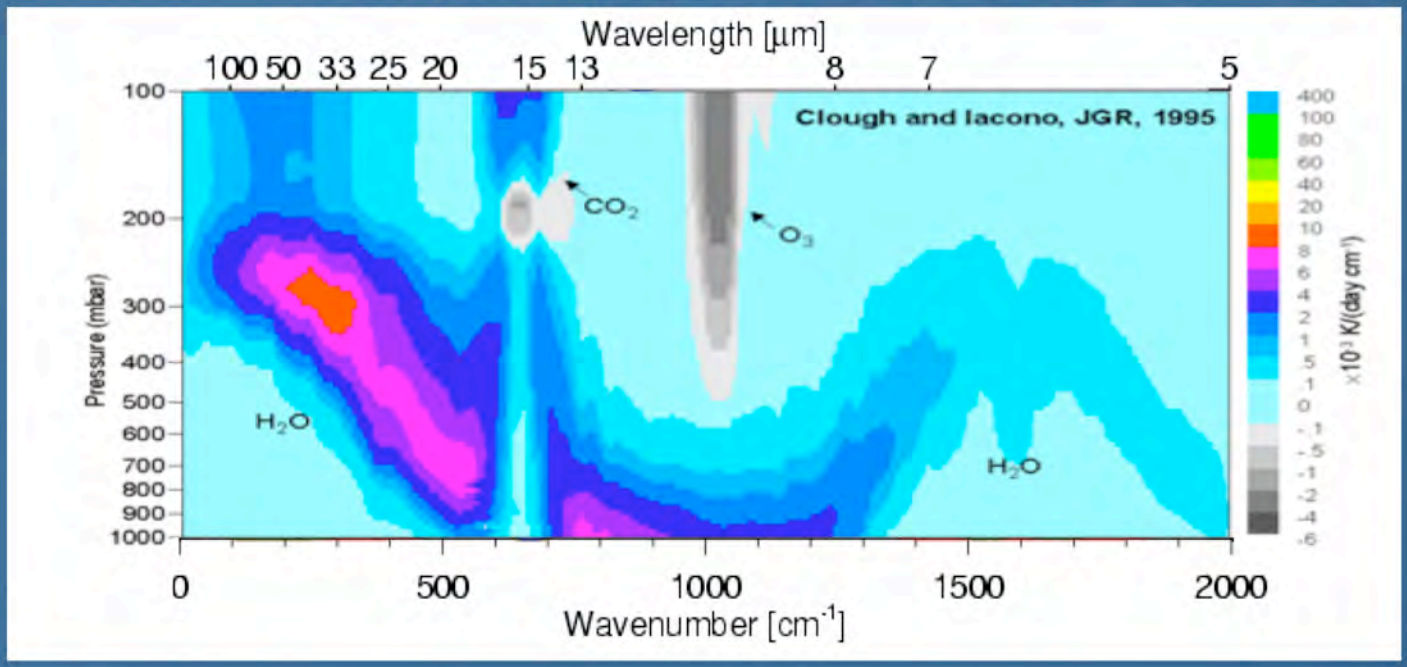

- RHUBC-I, ARM NSA site, Barrow, AK, Feb-Mar 2007
  - min(PWV) ~ 0.95 mm (observed)
  - Three 183 GHz radiometers, AERI-ER, TAFTS
- RHUBC-II, Cerro Toco, Chile, Aug-Oct 2009
  - min(PWV) ~0.15 mm (anticipated)
  - AERI-ER, FIRST, REFIR-PAD, TAFTS, ASTI, Harvard FTS

PIs: Turner and Mlawe

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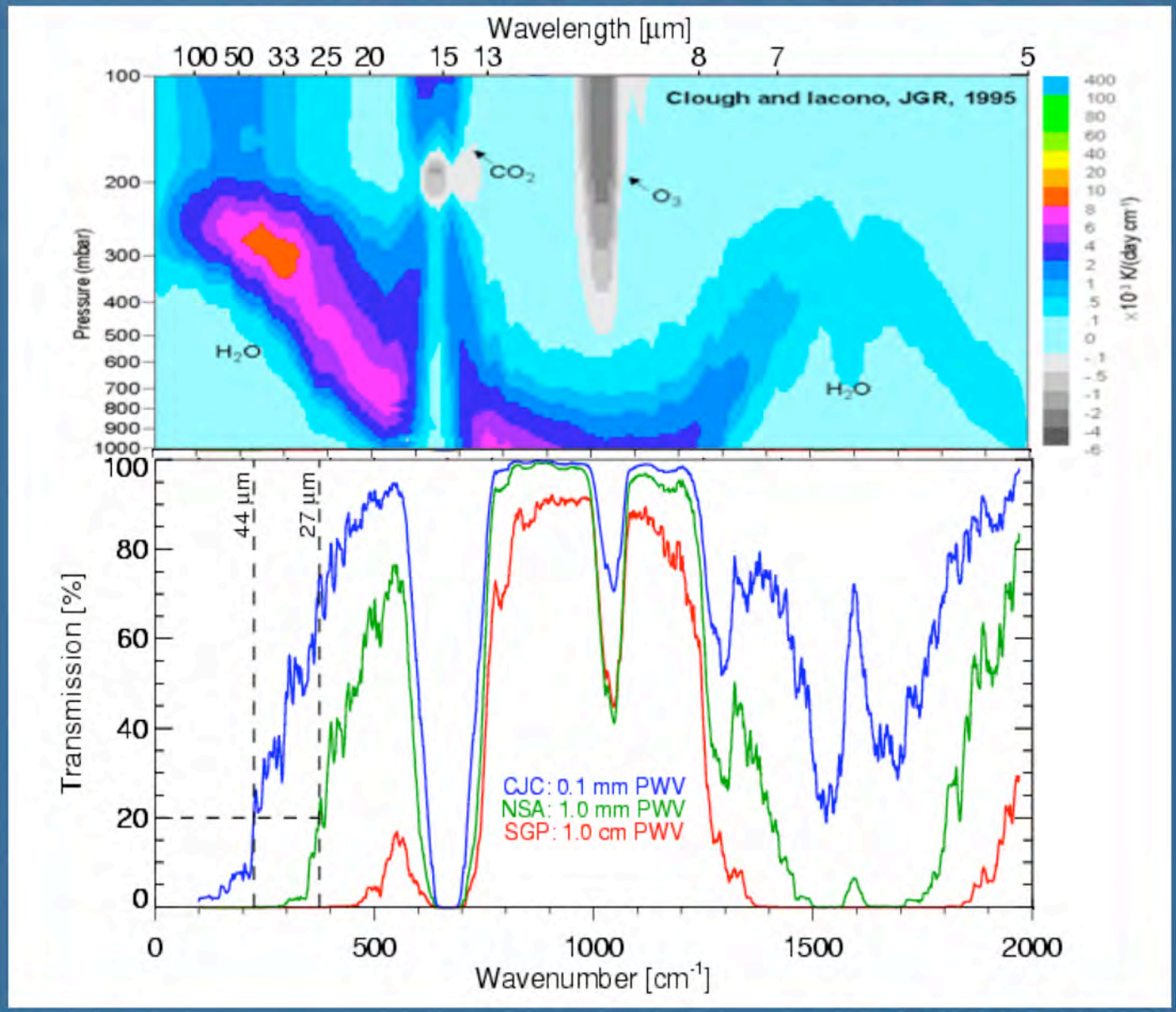
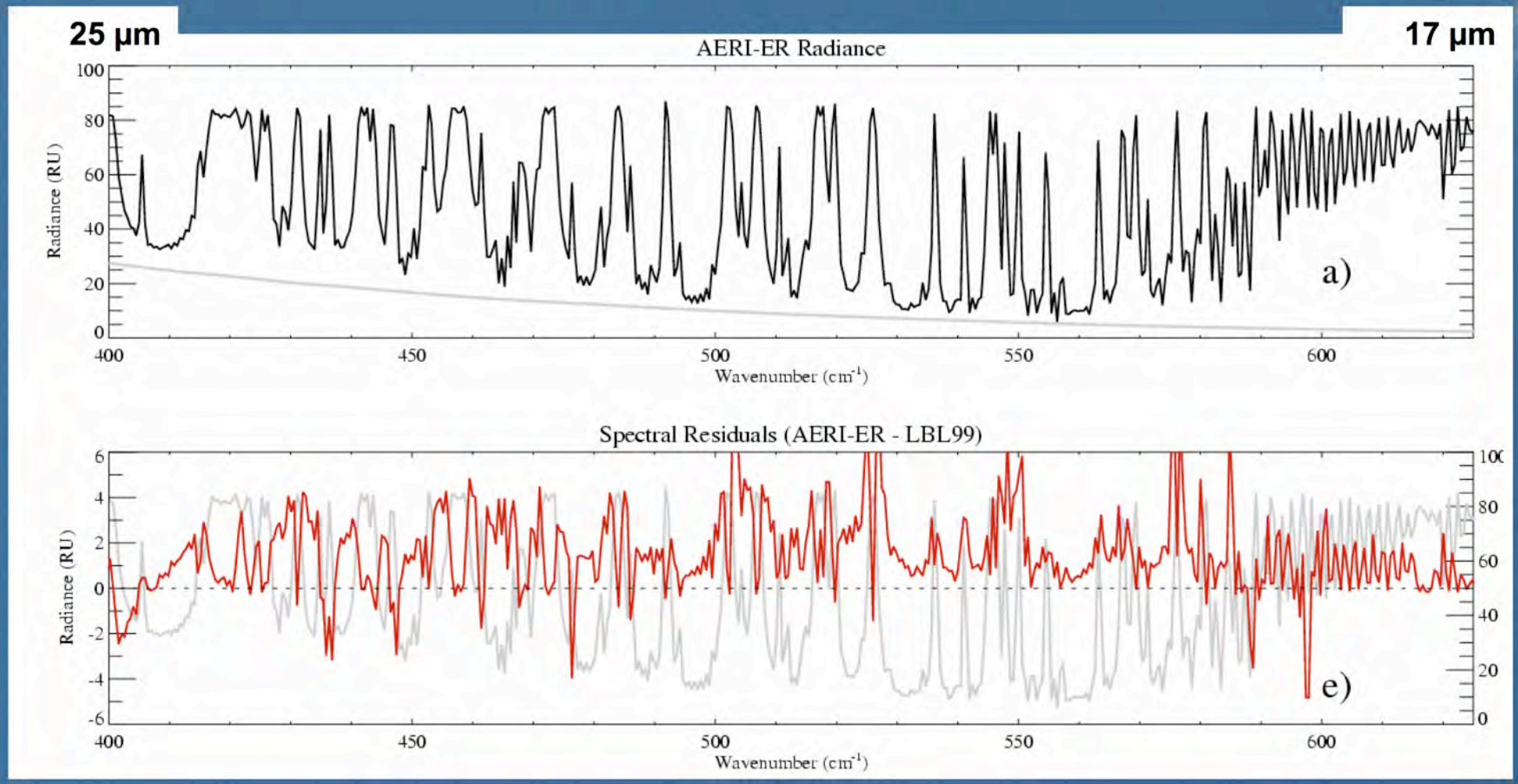


PIs: Turner and Mlawe

Clear Sky Far-IR Closure

RHUBC-I Results



Residuals after SHEBA (circa 1999, after Tobin et al.)

Delamere et al.

Clear Sky Far-IR Closure

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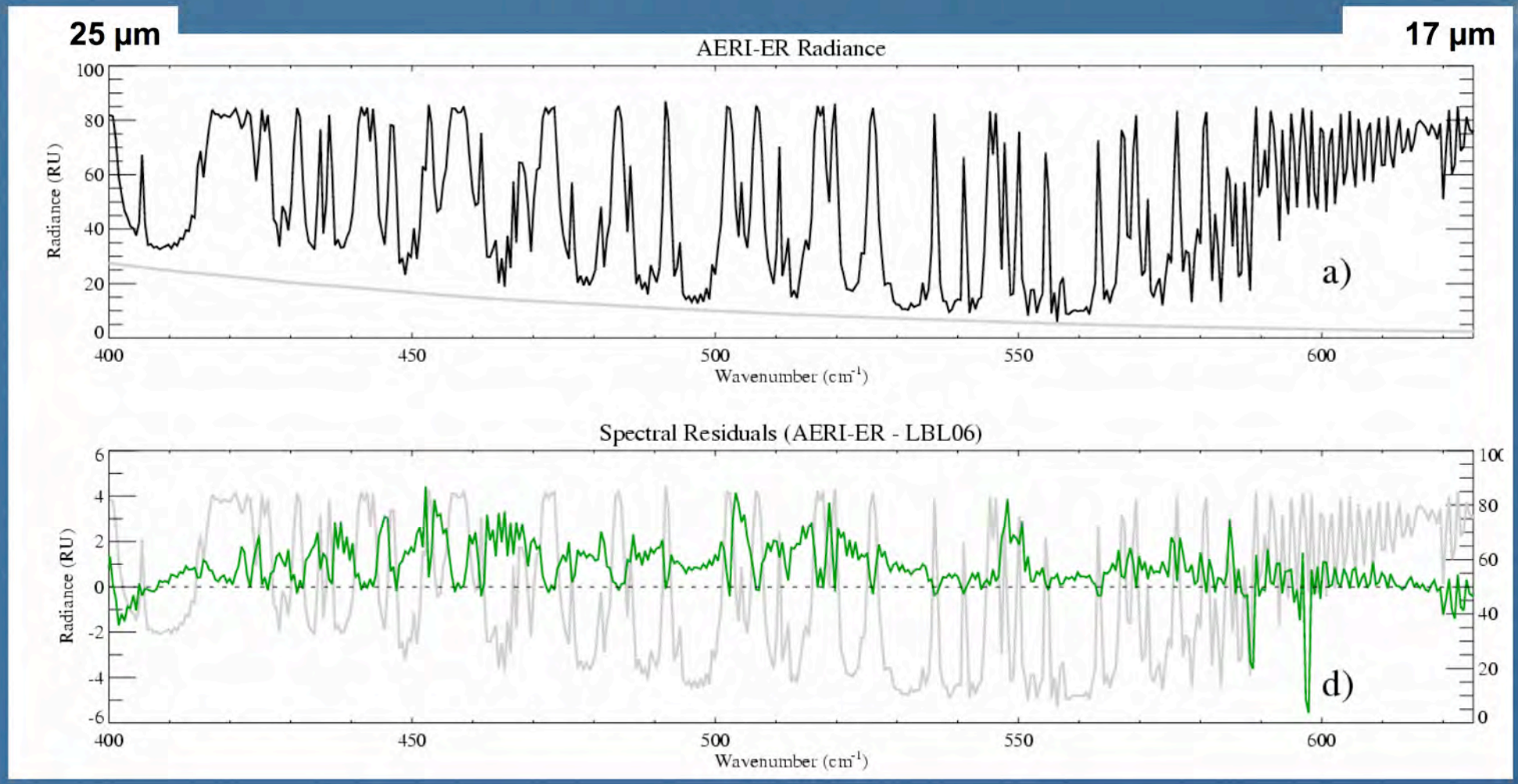

Residuals before RHUBC-I (2006)

Delamere et al.

Clear Sky Far-IR Closure

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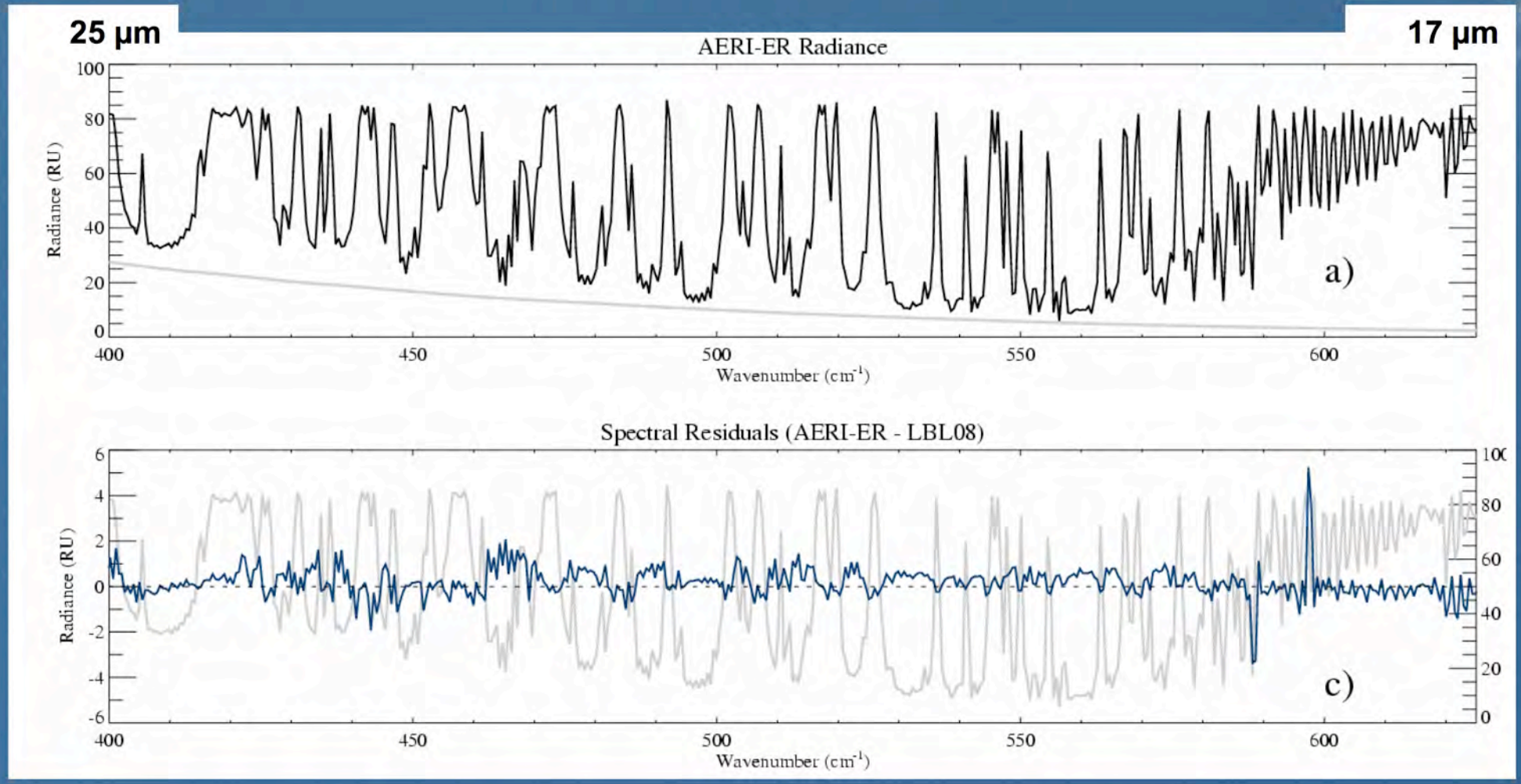


Residuals after RHUBC-I (2008)

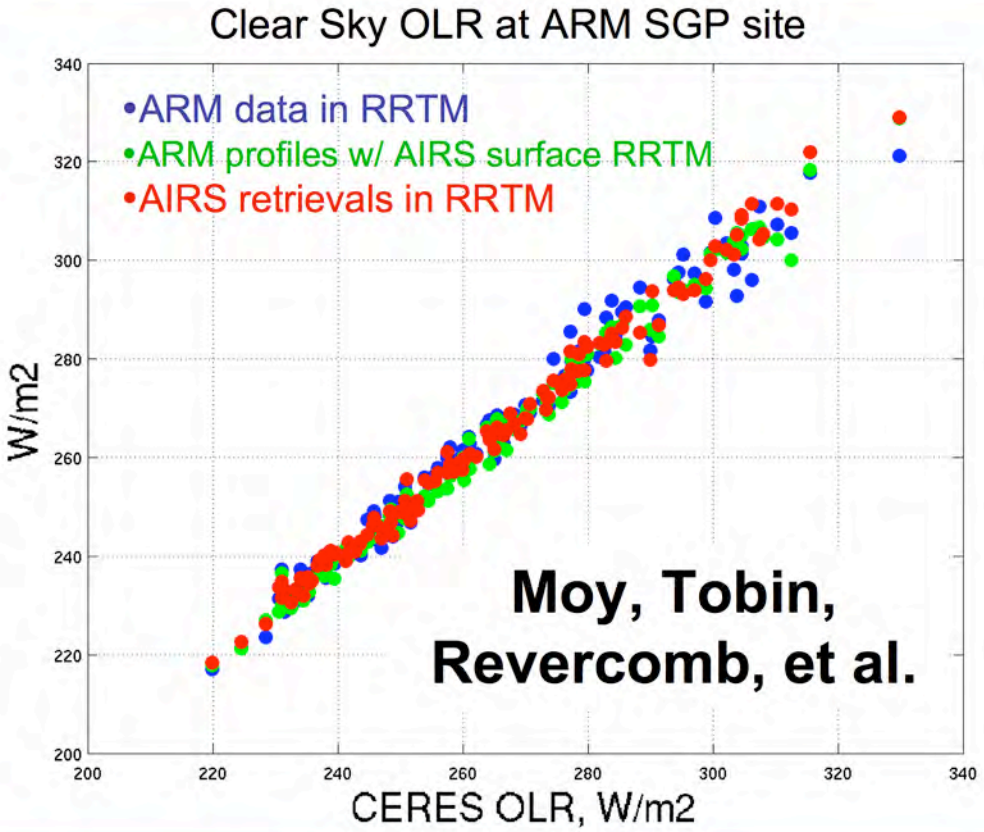
Delamere et al.

Assessing ARM Clear Sky BBHRP with CERES and AIRS

The RRTM calculations of clear sky OLR agree with CERES observations to ~1 W/m^2 with an uncertainty of ~1 W/m^2.

* True at SGP over 2.5 years, true globally (with some *understood* regional exceptions) for study day.

* True using ARM data as input to RRTM, true using AIRS sounding retrievals as input to RRTM.



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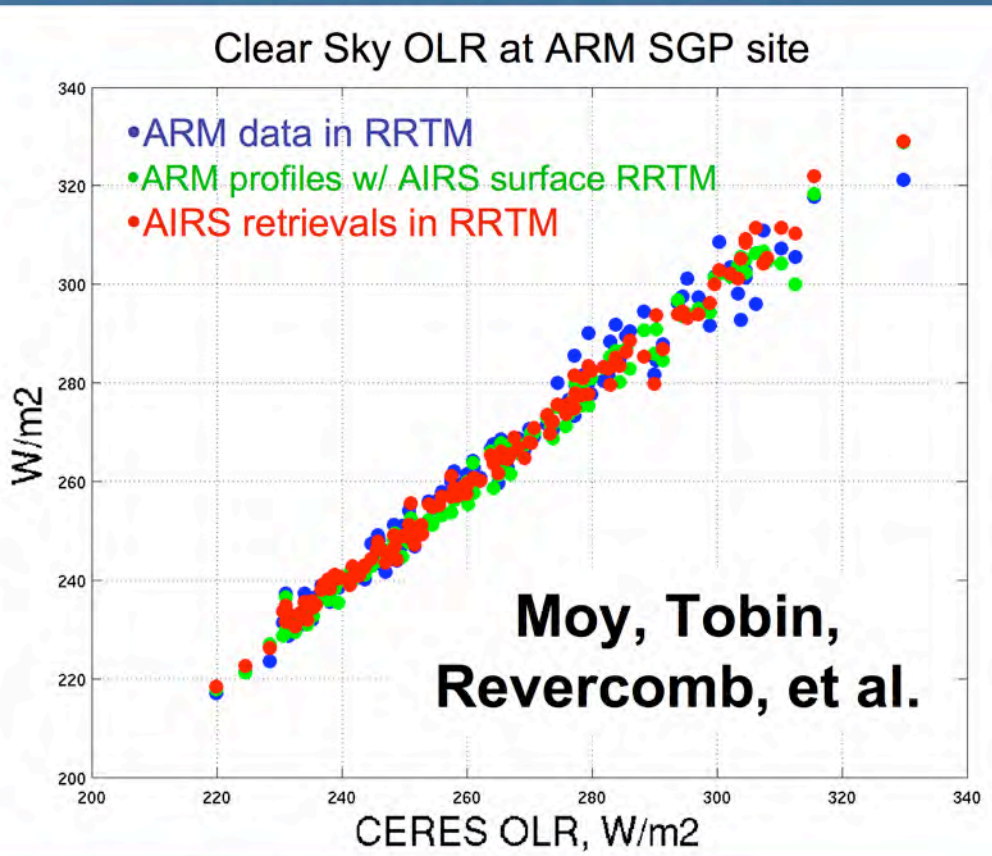

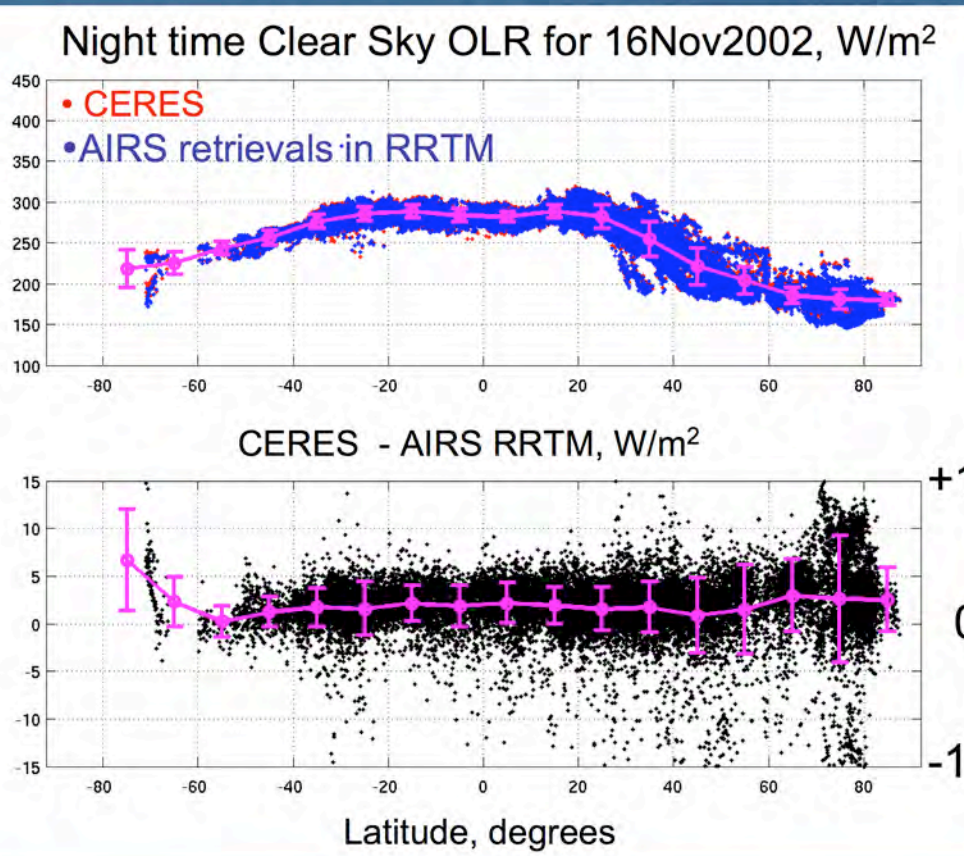

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Spectral Range	Weight [%]	Flux [W/m^2]	Percent Residual Definition	%
Total OLR	100	263	(CERES-AIRS RRTM) / CERES	0.2
AIRS Spectra	54	144	$(Flux_{AIRS,obs} - Flux_{AIRS,calc}) / Flux_{AIRS,obs}$	0.3
Far-IR	45	116		~0.3

Moy et al, JGR, submitted 2008

Broadband Heating Rate Profile (BBHRP) Project

Joint effort of all ARM Working Groups

Key objectives:

- Compute radiative heating rate profiles for all ACRFs based on ARM measurement
- Evaluate new data sources through radiative closure

Core emphasis is the evaluation of cloud retrieval methods:

- SGP - Multiple retrieval approaches evaluated, more to come
- NSA - Shupe-Turner compared to Microbase
- PYE - intercomparison for CLOWD cases underway
- TWP - in pipeline

Mlawer et al.

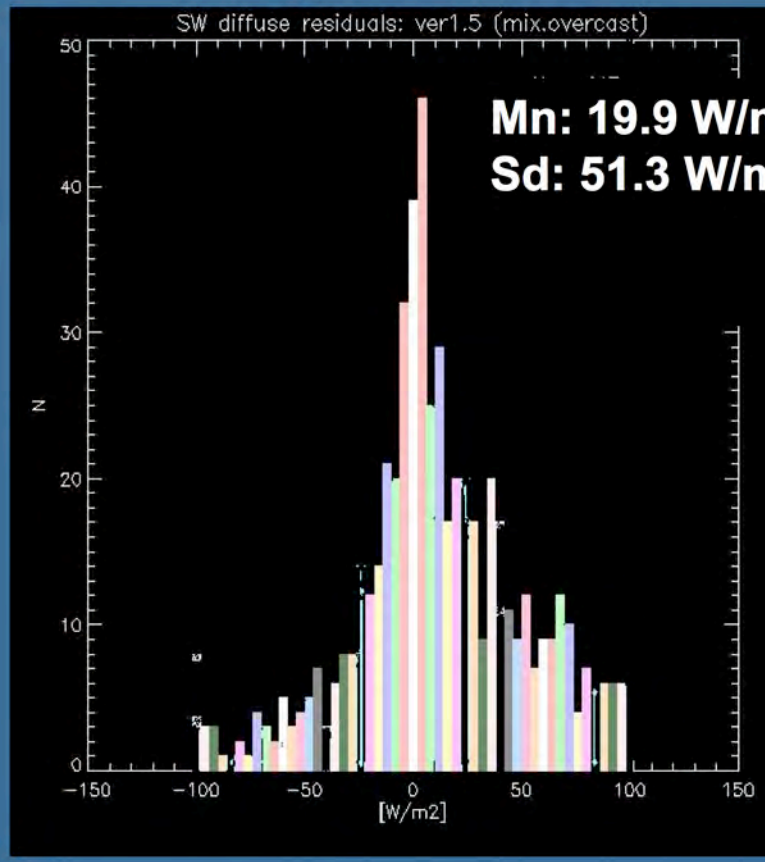
Reasonable Simple Assumptions Yield Equivalent Results

SW Diffuse Residuals at Surface at SGP Site

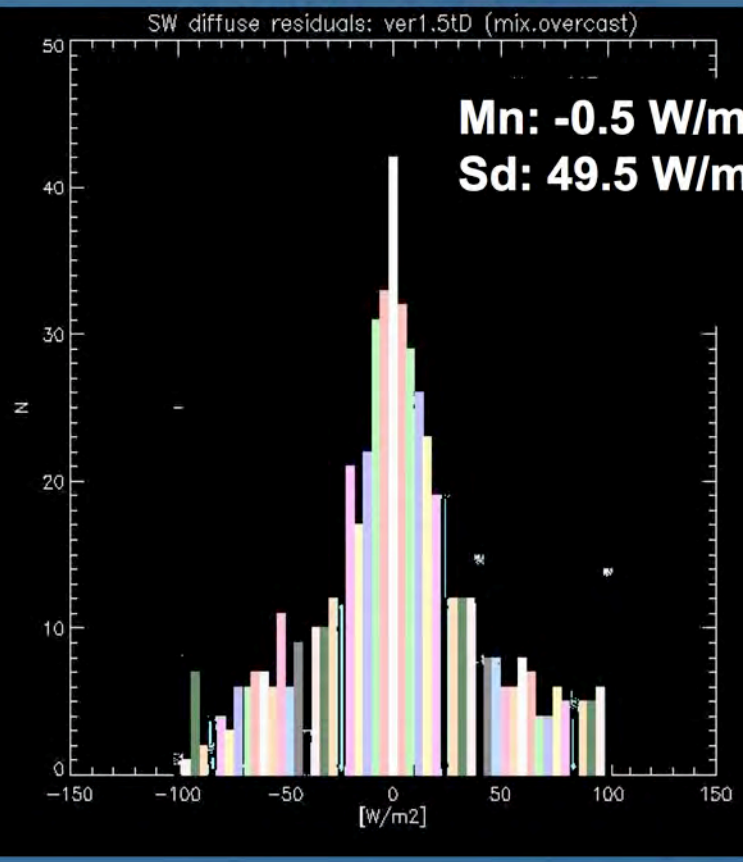
Mixed-phase clouds

(all cases overcast)

Microbase
MWR LWP
$N_d = 200/cm^3$

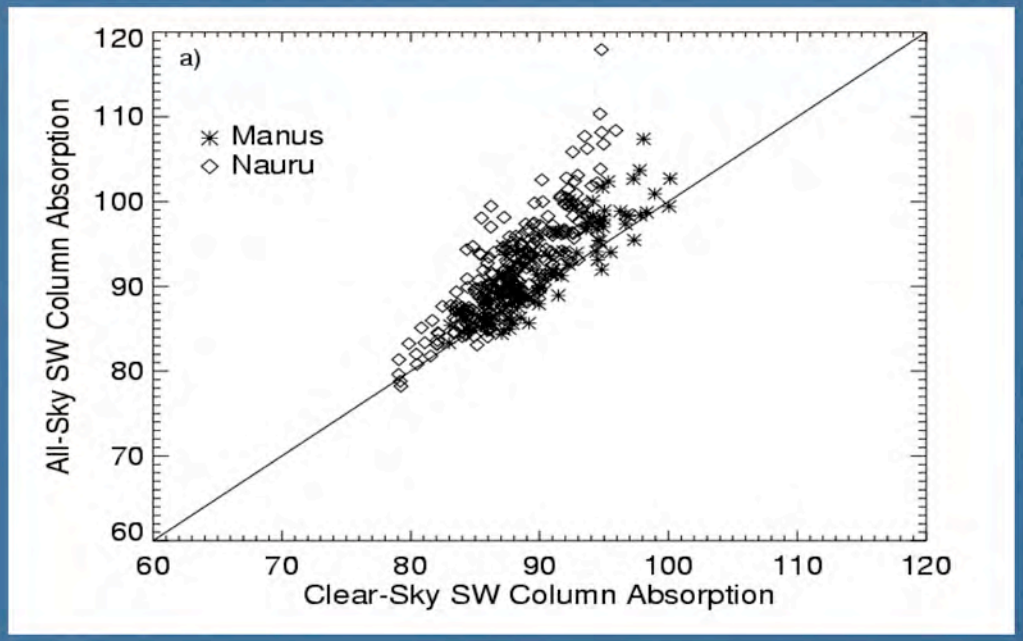


'Sengupta'
MWR LWP
$r_{eff} = 7.5\ \mu m$

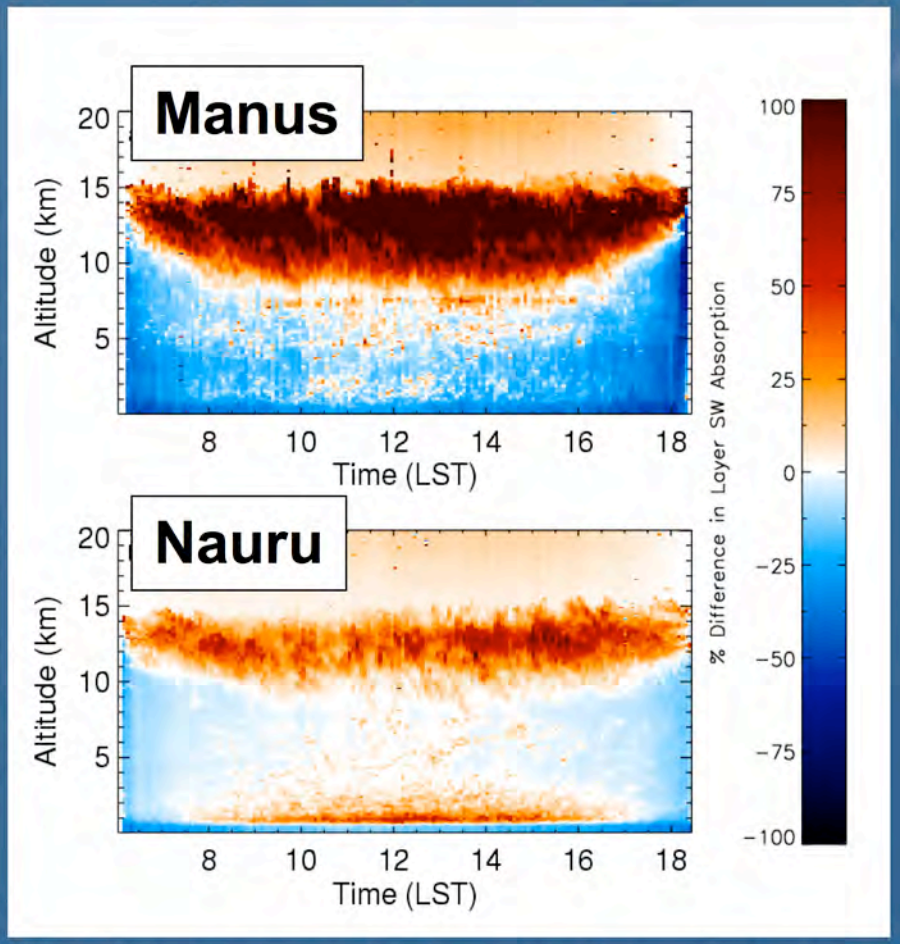


Mlawer et al.

Effect of clouds on the vertical distribution of SW absorption in the Tropics



All-sky versus clear-sky SW column absorption at Manus and Nauru

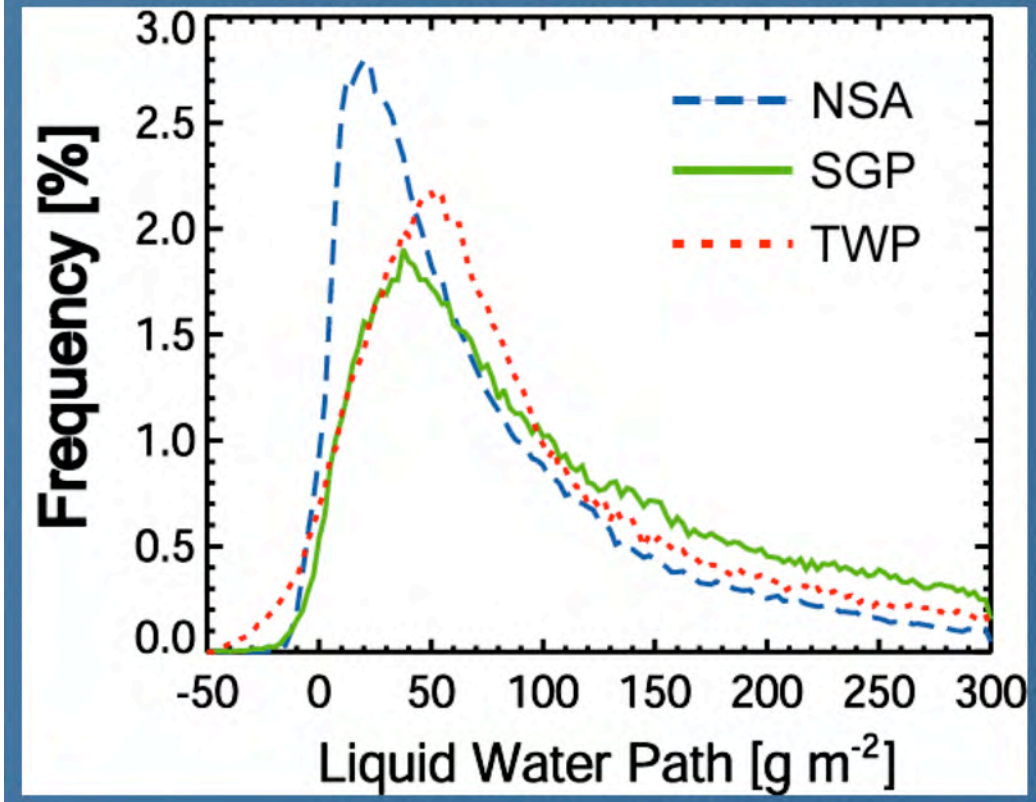


% change in layer absorption due to clouds

McFarlane et al, *JGR, 2008*

CLOWD

- Clouds with low liquid optical depth (LWP < 100 g/m^2)
- Occur quite frequently all over the globe



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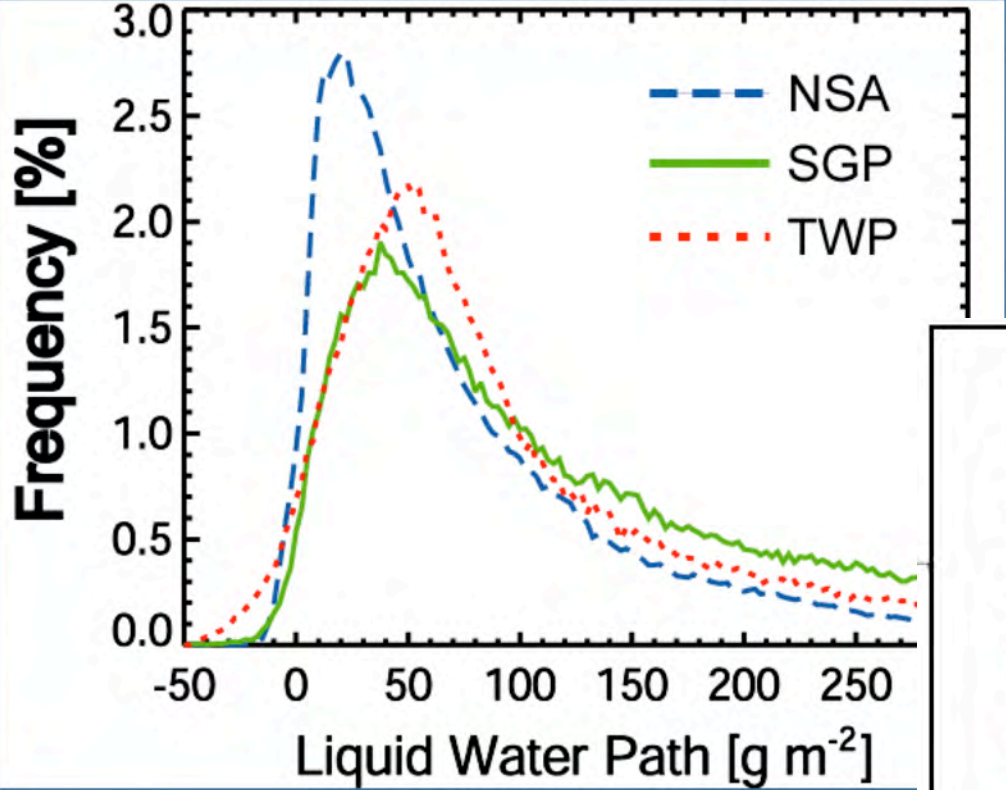
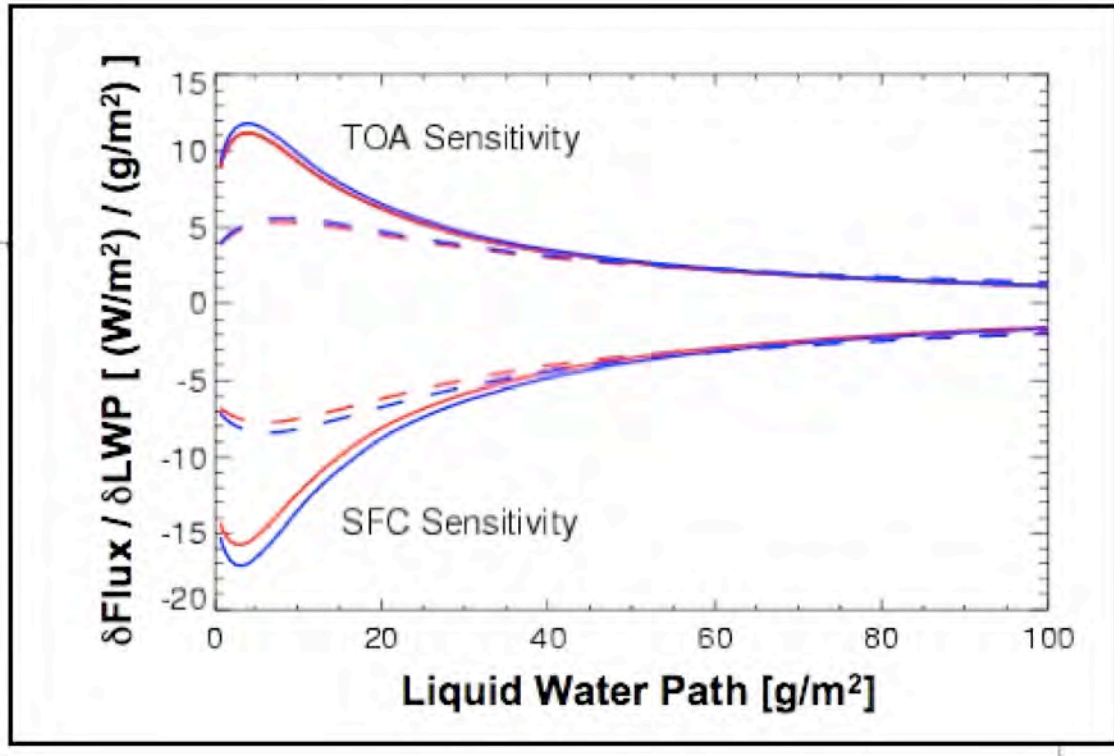
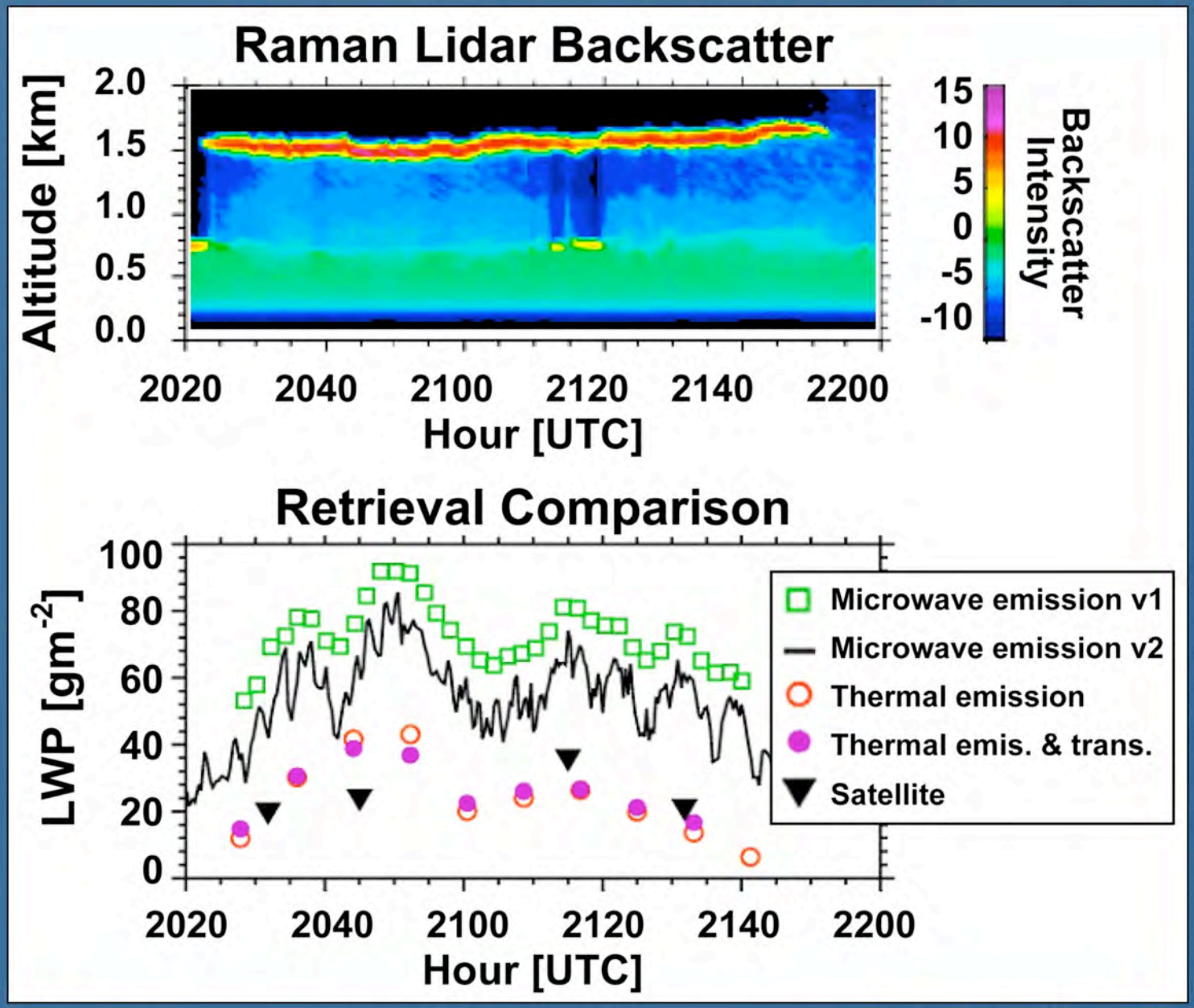


- Very important radiatively
- Small errors in LWP yield big errors in radiative flux

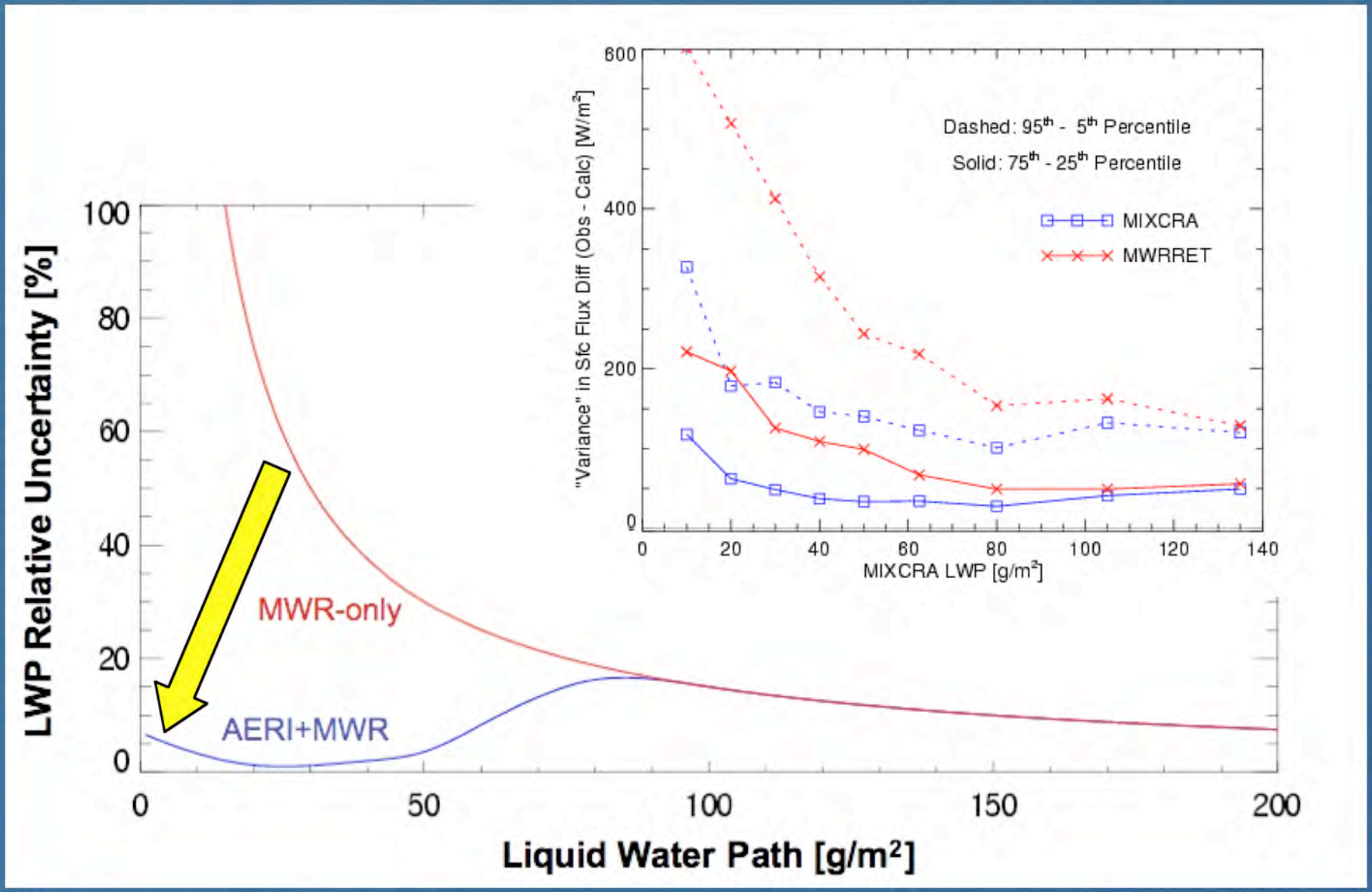


CLOWD Problem



Turner et al, BAMS, 2007

One Possible Ground-based Solution

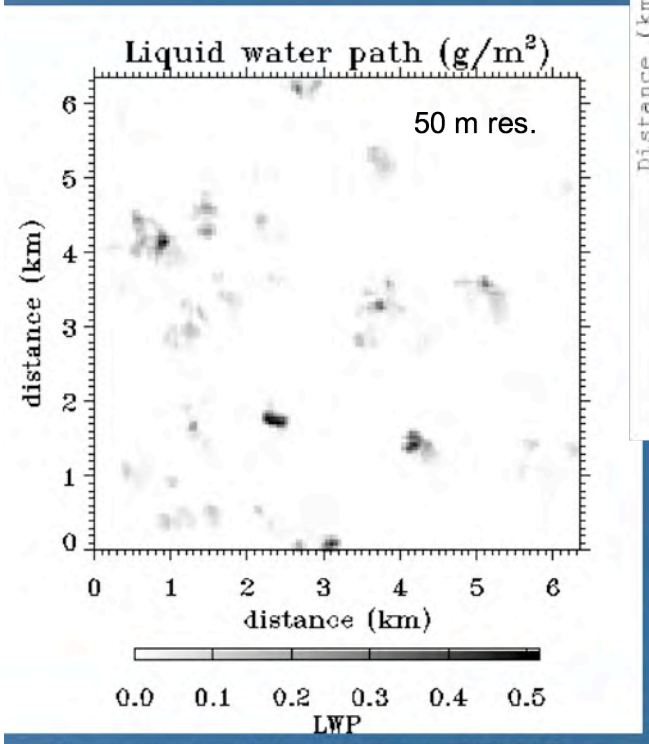


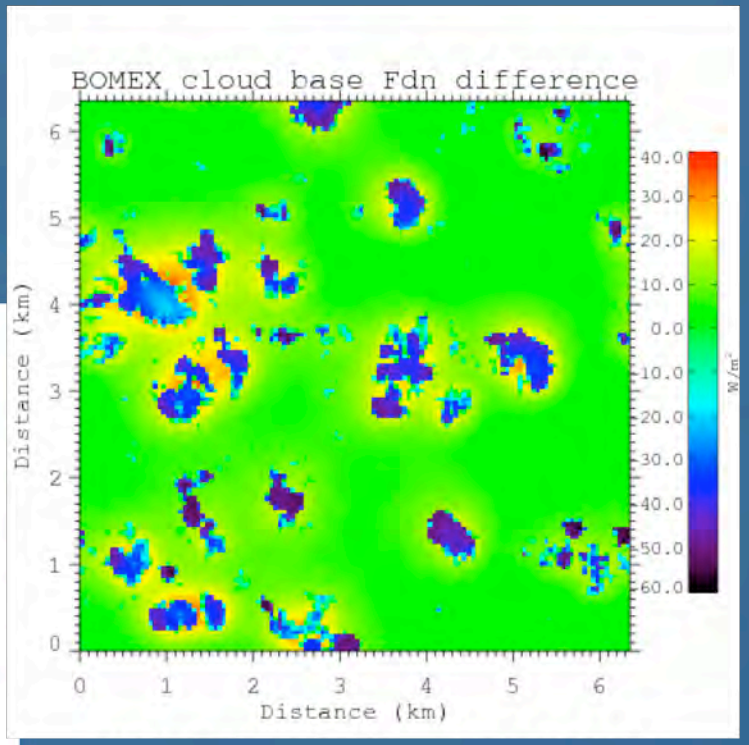
Turner, JGR, 2007

Longwave ICRCCM III: Monte Carlo vs. Independent Pixel Approx.

BOMEX Case
Cu: 0.3 to 1.0 km MSL

LWP





F↓(3D MC) – F↓(IPA)
at the cloud base

Kablick, Gu, Takara and Ellingson

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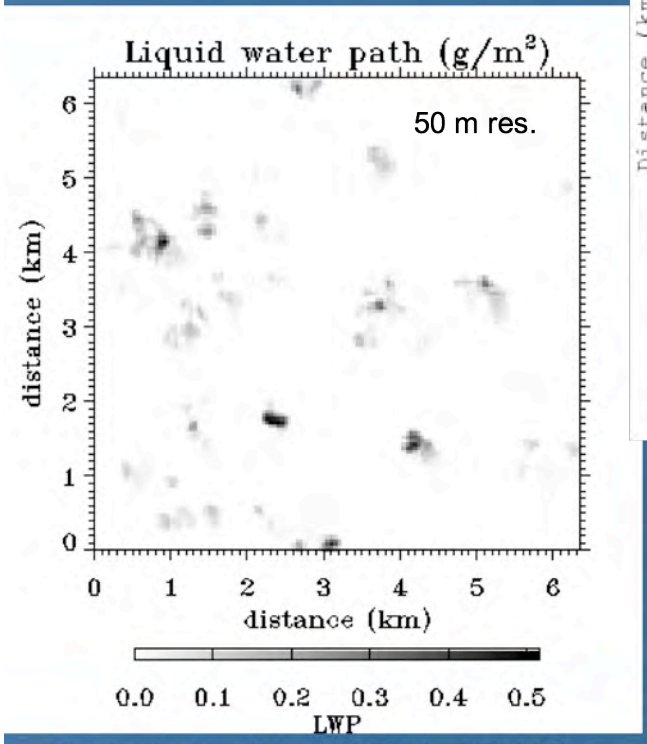

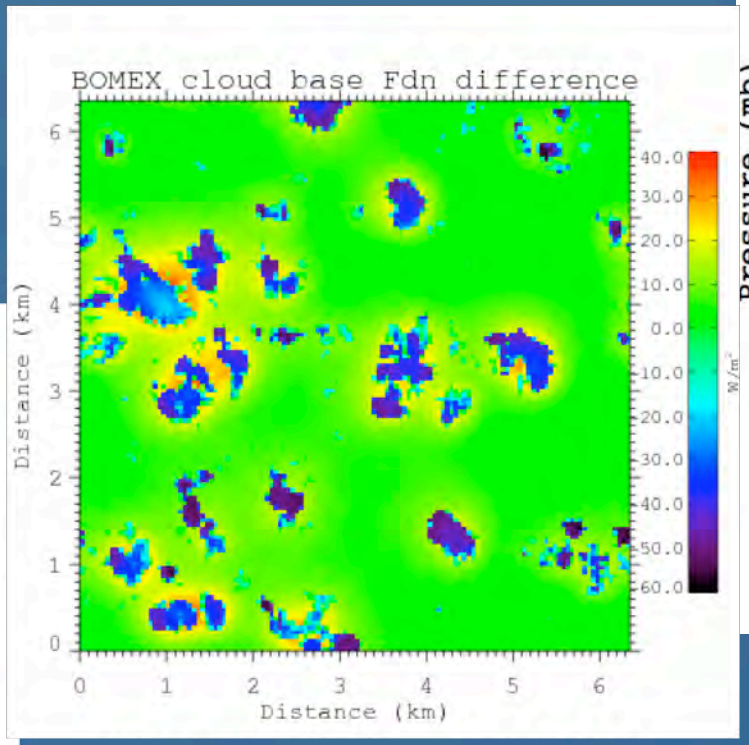

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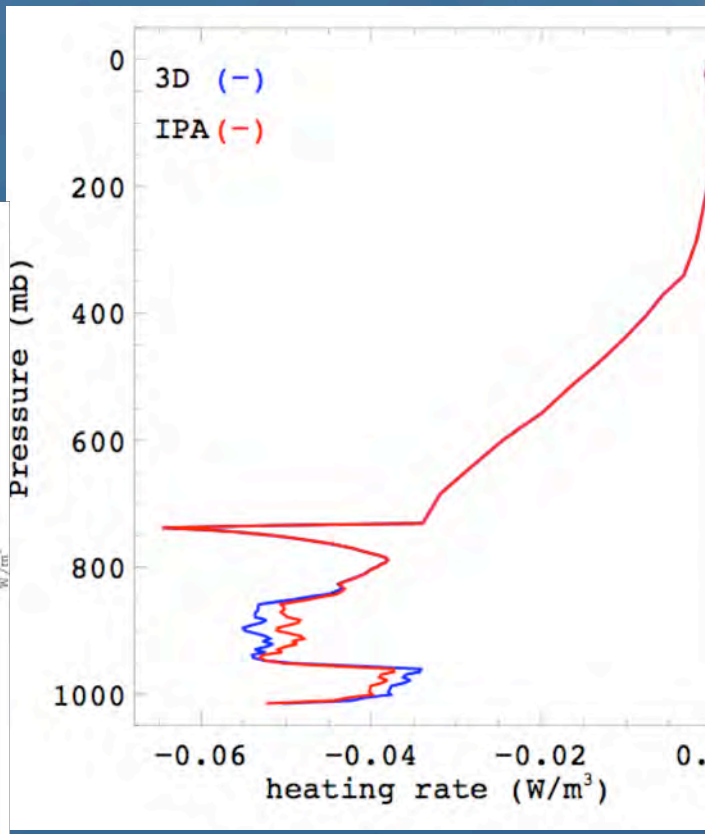

Domain averaged
heating rate for
3D MC and IPA

Kablick, Gu, Takara
and Ellingson

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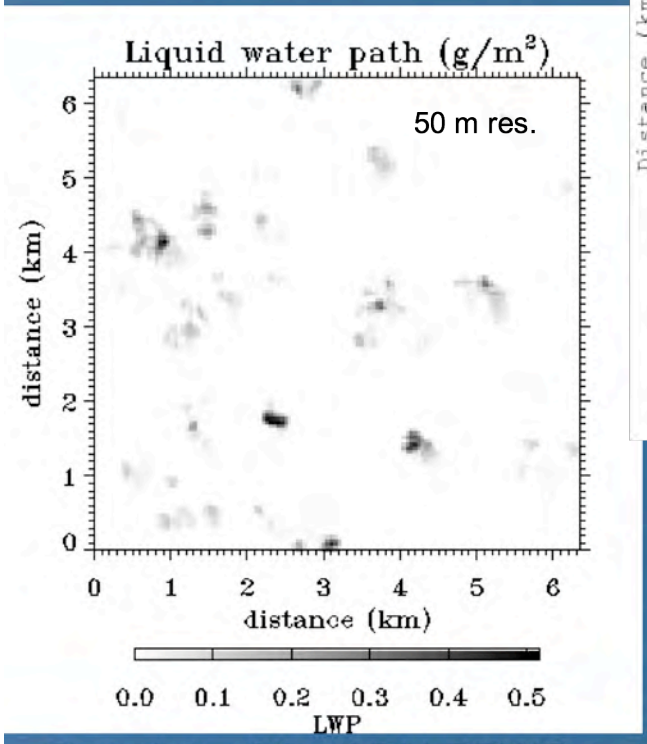

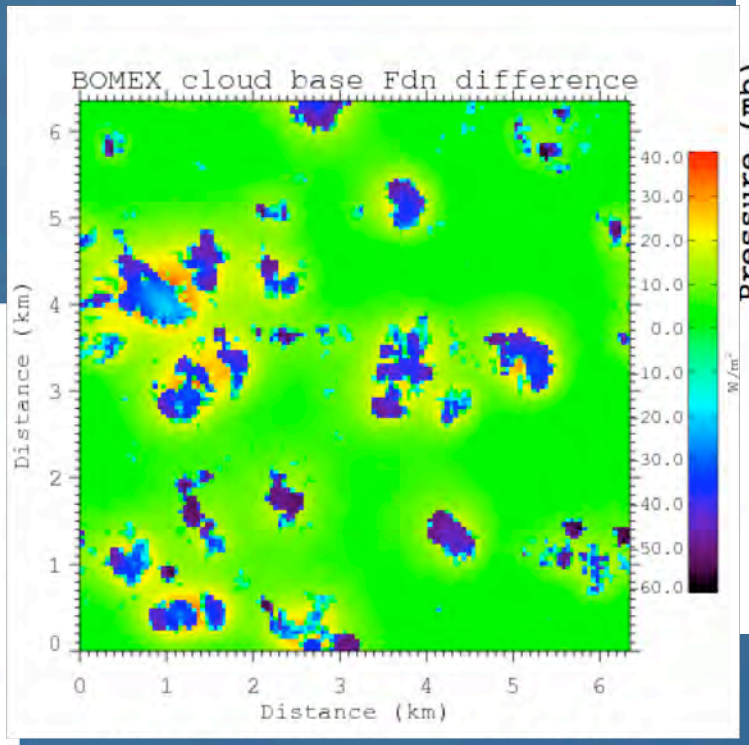

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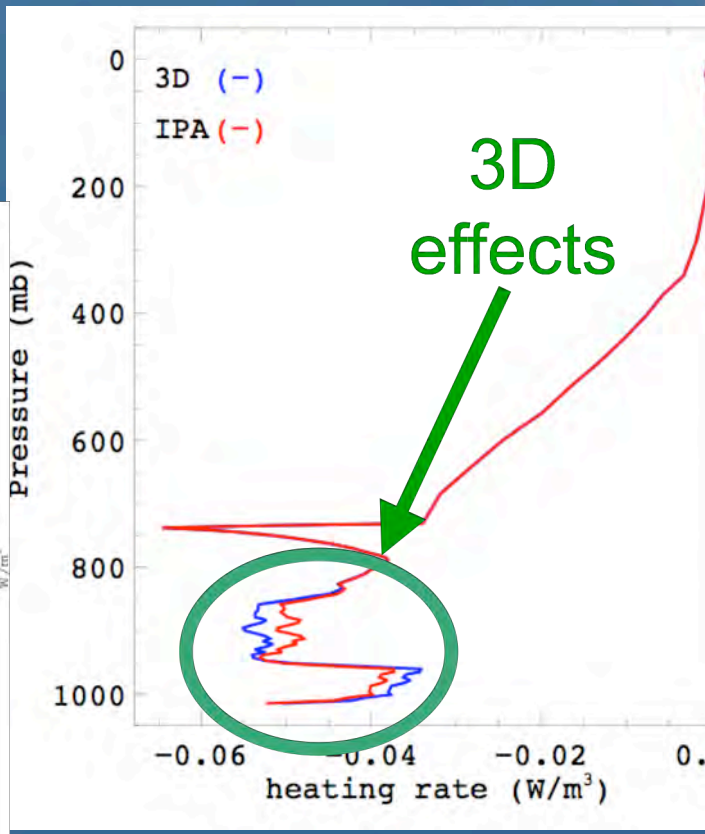

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Continuous Intercomparison of Radiation Codes (CIRC)

- Sponsored by ARM and endorsed by GEWEX Radiation Panel
- Aims to become the standard for documenting the performance of SW and LW RT codes in Large-Scale Models
- Goal is to have RT codes of IPCC models report performance against the CIRC cases
- Phase I launched summer 2008: http://www.circ-project.org

Differences from previous intercomparisons:

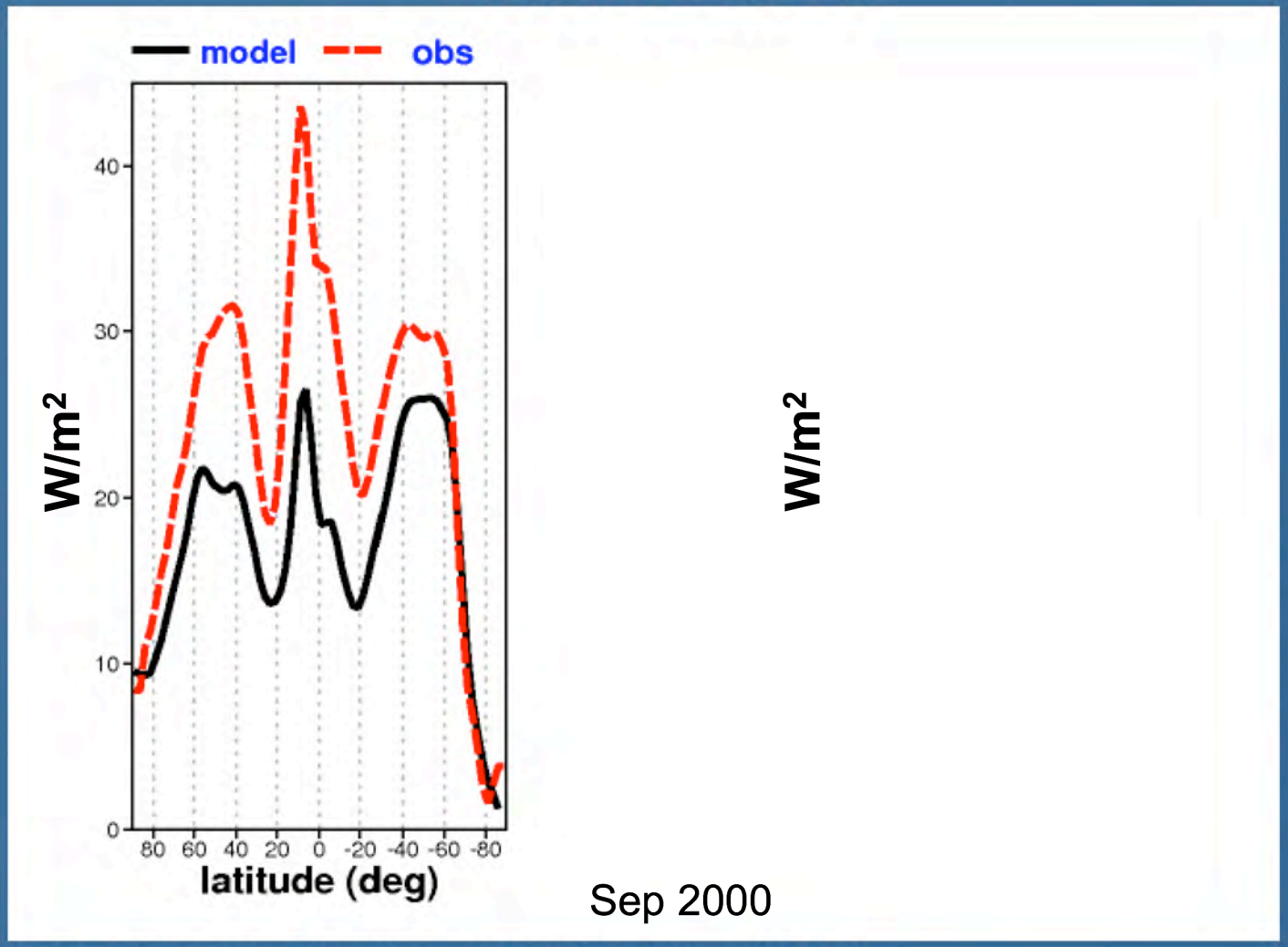
- *Observation-tested* LBL calculations to used as radiative benchmarks
- Benchmark results are publicly available
- ARM observations provide input (largely select BBHRP cases)
- Flexible structure and longer lifespan than previous intercomparisons

Core team: Oreopoulos, Mlawer, Delamere, Shippert

Improvement in Annual TOA LW Cloud Forcing at ECMWF

Before RRTM

After RRTM



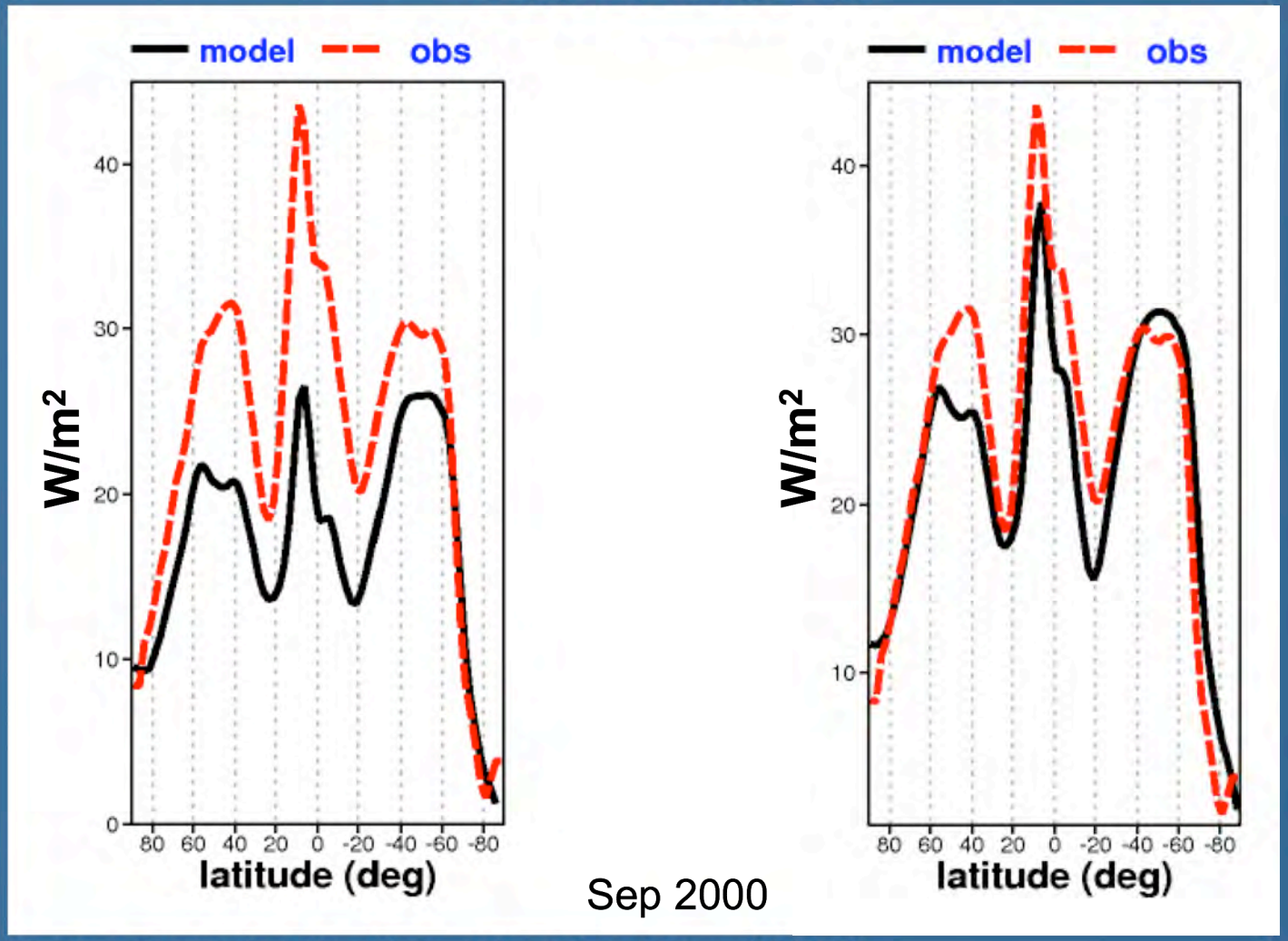
Morcrette et al., submitted to *Mon. Weather Rev.* (2007)

PIs: Iacono/Mlawer

Improvement in Annual TOA LW Cloud Forcing at ECMWF

Zonal Means

Before RRTM



Sep 2000

After RRTM

Morcrette et al., submitted to *Mon. Weather Rev.* (2007)

PIs: Iacono/Mlawer

Conclusions

- ARM's spectrally resolved and broadband radiance/flux observations have led to important new insights into cloud / aerosol / water vapor / radiation interactions
- ARM radiation observations have led to improvements in the parameterizations used in GCMs and other models
- Significant uncertainties still remain, but new instruments and experiments are addressing these issues