Overview of the Radiative Processes Working Group

Dave Turner

RPWG Chair

2008 ARM Science Team Meeting
11 March 2008
Norfolk, Virginia

RPWG Steering Group

- Bob Ellingson
- Chuck Long
- Sally McFarlane
- Andy Vogelmann

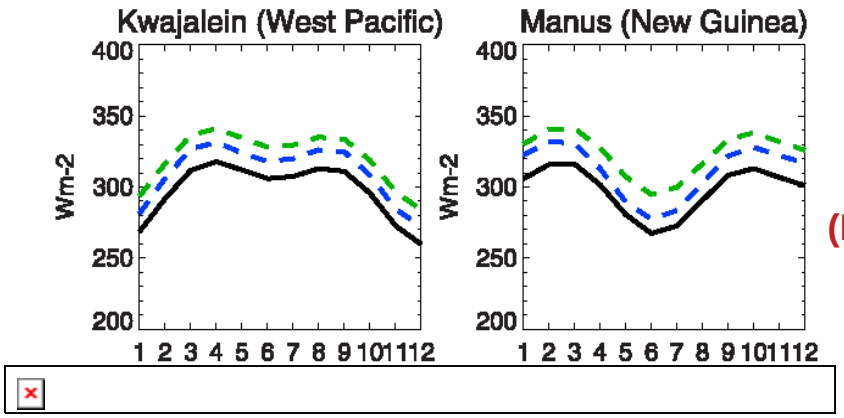
Represent about 40 RPWG members

ARM Program Objectives

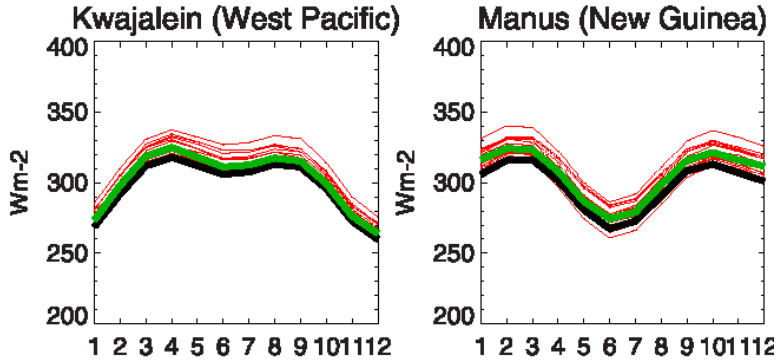
- Relate observed radiative energy (spectrally and temporally resolved) to temperature and composition of the atmosphere
- Develop and test parameterizations of the radiative properties and processes of water vapor, clouds, and aerosols, and incorporate these parameterizations in GCMs

ARM Science Plan
October 2004

Clear-sky GCM vs observations comparisons

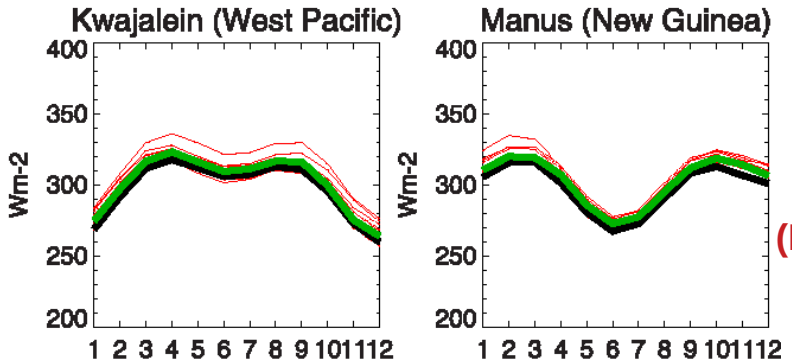


AMIP1
(Late 1980's)



AMIP2
(Late 1990's)

Median AMIP II — AMIP II Models — Observed



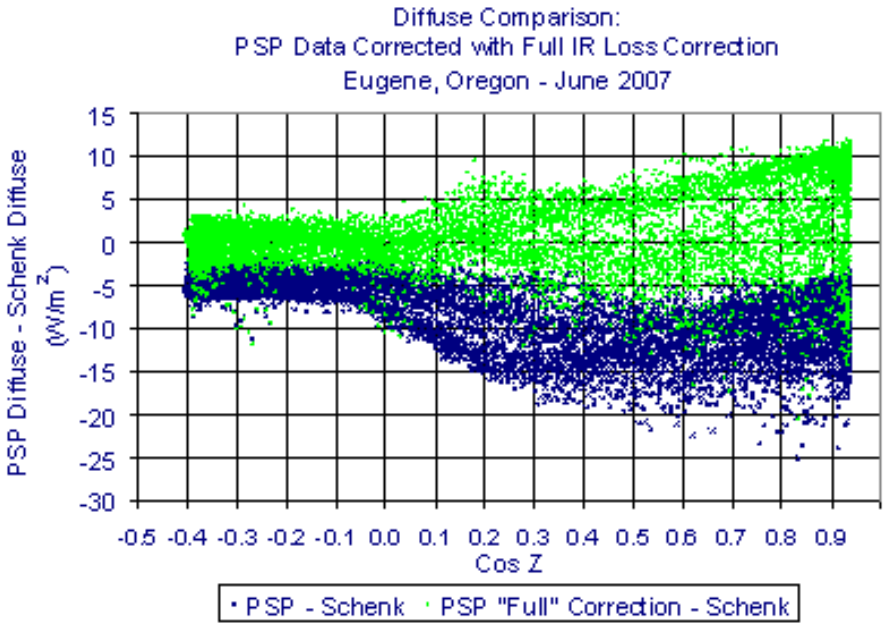
AR4
(Early 2000's)

Median IPCC-AR4 — IPCC-AR4 Models — Observed

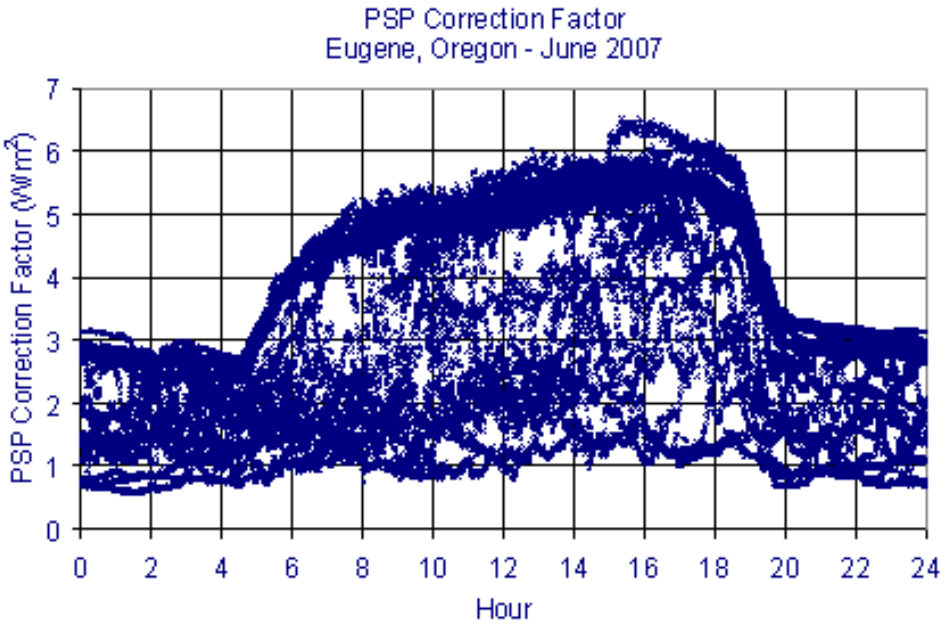
Improved agreement for clear-sky SW from AMIP1 (top) through AMIP2 (middle), to AR4 (bottom) series comparisons due to better representation of water vapor and aerosols in the models.

Wild, Long, Ohmura, 2006, JGR

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 greater during daylight hours than at night (below).

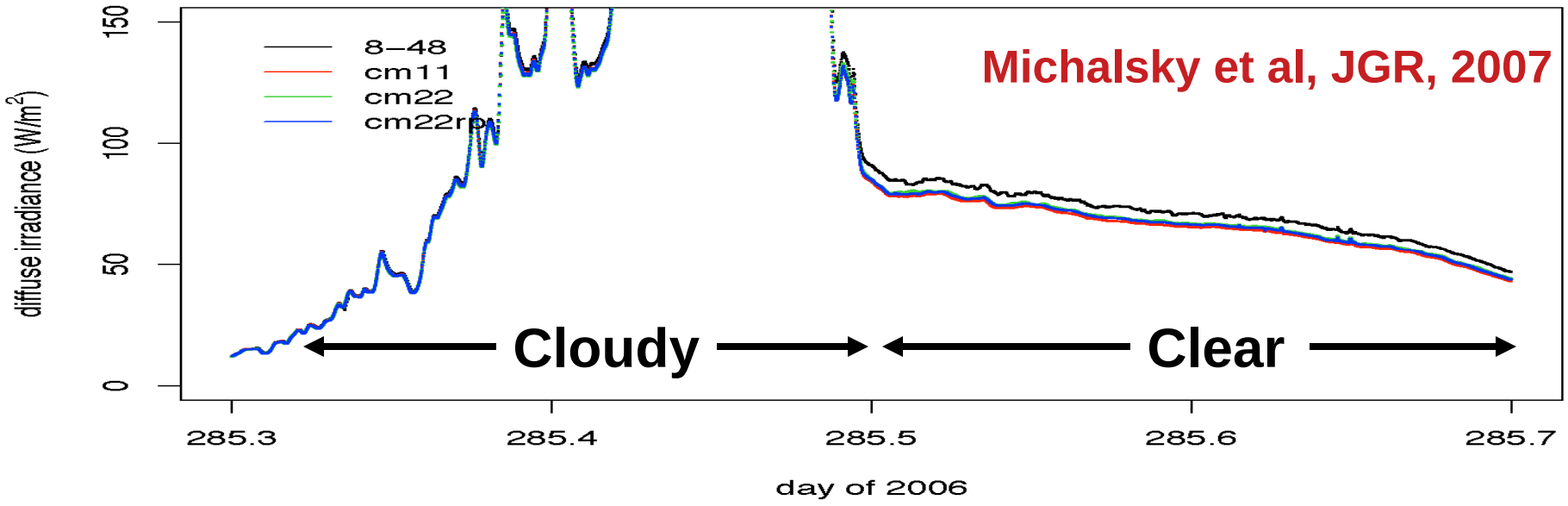


Vignola, Long, and Reda, OMMSES, 2007.

Overview

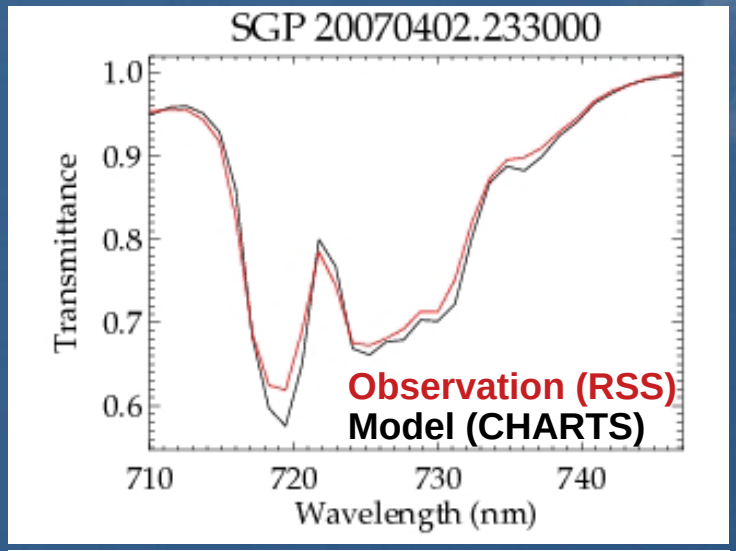
SW Diffuse Radiation ‘Standard’

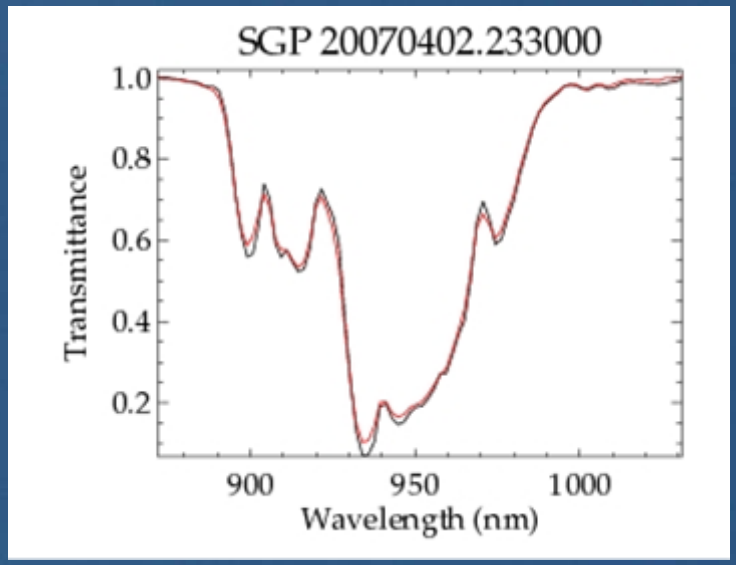
- Carefully characterized 4 diffuse pyranometers
- Shade/unshaded calibration performed during Diffuse IOP at SGP site
- Excellent agreement in cloudy scenes, only the ‘8-48’ diverges slightly in clear skies



The Shortwave QME Paradigm

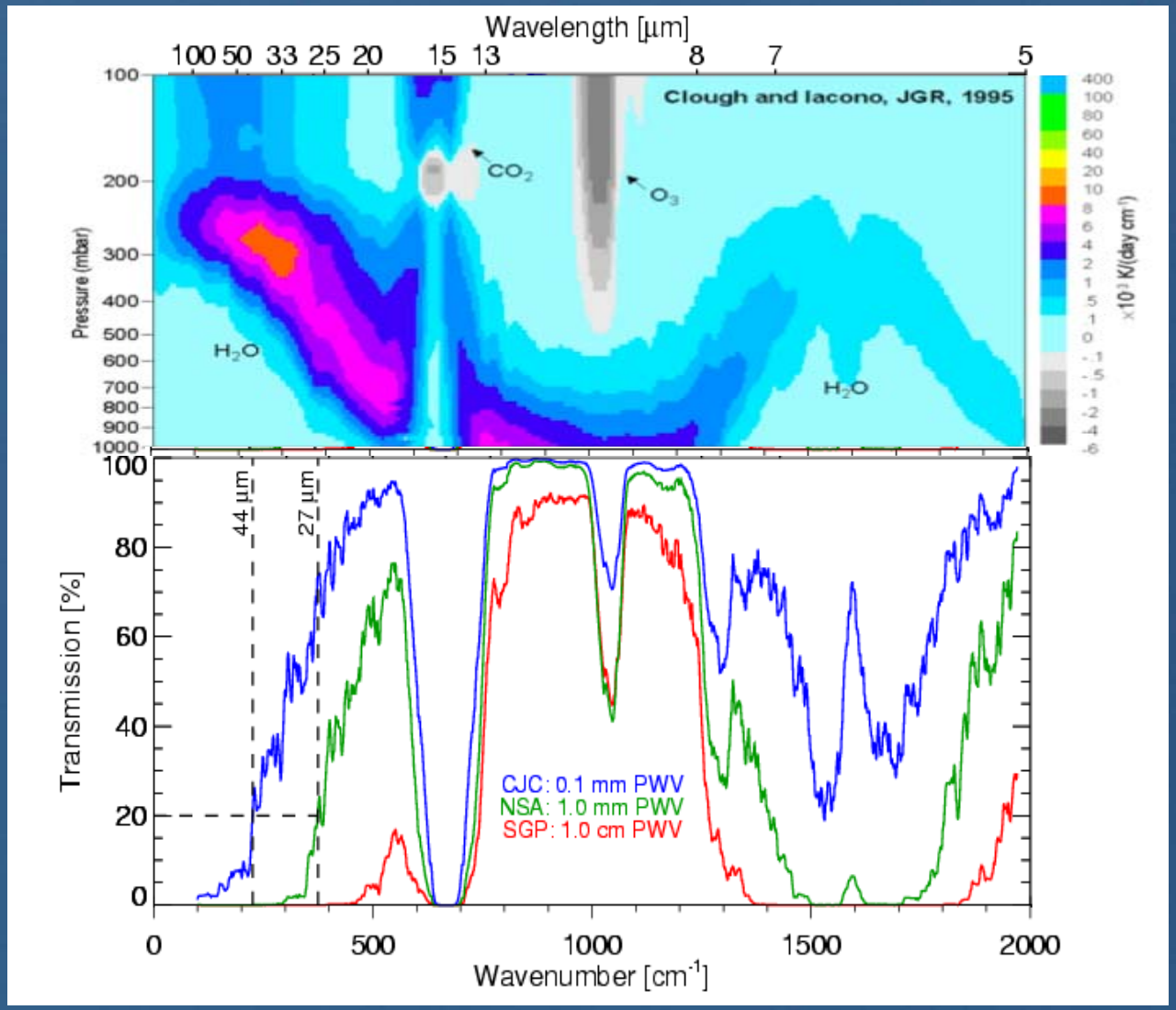
- Critical evaluation of all components of closure study in the shortwave:
  - Measurement Quality
  - Accuracy of calculation
    - Line parameters (HITRAN)
    - MT_CKD continuum model
    - Extraterrestrial spectrum
  - Model inputs
    - Spectral Surface Albedo
    - Aerosol Properties (e.g. spectral dependence of SSA, vertical distribution of aerosol)
    - Cloud Properties
    - Atmospheric state





Delamere et al.

Radiative Heating in Underexplored Bands Campaign (RHUBC)



PIs: Turner and Mlawer

183.31 GHz Water Vapor Line Half-Width

Measurement: G-band Vapor Radiometer (GVR)

183.31 +/- 1, 3, 7, 16 GHz

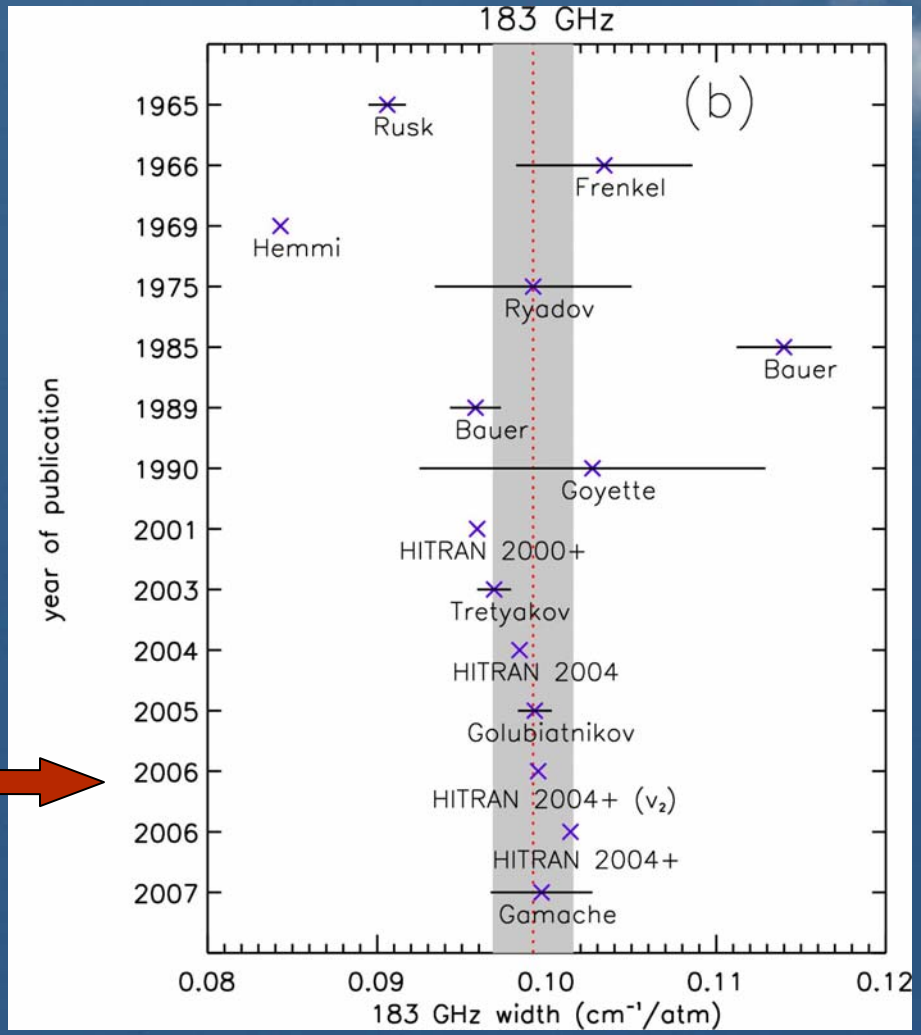
Model: MonoRTM

HITRAN line parameters

CKD Continuum Model

- Evaluated 183.3 GHz line parameters

  -New value of air-broadened half-width



Payne et al., TGRS, 2008 (submitted)

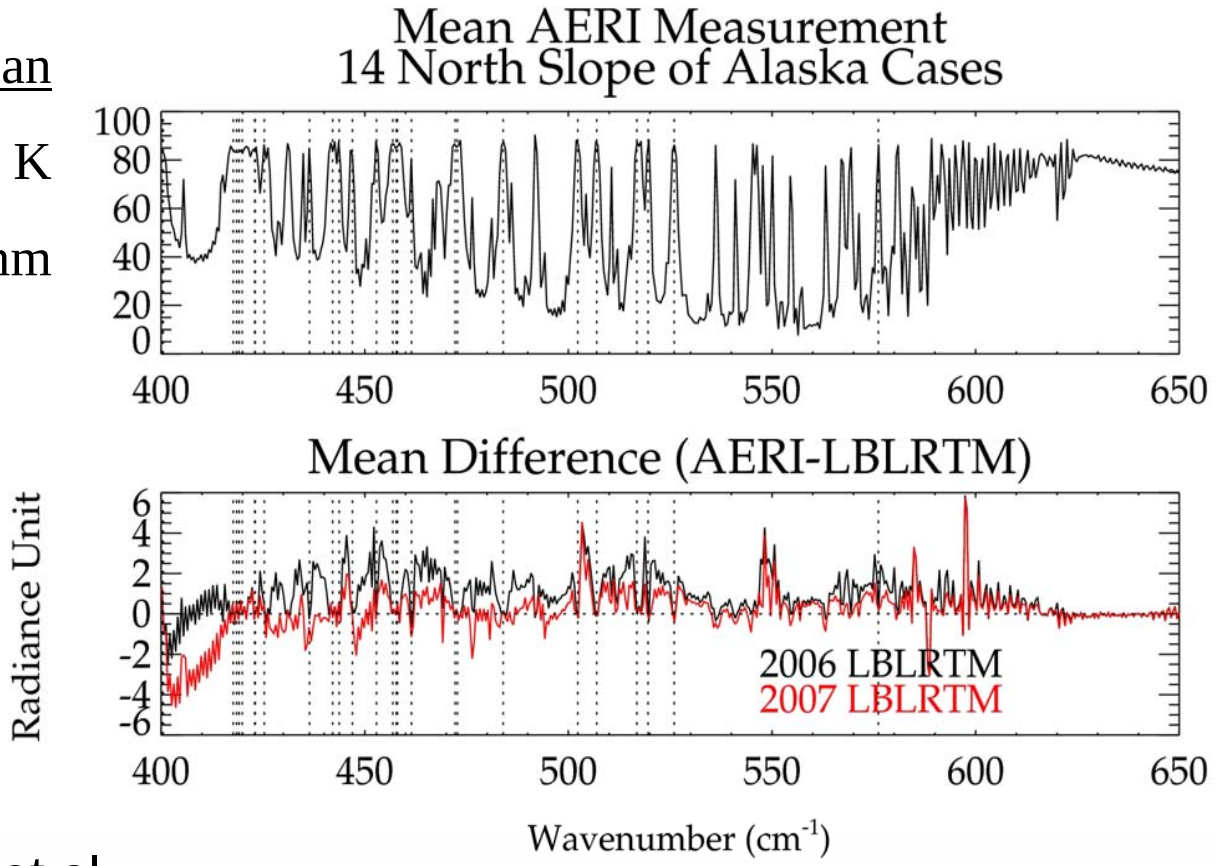
Clear Sky Far-IR Closure Results

- Update Continuum Model
  - Adjusted foreign water vapor continuum
- Update HITRAN line parameters
  - New water vapor air-broadened half-widths

Mean

T_{sfc}: 245 K

PWV: 1.6 mm



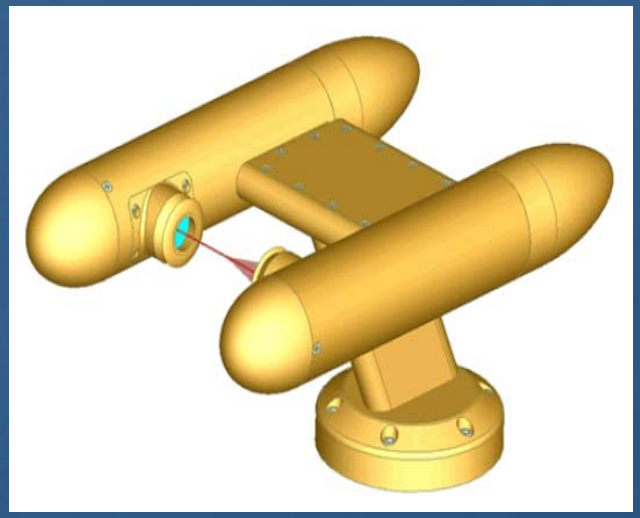
Delamere et al.

Measurements of Small Ice Crystals (D < 50 μm)

Cloud and Aerosol Spectrometer

Shroud **Inlet**

Cloud Droplet Probe

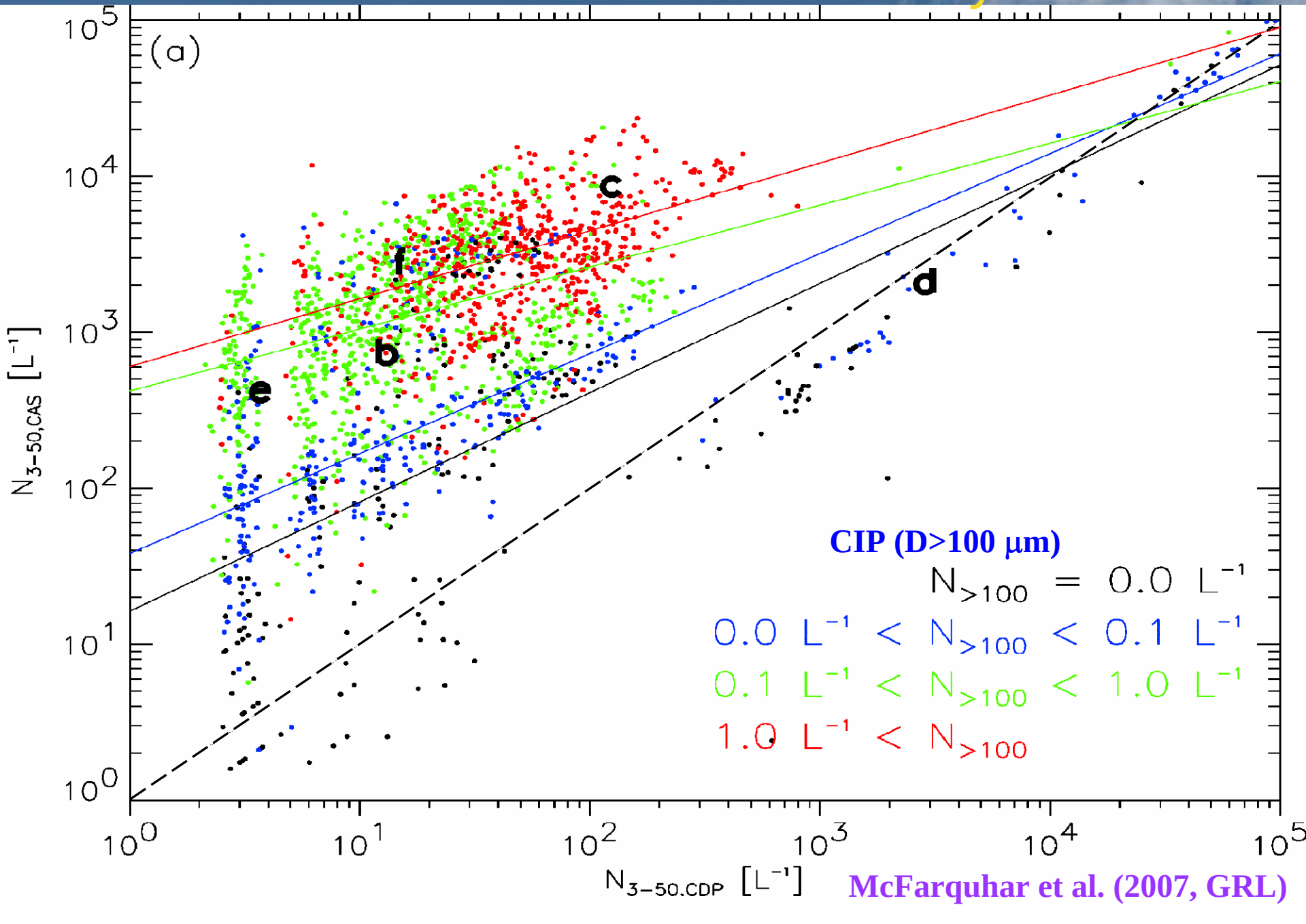


- Open path
- Neither inlet nor shroud

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

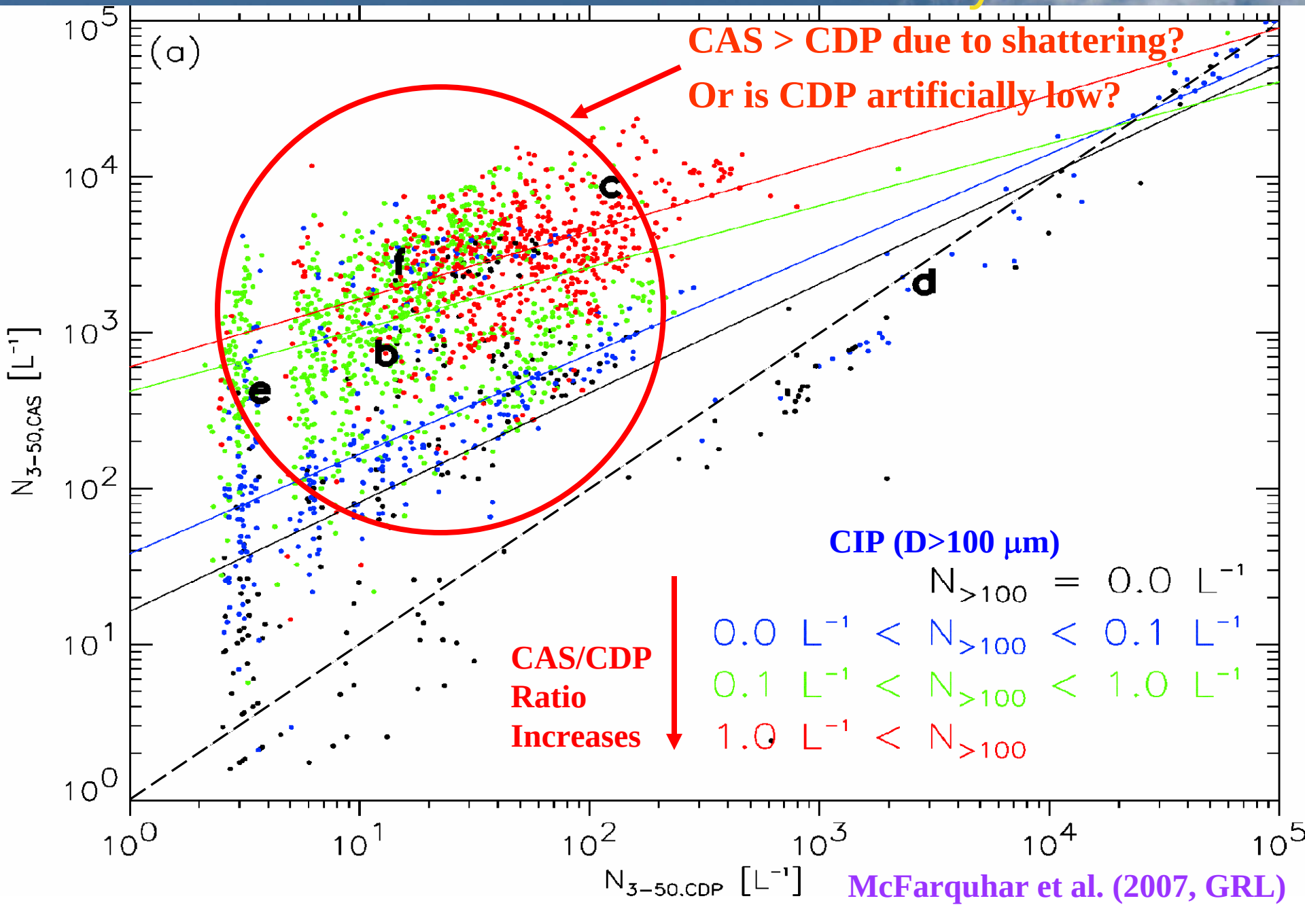
McFarquhar et al. (2007, GRL)

Measurements of Small Ice Crystals



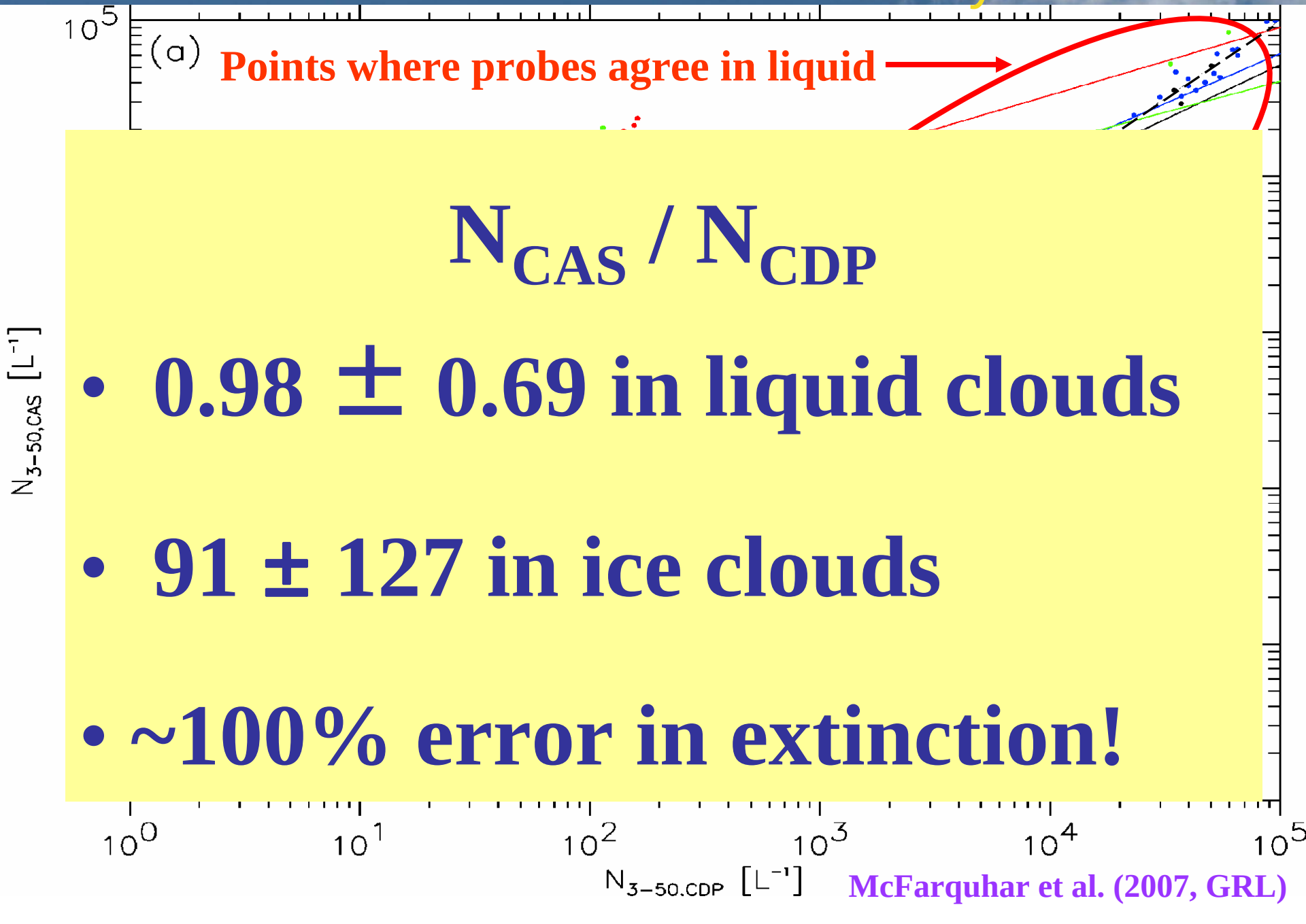
McFarquhar et al. (2007, GRL)

Measurements of Small Ice Crystals



McFarquhar et al. (2007, GRL)

Measurements of Small Ice Crystals



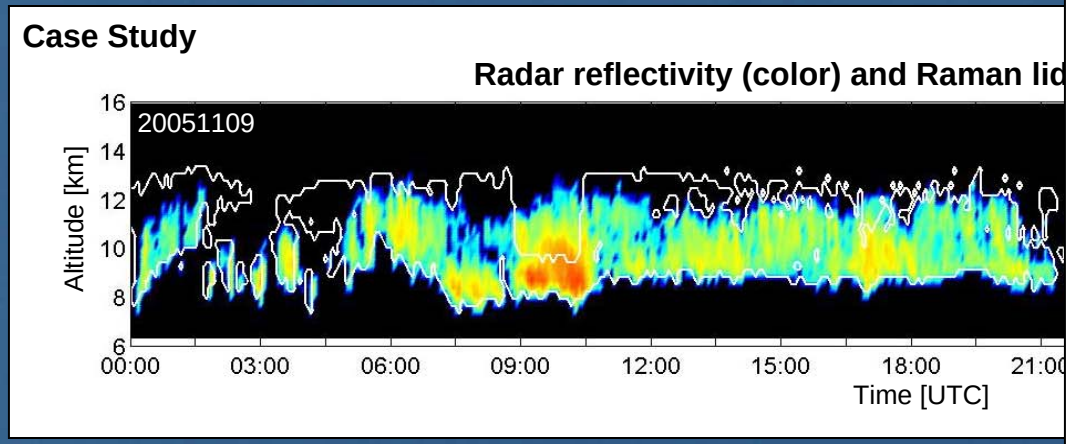
$$N_{CAS} / N_{CDP}$$

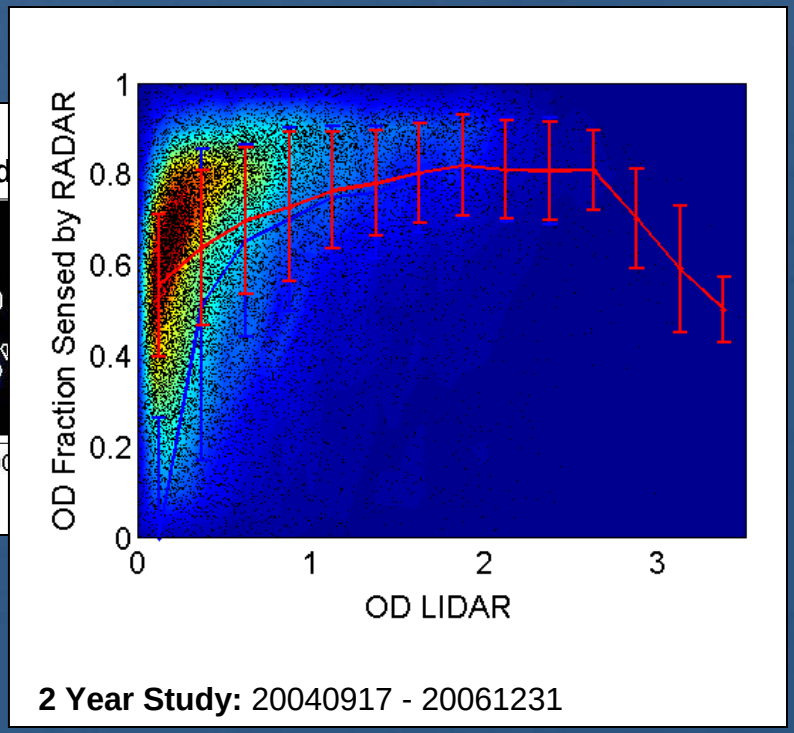
- **0.98 ± 0.69 in liquid clouds**
- **91 ± 127 in ice clouds**
- **~100% error in extinction!**

McFarquhar et al. (2007, GRL)

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





2 Year Study: 20040917 - 20061231

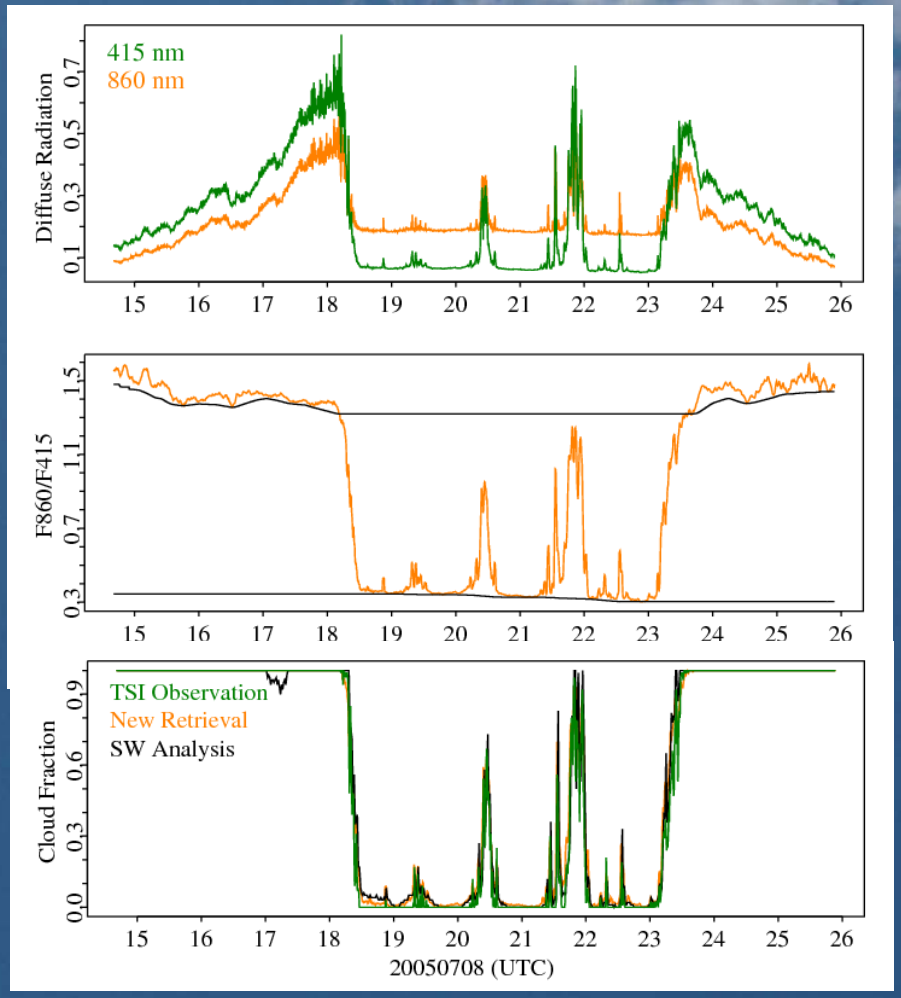
Conclusions:

- 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.

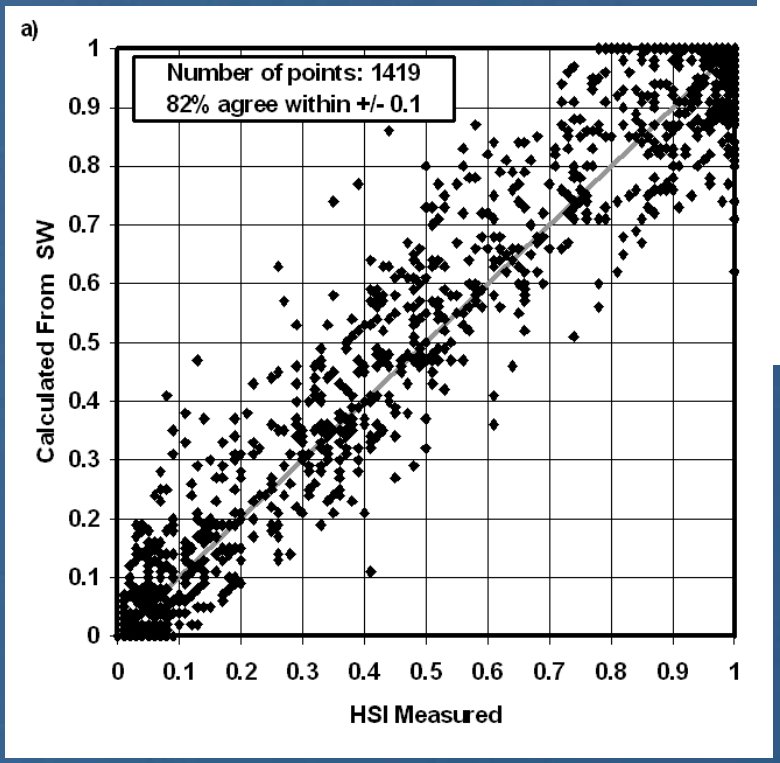
Estimating Cloud Sky Cover from Spectral Radiation Obs

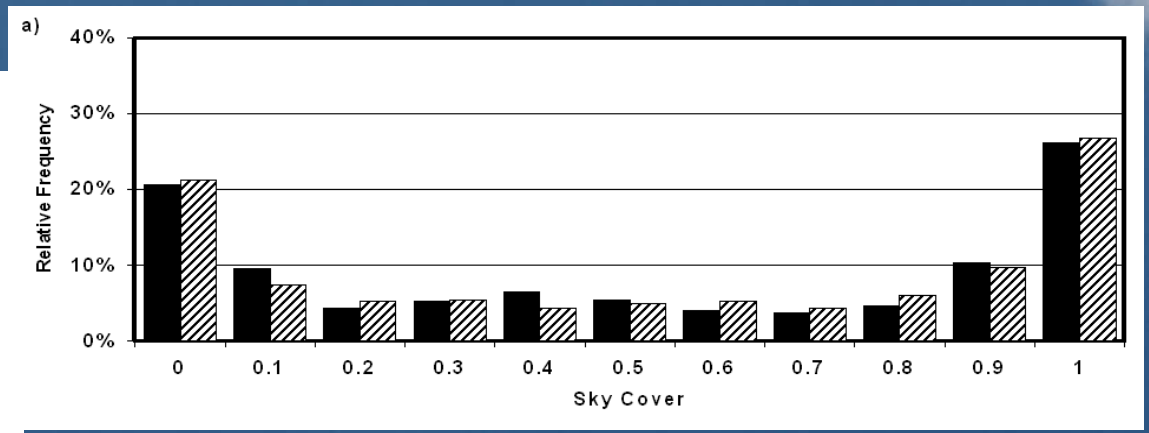
- Transmittance ratio at 415 and 860 nm is insensitive to SZA, gaseous absorption, abs cal. Only weakly sensitive to changes in cloud and aerosol optical properties
- Uncertainty of method is estimated to be less than 10%



Min and Wang

SW Fractional Sky Cover



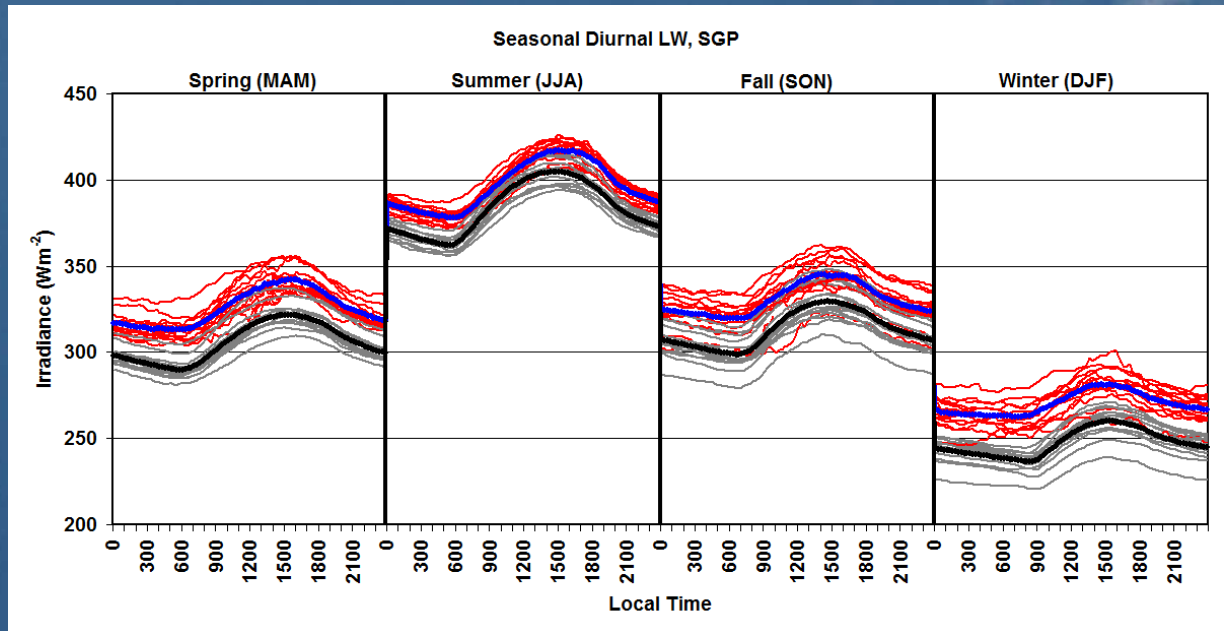


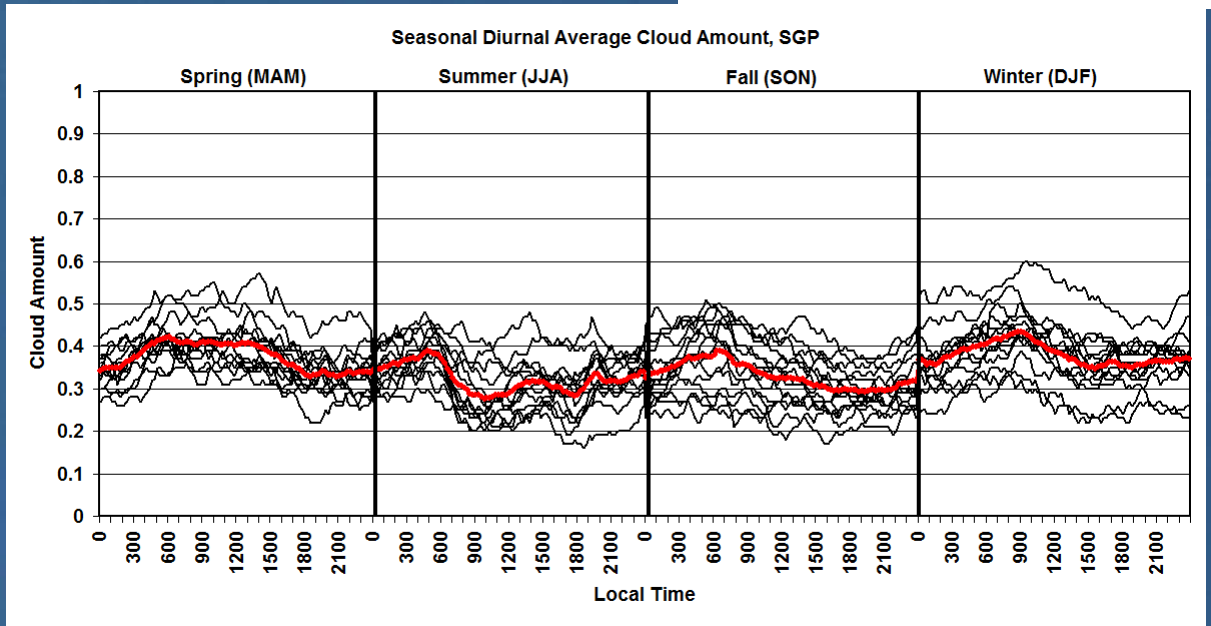
Fractional sky cover retrievals from SW measurements show better than 10% agreement with sky imager retrievals (left) and similar frequency distributions (above).

Long, Ackerman, Gaustad, Cole, JGR, 2006

Results from LW Radiative Flux Analysis

SGP seasonal diurnal all-sky and clear-sky surface LW flux





SGP seasonal diurnal LW effective sky cover

Long and Turner, JGR, Submitted

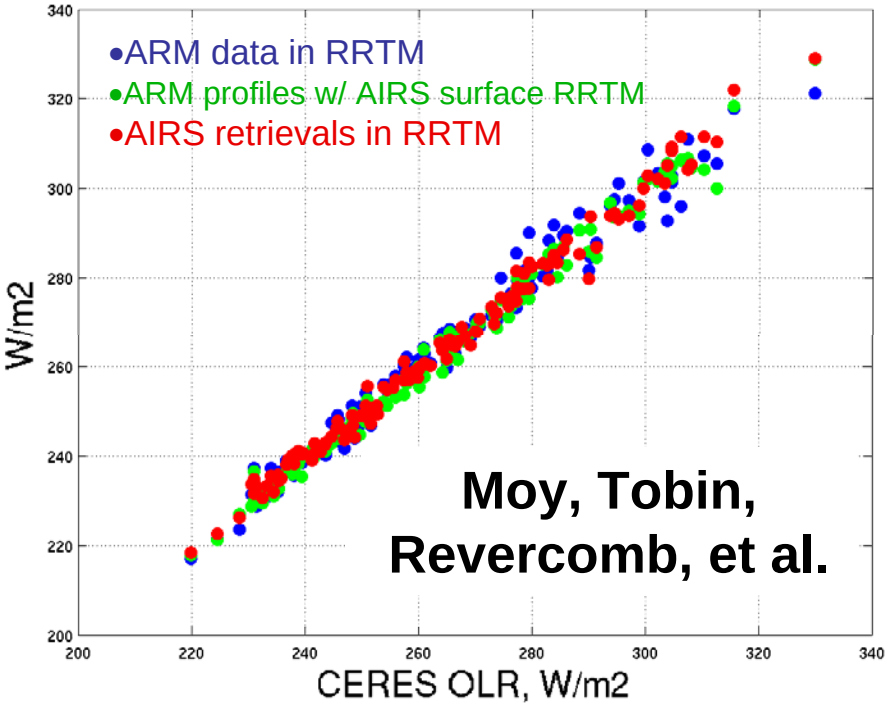
Assessing ARM Clear Sky BBHRP with CERES and AIRS

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

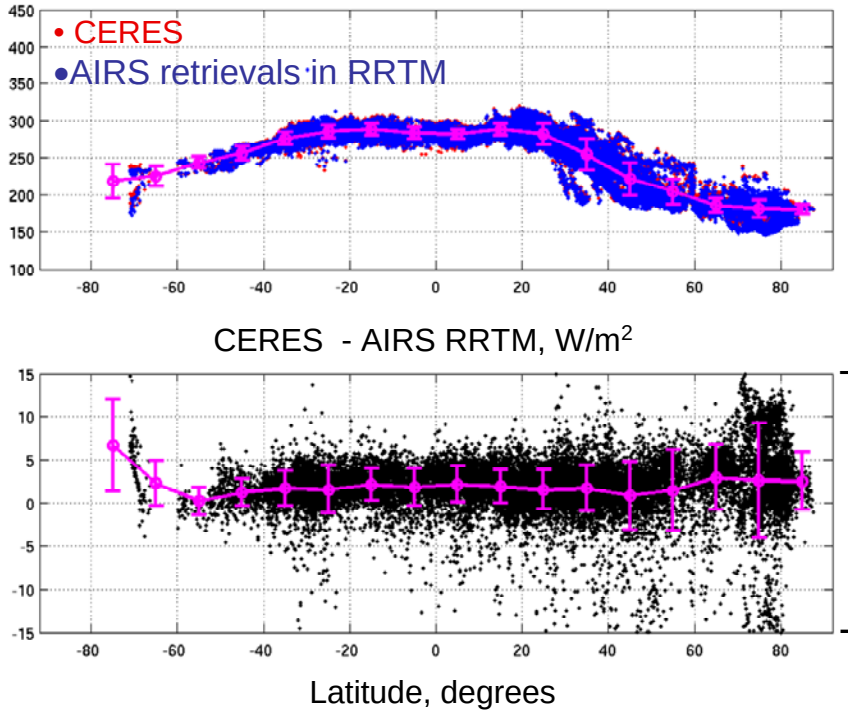
* True at SGP over 2.5 years, true globally (with some *understood* regional exceptions) for study day.

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

Clear Sky OLR at ARM SGP site



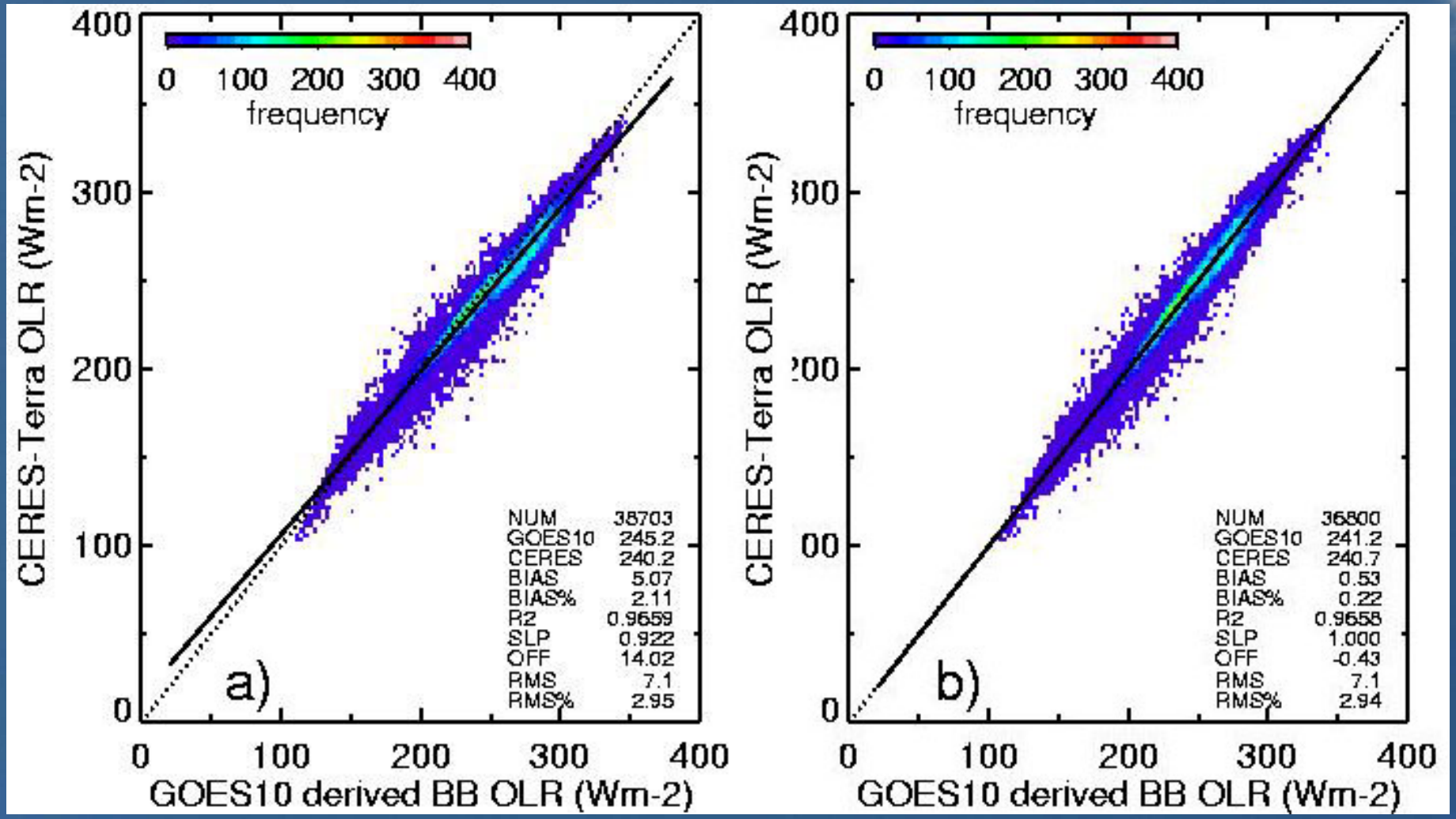
Night time Clear Sky OLR for 16Nov2002, W/m^2



GOES-10 Derived BBLW Fluxes vs CERES

Sep05-Feb06 SGP

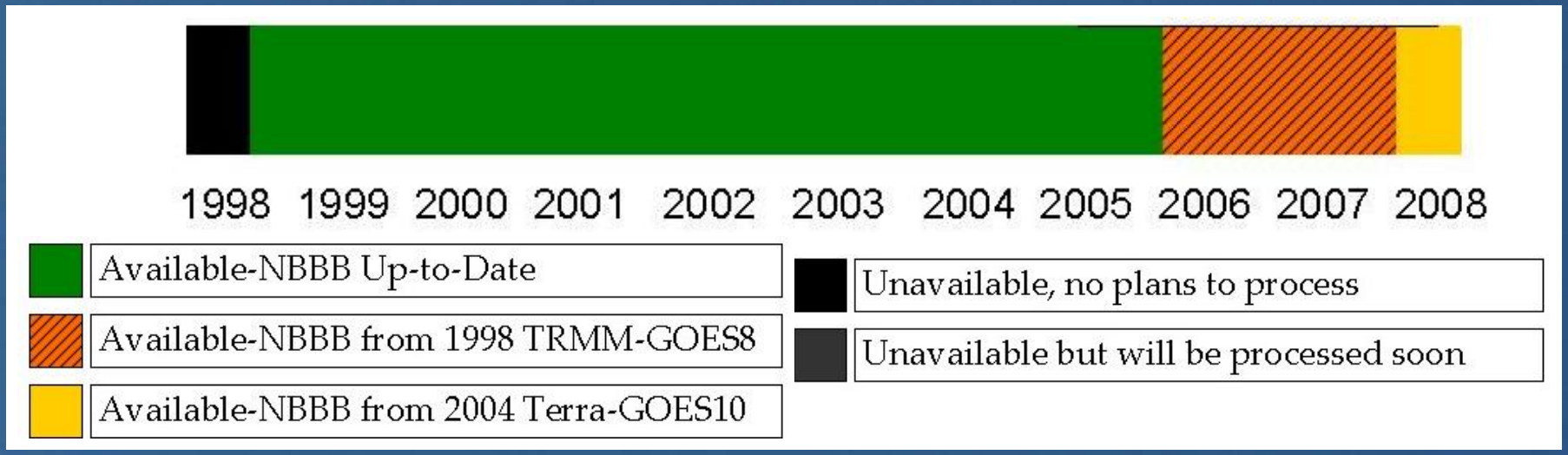
OLD VISST V2 (1998) NEW VISST Val (2004)



Minnis, Khaiyer, et al.

SGP GOES-x VISST in ARM Archive

- ARM Archive deliveries:
  - May98-Sep05 pixel-level, 0.5° gridded netcdf files
  - Near-realtime VISST delivered ~1 month lag
- New, Improved SGP NB-BB fits:
  - GOES-8/Terra; GOES-10/Terra now used in near-realtime VISST
  - Interfacing w/ BBHRP; working on day/night/seasonal NB-BB fit



Minnis, Khaiyer, et al.

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 upcoming
- TWP - in pipeline

Mlawer et al.

Reasonable Simple Assumptions Yield Equivalent Results

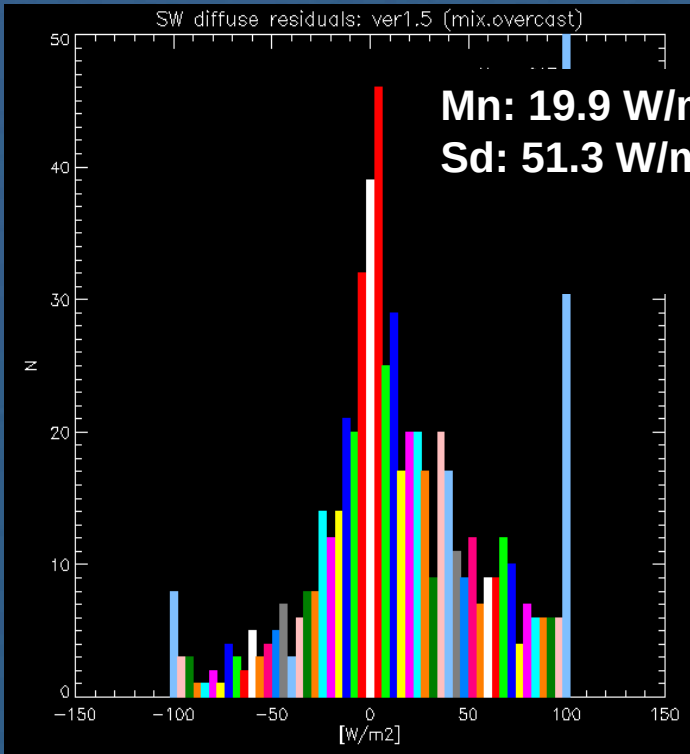
SW Diffuse Residuals at Surface

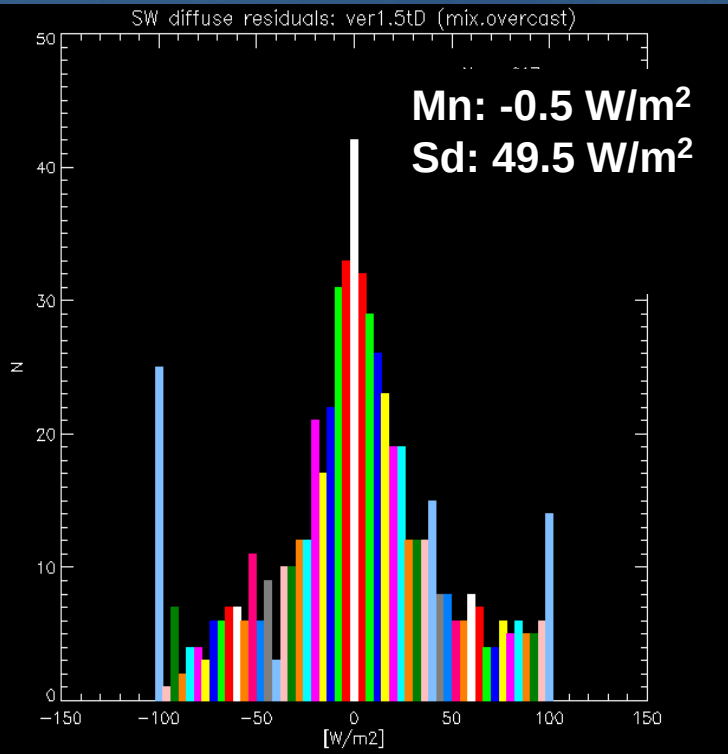
Mixed-phase clouds

(all cases overcast)

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

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



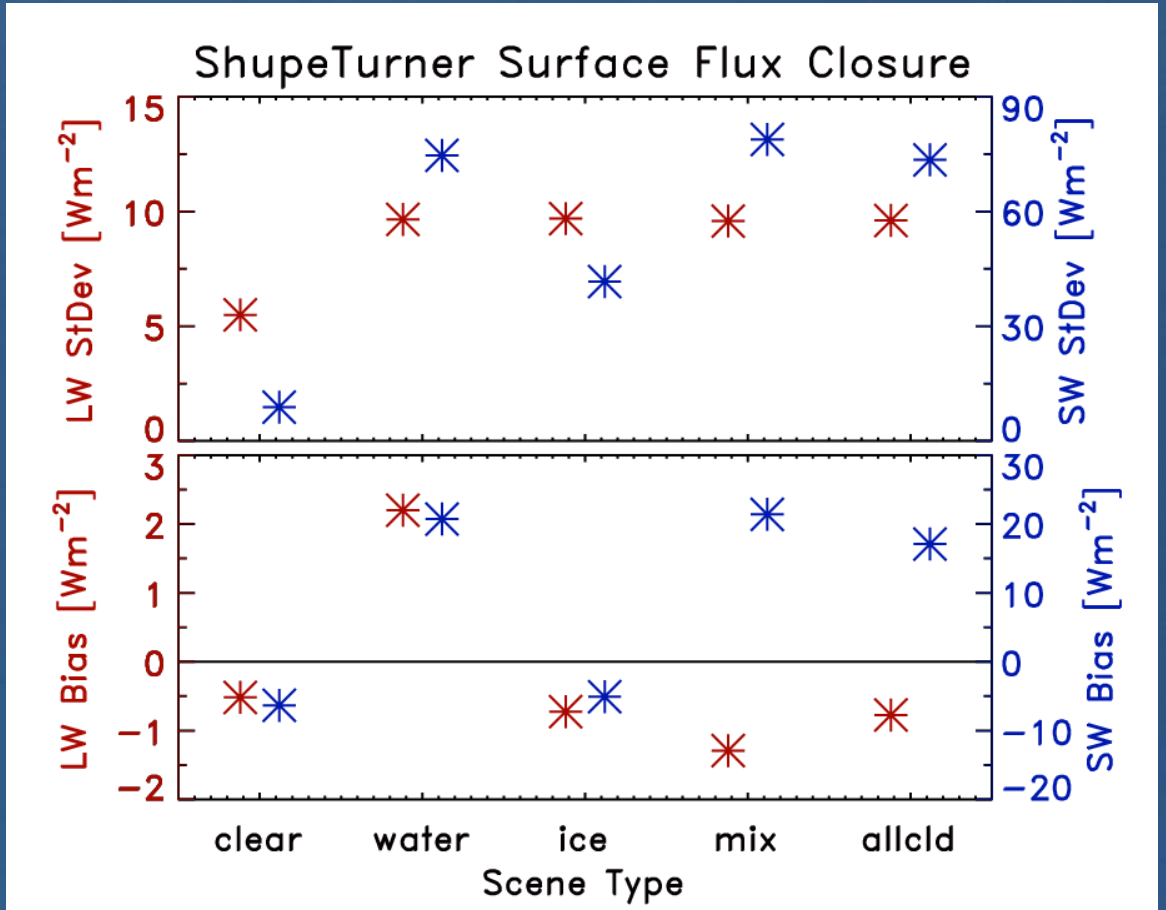


Mlawer et al.

Evaluating Cloud Properties at NSA with the BBHRP Framework

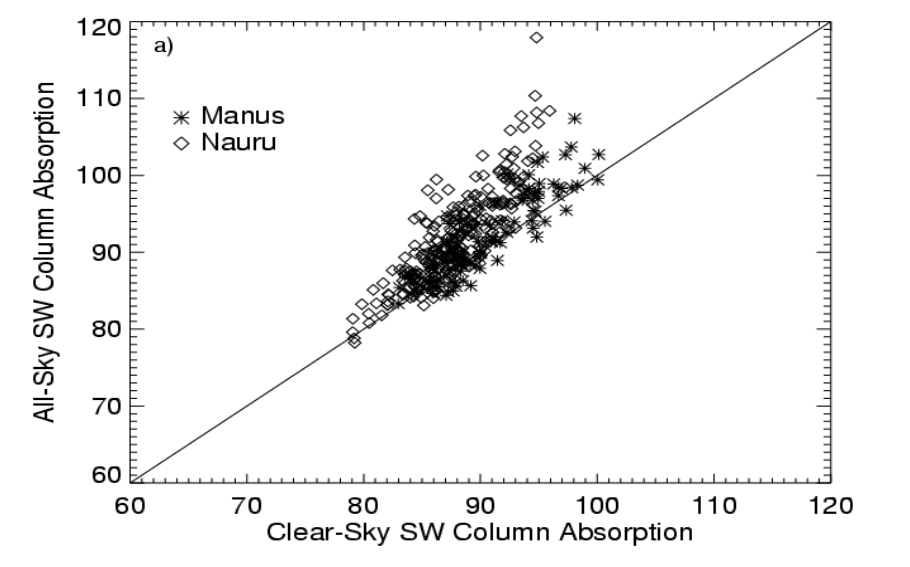
WRT to the standard ARM Microbase product at the NSA site, the S-T cloud properties reduced:

- LW StDev 25%
  - 43% for liq clds
- SW StDev 20%
  - 36% for liq clds
- LW bias by 75%
- SW bias 50%

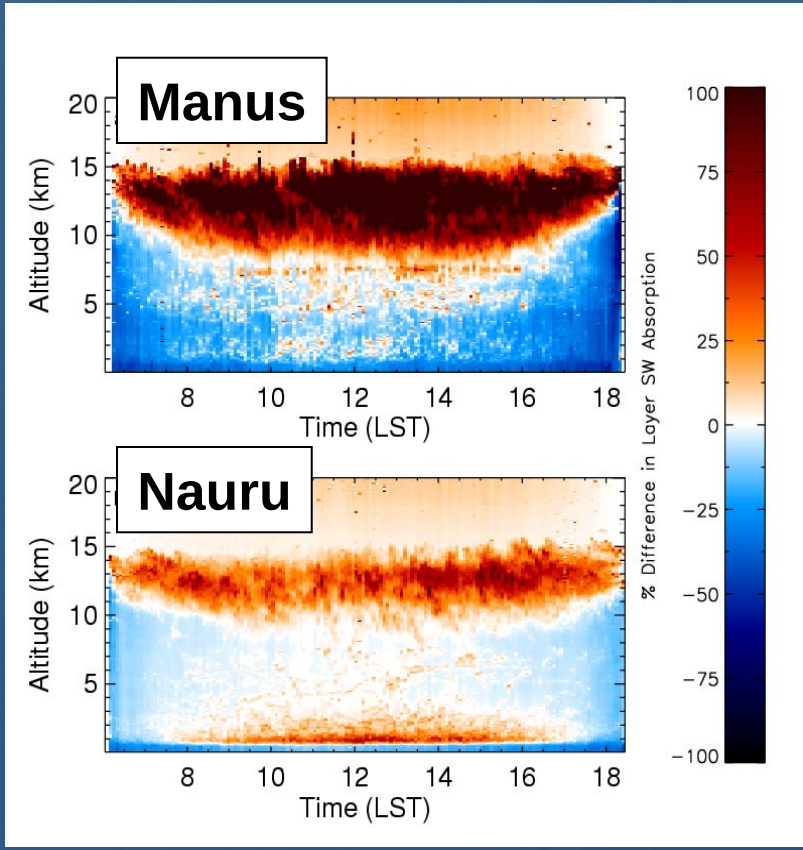


Shupe et al.

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

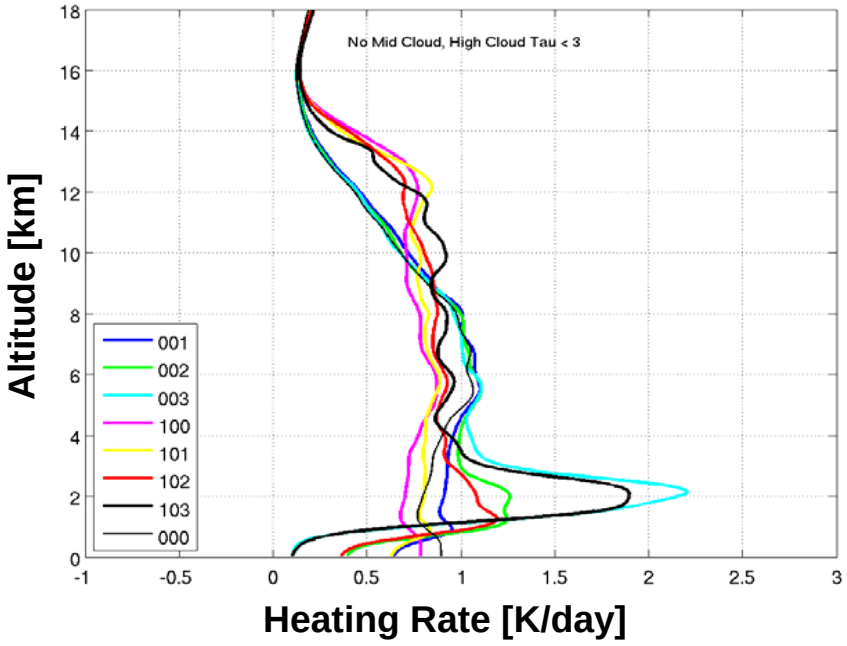


% change in layer absorption due to clouds

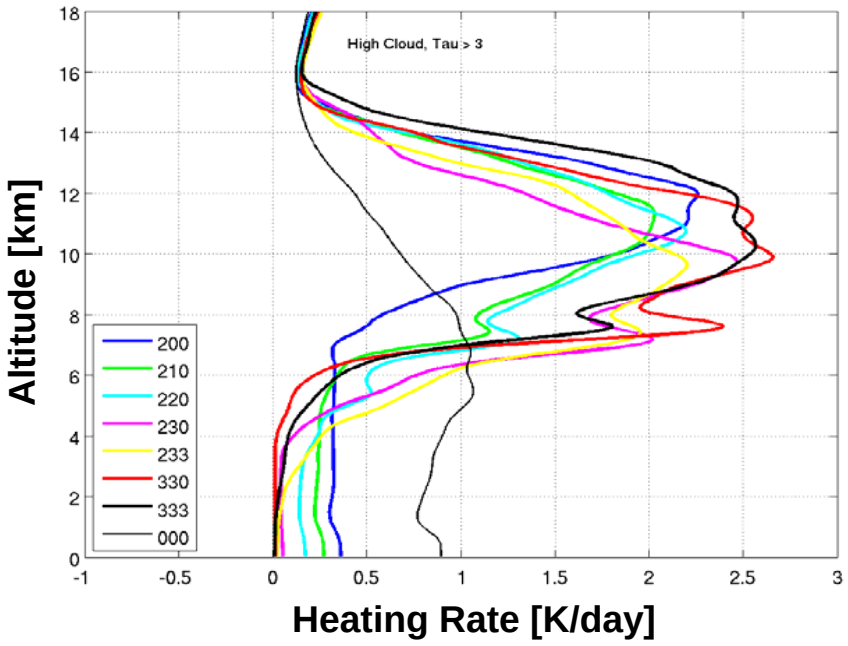
McFarlane et al,
in revision, JGR

Heating Rate Profile Classification

High Cld: tau < 3
Mid Cld: none
Low Cld: variable



High Cld: tau > 3
Mid Cld: variable
Low Cld: variable



Shortwave only

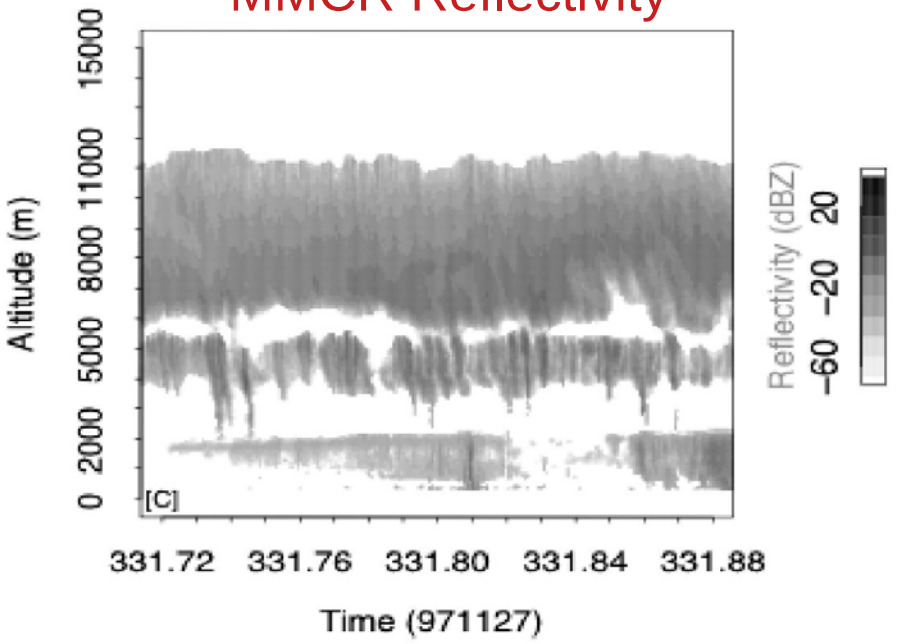
(LW results also available)

Mather and McFarlane

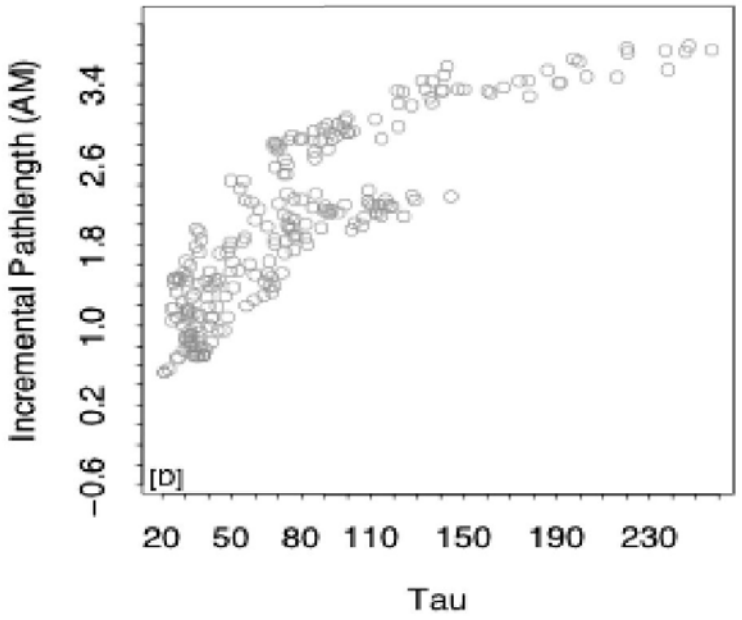
Hi-Res O_2 A-Band Spectroscopy

- New and unique measurement
- Direct measure of atmospheric absorption
- Information on cloud thickness, separation, and deviation from “plane parallel-ness”

MMCR Reflectivity



O_2 A-band pathlength

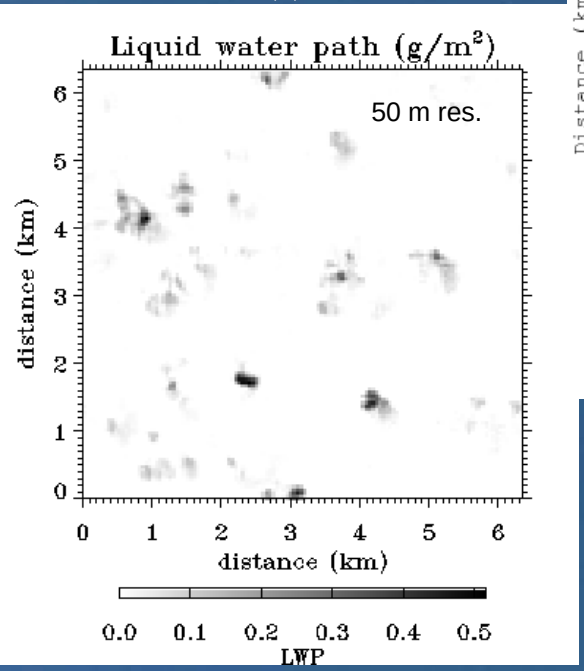


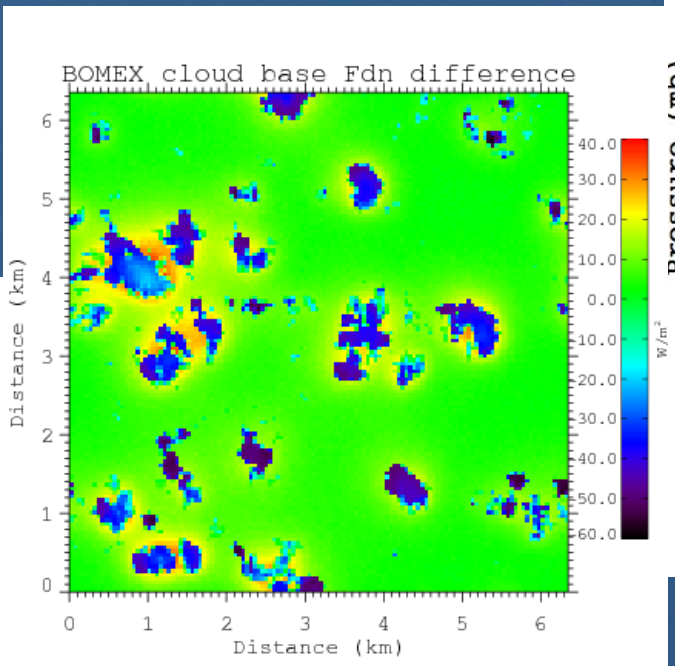
Davis and Min

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

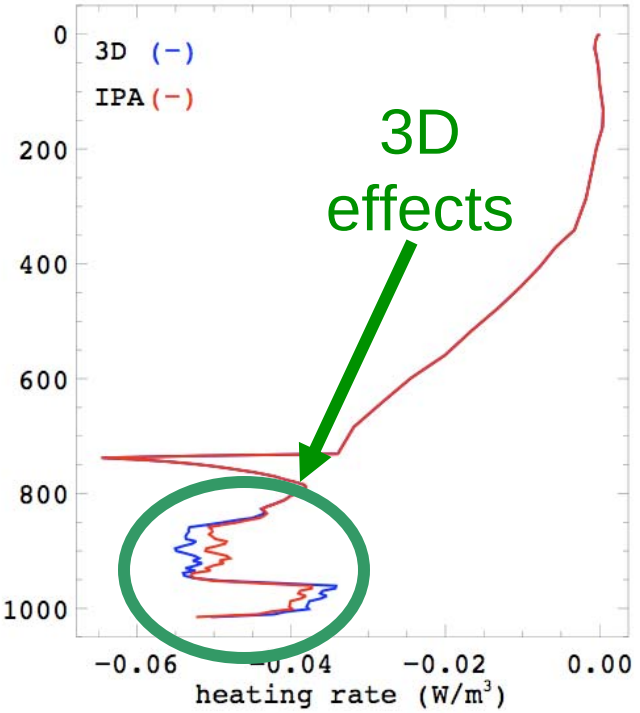
BOMEX Case
Cu: 0.3 to 1.0 km MSL

LWP





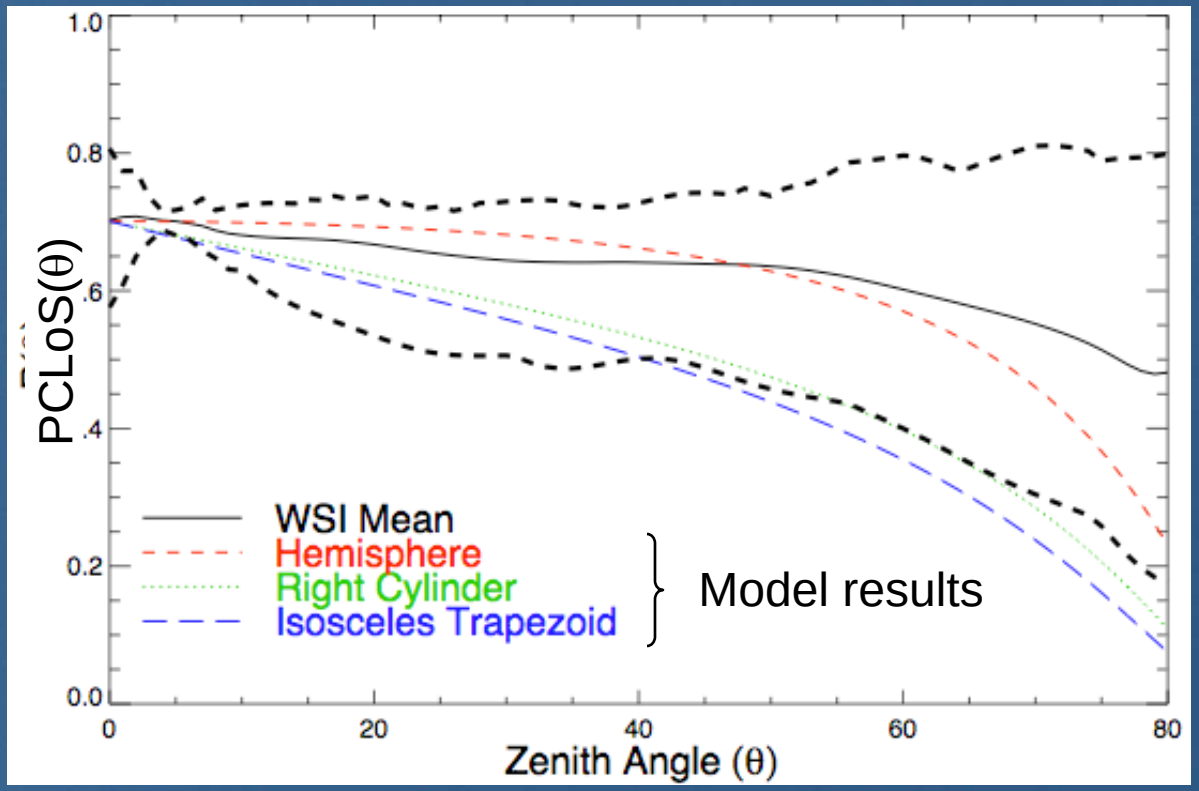
F↓(3D MC) – F↓(IPA)
at the cloud base



Domain averaged heating rate for 3D MC and IPA

Kablick, Gu, Takara and Ellingson

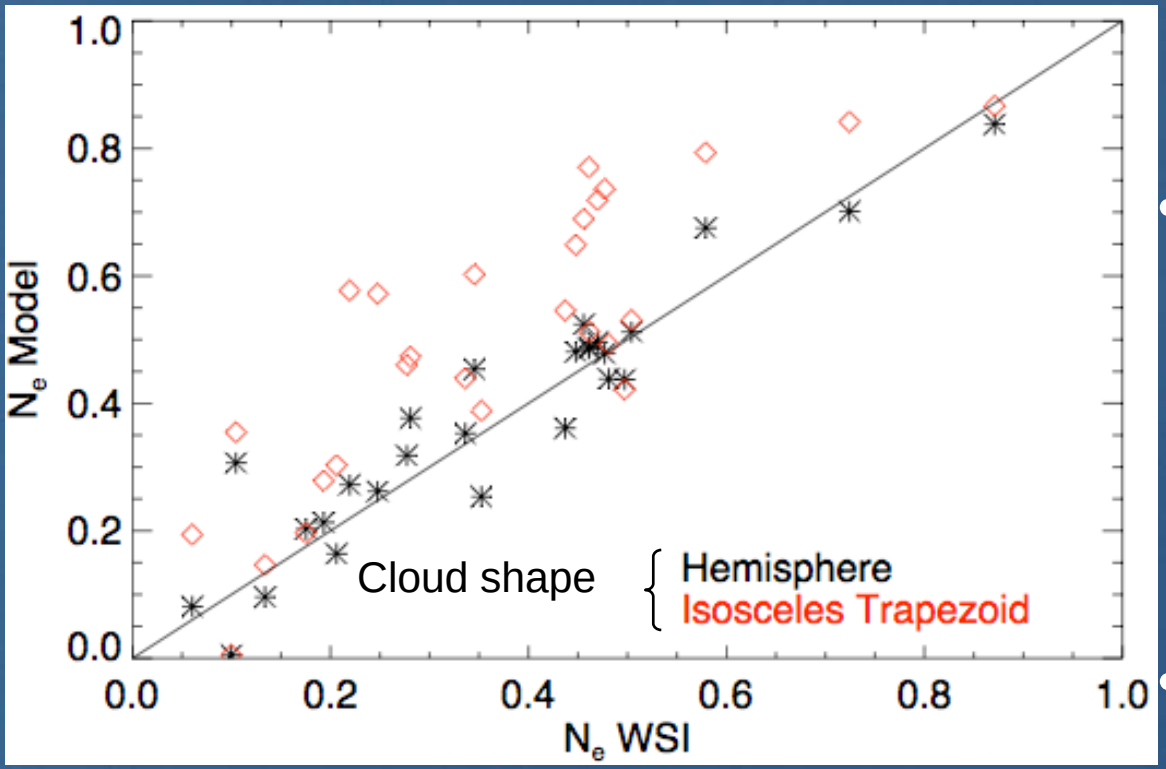
Probability of Clear Line of Sight (PCLoS) Through Single-Layer Cumulus Cloud Fields in the TWP



- PCLoS is easily related to the *effective cloud fraction* - N_e
- Provides a simple and effective means of parameterizing 3D cumulus cloud radiative effects in GCMs

Taylor and Ellingson, accepted in JAS

Effective Cloud Fraction and Downwelling Surface Flux (F↓) Results



- Hemispheric clouds N_e agree with WSI in the range of 0.01–0.12.
- F↓ calculations are improved by ~2–3 Wm^{-2} relative to observations using hemispherically shaped clouds instead of PPH.
- Observed cloud side effect was ~ 3–4 Wm^{-2} on average.

Taylor and Ellingson, accepted in JAS

Continuous Intercomparison of Radiation Codes (CIRC)

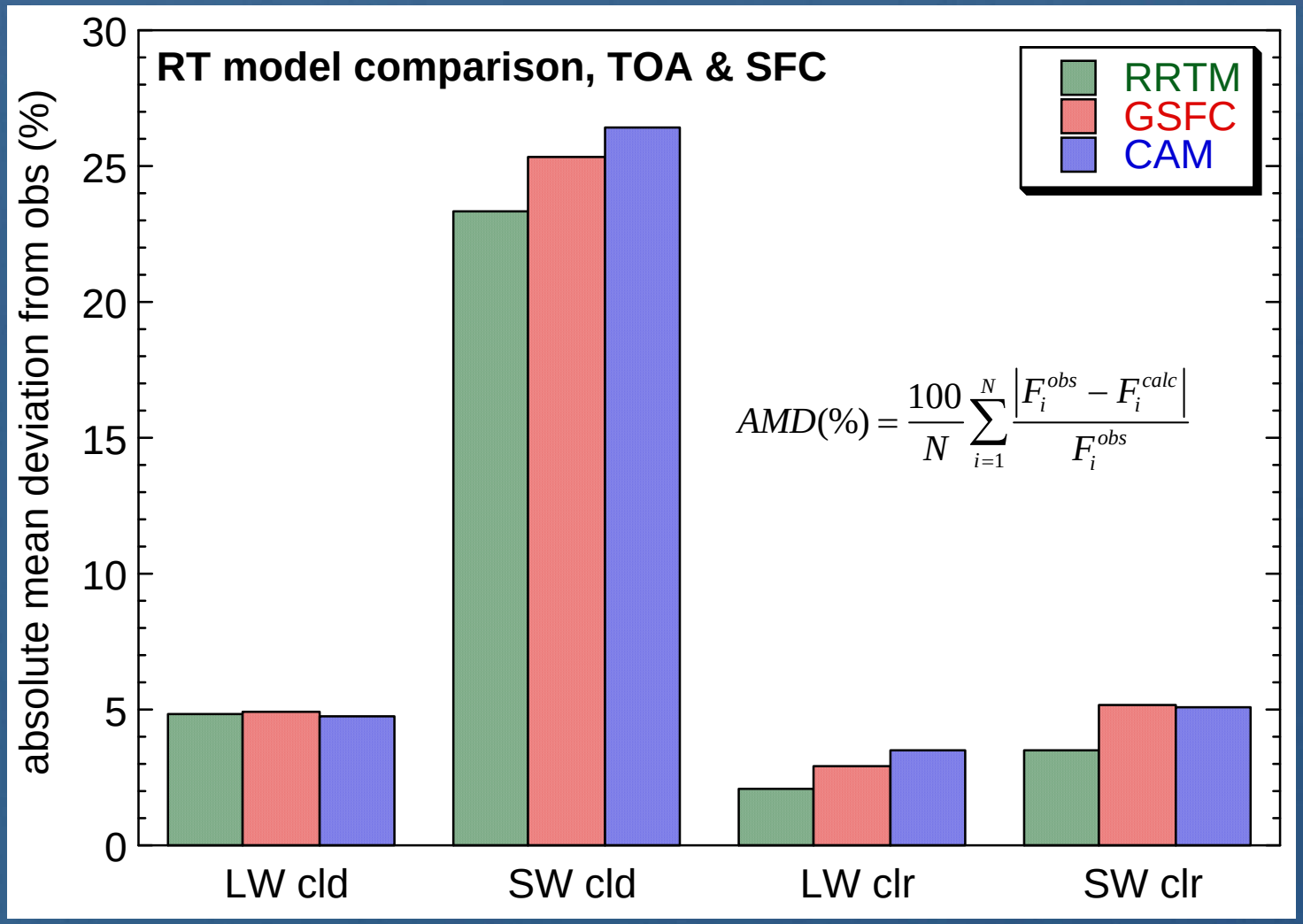
- Sponsored by ARM and endorsed by GEWEX Radiation Panel
- Aims to become the standard for documenting the performance of SW and LW RT codes in Large-Scale Models
- Goal is to have RT codes of IPCC models report performance against the CIRC cases
- Phase I to be launched in the following weeks: http://www.circ-project.org

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

BBHRP with Different RT Models

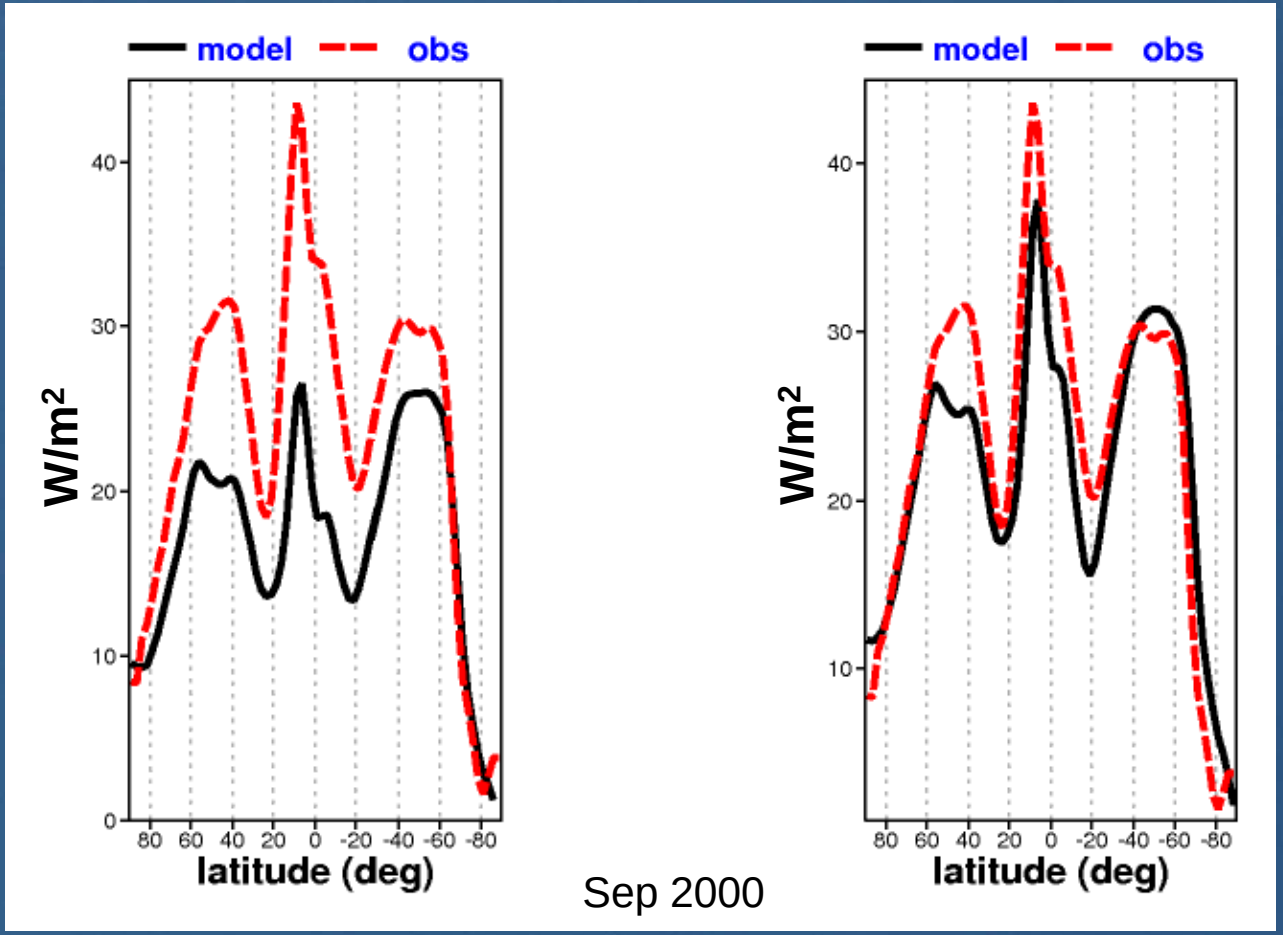


Oreopoulos/Mlawer/Shippert

Improvement in Annual TOA LW Cloud Forcing at ECMWF

Zonal Means

Before RRTM



After RRTM

Sep 2000

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

PIs: Iacono/Mlawer

ARM-Supported Radiation for GCMs: RRTMG Applications

- GCMs
  1. ECMWF forecast model (using LW and SW)
  2. NCEP Global Forecast System (GFS, CFS) (using LW and testing SW)
  3. NCAR Community Atmosphere Model (CAM3.5) (testing LW and SW)
  4. GFDL climate model (AM2) (testing LW and SW)
  5. Max Planck Institute climate model (ECHAM5) (using LW)

- Mesoscale/Regional Models
  1. Penn State/NCAR (MM5) (using LW)
  2. Weather Research and Forecasting (WRF) (using LW in NCAR/EM)
  3. UC/CIRES Arctic regional climate model (ARCSyM) (using LW)

- ARM
  1. Single Column Models (Scripps, LLNL, etc.) (using LW)

- RRTMG information and code available at www.rtweb.aer.com

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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