CloudSat, ARM, and the Multi-scale Modeling Framework (MMF) in the Tropical Western Pacific

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Collaborators on the ARM Project

- Roger Marchand, U. Washington
- Steve Klein, LLNL
- Sally McFarlane, PNNL
- Robert Pincus, U. Colorado (NY office)
- Kuan-Man Xu, NASA Langley

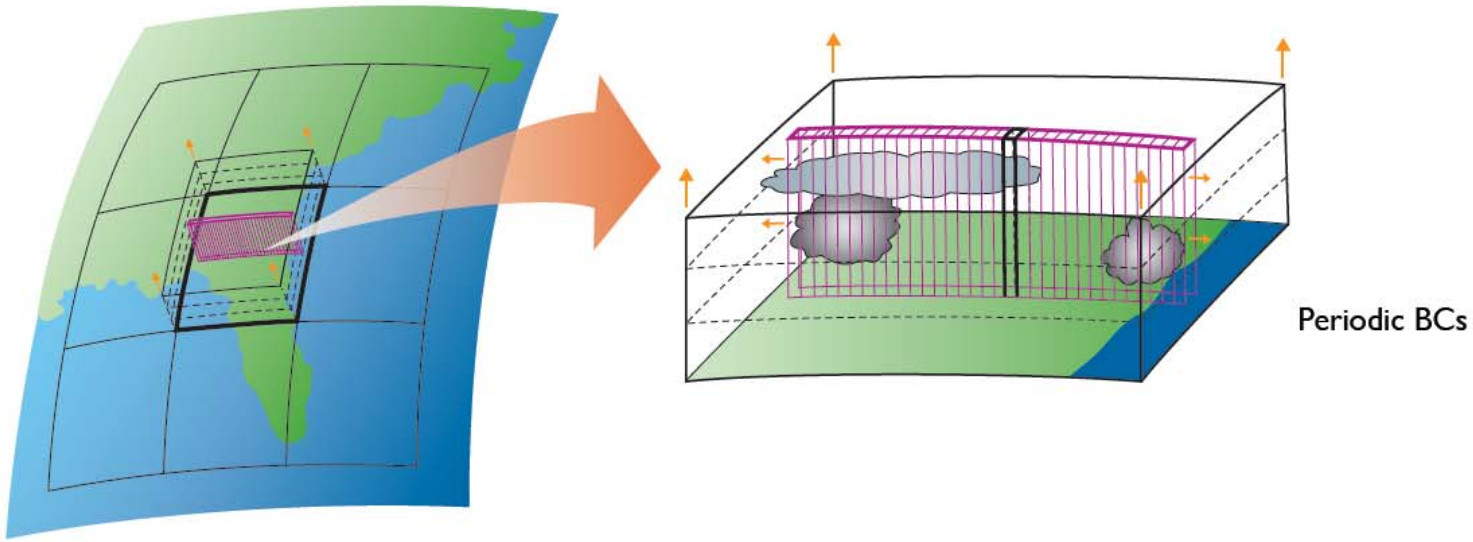
- Anning Chen, Hampton University
- Pete Henderson, U. Colorado
- Yunyan Zhang, LLNL
- Zheng Liu, U. Washington

Our goals

- Improve climate model treatments of clouds and radiation by evaluating model cloud properties using high-resolution data
- Specifically,
  - Develop diagnostics and evaluative frameworks that can be used and re-used
  - Provide a quantitative framework for analysis – moving towards scoring systems
  - Ensure reproducible results – portable data sets *and* diagnostic frameworks
  - Evaluate the MMF and improve its cloud simulations

Super-Parameterization

(a.k.a. the Multiscale Modeling Framework, or MMF)

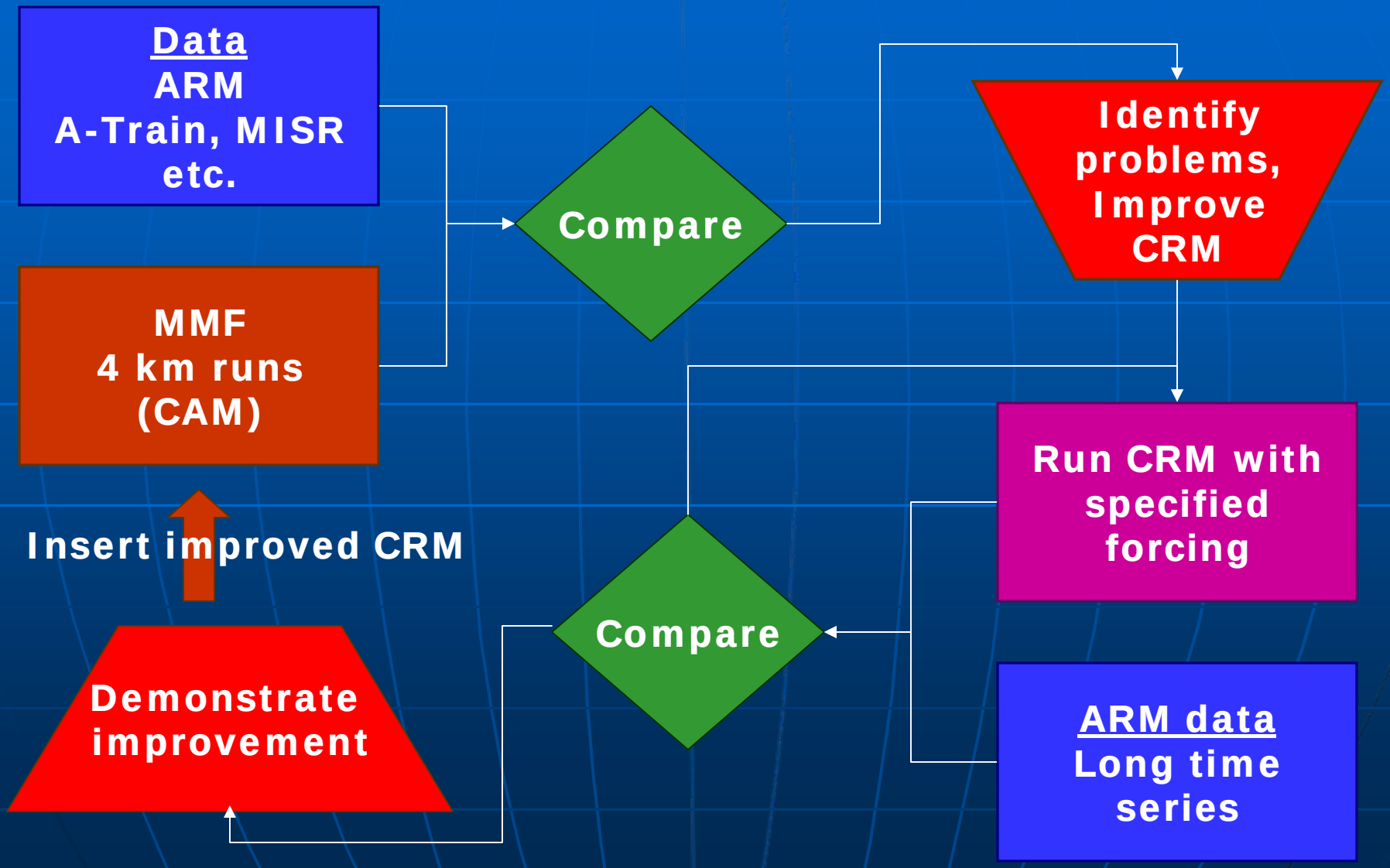


A super-parameterized climate model is about 250 times slower than a conventional GCM with climate resolution.

It is more flexible and less expensive, but also more complicated, than a global cloud-resolving model.

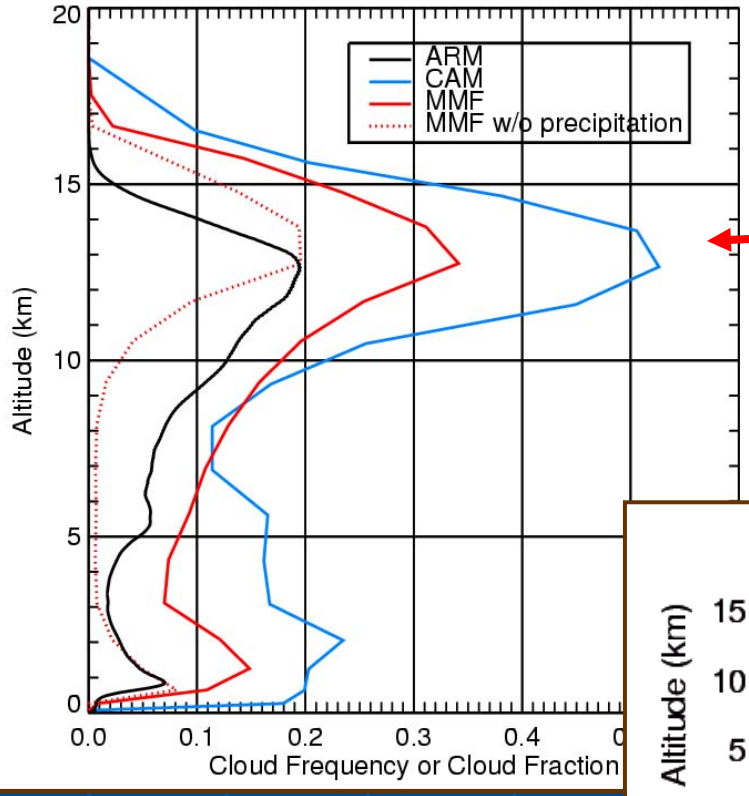
Borrowed from Dave Randall, CSU

The big picture ….



Heating rate comparison

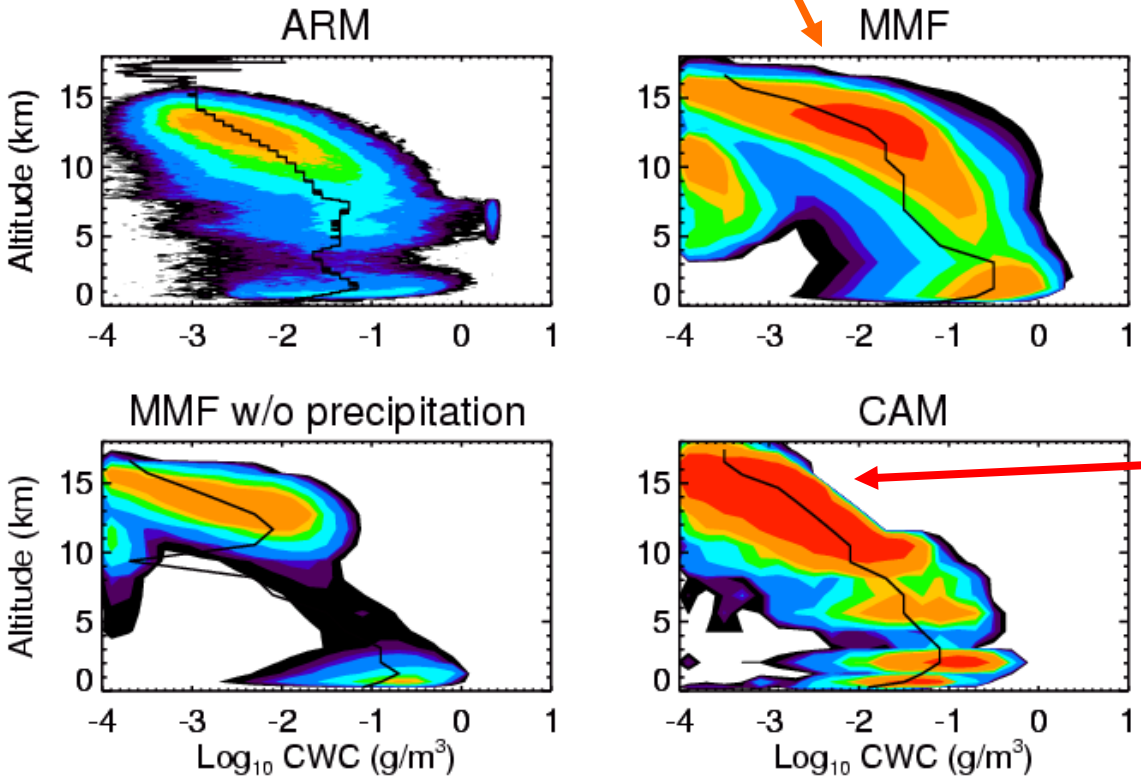
- Use ARM data from TWP
- Compare
  - Cloud occurrence
  - Condensed water profiles
  - Heating rates
- Paper by McFarlane et al.



MMF and CAM

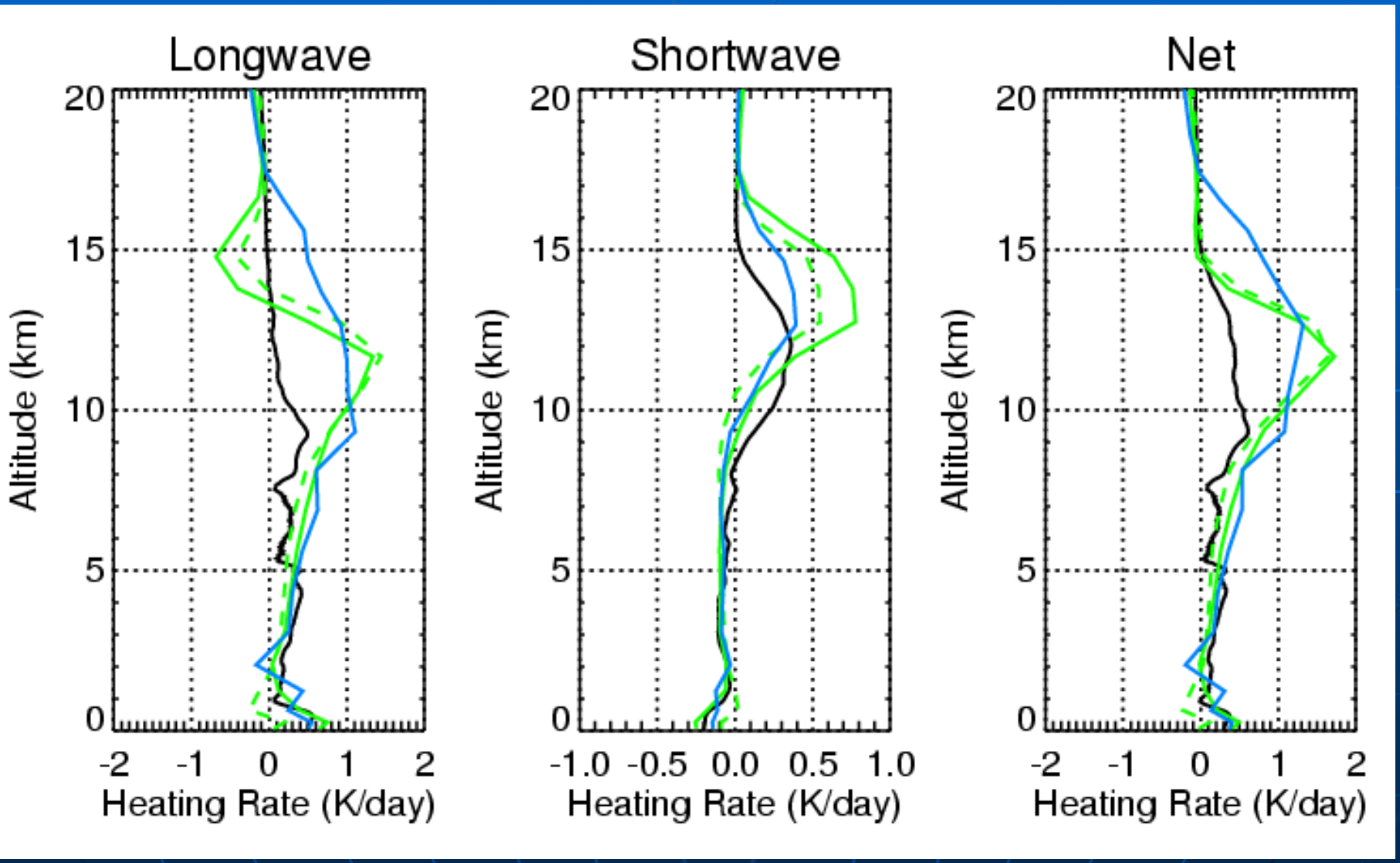
Too much cloud

Too much CWC



Cloud impact on HR (all-sky HR – clear-sky HR)

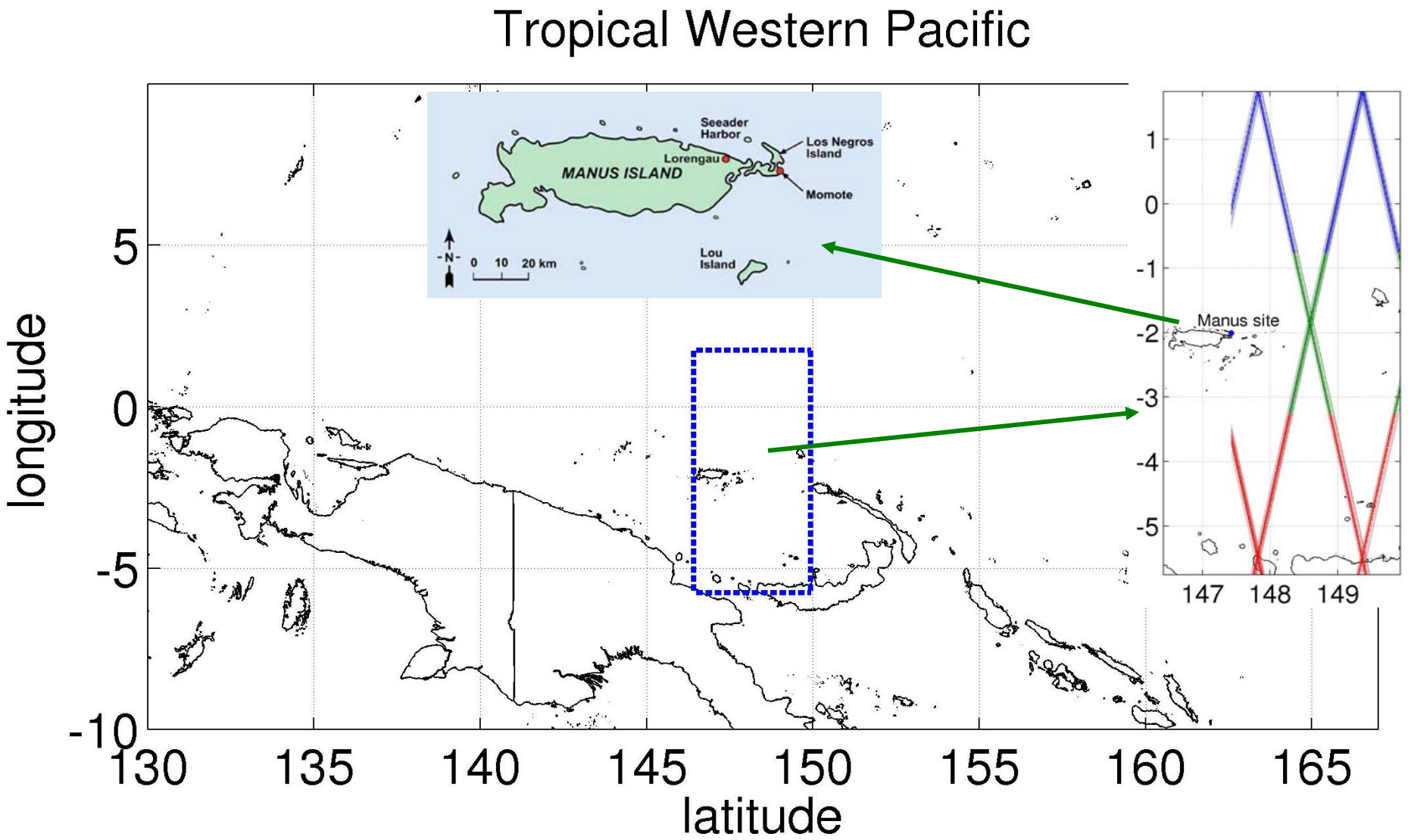
Black = ARM; Green = MMF w/wo precip; Blue = CAM



But, ARM Manus site is a single location within a large GCM grid square …

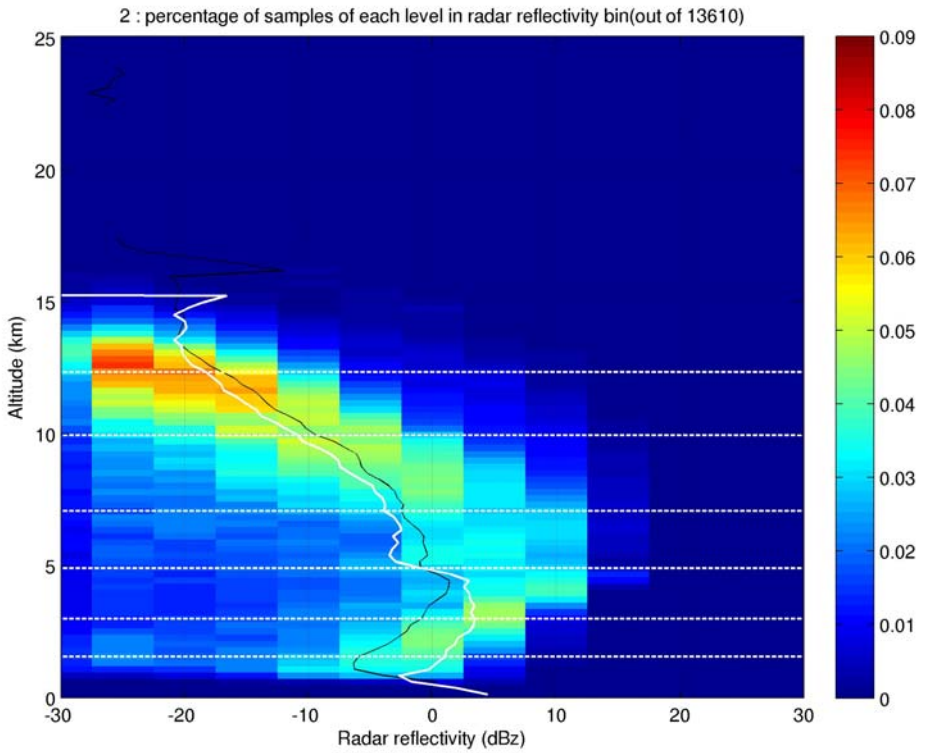
How do we know it is representative of broader area?

Using CloudSat

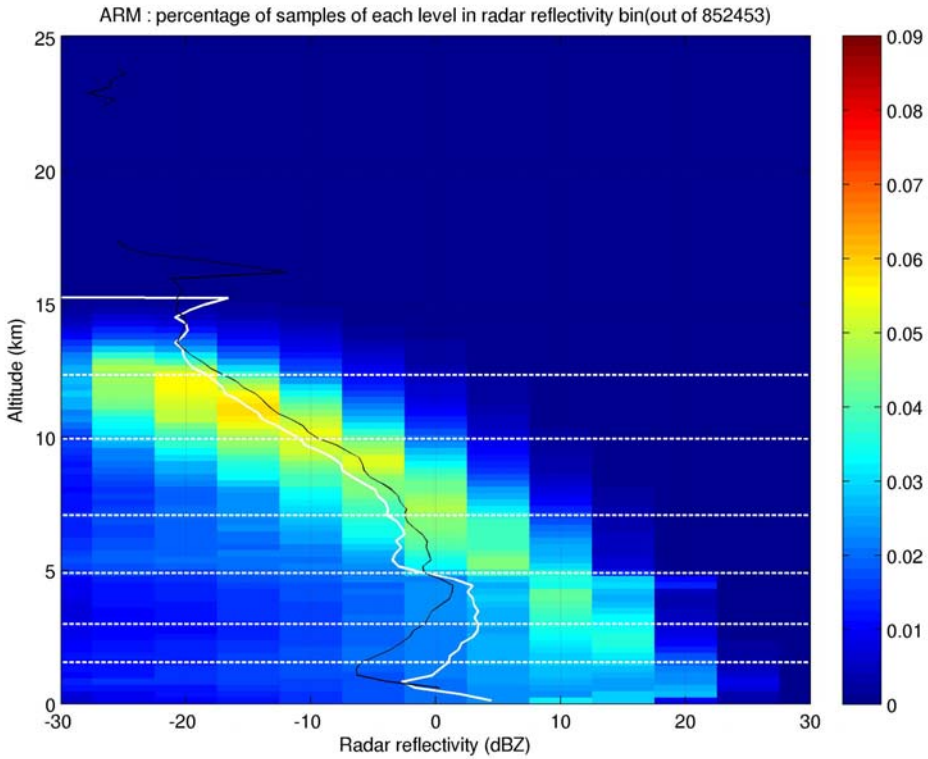


Procedure

- QuickBeam simulator
  - Takes cloud and precip mixing ratios from CRM
  - Uses specified size distributions of spheres for each class
  - Calculates dBZe (truncated at -27.5 dBZe for this study)
- CloudSat data from June 06 to May 07
- MMF runs
  - Observed SST
  - Averaged over 4 years from mid-1998 to mid-2002
- CloudSat - MMF TWP comparisons use 5 X 5 box
- CloudSat - ARM comparisons use 2.5 x 2.5 box



CloudSat 95 GHz – Center



ARM 35 GHz

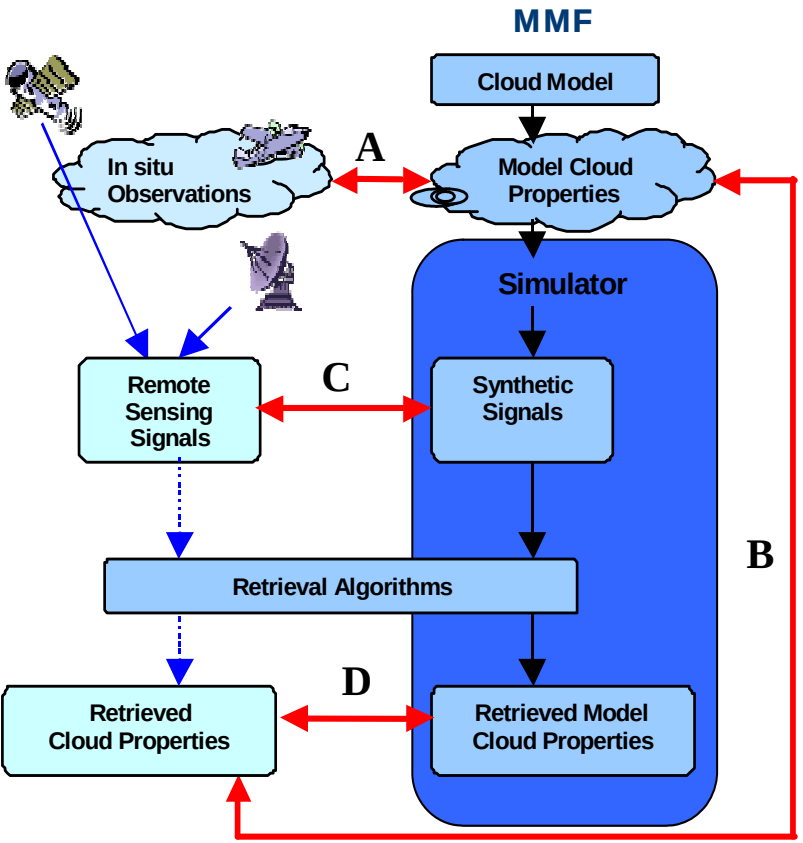
Differences in histograms due to

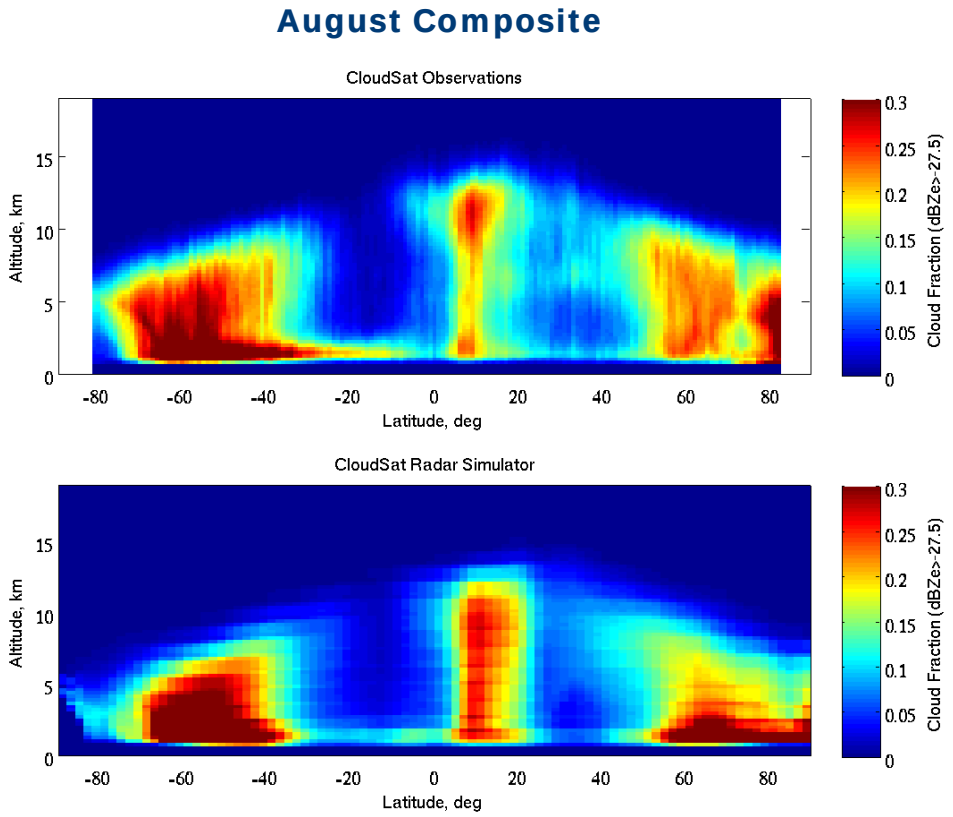
1) Different frequencies give different max value of scattering signal in precipitation

2) Different attenuation by liquid water from top down and bottom up

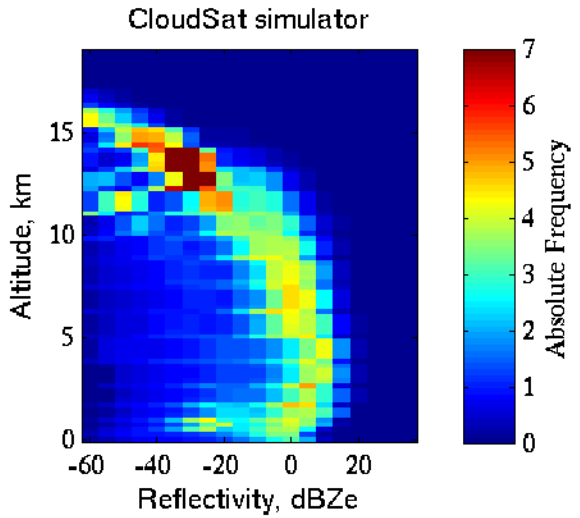
Additional comparisons in progress – talk and poster by Liu et al.

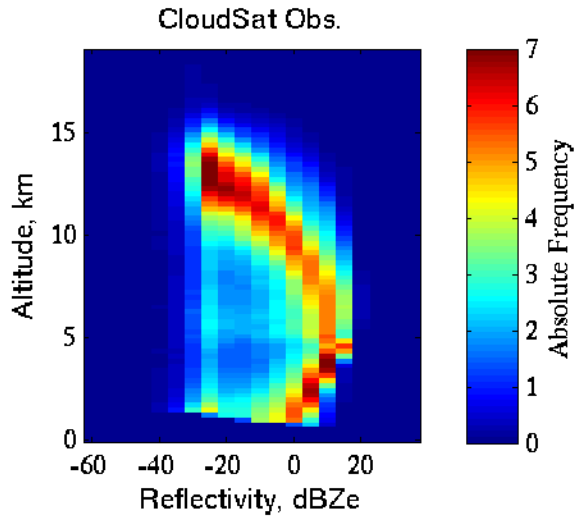
CloudSat Instrument Simulator

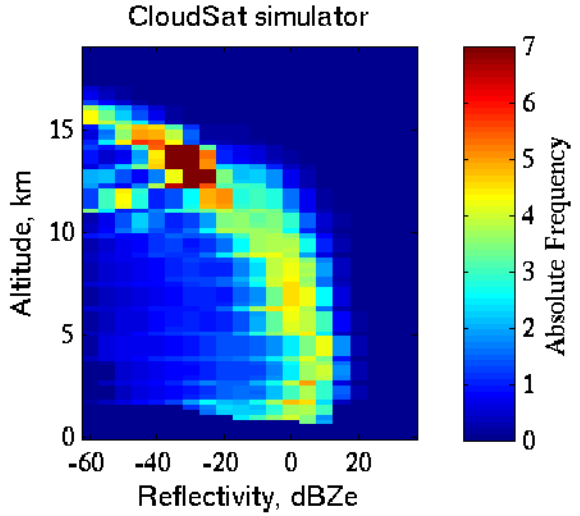


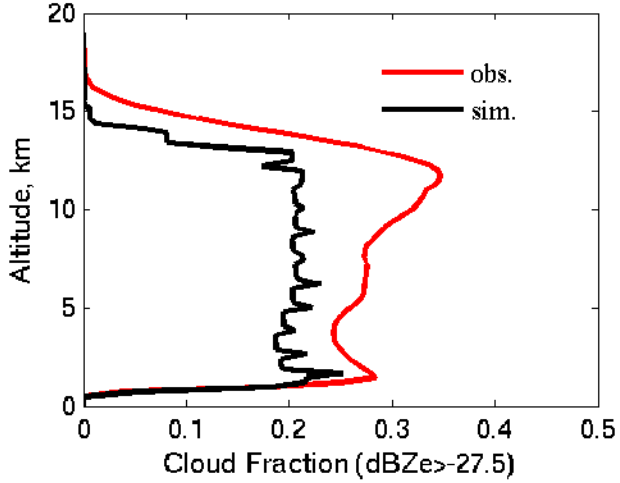


TWP - June

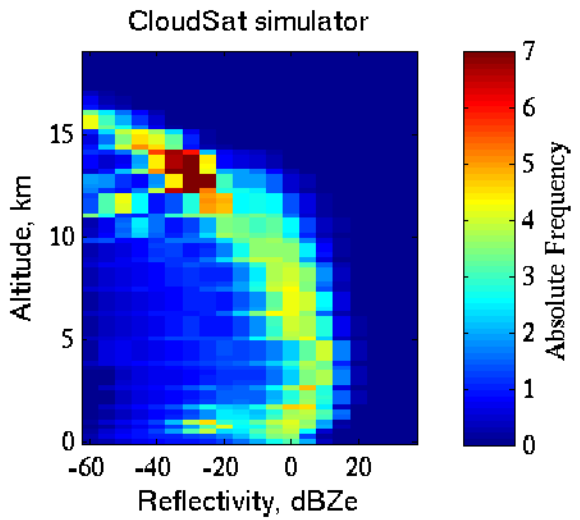

CloudSat simulator
Altitude, km
Reflectivity, dBZe
Absolute Frequency

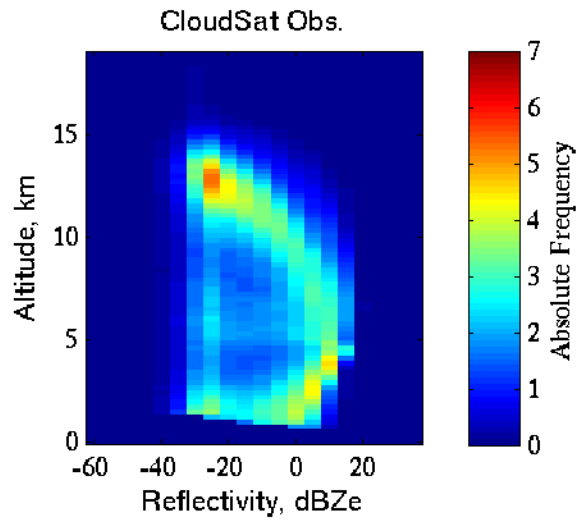

CloudSat Obs.
Altitude, km
Reflectivity, dBZe
Absolute Frequency

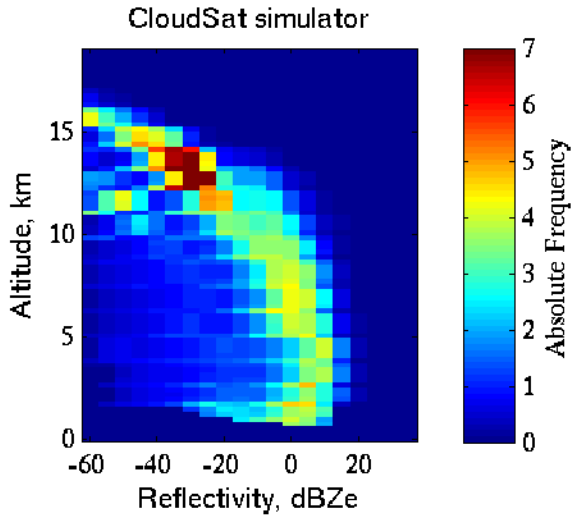

CloudSat simulator
Altitude, km
Reflectivity, dBZe
Absolute Frequency

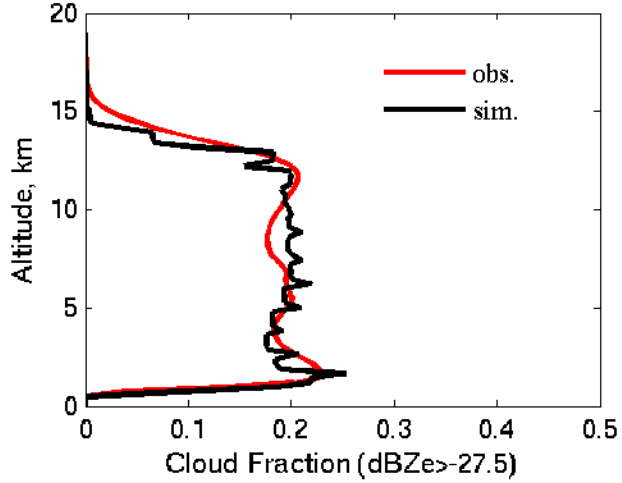

obs.
sim.
Altitude, km
Cloud Fraction (dBZe>-27.5)

TWP - July

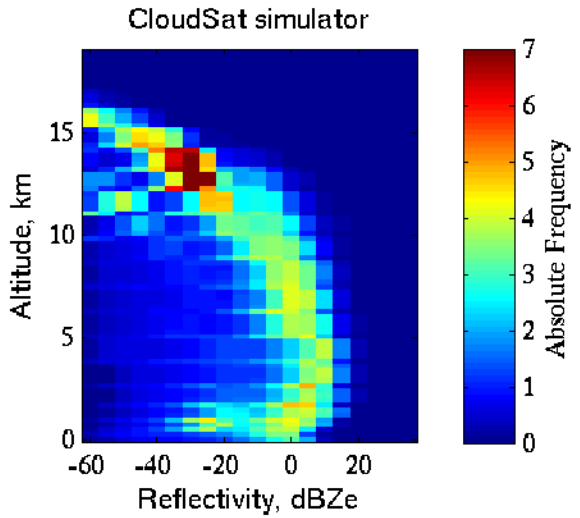

CloudSat simulator
Altitude, km
Reflectivity, dBZe
Absolute Frequency

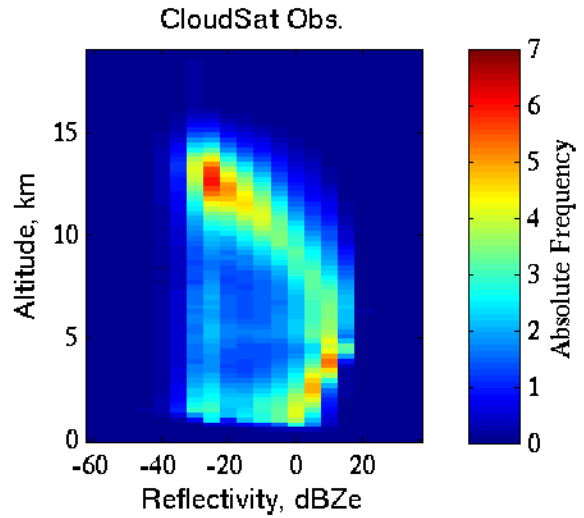

CloudSat Obs.
Altitude, km
Reflectivity, dBZe
Absolute Frequency

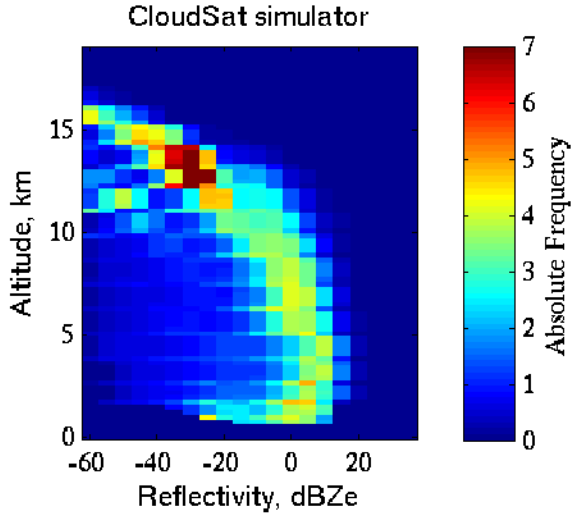

CloudSat simulator
Altitude, km
Reflectivity, dBZe
Absolute Frequency

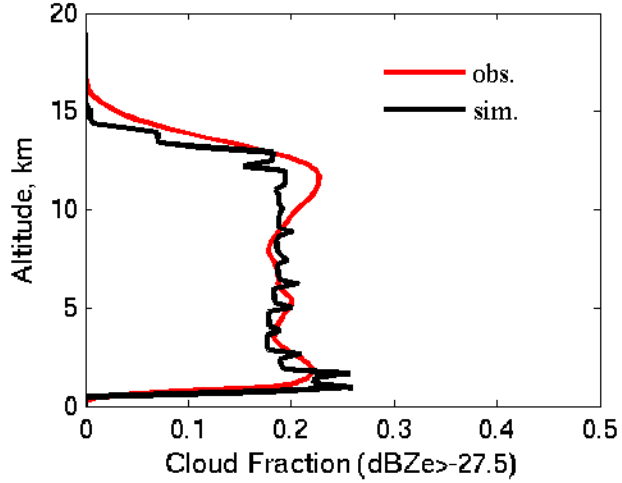

obs.
sim.
Altitude, km
Cloud Fraction (dBZe>-27.5)

TWP - August


CloudSat simulator
Altitude, km
Reflectivity, dBZe
Absolute Frequency


CloudSat Obs.
Altitude, km
Reflectivity, dBZe
Absolute Frequency


CloudSat simulator
Altitude, km
Reflectivity, dBZe
Absolute Frequency


obs.
sim.
Altitude, km
Cloud Fraction (dBZe>-27.5)

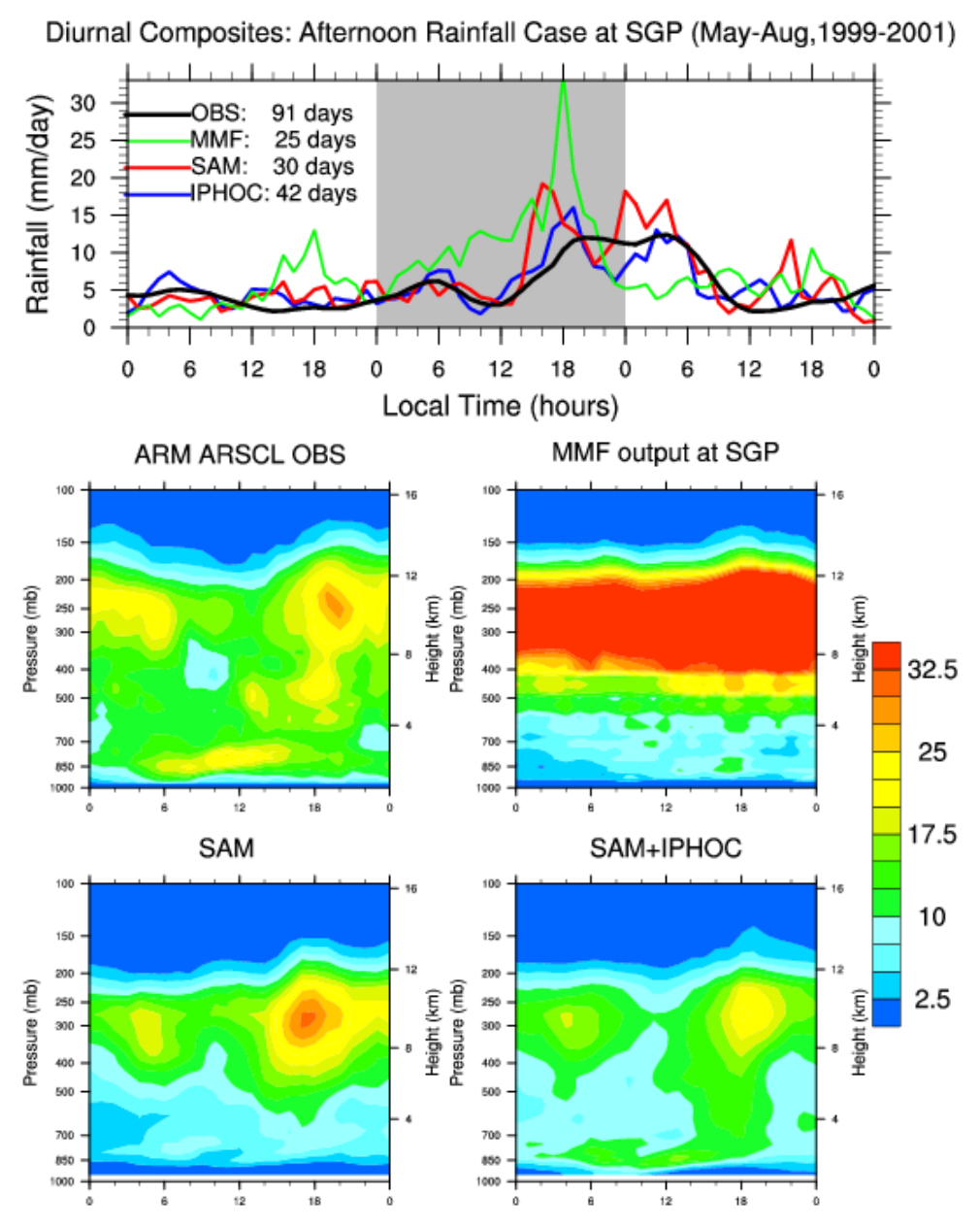
TWP studies

- Now comparing CWC and mean particle size
  - ARM retrievals
    - Two different schemes (McFarlane and Marchand)
  - CloudSat retrieval
  - MMF simulation

A brief segue to the SGP

- Two studies in progress (see posters)
- Zhang et al.
  - The MMF diurnal cycle: diagnostics and an improved CRM
- Marchand et al.
  - MMF vertical cloud structure: neural net classification and comparison by class

Diurnal Cycle at ARM SGP



- Afternoon Rainfall case has precipitation > 1mm/day at 1800 LST and cloud fraction maximum around the same time in the ARM observation
- High cloud overcast and fewest rainy days in MMF output at SGP
- SAM (the CRM embedded in MMF) is driven by 3-year SGP continuous forcing to examine its behavior in simulating diurnal cycle.
- SAM with IPHOC improves boundary layer clouds and produces less high clouds

Conclusions

- ARM data and high-resolution satellite data are highly complementary sets for analyzing model cloud properties
  - ARM => high temporal resolution, high quality retrievals
  - Satellite => spatial context
- Evaluation framework
  - Now in place
  - Identified deficiencies in MMF clouds
  - Now working to improve CRM cloud simulation and (we hope!) MMF

Current research projects

- Developing CRM
  - Higher order turbulence closure (IPHOC)
  - Additional fixed vertical levels in BL
  - Variable grid spacing in BL
- Running MMF
  - 1 km (rather than 4 km) MMF
- Evaluating MMF
  - CloudSat – ARM comparison and CloudSat – MMF comparisons
  - MISR – MMF 2D ISCCP-like histogram comparison
- See posters by Liu, Marchand, Henderson, Cheng, Zhang, McFarlane


Thank you for your attention!