

A Comparison of ARM Observations with the MMF and CAM

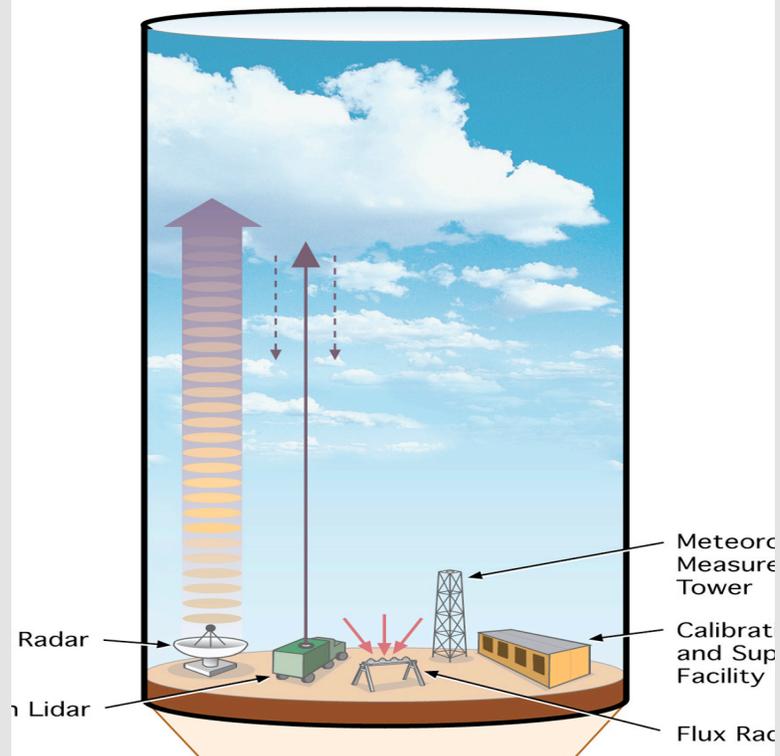
Tom Ackerman

Sally McFarlane, Jim Mather, Roger Marchand

Research support provided by the Laboratory Directed Research and
Development Program at PNNL; Computer time provided by the
Molecular Science Computing Facility

Comparing the column radiation budget

**Satellite fluxes:
CERES, GEO. Satellites**



Surface fluxes

**Measure cloud / aerosol
properties**

**Use as inputs to radiative
transfer code**

**Compute radiative fluxes
and heating profiles**

**Compare to measured
fluxes at top and bottom**

Compare to model results

ARM Tropical Western Pacific Sites



ARM Data Processing

▶ Heating Rate Profiles

- Temperature and water vapor profiles from radiosondes, scaled to microwave radiometer precipitable water and surface temperature
- Vertical profiles of cloud microphysical properties calculated from ARM millimeter wave radar data (data has 10-second temporal and 45 m vertical resolution)
- Sample the cloud properties every 5 minutes and perform radiative transfer only on the sampled profiles.
- Calculate broadband fluxes and vertical profile of heating rates.

ARM Data Processing (con't)

▶ Surface fluxes

- Measured solar (direct and diffuse) and IR once per minute
- Use Long and Ackerman approach to infer clear-sky fluxes from observations
- Average to daily values for current study
- Difference (all-sky – clear sky) to get effect of clouds on surface budget

Satellite Data

- ▶ Hourly radiance data from GMS
- ▶ Converted to OLR and solar albedo by Minnis et al.
- ▶ Combine with surface flux measurements to provide a daily radiation budget for the atmospheric column
- ▶ Work in progress – not included in this presentation

Simulations

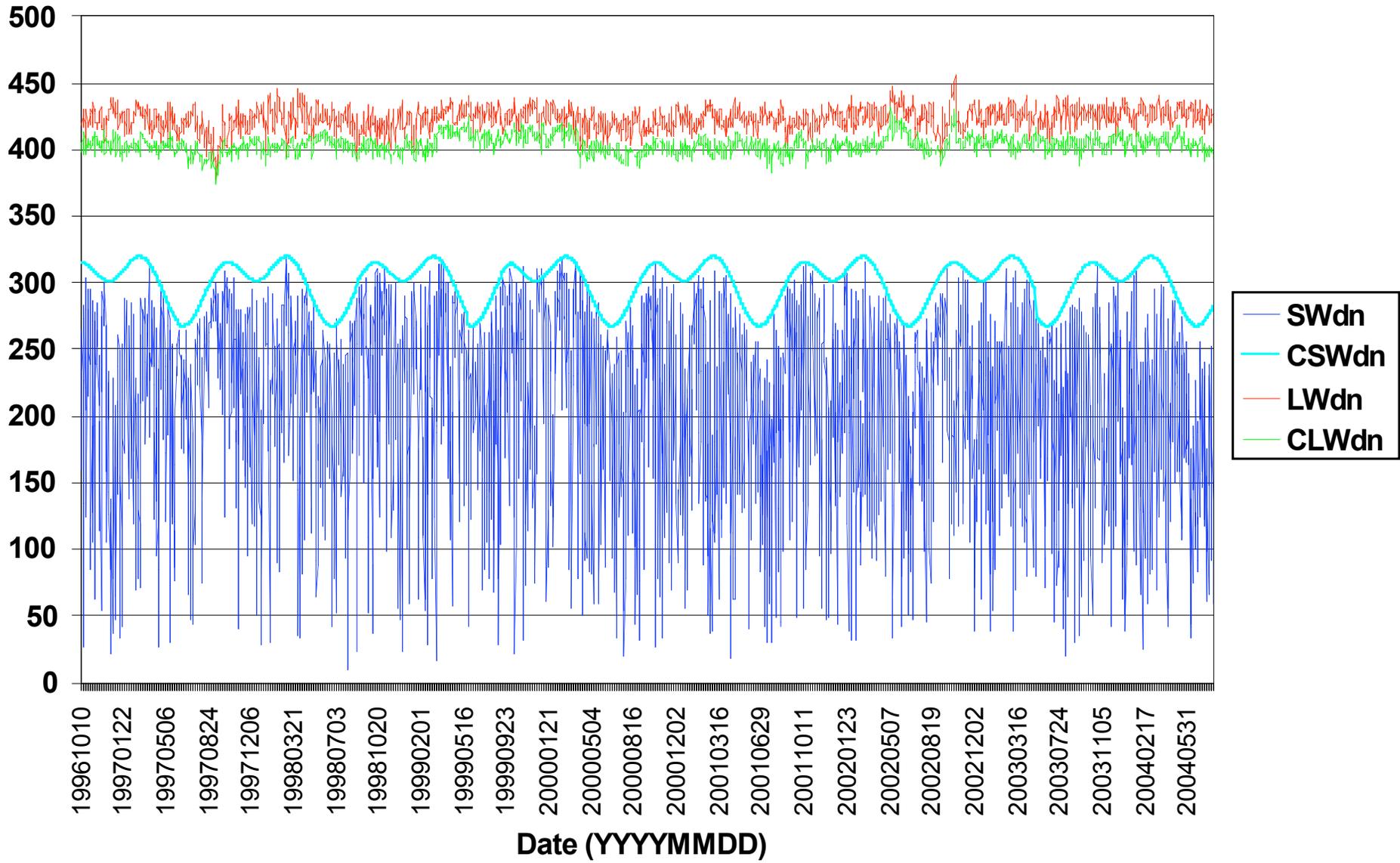
- ▶ MMF simulations with CSU model *
 - Run with observed SST values
 - Start in January 1998 and run into 2001
 - Second run for 2000 started from different initial conditions
- ▶ CAM simulations
 - Run with observed SST values for same period
- ▶ For the CAM-only runs, we examine output from the gridbox containing the ARM site
- ▶ For MMF runs, we examine the average over the 64 CRM columns within the gridbox containing the ARM site

** Model output available to any interested scientists*

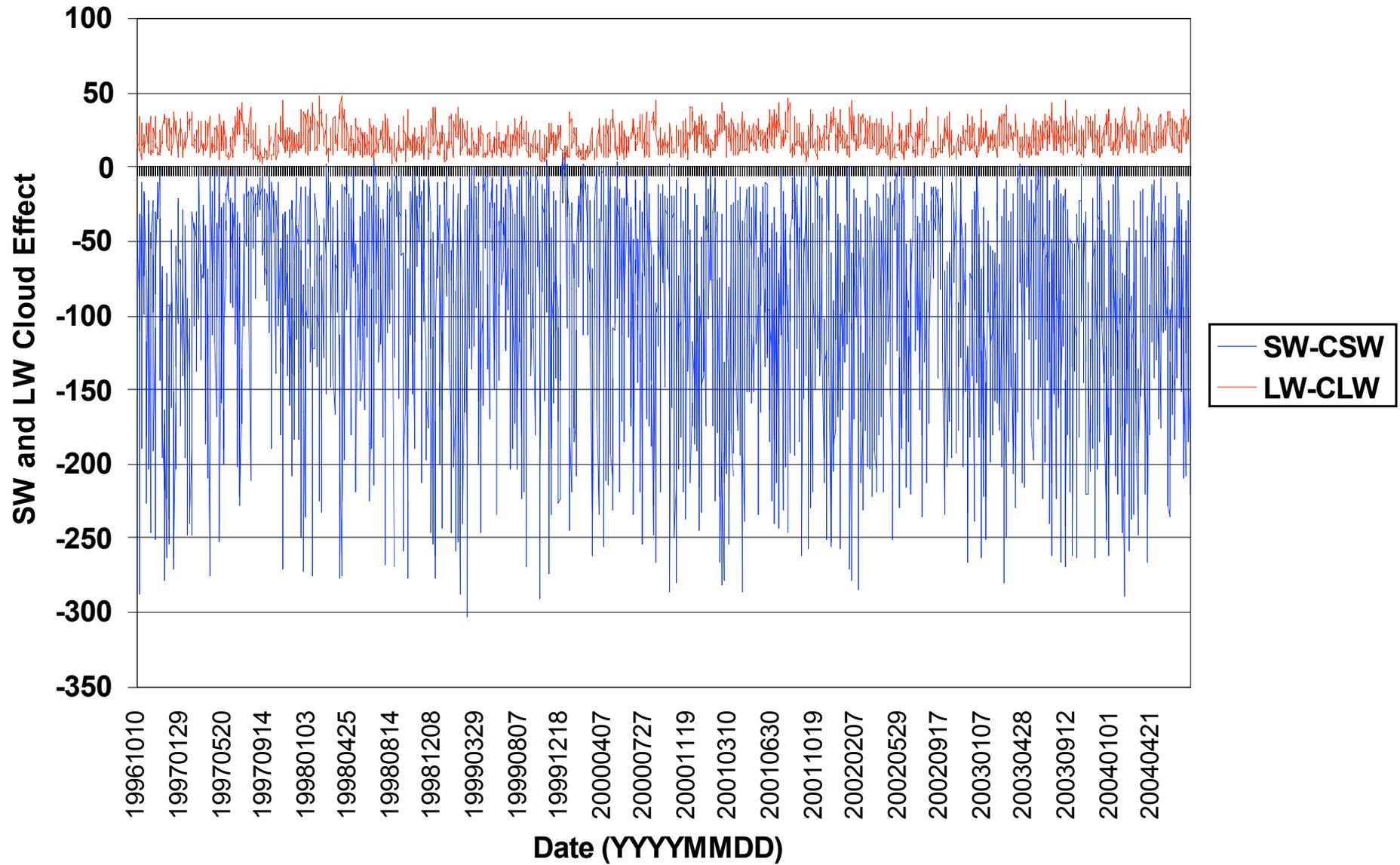
Manus



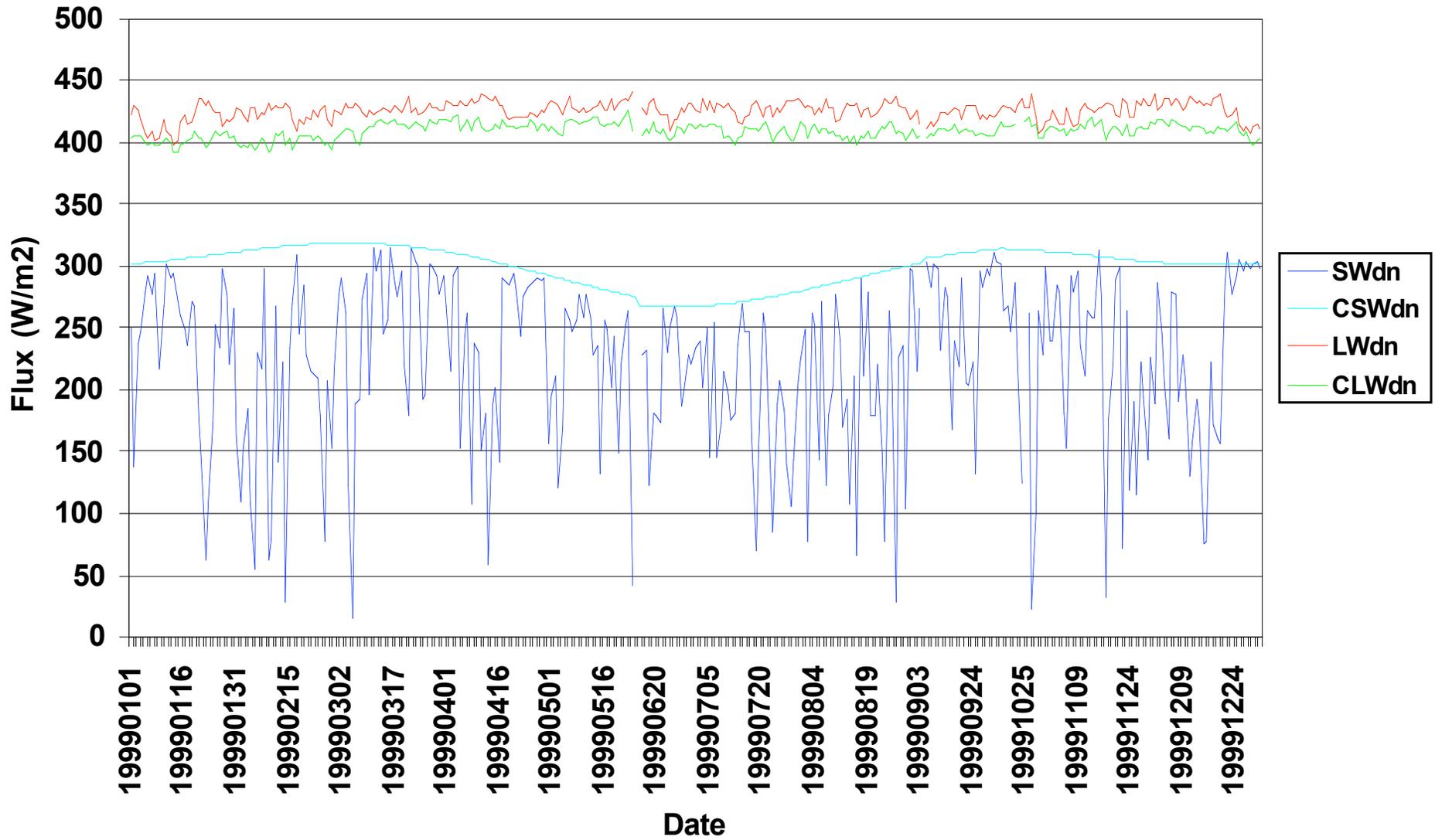
Manus Daily (24 Hr) Averages



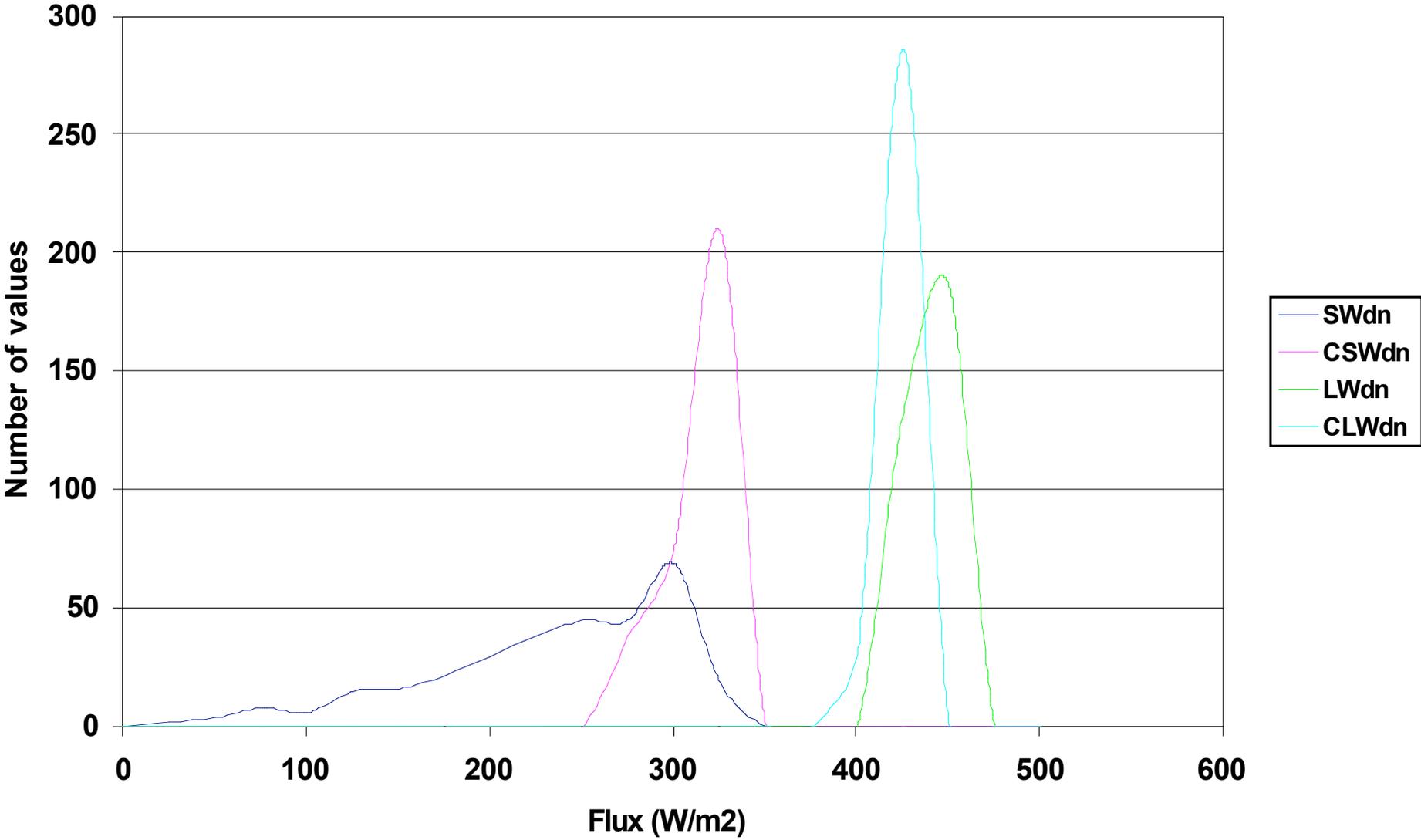
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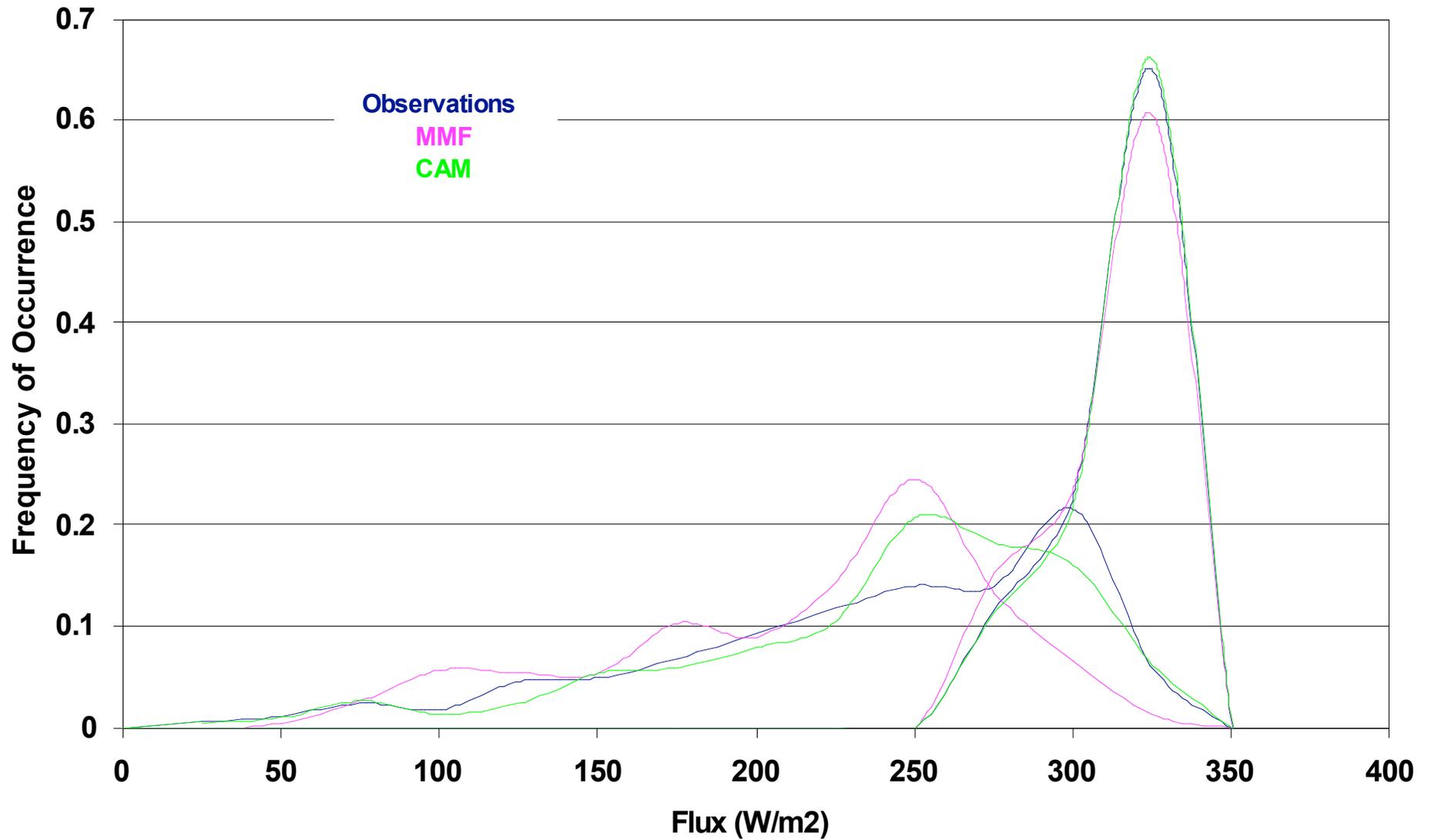
Surface Flux Data 1999



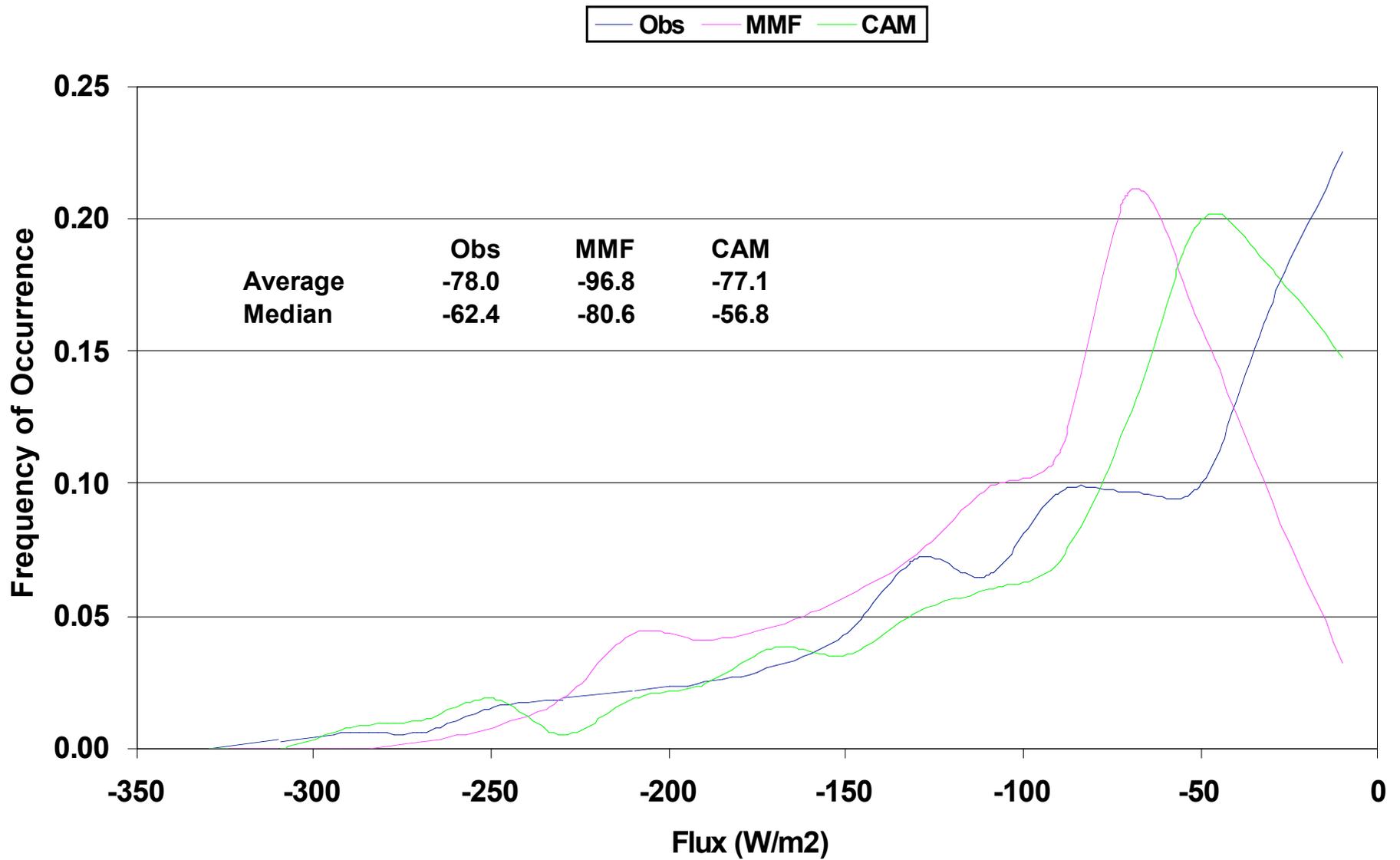
Manus Surface Flux Observations - 1999



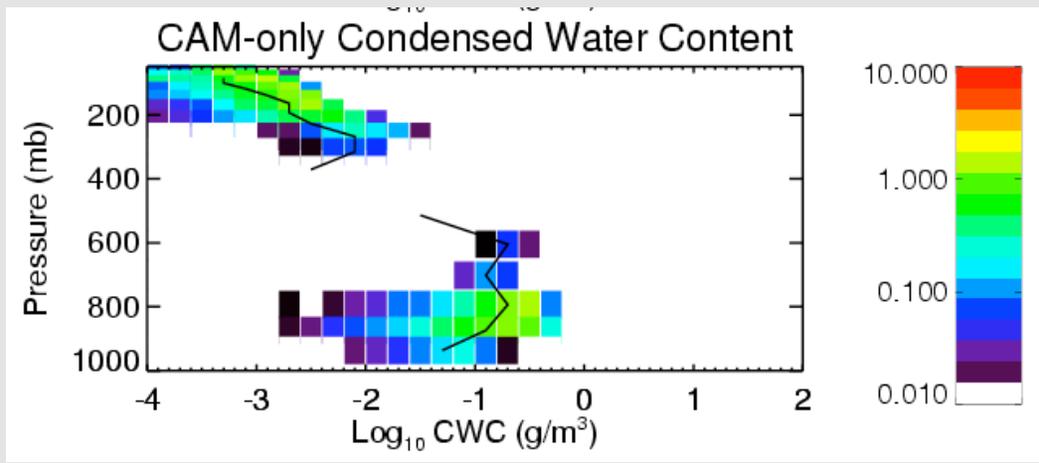
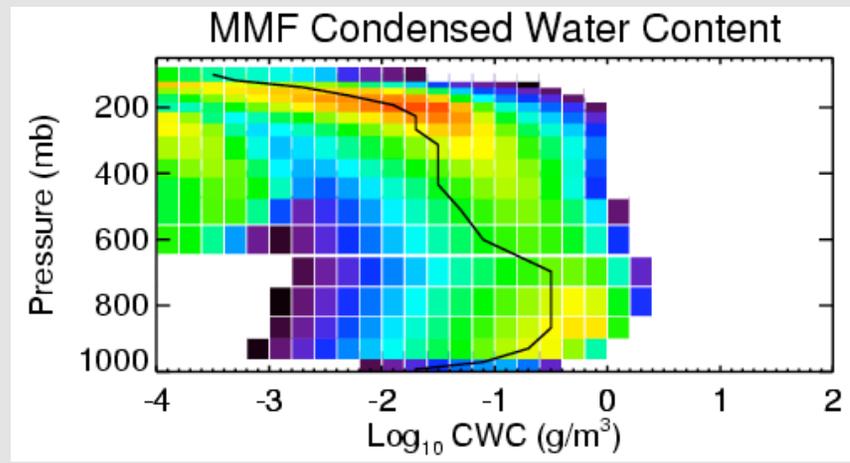
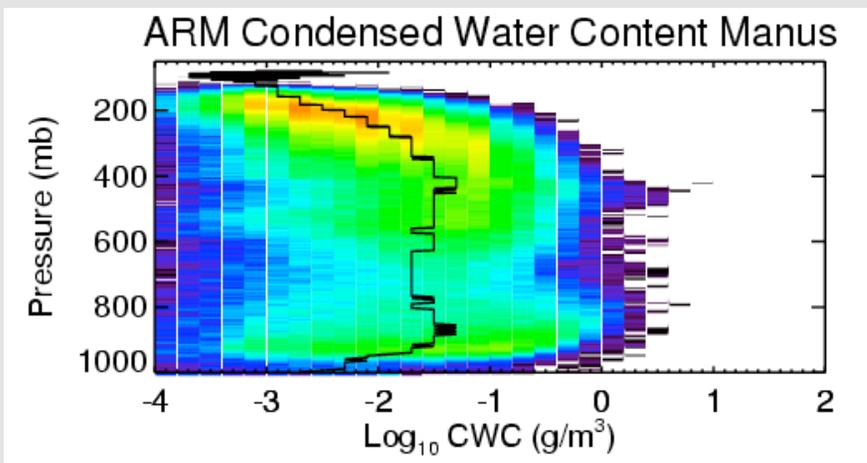
Surface Downward Shortwave Flux at Manus - 1999



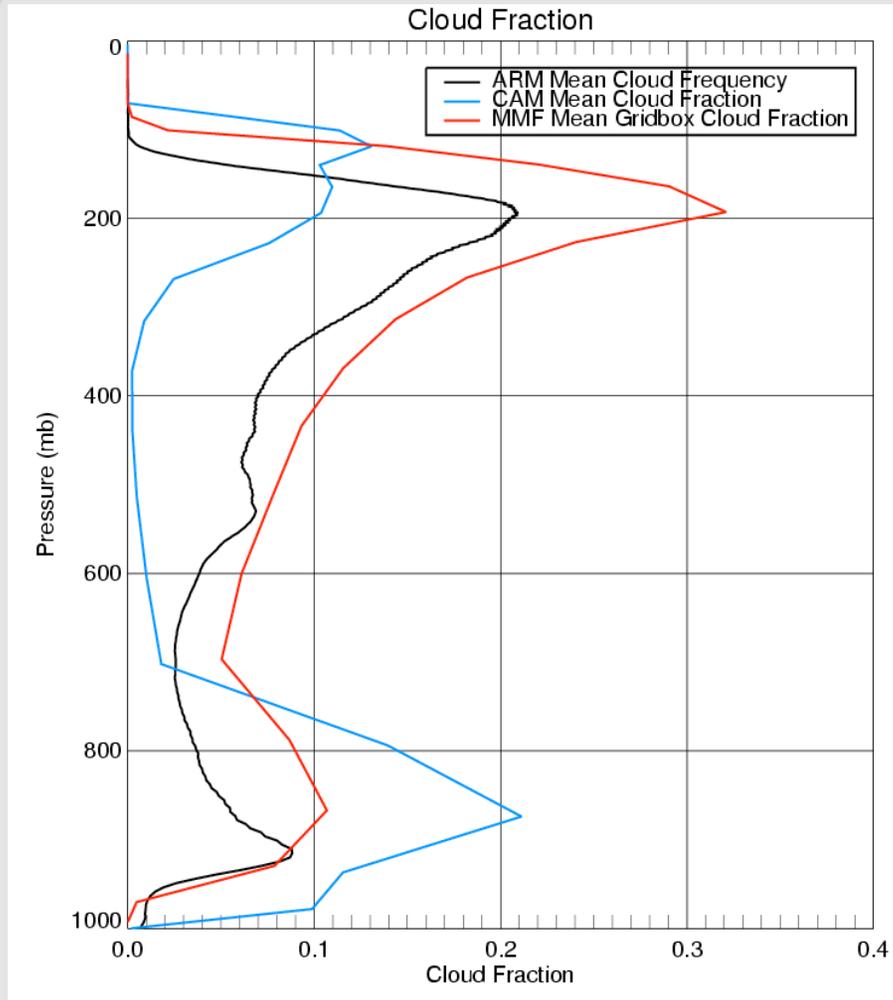
Surface SW Cloud Effect (All sky - clear sky) - Manus, 1999



Condensed Water Frequency Distributions - Manus



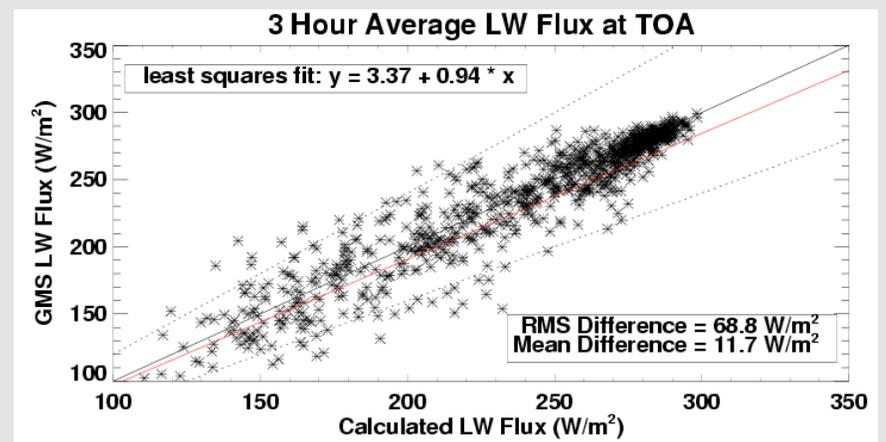
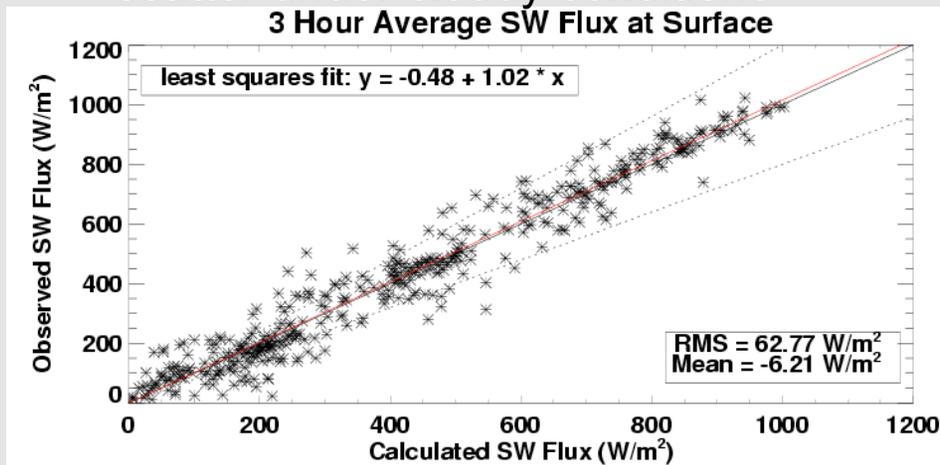
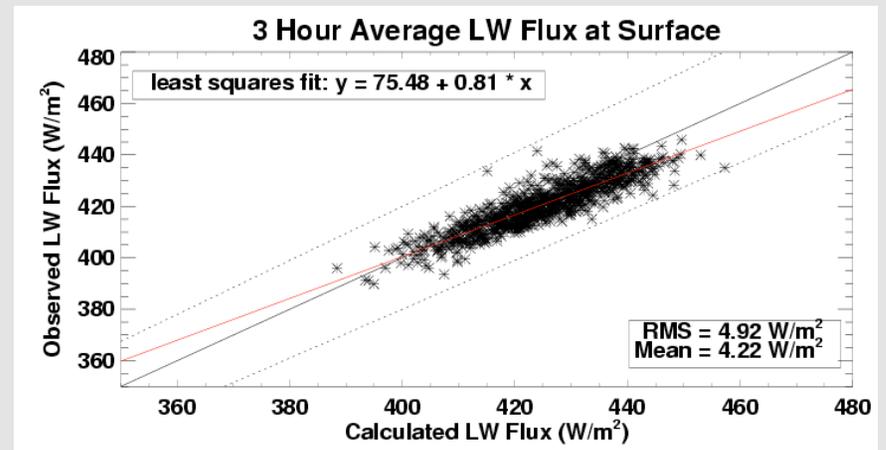
Cloud Fraction



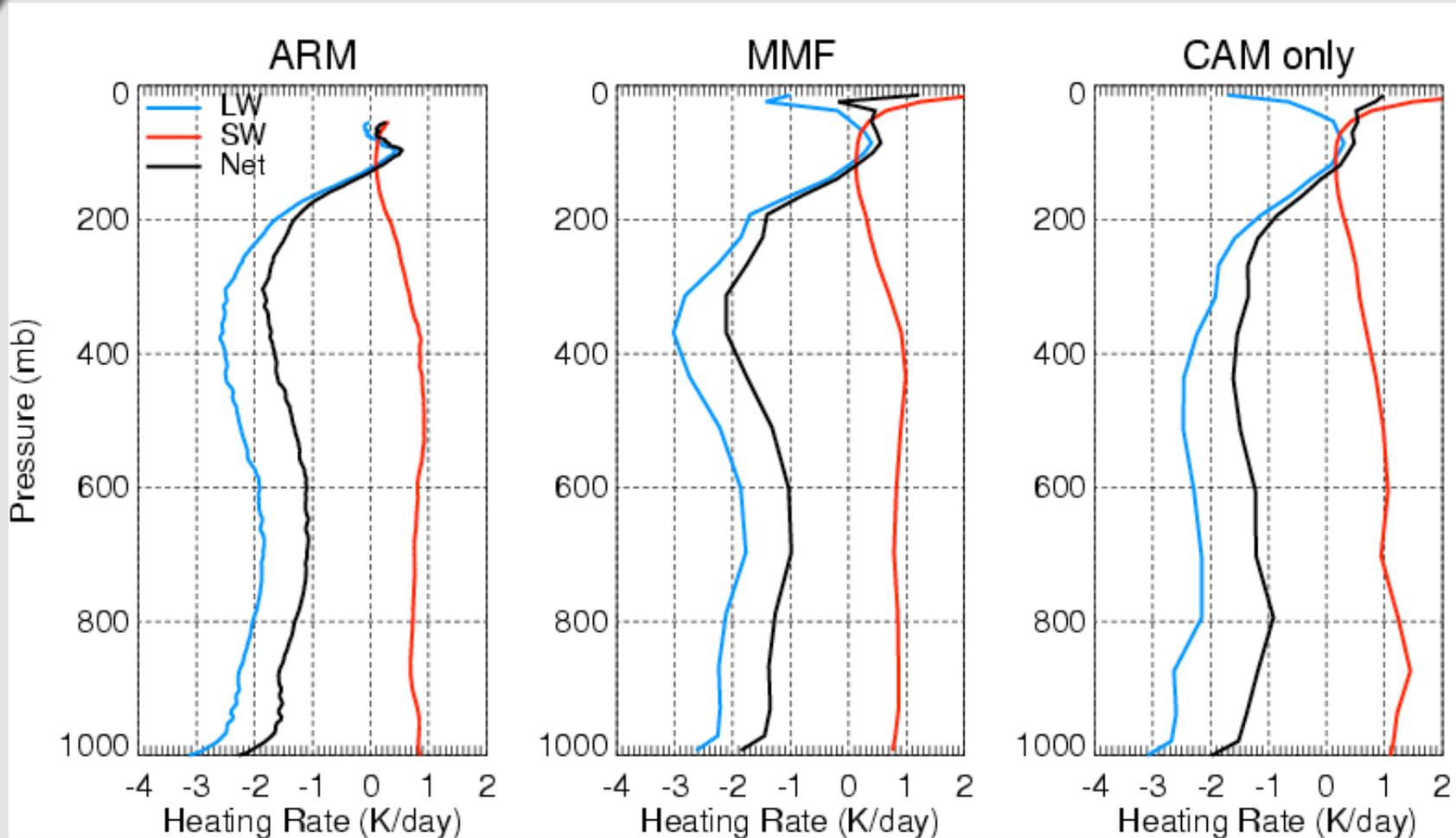
- ARM cloud frequency is percent of time reflectivity is greater than -40 dBZ at given level
- CAM cloud fraction is mean gridbox cloud fraction from cloud parameterization
- MMF cloud fraction is number of cloudy CRM columns within CAM gridbox

Surface and TOA Flux Comparisons (RT model and Data)

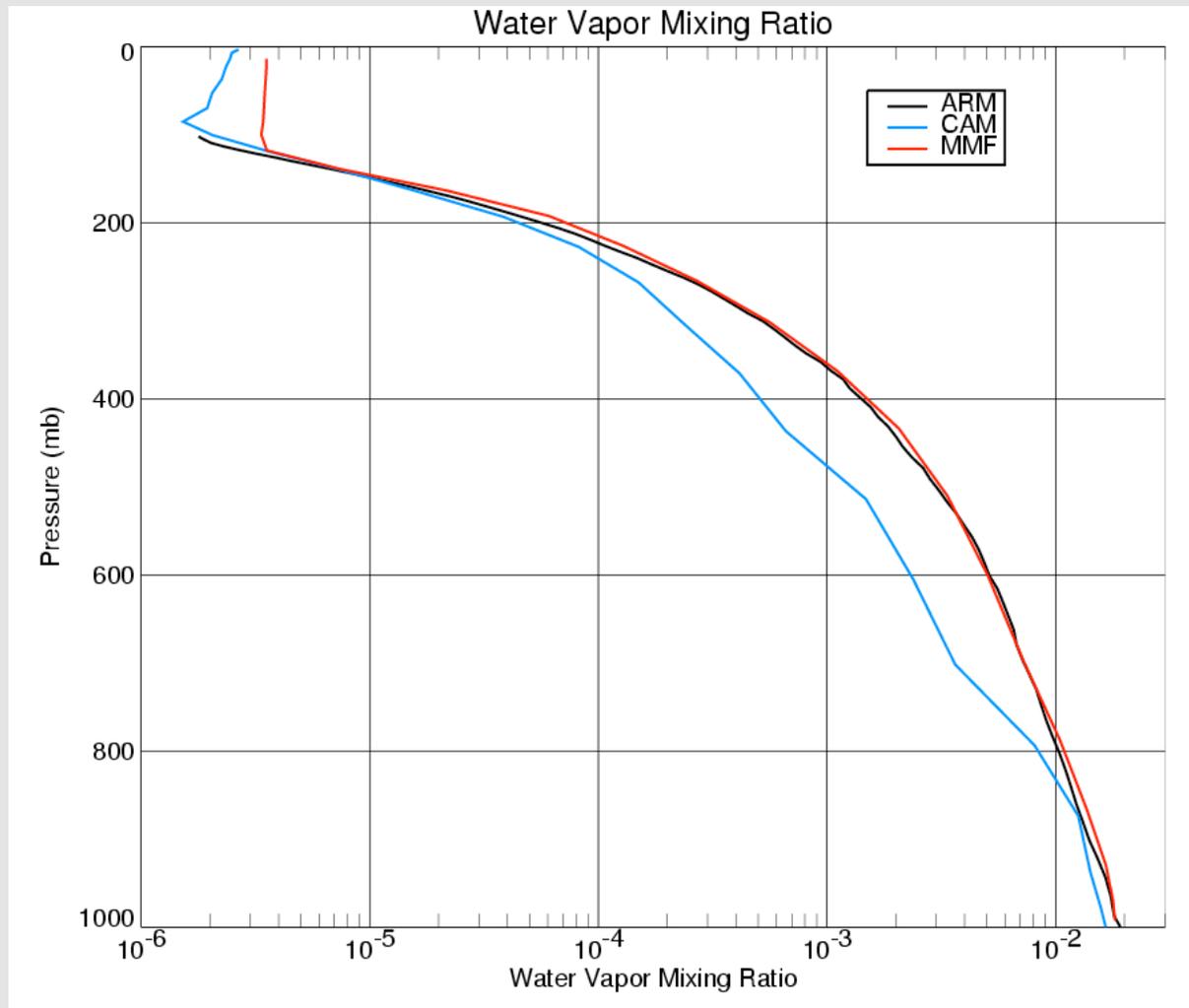
- SW surface comparisons show strong correlation, little bias
- LW surface comparisons are biased towards model overestimate of LW flux under cloudy conditions
- LW TOA comparisons show large scatter under cloudy conditions



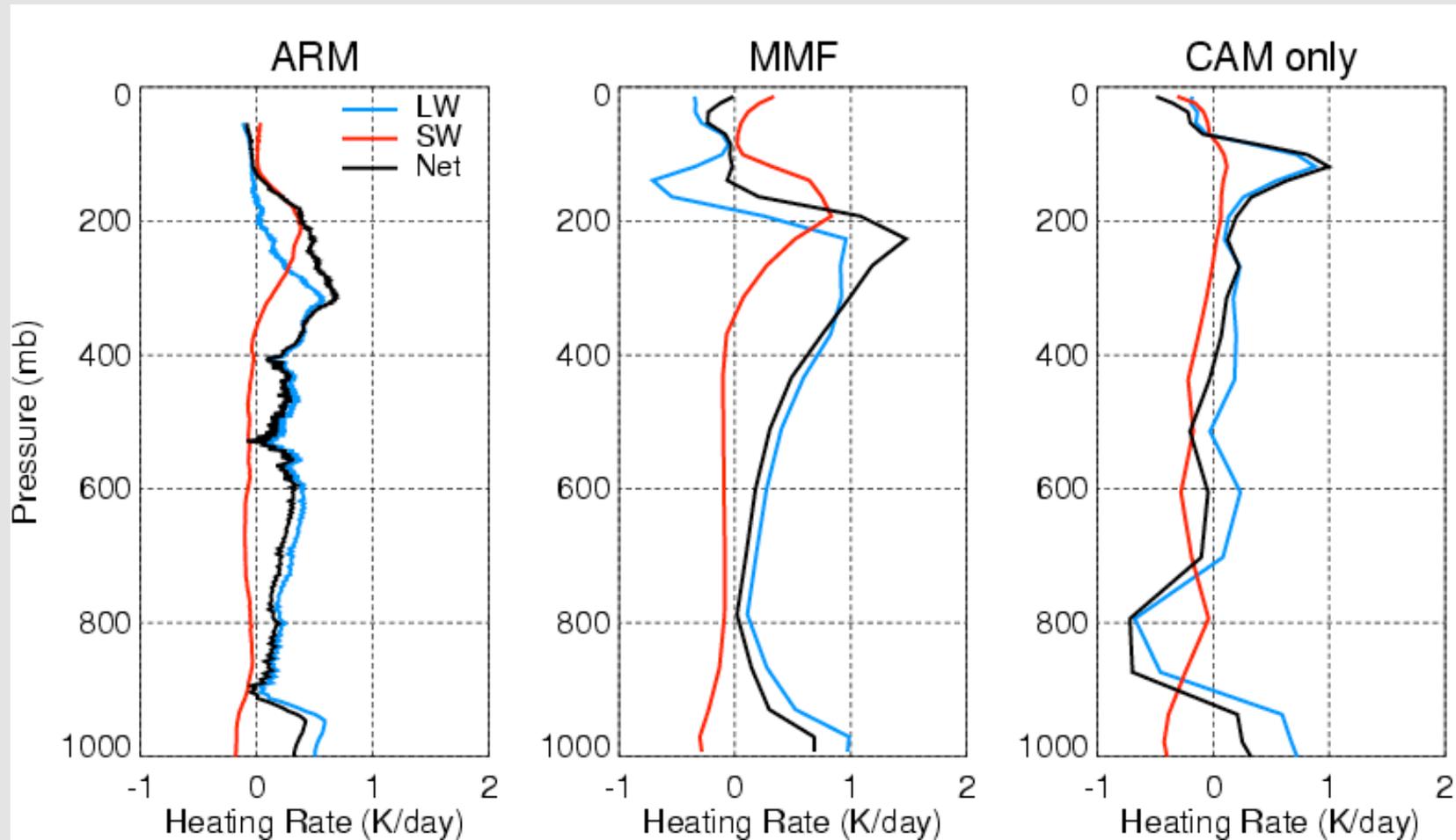
Heating Rates: Clear Sky

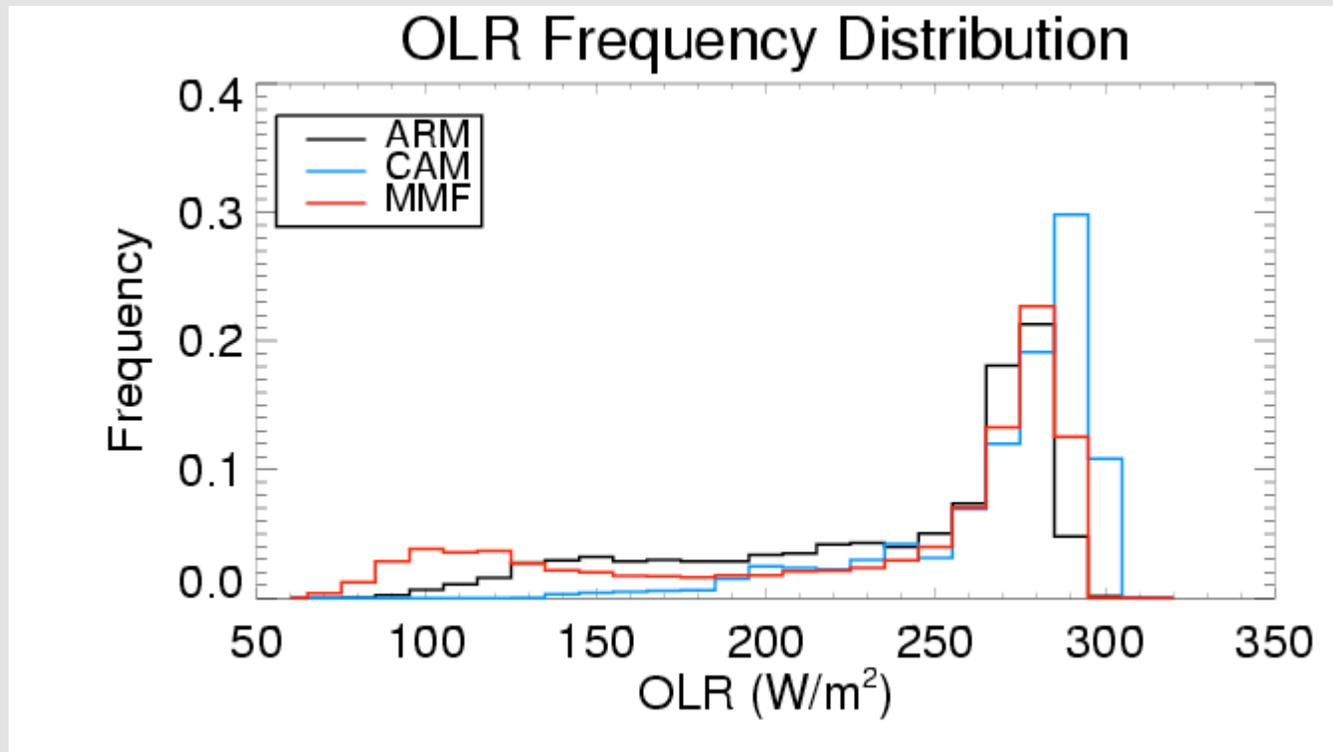


Average Water Vapor Profiles



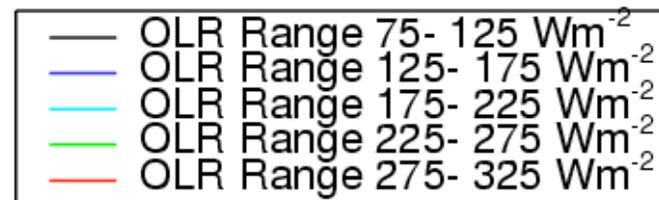
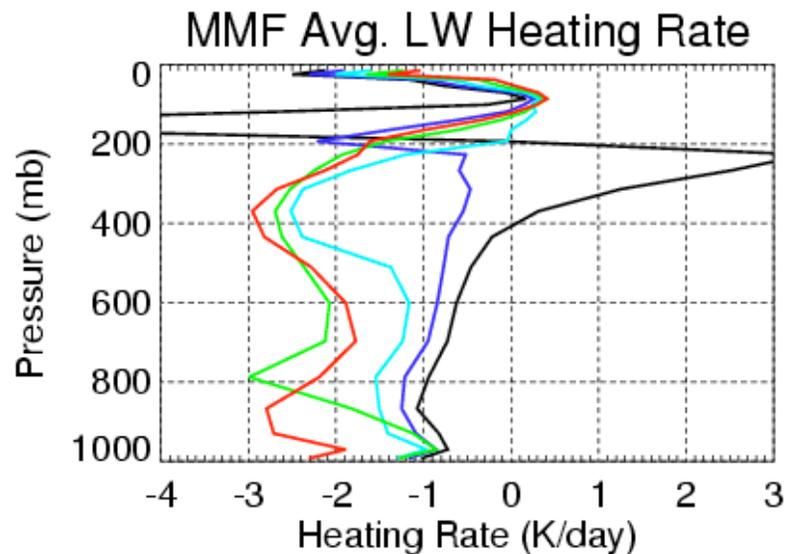
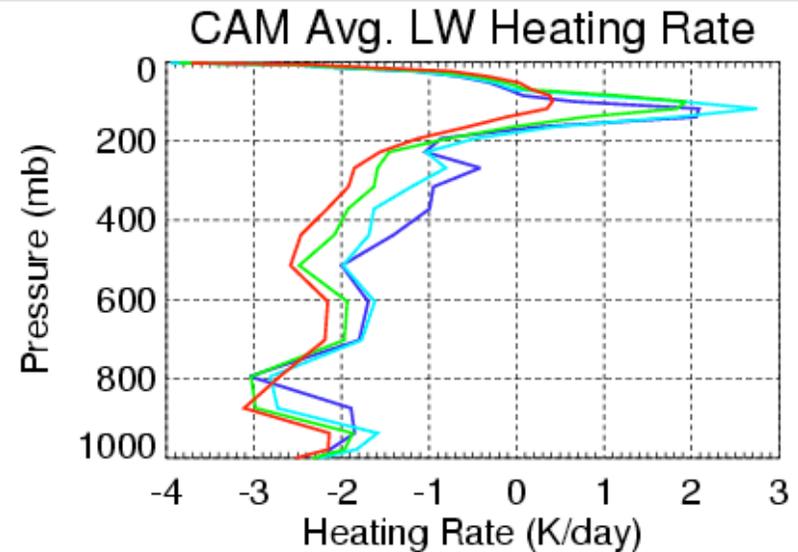
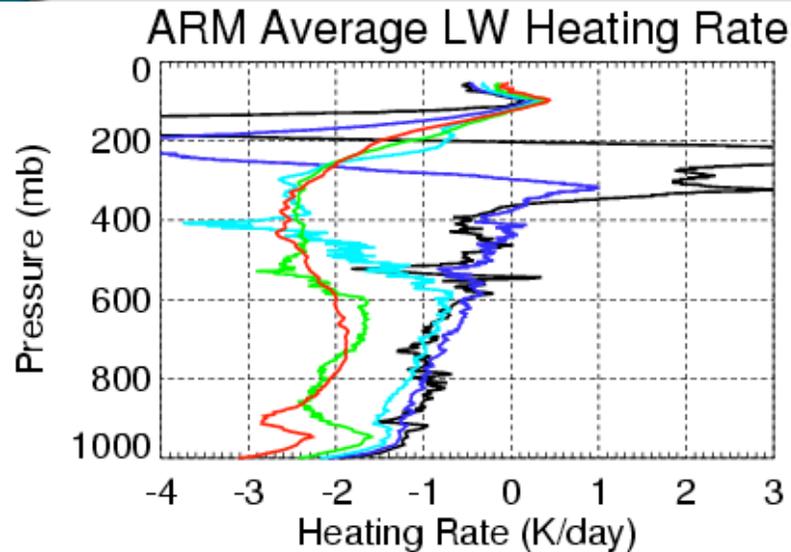
Heating Rates All Sky – Clear Sky





- CAM has no OLR values below 175 W/m^2 ; larger frequency of very high OLR
- MMF/ARM frequency distributions similar; MMF has more very low OLR values

Heating Rates for Various OLR Ranges



Conclusions – Manus

- ▶ MMF reproduces observed water vapor profile and clear sky heating rates better than CAM
- ▶ High clouds
 - CAM has too little cirrus, its optical depth is too small and it is too high in the troposphere
 - MMF overestimates cirrus amount and cirrus is too optically thick
- ▶ Middle clouds
 - CAM has virtually no mid-level or deep cloud
 - MMF overestimates condensed water content
- ▶ Low clouds
 - MMF boundary layer cloud feature is higher than observed and LWC is too large
 - CAM clouds are very deep and too frequent

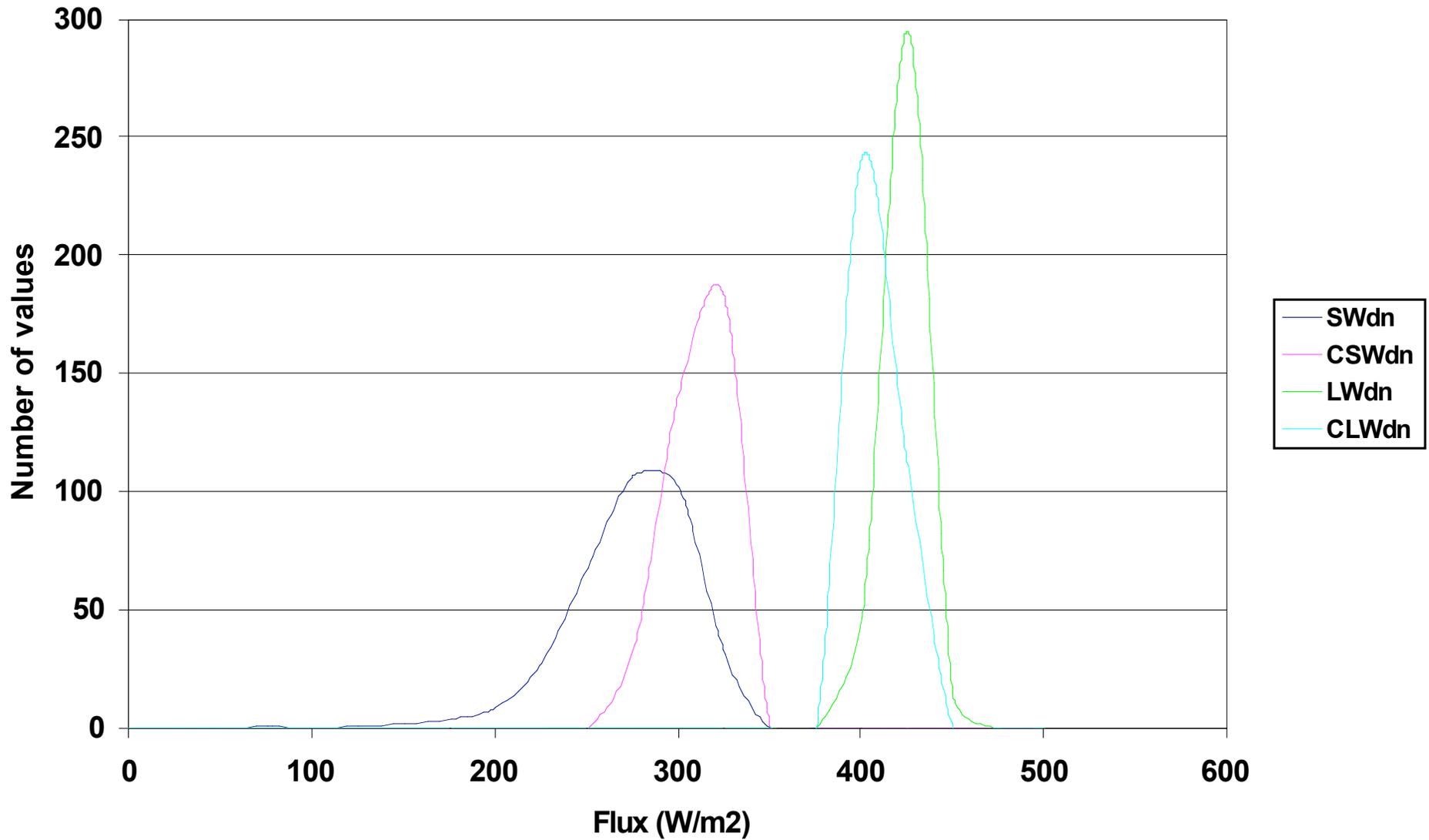
Conclusions – Manus

- ▶ Surface cloud effect
 - MMF overestimates cloud effect
 - CAM agrees very well with data
- ▶ Heating rate profiles
 - CAM overestimates clear-sky OLR due to poor water vapor profile
 - CAM has too strong and too high tropopause heating (ice clouds too high) and boundary layer cooling (no mid-level clouds)
 - MMF has too strong tropopause heating (clouds too thick)
- ▶ OLR classification
 - CAM has no very low OLR cases and poor representation of profiles
 - MMF has good representation of profiles but too many low OLR cases; may indicate overactive convection in MMF (alternate possibility is an underestimate of cloud top during precipitating cases in observations)

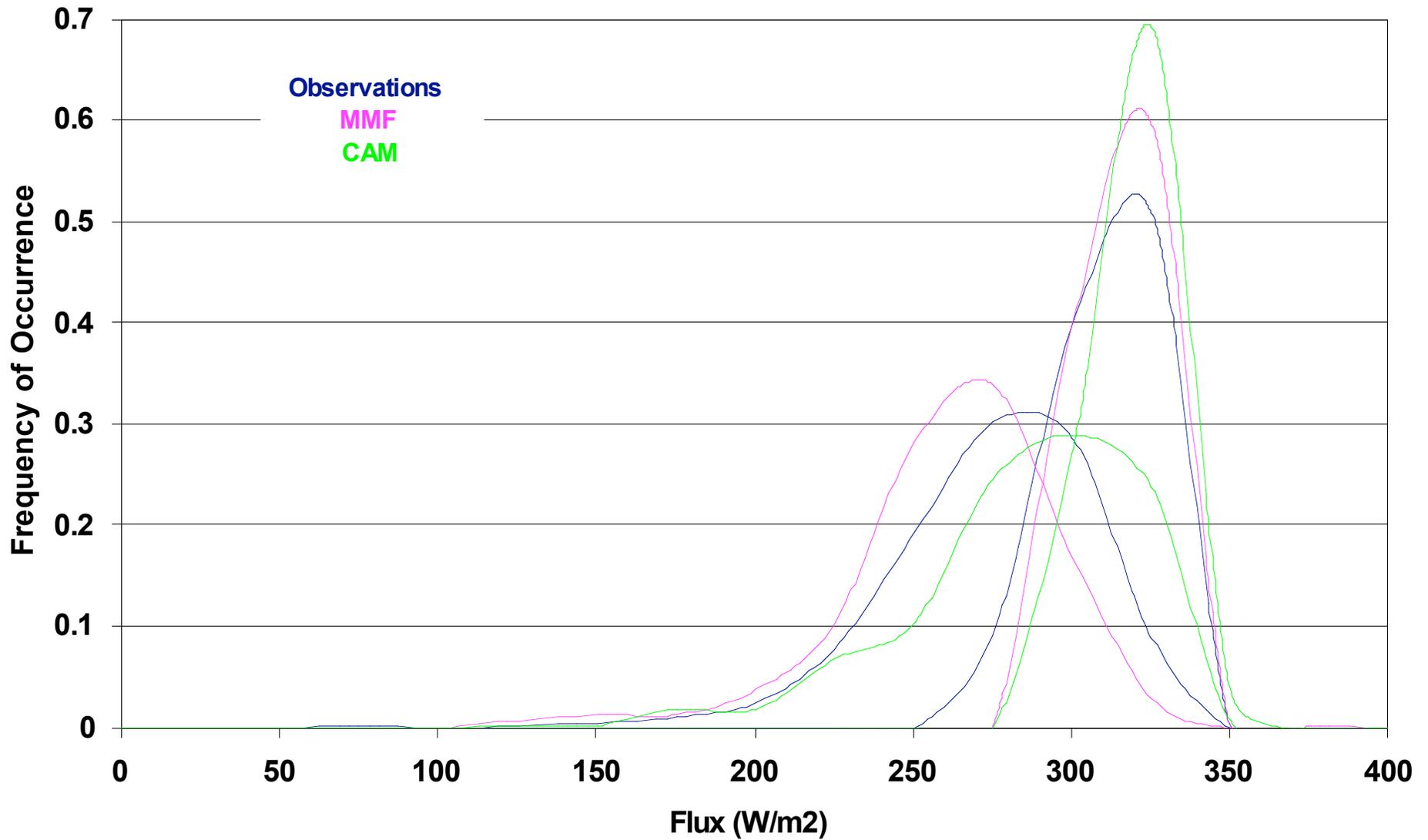
Nauru



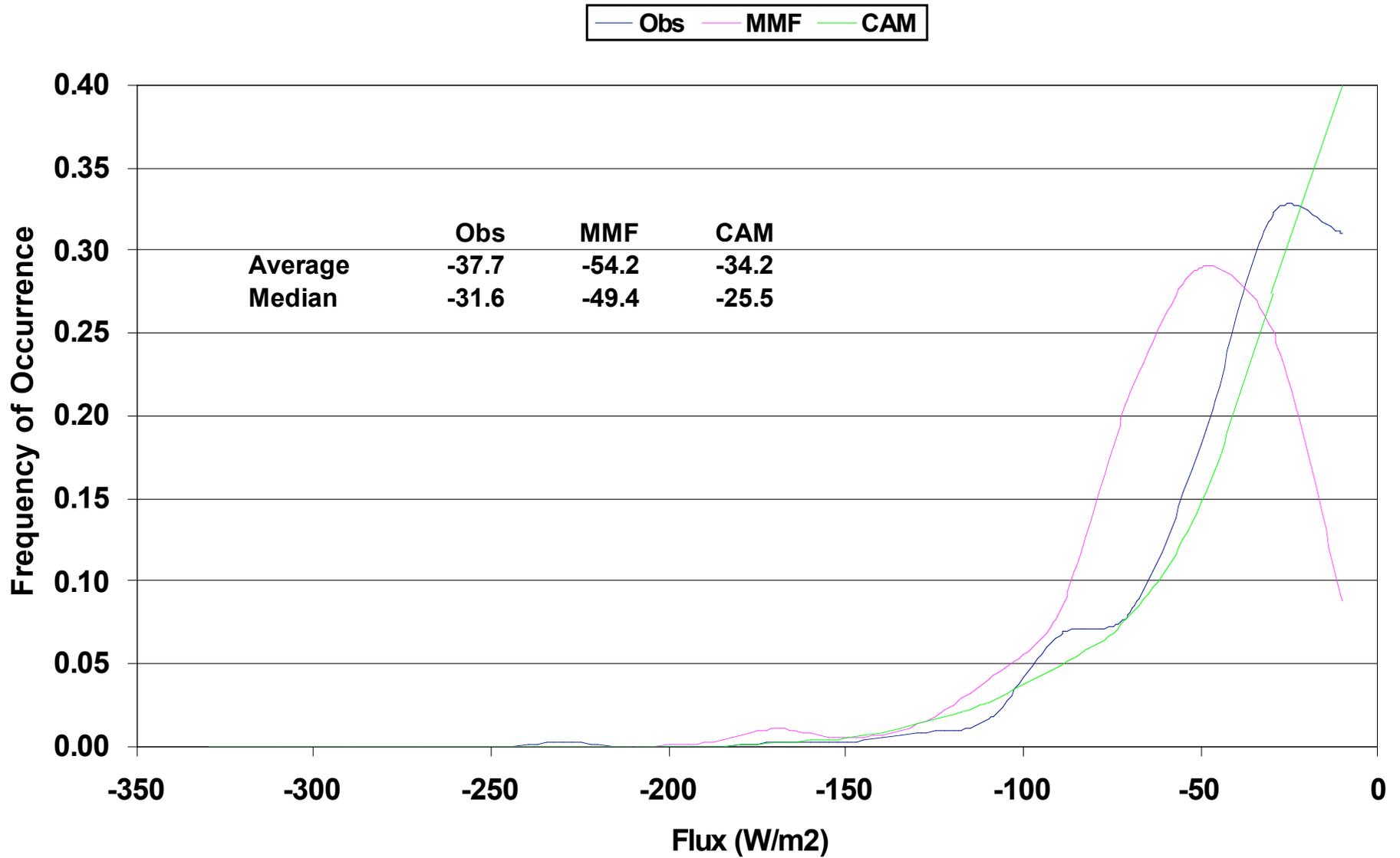
Nauru Surface Flux Observations - 1999



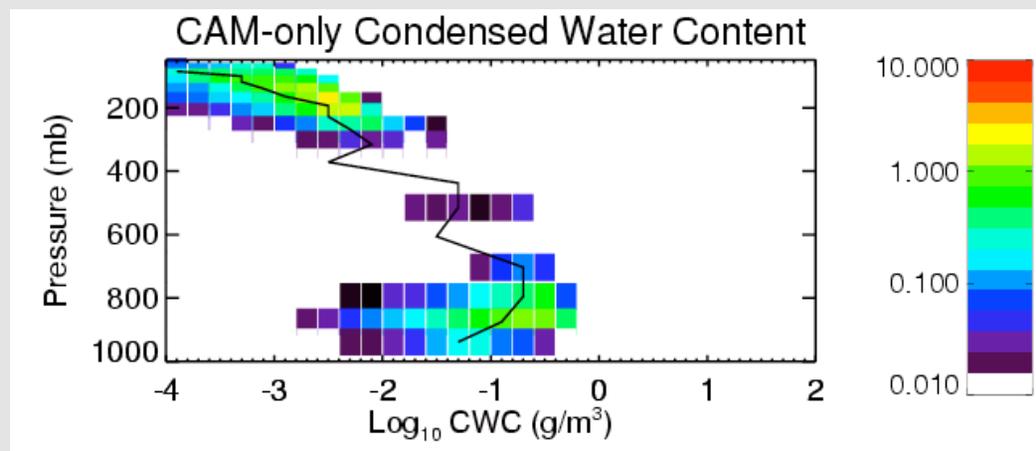
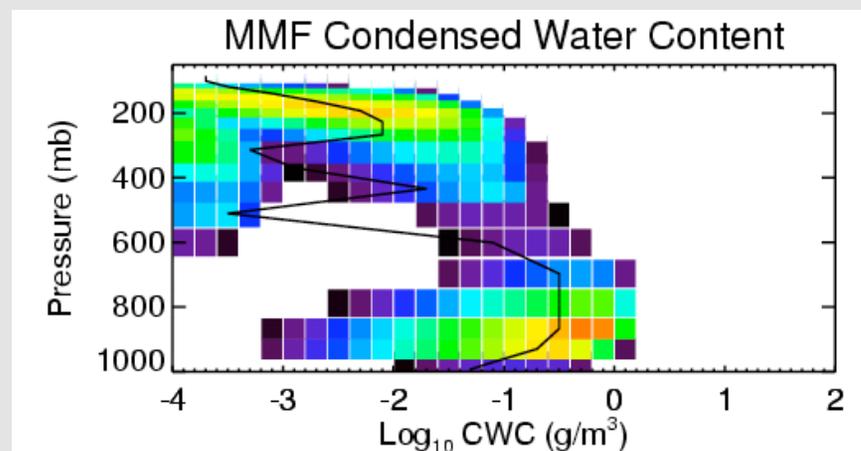
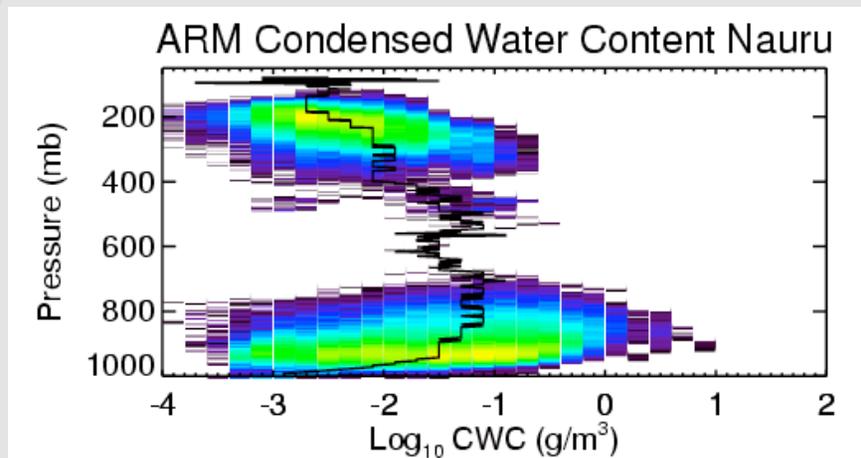
Surface Downward Shortwave Flux at Nauru - 1999



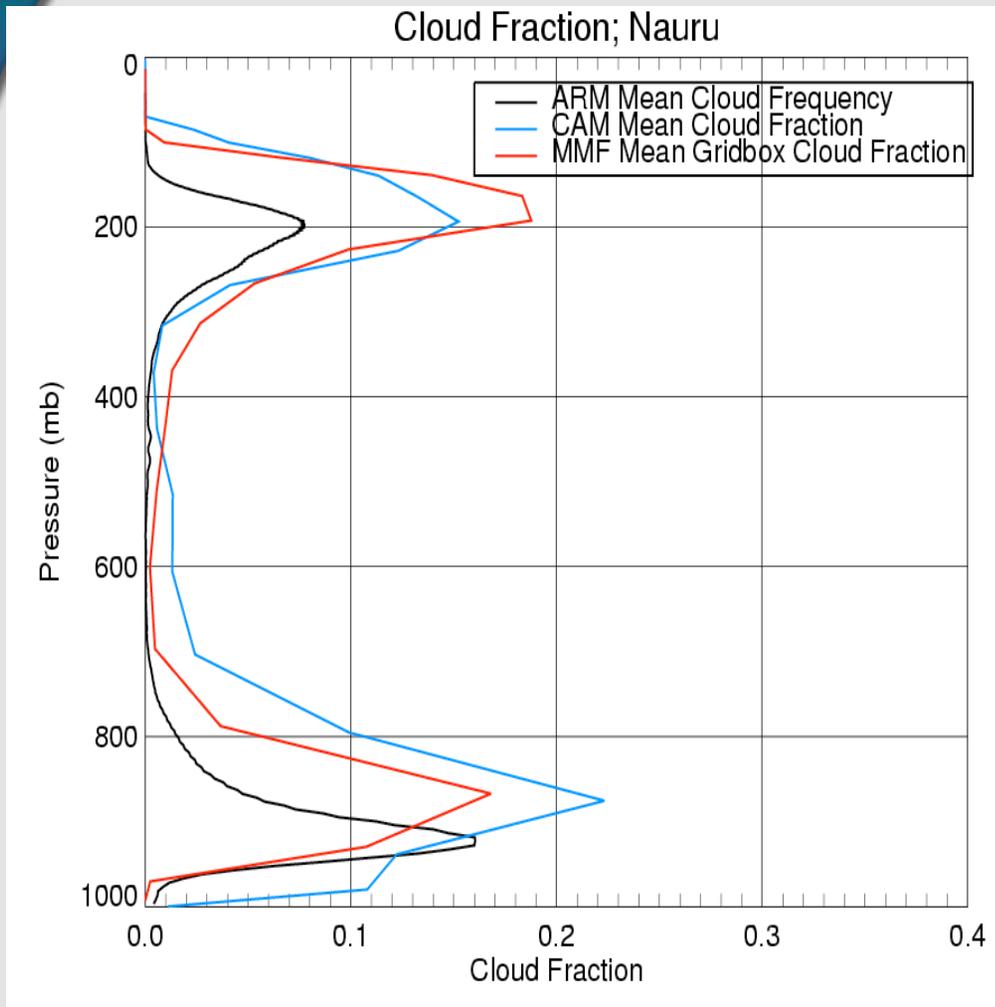
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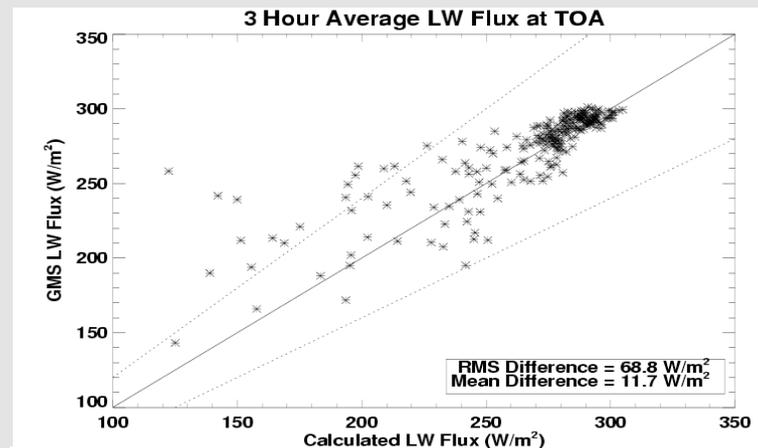
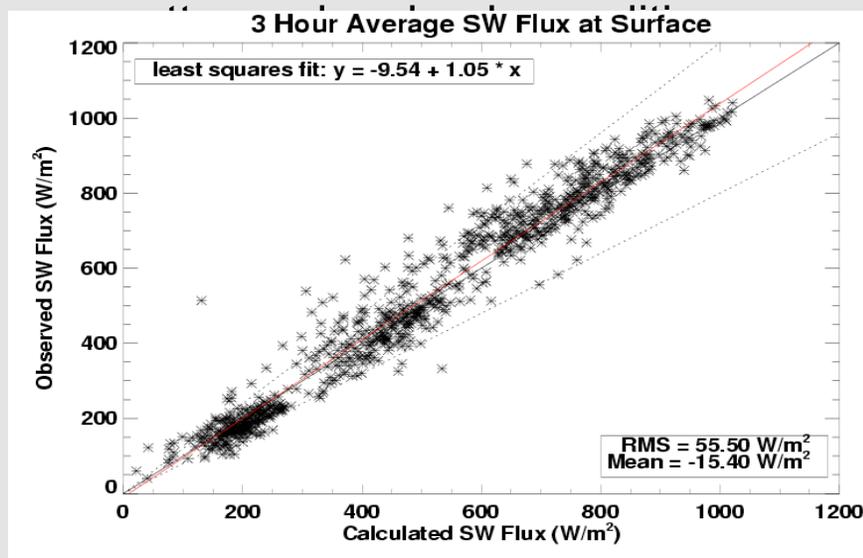
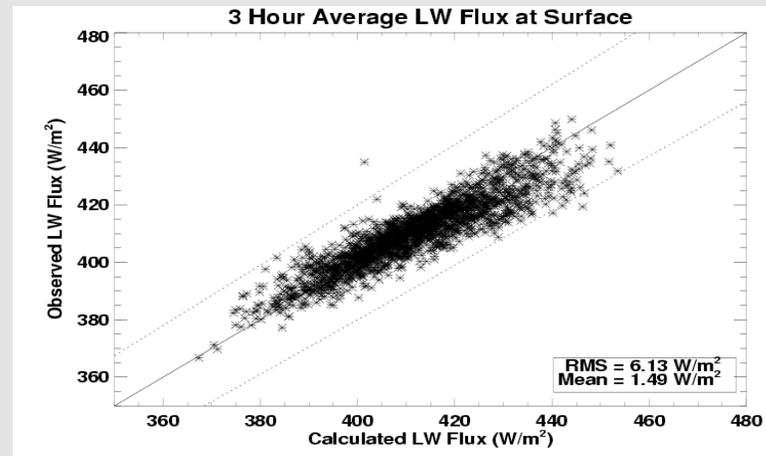
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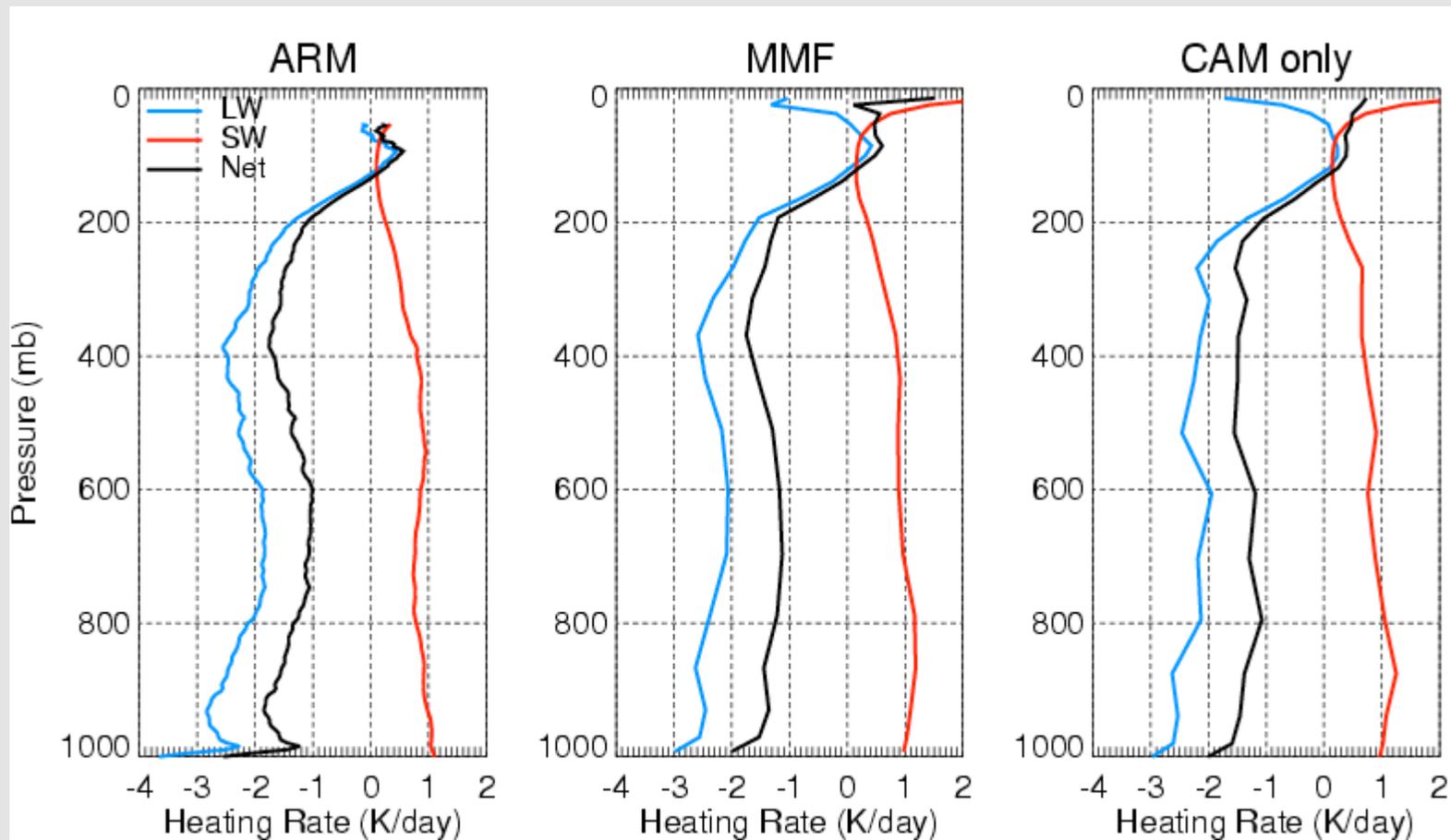
Surface and TOA Flux Comparisons; Nauru

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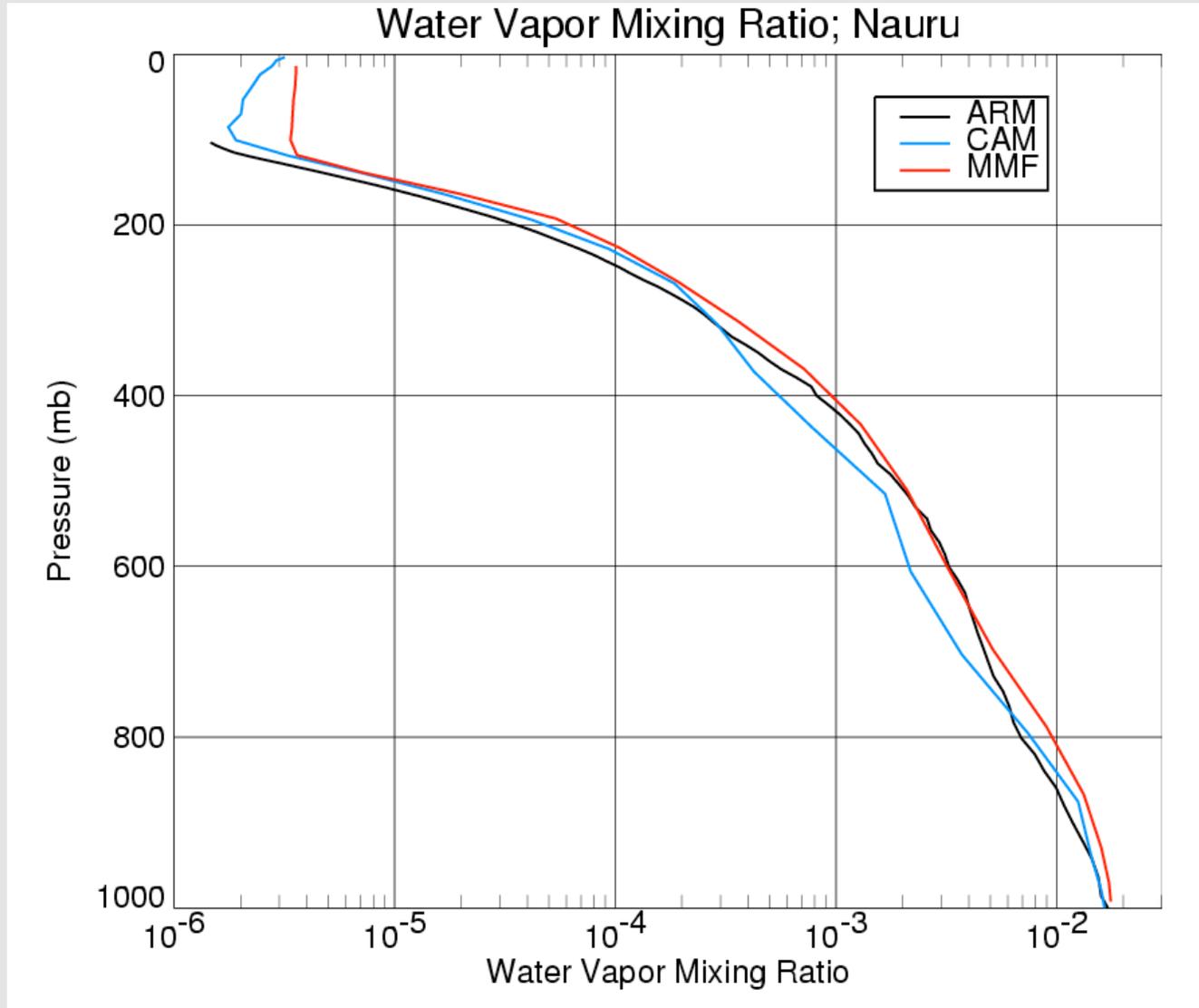


Currently we have only downloaded
1 month of LW TOA data at Nauru

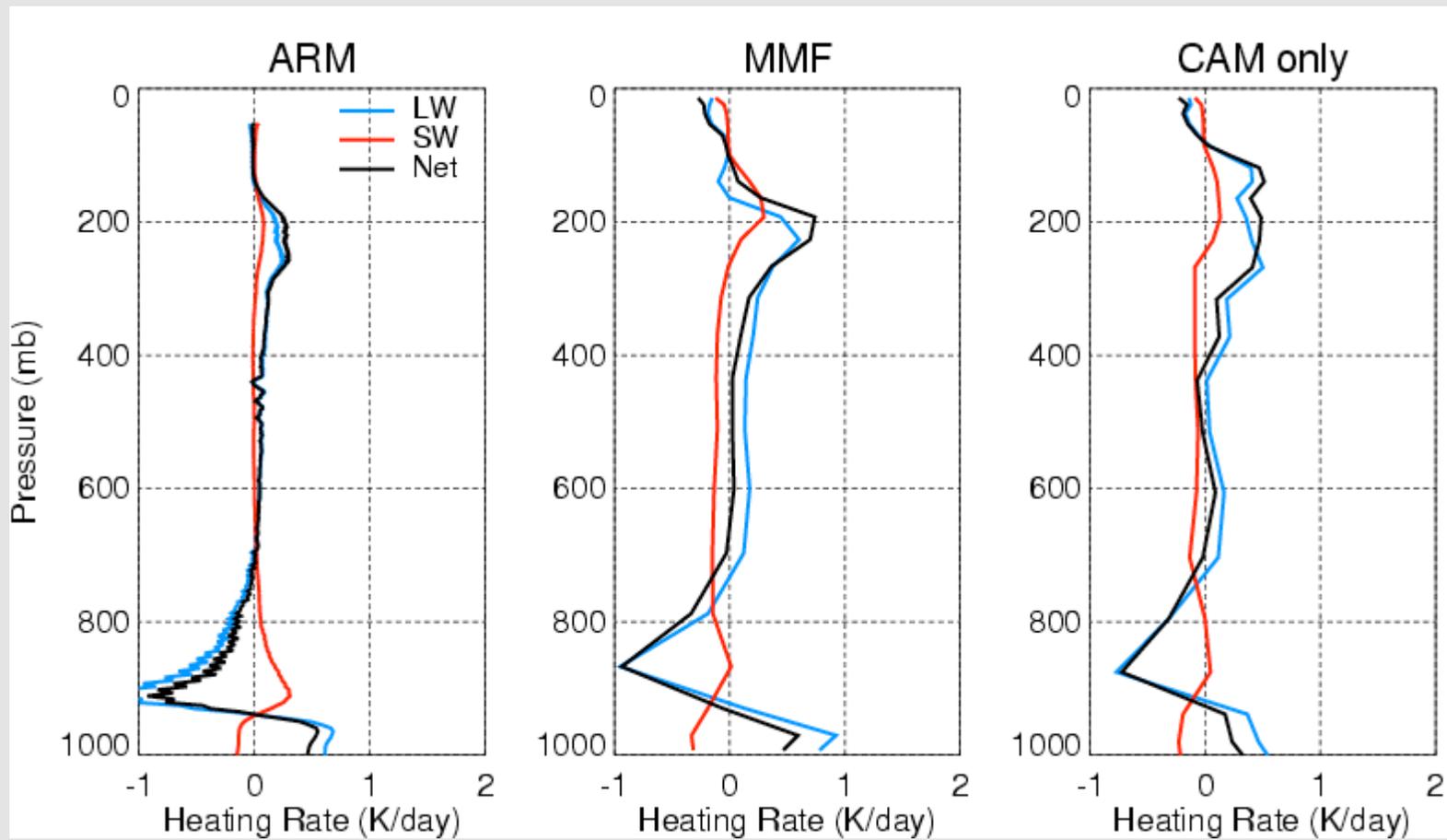
Heating Rates: Clear Sky; Nauru



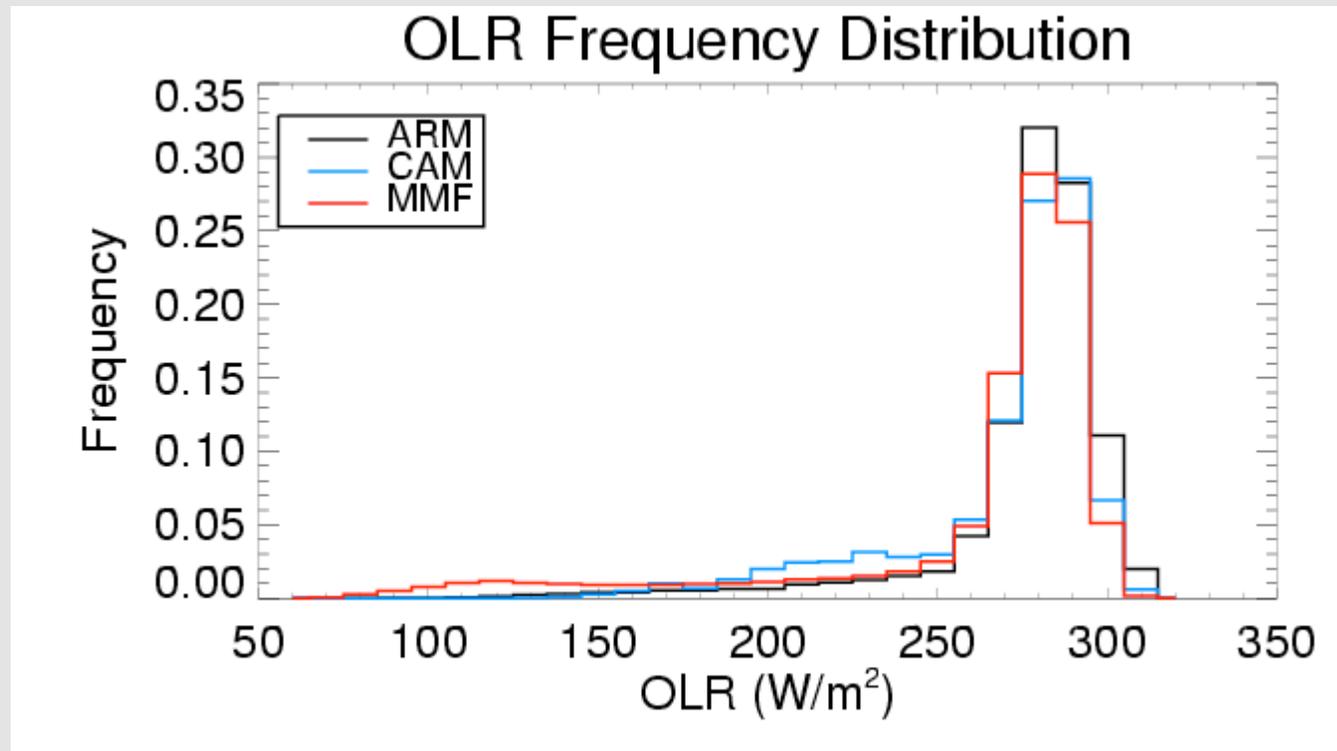
Average Water Vapor Profiles



Heating Rates All Sky – Clear Sky (Nauru)

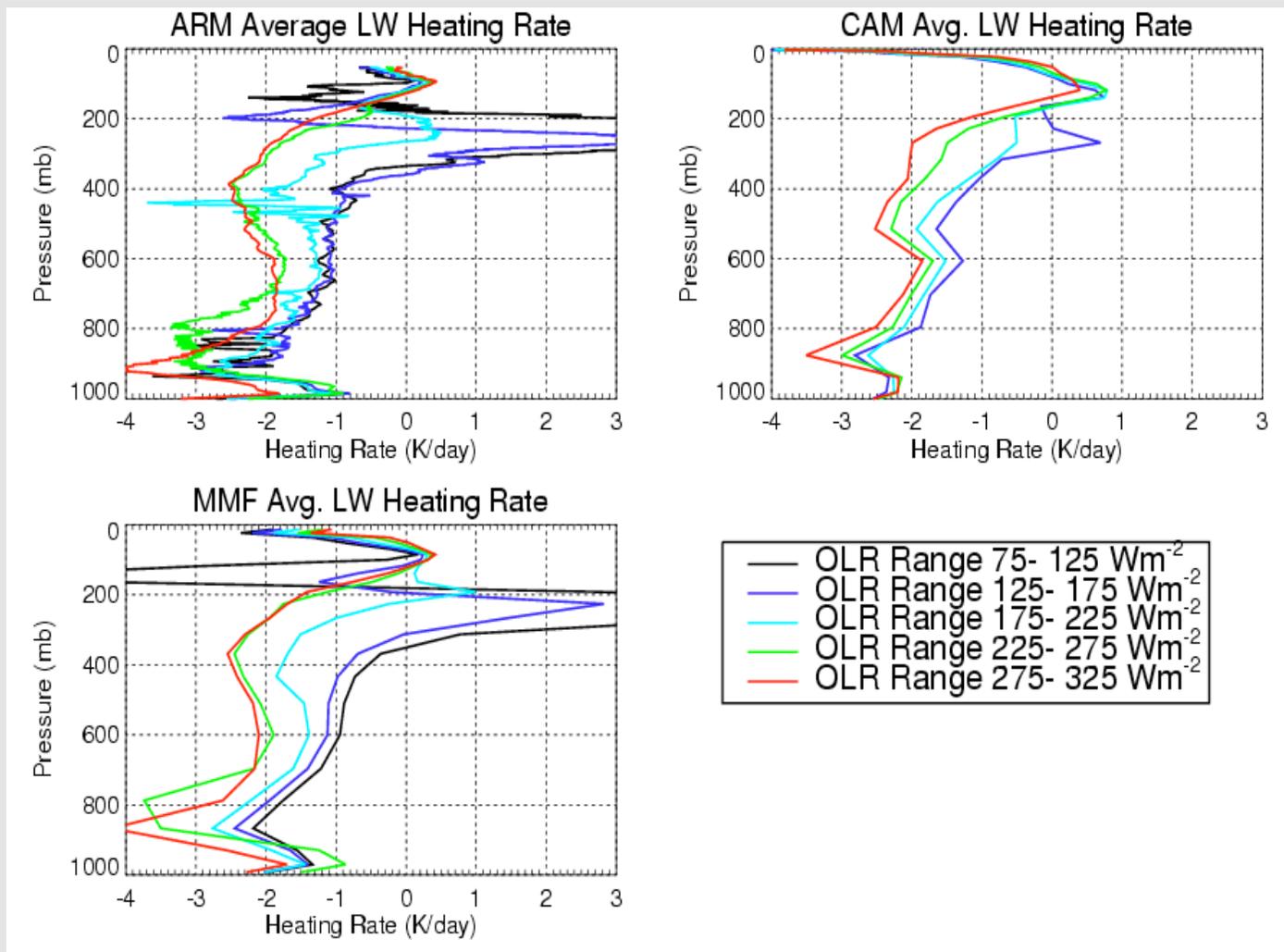


OLR Frequency; Nauru



- CAM and ARM have very few OLR values below 150 W/m^2
- MMF has more very low OLR values than CAM or observations

Heating Rates for Various OLR Ranges; Nauru



Conclusions – Nauru

- ▶ MMF slightly better match to observed water vapor profile than CAM; small impact on clear sky heating rates
- ▶ High clouds
 - Both models overestimate amount of high clouds
- ▶ Middle clouds – virtually none in this time period
- ▶ Low clouds
 - Both models, particularly CAM, overestimate amount of low cloud and place clouds too high

Conclusions – Nauru

- ▶ Surface cloud effect
 - MMF substantially overestimates cloud effect (low clouds too thick)
 - CAM agrees very well with data
- ▶ Heating rate profiles
 - Both models have too much heating near tropopause
 - CAM heating too high due to cloud location
- ▶ OLR classification
 - MMF has low OLR values – high clouds are too optically thick; profile shapes are good, except for lowest OLR category
 - CAM profiles are too smooth – clouds are too geometrically thick and too high

Overall

▶ CAM

- Solar cloud effect agrees very well with observations
- Cloud vertical distribution and optical properties have severe errors
- Vertical moisture profile is in error, particularly in convective regime

▶ MMF

- Considerable overestimate of solar cloud effect
- Good vertical distribution of clouds but too much high cloud with too large an optical depth, probably due to overactive convection

Ongoing work

- ▶ Finish column radiation budget – TOA fluxes
- ▶ Extend for longer time periods
 - Convective regime at Nauru
- ▶ Sort by regimes
 - Use ISCCP classes defined by Jakob et al.
- ▶ Extend to other sites
- ▶ Do differences in heating rates affect dynamical response? How do we tell?