# A CPT for Cloud Parameterization and Aerosol Indirect Effects

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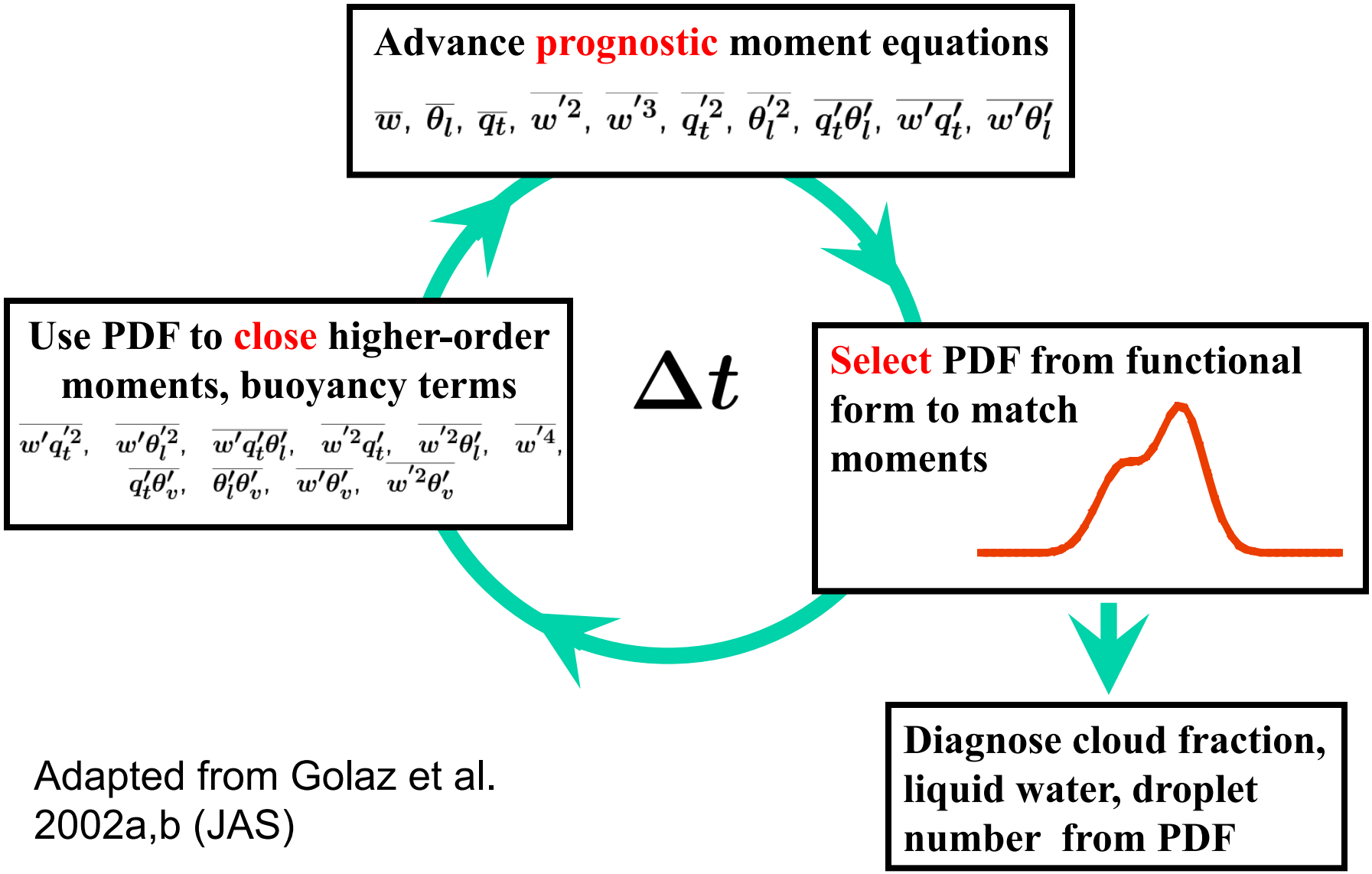
Update for CMMAP August 2011

# Overview: Progress Since January 2011 CMMAP

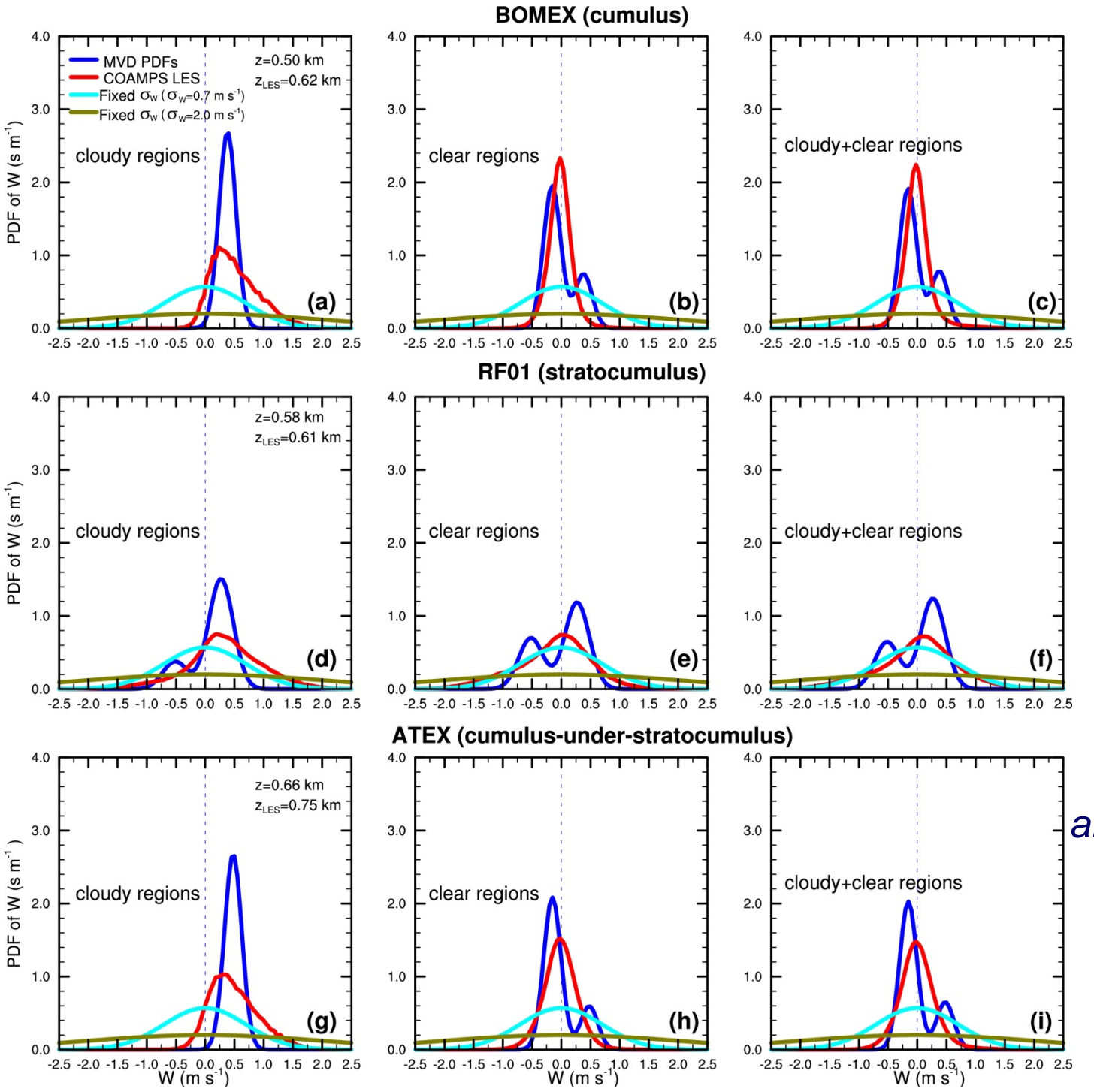
- Using multi-variate probability density functions with dynamics to parameterize boundary layers and clouds
- Application to mixed-phase clouds
- Analysis of physical mechanism underlying reduced liquid in some cases with high aerosol concentrations
- Issues related to using field observations for evaluation
- Implementation in AM3 and CAM

# Building a PDF-based parameterization




Adapted from Golaz et al. 2002a,b (JAS)

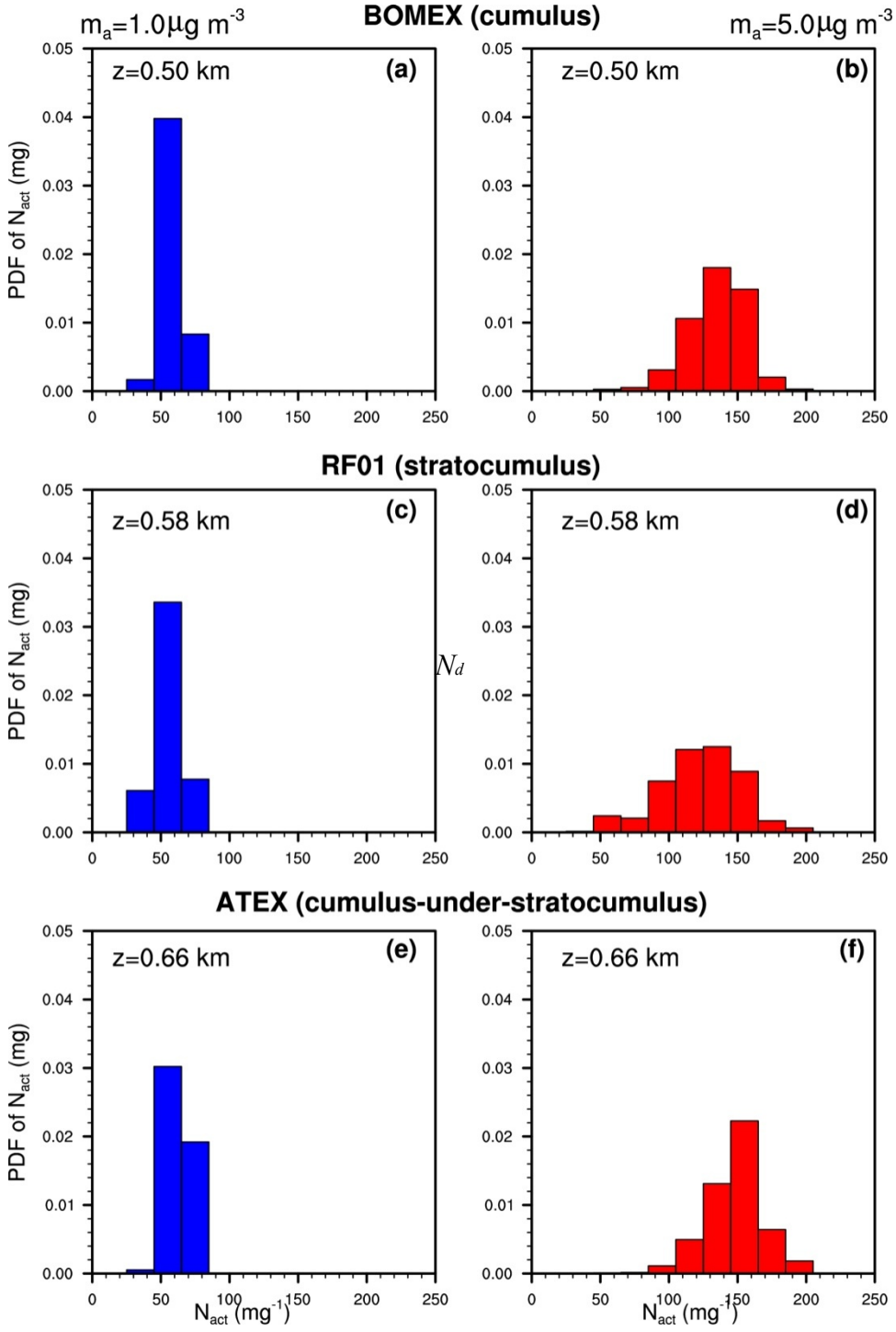
# *W* PDF




from Guo *et al.* (2010, *GMD)*

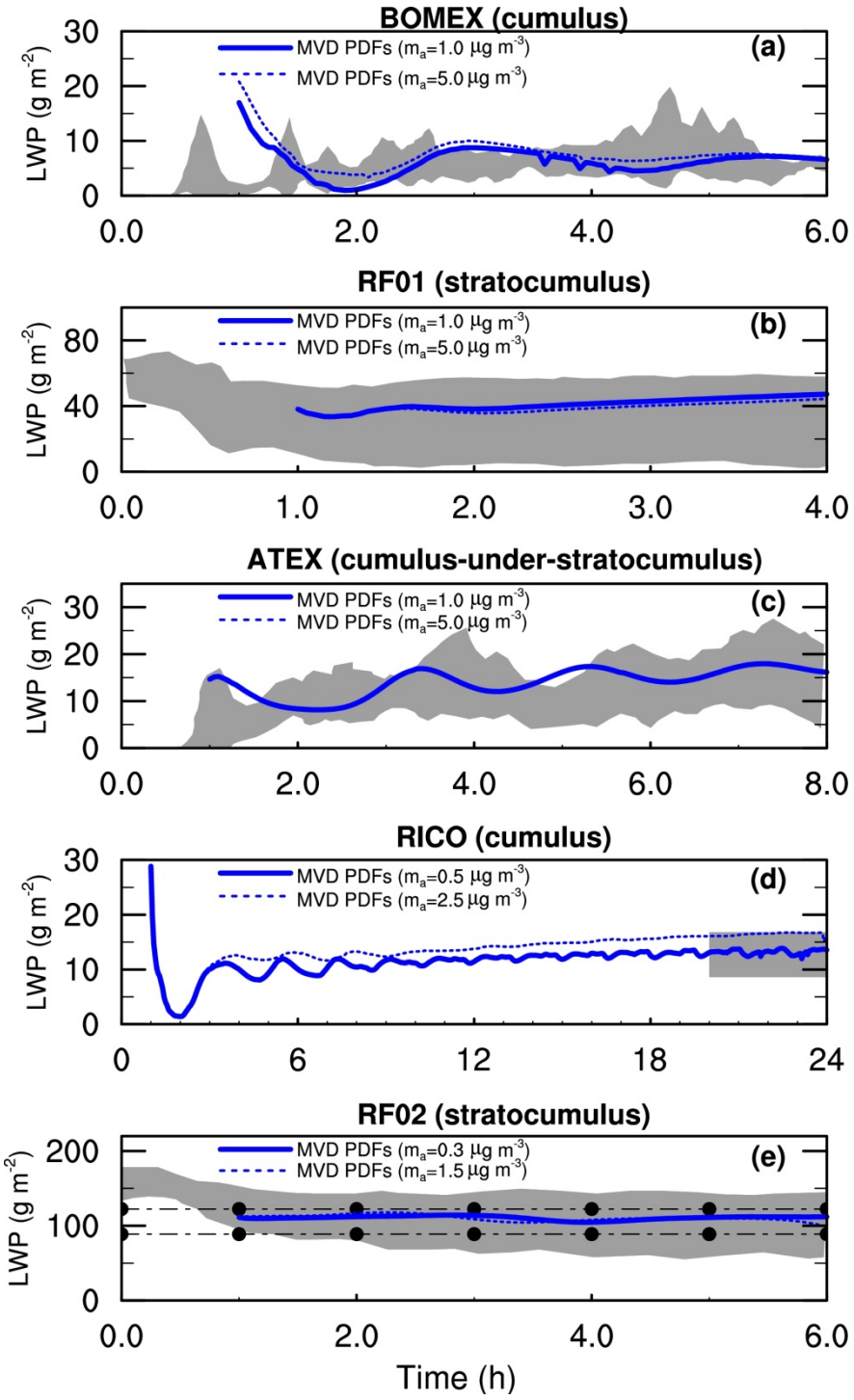
$N_d$

PDF




from Guo *et al.* (2010, *GMD*)

AM3 Single Column Model using Multi-Variate Probability Density Function with Dynamics, Aerosol Activation, and Double-Moment Microphysics



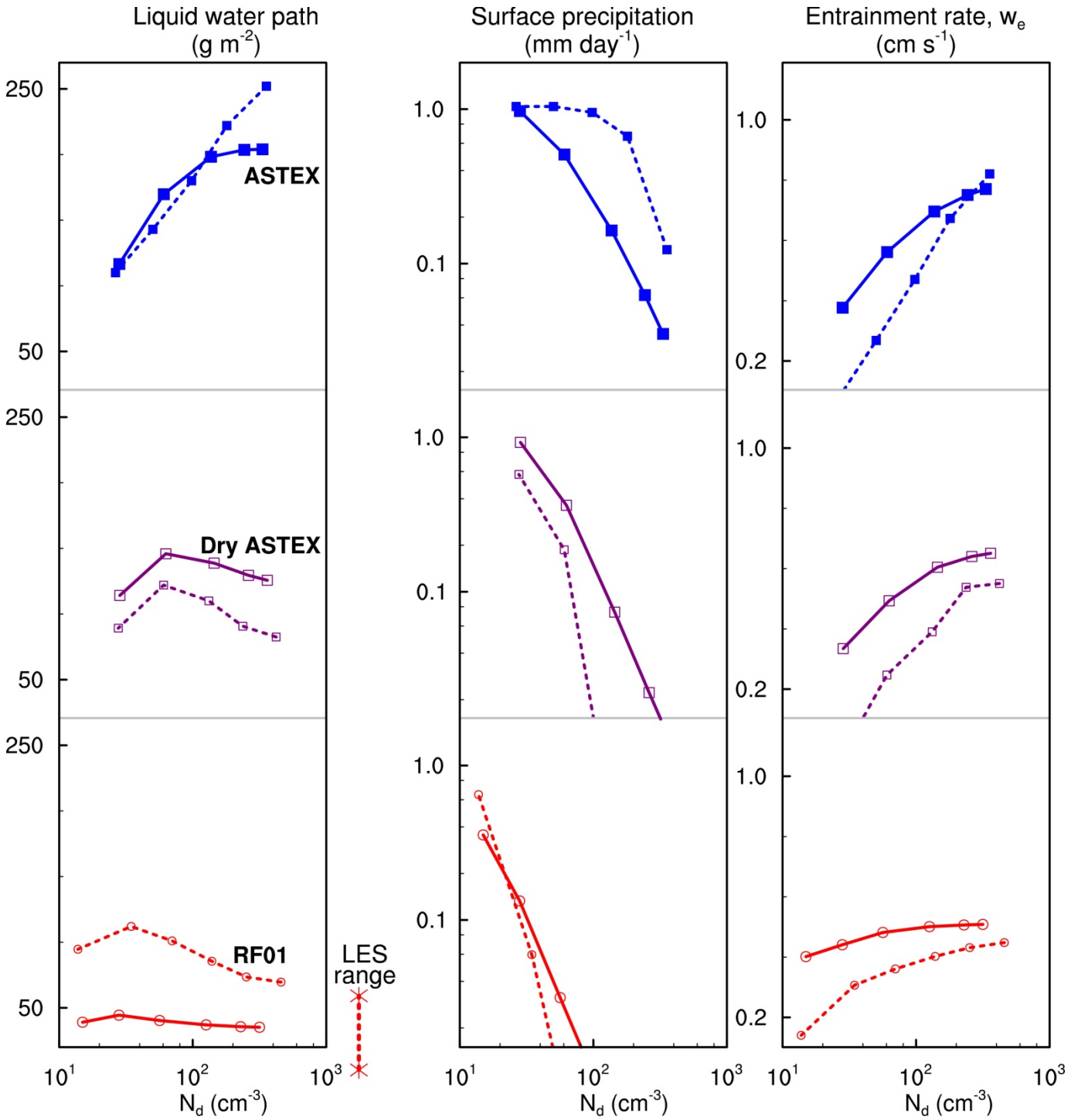

from *Guo et al.* (2010, *Geosci. Model Dev.*)

# Next Steps

- Working with process modelers and field experimentalists to develop test cases with aerosols
- Mixed-phase clouds
- GCM implementation
- Deep convection and shallow clouds together

Solid: MVD PDFs

Dashed: LES from Ackerman *et al.* (2004, *Nature*)




LES range from Guo *et al.* (2010, *GMD*)

cf., Guo *et al.* (2011, *GRL,* in revision)

# Two mixed-phase cases

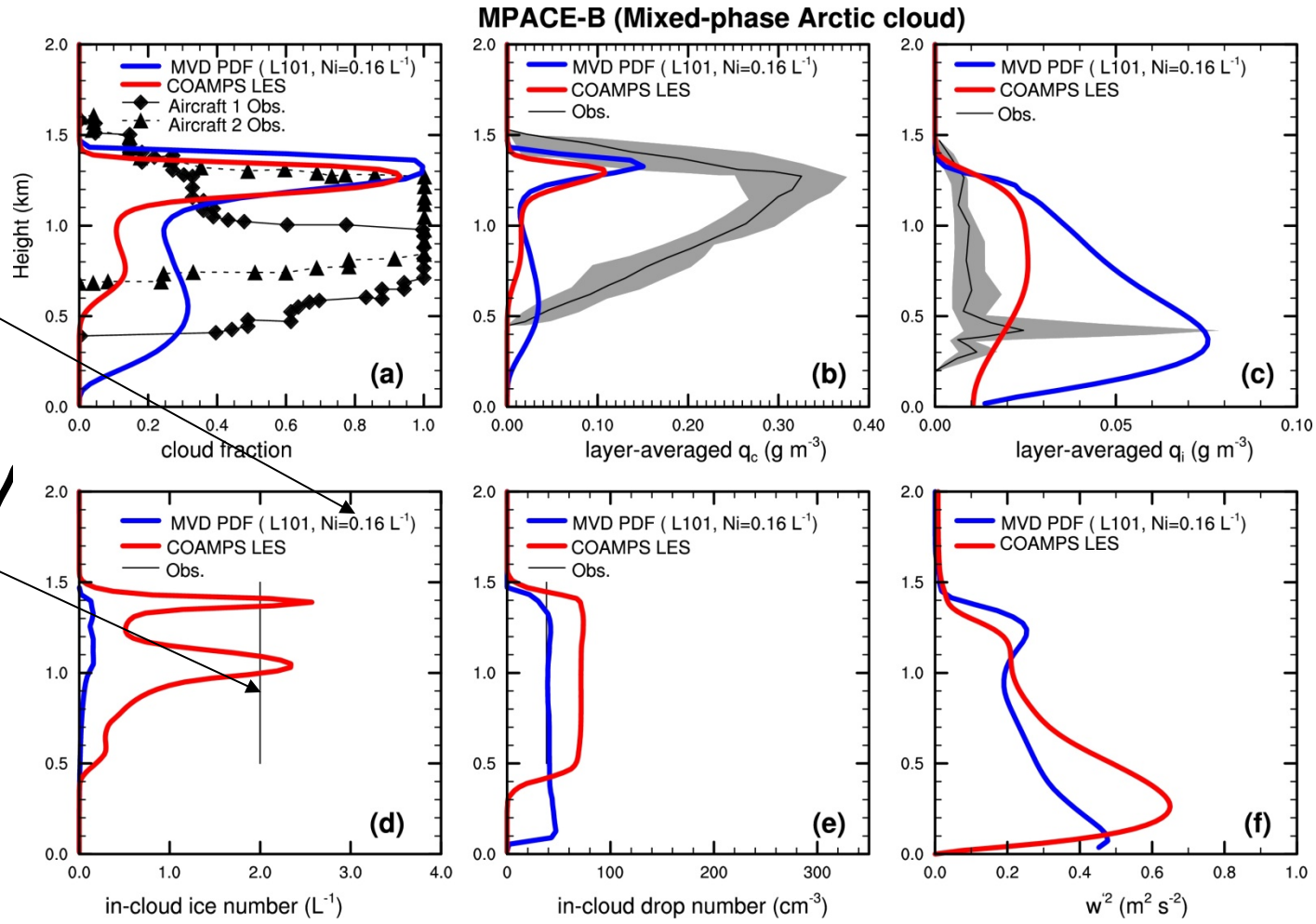
**Precipitating**
- MPACE-B (pristine, warmer)
- SHEBA (polluted, colder)

# MPACE-B: profiles

ice nuclei (0.16/L)

ice number (2/L)

ice multiplication

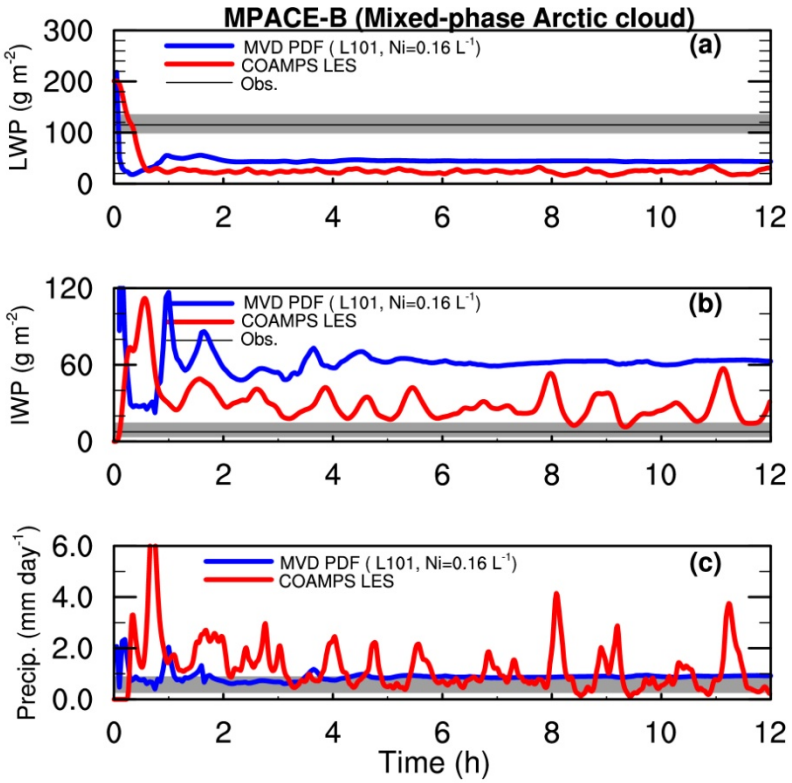



Aircraft obs, cf. Klein *et al.* (2009, *QJRMS*)

August 2011

from Huan Guo, GFDL

# MPACE-B: time series



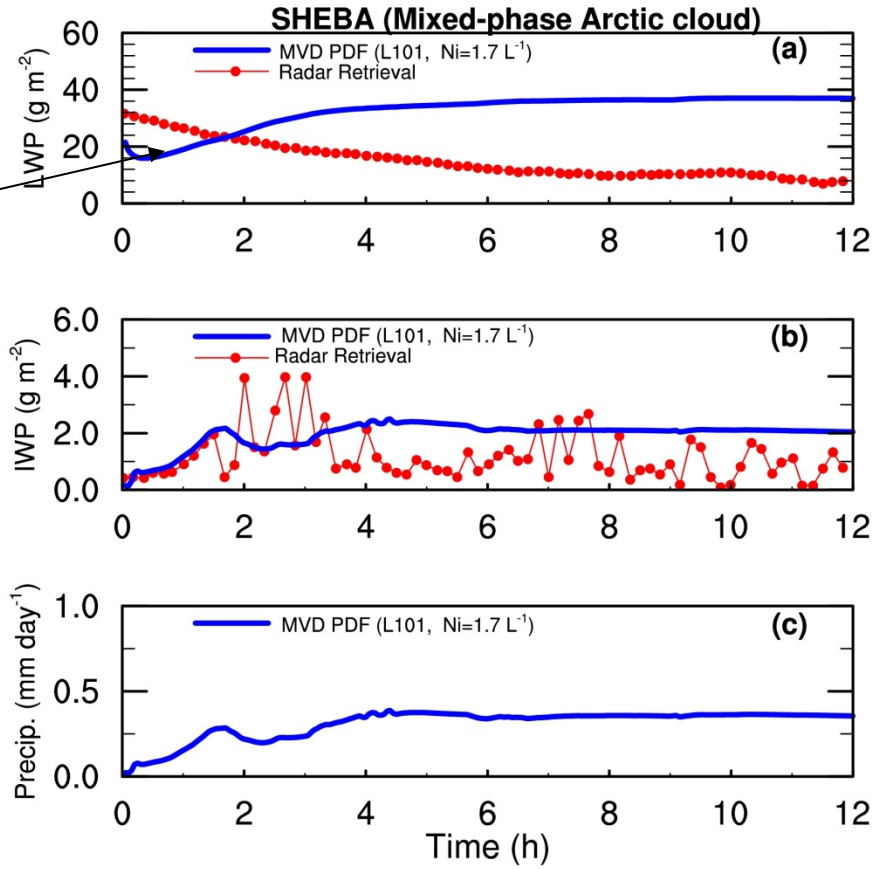

avg. over 4-12 hour

| | | LWP (g/m2) | IWP (g/m2) | Precip. (mm/day) |
|---|---|---|---|---|
| | MVD PDF | 44.2546 | 61.9714 | 0.8779 |
| | COAMPS LES | 23.8739 | 26.2158 | 1.0155 |
| Aug 11 | Obs. Esti. | 115.3000 | 7.6000 | 0.9000 |

# SHEBA (Time series)

overestimate

LWP

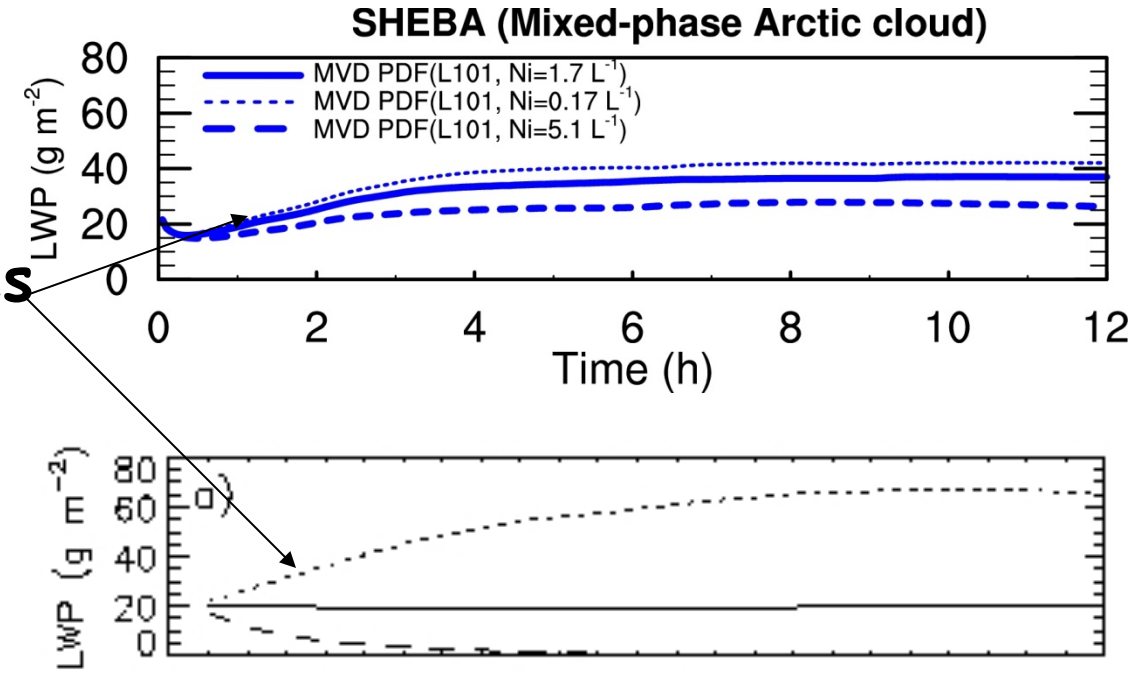



avg. over 4-12 hour

| | LWP (g/m2) | IWP (g/m2) | Precip. (mm/day) |
|---|---|---|---|
| MVD PDF | 35.6580 | 2.1440 | 0.3530 |

# SHEBA: sensitivity to IN

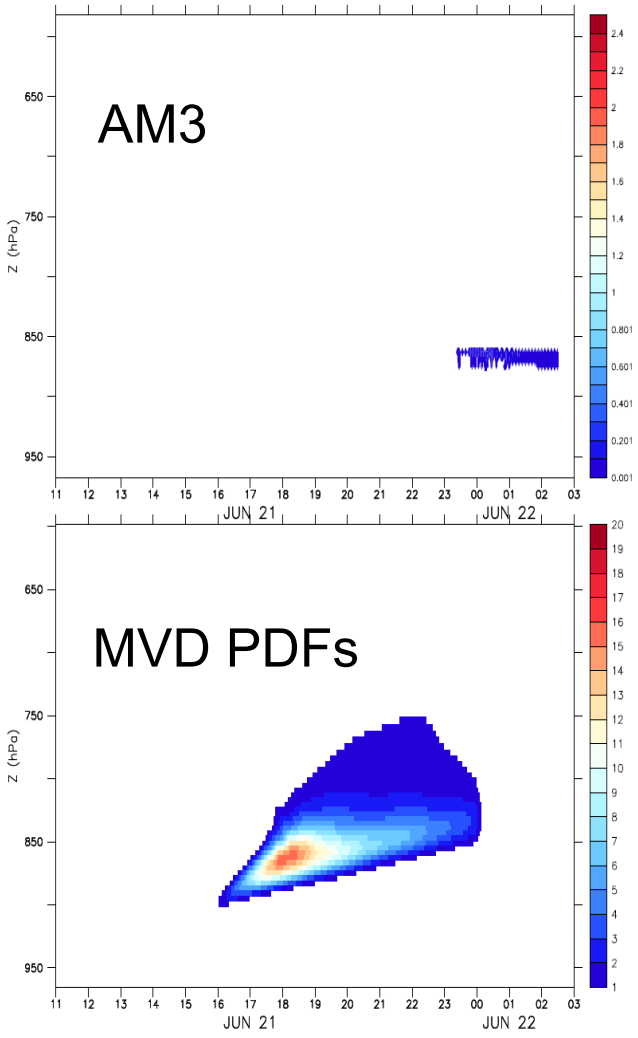
LWP decreases with IN



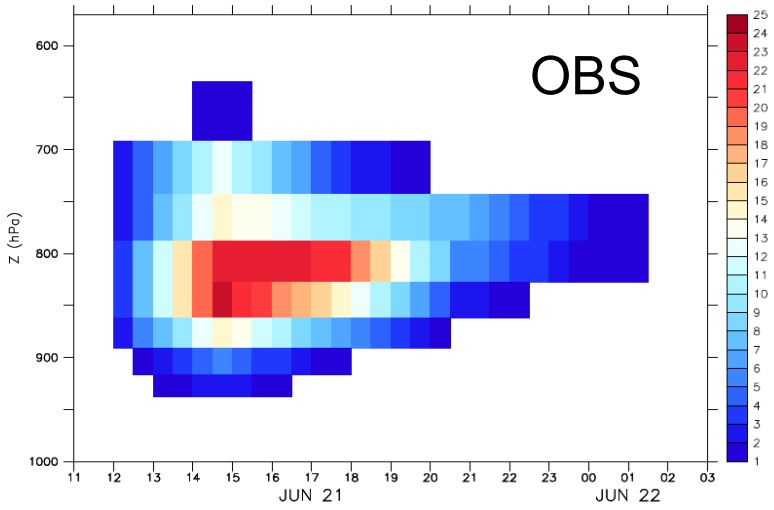

Morrison et al., 2011


# Observations for SCM Evaluation


# GCSS ARM case

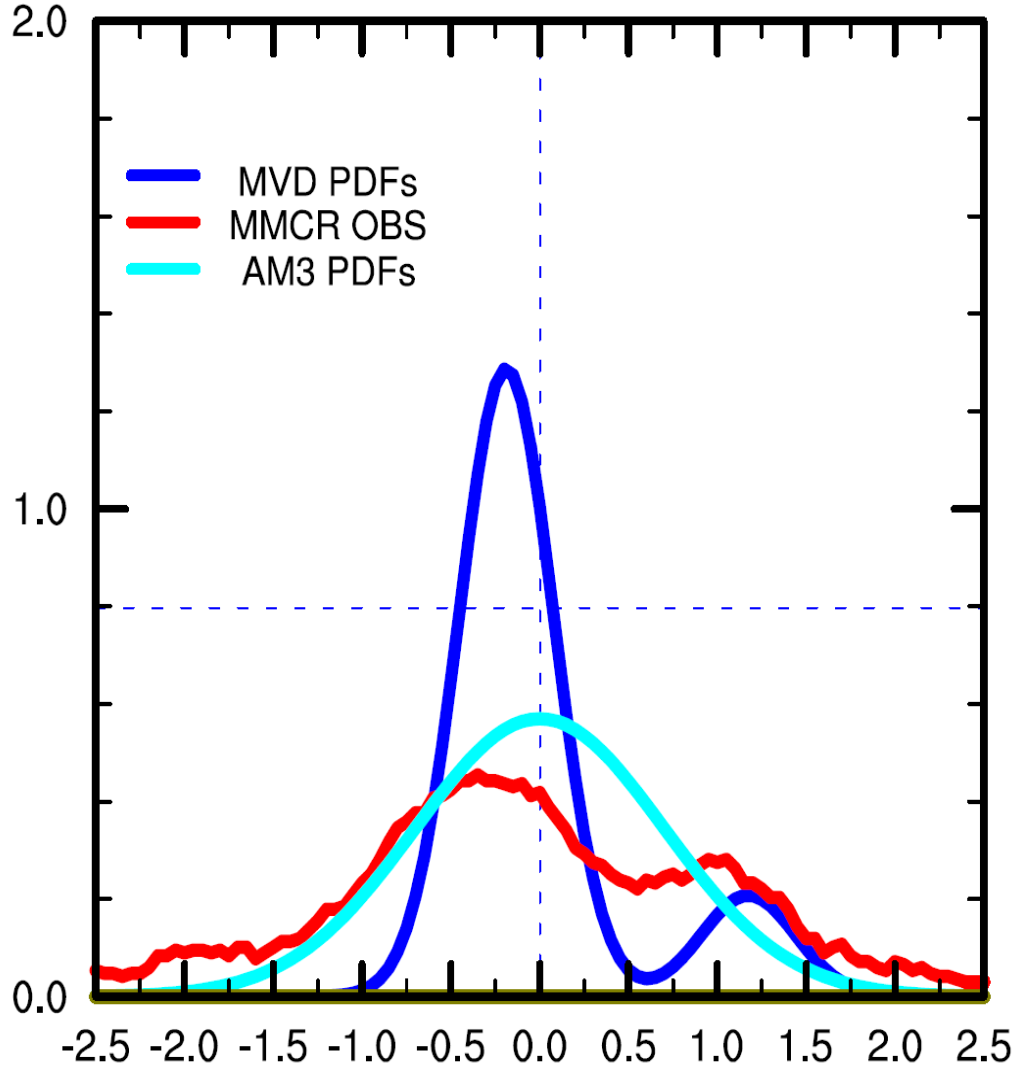



Cloud fraction



# Vertical motion PDF comparison

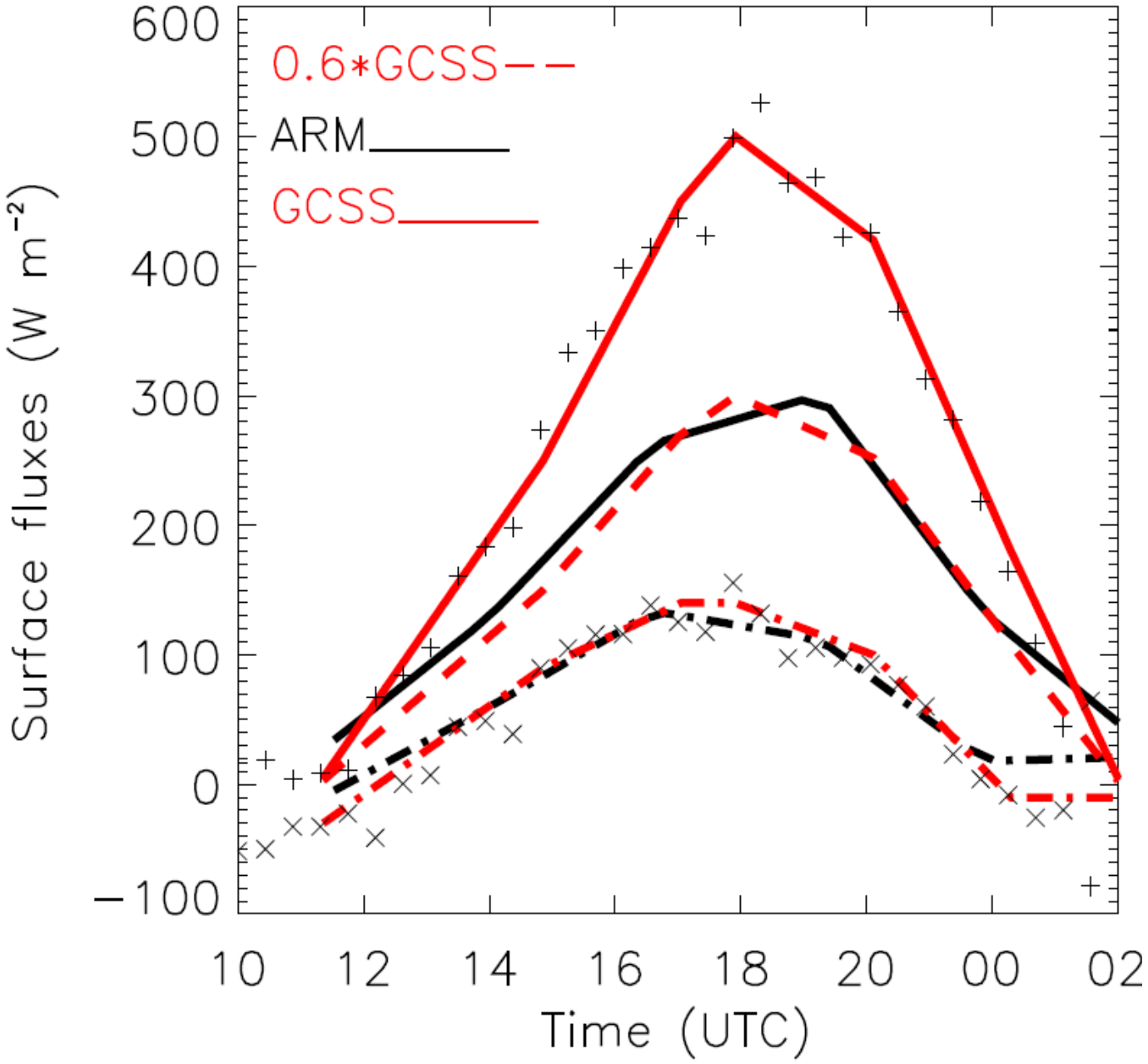
ARM GCSS
21 June 97
Brown *et al.*
(*QJRMS*, 2002)



Surface latent and sensible heat flux from ARM variational analysis and GCSS forcing

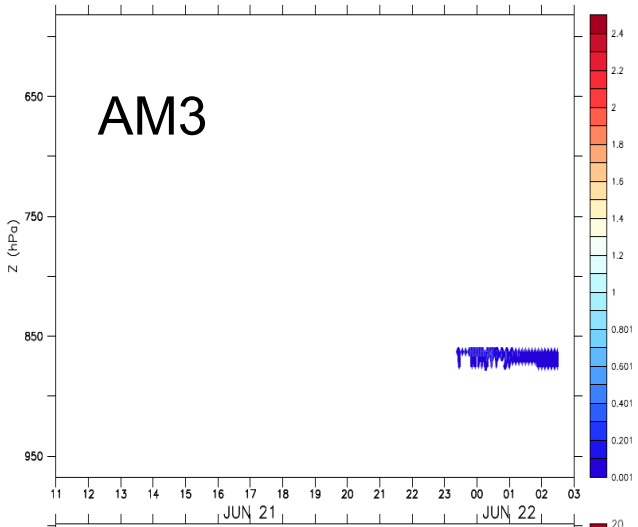
LH: solid line
SH: dashed lines

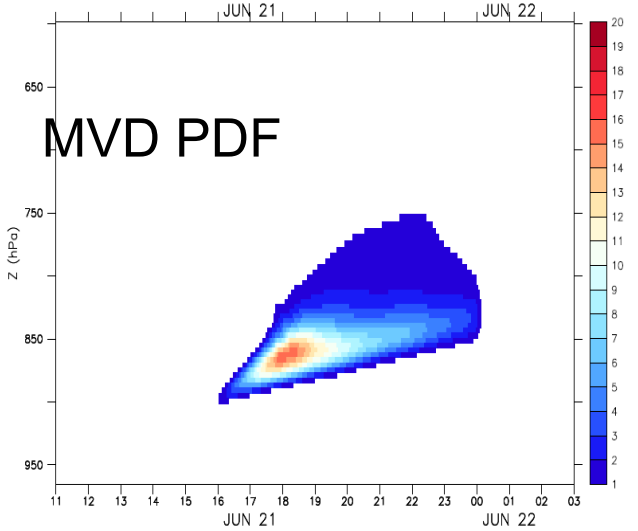
Symbols are fluxes at the central facility.

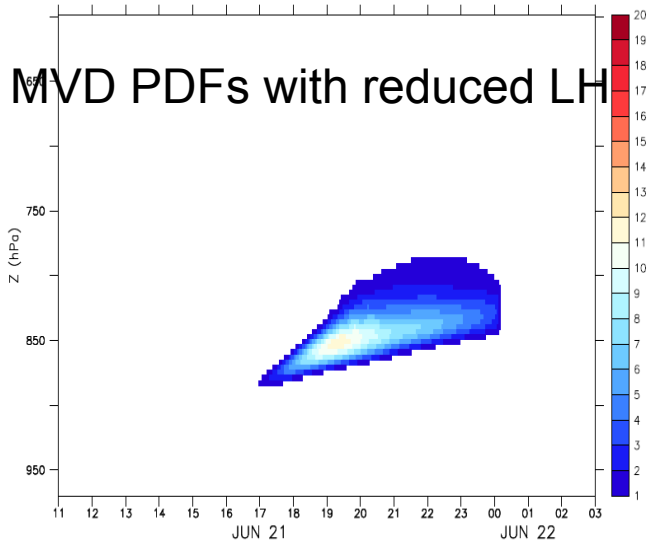


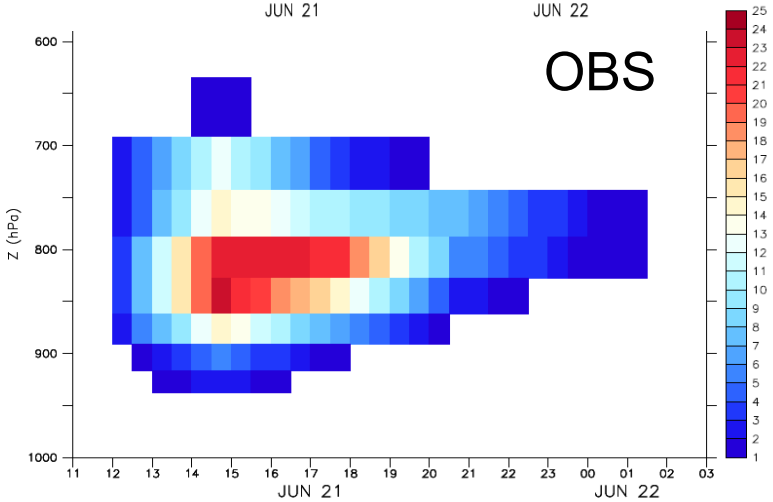
# GCSS ARM case

Cloud fraction

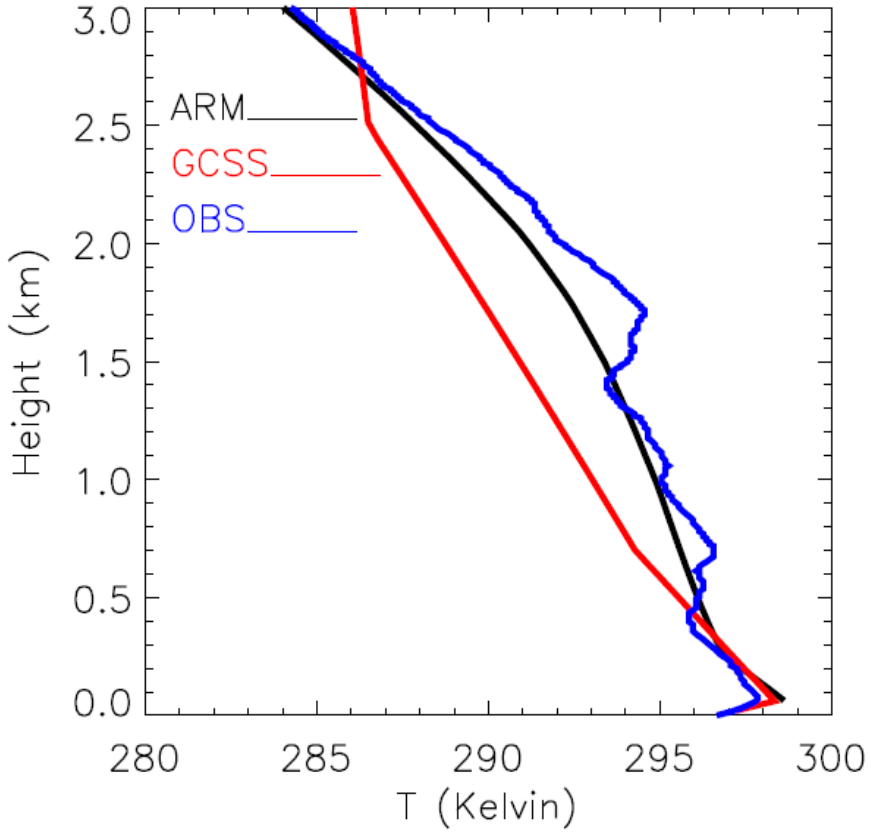


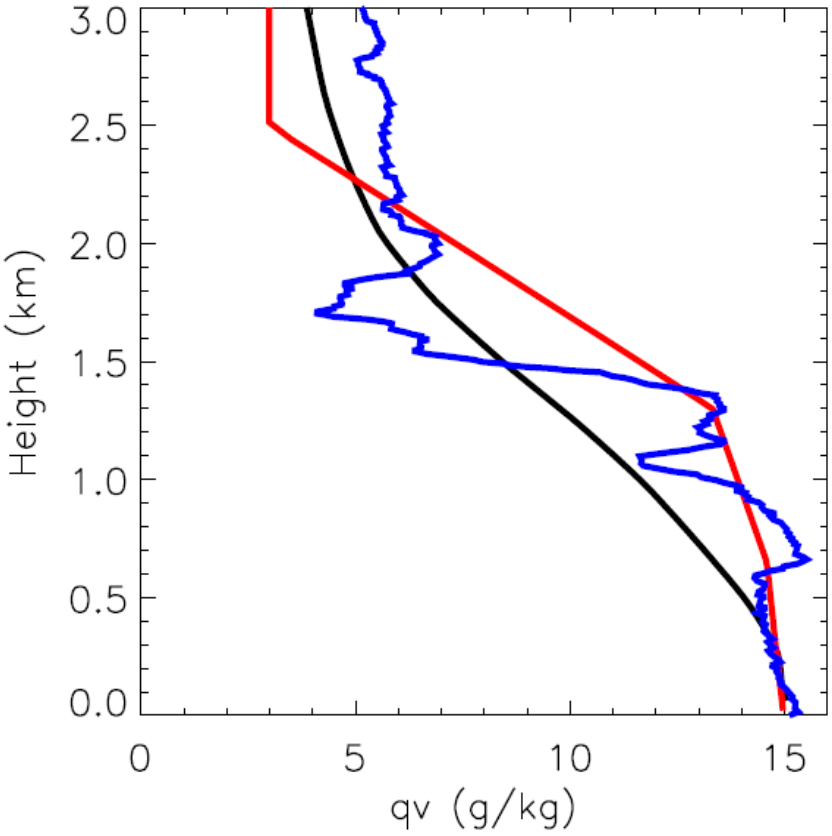



# Initial T and Qv

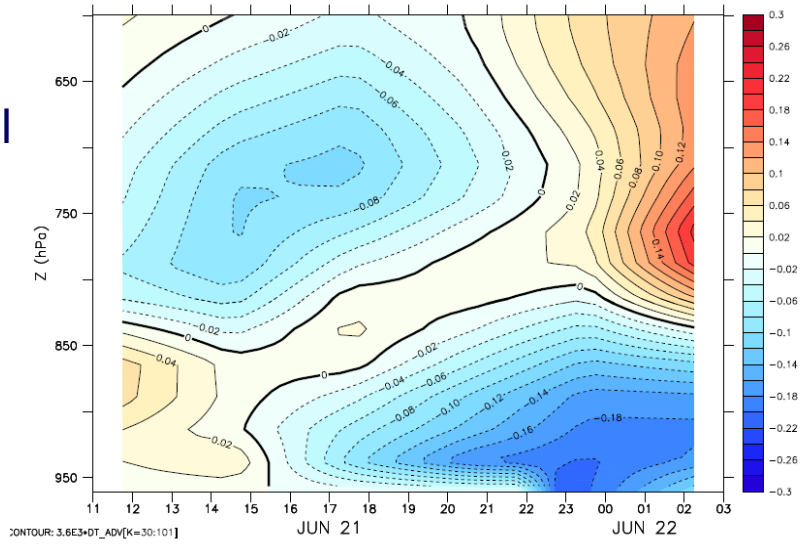


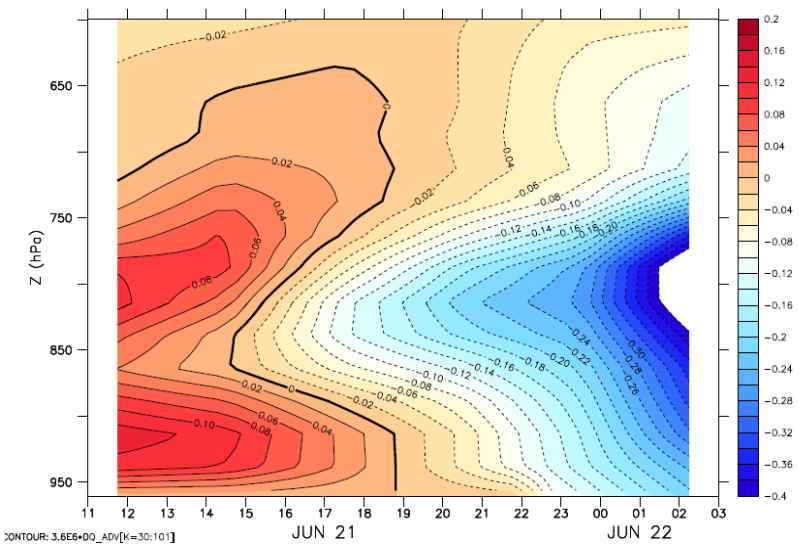



# T adv

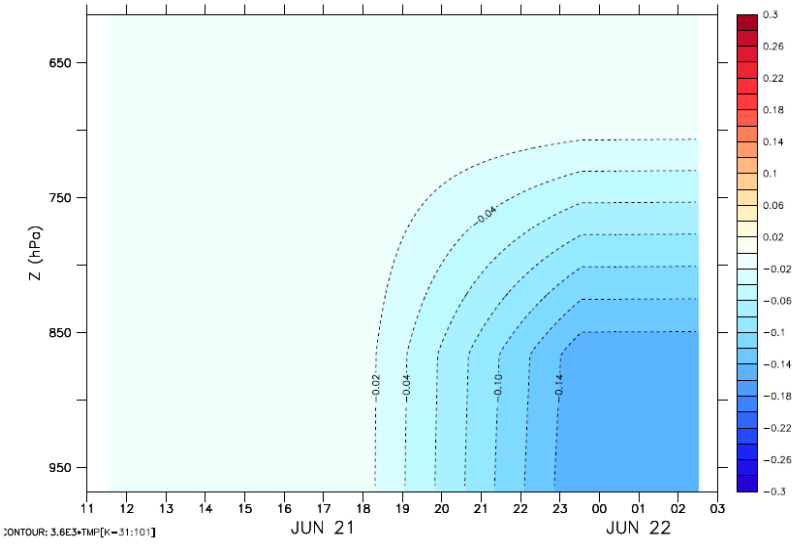
# qv adv

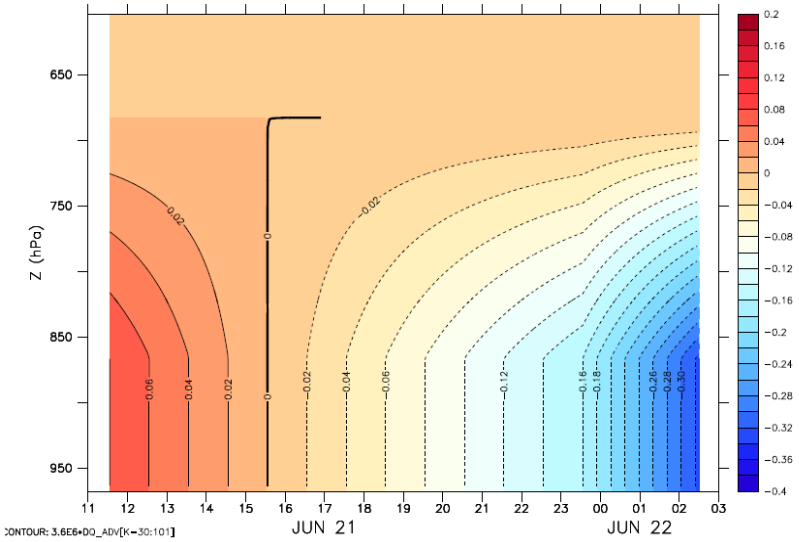
GATE Variational




GCSS

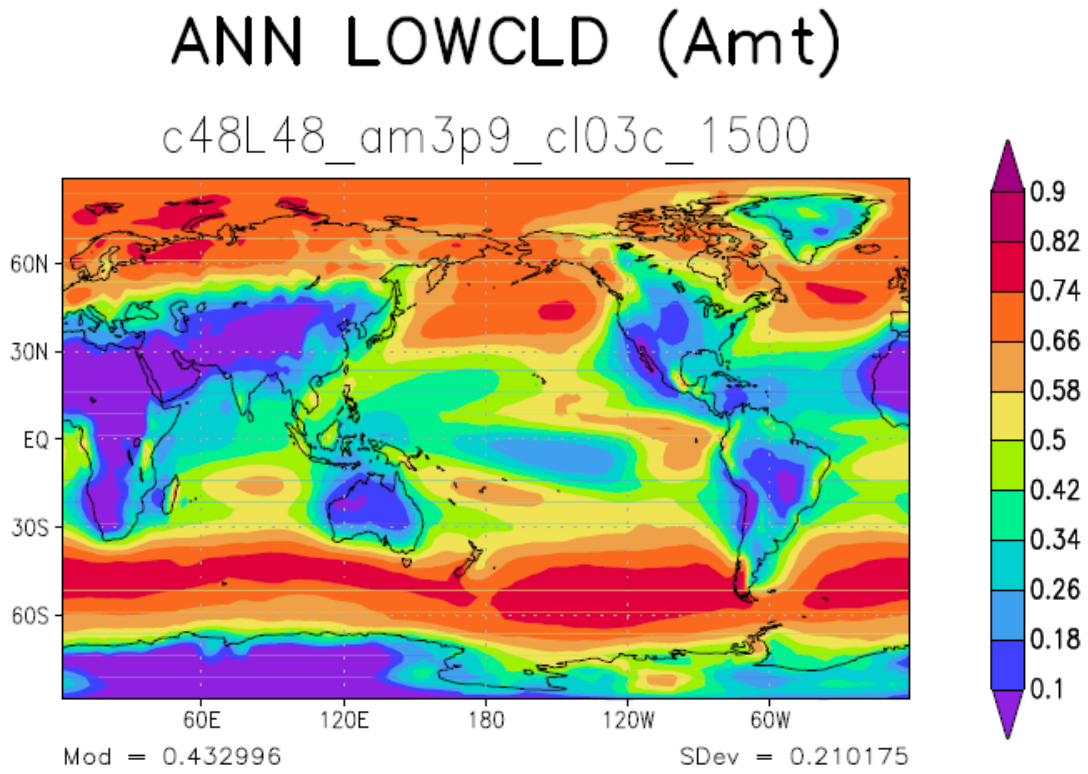


# MVD PDF fails to produce cloud using ARM variational analysis

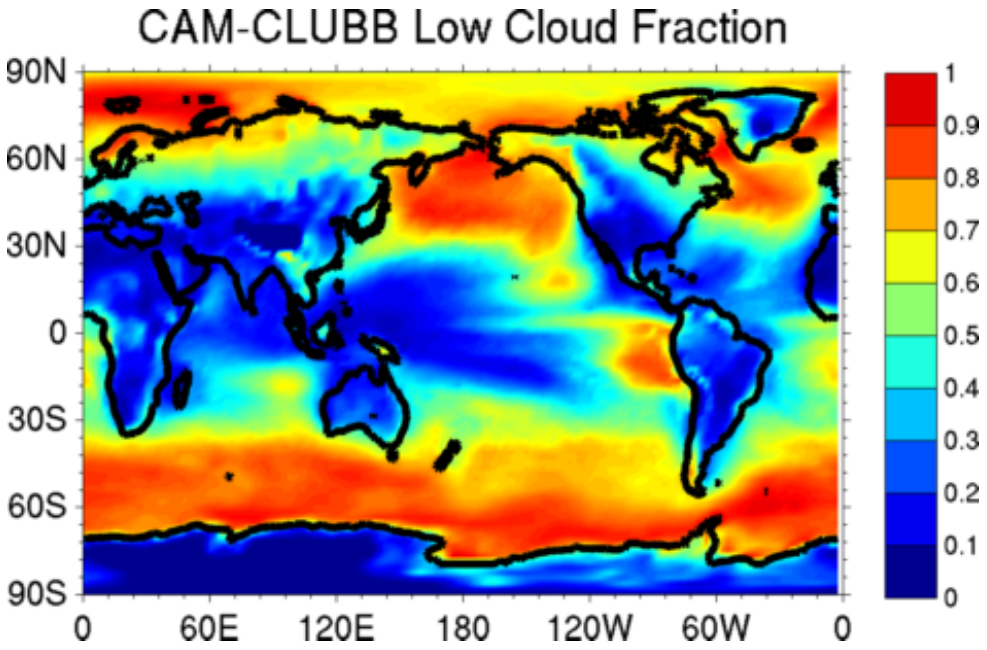
# MVD PDFs with AM3 and CAM Dy-cores and Uncoupled Deep Convection

# GFDL CPT Progress: AM3-CLUBB




- CLUBB incorporated into GFDL GCM (AM3)
  - CLUBB replaces AM3 large-scale cloud, PBL and shallow convection schemes.
  - Initial results in April
  - Performed several two decade-long AMIP experiments
  - Computational cost of CLUBB is relatively modest (10-15% of total CPU time)
  - Working on improving coupling with other physics parameterizations (deep convection, micro-physics)

# NCAR CPT Progress: CAM-CLUBB




Vertically integrated low cloud fraction from a one year simulation of CAM-CLUBB

- CLUBB implemented into CAM5
  - Replaces existing UW eddy scheme, shallow convection, and macrophysics
  - Single-column tests on several GCSS cases yields promising results compared to LES
  - Preliminary one-year simulation produces encouraging results in the representation of boundary layer clouds, but more progress is needed to match CAM-5

# Summary

- MVD PDFs successfully simulate cloud fraction, water path, and droplet numbers for Sc and shallow Cu GCSS cases.
- MVD PDFs indicate both positive and negative indirect effects on LWP. Entrainment/aerosol interaction similar to LES.
- Microphysical issues emerge in mixed-phase applications of MVD PDFs.
- Scale of observed forcing critical in MVD PDF simulations.
- GFDL and NCAR have implemented MVD PDFs in AM3 and CAM but without linking to deep convection.