PDF Parameterizations for Clouds, Forcing, and Scale: Inferences from the ARM SGP Observations

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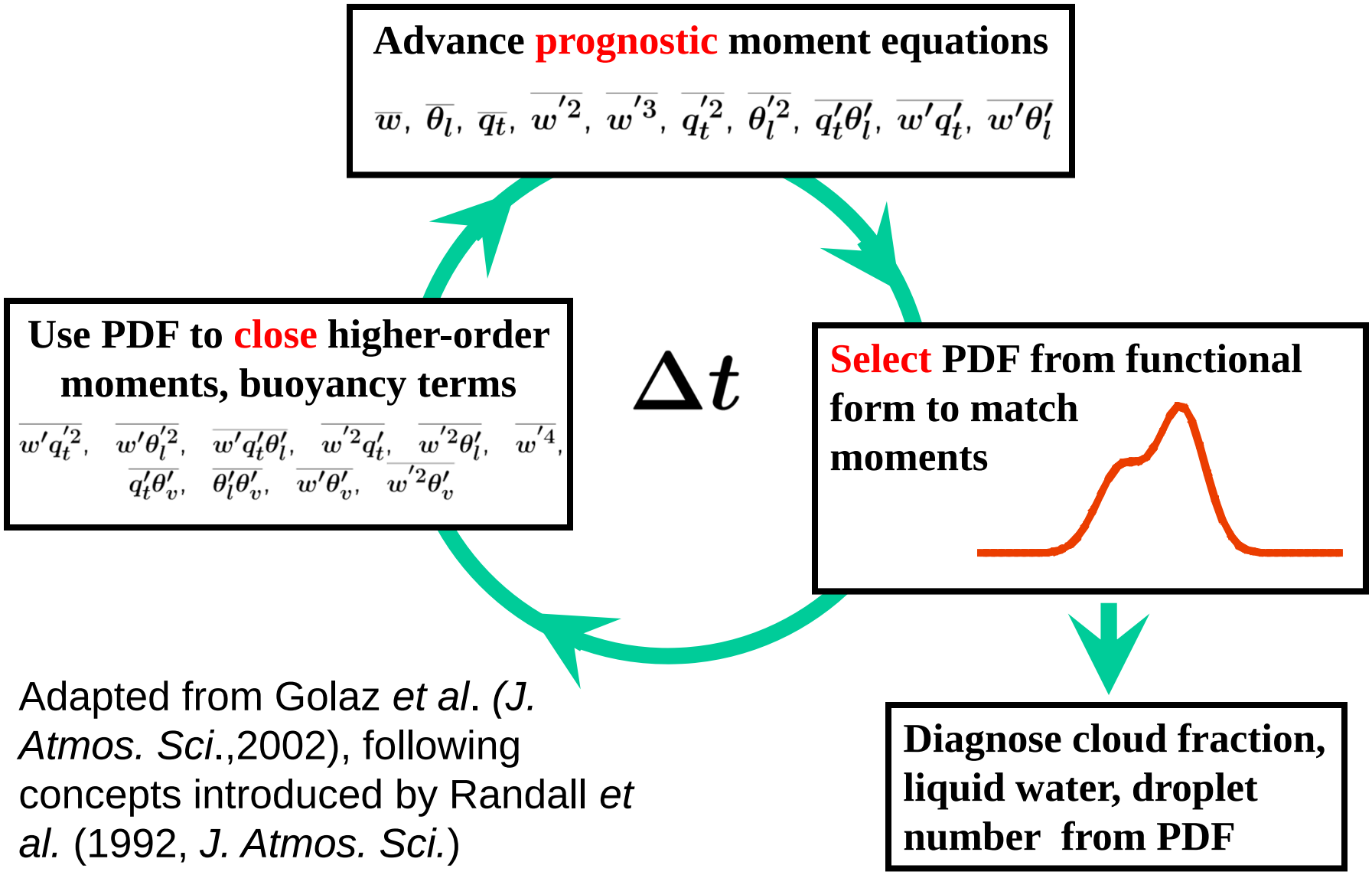
Motivation

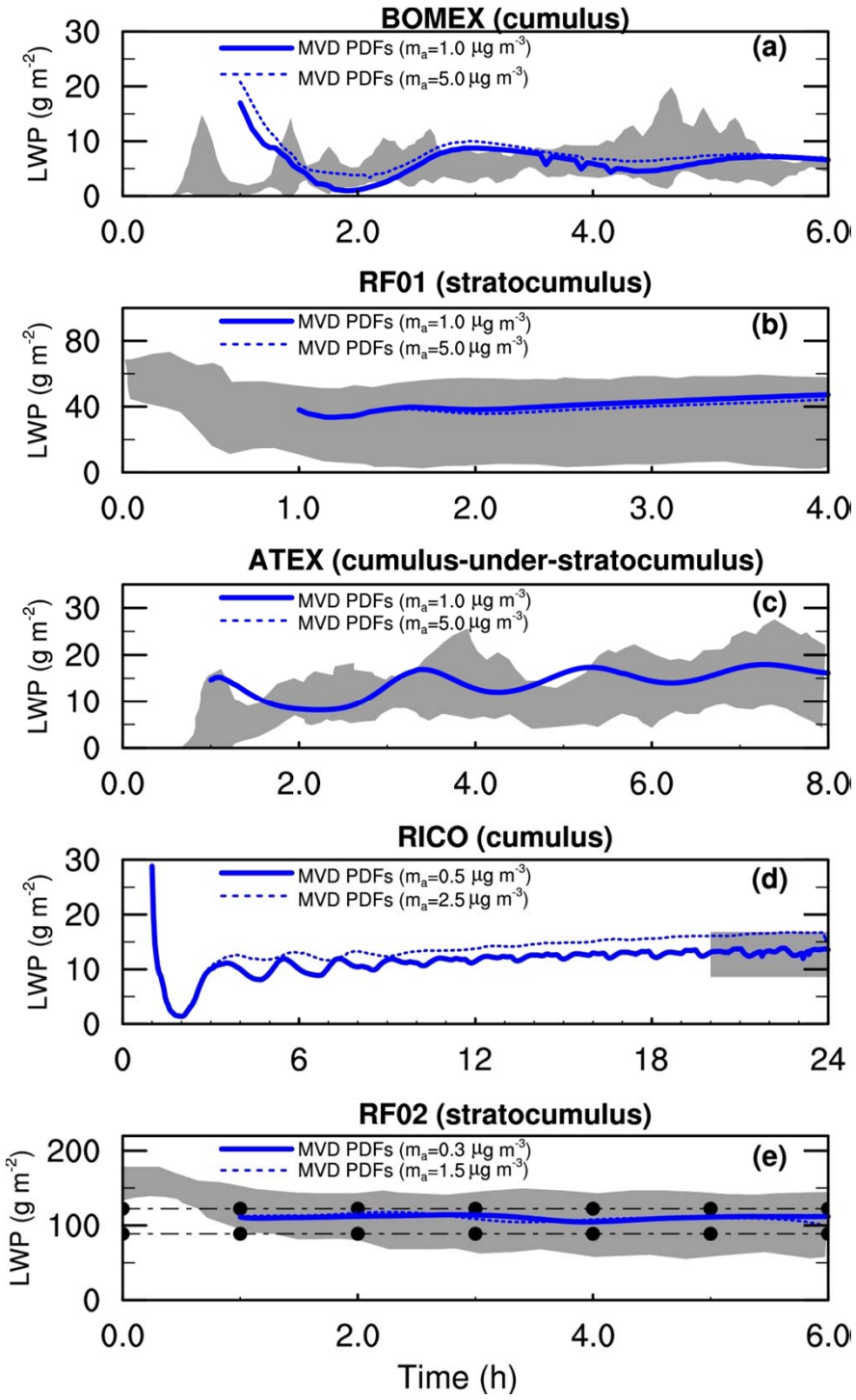
- Use multi-variate probability density functions with dynamics (MVD PDFs) to parameterize boundary layers and clouds
- ARM GCSS shallow cumulus SCM test behaves differently from SCM tests with ARM analysis
- Moisture profile in ARM analysis differs appreciably from GCSS analysis, which is closer to single sounding
- Does horizontal scale of the analysis driving the SCM influence the success of the MVD PDFs? How well does LES perform? Limits to parameterization?

Building a PDF-based parameterization



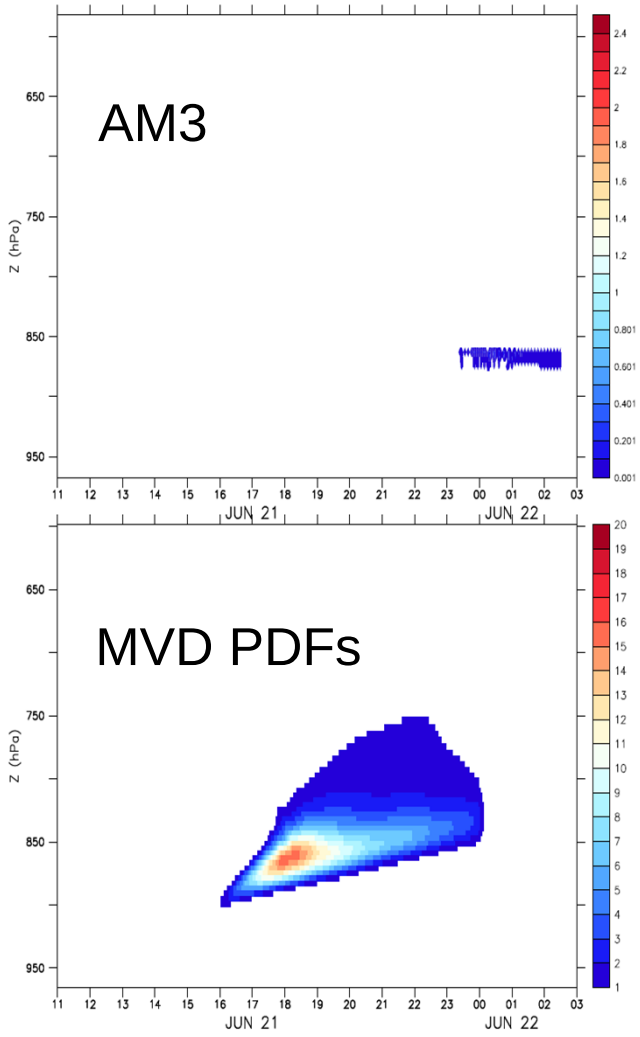
Adapted from Golaz *et al*. *(J. Atmos. Sci*.,2002), following concepts introduced by Randall *et al.* (1992, *J. Atmos. Sci.*)

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

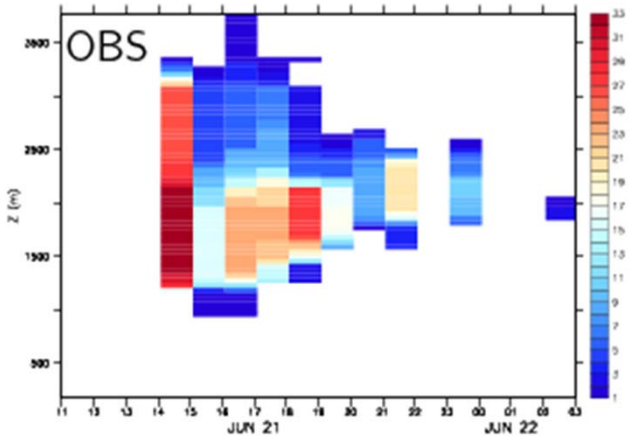


from *Guo et al.* (2010, *Geosci. Model Dev.*)

GCSS ARM case

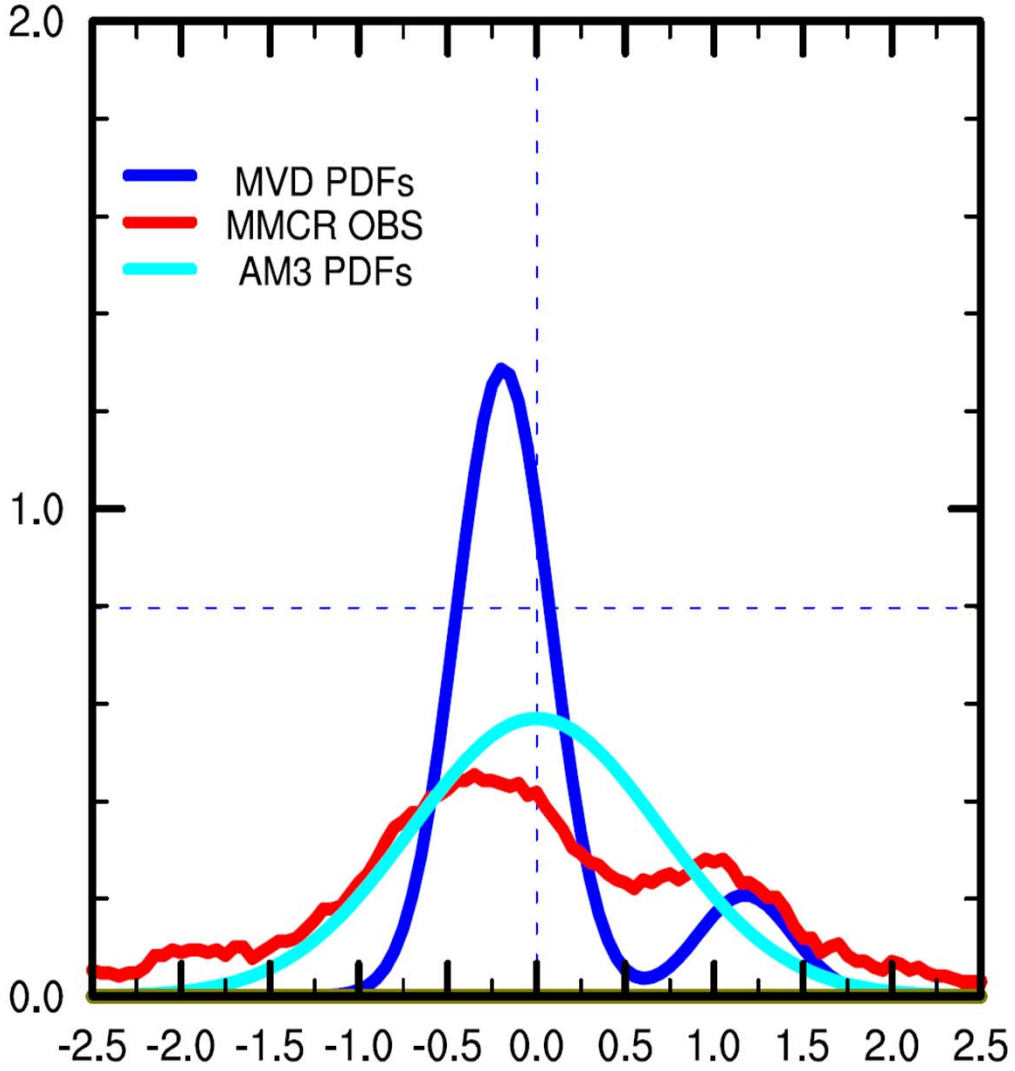


Cloud fraction



Vertical motion PDF comparison

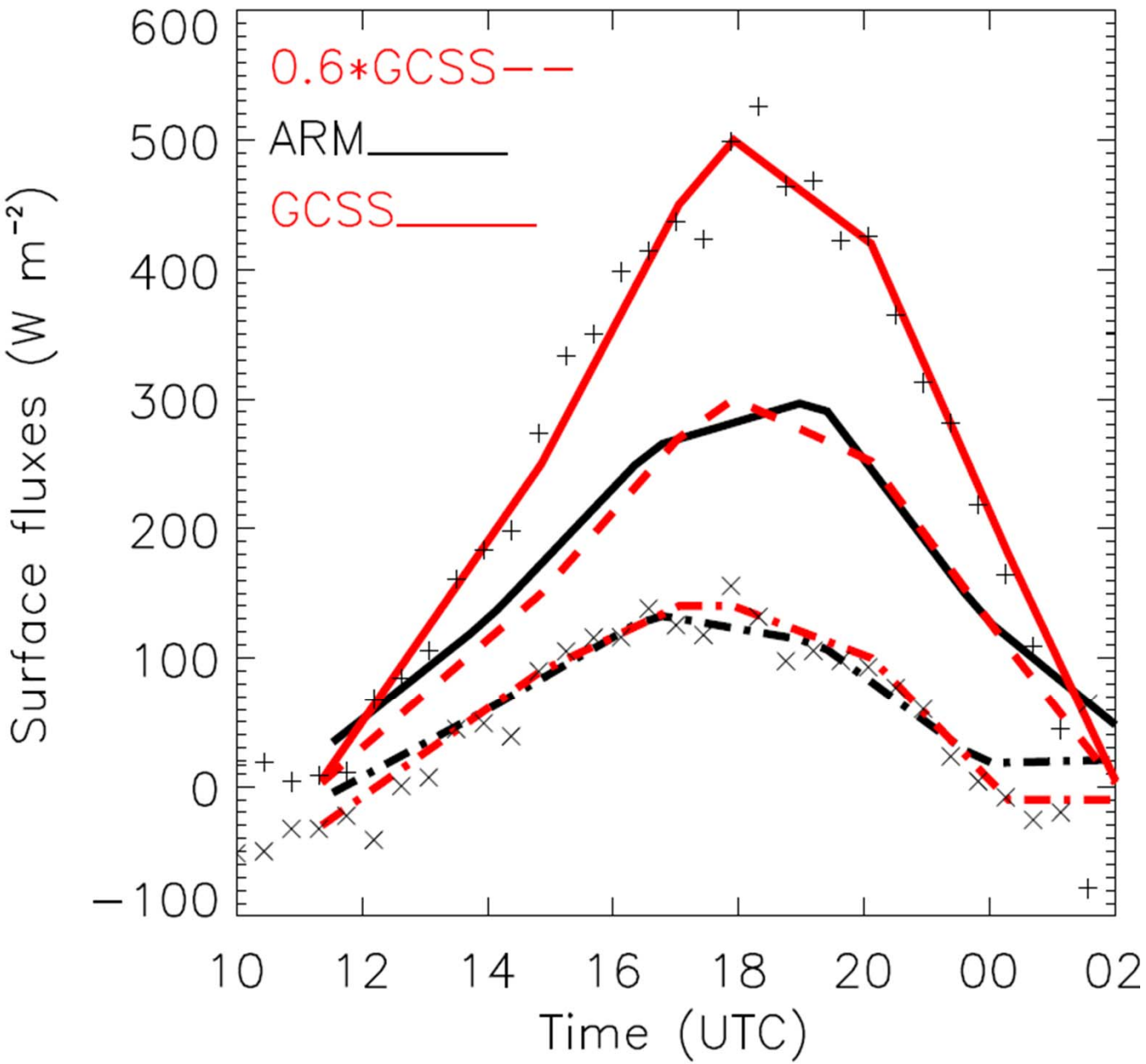
ARM GCSS
21 June 97
Brown *et al.*
(*QJRMS*,
2002)



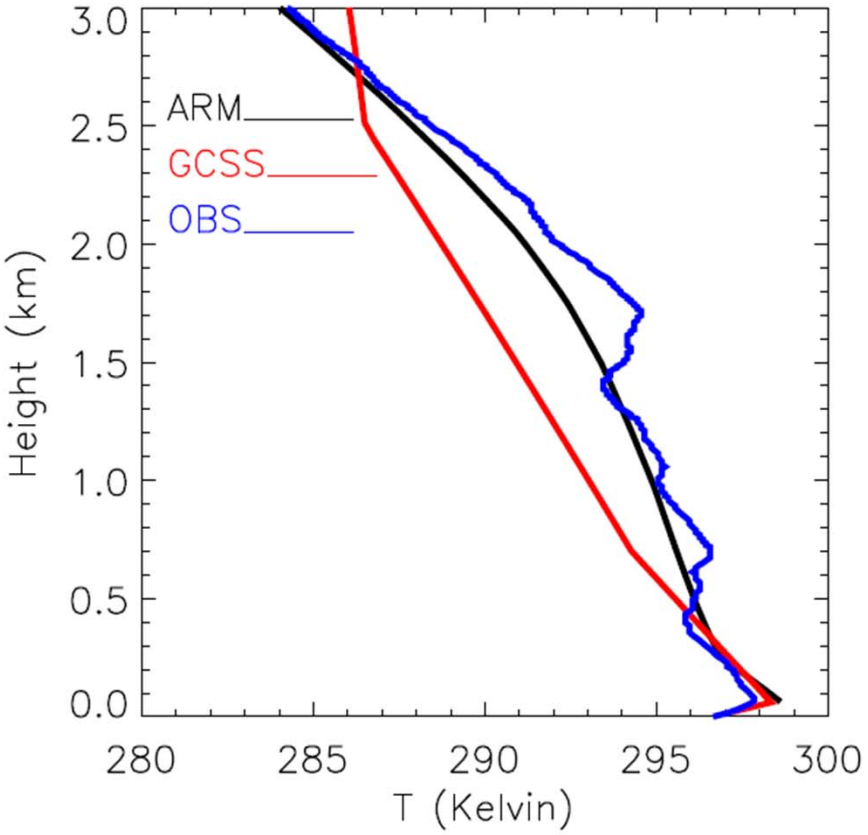
Surface latent and sensible heat flux from ARM variational analysis and GCSS forcing

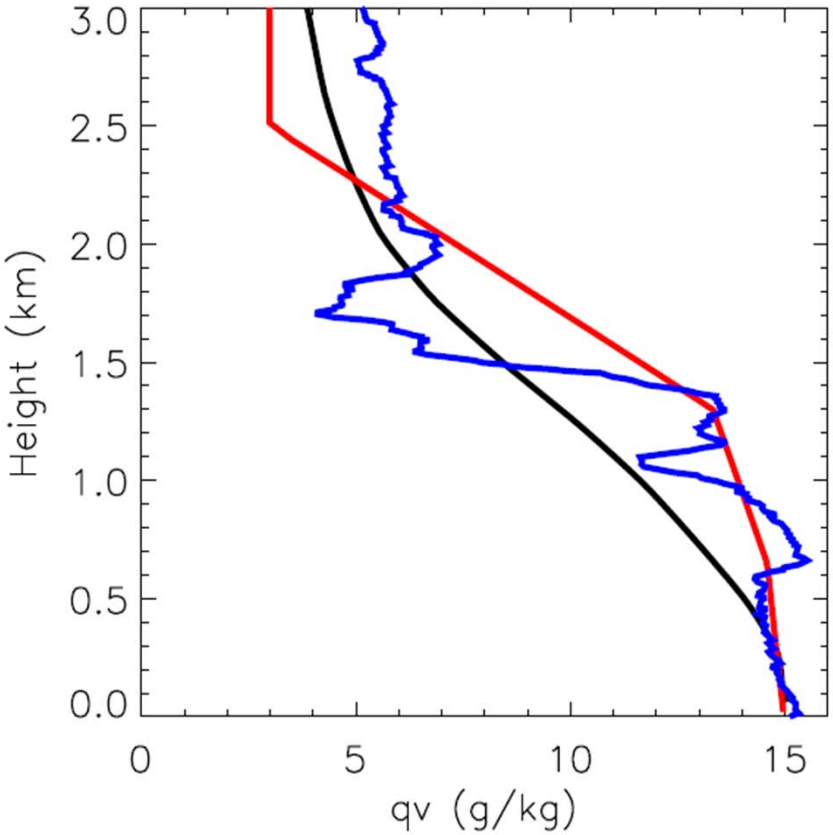
LH: solid line
SH: dashed lines

Symbols are fluxes at the central facility.



Initial T and Qv



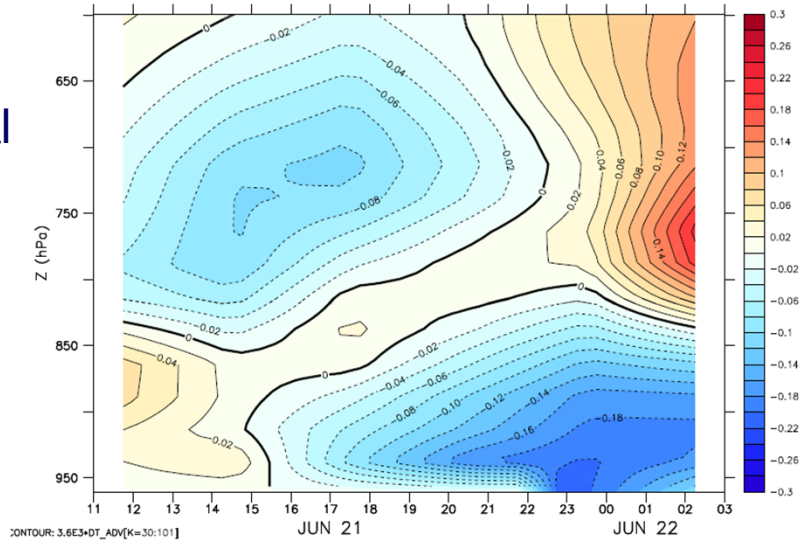


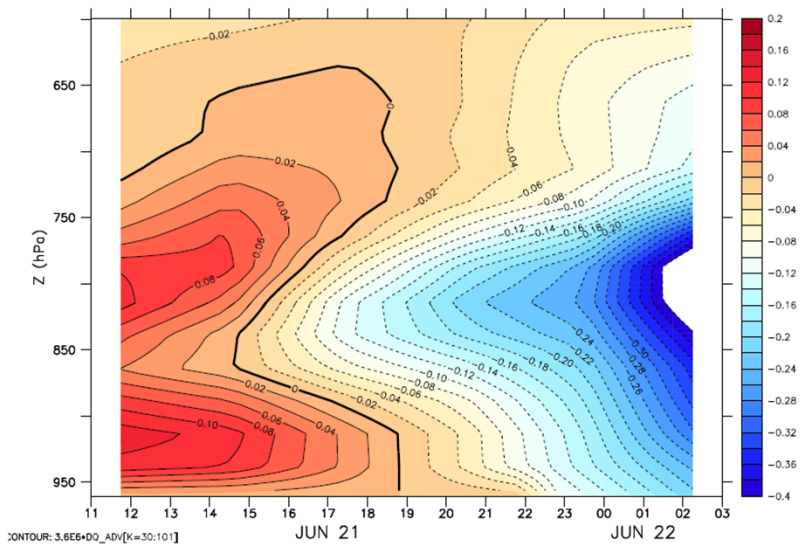
T adv

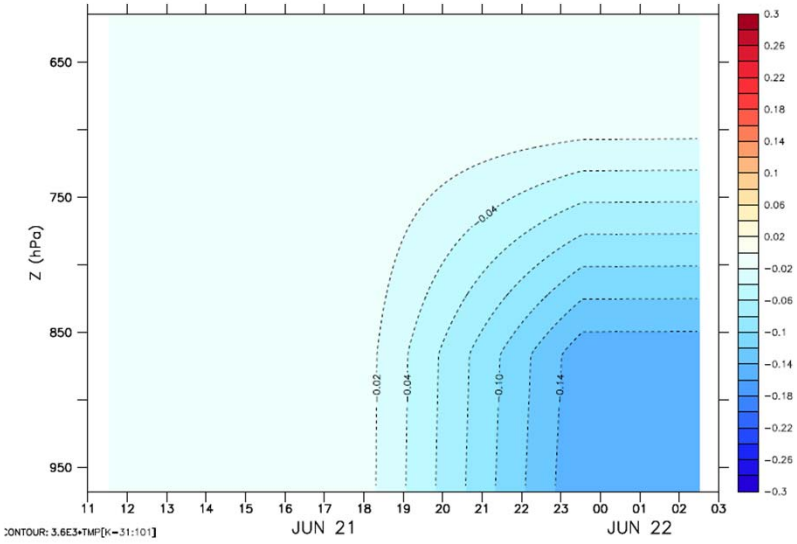
qv adv

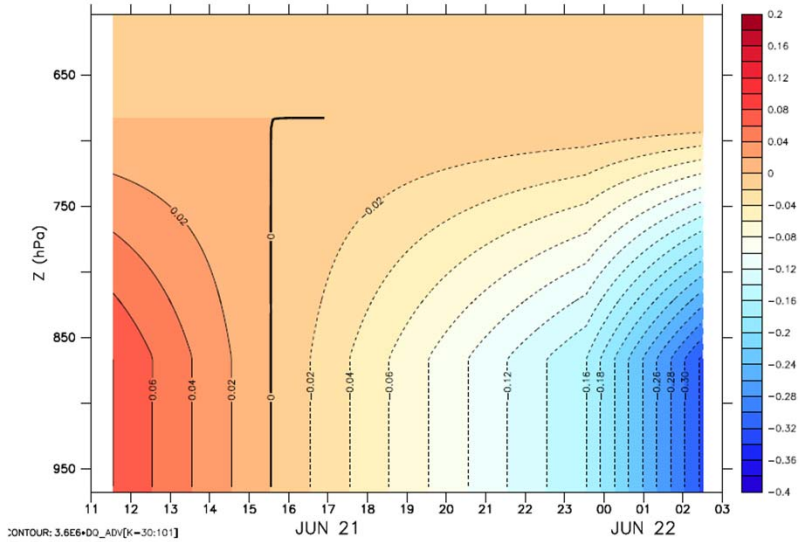
ARM Variational

GCSS



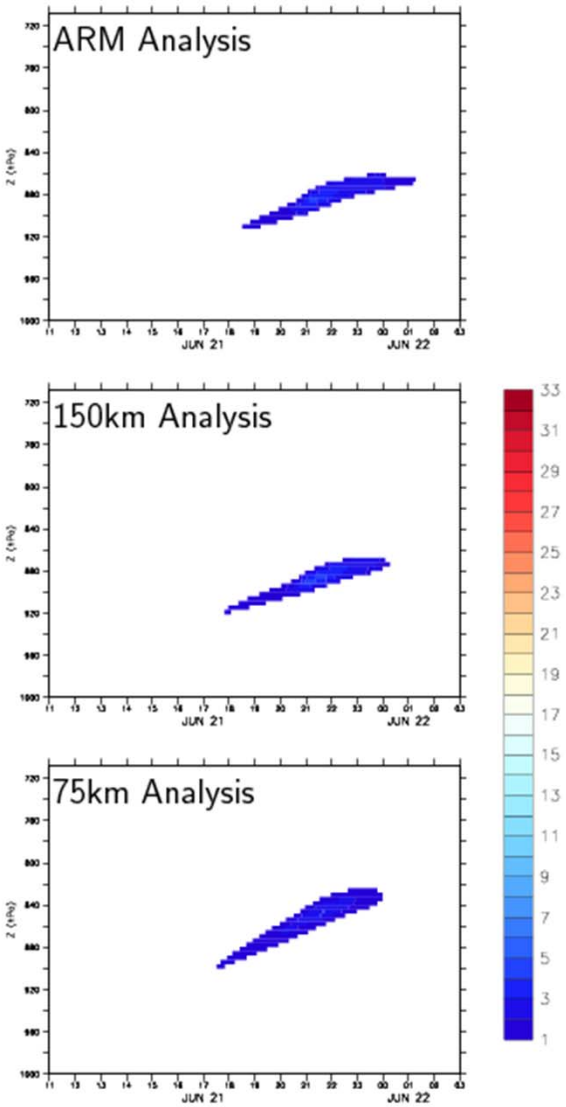


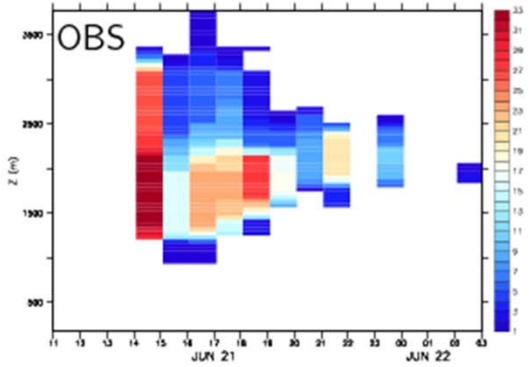




- MVD PDFs fail to produce cloud using ARM (300 km) variational analysis
- GCSS and ARM analysis differ in initial *T* and *q* soundings, surface fluxes, and advection of *T* and *q*
- Analyze dependence of MVD PDFs on initial conditions and scale of analysis
- Compare with LES

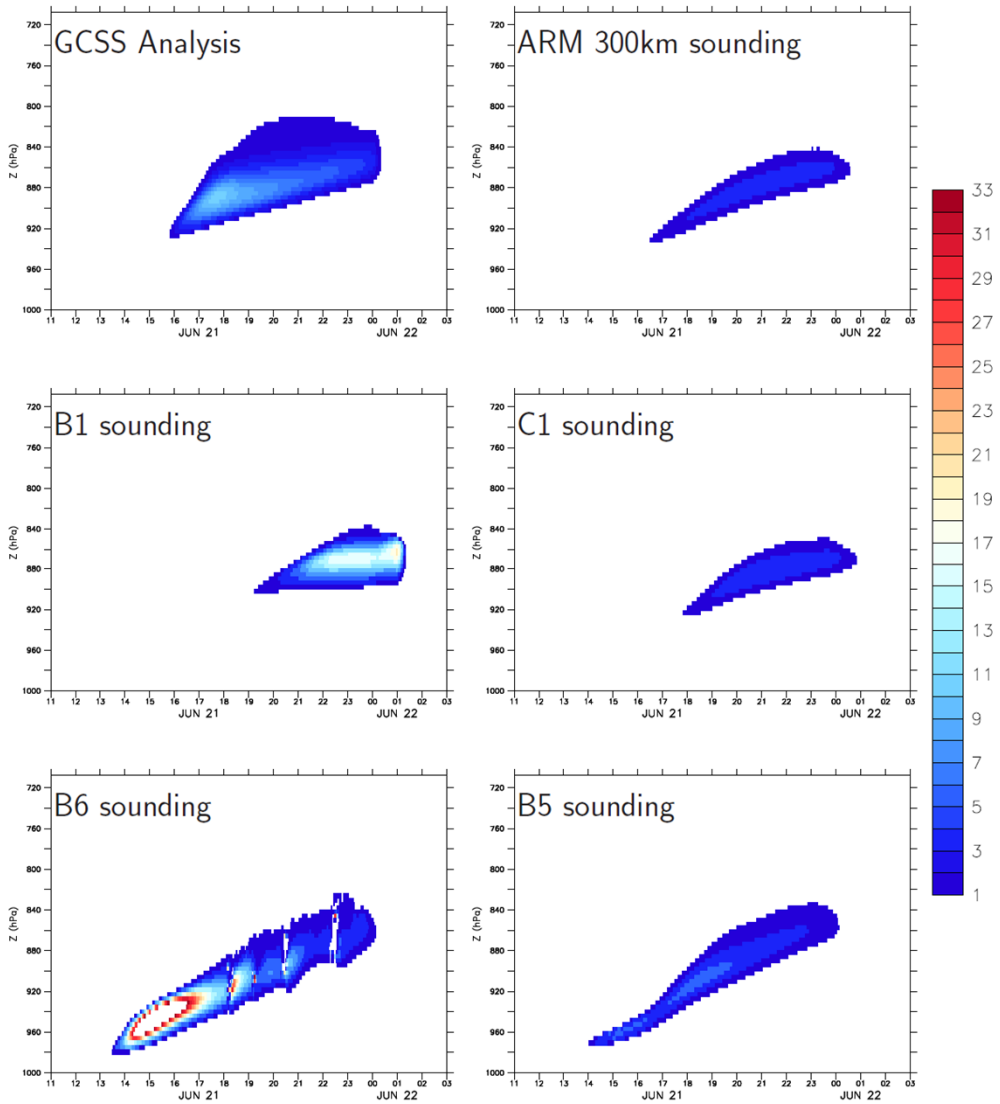
Scale of ARM analysis has little effect on MVD PDF simulations. Simulated cloud fractions well below observed.

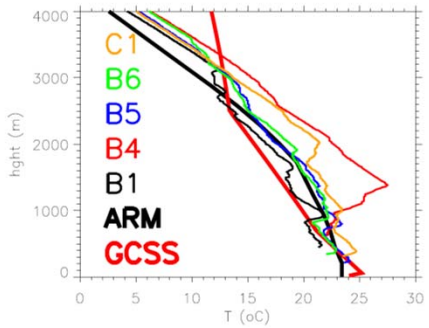


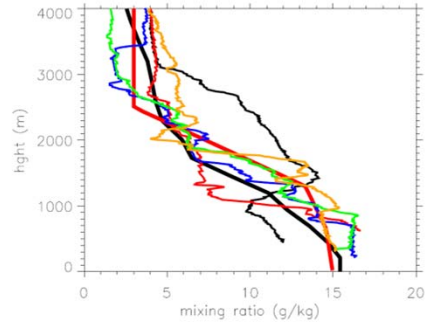


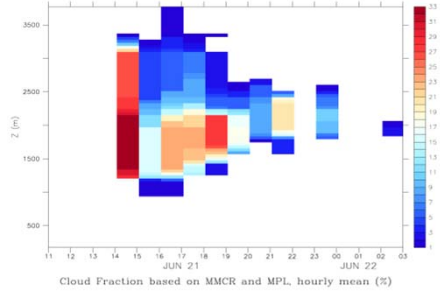
MVD PDFs have been “tuned” by restricting characteristics of bi-normals, slightly increasing cloud fraction when ARM analysis is used.

MVD PDF simulations depend strongly on initial conditions. GCSS sounding moister and less stable (below 2km) than ARM sounding.



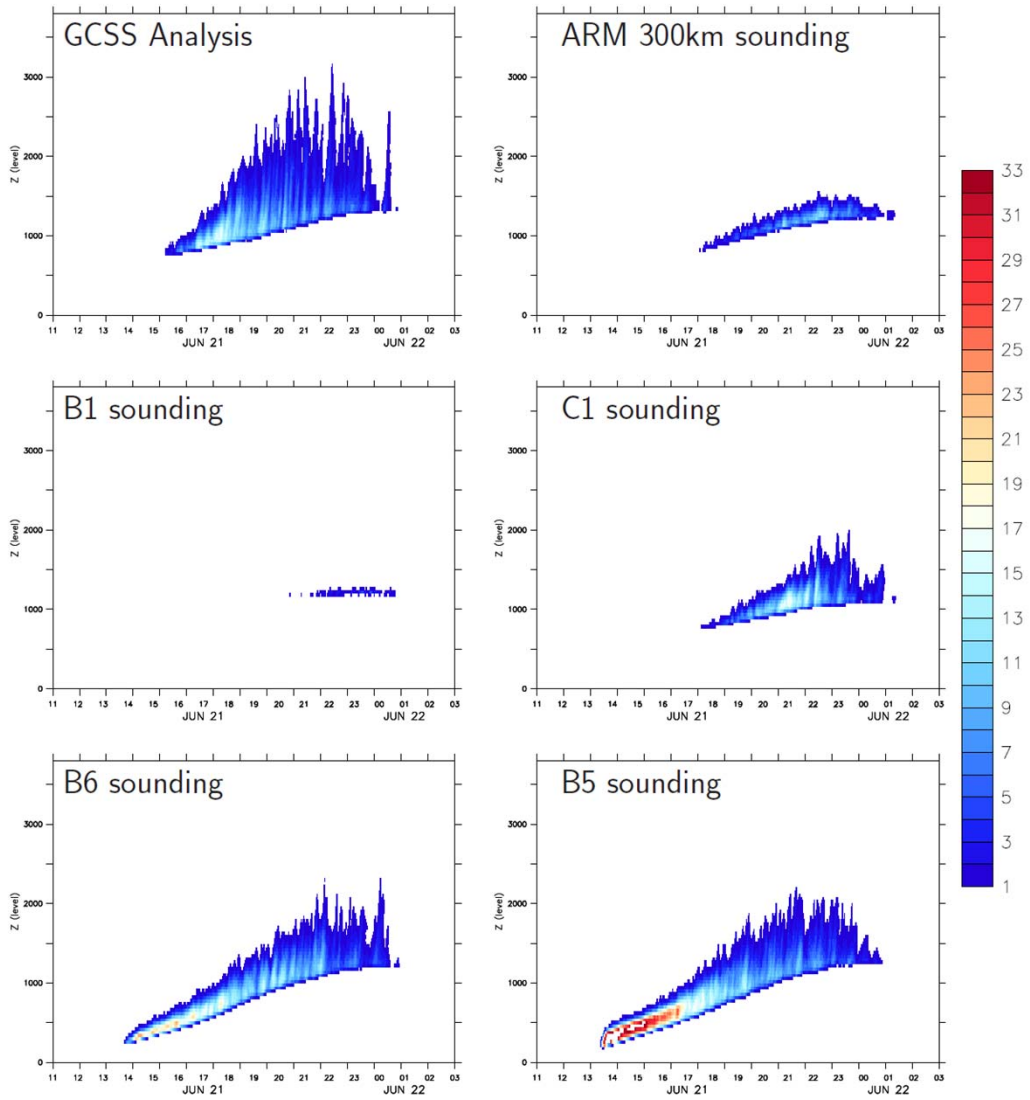


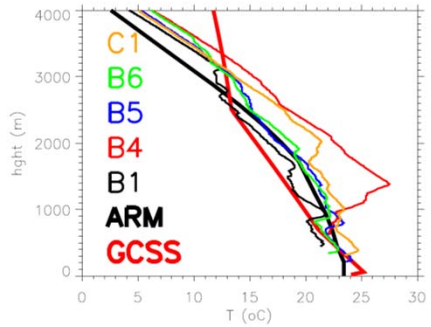


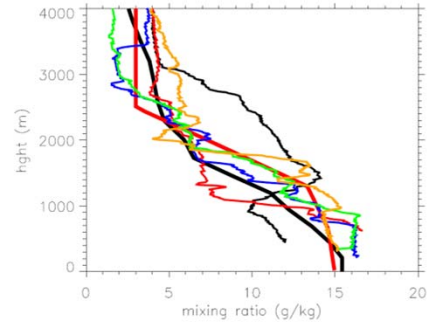


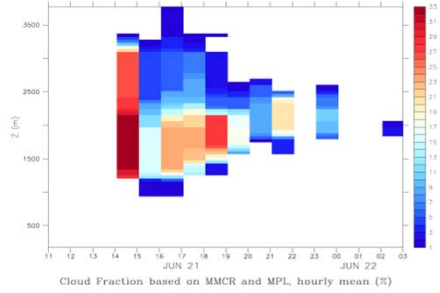
GCSS forcing in all simulations

LES (Golaz *et al.*, 2005, *Boundary-Layer Meteorol.*) also strongly dependent on initial sounding and exhibit many common characteristics with MVD PDFs.









GCSS forcing in all simulations

Summary

- MVD PDFs successfully simulate cloud fraction, water path, and droplet numbers for Sc and shallow Cu GCSS cases
- MVD PDF simulations are not as successful using ARM-scale analysis, with strong dependence on initial conditions
- LES also depends on initial conditions, with cloud amounts compared to MVD PDFs sounding-dependent
- Results suggest limits on parameterization at coarser resolutions

GCSS ARM case

Cloud fraction