Activities of the ARM Cloud Modeling Working Group

Stephen A. Klein

Lawrence Livermore National Laboratory

CMWG Steering Committee: Larry Berg, Chris Bretherton, Anthony Del Genio, Ann Fridlind, Christian Jakob, and Minghua Zhang

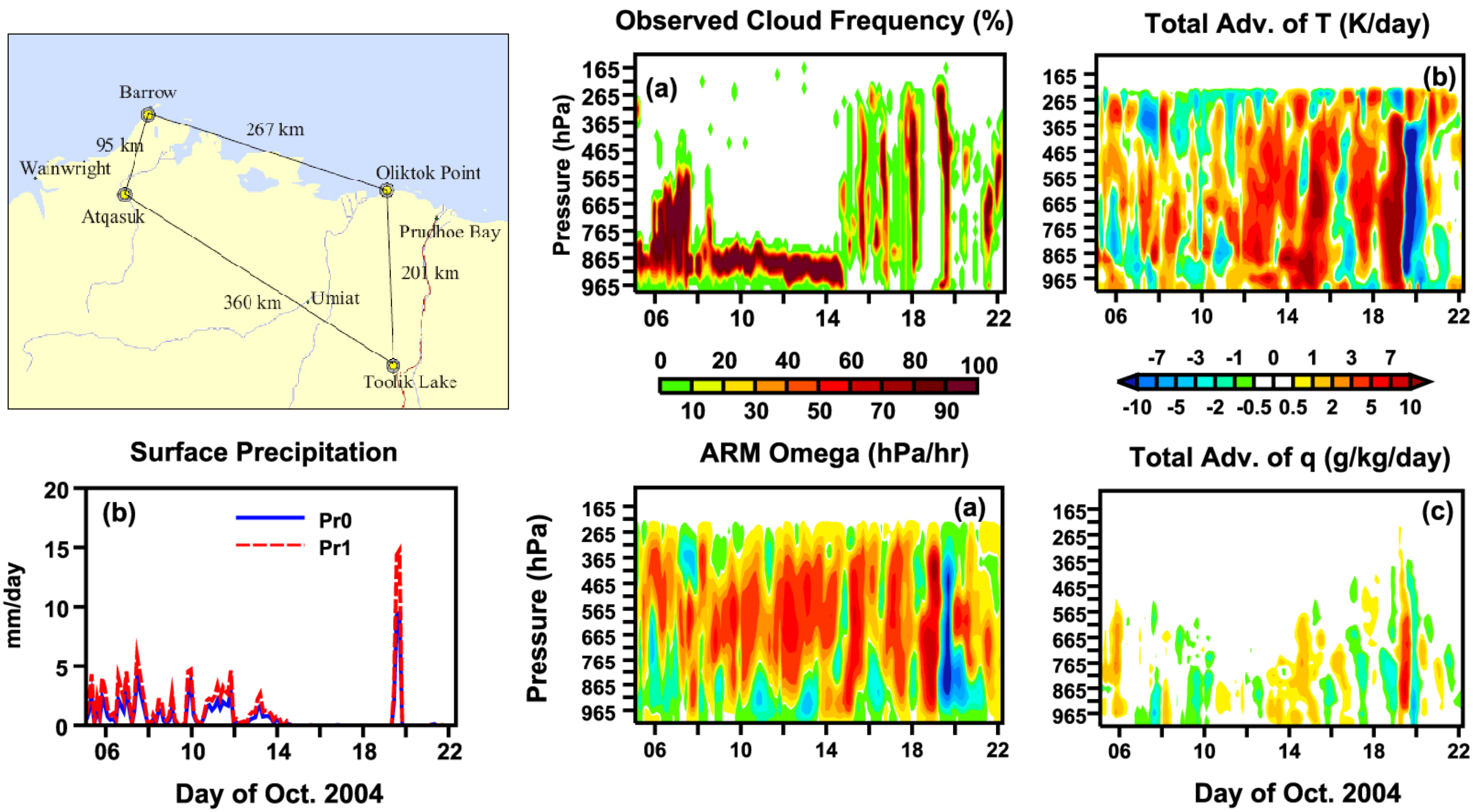
17th ARM Science Team Meeting, Monterey, California, March 27, 2007

Outline

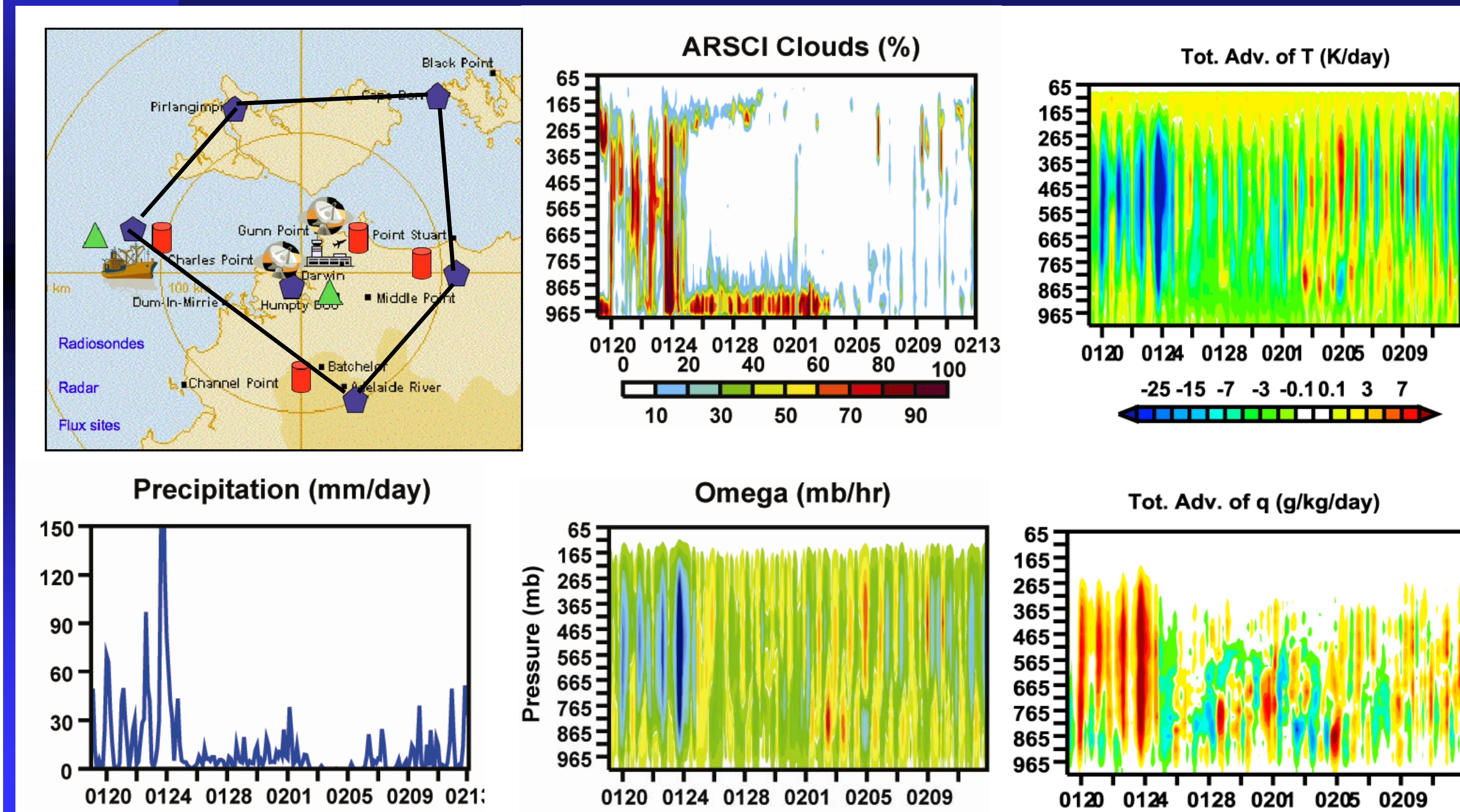
- New Analysis Datasets
- Selected M-PACE Results
- Statistical Assessment of Models with ARM data
- Three Items
- Future work

New Analysis Datasets

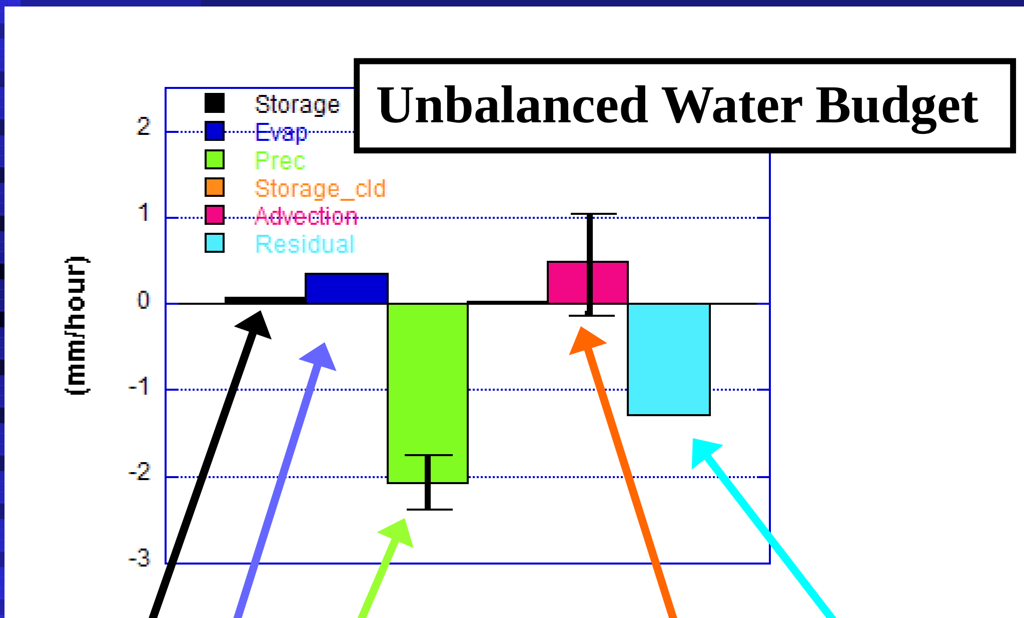
M-PACE (S. Xie et al.)



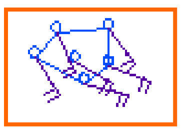
TWP-ICE (S. Xie, T. Hume et al.)

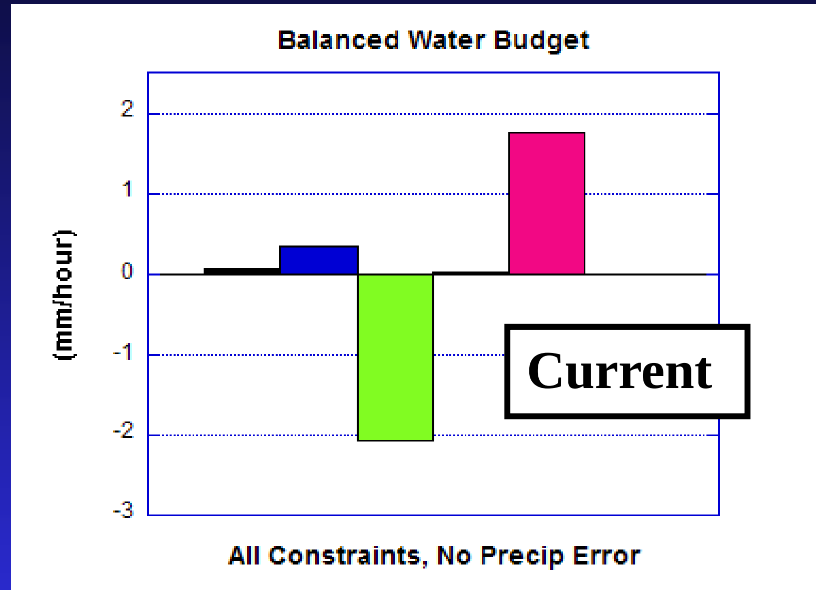


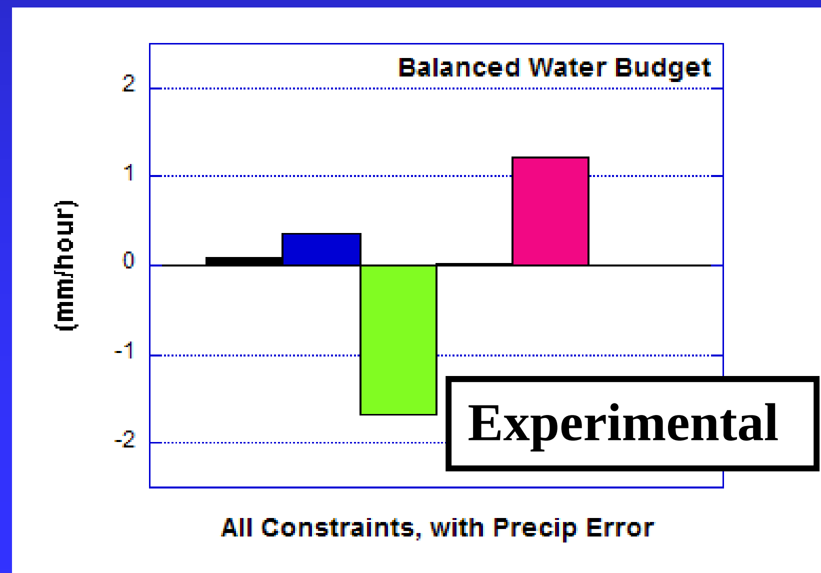
Extensions to Analysis Techniques (M. Zhang)



$$\frac{\partial < q >}{\partial t} = E - Prec - \frac{\partial < q_c >}{\partial t} - < \nabla \times \vec{V} q > - Residual$$

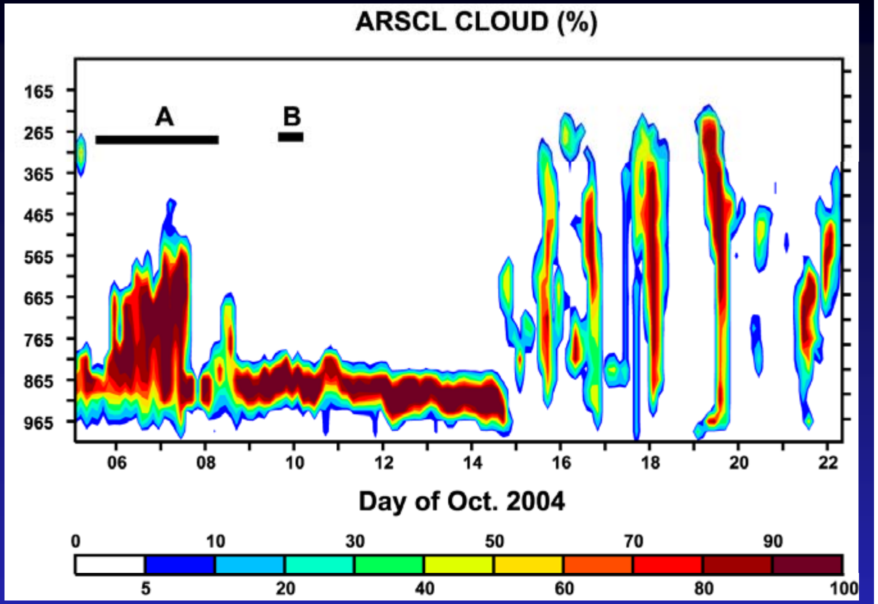




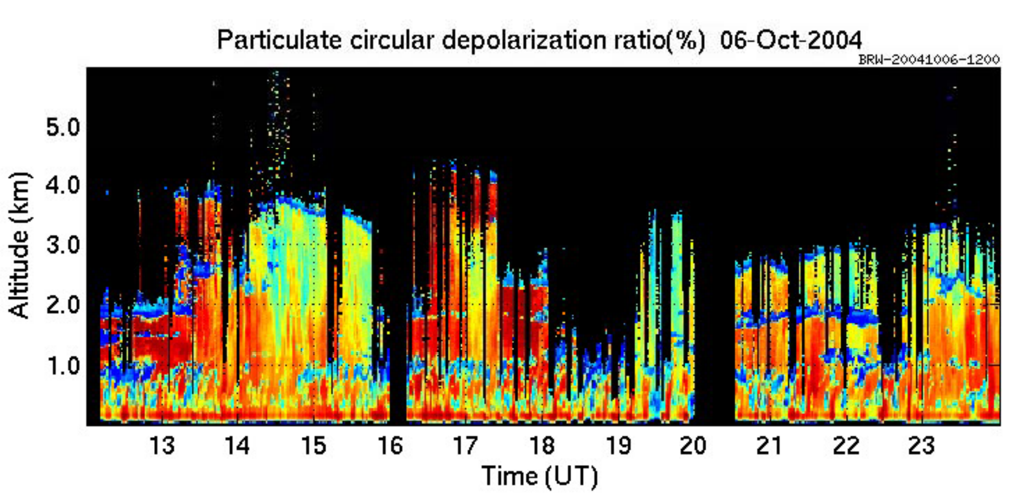


Selected M-PACE Results

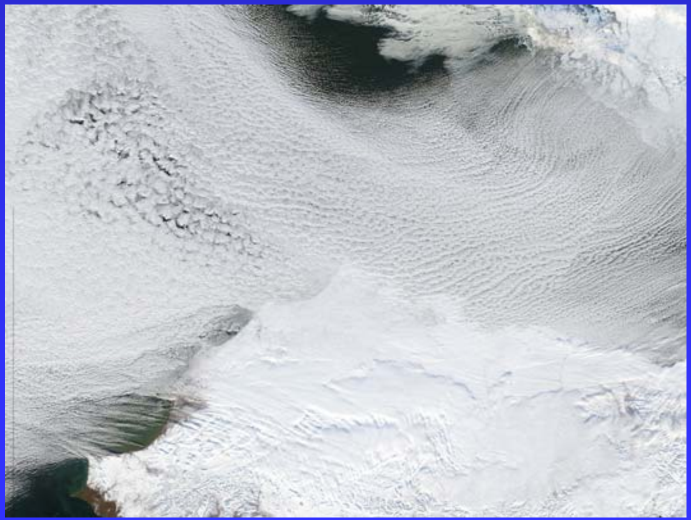
M-PACE Model Intercomparison



Period A

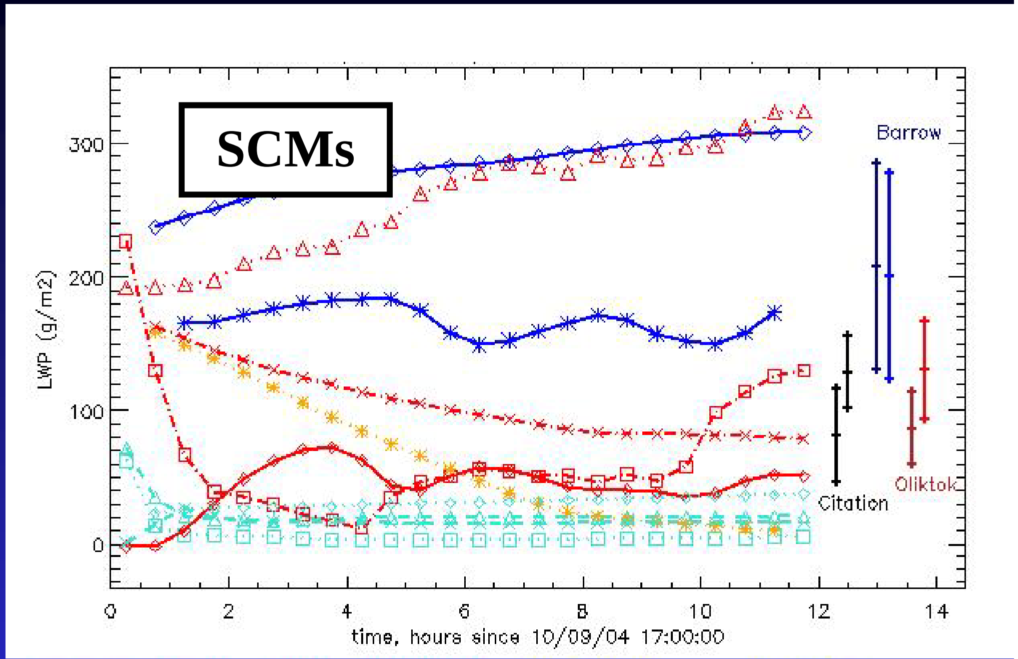


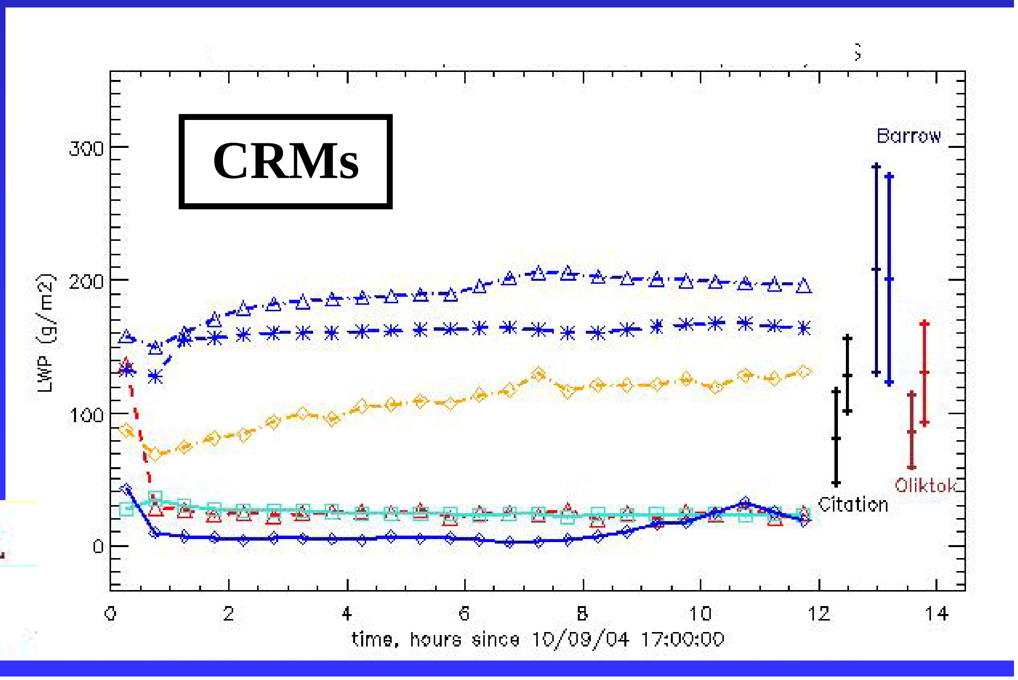
Period B



Liquid Water Path

- CRMs are not superior to SCMs
- Aerosol-Cloud Microphysics (first) and turbulent transport (second) are more important





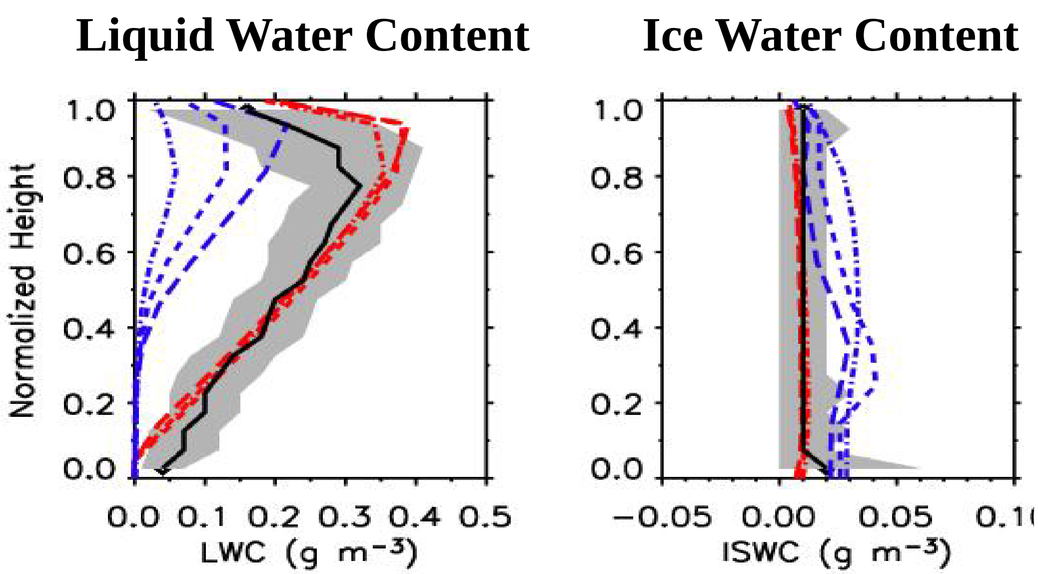
Single moment, T-part. Single m., non-T-part.

Double moment Bin resolved

Sensitivity to Aerosol-Cloud Microphysics for Arctic Clouds

UCLA LaRC Cloud Resolving Model

(Y. Luo et al.)



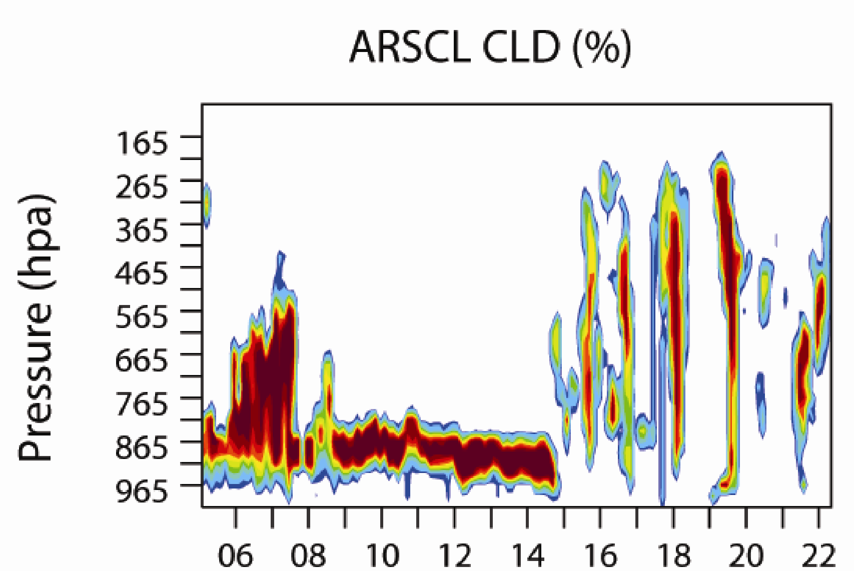
Aircraft Obs

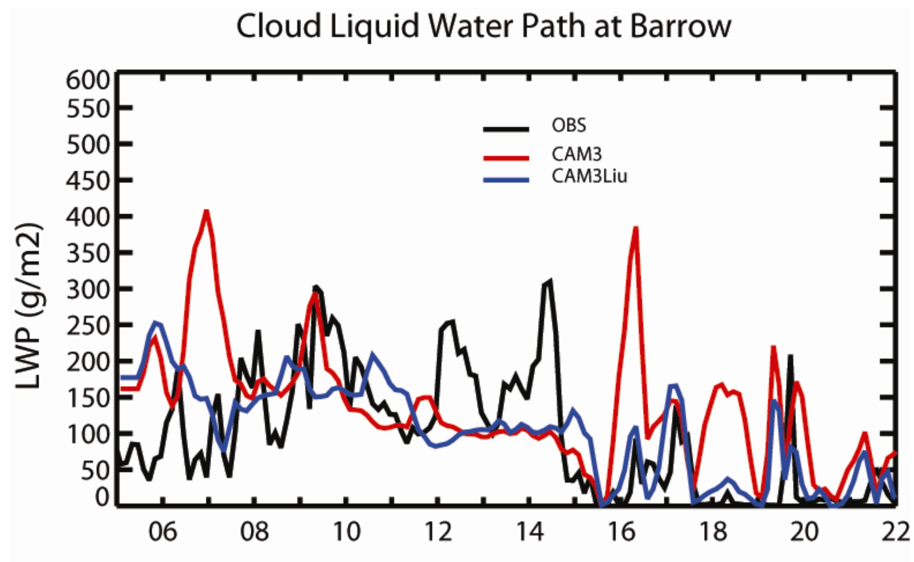
One Moment (Modified Lin et al. 1983)

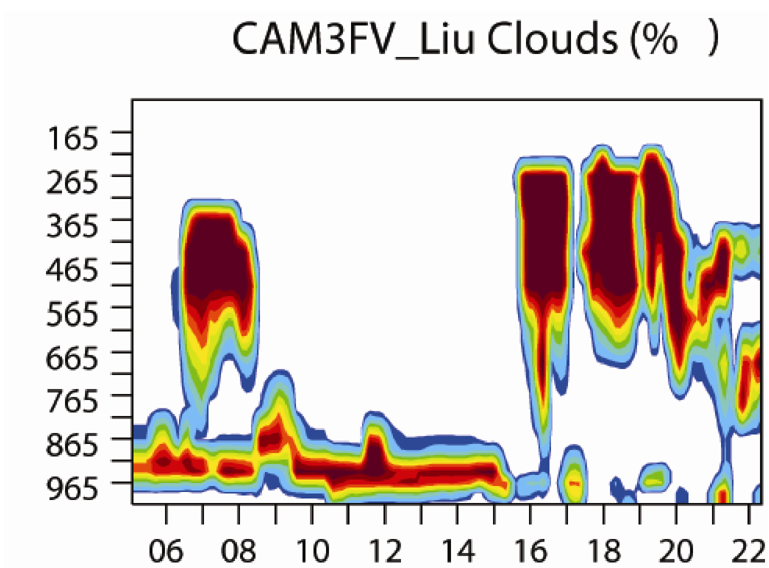
Two Moment (Morrison et al. 2005)

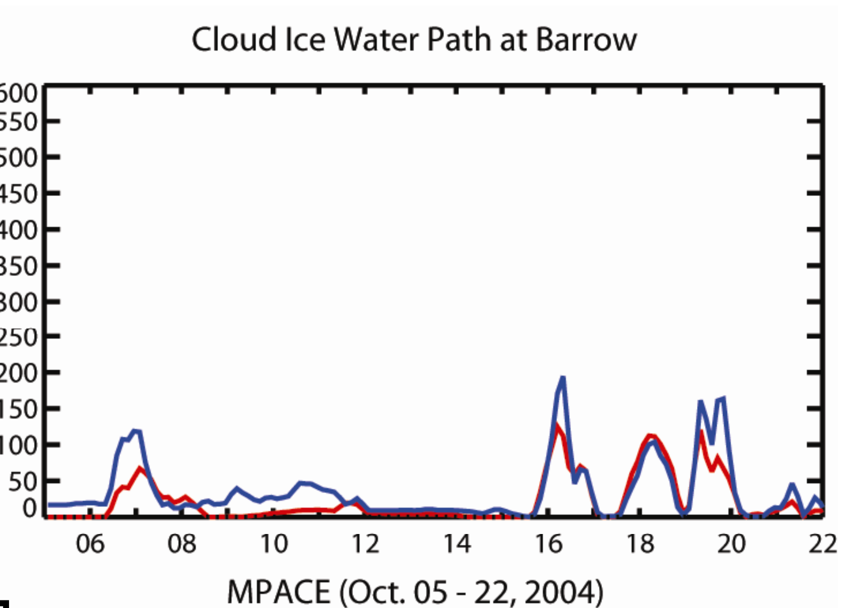
Sensitivity to Aerosol-Cloud Microphysics for Arctic Clouds

- X. Liu et al. insert a double moment microphysics parameterization for cloud ice into the NCAR CAM climate model
- This replaces the single moment temperature partitioning of cloud condensate
- This has been tested in SCM and CAPT integrations of the NCAR CAM





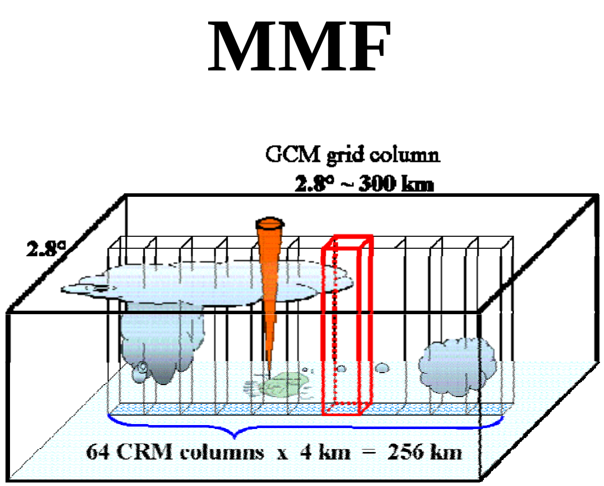


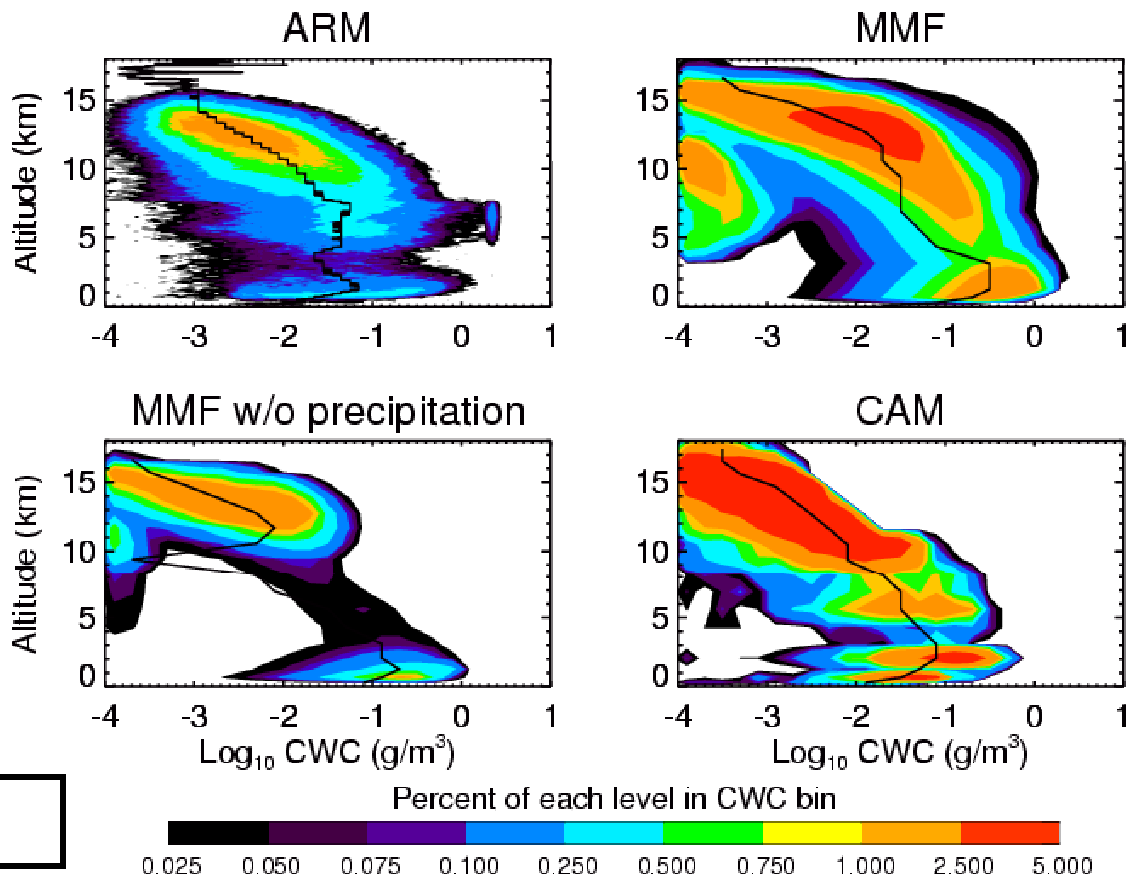


X. Liu et al. and the CAPT team

Statistical Assessment of Models with ARM Data

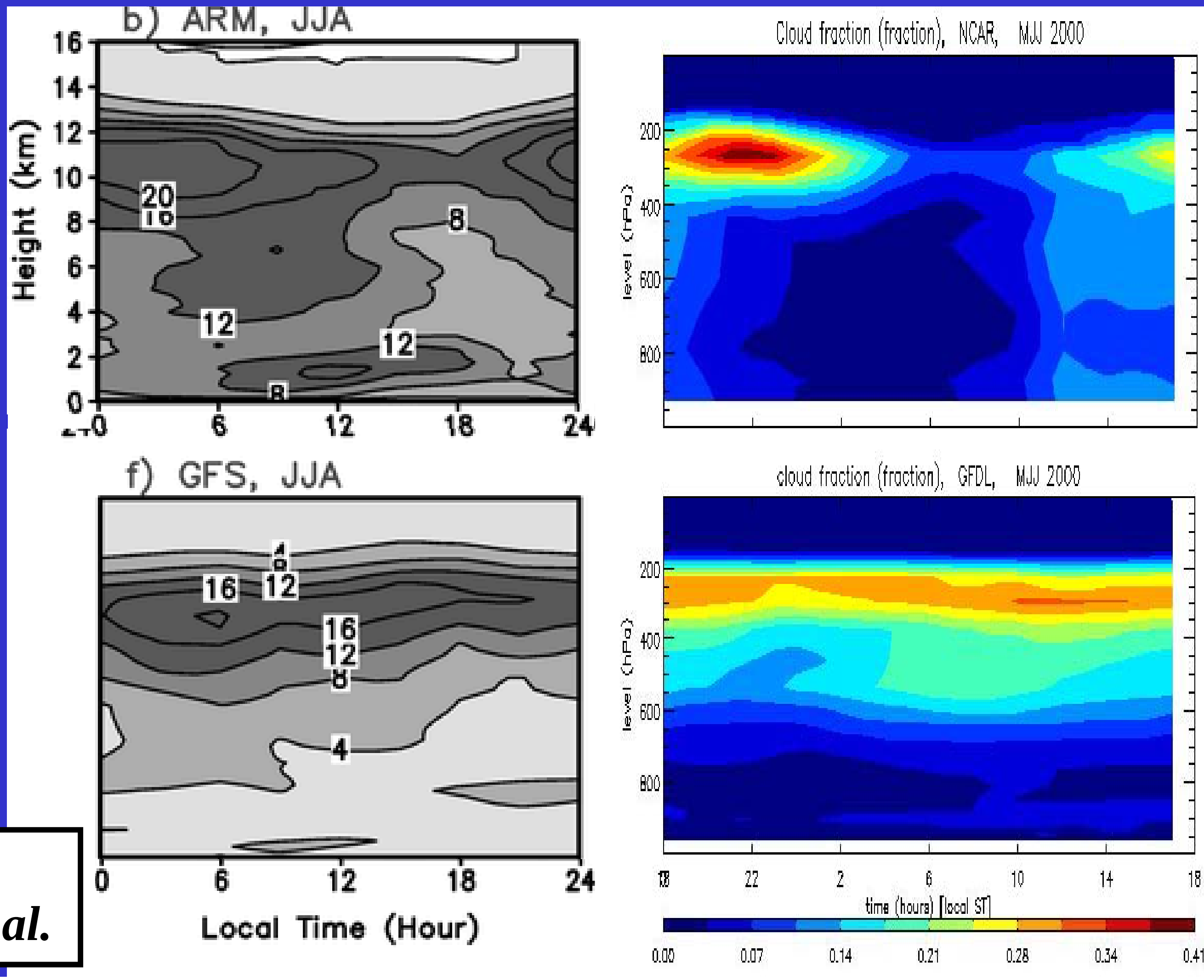
Manus Condensate: ARM vs. MMF and CAM





S. McFarlane et al.

SGP Diurnal Cycle of Cloudiness: ARM vs. Large-scale Models



ARM

NCAR

NCEP

GFDL

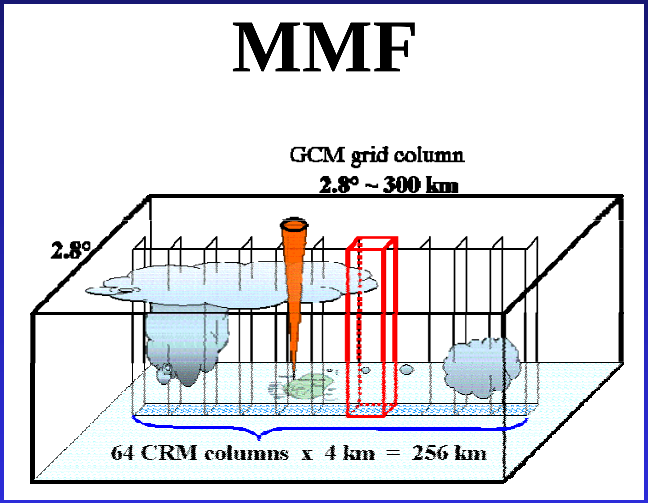
F. Yang

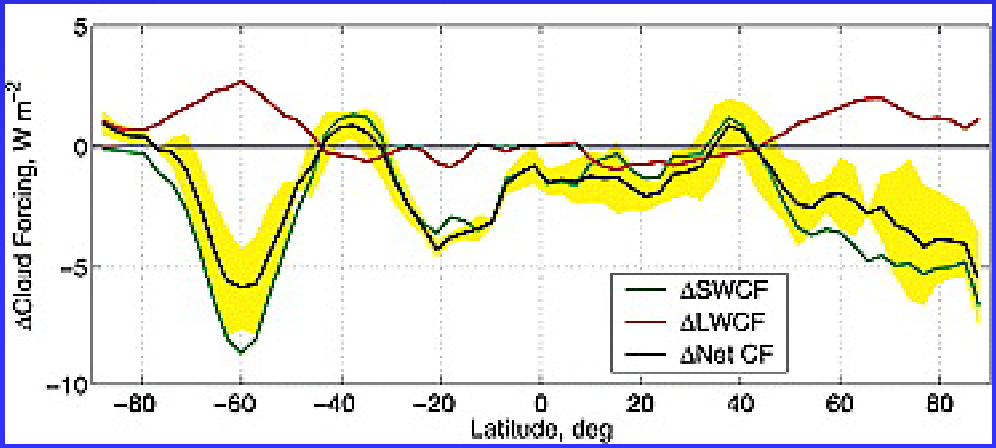
R. McCoy et al.

Three Items…

Climate sensitivity with MMF (M. Wyant et al.)

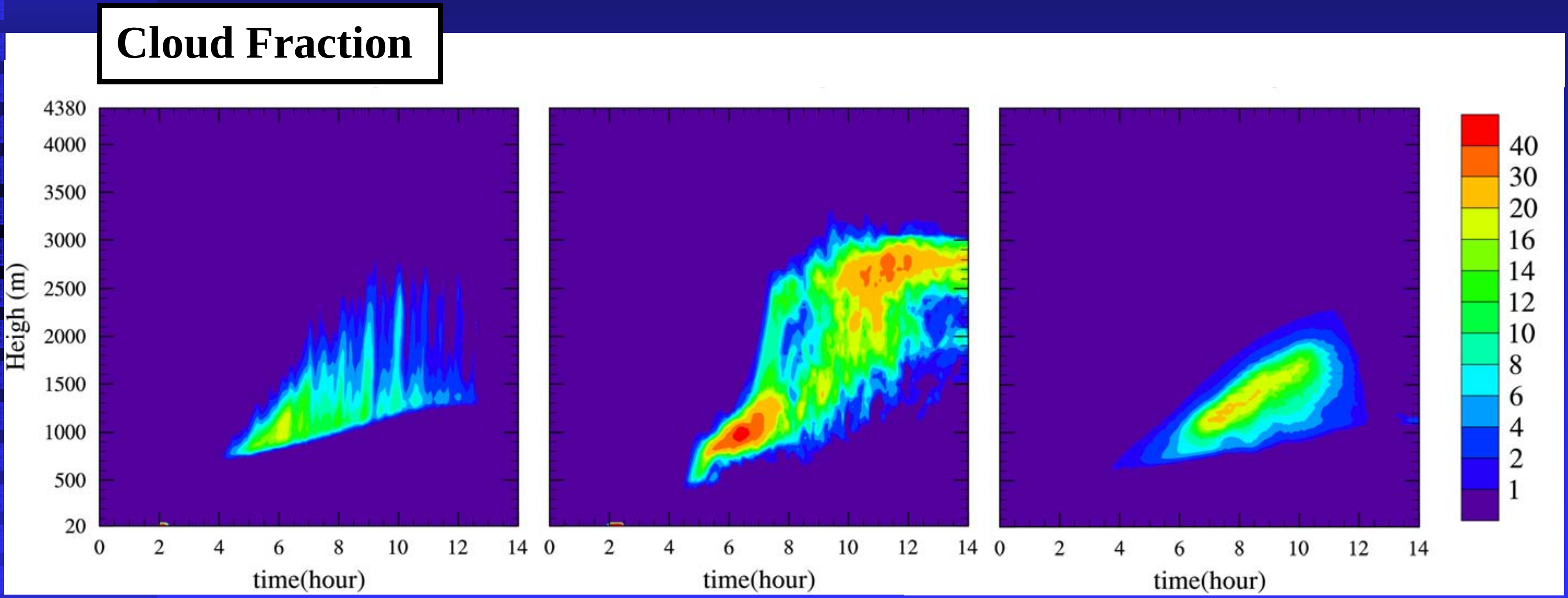
- A ‘Cess’ perturbation experiment was performed whereby the sea-surface temperature was raised 2K
- Water vapor feedback confirmed
- Cloud feedback surprisingly negative





Improving MMF shallow clouds (A. Cheng et al.)

ARM Shallow Cumulus



3D LES @ 100 m

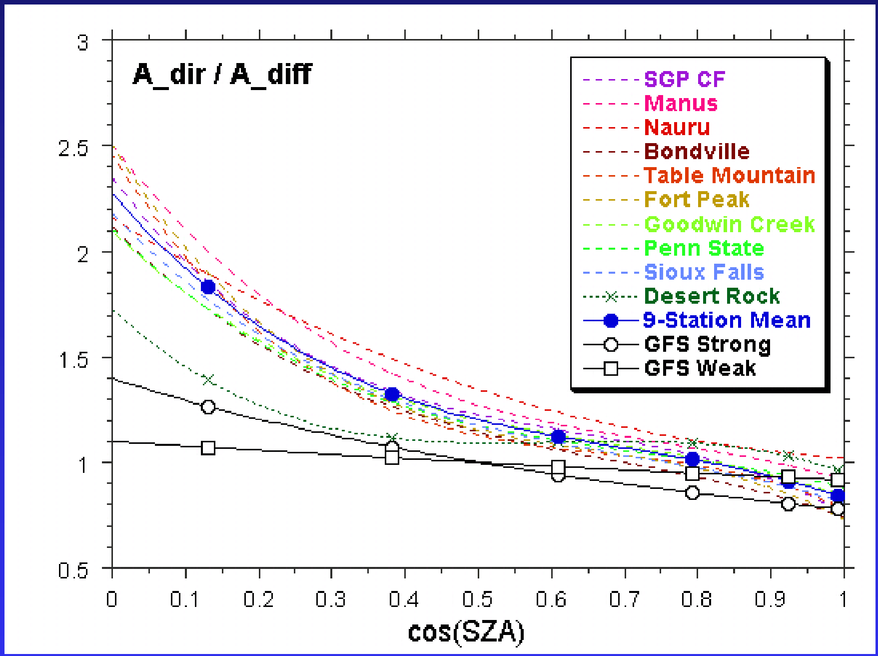
2D @ 4 km

2D @ 4 km w/ TOC

Third-Order Closure

ARM Fellows (F. Yang – NCEP)

- Direct beam albedo was underestimated in comparison to ARM data
- Found that the normalized direct albedo could be parameterized as a function of the solar zenith angle (SZA) and was independent of the surface type



- Parameterization is currently being incorporated into the GFS model

Future Work

‘Simulators’

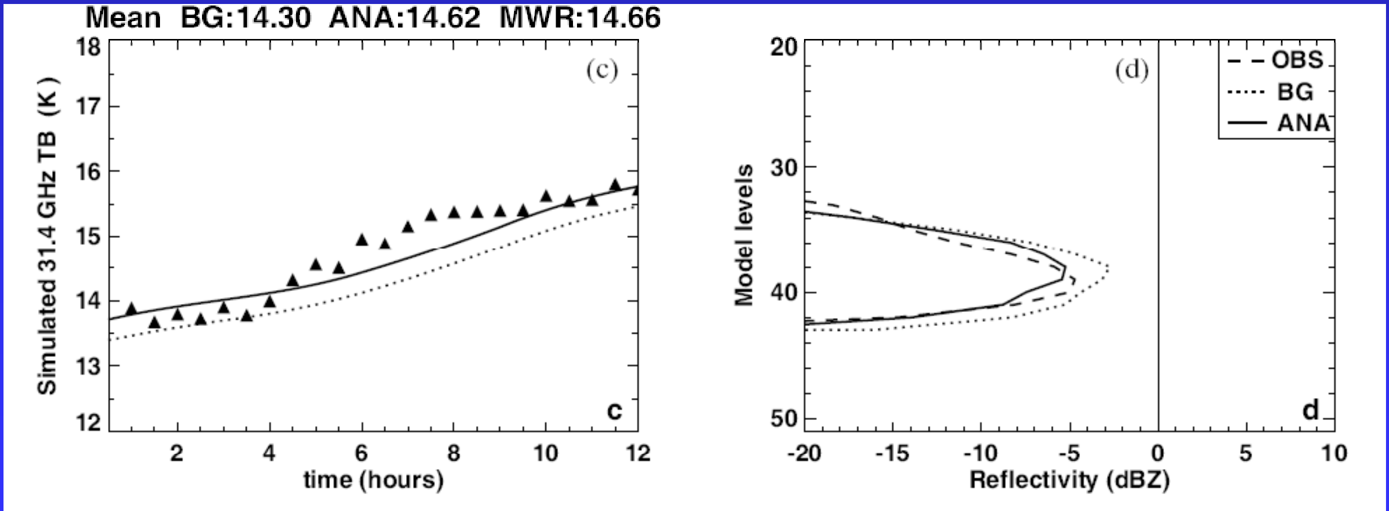
Q. J. R. Meteorol. Soc. (2006), **132**, pp. 1325–1347 doi: 10.1256/qj.05.24

Experimental 2D-Var assimilation of ARM cloud and precipitation observations

By PHILIPPE LOPEZ*, ANGELA BENEDETTI, PETER BAUER, MARTA JANISKOVÁ and MARTIN KÖHLER
European Centre for Medium-Range Weather Forecasts, Reading, UK

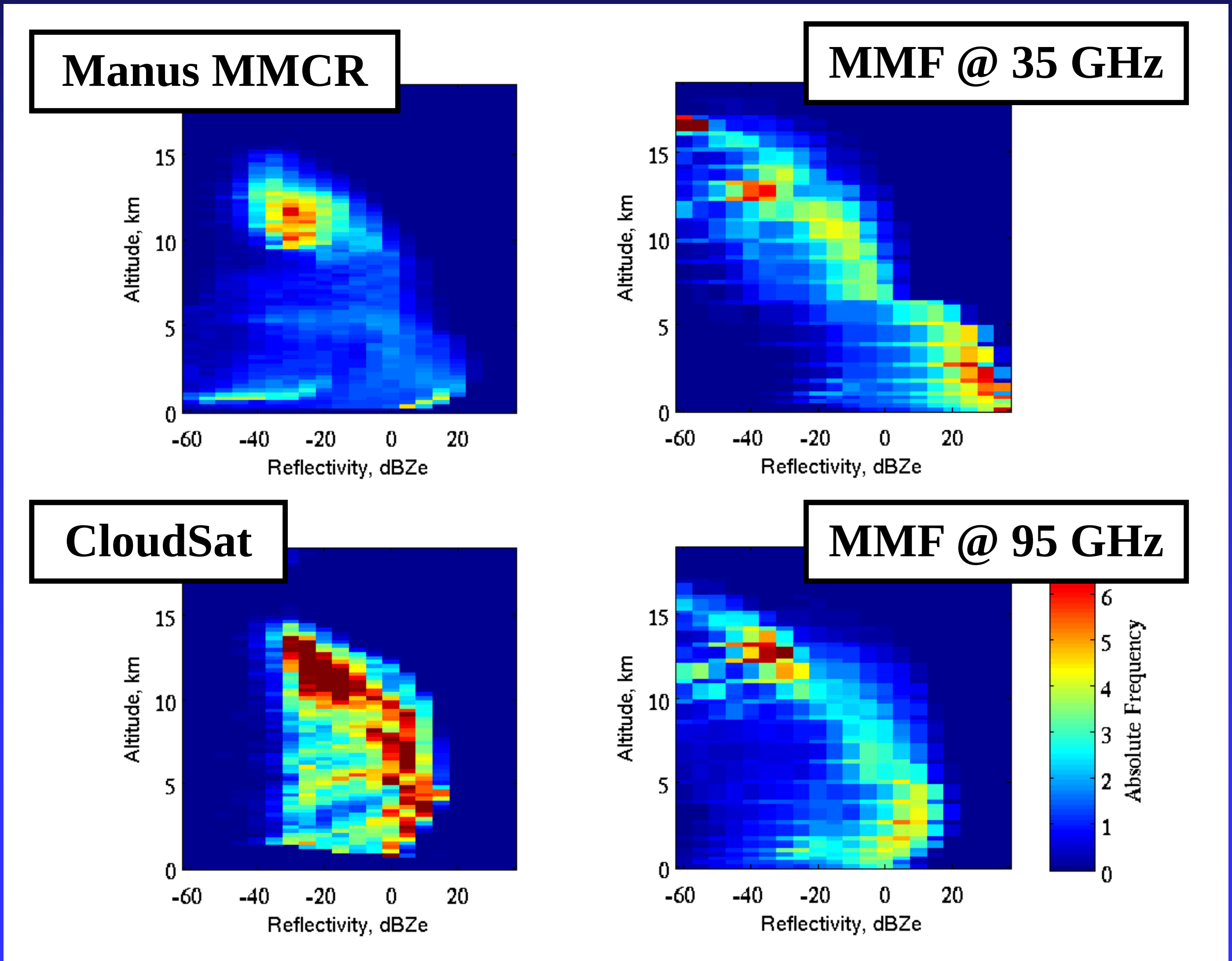
Microwave Brightness Temperature

Radar Reflectivity



OBS = ACRF observations, BG = background or first guess, ANA = analysis or model after data assimilation

Radar Reflectivity: ARM/CloudSat vs. MMF (R. Marchand et al.)



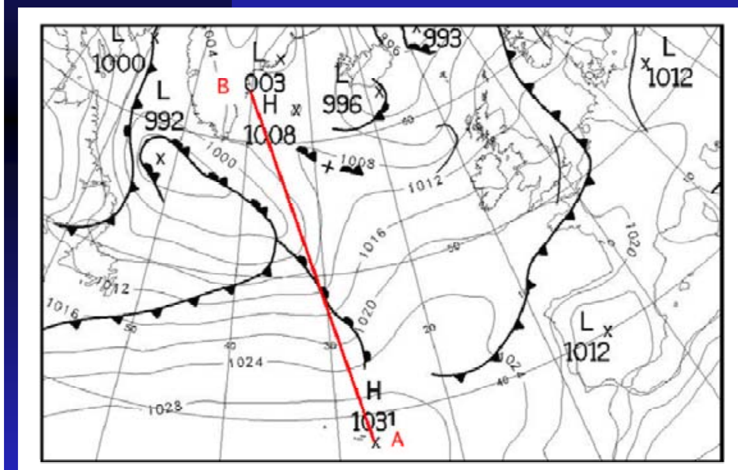
Future Work

…Tropical convection…

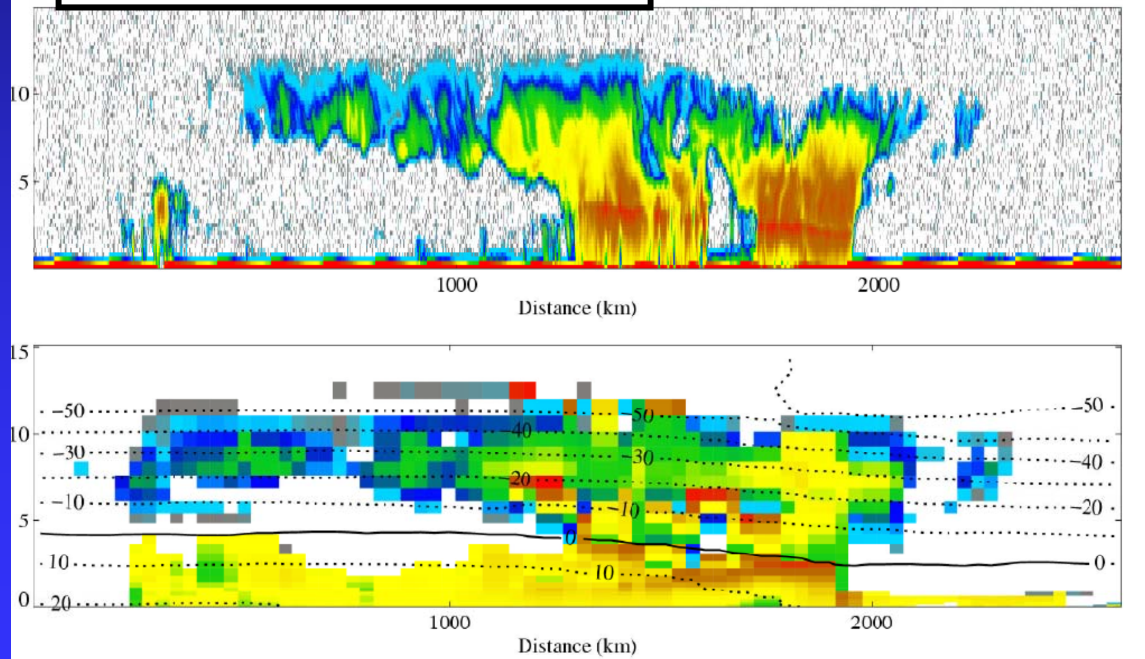
The End

Extra Slides

CloudSat Simulator
(A. Bodas-Salcedo, J. Haynes et al.)



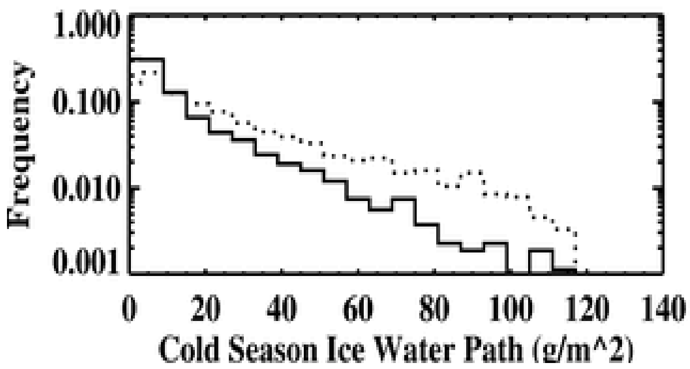
CloudSat Radar Reflectivity (dBZ)



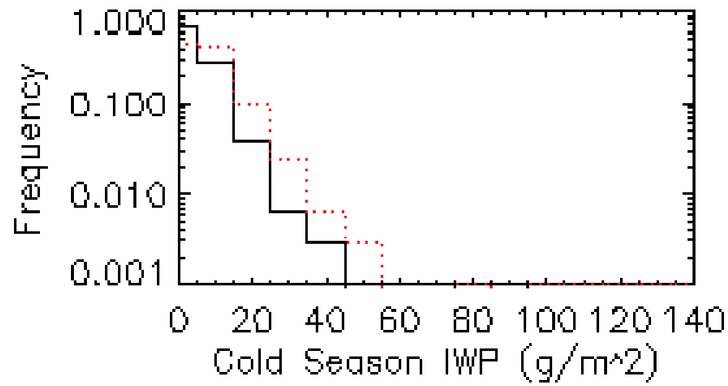
UK MetOffice NWP model through the lens of a simulator

SGP Cirrus Ice Water Path: ARM vs. Large-scale Models

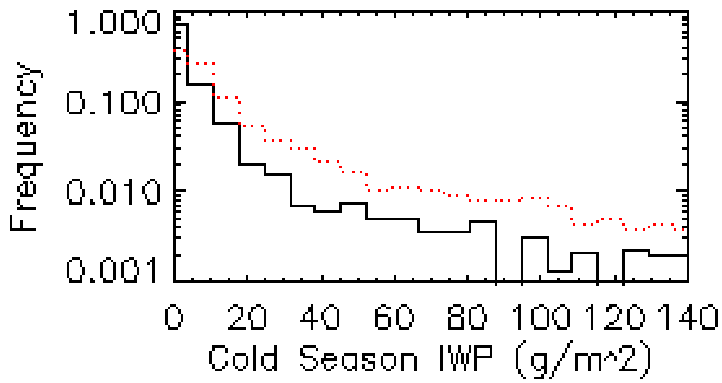
M06 OBS



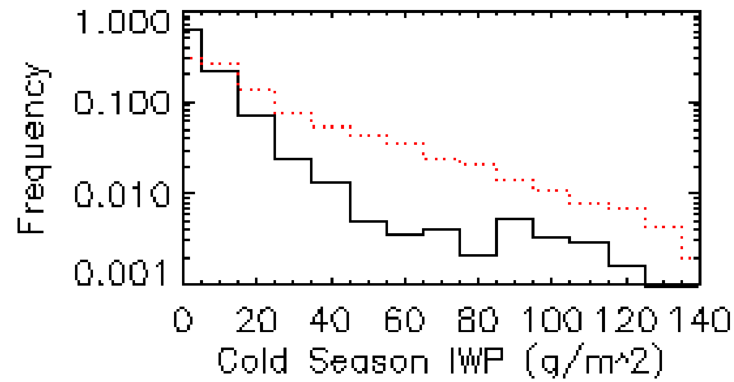
C-CAM3



ECMWF



C-AM2



D. Hartsock et al. and the CAPT team

VOLUME 7 JOURNAL OF HYDROMETEOROLOGY DECEMBER 2006

Do Global Models Properly Represent the Feedback between Land and Atmosphere?

PAUL A. DIRMEYER

Center for Ocean–Land–Atmosphere Studies, Calverton, Maryland

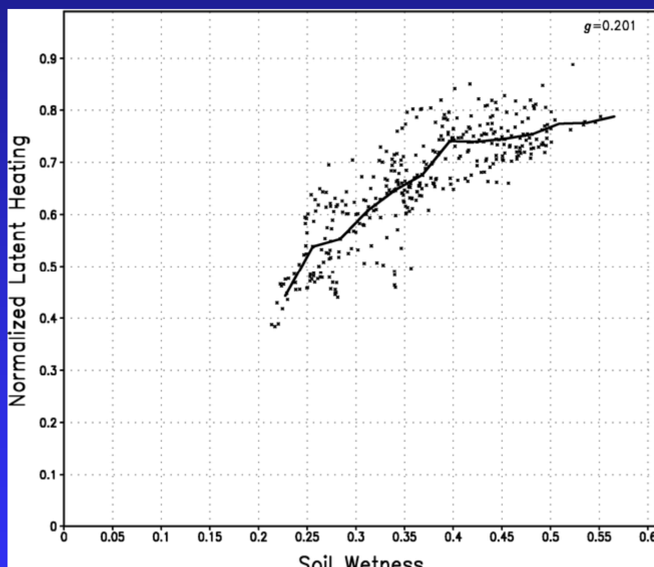
RANDAL D. KOSTER

Global Modeling and Assimilation Office, NASA Goddard Space Flight Center, Greenbelt, Maryland

ZHICHANG GUO

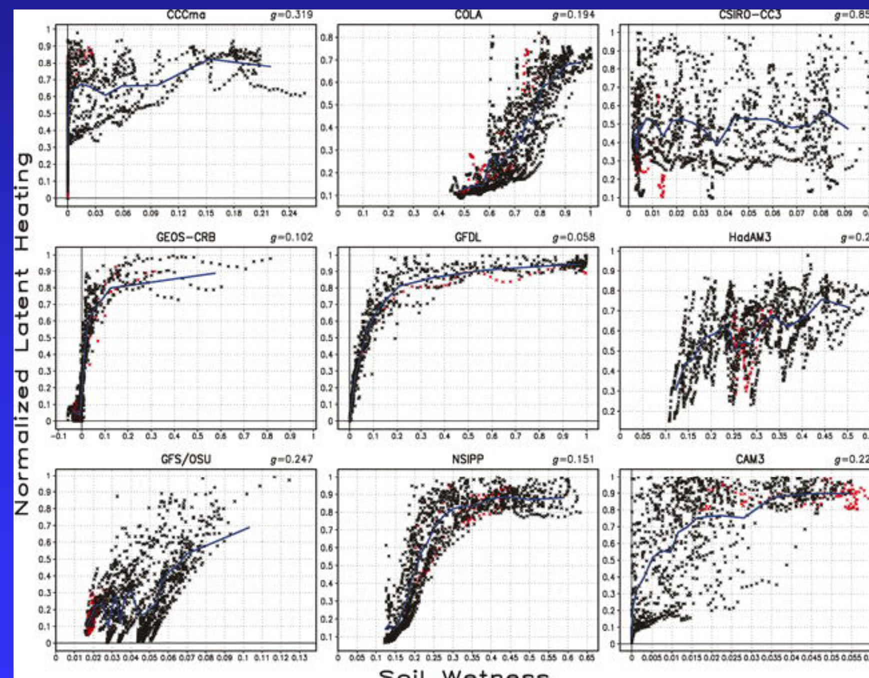
Center for Ocean–Land–Atmosphere Studies, Calverton, Maryland

ACRF Observations



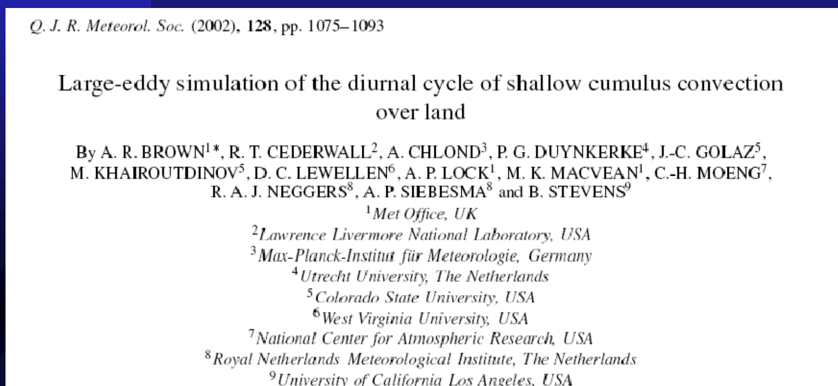
A scatter plot of the latent heat flux normalized by the net radiation to soil wetness normalized by its variability

Climate and Weather Models



- Models vary widely and do not match observations well

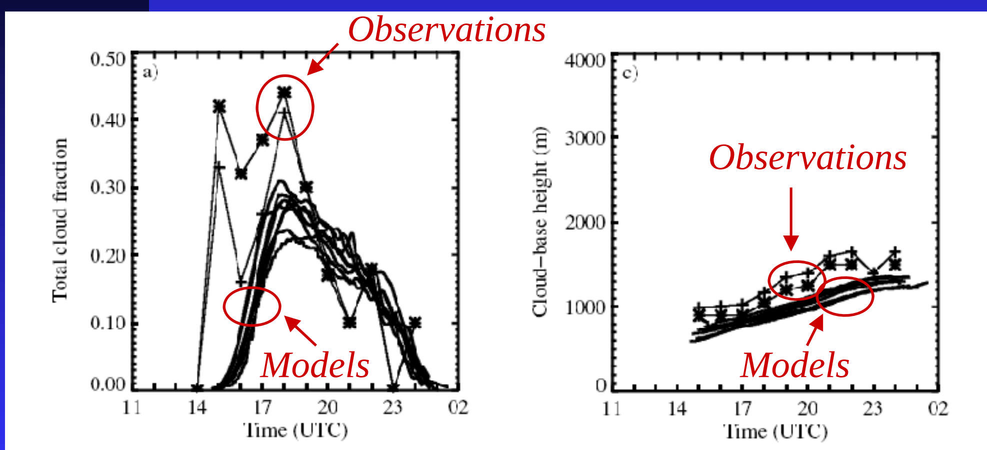
Use of ACRF data in Cloud Resolving Modeling


Q. J. R. Meteorol. Soc. (2002), **128**, pp. 1075–1093

Large-eddy simulation of the diurnal cycle of shallow cumulus convection over land

By A. R. BROWN[1]*, R. T. CEDERWALL[2], A. CHLOND[3], P. G. DUYNKERKE[4], J.-C. GOLAZ[5], M. KHAIROUTDINOV[5], D. C. LEWELLEN[6], A. P. LOCK[1], M. K. MACVEAN[1], C.-H. MOENG[7], R. A. J. NEGGERS[8], A. P. SIEBESMA[8] and B. STEVENS[9]

[1]*Met Office, UK*
[2]*Lawrence Livermore National Laboratory, USA*
[3]*Max-Planck-Institut für Meteorologie, Germany*
[4]*Utrecht University, The Netherlands*
[5]*Colorado State University, USA*
[6]*West Virginia University, USA*
[7]*National Center for Atmospheric Research, USA*
[8]*Royal Netherlands Meteorological Institute, The Netherlands*
[9]*University of California Los Angeles, USA*



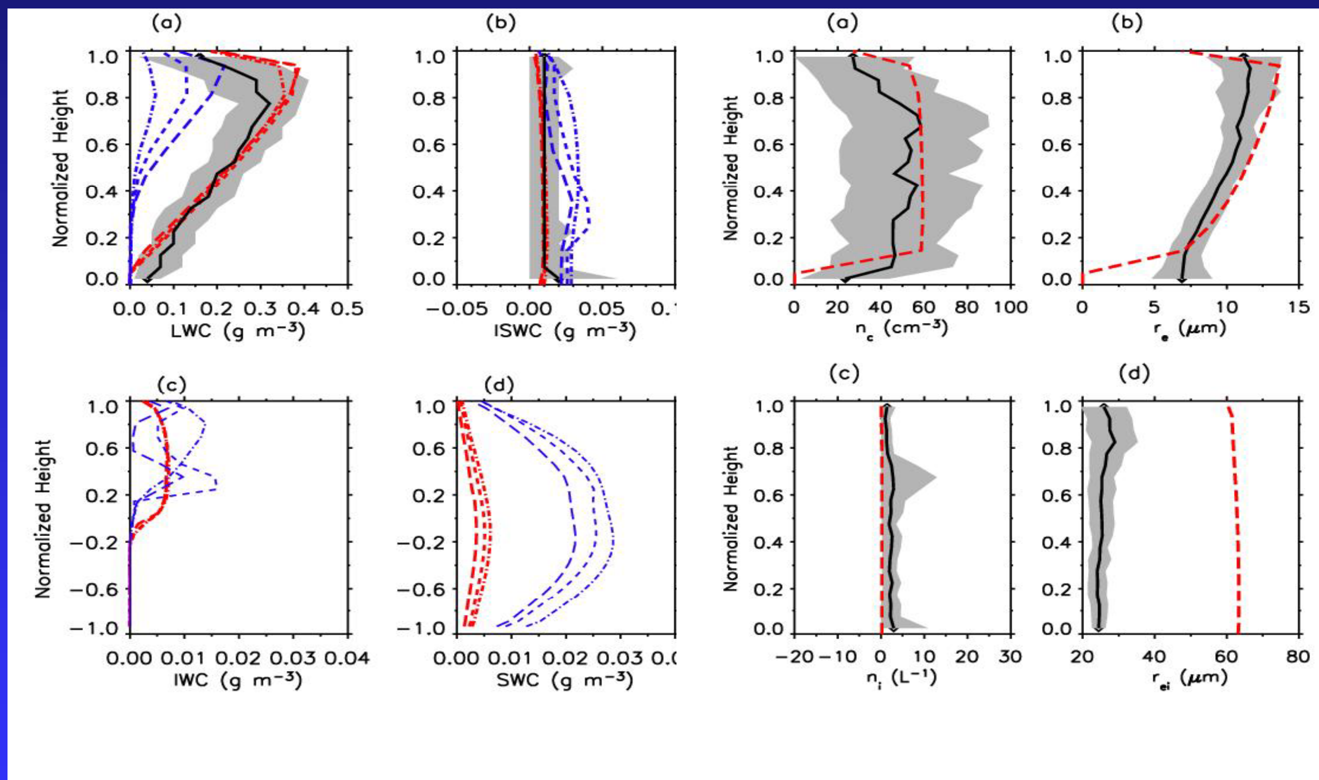
Evolution of cloud fraction and cloud base height between sunrise (11 UTC) and sunset (02 UTC) from the observations at the ACRF Oklahoma site and 8 cloud models

- The international organization GCSS conducts intercomparisons of cloud models using a case study approach
- This case study, *involving mostly non-ACRF funded scientists*, used ACRF data to evaluate the diurnal cycle of shallow cumulus clouds

Comparison of one- and two-moment bulk microphysics parameterization: MPACE

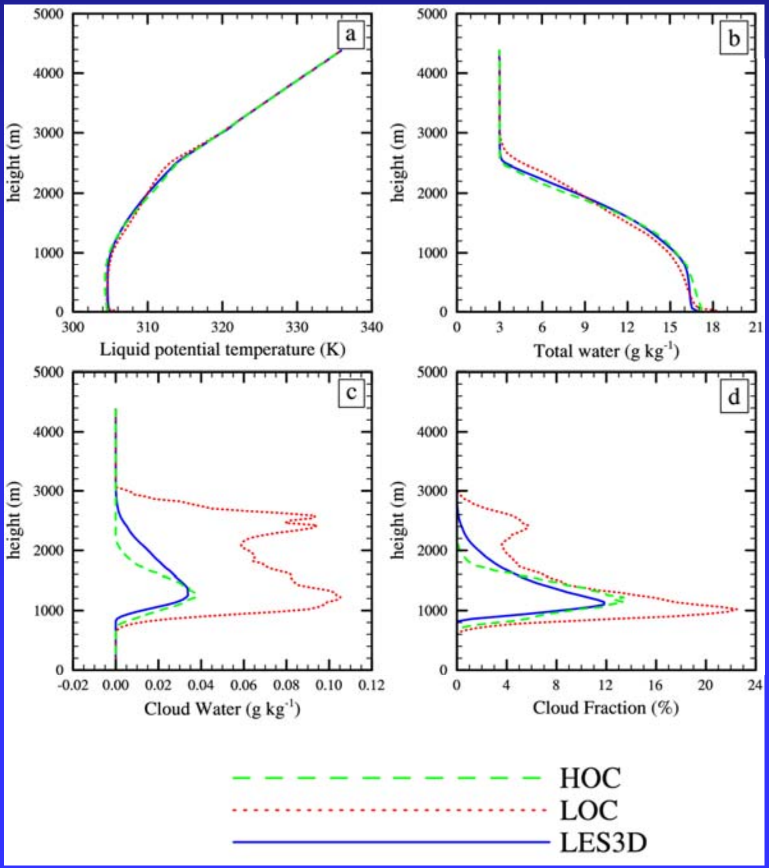
Observations

OneM, TwoM



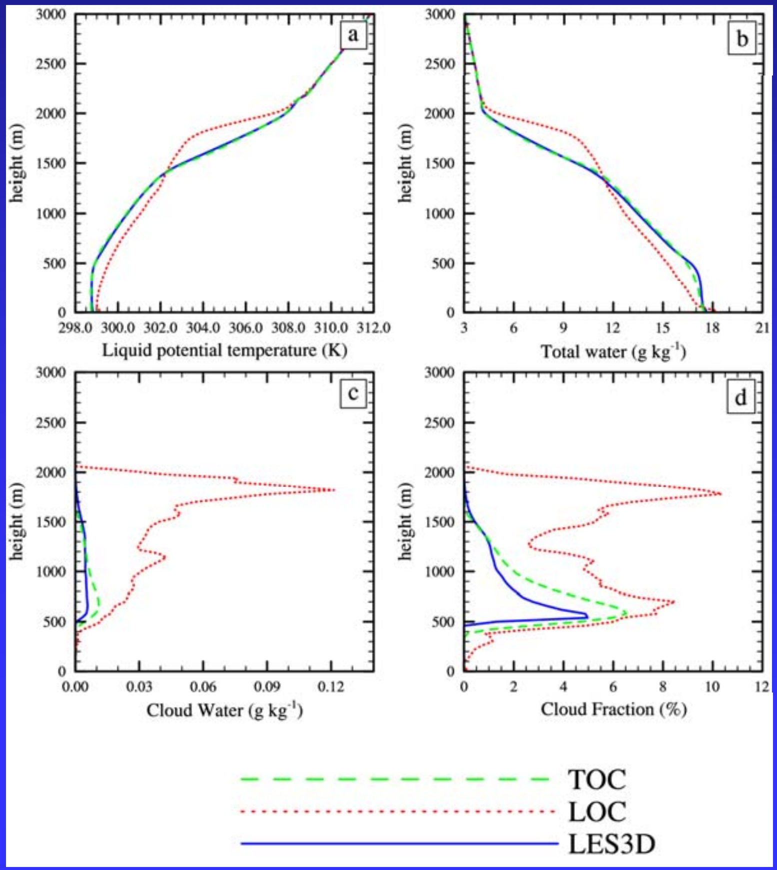
ARM Shallow Cu Cloud Fraction /Liquid Water

- Average from hours 6-9 (11am-2pmLT)



BOMEX Shallow Cu Cloud Fraction /Liquid Water

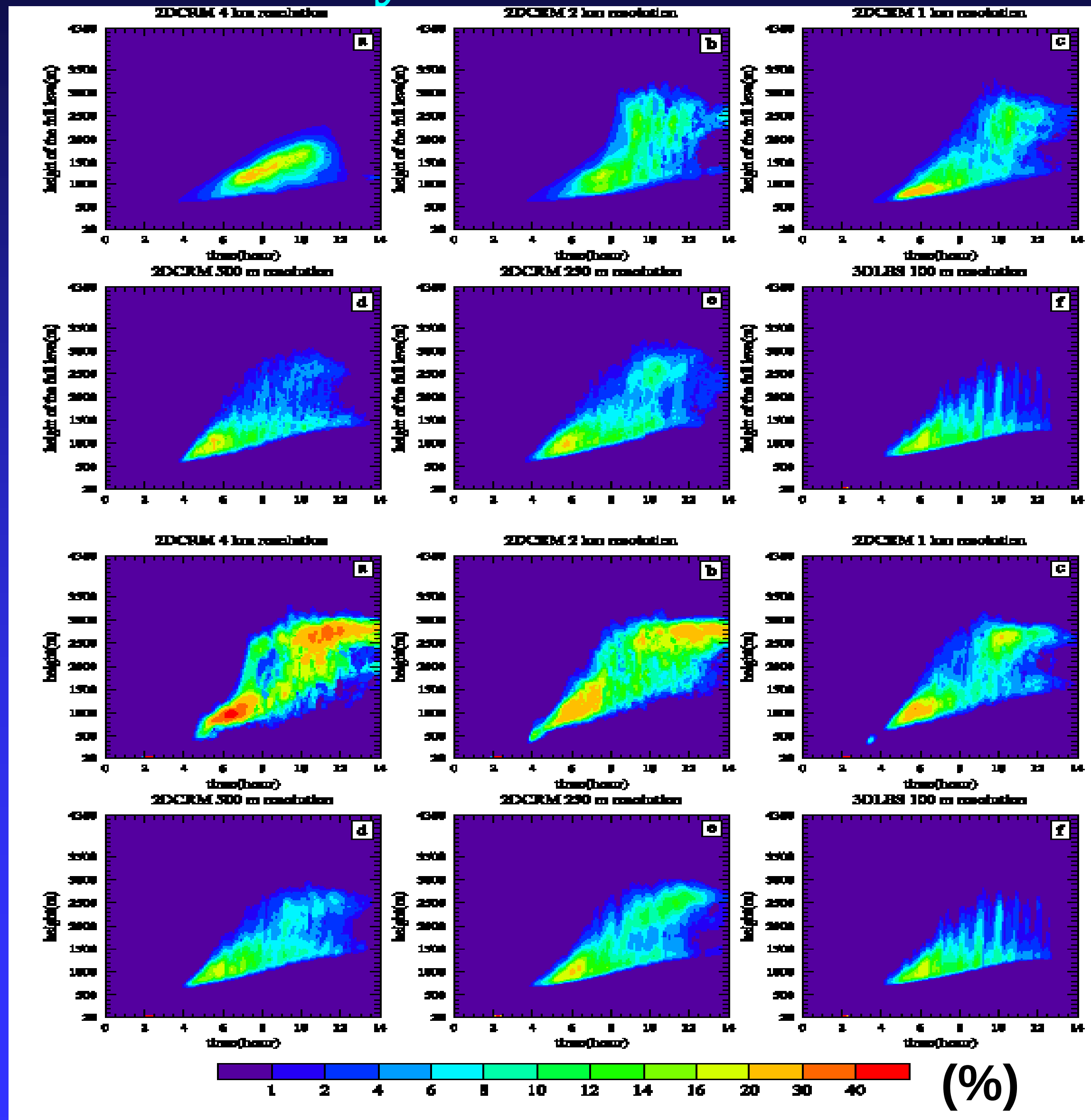
- Average from hours 4-6



Low- and higher-order turbulence closures: ARM BL clouds simulated by CRM and LES

CRM w/ higher-order closure

CRM w/ low-order closure

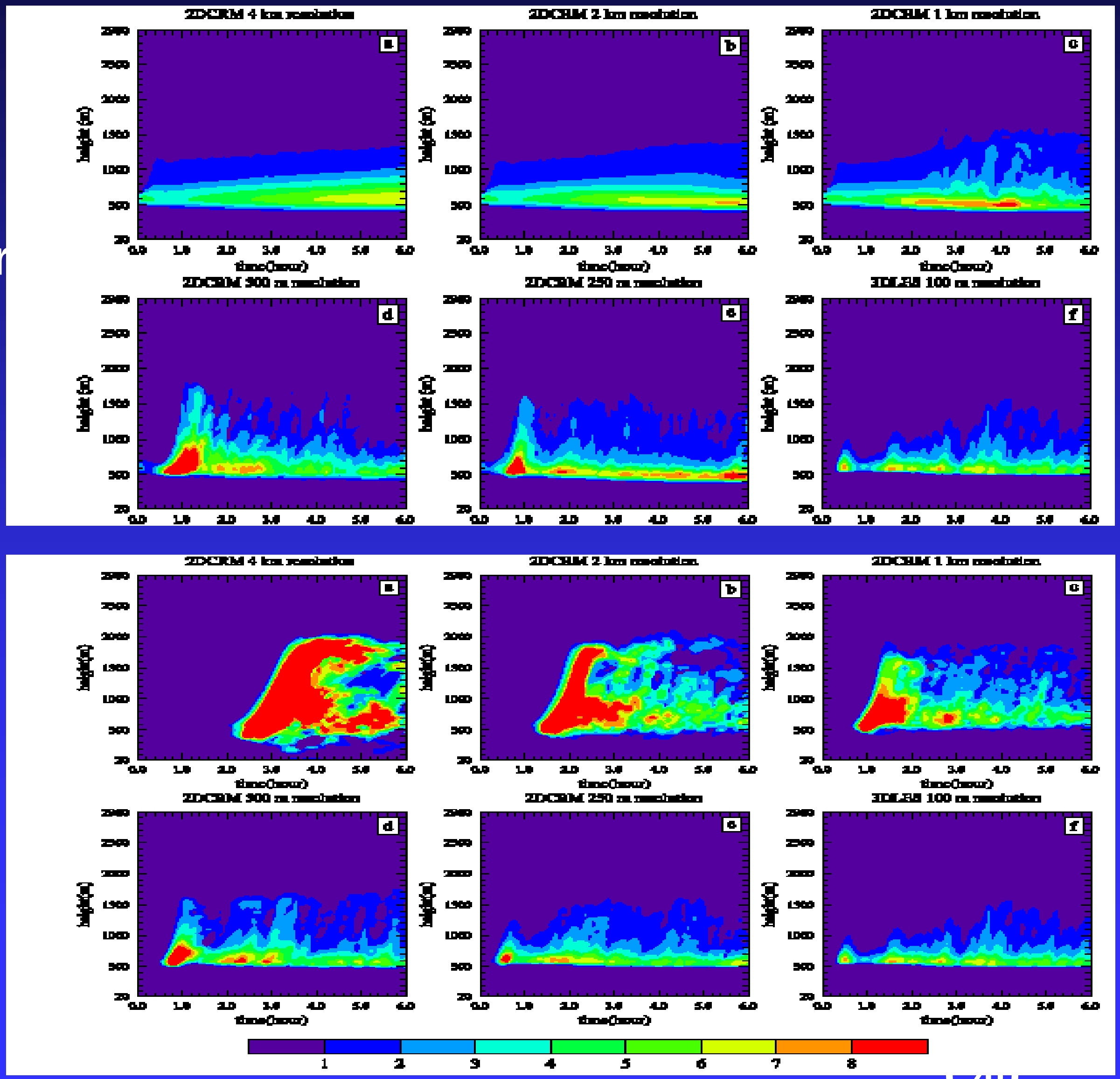


LES

Low- and higher-order turbulence closures: BOMEX BL clouds simulated by CRM and LES

CRM w/ higher order closure

CRM w/ low-order closure



LES

(%)