Heating Rates of Observed and Simulated Anvil Clouds over Niamey

Scott W. Powell[1], Xiping Zeng[2], Robert A. Houze, Jr.[1], Wei-Kuo Tao[2]

[1]*Department of Atmospheric Science, University of Washington; Seattle, WA*

[2]*Laboratory for Atmospheres, NASA Goddard Space Flight Center; Greenbelt, MD*

ASR Science Team Meeting, San Antonio, 29 March 2011

1. Introduction

• Anvil clouds play an important role in radiative heating in upper troposphere and impact the general circulation in the tropics.

• A high-resolution cloud resolving model is used to simulate mesoscale convective systems (MCSs) that may be compared to observed MCSs.

• Anchoring model microphysics to observations allows us to study radiative heating effects of anvil clouds as well as the water budget and dynamics of MCSs.

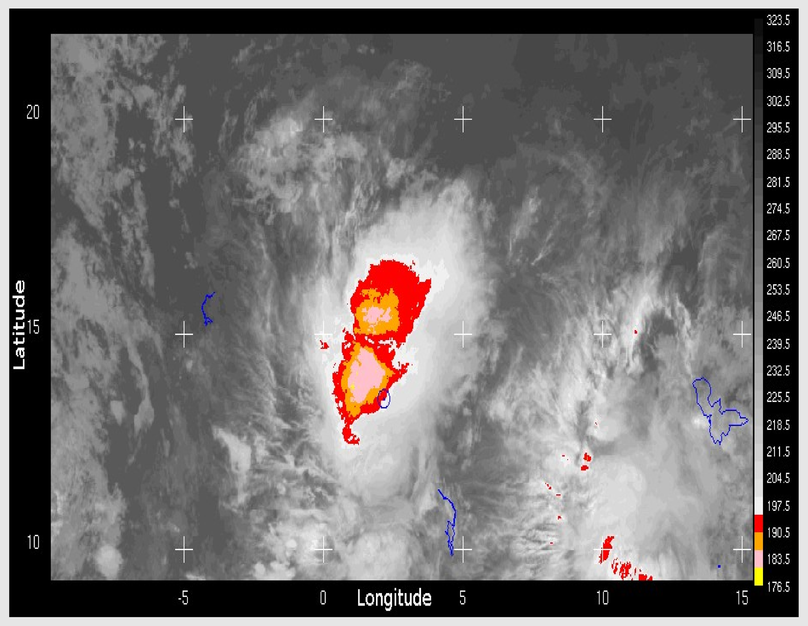
2. Model

- Goddard Cumulus Ensemble (GCE)[1]
- Forced with sounding budget data from AMMA processed at Colorado State University.
- Domain: 1024km x 1024km centered over Niamey, Niger
- Spatial Resolution: 1km
- Vertical levels: 63 with 300m or better resolution
- One-moment microphysics scheme[2] introducing ice crystal concentration in mixed phase region[3].

3. MCS of August 10-11, 2006

•METEOSAT-8 infrared satellite imagery detects an MCS passing over Niamey (13N, 2E) on Aug. 10-11, 2006.

•Instruments at the ARM site sampled a small region of leading anvil, a convective and stratiform region, and a trailing anvil.



August 11, 2006, 06UTC

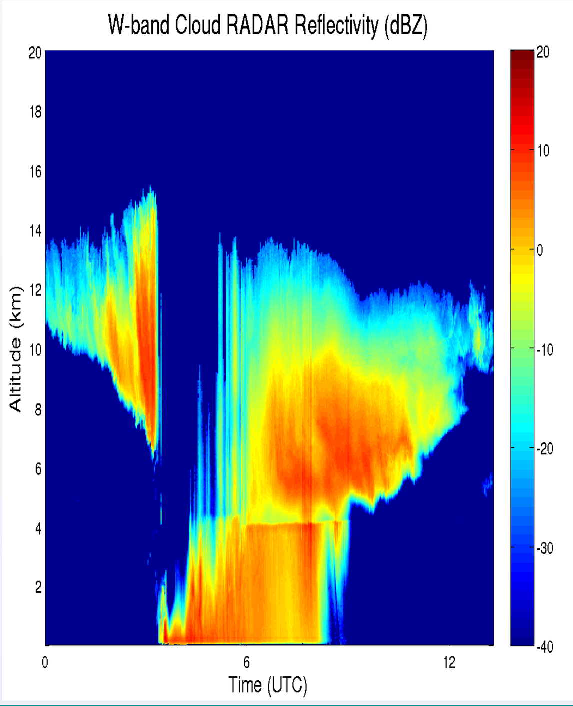
4. ARM Observations

• GCE is anchored to ARM vertically pointing W-band cloud radar observations from Niamey, Niger.

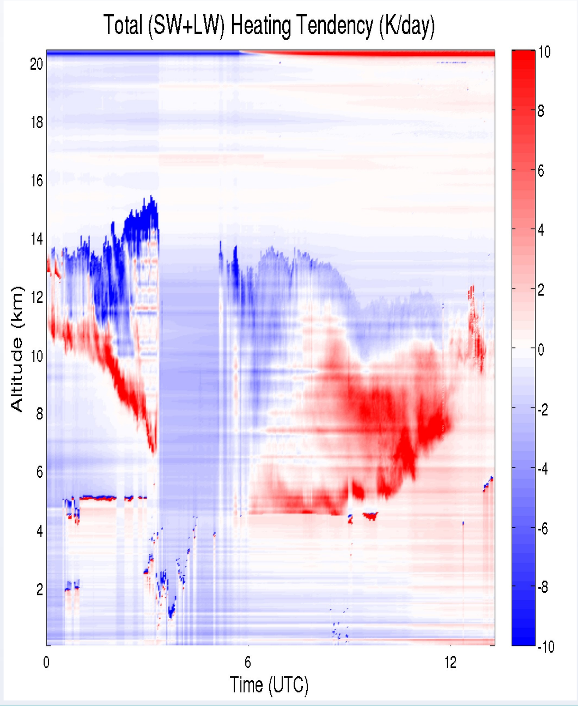
• Radar-lidar retrieval used; retrieved cloud properties entered into radiative transfer code[4].

• Contour interval for joint PDF is 0.001 from 0.001 (blue) to 0.018 (red).

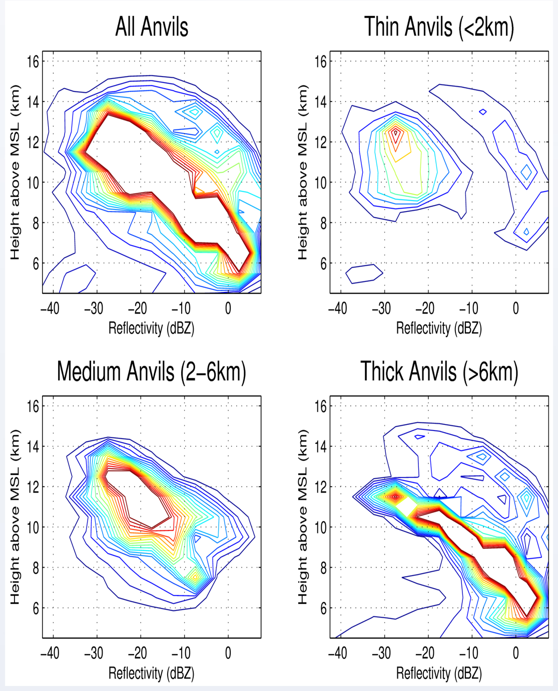
W-band (94GHz) reflectivity



Retrieved Heating Rates[4]



Joint PDF of Reflectivity and Altitude (CFAD[5])



5. Model Evaluation

a. *Microphysics*

• We compare modeled anvils to the observed anvil using joint probability density functions of reflectivity and altitude.

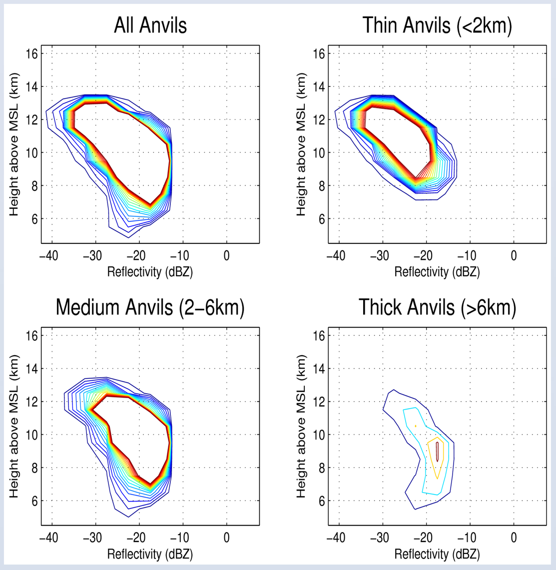
• Reflectivity of modeled anvils is estimated using a radar simulator[6] with parameterizations for cloud ice[7,8].

• Simulation 1: Ice crystal concentration (ICC) in mixed phase region (MPR) of 1.2e-5cm^{-3}.

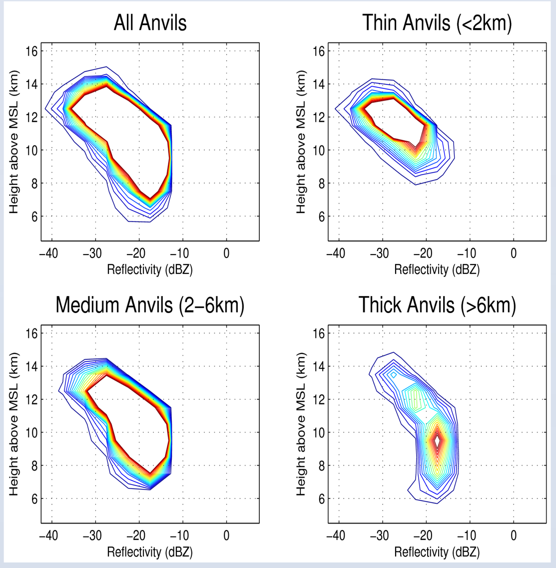
• Simulation 2: ICC in MPR of 1.2e-4cm^{-3}.

i. CFADS (include cloud ice only)

Simulation 1



Simulation 2



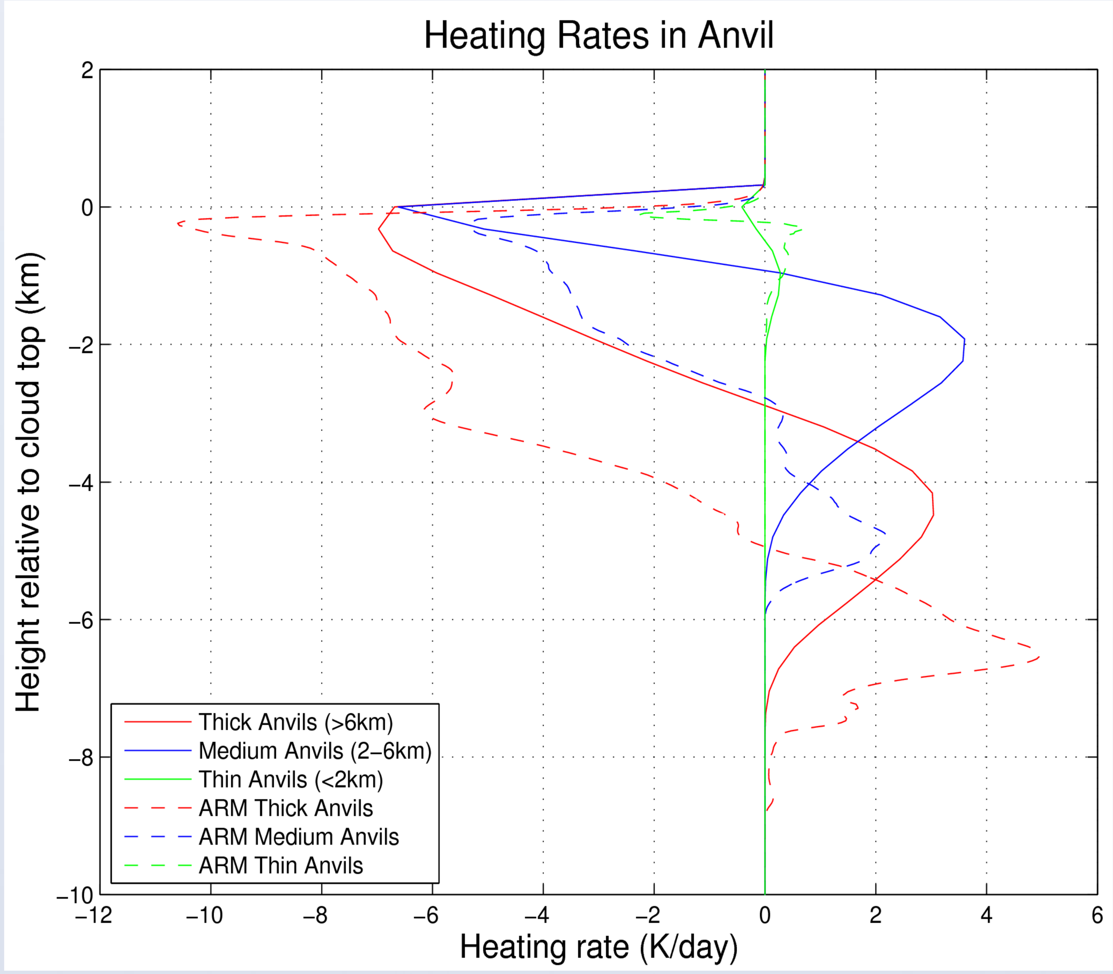
ii. Fraction of total anvil that is thin, medium, or thick

	Observations	Simulation 1	Simulation 2
Thin Anvil	55.8%	63.5%	52.8%
Medium Anvil	20.8%	35.6%	42.4%
Thick Anvil	23.3%	0.9%	4.8%

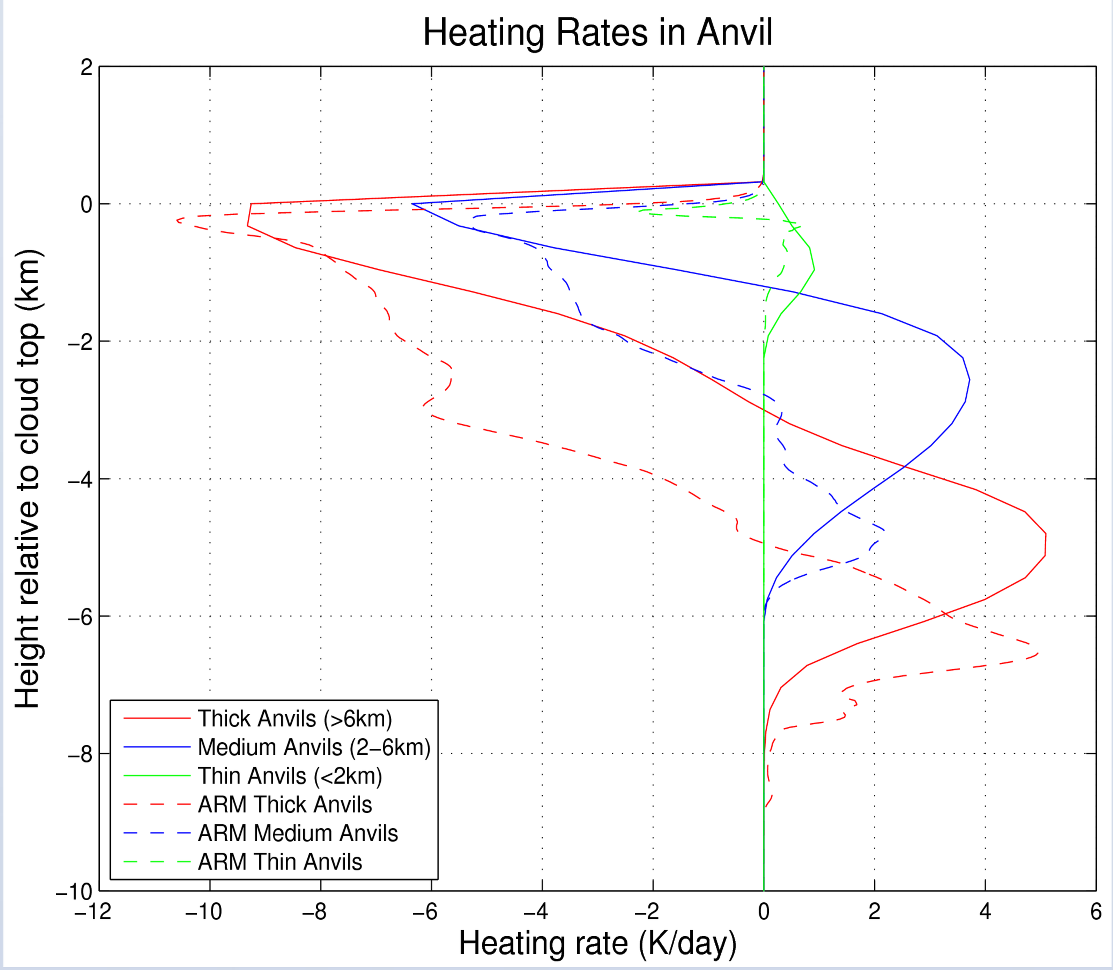
b. *Radiative heating profiles*

Since modeled MCSs occur at different times of day than observed systems, only longwave fluxes are considered for comparison.

Simulation 1



Simulation 2



6. Summary

• GCE generates thin anvil, medium anvil, and the tops of thick anvil with appropriate reflectivities at altitudes similar to that seen in observations.

• Higher ice nucleus concentrations in the mixed phase regions are required for sufficient anvil areal coverage.

• Magnitude of maximum modeled radiative heating is similar to observed heating rates.

• Although more cases should be studied, results suggest that MCSs can be modeled in a general circulation model to determine affects of anvil on tropical circulation.

7. References

[1]Tao, W.-K., 2003: *Meteor. Monogr.*, 51, Amer. Meteor. Soc., 103-38.

[2]Rutledge, S.A., and P.V. Hobbs, 1984: *J. Atmos. Sci.*, 41, 2949-72.

[3]Zeng, et al., 2008: *J. Met. Soc. Japan*, 86A, 45-65.

[4]Fu, Q., and K.N. Liou, 1992: J. Atmos. Sci., 49, 2139-2156.

[5]Yuter, S.E., and R.A. Houze, Jr., 1995: *Mon. Wea. Rev.*, 123, 53-99.

[6]Haynes, J.M, R.T. Marchand, Z. Luo, A. Bodas-Salcedo, and G.L. Stephens, 2007: *Bull. Amer. Meteor. Soc.*, 88, 1723-27.

[7]Fueglistaler, S. and Q. Fu, 2006: *J. Geophys. Res.*, 111, D23202, doi:10.1029/2006JD007273.

[8]Heymsfield, A.J, A. Bansemer, and C.H. Twohy, 2007: *J. Atmos. Sci.*, 64, 1047-67.

8. Acknowledgements

The presenters thank Paul Ciesielski (CSU) for providing the forcing used for producing the simulations shown and Sally McFarlane and Jennifer Comstock (PNNL) for providing cloud retrievals.

9. Corresponding Author

Scott Powell
University of Washington
Box 351460
Seattle, WA 98195
Email: spowell@atmos.uw.edu