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

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

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).

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\(^5\) with parameterizations for cloud ice\(^6\).
- 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

<table>
<thead>
<tr>
<th>Anvil Type</th>
<th>Simulation 1</th>
<th>Simulation 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin Anvil</td>
<td>55.8%</td>
<td>63.5%</td>
</tr>
<tr>
<td>Medium Anvil</td>
<td>20.8%</td>
<td>35.6%</td>
</tr>
<tr>
<td>Thick Anvil</td>
<td>23.3%</td>
<td>0.9%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Heating Rates in Anvil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height relative to cloud top (km)</td>
</tr>
<tr>
<td>Heating rate (K/day)</td>
</tr>
<tr>
<td>Thin Anvil (Obs)</td>
</tr>
<tr>
<td>Thin Anvil (GCE)</td>
</tr>
<tr>
<td>Thin Anvil (GCE)</td>
</tr>
</tbody>
</table>

Simulation 2

<table>
<thead>
<tr>
<th>Heating Rates in Anvil</th>
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</thead>
<tbody>
<tr>
<td>Height relative to cloud top (km)</td>
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</tr>
<tr>
<td>Thin Anvil (GCE)</td>
</tr>
</tbody>
</table>

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

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8. Acknowledgements

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