Boundary Layer Variability Associated with Downdrafts and Coldpools

Katherine Thayer-Calder (1) *and David Randall* (2)

(1) Unv of Wisconsin-Milwaukee and NCAR (2) Colorado State Unv

Introduction

Downdrafts form within clouds when air becomes negatively buoyant, either through loading of liquid water condensate or through evaporation of liquid water. These downdrafts can become violent if heavy precipitation falls through dry air, leading to destructive severe weather in gust fronts and microbursts. Even less powerful downdrafts forming in moist, tropical environments can greatly impact the boundary layer and formation of future convection. This study uses 3D cloud-resolving modeling to look at boundary layer variability in the presence of normal, tropical downdrafts.

Fig 1. (above) Intense downdrafts in Pheonix produce a dramatic dust storm.

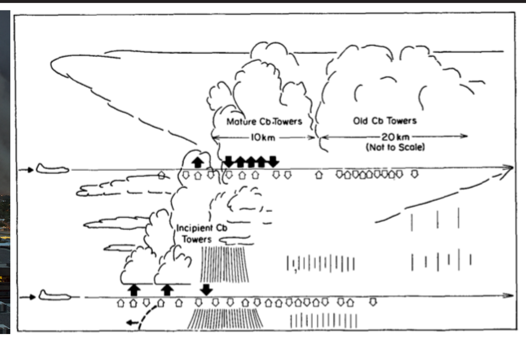

Fig 2. A schematic of composite cores and drafts in tropical mesoscale systems observed during the GATE campaign. From Zipser and LeMone (1980).

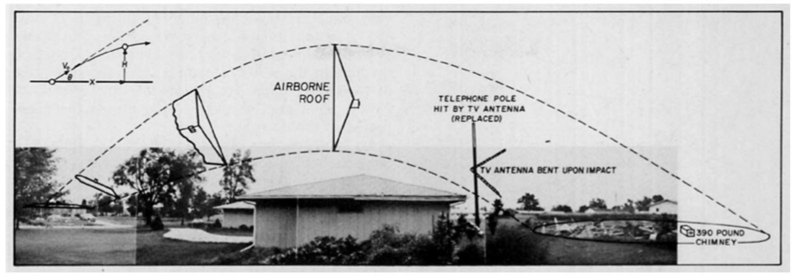

Fig 3. (right) Microburst wind speed calculations from damage in Fujita and Wakimoto (1981)

Our cloud model is the **System for Atmospheric Modeling (SAM) v6.8.2.** Data in this study is primarily from two simulations:

1. TOGA-COARE run (TC)
   - Large-scale forcing from 21 days of IOP of the TOGA-COARE field project.
   - 1 km horiz resolution with 64 vert levels up to 5hPa
   - 128x128km domain and 10 sec timestep
2. Simple Radiative-Convective balance (RC)
   - No large-scale forcing
   - Same resolution, domain and timestep.

Single Timestep Example From TC During Intense Downdraft Event

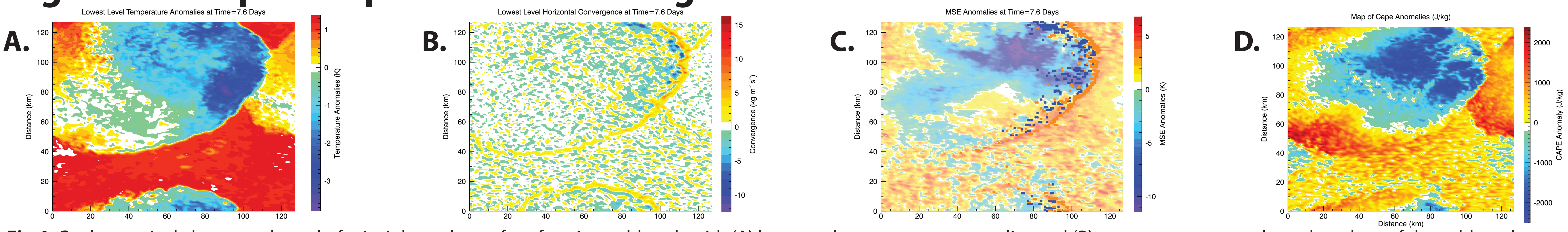

Fig 4. Cool, negatively buoyant downdraft air sinks to the surface forming coldpools with (A) large cool temperature anomolies and (B) mass convergence along the edges of the cold pool. (C) Convergence and increased surface fluxes lead to high MSE anomolies where updrafts preferentially form, and (D) higher CAPE around the edges of the coldpool wake.

BL Variability and Downdraft Intensity During 21 Days of TC

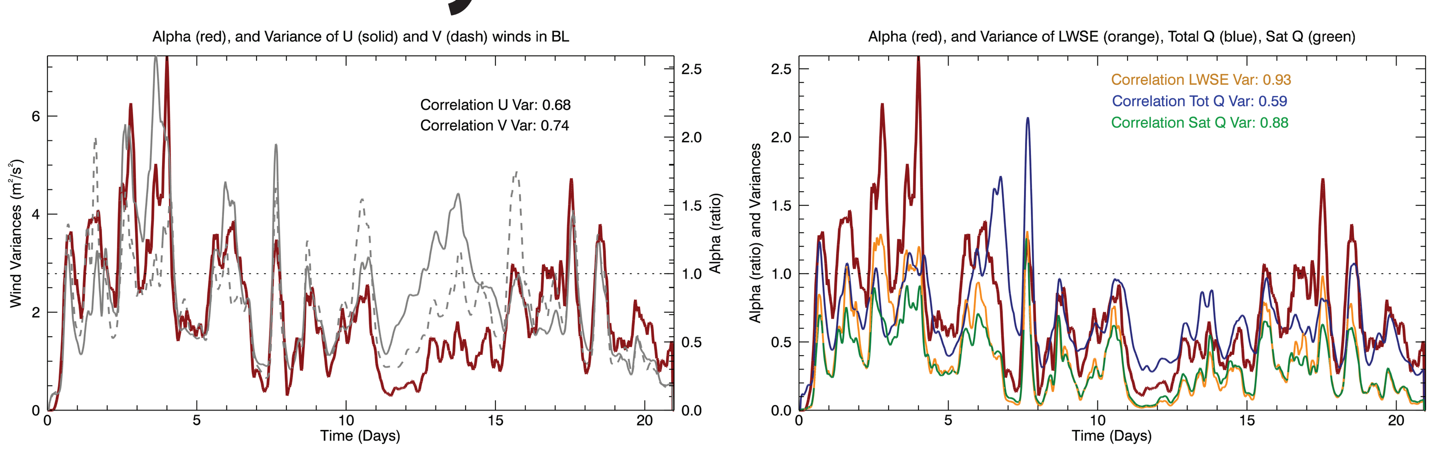

Fig 5. The variances of U and V winds increase with a high correlation to alpha, the ratio of downdraft to updraft mass flux at cloud base. Thermodynamic variables that are very temperature sentive are also highly correlated to alpha, but moisture sensitive variable are less so.

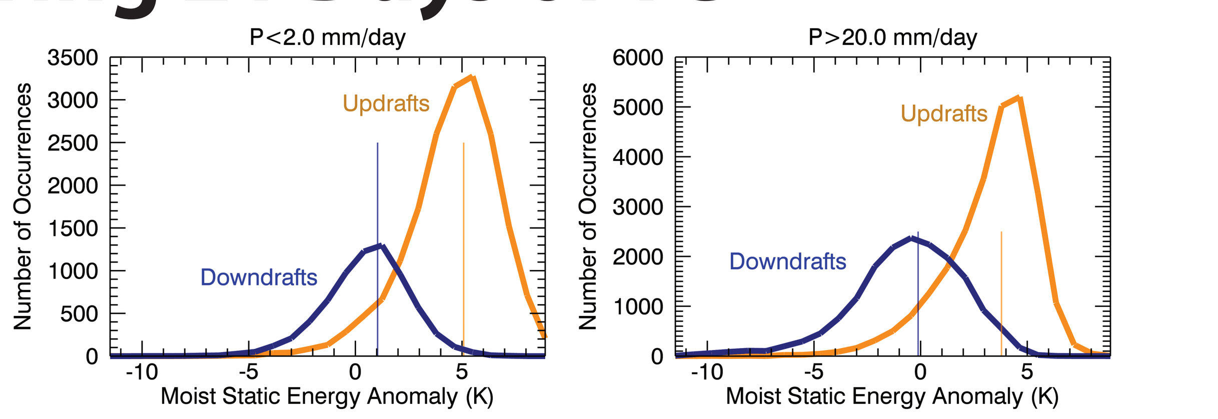

Fig 6. Histograms of MSE anomolies during low precip (left) and high precipitation time steps (right). Updrafts have high MSE anomolies, but downdrafts often do as well. This is linked to the fact that downdrafts occur in moist gridcells, and entrain cloudy, moist air as they descend.

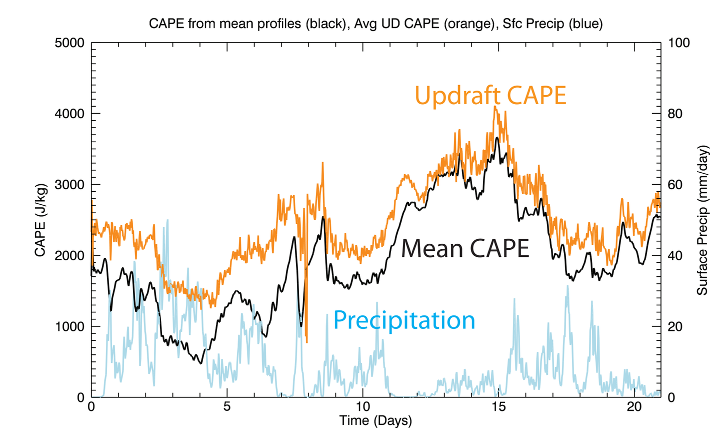

Fig 7. During high precipitation periods of TC, updraft CAPE is much higher than the mean value of CAPE in the domain. This has important consequences for convective parameterization.

Surface Fluxes and Downdrafts Have a Complex Relationship

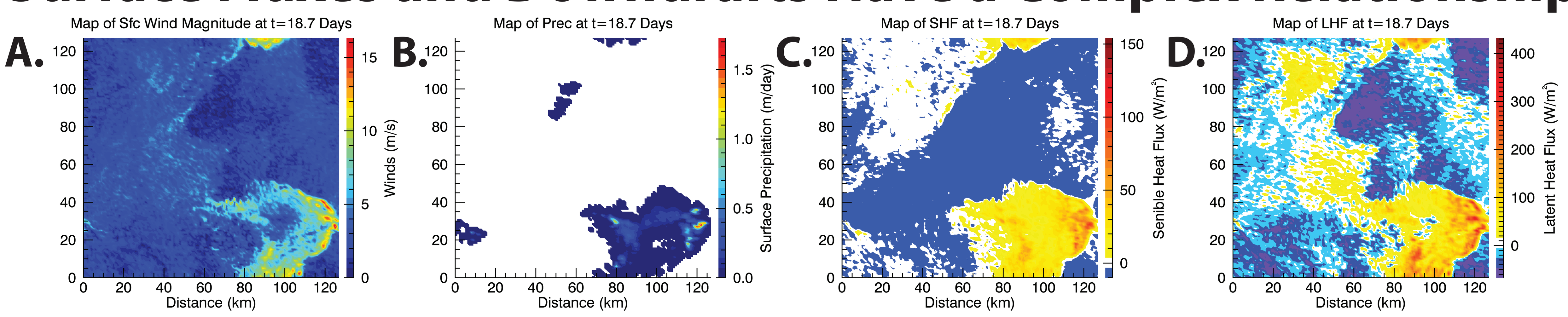

Fig 8. This single timestep from TC shows surface wind magnitudes (A) and precipitation (B) associated with a convective system. Postive sensible heat flux (C) is primarily located in the precipation regions, but positive latent heat flux anomolies (C) happen over the whole domain. They do appear to be enhanced by local outflow gustiness as well.

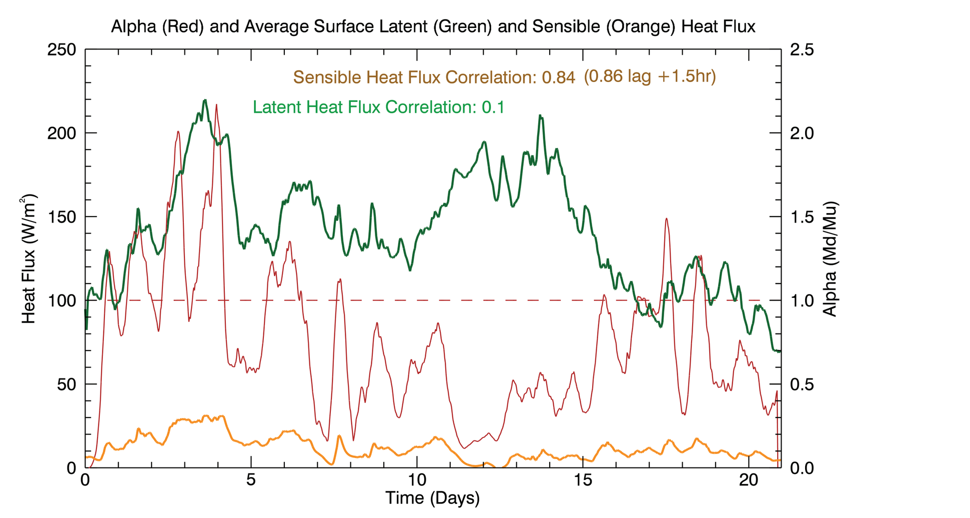

Fig 9. Over the course of the TOGA simulation, mean LH Flux is not well correlated with downdraft activity. This is likely due to the impact of large-scale effects such as high surface temps and mean winds. Sensible heat flux is highly correlated to downdraft activity.

Transport of Low MSE into the BL is Dominated by the Environment

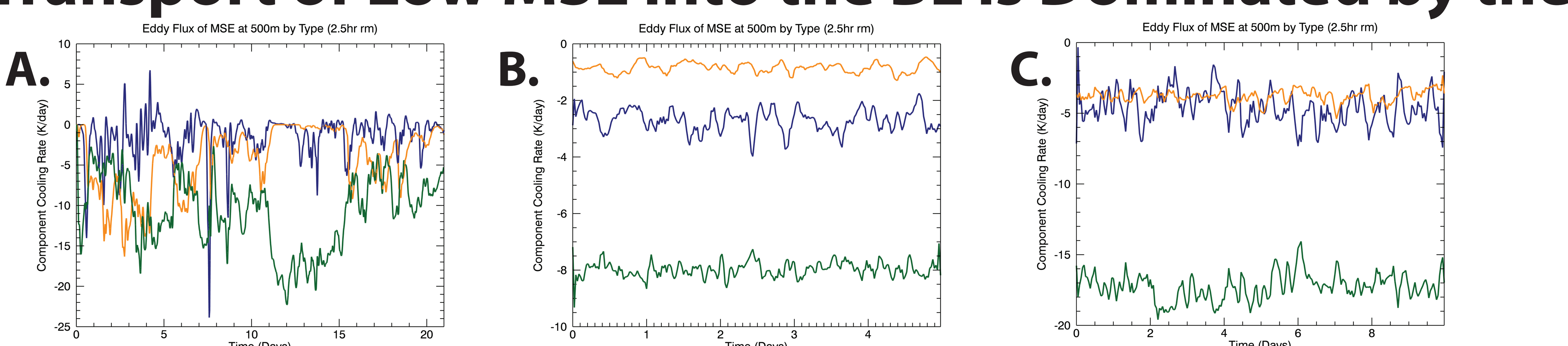

Fig 10. Flux of MSE by the environment (green), downdrafts (blue) and updrafts (orange) at 500m in the (A) TC run, (B) RC run, and (C) an offshoot of RC with enhanced low-level shear. In all cases, the environmental flux of MSE dominates - in part because it has the highest fractional area, and also because downdrafts do not always have negative MSE anomolies.

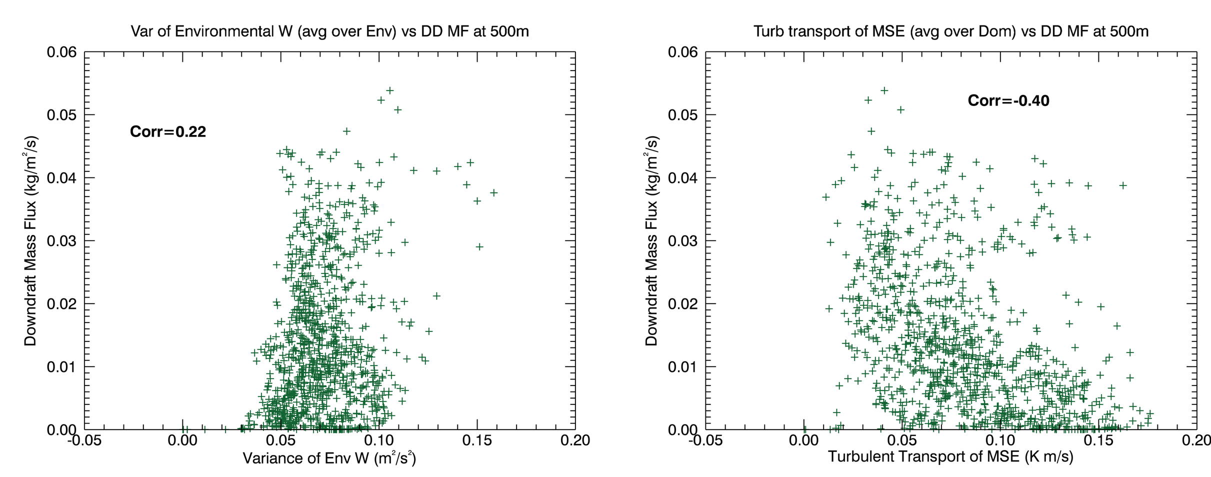

Fig 11. The variance of vertical velocities in the environment has a slight positive correlation with downdraft mass flux, suggesting downdrafts could stir up turbulence in the BL. The actual transport of MSE by the environment decreases as downdraft mass flux increases.

Summary

Downdrafts are notoriously difficult to observe because of their transient nature and negative impacts on radiosondes. However, high-resolution 3D cloud resolving models can give us a detailed view of the structure and effects of downdrafts.

Cloud resolving model results can help us better understand cloud processes that are not resolved in global climate models (GCMs). Because of the coarse resolution of GCMs, cloud impacts and processes are currently parameterized. Most GCMs are highly sensitive to these parameterizations, but the parameterizations themselves are based on many assumptions and empiracle relationships. In particular, *downdrafts* are poorly understood and often parameterized with very simple relationships. Our results suggest that convective parameterizations should include the impact of downdrafts and coldpools to better capture the magnitude of convection (via actual updraft CAPE and surface fluxes) as well as the import of MSE by the environment, rather than overly cooled downdrafts.

References

Fujita, T. T. and R. M. Wakimoto, 1981: Five scales of airflow associated with a series of downbursts on 16 July 1980. *Mon. Wea. Rev.*, **109**, 1438-1456.

Khairoutdinov, M. F. and D. A. Randall, 2001: A cloud resolving model as a cloud parameterization in the NCAR Community Climate System Model: Preliminary results. *Geophys. Res. Lett.*, **28**, 3617-3620.

Khairoutdinov, M. and D. A. Randall, 2003: Cloud Resolving Modeling of the ARM Summer IOP: Model Formulation, Results, Uncertainties, and Sensitivities. *J. Atmos. Sci.*, **54**, 1359-1378.

Zipser, E. J. and M. A. LeMone, 1980: Cumulonimbus Vertical Velocity Events in GATE. Part II: Synthesis and Model Core Structure. *J. Atmos. Sci.*, **37**, 2458-2469.

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