CRM Simulations of Organized Convection During TWP-ICE and Their Implications for Cumulus Parameterization

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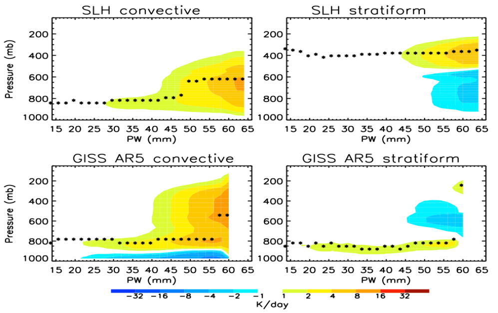
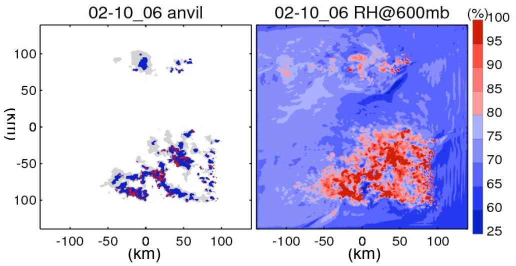
Introduction

Most GCMs neglect the mesoscale organization of moist convection, which affects the diabatic heating profile, precipitation, radiation budget, and tropical general circulation. Cloud-resolving models (CRMs) can potentially provide insights into relationships between convection, stratiform rain and anvil regions, and the environment to guide parameterization development. We use simulations of the TWP-ICE active and break periods with WRF V3.2 at 600 m resolution to explore possible approaches to parameterize mesoscale updrafts.



Satellite-derived latent heating profiles from TRMM (Shige et al. 2007, JAMC), composited by column water vapor and decomposed into convective and stratiform contributions, show that GISS GCM deep convective heating at upper levels compensates for an almost complete absence of stratiform anvil heating and stratiform cooling that peaks at midlevels rather than the lower troposphere. This points to the need for a mesoscale updraft parameterization in the model.

Classification scheme for clusters

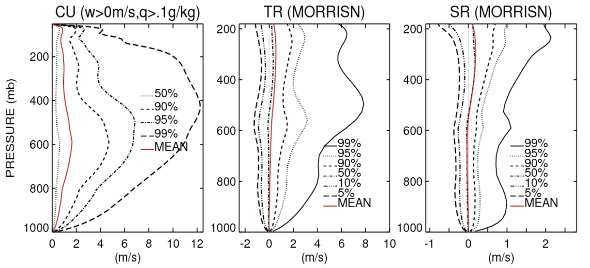


600mb Relative Humidity (Morrison scheme)

Time mean rh@600mb (%)	active	break
CU	98.8	94.4
TR	96.3	82.2
SR	96.0	77.3
DOMAIN	96.5	66.4

We divide convective clusters into 3 regions: Convective updraft (CU: w > 0 m/s, q_h > 0.1 g/kg, base > 750 mb, top < 0°C), transition rain (TR: non-CU, RR > 5 mm/hr q_h > 0.1 g/kg, top < 0°C), stratiform rain (SR: like TR but 5 mm/hr > RR > 0.5 mm/hr). These are color coded as red (CU), blue (TR) ,and gray (SR) in the upper left panel. Air entrained into the updrafts during the break period (primarily TR or SR air) is 10-20% (in RH) wetter than most other air in the domain, due to prior turbulent mixing at cloud edges, detrainment and rain evaporation, thus reducing the efficacy of entrainment (cf. Mapes and Neale 2011, JAMES). This is not so during the almost-saturated active period.

Updraft Speed PDFs in WRF Active Monsoon Simulations

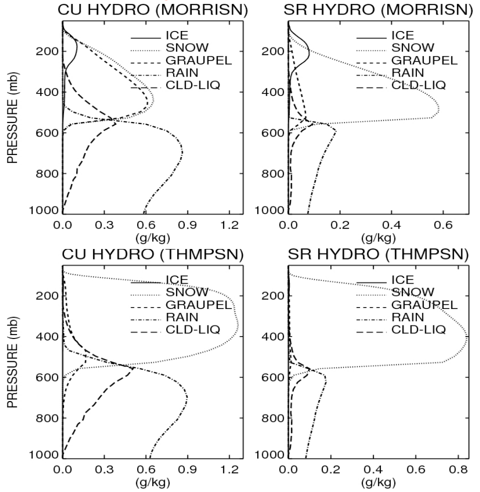


Updraft speed profiles during the active period are typical of those observed in field experiments, with the strongest updraft speeds ~2-12 m/s in the CU region and ~20-100 cm/s in the SR region. TR updraft speeds are somewhat weaker than those in the CU region but much stronger than those in the SR region. The TR region thus appears to represent buoyant air detrained from the CU region and may capture the initiation stage of the anvil. It is also the location of the strongest downdrafts, with speeds of ~1-2 m/s.

Areal coverage (%) for different microphysics schemes

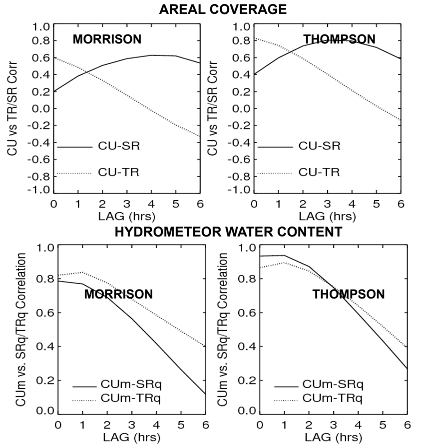
	Morrison	Thompson	Observed
Deep convective	3.2	3.1	8.6
Transition rain	10.9	9.5	-
Stratiform rain	40.3	34.3	33.2

Hydrometeor Profiles



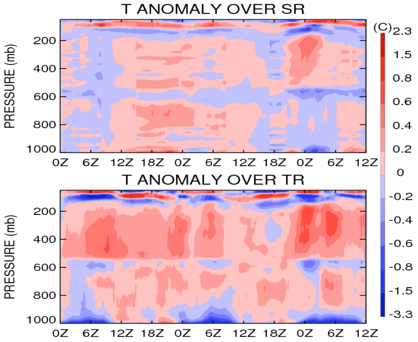
Relative to the Darwin C-POL analysis of Frederick and Schumacher (2008, MWR), the WRF simulates reasonable CU and SR areas during the active period when run with either the Morrison et al. or the Thompson et al. microphysics schemes. The two schemes produce very different amounts of the different hydrometeor types, though. Morrison makes as much CU graupel as snow and even some SR graupel, while Thompson makes much more snow, and almost no graupel in the SR region. The Thompson scheme is designed to simulate drizzle well and assumes large intercepts for its PSDs and hence slow fall speeds.

Lag Correlations CU vs. TR and SR



Relationships between the convective updraft and the anvil are similar for the two microphysics schemes. CU area is correlated with TR area at lag 0 in both schemes, and with SR area at lag 4-5 hr (Morrison) and 3-4 hr (Thompson); Frederick and Schumacher suggest a ~1 hr lag. CU mass flux is a good predictor of TR and SR hydrometeor water content with little lag, suggesting that mesoscale updrafts primarily just re-supply ice lost by sedimentation.

Temperature Anomaly



The TR upper troposphere is ~0.5-1 °C warmer than the domain mean, supporting the idea that this is detrained buoyant convective updraft air. The TR region is also the location of the downdraft cold pools. The SR region is within ~0.2-0.4°C of the domain mean, suggesting that mesoscale updraft adiabatic cooling approximately balances diabatic heating there.

Conclusions

- ➢ Convective updrafts entrain air that is ~10-20% more humid than the typical environment, halving the efficacy of entrainment.
- ➢ WRF relationships between the properties of the convective and stratiform regions are surprisingly similar for two microphysics schemes with different hydrometeor distributions and suggest that mesoscale updrafts merely compensate ice lost by sedimentation.
- ➢ A mesoscale updraft parameterization initialized with the mass flux of detrained air and evolving to a balance between diabatic heating and adiabatic cooling is a plausible approach for GCMs.