P1A.4 RADAR REFLECTIVITY SIMULATED BY A 2-D SPECTRAL BIN MODEL AND ITS SENSITIVITY ON CLOUD-AEROSOL INTERACTION

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1. INTRODUCTION

The Goddard Cumulus Ensemble (GCE) model coupled with the Hebrew University Cloud Model (HUCM) is used to simulate a tropical convective system during TOGA COARE (1993) experiment. GCE and HUCM are fully coupled to simulate realistic interactions between dynamics and microphysics. The model has 1026 horizontal grids and 33 vertical grids. The horizontal resolution is fixed at 750m at the center domain and is stretched towards lateral boundaries. The vertical coordinate was stretched with smallest resolution near the ground. HUCM explicitly simulates microphysical processes for 7 hydrometeorite types: cloud/rain, 3 types of ice (plate, column and branch), aggregates, graupel, hail/frozen drops. Each hydrometeorite type, as well as the atmospheric aerosols is represented by 33 drop size bins. The initial CCN concentration can be varied to assess cloud-aerosol interactions and its effect on precipitation systems. Melting is explicitly represented in this model. A lower level cool pool was used to start the precipitation system. Radiation and surface fluxes were not included in these simulations.

2. SIMULATIONS

Three sensitivity tests are performed to study the aerosol-cloud interaction and its effect on precipitation process. The initial aerosol concentration is specified in terms of cloud condensation nuclei (CCN), which depends on supersaturation S(%): $N_{CCN} = CS^k$. C (cm^{-3}) and k are parameters for different total concentration of atmospheric aerosols. Three pairs of parameters C and k, i.e., (100, 0.42), (600, 0.42), and (2520, 0.308) are used in our simulations. C=100 corresponds to a pristine ocean background, whereas C=2520 represents a heavily polluted background.

Time span of the 2-D bin spectral model simulation is 10 hours. Evolutions of convective systems for all 3 cases are similar. Warm rains dominate in the first 3-4 hours. Strong, deep convections with significant ice contents appear after shallow convection. The intensity of deep convection tends to decrease with time. Some stratiform features start to show at later stage of the 10 hour simulation. Variations of the initial atmospheric aerosol concentration significantly change the duration of the shallow convection stage. The starting time of the deep convection, defined as when the radar echo first reaches 15 km height, is 260 min, 210 min and 180 min for C equals 100, 600, and 2520, respectively.

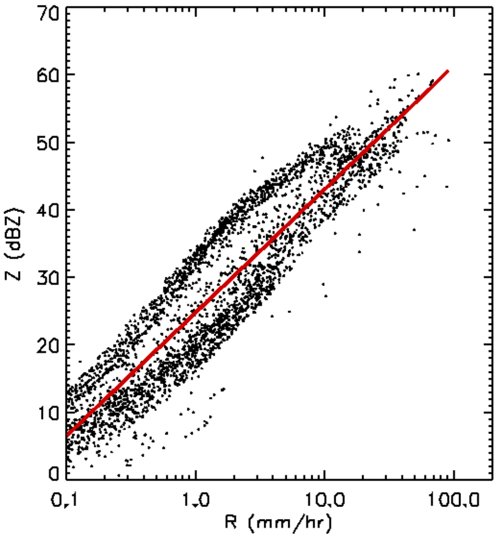

Fig.1: Simulated Z-R relation for C=100 cm^{-3}, k=0.42 case. The best-fit line corresponds to Z=306R$^{1.83}$.

Instantaneous raindrop size distributions at 3.1 km were recorded every 6 minutes at each grid point. Figure 1 shows the Z-R relation for C=100 cm^{-3} case. Vertical air velocity (w) is included in rainfall rate calculations. The least-square fit line is also shown in figure 1, which corresponds to Z-R relation of Z=306R$^{1.83}$. Z-R relations for 3 different sensitivity tests at both 3.1km height and the surface are listed in table 1. At 3.1km, Z-R relation is calculated with or without w. Generally, for a given Z value, the best-fit Z-R relation results less rainfall in more heavily polluted cases. Since Z represents higher momentum of raindrop diameter than R, this means that the polluted air produces rain that has larger mean diameters. Z-R relations listed in table 1 also indicate that they vary with height. At 3.1km, it also depends weakly on if w is considered in rainfall calculation.

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Table 1. Z-R relations in TOGA COARE.

Case	C=100	C=600	C=2520
Surface	$Z=433R^{1.69}$	$Z=495R^{1.70}$	$Z=616R^{1.67}$
3.1 km with w	$Z=306R^{1.83}$	$Z=382R^{1.76}$	$Z=532R^{1.65}$
3.1 km without w	$Z=287R^{1.74}$	$Z=356R^{1.70}$	$Z=514R^{1.60}$
Yuter et. al. (1997)	$Z=261R^{1.45}$ (6s); $Z=137R^{1.76}$ (18s)		
Tokay et.al. (1996)	$Z=315R^{1.20}$		

3. COMPARISON WITH OBSERVATIONS

Two independent raindrop size distribution measurements during TOGA COARE experiment, one from aircraft and the other at surface, are used for comparison with our model simulation. Yuter and Houze (1997) analyzed data collected by PMS 2D precipitation monoprobe mounted on NCAR Electra aircraft. Their data were accumulated over 6s intervals. The flight track over 6s is approximately 750m horizontal distance, which is about the same as the model resolution. The aircraft data were collected between altitude of 2.7 and 3.3 km. Two best-fit Z-R relations were calculated in their paper, with 6s and 18s interval data. The vertical air velocity was assumed zero in their calculation. As listed in table 1, Yuter et. al's observation is comparable with model simulation at 3.1 km. The general pattern of scatter plot shown in figure 1 is also consistent with observed scatter plot. However, both the intercept and slope in simulated Z-R relation tends to be larger than aircraft observation.

Tokay and Short (1996) used distrometer data observed during TOGA COARE to analyze surface Z-R relation. The data were collected by a RD-69 Joss-Waldvogel type distrometer with 1 minute collection resolution. Their best-fit Z-R relation is also listed in table 1. There are differences between surface and aircraft observation, but even larger bias exists when simulations and observations are compared. Again, simulation tends to produce larger drops compared with surface observation.

Figure 2 shows the differences between observation and simulation in more details. Probability matching, which matches the percentile values of Z and R, are plotted for both simulation ($C=100cm^{-3}$) and Yuter et. al.'s observation. In light rains ($R<1mm\ hr^{-1}$), simulation and observation matches very well. However, when rainfall rate is larger than $2mm\ hr^{-1}$, differences between simulation and observation become quite large. The simulations systematically produce larger raindrops at larger rainfall rate. Model simulation also shows that ignoring vertical air velocity at 3.1km does not result large errors in Z-R, which is consistent with Yuter et. al.'s analysis. Compare probability matching curves on the ground and at 3.1km, we find that the discrepancy is mainly at low rainfall rate end. Mean raindrop size is larger at the ground than it is aloft. This may be caused by the raindrop evaporation in these light rain areas.

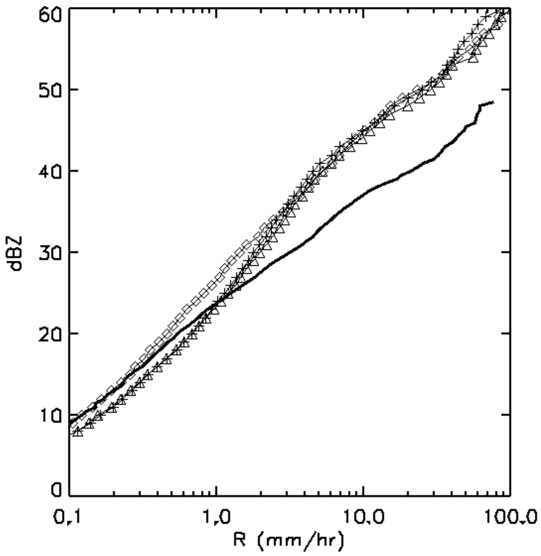

Fig. 2: Probability matching plots of Yuter et. al.Õs observation (solid line), simulated Z-R at surface (diamond), 3.1km with vertical air velocity (+), and 3.1km assuming w=0 (triangle).

4. DISCUSSION

2-D bin spectral model shows that the initial atmospheric aerosol concentration affects both precipitation process and raindrop size distribution in a TOGA COARE convective system simulation.

Z-R relation is a very useful tool in validating simulated raindrop size distribution in our 2-D spectral bin model. Despite uncertainties inherited in different observations, the comparison reveals that 2-D model produces larger raindrops than observations, especially at higher rainfall rates. Further data analysis and model improvement is underway to bring the observed and simulated Z-R relation together.

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