Cloud-Resolving Model Simulation of the July 1997 IOP: Comparison with ARM Data on Short, Medium, and Long Subperiods

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Introduction

The Atmospheric Radiation Measurement (ARM) July 1997 Intensive Operational Period (IOP) data set is used to compare with simulations of University of California-Los Angeles/Colorado State University (UCLA/CSU) cloud resolving model (CRM) over ten subperiods of various durations during the 29-day IOP. Eight of the ten subcases except for Y and Z described below are designed for the ARM/Global Energy and Water Cycle Experiment Cloud Systems Study (GCSS) WG4 intercomparison study (Figure 1; Cederwall et al. 2000; Xu et al. 2000):

- Subcase X (long period): The entire IOP with mixed dry and precipitating subperiods.
- Subcases Y and Z (medium period): The first 15 and the last 15 days of the IOP (with an overlap over 1 day), respectively.
- Subcases A, B, C, and S (short period): 4 to 5 days of mostly precipitating subperiods.
- Subcases R, T, and U (short period): 3 to 4 days of nonprecipitating subperiods.

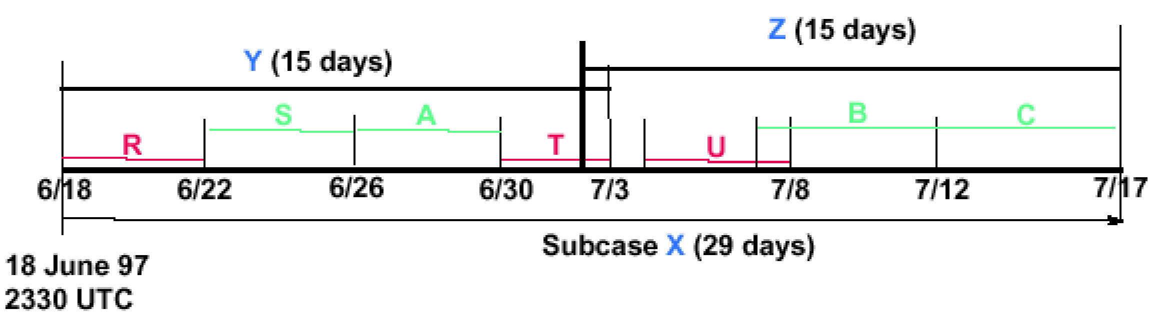

Figure 1. Durations of various subcases from the July 1997 IOP.

The objectives of this study are to estimate 1) the impact of interactive radiation, 2) the performance of the model, and 3) the accuracy of the forcing data on short, medium, and long subperiods. To achieve these objectives, two sets of simulations are performed for all ten subcases, one with interactive radiation (mode 1) and the other with prescribed radiative heating rates (mode 4) obtained from the European Center for Medium-Range Weather Forecasts (ECMWF) (EC Rad).

Results

Against Observations

Figure 2 shows time series of simulated and observed surface precipitation rates and liquid water paths for the entire IOP (subcase X), with both interactive and prescribed radiation. Both simulations produce reasonable results as far as the temporal evolution of convective activity is concerned. The root mean square (rms) errors of temperature (Figure 3) are comparable to the CRM simulations with the July 1995 IOP data (Ghan et al. 2000; Xu and Randall 2000).

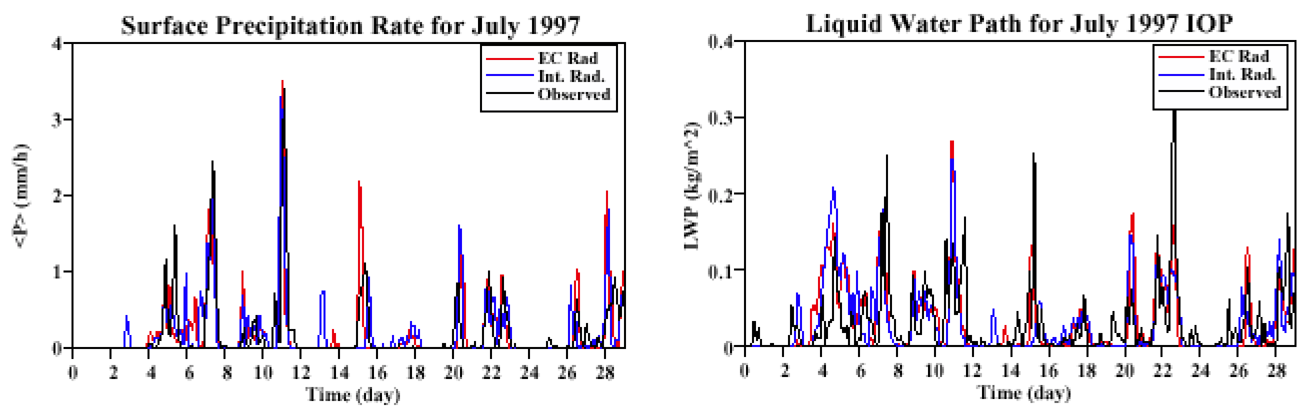

Figure 2. Time series of surface precipitation rates and liquid water paths for subcase X.

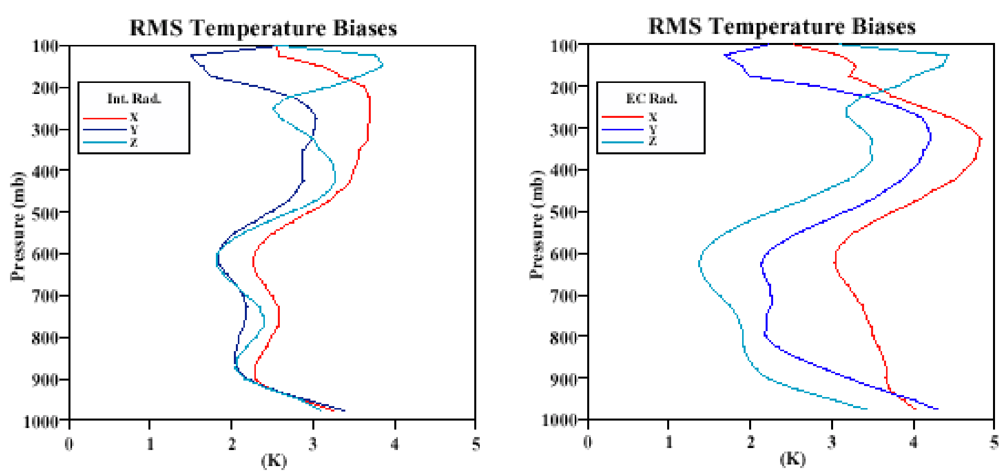

Figure 3. Root mean square errors of temperature with interactive and prescribed radiation.

Impact of Interactive Radiation

The impact of interactive radiation can be assessed with a comparison between interactive and prescribed radiation simulations shown in Figures 3 and 4. For medium and long subperiods, the results clearly show that the presence of cloud-radiation interactions reduces the temperature errors (slightly smaller moisture errors, not shown) except for the middle troposphere in subcase Z. For shorter subperiods (Figure 4), cloud-radiation interactions do not substantially impact the temperature errors of the simulations. The temporal correlation coefficients for temperature and moisture (not shown) support the same conclusions obtained from Figures 3 and 4.

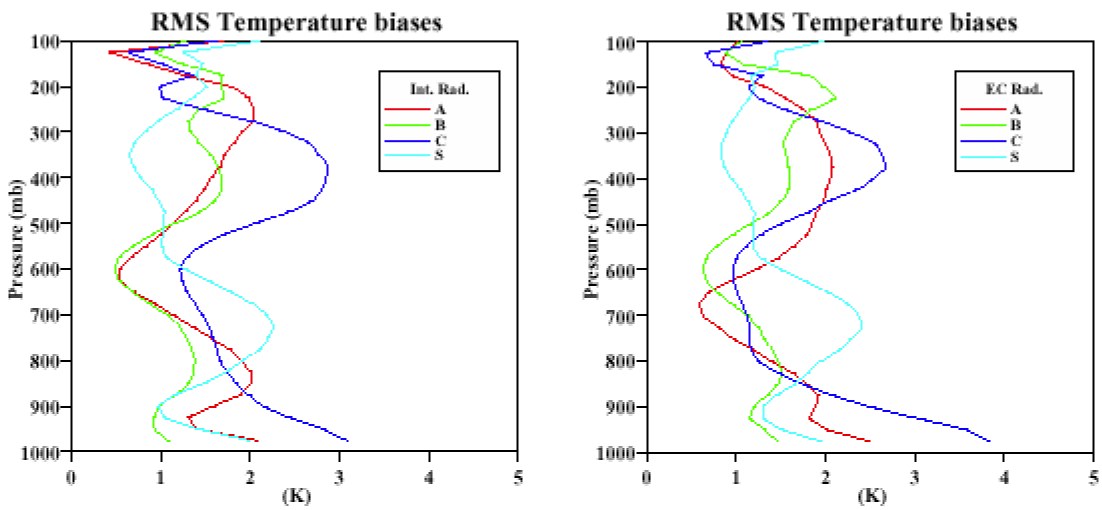

Figure 4. Same as Figure 2 except for subcases A, B, C, and S.

Performance of the Model and the Accuracy of the Forcing Data

The performance of the model can be seen from Table 1, which shows the subcase mean precipitable water, liquid water path, surface precipitation rate, and column cloud fraction. A few features can be summarized from Table 1: a) the simulated precipitable water is rather close to the observed with the prescribed ECMWF radiative heating rates, but underestimated with the interactive radiation; b) liquid water path and surface precipitation rates are close to the observed in both modes of simulations for medium and long subperiods, but more underestimated with the prescribed ECMWF radiation for short-period simulations, and c) the CRM consistently underestimates the column cloud fraction. The second feature is partially related to the initiation processes in the model, due to the lack of mesoscale circulations at the beginning of each simulation. The underestimate of column cloud fraction is related to both cloud microphysics parameterization in the model and the lack of horizontal condensate advection (Xu et al. 2000).

Table 1. A comparison of subcase mean properties.

	X1	X4	Obs.		Y1	Y4	Obs.
Precipitable Water, mm	32.62	35.55	36.52		33.98	36.59	36.55
LWP, mm	0.031	0.032	0.030		0.035	0.037	0.030
<P>, mm h^{-1}	0.186	0.177	0.179		0.204	0.202	0.198
Cloud Fraction, %	28.1	27.1	44.1		25.9	26.5	38.9
	A1	**A4**	**Obs.**		**B1**	**B4**	**Obs.**
Precipitable Water, mm	37.04	38.49	39.07		38.66	41.02	41.25
LWP, mm	0.027	0.029	0.047		0.032	0.034	0.041
<P>, mm h^{-1}	0.330	0.304	0.343		0.197	0.174	0.194
Cloud Fraction, %	15.1	11.8	47.0		18.9	17.7	52.7
	C1	**C4**	**Obs.**		**S1**	**S4**	**Obs.**
Precipitable Water, mm	36.66	38.67	38.39		39.91	41.02	41.41
LWP, mm	0.021	0.021	0.028		0.051	0.052	0.048
<P>, mm h^{-1}	0.172	0.160	0.174		0.365	0.354	0.390
Cloud Fraction, %	20.6	20.8	53.5		34.6	33.7	66.9

Against ECMWF Radiation

Figure 5 shows a comparison between the simulated and prescribed ECMWF radiative heating rates for all subcases. The temporal correlation coefficients exceed 0.5 for most heights except for the upper troposphere (above 300 h Pa) and near the surface. The correlation is also higher for dry subperiods and short subperiods than it is for the long subperiods. The mean errors for each subcase are mostly negative for precipitating subperiods, which may be related to the underestimate of the column cloud fractions by the model (Table 1). For the dry subperiods, positive mean errors occur for one subcase. Overall, the CRM radiative heating rates show some differences from the ECMWF data, which impact the simulated results previously discussed.

Summary of the Results

1. Interactive radiation in the CRM has more impacts on longer-period simulations, which tends to produce smaller rms errors (~1 K and ~0.5 g/kg).

2. The simulated amount of precipitation tends to agree with observation better with interactive radiation than with prescribed radiative heating rates; the opposite is, however, basically true for precipitable water.

3. The largest biases occur at selected short durations for short- or long-period simulations, implying inherent errors in the forcing data.

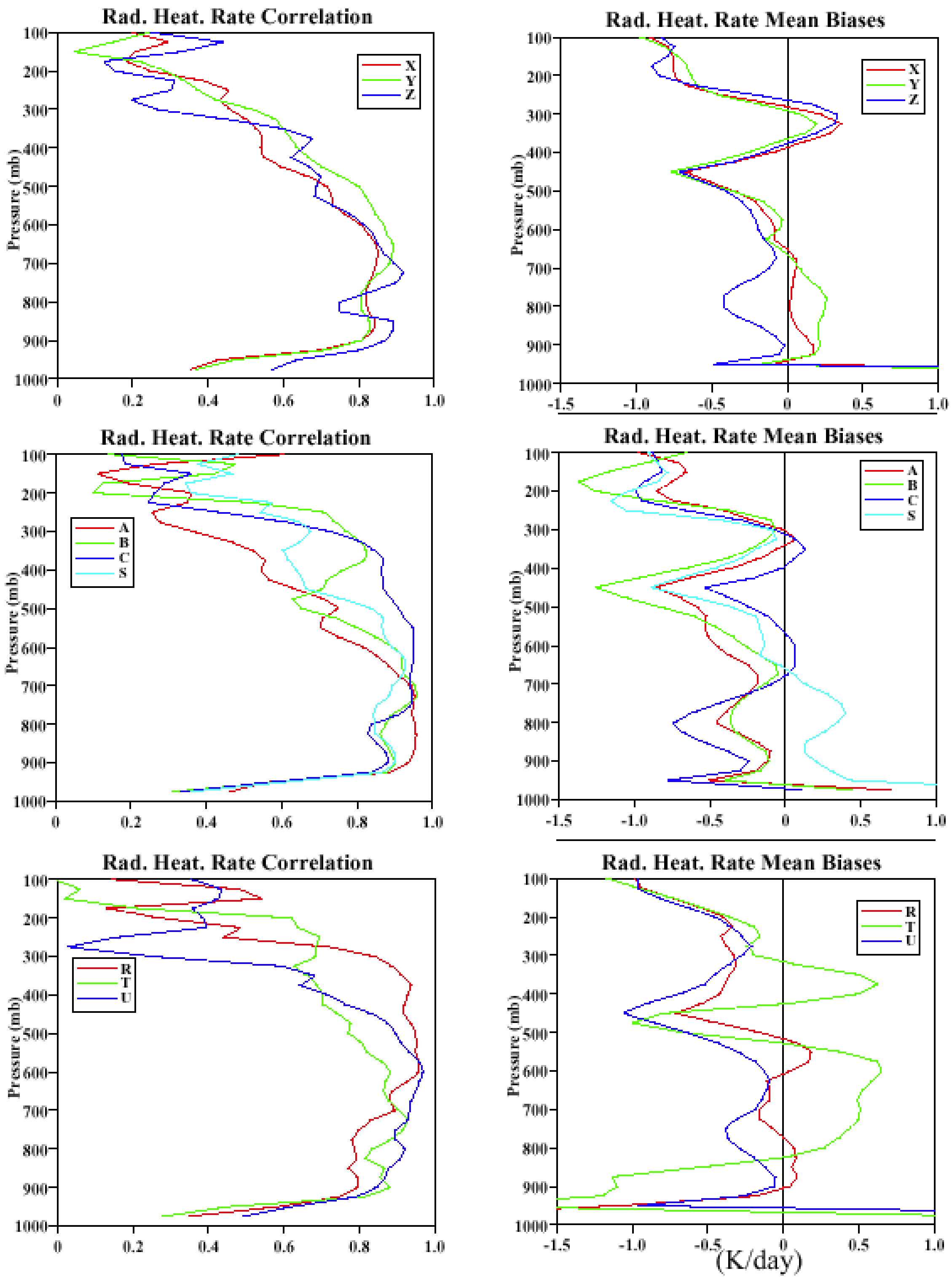

Figure 5. Vertical profiles of the temporal correlation coefficients and the mean errors of radiative heating rates for all subcases.

4. The simulations for nonprecipitating subperiods are not necessarily better than for precipitating subperiods.

5. The model has comparable or slightly underestimated case-mean liquid water paths than the observed, but significantly underestimated column cloud fractions, compared to satellite observations, especially for short-period simulations. The homogeneous initial soundings for short-period simulations, cloud microphysics parameterization, and the lack of large-scale advection of condensate are possible causes.

6. The CRM produces more radiative cooling than the ECMWF radiation but their correlation is always positive and very high. Underestimates of clouds are partially responsible for this discrepancy.

7. Although the rms errors of temperature and moisture are smaller for short-period simulations, it is more difficult to get higher correlation between observed and simulated variables for such simulations, due to the difficulties with the initiation processes in the model. Adding some initial mesoscale circulations to the initial homogeneous sounding may be helpful.

Acknowledgments

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