8.3 A CLOUD MODEL SENSITIVITY STUDY OF THE ENVIRONMENTAL TEMPERATURE PROFILE ON THE THUNDERSTORM DEVELOPMENT

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1. INTRODUCTION

It is well known that atmospheric temperature and humidity conditions affect the thunderstorm development as they are the main deciding factors influencing the storm thermodynamics. Previous studies show that thermodynamic indices are useful in predicting the thunderstorm development.

However, the detailed processes in which a storm may respond to changing environmental temperature and humidity conditions are not well understood (Ye et al., 1998). It is often difficult to study such processes by comparing one storm with another from observational data because of the very complicated environmental conditions associated with these storms. Soundings that are related to the storms are often taken before or after the storms and it is quite possible that storms developed in very different environmental conditions not represented by these soundings. On the other hand, a well-formulated storm model is very convenient for this purpose because one can vary key parameters while keeping others unchanged. This paper reports on the results on a sensitivity study based on this technique.

2. NUMERICAL MODEL DESCRIPTION

The model used in these studies is Wisconsin Dynamical/Microphysical Model (WISCDYMM) (Straka, 1989; Johnson et al., 1993, 1995; Wang, 2003; Lin et al., 2005). It is a time dependent, three dimensional, non-hydrostatic cloud model based on the primitive equations cast in quasi-compressible form. Twelve dependent variables are predicted, which include velocity components in X, Y and Z directions (u,v,w), pressure (p), potential temperature (θ), turbulent kinetic energy(TKE), mixing ratio of water vapor (qv), bulk cloud water (qc), bulk cloud ice (qi), bulk rain water (qr), bulk snow aggregates (qs), and bulk graupel/hail (qh) (Straka, 1989). The model considers 38 microphysical processes incorporated in the model, which including nucleation, condensation, evaporation, freezing, melting, sublimation, deposition, autoconversion and accretion.

The domain used for this study was 55 x 55 x 20 km^3 with a 1 km horizontal resolution and 200m vertical resolution. A 2-sec time step was used in all experiments and the model output was analyzed every 2 min.

The convection was triggered by a warm bubble, similar that used in Klemp and Wilhelmson (1978). The warm bubble was located in the center of the horizontal domain and 2km above the surface, and its size was 20km horizontally and 4km deep. The maximum thermal perturbation is 3.5K in the center of the bubble and the relative humidity (RH) is made to be the same as that in the surrounding area.

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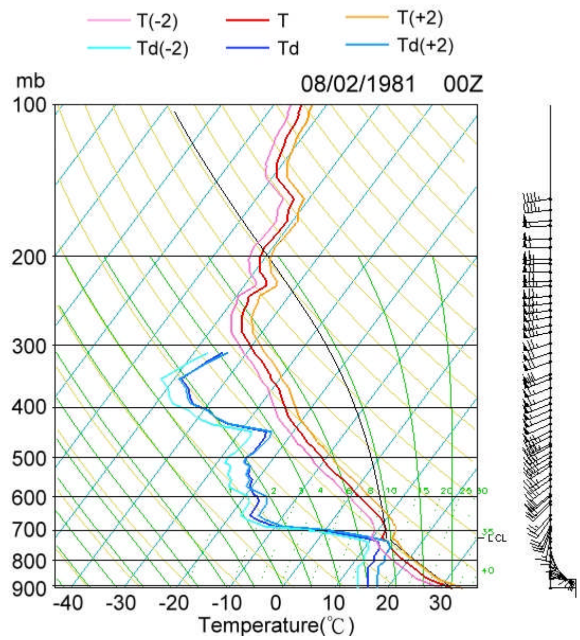

Figure 1 The initial vertical profiles of the experiments. The COOPE sounding is used for control run, and modify the temperature profile by adding +2℃ (warm case) and -2℃ (cold case) to the temperatures at each level. In all experiments, the relative humidity and vertical wind shear are fixed. The CAPE values are 3718.72 J/kg, 3277.78 and 4208.71 J/kg for the control run, cold case and warm case.

In order to keep the storm within the domain during the simulation, we subtracted the mean horizontal wind (u,v), which depends on the storm movement, so as to locate the storm (defined as the position of the strongest vertical motion) near the center of the domain.

3. SIMULATION SETTING

The model storm used in this study was a super-cell storm, which passed through the center of the Cooperative Convective Precipitation Experiment (CCOPE) observational network in southeastern Montana on 2 August1981 (Knight, 1982). The control case using the original CCOPE sounding is executed first. Then the temperature profile was modified by adding +2℃ (warm case) and -2℃ (cold case) to the temperatures at each level. In all experiments, the relative humidity and vertical wind shear were kept constant. Figure 1 shows the three soundings (one original plus two modified) used for this study.

4. RESULTS AND DISCUSSION

4.1 Thunderstorm development

The convections were triggered successfully in all three experiments. Figure 2 shows the simulated of 90% RHi (relative humidity with respect to ice) contour surfaces for the three cases at t = 120 min. It is clear that the upstream edge of the anvil in warm case is higher and the anvil wider at 120 min into the simulation. But the warm case the cloud appeared later and the cloud layer thinner in the first 10 min

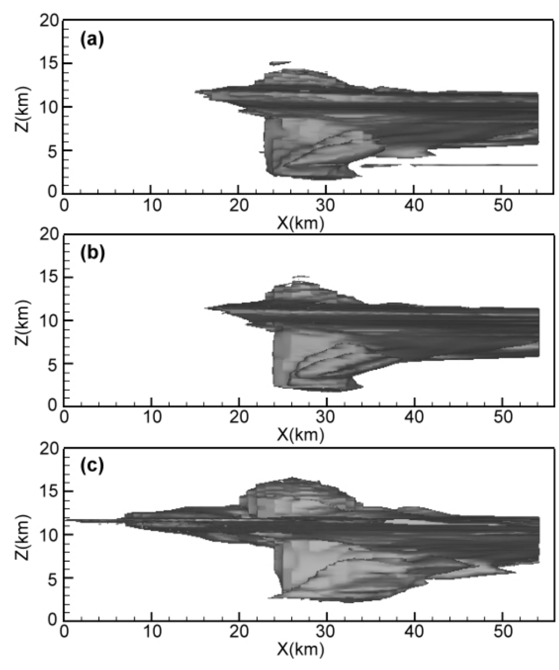

Figure 2 The side view of the simulated 90% RHi surface at 120 min. (a) control case, (b) cold case, and (c) warm case.

than the other two cases. The cold storm not only has thicker initial cloud layer but also more vigorous cloud top plum.

4.2 Vertical motion

Figure 3 shows the vertical velocity contours at the 40 and 60 min. The warm case has strongest updraft and induces strongest divergence at the cloud top. Somewhat surprising is the updraft of the cold case which was stronger than the control case between 30 min and 70 min. This is probably because the latent heat release in the cold case is stronger than the control case. This is demonstrated in figure 4 which shows that the mixing ratios of water substance in the cold case are larger than the control

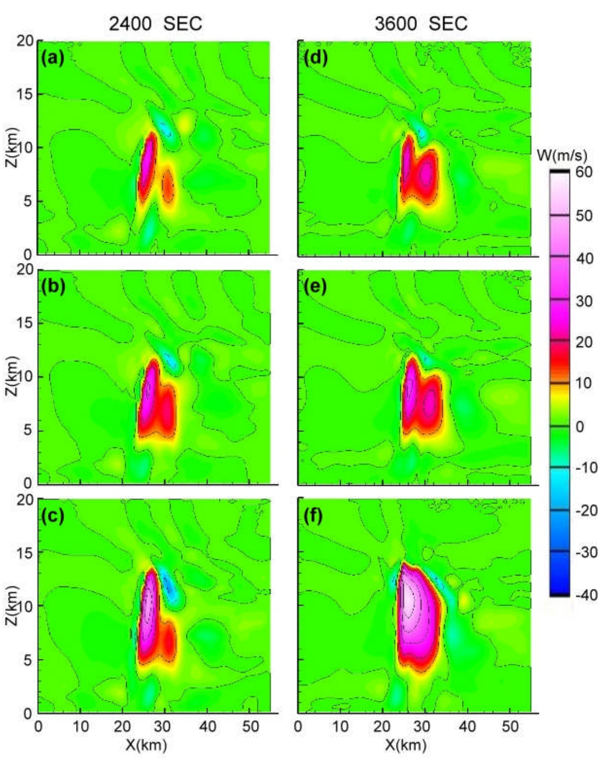

Figure 3 The X-Z cross section (y=28 km) of vertical velocity w at 2400 sec and 3600 sec. (a) & (d) control case, (b) & (e) cold case, and (c) & (f) warm case. The contour interval is 10 m/s.

case except the bulk snow aggregates. This results in more latent heat release that may trigger stronger updrafts.

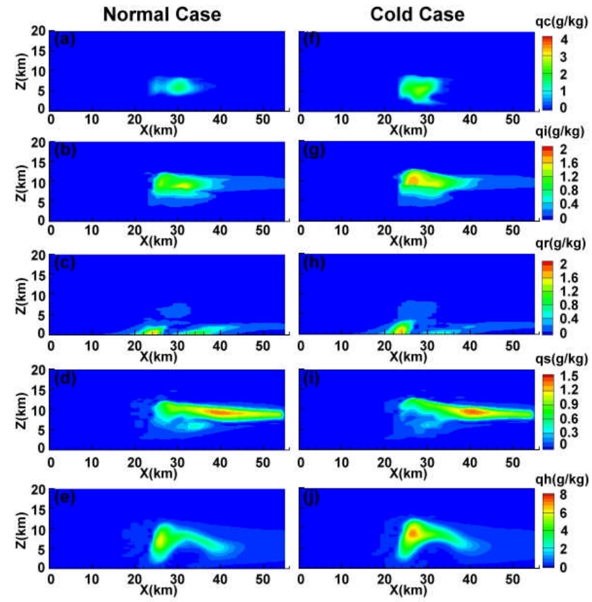

Figure 4 The X-Z cross section (y=28 km) of water substance content at 3600 sec output. (a) to (e) control case and (f) to (j) cold case. The water substance include the mixing ratio of bulk cloud water (qc), bulk cloud ice (qi), bulk rain water (qr), bulk snow aggregates (qs), and bulk graupel/hail (qh).

Other results of the sensitivity study will be reported in the conference.

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