Numerical Simulations of Flanking Line Phenomena

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1 Introduction

One feature of a supercell thunderstorm which is regularly observed is the flanking line, a line of cumulus congestus which forms behind the leading edge of the gust front. While much of the numerical research on the dynamical behavior of isolated supercell thunderstorms has focused on the main updraft/downdrafts and on the tornadic region of the storm, exploration of flanking line behavior has remained predominately an observational exercise. Lemon (1976) observed that the strength of an observed supercell was intensified as the cells from the flanking line merged with the main updraft. Recently, similar updraft intensification via cell merging has been observed in numerical simulations of high-precipitation supercells (Kulie and Lin 1998; Finley et al. 2001).

2 Objectives of this study

Continuing the work done by Mlodzik (1998), this study's focus is flanking line, specifically its evolution, sensitivity to environmental factors, and influence on the main supercell updraft. ICOMMAS, a three-dimensional nonhydrostatic cloud model with explicit ice microphysics, is used for these numerical simulations. ICOMMAS is a descendant of the COMMAS (Collaborative Model for Multiscale Atmospheric Simulation) model, which itself is based upon the Klemp-Wilhelmson three-dimensional cloud model (Klemp and Wilhelmson 1978).

3 Methodology

A control run is made which produces a flanking line which is the source of notable convection. This control run is initialized with an environment based upon the

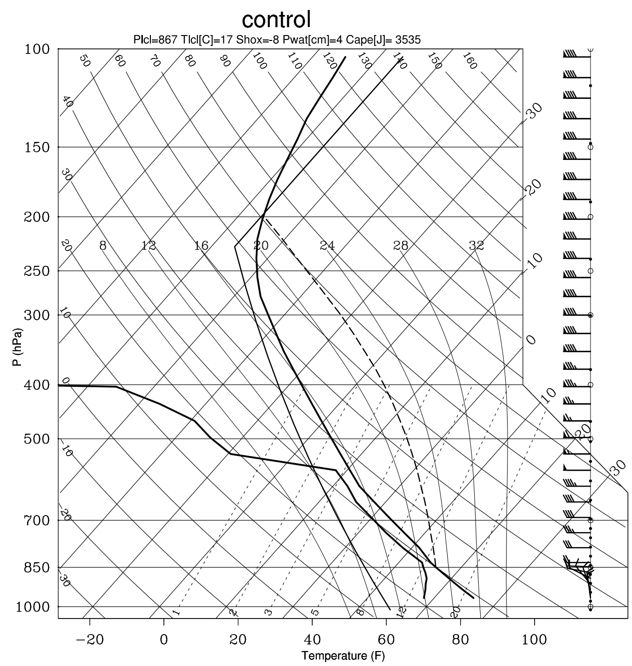

Figure 1: Environmental sounding used for the control simulation.

3 April 1964 Wichita Falls sounding (Wilhelmson and Klemp 1981) (see Fig. 1). In addition, four other simulations are integrated, each of which contains an environment slightly perturbed from the control environment. A capping inversion is included in two of the perturbed soundings, and one sounding contains a significantly dryer mid-atmosphere. The fourth contains both a cap and a dry mid-atmosphere.

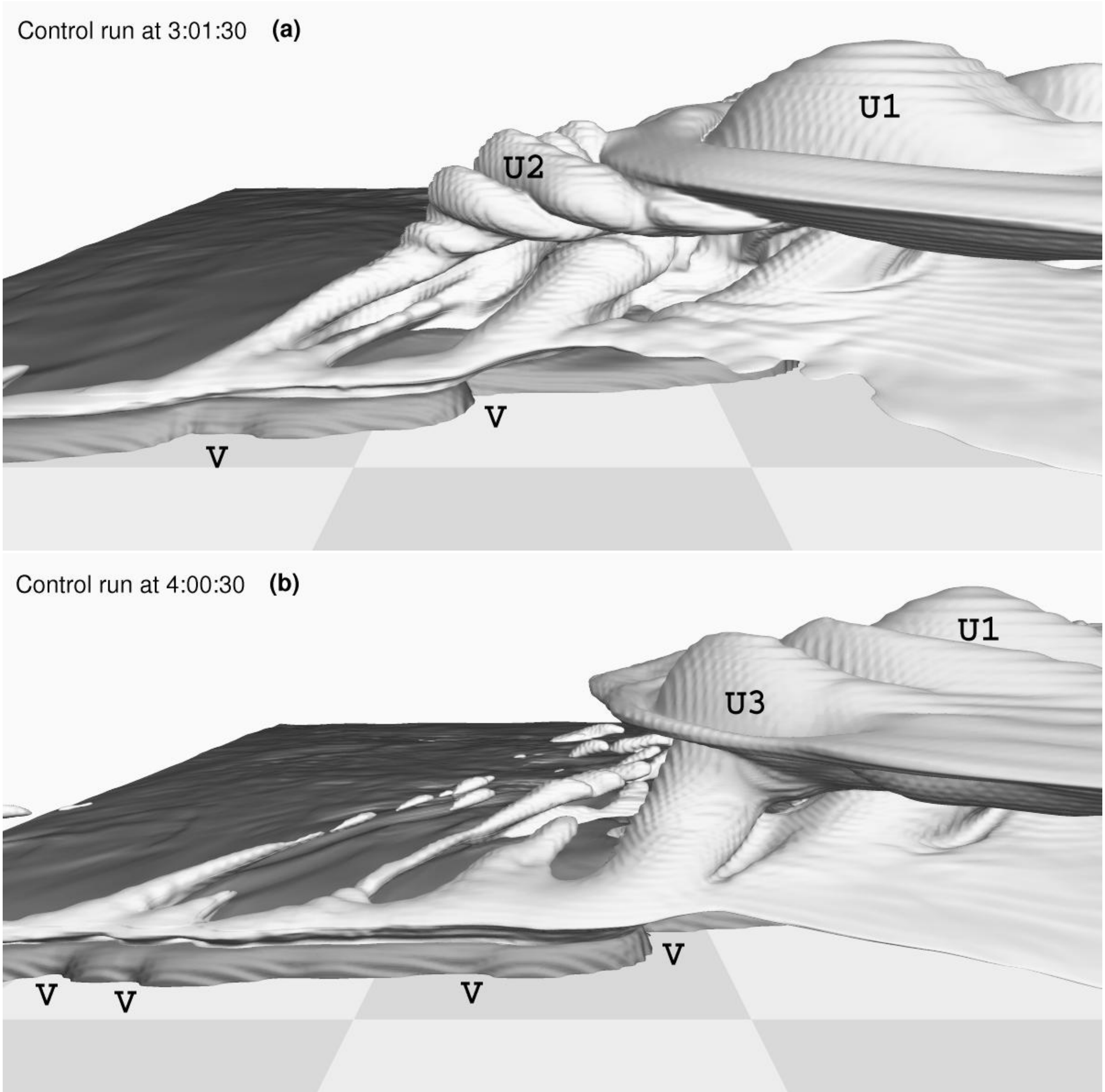

Figure 2: Control run isosurface renderings of cloud water and cloud ice (Qc+Qi = 0.2 $g\,kg^{-1}$, light grey surface) and potential temperature ($\theta = 302\,K$, dark grey surface) at (a) 3h01m30s and (b) 4h00m30s. U1 represents the location of the main supercell updraft. U2 and U3 represent the location of updrafts which form along the flanking line. V marks the location of vertical vorticity maxima. Grid squares are 20 km $\times$ 20 km.

4 Simulations

At the time of this writing, the control simulation has been integrated out to 6 hours model time. The control simulation exhibits a long-lived supercell with an updraft consistently exceeding 45 $\mathrm{m\,s^{-1}}$ (labeled U1 in Fig. 2) and a distinct flanking line which evolves throughout the simulation, producing convection with updrafts in excess of 30 $\mathrm{m\,s^{-1}}$. Convection along the flanking is swept behind and into convection of the main supercell; however, updraft mergers are not clearly observed in this simulation. In fact, the cell labeled U3 in Fig. 2b appears to "spin off" of the supercell updraft before dissipating.

Throughout the control run, low-level vertical vorticity maxima occur along the leading edge of the cold pool and propagate away from the main storm. These vorticity maxima (labeled V in Fig. 2) are associated with flanking line convection which in some cases grows to produce updrafts in excess of 30 $\mathrm{m\,s^{-1}}$. U2 and U3 from Fig. 2 are two such updrafts. It is unclear whether convection at these locations is initiated by the voritcity maxima or some other mechanism; however, convection does appear to enhance vorticity, and a likely mechanism is stretching of existing vorticity by the updrafts. The vorticity maxima are never observed to propagate towards the supercell during the control simulation.

5 Work In Progress

A new cloud model has been used to create a long integration of a supercell thunderstorm which contains a persistent flanking line. The flanking line is the source of notable convection and is associated with vorticity maxima which occur along the leading edge of the cold pool. However, the cause of these features and their correlation with convection is currently not known. Work in progress includes a deeper analysis of the control run simulation including vorticity budget and trajectory analysis. Once the control simulation has been analyzed, simulations with perturbed environments will be integrated and analyzed in order to understand the factors which influence the morphology of the flanking line and its influence on the main supercell updraft.

6 Acknowledgments

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