WHAT CAUSES MAMMATUS?

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I. INTRODUCTION

Mammatus are hanging lobes on the underside of clouds, typically cumulonimbus anvils, although many other parent cloud types have been observed (e.g., Schultz et al. 2006). Despite mammatus being some of the most photographed and aesthetically pleasing cloud forms, relatively little is known about the environment, origin, structure, size, microphysical properties, and dynamics of mammatus. A comprehensive review of observations and proposed formation mechanisms appears in Schultz et al. (2006), who documented no less than ten different proposed formation mechanisms. Because observations of mammatus are often limited to those taken from just one type of observing system and do not include all the thermodynamic, moisture, and dynamic measurements complete in space and time, rigorous evaluation of these proposed mechanisms is difficult. Thus, numerical simulations provide an attractive methodology to evaluate some of these proposed formation mechanisms.

Our purpose is to evaluate several of the proposed formation mechanisms discussed in Schultz et al. (2006) using idealized numerical simulations of cirrus anvils of cumulonimbus. These model experiments allow systematic evaluation of several of the proposed mechanisms. Thus, we can explore the sensitivity of the modeled mammatus to changes in physical processes and the environment.

II. METHODOLOGY

The model is the Straka Atmospheric Model, a three-dimensional, fully compressible nonhydrostatic model. The model domain consists of a portion of the anvil, and the simulations are initialized with observed soundings from environments characterized by anvils with and without mammatus observed on their underside. The simulations in this study build upon Kanak and Straka (2006), who explicitly simulated mammatus in a model simulation initialized with an observed cirrus anvil over Norman, Oklahoma, on 20 May 2001. This anvil had mammatus around the time of the sounding launch.

III. RESULTS AND CONCLUSIONS

The model simulation was performed for a total of 40 minutes. After about 15–20 minutes, the descending layers of hydrometeors began to develop perturbations on the lower cloud surface By 30 minutes, these perturbations had developed into fully developed mammatus (Fig. 1). To represent the visual boundaries of mammatus that closely represent what a human observer would see from the round, mean snow-aggregate diameter is plotted because it is related to cloud opacity and visibility.

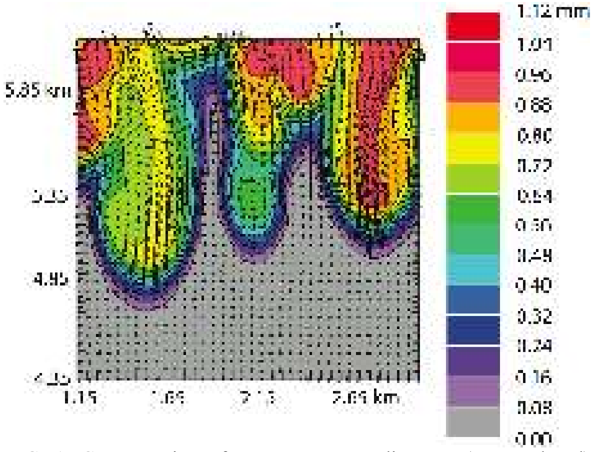

FIG. 1: Cross section of snow-aggregate diameter (mm, colored) with velocity vectors. The longest vector corresponds to a wind speed of 7.57 m s^{-1}.

The descent of the mammatus-laden cloud deck resulted in cooling and moistening of the initial sounding. Our experiments, described in Kanak and Straka (2006) and Kanak et al. (2007), show that cooling due to sublimation was the largest term producing negative buoyancy in the mammatus and is the mostly likely process associated with mammatus formation in this experimental setup.

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V. REFERENCES

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