P4.2 MODELING FREEZING DRIZZLE IN CLOUD AND Mesoscale MODELS.

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Introduction

Understanding the physical processes that lead to the formation of freezing drizzle is of critical importance to forecasting aircraft icing conditions in cloud-resolving and mesoscale forecast models. Freezing drizzle is normally formed by either classical or non-classical mechanisms. The classical mechanism is involves ice particles falling through a warm melting layer and subsequently into a cooler sub-freezing layer. Such situations often occur during wintertime warm fronts in the mid-west and eastern U.S. The non-classical mechanism entails the formation of drizzles by condensation of cloud droplets followed by collision and coalescence growth. This process is often termed the warm-rain process. This mechanism typically occurs within a temperature range of 0 C. to -10 C. where significant cloud water exists and little natural ice nuclei are active. The current thought is that the non-classical mechanism is not sufficiently represented by current microphysical parameterizations used in operational forecast models.

The early work of Kessler (1969) provided a popular method to predict the formation of rain water from cloud water. This method continues to be in widespread use today. The method is based upon a scale analysis of precipitation formation. A short coming of the Kessler scheme is the lack of any treatment of cloud droplet nucleation from cloud condensation nuclei (CCN) and the dependence of the auto-conversion threshold on cloud droplet spectral shape. The present work is inspired by the warm-rain parameterization schemes of Cohard *et. al.* (1998), Cohard and Pinty (2000a,2000b), and Khairoutdinov and Kogan (2000), who have developed warm-rain parameterizations that include these important physical details of condensation and coalescence. These methods are based upon extensive comparisons of detailed bin spectral models.

Model Description

The present dynamical framework is the dynamical nested grid non-hydrostatic Penn State-NCAR Mesoscale Model (MM5), (Dudhia,1993). The bulk physical microphysical parameterization scheme for the ice phase generally follows the work of Reisner *et. al.* (1998) that is based upon the earlier works of Rutledge and Hobbs (1983,1984), Lin, Farley and Orville (1983), and Murakami (1990). For the liquid water phase (cloud droplets and rain), the Cohard *et. al.* (1998) analytical treatment of cloud condensation nucleation and the Khairoutdinov and Kogan (2000) stochastic collision-coalescence bulk parameterization are included. A numerical simulation of the 1990 Valentine's Day storm that occurred during the WISP 1990 field project was made. The cloud condensational nuclei spectra assumed a simple power law,

$$\eta = CS^k \tag{1}$$

where S is the supersaturation with respect to water for the present simulation. The more complex activation function of Cohard *et. al.* (1998) will be used in the future. Results from 3 microphysical treatments will be presented. The 3 cases are:

1. Kessler scheme with a well tuned auto-conversion threshold of 0.35 g/kg.
2. New approach with C= 100/cc and k=0.5.
3. New approach with C= 1000/cc and k=0.5.

1990 Valentine's Day Storm

The 1990 Valentine's Day arctic outbreak case study, (Rasmussen *et. al.*,1995), provides an excellent example of a freezing drizzle and snow event along the front range of the Colorado Rocky mountains. This case has a well-documented temporal and spatial mesoscale storm structure and additional *in situ* microphysical data are available for model verification.

The MM5 model experimental set-up included 3 nested domains with horizontal resolutions of 60, 20, and 6.67 km. The vertical coordinate in each domain was the same with 31 levels with a stretched vertical resolution of 40 meters near the surface increasing smoothly to 1 km at 14 km level (top of domain). Domain 1 is on a continental scale covering the US and parts of Canada and Mexico with the 2nd and 3rd domains with increasing resolution focusing on a regional scale centered along the Colorado Rocky Mountain front range. The model was

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initialized at 12 UTC Feb. 12, 1990 and run for 36 hours until 00 UTC Feb 14, 1990. Domains 2 and 3 were started 2 hours and 3 hours, respectively, from the initial start time.

The mesoscale flow structure for this day is complex as are most wintertime upslope events associated with cold frontal systems. Plotted in figures 1 and 2 are the horizontal wind vectors at the 2 km and 3 km levels at 1 UTC Feb 13. The terrain of the 3rd domain is also presented with the Colorado state boundary with Wyoming, Nebraska, and Kansas given for reference. These figures show the presence of a low-level anti-cyclonic vortex. At this time the initial cold front was just beginning to enter the state of Colorado. These low-level circulations have a strong influence on the formation of freezing drizzle. Figure 3 for case 2 shows a darkened area where the freezing drizzle exceeds 0.01 g/kg and the 2.5 km horizontal wind vectors. It can be seen that the low level pre-frontal anti-cyclone is providing some enhanced dynamical uplifting that contributes to the drizzle formation.

By 9 UTC the initial front had moved south through the 3rd domain region leaving only a few remnants of the front that had not risen over the Palmer Divide. At this time the low level circulation had changed to a cyclonic vortex. This is illustrated in figures 4 and 5 showing the horizontal wind vectors at the 2 km and 3 km levels at 9 UTC Feb 13. Shown in figure 6 is the location of the freezing drizzle with the 2.5 km vectors at 9 UTC for case 2. It is clear evidence that the mesoscale circulation is affecting the location and magnitude of the drizzle production.

Figures 7 and 8 are, respectively, results from cases 1 and 3 showing the location of the freezing drizzle with the 2.5 km vectors at 9 UTC. Figure 7 shows that using a well-tuned Kessler scheme with an auto-conversion threshold of 0.35 g/kg (case 1) yields somewhat larger amounts of freezing drizzle. Figure 8 illustrates that using a more continental CCN spectra will result in much less drizzle formation via the coalescence processes.

Future work

The incorporation of the improved physically based warm rain bulk parameterization yielded freezing drizzle amounts that are sensitive to the assumed CCN spectra. Many questions remain as to the suitability of using explicit bulk parameterization schemes where the dynamical representation may be inadequately representing the dominant motions controlling precipitation development. Further work includes testing the application of other cloud condensation activation spectra and the analysis of the ice phase role in providing competing processes to drizzle formation. A complete analysis of the case, including much finer resolution studies, will be reported at the conference.

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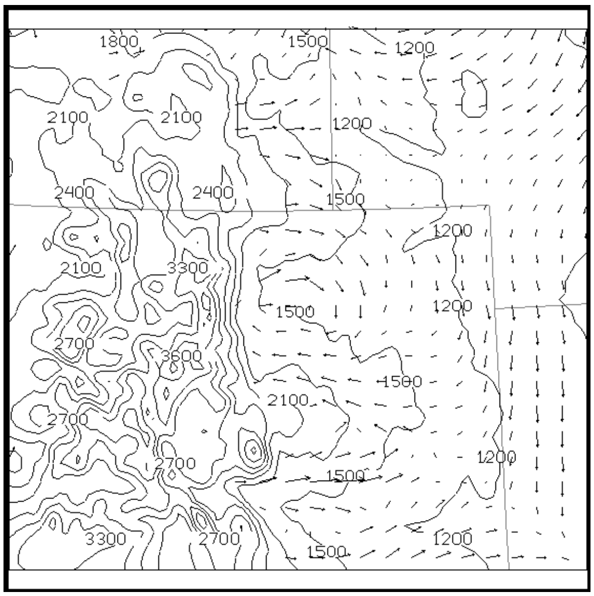

Figure 1: Horizontal Wind vectors at 2 km at 1 UTC Feb 13.

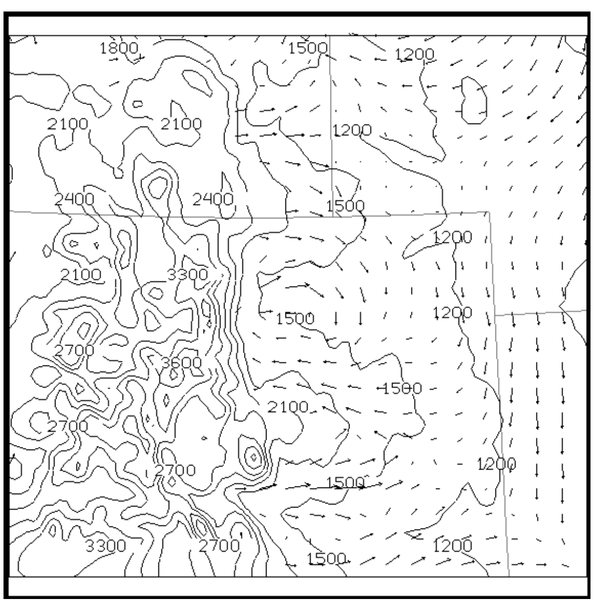

Figure 2: Horizontal Wind vectors at 3 km at 1 UTC Feb 13.

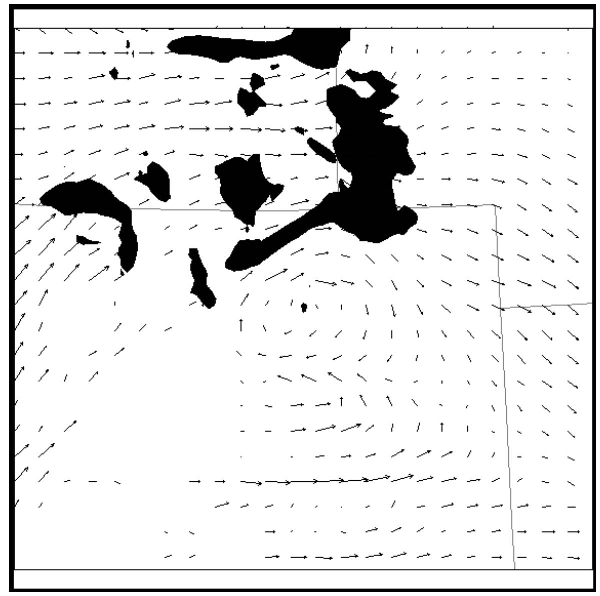

Figure 3: Horizontal Wind vectors at 2.5 and dark area showing region where the drizzle concentration is greator than 0.01 g/kg at 1 UTC for case 2.

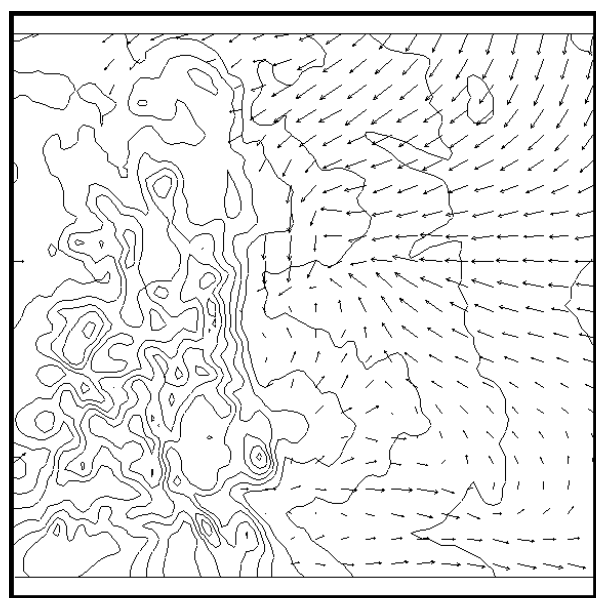

Figure 4: Horizontal Wind vectors at 2 km at 9 UTC.

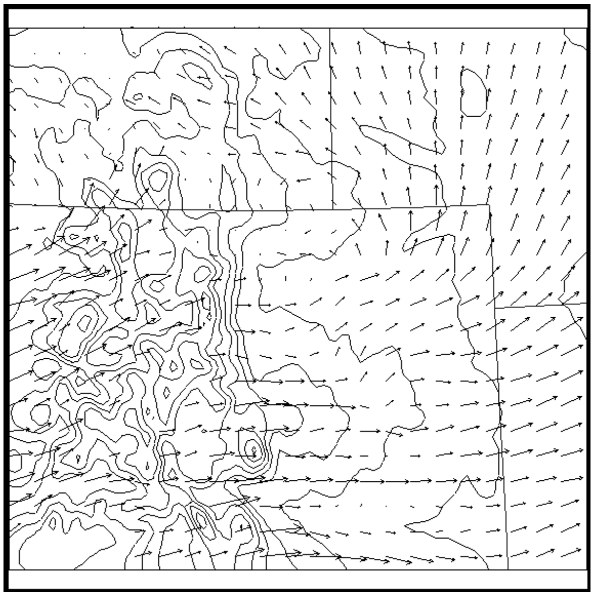

Figure 5: Horizontal Wind vectors at 3 km. at 9 UTC.

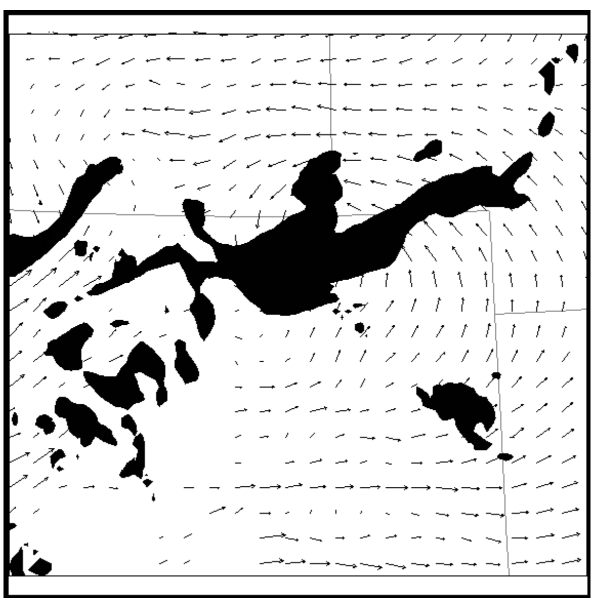

Figure 6: Horizontal Wind vectors at 2.5 and dark area showing region where the drizzle concentration is greator than 0.01 g/kg at 9 UTC for case 2.

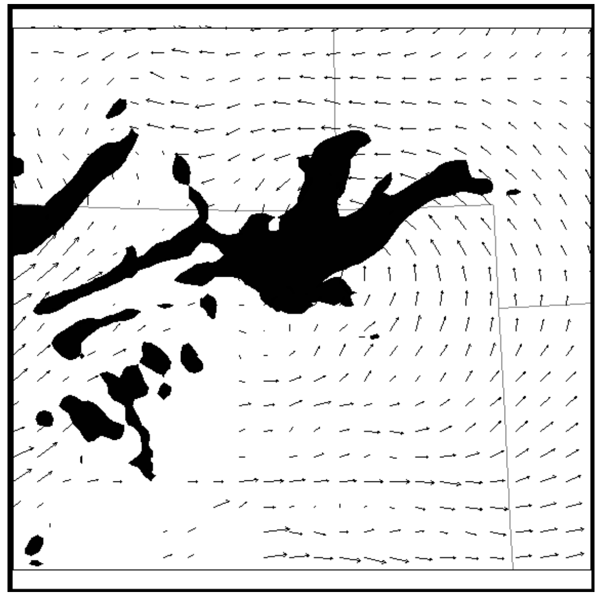

Figure 7: Horizontal Wind vectors at 2.5 and dark area showing region where the drizzle concentration is greator than 0.01 g/kg at 9 UTC for case 1.

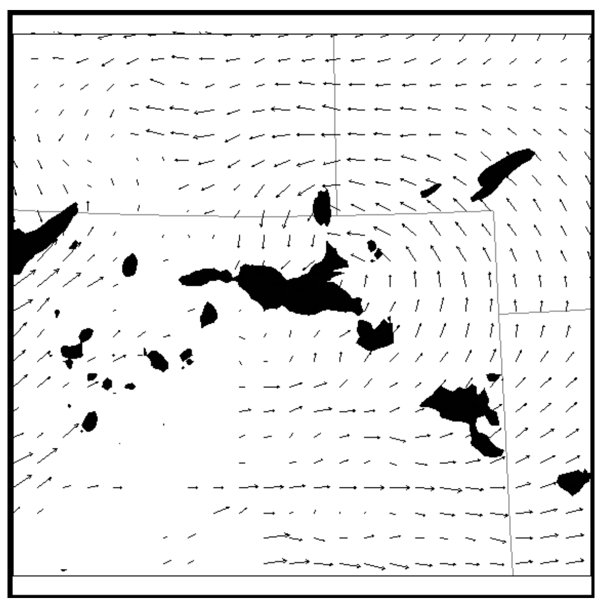

Figure 8: Horizontal Wind vectors at 2.5 and dark area showing region where the drizzle concentration is greator than 0.01 g/kg at 9 UTC for case 3.