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9B.6 PREDICTION OF THE TIMING OF CONVECTIVE INITIATION ALONG A DRYLINE IN A HIGH-RESOLUTION MODEL

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1. INTRODUCTION

Convective initiation (CI) in the atmosphere is a classic example of nonlinear behavior. The details of how CI occurs depends on how factors supporting CI (instability, quasi-geostrophic forcing, low-level convergence, the action of horizontal convective rolls (Xue and Martin 2006a,b), terrain effects, etc.) combine with factors suppressing CI (inversion strength, cloudiness, etc.). (Mullen and Baumhefner 1994) found that small perturbations in low-level moisture in a domain could lead to CI when it otherwise would not happen, and Martin and Xue (2006) found that perturbations in boundary-layer humidity over an area as small as 27 km^2 can make the difference between the initiation of a strong storm and no storm at all.

The evolution of the dryline, a common location for CI, has also been found to be sensitive to modeling parameters. Ziegler et al. (1995) found that the location of the dryline in the afternoon strongly depended on the soil moisture gradient.

From a forecasting perspective, the timing and location of CI (and whether convection initiates or not) present an important problem. The future weather can depend dramatically on the details of CI.

In this paper we look in some detail at factors which are believed to affect CI by experiments with a high-resolution numerical model for a particular case.

The model used for the experiments is the ARPS model. The experiments focus on a dryline CI case from the IHOP field program which occurred on 24 May 2002.

The model simulation is first run at 3 km resolution from an 18 UTC initial condition for 6 hours to 0 UTC. Subsequently, a nested 1km run is integrated over the same time using boundary conditions from the 3 km run. A run at 250 m resolution nested within the 1 km run is planned in the near future.

1. EFFECT OF CYCLING FREQUENCY

In Xue and Martin (2006a,b), the initial condition for a 6-hour high-resolution forecast for this case was obtained by a single application of cycling. A model background state at 12 UTC 24 May 2002 was interpolated from the NCEP ETA analysis. This was combined with observations at 12 UTC using a Bratseth successive correction scheme called ADAS (ARPS Data Analysis System). The model was then run for 6 hours until 18 UTC at which time observations were again assimilated using the 6 hour forecast as the background state. The 6 hour forecast from the 18 UTC time is then made from this cycled initial condition.

Synoptically, this was a case of convective initiation from the IHOP field program, with storms initiating in nature in the southeastern Texas Panhandle near a dryline/cold front triple point at approximately 20 UTC. The model simulation demonstrated excellent timing for the CI. However the model did produce excessive rain ahead of the dryline in southern Texas,

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which was not observed. In order to improve the details of the simulation, 1 hour cycling was employed.

Figure 1 (left) shows the 21 UTC forecast of vertically integrated liquid water (VIL). This figure shows the correctly initiated storms just southwest of the southwest corner of Oklahoma. It also shows the spurious convection in the southern part of the domain. Figure 1 (right) differs from Figure 1(left) only in that 1-hour cycling was used. For 1 hour cycling, an ADAS analysis cycle combining hourly observations with the forecast background is conducted each hour from 12 UTC to 18 UTC. This gives 6 applications of cycling to obtain the 18 UTC initial condition, which is then integrated for a forecast. Figure 1 (right) shows that the spurious southern domain precipitation is largely absent. However, convective initiation occurs approximately 1 hour earlier, as indicated by the more highly developed convection in the southeast Texas panhandle relative to Fig. 1 (left).

The 1-hour cycled initial condition is probably superior to the single-cycled IC, and it is possible that other problems in the modeling system become apparent when this improvement is used.

2. EFFECT OF VERTICAL MODEL RESOLUTION

Because CI may depend on dynamics of the capping inversion, we substantially increased the vertical resolution of the model as a test to see if this would enhance the forecast accuracy of CI.

The model runs from Xue and Martin (2006a,b) had a stretched vertical grid with a 20 m minimum resolution at the surface level, stretching to approximately 300 m at 3km, near the level of the inversion, for a total of 53 levels. This was changed in the high-vertical resolution runs (HI-Z) so as to provide many more levels in the boundary layer for a total of 92 levels. This has the disadvantage of nearly doubling the amount of storage and computational resources required, however the increase in vertical resolution of the inversion layer may well be worth it. Figure 2 (left) shows a vertical cross-section through the dryline for a 1-hour forecast from the 3km control run with standard vertical resolution and Fig. 2 (right) shows the same cross section from the 3km HI-Z run. The wind vectors are plotted at each grid point so that the resolution of the grid can be viewed. The higher vertical resolution has resulted in substantially better definition of the vertical structure of the inversion.

However, despite this success in more realistically representing the inversion, the forecast of CI was not dramatically altered, being only slightly later than the 1-hourly cycled run. Figure 3 (left) shows the forecast 21 UTC VIL field from the HI-Z test, which compares with the standard vertical resolution run of Fig. 1 (right). While CI was still too early, the evolution of features for the HI-Z test case is much more similar to the observations as described in Xue and Martin (2006a), though the features occur at early times.

3. EFFECT OF THE TURBULENCE MODEL

As shown in Xue and Martin (2006b), CI can depend on the interaction of horizontal convective rolls (HCRs) with the inversion at the dryline. The numerical modeling of such rolls is problematic because the turbulence model typically used for such simulations dampens planetary boundary layer (PBL) structures. In principle, the turbulence model can account for all of the PBL mixing and completely eliminate HCRs. If the HCRs are coherent and persistent enough, however, they can occur in the model even when a PBL scheme is used, as seen in Xue and Martin (2006b).

Because of the importance of HCRs and the difficulty in modeling them, we attempted a further test varying the turbulence model. For the control case, a 1.5 order TKE formulation using the PBL scheme of Sun and Chang (1986) is employed. For the test case, the PBL turbulence model is turned off, and only subgrid mixing is used. The test case is, thus, run as a large eddy simulation (LES). This is still run at 1km horizontal resolution. At this resolution, the assumption of an LES may be invalid as a resolution as low as 100m may be needed (Xue et al. 1996). The 250 m resolution which will be attempted is expected to improve upon the realism of the use of an LES for the PBL turbulence.

Figure 3 shows the forecast VIL filed at 21 UTC from the standard PBL scheme (left), and from the LES scheme (right). For this test, the LES scheme has produced a later and more accurate CI time, though still earlier that the single-cycled low-vertical resolution forecast of Xue and Martin (2006a) (Fig. 1 left).

4. FURTHER WORK

Clearly, the details of CI are sensitively dependent on details of PBL physics, and, consequently, also on the details of models. Further work on this project will include analyzing the success of a 250m nested run with high vertical resolution on simulating PBL structures which are involved in the immediate generation of CI, in both PBL turbulence and LES modes. Comparisons of the results of these high-resolution runs with data taken during the IHOP field program will also be accomplished. This will serve as validation of the model and will also suggest areas in which the model is in need of improvement.

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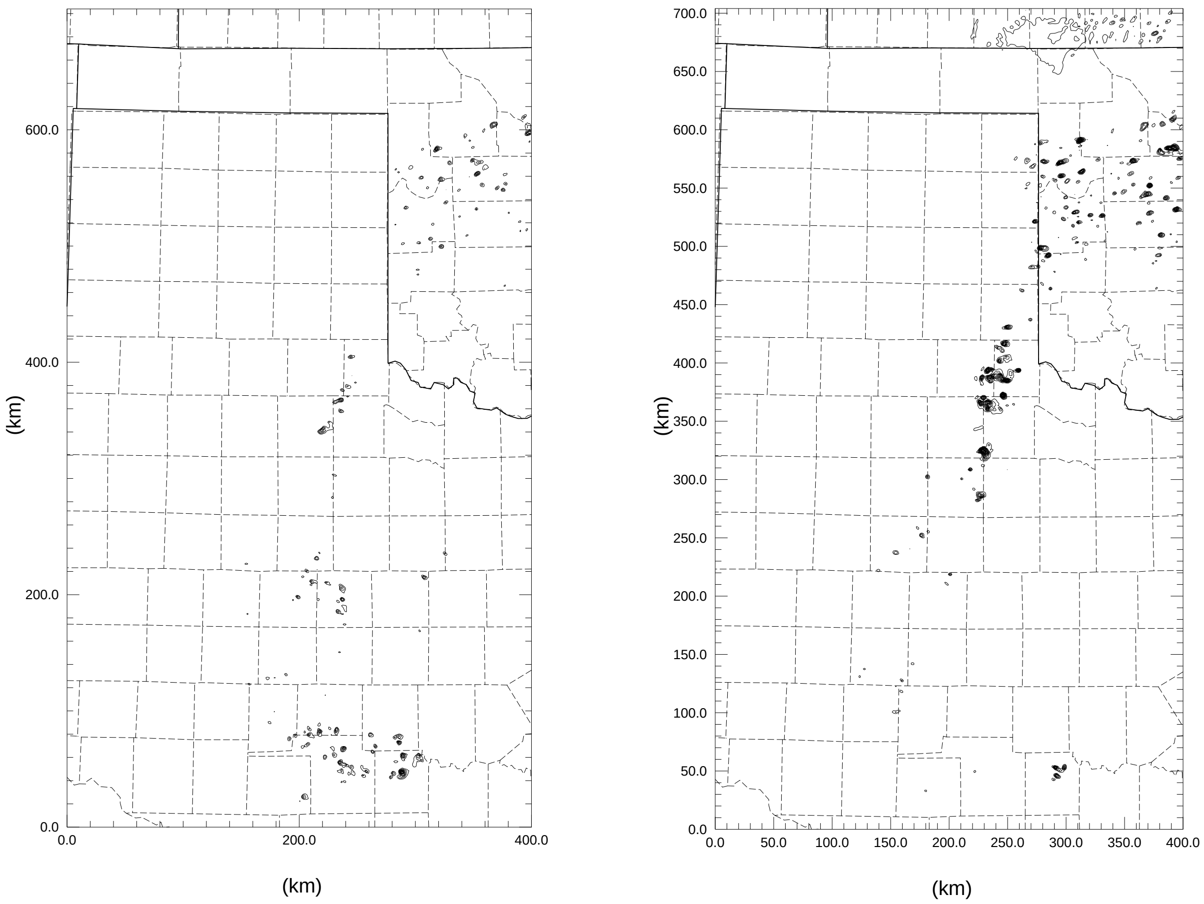

Figure 1. 3 hour vertically integrated liquid water forecast at 21 UTC from (left) 1 km nested run from a single 6 hour cycled initial condition and from (right) 1km nested run from a 1 hourly cycled initial condition.

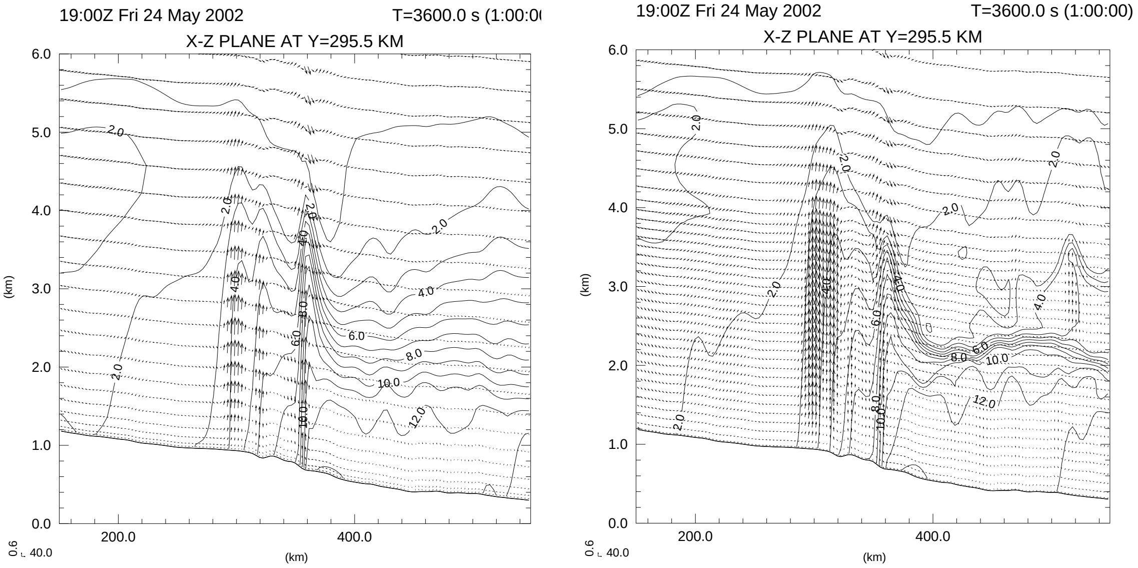

Figure 2. Vertical cross-section through the dryline at 19 UTC (1 hour forecast). (Left) is from the standard vertical resolution. (Right) is from the high vertical resolution. Plotted is the field of water vapor mixing ratio and wind vectors at each grid-point.

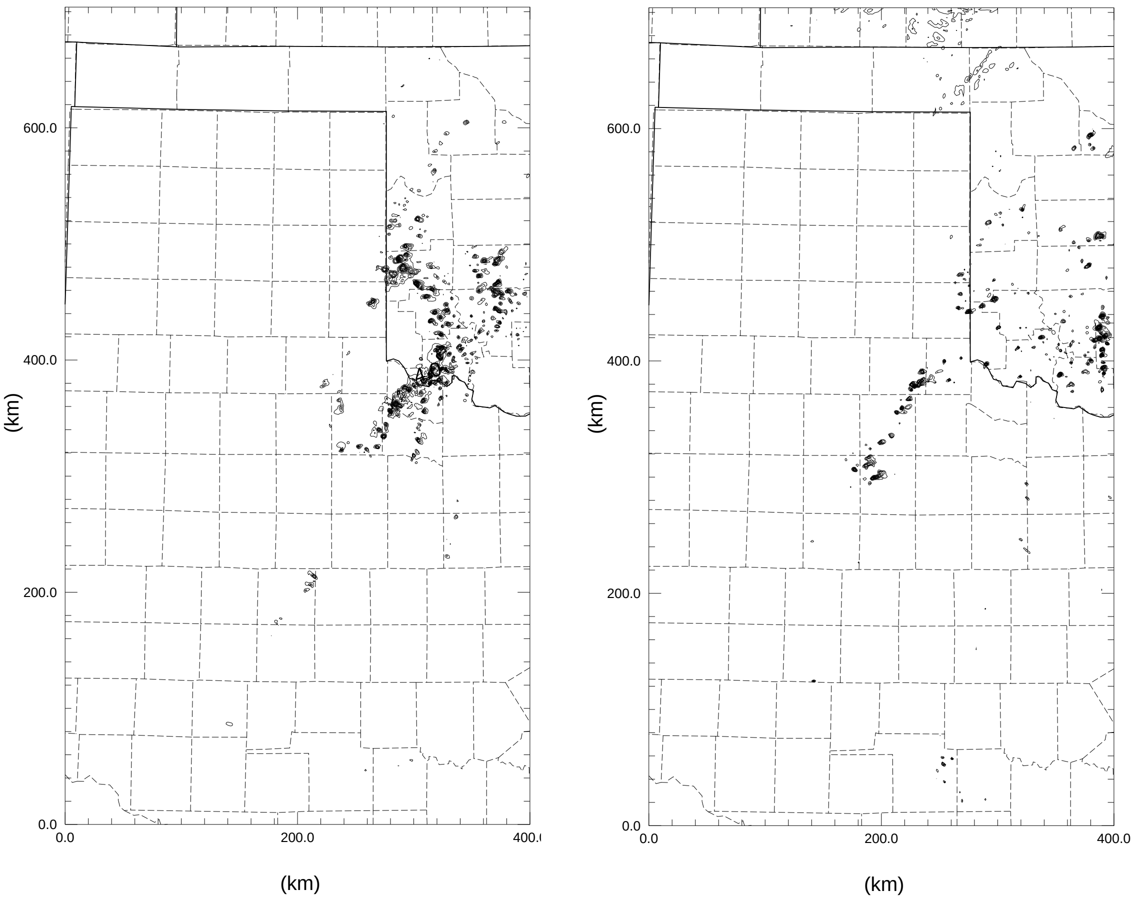

Figure 3. As Fig. 1, but for a high vertical resolution with 1-hour cycling, and for (left) the standard PBL scheme and (right) an LES scheme.