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PRELIMINARY SIMULATIONS OF THE LARGE-SCALE ENVIRONMENT DURING THE FIRE CIRRUS IFO

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INTRODUCTION

Large-scale forcing (scales greater than 500 km) is the dominant factor in the generation, maintenance, and dissipation of cirrus cloud systems. However, the analyses of data acquired during the first Cirrus IFO have highlighted the importance of mesoscale processes (scales of 20 to 500 km) to the development of cirrus cloud systems (Starr and Wylie, 1989). Unfortunately, Starr and Wylie found that the temporal and spatial resolution of the standard and supplemental rawinsonde data were insufficient to allow an explanation of all of the mesoscale cloud features that were present on October 27-28, 1986. Below we will describe how dynamic initialization, or four-dimensional data assimilation (FDDA), can provide us with a method to address this problem. Then we will describe our first steps towards application of FDDA to FIRE.

FOUR-DIMENSIONAL DATA ASSIMILATION

In FDDA, asynoptic data are allowed to modify a numerical forecast by adding additional terms to the equations in the model which will force, or 'nudge', the model state towards the observations. The additional terms are weighted according to the proximity, both in time and space, of the observation to the model grid point. In this manner, the resultant modeled state reflects the observations in the vicinity where they were taken, and utilizes the model's forecast ability to determine the atmospheric state in data-sparse regions. For FIRE, the supplemental rawinsonde network data from the first Cirrus IFO and the anticipated time-continuous profiler data from the second Cirrus IFO can be systematically processed to form four-dimensional datasets describing the IFO's.

The FDDA method has been successfully applied to the Penn State/NCAR mesoscale model in studies of tropical cyclones (Anthes, 1974), severe weather (Kuo and Guo, 1989), terrain-induced flow (Stauffer and Seaman, 1987), and developing continental cyclones (Stauffer and Seaman, 1988). The study by Kuo and Guo has particular relevance to the Kansas IFO since they studied the impact, on mesoscale simulations, of FDDA of a network of 77 *simulated* wind profilers. Assimilation of the profiler data was effective in recovering mesoscale circulations which were not resolved by the conventional analyses of the rawinsonde data. In particular, the divergence field, which is critical for vertical motions, clouds, and precipitation, was significantly improved. Kuo and Guo suggest that even a small network of profilers, such as that which will be available in 1990, will improve the analyses; however, the impact is greatest in the region covered by the profilers.

PSU/NCAR MESOSCALE MODEL

As a first step towards applying FDDA to the FIRE IFO's, we have made a preliminary simulation over the continental United States from 0000 to 1200 UT, November 1, 1986 with the basic version of the PSU/NCAR mesoscale model *without* FDDA.

The PSU/NCAR mesoscale model used here is described in detail by Anthes *et al.* (1987). It is a hydrostatic, three-dimensional, primitive-equations model with a terrain-following vertical coordinate (σ). The model has a sophisticated multi-level planetary boundary layer parameterization and simple diagnostic parameterizations of convective and non-convective precipitation. The experiment described here was performed on a 61X46 grid with a 70-km mesh. We define the model top at 100 mb and the boundaries of the vertical levels at $\sigma = 1.0$, 0.99, 0.95, 0.9, 0.8, 0.7, 0.6, 0.5, 0.43, 0.36, 0.29, 0.22, 0.15, 0.1 and 0.0. These midpoint of these layers are approximately at 995, 970, 930, 865, 775, 685, 595, 520, 455, 390, 330, 265, 210, and 145 mb.

NOVEMBER 1, 1986 STUDY

We use NMC 2.5° analyses, interpolated to our grid, to initialize the model at 0000 UT November 1, 1986 (Fig. 1a). During this period a ridge lies to the east of Wisconsin and a trough to the west. Wisconsin is in generally WSW flow at 0000 UT and nearly zonal flow at 1200 UT. We then carry out a 12-hour simulation.

The results of this simple experiment demonstrate the ability of even a simple version of the mesoscale model to develop mesoscale features starting from the initial highly smoothed NMC analyses. As an example, we show in Figs. 1a-c the 0000 UT and 1200 UT analyses, and the 1200 UT simulation of 325 mb relative humidity. Both analyses show a smooth field with high values of relative humidity aligned parallel with the large-scale wave. In the 1200 UT simulation the horizontal gradients are sharper, especially along the northern boundary, and the separation in the moisture field over Wisconsin is more distinct than in the analyses. In Figs. 2a-c we show the 0000 UT and 1200 UT analyses and the 1200 UT simulation of relative humidity and potential temperature along a cross-section running southeast from the point **A** in Fig. 1 just north of International Falls, through Wisconsin, to the point **B** on the Indiana-Ohio border. A comparison with the 0000 UT and 1200 UT analyses (Fig. 2a-b) indicates that dry air at mid-levels has descended north of the front and that the relative humidity has increased at upper-levels directly above and south of the front. The 1200 UT simulated thermal structure (Fig. 2c) is nearly identical to the 1200 UT analyses. The 1200 UT simulated relative humidity exhibits the same trends seen in the analyses. However, the horizontal and vertical gradients of relative humidity are sharper and three maxima in the relative humidity field, not found in the NMC analyses, have developed between 300 and 200 mb (9.5 and 12 km). At the southern two maxima, the model has injected moisture above the tropopause. This is unrealistic and probably related to the simple moisture physics used for this experiment and to the coarse vertical resolution at the model top. Nevertheless, the model has developed vertical and horizontal structure in the moisture fields with scales of order 200 km that were not found in the NMC analyses. We are currently comparing both the analyses and the simulation with the observations.

FUTURE APPLICATIONS

The general structure of the PSU/NCAR mesoscale model and its widespread use allow us to easily optimize the model for this study. In subsequent runs we will increase model resolution to 40 km in the horizontal and to 0.5 km in the vertical in the upper half of the troposphere and in the vicinity of the tropopause. We will improve the initial conditions by using the rawinsonde data to *desmooth* the NMC analyses. Then we will use the FDDA scheme to produce a four-dimensional dataset for the first Cirrus IFO. We will then have the capability and experience required for handling the large amount of profiler data that is expected during the second Cirrus IFO. We have long-range plans to replace the model moisture scheme with an explicit prediction scheme (Toon *et al.*, 1988) that will resolve the spectra of ice particles. We will also add a detailed radiative transfer scheme (Toon *et al.*, 1989). A discussion of these topics, however, is beyond the scope of this paper.

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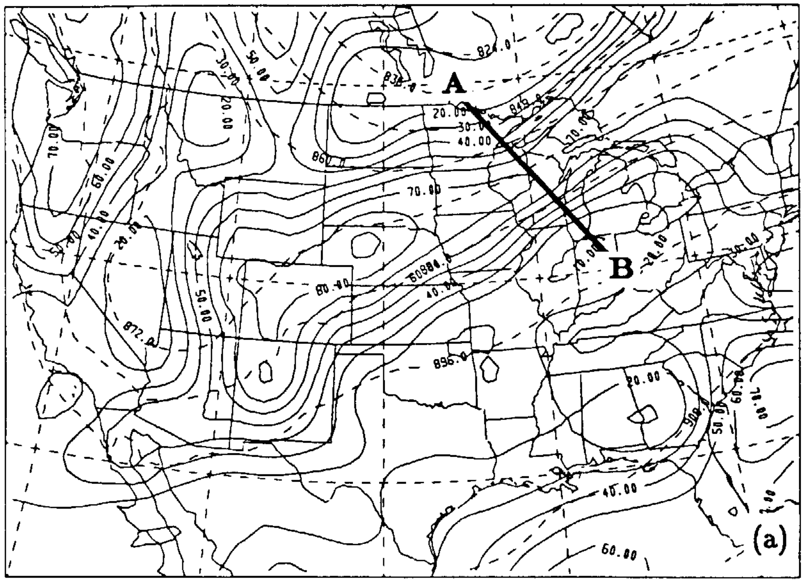

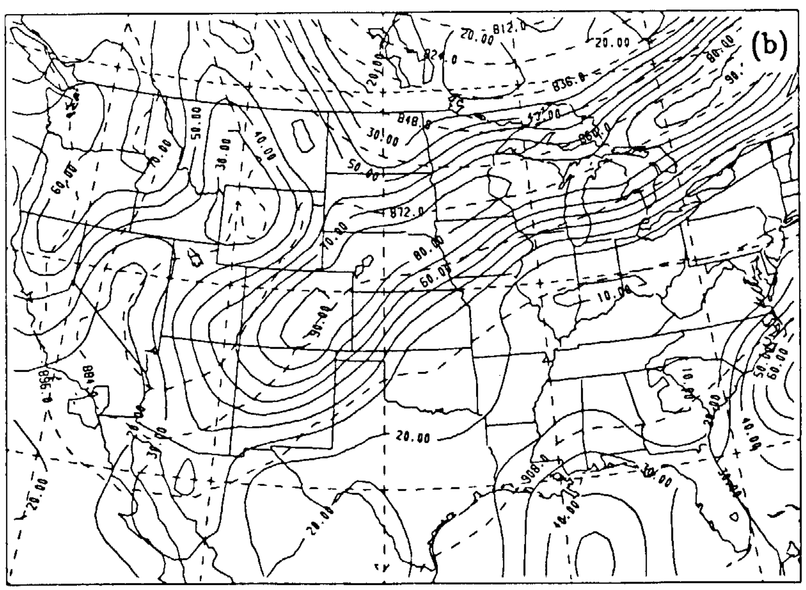

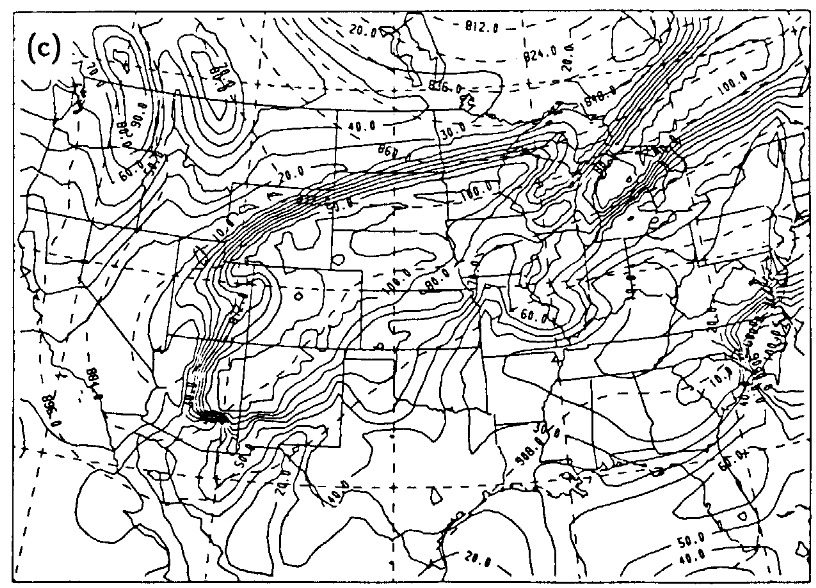

Fig. 1: 325 mb fields of relative humidity (solid lines, contour interval of 10%) and geopotential height (dashed lines, contour interval of 12 dam) for November 1, 1986. (a) 0000 UT NMC analysis and model initial condition; (b) 1200 UT NMC analysis; and (c) 1200 UT PSU/NCAR mesoscale model simulation. The line **A-B** denotes the location of the cross-section shown in Fig. 2.

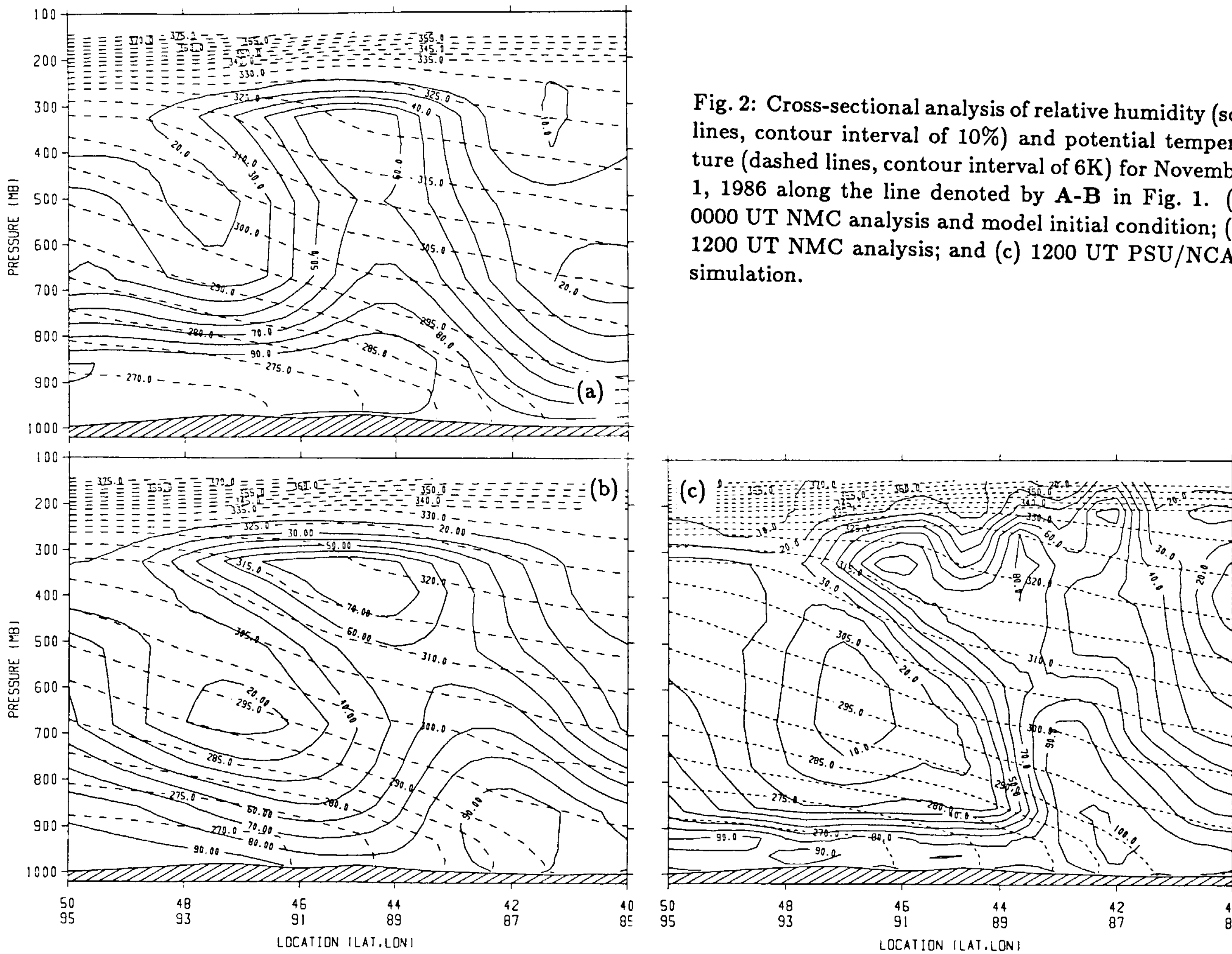

Fig. 2: Cross-sectional analysis of relative humidity (solid lines, contour interval of 10%) and potential temperature (dashed lines, contour interval of 6K) for November 1, 1986 along the line denoted by **A-B** in Fig. 1. (a) 0000 UT NMC analysis and model initial condition; (b) 1200 UT NMC analysis; and (c) 1200 UT PSU/NCAR simulation.