2.3 LIFE CYCLE DIFFERENCES BETWEEN CONSECUTIVE RAPIDLY DEEPENING CONTINENTAL CYCLONES

Steven G. Decker and Jonathan E. Martin
University of Wisconsin-Madison, Madison WI

1. INTRODUCTION

In the second week of April 2001, two powerful cyclones developed over and traveled across central North America, one immediately following the other. The storms evolved out of quite similar large-scale environments and both reached minimum sea-level pressures (SLPs) near or below 980 hPa. Both storms also qualified as explosively deepening cyclones, which are relatively rare events over the continent.

Here we present observations of these two storms from complimentary perspectives. First, a local energetics analysis that centers on investigating the processes that contributed to the eddy kinetic energy (EKE) changes characterizing these two storms during their life cycles is presented. Secondly, a cursory examination of cyclone-scale differences between these storms is given. In the presentation this will be complemented by a piecewise potential vorticity (PV) inversion performed using output from successful numerical simulations of these two events performed using the PSU/NCAR MM5. We begin with a synoptic overview of the two storms.

2. OVERVIEW

Figure 1 shows the tracks and sea-level pressures of each storm for 3 day periods at 12 h intervals.

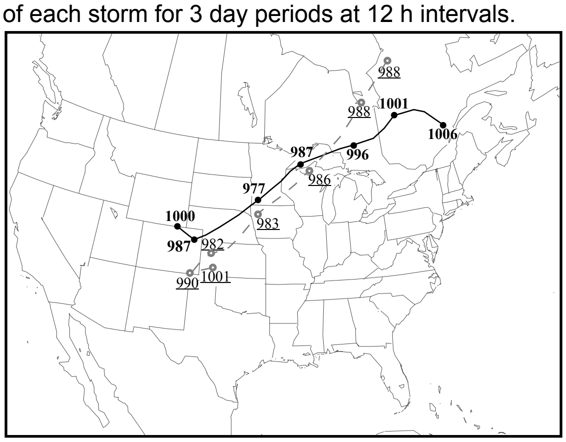

Fig. 1 Surface tracks of the two cyclones described in this study. Solid circles are positions of cyclone 1 at 12 h intervals beginning at 1200 UTC 6 April 2001. Sea-level pressure indicated in bold black numbers. Open circles are positions of cyclone 2 at 12 h intervals beginning at 1200 UTC 10 April. Sea-level pressure indicated in bold underlined black numbers.

The first storm originated in the immediate lee of the Rocky Mountains and experienced 23 hPa of deepening in the 24 h from 1200 UTC 6 April to 1200 UTC 7 April. After this time, this storm commenced a period of fairly rapid filling as the SLP increased 19 hPa in the ensuing 24 h.

The second storm also originated in the lee of the Rockies. It deepened 19 hPa in the 24 h ending at 1200 UTC 11 April as it finally reorganized in western Kansas. After the initial deepening, the SLP minimum of this second storm remained robust, filling to only 988 hPa in the subsequent 48 h.

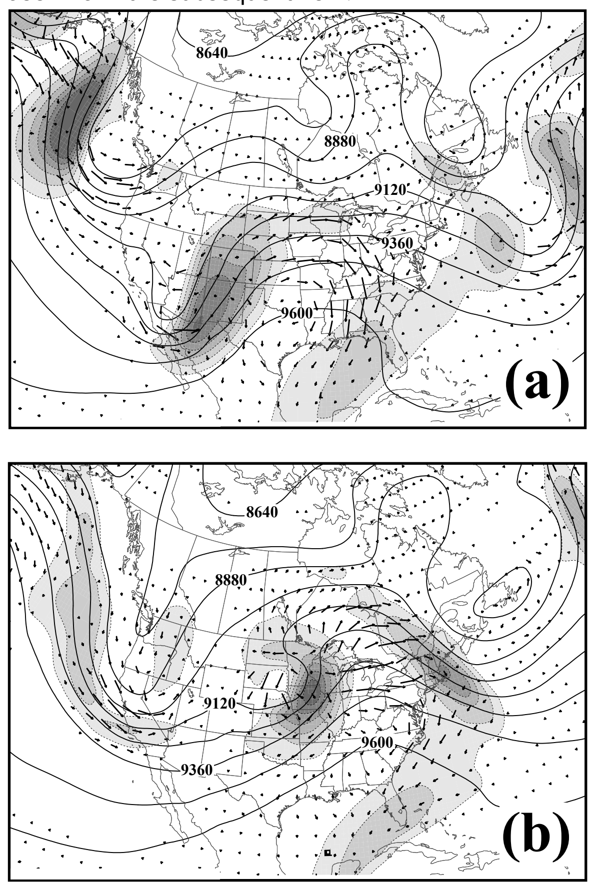

Fig. 2 (a) AVN model analyses of vertically integrated EKE, AGF vectors, and 300 hPa geopotential height at 1200 UTC 6 April 2001. EKE is given in units of m^2 s^{-2} and shaded every 100 m^2 s^{-2} beginning at 100 m^2 s^{-2}. Geopotential height is labeled in m and contoured every 120 m. (b) As for Fig. 2a but for 1200 UTC 7 April 2001.

3. LOCAL ENERGETICS

The contrasting post-development behaviors of these 2 storms occurred in rather similar large-scale environments. A convenient framework for examining these differences is the local energetics perspective employed by Orlanski and Sheldon (1995). Figure 2a shows that the first surface cyclone was clearly con-

Corresponding author address: J. E. Martin, Dept. of AOS, University of Wisconsin-Madison, 1225 W. Dayton Street, Madison, WI 53706; e-mail: jon@meteor.wisc.edu

nected to a significant upper tropospheric trough centered over the AZ/CA border at 1200 UTC 6 April. This trough was characterized by a significant EKE maximum on its eastern flank with considerable downstream ageostrophic geopotential flux (AGF) out of this center. In the subsequent 24 h, this EKE maximum moved northeastward with the upper trough (Fig. 2b) and continued to be characterized by downstream AGF which promoted intensification of the EKE center located over New England. This 24 h period encompassed the period of most rapid deepening of the cyclone.

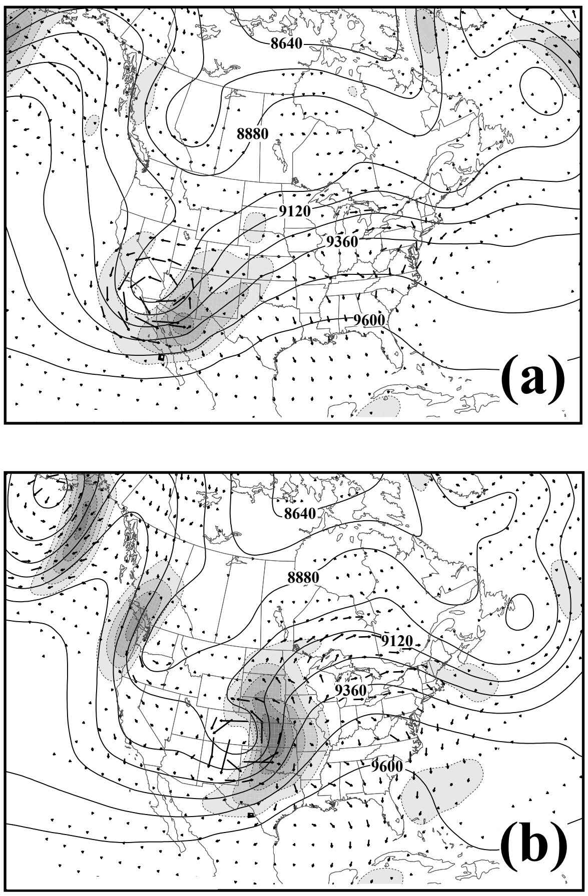

Fig. 3 (a) As for Fig. 2a but for 1200 UTC 10 April 2001. (b) As for Fig. 3a but for 1200 UTC 11 April 2001.

Figure 3a shows a similar analysis for 1200 UTC 10 April, the beginning of the 24 h period of most rapid intensification for the second cyclone. Note the clear similarity in the large-scale flow over North America between this cyclone event and the preceding one. Quite different, however, is the almost complete lack of AGF heading downstream in this case. That difference remains quite evident 24 h later as well (Fig. 3b). A pronounced AGF circulation, centered over southern CA (Fig. 3a) and then over southeast CO (Fig. 3b) is instead evident.

In the first cyclone, significant baroclinic generation of EKE occurred only in the 24 h of most rapid deepening and thereafter was reduced to very small magnitude (not shown here). In the second storm, significant baroclinic generation of EKE was sustained for 48 h (not shown). More detailed examination of the EKE budgets of these two storms is offered in the oral presentation.

4. CYCLONE-SCALE DIFFERENCES

The distribution of mid-tropospheric QG forcing near the time of peak intensity of both cyclones was also examined. A partitioning of the Q-vector (Hoskins et al, 1978) into its along- and across-isentrope components, as suggested by Keyser et al. (1992) and Martin (1999), can be used to describe the cyclone-scale forcing for ascent.

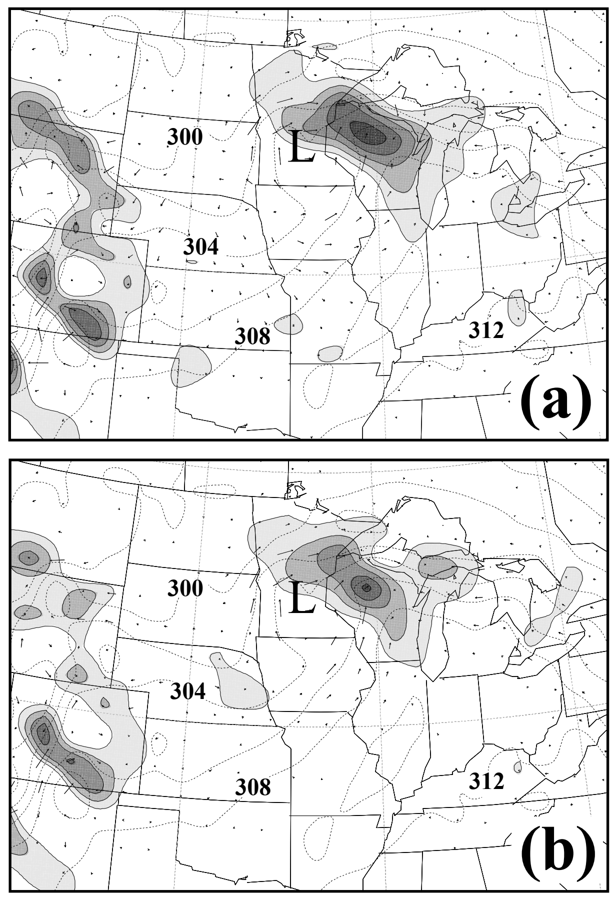

Fig. 4 (a) 500-900 hPa column averaged isentropes, Q-vectors and Q-vector convergence at 1800 UTC 6 April 2001. Isentropes are dashed and labeled in K and contoured every 2 K. Q divergence is labeled in 10^{-15} m^2 s^{-1} kg^{-1} and contoured every -5×10^{-15} m^2 s^{-1} kg^{-1} beginning at -5×10^{-15} m^2 s^{-1} kg^{-1}. Shading becomes darker as the values become more negative. (b) As for Fig. 4a but for along-isentrope component of Q, Q_s.

Figure 4a shows the 500-900 hPa column averaged Q-vectors and their convergence at 1800 UTC 7 April, near the time of peak intensity for storm 1.

Most of the total Q convergence is accounted for by the along-isentrope component, Q_S (Fig. 4b) suggesting that cyclone-scale forcing predominated in storm 1. Also noteworthy is the fact that the forcing is located to the east of the SLP minimum. A similar analysis for storm 2 at 0000 UTC 12 April, near its peak intensity, demonstrates notable differences (Fig. 5). Firstly, the total Q convergence is of larger magnitude in association with this storm. Secondly, a significant portion of this forcing is located to the west and southwest of the SLP minimum. This characteristic remains the case for an extended period of time (not

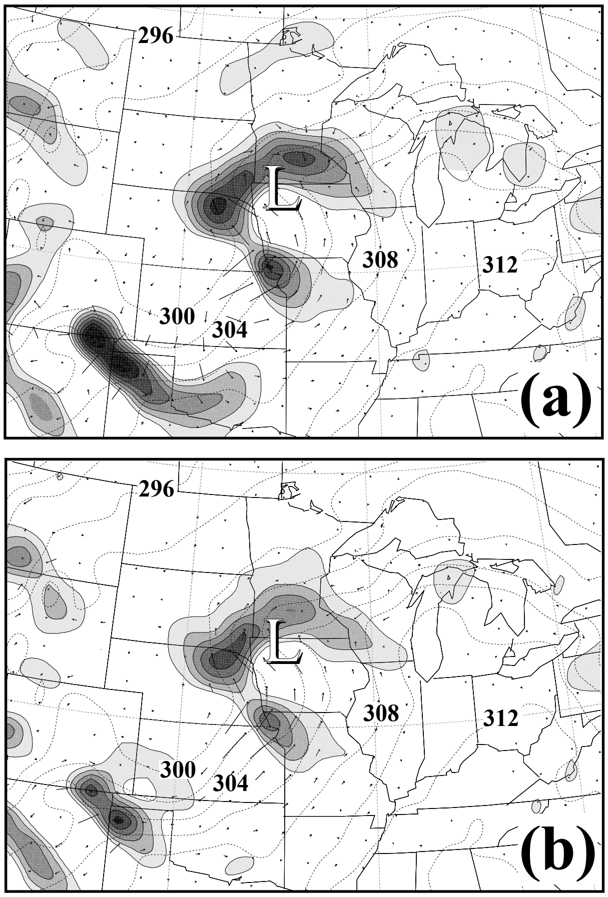

Fig. 5 (a) As for Fig. 4a but for 0000 UTC 12 April 2001. (b) As for Fig. 4b but for 0000 UTC 12 April 2001.

shown). The piecewise PV analysis to be shown in the presentation will demonstrate the profound effect that this sustained forcing for ascent in the immediate vicinity of the cyclone center had on the lower tropospheric height field.

REFERENCES

Hoskins, B. J., I. Draghici, and H. C. Davies, 1978: A new look at the ω-equation. *Quart. J. Roy. Meteor. Soc.*, **104**, 31-38.

Keyser, D., B. D. Schmidt, and D. G. Duffy, 1992: Quasigeostrophic vertical motions diagnosed from along- and across-isentrope components of the Q-vector. *Mon. Wea. Rev.*, **120**, 731-741.

Martin, J. E., 1999: The separate roles of geostrophic vorticity and deformation in the midlatitude occlusion process. *Mon. Wea. Rev.*, **127**, 2404-2418.

Orlanski, I., and J. P. Sheldon, 1995: Stages in the energetics of baroclinic systems. *Tellus*, **47A**, 605-628.

ACKNOWLEDGEMENTS: This work was funded by the National Science Foundation under Grant ATM-9733127.