P1.1

THE SYNOPTIC ENVIRONMENT OF THE 11 APRIL 2001 CENTRAL PLAINS TORNADO OUTBREAK VIEWED IN THREE DIMENSIONS

Daniel D. Nietfeld *
NOAA/NWS/WFO Omaha/Valley, NE

1. INTRODUCTION

A powerful low pressure system moved through the central plains states on 11 April, 2001. Associated with this weather pattern was a large outbreak of tornadoes during the late morning and afternoon hours over northern Missouri and Iowa. There were a total of 32 tornadoes in Iowa and Missouri between the hours of 10:00 am CDT and 6:00 pm CDT on 11 April 2001 (Stormdata, 2001). These tornadoes were a subset of a much larger occurrence of tornadoes across the entire southern and central plains states on 10 April and 11 April, 2001 (82 tornadoes total).

The synoptic environment of this event was viewed using a software package known as Display 3-Dimension (D3D), from the NOAA Forecast Systems Laboratory (FSL). The D3D software allows the user to view gridded numerical weather prediction model output in a three-dimensional perspective by utilizing Vis5D (McCaslin, et al. 1999). The three-dimensional perspective provides a more spatially coherent vertical and horizontal view of the model data. This can lead to a quicker identification of important meteorological features and conceptual models. This paper will focus on various examples in which the D3D perspective showed important synoptic scale features associated with the 11 April 2001 central plains tornado outbreak.

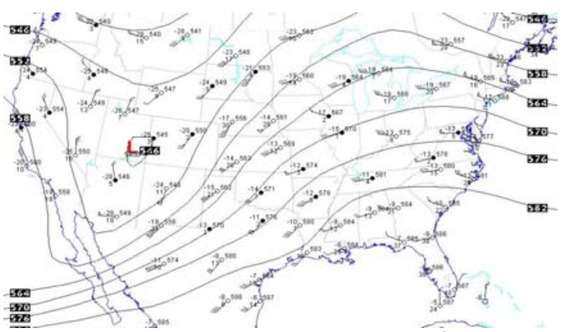

Figure 1. 500 hPa heights on 00 UTC 11 April 2001.

Corresponding Author Address:
Daniel D. Nietfeld
6707 North 288th Street Valley, NE 68064
e-mail: dan.Nietfeld@noaa.gov

2. EVENT OVERVIEW

A long-wave 500 hPa trough had moved into the western United States during the evening of 10 April 2001 (00 UTC 11 April 2001)(Fig. 1). By 1200 UTC 11 April 2001, the 500 hPa trough was evolving into a closed low, moving into northwest Kansas (Fig. 2). The surface low pressure was centered over Kansas at 1700 UTC, with the lowest pressure approximately 990 mb. An occluded frontal system extended from the surface low into the plains, with a pronounced warm front moving into southern Iowa (Fig 3.).

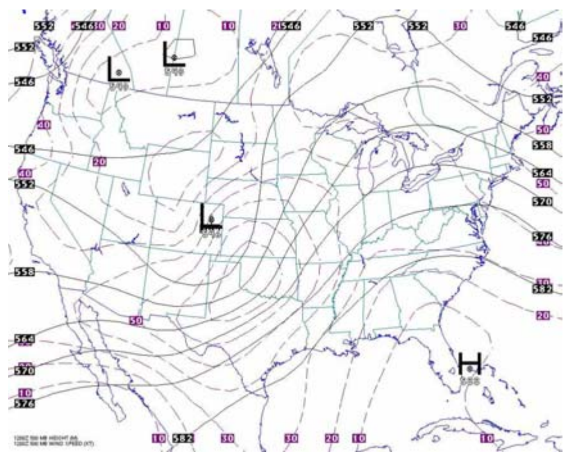

Figure 2. 500 hPa heights (solid) and isotachs (dashed) on 12 UTC 11 April 2001.

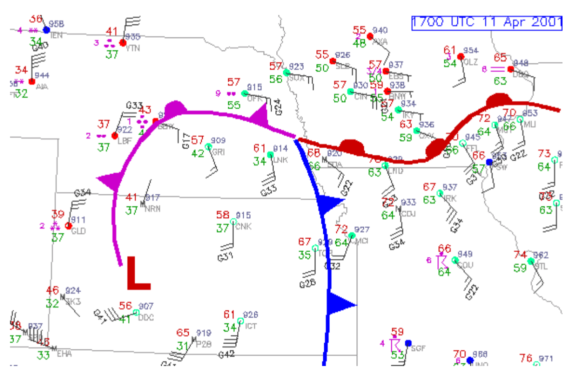

Figure 3. Surface plots and fronts, 1700 UTC 11 April 2001.

3. SYNOPTIC FEATURES

3.1 *Jet Structure*

One critical factor with this event was the presence of a 100 knot jet streak, which lowered to below 500 hPa as it moved into the central plains (Fig. 4). This jet streak lowering is depicted well using the D3D view, and this feature would have been quite small on a 2-dimensional map. Figure 5 shows the jet stream view looking from the south to the north, and the 250 hPa, 300 hPa, and 500 hPa height levels are shown. This is an example of how D3D can be used to determine which 2-dimensional map should be viewed to further investigate the feature.

This 100 knot jet streak at 500 hPa created a more favorable vertical wind shear environment for tornadoes (Thompson, 1998), which was also found in the 3 May 1999 Oklahoma tornado outbreak (Edwards, et al., 2002).

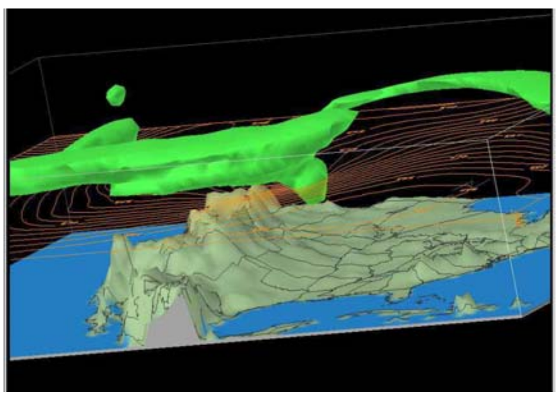

Figure 4. Eta model forecast of the 100 knot isosurface, and 500 hPa height contours, valid at 1800 UTC 11 April 2001.

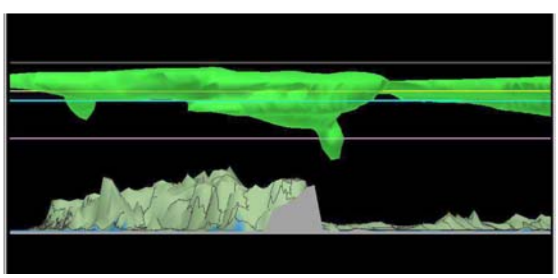

Figure 5. South view of the eta model forecast of the 100 knot isosurface valid at 1800 UTC 11 April 2001. The yellow, cyan, and purple lines are the 250 hPa, 300 hPa, and the 500 hPa height lines, respectively.

3.2 *Potential Vorticity Anomaly*

Associated with the jet streak was a penetration of potential vorticity into the troposphere, associated with a tropopause fold (Fig 6). Three potential vorticity units were indicated as low as 500 hPa from the eta model forecast valid at 1800 UTC 11 April 2001 (Fig. 7).

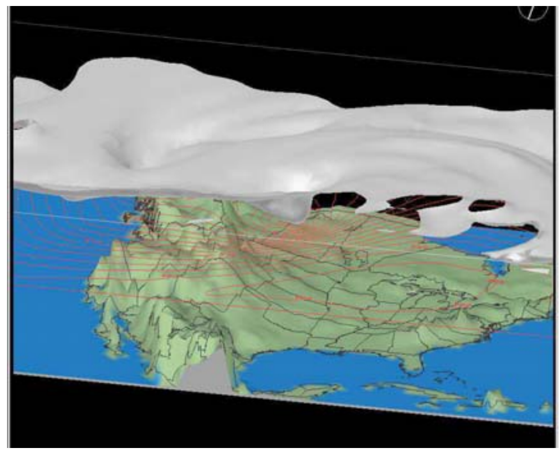

Figure 6. Eta model forecast of the 3.0 potential vorticity unit isosurface, and 500 hPa height contours, valid at 1800 UTC 11 April 2001.

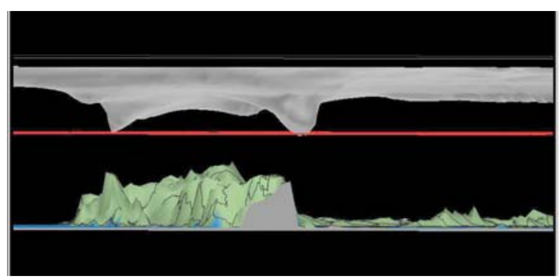

Figure 7. Same as Figure 6, except a south view, and the 500 hPa height line.

3.3 *Divergence of the Wind*

The upper level wind structure associated with the extratropical cyclone resulted in substantial divergence, which is depicted in Figure 8. Rotating the perspective of the D3D image allows the user to see that divergence is occurring in the favored right-rear and left-front regions of the jet streak.

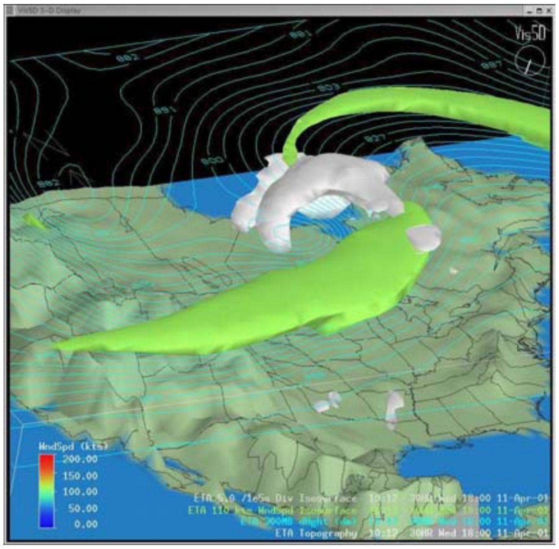

Figure 8. Eta model forecast of the 100 knot wind isosurface (green), and the 5.0 unit divergence isosurface in gray, valid 1800 UTC 11 April 2001. Solid cyan contours are the 300 hPa heights.

3.4 *Parcel Trajectories*

Another feature of the D3D software is the ability to view parcel trajectories (Fig. 9). In the case of 11 April, 2001, parcels originating in the low levels of the southern Plains were following the classic warm conveyor belt, and parcels originating in the Rockies were following the dry conveyor belt, as described by Carlson (1980). These parcel trajectories are difficult to view in two dimensions.

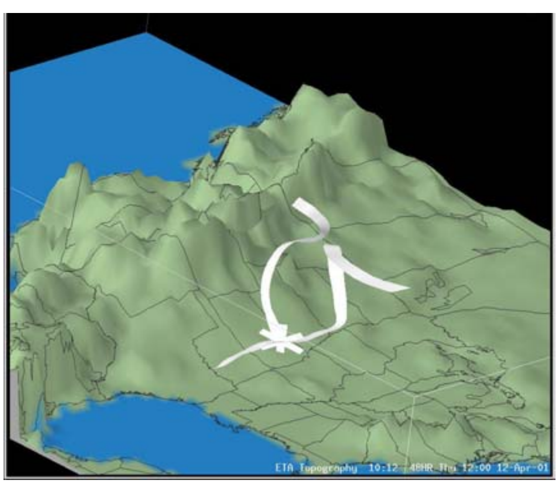
Figure 9. Eta model forecast of parcel trajectories, valid at 1800 UTC 11 April 2001.

3.5 *Moisture*

The extent of moisture fields can be assessed in D3D, which shows the vertical and horizontal extent of the moisture. Figure 10 shows the isosurface of the 12C dewpoint, and the view is from the north looking south. The 12C dewpoint can be seen as far north as Iowa, and the isosurface deepens with the southward extent. For reference, altitude lines can be overlaid on the image, as in Figure 10. The “dry punch” which is often present with extratropical cyclones can also be visualized in the relative humidity field (Fig. 11). The structure of the dry air intrusion can be assessed horizontally and vertically in the atmosphere using a three-dimensional perspective.

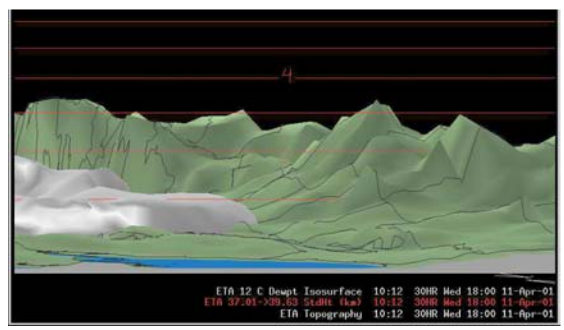

Figure 10. Eta model forecast of the 12C temperature isosurface valid 1800 UTC 11 April 2001. Red horizontal lines are altitude reference lines.

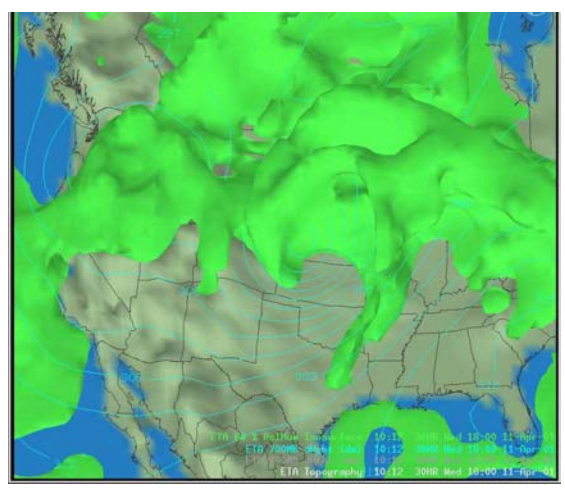
Figure 11. Eta model forecast of the 80 percent relative humidity isosurface (green), and the 700 hPa height contours (cyan), valid at 1800 UTC 11 April 2001.

3.6 *Isentropic Fields*

The combined ingredients of moisture and lift can be seen through the advection of pressure and the advection of moisture on an isentropic surface. D3D shows the topography of an isentropic isosurface well. The winds or streamlines, and values of specific humidity can be overlaid on the surface. Alternatively, the isentropic surface can be colored according to the value of specific humidity found on the surface, as in Figure 12. This allows the forecaster a quick view of moisture advection and isentropic lift in one image.

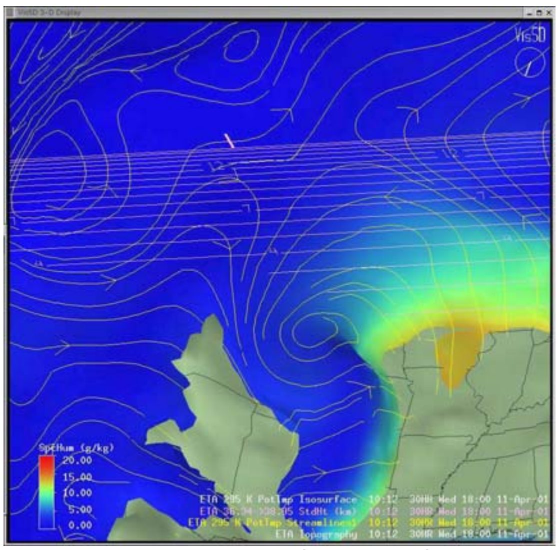

Figure 12. Eta model forecast of the 295K potential temperature isosurface, colored according to the value of specific humidity. Warmer colors correspond to higher values of specific humidity, and cooler colors correspond to lower values of specific humidity. Yellow lines are streamlines on the 295K potential temperature isosurface, and purple lines are altitude lines for reference. The forecast is valid at 1800 UTC on 11 April 2001.

3.7 *TROWEL Airstream*

Martin (1998) has given the concept of the towel airstream renewed attention, which is a pressure ridge present on an equivalent potential temperature surface. The trowel and its attendant airstream helps explain the forcing and advections taking place in the "comma head" region of an extratropical cyclone. This trowel is well defined using a three dimensional view, as was the case by 12 UTC on 12 April 2001 (Fig. 13).

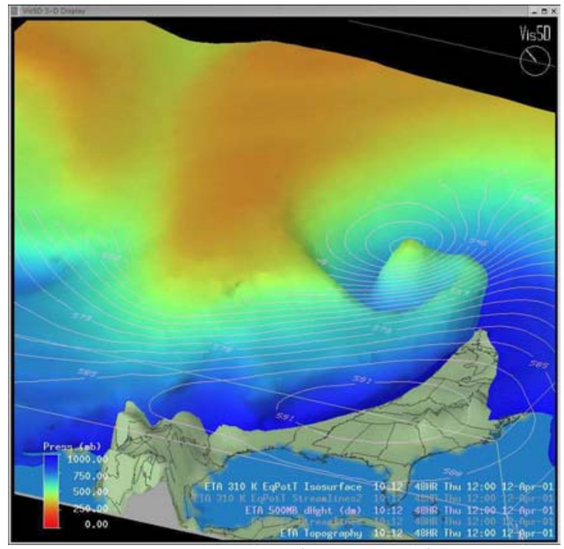

Figure 13. Eta model forecast of the 295K potential temperature isosurface, colored according to pressure values. Purple lines are 500 hPa height contours. Forecast is valid 12 UTC 12 April 2001.

4. CONCLUSION

Some of the more important synoptic features which led to a tornado outbreak over the central plains on 11 April 2001 were presented in a three-dimensional perspective. This perspective allows the forecaster to identify conceptual models quicker, and obtain a more cohesive mental picture of the atmosphere. It is important to note that the images were of model data only, and the limitations of the model data must be taken into account. Utilizing the D3D visualization in conjunction with a 2-dimensional map should allow the forecaster to take a closer examination of important synoptic and sub-synoptic scale features, resulting in improved forecasts.

5. REFERENCES

Carlson, Toby N., 1980: Airflow Through Midlatitude Cyclones and the Comma Cloud Pattern. *Monthly Weather Review*: Vol. **108**, No. 10, pp. 1498–1509.

Edwards, Roger, Stephen F. Corfidi, Richard

L. Thompson, Jeffry S. Evans, Jeffrey P. Craven, Jonathan P. Racy, Daniel W. McCarthy, Michael D. Vescio, 2002: Storm Prediction Center Forecasting Issues Related to the 3 May 1999 Tornado Outbreak. *Weather and Forecasting:* Vol. **17**, No. 3, pp. 544–558.

Martin, Jonathan E., 1999: Quasigeostrophic Forcing of Ascent in the Occluded Sector of Cyclones and the Trowal Airstream. *Monthly Weather Review*: Vol. **127**, No. 1, pp. 70–88.

McCaslin, P. T., P.A. McDonald, and E. J. Szoke, 1999: Developing and Testing a 3D Visualization Workstation Application at FSL. *Proc., 15th Inter. Conf. On IIPS for Meteorology, Oceanography, and Hydrology*, Dallas, TX. Amer. Meteor. Soc., p.498-501.

NOAA, 2001, Storm Data, National Climatic Data Center, Asheville, NC.

Thompson, Richard L., 1998: Eta Model Storm-Relative Winds Associated with Tornadic and Nontornadic Supercells. *Weather and Forecasting:* Vol. **13**, No. 1, pp. 125–137.