9.126 THE INFLUENCE OF TOPOGRAPHY ON THE BARNEVELD TORANDO FAMILY THAT OCCURRED ON 8 JUNE 1984 IN SOUTHERN WISCONSIN

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1. INTRODUCTION

On the afternoon of 7 June 1984 a severe weather outbreak began across the upper Midwest lasting until the early morning hours of 8 June. A total of 42 tornadoes were reported across Kansas, Nebraska, South Dakota, Missouri, Iowa, Minnesota, and Wisconsin. Ten of these tornadoes were reported in Wisconsin, eight of which were associated with supercells (Figure 1) in our study region. The Wisconsin tornadoes developed in the early morning hours of 8 June. The largest of these tornadoes was the F5 that devastated the village of Barneveld, WI. This tornado began at 0541 UTC lasting until 0640 UTC on 8 June, traveling a total of 60 km, injuring 200, and killing nine people. Nearly 90% of the village of Barneveld was damaged or destroyed, resulting in an estimated $25 million in damage just in Barneveld. The tornado continued on toward the town of Black Earth, WI where more structural damage occurred. For the remainder of the path, the tornado destroyed farm buildings and damaged forested regions before reaching its final end point near Lodi, WI. In total, the estimated cost of damage for the 60-km track was $40 million. This research examines the synoptic and mesoscale conditions of this event along with the influence topography had in enhancing these conditions.

2. SYNOPTIC SCALE OVERVIEW

The synoptic scale conditions on 7 June through 8 June 1984 were typical for a severe weather outbreak across the upper Midwest. At 300-hPa, there was a strong jet streak moving through the central part of the U.S. The study region was under the influence of the left-front quadrant of the jet streak. The main core of this jet streak moved into the central Iowa region by 0600 UTC 8 June 1984 (Figure 2; top panel). In addition, at 500-hPa there was a long-wave trough situated across the central part of the U.S. that had repeated shortwaves eject into the study region. One of these shortwaves was moving into the southern Wisconsin area at the time of the Barneveld tornado touchdown (Figure 2, second panel from top).

At 850-hPa level, a strong low-level jet (LLJ) was present from Oklahoma through southwestern Wisconsin at 0000 UTC (not shown). This LLJ stayed in approximately the same place but intensified through

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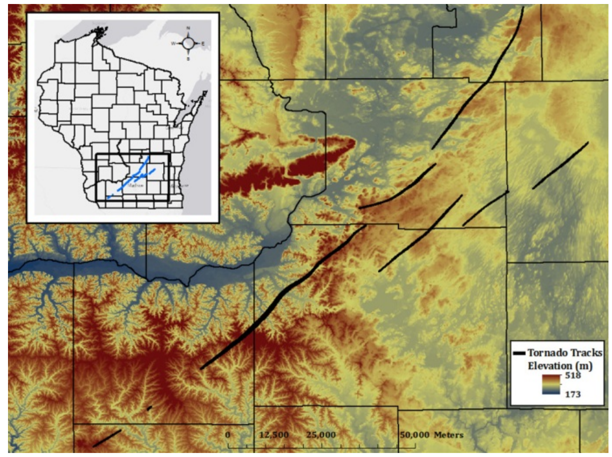

Figure 1: Tracks of the eight tornadoes that occurred in southern Wisconsin on 8 June 1984. The base map is a topographic map for reference.

0600 UTC (Figure 2, third panel from top). This intensification was due to the typical behavior of the nocturnal LLJ and the approach of an intensifying low pressure system. This LLJ supplied the low-levels with heat and moisture aiding in the development of strong supercell thunderstorms.

The surface conditions in place also provided the atmosphere for explosive convective development despite it occurring in the overnight hours. At the surface, a strong low pressure center moved from southeastern South Dakota/northeastern Nebraska into central Minnesota from 0000 to 0600 UTC (0600 UTC is shown in Figure 2, bottom panel). The warm front associated with this cyclone remained north of the Barneveld area most of 7 June 1984 allowing southerly flow into the region. As the surface low continued to move to the east a strong high pressure remained in place off the coast of the Carolinas. This allowed for a stronger pressure gradient to develop across Tennessee and Ohio River Valleys as well as the southern Great Lakes region. This strong flow from the south supplied the study area with low-level moisture and heat for the storms that developed.

3. MESOSCALE OVERVIEW

The synoptic conditions present on 7 June and 8 June 1984 primed the atmosphere for the development of strong supercell thunderstorms. The mesoscale conditions played a role in the initiation and track of the tornadoes in the southern Wisconsin. In this section, we address two specific mesoscale features that played a role in the development of the tornadoes. In section 4,

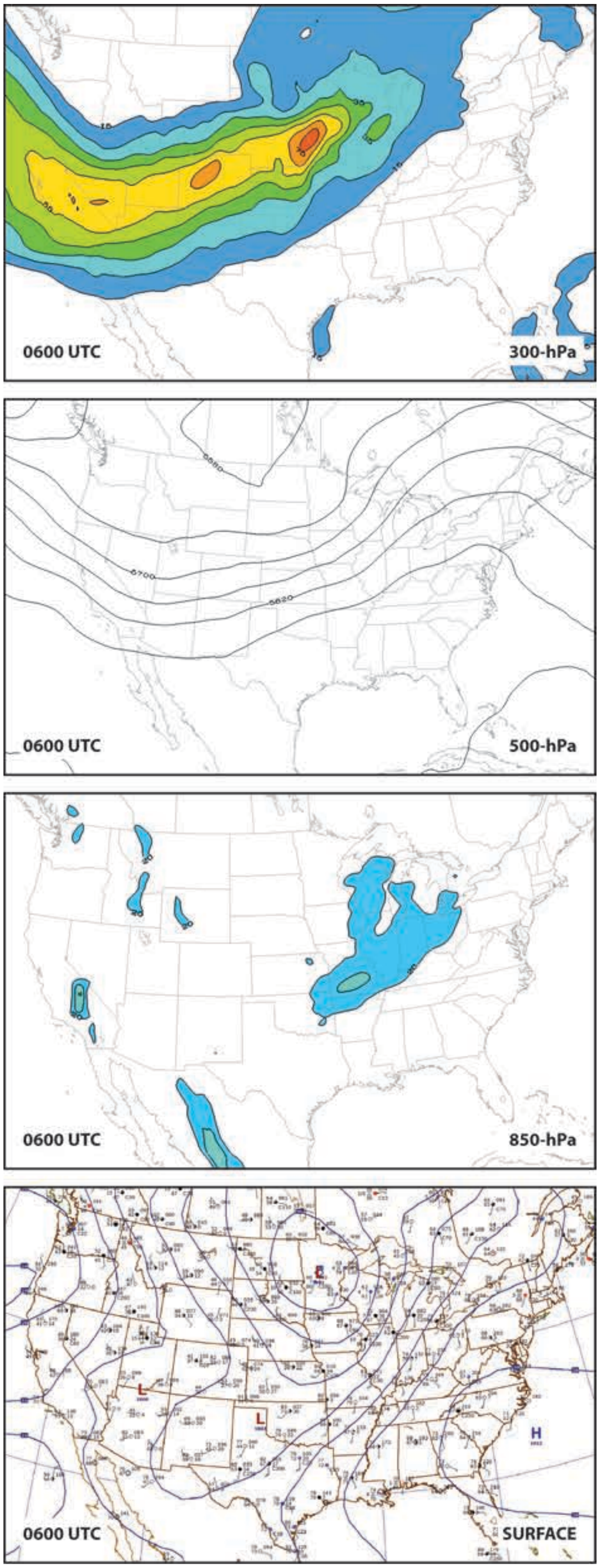

Figure 2: Synoptic scale conditions for 0600 UTC 8 June 1984. Levels shown are: 300-hPa wind speeds (top panel), 500-hPa heights (second panel), 850-hPa winds (third panel), and surface (bottom panel).

the topographical influence on these mesoscale features is addressed.

3.1 *COLD POOL*

In the early part of 7 June 1984 precipitation fell throughout southwestern Wisconsin, northern Illinois, and northeast Iowa. The precipitation lead to an enhancement of cloud cover throughout the daylight hours of 7 June 1984 (Figure 3). The persistent cloud cover and wet ground from the precipitation caused a cold pool of air to develop in this region. The temperature difference across the region was approximately 2-4°F cooler than the surrounding areas throughout most of the daylight hours of 7 June 1984.

The northern boundary of the cold pool was aligned with a ridgeline through the driftless area in southwest Wisconsin. Once sunset occurred on 7 June 1984 and up to the time of tornadogenesis at 0541 UTC this boundary could have been enhanced through radiational cooling process. Evidence of the cold pool and cloud cover can be seen via the Visual Flight Rules (VFR) reports at 0000, 0300, and 0600 UTC surface maps (not shown). This cold pool was still present as the cluster of storms that developed in south-central Iowa move into the region. As these storms interacted with this cold pool they bifurcated with one portion moving south of the cold pool and a new storm cell initiating and strengthening as it moves along the northern boundary of the cold pool into southwest part of Wisconsin. This northern storm is the one which produced the Barneveld F5 tornado at 0541 UTC.

3.2 *GRAVITY WAVES*

The formation of gravity waves associated with convection has been widely studied and it has been concluded that they can form under varying conditions (Uccellini 1975, Savage et al. 1988, Paxton and Sobien 1998). Uccellini (1975) found that gravity waves can be associated with strong jet streaks aloft and these gravity waves can initiate and enhance convection. Savage et al. (1988) found that gravity waves have been associated with mid-latitude cyclones. Miller and Sanders (1980) found similar results with gravity waves developing in the warm sector of the mid-latitude cyclone. Paxton and Sobien (1998) found low level inversion layers along with an unstable layer aloft supports the production of gravity waves.

Paxton and Sobien (1998) also found strong shear in the low-levels helps the production of gravity waves. The skew-T diagram from Peoria, IL (Figure 4) shows the conditions in the warm sector of the associated cyclone on 8 June 1984 0000 UTC. An inversion layer in the low levels and strong low-level shear are both present at that time. The pressure change recorded at Dane County Regional Airport in Madison, WI (Figure 5) from 0000 UTC until 1200 UTC 8 June 1984 is indicative of the passage of a gravity wave. Further microbarograph readings (not shown) from Anderson

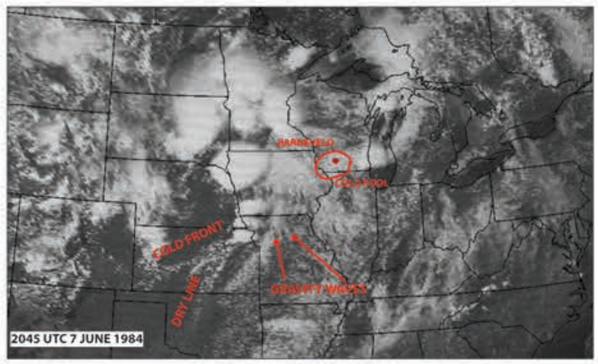

Figure 3: Visible satellite from 2045 UTC 7 June 1984. The location of the cold pool, cold front, dry line, and gravity waves are identified at this time.

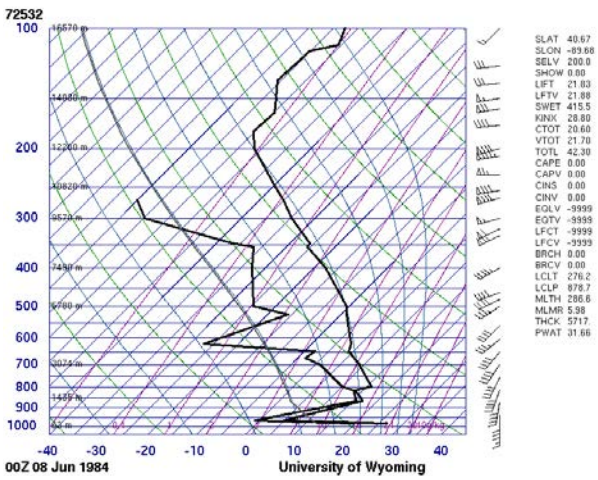

Figure 4: Skew-T diagram from Peoria, Illinois at 0000 UTC 8 June 1984. The strong low-level shear is indicative of conditions that help gravity waves form.

(1985) also indicated similar pressure changes at multiple stations in the Madison, Wisconsin region. These pressure fluctuations have been seen in other case studies associated with gravity waves (e.g., Uccellini 1975).

The visible satellite image (Figure 3) shows the possible detection of the gravity waves at 2045 UTC on 7 June 1984. This would be the developing stages of the gravity waves in the warm sector of the mid-latitude cyclone. This system and developing storms continued for the next several hours moving into southwestern Wisconsin around 0500 UTC. Examining the infrared (IR) satellite (Figure 6) the notch that is located on the back side of the convection could possibly be associated with the gravity wave similar to the clearing seen by Savage et al. (1988) in another Midwest case. Tracing the notch/gravity wave the Barneveld storm strengthened when this feature interacted with the northern boundary of the cold pool discussed above.

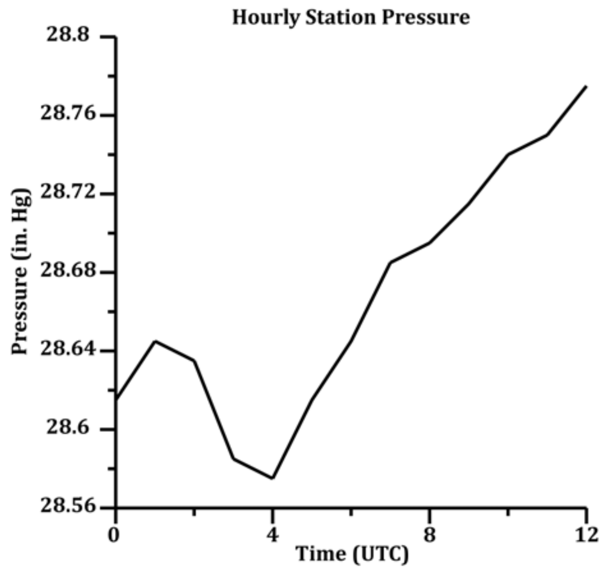

Figure 5: Pressure trace from Dane County Regional Airport in Madison, Wisconsin from 0000 UTC 8 June 1984 to 1200 UTC 8 June 1984. The pressure drop which occurs from 0200 to 0400 UTC is representative of pressure drops that have been experienced with the passage of gravity waves. The Barneveld tornado initiated around 0541 UTC.

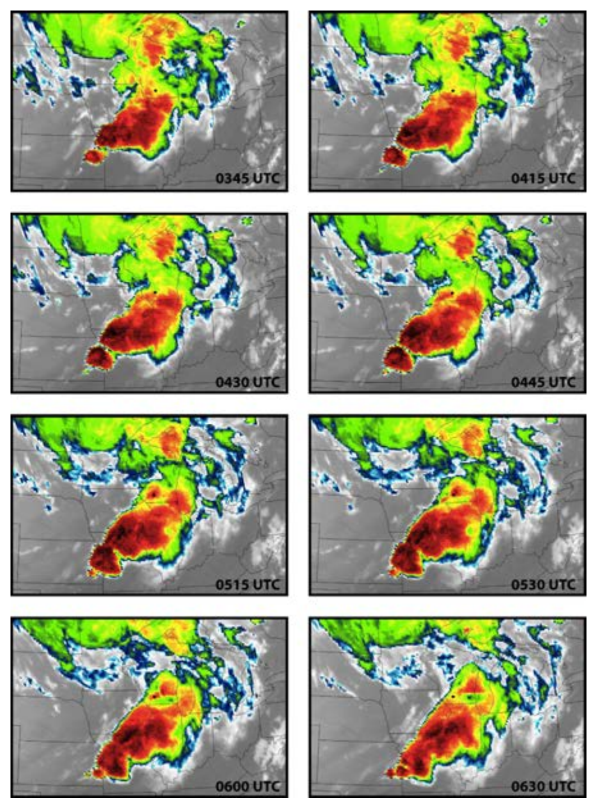

Figure 6: Infrared (IR) images from 0315 UTC to 0630 UTC on 8 June 1984. Storm bifurcation is seen at 0445 UTC. The gravity wave formation can also be seen on the west southwest side of the storm system.

4. TOPOGRAPHICAL INFLUENCES

The elevation profile (Figure 7, top panel) illustrates the first three tornadoes in the sequence of eight tornadoes that occurred in Southern Wisconsin. The tornado paths are represented by red lines whereas the blue lines represent the area in between the tornadoes. The elevation profile was created using a 10 meter United States Geological Society's Digital Elevation Model (DEM). The tornado track data were from a survey conducted by National Weather Service Office at Madison, WI, the Wisconsin State Climatologist Office, and the University of Chicago. Tornado one on the elevation profile was rated an F2 starting near Belmont, WI. In the official storm data publication the tornado was classified as "skipping" across the landscape to near Mineral Point, WI. Tornado two on the image above is the final segment of the original "skipping" portion of the path.

Tornado three began its 60 km path of destruction on a downward slope southeast of Barneveld. This tornado is better known as the Barneveld tornado, due to the F5 damage that it caused in the village of Barneveld. Figure 7 shows a south facing (middle panel) and north facing (bottom panel) 3-D view, with respect to topography, of the tornado paths that occurred in Southwest Wisconsin 8 June 1984. Specifically, you can see that tornado three stayed on a ridge line that runs southwest to northeast through the state of Wisconsin.

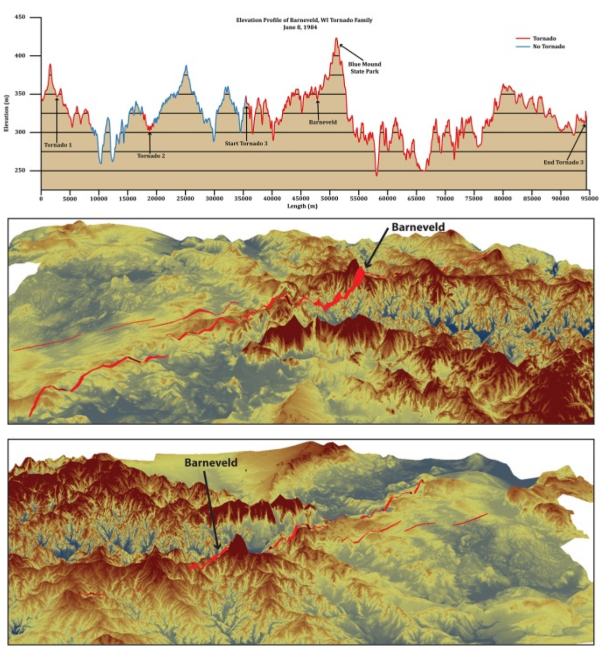

Figure 7: Top panel: Elevation profile of the first three tornadoes that occurred on 8 June 1984. The tornado paths are shaded in red, while non-tornado tracks are shaded in blue. Middle panel: South facing 3-D view of all the tornado tracks overlaid on the terrain in southern Wisconsin. Bottom panel: North facing 3-D view of all the tornado tracks overlaid on the terrain in southern Wisconsin.

5. CONCLUSION

In conclusion, the synoptic scale conditions provided the backdrop for thunderstorm development and possible formation of gravity waves in southwestern Wisconsin. The mesoscale conditions assisted in the enhancement of conditions that lead to the F5 Barneveld tornado on 8 June 1984 in southern Wisconsin.

6. REFERENCES

Anderson, C.E., 1985: The Barneveld Tornado: A NeW Type of Tornadic Storm in the Form of a Spiral Mesolow. Preprints, 14th Conf. on Severe Local Storms, 289-292, Amer. Meteor. Soc., Boston, MA.

Coleman, T.A. and K.R. Knupp, 2007: Rapid Local Changes in Helicity and Vertical Wind Shear Associated with the Passage of Ducted Gravity Waves. Draft Submitted to Weather and Forecasting.

Harrington, A.: Residual Outflow Boundary Impacts on CAPE versus Shear Contributions to Tornadic Supercells: the F-5 Barneveld, Wisconsin Tornado Revisited. University of Wisconsin-Madison, Cooperative Institute for Meteorological Satellite Studies. Web. 30 June 2014, http://www.aos.wisc.edu/uwaos journal/Volume1/AOS453/FCS_Harrington.pdf

Miller, D.A. and F. Sanders, 1980: Mesoscale Conditions for the Severe Convection of 3 April 1974 in the east-central United States. *J. Atmos. Sci.*, 37, 1041-1055.

NCDC, 1984: Storm Data. Volume 26, Number 6, 67 pp.

Paxton, C.H. and D.A. Sobien, 1998: Resonant Interaction between an Atmospheric Gravity Wave and Shallow Water Wave along Florida's West Coast. *Bull. Amer. Meteor. Soc.*, 2727-2732.

Savage, M.L., G.A. Weidner, and C.R. Stearns,1988: A Diagnostic Study of the Influence of a Gravity Wave upon Regional Weather. *Mon. Wea. Rev.*, 347-357.

Swedlund, B.: An Investigation of the June 1984 Barneveld, WI Tornado. University of Wisconsin-Madison. 13 May 2007. Web. 30 June 2014. <http://www.aos.wisc.edu/uwaosjournal/Volume3/AOS453/FCS_Swedlund.pdf>

Uccellini, L.W., 1975: A case study of apparent gravity wave initiation of severe convection storms. *Mon. Wea. Rev.*, 103, 497-513.