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A Review of a Southern Appalachian High Wind Event

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1. Introduction

This paper will investigate the meteorological parameters which led to a high wind event over the higher terrain in extreme southeastern Kentucky, western Virginia, and eastern Tennessee on the evening of October 16, 2006. Winds caused damage in Eolia in Letcher County Kentucky, and Cumberland in Harlan County (Figure 1), with numerous trees and power lines reported down in both areas.

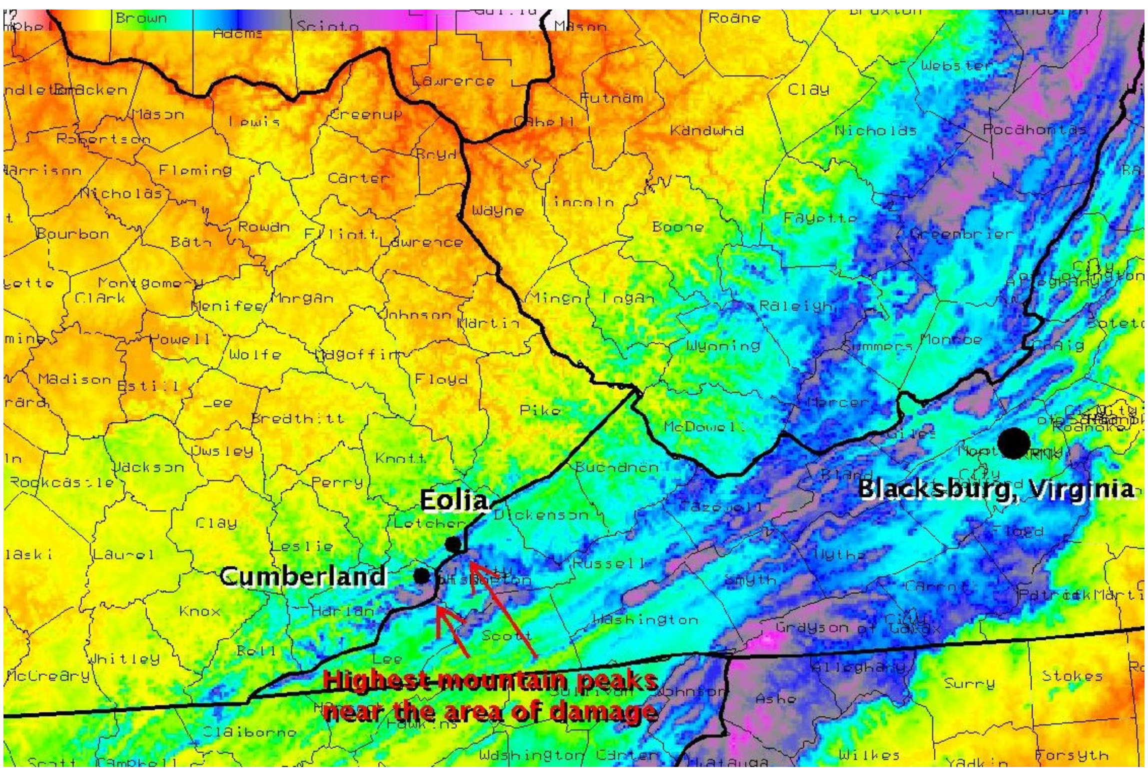

Figure 1. AWIPS 1-km resolution topography map

2. Synoptic Overview

At 0000 UTC 17 October 2006, a surface low was centered over northeastern Arkansas. The minimum pressure of the low was 995 mb. A warm front extended southeast from the low through Mississippi and Alabama. A cold front extended southwest from the low center through northwest Louisiana and southeast Texas. A weak surface trough was apparent east of the low, extending from near Paducah to Jackson, Kentucky. A surface high pressure was centered over Massachusetts.

This synoptic situation led to a tight pressure gradient over eastern Kentucky. The 1018 mb surface isobar passed through the extreme eastern portion of Pike County, while the 1013 mb isobar passed through Lexington and central Kentucky. This gradient was causing surface winds in the eastern portion of Kentucky between 5 and 15 mph (Figure 2).

The 925-mb analysis valid at 0000 UTC 17 October 2006 showed a 40 kt wind observed at Wilmington, Ohio from 160 degrees. There was a strong height gradient depicted, similar to the pressure pattern at the surface. The 925-mb low was located over northern Arkansas, with a warm front draped across western Tennessee and Alabama. The cold front extended southwest from the low to Texas (Figure 3).

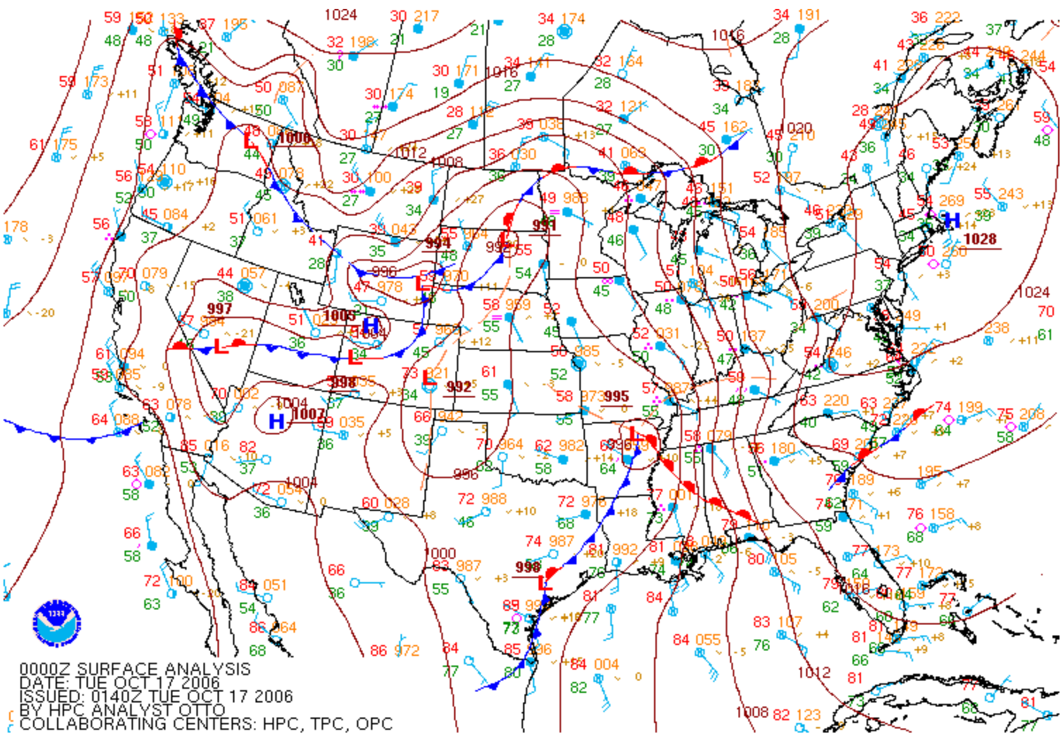

Figure 2. Hydrometeorological Prediction Center surface analysis – 0000 UTC 17 October 2006

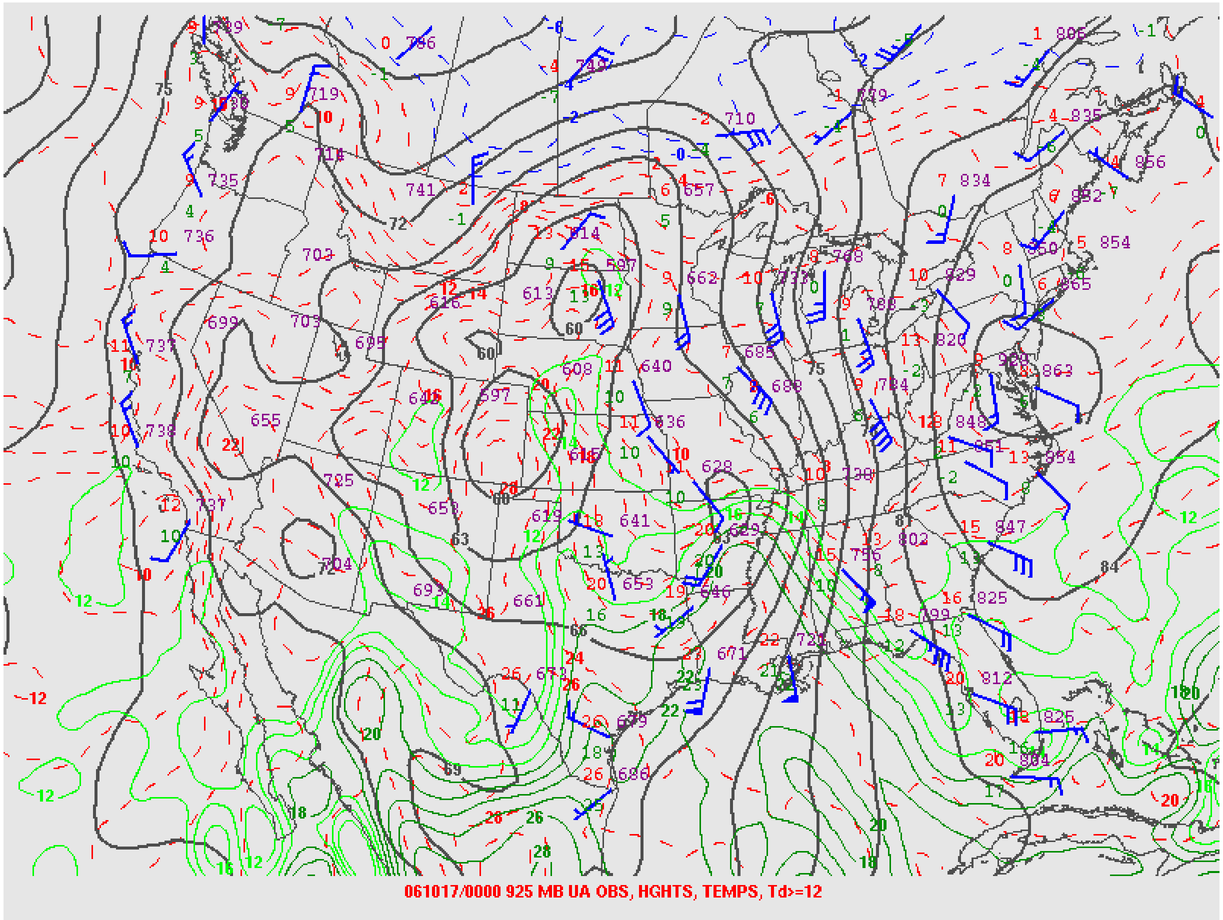

Figure 3. Storm Prediction Center (SPC) 925-mb upper-air analysis – 0000 UTC 17 October 2006

The 850-mb analysis showed a 45 kt wind from 150 degrees at Wilmington, with warm air advection underway across much of the eastern United States. Dewpoints near 10°C were advecting into Kentucky. An 850-mb high was located near the Virginia and North Carolina border (Figure 4).

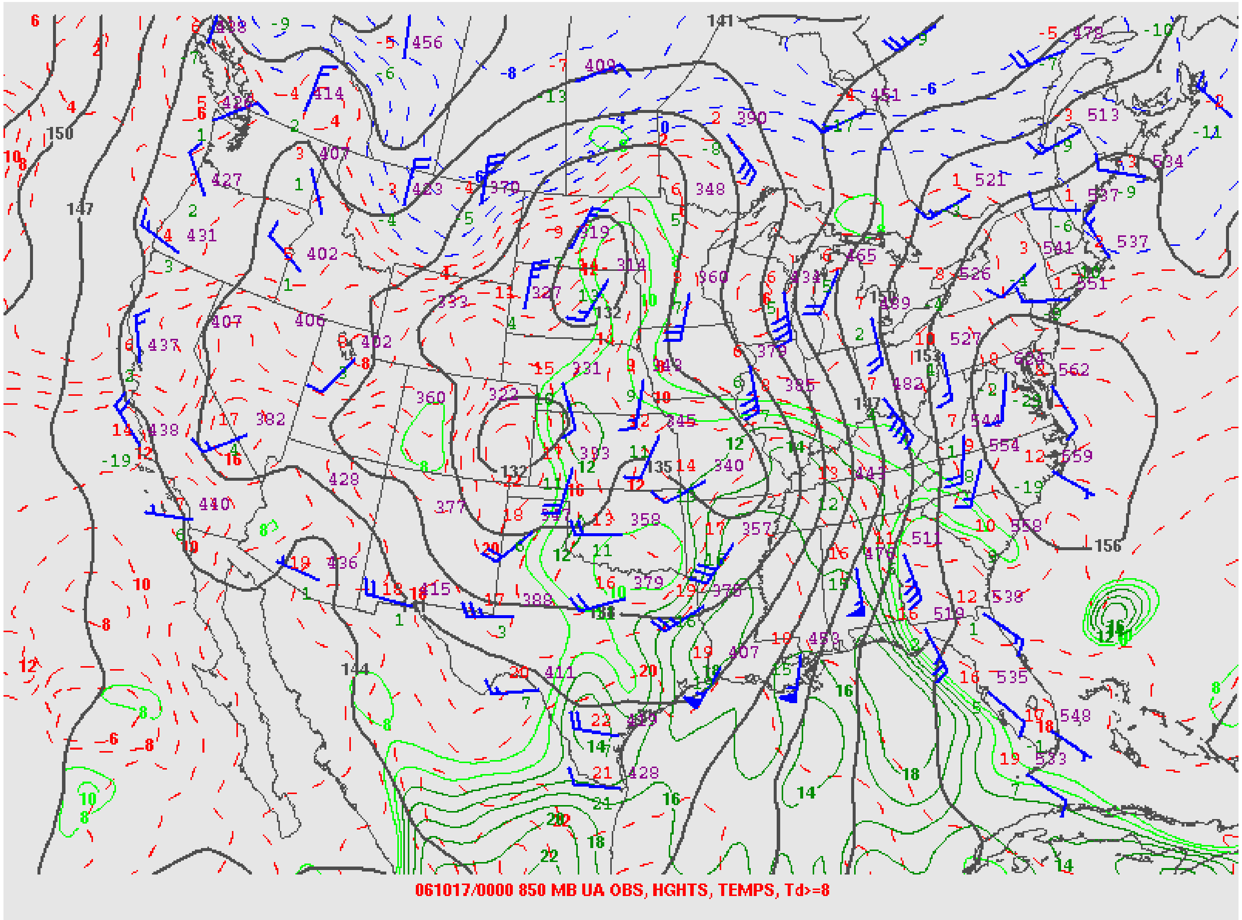

Figure 4. SPC 850-mb upper-air analysis – 0000 UTC 17 October 2006

At 700 mb, a 55 kt wind speed maximum was located over Nashville, Tennessee. A tight height gradient was also observed over Kentucky and West Virginia (Figure 5).

At 500 mb, a 50 kt jet was located from southern Missouri to southern Ohio. A 500 mb trough was located from Oklahoma to Texas. Observed winds at Wilmington, Ohio were 50 kt from 230 degrees (Figure 6).

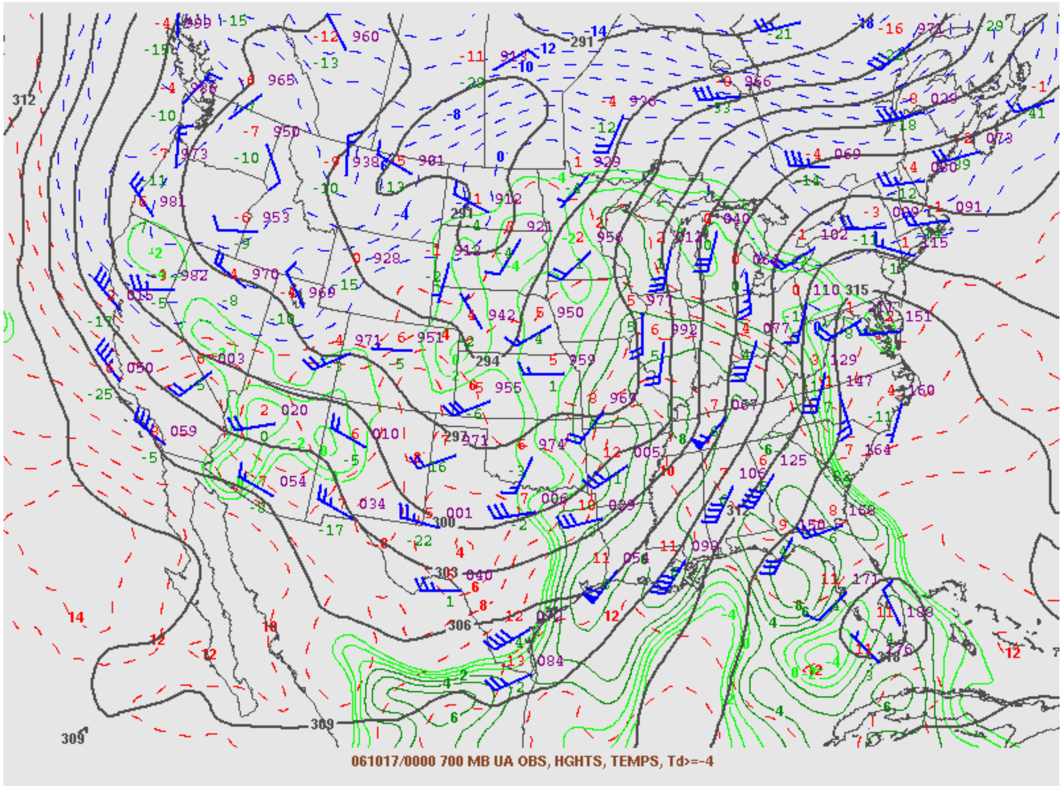

Figure 5. SPC 700-mb upper-air analysis – 0000 UTC 17 October 2006

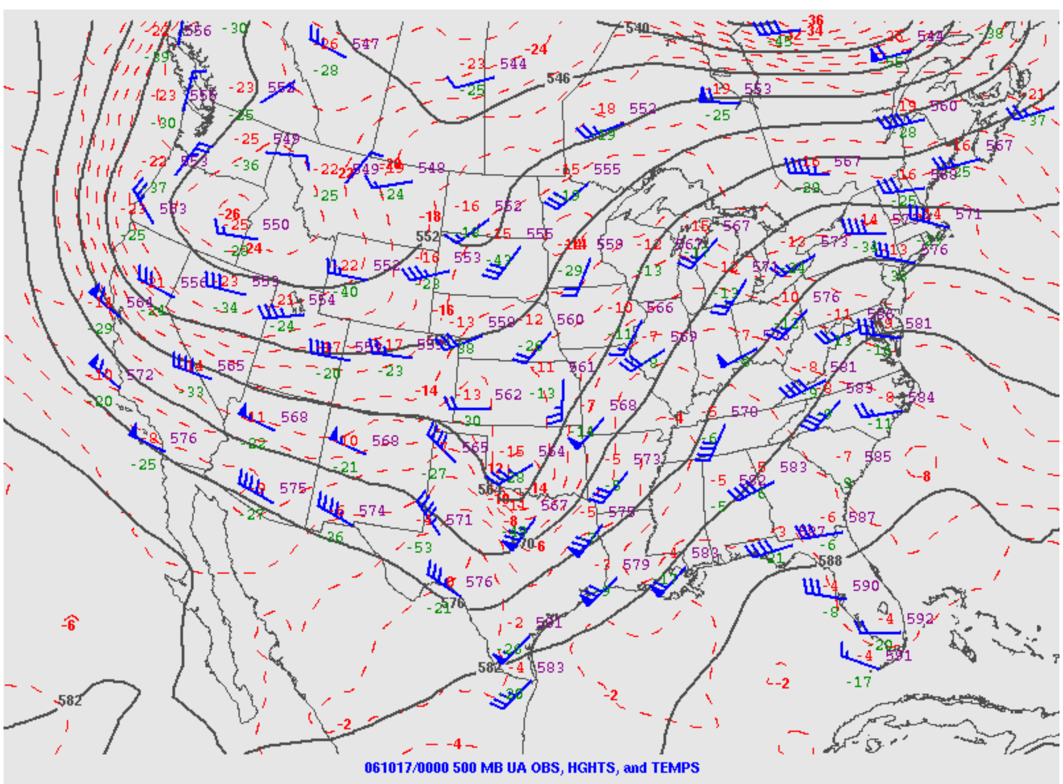

Figure 6. SPC 500-mb upper-air analysis – 0000 UTC 17 October 2006

The 250-mb analysis showed a jet with speeds in excess of 100 knots extending from Texas to Michigan (Figure 7).

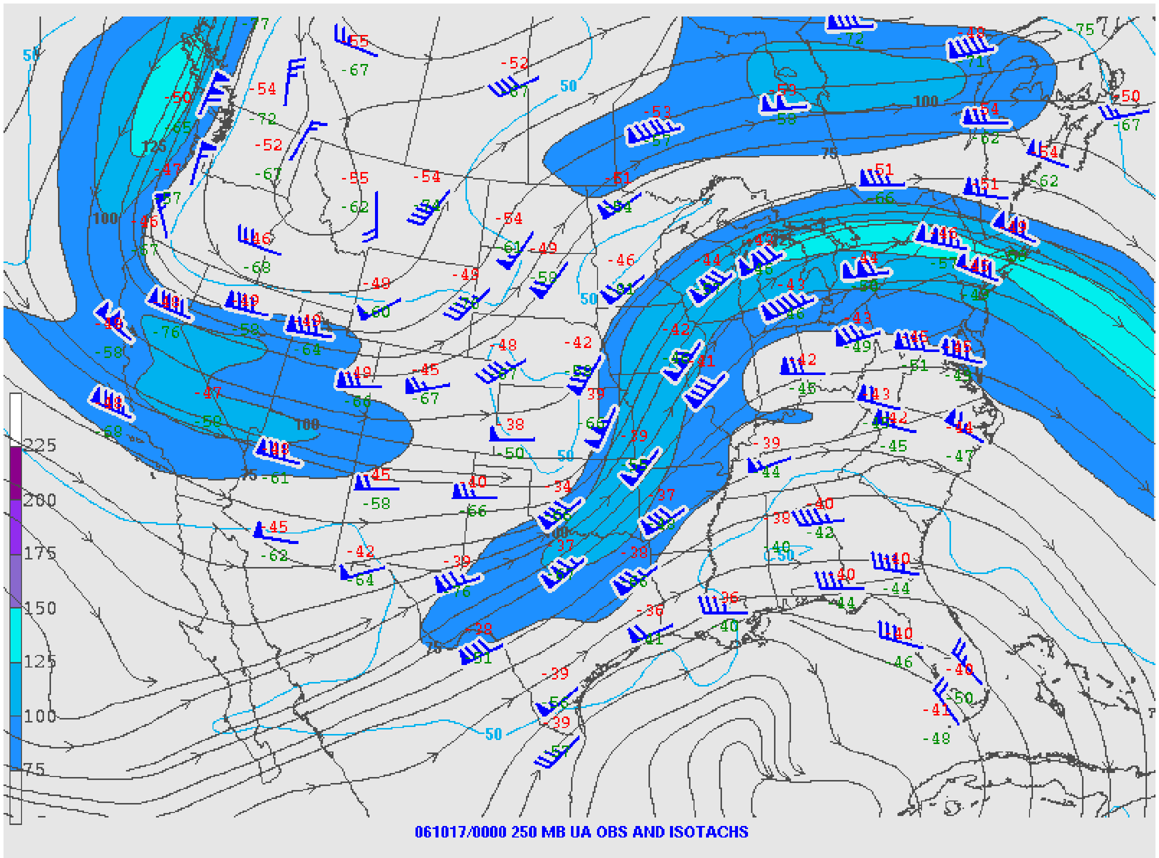

Figure 7. SPC 250-mb upper-air analysis – 0000 UTC 17 October 2006

Strong warm air advection was noted between 925 mb and 850 mb. This warming caused a mountain top inversion to develop. South to southeast winds were observed between 925 mb and 850 mb, with high heights off the Virginia coast, and a warm front approaching from the southwest. Weak warm air advection was noted from the 850-mb level through the 725-mb level, resulting in a dry adiabatic lapse rate.

3. Radar Data

The Jackson, Kentucky velocity azimuth display (VAD) showed a veering wind profile at 0232 UTC, with southeast winds close to the surface shifting to the southwest higher above the surface. Wind speeds at 2,000 feet above the surface were measured at 25 kt by the WSR-88D. At 3,000 feet, winds were indicated to be 40 kt. Winds of 55 kt were shown at 4,000 feet, with increasing speeds to 60 kt at 5,000 feet (Figure 8 and 9).

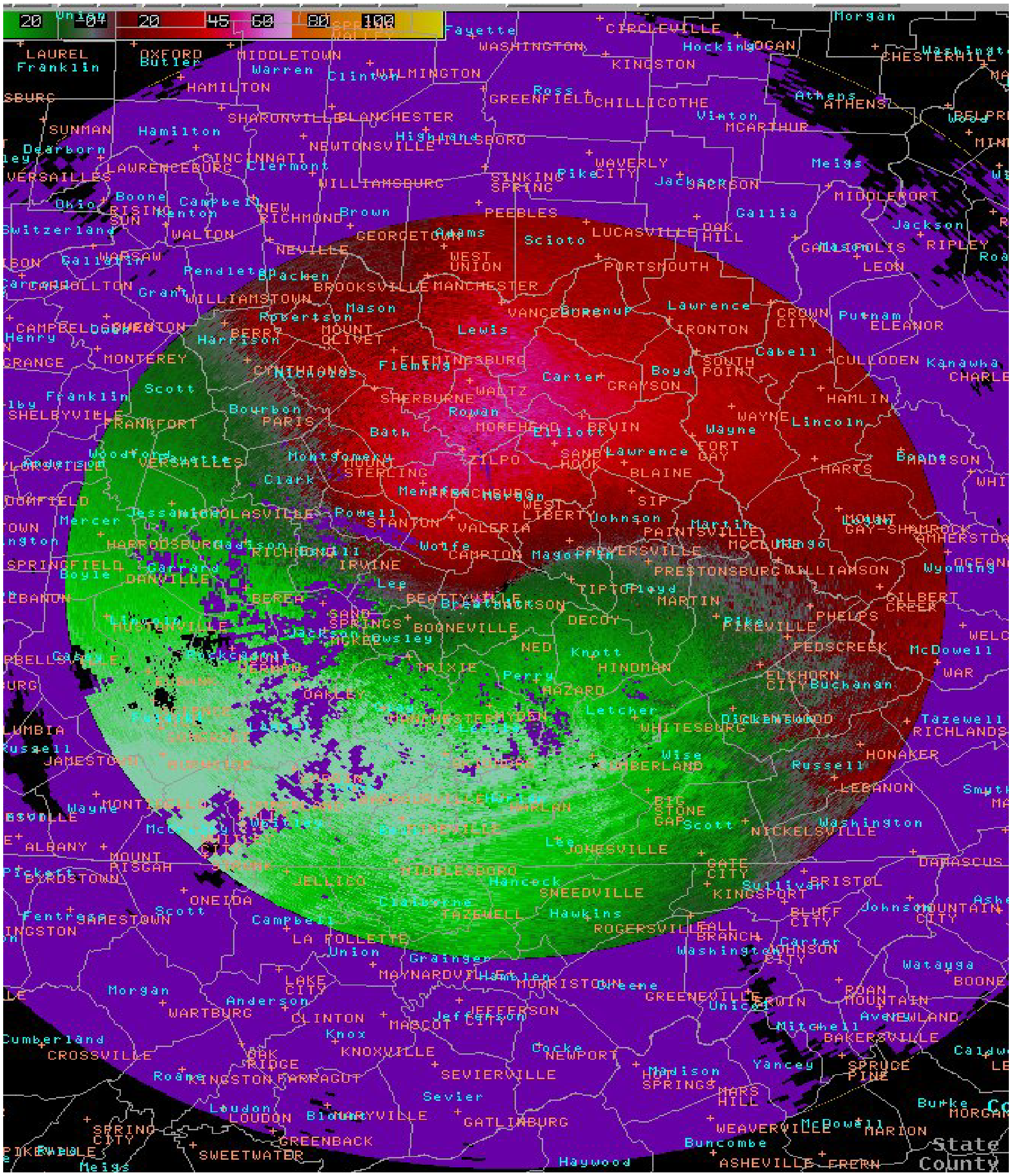

Figure 8. KJKL WSR-88D base velocity – 0227 UTC 17 October 2006

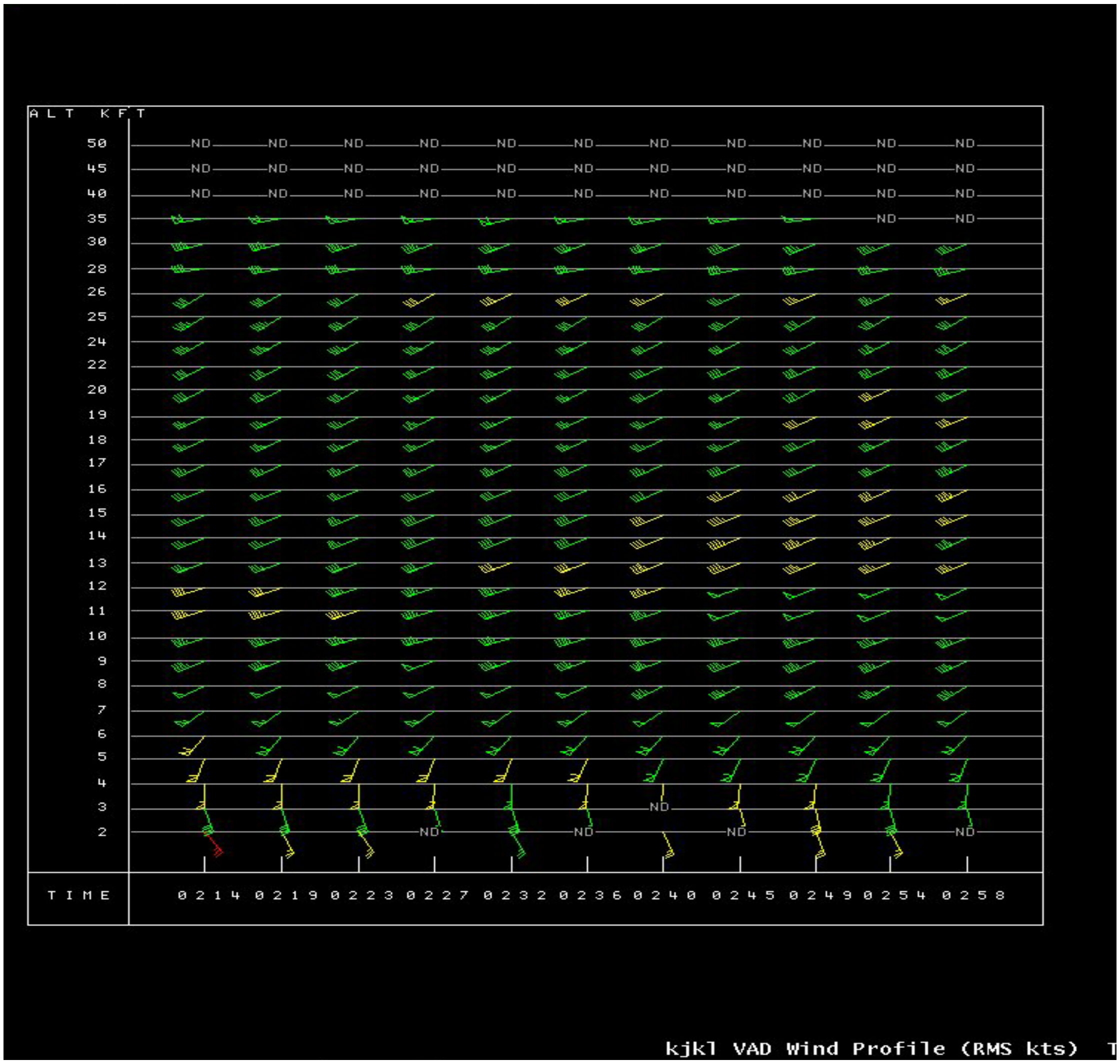

Figure 9. KJKL WSR-88D VAD wind profile – 0258 UTC 17 October 2006

4. Observations

Surface observations from the AWOS at Lonesome Pine Airport in Wise, Virginia, showed south-southeast winds for most of the day. Sustained winds early in the evening ranged from 10 to 15 mph, with numerous gusts to around 20 mph. Winds increased to 15 to 25 mph, with numerous gusts between 25 and 35 mph around 0200 UTC. A peak wind speed of 38 mph was observed at 0317 UTC, shortly after the damage was reported in Letcher and Harlan counties. School mesonet sites in western Virginia, just east of Harlan and Letcher counties in Kentucky, showed wind gusts of 25 to 35 mph. Several more stations had gusts over 50 mph. The highest wind gust reported was 73 mph. This occurred in northwest Tazewell County. MesoWest data in the Weather Forecast Office (WFO) Knoxville, Tennessee (MRX) county warning area (CWA) showed a gust of 46 mph in Wise County, Virginia, near Powell Mountain on State Route 23.

Other MesoWest observations in the MRX CWA showed numerous gusts of 40 to 50 MPH in the higher terrain of the Smokey Mountains in Tennessee. The highest wind gust reported was 64 mph at the Coker Creek Fire Tower in southeast Monroe County Tennessee.

LOCATION	**PEAK WIND SPEED**
Coker Creek, TN	64 MPH
RT 23 and Powell Mtn, VA	44 MPH
Prentice Cooper, TN	40 MPH
Lonesome Pine Arpt, Wise VA	38 MPH

Table 1. Peak wind speed observations

The 0000 UTC upper-air sounding from Blacksburg, Virginia showed a stable layer from the surface (950 mb) through 810 mb, with a conditionally unstable layer from 810 mb to 725 mb. Some drying in the lower levels was also observed, with a relatively dry layer extending from near the surface to 725 mb. (Figure 10)

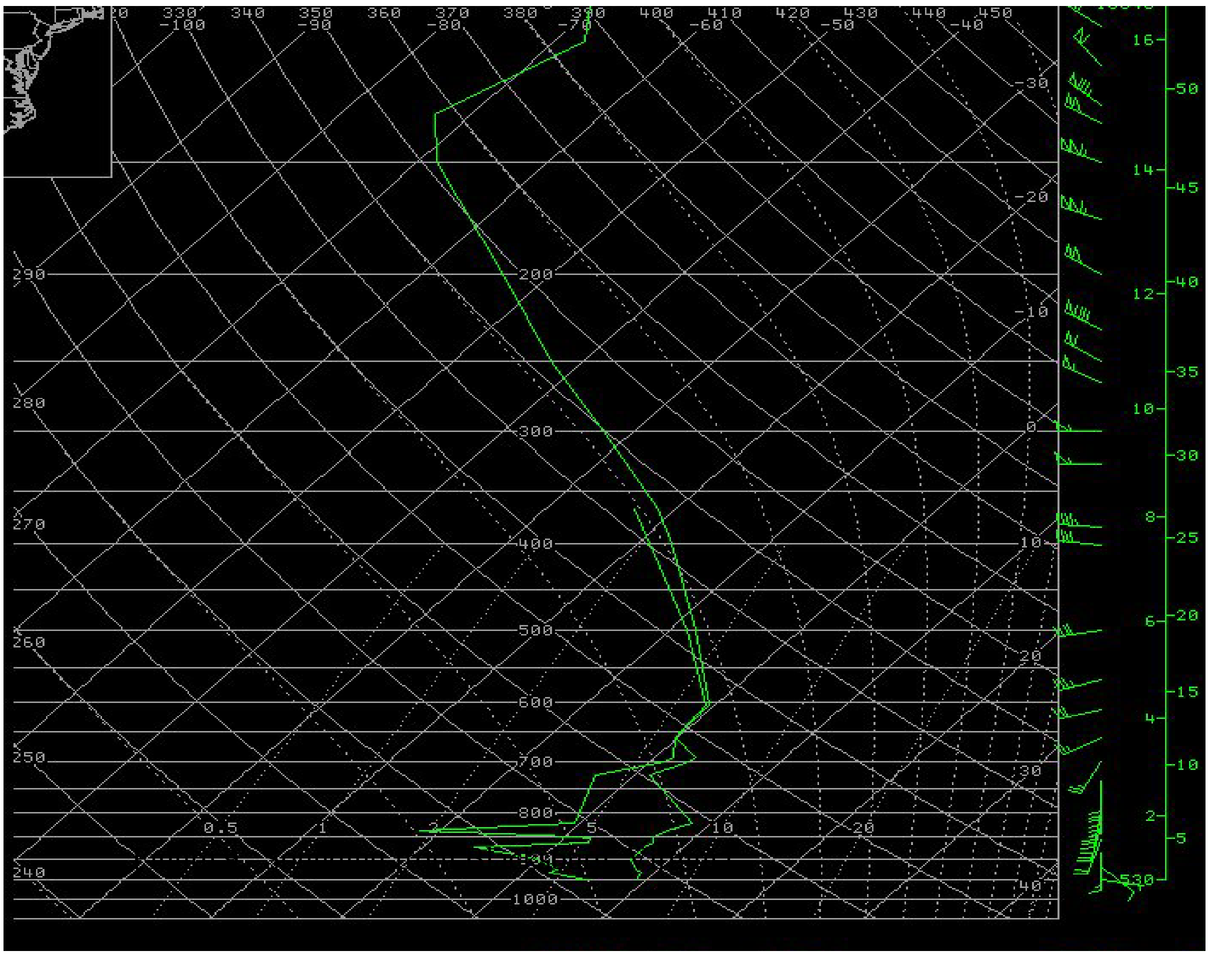

Figure 10. Sounding from Blacksburg, Virginia – 0000 UTC 17 October 2006

The model sounding from the 1800 UTC NAM for Eolia, Kentucky (Figure 11), valid at 0000 UTC, appears much moister in the lower levels below 700 mb, when compared to the observed sounding from Blacksburg. The model does not appear to capture the downslope induced drying in the lower layers. The model sounding shows a conditionally unstable layer from the surface (975 mb) through 910 mb, with a stable layer from 910 mb through 750 mb. The model sounding does not depict the conditionally unstable layer from 810 mb through 725 mb, as the observed sounding from Blacksburg does.

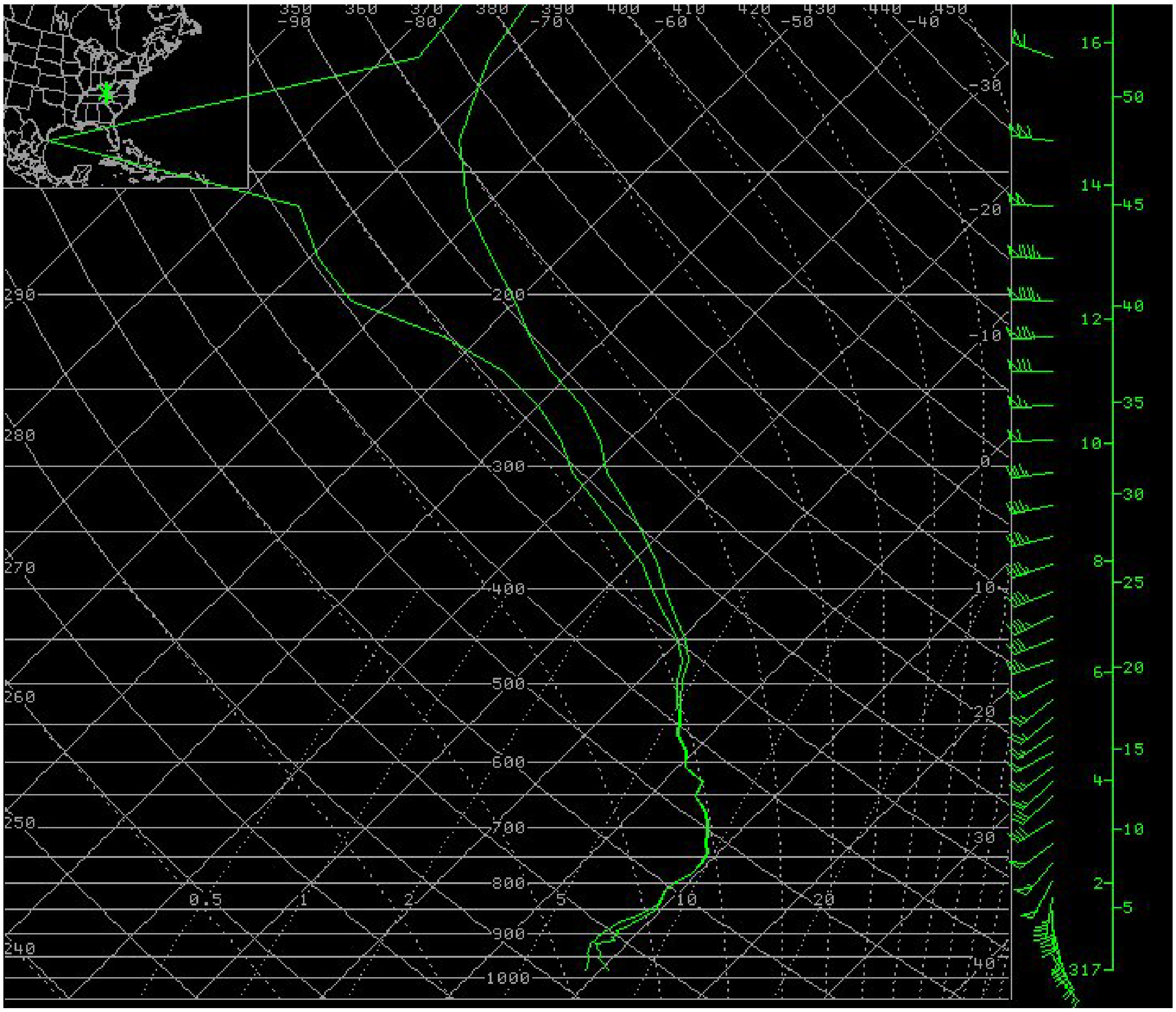

Figure 11. 1800 UTC NAM sounding for Eolia, Kentucky – valid 0000 UTC 17 October 2006

The NAM sounding near Blacksburg, valid at 0300 UTC, closely resembles the 0000 UTC sounding from Blacksburg, showing a surface inversion through 950 mb, with an unstable layer above through 900 mb (Figure 12). A mountain top inversion is depicted from 900 mb through 860 mb, with a dry adiabatic layer above.

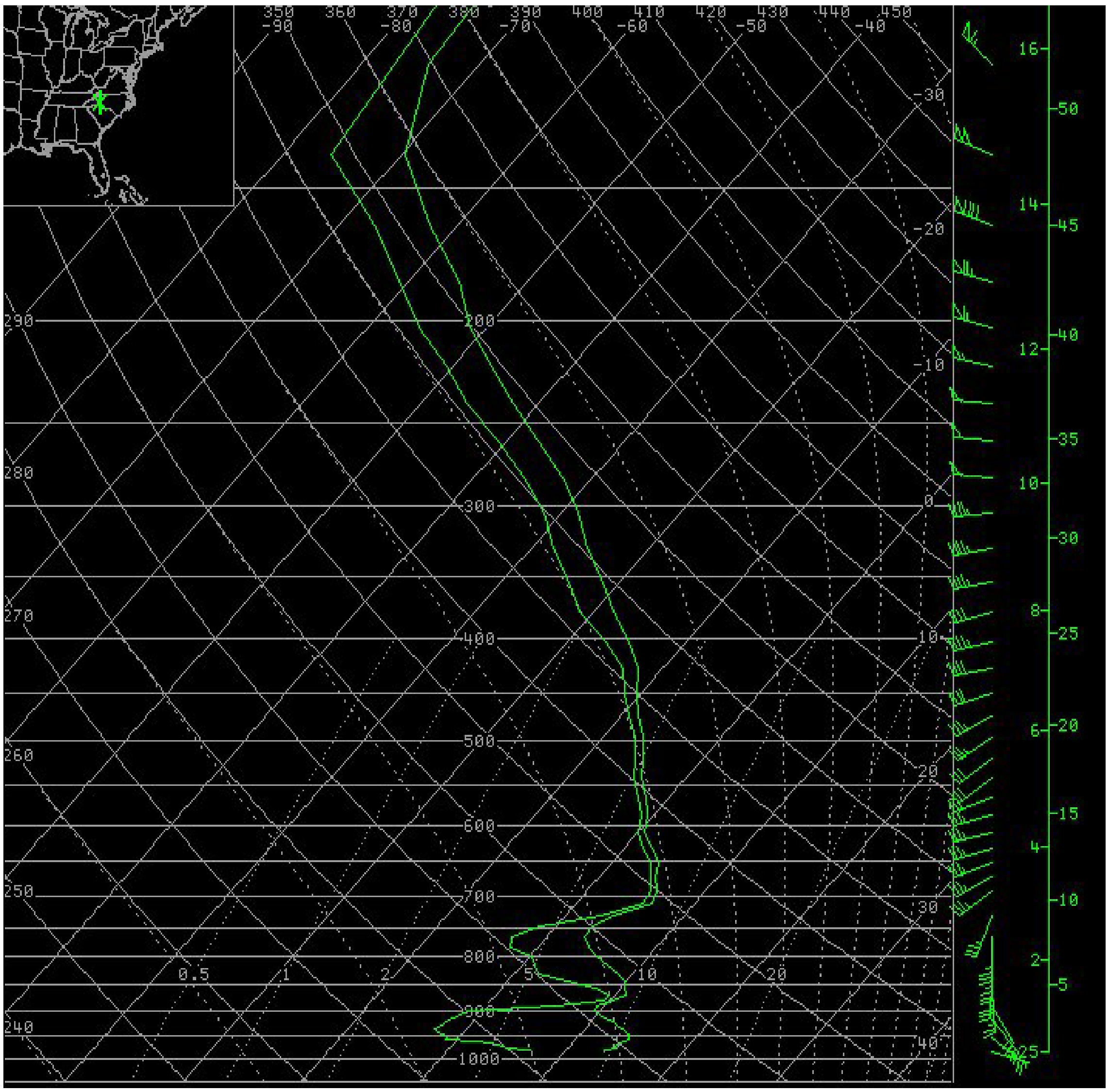

Figure 12. 0000 UTC NAM sounding near Blacksburg, Virginia – valid 0300 UTC 17 October 2006

5. Topography Effects and Analysis

Using the high resolution topography map in the Advanced Weather Interactive Processing System (AWIPS), some valuable information was obtained. When comparing the highest wind speed using all available sources of observational information, it appears that the highest wind gusts occurred immediately north-northwest of the highest elevations. Surface winds were from 150 to 160 degrees. This is exactly perpendicular to the orientation of the mountains in the area. Further analysis showed that wind gusts of 45 mph or greater occurred on the lee side of mountains that reach an elevation of 3500 feet above MSL.

The areas where the most significant wind damage was reported in Harlan and Letcher Counties were also located on the lee side of the highest mountain peaks. The wind damage occurred immediately on the lee side of mountain peaks that reached between 3,500 and 4,000 feet. The elevation of Cumberland, Kentucky in Harlan County is 1,500 feet MSL. The elevation of Eolia, Kentucky in Letcher County is 1,700 feet MSL.

6. Conclusions

A possible cause of the high winds is a mountain wave. These waves are most likely to form when the flow is perpendicular to the mountain range. Depending on instability, flow, and topographic conditions, it has been shown that winds strong enough to cause structural damage can occur (Whiteman 2000). This is especially true when wind speeds increase rapidly with height. It has been shown that wind speeds of at least 30 kt at the mountain top level is enough to generate mountain waves (Vieira 2005). In this case, wind speeds were approximately 60 kt at the mountain top level. Observed and model soundings upstream of where the wind damage occurred indicate wind speeds at 1,500 to 1,700 feet MSL were 25 to 30 kt. These are the same heights MSL as Cumberland and Eolia, where winds were estimated to be between 60 and 70 kt. This results in an increase of 75 to 110 percent of the observed values upstream.

In the case on October 16, 2006, the wind flow was perpendicular to the orientation of the mountains. Winds of this orientation result in the maximum amount of rise over the shortest distance. As the air rises up the windward side of the mountain, it becomes displaced as it reaches the mountain top, which in this case is near 4,000 feet MSL. Although not depicted on the NAM sounding, a stable layer was noted on the sounding from Blacksburg. This layer extended from the surface to 825 mb, or near 7,000 feet MSL. A stable layer in place at the mountain top level would prevent any further upward movement of the displaced air. Under this scenario, the possibility exists that air parcels could be displaced. This would allow the parcels to accelerate rapidly down the lee side of the mountain, toward their point of equilibrium, resulting in mountain waves on the lee side of a mountain (Reichman

1972). This is one possible scenario that led to the damaging winds in eastern Kentucky on October 16, 2006.

There are three main factors that affect an air parcel's interaction with a mountain (Whiteman 2000). These are the stability, speed of the air, and the topographic characteristics of the terrain. The synoptic set up during this event was favorable for mountain wave formation. Studies have shown that a stable layer in the lower levels of the atmosphere, with an unstable layer above, is conducive to mountain waves that produce high winds (Klemp and Lilly 1975). Further, it has been shown that a stable layer near mountain top is also a favorable indicator associated with the development of mountain waves (Vieira 2005). With a stable layer in place in the lower levels of the atmosphere, the air on the windward side of a mountain is displaced.

As the air parcel reaches the top of the mountain, the stability of the lower levels causes the air parcel to be accelerated back towards its original point. It is possible acceleration similar to that described above may have caused the high wind speeds observed in this case. This effect is maximized when the flow of air is exactly perpendicular to the orientation of the mountain range.

7. Acknowledgments

The map in Figure 2 was obtained from NOAA's Hydrometeorological Prediction Center web site, http://www.hpc.ncep.noaa.gov

The charts in Figure 3 through Figure 7 were obtained from the National Weather Service Storm Prediction Center web site,
http://www.spc.noaa.gov

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8. References

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