Orographically Induced Cirrus Clouds In the Lee of the Southern Appalachian Mountains

Ryan Ellis and Jonathan Blaes, NOAA/National Weather Service, Raleigh, NC
Lindsey Anderson North, Carolina State University, Raleigh, NC

Motivation

The development of orographically induced cirrus clouds east of the southern Appalachian Mountain chain can result in areas of unanticipated cloudiness downstream from the higher terrain across the Carolinas and Virginia. Both the degree of cloudiness and its impact on surface temperatures can have an adverse impact on forecast accuracy. This study will attempt to quantify the conditions necessary for orographic cirrus development across the southern Appalachian Mountains. This study will also evaluate null events of orographic cirrus when atmospheric conditions are conducive for cirrus development but none occurs. A case study will be presented from October 2008 illustrating a classic orographic cirrus event and its impacts on local forecast variables.

Data and Results

A total of 23 unique cases of orographic cirrus were observed in part I of the experiment along the southern Appalachians from March 2009 through February 2010. A total of 42 unique cases were observed in part II of the experiment from September 2011 to April 2012. 65 total cases were observed. 123 atmospheric soundings were collected from these events.

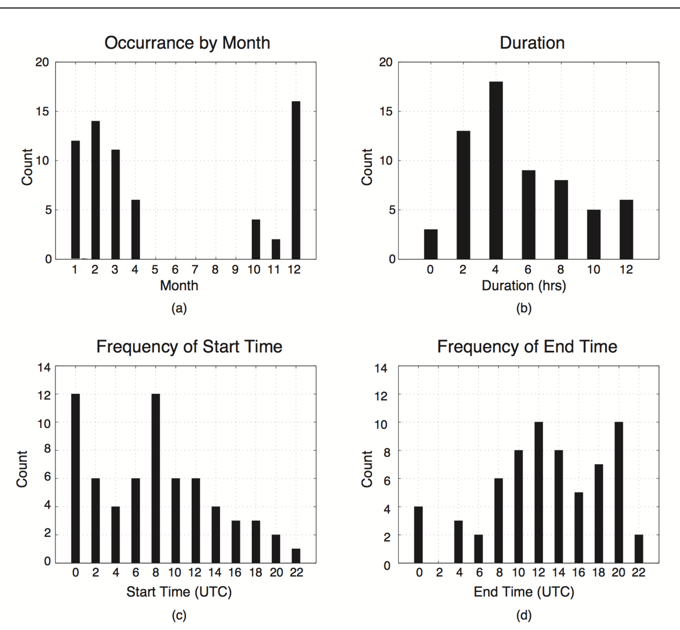

Figure 1: Frequency of orographic cirrus events by month (a), duration (b), start time (c), and end time (d).

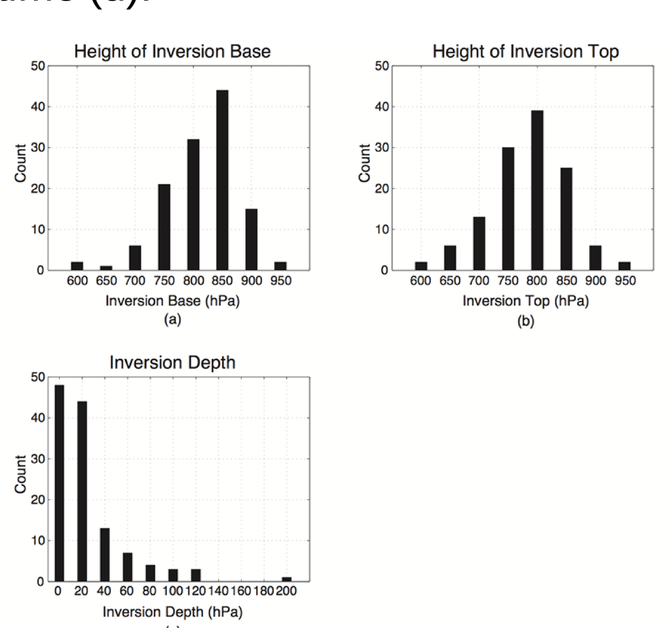

Figure 2: Histograms showing cirrus event inversion statistics including (a) inversion base (b) top and (c) depth.

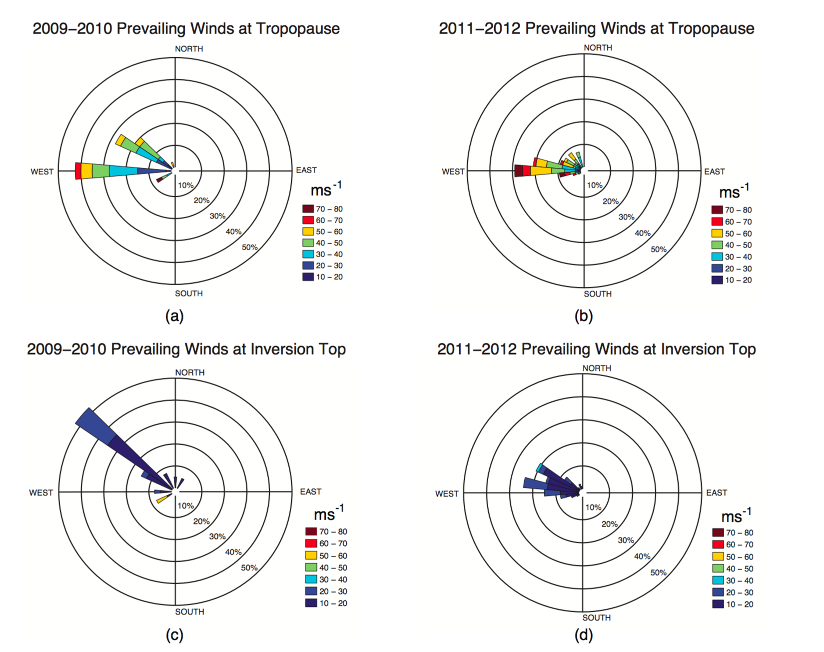

Figure 3: Wind roses for (left) 2009-2010 and (right) 2011-2012. Frequency and strength of wind speed and direction at the (top) tropopause and at the (bottom) inversion top.

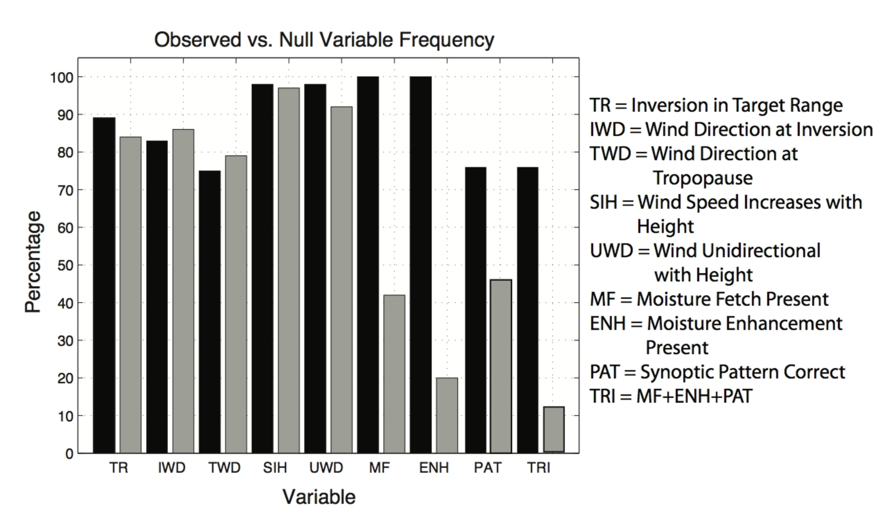

Figure 4: Observed (black) vs. null (grey) variable frequency for orographic cirrus events during the 2011-2012 cool season. Each bar represents a variable from the list on the right.

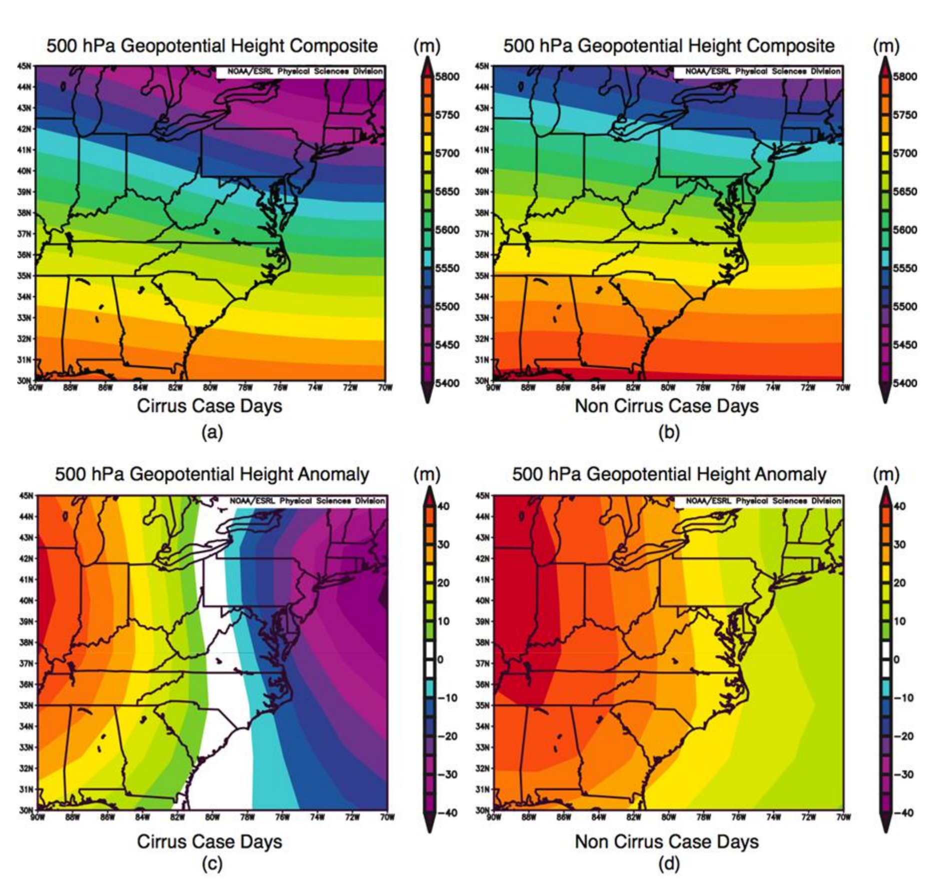

Figure 5: 500 hPa geopotential height composite of (a) cirrus days and (b) non-cirrus days from NCEP/NCAR Reanalysis data. 500 hPa geopotential height anomaly field as compared to 1981-2010 climatology for (c) cirrus and (d) non-cirrus days.

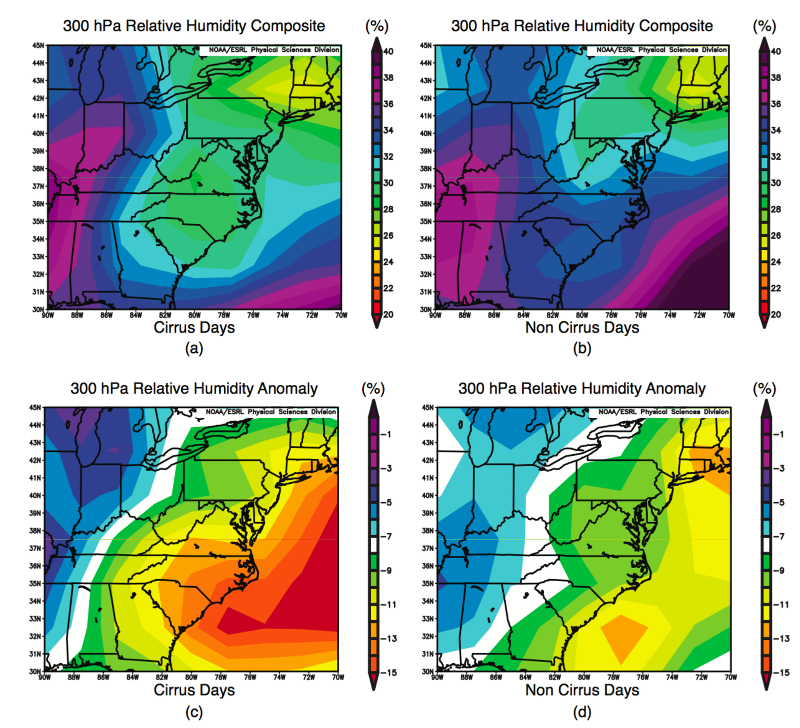

Figure 6: 300 hPa relative humidity composite of (a) cirrus days and (b) non-cirrus days from NCEP/NCAR Reanalysis data. 300 hPa relative humidity anomaly field as compared to 1981-2010 climatology for (c) cirrus and (d) non-cirrus days.

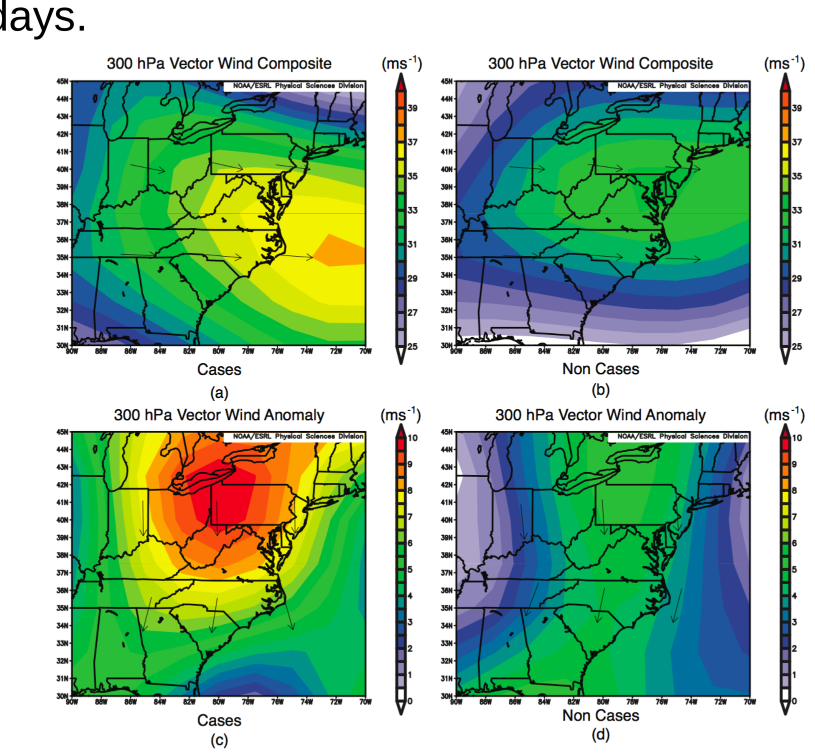

Figure 7: 300 hPa vector wind composite of (a) cirrus days and (b) non-cirrus days from NCEP/NCAR Reanalysis data. 300 hPa vector wind anomaly field as compared to 1981-2010 climatology for (c) cirrus and (d) non-cirrus days.

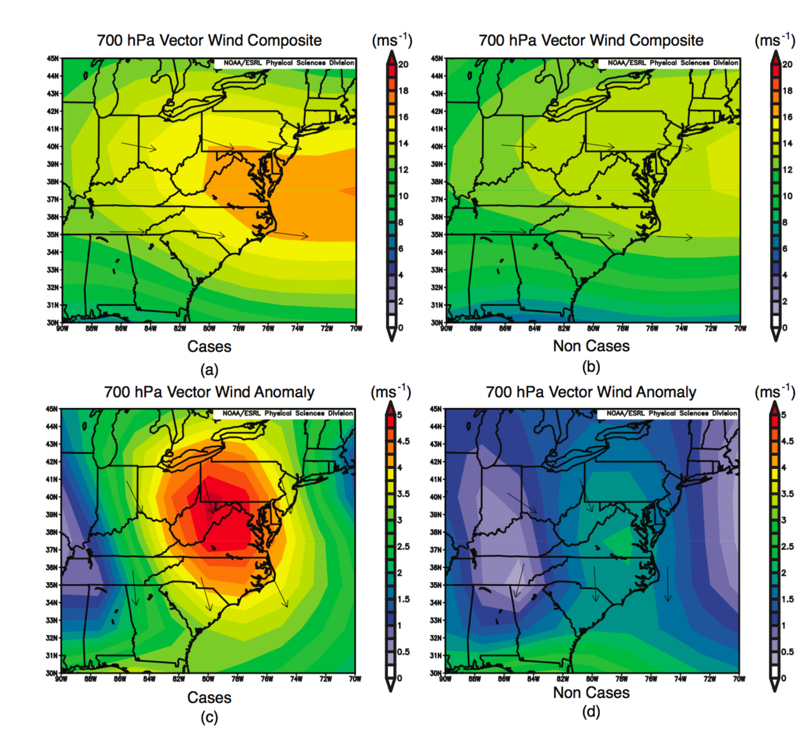

Figure 8: 700 hPa vector wind composite of (a) cirrus days and (b) non-cirrus days from NCEP/NCAR Reanalysis data. 700 hPa vector wind anomaly field as compared to 1981-2010 climatology for (c) cirrus and (d) non-cirrus days.

Case Study: 29 October 2008

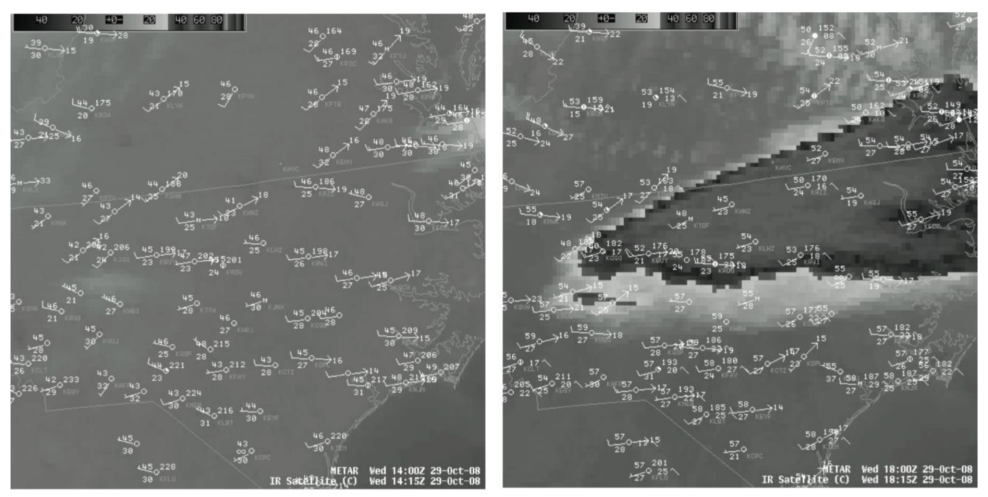

Figure 9: GOES infrared satellite imagery from (a) 1415 UTC and (b) 1815 UTC 29 October 2008 with overlay of METAR station observations.

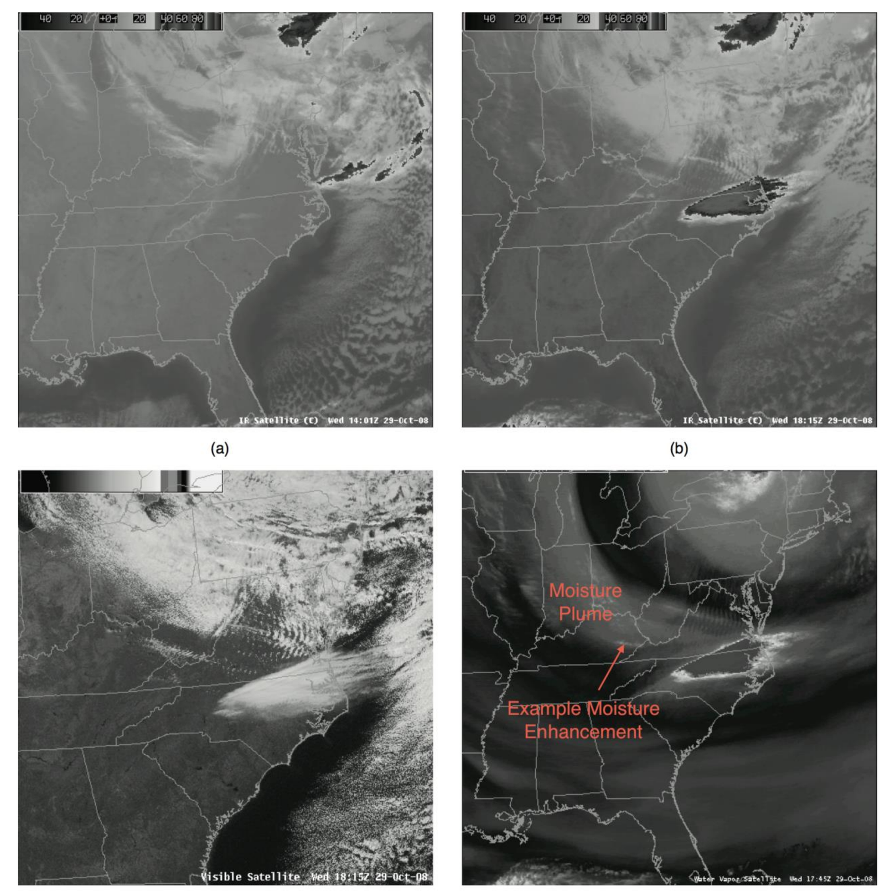

Figure 10: GOES infrared satellite imagery from (a) 1401 UTC and (b) 1815 UTC 29 October 2008 along with GOES visible satellite imagery from (c) 1815 UTC and (d) water vapor imagery from 1745 UTC. The upstream moisture plume and an example of a moisture enhancement are annotated in (d).

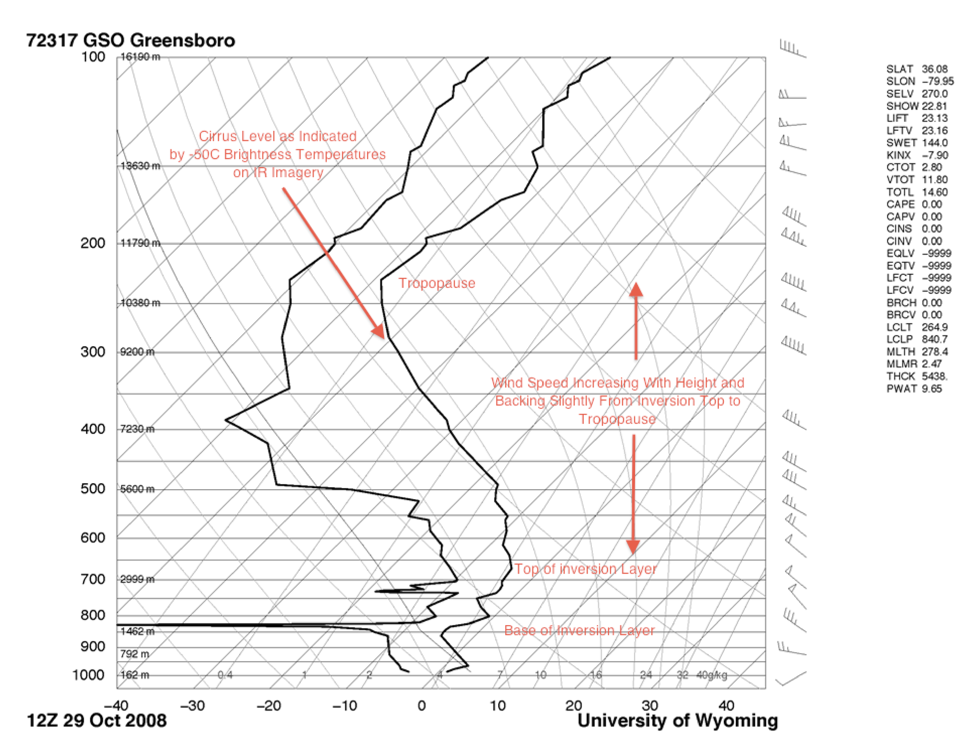

Figure 11: Atmospheric sounding from Greensboro, NC (KGSO) from 1200 UTC 29 October 2008 from the University of Wyoming. Key requirements for potential orographic cirrus are highlighted on the figure as well as the level of -50 C brightness temperatures seen in Fig. 9b and Fig. 10b.

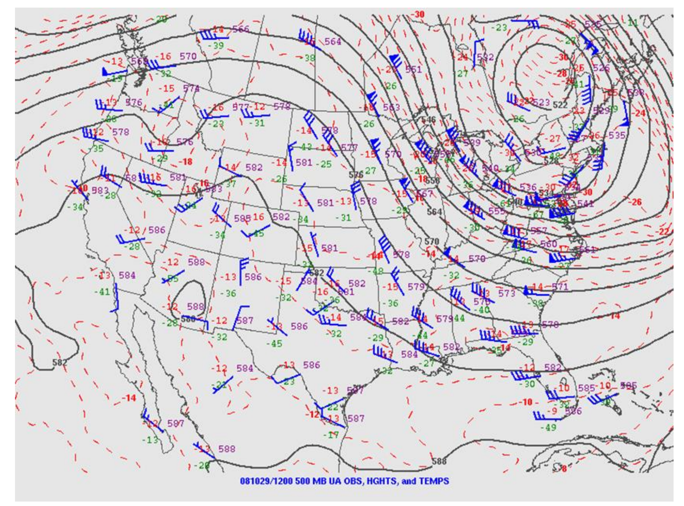

Figure 12: 500 hPa analysis from 29 October 2008 courtesy of the Storm Prediction Center.

Conclusions

- Orographic cirrus outbreaks can affect temperatures by as much as 10˚F.
- Outbreak events usually set up in a stable environment with a mid to upper-level low pressure system to the northeast and a strong upper level ridge to the west.
- An inversion typically exists between 850 and 700 hPa.
- Winds are generally unidirectional from the northwest with some slight backing throughout the profile from the top of the inversion to the tropopause.
- A pre-existing upper-level upstream moisture source is usually necessary to trigger the onset of an orographic cirrus outbreak.
- Orographic cirrus events most frequently occur in the cool season, last between 4 and 8 hours, typically begin during the evening or early morning hours and dissipate during the morning or early afternoon hours.
- In addition to forecast and observed soundings, satellite data is a vital component to the process to identify the potential for orographic cirrus.
- An operational forecasting technique for orographic cirrus has been outlined and implemented at WFO Raleigh.

References

1983 Ellrod, G. “Orographic Cirrus Along the Appalachian Mountains,” *Satellite Applications Information Note;* **83/2.**

Acknowledgements

We would like to thank Brian Miretzky, Frank Alsheimer, and Bryan Jackson for their reviews and contributions to this research. Composite Imagery provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.esrl.noaa.gov/psd/. Sounding data provided by the University of Wyoming.