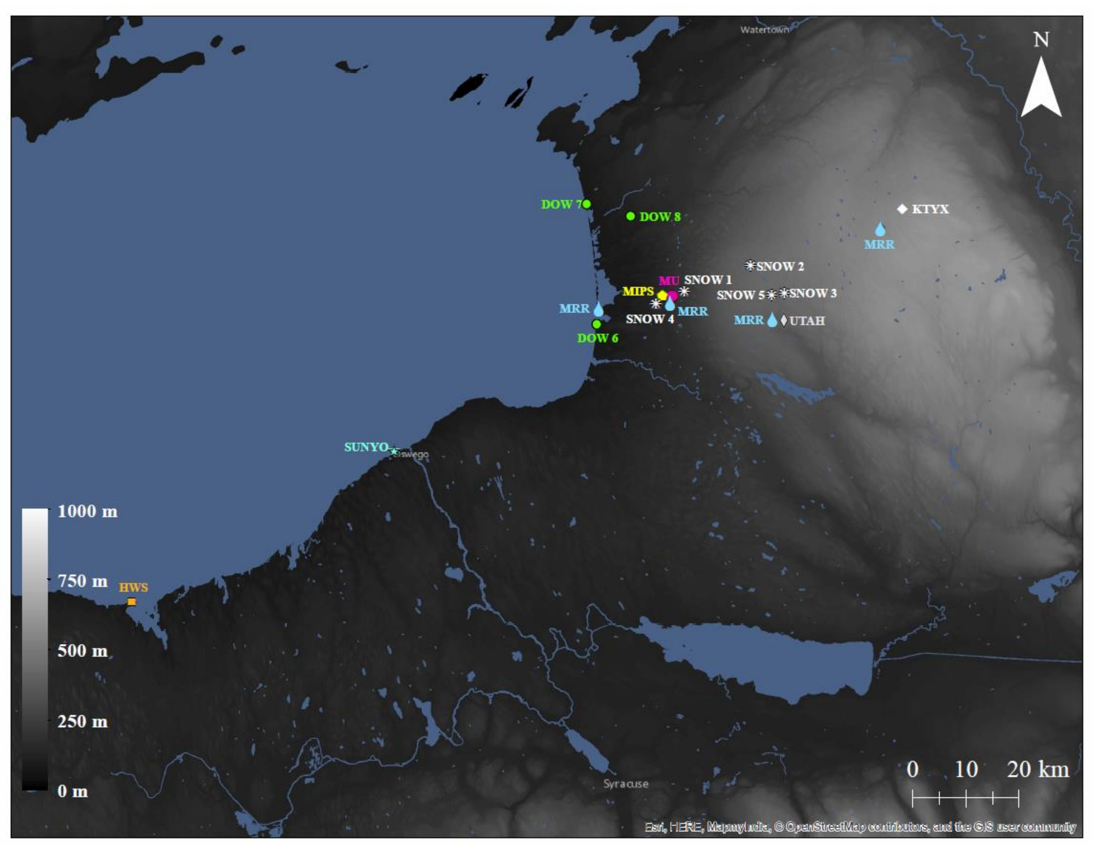
Mobile Doppler Radar Observations of an Intense Long-Lake-Axis-Parallel Lake-effect Snow band on 10–12 December 2013 During the Ontario Winter Lake-effect Systems Project

Dustin Conrad, Nicholas Zelasko, Jeffrey Frame, and Jake Mulholland
University of Illinois at Urbana-Champaign, Urbana, IL

Introduction

This study examines a long-lake-axis-parallel lake-effect snow band over Lake Ontario that occurred on 10-12 December 2013 during the Ontario Winter Lake-effect Systems (OWLeS) Project. Three Doppler on Wheels (DOW) radars, the University of Wyoming King Air instrumented aircraft, the University of Alabama-Huntsville Mobile Integrated Profiling System MIPS), mobile rawinsondes teams, and multiple ground-based instrumented mesonets sampled this band. The close proximity of the mobile radars to the band allows for high-resolution analyses of wind shifts and misovortices within the band.



Above: Location of selected ground-based OWLeS assets and the KTYX WSR-88D radar at 0120 UTC 11 December. Grayscale shading indicates elevation above mean sea level (ASL; m).

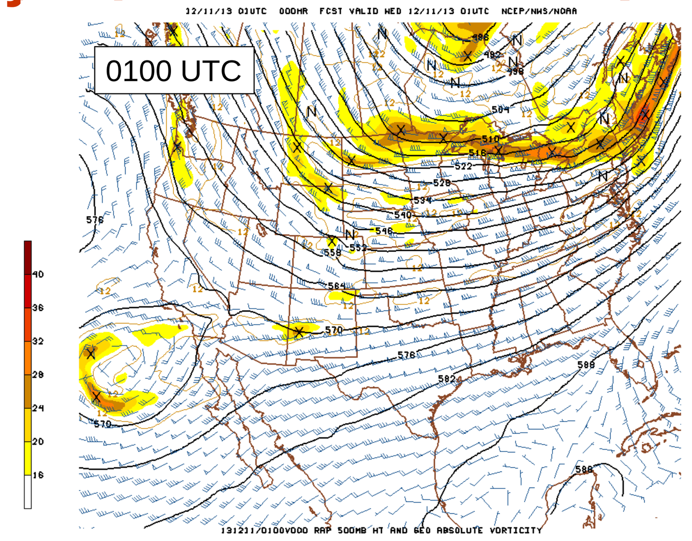
Methodology

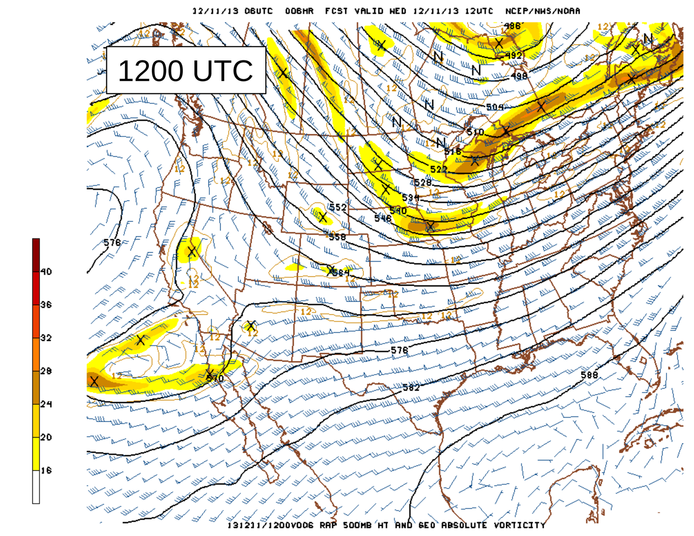
The DOW radars are mobile X-band (3-cm) wavelength radars with dual-polarization capabilities. The beam width is 0.93^{0}. Both DOW6 and DOW7 deployed at 2300 UTC on 10 Dec (see map above) and remained in place until 0000 UTC on 12 Dec.

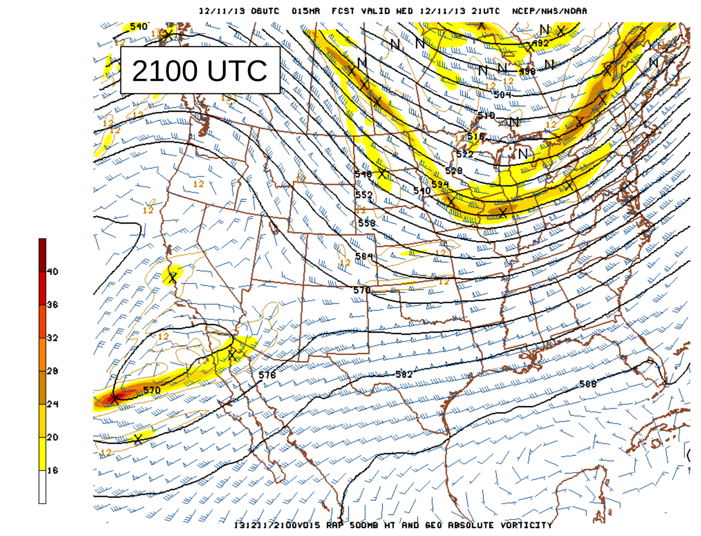
Data were edited using Solo3 software. If the normalized coherent power (NCP) fell below 0.3, the data were determined to be of poor quality and were removed. Areas of ground and sea clutter were manually determined from the reflectivity, radial velocity, and correlation coefficient (RHOHV) fields and were also removed.

Data were mapped to a regular Cartesian grid using a two-pass Barnes analysis. For all analyses, the horizontal grid spacing is 400 m and the vertical grid spacing is 100 m. The Barnes smoothing parameter in the horizontal directions is 1.66 km^2 and 0.059 km^2 in the vertical direction. The multiplier, gamma, for the second pass, is 0.3.

Synoptic and Thermodynamic Environment



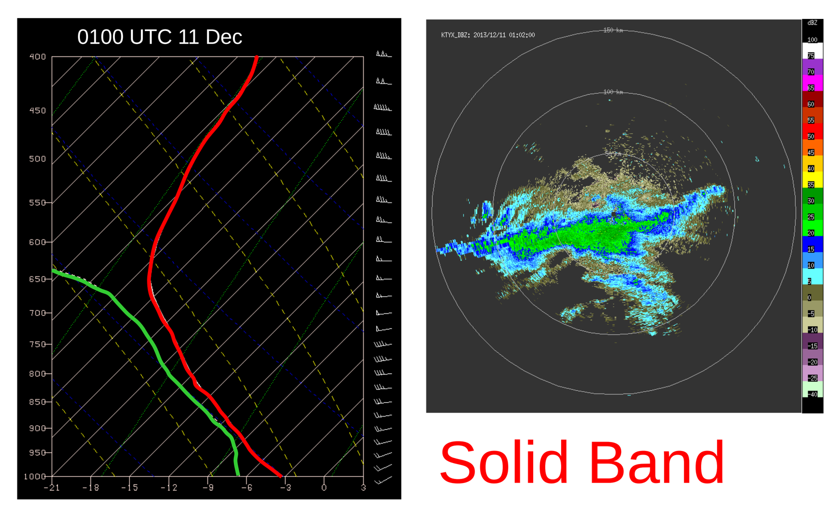


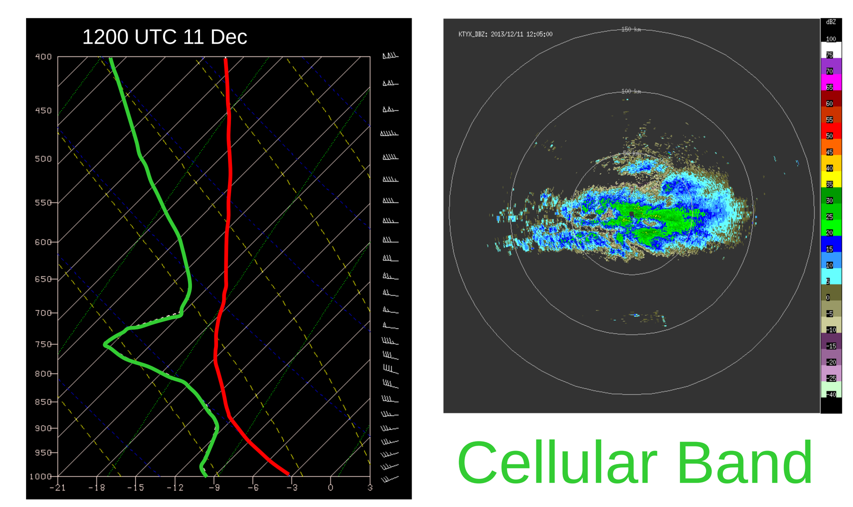


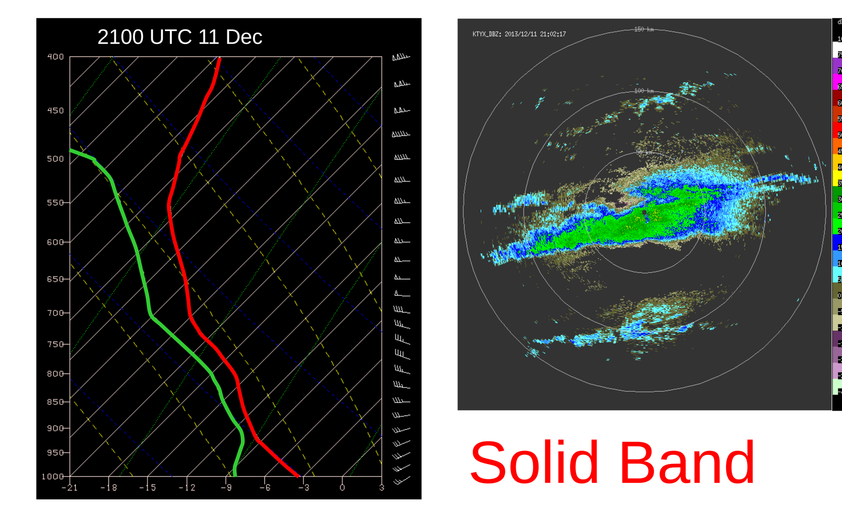
Above: 500 mb heights and absolute vorticity at 0100 UTC. Lake Ontario is in a region of differential positive vorticity advection (DPVA), leading to ascent and midlevel cooling.
Below Left: SUNY-Oswego WRF sounding for Oswego, NY, valid at 0100 UTC. Note the steep lapse rates through the depth of the troposphere and equilibrium level above 650 mb.
Below right: KTYX WSR-88D reflectivity at 0102 UTC.

Above: 500 mb heights and absolute vorticity at 1200 UTC. Lake Ontario is in a region of differential negative vorticity advection (DNVA), leading to descent and midlevel warming.
Below Left: SUNY-Oswego WRF sounding for Oswego, NY, valid at 1200 UTC. Steep lapse rates are limited to the surface – 900 mb layer.
Below right: KTYX WSR-88D reflectivity at 1205 UTC.

Above: 500 mb heights and absolute vorticity at 2100 UTC. The DNVA regime has ended, but DPVA from the next shortwave trough has yet to begin.
Below Left: SUNY-Oswego WRF sounding for Oswego, NY, valid at 2100 UTC. Midlevel cooling has occurred since 1200 UTC.
Below right: KTYX WSR-88D reflectivity at 2102 UTC.

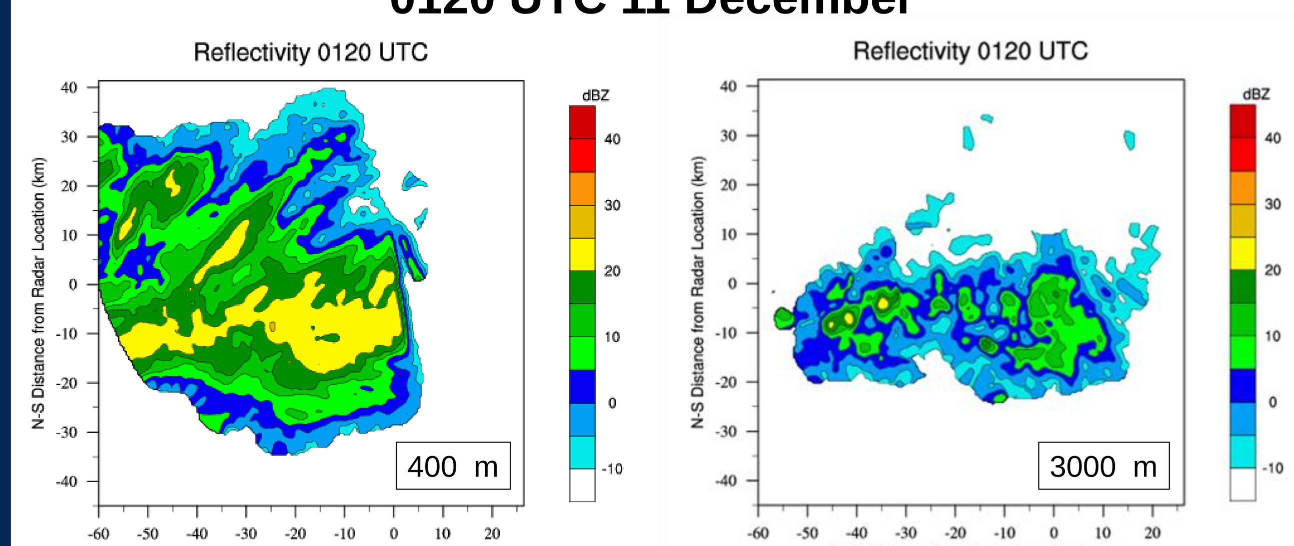




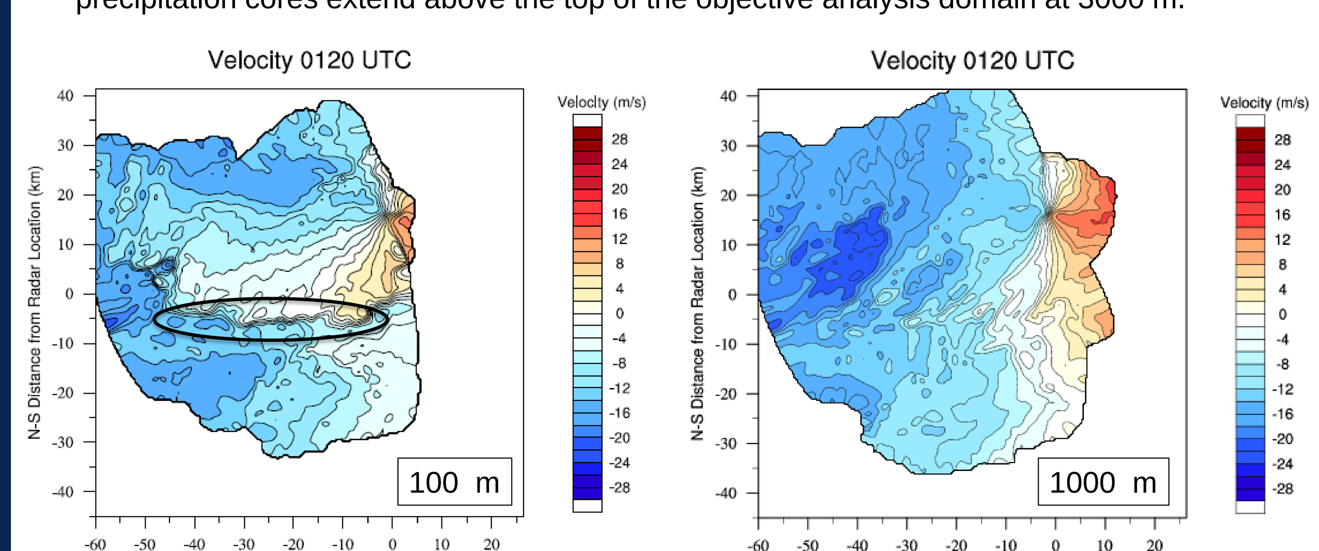


Radar Objective Analyses

0120 UTC 11 December

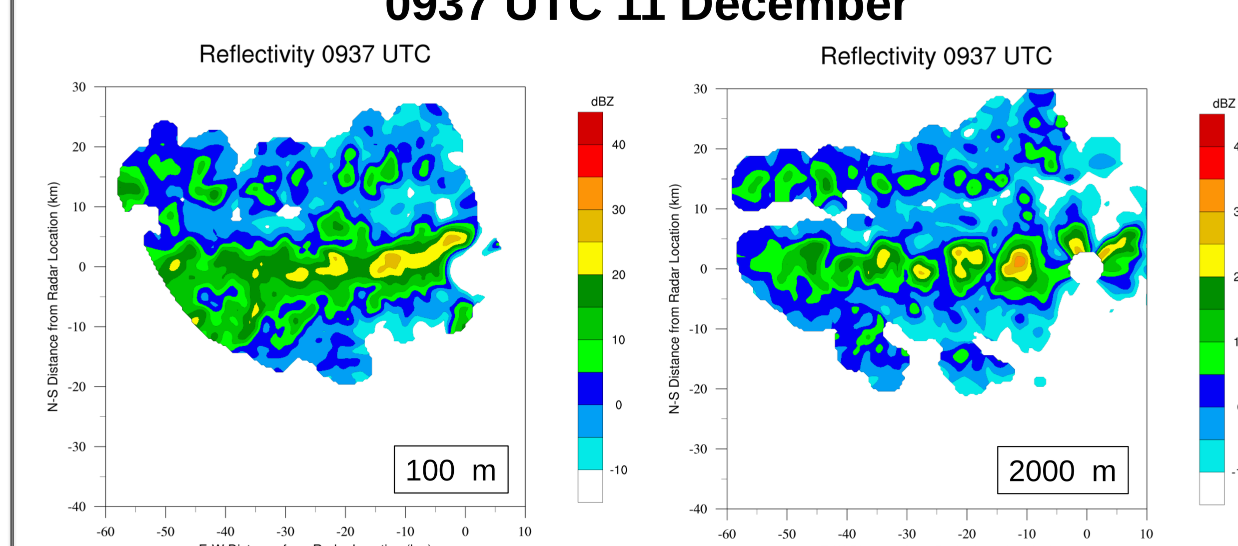


Above: Objectively analyzed radar reflectivity factor from DOW7 at 0120 UTC at 400 m above ground level (AGL; left) and at 3000 m AGL (right). At this time, the strongest precipitation cores extend above the top of the objective analysis domain at 3000 m.

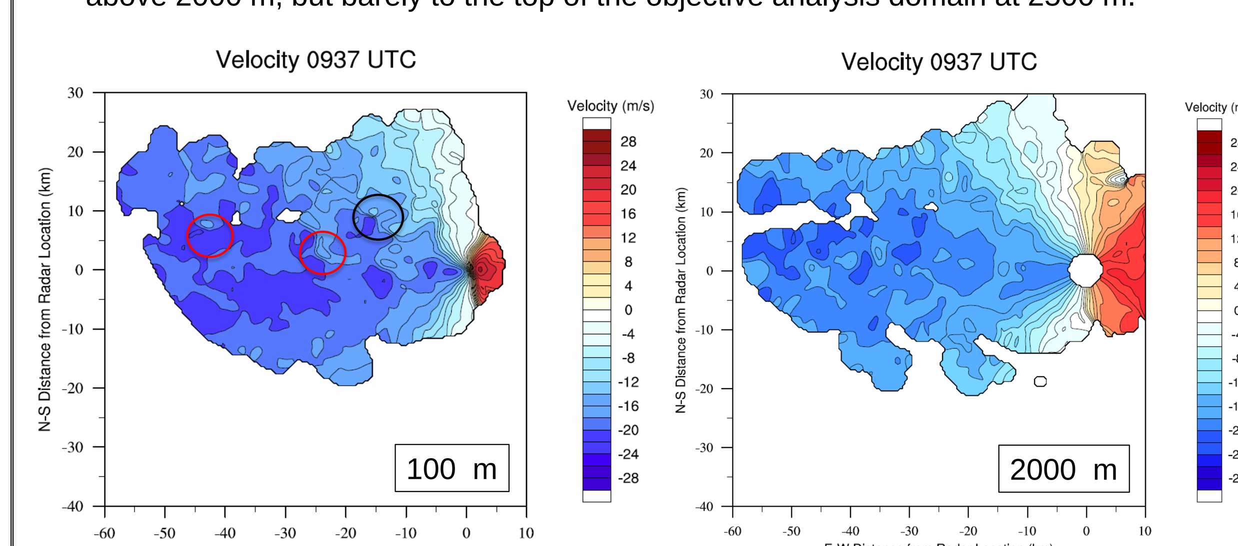


Above: Objectively analyzed radial velocity from DOW7 at 0120 UTC at 100 m AGL (left) and 1000 m AGL (right). A sharp wind shift is circled in black on the left image, and extended to just below 1000 m AGL, so is not apparent in the right image. Winds north of this boundary are approximately northwesterly, while winds south of it are approximately southwesterly, implying a solenoidal circulation within the band.

0937 UTC 11 December



Above: Objectively analyzed radar reflectivity factor from DOW6 at 0937 UTC at 100 m AGL (left) and 2000 m AGL (right). Note that intense precipitation cores extend above 2000 m, but barely to the top of the objective analysis domain at 2500 m.



Above: Objectively analyzed radial velocity from DOW6 at 0937 UTC at 100 m AGL (left) and 2000 m AGL (right). The strongest vortex at 100 m AGL is circled in black and weaker vortices are circled in red. The strongest vortex extends to 600 m AGL, while the two weaker vortices only extend 300-400 m AGL. The radial velocity differential across the strongest vortex is 10 m s^{-1} while only 6 m s^{-1} for the weaker vortices.

Conclusions

Differential positive vorticity advection creates synoptic scale ascent, which leads to cooling above 800 mb, a higher equilibrium level, and a more favorable thermodynamic environment for lake-effect systems. The band exhibited a more solid structure when the thermodynamic environment was more favorable (0100 and 2100 UTC), but was composed of broken cellular convection when the environment was less favorable (1200 UTC), outside of regions of orographic enhancement.

Objectively analyzed Doppler radar data at 0120 UTC reveal a solid band with echo tops above 3000 m AGL. Also at this time, a wind shift was observed within the southern portion of the band, with vortices located along it, consistent with vortex formation owing to horizontal shear instability (Steiger et al. 2013). The wind shift extended from the surface to just below 1000 m AGL. This convergence line moved southward and cleared the southern edge of the band just after 0200 UTC.

Objectively analyzed Doppler radar data at 0937 UTC illustrate a narrower band with the most intense cores only reaching 2500 m. Single-Doppler radial velocity data depict a few vortices within the band near the northern edge of heaviest precipitation. These vortices are not located along a wind shift and are 400-600 m in depth.

Future Work

Perform dual-Doppler wind syntheses at these and other times.

Determine the thermodynamic characteristics on both sides of the southward-propagating wind shift around 0130 UTC.

Examine vertically-pointing radar data from the Wyoming Cloud Radar and the UAH MIPS as well as in situ microphysical data.

Acknowledgments

We thank Prof. Bob Rauber and Joe Finlon for their assistance with radar data editing and analysis along with Christopher Johnston of UIUC for plotting the deployment map. We are grateful to all of the OWLeS volunteers who assisted with the data collection. Support from NSF Grant No. AGS 12-59257 is also acknowledged.

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN