Using Wind Profilers to Examine Non-Convective Low-Level Wind Shear in North Carolina

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Goals

- Utilize wind profilers to observe low-level wind shear (LLWS) events and verify forecasts
- Analyze statistics of LLWS in Terminal Aerodrome Forecasts (TAF) and observations at WFO Raleigh, NC (RAH)
- Identify typical patterns that result in LLWS in order to improve recognition and forecasts

Background and Motivation

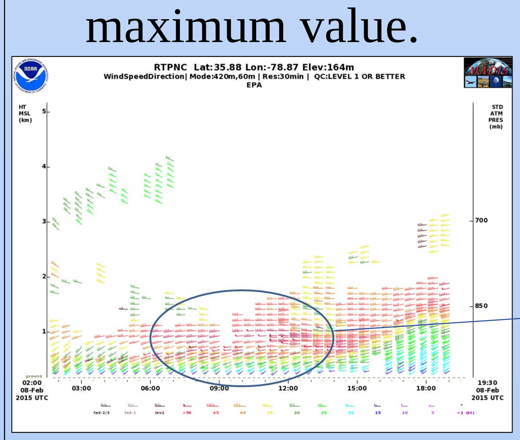
- Non-convective wind shear is defined as "*a change in horizontal wind speed and/or direction, and/or vertical wind speed with distance, measured in a horizontal and/or vertical direction…. A sufficient difference in wind speed, wind direction, or both, can severely impact airplanes, especially within 2,000 ft AGL because of limited airspace for recovery*" – NOAA Technical Memorandum NWS FCST-23
- Low-level wind shear events are difficult to observe, forecast, and verify due to the high vertical and temporal resolution required to properly observe the phenomenon. PIREPs are unreliable while observational and forecast data within the boundary layer are often too sparse to properly sample LLWS. Wind profilers observe the boundary layer with enough vertical sampling to capture LLWS and be used for forecast verification.

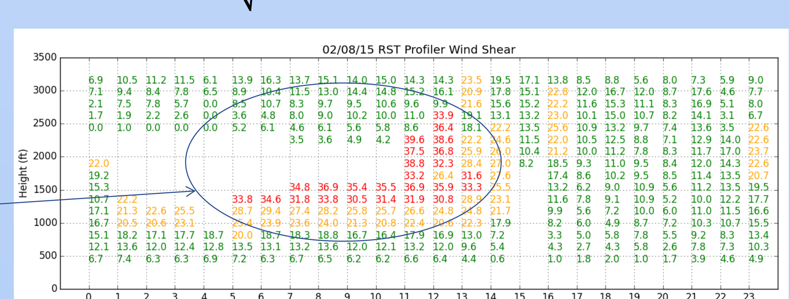
Methodology and Event Identification

915 MHz phased array wind profiler

- Wind profiler data spans time frame of November 2013 to April 2016. Data is supplied by the Earth Systems Research Laboratory and profilers are owned by the NC Department of Air Quality (Clayton:CTN) and the Environmental Protection Agency (Research Triangle Park: RST)
- TAFs were evaluated for presence of forecasted LLWS.
- Observations were evaluated based on presence of LLWS in the TAF.
- A LLWS event was counted from the time the profiler observed >30 kts below 2000 ft to the time it ceased.
- Wind shear is calculated by comparing observations of wind speed and direction at all levels below 2000 feet to each other using the equation below and then obtaining the maximum value.

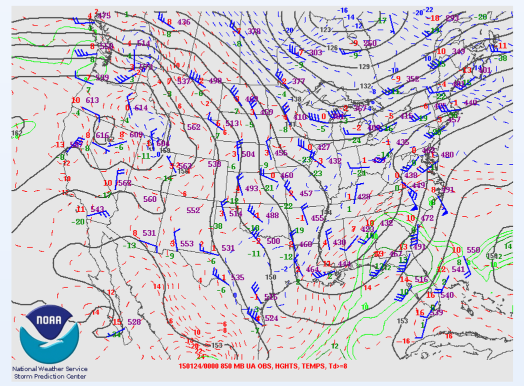
$$LLWS = \sqrt{(v_1^2 + v_2^2) - [2v_1v_2\cos(\theta_2 - \theta_1)]}$$



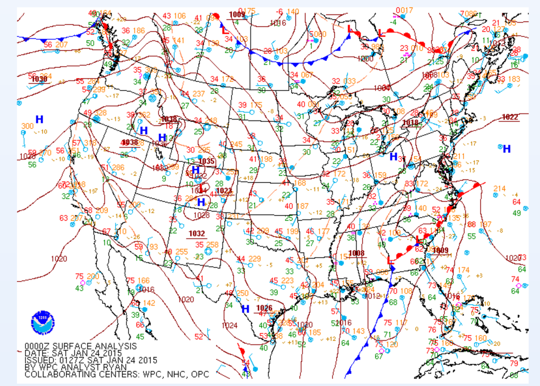


An example of the raw wind profiler output (left) and the resultant output (right) of the wind shear calculation using the equation below.

Case Example - January 24, 2015

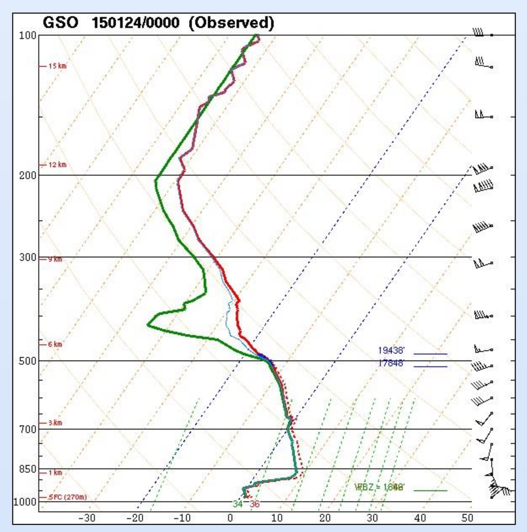


850mb analysis from 00 UTC, 24 January 2015

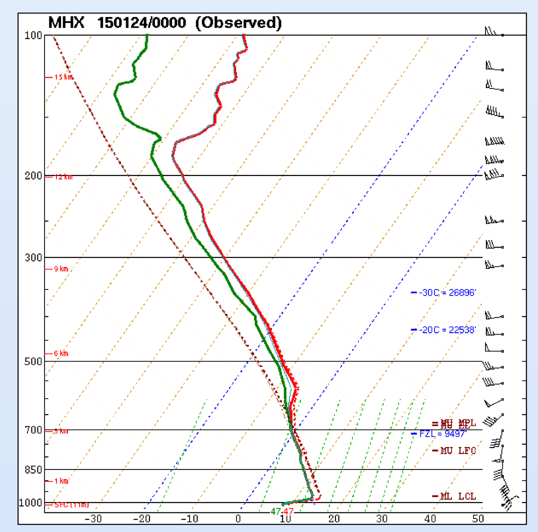


Surface analysis from 00 UTC, 24 January 2015

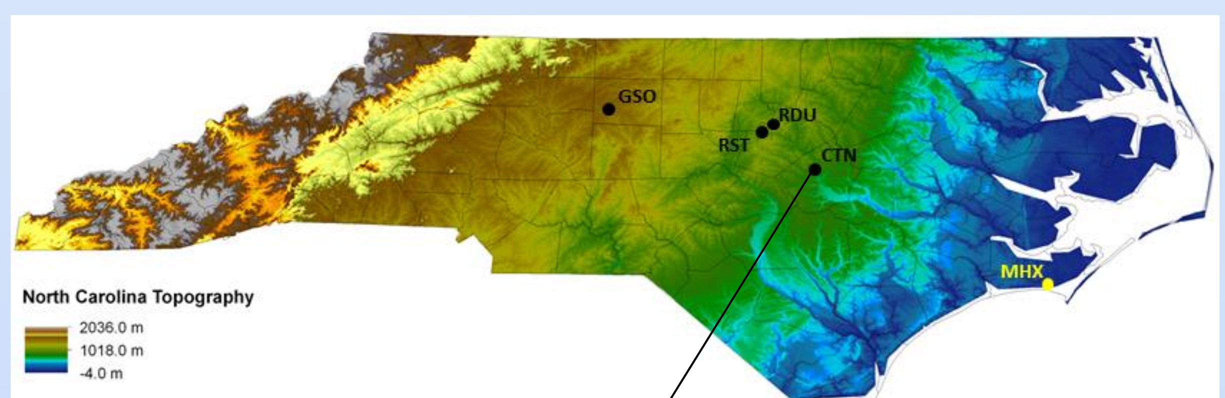
- A deep trough over the east-central U.S. provided strong southwesterly flow atop a stable cold-air damming airmass over the NC Piedmont.
- Cold air damming often provides the strong inversion necessary for a sharp change in wind speed/direction.

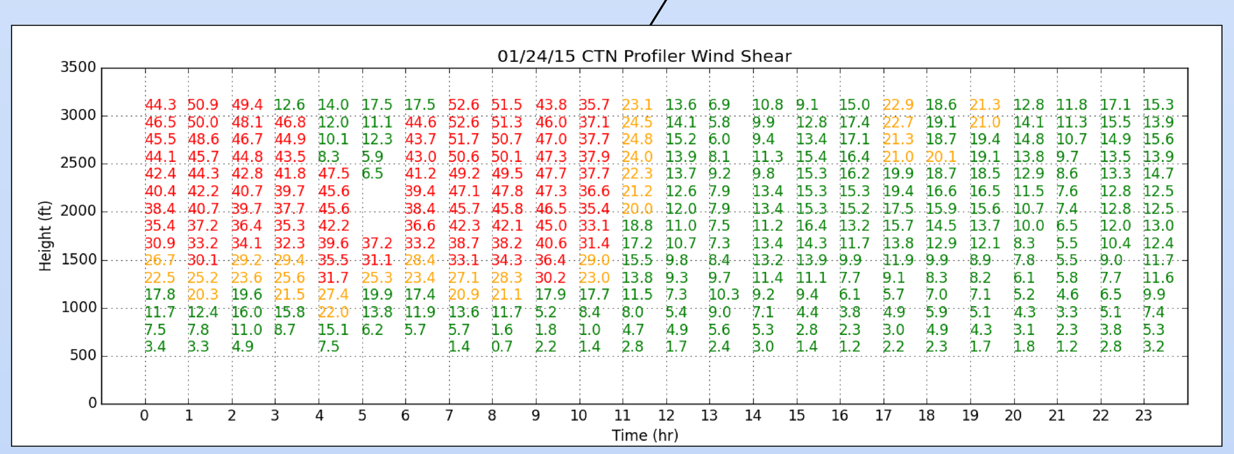


Greensboro, NC (KGSO) RAOB from 00 UTC, 24 January 2015



Morehead City, NC (KMHX) RAOB from 00 UTC, 24 January 2015





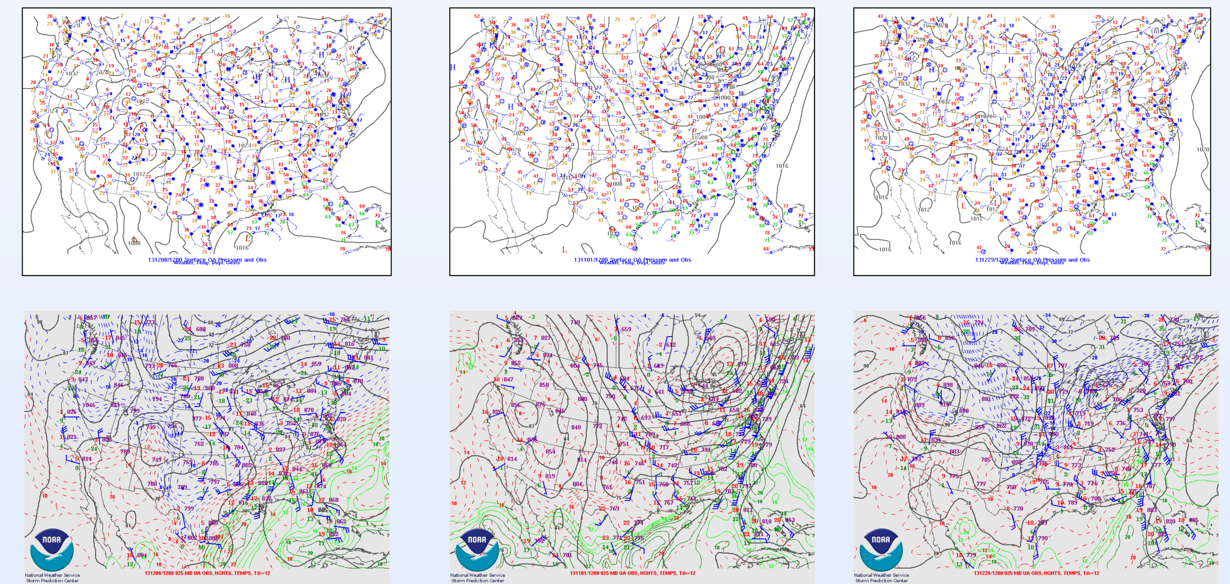
Wind shear values (kts) derived from the wind profiler in Clayton, NC (CTN)

- LLWS was observed at KGSO (~3,000ft) at a higher altitude than at KMHX (~1,000ft) owing to a deeper cold pool at KGSO.
- The wind profiler in Clayton, NC provided valuable observations of the LLWS between the two RAOB sites, with the LLWS peaking around 50 kt near 3,000ft.

- <u>Max observed LLWS (kt) in lowest 3,000ft at 00Z</u>
  - GSO: 31
  - CTN: 46
  - RTP: 47
  - MHX:41

Favored Synoptic Patterns

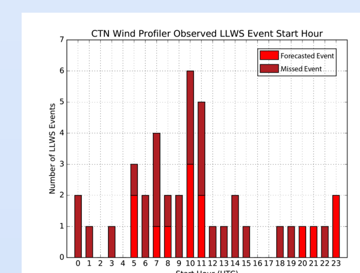
Cold Air Damming | Strong Northern Stream Low | Southern Stream Low – Miller A/B

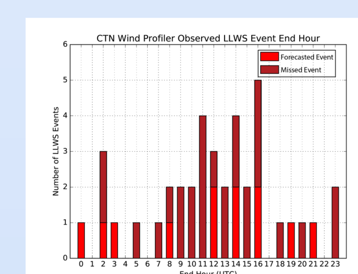


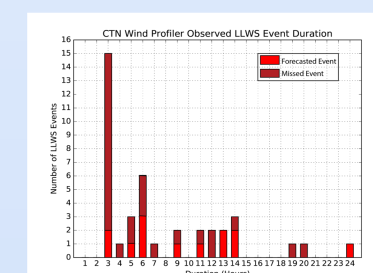
POD = 54% (7 for 13) | POD = 36% (5 for 14) | POD = 0% (0 for 8)

Observations and Verification

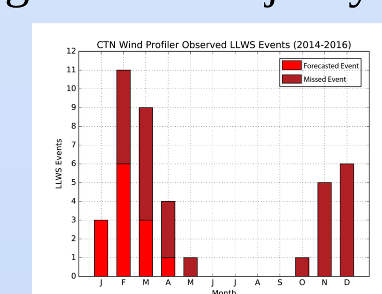
- The following statistics represent a very small dataset of CTN profiler observations vs. RDU TAF forecasts. Only observations are available for start time, end time and duration because of the 6 hour latency of the TAFs.

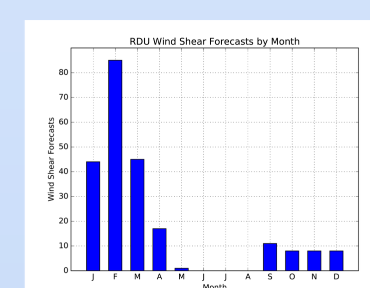




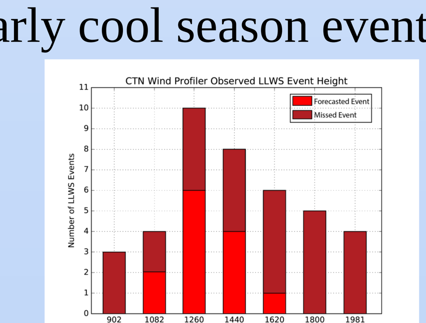


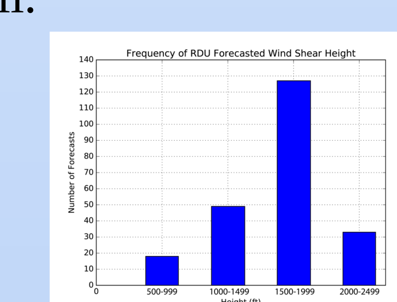
- Event start time favored overnight and pre-dawn hours as expected but end times and duration had less of a clear signal. The majority of missed events were short duration.



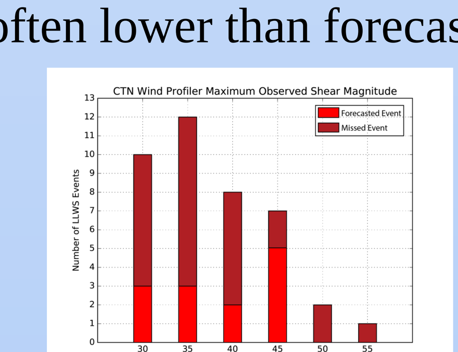


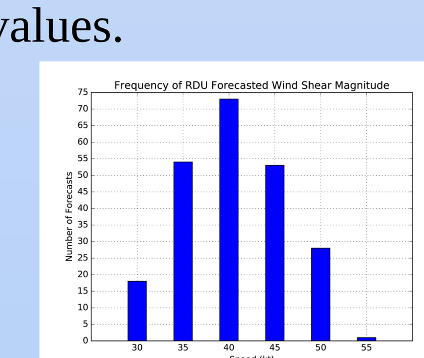
- Observations showed that favored months were later in the cool season but matched forecasts well. We did not forecast early cool season events well.





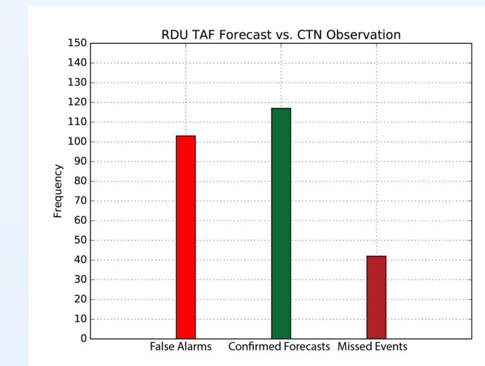
- Observations (heights correspond to profiler levels) were often lower than forecasted values.



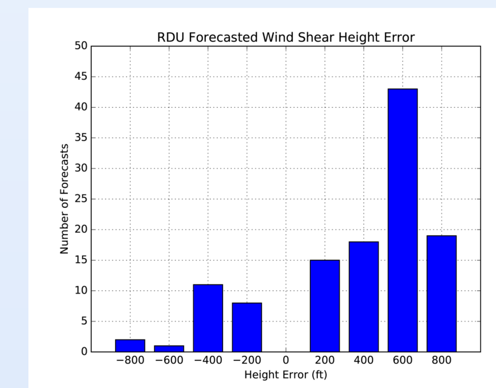


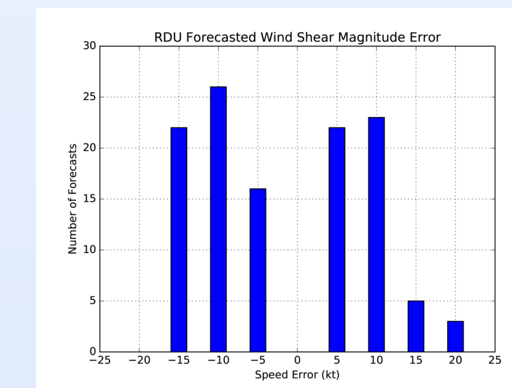
- The majority of missed events were 40 kts or less in magnitude. Observed and forecasted values were rarely over 50 kts.

Forecast Error



- Verification showed that 117 TAFs forecasted a LLWS event. False alarms occurred 103 times. There were 42 TAF issuance times counted as missed events.





- Forecast error for shear height and magnitude showed that forecasted LLWS height is often higher than observed. Magnitude errors were more equally biased and forecasts usually are within 10 kts of the observed magnitude.

Conclusions/Future Work

Conclusions

- LLWS can be calculated from wind profiler data can be useful in detecting/verifying LLWS.
- LLWS is a cool season phenomenon in central NC.
- 3 favored synoptic patterns included CAD, strong northern stream low, and southern stream low (Miller A/B). Southern stream low events were missed 100% of the time.
- Many short duration (~3hrs) missed events occurred in the vicinity of a frontal passage with a strong northern stream low across the northeastern CONUS.
- Forecast height of wind shear verified too high.
- Magnitude forecast errors were near zero but this was due to a nearly equal amount of positive and negative error as opposed to implying a nearly perfect forecast.
- Events were observed 53% of the time LLWS was forecast.

Future Work

- Develop a LLWS guidance product for forecasters based on short term high resolution model output.

Acknowledgements

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