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 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

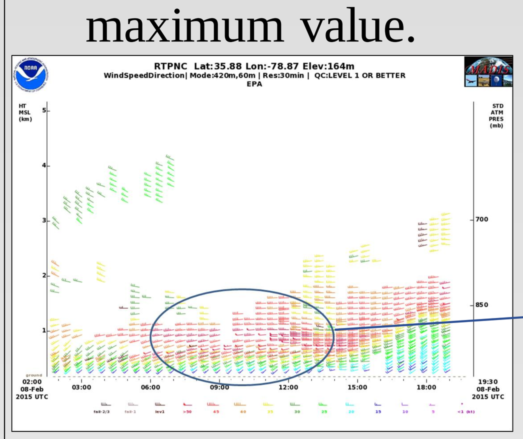
- Non-convective wind shear is defined as "*a change in horizontal wind speed and/or direction, and/or vertical wind speed with distance, measured in a horizontal and/or vertical direction…. A sufficient difference in wind speed, wind direction, or both, can severely impact airplanes, especially within 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.

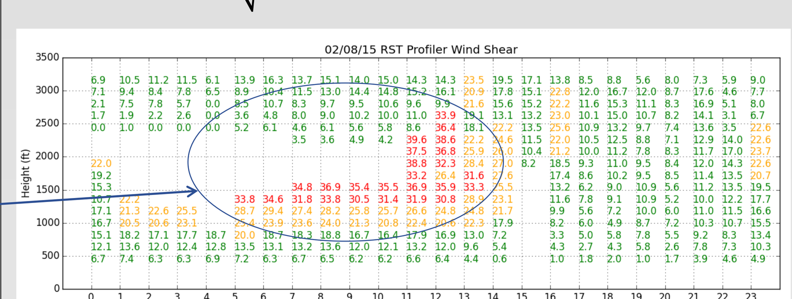
Methodology and Event Identification

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 inclusion of 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.

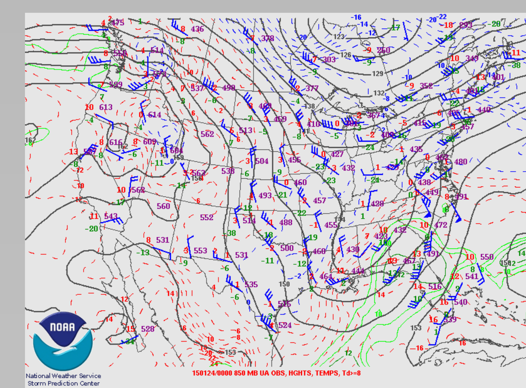
$$LLWS = \sqrt{(v_1^2 + v_2^2) - [2v_1v_2\cos(\theta_2 - \theta_1)]}$$



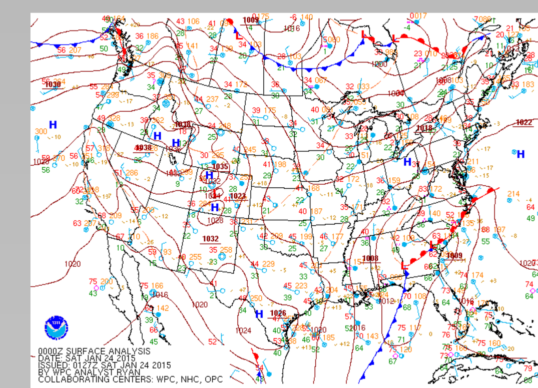


An example of the raw wind profiler output (left) and the resultant output (right) of the wind shear calculation using the equation below.

Case Example - January 24 ,2015

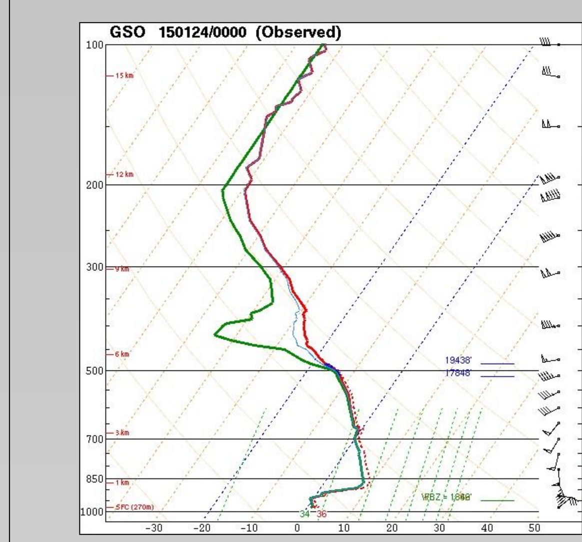


850mb analysis from 00 UTC, 24 January 2015

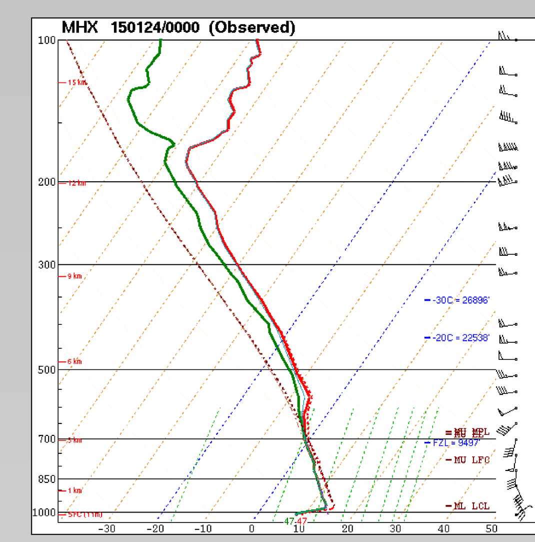


Surface analysis from 00 UTC, 24 January 2015

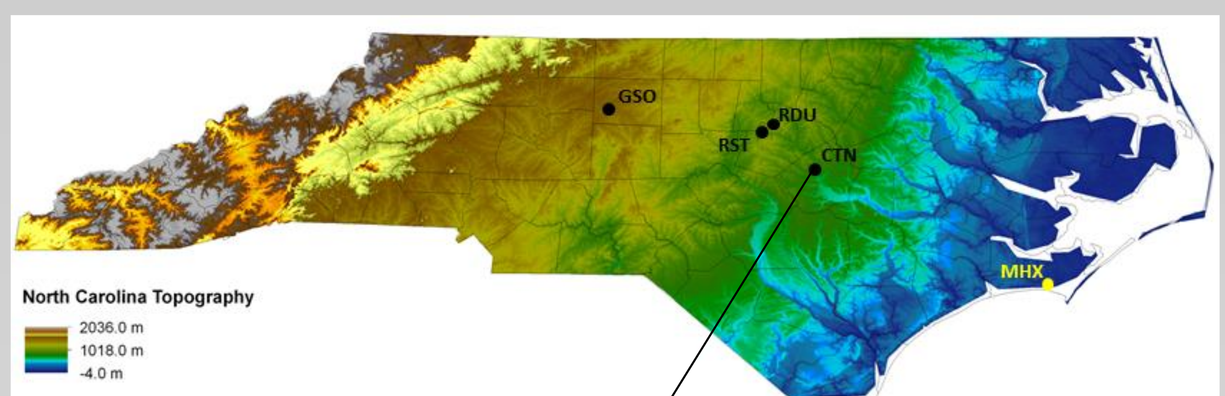
- A deep upper-level trough over the east-central U.S provided strong southwesterly flow atop a stable cold-air damming air mass over the NC Piedmont.
- Cold-air damming often provides the strong inversion necessary for a sharp change in wind speed/direction.

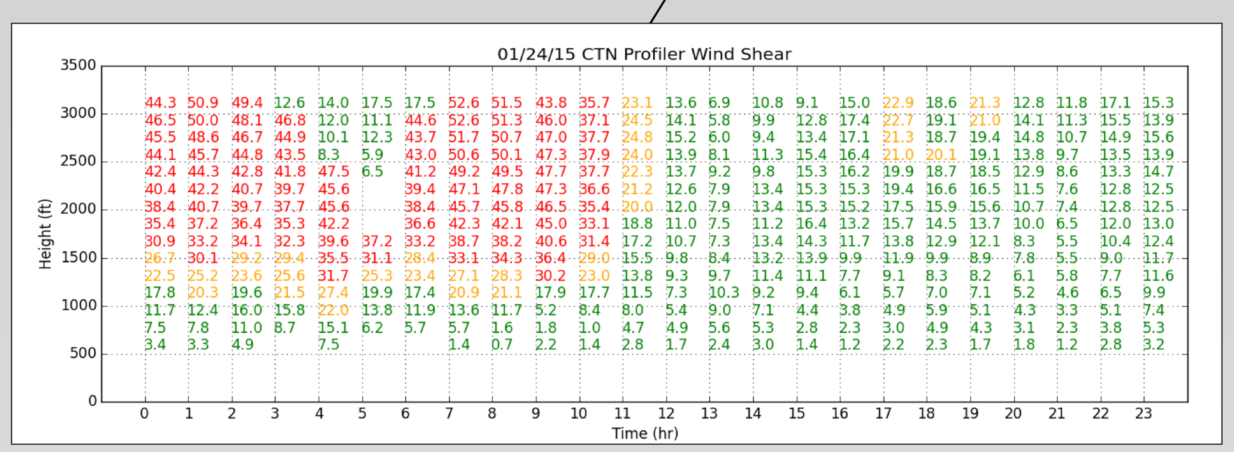


Greensboro, NC (KGSO) RAOB from 00 UTC, 24 January 2015



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





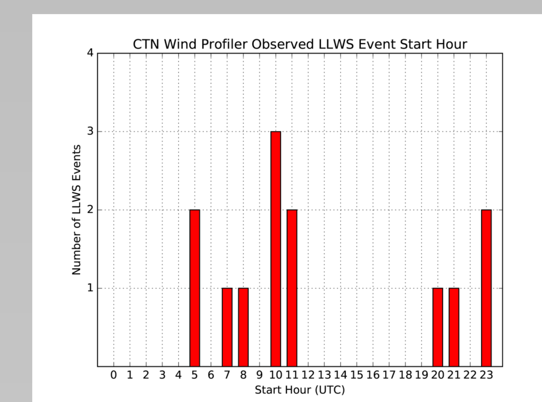
Wind shear values (kts) derived from the wind profiler in Clayton, NC (CTN)

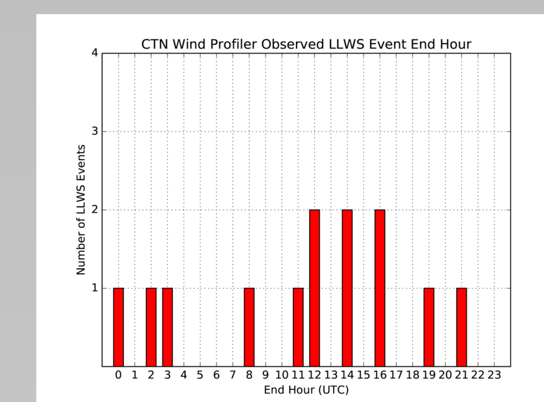
- LLWS was observed at KGSO (~3,000ft) at a higher altitude than at KMHX (~1,000ft) owing to a deeper cold pool at KGSO.
- The wind profiler at CTN provided valuable observations of the LLWS between the two RAOB sites, with the LLWS peaking around 50kt near 3,000ft.

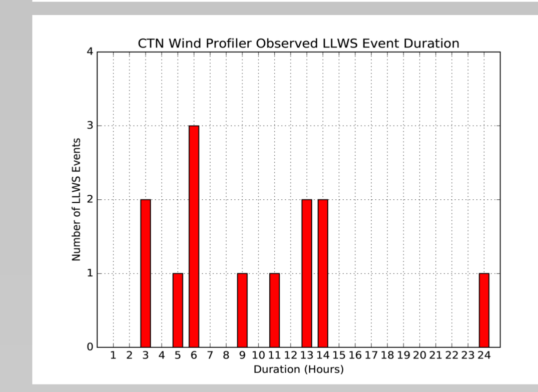
- <u>Max observed LLWS (kt) in lowest 3,000ft at 00Z</u>
  - GSO: 31
  - CTN: 46
  - RST: 47
  - MHX:41

Observations and Verification

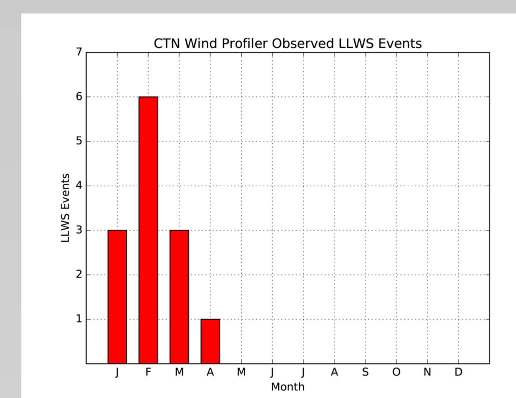
- The following statistics represent a very small and preliminary dataset of CTN profiler observations vs. RDU TAF forecasts. Start time, end time, and duration are not available for forecasts due to the multiple issuance nature of the TAF forecasts.

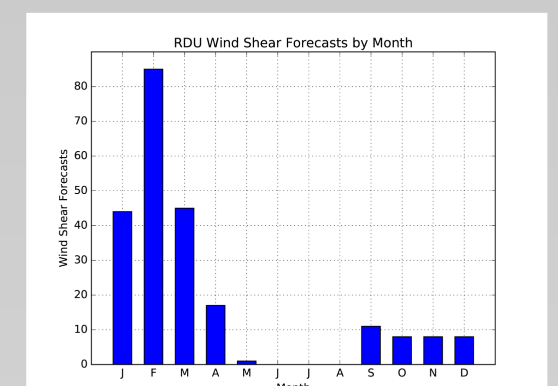




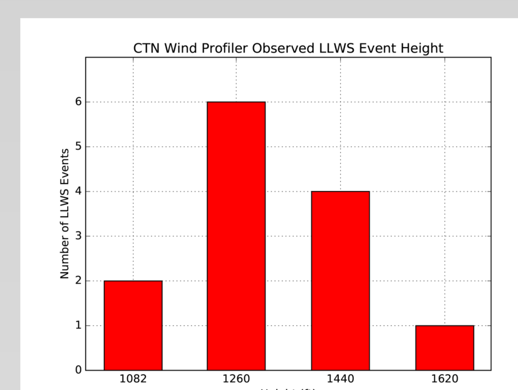


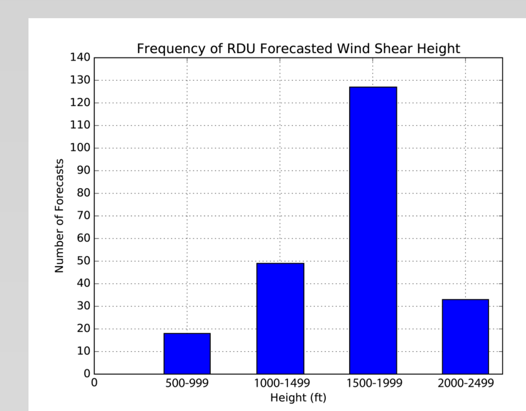
- Event start time favored overnight and pre-dawn hours as expected but end times and duration had a less clear signal.



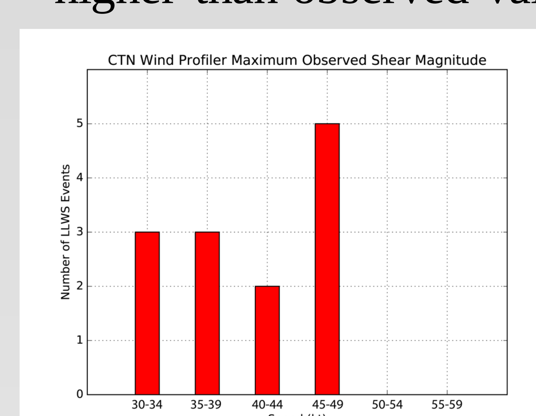


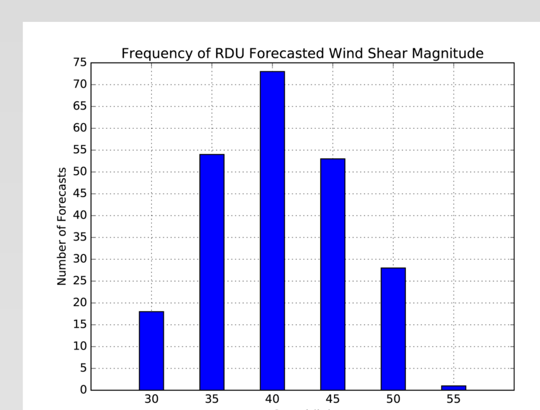
- Observations showed that favored months were later in the cool season but matched forecasts well.





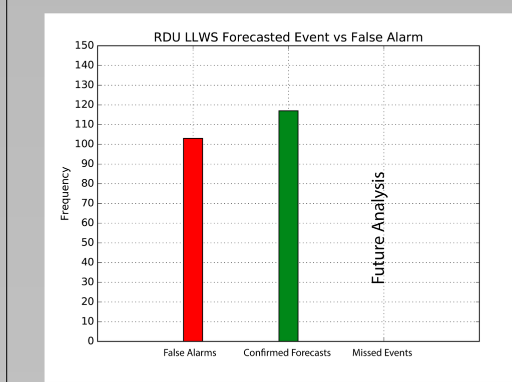
- Observations (heights correspond to profiler levels) showed that forecast values of LLWS height were often higher than observed values.



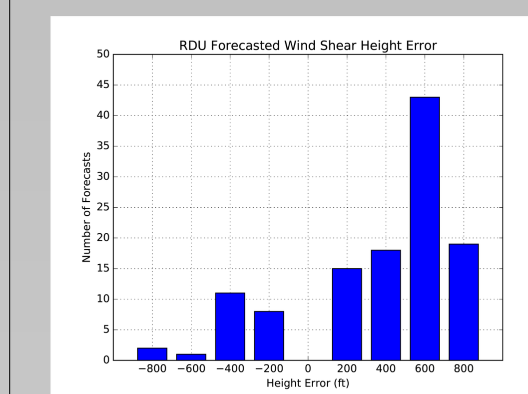


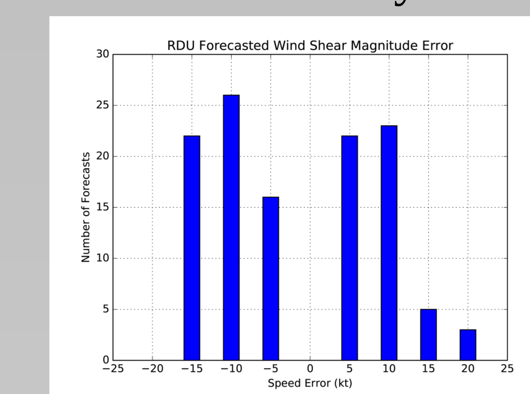
- Observations never reached 50 kts or greater in magnitude but the forecast exceeded 50 kts nearly 30 times.

Forecast Error



- Wind profiler observations showed that 117 TAFs forecasted an observed LLWS event. False alarms occurred 103 times. Since observational data was only gathered based on LLWS forecasts, missed events were not analyzed.





- Forecast error histograms 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 and can be useful in detecting/verifying LLWS.
- Nearly all of the TAFs that included LLWS coincided with a cold-air damming episode.
- Reanalysis composites of the days in which LLWS was forecast suggest forecasters recognize a pattern featuring strong southwesterly flow aloft and cold-air damming at the surface is favored for LLWS.
- Wind shear height forecasts 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 slightly more than 50% of the time LLWS was forecast.

Future Work

- Develop an abbreviated climatology of LLWS in central NC based on available wind profiler data.
- Look into non cold-air damming LLWS events.
- Analyze non-forecasted LLWS events.
- Develop a LLWS guidance product for forecasters based on short term high resolution model output.

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