Profiling the Local Tornadic Environment: the Windsor Tornado

Steven E. Koch
NOAA National Severe Storms Laboratory (NSSL)

Marta Nelson
Radiometrics Corp.

Randolph Ware
Radiometrics, NCAR, CIRES

Steve Albers
NOAA Earth System Research Laboratory and Cooperative Institute for Research in the Atmosphere (CIRA)
Outline

• Needs for profiling the local storm environment
• Overview of the 22 May 2008 Windsor Colorado tornado event
• Continuous thermodynamic and wind profiles obtained during the Windsor event
• High resolution local analysis including Doppler radar data of the local storm environment
• Conclusions
Recommendations from National Research Council Reports

- As a high infrastructure priority, federal agencies and their partners should deploy lidars and radio frequency profilers nationwide at approximately 400 sites to continually monitor lower tropospheric conditions.

- Humidity, wind, and diurnal boundary layer structure profiles are the highest priority for a network, the sites for which should have a characteristic spacing of ~125 km but could vary between 50 and 200 km based on regional considerations.

“Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks”, Committee on Developing Mesoscale Meteorological Observational Capabilities to Meet Multiple Needs, National Research Council, 2008.
Windsor was hit by a mile-wide EF3 tornado – the costliest tornado in Colorado history - around lunch time on 22 May 2008. The tornado tracked northwestwardly on the ground for 55 km through northern Colorado.
The time of day, time of year, intensity, direction of motion, and track length were all highly unusual for this region. More typically, northern Colorado experiences weak tornadoes in the late afternoon or early evening in June or July, and tracking for short distances with an easterly component.
Severe Weather Ingredients
(Schumacher et al. 2010)

- Moisture
- Instability
- Lift
- Vertical Wind Shear

- Td = 55°F, LCL = 1.1 km AGL
- Modified 18Z DEN sounding
  MLCAPE = 2094 J kg\(^{-1}\)
- Storm initiation along dryline-warm front boundary intersection beneath exit region of very strong ULJ
- 0–1 km vector shear = 19.5 m s\(^{-1}\)
- Storm-relative helicity = 219 m\(^2\)s\(^{-2}\)
- Geerts et al. (2009): mesocyclone acquired some of its vertical vorticity from PV banners initiated along the Front Range
Observing systems near Windsor storm
(11:44 am MDT image 18 min after tornado touchdown near Platteville)
Passive Microwave Radiometer

- Typically measure brightness temperatures at multiple frequencies in the 20–60 GHz frequency range, in which atmospheric thermal emission is due to gases (primarily oxygen and water vapor) and liquid water.
- MWR is able to profile with high temporal resolution (<30 s) under all weather conditions including precipitation.
- Optimal estimation methods derive temperature and moisture profiles from the measured blackbody temperature (the “inverse problem”) by coupling MWR observations with representative historical radiosonde profiles (neural network – used here) or with NWP models (1DVAR).
- Vertical resolution degrades from ~50m near the surface to 300m aloft. Most information above ~3 km comes from the background state.
- MWR are robust and are being deployed in networks internationally.
UHF Wind Profiler

- Most commonly operate in the UHF to VHF 915 – 400 MHz range.
- NOAA has operated a network of 404-MHz tropospheric wind profilers since 1992, but there is currently no plan to make these operational.
- NOAA Profiler samples in two modes: low mode (ground to 7.5 km AGL at 250-m vertical resolution) and high mode (9.25 to 16.25 km AGL with 1000-m vertical resolution) from 3 beams (zenith + 16.3° off-zenith)
- Temporal sampling: 6 min, consensus averaged to hourly profiles
- Fluctuations in the radio refractive index are the primary energy scattering mechanism (Bragg scatter). Assumption: these fluctuations are advected by the mean wind and that horizontal homogeneity exists across all three beams (violated in deep convection).
0800 UTC: Storm Character = Ordinary weak

LCL = 896 m, CAPE = 1614 J/kg, 0–4 km SHEAR = 4 m s⁻¹, 0–3 km SRH = 77 m² s⁻²

Soundings are from MWR using neural networks trained with historical radiosonde data. Hourly winds are from Platteville Wind Profiler located where tornado first touched down.
1100 UTC: Storm Character = Strong multicell

LCL = 277 m, CAPE = 2326 J/kg, 0–4 km SHEAR = 18 m s\(^{-1}\), 0–3 km SRH = 49 m\(^2\) s\(^{-2}\)
1400 UTC: Storm Character = **Supercell**

LCL = 127 m, CAPE = 2276 J/kg, 0–4 km SHEAR = 19 m s$^{-1}$, 0–3 km SRH = 154 m$^2$ s$^{-2}$

Soundings are from MWR using neural networks trained with historical radiosonde data. Hourly winds are from Platteville Wind Profiler located where tornado first touched down.
1700 UTC: Storm Character = Strong supercell

LCL = 403 m, CAPE = 2808 J/kg, 0–4 km SHEAR = 30 m s⁻¹, 0–3 km SRH = 151 m² s⁻²

Soundings are from MWR using neural networks trained with historical radiosonde data. Hourly winds are from Platteville Wind Profiler located where tornado first touched down.
2000 UTC: Storm Character = Ordinary strong

LCL = 2081 m, CAPE = 1226 J/kg, 0–4 km SHEAR = 32 m s\(^{-1}\), 0–3 km SRH = 221 m\(^2\) s\(^{-2}\)
Radiometer detected extreme instability (CAPE >3,500 J/kg) at Boulder >1 hr before Windsor tornado touchdown at Platteville (LAPS is a NOAA numerical weather model)
Retrieved thermodynamic information from Microwave Radiometer: 00 – 23 UTC

Mid-tropospheric destabilization

Equivalent Potential Temperature (K)

Dryline

Mixing Ratio (g/kg)

Warm front

Windsor
Potential Instability doubles in last 2 hours
Radar Reflectivity:
1.7km STMAS Forecast (1700 – 1750 UTC) vs. WSR-88D Radar Mosaic
1500 – 1930 UTC CAPE Analyses
For more information on the local analysis and forecast of the Windsor tornado event, please see:

“Evaluation of the Improved Humidity Analysis in Multiscale Data Assimilation on Windsor Tornado”

Hongli Jiang, Y. Xie, S. Albers, D. L. Birkenheuer, Z. Toth, H. Yuan, S. Koch, and R. Ware

Poster Session P6 (3:00 pm Wed)
Summary

- Windsor Tornado case demonstrates how rapidly local boundary layer thermodynamic and wind shear conditions can change and the need to monitor them.

- Combined use of a microwave radiometric profiler and a UHF Wind Profiler captured these hourly changes well. Results are consistent with short-range hi-res NWP model.

- Although a Federal program to establish a national network of wind profiling radars and microwave thermodynamic profilers was recently terminated, the private sector is operating a Boundary Layer Network currently at 8 sites with plans for expansion to include 100 or more national sites.