# THE 'CROSS-BORDER' TORNADO OUTBREAK OF 24 AUGUST 2016 – ANALYSIS OF THE TWO TORNADOES IN ONTARIO

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## 1. INTRODUCTION

During the afternoon and evening hours of August 24th, 2016, there was an outbreak of tornadoes that affected the US states of Indiana and Ohio and the Canadian province of Ontario (see Fig. 1). A total of 26 tornadoes were verified with damage rated at EF0 (12), EF1 (7), EF2 (5) and EF3 (2) on the Enhanced Fujita (EF) Scale (see Sills et al. 2014).

This paper will examine the details of the two Ontario tornadoes and compare the observed tornado development with that for the US tornadoes.

## 2. DAMAGE SURVEYS

The Ontario tornado damage areas were investigated by surveyors from ECCC, and from the Northern Tornadoes Project (see Sills et al. 2018). Fig. 2 shows the identified paths of the tornadoes through the Town of LaSalle and the City of Windsor, both in Essex County. The Insurance Bureau of Canada estimates that total insured losses are between $10M and $25M (Canadian dollars).

The location and orientation of this overall path is quite similar to past significant events in Windsor including the 17 June 1946 F4 tornado and the 3 April 1974 F1 tornado (part of the so-called 'super-outbreak' of tornadoes, also a 'cross-border' outbreak). Both of these tornadoes are among Canada's worst tornado disasters given the associated number of fatalities (17 and nine, respectively) and injuries.

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+ Local time (EDT) = UTC - 4 hours

### *2.1 LaSalle EF1 Tornado*

Video and photographs show that this tornado developed at 2300 UTC+ over the Detroit River west of Fighting Island, having a well-developed spray ring. Some tree damage was found on Grassy Island, a narrow island to the east of Fighting Island. A marina on the Ontario shore of the Detroit River had damage to trees, and two aluminum boats and a shed were tossed.

Further inland, one house had roughly 25% removal of its gable roof including structural components (Fig. 3). Several houses had some removal of roofing material and/or broken windows or doors. Additionally, large trees were uprooted and snapped, and a hydro pole was snapped and thrown a short distance. The most intense damage was rated at EF1 on the EF-scale with a maximum estimated wind speed of 155 km/h (DI FR12 / DOD 4 / expected value).

The path length was 4.6 km, the maximum path width was 300 m, and motion was from 250 degrees or west-southwest. The worst damage was located at 42.2185N, 83.0976W. No injuries or fatalities were reported.

### *2.2 Windsor EF2 Tornado*

This tornado developed over south-central Windsor at 2315 UTC. It caused light damage in residential areas before strengthening over an industrial area. It then began to gradually dissipate with the last damage found on Peche Island in the Detroit River, just north of east Windsor. The investigation along the tornado path found trees snapped and uprooted, damage to house roofs, sheds lifted or shifted, metal dumpsters tossed, power poles snapped, industrial buildings damaged or destroyed, and traffic light poles bent.

Assessment of the damaged structures included inspection of failed connections and structural members. In the location of the most severe damage, a metal warehouse building was observed to have been partially moved from its foundation and completely collapsed. Our investigation indicated that material failures occurred at the connections between the foundation and the bases of the columns, with an example shown in Fig. 4.

Structural analysis of the foundation connections includes assessing the strength of the foundation concrete as well as the strength of the embedded steel anchor rods. Premature failure of both components was observed in different locations. Therefore this damage was rated at EF2 on the EF-scale with a maximum estimated wind speed of 210 km/h (DI MBS / DOD 8 / lower bound value).

The path length was 12.7 km, the maximum path width was 300 m, and motion was from 220 degrees or southwest. The worst damage was located at 42.2805N, 82.9778W. While no fatalities were reported, there were four injuries.

## 3. METEOROLOGICAL ANALYSIS

### *3.1 Synoptic and Regional Scale*

The tornado outbreak occurred in the warm sector of a low-pressure system centred over north-western Ontario. Over the portions of Indiana and Ohio affected by the outbreak, convective instability and deep-layer shear were favourable for the development of supercell thunderstorms, and low-level shear and the lifting condensation level were conducive to supercell tornado development,. The Significant Tornado Parameter from the US Storm Prediction Center's mesoscale analysis system clearly shows the axis of tornado potential at 2300 UTC (Fig. 5). The Windsor area was in a region of marginal potential to the north. More information on the regional storm environment plus details on the US tornadoes can be found in a study of this event by Gray (2018).

### *3.2 Storm Scale*

The storm that generated the Ontario tornadoes developed over Michigan and well north of the primary axis of the tornado outbreak through Indiana and Ohio. DTX NEXRAD radar echo tops (not shown) increased from less than 9 km at 2234 UTC to nearly 14 km by 2301 UTC (when the first lightning flash was recorded by the North American Lightning Detection Network). The LaSalle tornado developed nearly simultaneously at 2300 UTC.

Fig. 6 (top left panel) shows the lowest-level (0.5º) reflectivity from the DTX NEXRAD radar at 2319 UTC, close to the time that EF2 damage was occurring. Note the lack of classic supercell features at the rear right flank (southwest side) of the storm such as a strong reflectivity core and gradient, and an appendage or hook echo. In fact, the strongest reflectivities approaching 60 dBZ are located in the *left* rear flank of the storm (northwest side).

Fig. 6 (top right panel) shows the associated storm-relative radial velocity at the same time, with a prominent mesocyclone at the right rear flank.

The bottom left panel of Fig. 6 shows a cross-section through storm-relative radial velocity data from the DTX NEXRAD radar at the same time. Note that all rotation is confined below 3 km, with the strongest rotation below 1.5 km. A mid-level mesocyclone is absent, and was not present during the lifetime of the storm.

Fig. 6 (bottom right panel) shows the DTX NEXRAD radar's 0.5º cross-correlation dual-polarization product with evidence of lofted tornado debris at 2324 UTC, shortly after the tornado was at its strongest. This tornado debris signature broadened and extended downwind toward the northeast after this time. A weaker tornado debris signature was also noted with the LaSalle tornado (not shown).

In contrast, the tornadoes that occurred in Indiana and Illinois exhibited more classic supercell indicators. The radar presentation for an EF2 tornado that occurred in northeastern Ohio is shown in Fig. 7. The classic reflectivity features typical of supercell storms are evident.

## 4. INFLUENCES ON TORNADOGENESIS

The above analysis suggests that although the Windsor area was in an environment that had at least marginal supercell tornado potential, the parent thunderstorm was not a typical supercell thunderstorm. Though there was persistent rotation during the lifetime of the storm, it was shallow and occurred within only the lowest portions of the storm. The rotation (and first tornado) also developed at the same time that the storm began to rapidly develop and generate lightning.

In fact, 'bottom up' tornado development associated with a rapidly developing thunderstorm is a defining feature of so-called 'landspout' tornadogenesis, otherwise known as non-supercell or non-mesocyclone tornadogenesis (Brady and Szoke 1989, Wilson and Wakimoto 1989, Lee and Wilhelmson 1997). Such tornadoes are thought to occur regularly in Ontario in association with lake-breeze fronts (Sills and King 2000, King et al. 2003).

Fig. 8 is a mesoscale analysis plot incorporating radar reflectivity, visible-channel satellite imagery and surface observations during the afternoon preceding the event (valid 1800 UTC). Also shown are the positions of manually analyzed lake-breeze fronts (magenta). One lake-breeze front segment associated with the Lake Erie lake breeze was identified along the west side of the Detroit River, where the initial tornadogenesis occurred. However, lake-breeze fronts were not able to be detected with confidence later in the evening prior to the event.

It has also been shown that storm mergers can result in storm intensification and even tornadogenesis (see for example Wurman et al. 2007). The TDWR radar at Detroit Metro Airport at 2245 UTC depicts a cell merger about to occur just as the main storm cluster began to cross the Detroit River from the west (Fig. 9). There was no lightning at this time. The first lightning, and the LaSalle tornado, developed just east of the location of the merger approx. 15 minutes later.

It is possible that the parent storm of the LaSalle and Windsor tornadoes was a hybrid combining some features of both supercell and 'landspout' tornadogenesis. A more detailed study would be required to fully characterize the tornadogenesis mode for this event.

## 5. CONCLUSIONS

Two of the 26 tornadoes that developed on August 24th, 2016, occurred in Ontario, Canada, making it a 'cross-border' tornado outbreak. Both the LaSalle EF1 tornado and the Windsor EF2 tornado were generated by a thunderstorm that exhibited both supercell and non-supercell characteristics, possibly a hybrid. This is in contrast to the tornadoes that occurred in the US (in an environment more conducive to supercell tornado development) that appeared to be generated by more typical supercell thunderstorms.

A lake-breeze front and/or a cell merger may also have contributed to the development of the parent storm and tornadoes. Additional research would be required to accurately identify the tornado-genesis process at work.


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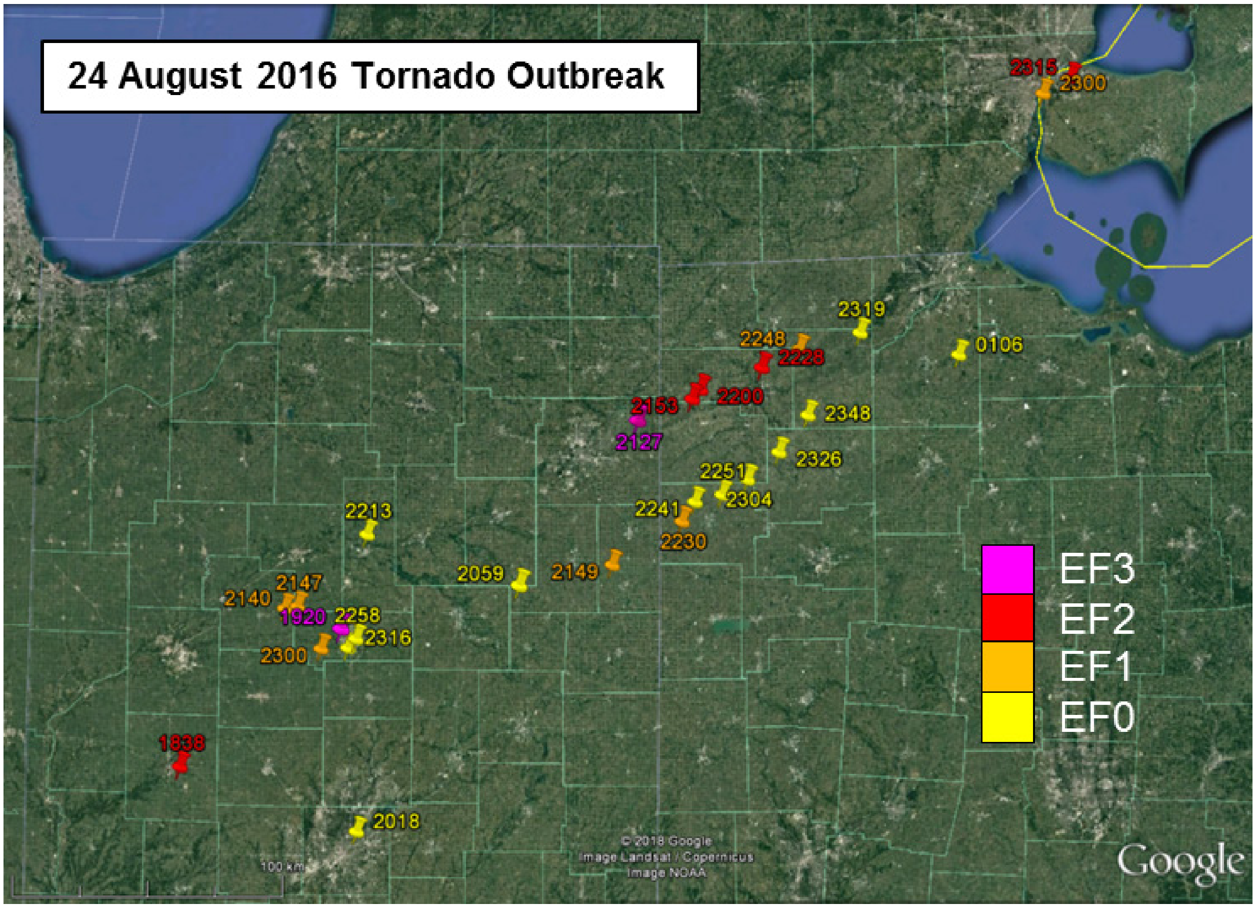


Figure 1. Map showing the 24 US tornadoes and the two Canadian tornadoes. Start times in UTC are labelled and colours indicate EF-scale damage ratings. US tornado data are from the US National Centers for Environmental Information, and the Canadian tornado data are from the ECCC tornado database.

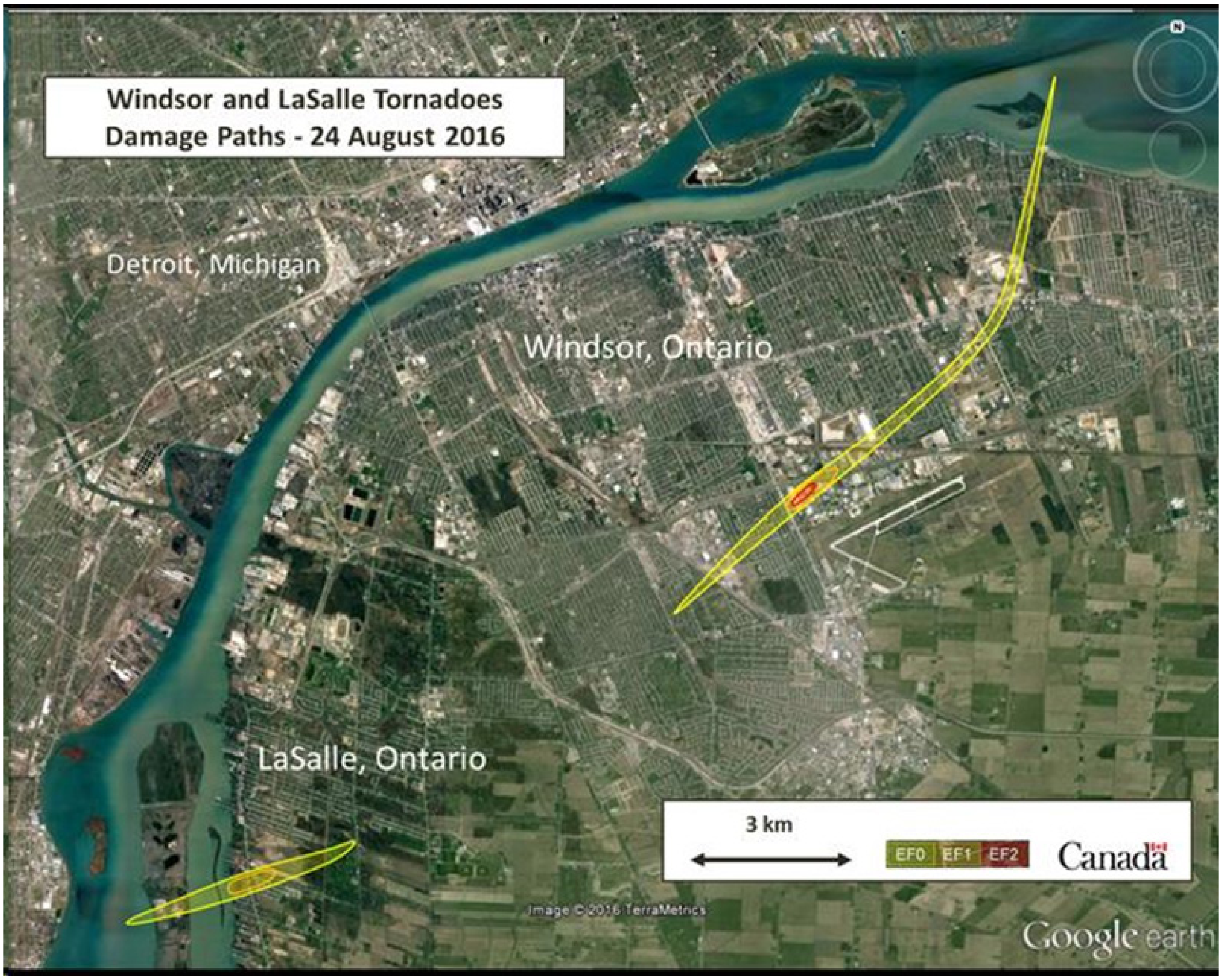


Figure 2. Map showing the paths and EF-scale contours for the LaSalle and Windsor tornadoes.

Figure 3. Photograph of EF1 tornado damage at a house on Victory Road in LaSalle, Ontario facing roughly north. Source: Hindi, Rob (rhindi800). "Victory Street in @TownofLaSalle after a possible tornado. @AM800News #cklw https://t.co/1bAOreYWoF". 25 Aug 2016, 00:10 UTC. Tweet.


Figure 4. Photograph facing roughly northeast showing EF2 damage, including a metal warehouse that collapsed completely and was partially moved off its foundation. Premature material failures were found to have occurred at the connections between the foundation and the bases of the columns (one of which is circled in the photograph).

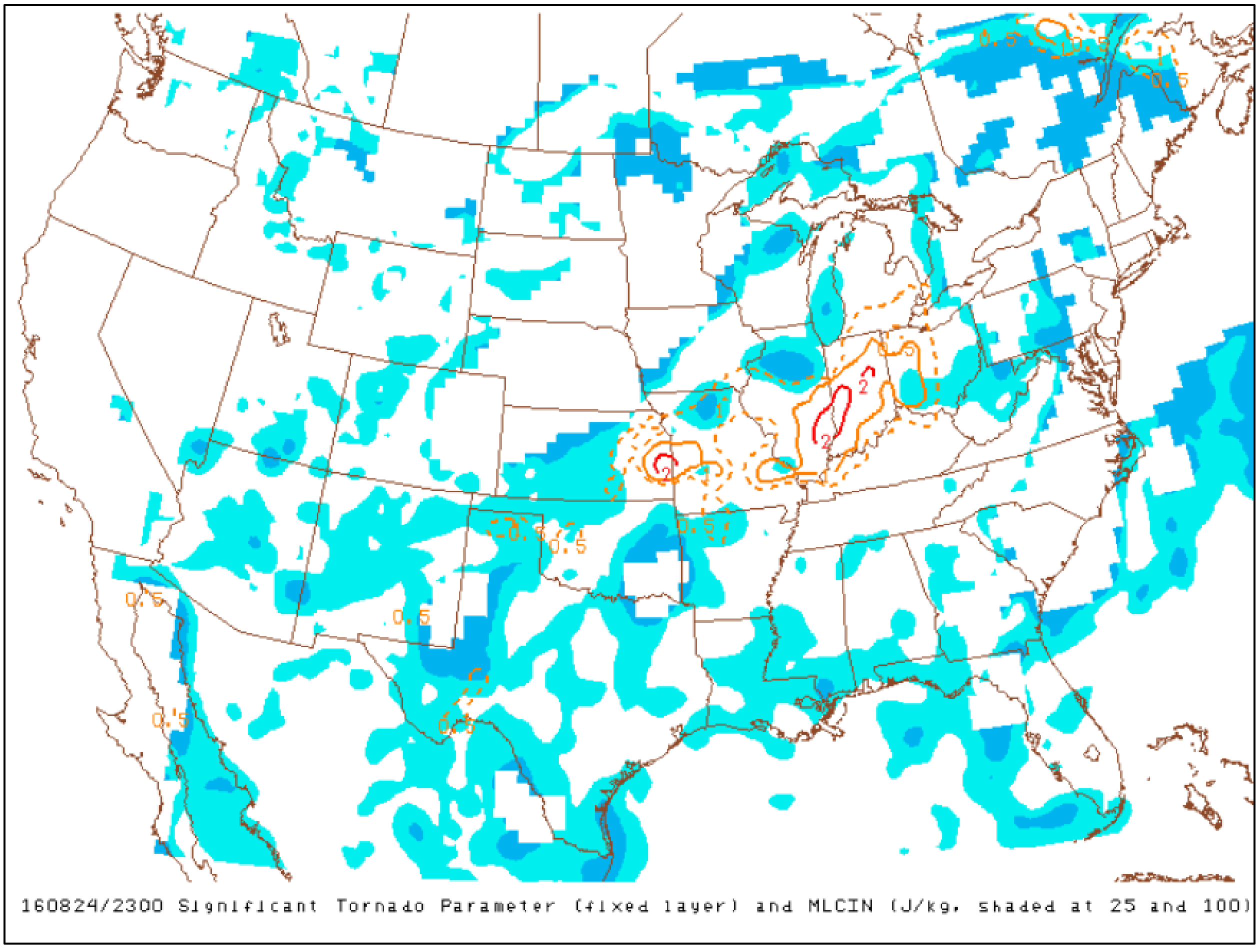


Figure 5. Significant Tornado Parameter (STP) and Mean Layer Convective Inhibition (MLCIN) from the US Storm Prediction Center's mesoscale analysis system depicting an axis of enhanced tornado potential at 2300 UTC from southern Illinois to western Ohio. In Ontario, only Windsor is located within the marginal potential area (dashed contour). Source: https://www.spc.noaa.gov/

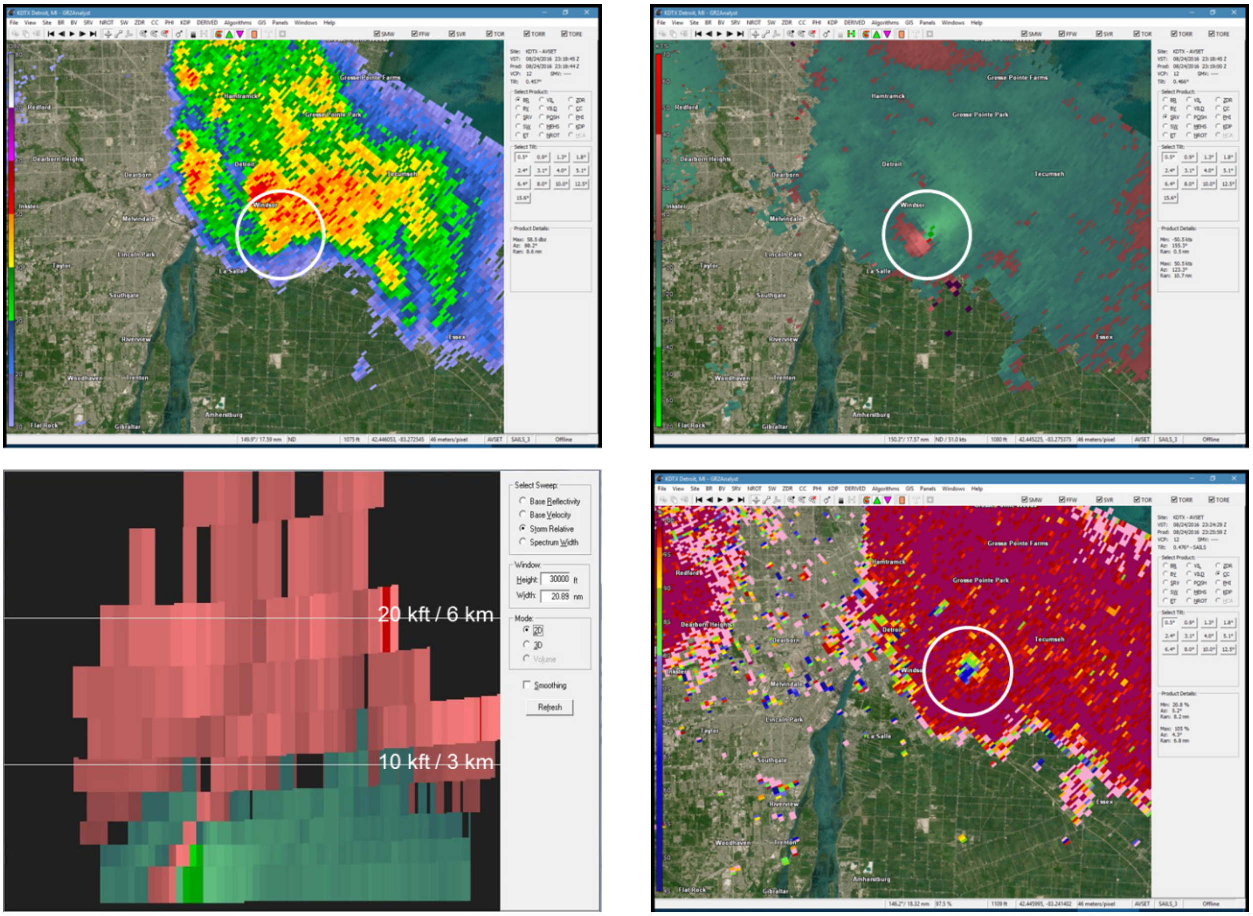


Figure 6. Top left shows the lowest-level (0.5º) base reflectivity from the DTX NEXRAD radar at 2319 UTC, close to the time that EF2 damage was occurring. Top right shows the storm-relative radial velocity at the same time. Bottom left shows cross-section through storm-relative radial velocity data from the DTX radar at 2319 UTC when the tornado was at its strongest. Bottom right shows the 0.5º DTX Cross-Correlation dual-pol product showing evidence of lofted tornado debris at 2324 UTC, shortly after the tornado was at its strongest. The white circles indicate the area of greatest interest.

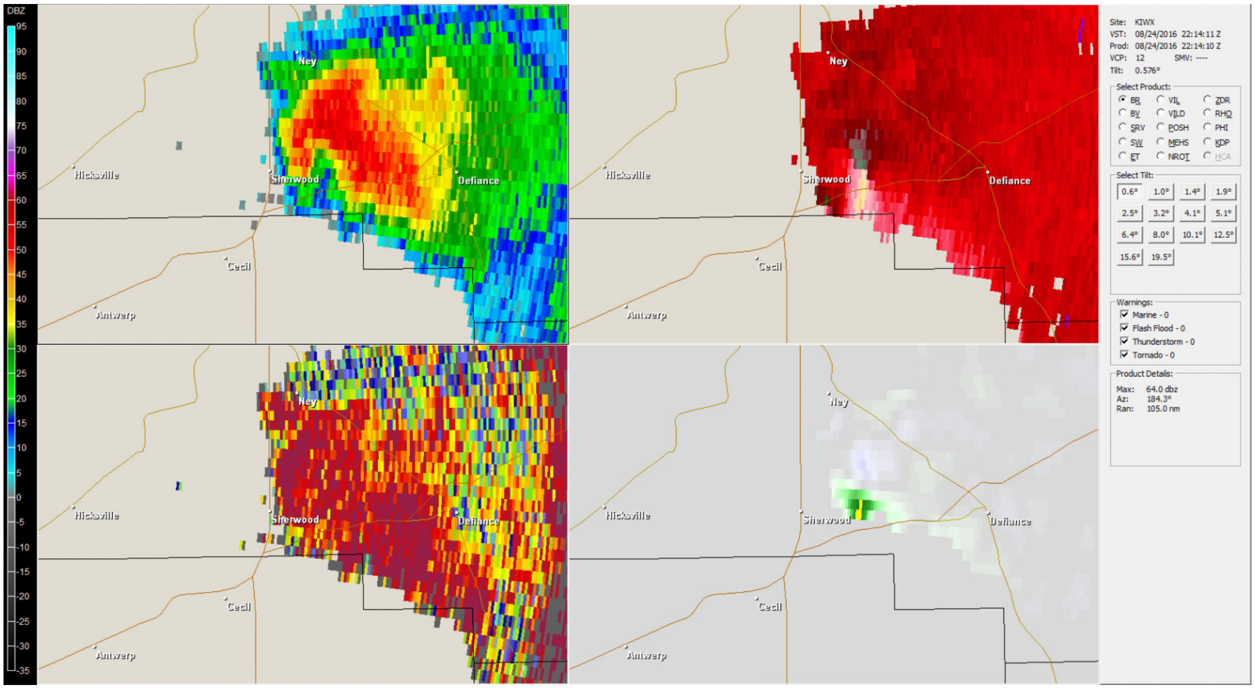


Figure 7. Four panel radar data at 2214 UTC on August 24th for the supercell thunderstorm that produced an EF2 tornado in Mark Center, Ohio. Note the strong reflectivity core (greater than 60 dBZ) and gradient, and prominent hook echo (top left). A strong base velocity shear couplet is shown at top right. The cross-correlation dual-polarization product is shown at bottom left and the normalized rotation (NROT) product is shown at bottom right. Source: https://www.weather.gov/iwx/20160824_TornadoOutbreak

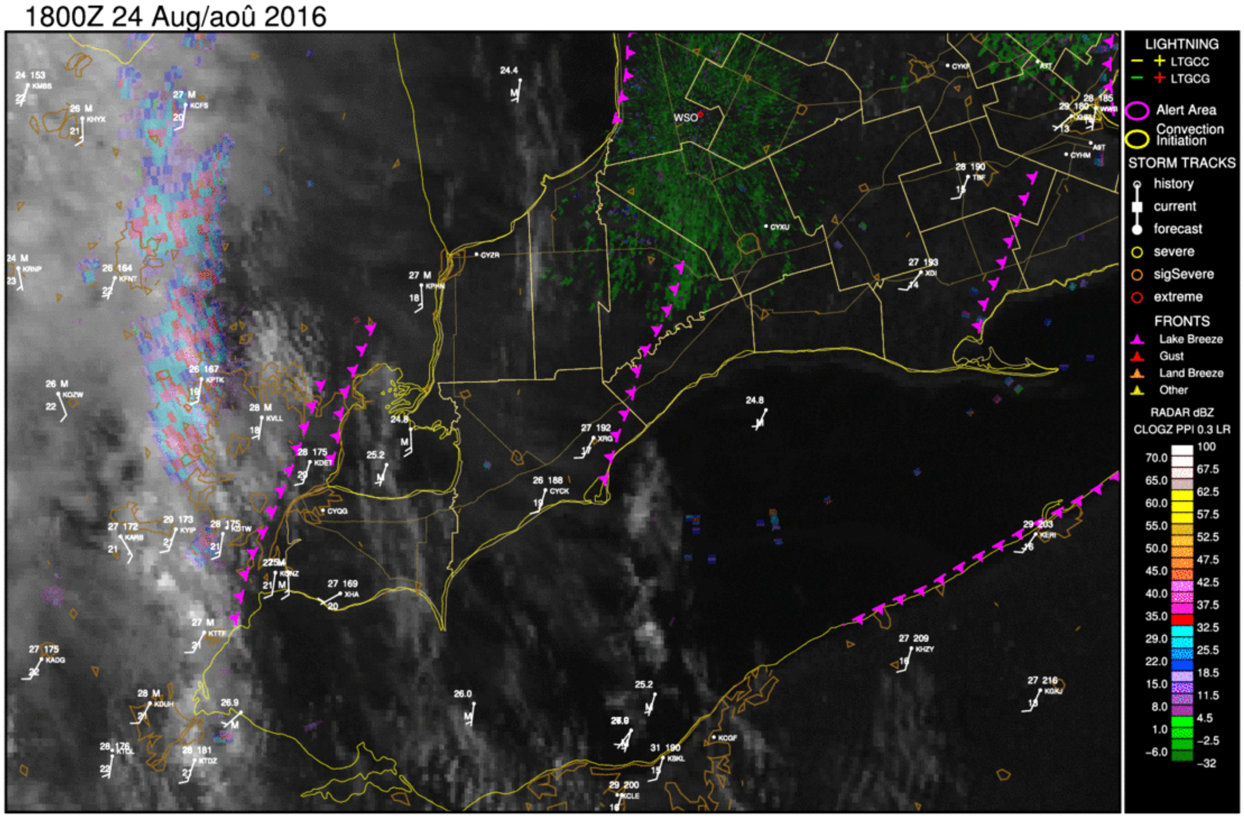


Figure 8. Mesoanalysis showing the positions of manually analyzed lake-breeze fronts (magenta) during the afternoon preceding the event (valid 1800 UTC). Data shown include radar reflectivity, visible channel satellite imagery and surface observation plots with temperatures in Celsius and wind speed in knots. Surface pressure is also indicated at selected surface stations.

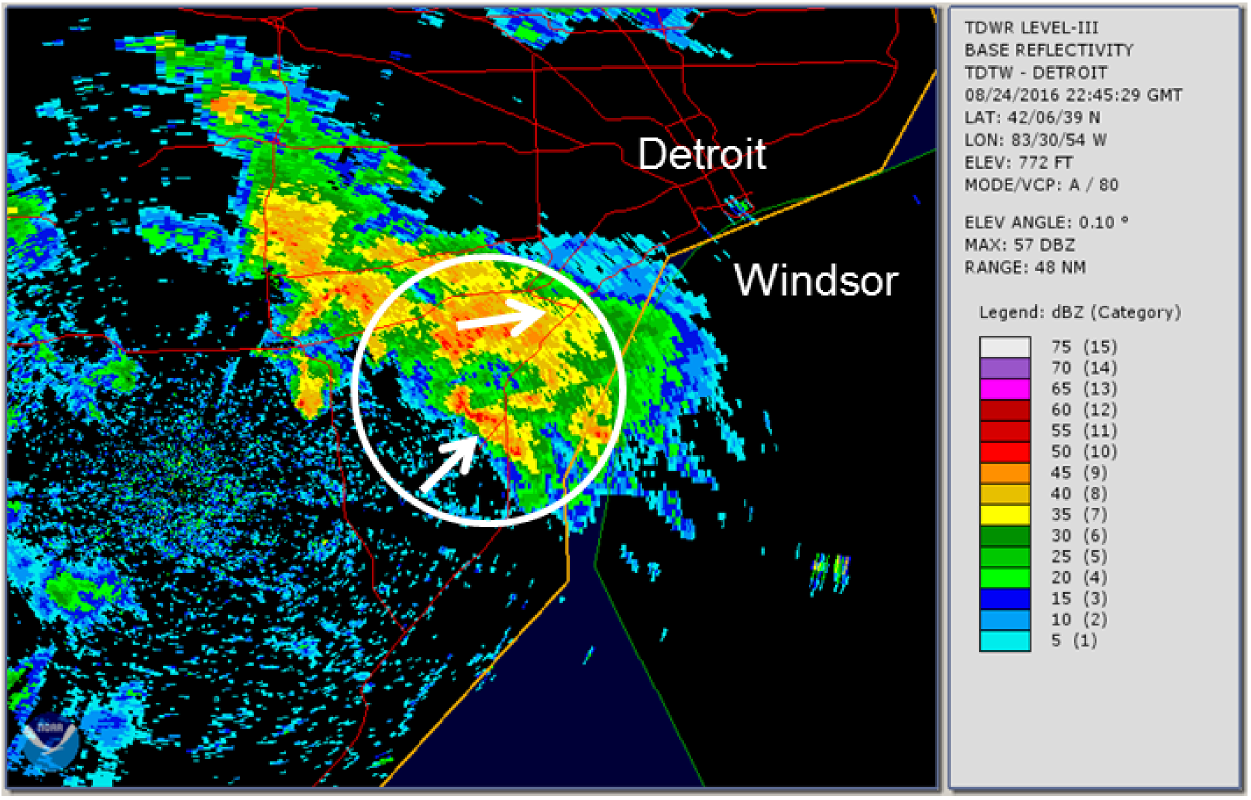


Figure 9. TDWR radar base reflectivity from Detroit Metro Airport showing a cell merger about to occur just as the main cluster began to cross the Detroit River from the west. White arrows show the directions of movement of both the main cluster and the more compact storm moving from the southwest. There was no lightning at this time (2245 UTC), just 15 minutes before the first tornado.