The 30 June 2014 Midwestern Double Derecho Event, Part 2: Analysis of a Complex Tornado Cluster during the Second Derecho

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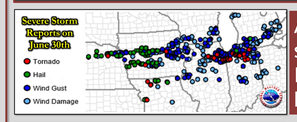
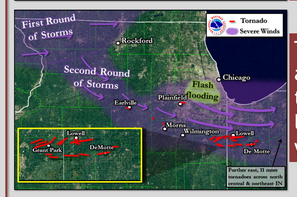
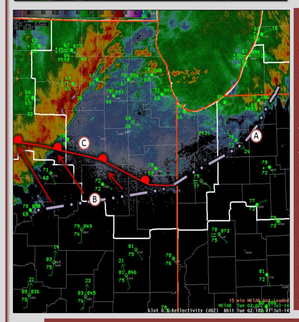
Event Overview



A pair of derecho-producing quasi-linear convective systems (QLCSs) impacted northern Illinois and northern Indiana from the evening of 30 June to the predawn hours of 1 July 2014.



The second QLCS trailed the first one by only 250 km and approximately three hours, producing 30+ confirmed tornadoes (18 in the Kankakee River Valley, from two large mesovortices) and many areas of straight-line winds estimated at 40-50 m s^{-1}.



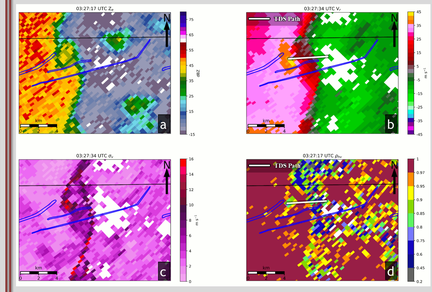
Interaction with a stalled outflow boundary from first QLCS is believed to be critical to the evolution of the second QLCS, particularly in the Kankakee Valley.

At 0200 UTC on 1 July 2014 this image shows:
A—Current leading edge of cold pool from the first QLCS.
B—Original southern extent of cold pool from the first line.
C—Current position of mesoscale warm front as the cold pool lifts back north.
From Lyza et al. 2017

Additional analysis after tornado results were published in Storm Data shed new light on some of the initial findings, prompting further investigation.

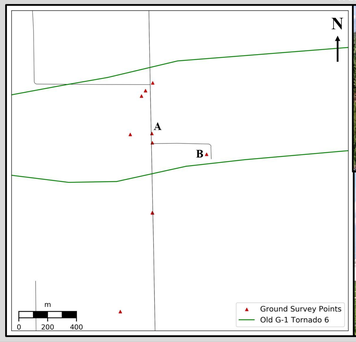
Reanalysis: Motivation and Methodology

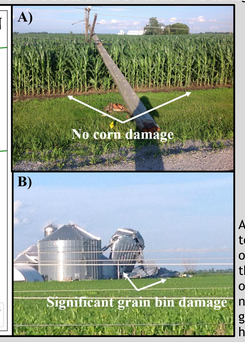
Several observations combined led to similar conclusions: the Kankakee Valley tracks needed to be reanalyzed.

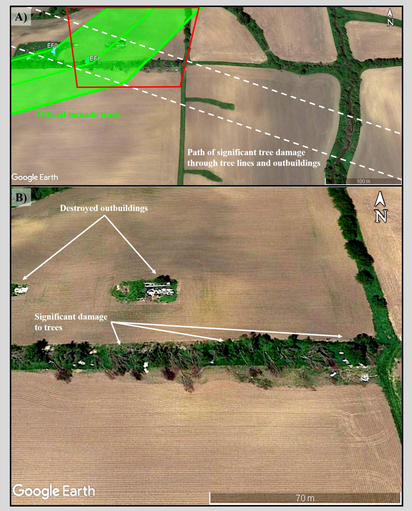


Left: 0327 UTC 1 July 2014 KLOT 0.5° base reflectivity (dbZ, a), base radial velocity (m s^{-1}, b), spectrum width (m s^{-1}, c), and correlation coefficient (% ρ_{hv}, d). The official Storm Data tornado tracks are in blue. The white line indicates the path of the TDS shown in (d). Note the inconsistency between the tornado tracks and the TDS motion.

Below: Example of one of several inconsistencies in the survey findings that remained as the original Storm Data results were published. At point A, a power pole was snapped, but the surrounding corn field was left undamaged. Meanwhile at point B, a snapped power pole was surrounded by extensive structural and crop damage. Both points were originally lumped into the same tornado track, despite evidence that the winds around point A were likely weak, and the power pole was likely snapped by forces exerted down the power lines from the areas of more intense wind damage.

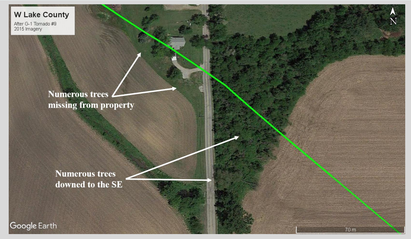




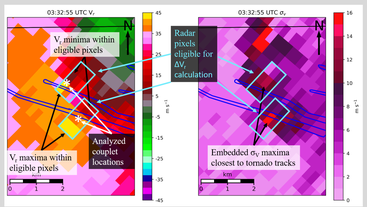


Above: The key piece of evidence that the tornado tracks in the Kankakee Valley needed to be reassessed was found in the Google Earth satellite imagery above. In (A), the original track of tornado 2 from the northern mesovortex is shown in green. However, the imagery clearly shows a narrow path of damage oriented roughly normal to the official track, connected tree damage that could only be seen from a distance in the northwestern tree line to damage to another tree line that could not be seen during the ground survey. Panel (B) shows a zoomed-in view of the damage within the red area highlighted in (A).

Reanalysis Methodology



Areas of additional possible tornado damage (based on proximity to damage found during the original surveys and radar data) were examined in post-event Google Earth imagery for evidence of damage. Phone calls also were made to select locations to confirm what was seen in Google Earth.



Radar data were used to aid in identifying where additional damage not previously documented may have occurred, using velocity, spectrum width (Spoden et al. 2012, Borchardt et al. 2016), and correlation coefficient (Clayton et al. 2016). Velocity couplets and spectrum width maxima embedded within the broader mesovortices were analyzed and matched to many of the tornado tracks identified in the reanalysis. To calculate rotational velocity of couplets embedded within the mesovortices, maximum and minimum Doppler velocities were identified within one pixel of the given spectrum width maximum, as illustrated above.

Official NWS Storm Data Results

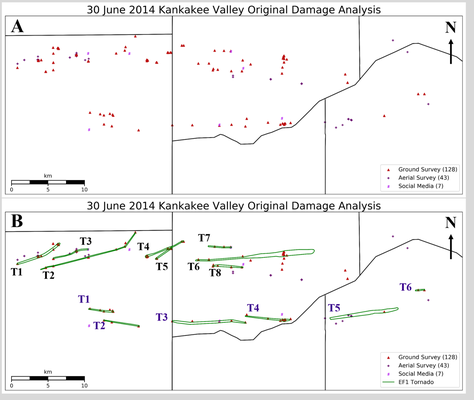
Official Kankakee Valley tornado paths for Storm Data were determined via two ground surveys, an aerial survey, and examination of radar data. But there were shortcomings:

- Focused on areas of known/reported/discovered damage – no tornadoes were seen
- Aerial survey too late and too limited – debris was cleaned up, crops had recovered
- Scope, extent, and evolution of the event were not fully understood

Damage on a farm northwest of Grant Park, IL, near location of TDS in radar imagery.

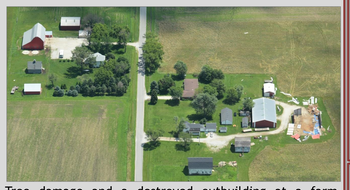
A destroyed barn northeast of Grant Park, IL.

Collapsed silo south of Lowell, IN.



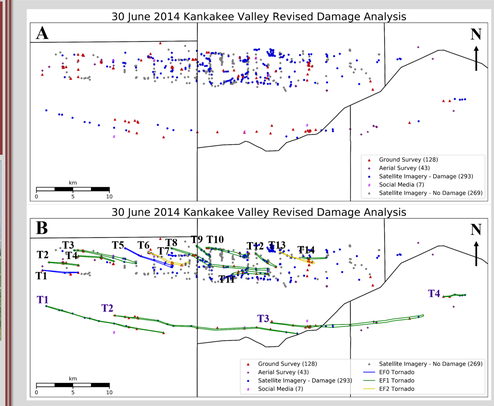
Above: Overview map depicting (A) the points of information gathered during surveys of the Kankakee Valley tornado cluster in July 2014 and (B) the official Storm Data tornado tracks overlaid the information points. The labels "T1", "T2", etc., identify each tornado in the order they were estimated to have formed. The black labels reference tornadoes from the northern mesovortex, and blue reference tornadoes from the southern mesovortex. The challenge was to determine the orientation of multiple tornado paths given many closely spaced damage points.

Silo damage on a farm west of Forest City, IN.



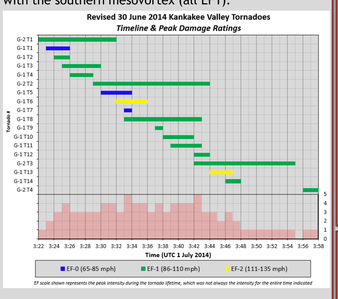
Tree damage and a destroyed outbuilding at a farm northwest of Grant Park, IL, near location of TDS annotated in radar imagery.

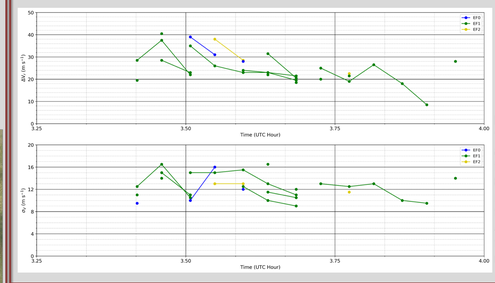
Reanalysis Results



Left: New assessment of the Kankakee Valley tornado tracks that resulted from the reanalysis process. The labels "T1", "T2", etc., identify each tornado in the order they were estimated to have formed. The black labels reference tornadoes from the northern mesovortex, and blue reference tornadoes from the southern mesovortex. The initial Storm Data analysis of the tornado cluster included 8 EF1 tornadoes with the northern mesovortex and 6 EF1 tornadoes with the southern mesovortex. The addition of satellite data allowed for numerous additional damage locations to be identified with both mesovortices and more confident declaration of how the damage evolved. The reanalysis led to the identification of 14 tornadoes with the northern mesovortex (three EF0, eleven EF1, and two EF2), many of which evolved far differently than the official Storm Data results. While the initial assessment of the southern mesovortex indicated that the initial Storm Data results were not substantially in error, the satellite imagery led to the identification of damage across largely inaccessible areas that allowed for the merger of two pairs of tornadoes. The end result was a reduction from 6 to 4 tornadoes identified with the southern mesovortex (all EF1).

Right: Timeline of tornado occurrence for the tornadoes in the Kankakee Valley tornado cluster, as identified in the reanalysis. The "tornado #" references the tornadoes as labeled on the map above. From the beginning of the first tornado of the cluster (G-2 T2) to the end of the last (G-2 T4), the entire Kankakee Valley tornado cluster occurred over a span of 36 min., from 0322 to 0358 UTC. On average, a new tornado formed in the cluster every 1.9 min. Up to 5 tornadoes were estimated to have been ongoing simultaneously during the event.

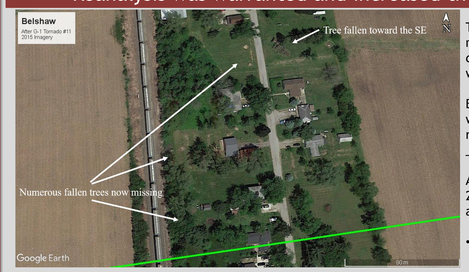




Left: Time series of the radar analysis described in the "Reanalysis Methodology". All 18 tornadoes were associated with local spectrum width maxima and identifiable embedded velocity couplets for at least one 0.5° scan from the Chicago-Romeoville WSR-88D radar (KLOT). Tornadoes detected over multiple scans tended to feature an early peak in rotational velocity (V_{ROT}). Additionally, an overall trend in decreasing V_{ROT} over time can be seen in panel (A), likely owing to the mesovortices moving farther away from KLOT.

Conclusions, Messaging Challenges, and Remaining Uncertainties

Reanalysis was warranted and increased the understanding of this complex event.



Top: Evidence of tree damage associated with tornado 11 of the northern mesovortex in Belshaw, IN, as seen from Google Earth imagery. This damage was documented and corroborated in a ground survey in the wake of the event.

Bottom: Examples of damage observed in the initial ground surveys that was attributed tornado 8 of the northern mesovortex during the reanalysis.

A case as complex as the Kankakee Valley tornado cluster on 30 June 2014 poses a number of challenges to operational and post-operational activities:

- Radar velocity signatures associated with the individual tornadoes were subtle and embedded within the larger-scale rotation observed in association with the broader mesovortices.
- Many of the tornadoes associated with the northern mesovortex were short-lived and likely ongoing concurrently. Despite KLOT running in a SAILS scan strategy, many of the tornadoes were only associated with a velocity couplet and spectrum width maximum on one 0.5° scan. Tornadoes with the southern mesovortex tended to be long-lived, but detection issues still arose due to the southern mesovortex being farther away from KLOT.
- Within NWS warning products, what is the best way to message an event such as this one, with multiple closely spaced tornadoes that are difficult to discern in real-time?
- With extremely fast forward motions (approximately 26 m s^{-1}/60 MPH), indications of cyclonic rotation were muted in many of the tornado tracks. Survey crews had to rely on seeing convergence (sometimes subtle) in tree fall and debris dispersion patterns, as well as assessment of length-to-width aspect ratio (Knupp 2000) to identify tornado damage.
- Damage from other events, preventative clearing, and loss of trees due to insect infestation had to be taken into account when assessing satellite imagery.

For More Information

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Lyza, A. W., R. Castro, E. Lenning, M. T. Friedlein, B. S. Borchardt, A. W. Clayton, and K. R. Knupp, 2019: Multi-platform reanalysis of the Kankakee Valley tornado cluster on 30 June 2014. *Electronic J. Severe Storms Meteor.*, **14** (3), 1–64.

Also see Part 1 of this presentation:
The 30 June 2014 Midwestern Double Derecho Event, Part 1: Environmental Overview and Radar Analysis of the Second Derecho

Acknowledgements

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