A Long-Lived Supercell with Intense Gustnadoes on 3 April 2011

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INTRODUCTION

On 3 April 2011, a long-lived supercell formed in northeast Kansas, on the cool side of an advancing cold front and produced a swath of golf ball-sized hail north of the main updraft and damaging winds along the leading edge of the rear flank downdraft. Aside from the widespread damaging winds, two intense gustnadoes formed at the intersection of the cold front and RFD gust front.

The focus of this study addressed the following:

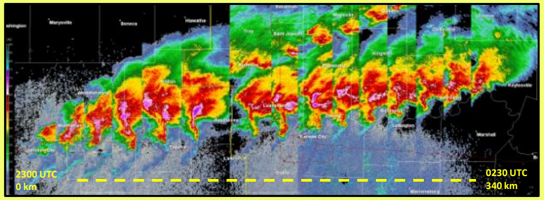
- Diagnosing favorable mesoscale conditions that supported strong, long-lived gustnado formation.
- Identifying radar signatures associated with these intense gustnadoes.
- The challenges linked with warning decision making while conflicting reports of tornadoes and gustnadoes were received.
- Illustrating the significant damage caused by intense gustnadoes.

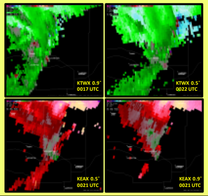
AMS DEFINITIONS

Tornado - A violently rotating column of air, in contact with the surface, pendant from a cumuliform cloud, and often, but not always, visible as a funnel cloud.

Gustnado – A short-lived, shallow, generally weak, vertically oriented vortex found along a gust front. Gustnadoes are usually visualized by a rotating dust or debris cloud.

RADAR



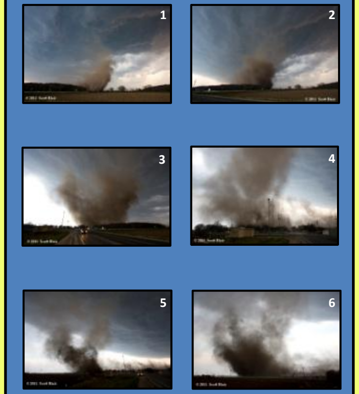


The supercell originated west of Manhattan, KS, ~20 km behind the cold front, and travelled ~340 km, over a span of 3.5 hours (top). SRM velocity images show vertical and temporal continuity of the cyclonic rotational couplet associated with the gustnado near Williamstown, KS. It is particularly impressive that the circulation was resolved by local radars, as most gustnadoes are not detected by the WSR-88D due to the shallow nature of the circulation.

The Williamstown, KS gustnado (red X) was located at the intersection of the well-resolved RFD gust front and cold front, ~10 km southeast of the mesocyclone. The red arrows approximate the surface winds based on local mesonet observations and WSR-88D velocity data (left).

IMAGES

The NWS conducted a damage survey and found a large outbuilding destroyed (top) along with this center-pivot irrigation system (bottom) near Williamstown, Kansas. Winds were estimated around 80 mph based upon damage.



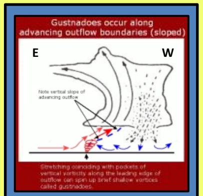


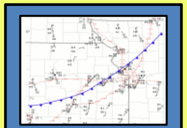
Image Courtesy: Jon Davies

This sequence of photos shows the evolution of the Williamstown, KS gustnado. Early in its lifespan, the vortex was characterized by a very tight and organized structure, and contained strong surface corner flow (Images 1-2). With time, the cyclonic circulation broadened and RFD outflow winds beneath the shelf cloud helped propagate the vortex (Images 4-6).

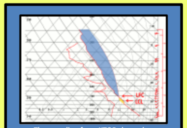
The diagram illustrates the development of gustnadoes, which typically form along the leading edge of a thunderstorm gust front. Vortex rotation can be enhanced by stretching of preexisting vertical vorticity and strong low-level lapse rates (left).

MESOSCALE ENVIRONMENT

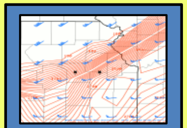
Analysis from 00z 4 April 2011



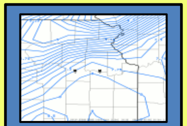
The surface cold front was located between Topeka and Lawrence, with warm moist air ahead of the boundary, and cool dry air behind the front.



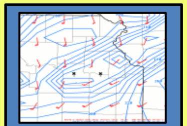
The sounding from KTOP showed an abundance of CAPE above a relatively high LCL, with a small amount of CINH.



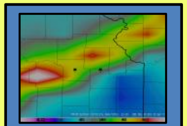
Moderate instability of 2000 J/Kg to 2500 J/Kg of SBCAPE and 40 knots to 50 knots of 0-6 km bulk shear were present, supportive of strong persistent updrafts.



Steep low-level lapse rates, between 7.5 C/km and 8 C/km, indicated the potential for strong vertical low-level motion, enhancing preexisting surface vorticity.



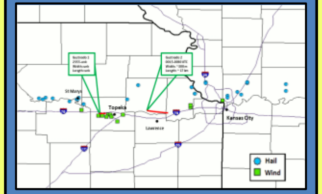
0-1 km SRH values between 100 m^2/s^2 and 120 m^2/s^2 indicated turning in the lowest levels of the atmosphere.



An area of enhanced surface vorticity in conjunction with the steep low-level lapse rates likely supplied some of the necessary ingredients for gustnado formation.

The observed sounding showed nearly dry adiabatic lapse rates in the lowest 3 km, which indicated high instability near the surface. The high LCL, near 2000 m, in combination with the main updraft's location on the cool side of the boundary, made mesocyclone-associated tornadogenesis unlikely. The low-level instability allowed strong inflow into the thunderstorm, which stretched the preexisting surface vorticity located along the surface cold front, and enhanced the rotation. This process, similar to that of dust devil creation, led to the intense vortices, which occurred ~2355 UTC and ~0015 UTC near Topeka, KS and Williamstown, KS, respectively.

REPORTS



Severe weather reports of hail ≥ 1.00 in., winds ≥ 58 mph, and the two known gustnadoes (red lines) are plotted above. Multiple locations received 1.75 in. hail, and the strongest wind, near 80 mph, occurred with the gustnado near Williamstown, KS.

CONCLUSION

Two prominent gustnadoes occurred near the intersection of the RFD gust front and surface cold front. Although the vortices were located ~10 km south of the main updraft, they formed beneath the flanking line updraft of the storm.

The intense gustnado near Williamstown, KS had similar physical and developmental characteristics to landspouts, with steep low-level lapse rates, enhanced surface vorticity near the boundary intersection, and strong inflow into the storm. Presumably, the stretching of the preexisting surface vorticity led to a tight, rapidly rotating vortex with visible surface inflow jets and a large amount of debris.

Warning decision making for the gustnadoes was complicated by numerous reports of tornadoes from the public and trained spotters. Ultimately, reliable field reports and knowledge of the environment led to the issuance of a strongly worded severe thunderstorm warning of anticipated winds of 80 mph.

Warning forecasters should be aware of environmental conditions supportive of strong gustnadoes. The location of the reports relative to the main updraft should serve as an indicator of whether the storm is producing gustnadoes as opposed to tornadoes. WSR-88D may occasionally resolve the deepest circulations at reasonable distances from the radar site.

When gustnadoes are occurring with strong outflow winds, severe thunderstorm warnings with enhanced wording, in lieu of tornado warnings, is a scientifically accurate product that satisfies both the scientific integrity and service to our partners.