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An Elevated Supercell with Damaging Wind From the Morning of 12 March 2006

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1. Introduction

An intense, right-moving supercell thunderstorm formed the morning of 12 March 2006 in eastern Kansas and moved to the east-northeast across the Lawrence, Kansas, and the Kansas City metropolitan areas into north central Missouri. This supercell produced a swath of damaging winds up to 78 kt that resulted in widespread property damage across Lawrence, as well as hail up to 2.75 inches in diameter (Storm Data 2006). The convective cluster within which this storm developed represented the preliminary stages of what later became a major tornado outbreak across Missouri from the afternoon of 12 March through the early morning hours of 13 March.

A particularly interesting aspect of this case was the occurrence of damaging winds with a thunderstorm rooted above a pronounced stable layer at the ground, with surface temperatures in the upper 40s F. Damaging winds are rarely considered to be a substantial threat with elevated convection due to the presence of a near-ground stable layer. However, a close examination of the near-storm environment reveals an unusual thermodynamic stratification favoring updrafts rooted well above the ground, and yet downdrafts capable of penetrating the surface stable layer.

Local surface observations and regional soundings support the presence of an “overshooting” downdraft of mid-level origins penetrating the stable layer and reaching the ground on the rear flank of this supercell.

2. Synoptic and mesoscale environment

A strong low-level warm advection regime was present over eastern Kansas during the early morning hours of 12 March 2006, north of a surface warm front (Fig. 1). Several thunderstorms developed during the pre-dawn hours over south central Kansas, with convection apparently rooted in the 900-850 mb layer based on the 12 UTC and 18 UTC soundings from Lamont, Oklahoma (LMN) and Topeka, Kansas (TOP) – Figs 2a-2d.

The storm updraft was likely elevated, given the absence of surface-based CAPE in both the LMN and the TOP 12 UTC soundings, no appreciable changes in surface conditions prior to the arrival of the supercell, and effective inflow bases (Thompson et al. 2006) ranging from 283-644 m AGL (Figs. 2a and 2d). The environment north of the surface warm front was characterized by most-unstable parcel CAPE values increasing from roughly 600 J kg^{-1} to 2800 J kg^{-1} from 12 to 18 UTC at TOP in conjunction with low-level warming and moistening. The resulting 18 UTC sounding at TOP was similar to the truncated 12 UTC profile from LMN (immediately north of the surface warm front), which infers that similar profiles existed over eastern Kansas during the morning.

The combination of rich low-level mixing ratios near 13 g kg^{-1}, nearly dry adiabatic lapse rates in the mid troposphere, and strong vertical wind shear through the lower half of the storm depth was favorable for elevated supercells with very large hail. Local radar observations confirmed supercell structures in several storms during the morning over northeast Kansas.

3. Near-storm observations

The Lawrence/Kansas City supercell initiated as an isolated cell over southern Sumner County, Kansas at 10 UTC, south of Wichita, Kansas and roughly 150 km north of the surface warm front in northern Oklahoma. Additional thunderstorm development occurred to the west and north of this initial storm by 11-12 UTC (Fig. 1a), though this supercell remained the southeastern-most of the cluster of storms. Surface temperatures were in the lower 50s F in proximity to the storm at initiation, and the supercell traversed an area with surface temperatures in the mid 40s F, and dew

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point temperatures in the upper 30s F through its passage over Lawrence just after 14 UTC.

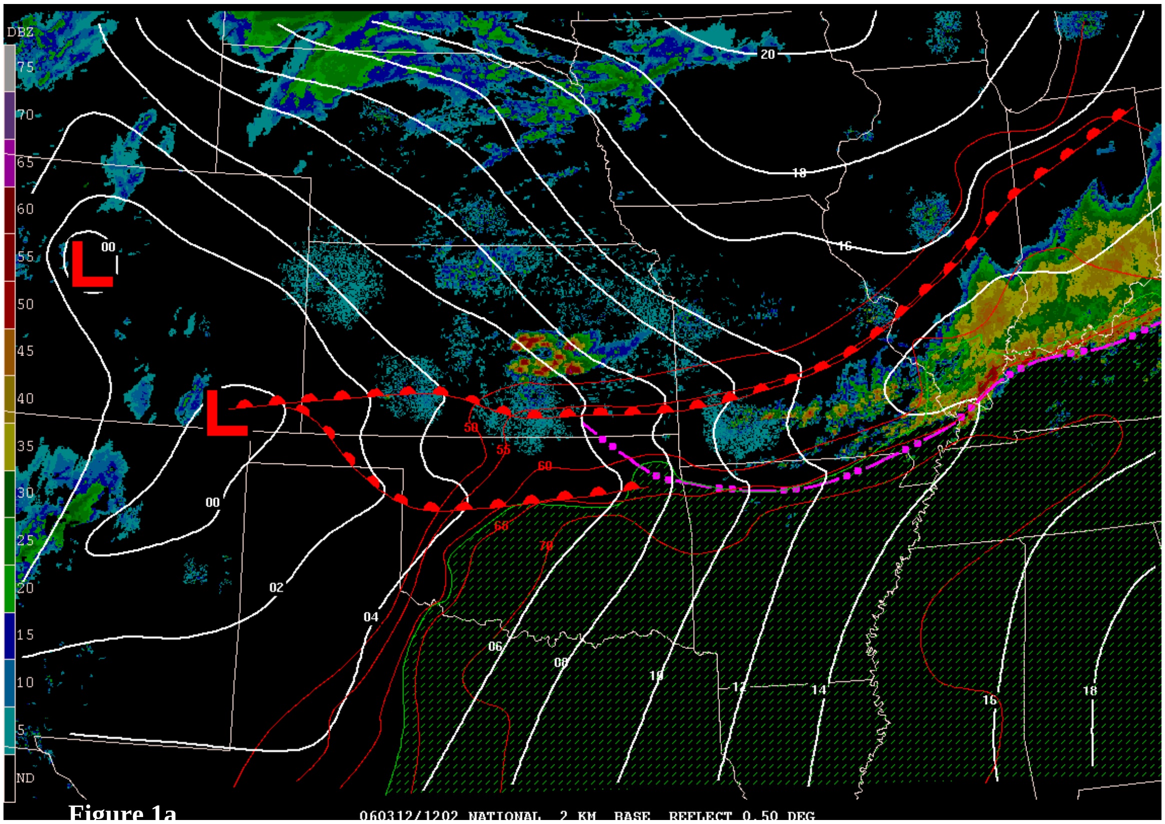
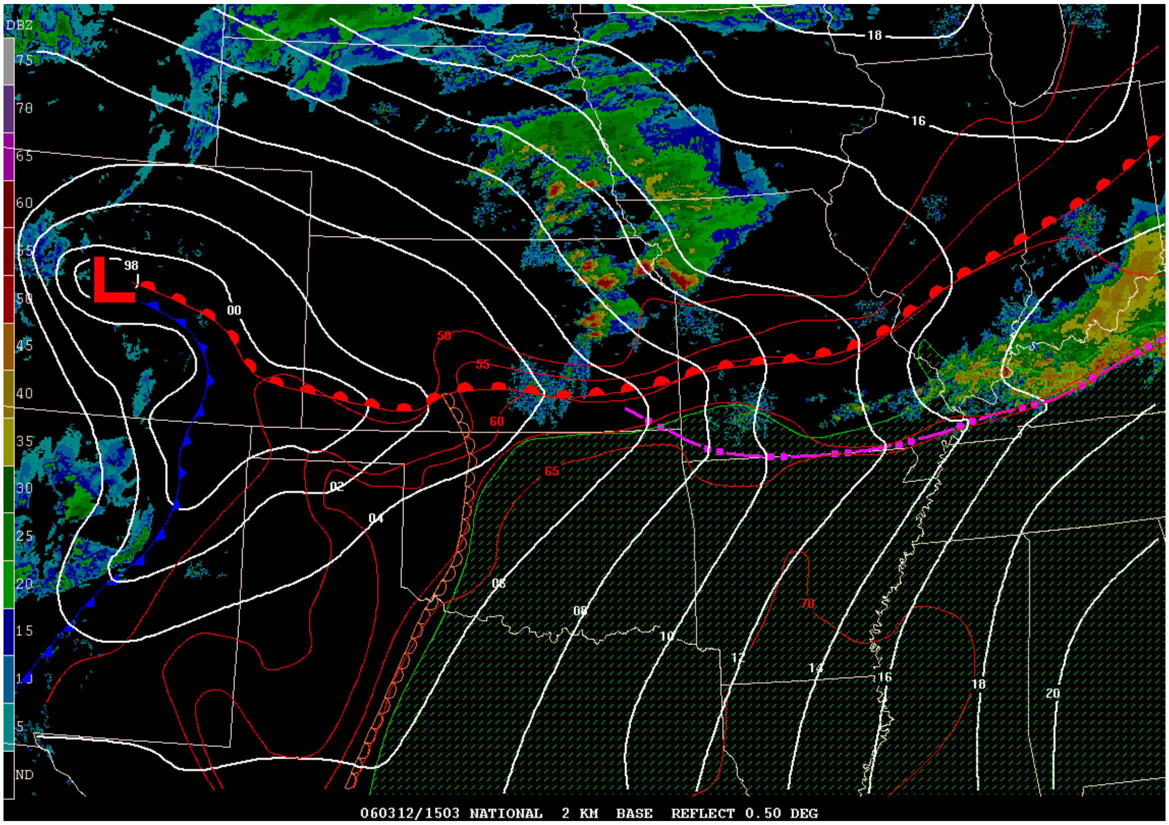
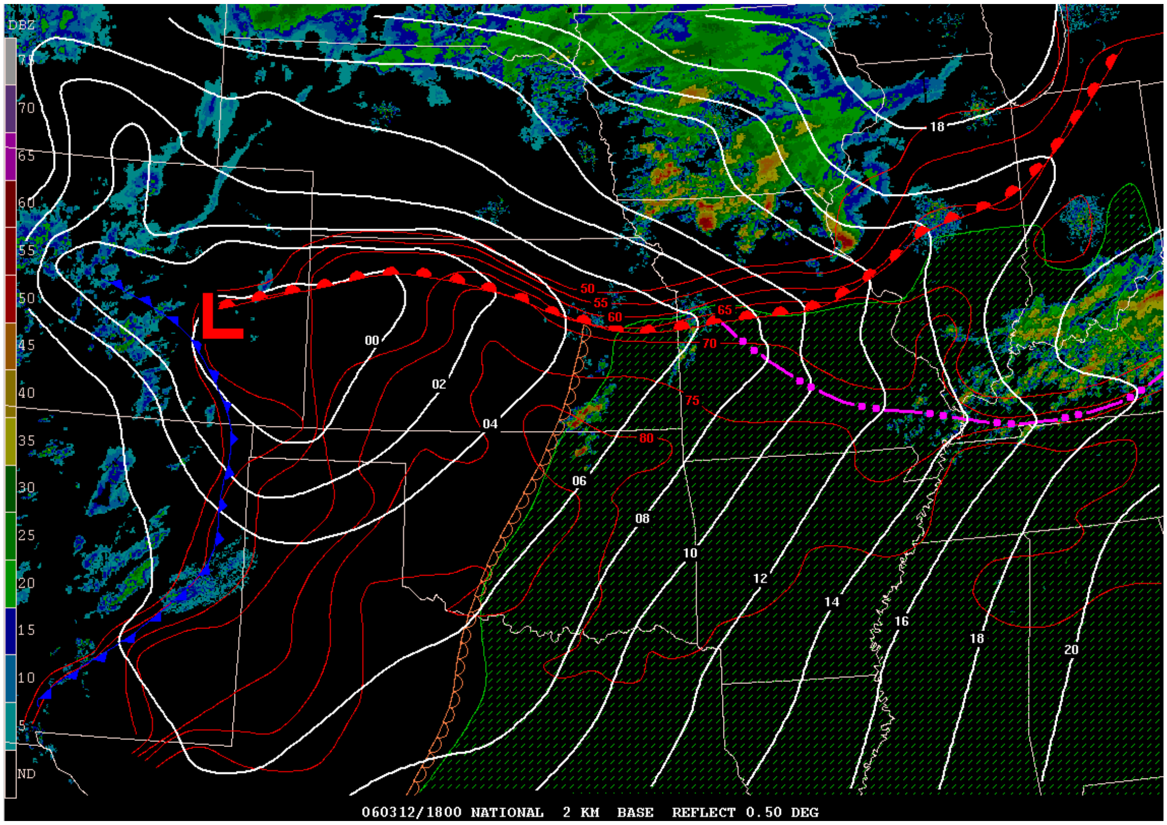


Figure 1a





Figures 1a-1c. Series of surface analyses valid at a) 1200 UTC, b) 1500 UTC, and c) 1800 UTC. Each analysis displays isotherms (every 5 F, red), isobars (every 2 mb, white), an isodrosotherm (shaded ≥ 60° F), and conventional frontal symbols. Corresponding WSR-88D 0.5° reflectivity mosaics accompany each analysis.

Between 14 and 15 UTC, the supercell moved through Lawrence and Kansas City, producing widespread wind damage and large hail. Local surface observations during this time revealed warming of 5-8° F with passage of the mesocyclone and rear flank gust front (Fig. 3). The warming was coincident with surface pressure rises and a surface wind shift indicative of divergent outflow in the immediate wake of the storm. Please note that although surface temperatures within the downdraft air behind the gust front were warmer than the ambient surface environment, the processes which resulted in this warming are not analogous to those responsible for the warming observed in heat burst events. Warming in heat burst events is due to an unsaturated downdraft warming dry-adiabatically during its decelerating descent (Johnson, 1983); the "warm" downdraft in this case was a saturated downdraft, whose temperature, after moist-adiabatic descent to ground level, happened to be warmer than the cool, ambient surface environment.

Surface temperatures remained relatively steady in the lower 50s F from 15-17 UTC at the locations impacted by the supercell from Lawrence to Kansas City, while pronounced warming and moistening commenced along and south of the Missouri River by 18 UTC with warm frontal passage (Fig. 1c).

4. Discussion and future work

Operational meteorologists often reference the presence of a sharp stable layer near the ground as a limiting factor, in terms of forecasting damaging winds at ground level. However, near-storm surface observations during the morning of 12 March 2006 support the presence of "overshooting" downdrafts, presumably of mid-level origin, penetrating the near-ground stable layer and reaching the surface as damaging wind gusts.

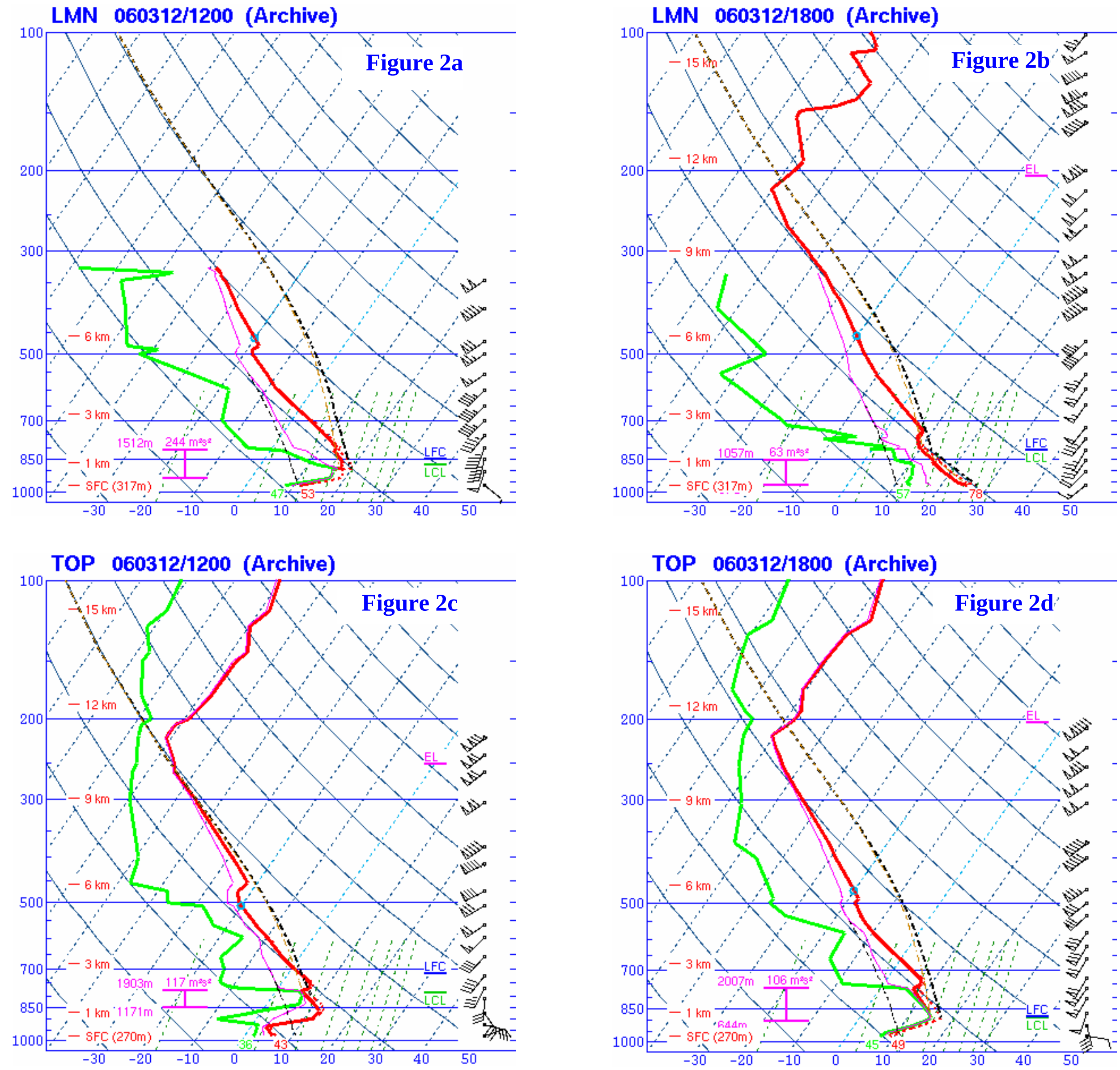


Figure 2a-2d. Skew-T log P plots from 12 March 2006 for Lamont, OK at a) 1200 UTC and b) 1800 UTC, and for Topeka, KS at c) 1200 UTC and d) 1800 UTC. The effective inflow layer (magenta) is plotted to the left of the temperature and dew point traces. The DCAPE parcel trace (minimum Θ_e in the lowest 400 mb of the sounding) is marked by the blue dashed curve to the left of the temperature trace.

In retrospect, the specific configuration of the temperature and moisture profiles on the morning of 12 March 2006 appear to support such penetrative downdrafts. Specifically, the soundings from LMN and TOP (Figs. 2a-d) revealed rich moisture near the top of a sharp, surface-based temperature inversion. Atop the inversion, a relatively dry mid-tropospheric layer characterized by steep lapse rates was observed. This particular thermodynamic profile allowed for large DCAPE (Gilmore and Wicker 1998) values in excess of 900 J kg^{-1}, supportive of strong saturated downdrafts originating in the dry, steep lapse rate layer above the surface-based inversion. Despite difficulties associated with determining and quantifying the specific characteristics of downdraft parcels in real time, utilizing DCAPE as a predictor appears to be reasonable, in this case, given the correlation between observed surface conditions associated with the downdraft and those which would be anticipated utilizing DCAPE/parcel theory assumptions. The DCAPE parcels derived from the 12 UTC LMN and 18 UTC TOP soundings suggested surface downdraft temperatures in the lower 50s F, which correlated well with surface observations revealing temperature rises of 5-8º F -- into the low to mid 50s F – in the immediate wake of the Lawrence/Kansas City supercell.

Horgan et al. (2006) investigated severe thunderstorms on the cool side of baroclinic zones and found a subset of cases where the storms were likely elevated, but the only severe storm reports were damaging winds. There are some similarities between the structure of their “type A” case and the 18 UTC TOP sounding, with a sharp surface-based inversion and substantial DCAPE. The similarities warrant examination of a larger sample of elevated thunderstorm cases, along with numerical simulations of deep convection in such a thermodynamic and kinematic environment. The 12 March 2006 environment may be archetypical of a broader range of damaging convective wind storms where the storm updrafts are elevated, but the storm downdrafts strongly impact the ground.

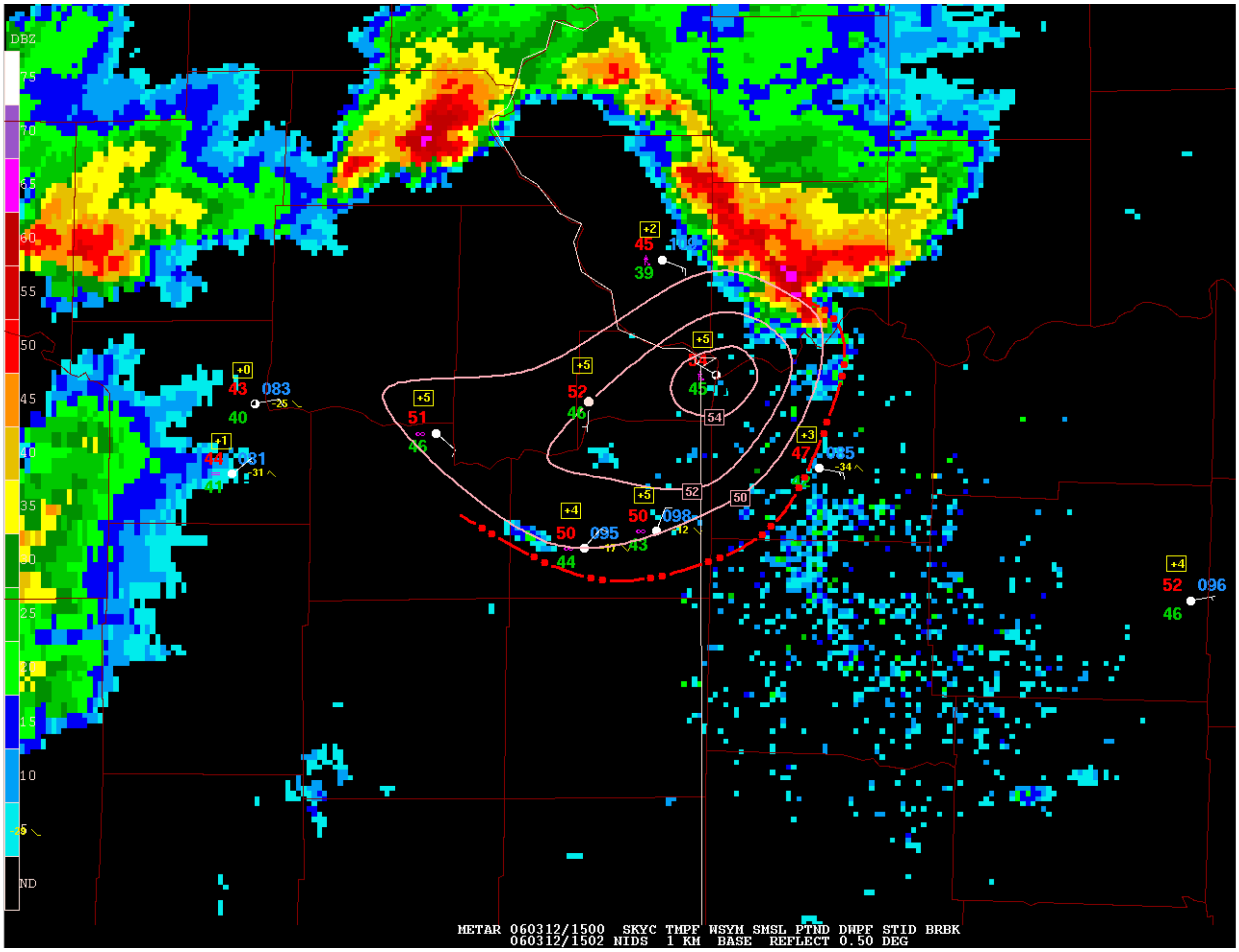


Figure 3. WSR-88D 0.5° reflectivity image for 1452 UTC from Topeka, KS. Standard surface station model plots with 15 UTC synoptic observations are included on the image. The alternating dash-dot line denotes the location of the rear flank gust front associated with the supercell moving across Kansas City, MO. The light red contours are isotherms (F), and the temperature change from 1400 to 1500 UTC is plotted in the yellow box above each observation.

5. Acknowledgements

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6. References

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