

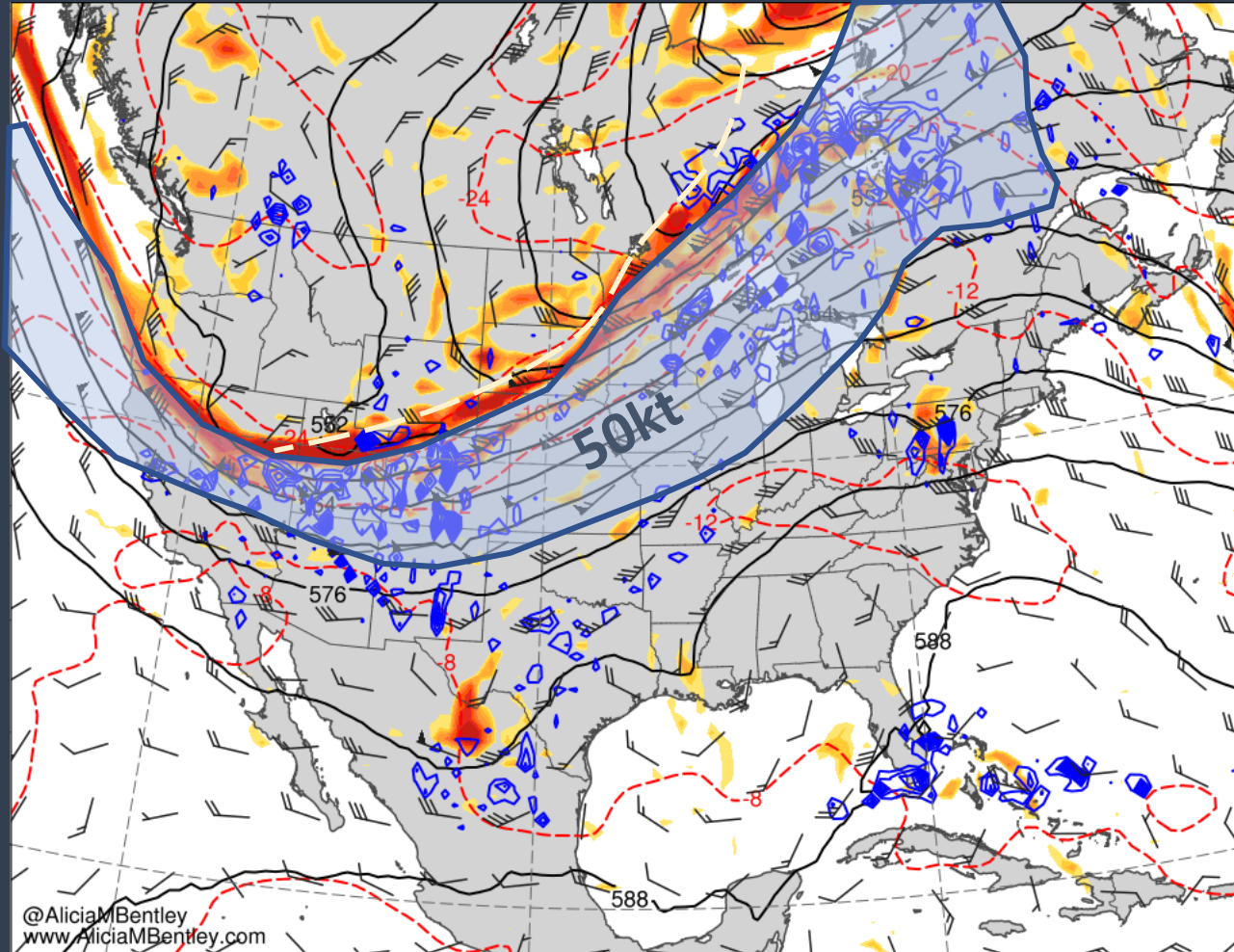


# The Gaylord MI EF-3 Tornado of 20 May 2022

Great Lakes Operational Meteorology Workshop  
Madison WI -- 24 May 2023

John Boris  
National Weather Service Gaylord MI

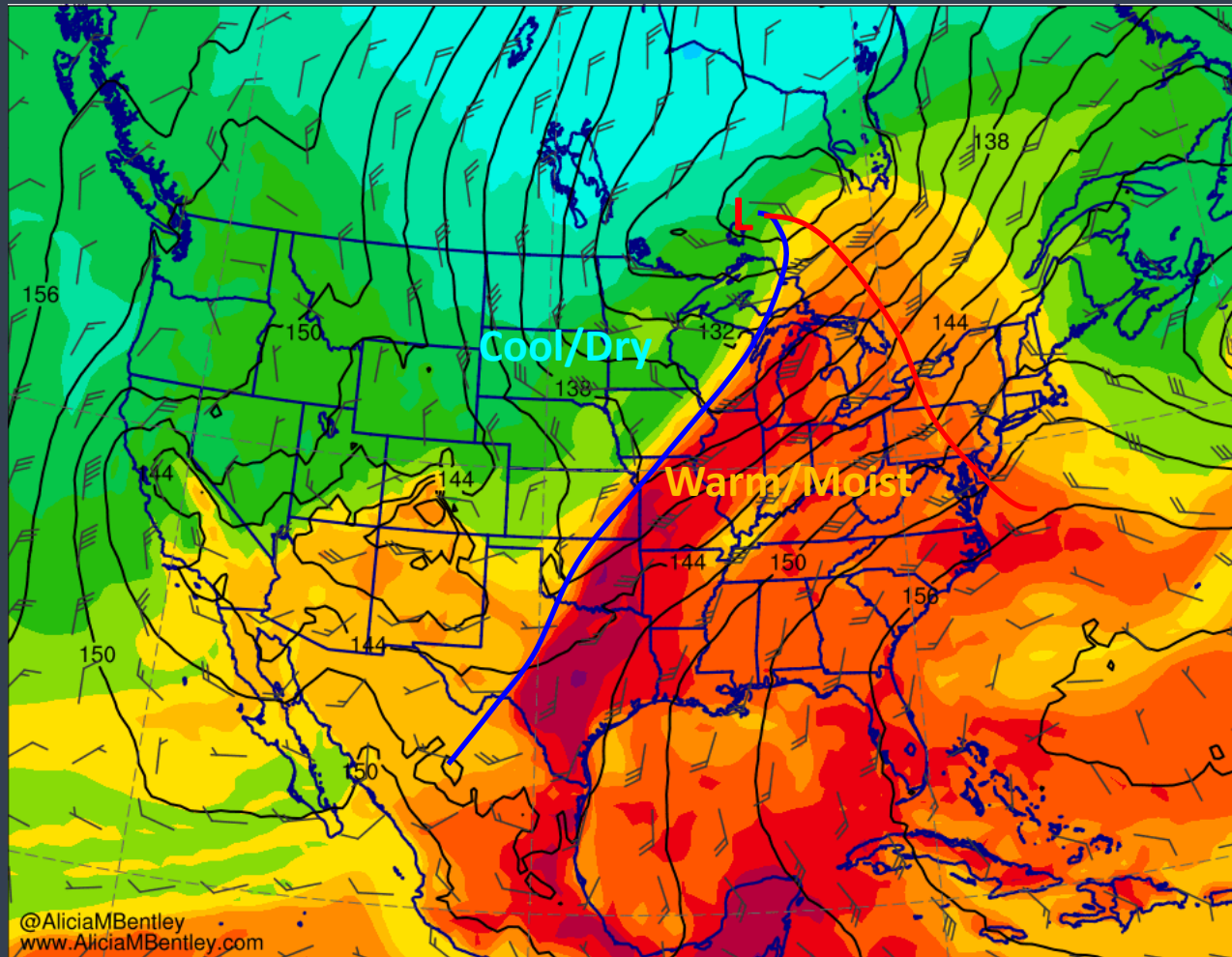
# Environmental Overview: 18:00Z 20 May 2022



## 500mb Heights/Temp/Wind 500mb Vorticity (Shaded)

- Short wave trough axis well upstream of the upper Great Lakes.
- Increasing southwest flow ahead of the trough axis (60-70kts).

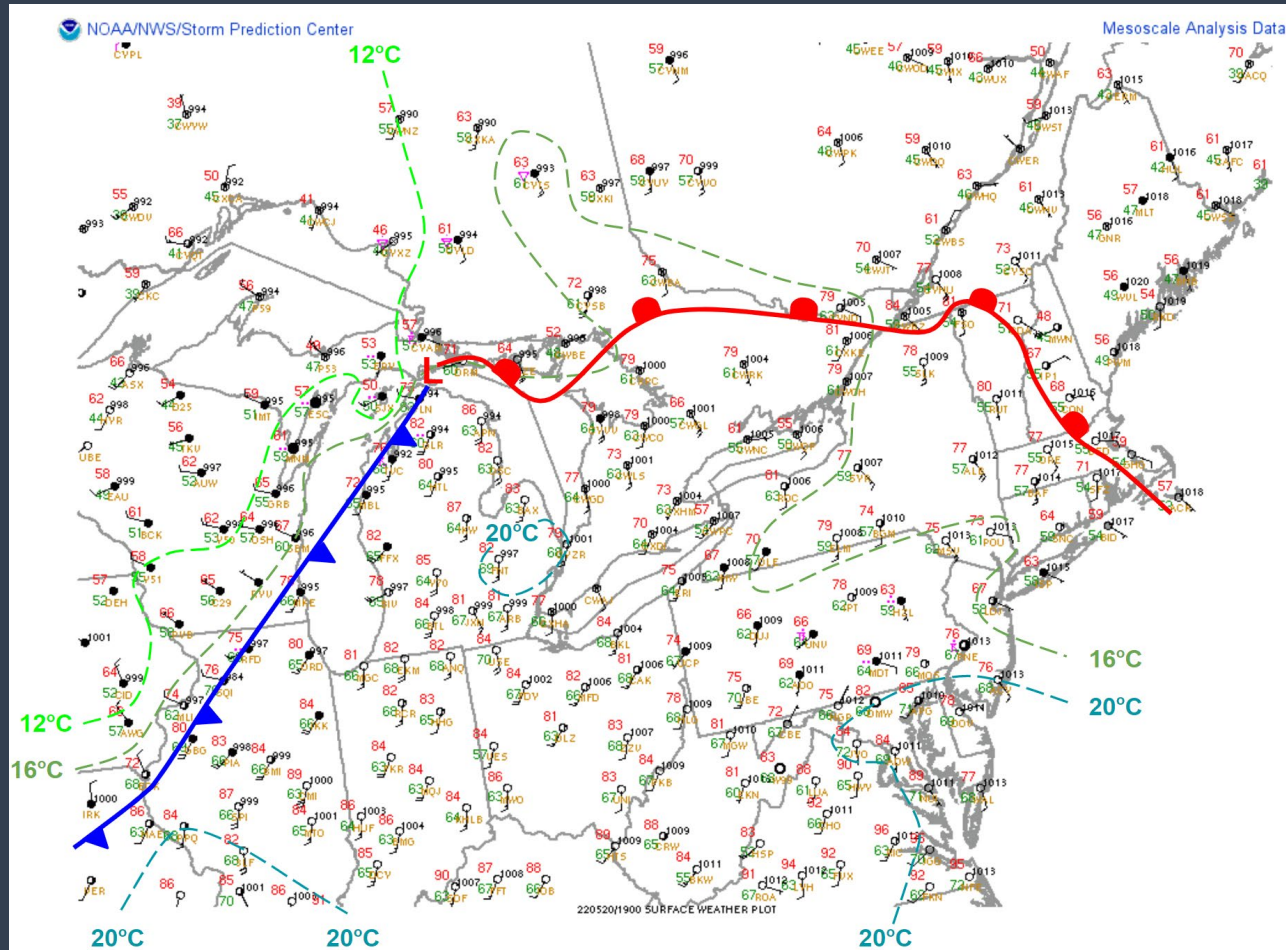
# Environmental Overview: 18:00Z 20 May 2022



## 850mb Heights/Wind 850mb Theta-e (Shaded)

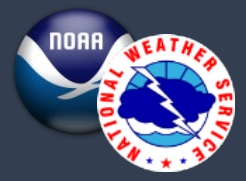
- Axis of warm/moist air ahead of an approaching cold front.
- 30-40kts southwest flow across southeast Wisconsin/Lower Michigan ahead of a cold front.

# Environmental Overview: 19:00Z 20 May 2022

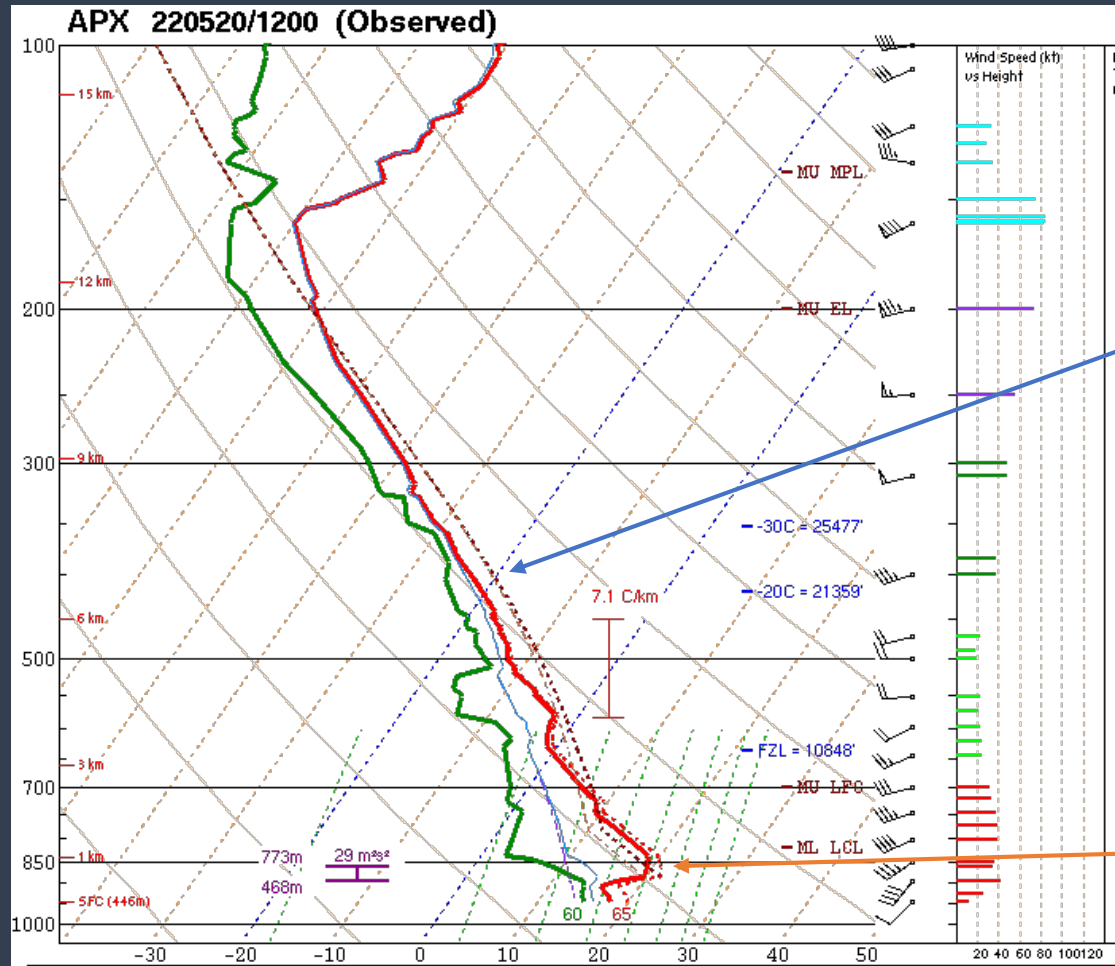


## Surface Analysis

- About 35 minutes prior to tornado development...northern Lower Michigan was tucked into the warm sector south of a weak frontal wave moving through the Straits...and a cold front pressing in from the west.
- Temperatures warmed into the lower-mid 80s across Lower Michigan along with dew points in the 60s ahead of the cold front.
- Meanwhile temperatures across eastern Upper Michigan were mainly in the 50s on the cool side of the warm front.



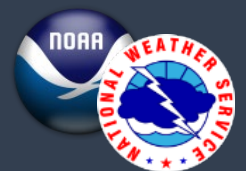
# APX Sounding: 12:00Z 20 May 2022



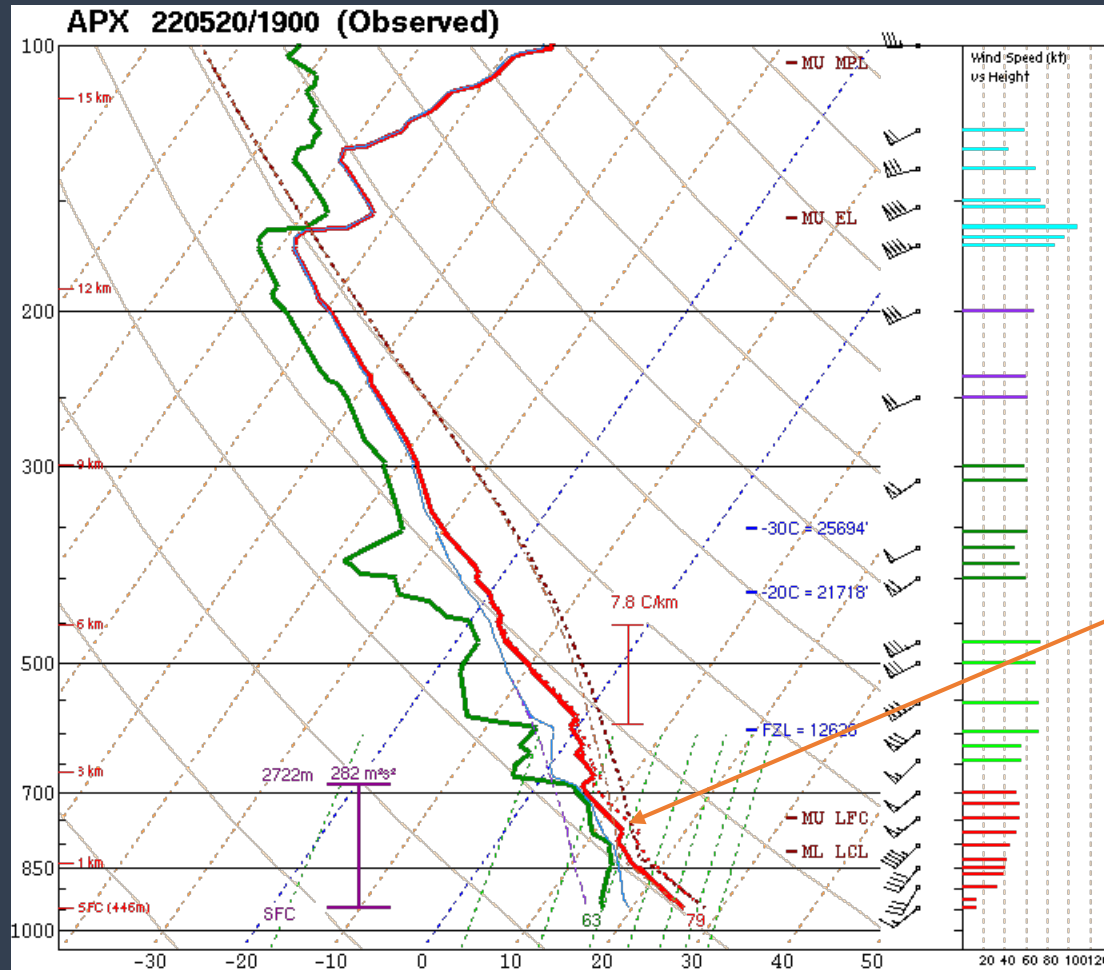
Steep Lapse Rates: 7.3°C/km 700-500mb

Capping inversion 900-850mb:

MLCINH: -233J/kg



# APX Sounding: 19:00Z 20 May 2022



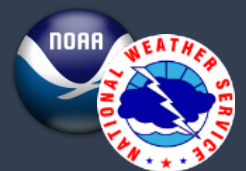
We did send up a special sounding at 19:10Z...about 25 minutes prior to tornado formation. So this ended up being a pretty good observed proximity sounding.

Capping inversion has lifted and been reduced substantially:

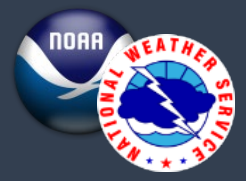
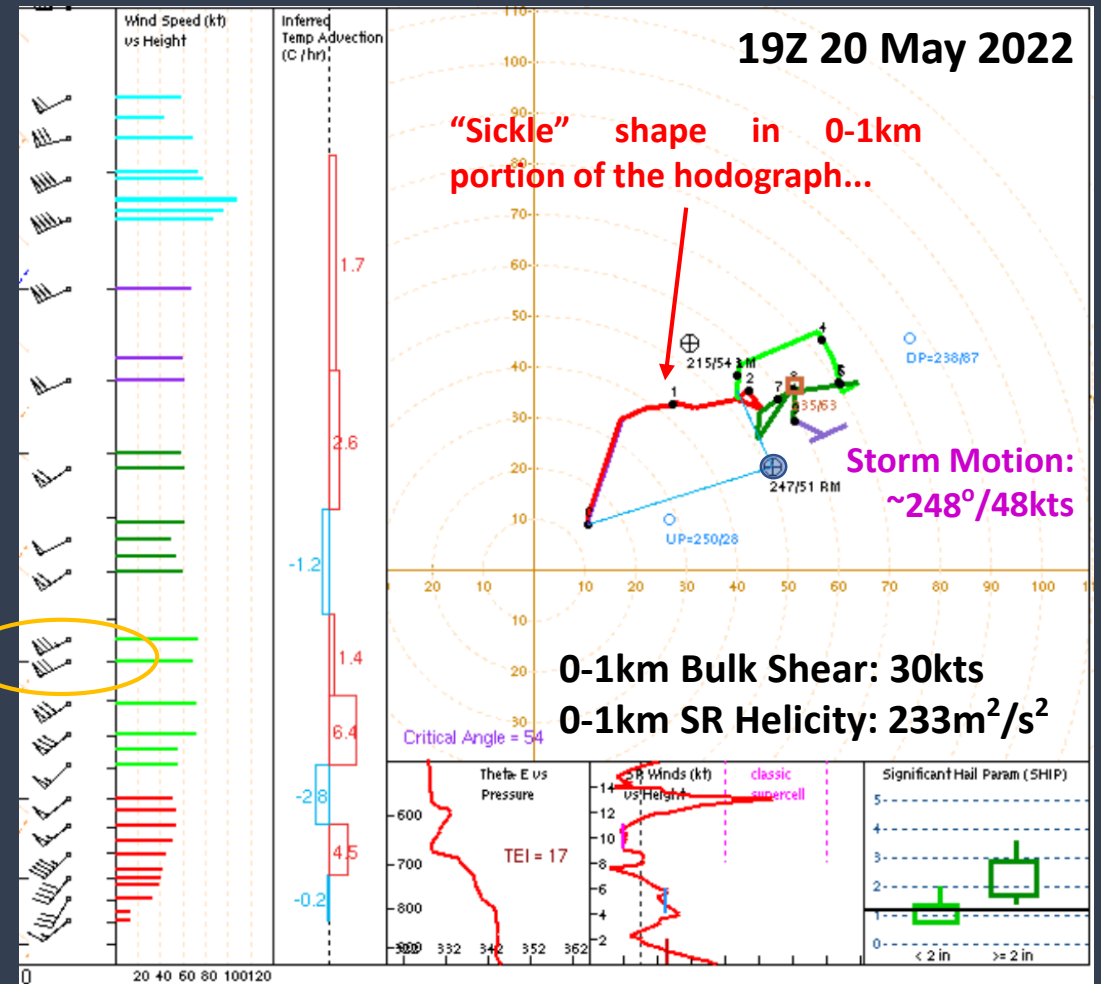
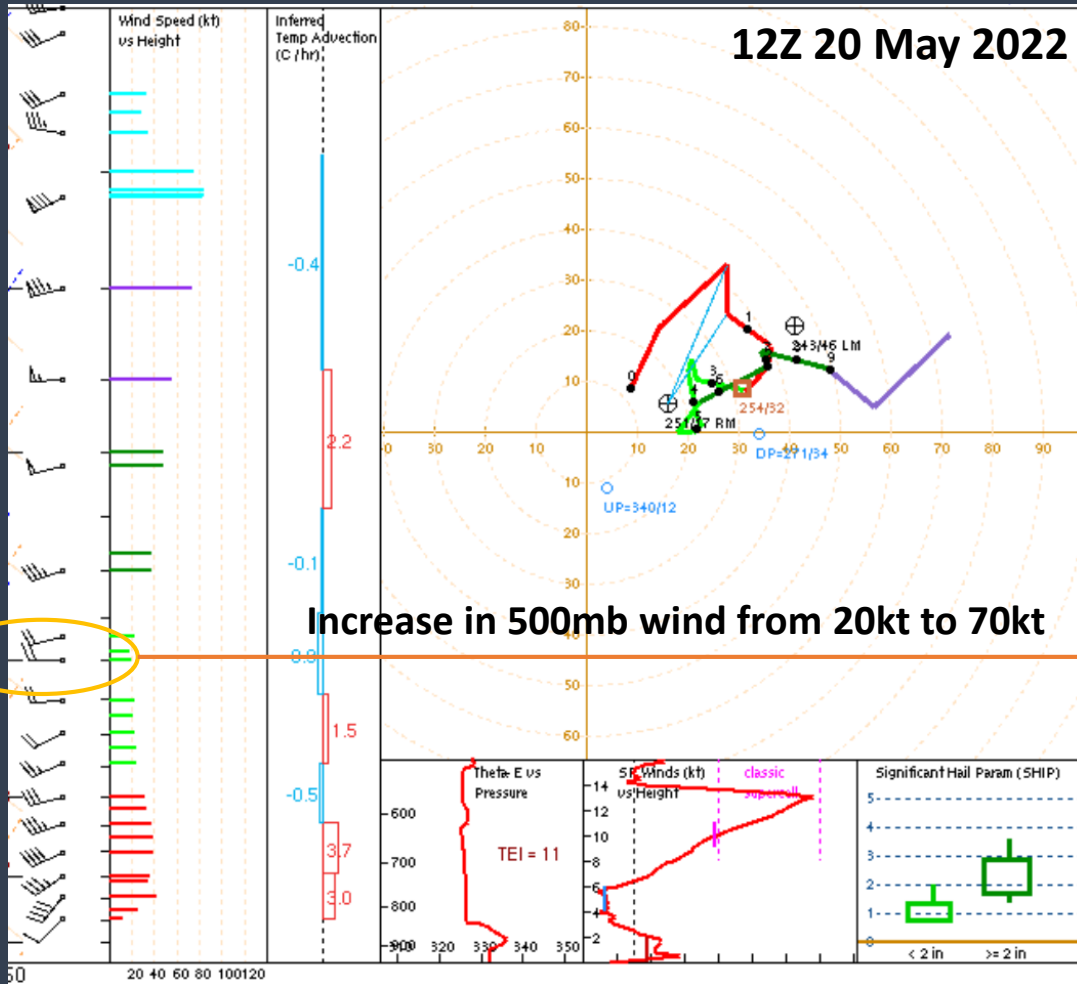
**MLCAPE: 1945J/kg**

**MLCINH: -19J/kg**

**0-3km CAPE: 63J/kg**



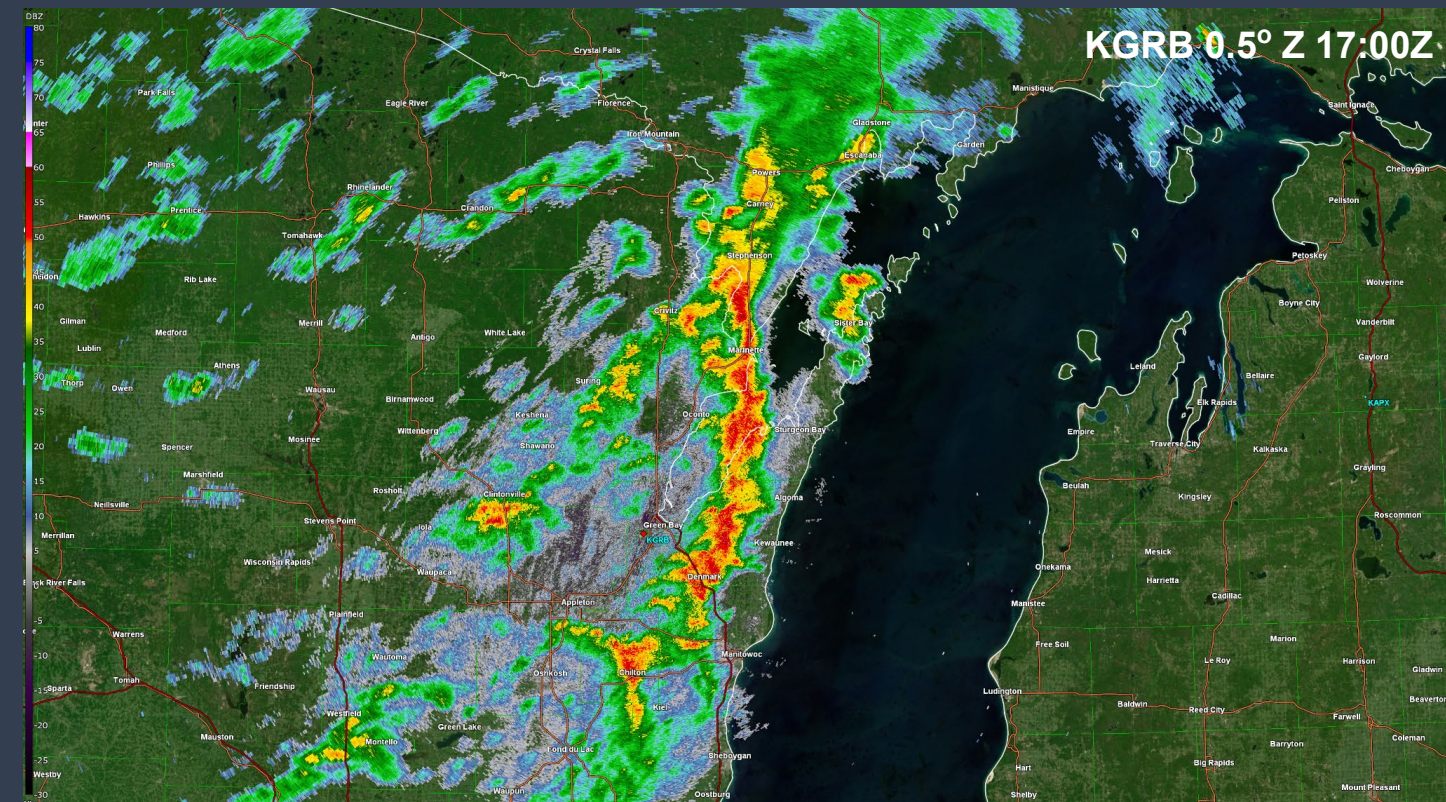
# APX Hodographs:



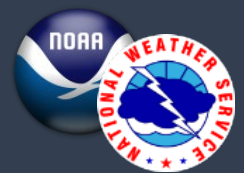
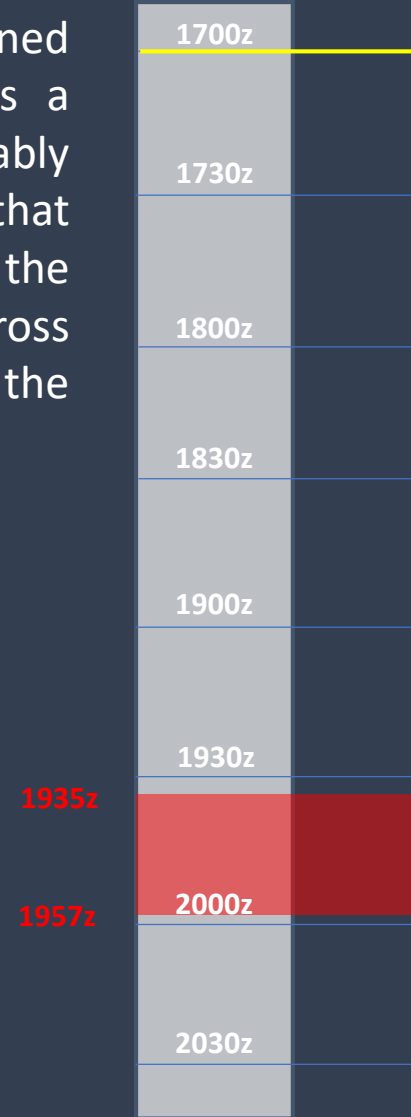
# Storm Evolution



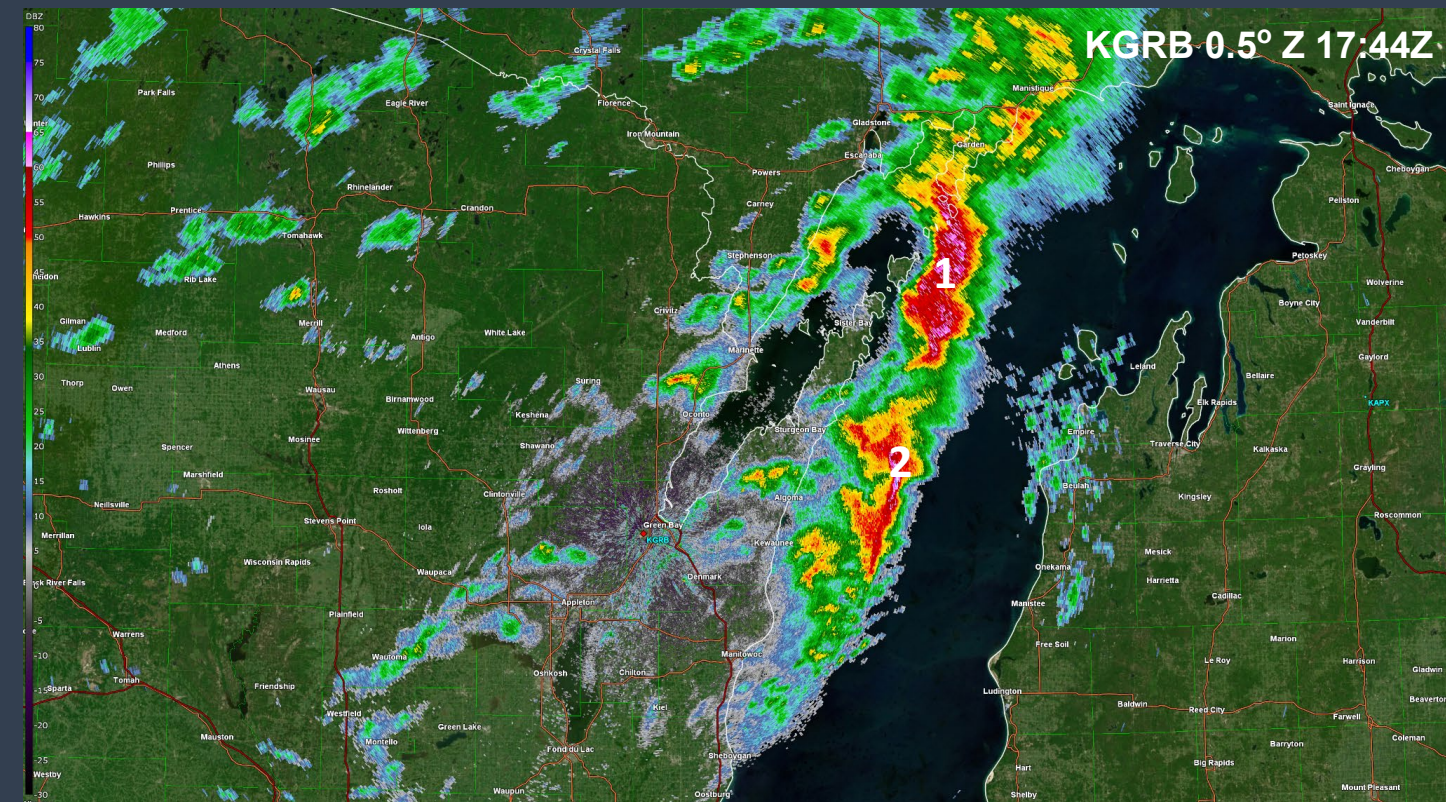
# Storm Evolution: QLCS Phase



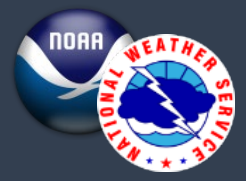
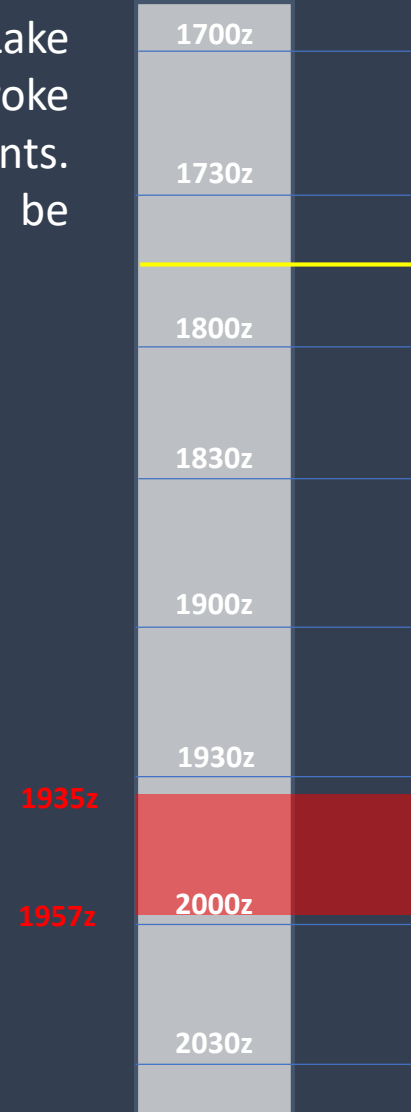
The storm that eventually spawned the Gaylord tornado began as a part of a larger squall line (probably somewhat elevated) that developed ahead of the approaching cold front across northeast Wisconsin during the morning hours on 20 May.



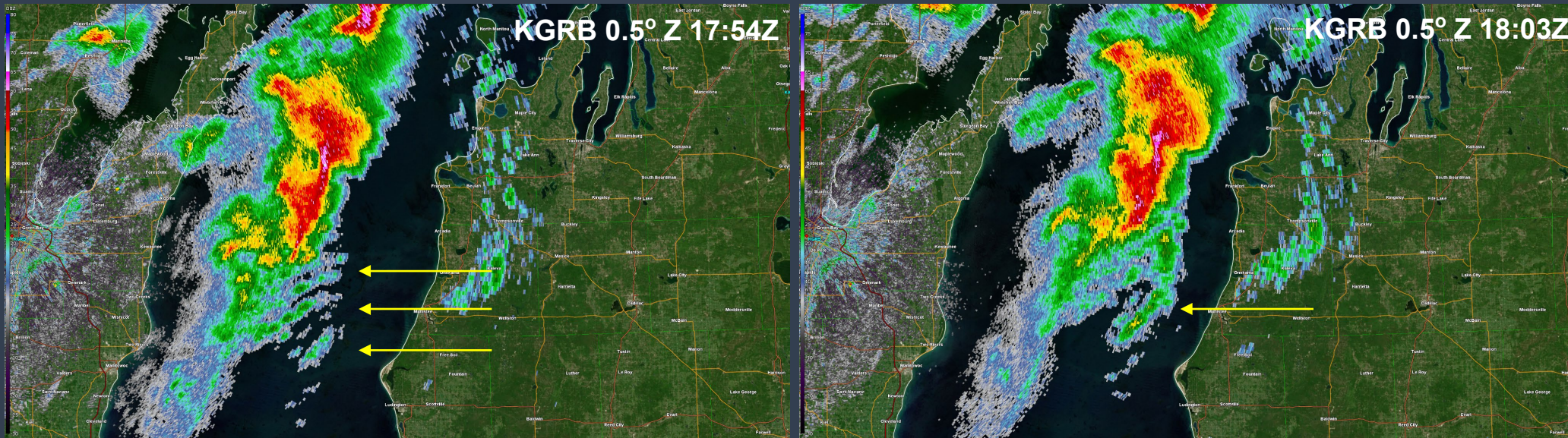
# Storm Evolution: QLCS Phase



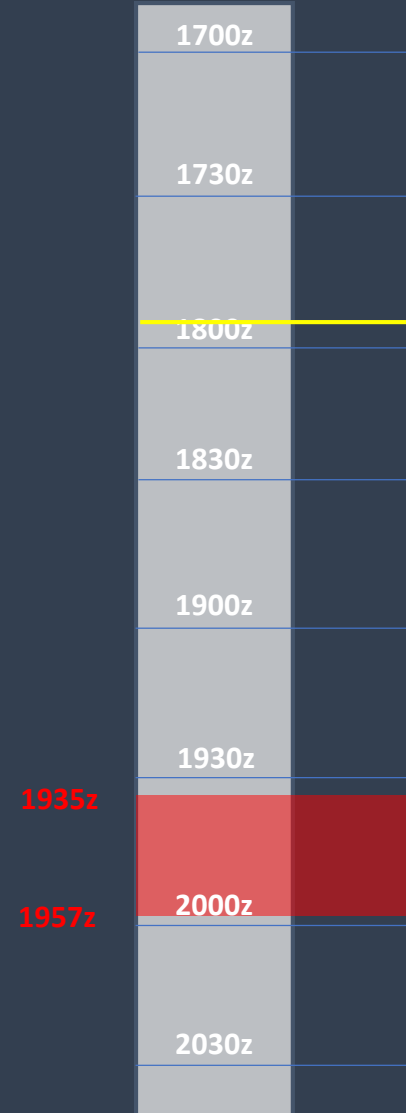
As the line crossed western Lake Michigan it strengthened and broke up into a couple of line segments. The southern segment (2) will be our storm of interest.



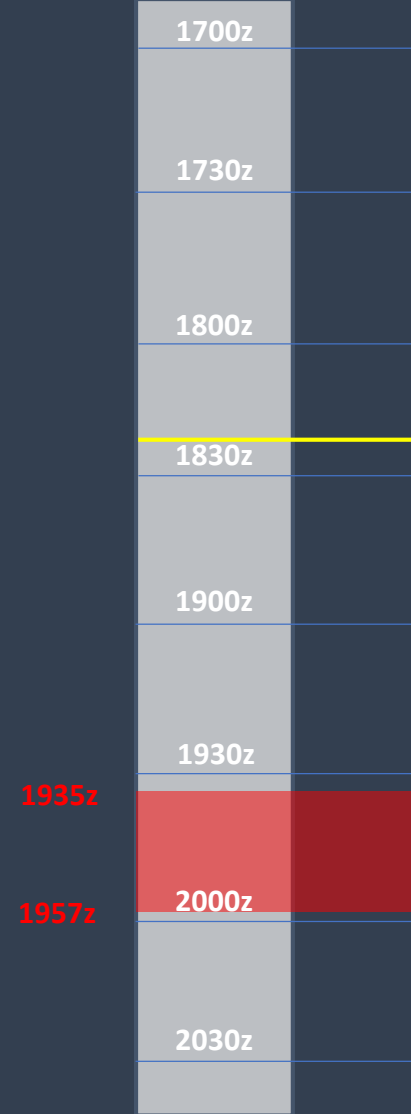
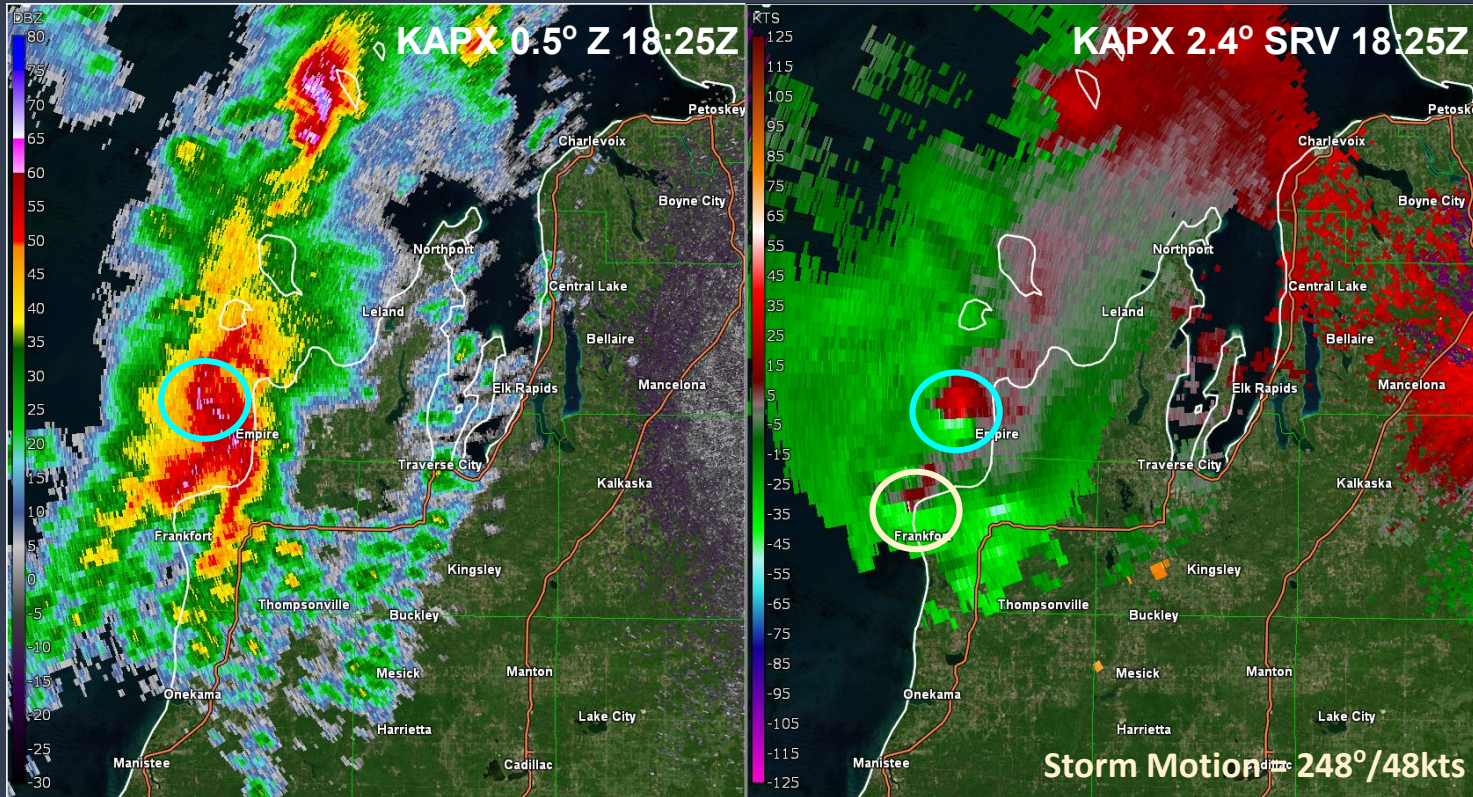
# Storm Evolution: QLCS Phase



A closer look at the southern storm shows what appears to be a northeastward propagating gravity wave train (left) which is interacting with the southern end of this storm cluster. These reflectivity tags eventually merge into a north-south oriented “appendage” echo (right).

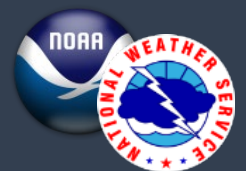


# Storm Evolution: Bookend Vortex Development

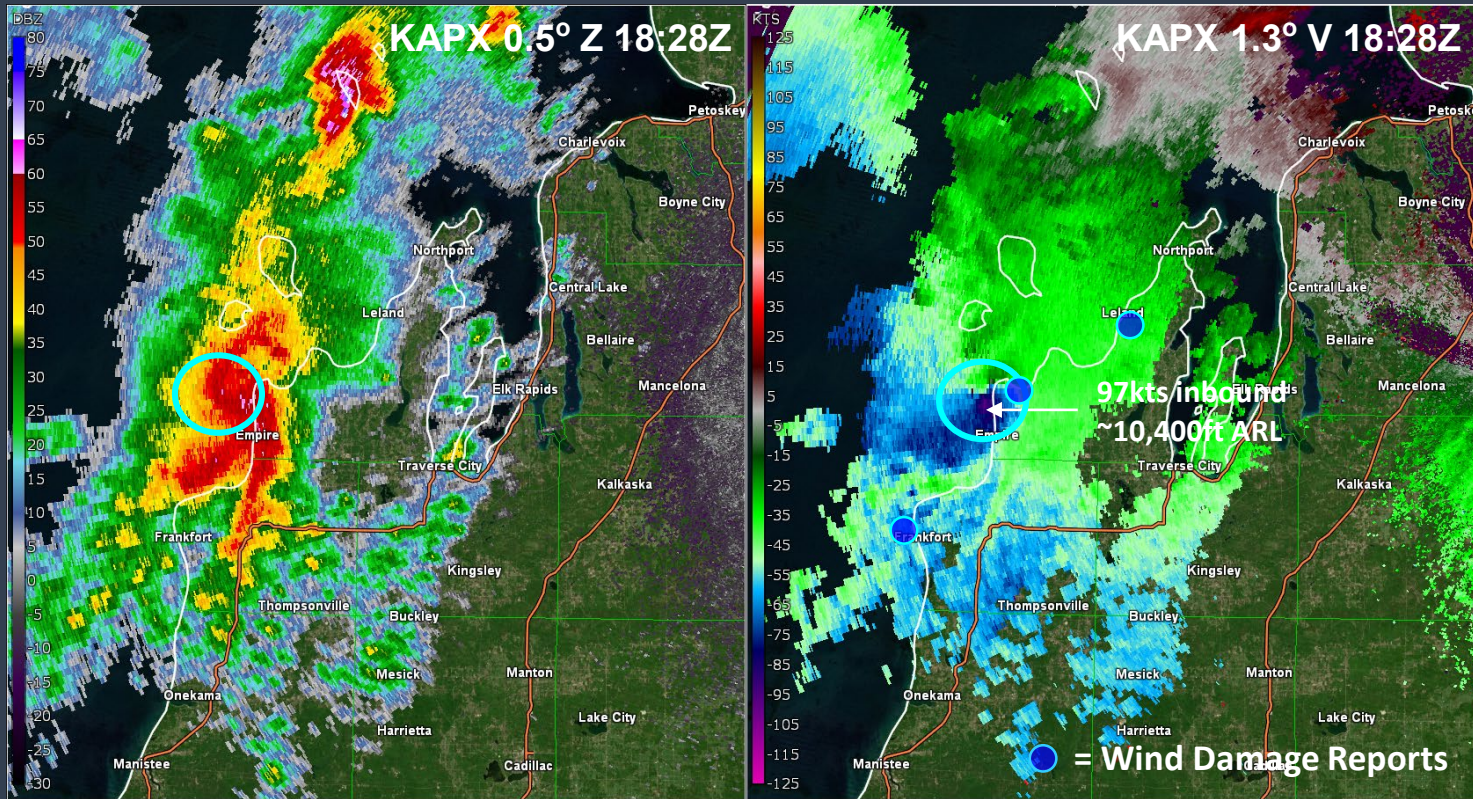


As the storm reached the western Lower Michigan shoreline there were two circulations of note:

- A bookend vortex developed along the northern flank of the line segment (cyan circle).
- Mid level mesocyclone associated with an updraft pulse on the southern flank of the line segment (yellow circle).

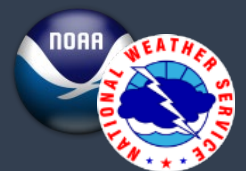


# Storm Evolution: Bookend Vortex Development

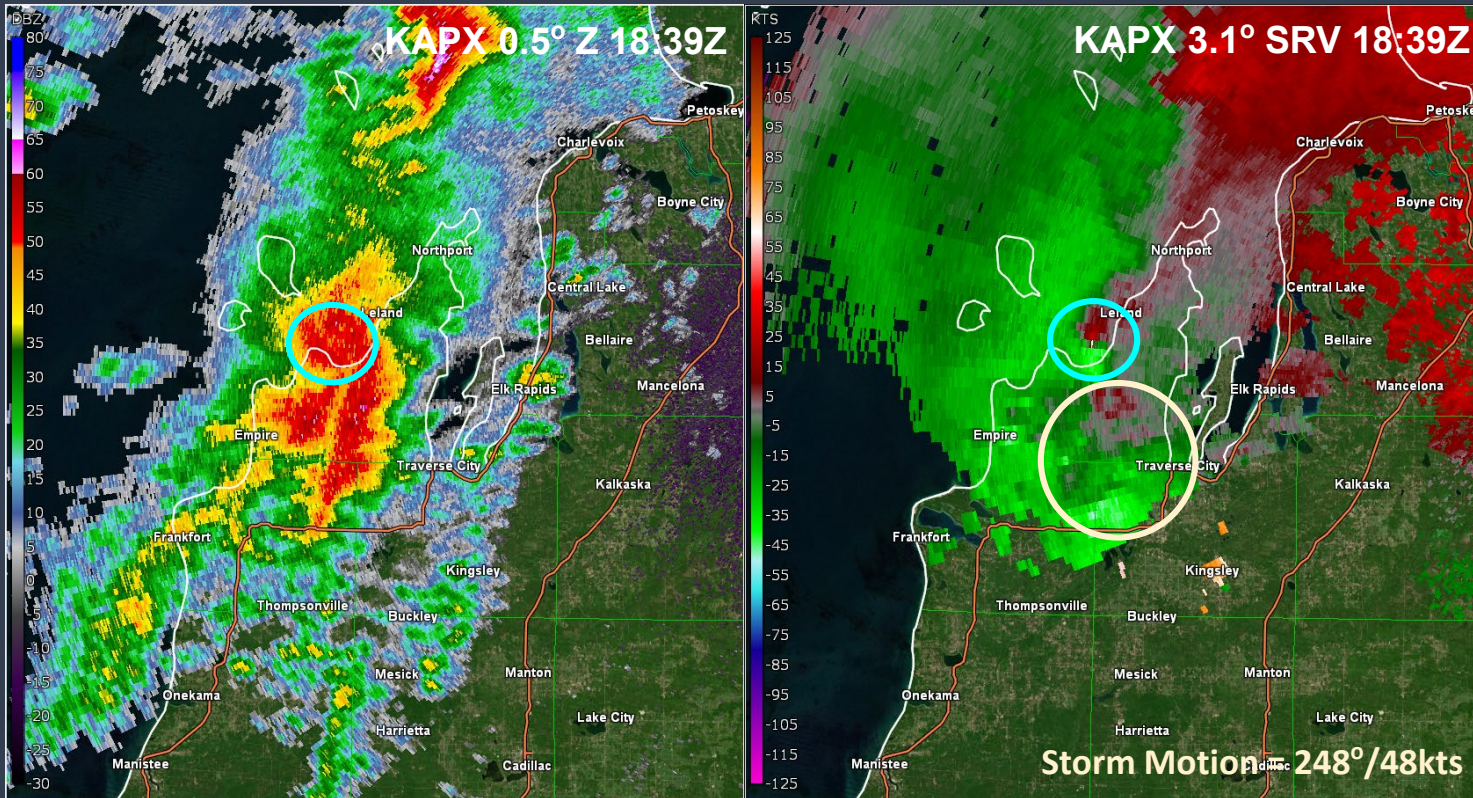


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Development of the bookend vortex “goosed” the rear inflow jet and contributed to damaging wind gusts in Glen Arbor and Leland in Leelanau county. In addition a 66kt wind gust was measured at Frankfort Light in Benzie county (southernmost blue dot in right image).

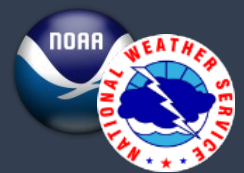


# Storm Evolution: Bookend Vortex Evolution

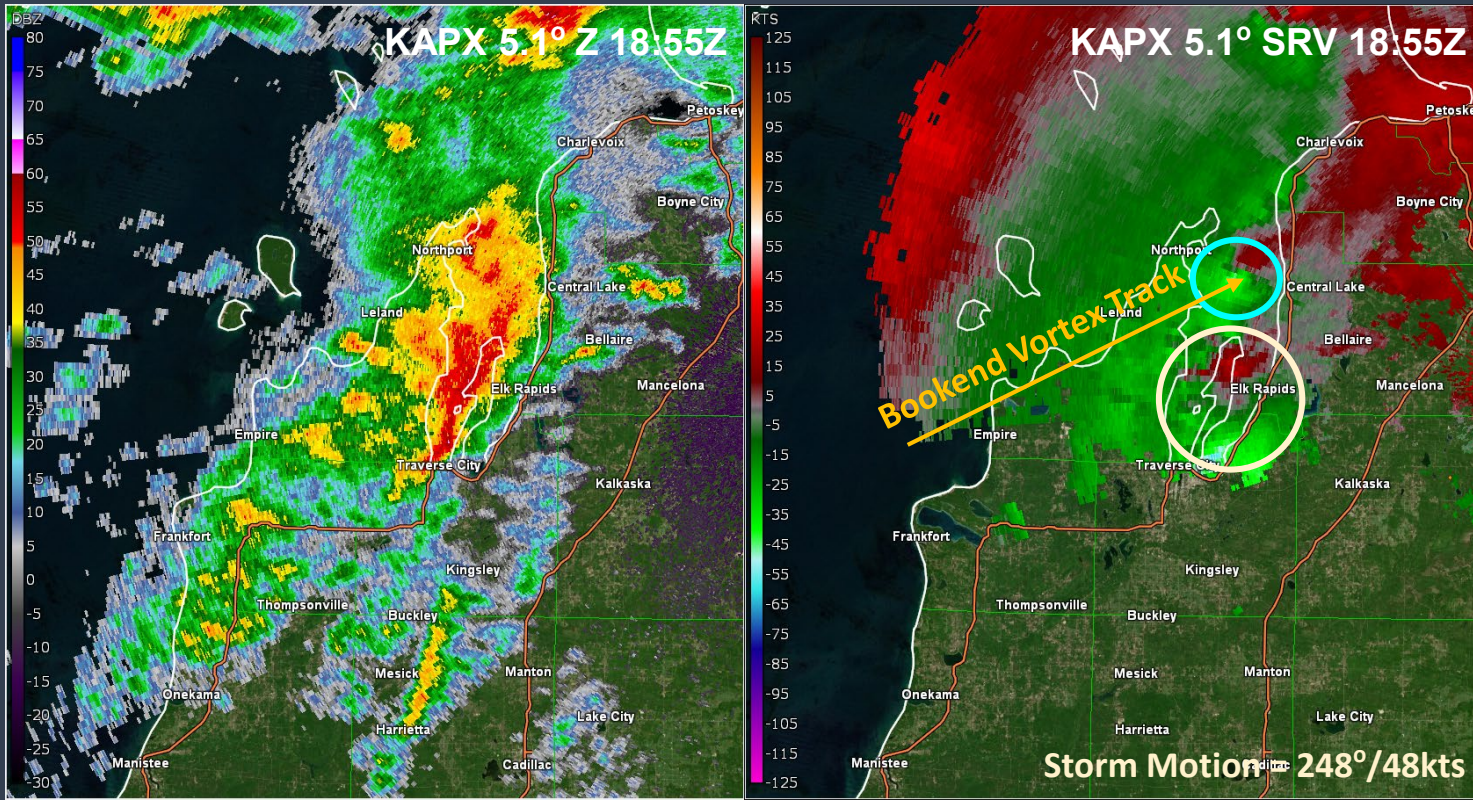


Eleven minutes later the bookend vortex continues to track northeast toward northern Leelanau county (cyan circle). The original rotation in the southern flank of this segment has temporarily weakened and broadened (yellow circle).

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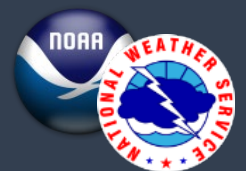


# Storm Evolution: Bookend Vortex Evolution

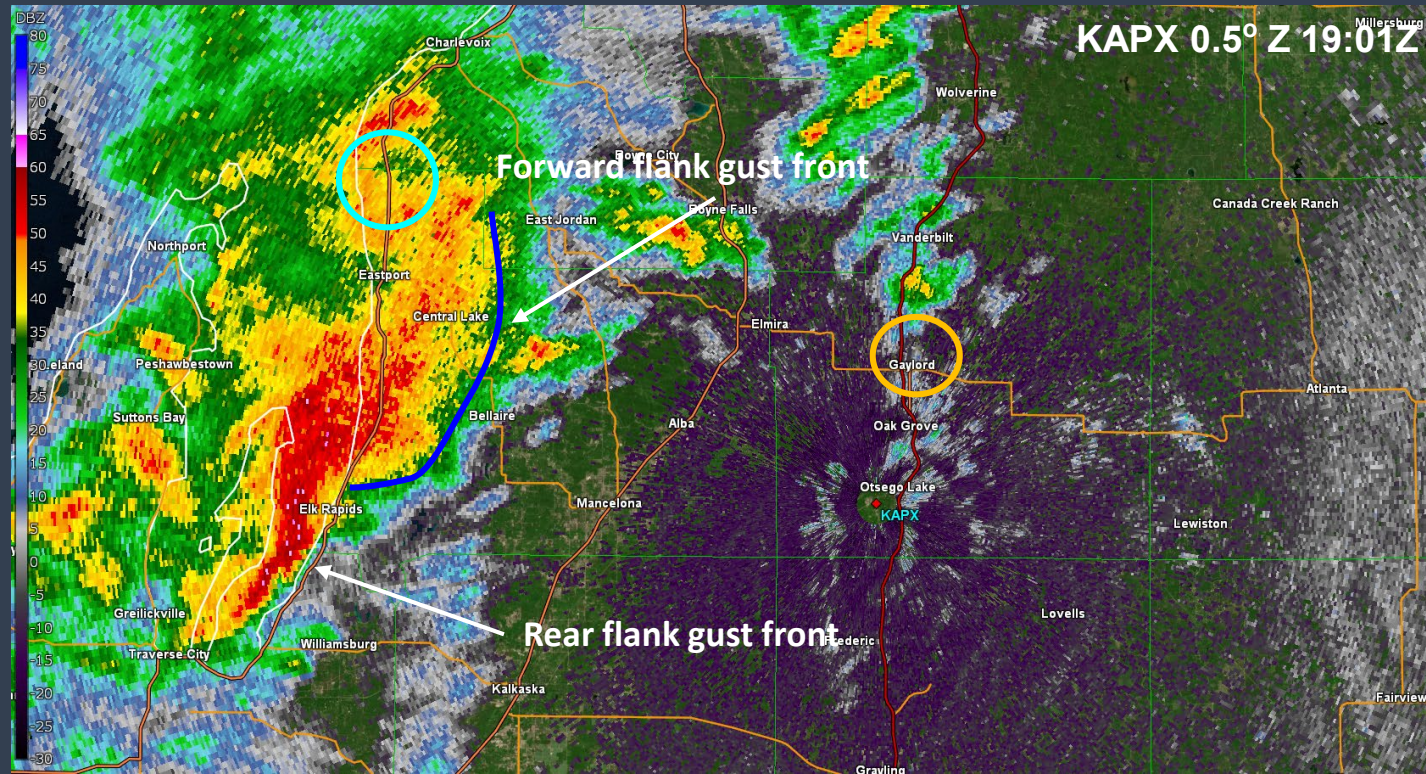


1700z
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Sixteen minutes further along and the bookend vortex is crossing northern Grand Traverse Bay. The southern circulation is still broad but is becoming better defined (stronger inbound and outbound velocities).



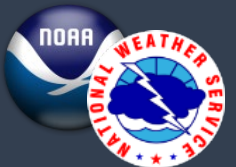
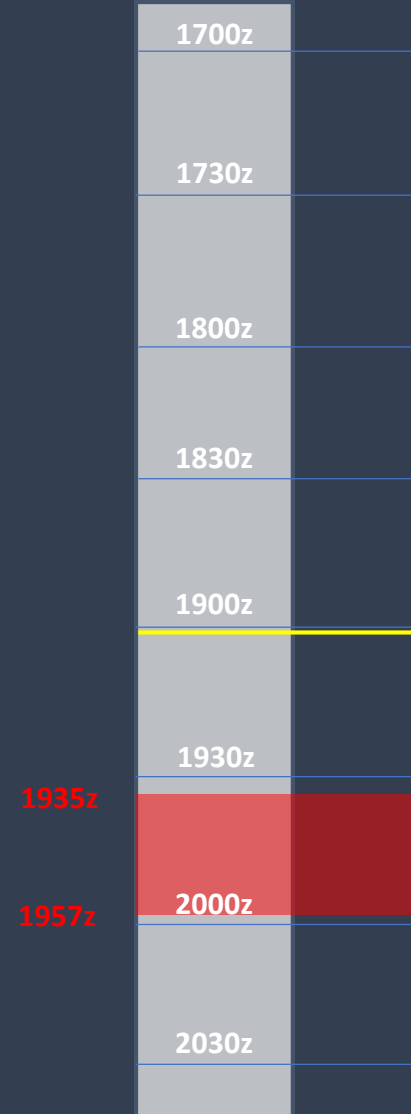
# Storm Evolution: Transition to Supercell



A storm scale source of low level horizontal vorticity...combined with 0-3km MLCAPE and substantial low level shear allowed for strengthening and lowering of the mesocyclone and set the stage for tornadogenesis.

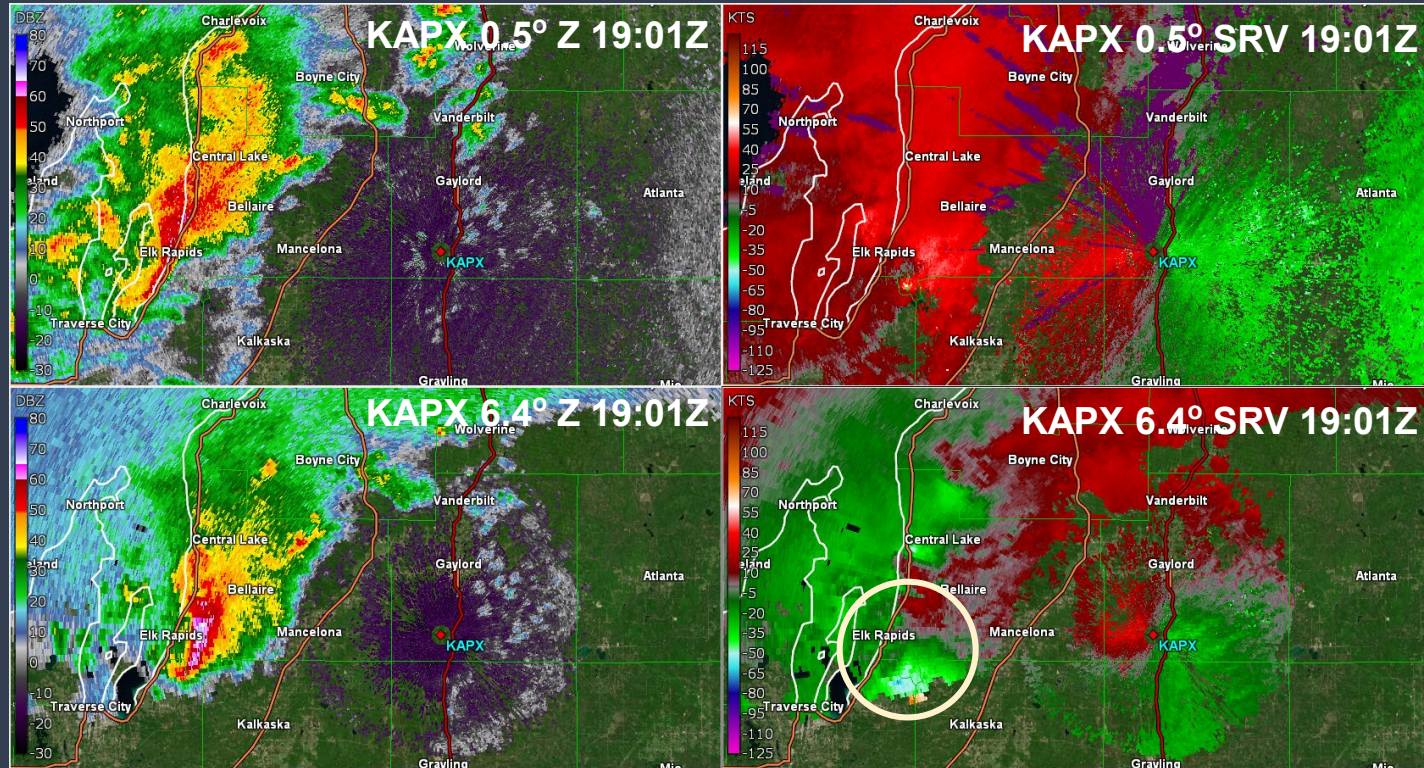
The bookend vortex begins to outpace the southern portion of the line segment.

This in turn pushed the precipitation shield from the northern half of the line segment ahead of the bookend vortex and laid out an outflow boundary (blue line) that extended back to the west and intersected the mid portion of the convective line.





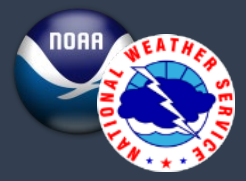
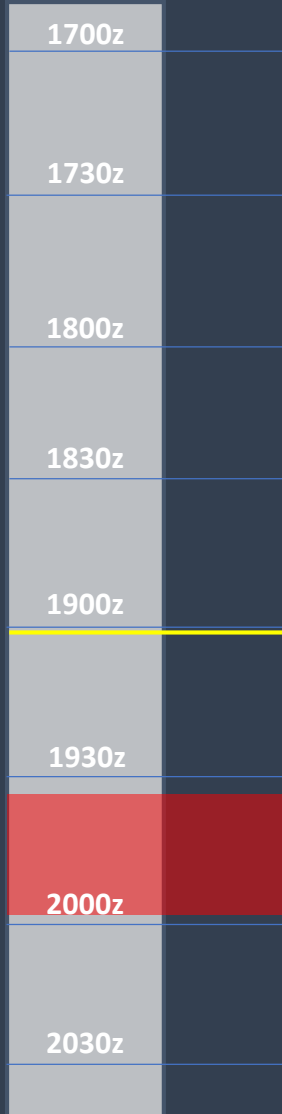
# Supercell Evolution:



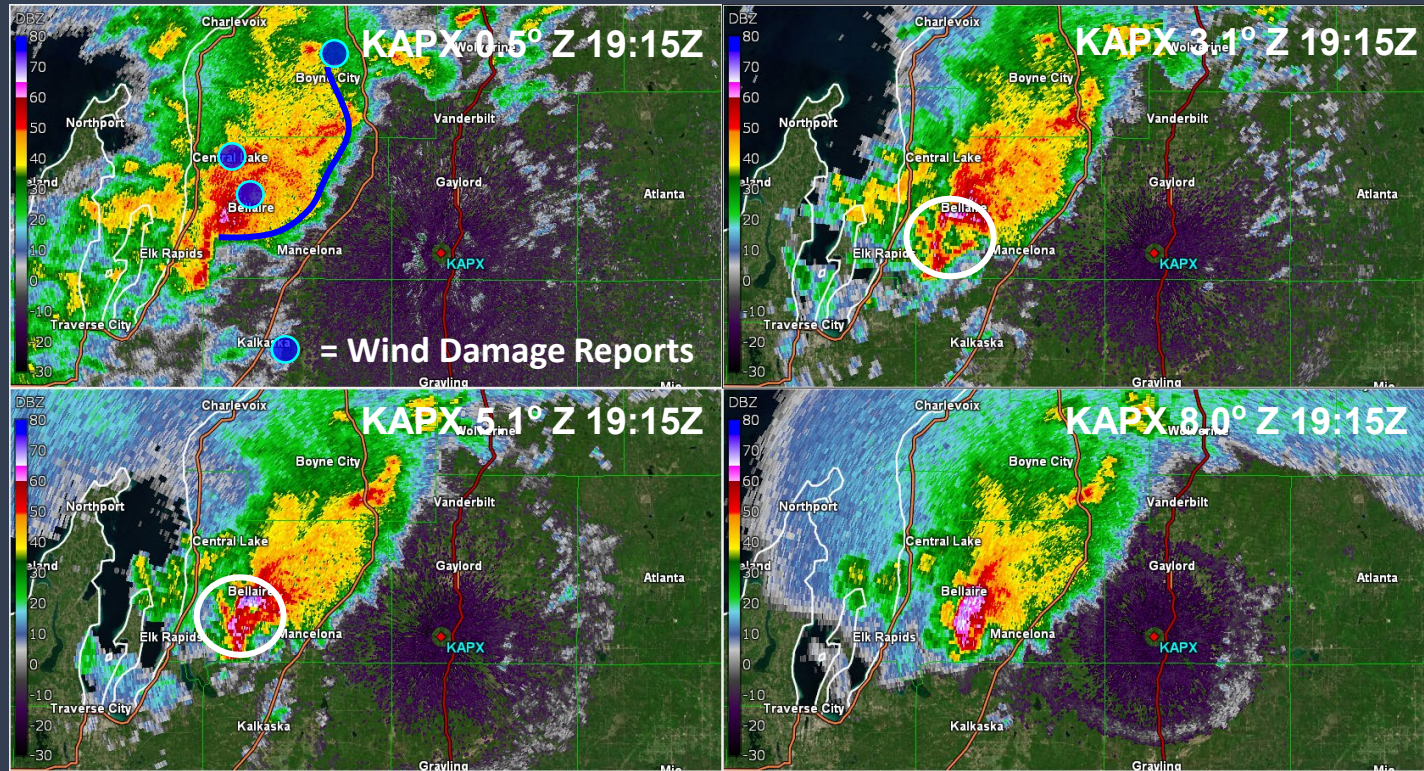
Max Rotational Velocity: 45kts  
 Diameter: 9nm  
 Elevation Angle/Height (ARL): 6.4°/18,000ft

From the same volume scan...rotation aloft continues to strengthen once again though was still broad (9nm between  $V_{max}$  and  $V_{min}$ ).

This is 34 minutes prior to tornado touchdown.



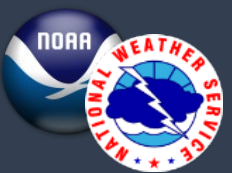
# Supercell Evolution: Bounded Weak Echo Region



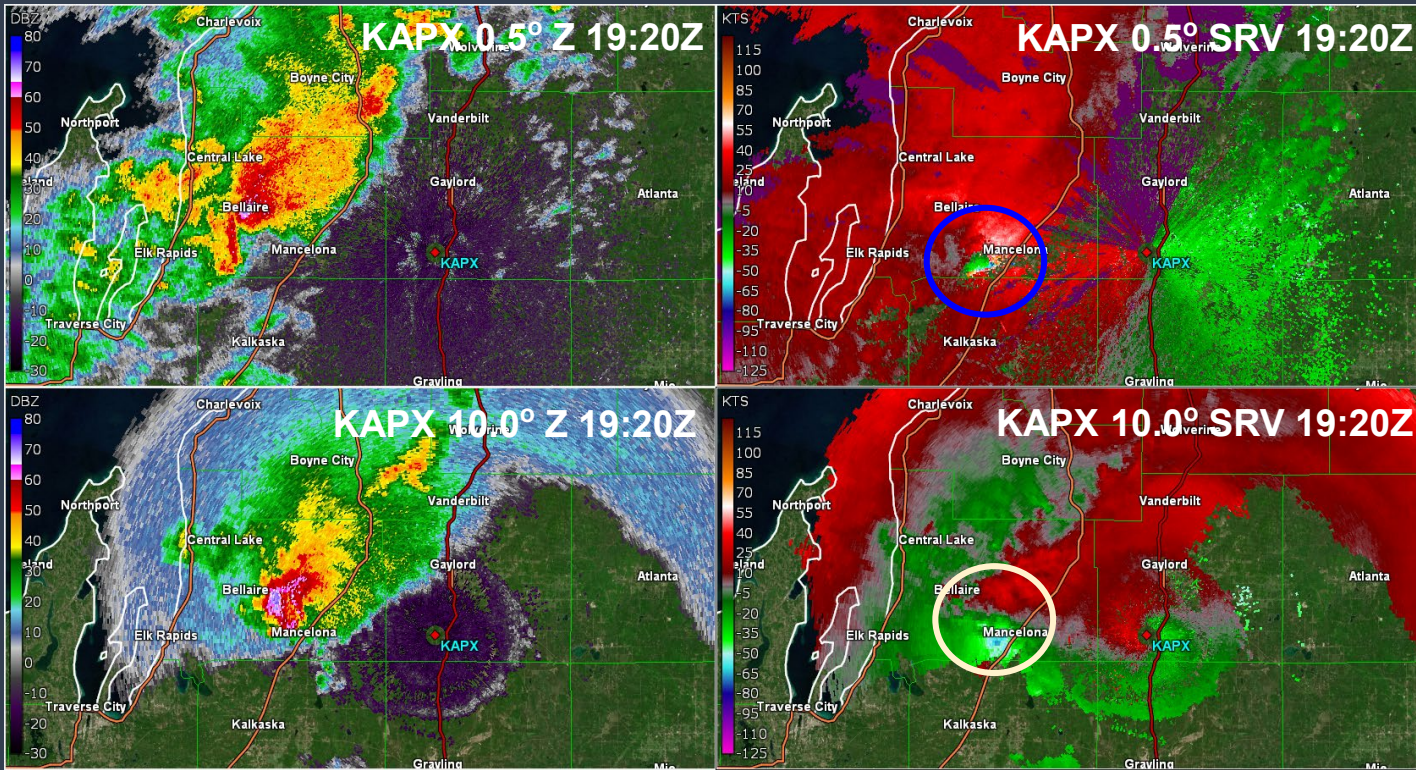
The impacts of the mesocyclone on updraft strength becomes more evident with the development of a BWER after 19:10Z (white circles).

The storm continued to produce wind damage from Central Lake to Bellaire (blue dots top left image).

1700z
1730z
1800z
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1935z
2000z
2030z



# Supercell Evolution:

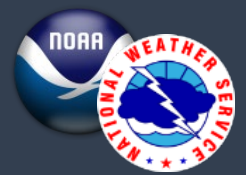


Rotation continues to increase and tighten up aloft (bottom right).

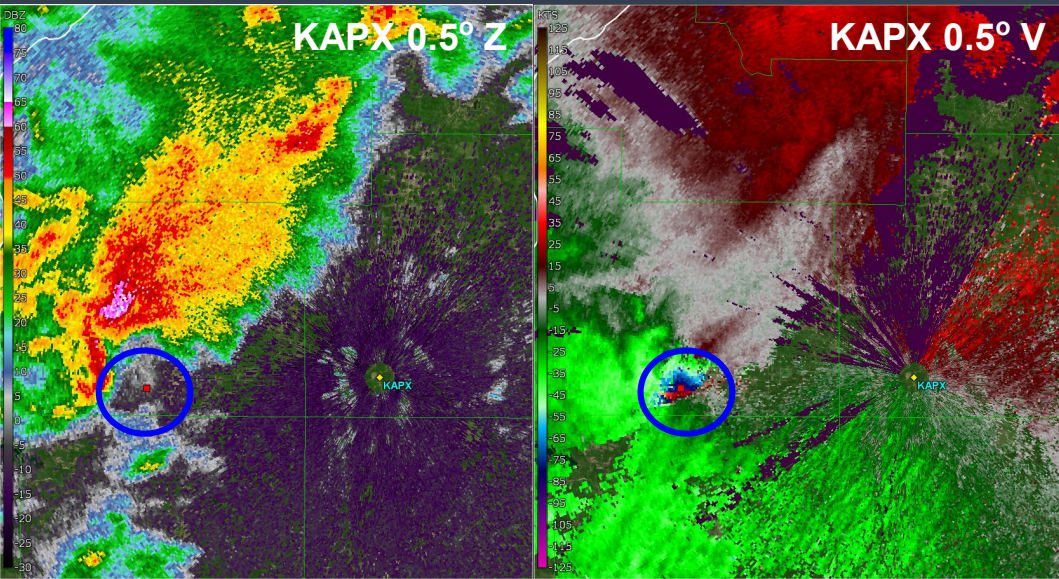
But we also begin to see the effects of vertical sidelobe contamination in the lowest elevation angle (blue circle top right)...

Max Rotational Velocity: 51kts  
 Diameter: 5nm  
 Elevation Angle/Height (ARL): 10.0°/17,500ft

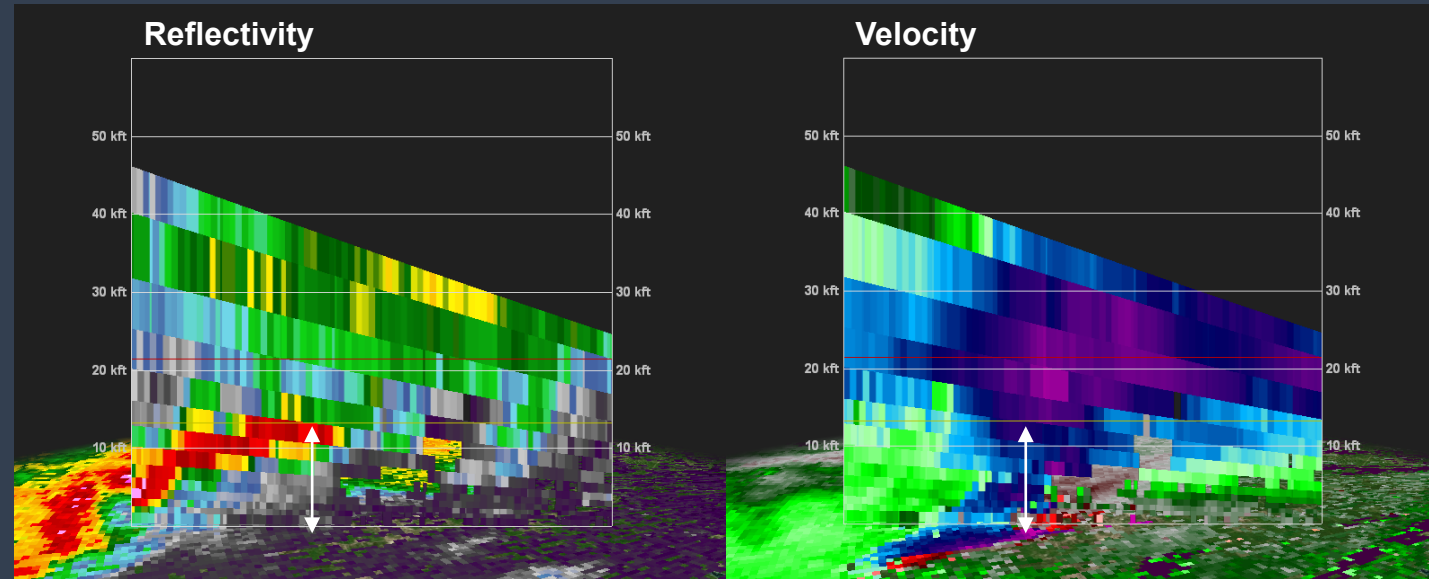
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# Supercell Evolution: Vertical Sidelobe Contamination



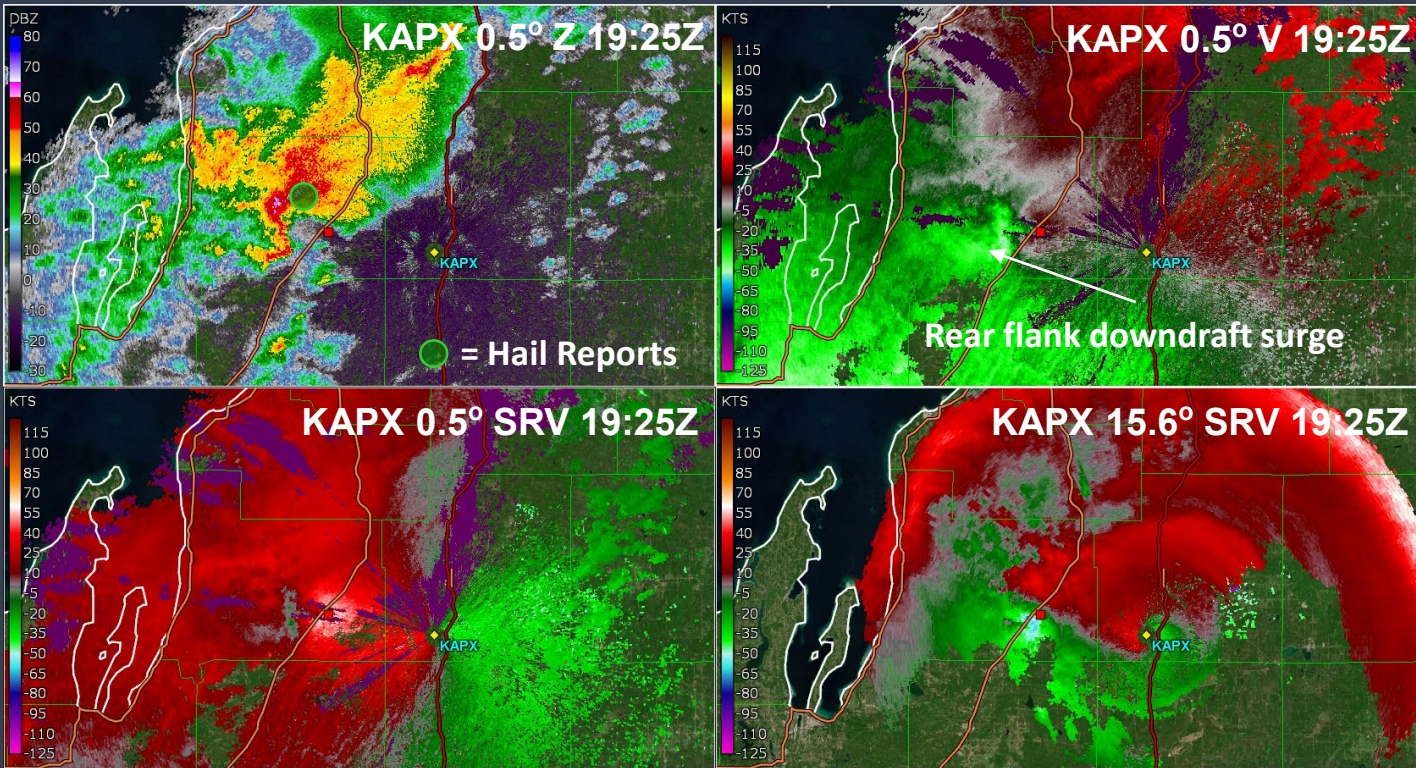
Strong inbound velocities (89kts) located in an area with minimal radar returns (blue circle).



Velocities associated with echo overhang being projected into the lower elevation angles.

Vertical sidelobe contamination was evident for about 25 minutes (11 0.5° elevation scans).

# Supercell Evolution:

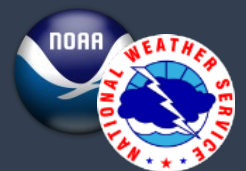
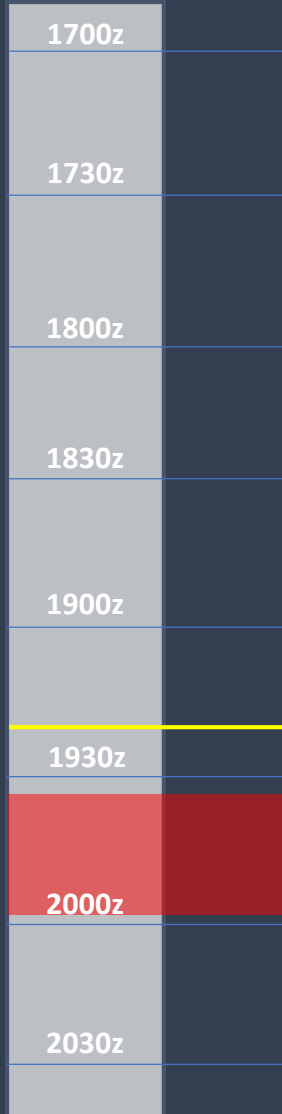


Max Rotational Velocity: 59kts  
 Diameter: 3.9nm  
 Elevation Angle/Height (ARL): 15.6°/23,100ft

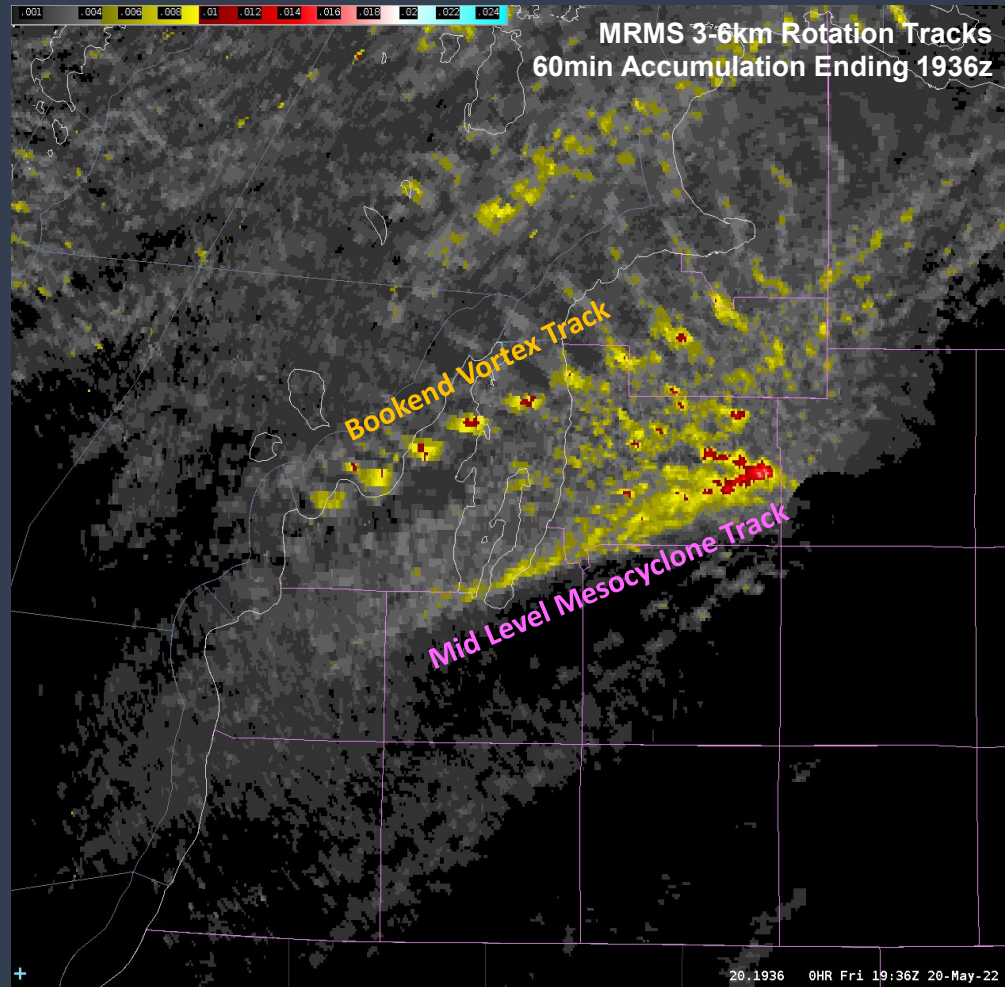
Vertical sidelobe contamination was gone by 19:25Z in time to reveal a rear flank downdraft surge (54kts inbound velocity at 1000ft ARL).

Rotation aloft continued to strengthen and contract (bottom right panel). Convergence signal but no rotation yet at the lowest elevation angle (0.5° bottom left).

First reports of hail (1 inch diameter) occurred at this time.



# Supercell Evolution: Mid Level Mesocyclone Track



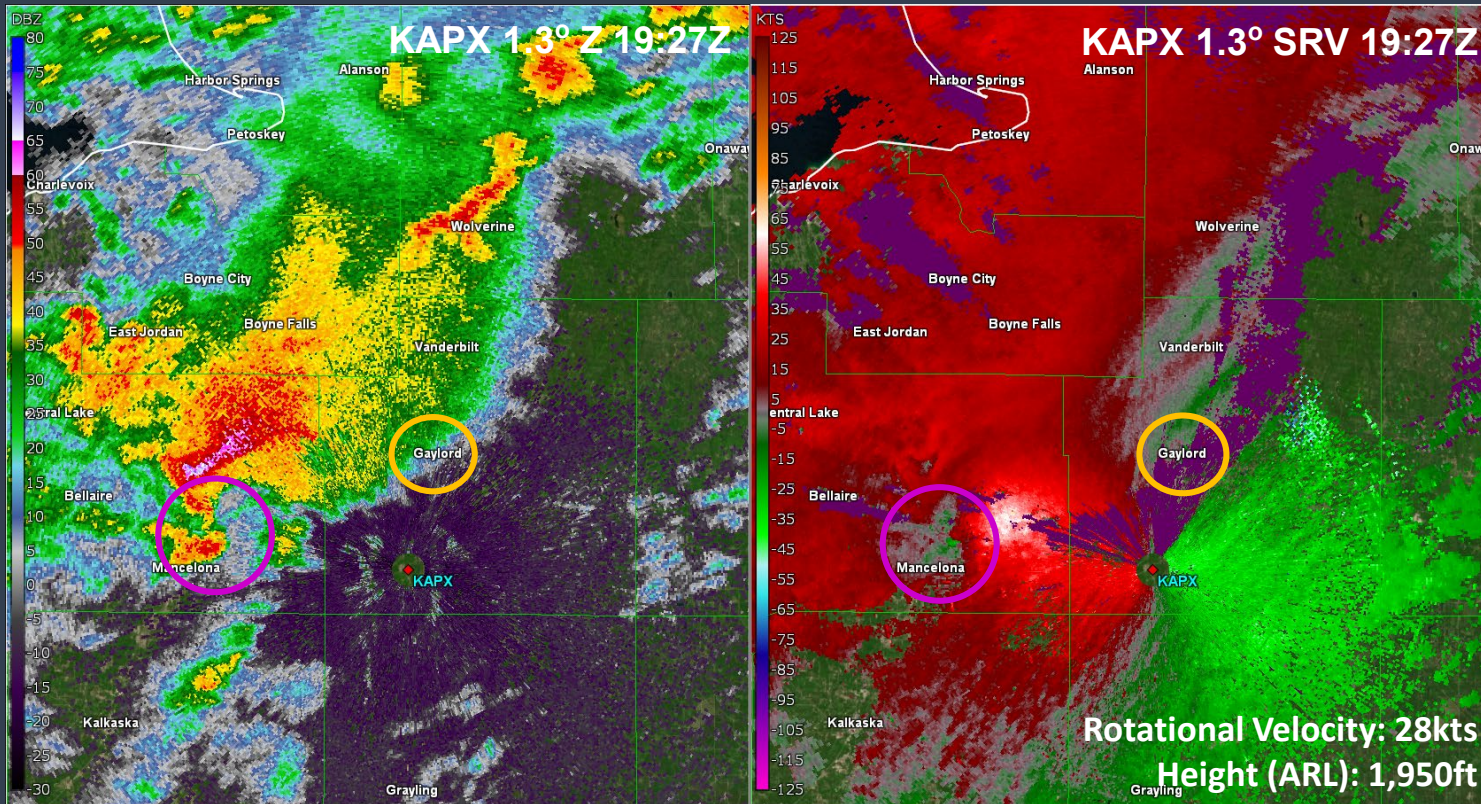
We can use the accumulated Mid Level (3-6km) Rotation Tracks product from the Multi-Radar/Multi-Sensor (MRMS) system to illustrate the development of the mid level mesocyclone.

**Track of the bookend vortex:** To the north coming across the tip of the Leelanau Peninsula and Grand Traverse Bay and into Charlevoix/Emmet/Cheboygan counties.

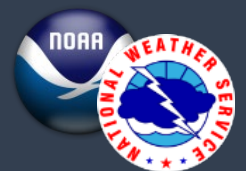
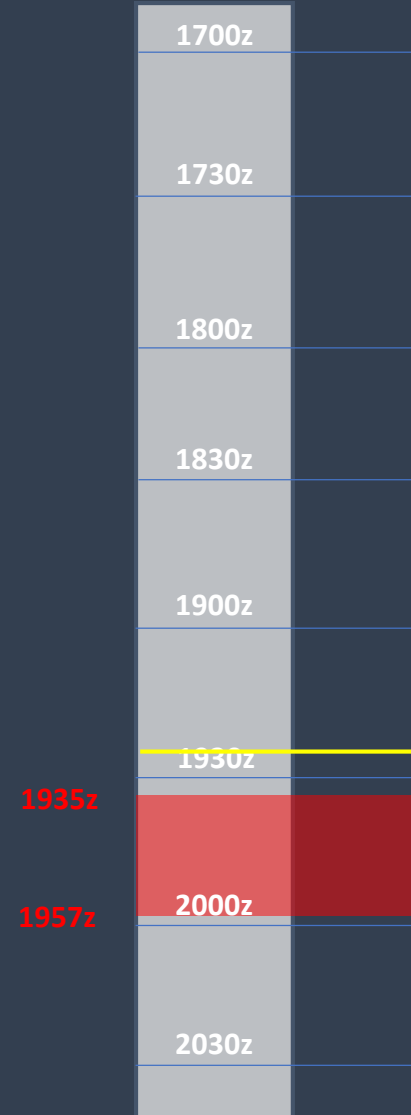
**Track of the mesocyclone:** To the south starting as increasing rotation across the southern end of Grand Traverse Bay. Rotation strengthens with time...with the increase in rotation at the end of the mesocyclone track (red shading) being coincident with tornadogenesis.

# Tornado Evolution

# Tornado Evolution: 3:27pm

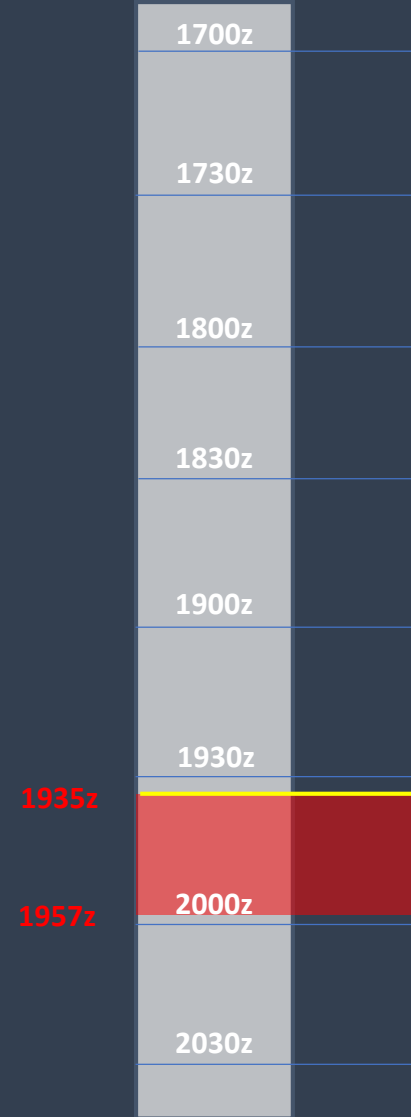
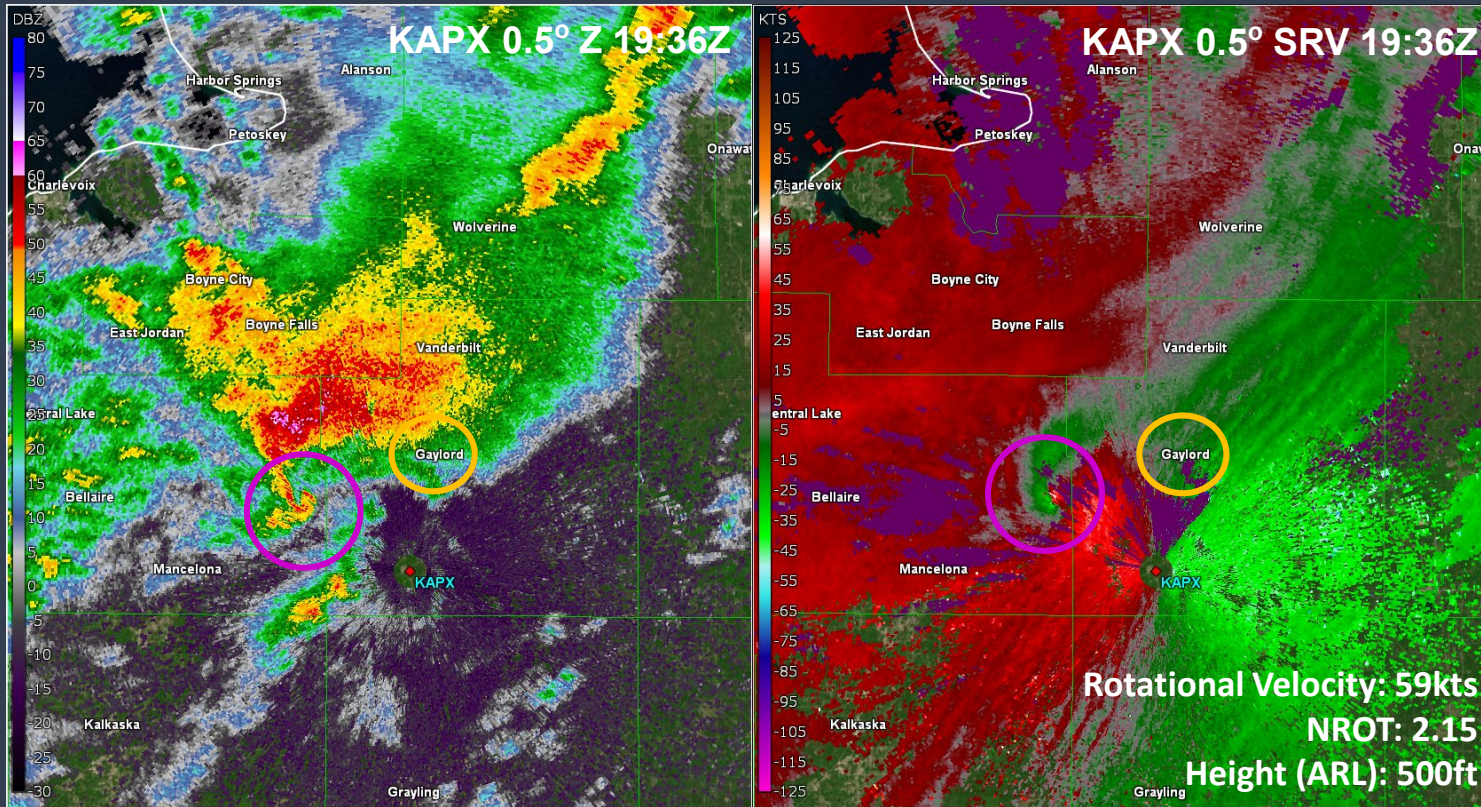


About 8 minutes prior to tornado touchdown. Rotation now below 2,000ft ARL...

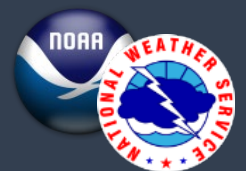




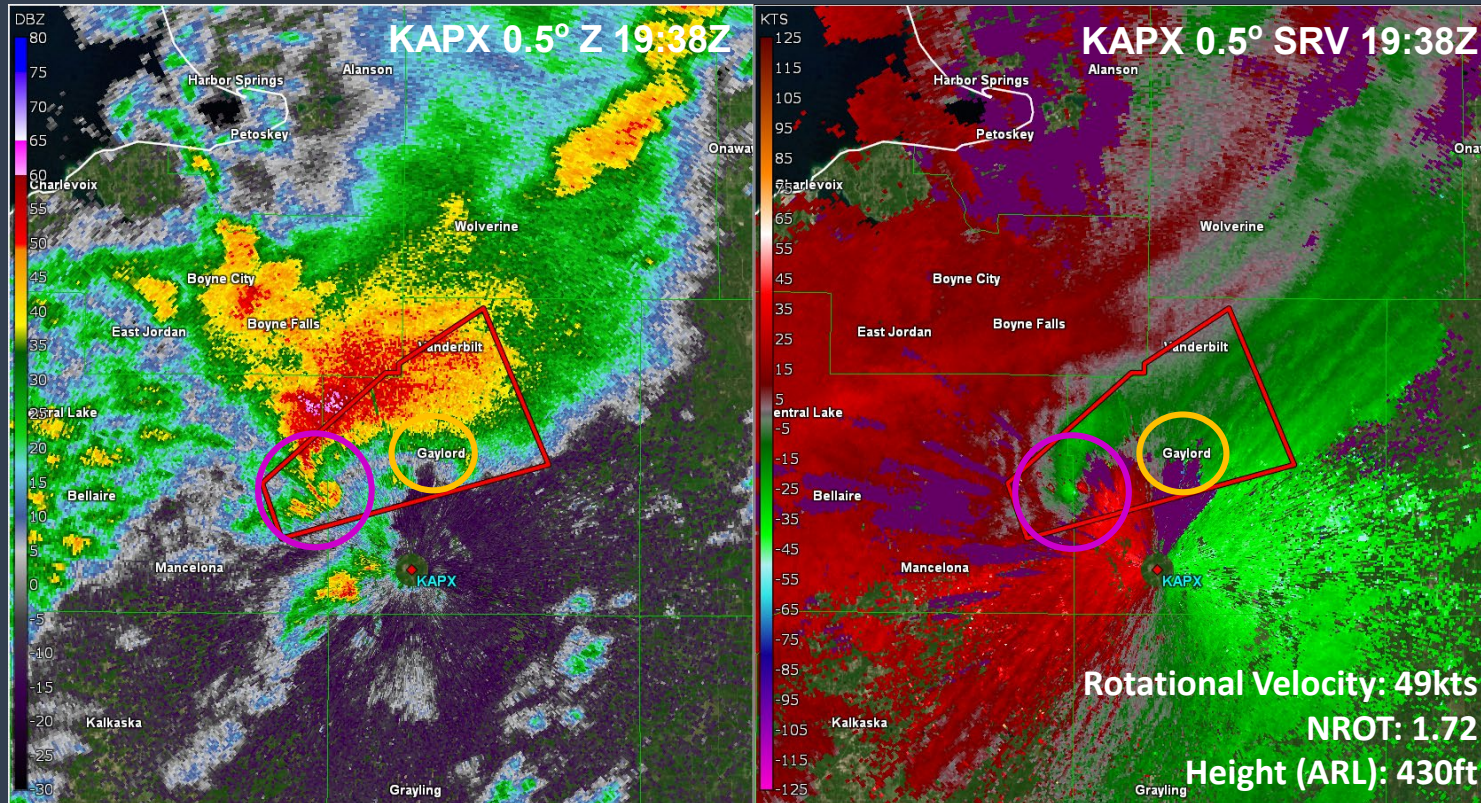
# Tornado Evolution: Initial Touchdown 3:35pm



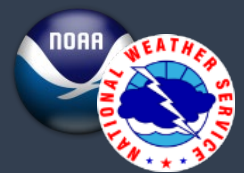
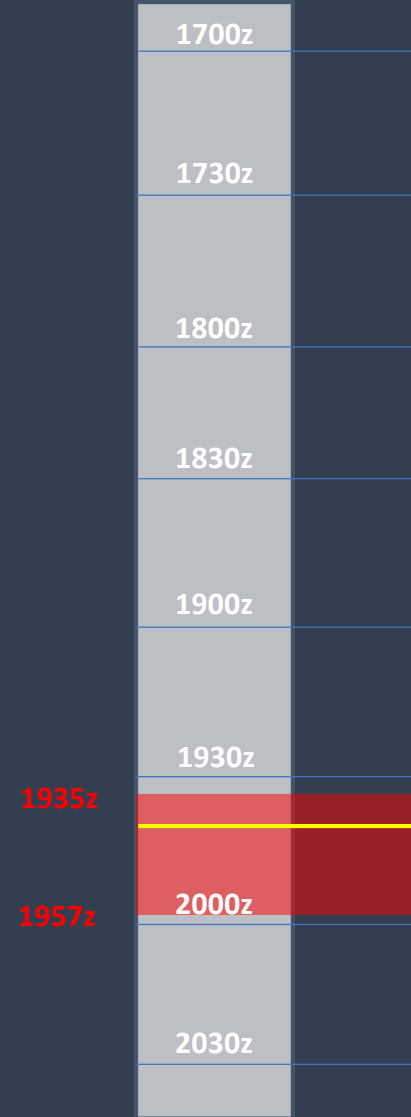
The initial tornado touchdown occurred around this time (3:35pm) about 4.5 miles east of the small town of Alba in southeast Antrim county. Well-defined “fish hook” at the end of the appendage as rotation ramps up in the lowest elevation slice (500ft ARL/ $V_{ROT} = 59\text{kts}$ ). The tornado was about 10 miles southwest of Gaylord at this point.



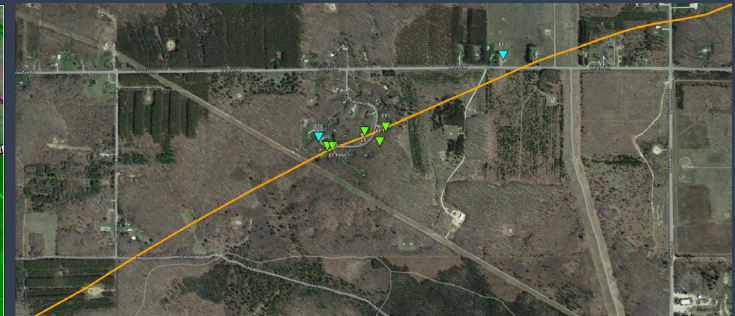
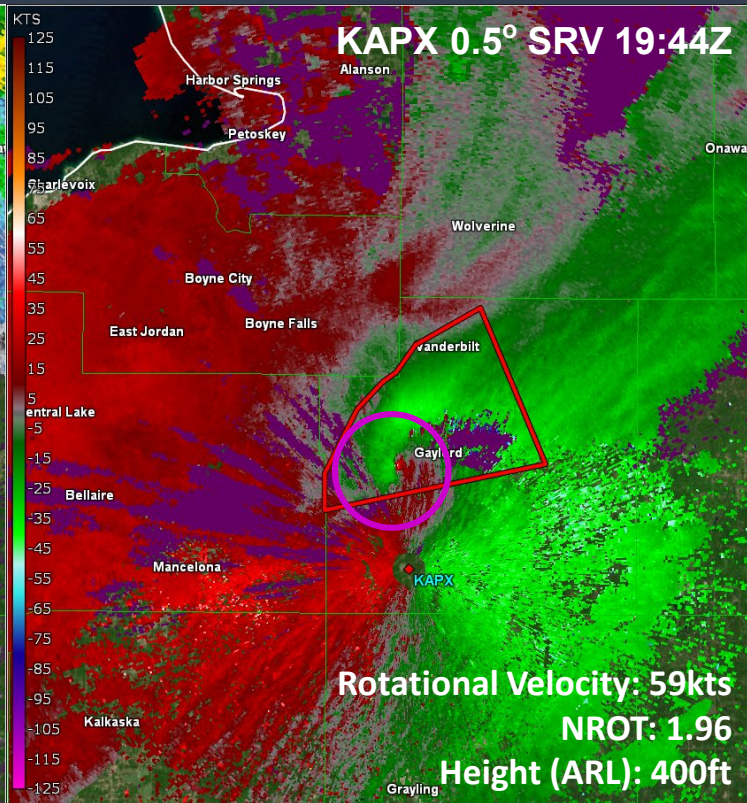
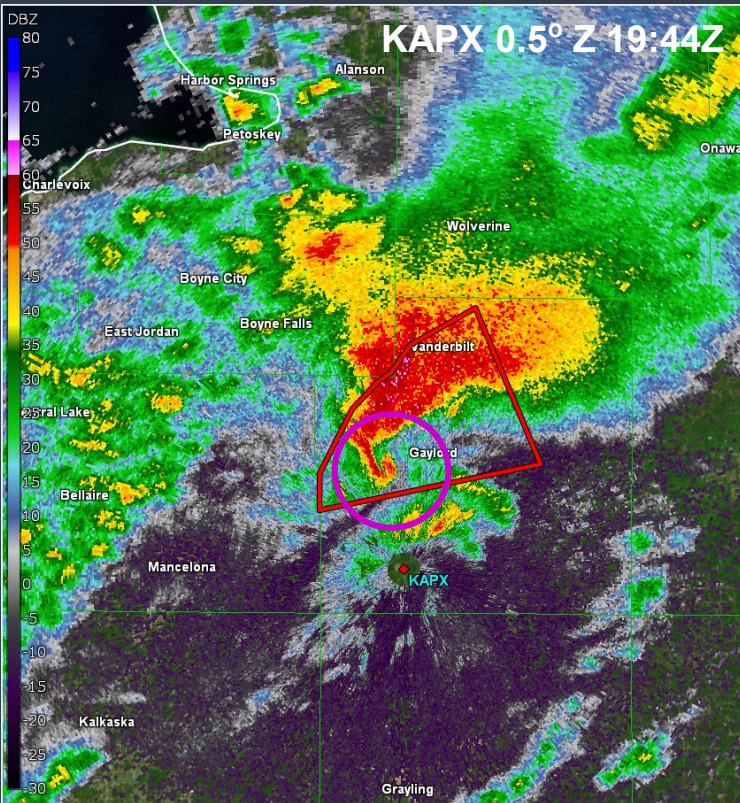
# Tornado: Tornado Warning 3:38pm



Tornado Warning was issued at 3:38pm. Tornado was located less than 8 miles southwest of Gaylord...moving through mostly rural areas at this point.

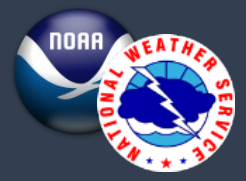


# Tornado: 3:44pm

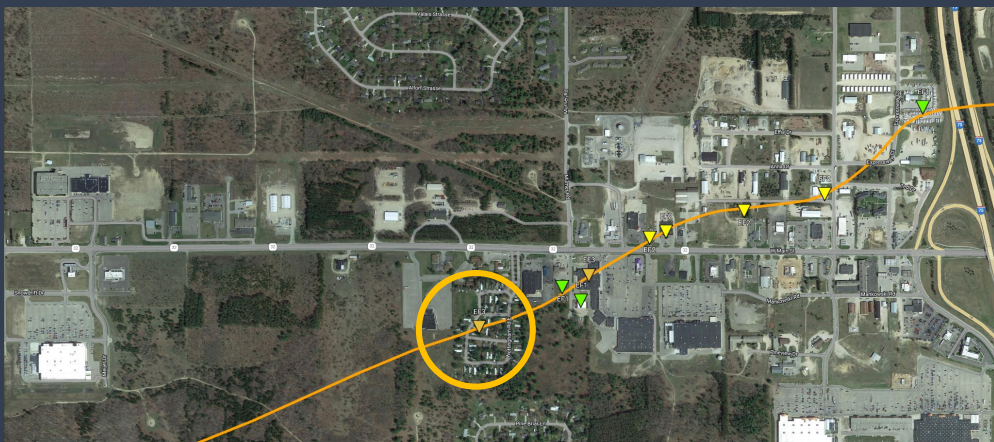
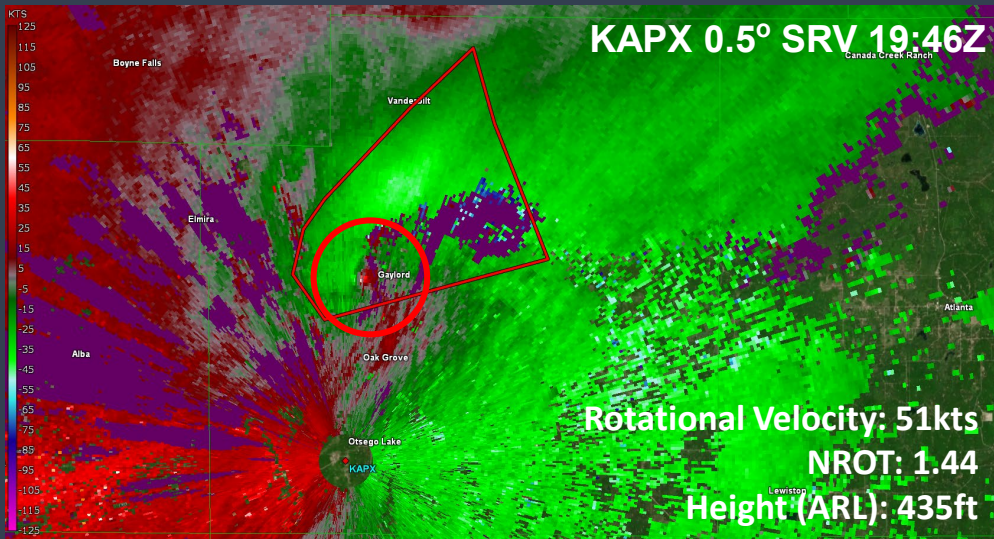


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After causing some sporadic EF0-EF1 damage...tornado reaches the Shady Brook Ln neighborhood about 1 mile west of the Gaylord Regional Airport. Six homes impacted here with EF-1 damage.



# Tornado: 3:46pm – Gaylord Western City Limits



The first visual report of the tornado came into our office at 3:46pm when the storm reached the western city limits of Gaylord.

At this time the tornado was moving through the Nottingham Forest mobile home park (gold circle bottom image). This was the first area where damage rated at EF-3 was observed...and also where the two fatalities from this event occurred.

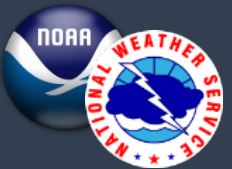
Over the next minute after leaving the mobile home park...the tornado will:

- Slam into the back of a strip mall (more damage rated at EF-3).
- Cross M-32 (main east-west thoroughfare through Gaylord) and hit a Quick Lube Oil Change/Goodwill store/Little Caesars Pizza.
- Pass behind another strip mall and damage more businesses including piling up 100 RVs at Northern Michigan RV (and tossing one a couple hundred yards to the other side of I-75).

1935z

1957z

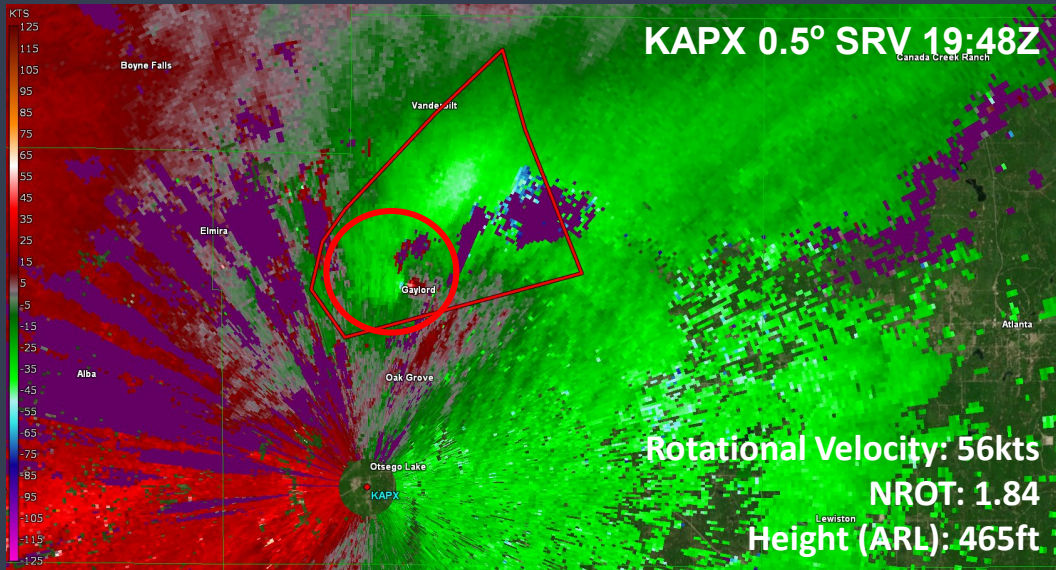
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# Tornado: 3:47pm

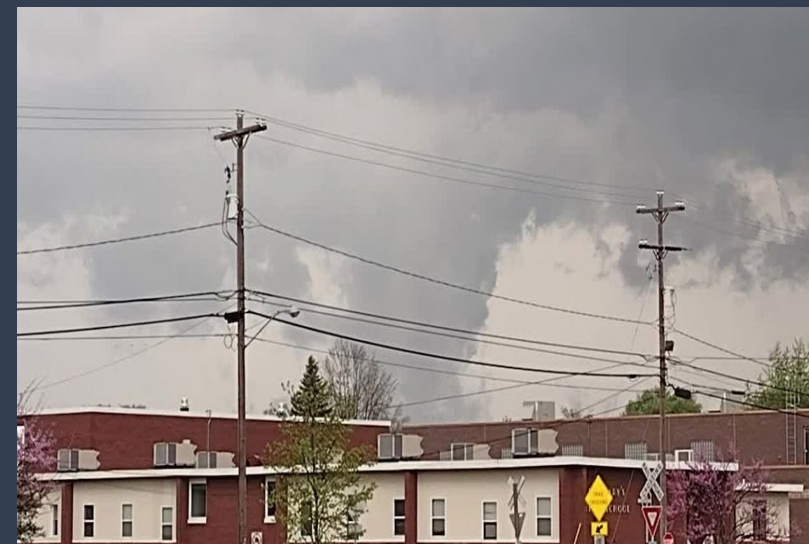


# Tornado: 3:48pm

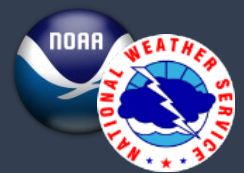


Tornado crosses I-75 north of the exit 282 interchange:

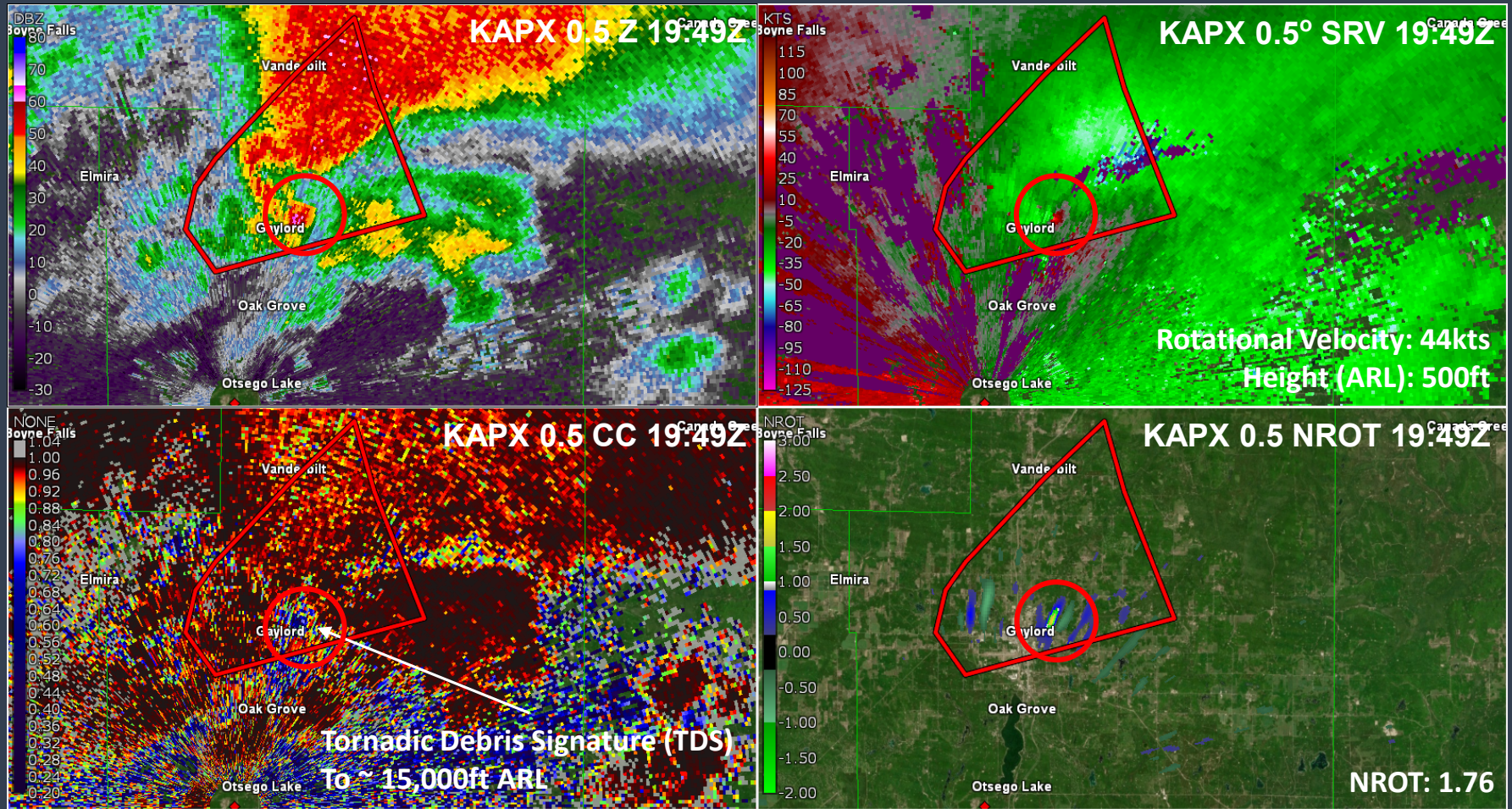
- Tracks between St. Mary Cathedral Church and St. Mary School.
- Crosses Old 27 north of downtown and misses the hospital by one-tenth of a mile.
- EF-3 damage to four homes in the Summerfield Village neighborhood.
- Damages two homes along the Otsego Club Classic golf course.



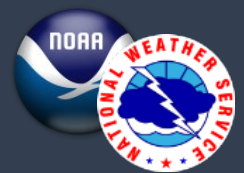
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1957z
2000z
2030z



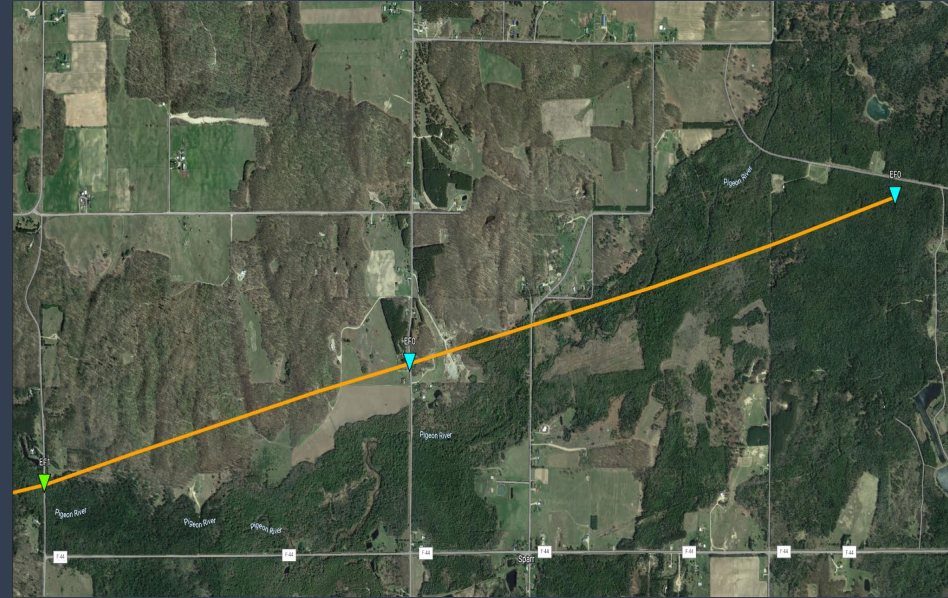
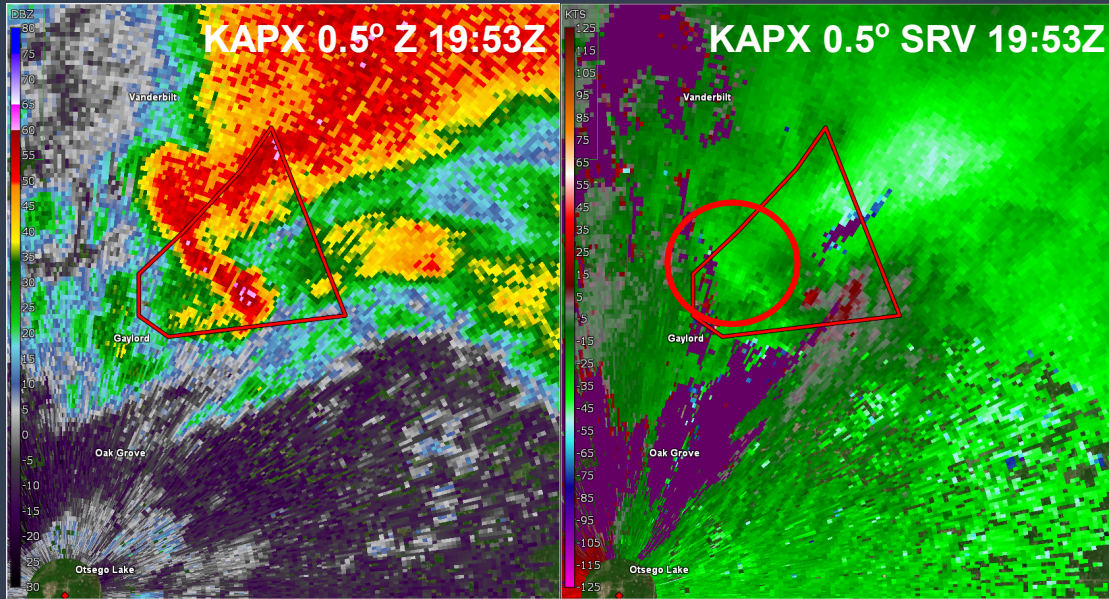
# Tornado: 3:49pm



1700z
1730z
1800z
1830z
1900z
1930z
1935z
1957z
2000z
2030z



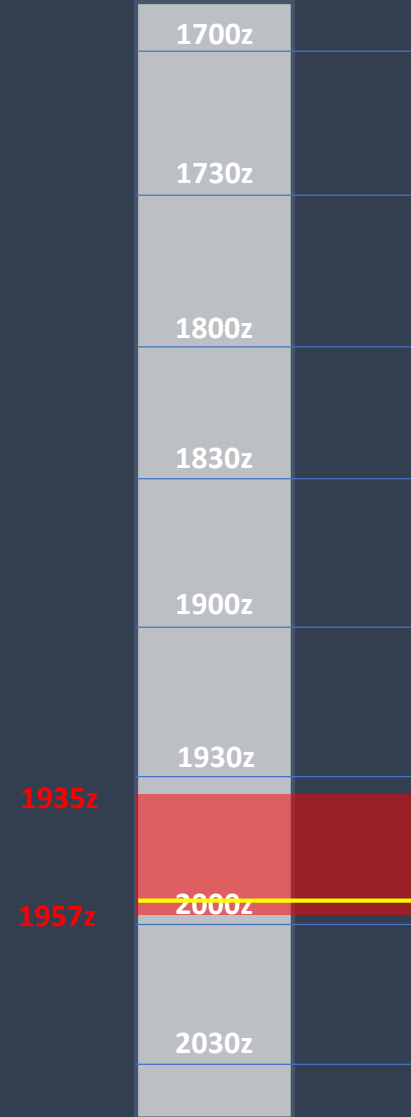
# Tornado: 3:53pm



Moving at 55mph the tornado went through Gaylord in about 3 minutes.

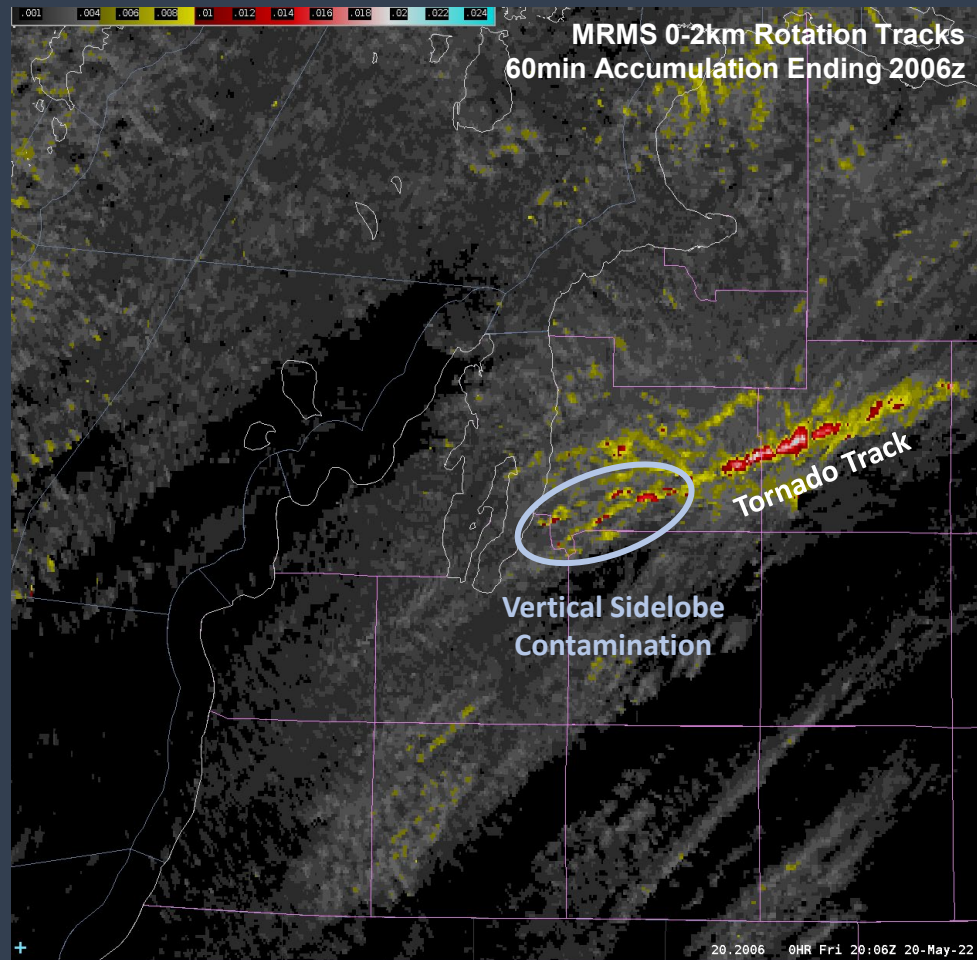
Damage become more sporadic as the tornado moved through more rural areas to the northeast of Gaylord. However several more homes lay in the path of the tornado and sustained damage.

The tornado dissipated around 3:57pm prior to reaching the Pigeon River Country State Forest.





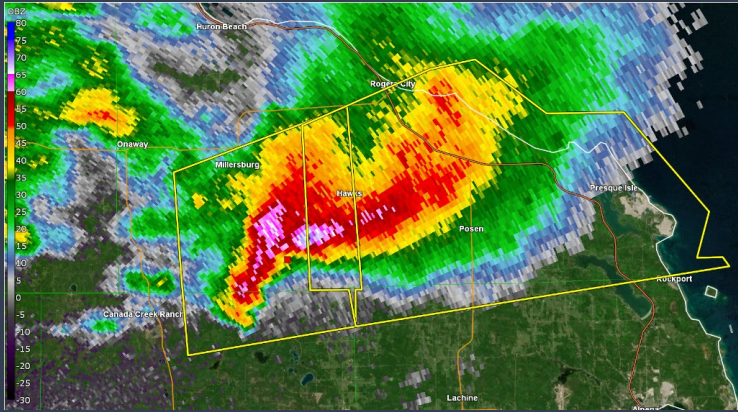
# Tornado Evolution: Low Level Rotation Track



Tornado track illustrated via the use of MRMS Low Level (0-2km) Rotation Tracks (60 minute accumulation ending 2006z).

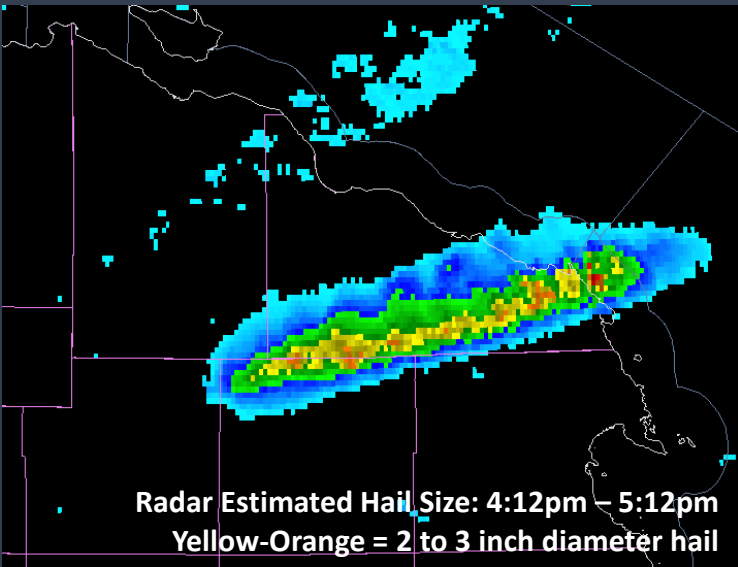
The first part of the track suffered from vertical sidelobe contamination...but the increase in rotation is dramatic at the point of initial tornado touchdown in far eastern Antrim county. Rotation strength increased as the tornado crossed into Otsego county and remained strong until passing northeast of Gaylord.

# Supercell Evolution:

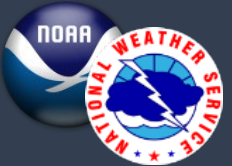
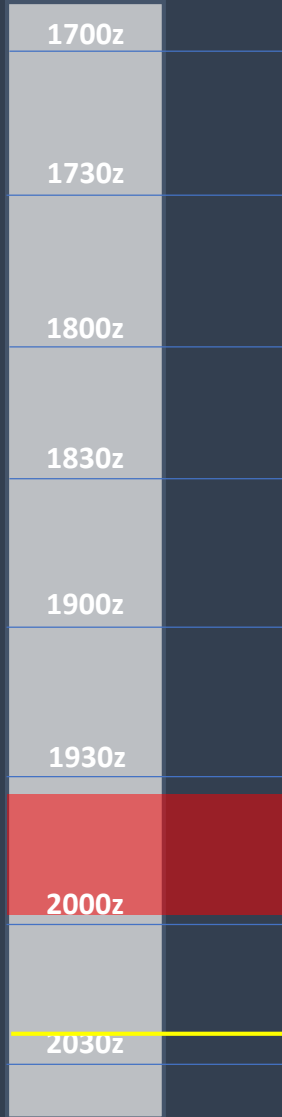


The storm that produced the tornado wasn't finished as it propagated into northeast Lower Michigan:

- 1.50 inch hail (4N Clear Lake SP)
- 2.00 inch hail (Hawks)
- 2.75 inch hail (Posen)
- 3.00 inch hail (Presque Isle)

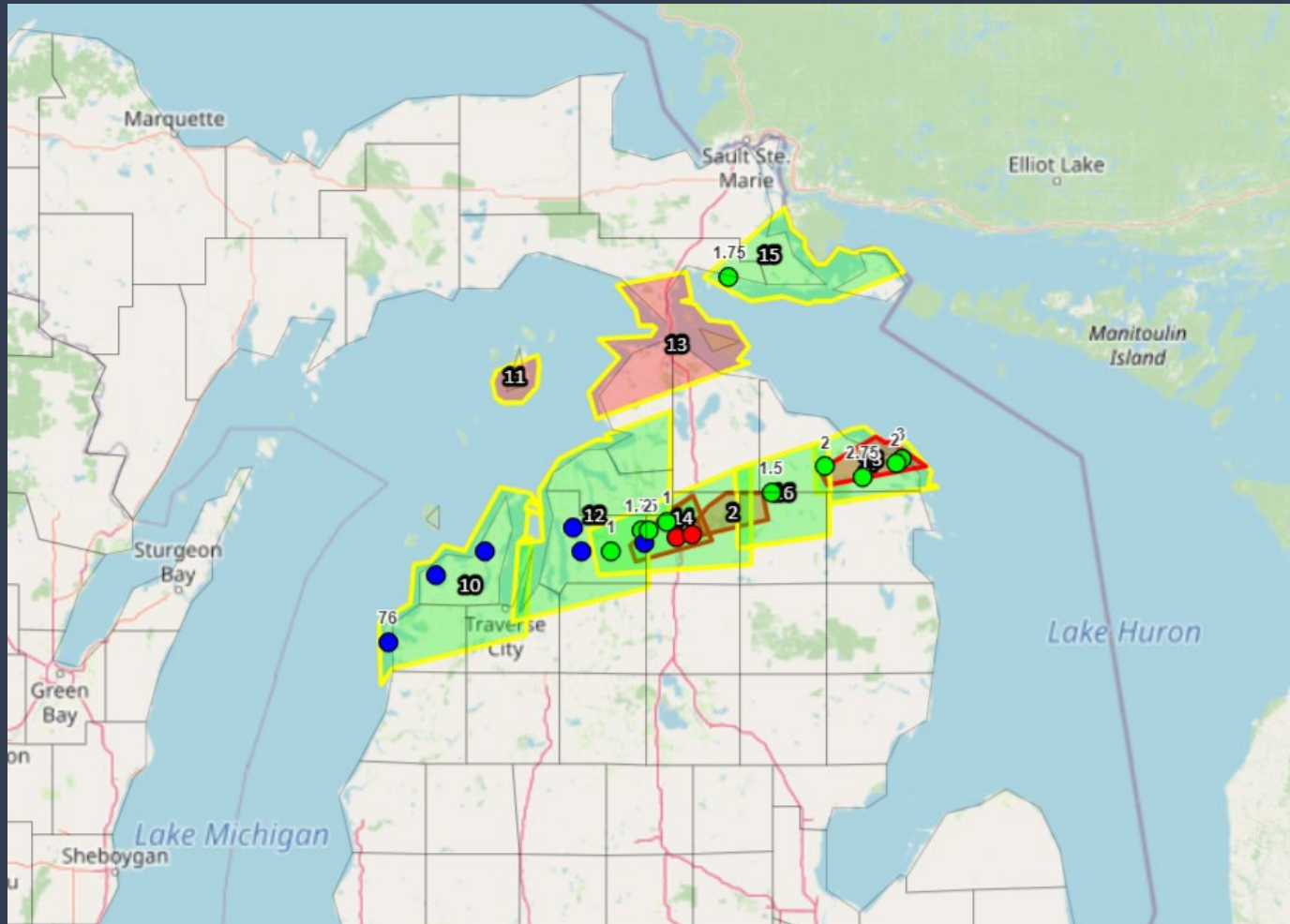


The storm moved into Lake Huron by 5:00pm...dissipating before reaching Manitoulin Island.



Aftermath

# Total Land Based Warning Polygons/Storm Reports



Hail ●

Wind ●

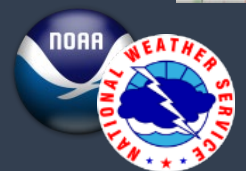
Tornado ●

Yellow Outline = SVR

Red Outline = TOR

Verified Warnings = Green Shading

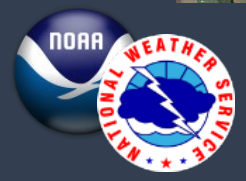
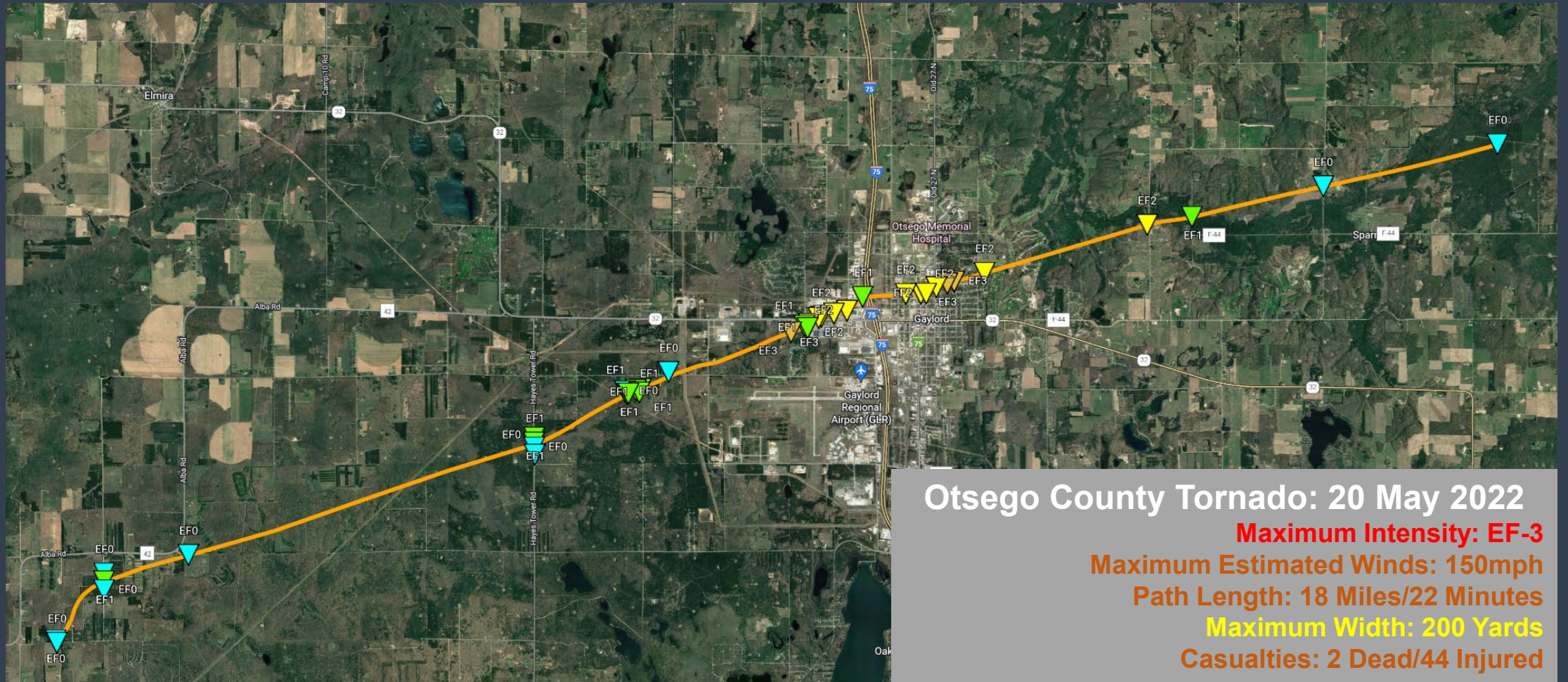
Unverified Warnings = Red Shading



# The Day After: Saturday 21 May 2022 (Storm Survey Day)



# Tornado Damage Track: 20 May 2022



# Questions?

