Northeast US Tornadoes and Tornado Debris Signatures

Ryan Hanrahan / WVIT-TV
NBC Connecticut

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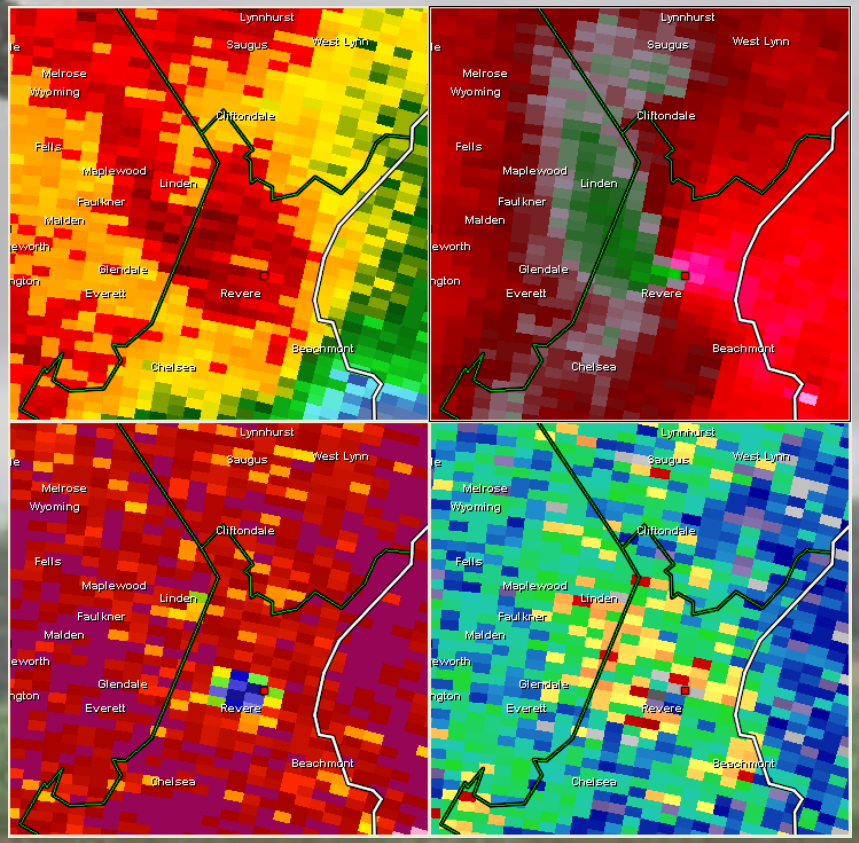
About Tornadoes in the NE US

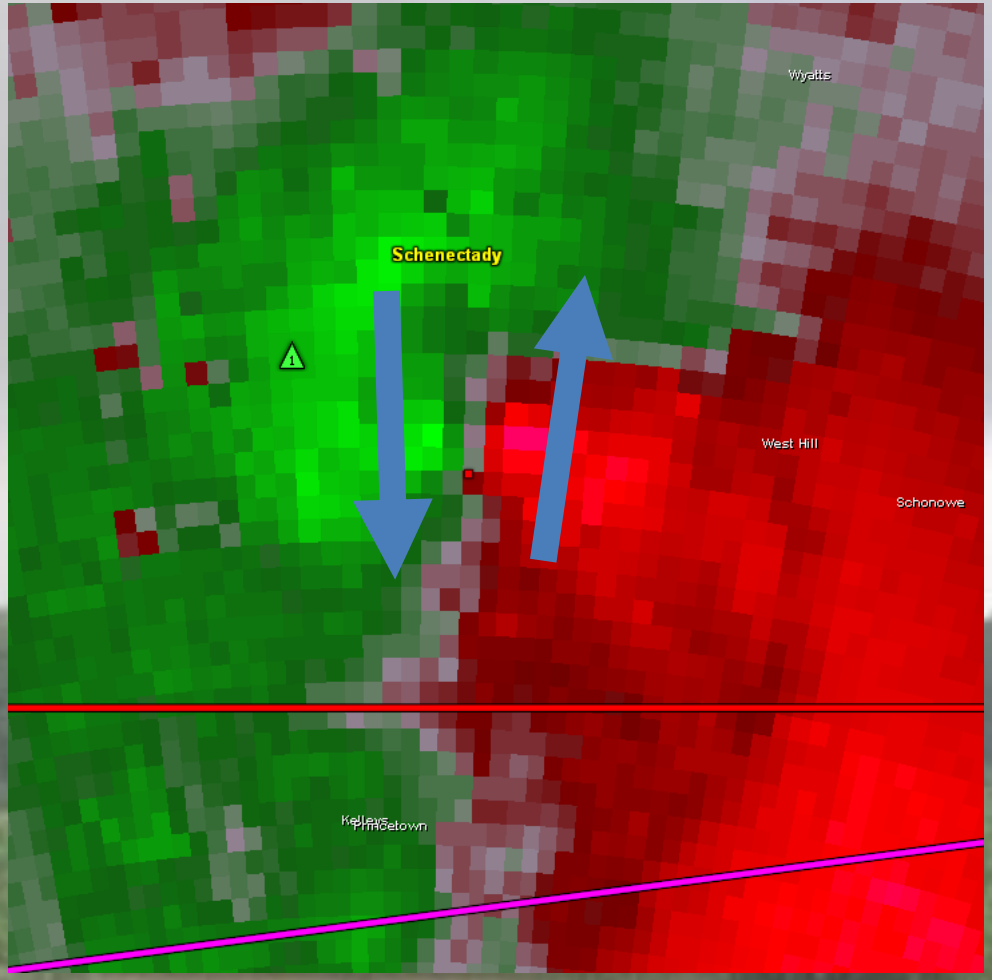
- Since the dual-pol WSR-88d upgrade in 2012 there have been 54 tornadoes in New York, New Jersey and New England.
- Tornadoes are relatively rare but can be destructive and deadly (1953, 1979, 1989, 2011, etc.)
- Communicating the risk and danger posed by tornadoes can be challenging here since they don’t happen with great regularity.

Doppler Radar & Tornadoes



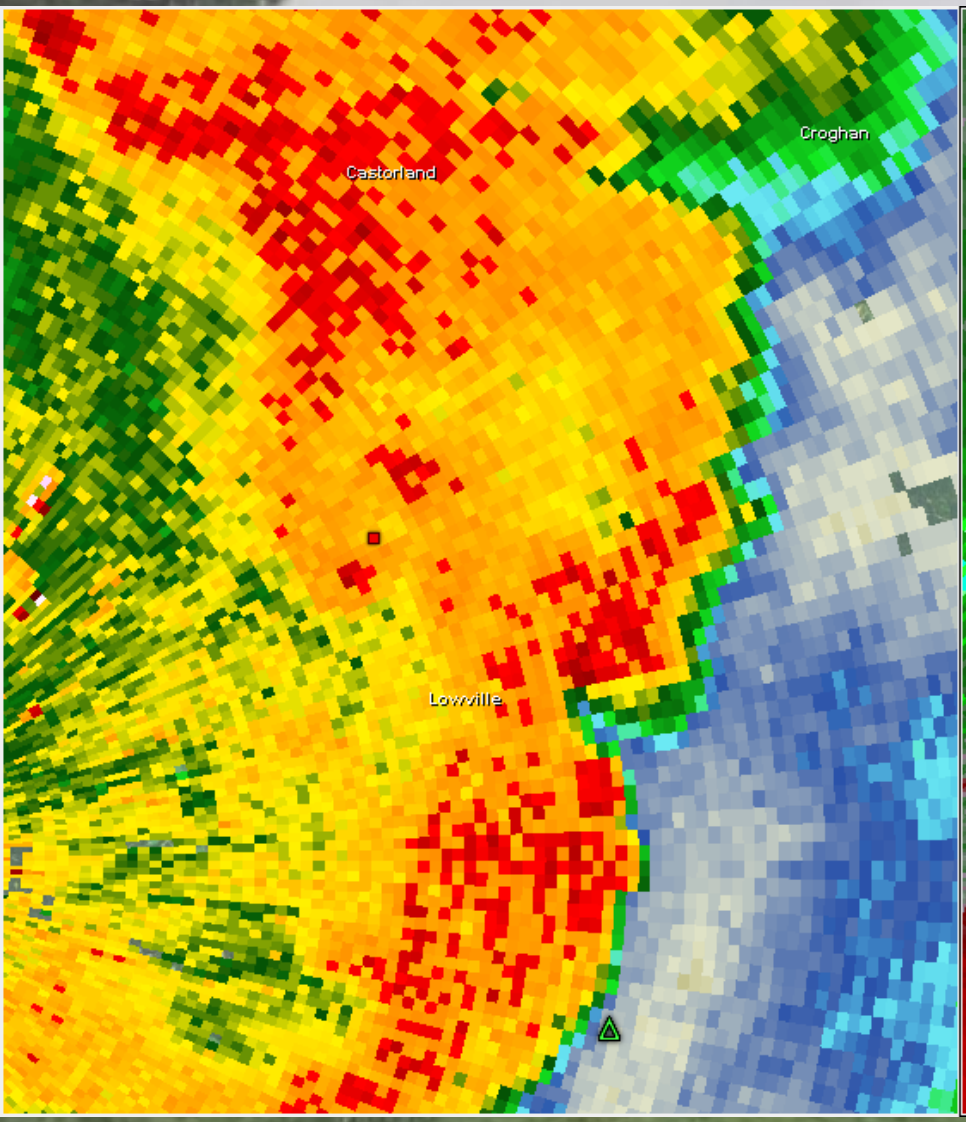
- Doppler radar allows us to determine the radial velocity of targets (rain, hail, etc.)
- Strong inbound velocities next to strong outbound velocities suggest rotation or spin of a thunderstorm.

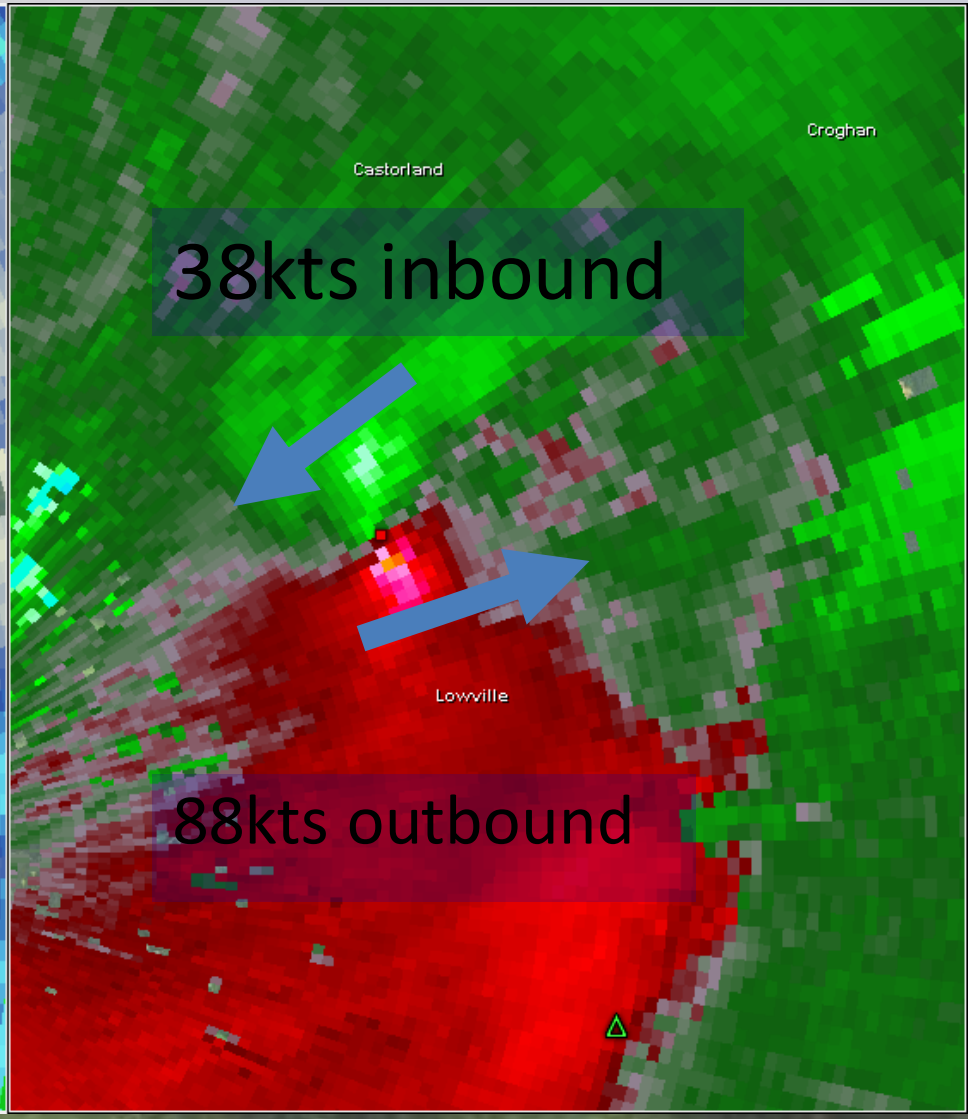
Velocity Signatures



- Vrot = (Max Outbound + Max Inbound) / 2

Not All Velocity Signatures are Equal





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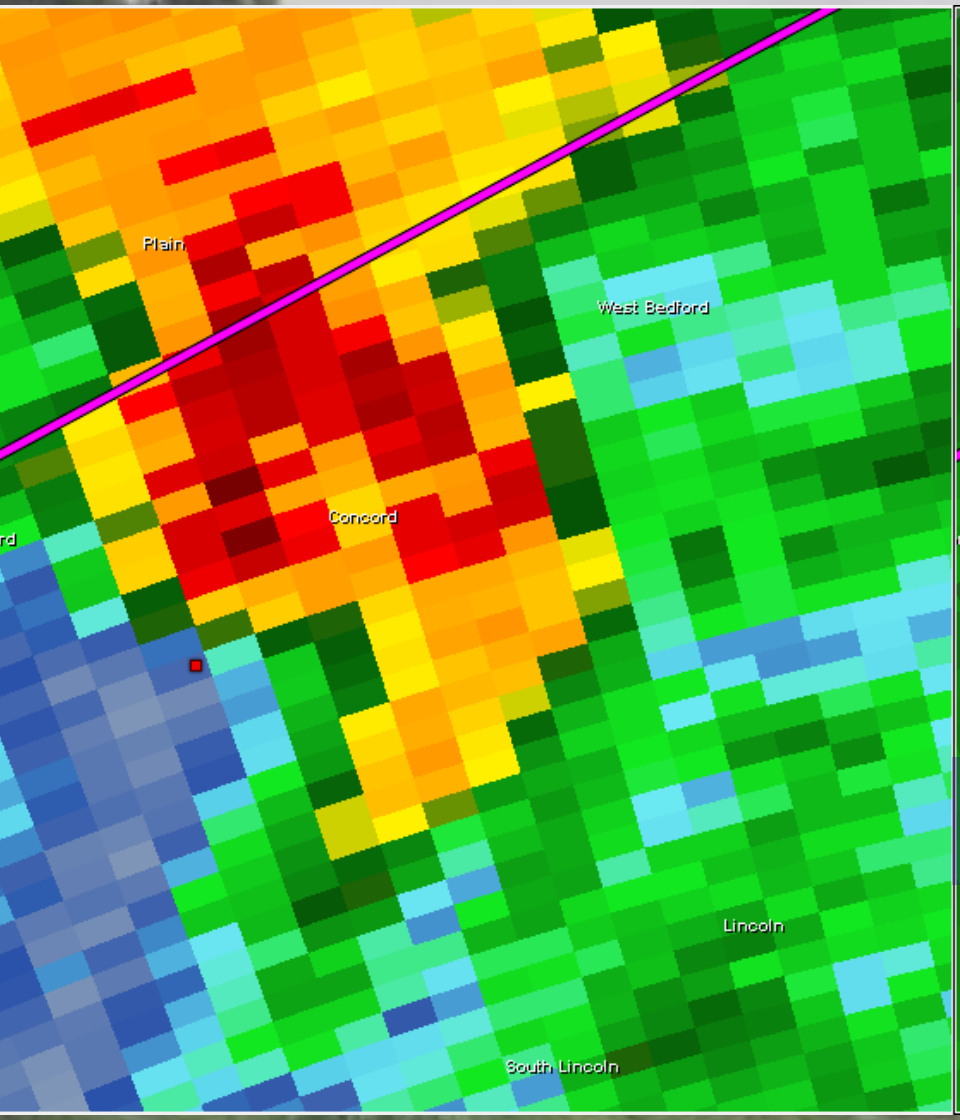

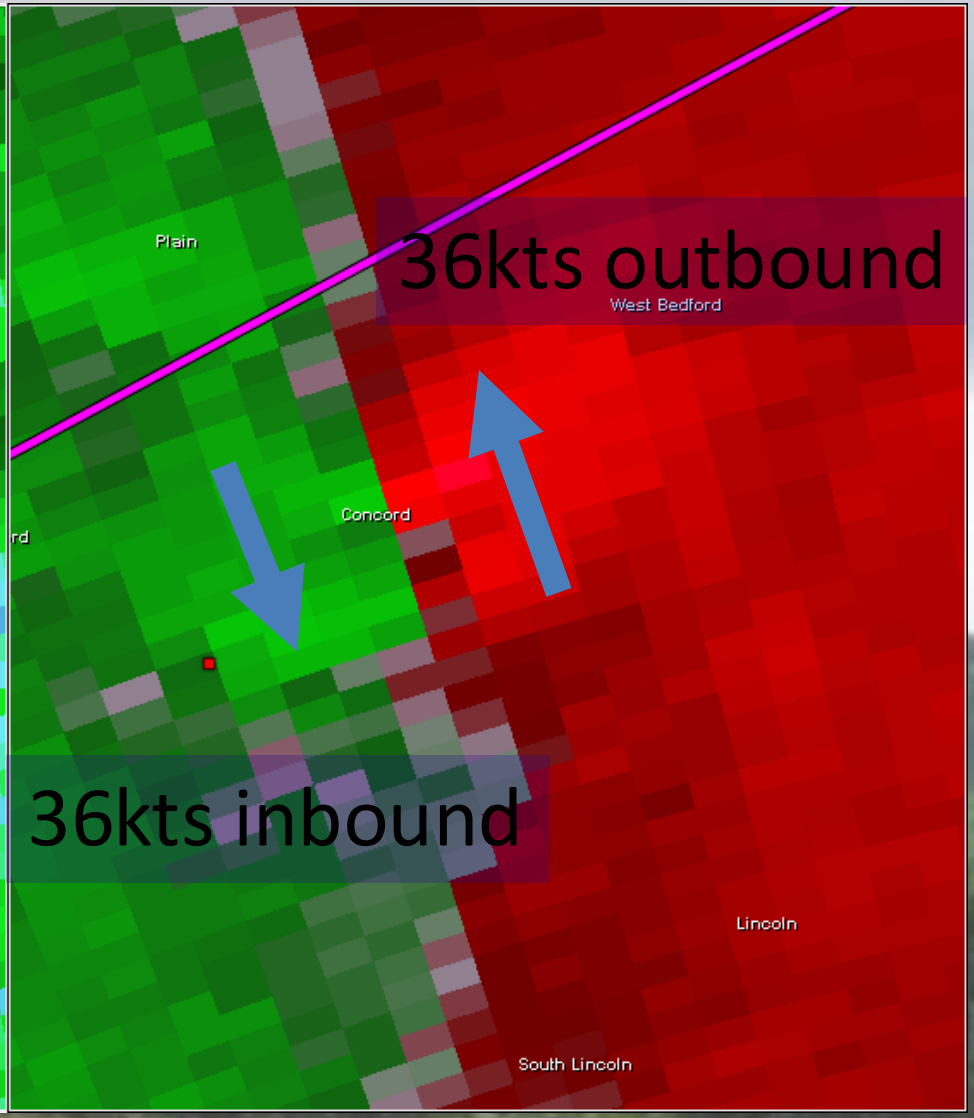

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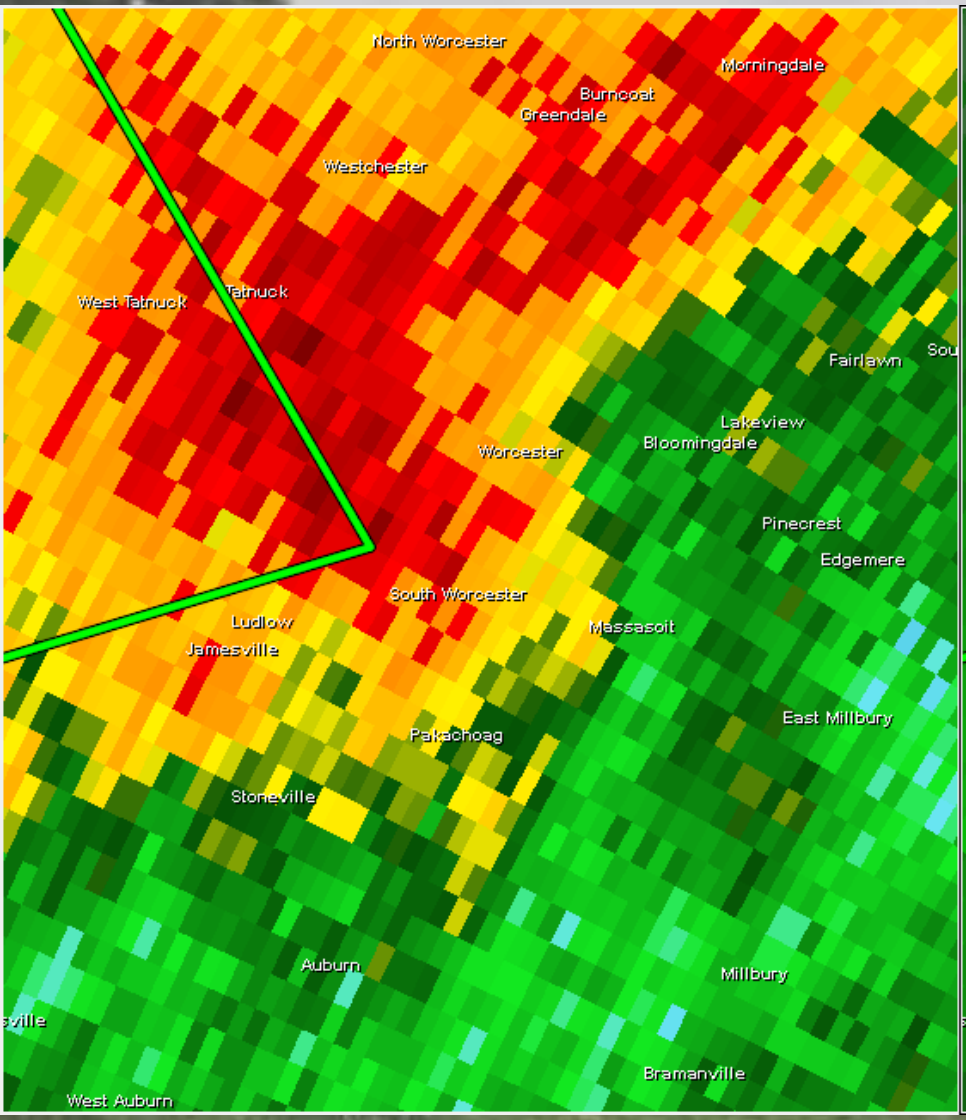
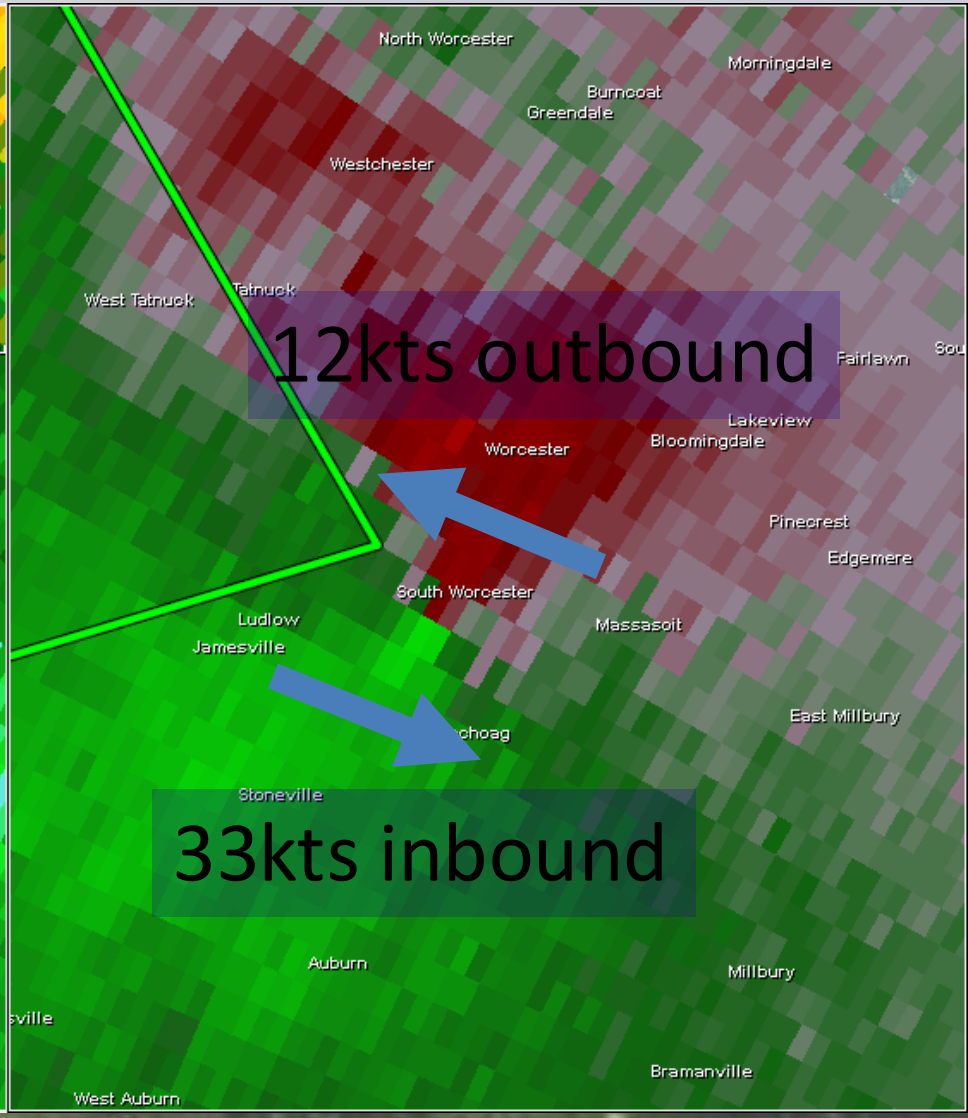
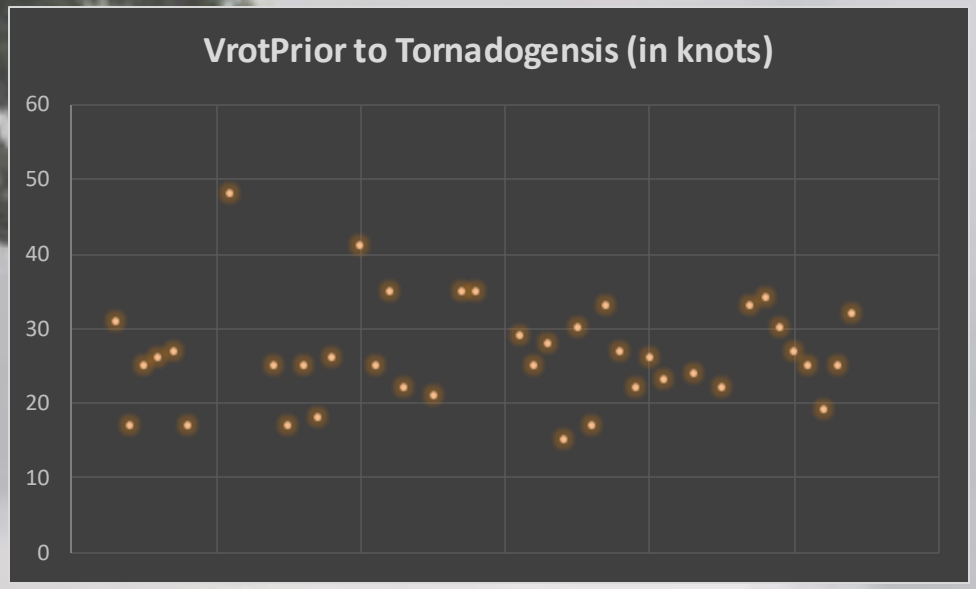




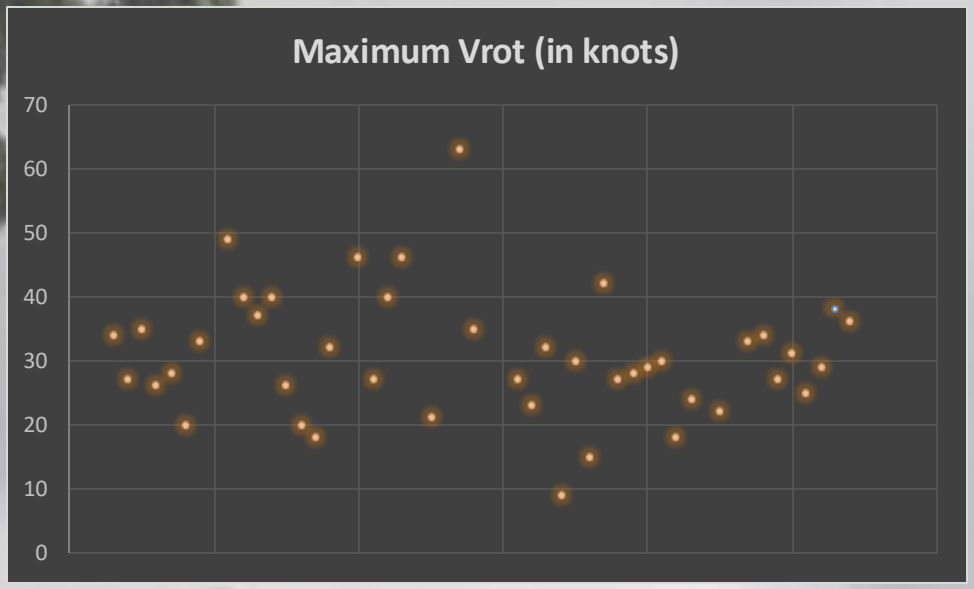
Velocity Signatures



	Vrot Prior
Mean	26.6 knots
Median	25.5 knots

- Immediately prior to tornadogenesis 14 of 54 (26%) had no discernible low level rotation

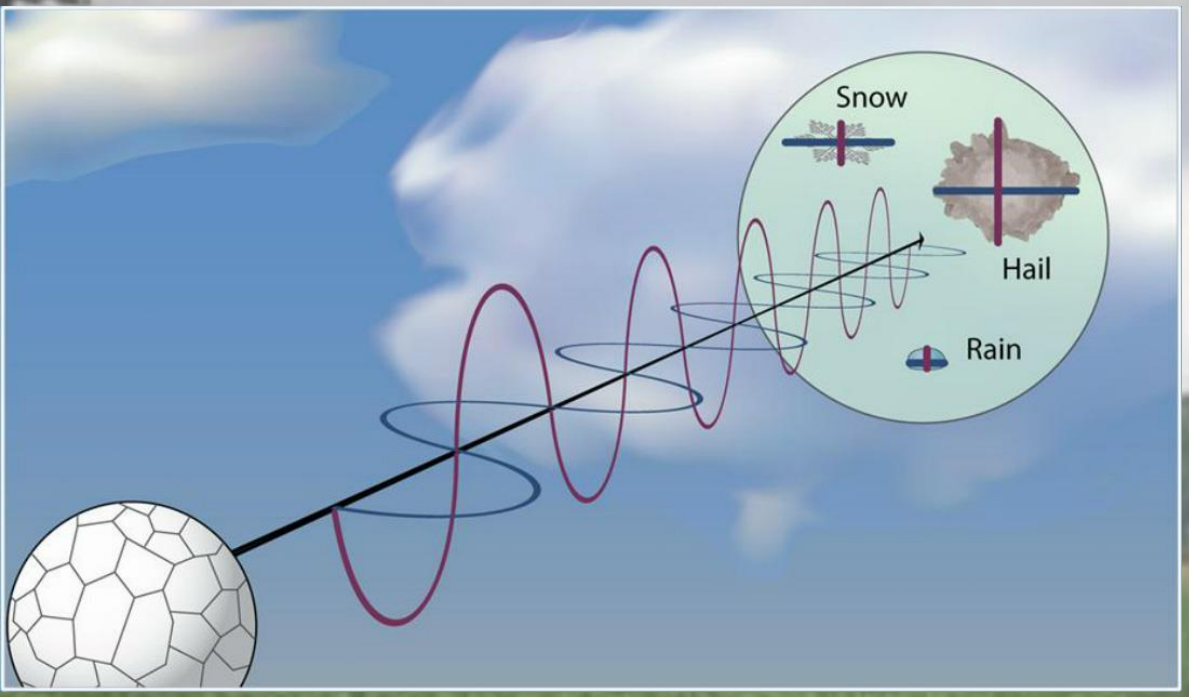
Velocity Signatures



- During life of the tornado 10 of 54 (18%) had no discernible low level mesocyclone.

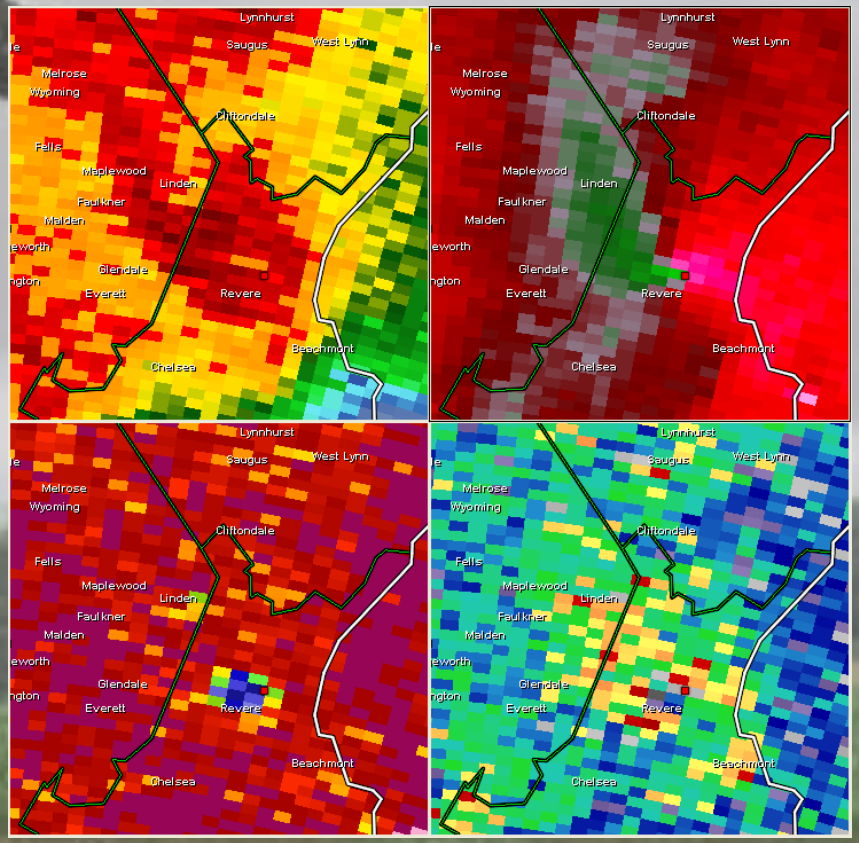
	Vrot Max
Mean	30.7 knots
Median	29.5 knots

What is Dual Pol Radar?



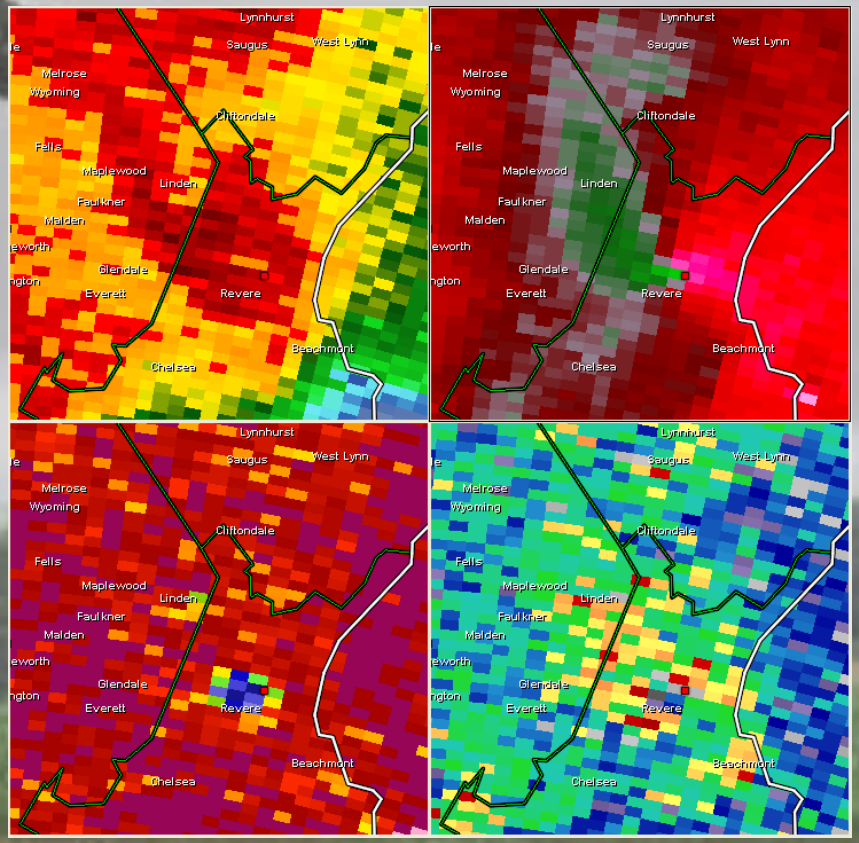
- Radar sends out 2 pulses – a horizontal and a vertical pulse.
- This allows us to determine size, shape and variety of targets.
- We can also discriminate between meteorological and non-meteorological targets.

What's a Tornado Debris Signature?



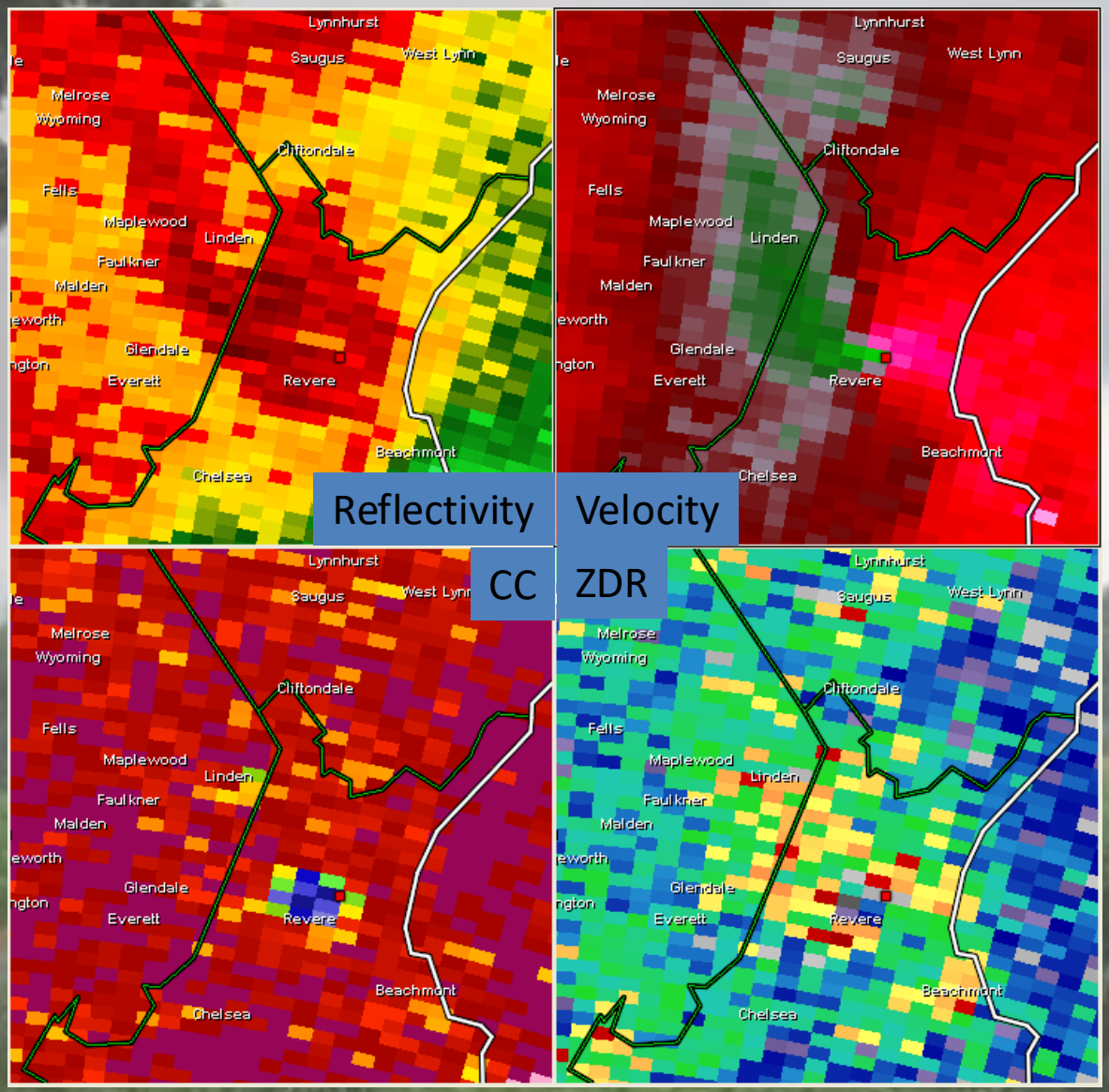
- Large variability in shapes of tornado debris produces a unique signature on dual pol radar.
- Tornado debris also "tumbles" through the air as it falls. This tumbling motion makes the radar think it is detecting a spherical object.

What's a Tornado Debris Signature?



- A TDS can be used as confirmation a tornado is occurring – it's as good as a spotter report!
- A TDS can't give lead time – once a TDS has appeared the tornado is already doing damage.

TDS Detection – Step By Step

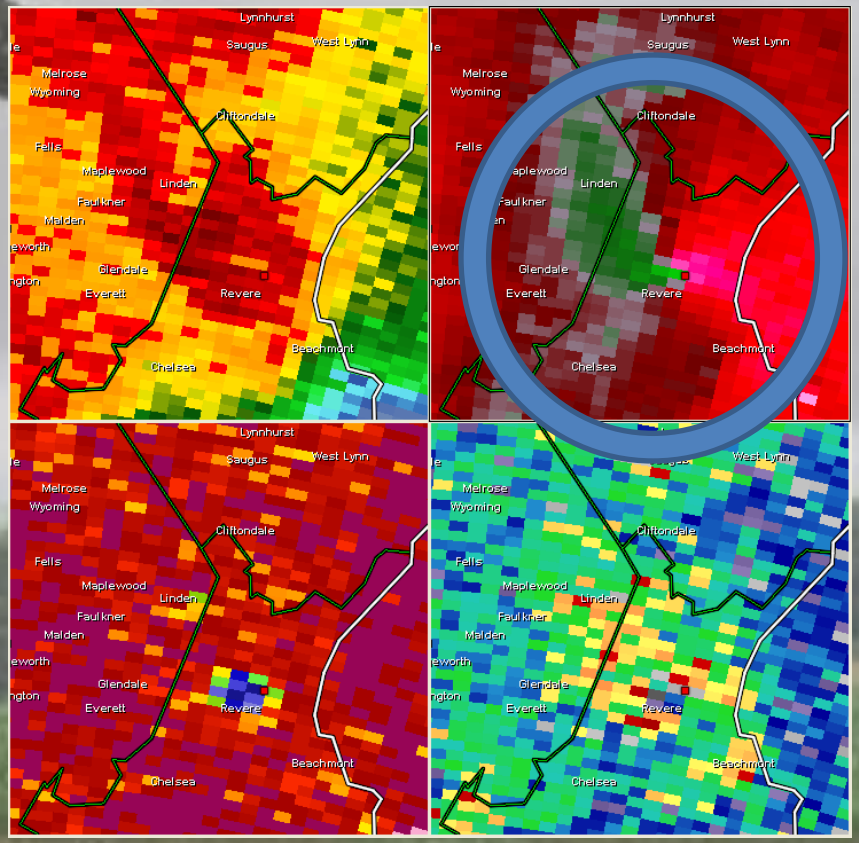


I like using 4-panel radar charts on GR2Analyst.

You need reflectivity, velocity, and correlation coefficient. In my 4th panel I use either differential reflectivity or normalized rotation.

Radarscope works too – but it can be tricky.

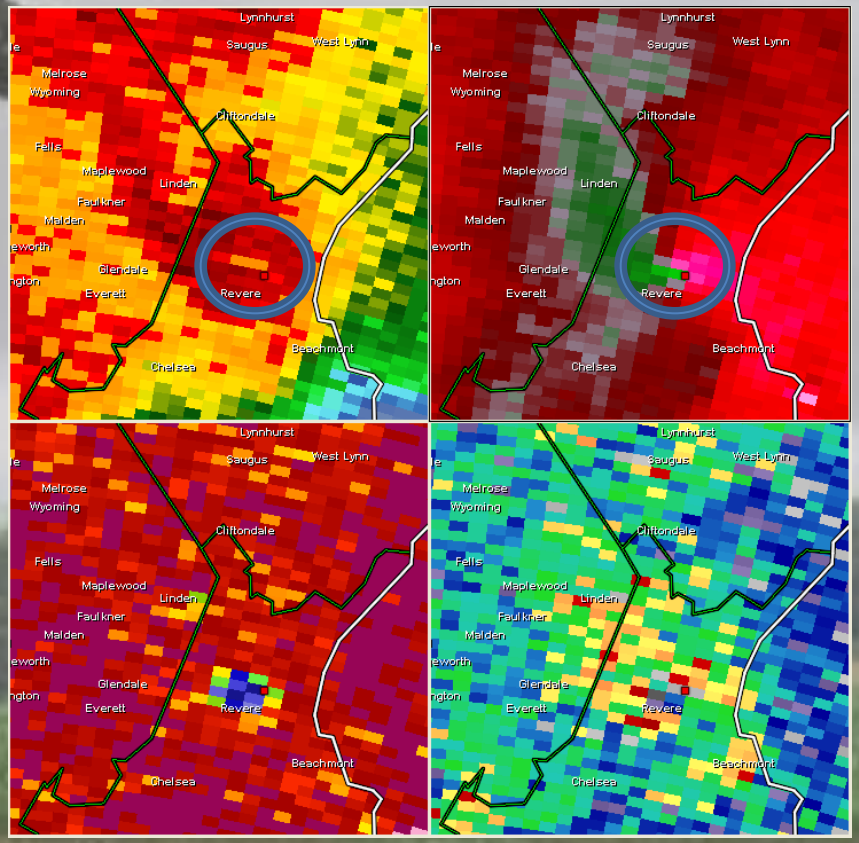
TDS Detection – Step #1



Using Storm Relative Velocity identify an area of rotation - Strong inbound velocity next to strong outbound velocity.

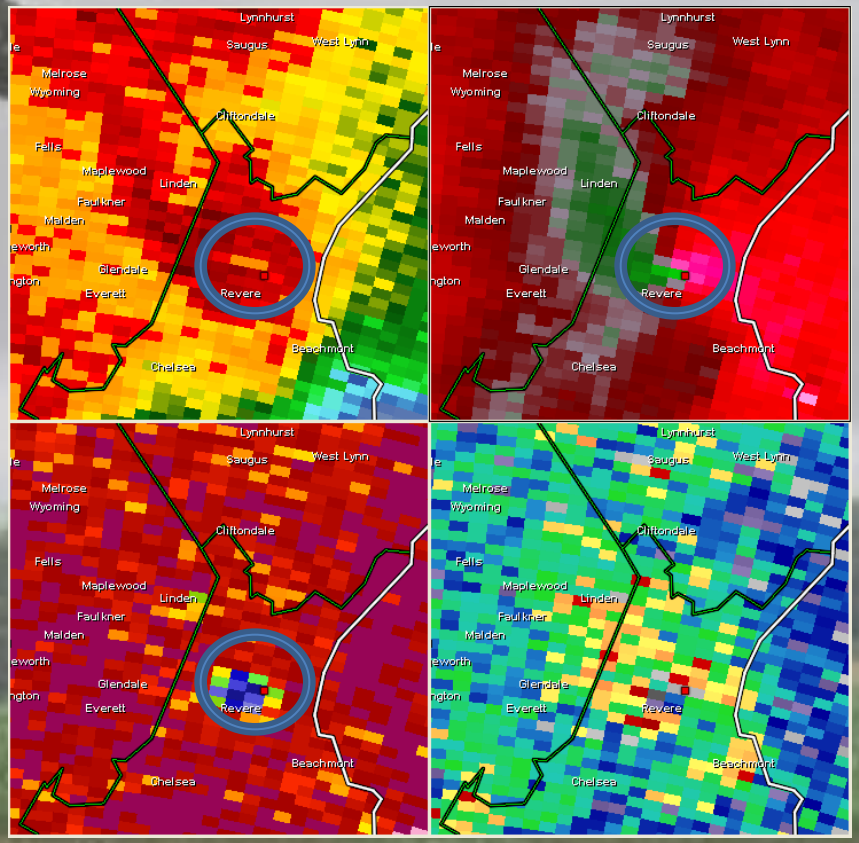
This tells you that a storm is rotating/has a mesocyclone.

TDS Detection – Step #2



Confirm there is sufficient reflectivity (Z >30 dbz) co-located with the low level mesocyclone.

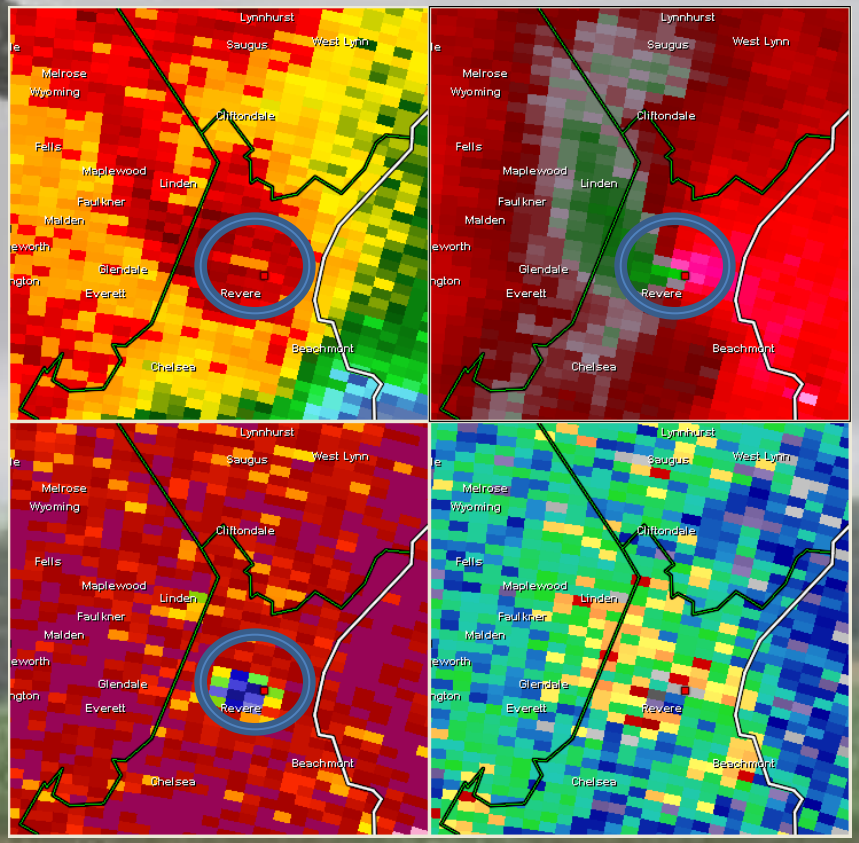
TDS Detection – Step #3



Correlation Coefficient tells us how similar target are to one another.

Steady rain/snow	CC = 0.95-1.0
Rain & Melting Hail	CC = 0.9-1.0
Biological Scatters	CC - 0.5-0.9
Tornado debris	**CC <0.9**

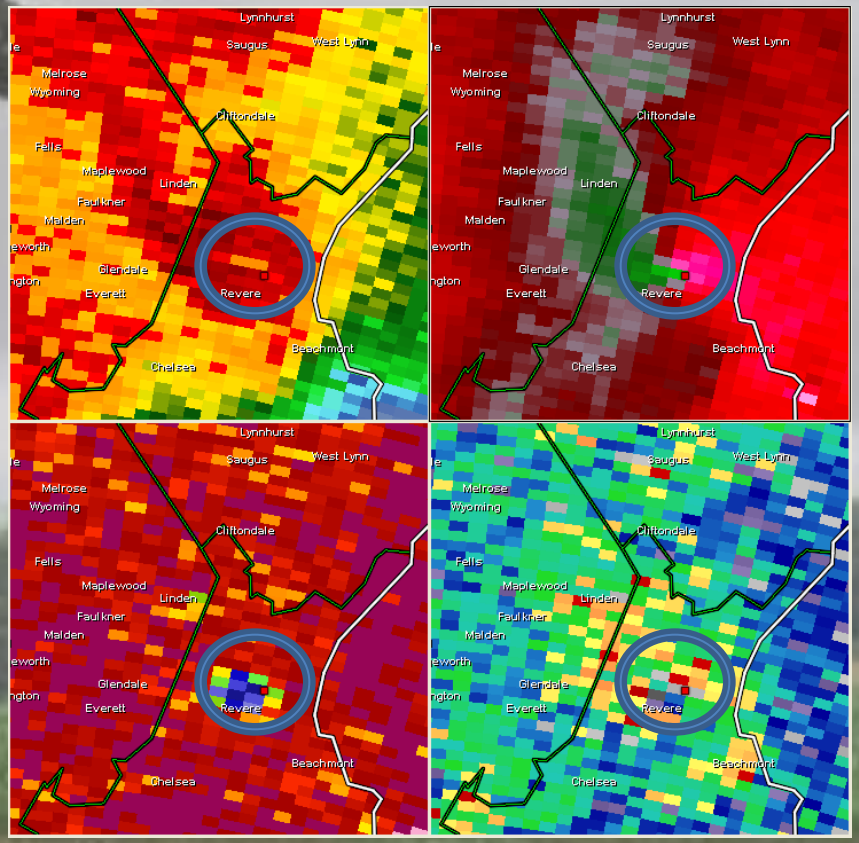
TDS Detection – Step #3



Look for relatively reduced CC coincident with reflectivity and rotation. CC < 0.9 is a good guideline to use. CC can drop to <0.5 in some cases.

Also – look for temporal and vertical continuity!

TDS Detection – Step #4

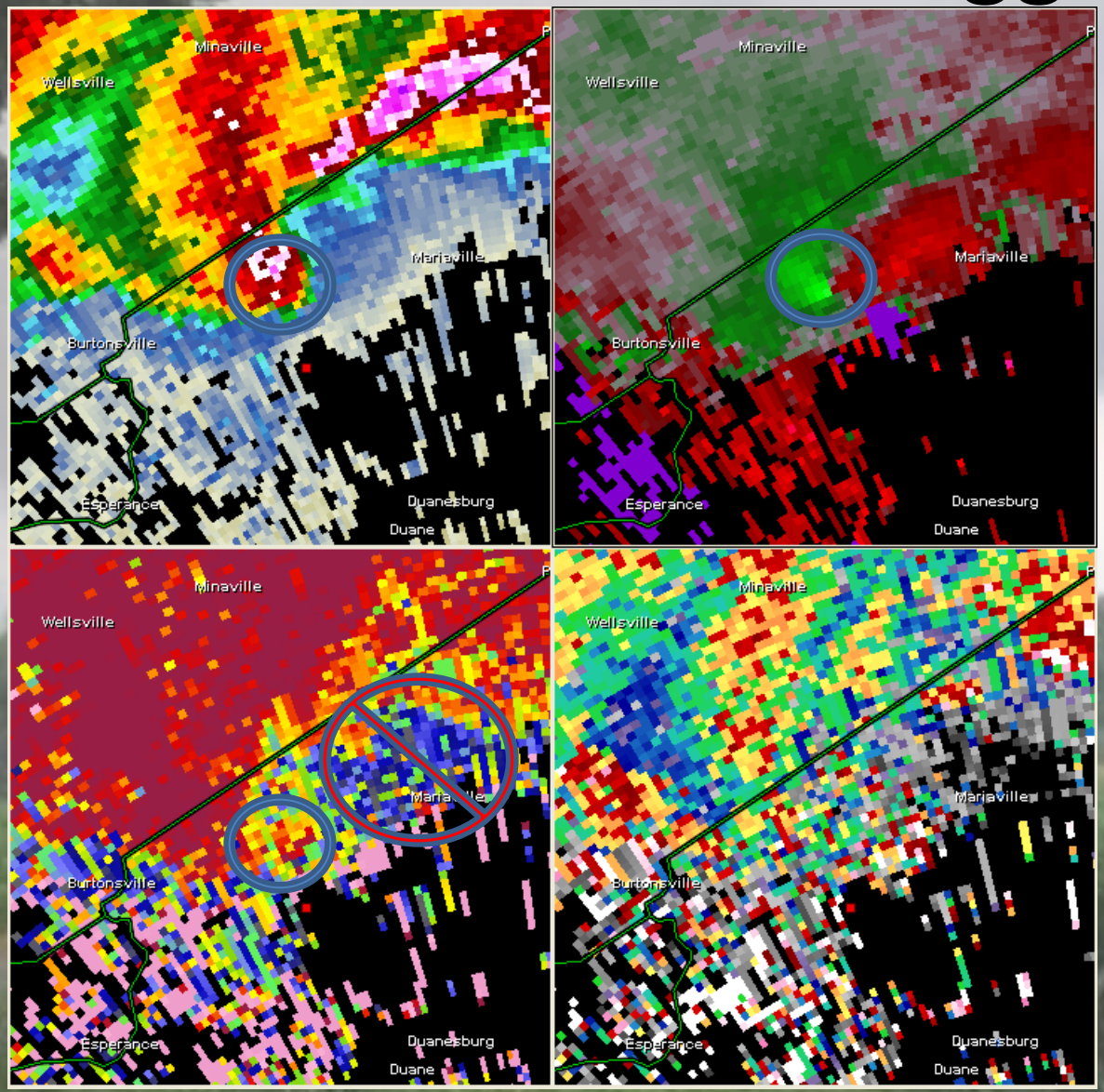


Look for differential reflectivity (ZDR) near 0.

ZDR tells us the shape of echoes and the radar thinks tumbling debris is spherical - so it should be seeing equal horizontal and vertical returns.

This is not necessary but gives you a nice confidence boost!

TDS Detection – Biggest Mistake

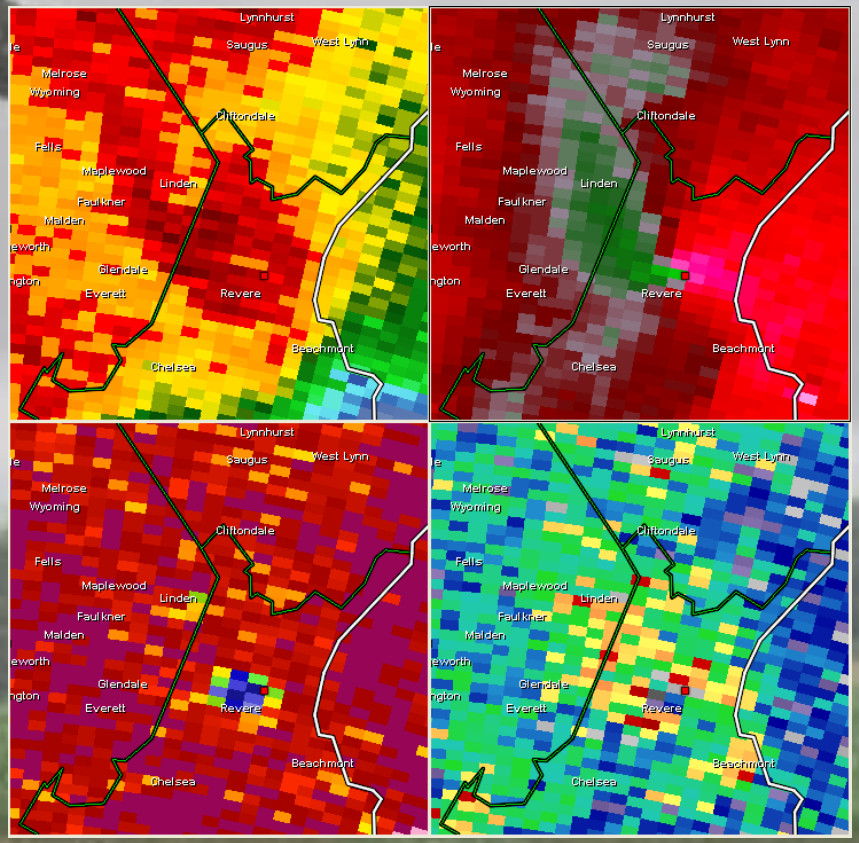


The inflow region!!!

CC is typically very low in a storm's inflow region. Bugs, birds, dust and so on get sucked into a storm's updraft.

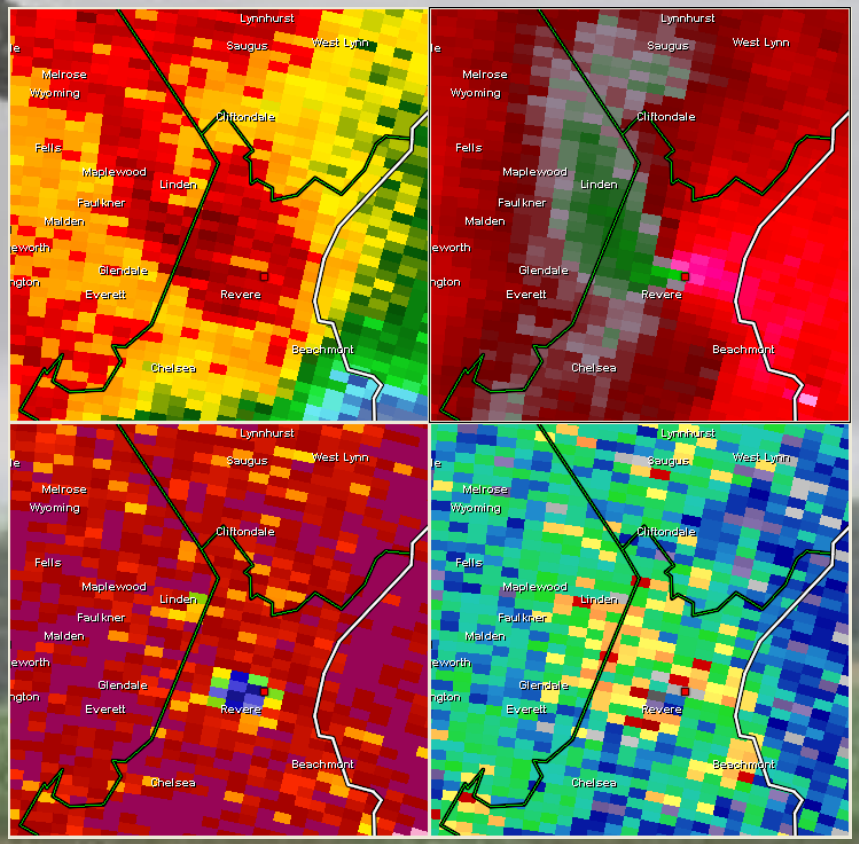
Make sure low CC is associated with rotation AND sufficient reflectivity.

TDS Cheat Sheet



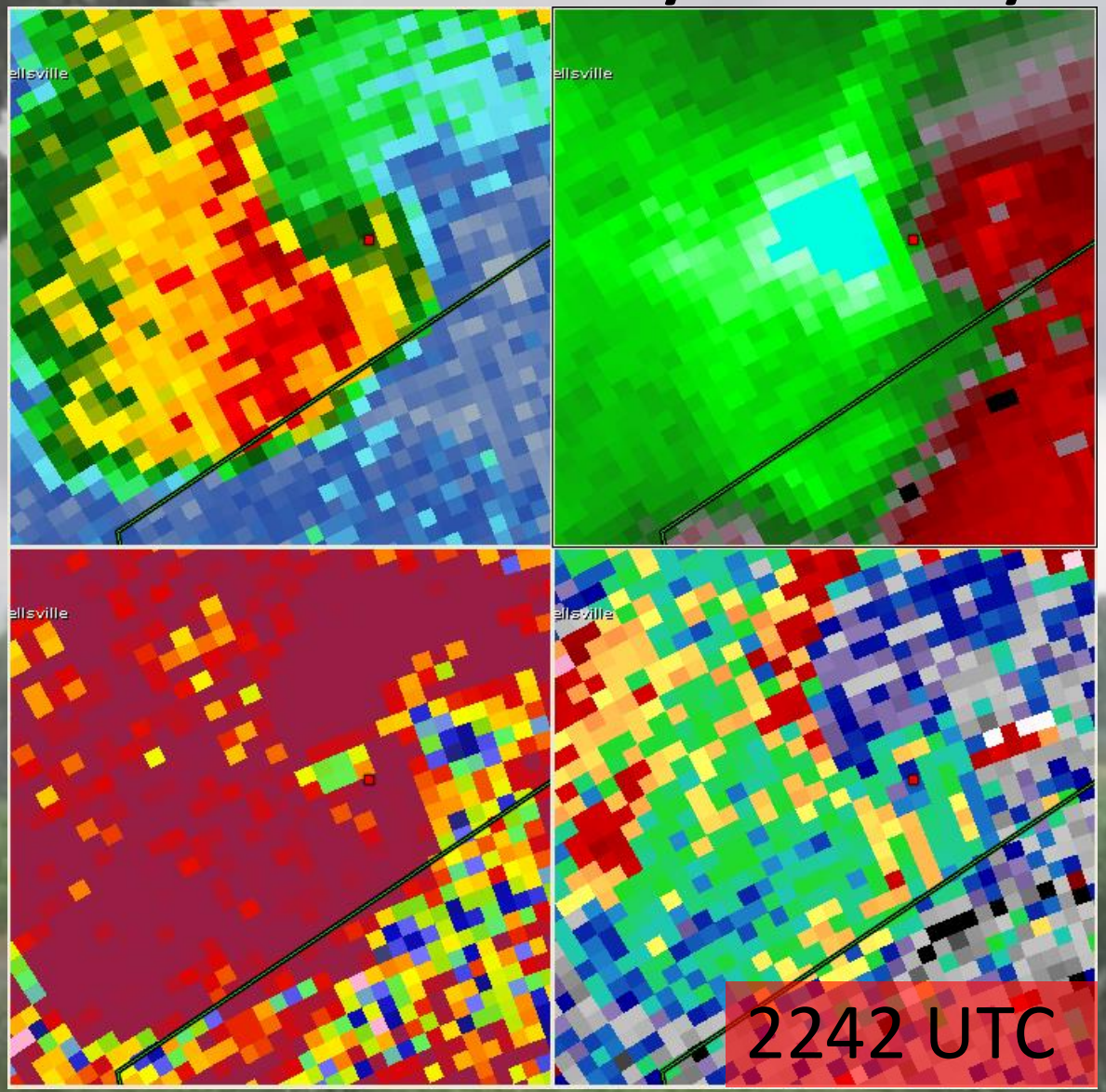
- Reflectivity (>35 dBZ)
- CC < 0.90
- ZDR near 0 (not necessary but adds confidence)
- ALL COINCIDENT WITH STRONG ROTATION/TVS

NE US Tornado Debris Signatures



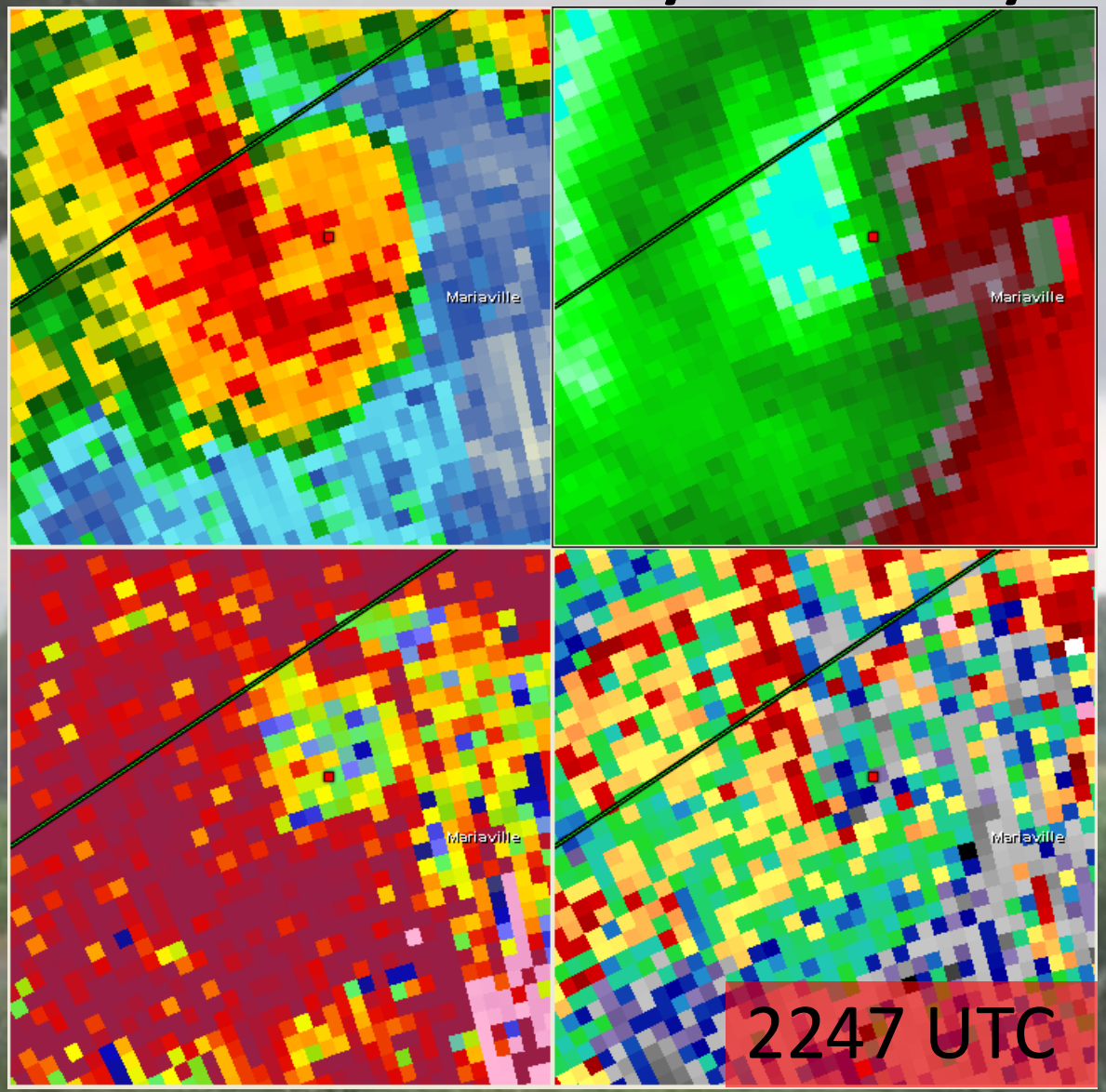
- Out of 54 tornadoes since 2012…
- 14 have produced debris signatures or 26%!!

Schenectady County NY 5/29/13



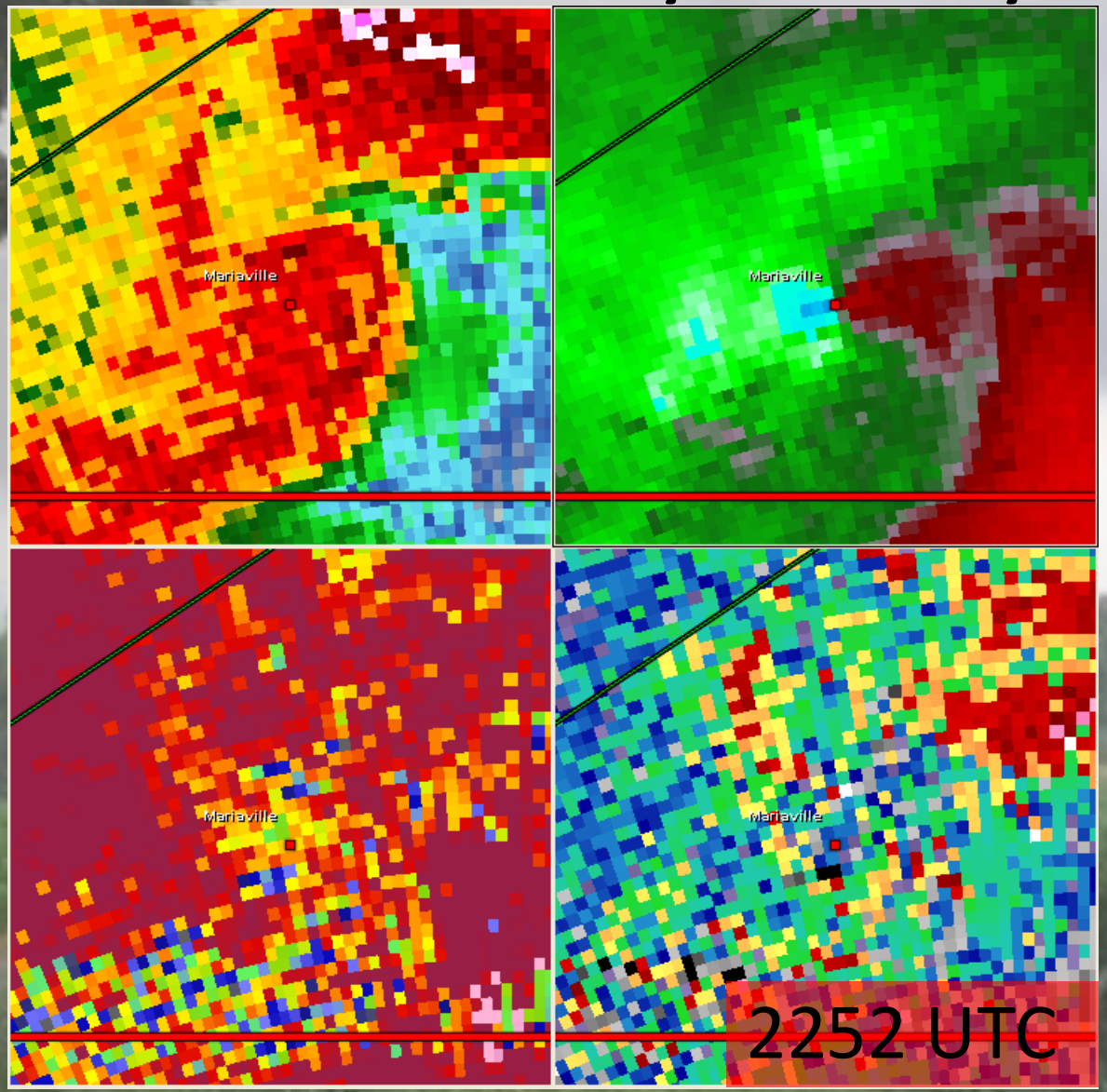
- 48 knots Vrot around time of tgen
- TDS? Probably (CC 0.80-0.85) with Z ~ 35 dbz
- 1000ft ARL

Schenectady County NY 5/29/13



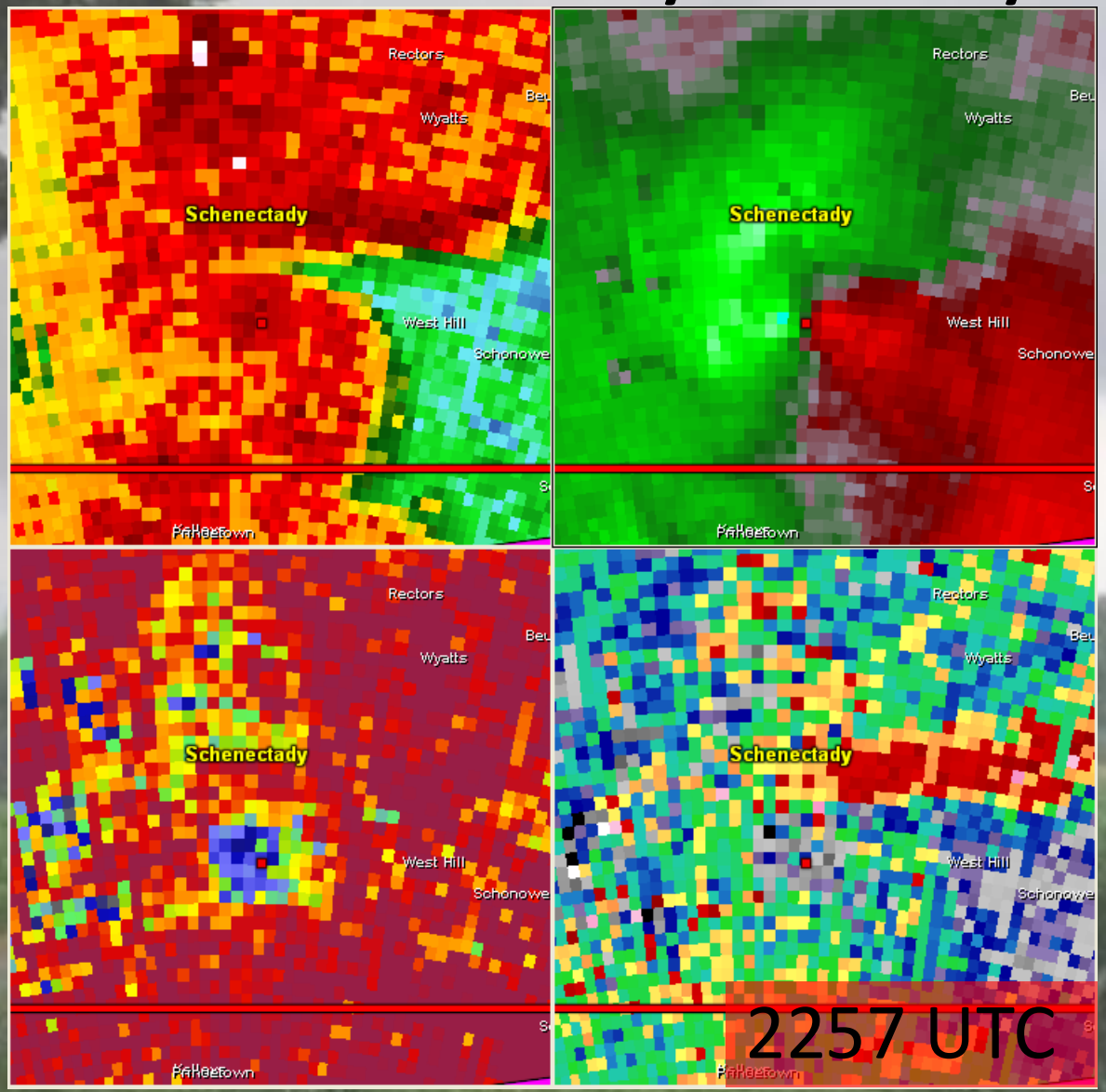
- Clearer TDS at this point.
- Rotation remains broad but strong (NROT not shown up to 1.36)

Schenectady County NY 5/29/13



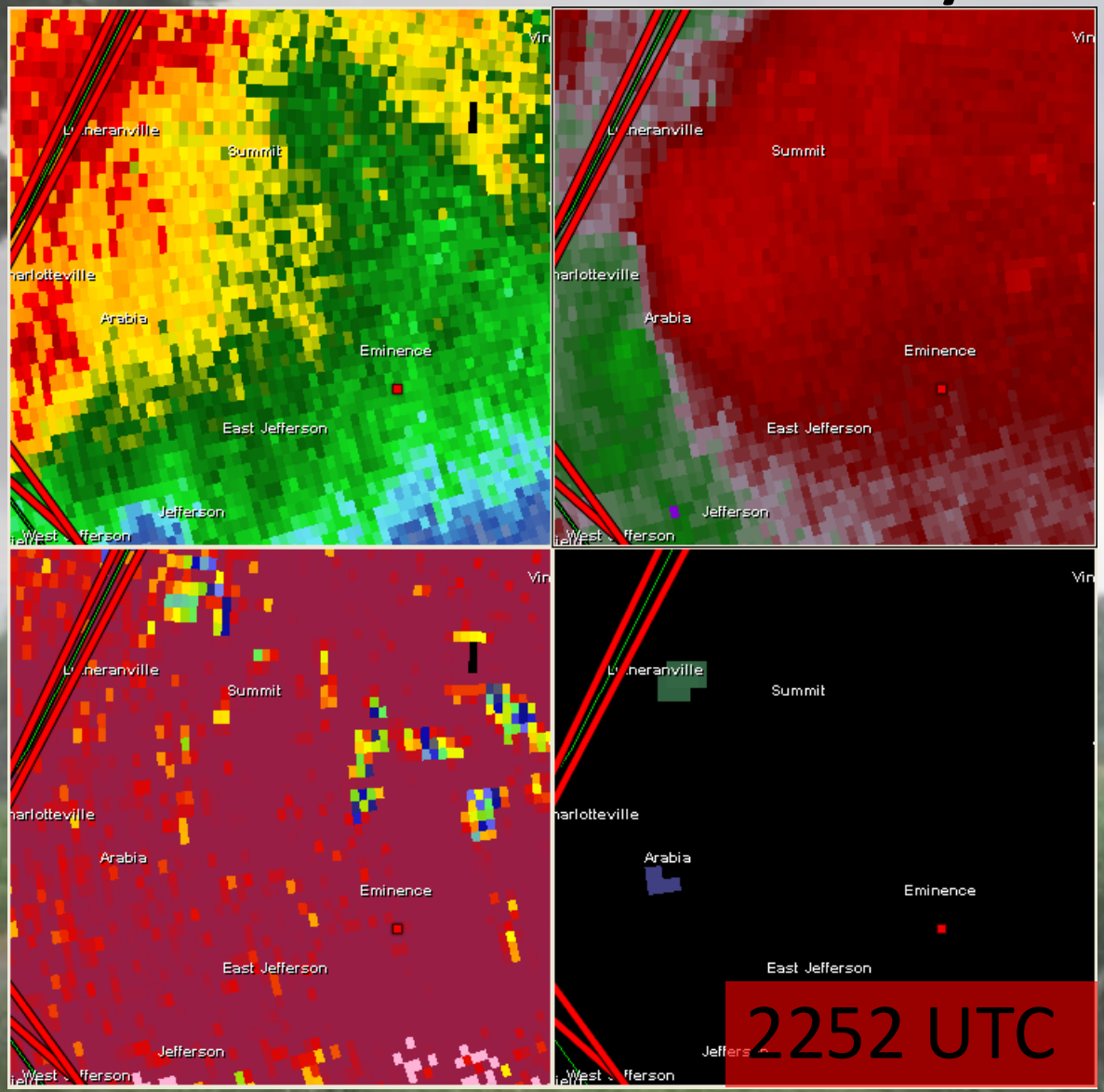
- Couplet tightens dramatically. Vrot 49 knots.
- EF-2 damage in the town of Mariaville.
- Weak TDS still visible.

Schenectady County NY 5/29/13



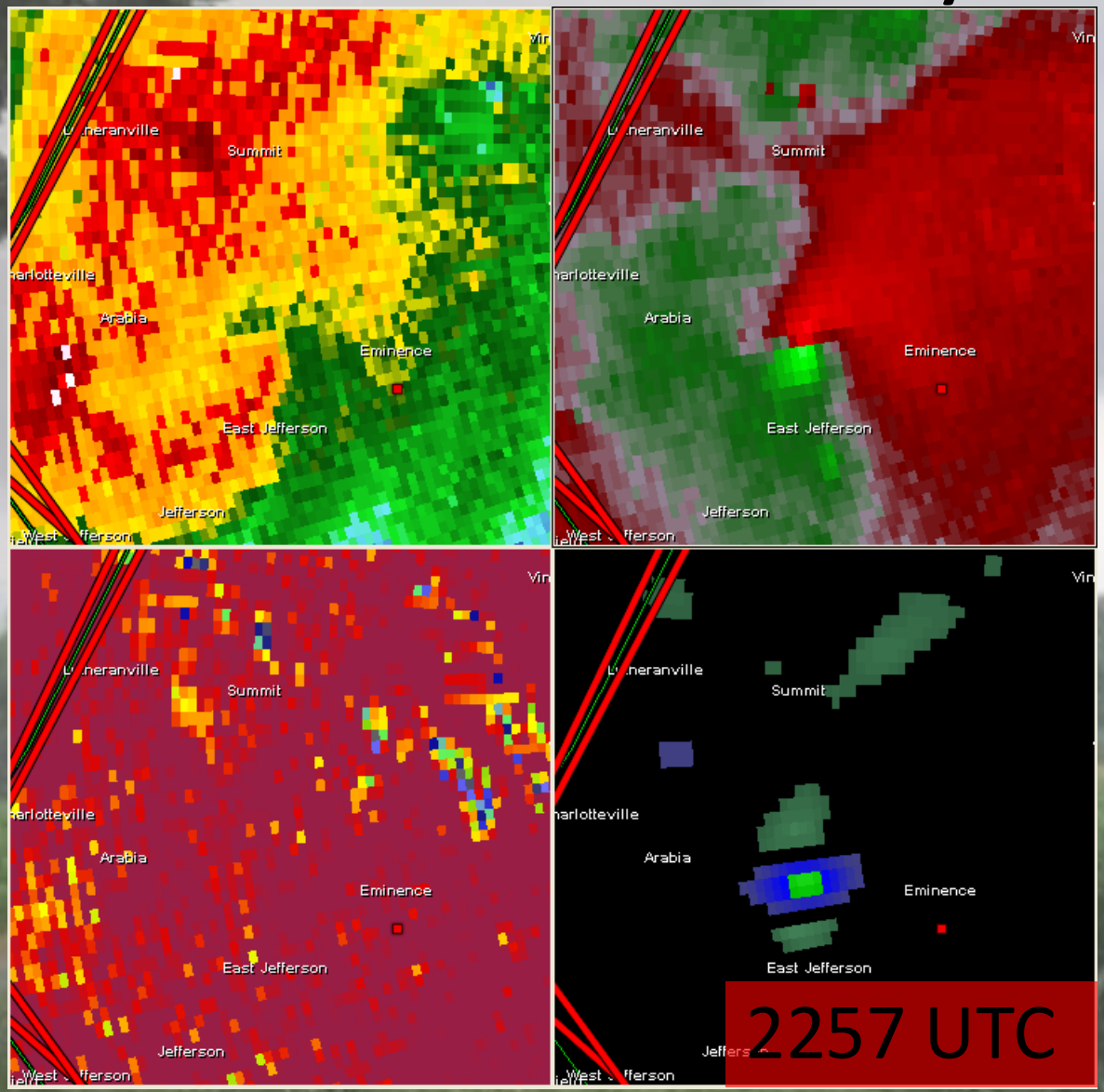
- Much more impressive TDS after tornado hits Mariaville.
- TDS clear up through 6200 ft ARL.

Schoharie County NY 5/29/13



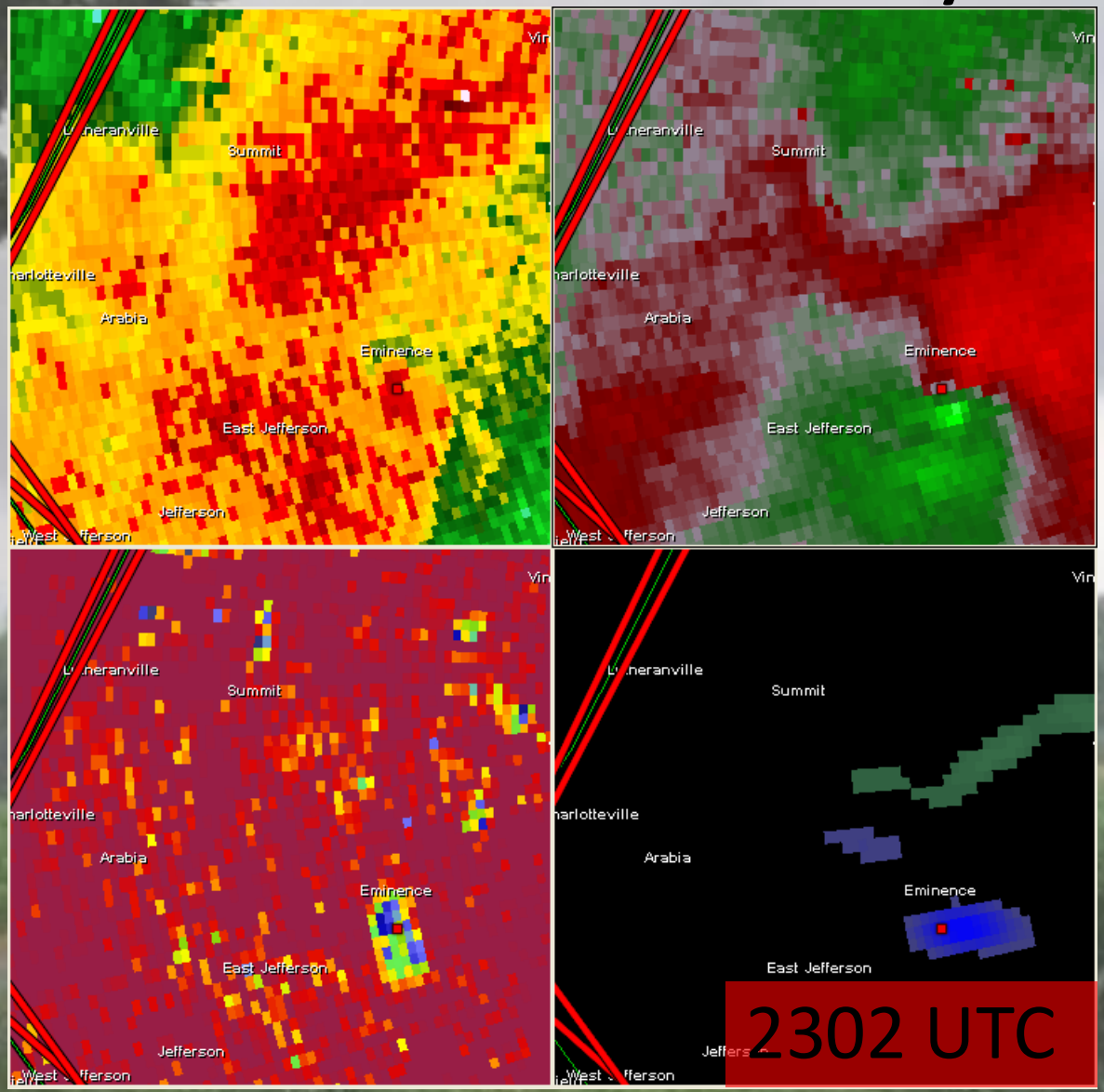
- No rotation detected on radar prior to tgen.
- Pretty blah looking storm.

Schoharie County NY 5/29/13



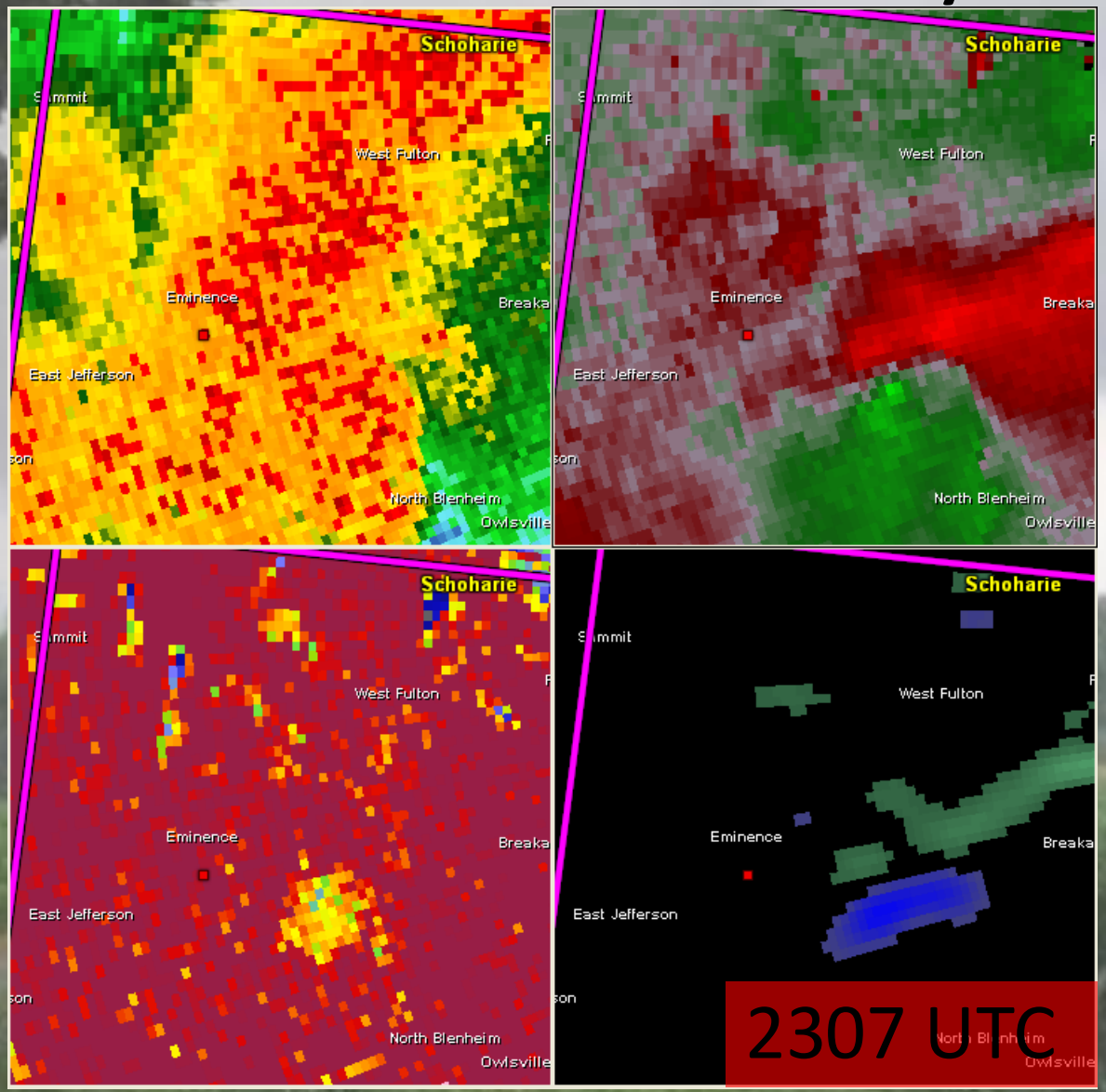
- 5 minutes later… whoa!
- 40 knots of Vrot (40 inbound, 40 outbound)
- No TDS

Schoharie County NY 5/29/13



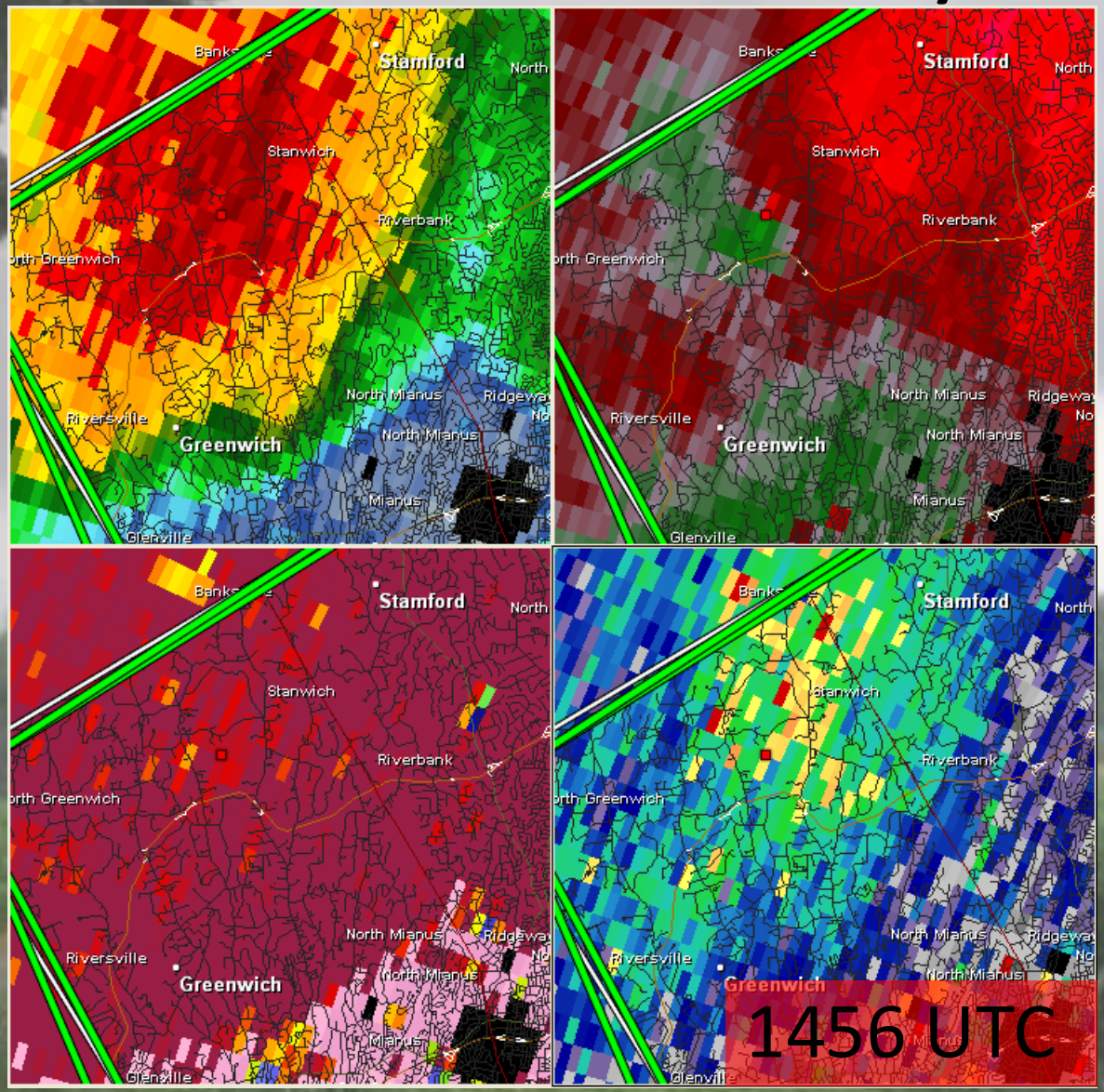
- Clear TDS
- Tornado has lifted by this point.

Schoharie County NY 5/29/13



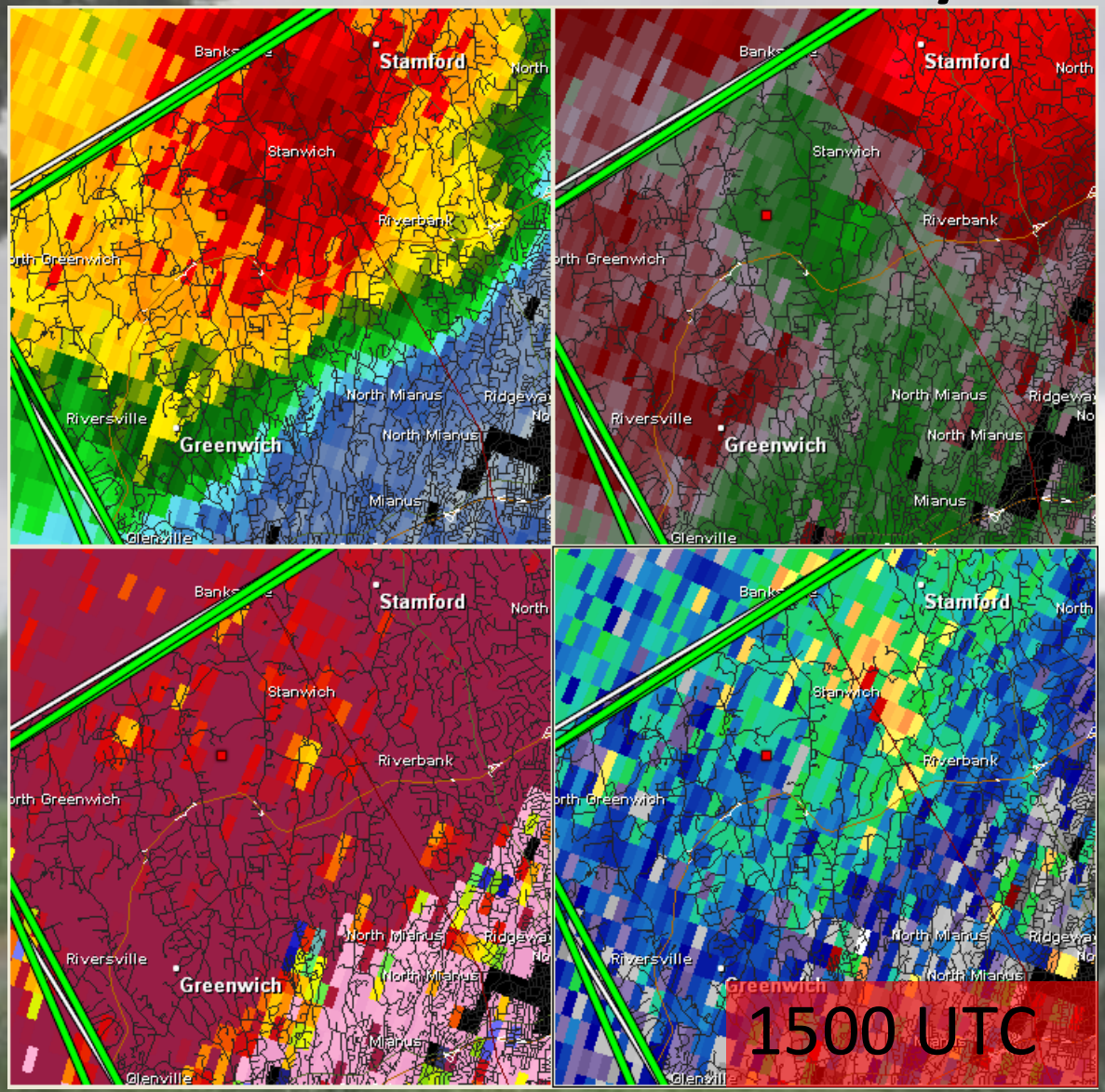
- TDS signature less impressive.
- Max height of lofted debris around 3400 ft ARL.

Fairfield County CT 7/1/13



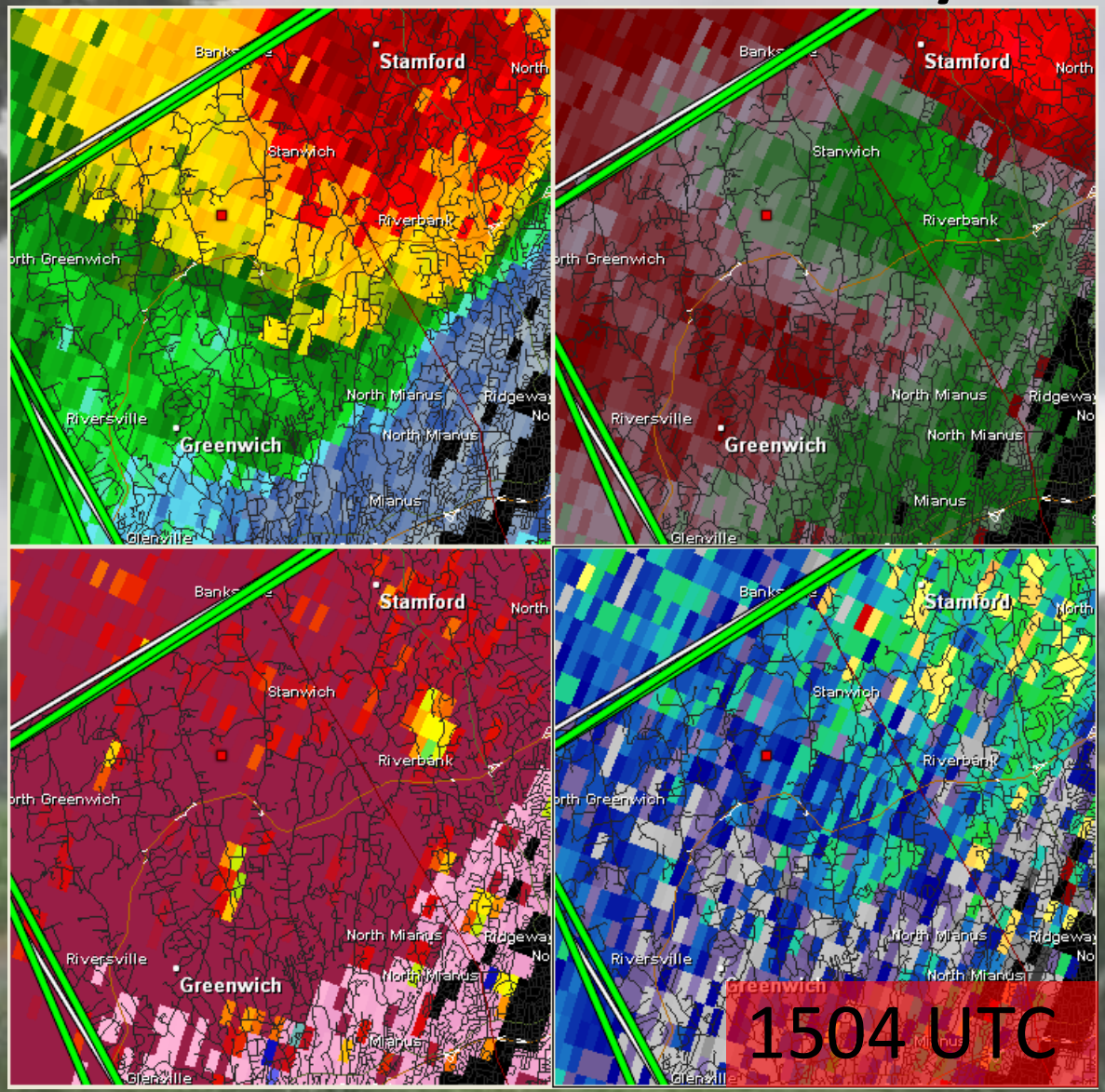
- Borderline case!
- At time of touchdown Vrot of 26 knots (close to median value of all tornadoes).

Fairfield County CT 7/1/13



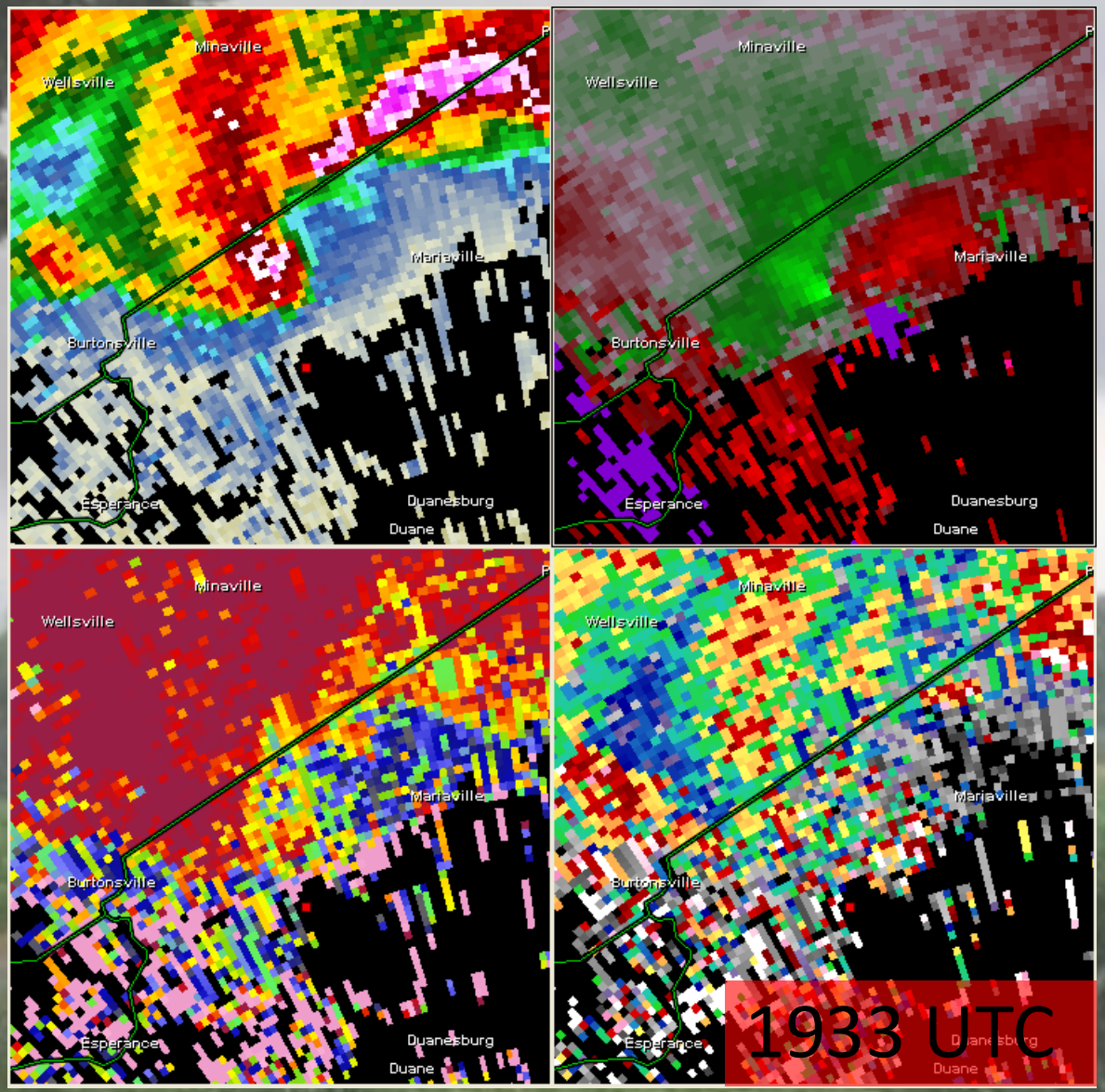
- Tornado still on the ground.
- 3.7 miles, 10 minutes.
- EF-0 damage.
- Slight CC depression (0.90 with couplet)

Fairfield County CT 7/1/13



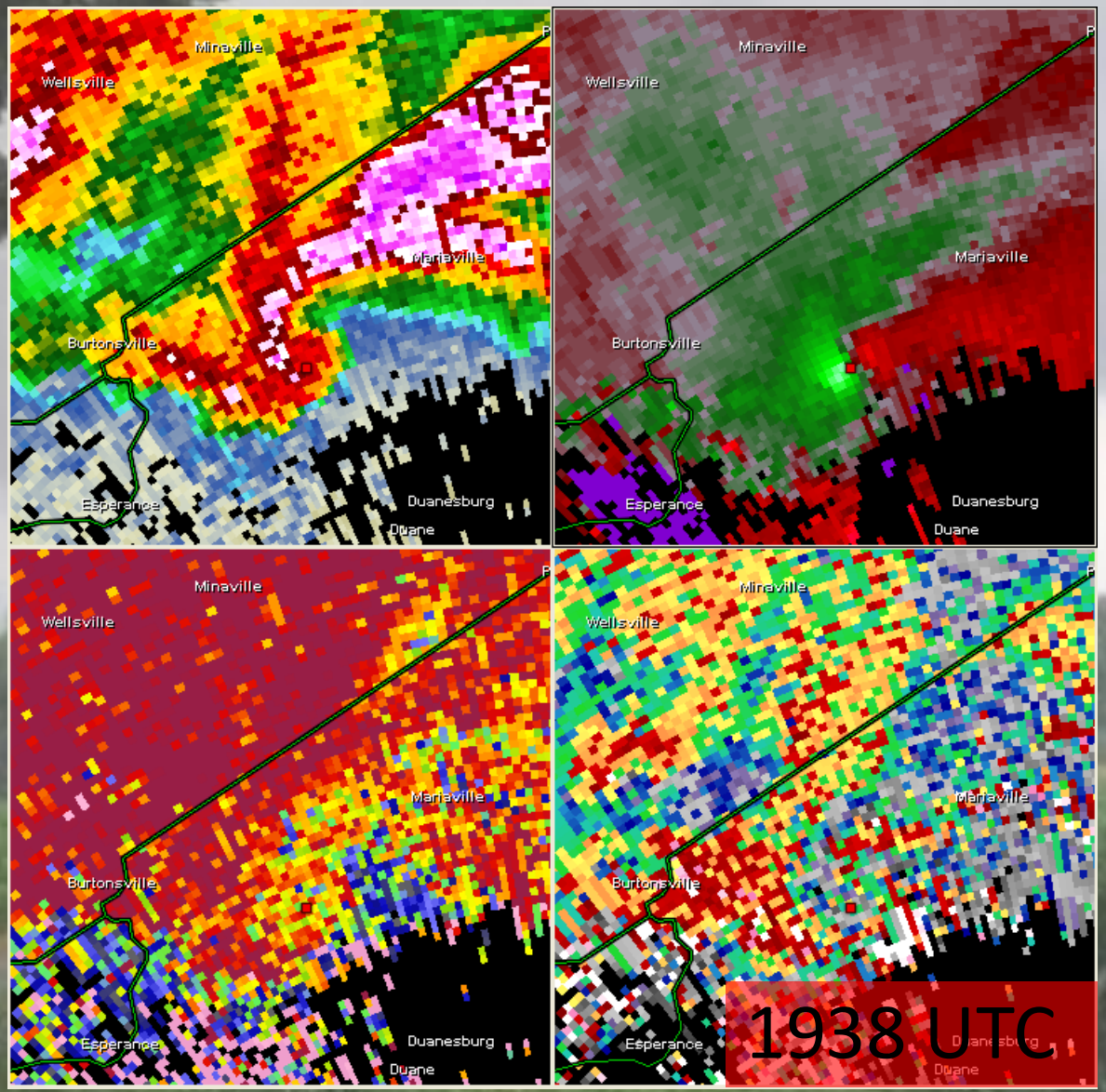
- TDS visible here – CC 0.85-0.90 along with ZDR near zero.
- Only a few pixels – but coincident with damage path.

Schenectady/Albany County NY 5/22/14



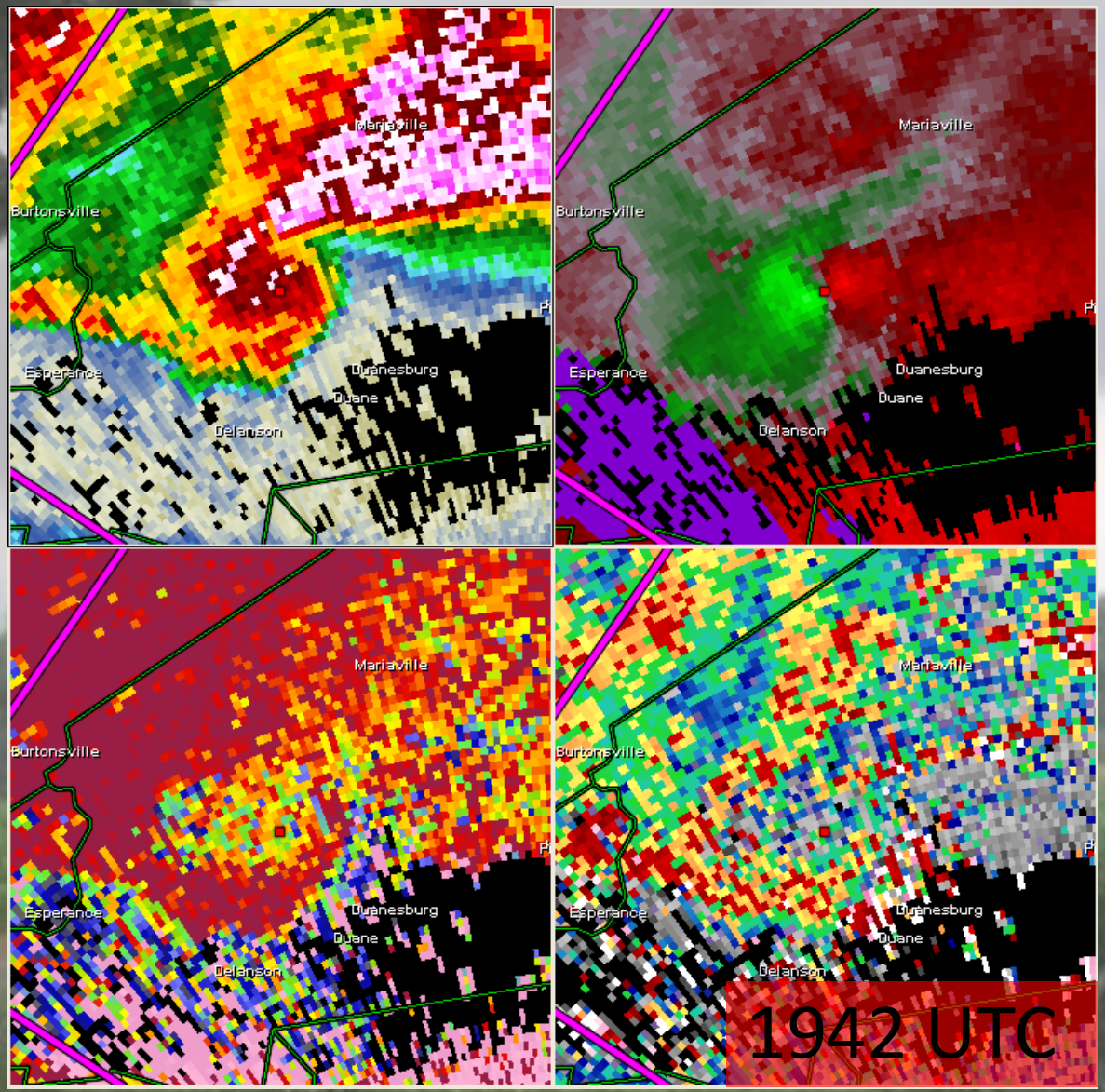
- 40 knots of Vrot at time of tgen – well above median of all cases.

Schenectady/Albany County NY 5/22/14



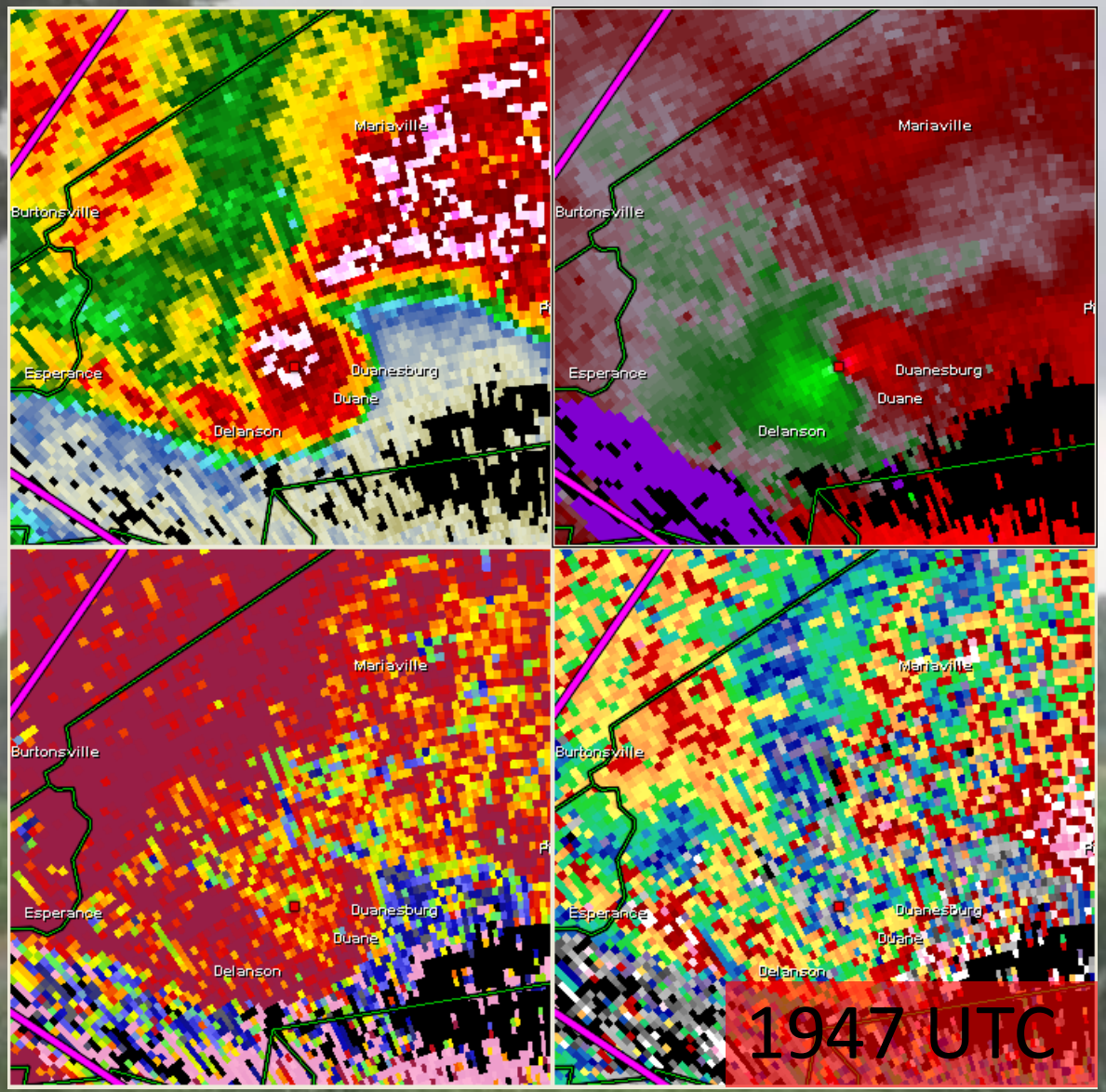
- Rotation tightens significantly.
- Classic “hook echo” on reflectivity.
- Only ~800ft ARL.
- Low CC likely hail falling through updraft.

Schenectady/Albany County NY 5/22/14



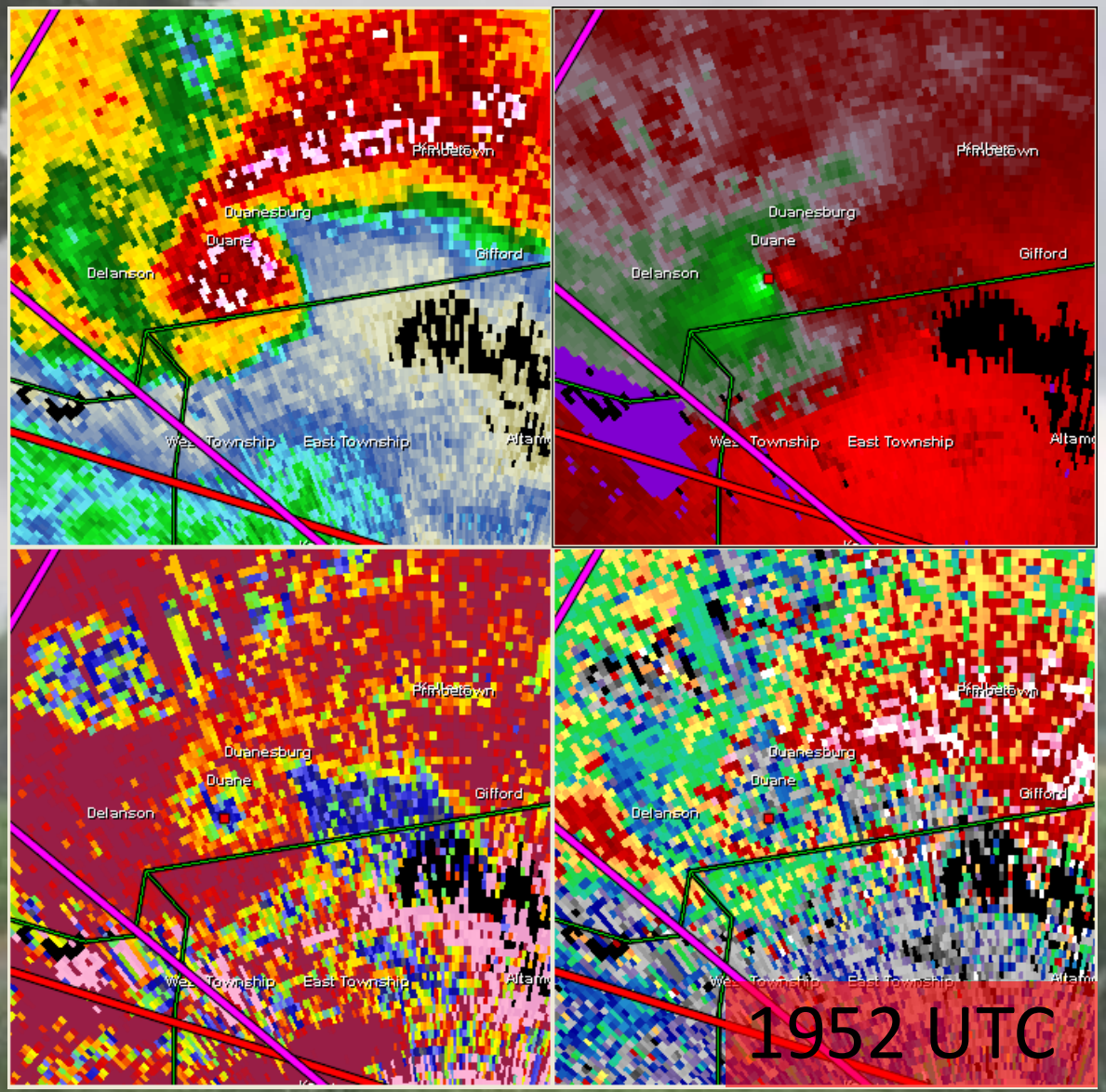
- Signal dominated still by hail.
- Arc of noisy/low CC and ZDR into ”hook”
- Still about 40 knots of Vrot.

Schenectady/Albany County NY 5/22/14



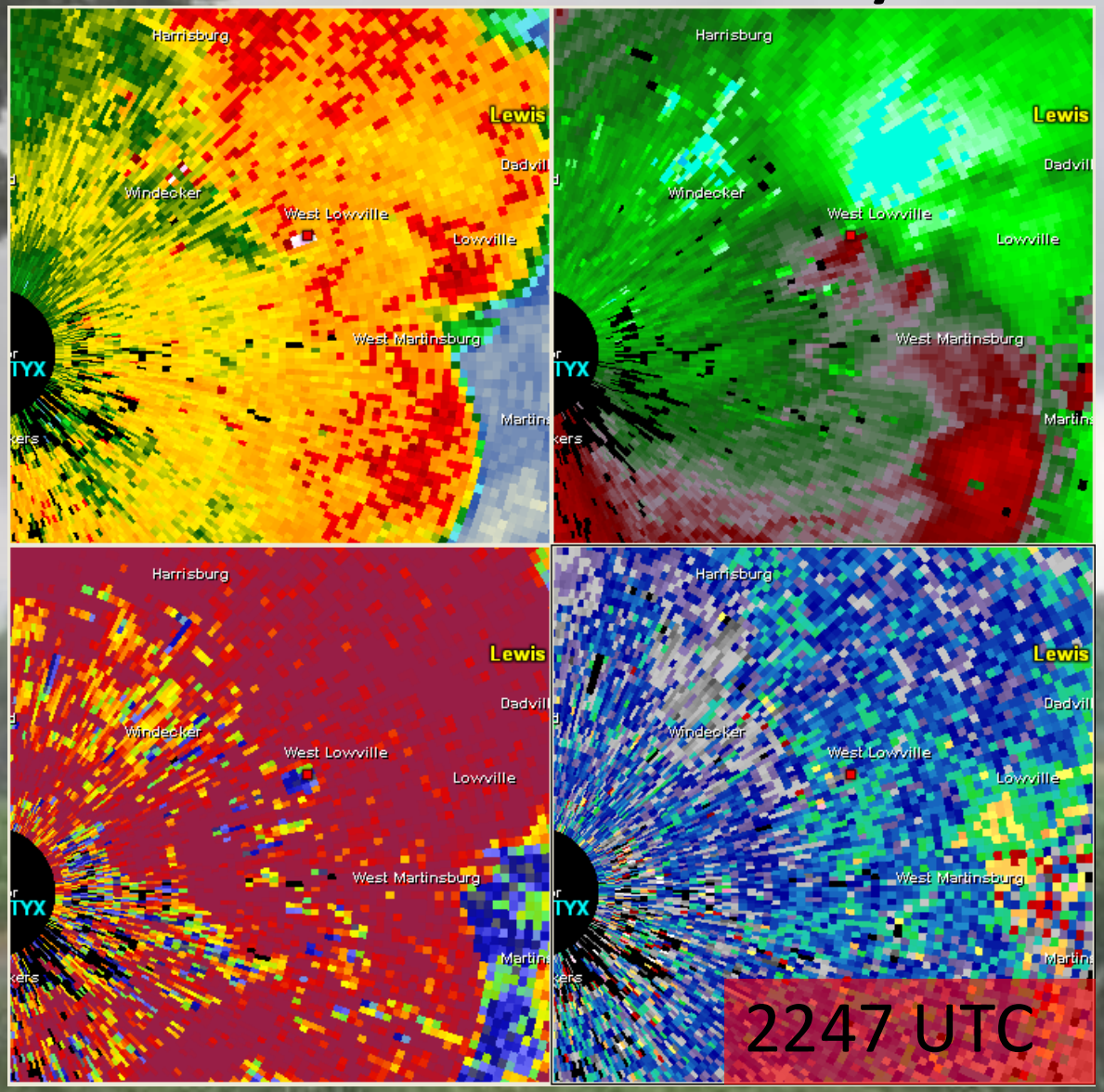
- Rotation strengthens near town of Delanson.
- EF-3 damage.
- Vrot ~46 knots.
- Possibly a TDS here?

Schenectady/Albany County NY 5/22/14



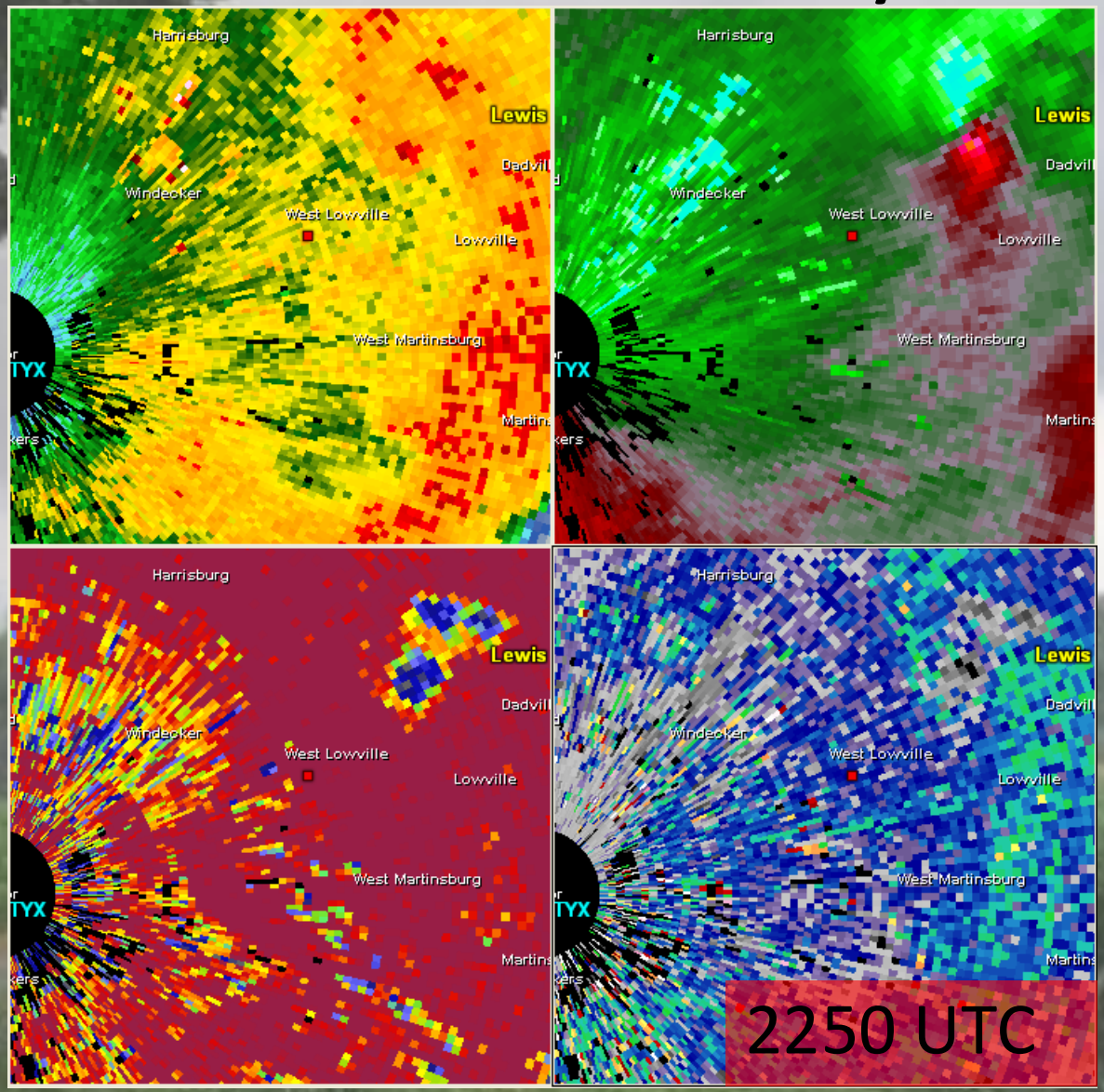
- Very clear TDS.
- Maximum Vrot of nearly 50 knots.
- Finally… a very clear TDS.

Lewis County NY 7/8/14



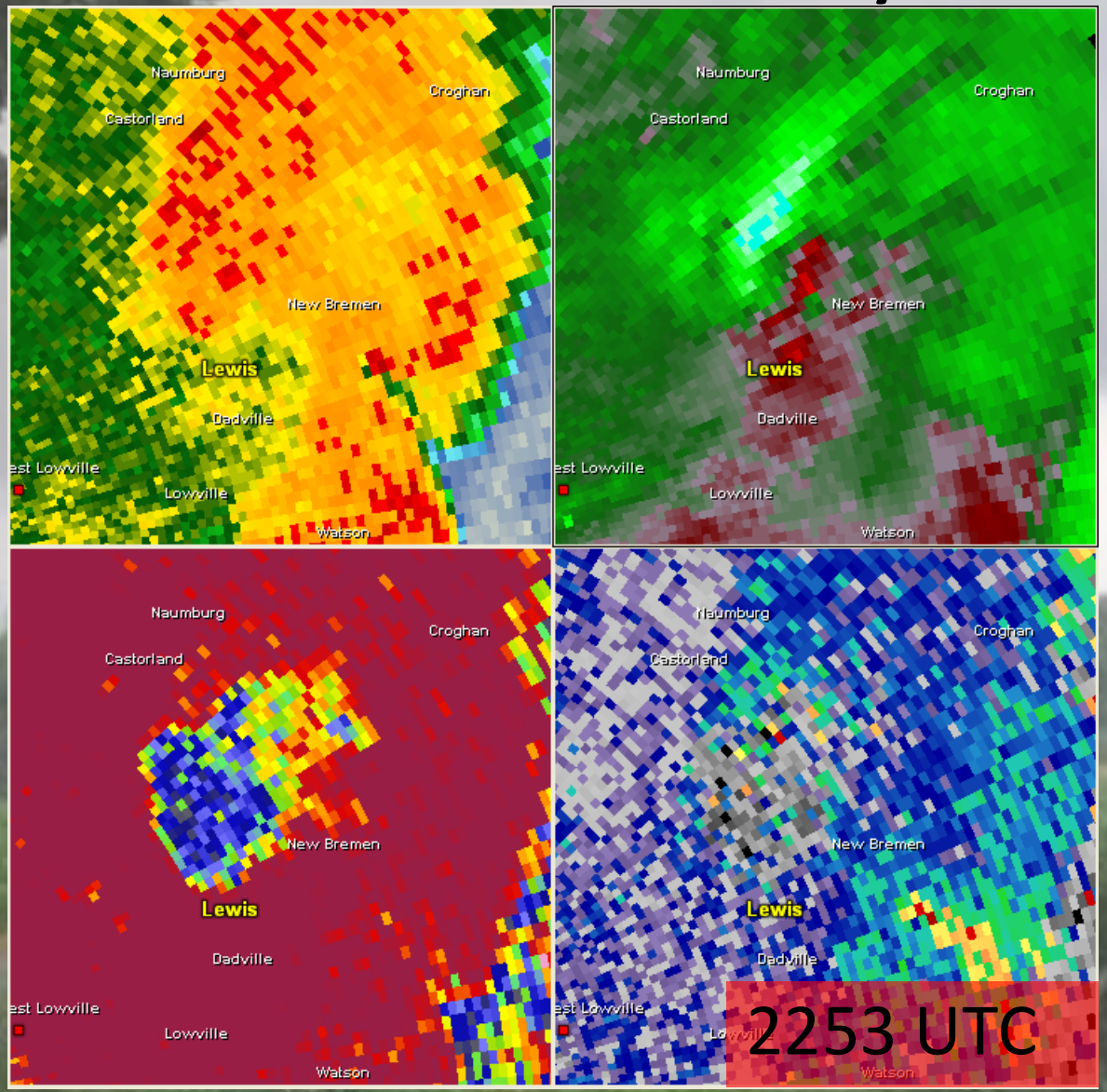
- Strongest velocity signature of all cases.
- 35 knots Vrot prior to tornado.

Lewis County NY 7/8/14



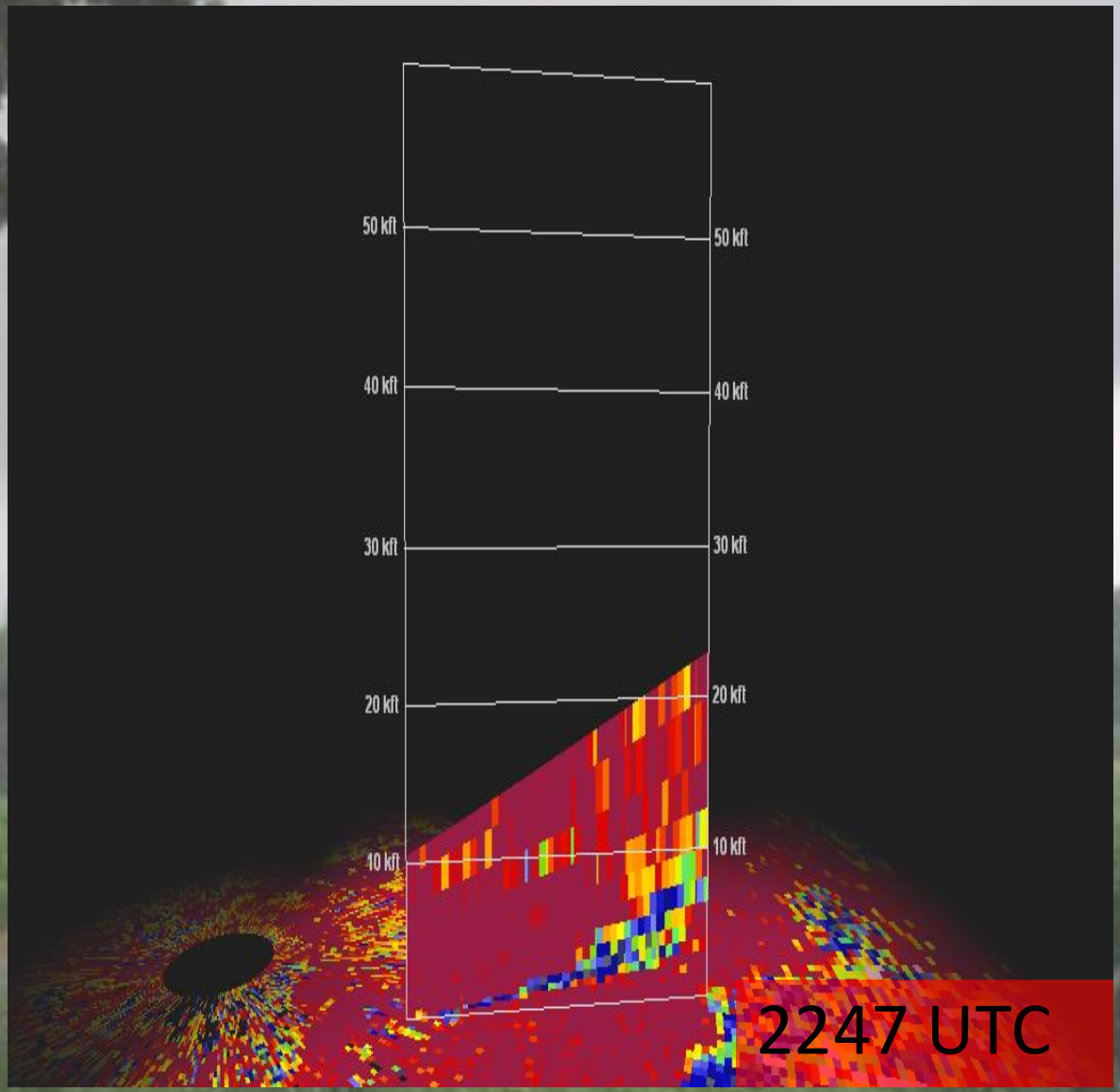
- Large/classic TDS.
- Vrot approaching 65 knots!

Lewis County NY 7/8/14



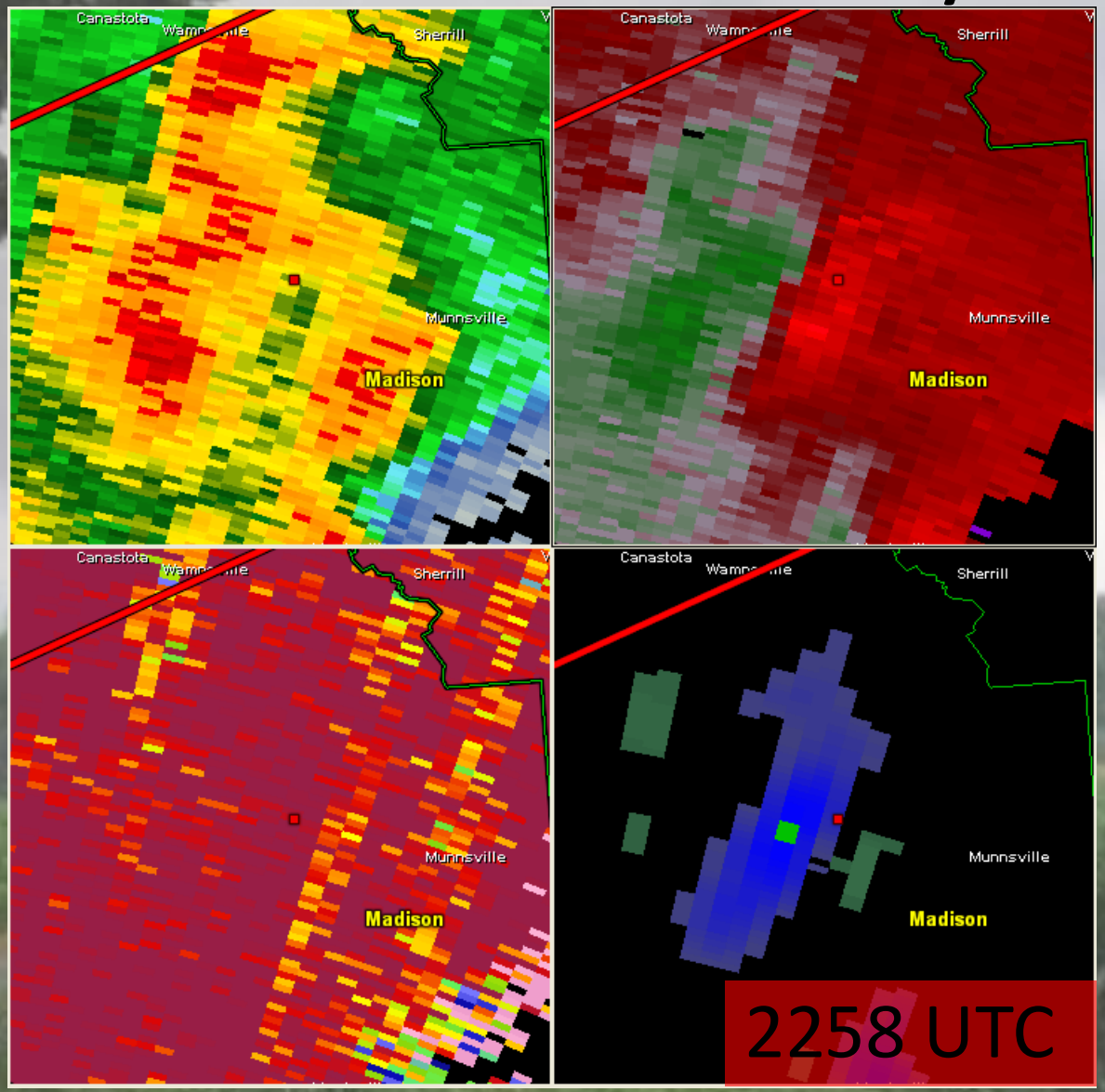
- Couplet weakens but TDS grows.

Lewis County NY 7/8/14



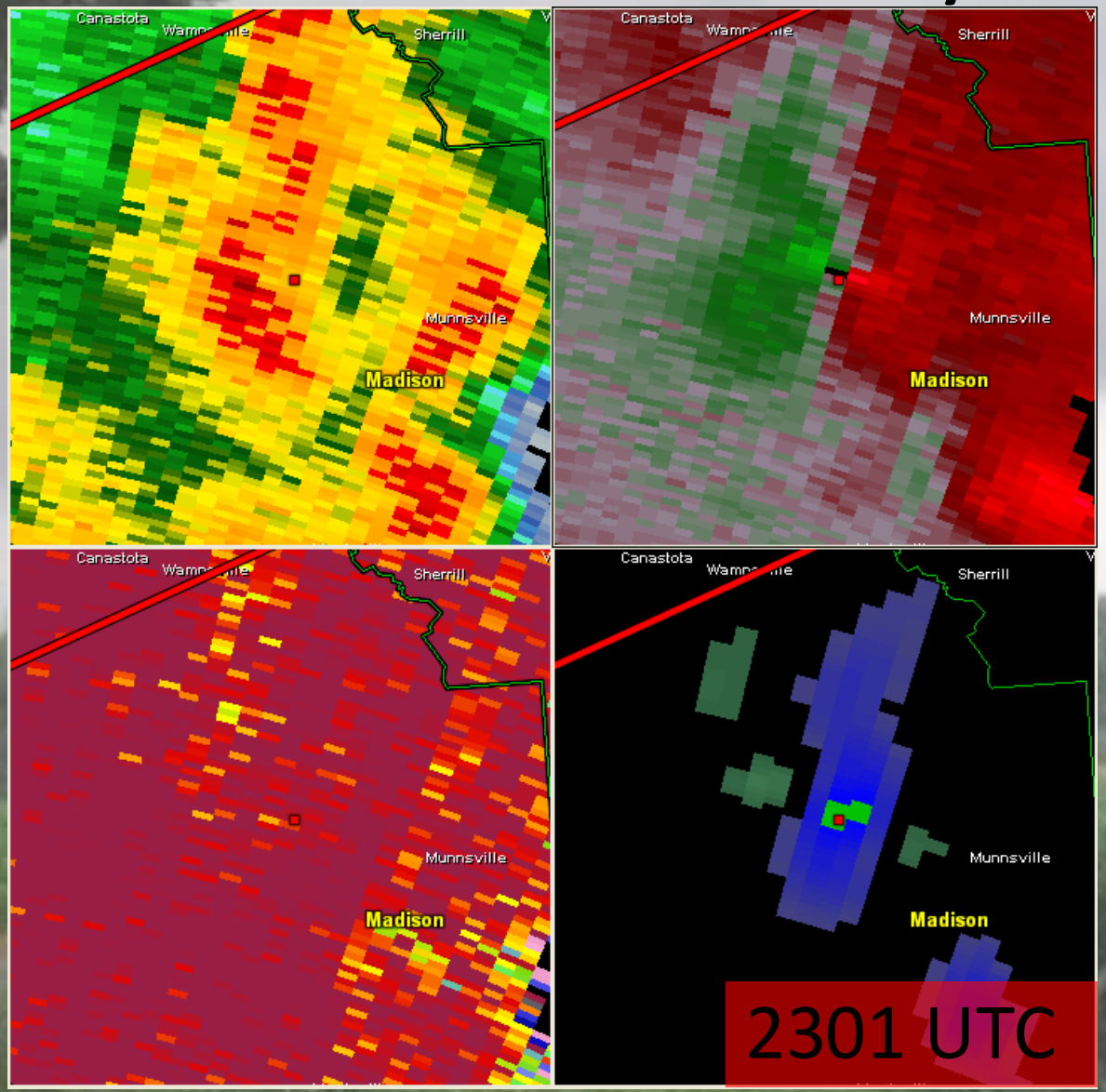
- Tornado debris reaches nearly 9,000 feet ARL.
- EF-1 strength, 12 mile path.

Madison County NY 7/8/14



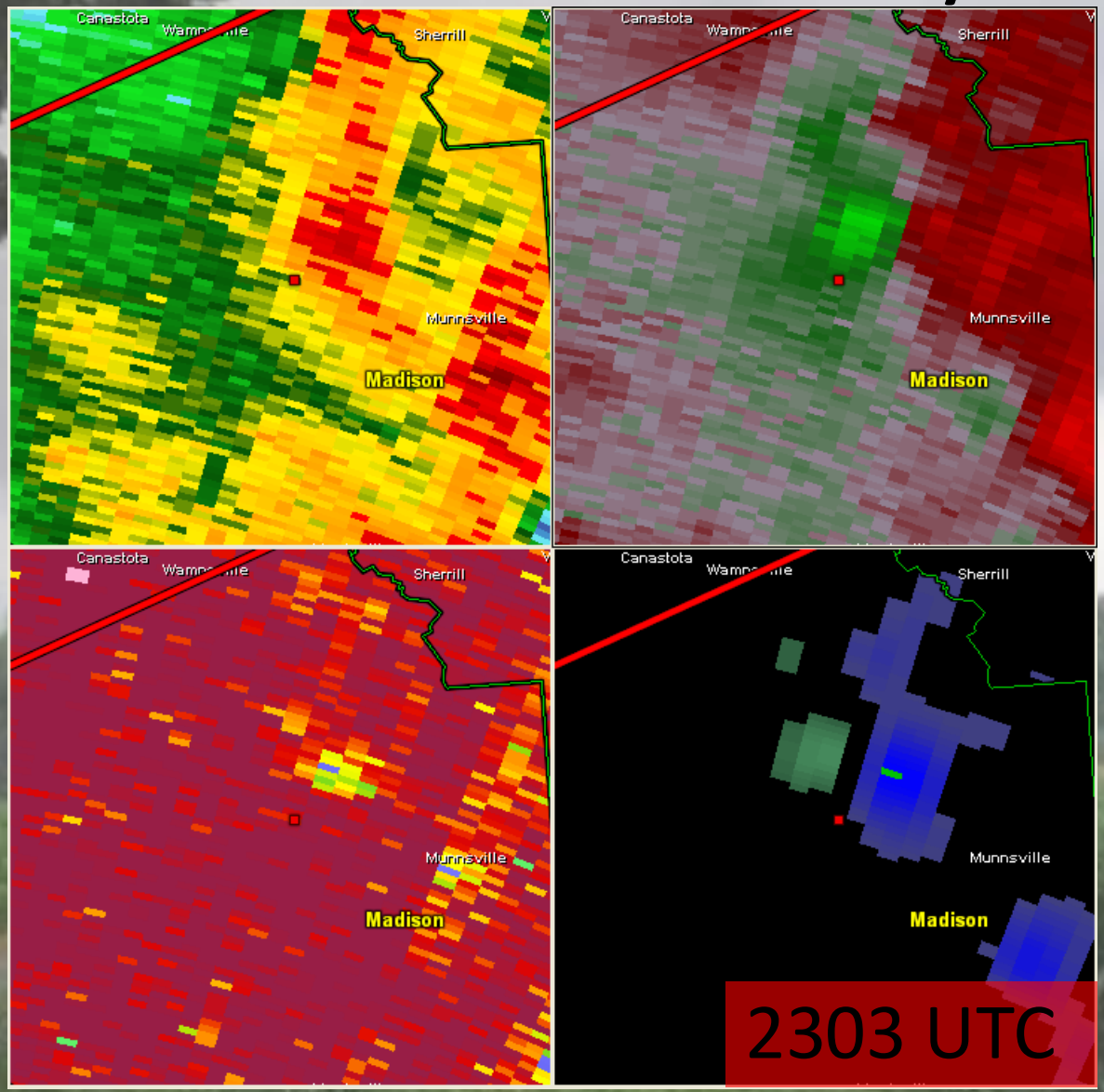
- 4 fatalities / EF-2 tornado.
- Broad meso prior to tgen.
- NROT > 1.00

Madison County NY 7/8/14



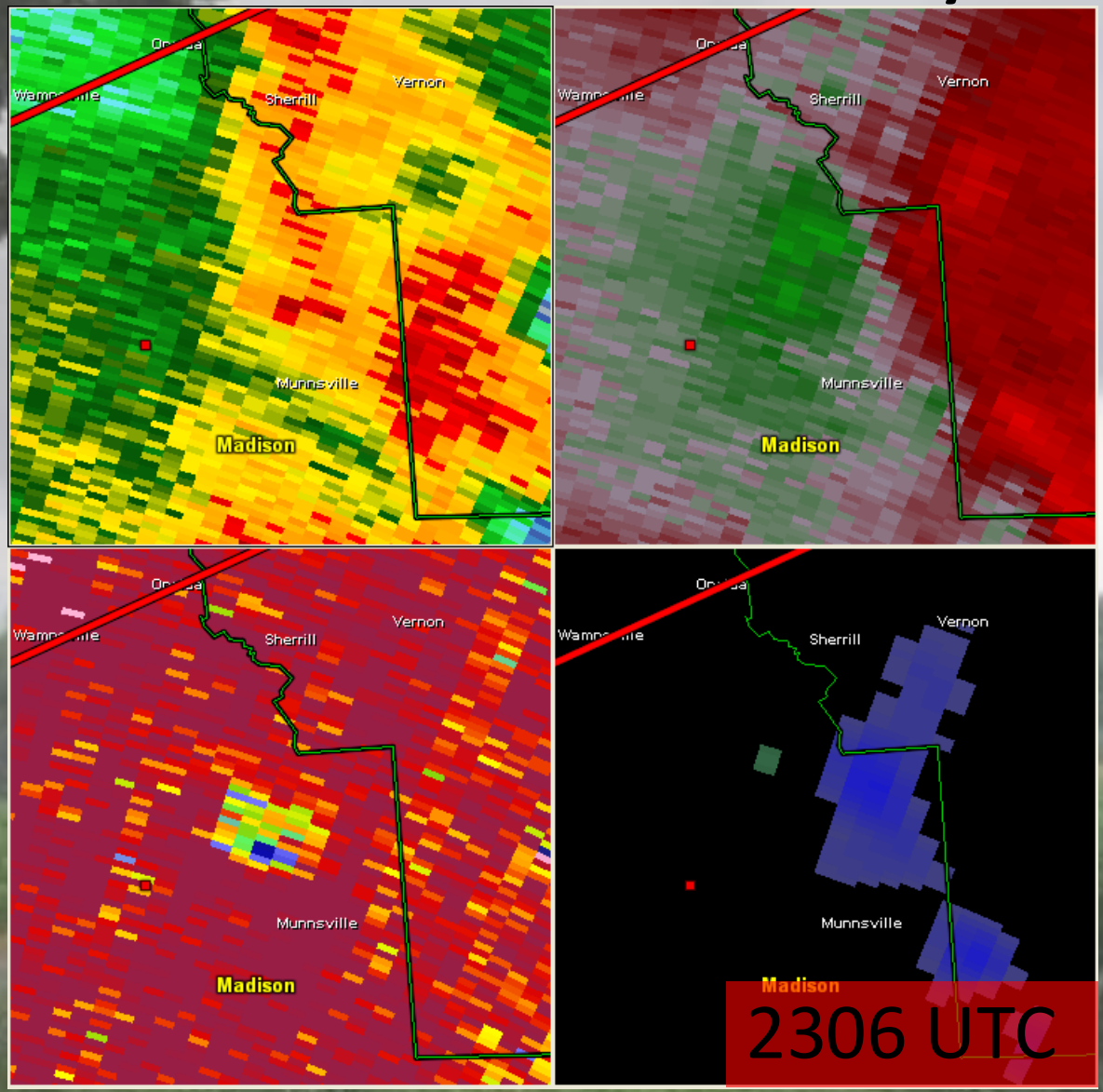
- Rapid tightening of low level rotation.
- Vrot of 35 knots at time of touchdown.

Madison County NY 7/8/14



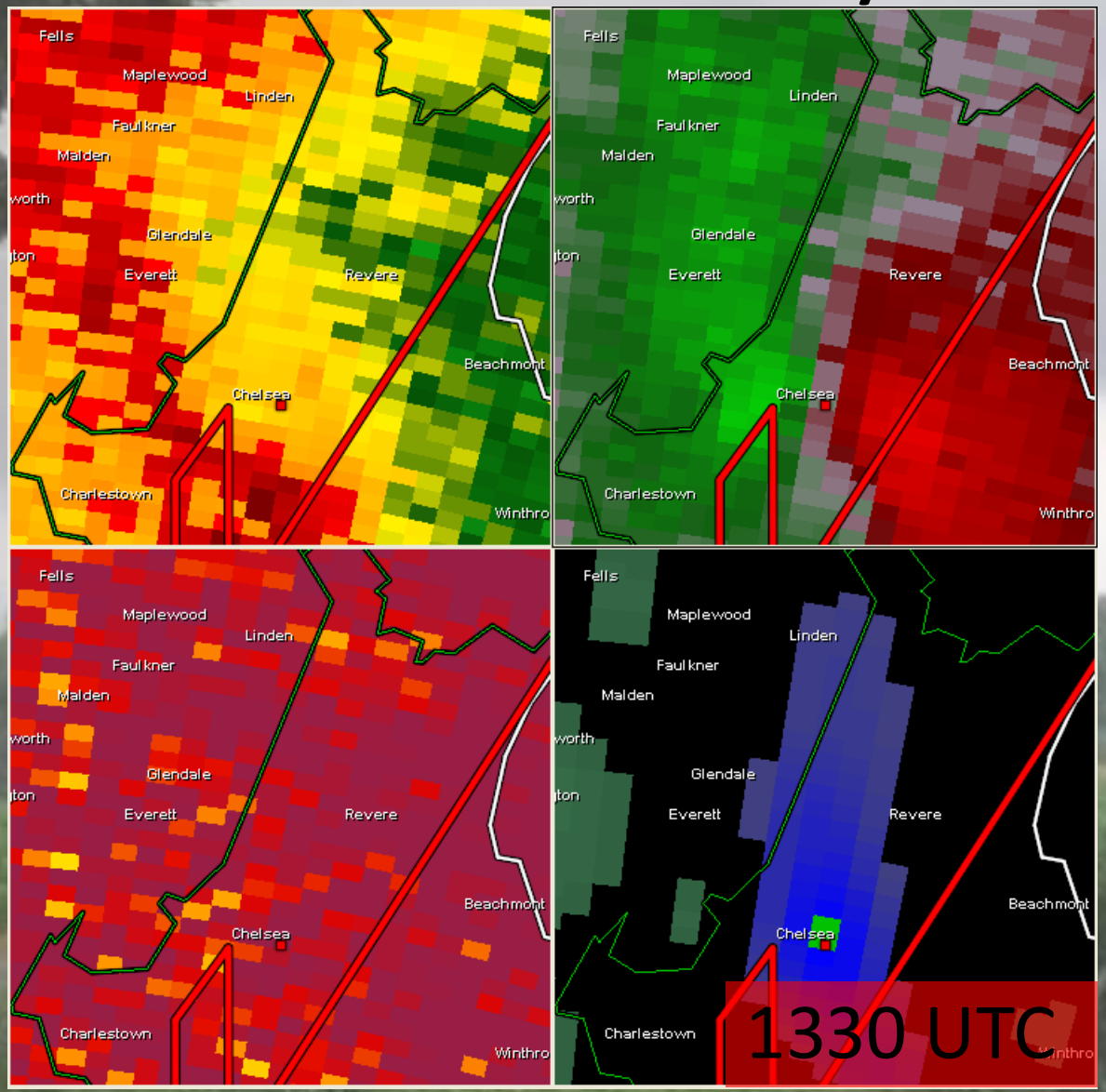
- TDS now apparent.

Madison County NY 7/8/14



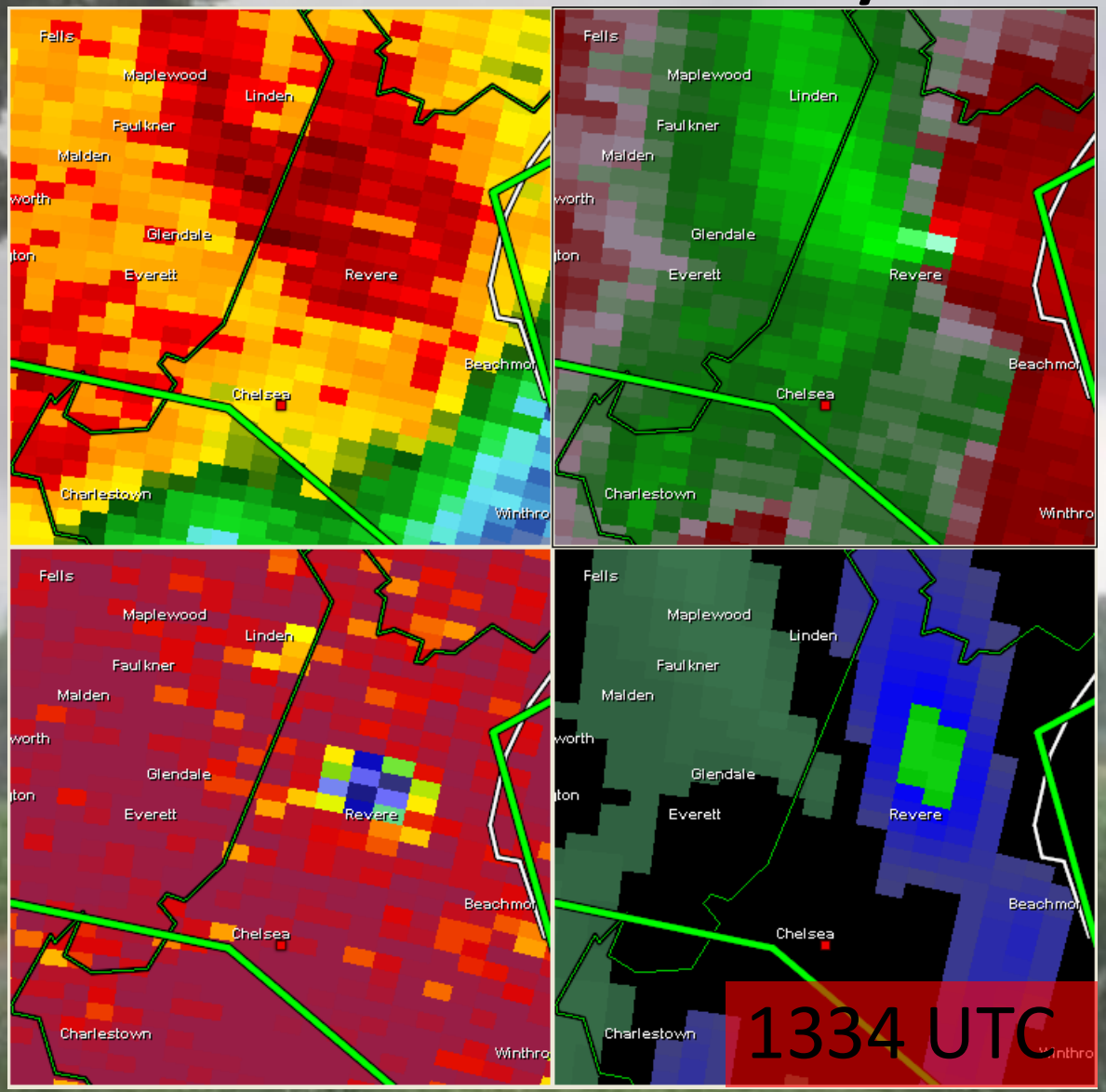
- Rotation has weakened, TDS remains.

Suffolk County MA 7/13/14



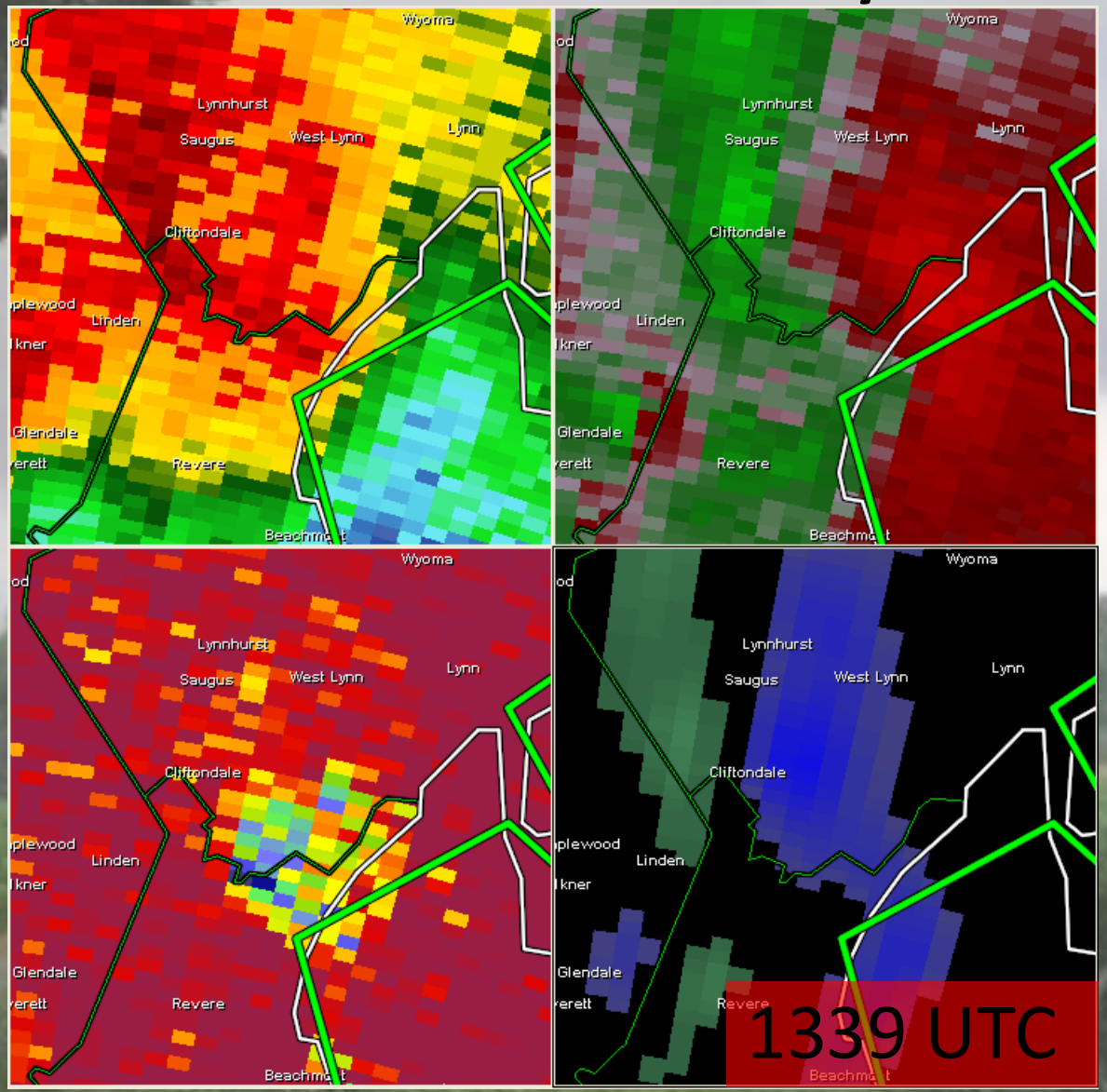
- Prior to touchdown 33 knots of Vrot (though not gate to gate)
- NROT >1.0

Suffolk County MA 7/13/14



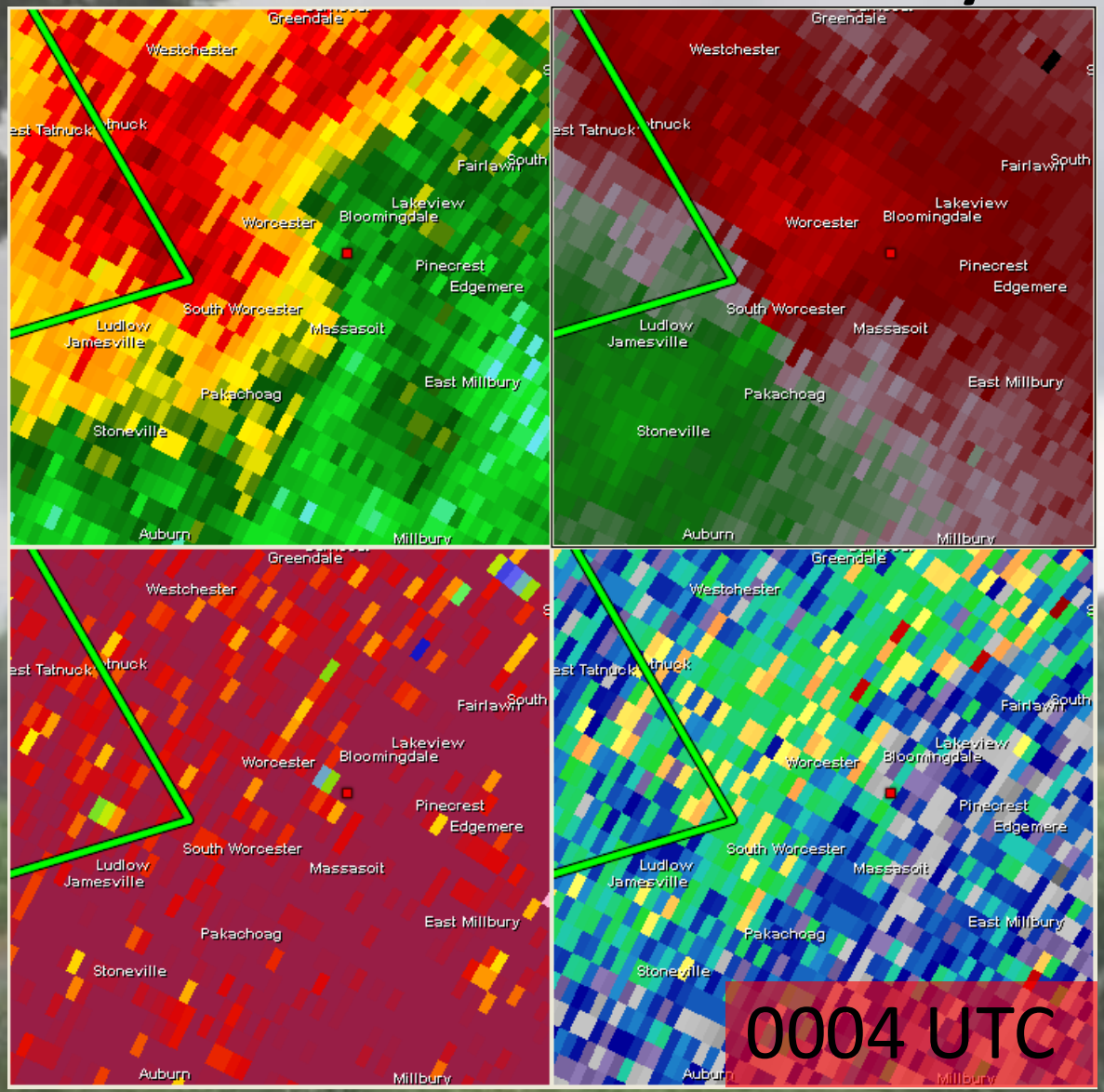
- VROT spikes to 42 knots after touchdown.
- NROT >1.0
- TDS extends up to 6100ft ARL.

Suffolk County MA 7/13/14



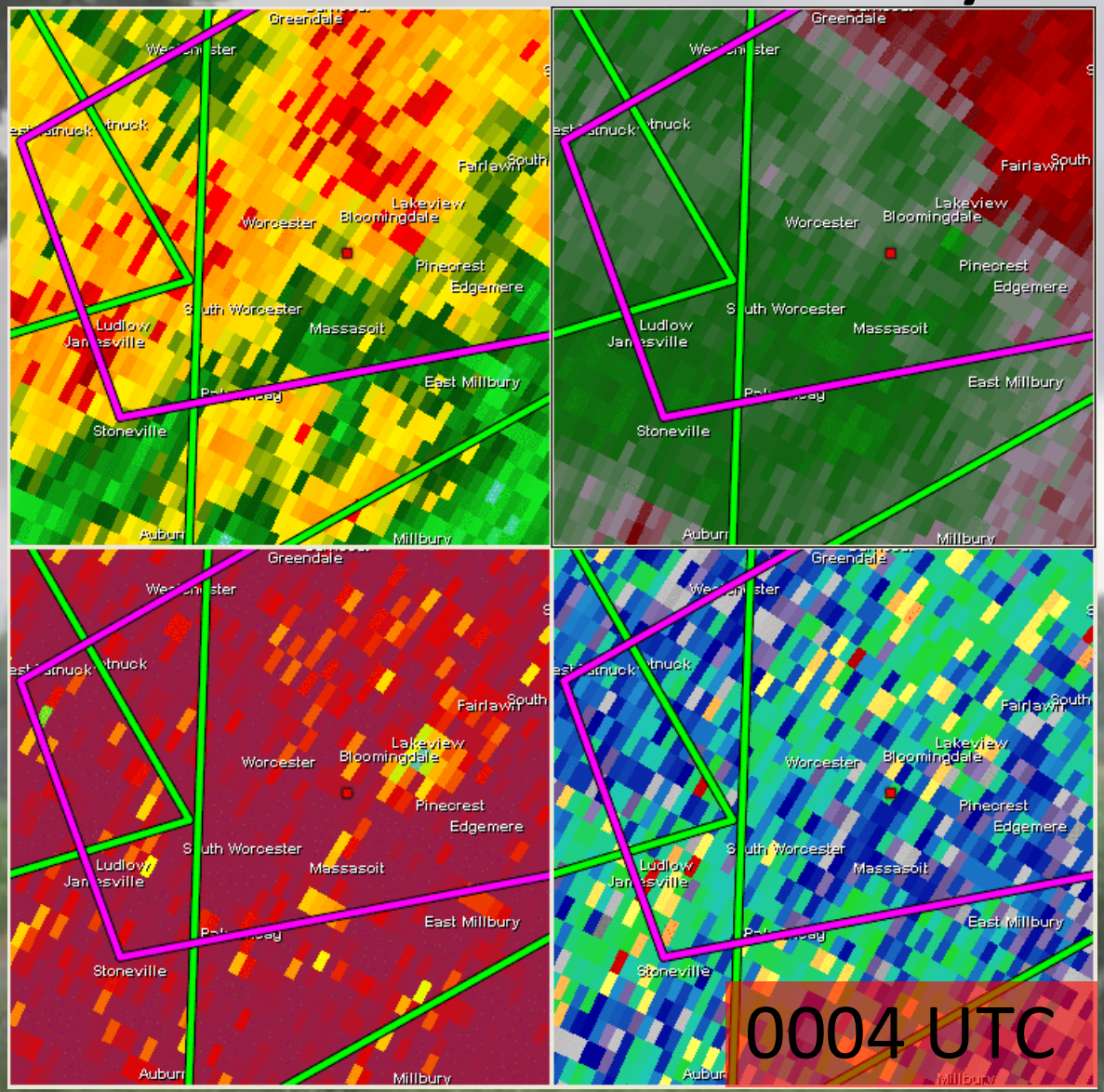
- Tornado lifts but debris remains lofted more than 5 minutes after tornado dissipates.

Worcester County MA 9/1/14



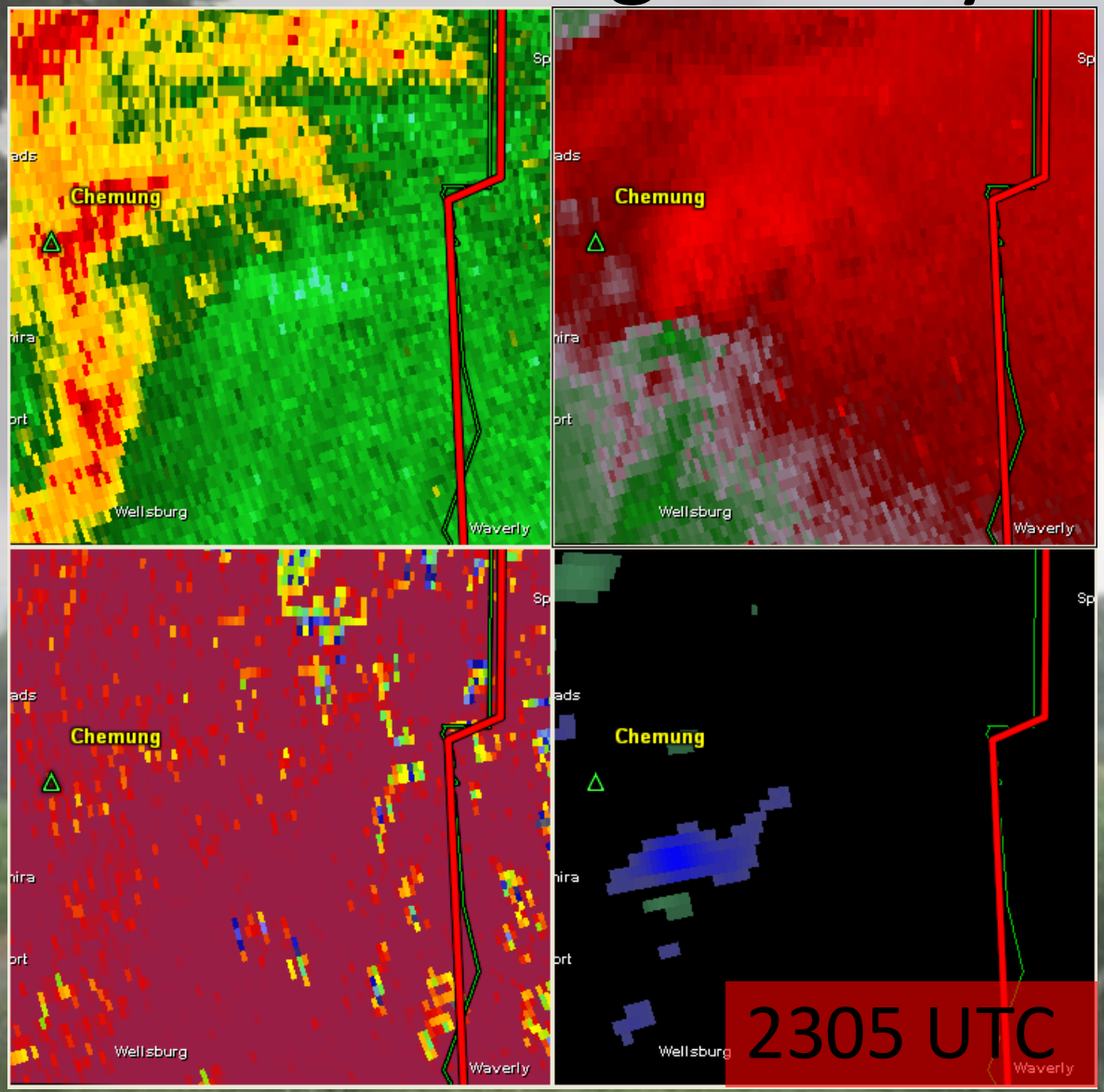
- 22 knots rotational velocity prior to touchdown.
- NROT = 0.81

Worcester County MA 9/1/14



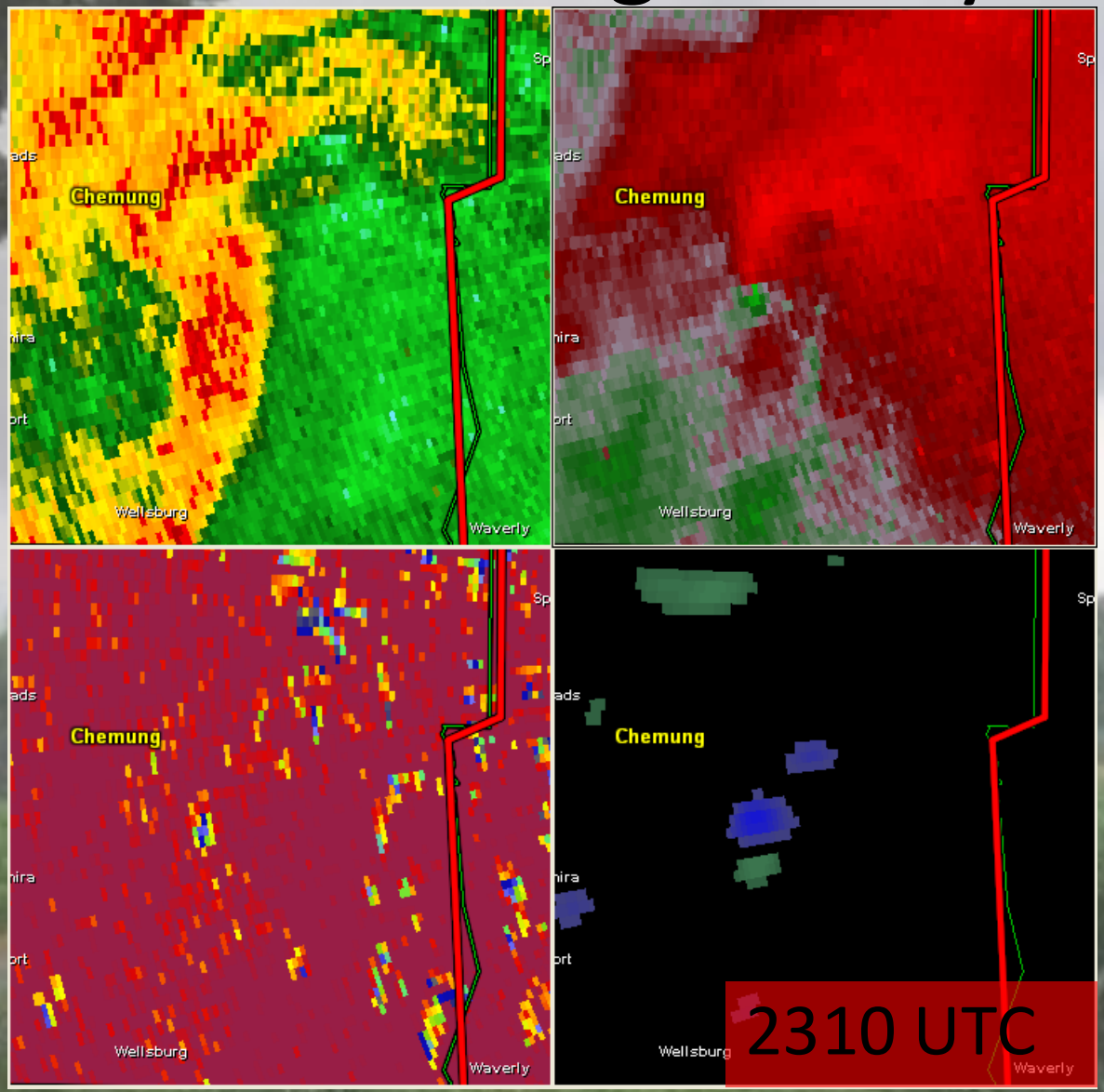
- Peak VROT (not gate to gate) of 28 knots.
- Small TDS does have vertical continuity 0.5 and 0.9 deg scans.

Chemung County NY 9/2/14



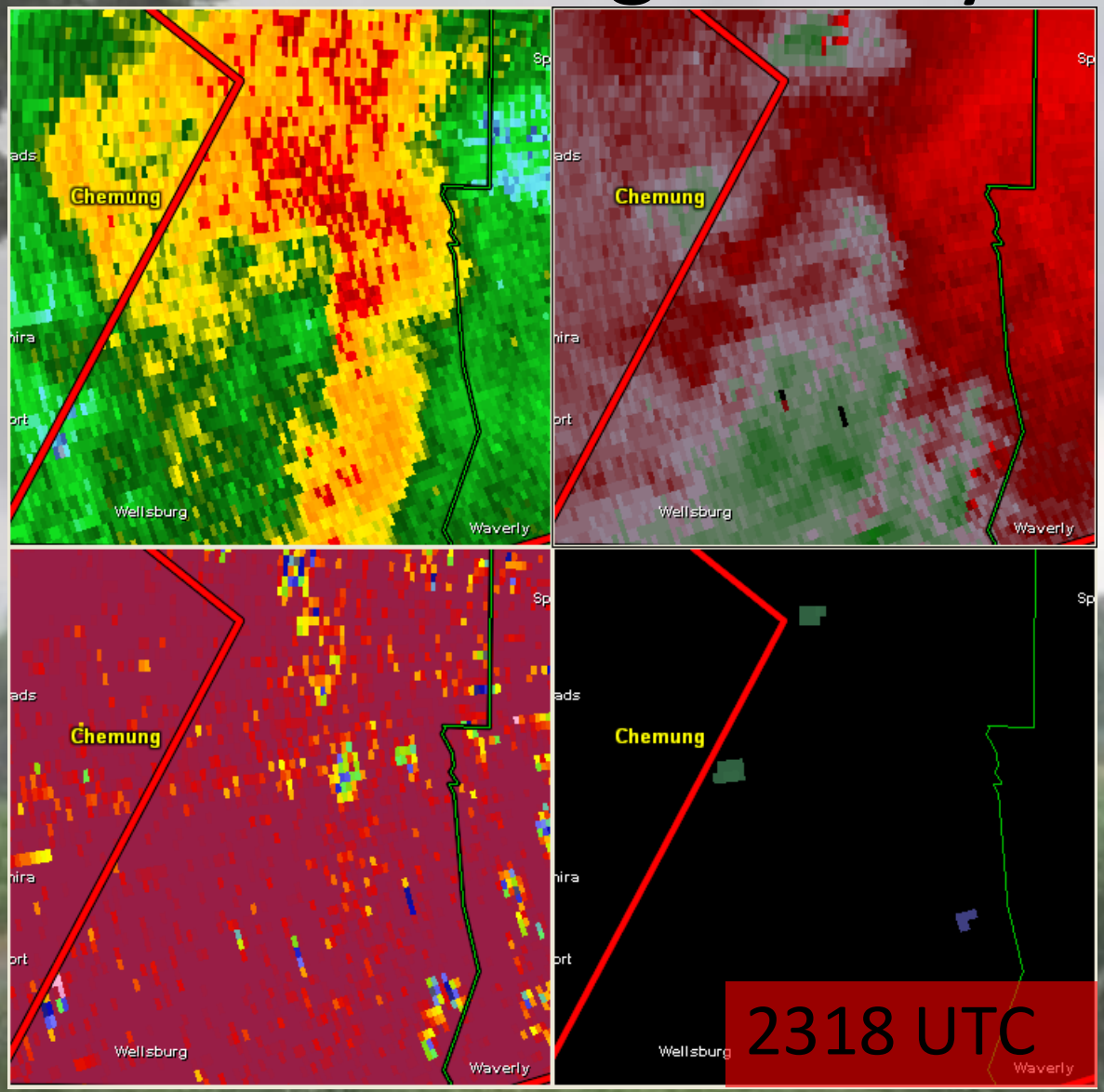
- Vrot of 26 knots prior to tgen.
- NROT = 0.93

Chemung County NY 9/2/14



- TDS reaches 9200ft ARL!
- Maximum Vrot of 29 knots.

Chemung County NY 9/2/14



- TDS lingers for nearly 10 minutes after tornado lifts.

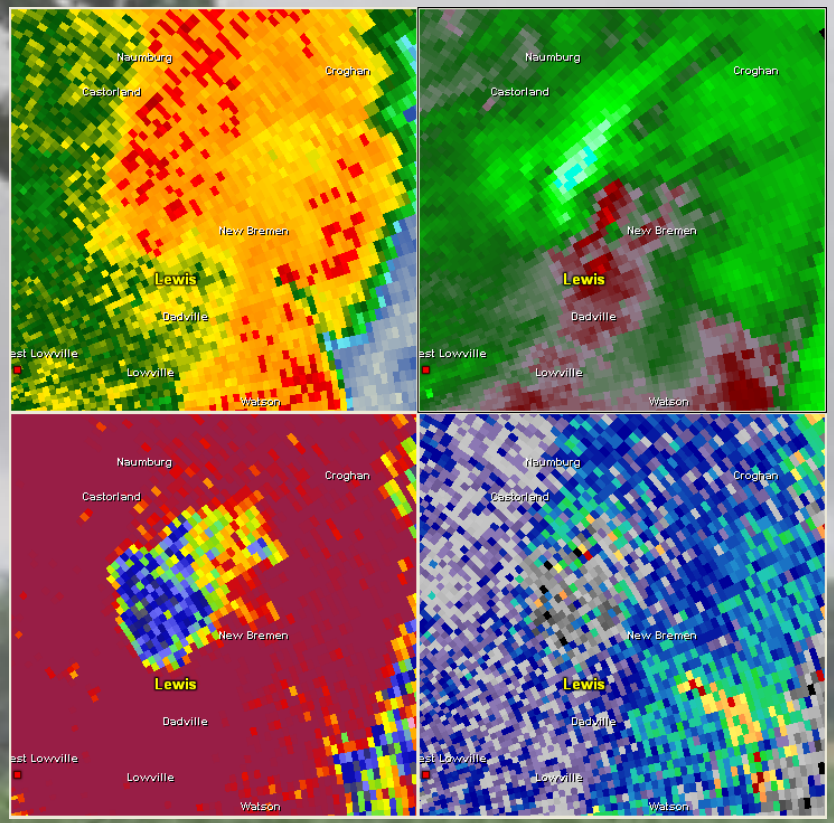
Summary

	Vrot Prior (kts)
Mean	25.5
Median	26.6

	Vrot Max (kts)
Mean	29.5
Median	30.7

- Rotational velocity exceeding 25 knots is a good threshold for “concern”.
- Previous CT-based study had 22.5 knots of Vrot… with many pre-super resolution cases.
- 3 out of the 4 EF-2 or greater tornadoes had Vrot >40 knots.

Summary



- Tornado warnings preceded TDS only 2 of 14 times.
- Can be useful to issue a warning in borderline case?
- Still, 10 of 54 tornadoes had no velocity signature at all.