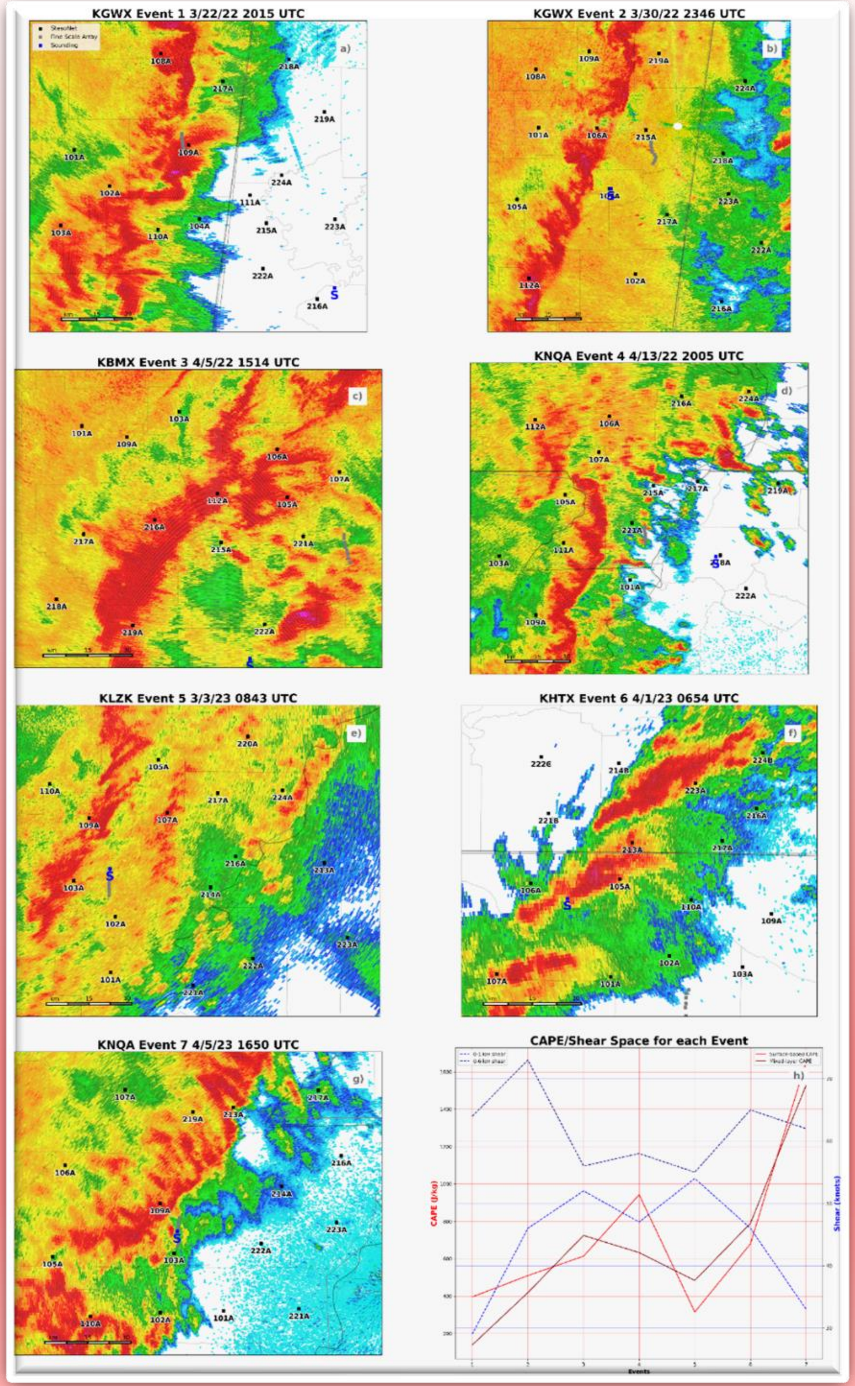

TEXAS TECH UNIVERSITY
Department *of* Geosciences

Texas Tech StickNet Near-Mesovortex Observations during PERiLS

Joshua Ostaszewski and Christopher Weiss

Ostaszewski J. S., and C. C. Weiss, 2023: Surface Cold Pool Observations near Tornadic and Nontornadic QLCS Mesovortices during PERiLS. *In Prep*.

Acknowledgements: *Jessica McDonald, TTU PhD Candidate*
Alex Schueth, TTU PhD Candidate
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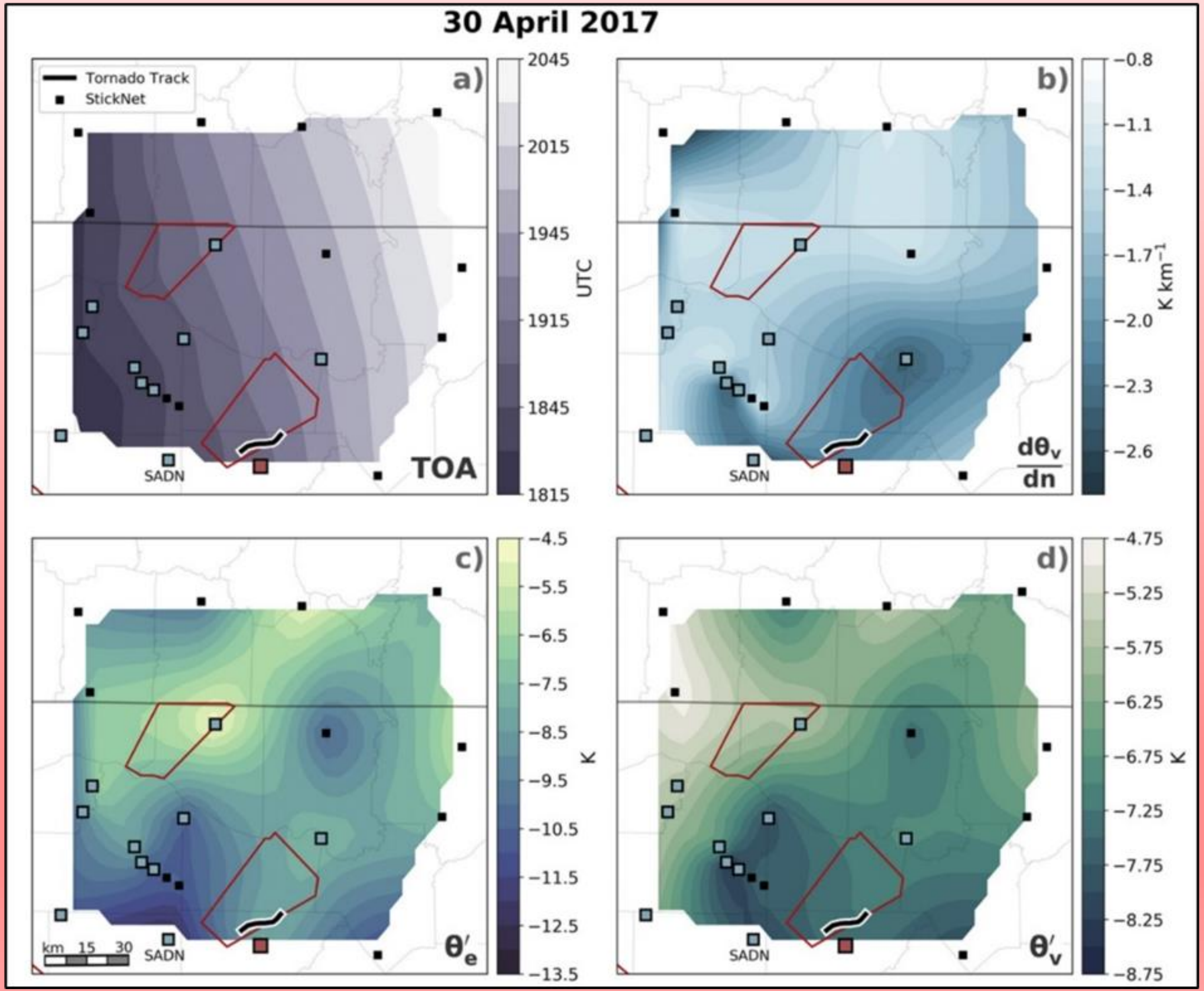
Correlation between Horizontal Baroclinic Vorticity Generation and Tornado likelihood

- McDonald and Weiss 2021 found during the VORTEX-SE field project that the strongest horizontal θ_v gradients were near tornadic portions of the QLCS
  - Greater relative baroclinity near rotation
  - A *possible* source of vorticity for tornadogenesis through the implied baroclinic vorticity generation
  - Same correlation not found in the deficits
  - Contradicts supercell cold pool studies

1. *Do similar thermodynamic gradient and deficit findings from McDonald and Weiss (2021) translate to the QLCSs observed during PERiLS?*
2. *How do thermodynamic gradients and deficits change north vs. south of a mesovortex?*
3. *Are thermodynamic gradients and deficits near tornadic mesovortices dependent on the time relative to the tornado occurring?*
4. *Do supercells in HSLC environments have weaker overall cold pools?*
5. *What are the differences in cold pool characteristics of 'hybrid mesovortices' that are attributed to supercell-QLCS mergers?*



McDonald and Weiss 2021 (Fig.8)

PERiLS Overview and StickNet Intercept Totals

166 total cold pool intercepts!
142 HSLC intercepts!

Year One

Storm Mode	IOP1	IOP2	IOP3	IOP4	TOTAL
Linear: NR	1	0	5	6	12
Linear: MV	3	22	11	16	52
MC	6	0	1	0	7
Mixed	16	0	2	0	18
Hybrid	4	2	4	0	10

Rotating Storms	IOP1	IOP2	IOP3	IOP4	TOTAL
MV-NT	2	12	11	4	29
MV-TOT	1	10	0	3	14
MV-PRE	0	0	0	1	1
MV-POST	0	0	0	8	8
MC-NT	4	0	1	0	5
MC-TOT	1	0	0	0	1
MC-PRE	0	0	0	0	0
MC-POST	1	0	0	0	1
Mixed-NT	4	0	2	0	6
Mixed-TOT	10	0	0	0	10
Mixed-PRE	1	0	0	0	1
Mixed-POST	1	0	0	0	1
Hybrid-NT	3	0	1	0	4
Hybrid-TOT	0	1	1	0	2
Hybrid-PRE	0	1	2	0	3
Hybrid-POST	1	0	0	0	1

Year Two

Storm Mode	IOP1	IOP2	IOP3	IOP4	IOP5	TOTAL
Linear: NR	0	11	0	0	0	11
Linear: MV	0	4	0	0	20	24
MC	0	0	0	28	0	28
Mixed	0	0	0	0	0	0
Hybrid	0	0	0	0	4	4

Rotating Storms	IOP1	IOP2	IOP3	IOP4	IOP5	TOTAL
MV-NT	0	4	0	0	20	24
MV-TOT	0	0	0	0	0	0
MV-PRE	0	0	0	0	0	0
MV-POST	0	0	0	0	0	0
MC-NT	0	0	0	27	0	27
MC-TOT	0	0	0	1	0	1
MC-PRE	0	0	0	0	0	0
MC-POST	0	0	0	0	0	0
Mixed-NT	0	0	0	0	0	0
Mixed-TOT	0	0	0	0	0	0
Mixed-PRE	0	0	0	0	0	0
Mixed-POST	0	0	0	0	0	0
Hybrid-NT	0	0	0	0	4	4
Hybrid-TOT	0	0	0	0	0	0
Hybrid-PRE	0	0	0	0	0	0
Hybrid-POST	0	0	0	0	0	0

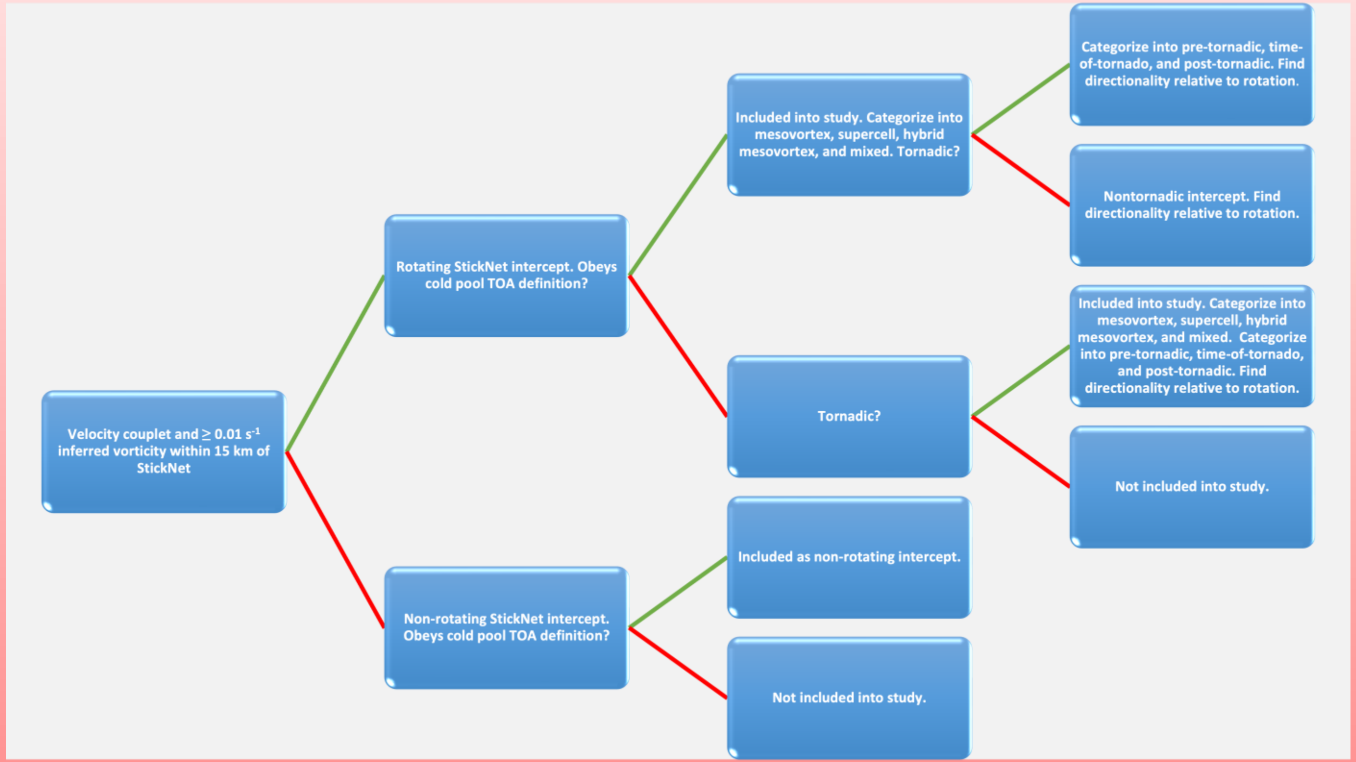
Y1+Y2

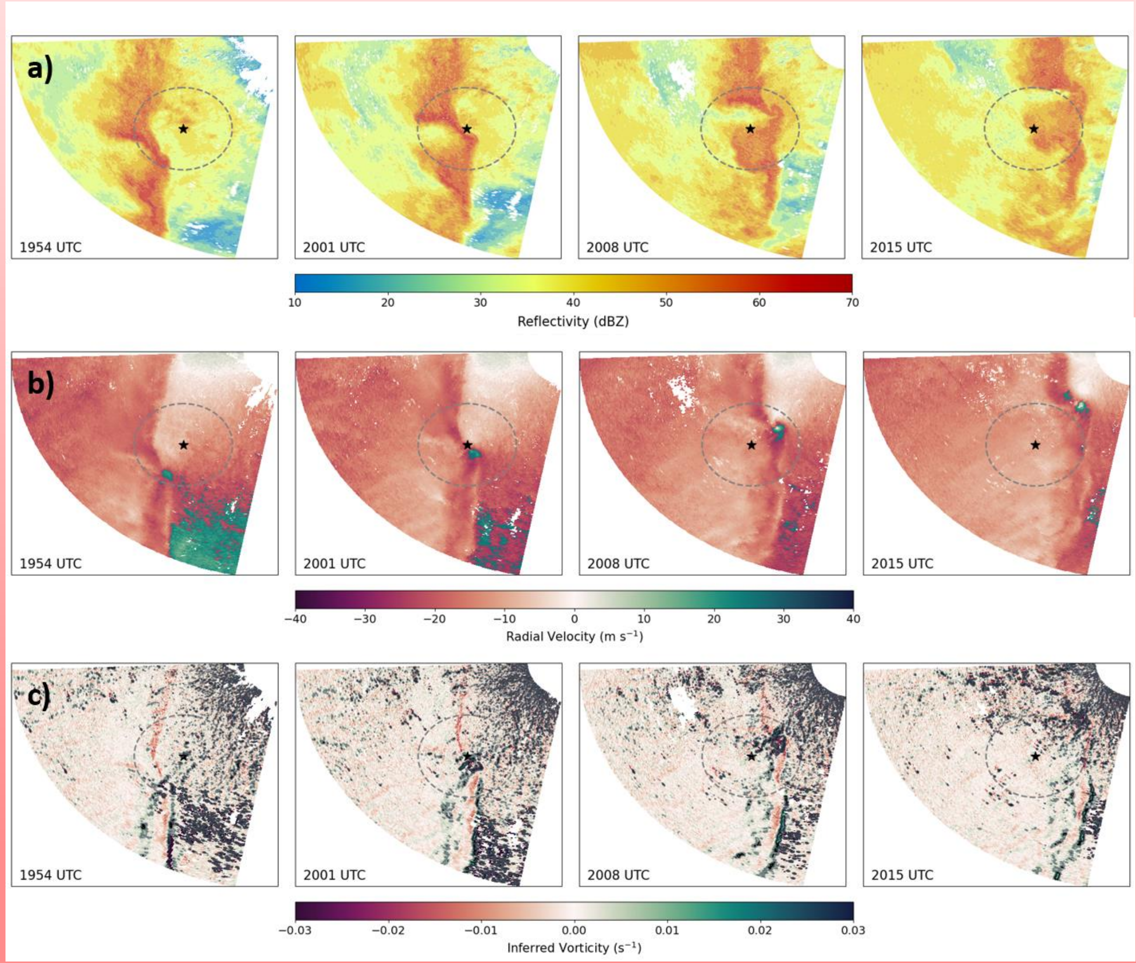
Storm Mode	TOTAL	
Linear: NR	23	
Linear: MV	76	*56 HSLC MVs
MC	35	
Mixed	18	
Hybrid	14	*10 HSLC H

Rotating Storms	TOTAL	
MV-NT	53	*33 HSLC NT MVs
MV-TOT	14	
MV-PRE	1	
MV-POST	8	
MC-NT	32	
MC-TOT	2	
MC-PRE	0	
MC-POST	1	
Mixed-NT	6	
Mixed-TOT	10	
Mixed-PRE	1	
Mixed-POST	1	
Hybrid-NT	8	*4 HSLC NT H
Hybrid-TOT	2	
Hybrid-PRE	3	
Hybrid-POST	1	

*Does not include the 17 NT MCs from IOP2 and the 26 NT MCs from IOP3 due to not being HSLC

StickNet Intercept Definition





A StickNet intercept is deemed near rotation if a collocation of a ***radial velocity couplet*** *and* ***inferred vorticity > 0.01 s^{-1}*** *occurred within a* *<u>15 km radius of the probe</u>*

**Used the closest WSR-88D*

$$\zeta_i = \frac{2}{r\sin(\varphi)}\frac{\partial V_r}{\partial \theta}$$

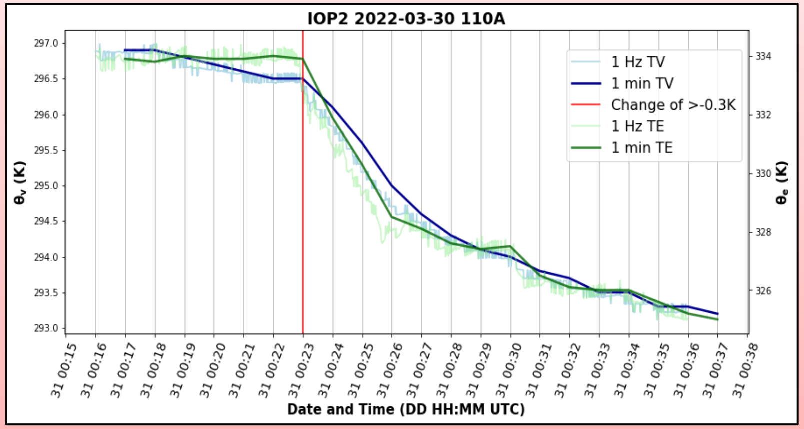
r :radial distance from the radar

φ:radar zenith angle

V_r: radar radial velocity field

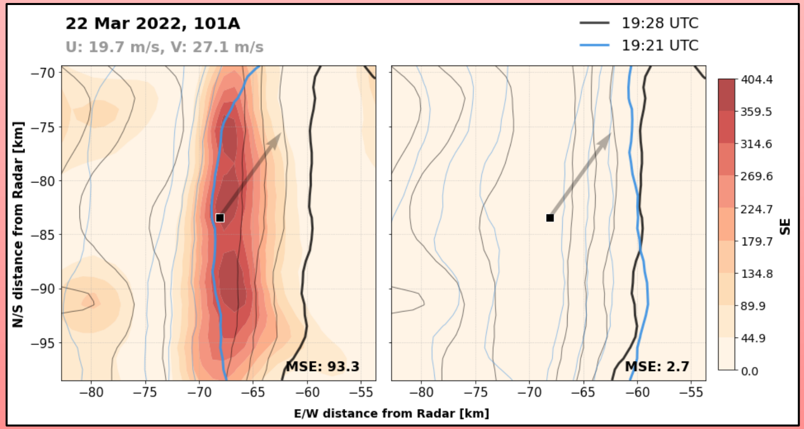
θ: radar azimuth

Characterization of Cold Pools



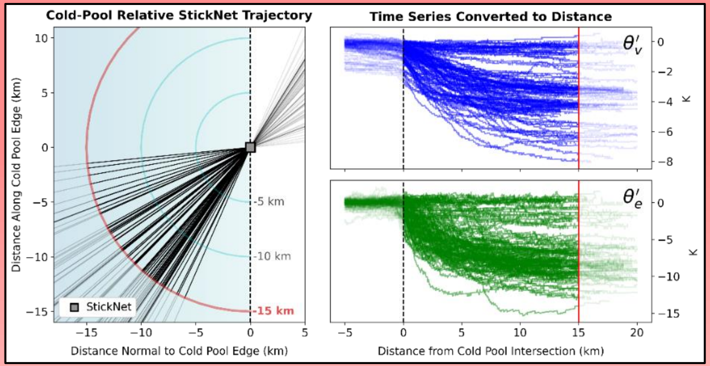
Identify cold pool TOA

A one-minute decrease in θ_v of 0.3 K, 0.2 K, or 0.1 K that occurs over at least two consecutive minutes



Calculate Storm Motions

Two ref scans are interpolated on a 1 km grid, subset to a 30 km box, and the first scan is shifted to the next to find the exact orientation that minimizes the MSE



Calculate Base State and Deficits

BS: Time-to-space conversions then averaging 10-15 km before TOA.

Deficits: Subtract BS from minimum found within 15 km of the cold pool

Storm Mode Types

- **Linear-NR:** Non-rotating segments of QLCS
- **Mesovortex (MV):** Embedded circulation along leading edge of QLCS
- **Hybrid (H):** MV with part of circulation attributed and traced back from MC/QLCS merger upstream
- **Mesocyclone (MC):** Discrete circulation clearly separated from QLCS
- **Mixed (M):** Sampled QLCS with a MC within 15 km. Unable to separate cold pools

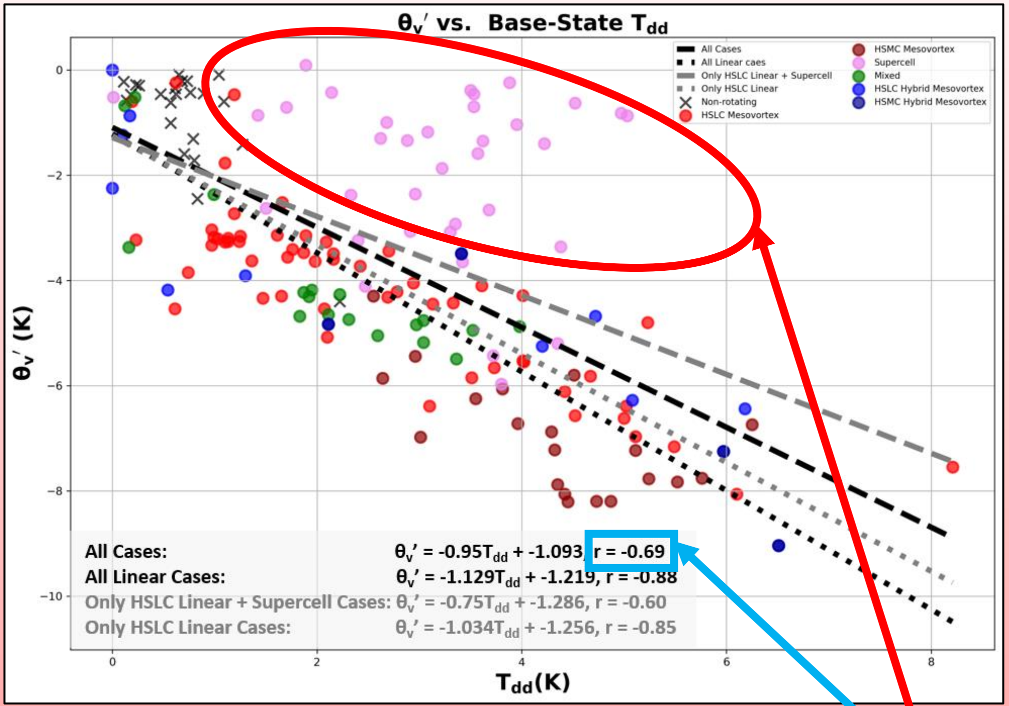
Tornadic Intercepts

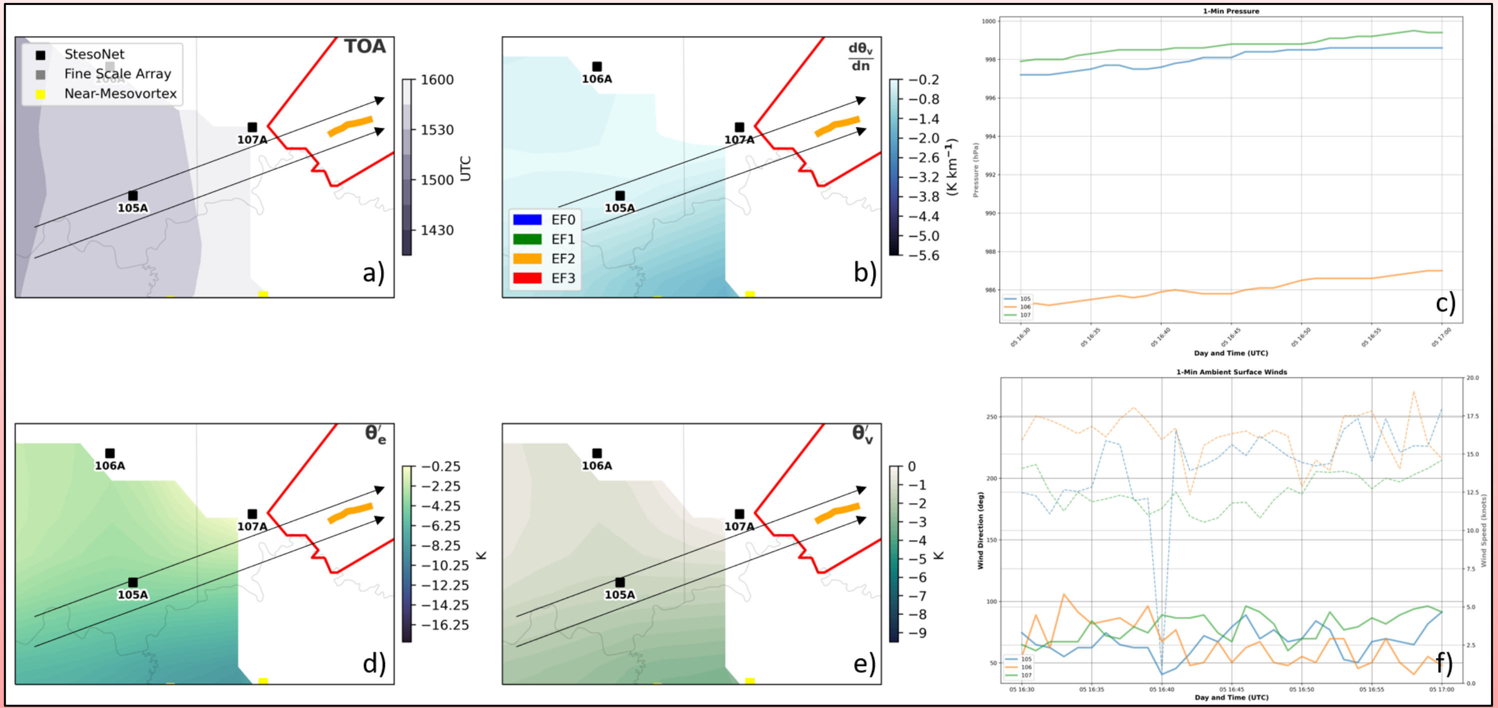
Time of Tornado: Tornado occurred within 15 km of a probe

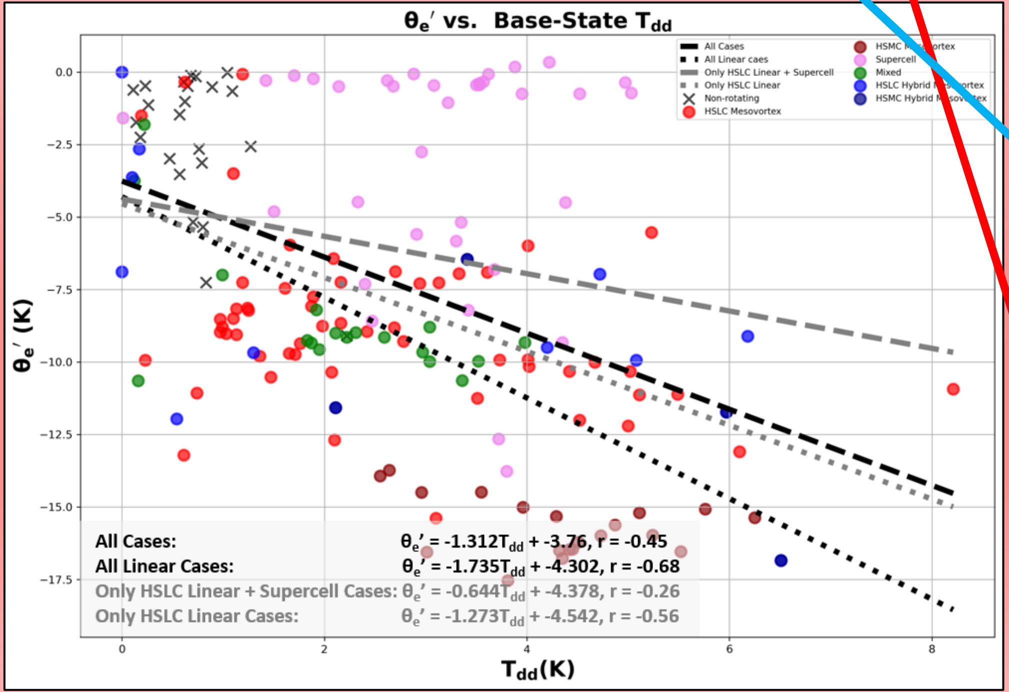
Pre-Tornadic: Tornado occurred >15 km radius, -30 mins of TOA

Post-Tornadic: Tornado occurred >15 km radius, +30 mins of TOA

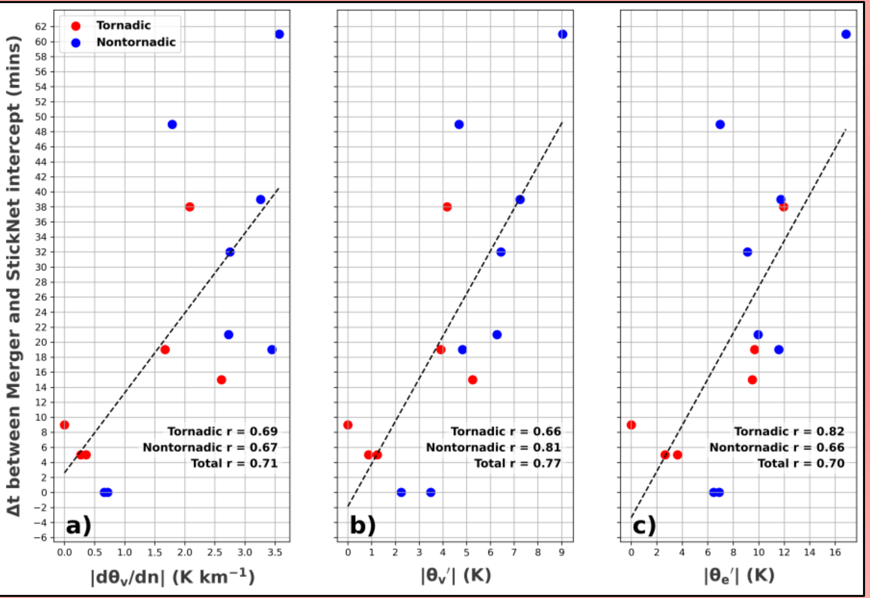
Hybrid Mesovortex Intercepts



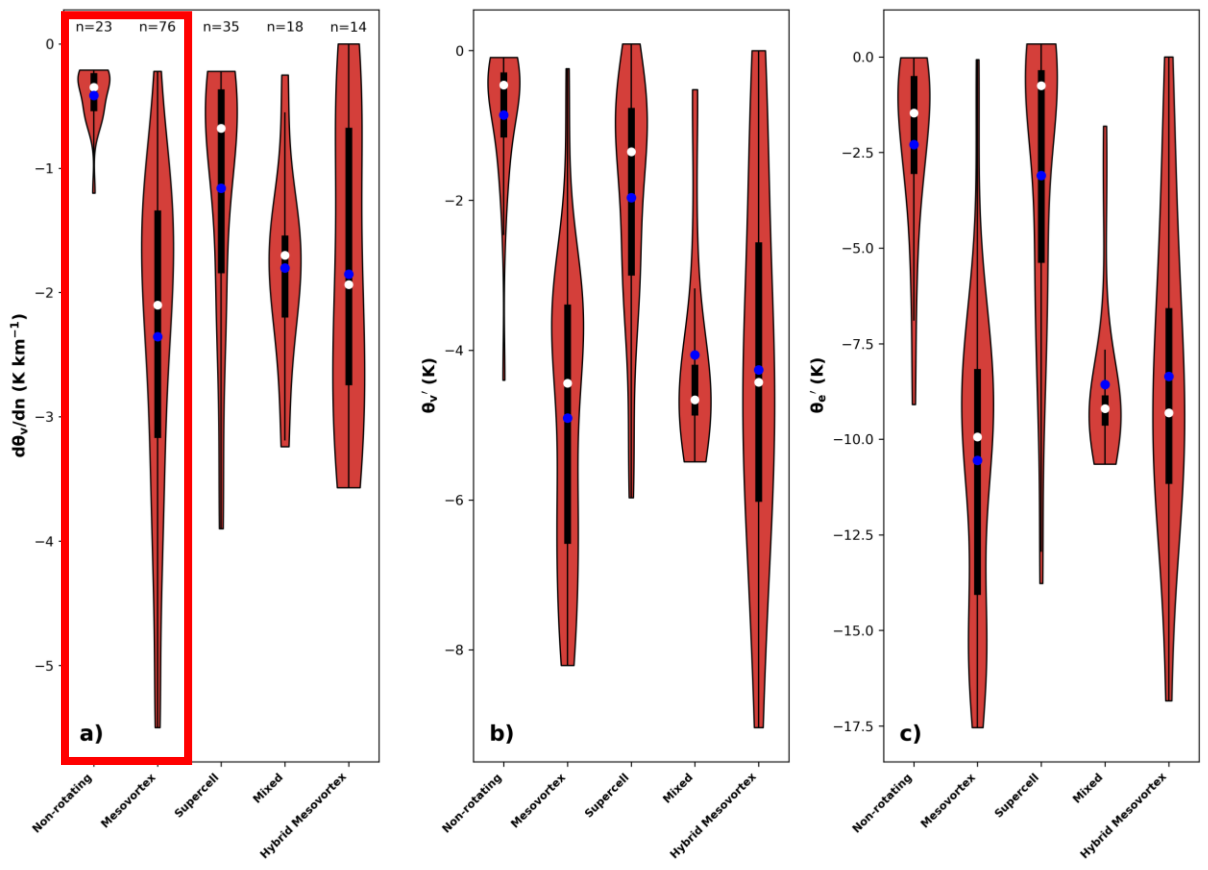




- Correlation between deficits and Tdd similar to other cold pool studies
- Supercells have weaker cold pools
- Cold pool properties are weakened closest to time-of-merger

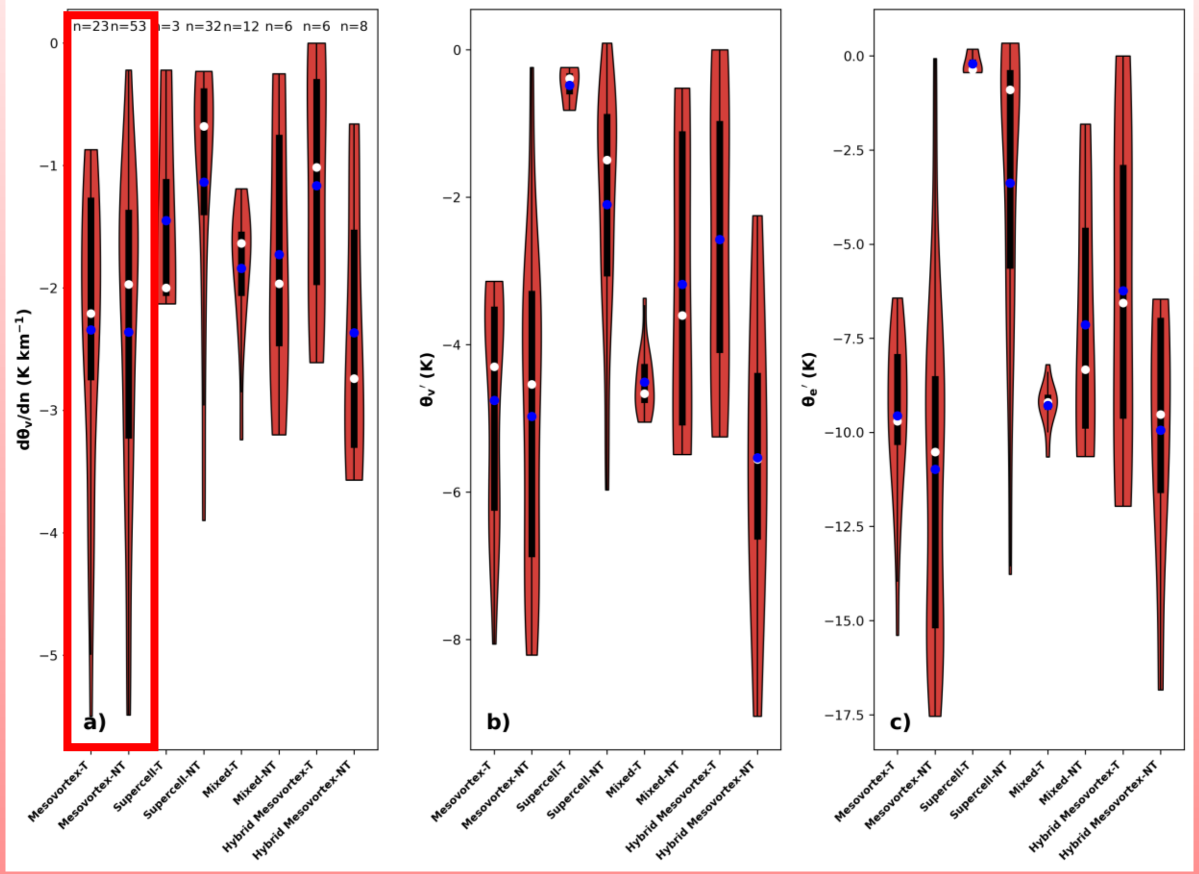


Rotating vs Non-rotating



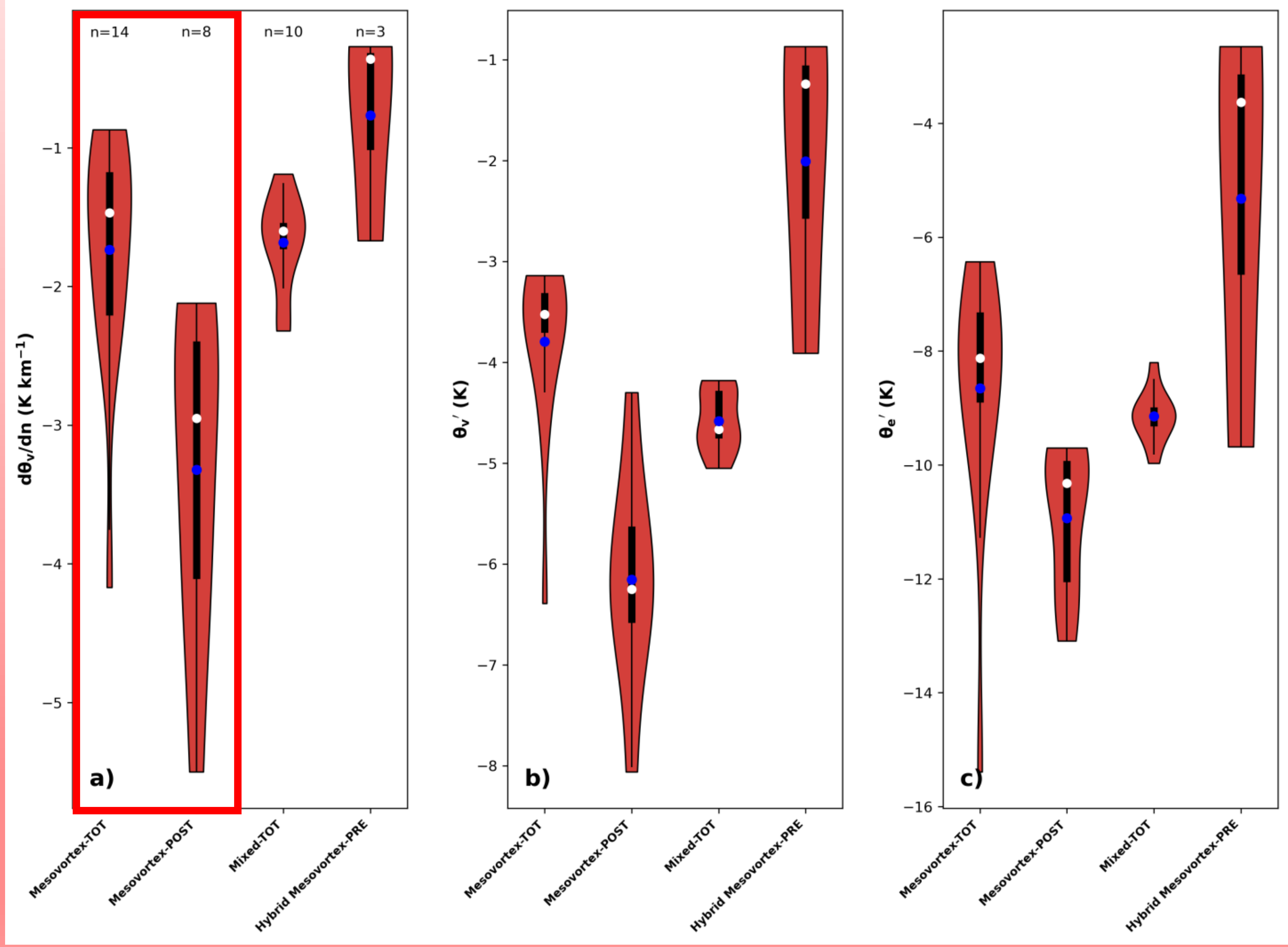
	# Samples	Mean	Median	Std	Cov (TE')	Cov (TV')	r (TE')	r (TV')
Linear-NR	23	-0.414	-0.35	0.228	0.429	0.192	0.761	0.839
MV-R	76	-2.355	-2.1	1.294	3.336	1.958	0.645	0.767
MC-R	35	-1.161	-0.68	1.04	1.145	0.347	0.28	0.21
Mixed-R	18	-1.803	-1.7	0.766	1.323	0.82	0.733	0.72
Hybrid-R	14	-1.851	-1.935	1.213	4.879	2.987	0.893	0.925

Tornadic vs Nontornadic



	# Samples	Mean	Median	Std	Cov (TE')	Cov (TV')	r (TE')	r (TV')
MV-T	23	-2.34	-2.21	1.19	1.139	1.182	0.427	0.634
MV-NT	53	-2.361	-1.97	1.335	4.321	2.322	0.716	0.809
MC-T	3	-1.45	-2	0.871	0.359	0.211	0.998	0.655
MC-NT	32	-1.134	-0.68	1.051	1.321	0.412	0.313	0.246
Mixed-T	12	-1.84	-1.635	0.529	0.08	0.066	0.24	0.257
Mixed-NT	6	-1.728	-1.965	1.092	4.129	2.524	0.946	0.924
Hybrid-T	6	-1.165	-1.015	0.999	4.835	2.315	0.926	0.99
Hybrid-NT	8	-2.366	-2.74	1.099	3.428	2.153	0.841	0.847

Time-Relative to Tornado



	# Samples	Mean	Median	Std	Cov (TE')	Cov (TV')	r (TE')	r (TV')
MV-TOT	14	-1.735	-1.47	0.827	0.237	0.061	0.124	0.083
MV-PRE	1	-3	-3					
MV-POST	8	-3.323	-2.95	1.114	0.348	0.658	0.226	0.512
MC-TOT	2	-1.175	-1.175					
MC-PRE	0							
MC-POST	1	-2	-2					
Mixed-TOT	10	-1.684	-1.6	0.336	0.042	0.056	0.253	0.504
Mixed-PRE	1	-2	-2					
Mixed-POST	1	-3.24	-3.24					
Hybrid-TOT	2	-1.04	-1.04					
Hybrid-PRE	3	-0.767	-0.36	0.64	2.932	1.281	0.986	0.983
Hybrid-POST	1	-2.61	-2.61					

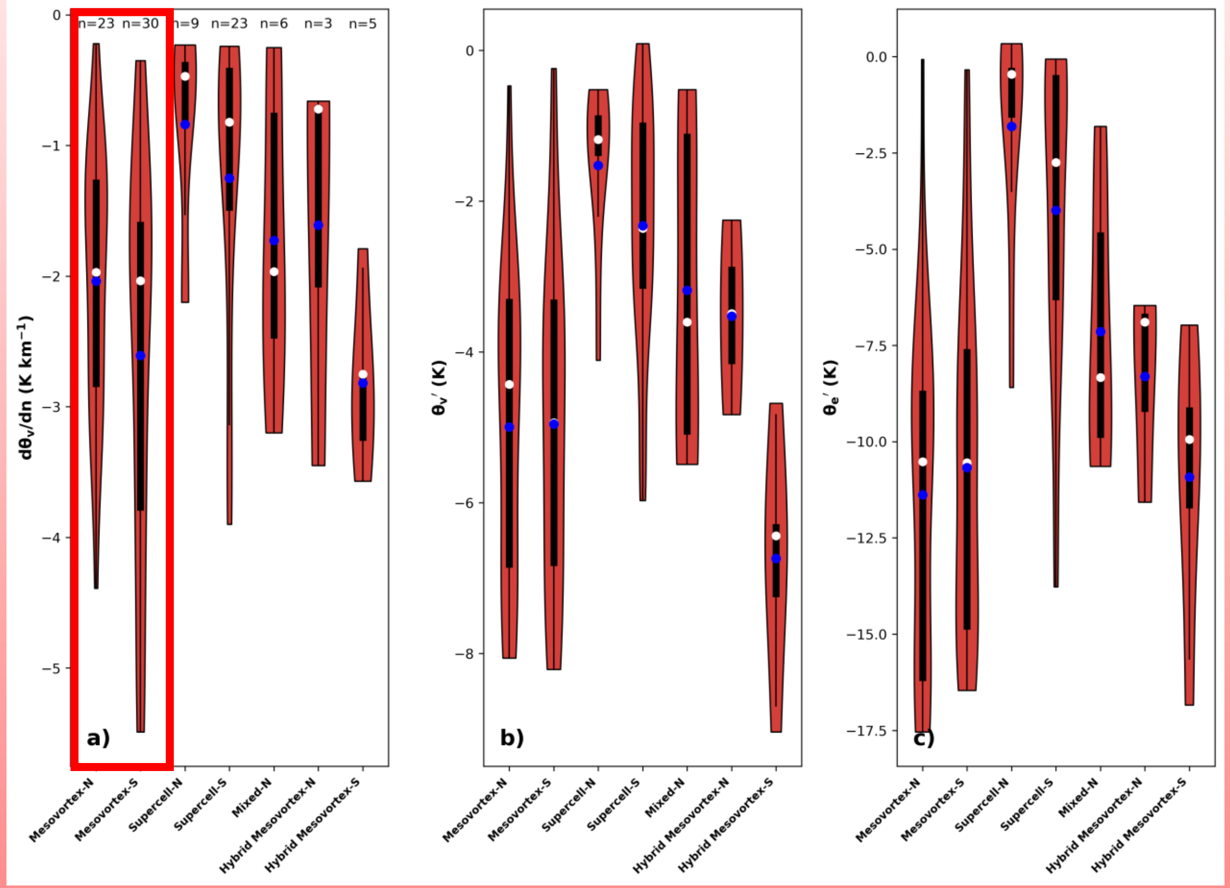
-Lack of pre-tornadic mesovortex intercepts

-No pre-mesovortex intercepts

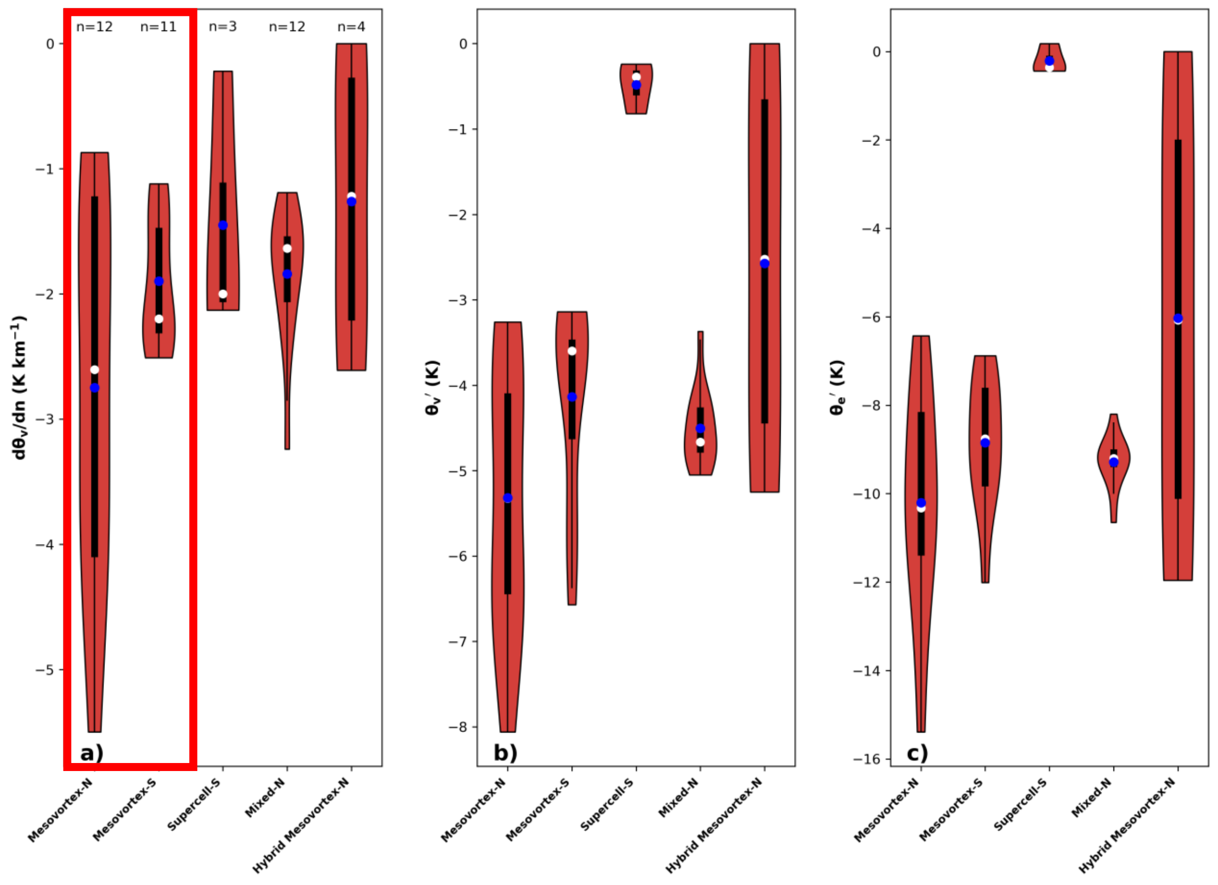
-Strongest baroclinic zones occurred near post-tornadic intercepts, although, how did these baroclinic zones evolve to this state?

Directionality

Nontornadic Samples



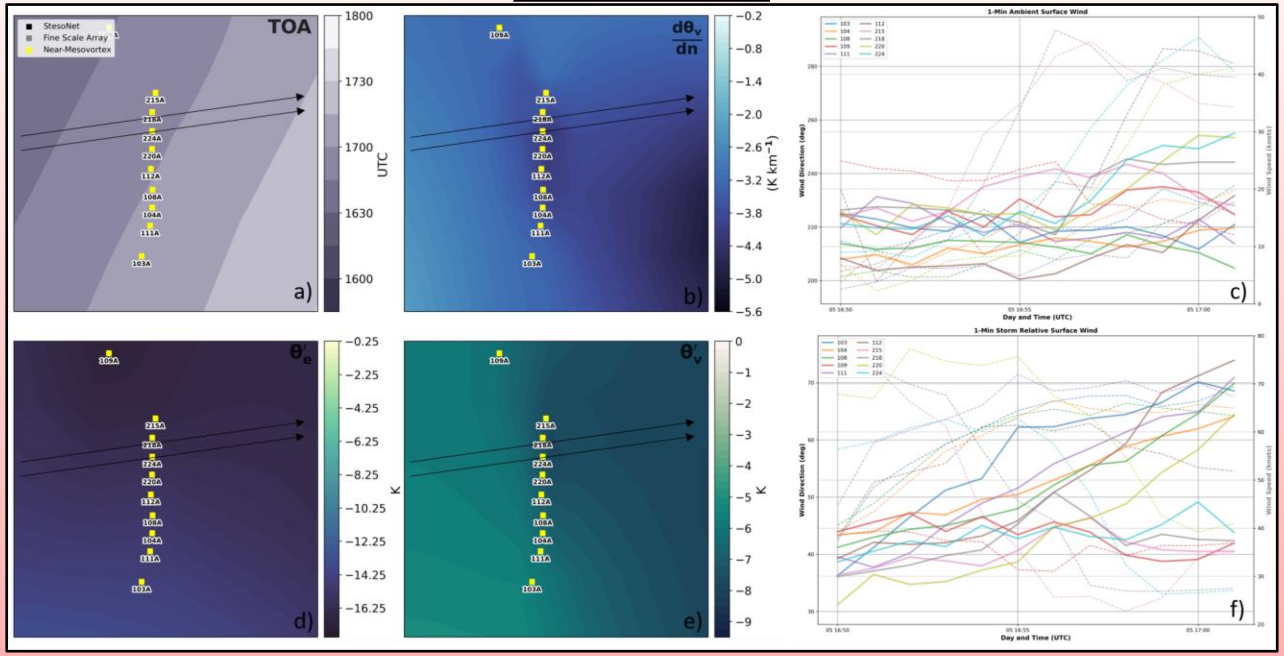
Tornadic Samples



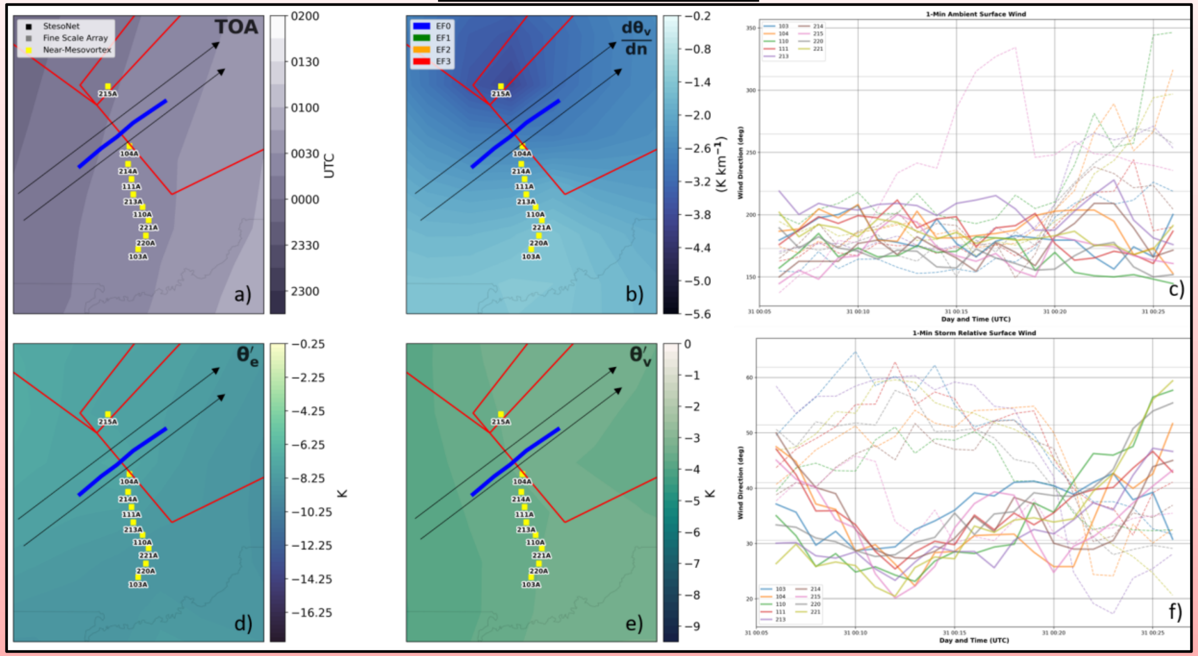
	# Samples	Mean	Median	Std	Cov (TE')	Cov (TV')	r (TE')	r (TV')
MV-NT-N	23	-2.04	-1.97	0.998	3.326	1.578	0.726	0.748
MV-NT-S	30	-2.607	-2.035	1.498	5.404	2.977	0.784	0.883
MC-NT-N	9	-0.828	-0.47	0.744	1.239	0.442	0.528	0.49
MC-NT-S	23	-1.25	-0.82	1.128	1.146	0.322	0.239	0.167
Mixed-NT-N	6	-1.728	-1.965	1.092	4.129	2.524	0.95	0.924
Mixed-NT-S	0							
Hybrid-NT-N	3	-1.61	-0.72	1.301	4.497	1.822	0.996	0.886
Hybrid-NT-S	5	-2.82	-2.75	0.605	2.27	1.033	0.901	0.962

	# Samples	Mean	Median	Std	Cov (TE')	Cov (TV')	r (TE')	r (TV')
MV-T-N	12	-2.749	-2.605	1.468	1.382	1.455	0.353	0.583
MV-T-S	11	-1.898	-2.2	0.503	0.322	0.422	0.405	0.674
MC-T-N	0							
MC-T-S	3	-1.45	-2	0.871	0.359	0.211	0.998	0.655
Mixed-T-N	12	-1.84	-1.635	0.529	0.08	0.066	0.24	0.257
Mixed-T-S	0							
Hybrid-T-N	4	-1.263	-1.22	1.106	6.729	3.235	0.885	1
Hybrid-T-S	2	-0.97	-0.97					

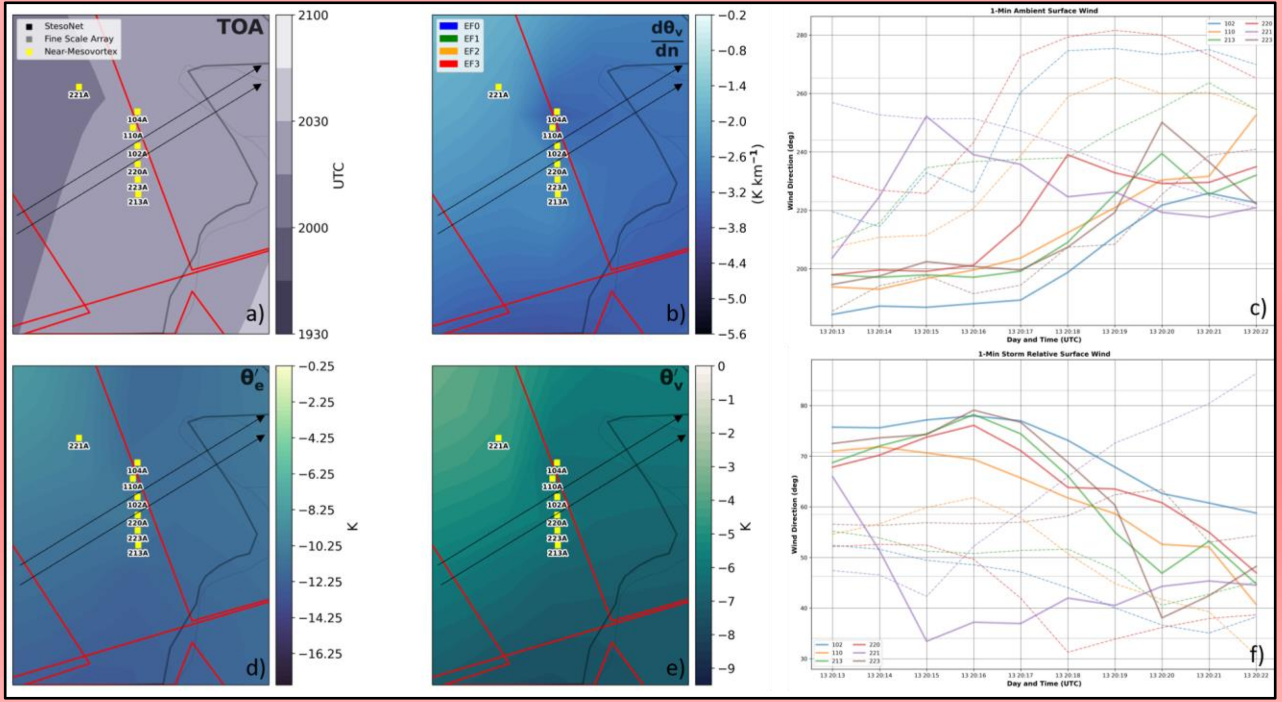
Nontornadic MV



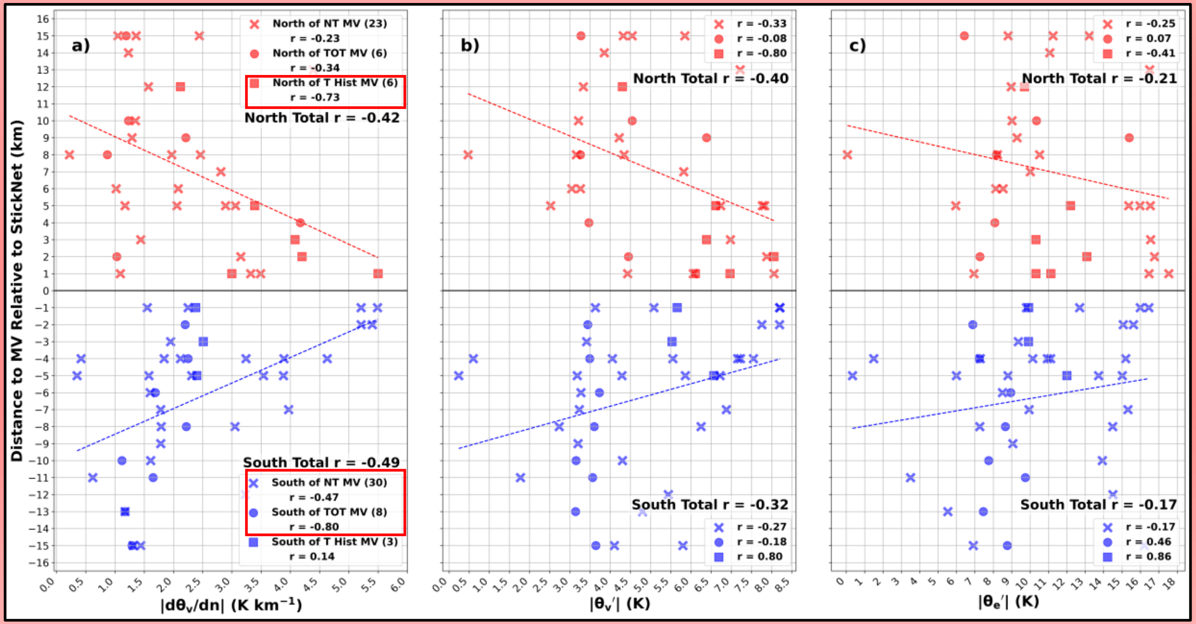
Time-of-Tornado MV



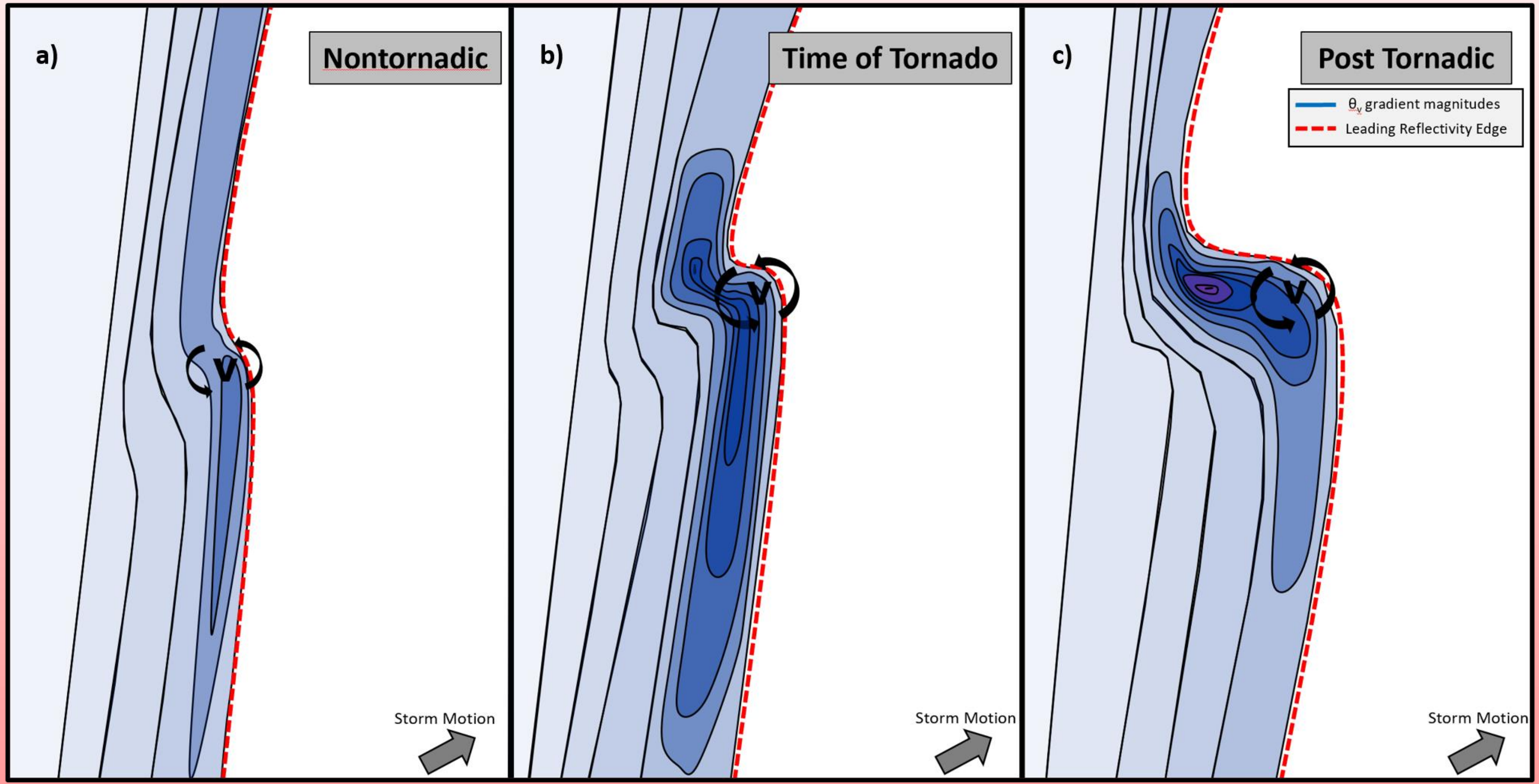
Post-Tornadic MV



All MV intercepts



Conclusions



1. Greater baroclinity found near rotating segments than the parent QLCS
2. Preferential baroclinic zones evolve during an **already present** MV lifecycle
3. HSLC supercell cold pools are weaker than supercells in larger buoyancy environments, and supercells leading a QLCS tend to weaken the immediate cold pool when absorbed by the QLCS (i.e., hybrid MV)

Challenges

1. No pre-mesovortex/-tornadic samples
2. No parcel trajectories (lack of dual Doppler)
3. Only surface measurements. What is happening just above (~lowest 100 m)?
4. Baroclinity present but cannot discredit other vorticity sources simultaneously present

Future Work

1. Explore frictional and barotropic effects
2. Assess rapid destabilization within the StesoNet
3. Add a modeling component to explore how much baroclinic vorticity is important during and downstream of HSLC QLCS-supercell mergers