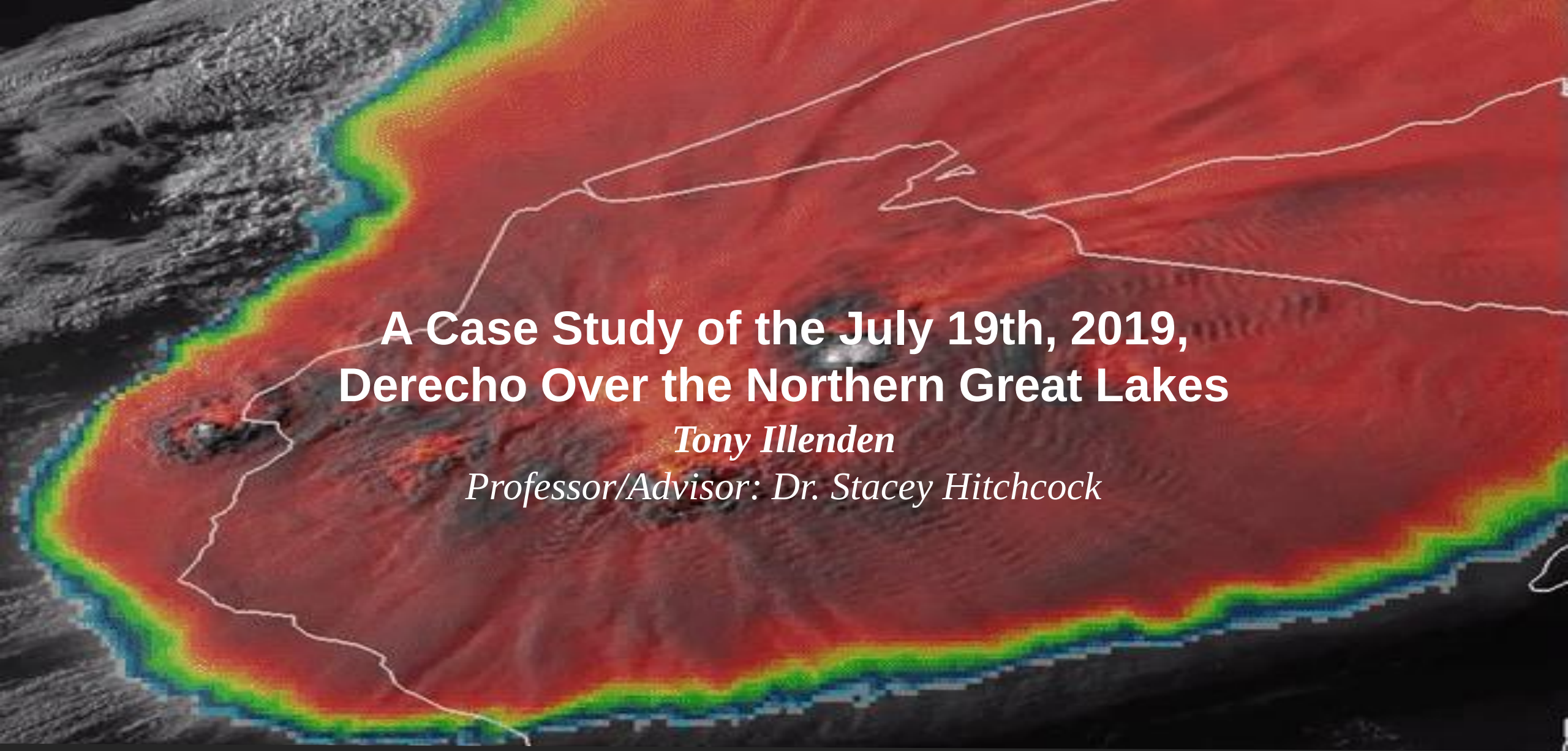


A Case Study of the July 19th, 2019, Derecho Over the Northern Great Lakes

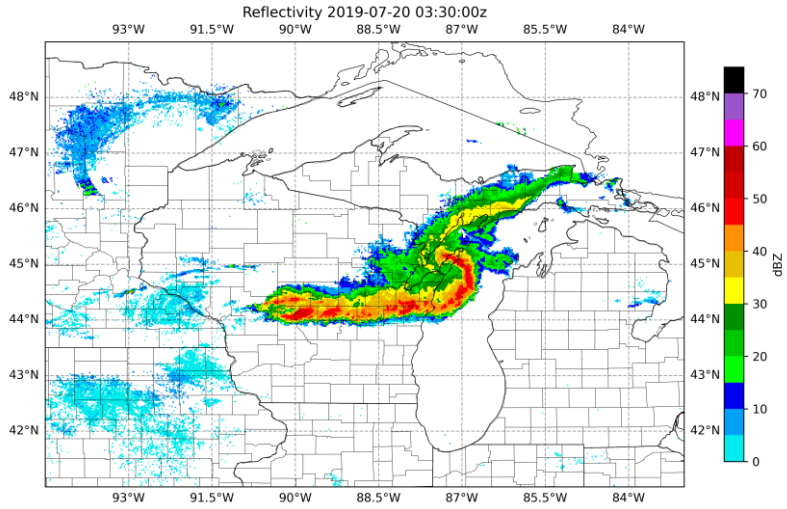
Tony Illenden

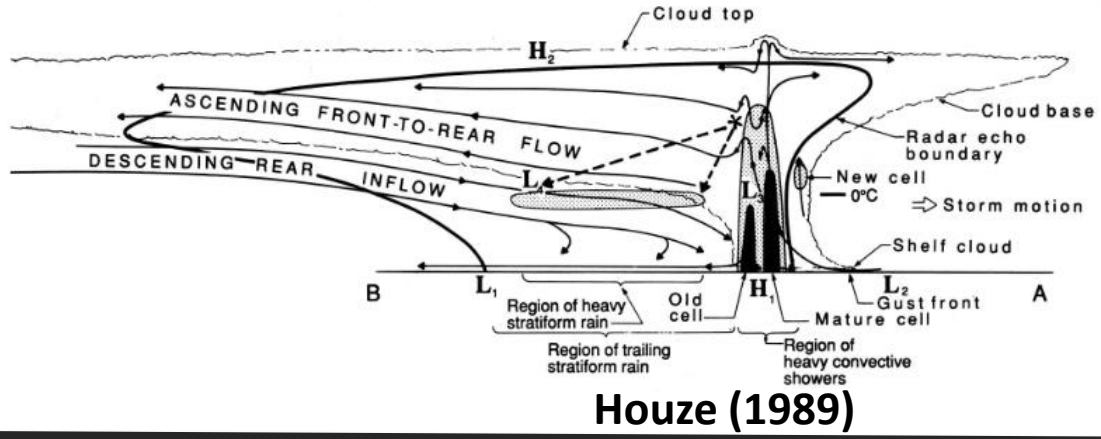
Professor/Advisor: Dr. Stacey Hitchcock

The UNIVERSITY of OKLAHOMA
SCHOOL OF METEOROLOGY

Background – Definition

- What even is a derecho?
  - “A derecho is a family of damaging downburst clusters associated with a forward-propagating, mesoscale convective system (MCS) that, during part of its existence, displays evidence of one or more sustained bow echoes with mesoscale vorticities and/or rear-inflow jet” – Corfidi et. al (2016)

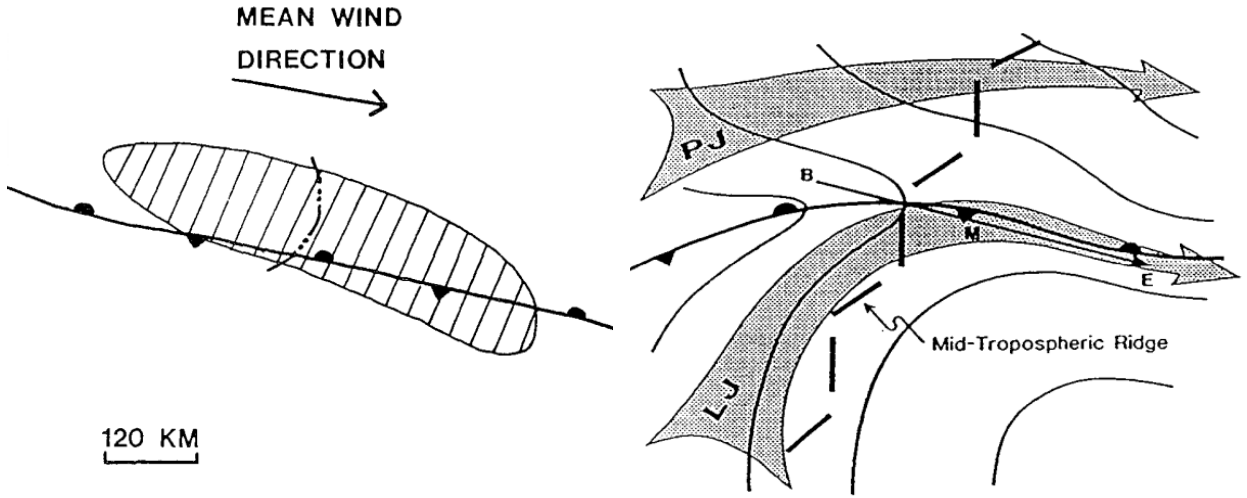




Houze (1989)

Background – Derecho Environments

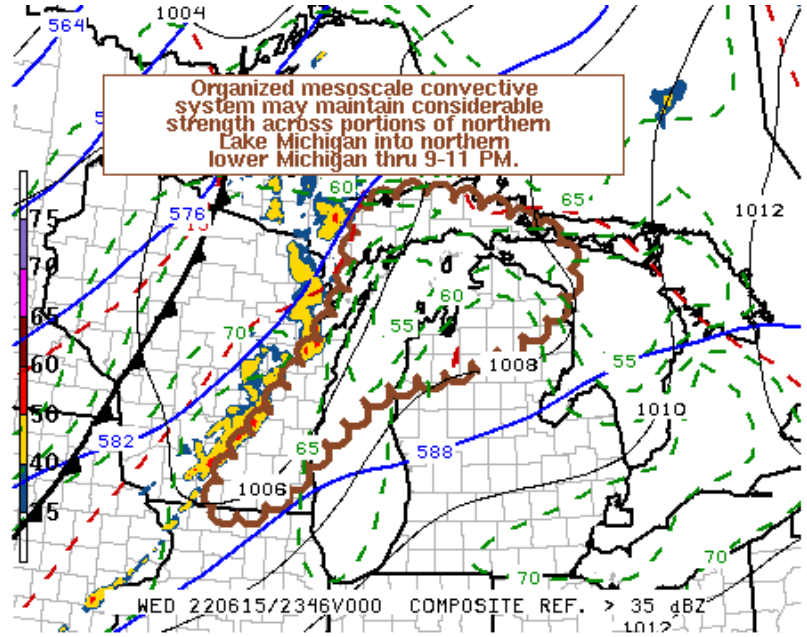
- In what type of environments do derechos form?
  - According to Johns (1993) it depends on the type of derecho, but in the case of a warm-season progressive derecho they are characterized by:
    - Weak large-scale ascent
    - Strong to extreme instability
    - Quasi-stationary surface boundary



Johns (1993)

Motivation

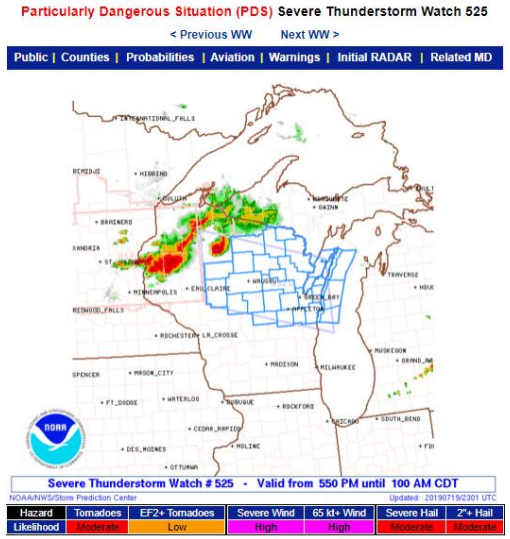
- Notable short-term issue for forecasters in the Great Lakes that can be **high-impact** at times!!!
- **Little to no** research has been done on this topic
  - Metz (2011) analyzed **synoptic characteristics** that favor the persistence MCSs over Lake Michigan
    - "BUT THE MESOSCALE MATTERS" – Dr. Parsons

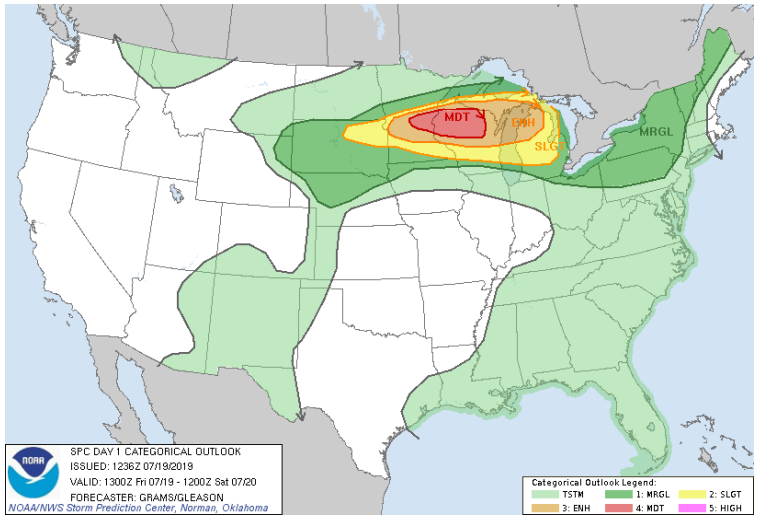


coverage. Uncertainty exists in whether or not the convection will persist as it crosses northern parts of Lake Michigan and entering into the L.P. of Michigan. Presently there exists a corridor of

Event Overview – Forecast

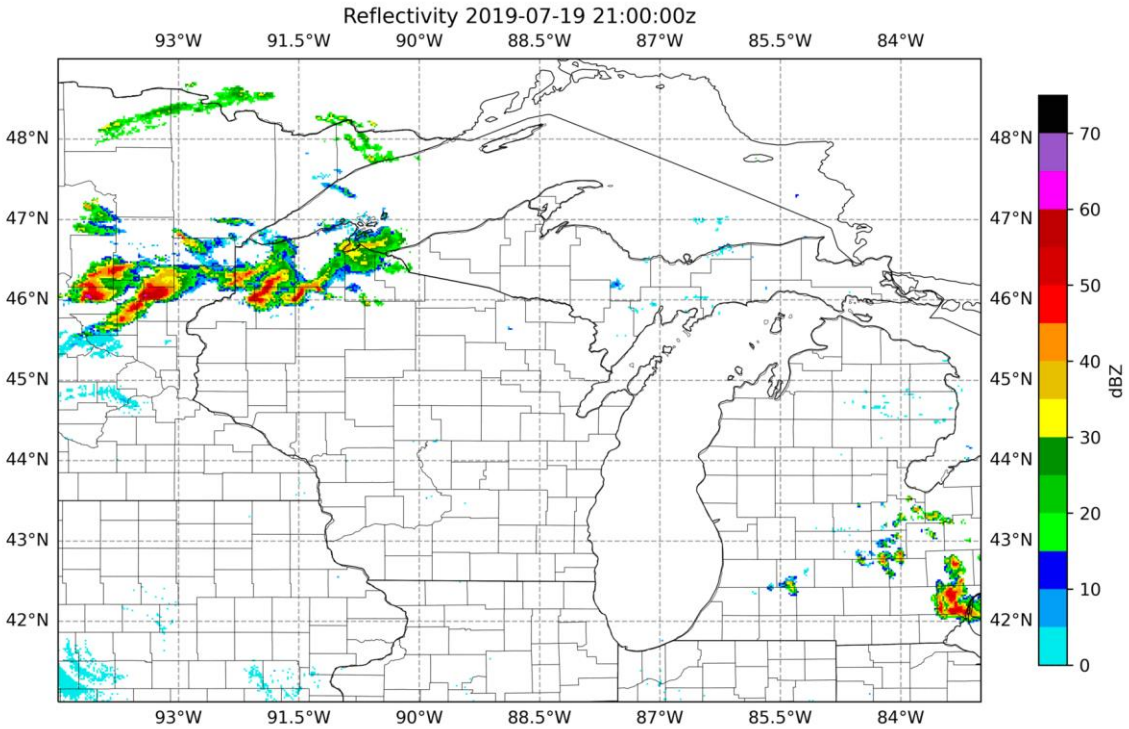
- Moderate/Level-4 Risk for the 1300 UTC Convective Outlook
  - "For the potential threats of multiple **strong tornadoes** and a **derecho** later this afternoon and evening"
- PDS Severe Thunderstorm watch at 0000 UTC
  - "Widespread damaging winds and scattered **significant gusts to 105 mph** expected"





Event Overview - Radar

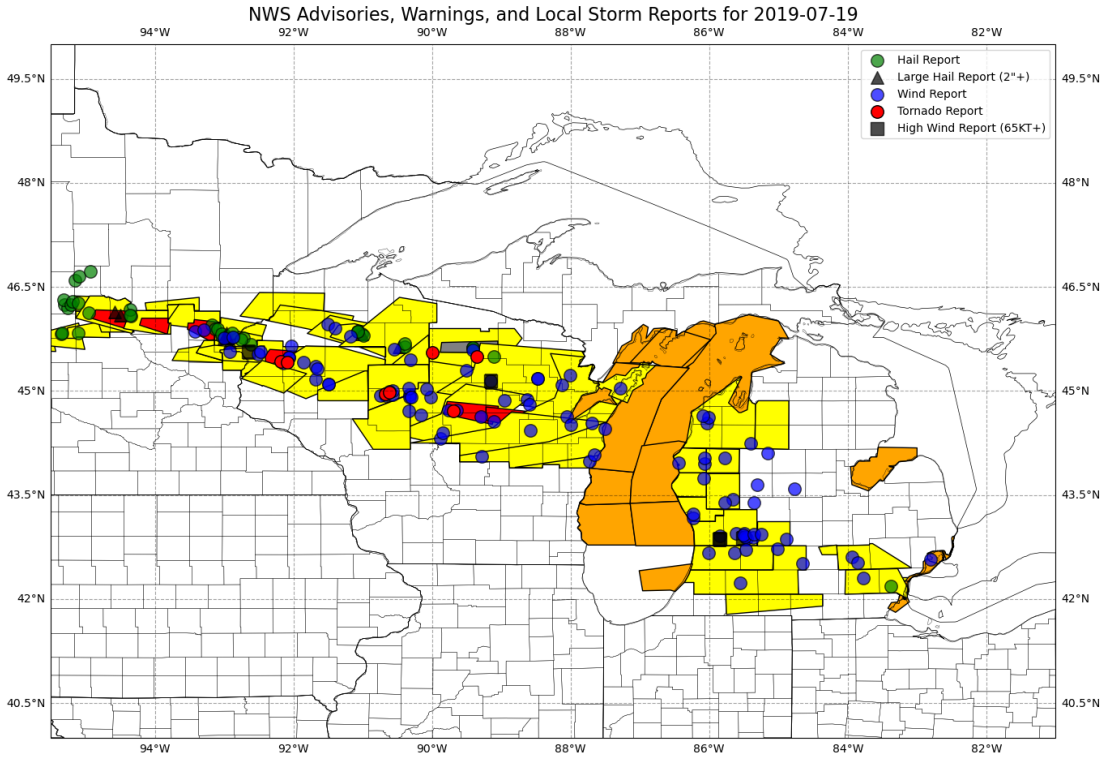
- A few supercells developed in MN and WI and grew upscale into an MCS
- This MCS merged with a discrete supercell and began to bow shortly thereafter
- Persisted over the lake and into MI



Event Overview – Storm Reports & Warnings

- From MN to MI, there were numerous tornadoes (EF-0 and EF-1), large to very large hail (2.75”), and widespread damaging winds (including some significant)

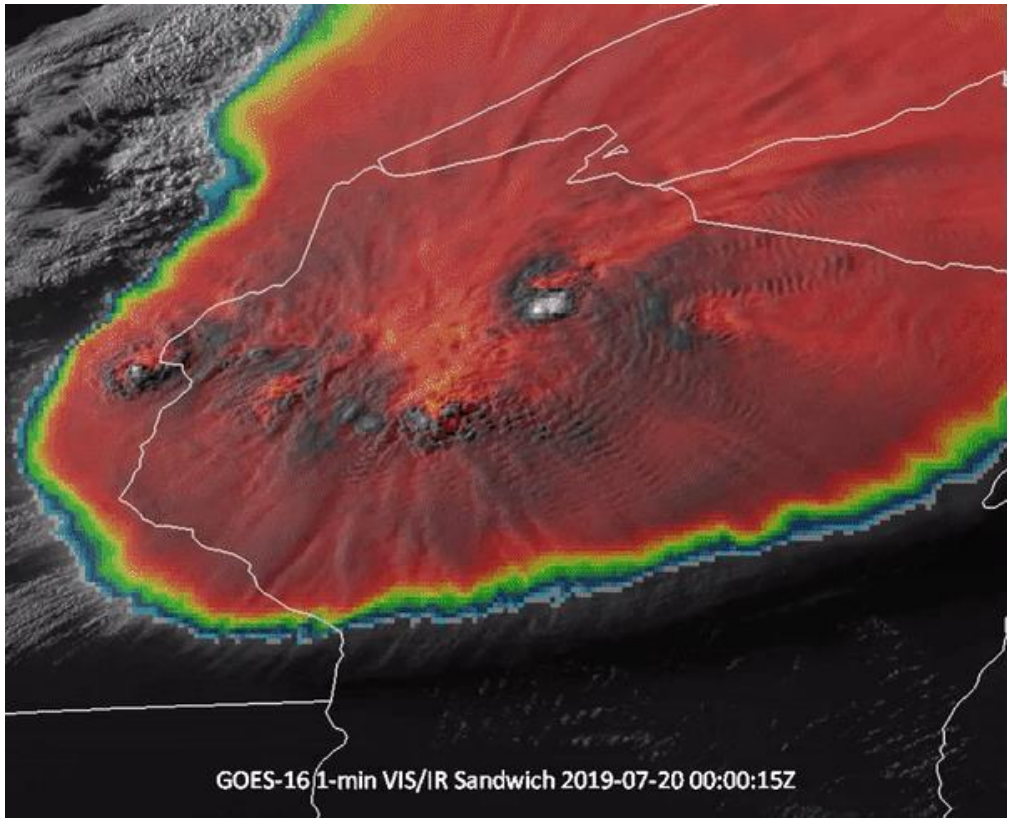
- The strongest winds were estimated to be >100 mph per NWS Green Bay



Research Questions

1. Does the downstream synoptic and mesoscale environment support the persistence of an MCS over the lake?

2. Does the cold pool change when it encounters the marine stable layer (MSL) and how does that influence the MCS?



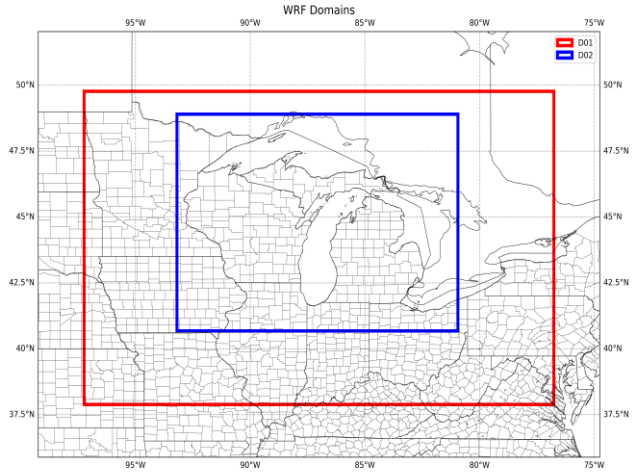
Data and Methods – Obs. & Simulations

Observations:

- Radar: GridRad
- RAOB: University of Wyoming and SPC
- Surface and UA: ISU IEM and SPC
- LSR: SPC
- Buoy: NBDC
- NWS Warnings: ISU IEM

Simulations:

- Model: WRF-ARW v4.5
- Domain: D01 (10 km) and D02 (3 km)
- Parameterization: Below



Parameterization	Scheme/Model
Microphysics	Morrison 2-moment
Cumulus	Newer Tiedtke
Planetary Boundary Layer	MYNN 2.5 level TKE
Shortwave Radiation Physics	RRTMG
Longwave Radiation Physics	RRTMG
Surface Layer	Monin-Obukhov (Janjic Eta Similarity)

Setting	WRF Simulations
Start Date	2019-07-19 00:00
End Date	2019-07-20 12:00
Model Initialization	ERA5 2019-07-19 00:00
Model Boundary Conditions	ERA5 every 3h
$\Delta x, \Delta y$	10000
c_{we}	150, 271
c_{sn}	130, 271
Ref Lat, Ref Lon	44, -87
True Lat 1, True Lat 2	38, 49
Vertical Levels	45

Pre-Convective Environment – Persistence Checklist

WFO Gaylord Michigan - Lake Michigan Crossing MCS Persistence Checklist

First Ingredient: Upstream MCS arriving over Wisconsin

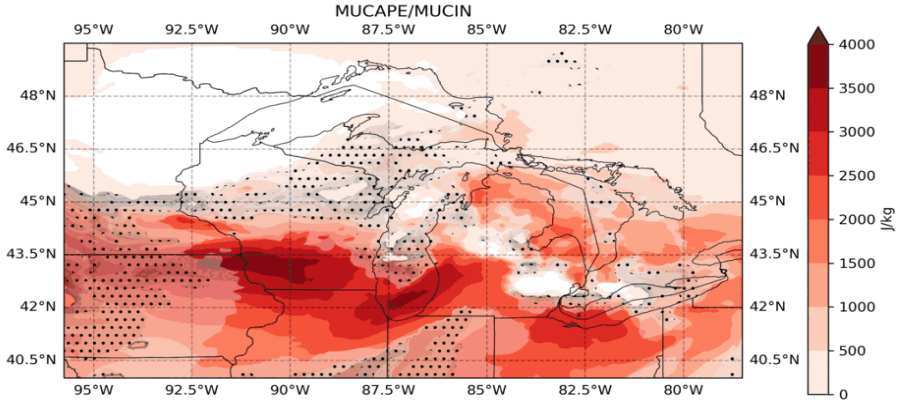
1. Is there >= 1000 J/kg of MUCAPE over a portion of the APX CWA?	YES	NO
2. Is there an 850mb LLJ >= 30kts incident on MCS?	YES	NO
3. Is there a downstream jetstreak >= 80kts?	YES	NO
4. Will the MCS travel in the right entrance region of the jet streak?	YES	NO
5. Is there at least 900 j/kg of environmental DCAPE over a portion of the APX CWA?	YES	NO
6. Is there the presence of an elevated (800-600 mb) mixed layer?	YES	NO
7. Is the Lake Michigan Buoy air-water delta T >=3C (Apr-Jun) >= 1C (Jul-Sep)	YES	NO

Tabulate Number of "Yes" responses above	
0-2	MCS Unlikely to survive
3-4	Possible MCS Survival
5-7	MCS Survival Likely - SIG SVR!

Metz and Arnott

Pre-Convective Environment – MUCAPE

WRF Analysis for 2019-07-19 12:00 UTC



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Metz and Arnott

Pre-Convective Environment – 850 LLJ

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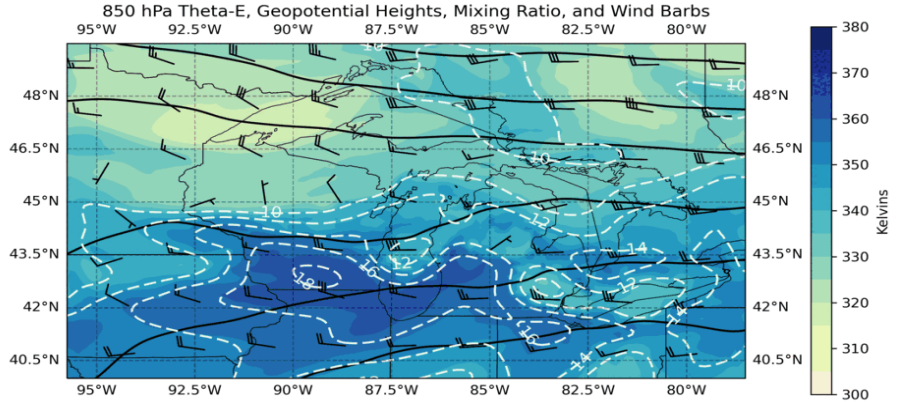

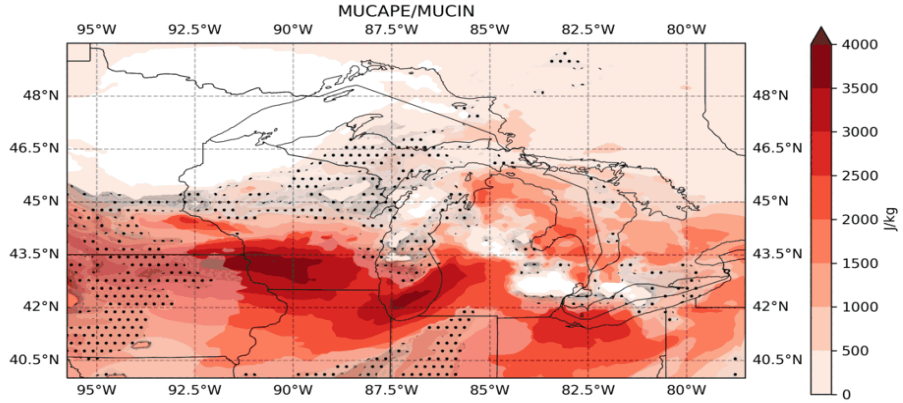

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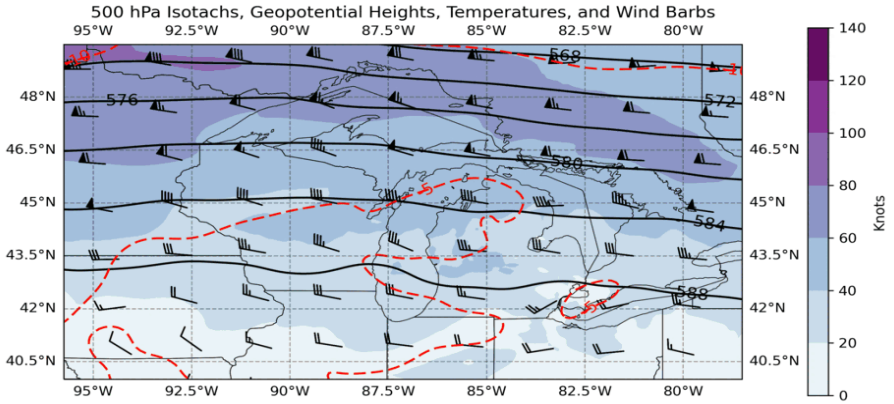

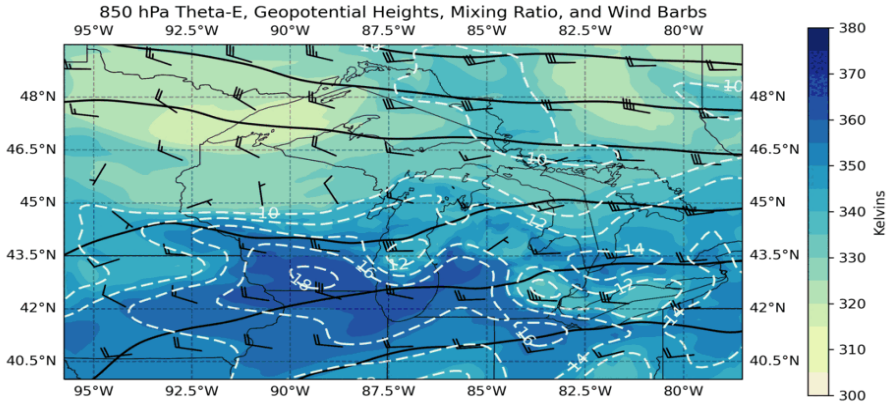

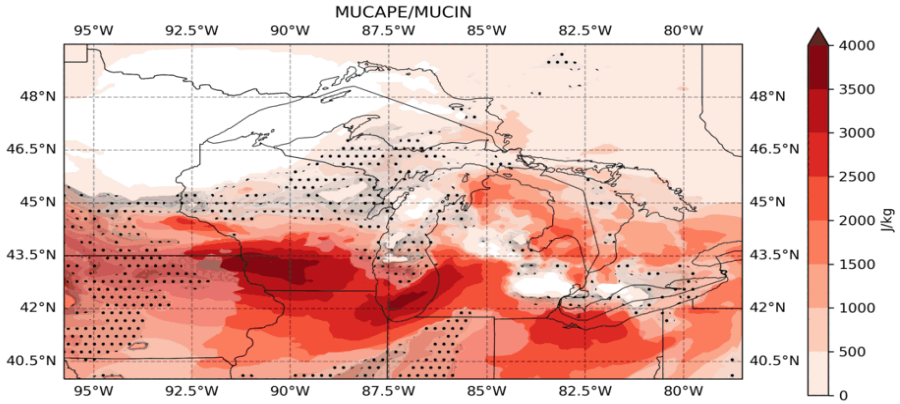

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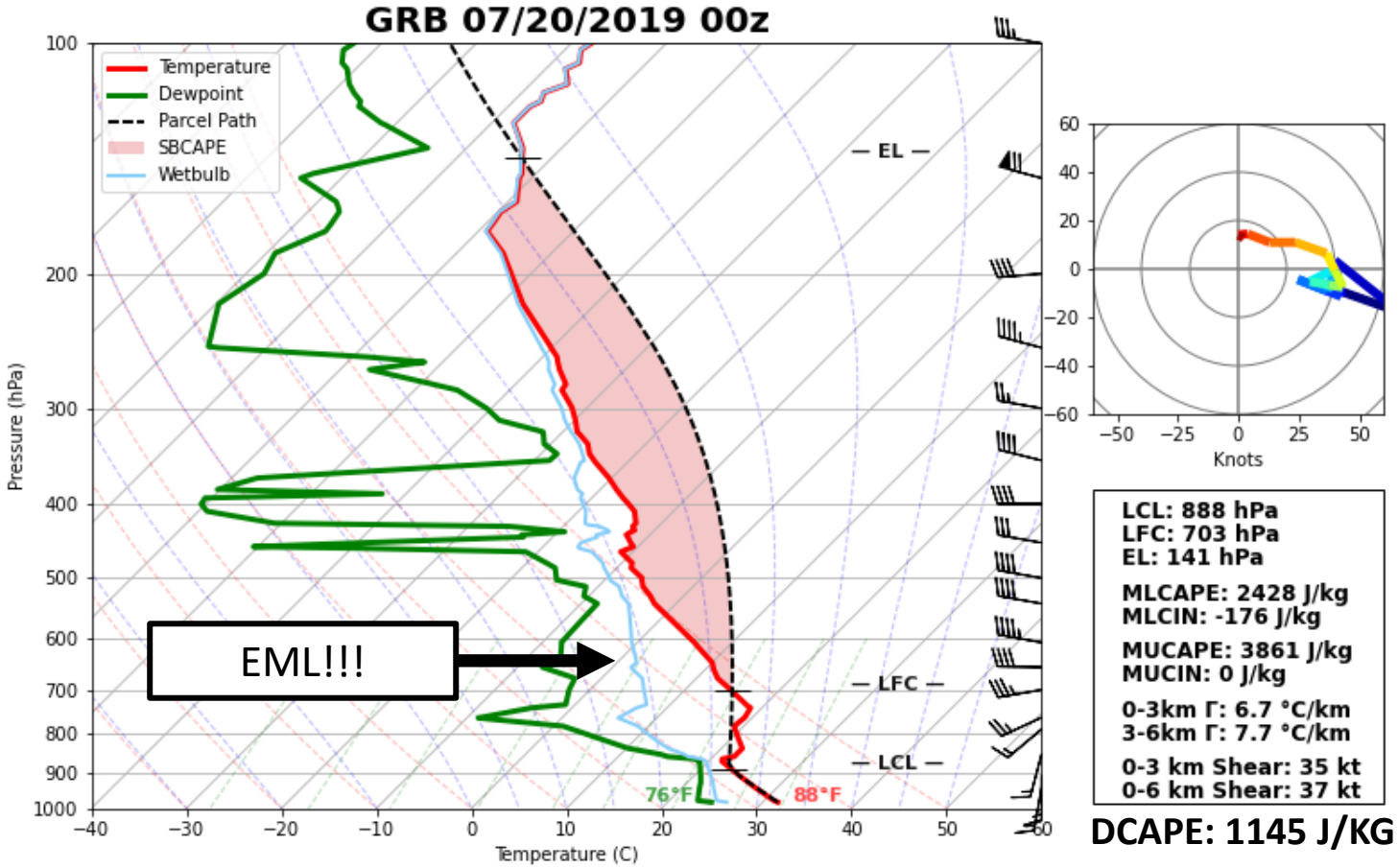
Metz and Arnott

Pre-Convective Environment – EML and DCAPE



DCAPE: 1145 J/KG

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Metz and Arnott

Pre-Convective Environment – 850 LLJ

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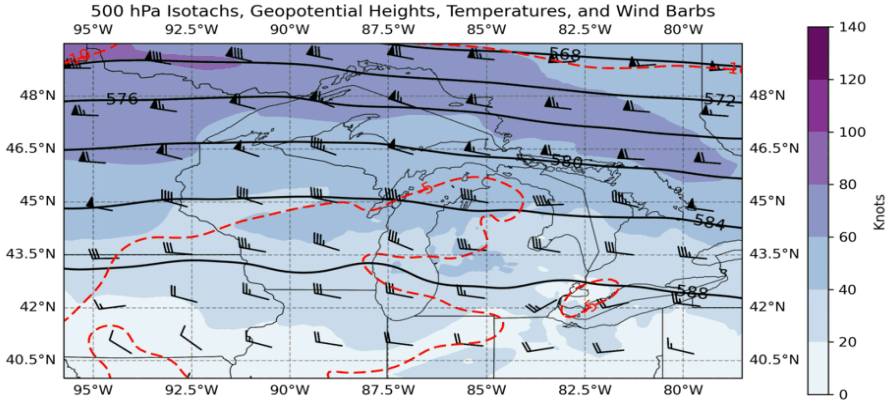

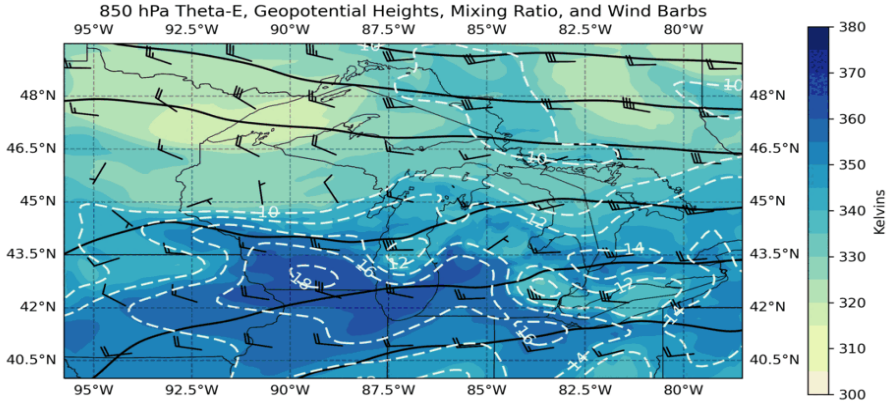

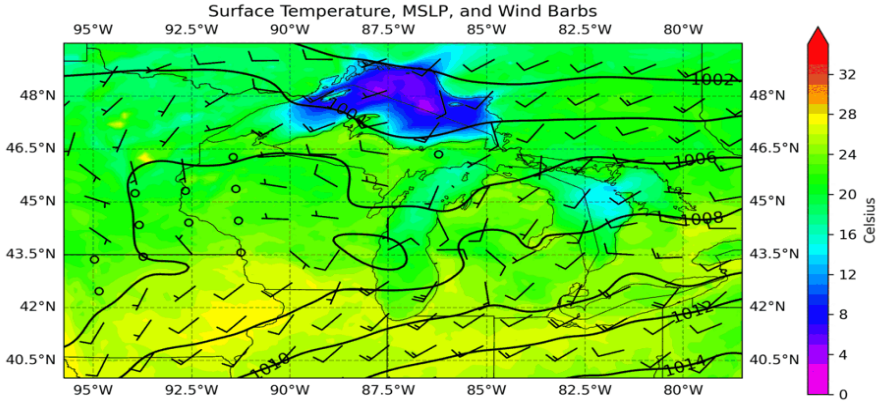

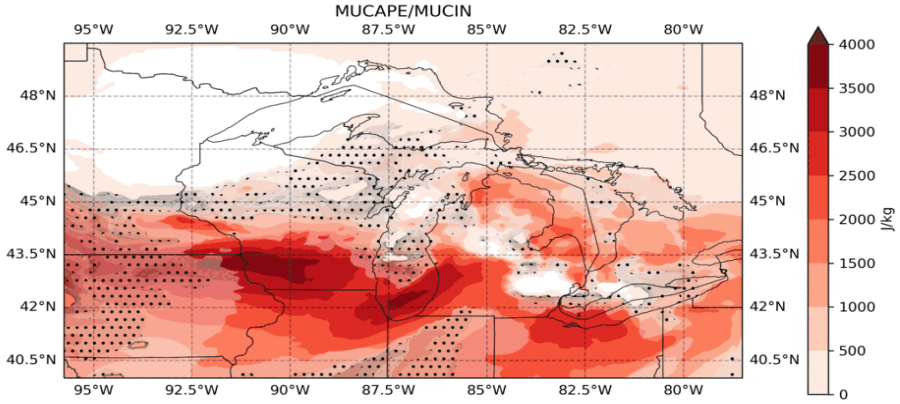

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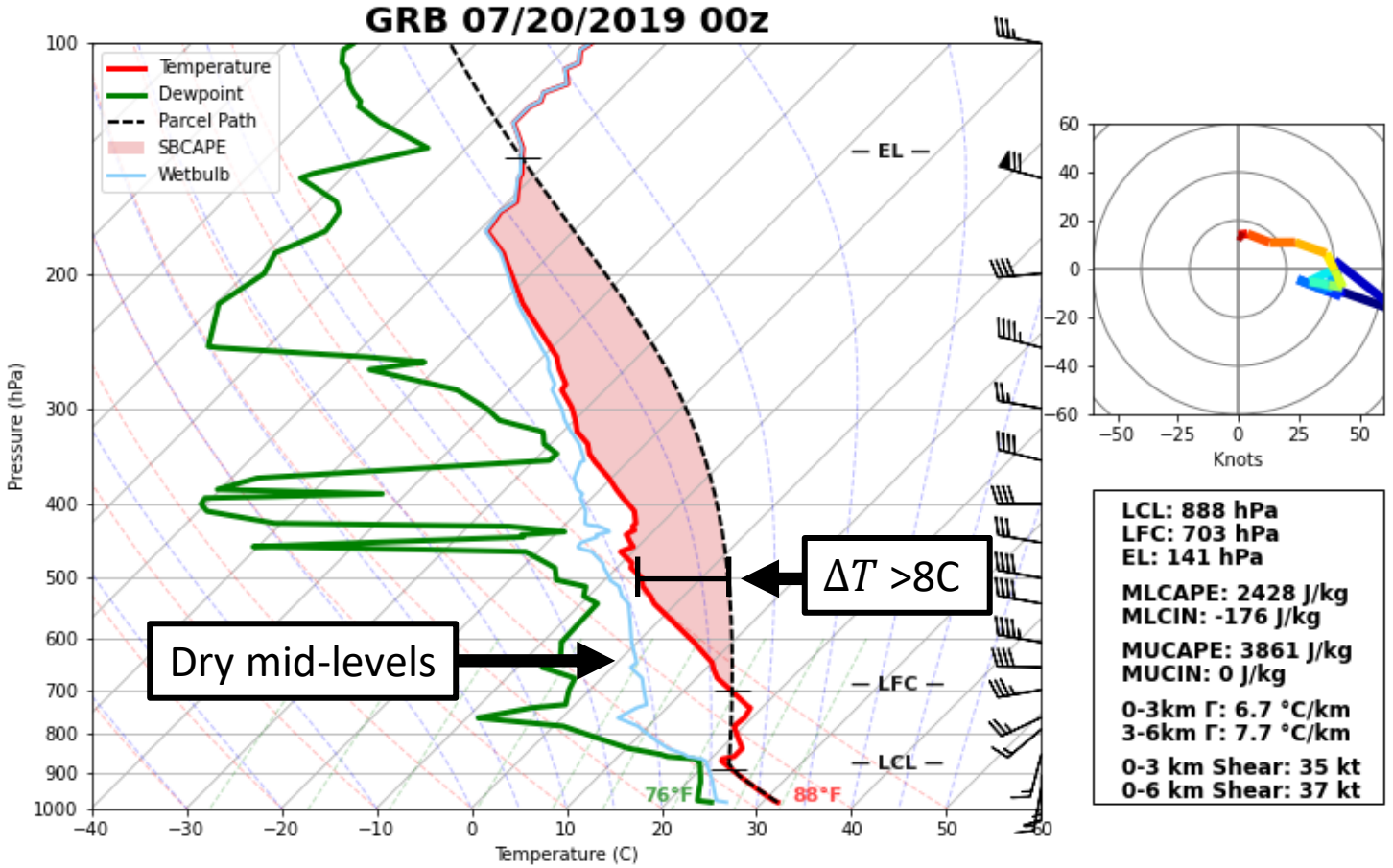
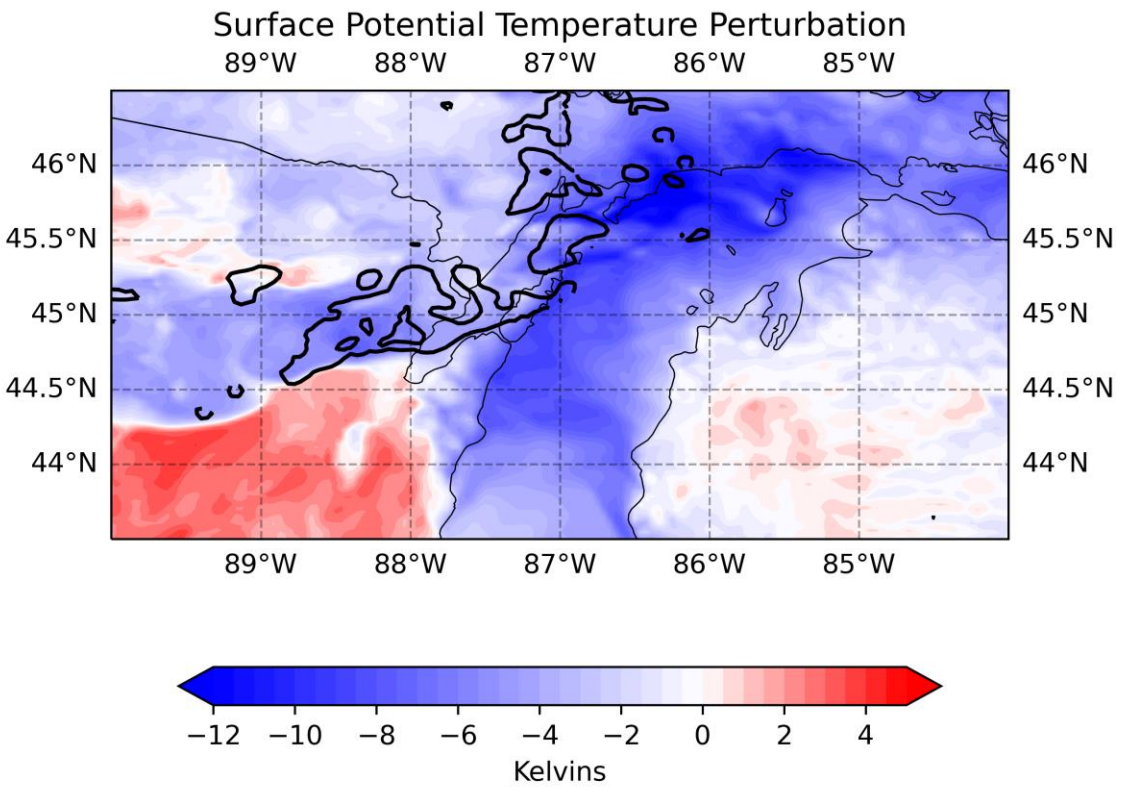
Metz and Arnott

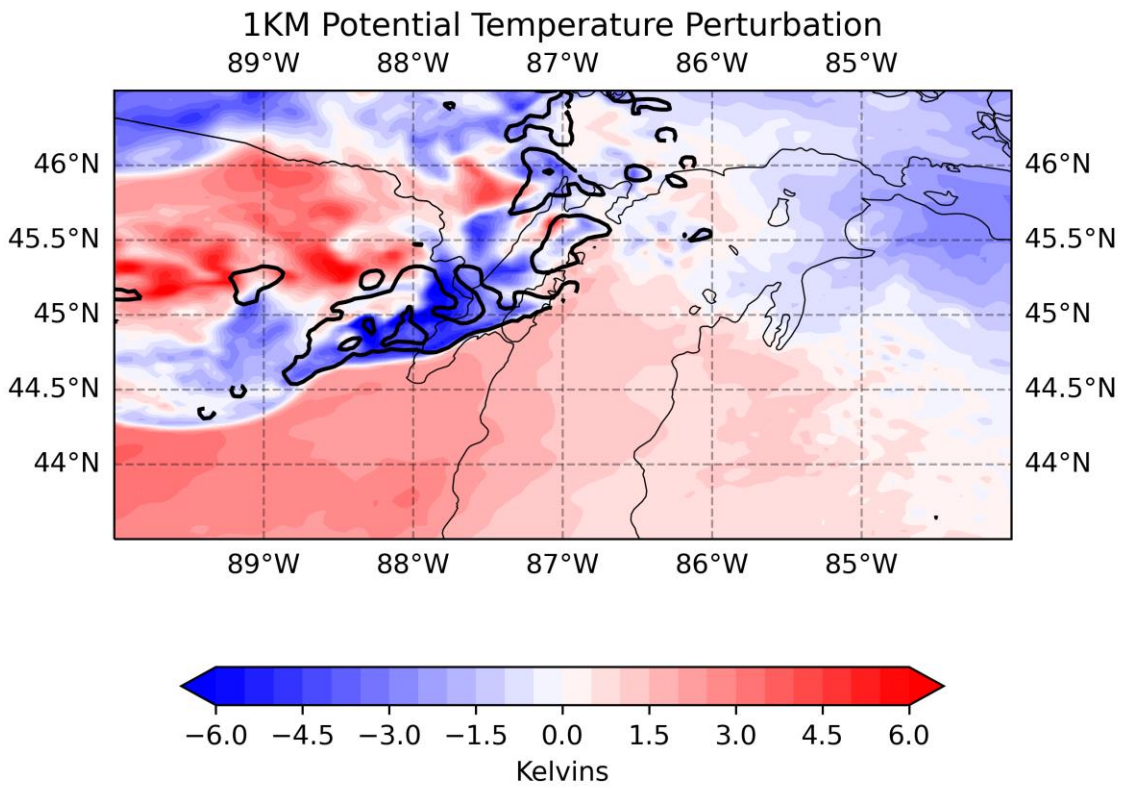
Pre-Convective Environment – Downdraft and RIJ



Cold Pool and MSL Interaction - θ’

WRF Potential Temperature Perturbation and Vertical Velocity 2019-07-20 04:30 UTC





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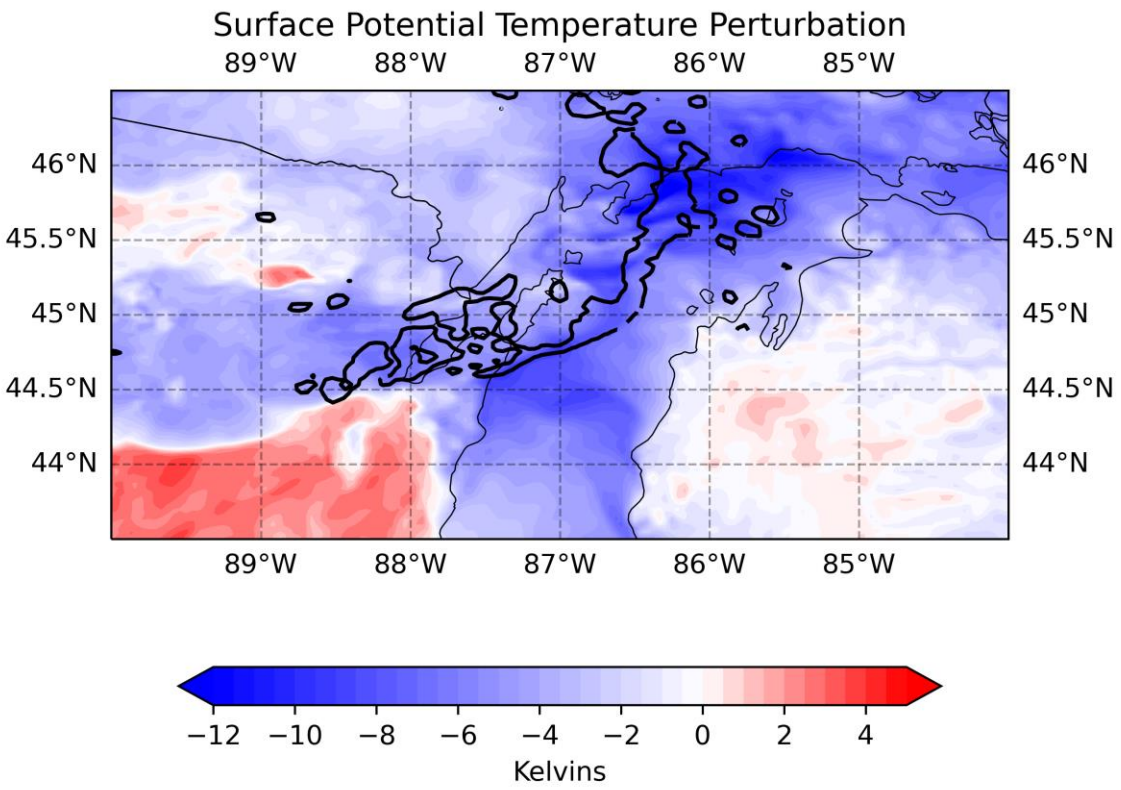
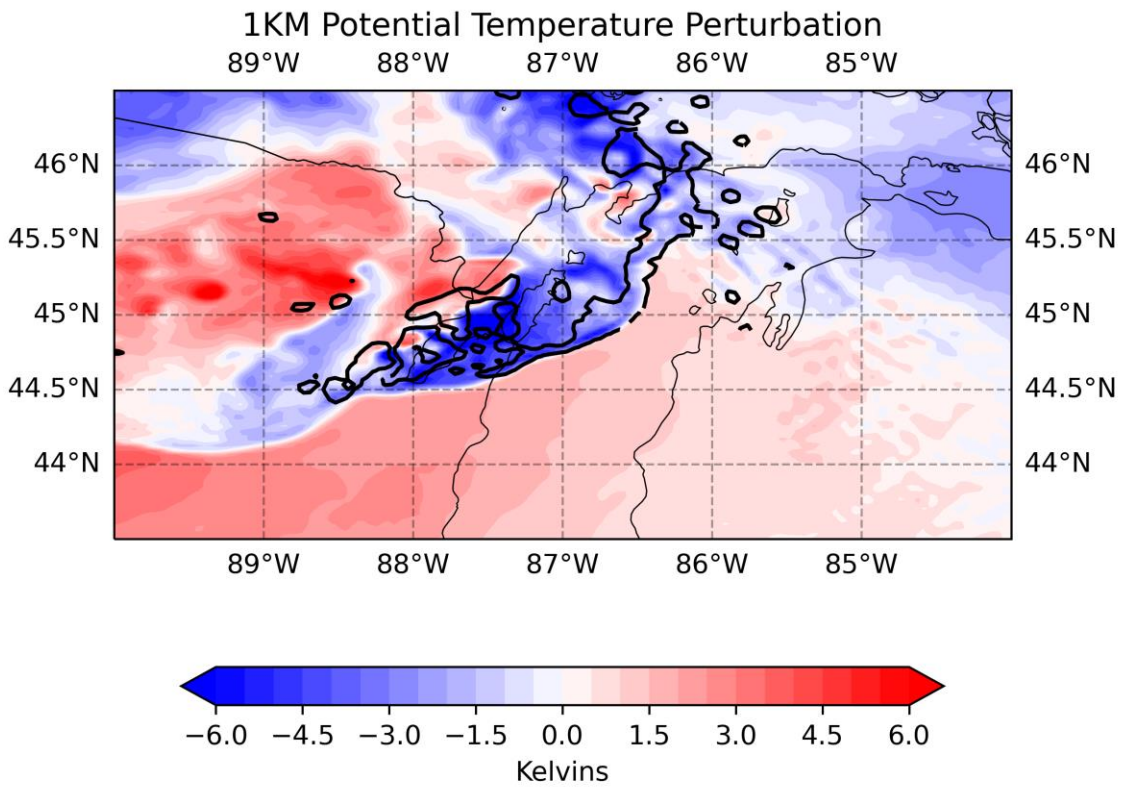
WRF Potential Temperature Perturbation and Vertical Velocity 2019-07-20 05:00 UTC





Cold Pool and MSL Interaction - θ’

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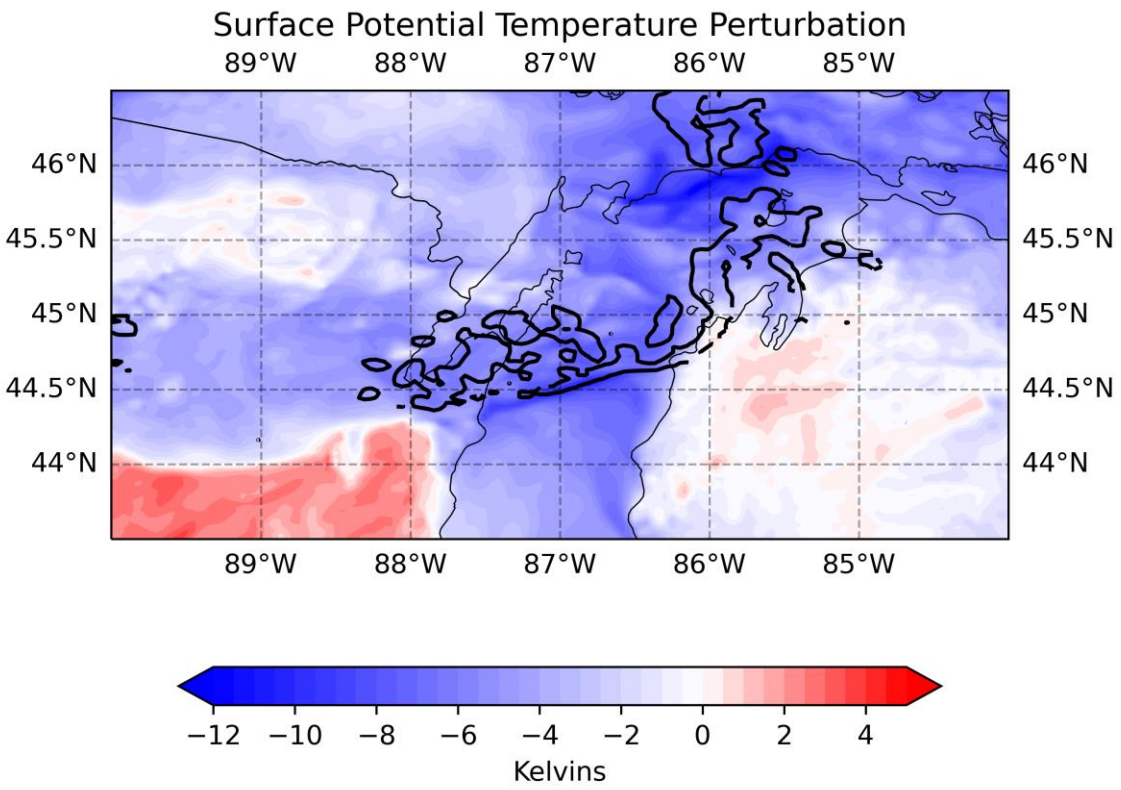
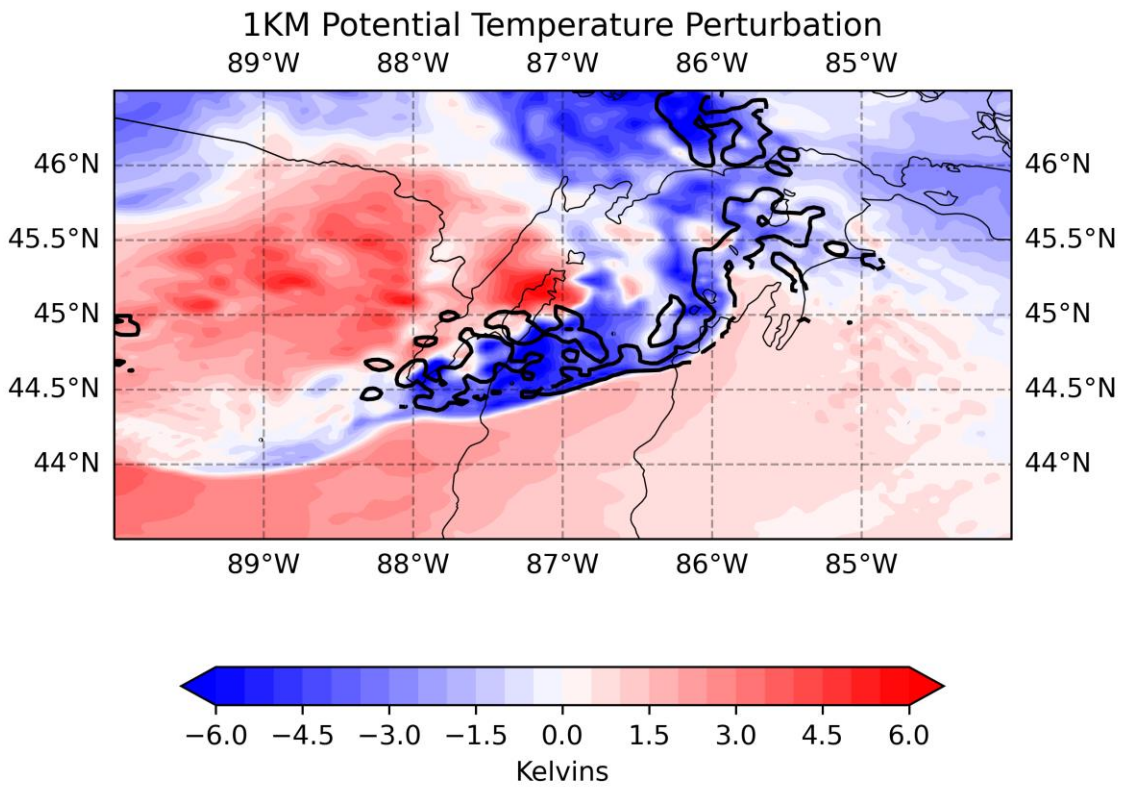
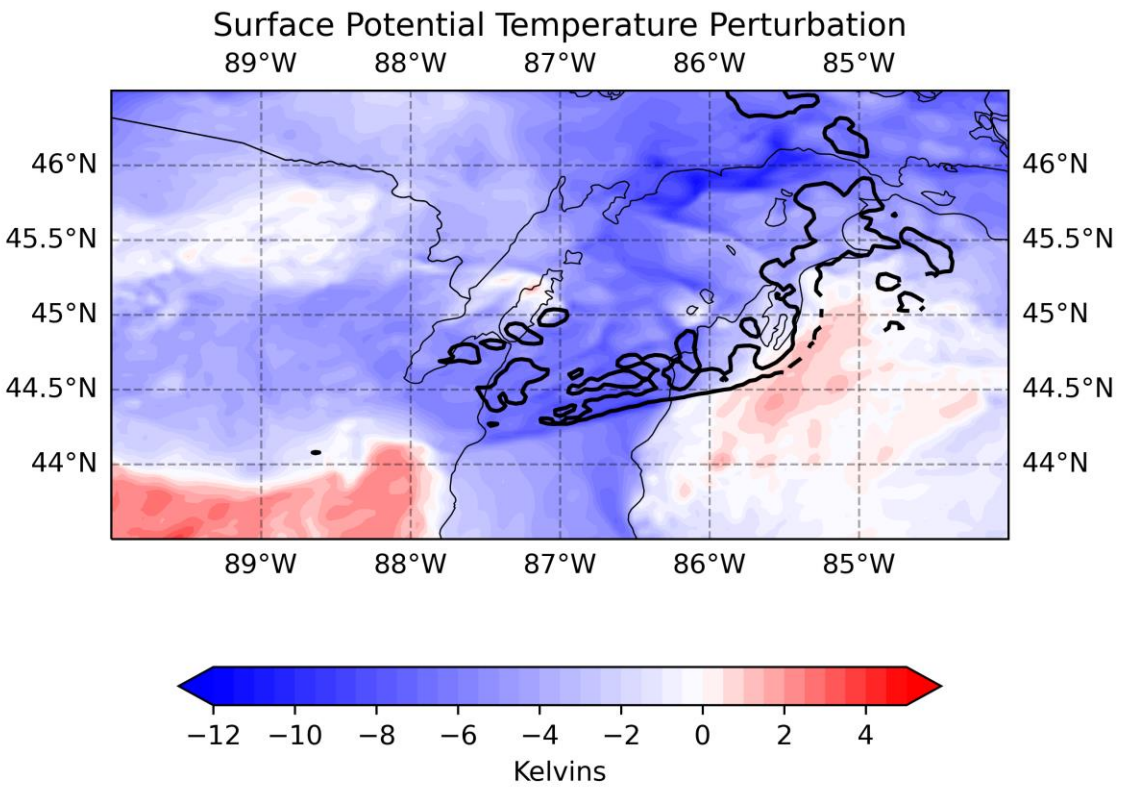
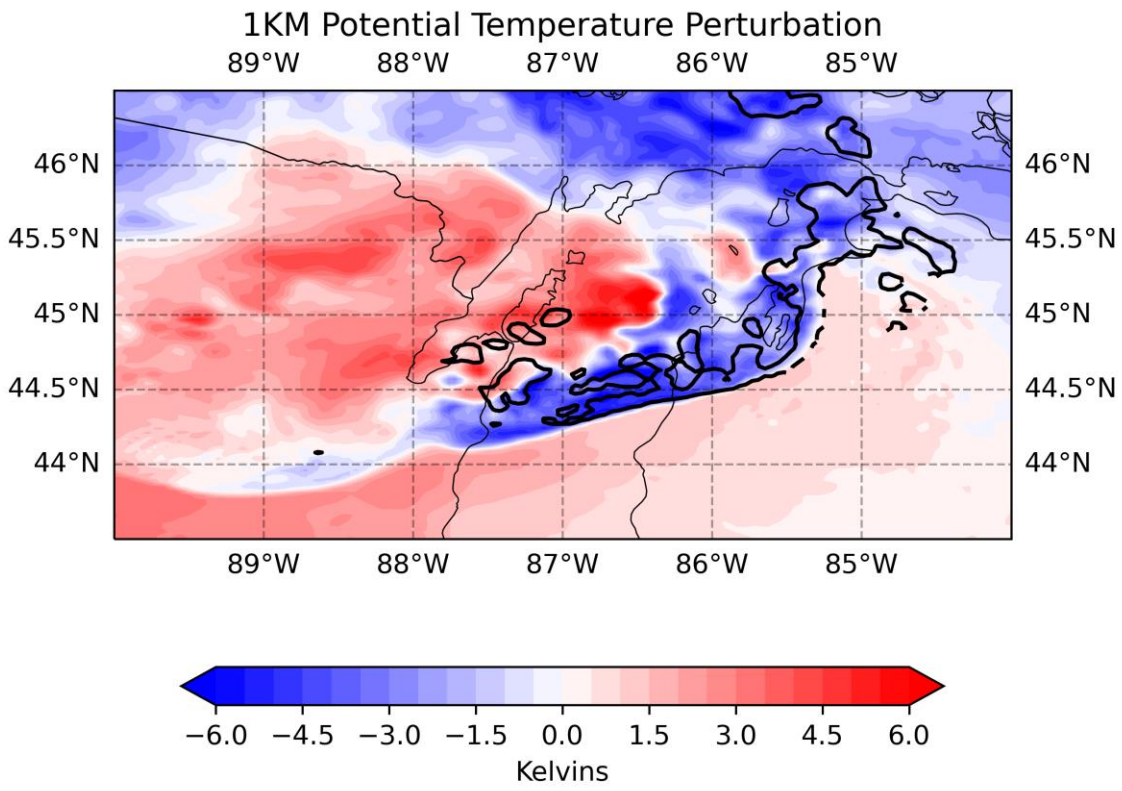




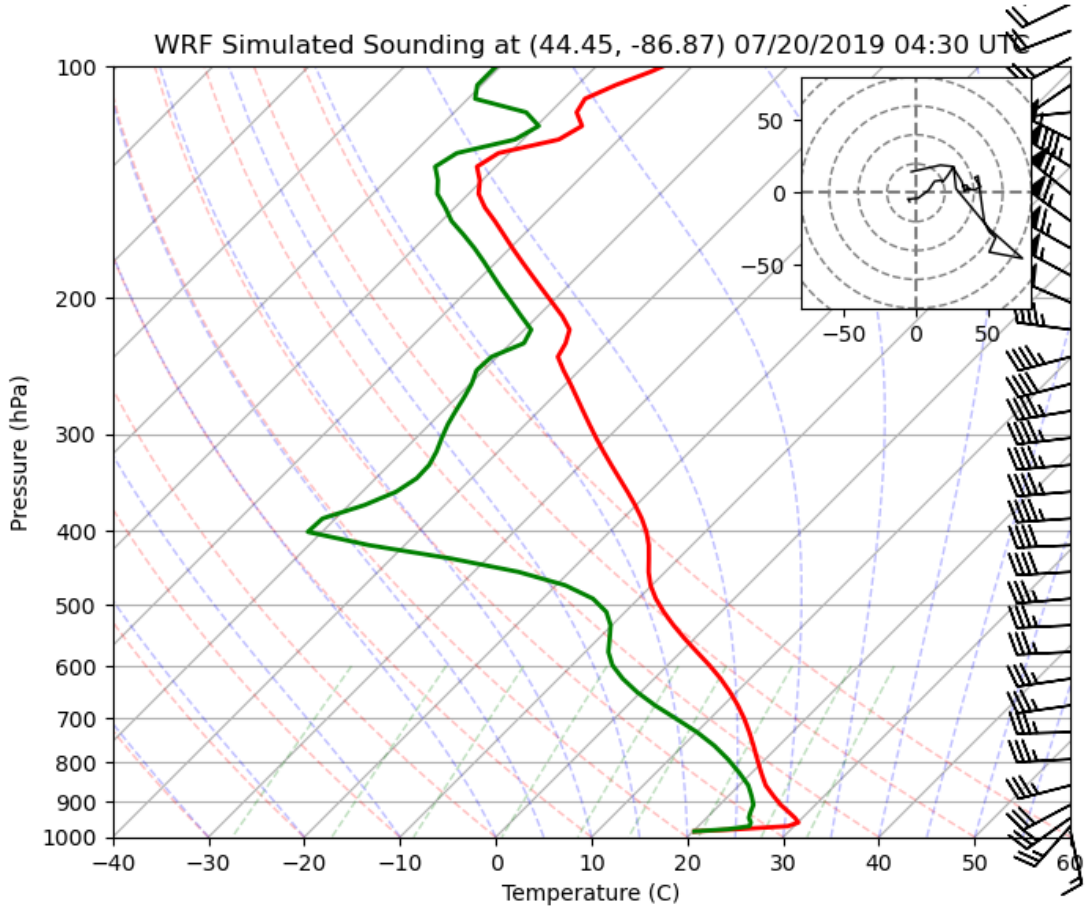
Cold Pool and MSL Interaction - θ’

WRF Potential Temperature Perturbation and Vertical Velocity 2019-07-20 06:00 UTC





Cold Pool and MSL – Depth of MSL (Shallow)



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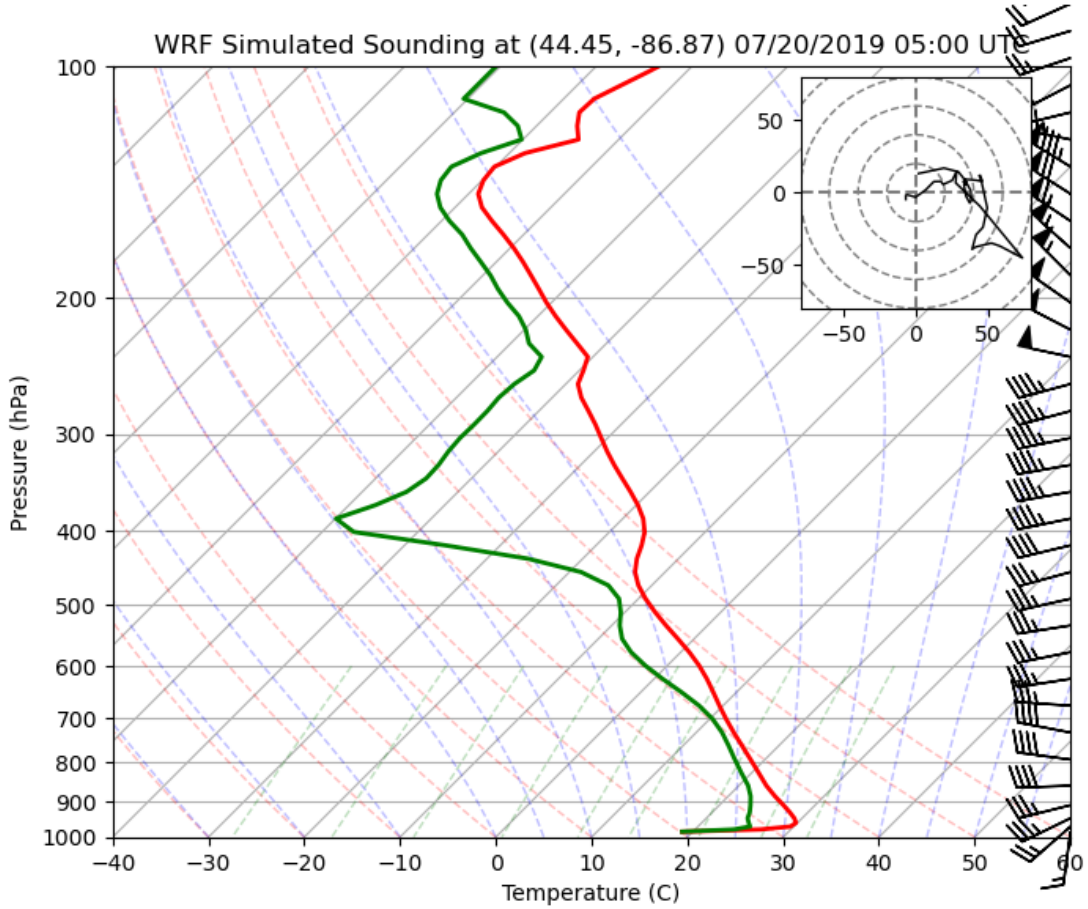

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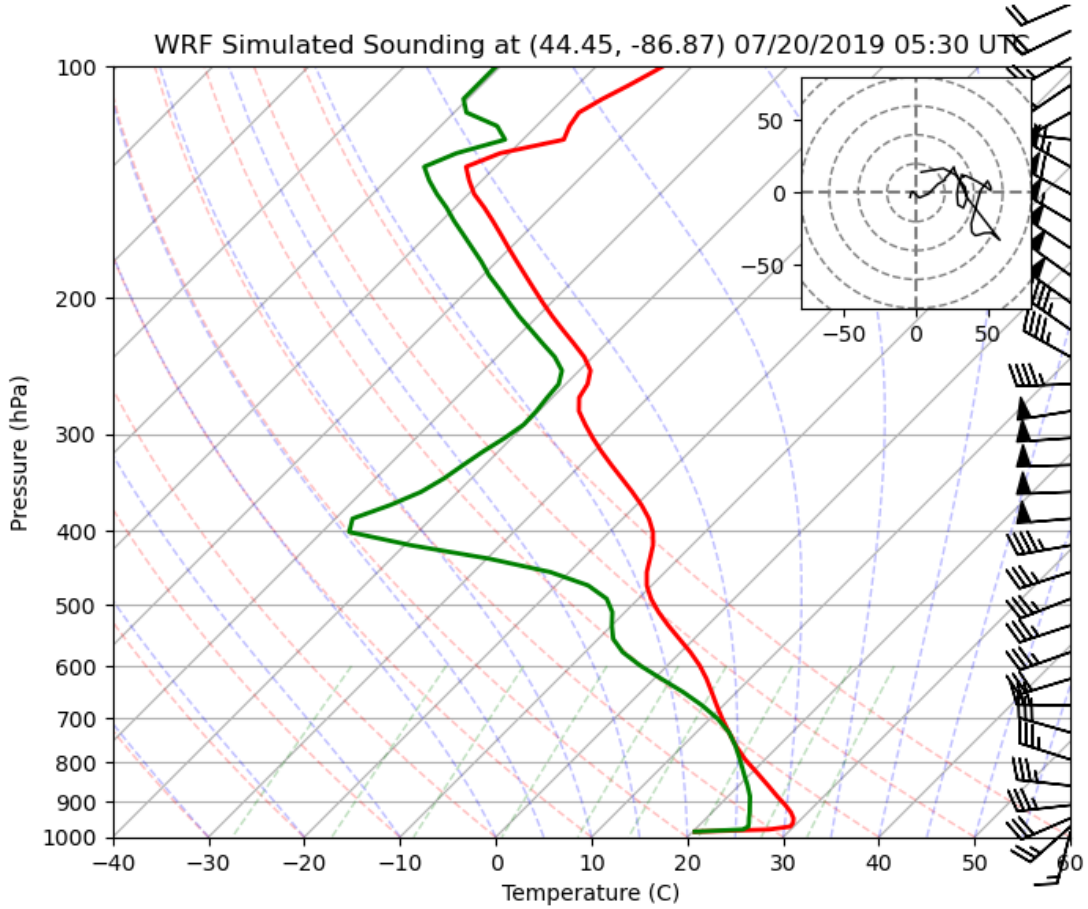

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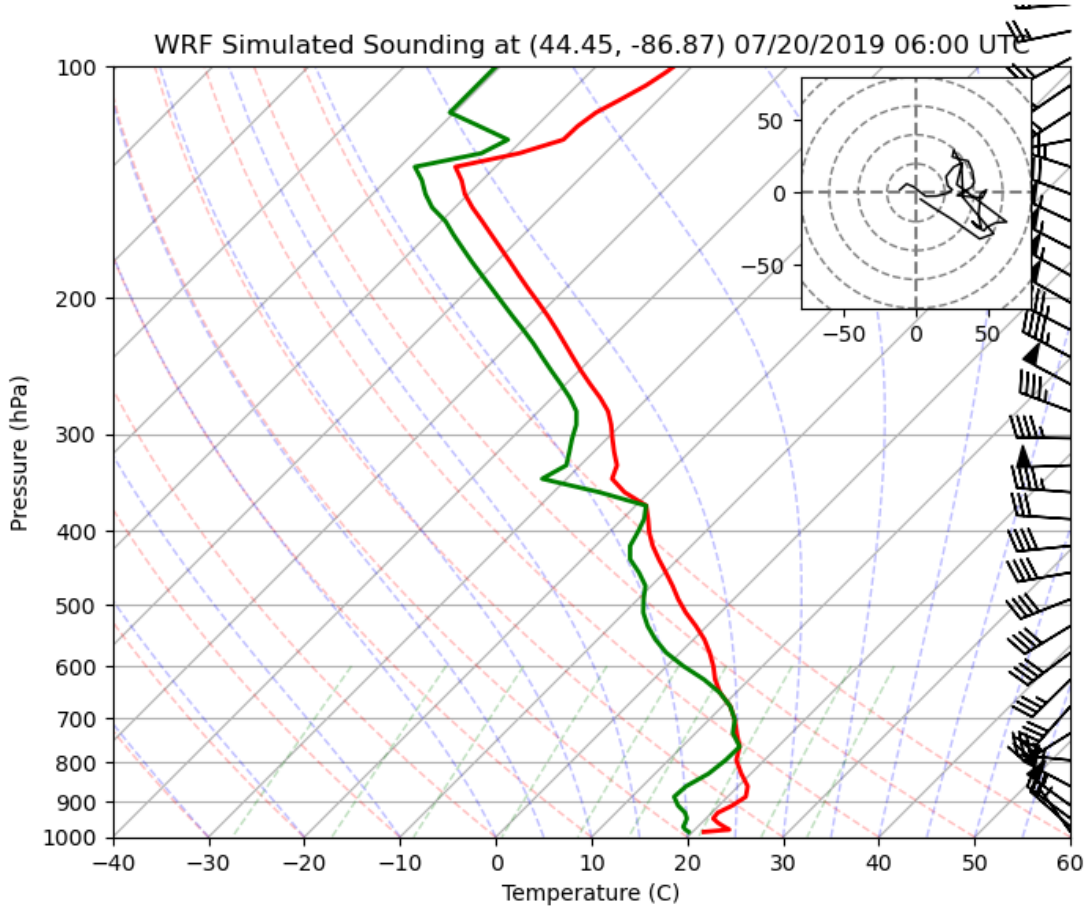
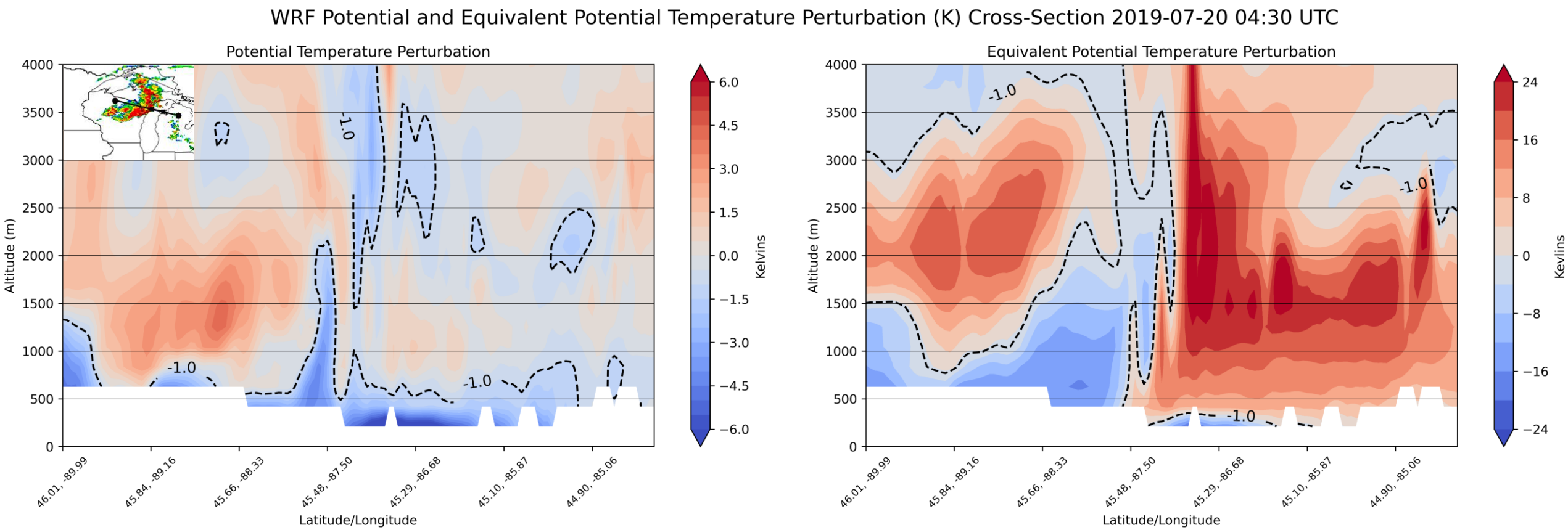


Cold Pool and MSL Interaction - θ' and θ_e'



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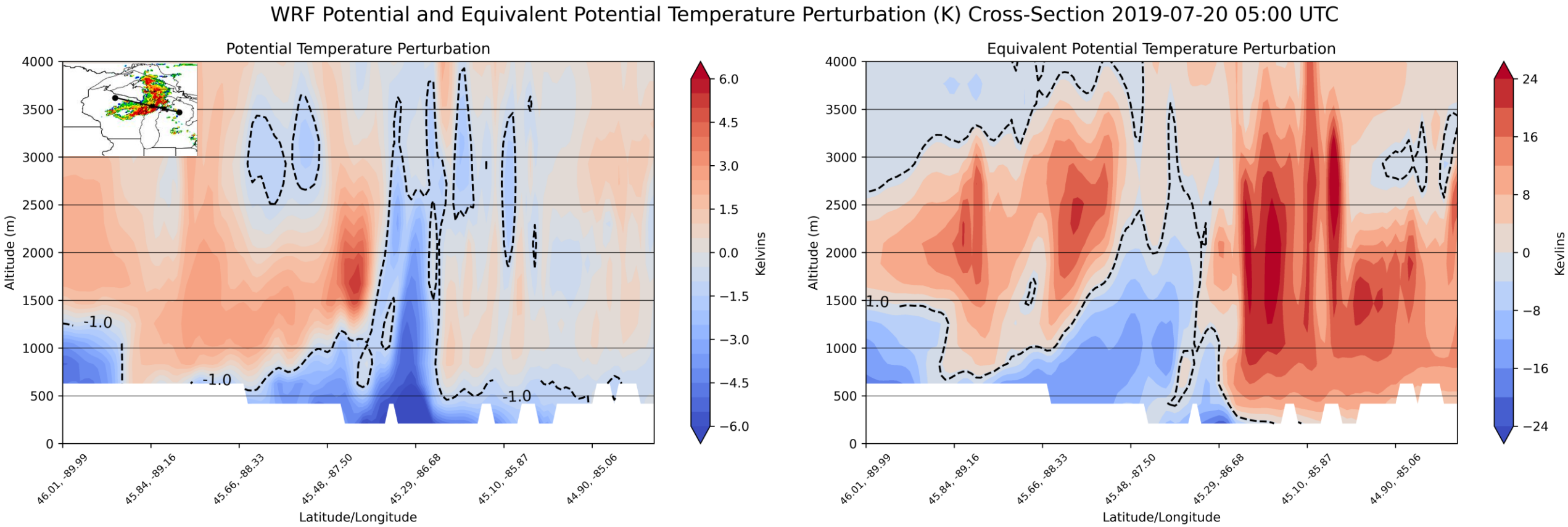

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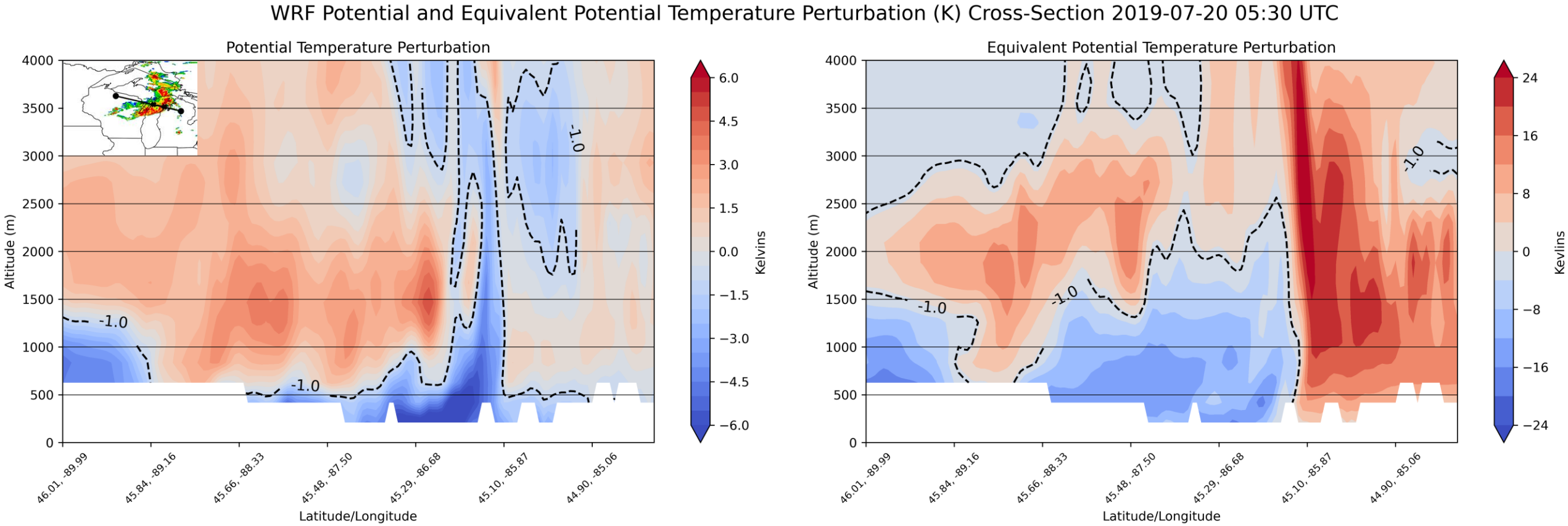
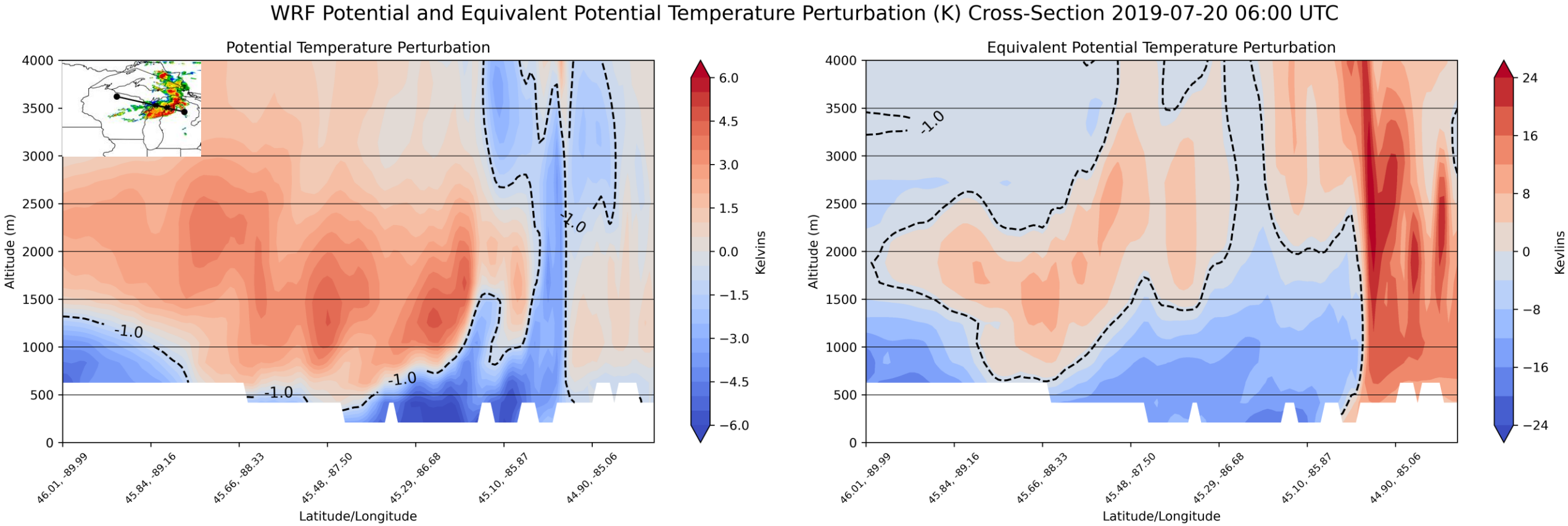
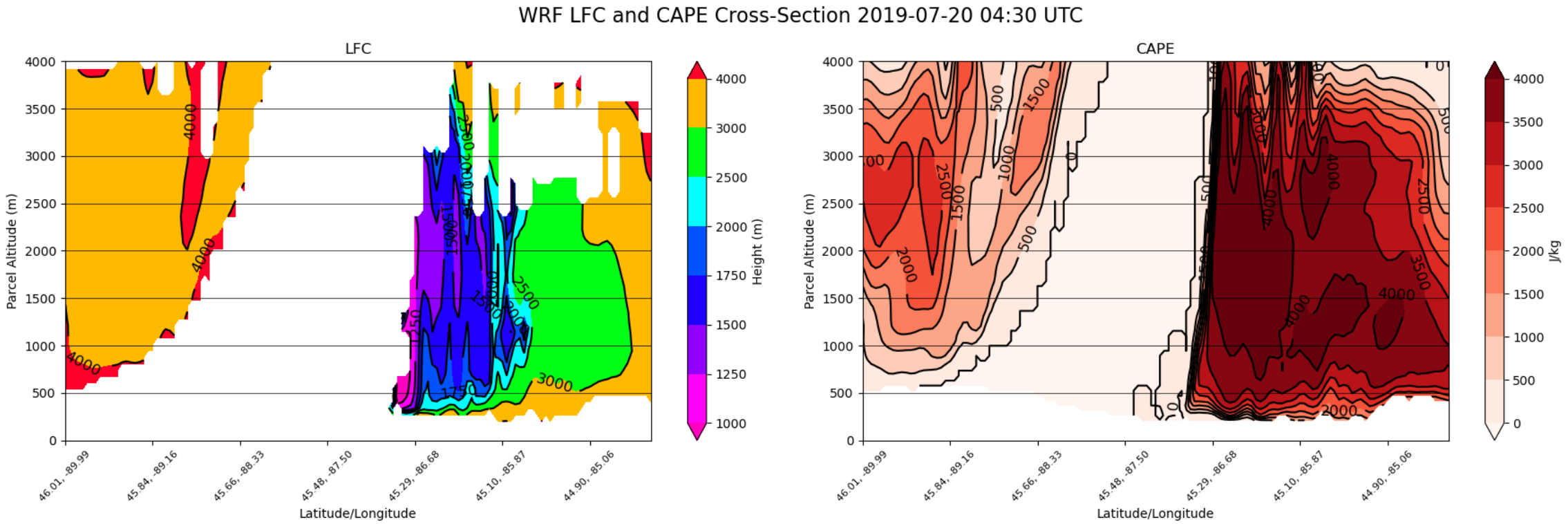


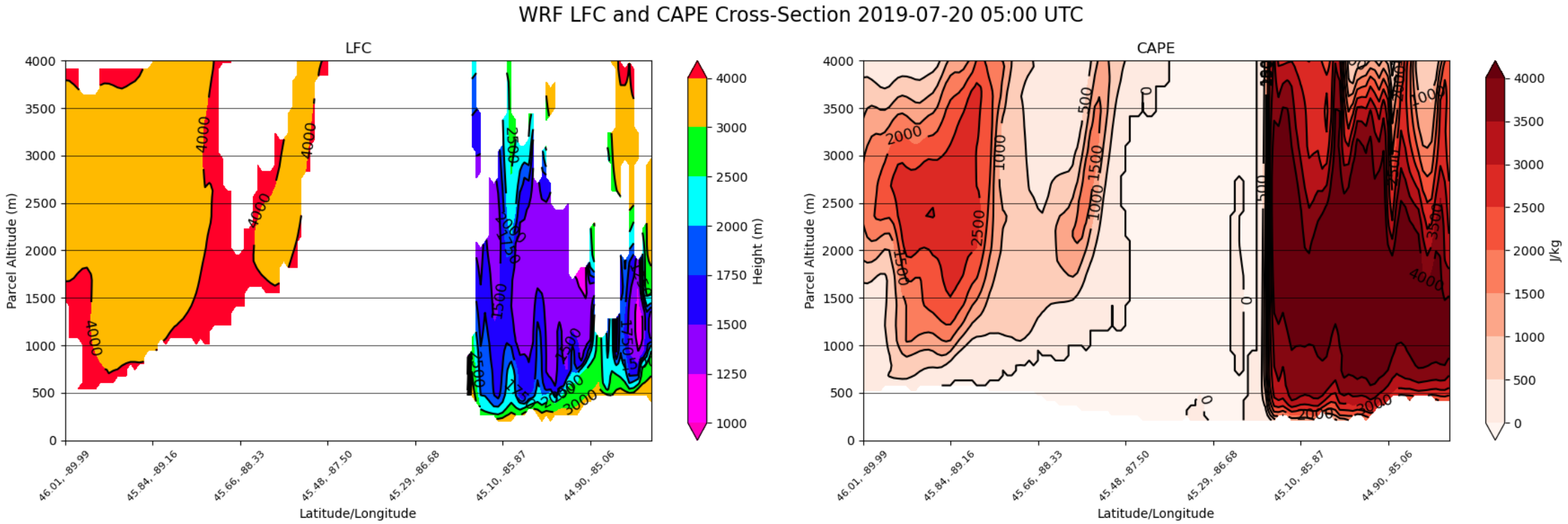
Cold Pool and MSL Interaction - θ' and θ_e'



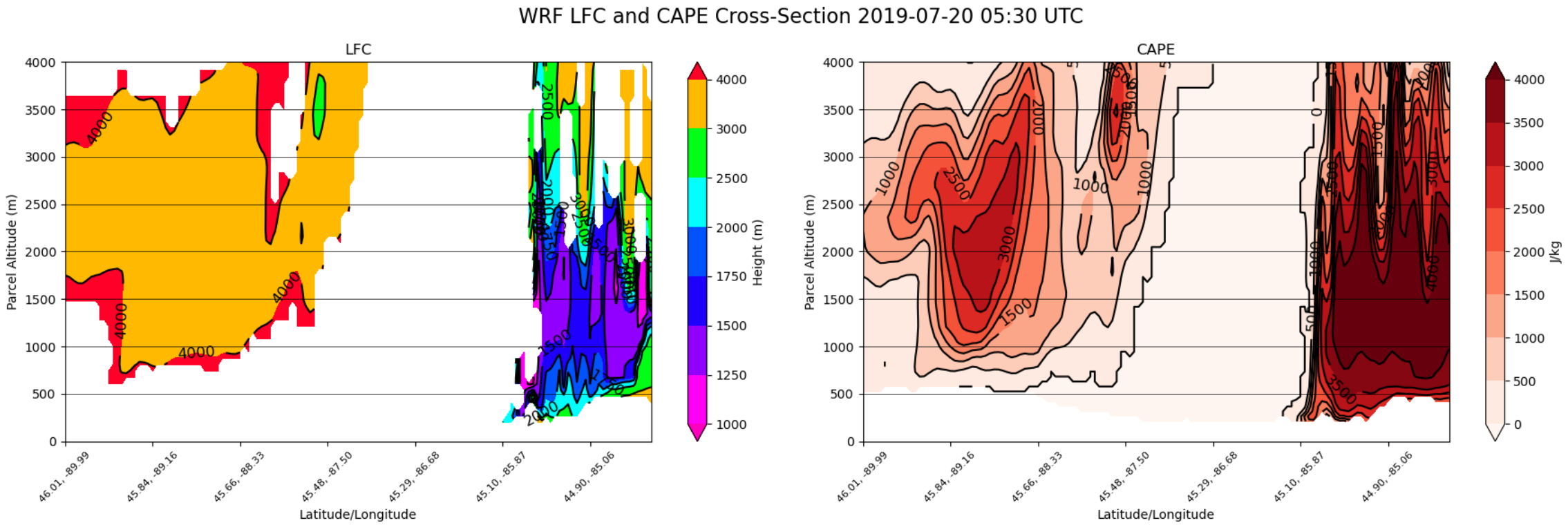
Cold Pool and MSL Interaction - LFC



Cold Pool and MSL Interaction



Cold Pool and MSL Interaction



Conclusion

1. Does the downstream environment support the persistence of an MCS over the lake?
   - Yes, the downstream environment was similar to Johns' (1993) classic warm-season progressive derecho and satisfied Metz (2011) Lake Michigan Crossing MCS Persistence Checklist.
2. Does the cold pool change when it encounters the marine stable layer (MSL) and how does that influence the MCS?
   - Yes, the cold pool changed structure when it interacted with the MSL, it strengthened and increased in depth.
   - The cold pool was deeper than the LFC, so convection will continue to initiate ahead of it, allowing for the MCS to persist over the lake.

Future Work

1. Add another nested domain (DO3) with a higher resolution (1 km) and smaller time step (15 minutes) to our WRF simulation.

2. Add a case of an MCS that dissipated over the lake to see if there are any differences between MCSs that persist and dissipate.

3. *Ideally* alter the surface conditions such that the temperatures are homogeneous rather than heterogeneous (i.e., ignore the lake).

Questions

- This is just a fraction of what we have done this semester. Feel free to email me (anthony.lllenden@ou.edu) or Stacey (stacey.hitchcock@ou.edu) for more information and please provide any feedback—we want to continue working on this project in the future!