The Late April/Early May 2023 Winter Storm in Upper Michigan

Dan Thompson
NOAA/NWS/WFO Marquette, MI

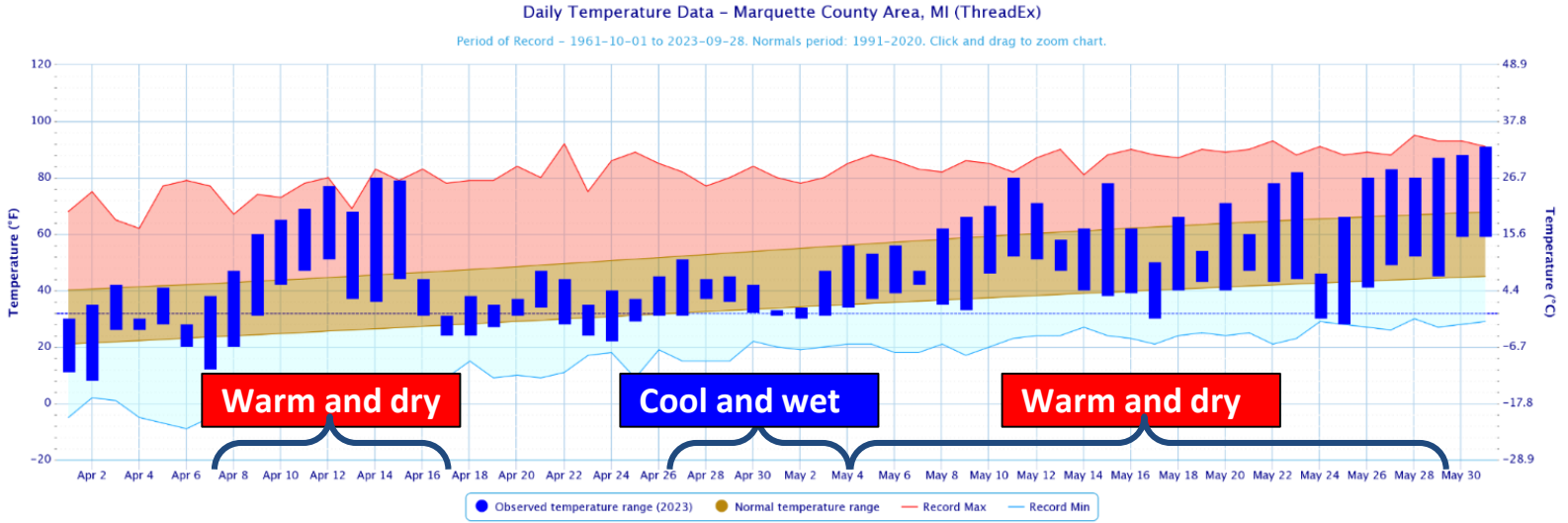
Image Credit:
Daniel Jablonski

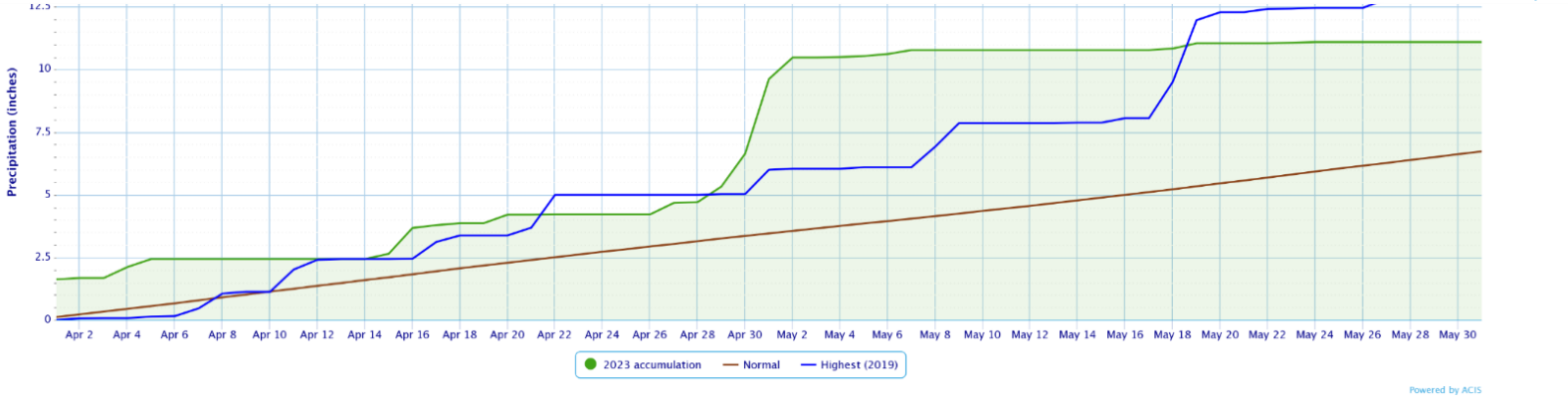
Bottom Line Up Front

- Prolonged period of rain, snow, and high winds 29 April–2 May over Michigan's Upper Peninsula (UP)
- Snowfall totals of 9–18" over the western UP, 24–48" over the north-central; May snowfall records broken in some areas
- Sharp snowfall gradient near the Lake Superior shoreline
- Wind gusts of 40–50 mph combined with heavy, wet snow led to numerous power outages and hazardous to impassable road conditions
- Subsequent melt-off of record snowpack resulted in flooding impacts

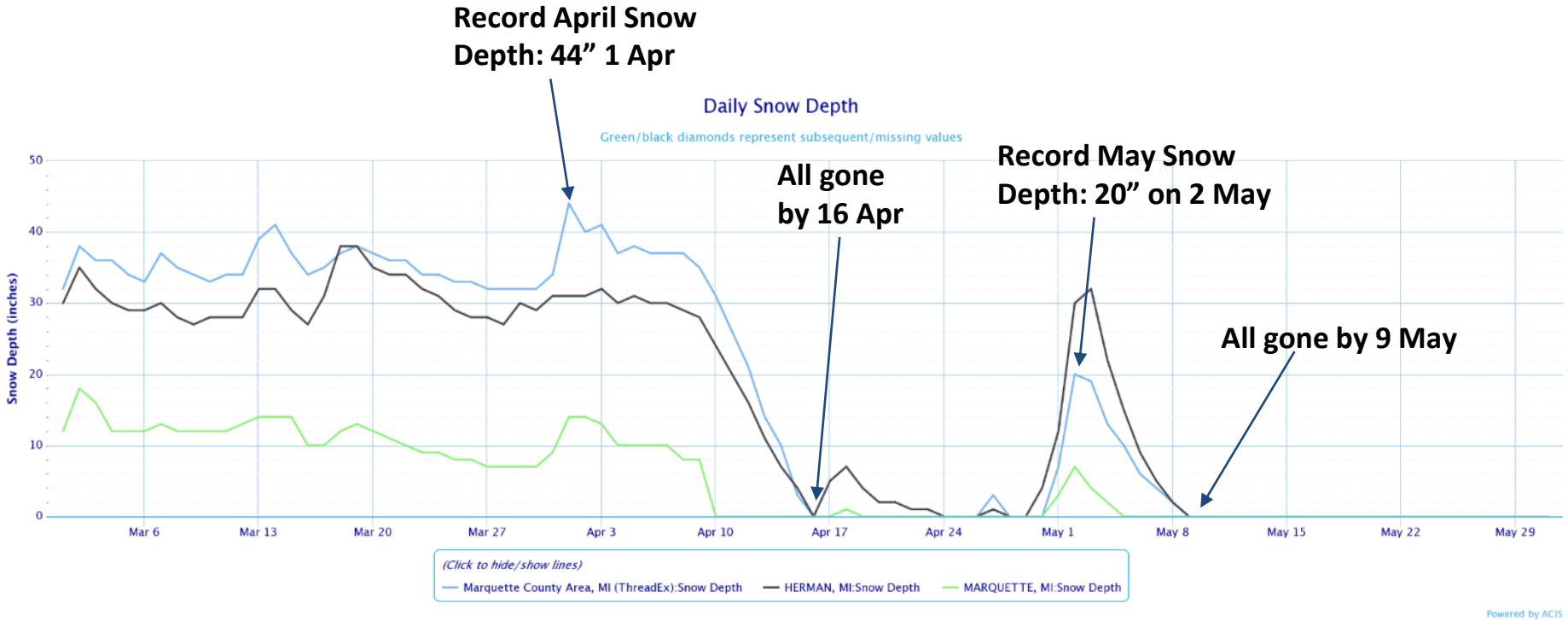
Credit: James Salzwedel

A Spring of Extremes



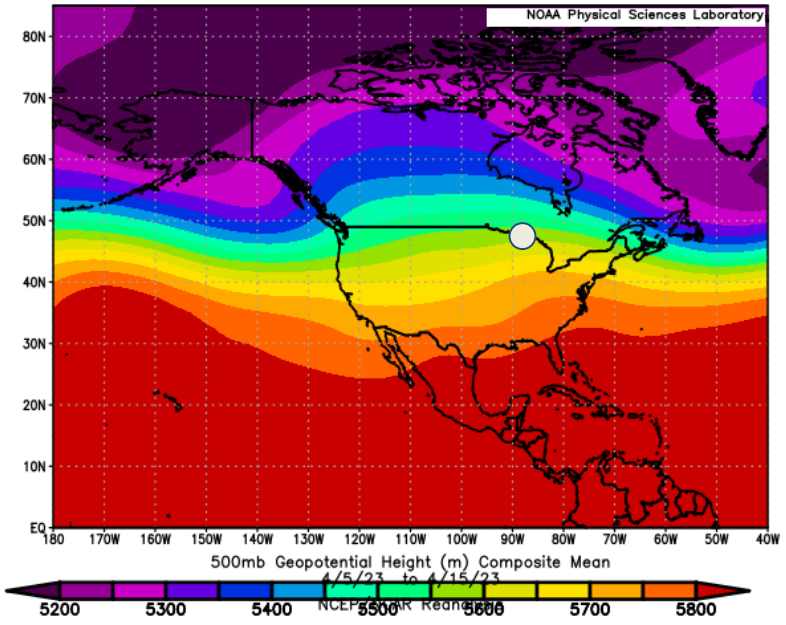


A Spring of Extremes

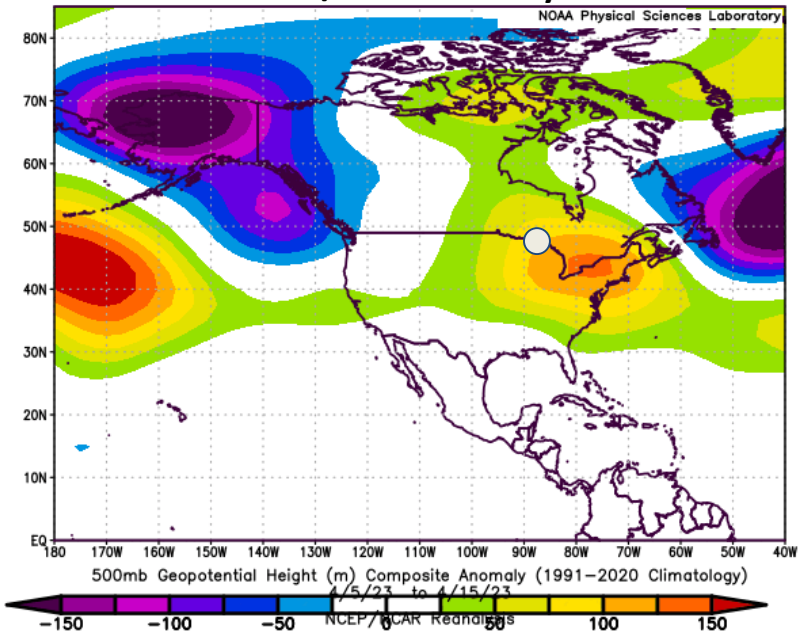


Time-Mean Synoptic-Scale Flow Pattern

500 mb Mean Heights 5–15 Apr 2023
NCEP/NCAR Reanalysis



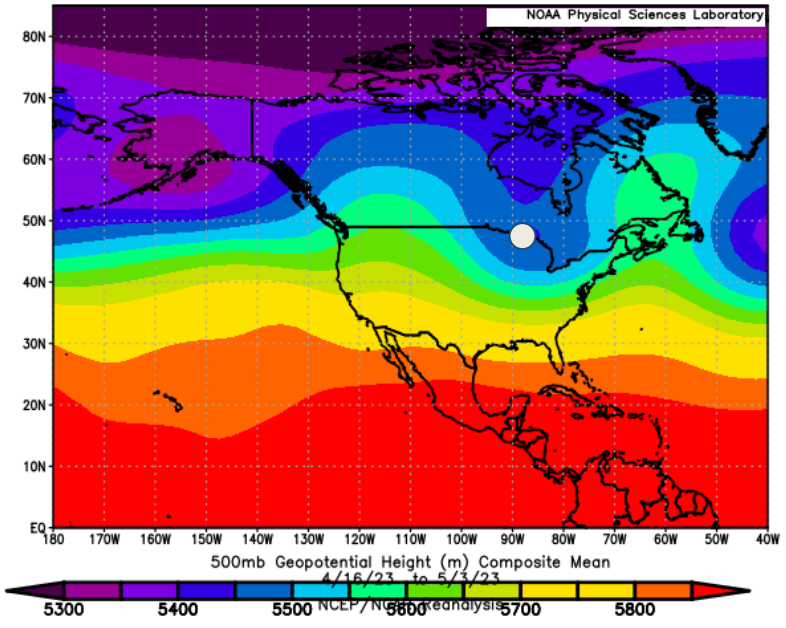
500 mb Height Anomaly 5–15 Apr 2023
NCEP/NCAR Reanalysis



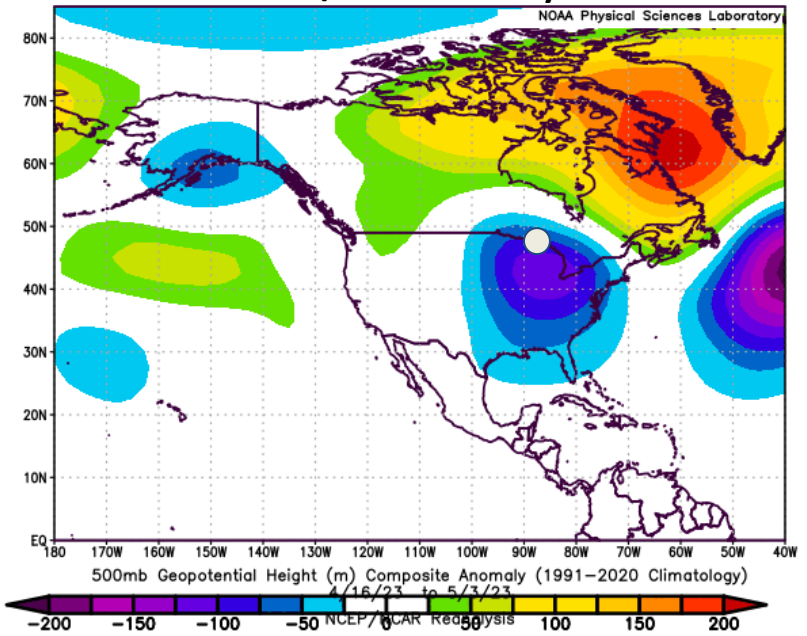
UP on western flank of positive height anomaly max during early/mid-April

Time-Mean Synoptic-Scale Flow Pattern

500 mb Mean Heights 16 Apr–3 May 2023
NCEP/NCAR Reanalysis



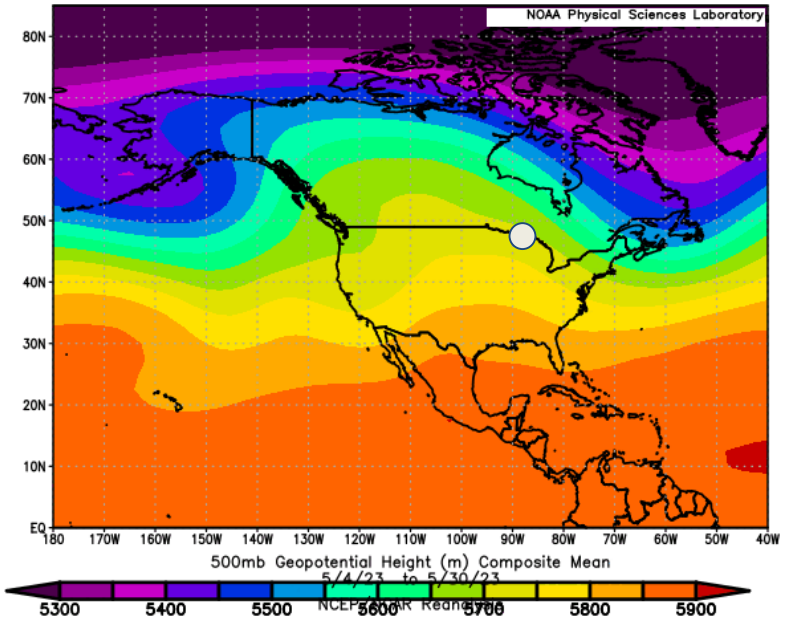
500 mb Height Anomaly 16 Apr–3 May 2023
NCEP/NCAR Reanalysis



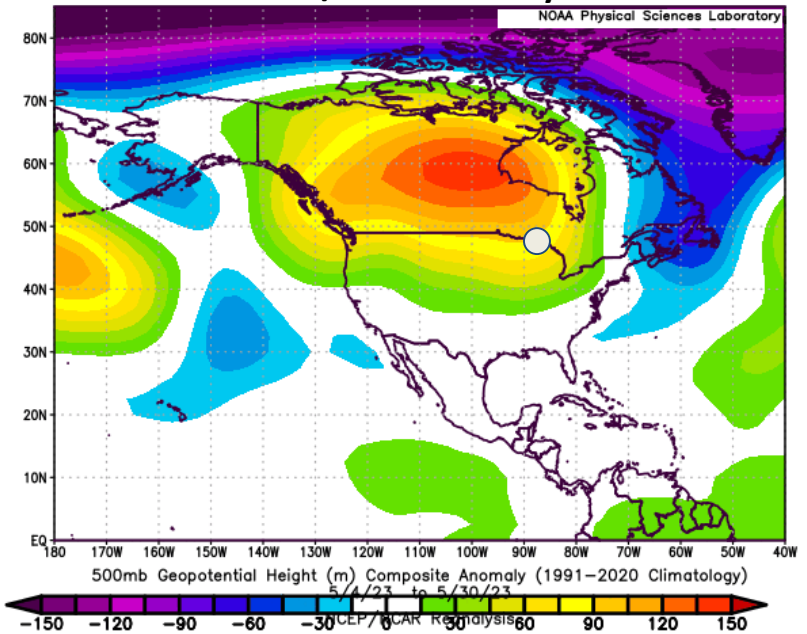
Transition to Rex block-type pattern with anomalous troughing over the Great Lakes and ridging over much of central/eastern Canada

Time-Mean Synoptic-Scale Flow Pattern

500 mb Mean Heights 4–30 May 2023
NCEP/NCAR Reanalysis

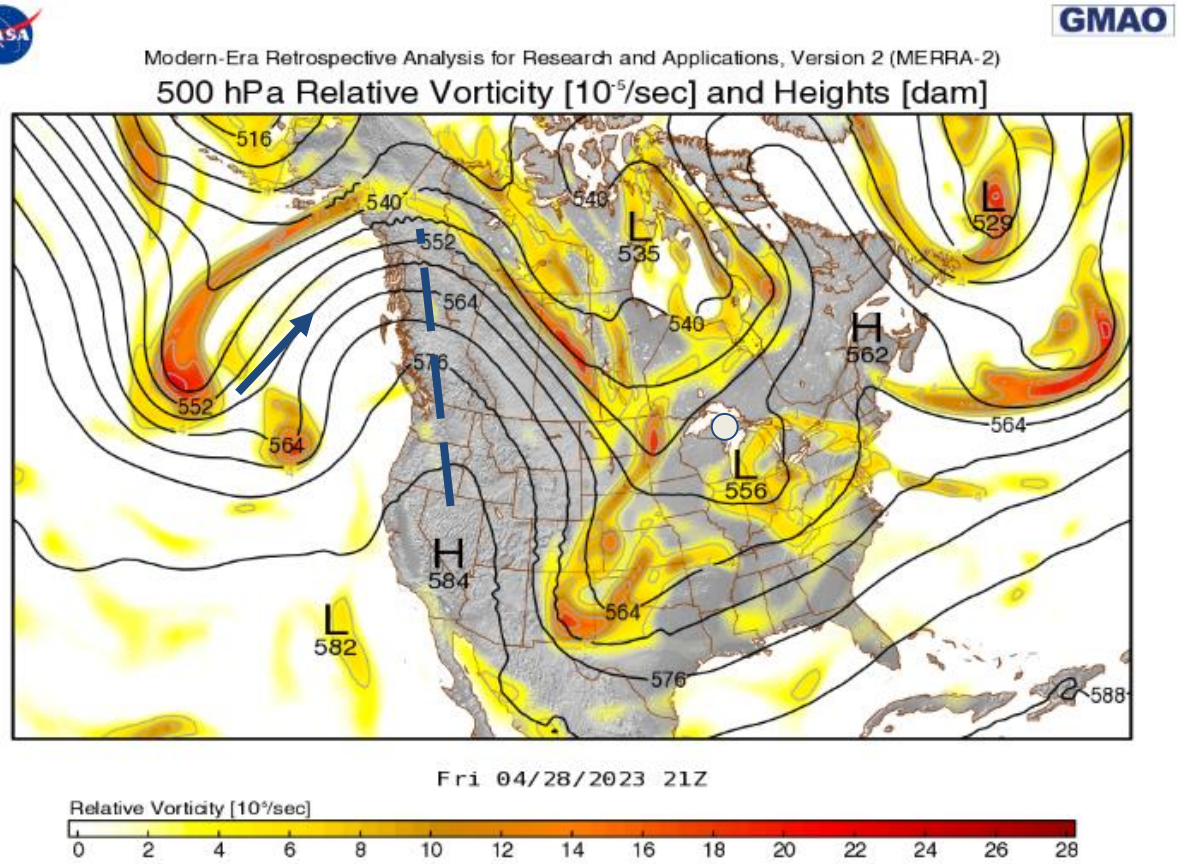


500 mb Height Anomaly 4–30 May 2023
NCEP/NCAR Reanalysis



Massive ridge took over much of central/western Canada for the rest of May. Mean northwesterly flow over the UP implied subsidence, accounting for the dry stretch. This pattern was coincident with the start of the historic fire season in Canada.

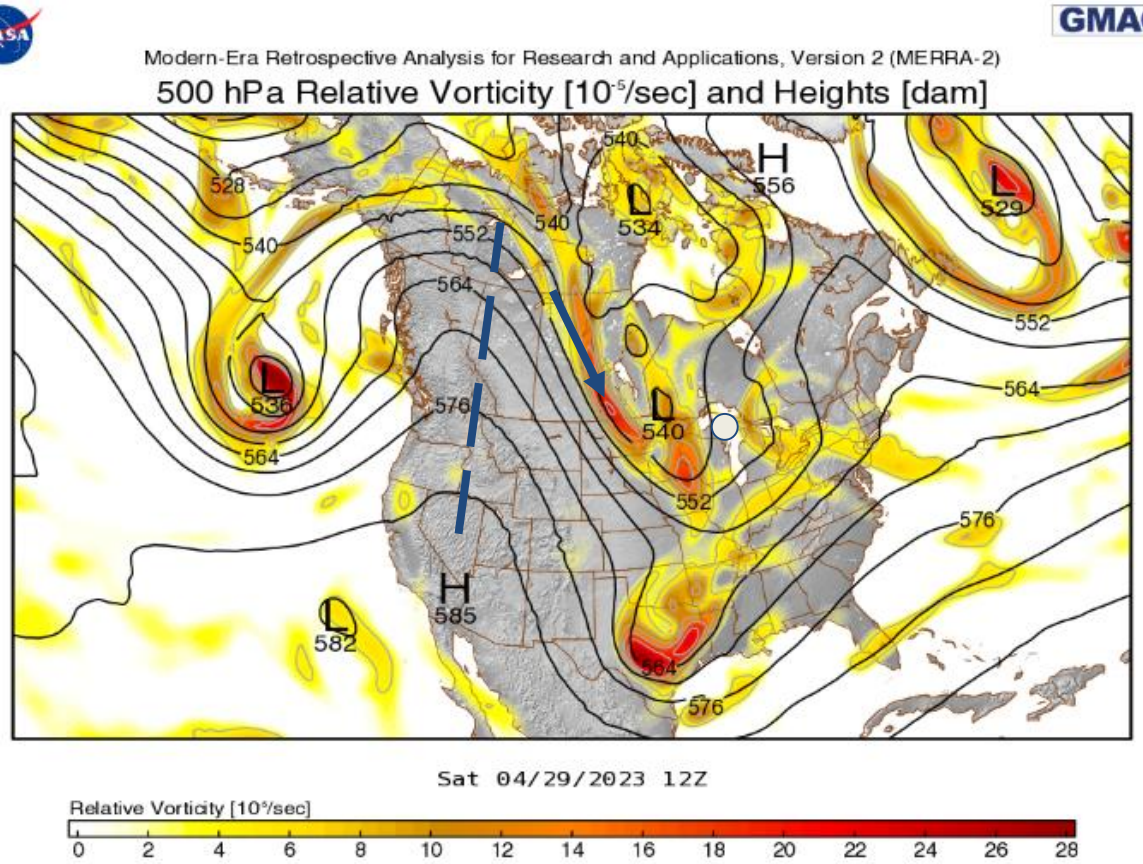
500 mb Flow Evolution



21Z 28 Apr

Western North America ridge builds downstream of pair of vorticity maxima in the Eastern Pacific

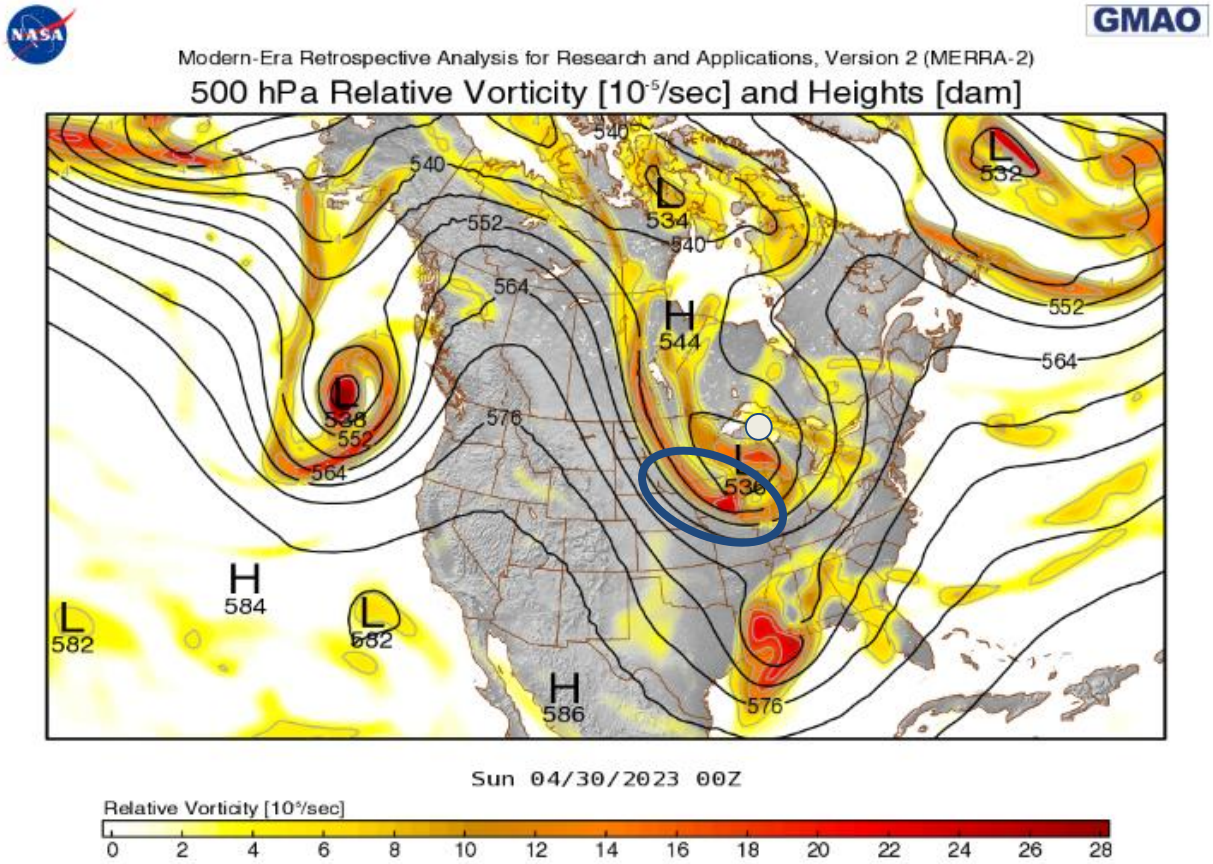
500 mb Flow Evolution



12Z 29 Apr

Building western Canada ridge forces area of shear vorticity southeastward into the Northern Plains

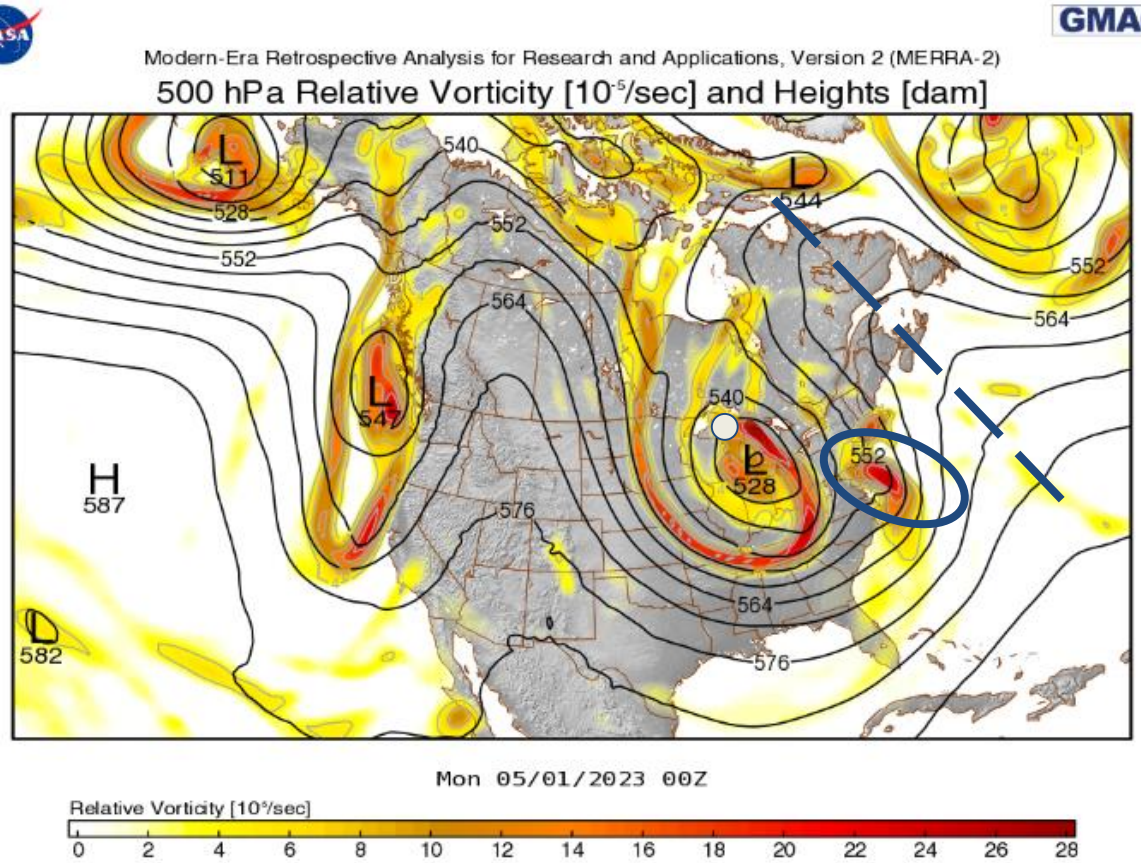
500 mb Flow Evolution



00Z 30 Apr

Vorticity consolidates over Iowa, midlevel low cuts off over Wisconsin

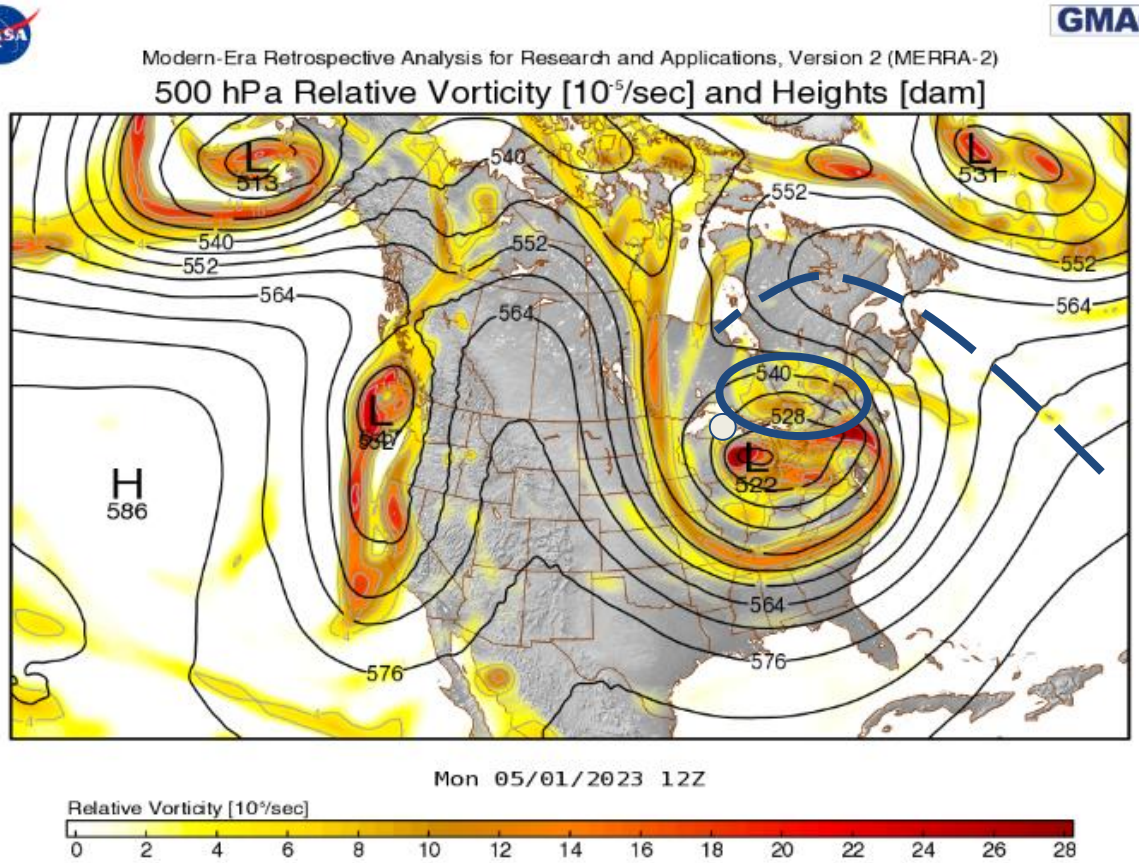
500 mb Flow Evolution



00Z 1 May

Midlevel low continues to strengthen over Lower Michigan. Eastward progress blocked by high-amplitude ridge over eastern Canada. Southern stream vorticity maximum ejects up the Eastern Seaboard.

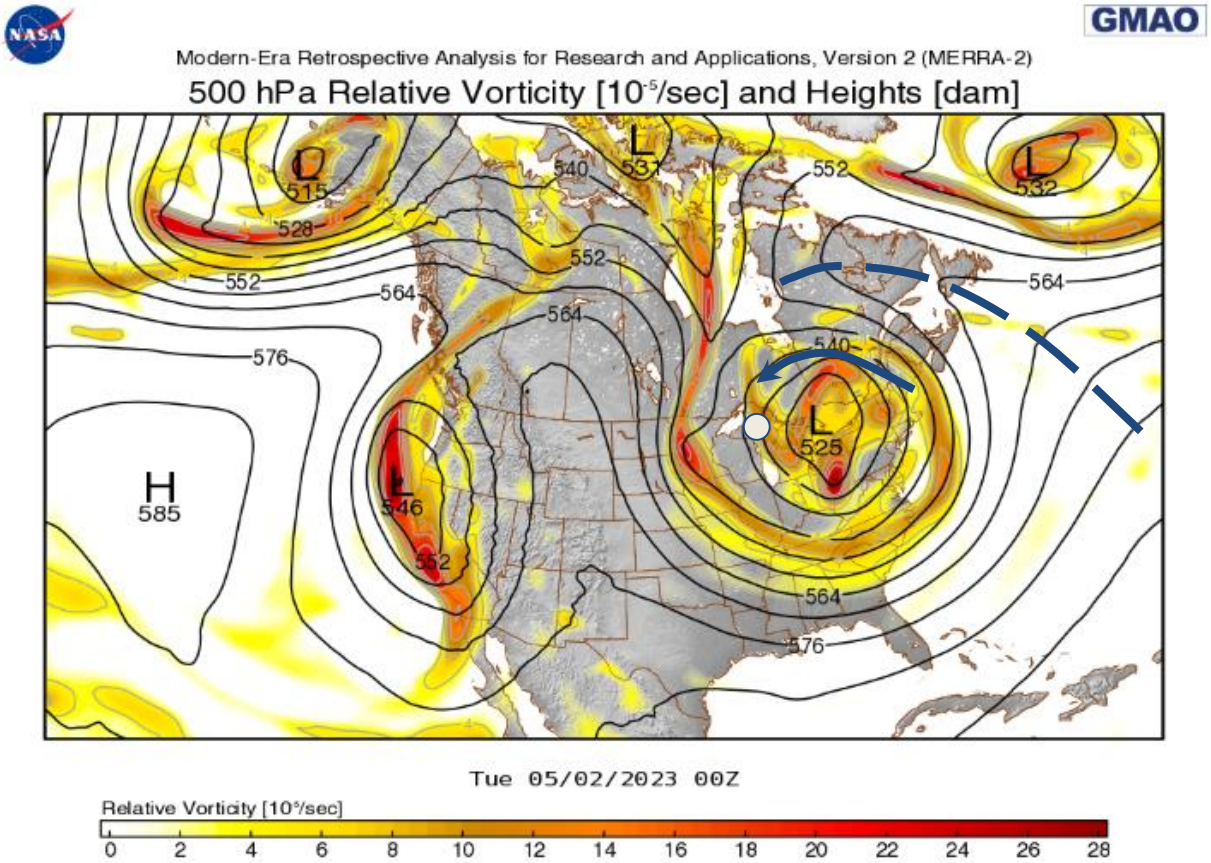
500 mb Flow Evolution



12Z 1 May

Massive cutoff low remains stationary over lower Michigan as eastern US vorticity maximum gets absorbed into the circulation

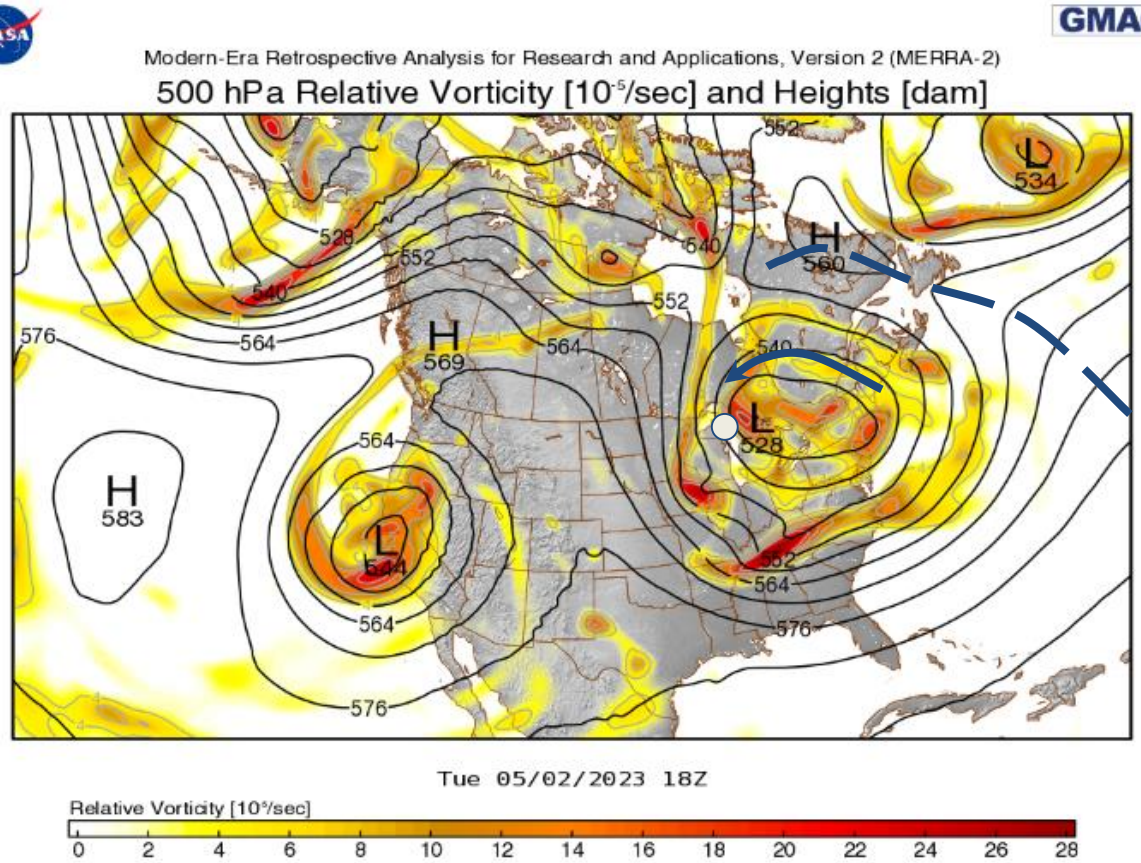
500 mb Flow Evolution



00Z 2 May

Vorticity maxima continue to retrograde into the upper Great Lakes around the slowly-weakening low. Low remains blocked by bent-back ridge over eastern Canada.

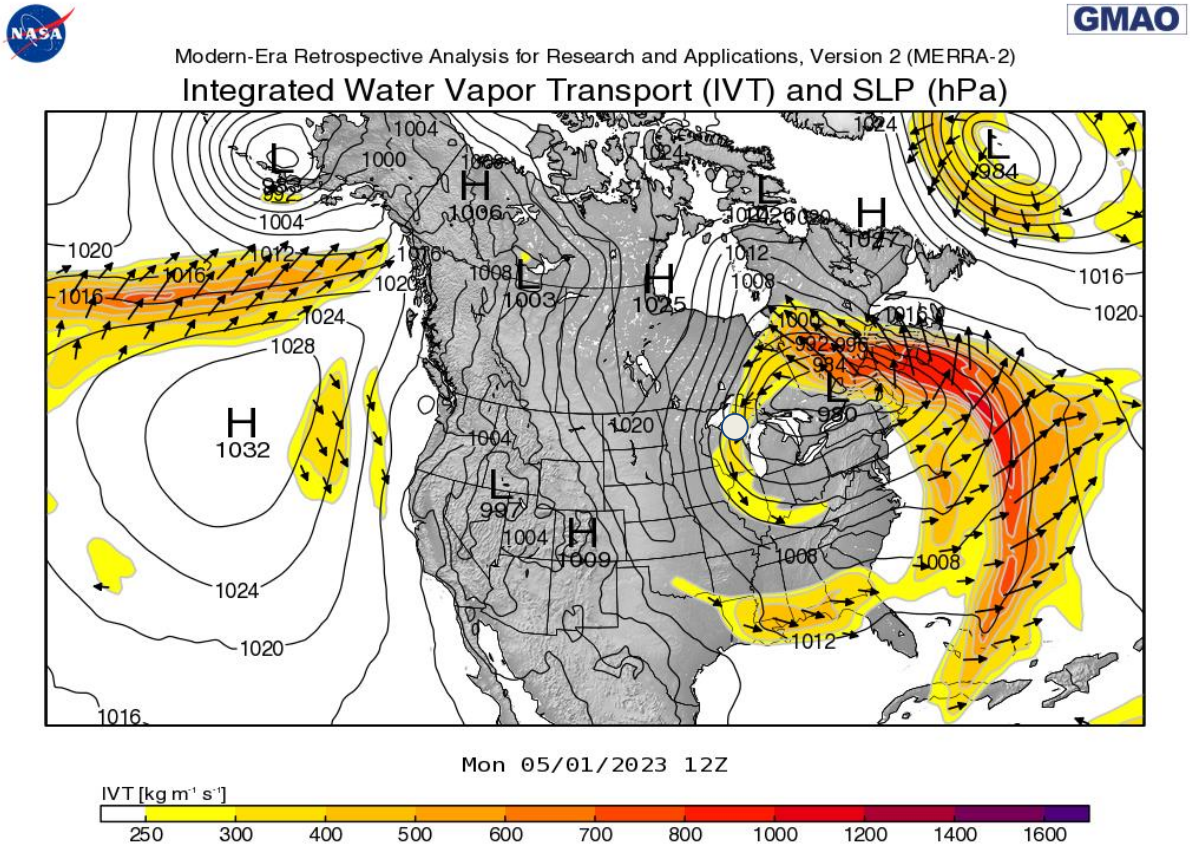
500 mb Flow Evolution



18Z 2 May

Vorticity maxima continue to retrograde into the upper Great Lakes around the slowly-weakening low. Low remains blocked by bent-back ridge over eastern Canada.

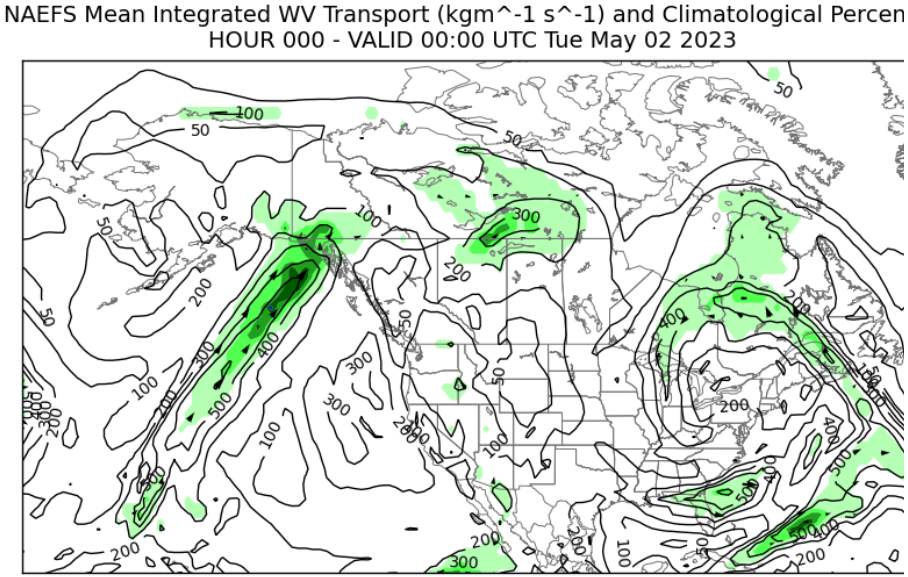
Integrated Water Vapor Transport

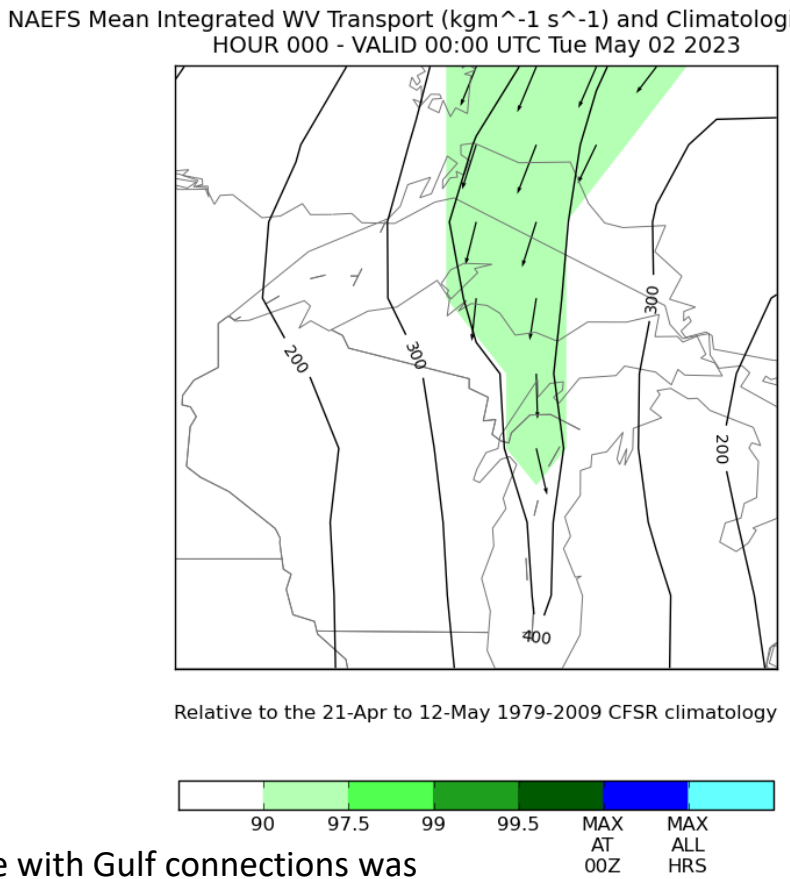


12Z 1 May

Tropical moisture transported northward via atmospheric river, wrapped back around retrograding low into the Great Lakes

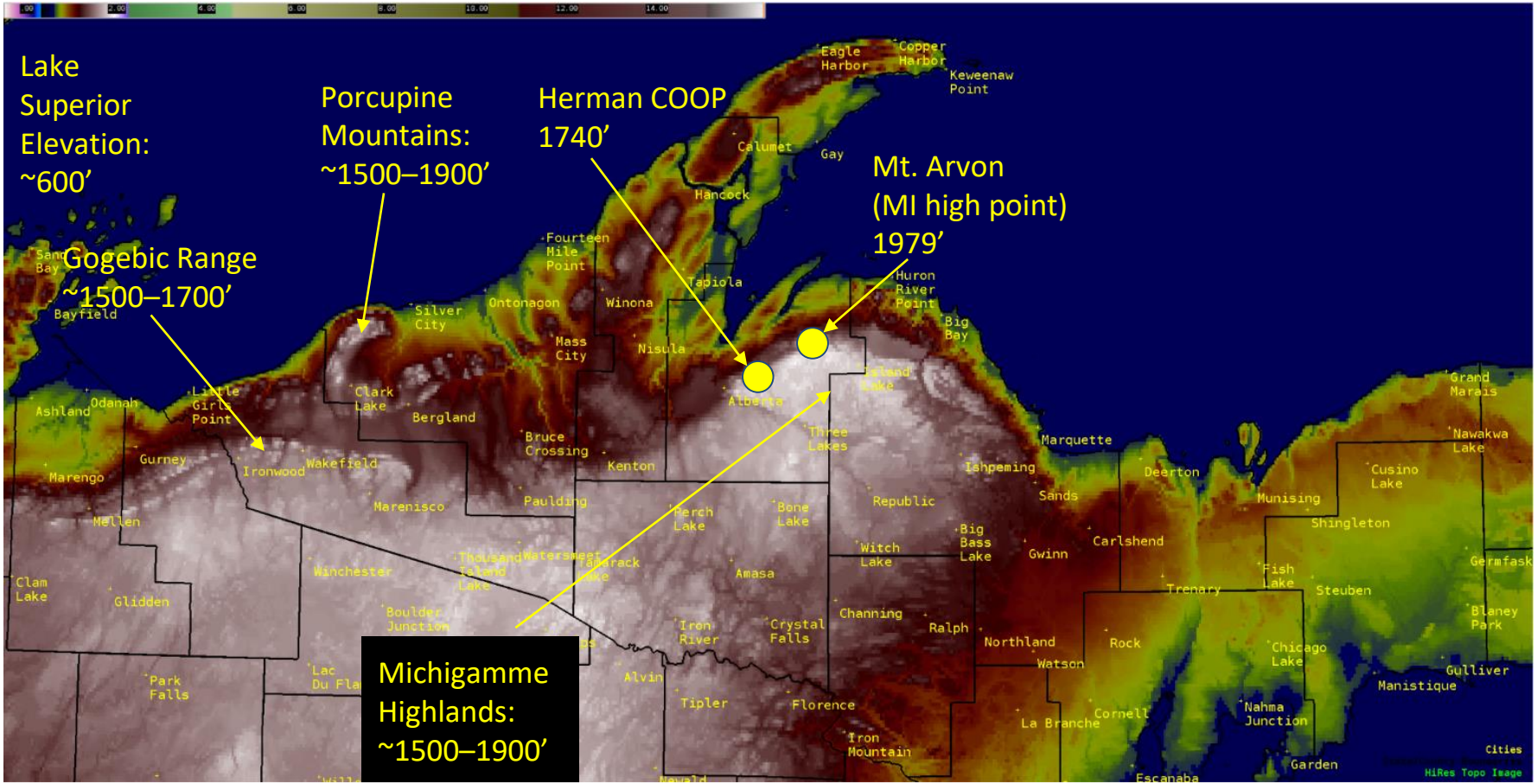
Integrated Water Vapor Transport



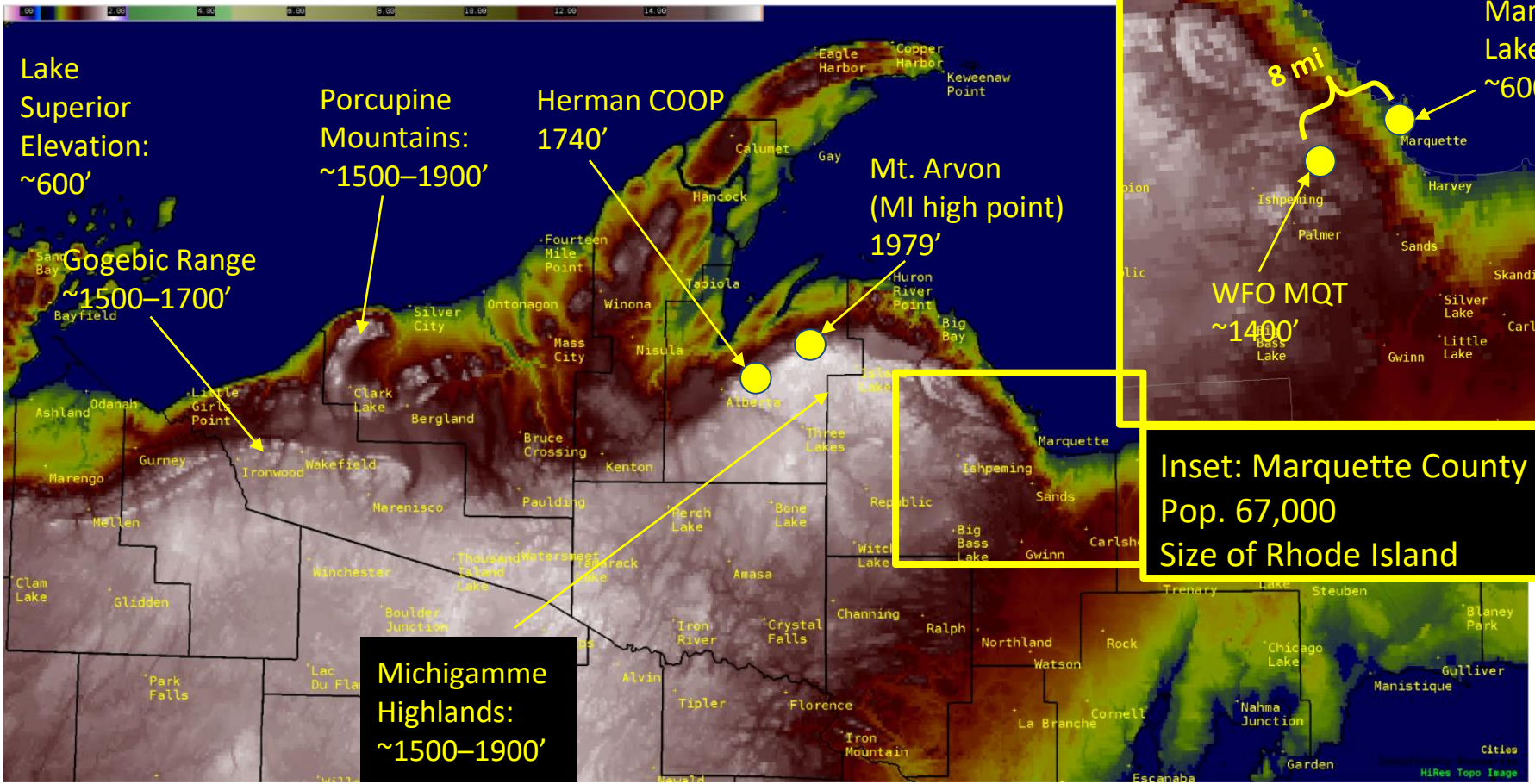


> 90th percentile IVT…from the north! This feed of moisture with Gulf connections was key to the extreme precipitation amounts observed during this storm.

Upper Peninsula Topography



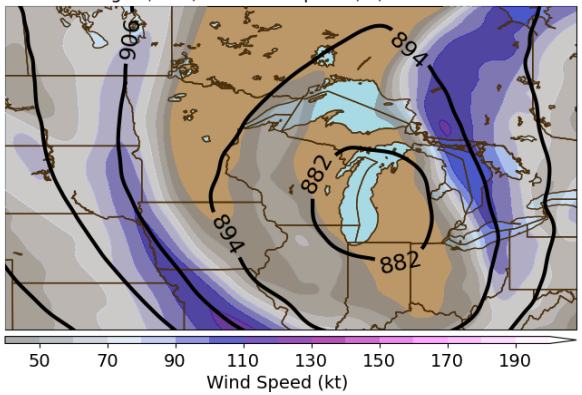
Upper Peninsula Topography



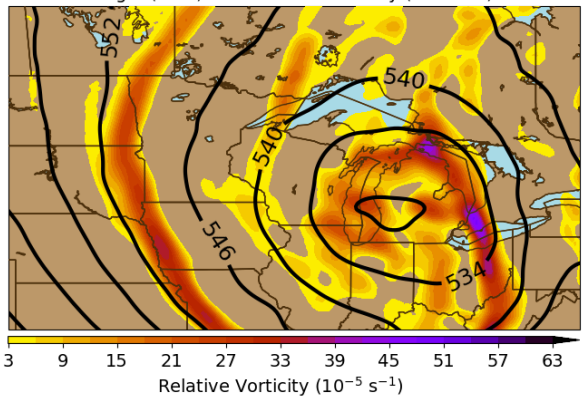
Round 2: Northern UP, 01.00Z–02.18Z

RAP Analysis VALID: 0000 UTC Mon May 01 2023

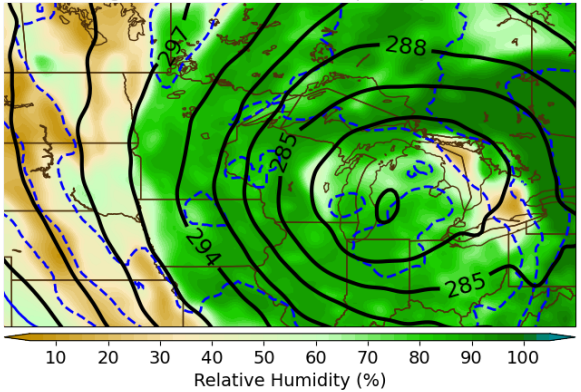
300 hPa Height (dam) and Wind Speed (kt)



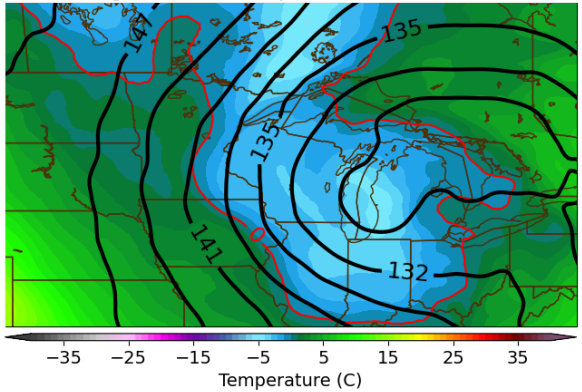
500 hPa Height (dam) and Relative Vorticity (10^{-5} s^{-1})



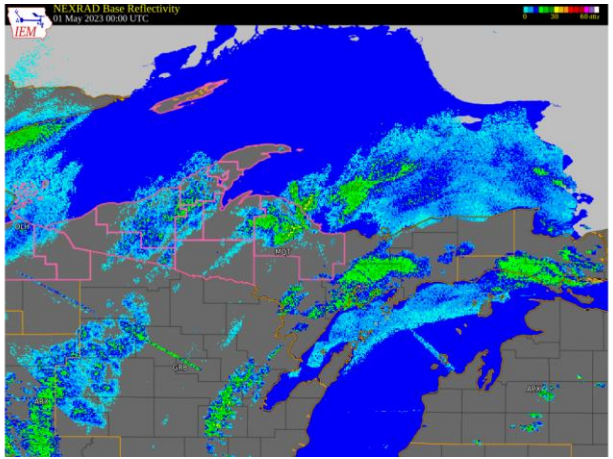
700 hPa Height (dam), RH (%), and Temp (every 3 C)



850 hPa Height (dam) and Temp (C)



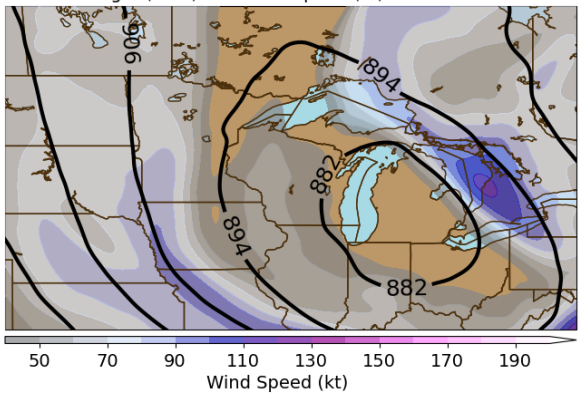
- Midlevel low center elongates and drifts east
- Spokes of vorticity wrap around the low and move over the UP from the northeast
- Continued robust moist conveyor belt



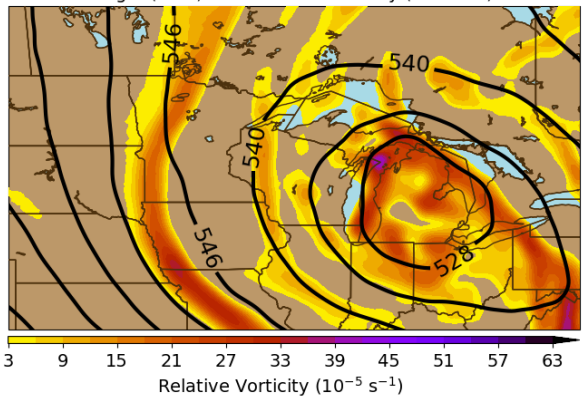
Round 2: Northern UP, 01.00Z–02.18Z

RAP Analysis VALID: 0600 UTC Mon May 01 2023

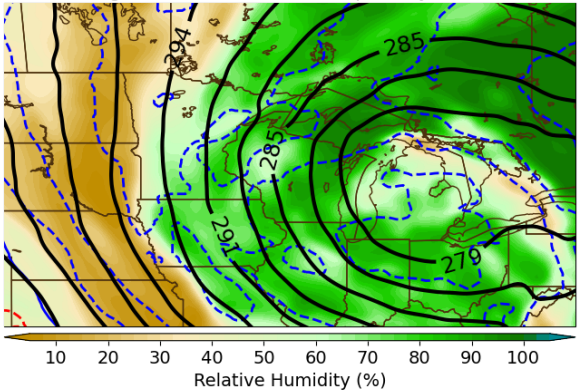
300 hPa Height (dam) and Wind Speed (kt)



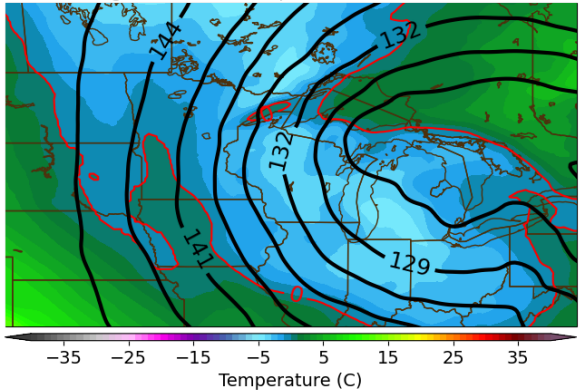
500 hPa Height (dam) and Relative Vorticity (10^{-5} s^{-1})



700 hPa Height (dam), RH (%), and Temp (every 3 C)



850 hPa Height (dam) and Temp (C)



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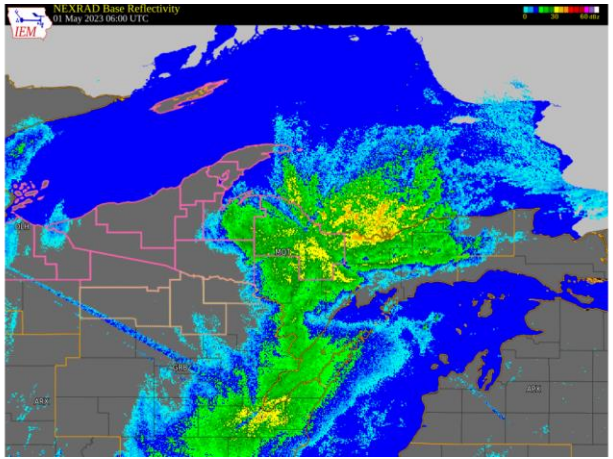
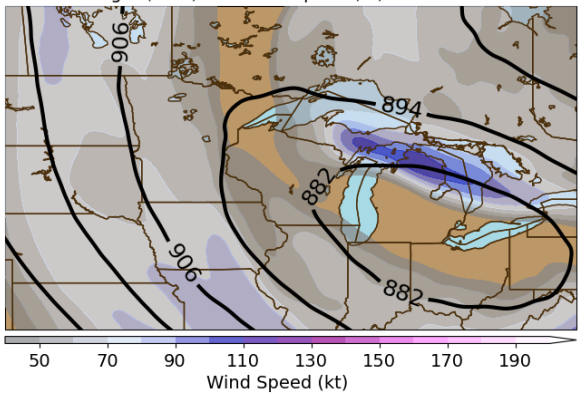


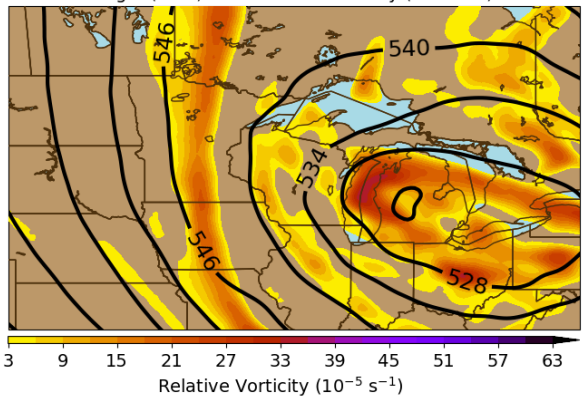
Round 2: Northern UP, 01.00Z–02.18Z

RAP Analysis VALID: 1200 UTC Mon May 01 2023

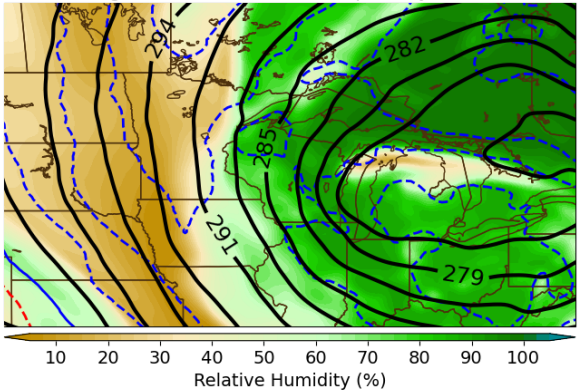
300 hPa Height (dam) and Wind Speed (kt)



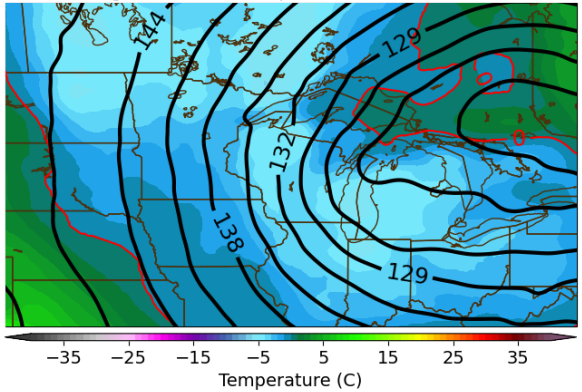
500 hPa Height (dam) and Relative Vorticity (10^{-5} s^{-1})



700 hPa Height (dam), RH (%), and Temp (every 3 C)



850 hPa Height (dam) and Temp (C)



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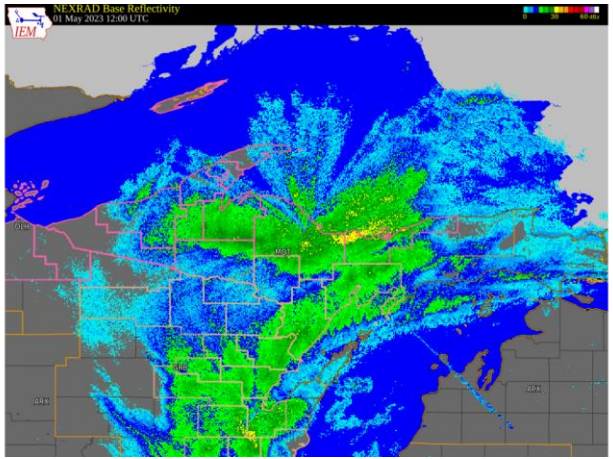
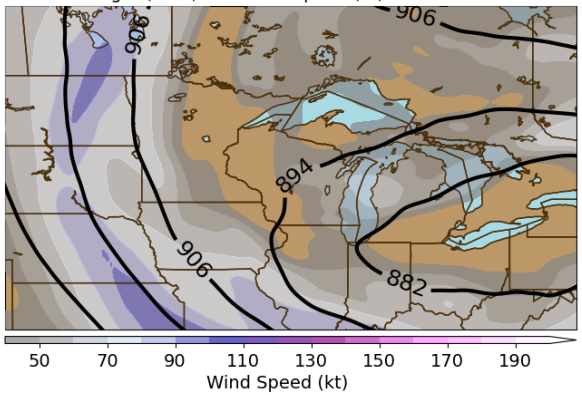


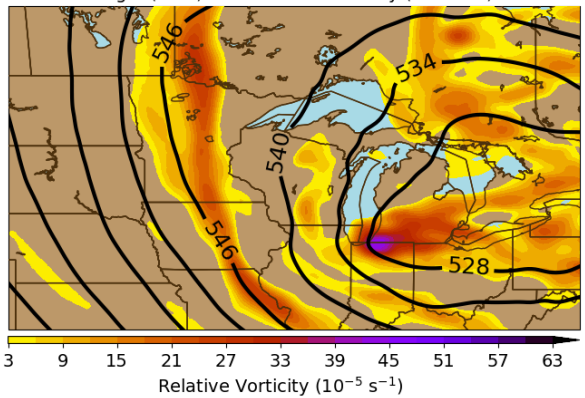
Round 2: Northern UP, 01.00Z–02.18Z

RAP Analysis VALID: 1800 UTC Mon May 01 2023

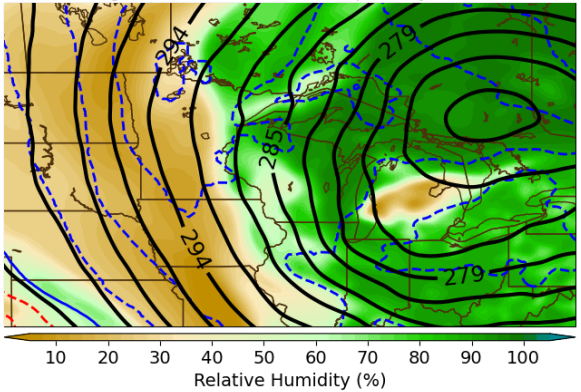
300 hPa Height (dam) and Wind Speed (kt)



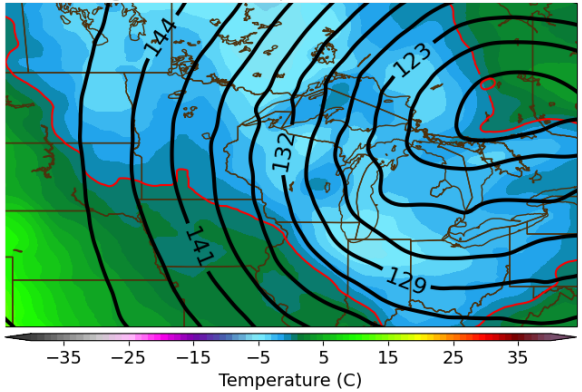
500 hPa Height (dam) and Relative Vorticity (10^{-5} s^{-1})



700 hPa Height (dam), RH (%), and Temp (every 3 C)



850 hPa Height (dam) and Temp (C)



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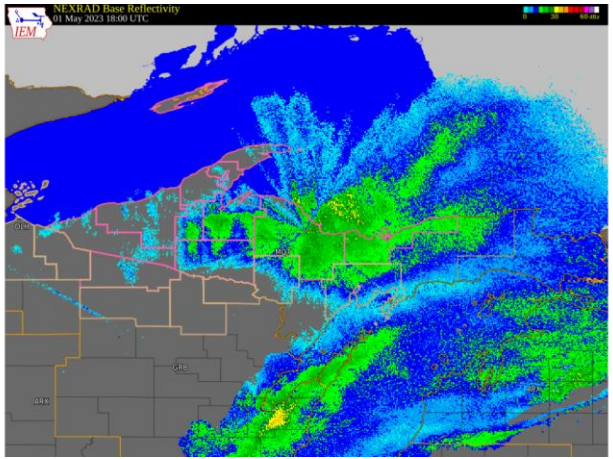
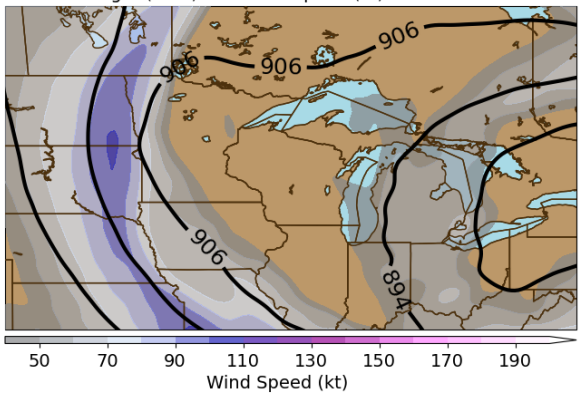


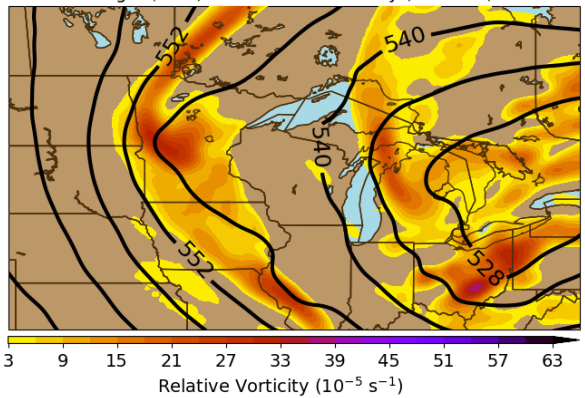
Round 2: Northern UP, 01.00Z–02.18Z

RAP Analysis VALID: 0000 UTC Tue May 02 2023

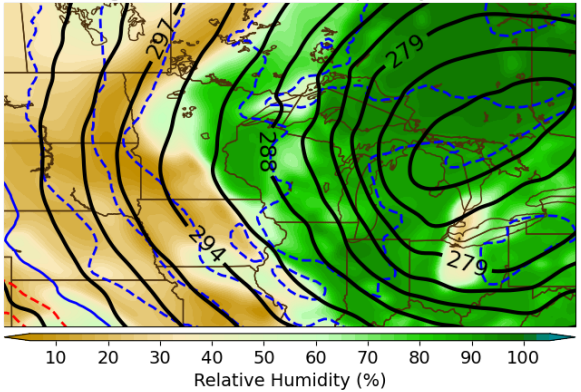
300 hPa Height (dam) and Wind Speed (kt)



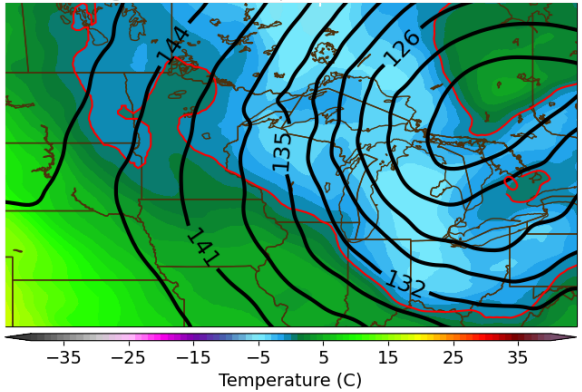
500 hPa Height (dam) and Relative Vorticity (10^{-5} s^{-1})



700 hPa Height (dam), RH (%), and Temp (every 3 C)



850 hPa Height (dam) and Temp (C)



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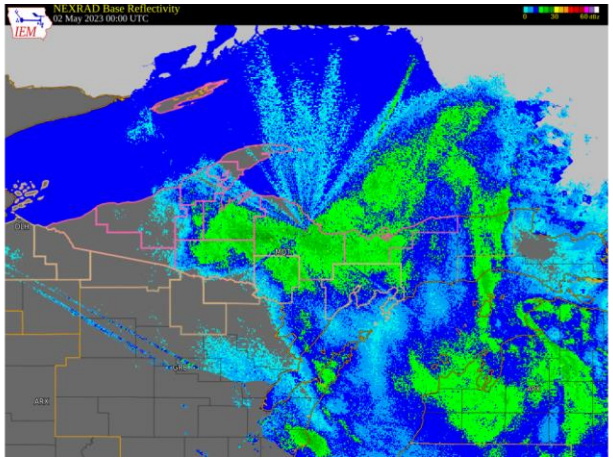
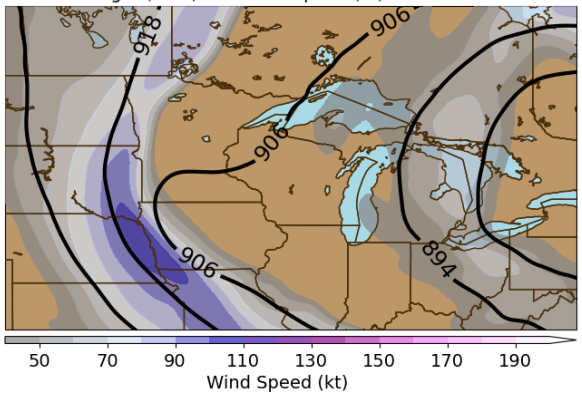


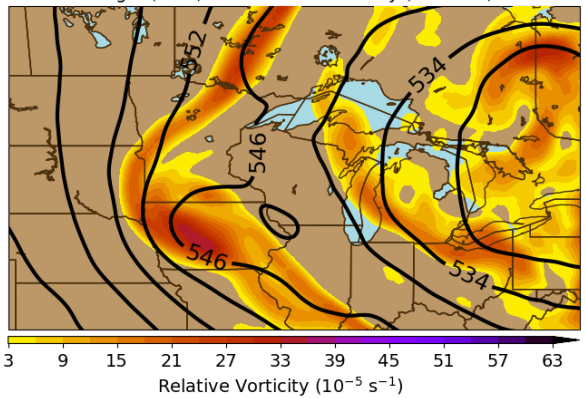
Round 2: Northern UP, 01.00Z–02.18Z

RAP Analysis VALID: 0600 UTC Tue May 02 2023

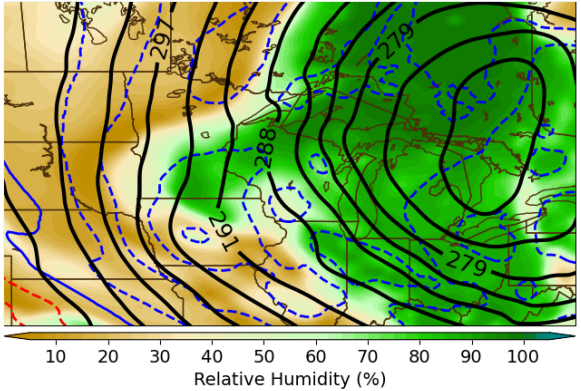
300 hPa Height (dam) and Wind Speed (kt)



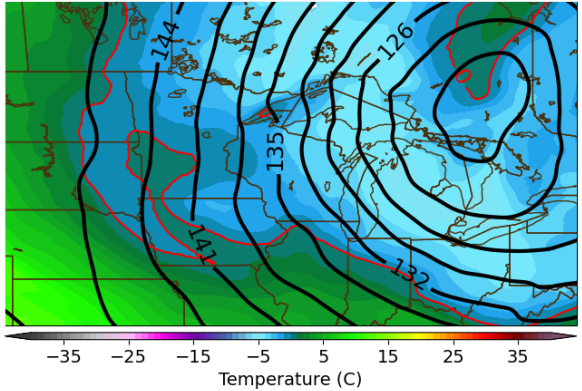
500 hPa Height (dam) and Relative Vorticity (10^{-5} s^{-1})



700 hPa Height (dam), RH (%), and Temp (every 3 C)



850 hPa Height (dam) and Temp (C)



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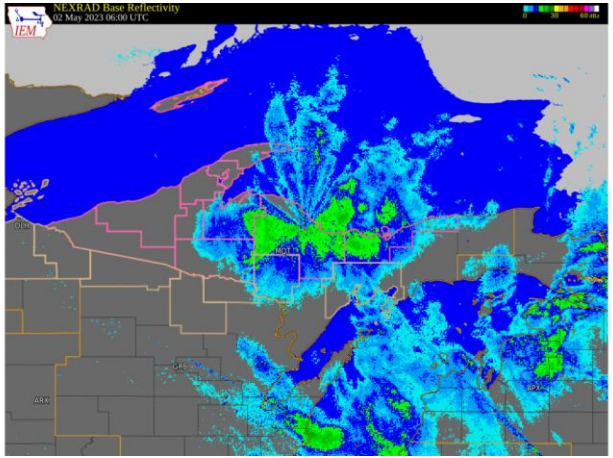
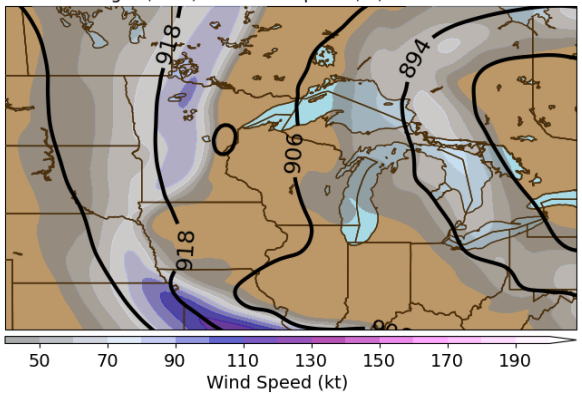


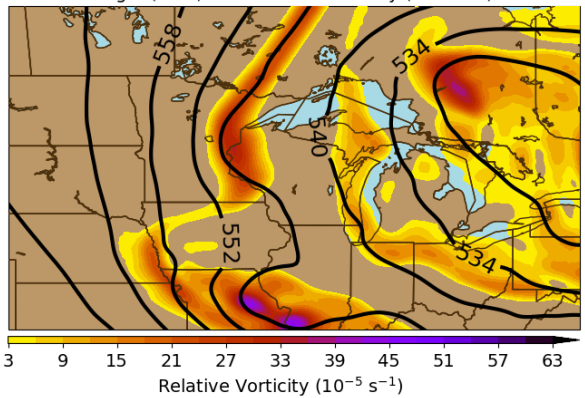
Round 2: Northern UP, 01.00Z–02.18Z

RAP Analysis VALID: 1200 UTC Tue May 02 2023

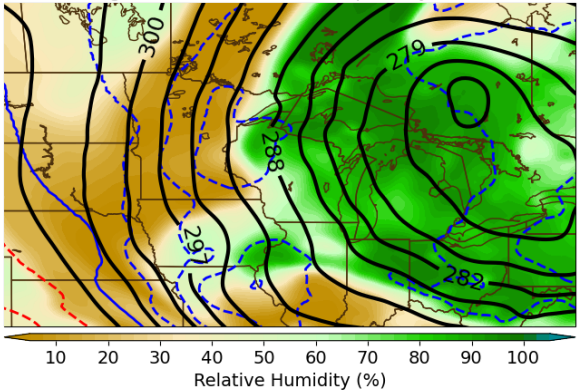
300 hPa Height (dam) and Wind Speed (kt)



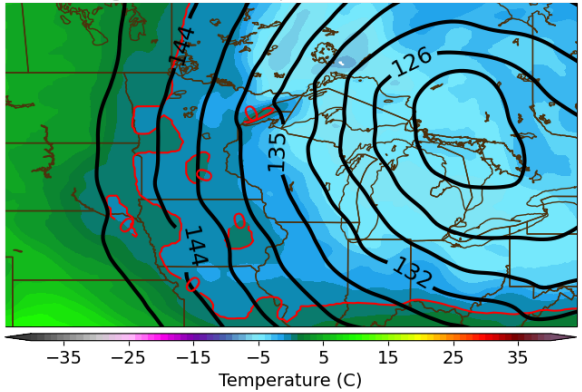
500 hPa Height (dam) and Relative Vorticity (10^{-5} s^{-1})



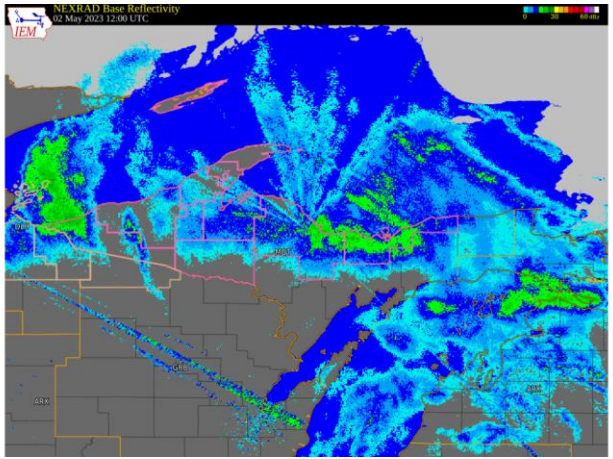
700 hPa Height (dam), RH (%), and Temp (every 3 C)



850 hPa Height (dam) and Temp (C)



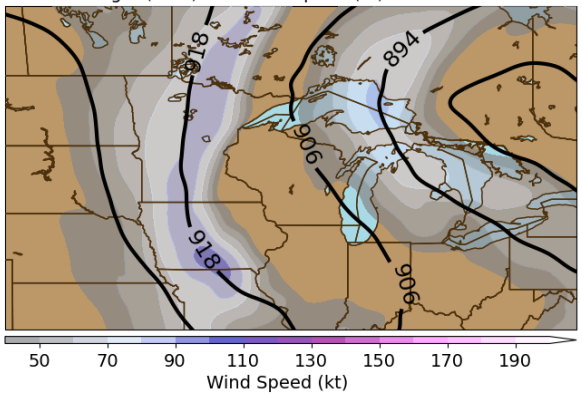
- Midlevel low center elongates and drifts east
- Spokes of vorticity wrap around the low and move over the UP from the northeast
- Continued robust moist conveyor belt



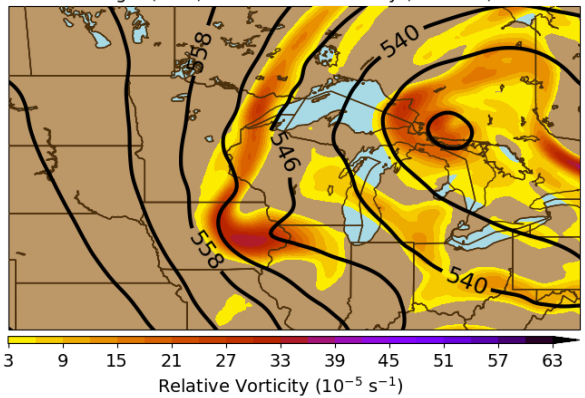
Round 2: Northern UP, 01.00Z–02.18Z

RAP Analysis VALID: 1800 UTC Tue May 02 2023

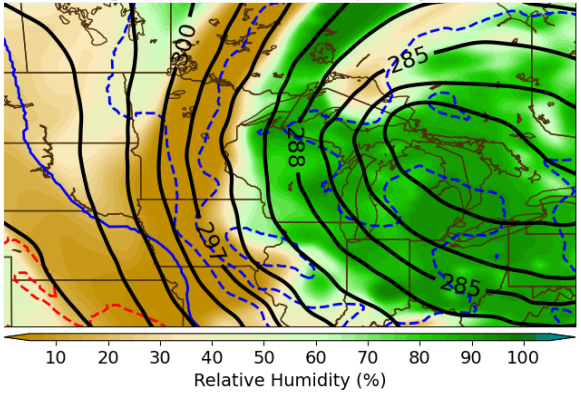
300 hPa Height (dam) and Wind Speed (kt)



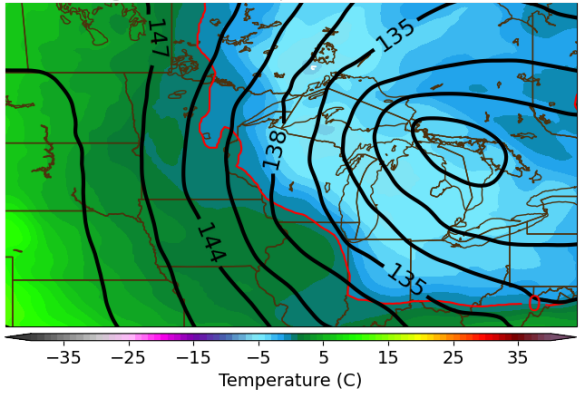
500 hPa Height (dam) and Relative Vorticity (10^{-5} s^{-1})



700 hPa Height (dam), RH (%), and Temp (every 3 C)



850 hPa Height (dam) and Temp (C)



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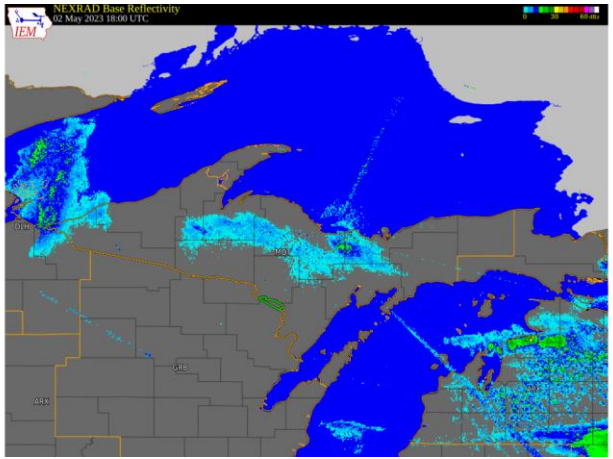
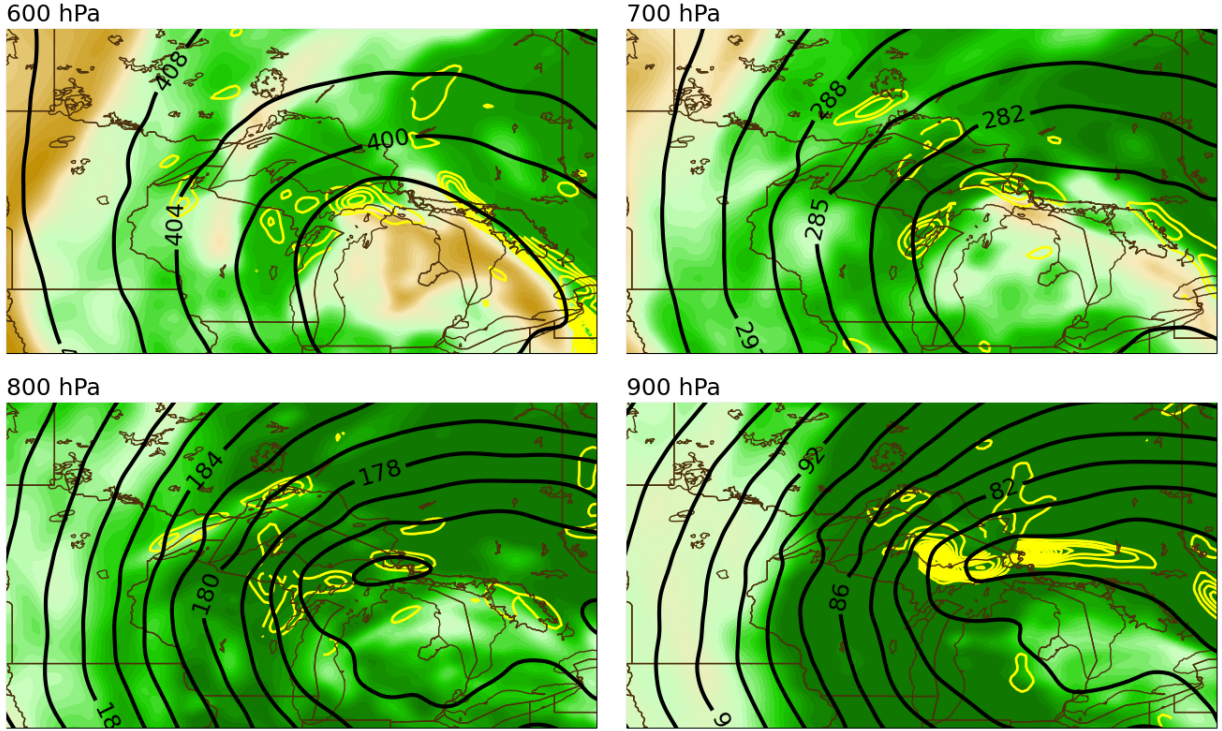


Round 2: Northern UP, 01.00Z–02.18Z

RAP Analysis Height (dam), Fgen (K 100 km^{-1} 3 hr^{-1}), and RH (%)
0600 UTC Mon May 01 2023



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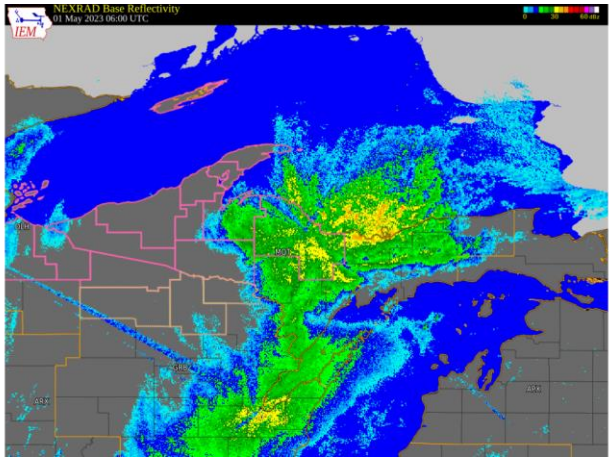
- Little frontogenesis noted thereafter, coinciding with precip focused on orographically favored areas



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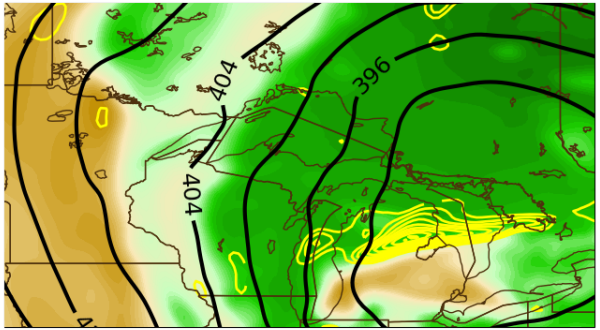
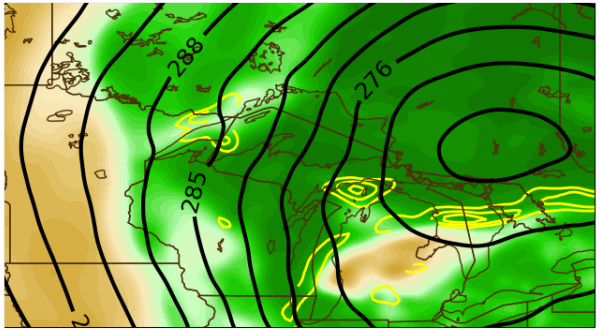
1800 UTC Mon May 01 2023

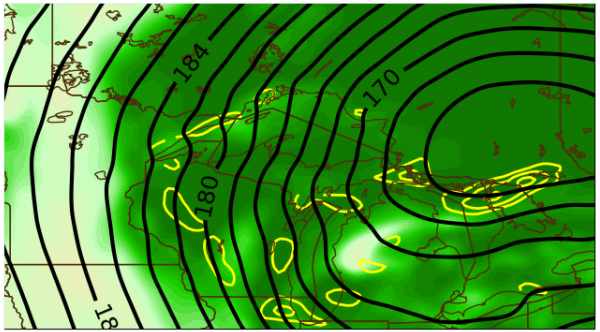
600 hPa



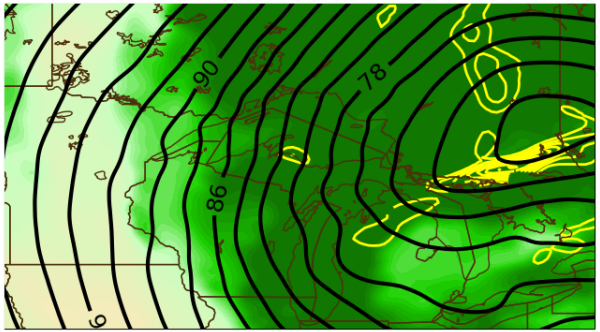
700 hPa

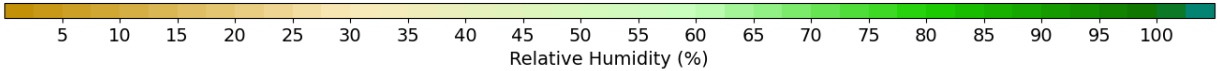


800 hPa



900 hPa





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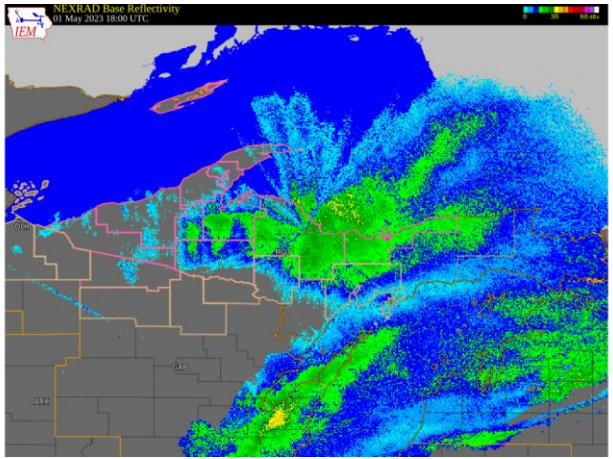

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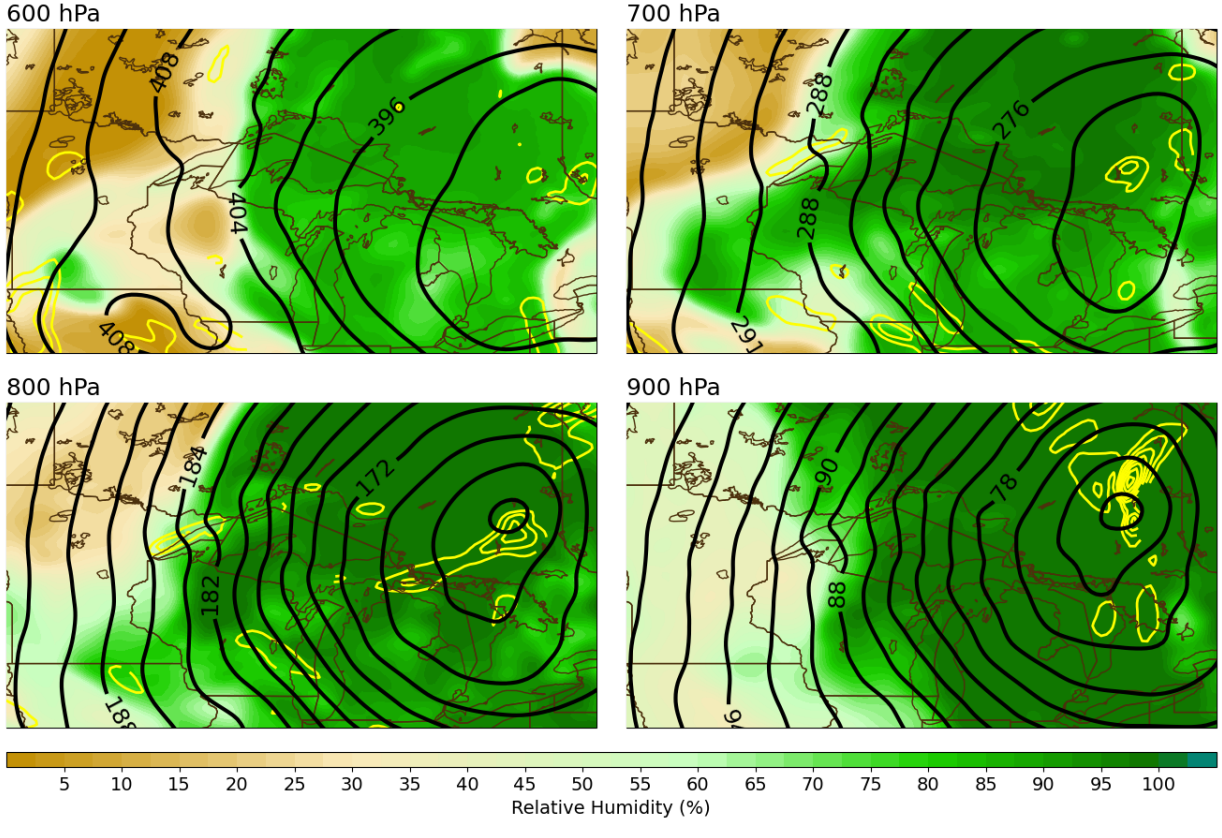
RAP Analysis Height (dam), Fgen (K 100 km^{-1} 3 hr^{-1}), and RH (%)
0600 UTC Tue May 02 2023



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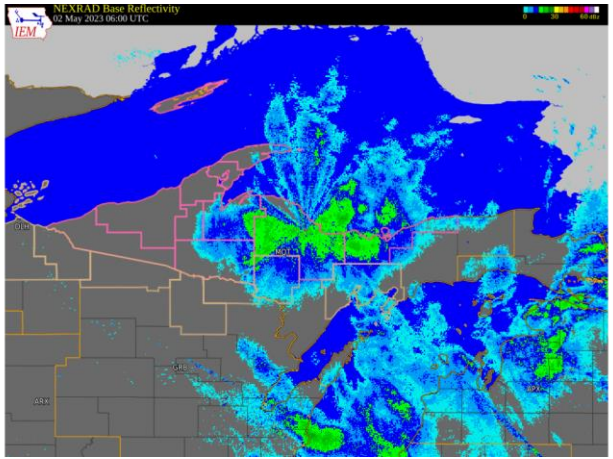

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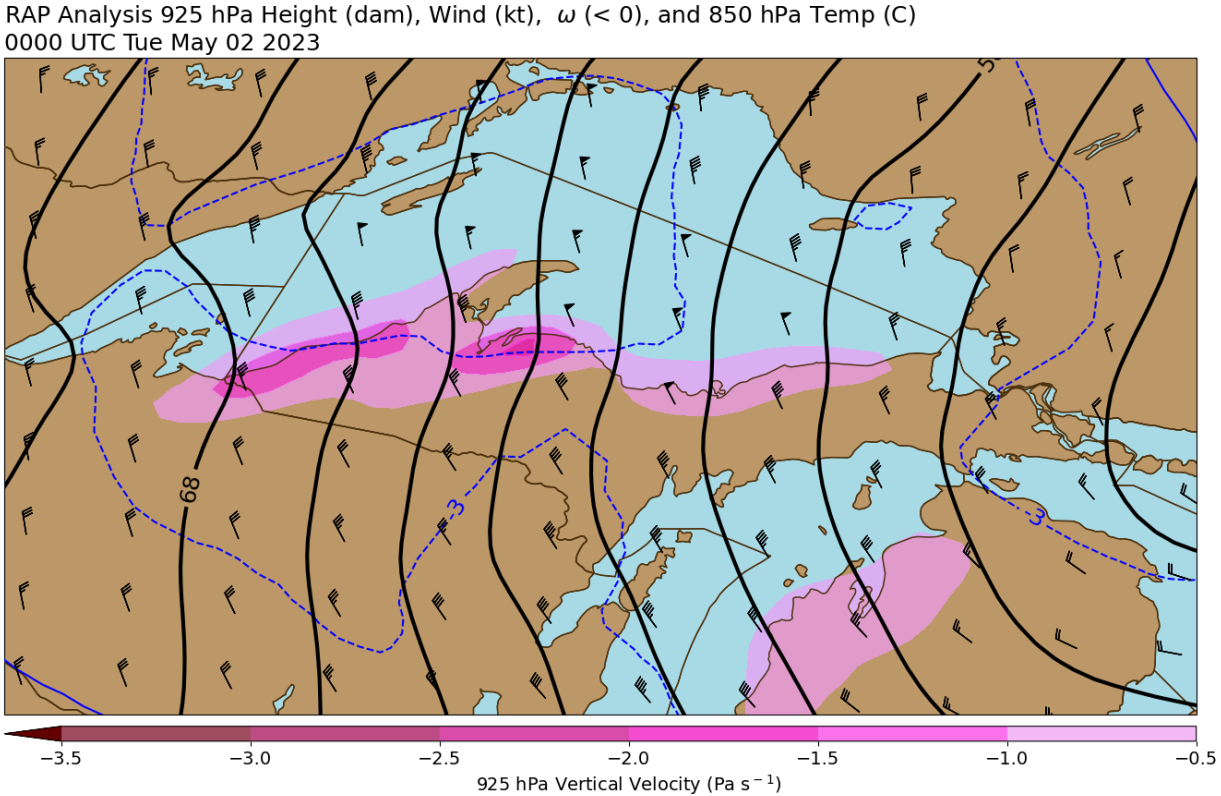
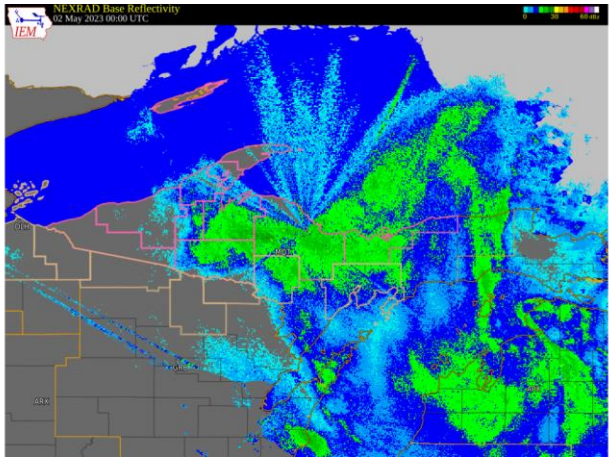


- 925 mb omega highlights orographically favored areas in north-northwesterly low-level flow
- Actual precip amounts modulated by availability of deep layer moisture (e.g., greater amounts over the north-central compared with the west)



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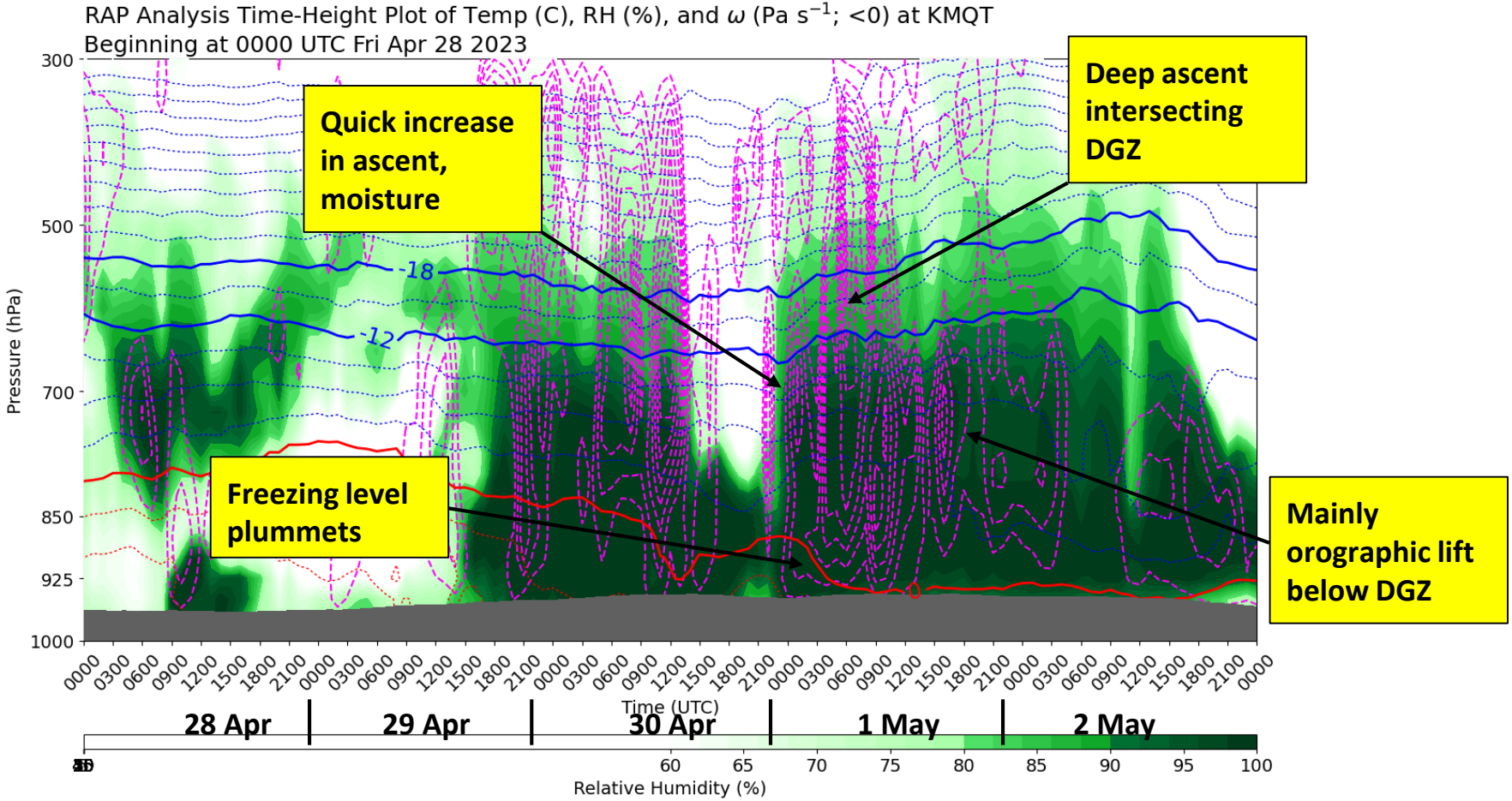
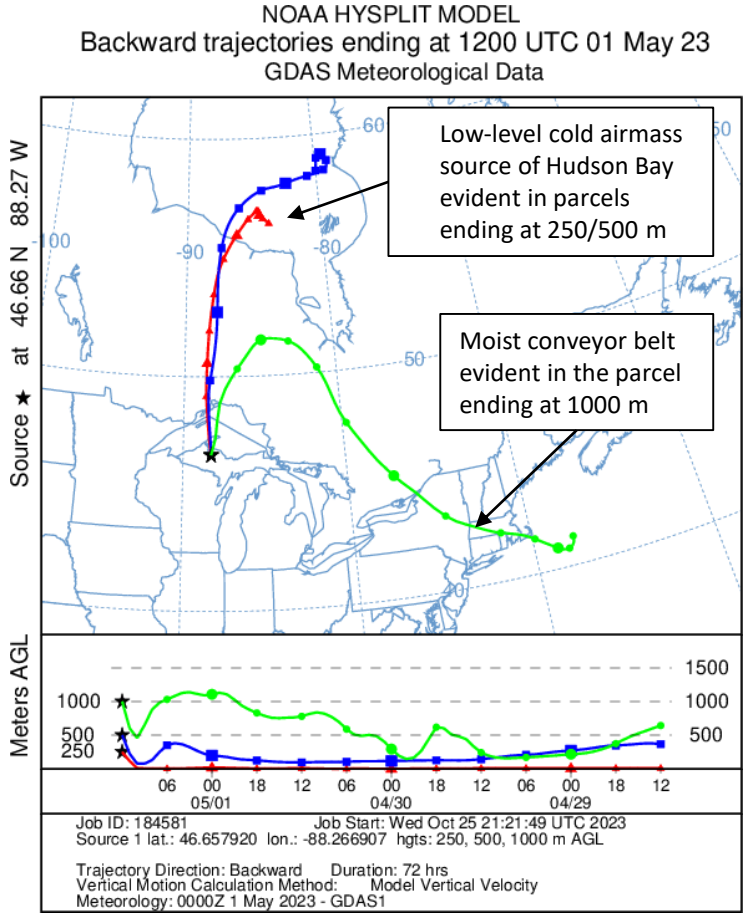
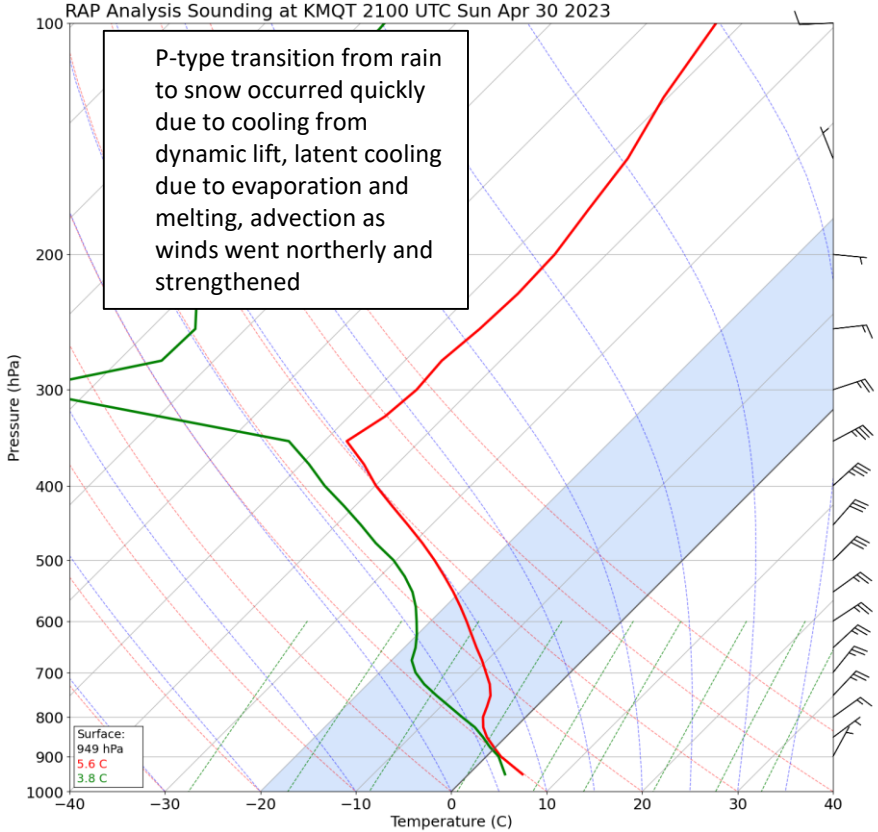


Round 2: Northern UP, 01.00Z–02.18Z





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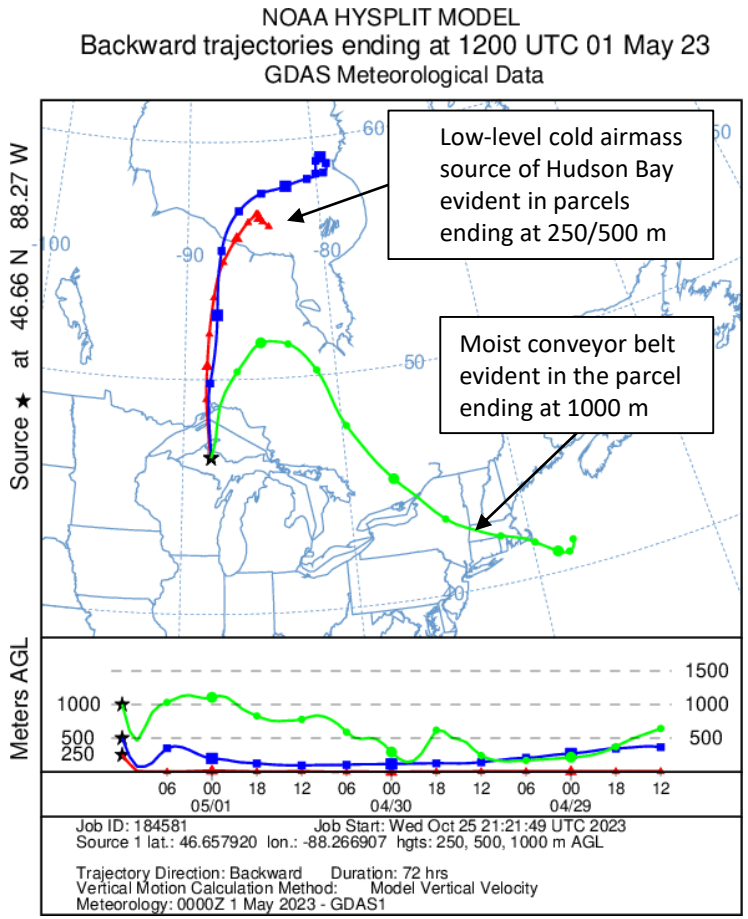

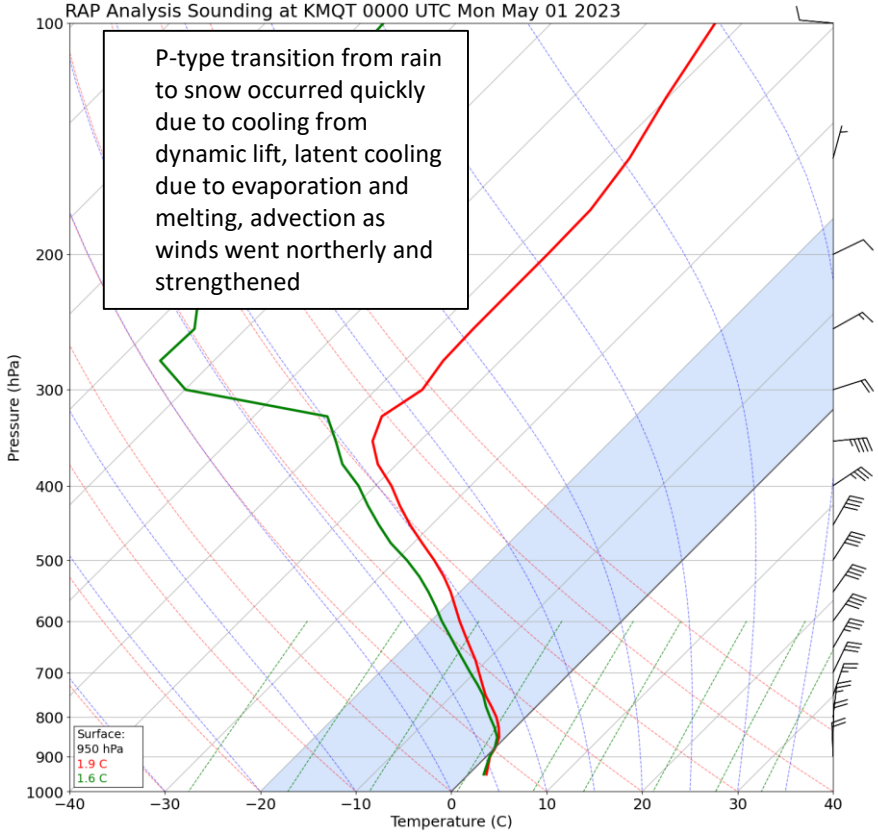

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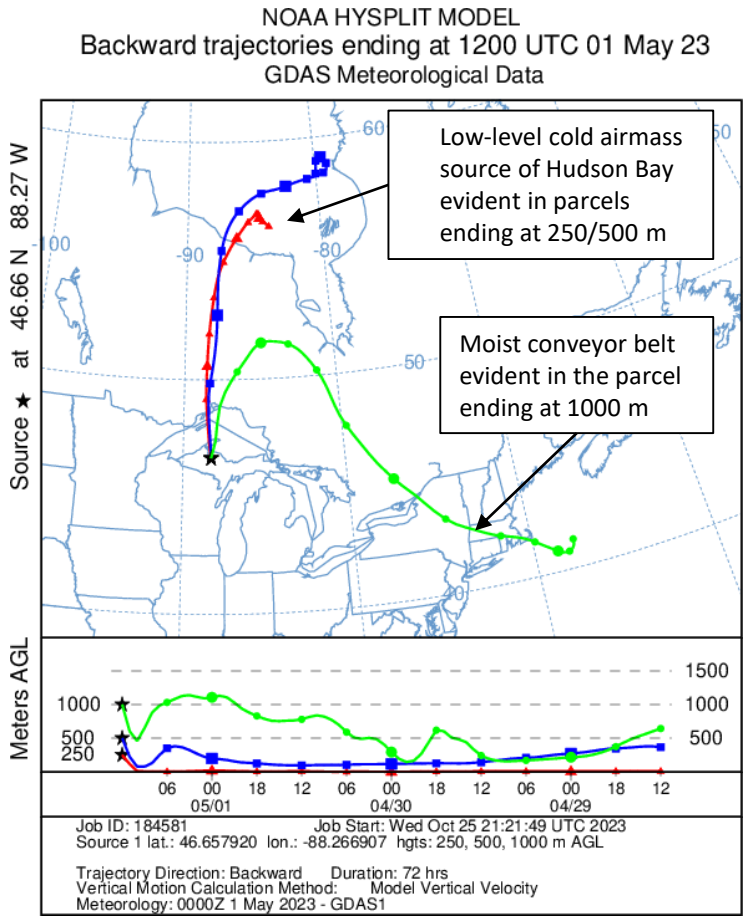
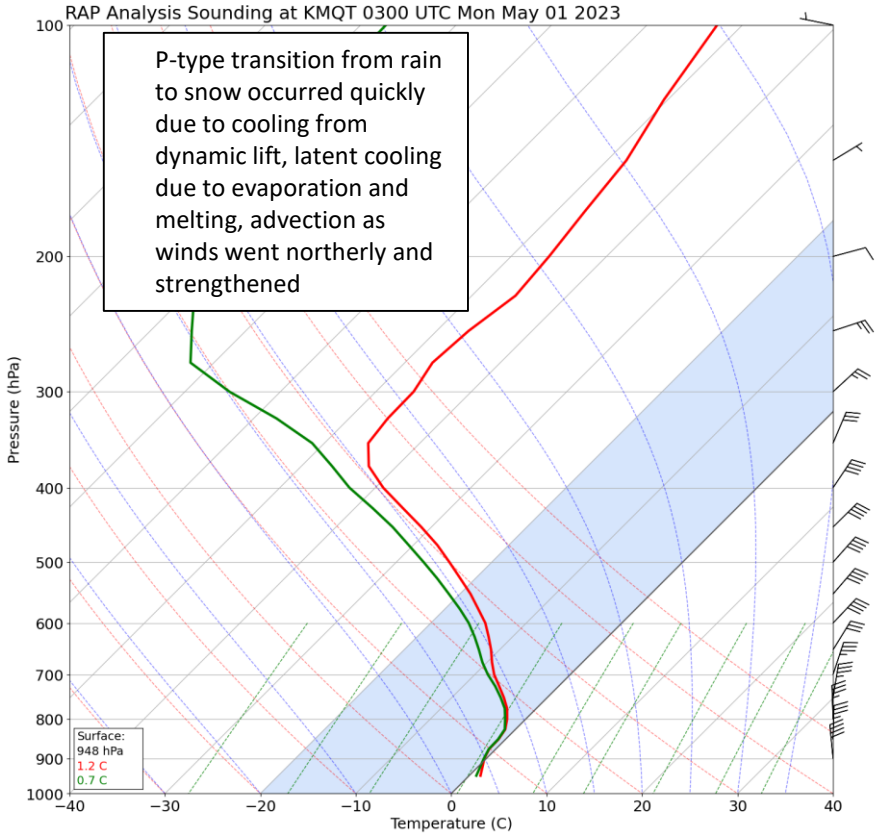
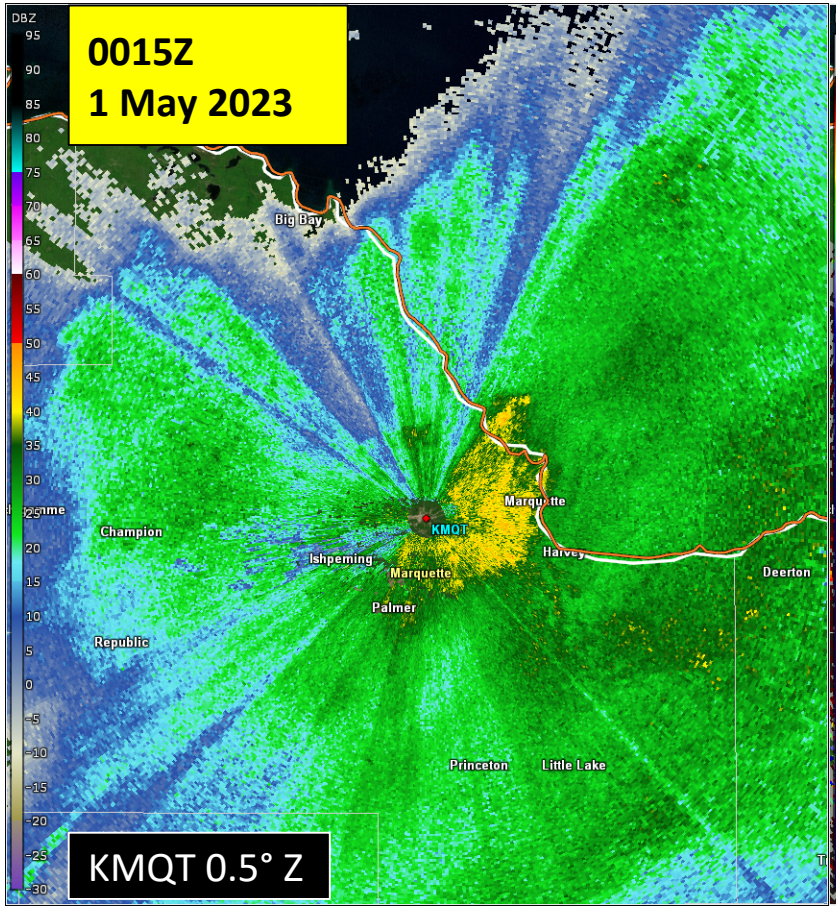
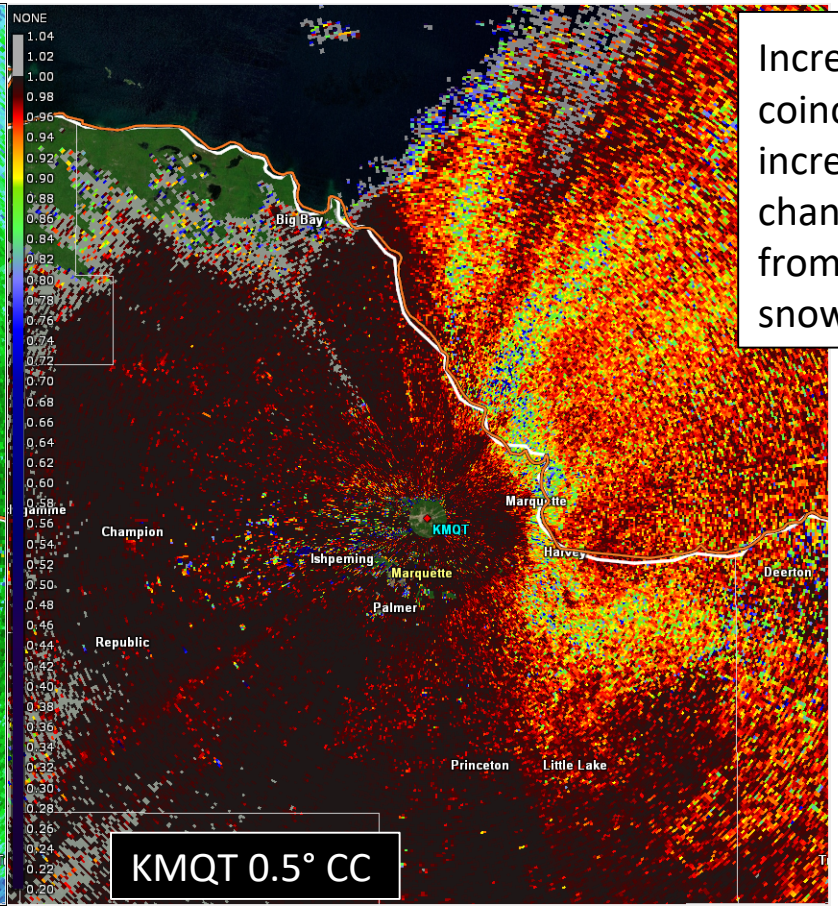




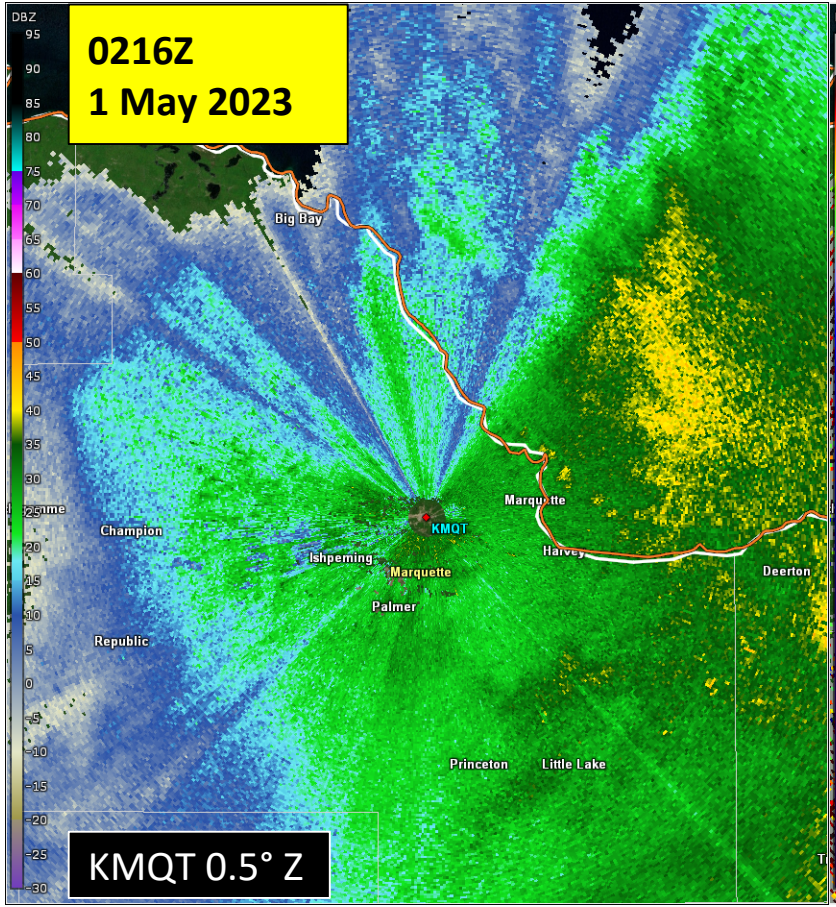
Observations

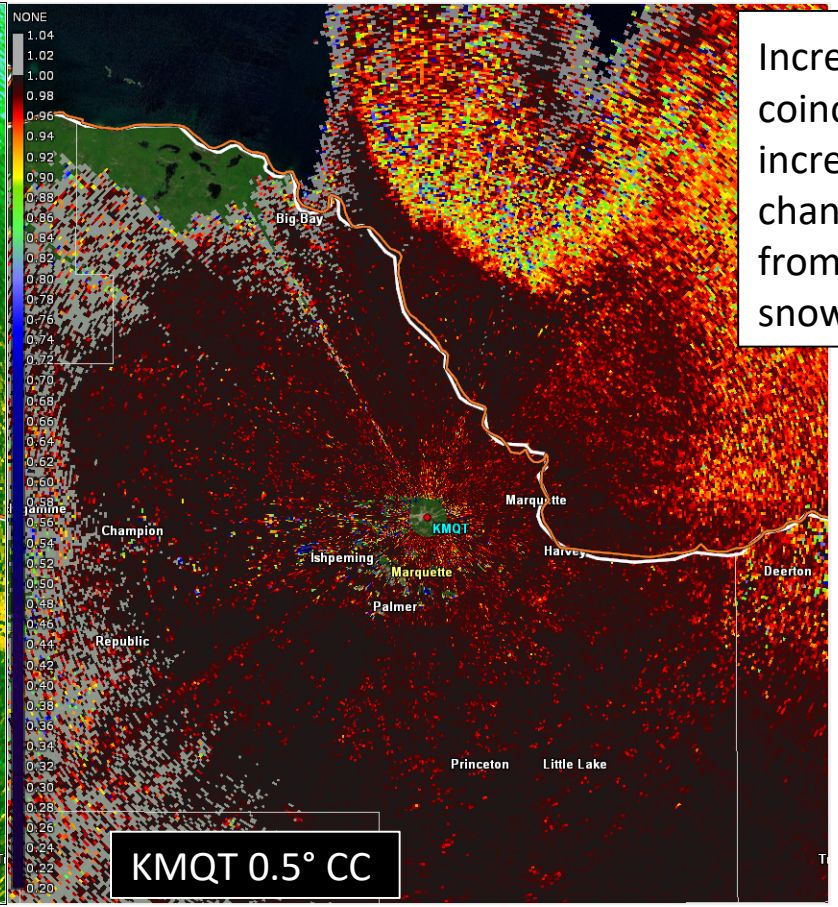




Increase in CC coincident with increasing lift, changeover from rain to snow

Observations





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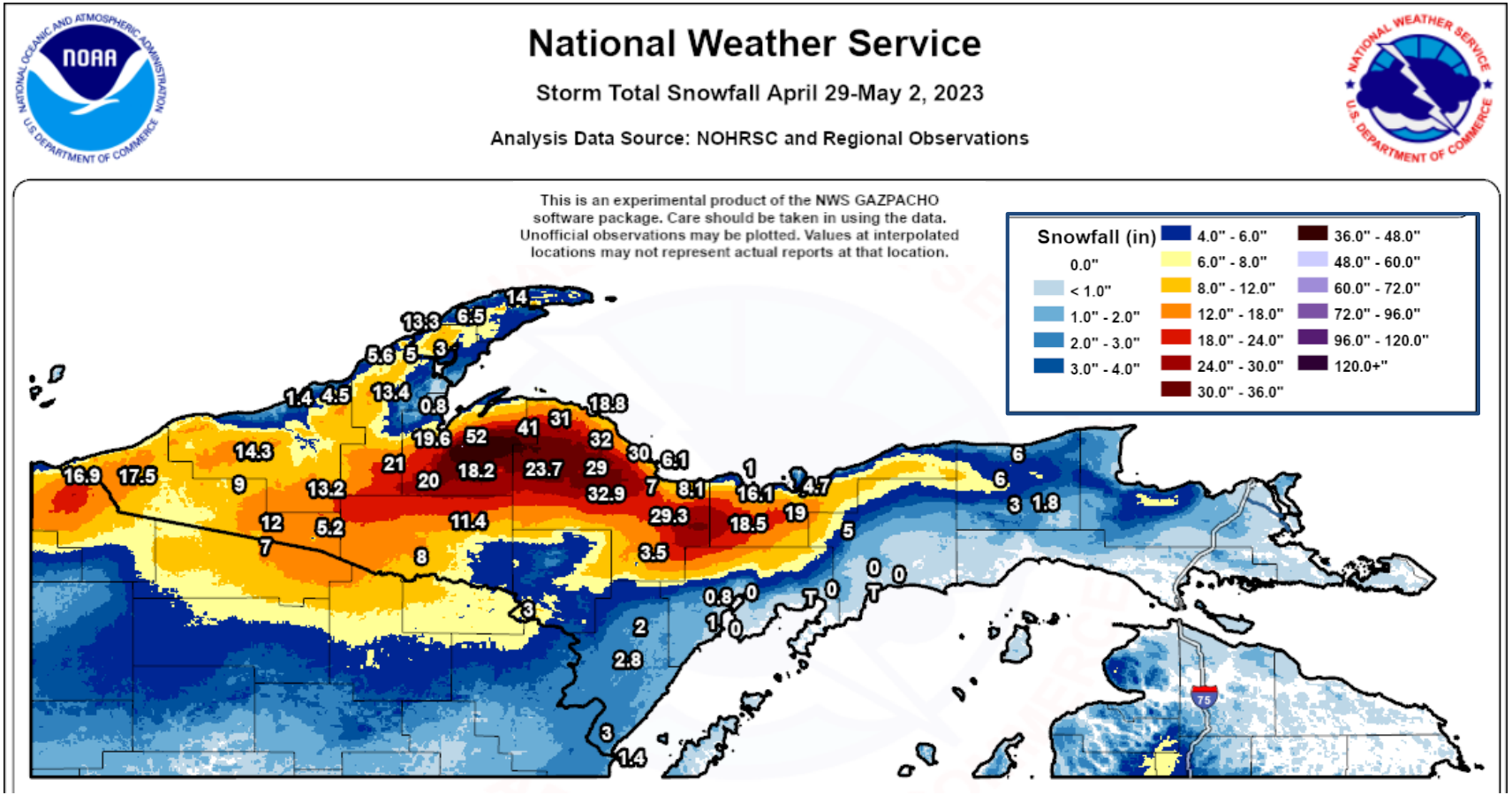
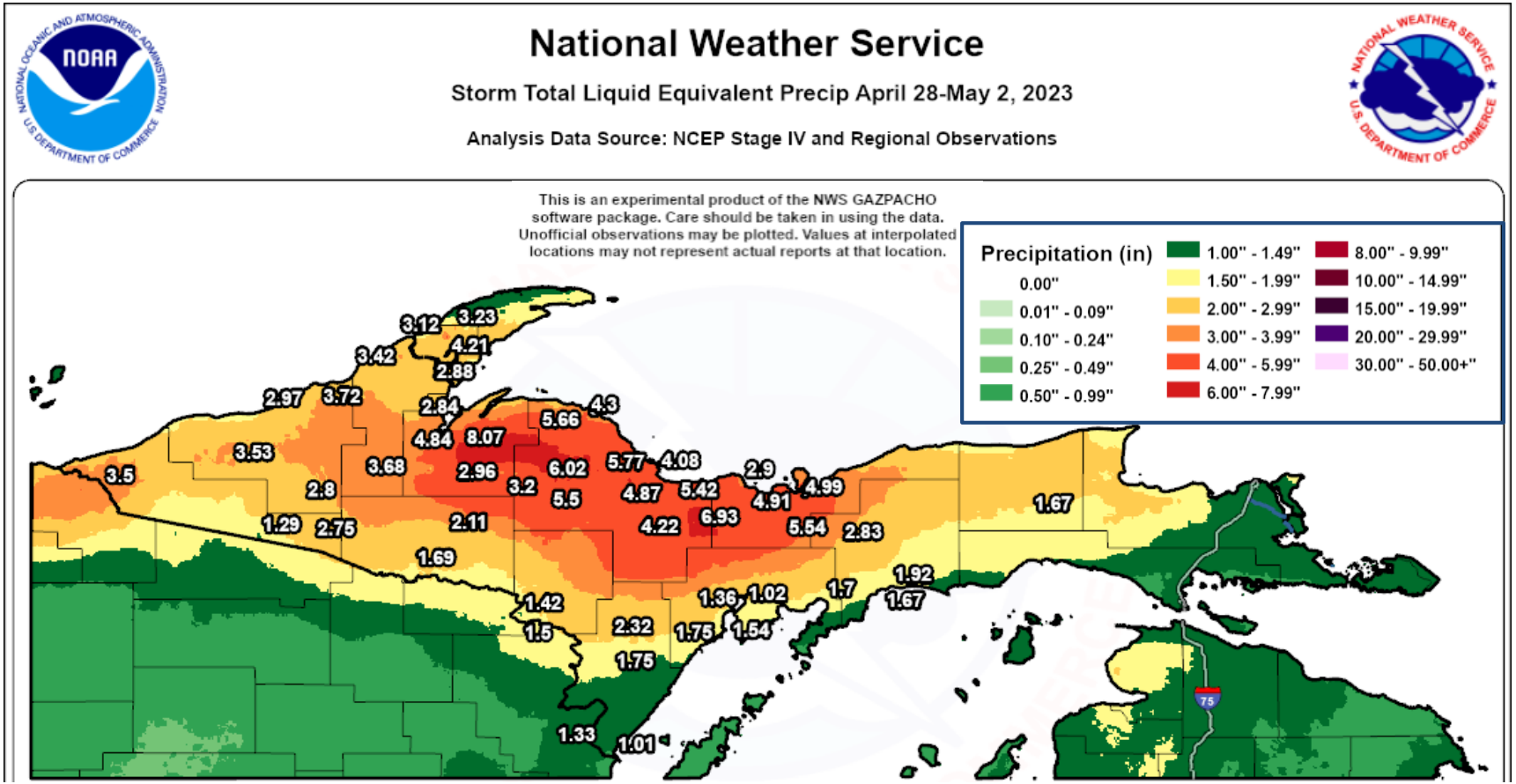


Observations



Records

Historic Snowstorm Breaks Records at the Marquette National Weather Service

Records Set May 1-2, 2023

- Greatest Calendar Snowfall in May 19.8 inches – May 1st
- Greatest 2-day Snowfall in May – 26.2 inches
- Snowiest May on Record – 26.2 inches
- Greatest May Snow Depth – 20 inches at 8 AM May 2nd.
- Current snowfall for the season is now 265.1 inches.

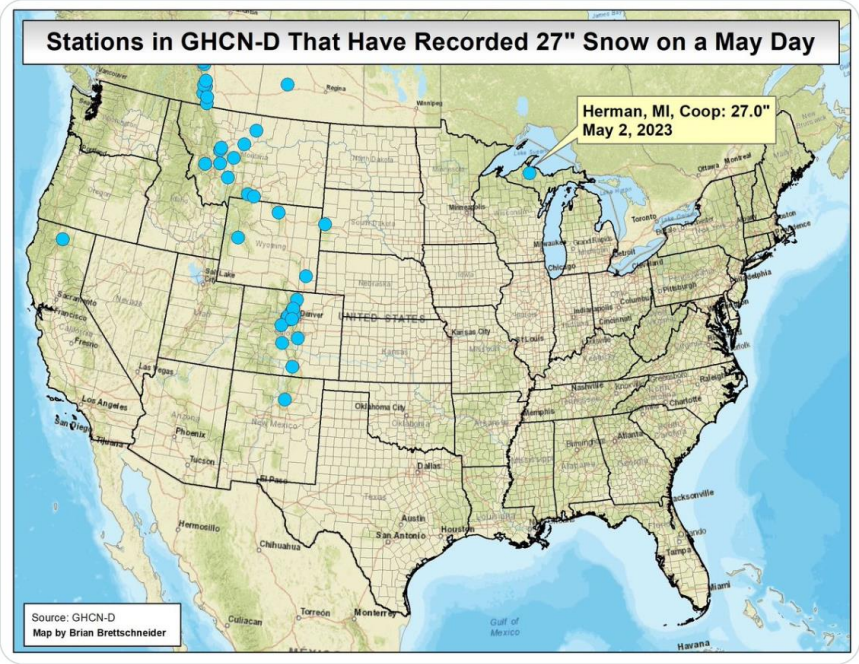
Check back on Wednesday, May 3rd when we'll post some of the greatest snow accumulations that occurred in north central Upper Michigan from this historic snowstorm.

POR: 1961 to present

Observations/Records

Brian Brettschneider
@Climatologist49

The Herman, Michigan, Cooperative station reported 27.0" of snow for the calendar day. This is the greatest 1-day May snowfall east of 100°W longitude in the official U.S. climate record. @NWSMarquette

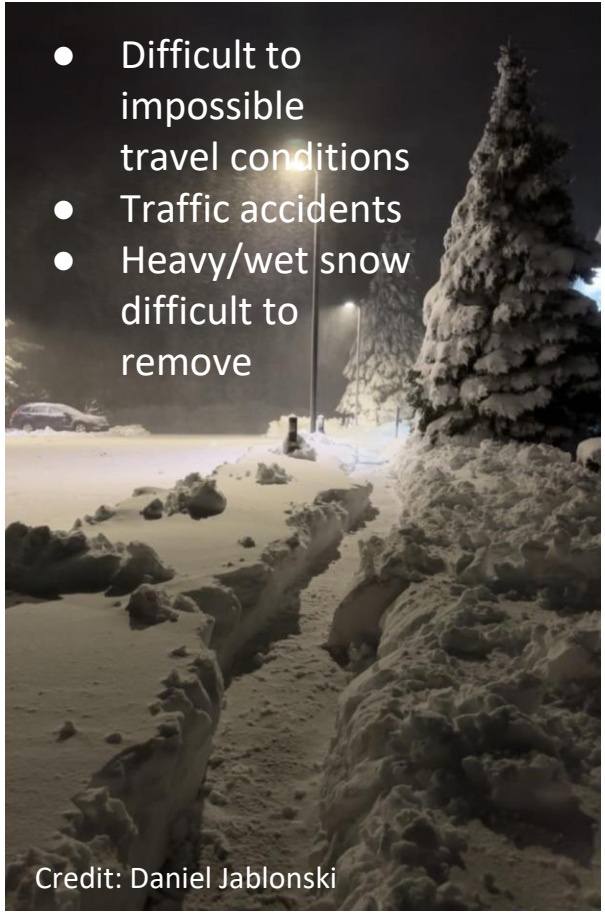


Location	Snowfall	Liquid
Herman	52.0”	7.96”
Three Lakes	35.5”	M
Carlshend	29.3”	6.93”
WFO Marquette	28.7”	5.77”
Clarksburg	23.7”	6.00”
7.2 SW Ishpeming	22.7”	5.44”
2 WSW Watton	21.0”	3.63”
Chatham Exp Farm	18.5”	4.91”
3 WNW Michigamme	18.2”	2.93”
Ironwood	17.5”	3.12”
9.0 SE Big Bay	12.7”	5.17”
Bergland Dam	12.5”	2.91”

Station	Snowfall	Appx. liquid equiv. as snow	Appx. SLR
Herman	52.0”	6.45”	**8:1**
Carlshend	29.3”	5.90”	**5:1**
WFO MQT	28.7”	4.45”	**6:1**
7.2 SW Ishpeming	22.7”	4.09”	**6:1**
11.1 SW Munising	19.0”	4.32”	**4:1**

Impacts

- Difficult to impossible travel conditions
- Traffic accidents
- Heavy/wet snow difficult to remove


Credit: Daniel Jablonski


Credit: James Salzwedel


Credit: Evan Kutta


Credit: James Salzwedel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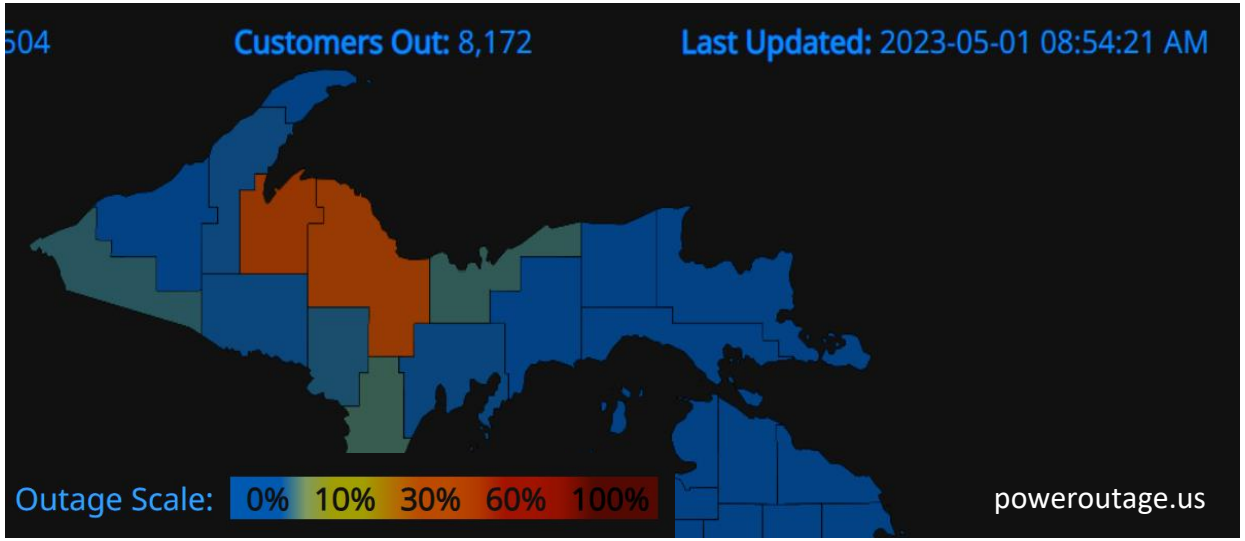
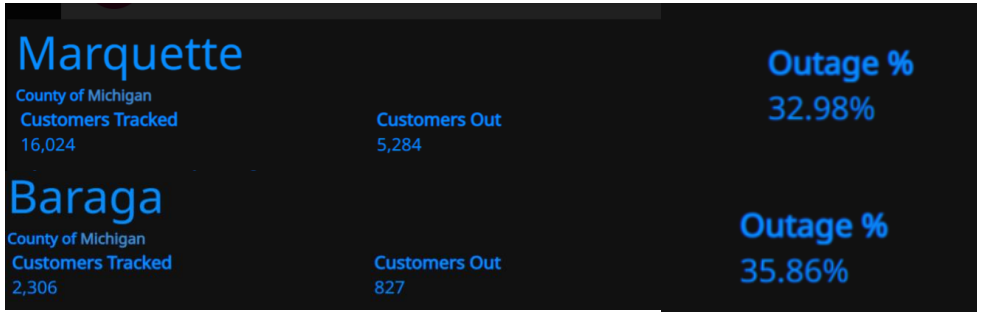
Impacts



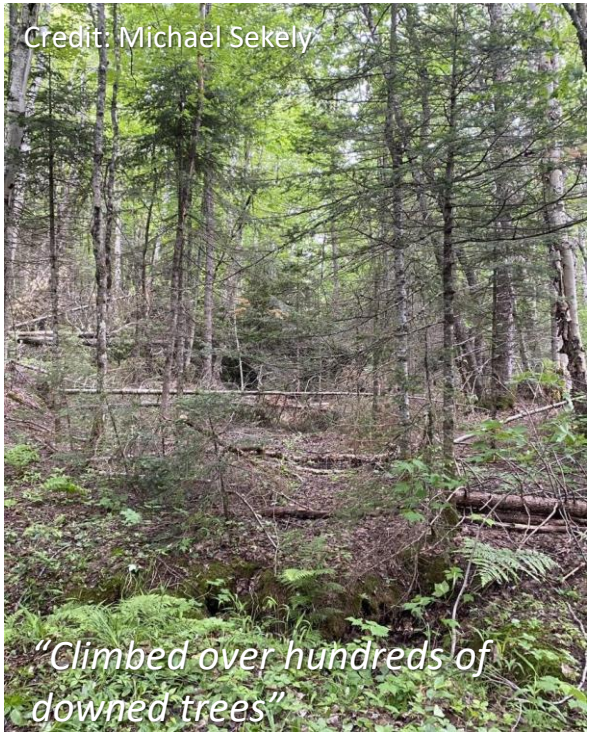


- At least 10k power outages
- At least a third of customers in Marquette/Baraga Counties lost power

Impacts

Images and quotes from North Country Trail Association Marquette Chapter Facebook Page

- **At least 10k power outages**
- **Extensive tree damage**



Impacts

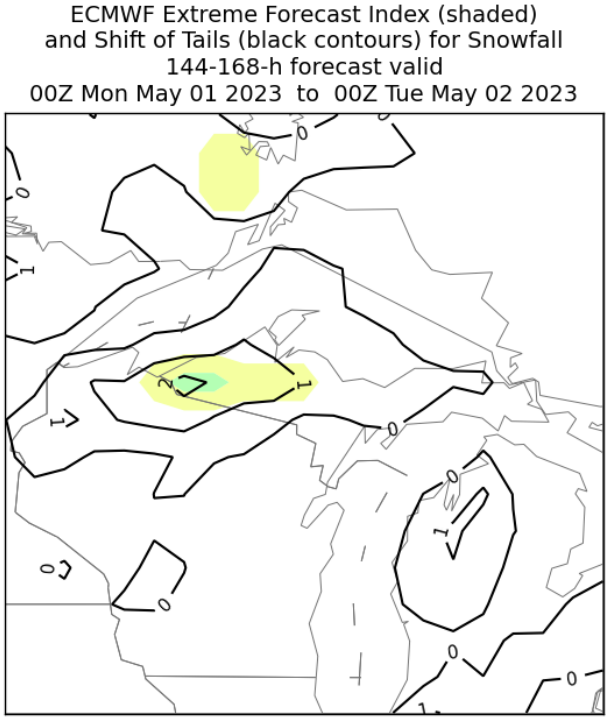
- Subsequent thaw was not accompanied by additional rainfall, so flooding impacts were mainly minor

- However, there were fairly widespread reports of nuisance/basement flooding

- One instance of a house evacuated due to water backing up at a lake outlet

- Lots of standing water during mosquito breeding season

Predictability



EFI (Extreme Forecast Index):
Difference between EPS and M-Climate CDF

SoT (Shift of Tails):
Comparison of top 10% of EPS and M-Climate CDF

Guidance for EFI Values

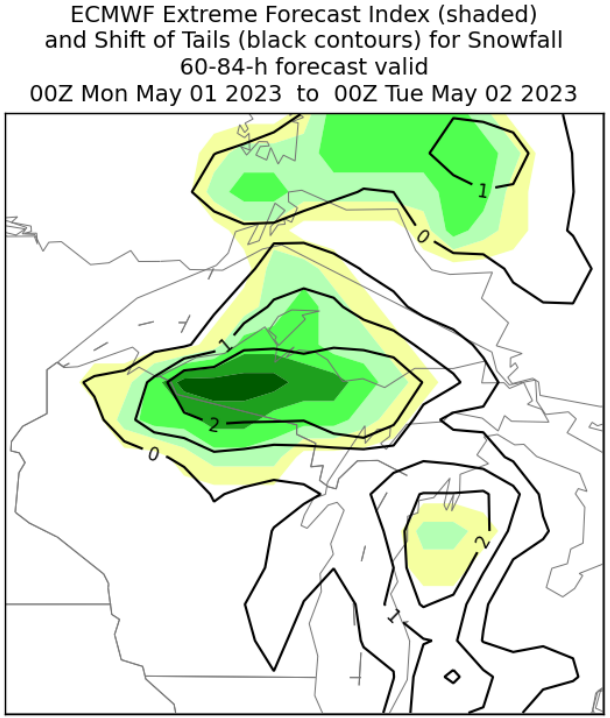
- Values of **+/- 0.5 to 0.8** typically signal that an "unusual event" is likely.
- Values **above +/- 0.8** signal that a "very unusual" event is likely.
- Values of **+/- 1** indicate ALL ensemble members are beyond the model climate.

Guidance for SoT Values

- Values of **0.0 or greater** indicate that at least 10% of the ENS members lie above(below) the 99th(1st) percentile of the M-climate.
- Values of **1.0 or greater** "up the ante" for the potential of an increasingly extreme event.
- Contours capped at **10** on Ensemble Situational Awareness Table EFI/SoT website.

- ECMWF EFI/SoT highlighted potential for an unusual event as early as the 168h forecast
- Highest values shifted east between the 84h and 36h forecast
- EFI values approaching 1.0 indicated all ensemble members were beyond the model climate

Predictability



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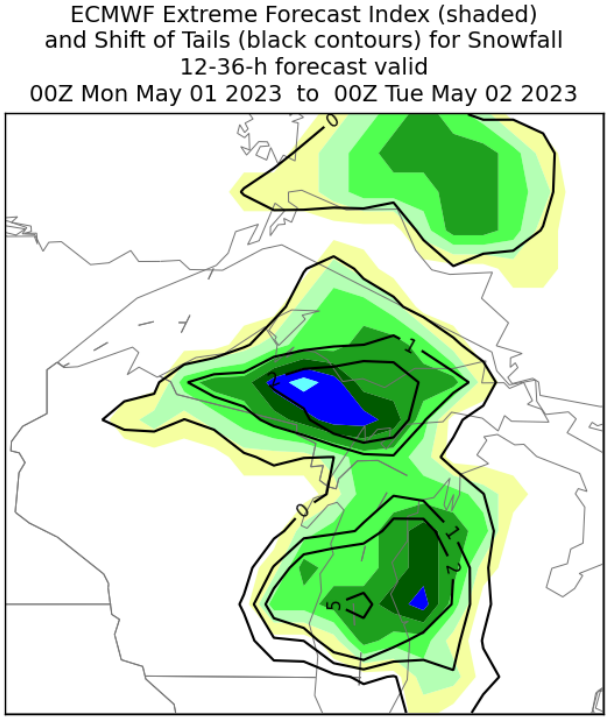
Predictability



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Guidance for SoT Values

- Values of **0.0 or greater** indicate that at least 10% of the ENS members lie above(below) the 99th(1st) percentile of the M-climate.
- Values of **1.0 or greater** "up the ante" for the potential of an increasingly extreme event.
- Contours capped at **10** on Ensemble Situational Awareness Table EFI/SoT website.

- ECMWF EFI/SoT highlighted potential for an unusual event as early as the 168h forecast
- Highest values shifted east between the 84h and 36h forecast
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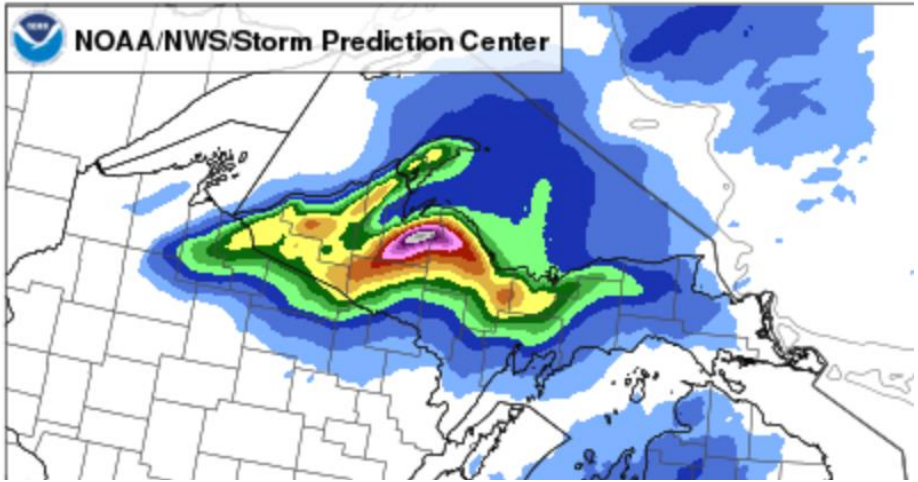
Predictability

Run: Sun 2023-04-30 12:00 UTC
Valid: Tue 2023-05-02 12:00 UTC

- HREF mean and PMM forecasted extreme snowfall amounts. PMM was a bit overdone.

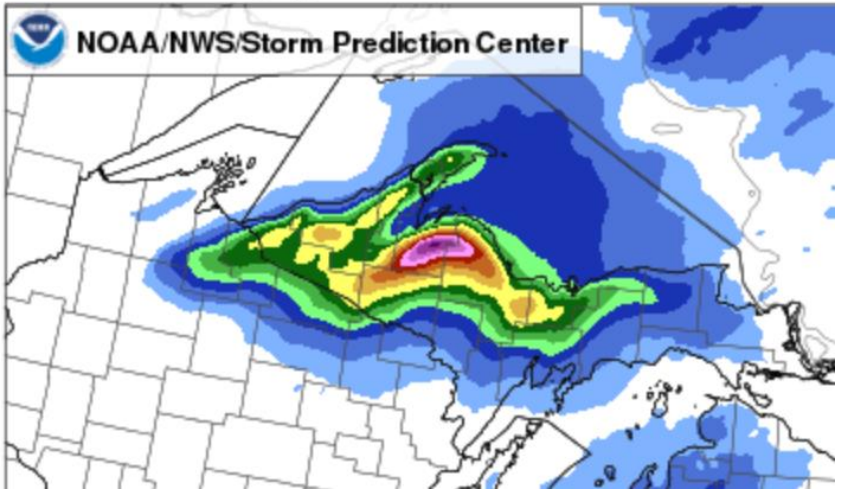
HREF

24-hr snowfall (in), ensemble probability-matched mean



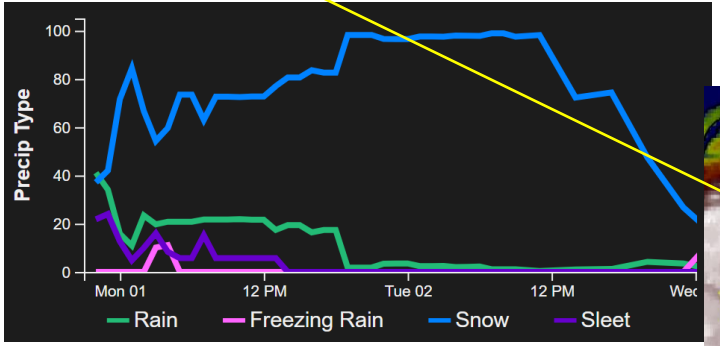
HREF

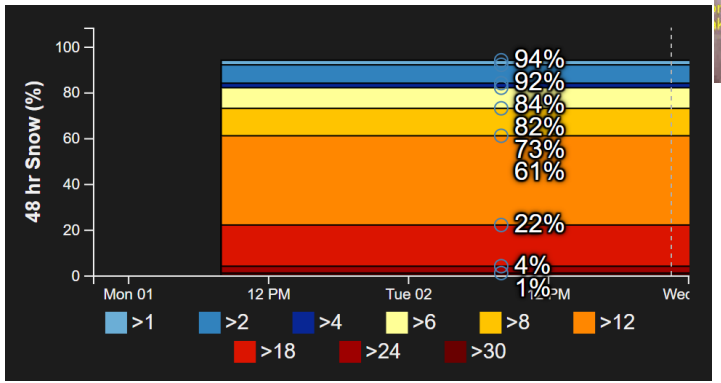
24-hr snowfall (in), ensemble mean



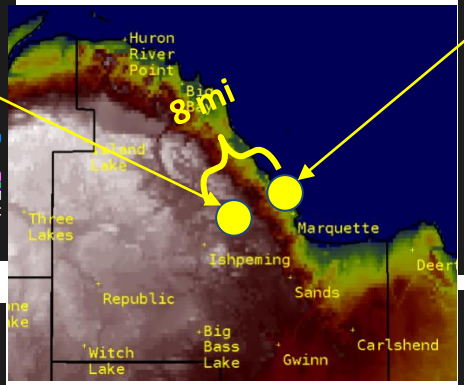
Predictability

WFO MQT
~1400’



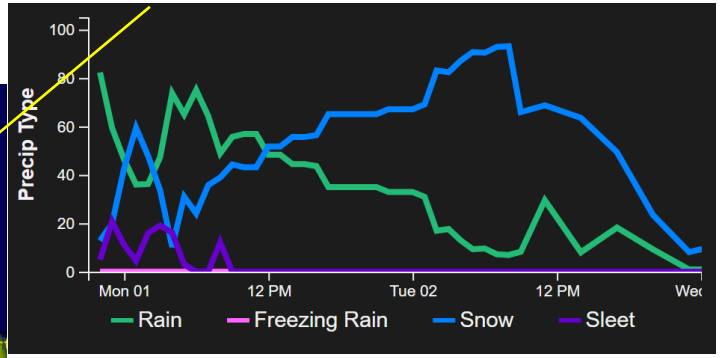


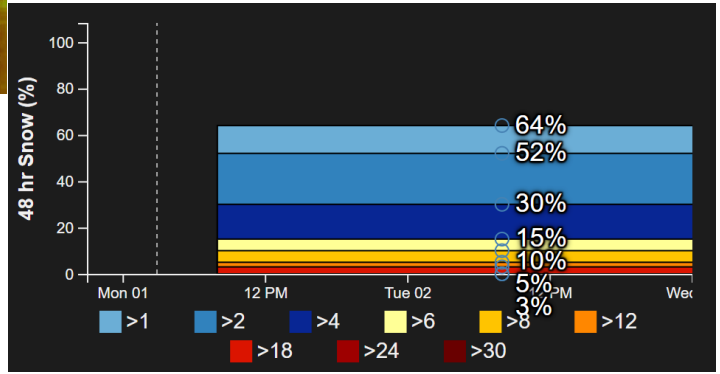
01.01Z NBM



Significant challenges related to p-type and resulting accumulation near the lakeshore

Marquette Lakeshore (~600’)





Messaging Challenges

- Sharp gradients in snowfall amounts and resulting impacts
- Long-duration, multi-hazard storm with areas of impact varying in space and time
- Unusual/historic/unprecedented event
- Temps in the 80s two weeks ago - many may have thought winter was over
- Headline management

```
.MQT WATCHES/WARNINGS/ADVISORIES...
Upper Michigan...
  Flood Watch through Tuesday evening for MIZ001>006-009>011-084.

  Winter Storm Warning until 8 AM EDT Tuesday for MIZ001-003.

  Lakeshore Flood Warning from 2 AM Monday to 5 AM EDT Tuesday for
     MIZ001.

  Winter Storm Warning until 2 AM EDT /1 AM CDT/ Tuesday for
     MIZ002-009.

  Winter Storm Warning until 11 AM EDT Tuesday for MIZ004-005.

  Lakeshore Flood Warning from 2 AM Monday to 8 AM EDT Tuesday for
     MIZ005-006.

  Winter Storm Warning from 8 AM Monday to 11 AM EDT Tuesday for
     MIZ006.

  Winter Storm Warning until 2 AM EDT /1 AM CDT/ Tuesday for
     MIZ010-084.

  Winter Weather Advisory from 8 AM EDT /7 AM CDT/ Monday to 2 AM
     EDT /1 AM CDT/ Tuesday for MIZ011-013.
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Messaging

- WFO MQT began highlighting potential for impactful weather as early as 27 April in Hazardous Weather Outlook

- AFD compared this storm to previous May storm of record in the UP

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Guidance continues to be bullish with a historic May snowfall
potential for parts of the U.P. rivaling the storm from May 9-10 of
1990 which dumped over 2 feet of heavy west snow on parts of the
area.
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- As impacts unfolded, stronger wording was used

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into Tuesday morning. IF YOU DON'T HAVE TO TRAVEL, PLEASE STAY OFF
THE ROADS, AS DRIVING CONDITIONS COULD BE DANGEROUS IN SPOTS,
PARTICULARLY ALONG THE HIGHER TERRAIN AREAS OF BARAGA AND MARQUETTE
COUNTIES NORTH AND WEST OF NEGAUNEE!!! In addition, with strong
```

Messaging

WFO MQT social media post 30 Apr 7:19 am

Surge of Colder Air Arrives Later Today into Tonight

What's most likely right now:

- Heavy-Wet Snow: west & north-central highlands late today into early Tue
- Increasing north winds tonight out of the N-NW gusting **35-50** mph into early Tue.

Slushy, very hazardous roads

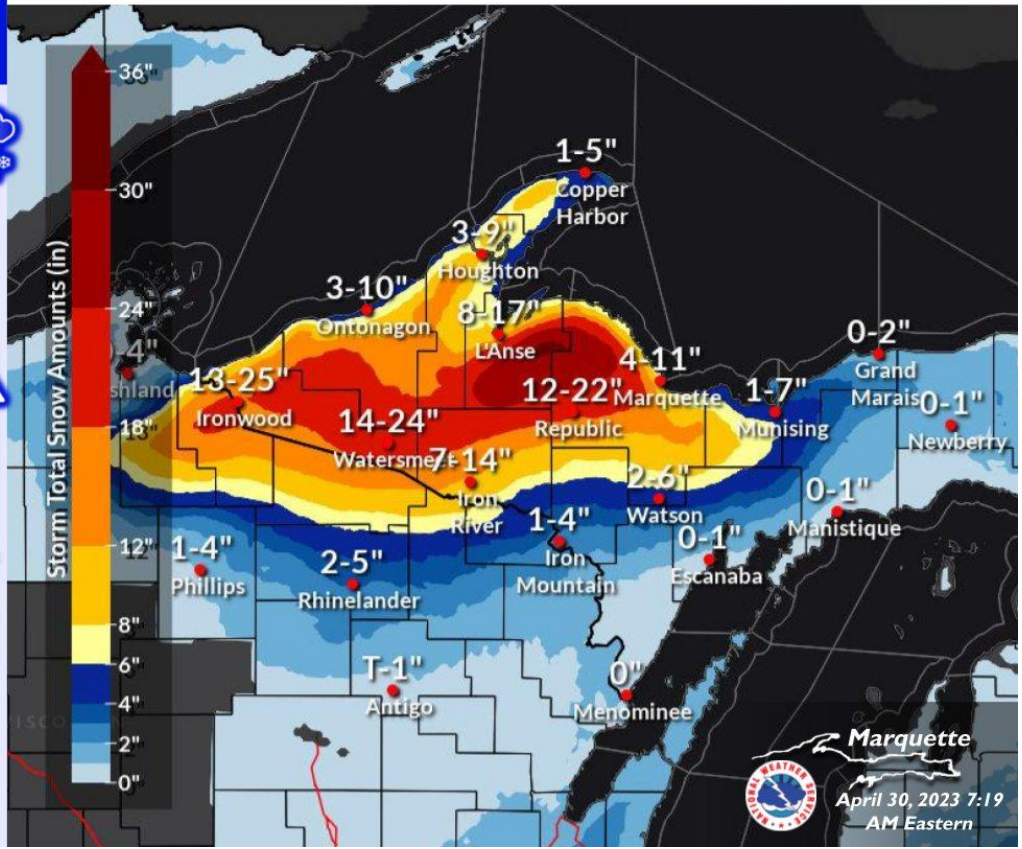
Power Outages are Possible

Heavy-wet snow and strong winds may break limbs and cause power outages; late tonight into early Tuesday.

What you should do right now:

- Continue to monitor the forecast for changes
- Prepare to change travel plans
- **Expect rises on streams & rivers**

Expected Total Snowfall into Early Tuesday Afternoon



Messaging

WFO MQT DSS briefing slide 30 Apr 10:47 am

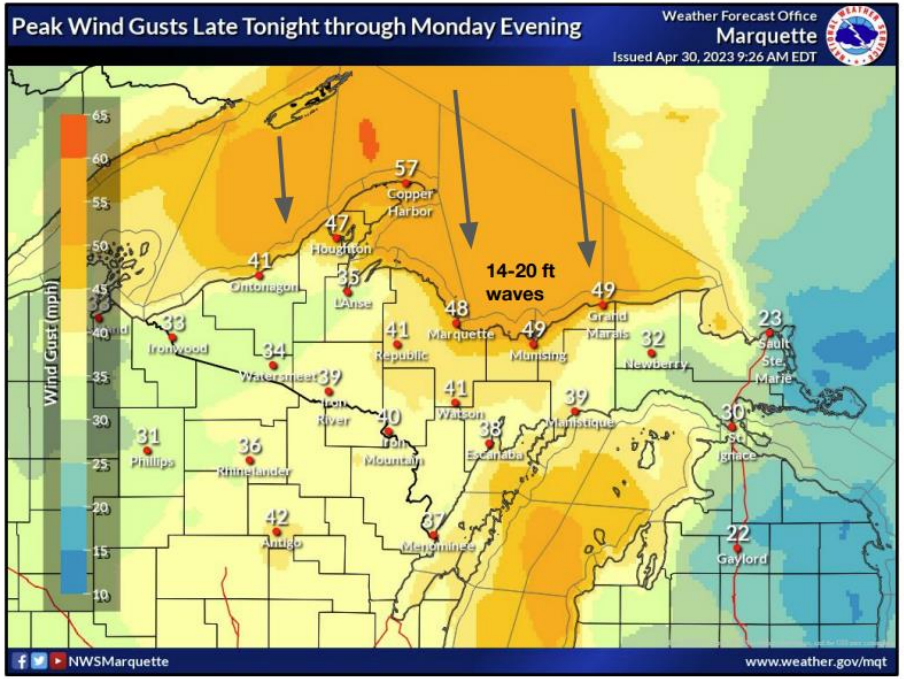
Historic Late Season Snow

April 30, 2023
10:47 AM

Significant wet, dense snow expected

Impacts - Power Outages

- Due to the exceptionally wet, heavy snow loading onto trees and power lines, tree damage and power outages are expected, especially late tonight through Monday evening when north wind strengthen, gusting to 30 to 45 mph. This will further increase stress on trees and power lines. Power outages could become widespread and tree damage could become extensive



National Oceanic and Atmospheric Administration
U.S. Department of Commerce

National Weather Service
Marquette, MI

Messaging

WFO MQT social media post 1 May 3:15 pm

Reach (this post):
486,740

Reach (all other posts from April 30–May 1 combined):
81,025

Conclusions/Credits

Conclusions

- Historic late-season winter storm brought record snowfall and high winds to the UP, resulting in dangerous travel conditions, extensive tree damage, and numerous power outages
- Slow-moving cutoff low entrained Gulf/Atlantic moisture, providing favorable conditions for a long-duration, heavy precip event
- Spatial extent of heavy snowfall was modulated by terrain
- Cooling due to dynamic and orographic lift, latent cooling due to melting and evaporating hydrometeors, and a cold air supply modified little by a cold Lake Superior were all factors that led to the precip type remaining mostly snow

Credits

- Evan Kutta, WFO MQT
  - Proofreading
- Nick Langlieb, WFO MQT
  - Technical support
- Ryan Connelly, Aviation Weather Center
  - Code for graphics production