A Retrospective Look at the Great Armistice Day Storm of 1940:

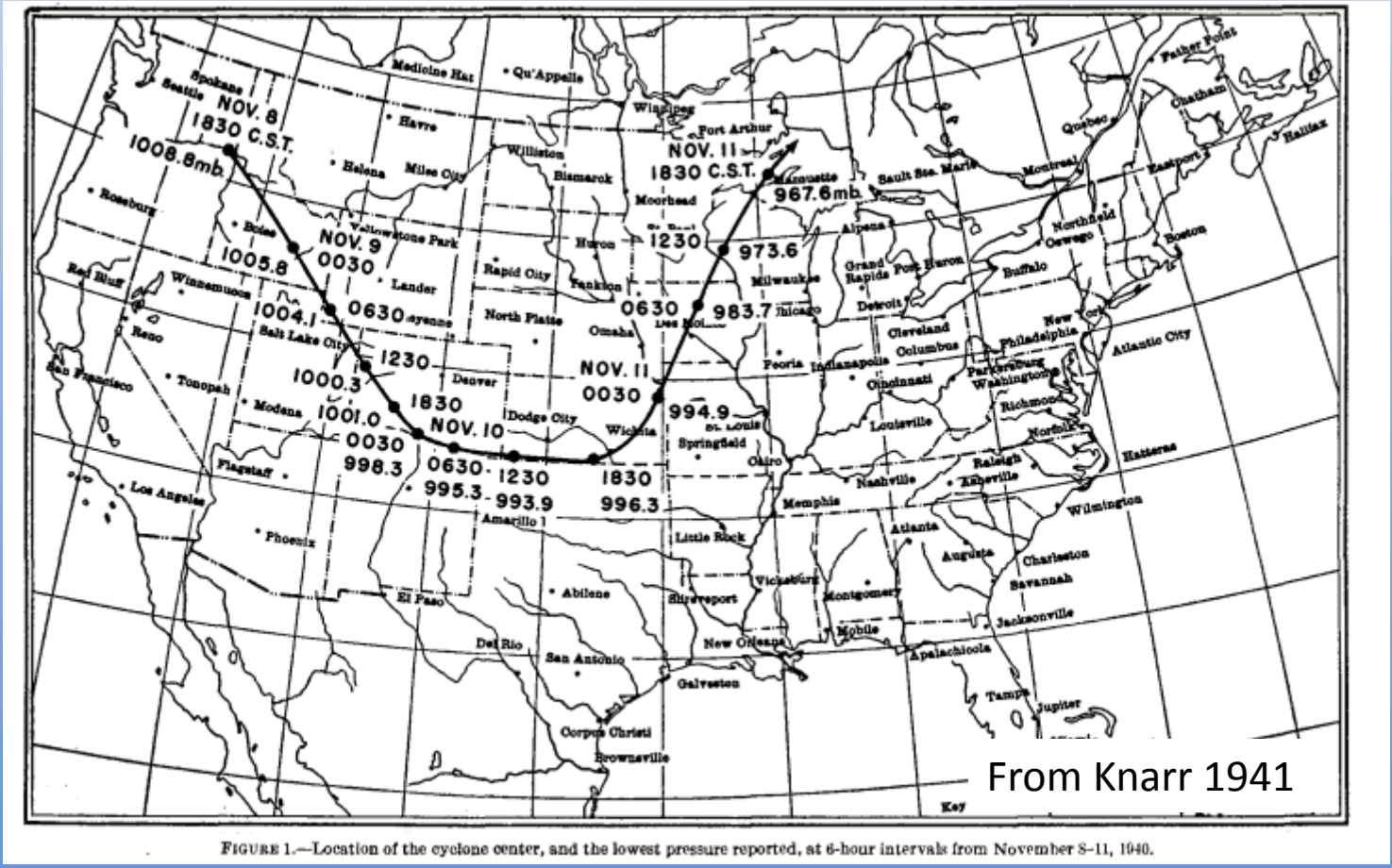
Using Numerical Modeling to Simulate Conditions on the Great Lakes during this Fateful Storm

Michael Dutter
NOAA/NWS Marquette, MI

Great Lakes Operational Meteorology Workshop
Grand Rapids, MI
25 Aug 2015

Background Photo from:
http://www.ricmixter.com/lectures/

Low Track – 08-11 Nov 1940



From Knarr 1941

FIGURE 1.—Location of the cyclone center, and the lowest pressure reported, at 6-hour intervals from November 8–11, 1940.

Overview of the Storm (Great Lakes)

- Arguably one of the strongest storms to affect the Great Lakes and Upper Midwest in the past 100 years
  - 154 deaths for the entire storm
  - Capt. Harold B. McCool – master of the Crescent City: "In my opinion, this storm was even more severe than the disasterous storm during the Fall of 1913."
- At least 10 ships foundered on the Great Lakes with 69 lives lost, mostly on Lake Michigan
- Strongest Wind Gust Reported – 70 kt at GRR
  - Widespread 50-60kt wind gusts across much of the Great Lakes Region

Background Photo from http://www.masoncountypress.com/2012/11/13/the-armistice-day-storm-of-1940-and-the-mighty-pentwater-heroes/

Lowest Pressure (in of HG) and Maximum Wind (mph) at several stations

Station	Lowest pressure (sea-level)	Maximum wind (5 minutes)
	Inches	*Miles*
Illinois:		
Cairo	29.45	SW. 37
Chicago	29.09	SW. 42
Peoria	29.15	SW. 29
Springfield	29.23	SW. 46
Indiana:		
Fort Wayne	29.27	SW. 53
Indianapolis	29.36	SW. 37
Terre Haute	29.34	SW. 47
Evansville	29.45	SW. 47
Iowa:		
Charles City	28.92	W. 34
Davenport	29.09	SW. 38
Des Moines	29.06	NW. 36
Dubuque	28.99	SW. 22
Keokuk	29.15	W. 41
Sioux City	29.54	NW. 43
Michigan:		
Alpena	29.06	SW. 47
Detroit	29.32	SW. 45
Escanaba	28.77	S. 43

Station	Lowest pressure (sea-level)	Maximum wind (5 minutes)
	Inches	*Miles*
Michigan—Continued.		
Grand Rapids	29.10	SW. 65
Lansing	29.16	SW. 41
Marquette	28.67	S. 33
Saulte Ste. Marie	28.95	SW. 34
Minnesota:		
Duluth	28.66	NW. 52
Minneapolis	28.93	W. 38
Ohio:		
Cleveland	29.45	SW. 59
Columbus	29.53	SW. 53
Dayton	29.53	S. 47
Sandusky	29.40	SW. 42
Toledo	29.35	W. 38
Wisconsin:		
Green Bay	28.80	S. 47
La Crosse	28.72	SW. 24
Madison	28.92	SW. 40
Milwaukee	28.94	SW. 54

From Knarr 1941

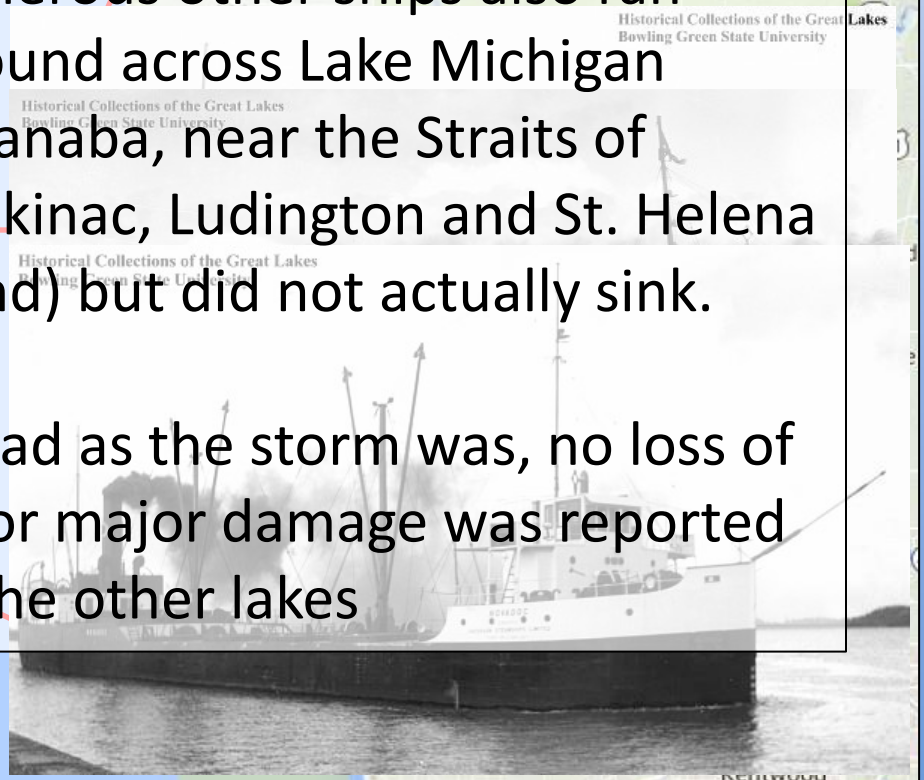
Lowest Pressure in any United States observing site – 967mb at Houghton, MI

Shipwrecks from the Storm

- **Anna C. Minch**
- **William B. Davock**
- **Novadoc**
- Indian
- **Richard H.**
- Nancy Jane?

Numerous other ships also ran aground across Lake Michigan (Escanaba, near the Straits of Mackinac, Ludington and St. Helena Island) but did not actually sink.

As bad as the storm was, no loss of life or major damage was reported on the other lakes

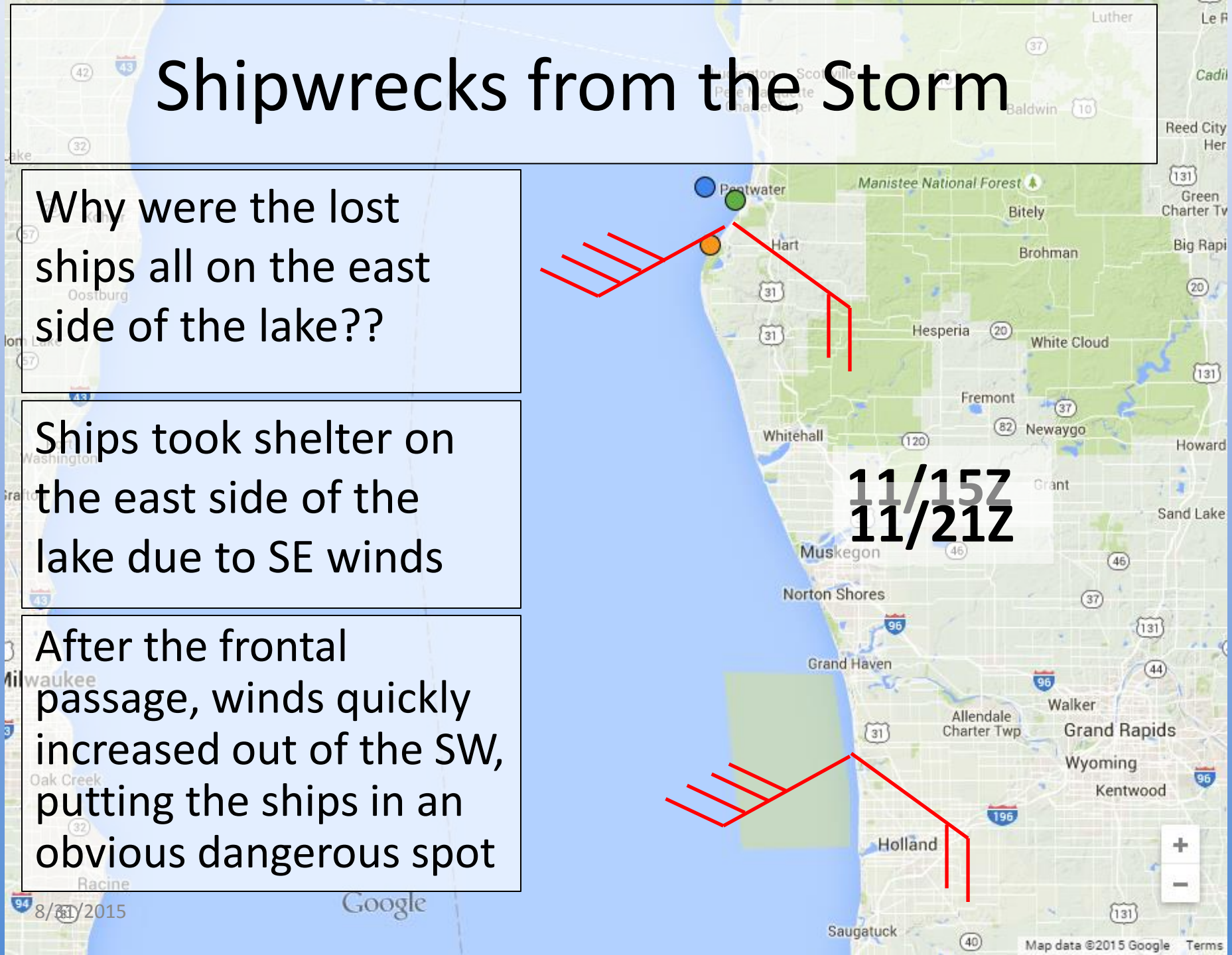


Shipwrecks from the Storm

Why were the lost ships all on the east side of the lake??

Ships took shelter on the east side of the lake due to SE winds

After the frontal passage, winds quickly increased out of the SW, putting the ships in an obvious dangerous spot



Overview of the Storm (Cold Side)

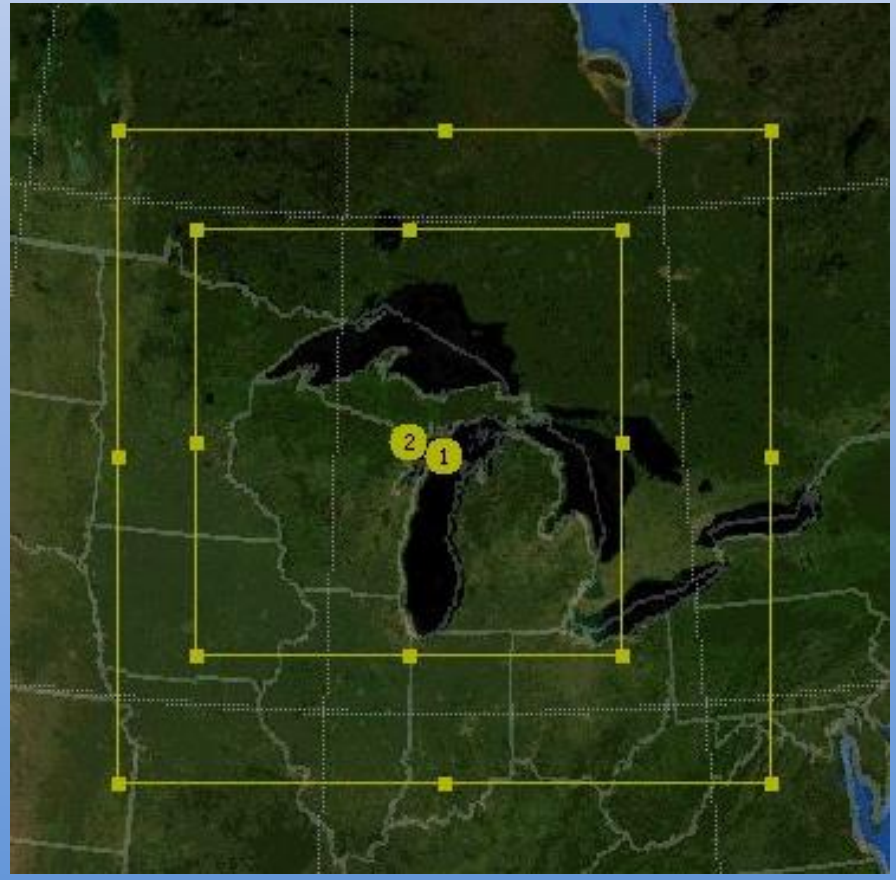
- One of the more significant blizzards to affect the Upper Mississippi Valley
  - Twelve Duck Hunters perished on the Mississippi River.
  - Fourty-nine deaths alone in MN
- Wind blown snowfall in excess of 12 inches across much of the Upper Mississippi Valley (many places in excess of 20 inches)
  - Twenty foot drifts near Willmar, MN
- Side Note: Strong winds associated with this storm was also responsible for the collapse of the Tacoma Narrows Bridge on 07 Nov.

Why a numerical simulation?

- There are over land reports of strong winds, however wind data was severely lacking across the Great Lakes waters
- Only antidotal reports of wave information, however the waves (height and direction) were likely critical in the sinking of the ships
- Focus of the simulation will be on the Great Lakes

WRF Numerical Model Details

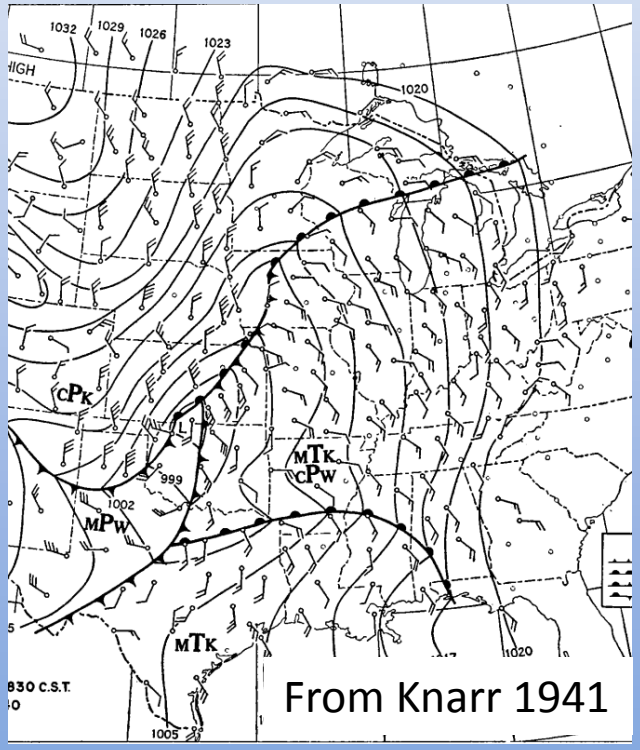
- WRF-ARW V3.5.1
- Initial and Boundary Conditions from 20th Century Reanalysis (20thCR)
  - Reanalysis using only surface data to recreate the entire atmosphere
- 5km/1.67km horizontal resolution
- 45 vertical levels
- Explicit Convection

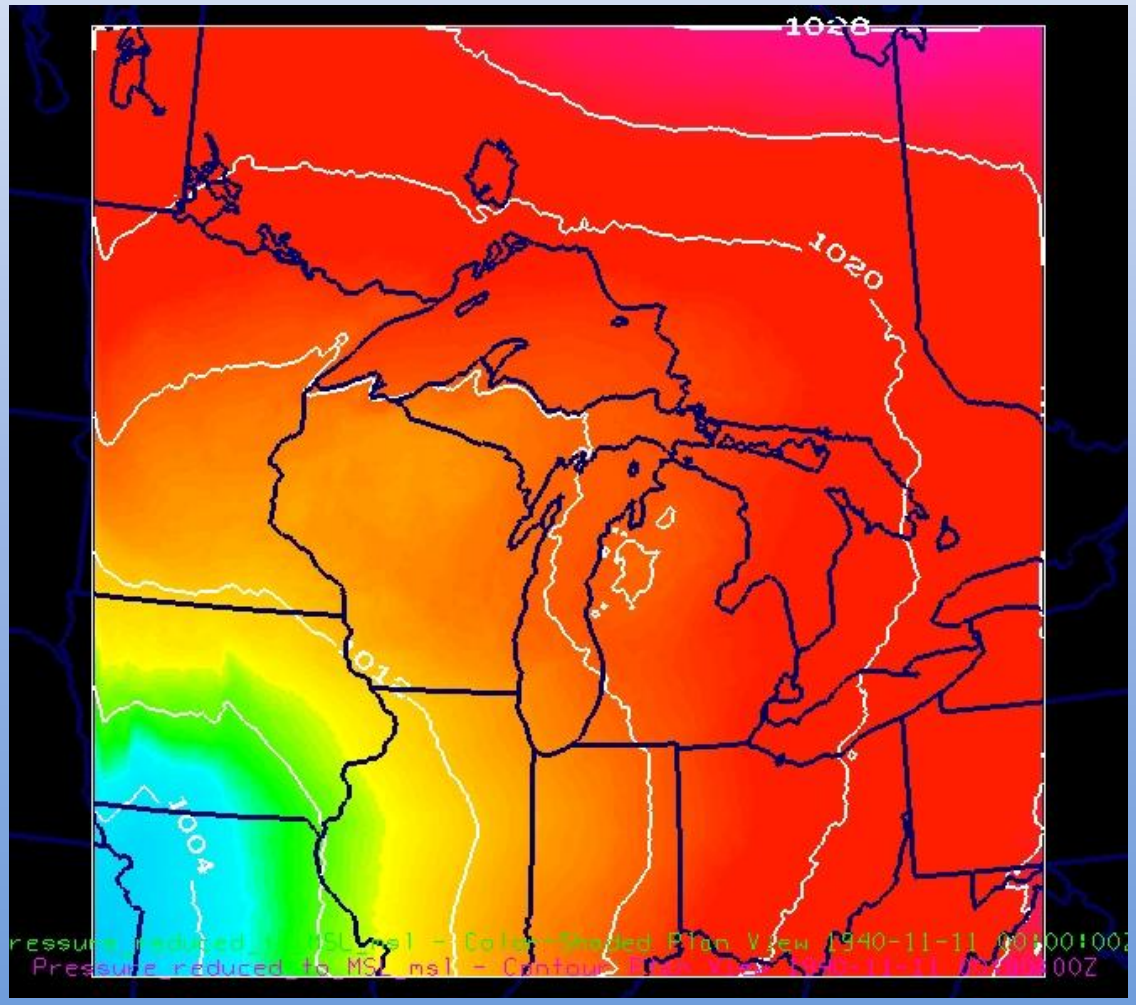


GLERL Donelon Wave Model

- Locally ran at 5km resolution
- Solves equations for significant wind wave height
  - "Maximum Wave" Calculations are also shown (highest 5% of waves)
- Ran over Lakes Superior, Michigan, Huron and Erie
- Used WRF model simulated 10m winds and surface temperatures for input

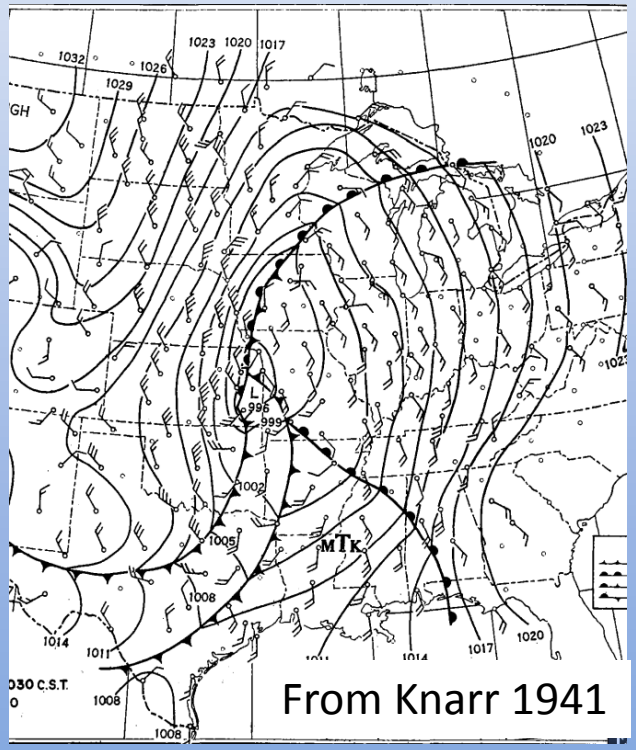
Surface Comparison – 00 UTC 11/11/1940



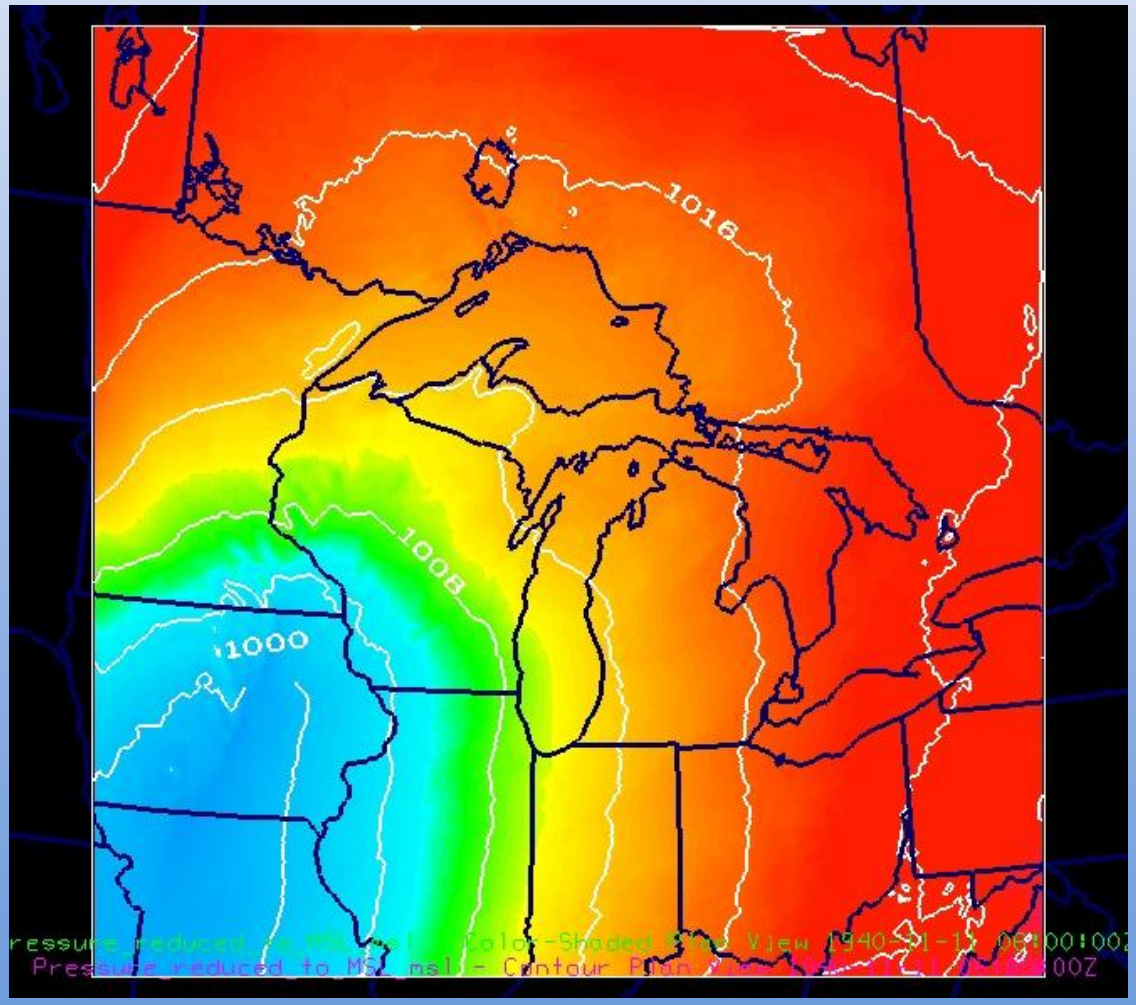


The low is just developing as a 999mb low over northern OK.

Surface Comparison – 06 UTC 11/11/1940

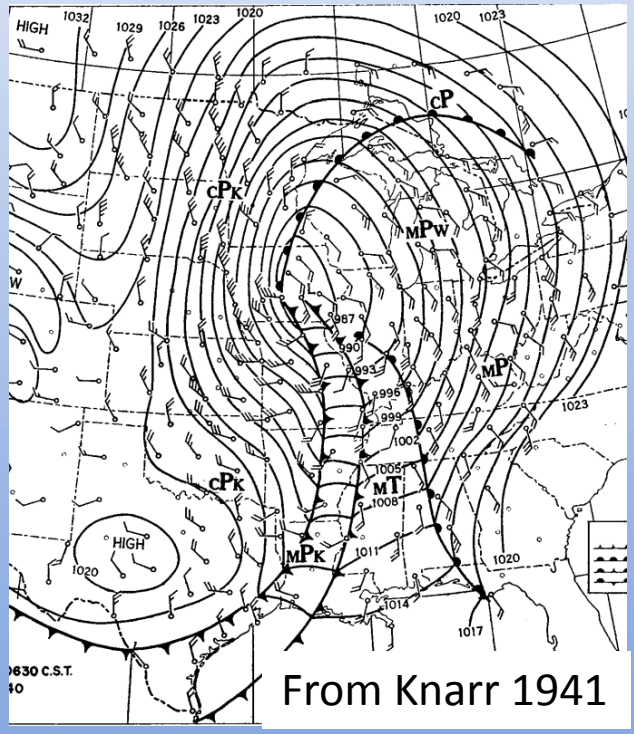


From Knarr 1941



Deepening commences, with the low strengthening to 995 mb just west of Kansas City. At this point, southeasterly winds are starting to increase over southern Lake Michigan.

Surface Comparison – 12 UTC 11/11/1940



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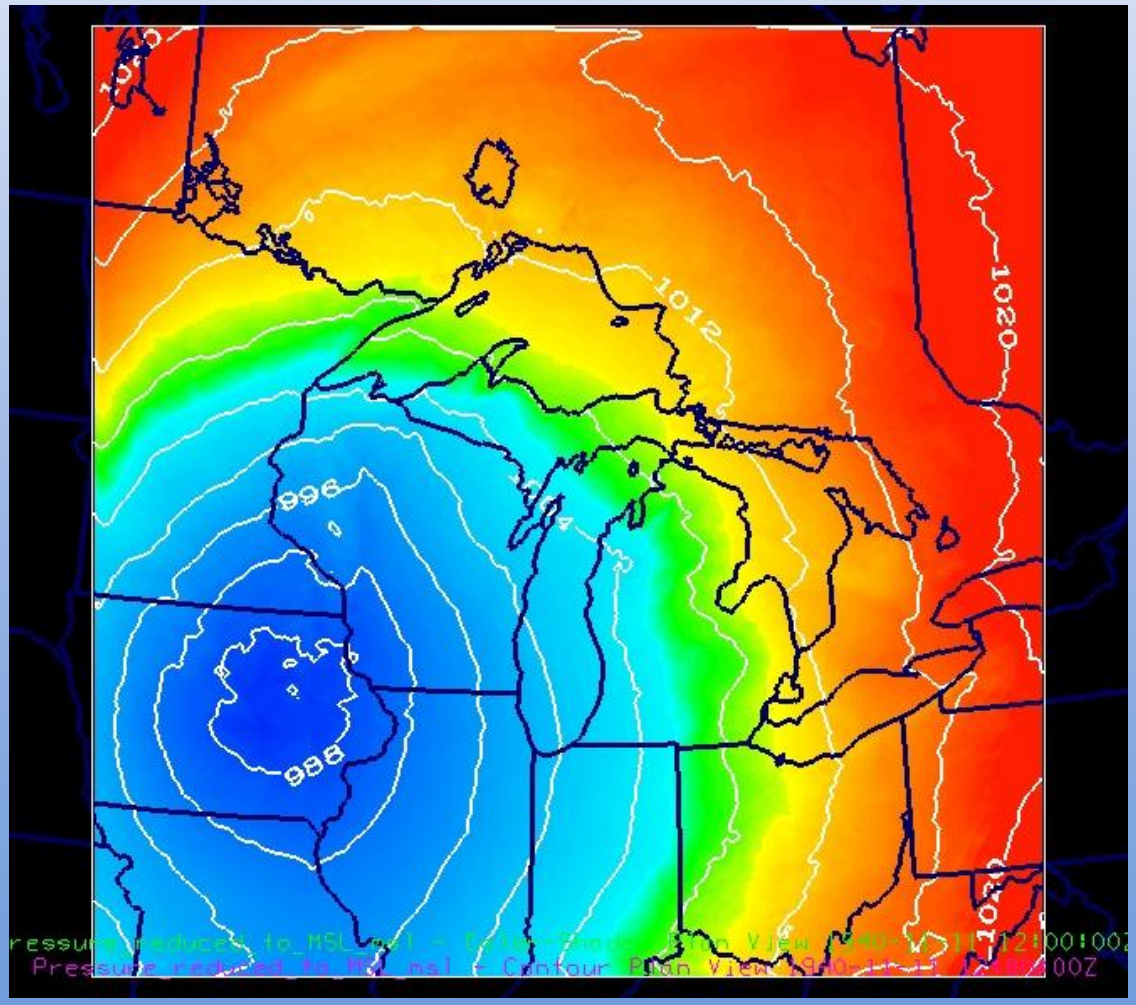


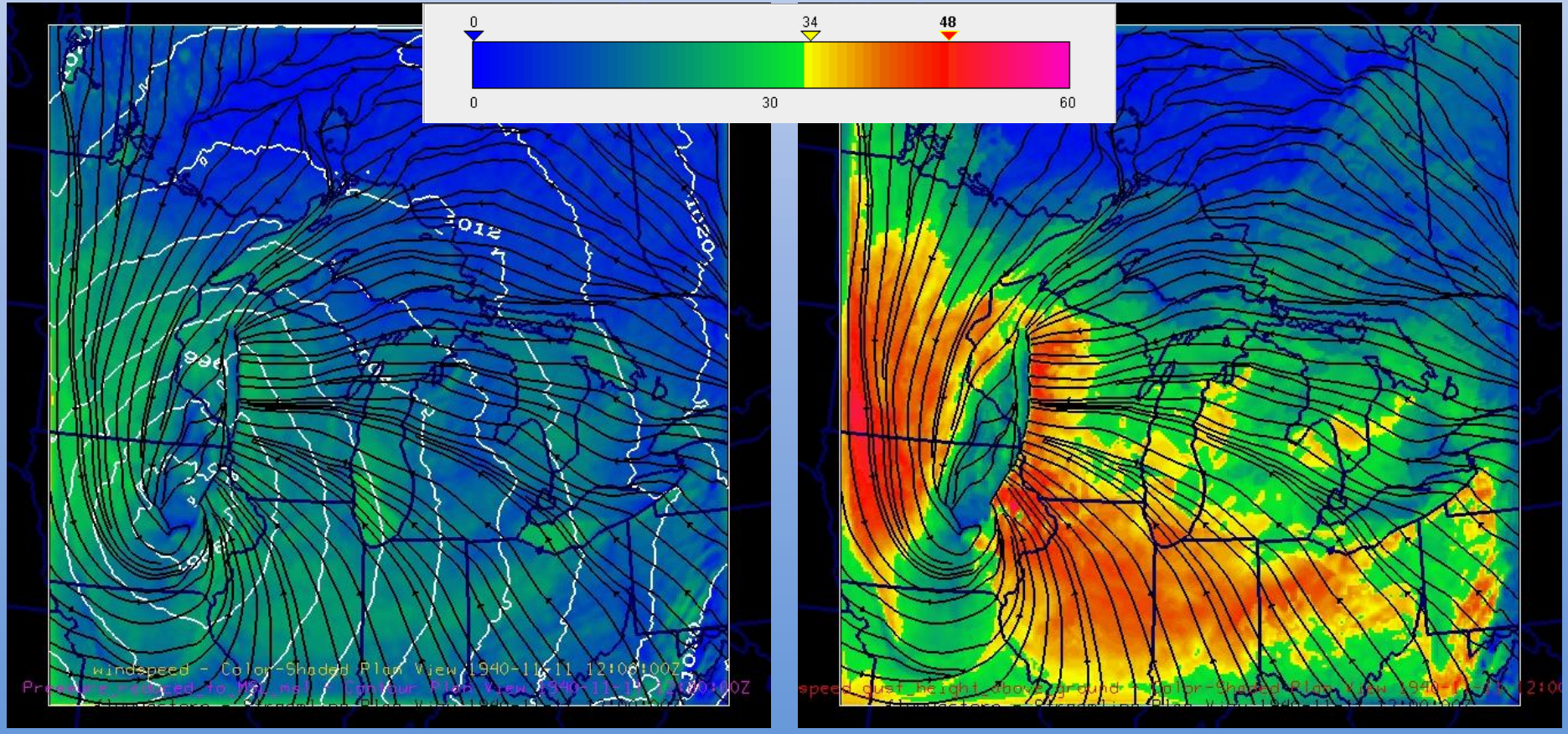
Rapid deepening occurs between 06UTC and 12UTC with nearly 12mb of deepening in 6 hr.

The analyzed 984mb low pressure system is over east central Iowa. The numerical simulation shows this deepening very well with a position only slightly to the east of the analysis.

Winds (kt) - 12 UTC 11/11/1940

10m Wind/Streamlines/PMSL

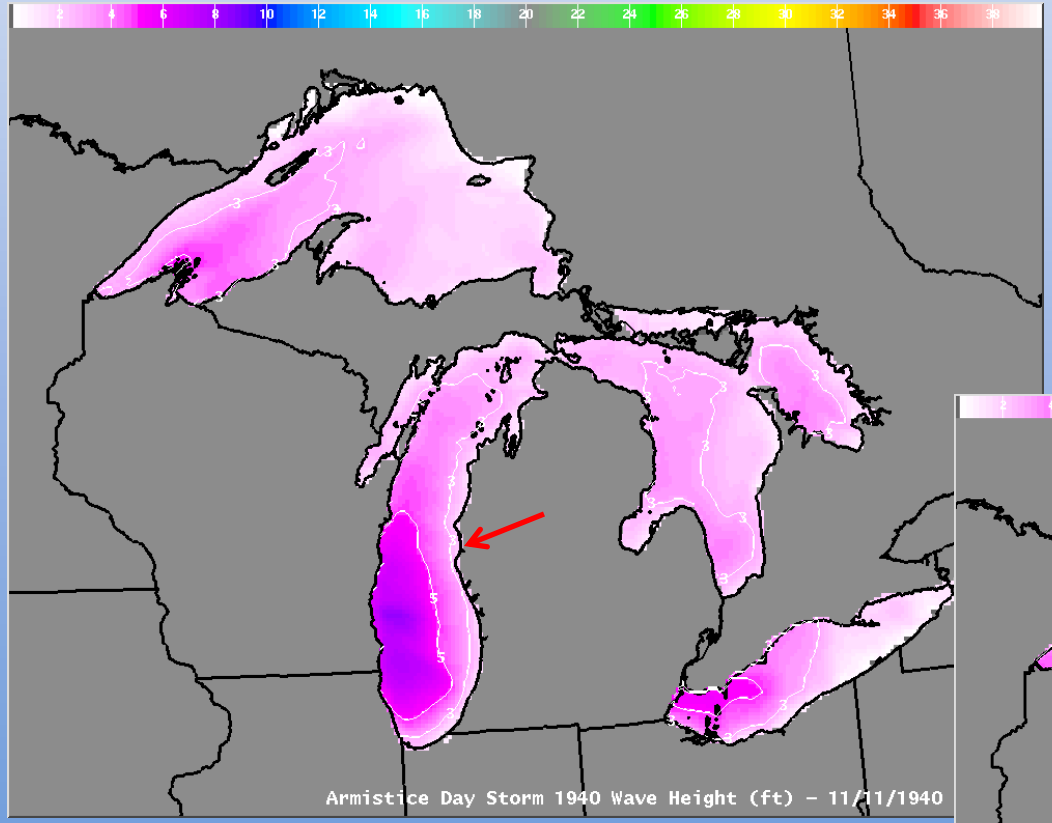
10m Wind Gust/Streamlines



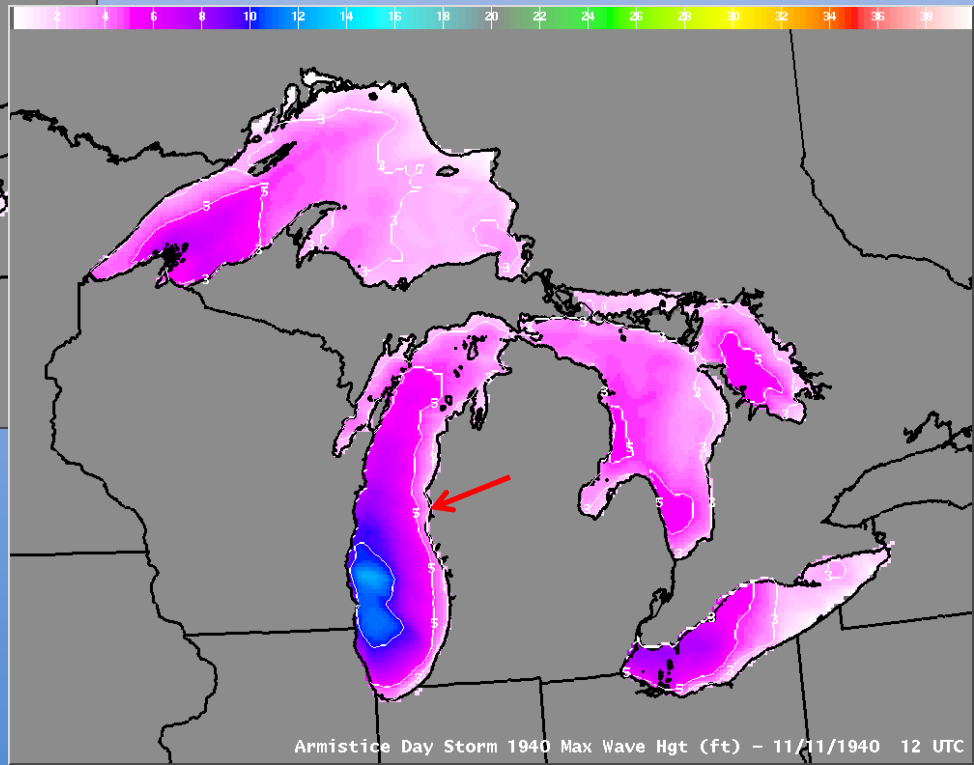
By 12 UTC, southeast gale force wind gusts were certainly possible across far southern Lake Michigan. At this point, the ships were likely opting to take shelter on the east side of the lake.

Waves (ft) - 12 UTC 11/11/1940

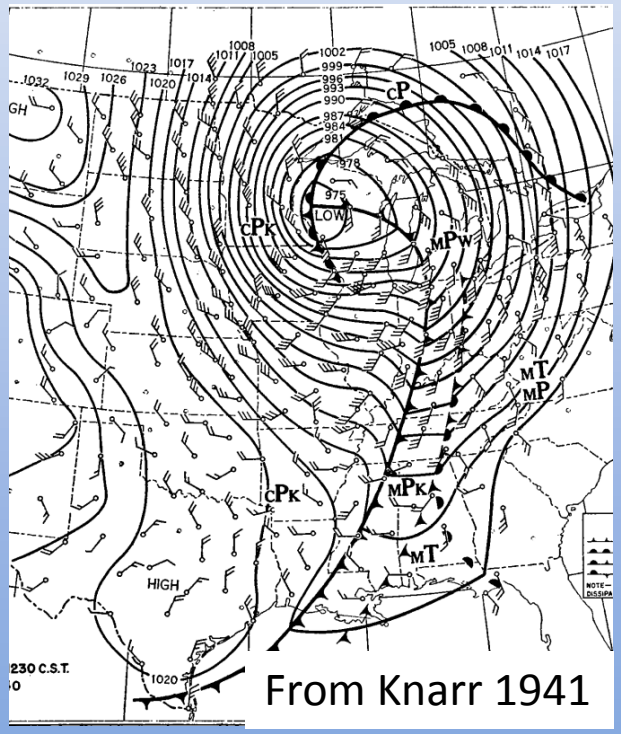
Significant Wave



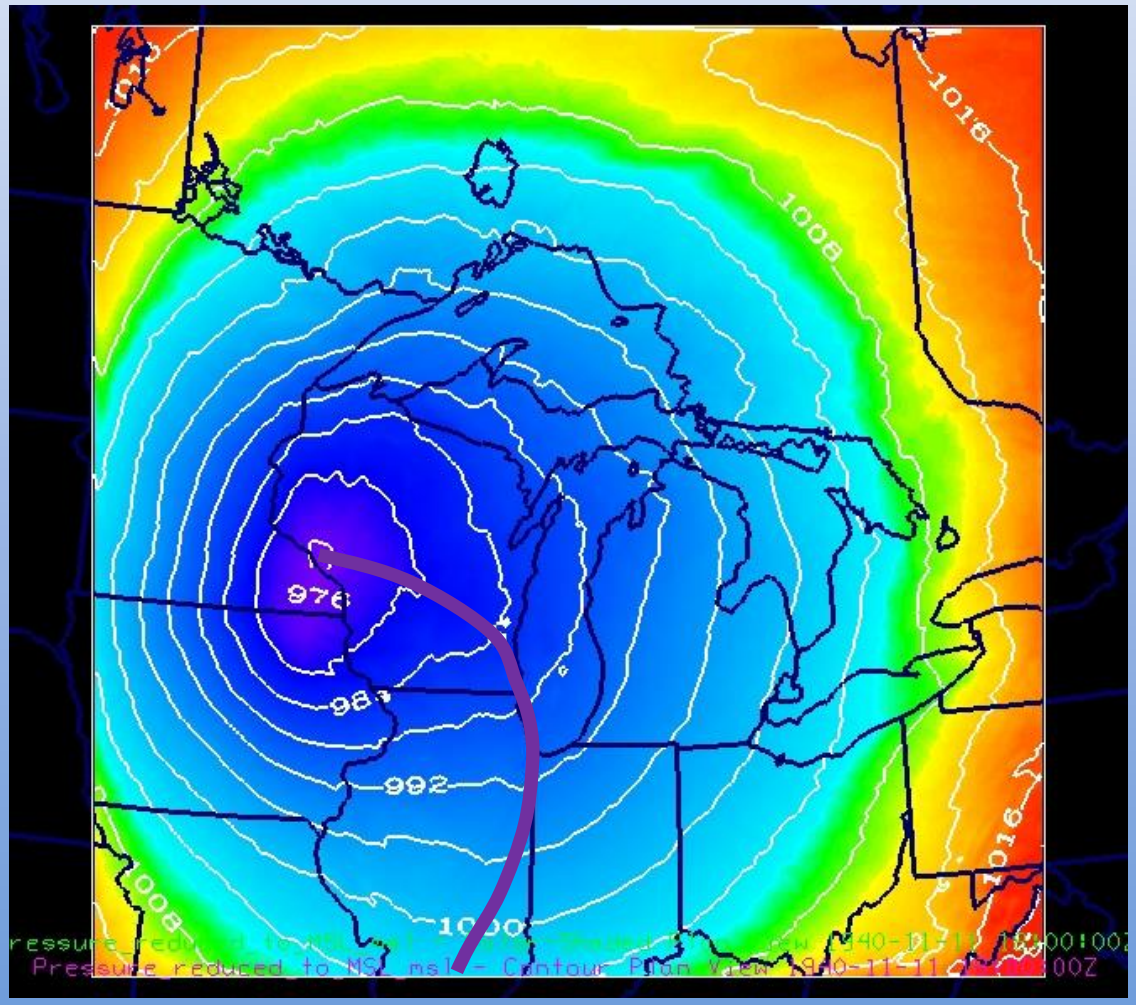
Maximum Wave



Surface Comparison – 18 UTC 11/11/1940



From Knarr 1941

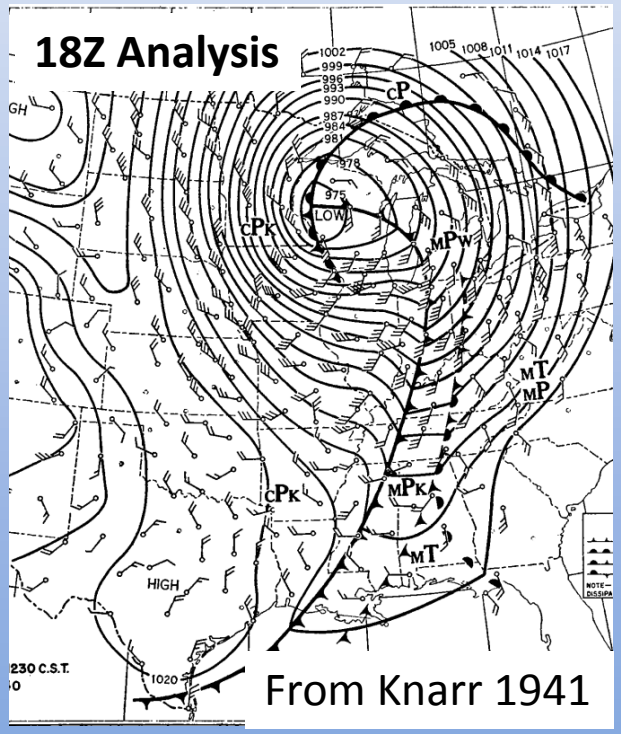


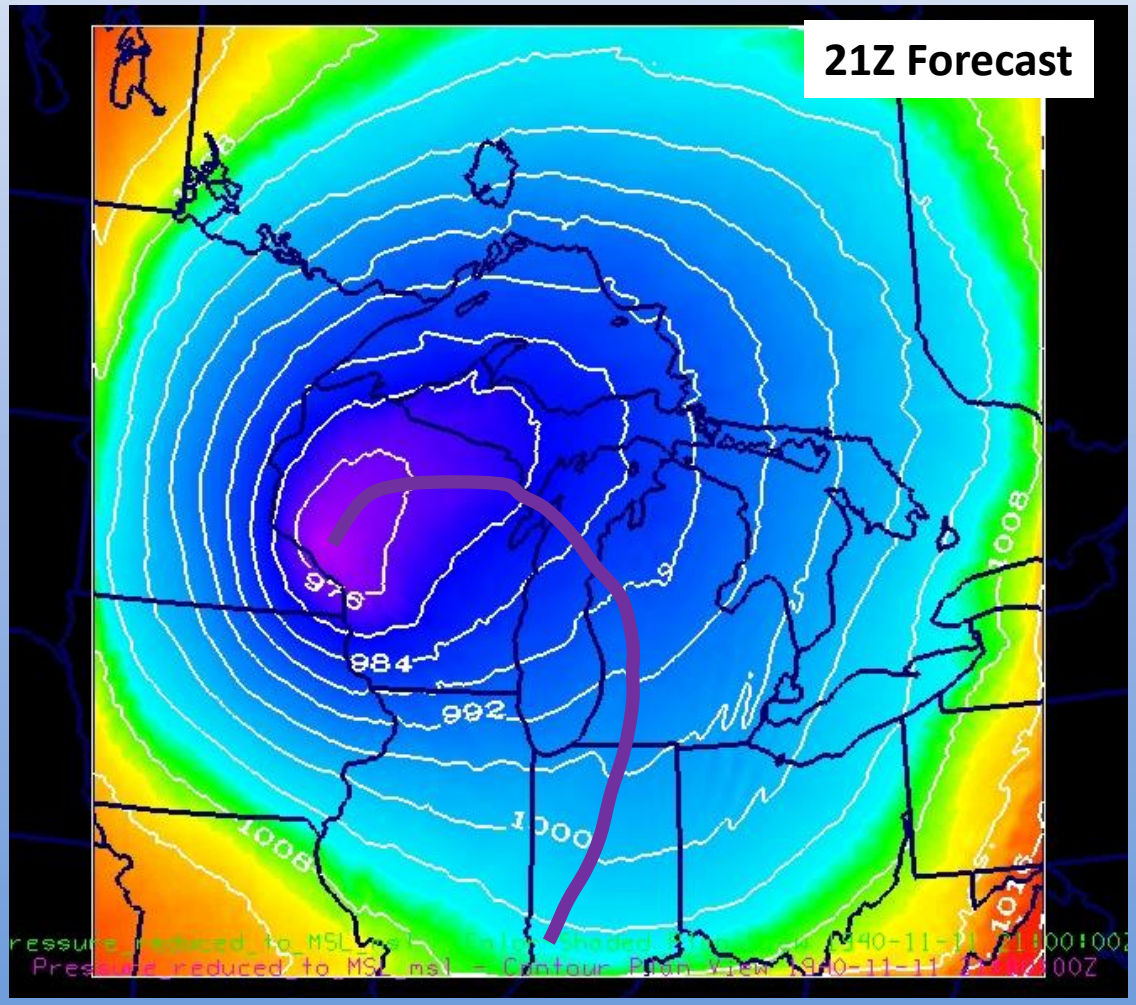
Rapid deepening continues between 12 and 18UTC with the low now near LaCrosse, WI.

The analyzed 974mb low pressure system is slightly stronger than the modeled 975mb low, however the positions are remarkably close.

At this point, the cold front was analyzed east of Chicago (winds turned SW by 16UTC), while the modeled simulation suggests it is still slightly west.

Surface Comparison – 21 UTC 11/11/1940



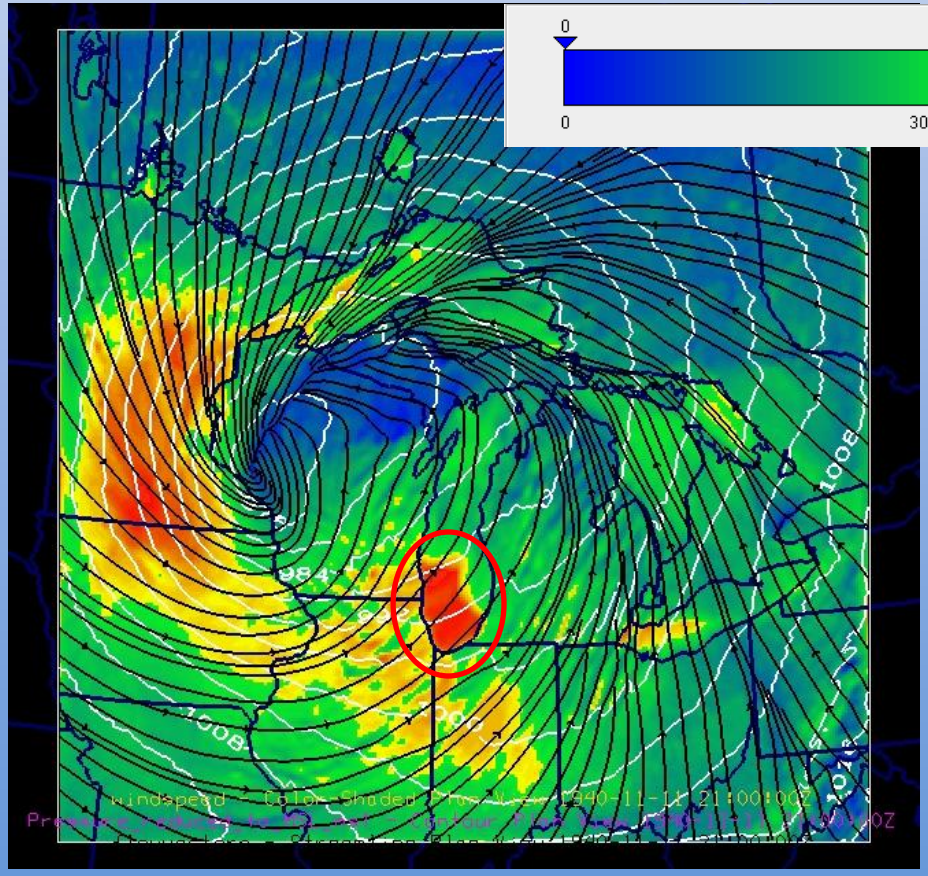


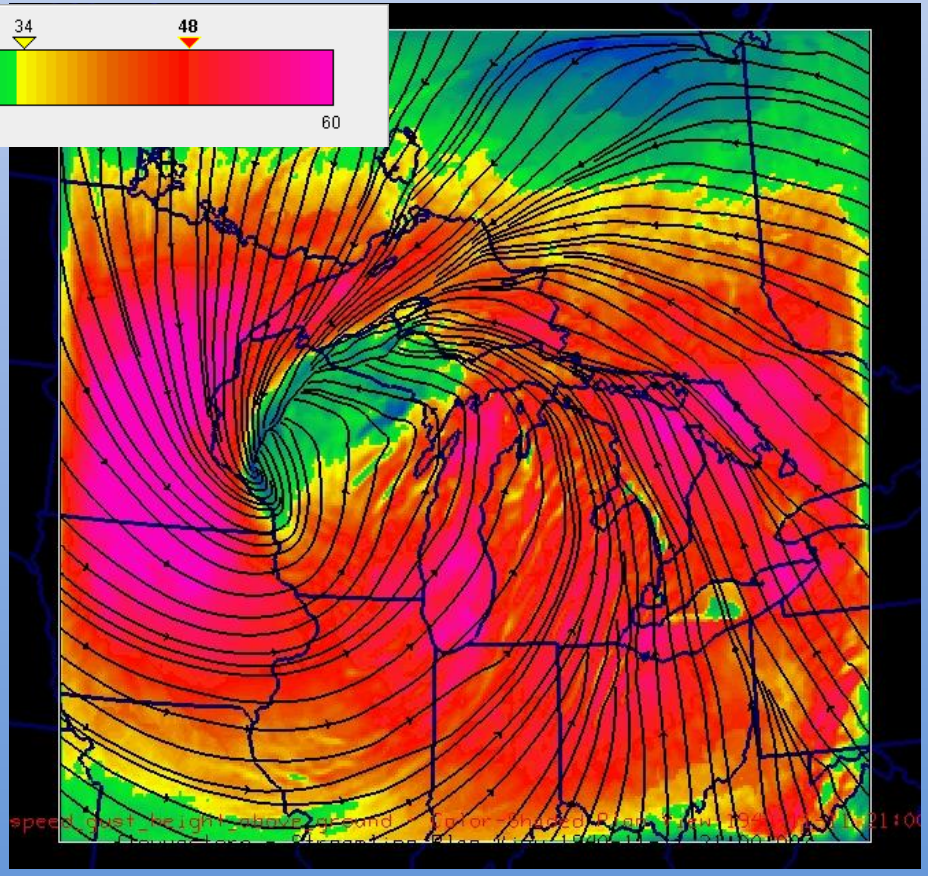
The 21UTC model forecast may be in much better agreement with the 18UTC analysis, suggesting that the model is slightly slower (3-4 hr) than the analysis.

Winds (kt) - 21 UTC 11/11/1940

10m Wind/Streamlines/PMSL

10m Wind Gust/Streamlines

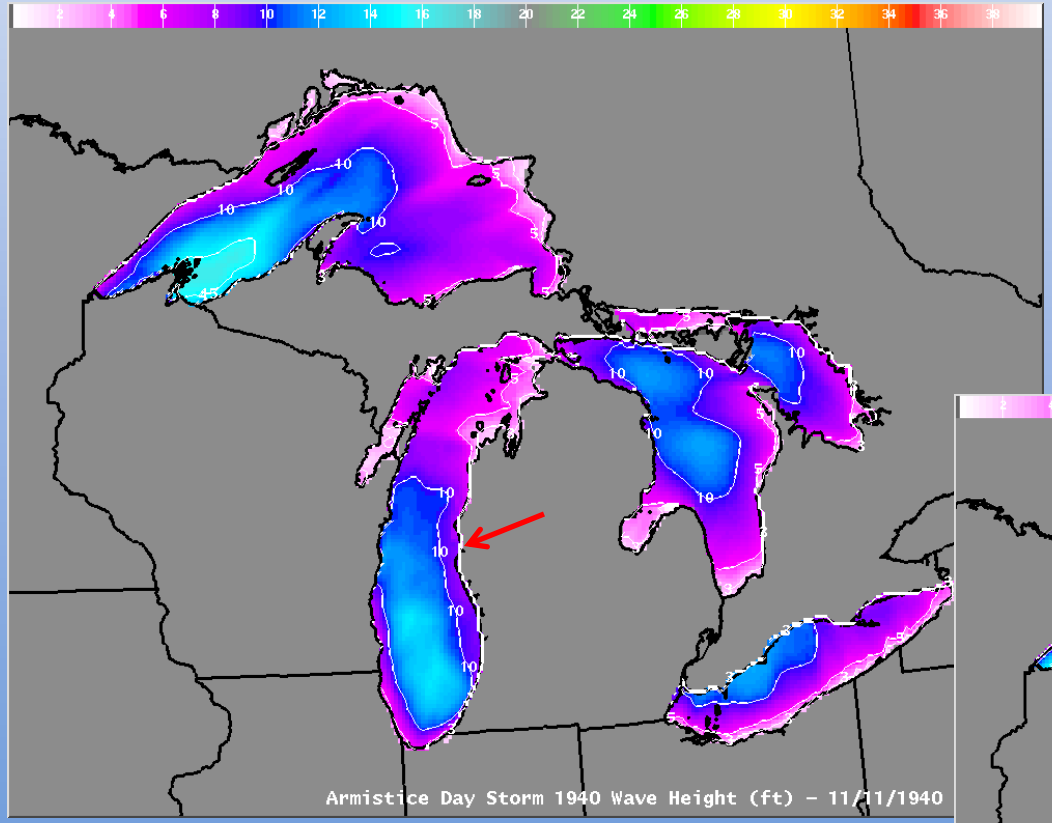




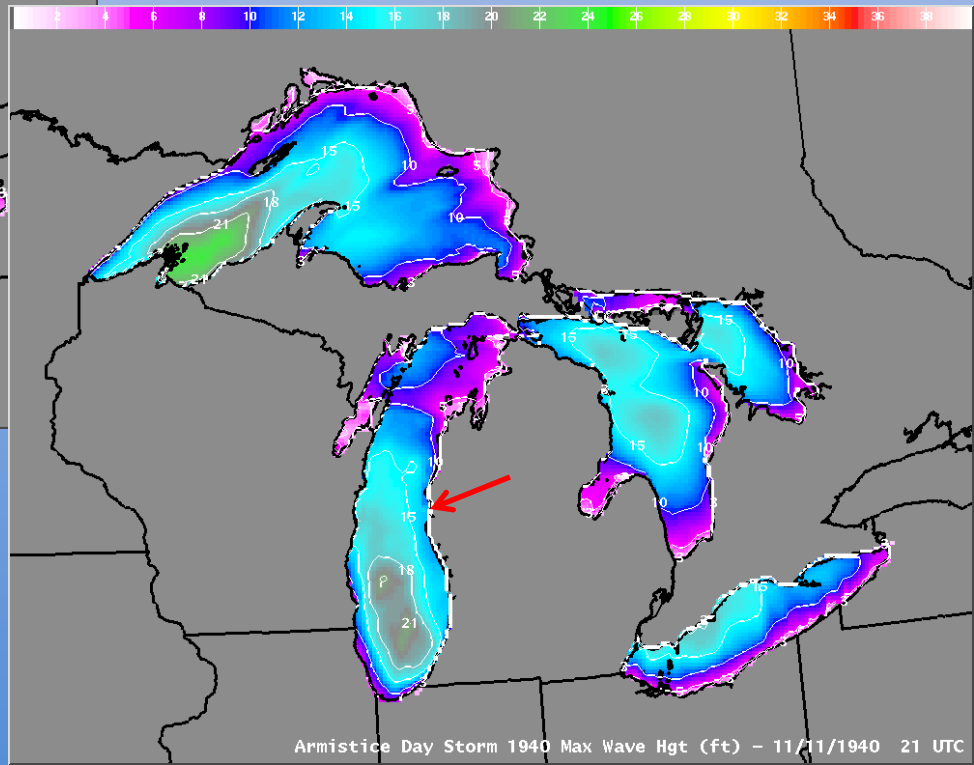
The model 21UTC forecast suggested storm force sustained winds over the southern 1/3 of Lake Michigan. Note the “odd” shape of the storm force winds. There is likely a skin temperature problem in the 20thCR across the eastern part of Lake Michigan (SST too cold) which likely caused mixing problems initially.

Waves (ft) - 21 UTC 11/11/1940

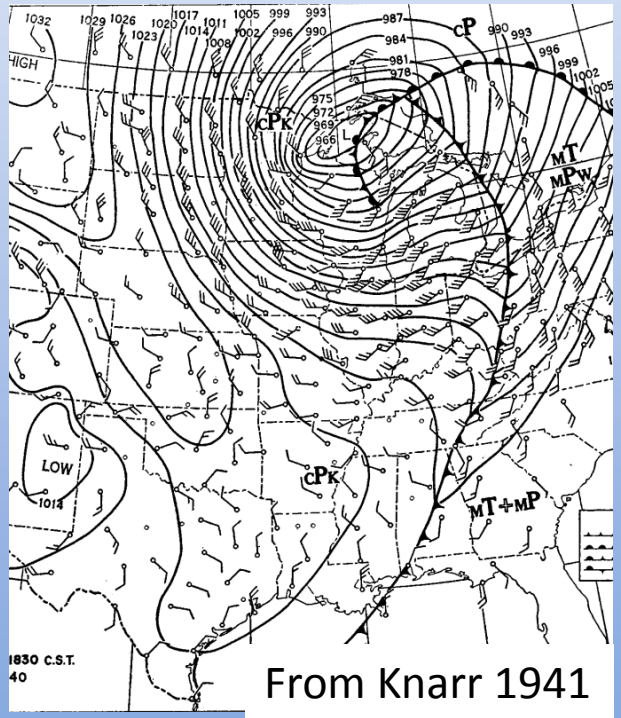
Significant Wave



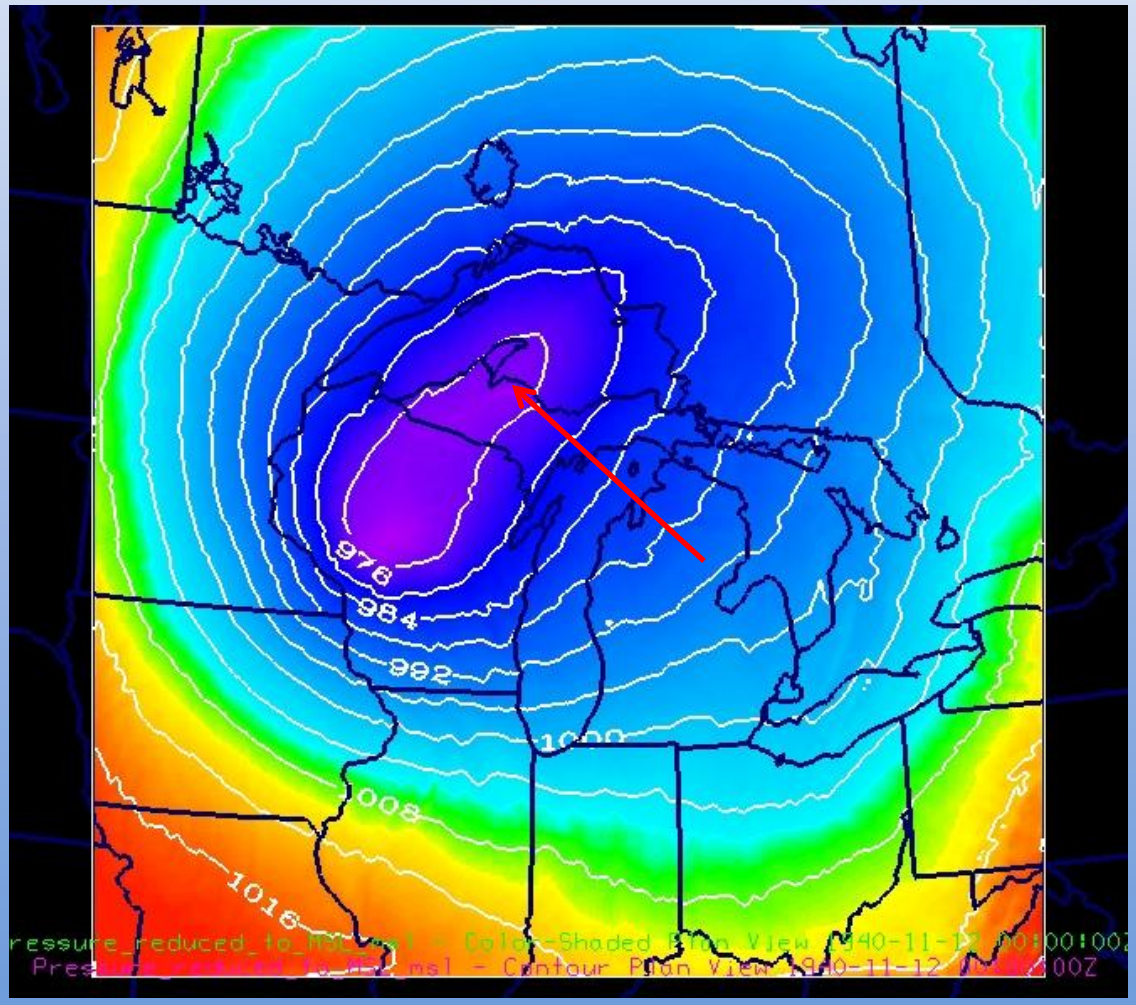
Maximum Wave



Surface Comparison – 00 UTC 11/12/1940



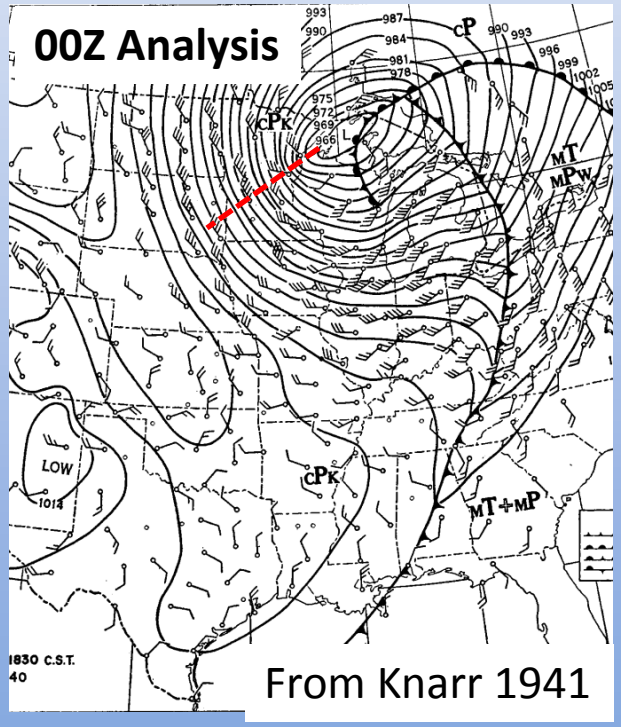
From Knarr 1941



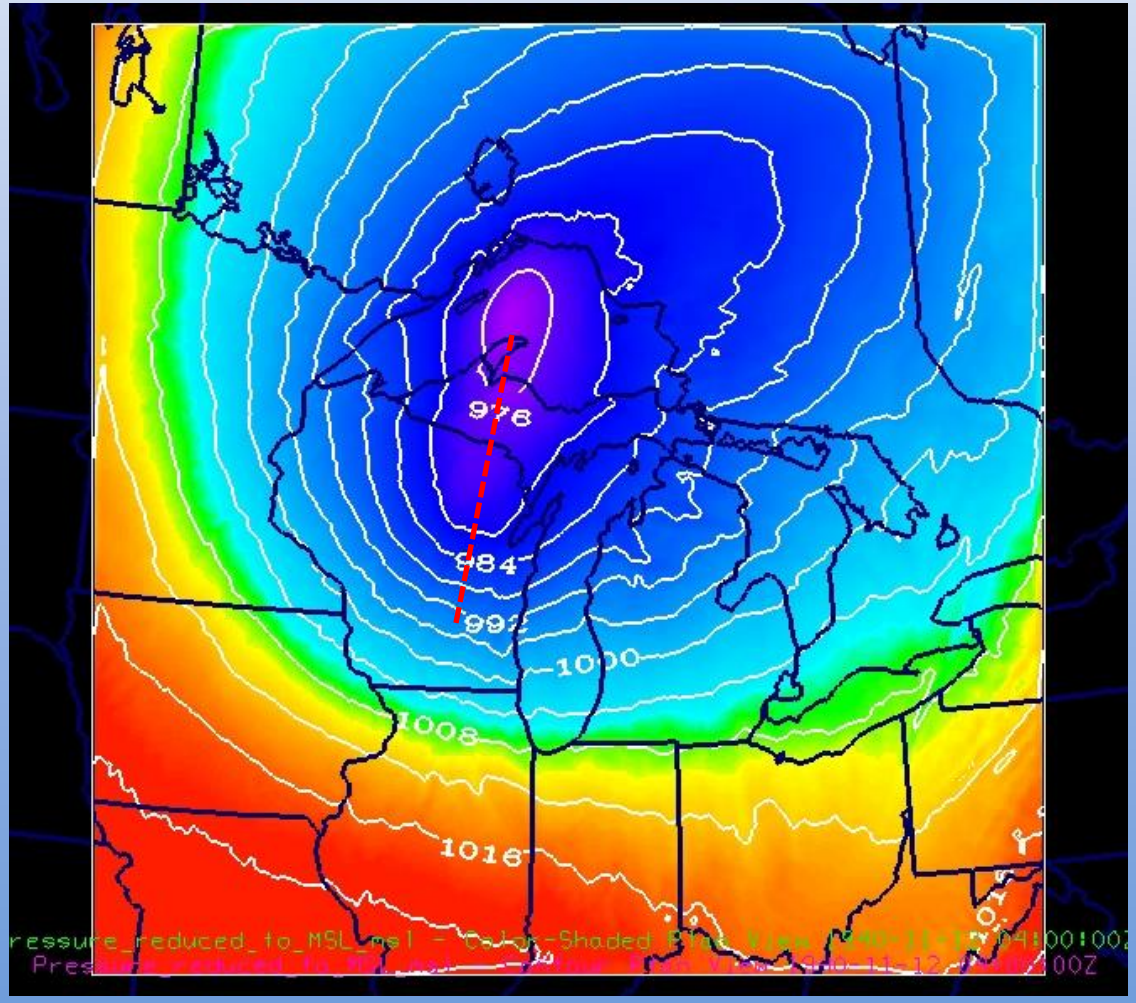
By 00UTC, the model diverges rather dramatically from the analysis as the main low is still over WI. However, note the "secondary" low development over western Upper Michigan.

This is about the approximate time when the Novadoc aground. In addition, the next 6 hours is likely the peak intensity of the storm.

Surface Comparison – 04 UTC 11/12/1940



From Knarr 1941



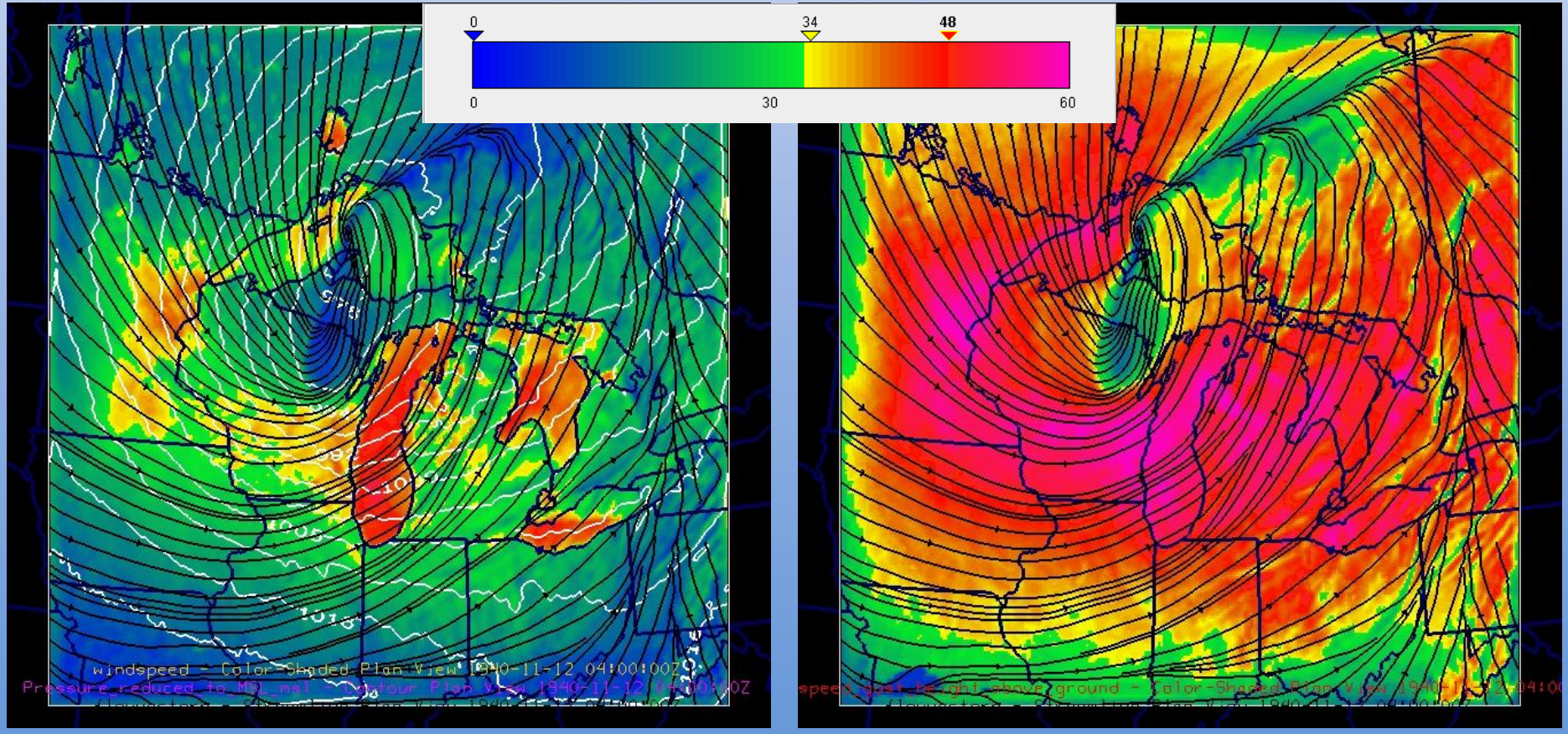
Remember the model being 3-4 hours "behind"? At 04UTC, the model clearly depicts a "redevelopment" near the Keweenaw Peninsula. However, the model did not depict the orientation of the SW oriented trough axis well.

Still, at this point, this is peak intensity of the simulated low with 973mb pressure near Copper Harbor. Further investigation is needed on exactly why the model simulation did not pick up on the continued intense deepening between 18 and 00 UTC

Winds (kt) - 04 UTC 11/12/1940

10m Wind/Streamlines/PMSL

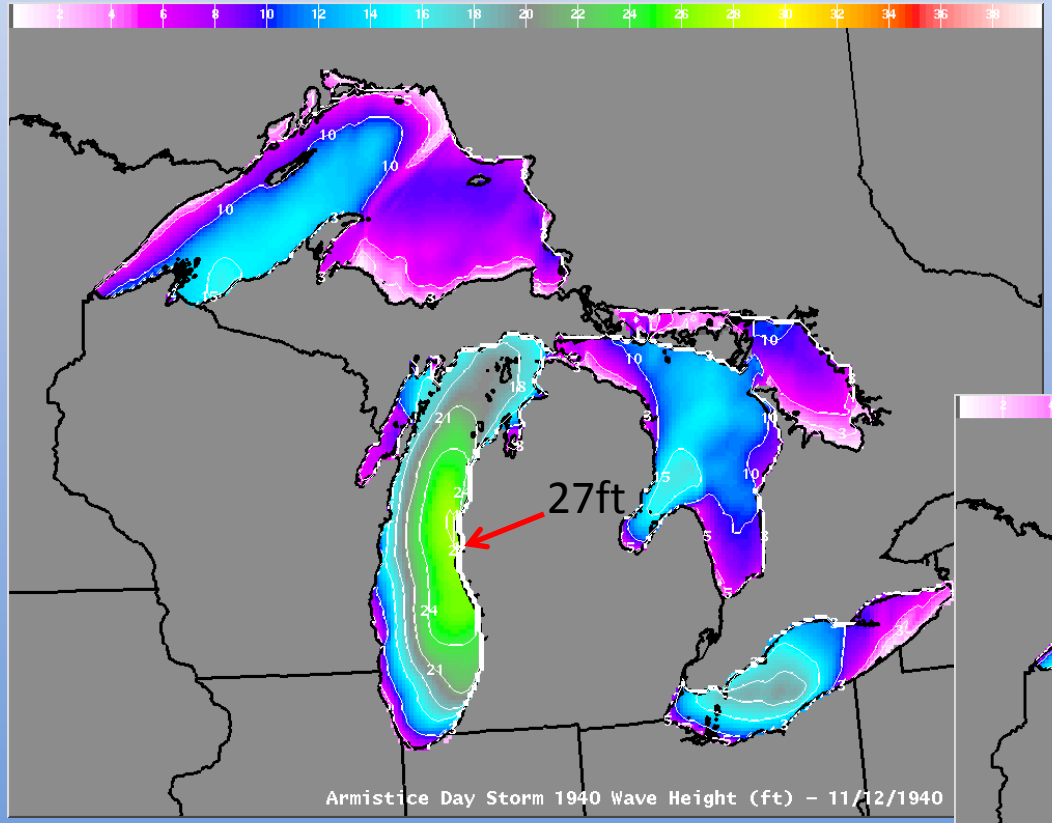
10m Wind Gust/Streamlines



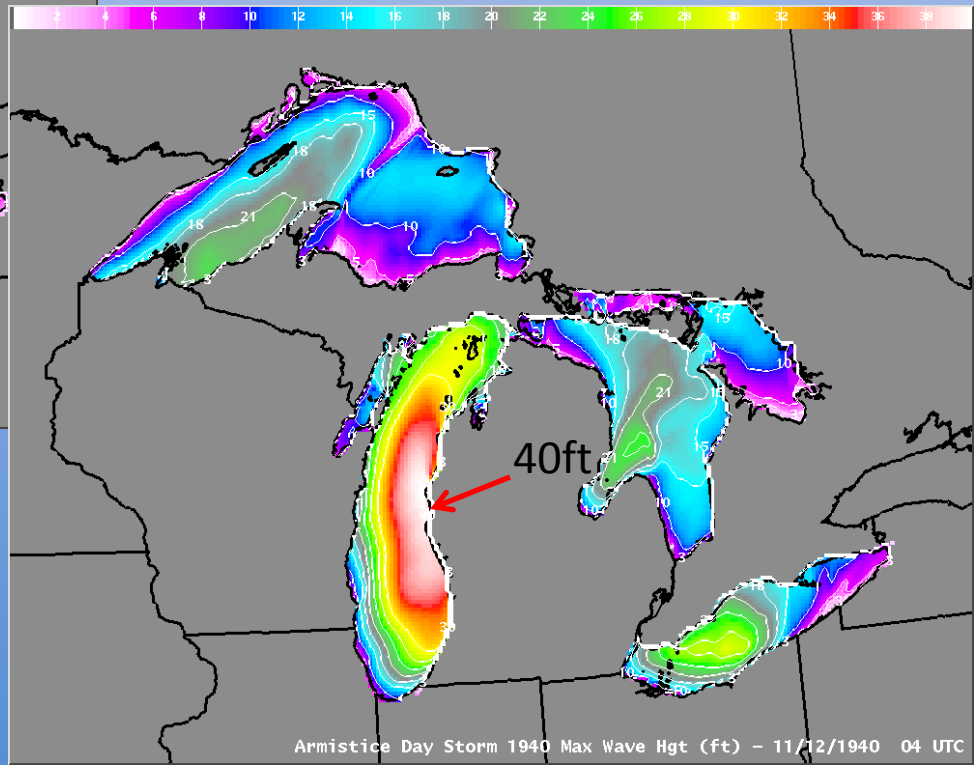
Most of Lake Michigan was covered by near storm force winds (48kt) or greater. Storm Force winds also simulated in Lakes Huron (channelling up Saginaw Bay) and Erie. Gusts to 60kt was also simulated (with a peak to hurricane force just off of Milwaukee).

Waves (ft) - 04 UTC 11/12/1940

Significant Wave

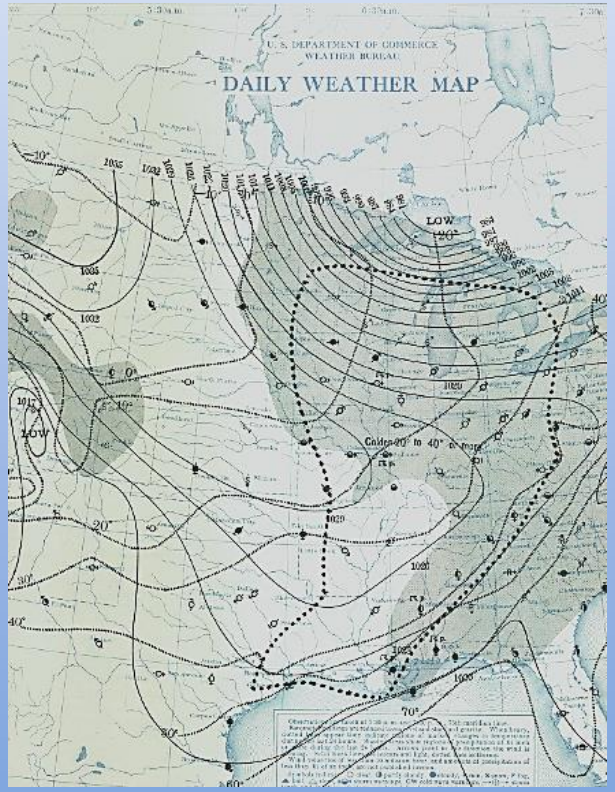


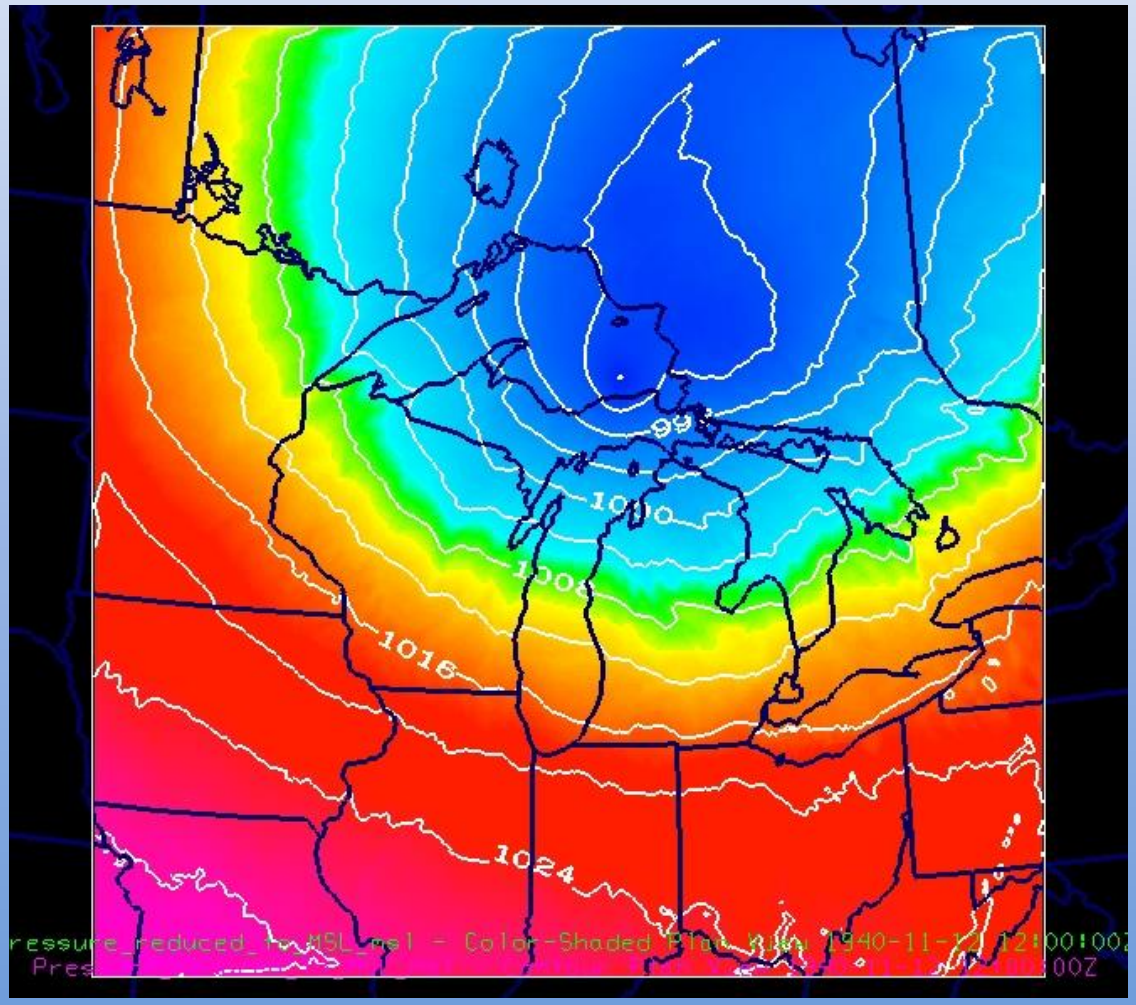
Maximum Wave



Peak significant waves of 27 ft were modeled just off Pentwater, MI. Maximum waves of 40 ft were theoretically possible as well.

Surface Comparison – 12 UTC 11/12/1940



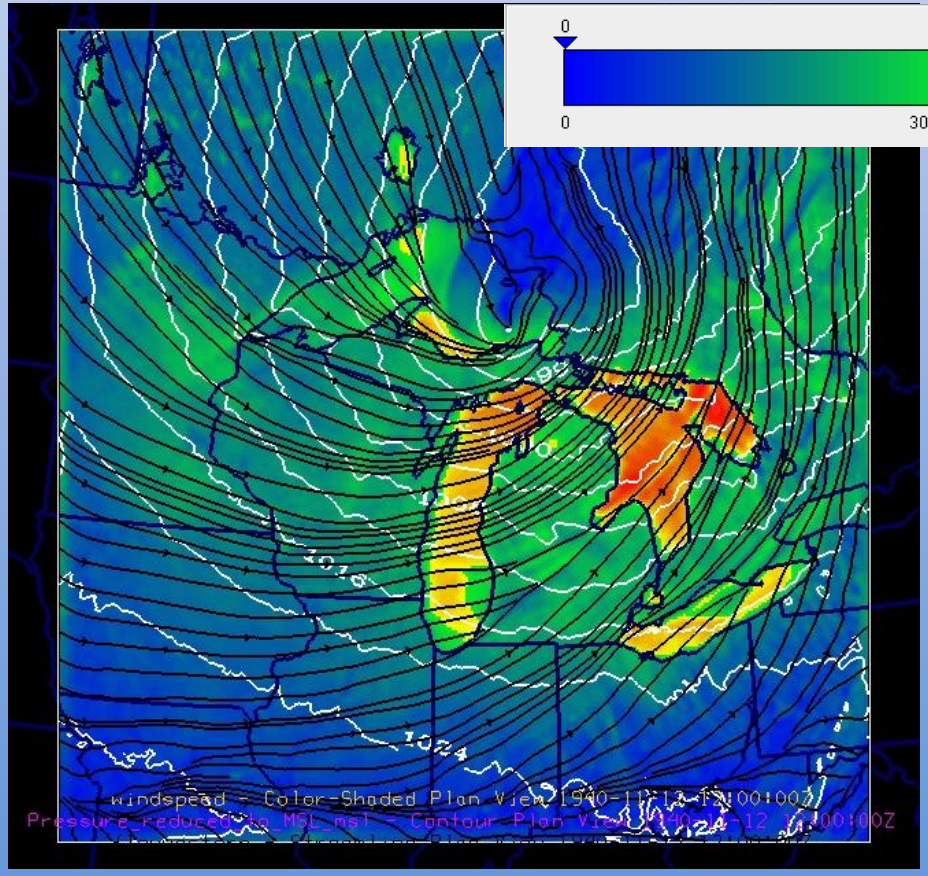


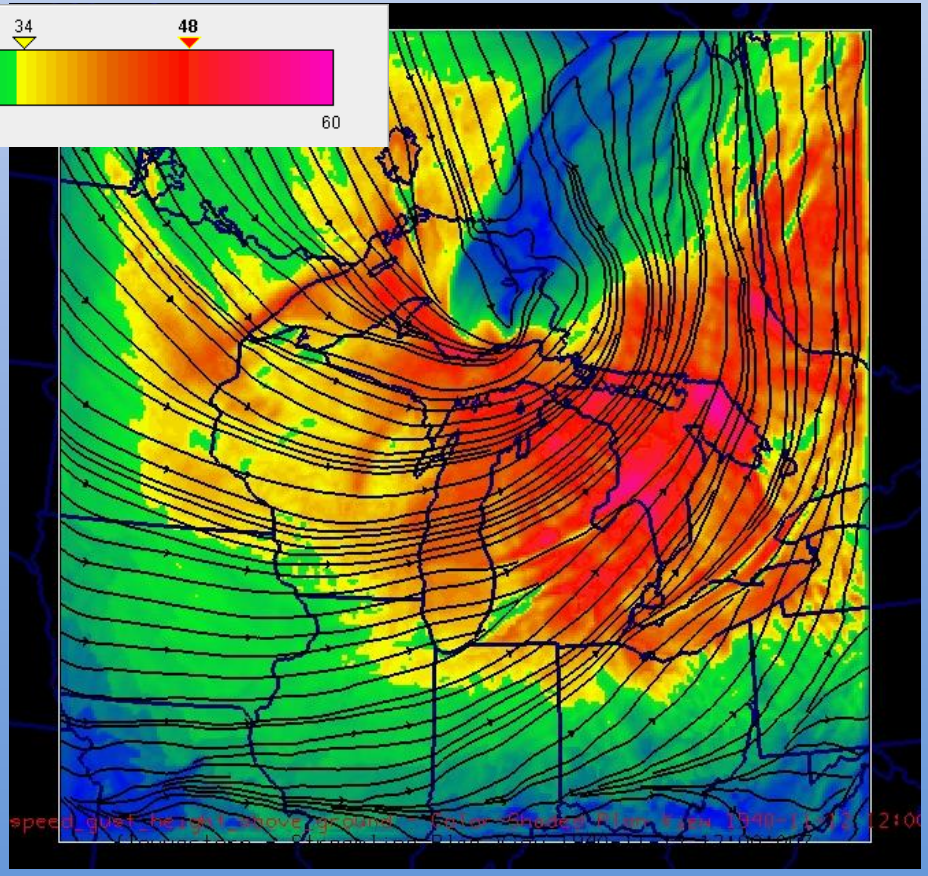
Despite the simulation not forecasting the 966mb low near Houghton at 00UTC, the model still showed a very strong 984 mb low near Grand Marais, MI which compares quite well to the analyzed strength and position.

Winds (kt) - 12 UTC 11/12/1940

10m Wind/Streamlines/PMSL

10m Wind Gust/Streamlines

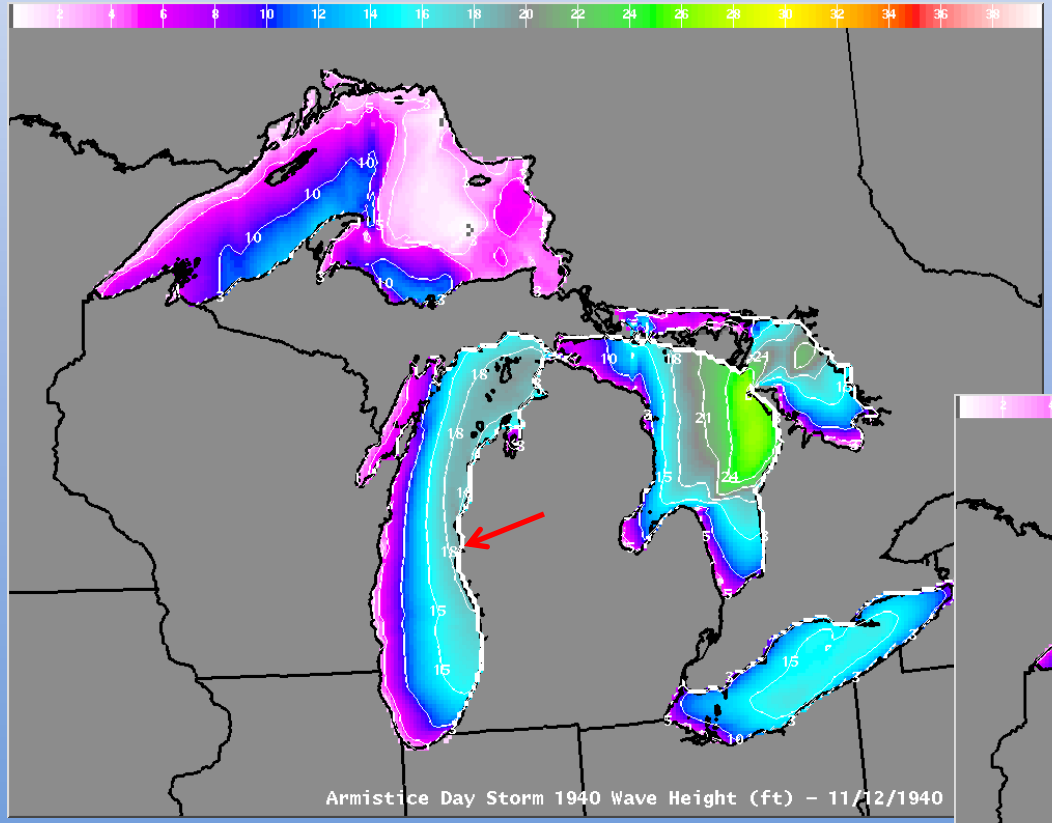




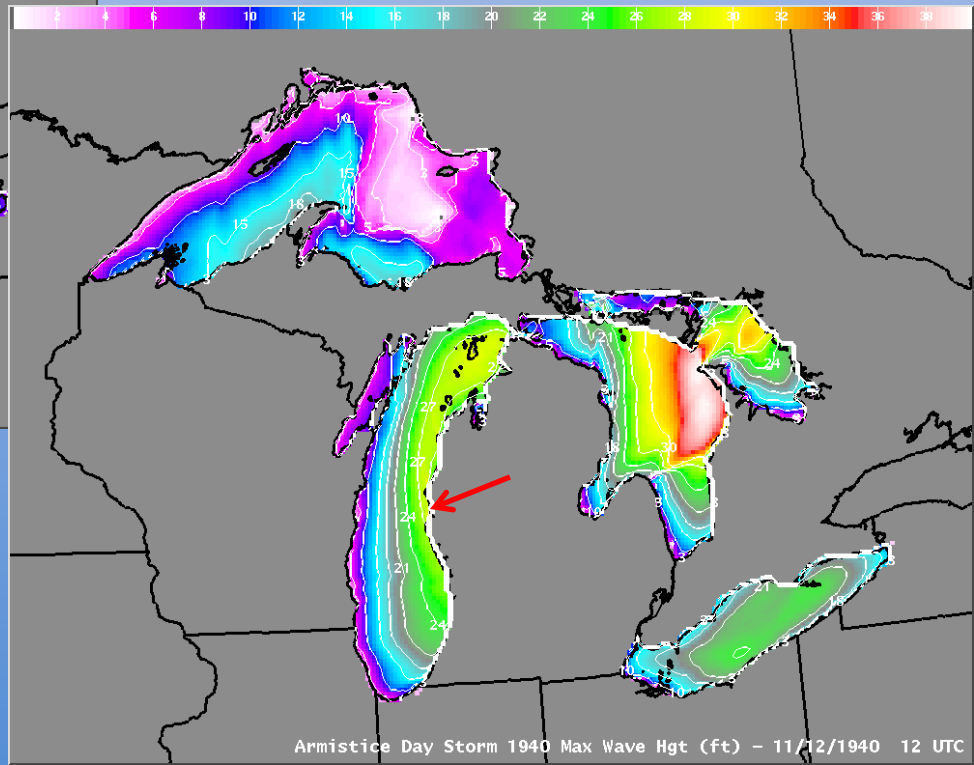
Winds are starting to subside across Lake Michigan, but have picked up overnight across Lake Huron. Also note the lack of strong winds across Lake Superior, which is not surprising given the lack of significant damage.

Waves (ft) - 12 UTC 11/12/1940

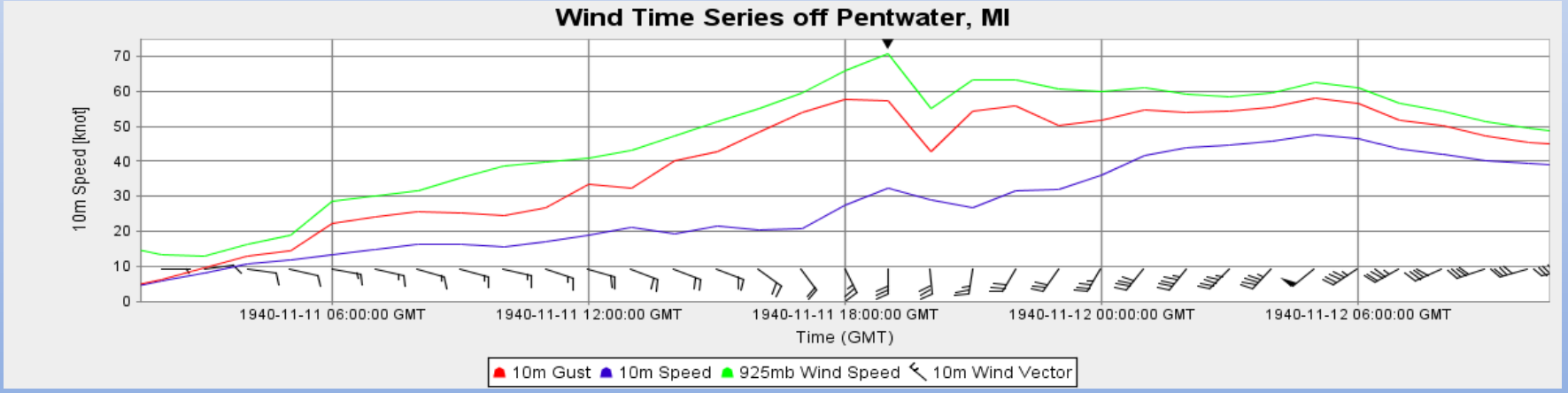
Significant Wave

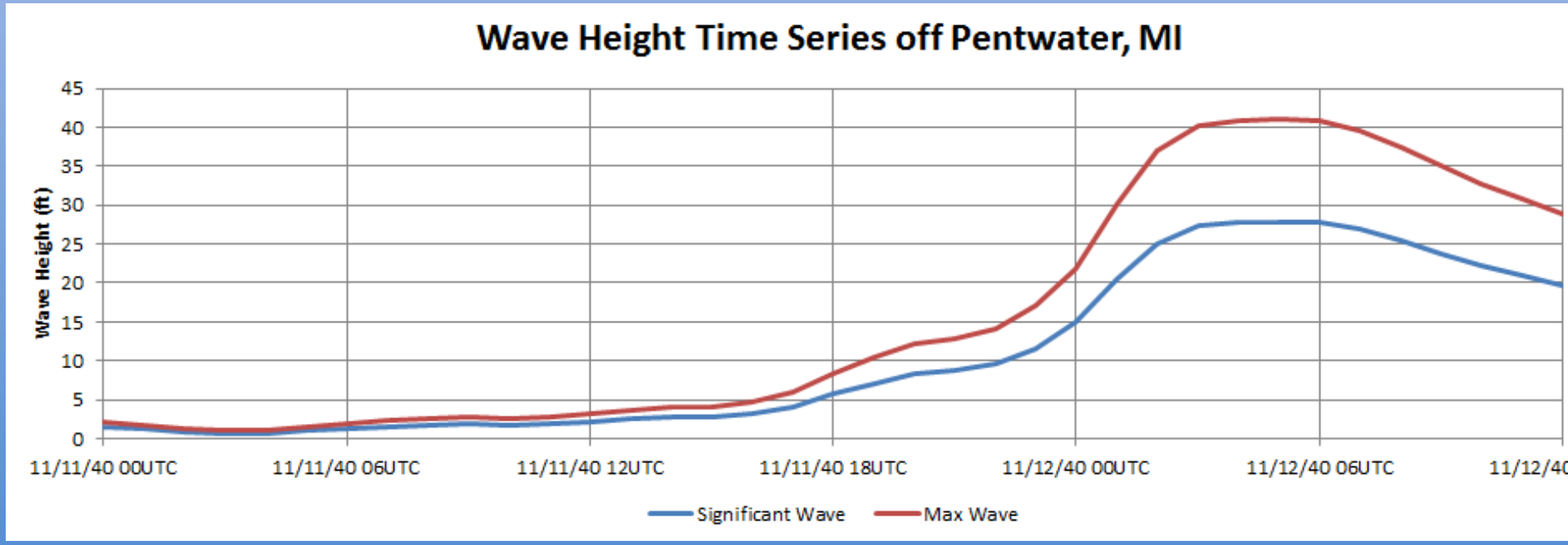


Maximum Wave



Wind/Wave Time Series off Pentwater,MI





Conclusions

- As was shown in the 1913 “White Hurricane” simulation (Mann et al. 2013), the 20th Century Reanalysis is an good initialization and boundary condition source for the WRF-ARW to recreate historic storms.
- The model simulations confirmed that this storm was extreme, with some of the largest winds and waves over such a widespread area of Lake Michigan in recent history.
- The numerical simulation performed remarkably given the sparse data from 1940 (little upper air data and fewer surface observations compared to today).

References

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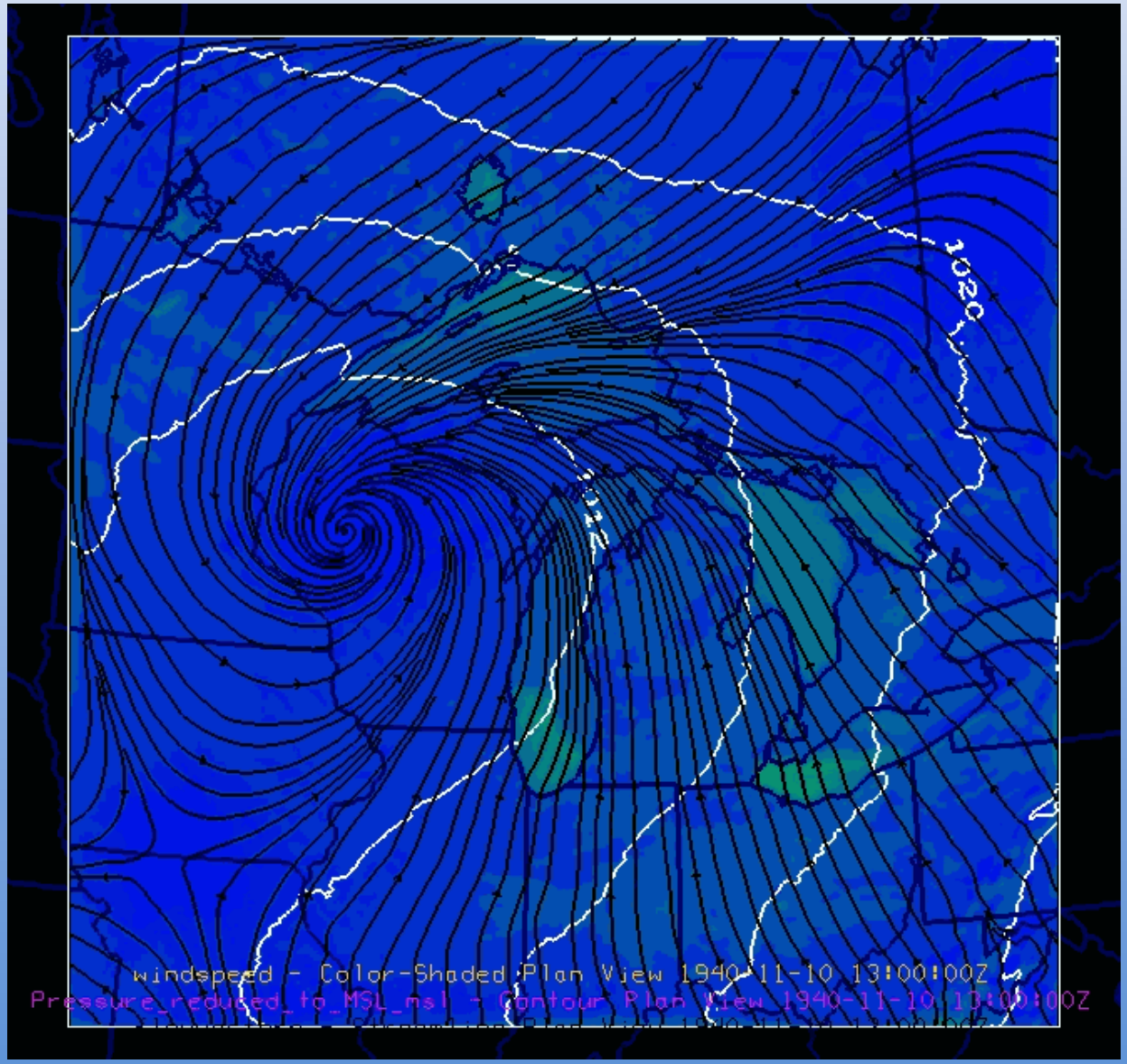
Acknowlegements

- Dr. Greg Mann (SOO NWS Detroit/White Lake) for scripts to convert WRF data into format to ingest into the GDM
- Tom Hultquist (SOO NWS Twin Cities) for assistance in using the 20thCR into the WRF
- NWS MQT Staff

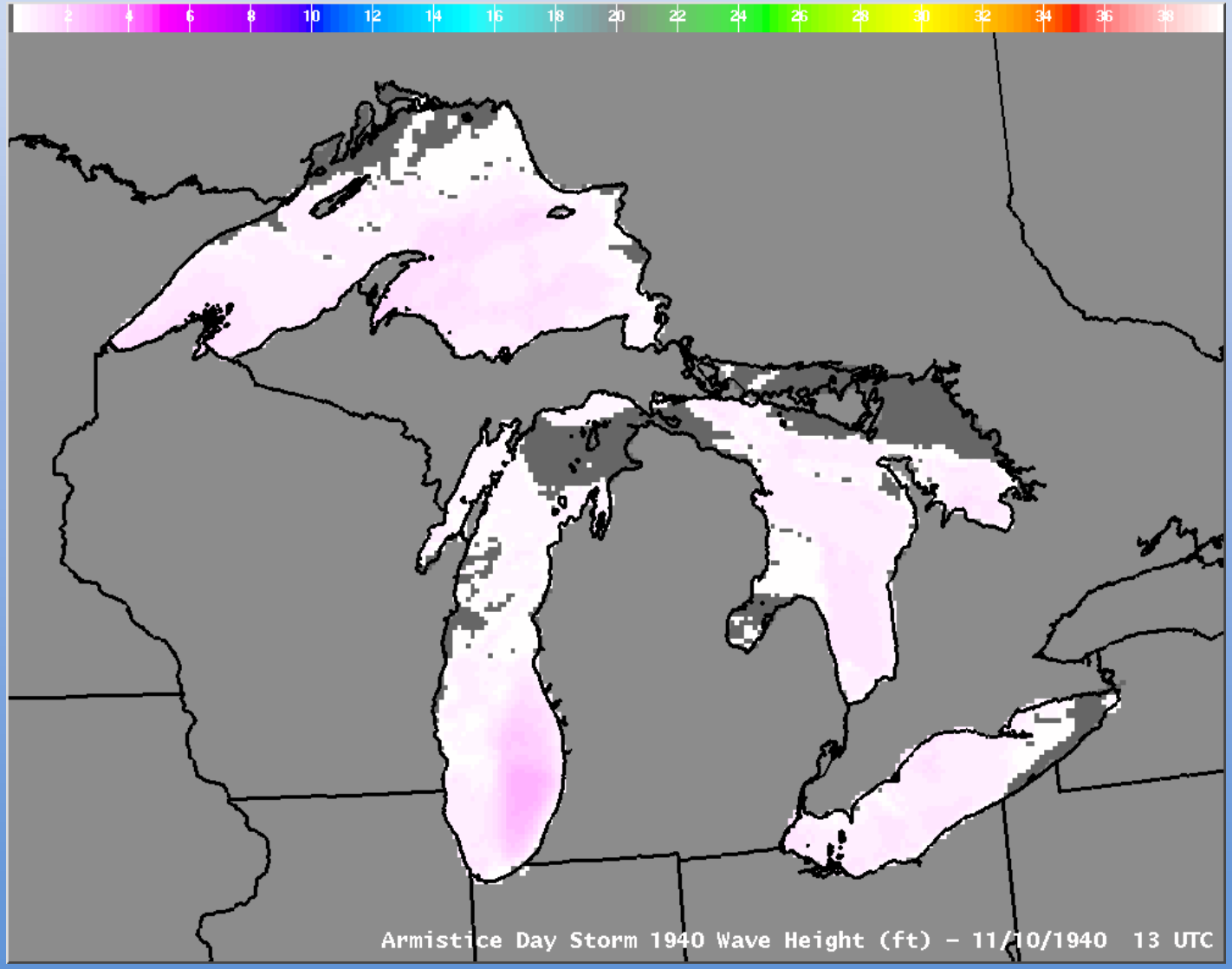
THANK YOU!!

Contact: **michael.dutter@noaa.gov**

PMSL/10m Wind Speed/Streamlines



Significant Wave Height (ft)



Maximum Wave Height (ft)