



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

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Background Photo from:

<http://www.ricmixter.com/lectures/>

Low Track – 08-11 Nov 1940

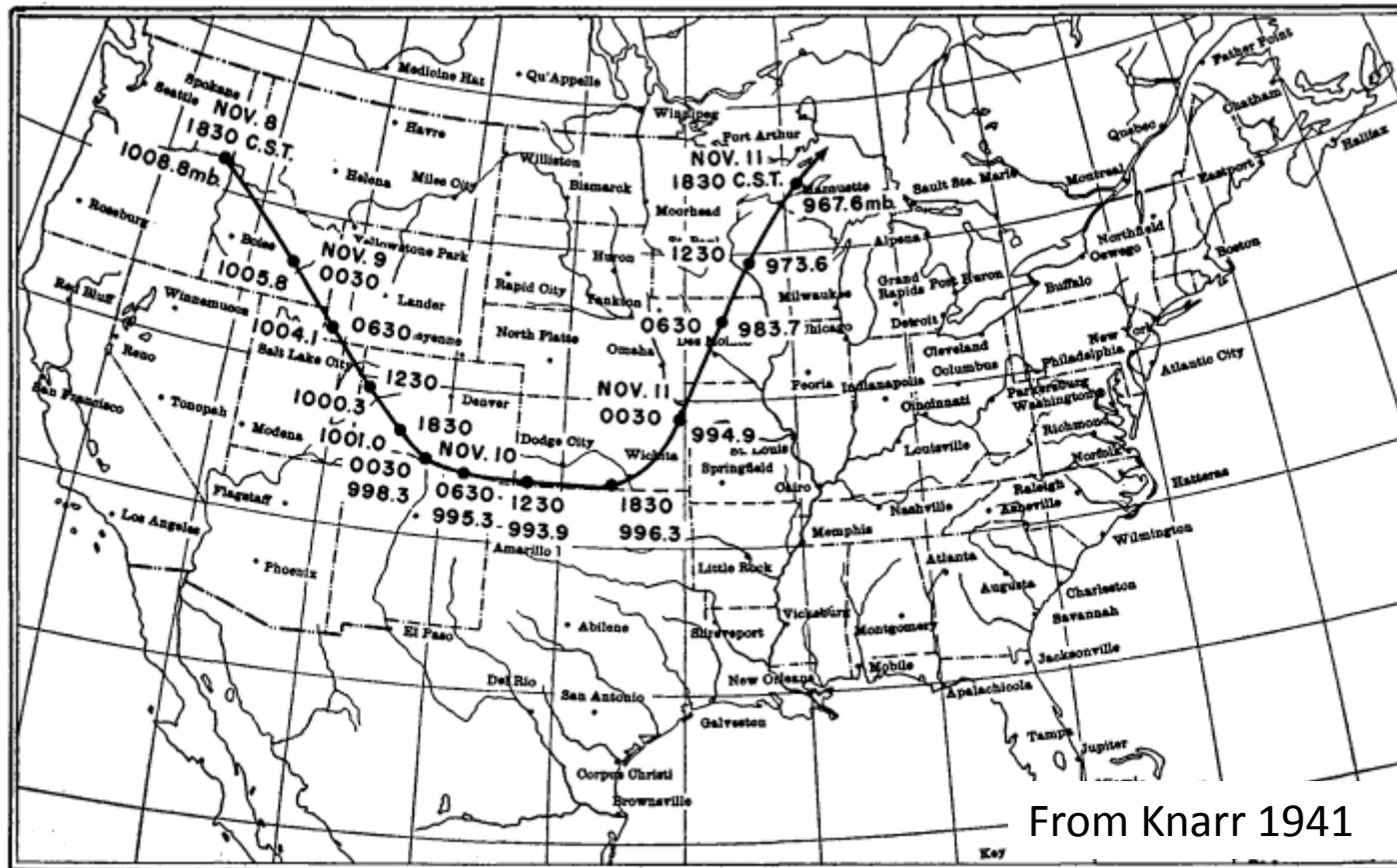


FIGURE 1.—Location of the cyclone center, and the lowest pressure reported, at 6-hour intervals from November 8–11, 1940.

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 disastrous 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/>

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

Station	Lowest pressure (sea-level)	Maximum wind (5 minutes)	Station	Lowest pressure (sea-level)	Maximum wind (5 minutes)
Illinois:	<i>Inches</i>	<i>Miles</i>	Michigan—Continued.	<i>Inches</i>	<i>Miles</i>
Cairo.....	29.45	SW. 37	Grand Rapids.....	29.10	SW. 65
Chicago.....	29.09	SW. 42	Lansing.....	29.16	SW. 41
Peoria.....	29.15	SW. 29	Marquette.....	28.67	S. 33
Springfield.....	29.23	SW. 46	Saulte Ste. Marie.....	28.95	SW. 34
Indiana:			Minnesota:		
Fort Wayne.....	29.27	SW. 53	Duluth.....	28.66	NW. 52
Indianapolis.....	29.36	SW. 37	Minneapolis.....	28.93	W. 38
Terre Haute.....	29.34	SW. 47	Ohio:		
Evansville.....	29.45	SW. 47	Cleveland.....	29.45	SW. 59
Iowa:			Columbus.....	29.53	SW. 53
Charles City.....	28.92	W. 34	Dayton.....	29.53	S. 47
Davenport.....	29.09	SW. 38	Sandusky.....	29.40	SW. 42
Des Moines.....	29.06	NW. 36	Toledo.....	29.35	W. 38
Dubuque.....	28.99	SW. 22	Wisconsin:		
Keokuk.....	29.15	W. 41	Green Bay.....	28.80	S. 47
Sioux City.....	29.54	NW. 43	La Crosse.....	28.72	SW. 24
Michigan:			Madison.....	28.92	SW. 40
Alpena.....	29.06	SW. 47	Milwaukee.....	28.94	SW. 54
Detroit.....	29.32	SW. 45			
Escanaba.....	28.77	S. 43			

From Knarr 1941

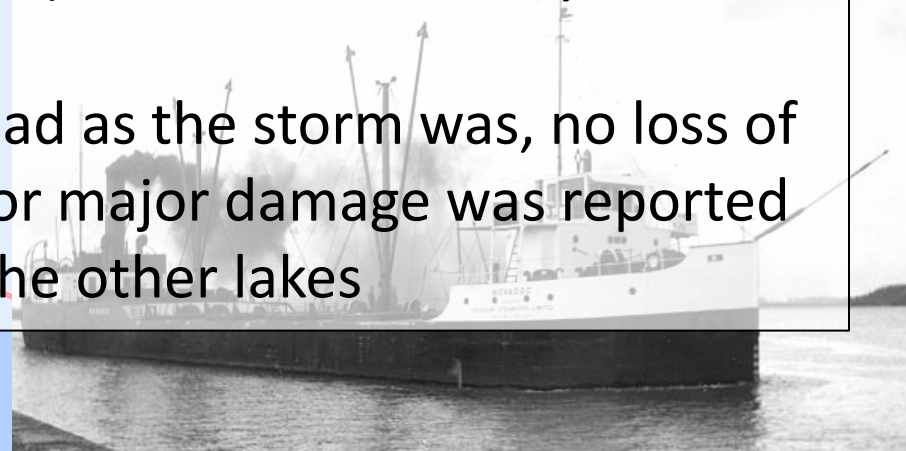
Lowest Pressure in any United States observing site – 967mb at Houghton, MI

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

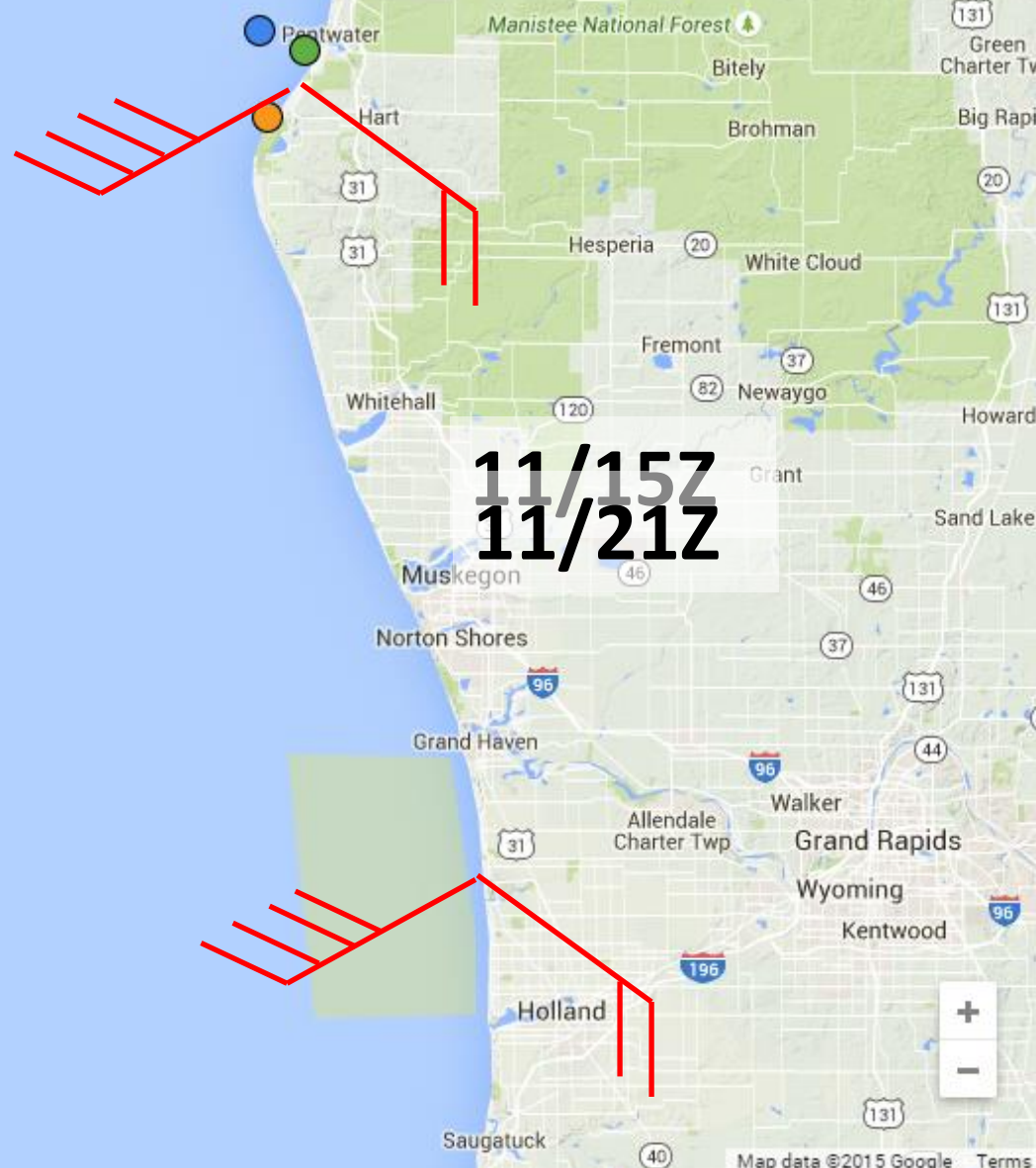


Shipwrecks from the Storm

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)

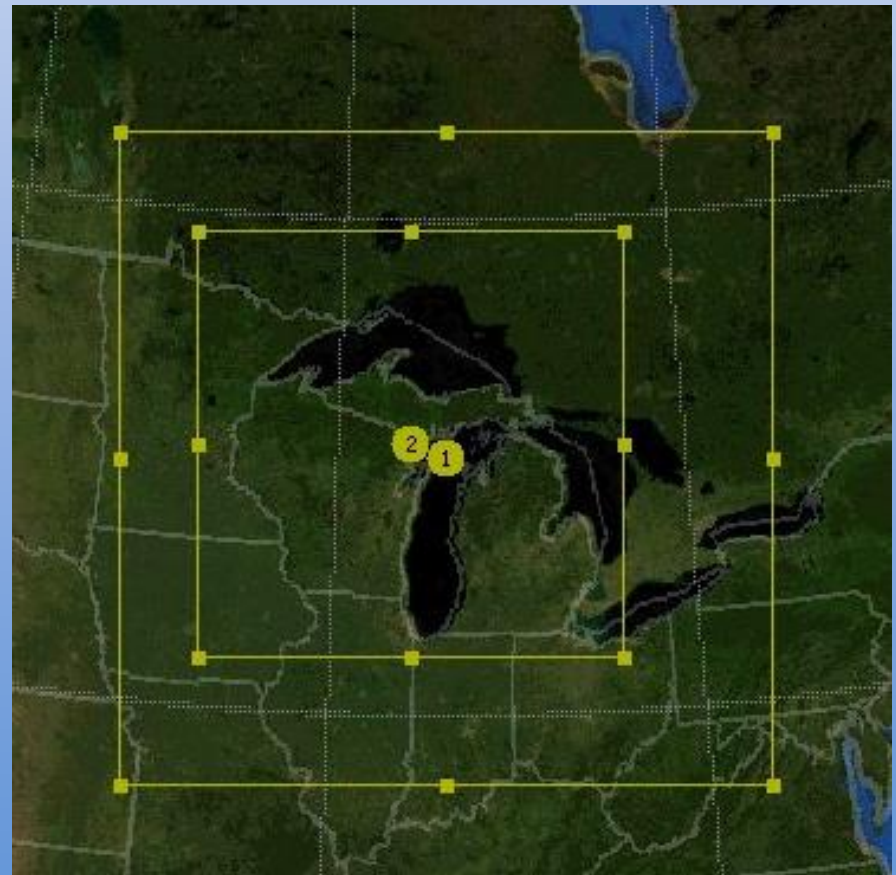
- One of the more significant blizzards to affect the Upper Mississippi Valley
 - Twelve Duck Hunters perished on the Mississippi River.
 - Forty-nine deaths alone in MN
- Wind blown snowfall in excess of 12 inches across much of the Upper Mississippi Valley (many places in excess of 20 inches)
 - Twenty 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

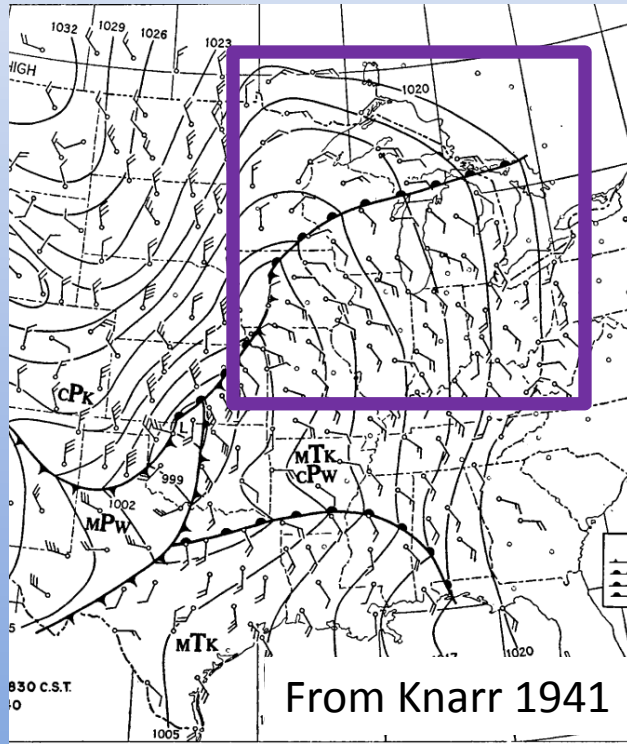
- WRF-ARW V3.5.1
- Initial and Boundary Conditions from 20th Century Reanalysis (20thCR)
 - Reanalysis using only surface data to recreate the entire atmosphere
- 5km/1.67km horizontal resolution
- 45 vertical levels
- Explicit Convection



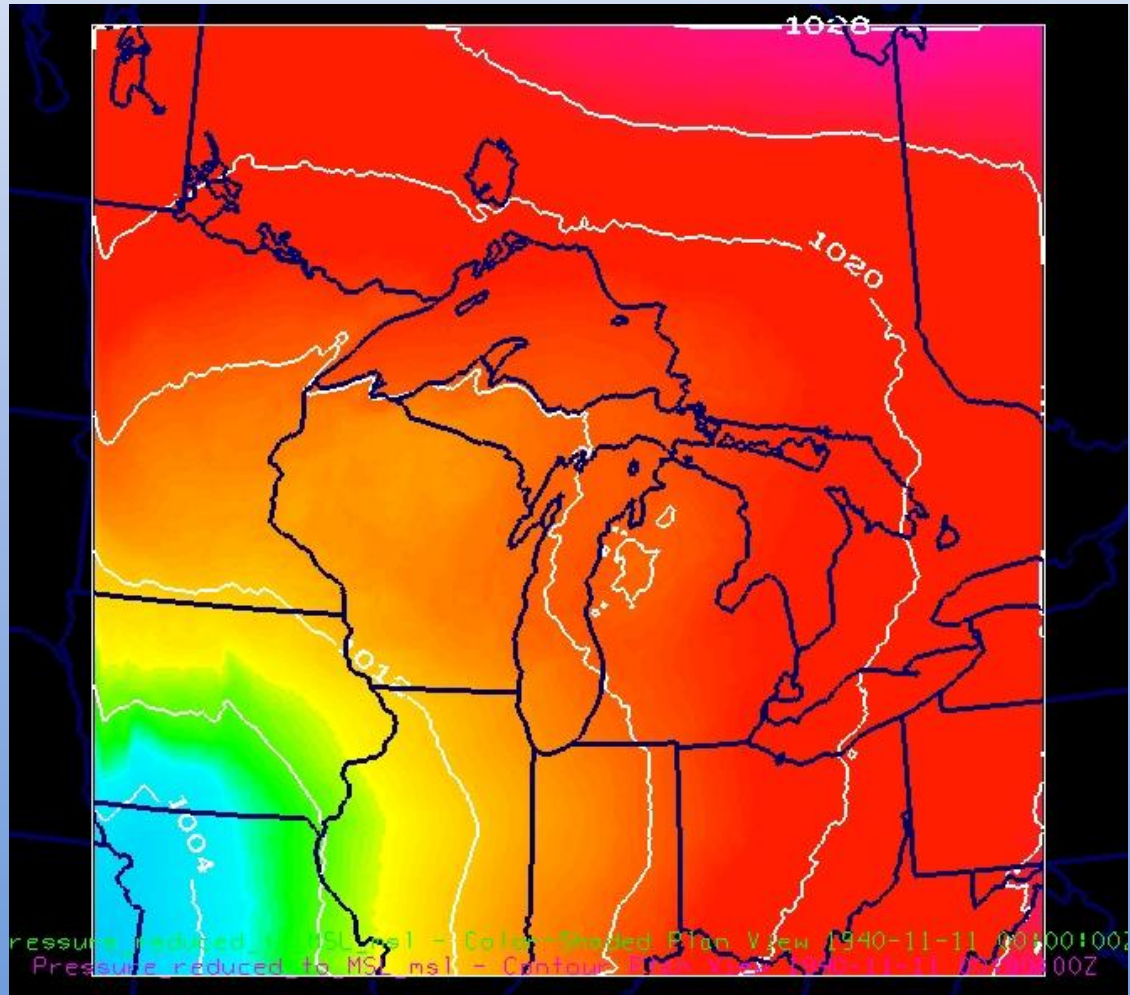
GLERL Donelon Wave Model

- 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

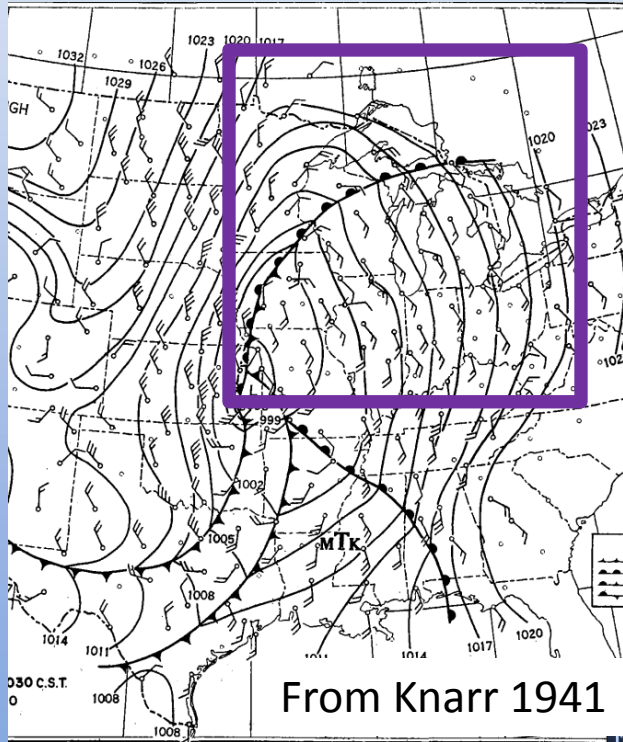
Surface Comparison – 00 UTC 11/11/1940



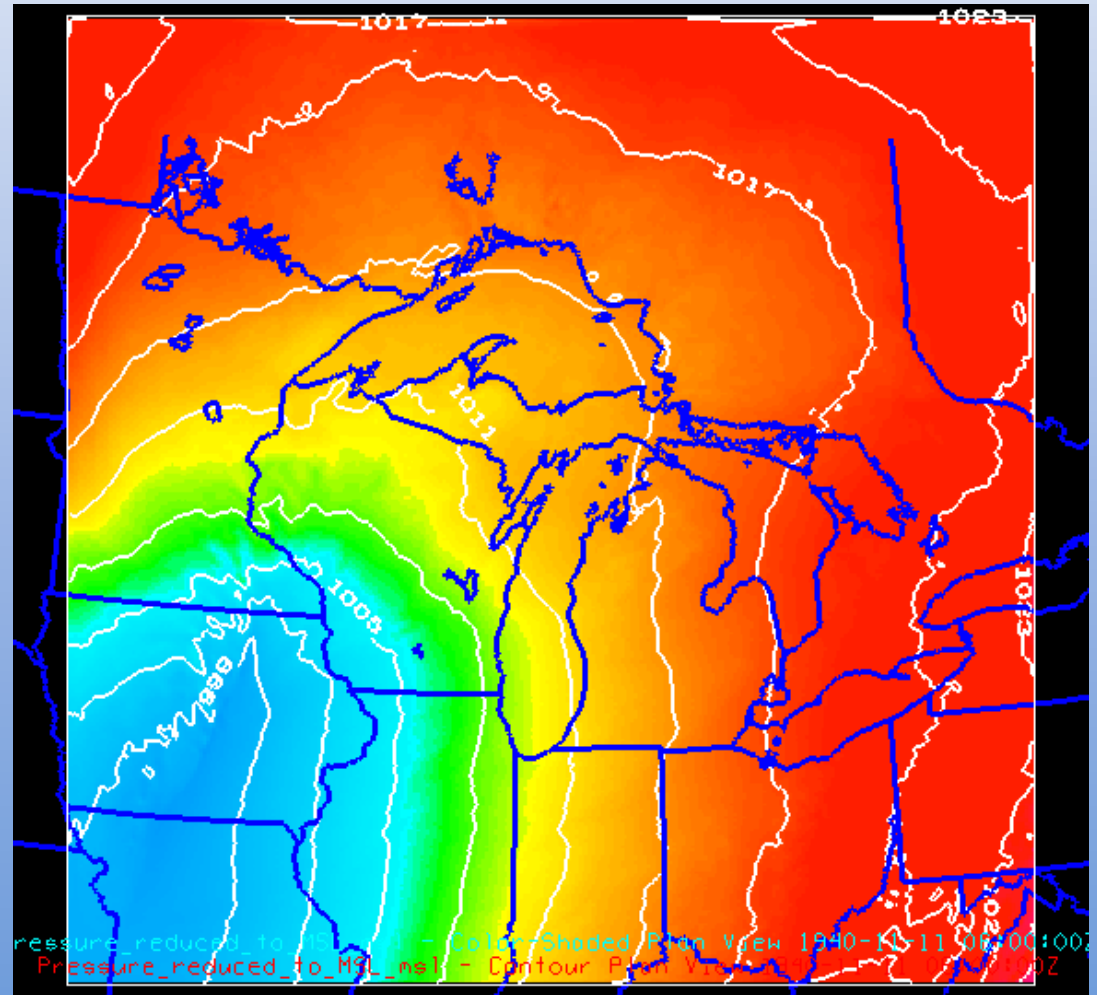
The low is just developing as a 999mb low over northern OK.



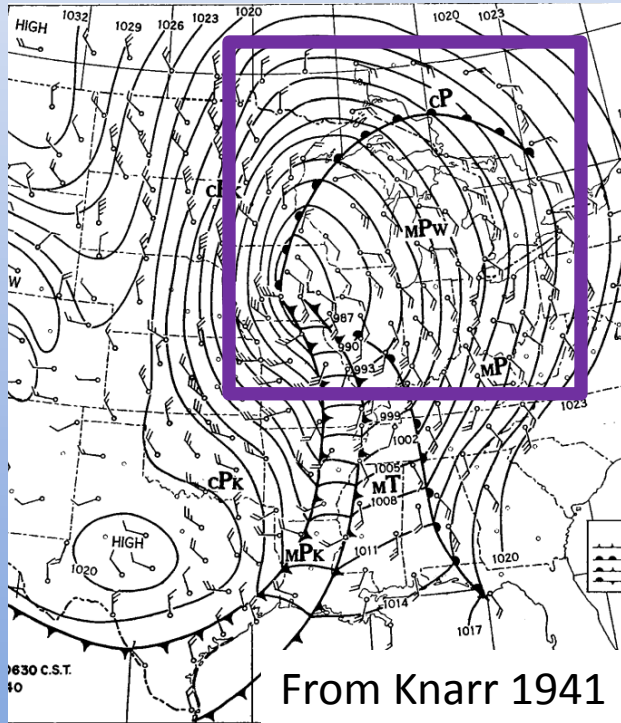
Surface Comparison – 06 UTC 11/11/1940



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.

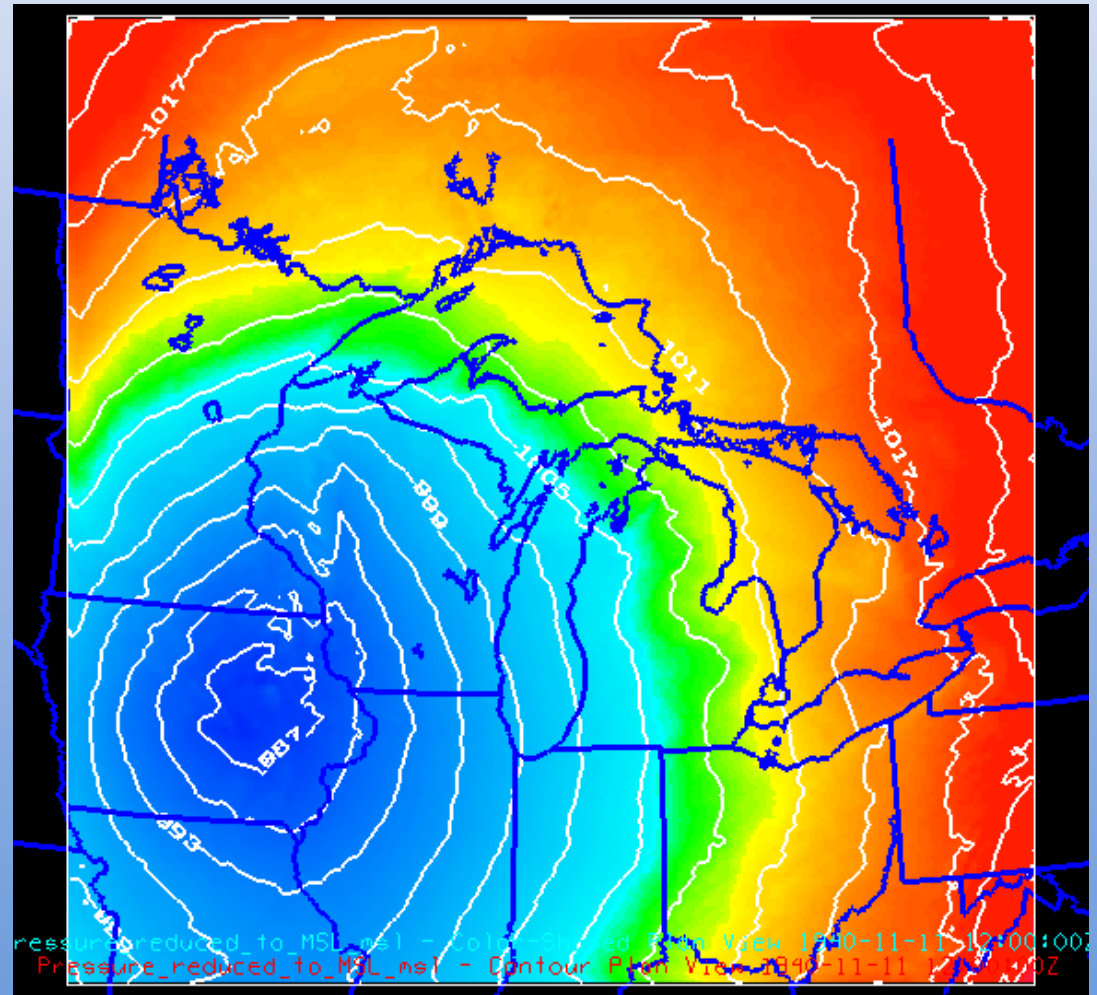


Surface Comparison – 12 UTC 11/11/1940



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

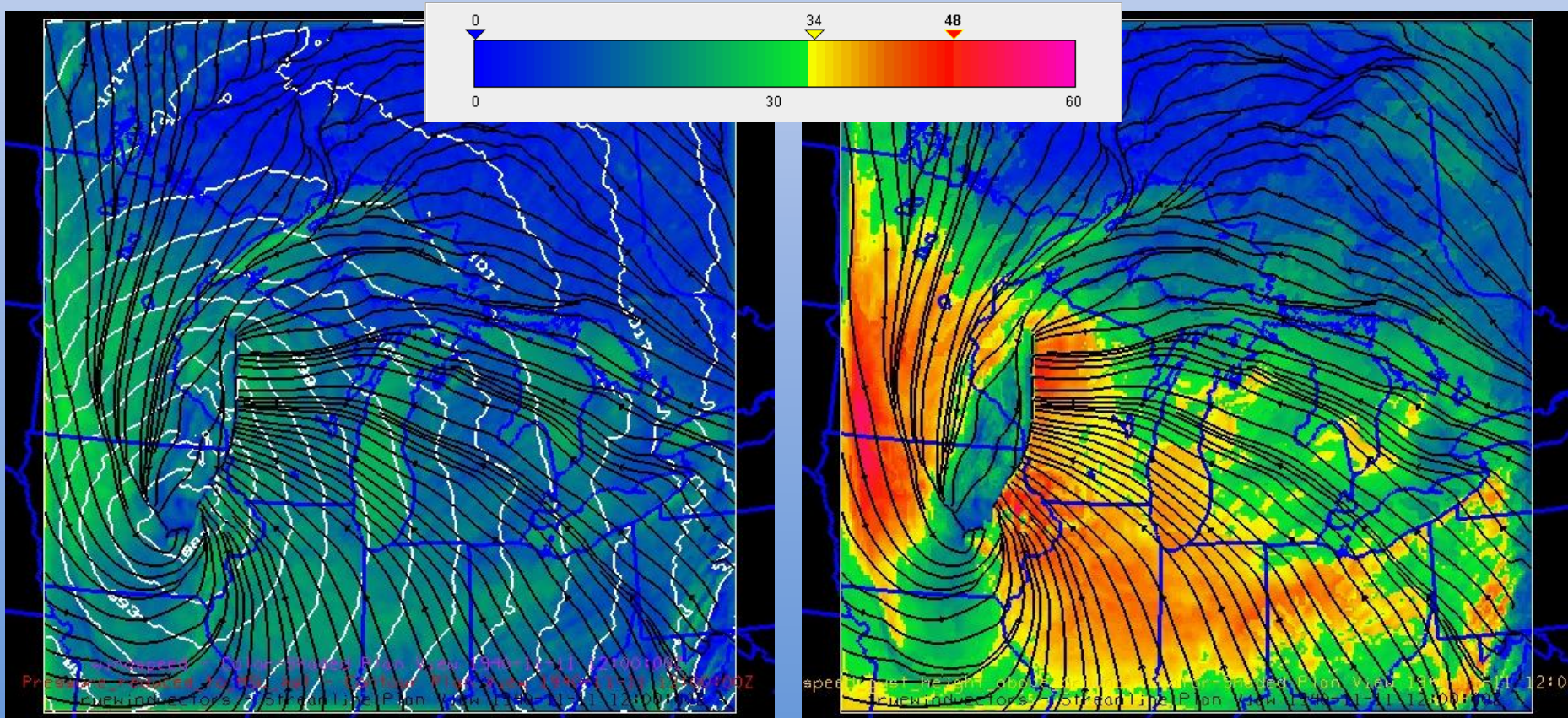
The analyzed 984mb low pressure system is over east central Iowa. The numerical simulation shows this deepening very well with a position only slightly to the east of the analysis.



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

10m Wind/Streamlines/PMSL

10m Wind Gust/Streamlines

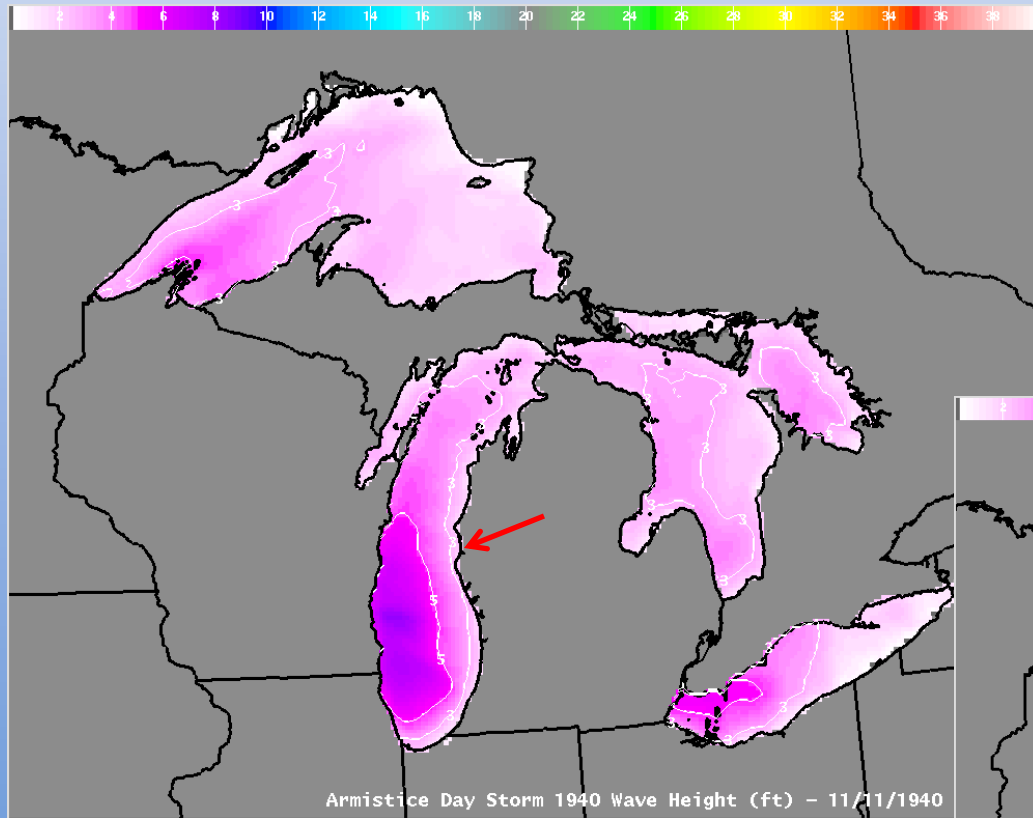


By 12 UTC, southeast gale force wind gusts were certainly possible across far southern Lake Michigan. At this point, the ships were likely opting to take shelter on the east side of the lake.

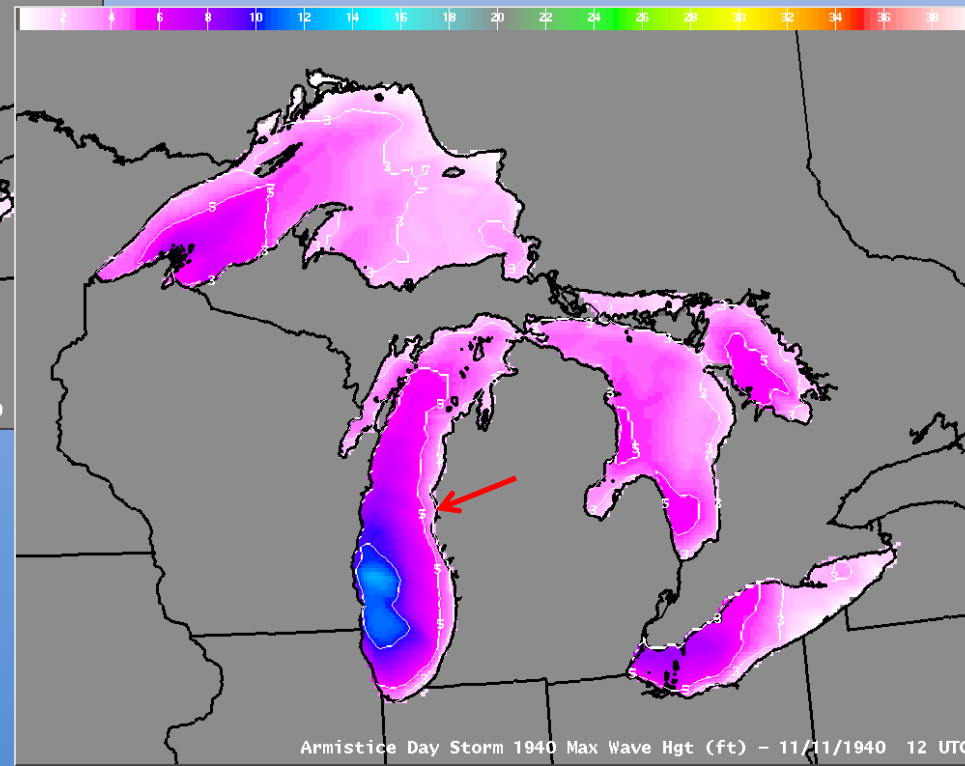
Waves (ft) - 12 UTC 11/11/1940



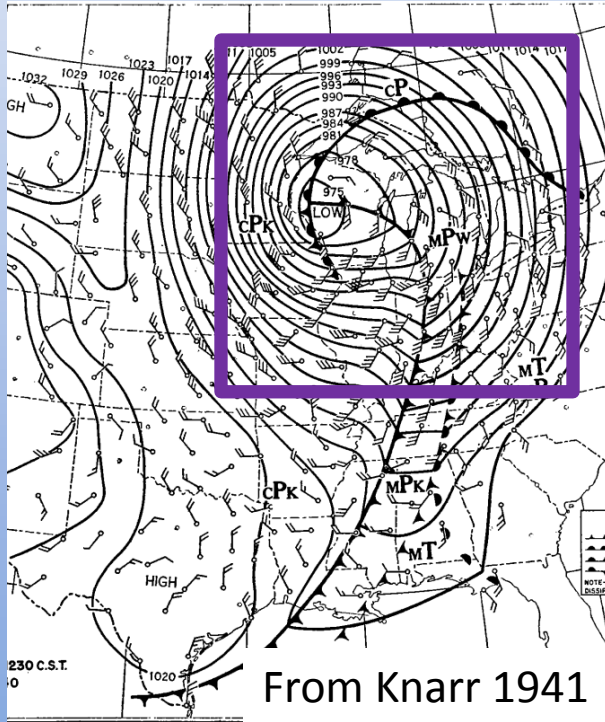
Significant Wave



Maximum Wave



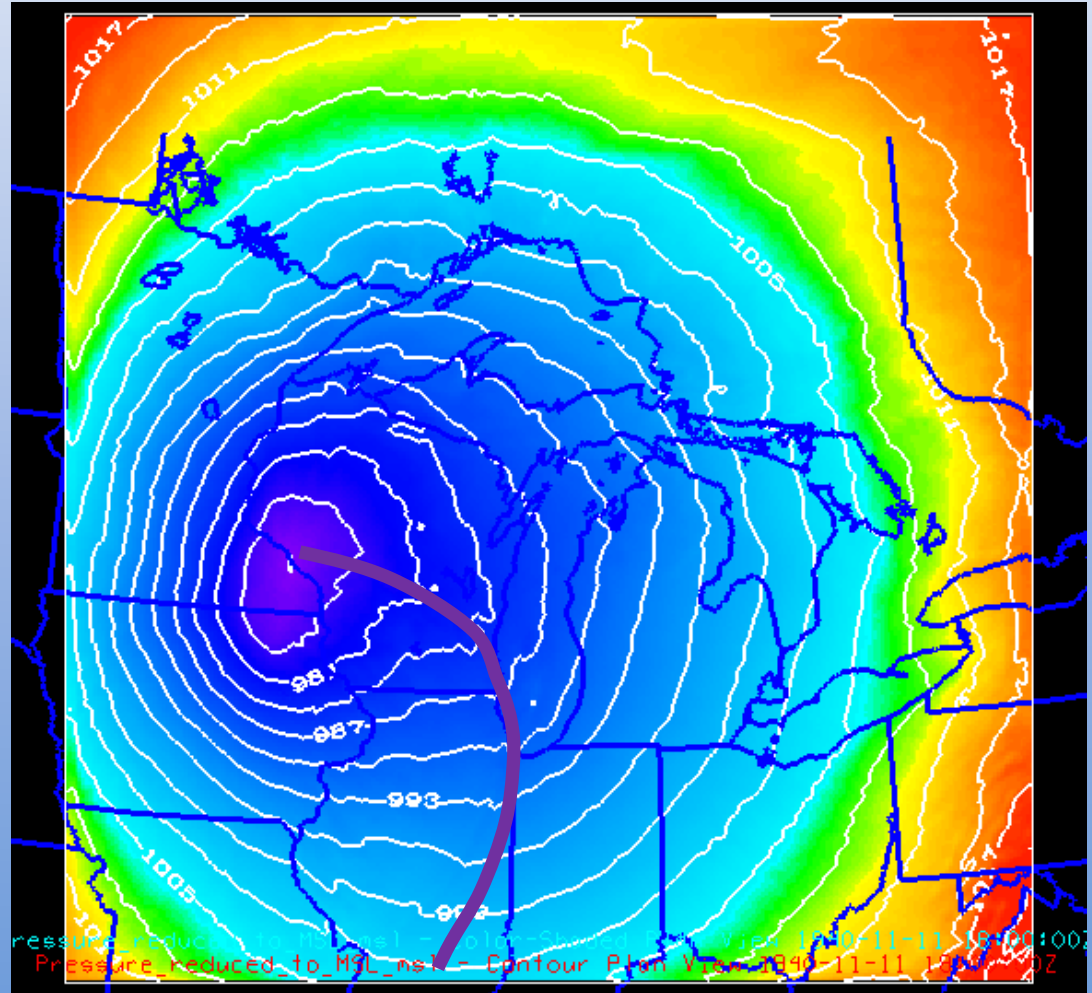
Surface Comparison – 18 UTC 11/11/1940



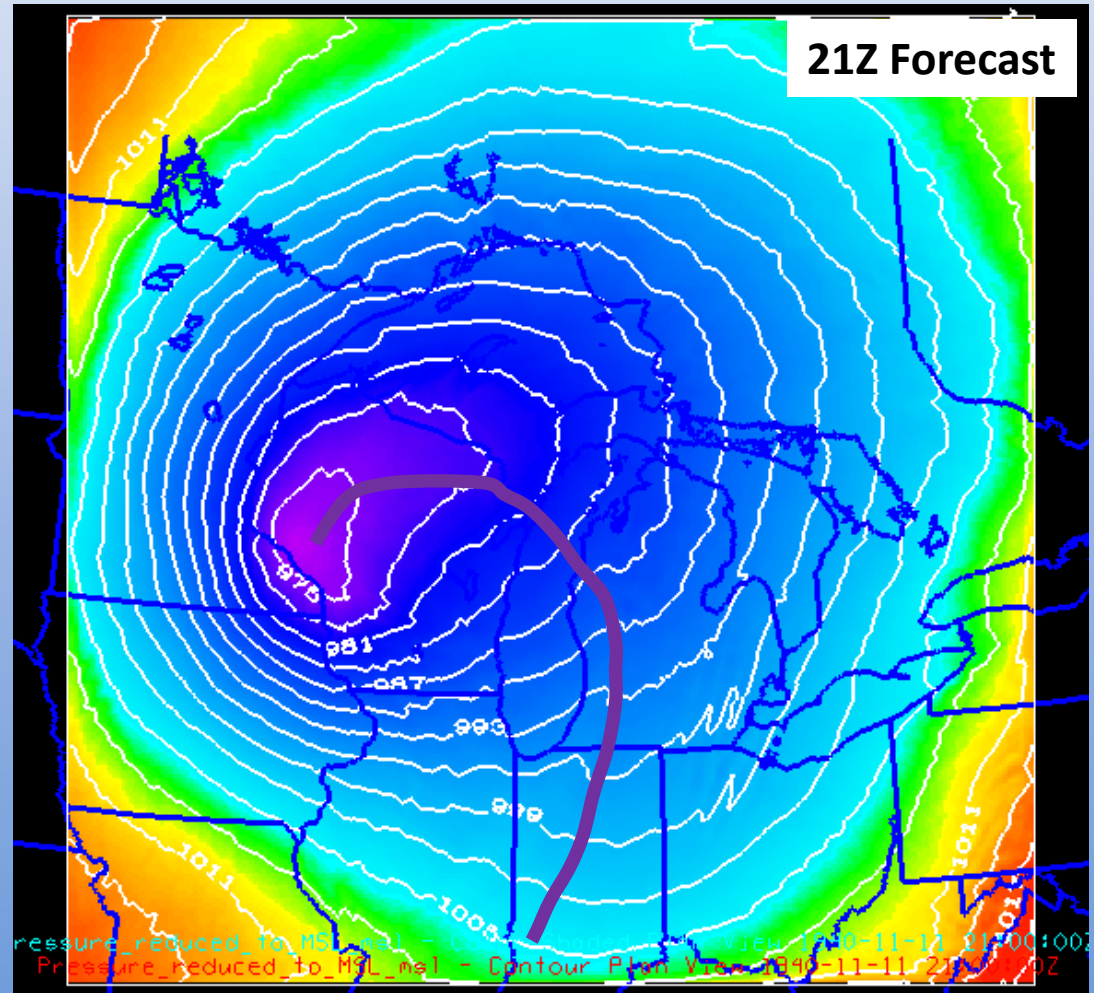
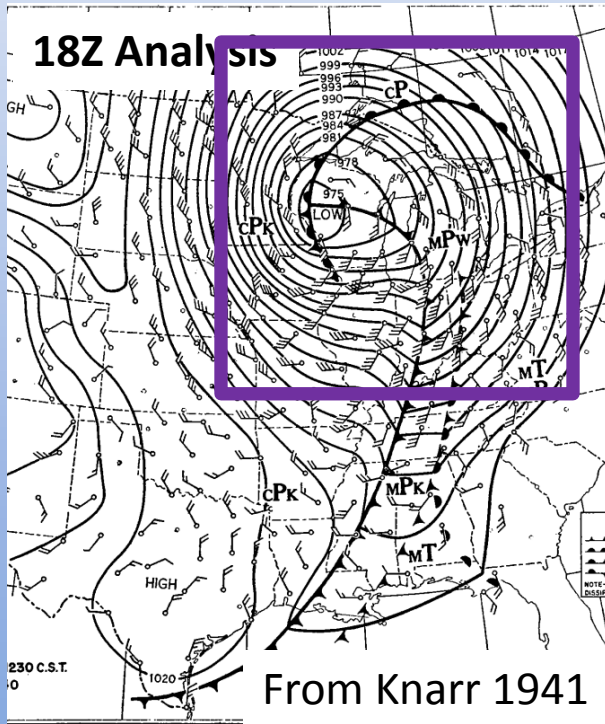
Rapid deepening continues between 12 and 18UTC with the low now near Eau Claire, WI.

The analyzed 974mb low pressure system is nearly identical to the simulated low, and 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 just passing through Chicagoland.



Surface Comparison – 21 UTC 11/11/1940

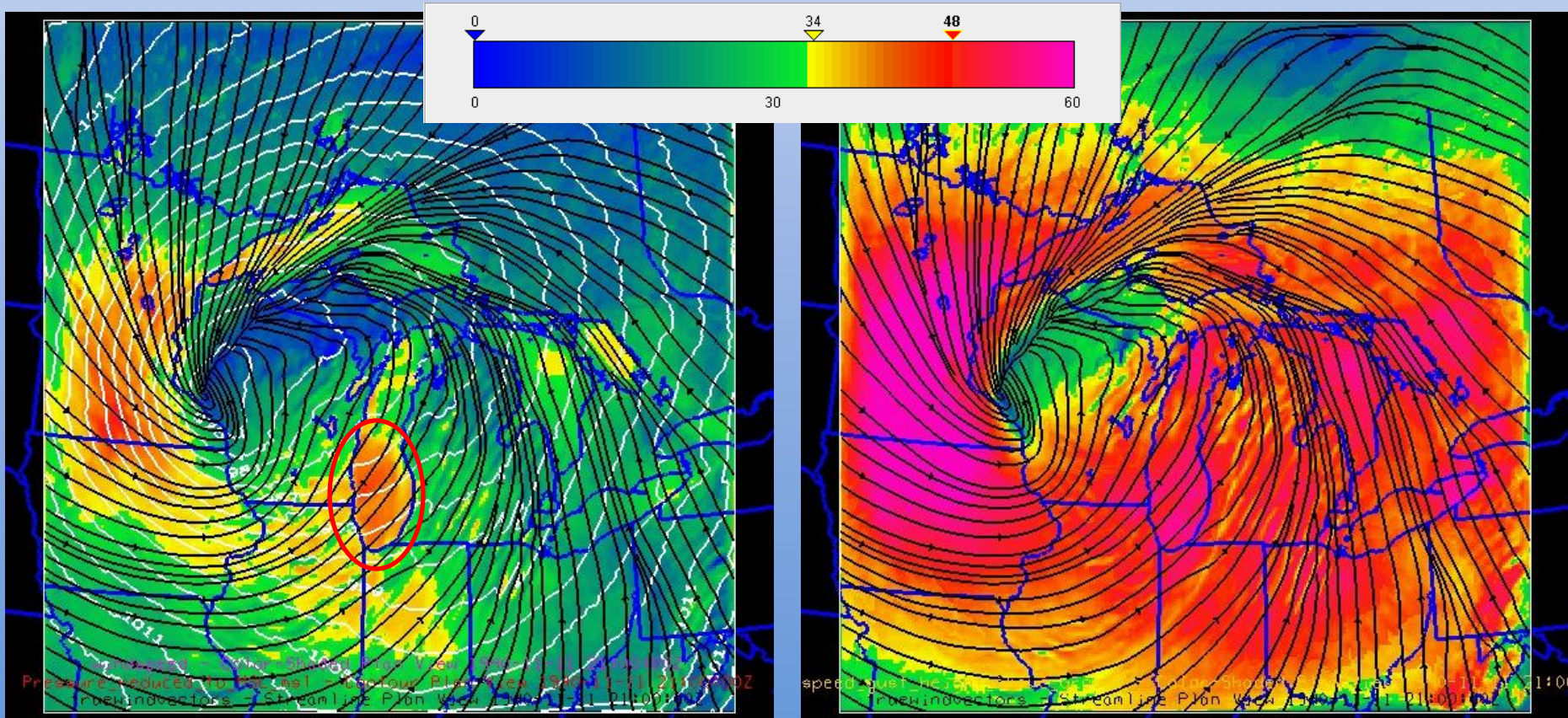


The 21UTC model forecast may be in much better agreement with the 18UTC analysis, suggesting that the model is slightly slower (3-4 hr) than the analysis.

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

10m Wind/Streamlines/PMSL

10m Wind Gust/Streamlines



The model 21UTC forecast suggested near storm force sustained winds with gusts close to hurricane force over the southern 1/2 of Lake Michigan. Note the gusts close to hurricane force also near Grand Rapids, MI.

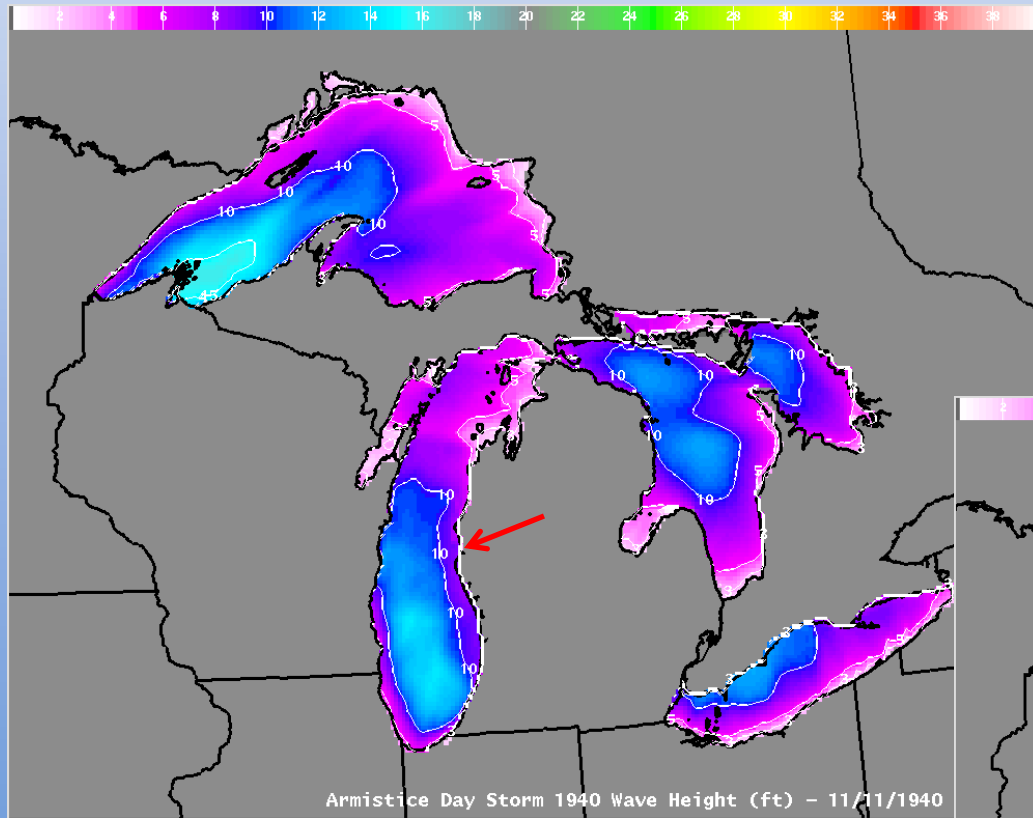
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This corresponds well to the 70kt gust reported at GRR.

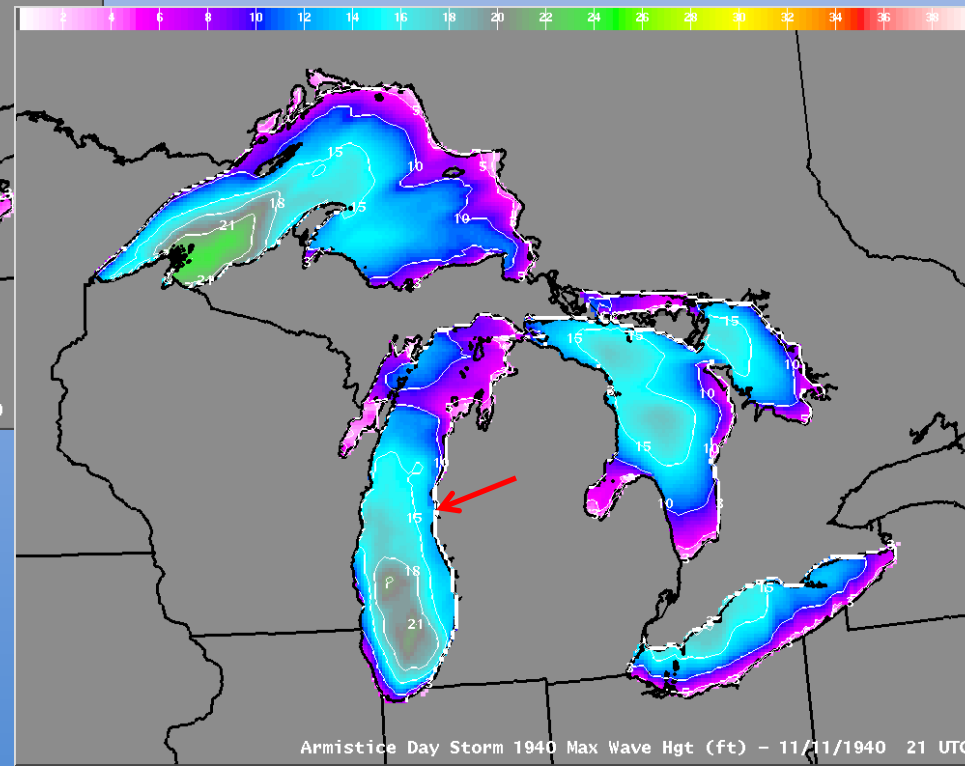
Waves (ft) - 21 UTC 11/11/1940



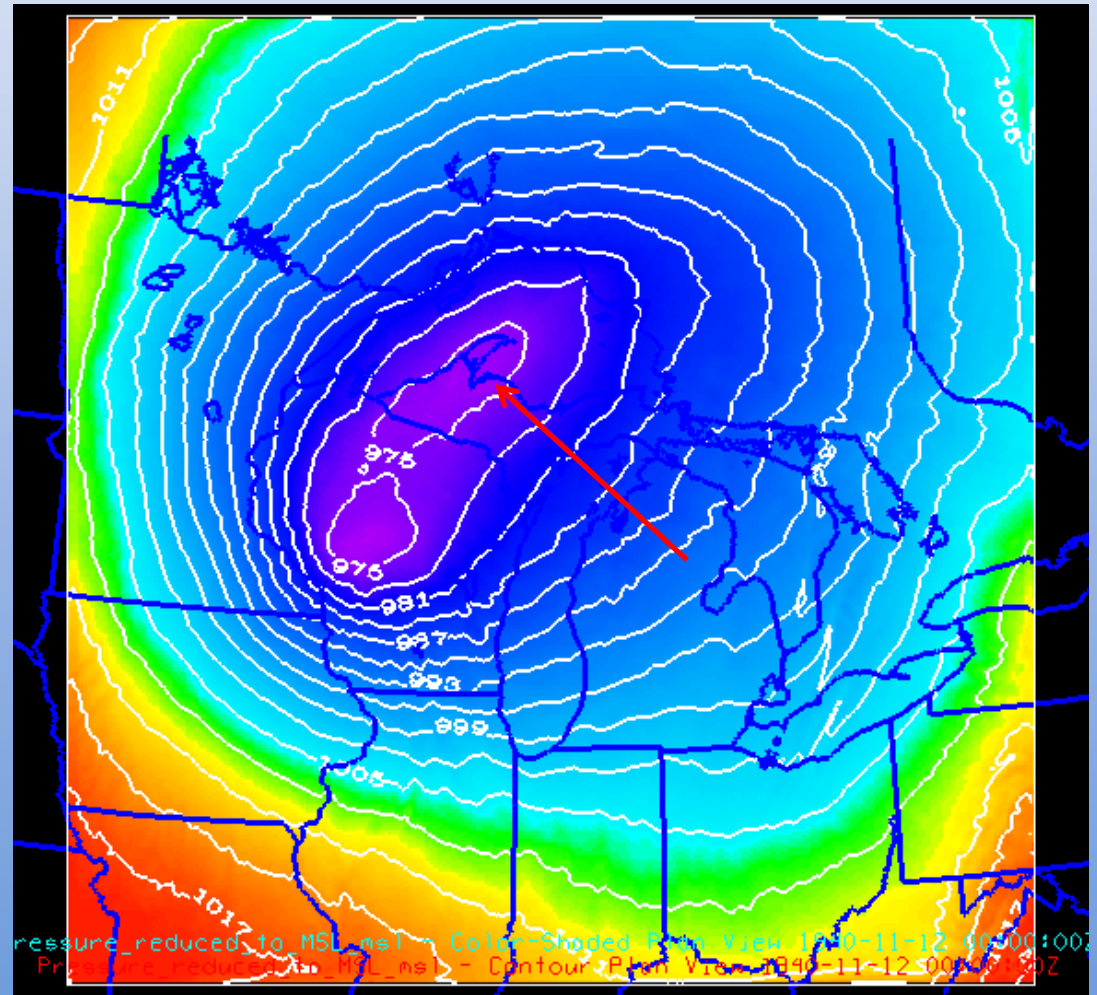
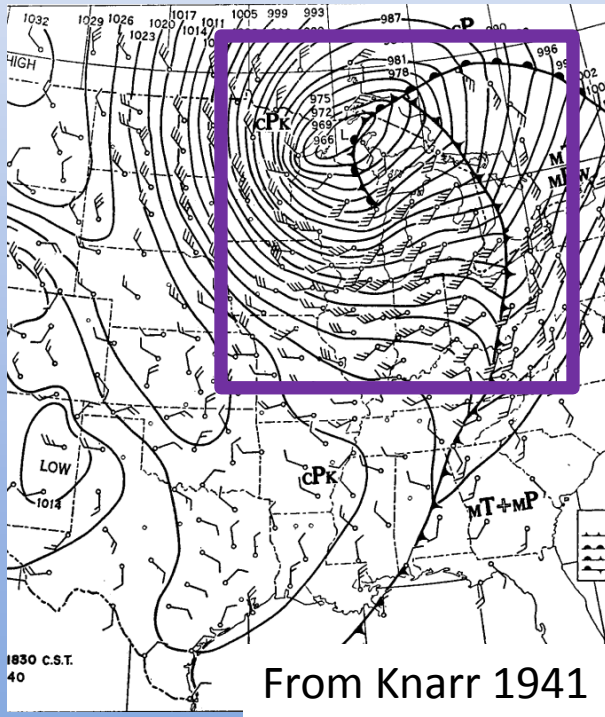
Significant Wave



Maximum Wave



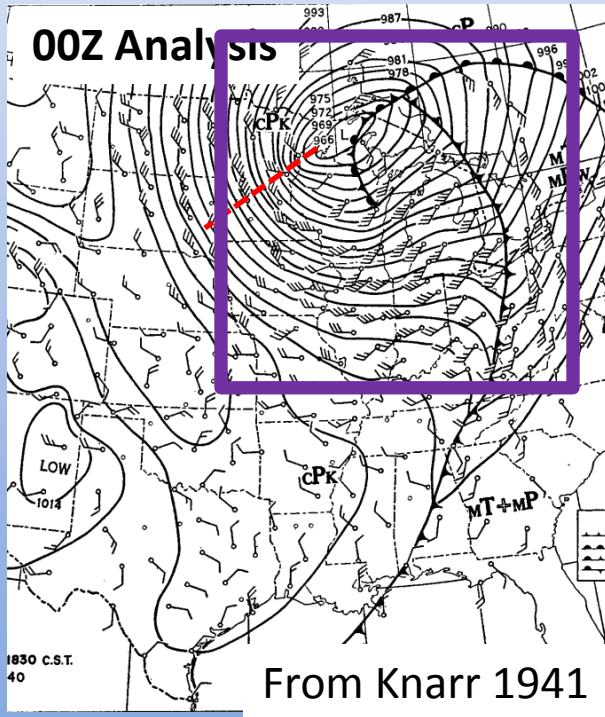
Surface Comparison – 00 UTC 11/12/1940



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.

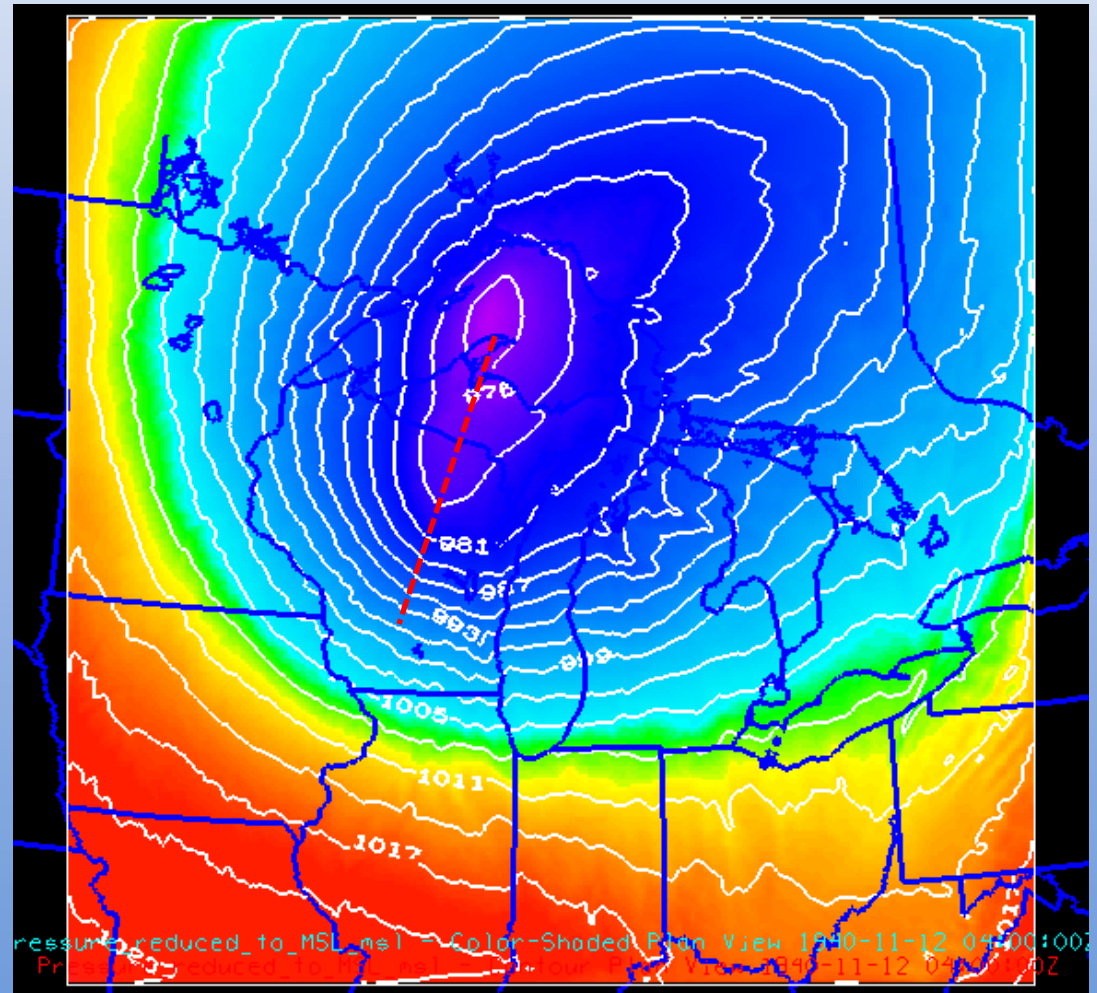
This is about the approximate time when the Novadoc aground. In addition, the next 6 hours is likely the peak intensity of the storm.

Surface Comparison – 04 UTC 11/12/1940



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.

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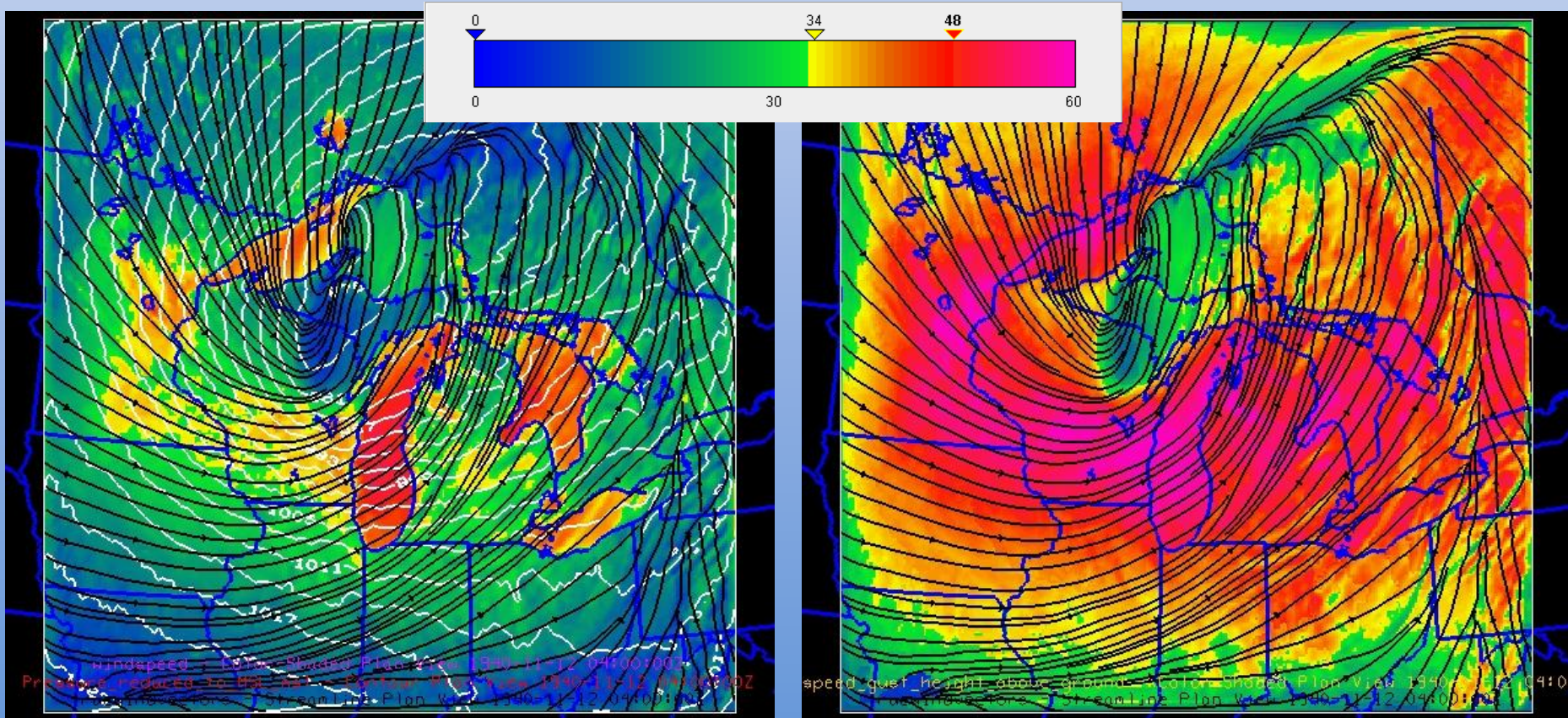


Still, at this point, this is peak intensity of the simulated low with 973mb pressure near Copper Harbor. Further investigation is needed on exactly why the model simulation did not pick up on the continued intense deepening between 18 and 00 UTC

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

10m Wind/Streamlines/PMSL

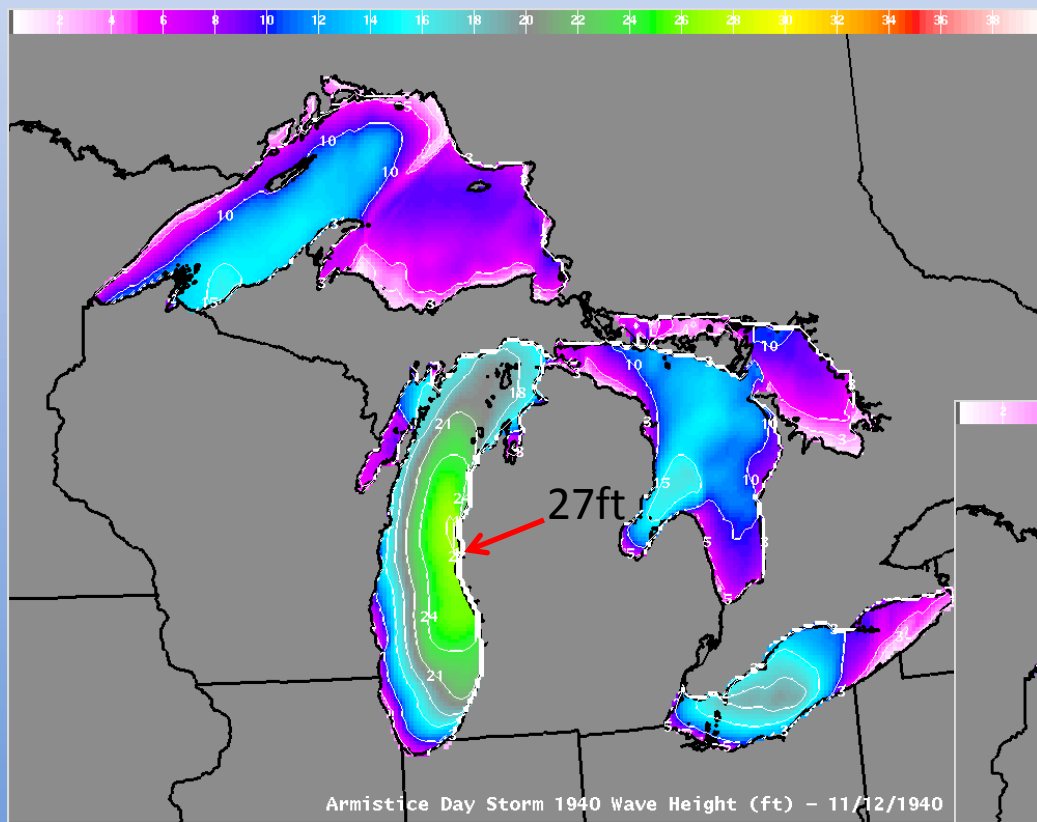
10m Wind Gust/Streamlines



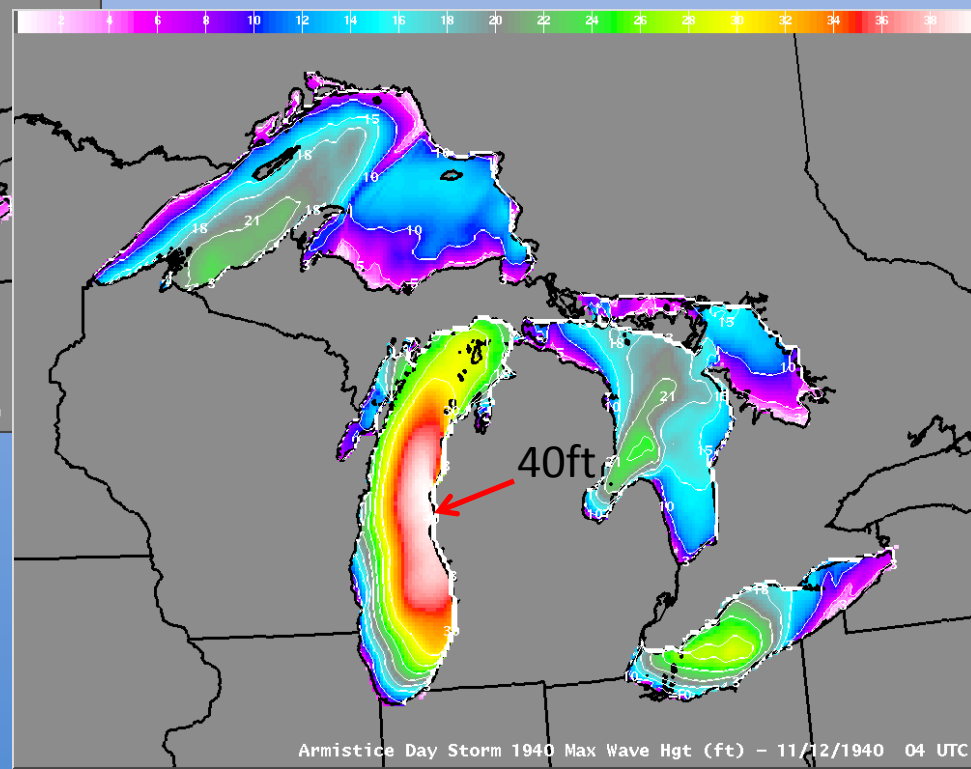
Most of Lake Michigan was covered by near storm force winds (48kt) or greater. Storm Force winds also simulated in Lakes Huron (channeling up Saginaw Bay) and Erie. Gusts to at or above hurricane force over much of Lake Michigan.

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

Significant Wave

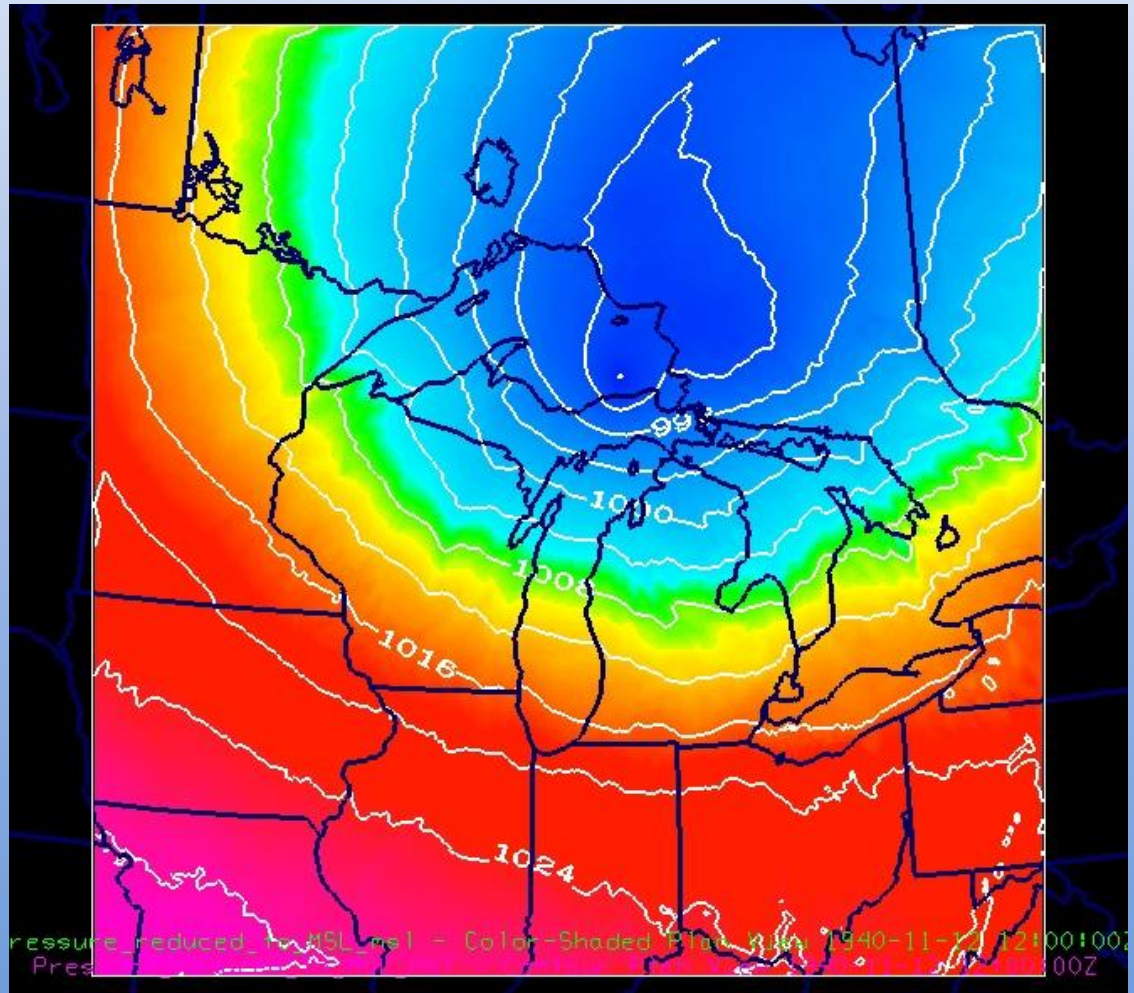
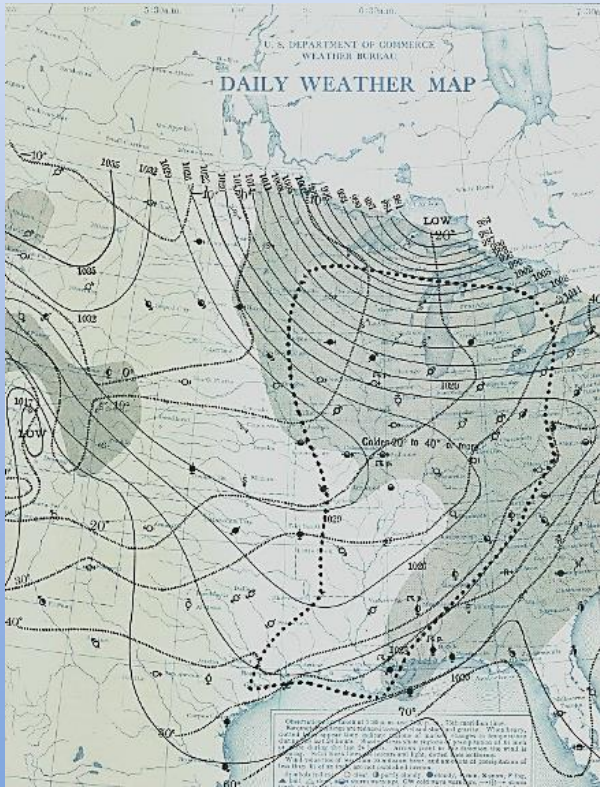


Maximum Wave



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



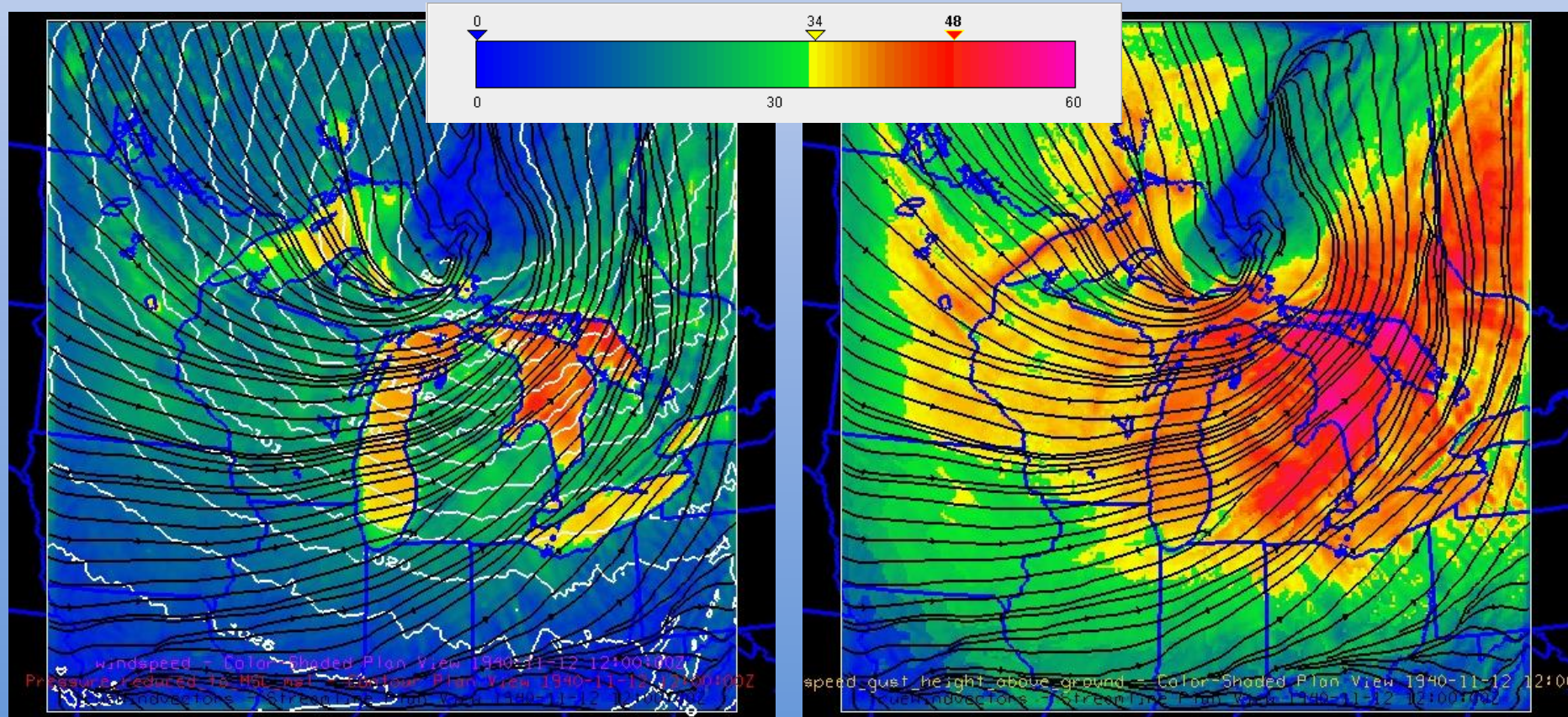
Despite the simulation not forecasting the 966mb low near Houghton at 00UTC, the model still showed a very strong 984 mb low near Grand Marais, MI which compares quite well to the analyzed strength and position.

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

10m Wind/Streamlines/PMSL

10m Wind Gust/Streamlines



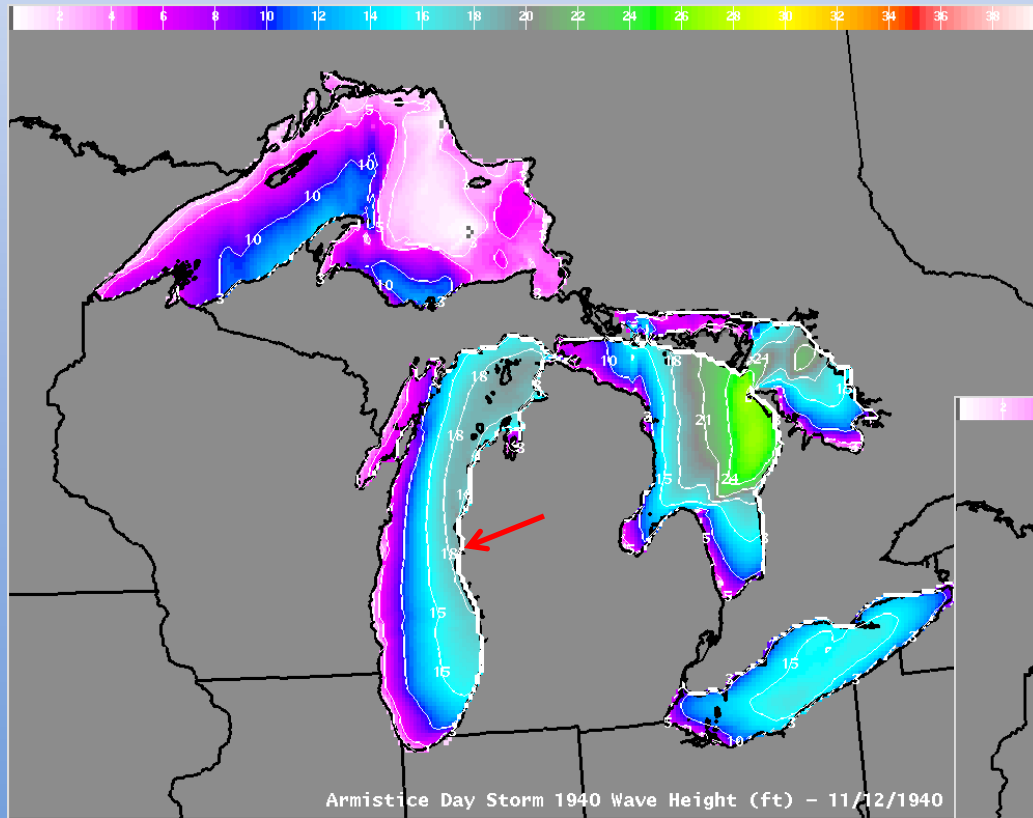
Winds are starting to subside across Lake Michigan, but have picked up overnight across Lake Huron. Also note the lack of strong winds across Lake Superior, which is not surprising given the lack of significant damage.

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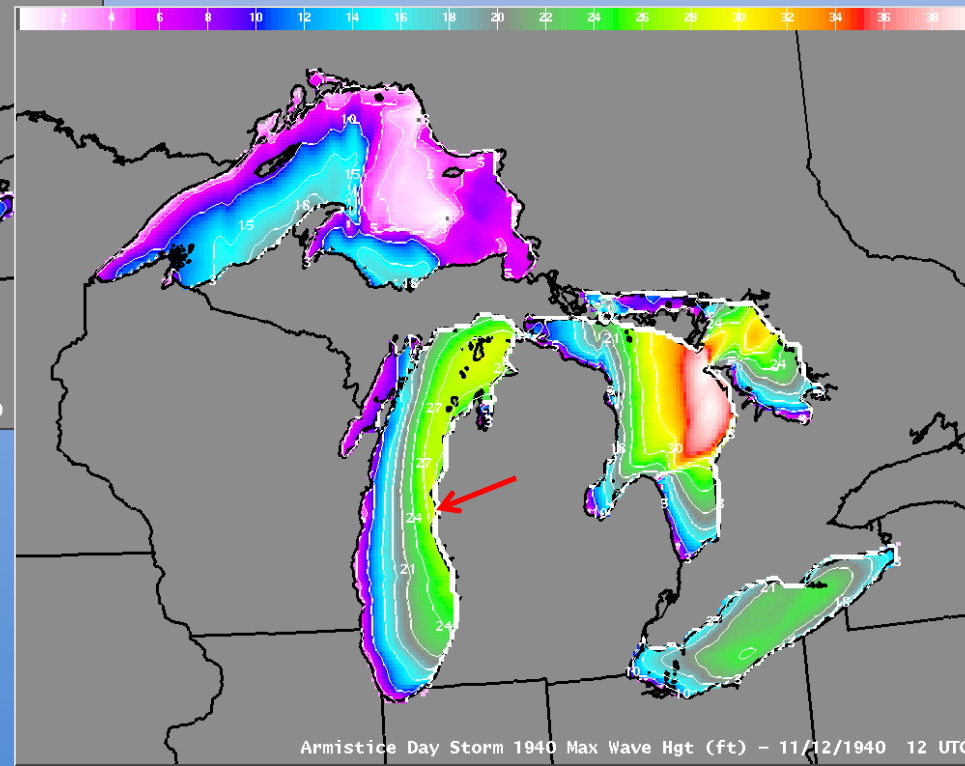
Waves (ft) - 12 UTC 11/12/1940



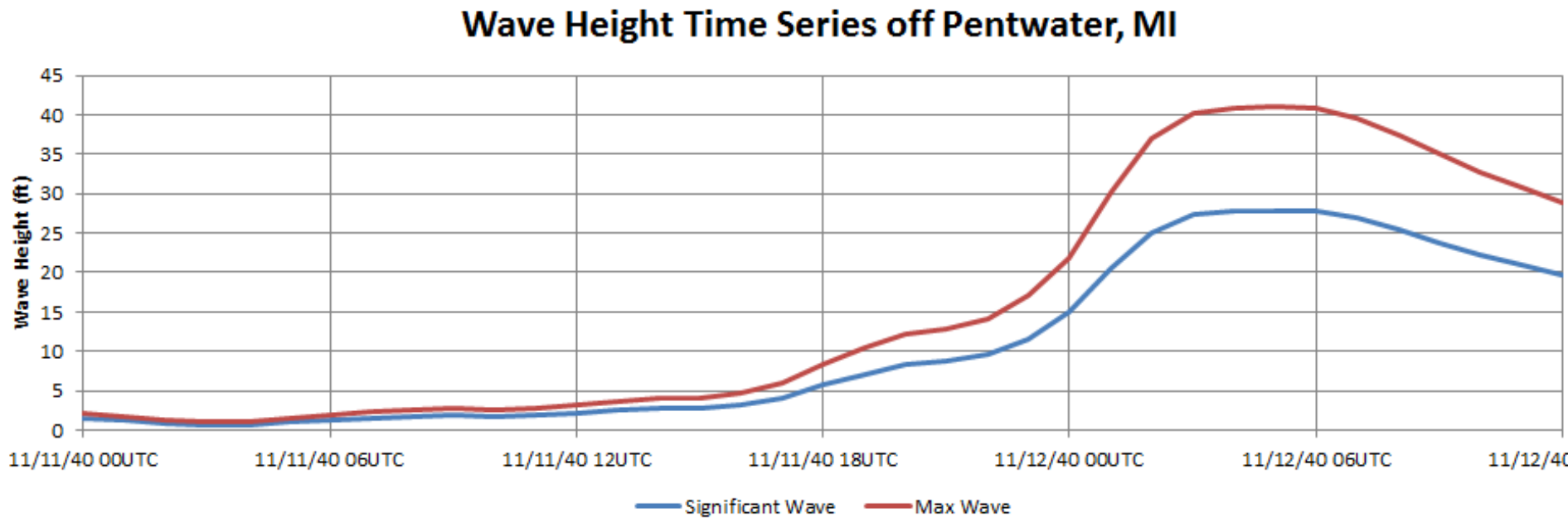
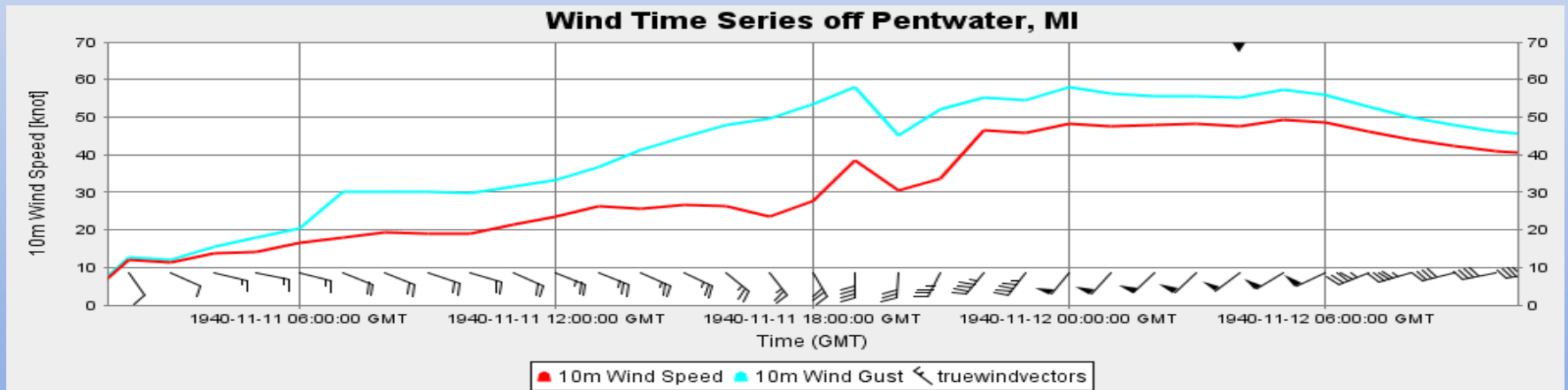
Significant Wave



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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Acknowledgements

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- Tom Hultquist (SOO NWS Twin Cities) for assistance in using the 20thCR into the WRF
- NWS MQT Staff

THANK YOU!!

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