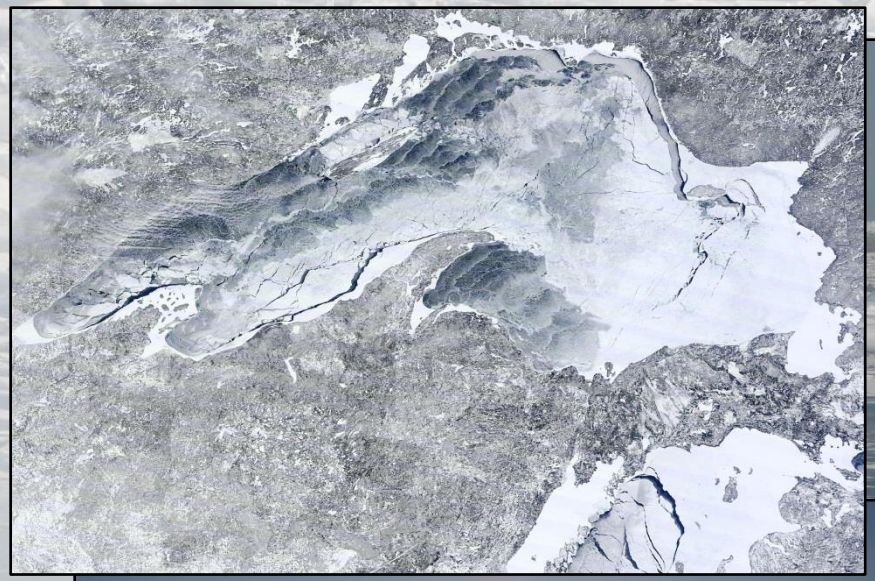
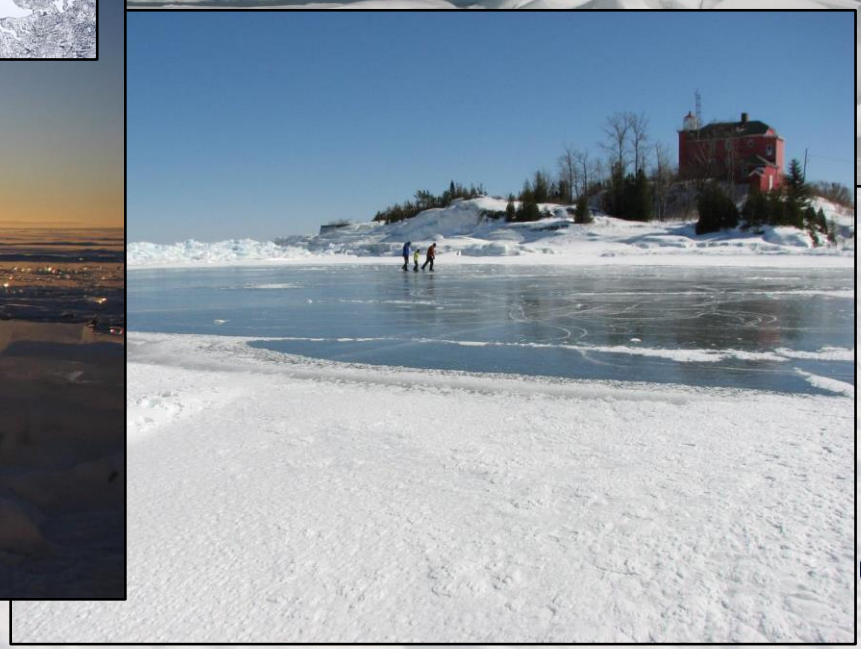
A Review of the Historic Record Cold Winter of 2013-2014





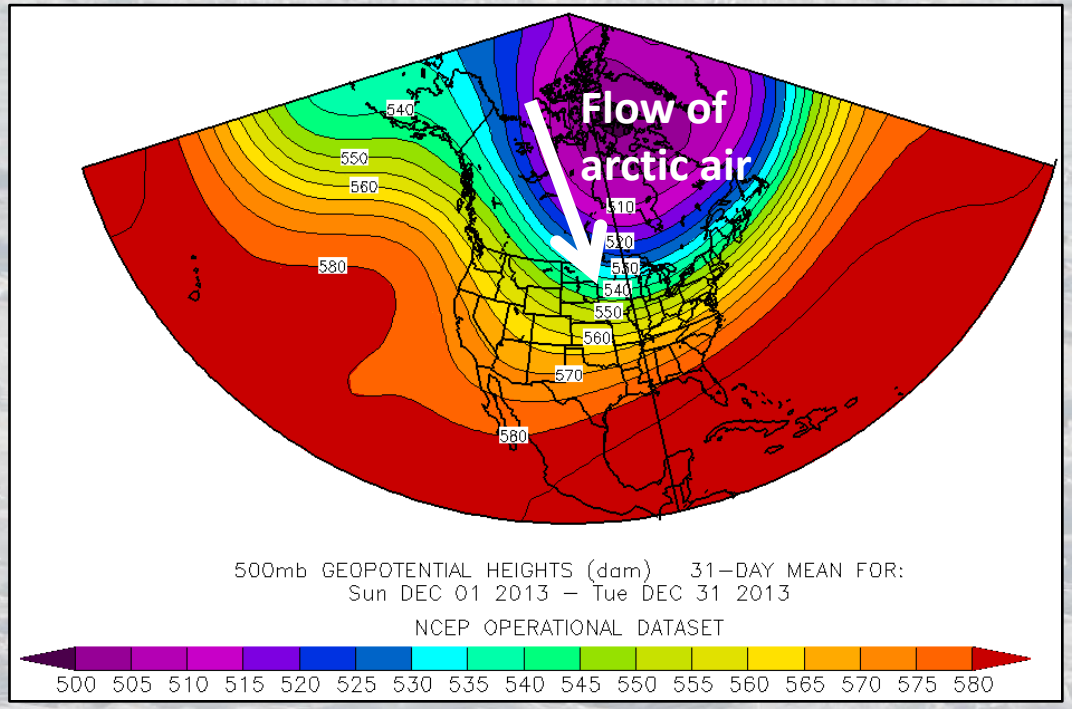
A Review of the Record Cold Winter of 2013-2014

- With some exceptions, the cold weather this past winter and early spring was generally not unusual in terms of the severity of cold on any given day as there were not a significant number of record low temperatures set. Rather, what was extremely unusual was the persistence of below and well below normal temperatures over a several month period that encompassed the climatologically coldest period of weather during the year.
- In this presentation, the period of December 2013 through March 2014 will be examined as these four months had persistently significant temperature departures from normal.

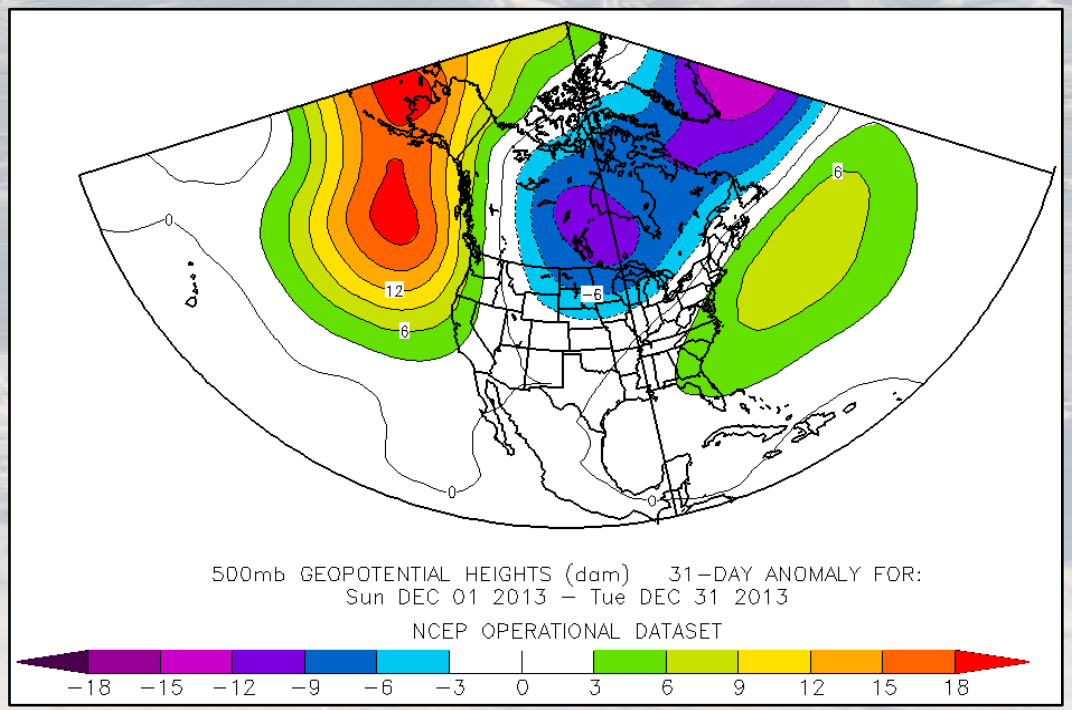
A Review of the Record Cold Winter of 2013-2014

- Temperatures were examined primarily at the following locations:
  * Houghton ---------- records begin in 1887
  * Iron Mountain ---------- records begin in 1889
  * Ironwood ---------- records begin in 1901
  * Manistique ---------- records begin in 1896
  * Marquette NWS office (Negaunee Township)---- records begin in 1961
  * Marquette City ---------- records begin in 1871
  * Munising ---------- records begin in 1911
  * Newberry ---------- records begin in 1896

December 2013 Pattern Overview

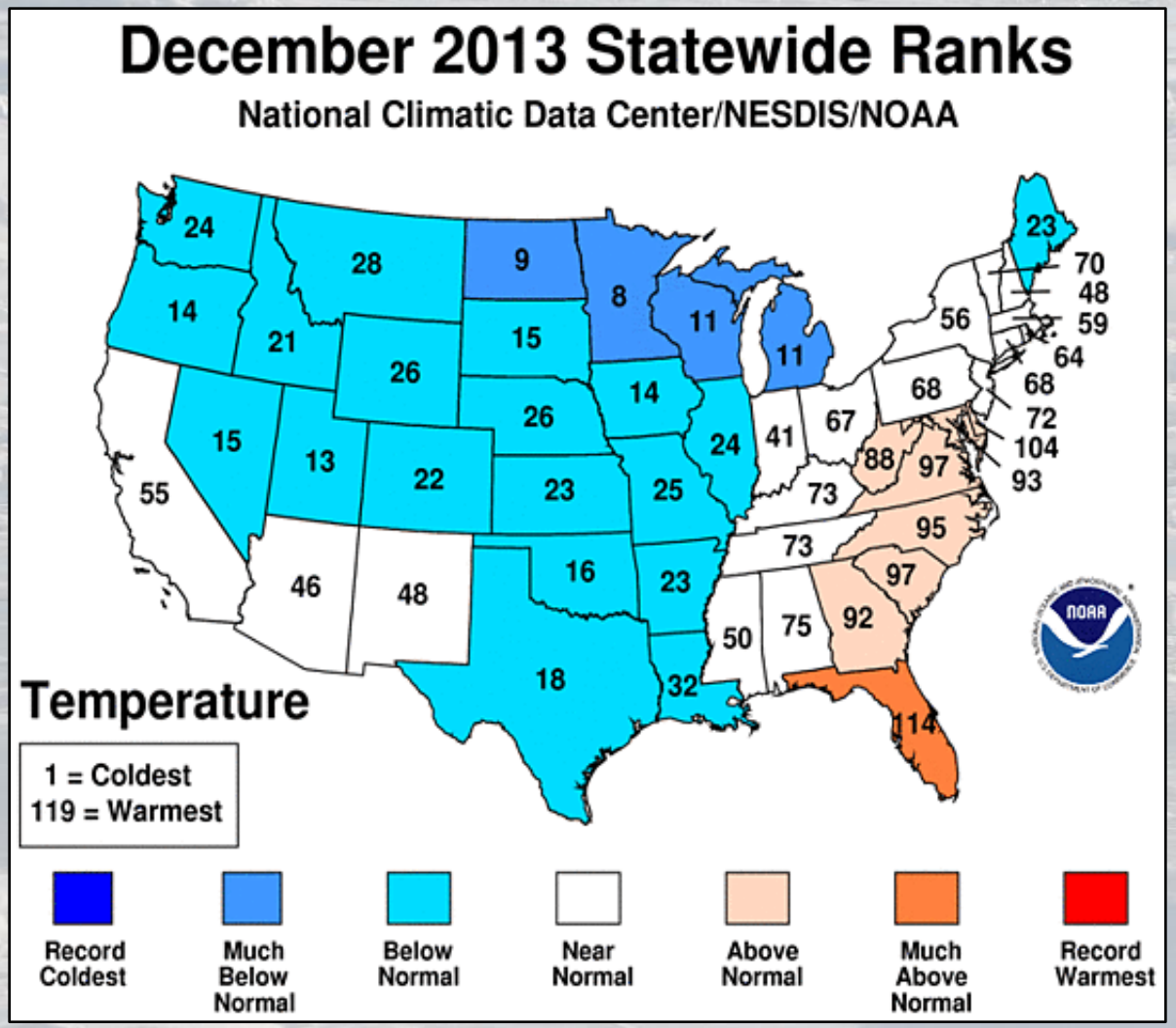


As shown in the image to the left, on average during December, a ridge was positioned off the west coast of North America with a deep trough extending from northern Canada into the central and eastern United States. This pattern allowed for persistent transport of arctic air south into portions of the central and eastern U.S.



As shown in the image to the left, the trough was deepest compared to December climatology just to the northwest of the Upper Great Lakes, over Manitoba and northern Ontario (purple shading). This implies that the coldest air with respect to December climatology was positioned just northwest of Upper Michigan.

December 2013 Temperatures



Out of 119 years of data, December 2013 ranked as the 11th coldest December on record for the state of Michigan and 11th coldest for the state of Wisconsin.

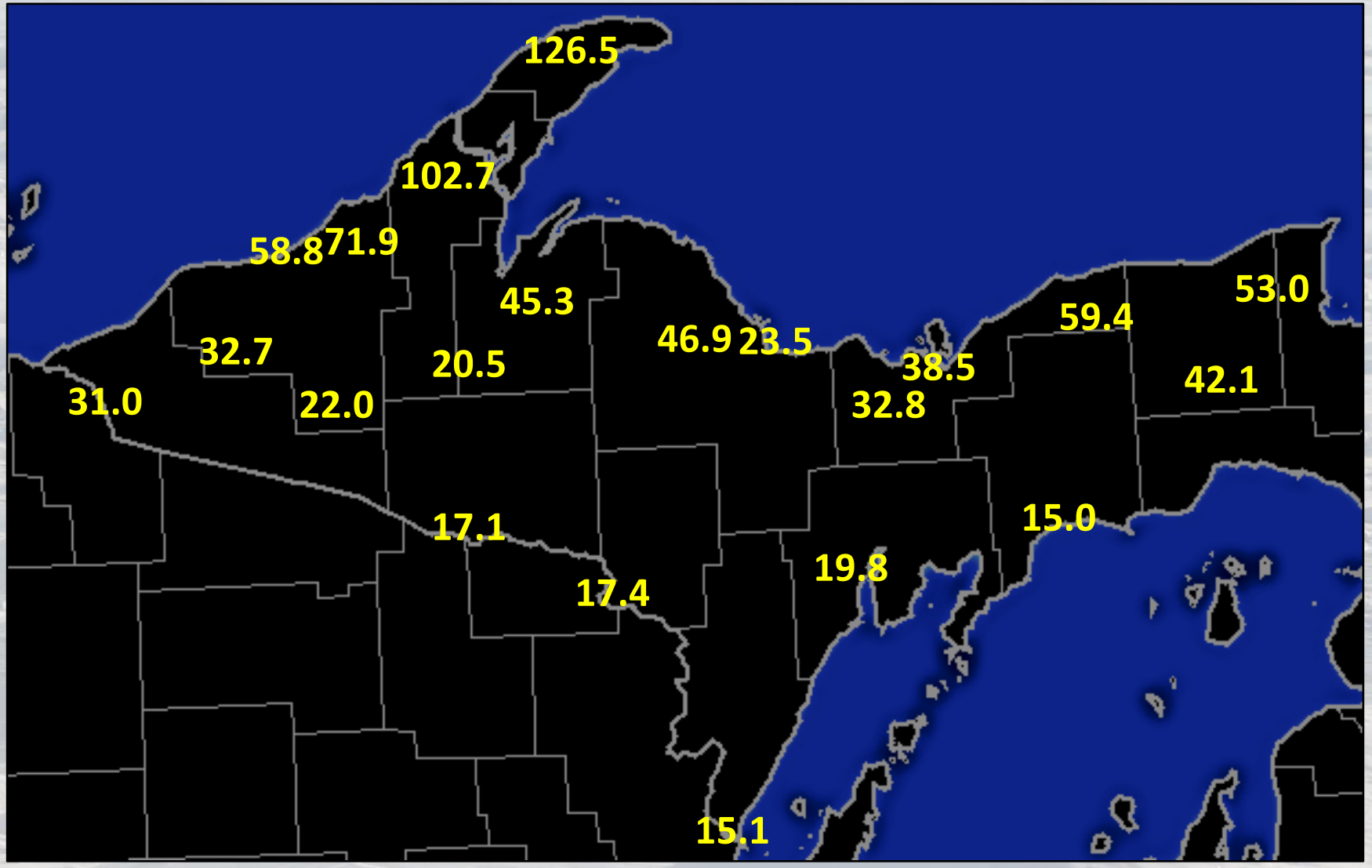
Upper Michigan December 2013 Temperatures

Location	Rank	Mean Temperature (F)	Departure from Normal (F)	Record Lowest Mean Temperature (F)
Newberry	3rd coldest	12.8	-9.4	9.0 in 1989
Manistique	5th coldest	14.2	-9.1	11.1 in 1989
Munising	5th coldest	15.0	-7.9	10.8 in 1919
Marquette NWS	5th coldest	10.9	-7.6	8.5 in 1976
Ironwood	8th coldest	7.5	-9.1	5.0 in 1983
Iron Mountain	8th coldest	11.2	-8.2	7.1 in 1989
Houghton	8th coldest	12.7	-7.5	11.2 in 1917
Marquette City	9th coldest	16.8	-6.7	13.7 in 1919

- The lowest temperature observed in west or central Upper Michigan during December was -27 F at Stambaugh on December 31st.

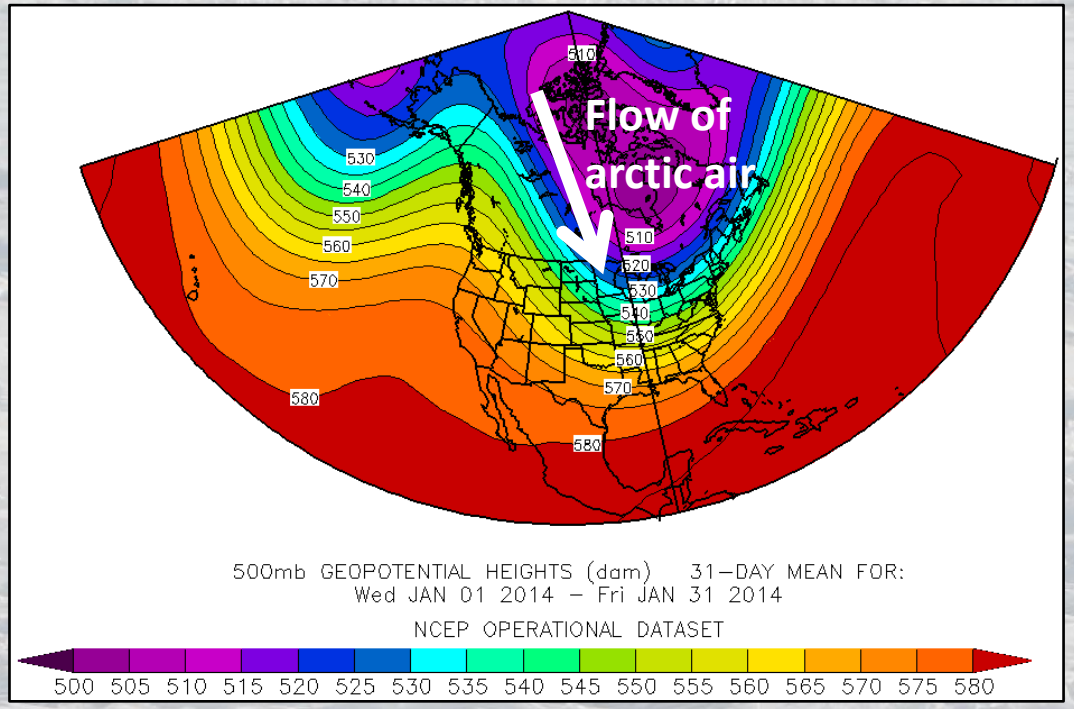
- Lowest average December temperature was 6.8 F at Stambaugh in Iron County.

December 2013 Snowfall (inches)

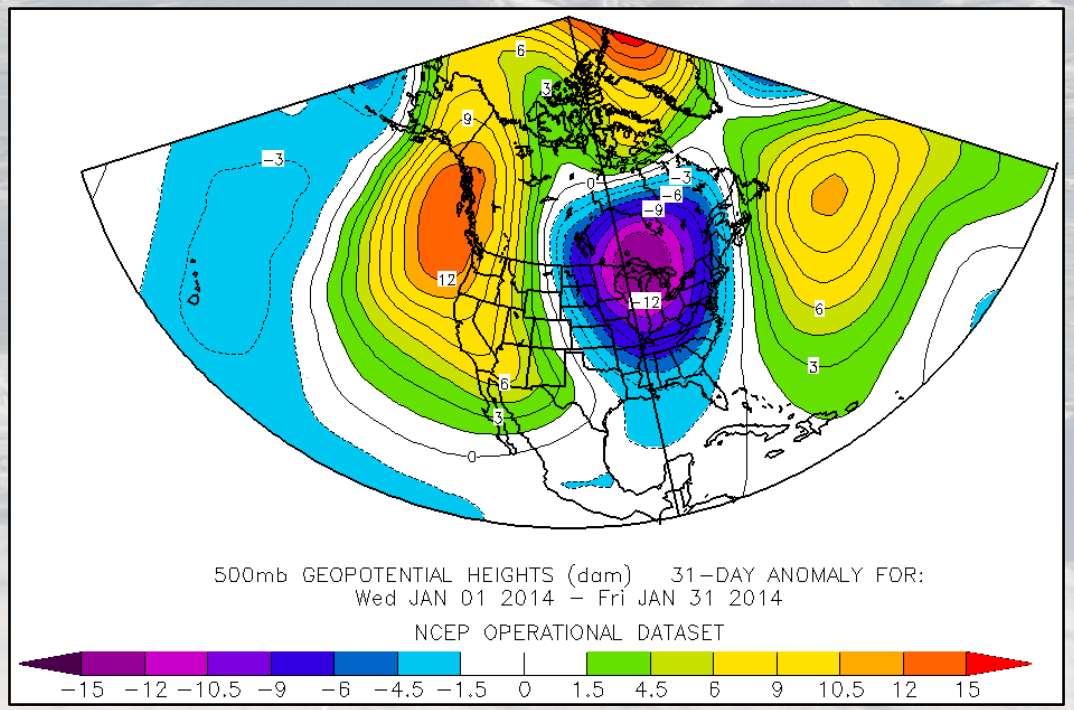


In December 2013, snowfall was above normal over northwest Upper Michigan, the Keweenaw in particular. The rest of west and central Upper Michigan had snowfall close to normal.

January 2014 Pattern Overview

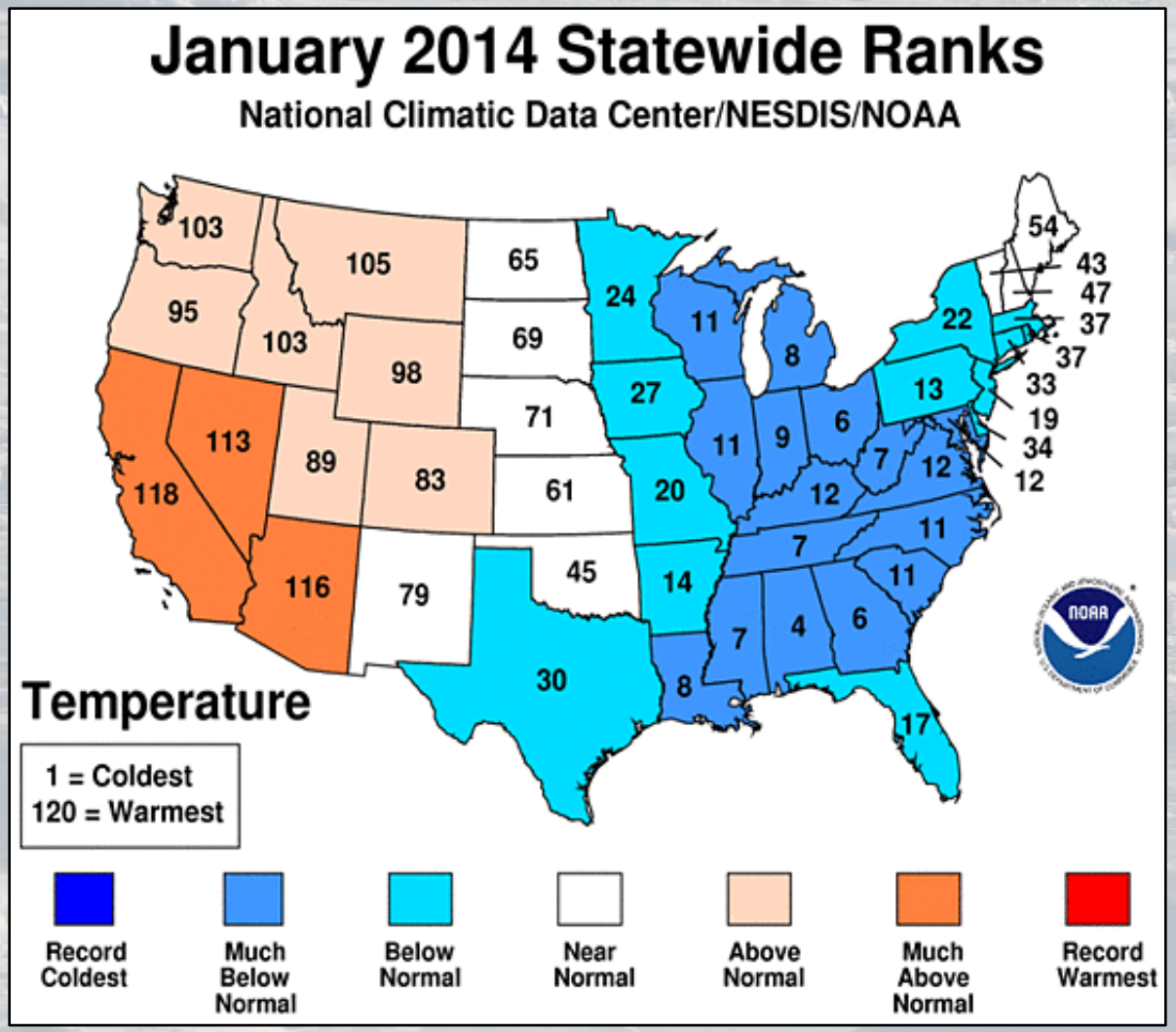


As shown in the image to the left, on average during January, a ridge remained along the west coast of North America, but it was slightly farther east and sharper than it was during December. A deep trough still extended from northern Canada into the central and eastern United States. This pattern continued to allow for persistent transport of arctic air south into the central and eastern U.S.



As shown in the image to the left, the trough was deepest compared to January climatology over the Upper Great Lakes (purple shading). This implies that the coldest air with respect to January climatology was positioned over the Upper Great Lakes.

January 2014 Temperatures



Out of 120 years of data, January 2014 ranked as the 8th coldest January on record for the state of Michigan and 11th coldest for the state of Wisconsin. Note the near record warmth in the southwest portion of the U.S.

Upper Michigan January 2014 Temperatures

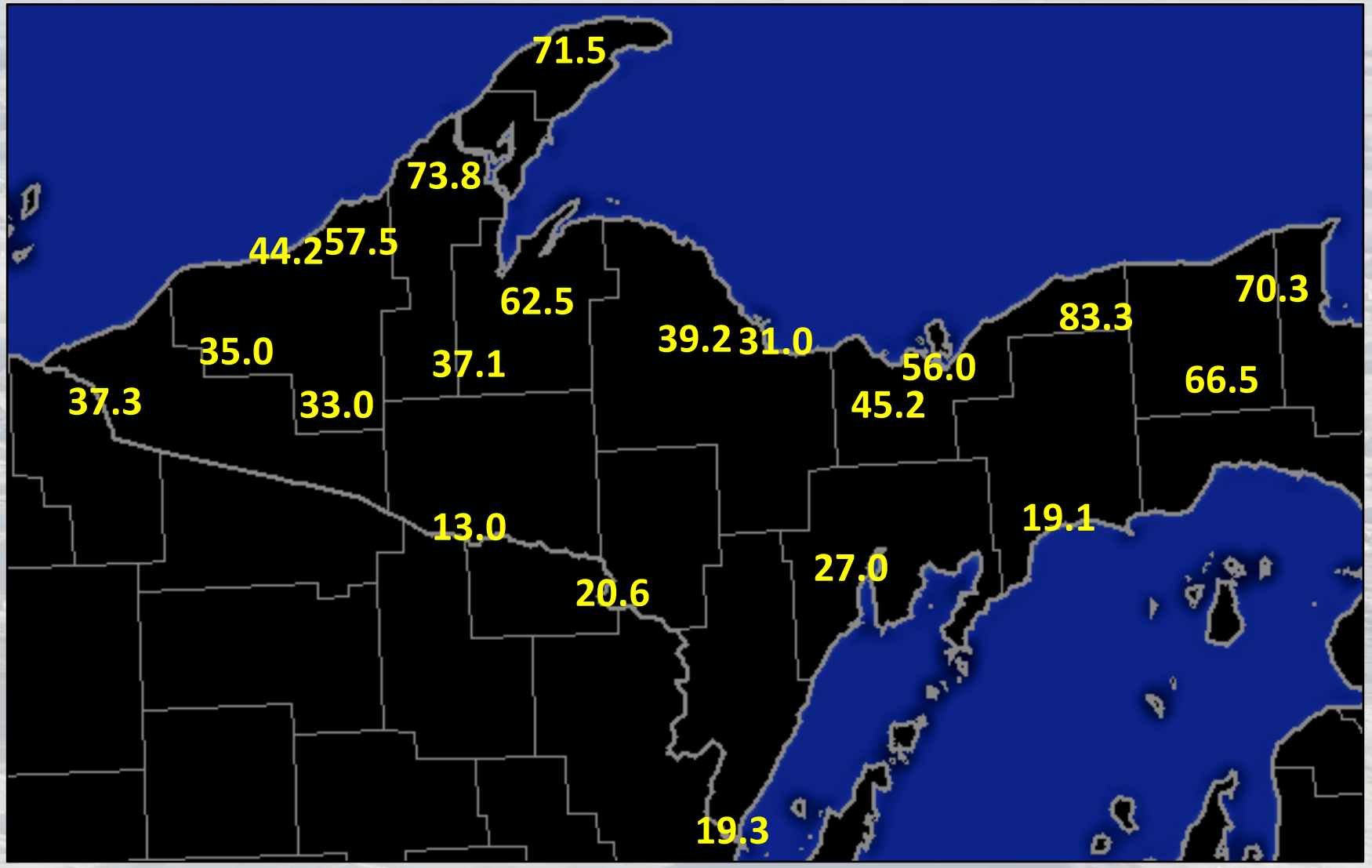
Location	Rank	Mean Temperature (F)	Departure from Normal (F)	Record Lowest Mean Temperature (F)
Iron Mountain	3rd coldest	4.4	-9.3	-1.9 in 1912
Manistique	5th coldest	10.4	-7.2	5.8 in 1994
Marquette NWS	6th coldest	5.8	-7.8	2.8 in 1994
Ironwood	8th coldest	2.5	-9.1	-5.3 in 1912
Munising	9th coldest	9.7	-8.2	3.6 in 1912
Newberry	9th coldest	9.7	-7.0	5.3 in 1994
Houghton	11th coldest	7.8	-7.7	-1.2 in 1912
Marquette City	14th coldest	10.2	-8.6	1.3 in 1912

- Using satellite data to monitor global temperatures, a joint project between University of Alabama Huntsville, NOAA and NASA determined that the coldest place on Earth in January **compared to seasonal normal** was in western Upper Michigan, near Iron River.

- The lowest temperature observed in west or central Upper Michigan during January was -35 F at Stambaugh on January 9th.

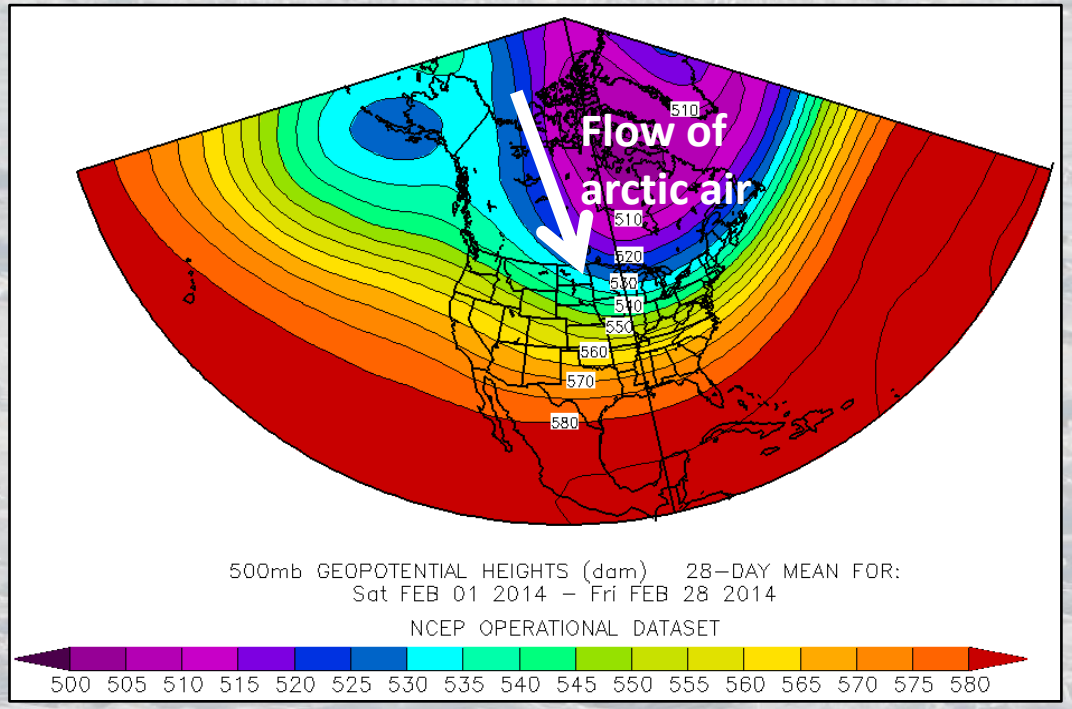
- Lowest average January temperature was 1.9 F at Stambaugh.

January 2014 Snowfall (inches)

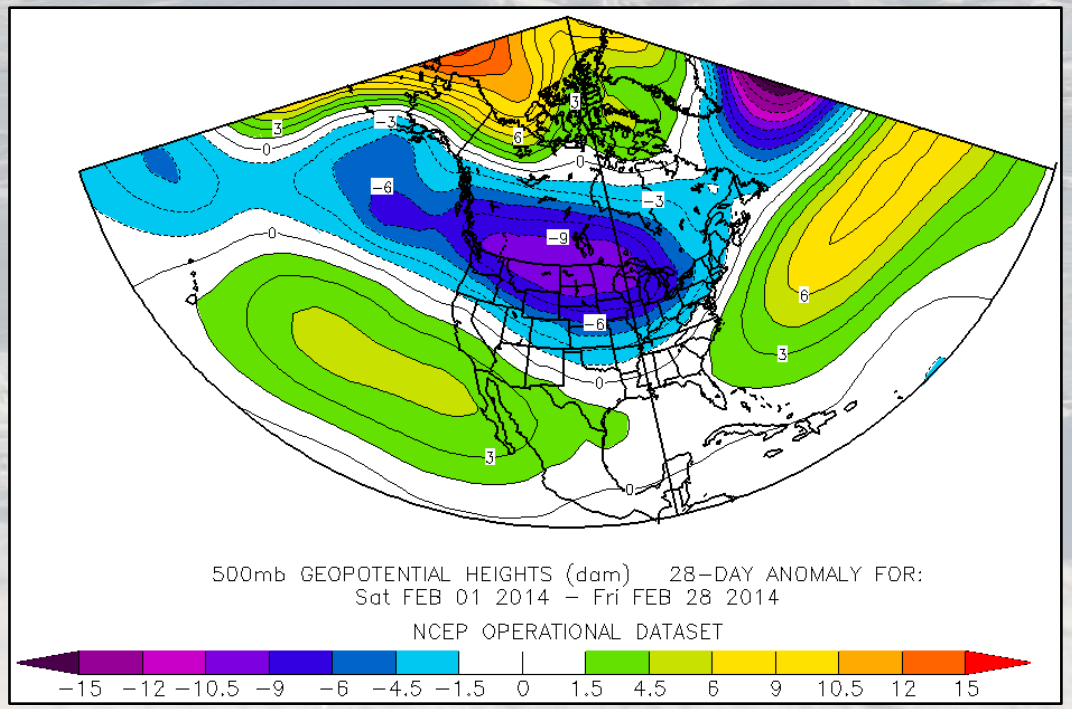


In January 2014, snowfall was mostly above normal in the snow belts favored by northwest winds and also over south central Upper Michigan. Snowfall was near to above normal across the rest of west and central Upper Michigan.

February 2014 Pattern Overview

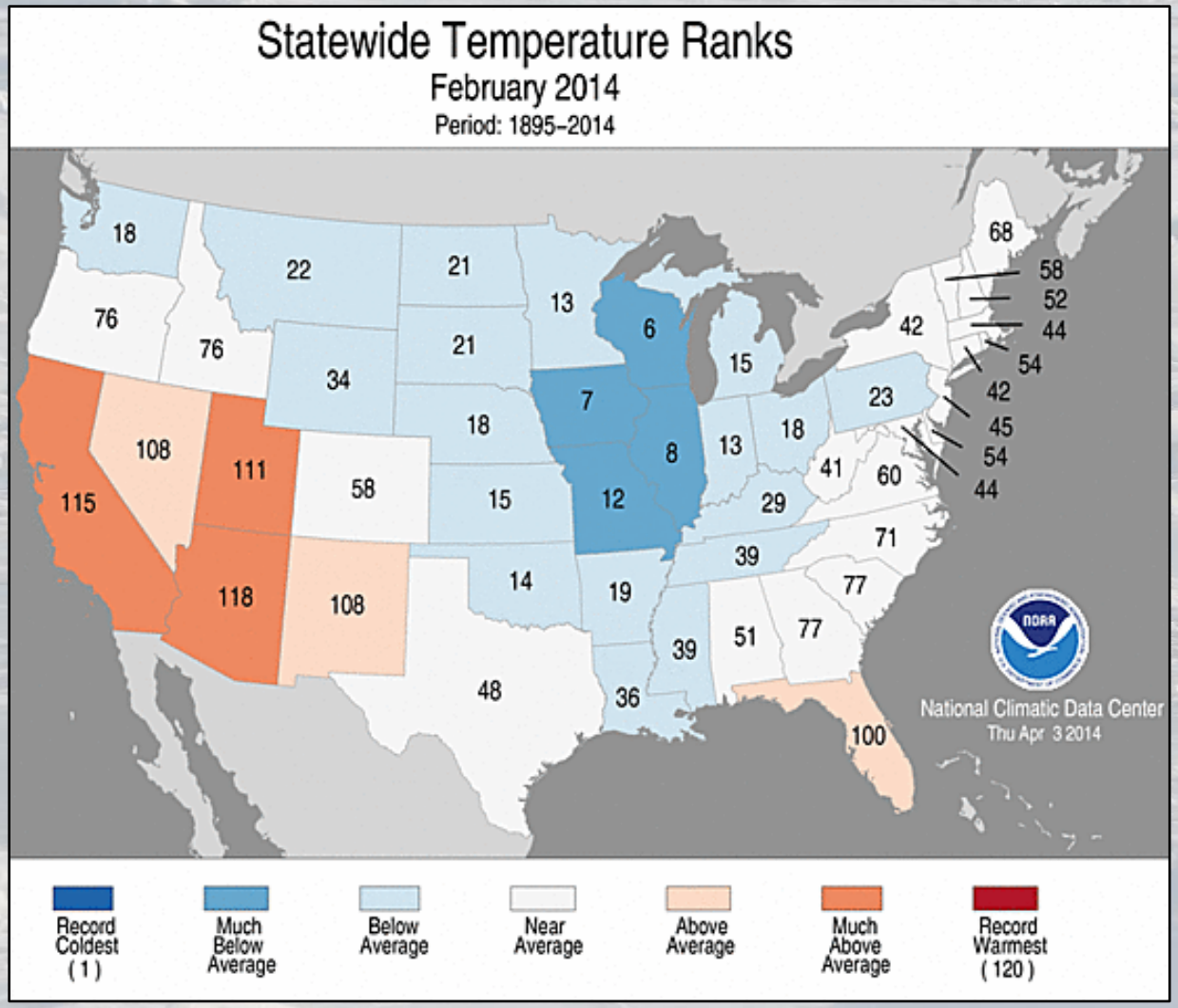


As shown in the image to the left, the ridge near the west coast that dominated December and January broke down across the Pacific Northwest and western Canada in February. However, a trough still extended from northern Canada into the central and eastern United States, continuing to allow for persistent transport of arctic air south into the central and eastern U.S.



As shown in the image to the left, troughing was deepest compared to February climatology from the Upper Great Lakes to the northern Rockies (purple shading). This implies that the coldest air compared to February climatology was located from the northern Rockies to the Upper Great Lakes.

February 2014 Temperatures



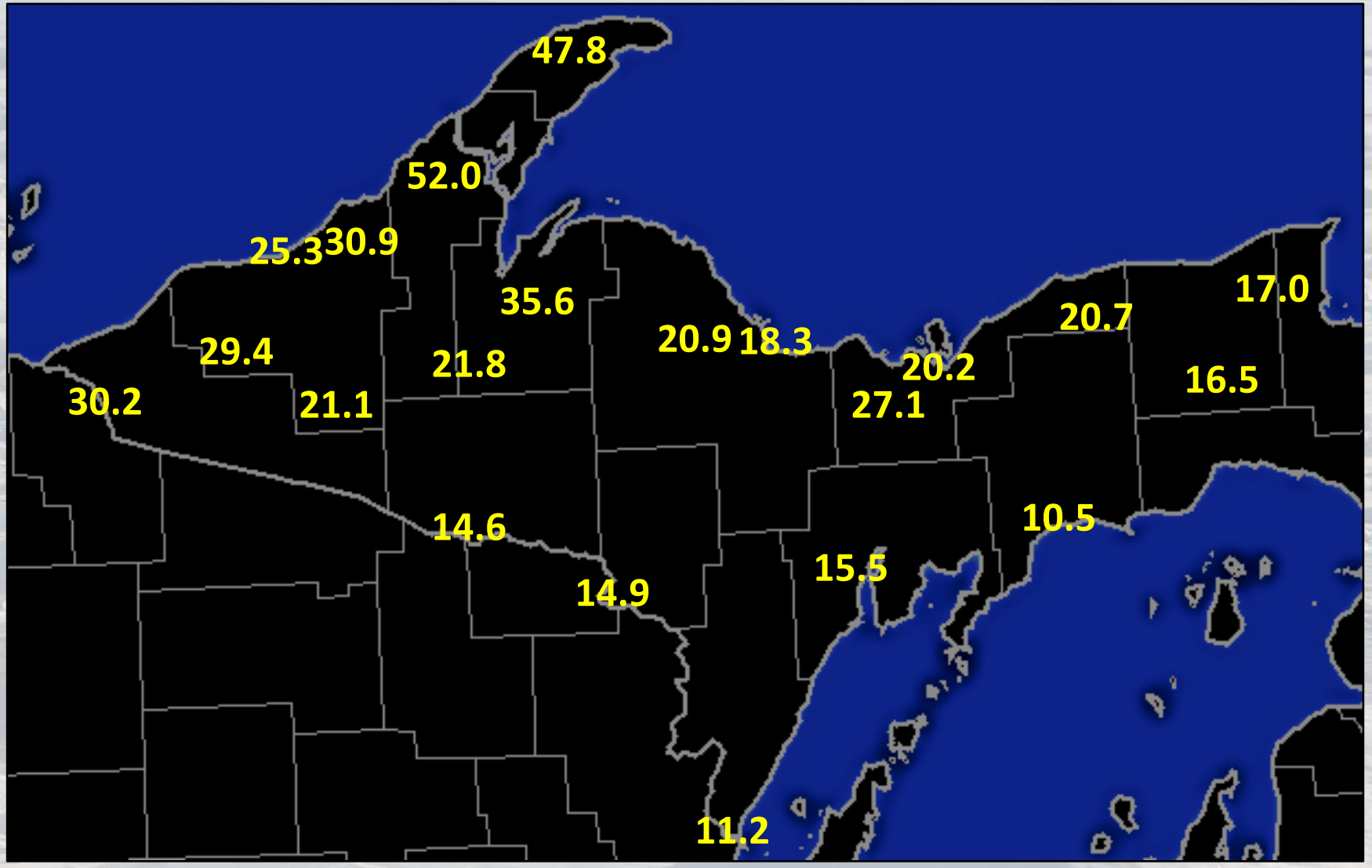
Out of 120 years of data, February 2014 ranked as the 15th coldest February on record for the state of Michigan and 6th coldest for the state of Wisconsin. Note the near record warmth in the southwest portion of the U.S.

Upper Michigan February 2014 Temperatures

Location	Rank	Mean Temperature (F)	Departure from Normal (F)	Record Lowest Mean Temperature (F)
Marquette NWS	Record coldest	5.6	-9.9	Previous 5.7 in 1963
Iron Mountain	2nd coldest	5.9	-11.6	4.1 in 1904
Munising	3rd coldest	8.4	-11.0	4.8 in 1936
Newberry	3rd coldest	7.4	-11.3	5.7 in 1917
Houghton	5th coldest	6.8	-10.1	1.7 in 1936
Manistique	4th coldest	9.4	-9.9	8.5 in 1994
Ironwood	5th coldest	5.3	-9.6	-0.3 in 1936
Marquette City	9th coldest	10.9	-9.8	1.8 in 1875

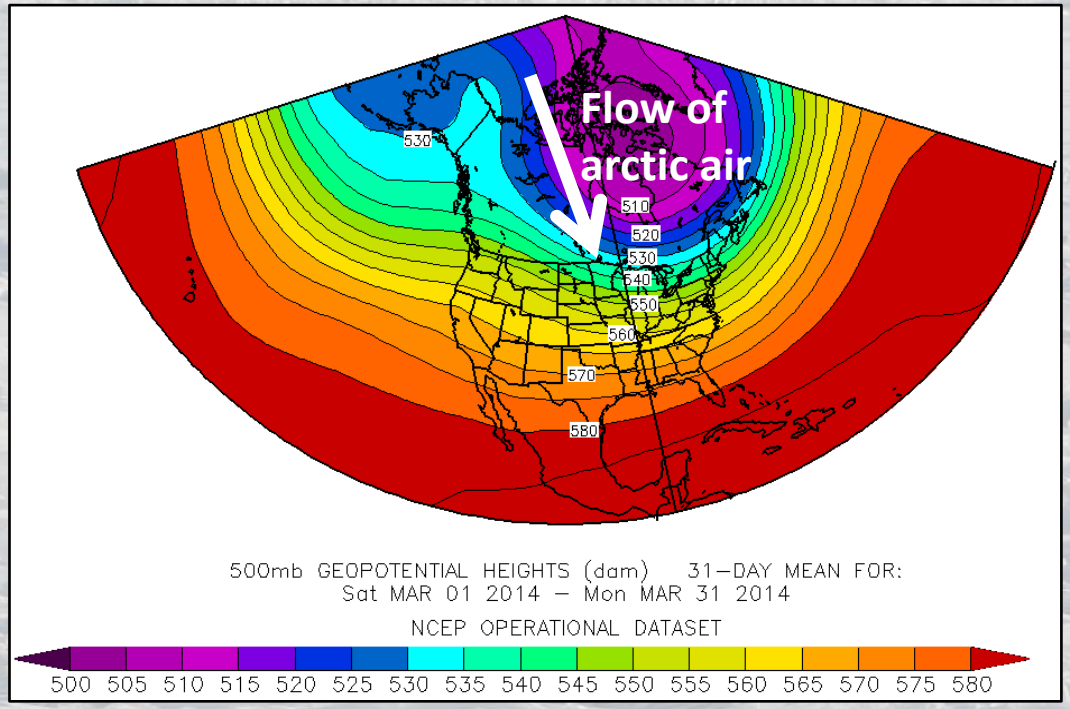
- The lowest temperature observed in west or central Upper Michigan during February was -41 F near Newberry on February 28th.
- Lowest average February temperature was 1.8 F at Stambaugh in Iron County.

February 2014 Snowfall (inches)

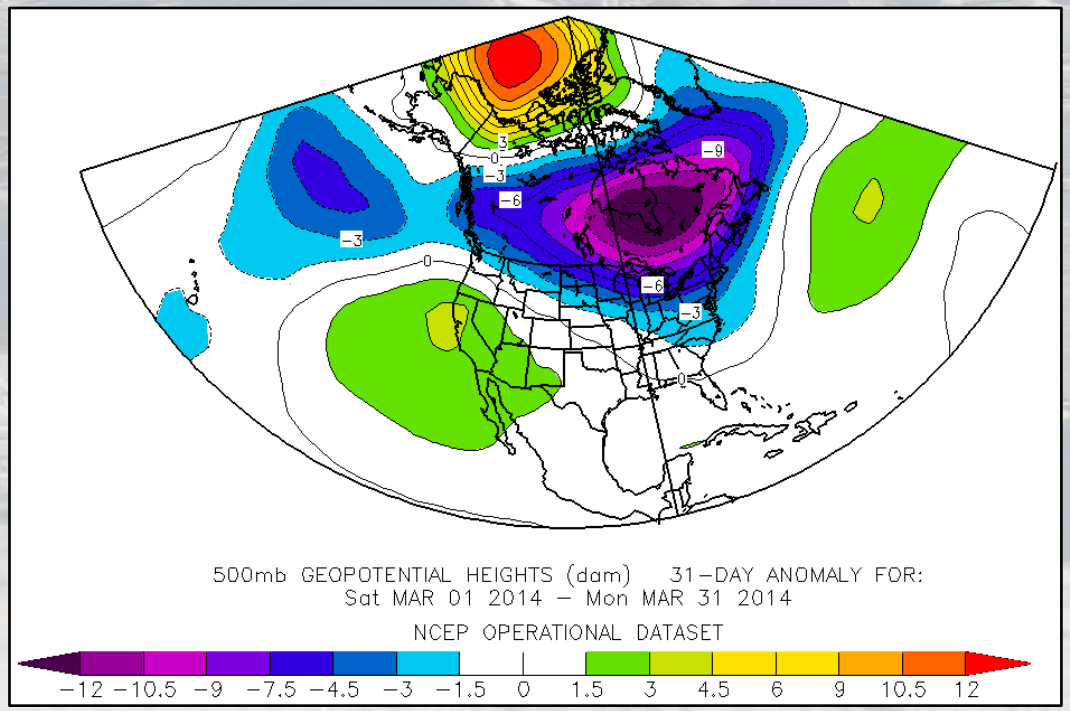


In February 2014, snowfall was generally above normal over western and south central Upper Michigan and generally below normal over north central and east central Upper Michigan. Of note, Painesdale in Houghton County reached a snow depth of 60 inches on February 24th.

March 2014 Pattern Overview

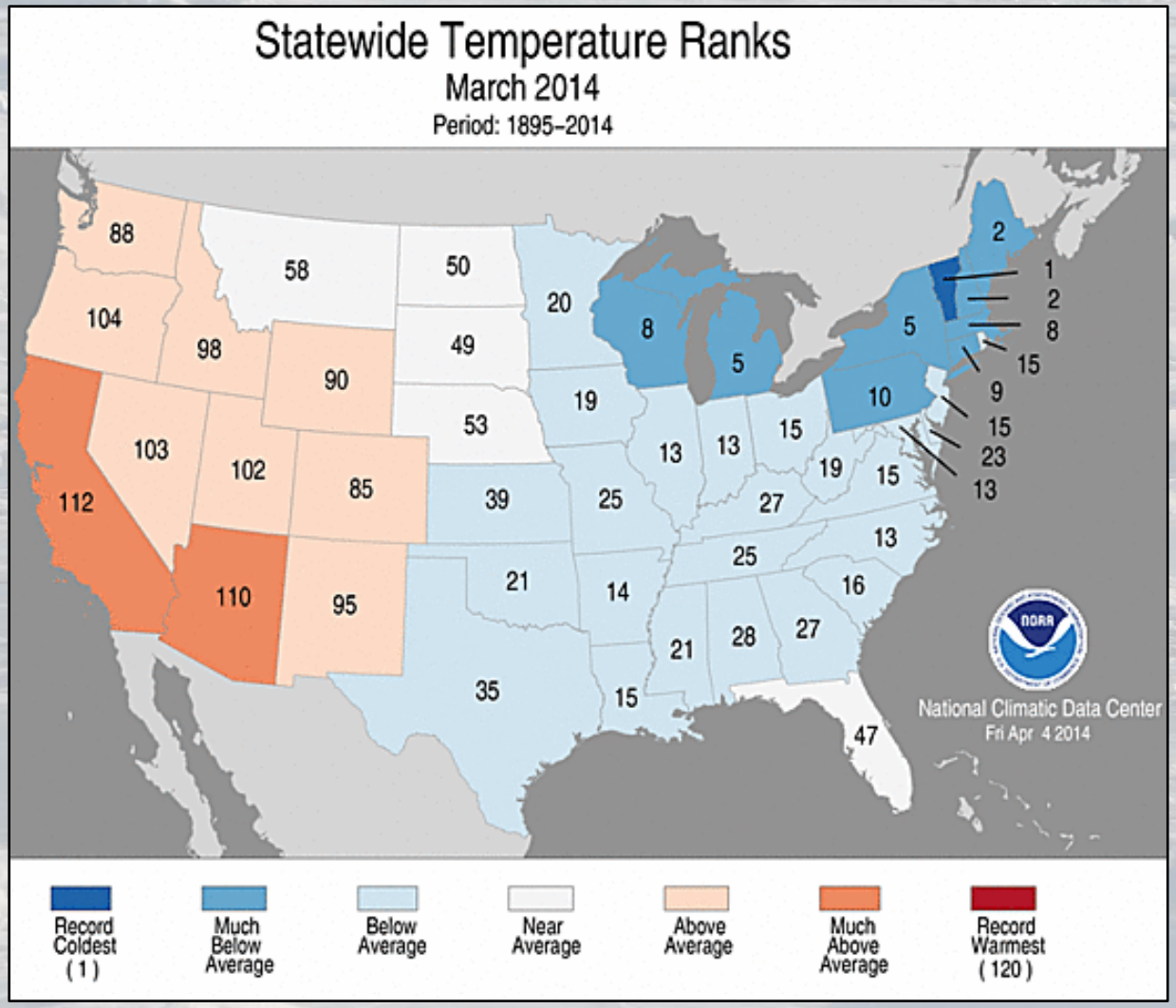


As shown in the image to the left, the pattern that prevailed during February continued through March. A deep trough extended from northern Canada into portions of the central and eastern United States, continuing to allow for frequent transport of late season arctic air south into the central and eastern U.S.



As shown in the image to the left, the trough was deepest compared to March climatology to the north and northeast of the Upper Great Lakes, over northern Ontario, Quebec and Hudson Bay (purple shading). This implies that the coldest air compared March climatology was positioned just to the north and northeast of the Upper Great Lakes.

March 2014 Temperatures



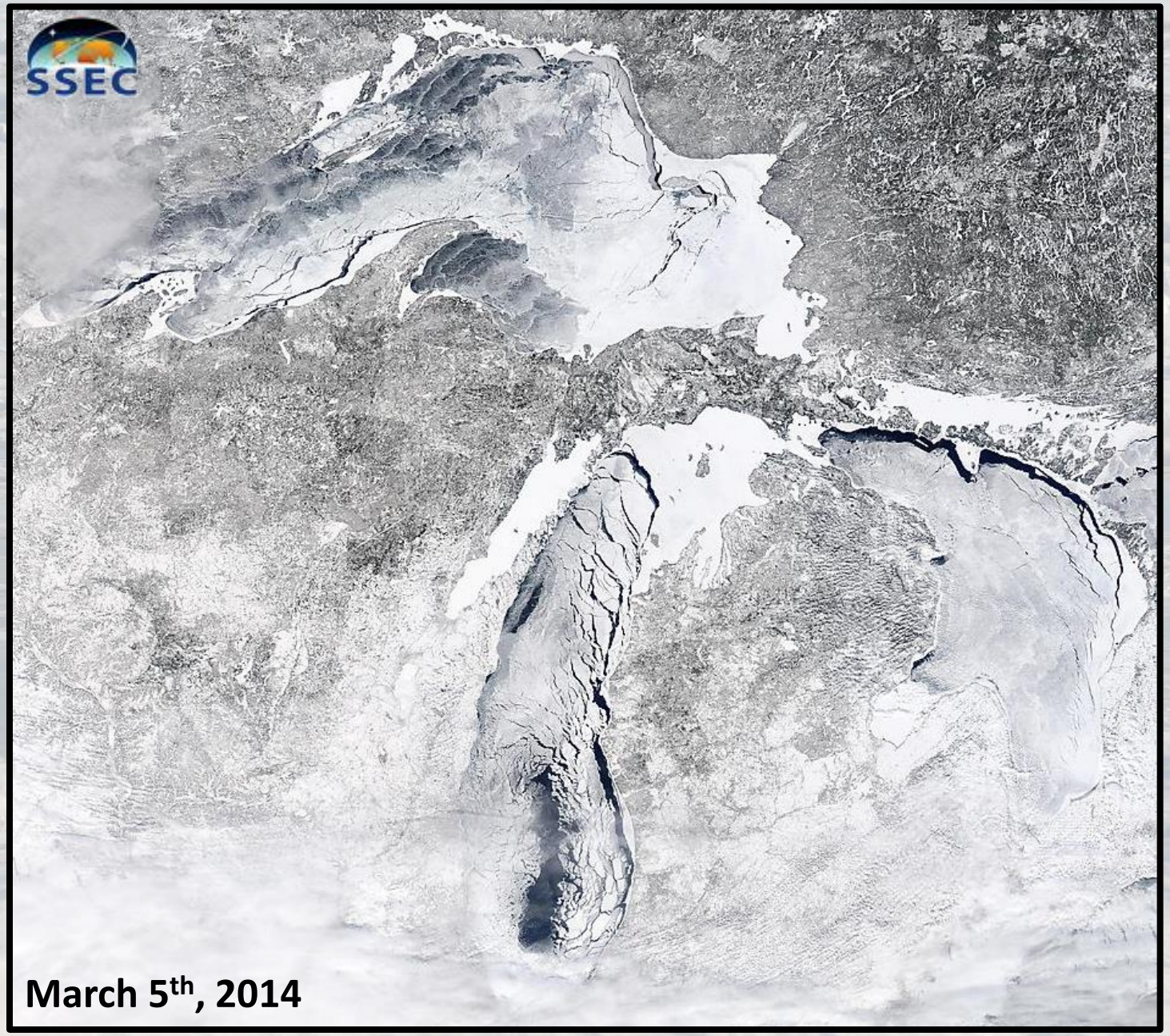
Out of 120 years of data, March 2014 ranked as the 5th coldest February on record for the state of Michigan and 8th coldest for the state of Wisconsin. Once again, the southwest portion of the U.S. had near record warmth.

Upper Michigan March 2014 Temperatures

Location	Rank	Mean Temperature (F)	Departure from Normal (F)	Record Lowest Mean Temperature (F)
Marquette NWS	Record coldest	15.6	-8.6	Previous 16.9 in 1965
Munising	Record coldest	14.7	-13.0	Previous 15.6 in 1923
Manistique	Record coldest	15.4	-11.7	Previous 17.7 in 1999
Ironwood	Record coldest	14.3	-10.8	Previous 16.1 in 1996
Iron Mountain	2nd coldest	17.4	-10.5	16.9 in 1899
Houghton	4th coldest	15.2	-10.0	13.2 in 1888
Newberry	4th coldest	16.4	-10.4	15.7 in 1923
Marquette City	5th coldest	17.5	-11.4	12.3 in 1885

- The lowest temperature observed in west or central Upper Michigan during March was -34 F at Wakefield on March 3rd.
- Lowest average March temperature was 11.0 F at Watton in Baraga County.

Western Great Lakes Maximum Ice Cover Reached in Early March



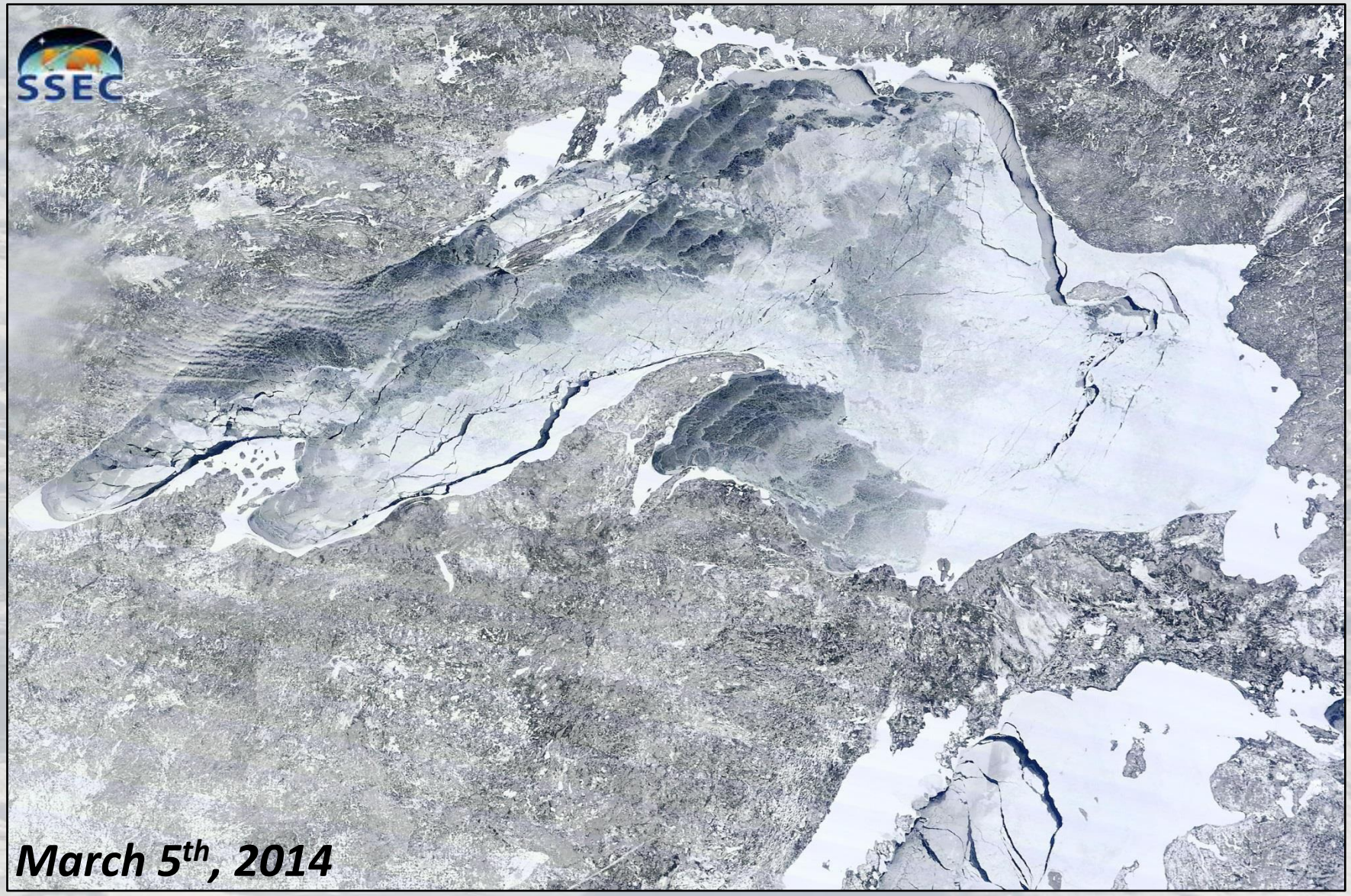
Maximum ice cover on Lake Superior was reached on March 5th with 95.74 percent ice cover.

Maximum ice cover on Lake Michigan was reached on March 8th with 93.29 percent ice cover.

Maximum ice cover on Lake Huron was reached on March 6th with 96.30 percent ice cover.

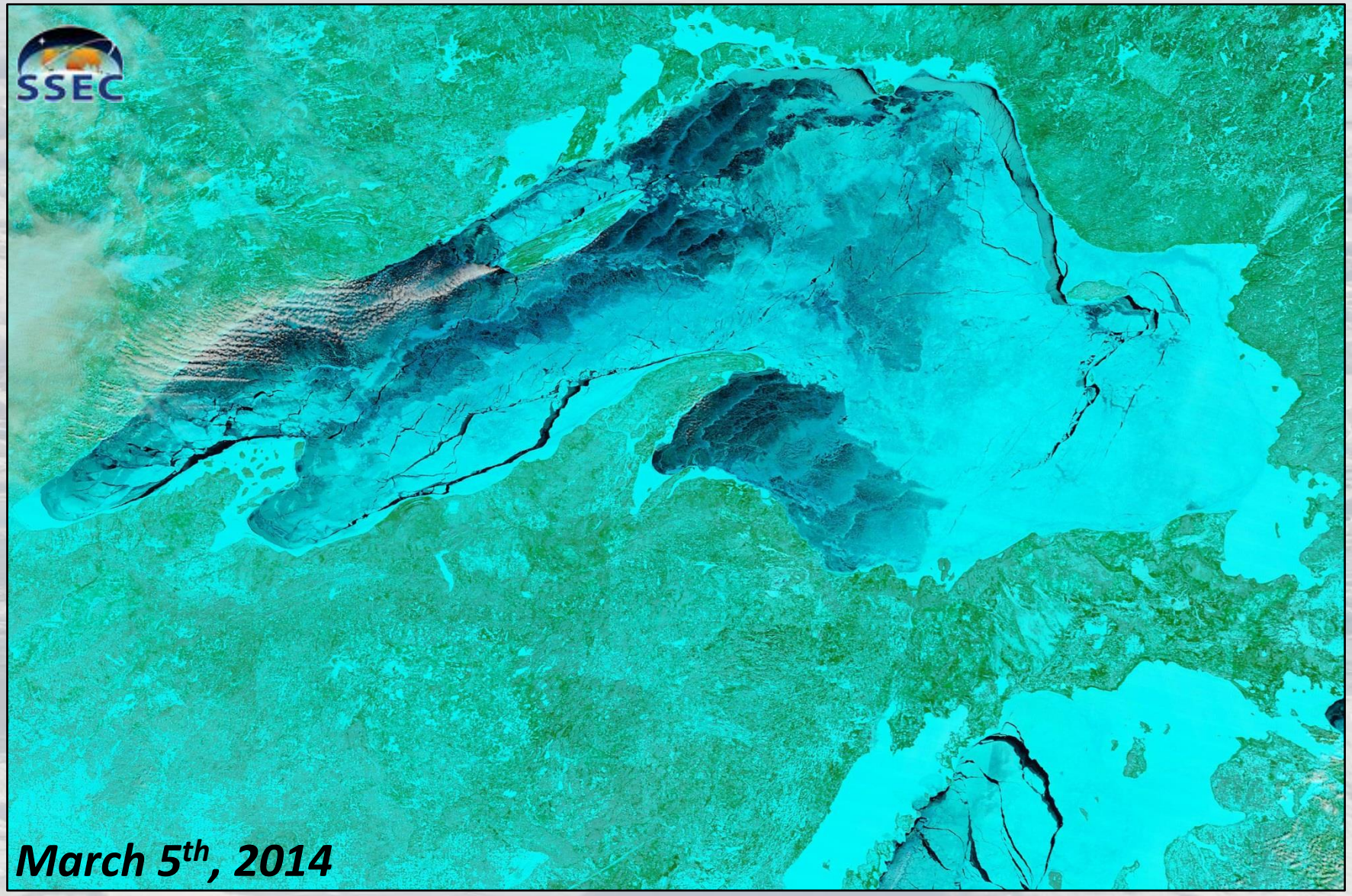
NATIONAL WEATHER SERVICE
MARQUETTE, MICHIGAN

Lake Superior Reaches Maximum Ice Cover on March 5th 2014



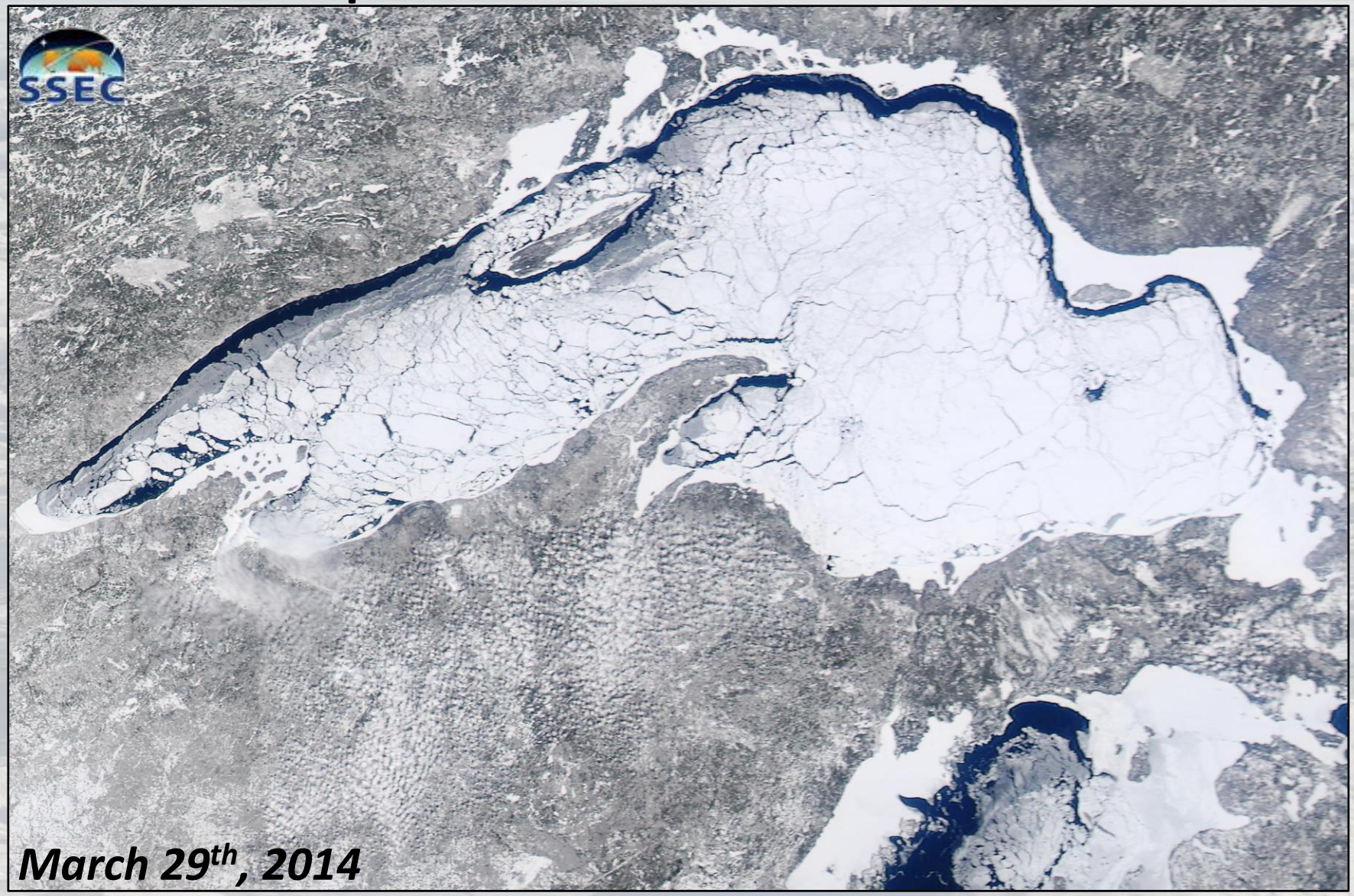
On March 5th, 2014, ice covered 95.74 percent of Lake Superior.

Lake Superior Reaches Maximum Ice Cover on March 5th 2014



In this false color image, snow and ice appear as an aqua color, open water appears as black and clouds appear white.

Lake Superior Ice Cover in Late March 2014



Due to the persistently cold pattern, ice cover during mid and late March changed little since the maximum coverage was reached on March 5th.

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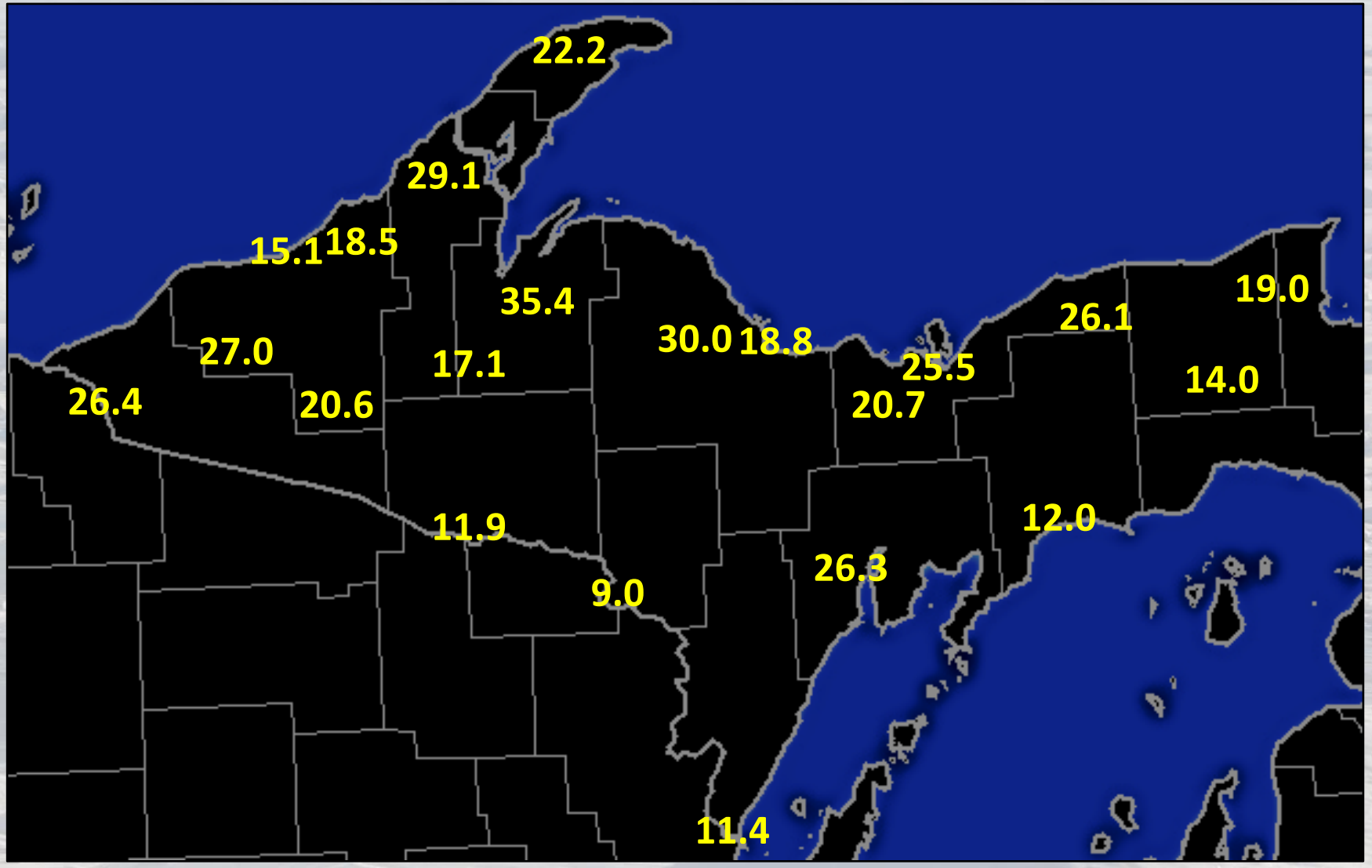
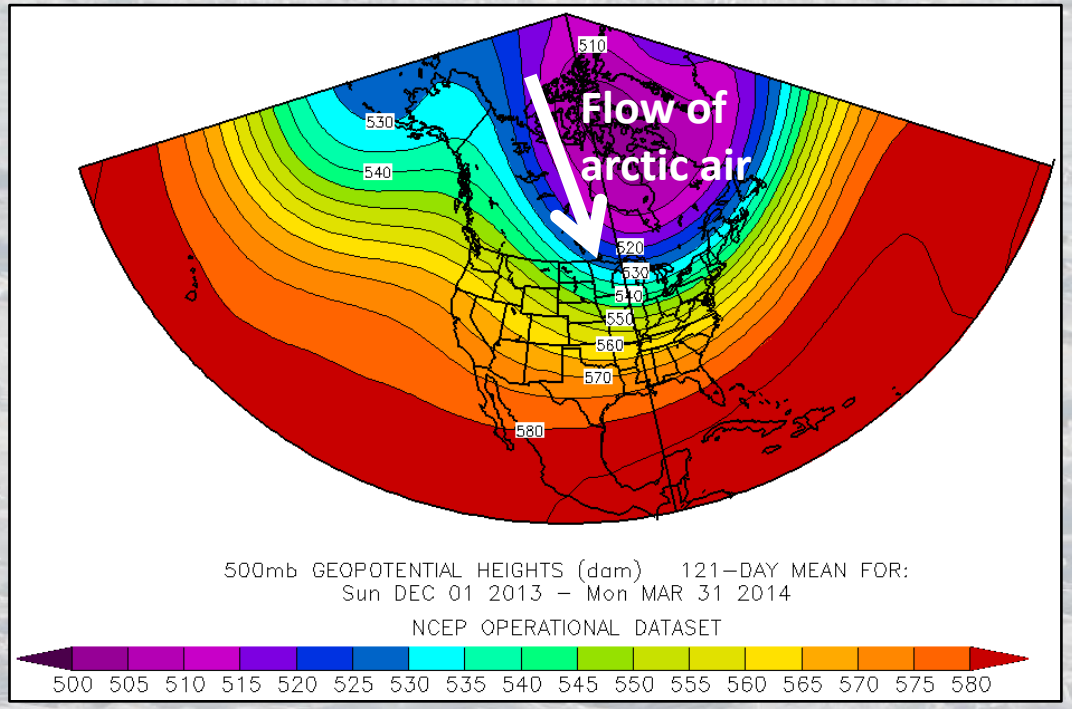
MARQUETTE, MICHIGAN

March 2014 Snowfall (inches)

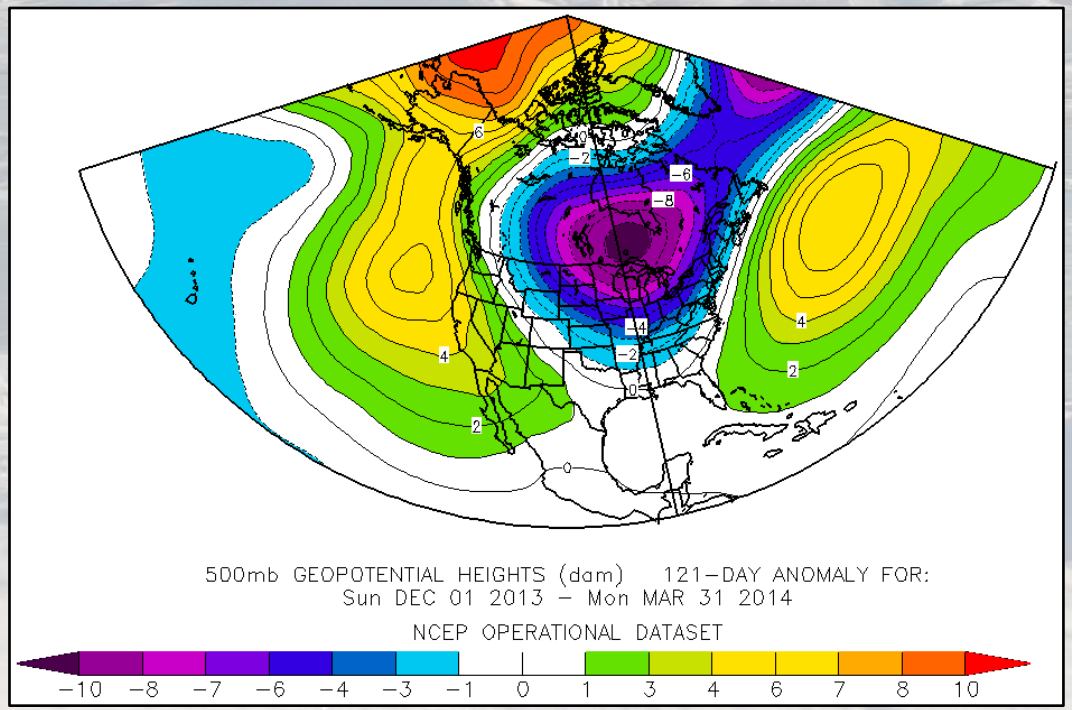


In March 2014, snowfall was mostly below normal. The exception was above normal snowfall over portions of east central Upper Michigan.

December 2013 Through March 2014 Pattern Overview

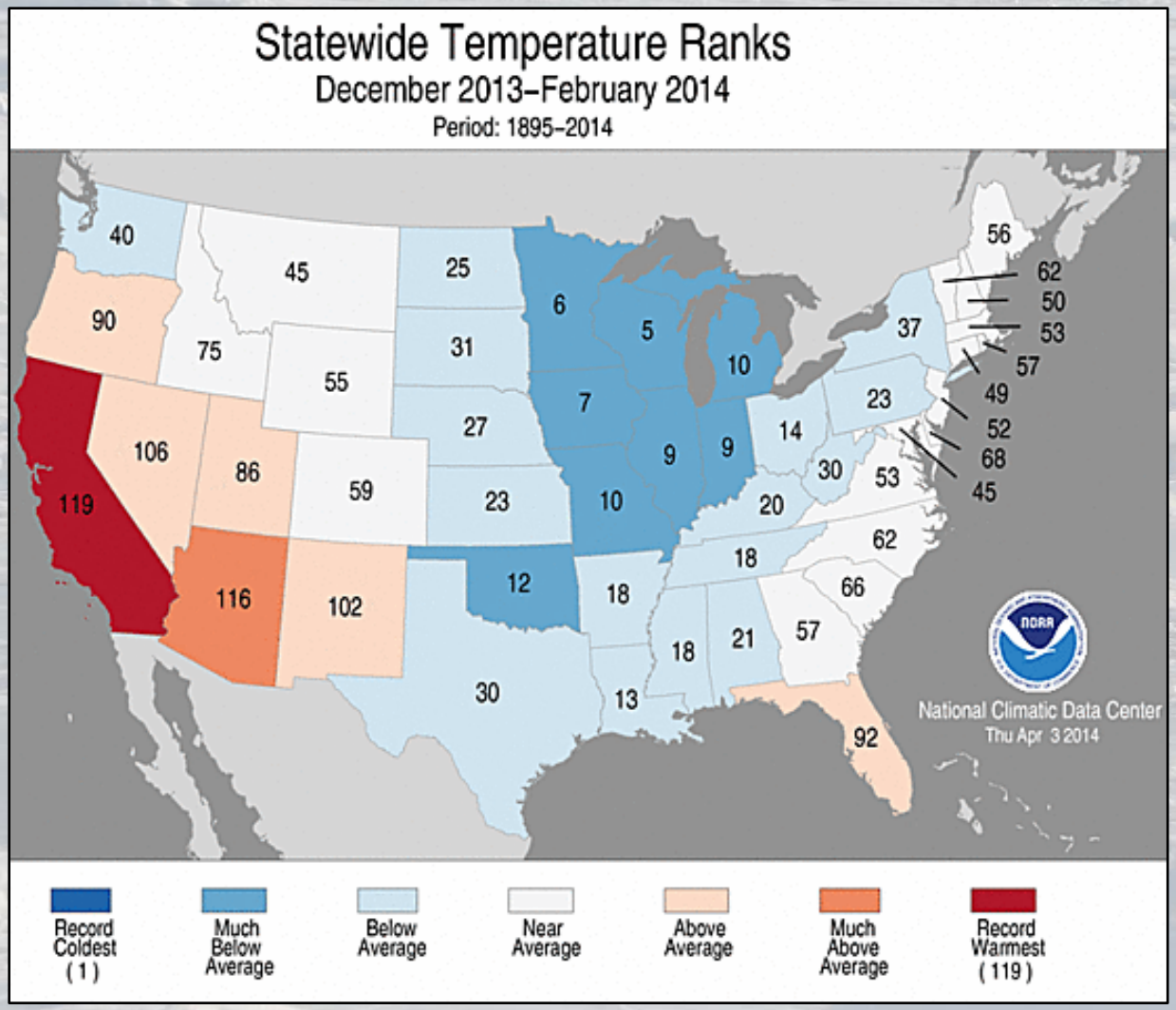


As shown in the image to the left, on average during the December through March period, a ridge was located near the west coast of North America with a deep trough extending from northern Canada into the central and eastern United States. This allowed for frequent transport of arctic air south into the central and eastern U.S.



As shown in the image to the left, the trough was deepest compared to long term climatology over northern Ontario and the Upper Great Lakes (darker purple shading). This implies that the coldest air compared to December through March climatology was positioned over northern Ontario and the Upper Great Lakes region.

December 2013 through February 2014 Temperatures

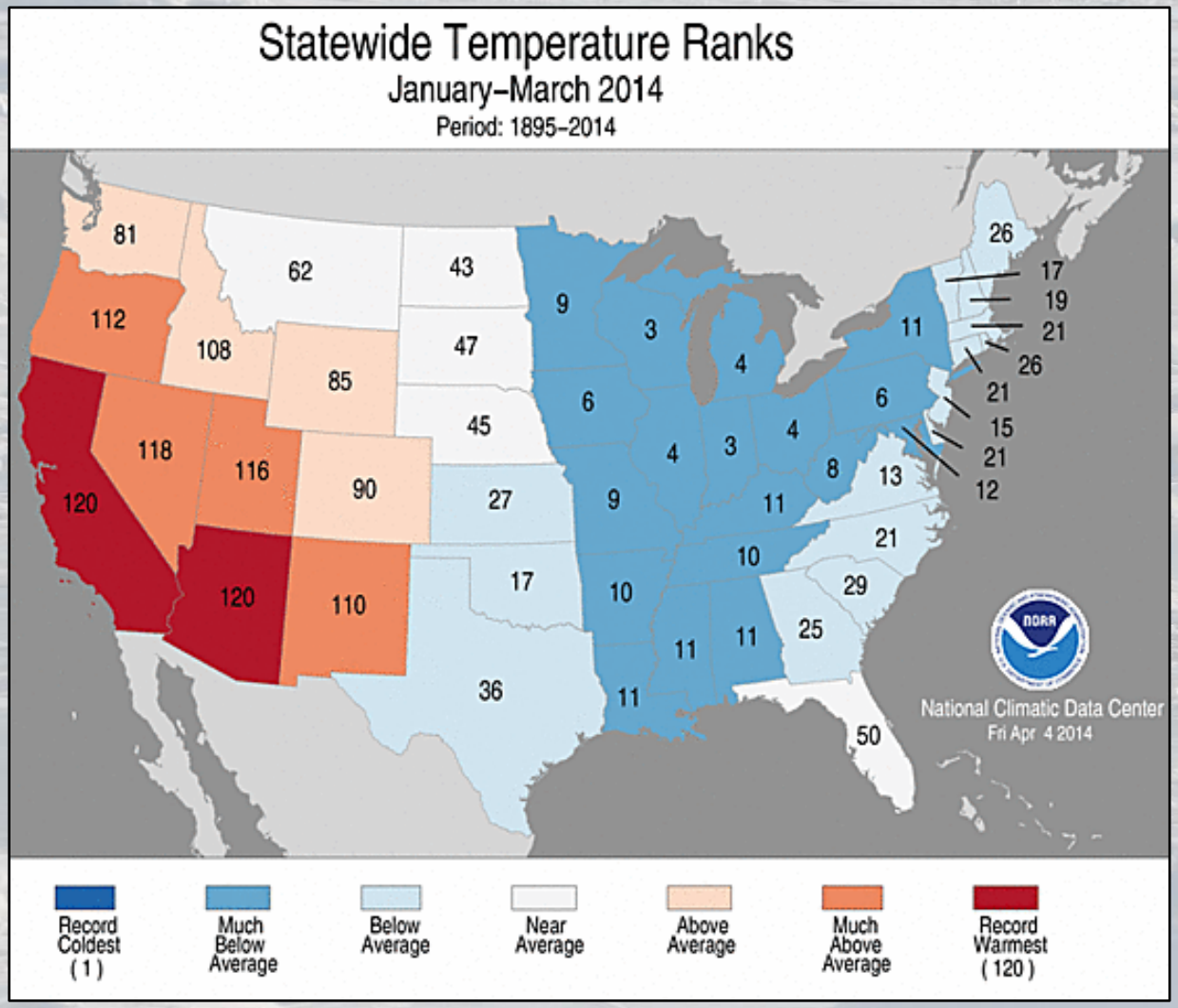


Out of 119 years of data, December 2013 through February 2014 ranked as the 10th coldest December through February on record for the state of Michigan and 5th coldest for the state of Wisconsin. Note that California had its warmest December through February on record.

Upper Michigan December 2013 through February 2014 Temperatures

Location	Rank	Mean Temperature (F)	Departure from Normal (F)	Record Lowest Mean Temperature (F)
Ironwood	Record coldest	5.1	-9.3	Previous 5.9 in 1978-79
Newberry	Record coldest	10.1	-9.1	Previous 11.0 in 1919-20
Iron Mountain	Record coldest	7.2	-8.8	Previous 8.7 in 1903-04
Manistique	Record coldest	11.4	-8.7	Previous 13.3 in 1976-77
Marquette NWS	Record coldest	7.5	-8.4	Previous 8.5 in 1976-77
Munising	2nd coldest	11.1	-9.0	9.1 in 1919-20
Houghton	2nd coldest	9.2	-8.4	8.8 in 1917-18
Marquette City	5th coldest	12.7	-8.3	11.2 in 1884-85

January 2014 through March 2014 Temperatures



Out of 120 years of data, January 2014 through March 2014 ranked as the 4th coldest January through March on record for the state of Michigan and 3rd coldest for the state of Wisconsin. Note that California and Arizona had the warmest January through March on record.

Upper Michigan December 2013 through March 2014 Temperatures

Location	Rank	Mean Temperature (F)	Departure from Normal (F)	Record Lowest Mean Temperature (F)
Ironwood	Record coldest	7.5	-9.6	Previous 10.3 in 1903-04
Marquette NWS	Record coldest	9.6	-8.4	Previous 12.2 in 1962-63
Iron Mountain	Record coldest	9.8	-9.9	Previous 12.7 in 1903-04
Houghton	Record coldest	10.7	-8.8	Previous 12.4 in 1911-12
Newberry	Record coldest	11.7	-9.5	Previous 13.9 in 1898-99
Munising	Record coldest	12.0	-10.0	Previous 12.4 in 1919-20
Manistique	Record coldest	12.4	-9.5	Previous 16.1 in 1958-59
Marquette City	3rd coldest	13.9	-9.2	11.5 in 1884-85

With the exception of Marquette City and Munising, note how much lower the December 2013 through March 2014 mean temperature was compared to the previous record coldest. With the period of record at Ironwood, Iron Mountain, Houghton, Newberry and Manistique dating back anywhere from 103 to 127 years, it is extremely impressive to break a 4 month mean temperature record by 2 to nearly 4 degrees. This emphasizes the point made at the beginning of this presentation that the persistence of the cold during winter and early spring was what made winter-early spring 2013-2014 so historic.

Other Notable Temperature Statistics and Records Set

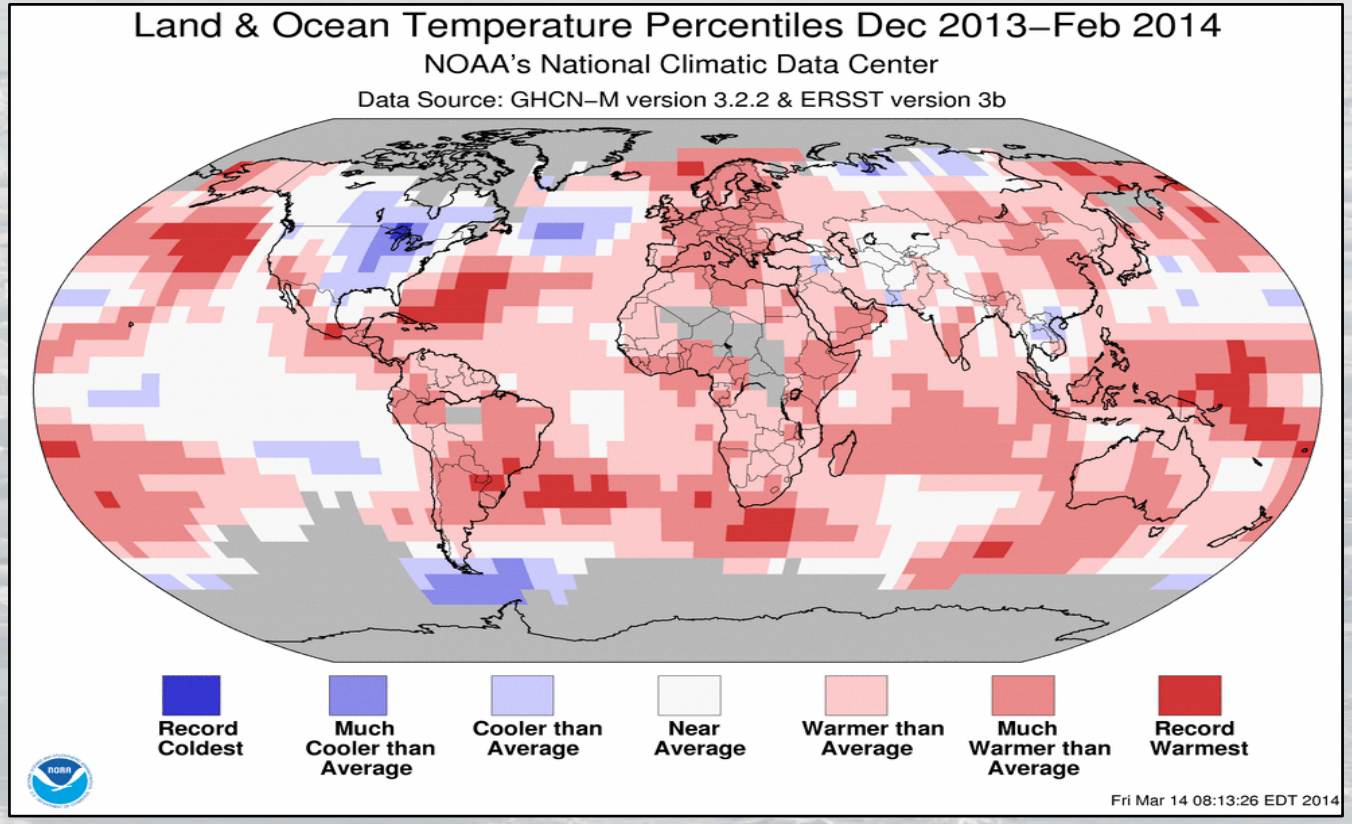
Location	Number of Days with High Temperature at or below 32 F	Beginning Date	End Date
Herman	90	November 22, 2013	February 19th 2014
Marquette NWS	75	December 6th, 2013	February 18th, 2014
Ishpeming	75	December 6th, 2013	February 18th, 2014
Ahmeek	53	December 28th 2013	February 18th 2014
Clarksburg	52	December 29th 2013	February 18th 2014
Watton	52	December 29th 2013	February 18th 2014

The 75 days at the Marquette NWS was a record. The previous record was 72 days beginning December 13th, 1978 and ending February 22nd, 1979.

Subzero Days

At the Marquette NWS, the temperature fell below zero on 65 days, setting a record. The previous record for subzero days during late fall through early spring was 57 set in 1962-1963. The record for the least number of subzero days is only 9, set just 2 years ago in 2011-2012. Over the last 53 years of records at the NWS location in Negaunee Township, the average number of subzero days from late fall through early spring is 32. NWS Marquette also recorded its latest subzero low temperature on record (-5 on April 16th) and its latest subzero maximum temperature on record (-1 on February 27th).

Global Temperature Departures for Dec 2013 through Feb 2014



Finally, from a global perspective, the only record cold temperature anomaly was centered over Lake Superior and Upper Michigan. Although below average temperatures dominated most of eastern North America, much of the globe experienced temperatures near or above average from Dec 2013 through Feb 2014 with respect to the historical record (80-135 years of data). In fact, the combined averaged temperature over global land and ocean surfaces for Dec through Feb was the 8th highest on record for this period at 1.03 F above the 20th century average. In the 135-year period of record, the Northern Hemisphere had its 8th warmest winter and the Southern Hemisphere tied with 2005 and 2013 for its 6th warmest summer. The Arctic sea ice maximum this winter was the 5th lowest in the 1978 to 2014 record.

A Forecast for the Winter of 2014-2015?

Long range, seasonal forecasting is a significant challenge, and at this point so early in the year, a forecast for the winter of 2014-2015 would have very little skill. However, in early May, the National Weather Service Climate Prediction Center (CPC) indicated that the chance of El Nino developing this summer exceeds 65 percent. Depending on its strength, El Nino can have a strong impact on winter temperatures over the Upper Great Lakes region.

- If El Nino is weak, it will have little affect on winter temperatures in Upper Michigan.
- If El Nino is moderately strong, there is an increased chance of above normal winter temperatures in Upper Michigan.
- If El Nino is strong, Upper Michigan will experience above normal winter temperatures.

The forecast of El Nino and its potential strength will be refined in the coming months. Until next winter, we have a soon to arrive Upper Michigan summer to enjoy.