The Historic March 2012 Heat Wave: *A Meteorological Retrospective*

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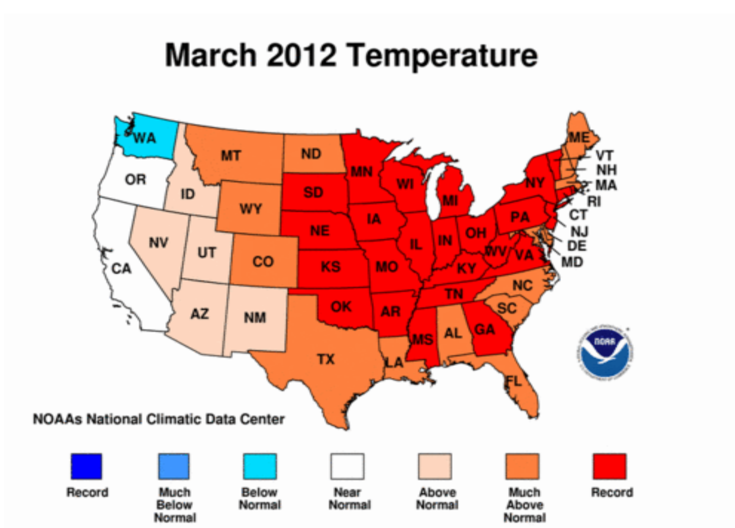
I. Introduction:

While most people were preparing to transition over to spring, this March had people believing that summer had already arrived. March 2012 was a month for the record books in northern Illinois and northwest Indiana! From the 14-23 of the month, the northeastern quadrant of the continental United States, as well as south central and southeastern Canada, experienced an unprecedented early season heat wave. There were many key factors that accounted for the incredibly far above-average temperatures this March, including the building of the upper-level ridge in the eastern US, the predominantly southerly flow, as well as the tight pressure gradient between the ridge in the east and the trough in the west.

The March 2012 heat wave had people breaking out in a sweat earlier than anticipated. Within this brief period of time, Chicago met or exceeded 9 previous temperature records in 9 straight days, whereas Rockford, IL, had broken 8 previously recorded high and low temperatures. Prior to March 2012, there had only been 10 days in March where temperatures had reached the 80 degree mark in Chicago, and only 12 in the Rockford area. This past month, we had 8 days alone reach 80 degrees in the Chicagoland area. Rockford temperatures reached 80 degrees 6 days in March. Chicago has only experienced such consecutive record breaking temperatures like this one other time before--back in late August and early September of 1953. Overall, this March shattered the previous record warmest March at historical climate sites across the area by an astounding 4 to 5 degrees, equating the largest difference between first and second place amongst record warm or cold months. With average temperatures for the month of March only in the upper 30s, this March finished with Chicago reporting an average temperature of 53.5 degrees and Rockford reporting an average of 52.4 degrees. Overall, Chicago experienced a 15.6 degree departure from normal, while Rockford a 15.2 degree departure from normal.

Figure 1.1

Figure 1.1 shows the distribution of temperature deviations across the continuous US in March 2012. The map depicts that many of the states in the eastern 1/2 – 2/3 of the US had an all-time record warm March



II. Meteorological Analysis:

When looking back on this past March, a number of key factors were present to give us our record setting temperatures. During the heat wave, a large and unusually strong upper level high-pressure ridge resided over much of the eastern half to two-thirds of the US. At the same time, an anomalously deep and slow moving upper level low-pressure system or trough brought cold weather and snow to many areas in the western third of the US. This produced a very tight west to east pressure gradient, shown in Figures 2.2 and 2.4, between the abnormally low pressures to the west and the abnormally high pressures to the east, which extended from the upper levels down to the lower levels of the atmosphere. The result of this tight pressure gradient was the formation of a strong southerly low-level (850 mb) jet (Figure 2.3), which persisted over the region for days due to the extremely slow moving nature of the weather pattern. This persistent southerly flow was a key component in allowing an air mass more typical of the Gulf of Mexico coastal region, to be transported northward across the Great Lakes. Furthermore, the remarkably persistent southerly flow also drew plenty of Gulf of Mexico moisture northward across our area, thus resulting in unseasonably humid conditions that also helped keep overnight temperatures extremely warm for mid and late March. The summer-like overnight temperatures provided an excellent springboard for the heat experienced during the daytime. In fact, during the heat wave, low temperatures were at or well above the normal high temperatures. The temperature departures from normal at the 850 millibar (mb) level (~5,000 foot) of the atmosphere nearly mirrored those at the surface, showing that the atmosphere was completely coupled from aloft down to the surface in terms of its incredible warmth.

Another factor was the fact that the ground temperatures in the northern tier of the country were running well above normal due to the very warm meteorological winter of 2011-2012, enhanced further by a lack of snow cover over much of the region during the winter. Although likely not a predominant factor, the warm ground temperatures may have contributed to the incredible heat by not suppressing the warmth for at least the first few days of the heat wave, as well as resulting in less efficient radiational cooling overnight.

Mid-level atmospheric 500 mb (~18,000 ft agl) geopotential height anomalies in dam (decameters) show the entire eastern portion of the United States under a positive anomaly (Figure 2.2). This deviation from the mean is indicative of much higher than normal heights (and pressures) over the northeastern quadrant of the US and much of southern Canada.

With the upper-level ridge in place, the anomaly correlated well with the regions experiencing record shattering warm temperatures (Figure 2.1). Surface temperature anomalies show an average of +15 degrees (F) over Northern Illinois. 850 mb wind vector anomalies show the highest deviations from the mean over Missouri and western Illinois, thus correlating with the placement of the lower-level jet (Figure 2.3).

Figure 2.1

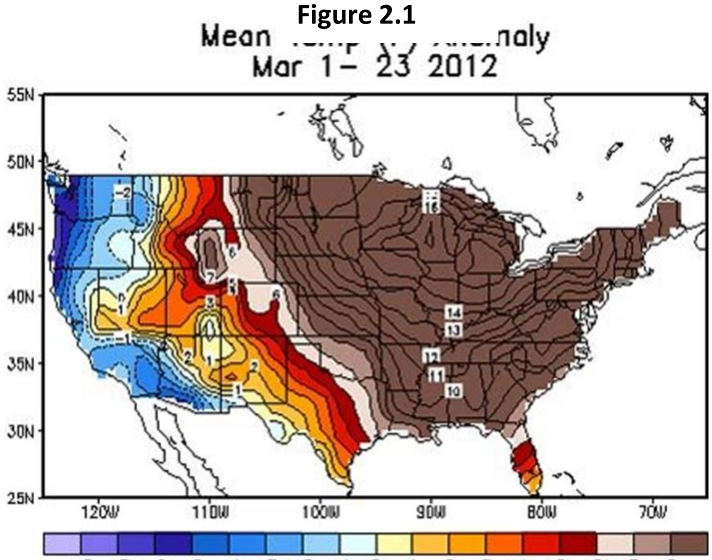


Fig. 2.1 shows the average surface temperature anomalies from March 1-March 23, 2012. Much of the upper Midwest exhibited a 15 degree departure from normal.

Figure 2.2

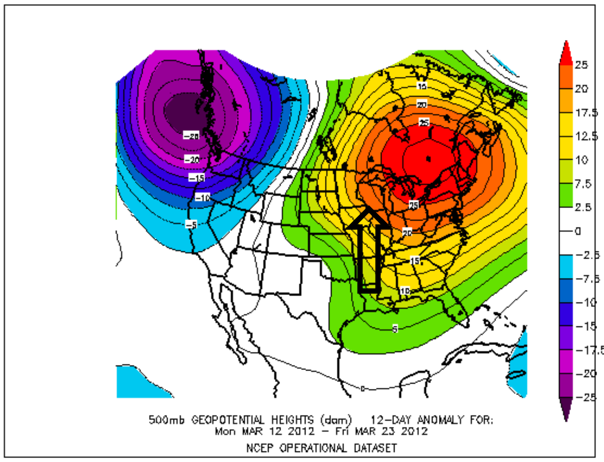


Figure 2.2 shows the 500 mb average geopotential height anomaly across the CONUS throughout the period of the heat wave. The upper Midwest exhibited a 10 dam above normal, corresponding well with the above average temperatures. The contours help to show that tight gradient between the high and the low, resulting in the persistent southerly low level jet in 2.3.

Figure 2.3

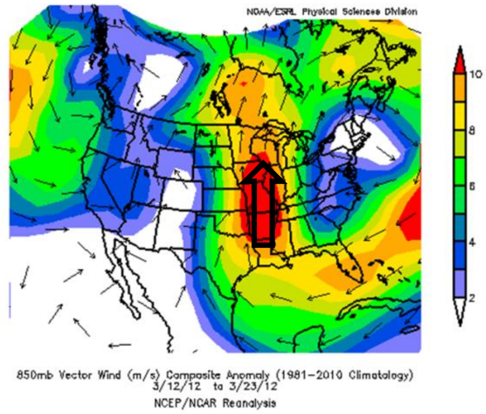


Figure 2.3 indicates the average 850 mb wind vector anomaly throughout the period of the heat wave. The arrow indicates the placement of the southerly low level jet.

Figure 2.4

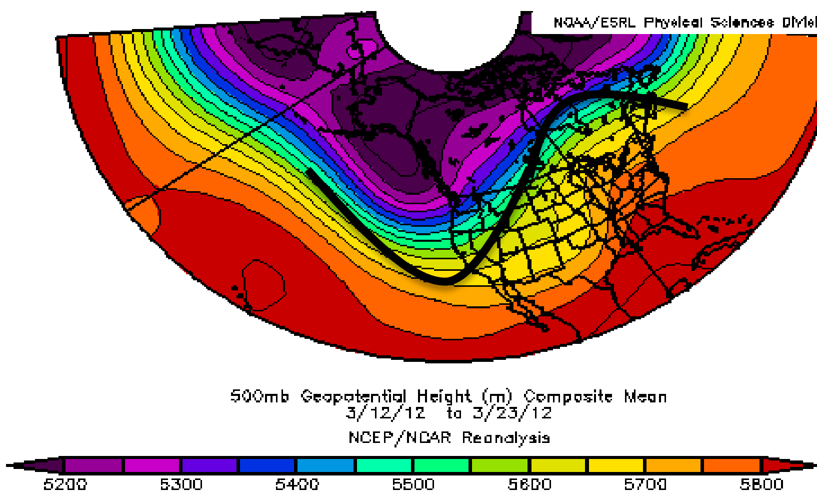


Figure 2.4 depicts the composite mean of the 500 mb geopotential height. The black line indicates the general placement of the trough in the west and the ridge in the east.

To conclude this meteorological analysis of the event, the upper level height configuration during the event, as shown above, was strongly indicative of the core of the jet stream (strong upper level winds that play a large role in the development and track of synoptic weather systems) being directed well north of the region. This not only kept cold air well north in Canada, but large scale weather systems were also deflected well to the north. Thus, aside from occasional very summer-like occurrences of pop-up type thunderstorms, most days of the heat wave featured plenty of sunshine, with all the days defined as clear to partly cloudy in the preliminary monthly climate data (F-6 form) for March at both Chicago and Rockford. In mid to late March, the mid-day sun angle and hours of daylight are roughly the equivalent of mid to late September. So, with the antecedent extremely warm conditions in place, given the multiple hours of sunshine experienced each day, temperatures were really able to soar, similar to very warm days typical in the late summer and early fall.

III. Teleconnection Analysis:

North Atlantic Oscillation (NAO) and Arctic Oscillation (AO)

While we were under the influence of weakening La Nina episode in the tropical Pacific Ocean in March, the NAO and AO were in a strongly positive phase during the height of the heat wave (see Figures 3.1 and 3.2). In strong positive phases of the NAO and AO in the cool season, the eastern portion of the US will typically experience above normal temperatures. For a more in-depth description of the NAO and AO, please visit the outlook for the remainder of the 2011-12 winter posted on December 22, 2011:

http://www.crh.noaa.gov/images/lot/newsletter/Rest_of_Winter_12_Outlook.pdf

The winter (Dec-Feb) temperature composites featured in the article for the NAO and AO during La Nina episodes are very similar to those for the month of March in regards to their placement of positive surface temperature anomalies.

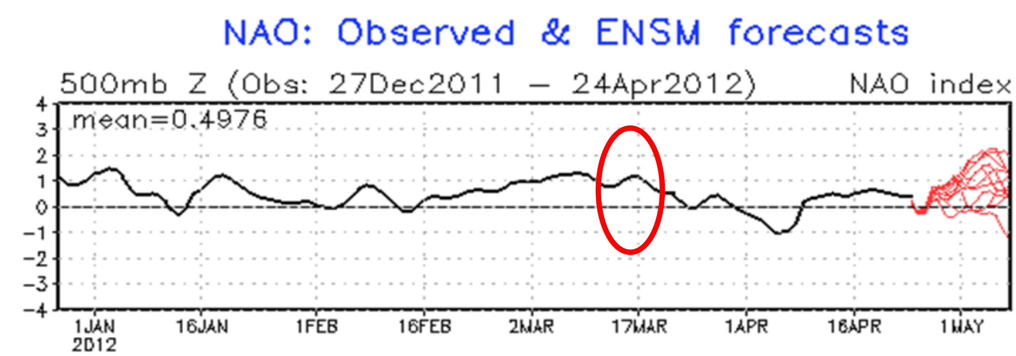


Figure 3.1

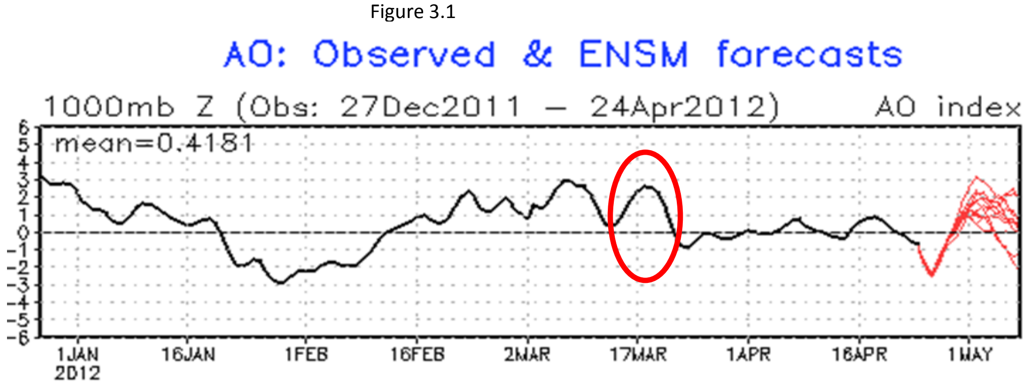


Figure 3.2

Figures 3.1 and 3.2 show the observed and forecasted North Atlantic Oscillation and Artic Oscillation phases. The observed phases of each are shown in black, whereas the forecasted phases are shown in red. The red circle on both charts highlights the positive phases of each oscillation in correlation with the time period of the heat wave.

The Madden-Julian Oscillation (MJO)

The MJO may have also played an important contributory role in the long duration period of summer-like warmth. The MJO is an eastward propagating tropical disturbance (related to enhanced and suppressed areas of tropical convection) that is thought to have impacts on ENSO. The phase (based upon the location from which the tropical convection is most enhanced) and strength of the MJO can impact atmospheric circulation patterns across the US, which can in turn influence surface temperature and precipitation patterns.

In mid-March, an MJO wave propagated into the Western Pacific (Phase 6) region, from the phase 5 region, on Figure 4.1. This figure is a phase diagram marking progression over time of the MJO through numbered MJO regions (phases), as well as the strength of the MJO wave (denoted by distance from the center circle of the solid MJO tracking line). From the diagram, you can see that this was a very strong MJO wave propagating from the phase 5 region into the phase 6 region (Western Pacific) during the time of the heat wave.

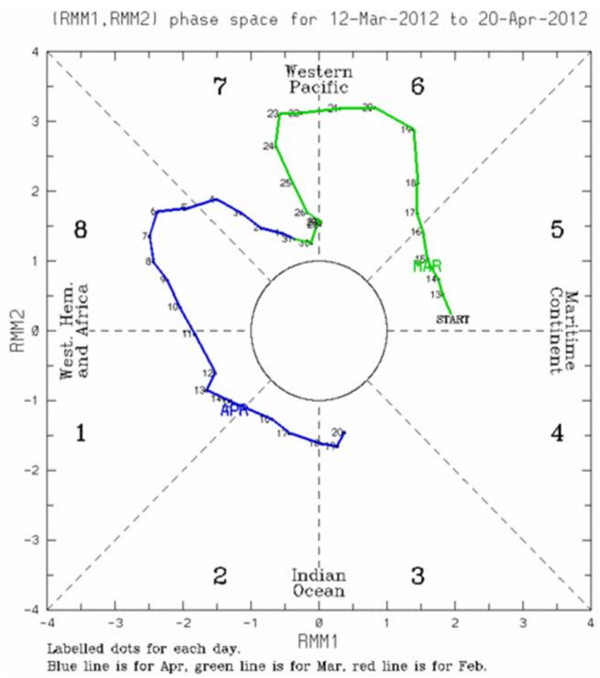


Figure 4.1

Figure 4.1 shows the phase diagram of the MJO from March 12-April 20, 2012.This shows that the MJO was strong in Phase 6 while it was over the Western Pacific during the time of our heat wave.

Figure 4.2

Figure 4.2 shows the temperature anomaly composite in correspondence with the phase 6 from the phase diagram. Red indicates areas with above average temperatures, while blue indicates areas with temperatures below average.

Figure 4.2 shows that phase 6 of the MJO in the January-March period correlates with much warmer than normal temperatures over the eastern half of the US, which matched well with the placement of the positive temperature anomalies in March, though the actual positive anomalies did extend farther northwest into the Northern Plains than on the composite. In fact, phase 5, which the MJO was in at the start of the heat wave, also correlates well with much above normal temperatures in the January to March period. Additionally, both of the above composites have shown a high level of statistical significance, increasing their usefulness and predictability. With this in mind, the phase and strength of the MJO is thought to have played a contributory role in our summer in March episode.

For more information on the MJO, please visit:

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/MJO_1page_factsheet.pdf - ***simple fact sheet***
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/MJO_summary.pdf - ***much more detailed description***

Furthermore, composite charts similar to that of Figure 2. can be found at this link:
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjo.shtml#composite.

IV. Conclusion:

Altogether, there were a number of factors responsible for the March 14-22, 2012 heat wave in northern Illinois and northwest Indiana. The almost stationary upper level high-pressure ridge over the eastern portion of the US, coupled with a very slow moving and deep upper level low pressure trough over the western third of the US, set up the perfect conditions for the record-breaking warm weather. The pressure gradient between the two systems generated a strong southerly low-level jet, which allowed for Gulf moisture to surge north into much higher latitudes than is typical for March. This access of moisture set the standard for our climbing temperatures and dewpoints throughout the time period. The jet stream pattern blocked the cold air to the north and west from shunting south and east. The unusually warm winter also kept ground temperatures warmer than usual. This may have lessened the cooling effect that colder ground temperatures can have over warm air masses.

Looking at mid and upper level height and wind anomalies also gives us a good idea of where to expect surface temperatures either above or below-average of the climatological mean. In March 2012, some of the prominent anomalies discussed for the period of the heat wave were 500 mb height anomalies and 850 mb wind vector anomalies. The 500 mb geopotential height pattern corresponded with the temperature anomalies by being approximately 10 dam above the climatological normal. 850 mb wind vector anomalies highlighted the unusually persistent and strong southerly low level jet into the region, which corresponded well with the southerly flow dominating the region throughout the time period at the surface. These two prominent positive anomalies contributed to the incredible 15-16 degree departures above normal for area historical observation sites.

Teleconnection patterns also likely contributed to the historic warmth that was experienced. The NAO and AO were simultaneously in their positive phases, which correlates to above average temperatures over much of the eastern portion of the US during the cool season. The MJO also may have played an important role; it was in a strong phase in the Western Pacific region during the heat wave, which according to January-March MJO composites, corresponds to well above normal temperatures over much of the area that experienced extreme heat in March 2012. Overall, the factors listed above are just a few of the many that helped produce the extreme heat during the March 14-22 heat wave, and ultimately resulted in March 2012 shattering the record for warmest March at historical climate sites across the region.

For more information regarding the heat wave in its entirety, please visit:

http://www.esrl.noaa.gov/psd/csi/events/2012/marchheatwave/index.htm

For a detailed local statistical summary of the record shattering heat wave, please visit:

http://www.crh.noaa.gov/news/display_cmsstory.php?wfo=lot&storyid=80740&source=2

V. References:

- "U.S. Climate at a Glance." http://www.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html. N.p., n.d. Web. 17 Apr. 2012. <http://www.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html>.

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- "Reflecting on the Historic & Unprecedented Warmth of March 2012." National Weather Service, Chicago, IL. N.p., n.d. Web. 17 Apr. 2012. <http://www.crh.noaa.gov/news/display_cmsstory.php?wfo=lot&storyid=80740&source=2>.