July 8, 2019

Special blog on winter 2018/2019 retrospective can be found here - http://www.aer.com/winter2019

Special blog on winter 2017/2018 retrospective can be found here - http://www.aer.com/winter2018

Special blog on winter 2016/2017 retrospective can be found here - http://www.aer.com/winter2017

Special blog on winter 2015/2016 retrospective can be found here - http://www.aer.com/winter2016

Dr. Judah Cohen from Atmospheric and Environmental Research (AER) recently embarked on an experimental process of regular research, review, and analysis of the Arctic Oscillation (AO) and Polar Vortex (PV). This analysis is intended to provide researchers and practitioners real-time insights on one of North America's and Europe's leading drivers for extreme and persistent temperature patterns.

With the start of spring we transitioned to a spring/summer schedule, which is once every two weeks. Snow accumulation forecasts will be replaced by precipitation forecasts. Also, there will be less emphasis on ice and snow boundary conditions and their influence on hemispheric weather.

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The AO/PV blog is partially supported by NSF grant AGS: 1657748.

Summary

- The Arctic Oscillation (AO) is currently strongly negative and is predicted to trend positive to over the next two weeks towards neutral.
- The current negative AO is reflective of positive pressure/geopotential height anomalies across the Arctic and mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is also negative as positive pressure/geopotential height anomalies are spread across Greenland and is predicted to remain mostly negative over the next two weeks as geopotential height anomalies are predicted to remain positive across Greenland.
- Troughing/negative geopotential height anomalies currently dominate much of Europe. However, troughing/negative geopotential height anomalies are

predicted to slide east into Western Russia allowing for ridging/positive geopotential height anomalies to dominate by the third week of July. This pattern favors normal to below temperatures across much of Europe for this week but especially Northern Europe with normal to above normal temperatures for Western Europe including the United Kingdom (UK) and Southern Europe. However, over time above normal temperatures are predicted to become more widespread across Europe.

- Ridging/positive geopotential height anomalies with relatively warm temperatures are predicted to dominate much of Asia with the exception of troughing/negative geopotential height anomalies with normal to below normal temperatures in Western Russia over the next two weeks. Troughing/negative geopotential height anomalies with normal to below normal temperatures will dominate Far East Asia especially over the next week.
- Currently troughing/negative geopotential height anomalies with normal to below temperatures dominate the United States (US) and Western Canada with ridging/positive geopotential height anomalies and relatively warm temperatures across Alaska and Eastern Canada. However, the forecast is for above normal geopotential heights and relatively warm temperatures to become more widespread across the Eastern US and into Eastern Canada over the next two weeks. One exception is a trough and accompanying cool temperatures that is predicted to enter the Pacific Northwest from the Gulf of Alaska.
- In the Impacts section I continue to discuss my thoughts about the long streak of high latitude blocking.

Impacts

The long streak of positive tropospheric polar cap geopotential heights (PCHs) and high latitude blocking seems to be waning. Positive geopotential height anomalies over the Central Arctic are predicted to transition to negative anomalies. But before discussing the implications of the transition of positive to neutral and possibly negative PCHs, I thought to share some reflections on this event.

In **Figure i**, I present the PCH plot from January 1st through June 30th. There appear to be two distinct stratosphere-troposphere coupling events this year dominated by positive/warm values. There also appears to be an impressive stratosphere-troposphere coupling event involving negative/cold PCHs in March, but I will not discuss this here. The first is the stratospheric polar vortex split in early January and subsequent “dripping” of positive/warm PCHs from mid-January through at least mid-February and the second is the Final Warming but was amplified by unusually late poleward heat flux/vertical wave driving. What followed is probably better described by a waterfall rather than a drip. The period from late April through late June may be the most impressive streak of positive PCH from the surface through at least the mid-stratosphere that I can recall and stands in stark contrast to the stratosphere-

troposphere coupling earlier in the year. In the earlier event the warm PCHs in the mid to lower troposphere were sporadic at best.

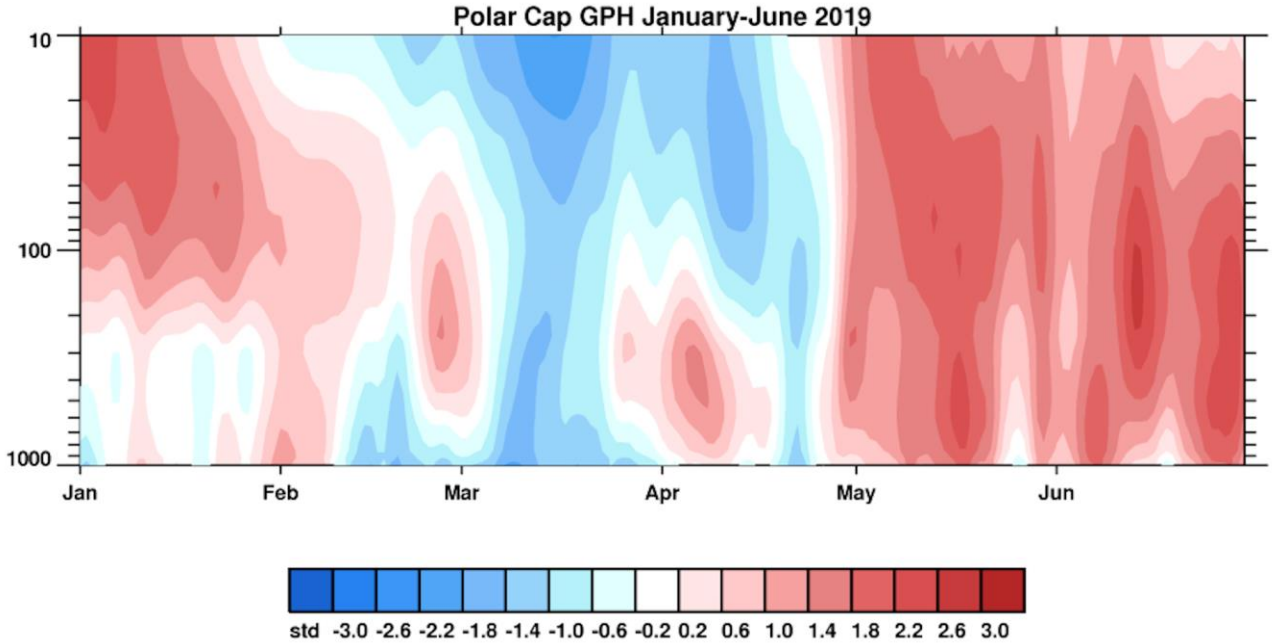

Figure i. Observed daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies from 1 January – 30 June 2019.

The obvious question to me why the difference? I don't have a good answer. In the February 18th blog I did discuss that the downward propagation of positive/warm PCHs is more emphatic during periods when the Arctic is relatively warmer. The Arctic was relatively warmer or more anomalously warm in late spring and early summer compared to mid-winter and that may be the best explanation. But had the downward propagation in January and February matched the similar coupling in May and June, I have no doubt this winter would have been strikingly different in the Eastern third of the US and in Northern Europe.

Though I don't think the influence on the hemispheric circulation was as dramatic as it would have been in the winter, still the influence on the early summer circulation/weather is fairly apparent. In **Figure ii**, I show the 500 hPa geopotential heights for June and early July. Strong high latitude blocking is evident with three dominant centers over Alaska, Greenland and the Laptev Sea. Each blocking/positive height center forced downstream troughing with relatively cool temperatures. The center over the Laptev Sea forced troughing over East Asia, the center over Alaska combined with the center over Greenland forced broad troughing over much of the US and the center over Greenland forced troughing in the eastern North Atlantic and the western Russia. In winter, blocking over Greenland would have likely forced a trough

over Northern Europe and not the Urals. In summer the wavelengths shorten relative to winter and this allowed for ridging over Europe; but why was Europe under a ridge and not a trough I don't have a good explanation. But as I discussed previously, there is a strong trend for ridging over Europe and troughing over Western Russia and this is clearly continuing into this summer, almost regardless of the circulation elsewhere across the hemisphere.

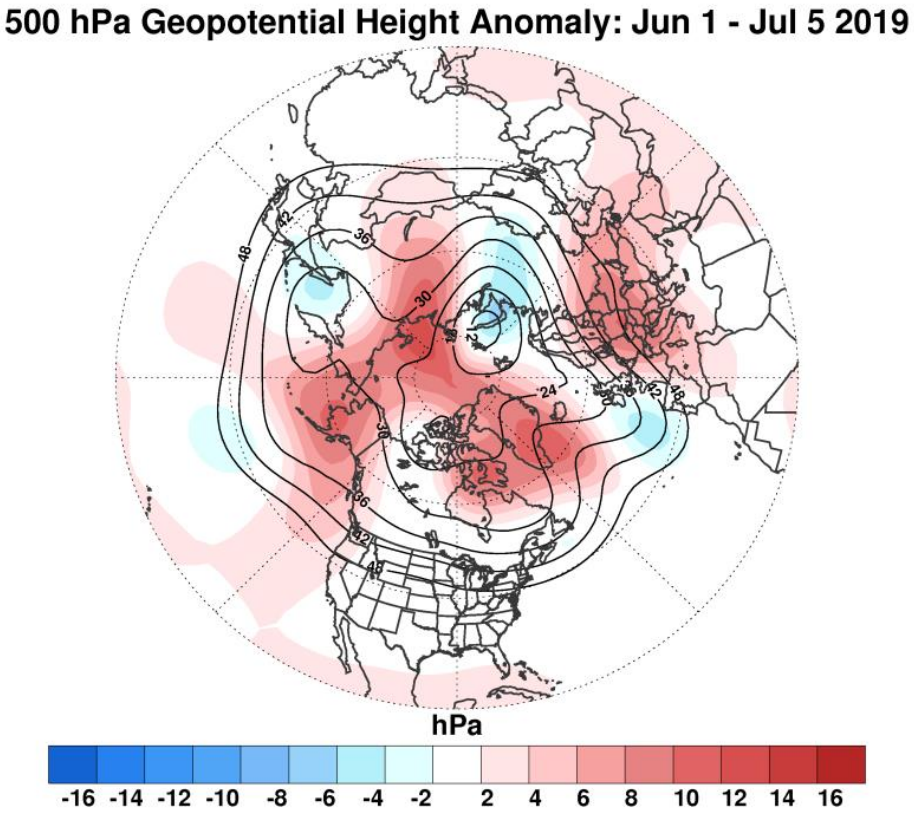

Figure ii. Observed average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 1 June – 5 July 2019.

Finally, in **Figure iii** I show the surface temperature anomalies so far this summer. Overall temperatures are above normal across the Northern Hemisphere (NH) but below normal regionally under the mid-latitude troughing downstream of the high latitude blocking centers across much of the US, parts of Canada, far Western Europe, Western Russia and parts of Northeast Asia. I do believe that the late season stratosphere-troposphere coupling of 2019 has been more influential on our weather than is typical for summer.

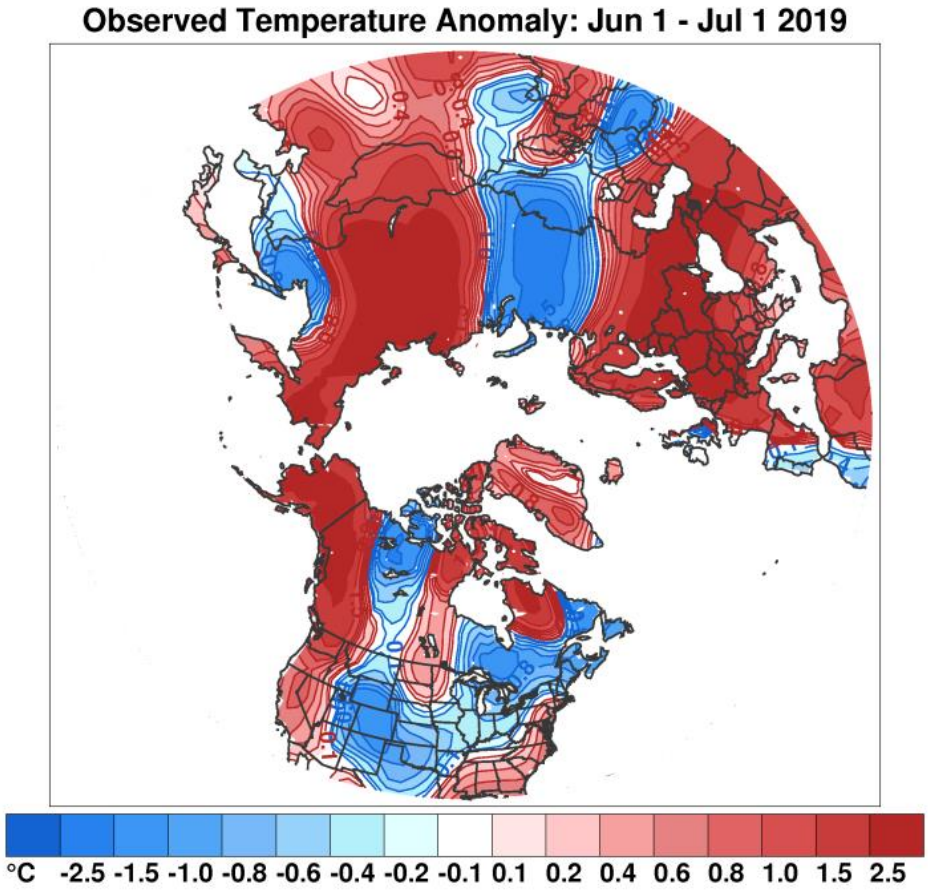

Figure iii. Observed surface temperature anomalies (°C; shading) across the Northern Hemisphere from 1 June – 1 July 2019.

Though the active season of stratosphere-troposphere coupling is usually winter in the NH, the active season is spring in the Southern Hemisphere (SH). In the SH the polar vortex (PV) is too strong and wave driving too weak to cause major PV disruptions. Presumably (if you are disappointed in the adverb, I am just admitting that my knowledge of the SH dynamics is lacking) the stratospheric PV becomes vulnerable to wave driving only once the PV weakens due to incoming solar radiation and that is when stratosphere-troposphere coupling is possible. I don't have a good example of PCHs for the Southern Hemisphere other than this plot of the correlation of ozone anomalies with the PCH in the Southern Hemisphere (**Figure iv**). When ozone is high PCHs are positive/warm in the stratospheric PV in October and November and the positive/warm propagate down to the surface in the early winter. This result was first shown in Thompson and Solomon 2002). It does seem to me that the best analog for

the strong stratosphere-troposphere coupling this spring and summer in the NH is SH stratosphere-troposphere coupling also in the spring.

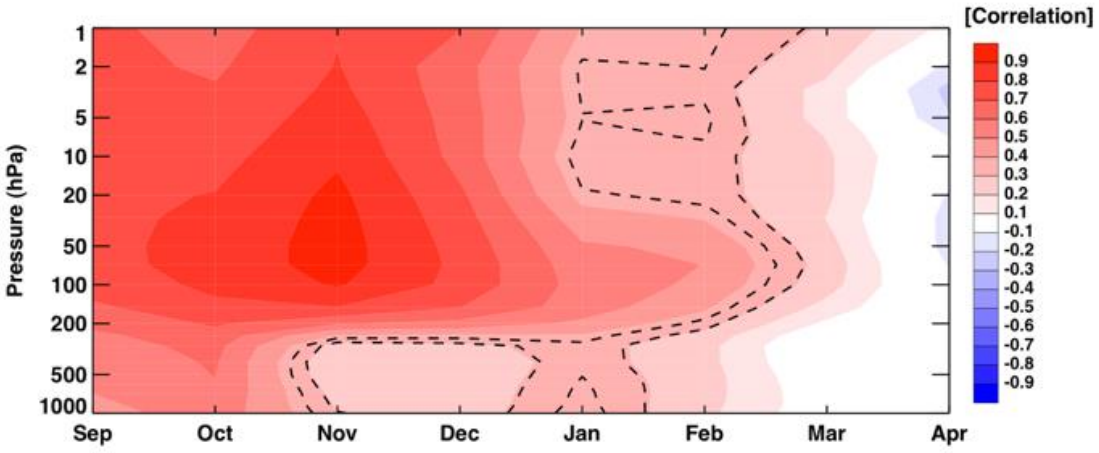

Figure iv. Correlation of stratospheric ozone anomalies with Southern Hemsiphere polar cap geopotential height anomalies.

Now that the streak of positive/warm PCHs and high latitude blocking seems to be coming to an end what should we expect for the remainder of the summer. With a more typical summer circulation in place I can see no better rule than "the trend is your friend." I would expect wide-spread, almost universal above normal temperatures across the NH continents. The most likely exception being Western Russia, which is also consistent with the trend for reasons that I can't explain. Some residual blocking is predicted to persist across Greenland so more cool weather in the Northeastern US and/or Western Europe seems possible as well.

Near Term Conditions

1-5 day

The AO is currently strongly negative **(Figure 1**) with positive geopotential height anomalies across the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with positive geopotential height anomalies across Greenland and Iceland (**Figure 2**), the NAO will be negative this week as well.

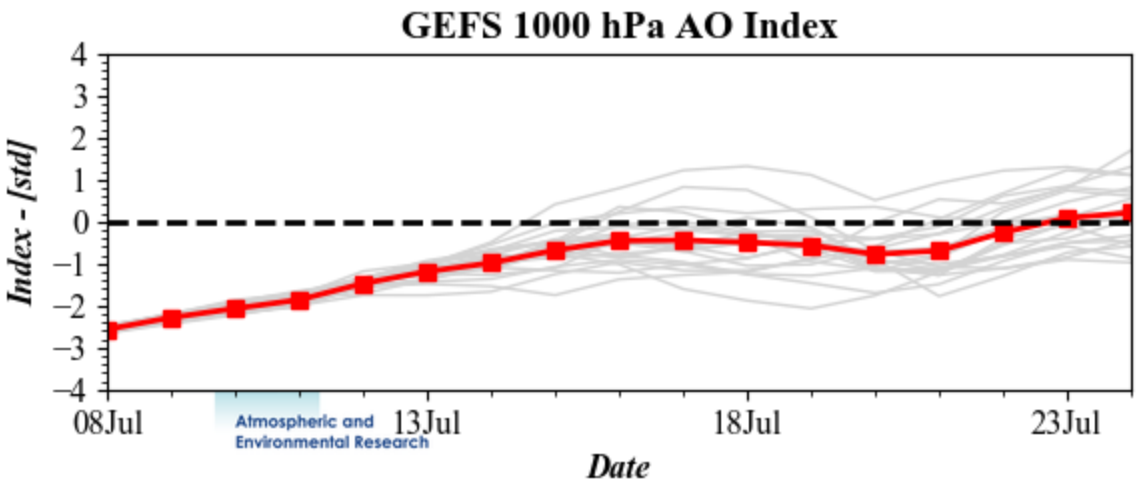

Figure 1. The predicted daily-mean AO at 10 hPa from the 00Z 8 July 2019 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Troughing/negative geopotential height anomalies centered over Eastern Europe will dominate much of Europe with ridging/positive geopotential height anomalies limited to Western and Southern-most Europe (**Figure 2**). This pattern is predicted to result in normal to below normal temperatures across much of Europe except for normal to above temperatures across Western Europe including the UK and along the Mediterranean (**Figure 3**). Much of Southwestern, Central and Northeastern Asia will be dominated by ridging/positive geopotential height anomalies with troughing/negative geopotential height anomalies in Western Russia and Southern and Eastern Asia (**Figure 2**). This is predicted to yield normal to above normal temperatures for much of Asia including the Middle East, Central Asia, Siberia and Southeast Asia and normal to below normal temperatures Western Russia and Far East Asia including Eastern China, Korea and Japan **(Figure 3**).

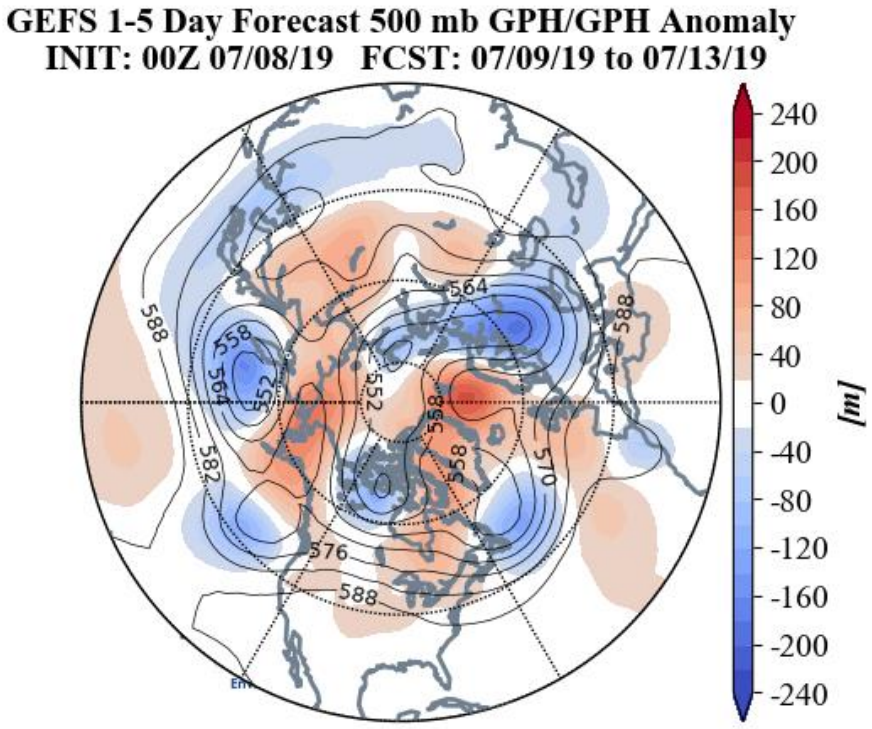

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 9 – 13 July 2019. The forecasts are from the 8 July 00z GFS ensemble.

Ridging/positive geopotential height anomalies stretch from Alaska down along the west coast of North America with weak geopotential height anomalies downstream across the remainder of North America (**Figure 2**). This pattern is predicted to bring normal to above normal temperatures in Alaska, the West Coast of Canada, and Eastern Canada with normal to below normal temperatures for much of the US and Northwestern Canada **(Figure 3).**

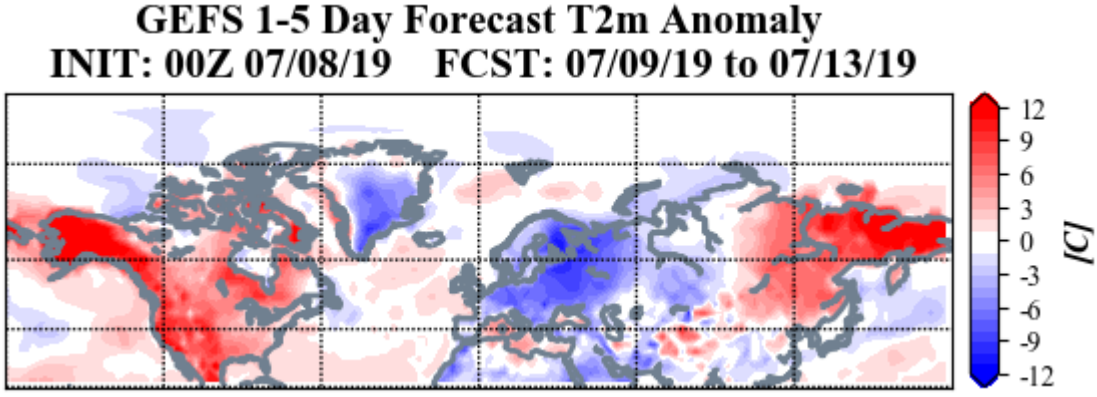

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 9 – 13 July 2019. The forecast is from the 00Z 8 July 2019 GFS ensemble.

Much of Eurasia is predicted to receive below normal precipitation (**Figure 4**). Troughing is predicted to bring above normal rainfall to the Spain, the monsoon region of Southeast Asia and the Eastern US (**Figure 4**).

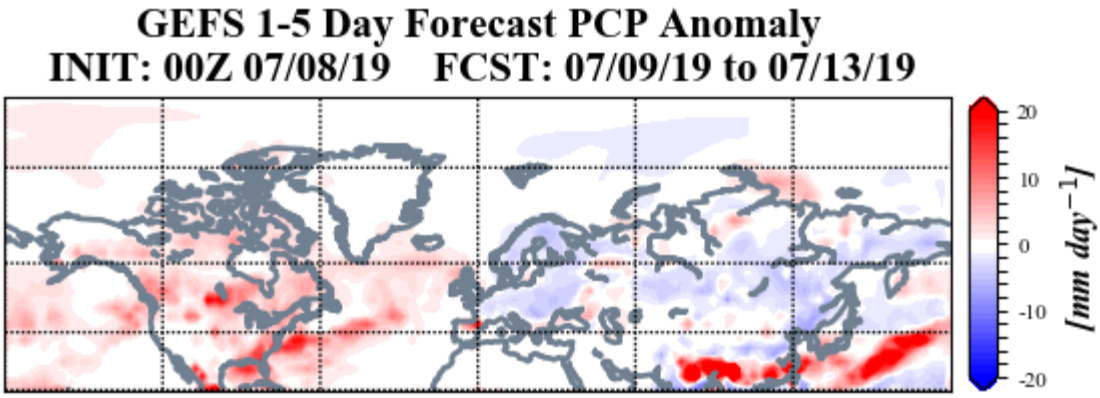

Figure 4. Forecasted rainfall anomalies (mm/day; shading) from 9 – 13 July 2019. The forecast is from the 00Z 8 July 2019 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain weakly negative this period **(Figure 1**) with mixed geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with persistent positive geopotential height anomalies across Greenland (**Figure 5**), the NAO will likely remain negative as well.

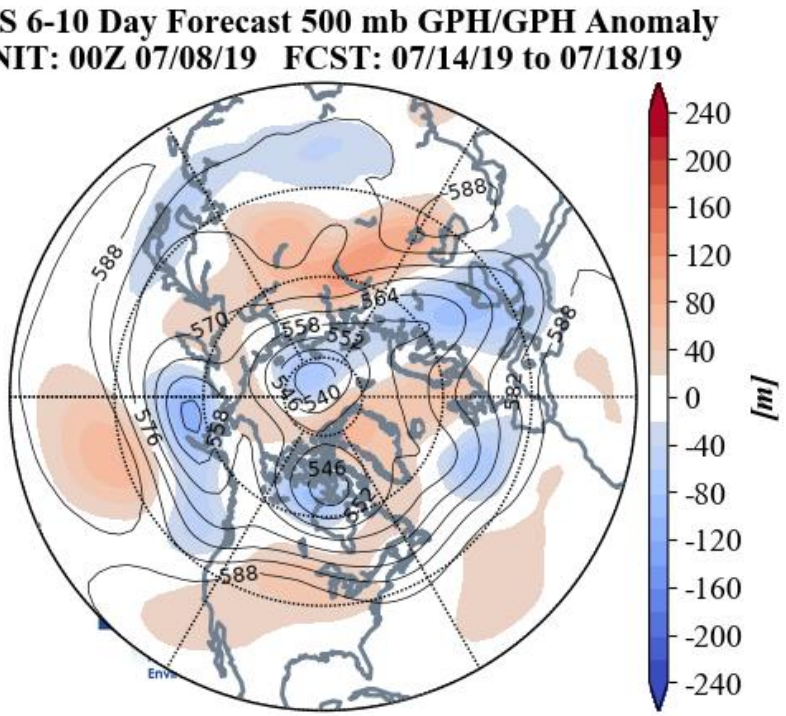

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 14 – 18 July 2019. The forecasts are from the 8 July 00z GFS ensemble.

Ridging/positive geopotential height anomalies previously confined to far Western Europe are predicted to slowly spread into Central Europe this period as troughing/negative geopotential height anomalies in Eastern Europe slowly slide into Western Russia (**Figure 5**). This pattern is predicted to result in normal to above normal temperatures across much of Western and Central Europe including the UK with normal to below normal temperatures across Eastern Europe (**Figure 6**). Cool temperatures are possible again across Portugal (**Figure 6**) due to proximity of continuing mid-tropospheric troughing in the eastern North Atlantic (**Figure 5**). Ridging/positive geopotential height anomalies are predicted to dominate much of the interior of Asia with troughing/negative geopotential height anomalies in Western Russia and Southern and Eastern Asia (**Figure 5**). This is predicted to yield widespread normal to above normal temperatures for much of Asia including the Arabian Peninsula and Southeast Asia with normal to below normal temperatures across Western Russia, the northern Middle East, the Tibetan Plateau region, parts of Eastern China, South Korea and Japan **(Figure 6**).

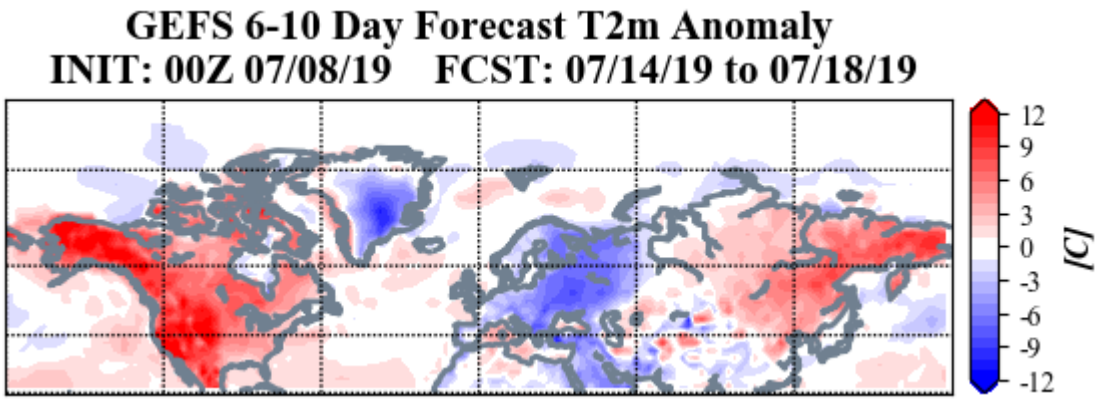

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 14 – 18 July 2019. The forecasts are from the 00Z 8 July 2019GFS ensemble.

Ridging/positive geopotential height anomalies previously over Alaska and the West Coast of Canada are predicted to slide east over the Eastern US and Eastern Canada as troughing/negative geopotential height anomalies previously near the Dateline begin to overspread Alaska and the Gulf of Alaska (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across Alaska, much of Canada and the US with normal to below normal temperatures for Northwestern Canada and around the Gulf of Mexico **(Figure 6).**

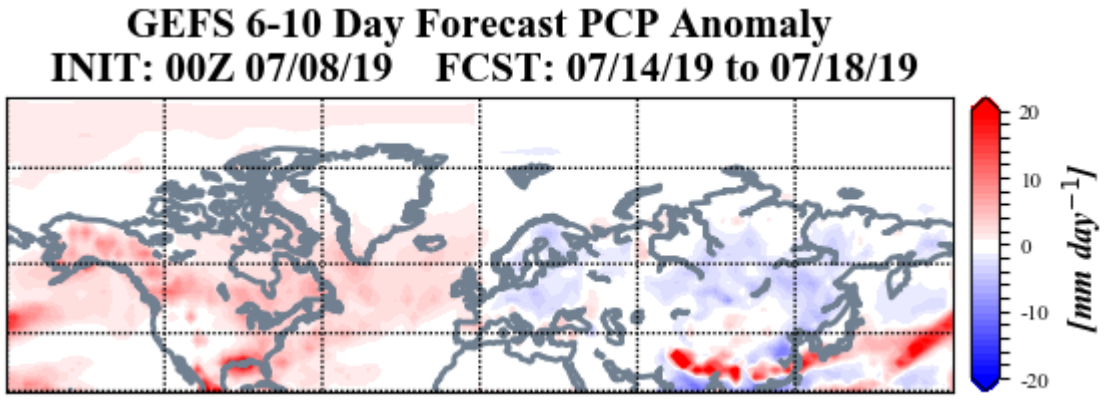

Figure 7. Forecasted rainfall anomalies (mm/day; shading) from 14 – 18 July 2019. The forecasts are from the 00Z 8 July 2019 GFS ensemble.

Much of Eurasia is predicted to receive below normal precipitation (**Figure 7**). Troughing is predicted to bring above normal rainfall to the Spain, the monsoon region of Southeast Asia, Western Canada and the Eastern US (**Figure 7**).

11-15 day

With mixed height anomalies predicted for the Arctic (**Figure 8**), the AO is likely to remain negative to neutral this period (**Figure 1**). With predicted mostly positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is likely to be slightly negative this period.

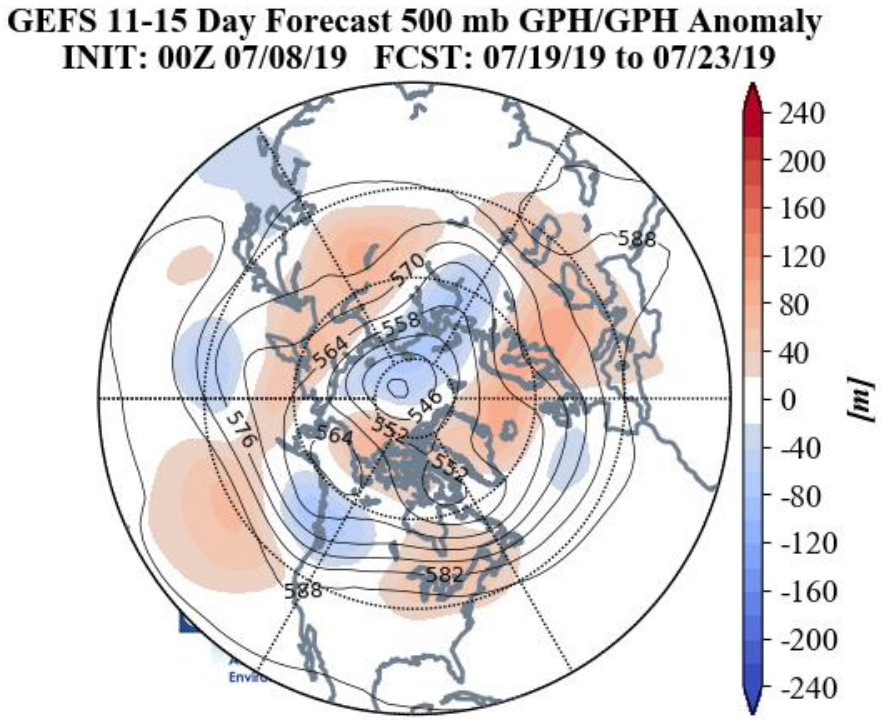

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 19 – 23 July 2019. The forecasts are from the 8 July 00z GFS ensemble.

Troughing/negative geopotential height anomalies previously in Eastern Europe are predicted to continue sliding east allowing ridging/positive geopotential height anomalies previously confined to Western Europe to overspread much of Europe this period (**Figure 8**). This pattern is predicted to result in seasonable to above normal temperatures for most of Europe including the UK (**Figure 9**). Little change is predicted for Asia this period. Ridging/positive geopotential height anomalies are predicted to dominate Central Asia and Siberia this period with troughing/negative geopotential height anomalies in Western Russia and Far East Asia (**Figure 8**). This pattern favors normal to above normal temperatures for most of Asia including Southeast Asia and the Middle East with normal to below normal temperatures in Western Russia, the Tibetan Plateau region, parts of Eastern China and Japan (**Figure 9**).

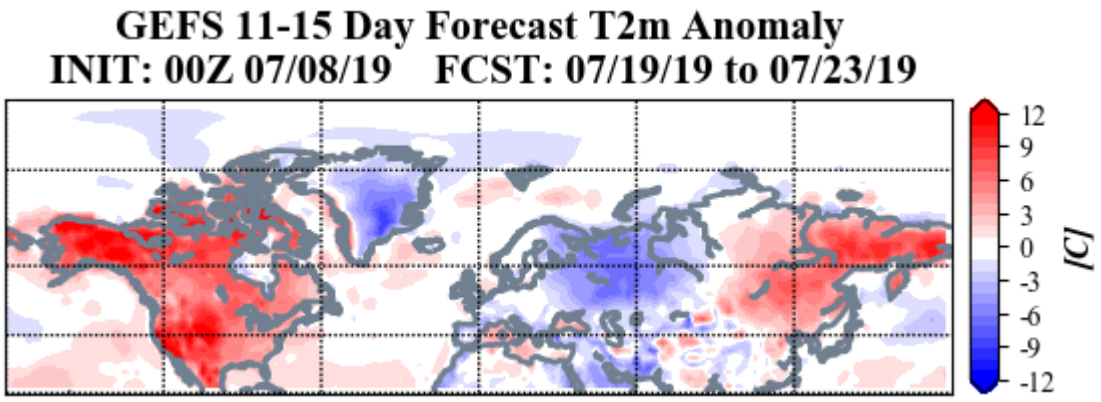

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 19 – 23 July 2019. The forecasts are from the 00Z 8 July 2019 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to dominate much of eastern North America with troughing/negative geopotential height anomalies in western North America (**Figure 8**). This will favor normal to above normal temperatures across Alaska, much of Northern and Eastern Canada and the US with normal to below normal temperatures for Southwestern Canada and the US Pacific Northwest (**Figure 9**).

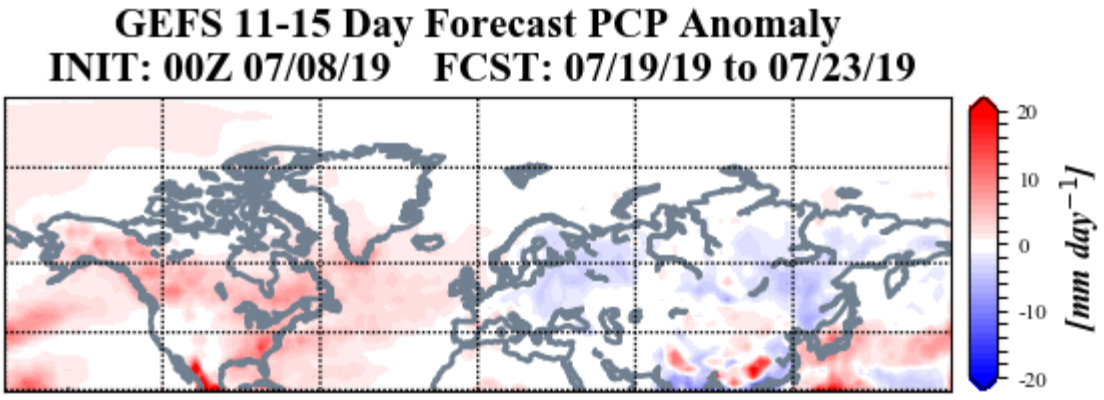

Figure 10. Forecasted rainfall anomalies (mm/day; shading) from 19 – 23 July 2019. The forecasts are from the 00Z 8 July 2019 GFS ensemble.

Much of Eurasia is predicted to receive below normal precipitation (**Figure 10**). Troughing is predicted to bring above normal rainfall to the Spain, the monsoon regions of Southeast Asia and Mexico and the Eastern US (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential heights (PCHs) shows currently normal to below normal PCHs in the stratosphere and above normal PCHs throughout the troposphere (**Figure 11**). In the lowest troposphere PCHs are above normal, consistent with a negative AO (**Figure 1**).

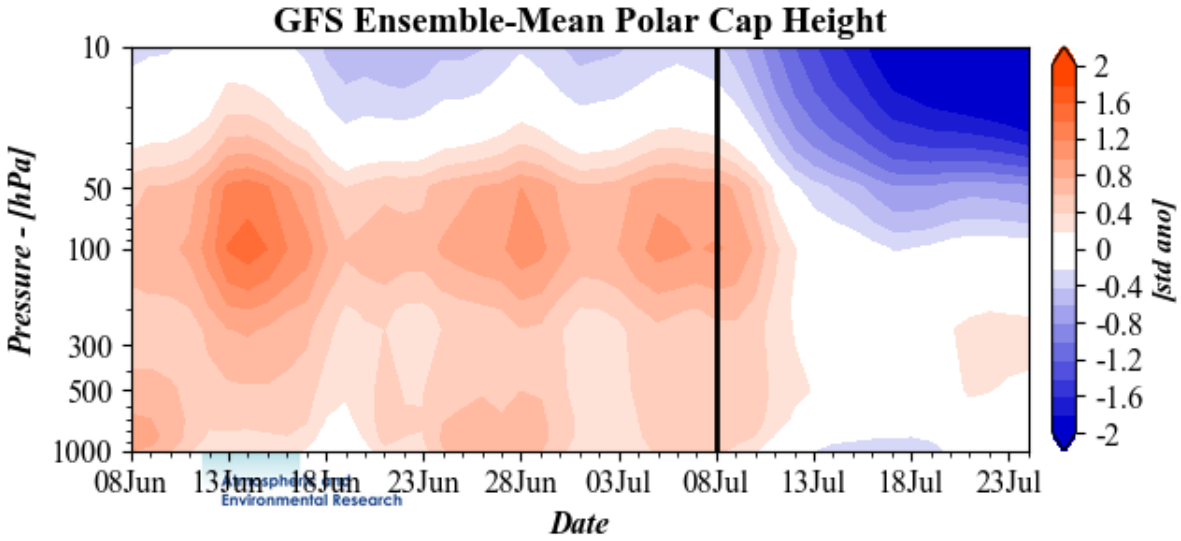

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 8 July 2019 GFS ensemble.

Positive PCHs in the mid to lower troposphere are predicted to weaken close to normal by the end of the week consistent with a predicted neutral trend in the AO (**Figure 11**). The return of near normal PCHs in the troposphere and even the possibility of negative PCHs in the lower troposphere suggest a decreased probability of high latitude blocking coupled with more ridging in the mid-latitudes. Therefore, I believe that the overall GFS forecast of widespread warm temperatures across the mid-latitudes is consistent with the PCH forecast.

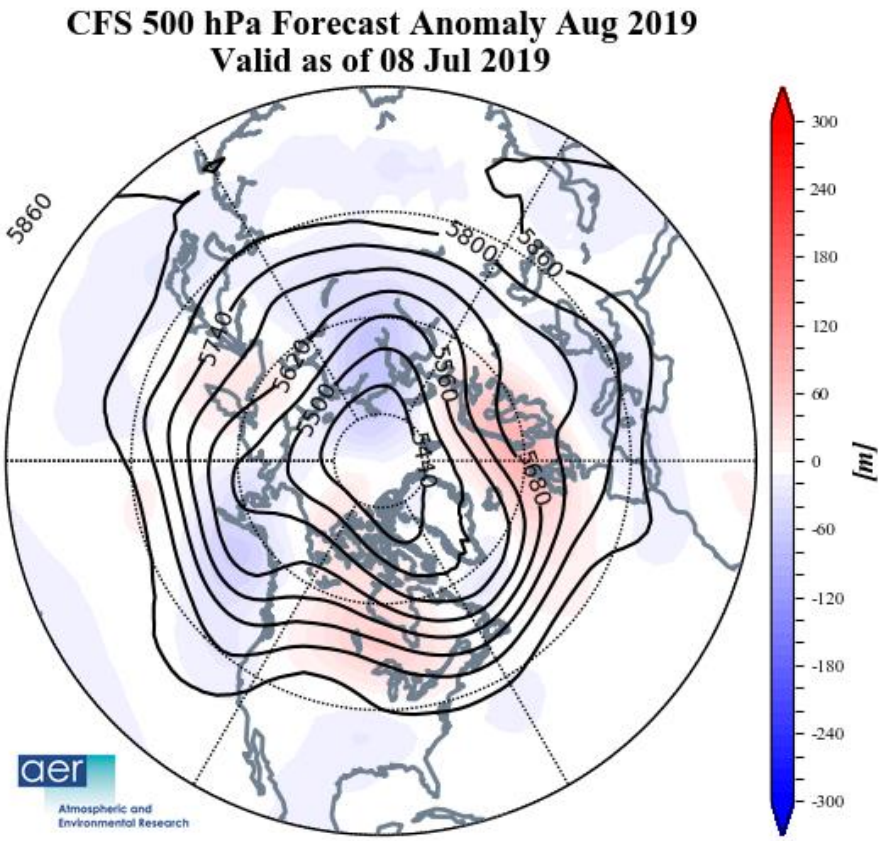

Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for August 2019. The forecasts are from the 8 July 2019 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and the surface temperatures (**Figure 13**) forecast for August from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging centered across Northern Europe, Northeast Asia, the Dateline, Central and Eastern Canada with troughs in Southern Europe, Western Russia, Southeast Asia, Alaska, the Gulf of Alaska and the Southeastern US (**Figure 12).** This pattern favors relatively cool temperatures for Southern Europe, Western and Southeast Asia, Alaska and possibly the Southeastern US with relatively warm temperatures for Northern Europe, Northeast Asia and much of Canada and the Northern US (**Figure 13**)**.**

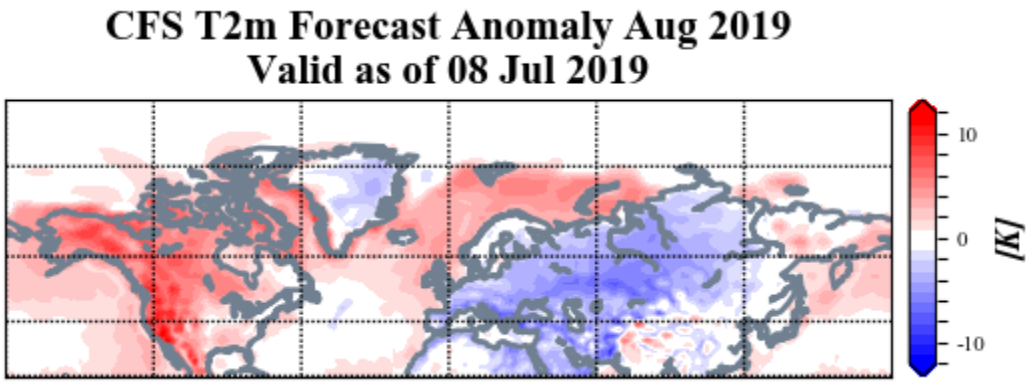

Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for August 2019. The forecasts are from the 8 July 2019 CFS.

Surface Boundary Conditions

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies have cooled and whether El Niño conditions will continue has become questionable (**Figure 14**). Observed SSTs across the NH remain well above normal especially near Alaska though below normal SSTs exist regionally especially west of South America.

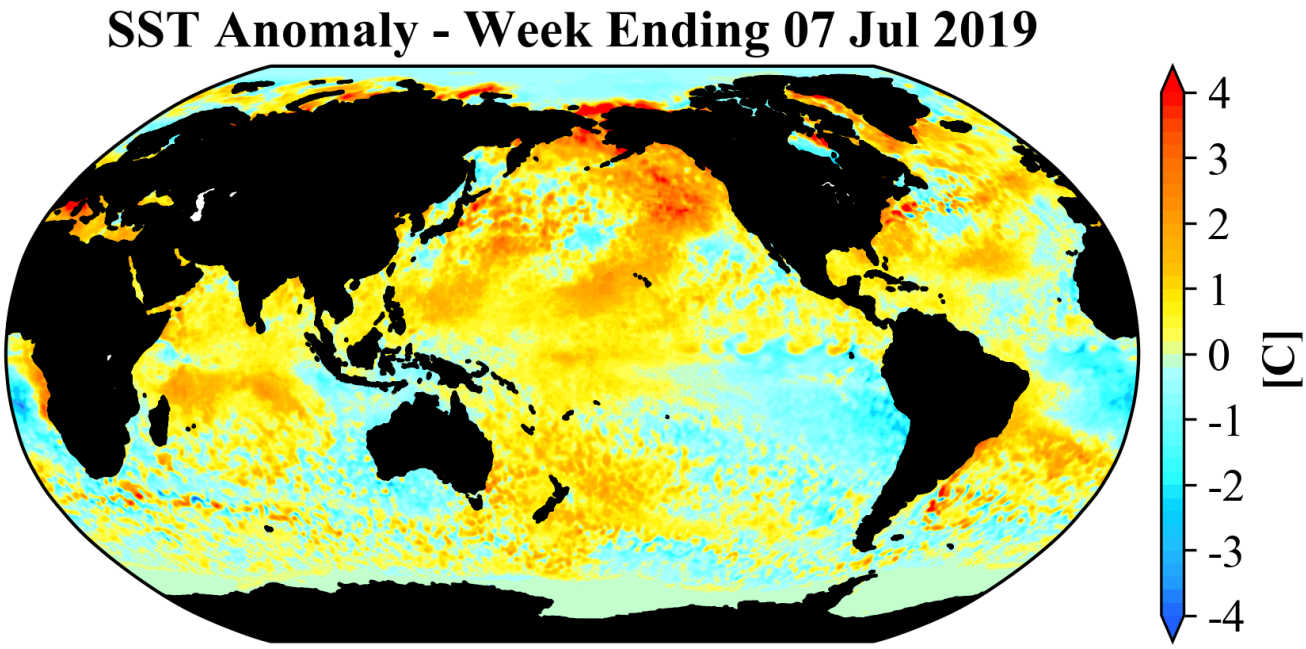

Figure 14. The latest weekly-mean global SST anomalies (ending 7 July 2019). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase one (**Figure 13**). And the forecasts are for the MJO to enter phase two and then where no phase of the MJO is favored. Phases one and two favor formation of ridging in the Northeastern US and troughing in Western Canada consistent with the model forecasts.

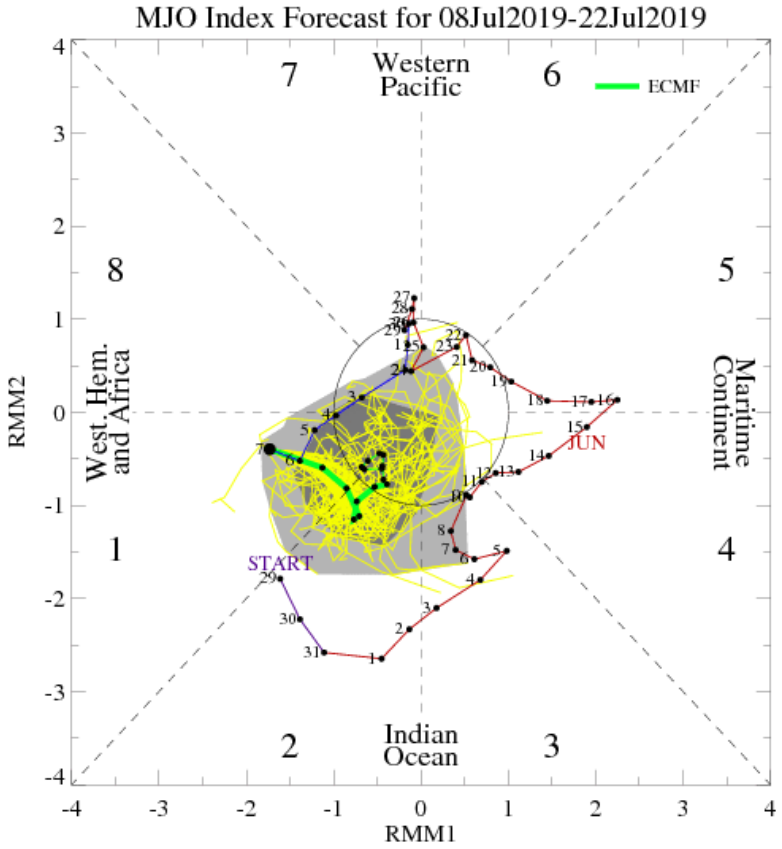

Figure 13. Past and forecast values of the MJO index. Forecast values from the 00Z 8 July 2019 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate the phase of the MJO, with geographical labels indicating where anomalous convection occurs during that phase. Image source: http://www.atmos.albany.edu/facstaff/roundy/waves/phasediags.html