Arctic Oscillation and Polar Vortex Analysis and Forecasts

July 6, 2020

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.

During the winter schedule the blog is updated once every week. Snow accumulation forecasts replace precipitation forecasts. Also, there is renewed emphasis on ice and snow boundary conditions and their influence on hemispheric weather. With the start of spring we transition 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 near neutral and is predicted to remain neutral to slightly negative over the next two weeks.
- The current neutral AO is reflective of mixed pressure/geopotential height anomalies across the Arctic with mixed pressure/geopotential height anomalies

across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently also neutral with weak pressure/geopotential height anomalies spread across Greenland; and the NAO is predicted to remain near neutral the next two weeks as pressure/geopotential height anomalies remain weak across Greenland and Iceland.

- The predicted weather pattern for Europe including the United Kingdom (UK) this week is general troughing/negative geopotential height anomalies with normal to below normal temperatures. However next week, ridging/positive geopotential height anomalies will strengthen across Northern Europe bringing with it warming temperatures across Europe including the UK.
- The predicted general pattern for Asia this week is ridging/positive geopotential height anomalies with normal to above normal temperatures in Western Asia with troughing/negative geopotential height anomalies with normal to below normal temperatures in Eastern Asia. However, next week ridging/positive geopotential height anomalies and above normal temperatures are predicted to become more widespread across Asia, especially Northern Asia.
- This week, troughing/negative geopotential height anomalies accompanied by normal to below normal temperatures are predicted for western North America with ridging/positive geopotential height anomalies and normal to above normal temperatures in eastern North America. However, the forecast for next week is for ridging/positive geopotential height anomalies and normal to above normal temperatures to become more widespread across North America with troughing and normal to below normal temperatures mostly limited to the West Coast of the United States (US).
- In the Impacts section I discuss Arctic change may be contributing to split jet streams, more stagnant weather systems including heat domes and extreme rainfall across the mid-latitude continents of the Northern Hemisphere (NH).

Impacts

Certainly, one of the biggest if not the biggest weather news story of the summer so far has been the high-pressure system/heat dome that setup over Siberia in June leading to record breaking high temperatures and wildfires across Siberia. The exceptional warmth has caused sea ice to melt at a record pace in the Laptev Sea adjacent to Siberia and has contributed to an overall acceleration of sea ice melt for the entire Arctic basin over the past several weeks. That high pressure system that sat over Siberia for much of June has now drifted into the Central Arctic centered near the North Pole.

Therefore, the circulation pattern in the Central Arctic is likely to be very different from recent Julys. The circulation in the Central Arctic has been dominated by low pressure resulting in relatively cloudy, cool weather. So even though Arctic sea ice at the end of the winter was at or near record low extent no new record annual minimums have been observed since 2012 because summer low pressure in the Central Arctic slowed sea ice melt. However, at a minimum for the first half of July, the Central Arctic will be dominated by high pressure favoring relatively sunny and warm weather, which is conducive to accelerated sea ice melt. There does seem to be a higher probability that the sea ice minimum in 2020 will be lower than recent summers and may even challenge the record low of summer 2012.

The high pressure drifting towards the North Pole does seem to be contributing to cooler weather across Northern Europe as the Arctic high-pressure locks in low pressure/troughing and relatively cool temperatures for Europe. The Arctic high is predicted to dissipate for the second half of July, and if correct, will likely result in warming temperatures. However, the opposite seems to be true for North America. The models are predicting that the high heights/pressure that started over Siberia and are now over the North Pole will eventually drift towards the Aleutians. Ridging near the Aleutians will force troughing along the North American west coast with more ridging and a new heat dome over the interior of the North American continent potentially resulting in a very warm and dry July for large parts of the US and Canada.

Given that these slow moving summer high pressure systems/heat domes seem to be in the news with greater frequency in recent years, I thought to share a simplistic discussion how climate change in general but Arctic change in particular may be contributing to an increasing frequency of these nearly stationary heat domes that result in record high temperatures, drought and wildfires. Though this explanation is not limited to heat and drought extremes but also extreme rainfall and flooding as well. This is not a topic that I have researched in any detail personally, as my focus is on the winter season, but the ideas that I present below and the influence of Arctic change on Northern Hemisphere summer weather is nicely reviewed in Coumou et al. 2018.

Weather systems are steered across the globe by the Jet Stream in a steady west to east direction. Jet streams arise in each hemisphere, in part, due to temperature differences between the poles and the equator, a margin known as a temperature gradient. If the temperature difference between the equator and poles is high, then the gradient is strong resulting in a strong Jet Stream. As that temperature gap closes, the gradient is then weakened, and the Jet Stream slackens.

Typically, there is a smooth and gradual change in temperature from the equator to the poles with temperatures hottest near the equator and coldest near the poles. Under these typical conditions there is one Jet Stream that circumnavigates the hemisphere in between the equator and the poles across the mid-latitudes where the temperature gradient or differential is greatest (see **Figure i**). However, over the past two decades the Arctic has warmed two to three times faster than the rest of the globe, weakening the temperature gradient between the North Pole and the equator that could potentially disrupt the natural behavior of the Jet Stream.

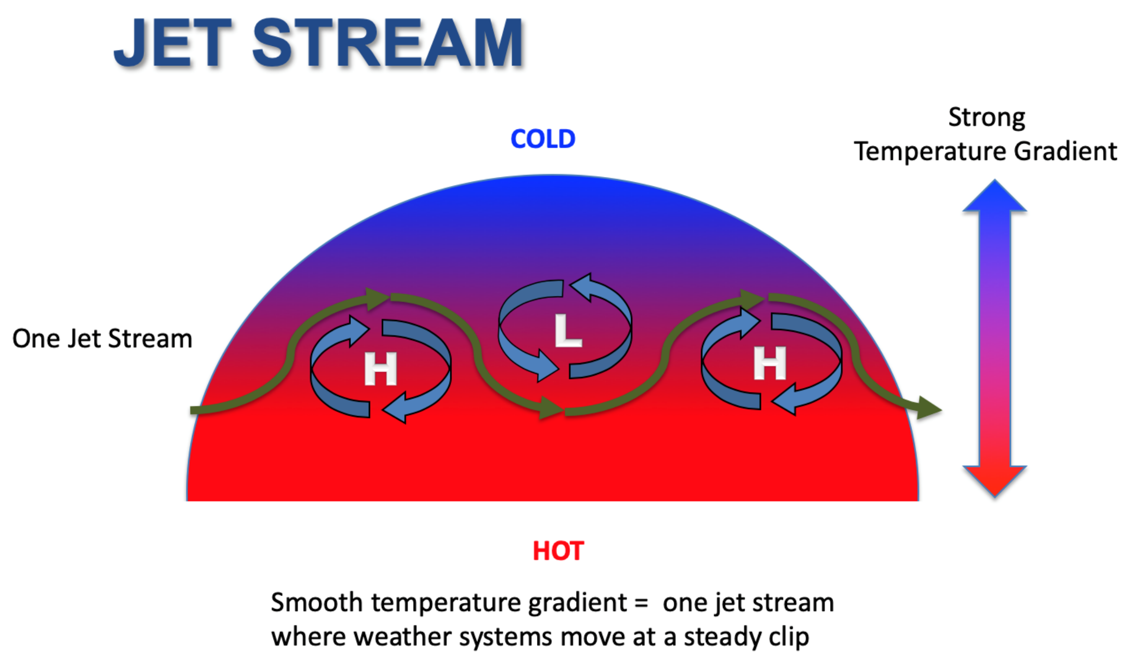

Figure i. Schematic of summer Jet Sream and weather sytems under a typical temperature gradient.

The general weakening of the temperature gradient between the equator and the North Pole is happening in both the winter and the summer, therefore the North Pole-equator temperature gradient has grown weaker all year round. However, the gradient between the North Pole and the northern edges of the continents during the summer is actually strengthening. The greatest warming is transpiring on this northern continental edge due to accelerated melt of both spring snow cover and sea ice along the continental edges, where darker surfaces absorb more sunlight. In contrast in the Central Arctic sea ice persists reflecting much of the incoming sunlight. Therefore, the temperature differential is increasing between the Central Arctic and the northern continental edges, strengthening the gradient supportive of an active Jet Stream. Further south, with the northern edges of the continents warming faster than the central or southern edges of the continents, the temperature gradient across the mid-latitudes has slackened, which is not supportive of an active Jet Stream. Finally, with warming relatively evenly distributed across the mid and lower latitudes, the temperature gradient between the equator and the mid-latitudes is comparable to previous decades supportive of an active Jet Stream.

Ultimately, the strengthened gradient in the high latitudes (between the North Pole and the northern edges of the continents), the weakened gradient from the northern to the central and southern edges of Eurasia and North America, and the relatively unchanged gradient between the mid-latitudes and the equator could contribute to a split in jet streams during the summer—one to the north, and the other to the south (see **Figure ii**).

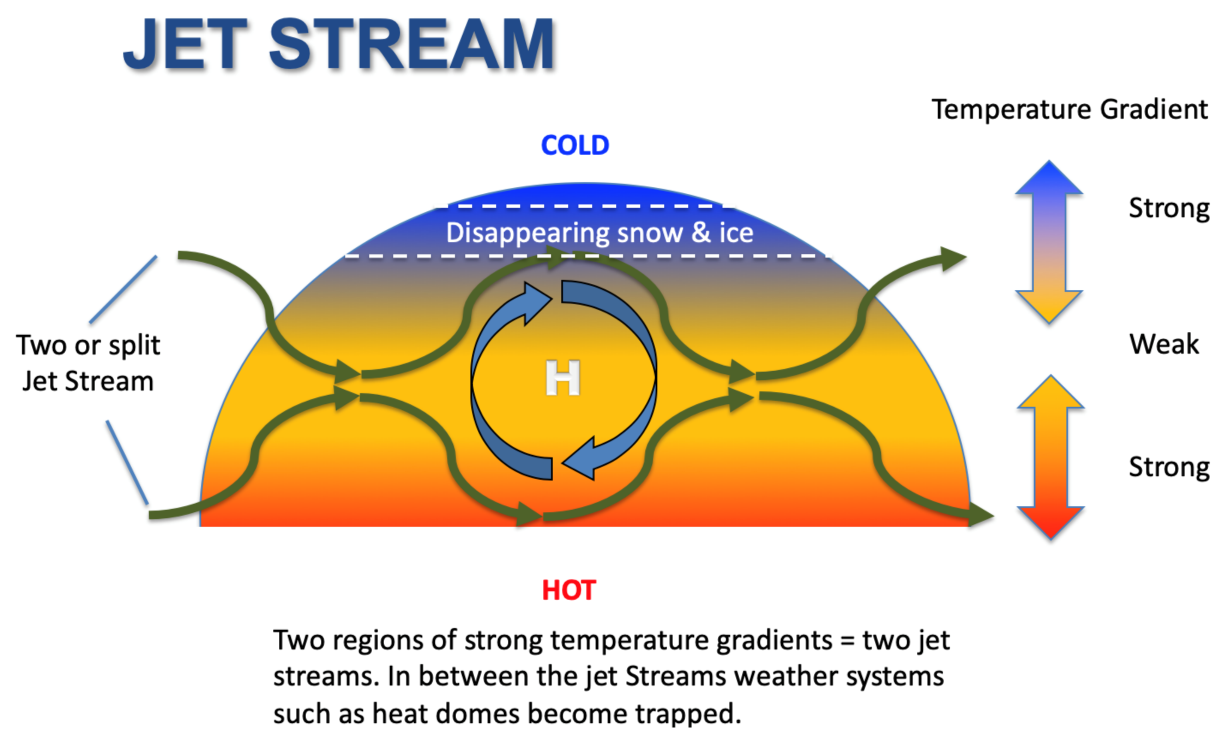

Figure ii. Schematic of summer Jet Stream and weather systems where temperatures are warming faster along the northern edges of the continents.

This split Jet Stream allows weather systems to move more slowly across the Northern Hemisphere. In between the two streams the normal west to east winds slacken or even disappear completely, causing weather systems to become trapped or stationary between the two or split jet streams (see **Figure ii**). When weather systems become stationary, it is favorable for these weather systems to strengthen and create extreme weather. Over the past several summer we have observed nice examples of split jet streams with trapped weather systems in between including heat domes. Favorable positions for these heat domes have been western North America, Europe and Siberia resulting in extreme heat, drought and wildfires. This summer, the most impressive heat dome has been located over Siberia, but one existed earlier this summer over Northern Europe and another is predicted over the interior of North America. But it isn't just heat domes but also low pressure with extreme rainfall that can become trapped. A current example is persistent low pressure in Far East Asia leading to flooding rains in Japan.

1-5 day

The AO is currently near neutral **(Figure 1**) with a strong positive geopotential height anomaly in the Central Arctic but negative geopotential height anomalies elsewhere in the Arctic and mixed geopotential height anomalies across the mid-latitudes of the NH

(**Figure 2**). And with predicted weak geopotential height anomalies across Greenland (**Figure 2**), the NAO is predicted to straddle neutral this week as well.

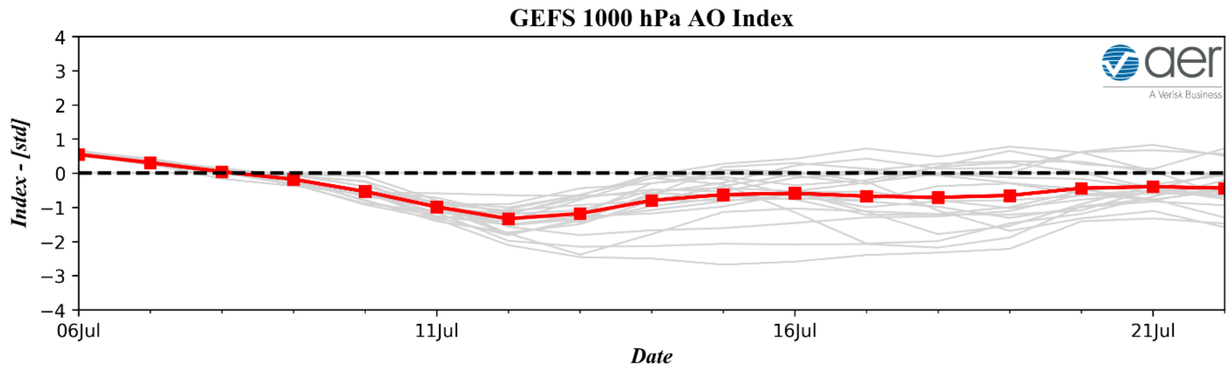

Figure 1. The predicted daily-mean AO at 1000 hPa from the 00Z 6 July 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies in the central Arctic will contribute to troughing/negative geopotential height anomalies with normal to below normal temperatures for much of Europe including the UK with the possible exception of ridging/positive geopotential height anomalies and normal to above normal temperatures in Spain and far Southern Europe (**Figures 2 and 3**). Ridging/positive geopotential height anomalies in in Western Asia, will help to anchor troughing/negative geopotential height anomalies in Eastern Asia except for ridging/positive geopotential height anomalies in Eastern Siberia (**Figure 2**). This pattern favors normal to above normal temperatures across Western Asia and Eastern Siberia with normal to below normal temperatures in East Asia **(Figure 3**).

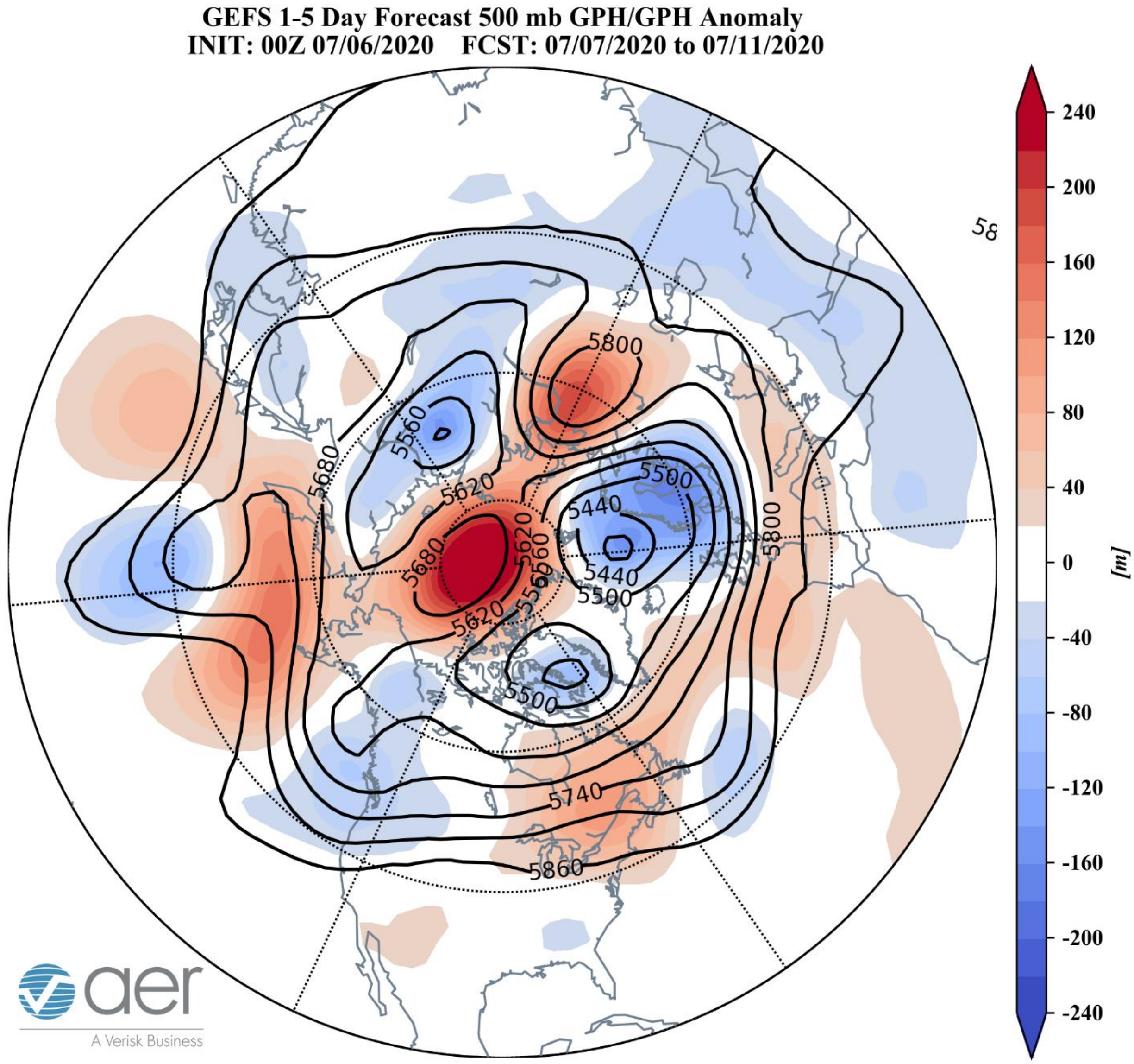

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 7 – 11 July 2020. The forecasts are from the 00z 6 July 2020 GFS ensemble.

This week, troughing/negative geopotential height anomalies are predicted for western North America with ridging/positive geopotential height anomalies in eastern North America (**Figure 2**). This pattern is predicted to bring normal to below normal temperatures across Alaska, Western Canada and the Western US with normal to above normal temperatures for much of Eastern Canada and the Eastern US (**Figure 3**). Some weak troughing could bring seasonably cool temperatures to the Southeastern US **(Figures 2 and 3).**

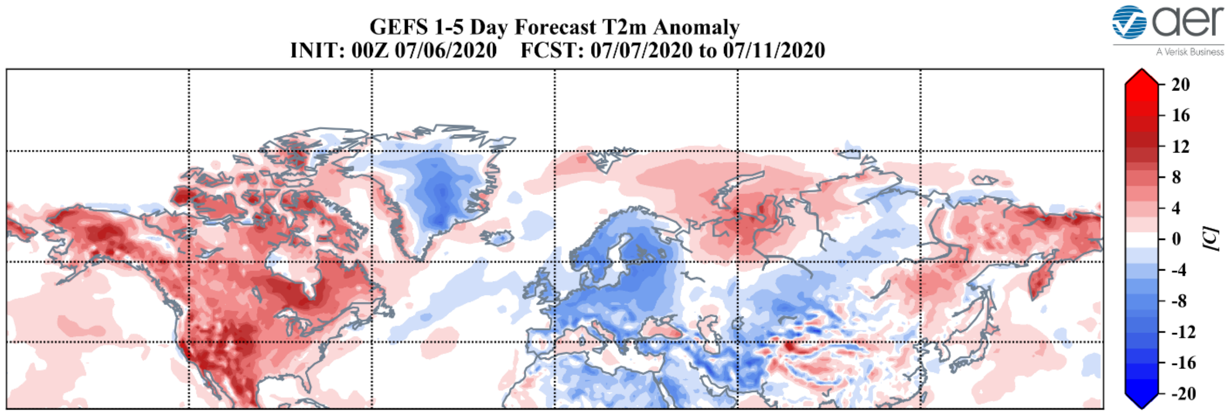

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 7 – 11 July 2020. The forecast is from the 00Z 6 July 2020 GFS ensemble.

Below normal precipitation is predicted for much of Europe and Asia with the exceptions of above normal precipitation for Northern Europe and especially Southeast Asia including Japan where heavy precipitation is predicted (**Figure 4**). Below normal precipitation is predicted for much of North America with above normal precipitation across Western Canada, the Pacific Northwest, the Great Lakes and the US East Coast (**Figure 4**).

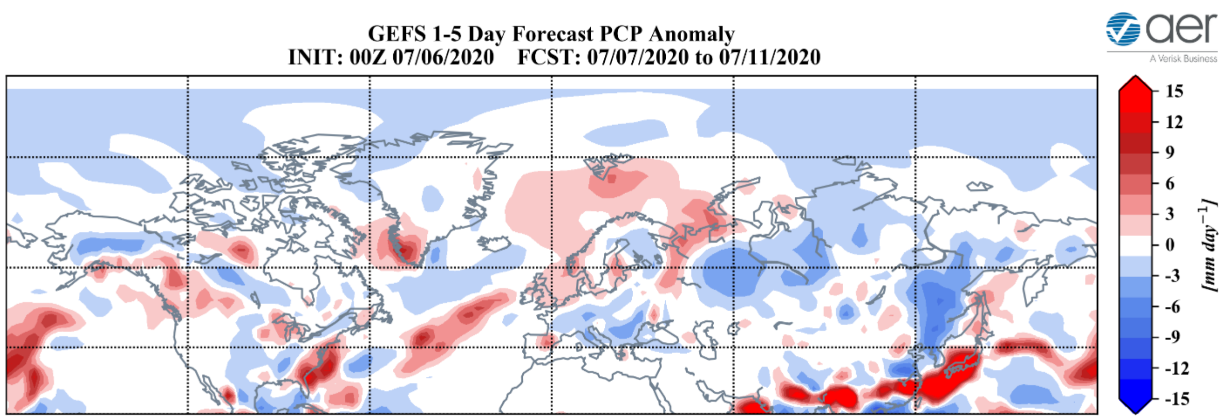

Figure 4. Forecasted precipitation anomalies (mm/day; shading) from 7 – 11 July 2020. The forecast is from the 00Z 6 July 2020 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to turn more negative (**Figure 1**) as positive geopotential height anomalies become more widespread across the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with weak geopotential height anomalies predicted across Greenland (**Figure 5**), the NAO is predicted to remain near neutral.

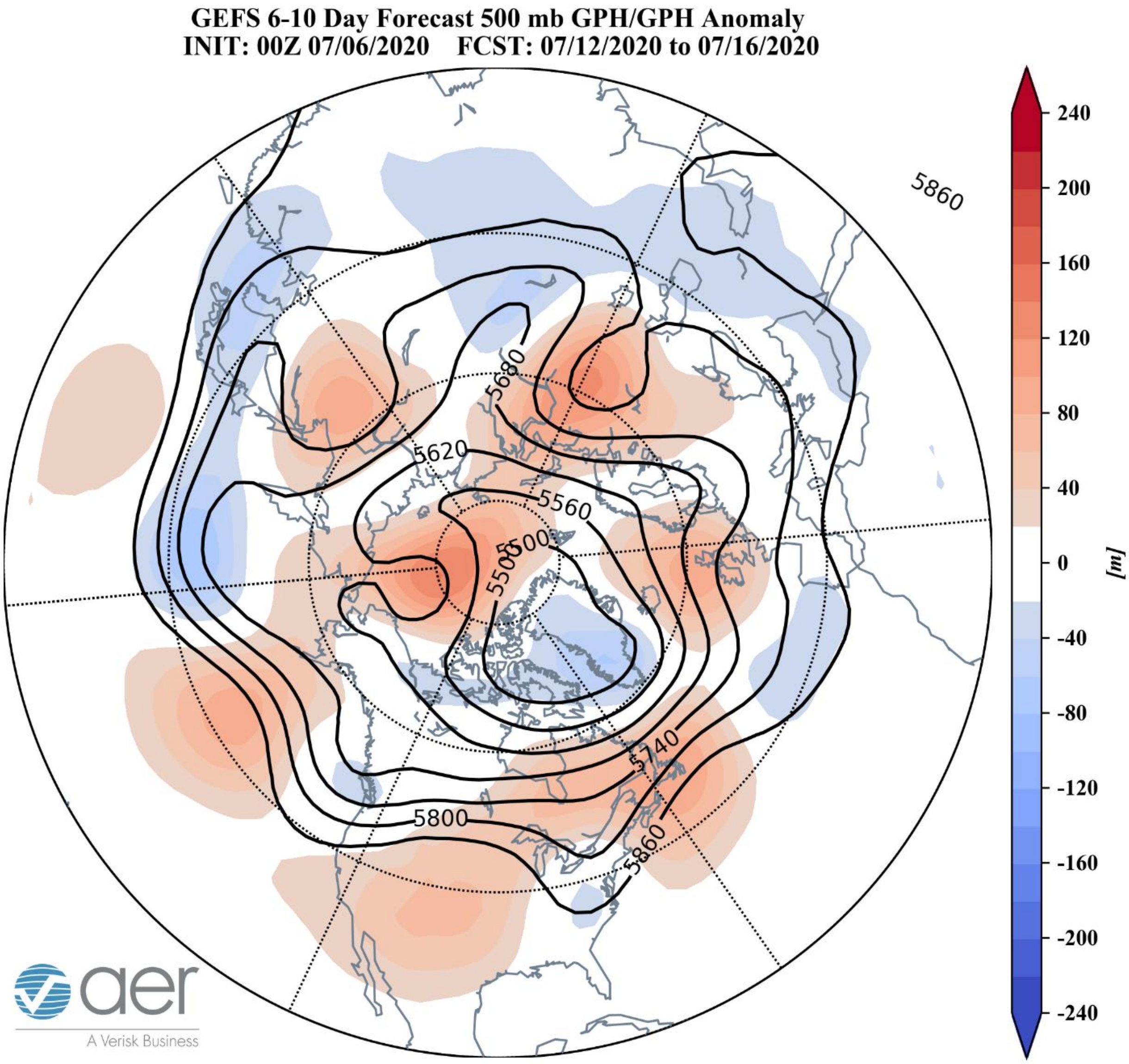

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 28 June – 2 July 2020. The forecasts are from the 00z 6 July 2020 GFS ensemble.

As ridging/positive geopotential height anomalies in the Central Arctic weaken so does troughing/negative geopotential height anomalies across Northern Europe allowing for more ridging across the remainder of Europe (**Figures 5).** Despite rising heights across Northern Europe temperatures are still predicted to remain normal to below normal across much of Europe including the UK with the exception of normal to above normal temperatures across Spain and far Southern Europe (**Figure 6**). Ridging/positive geopotential height anomalies are predicted to persist in Western Asia however ridging/positive geopotential height anomalies are predicted to become more widespread across East Asia with the exception of troughing/negative geopotential height anomalies in Far East Asia and in parts of Central Asia (**Figure 5**). This is predicted to yield normal to above normal temperatures in much of Northern Asia with normal to below temperatures In Far East Asia and Kazakhstan **(Figure 6**). Some weak troughing/negative geopotential height anomalies across the Northern Indian subcontinent will favor normal to below normal temperatures across that region (**Figures 5 and 6**).

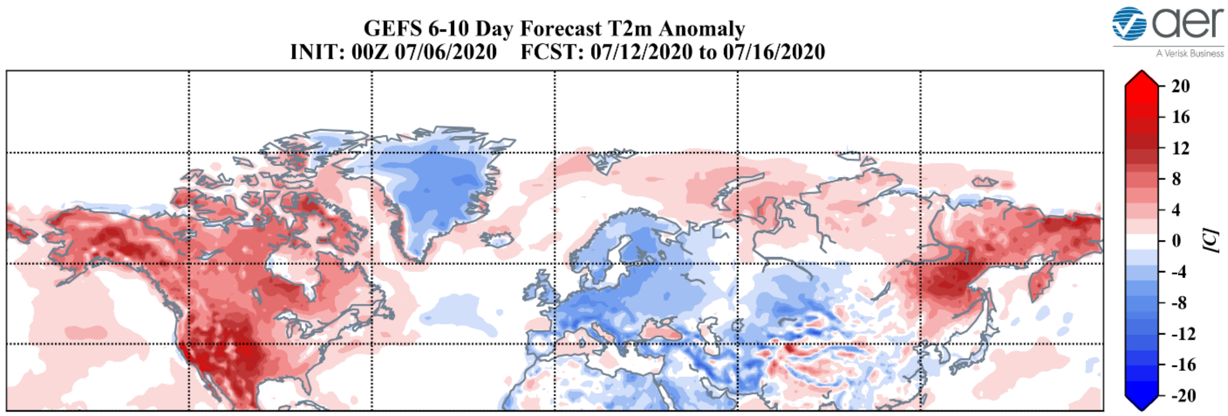

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 12 – 16 July 2020. The forecasts are from the 00Z 6 July 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to strengthen across North America with troughing/negative geopotential height anomalies along the West Coasts of the US and Canada and in the US Mid-Atlantic States this period (**Figure 5**). This pattern is predicted to bring widespread normal to above normal temperatures across Alaska, Eastern Canada and the Western US with normal to below normal temperatures for the US Pacific Northwest, Southwestern Canada and the US Ohio Valley **(Figure 6).**

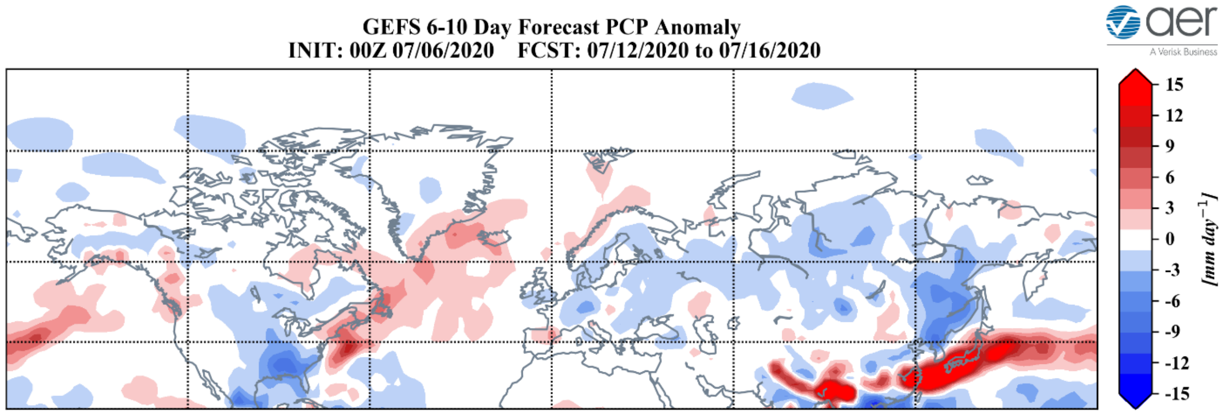

Figure 7. Forecasted precipitation anomalies (mm/day; shading) from 12 – 16 July 2020. The forecasts are from the 00Z 6 July 2020 GFS ensemble.

Normal to below normal precipitation is predicted for much of Eurasia with the exceptions of above normal precipitation across Norway, Spain and especially Southeastern Asia including Japan (**Figure 7**). Normal to below normal precipitation is predicted for much of North America with above normal precipitation predicted for the Pacific Northwest and the Northeastern US into Nova Scotia (**Figure 7**).

11-15 day

With predicted weak positive geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO is predicted to be weakly negative this period (**Figure 1**). With weak positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is likely to be weakly negative as well.

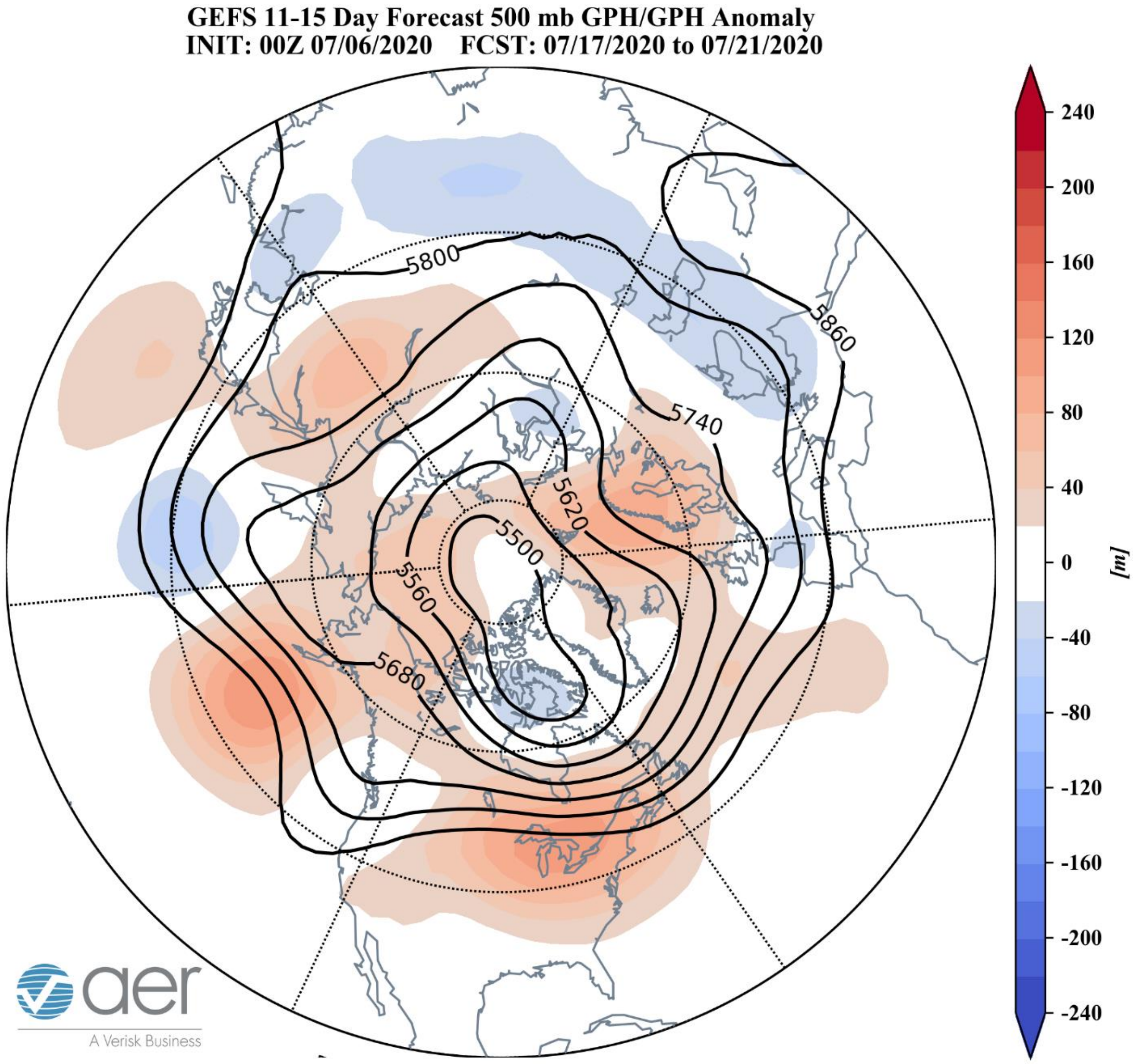

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 17 – 21 July 2020. The forecasts are from the 00z 6 July 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to spread across Northern Europe with weak troughing/negative geopotential height anomalies across Southern Europe this period (**Figures 8**). The forecast is for normal to above normal temperatures across Northern Europe including the UK with normal to below normal temperatures across Southern Europe this period (**Figures 9**). The general pattern is predicted to be troughing/negative geopotential height anomalies in Western Asia, Far East Asia and much of Southern Asia with ridging/positive geopotential height anomalies across much of Northern and Eastern Asia this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across Northern and

Eastern Asia with normal to below normal temperatures in Western and Southern Asia and far East Asia (**Figure 9**).

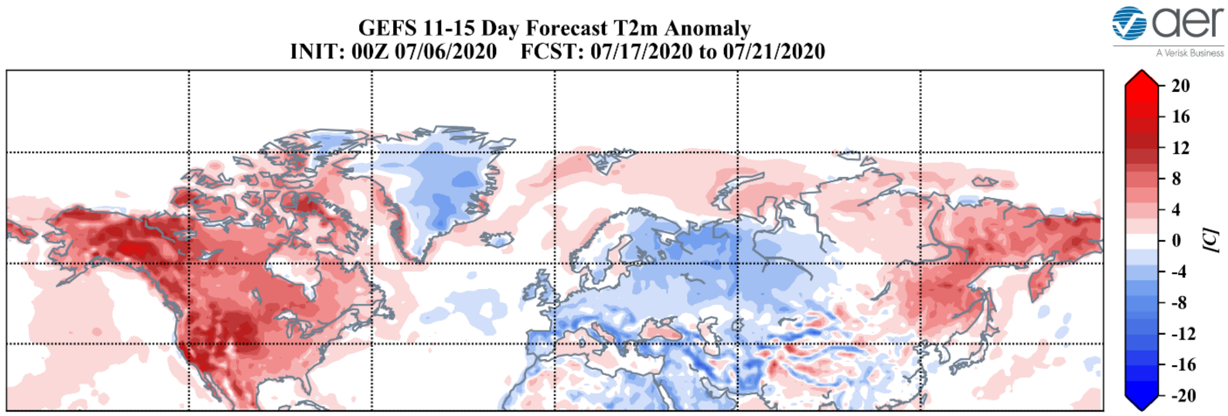

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 17 – 21 July 2020. The forecasts are from the 00z 6 July 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to dominate North America with the exception of troughing/negative geopotential height anomalies along the US West Coast (**Figure 8**). This pattern favors widespread normal to above normal temperatures across Alaska, Canada and much of the US with the possible exception of normal to below normal temperatures for the US West Coast (**Figure 9**).

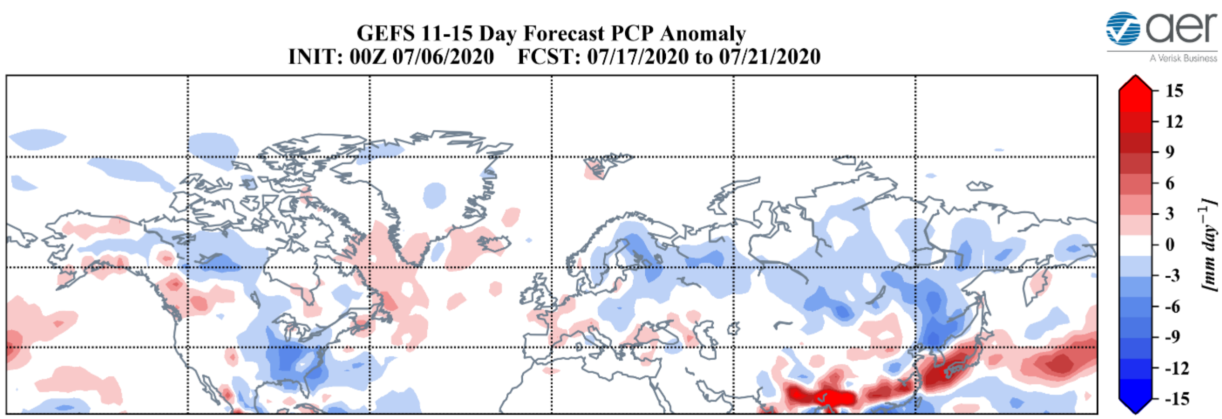

Figure 10. Forecasted precipitation anomalies (mm/day; shading) from 17 – 21 July 2020. The forecasts are from the 00z 6 July 2020 GFS ensemble.

Normal to below normal precipitation is predicted for much of Eurasia except for normal to above normal precipitation for Western Europe and especially Southeast Asia including Japan (**Figure 10**). Normal to below normal precipitation is predicted for much of North America except for above normal precipitation for Southwestern Canada and the Canadian Maritimes (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to above normal PCHs in both the troposphere and the lower stratosphere with normal to below normal PCHs in the mid-stratosphere (**Figure 11**). However, PCHs in the lower stratosphere are predicted to reverse to normal to below normal while PCHs in the troposphere are predicted to remain mostly positive (**Figure 11**). The GFS forecasts of a reversal to cold stratospheric PCHs have been overdone much of the spring and I wouldn't consider the forecast reliable.

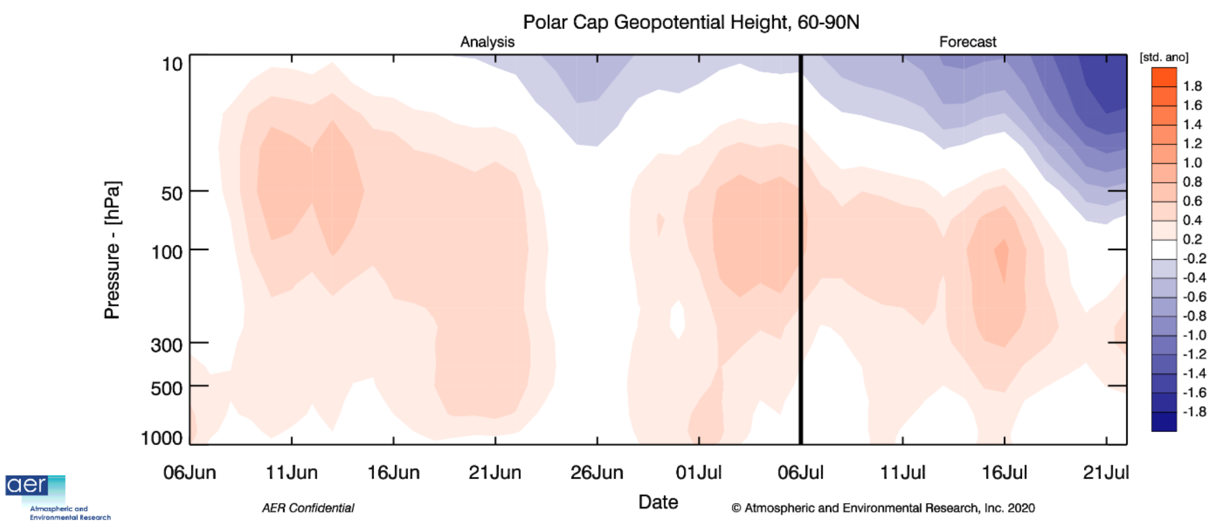

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 6 July 2020 GFS operational run.

The normal to above normal PCHs in the lower troposphere are consistent with the predicted neutral to weakly negative AO over the next two weeks (**Figure 1**). I do believe that the overall below normal sea ice and Arctic warming favor mostly normal to above normal PCHs in the troposphere throughout the summer months, with typical synoptic timescale variability.

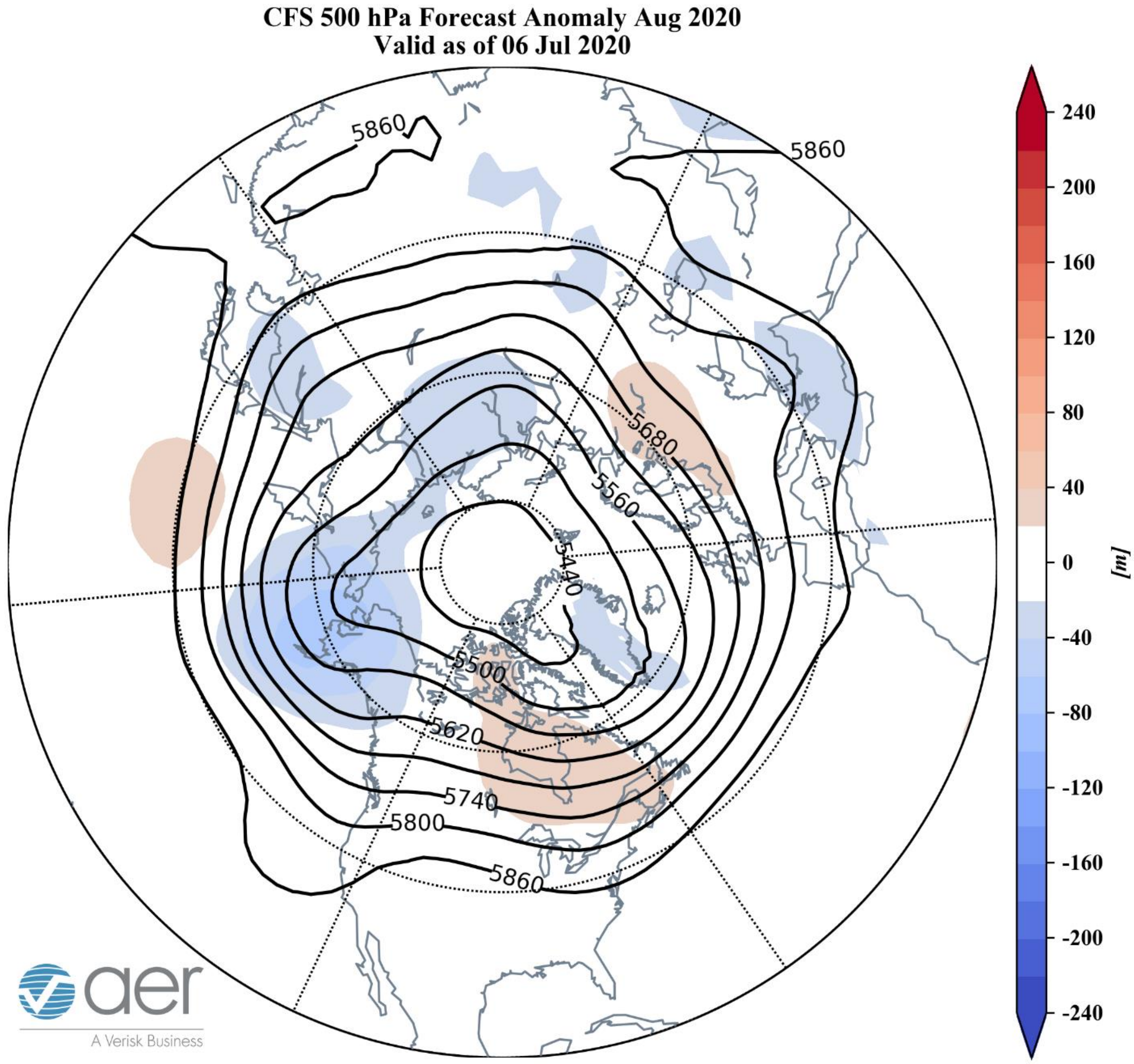

Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for August 2020. The forecasts are from the 00Z 6 July 2020 CFS.

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 in Northern Europe, Eastern Siberia and Eastern Canada with troughing in the Eastern Mediterranean, Western Asia, Western and Eastern Siberia, East Asia, Alaska, the US West Coast and Greenland (**Figure 12).** This pattern favors relatively warm temperatures for Northern Europe, much of Northern and Eastern Asia, much of Canada and the US with seasonable to relatively cool temperatures for Western Asia, Eastern Siberia, the Far East and the US West Coast (**Figure 13**)**.** There is a clear cold bias in the temperature plot across Eurasia and probably a warm bias across North America.

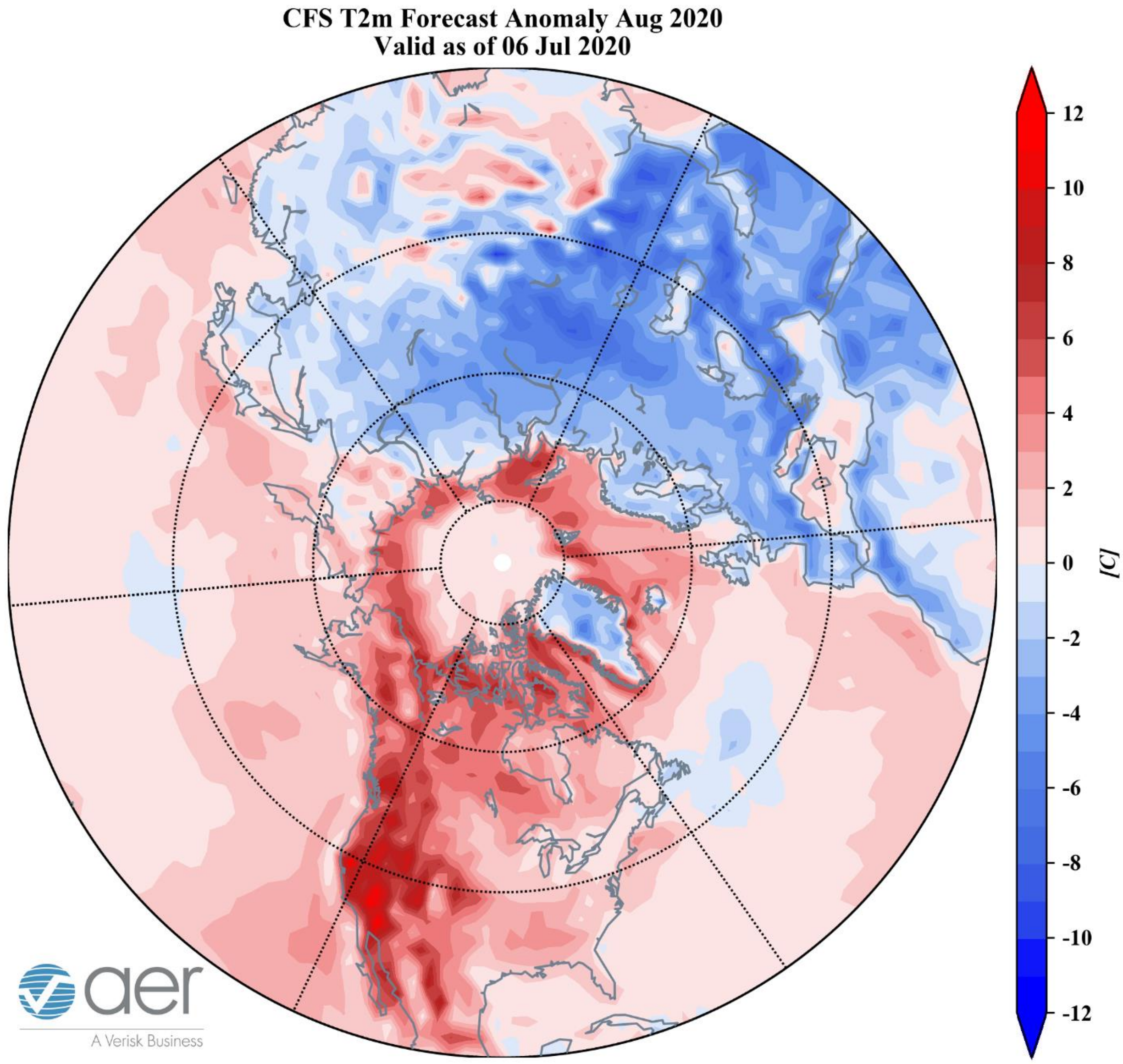

Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for August 2020. The forecasts are from the 00Z 6 July 2020 CFS.

Surface Boundary Conditions

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies continue to cool slowly but neutral El Niño/Southern Oscillation (ENSO) conditions seem most likely this summer (**Figure 14**) though a La Niña is expected by this fall. Observed SSTs across the NH remain well above normal especially near Alaska and in the Gulf of Alaska and the western North Pacific though below normal SSTs exist regionally especially west of South America and south of Iceland. Warm SSTs in the Gulf of Alaska may favor mid-tropospheric ridging in the region.

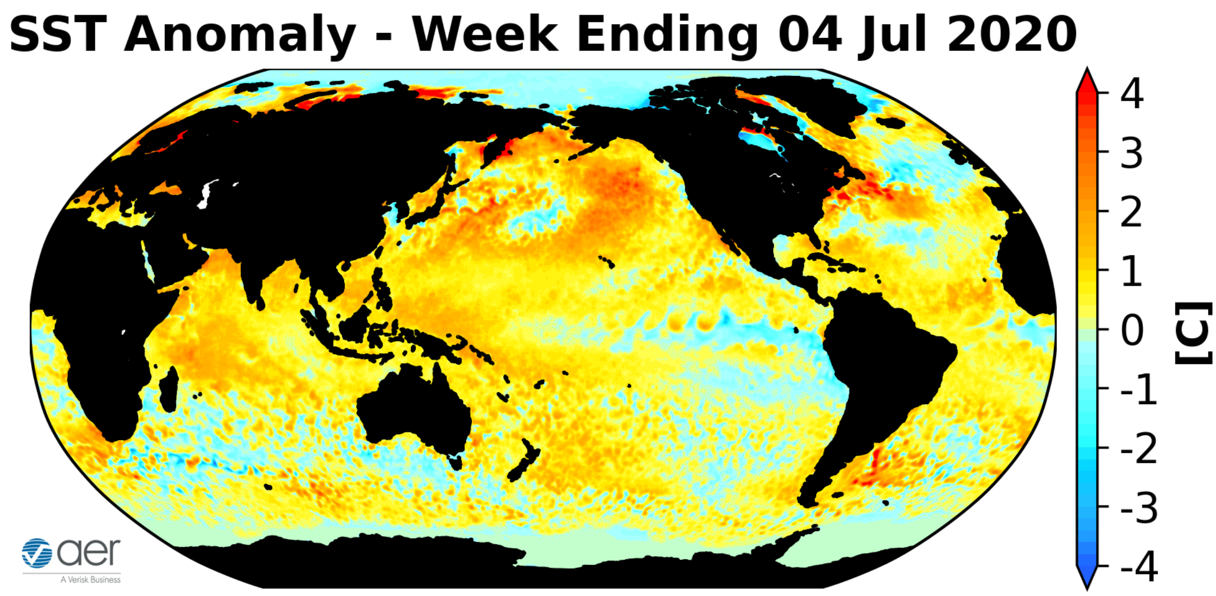

Figure 14. The latest weekly-mean global SST anomalies (ending 4 July 2020). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase one (**Figure 15**). The forecasts are for the MJO to move into phase two and then stall. MJO phase two initially favors ridging in Eastern Canada and troughing in Western Canada and then transitioning to troughing near the Aleutians and ridging in the Western US. The MJO could be contributing to the current pattern but the forecasts suggest that the MJO is not contributing to the upcoming weather patterns across North America over the next two weeks.

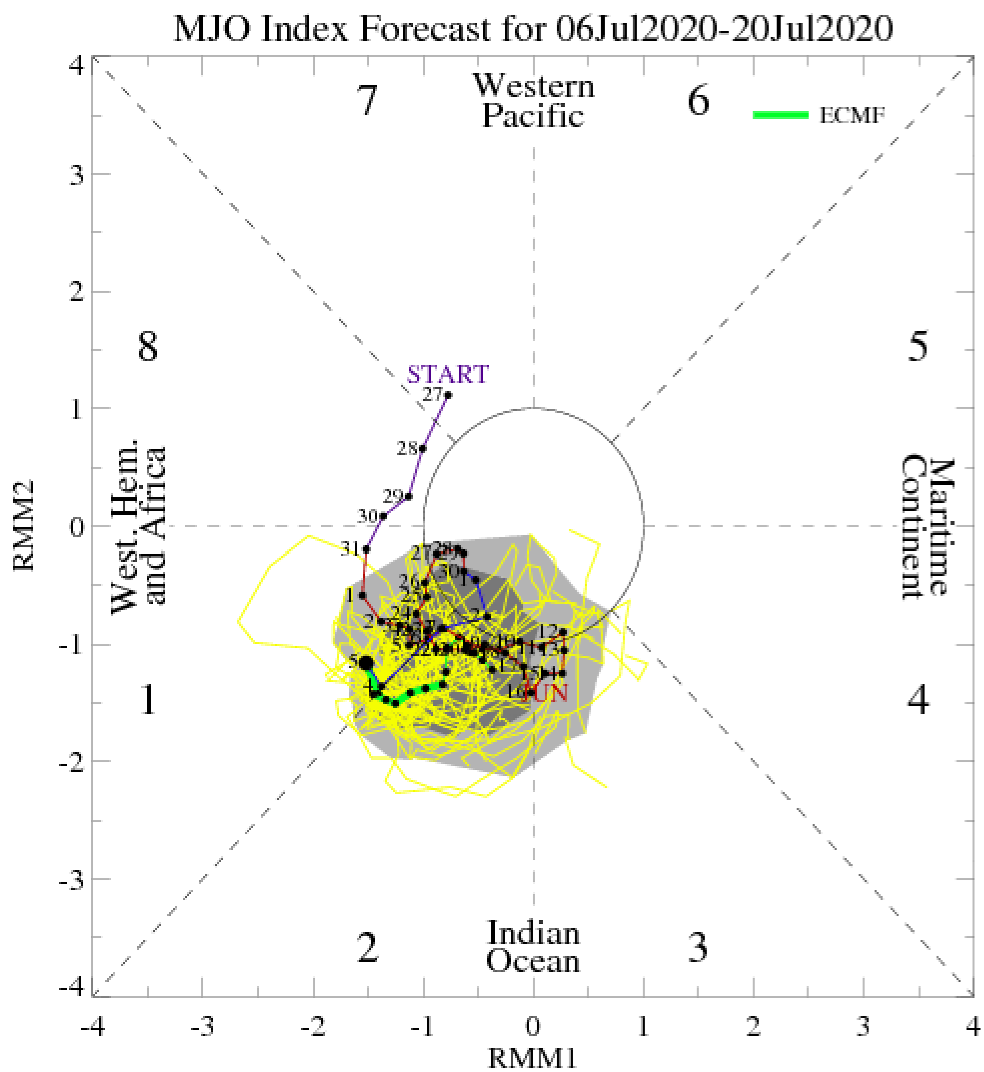

Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 6 July 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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