

Arctic Oscillation and Polar Vortex Analysis and Forecasts

July 12, 2021

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) 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.

Subscribe to our email list or follow me on Twitter (@judah47) for notification of updates.

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

Summary

- The Arctic Oscillation (AO) is currently positive and is predicted to remain positive over the next two weeks as pressure/geopotential height anomalies in the Central Arctic are predicted to be normal to below normal with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently also positive and is predicted to remain

positive over the next two weeks as pressure/geopotential height anomalies are predicted to continue negative across Greenland the next two weeks.

- The general predicted pattern across Europe the next two weeks is ridging/positive geopotential height anomalies centered across Northern Europe coupled with normal to above normal temperatures across much of Europe including the United Kingdom (UK). One exception is this week as mid-tropospheric troughing/negative geopotential height anomalies coupled with normal to below temperatures slowly moves through Western Europe.
- Over the next two weeks much of Asia will be bifurcated with ridging/positive geopotential height anomalies coupled with normal to above normal temperatures in Eastern Asia with troughing/negative geopotential height anomalies coupled with normal to below temperatures in and Western Asia.
- This general pattern across North America over the next two weeks is ridging/positive geopotential height anomalies coupled with normal to above normal temperatures. A couple of exceptions are troughing/negative geopotential height anomalies coupled with normal to below temperatures across parts of Alaska into Northwestern Canada and the Central United States (US).
- In the Impacts section I once again discuss the summer pattern across the Northern Hemisphere (NH).

Impacts

Once again, I find myself wanting to provide anything profound about the summer outlook other than to say the “trend is your friend” consistent with my recent blog posts. In this regard, I feel summer and winter diverge. The broad strokes of the summer pattern of temperature anomalies seem to be quite predictable yet winter can show year to year variability and volatility. The difference in observed temperatures across Siberia between winter 2019/20 and 2020/21 was extreme and may be unprecedented in magnitude in the observational record (though to be honest I don’t know). I have seen no evidence of that kind of reversal in summer. Of course, this is overly simplistic but one important difference between summer and winter is the existence of the polar vortex. But why the summer temperature anomalies have settled into a particular and repeatable pattern is an interesting question that I have pondered often in the blog.

In **Figure i**, I include the observed temperature anomalies for June 2021 from [Karsten Haustein](#)’s analysis website. Overall, the NH is experiencing warmer than normal temperatures, but three regions stand out for more amplified warming relative to normal: the Western US and Western Canada, Northeastern Europe and Siberia. All three regions have been in the news as well for record or near record warmth e.g., see [NY Times record warm June](#). Also exceptionally hot are the Middle East and North Africa. Death Valley’s heat has been in the news possibly achieving a new global record high temperature at the end of the week (tied with last summer at 130°F) but I haven’t

heard about North Africa yet based on **Figure i** and many of the GFS surface temperature forecast plots that I share in the blog and on Twitter it has been impressively hot in North Africa as well. And [@extremetemps](#) has been posting updates on North African record heat on Twitter. Finally looking at the GFS forecast temperature plots below there is every expectation for the overall temperature pattern to continue for much of July.

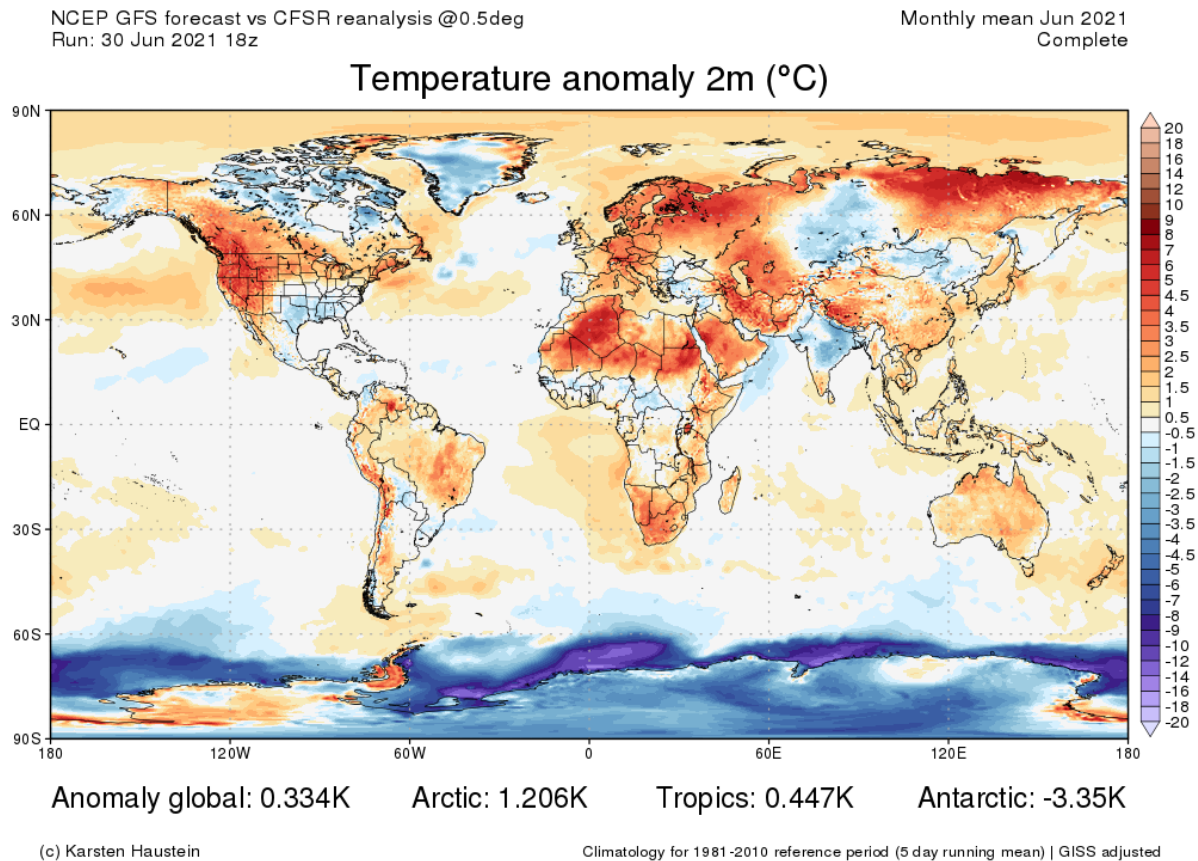


Figure i. Observed surface temperature anomalies over the globe for June 2021 based on GFS analysis. Plot taken from <http://www.karstenhaustein.com/climate>.

In **Figure ii**, I show the change in surface temperatures over the past 30 years. To me it is quite striking how closely the summer temperature trend matches the observed temperature anomalies from June 2021 so closely. Over the past thirty years the regions warming the fastest are western North America, Northern and Eastern Europe and Siberia. Also showing accelerated warming are the Middle East and North Africa. And in the US, there is a secondary warming maximum in the Northeast coastal plain (thought it might be hard to discern from my map) again consistent with the record warm June here in Southern New England. Regions that are not warming as fast are the Central and Southeastern US, Western Europe and near the Urals. And to a good

first approximation the multi-annual trend is a good predictor for this summer. It seems that Alaska is not as warm as the trend suggests and the relatively cool/ warmer pattern across the Urals and Siberia might be shifted a bit east this summer relative to the recent 30-year trend. Yet overall a very good match.

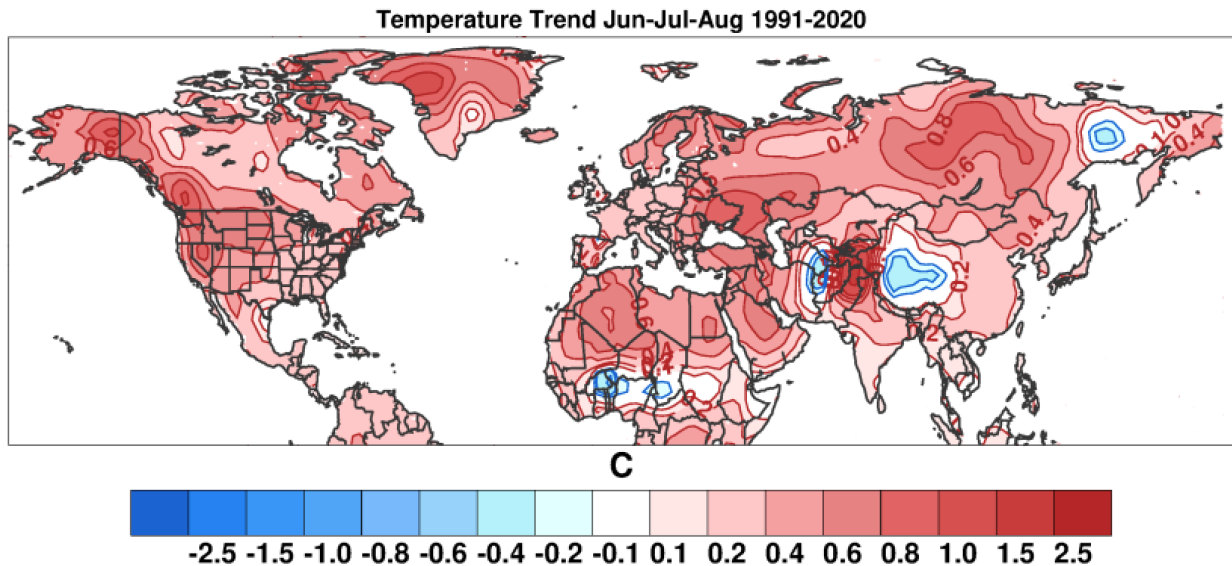


Figure ii. Observed surface temperature change from 1991-2020 over the NH for June, July and August in degrees Celsius. Data taken from NCEP/NCAR.

I will conclude with that I did believe that Arctic sea ice extent would not threaten the record low extent minimum of 2012 or even the near record low of last summer. But so far, summer 2021 is giving those two summers a run for their money. I still think that the overall positive AO pattern and low geopotential heights in the Central Arctic favor a slower melting of sea ice in the Arctic basin but so far that has not helped to preserve the ice.

1-5 day

The AO and NAO are predicted to be positive this week (**Figure 1**) as geopotential height anomalies are predicted to be mostly negative in the Central Arctic and across Greenland with mostly positive geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**).

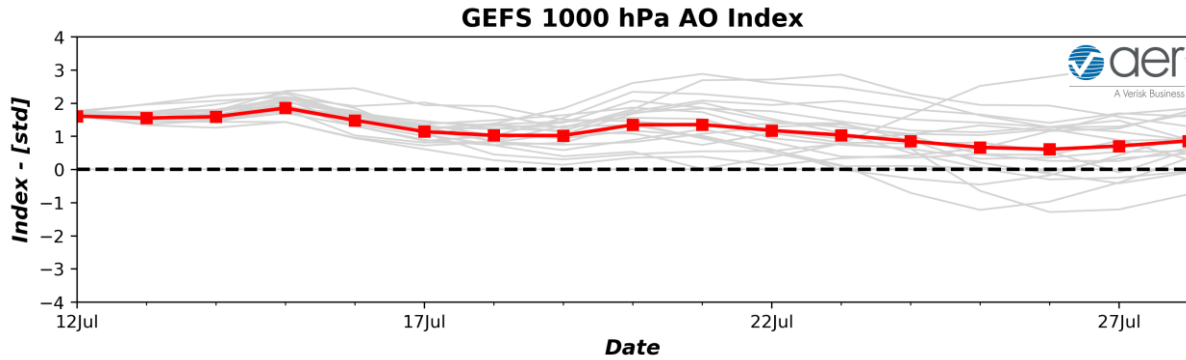


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 12 July 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Trouching/negative geopotential height anomalies across Greenland are predicted to favor ridging/positive geopotential height anomalies across much of Europe especially across Northern Europe though one exception is trouching/negative geopotential height anomalies across Western Europe (**Figures 2**). This will favor normal to above normal temperatures across much of Europe especially Northern Europe including the UK with normal to below normal temperatures across Western Europe (**Figure 3**). The general pattern across Asia this period is ridging/positive geopotential height anomalies across Eastern Asia with trouching/negative geopotential height anomalies in Western Asia (**Figure 2**). This pattern favors normal to above normal temperatures across much of Central and East Asia with normal to below normal temperatures in much of Western Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 07/12/2021 FCST: 07/13/2021 to 07/17/2021

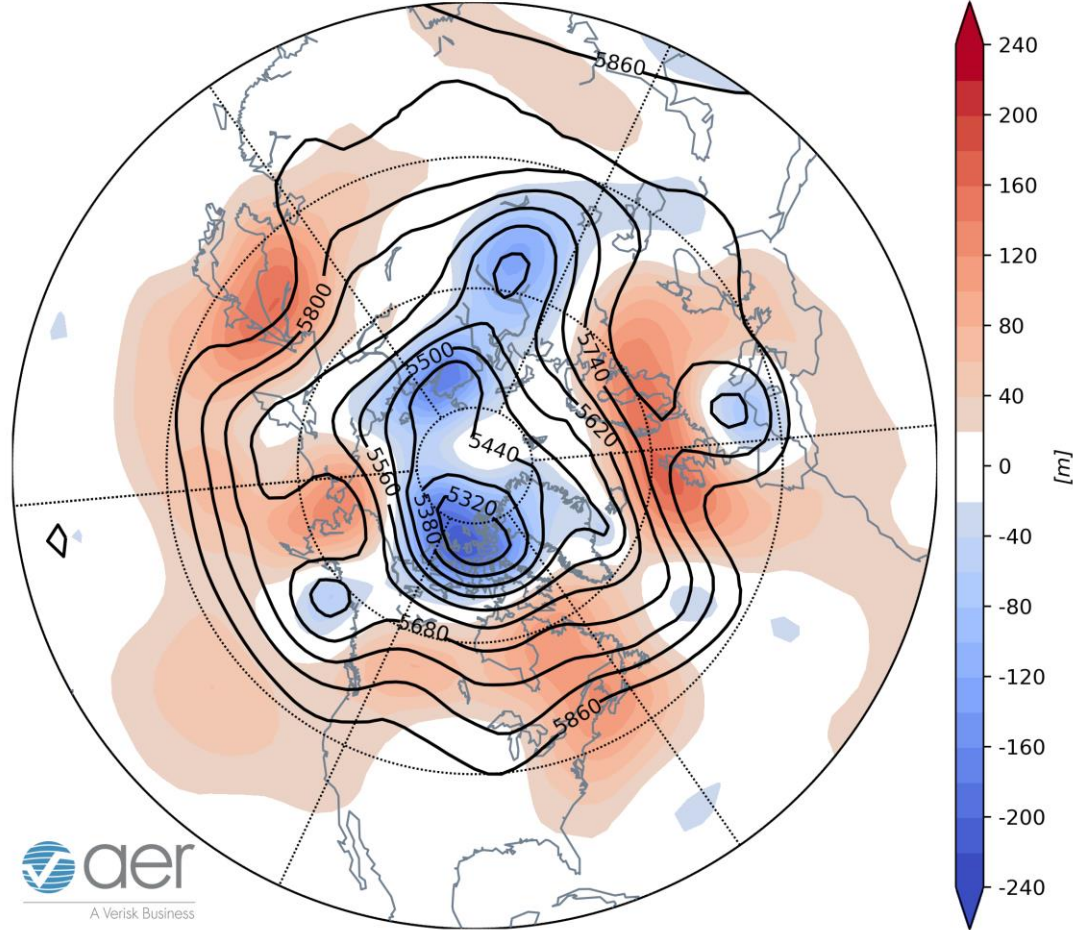


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 13–17 July 2021. The forecasts are from the 00z 12 July 2021 GFS ensemble.

Widespread ridging/positive geopotential height anomalies are predicted across much of North America with troughing/negative geopotential height anomalies across Northwestern Canada and in the Central US (**Figure 2**). This pattern is predicted to bring normal to above normal temperatures across much of Canada the Western and Northeastern US with normal to below normal temperatures across Western Alaska, Northwest Canada and the US Plains (**Figure 3**).

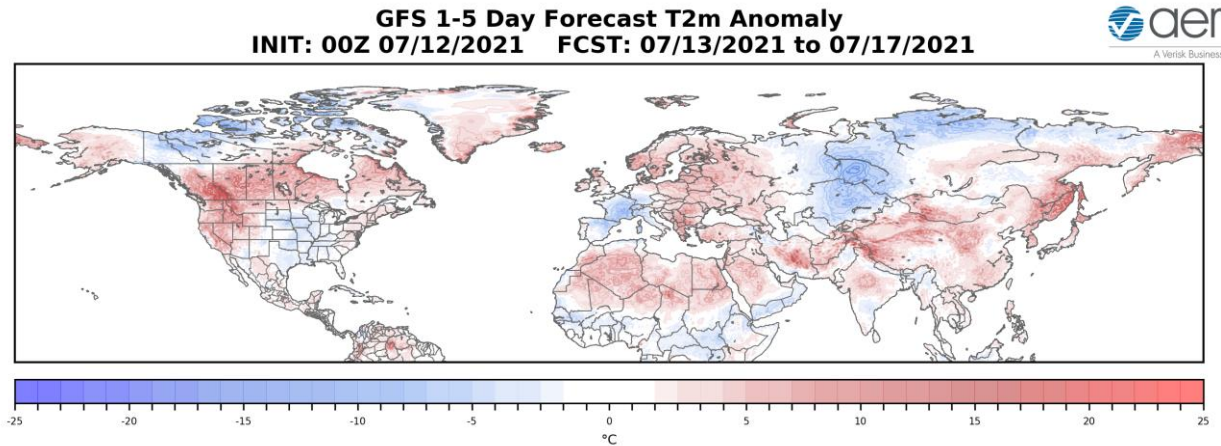


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 13– 17 July 2021. The forecast is from the 00Z 12 July 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia with the exceptions of above normal precipitation across Central Europe, the Baltic States, Southern and Eastern Asia (**Figure 4**). Normal to below normal precipitation is predicted for much of North America with the exceptions of normal to above normal precipitation in the Alaska Panhandle, the Eastern US and the Canadian Maritimes (**Figure 4**).

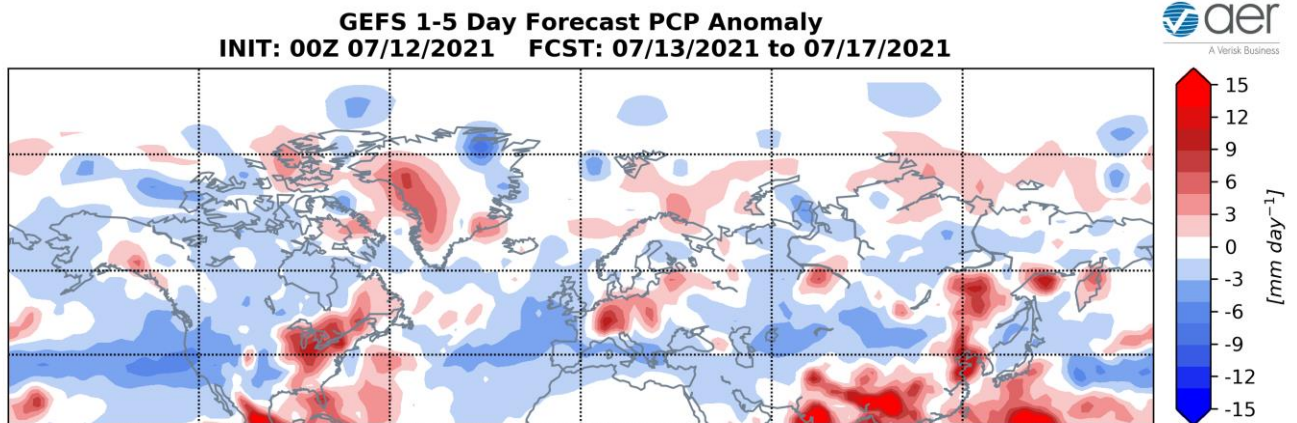


Figure 4. Forecasted precipitation anomalies (mm/day; shading) from 13– 17 July 2021. The forecast is from the 00Z 12 July 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain positive this period (**Figure 1**) as geopotential height anomalies remain normal to below normal across the Central Arctic with mostly

positive geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with normal to below normal geopotential height anomalies continuing across Greenland (**Figure 5**), the NAO is predicted to also remain positive this period.

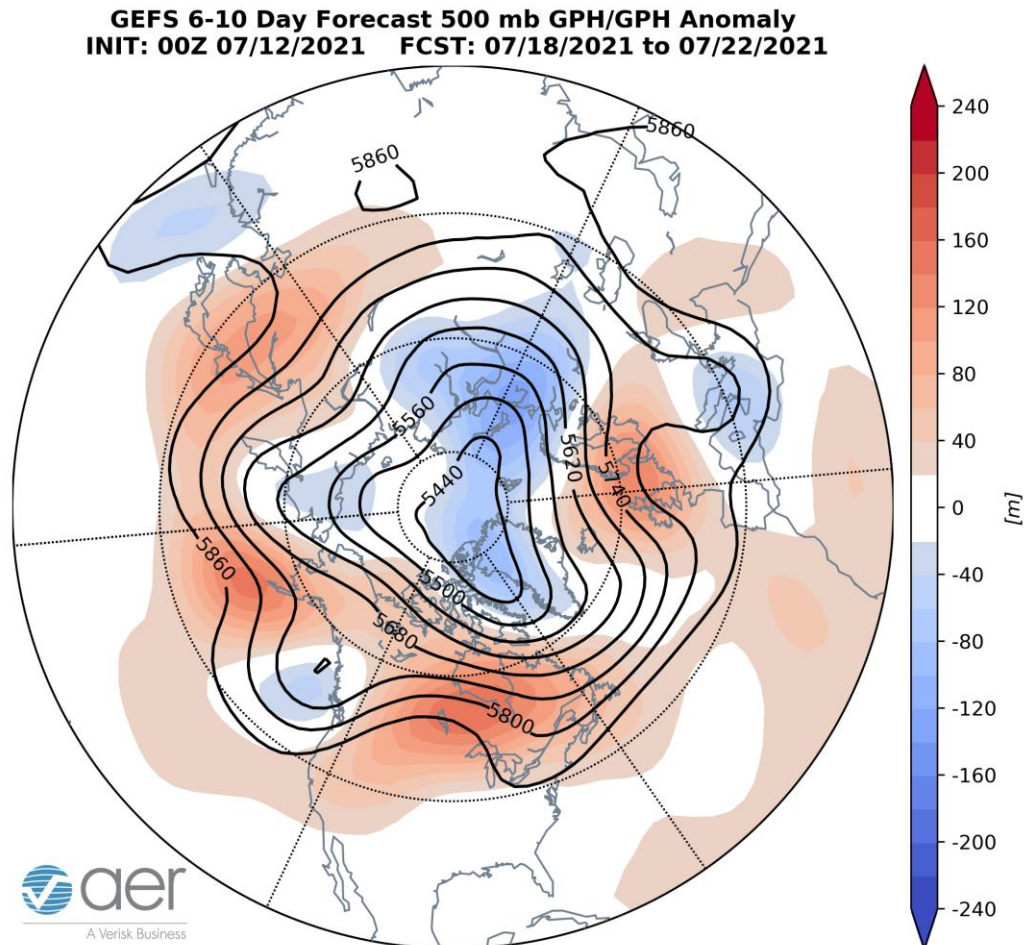


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 18 – 22 July 2021. The forecasts are from the 00z 12 July 2021 GFS ensemble.

General troughing/negative geopotential height anomalies across Greenland into the northern North Atlantic will contribute to persistent ridging/positive geopotential height anomalies across Europe especially Northern Europe with the exception of troughing/negative geopotential height anomalies centered over the Adriatic Sea (**Figures 5**). This will favor widespread normal to above normal temperatures across much of Europe including the UK with the possible exception of normal to below normal temperatures confined across Italy and into the Balkans (**Figure 6**). Ridging/positive geopotential height anomalies are predicted to dominate Eastern Asia with troughing/negative geopotential height anomalies across Western Russia (**Figure 5**). This pattern favors normal to above normal temperatures across much of Eastern

and Central Asia with normal to below normal temperatures in Northwestern Asia (**Figure 6**).

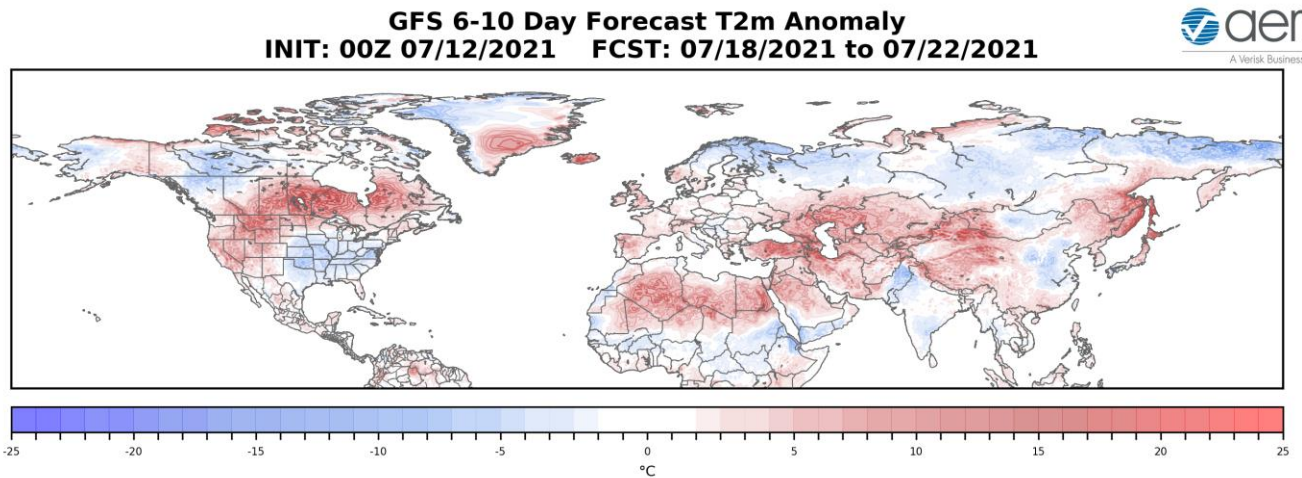


Figure 6. Forecasted surface temperature anomalies (°C; shading) from 18 – 22 July 2021. The forecasts are from the 00Z 12 July 2021 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to continue to dominate North America with the exception of troughing/negative geopotential height anomalies in Northern Canada and the Eastern US (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across much of Alaska, Southern Canada, the Western US and New England with normal to below normal temperatures across the Canadian Arctic Archipelagos and much of the Eastern US (**Figure 6**).

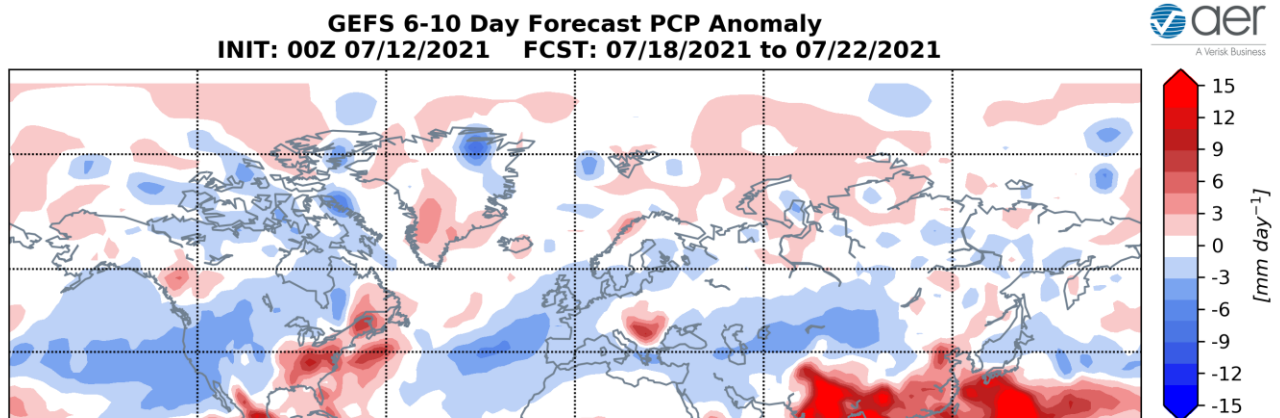


Figure 7. Forecasted precipitation anomalies (mm/day; shading) from 18 – 22 July 2021. The forecasts are from the 00Z 12 July 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia with the exceptions of above normal precipitation in Southeastern Europe and Southeast Asia (**Figure 7**). Normal to below normal precipitation is predicted for much of North America except for normal to above normal precipitation in Northwest Canada, the Eastern US and the Canadian Maritimes (**Figure 7**).

11-15 day

With persistent normal to below normal geopotential height anomalies across the Central Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO should remain positive this period (**Figure 1**). With possibly weak negative pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is predicted to remain neutral to positive this period as well.

GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 07/12/2021 FCST: 07/23/2021 to 07/27/2021

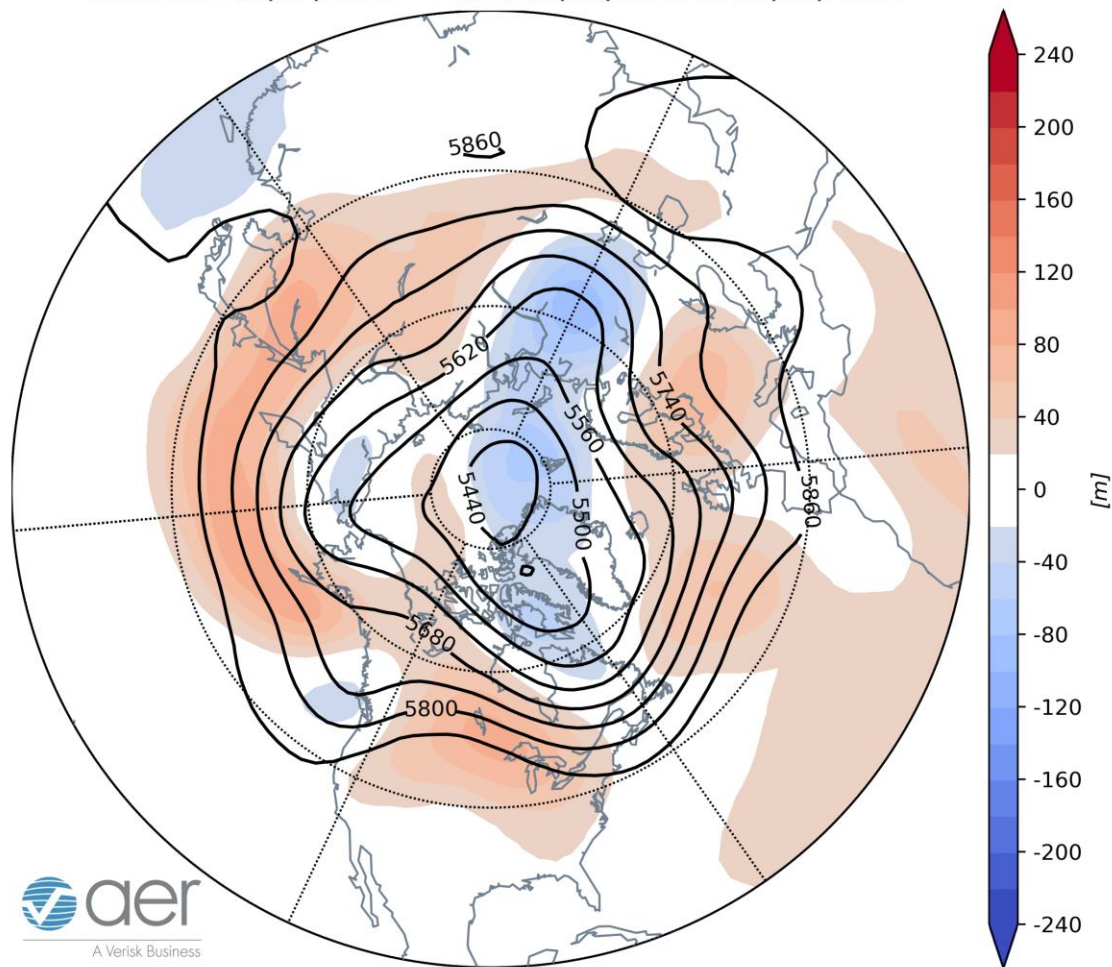


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 23 – 27 July 2021. The forecasts are from the 00z 12 July 2021 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to continue to dominate Europe, especially Northern Europe this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across much of Europe including the UK (**Figures 9**). Persistent ridging/positive geopotential height anomalies are predicted to dominate East Asia with troughing/negative geopotential height anomalies in Western Asia this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across much of Asia but especially Central into Northeastern Asia with the exception of normal to below normal temperatures across Northwestern Asia (**Figure 9**).

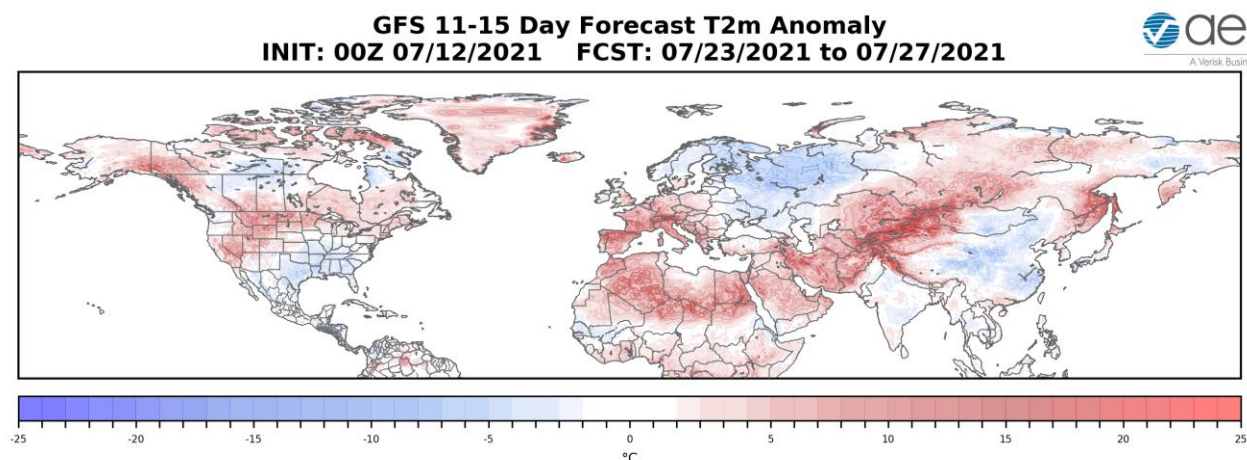


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 23 – 27 July 2021. The forecasts are from the 00z 12 July 2021 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to continue to dominate North America, but the center of the ridging is predicted to slide a bit more east into Southcentral Canada with troughing/negative geopotential height across Western Alaska, Northeastern Canada and the Central US this period (**Figure 8**). This pattern favors normal to above normal temperatures for much of Canada, the Western US and US East Coast with normal to below normal temperatures across Western Alaska, Northeastern Canada, the Canadian Arctic Archipelagos and much of the Central US (**Figure 9**).

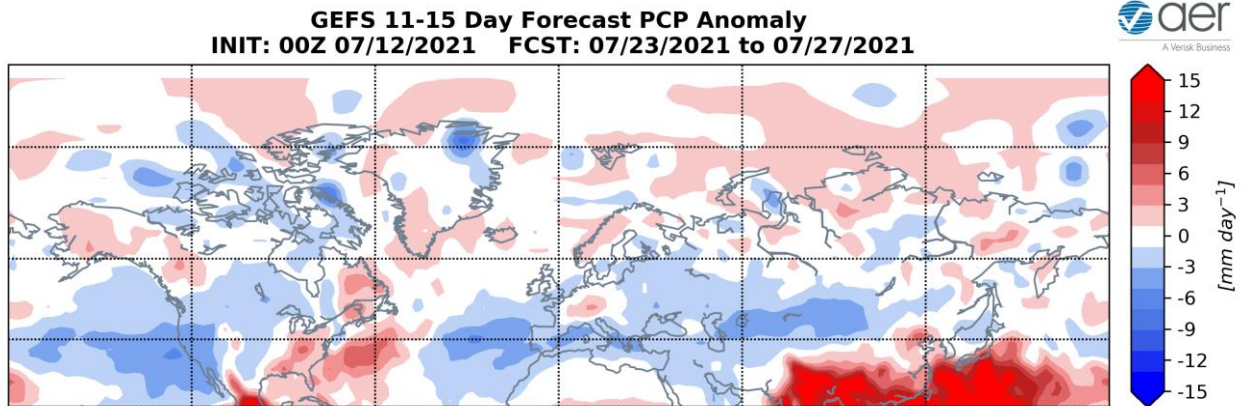


Figure 10. Forecasted precipitation anomalies (mm/day; shading) from 23 – 27 July 2021. The forecasts are from the 00z 12 July 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia except for above normal precipitation in Central Europe and Southeast Asia (**Figure 10**). Normal to below normal precipitation is predicted for much of North America except for normal to above normal precipitation in Alaska, Northwest Canada, the Eastern US 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 cold/negative PCHs in the upper stratosphere and low to mid troposphere with warm/positive PCHs in the mid to low stratosphere and upper troposphere (**Figure 11**). The pattern high heights sandwiched by low heights does seem odd to me and curious to how it can come about.

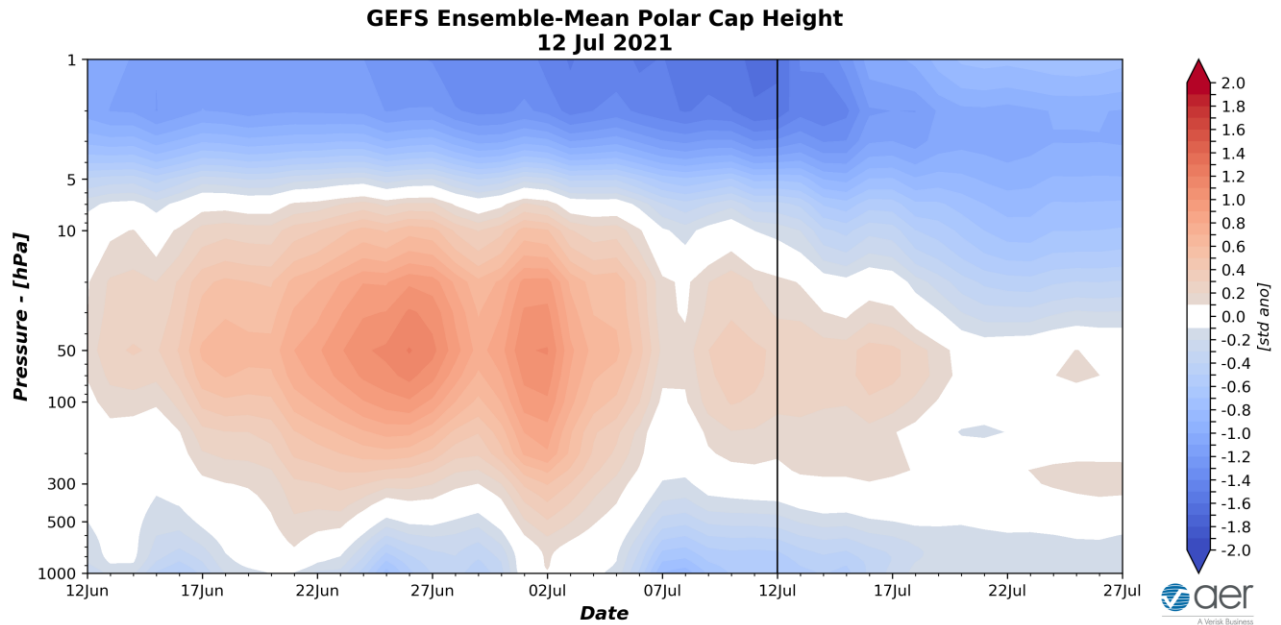


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 12 July 2021 GFS ensemble.

The overall predicted cold/negative PCHs in the lower troposphere are consistent with the predicted positive bias in the surface AO for the next two weeks (**Figure 1**). There are no signs of this reversing into the foreseeable future.

**CFS 500 hPa Forecast Anomaly Aug 2021
Valid as of 12 Jul 2021**

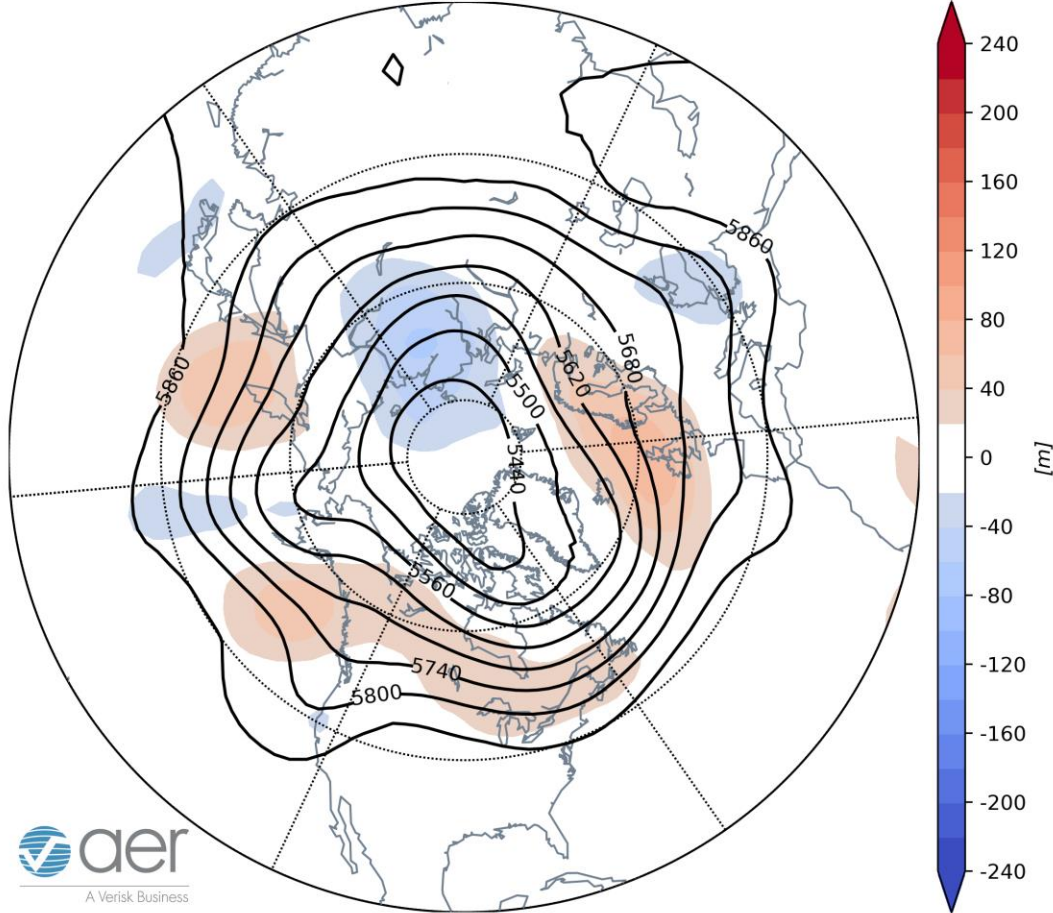


Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for August 2021. The forecasts are from the 00Z 12 July 2021 CFS.

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 the northern North Atlantic from Iceland to Northern Europe, Eastern Asia and the interior of North America with troughing in Southeastern Europe, Western Asia, near the Dateline and along the US West Coast and eastern North America (**Figure 12**). This pattern favors seasonable to relatively cool temperatures for Central and Southern Europe, Western Asia, Western Alaska, the US West Coast and the Central US with seasonable to relatively warm temperatures for Northern Europe, Central and East Asia, Alaska, much of Canada but especially Western Canada, the US Rockies and New England (**Figure 13**).

CFS 20-50 Day Forecast T2m Anomaly
INIT: 00Z 07/12/2021 FCST: 08/01/2021 to 08/31/2021

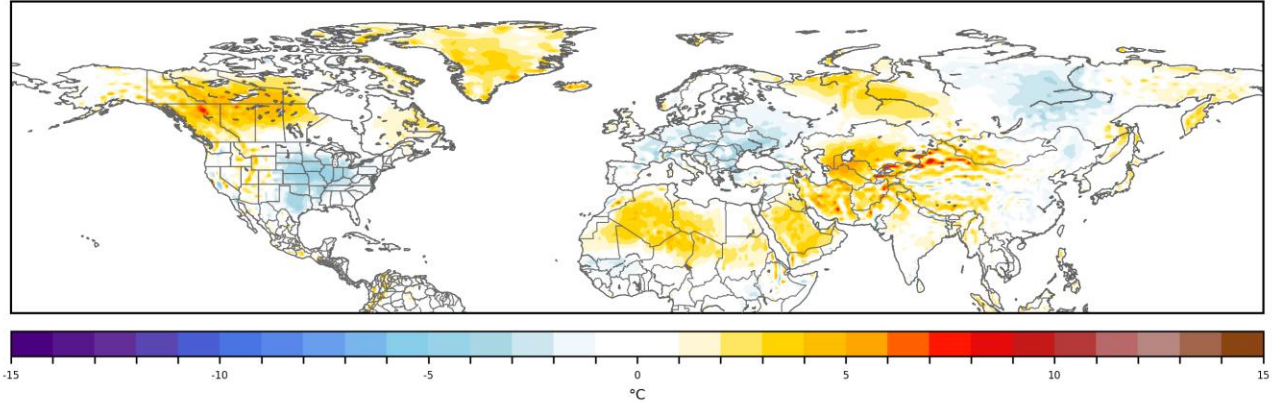


Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for August 2021. The forecasts are from the 00Z 12 July 2021 CFS.

Surface Boundary Conditions

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are close to normal and we continue to observe neutral conditions (**Figure 14**) and neutral conditions are expected through the summer. Observed SSTs across the NH remain well above normal especially in the Baltic Sea, Gulf of Alaska, the western North Pacific and offshore of eastern North America though below normal SSTs exist regionally especially in the Southern Hemisphere and south of Iceland. Warm SSTs in the Gulf of Alaska may favor mid-tropospheric ridging in the region.

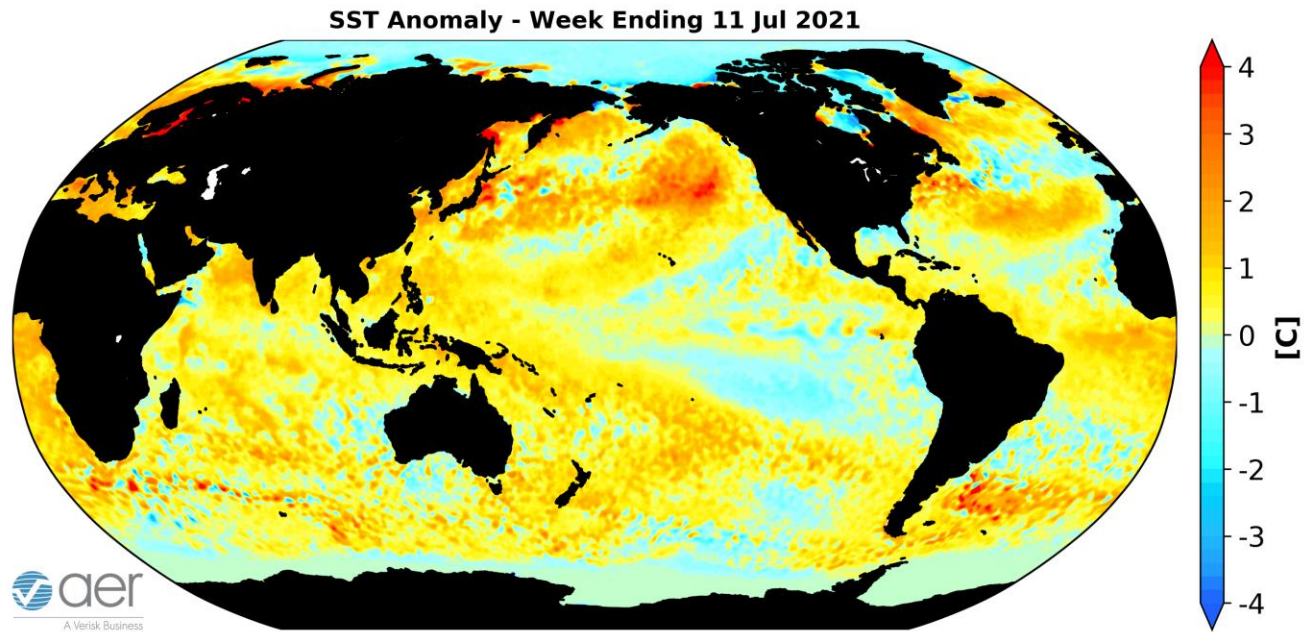


Figure 14. The latest weekly-mean global SST anomalies (ending 11 July 2021). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase three but weak (**Figure 15**). The forecasts are for the MJO to quickly transition to where no phase is favored. Therefore it does not appear that the MJO is not contributing to the predicted weather pattern across North America but admittedly this is outside of my expertise.

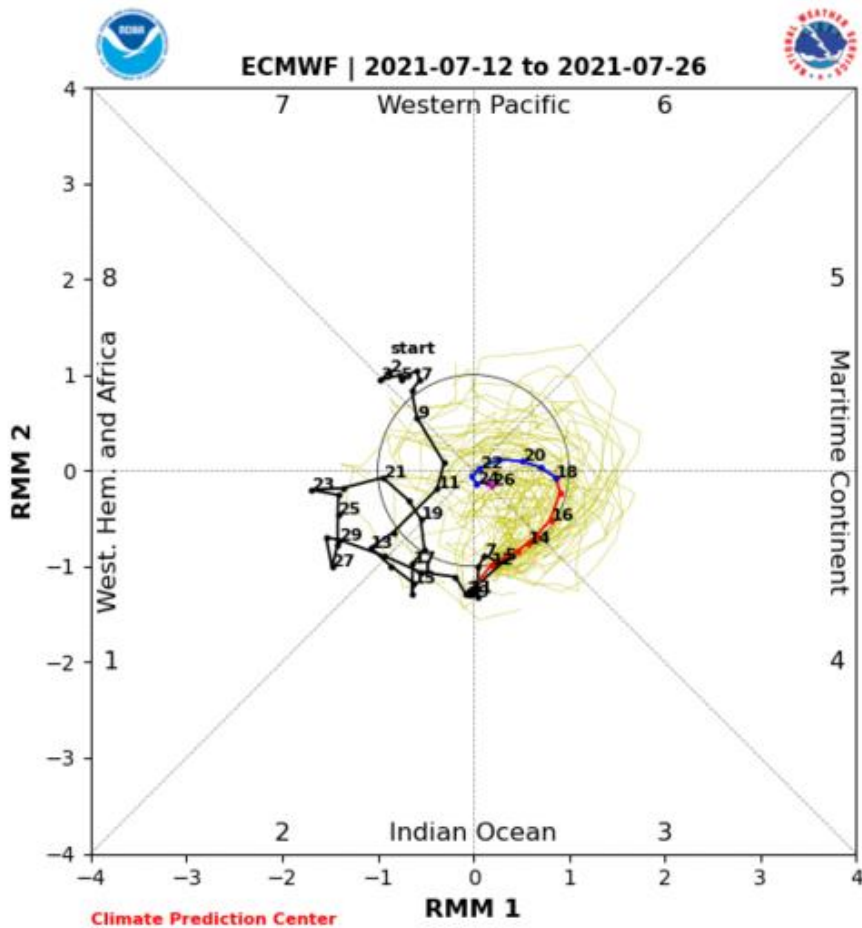


Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 12 July 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>