

Arctic Oscillation and Polar Vortex Analysis and Forecasts

June 28, 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.

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Summary

- The Arctic Oscillation (AO) is currently positive and is predicted to dip negative briefly later this week but otherwise 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 dip negative briefly at the end of the week and then remain positive over the next two weeks as pressure/geopotential height anomalies are predicted to turn first positive later this week and then negative next week across Greenland.

- The general predicted pattern across Europe the next two weeks is ridging/positive geopotential height anomalies coupled with normal to above normal temperatures across much of Europe. One exception is this week as ridging/positive geopotential height anomalies centered near Iceland will force troughing/negative geopotential height anomalies coupled with normal to below temperatures across Western Europe this week including the southern United Kingdom (UK).
- Over the next two weeks Asia will be dominated by 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 in Eastern Asia this week and Western Asia next week.
- This general pattern across North America over the next two weeks is ridging/positive geopotential height anomalies coupled with normal to above normal temperatures. This week the ridging will be centered over western North America but will slide east over the next two weeks. A couple of exceptions are troughing/negative geopotential height anomalies coupled with normal to below temperatures across Alaska and the Central and Southern Plains of the United States (US).
- In the Impacts section I discuss the summer pattern across the Northern Hemisphere (NH).

Impacts

I don't have much profound to discuss today but continuing the theme from the previous blog, looks like the summer pattern so far and predicted, is similar to most recent summers with the possible exception of last summer. The pattern can generally be described as a positive AO with generally low pressure/geopotential heights centered near the North Pole surrounded by above normal to even well above normal pressure/geopotential heights across the mid to high latitudes generally between 40 and 60 and as poleward as 70°N. Equatorward of 40°N pressures/geopotential heights are closer to normal. The anomaly pattern when averaged over days to weeks gives the impression of an annulus with relatively low heights in the Central Arctic surrounded by relatively high heights around the periphery but focused across the northern continents. For some reason the term "ring of fire" comes to my mind. This term is commonly used in meteorology to describe diurnal thunderstorms that fire up on the periphery of subtropical ridging. But to me it also conjures up the exceptional heat across the NH far to the north such as the Pacific Northwest, Western Canada, Northern Europe and even Western Russia that have experienced temperatures this summer more typical of areas well to their south. And maybe more metaphorically apt, these

regions will become increasingly vulnerable to wildfires as the vegetation desiccates in the heat.

The two regions that have experienced the most positive anomalous temperatures so far this summer are Western US/Canada and Northeastern Europe/Northwestern Russia. It has also been quite warm relative to normal in the Northeastern US/Southeastern Canada and parts of East Asia. This seems to me generally consistent with the general temperature pattern of recent summers. Across North America the largest positive temperature departures from normal have been observed in western North America with a secondary maximum in eastern North America with temperatures close to seasonable or even seasonably cool in the interior of North America especially in the Central US. This is looking more and more likely to be the general pattern of summer 2021 for North America. Across Eurasia there have been two temperature anomaly maximums one centered over Europe and the other over East Asia, especially Northeast Asia with more seasonable temperatures across Western Russia near the Urals. This summer a temperature anomaly maximum centered near Europe is looking likely (this despite the relatively cool and wet European spring) but so far it has extended farther east than recent summers and this has contributed to a cooler summer across Siberia at least relative to recent summers and temperatures have been warmer across Western Russia this summer than recent summers. Though based on the forecasts the pattern across Eurasia will better match recent summers with temperature anomaly maximums across Europe and East Asia with more seasonable temperatures centered near the Urals.

In summary at least in summer it does seem that “what’s past is prologue” and that recent summers provide a good early indication of what to expect for the upcoming summer. Or it does seem that summer temperature pattern is easier to predict based on recent summers more so than predicting the upcoming winter based on recent winters. And as I have discussed in previous summers why this summer pattern seems to show good consistency from year to year remains an open question. I wonder one possibility, which I have not discussed previously, is that subtropical ridging over the oceans in summer such as the Bermuda high and Azores high have expanded north and over the continents in recent summers causing the continental edges to warm faster than the interiors.

1-5 day

The AO and NAO are predicted to begin the week positive but then dip negative at the end of the week (**Figure 1**) as geopotential height anomalies are predicted to be mostly negative in the Central Arctic and across Greenland but then turn positive over the weekend across Greenland with mostly positive geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**).

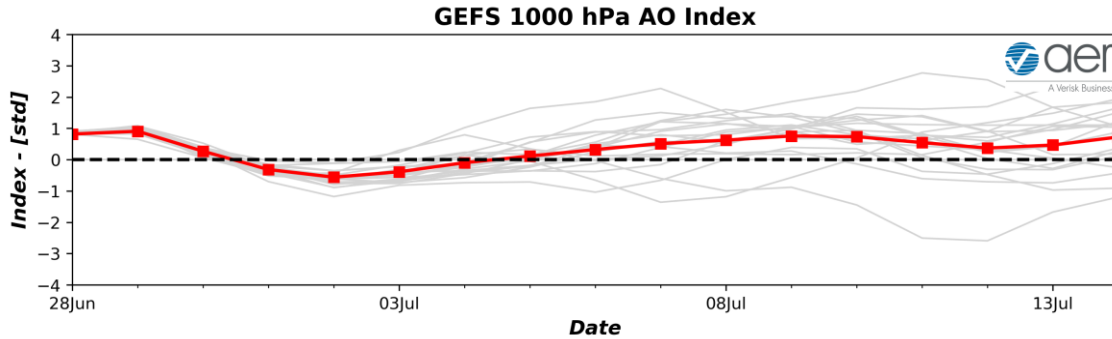


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 28 June 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

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 underneath the center of the ridging near Iceland (**Figures 2**). This will favor normal to above normal temperatures across much of Europe with normal to below normal temperatures across Western Europe including the Southern UK (**Figure 3**). The general pattern across Asia this period is ridging/positive geopotential height anomalies across much of Asia with ridge centers in Western Asia and Eastern Siberia with trouching/negative geopotential height anomalies in East Asia (**Figure 2**). This pattern favors normal to above normal temperatures across much of Asia but especially Western Asia and Eastern Siberia with normal to below normal temperatures in much of East Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 06/28/2021 FCST: 06/29/2021 to 07/03/2021

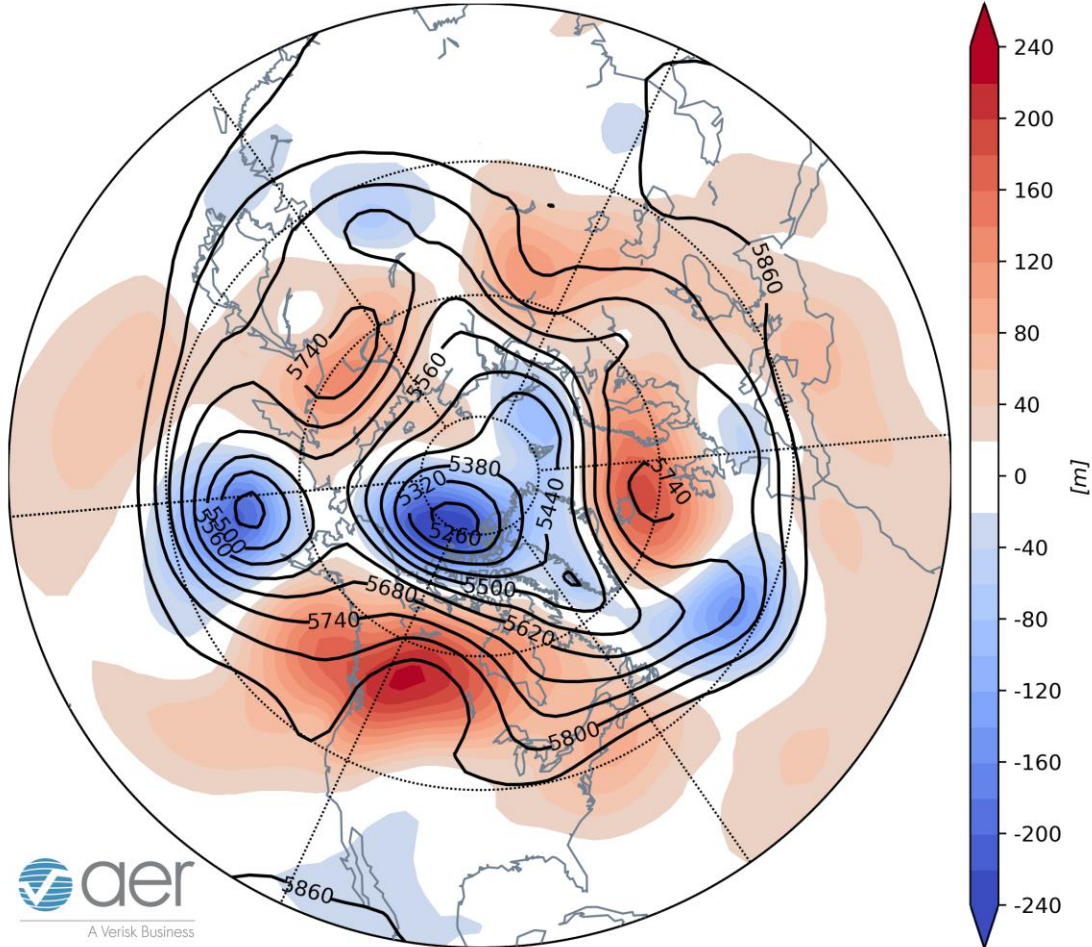


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 29 June – 3 July 2021. The forecasts are from the 00z 28 June 2021 GFS ensemble.

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

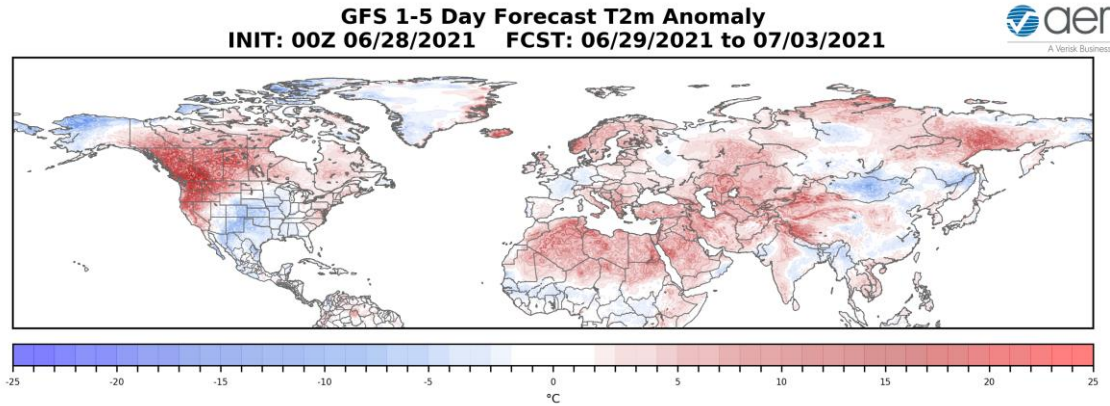


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 29 June – 3 July 2021. The forecast is from the 00Z 28 June 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia with the exceptions of above normal precipitation across Germany, Northwest Russia, 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 Western Alaska and the Eastern US (**Figure 4**).

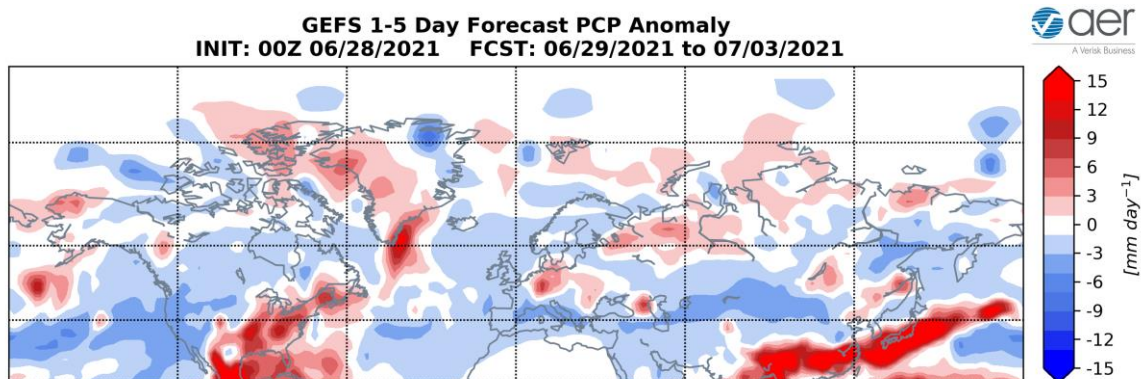


Figure 4. Forecasted precipitation anomalies (mm/day; shading) from 29 June – 3 July 2021. The forecast is from the 00Z 28 June 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to return to 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 predicted to return across Greenland (**Figure 5**), the NAO is predicted to turn positive this period.

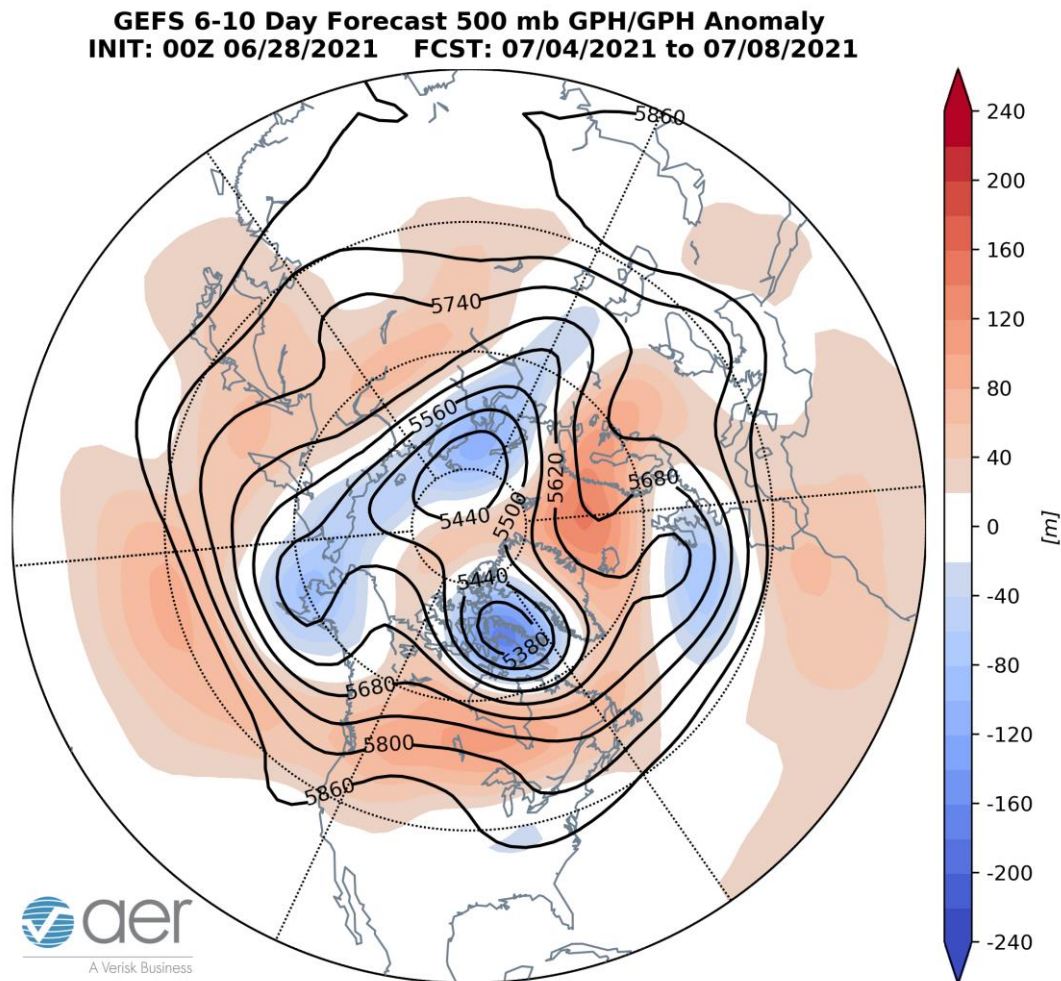


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 4 – 8 July 2021. The forecasts are from the 00z 28 June 2021 GFS ensemble.

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 across Northwestern Europe (**Figures 5**). This will favor widespread normal to above normal temperatures across much of Europe with the possible exception of normal to below normal temperatures confined across Northwestern Europe including the UK (**Figure 6**). Ridging/positive geopotential height anomalies are predicted to dominate Asia with the most notable exception of troughing/negative geopotential height anomalies dropping out of the Arctic and into Western Russia (**Figure 5**). This pattern favors normal to above normal temperatures

across much of Asia especially Central Asia with biggest of exception of normal to below normal temperatures in Northwestern Asia (**Figure 6**).

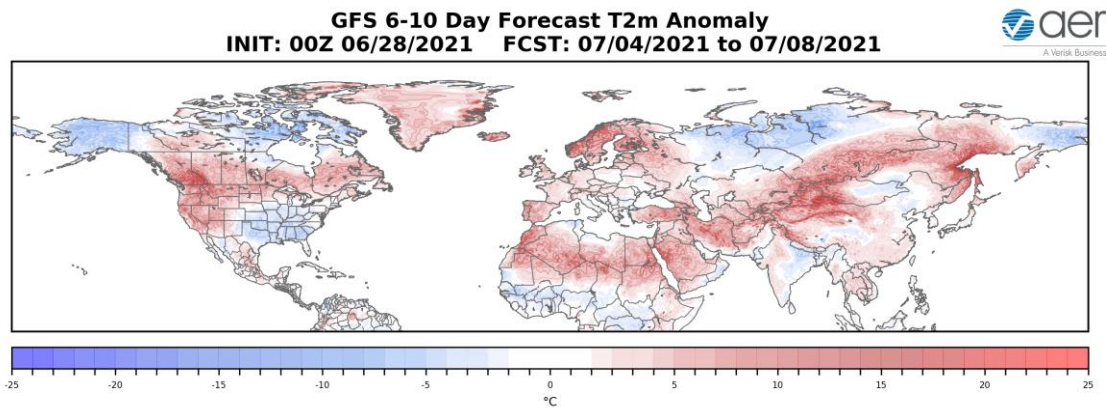


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 4 – 8 July 2021. The forecasts are from the 00Z 28 June 2021 GFS ensemble.

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

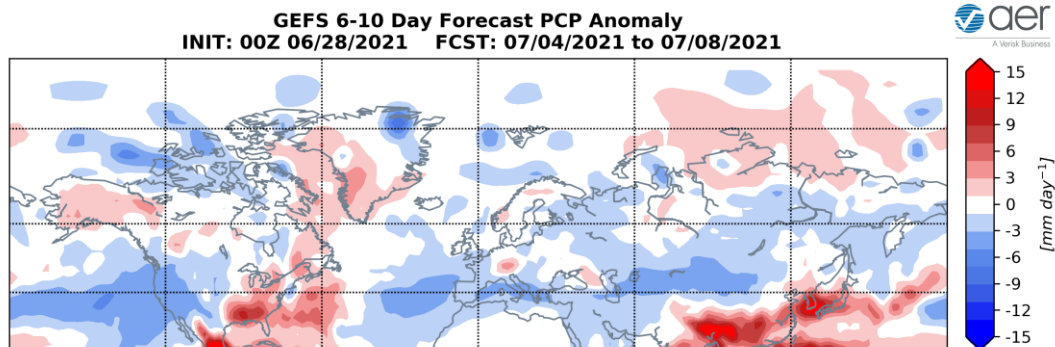


Figure 7. Forecasted precipitation anomalies (mm/day; shading) from 4 – 8 July 2021. The forecasts are from the 00Z 28 June 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia with the exceptions of above normal precipitation in the Alps 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.

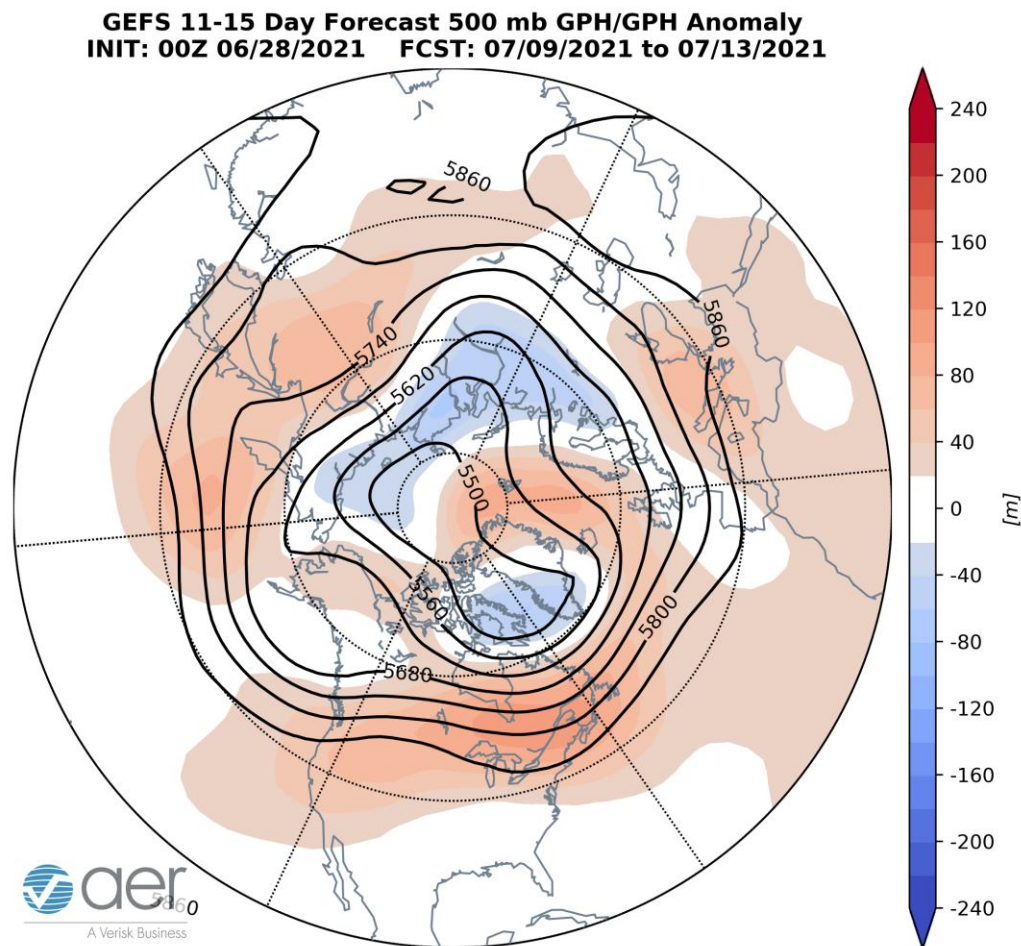


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 9 – 13 July 2021. The forecasts are from the 00z 28 June 2021 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to continue to dominate 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 Asia with the notable exception of 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 Western Asia (**Figure 9**).

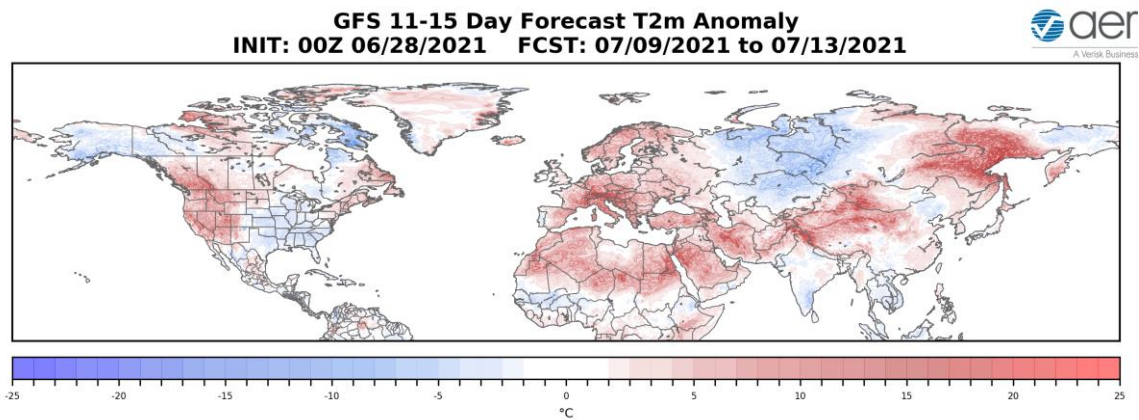


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 9 – 13 July 2021. The forecasts are from the 00z 28 June 2021 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to continue to dominate North America, but the center of the ridging is predicted to slide into Southeastern Canada with troughing/negative geopotential height across Alaska and the Gulf of Alaska this period (**Figure 8**). This pattern favors normal to above normal temperatures for much of Canada, the Western US and New England with normal to below normal temperatures across Alaska, Northwestern Canada, the Canadian Arctic Archipelagos and much of the Eastern US (**Figure 9**).

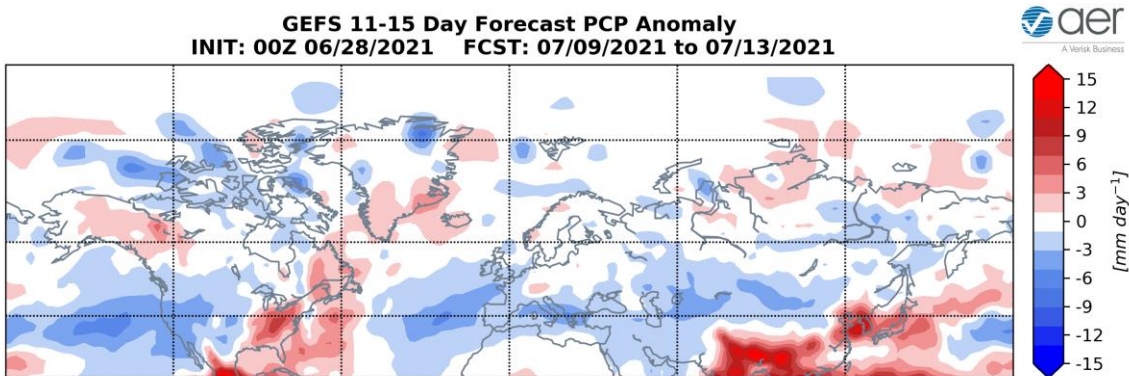


Figure 10. Forecasted precipitation anomalies (mm/day ; shading) from 9 – 13 July 2021. The forecasts are from the 00z 28 June 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia except for above normal precipitation in Southeast Asia (**Figure 10**). 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 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 near the surface with warm/positive PCHs in the mid to low stratosphere and upper to mid troposphere (**Figure 11**). However, later this week the warm/positive PCHs in the stratosphere are predicted to descend briefly into the lower troposphere (**Figure 11**).

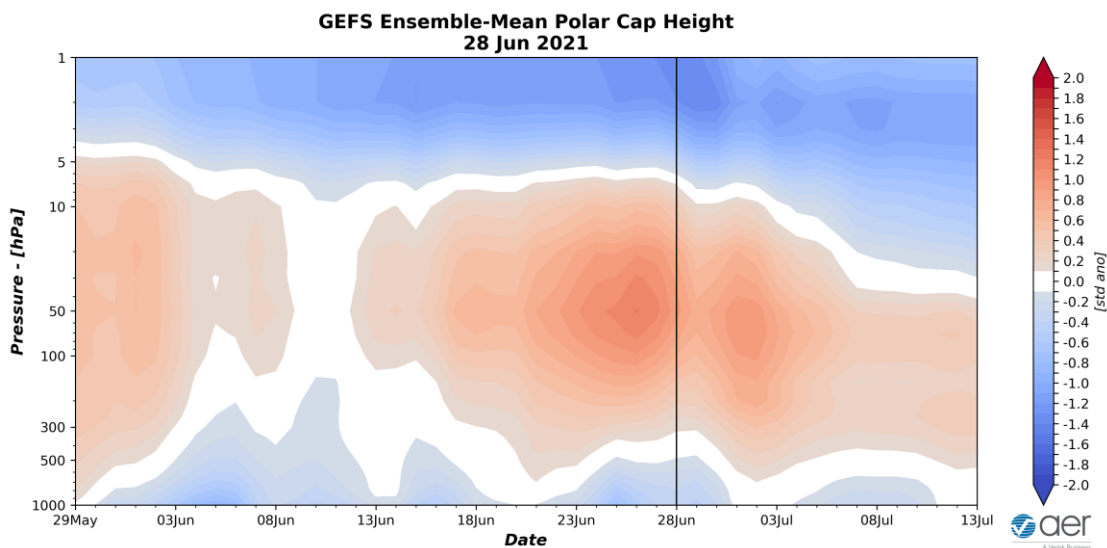


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 28 June 2021 GFS ensemble.

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**). The one exception is when warm/positive PCHs in the upper to mid troposphere descend into the lower troposphere at the end of the week favoring a brief deep of the AO into negative territory (**Figure 1**).

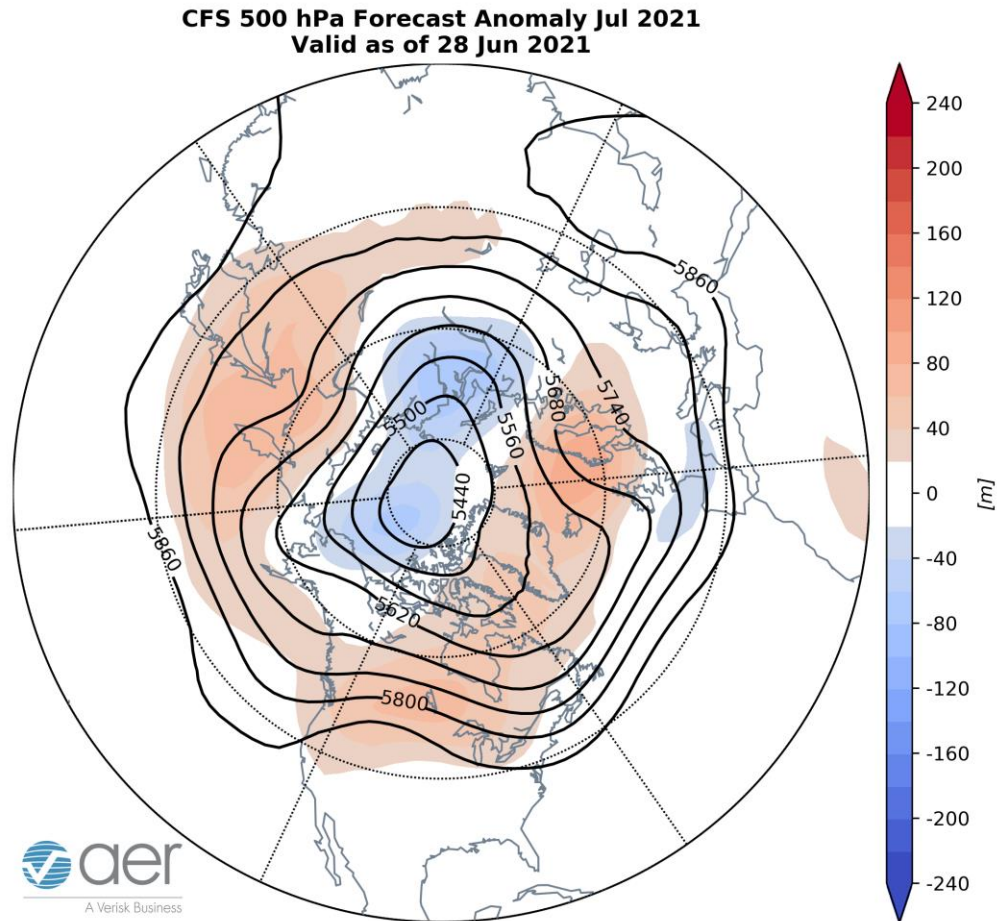


Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for July 2021. The forecasts are from the 00Z 28 June 2021 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and the surface temperatures (**Figure 13**) forecast for July 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 Greenland into Northern Europe, Eastern Asia and the interior of North America with troughing in Southern Europe, Western Asia, near the Dateline and along the east coast of North America (**Figure 12**). This pattern favors seasonable to relatively cool temperatures for Western Europe, Western Asia into Western Siberia, Alaska, Northwestern Canada and the Central US with seasonable to relatively warm temperatures for Northern Europe, Central and East Asia, Alaska, Western and Eastern Canada, the Western US and New England (**Figure 13**).

CFS 3-33 Day Forecast T2m Anomaly
INIT: 00Z 06/28/2021 FCST: 07/01/2021 to 07/31/2021

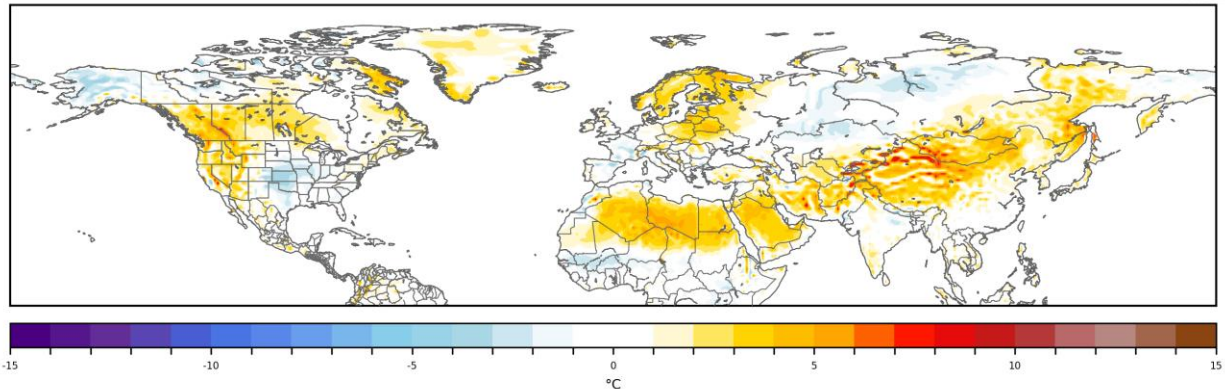


Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for July 2021. The forecasts are from the 00Z 28 June 2021 CFS.

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 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.

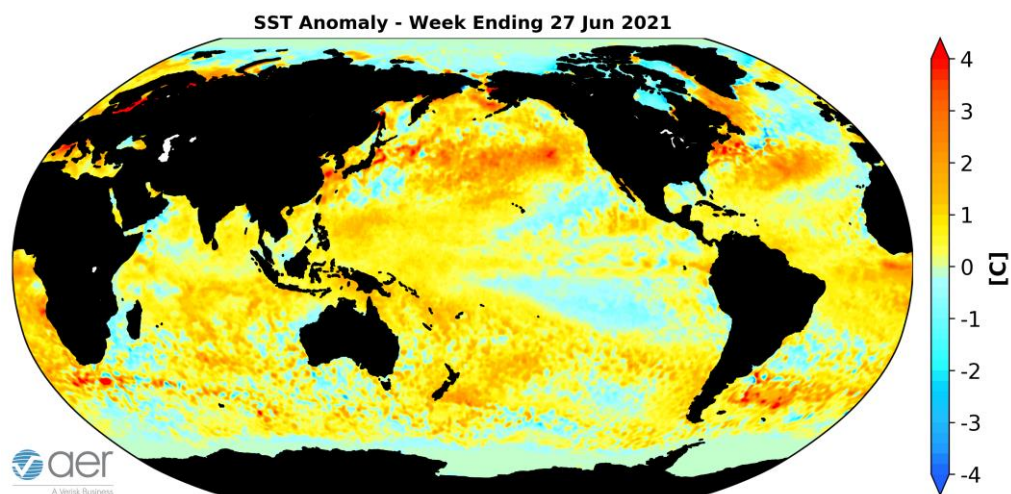


Figure 14. The latest weekly-mean global SST anomalies (ending 27 June 2021). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase one (**Figure 15**). The forecasts are for the MJO to transition to phase two and then weaken to where no phase is favored. However overall, the MJO is predicted to remain weak. MJO phase one initially favors ridging across Eastern Canada and the Eastern US but then eventually favors ridging in western North America and troughing in central North America. Therefore it is possible that the MJO is contributing weakly to the predicted weather pattern across North America but admittedly this is outside of my expertise.

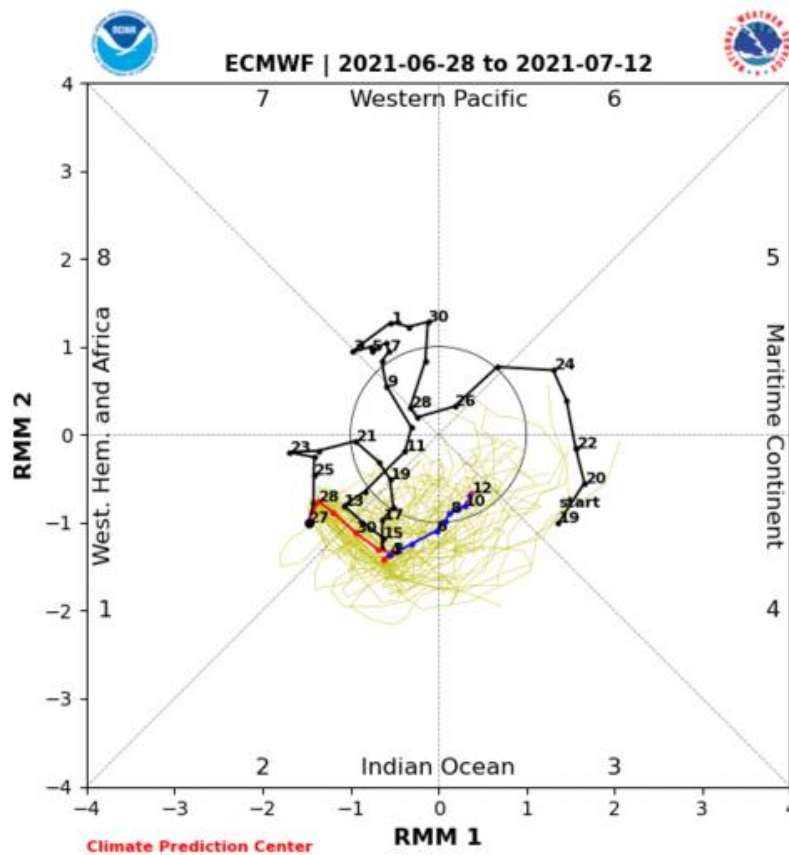


Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 28 June 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>

