Arctic Oscillation and Polar Vortex Analysis and Forecasts

June 7, 2022

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 negative and is predicted to trend positive and turn positive next week as mostly positive pressure/geopotential height anomalies currently across the Arctic including the North Atlantic side of the Arctic transition to mostly negative with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently negative and is predicted to trend positive as pressure/geopotential height anomalies are predicted to become increasingly negative across Greenland over the next two weeks.
- Over the next two weeks troughing/negative geopotential height anomalies across Greenland will support mostly ridging/positive geopotential height anomalies across Europe though starting next week troughing/negative geopotential height anomalies will come ashore in Western Europe next week. This pattern favors widespread normal to above normal temperatures across much of Europe this week with the exception of normal to below normal temperatures in far Western Europe including the UK starting next week.
- The general pattern across Asia the next two weeks is a quasi-omega block pattern with troughing/negative geopotential height anomalies across West and

East Asia bookending ridging/positive geopotential height anomalies centered in Central Asia. This pattern favors widespread normal to above normal temperatures across much of Asia, especially Central Asia including Western and Central Siberia with regional normal to below normal temperatures focused across Western Asia and Eastern Asia the next two weeks.

- The general pattern this week across North America is ridging/positive geopotential height anomalies across western North America forcing widespread troughing/negative across eastern North America especially the Eastern United States (US). However, starting next week, the pattern will begin to evolve into an omega block pattern with ridging/positive geopotential height anomalies centered in the interior of the continent bookended by troughing/negative geopotential height anomalies across the coasts of North America especially the Northwestern and Northeastern US. The pattern favors this week normal to below normal temperatures across much of Southeastern Canada, the Great Lakes and Northeastern US with normal to above normal temperatures across Alaska, Western Canada and the Western US. Then beginning next week normal to below normal temperatures will become widespread across Alaska, Southwestern and Southeastern Canada and the Northwestern and Northeastern US with normal to above normal temperatures across Northern Canada and the Central and Southern US.
- In the *Impacts* section I discuss some differences in the model summer temperature forecasts and possible divergence from recent interannual trends.

Plain Language Summary

In the most recent archived blog, I posted the summer temperature forecast and the unmistaken message from the model forecasts is widespread relative warmth. However, some regions of influence in the ocean and atmosphere could potentially lead to some regional cooling relative to the forecasts and/or recent interannual trends including the west coast of North America and the Northeastern US.

Impacts

I posted in the blog dated 23 May 2022 the summer temperature anomaly forecast from the NMME (North American ensemble), C3S (European ensemble) and AER models. Overall, the forecasts were fairly consistent (widespread warmth across the continents) not only with each other but with the observed trends from recent summers with just some regional differences. From what I can see in today's forecast plots shown below, the overall summer forecast looks to be on track, but they are some regions where I am monitoring for a divergence from the forecast and what will eventually be the observed temperature anomalies.

The first region that I can envision a divergence at least from the recent summer trends are well above normal temperatures along the west coast of North America including

Alaska and the Pacific Northwest. There has been a tendency for troughing and relatively cool temperatures in this region so far this spring and based on the forecast plots below, this trend is predicted to continue. A cool summer relative to recent summers is consistent with the NMME and C3S forecasts but less so with the AER model. Presumably the higher probability of a relatively cool summer is being forced by the ongoing La Niña and sea surface temperatures in the North Pacific, which are consistent with the negative phase of the Pacific Decadal Oscillation (PDO). If troughing coupled with cooler temperatures is characteristic of this summer, then it is also likely that the core of the heat will be focused further east relative to recent summers. Maybe this is obvious to many of the readers, but this is admittedly not my expertise.

The second region that I am paying close attention to is the Northeastern US. It has been a cool June so far and based on the forecast plots below, June is looking relatively cool. A cool June does not guarantee a cool summer and I would not be confident of an overall cool summer until well into July and maybe even August. But there has been a tendency for blocking/high pressure in the northern North Atlantic and in and around Greenland. This pattern will relax over the next week or so but based on recent interannual trends and even the forecast from the CFS (the July forecast is shown in **Figure 12,** and I include the August forecast in **Figure i**) there is reason to expect it's return. It seems to me that if blocking/high pressure is persistent enough this summer in and around Greenland, temperatures in the Northeastern US can be cooler than predicted by all of the forecasts. Another region that could be biased cooler by persistent blocking/high pressure in and around Greenland is Europe. I think the best possibility is Western Europe with above normal temperatures in Eastern Europe, consistent with recent interannual trends, but cooler temperatures could be even more widespread but so far there are no indications of more widespread relatively cool temperatures in Europe.

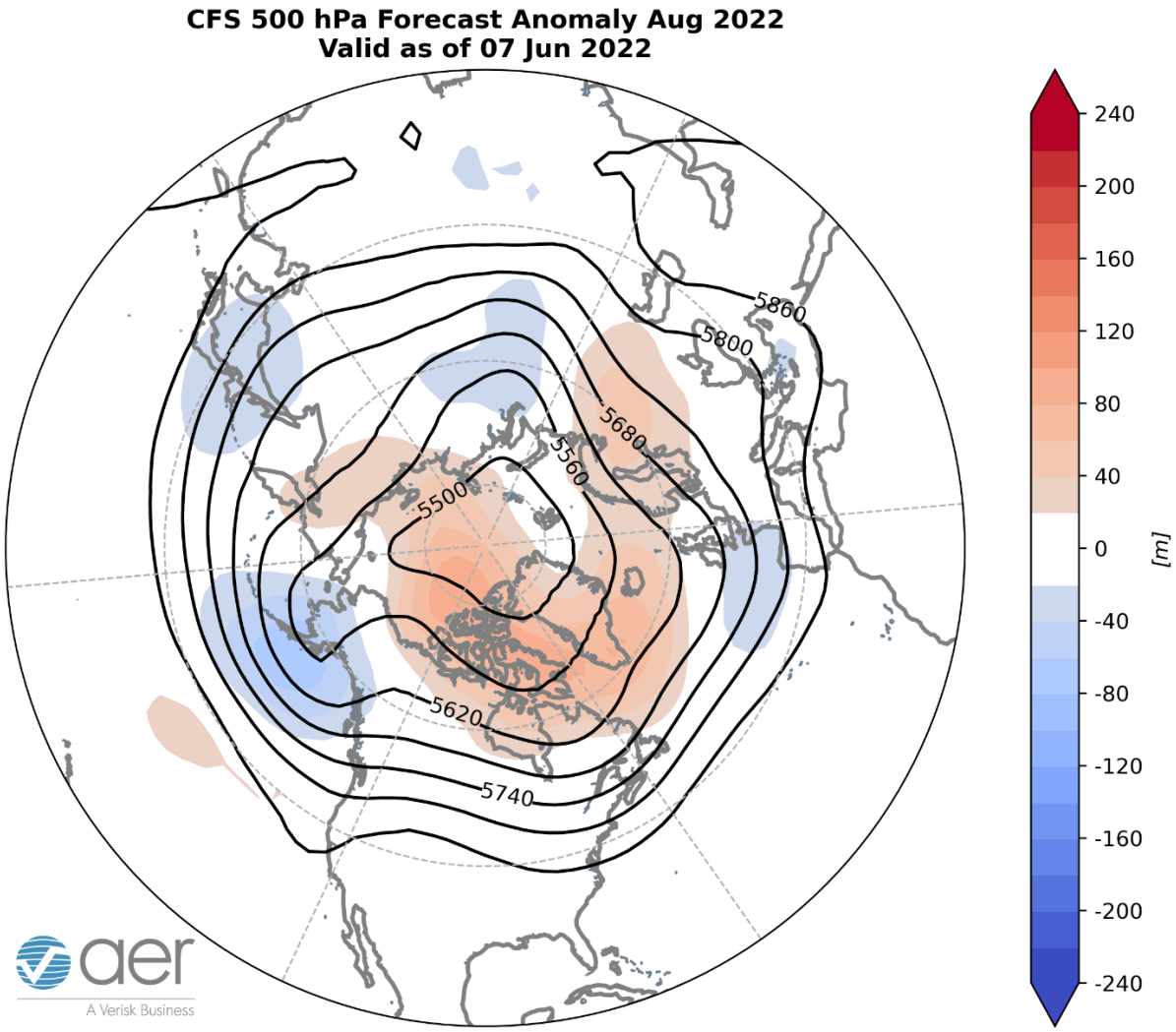

Figure i. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for August 2022. The forecasts are from the 00Z 7 June 2022 CFS.

During recent summers, Siberia has been on fire, figuratively and literally. I think there was every reason to expect this trend to continue this summer, especially given the rapid disappearance of snow cover across Siberia this spring. And all the models are predicting a relatively warm summer for Siberia, but the NMME is the most aggressive with its warm forecast. Looking at the forecast below, well above normal temperatures are predicted over the next two weeks for much of Siberia and at least after the first week of summer, the most aggressive warm forecast is looking best, especially for Western and Central Siberia.

1-5 day

The AO is predicted to be negative this week **(Figure 1**) with mostly positive geopotential height anomalies predicted across the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with predicted positive geopotential height anomalies this week across Greenland, mostly early in the week (**Figure 2**), the NAO is predicted to also be negative this week (**Figure 1**).

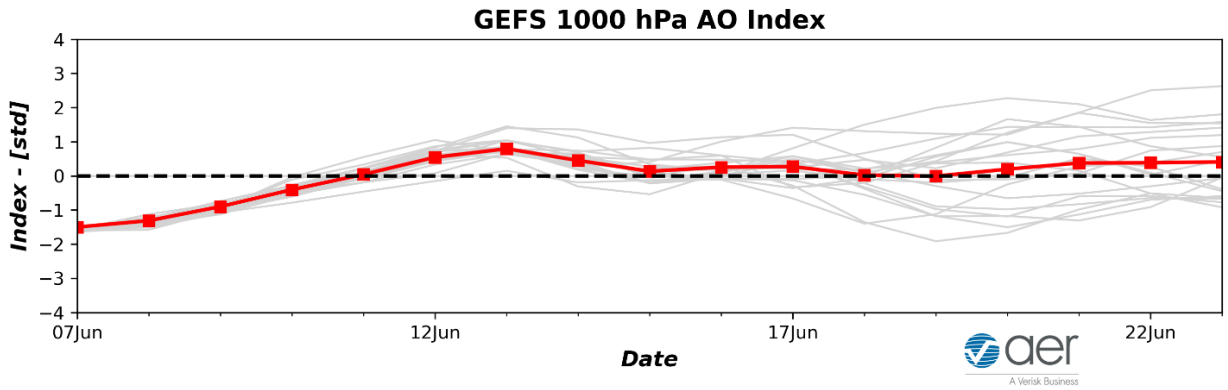

Figure 1. The predicted daily-mean AO at 1000 hPa from the 00Z 7 June 2022 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Increasing troughing/negative geopotential height anomalies across Greenland this week will support increasing ridging/positive geopotential height anomalies across much of Europe centered in Western Europe with troughing/negative geopotential height anomalies limited to the Balkans (**Figures 2).** This will favor widespread normal to above normal temperatures across most of Europe including the UK with normal to below normal temperatures mostly limited to the Balkan States (**Figure 3**). Troughing/negative geopotential height anomalies is predicted across Western and Eastern Asia with ridging/positive geopotential height anomalies across Central Asia this period (**Figure 2**). This pattern favors widespread normal to above normal temperatures across much of Asia with normal to below normal temperatures limited to Western Russia, Mongolia and Northeastern China **(Figure 3**).

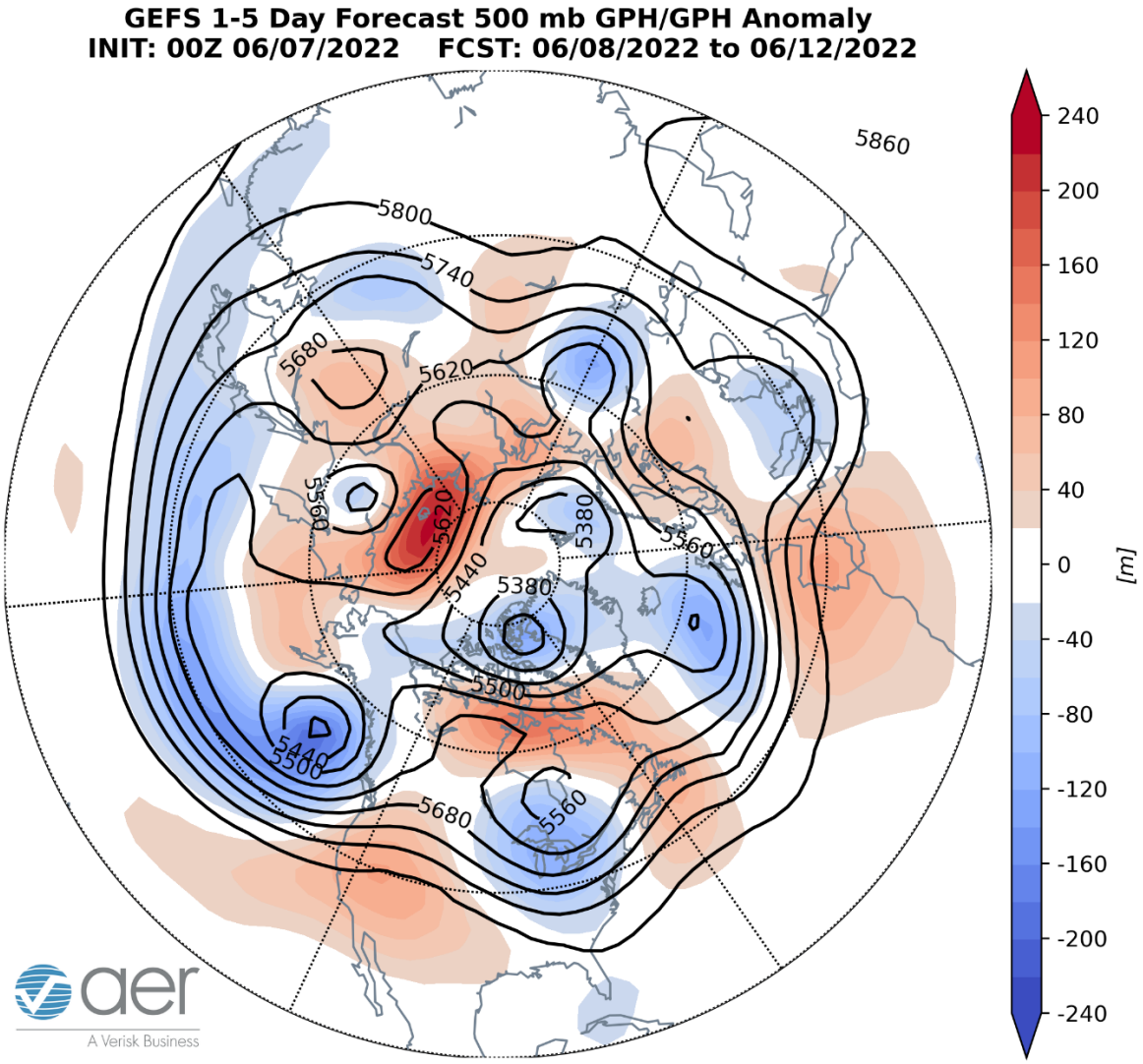

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 8 – 12 June 2022. The forecasts are from the 00z 7 June 2022 GFS ensemble.

Troughing/negative geopotential height anomalies in the Gulf of Alaska will force ridging/positive geopotential height anomalies across western North America with troughing/negative geopotential height anomalies centered in the Great Lakes **(Figure 2).** The pattern will favor normal to above normal temperatures across Southern Alaska, much of Western and Northern Canada and the Western and Southern US with normal to below normal temperatures across Northern Alaska, Southeastern Canada and the Northern and Eastern US **(Figure 3).**

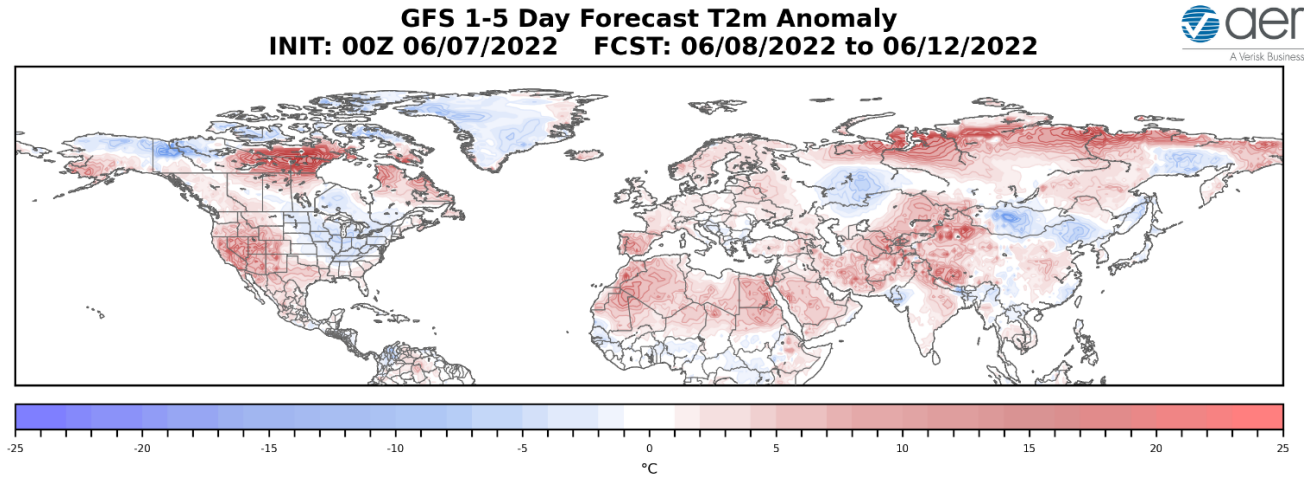

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 8 – 12 June2022. The forecast is from the 00Z 7 June 2022 GFS ensemble.

Mostly below normal precipitation is predicted across Eurasia with above normal precipitation predicted for the Balkans and parts of Southeast Asia (**Figure 4**). Mostly below normal precipitation is predicted across North America with above normal precipitation predicted for Western and Southeastern Canada and the Northeastern US (**Figure 4**).

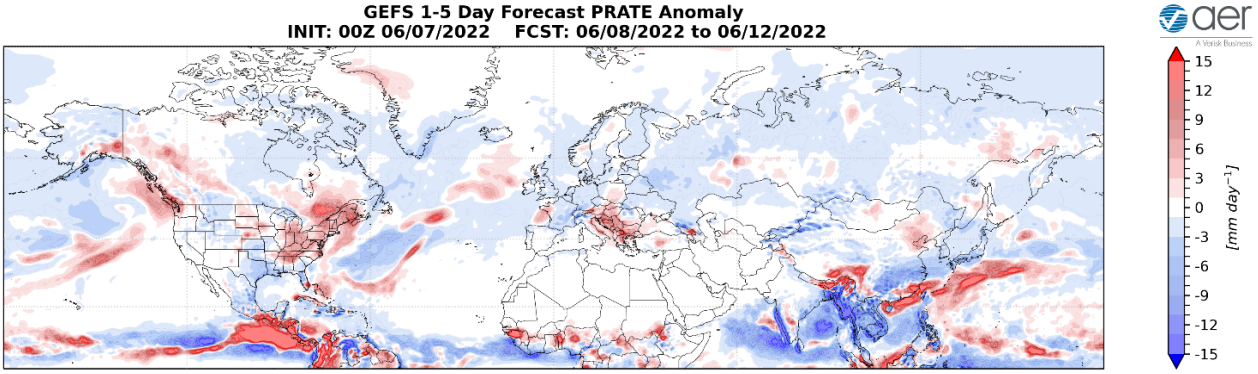

Figure 4. Forecasted precipitation rate (mm/day; shading) from 8 – 12 June 2022. The forecast is from the 00Z 7 June 2022 GEPS ensemble.

Mid-Term

6-10 day

The AO is predicted to reverse to positive this period **(Figure 1**) as geopotential height anomalies turn mostly negative across the Arctic, especially the North Atlantic side of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH

(**Figure 5**). And as geopotential height anomalies also reverse to negative across Greenland and Iceland (**Figure 5**), the NAO is predicted to turn positive this period as well.

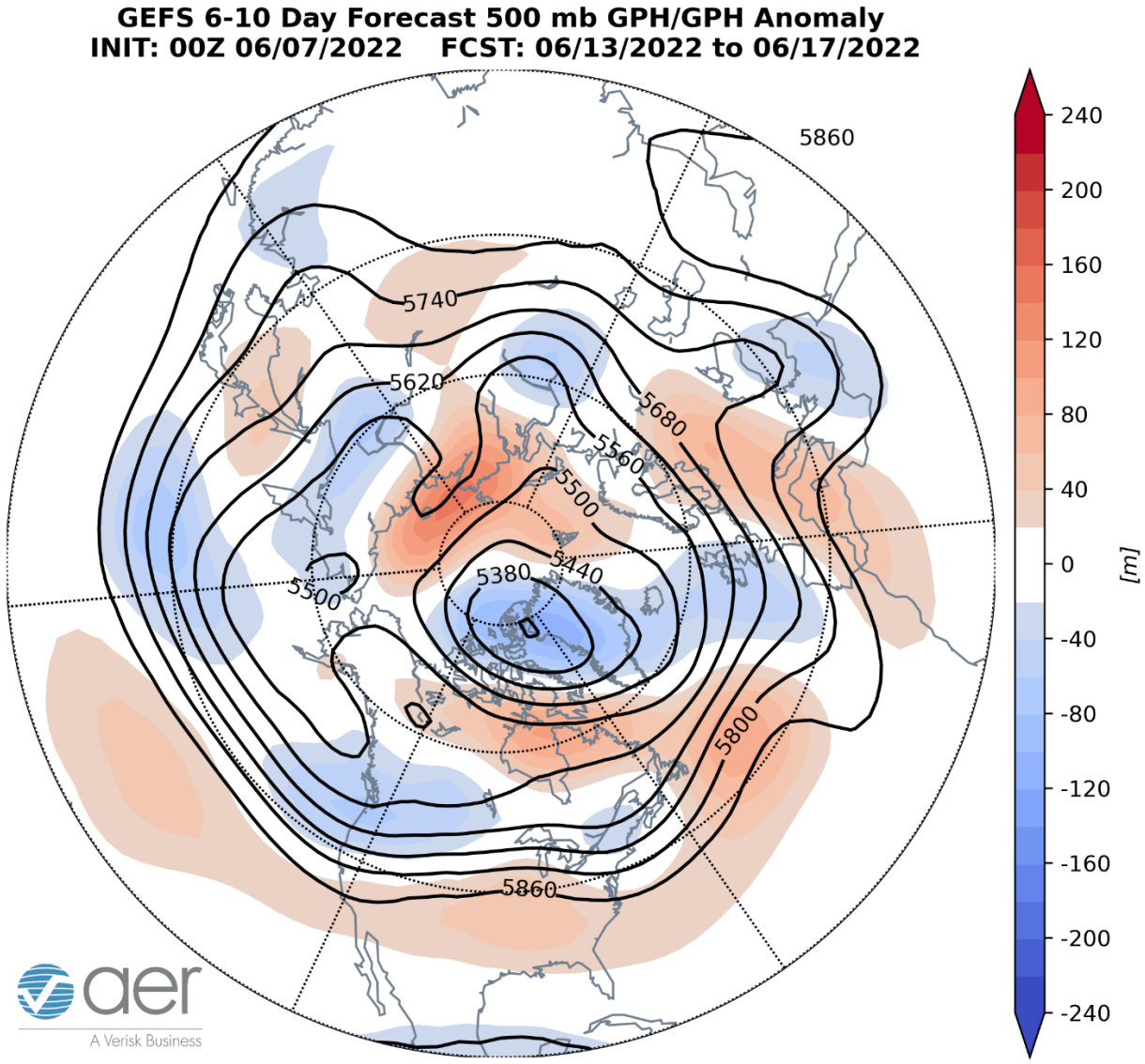

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 13 – 17 June 2022. The forecasts are from the 00z 7 June 2022 GFS ensemble.

Predicted troughing/negative geopotential height anomalies centered across Greenland will force ridging/positive geopotential height anomalies centered across Central Europe with regional troughing/negative geopotential height anomalies across far Western and Southeastern Europe this period (**Figures 5).** This will result in normal to above normal temperatures across much of Europe with normal to below normal

temperatures limited to the UK and Turkey (**Figure 6**). The omega block pattern across Asia is predicted to persist with troughing/negative geopotential height anomalies across Northwestern and Northeastern Asia sandwiching ridging/positive geopotential height anomalies across Central Asia, focused in Western Siberia this period (**Figure 5**). This pattern favors normal to below normal temperatures across Western Russia, Kazakhstan and Northeastern Asia with normal to above normal temperatures widespread across Siberia and Central and Southern Asia **(Figure 6**).

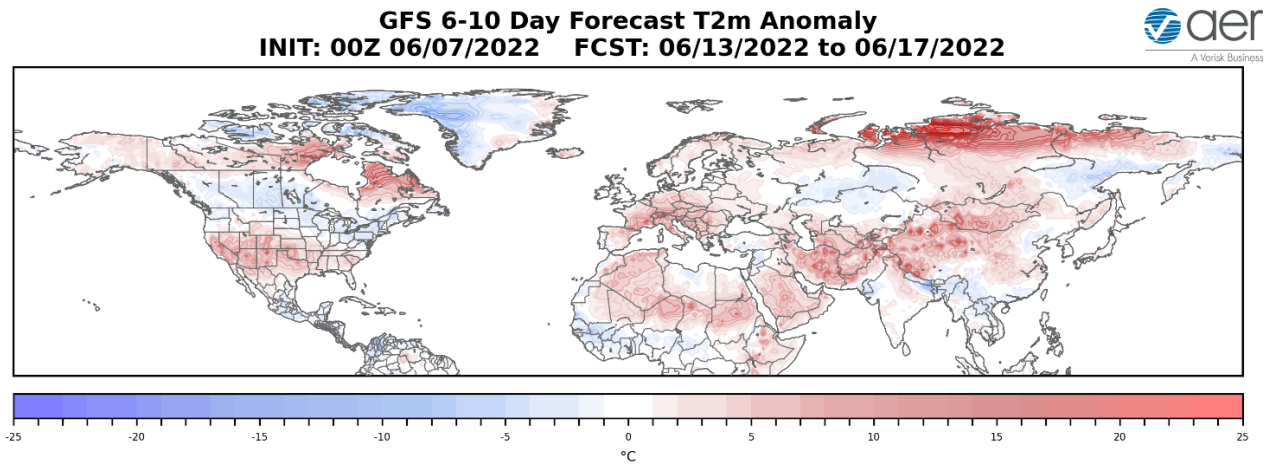

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 13 – 17 June 2022. The forecasts are from the 00Z 7 June 2022 GFS ensemble.

Troughing/negative geopotential height anomalies previously in the Gulf of Alaska are predicted to enter the Pacific Northwest splitting ridging/positive geopotential height anomalies across Northern Canada and the Southern US **(Figure 5).** This will favor normal to above normal temperatures across Northern Canada and the Southern US sandwiching normal to below normal temperatures across Southern Canada and the Northern US **(Figure 6).**

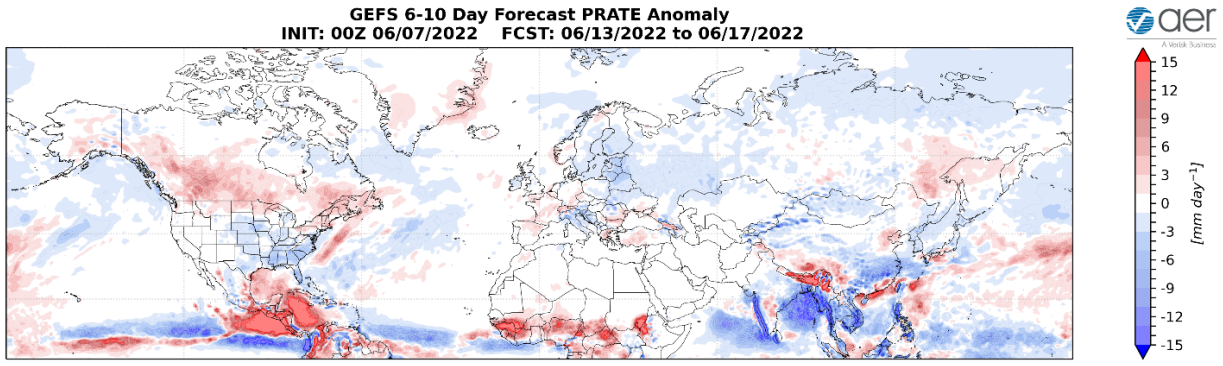

Figure 7. Forecasted precipitation rate (mm/day; shading) from 13 – 17 June 2022. The forecast is from the 00Z 7 June 2022 GEPS ensemble.

Mostly below normal precipitation is predicted across Eurasia with above normal precipitation predicted for Western Europe, Northeastern and Southeastern Asia (**Figure 7**). Mostly below normal precipitation is predicted across North America with above normal precipitation predicted along the US-Canadian border (**Figure 7**).

11-15 day

Geopotential height anomalies are predicted to remain mostly negative across the Arctic this period (**Figure 8**), therefore the AO should remain positive to neutral (**Figure 1**). With predicted negative pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is predicted to also remain positive to neutral this period.

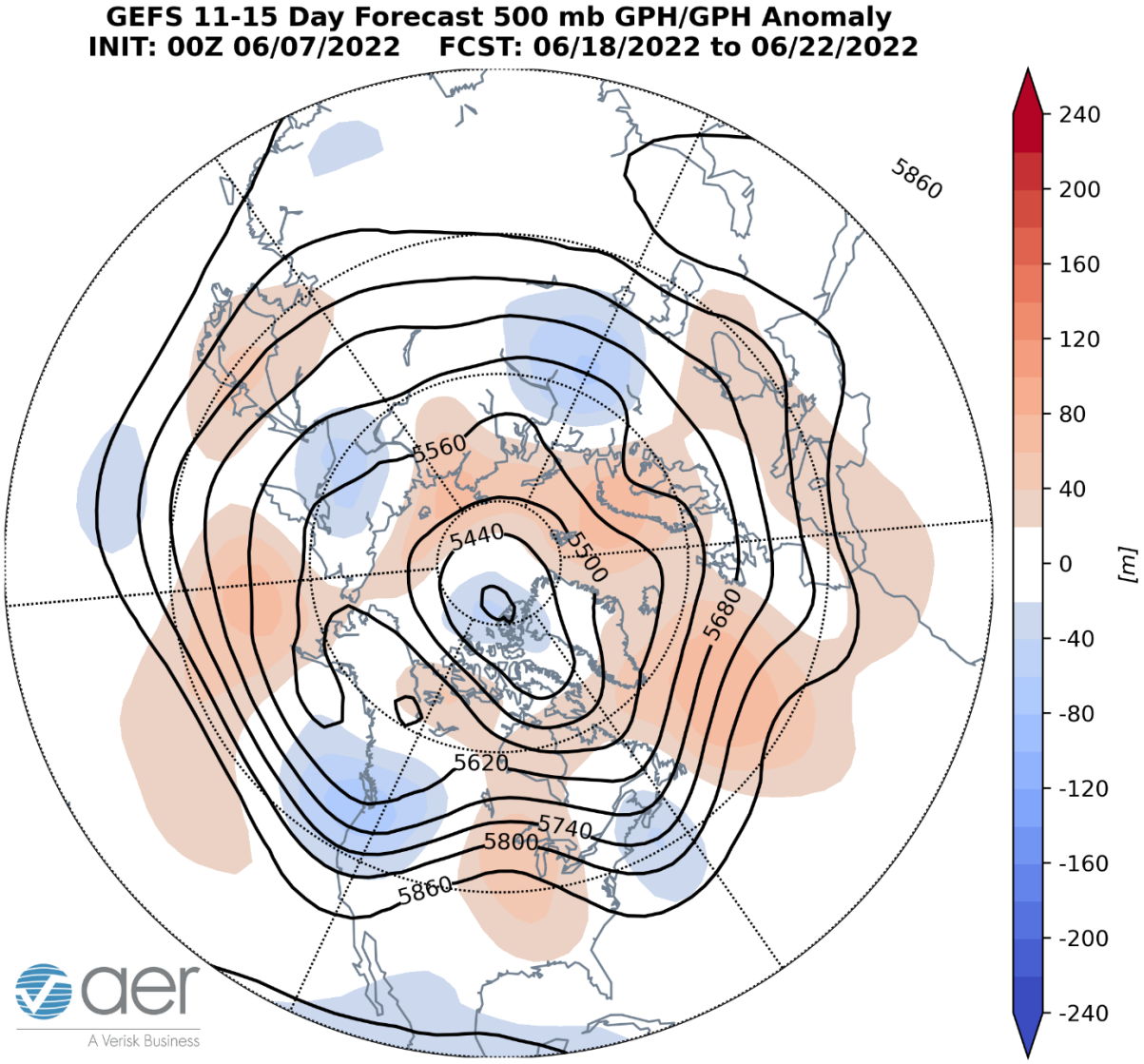

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 18 – 22 June 2022. The forecasts are from the 00z 7 June 2022 GFS ensemble.

Persistent troughing/negative geopotential height anomalies across Greenland will continue to favor ridging/positive geopotential height anomalies across Europe with the exception of troughing/negative geopotential height anomalies across far Western Europe this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across Europe with the exception of normal to below normal temperatures across far Western Europe including the UK (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to remain widespread across Asia but still centered in Central Asia especially Western Siberia this period with troughing/negative geopotential height anomalies mostly limited to Northwest and Northeast Asia (**Figure 8**). This pattern favors widespread normal to above normal temperatures across much of Asia with normal to below normal temperatures mostly limited to and Western Russia, Kazakhstan and Northeastern Asia (**Figure 9**).

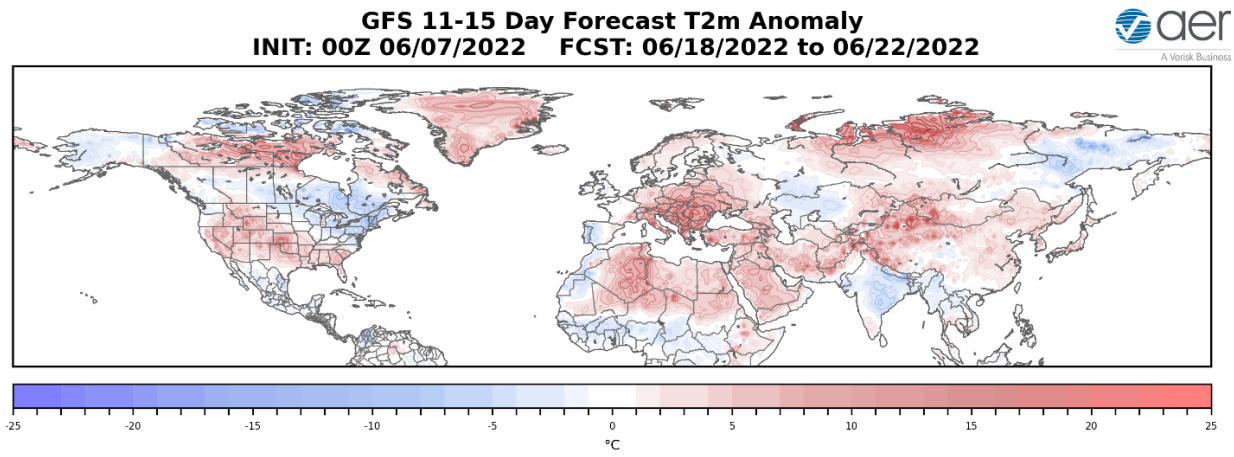

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 18 – 22 June 2022. The forecasts are from the 00z 7 June 2022 GFS ensemble.

The pattern across North America will evolve into an omega block pattern with ridging/positive geopotential height anomalies predicted for the interior of North America with troughing/negative geopotential height anomalies centered in the Pacific Northwest and the Northeastern US this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across much of North America but especially Northern Canada and the Southern US with normal to below normal temperatures across Alaska, Southwestern and Southeastern Canada and the Northwestern and Northeastern US (**Figure 9**).

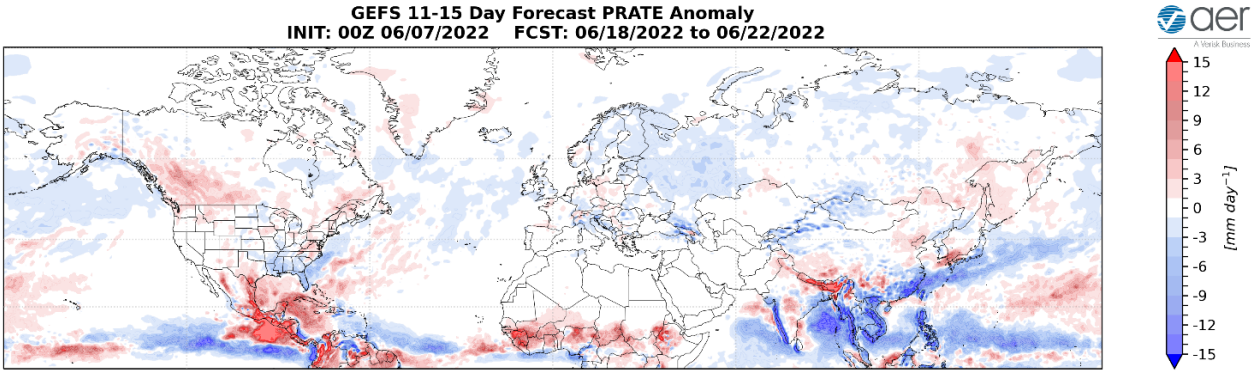

Figure 10. Forecasted precipitation rate (mm/day; shading) from 18 – 22 June 2022. The forecast is from the 00Z 7 June 2022 GEPS ensemble.

Mostly below normal precipitation is predicted across Eurasia with above normal precipitation predicted for Southern and Eastern Asia (**Figure 10**). Mostly below normal precipitation is predicted across North America with above normal precipitation predicted for Western Canada, the Northeastern US and Southern Texas (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows cold/negative PCHs in the upper stratosphere with warm/positive PCHs in the lower stratosphere and the troposphere (**Figure 11**). Cold/negative PCHs in the upper stratosphere are predicted to descend into the troposphere next week (**Figure 11**).

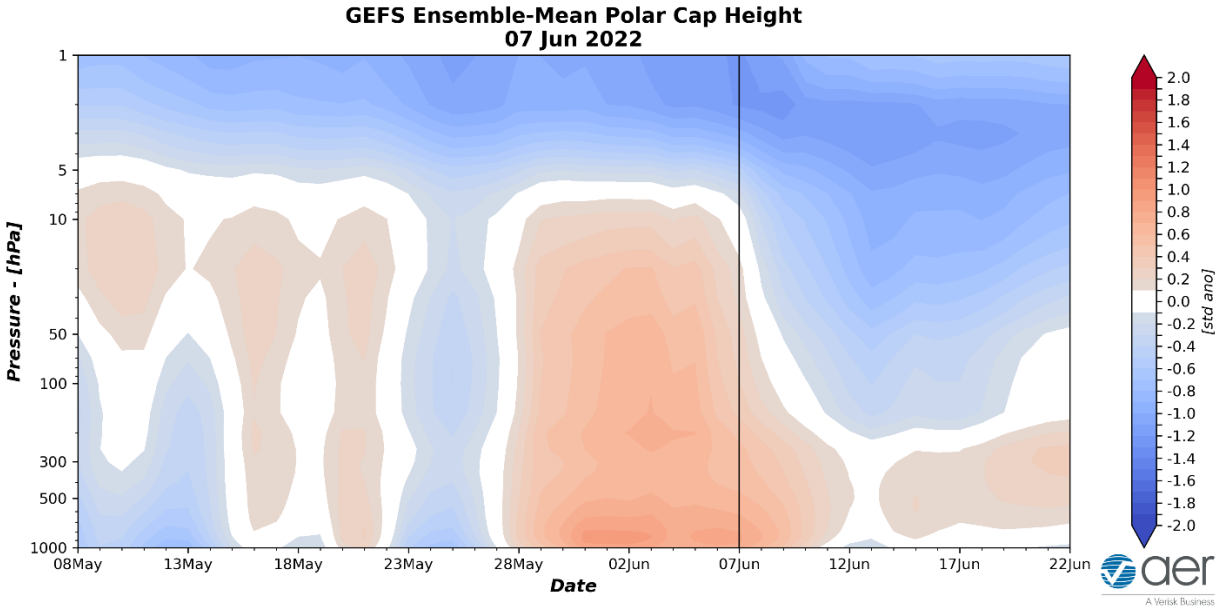

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 7 June 2022 GFS ensemble.

The warm/positive PCHs predicted this week in the lower troposphere are predicted to turn cold/negative next week and then remain cold/negative through the third week of June (**Figure 11**). The warm/positive PCHs this week transitioning to cold/negative PCHs next week are consistent with the surface AO starting negative this week and then reversing to positive next week (**Figure 1**).

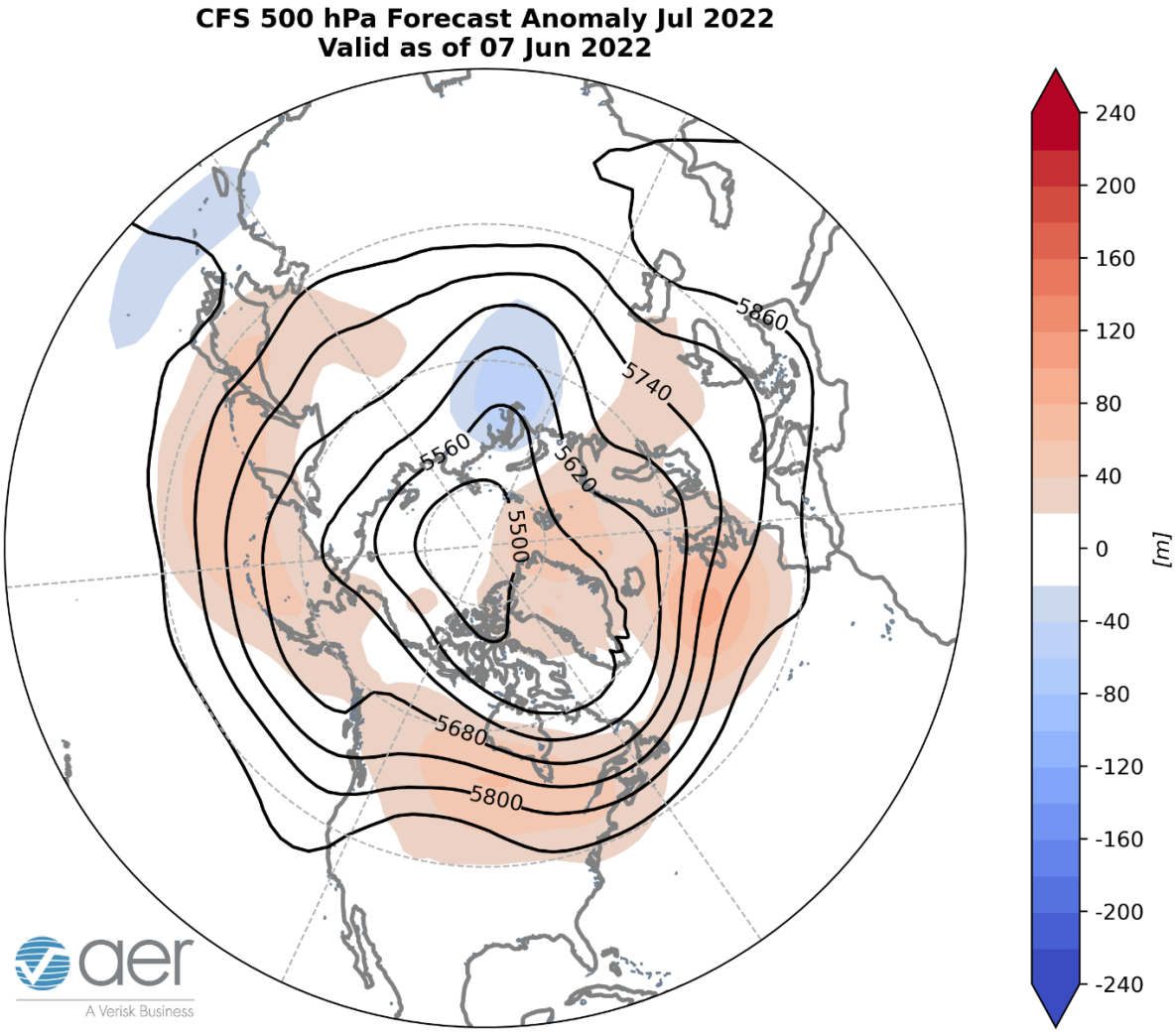

Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for July 2022. The forecasts are from the 00Z 7 June 2022 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and surface temperatures for July (**Figure 13**) from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging centered just west of Western Europe and extending across Northern Europe, Western Asia, the Dateline and much of Canada with troughing across Eastern Europe, across the Urals, the Western US, Eastern Canada and the Northeastern US (**Figure 12).** This pattern favors seasonable to relatively warm temperatures across Northern and Eastern Europe, much of Asia but especially Central Asia, Alaska, Western Canada and the Western and Northeastern US with seasonable to relatively cool temperatures across Western Europe, Kazakhstan, Siberia, Northern Canada and the Central and Southeastern US (**Figure 13**).

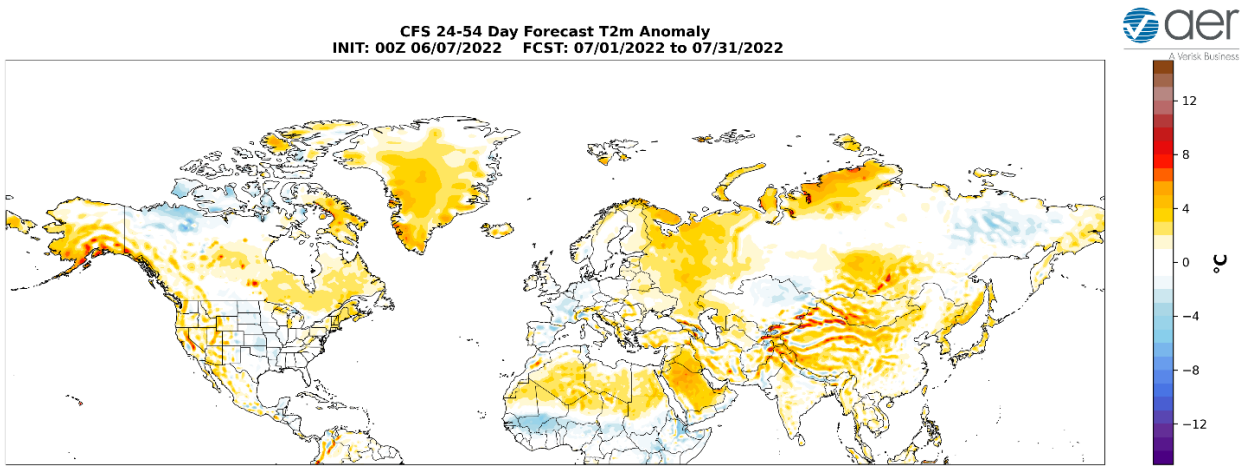

Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for July 2022. The forecasts are from the 00Z 7 June 2022 CFS.

Surface Boundary Conditions

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are below normal and we continue to observe weak La Niña conditions (**Figure 14**) and La Niña conditions are expected through the summer. La Niña could favor a North America heat dome during the summer months and a more active North Atlantic hurricane season. Observed SSTs across the NH remain well above normal especially in the central North Pacific (west of recent years), the western North Pacific and offshore of eastern North America though below normal SSTs exist regionally especially in the North Pacific.

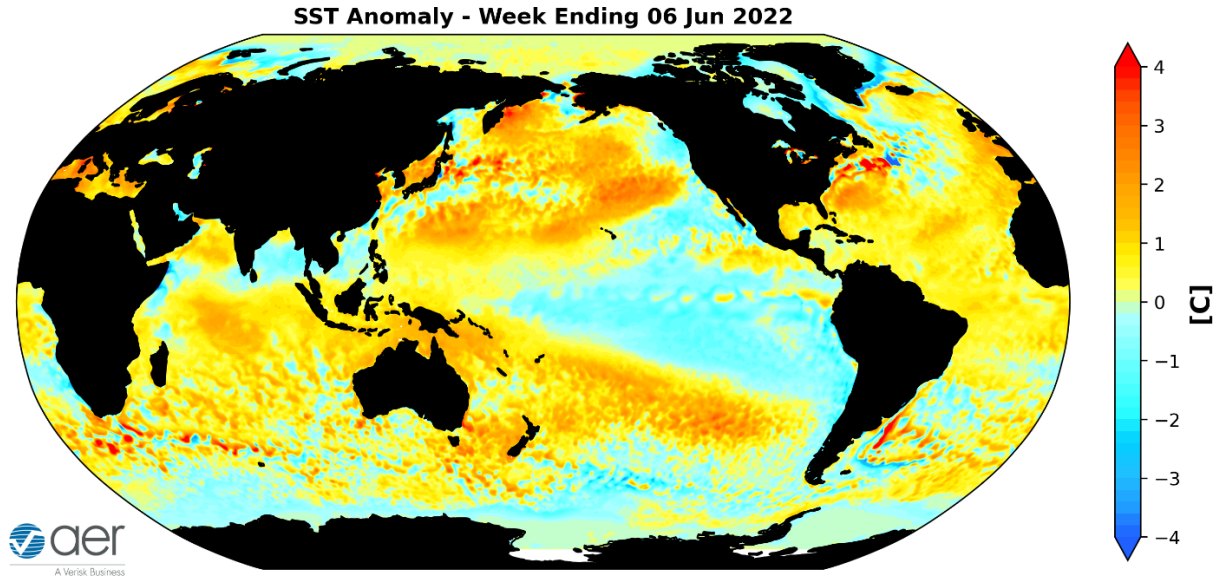

Figure 14. The latest weekly-mean global SST anomalies (ending 6 June 2022). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase 8 (**Figure 15**). The forecasts are for the MJO to enter phase 1 and then weakened to where no phase is favored. Phases 8 and 1 favor ridging and relatively warm temperatures in Canada with troughing and relatively cool temperatures in the Eastern US and then transitioning to ridging and warm temperatures in the Eastern US. Therefore there could be some MJO influence on the near term the weather across North America. But admittedly this is outside of my expertise.

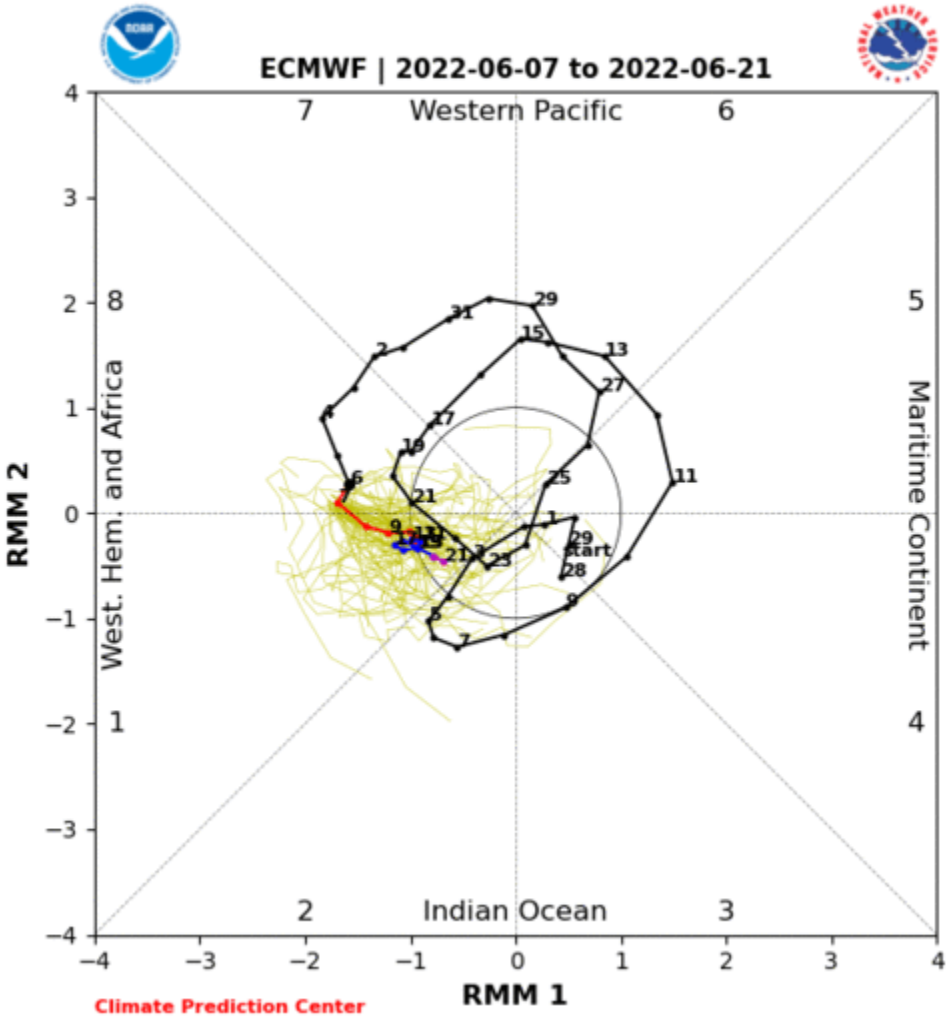

Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 7 June 2022 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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