

Arctic Oscillation and Polar Vortex Analysis and Forecasts

June 5, 2023

Dear AO/PV blog readers:

We have shifted the public release of the Arctic Oscillation/Polar Vortex blog to Wednesday through the winter season.

For those who would like an early look on Mondays, we will be offering at a nominal price (US \$50) a PDF version of the upcoming blog, and we will be rolling out access to the datasets used in the production of this blog. At present we plan to make available in comma-separated values the timeseries of the Polar Cap Height and the timeseries of the Wave Activity Flux (vertical component), though we would appreciate to hear your suggestions for additional data of interest to you all.

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.

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. 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.

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 negative and is predicted to trend positive the next two weeks but remaining negative to neutral as pressure/geopotential

height anomalies across the Arctic are currently mostly positive and are predicted to slowly become increasingly negative over the next two weeks. The North Atlantic Oscillation (NAO) is currently negative and is predicted to remain negative to neutral the next two weeks as pressure/geopotential height anomalies will remain mostly positive across Greenland.

- Over the next two weeks predicted troughing/negative geopotential height anomalies centered in the central North Atlantic will anchor ridging/positive geopotential height anomalies across Northern Europe with troughing/negative geopotential height anomalies across Southern Europe. This pattern favors the next two weeks normal to above normal temperatures across Northern and Central Europe including the United Kingdom (UK) with normal to below normal temperatures across Southern Europe along the Mediterranean.
- This week predicted troughing/negative geopotential height anomalies centered in Northwestern and Eastern Asia will bookend ridging/positive geopotential height anomalies in Central Asia. However increasing Greenland ridging will allow troughing in Northwestern Asia to expand across much of Siberia. This pattern favors normal to above normal temperatures widespread across much of Northern, Central and Southern Asia with normal to below normal temperatures limited to Western Russia and parts of East Asia. However next week below normal temperatures will spread across much of Siberia with normal to above normal temperatures across Central and Southern Asia.
- The general pattern predicted across North America this week is ridging/positive geopotential height anomalies across western North America with troughing/negative geopotential height anomalies across eastern North America especially the Eastern United States (US). However, starting next week ridging will expand into eastern North America with new troughing coming ashore in the Western US. This pattern generally favors normal to above normal temperatures across Alaska, much of Canada and the Northwestern US with normal to below normal temperatures mostly limited to the Southern and Eastern US this week. However, starting next week, warmer temperatures will expand deeper into eastern North America as cooler temperatures enter Western Canada and the Western US.
- In the Impacts section I discuss the dramatic change in the atmospheric circulation across the Northern Hemisphere (NH) and the implications in the coming weeks.
- **I am going to try experimenting with moving the blog schedule to Tuesday and Thursdays over the coming weeks.**

Plain Language Summary

The model forecasts are signaling a major shakeup of the atmospheric circulation moving from a double jet Stream structure to one of just one Jet Stream (e.g., see **Figure iii**). This pattern should help to moderate well above normal temperatures in Canada and Siberia (e.g., see **Figure ii**) to one of slowly warming temperatures in the Eastern US and Europe (see **Figure 9**).

Associated with these heat domes are the largest positive departures from normal or warm anomalies across the Northern Hemisphere in Canada, Siberia and to a lesser extent Northwest Europe (see **Figure ii**). However, because the warmest flow of air associated with the heat domes is the southwest flow of air upstream of the high center, the European anomalies are of far less in magnitude than in Canada and Siberia (see **Figure ii**). The amplified heat domes/ridging in Canada and Northwestern Europe have resulted in unusually cool temperatures, at least relative to recent summers in the Eastern US and Eastern Europe.

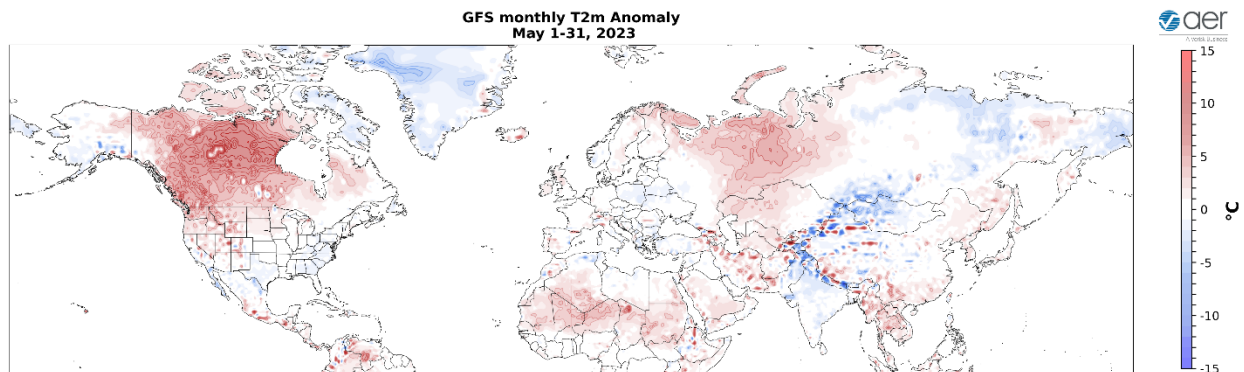


Figure ii. Observed surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere from 1 – 31 May from the initialized GFS ensemble.

Canada seems to be the real standout for above normal temperatures (see **Figure ii**) and as illustrated in this tweet of [temperature rankings](#) from @Climatologist49. This has resulted in an early and expansive wildfire season in Canada. With fire comes smoke and thanks to strong northerly flow has resulted in persistent unhealthy air quality in the Northeastern US (see [air quality warning](#) from @RhodeIslandDEM).

On Thursday I posted a [tweet on jet dynamics](#) where the NH circulation is about to undergo a dramatic transformation from a hemispheric circulation dominated by a double jet structure to one dominated by a single jet structure. I include an update of one of the figures from that thread clearly showing the predicted transition from a double to single jet structure, at least in the zonal mean (see **Figure iii**). I find this all very fascinating, but this is not something that I understand much about. One possibility it is the result of the decaying of the very amplified pattern with the energy from these large atmospheric waves dispersing.

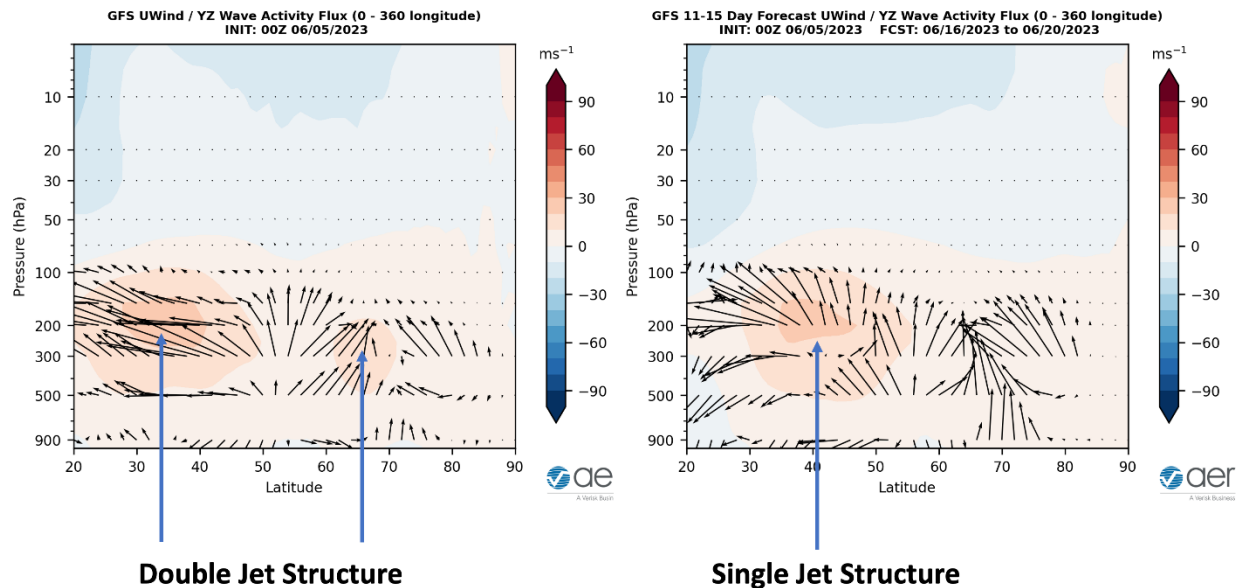


Figure iii. Latitude-height cross section of zonal-mean zonal wind (shading) and wave activity flux (vectors) forecasted initialized at 00z 5 June (left) and predicted for 16 – 20 June 2023 (right). The forecast is from the 00Z 5 June 2023 GFS ensemble.

It does seem that one result of the jet structure transition is a NH surface temperature pattern more similar to previous summers with the regions of cool or more seasonable temperatures migrating to Western Russia and the Central US rather than the US East Coast and Eastern Europe respectively. On the flip side temperatures should begin to rebound in the Eastern US and Eastern Europe (see **Figure 9**) but the change to warmer temperatures might be slow. The models are predicting a consolidation of high latitude heat domes from three to one, centered over Greenland. An increased frequency of Greenland blocking or high pressure is also a characteristic of recent summers but mostly in the month of July.

In previous blogs I have also discussed how if the "ring of fire" has a silver lining, it is beneficial for Arctic sea ice. So far Arctic sea ice melt during the spring of 2023 has been relatively moderate. But the circulation change, especially the migration of higher geopotential heights into the Central Arctic could result in an acceleration of Arctic sea ice melt. Greenland blocking is also favorable for melting the Greenland ice sheet. So, something to watch in the coming months.

Wednesday Update

The atmospheric pattern transition discussed on Monday is still predicted to occur over the next week or two. The biggest change is the disappearance of the two dominant

heat domes, one over Canada and the other over Siberia being replaced by one heat dome or at least high-pressure ridging across the northern North Atlantic including Greenland (see **Figure iv**).

GEFS 6-10 Day Forecast 500 hPa Anomaly
INIT: 00Z 06/07/2023 FCST: 06/13/2023 to 06/17/2023

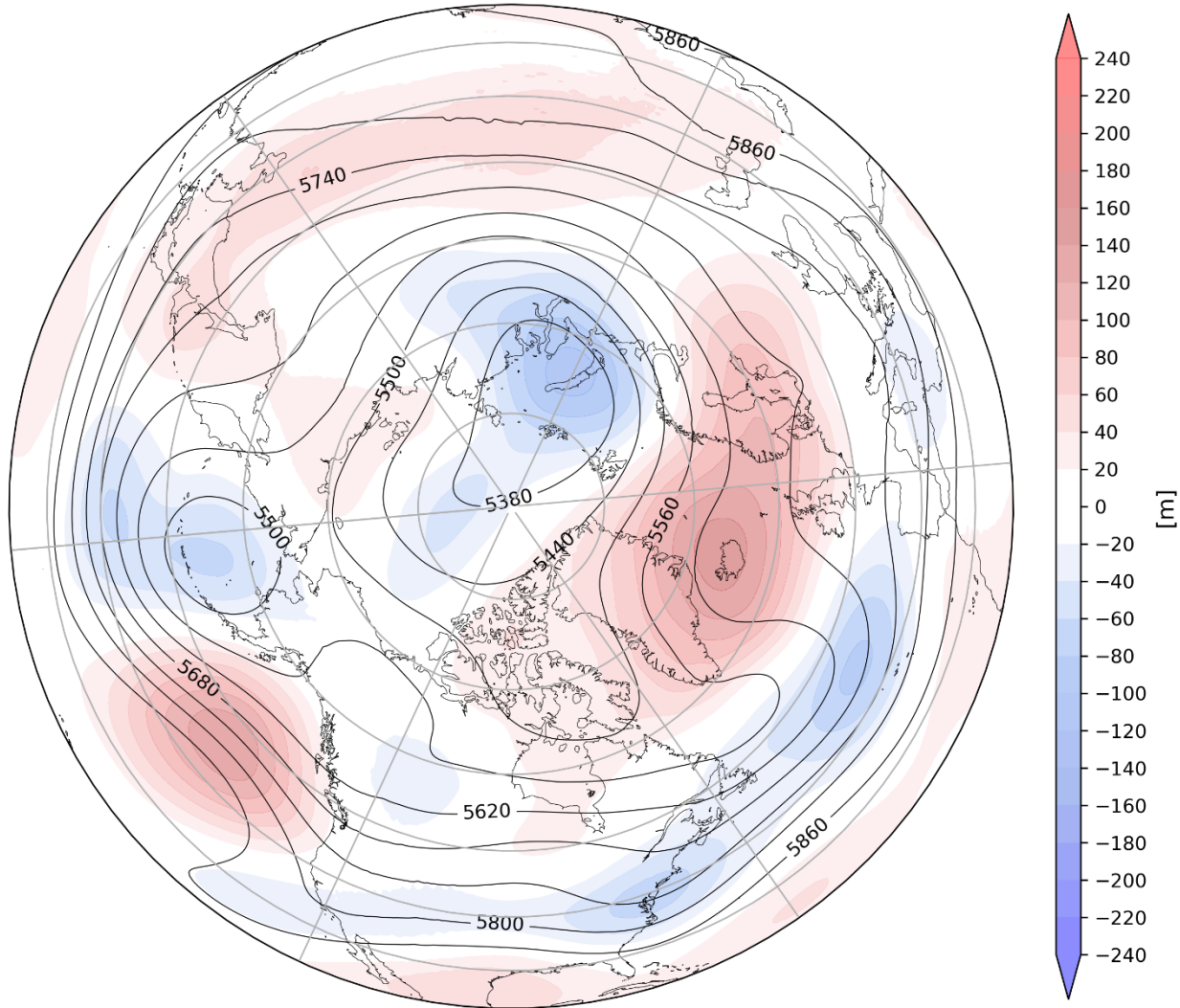


Figure iv. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 13 – 17 June 2023. The forecasts are from the 00z 7 June 2023 GFS ensemble.

The pattern transition will result in a dramatic cooling of temperatures in Canada and especially Siberia (see **Figure v**). Siberia has been more in the weather headlines during the summer months for record warmth and intense wildfires, so the predicted widespread relatively cool temperatures is a departure from recent summers but has been more common in the winter months. In contrast the potential is there for Europe

and the Eastern US to warm-up but for now the most impressive warming is looking most likely across Northern Europe.

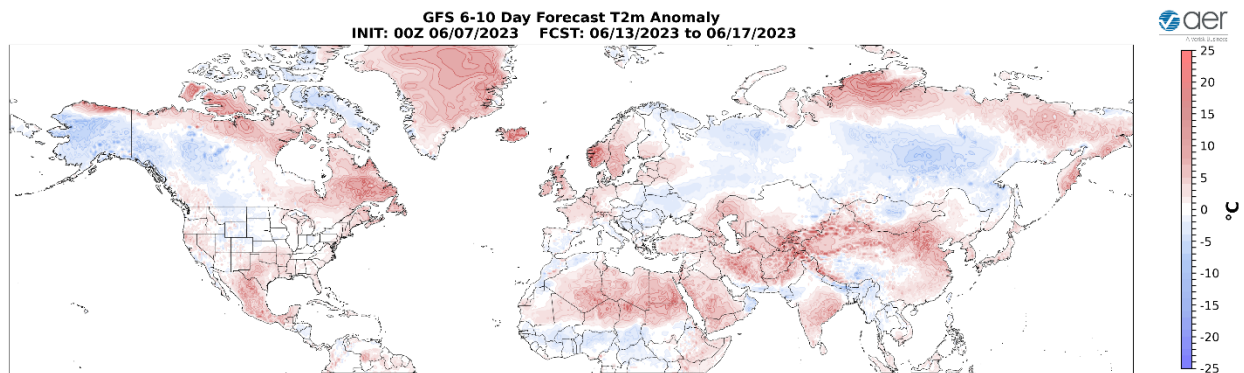


Figure v. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 13 – 17 June 2023. The forecast is from the 00Z 7 June 2023 GFS ensemble.

Recent and Very Near Term Conditions

The AO is currently negative (**Figure 1**) with mostly positive geopotential height anomalies across the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). With mostly positive geopotential height anomalies across the northern North Atlantic with negative height anomalies further south (**Figure 2**), the NAO is predicted to be negative this period.

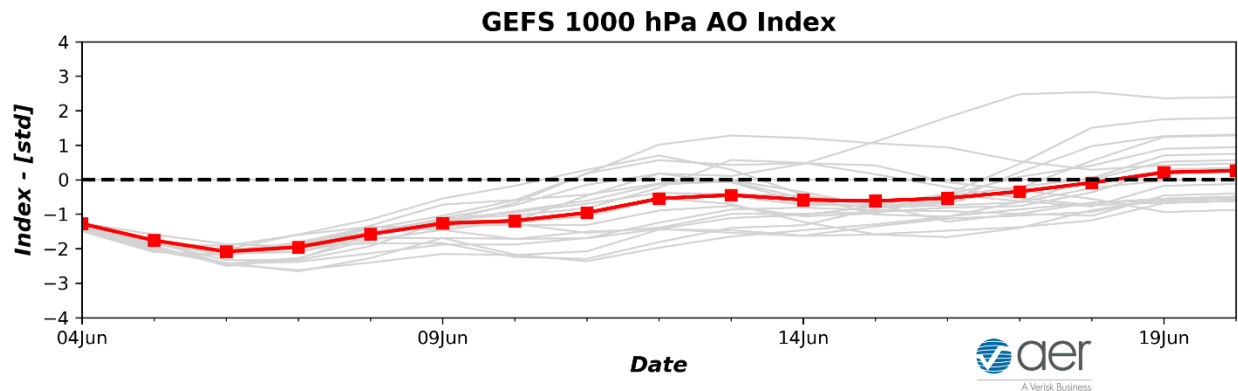


Figure 1. The predicted daily-mean AO at 1000 hPa from the 00Z 5 June 2023 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Trouching/negative geopotential height anomalies strung across the mid-latitudes of the North Atlantic will force ridging/positive geopotential height anomalies across Northern Europe centered over the British Isles with troughing/negative geopotential height anomalies draped across Southern Europe (**Figures 2**). This pattern favors normal to

below normal temperatures across the Mediterranean region and northern Scandinavia with normal to above normal temperatures across Northern and Central Europe including the UK (**Figure 3**). Troughing/negative geopotential height anomalies in Northwest and Eastern Asia are predicted to sandwich ridging/positive geopotential height anomalies centered across Central Asia this period (**Figure 2**). This pattern favors normal to above normal temperatures across Northern, Central and Southern Asia with normal to below normal temperatures across Western Russia Northeast China (**Figure 3**).

GEFS 1-5 Day Forecast 500 hPa Anomaly
INIT: 00Z 06/05/2023 FCST: 06/06/2023 to 06/10/2023

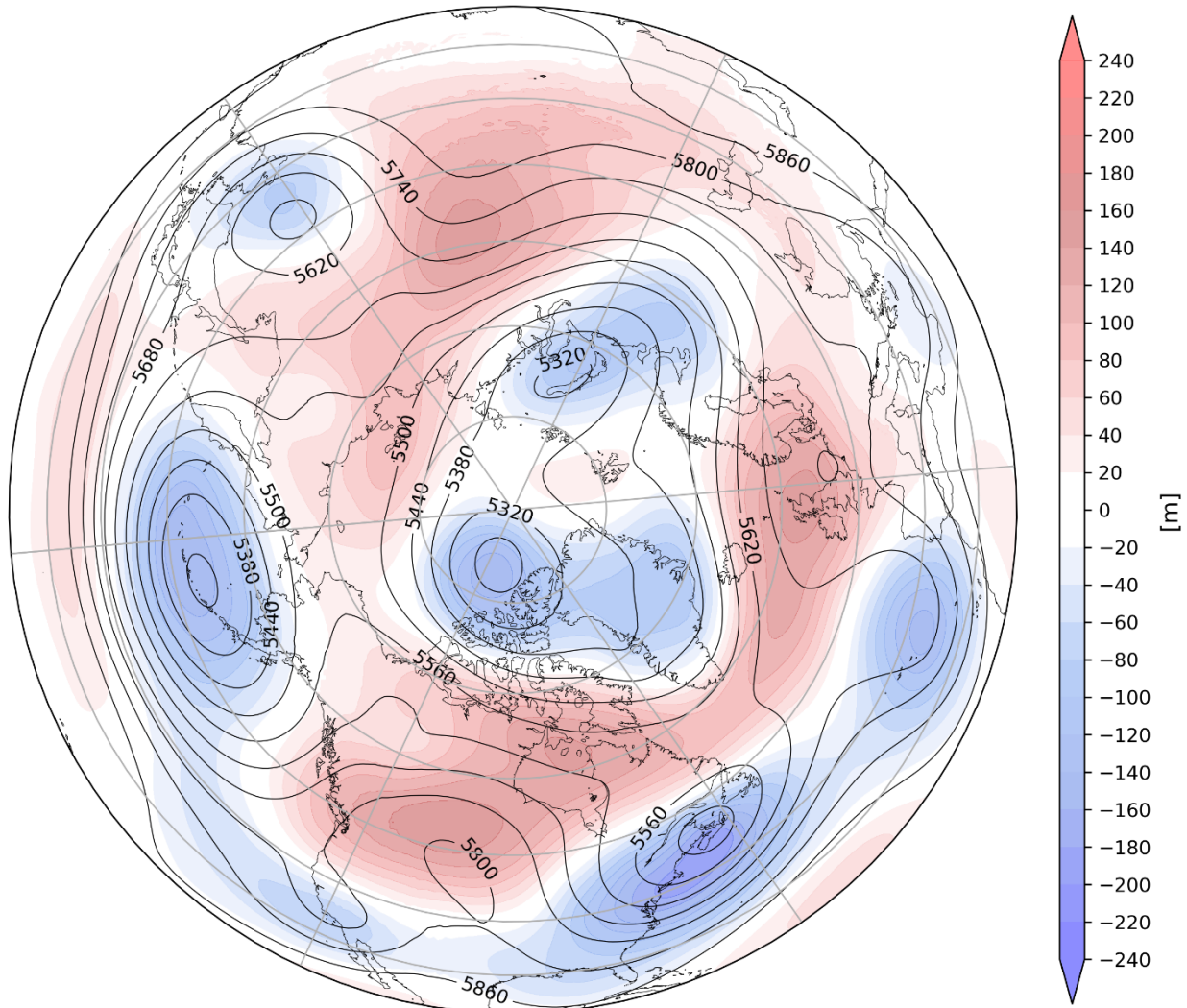


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 6 – 10 June 2023. The forecasts are from the 00z 5 June 2023 GFS ensemble.

The pattern this week across North America is ridging/positive geopotential height anomalies centered in the interior of the continent but widespread across western North America with troughing/negative geopotential height anomalies in the Southeastern Canada and the Eastern US this period (**Figure 2**). This pattern will favor widespread normal to above normal temperatures across northern Alaska, much of Canada and the Northwestern US with normal to below normal temperatures across Southeastern Canada, the Eastern and the Southwestern US (**Figure 3**).

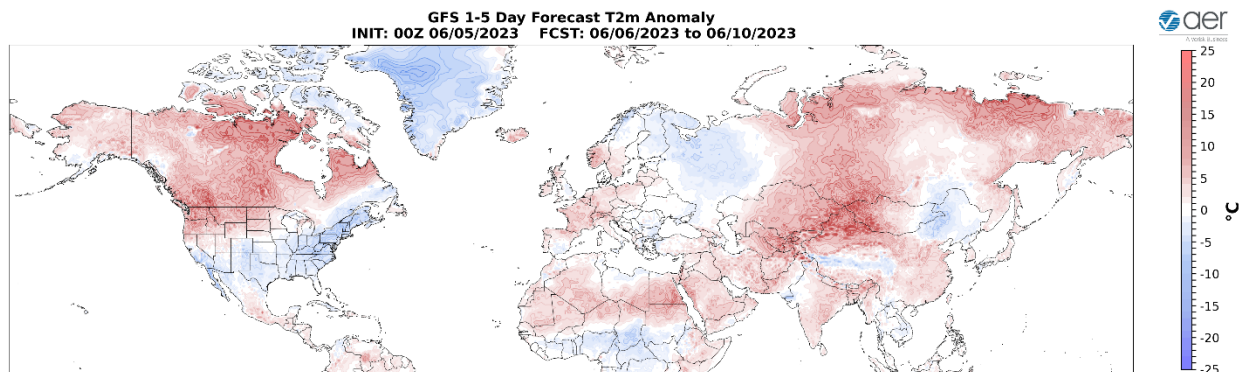


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 6 – 10 June 2023. The forecast is from the 00Z 5 June 2023 GFS ensemble.

Mostly normal to dry conditions are predicted across Europe and Asia with the exceptions of normal to wet conditions across Southern Europe, Western Siberia, the Tibetan Plateau and parts of East Asia this week (**Figure 4**). Mostly normal to dry conditions are predicted across Canada and the US with the exceptions of normal to wet conditions across the mountain ranges of Alaska, Northern Canadian, the US Rockies and the Canadian Maritimes (**Figure 4**).

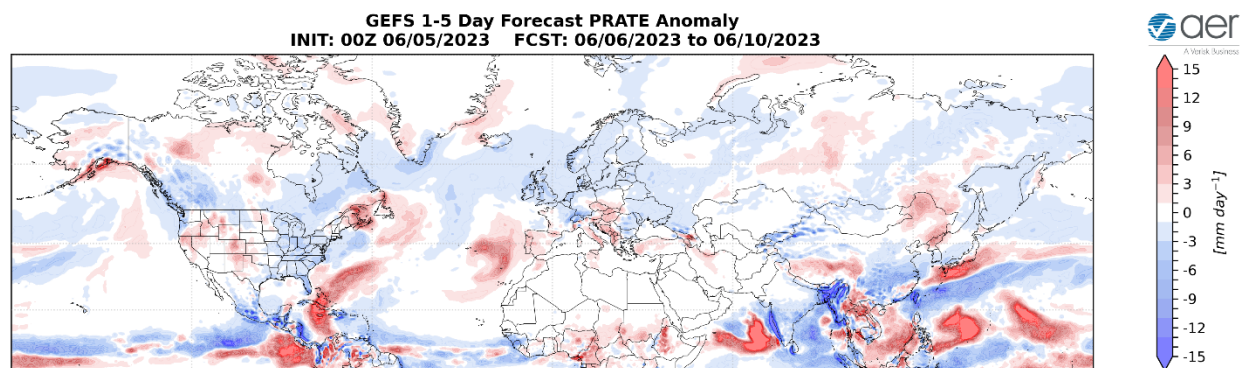


Figure 4. Forecasted precipitation rate (mm/day; shading) from 6 – 10 June 2023. The forecast is from the 00Z 5 June 2023 GFS ensemble.

Near-Term

1-2 week

With mostly positive geopotential height anomalies across the Arctic and with mixed geopotential height anomalies across the mid-latitudes this period (**Figure 5**), the AO should remain negative this period (**Figure 1**). With predicted positive pressure/geopotential height anomalies across Greenland (**Figure 5**), the NAO will likely remain negative this period as well.

GEFS 6-10 Day Forecast 500 hPa Anomaly
INIT: 00Z 06/05/2023 FCST: 06/11/2023 to 06/15/2023

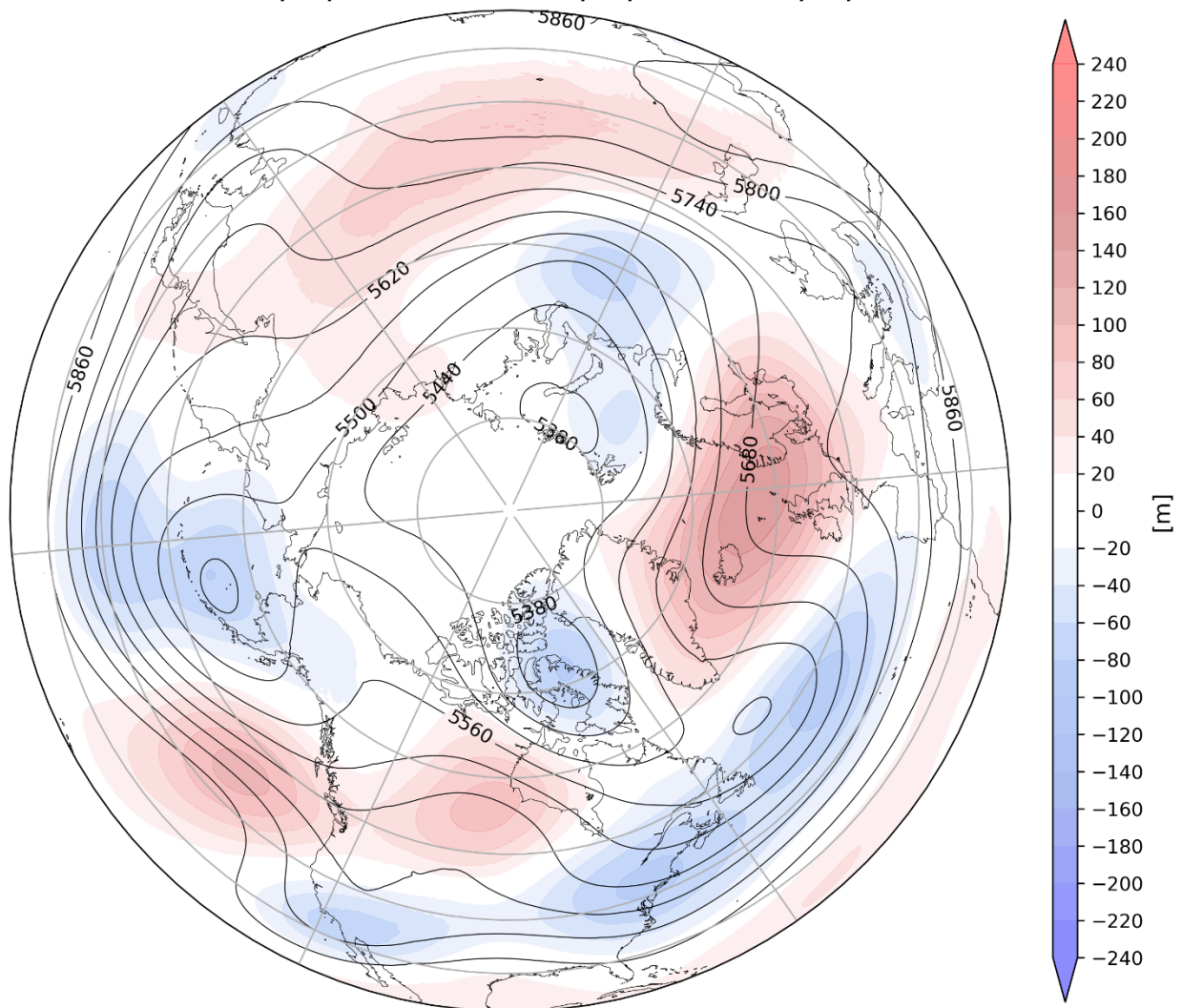


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 11 – 15 June 2023. The forecasts are from the 00z 5 June 2023 GFS ensemble.

Persistent troughing/negative geopotential height anomalies centered in the mid-latitudes of the North Atlantic will continue to support ridging/positive geopotential height anomalies across Northern Europe with troughing/negative geopotential height anomalies across Southern Europe this period (**Figure 5**). This pattern should continue to favor normal to above normal temperatures across Northern Europe including the UK with normal to below normal temperatures across Southern Europe especially along the Mediterranean (**Figures 6**). Increasing ridging/positive geopotential height anomalies across Greenland will support expanding troughing/negative geopotential height anomalies across Siberia with ridging/positive geopotential height anomalies in Central and Southern Asia this period (**Figure 5**). The pattern favors normal to below normal temperatures across Western Russia and expanding eastward across Siberia with normal to above normal temperatures across Central and Southern Asia this period (**Figure 6**).

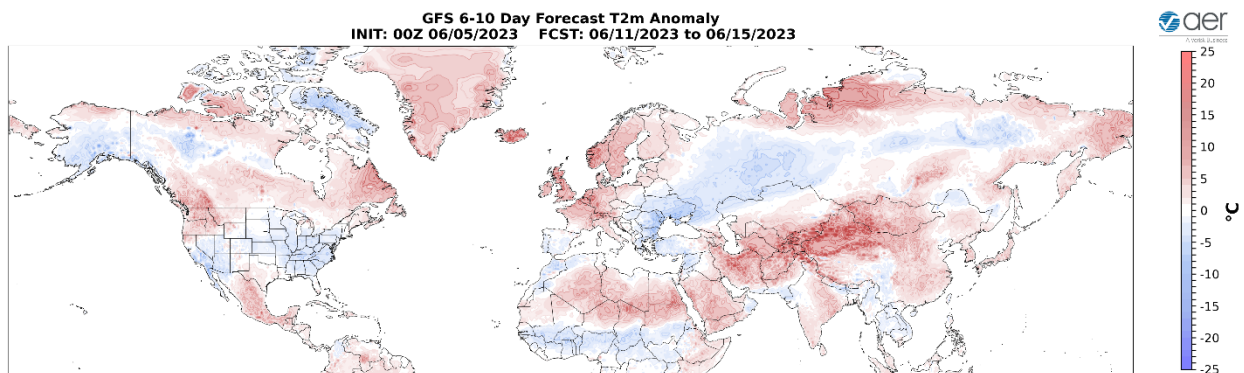


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 11 – 15 June 2023. The forecast is from the 00Z 5 June 2023 GFS ensemble.

Persistent ridging/positive geopotential height anomalies in the interior are predicted to contract with new troughing/negative geopotential height anomalies in the Southwestern US and persisting in the Eastern US this period (**Figure 5**). This pattern favors normal to above normal temperatures across northern Alaska, much of Canada and the Northwestern US with normal to below normal temperatures across southern Alaska, the Southwestern and Eastern US (**Figure 6**).

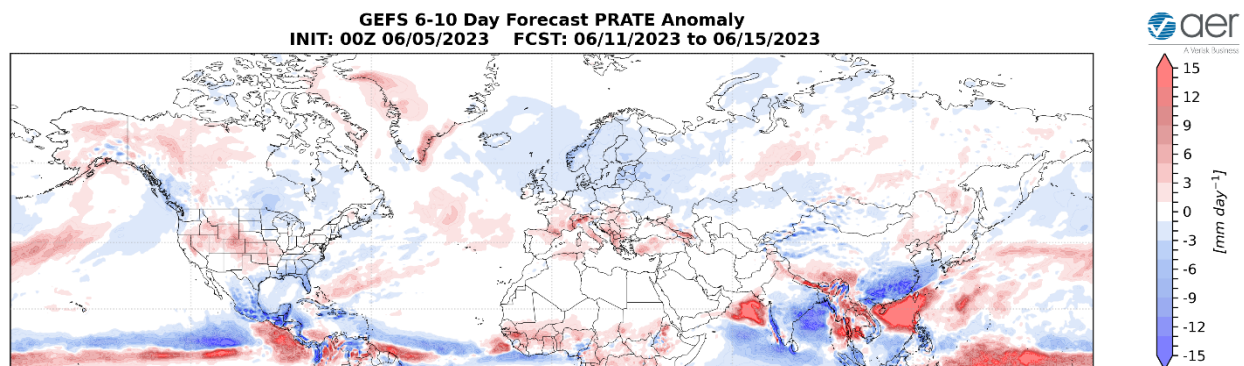


Figure 7. Forecasted precipitation rate (mm/day; shading) from 11 – 15 June 2023. The forecast is from the 00Z 5 June 2023 GFS ensemble.

Mostly normal to dry conditions are predicted across Europe and Asia with the exceptions of normal to wet conditions across Southern Europe and the Tibetan Plateau this period (**Figure 7**). Mostly normal to wet conditions are predicted across Alaska, Western Canada and the Western US with normal to dry conditions across Eastern Canada and the Eastern US (**Figure 7**).

3-4 week

With mostly positive geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes this period (**Figure 8**), the AO should remain negative to neutral this period (**Figure 1**). With mostly weak pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO will likely be negative to neutral this period.

GEFS 11-15 Day Forecast 500 hPa Anomaly
INIT: 00Z 06/05/2023 FCST: 06/16/2023 to 06/20/2023

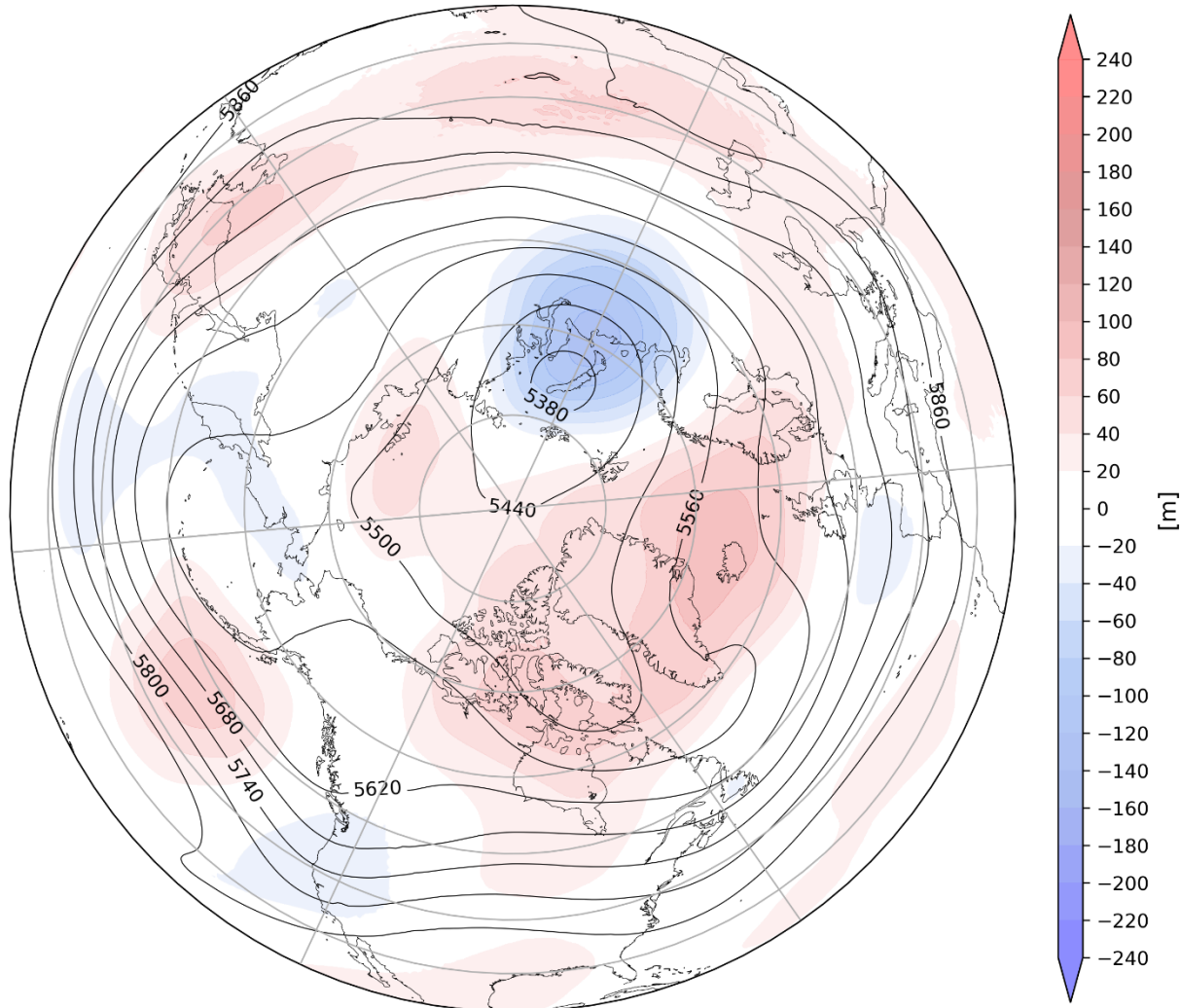


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 16 – 20 June 2023. The forecasts are from the 00z 5 June 2023 GFS ensemble.

Ongoing albeit weakening troughing/negative geopotential height anomalies centered in the North Atlantic will continue to favor ridging/positive geopotential height anomalies across Northern Europe with troughing/negative geopotential height anomalies draped across the Mediterranean this period (**Figure 8**). This pattern should favor normal to above normal temperatures across Northern and Central Europe including the UK with normal to below normal temperatures mostly limited to the Mediterranean region this period (**Figures 9**). Ongoing ridging/positive geopotential height anomalies across Greenland and Iceland will continue to anchor troughing/negative geopotential height anomalies across Siberia but especially the Urals with ridging/positive geopotential height anomalies across Southern Asia this period (**Figure 8**). The predicted pattern

favors widespread normal to above normal temperatures across much of Asia with normal to below normal temperatures across much of Northern Asia except for far Northern Siberia this period (**Figure 9**).

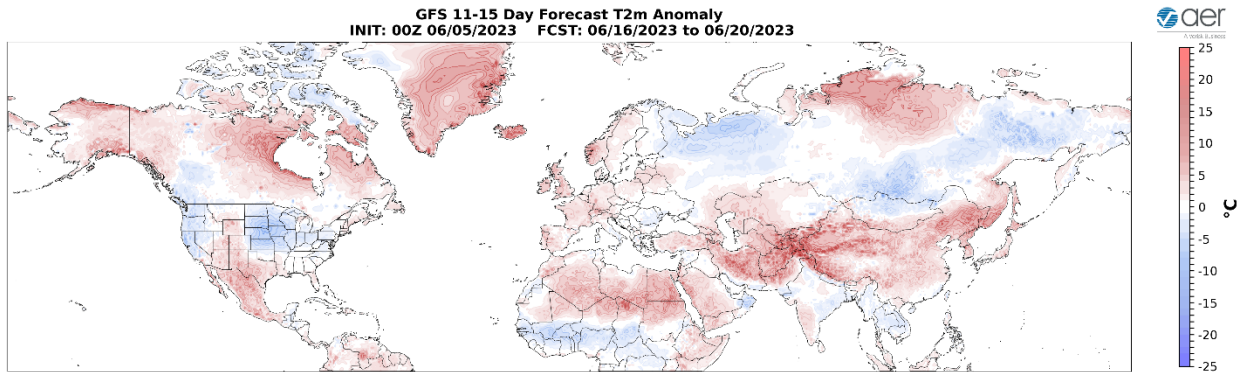


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 16 – 20 June 2023. The forecast is from the 00Z 5 June 2023 GFS ensemble.

Ridging/positive geopotential height anomalies previously centered in Central Canada will continue its slow migration into Eastern Canada with more widespread troughing/negative geopotential height anomalies across Western Canada and the Western US this period (**Figure 8**). This pattern favors normal to above normal temperatures across Alaska, much of Canada, New England and the US Rockies with normal to below normal temperatures across Southwestern Canada, the US West Coast and much of the Eastern US (**Figure 9**).

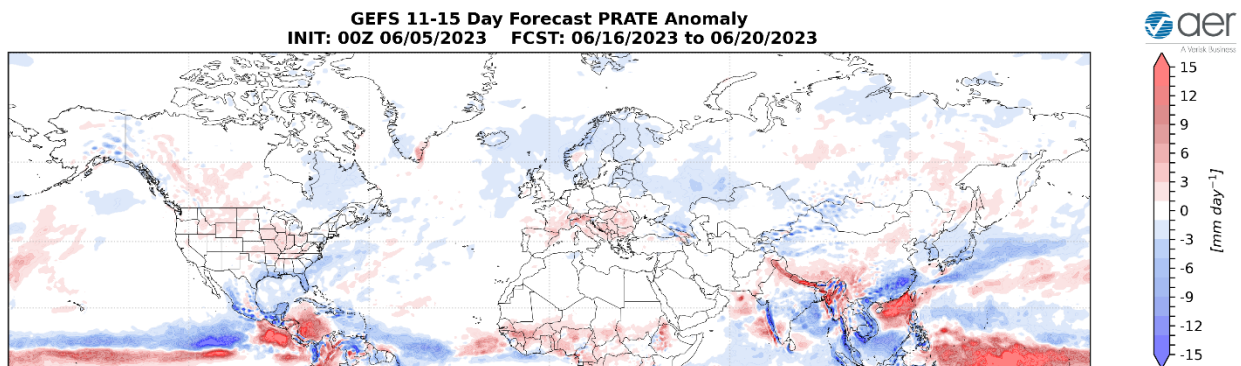


Figure 10. Forecasted precipitation rate (mm/day; shading) from 16 – 20 June 2023. The forecast is from the 00Z 5 June 2023 GFS ensemble.

Mostly normal to dry conditions are predicted across Europe and Asia with the exceptions of normal to wet conditions across Southern Europe and the Tibetan Plateau this period (**Figure 10**). Mostly weak and mixed precipitation conditions are predicted across Alaska, Canada and the US (**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 mid to upper stratosphere with warm/positive PCHs in the troposphere and lower stratosphere (**Figure 11**). However, next week warm/positive PCHs in the troposphere are predicted to contract and weaken (**Figure 11**).

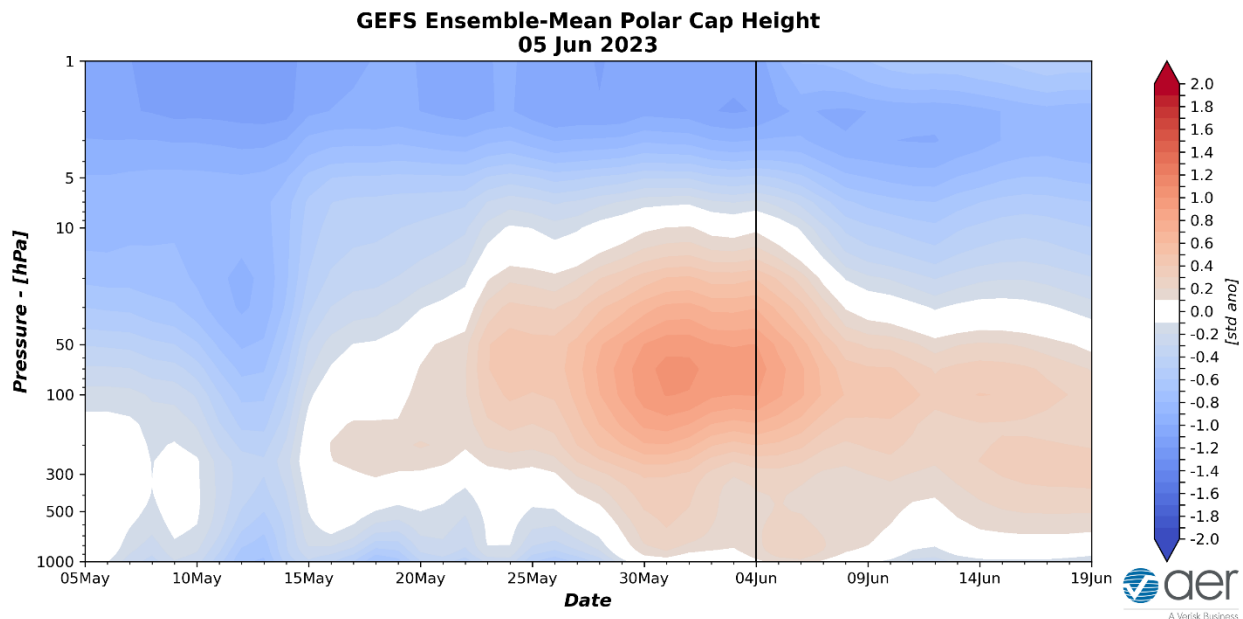


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 5 June 2023 GFS ensemble.

The predicted warm/positive PCHs in the lower troposphere this week and into next week (**Figure 11**) are consistent with the predicted negative surface AO over the next week (**Figure 1**). However, the AO is predicted to return to neutral later next week (**Figure 1**) coinciding with the predicted contraction of warm/positive PCHs in the troposphere focused near the tropopause (**Figure 11**).

CFS 500 hPa Forecast Anomaly Jul 2023
Valid as of 05 Jun 2023

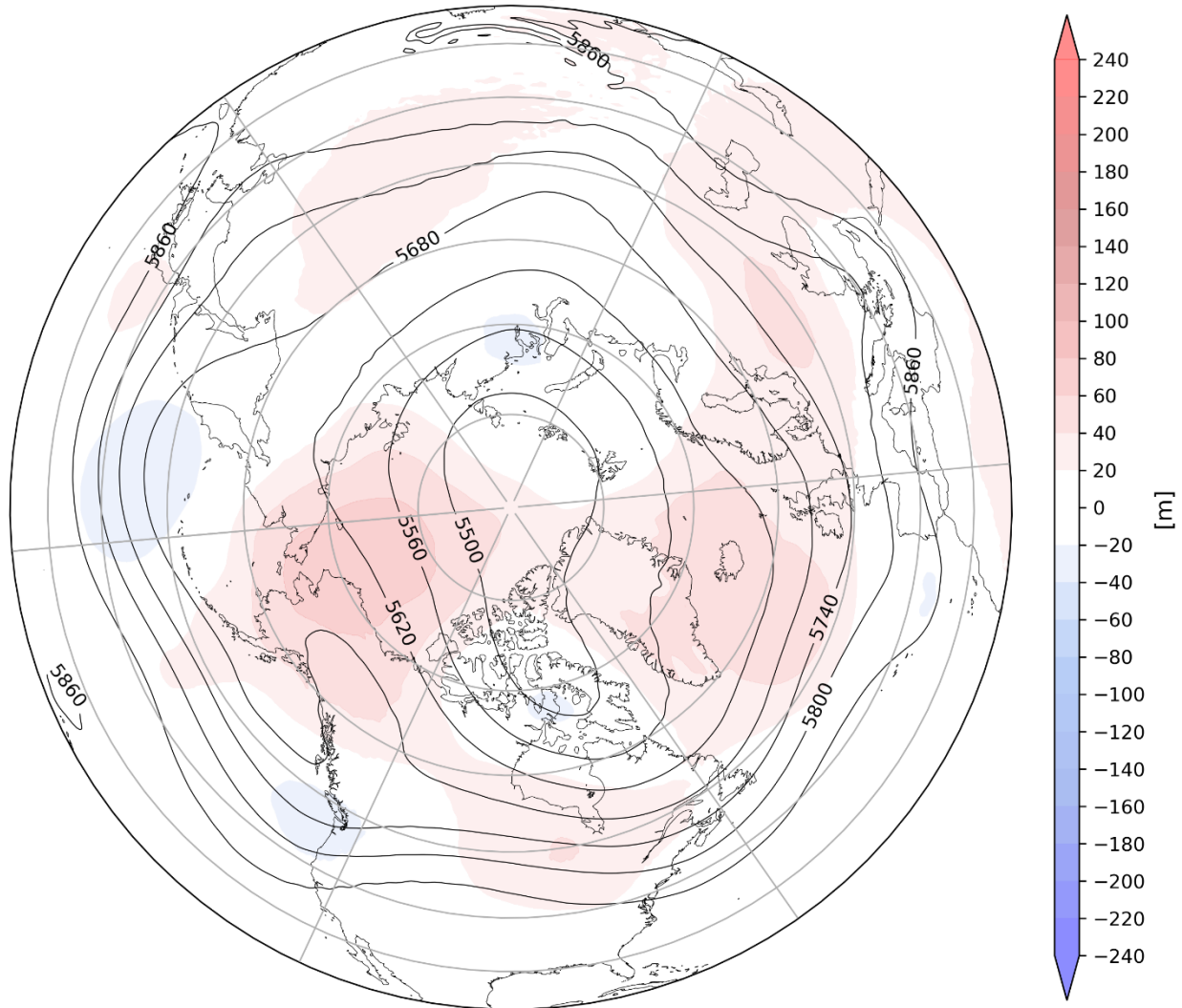


Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for July 2023. The forecasts are from the 00Z 5 June 2023 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 13**) and surface temperatures for July (**Figure 14**) from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging across Greenland, Iceland, Northern Europe, Central Asia, the Beaufort Sea, Alaska, Central Canada and the Great Lakes with troughing across Southern Europe, the Urals, Siberia and the Southwestern US (**Figure 13**). This pattern favors seasonable to relatively warm temperatures across Northern and Central Europe, far Northern Siberia, Central, Southern and Eastern Asia, Alaska, much of Canada, the US Rockies and the Eastern US with seasonable to relatively cool temperatures across the

Mediterranean, Southern Siberia, Kazakhstan, the US West Coast and the Central US (Figure 14).

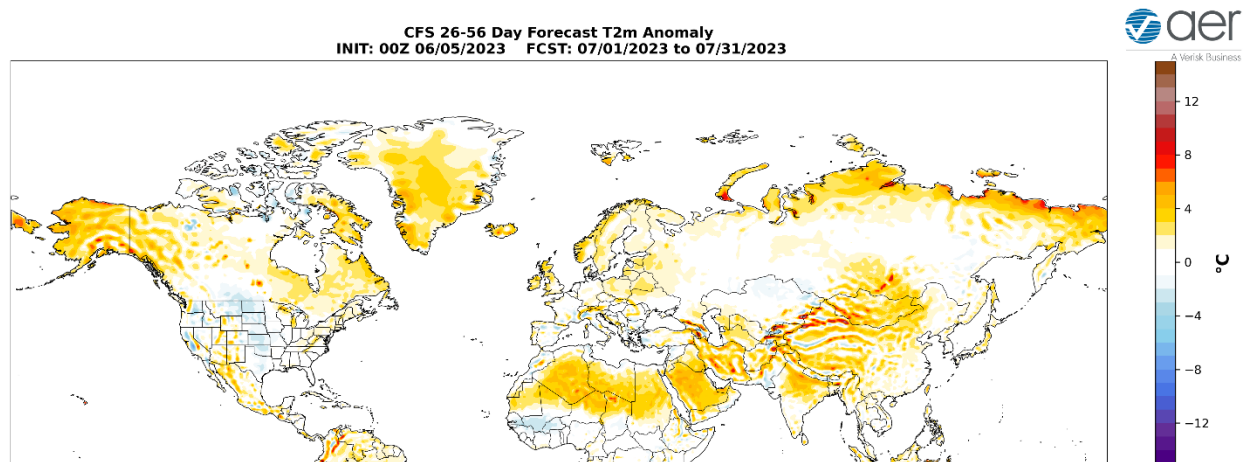


Figure 13. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for July 2023. The forecasts are from the 00Z 5 June 2023 CFS.

Boundary Forcings

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are above normal, especially along the South America coast, indicating that the transition from La Niña to El Niño is complete (**Figure 14**) and El Niño conditions are expected through the fall. Observed SSTs across the NH remain well above normal especially in the central North Pacific (west of recent years), the western North Pacific, the eastern North Atlantic and offshore of eastern North America though below normal SSTs exist regionally especially in the South Pacific.

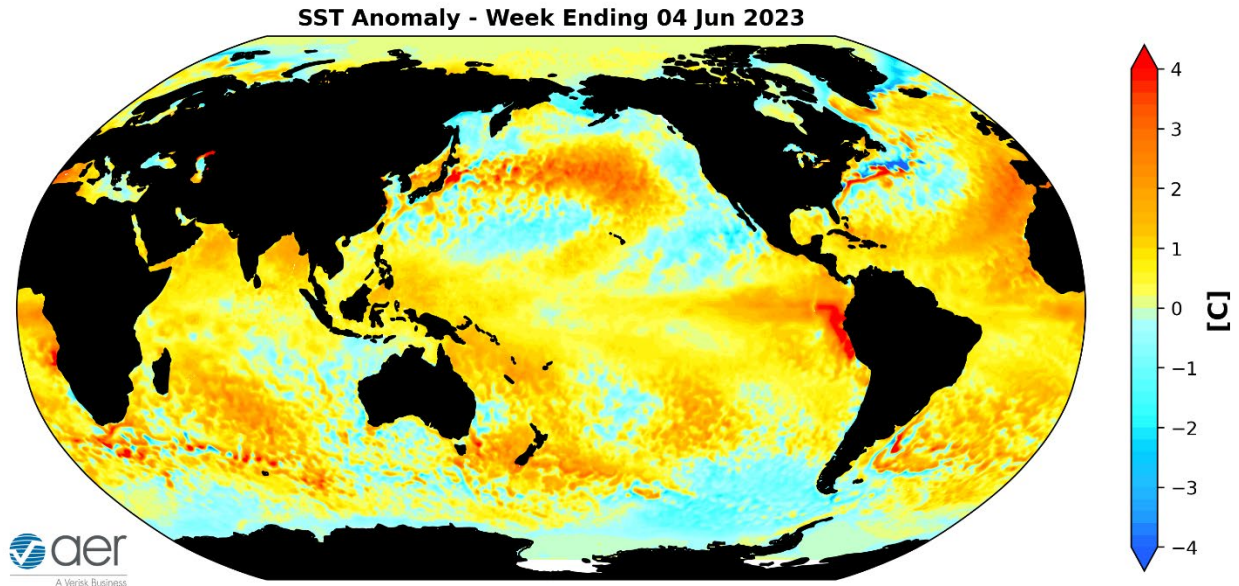


Figure 14. The latest weekly-mean global SST anomalies (ending 4 June 2023). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently phase one of the Madden Julian Oscillation (MJO) is favored (**Figure 16**). The forecasts are for the MJO to weaken to where no phase is favored and eventually emerge into phases four and five. Phase one favors ridging over Canada and over the Eastern US. Seems that the MJO is having some influence on the weather across Canada in the short term. But admittedly this is outside of my expertise.

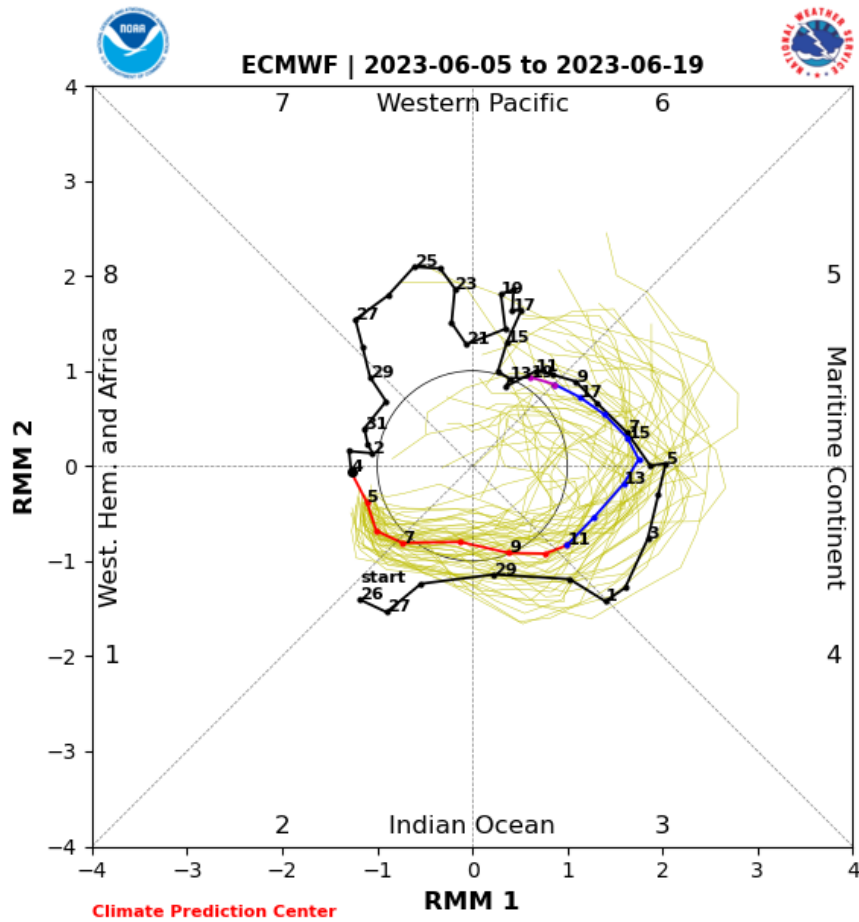


Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 5 June 2023 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate the phase of the MJO, with geographical labels indicating where anomalous convection occurs during that phase.

Image source:

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar_wh.shtml