

# Arctic Oscillation and Polar Vortex Analysis and Forecasts

May 22, 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.

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

**Summary**

- The Arctic Oscillation (AO) is currently positive and is predicted to trend negative the next two weeks dipping into negative territory next week as pressure/geopotential height anomalies across the Arctic are currently mostly negative and are predicted to become increasingly positive over the next two weeks. The North Atlantic Oscillation (NAO) is currently positive and is predicted to trend negative towards neutral the next two weeks as pressure/geopotential height anomalies are currently negative and are predicted to become increasingly mixed across Greenland the next two weeks.
- Over the next two weeks the predicted general pattern across Europe is ridging/positive geopotential height anomalies across Northern Europe, centered near the British Isles, with troughing/negative geopotential height anomalies across Southern Europe. This pattern favors the next two weeks normal to above normal temperatures across Northern Europe including the United Kingdom (UK) with normal to below normal temperatures across Central and Southern Europe. Next week above normal temperatures should become more widespread across Europe with below normal temperatures mostly isolated to the Iberian Peninsula
- The next two weeks predicted ridging/positive geopotential height anomalies centered near the Urals will anchor troughing/negative geopotential height anomalies across Siberia and East Asia. This pattern favors normal to above normal temperatures widespread across much of Western and Southern Asia with normal to below normal temperatures across Central Siberia, Central and Northeast Asia the next two weeks.
- The general pattern predicted across North America the next two weeks is ridging/positive geopotential height anomalies centered in Central Canada with troughing/negative geopotential height anomalies across the Southeastern United States (US). This pattern generally favors normal to above normal temperatures across Alaska, Canada and much of the US with normal to below normal temperatures limited to the Southwestern and Eastern US this week and the Southeastern US the next two weeks.
- In the Impacts section I present the summer temperature forecast across the Northern Hemisphere (NH).

### **Plain Language Summary**

The model forecasts are signaling that the atmosphere is already in full summer mode with the large-scale circulation dominated by heat domes (where surface temperatures are well above normal) with one center near the British Isles, a larger one over Canada but the most impressive one will be centered near the Urals (e.g., see **Figure 5**). This pattern favors widespread above normal temperatures across the Northern Hemisphere and focused especially in Canada and Western Asia (e.g., see **Figure 6**). The summer forecast is presented in **Figure ii**.

### **Impacts**

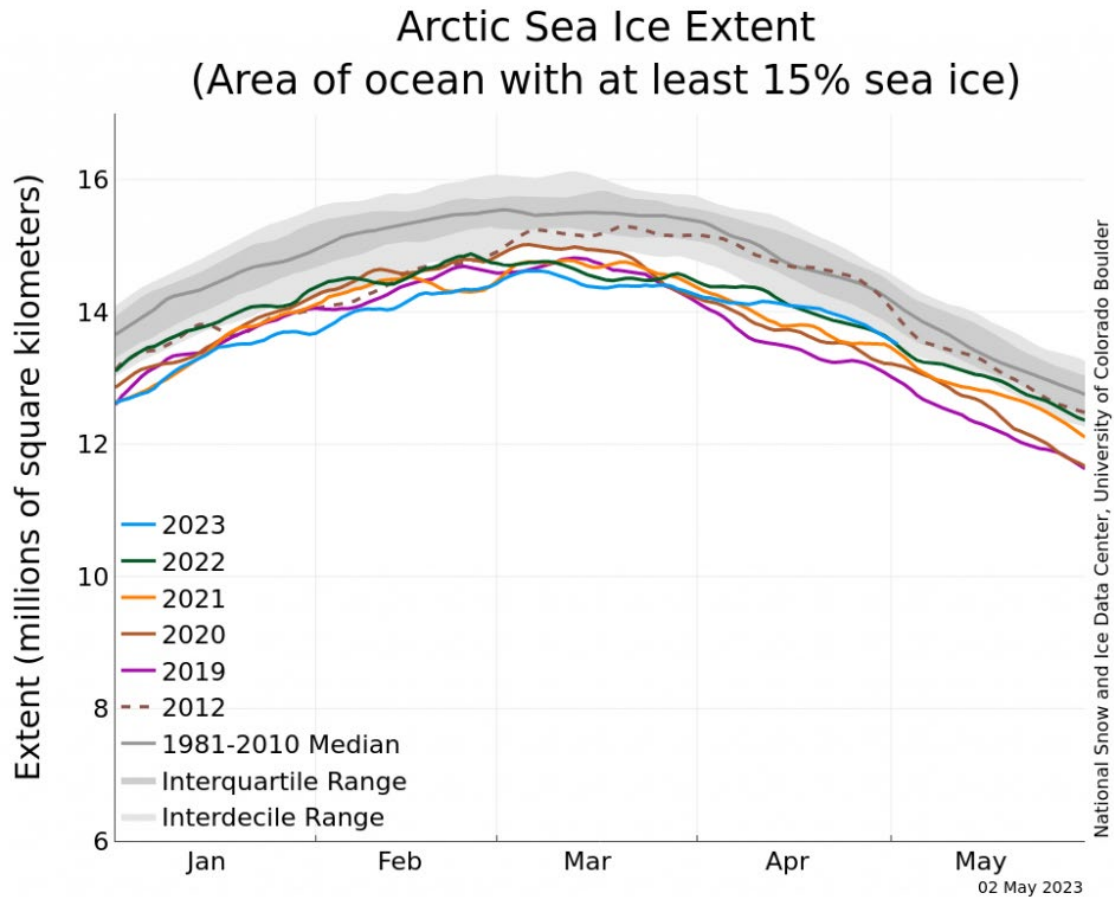
In the previous blog I discussed the atmosphere is getting a jump on the typical circulation of recent summers with a ring of heat domes forming along the northern edge of the continents. “Heat dome” is used to describe regions that are maximum centers of mid-tropospheric geopotential height anomalies coupled with surface temperatures that are well above normal. In the Wednesday update I went further to describe it as a “ring of fire,” not my original term but borrowed from plate tectonics (or maybe even thunderstorms surrounding subtropical ridging). Today’s weather model forecasts are still consistent with this overall pattern. The geopotential height centers are predicted to be quasi-stationary over Canada, Northwest Europe and the Urals (e.g., see **Figure 5**). The term “ring of fire” isn’t just a figurative term, but the placement of heat domes strung across the mid to high latitudes of the continents creates an environment that is favorable for wildfires in the boreal forests of the NH. The most impressive heat dome of May has been in Canada, and it has helped spark an unusually early and prolific fire season in Canada. And I can tell you from living in Boston, we have had an usual number of days with smoke in the atmosphere. @burgwx tweeted this nice animation of smoke plumes emanating from the Canada wildfires: [Canadian smoke](#) and spreading across the entire NH.

High pressure cells in summer are known as subtropical highs typically centered near Bermuda, the Azores and Pacific highs (off the US West Coast) and form a ring of high pressure in the subtropics close to 30°N. They are not known as the Canadian, British Isles and Urals highs centered close to 55 and even 60°N! To me this has been one of the most dramatic changes to the atmospheric circulation in recent years and will be interesting if this dramatic migration northward of summer high pressure centers will continue and become a persistent feature of the summer season with potentially devastating consequences for the environment of the northern continents.

One fairly consistent heat dome of recent summers has been across Northwest North America so the Canadian heat dome of this May is shifted a bit east but not too far from where it has been observed in recent summers. A heat dome over the ocean does not typically bring the heat of its continental cousin, so the high-pressure center in the Northeastern Atlantic is not resulting in well above normal temperatures for Europe. But a slight shift eastward and temperatures could potentially soar across parts of Europe. What is most different right now from recent summers is the high-pressure center over the Urals. Typically, it has been observed further east over Siberia and East Asia and it will be interesting to see if this becomes a dominant feature of the summer or takes up residence further east more consistent with recent summers.

The “ring of fire” is a story of fire and ice and if this cloud has a silver lining, while this circulation pattern is devastating for the northern continents, it is beneficial for Arctic sea ice. This annular pattern with low pressure centered near the North Pole insulates the Central Arctic from the continental heat. Arctic sea ice has melted relatively slowly this spring (see **Figure i**) and that trend could continue. The argument could be made that spring snow cover fell on its sword to preserve summer Arctic sea ice. Snow cover has retreated rapidly across the continental high latitudes. Rapid snow melt is favorable for the northward shift of heat domes, creating a “ring of fire” pattern that helps to preserve

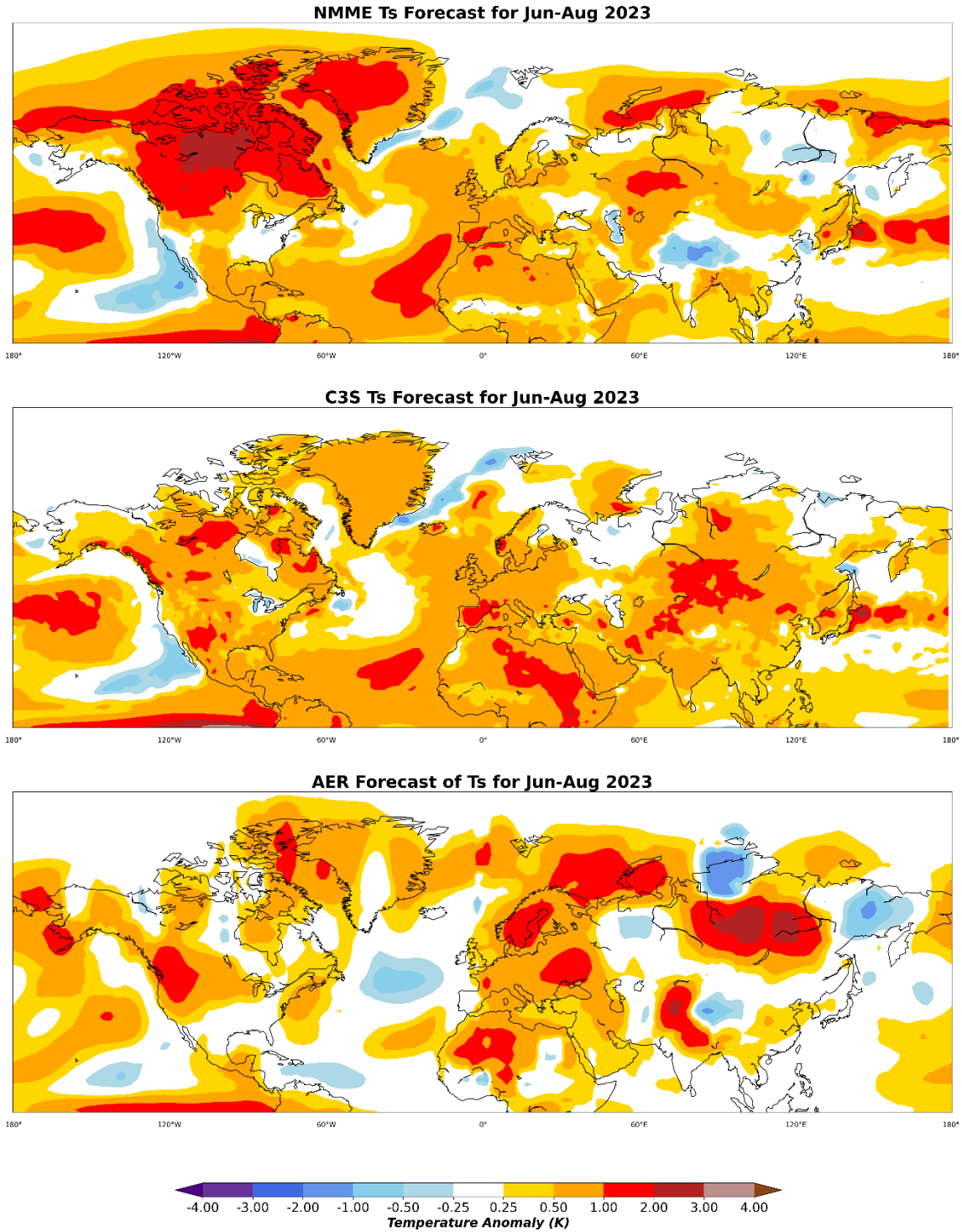
sea ice. Of course, heat looks to build in at least parts of the northern continents and a shift in the pattern can transport the hot surface air across the Arctic sea ice. Arctic sea ice might be extensive relative to recent Mays, but it is still thin and therefore vulnerable to rapid melt under the right atmospheric conditions.



**Figure i.** The graph above shows Arctic sea ice extent as of May 2, 2023, along with daily ice extent data for four previous years and the record low year. 2023 is shown in blue, 2022 in green, 2021 in orange, 2020 in brown, 2019 in magenta, and 2012 in dashed brown. The 1981 to 2010 median is in dark gray. The gray areas around the median line show the interquartile and interdecile ranges of the data. Figure taken from <https://nsidc.org/arcticseaicenews/>

Since this is the last blog post of the month of May I include the summer temperature anomaly forecast for June through August 2023. In **Figure ii** I include the summer temperature anomaly forecast from the North American multi-Model Ensemble (NMME - top panel), the C3S ensembles (European multi model ensemble including ECMWF - middle panel) and the AER statistical model (bottom panel). Please also look at the forecasts from the websites included in the figure caption as my plots do slightly differ from the posted plots. All three forecasts show almost universal warmth or above

normal temperatures. What differs among the three forecasts are the regions of above normal temperature maximums and if there are some more local regions of below normal temperatures. For North America the NMME show some impressive warmth for Canada. That is a pretty crazy forecast but would do well if simple persistence from May wins out. The C3S shows just amorphous warmth across the US and Canada while the AER forecast shows two warm maxima, one in the west and one in the east. Though it is not apparent in this plot the AER model is predicting relatively cool temperatures for the Southeastern US.

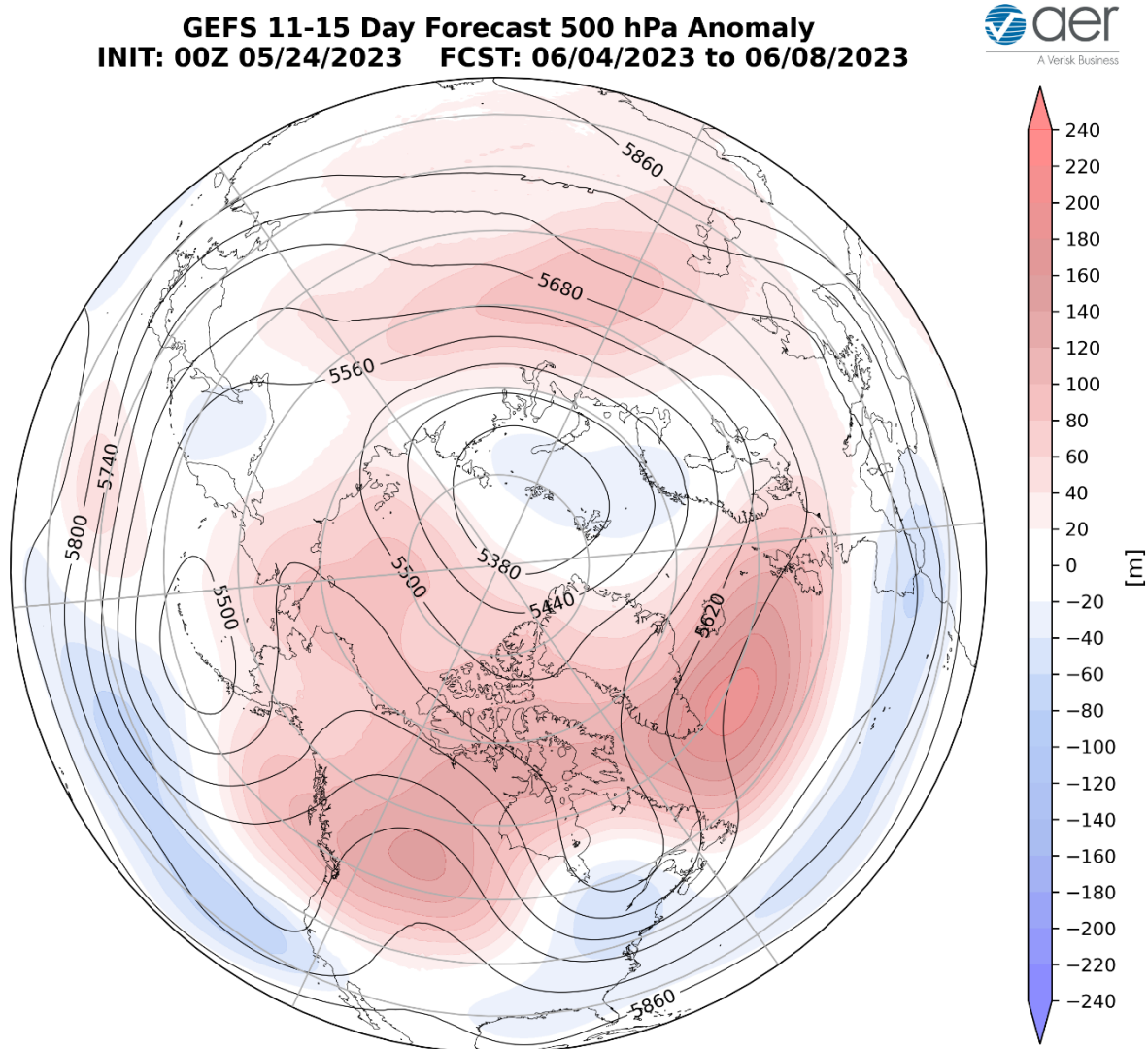


**Figure ii.** The NMME summer temperature anomaly forecast for June, July and August 2023 from <https://www.cpc.ncep.noaa.gov/products/NMME/> (top). The C3S summer temperature anomaly forecast for June, July and August 2023 from <https://www.copernicus.eu/en> (center). c) The AER summer temperature anomaly forecast for June, July and August 2023 (bottom).

For Europe the NMME and C3S show the relatively warmest temperatures in Western Europe while the AER forecast predicts the relatively warmest temperatures in Eastern Europe. Across East Asia it seems all three forecasts show mixed temperature forecasts with the AER warmest for Siberia and the NMME the coolest. Overall, the NMME forecast is the closest to a persistence forecast with the strongest warming near the Urals.

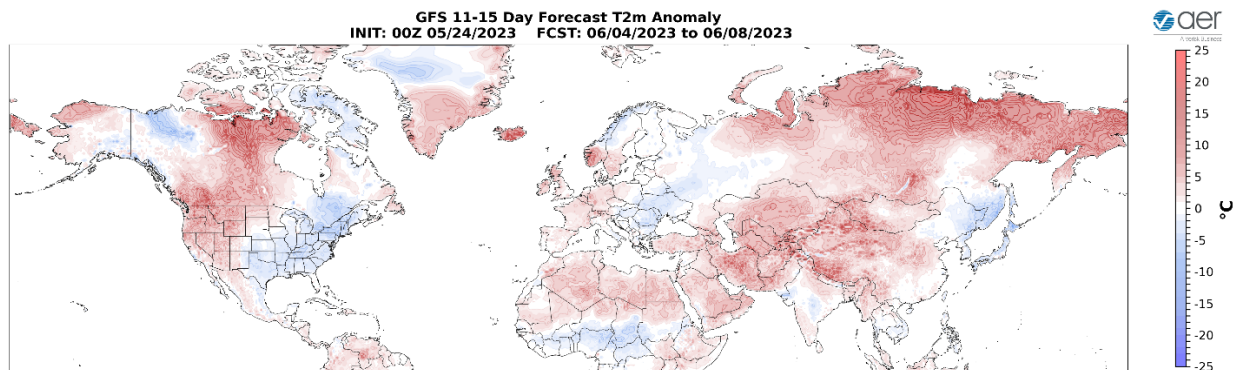
### Wednesday Update

Today's 11–15-day forecasts are showing a bit of a different mid-tropospheric circulation pattern, still annular but no longer centered on the North Pole (see **Figure iii**). What jumps out at me are the heat domes over Siberia but especially Canada and looks like the very warm May in Canada will continue into the summer but now including Siberia (see **Figure iv**).



**Figure iii.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 4 – 8 June 2023. The forecasts are from the 00z 24 May 2023 GFS ensemble.

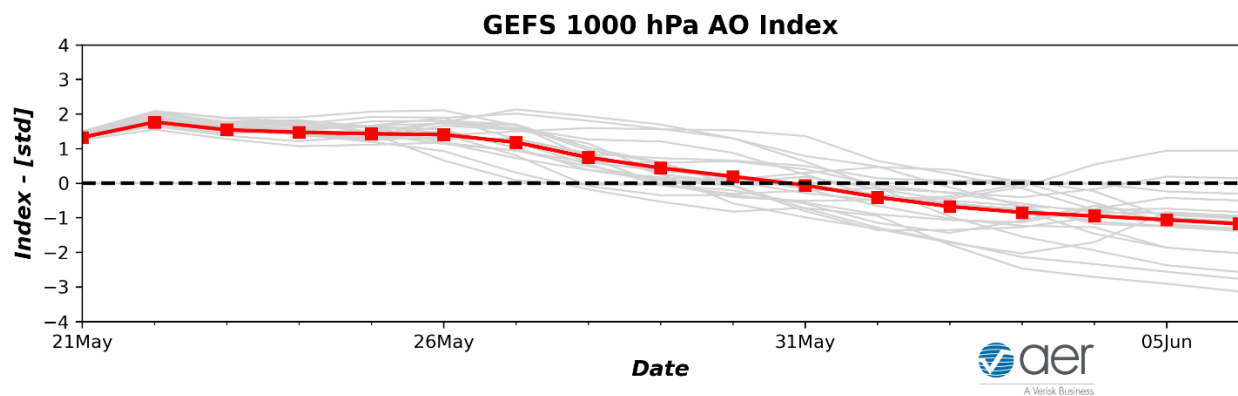
There is also now some Greenland blocking, increased Greenland blocking has been a common feature of recent summers (Hanna et al., 2018) and it will be interesting to see if we have a repeat this summer. Greenland blocking leads to increased summer melt of the ice sheet. But also with positive geopotential height anomalies predicted to push into the Central Arctic, sea ice is becoming increasingly vulnerable to rapid melt.



**Figure iv.** Forecasted surface temperature anomalies (°C; shading) from 4 – 8 June 2023. The forecast is from the 00Z 24 May 2023 GFS ensemble.

### Recent and Very Near Term Conditions

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

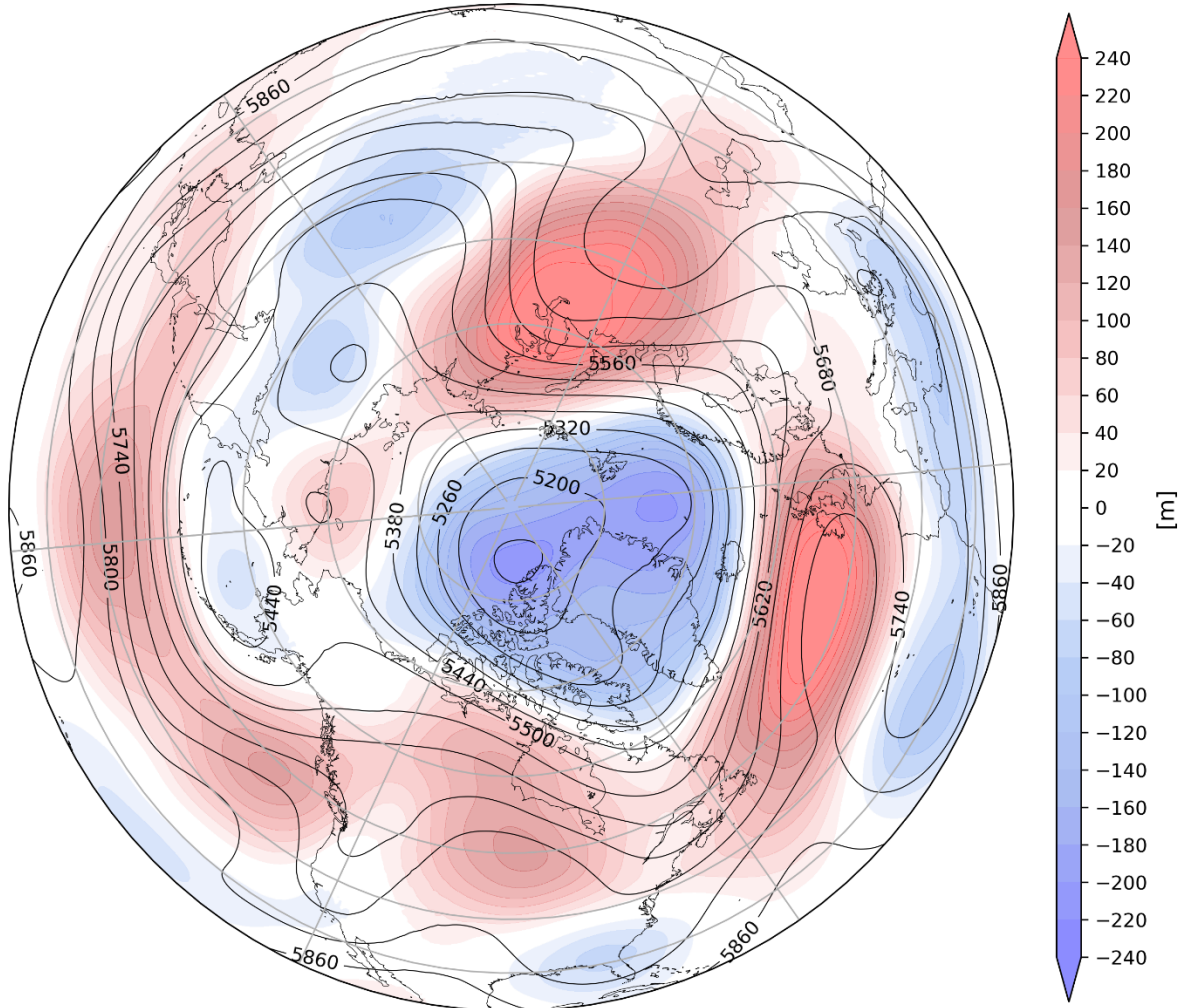




**Figure 1.** The predicted daily-mean AO at 1000 hPa from the 00Z 22 May 2023 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

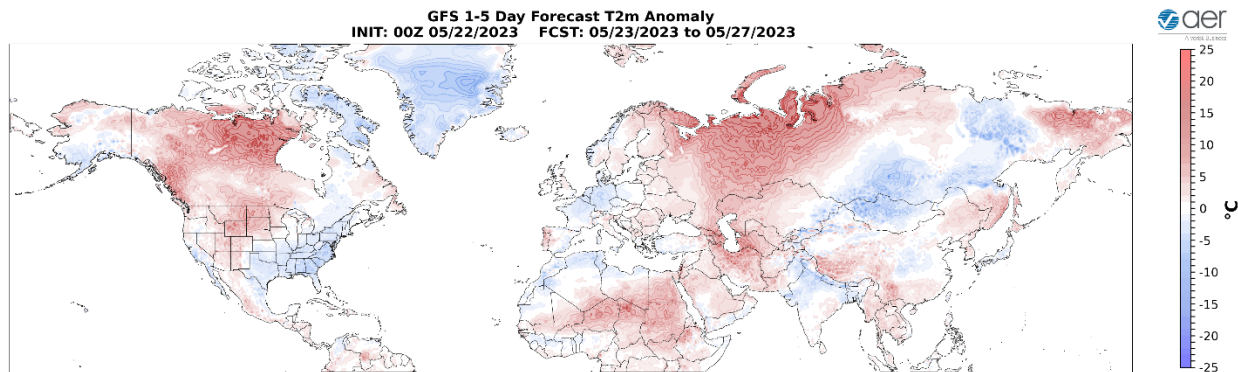
Trouching/negative geopotential height anomalies centered north of Greenland will force ridging/positive geopotential height anomalies across Northern Europe but centered west of the British Isles with troughing/negative geopotential height anomalies draped across Southern Europe (**Figures 2**). This pattern favors normal to below normal temperatures across much of Central and Southern Europe with normal to above normal temperatures across Northern and Eastern Europe including the UK and Portugal (**Figure 3**). Predicted ridging/positive geopotential height anomalies centered near the Urals will force troughing/negative geopotential height anomalies across Central Siberia that trails southwestward towards Central Asia with ridging/positive geopotential height anomalies across Central Asia and the east coast of Asia this period (**Figure 2**). This pattern favors normal to above normal temperatures across Western, much of Southern and far East Asia with normal to below normal temperatures across Central Siberia, Central Asia and northern India (**Figure 3**).

**GEFS 1-5 Day Forecast 500 hPa Anomaly**  
**INIT: 00Z 05/22/2023 FCST: 05/23/2023 to 05/27/2023**



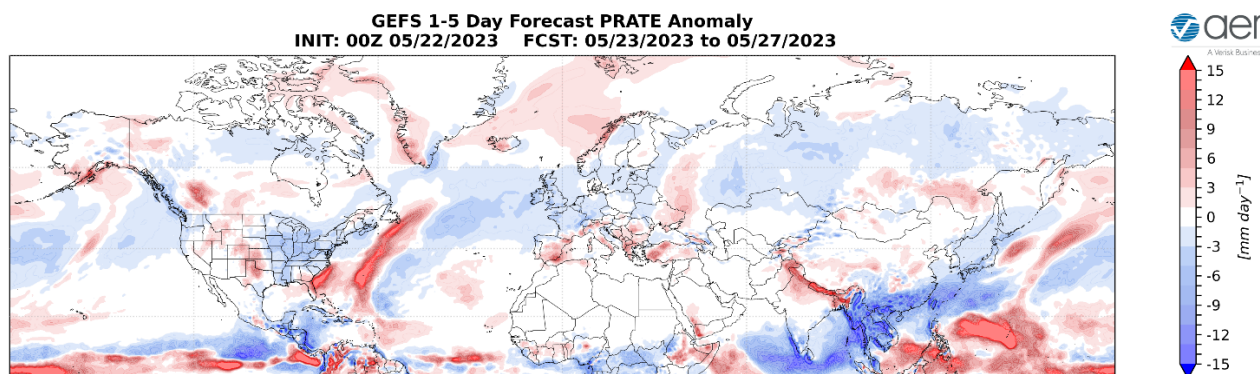
**Figure 2.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 23 – 27 May 2023. The forecasts are from the 00z 22 May 2023 GFS ensemble.

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



**Figure 3.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 23 – 27 May 2023. The forecast is from the 00Z 22 May 2023 GFS ensemble.

Mostly normal to dry conditions are predicted across Europe and Asia especially Southeast Asia with the exceptions of normal to wet conditions across Southern Europe, western Russia, Southern Siberia and the Tibetan Plateau 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 coastal ranges of Alaska the Canadian and US Rockies and the Central US (**Figure 4**).



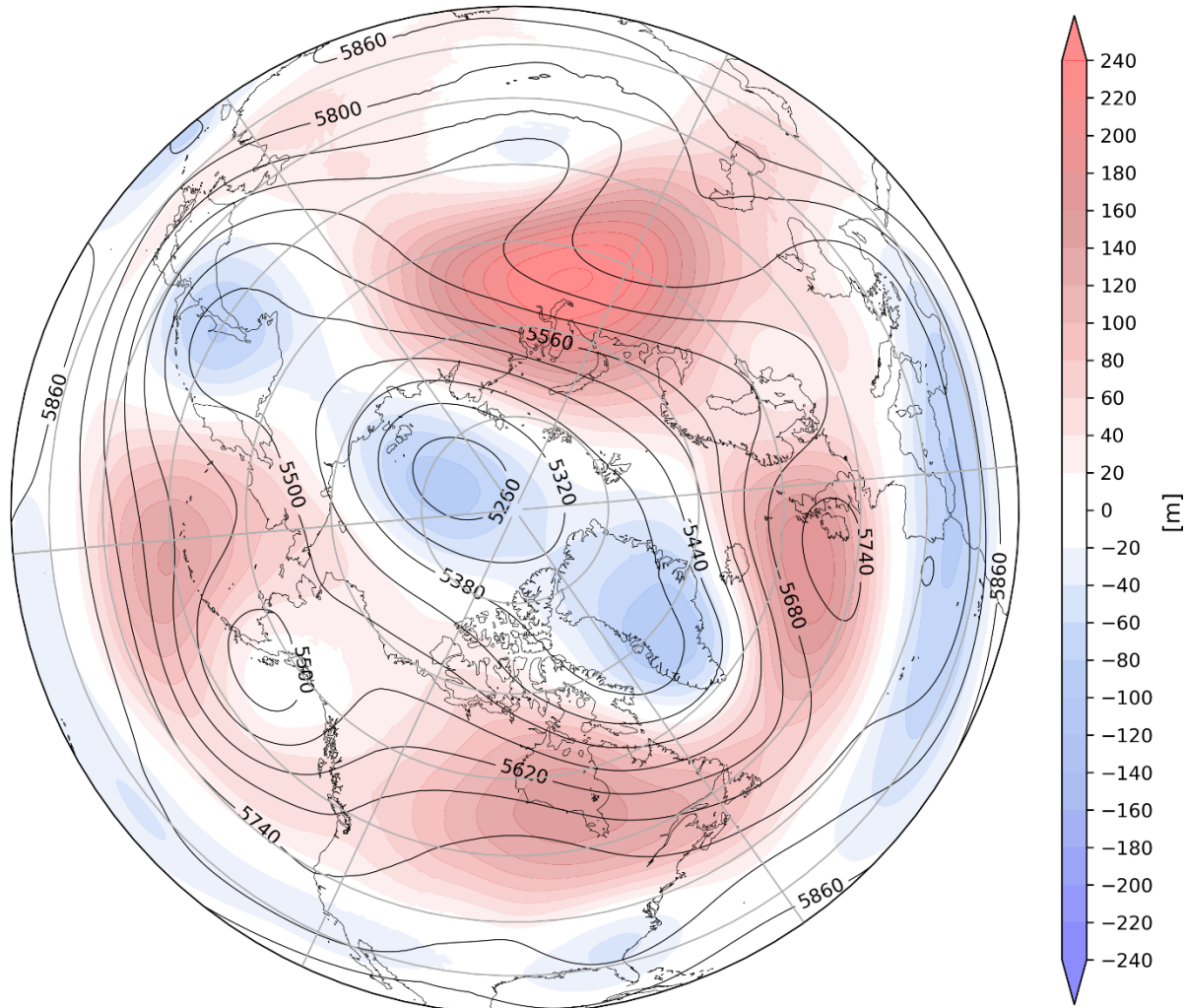
**Figure 4.** Forecasted precipitation rate (mm/day; shading) from 23 – 27 May 2023. The forecast is from the 00Z 22 May 2023 GFS ensemble.

### **Near-Term**

#### *1-2 week*

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

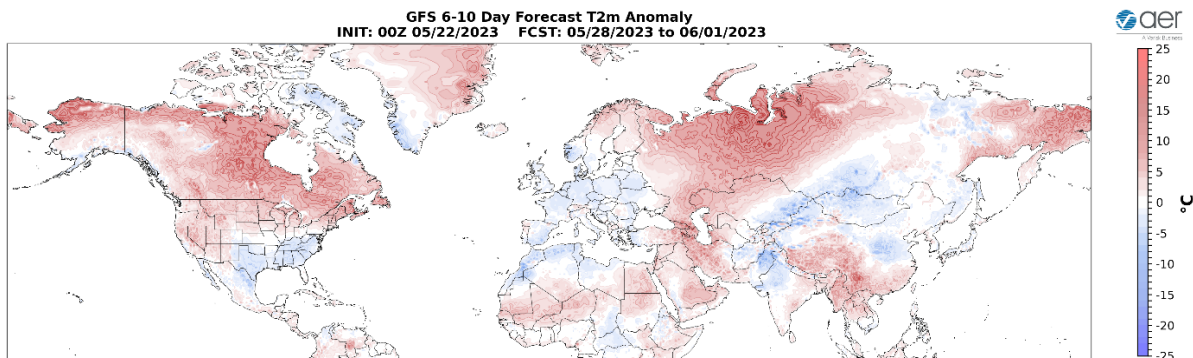
**GEFS 6-10 Day Forecast 500 hPa Anomaly**  
**INIT: 00Z 05/22/2023 FCST: 05/28/2023 to 06/01/2023**



**Figure 5.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 28 May – 1 June 2023. The forecasts are from the 00z 22 May 2023 GFS ensemble.

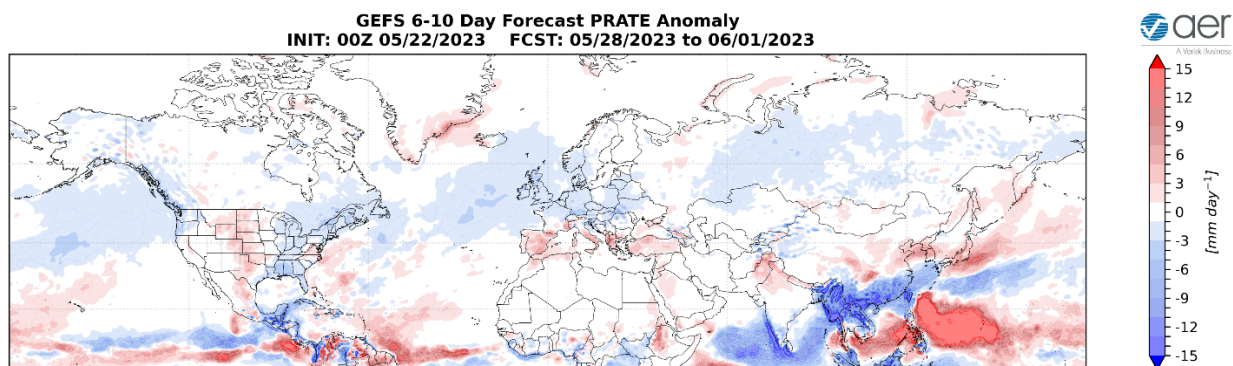
Persistent troughing/negative geopotential height anomalies centered near Greenland will continue to support ridging/positive geopotential height anomalies across Northern Europe with troughing/negative geopotential height anomalies across Southern Europe this period (**Figure 5**). This pattern should continue to favor normal to above normal temperatures across Northern Europe including the UK with normal to below normal temperatures across Central and Southern Europe (**Figures 6**). Persistent ridging/positive geopotential height anomalies centered near the Urals will anchor troughing/negative geopotential height anomalies in Central Siberia and East Asia with more ridging/positive geopotential height anomalies in Southeast Asia this period (**Figure 5**). The pattern favors normal to above normal temperatures across Western

and much of Southern Asia with normal to below normal temperatures across Central Siberia, Central and Northeast Asia this period (**Figure 6**).



**Figure 6.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 28 May – 1 June 2023. The forecast is from the 00Z 22 May 2023 GFS ensemble.

Persistent ridging/positive geopotential height anomalies are predicted to remain expansive across Canada and now Alaska with troughing/negative geopotential height anomalies in the Southwestern and the Southeastern US this period (**Figure 5**). This pattern favors normal to above normal temperatures across Alaska, much of Canada and the Western and Northern US with normal to below normal temperatures mostly limited to the Southeastern US and Ellesmere Island (**Figure 6**).

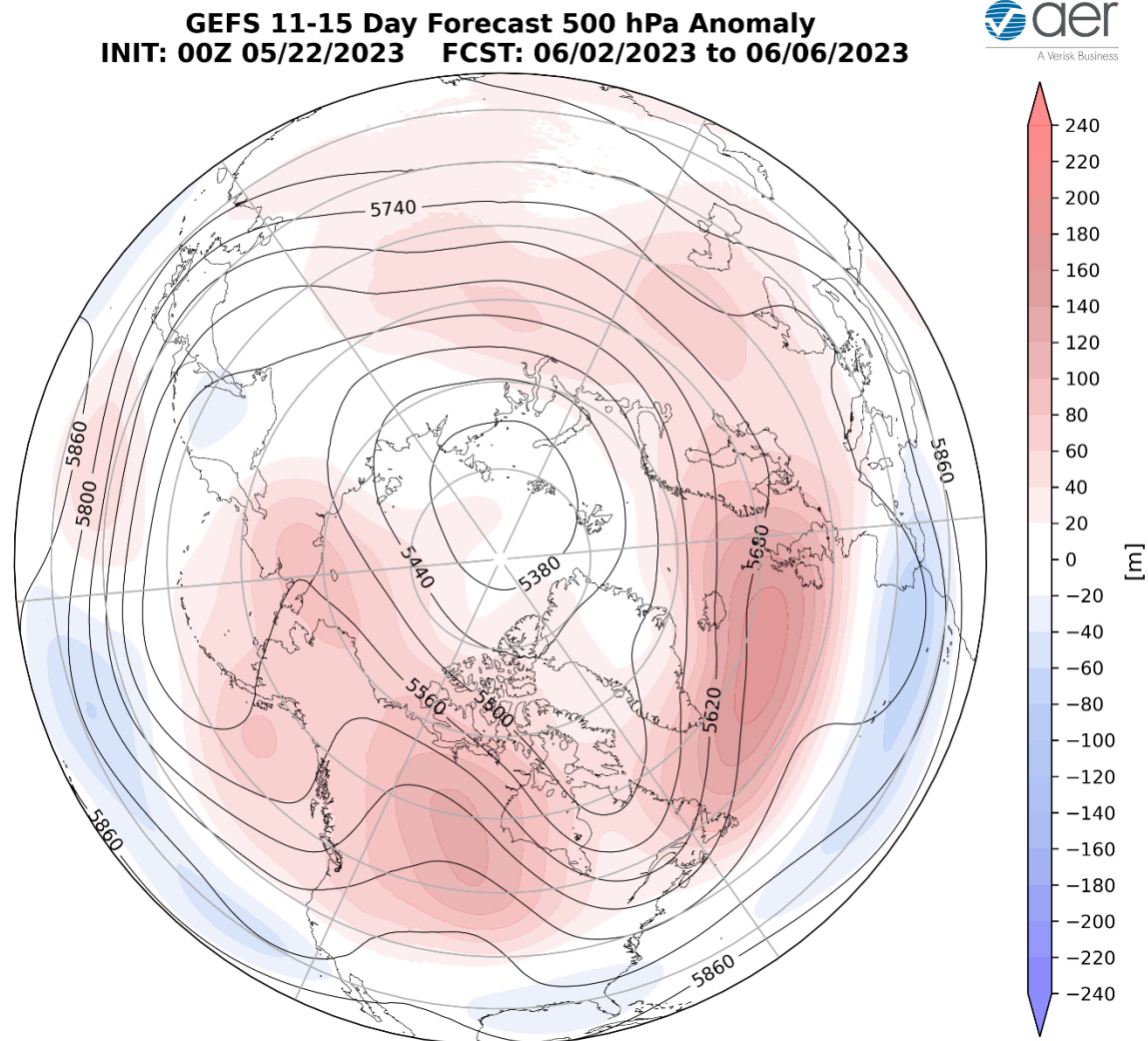


**Figure 7.** Forecasted precipitation rate (mm/day; shading) from 28 May – 1 June 2023. The forecast is from the 00Z 22 May 2023 GFS ensemble.

Mostly normal to dry conditions are predicted across Europe and Asia with the exceptions of normal to wet conditions across the Mediterranean, the Tibetan Plateau and parts of China, Japan and Southeast Asia this period (**Figure 7**). Mostly normal to dry conditions are predicted across Alaska, Canada and the Eastern US with normal to wet conditions across in the Central US (**Figure 7**).

3-4 week

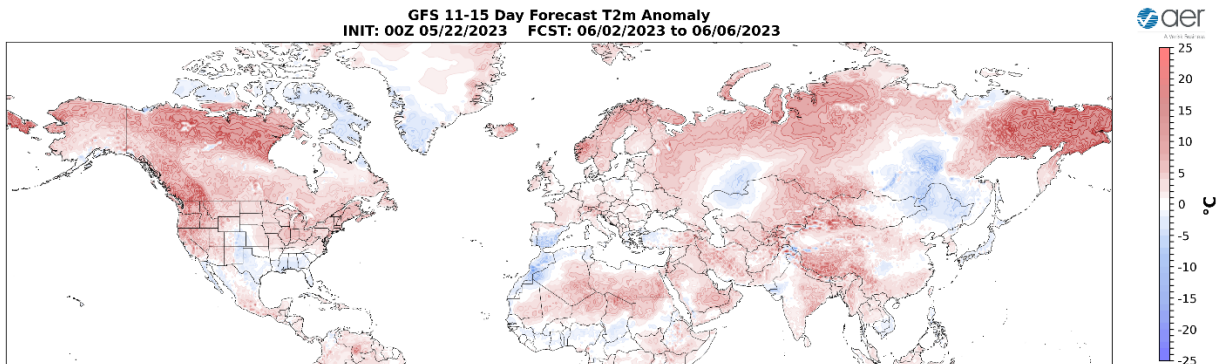
With mostly positive geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes this period (**Figure 8**), the AO should transition to negative this period (**Figure 1**). With mostly weak pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO will likely be close 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 2 – 6 June 2023. The forecasts are from the 00z 22 May 2023 GFS ensemble.

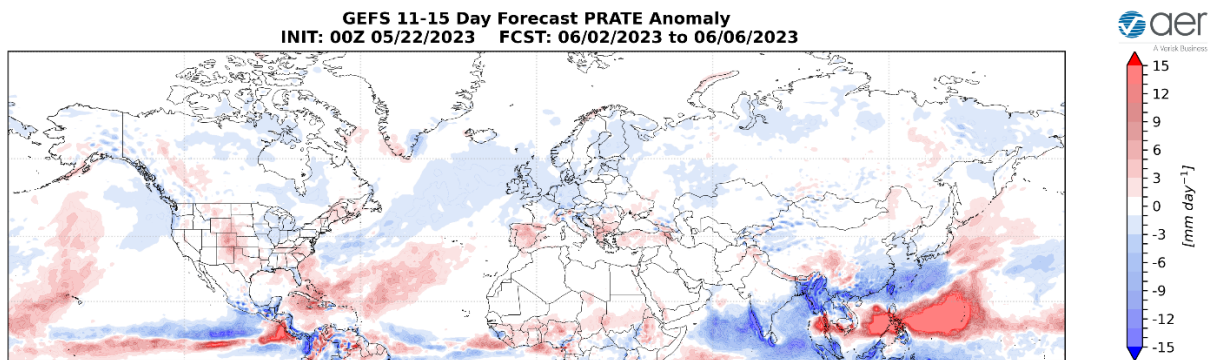
Ongoing albeit weakening troughing/negative geopotential height anomalies centered near Greenland will continue to favor ridging/positive geopotential height anomalies across Northern Europe with troughing/negative geopotential height anomalies across Southern Europe but centered just west of the Iberian Peninsula this period (**Figure 8**). This pattern should favor normal to above normal temperatures across Northern and Central Europe with normal to below normal temperatures mostly limited

to the Mediterranean region but especially the Iberian Peninsula this period (**Figure 9**). Persistent ridging/positive geopotential height anomalies across Western Asia will continue to anchor troughing/negative geopotential height anomalies across Central Siberia and into Northeast 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 limited to parts of Southern Siberia, Northeast Asia and western Kazakhstan this period (**Figure 9**).



**Figure 9.** Forecasted surface temperature anomalies (°C; shading) from 2 – 6 June 2023. The forecast is from the 00Z 22 May 2023 GFS ensemble.

Persistent ridging/positive geopotential height anomalies centered Central Canada and including Alaska, Western Canada and the Northwestern US will continue to favor limited troughing/negative geopotential height anomalies across the Southeastern US this period (**Figure 8**). This pattern favors normal to above normal temperatures across Alaska, much of Canada and the Western and Northern US with normal to below normal temperatures limited to Ellesmere Island and the Southeastern US (**Figure 9**).



**Figure 10.** Forecasted precipitation rate (mm/day; shading) from 2 – 6 June 2023. The forecast is from the 00Z 22 May 2023 GFS ensemble.

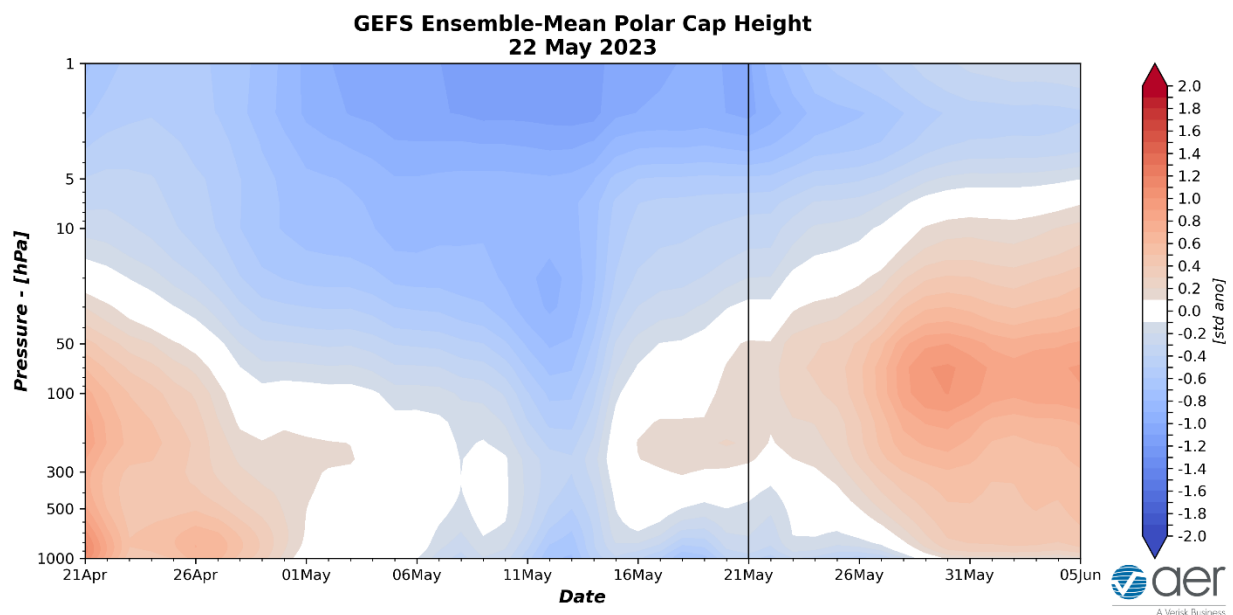
Mostly normal to dry conditions are predicted across Europe and Asia with the exceptions of normal to wet conditions across Spain, the Balkan States, Turkey and

Southern China this period (**Figure 10**). Mostly normal to dry conditions are predicted across Alaska, Canada and the Great Lakes with normal to wet conditions across the Canadian and US Rockies, the Central and the Southern US and along the US East Coast (**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 and lower troposphere with warm/positive PCHs in the upper troposphere and lower stratosphere (**Figure 11**). However, next week warm/positive PCHs are predicted to strengthen and expand to include all of the troposphere (**Figure 11**).

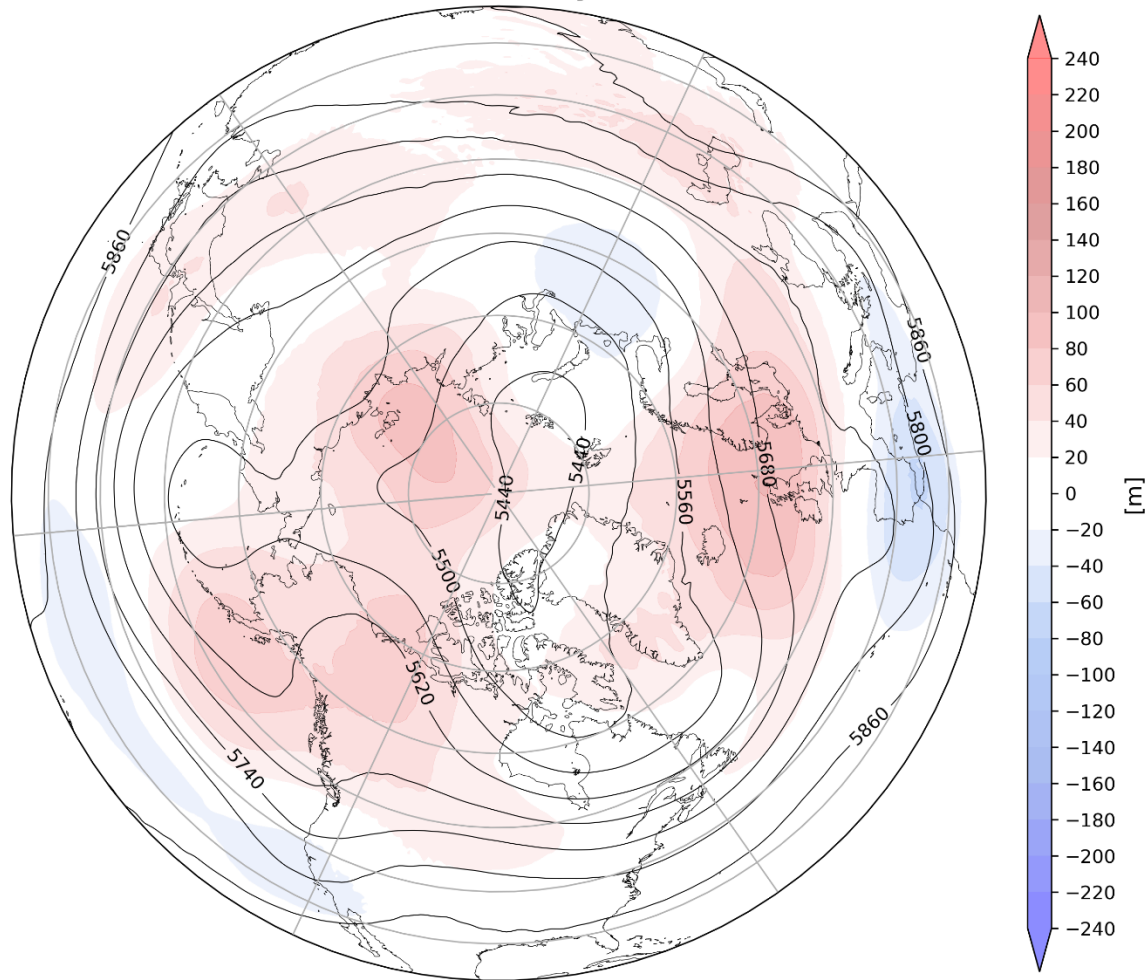


**Figure 11.** Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 22 May 2023 GFS ensemble.

The predicted cold/negative PCHs in the lower troposphere this week and into next week (**Figure 11**) are consistent with the predicted positive surface AO over the next week (**Figure 1**). However, the AO is predicted to flip negative later next week (**Figure 1**) coinciding with the predicted expansion of warm/positive PCHs in the troposphere all the way to the surface (**Figure 11**).



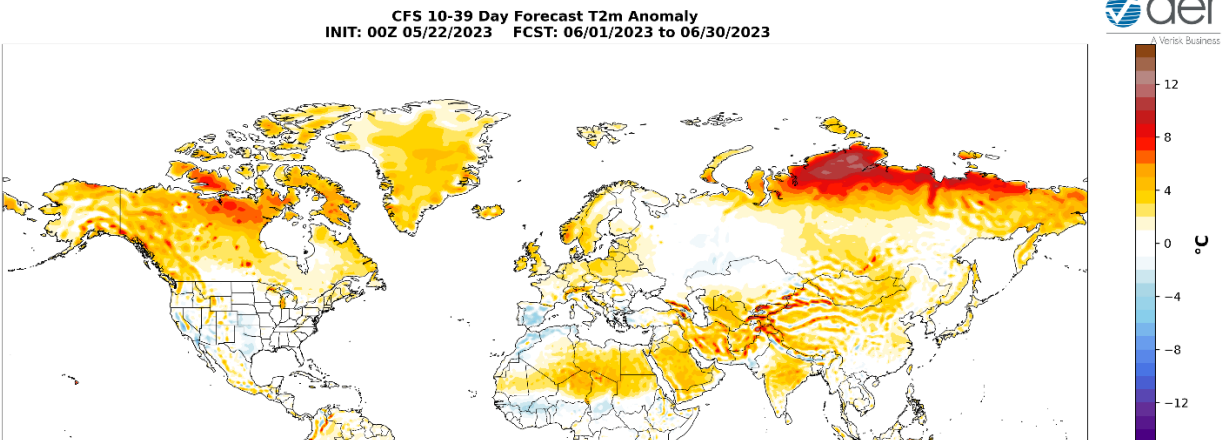
**CFS 500 hPa Forecast Anomaly Jun 2023**  
**Valid as of 22 May 2023**



**Figure 12.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for June 2023. The forecasts are from the 00Z 22 May 2023 CFS.

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

## Southeastern US (Figure 14).

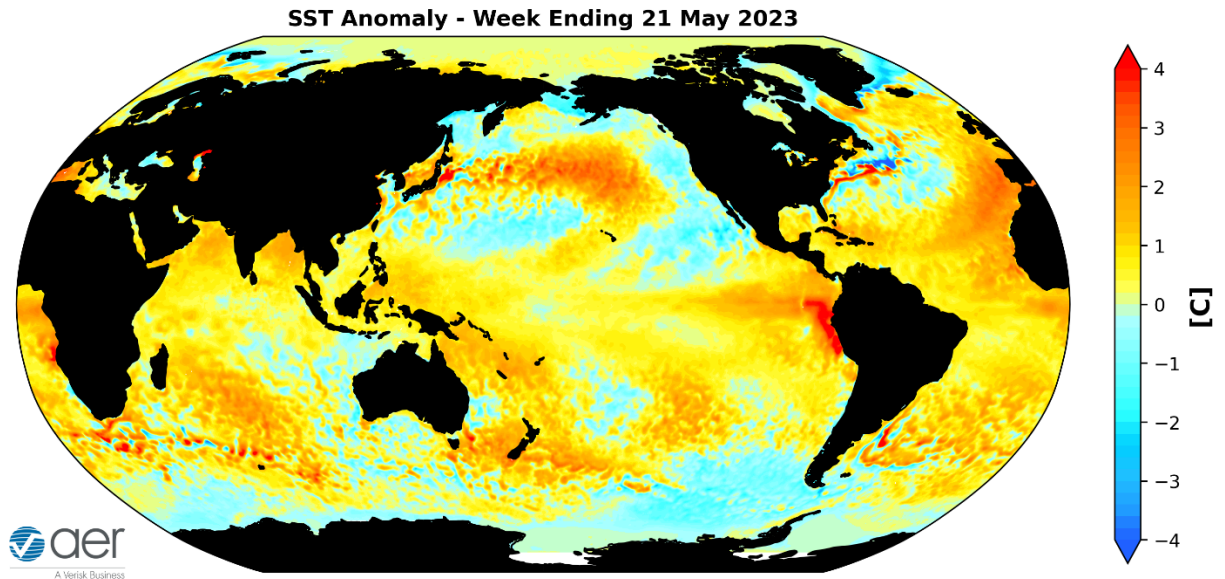


**Figure 13.** Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for June 2023. The forecasts are from the 00Z 22 May 2023 CFS.

### **Boundary Forcings**

#### *SSTs/El Niño/Southern Oscillation*

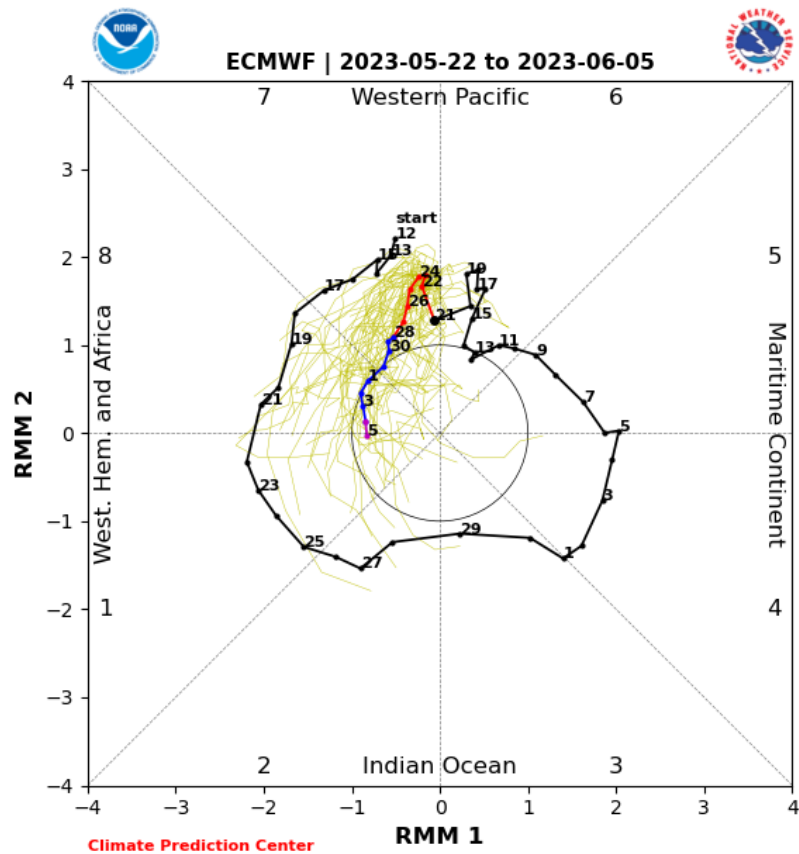
Equatorial Pacific sea surface temperatures (SSTs) anomalies are above normal, especially along the South America coast, indicating that the transition from La Niña to El Niño is complete (**Figure 14**) and El Niño conditions are expected through the fall. Observed SSTs across the NH remain well above 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 21 May 2023). Data from NOAA OI High-Resolution dataset.

### *Madden Julian Oscillation*

Currently phase seven of the Madden Julian Oscillation (MJO) is favored (**Figure 16**). The forecasts are for the MJO to weaken to where no phase is favored. Phases seven favors ridging over Canada and troughing over the Eastern US. Seems that the MJO is having some influence on the weather across North America 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 22 May 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](https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar_wh.shtml)