

Arctic Oscillation and Polar Vortex Analysis and Forecasts

April 10, 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.

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

Summary

- The Arctic Oscillation (AO) is currently positive and is predicted to flip negative later this week and then remain negative to neutral the next two weeks as pressure/geopotential height anomalies across the Arctic are currently mostly negative and are predicted to become increasingly positive except near the North Pole the next two weeks. The North Atlantic Oscillation (NAO) is currently positive and is predicted to flip negative later this week and remain negative to neutral the next two weeks as pressure/geopotential height anomalies are currently mixed and are predicted to turn positive across Greenland later this week.
- The next two weeks predicted troughing/negative geopotential height anomalies centered south of Greenland will support ridging/positive geopotential height anomalies centered across much of Europe with the exception of troughing/negative geopotential height anomalies across Southeastern Europe. This pattern favors the next two weeks normal to above normal temperatures across much of Europe except for normal to above normal temperatures across Southeastern Europe and the United Kingdom (UK) this week.
- The next two weeks predicted European ridging/positive geopotential height anomalies will anchor troughing/negative geopotential height anomalies across much of Siberia with ridging/positive geopotential height anomalies draped across Southern Asia. This pattern favors normal to above normal temperatures widespread across much of Asia with normal to below normal temperatures across Siberia with the exception of normal to above normal temperatures across Eastern Siberia next week.
- The general pattern predicted across North America the next two weeks is ridging/positive geopotential height anomalies centered near the Aleutians forcing troughing/negative geopotential height anomalies across the, Alaska, Western Canada and the Western United States (US) with more ridging/positive geopotential height anomalies across Eastern Canada and the Eastern US. However next week some of the Western troughing will slowly push eastward across the US. This pattern generally favors normal to below normal temperatures across Alaska, Western Canada and the Western US with normal to above normal temperatures across Eastern Canada and the Eastern US. However, next week some of the lower geopotential heights in the Western US along with normal to below normal temperatures will slowly push eastward east of the Rockies.
- Looks like the atmosphere is getting a jump on settling into the dominant summer pattern of recent years and in today's blog I discuss how will this impact the weather across the Northern Hemisphere (NH).

Plain Language Summary

The predicted short and long term pattern is for low pressure near the North Pole and higher pressure across the continents creating a ring or donut in the pressure fields across the Northern Hemisphere (see **Figures i** and **8**). This pattern favors widespread above normal temperatures across, Europe, Asia and North America with a few exceptions (see **Figures ii** and **9**).

Impacts

What is most striking to me is how quickly the atmosphere transitioned from winter to what has become the dominant tropospheric circulation during the summer months – relatively low pressure/heights centered near the North Pole surrounded by a ring of relatively high pressure/heights across the mid-latitude continents (see for example **Figures 5 and 8**). This pattern would keep temperatures in the Central Arctic close to normal based on multi-decadal averages but would favor above normal temperatures across the Northern Hemisphere (NH) continents and even well above normal temperatures especially along the northern edges of the NH continents.

I included the CFS forecast for May below in **Figures 13 and 14**. And though the forecast skill of the CFS is relatively low, I do include the June 500 hPa geopotential heights in **Figure i** and surface temperature anomalies in **Figure ii**. We shall see how accurate the forecast is in the end, but it is at least consistent with recent summers and what I have been describing. The CFS is predicting relatively low pressure/heights centered near the North Pole surrounded by a ring of relatively high pressure/heights across the mid-latitude continents including Europe, Asia and North America. This circulation pattern yields widespread above normal temperatures across the NH continents with the exceptions of near the Urals and the Central US, two regions that have bucked recent continental warming trends.

CFS 500 hPa Forecast Anomaly Jun 2023
Valid as of 10 Apr 2023

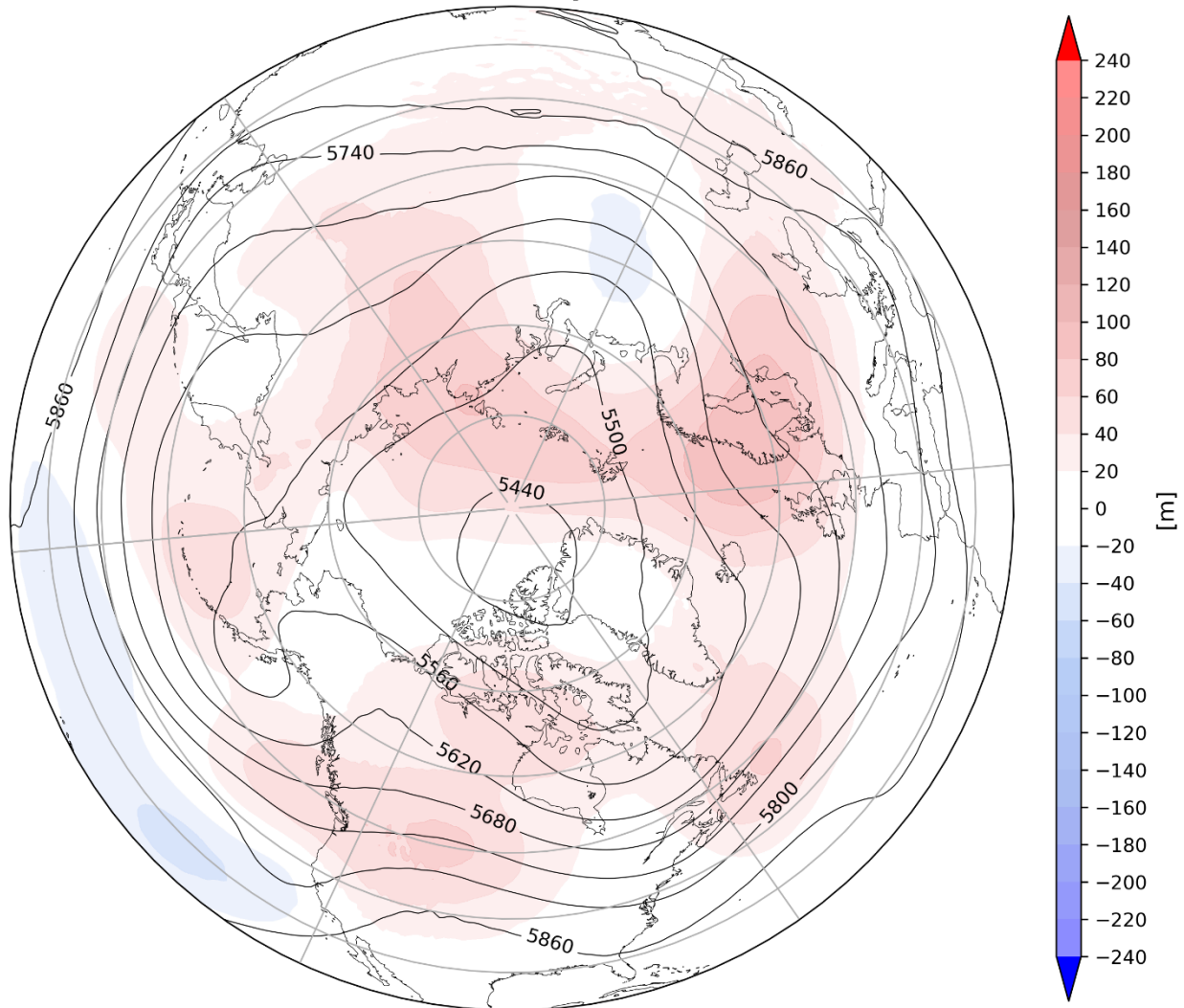


Figure i. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for JUNE 2023. The forecasts are from the 00Z 10 April 2023 CFS.

One phenomenon that could either delay or interrupt the warming trend at least regionally, is ongoing troposphere-stratosphere-troposphere (TST) coupling. It seems likely to me that the last “drip” of warm/positive polar cap geopotential height anomalies (PCHs) from the large polar vortex disruption that occurred in mid-February has already occurred but based on the PCH forecasts it is predicted to re-emerge. This will likely force a negative AO that could yield some cooler temperatures across the NH continents. Nothing impressive with the possible exception of Siberia, is currently predicted but it could be that the models are not correctly resolving the full impact of the anticipated warming tropospheric PCHs.

CFS 52-81 Day Forecast T2m Anomaly
INIT: 00Z 04/10/2023 FCST: 06/01/2023 to 06/30/2023

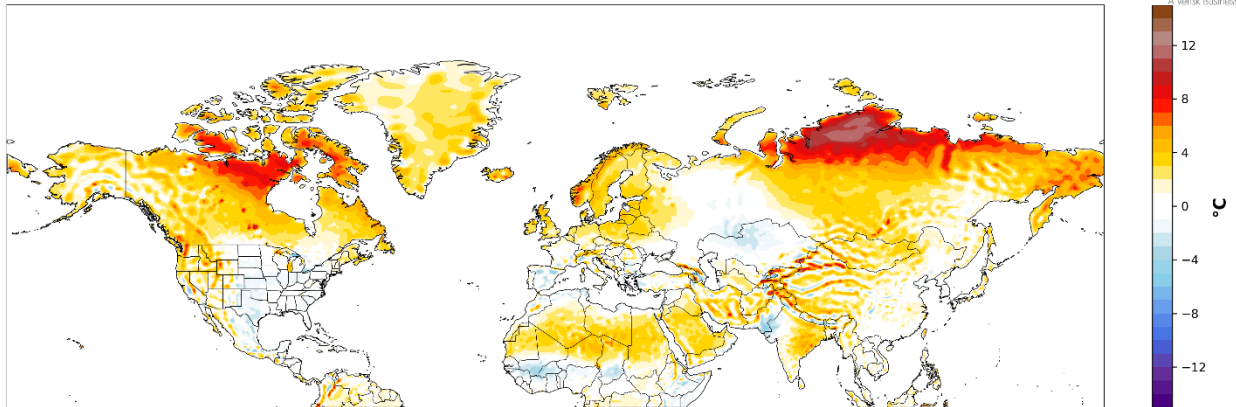


Figure ii. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for June 2023. The forecasts are from the 00Z 10 April 2023 CFS.

Even as the influence from this winter's major polar vortex disruption wanes there could still be a similar impact of warm/positive PCHs and a negative AO or something similar following a dynamic (forced by atmospheric dynamics and not solely by the strengthening sun) Final Warming. That is when the NH polar vortex disappears until next fall. Based on the GFS forecasts a dynamic Final Warming seems likely. Certainly, the predicted Scandinavian blocking/high pressure seems supportive to me of a dynamic Final Warming.

But even given any upcoming TST coupling I still think that the overall pattern predicted in the short term by the GFS and longer term by the CFS is the most likely to dominate the summer months. At least in the short term the largest departures from normal to the upside are predicted in the Northeastern US and Southeastern Canada. But the potential is there for well above normal temperatures in Europe as well. Looking like once again a hot summer for Europe is likely and continues one of the great weather mysteries for me, why is Europe the fastest warming region in the Northern Hemisphere during the summer months (see [WMO report](#))?

Wednesday Update

I forgot to mention on Monday is the role of snow cover in forcing this donut shape in the atmosphere or something I like to refer to as the "ring of fire" because it results in well above normal temperatures in almost a ring shape across the NH. It has been theorized that the early disappearance of snow cover can contribute to anomalous ridging or heat domes across the northern continents by leading to early desiccation of soils. Snow cover is well below normal across Eurasia but above normal across North America. So hard to know what role snow cover is playing if any on the model forecasts of the early appearance of continental ridges of high pressure that promotes well above normal temperatures.

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 mixed geopotential height anomalies across Greenland (**Figure 2**), the NAO is predicted to be mostly positive this period.

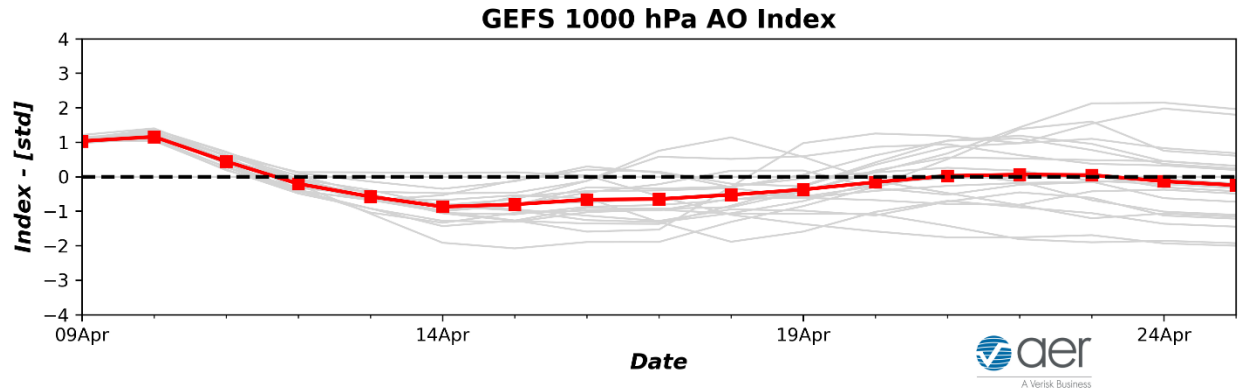


Figure 1. The predicted daily-mean AO at 1000 hPa from the 00Z 10 April 2023 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Trouching/negative geopotential height anomalies centered south of Greenland will force ridging/positive geopotential height anomalies across much of Europe with the exceptions of troughing/negative geopotential height anomalies across the Northwestern and Southeastern corners of Europe (**Figures 2**). This pattern favors widespread normal to above normal temperatures across much of Europe with the exceptions of normal to below normal temperatures across Northwestern and Southeastern Europe including the UK (**Figure 3**). Predicted European ridging this week will force troughing/negative geopotential height anomalies across Siberia and Northeastern Asia with ridging/positive geopotential height anomalies across Southern and Western Asia this period (**Figure 2**). This pattern favors widespread normal to above normal temperatures across Western and Southern Asia with normal to below normal temperatures across Siberia and into Northeastern Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 hPa Anomaly
INIT: 00Z 04/10/2023 FCST: 04/11/2023 to 04/15/2023

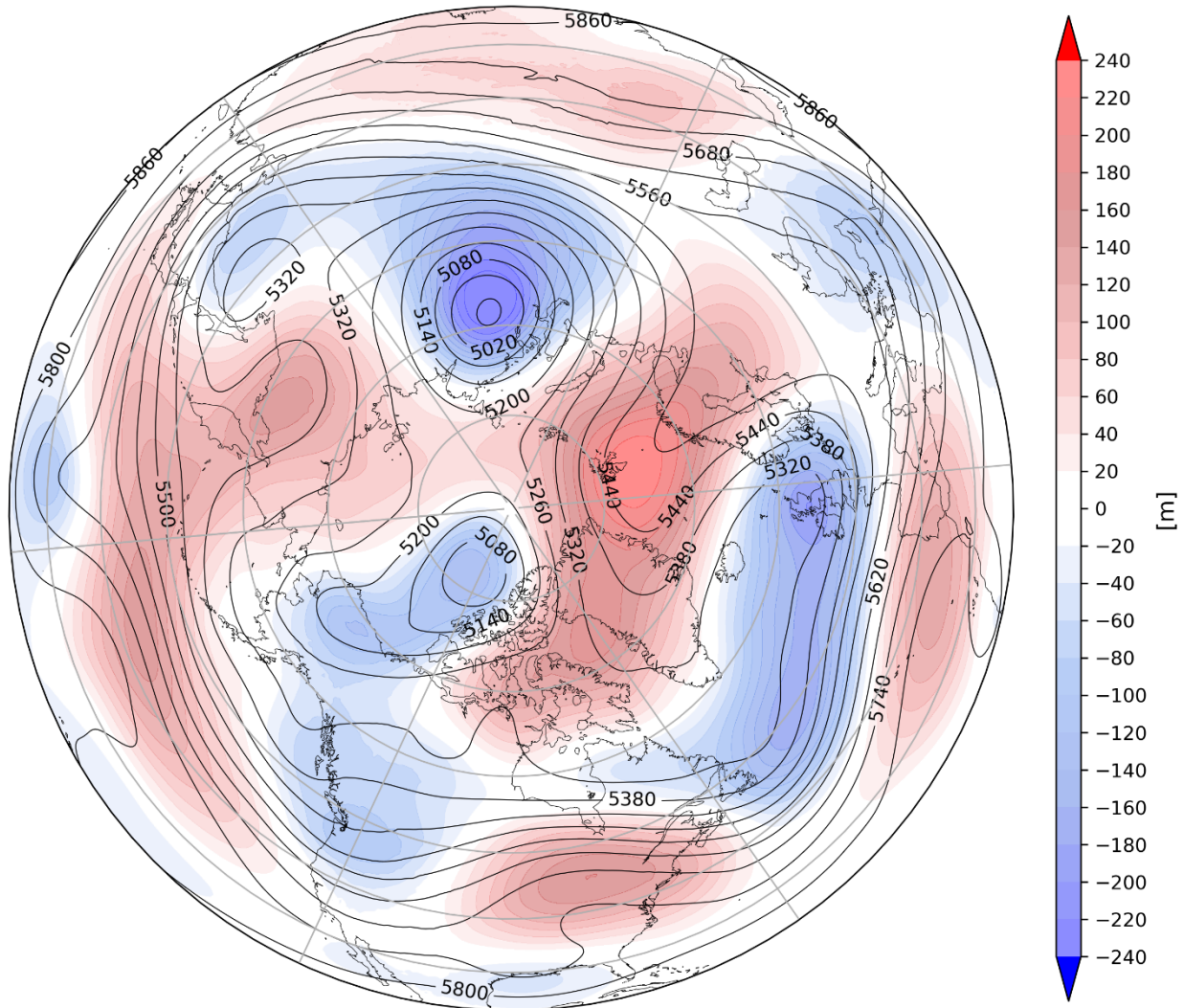


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 11 – 15 April 2023. The forecasts are from the 00z 10 April 2023 GFS ensemble.

The pattern this week across North America is ridging/positive geopotential height anomalies centered in the Aleutians forcing troughing/negative geopotential height anomalies across Western Canada and the Western US with more ridging/positive geopotential height anomalies in Eastern Canada and the Eastern US this period (**Figure 2**). This pattern will favor normal to below normal temperatures across Alaska, Western Canada and the Western US with normal to above normal temperatures across Eastern Canada and the Eastern US (**Figure 3**). Record warmth is possible in the Northeastern US and Southeastern Canada.

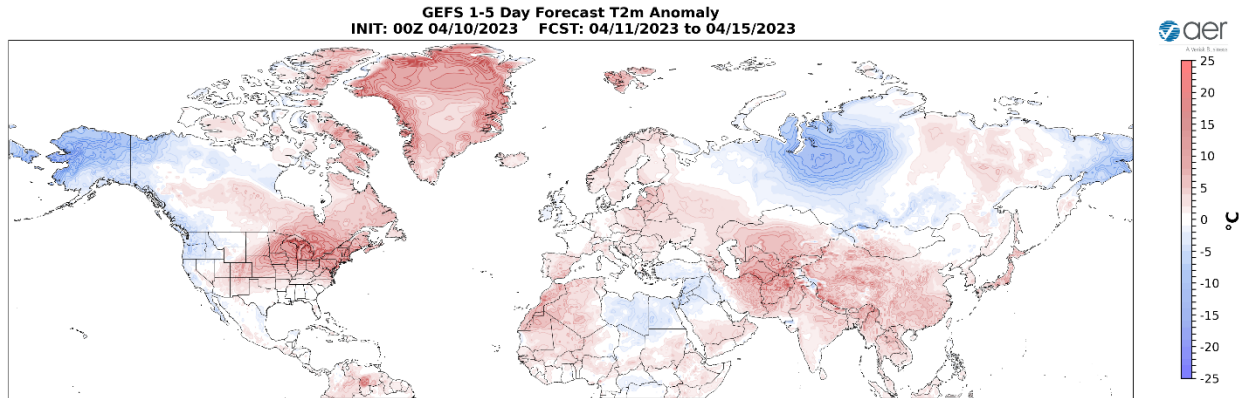


Figure 3. Forecasted surface temperature anomalies (°C; shading) from 11 – 15 April 2023. The forecast is from the 00Z 10 April 2023 GFS ensemble.

Mostly normal to dry conditions are predicted across Europe and Asia with the exceptions of normal to wet conditions across Northwestern Europe, the Middle East and parts of Northeast 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 Pacific Northwest and the US Upper Midwest (**Figure 4**).

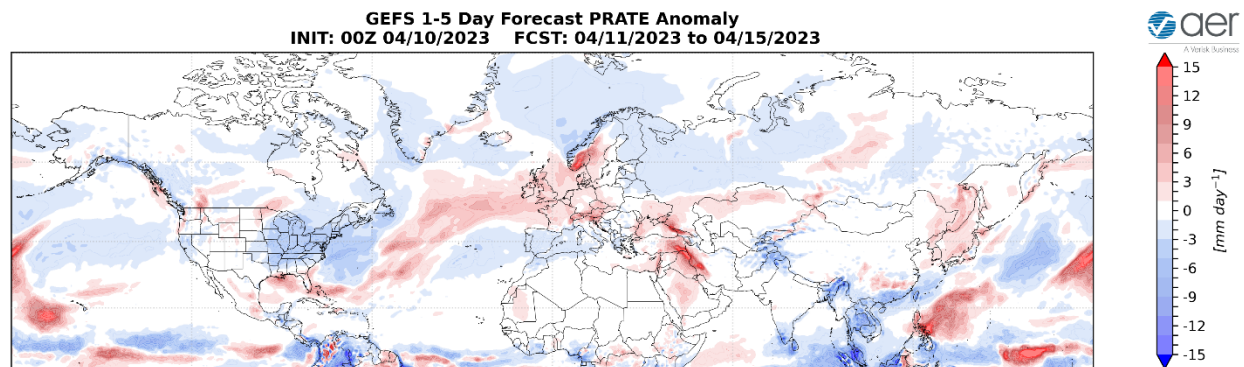


Figure 4. Forecasted precipitation rate (mm/day; shading) from 11 – 15 April 2023. The forecast is from the 00Z 10 April 2023 GFS ensemble.

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 be neutral to negative this period (**Figure 1**). With predicted weak and mixed pressure/geopotential height anomalies across Greenland (**Figure 5**), the NAO will likely trend positive this period.

GEFS 6-10 Day Forecast 500 hPa Anomaly
INIT: 00Z 04/10/2023 FCST: 04/16/2023 to 04/20/2023

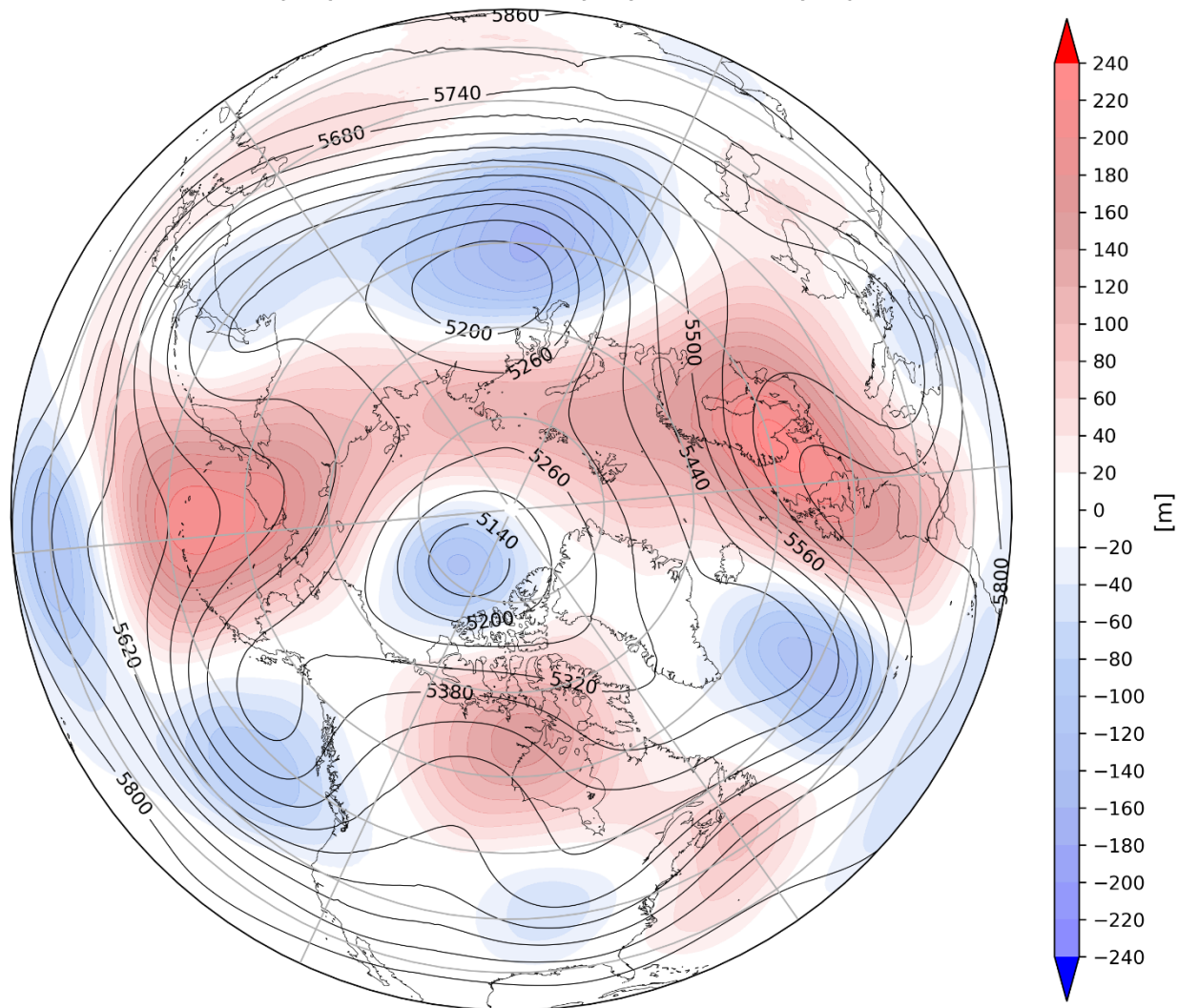


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 16 – 20 April 2023. The forecasts are from the 00z 10 April 2023 GFS ensemble.

Persistent troughing/negative geopotential height anomalies centered south of Greenland will continue to support ridging/positive geopotential height anomalies across most of Europe except for troughing/negative geopotential height anomalies across the Eastern Mediterranean this period (**Figure 5**). This pattern should continue to favor normal to above normal temperatures across much of Europe including the UK except for normal to below normal temperatures across the Balkan States (**Figures 6**). Persistent European ridging will continue to support troughing/negative geopotential height anomalies across Siberia with ridging/positive geopotential height anomalies across Southern Asia this period (**Figure 5**). The pattern favors widespread normal to above normal temperatures across Western, Southern Asia and Eastern

Siberia with normal to below normal temperatures across Central Asia including Western Siberia this period (**Figure 6**).

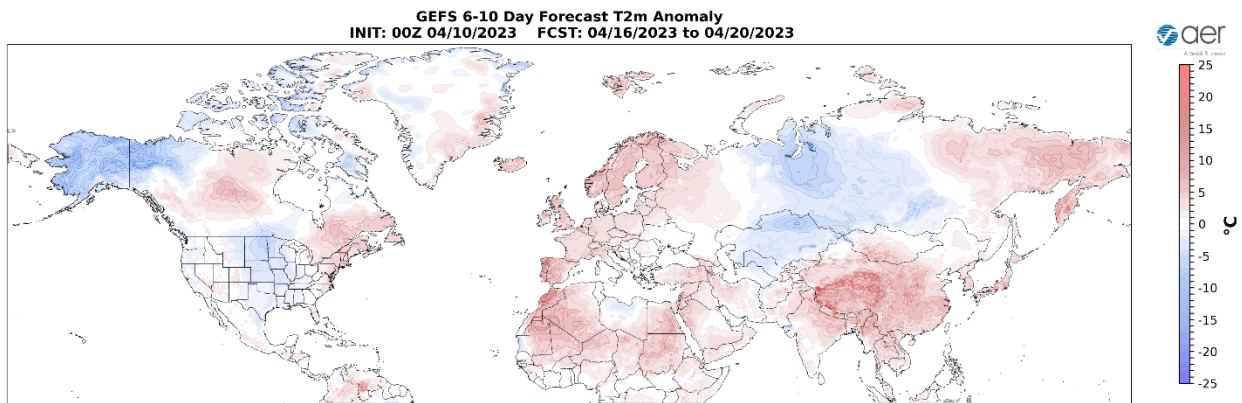


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 16 – 20 April 2023. The forecast is from the 00Z 10 April 2023 GFS ensemble.

Persistent ridging/positive geopotential height anomalies centered in the Aleutians will continue to anchor troughing/negative geopotential height anomalies in Alaska, Western Canada and the Western US that now pushes into the Central US with ridging/positive geopotential height anomalies in Central Canada and along the US East Coast this period (**Figure 5**). This pattern favors normal to below normal temperatures across Alaska, the West Coast of Canada and the Western and Central US with normal to above normal temperatures across much of Canada and the Eastern US (**Figure 6**). Record warmth is possible again in the Northeastern US and Southeastern Canada.

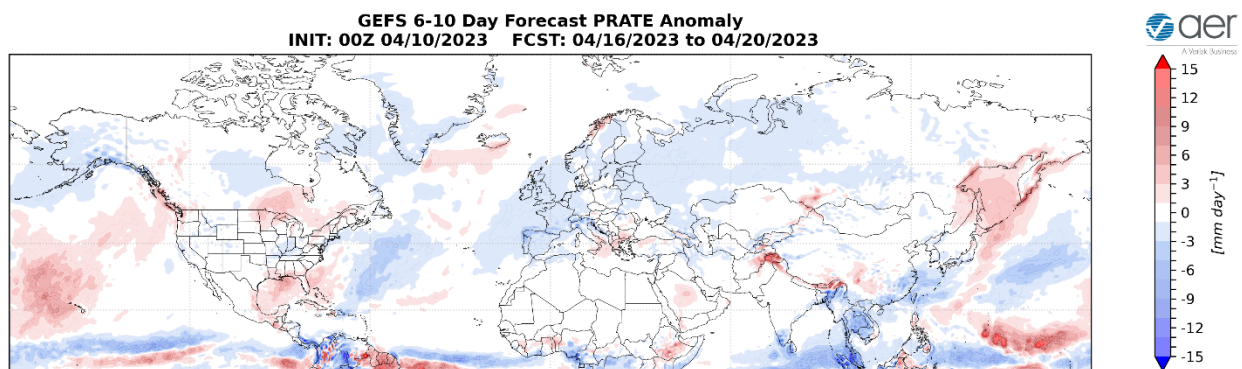


Figure 7. Forecasted precipitation rate (mm/day; shading) from 16 – 20 April 2023. The forecast is from the 00Z 10 April 2023 GFS ensemble.

Mostly normal to dry conditions are predicted across Europe and Asia with the exceptions of normal to wet conditions across Southeastern Europe, and parts of Northeast Asia this week (**Figure 7**). Mostly normal to dry conditions are predicted

across Canada and the US with the exceptions of normal to wet conditions across the US-Canadian border and along the Gulf of Mexico (**Figure 7**).

3-4 week

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

GEFS 11-15 Day Forecast 500 hPa Anomaly
INIT: 00Z 04/10/2023 FCST: 04/21/2023 to 04/25/2023

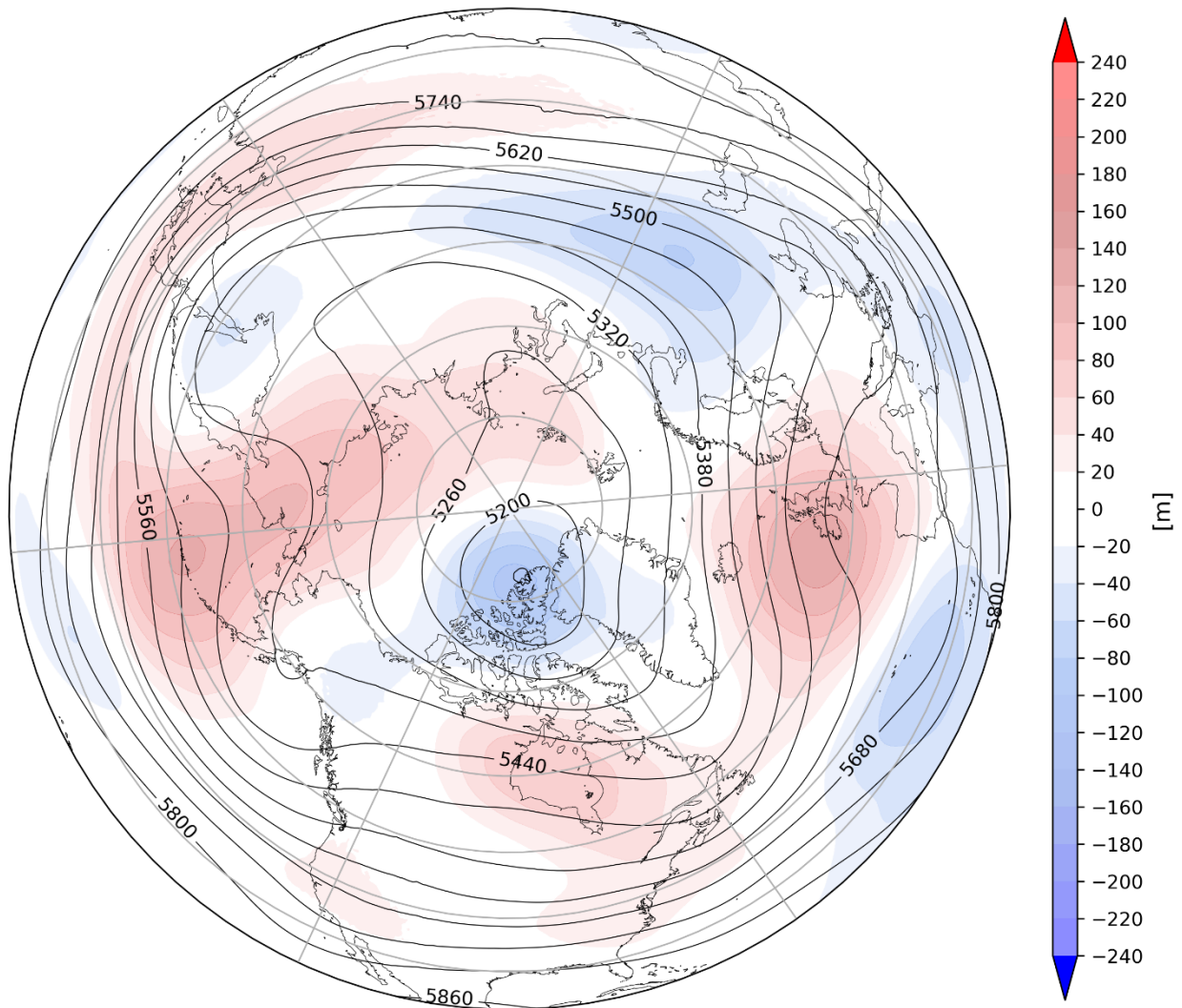


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 21 – 25 April 2023. The forecasts are from the 00z 10 April 2023 GFS ensemble.

Ongoing albeit weakening troughing/negative geopotential height anomalies centered south of Greenland will continue to favor ridging/positive geopotential height anomalies across Europe with the exception of troughing/negative geopotential height anomalies across far Eastern Europe this period (**Figure 8**). This pattern should continue to favor normal to above normal temperatures across much of Europe including the UK (**Figures 9**). European ridging will continue to support troughing/negative geopotential height anomalies across Northern Asia with ridging/positive geopotential height anomalies spread across Southern Asia this period (**Figure 8**). The predicted pattern favors widespread normal to above normal temperatures across much of Asia and Eastern Siberia with normal to below normal temperatures mostly across Siberia this period (**Figure 9**).

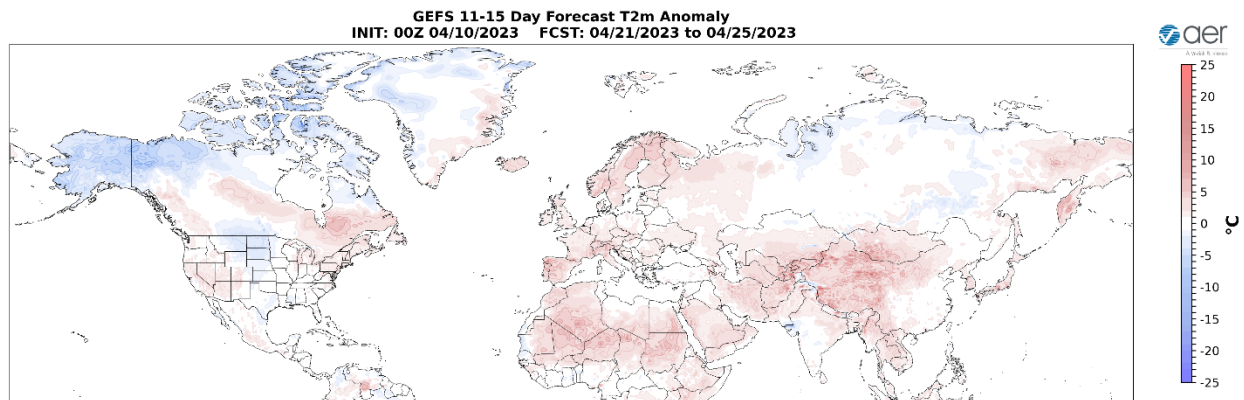


Figure 9. Forecasted surface temperature anomalies (°C; shading) from 21 – 25 April 2023. The forecast is from the 00Z 10 April 2023 GFS ensemble.

Persistent ridging/positive geopotential height anomalies centered near the Aleutians will continue to anchor troughing/negative geopotential height anomalies across Alaska, the Gulf of Alaska, Western Canada and the Central US with ridging/positive geopotential height anomalies across Eastern Canada and the Eastern US this period (**Figure 8**). This pattern favors normal to below normal temperatures across Alaska, Northern and Central Canada and the Central US with normal to above normal temperatures across Western and Eastern Canada and the Western and Eastern US (**Figure 9**).

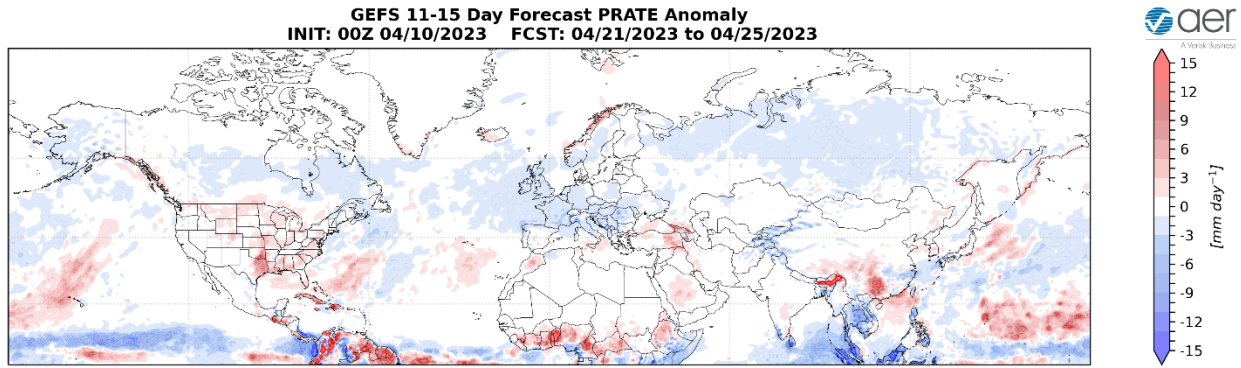


Figure 10. Forecasted precipitation rate (mm/day; shading) from 21 – 25 April 2023. The forecast is from the 00Z 10 April 2023 GFS ensemble.

Mostly normal to dry conditions are predicted across Europe and Asia with the exceptions of normal to wet conditions across Norway, and parts of Southeast Asia this period (**Figure 10**). Mostly normal to dry conditions are predicted across Canada with normal to wet conditions across the much of the US east of the Rockies (**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 stratosphere and in the troposphere (**Figure 11**). However later this week warm/positive PCHs are predicted to re-emerge in the troposphere (**Figure 11**). This seems to be a continuation of the last “drip” of warm/positive PCHs from the stratosphere into the troposphere that took place right at the end of March and very early April, commonly observed following major sudden stratospheric warming (SSW), which occurred back in mid-February (see **Figure 11**).

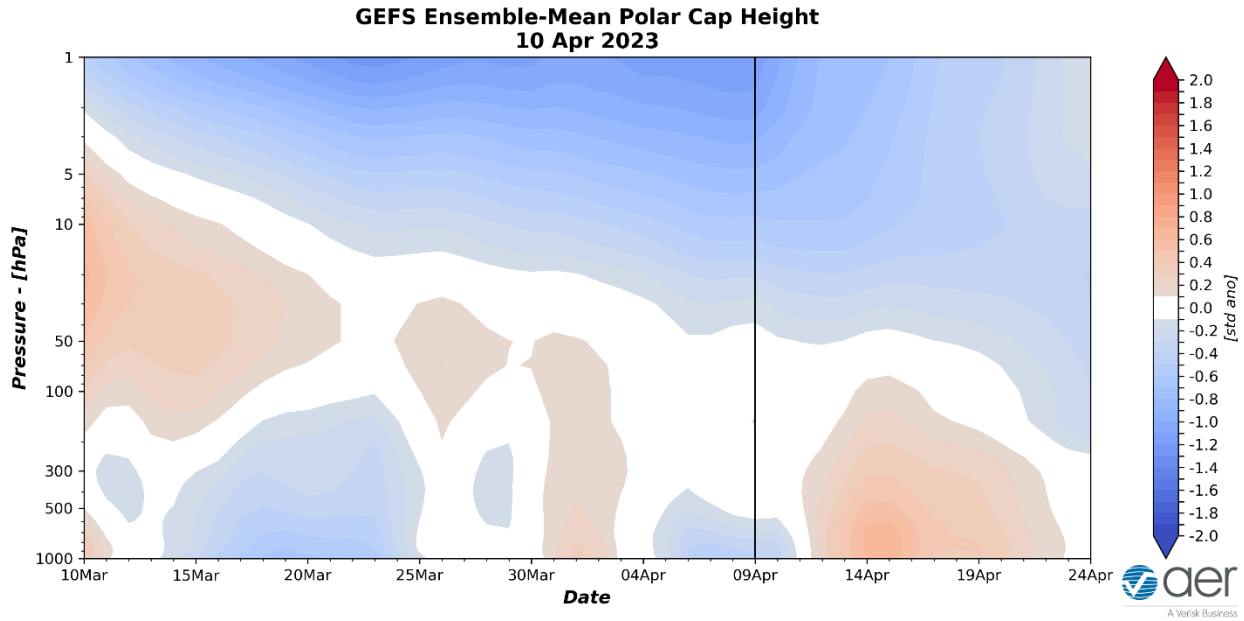


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 10 April 2023 GFS ensemble.

The turn to warm/positive PCHs in the lower troposphere this week (**Figure 11**) are consistent with the predicted transitions to a negative surface AO (**Figure 1**). However, the AO is predicted to become closer to neutral next week (**Figure 1**) coinciding when the warm/positive PCHs in the lower stratosphere are predicted to weaken in the troposphere (**Figure 11**).

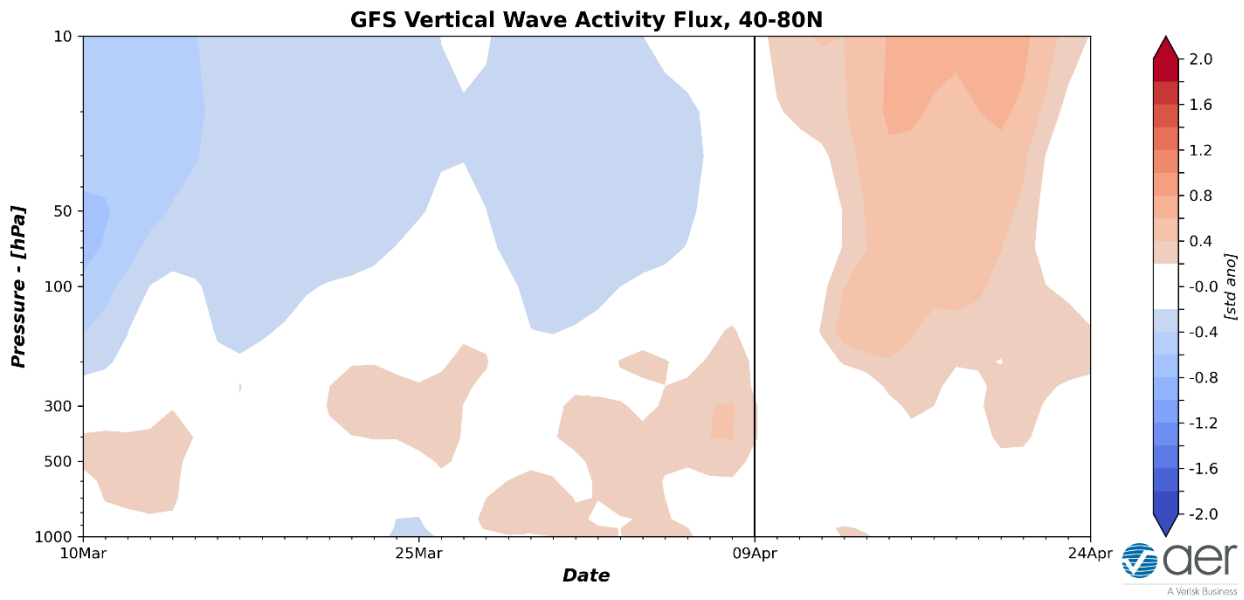


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 10 April 2023 GFS ensemble.

The Vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere or poleward heat transport in the stratosphere has been below normal since late February. However, WAFz is predicted to become active the next two weeks (**Figure 12**). The more active WAFz the next two weeks (**Figure 12**) will likely result in a dynamic Final Warming.

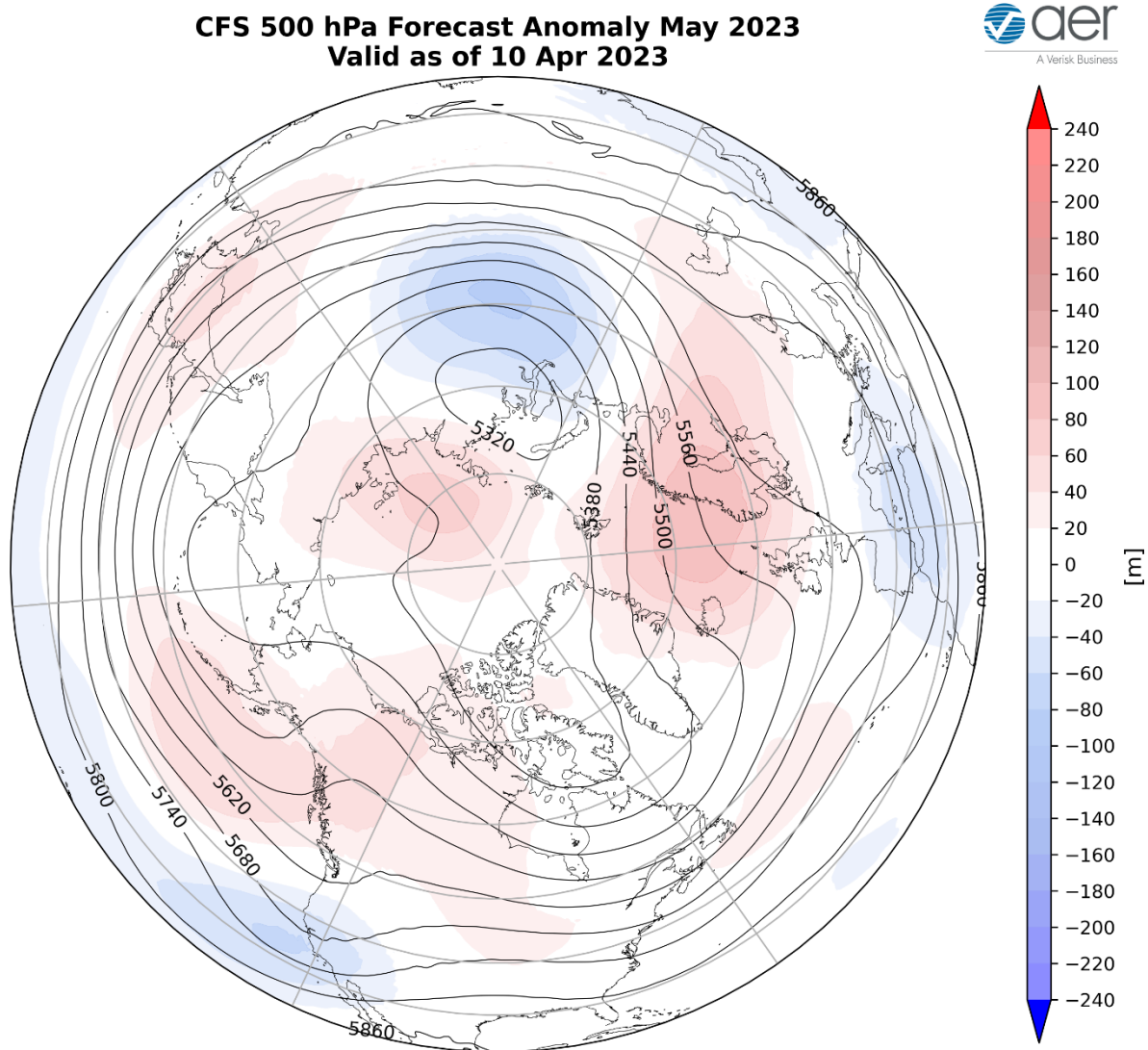


Figure 13. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for June 2023. The forecasts are from the 00Z 10 April 2023 CFS.

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

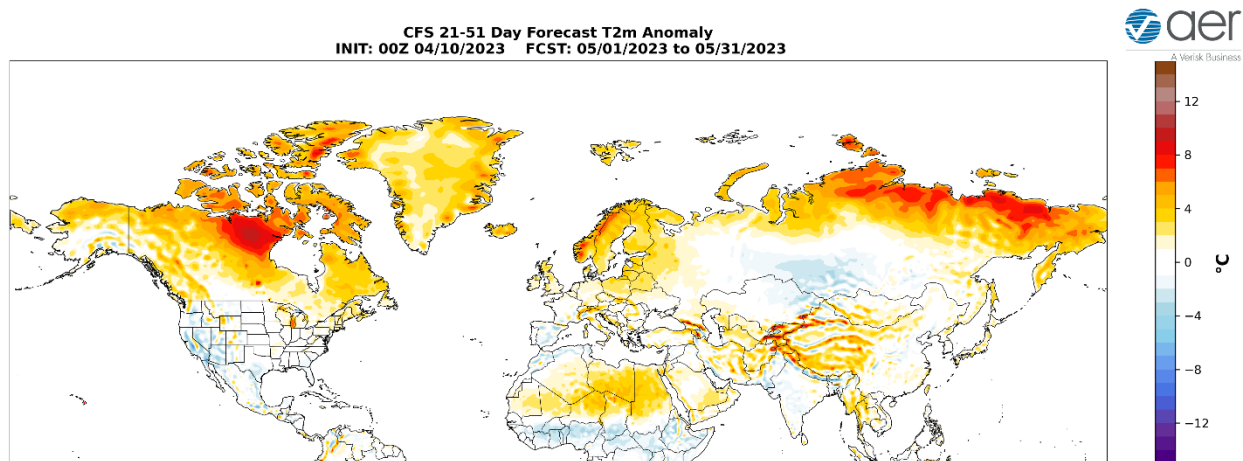


Figure 14. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for June 2023. The forecasts are from the 00Z 10 April 2023 CFS.

Boundary Forcings

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are above normal indicating that the transition from La Niña to El Niño is complete (**Figure 15**) 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 and offshore of eastern North America though below normal SSTs exist regionally especially in the South Pacific.

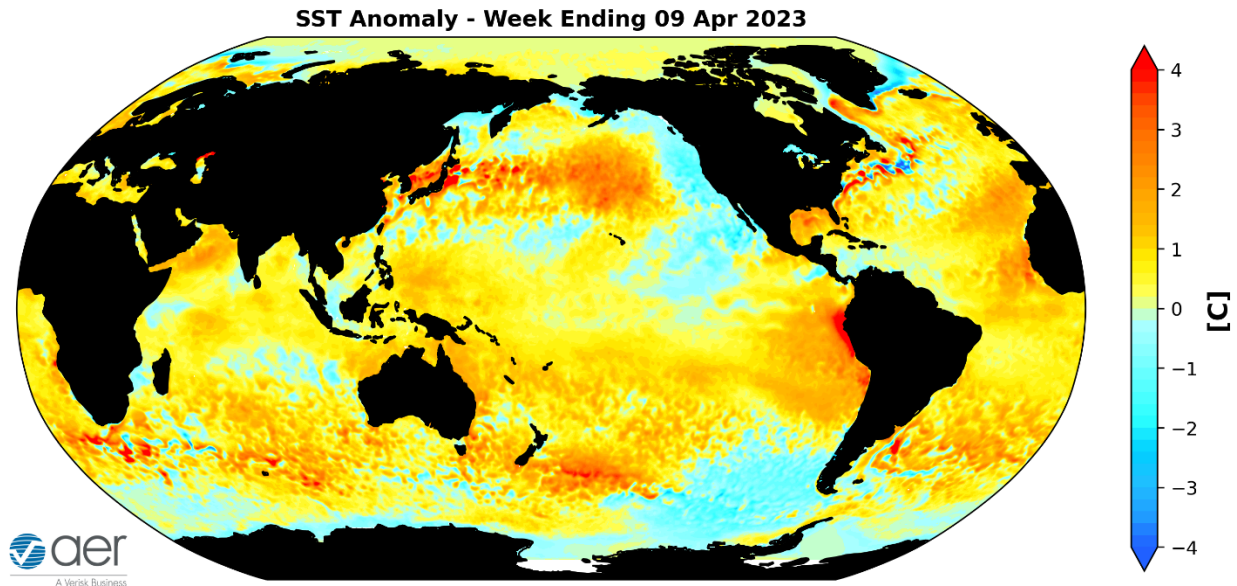


Figure 15. The latest weekly-mean global SST anomalies (ending 9 April 2023). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently phase six of the Madden Julian Oscillation (MJO) is favored (**Figure 16**). The forecasts are for the MJO to quickly transition into phases seven, eight and one. Phase six favors ridging near the Aleutians and ridging over eastern North America with troughing in western North America. Phases seven through one favor deep troughing near the Aleutians, which is not predicted by the weather models. Seems that the MJO is having some influence on the weather across North America in the short term but then seems to wane. But admittedly this is outside of my expertise.

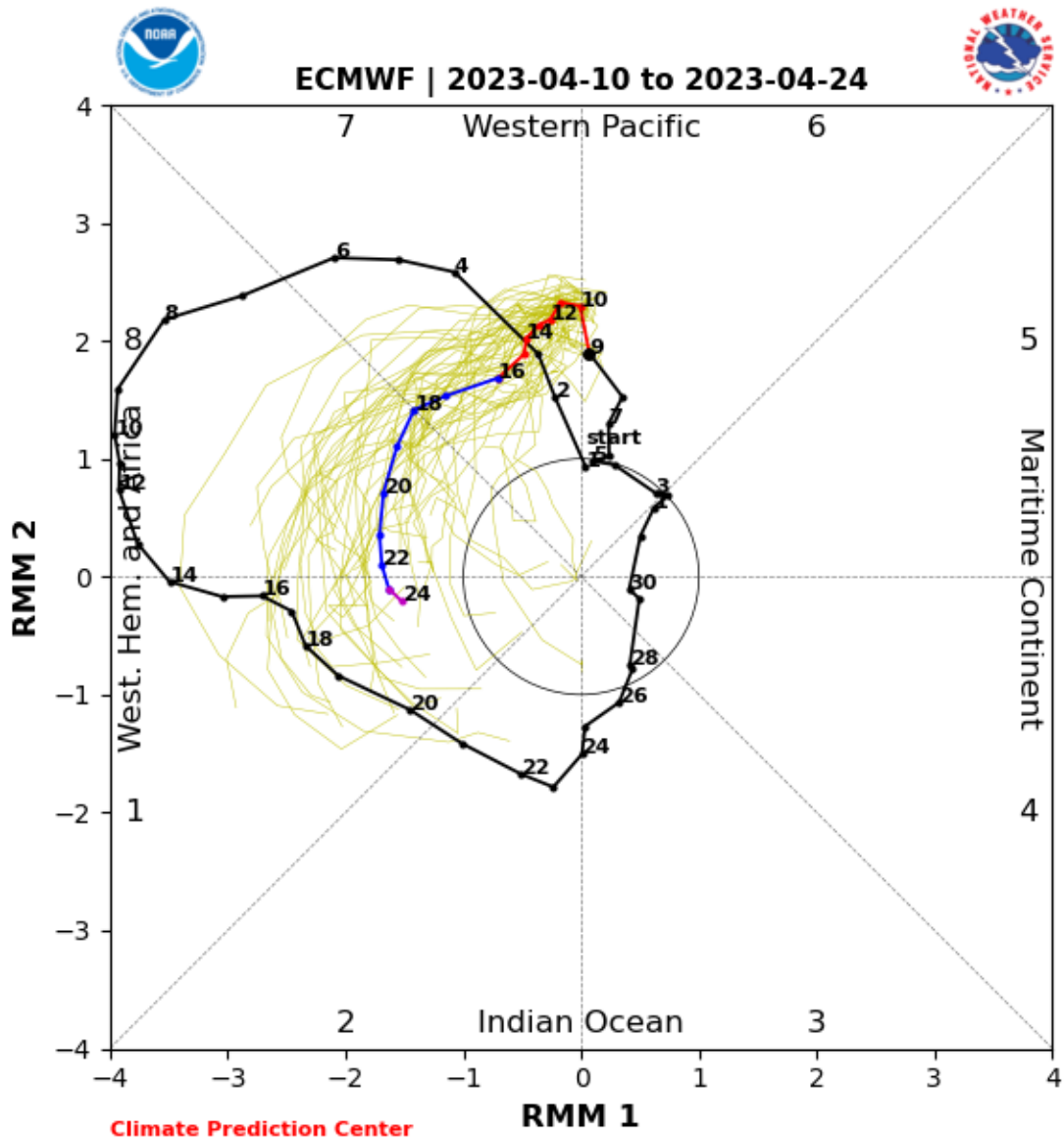


Figure 16. Past and forecast values of the MJO index. Forecast values from the 00Z 10 April 2023 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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