

Arctic Oscillation and Polar Vortex Analysis and Forecasts

August 1, 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 neutral and is predicted to slowly trend negative this week and then remain negative to neutral as pressure/geopotential height

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

Over the next two weeks ridging/positive geopotential height anomalies across Greenland and the Urals will anchor troughing/negative geopotential height anomalies across Europe with ridging/positive geopotential height anomalies mostly confined across Southwestern and Southeastern Europe. This pattern generally favors for the next two weeks normal to below normal temperatures across much of Europe including the United Kingdom (UK) with the exception of normal to above normal temperatures across far Southern and Eastern Europe.

The next two weeks, the general pattern across Asia is predicted to be ridging/positive geopotential height anomalies across Western Asia with troughing/negative geopotential height anomalies across Eastern Siberia that drifts westward with time. This pattern mostly favors normal to above normal temperatures widespread across much of Asia with the exception of normal to below normal temperatures across Eastern Siberia this week that slowly migrates into Central and Western Siberia starting next week.

The general predicted pattern predicted across North America the next two weeks is ridging/positive geopotential height anomalies across western and southern North America with troughing/negative geopotential height anomalies in eastern North America. This pattern generally favors normal to above normal temperatures for Western and Northern Canada and the Western and Southern United States (US) with normal to below normal temperatures across Southeastern Canada and the Northeastern US that gradually shifts into the the Plains of Canada and the US.

In the Impacts section I discuss the predicted the atmospheric circulation across the Northern Hemisphere (NH) and the implications for the remainder of the summer.

Through mid-September I have extended international travel planned and I also hope to post one to two more winter summaries, which will likely result in disruptions to blog postings for the remainder of the summer.

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Plain Language Summary

The weather has certainly been capturing many headlines this summer. I don't know the reason for the exceptional summer weather but regardless the overall pattern is reminiscent of past summers but with possibly more high latitude blocking. Overall, I don't see any big changes but the predicted unusually strong high latitude blocking

(see **Figure 5**) could result in accelerated melt of Arctic sea ice and Greenland land ice in August.

Impacts

I feel like I have been highlighting all summer long this strange atmospheric feature that suggests stratosphere-troposphere coupling where warm/positive polar cap geopotential height anomalies (PCHs) seems to be propagating down from the stratosphere to the surface and forcing a negative AO. This coupling persists (see **Figure 11**) and once again is supporting a negative AO/NAO and Greenland blocking well into August. In **Figure i**, I post the NAO the observed and predicted NAO index from NOAA's Climate Prediction Center and the NAO has been almost continuously negative since the start of summer. It is my experience that is very rare and showing my bias here but would love to see that repeated in winter!

NAO Index: Observed & GEFS Forecasts

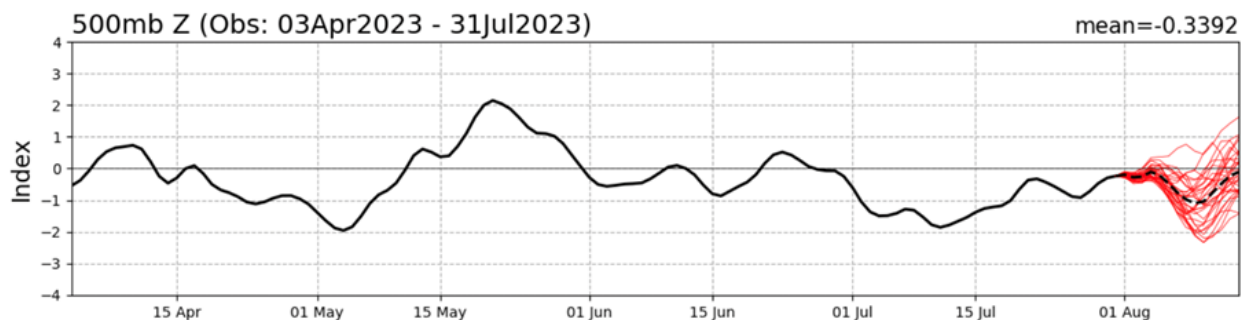


Figure i. The observed and predicted daily-mean NAO from CPC derived from the 00Z 1 August 2023 GFS ensemble. Red lines indicate the NAO index from each individual ensemble member, with the ensemble-mean AO index given by the black dashed line. Plot taken from

<https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.shtml>.

From **Figure 11**, it is predicted to peak next week and then weaken, but this feature has been pulsating all summer long, and I believe there is a good chance it will strengthen yet again before astronomical summer ends. And once again the negative NAO and its characteristic Greenland blocking should favor troughing and seasonable to even relatively cool temperatures in Northern Europe and the Northeastern US in the near term.

High latitude blocking seems to be a more common summer feature of late, but it does seem to me that the high latitude blocking is stronger this summer than other recent summers. Of course, there is still plenty of summer left but looking ahead to the transition to fall, if the strong high latitude blocking continues well into the fall months this could have important implications on the developing polar vortex, but I digress and/or get ahead of myself.

From social media and the news certainly seems that there have been many superlatives in the weather from record high sea surface temperatures, record high land temperatures, heavy rainfalls, the lethargic growth of Antarctic sea ice and extensive Greenland ice melt. I just came across this nice story from the [The Weather Channel](#) on some of the record heat in the US this summer. Why has the globe seemed to turn the heat dial to 11 this summer, is an interesting question and I certainly don't have the answer. At least some intuitive contributors are the developing El Niño and the Hunga Tonga volcanic eruption at the beginning of 2022. Unlike other explosive volcanoes it was sulfur poor but water vapor rich since it was an underwater volcano as discussed in this [EOS](#) article.

But despite the seemingly exceptional weather this summer across the Northern Hemisphere (NH), I think the overall pattern of surface temperature anomalies is consistent with recent summers and with summer forecasts from this past spring (the summer forecast was included in the [22 May 2023](#) blog post). In **Figure ii**, I post an update of the NH surface temperature anomalies for the summer so far. Above normal temperatures are widespread across the NH with two notable exceptions Western Russia and the Eastern US except for the Northeastern US and the far Southern US. These two regions have often been the exceptions to universal warmth in recent summers. The one posted forecast that showed seasonable to cool temperatures in these two regions was the AER forecast and overall, the AER is performing well relative to the other two dynamical forecasts. With a month left some of the details are going to change but the broad strokes are likely set for the summer.

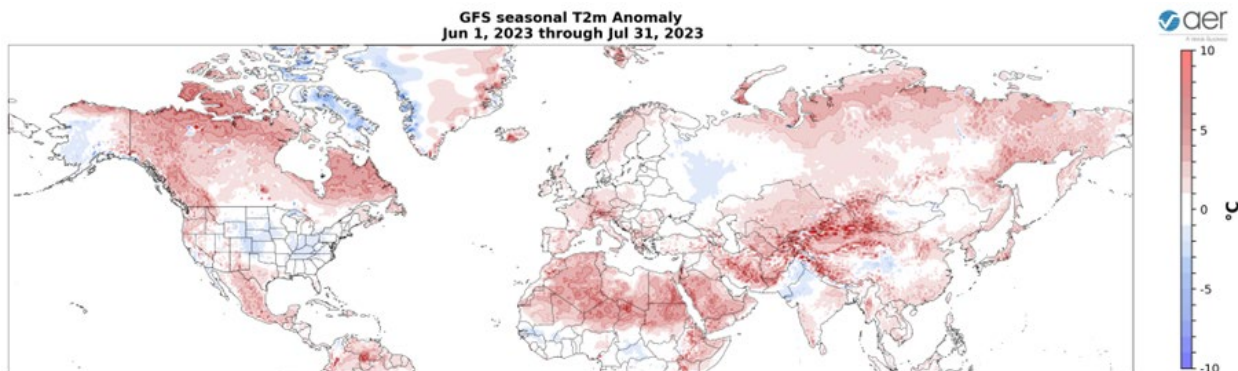


Figure ii. Observed surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere from 1 June – 31 July from the initialized GFS ensemble.

Arctic sea ice is low, as it is every summer now, but is higher than many recent summers. However, the predicted migration of higher geopotential heights into the Central Arctic (see **Figure 8**) could accelerate Arctic sea ice melt. But given that we are approaching the end of the melt season, for now I don't expect a record low sea ice extent.

Thursday Update

No big changes from Tuesday's post but I did happen to notice the AO at 10hPa forecast which is predicted to be between -3 to -4 standard deviations (see **Figure iii**) next week! That is incredibly negative for winter, but for summer must be even more rare since there is no polar vortex (PV) in summer. So rather than reversing from low to high pressure during sudden stratospheric warmings, which is what occurs for strongly negative AOs in winter, currently high pressure must be much stronger than normal to produce such negative AO values.

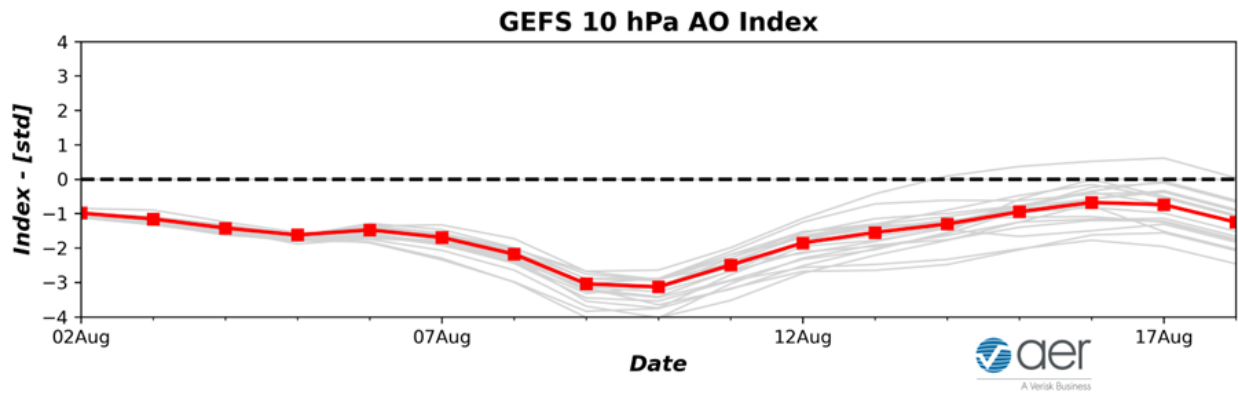


Figure iii. The predicted daily-mean stratospheric AO at 10 hPa from the 00Z 3 August 2023 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

The negative stratospheric AO is coupled to the surface AO that is also predicted to be unusually negative next week. This is associated with widespread high latitude blocking (see **Figure iv**) again more common in winter than summer. This includes Greenland but is focused in the Central Arctic.

GEFS 11-15 Day Forecast 500 hPa Anomaly
INIT: 00Z 08/03/2023 FCST: 08/14/2023 to 08/18/2023

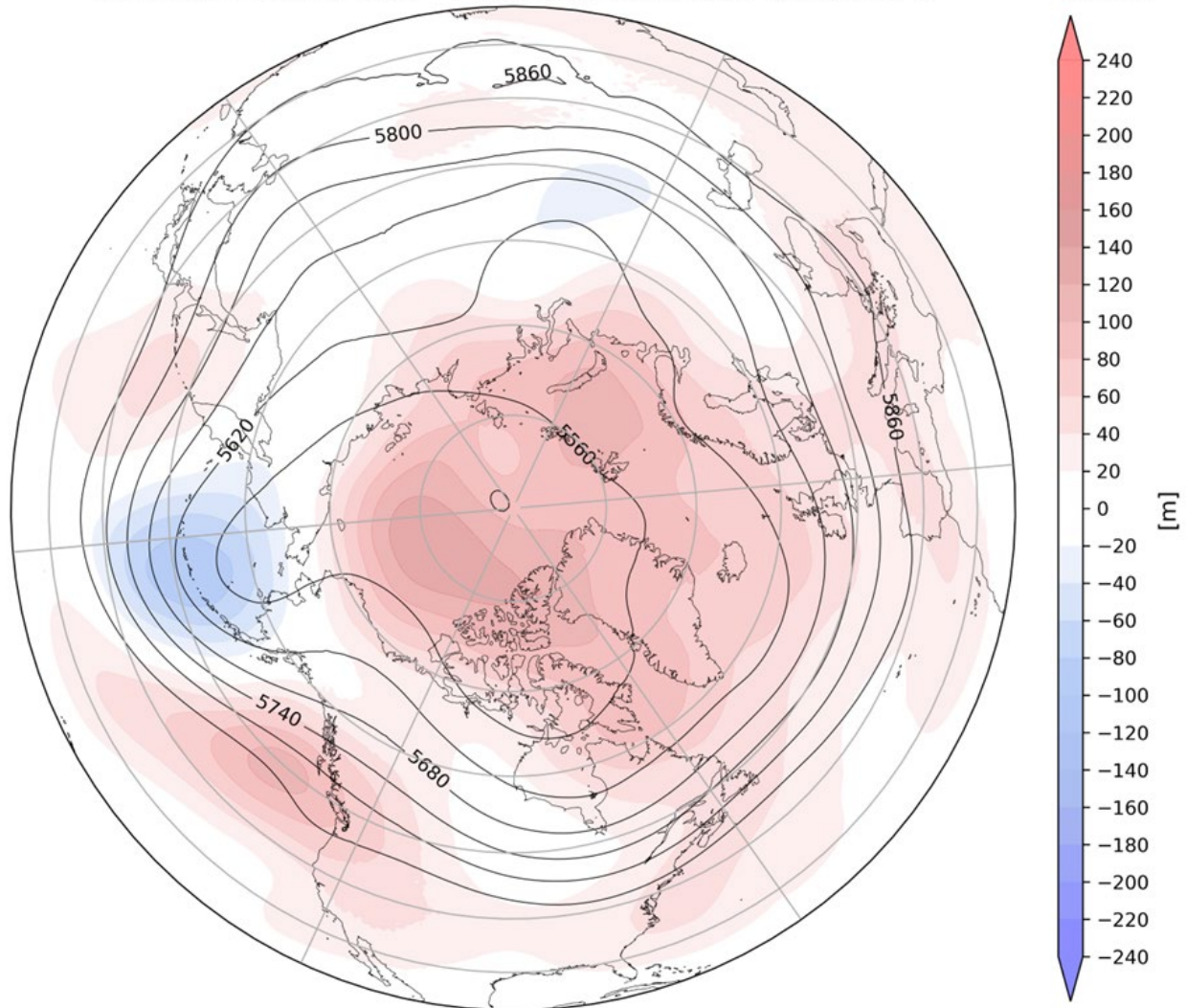


Figure iv. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 14 – 18 August 2023. The forecasts are from the 00z 3 August 2023 GFS ensemble.

At least the GFS temperature forecast looks just broad strokes warm (see **Figure v**) but I am thinking that the GFS might be struggling with the temperature forecast in mid-August. But given the strong high latitude blocking would continue to favor warm to very warm in western North America, Northern Canada and Siberia. Best chance of below normal temperatures is in the Plains of Canada and the US, and Western Russia. Looks like Europe and the Eastern US could go either way.

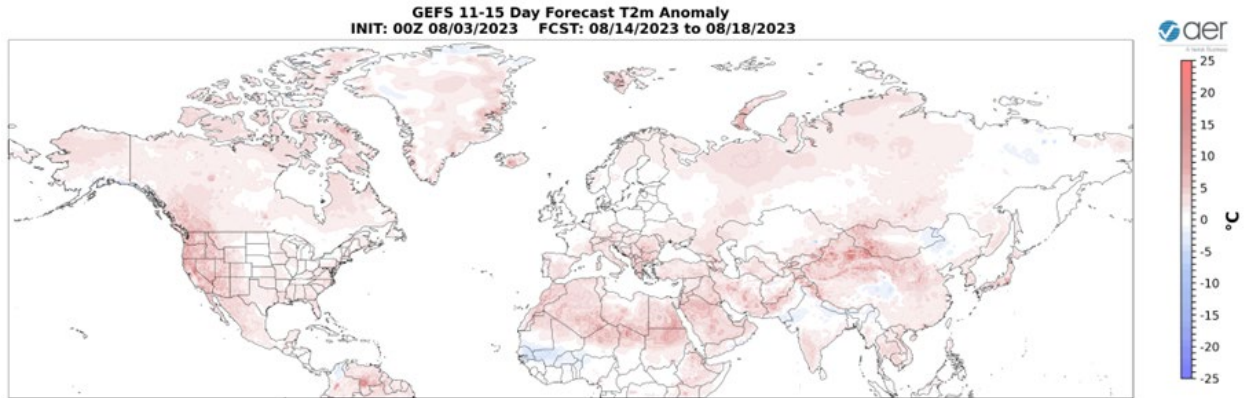


Figure v. Forecasted surface temperature anomalies (°C; shading) from 14 – 18 August 2023. The forecast is from the 00Z 1 August 2023 GFS ensemble.

Near-Term

This week

The AO is predicted to be neutral to negative this week (**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 weak and mixed geopotential height anomalies across Greenland (**Figure 2**), the NAO is predicted to be neutral to negative this period as well.

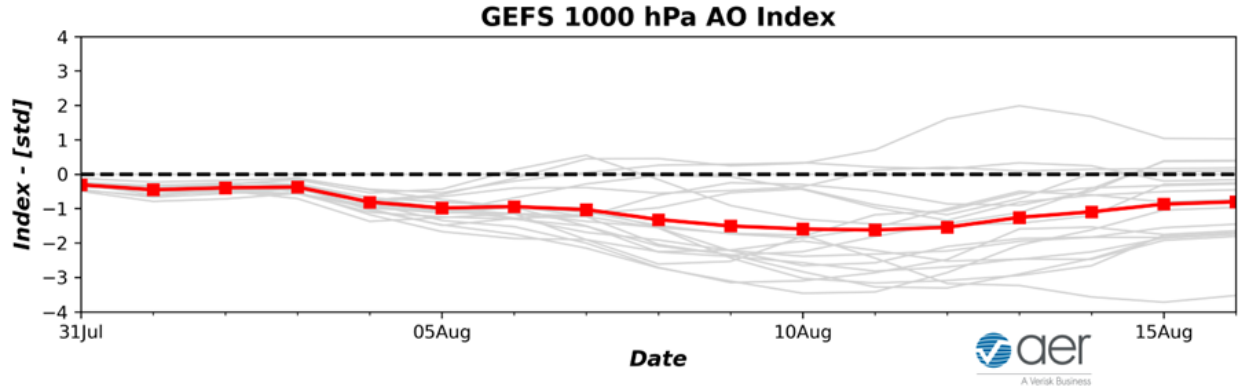


Figure 1. The predicted daily-mean AO at 1000 hPa from the 00Z 1 August 2023 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Ridging/positive geopotential height anomalies across the central North Atlantic and near the Urals will force troughing/negative geopotential height anomalies across Europe with the exception of ridging/positive geopotential height anomalies across Southeastern Europe (**Figures 2**). **This pattern favors normal to below normal**

temperatures across much of **Europe including the UK with the exception of** normal to above normal temperatures across Southeastern Europe (**Figure 3**). This week Asia is predicted to be dominated by unusually strong ridging/positive geopotential height anomalies centered near the Urals with troughing/negative geopotential height anomalies mostly limited to Eastern Siberia (**Figure 2**). This pattern favors widespread normal to above normal temperatures across Asia with normal to below normal temperatures limited to Eastern Mongolia, Northeast China and Eastern Siberia (**Figure 3**).

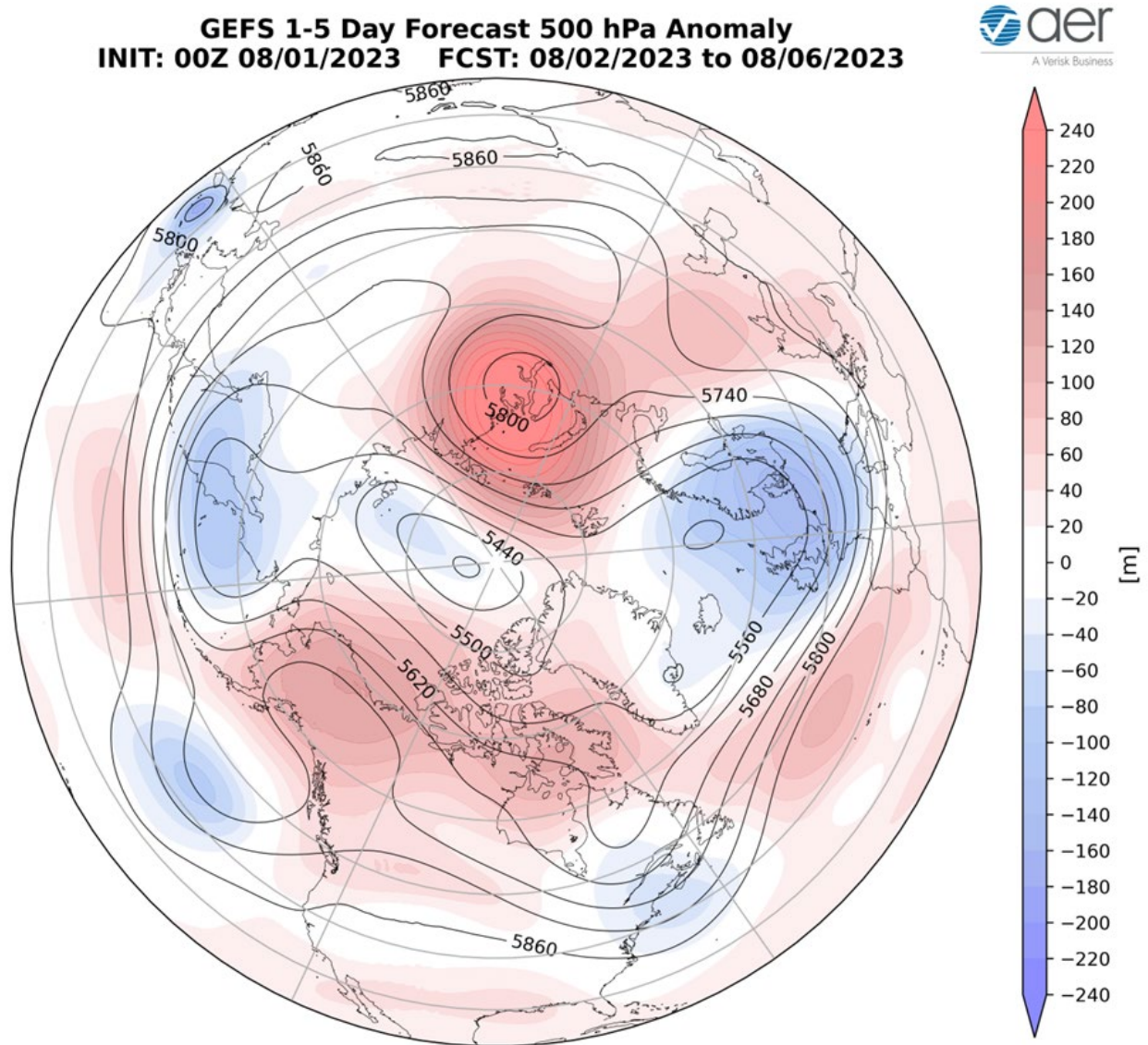


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 2 – 6 August 2023. The forecasts are from the 00z 1 August 2023 GFS ensemble.

The pattern this week across North America is ridging/positive geopotential height anomalies spread across western and southern North America with troughing/negative geopotential height anomalies in Eastern Canada and the Eastern US (**Figure 2**). **This pattern will favor widespread normal to above normal temperatures across Alaska, Western and Northern Canada and the Western and Southern US with normal to below normal temperatures across Southeastern Canada, and much of the Eastern US (Figure 3).**

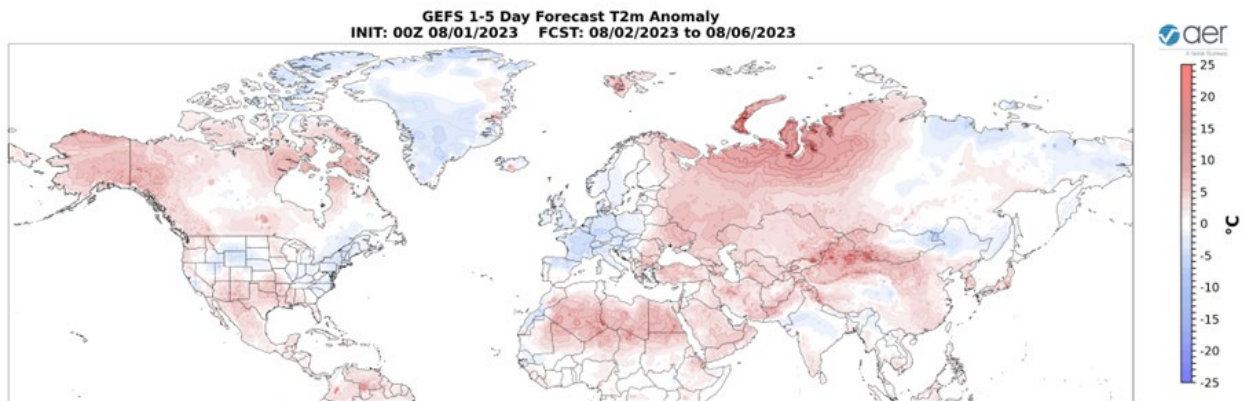


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 2 – 6 August 2023. The forecast is from the 00Z 1 August 2023 GFS ensemble.

Mostly normal to dry conditions are predicted across Eurasia with the exceptions of normal to wet conditions across Western and Central Europe, coastal Siberia, Northeastern China, northern India 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 Rockies, US Central and Northern Plains and the Tennessee Valley (**Figure 4**).

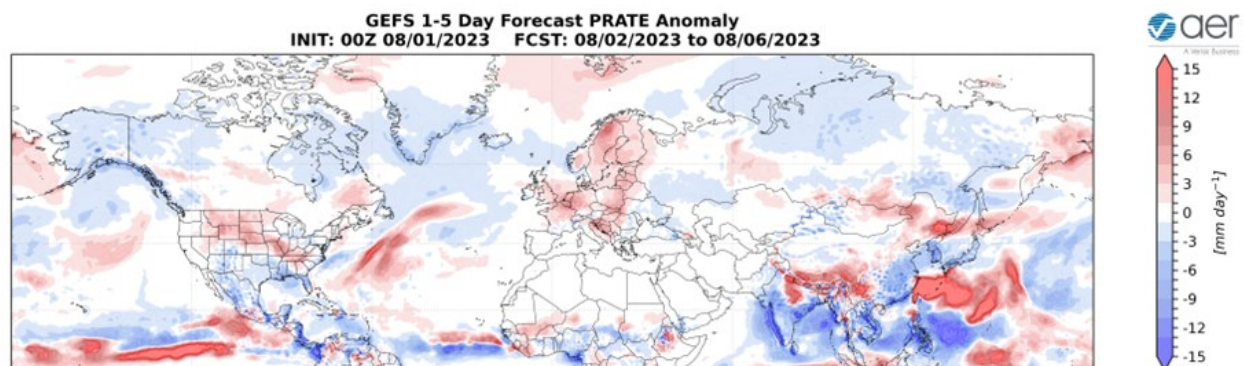


Figure 4. Forecasted precipitation rate (mm/day; shading) from 2 – 6 August 2023. The forecast is from the 00Z 1 August 2023 GFS ensemble.

Near-Mid Term

Next week

With increasingly 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 firmly negative this period (**Figure 1**). With predicted positive pressure/geopotential height anomalies across Greenland (**Figure 5**), the NAO will likely be negative this period as well.

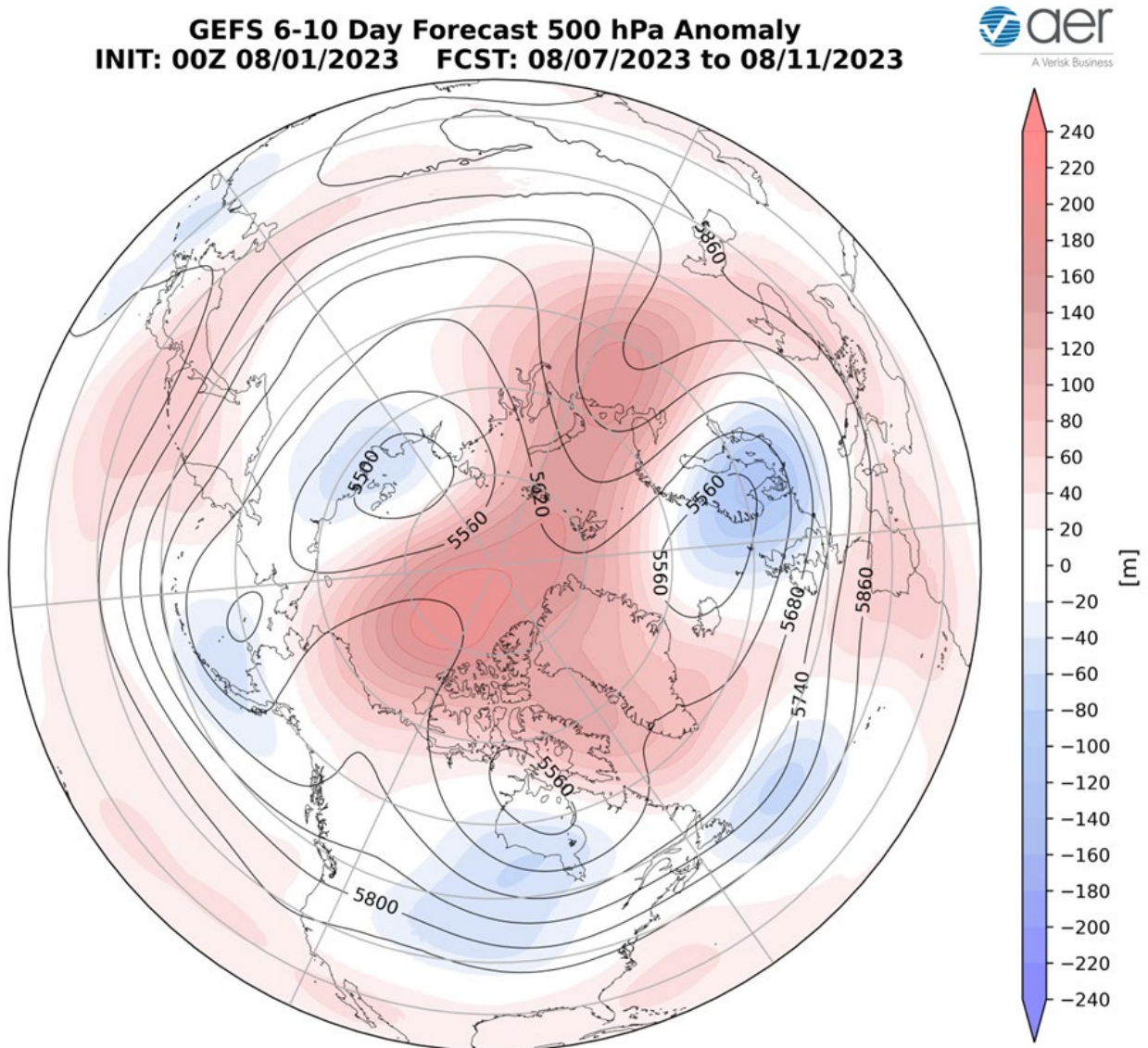


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 7 – 11 August 2023. The forecasts are from the 00z 1 August 2023 GFS ensemble.

Strengthening ridging/positive geopotential height anomalies across Greenland and the Urals will continue to support troughing/negative geopotential height anomalies across Europe with the exception of ridging/positive geopotential height anomalies across Southwestern Europe this period (**Figure 5**). This pattern should favor widespread normal to below normal temperatures across much of Europe including the UK with the exception of normal to above normal temperatures mostly limited to Spain, Portugal and European Russia (**Figures 6**). The general pattern across Asia is ridging/positive geopotential height anomalies across Western Asia with troughing/negative geopotential height anomalies spread across Siberia this period (**Figure 5**). The pattern favors normal to above normal temperatures across Western and Southern Asia with normal to below normal temperatures across much of Siberia, Eastern Mongolia and Northeast China this period (**Figure 6**).

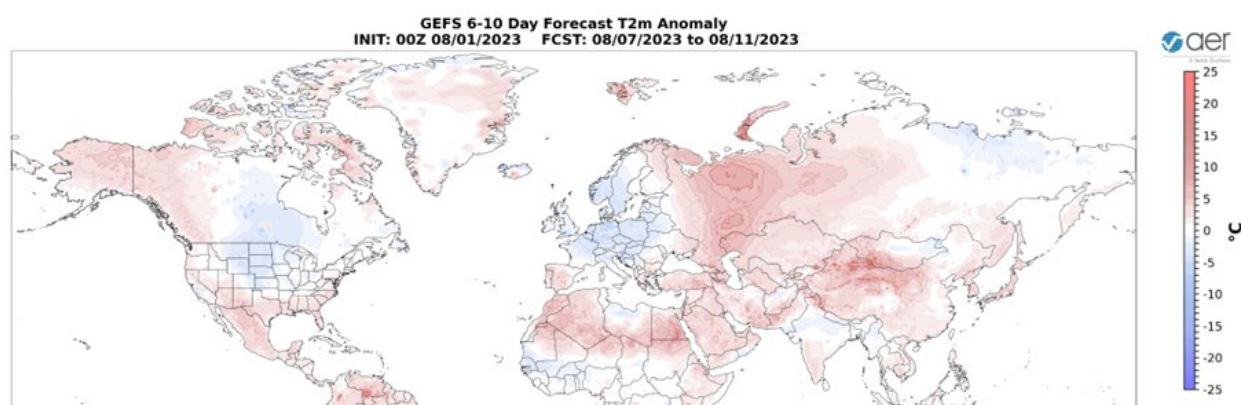


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 7 – 11 August 2023. The forecast is from the 00Z 1 August 2023 GFS ensemble.

The general pattern across North America this period is persistent ridging/positive geopotential height anomalies across western and southern North America with troughing/negative geopotential height anomalies in central and eastern North America (**Figure 5**). This pattern favors normal to above normal temperatures across Alaska, Western and Northern Canada and the Western and Southern US with normal to below normal temperatures across Central and Southeastern Canada, the US Plains and Northeastern US (**Figure 6**).

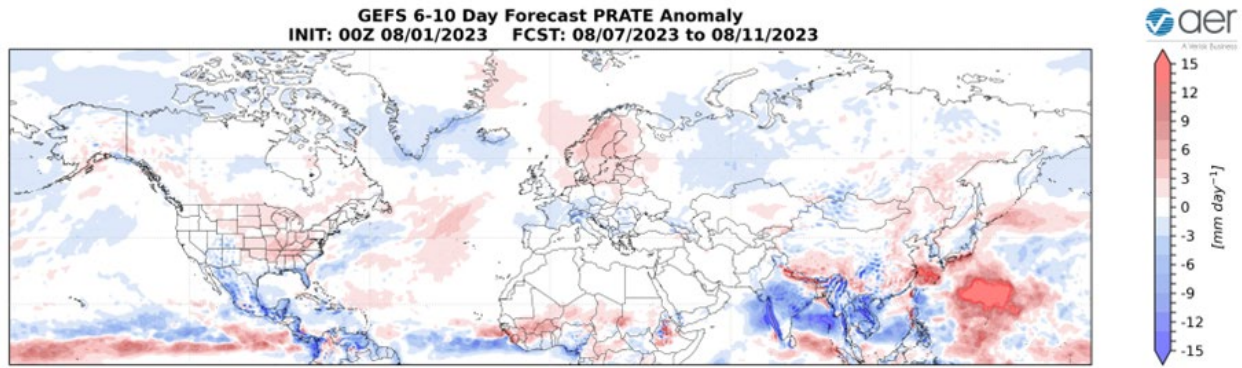


Figure 7. Forecasted precipitation rate (mm/day; shading) from 7 – 11 August 2023. The forecast is from the 00Z 1 August 2023 GFS ensemble.

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

Mid Term

Week Two

With predicted 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 this period (**Figure 1**). With predicted positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO will likely remain negative as well this period.

GEFS 11-15 Day Forecast 500 hPa Anomaly
INIT: 00Z 08/01/2023 FCST: 08/12/2023 to 08/16/2023

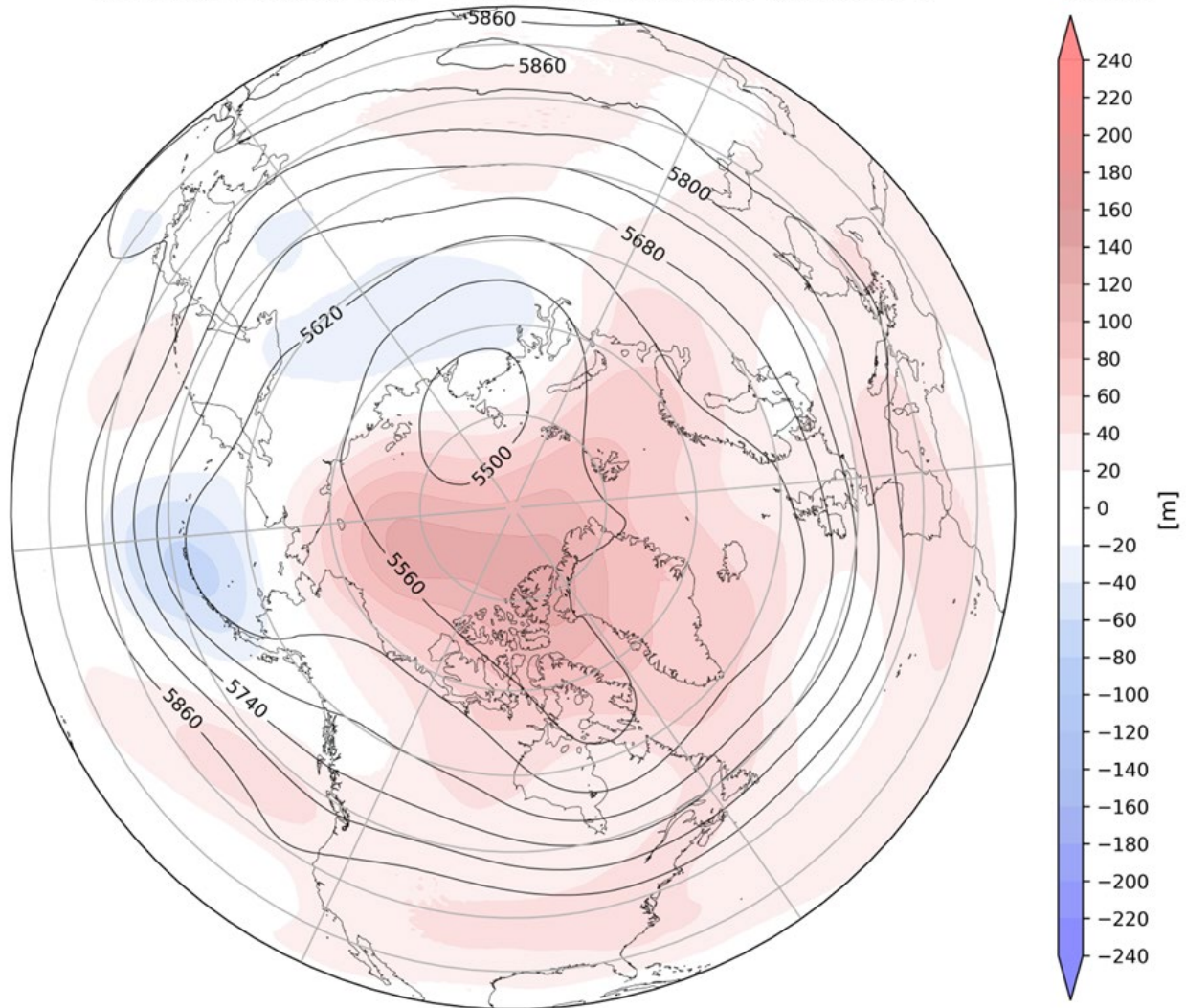


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 12 – 16 August 2023. The forecasts are from the 00z 1 August 2023 GFS ensemble.

Ongoing albeit weakening ridging/positive geopotential height anomalies centered across Greenland and the Urals will continue to favor weak troughing/negative geopotential height anomalies across Europe with ridging/positive geopotential height anomalies across Southeastern and Southwestern Europe this period (**Figure 8**). This pattern should favor normal to below normal temperatures across Central Europe with normal to above normal temperatures across Western and Eastern Europe including the UK this period (**Figures 9**). Again ridging/positive geopotential height anomalies is predicted to dominate Western Asia with troughing/negative geopotential height anomalies across Siberia and parts of 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 Western and Central Siberia this period (**Figure 9**).

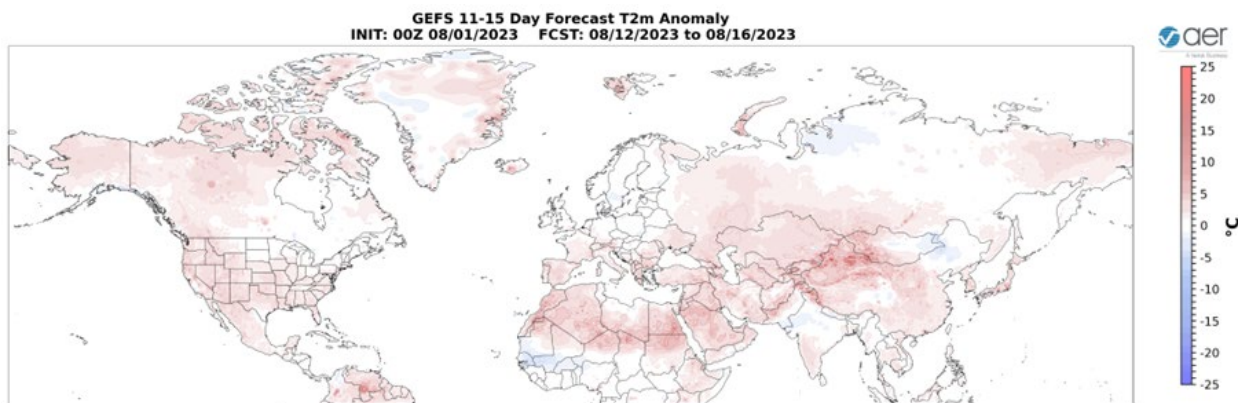


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 12 – 16 August 2023. The forecast is from the 00Z 1 August 2023 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to persist across western, southern and eastern North America with troughing/negative geopotential height limited to Central Canada and the Central US this period (**Figure 8**). This pattern favors normal to above normal temperatures across Alaska, Western and Northern Canada, the Canadian Maritimes and the Western, Southern and Eastern US with normal to below normal temperatures limited to Central to Eastern Canada and the Northcentral US (**Figure 9**).

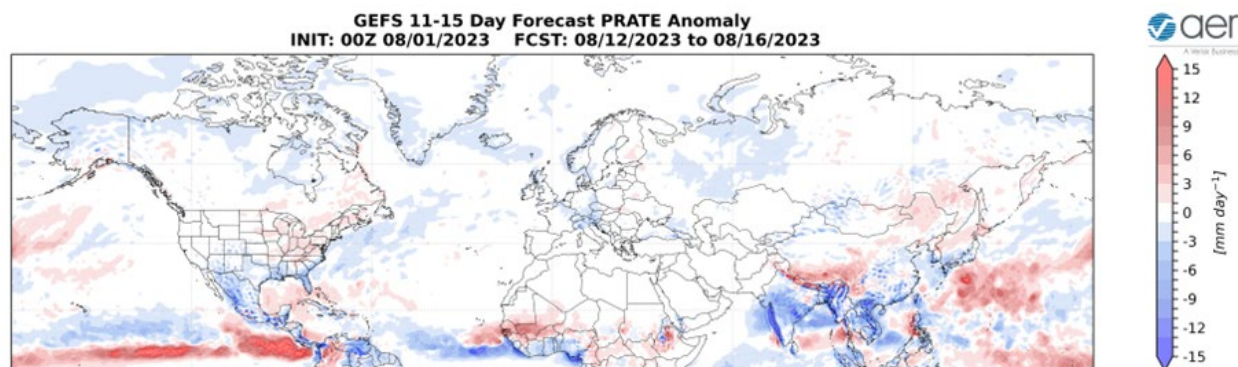


Figure 10. Forecasted precipitation rate (mm/day; shading) from 12 – 16 August 2023. The forecast is from the 00Z 1 August 2023 GFS ensemble.

Mostly normal to dry conditions are predicted across Eurasia with the exceptions of normal to wet conditions across Southwestern and Northeastern China and the Tibetan Plateau this period (**Figure 10**). Mostly normal to dry conditions are predicted across Canada and the US with the exceptions of normal to wet conditions across Southern Alaska and the Northeastern 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 lower stratosphere and troposphere (**Figure 11**). Next week the warm/positive PCHs in the lower stratosphere and upper troposphere are predicted to strengthen and appear to propagate downward (**Figure 11**).

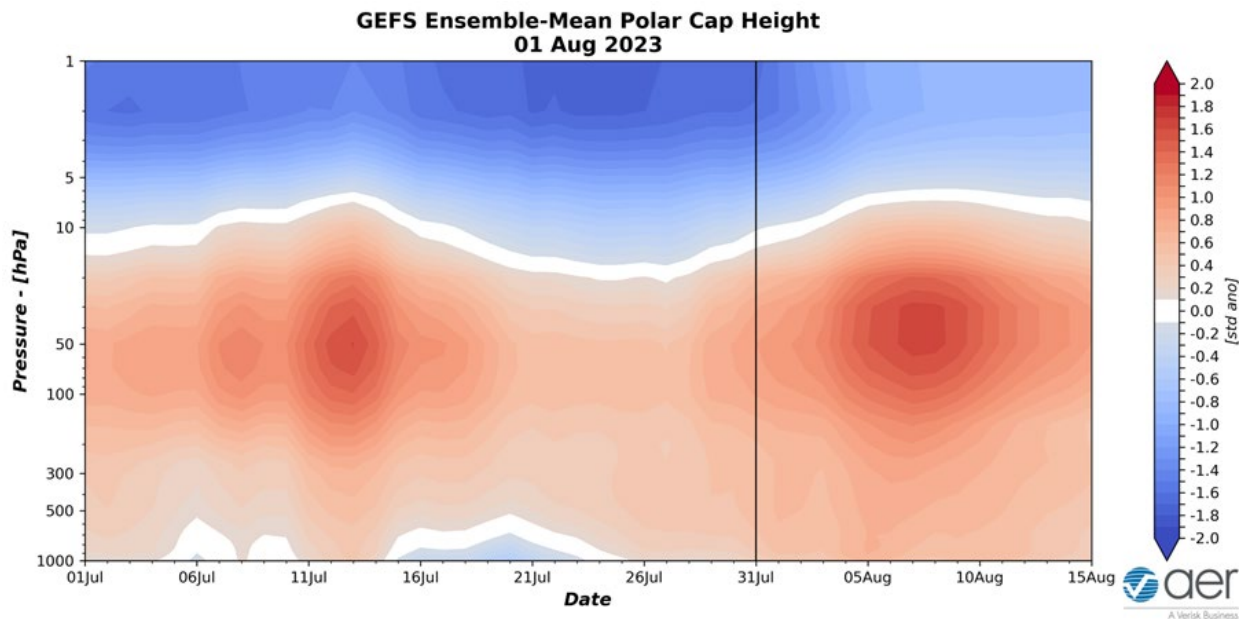


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 1 August 2023 GFS ensemble.

The predicted warm/positive PCHs in the lower troposphere this week and into next week (**Figure 11**) are consistent with the predicted neutral negative surface AO over the next two weeks (**Figure 1**). However, the AO is predicted to become more strongly negative next week (**Figure 1**) coinciding with the predicted downward propagation of stronger warm/positive PCHs from the upper troposphere (**Figure 11**).

CFS 500 hPa Forecast Anomaly Sep 2023
Valid as of 01 Aug 2023

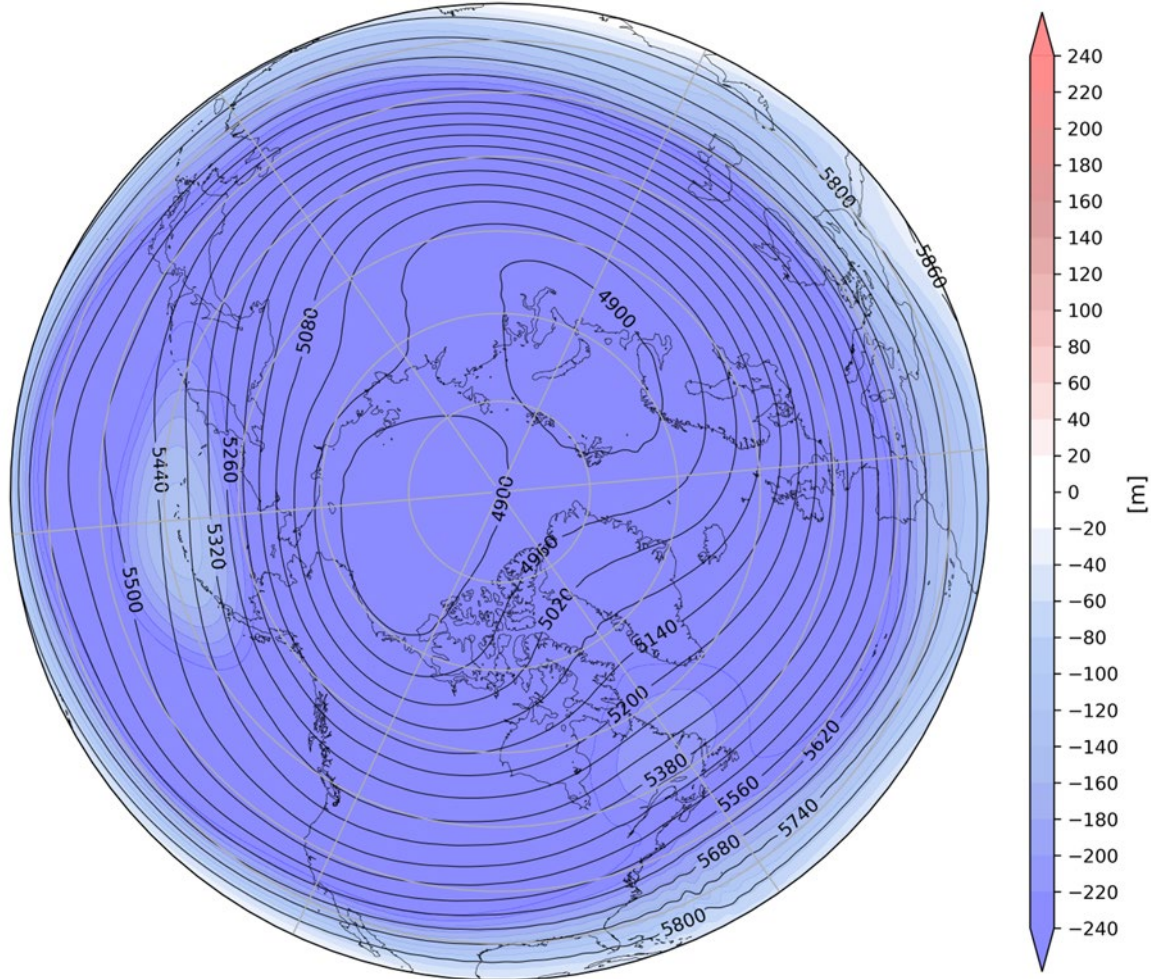


Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for September 2023. The forecasts are from the 00Z 1 August 2023 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and surface temperatures for September (**Figure 13**) from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging in the Urals, the Barents-Kara-Laptev Seas, the Beaufort Sea, Eastern Asia and south of Greenland with troughing across Western Europe, Central Asia, Eastern Siberia, Alaska, Eastern Canada and the Eastern US (**Figure 12**). **This pattern favors seasonable to relatively warm temperatures across Europe, Southern Asia, eastern Siberia, Northern and Western Canada, the Western US with seasonable to relatively cool temperatures across the Western and Central Siberia, Southeastern Canada and the Northcentral and Eastern US (Figure 13).**

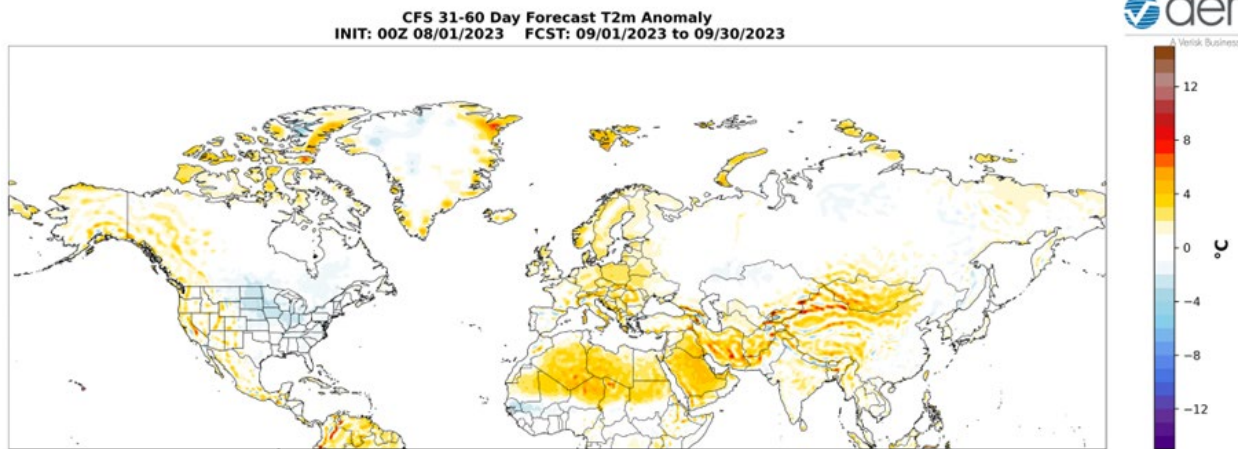


Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for September 2023. The forecasts are from the 00Z 1 August 2023 CFS.

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.

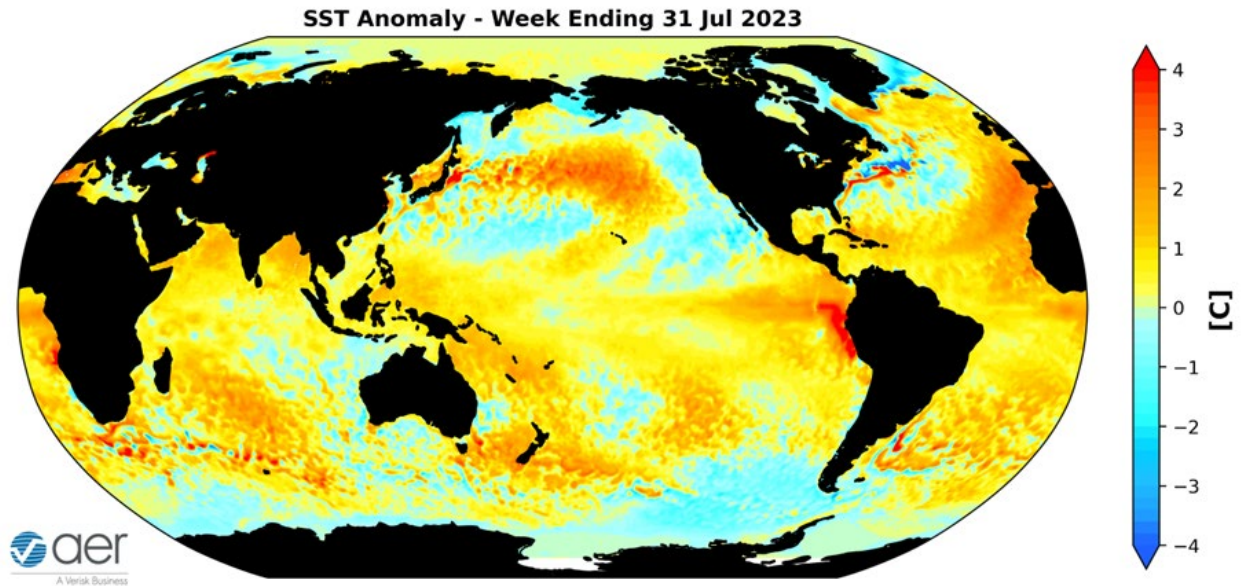


Figure 14. The latest weekly-mean global SST anomalies (ending 31 July 2023). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently phase one of the Madden Julian Oscillation (MJO) is favored (**Figure 15**). The forecasts are for the MJO to remain weak where no phase is favored over the next two weeks. Seems that the MJO is having little influence on the weather across Canada in the short term. But admittedly this is outside of my expertise.

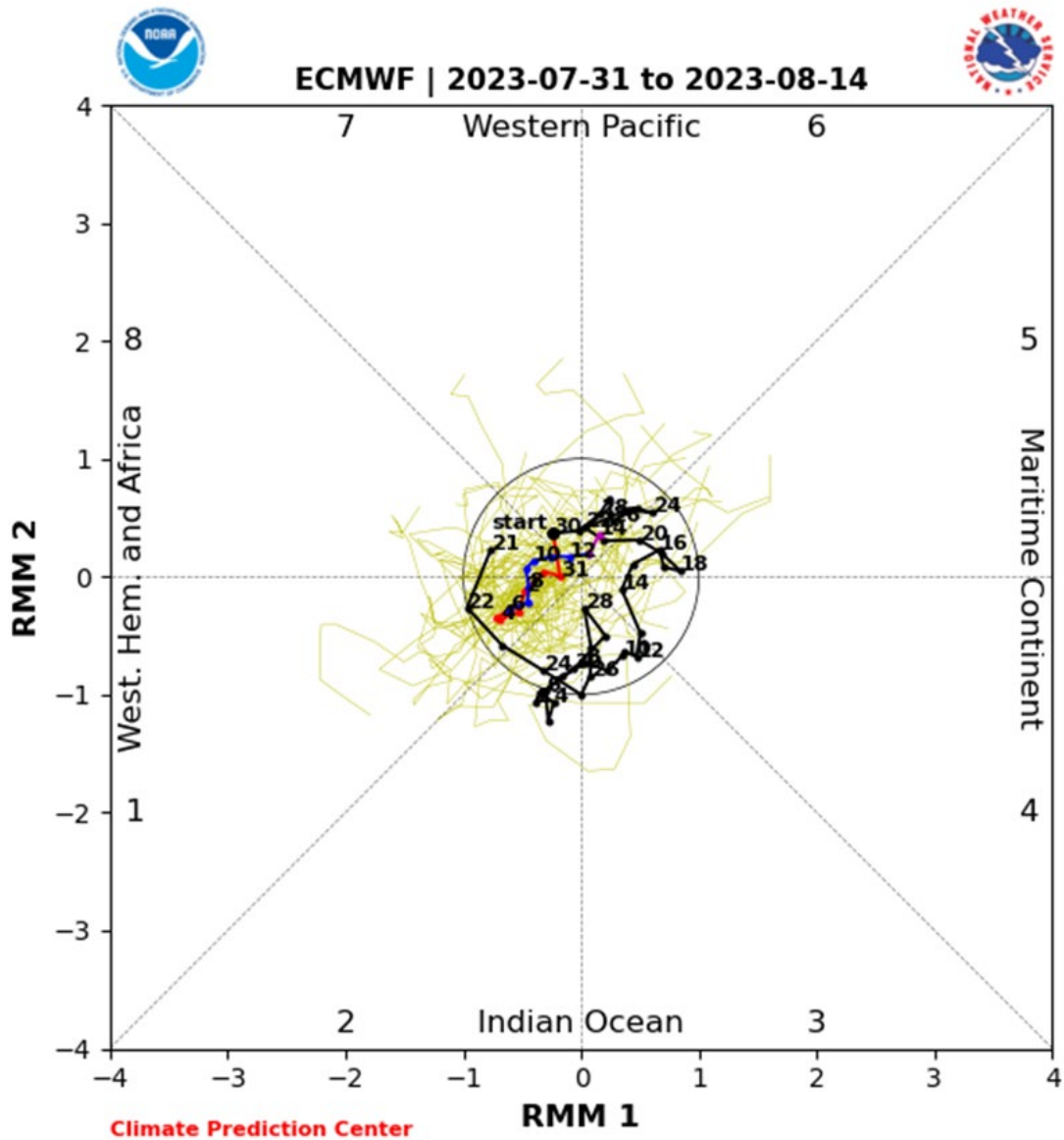


Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 1 August 2023 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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