

Arctic Oscillation and Polar Vortex Analysis and Forecasts

October 23, 2023

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. In late Spring, we transition to a spring/summer schedule, which is once every two weeks. Snow accumulation forecasts will be replaced by precipitation forecasts. Also, there will be less emphasis on ice and snow boundary conditions and their influence on hemispheric weather

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Summary

- The Arctic Oscillation (AO) is currently neutral and is predicted to remain very close to neutral the next two weeks as pressure/geopotential height anomalies across the Arctic are currently mostly positive and are predicted to remain mixed over the next two weeks. The North Atlantic Oscillation (NAO) is currently negative with mostly positive pressure/geopotential height anomalies across Greenland and the NAO is predicted to remain near neutral the next two weeks as pressure/geopotential height anomalies remain weak and mixed across Greenland.
- Over the next two weeks, the general predicted pattern across Europe is ridging/positive geopotential height over Southern Europe with troughing/negative geopotential height anomalies across Scandinavia. This zonal flow pattern will support normal to below normal temperatures mostly limited to Scandinavia with normal to above normal temperatures across Southern and Central Europe including the United Kingdom (UK) the next two weeks.
- This week the predicted pattern across Asia is ridging/positive geopotential height anomalies across Southern and Eastern Asia with troughing/negative

geopotential height anomalies across Western and Northern Asia. Then next week the troughing/negative geopotential height anomalies across Northwest Asia will slide eastward into Siberia with ridging/positive geopotential height anomalies centered across the Urals. This pattern favors normal to above normal temperatures widespread across much of Asia with normal to below normal temperatures limited to Western Russia this week and then spreading into Central Asia and eventually Northeast Asia next week.

- The general predicted pattern across North America this week is ridging/positive geopotential height anomalies dominating centered in the Gulf of Alaska and Alaska forcing downstream troughing/negative geopotential height anomalies across Western Canada and the Western United States (US) with more ridging/positive geopotential height anomalies in the Eastern US. However next the troughing/negative geopotential height anomalies in western North America will slide into eastern North America. This pattern generally favors this week normal to above normal temperatures across Alaska, far northern and Southeastern Canada and the Central and Eastern US with normal to below normal temperatures across much of Canada and the Western US. Next week below normal temperatures will spread into Central and Eastern Canada and the Central and Eastern US while slowly moderating.
- In the Impacts section I remain focused on Eurasian snow cover as I believe October is the critical month for predicting the upcoming winter circulation and weather. And I discuss a stretched polar vortex disruption this week into next.
- I continue the transition to the winter season, which should occur over the next few weeks.

Plain Language Summary

I use October Eurasian snow cover extent as one of our main winter predictors. The advance of snow cover remains unimpressive (see **Figure i**) but should accelerate this week. Still time for a turnaround even beyond October 31.

In the meantime, a stretching of the polar vortex like a rubber band being pulled on both ends should bring colder weather first to Central and East Asia and then eastern North America is ongoing (see **Figure 6**). I think this pattern can repeat in the second half of November.

Impacts

This whole month my focus is on the snow cover advance across Siberia and what impact it may have on the stratospheric polar vortex (PV). More extensive snow cover across Eurasia in October, and this mostly confined to Siberia, the more likely the PV will be weaker than normal during the winter months that favors widespread colder temperatures across the Northern Hemisphere (NH) but in particular in East Asia and the US east of the Rockies. It also includes Northern Europe, but the relationship is weaker across Europe and in my own research rarely is it statistically significant.

As I have been reporting all month the snow cover extent across Eurasia started out near normal but for most of the month has been below normal. But I have been expecting an acceleration of the snow cover advance across Siberia as the mid-tropospheric circulation transitions from one of a high-pressure ridge to a low-pressure trough over much of Siberia.

So, as I have been doing all month, I include an update to the plot of daily Eurasian snow cover extent (SCE) so far in October in **Figure i**. The black dashed line represents the mean value using October 2009 through 2022. So far, the advance is clearly below normal based on recent Octobers (which are on average above the longer-term mean). And October 2023 is competing with Octobers 2019 and 2022 for the bottom.

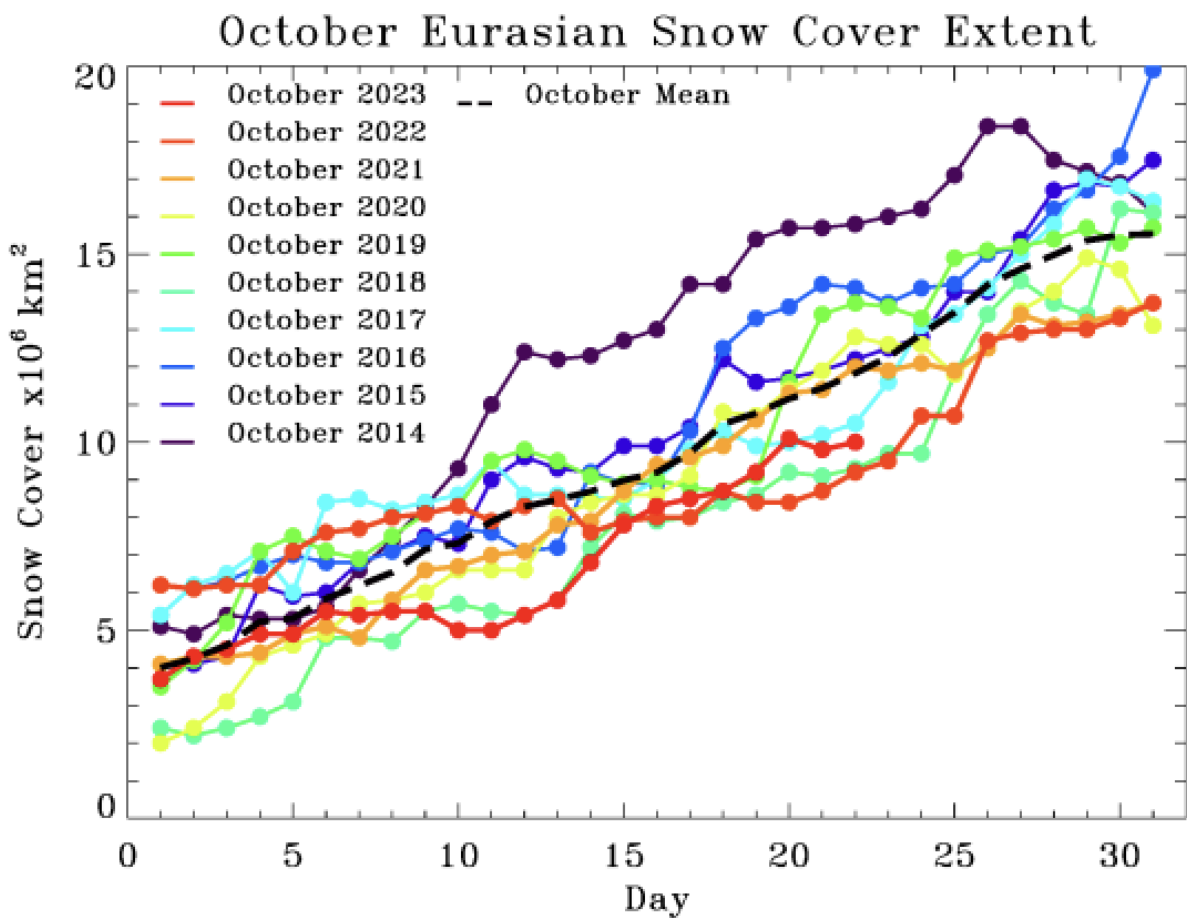


Figure i. Observed Eurasian daily snow cover extent (SCE) in millions of km squared for the month of October through 22 October 2023 (shown in red).

Though the SCE is accelerating as expected (though based on the last two days not very impressive I might add) there are some questions that I have. Much of the recent advance has not been across Siberia but rather the Tibetan Plateau (see **Figure ii**). It is my understanding that Extensive snow cover across the Tibetan Plateau does not

couple the same way as snow across Siberia. Where more extensive snow cover across Siberia favors a negative NAO/AO, in contrast more extensive snow cover across the Tibetan Plateau may favor a positive NAO/AO (see [Zhang et al. 2023](#)).

Also, regardless the total value of October 2023 SCE, the influence of SCE can continue through the ensuing months. Many recent studies have argued that it is not October but rather November that is the key month where SCE can force the winter circulation (for example [Wegmann et al. 2021](#)). I should add that unlike October where the pattern is above normal snow cover continent wide, for November the favorable pattern for exciting a negative NAO/AO is a dipole with above normal snow in Eastern Asia and below normal snow in Western Asia. And even January deep snow in Siberia, can force a large PV disruption in mid to late winter (see [Lv et al. 2020](#)). Therefore, I will be keeping my eye on Eurasian snow cover for months to come but maybe with not the same focus.

SCE is not only below normal across Eurasia, but especially in Siberia, but also across North America (see **Figure ii**). This is in contrast to recent falls when snow cover advance has been especially impressive across North America. However, the pattern supports not only a more rapid advance of snow cover across Siberia this week but also North America (see **Figure 4**). One caveat though, probably the largest snowfall will occur across the Northern US, south of the stable snowpack in Canada, that will melt off next week (see **Figure 7**).

Daily SCE Departure - October 22, 2023 (Day 295)

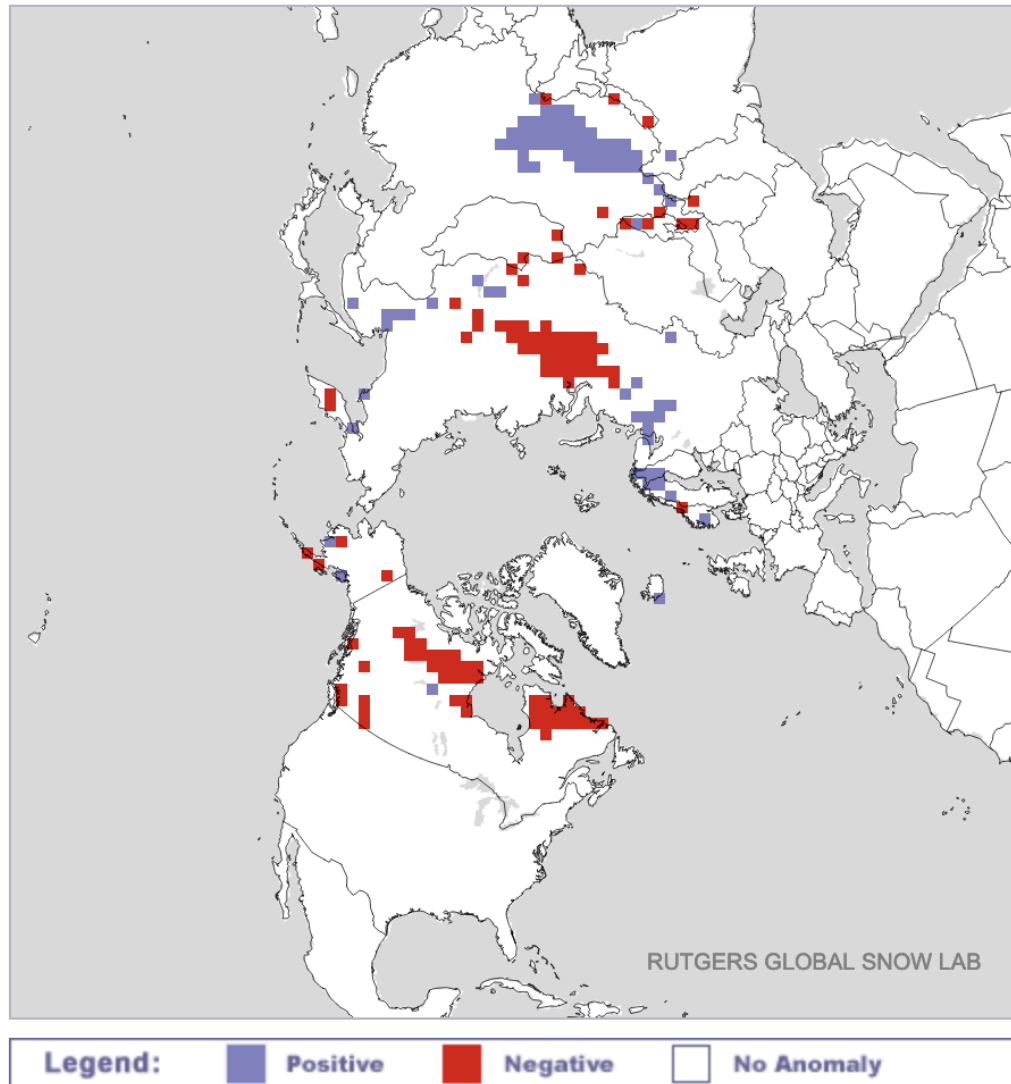


Figure ii. Observed Northern Hemisphere daily snow cover extent (SCE) anomalies for 22 October 2023. Plot taken from <http://climate.rutgers.edu/snowcover/>

The pattern change to colder, snowier weather not only across Siberia but also North America is related to a stretched PV which has begun and will continue into next week. A stretched PV is supportive of cold temperatures and an acceleration of snow advance across Central and Eastern Asia and North America mostly east of the Rockies. You can see in **Figure 12** that the PV is predicted to evolve from this week into next week. Cross polar flow from Siberia to Canada supports a surge south of Arctic air east of the Rockies.

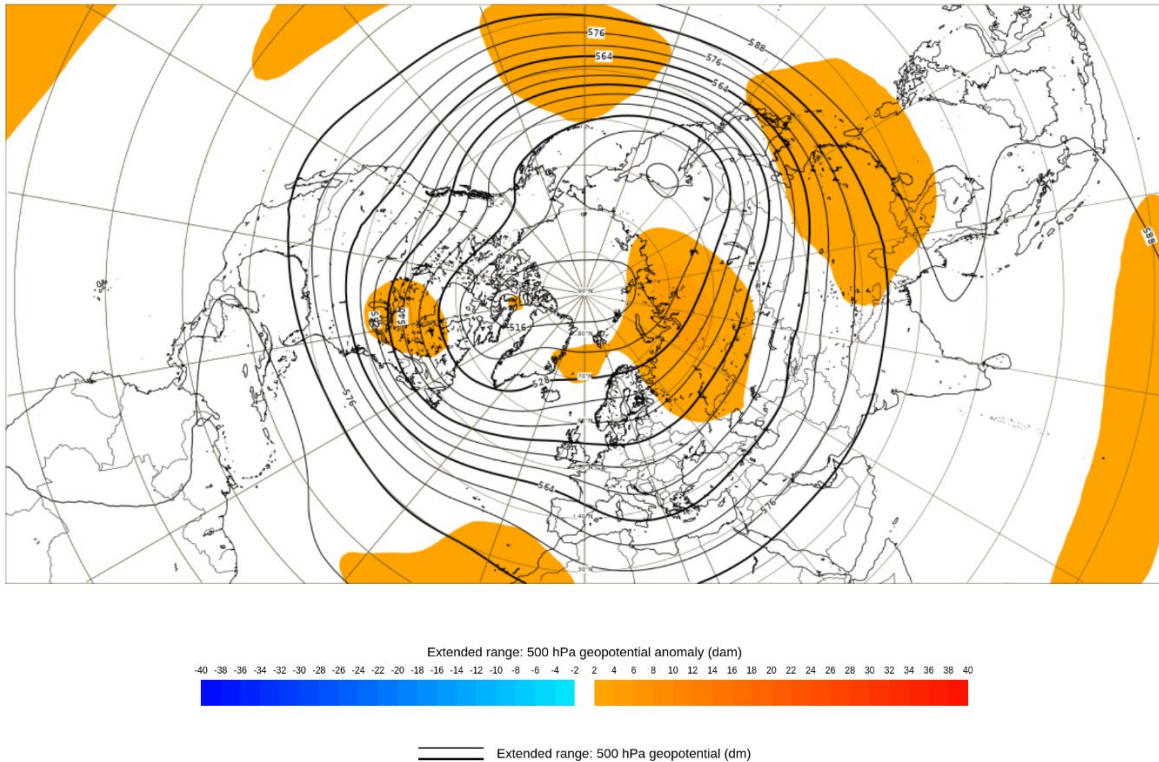
Stretched PV events typically last on the order of one to two weeks. Therefore, I would expect the colder weather to last until early November before relaxing and is already showing up in the weather models. For example, the surface temperature anomalies are mostly above normal across North America by early November (see **Figure 9**).

Stretched PVs can repeat and even eventually be a harbinger of a much bigger PV disruption or become an inflection point to a strengthening PV and too early to know today, how the PV will evolve through the month of November and into December. However, looking at the overall predicted pattern in both the GEFS/CFS and ECMWF models, I do think that the pattern is supportive of another stretched PV in the second half of November. I see no evidence of it yet, but something to watch.

Looking at the CFS forecast for November (see **Figure 13**) and even more impressively the ECMWF weekly forecasts are suggestive of Urals-Barents-Kara Seas blocking/high pressure ridging with downstream troughing across Siberia for much of November possibly into December (see **Figure iii**). And as I discussed last week, if this is correct, we can potentially observe a relatively early large PV disruption (i.e., sudden stratospheric warming or SSW), which I do believe is supported by an easterly quasi-biennial oscillation (QBO). The timing would likely be very late December into early January. And if there is a large PV disruption, the probability of cold and snowy weather greatly increases across the Northern Hemisphere (NH). In fact, I am of the opinion that the make or break for this winter across the Eastern US, Europe and probably East Asia is much earlier than usual. If the Scandinavian/Barents-Kara Seas/Ural blocking disappears and the PV strengthens in than a mild winter for these locations is all but assured.

500 hPa height: Weekly mean anomalies

Base time: Sun 22 Oct 2023 Valid time: Mon 27 Nov 2023 - Mon 04 Dec 2023 (+1032h) Area : North Pole



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Source: www.ecmwf.int
Licence: CC BY 4.0 and ECMWF Terms of Use (<https://apps.ecmwf.int/datasets/licences/general/>)
Created at 2023-10-23T16:56:55.88z



Figure iii. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (dam; shading) across the Northern Hemisphere from 27 November – 4 December 2023. The forecasts are from the 00z 22 October 2023 ECMWF ensemble. Plot taken from <https://charts.ecmwf.int/>

In conclusion as I did last week with Arctic sea ice (see **Figure iv**), it does appear to me that the lopsided negative anomalies almost completely in the North Pacific sector, are continuing to migrate into the North Atlantic sector. What would be interesting to monitor in the coming weeks – does the predicted high-pressure ridging and mild temperatures in the Barents-Kara Seas couple with increasing negative sea ice extent anomalies to reinforce each other? If they do and the high pressure ridging in the region can persist for multiple weeks, then this will pressure the PV in the coming weeks and months and maintain a perturbed PV. If the anomalies persist in the North Pacific sector, this might support a stretched PV but probably not an SSW.

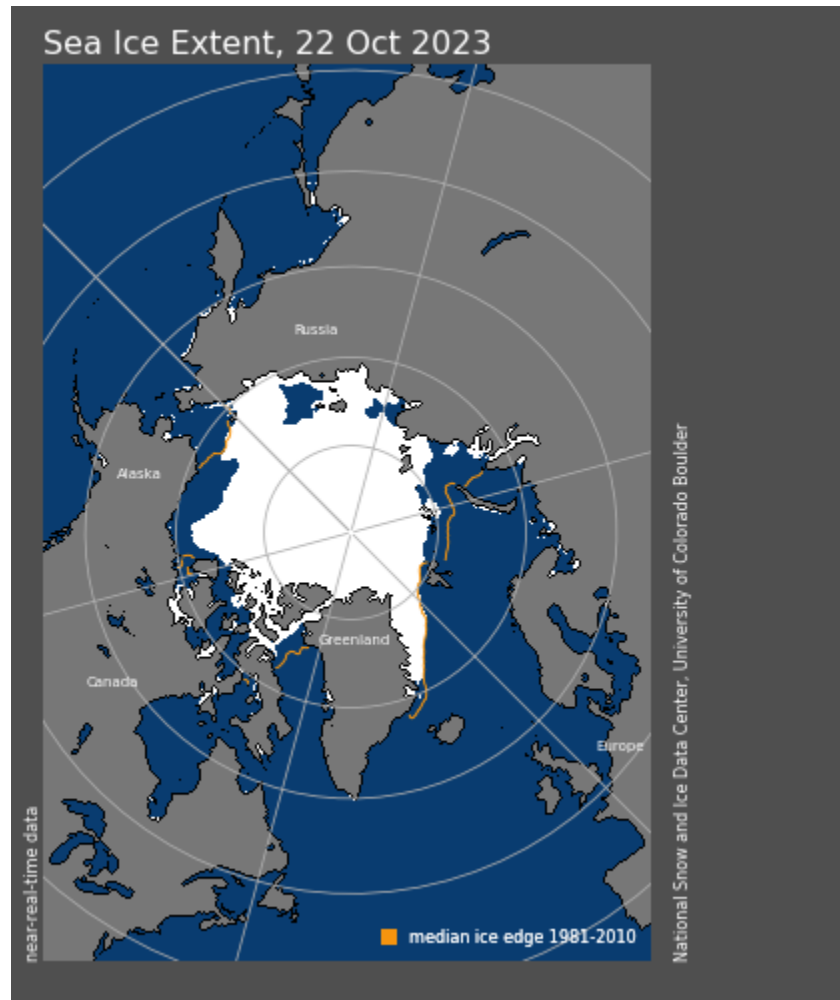


Figure iv. Observed Arctic sea ice extent on 22 October 2023 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

One final note, the predicted pattern of western North America troughing and eastern North America ridging might seem consistent with recent winters and La Niña and not El Niño. However, I don't think this is necessarily indicative of the pattern in mid to late winter. So, if you are telling yourself "here we go again," maybe but also maybe not.

Near-Term

This week

The AO is predicted to be neutral to negative this week (**Figure 1**) with mixed but mostly positive geopotential height anomalies across the Arctic and with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). With weak but mostly

positive geopotential height anomalies between Greenland (**Figure 2**), the NAO is predicted to be neutral to negative this period.

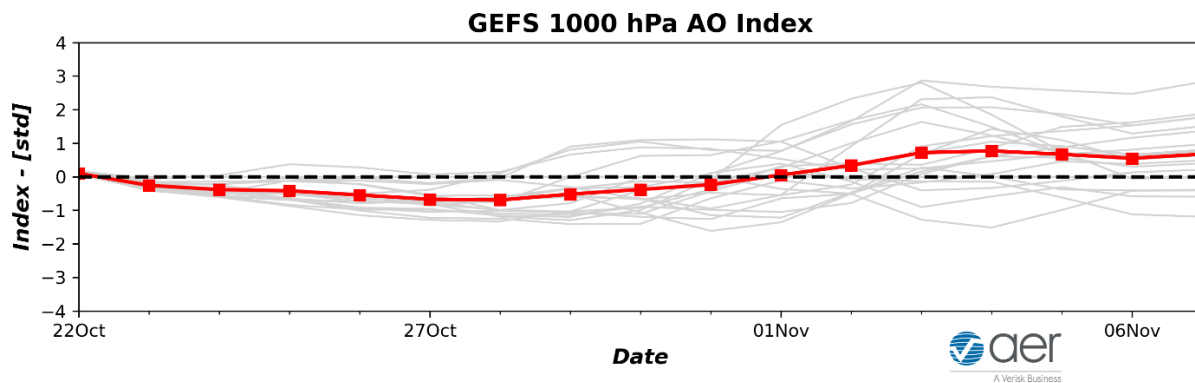


Figure 1. The predicted daily-mean AO at 1000 hPa from the 00Z 23 October 2023 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Ridging/positive geopotential height anomalies in the Barents-Kara Seas will support troughing/negative geopotential height anomalies across Northern and Central Europe with more ridging/positive geopotential height anomalies across Southern Europe (**Figures 2**). The induced zonal flow pattern favors normal to above normal temperatures across Central and Southern Europe including the UK with normal to below normal temperatures across Scandinavia (**Figure 3**). This week Asia is predicted to be dominated by ridging/positive geopotential height anomalies centered in Southern and Eastern Asia with troughing/negative geopotential height anomalies in Western and Northern Asia (**Figure 2**). This pattern favors widespread normal to above normal temperatures across much of Southern and Eastern Asia with normal to below normal temperatures limited to Western Russia (**Figure 3**).

GEFS 1-5 Day Forecast 500 hPa Anomaly
INIT: 00Z 10/23/2023 FCST: 10/24/2023 to 10/28/2023

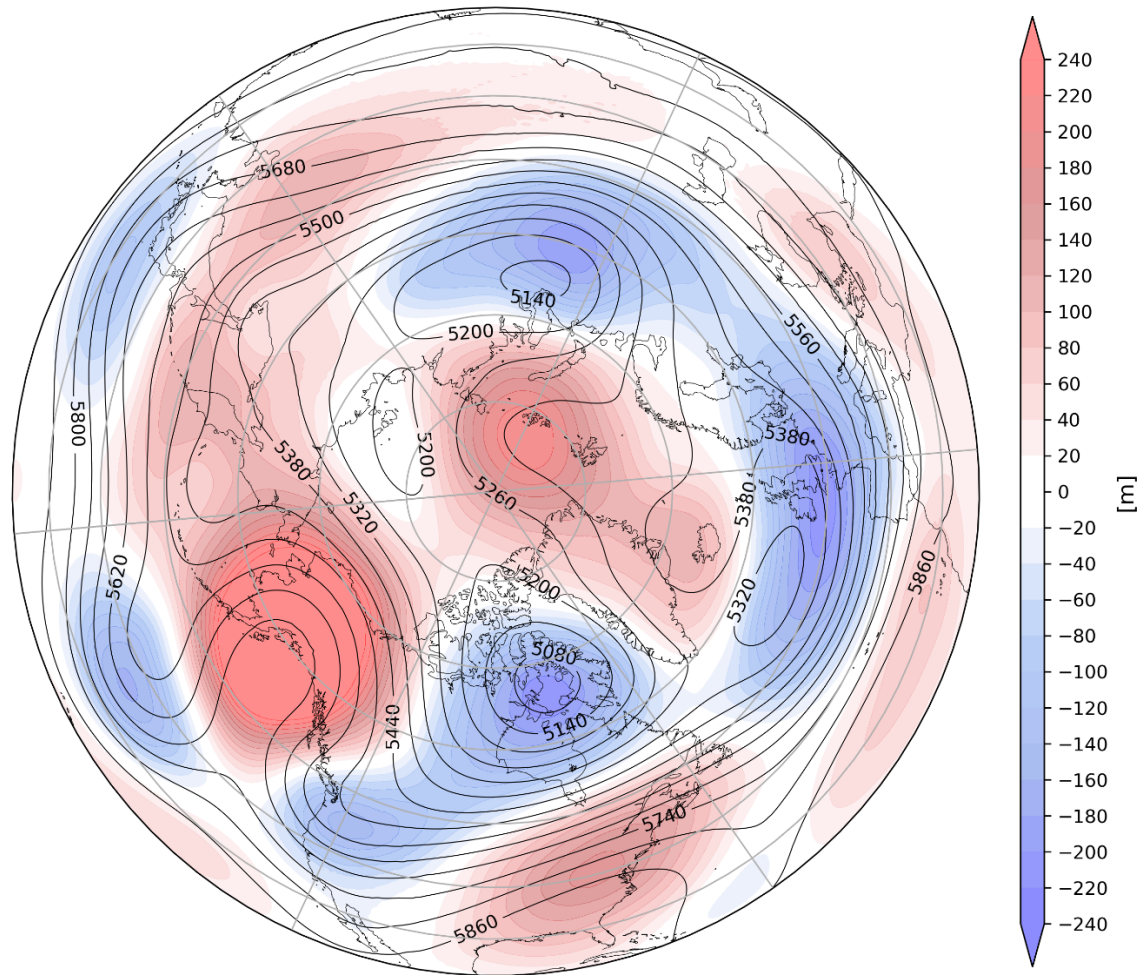


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 24 – 28 October 2023. The forecasts are from the 00z 23 October 2023 GFS ensemble.

The pattern this week across North America is ridging/positive geopotential height anomalies centered in the Gulf of Alaska and Alaska forcing troughing/negative geopotential height anomalies across Western Canada and the Western US with more ridging/positive geopotential height anomalies in the Eastern US (**Figure 2**). This pattern will favor widespread normal to above normal temperatures across Alaska, far northern and Southeastern Canada, the Central and Eastern US with normal to below normal temperatures across much of Canada and the Western US (**Figure 3**).

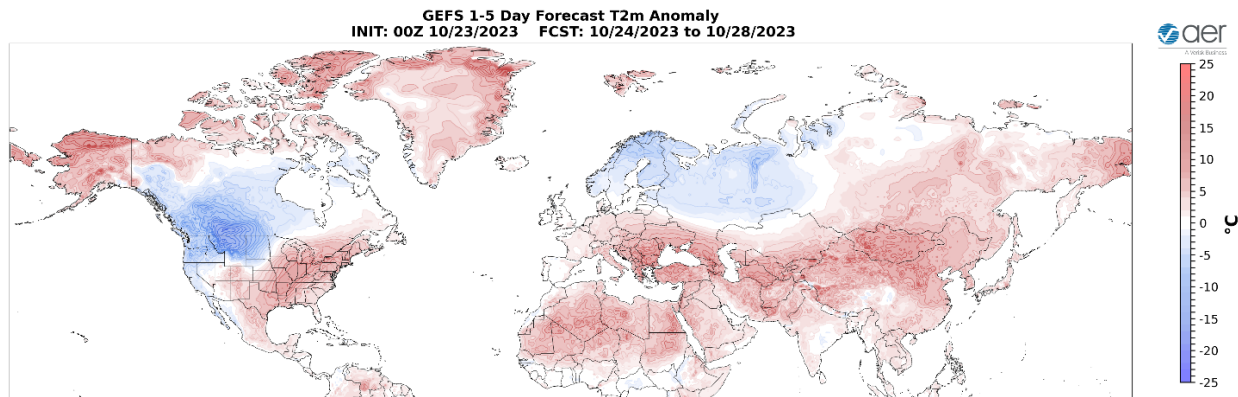


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 24 – 28 October 2023. The forecast is from the 00Z 23 October 2023 GFS ensemble.

Trouging and/or cold temperatures will support new snowfall across Scandinavia and Siberia this week (**Figure 4**). Trouging and/or cold temperatures will support new snowfall across Northern and Eastern Canada and the Northern Rockies and Plains while mild temperatures will support snowmelt across Alaska this week (**Figure 4**).

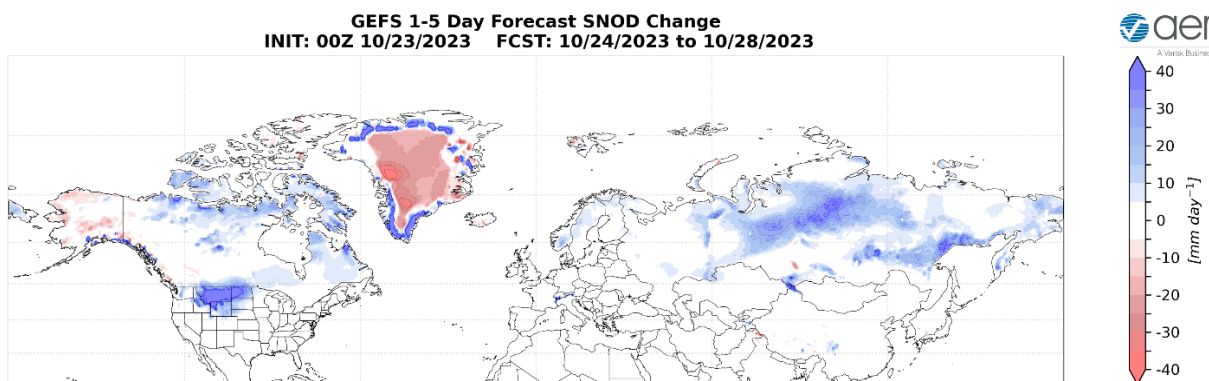


Figure 4. Forecasted snow depth changes (mm/day; shading) from 24 – 28 October 2023. The forecast is from the 00Z 23 October 2023 GFS ensemble.

Near-Mid Term

Next week

With mixed geopotential height anomalies across the Arctic and with mixed geopotential height anomalies across the mid-latitudes this period (**Figure 5**), the AO should straddle neutral this period (**Figure 1**). With predicted mixed pressure/geopotential height anomalies across Greenland (**Figure 5**), the NAO will likely be close to neutral this period.

GEFS 6-10 Day Forecast 500 hPa Anomaly
INIT: 00Z 10/23/2023 FCST: 10/29/2023 to 11/02/2023

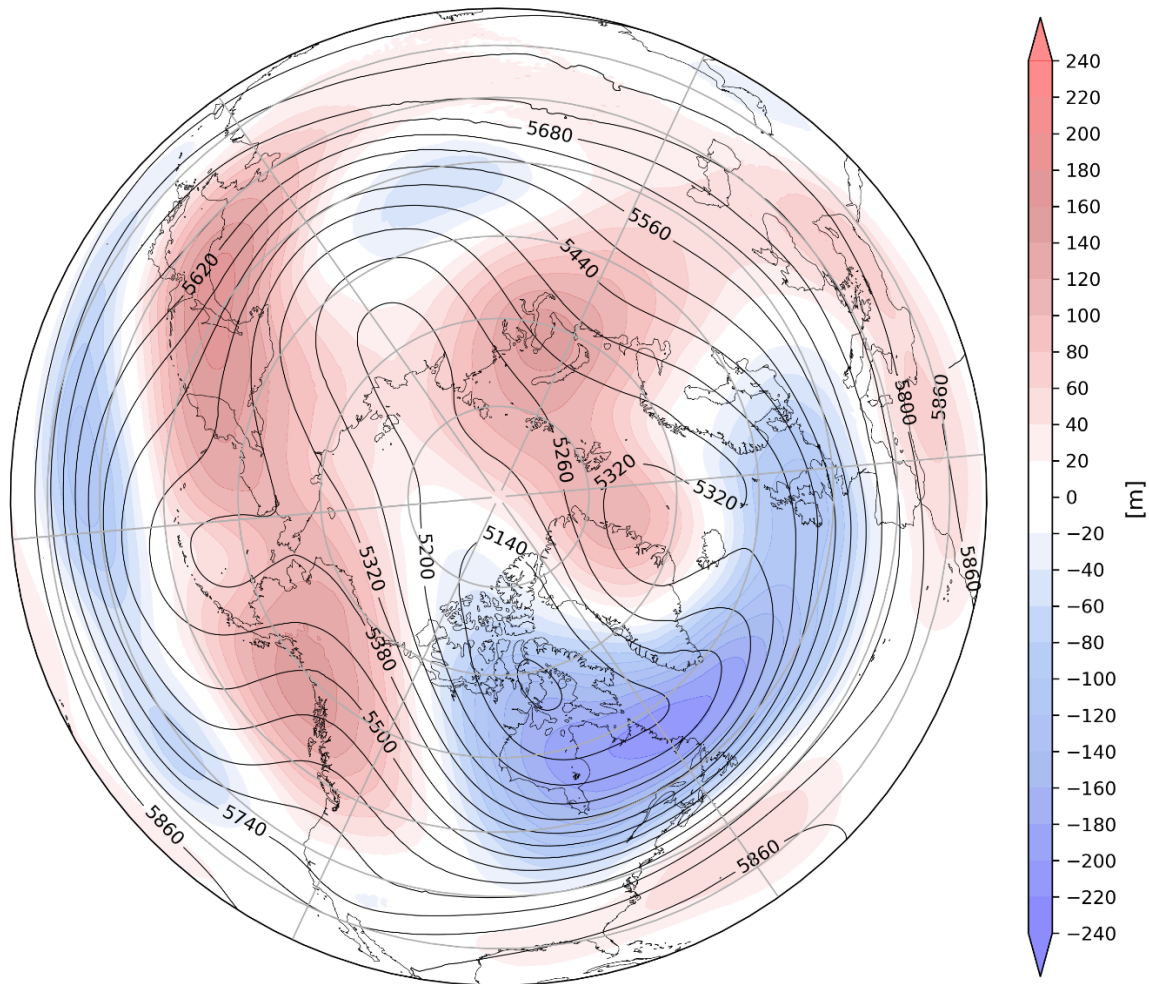


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 29 October – 2 November 2023. The forecasts are from the 00z 23 October 2023 GFS ensemble.

Persistent ridging/positive geopotential height anomalies between Greenland and the Barents-Kara Seas will continue to support troughing/negative geopotential height anomalies to the south across Northern Europe with more ridging/positive geopotential height anomalies across Southern Europe this period (**Figure 5**). This zonal flow pattern should favor normal to above normal temperatures across Southern and Central Europe including the UK with normal to below normal temperatures limited to Northern and Central Scandinavia (**Figures 6**). The general pattern across Asia is predicted ridging/positive geopotential height anomalies in Western and Eastern Asia with troughing/negative geopotential height anomalies in Central Asia this period (**Figure 5**). This pattern favors widespread normal to above normal temperatures

across Western, Eastern and Southern Asia with normal to below normal temperatures limited to much of Siberia and Eastern Kazakhstan this period (**Figure 6**).

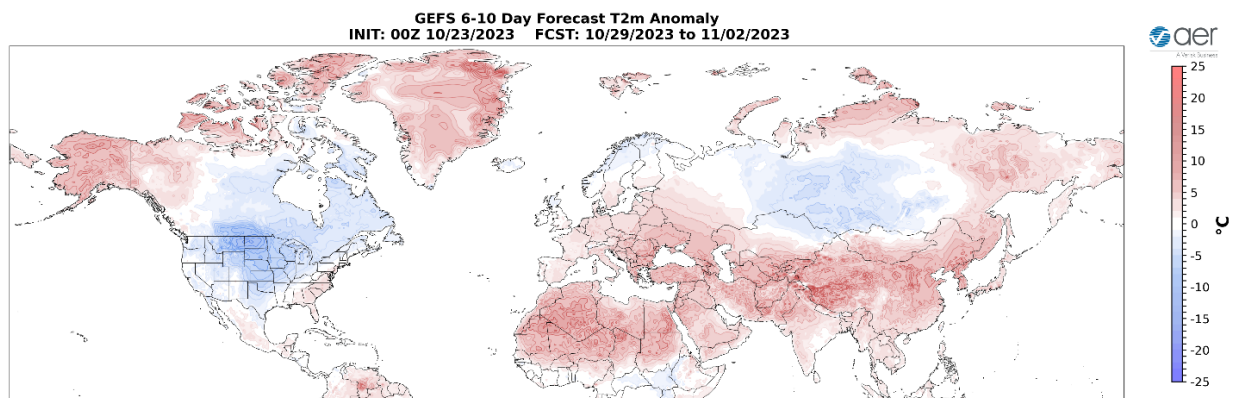


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 29 October – 2 November 2023. The forecasts are from the 00z 23 October 2023 GFS ensemble.

The predicted general pattern across North America this period is ridging/positive geopotential height anomalies across western North America forcing troughing/negative geopotential height anomalies across eastern North America with more ridging/positive geopotential height anomalies across the Southeastern US (**Figure 5**). This pattern favors normal to above normal temperatures across much of Alaska, Western Canada and the and the Southeastern US with normal to below normal temperatures across Central and Eastern Canada and much of the US east of the Rockies (**Figure 6**).

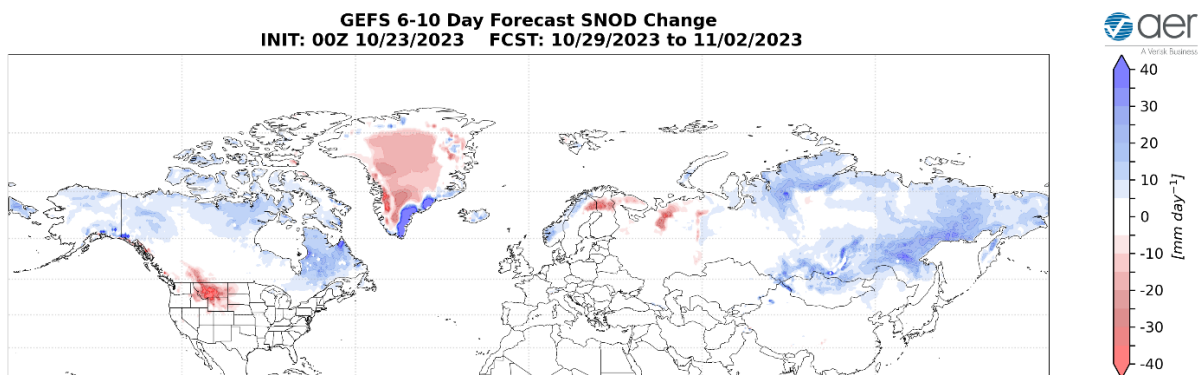


Figure 7. Forecasted snow depth changes (mm/day; shading) from 29 October – 2 November 2023. The forecast is from the 00Z 23 October 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across much of Siberia while mild temperatures will support snowmelt in Western Russia and Scandinavia this period (**Figure 7**). Troughing and/or cold temperatures will support new snowfall across northern and southern Alaska, Northern and Eastern Canada while mild temperatures will support snowmelt in the US Northern Rockies and Plains this period (**Figure 7**).

Mid Term

Week Two

With predicted mixed geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes this period (**Figure 8**), the AO should remain close to neutral but maybe with more of a positive bias this period (**Figure 1**). With predicted mixed and weak pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO will likely also remain close to neutral this period as well.

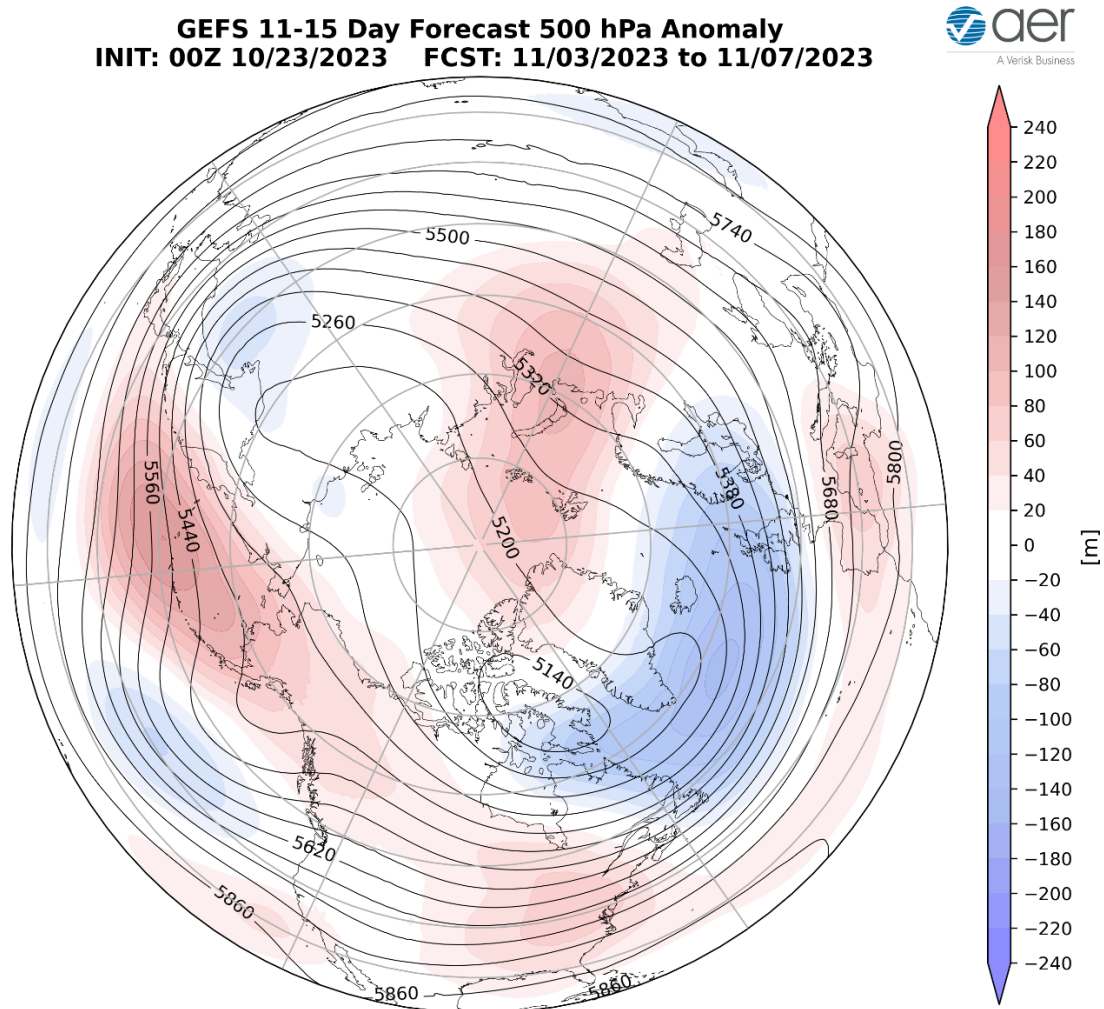


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 3 – 7 November 2023. The forecasts are from the 00z 23 October 2023 GFS ensemble.

Persistent ridging/positive geopotential height anomalies stretching from Greenland to the Barents-Kara Seas will continue to support troughing/negative geopotential height anomalies to the south across Northern Europe with more ridging/positive geopotential height anomalies across Southern Europe this period (**Figure 8**). The zonal flow pattern should favor normal to above normal temperatures across most of Europe with normal to below normal temperatures limited to Norway and the UK this period (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to consolidate in the Barents-Kara Seas and the Urals with troughing/negative geopotential height anomalies across Siberia and East 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 mostly limited to Southeastern Siberia and Northeast Asia this period (**Figure 9**).

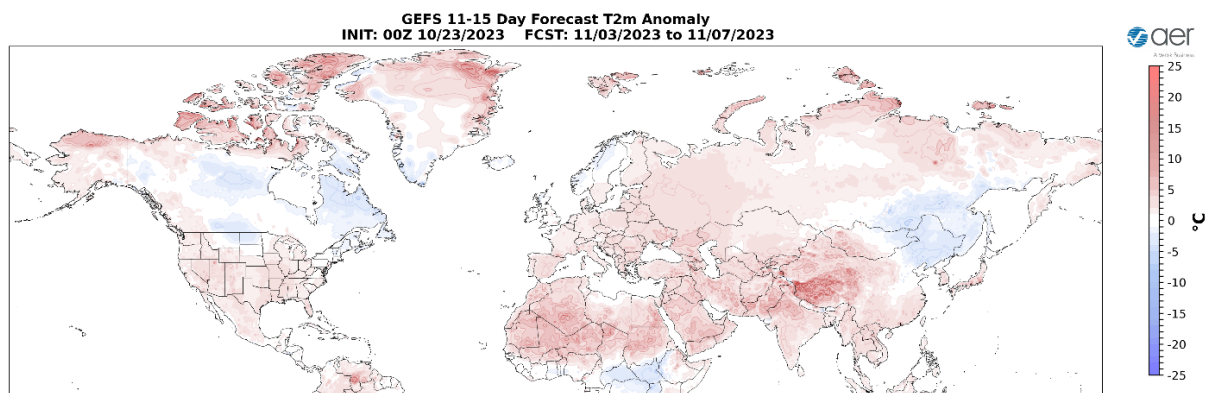


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 3 – 7 November 2023. The forecasts are from the 00z 23 October 2023 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to persist across Alaska and now returning to Eastern US with troughing/negative geopotential height anomalies across Eastern Canada this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across Alaska, Western Canada and much of the US with normal to below normal temperatures across Central and Eastern Canada and the US Northern Plains (**Figure 9**).

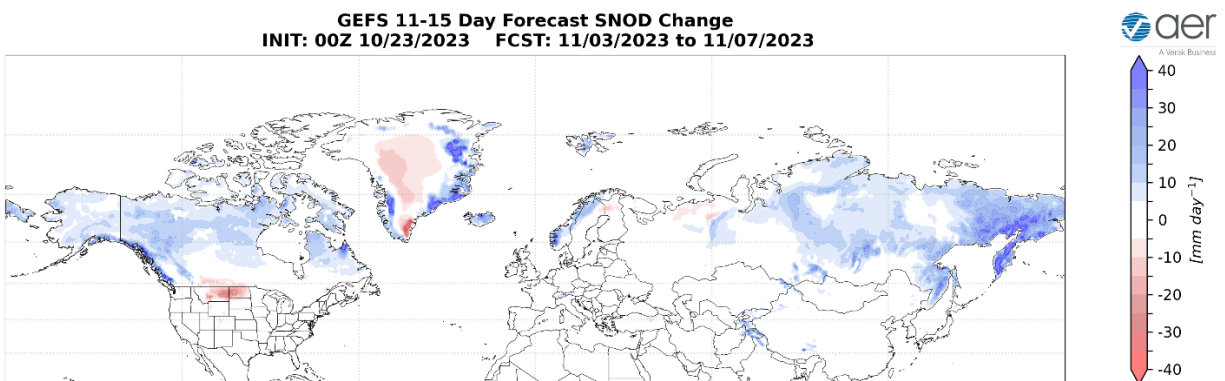


Figure 10. Forecasted snow depth changes (mm/day; shading) from 3 – 7 November 2023. The forecast is from the 00Z 23 October 2023 GFS ensemble.

Trouging and/or cold temperatures will support new snowfall across Norway, much of Siberia and the Tibetan Plateau while milder temperatures will support snowmelt across Northwest Russia and Scandinavia this period (**Figure 10**). Trouging and/or cold temperatures will support new snowfall across Alaska, Western and the northern half of Canada while milder temperatures will support snowmelt across the US Northern Rockies and Plains this period (**Figure 10**).

Longer Term

30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to warm/positive PCHs in the lower stratosphere and mid to upper troposphere with cold/negative PCHs in the upper stratosphere and the lower troposphere (**Figure 11**). This week and into next week warm/positive mid tropospheric PCHs are predicted to descend to the surface while cold/negative PCHs are predicted to expand across all of the stratosphere (**Figure 11**).

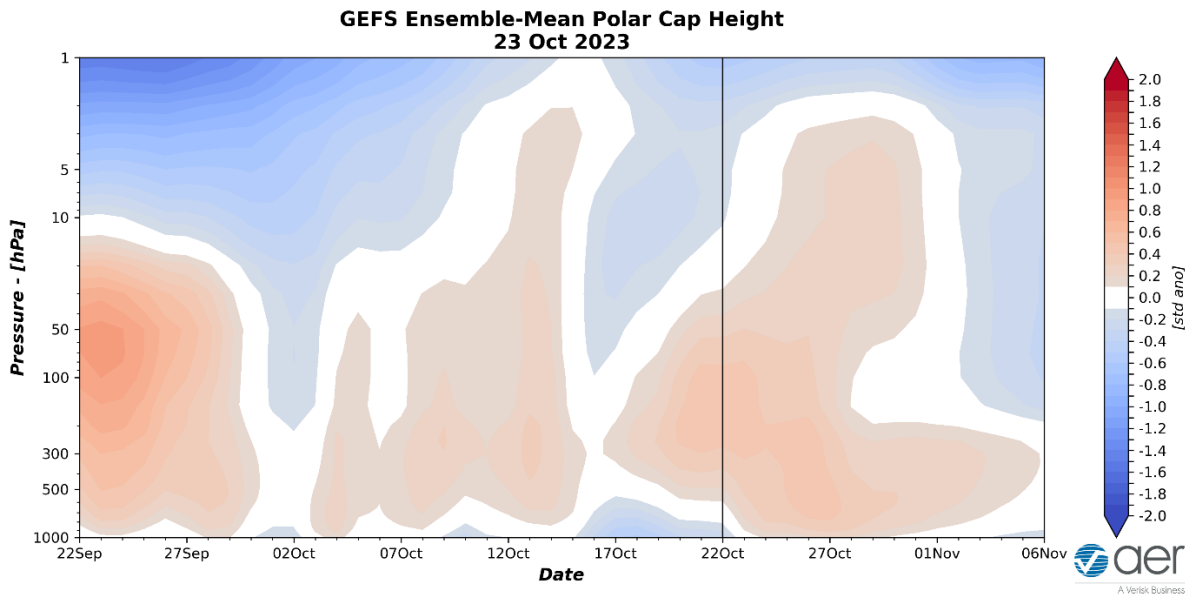


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 23 October 2023 GFS ensemble.

The predicted mixed and weak PCHs in the lower troposphere the next two weeks (**Figure 11**) are consistent with the predicted near neutral surface AO the next two weeks (**Figure 1**). However, the AO is predicted to become more biased negative this

week (**Figure 1**) coinciding with the predicted descending of warm/positive PCHs into the lower troposphere (**Figure 11**).

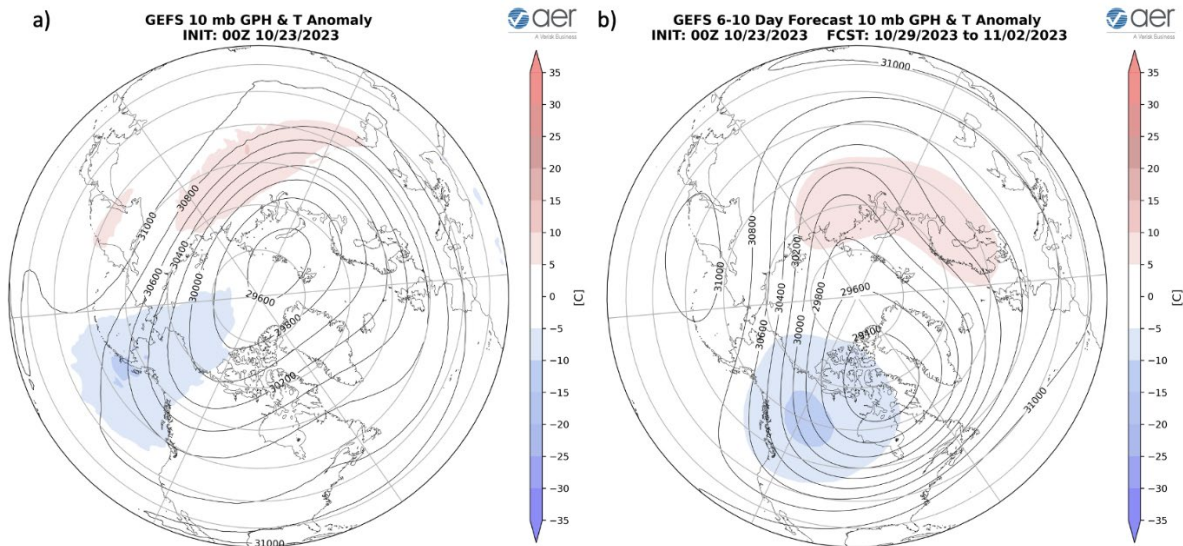


Figure 12. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for 23 October 2023. (b) Same as (a) except forecasted averaged from 29 October – 2 November 2023. The forecasts are from the 00Z 23 October 2023 GFS model ensemble.

This week the polar vortex (PV) is predicted to be contorted in shape where it is elongated along an axis from Western Russia to the Gulf of Alaska with the PV center shifted away from the North Pole centered near the Barents-Kara Seas (**Figure 12a**). The displaced PV center and elongation is a result of a minor PV disruption. However, for next week the PV center is predicted to shift to Hudson Bay while remaining elongated or stretched from Siberia to Western Canada (**Figure 12b**). This stretched PV configuration is a minor PV disruption that favors colder temperatures in both Central and East Asia and North America east of the Rockies.

CFS 500 hPa Forecast Anomaly Nov 2023
Valid as of 23 Oct 2023

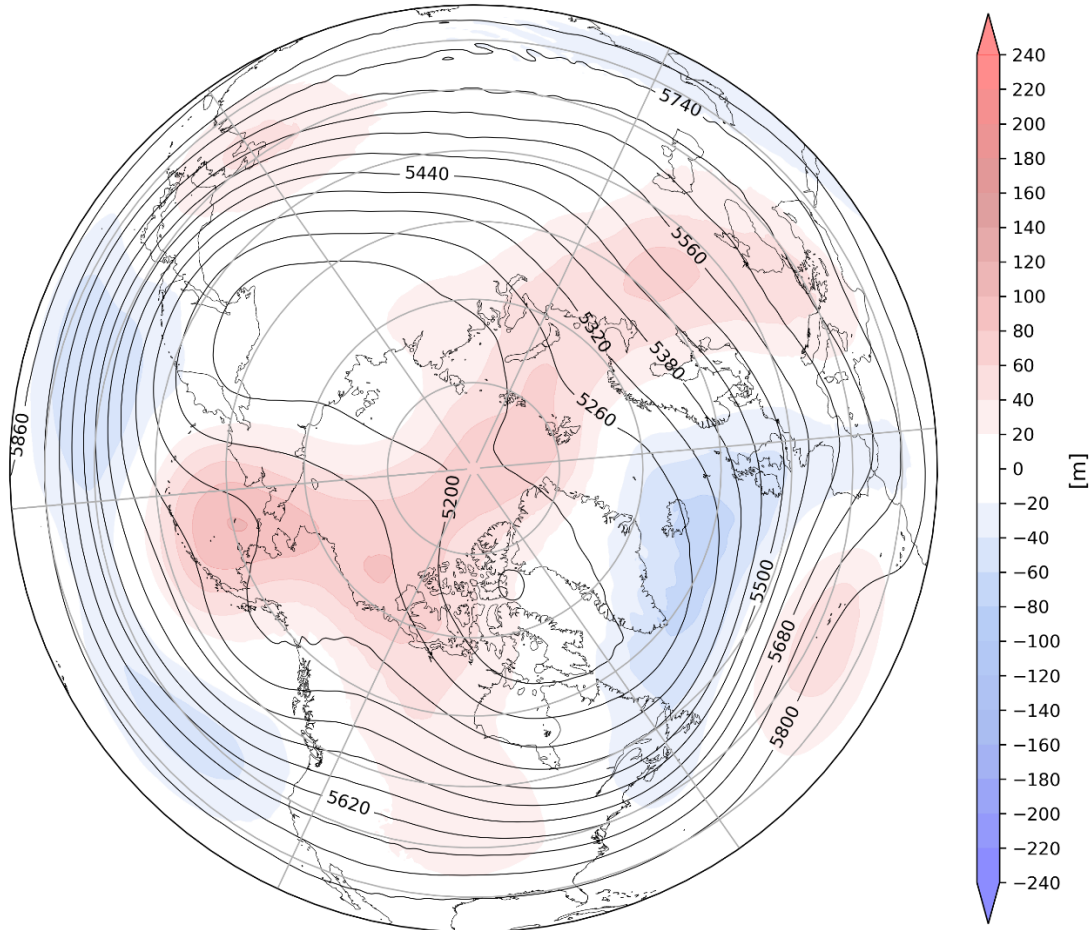


Figure 13. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for November 2023. The forecasts are from the 00Z 23 October 2023 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 13**) and surface temperatures for November (**Figure 14**) from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging extending from Western Asia, the Barents-Kara Seas, the Central Arctic, Alaska and the Aleutians bisecting the NH into two major regions of troughing the first being Siberia, Northeast Asia and into the North Pacific with the second in eastern North America, the North Atlantic and into Western Europe (**Figure 12**). This pattern favors seasonable to relatively warm temperatures across Central and Eastern Europe, Western and Southern Asia, Eastern Siberia, Alaska, Northern Canada and the Western US with seasonable to relatively cold temperatures across Western Europe, much of Siberia, Northeast Asia, Southern Canada and the Central and Eastern US (**Figure 13**).

CFS 9-38 Day Forecast T2m Anomaly
INIT: 00Z 10/23/2023 FCST: 11/01/2023 to 11/30/2023

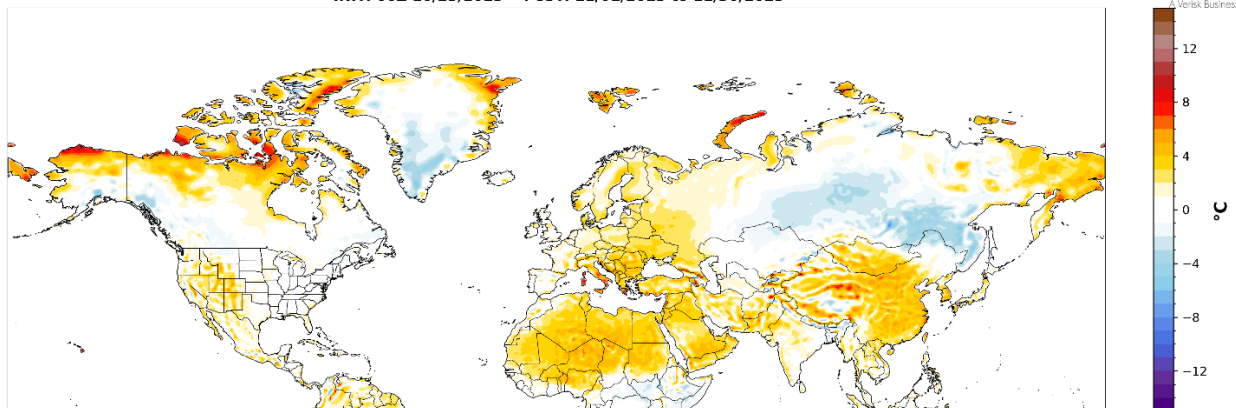


Figure 14. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for November 2023. The forecasts are from the 00Z 23 October 2023 CFS.

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 an El Niño is pretty much a sure thing (**Figure 15**) and El Niño conditions are expected through the winter. 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 and North Pacific and the North Atlantic.

SST Anomaly - Week Ending 22 Oct 2023

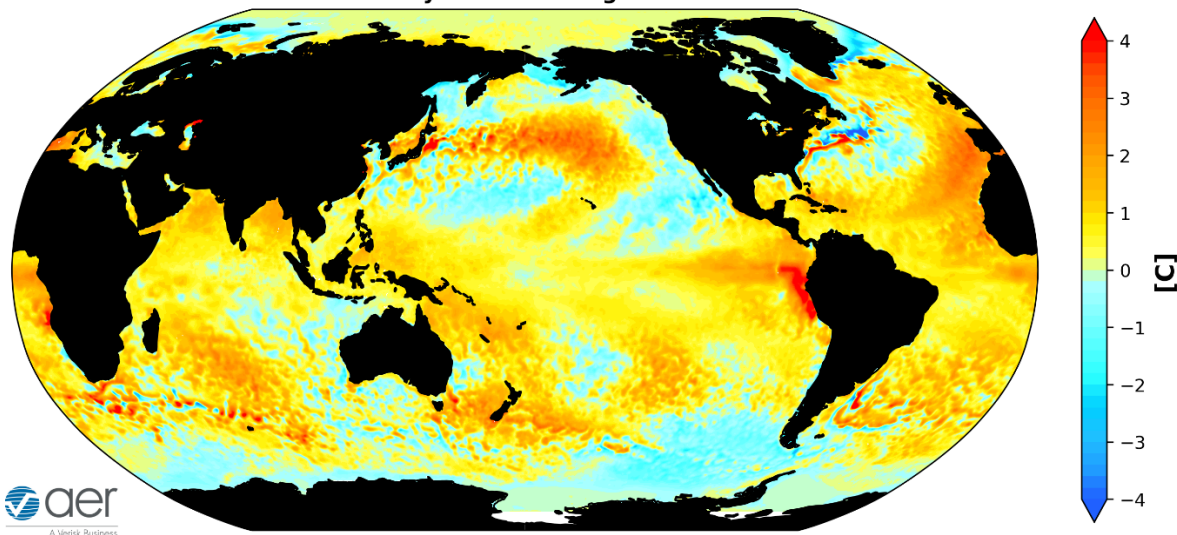


Figure 15. The latest weekly-mean global SST anomalies (ending 22 October 2023). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently the Madden Julian Oscillation (MJO) is in weak phase eight (**Figure 16**). The forecasts are for the MJO to remain weak into phase one and then to weaken further where no phase is favored. Seems that the MJO is having some influence on the weather across North America this week. Phases one and eight favor troughing along the west coast of North America and ridging in eastern North America. So the MJO could be influencing North American weather this week and into next week. But admittedly this is outside of my expertise.

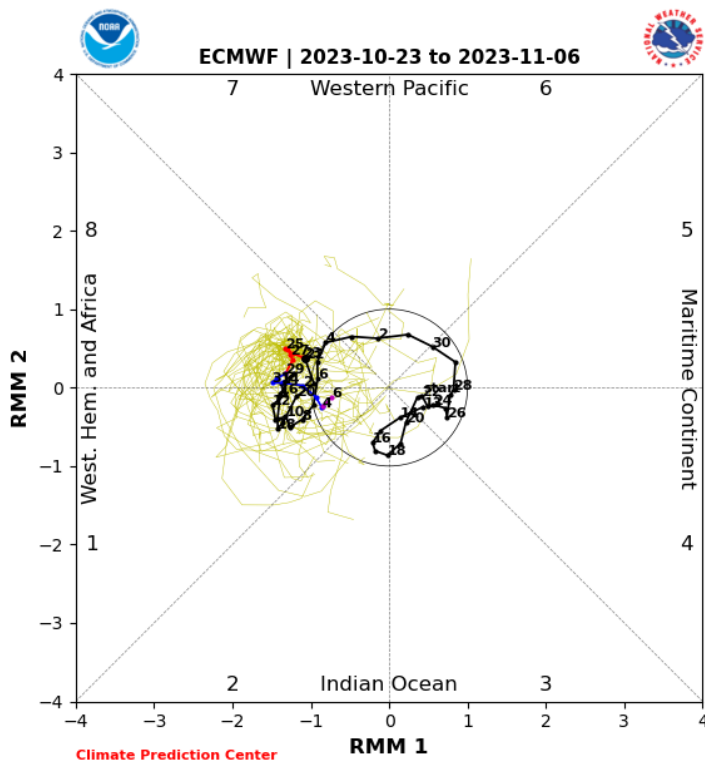


Figure 16. Past and forecast values of the MJO index. Forecast values from the 00Z 23 October 2023 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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

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