

Arctic Oscillation and Polar Vortex Analysis and Forecasts

November 6, 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 positive and is predicted to remain near neutral the next two weeks as pressure/geopotential height anomalies across the Arctic are currently mixed and are predicted to remain mixed over the next two weeks. The North Atlantic Oscillation (NAO) is currently near neutral with mixed 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 mostly mixed across Greenland.

Over the next two weeks, the predicted general pattern across Europe is troughing/negative geopotential height anomalies across Northern Europe and

ridging/positive geopotential height anomalies across Southern Europe. This mostly zonal pattern will support normal to above normal temperatures across much of Europe including the United Kingdom (UK) with normal to below normal temperatures mostly limited to Scandinavia the next two weeks.

This week the predicted pattern across Asia is ridging/positive geopotential height anomalies across Central Asia including Siberia with troughing/negative geopotential height anomalies across Eastern Asia. Then next week ridging/positive geopotential height anomalies will slide west and consolidate in Western Asia centered on the Urals while troughing/negative geopotential height anomalies will deepen in Siberia. This pattern favors normal to above normal temperatures across much of Asia including Northern Siberia with normal to below normal temperatures limited to East Asia and then next week normal to above normal temperatures across Southern and Western Asia with normal to below temperatures becoming more widespread across Siberia.

The general predicted pattern across North America the next two weeks is troughing/negative geopotential height anomalies in the Gulf of Alaska forcing ridging/positive geopotential height anomalies across much of North America with downstream troughing/negative geopotential height anomalies across the Canadian Maritimes. This pattern generally favors normal to above normal temperatures across Alaska, much of Canada and the United States (US) with normal to below normal temperatures limited to the west coast of North America, far Eastern Canada and New England.

in the Impacts section I try to wrap up on October Eurasian snow cover as I believe October is the critical month for predicting the upcoming winter circulation and weather. And I discuss the upcoming prospects of polar vortex behavior over the coming weeks.

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. I am close to having the final number (see **Figure i**). It is more than the last three years but not by much and I don't consider it a definitive predictor of this winter but is biased to a colder winter.

In the meantime, I have been expecting a stretching of the polar vortex like a rubber band being pulled on both ends to bring colder and snowier weather to Asia and North America in the second half of November. The driving from the troposphere is looking to be short-circuited this week and though it is still likely to happen, it looks like an unimpressive event.

Impacts

Now that we have turned the page on October and now in early November, I will start to share how I interpret the snow cover advance across Eurasia in October. In **Figure i**, I present the Eurasian snow cover extent (SCE) from 1979 to 2023 with 2023 being my estimate. I tend to underestimate the total value and hopefully the official value will be published later this week. It does seem that the late surge at the end of the month helped to push the final SCE value into positive territory but not by much. Also, the value is higher than the past three La Niña years but again not by much. And certainly, on average less than most recent years since 2013. But still the widespread above normal temperatures across the globe including Siberia, this is actually no small feat if my calculations are close to being correct.

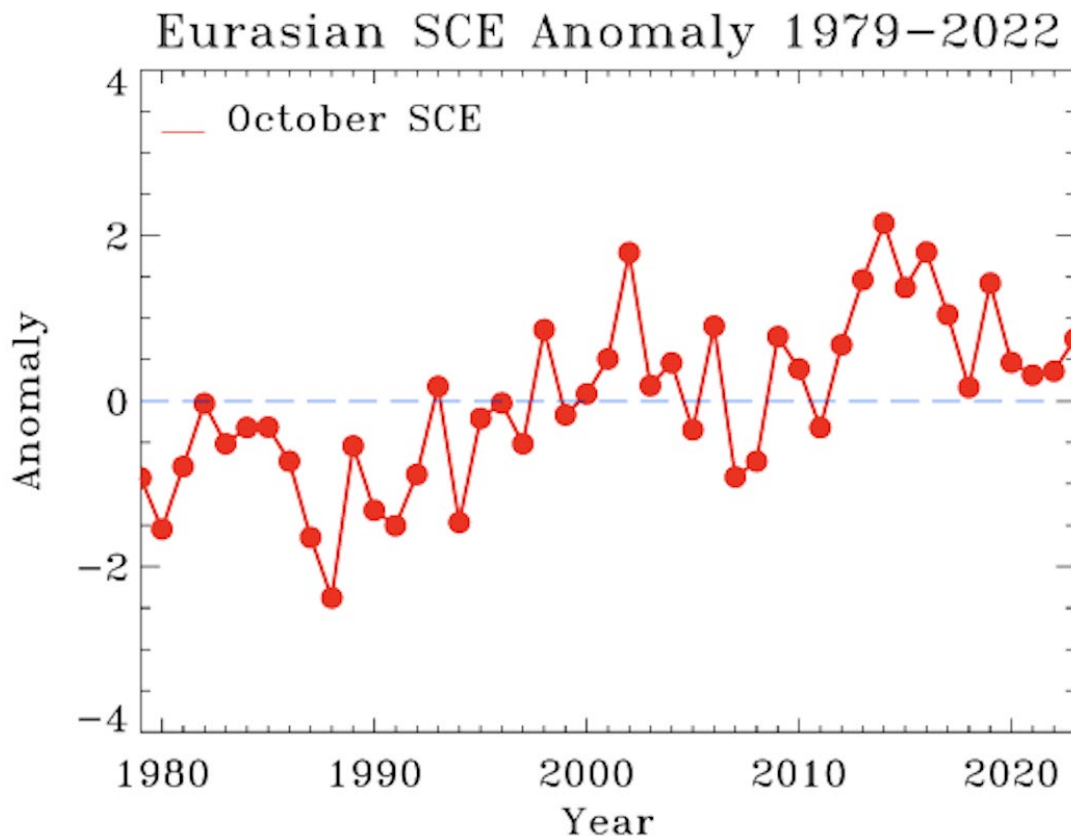


Figure i. Eurasian monthly snow cover extent (SCE) in millions of km squared for the month of October through 1979–2022 (shown in red). Blue dashed line shows average extent. Also included is an estimate of 2023.

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.

Not only do I compute the SCE but also the snow advance index (SAI) for October 2023. If you need a refresher on the SAI you can read [Cohen and Jones \(2011\)](#). The SAI came in at +0.5 for the month thanks to the late month surge of snow cover across Eurasia. Over the past several years I have interpreted a positive SAI as favoring a large PV disruption more likely in the earlier part of the winter and a negative SAI as more likely later in winter. Like SCE, the SAI isn't a big number and I don't consider it as a strong signal. So, in conclusion the SCE and SAI are suggestive of a weaker PV and colder weather but not decidedly so.

As I have been discussing in the blog, it has been my expectation that another stretched PV will occur in the second half of November. I do think that the evidence for one is strengthening this week but so far it is underwhelming. One of the classical signatures for a stretched PV is when the wave activity flux (WAF) in the vertical direction reflects off the PV. In **Figure ii**, I show the WAF in the vertical and latitudinal directions. Looking at the WAF vectors, they are directed upward over Asia (west of the Dateline) but directed downward over North America (east of the Dateline). This reflection of the WAF tends to elongate the PV over North America and deepens troughing east of the Rockies.

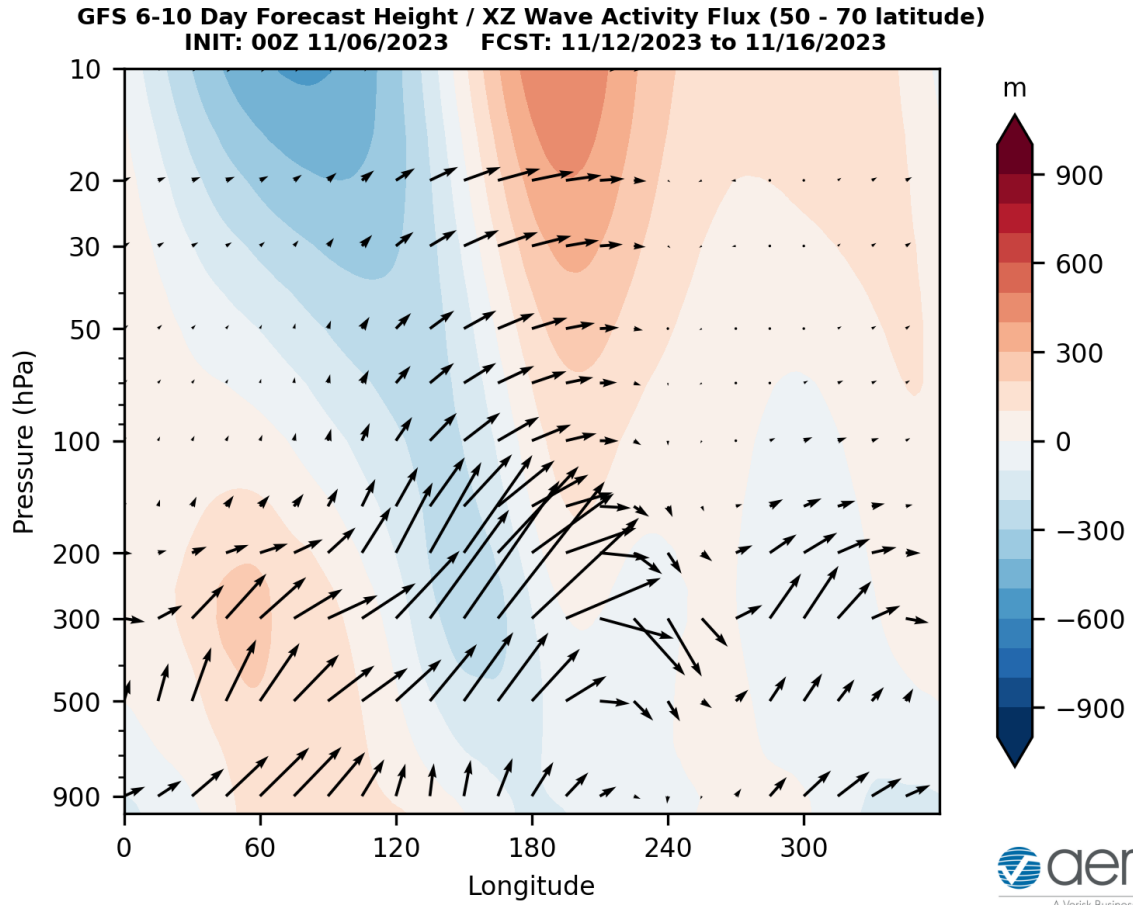


Figure ii. Longitude-height cross section of geopotential eddy height anomalies (shading) and wave activity flux (vectors) forecasted for 12-16 November 2023. The forecast is from the 00Z 6 November 2023 GFS ensemble.

In **Figure iii**, I show the forecast for the 10 hPa geopotential heights for the third week of November and compare to what I showed for last week. Both panels show an elongated PV but last week it was more extended equatorward and it was directed towards western North America whereas the predicted stretched PV is directed towards Southeastern Canada and the Northeastern US. This should support that any cold air will be focused much further east the second half of November than the cold air outbreak late October and early November. So far, the models are predicting a relatively minor event but often with these events the models are constantly playing catchup, so the forecast could trend colder with time but again most likely from the Great Lakes to the east. We did pull our machine learning model out of mothballs and just started running it, and it too isn't impressed with this stretched PV event only bringing above normal temperatures closer to normal towards the end of November.

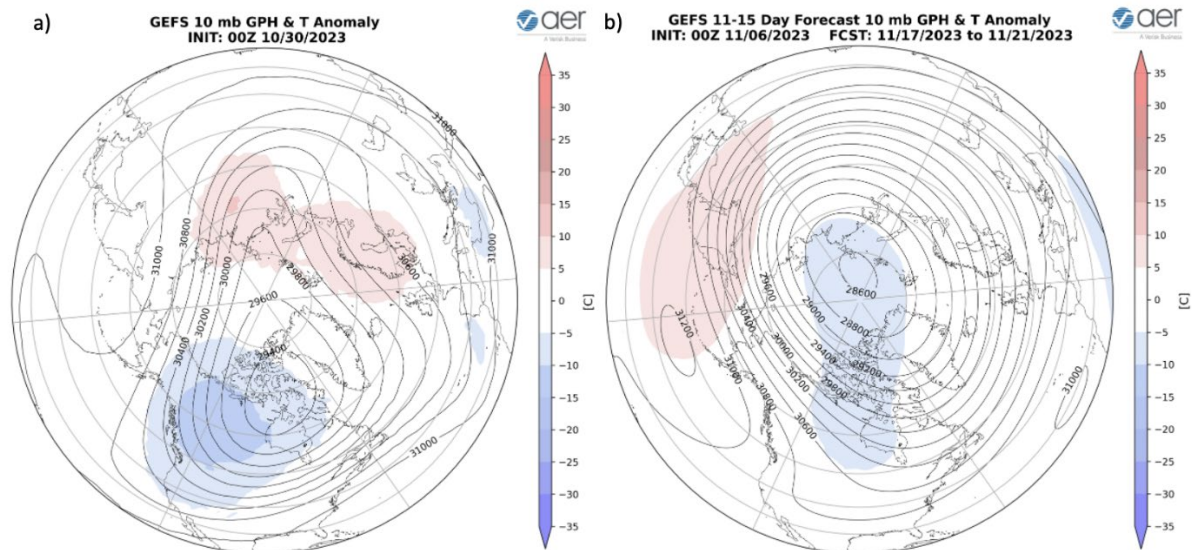


Figure iii. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for 30 October 2023. (b) Same as (a) except forecasted averaged from 17 – 21 November 2023. The forecasts are from the 00Z 6 November 2023 GFS model ensemble.

Yesterday I tweeted out about my own frustration with a predicted ridge of high pressure centered in Siberia (see **Figure 2**) where as recently as last week's blog the models were predicting a trough of low pressure in Siberia. Something similar happened in early October. Ridging over the Scandinavian/Urals region with troughing over Siberia often weakens the PV while the exact opposite pattern with troughing in the Scandinavian/Urals region with ridging over Siberia tends to strengthen the PV. So, after the models consistently predicted a persistent pattern of ridging over the Scandinavian/Urals region with troughing over Siberia the exact opposite is happening this week and I will admit this spooked me. This was the second time this happened in two months, and I don't know the reason for the forecast flops. I have been anticipating a stretched PV with a possible larger PV disruption in December ala the ECMWF weeklies based on this pattern verifying. But it is my belief that this is all moot with troughing in the Scandinavian/Urals region with ridging over Siberia. And even if this pattern is transitory as predicted by the models, without consistent ridging over the Scandinavian/Urals region, I feel it will be hard to achieve a meaningful PV disruption.

And as I have been discussing if the PV strengthens and high latitude blocking disappears, we could be off to the races with surface temperatures across the NH in December. And that will be hard to recover from even in the latter winter months. The models have been predicting consistently Urals-Barents-Kara Seas blocking/high pressure ridging with downstream troughing across Siberia for much of November and into December. The CFS remains on this wave "train" (see **Figure 14**) but the latest ECMWF weeklies have clearly gotten off this train. I am not going to bother to show since it is one forecast and the models seem to be struggling mightily. Ironically the

ECMWF is still maintaining a weakening PV but given the predicted tropospheric pattern, one of those forecasts is very likely to be wrong.

I consider that we are still at a crossroads where the PV can begin to weaken and we turn to a colder pattern or the PV strengthens and we turn to a milder pattern. I thought that the atmosphere was leaning more towards the first path. But now I am thinking that might have been a head fake and the atmosphere is now leaning towards the milder path probably at least through the end of the year. Certainly the latest polar cap geopotential height anomalies (PCHs) forecast (see **Figure 11**) is pointing in this direction.

Near-Term

This week

The AO is predicted to straddle neutral this week (**Figure 1**) with mixed geopotential height anomalies across the Arctic and with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). With mixed and weak geopotential height anomalies across Greenland (**Figure 2**), the NAO is predicted to be near neutral this period.

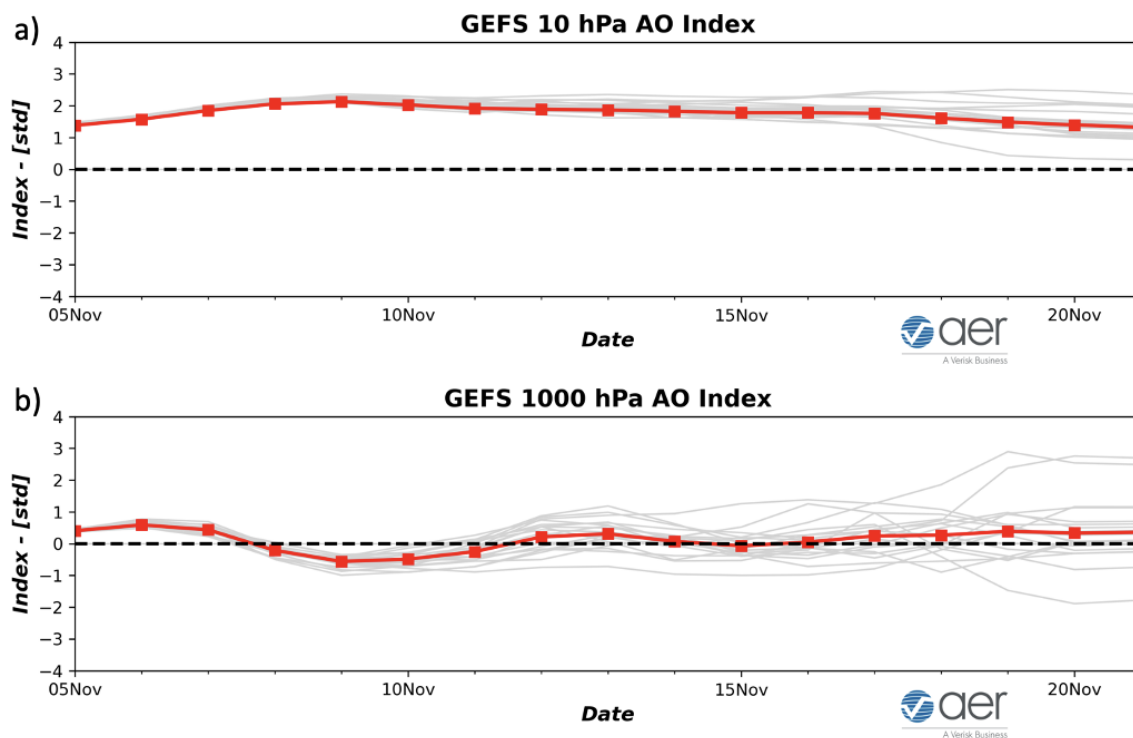


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 6 November 2023 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 6 November 2023 GFS ensemble. Gray lines indicate the AO index from each individual

ensemble member, with the ensemble-mean AO index given by the red line with squares.

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

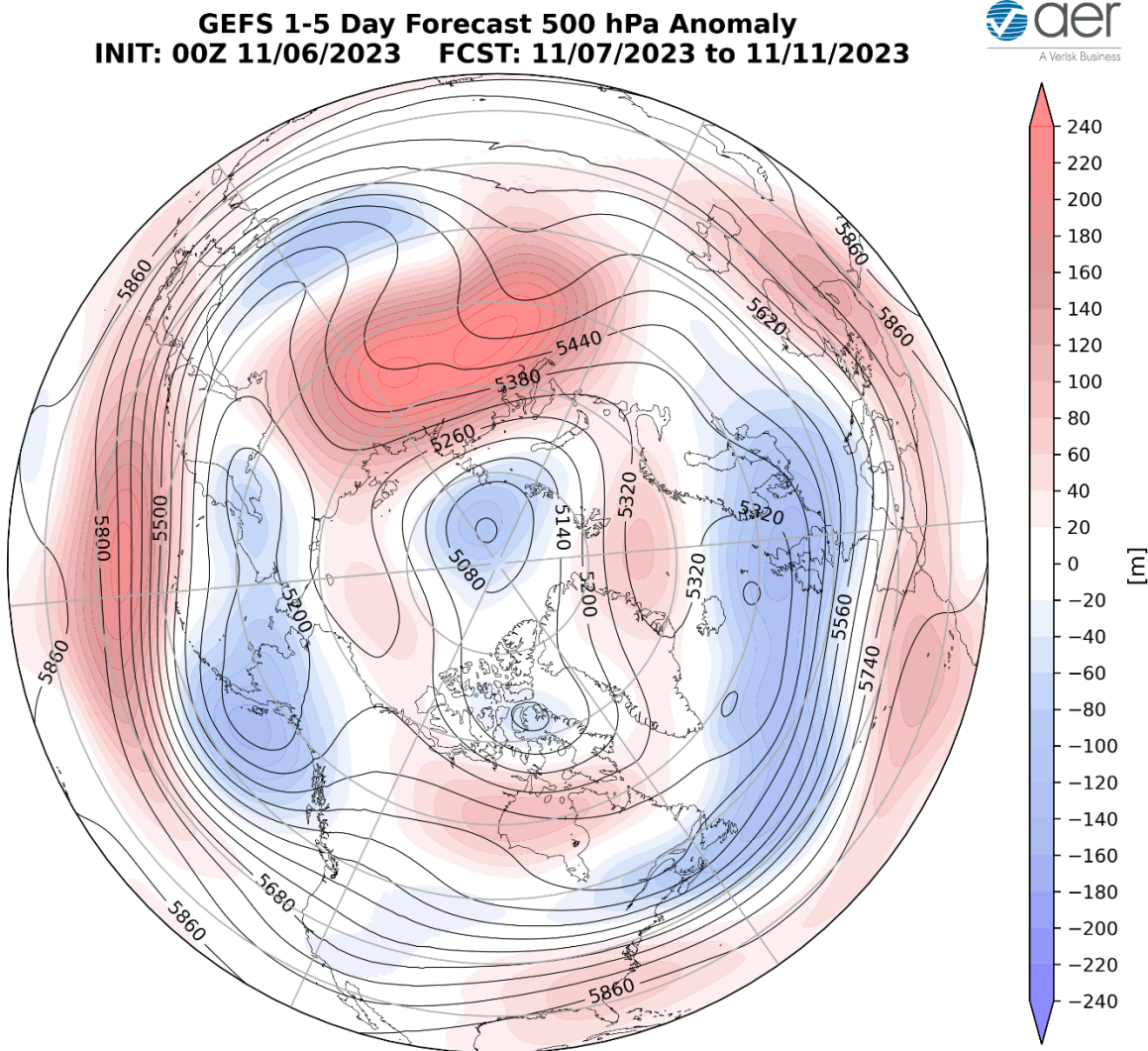


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 7 – 11 November 2023. The forecasts are from the 00z 6 November 2023 GFS ensemble.

The pattern this week across North America is troughing/negative geopotential height anomalies across western Alaska and the Gulf of Alaska forcing that extends into the west coast of North America forcing ridging/positive geopotential height anomalies centered in Hudson Bay with downstream troughing/negative geopotential height anomalies across the Canadian Maritimes and the Northeastern US (**Figure 2**). This pattern will favor widespread normal to above normal temperatures across Alaska, Western Canada, the Central and Southern US with normal to below normal temperatures across southwest Alaska, Eastern Canada, the Western and Northeastern US (**Figure 3**).

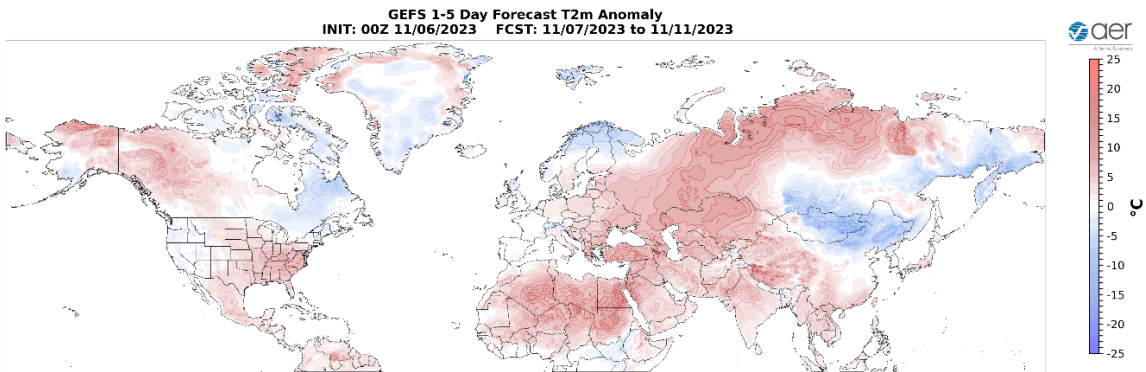


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 7 – 11 November 2023. The forecast is from the 00Z 6 November 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Scandinavia the Alps, Siberia and the Tibetan Plateau while mild temperatures will support snowmelt across Western Russia this week (**Figure 4**). Troughing and/or cold temperatures will support new snowfall across Alaska and much of Canada while mild temperatures will support snowmelt across the Canadian Southern Plains this week (**Figure 4**).

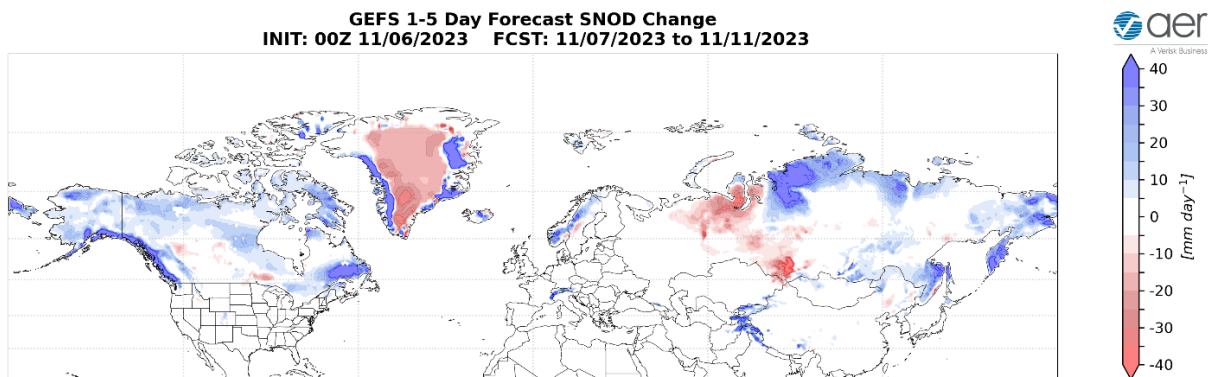


Figure 4. Forecasted snow depth changes (mm/day; shading) from 7 – 11 November 2023. The forecast is from the 00Z 6 November 2023 GFS ensemble.

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 remain tethered to neutral this period (**Figure 1**). With predicted mostly negative but weak pressure/geopotential height anomalies across Greenland (**Figure 5**), the NAO will likely be close to neutral this period.

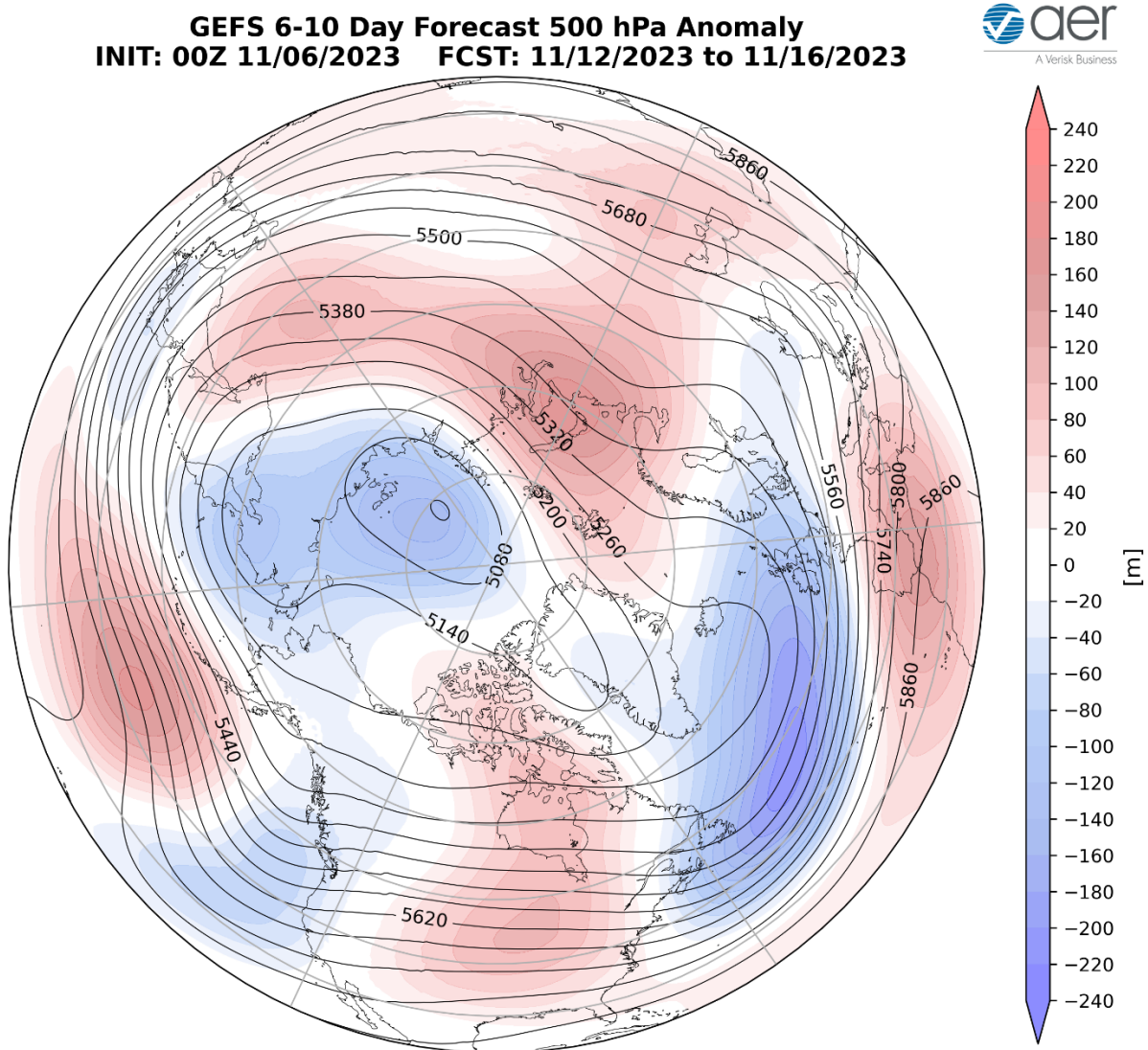


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 12 – 16 November 2023. The forecasts are from the 00z 6 November 2023 GFS ensemble.

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**). The induced westerly flow pattern will favor normal to above normal temperatures across much of Europe including the UK with normal to below normal temperatures limited to Scandinavia (**Figures 6**). The general pattern across Asia is strengthening ridging/positive geopotential height anomalies in Western Asia especially the Urals with downstream troughing/negative geopotential height anomalies in Eastern Asia this period (**Figure 5**). This pattern favors widespread normal to above normal temperatures across much of Asia with normal to below normal temperatures limited to far East Asia this period (**Figure 6**).

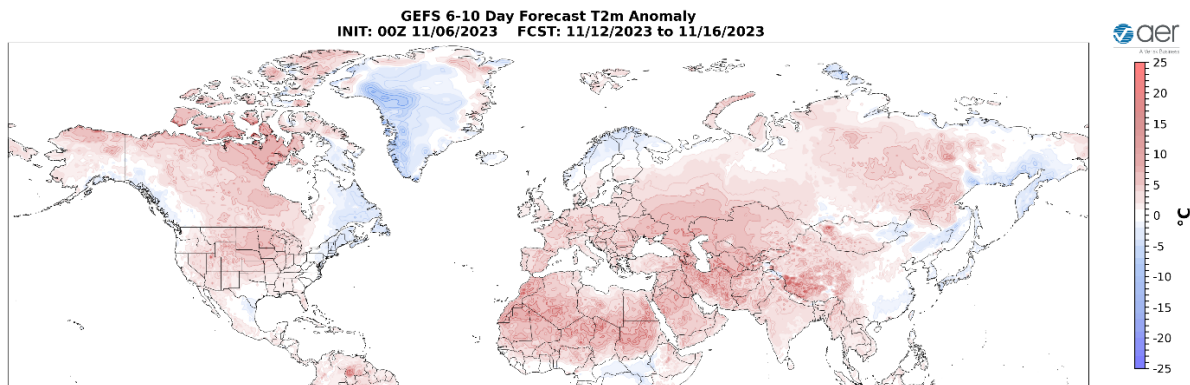


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 12 – 16 November 2023. The forecasts are from the 00z 30 October 2023 GFS ensemble.

The predicted general pattern across North America this period is troughing/negative geopotential height anomalies in the Gulf of Alaska forcing ridging/positive geopotential height anomalies across much of North America east of the Rockies except for troughing/negative geopotential height anomalies across the Canadian Maritimes (**Figure 5**). This pattern favors normal to above normal temperatures across much of Alaska, Canada and the US with normal to below normal temperatures limited to the West Coasts of Canada and the US, the Canadian Maritimes and the Northeastern US (**Figure 6**).

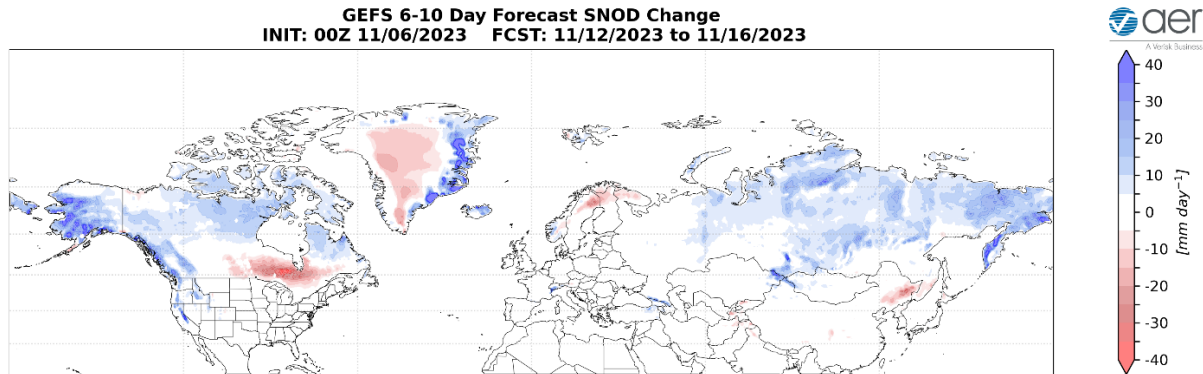


Figure 7. Forecasted snow depth changes (mm/day; shading) from 12 – 16 November 2023. The forecast is from the 00Z 6 November 2023 GFS ensemble.

Trouging and/or cold temperatures will support new snowfall across much of Siberia while mild temperatures will support snowmelt in Northeastern China and Scandinavia this period (**Figure 7**). Trouging and/or cold temperatures will support new snowfall across Alaska, Northern and Western Canada and the high elevations of the Western US while mild temperatures will support snowmelt in Southeastern Canada this period (**Figure 7**).

Mid Term

Week Two

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

GEFS 11-15 Day Forecast 500 hPa Anomaly
INIT: 00Z 11/06/2023 FCST: 11/17/2023 to 11/21/2023

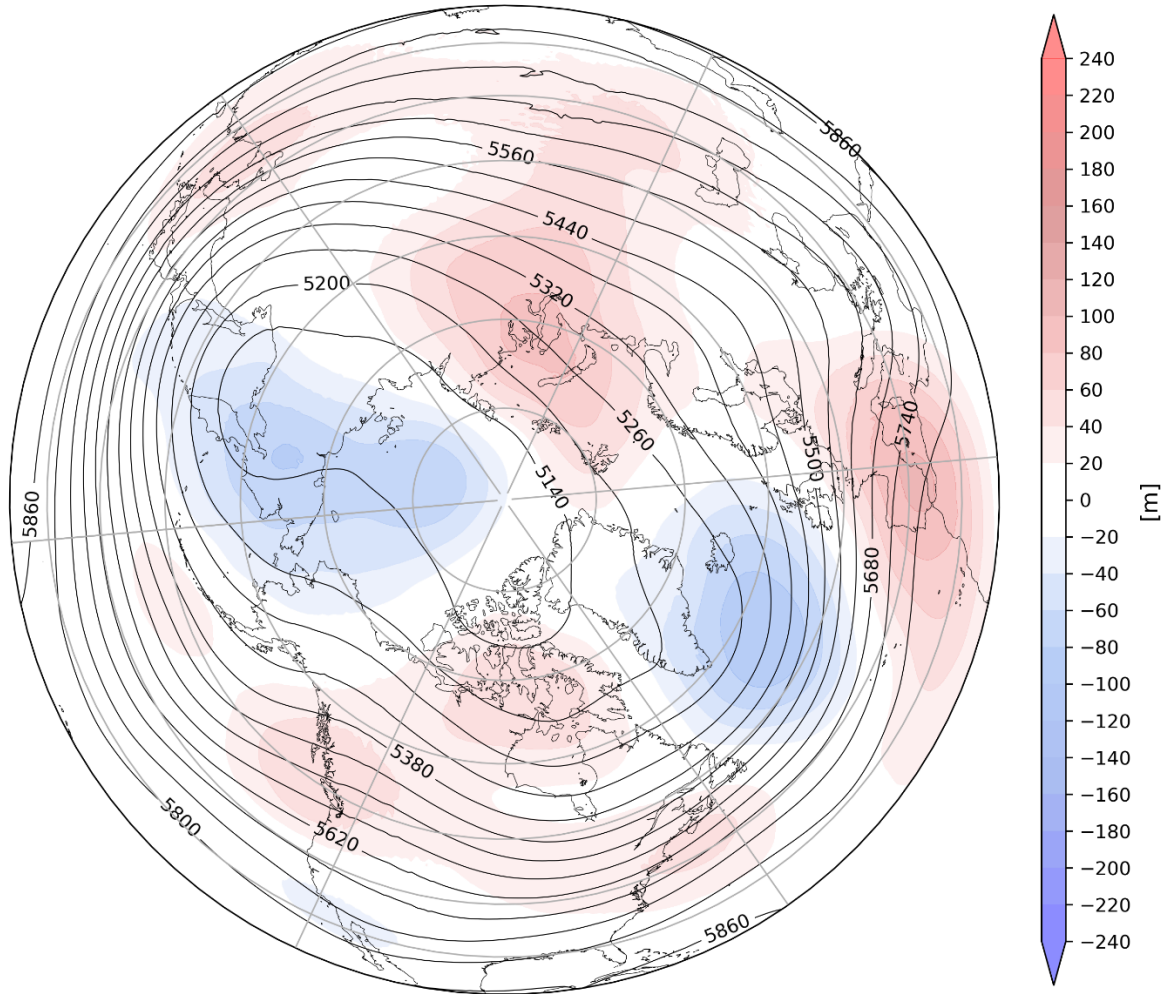


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 17 – 21 November 2023. The forecasts are from the 00z 6 November 2023 GFS ensemble.

With persistent ridging/positive geopotential height anomalies stretching from Greenland to the Barents-Kara Seas fading so will troughing/negative geopotential height anomalies to the south across Northern Europe, allowing ridging/positive geopotential height anomalies to push north across Europe this period (**Figure 8**). This pattern should favor normal to above normal temperatures across much of Europe including the UK with normal to below normal temperatures limited to Norway this period (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to continue to consolidate in the Barents-Kara Seas and the Urals with downstream 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 Western and Southern Asia with normal to below normal

temperatures mostly limited to Siberia and parts of Northeast Asia this period (**Figure 9**).

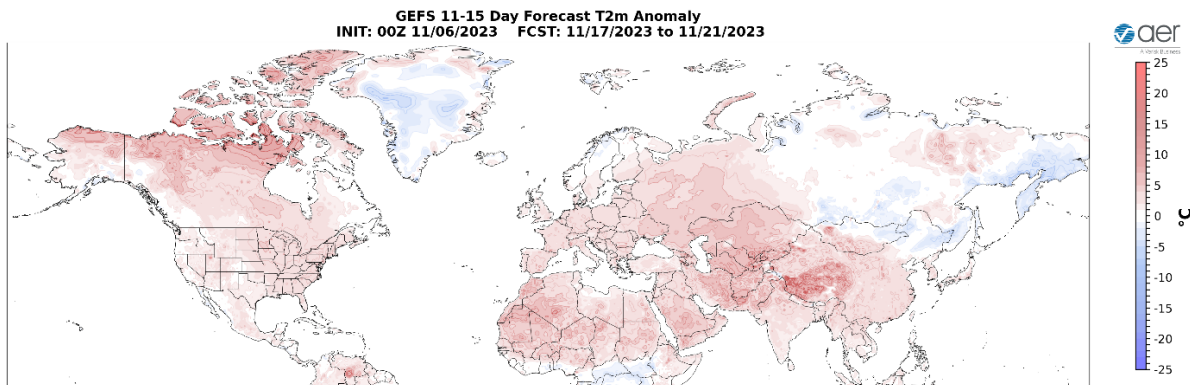


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 17 – 21 November 2023. The forecasts are from the 00z 6 November 2023 GFS ensemble.

Weak ridging/positive geopotential height anomalies are predicted to become focused across Alaska, Western Canada and the Western US with weak troughing/negative geopotential height anomalies across Eastern Canada and the Eastern US this period (**Figure 8**). This nearly zonal flow pattern favors widespread normal to above normal temperatures across Alaska, Canada and the US with normal to below normal temperatures limited to the West Coasts of Canada and the US and the Canadian Maritimes (**Figure 9**).

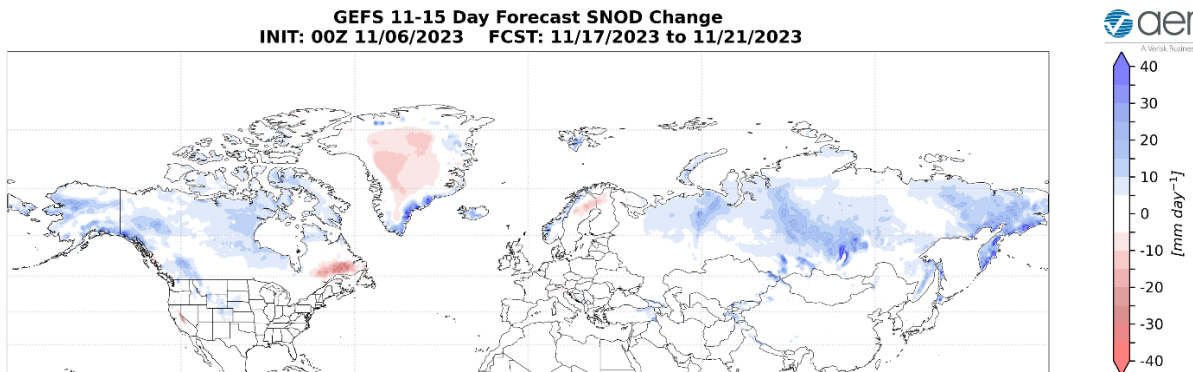


Figure 10. Forecasted snow depth changes (mm/day ; shading) from 17 – 21 November 2023. The forecast is from the 00Z 6 November 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Siberia while mild temperatures will support snowmelt in Scandinavia this period (**Figure 10**). Troughing and/or cold temperatures will support new snowfall across Alaska, Canada and the high elevations of the Western US while mild temperatures will support snowmelt in Southeastern Canada 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 troposphere with cold/negative PCHs in the stratosphere (**Figure 11**). This week and into next week cold/negative PCHs are predicted to deepen throughout the stratosphere and descend into the upper troposphere and eventually possibly to the surface while warm/positive PCHs are predicted to weaken and even disappear (**Figure 11**).

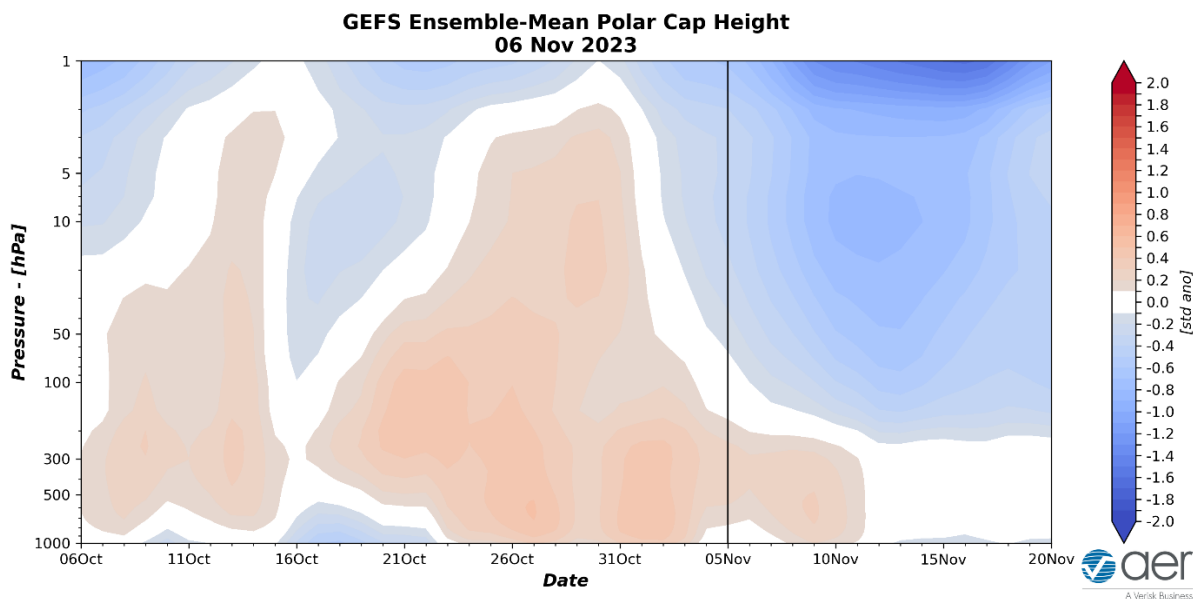


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 6 November 2023 GFS ensemble.

The predicted 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 surface AO is predicted to become more biased positive next week (**Figure 1**) coinciding with the predicted disappearance of warm/positive PCHs from the troposphere (**Figure 11**).

Also shown in **Figure 1** is the stratospheric AO. The stratospheric AO is currently positive but is predicted to become strongly positive for much of the next two weeks. This is consistent with cold/negative stratospheric PCHs and a strong PV that is often associated with widespread mild temperatures across the NH.

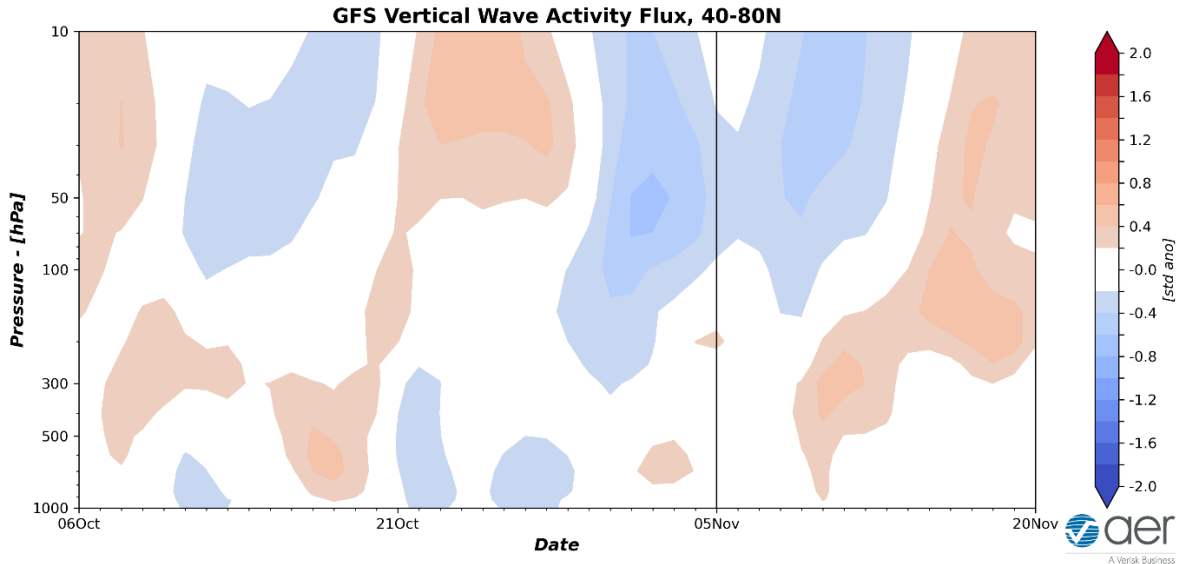


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 6 November 2023 GFS ensemble.

Vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere or poleward heat transport in the stratosphere has been overall less active than normal the past two weeks and this is predicted for the upcoming week as well (**Figure 12**). This favors cooling of the polar stratosphere (**Figure 11**) and a strengthening of the positive stratospheric AO (**Figure 1**). However next week the WAFz is predicted to become more active (**Figure 12**) and could lead to a minor disruption of the PV.

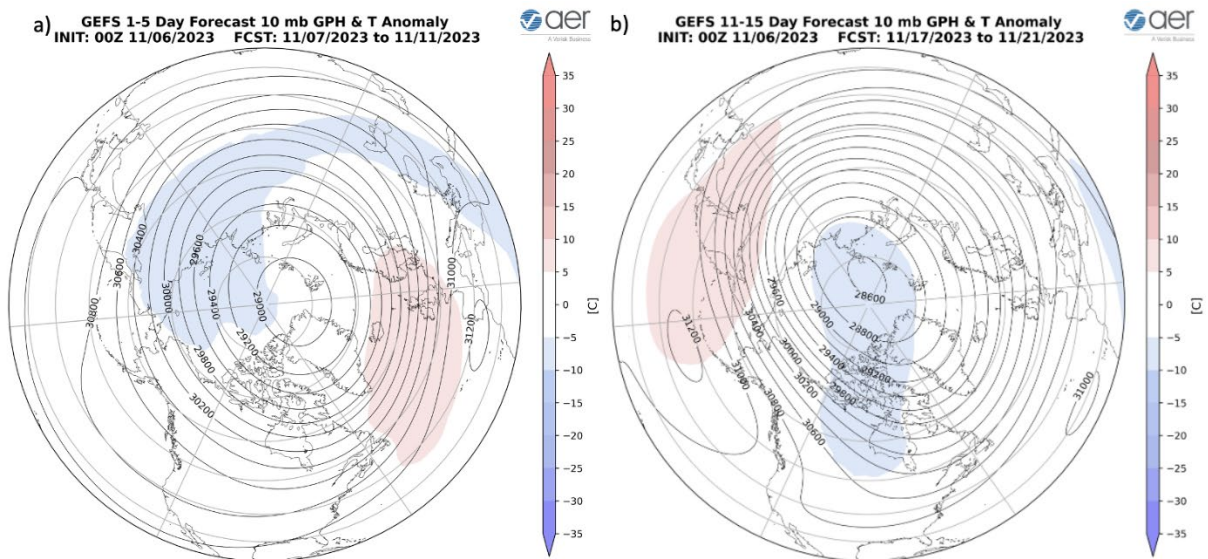


Figure 13. (a) Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for 7 – 11 November 2023 .
(b) Same as (a) except forecasted averaged from 17 – 21 November 2023. The forecasts are from the 00Z 6 November 2023 GFS model ensemble.

This week the polar vortex (PV) is predicted to be circular in shape with the PV center shifted slightly east of the North Pole (**Figure 13a**). The nearly circular PV shape is characteristic of a strong PV. However, starting next week and continuing into the third week of November, the PV shape is predicted to become more elongated (**Figure 13b**). This stretched PV configuration is characteristic of a stretched PV that often favors colder temperatures across East Asia and eastern North America. However, this stretched PV event looks to be relatively minor.

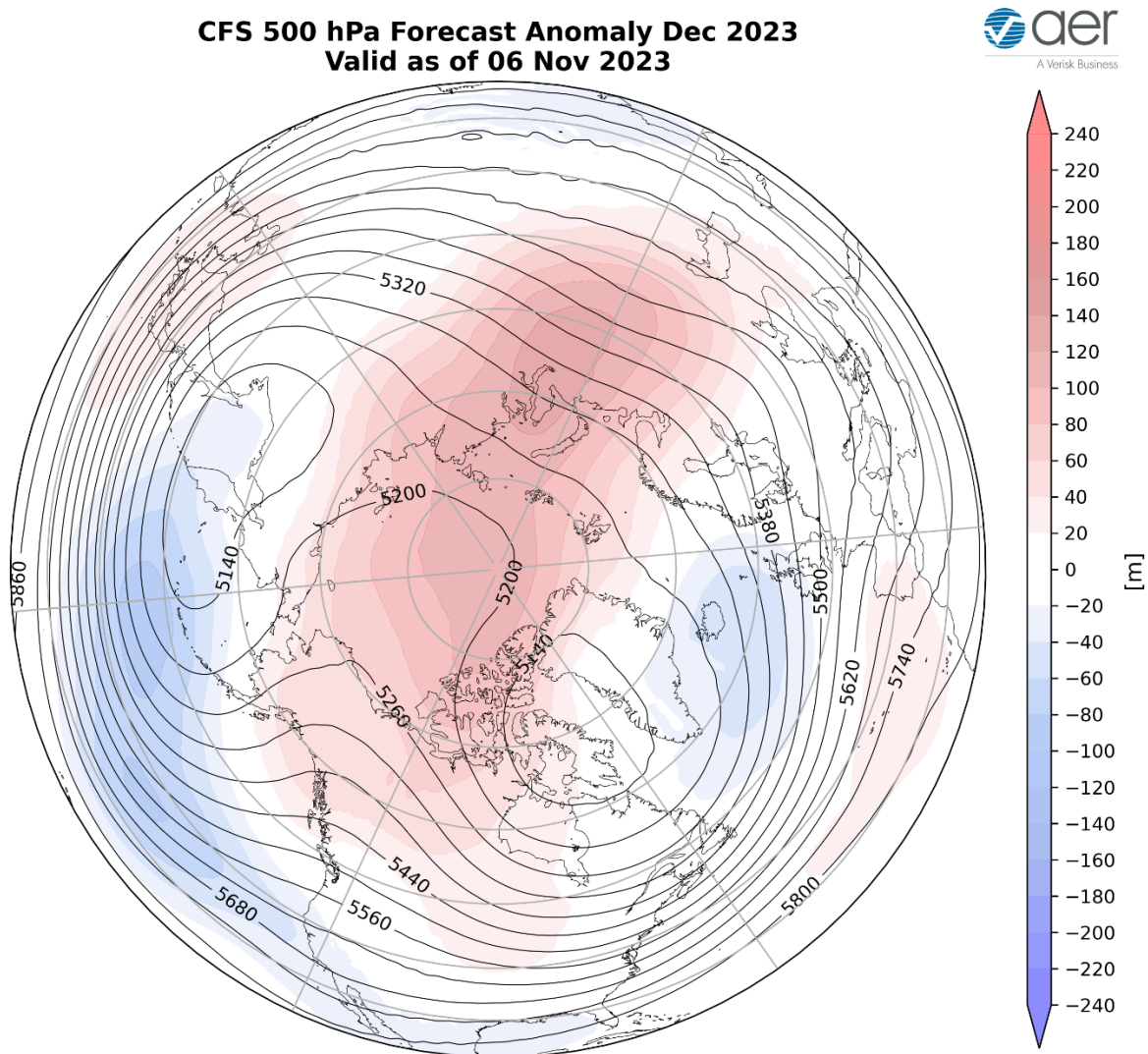


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for November 2023. The forecasts are from the 00Z 6 November 2023 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and surface temperatures for December (**Figure 15**) 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 to the Barents-Kara Seas, the North Pacific side of the Arctic, Alaska and Western Canada with troughing in Siberia, Northeast Asia and into the North Pacific, eastern North America extending into the North Atlantic and Greenland (**Figure 14**). This pattern favors seasonable to relatively warm temperatures across Europe, Northern Siberia, Western and Southern Asia, Alaska, Western Canada and the Western US with seasonable to relatively cold temperatures across Southern Siberia, Northeast Asia, Eastern Canada and the Eastern US (**Figure 15**).

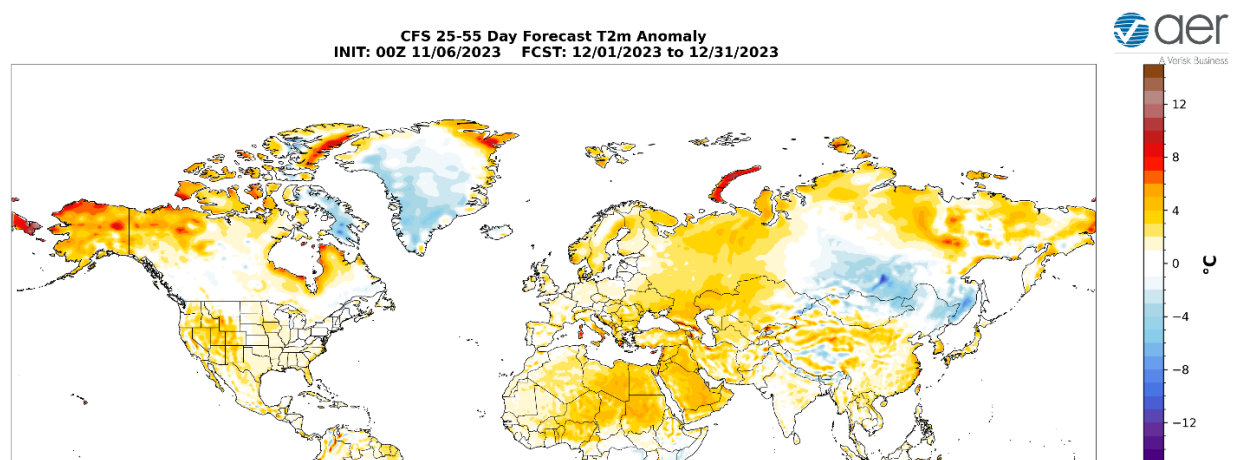


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for November 2023. The forecasts are from the 00Z 6 November 2023 CFS.

Boundary Forcings

Arctic sea ice extent

Arctic sea ice extent continues to grow at a good clip but especially in the North Pacific sector, with sea ice filled in on the Asian side. I continue to expect that the negative sea ice anomalies will become more focused in the North Atlantic sector. Blocking in the Barents-Kara sea region is critical from keeping a runaway PV that will squash any widespread and meaningful cold in Northern Eurasia and eastern North America for weeks and possibly even months to come.

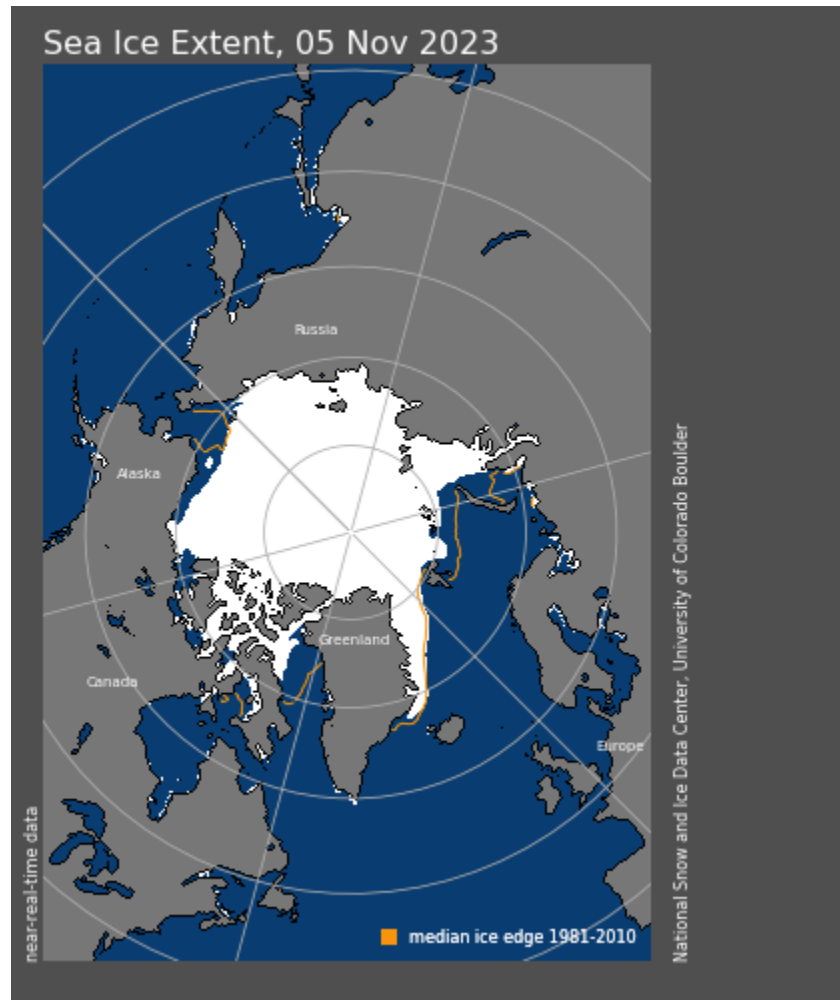


Figure 16. Observed Arctic sea ice extent on 5 November 2023 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

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 17**) 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.

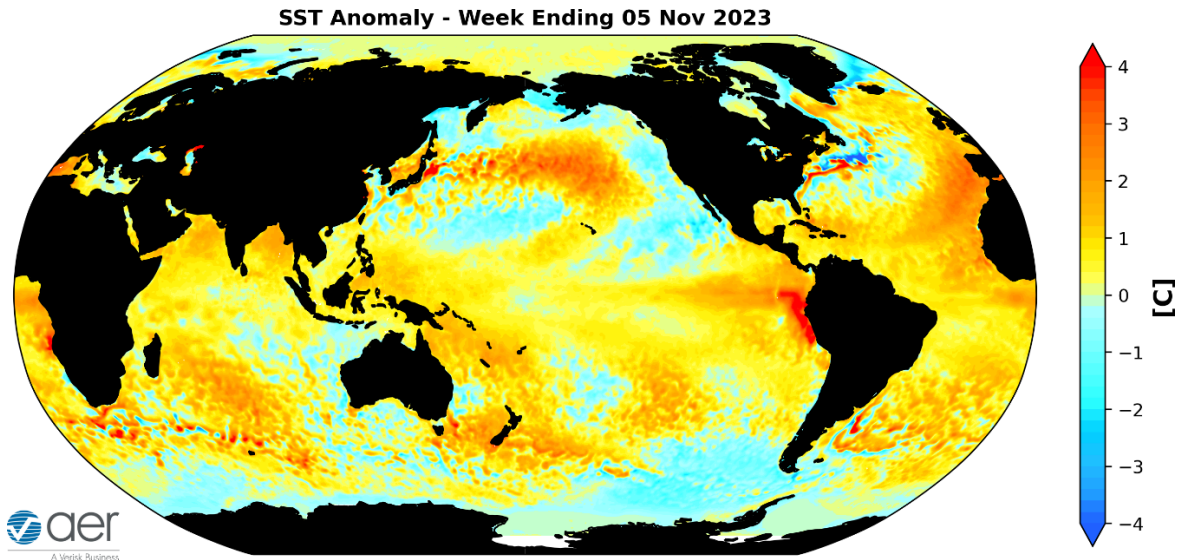


Figure 17. The latest weekly-mean global SST anomalies (ending 5 November 2023). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently the Madden Julian Oscillation (MJO) is weak where no phase is favored (**Figure 1**). The forecasts are for the MJO to remain weak where no phase is favored and emerge into phases eight and one. Phases eight and one favor troughing along the west coast of North America and ridging in eastern North America. Therefore it seems that the MJO is having little to none influence on North American weather this week and into next week. But admittedly this is outside of my expertise.

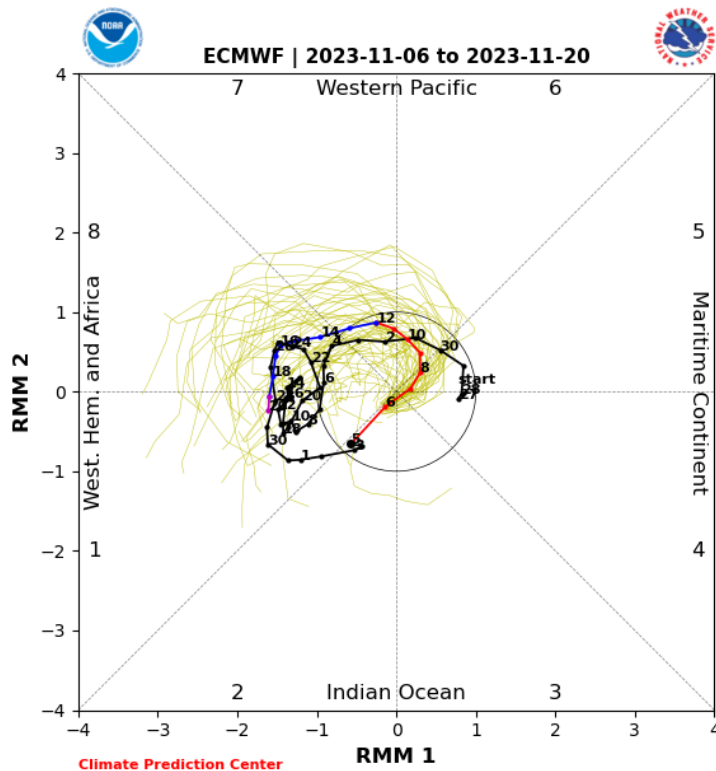


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 6 November 2023 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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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