Arctic Oscillation and Polar Vortex Analysis and Forecasts

November 13, 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 positive the next two weeks as pressure/geopotential height anomalies across the Arctic are mostly negative and are predicted to remain mostly negative over the next two weeks. The North Atlantic Oscillation (NAO) is currently negative with weak but mostly positive pressure/geopotential height anomalies across Greenland and the NAO is predicted to trend positive the next two weeks as pressure/geopotential height anomalies become increasingly negative 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 Southern and Eastern Asia with troughing/negative geopotential height anomalies across Northwestern Asia and Eastern Siberia. Then next week, troughing/negative geopotential height anomalies will spread east across Northern Siberia while ridging/positive geopotential height anomalies are suppressed south. This pattern favors this week widespread normal to above normal temperatures across much of Asia including Central and Western Siberia with normal to below normal temperatures limited to Northwest Russia and Eastern Siberia and then next week normal to above normal temperatures will continue to dominate Asia with normal to below temperatures becoming more widespread across Northern Siberia.

- The general predicted pattern across North America this week is a zonal pattern with troughing/negative geopotential height anomalies across Alaska and Northern Canada with ridging/positive geopotential height anomalies across the United States (US). Then next week the pattern will become more amplified with strengthening ridging/positive geopotential height anomalies across Alaska and Western Canada with deepening troughing/negative geopotential height anomalies in eastern North America. This pattern generally favors normal to above normal temperatures across Alaska, much of Canada and the United States (US) this week with normal to below normal temperatures becoming more widespread across Canada and the US east of the Rockies. Though the ECMWF is predicting the cold will be shifted further west across the US.

- in the Impacts section I discuss my expected evolution of polar vortex (PV) behavior over the coming weeks and the impact on Northern Hemisphere (NH) weather.

Plain Language Summary

I have been expecting a stretching of the polar vortex (PV) 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 for what like seems an eternity. Looks like the wait is finally over with all the models predicting an event the last week of November that should reverse a mild North American pattern to a colder one (see **Figure 9**). Though there are some model disagreements to where the coldest air will be focused.

Longer term looks like an uneventful period for the PV, through much if not all of December, which more often than not translates into an overall mild pattern across the NH. One possible exception is more rubber band stretching of the PV that brings colder weather to North America and even at times disruptive snowfalls possibly mid to late December.

Impacts

The long-awaited stretched PV (from me at least) for the second half of November is now predicted by all the weather models. Cold air is predicted to overspread a large area of North America the last week of November as seen in **Figure 9**.

So far, the models are predicting seasonably cold temperatures but often with these events the models are constantly playing catchup, so the forecast could still trend colder with time. Last week I discussed how the cold of the core should be focused further east than the previous event that began at the end of October, but the ECMWF differs with the placement of the cold, with the core of the cold once again focused across the Western US. I can see either solution as correct and it might depend on the orientation of the PV. But over the past three winters the cold has been focused further west so hard to bet against the trend. El Niño should favor the cold air further east, but El Niño might look impressive in the weekly sea surface temperature anomalies, but someone forgot to tell the atmosphere.

The impacts from stretched PV events typically last one to two weeks and I see no reason not to expect the same for this upcoming event. This should be followed by a relaxation of the pattern and a return to mostly mild temperatures across the NH. I occasionally discuss our polar vortex model that predicts the strength of the PV up to a month in advance. It has many issues so I rely on it sparingly, but it does predict that the strength of the PV will peak this week and then begin to weaken and then bottoming out second week of December. This is very speculative but based on this there could be another stretched PV event in mid-December. Anyway, something to watch.

However, I fail to see a more meaningful weakening or disruption of the PV for the foreseeable future. In **Figure i**, I show the CFS forecast of 500 hPa geopotential heights for the remainder of November and below normal heights can be seen in the Central Arctic and centered near the Urals. This is not a favorable pattern for a large disruption of the PV and could support the opposite or a strong PV. The ECWMF weeklies persist this tropospheric pattern well into December. I did mention last week that the ECMWF forecast of troughing near the Urals and a weak PV were mutually inconsistent and I see that the latest ECMWF forecast has finally backed off the weak PV for December. The CFS is predicting extensive high latitude blocking for December (see **Figure 14**). Of course anything is possible but hard for me to see that forecast verifying based on the November forecast.
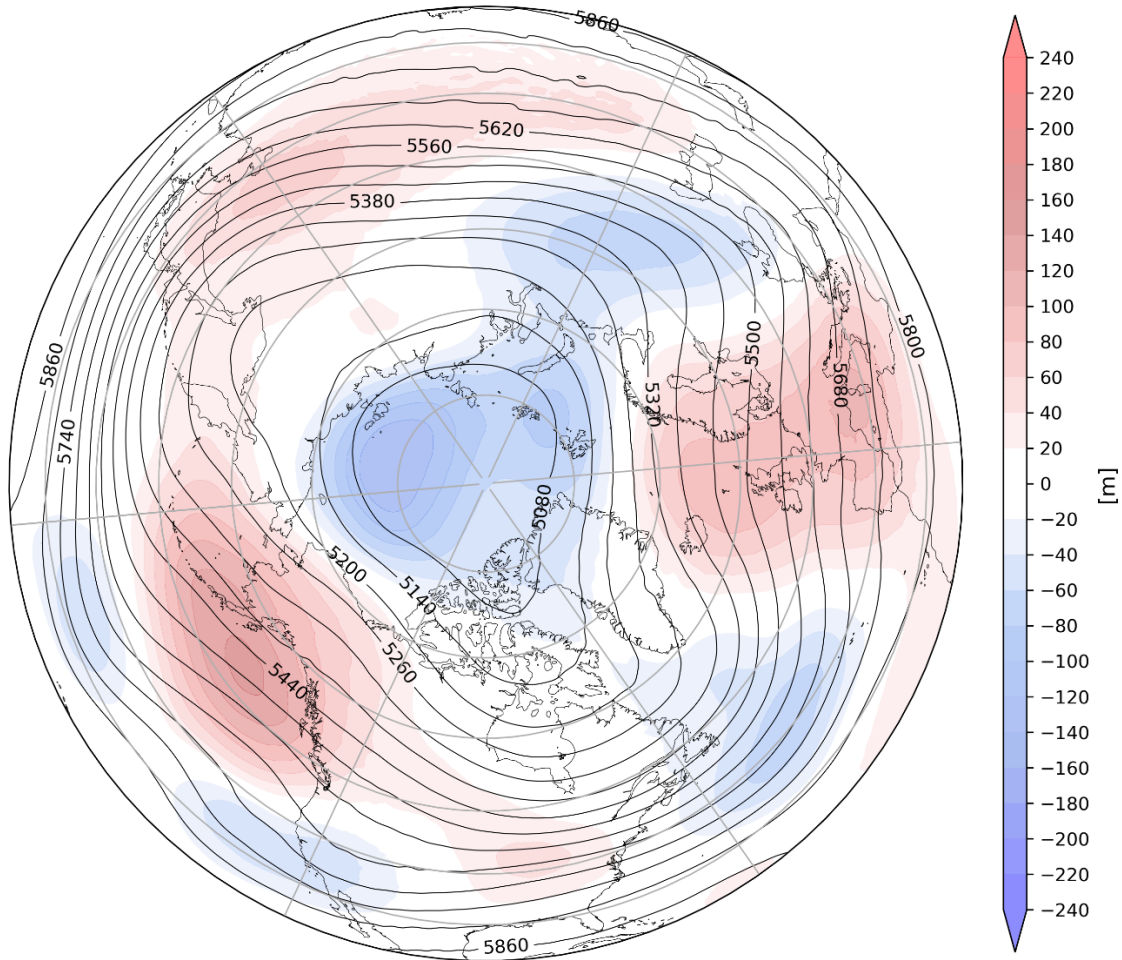
Figure i. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for November 2023. The forecasts are from the 00Z 13 November 2023 CFS.

At this point I don't see much possibility of a large PV disruption until 2024. The latest polar cap geopotential height anomalies (PCHs) are a sea of blue (see **Figure 11**). When a strong PV couples to a positive AO/lack of high latitude blocking, that takes time to unwind. I do believe that it is hard to get any sustained cold into Europe without a large PV disruption. Europe has been overall mild with the very notable exception of Scandinavia (see **Figure ii**). Not sure what is going on with Scandinavia, but it was cold last winter as well despite an overall mild winter across Europe. I don't understand why, but I guess that same trend can continue.
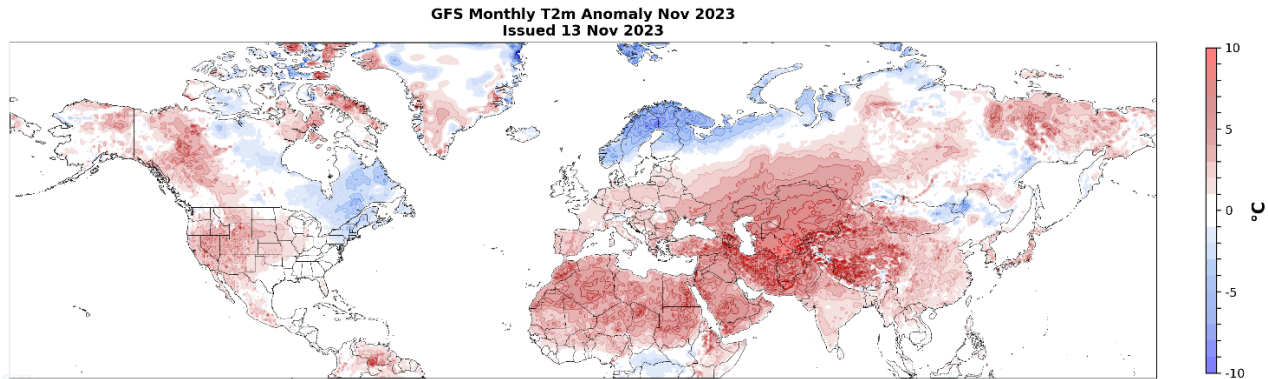
GFS Monthly T2m Anomaly Nov 2023
Issued 13 Nov 2023

Figure ii. Observed surface temperature anomalies (°C; shading) from 1 – 12 November 2023. The observations are from the GFS initializations.

The high latitude surface forcings that I follow closely are not showing much direction. In recent winters even when Eurasian snow cover extent has been low, snow depth in Siberia has been high. Lv et al. (2020) argued that deep snow in Siberia favors a weaker PV. However snow is shallow in large parts of Siberia as seen in **Figure iii** but shows up more dramatically in this tweet from the @WorldClimateSvc. Also Arctic sea ice extent is below normal but it is almost equally distributed in Baffin Bay, the Barents Kara Seas and the Beaufort Seas. Until the negative anomalies become focused in the Barents-Kara Seas this does not support a large PV disruption but could help support more stretched PV events.
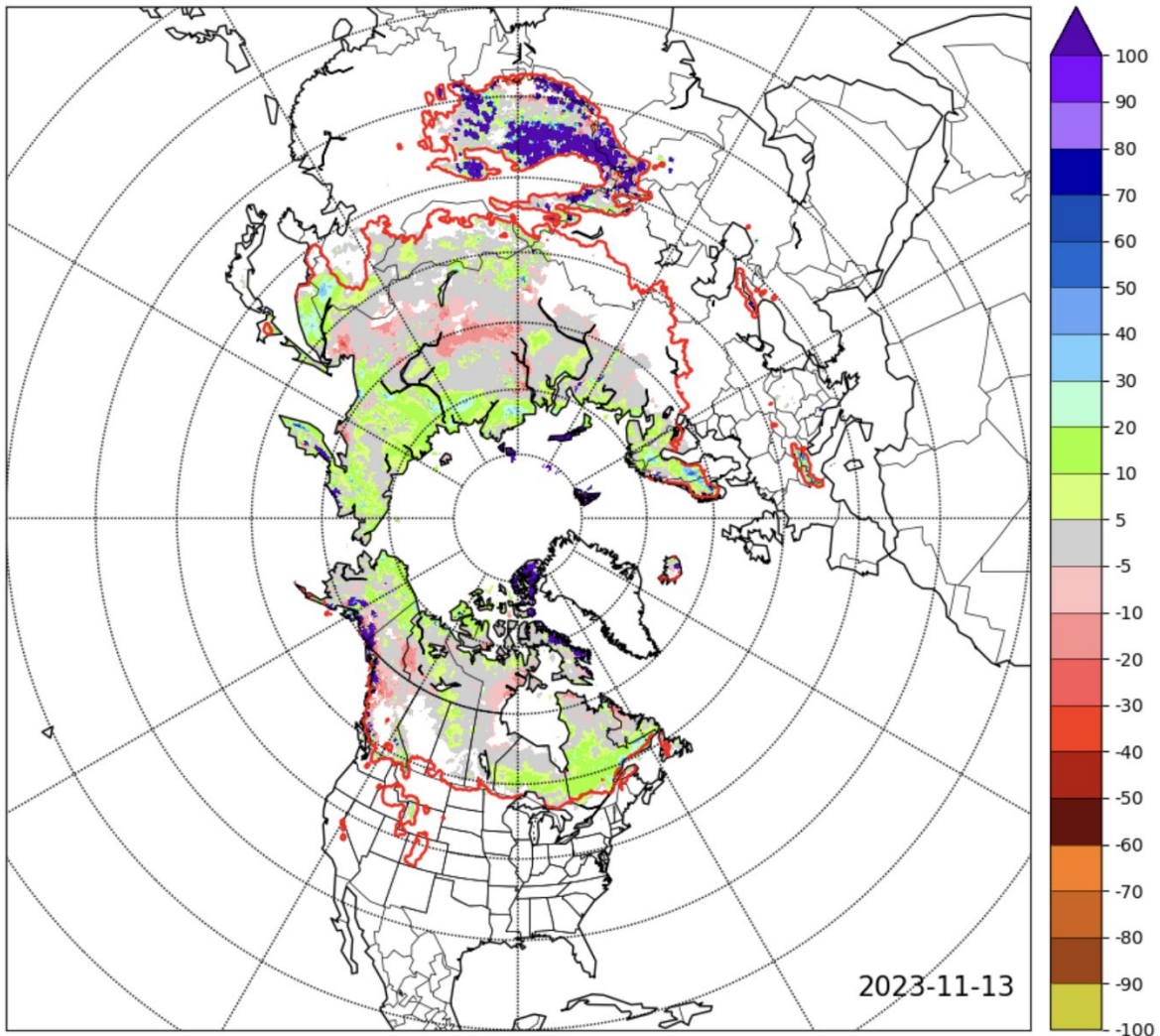
Figure iii. Northern Hemisphere snow depth anomalies. plot taken from
https://ccin.ca/index.php/ccw/snow/current/

The strongest case that I can present for an eventual weakening of the PV is a notable
west to east dipole in snow cover extent anomalies (below normal in the west and
above normal in the east) this month across Eurasia (see **Figure iv**). As I discussed in
the blog from 23 October 2023, research has shown this pattern can favor a weak PV
and a negative AO/NAO during the winter.

Daily SCE Departure - November 12, 2023 (Day 316)
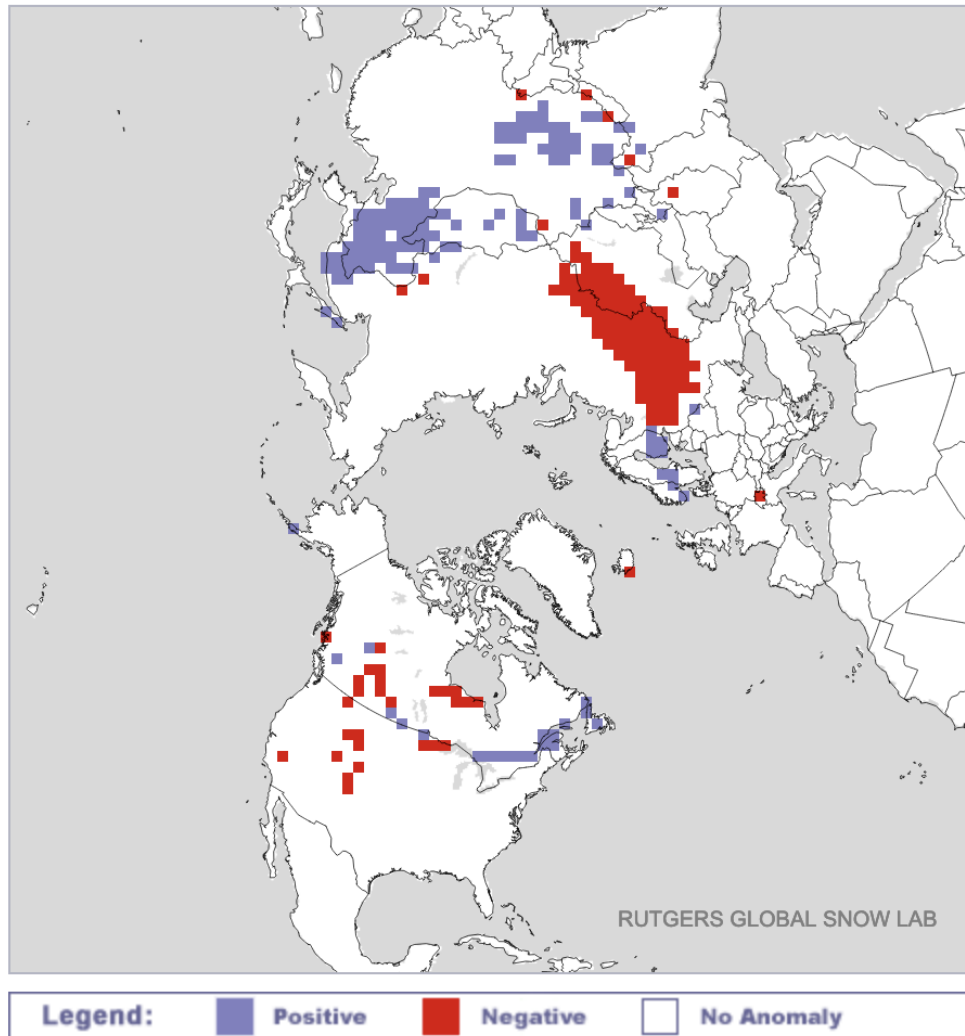
Figure iv. Northern Hemisphere snow cover extent anomalies for 12 November 2023.
Plot taken from http://climate.rutgers.edu/snowcover/index.php

In conclusion I don't see any large PV disruptions for the foreseeable future which tends to favor widespread relatively mild temperatures across the NH but especially Europe. With a lower threshold needed for stretched PVs, I have the mid- to late-December timeframe circled for another possible stretched PV but this is almost solely based on a long range model with lots of deficiencies, so caution with such a prediction is warranted.

Near-Term

This week

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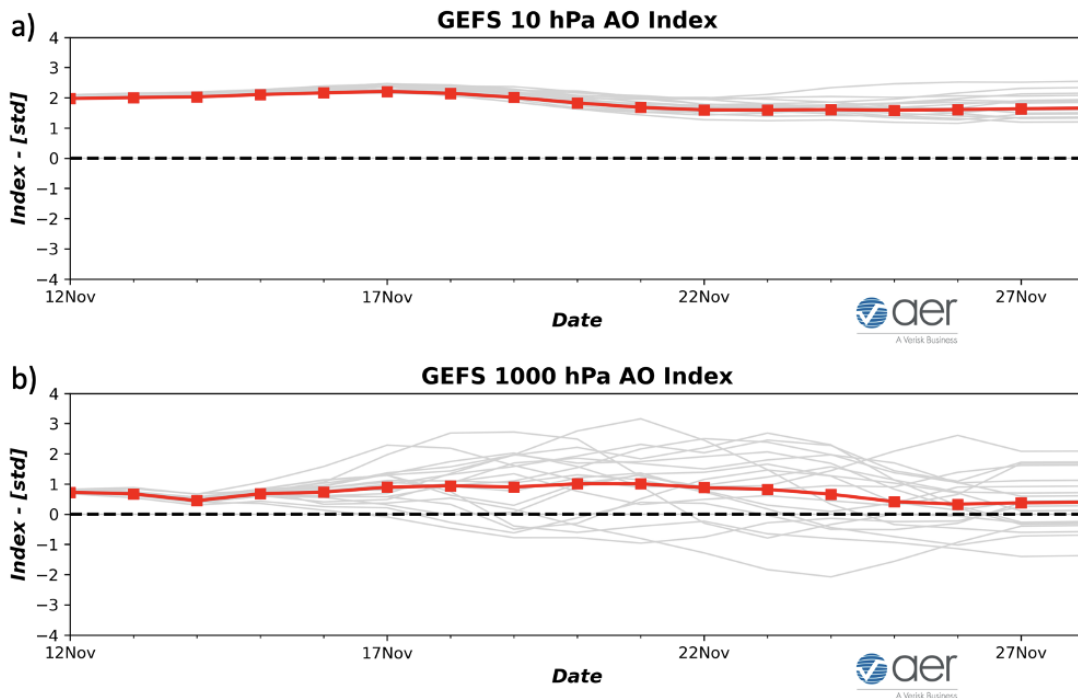

Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 13 November 2023 GFS ensemble. (b)The predicted daily-mean near-surface AO from the 00Z 13 November 2023 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Ridging/positive geopotential height anomalies stretching across Greenland 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 including the UK with normal to below normal temperatures limited to Scandinavia (**Figure 3**). This week Asia is predicted to be dominated by ridging/positive geopotential height anomalies centered in Southern and Eastern Asia including much of Siberia with troughing/negative geopotential height anomalies in Western Asia (**Figure 2**). This pattern favors widespread normal to above normal temperatures across much of Asia including most of Siberia with normal to below normal temperatures across Northwest Russia and Eastern Siberia (**Figure 3**).
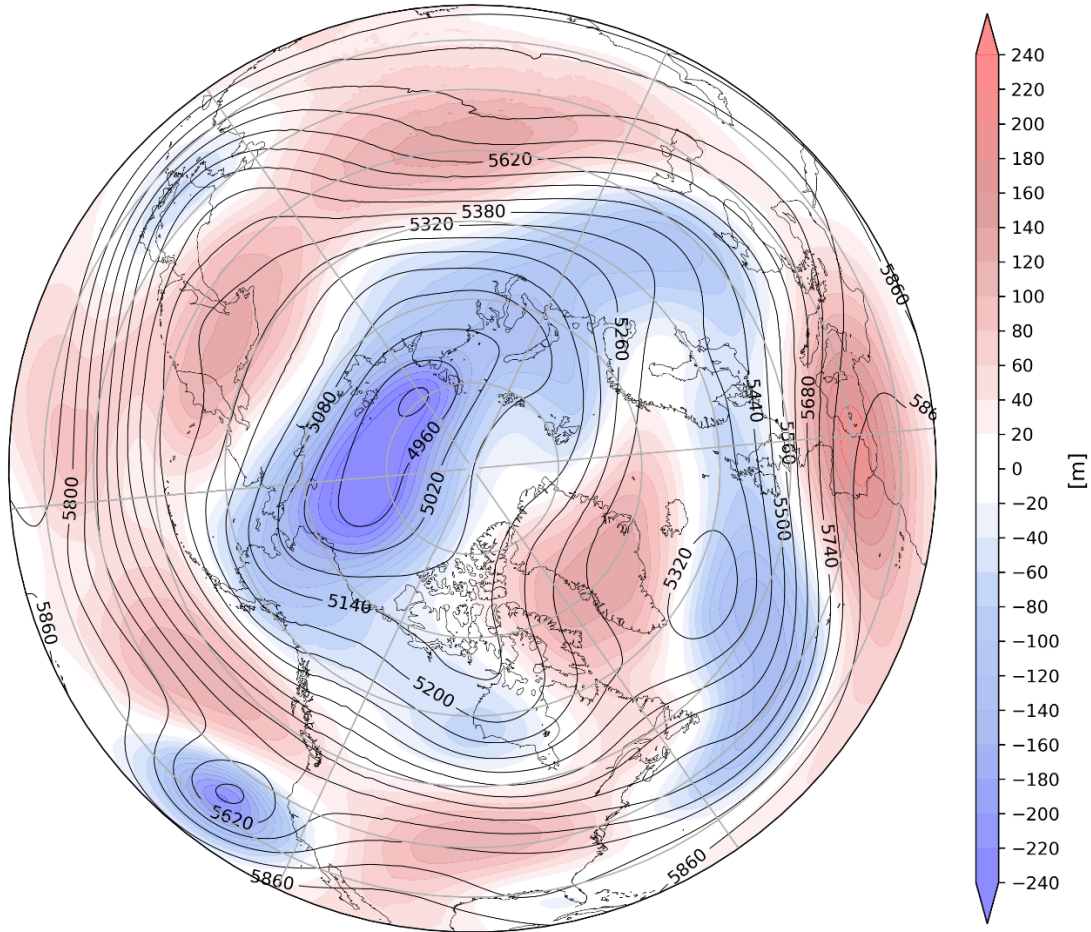
Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 14 – 18 November 2023. The forecasts are from the 00z 13 November 2023 GFS ensemble.

The pattern this week across North America is troughing/negative geopotential height anomalies across Alaska and Northern Canada with ridging/positive geopotential height anomalies cross the US centered in the US Plains **(Figure 2).** This pattern will favor widespread normal to above normal temperatures across Alaska, much of Canada and the US with normal to below normal temperatures limited to northern Hudson Bay and the Pacific Northwest **(Figure 3).**
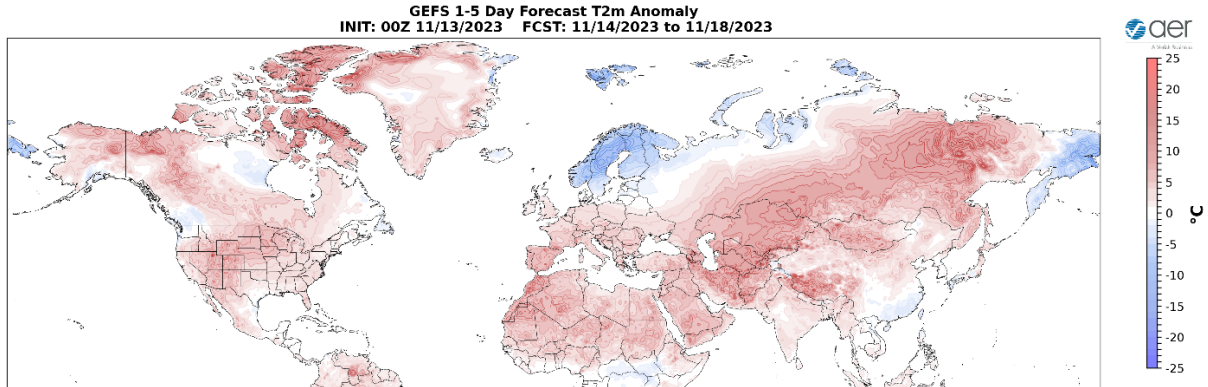
Figure 3. Forecasted surface temperature anomalies (°C; shading) from 14 – 18 November 2023. The forecast is from the 00Z 13 November 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Norway, the Alps and Siberia 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 Northern Canada while mild temperatures will support snowmelt across Southern Canada this week (**Figure 4**).
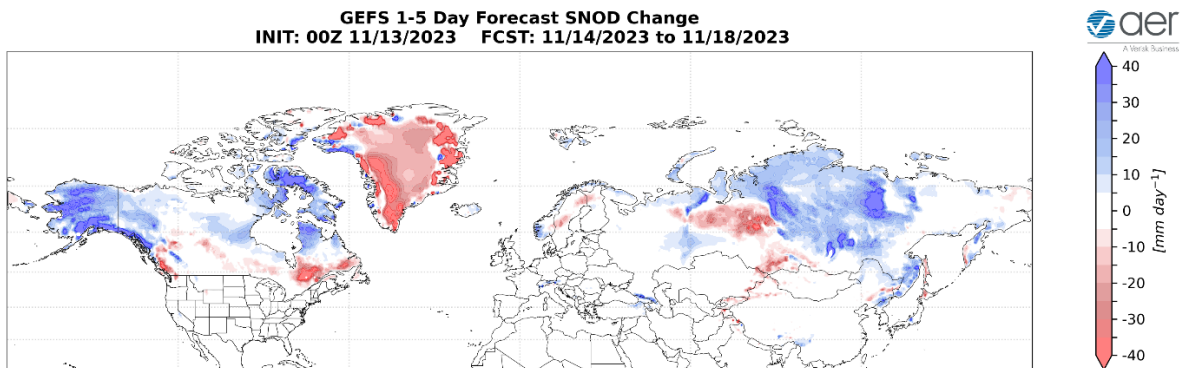

Figure 4. Forecasted snow depth changes (mm/day; shading) from 14 – 18 November 2023. The forecast is from the 00Z 13 November 2023 GFS ensemble.

Near-Mid Term

Next week

With mostly negative geopotential height anomalies across the Arctic and with mixed geopotential height anomalies across the mid-latitudes this period (**Figure 5**), the AO should remain positive 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.
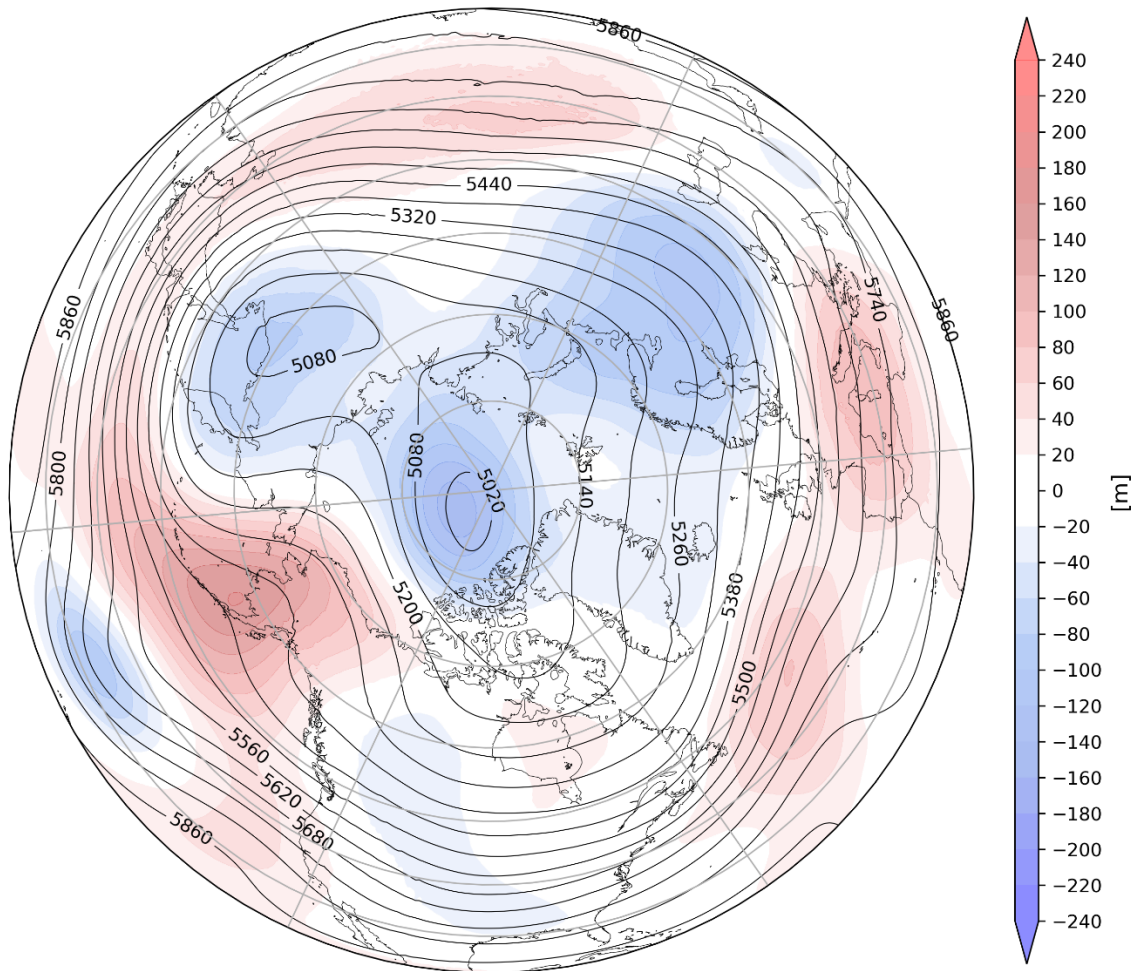
Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 19 – 23 November 2023. The forecasts are from the 00z 13 November 2023 GFS ensemble.

Persistent troughing/negative geopotential height anomalies across Northern Europe with more ridging/positive geopotential height anomalies across Southern Europe are predicted 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**). Persistent troughing/negative geopotential height anomalies in Northwest Asia are predicted to spread east into Siberia with ridging/positive geopotential height anomalies stretched across Southern Asia this period (**Figure 5**). This pattern favors widespread normal to above normal temperatures across much of Asia including Eastern Siberia with normal to below normal temperatures limited to far Northwest Asia and Northern Siberia this period (**Figure 6**).
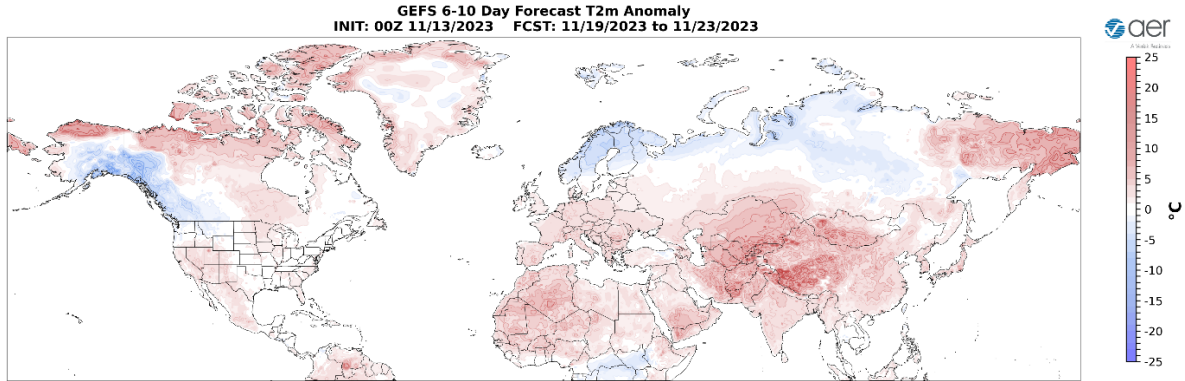
Figure 6. Forecasted surface temperature anomalies (°C; shading) from 19 – 23 November 2023. The forecasts are from the 00z 13 November GFS ensemble.

The predicted general pattern across North America this period is developing ridging/positive geopotential height anomalies across Alaska and the Gulf of Alaska forcing downstream troughing/negative geopotential height anomalies across western North America inducing southwest flow across eastern North America (**Figure 5**).   This pattern favors normal to above normal temperatures across northern Alaska, Canada, the Southwestern US and the US east of the Rockies with normal to below normal temperatures across Western Canada and the Northwestern US (**Figure 6**).
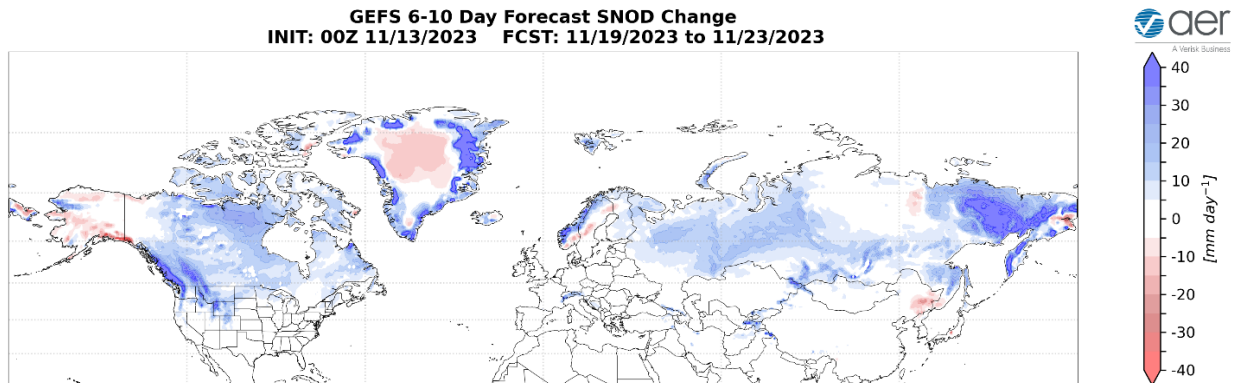

Figure 7. Forecasted snow depth changes (mm/day; shading) from 19 – 23 November 2023. The forecast is from the 00Z 13 November 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Norway, much of Siberia and the Tibetan Plateau while mild temperatures will support snowmelt in Northeastern China and Sweden this period (**Figure 7**). Troughing and/or cold temperatures will support new snowfall across much of Canada and the high elevations of the Western US while mild temperatures will support snowmelt in Southern Alaska 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 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.
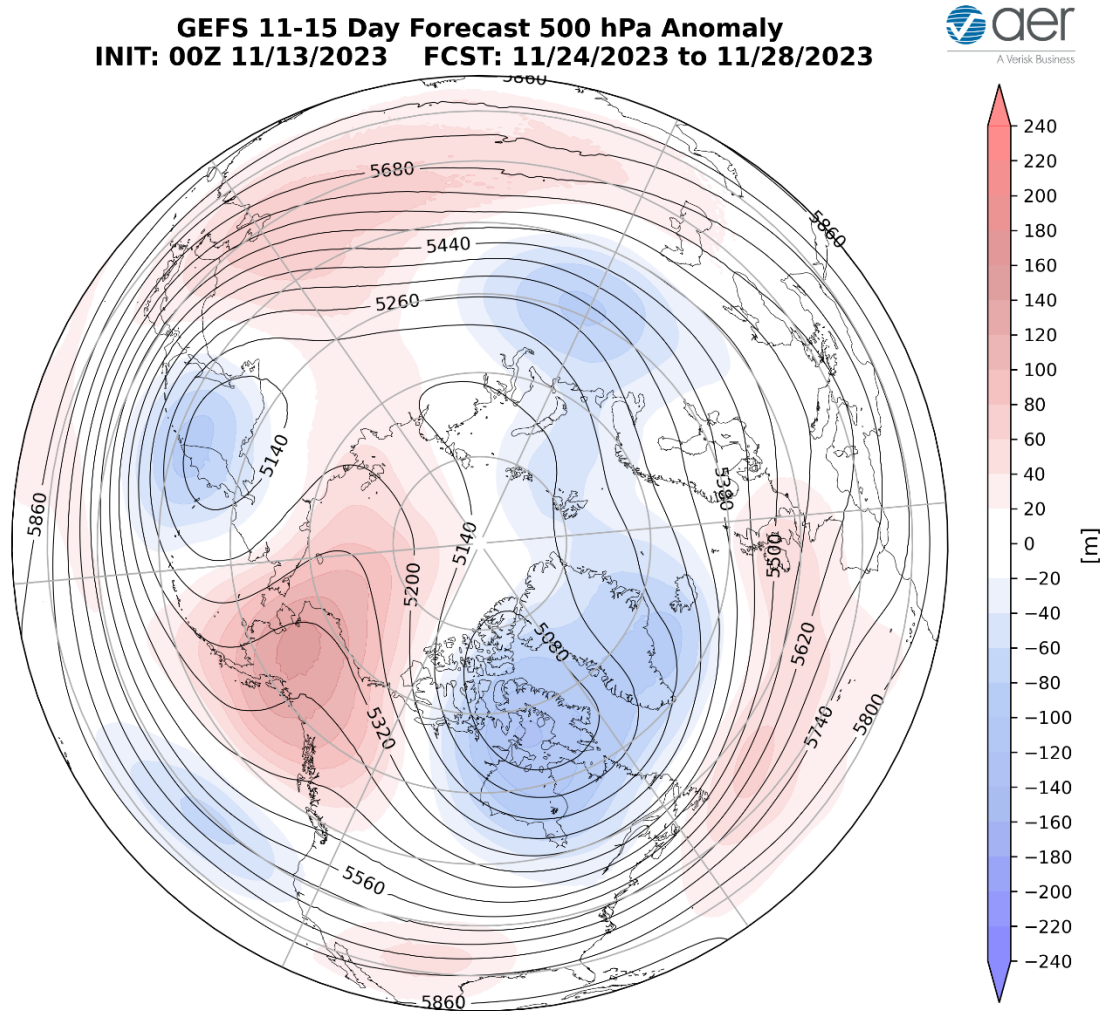

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 24 – 28 November 2023. The forecasts are from the 00z 13 November 2023 GFS ensemble.

The overall pattern of troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height anomalies across Southern Europe should persist 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 Scandinavia this period (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to continue to dominate Southern Asia with troughing/negative geopotential height anomalies spread across Northern Asia including Siberia 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 parts of Siberia and parts of Northwest Asia this period (**Figure 9**).
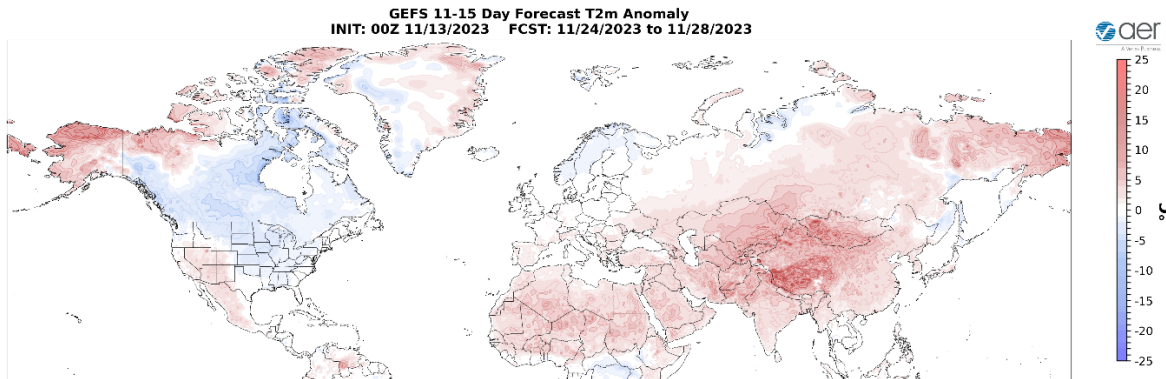

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 24 – 28 November 2023. The forecasts are from the 00z 13 November 2023 GFS ensemble.

Strengthening ridging/positive geopotential height anomalies centered across Alaska, will force downstream troughing/negative geopotential height anomalies across Eastern Canada and the Eastern US this period (**Figure 8**). This more meridional flow pattern favors widespread normal to above normal temperatures across Alaska, Northwest Canada and the Southwestern US with normal to below normal temperatures widespread across Canada and the Northern and Eastern US (**Figure 9**). However, the ECMWF is predicting that the cold will be shifted further west including much of the Western US with normal to above normal temperatures along the US East Coast.
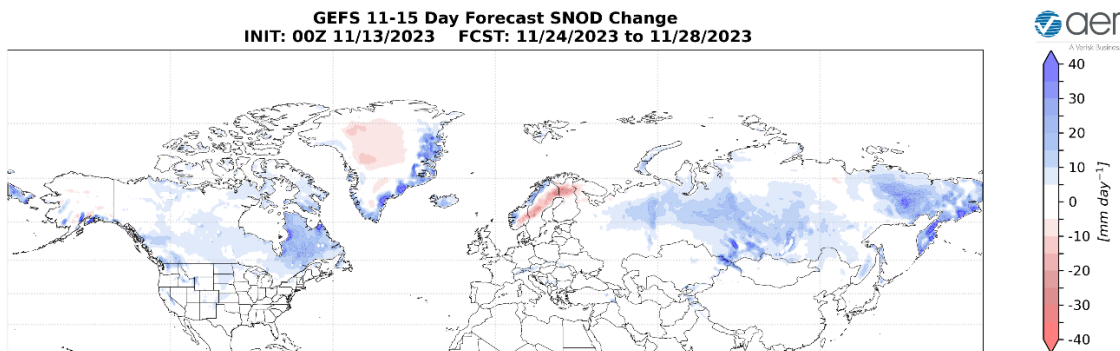

Figure 10. Forecasted snow depth changes (mm/day; shading) from 24 – 28 November 2023. The forecast is from the 00Z 13 November 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Siberia and Norway while mild temperatures will support snowmelt in Sweden this period (**Figure 10**). Troughing and/or cold temperatures will support new snowfall across parts of Canada and the high elevations of the Western US while mild temperatures will support snowmelt in parts of Alaska this period (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows cold/negative PCHs in the stratosphere and in the troposphere (**Figure 11**). This week and into next week cold/negative PCHs are predicted to dominate both the stratosphere and the troposphere with no real sign of warm/positive PCHs are predicted for the foreseeable (**Figure 11**).
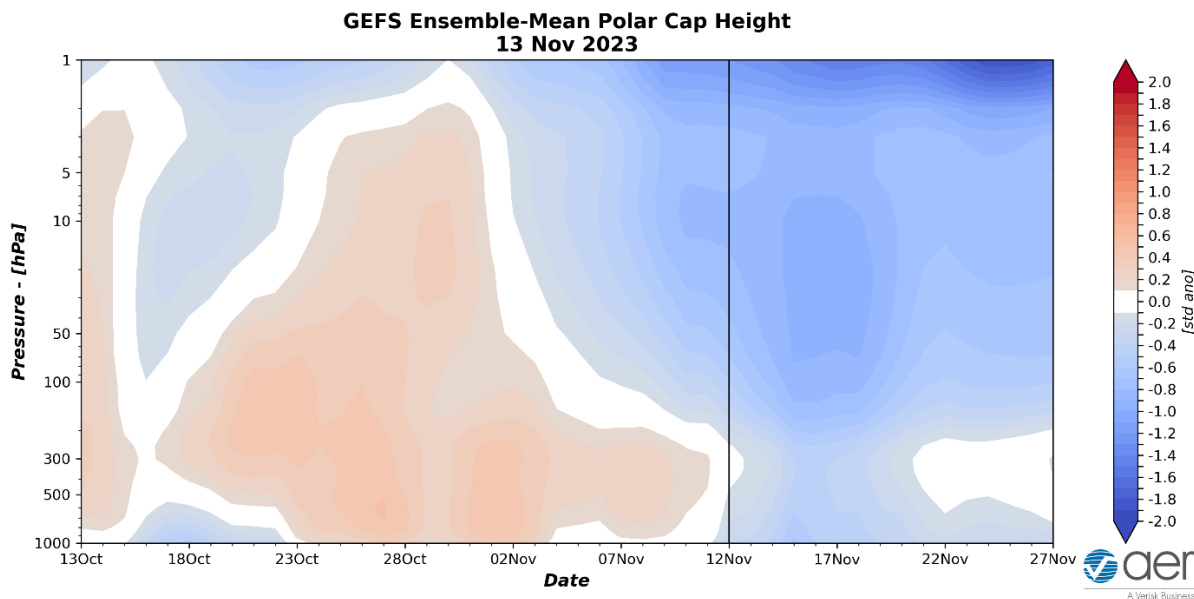

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 13 November 2023 GFS ensemble.

The predicted cold/negative PCHs in the lower troposphere the next two weeks (**Figure 11**) are consistent with the predicted positive surface AO the next two weeks (**Figure 1**).

Also shown in **Figure 1** is the stratospheric AO. The stratospheric AO is currently positive and is predicted to remain positive to 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.
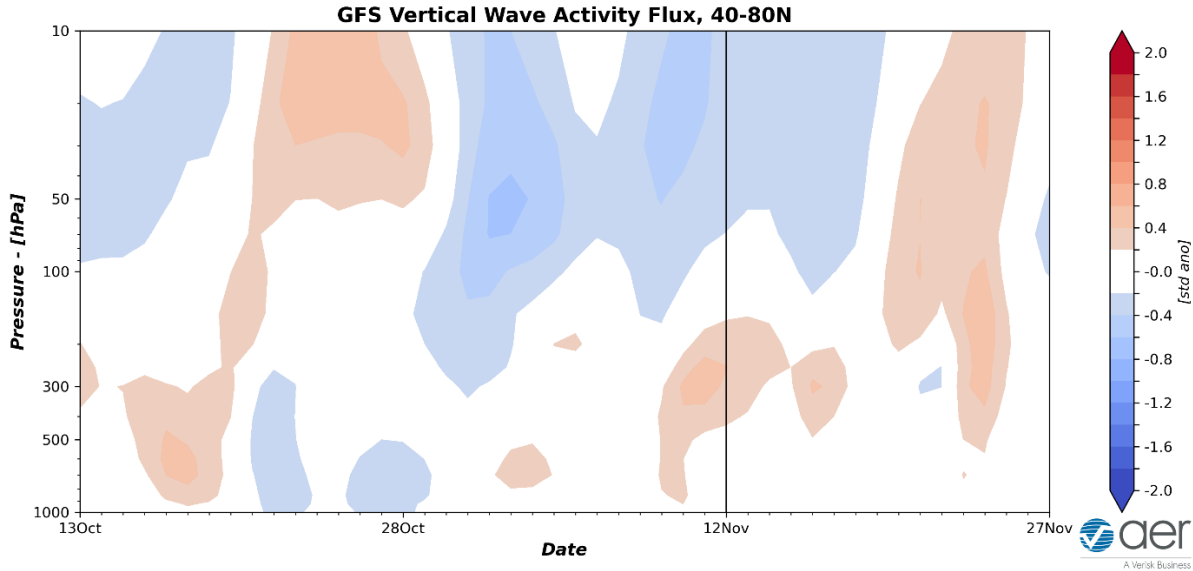
Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 13 November 2023 GFS ensemble.

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 since the end of October 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 somewhat more active (**Figure 12**) and could lead to a minor disruption of the PV later in December.
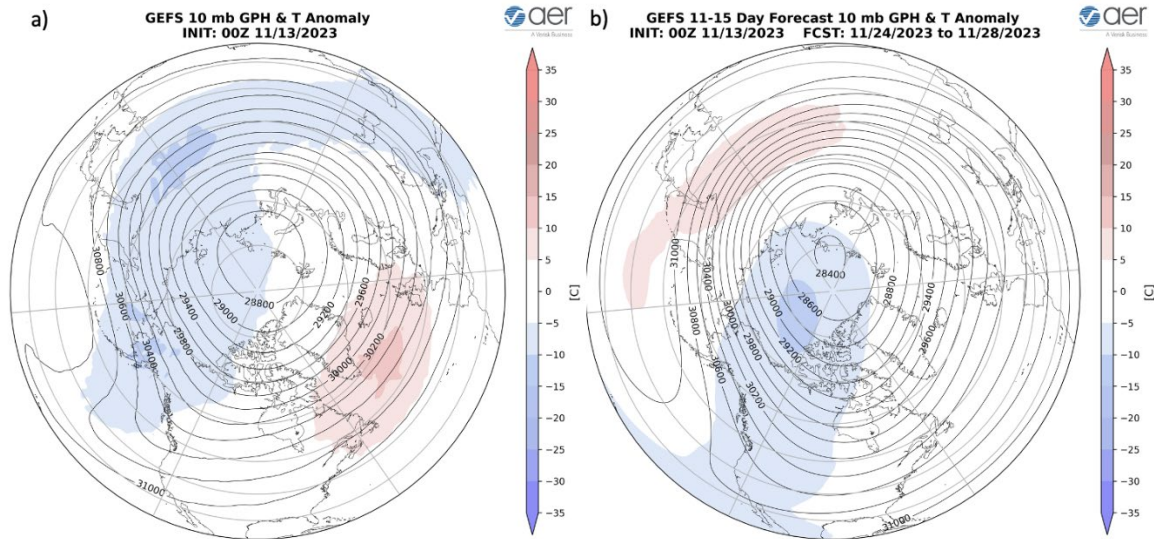
Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 13 November 2023 . (b) Same as (a) except forecasted averaged from 24 – 28 November 2023. The forecasts are from the 00Z 13 November 2023 GFS model ensemble.

Currently the polar vortex (PV) is predicted to be circular in shape with the PV center shifted slightly south of the North Pole centered in the Barents-Kara Seas (**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 along an axis from Western Siberia to Central Canada (**Figure 13b**). This elongated PV configuration is characteristic of a stretched PV that often favors colder temperatures across East Asia and eastern North America.
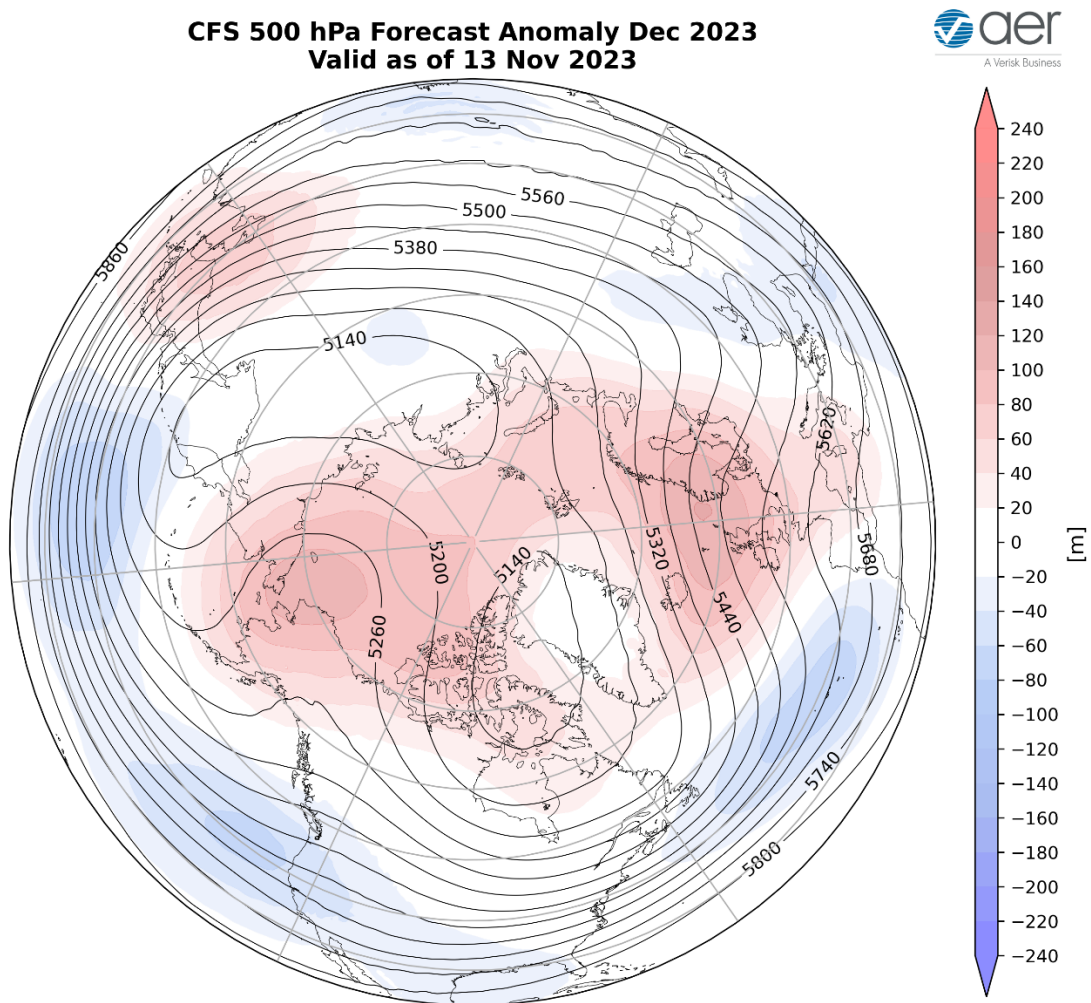

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for December 2023. The forecasts are from the 00Z 13 November 2023 CFS.

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 Iceland across to Scandinavia and then the Barents-Kara Seas, the Central Arctic, the Beaufort Seas and Alaska with troughing in Eastern Europe/Western Asia, Siberia, Northeast Asia and into the North Pacific, eastern North America and extending into the North Atlantic (**Figure 14**).   This pattern favors seasonable to relatively warm temperatures across Western Europe, Southern Asia, Eastern Siberia, Alaska, Northern Canada and the Western and Southern US with seasonable to relatively cold temperatures across Eastern Europe, Western and Central Siberia, Northeast Asia, much of Canada and the Northeastern US (**Figure 15**).
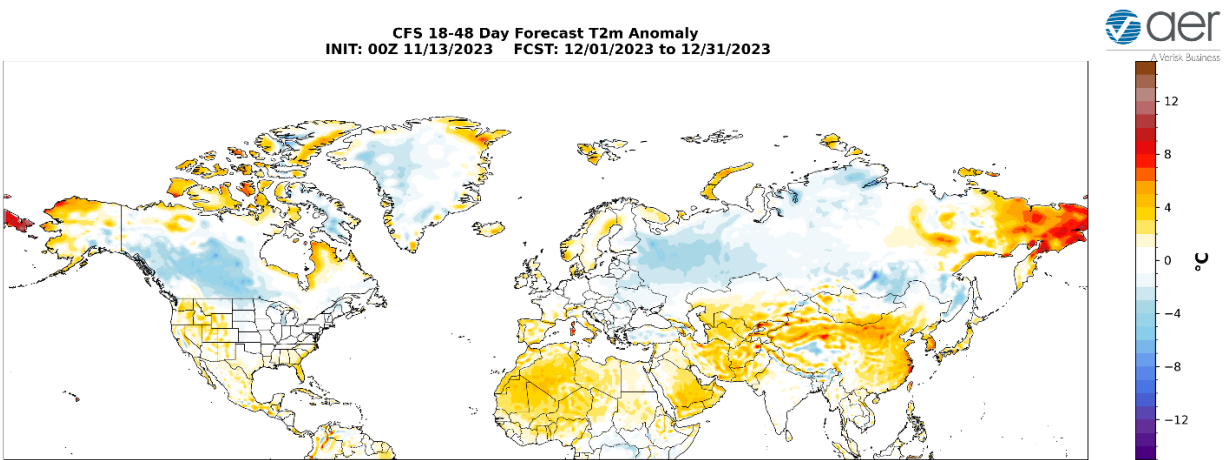

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for December 2023. The forecasts are from the 00Z 13 November 2023 CFS.

Boundary Forcings

Arctic sea ice extent

Arctic sea ice extent continues to grow at a good clip. I continue to expect that the negative sea ice anomalies will become more focused in the North Atlantic sector, though so far this has not happened. 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.
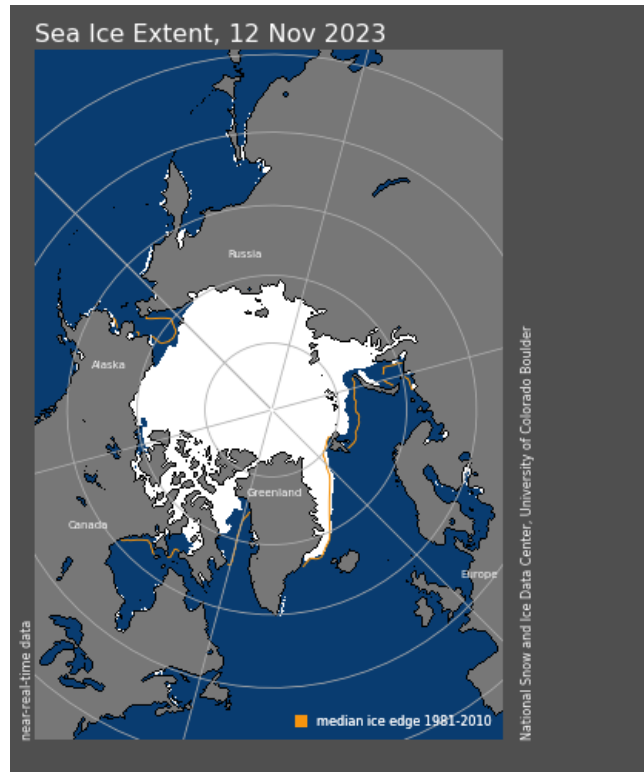
Figure 16. Observed Arctic sea ice extent on 12 November 2023 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are well above normal, especially along the South America coast, indicating that anEl Niño is pertty 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.
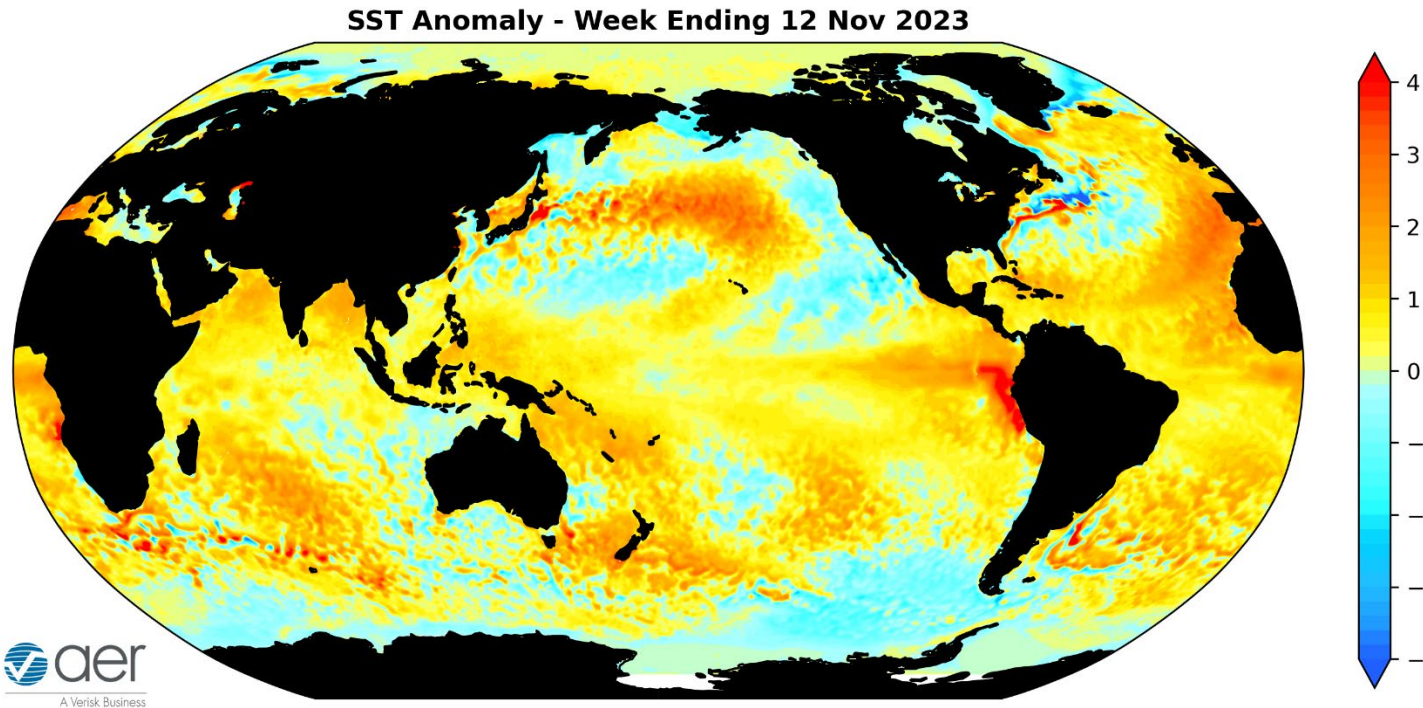
Figure 17. The latest weekly-mean global SST anomalies (ending 12 November 2023). Data from NOAA OI High-Resolution dataset.

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 then 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 could be having some influence on North American weather next week, especially according to the ECMWF. But admittedly this is outside of my expertise.
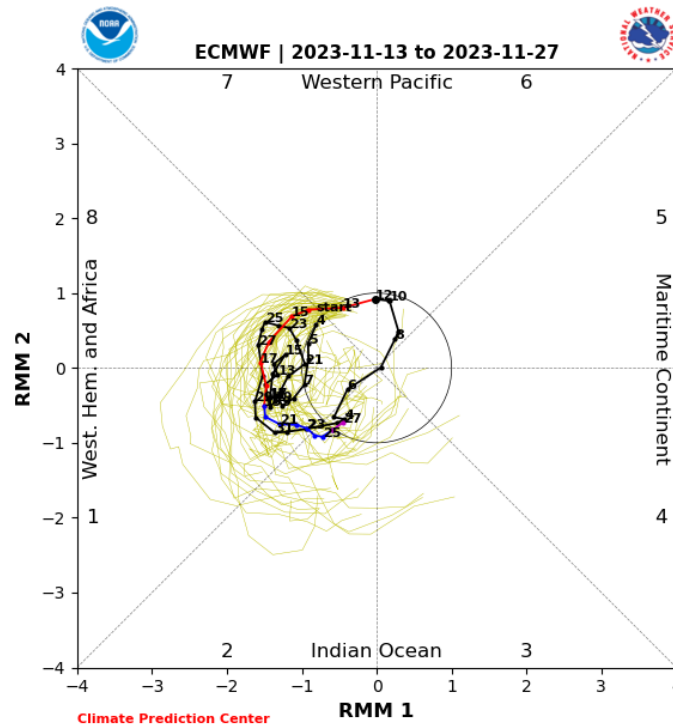
Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 13 November 2023 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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

Get Detailed Seasonal Weather Intelligence with sCast

We appreciate your taking the time to read the public Arctic Oscillation blog from Dr. Judah Cohen and the AER Seasonal Forecasting team.

Dr. Cohen's detailed monthly seasonal forecast, sCast, is also available for purchase. sCast provides a monthly 30-60-90-180-day outlook into temperature and precipitation, solar flux and wind anomalies across the globe, and regional population weighted cooling and heating degree forecasts for the US.

Our sCast principal engineer, Karl Pfeiffer, can help you use sCast and other AER seasonal forecast products to deliver important, long-lead time weather intelligence to your business. Please reach out to Karl today!