

Arctic Oscillation and Polar Vortex Analysis and Forecasts

November 4, 2024

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 briefly pop positive this week and then return to neutral next week 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 positive with negative pressure/geopotential height anomalies across Greenland and the NAO is predicted to slowly trend negative towards neutral the next two weeks as pressure/geopotential height anomalies are predicted to become mixed and then possibly positive across Greenland.
- This week troughing/negative geopotential height anomalies across Greenland will support mostly ridging/positive geopotential height anomalies centered on Northwestern Europe the next two weeks. Then next week as European ridging will consolidate week of the British Isles, troughing will slide into Eastern Europe from Western Asia. This pattern will support mostly normal to above normal temperatures across Europe including the United Kingdom (UK) while northerly flow and/or low heights will support normal to below normal temperatures Southeastern Europe.

- The general pattern predicted for Asia the next two weeks is ridging/positive geopotential height anomalies centered over Europe forcing troughing/negative geopotential height anomalies across Western Asia while ridging in the Central Arctic forcing troughing in Eastern Siberia. However next week troughing will slide across much of Siberia. This pattern favors widespread normal to above normal temperatures across much of Asia with normal to below normal temperatures limited to Western Asia and Eastern Siberia this week, however next week the colder temperatures are predicted to slide east across Northern Siberia.
- This week ridging/positive geopotential height anomalies are predicted to dominate North America with the exception of troughing/negative geopotential height anomalies in the Western United States (US). Then next week troughing beginning in Alaska will slide south across first Western Canada and then the Western US with more ridging/positive geopotential height anomalies across eastern North America. This pattern favors this week normal to above normal temperatures across Alaska, Canada and the Eastern US with normal to below normal temperatures across the Western US. However, next week colder temperatures will begin in Alaska and then slide south into Western Canada and the Western US as warm temperatures continue to dominate Eastern Canada and the Eastern US.
- In the Impacts section I discuss some early signs of a possible polar vortex stretch and Greenland blocking how they may impact the upcoming weather in the Northern Hemisphere (NH).

Plain Language Summary

The schizophrenic advance of snow cover across Asia in October that was fast in the first half and non-existent in the second half is over (see **Figure i**). This pretty much guarantees a weak signal at best using snow cover as a predictor for the upcoming winter. In the shorter term, the polar vortex is predicted to strengthen (see **Figure 12a**) and this will likely maintain warmer weather for eastern North America < Europe and East Asia (see **Figures 3 & 5**) for the foreseeable future. Some exceptions are western North America, Southeastern Europe, Western Russia (reminiscent of last winter) and Eastern Siberia. But there are developments that could be signaling a meaningful change in the pattern, but it will take time.

Impacts

It is officially November so this is my last blog discussing 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. Other research emphasizes November as an important month as discussed last month, something that I consider as well.

As I discussed all month, the snow cover extent across Eurasia got out of the gate quickly with snow cover extent (SCE) higher than any of the previous nine years through the second week of October and then crashed and burned. I include the full month update for the plot of daily Eurasian SCE for October in **Figure i**. The black dashed line represents the mean value using October 2009 through 2023.

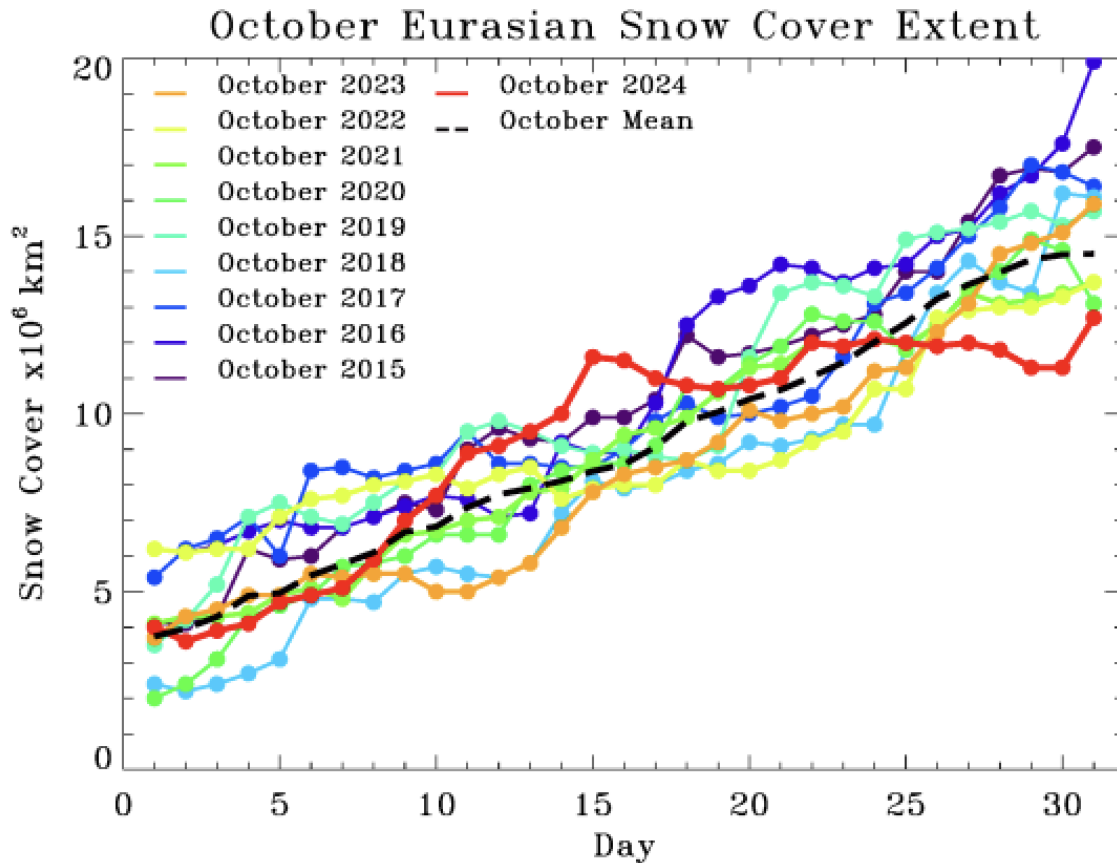


Figure i. Observed daily Eurasian snow cover extent through 31 October 2024. Included are the daily values from October 2015 through 2023 and the mean value the mean value from October 2009 through 2023 (black dashed line).

The SCE went from first in the first half of October to last in the second half of October. It seems to me that the collapse of Siberian SCE is almost unprecedented. And it does seem that rapid pull backs in the season of snow cover advance is happening more frequently as the globe warms. I still don't have the final value of the monthly mean for October 2024, but I still believe that it will be close to the past four years. I consider this to be a weak signal and doesn't provide much of a signal for the winter forecast and if anything would have me hedge warm, especially in the Eastern US.

What I am about to write is highly speculative and is of questionable value, but I do like to push the boundaries of what is possible. Sometimes I do think that the nature of the snow cover

advance across Eurasia can also tell us about the nature of the upcoming winter. Does the advance of SCE suggest more severe winter in the first half of winter ending with a whimper rather than a bang for the second half? If nothing else, it will be fun to watch.

Not only do I compute the SCE but also the snow advance index (SAI) for October. If you need a refresher on the SAI you can read [Cohen and Jones \(2011\)](#). The SAI came in at -0.5 for October 2024, so to be honest again not a strong signal. 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. But maybe or maybe not in contrast to what I just wrote above, the SAI suggests - don't expect a large PV disruption in early winter but could be favored more mid to late winter.

As I have also been discussing in the blog this month, another signal that I am watching closely and will over the next couple of months is Arctic sea ice extent (SIE) which continues to grow relatively slowly for now. In fact over the past week, like SCE, SIE has gone sideways with little growth occurring when it should be fairly rapid. And as I expected over the past several blogs, sea ice growth occurred preferentially in the North Pacific sector relative to the North Atlantic sector and the large negative anomaly in the North Atlantic sector compared to the North Pacific sector is now readily apparent (see **Figure ii**). This is important because it is the lack of sea ice in the Barents Kara Seas that favors a weak PV. Which region will feature the largest negative anomalies in the coming months remains uncertain but it is looking increasingly likely that it will favor a weaker PV in the winter months.

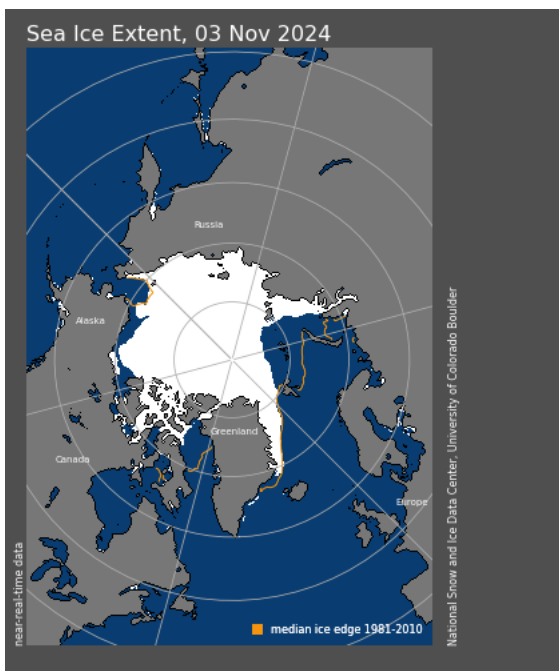


Figure ii. Observed daily snow cover extent anomalies on 27 October 2024. Included are the daily values from October 2015 through 2023 and the mean value from October 2009 through 2023 (black dashed line). Plot taken from: <http://climate.rutgers.edu/snowcover/index.php>.

While we are grasping at straws, another possible bright spot is that SCE across North America, which has really picked up over the past week. North American SCE is a little above normal after

being well below normal. SCE has spread across all of Northern Canada and will spread across Western Canada in the coming week or so. Probably favors colder weather in western North America but that could still change.

Another signal that I am watching closely and will over the next couple of months is Arctic sea ice extent which continues to grow relatively slowly for now. As I expected in last week's blog, sea ice growth occurred preferentially in the North Pacific sector relative to the North Atlantic sector (see **Figure iii**). This is important because it is the lack of sea ice in the Barents Kara Seas that favors a weak PV. However looking at the weather forecasts over the next two weeks (e.g., **Figures 8 & 9**), the pattern probably favors sea ice growth in the North Atlantic sector but maybe also in the North Pacific sector. Therefore which region will feature the largest negative anomalies in the coming months remains for now uncertain.

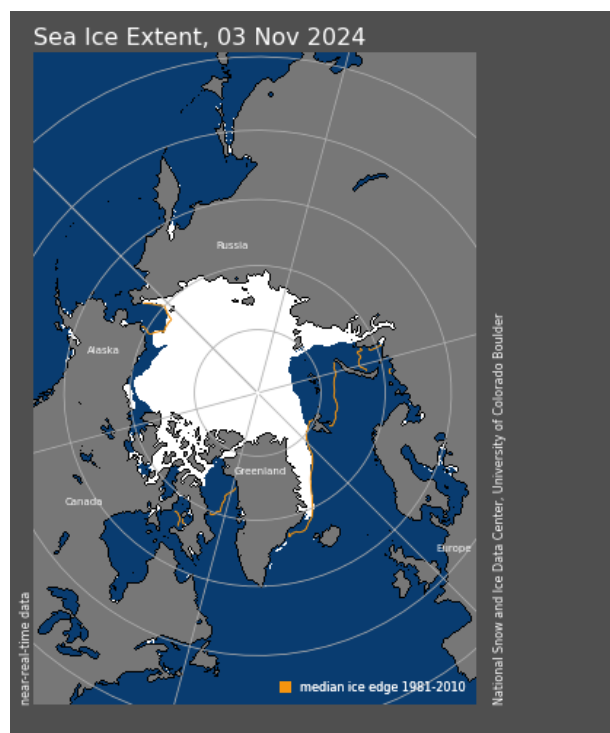


Figure iii. Observed Arctic sea ice extent on 3 November 2024 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC). URL: <https://nsidc.org/sea-ice-today>.

I have to admit that it has been a struggle to get excited about the weather this fall and anticipate what might happen this winter. The pattern has not been conducive to cold weather in many parts of the hemisphere, not in the short term and not even in the long term. Overall the pattern still doesn't look supportive of meaningful cold weather but at least there is something to watch and maybe hang your hat on.

As I discussed the past couple of weeks, what could finally change the pattern around are the warm/positive polar cap geopotential height anomalies (PCHs) that are shown to descend from the lower stratosphere to the lower troposphere now in mid-November (see **Figure 11**). The models seem to be consolidating around increasing high latitude blocking in the Central and/or North Atlantic sector of the Arctic including Greenland blocking. This could start a more favorable pattern of a wintry pattern in the Eastern US and northern Eurasia.

And looking at the regional PCHs limited to the North Atlantic sector it is even more apparent (see **Figure iv**). At the end of the second week of November we see a red pulsing of PCHs in the Greenland region that appear to descent to the surface shortly thereafter. This is consistent with the 500 hPa geopotential forecast seen in **Figure 8**. The GFS seems to be the most aggressive in predicting higher heights spreading across Northern Canada, but this pattern could finally bring at least more seasonable temperatures and more widespread cold than we have observed this fall so far. But a word of caution, the PCHs forecast is volatile, and one days shows a strong signal to be followed a day later by a weak or even non-existent signal. And over the past several weeks the forecast has been quite volatile.

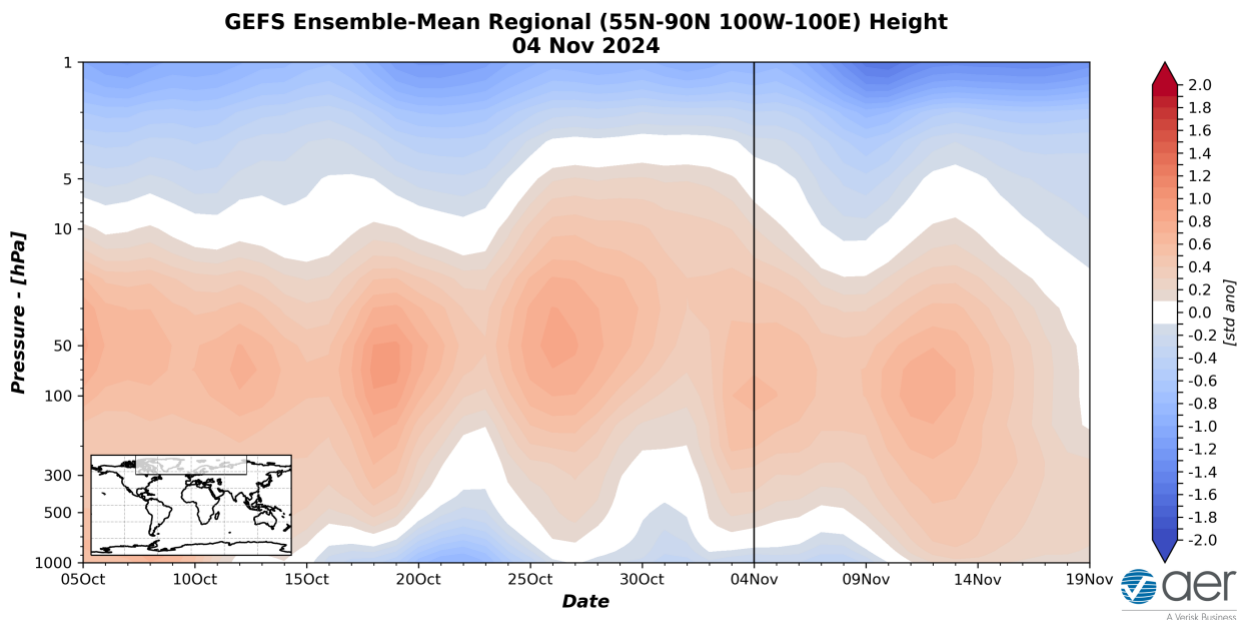


Figure iv. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies limited to the North Atlantic sector (see insert). The forecast is from the 00Z 4 November 2024 GFS ensemble.

Greenland blocking is best known for delivering cold air to Europe and this development should be watched. But our research has also shown that Greenland blocking can be a precursor of a stretched PV two weeks later. A stretched PV could finally result in a period, probably limited in time, of below normal temperatures. But this is still highly speculative and a ways off.

However looking at the PV forecasts it does seem to be evolving towards a stretched PV that would most likely favor colder weather in Western Canada and the Western US. This shows up nicely in the latest PV animation from this morning (see **Figure v**). At the end of the animation you can see the forecast of warm temperatures and high pressure emanating out of East Asia and heading towards Alaska in the polar stratosphere. At the same time, lower heights develop over Western Canada. This is all suggestive to me of seasonable and even unseasonable cold air building in Western Canada that would be favored to enter the Western US rather than the Eastern US. Again more speculation on my part, but at least finally an interesting development to follow. And I believe if cold temperatures can get established in Western Siberia that cold air could eventually make its way into the Eastern US.

Initialized 00Z 10 hPa HGT/HGTa 04-Nov-2024

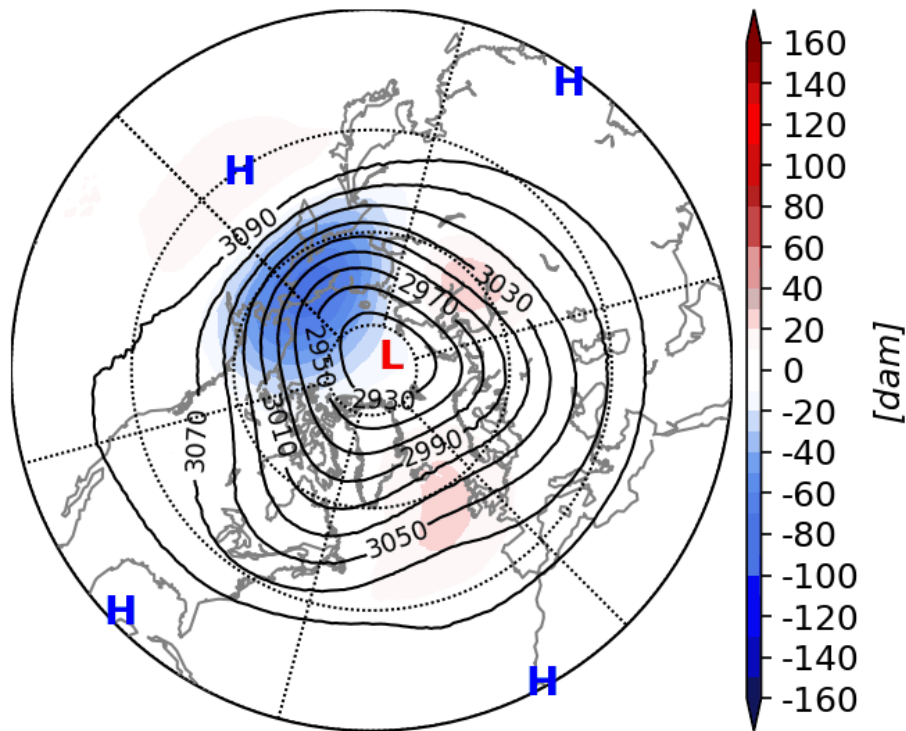


Figure v. Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 04 November 2024 and forecasted from 05 November to 19 November 2024. The forecasts are from the 00Z 04 November 2024 GFS model ensemble.

I should mention that I am on travel the next couple of Mondays so please do expect disruptions, delays to the blog updates.

Near-Term

This week

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

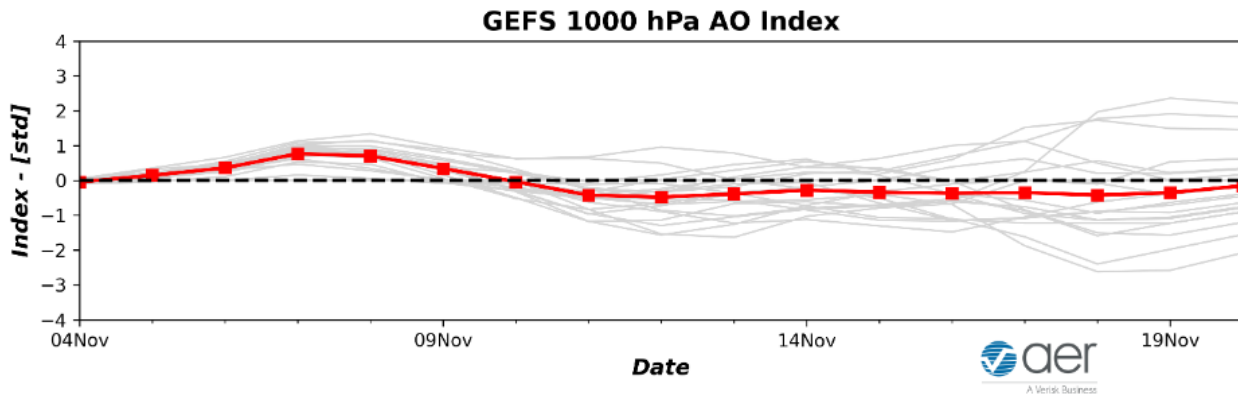


Figure 1. The predicted daily-mean AO at 1000 hPa from the 00Z 03 November 2024 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble mean AO index given by the red line with squares.

This week, troughing/negative geopotential height anomalies across Greenland will support ridging/positive geopotential height anomalies centered on Northern Europe (**Figures 2**). This pattern will favor normal to above normal temperatures across Europe including the UK while northerly flow will usher some normal to below normal temperatures across Southeastern Europe (**Figure 3**). This week the predicted pattern across Asia is ridging/positive geopotential height anomalies centered over Europe forcing troughing/negative geopotential height anomalies across Western Asia and more ridging in the Beaufort Sea forcing troughing over Eastern Siberia (**Figure 2**). This pattern favors normal to above normal temperatures across much of Asia with normal to below normal temperatures limited to parts of Western Asia and Eastern Siberia (**Figure 3**).

This week troughing/negative geopotential height anomalies near the Aleutians will force ridging/positive geopotential height anomalies across much of Canada and the Eastern US with more troughing/negative geopotential height anomalies across the Western US. (**Figure 2**). This pattern will favor normal to above normal temperatures across Alaska, much of Canada and the Eastern US with normal to below normal temperatures limited to the Western US (**Figure 3**).

GEFS 1-5 Day Forecast 500 hPa Anomaly
INIT: 00Z 11/04/2024 FCST: 11/05/2024 to 11/09/2024

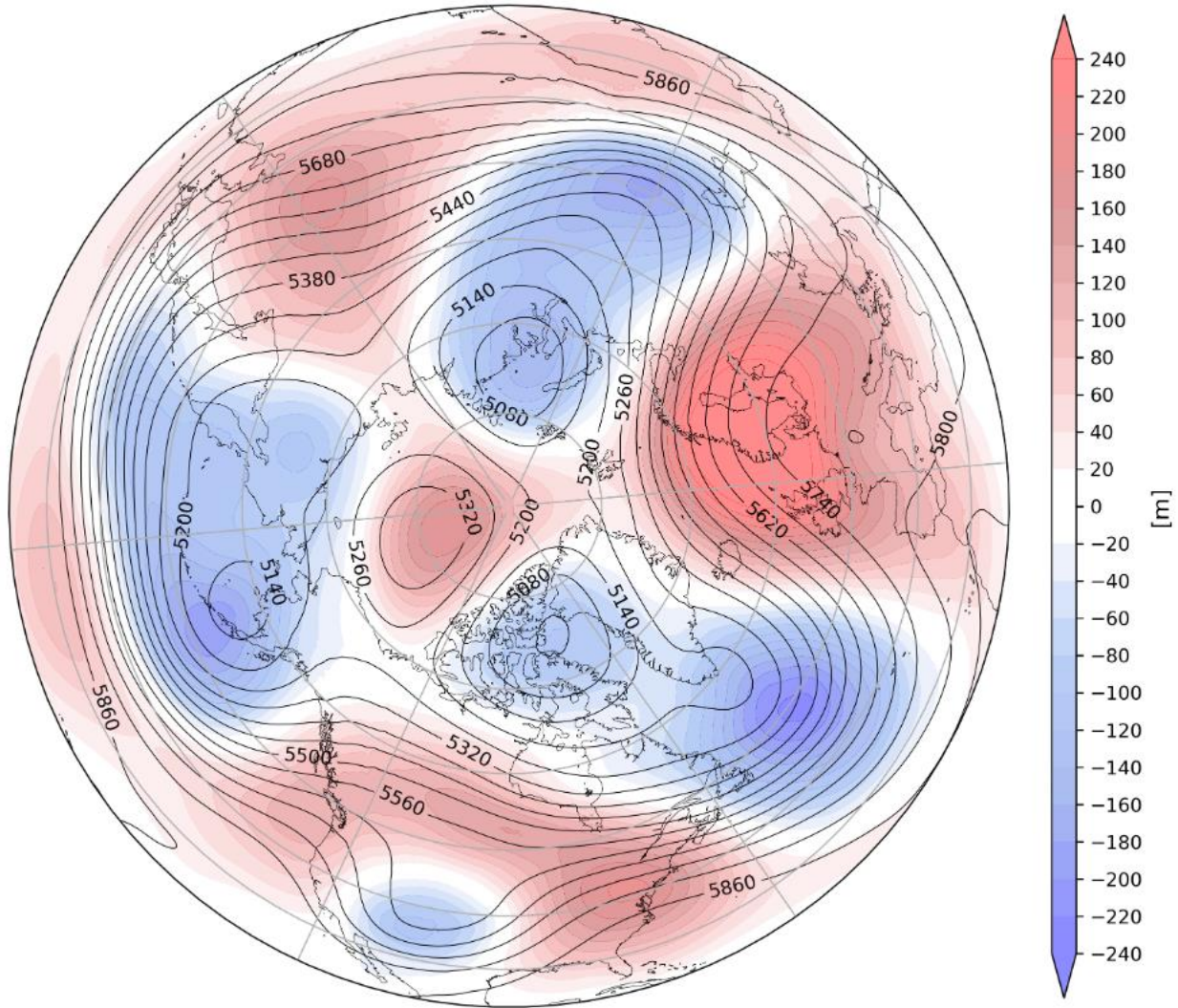


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 05 to 09 November 2024. The forecasts are from the 00z 04 November 2024 GFS ensemble.

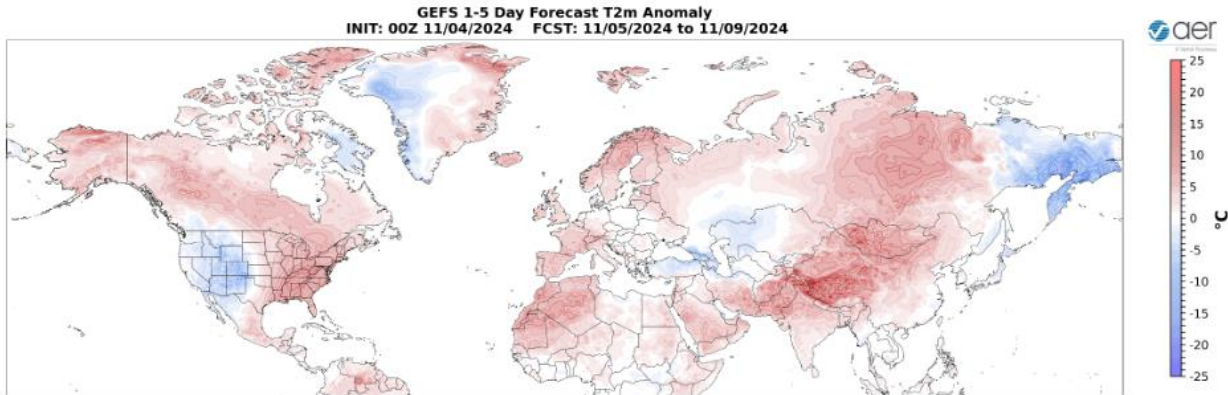


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 05 Nov – 09 Nov 2024. The forecast is from the 00Z 04 Nov 2024 GFS ensemble.

Trouthing and/or cold temperatures will support new snowfall across Siberia while warm temperatures will support snowmelt in Scandinavia, Eastern Europe and the Tibetan Plateau this week (**Figure 4**). Trouthing and/or cold temperatures will support new snowfall across southern Alaska, Northern Canada and the higher elevations of the Central Rockies while warm temperatures will support snowmelt in Western Canada this week (**Figure 4**).

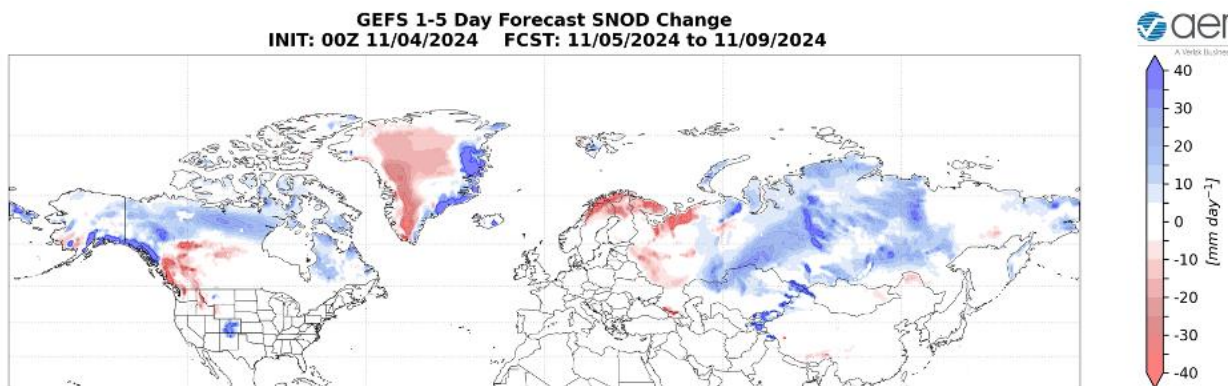


Figure 4. Forecasted snow depth changes (mm/day ; shading) from 29 Oct – 02 Nov 2024. The forecast is from the 00Z 28 October 2024 GFS ensemble.

Near-Mid Term

Next week

With geopotential height anomalies turning more mixed across the Arctic and with mixed geopotential height anomalies across the mid-latitudes this period (**Figure 5**), the AO will likely be close to neutral this period (**Figure 1**). With predicted weak but negative pressure/geopotential height anomalies across Greenland (**Figure 5**), the NAO will likely persist positive this period.

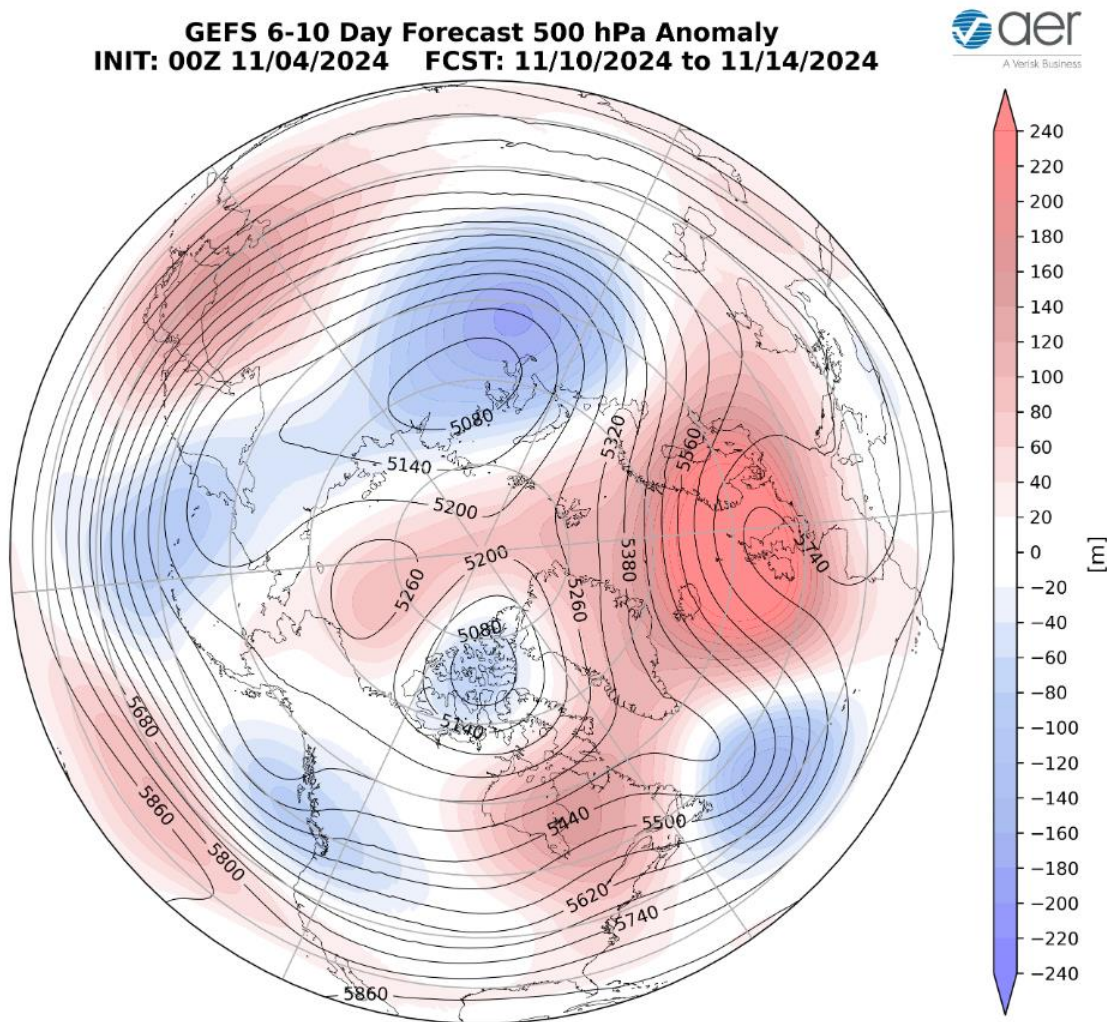


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 10 – 14 November 2024. The forecasts are from the 00Z 04 November 2024 GFS ensemble.

Weakening troughing/negative geopotential height anomalies across Greenland will continue to support ridging/positive geopotential height anomalies across Northwestern Europe with troughing in Southeastern Europe this period (**Figure 5**). This pattern will favor normal to above normal temperatures across much of Europe including the UK while induced northerly flow will usher in normal to below normal temperatures across Southeastern Europe (**Figure 6**). The predicted pattern across Asia is ridging/positive geopotential height anomalies centered over the Laptev Sea forcing troughing/negative geopotential height anomalies across the Urals and Eastern Siberia with more ridging/positive geopotential height anomalies across East Asia (**Figure 5**). This pattern favors widespread normal to above normal temperatures across much of Asia with normal to below normal temperatures limited to Western Russia and Eastern Siberia (**Figure 6**).

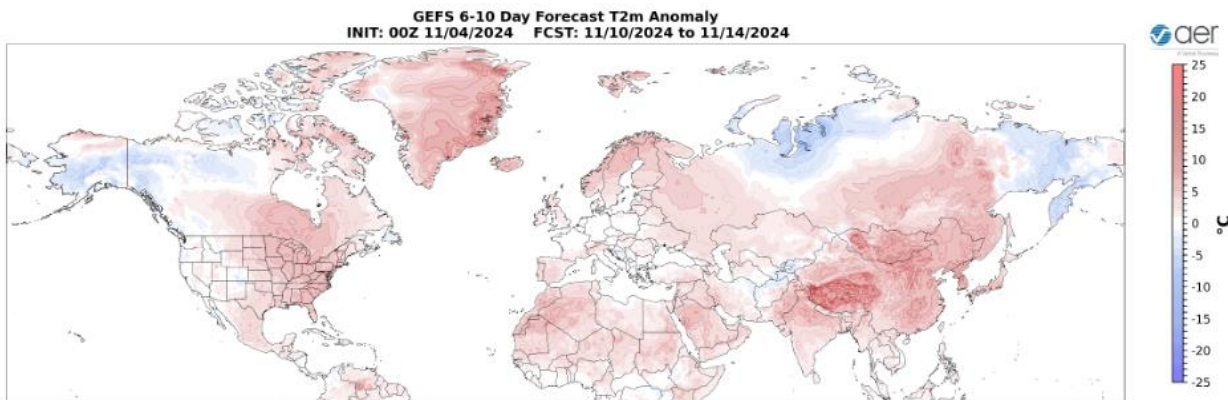


Figure 6. Forecasted surface temperature anomalies (°C; shading) from 10-14 November 2024. The forecasts are from the 00Z 04 November 2024 GFS ensemble

Troughing/negative geopotential height anomalies previously near the Aleutians will slide east and south across Alaska, Northern and Western Canada and parts of the Western US while forcing ridging/positive geopotential height anomalies across Eastern Canada and the Eastern US this period (**Figure 5**). This pattern will favor normal to below normal temperatures across Alaska, Northern and Western Canada, the Northwestern and Southwestern US with normal to above normal temperatures across Eastern Canada and the Eastern US (**Figure 6**).

Troughing and/or cold temperatures will support new snowfall across Norway, the Urals, Siberia and the Tibetan Plateau while warm temperatures will support snowmelt in Norway and eastern Kazakhstan this week (**Figure 7**). Troughing and/or cold temperatures will support new snowfall across Northern and Western Canada, the Cascades and the Northern Rockies while warm temperatures will support snowmelt in Quebec and Colorado this week (**Figure 7**).

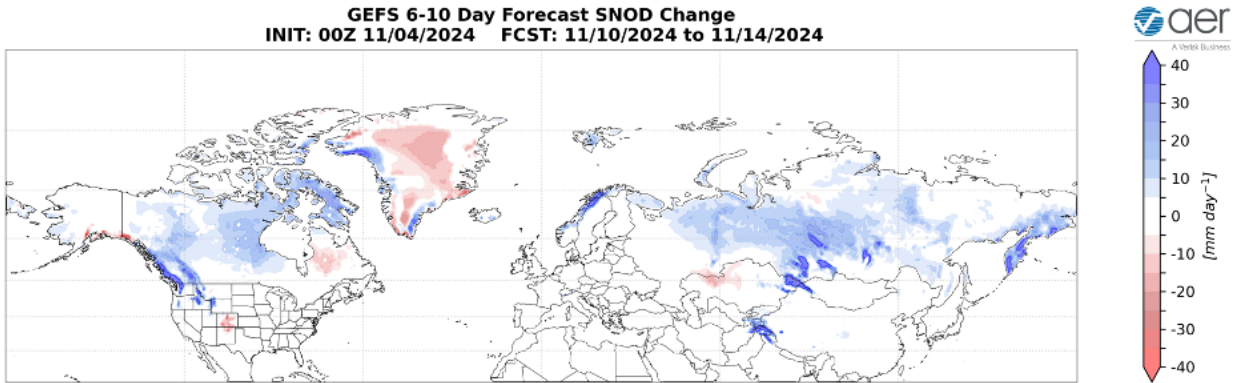


Figure 7. Forecasted snow depth changes (mm/day; shading) from 10 – 14 November 2024. The forecasts are from the 00Z 04 November 2024 GFS ensemble.

Mid Term

Week Two

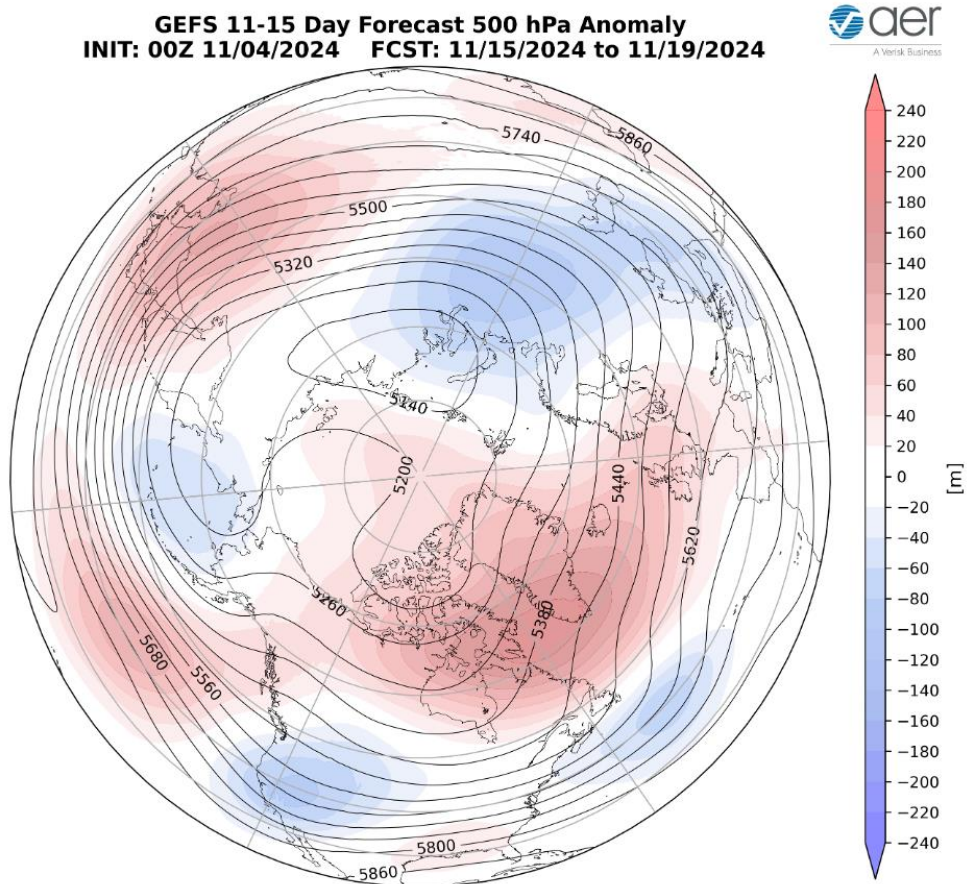


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 15 to 19 November 2024. The forecasts are from the 00Z 04 November 2024 GFS ensemble.

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

Increasing ridging/positive geopotential height anomalies centered between the UK and Greenland is predicted to extend into Northwestern Europe and will support troughing/negative geopotential height anomalies across Eastern Europe this period (**Figure 8**). This pattern should favor normal to above normal temperatures across Western Europe including the UK with normal to below normal temperatures across Eastern Europe this period (**Figures 9**). The predicted pattern across Asia this period is ridging/positive geopotential height anomalies widespread across Southern and Eastern Asia and centered on Eastern China with troughing/negative geopotential height anomalies across Western Russia and 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 limited to Northwestern Russia and the Urals, parts of Northern and Eastern Siberia this period (**Figure 9**).

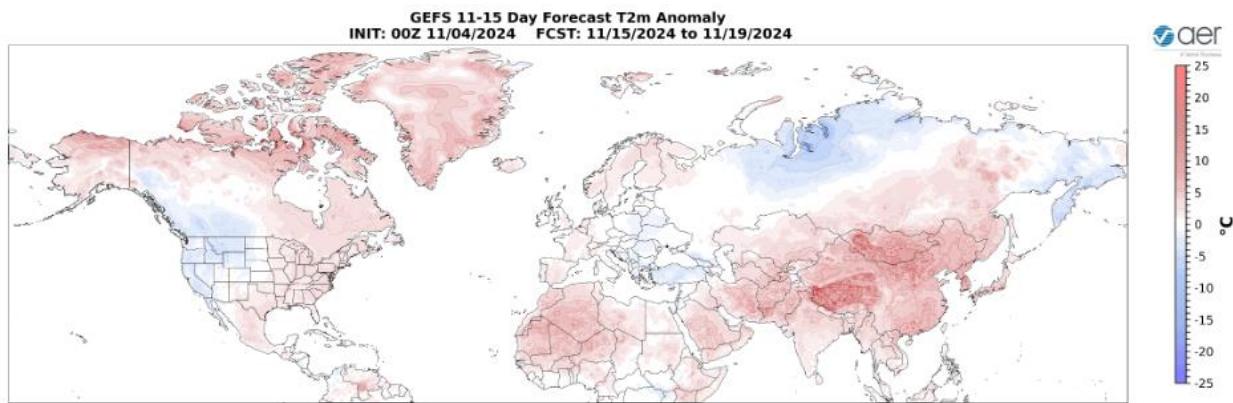


Figure 9. Forecasted surface temperature anomalies (°C; shading) from 15 – 19 November 2024. The forecast is from the 00Z 04 November 2024 GFS ensemble.

Predicted strengthening ridging/positive across Greenland, Northeastern Canada and the Gulf of Alaska will support troughing/negative geopotential height anomalies across Southwestern Canada and the Western US and even possibly the Northeastern US this period (**Figure 8**). This pattern will favor widespread normal to above normal temperatures across much of Alaska, Northern and Eastern Canada and the eastern US with normal to below normal temperatures limited to Southwestern Canada and the Western US this period (**Figure 9**). Not showing up in the forecasts, but colder air could also start to filter into the Northeastern US.

Troughing and/or cold temperatures will support new snowfall across Norway, the Urals, Siberia and the Tibetan Plateau and possibly the Alps and the Caucasus this week (**Figure 10**). Troughing and/or cold temperatures will support new snowfall across Alaska, Northern, Western and

Eastern Canada, the higher elevations of the Northwestern US and the US to mid-Northern Plains this week (**Figure 10**).

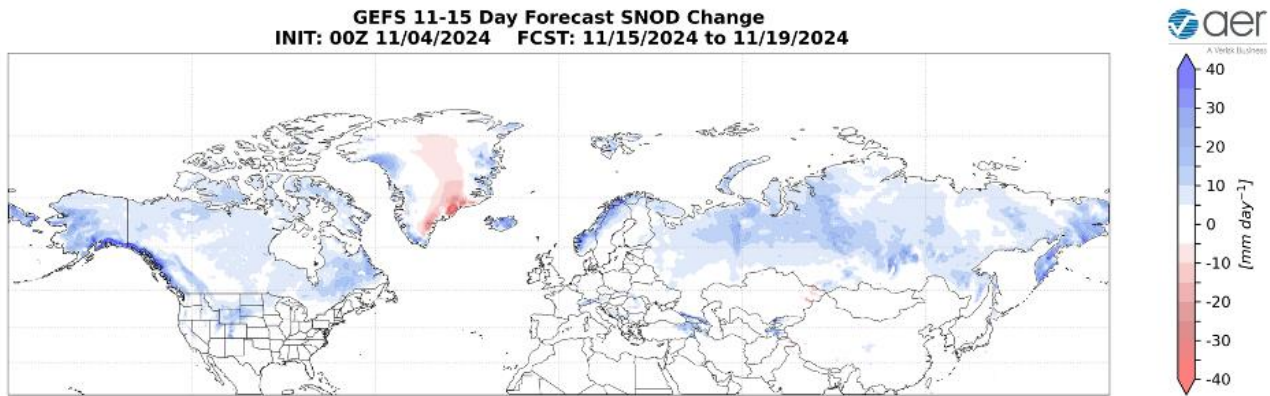


Figure 10. Forecasted snow depth change (mm/day; shading) from 15 – 19 November 2024. The forecast is from the 00Z 04 November 2024 GFS ensemble

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 the upper to mid-troposphere with cold/negative PCHs in the upper stratosphere and neutral in the lower troposphere (**Figure 11**). This week and into next week warm/positive mid tropospheric PCHs are predicted to descend close to the surface while cold/negative PCHs are predicted to expand into the mid-and lower stratosphere (**Figure 11**).

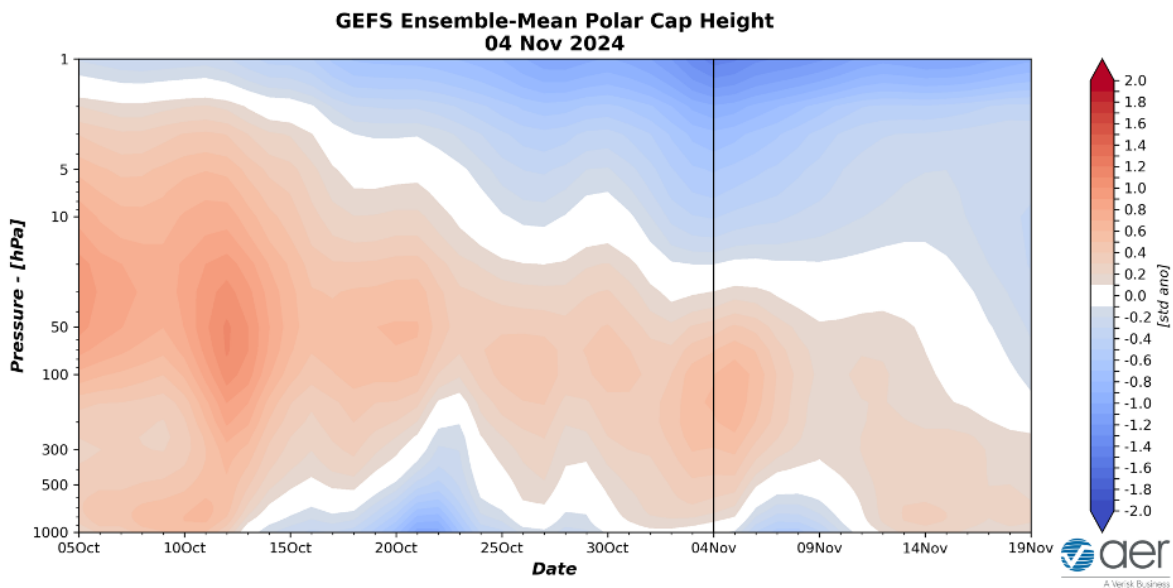


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 04 November 2024 GFS ensemble.

The predicted negative PCHs in the lower troposphere this week (**Figure 11**) are consistent with the predicted positive surface AO this week (**Figure 1**). However, the AO is predicted to become neutral next week (**Figure 1**) coinciding with the predicted descending of warm/positive PCHs into the lower troposphere (**Figure 11**).

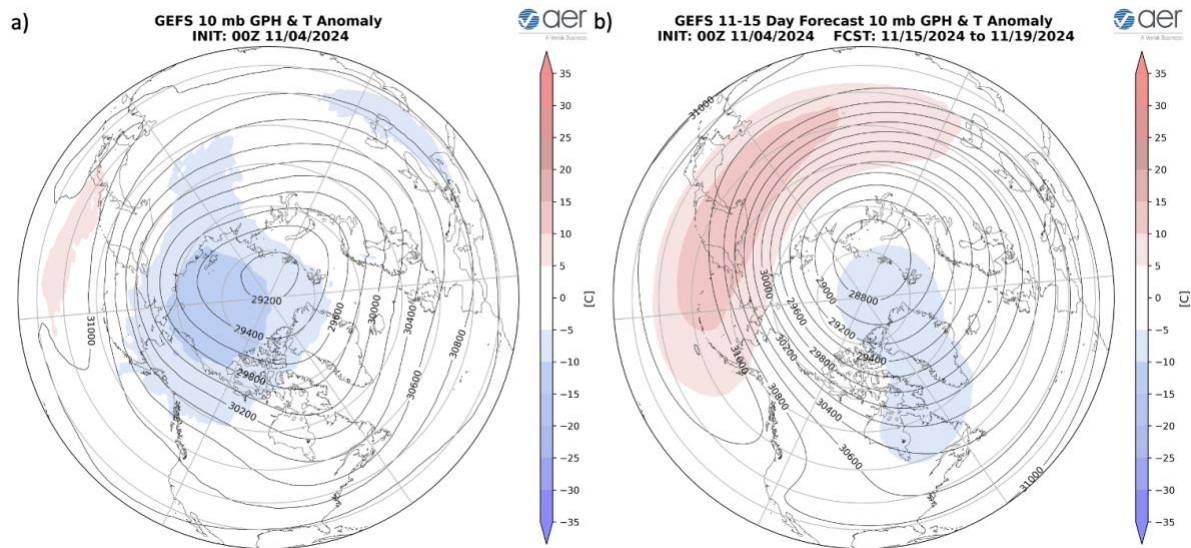


Figure 12. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 04 November 2024. (b) Same as (a) except forecasted averaged from 15-19 November 2024. The forecasts are from the 00Z 04 November 2024 GFS model ensemble.

This week the polar vortex (PV) is predicted to be nearly circular in shape with the PV center near the North Pole and relatively cold temperatures focused in the Arctic (Figure 12a). This is consistent with a relatively strong PV. However, for the third week of November the PV center is predicted to remain between the North Pole and the Kara Sea and begin to elongate towards Canada with warming extending out of Asia towards Alaska in the polar stratosphere (Figure 12b). This is a starting to resemble a stretched PV configuration that favors colder temperatures in Northern Asia and North America, probably focused in the West.

I include in this week’s blog the monthly 500 hPa geopotential heights (Figure 13) and surface temperatures for December (Figure 14) from the Climate Forecast System (CFS; the plots represent yesterday’s four ensemble members). The forecast for the troposphere is ridging centered between Greenland and the UK, East Asia, the Gulf of Alaska extending towards the North Pole with troughing spreading across Western Russia, Eastern Siberia extending to the Dateline and the Aleutians, the Western US and Eastern Canada (Figure 13). This pattern favors

seasonable to relatively warm temperatures across Northern and Western Europe, Southern Asia, Eastern Siberia, Alaska, Eastern Canada, the Eastern US with seasonable to relatively cold temperatures across Eastern Europe, Western Russia, Siberia especially in the north, Northern and Western Canada and the Western US (Figure 14).

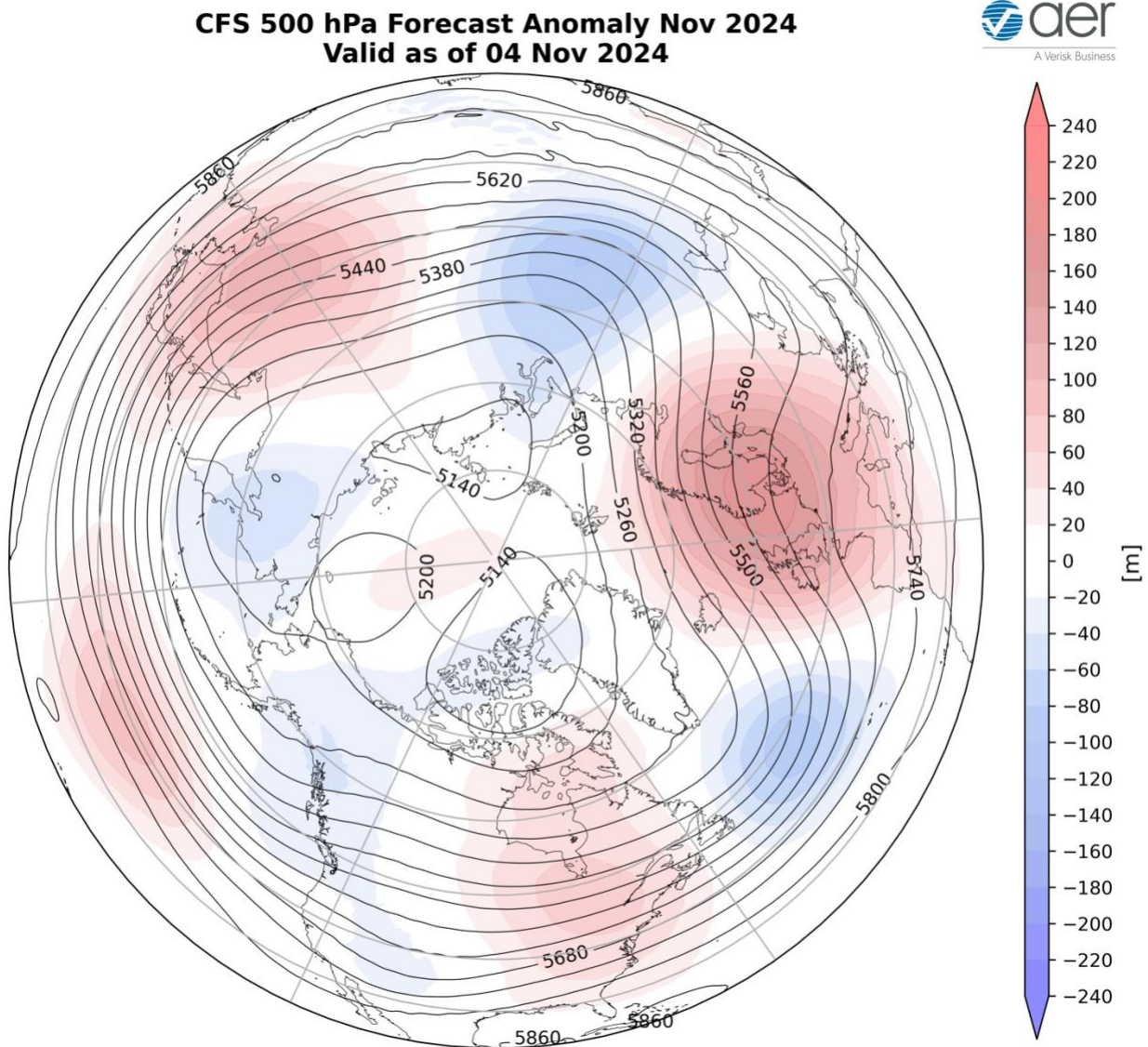


Figure 13. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for November 2024. The forecasts are from the 00Z 28 October 2024 CFS.

CFS 0-26 Day Forecast T2m Anomaly
INIT: 00Z 11/04/2024 FCST: 11/04/2024 to 11/30/2024

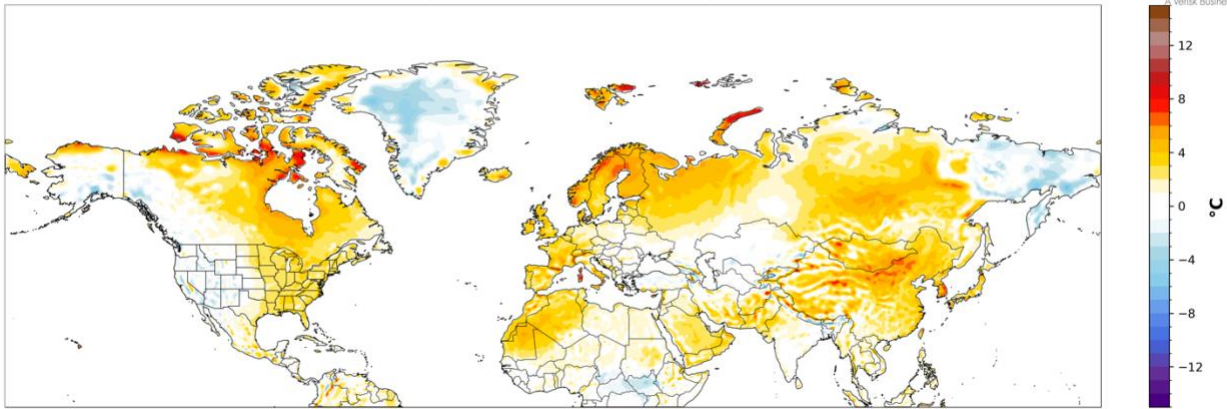


Figure 14. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for Nov 2024. The forecast is from the 00Z 04 Nov 2024 CFS.

Boundary Forcings

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are below normal, between the Dateline and the South America coast, indicating that an La Niña is emerging (Figure 15) and weak La Niña conditions are expected through the winter. Observed SSTs across the NH remain well above normal especially in the central North Pacific centered on the Dateline and the western North Pacific, much of the North Atlantic and offshore of eastern North America though below normal SSTs exist regionally especially in the South Pacific.

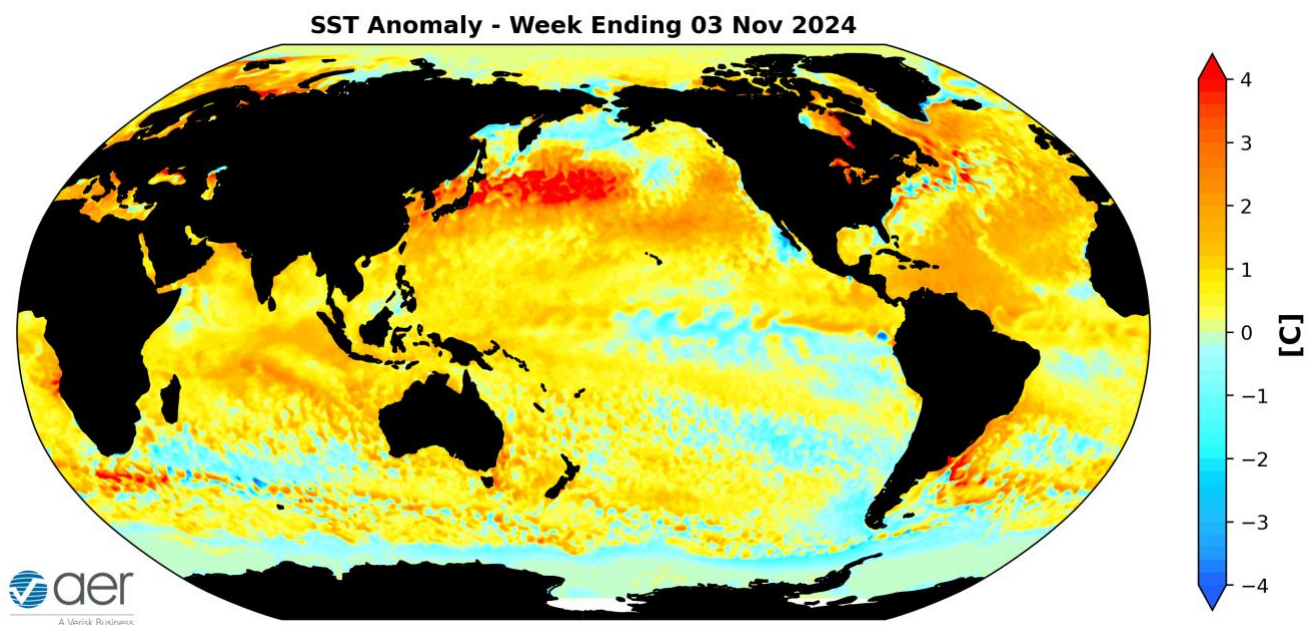


Figure 15. The latest daily-mean global SST anomalies (ending 03 November 2024). Data from NOAA OI High-Resolution dataset. Source: <https://psl.noaa.gov/map/clim/sst.shtml>

Madden Julian Oscillation

Currently the Madden Julian Oscillation (MJO) is currently in phase eight (Figure 16). The forecasts are for the MJO to quickly move to phase one and then weaken where no phase is favored. Phase one favors troughing in western 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. But admittedly this is outside of my expertise.

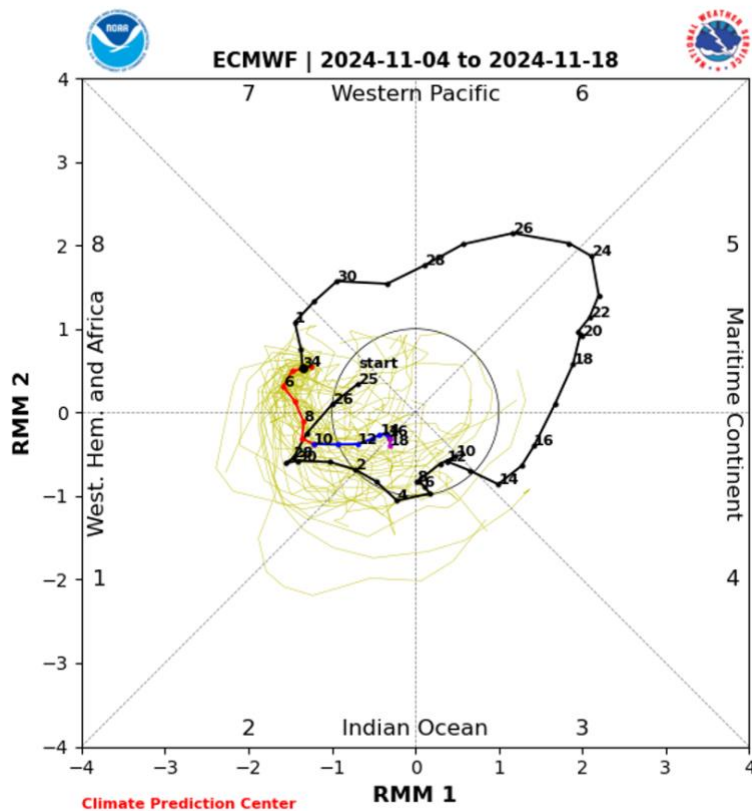


Figure 16. Past and forecast values of the MJO index. Forecast values from the 00Z 04 November 2024 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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/ecmf.shtml>

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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!