

# Arctic Oscillation and Polar Vortex Analysis and Forecasts

December 5, 2022

Dear AO/PV blog readers:

We have shifted the public release of the Arctic Oscillation/Polar Vortex blog to Wednesday through the winter season.

For those who would like an early look on Mondays, we will be offering at a nominal price (US \$50) a PDF version of the upcoming blog, and we will be rolling out access to the datasets used in the production of this blog. At present we plan to make available in comma-separated values the timeseries of the Polar Cap Height and the timeseries of the Wave Activity Flux (vertical component), though we would appreciate to hear your suggestions for additional data of interest to you all.

Dr. Judah Cohen from Atmospheric and Environmental Research (AER) embarked on an experimental process of regular research, review, and analysis of the Arctic Oscillation (AO) and Polar Vortex (PV). This analysis is intended to provide researchers and practitioners real-time insights on one of North America's and Europe's leading drivers for extreme and persistent temperature patterns.

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

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*The AO/PV blog is partially supported by NSF grant AGS: 1657748.*

## **Summary**

- The Arctic Oscillation (AO) is currently negative and is predicted to remain negative to strongly negative the next two weeks as pressure/geopotential height

anomalies across the Arctic are predicted to remain positive in the North Atlantic sector. The North Atlantic Oscillation (NAO) is currently negative and is predicted to remain negative the next two weeks as pressure/geopotential height anomalies are predicted to be positive to strongly positive across Greenland.

- Over the next two weeks strengthening ridging/positive geopotential height anomalies centered near Greenland will increasingly favor troughing/negative geopotential height anomalies across Europe. This pattern will generally favor a quasi-classic negative NAO pattern with normal to below normal temperatures across Northern and Western Europe including the United Kingdom (UK) with normal to above normal temperatures across Southern and Eastern Europe.
- Over the next two weeks, predicted Greenland coupled with Ural ridging/positive geopotential height anomalies will force troughing/negative geopotential height anomalies across Siberia that extend southward to Central and East Asia. This pattern favors normal to below normal temperatures across Northern Asia and initially Central Asia and then Eastern Asia with normal to above normal temperatures across Southern Asia and eventually Western Asia the next two weeks.
- The general pattern this week across North America is ridging/positive geopotential height anomalies centered near the Aleutians forcing downstream troughing/negative geopotential height anomalies in western North America with more ridging in the Eastern United States (US). However, next week ridging/positive geopotential height anomalies building west of Greenland will force increasing troughing/negative geopotential height anomalies in the Eastern US. This pattern favors this week widespread normal to above normal temperatures across Alaska, Western Canada and the Northwestern US with normal to below normal temperatures across Eastern Canada and the Eastern US. However, next week colder temperatures will spread east of the Rockies in the US.
- I discuss what we can expect in this period of large model forecast uncertainty and hints of possible changes in the behavior of the polar vortex (PV) in the coming weeks.

### **Plain Language Summary**

With large spread among dynamical model forecasts, I lay out some rules of thumb that I use to help clear the fog of uncertainty in the upcoming forecast. Also, I see some important changes in the anticipated behavior of the polar vortex that could have important implications on our short- and long-term weather.

### **Impacts**

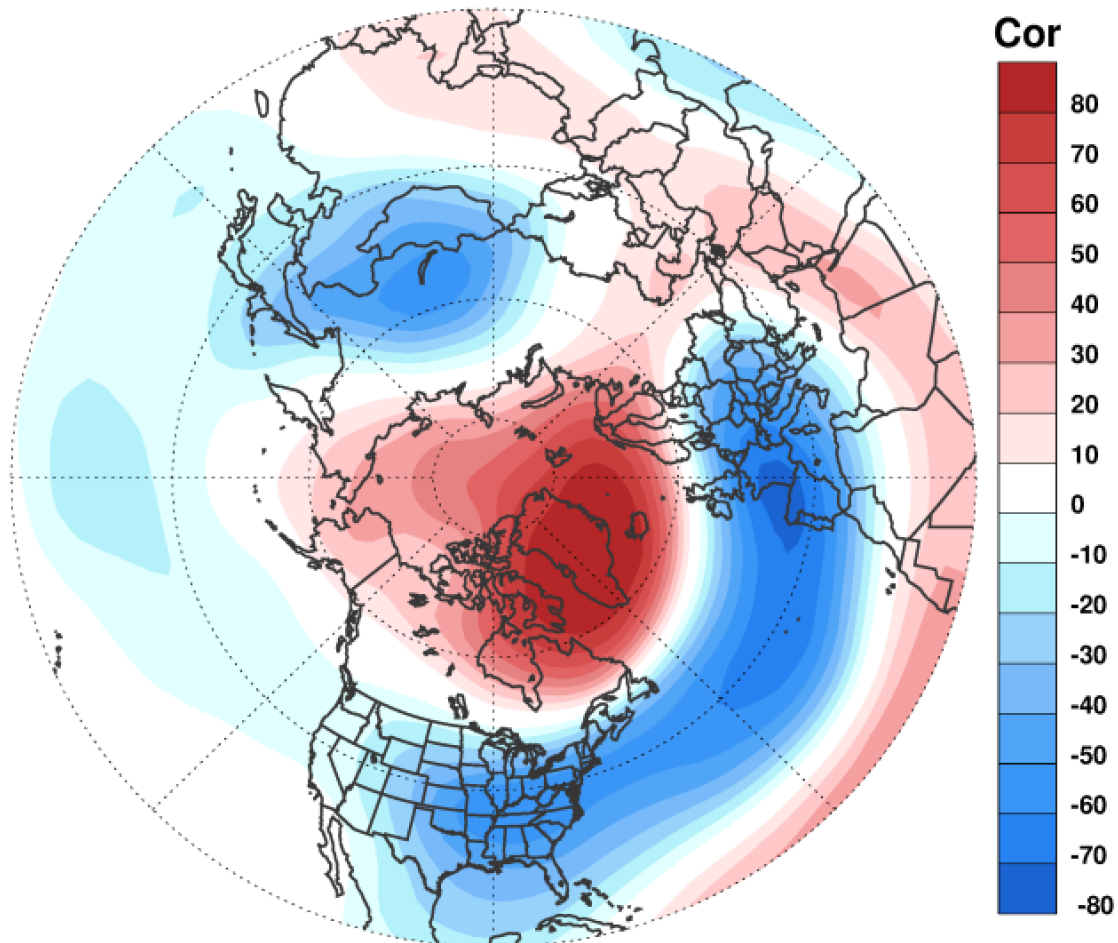
The dynamical model forecasts have shown large spread and uncertainty in their forecasts even in the short term, so what information can we glean from the dynamical model forecasts? I think during these times of unusually high uncertainty best to fall back on the basics.

First, models struggle when the atmospheric circulation is in transition like the current weather pattern in contrast to when the atmospheric circulation is relatively stable. So, I think skepticism of any model forecast is advisable.

Second, I do think that when the models advertise a pattern change more often than it being wrong, the model timing is premature. So, for example the ECWMF model forecast of the colder temperatures making it into the Eastern US, I think there is a reasonable chance that it is correct, just that it will be verified later than first predicted by the ECMWF. I see that there is still no model consensus that the cold air will actually arrive in the Eastern US, but I am leaning with the ECMWF solution.

Third, when the models are less reliable than usual, good to fall back on teleconnections. Greenland high pressure is related to low pressure over the Southeastern US (see **Figure i**). So, though the models are predicting initially high pressure ridging over the Southeastern US, I would still expect those anomalies to reverse to low pressure troughing with time. Also, the teleconnection of relative high pressure and warmth over Greenland is stronger with relative low pressure and cold with Europe and Asia than with the Eastern US (see **Figure ii**). So typical temperature and precipitation anomalies associated with the negative NAO are more likely to be observed in Europe and Asia than the Eastern US. It seems to be cold and even extreme cold has already verified in Siberia. It is cold in Europe, and I think extreme cold is still a risk. I think cold is coming for the Eastern US, but extreme cold is less likely than across Eurasia. Though looking at the very latest ECWMF week two forecast, it is suggesting "hold my beer." But for now my attitude is I will believe it when I see it with any 15 day forecast.

## Corr of DJF NAO and DJF 500 hPa 1979-2020

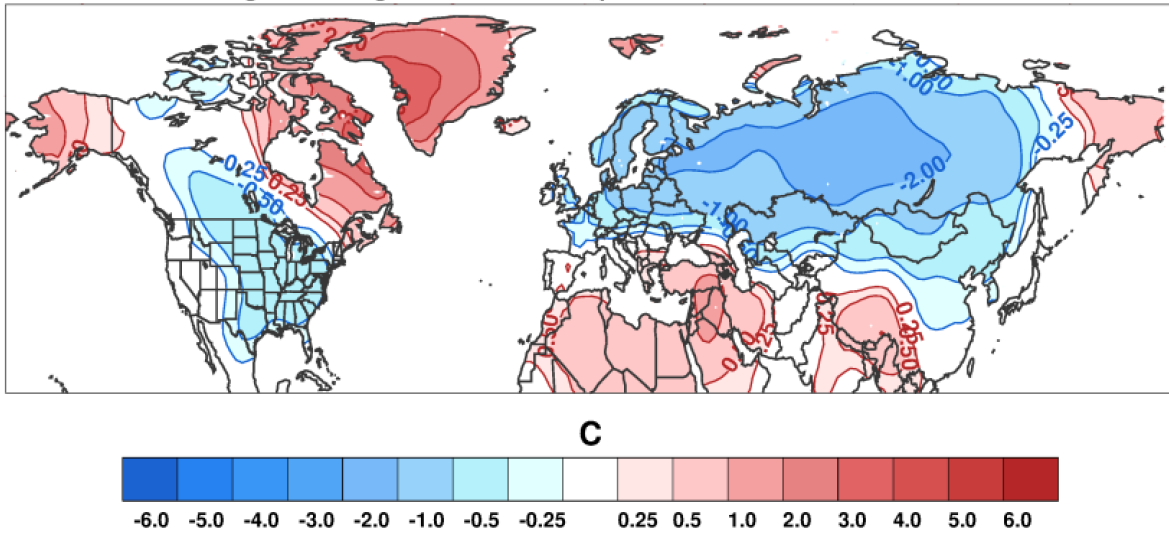


**Figure i.** Correlation of the negative winter (Dec-Jan-Feb) NAO index with winter 500 hPa geopotential heights for the winters 1979/1980-2020/21.

This is another story for another time but see how the pattern associated with a negative NAO shows cold temperatures right up to the Arctic Ocean across Asia. Yet if you look at the observed temperatures for far Northern Asia, it is extremely warm (see **Figure iii**). I do think this could be an artifact of climate change and in particular sea ice loss.

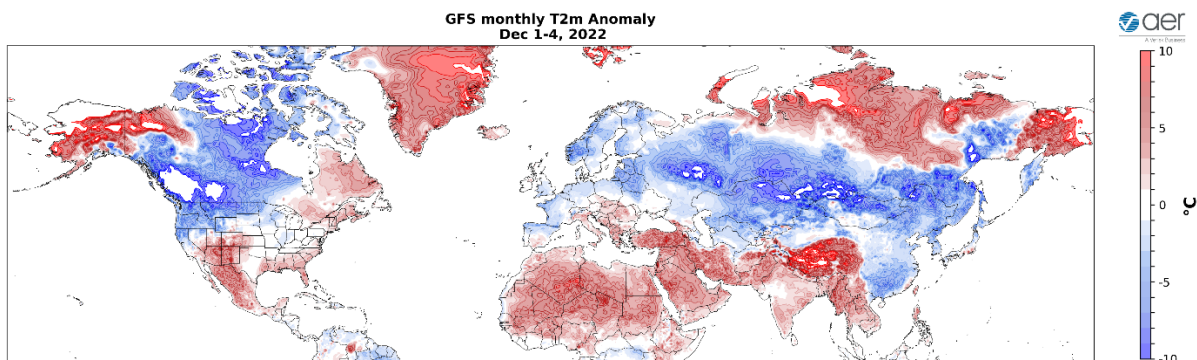


Regression negative NAO and Temperature Dec-Jan-Feb 1980-2022



**Figure ii.** Regression of winter (Dec-Jan-Feb) negative NAO with winter surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) for winters 1979/80-2021/22.

But will it get cold or will it not get cold in the Eastern US is not the main story this week in my opinion. As I shared in the meme from last week my focus is on Ural/Barents-Kara Seas and not Greenland. Though the models last week were predicting a hard shift of high latitude blocking/high pressure from the Urals to Greenland, the models today are now predicting a remnant of high pressure/ridging to persist across the Urals (see **Figures 2, 5** and **8**). Of course, I never have much confidence in the CFS forecast but the one below in Figure 14 predicts the Ural high pressure ridging to persist into January. Consistent with the high amplitude and persistent Ural high pressure ridging our experimental polar vortex (PV) model for the first time this year is predicting a meaningful weakening of the PV. Not ready just yet to predict a sudden stratospheric warming, but I do think that the probability of one has increased beginning in early January. As I have been discussing for weeks, I do believe that high latitude blocking centered in the Ural/Barents-Kara Seas/Scandinavia region is the feature that makes long term severe winter weather risk most probable.



**Figure iii.** Observed surface temperature anomalies (°C; shading) for 1 – 4 December 2022.

It seems to me that we had a stretched PV in late November. These typically result in colder temperatures east of the Rockies but this one seems to be a bit of a dud. Not sure what happened but the cold air never made it past the Upper Midwest. But moving forward I think upcoming upwelling energy from the troposphere will more likely be absorbed in the stratosphere rather than reflected. Reflection favors in the short-term cold weather in the Eastern US, but in contrast absorption favors milder weather. Not sure how that couples with strong Greenland blocking but something to keep in mind.

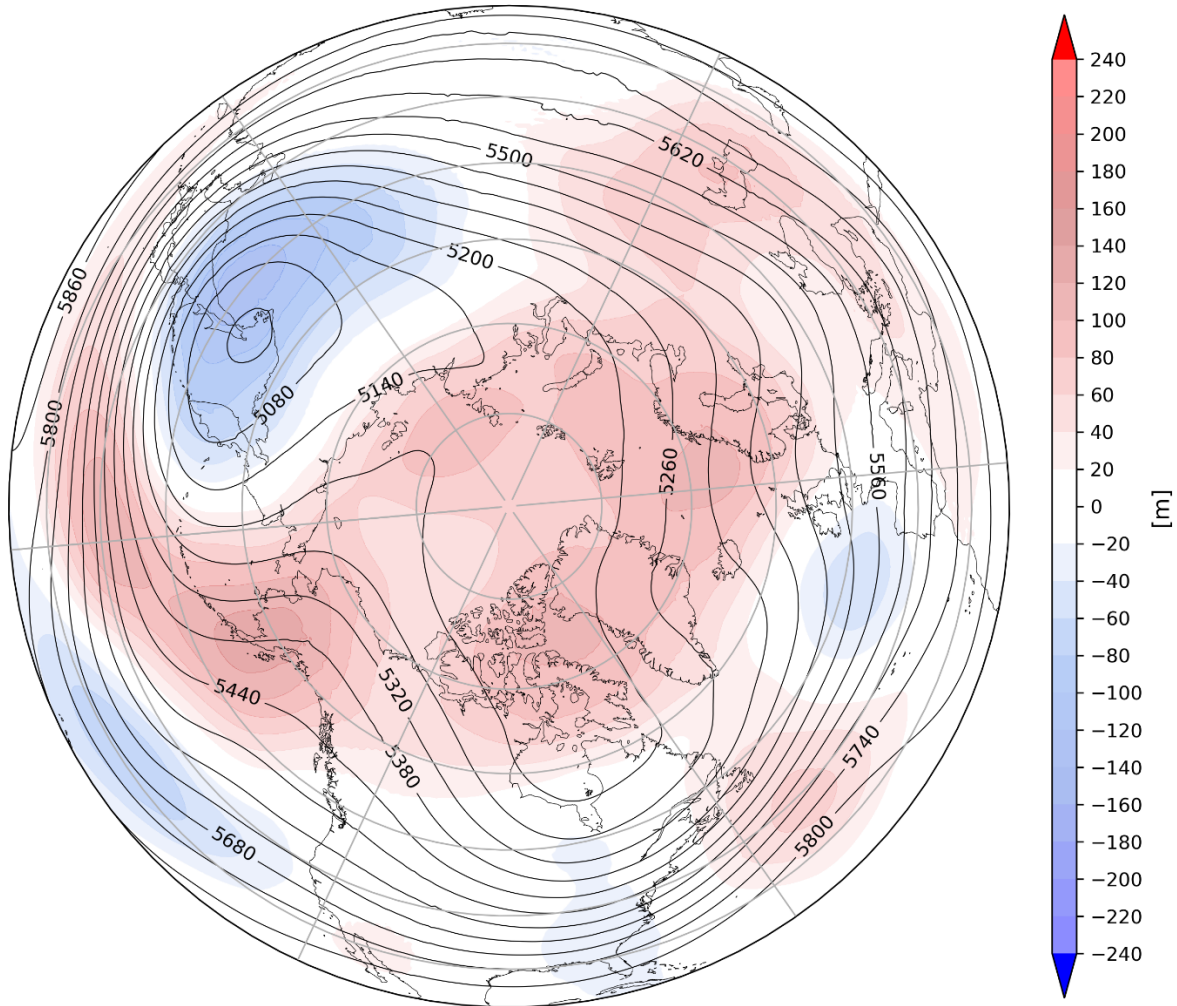
There is an idea that a negative NAO response is more likely following a sudden stratospheric warming (SSW) if a negative NAO is in place when the SSW occurs (e.g., [Domeisen et al. 2020](#)). So also, something to watch in the coming weeks.

I have Covid. Not seeking for sympathy or well wishes as I will be fine, but I apologize in the delay of the blog publication and if there are more typos than normal, as I definitely have Covid fog. Also, next week I will be attending Fall AGU and there might be some delay in posting of the blog again.

### **Wednesday Update**

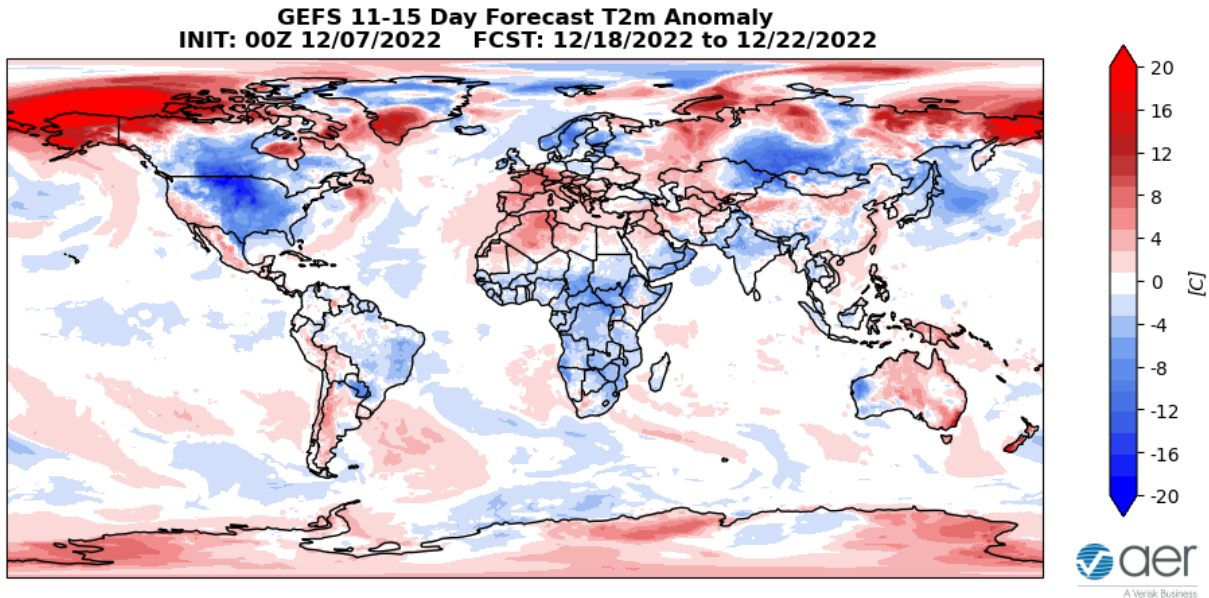
The biggest change that I can see is better consensus among the different dynamical models for North America the second half of December. All the models now agree that the high pressure ridging across Alaska and Northwestern Canada with low pressure troughing spread across all of the US (see **Figure iv**). And with more amplified ridging in western North America, the cold temperatures are finally able to push east of the Mississippi river in the longer range forecasts (see **Figure v**).

**GEFS 11-15 Day Forecast 500 hPa Anomaly**  
**INIT: 00Z 12/07/2022 FCST: 12/18/2022 to 12/22/2022**



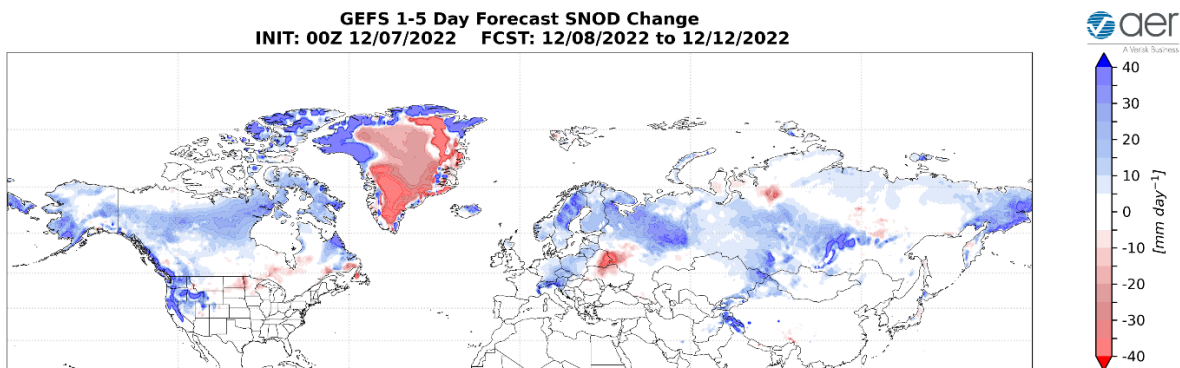
**Figure iv.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 18 – 22 December 2022. The forecasts are from the 00z 7 December 2022 GFS ensemble.

It does seem that the models compensated with more Alaskan ridging by weakening the Ural ridging (compare **Figure iv** with **Figure 8**). If ridging in the Urals mostly disappears then what I wrote above about increasing odds of a larger PV disruption would be in question. Still not sure that the GFS is catching on to an accurate trend.



**Figure v.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 18 – 22 December 2022. The forecast is from the 00Z 7 December 2022 GFS ensemble.

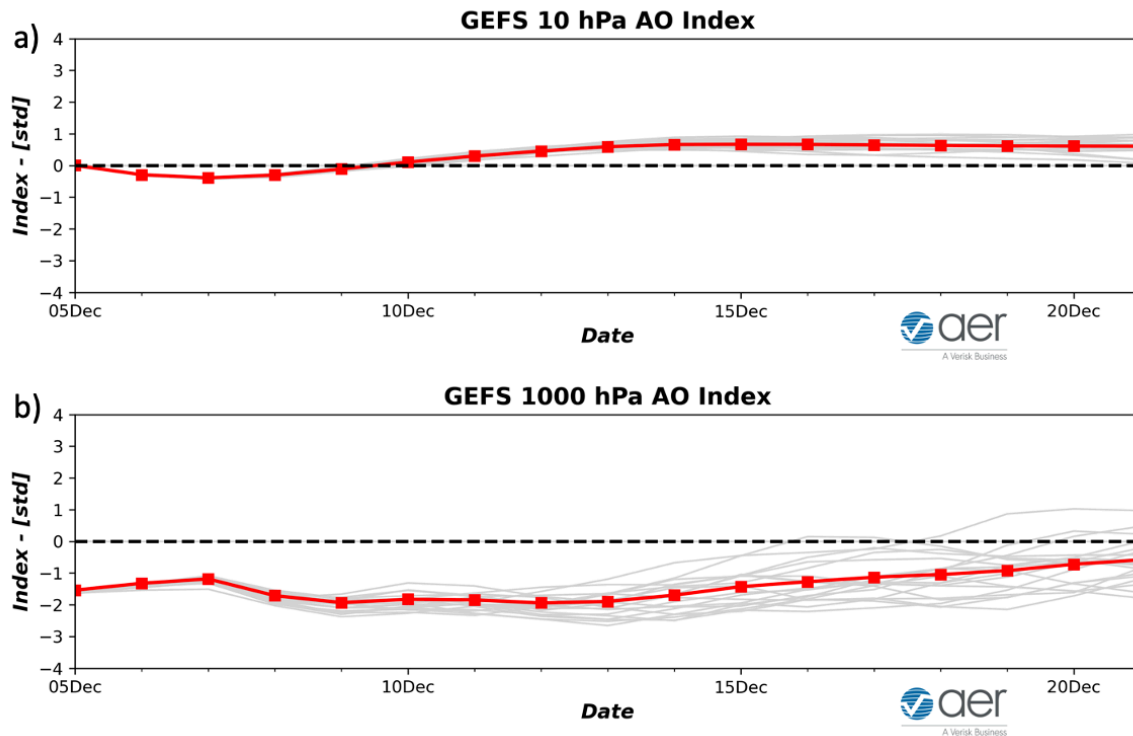
I will just end with; I think the negative NAO and even more importantly the warm/positive PCHs is of large enough magnitude to support severe winter weather. We are already seeing that in Siberia, parts of East Asia (I see on Twitter about heavy snowfall in Japan) and western North America, especially western Canada. Our snowfall maps look fairly impressive for snowfall potential in parts of Europe this week and into next week. I post one example from the GFS in **Figure vi.**



**Figure vi.** Forecasted snow depth changes ( $\text{mm}/\text{day}$ ; shading) from 8 – 12 December 2022. The forecast is from the 00Z 7 December 2022 GFS ensemble.

**Recent and Very Near Term Conditions**

The AO is predicted to be negative this week (**Figure 1**) with strong positive geopotential height anomalies predicted across the North Atlantic sector of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with strong positive geopotential height anomalies this week across Greenland (**Figure 2**), the NAO is predicted to be negative this week as well (**Figure 1**).

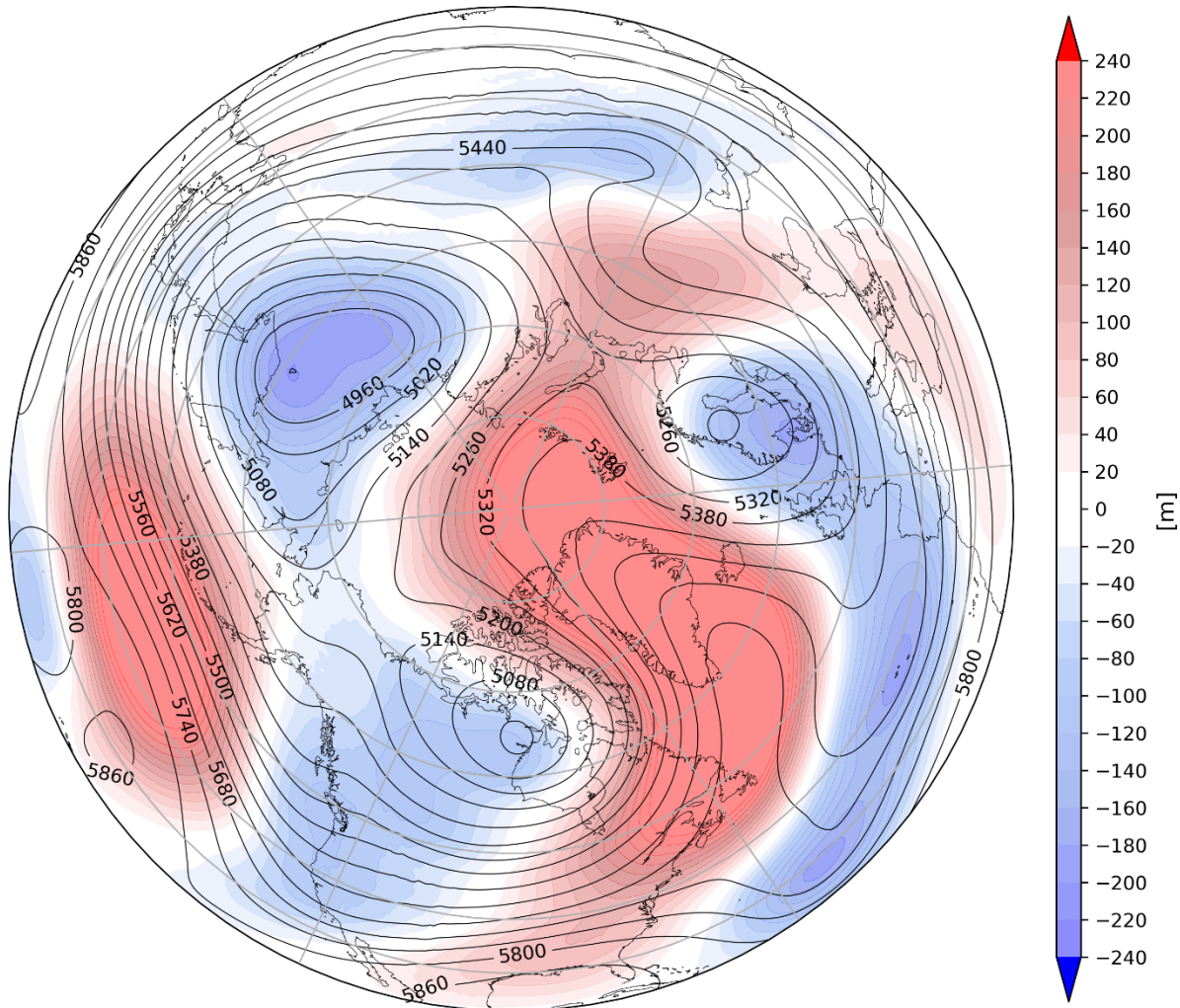


**Figure 1.** (a) The predicted daily-mean AO at 1000 hPa from the 00Z 28 November 2022 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 28 November 2022 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Strong ridging/positive geopotential height anomalies across Greenland will favor troughing/negative geopotential height anomalies across Europe with the exception of ridging/positive geopotential height anomalies across far Eastern Europe (**Figure 2**). **This will favor** normal to below normal temperatures across Northern and Western Europe including the UK with normal to above normal temperatures across much of Southern and Eastern Europe (**Figure 3**). Ridging/positive geopotential height anomalies stretching across the Urals, Barents-Kara Seas and over to Greenland are predicted to force downstream troughing/negative geopotential height anomalies across Siberia that extend southwestward into Central Asia (**Figure 2**). This pattern favors normal to below normal temperatures across Siberia and Central Asia except along the Siberian North Slope with normal to above normal temperatures across Southern and far Western Asia (**Figure 3**).

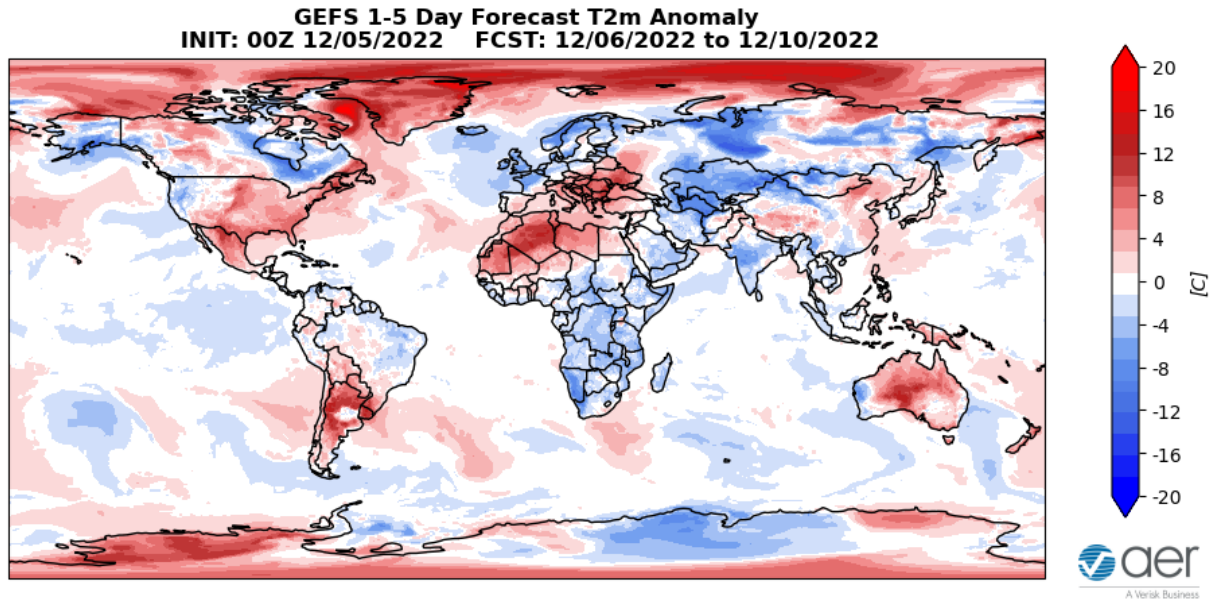


**GEFS 1-5 Day Forecast 500 hPa Anomaly**  
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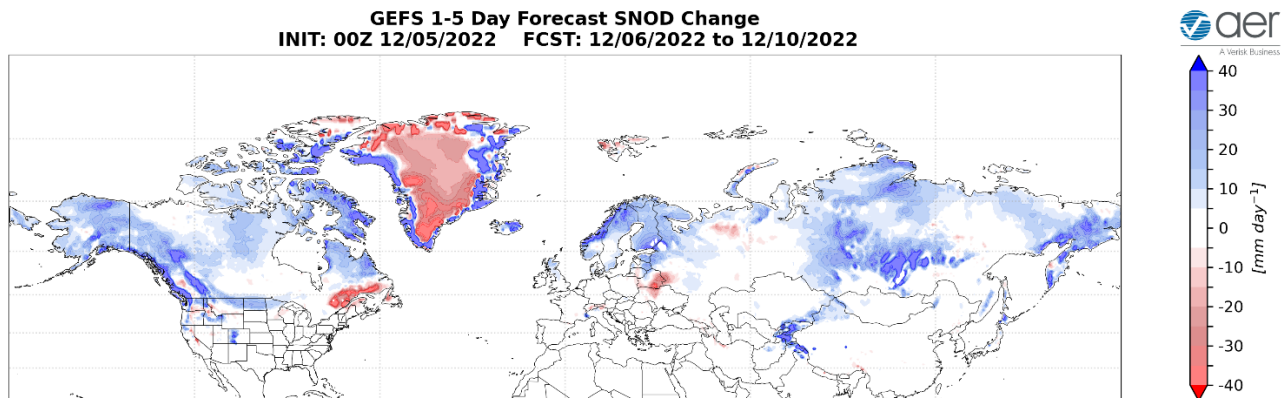
**Figure 2.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 6 – 10 December 2022. The forecasts are from the 00z 5 December 2022 GFS ensemble.

Ridging/positive geopotential height anomalies predicted to be centered near the Aleutians will force troughing/negative geopotential height anomalies across Western Canada and the Western US with more ridging/positive geopotential height anomalies in Eastern Canada and the US (**Figure 2**). The pattern will favor normal to above normal temperatures across Alaska, Southeastern Canada and the Southern and Eastern US with normal to below normal temperatures across Western and Central Canada and the Western US (**Figure 3**).



**Figure 3.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 6 – 10 December 2022. The forecast is from the 00Z 5 December 2022 GFS ensemble.

Trounging and/or cold temperatures will support new snowfall across Scotland, Scandinavia, the Baltics, Siberia and Central Asia while mild temperatures will support snowmelt in Eastern Europe (**Figure 4**). Trounging and/or cold temperatures will support new snowfall across northern Alaska, Northern, Western and Central Canada and the Northern and Western US while mild temperatures will support snowmelt across the Northern New England and Southeastern Canada (**Figure 4**).



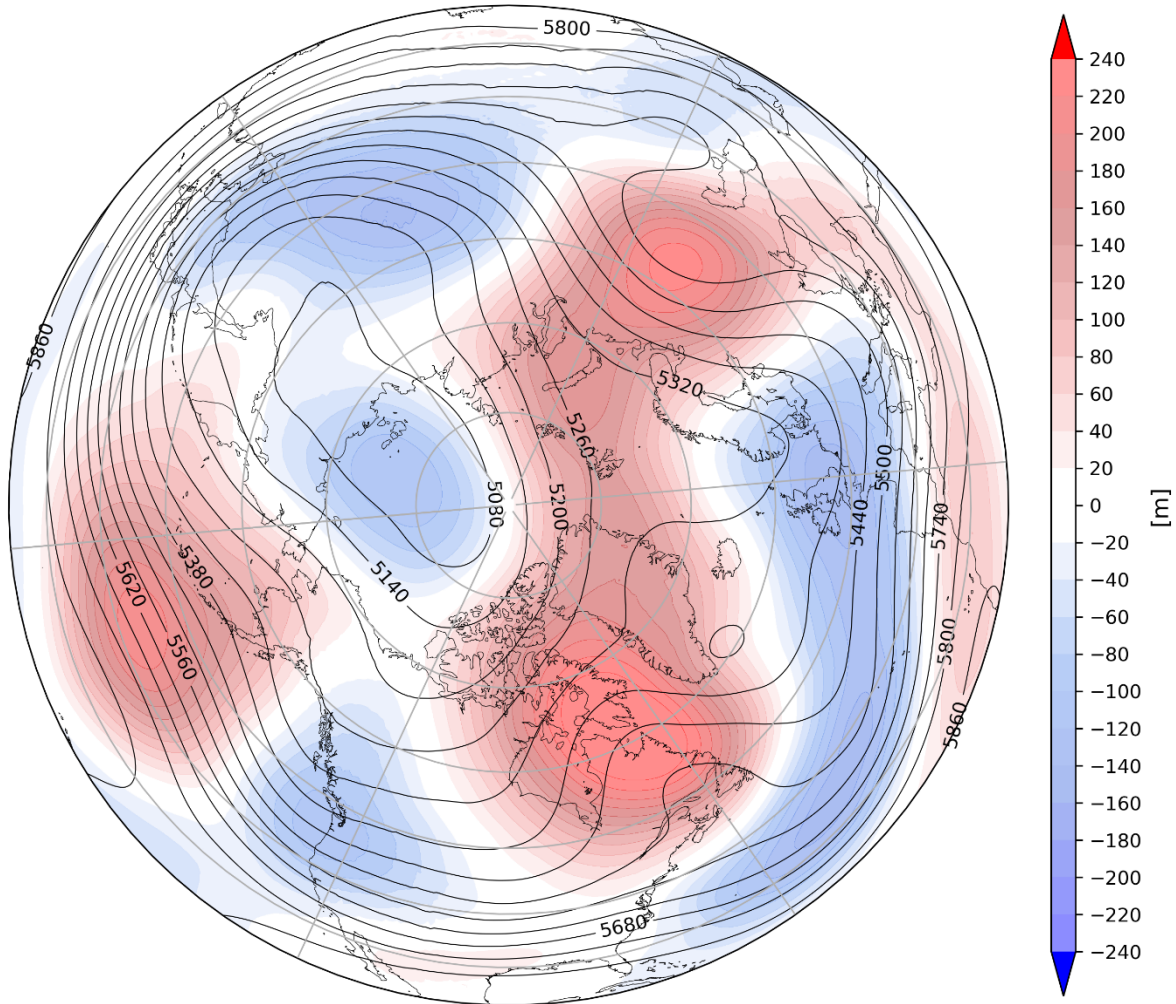
**Figure 4.** Forecasted snow depth changes ( $\text{mm}/\text{day}$ ; shading) from 6 – 10 December 2022. The forecast is from the 00Z 5 December 2022 GFS ensemble.

**Near-Term**

1-2 week

The AO is predicted to remain negative this period (**Figure 1**) as geopotential height anomalies remain positive across the North Atlantic sector of the Arctic and mixed across the mid-latitudes (**Figure 5**). With positive geopotential height anomalies across Greenland (**Figure 5**), the NAO is predicted to remain negative this period as well.

**GEFS 6-10 Day Forecast 500 hPa Anomaly**  
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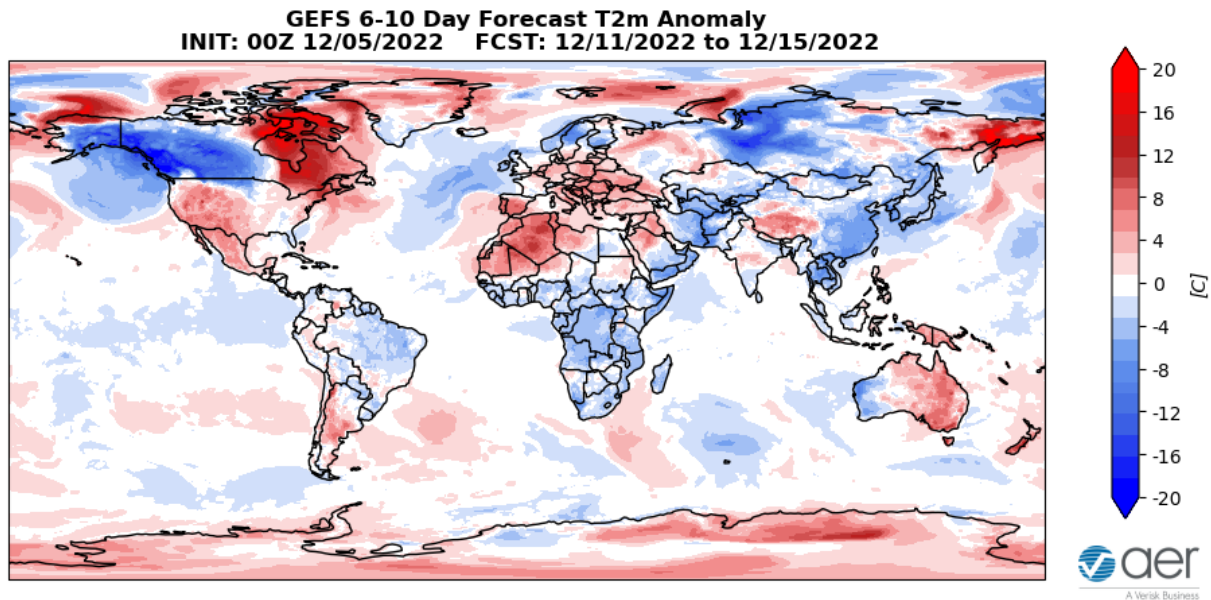


**Figure 5.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 11 – 15 December 2022. The forecasts are from the 00z 5 December 2022 GFS ensemble.

Predicted persistent ridging/positive geopotential height anomalies across Greenland will continue to favor troughing/negative geopotential height anomalies across Europe with the exception of ridging/positive geopotential height anomalies persisting across far Eastern Europe (**Figures 5**). The pattern is predicted to result in normal to below

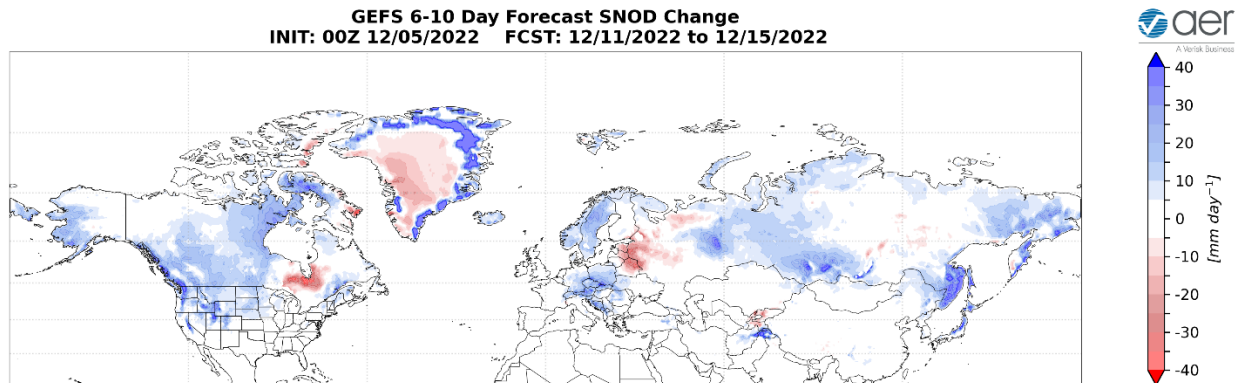


normal temperatures across Northern and Western Europe including the UK with normal to above normal temperatures across Southern and Eastern Europe (**Figure 6**). Persistent ridging/positive geopotential height anomalies stretching from the Urals, Barents-Kara Seas to Greenland are predicted to anchor downstream troughing/negative geopotential height anomalies across Siberia and Eastern Asia that extends southwestward into Central Asia with ridging/positive geopotential height anomalies in Western Asia this period (**Figure 5**). This pattern favors widespread normal to below normal temperatures across Northern, Eastern and Central Asia with normal to above normal temperatures across Southern and Western Asia (**Figure 6**).



**Figure 6.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 11 – 15 December 2022. The forecast is from the 00Z 5 December 2022 GFS ensemble.

Predicted persistent ridging/positive geopotential height anomalies near the Aleutians will force troughing/negative geopotential height anomalies in the Gulf of Alaska and across Western Canada and the Western US with ridging/positive geopotential height anomalies persisting across Eastern Canada this period (**Figure 5**). This pattern will favor normal to below normal temperatures across Alaska, Western Canada and the Western US with normal to above normal temperatures Eastern Canada and the Eastern US (**Figure 6**).



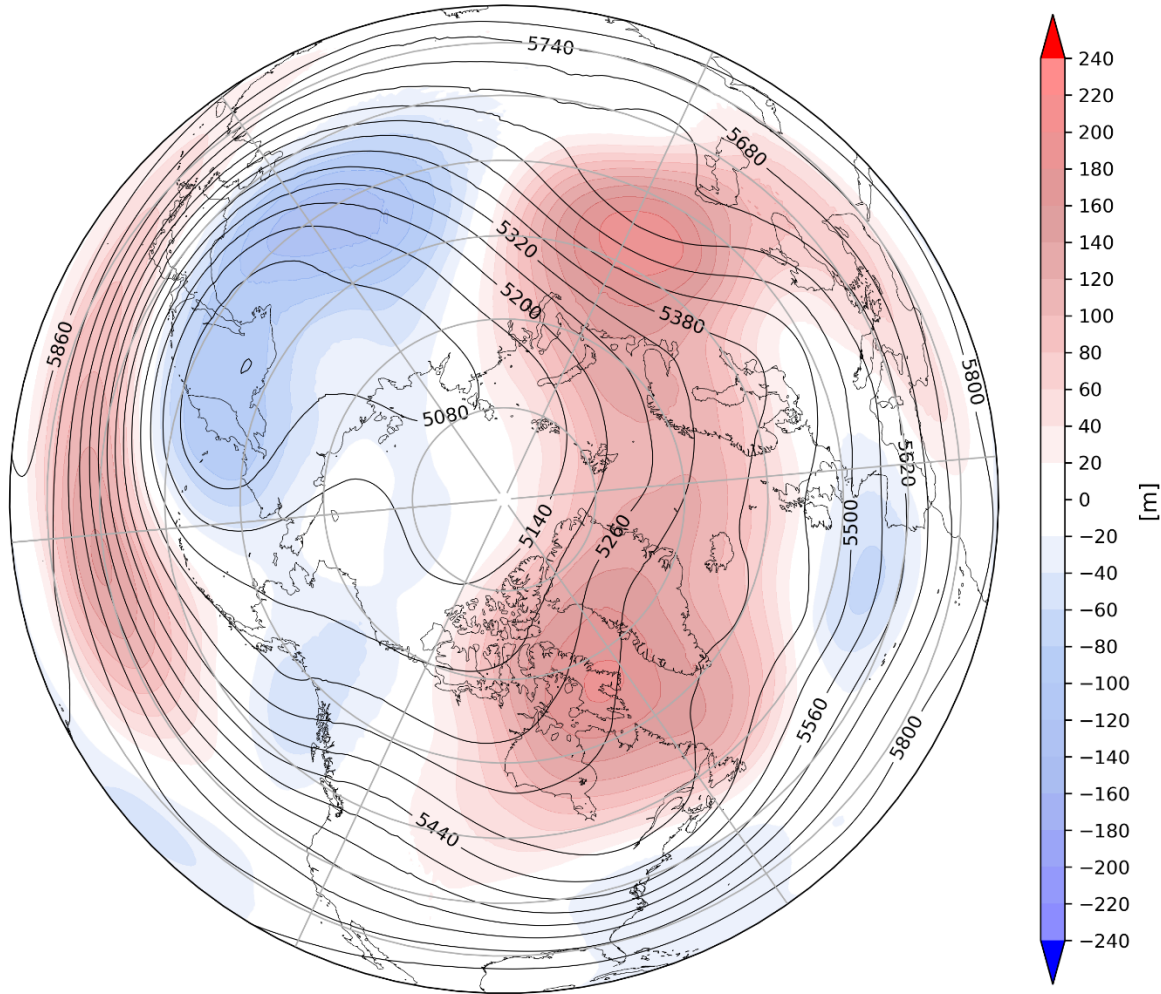
**Figure 7.** Forecasted snow depth changes (mm/day; shading) from 11 – 15 December 2022. The forecast is from the 00Z 5 December 2022 GFS ensemble.

Trouging and/or cold temperatures will support new snowfall across Scandinavia, Central Europe, Northern and Eastern Asia while mild temperatures will support snowmelt in Eastern Europe (**Figure 7**). Trouging and/or cold temperatures will support new snowfall across Alaska, Western and Central Canada and the Northern and Western US while mild temperatures will support snowmelt in Ontario, Canada (**Figure 7**).

#### *3-4 week*

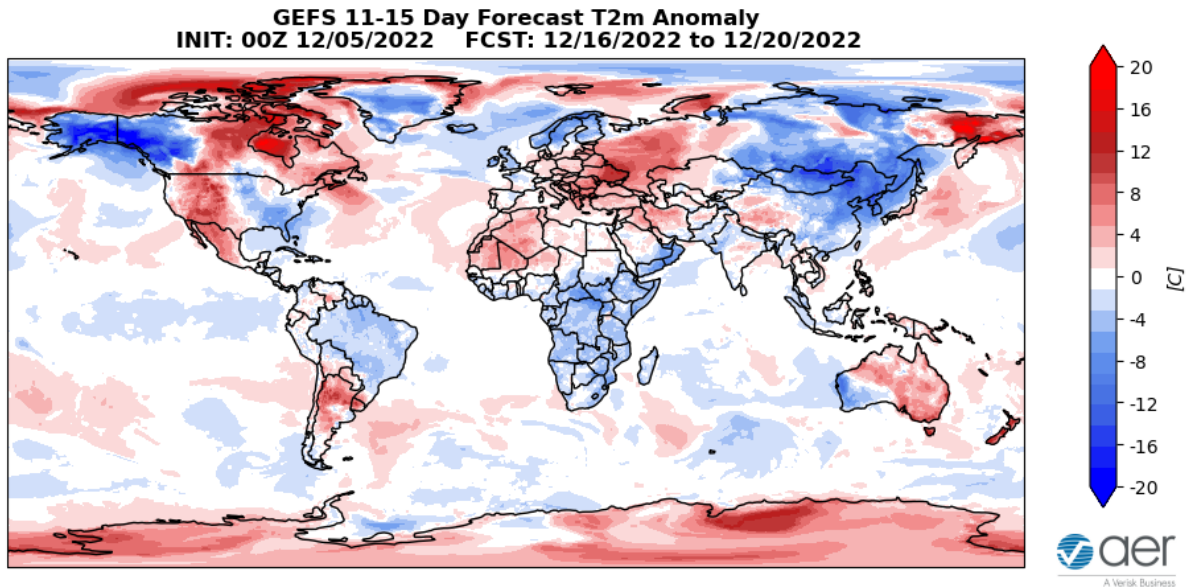
Positive geopotential height anomalies are predicted to continue to dominate the North Atlantic sector of the Arctic with mixed geopotential height anomalies across the mid-latitudes this period (**Figure 8**), therefore the AO should remain negative this period (**Figure 1**). With positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO will also remain negative this period.

**GEFS 11-15 Day Forecast 500 hPa Anomaly**  
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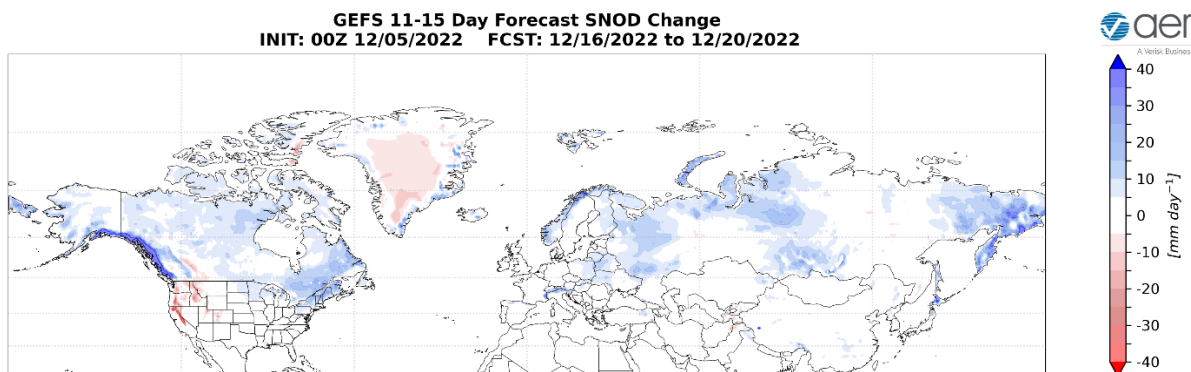
**Figure 8.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 16 – 20 December 2022. The forecasts are from the 00z 5 December 2022 GFS ensemble.

Predicted ridging/positive geopotential height anomalies across Greenland will continue to favor troughing/negative geopotential height anomalies across Europe this period (**Figure 8**). This pattern favors normal to below normal temperatures across Northern and Western Europe including the UK with normal to above normal temperatures across Southern and Eastern Europe (**Figures 9**). Predicted ridging/positive geopotential height anomalies centered across the Urals over to Greenland will help to anchor troughing/negative geopotential height anomalies across Siberia that extend southward into East Asia with ridging/positive geopotential height anomalies centered near the Urals (**Figure 8**). This pattern favors widespread normal to below normal temperatures across much of Northern and Eastern Asia with normal to above normal temperatures across Southern and Western Asia (**Figure 9**).



**Figure 9.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 16 – 20 December 2022. The forecast is from the 00Z 5 December 2022 GFS ensemble.

Predicted persistent ridging/positive geopotential height anomalies near the Aleutians will continue to favor troughing/negative geopotential height anomalies across Alaska, the Gulf of Alaska and Western Canada while ridging/positive geopotential height anomalies over Greenland will force troughing/negative geopotential height anomalies in the Eastern US this period (**Figure 8**). This pattern favors widespread normal to below normal temperatures across Alaska, Western Canada and the Eastern US with normal to above normal temperatures in Eastern Canada, the Western and New England (**Figure 9**). The ECMWF model is predicting more ridging in Western Canada that would favor a colder pattern across the Eastern US.



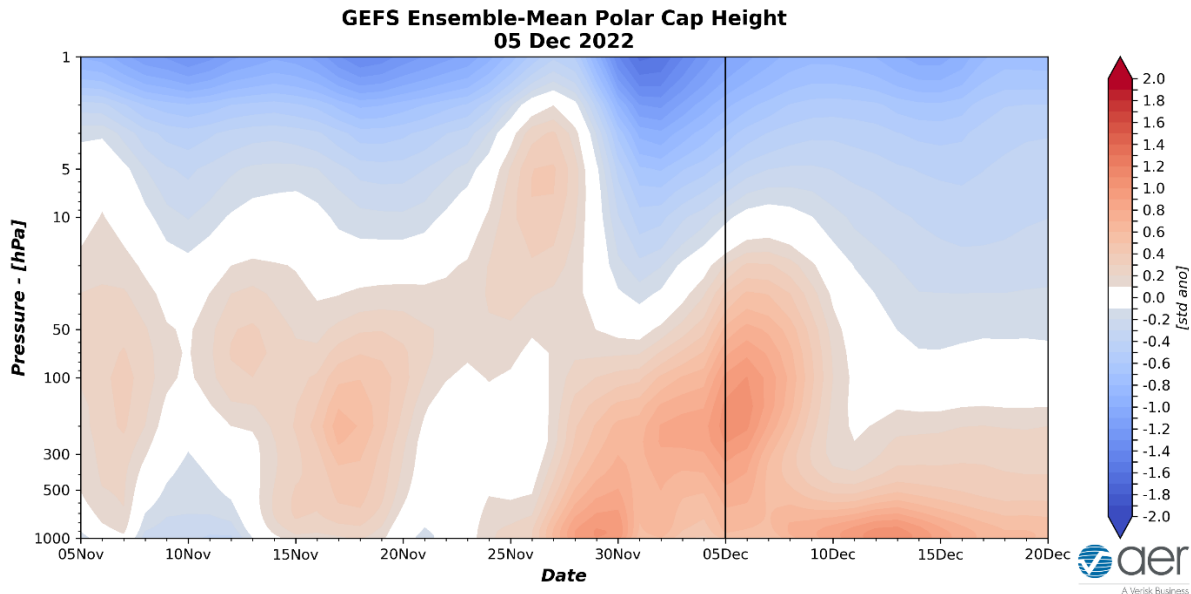
**Figure 10.** Forecasted snow depth changes ( $\text{mm}/\text{day}$ ; shading) from 16 – 20 December 2022. The forecast is from the 00Z 5 December 2021 GFS ensemble.

Trouching and/or cold temperatures will support new snowfall across Scotland, Norway, the Alps, Northeastern Europe, Northern and Eastern Asia and Eastern Siberia (**Figure 10**). Trouching and/or cold temperatures will support new snowfall across Alaska, much of Canada and the Northeastern US while mild temperatures will support snowmelt in the higher elevations of the Western US (**Figure 10**).

### Longer Term

#### 30-day

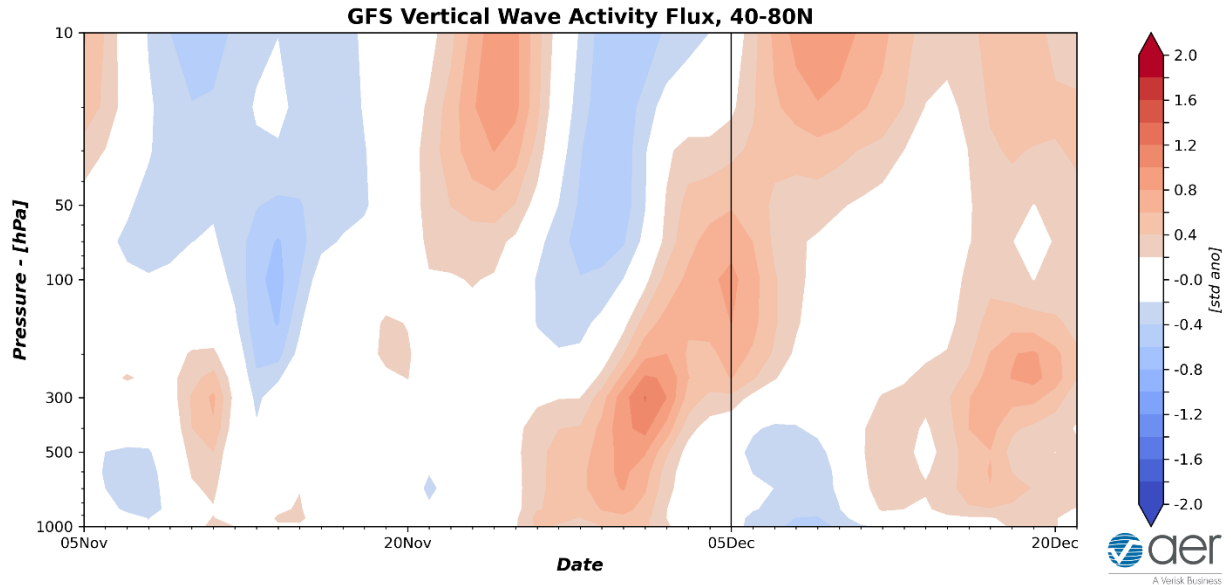
The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows cold/negative PCHs in the upper stratosphere with warm/positive PCHs in the mid to lower stratosphere and the troposphere (**Figure 11**). Cold/negative PCHs in the upper stratosphere are predicted to descend into the lower stratosphere over the next week (**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 5 December 2022 GFS ensemble.

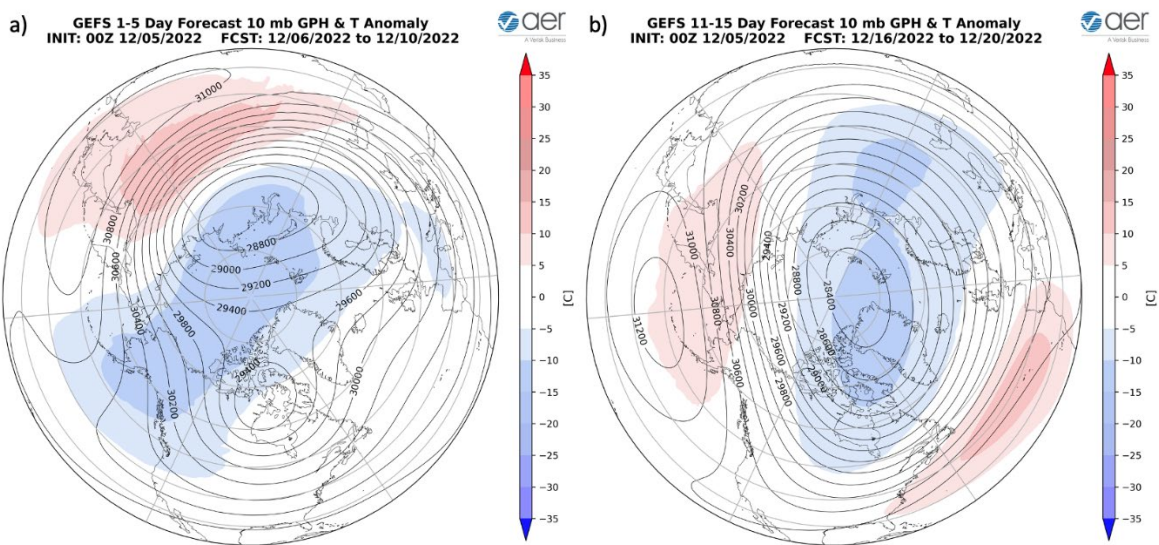
The warm/positive PCHs in the lower troposphere over the next two weeks (**Figure 11**) are consistent with the predicted negative surface AO (**Figure 1**). However this week into next week when the warm/positive PCHs in the lower troposphere are predicted to strengthen (**Figure 11**), the surface AO is predicted to be more strongly negative (**Figure 1**).





**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 5 December 2022 GFS ensemble.

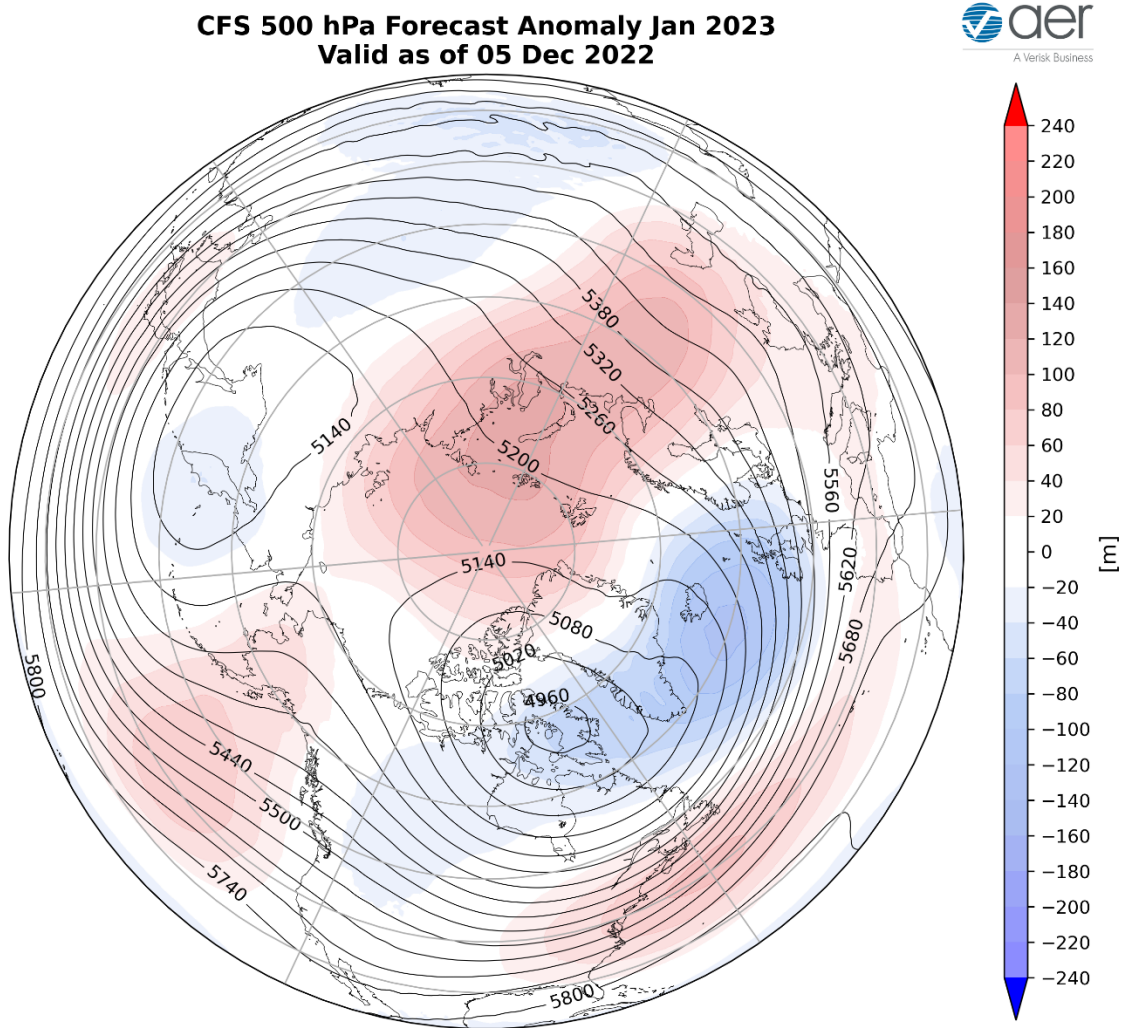
The near normal vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere or poleward heat transport in the stratosphere the past two weeks (**Figure 12**) has resulted in mixed stratospheric PCHs (**Figure 11**). The GFS is predicting a possible more active period of WAFz in the next two weeks (**Figure 12**), resulting in the lower to mid stratospheric PCHs to warm this week before cooling again (**Figure 11**).



**Figure 13.** (a) Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere from 6 – 10 December 2022.

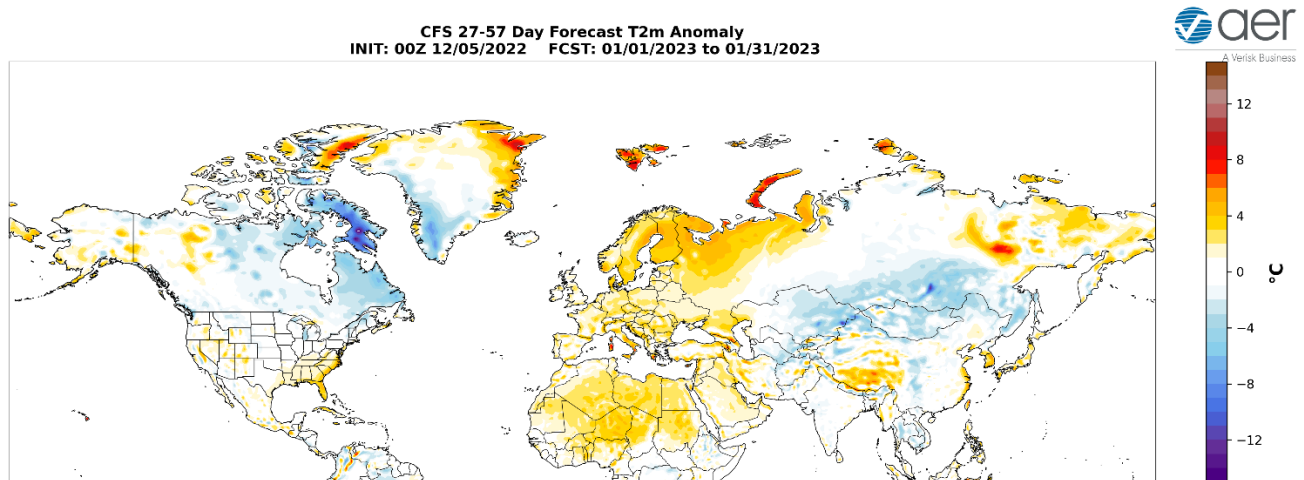
(b) Same as (a) except forecasted averaged from 16 – 20 December 2022. The forecasts are from the 00Z 5 December 2020 GFS model ensemble.

Still the somewhat active WAFz has caused a minor perturbation of the stratospheric PV with two PV centers with one center over the Laptev Sea and the other center over Hudson Bay (**Figure 13**). Not sure what to make of the configuration of the PV is it consistent with a stretched PV or more of a very minor split PV? However the positive WAFz values quickly followed by negative WAFz values is a signature of wave reflection or a stretched PV (**Figure 13**). The predicted active WAFz could force more perturbations to the PV with the GFS ensembles predicting a configuration that is consistent with a stretched PV the third week of December (**Figure 13**). However, the PV is predicted to be mostly normal to stronger than normal over the next two weeks despite the split and elongated configuration (**Figure 13**). Therefore, the stratospheric AO is predicted to remain neutral to positive over the next two weeks (**Figure 1**).



**Figure 14.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for January 2022. The forecasts are from the 00Z 5 December 2022 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and surface temperatures for January (**Figure 15**) from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging stretching across the Urals and into the Barents-Kara Seas, the Aleutians, Alaska and along the US East Coast with troughing across the Western Europe, Siberia, East Asia, Central Asia and Western Canada and the Central US (**Figure 14**). This pattern favors seasonable to relatively warm temperatures across Europe, Western Asia, Eastern Siberia, Alaska, the Western and Southern US with seasonable to relatively cold temperatures across Northern Asia, much of Canada and the Northeastern US (**Figure 15**).



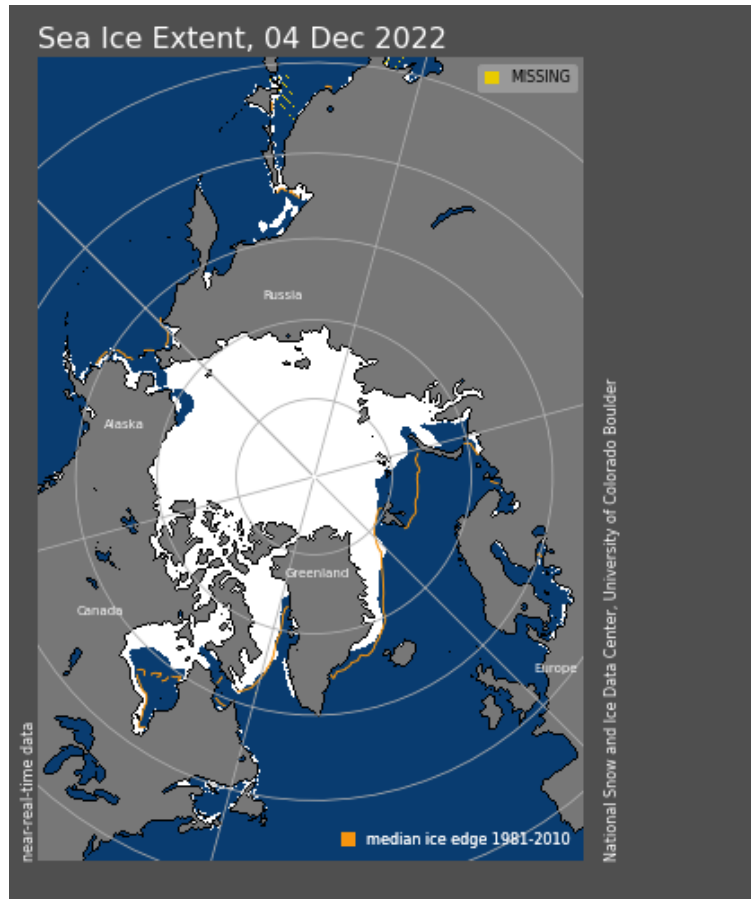
**Figure 15.** Forecasted average surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) across the Northern Hemisphere for January 2022. The forecasts are from the 00Z 5 December 2022 CFS.

## **Boundary Forcings**

### *Arctic Sea Ice*

Arctic sea ice, which as expected is below normal (see **Figure 16**) but the regional anomalies have been more extensive in recent years. I believe that the realization of a cold NH winter is most dependent on high latitude blocking in the North Atlantic sector, and that is where I am focused. Sea ice extent is below normal in the Barents-Kara Seas, which I believe favors high latitude blocking. Sea ice is below normal in the Chukchi and Bering Seas continues to approach normal. So it could be Arctic sea ice is increasingly favoring high latitude blocking in the Barents-Kara Seas region and PV disruptions.

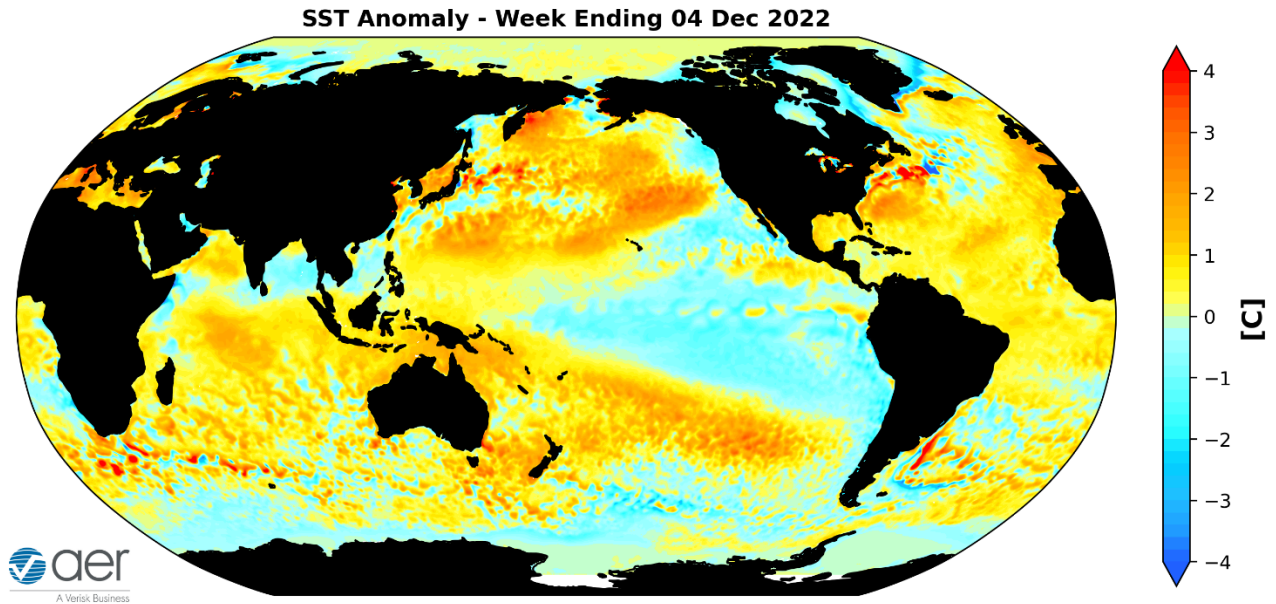




**Figure 16.** Observed Arctic sea ice extent on 4 December 2022 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC).

### *SSTs/El Niño/Southern Oscillation*

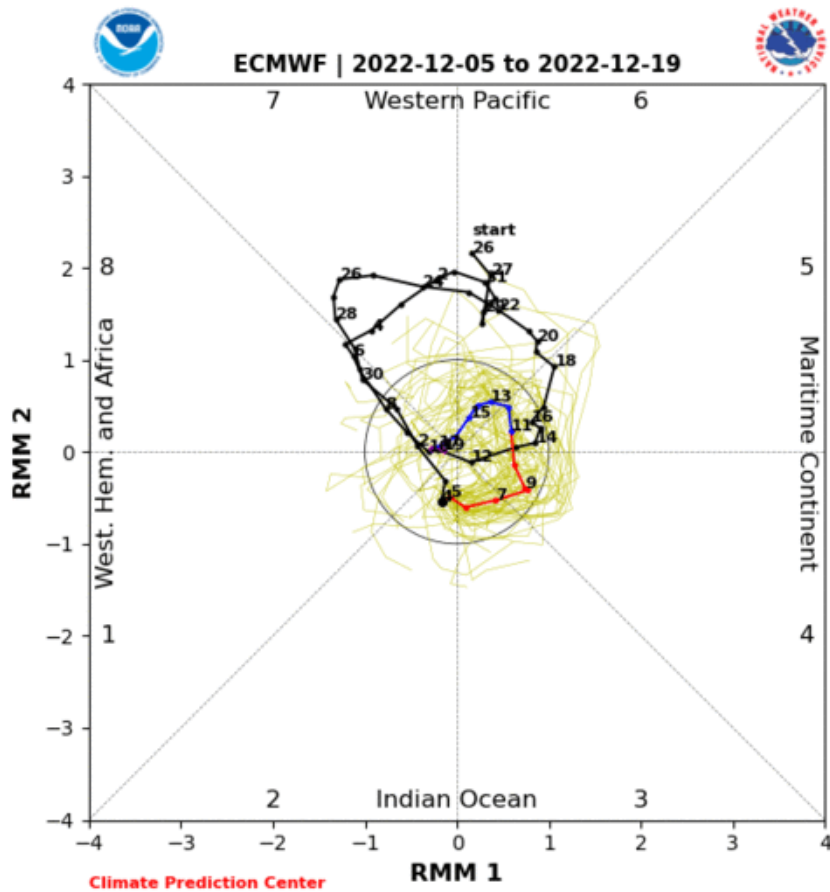
Equatorial Pacific sea surface temperatures (SSTs) anomalies are below normal and we continue to observe weak La Niña conditions (**Figure 17**) and La Niña conditions are expected through the fall. Observed SSTs across the NH remain well above normal especially in the central North Pacific (west of recent years), the western North Pacific and offshore of eastern North America though below normal SSTs exist regionally especially in the South Pacific.



**Figure 17.** The latest weekly-mean global SST anomalies (ending 4 December 2022). Data from NOAA OI High-Resolution dataset.

### *Madden Julian Oscillation*

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 18**). The forecasts are for the MJO to remain weak where no phase is favored over the next two weeks. Hard for me to see how the MJO could be having influence on the weather across North America in the short term. But admittedly this is outside of my expertise.

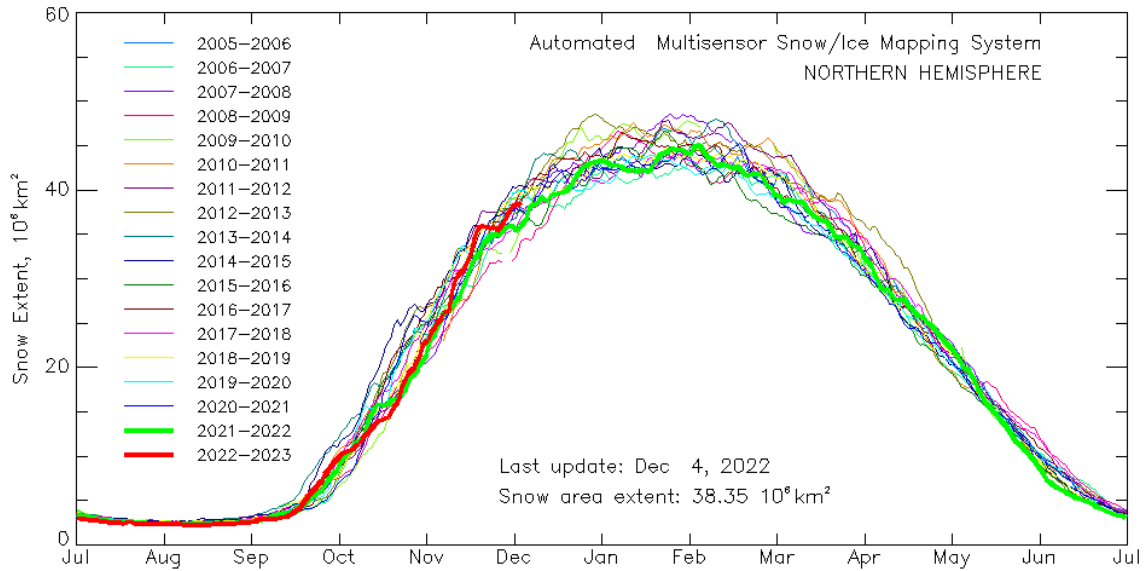


**Figure 18.** Past and forecast values of the MJO index. Forecast values from the 00Z 5 December 2022 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate the phase of the MJO, with geographical labels indicating where anomalous convection occurs during that phase. Image source:

<http://www.atmos.albany.edu/facstaff/roundy/waves/phasediags.html>

### *Snow Cover*

Snow cover extent across the NH has advanced again this week (see **Figure 19**), which occurred both in Eurasia and North America and remains near decadal means. With the predicted negative NAO, I expect snow cover to advance again in the coming weeks.



**Figure 19.** Observed North American snow cover extent through 4 December 2022. Plot from [https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow\\_extent\\_monitor.html](https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_monitor.html)

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