

Arctic Oscillation and Polar Vortex Analysis and Forecasts

December 12, 2022

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.

Subscribe to our email list or follow me on Twitter (@judah47) for notification of updates.

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

Summary

- The Arctic Oscillation (AO) is currently strongly negative and is predicted to remain negative to weakly negative the next two weeks as pressure/geopotential height anomalies across the Arctic are predicted to remain positive first mostly in the North Atlantic sector and then mostly in the North Pacific 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 ridging/positive geopotential height anomalies centered near Greenland will favor troughing/negative geopotential height anomalies across Europe, though at the end of the week there could be a brief weakening of the pattern. 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 Europe.

- Over the next two weeks, predicted Greenland coupled with Alaskan/Beaufort Sea ridging/positive geopotential height anomalies will force troughing/negative geopotential height anomalies across Siberia that extend southward to East Asia, though again towards the end of the week there could be a temporary weakening of the pattern. This pattern favors normal to below normal temperatures across Northern and Eastern with normal to above normal temperatures across Southern and Western Asia the next two weeks.
- The general pattern this week across North America is ridging/positive geopotential height anomalies centered in the Gulf of Alaska and in Northeastern Canada forcing downstream troughing/negative geopotential height anomalies in much of the United States (US). However, next week ridging/positive geopotential height anomalies in the Gulf of Alaska will push north into the Beaufort Sea forcing deep troughing/negative geopotential height anomalies in the interior of North America. This pattern favors this week widespread normal to above normal temperatures across Alaska, Northern and Eastern Canada and the Central US with normal to below normal temperatures across Western Canada, the Western US and the US East Coast. However, next week well below temperatures will spread east of the Rockies in Canada and the US.
- I discuss what we can expect in this period of shifting players in the atmosphere and possible coupling with the polar vortex (PV) in the coming weeks.
- I am at Fall AGU which has delayed the publishing of the blog and likely contribute to some additional typos, so thank you for your patience.

Plain Language Summary

It looks like the polar vortex (PV) will elongate or stretch for the middle of December. This pattern is supportive of cold temperatures east of the Rockies in North America and the rest of December is looking cold to potentially very cold across the US. This pattern also can promote milder weather in Europe and it does look like Europe will get at least a temporary respite from the severe winter weather. But heading into January lots of uncertainty.

Impacts

Since last week, the shorter-term weather (until the end of December) has come into better focus. Last Monday the models were ambivalent about bringing the cold temperatures from western North America into eastern North America. The trend was becoming clearer by the Wednesday update and now the models are very empathic about an Arctic outbreak east of the Rockies that certainly has the potential to be one of the most severe in December in recent memory. I discussed in the section on the polar stratosphere how the configuration of the polar vortex (PV) resembled that of a stretched PV but did also think that persistent Ural ridging could start favoring absorption of upwelling vertical wave energy rather than reflecting wave energy. Reflecting wave energy is what is necessary for a stretched PV. However, by

Wednesday the models were backing off of Ural ridging and I think we are looking at wave reflection/PV stretching rather than absorption of the upwelling wave energy through at least the end of the month.

As I look at the forecast maps, I see maybe not a textbook wave reflection but certainly a strong example of one. In our paper, [Cohen et al. 2021](#) we showed that Greenland blocking is often a precursor to wave reflection/PV stretching events and this December is turning out to be a great example of this. It's funny when we did the analysis, I was a bit incredulous and every time it happens in real time, I find myself surprised but maybe I shouldn't be so surprised anymore.

But the models are all consistently showing a wave reflection/PV stretching event with all the trappings. Maybe most impressively is the ridging in the eastern North Pacific that climaxes with a cutoff high-pressure center in the Beaufort Sea. This event reminds me of many of the wave reflection/PV stretching events from the winter of 2013/14 that we analyzed in my most recent paper [Cohen et al. 2022](#) and this event can be an opportunity for an illustrative or teaching moment.

In Cohen et al. 2022 wave energy diagnostics were critical for understanding the development of multiple Arctic outbreaks that winter. As we showed that winter, Wave Activity Flux (WAF) in the vertical and longitudinal directions was directed upward and eastward beginning with Ural high-pressure ridging, continued through East Asia troughing and then converged and reflected downward in the eastern North Pacific, strengthening high-pressure ridging between Eastern Siberia and Alaska contributing to downstream low-pressure troughing that results in Arctic outbreaks across North America east of the Rockies. Looking at the observed and predicted wave diagnostic show the same sequence of events. Currently WAF is propagating upward and eastward (vectors in **Figure ia**) out of high-pressure ridging in the Urals (positive geopotential height anomalies or orange shading at 60°E; see **Figure ia**). Also notice there is no sign of low-pressure troughing across eastern North America (lack of blue shading east of 240°E and below 100 hPa in **Figure ia**).

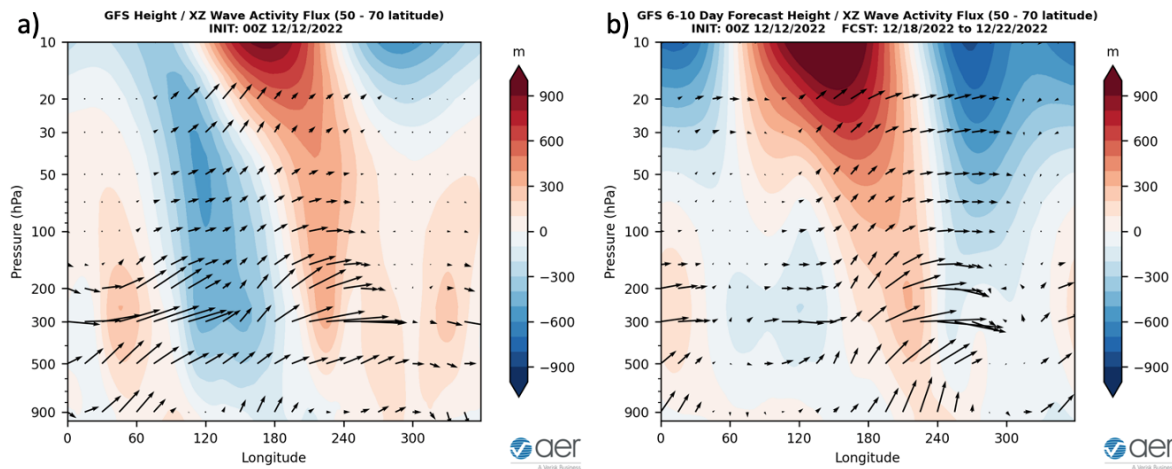


Figure i. Longitude-height cross section of geopotential eddy height anomalies (shading) and wave activity flux (vectors) a) initialized 12 December 2022 and b) forecasted for 18-22 December 2022.

Now looking at the forecast for next week, the WAF vectors (arrows in **Figure ib**) over North America are directed eastward and downward or wave reflection. Also, tropospheric high-pressure ridging in the eastern North Pacific (orange shading between 180-240°E below 200 hPa in **Figure ib**) is strengthened as well as deepening of low-pressure troughing in eastern North America (blue shading between 240-300°E below 200 hPa in **Figure ib**). And the PV is clearly predicted to take on a stretched configuration as seen in **Figure 13a**.

I thought PV stretching could be very important this winter and I would argue that the PV stretching and then snapping back has been dominant on the weather of the US this cold season at least through the end of December. It was also dominant last winter and played a critical role in the winter before that, in particular February 2021. I guess it is good timing that PV stretching has been the subject of my last two papers. Good timing or better to be lucky.

It also seems to me just as in winter 2013/14 the PV stretching events resulted in strong maritime flow of air across Europe, with this upcoming stretched PV something similar is likely though probably not as extreme. The pattern is predicted to become more zonal across Europe and this should result in some respite across Europe from the severe winter weather including a rare December snowfall in the city of London.

But what comes next? Comparing **Figures ia** and **ib** what is also apparent is the disappearance of Ural high pressure ridging as orange shading centered on 60°E reverses to blue shading. This is indicative of a significant weakening of the Ural ridging so important for weakening of the PV. With the absence of Ural ridging hard to see a

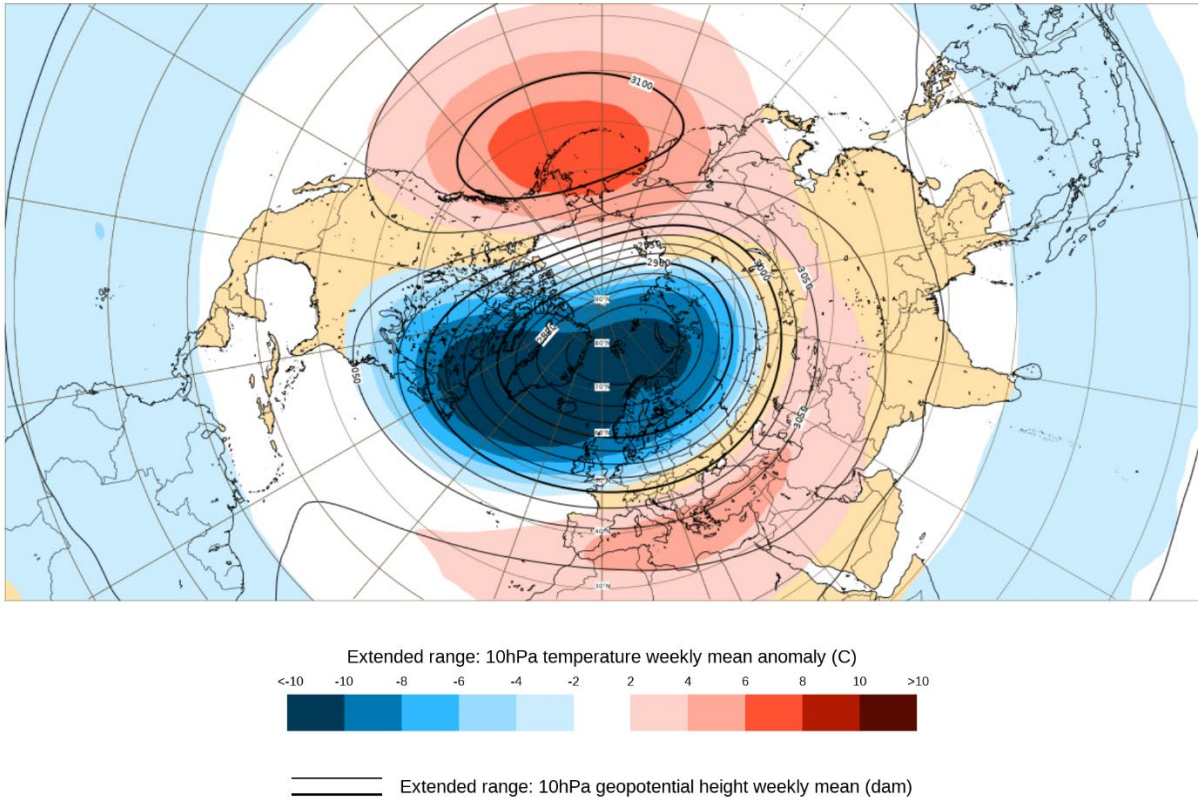
sudden stratospheric warming in the foreseeable future. In addition, reflective events often protect the PV from upwelling wave energy from the troposphere and from **Figure 11** the stratospheric polar cap geopotential height anomalies (PCHs) are predicted to cool, a sign of PV strengthening. Finally, seems like the high latitude blocking is playing musical chairs, starting off centered near the Urals, then making its way to Greenland and now predicted to settle north of Alaska, but where does it go from there? At least based on the GFS it is predicted to find itself in Eastern Siberia. If the pattern resolves to where there is ridging in East Asia and troughing near the Urals, this is an optimal pattern for quashing upwelling wave energy and therefore for strengthening the PV. If (and for now a big if) this were to happen, I think milder times ahead are inevitable.

I would like to point out that the cross polar flow in the polar stratosphere is predicted to be impressive (see **Figure 13a**) supportive of potential extreme cold in North America. But the orientation starts to rotate clockwise with the stretched PV axis on a line from Scandinavia to the Gulf of Alaska (see **Figure 13b**), this orientation with southwest flow across the US East Coast could maintain the core of the cold further to the west in North America with meaningful cold having a hard time making it east of the Appalachians. I don't see evidence of it in the model forecasts but something to keep an eye on.

I think what I have been saying all winter remains true it is an endurance test of what can last the longest, high latitude blocking or a strong PV. December is turning out to be an impressive month of winter weather across the Northern Hemisphere. But the focus of high latitude blocking in the North Pacific sector is potentially a boon for a strong and stable PV. Decembers 1983 and 1989 had strong wave reflection/PV stretching events in December followed by a strong PV into February and mostly mild weather. December 2017 had a strong wave reflection/PV stretching event that was followed by an SSW in early February and widespread severe winter weather. Late December 2013/early January 2014 had a wave reflection/PV stretching event that was then followed by repetitive strong wave reflection/PV stretching events in February and March 2014 and severe winter weather in North America. All seem plausible scenarios to me and will depend strongly on the high latitude blocking musical chairs of this winter so far.

10hPa temperature: Weekly mean anomalies

Base time: Mon 12 Dec 2022 00 UTC Valid time: Mon 09 Jan 2023 00 UTC - Mon 16 Jan 2023 00 UTC (+840h) Area : North Pole



© 2020 European Centre for Medium-Range Weather Forecasts (ECMWF)
Source: www.ecmwf.int
Licence: CC-BY-4.0 and ECMWF Terms of Use(<https://apps.ecmwf.int/datasets/licences/general/>)



Figure ii. Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for from 9 – 16 January 2023. The forecast is from the 00Z 12 December 2022 ECMWF ensemble.

And for what it's worth the latest EPS suggests to me more wave reflection/PV stretching events much more so than an SSW and even more so that a hemispheric wide mild pattern (see **Figure ii**) . In fact, I just looked at the EPS forecast for mid-January 2023 at the 10 hPa geopotential heights at that looks like a pretty clear stretched PV.

Wednesday Update

I probably start off every Wednesday update with not much new since Monday and I certainly feel the same this week. I still think that the dominant weather story is the evolving wave reflection/PV stretching event that will dominate the remainder of December and is predicted to transfer the most severe winter weather, certainly relative to normal, from Siberia (where it is as cold as $-61^{\circ}\text{C}/-78^{\circ}\text{F}$) to North America. The potential is there for an historical cold air outbreak across North America, but extreme cold is challenging to accurately predict and I expect the forecast to still be highly variable from day-to-day.

For me the big question is, after the big dump of Arctic air southward across North America, what happens next. As far as the weather, I would expect temperatures to moderate but for how long and how mild. The focus of high latitude blocking in the Beaufort Sea is not favorable for weakening the PV (see **Figure iii**) and the models are all predicting the PV to strengthen. A strong PV by itself would suggest an extended milder period. However, the counter argument is that in general, the high latitude blocking persists and even after a brief respite, high pressure ridging is predicted to make a return to Greenland (see **Figure iii**), which could reverse the milder trend in Europe. I find the protracted stalemate between the troposphere and the stratosphere is impressive and today's forecast of the PCHs remains unchanged with cold/negative PCHs in the stratosphere and warm/positive PCHs in the troposphere (see **Figure iv**). And as long as they remain uncoupled, forecasting is challenging beyond a week or so.

GEFS 11-15 Day Forecast 500 hPa Anomaly
INIT: 00Z 12/14/2022 FCST: 12/25/2022 to 12/29/2022

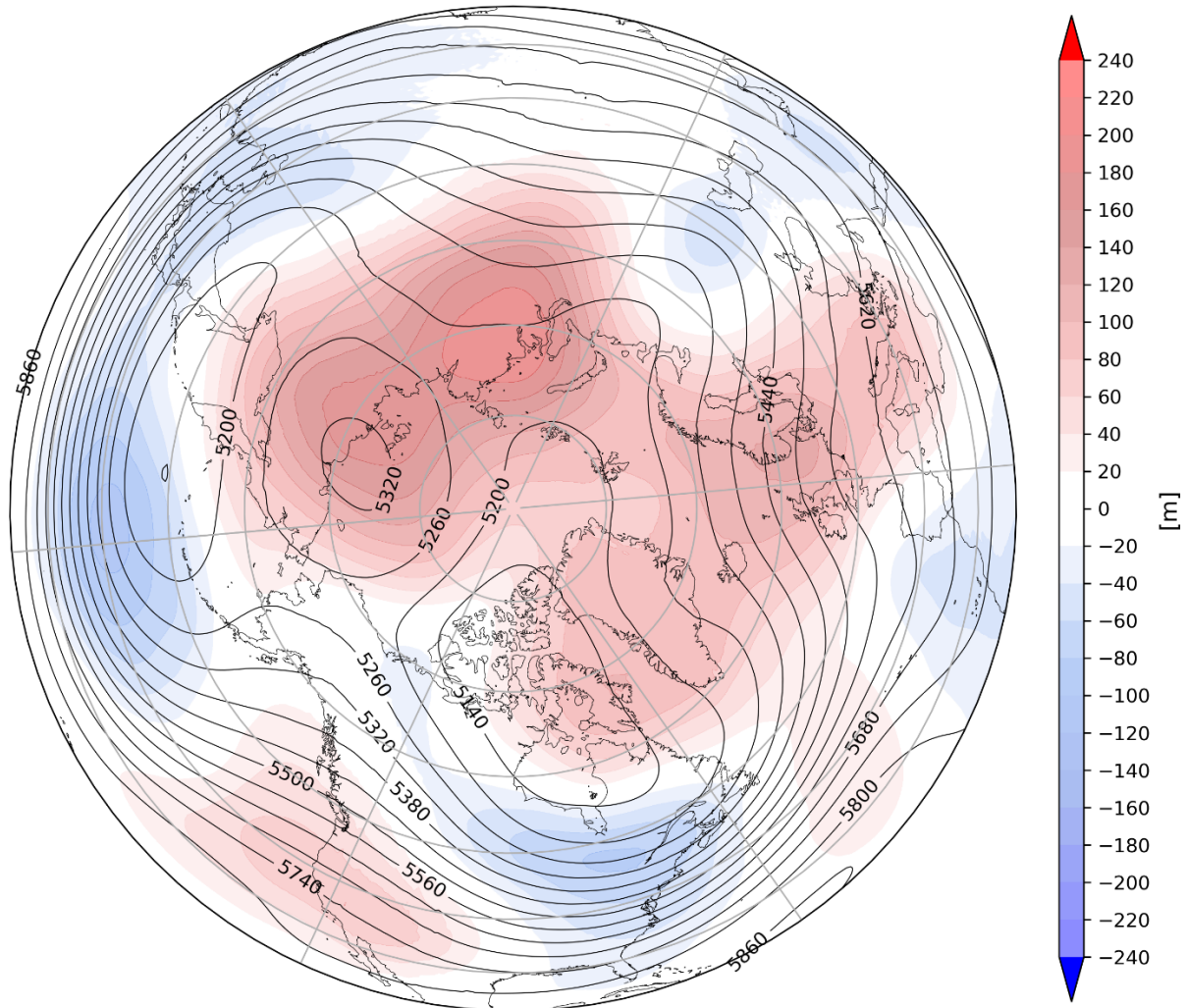


Figure iii. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 25 – 29 December 2022. The forecasts are from the 00z 14 December 2022 GFS ensemble.

But the week-two 500 hPa geopotential height forecast shows some interesting features. The first low pressure roughing from East Asia towards the Aleutians (see **Figure iii**); this is a relatively new development. But also, the models are suggestive that the high latitude blocking could make its way over back to the Urals/Barents-Kara Seas region (the ECMWF more so). One or even more so both of these atmospheric features would increase upwelling wave energy from the troposphere to the stratosphere. Seems like it is very difficult for this wave energy to get absorbed in the polar stratosphere this winter, but reflection/PV stretching is completely different with at least one event per month since October. Hard to argue right now why the streak shouldn't continue into January.

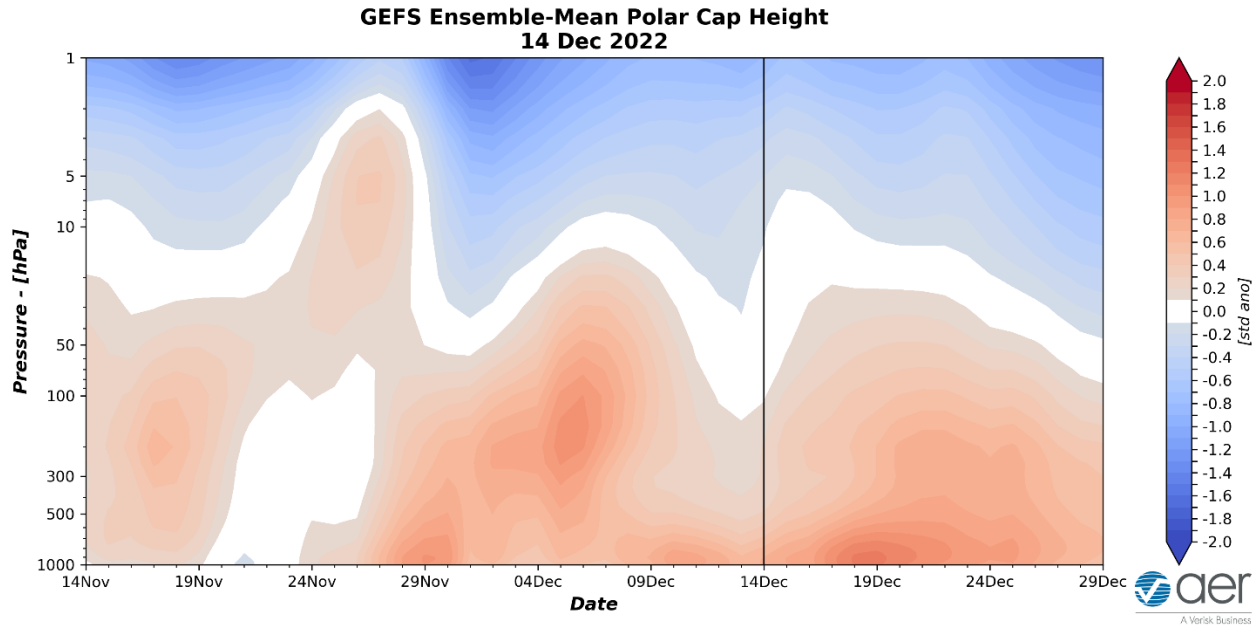


Figure iv. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 14 December 2022 GFS ensemble.

Recent and Very Near Term Conditions

The AO is predicted to be negative this week (**Figure 1**) with positive geopotential height anomalies predicted across the Central and 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**).

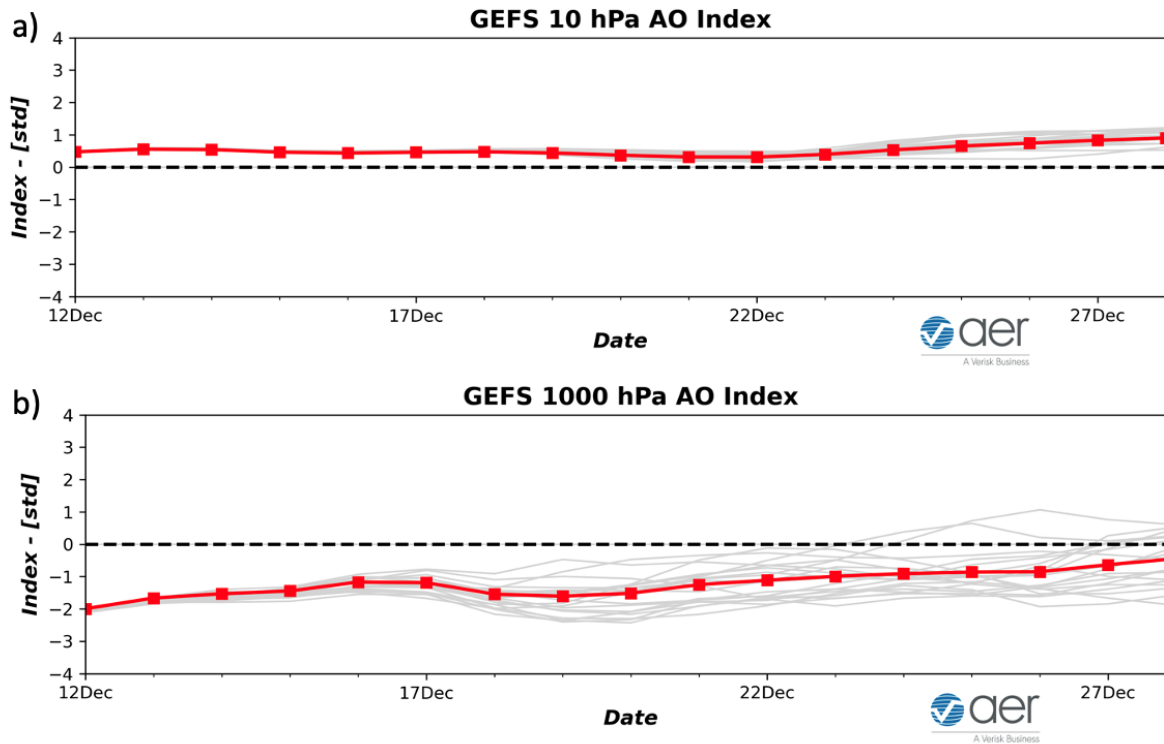


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 12 December 2022 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 12 December 2022 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Ridging/positive geopotential height anomalies across Greenland and Hudson Bay will favor troughing/negative geopotential height anomalies across Europe with the exception of ridging/positive geopotential height anomalies across Southeastern 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 across the Urals, Barents-Kara Seas and into the Central Arctic are predicted to force downstream troughing/negative geopotential height anomalies across Siberia that extend southeastward into East Asia (**Figure 2**). This pattern favors normal to below normal temperatures across Siberia and East Asia except along for parts of Eastern Siberian with normal to above normal temperatures across Southern and Western Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 hPa Anomaly
INIT: 00Z 12/12/2022 FCST: 12/13/2022 to 12/17/2022

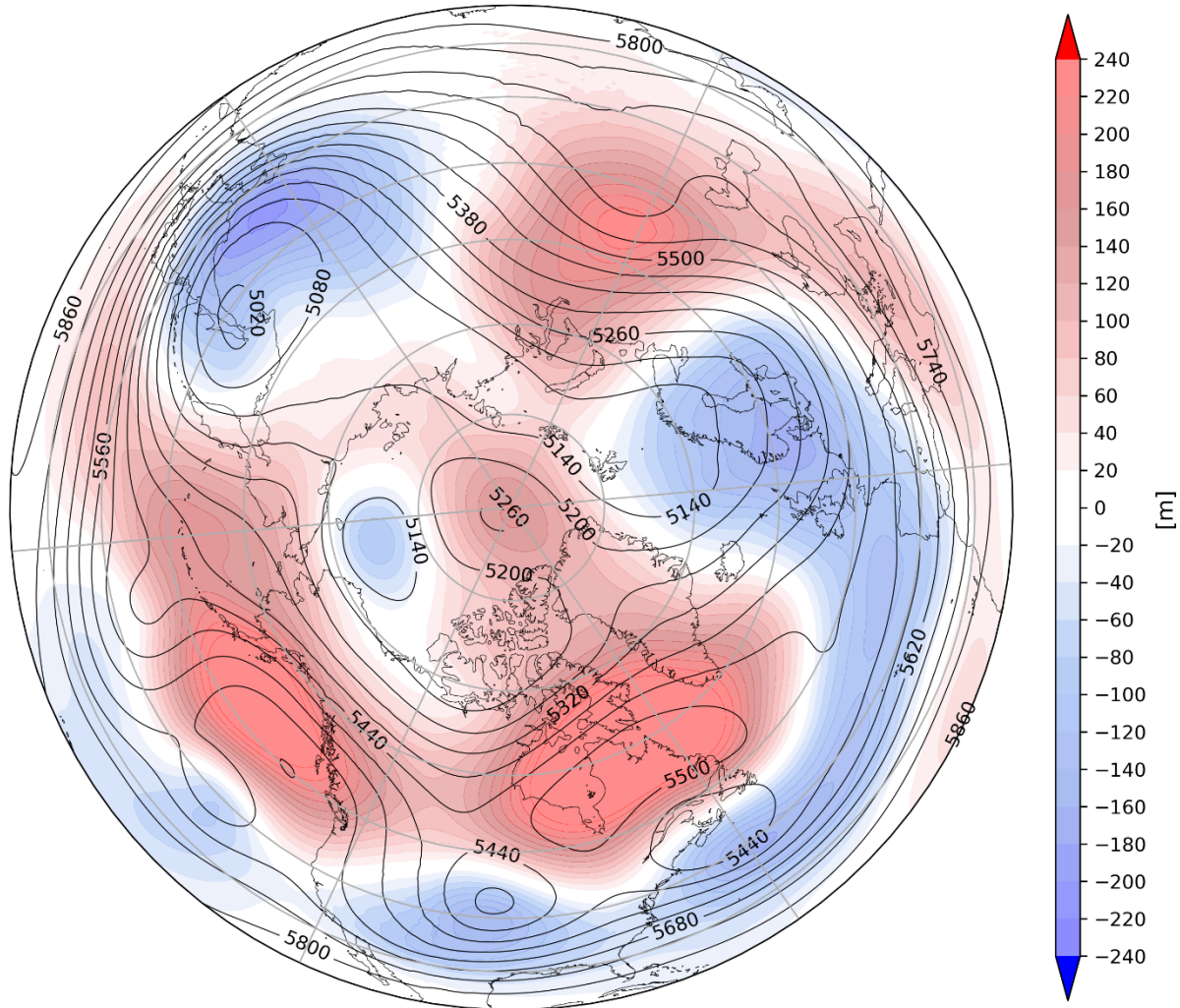


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 13 – 17 December 2022. The forecasts are from the 00z 12 December 2022 GFS ensemble.

Ridging/positive geopotential height anomalies predicted to be centered in the Gulf of Alaska and in Hudson Bay will force troughing/negative geopotential height anomalies in the Plains of Canada and the US (**Figure 2**). The pattern will favor normal to above normal temperatures across Alaska, much of Canada and the Southern and Central US with normal to below normal temperatures across Western Canada, the Western US and the Northeastern US (**Figure 3**).

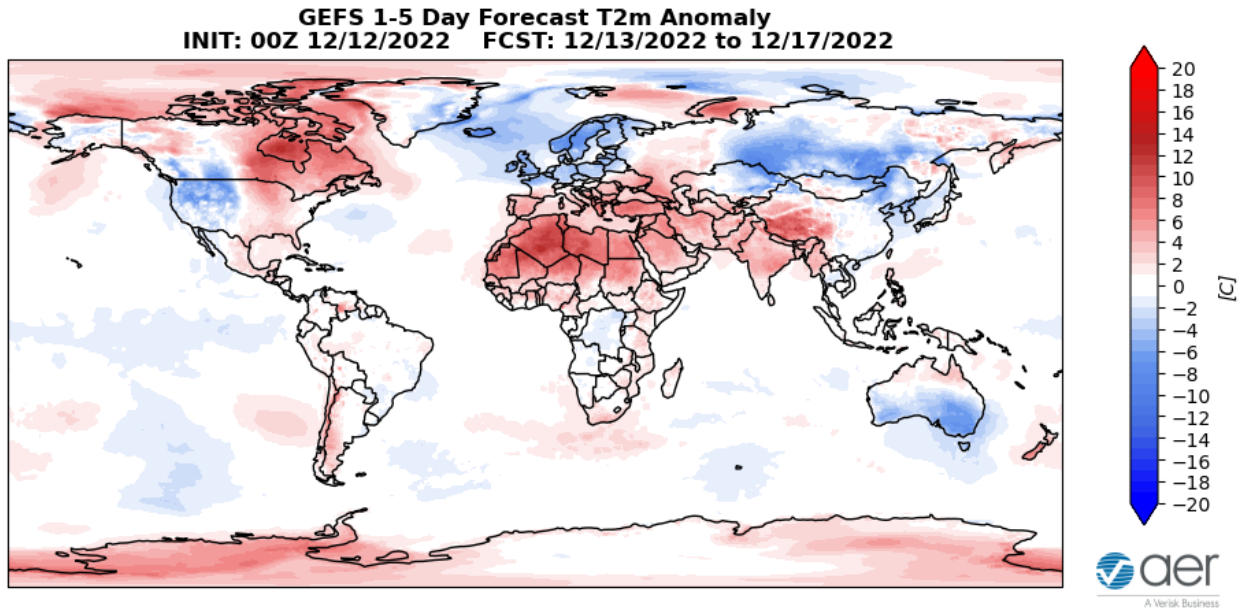


Figure 3. Forecasted surface temperature anomalies (°C; shading) from 13 – 17 December 2022. The forecast is from the 00Z 12 December 2022 GFS ensemble.

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

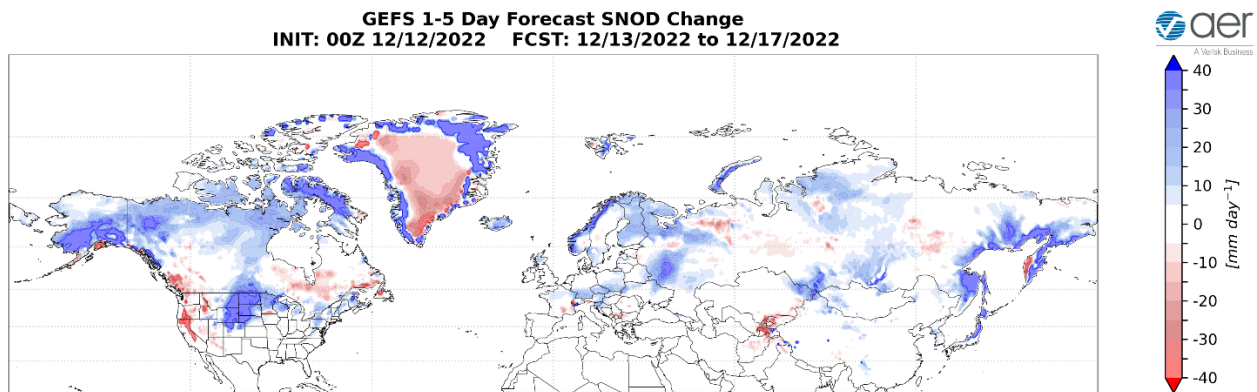


Figure 4. Forecasted snow depth changes (mm/day; shading) from 13 – 17 December 2022. The forecast is from the 00Z 12 December 2022 GFS ensemble.

Near-Term

1-2 week

The AO is predicted to remain negative this period (**Figure 1**) as geopotential height anomalies strongly rise across the North Pacific sector of the Arctic and mixed across the mid-latitudes (**Figure 5**). With mostly 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
INIT: 00Z 12/12/2022 FCST: 12/18/2022 to 12/22/2022

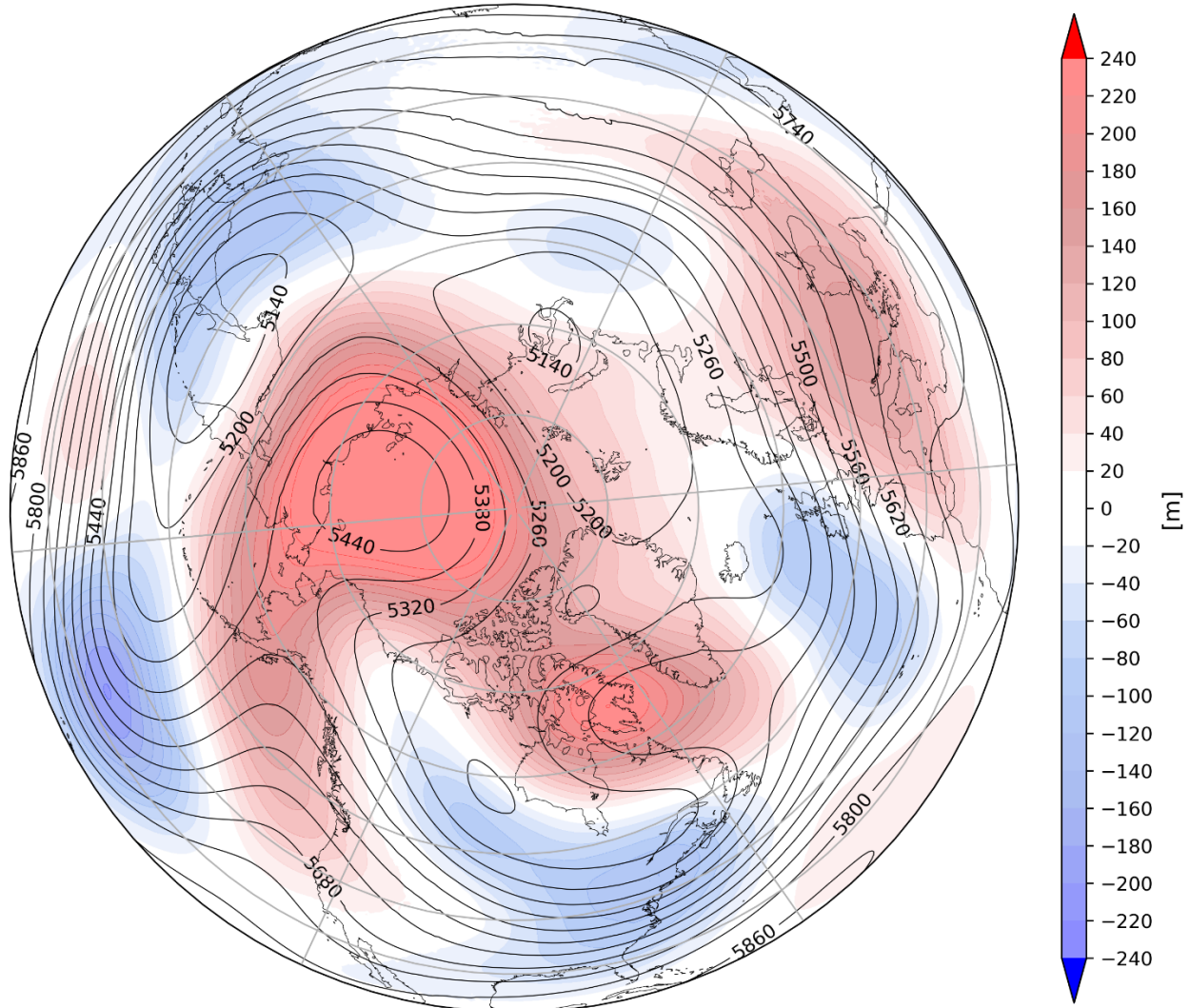


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 18 – 22 December 2022. The forecasts are from the 00z 12 December 2022 GFS ensemble.

With ridging/positive geopotential height anomalies predicted to weaken across Greenland ridging/positive geopotential height anomalies are predicted to replace troughing/negative geopotential height anomalies across Europe with the exception of troughing/negative geopotential height anomalies persisting across Northwestern Europe (**Figures 5**). Still normal to below normal temperatures are predicted to persist across Northern Europe including the UK with normal to above normal temperatures across Southern and Eastern Europe (**Figure 6**). Persistent ridging/positive geopotential height anomalies in Hudson Bay coupled with a new strong height center in the Beaufort Sea are predicted to anchor troughing/negative geopotential height anomalies across Siberia and Eastern 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 and Eastern Asia with normal to above normal temperatures across Southern and Western Asia and Eastern Siberia (**Figure 6**).

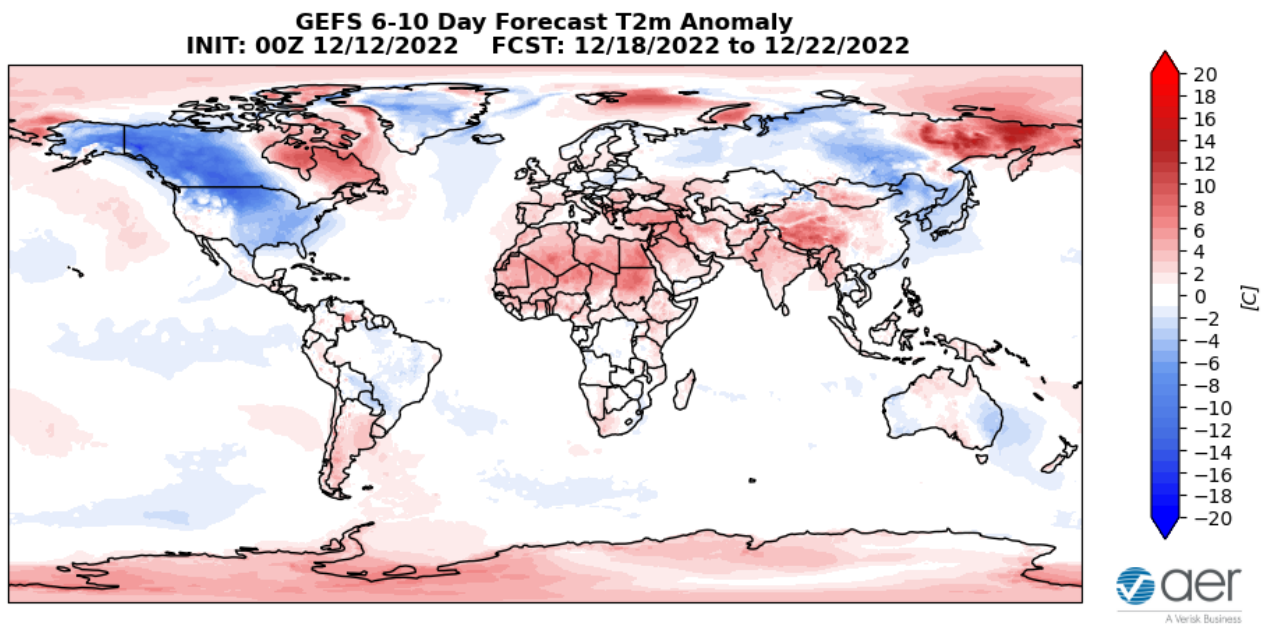


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 18 – 22 December 2022. The forecast is from the 00Z 5 December 2022 GFS ensemble.

Strong ridging/positive geopotential height anomalies are predicted to coalesce in the Beaufort Sea forcing downstream troughing/negative geopotential height anomalies in Central Canada and the Eastern US with more ridging/positive geopotential height anomalies along the west coast of North America and persisting near Baffin Bay this period (**Figure 5**). This pattern will favor normal to below normal temperatures widespread across Alaska, Canada and the US except for normal to above normal temperatures in Northeastern Canada and the Southwestern US (**Figure 6**).

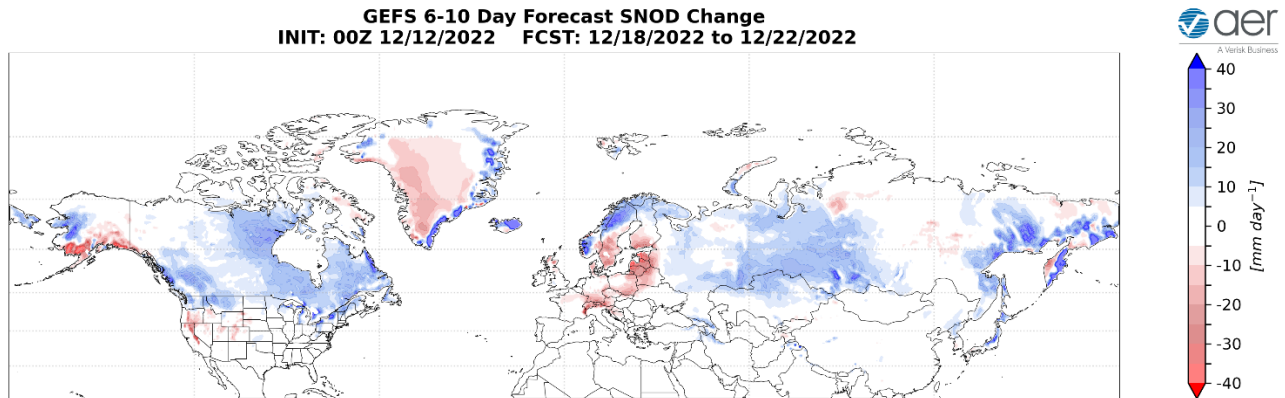


Figure 7. Forecasted snow depth changes (mm/day; shading) from 18 – 22 December 2022. The forecast is from the 00Z 12 December 2022 GFS ensemble.

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

3-4 week

Positive geopotential height anomalies are predicted to continue to dominate the North Pacific 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 weak but 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
INIT: 00Z 12/12/2022 FCST: 12/23/2022 to 12/27/2022

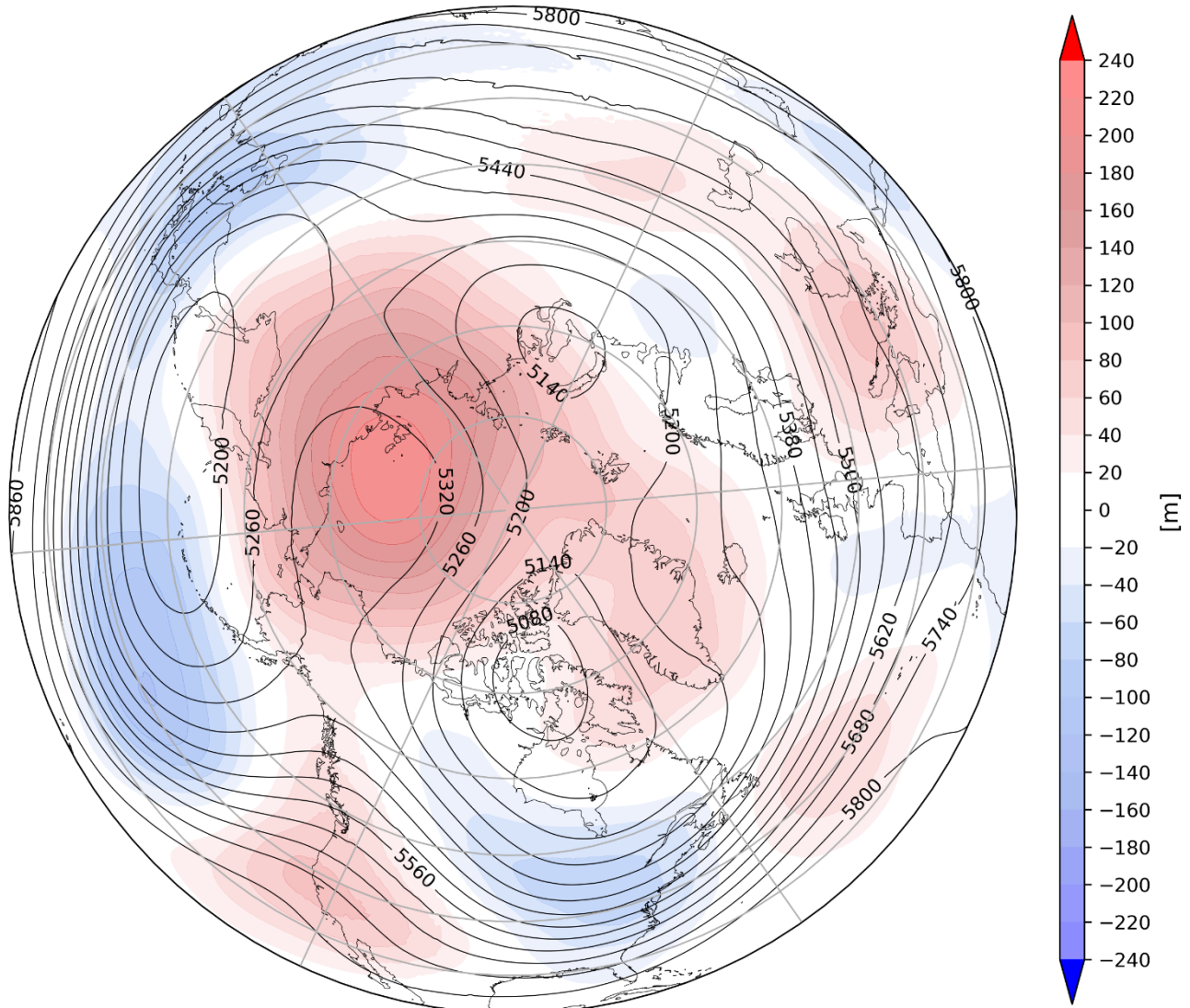


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 23 – 27 December 2022. The forecasts are from the 00z 12 December 2022 GFS ensemble.

With only weak ridging/positive geopotential height anomalies predicted across Greenland zonal flow will setup across Europe with troughing/negative geopotential height anomalies across Northern Europe and ridging/positive geopotential height anomalies across Southern Europe this period (**Figure 8**). This pattern favors normal to below normal temperatures across far Northern Europe including Scotland and Ireland with normal to above normal temperatures across Southern and Central Europe (**Figures 9**). Predicted ridging/positive geopotential height anomalies centered in the Chukchi Sea will help to anchor troughing/negative geopotential height anomalies

across Siberia that extend southward into East Asia with weak ridging/positive geopotential height anomalies in Central Asia (**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 and Eastern Siberia (**Figure 9**).

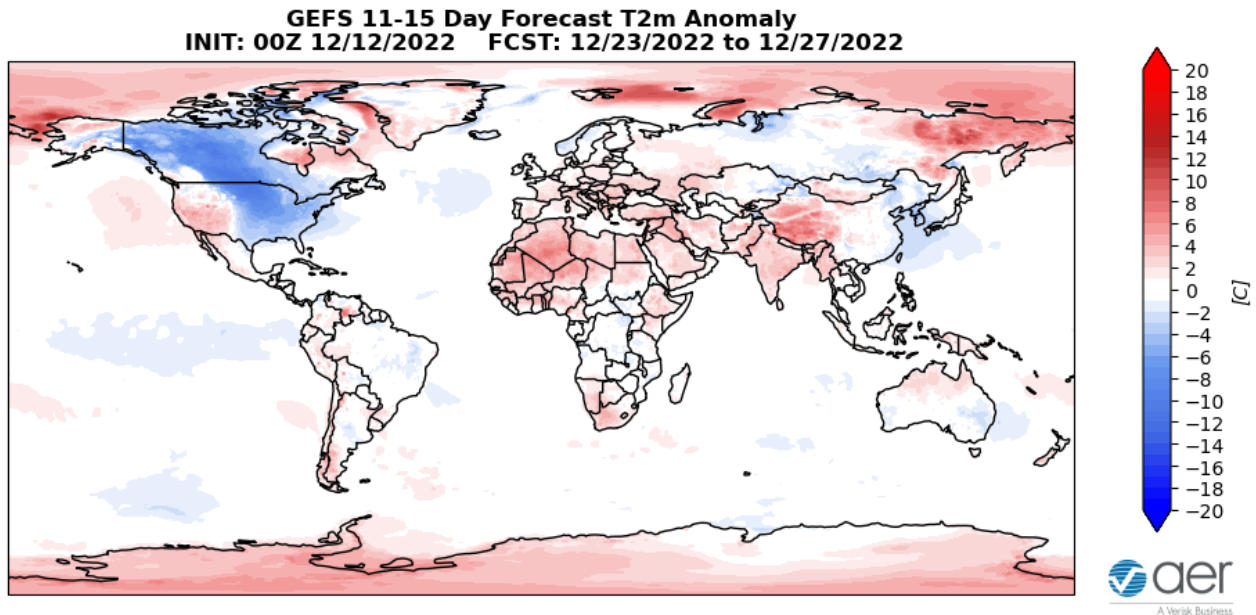


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 23 – 27 December 2022. The forecast is from the 00Z 12 December 2022 GFS ensemble.

Predicted persistent ridging/positive geopotential height anomalies in the Chukchi and Beaufort Seas will continue to favor troughing/negative geopotential height anomalies across Central Canada and the Eastern US while ridging/positive geopotential height anomalies will persist along the west coast of North America this period (**Figure 8**). This pattern favors widespread normal to below normal temperatures across interior Alaska, much of Canada and the US with normal to above normal temperatures limited to Northeastern Canada, the Southwestern US (**Figure 9**).

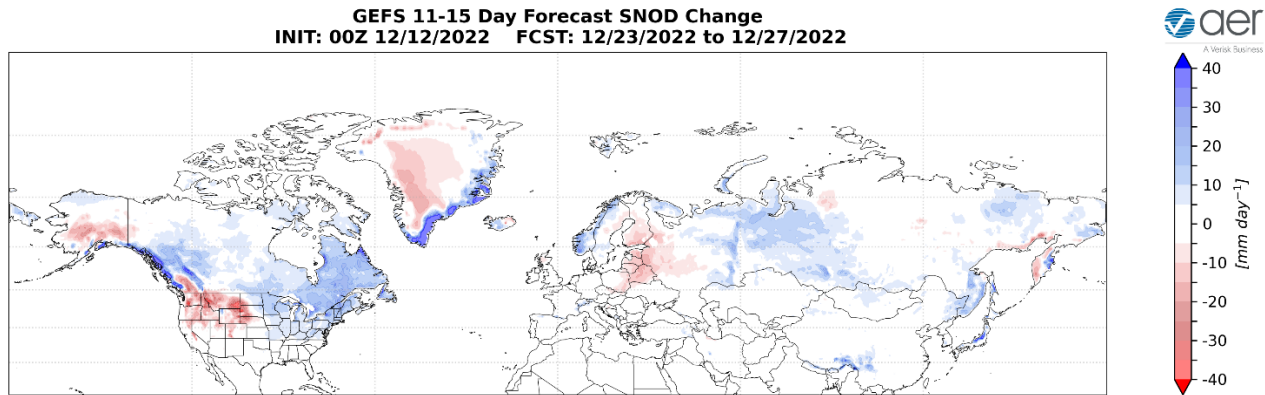


Figure 10. Forecasted snow depth changes (mm/day; shading) from 23 – 27 December 2022. The forecast is from the 00Z 12 December 2021 GFS ensemble.

Trouging and/or cold temperatures will support new snowfall across Scotland, Norway, the Northern and Eastern Asia while mild temperatures will support snowmelt in the Baltics (**Figure 10**). Trouging and/or cold temperatures will support new snowfall across northern 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 and mid stratosphere with warm/positive PCHs in the lower stratosphere and the troposphere (**Figure 11**). Cold/negative PCHs in the upper stratosphere are predicted to strengthen and descend into the lower stratosphere starting next week (**Figure 11**).

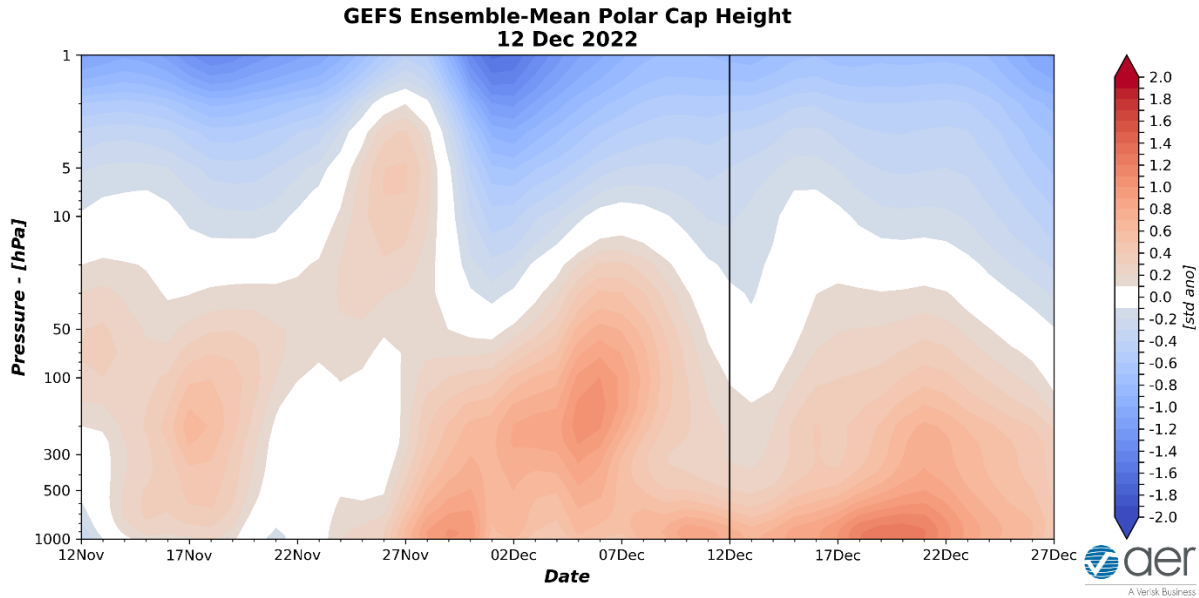


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 12 December 2022 GFS ensemble.

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 next week when the warm/positive PCHs in the lower troposphere are predicted to strengthen (**Figure 11**), as the Beaufort height center becomes strongly positive (**Figure 1**).

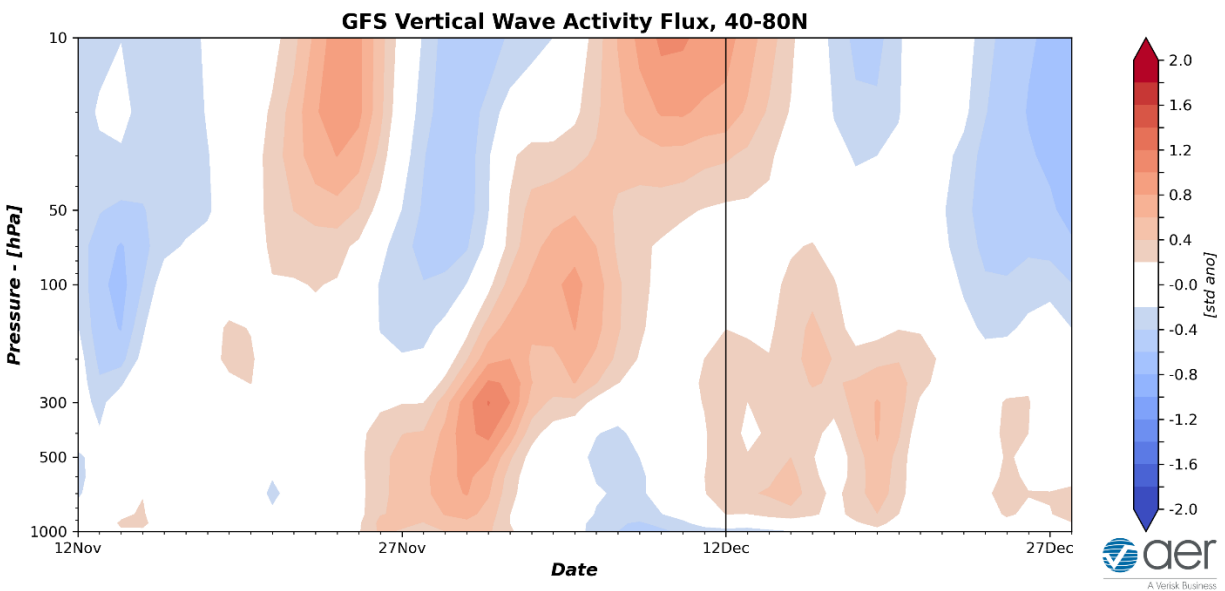


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 12 December 2022 GFS ensemble.

The slightly above 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 mixed period of WAFz in the next two weeks (**Figure 12**), resulting in overall cooling heading into the holiday season (**Figure 11**).

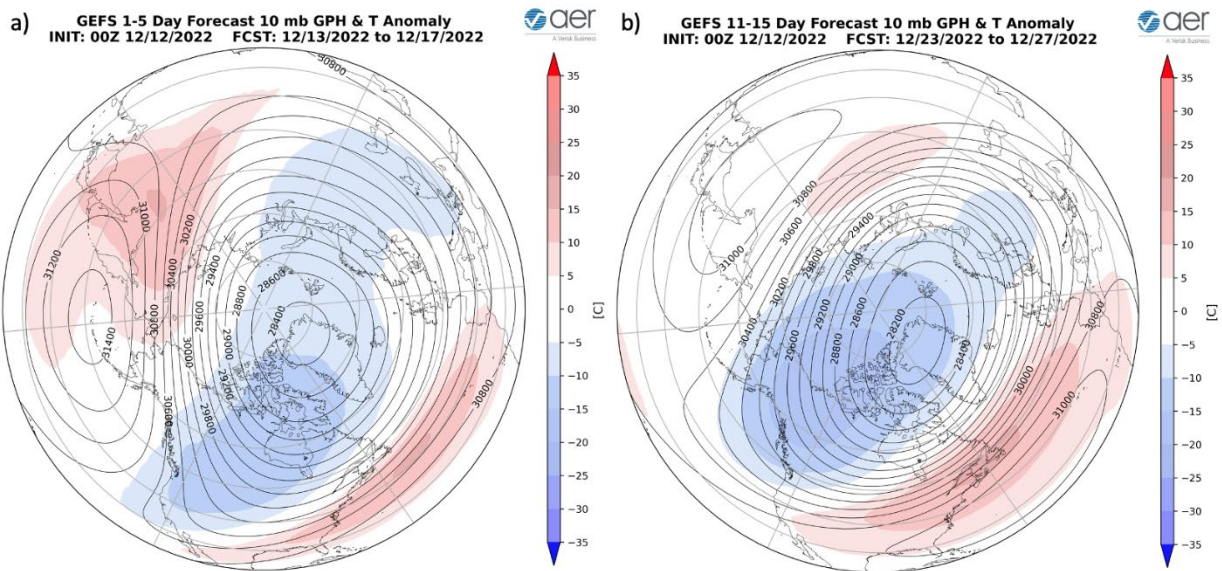


Figure 13. (a) Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere from 13 – 17 December 2022. (b) Same as (a) except forecasted averaged from 23 – 27 December 2022. The forecasts are from the 00Z 12 December 2020 GFS model ensemble.

Still the recent more active WAFz has caused a minor perturbation of the stratospheric PV with the PV center shifted over to Greenland with a ridge center near the Dateline (**Figure 13**). This configuration of the PV is consistent with a stretched PV. The predicted positive WAFz values quickly followed by negative WAFz values is a signature of wave reflection or a stretched PV (**Figure 13**). This configuration is predicted to continue into the last of week of December (**Figure 13**). However, the orientation of the PV is predicted to rotate with an axis from Scandinavia to the Gulf of Alaska (**Figure 13**). This could favor the core of the cold shifted into western North America. Regardless, the stratospheric AO is predicted to remain neutral to positive over the next two weeks (**Figure 1**).

**CFS 500 hPa Forecast Anomaly Jan 2023
Valid as of 12 Dec 2022**

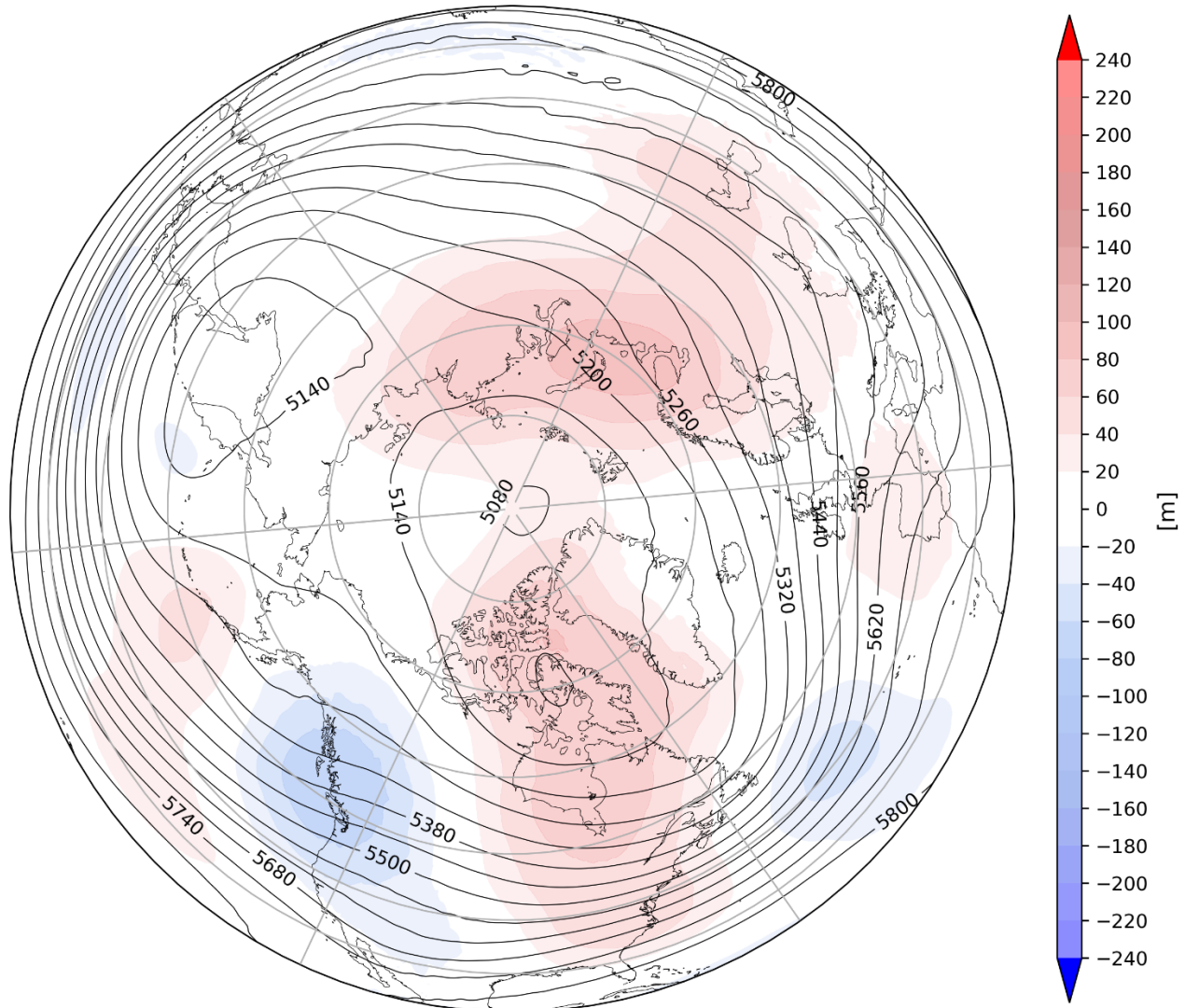


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for January 2022. The forecasts are from the 00Z 12 December 2022 CFS.

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 eastern North America with troughing across the eastern Mediterranean, Siberia, East Asia, Western Canada and the Western US (**Figure 14**). This pattern favors seasonable to relatively warm temperatures across Europe, Western Asia, Eastern Siberia, Eastern Canada and the Eastern US with seasonable to

relatively cold temperatures across Western and Central Siberia, East Asia, Alaska, Western Canada and the Western US (**Figure 15**).

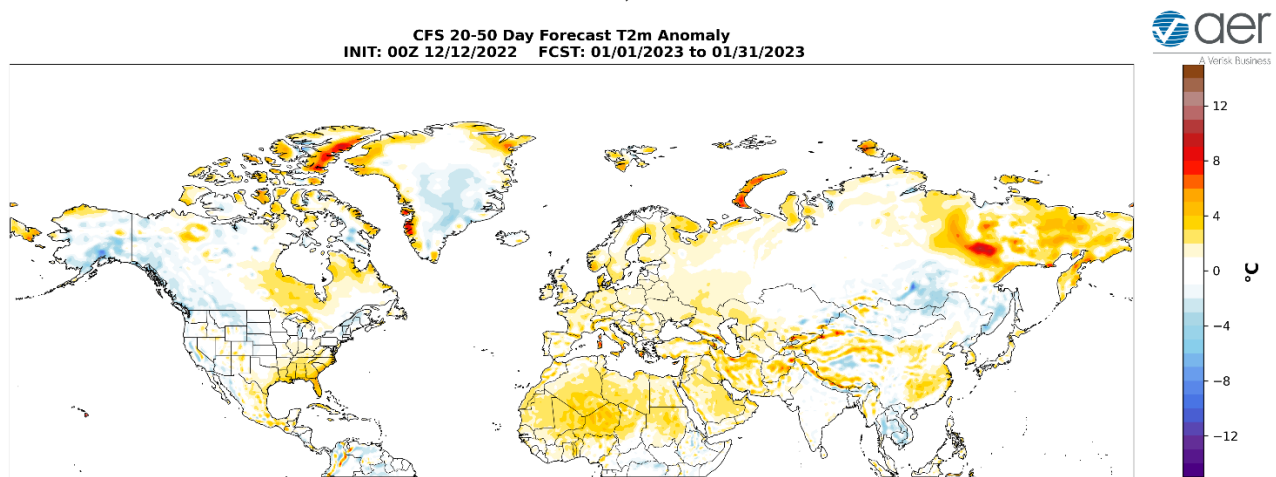


Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for January 2022. The forecasts are from the 00Z 12 December 2022 CFS.

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.

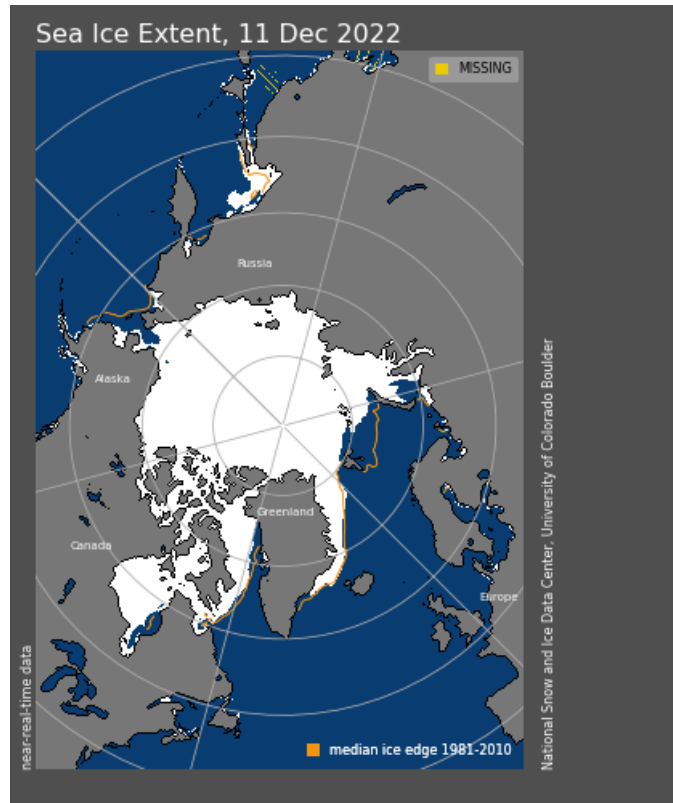


Figure 16. Observed Arctic sea ice extent on 11 December 2022 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC).

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.

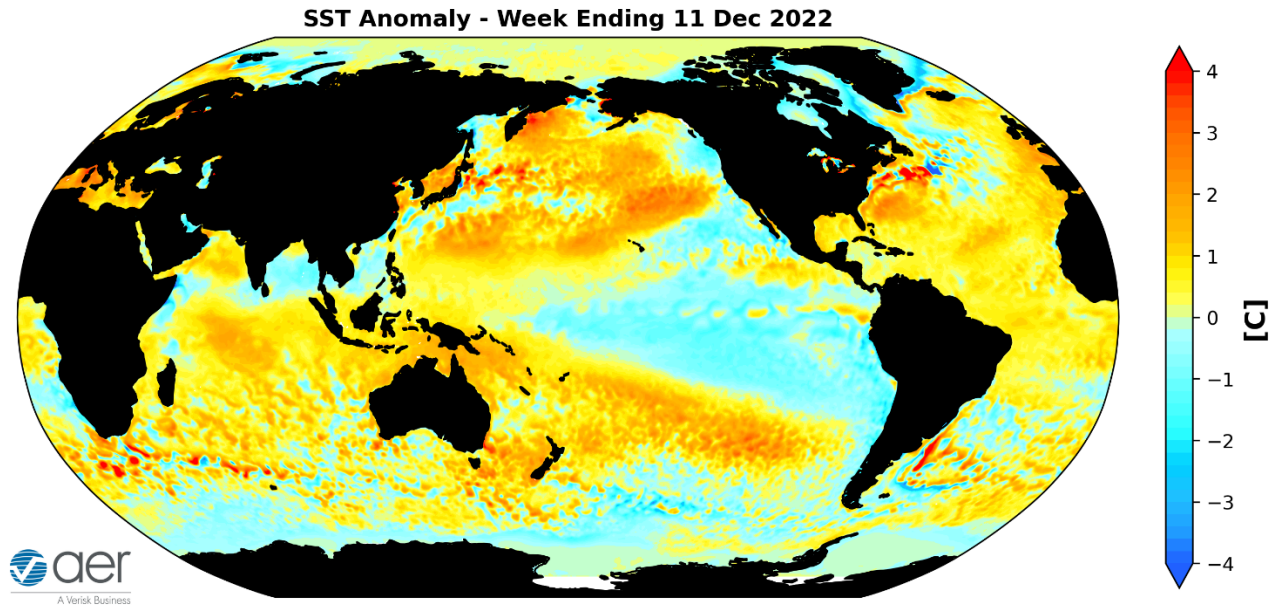


Figure 17. The latest weekly-mean global SST anomalies (ending 11 December 2022). Data from NOAA OI High-Resolution dataset.

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 and then emerge into phase four and then five next week. Phases four and five favor deep roughing over Alaska and ridging across eastern North America. Hard for me to see how the MJO could be having influence on the weather across North America for the remainder of the month. But admittedly this is outside of my expertise.

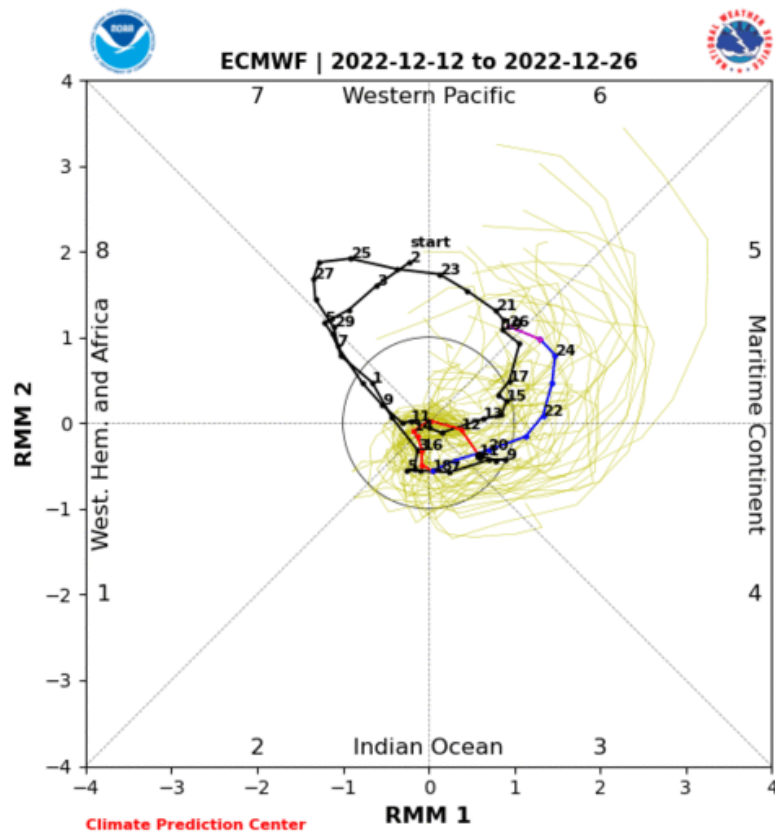


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 12 December 2022 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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 (SCE) across the NH has advanced again this week (see **Figure 19**), but more slowly as North American snow cover advance stalled this week. SCE remains near decadal means. With the predicted widespread cold across North America, I expect snow cover to advance again but especially across North America in the coming weeks.

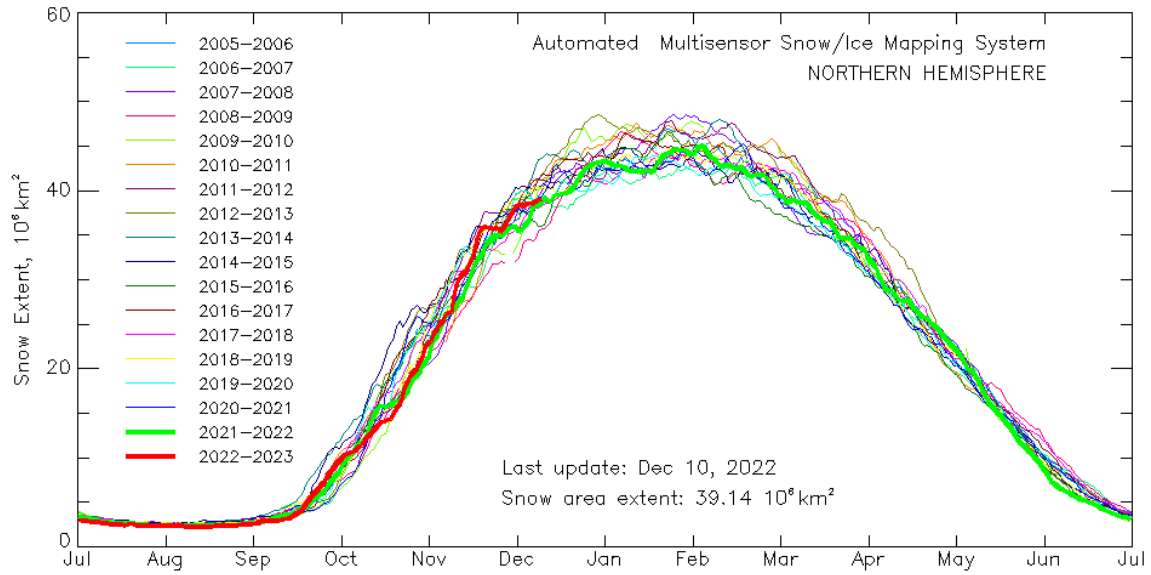


Figure 19. Observed North American snow cover extent through 11 December 2022. Plot from https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_monitor.html