Arctic Oscillation and Polar Vortex Analysis and Forecasts

November 28, 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.

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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 the next two weeks as pressure/geopotential height anomalies across the Arctic are mostly positive across the Arctic but are predicted to become increasingly positive in the North Atlantic sector. The North Atlantic Oscillation (NAO) is currently positive and is predicted to quickly turn negative for much of the next two weeks as pressure/geopotential height anomalies are predicted to turn 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 an increasingly classic negative NAO pattern with normal to below normal temperatures across Northern Europe including the United Kingdom (UK) with normal to above normal temperatures across Southern Europe.
- Over the next two weeks, predicted Scandinavian/Barents-Kara Seas ridging/positive geopotential height anomalies that drift westward towards

Greenland will force troughing/negative geopotential height anomalies across Siberia. This pattern favors normal to below normal temperatures across Northern Asia with normal to above normal temperatures across Southern 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 across 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 Southeastern Canada and the Southern and Eastern US. However, next week colder temperatures will expand will spread east of the Rockies in Canada and the US.
- I present the winter 2022/23 Northern Hemisphere (NH) temperature forecast and the related possible behavior of the polar vortex (PV) in the coming weeks.

Plain Language Summary

The AER winter forecast for the Northern Hemisphere is published below. Also included are the forecasts from the American and European suite of weather forecasting models. The ensemble forecast from the government forecast centers are almost universally warm except for relative cold across northwestern North America, a signature of La Niña. The AER forecast is colder especially for Asia, but the Arctic signals used in generating the AER forecast were weak this fall resulting in weak and mixed temperature anomalies.

Impacts

Seemed like the main message from my WCVB winter forecast interview (apologies but this link apparently only works in the US) was be ready to be surprised. That might sound vague enough to be uninformative but who had deep negative NAO to kick off December on their winter 2022/23 bingo card? I will readily admit that I did not have that on mine and did not consider seriously in the month of December a negative NAO, Greenland blocking and cold weather in Europe related to the Greenland blocking until my blog posting of the week of November 14th and discussed it in more depth in the blog post the week of November 21st. Decembers have been predominantly mild and a solid negative NAO in any of the three winter months (DJF) a rare phenomenon over the past decade with and without a sudden stratospheric warming (SSW). Recent exceptions are January 2021 and February 2018 following major SSWs (where the zonal wind at 10hPa and 60ºN reverses from westerly to easterly).

I have seen all kinds of tweets about the short-term weather, cold, not so cold but my opinion is that it is very hard to know, and I fully expect the models to struggle with such an anomalous pattern. The Texas Freeze of February 2021 was a truly historic event but the models only starting to predict close to the magnitude of what was observed, a week and less before the actual event. I am not predicting an historical event in December, but I think extreme winter weather is highly probable but maybe as the meteorological analog of the Heisenberg Uncertainty principle hard to know both the timing and location of the most extreme weather. Nothing has happened yet, and I am trying to not take anything for granted but today on the precipice of the start of December a cold Siberia, Northern Europe and the US is looking more likely than for most recent Decembers.

The two most recent Decembers with a strong negative NAO and widespread cold temperatures were the back-to-back Decembers of 2009 and 2010. I will no longer discuss winter 2009/10 as I don't think it is a good analog for this winter. It was an El Niño winter, and the quasi-biennial oscillation (QBO) was easterly making a major SSW more likely. But more importantly in my mind was that the negative NAO and widespread cold of December followed an SSW (not major though) in November, i.e., there was active stratosphere-troposphere coupling that December. For those interested, I wrote a paper on that very interesting winter (Cohen et. al. 2010). Instead, December 2010 is a much better candidate as an analog for this upcoming December. It was a La Niña winter, the QBO was westerly and the negative NAO that December was a troposphere only event.

Looking at the 500 hPa geopotential height anomalies from December 2010 (see **Figure i**), Greenland blocking is clearly evident with strong high-pressure ridging in and around Greenland with low pressure troughing in East Asia, Europe, the Eastern US but also in the Gulf of Alaska (a feature not typical of a strong negative NAO pattern). There was also a strong high-pressure ridge near the Dateline (likely associated with La Niña) and another weaker one near the Urals. The anomalous Greenland high pressure coupled with anomalous low pressure stretched across the mid-latitudes of the North Atlantic provide a classic negative NAO signature. The surface temperature anomalies were consistent with the strong negative NAO (see **Figure ii**) with widespread cold across the Northern Hemisphere including Northern Asia, Europe and the Eastern US and with the most impressive region of negative departures in Siberia.

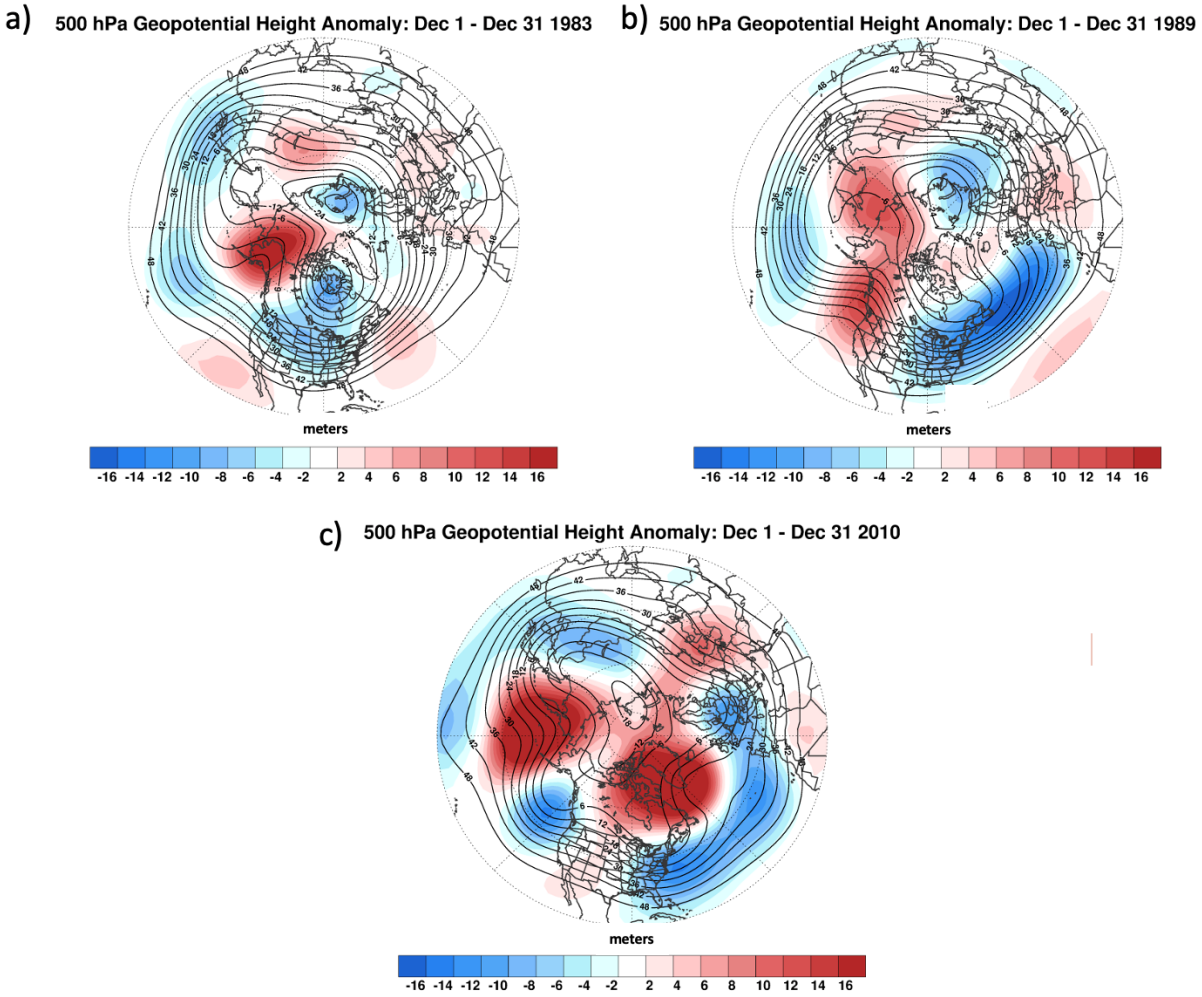


Figure i. Observed average 500 hPa geopotential heights (dam; contours) and geopotential height anomalies (meters; shading) across the Northern Hemisphere from a) December 1983 b) December 1989 and c) December 2010.

But what I think was most interesting feature from that winter was the polar cap geopotential height anomalies (PCHs; see **Figure iii**). Positive/warm PCHs persisted for a very long time continuously from late November through January with two major pulses one in December and the other in January. This length of a warm/positive PCH or negative NAO regime typically only occurs following an SSW yet the warm/positive PCHs in 2010/11 were almost completely isolated to the troposphere and there was no SSW observed. There was a stretched polar vortex event in early January that I would argue contributed to the severe winter weather in the Eastern US. But the longevity of the warm/positive tropospheric PCHs and negative NAO contributed to the widespread cold from December continuing into January and February (see **Figure iv**).

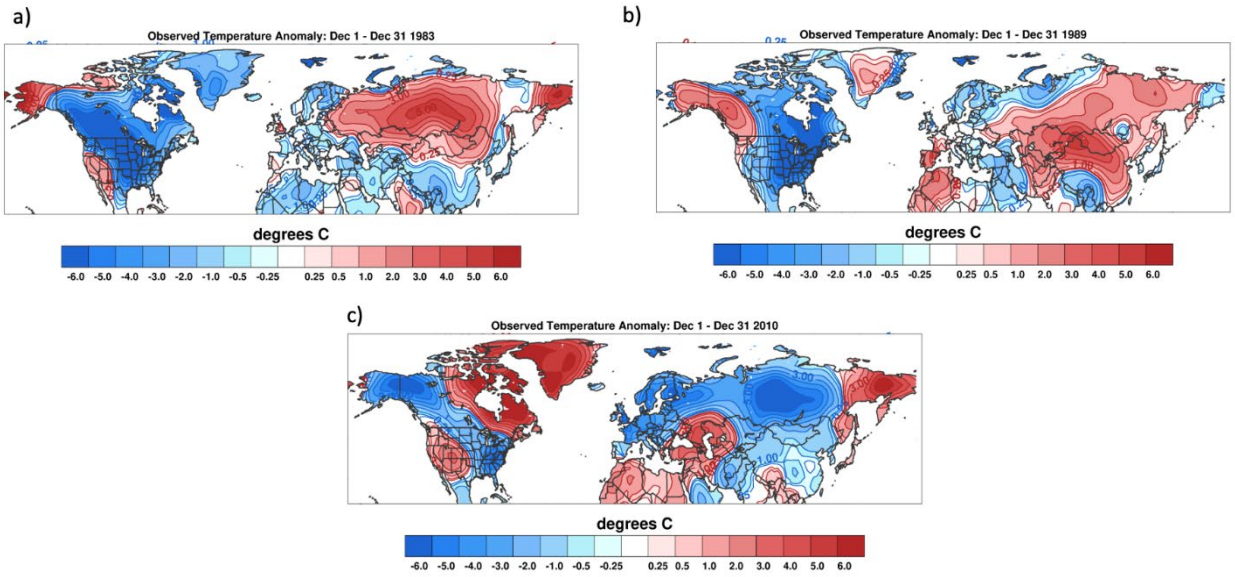


Figure ii. Observed surface temperature anomalies ((°C; shading) for a) December 1983, b) December 1983 and c) December 2010.

Another famously cold December that I remember from my school years was 1989. The NAO was also negative in December 1989 but looking at the 500 hPa geopotential height anomalies (see **Figure i**), Greenland blocking is much less impressive that 2010 instead high-pressure ridging was much more impressive along the west coast of North America. Looking at the NH surface temperature anomalies it was cold in Northern Europe and especially cold in the Eastern US but Siberia was warm that December (see **Figure ii**). Finally looking at the PCHs that winter there was again warm/positive PCHs are observed that are confined to the troposphere in December as in 2010 (see **Figure iii**). The big difference is that in winter 1989/1990 the PCHs flipped to negative/cold in January and February. I would consider this a more typical duration of PCHs anomalies that are troposphere only. Given the negative/cold PCHs in the troposphere it is not surprising then that in January and February it is relatively warm in the Eastern US, Europe and East Asia but Siberia was relatively cold as well as the North American Arctic (see **Figure iv**). But I think the best precursor to the warm January and February in 1990 was the warm Siberia in December 1989 (see **Figure ii**).

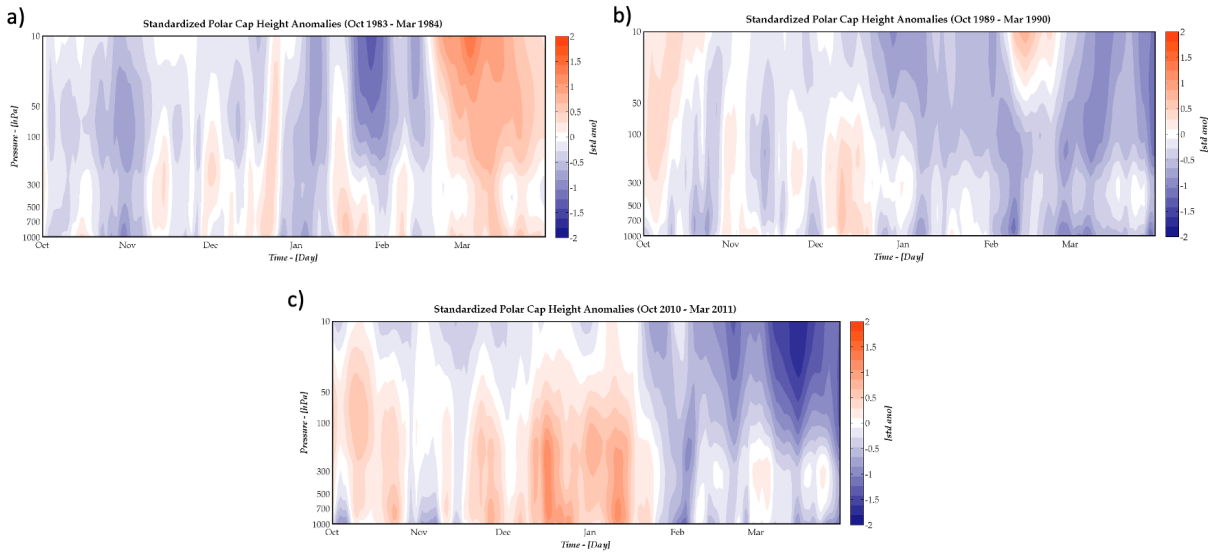


Figure iii. Observed daily polar cap height (i.e, area-averaged geopotential heights poleward of 60°N) standardized anomalies from October 1 through March 31 for a) winter 1983/84, b) winter 1989/90 and c) 2010/11.

Another famously cold US December was 1983. I included it for completeness' sake, but I don't think that it is a good analog. Looking at the 500 hPa geopotential height anomalies in December 1983 (see **Figure i**), Greenland blocking is absent with an Alaskan blocking high pressure the dominant feature in the high latitudes and there is more high pressure ridging over Siberia. Looking at the surface temperature anomalies temperatures (see **Figure ii**) they are mostly below normal across Europe and especially across much of Canada and the US but quite warm across Siberia. I would argue that the warm December in Siberia was a precursor to warm temperatures in the US (at least northern) and parts of Europe in January and February (see **Figure iv**). The tropospheric PCHs in December were mostly positive/warm but then vacillated between positive/warm and negative/cold for the rest of the winter (see **Figure iii**).

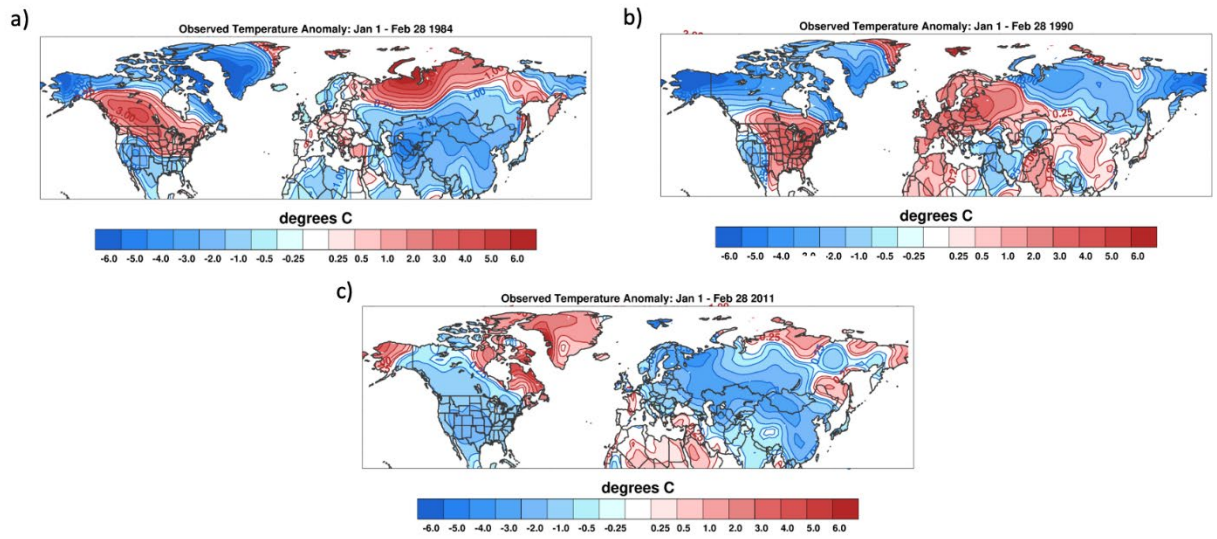


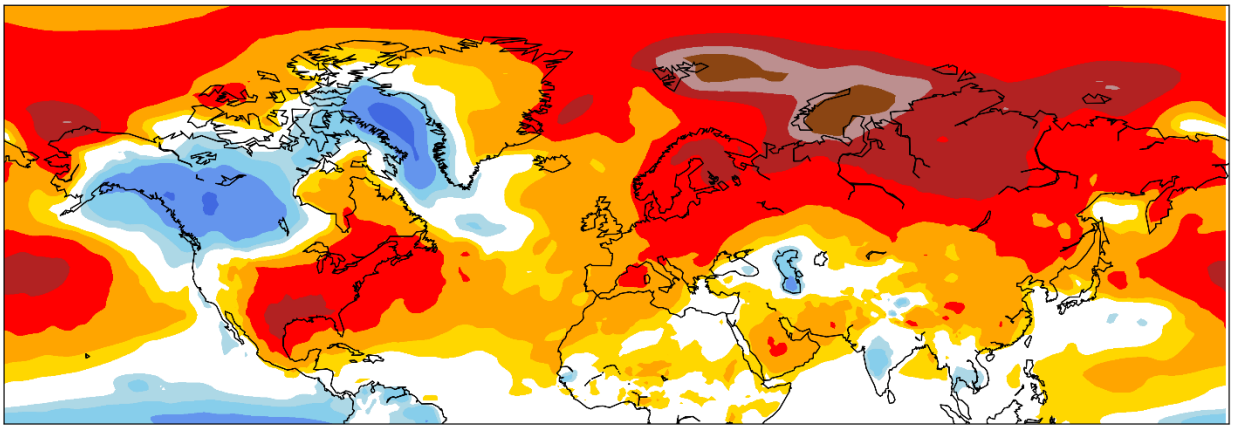
Figure iv. Observed surface temperature anomalies (°C; shading) for a) January and February 1984, b) January and February 1984 and c) January and February 2011.

Looking at the three possible analogs for this winter given the widespread cold predicted for December only 2010 saw a continuation of the cold in January and February 2011. What allowed the cold pattern to persist in my opinion was the unusual long duration of warm/positive tropospheric PCHs and a precursor to the persistent cold pattern was the cold December in Siberia. In contrast in December 1989 (I don't think 1983 is a great analog) a warm December in Siberia and the flip to cold/negative tropospheric PCHs that descended from the stratosphere signaled and/or ushered in a warmer January and February.

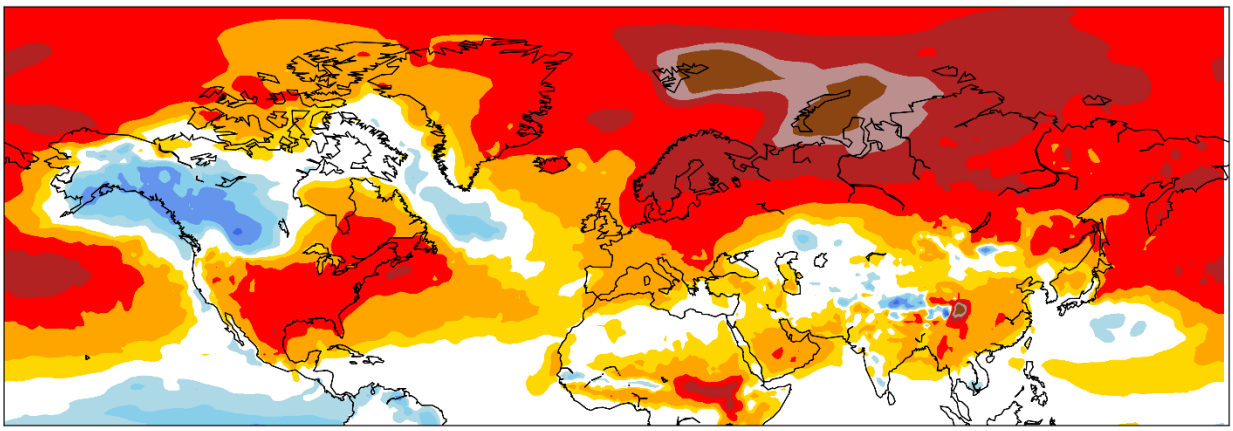
I have not discussed the winters of 1995/96 and 1996/97 when the December NAO was also strongly negative. I would describe winter 1995/96 similar to winter 2010 when warm/positive tropospheric PCHs in December persisted or rejuvenated into January and February in the absence of visible stratosphere-troposphere coupling. 1996/97 is more complicated and I need to investigate further.

This has been a long windup to the winter 2022/23 forecast. In **Figure v** I include the AER winter forecast, the North American Multi Model Ensemble (NMME) winter forecast and the C3S (a European model ensemble) winter forecast. I would like to say the AER winter forecast with weak anomalies is a result of the Solomonides decision to split the difference between winters of 2010/11 and 1989/90. However, the mixed and weak temperature anomalies are a result of only slightly above normal October Eurasian snow cover extent and below normal October Arctic sea ice extent that was relatively higher than recent years. Also included is La Niña that shifted the North American cold westward in the model. Relative cold is also predicted in Northern to Central Asia.

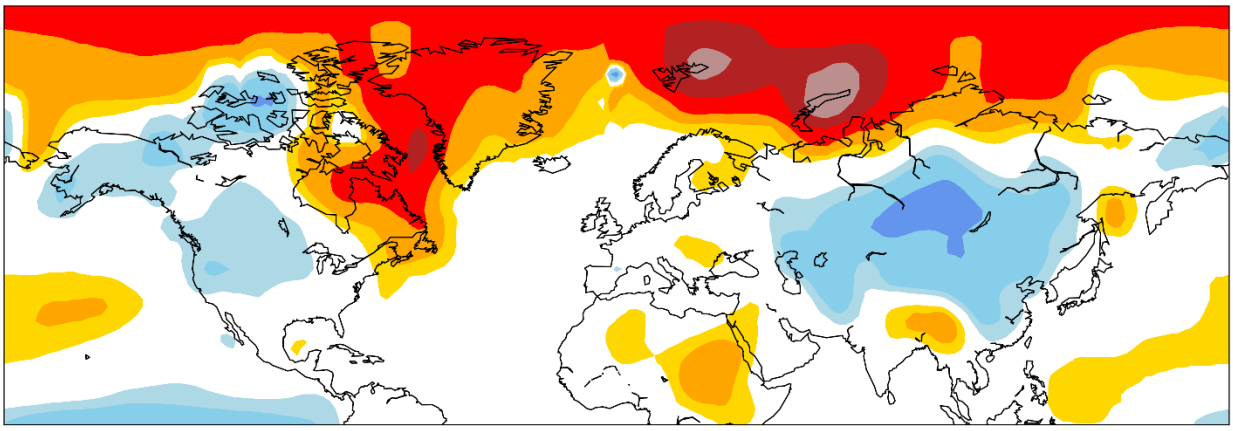
NMME Ts Forecast for Dec-Feb 2023



C3S Ts Forecast for Dec-Feb 2023



AER Forecast of Ts for Dec-Feb 2023



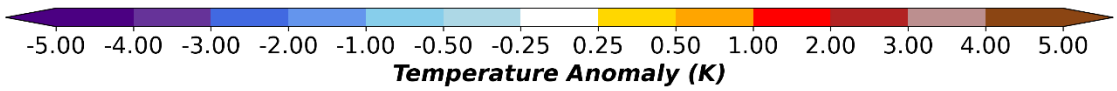


Figure v. The winter 2022/23 surface temperature anomalies forecast for the Northern Hemisphere (°C; shading) from the North American Multi-model Ensemble (NMME; top), b) the C3S model ensemble (ECMWF, UK Met and Meteo France models; middle) and the AER statistical model (bottom).

The two dynamical model forecasts, both the American ensemble and the European ensembles, predict almost universal relative warmth especially across northern Eurasia with the exception of below normal temperatures across northwestern North America. If you think the dynamical forecast looks familiar you would not be wrong; for all three recent La Niñas, the dynamical winter forecasts have been almost indistinguishable.

As I have been discussing in recent weeks, I believe whether we have a winter that matches the dynamical model forecasts with nearly universal warmth or a colder forecast that better matches the AER forecast or even possibly colder, will come down to which feature can persevere or endure the longest, a strengthening stratospheric polar vortex (PV) or high latitude high pressure blocking in the troposphere.

These two features are currently represented in the current PCH plot (see **Figure 11**) with cold/negative stratospheric PCHs a signature of the strong PV and warm/positive tropospheric PCHs a signature of high latitude blocking. The warm/positive tropospheric PCHs can be related to high latitude tropospheric blocking that could potentially persist well into January as in 2010/11, though I do consider such long lasting high latitude blocking events not related to stratosphere-troposphere coupling as rare.

Alternatively warm/positive tropospheric PCHs can be related to PV disruptions either stretched PVs or SSWs. Though I didn't include it as an analog, in January 2016 there was a warm/positive tropospheric PCH episode that was independent of stratosphere-troposphere coupling and this was followed by a major SSW in March 2016, this seems a plausible scenario to me. Though now that the models have converged on Greenland blocking rather than Ural blocking, this has increased the short-term risk of severe winter weather especially for Europe, I believe that this has delayed any possibility of an SSW and the long-term risk of severe winter weather that often follows and SSW for at least another month.

Finally, the cold/negative stratospheric PCHs could couple to the surface erasing high latitude blocking and forcing a milder pattern across the continents of the NH. This is what happened in winter 1989/1990 and is quite plausible at the end of December 2022. I do think that around the holidays the outlook for much of the winter will come into clearer focus. I also believe look towards Siberia for the first clues, so goes Siberia so goes the winter for the Eastern US, Europe and East Asia.

Wednesday Update

I did look into a little more the winters of 1995/96 and 1996/97. The negative NAO of December 1996 seemed to be related to an SSW (not major though) and therefore does not seem like a good analog in my opinion. But December 1995 seems unrelated to stratosphere-troposphere coupling and it was a La Niña winter.

Looking at the 500 hPa geopotential from December 1995 (see **Figure vi**) the pattern looks unusual with mirror patterns in the North Atlantic and North Pacific patterns, high pressure ridging to the north and low pressure troughing to the south separated by low heights in the Central Arctic. But clearly evident is a negative NAO pattern that is independent of the AO. Anyway, the surface temperature anomalies exhibit cold in the Eastern US and Europe as expected with a negative NAO but it is quite warm in Siberia which again seems very unusual to me (see **Figure vii**). Certainly, showing that a warm Siberia in December is a precursor to a warm Eastern US and Europe in January and February has at least one exception. The 500 hPa geopotential in January and February 1996 (see **Figure vi**) is very recognizable to me – one that is related to polar vortex stretching with ridging near Alaska and Scandinavian-Ural region and troughing in East Asia and eastern North America. Additionally, and possibly independent there is some residual negative NAO with ridging near Greenland and troughing in Europe. In January and February there is impressive widespread cold across North America, Europe and Asia (see **Figure vii**).

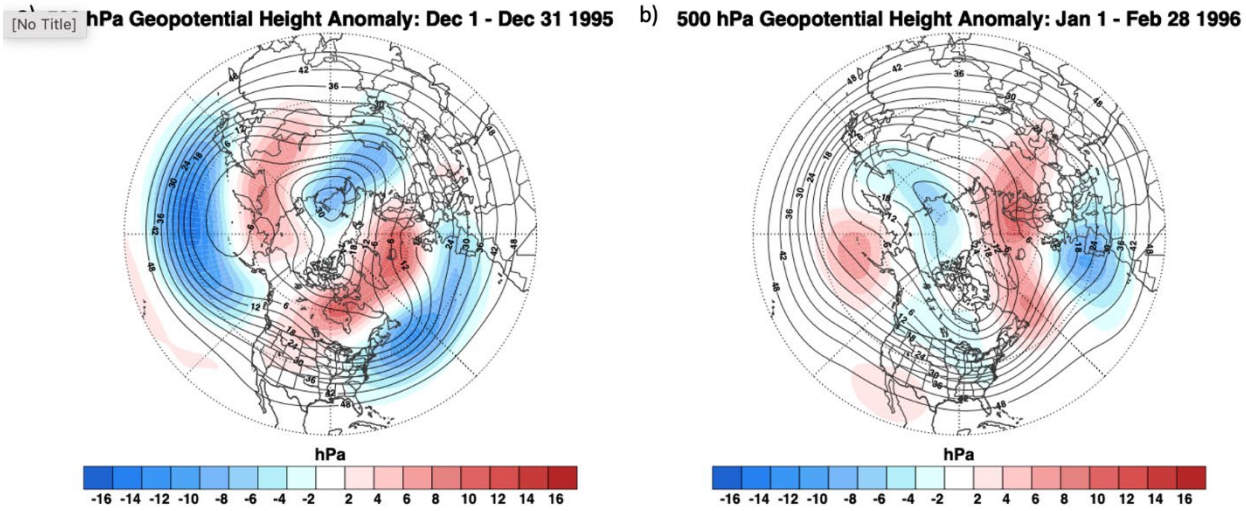


Figure vi. Observed average 500 hPa geopotential heights (dam; contours) and geopotential height anomalies (meters; shading) across the Northern Hemisphere from a) December 1995 and b) January and February 1996

I didn't include it but the circulation at 10 hPa in January and February also resembles that of a stretched PV. The tropospheric PCHs from 1995/96 were predominantly warm/positive while the stratospheric PCHs were exclusively cold/negative. So, in this regard it resembled winter 2010/11. I would summarize both winters 1995/96 and

2010/11 as dominated by unusually persistent high latitude blocking, not connected to an SSW, resulting in cold for Asia, Europe and the US but the cold in Asia and the US were likely enhanced by PV stretching.

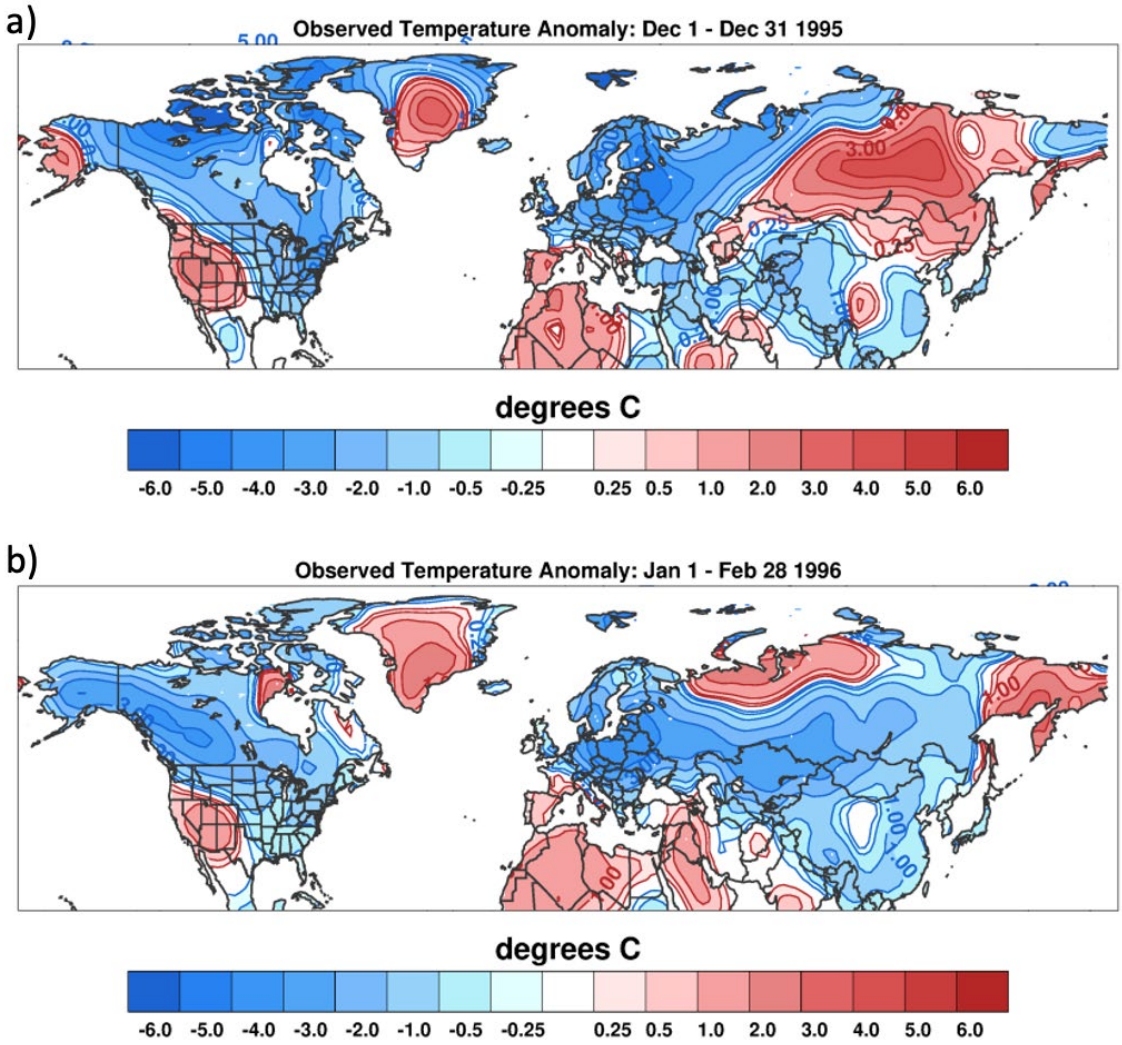


Figure vii. Observed surface temperature anomalies (°C; shading) for a) December 1995, b) January and February 1996.

Looking at the CFS 500 hPa geopotential height forecast from Monday (see **Figure 14**) or even from today (see **Figure viii**), in my opinion it best matches December 2010. I was debating whether to even show today's CFS December forecast. If someone asked me to draw up the ideal pattern to deliver cold it would be the CFS December forecast as it is predicting the trifecta of ridging for cold (and snow) – ridging over Greenland, Alaska and the Urals. Not only could that pattern deliver short term cold but disrupt the PV (more likely stretching but even an SSW) ensuring longer term cold as well. I think

skepticism for any CFS forecast is warranted regardless of the forecast, and today's is no exception.

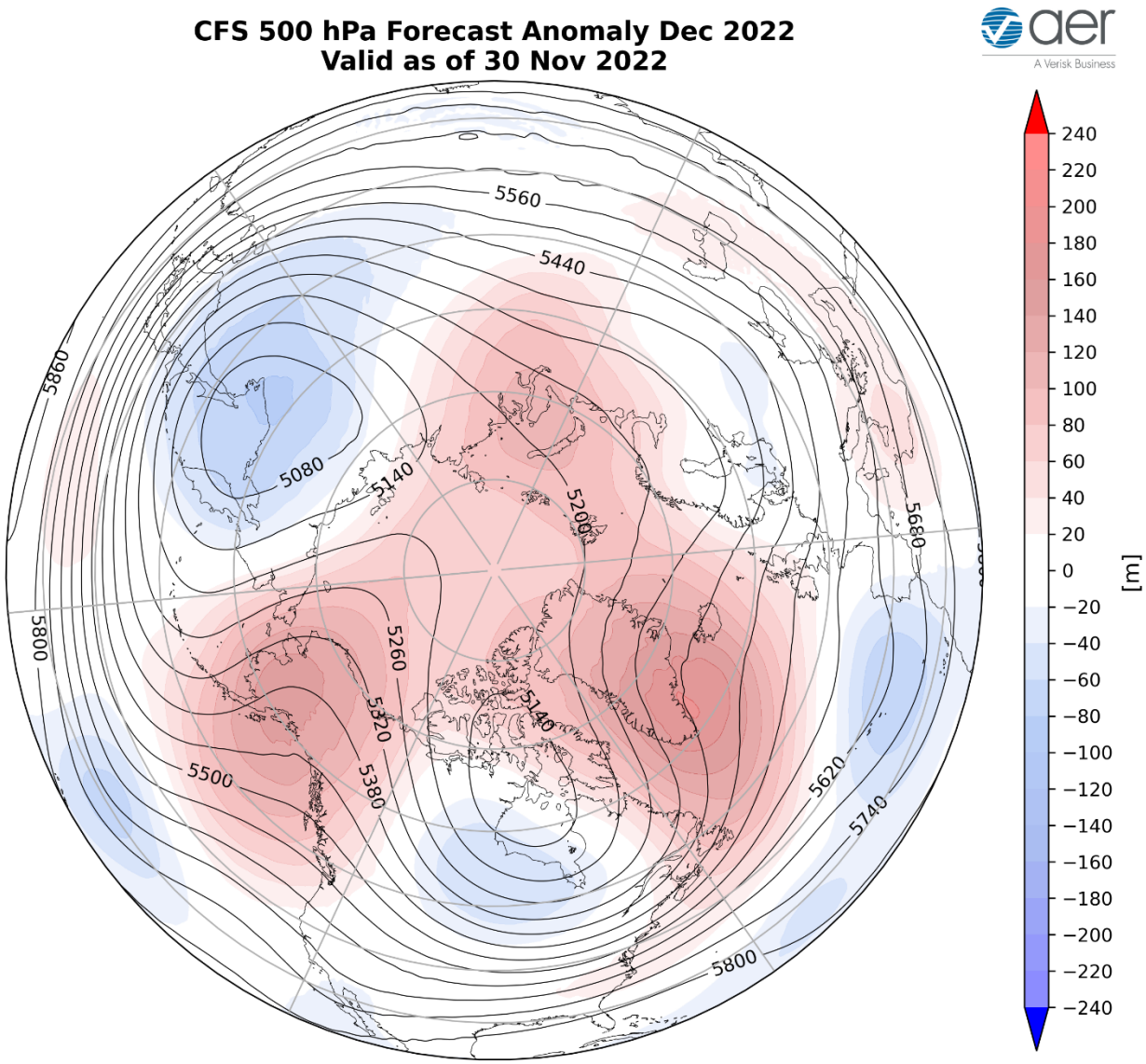


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for December 2022. The forecasts are from the 00Z 30 November 2022 CFS.

I tweeted out last night how there a large differences in the week two surface temperature forecasts for the Eastern US from the dynamical models, the ECMWF, the GFS and the Canadian. Yesterday the ECMWF was the coldest, the Canadian the mildest and the GFS was in between. Though last night's run from the GFS seems to have gone milder and now is closer to the Canadian. The ECMWF is the best weather model, and I would lean towards the ECMWF until it is clear otherwise.

Surface temperatures in Northern Europe and Asia are more strongly related to NAO variability than the Eastern US. So, I do believe that the risk of cold including extreme cold is higher across Northern Europe and Asia than the Eastern US. For the Eastern US Greenland blocking is more closely associated with the risk of snowfall than cold. But I do think a negative NAO can be associated with extreme cold especially, if it is accompanied by a stretched PV and/or high amplitude ridging along the west coast of North America. A negative NAO seems mostly independent of the PV stretching, maybe the negative NAO is forced by tropical convection. If an SSW occurs that is different.

While on the topic of a stretched PV, I haven't discussed much in this blog but so far there has been repeated PV stretching events so far this fall and I believe the potential for more PV stretching events this winter. As can be seen from **Figure 13** a stretched PV is occurring this week and is predicted for the second week of December and is another reason I would favor the ECWMF over the other two American models. However, some model runs and even the WAFz forecasts are suggestive of a bigger type of PV disruption with stratospheric warming near the North Pole. That could lower the cold risk short term but could heighten it longer term.

Recent and Very Near Term Conditions

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

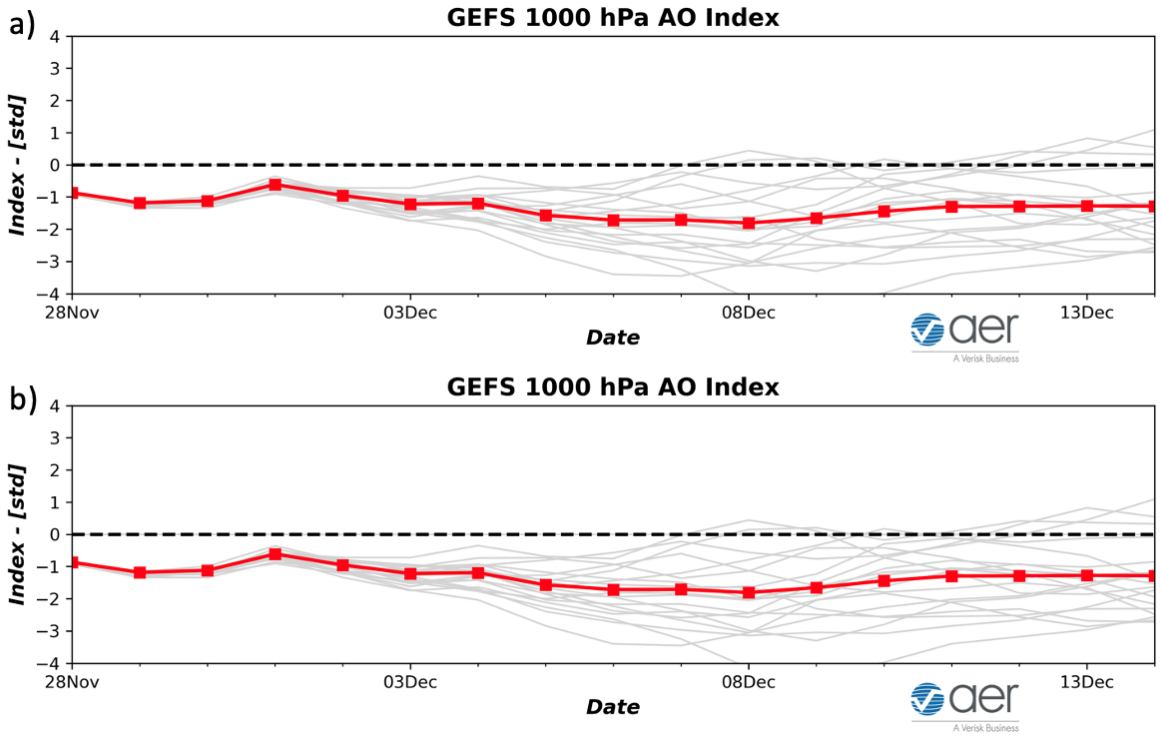


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 28 November 2022 GFS ensemble. (b)The predicted daily-mean near-surface AO from the 00Z 28 November 2022 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the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

Strengthening 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 Northern Scandinavia (**Figure 2). This will favor** normal to below normal temperatures across Northern Europe including the UK with normal to above normal temperatures across much of Southern Europe and Northern Scandinavia (**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 with ridging/positive geopotential height anomalies in Southern and Eastern 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 Asia **(Figure 3**).

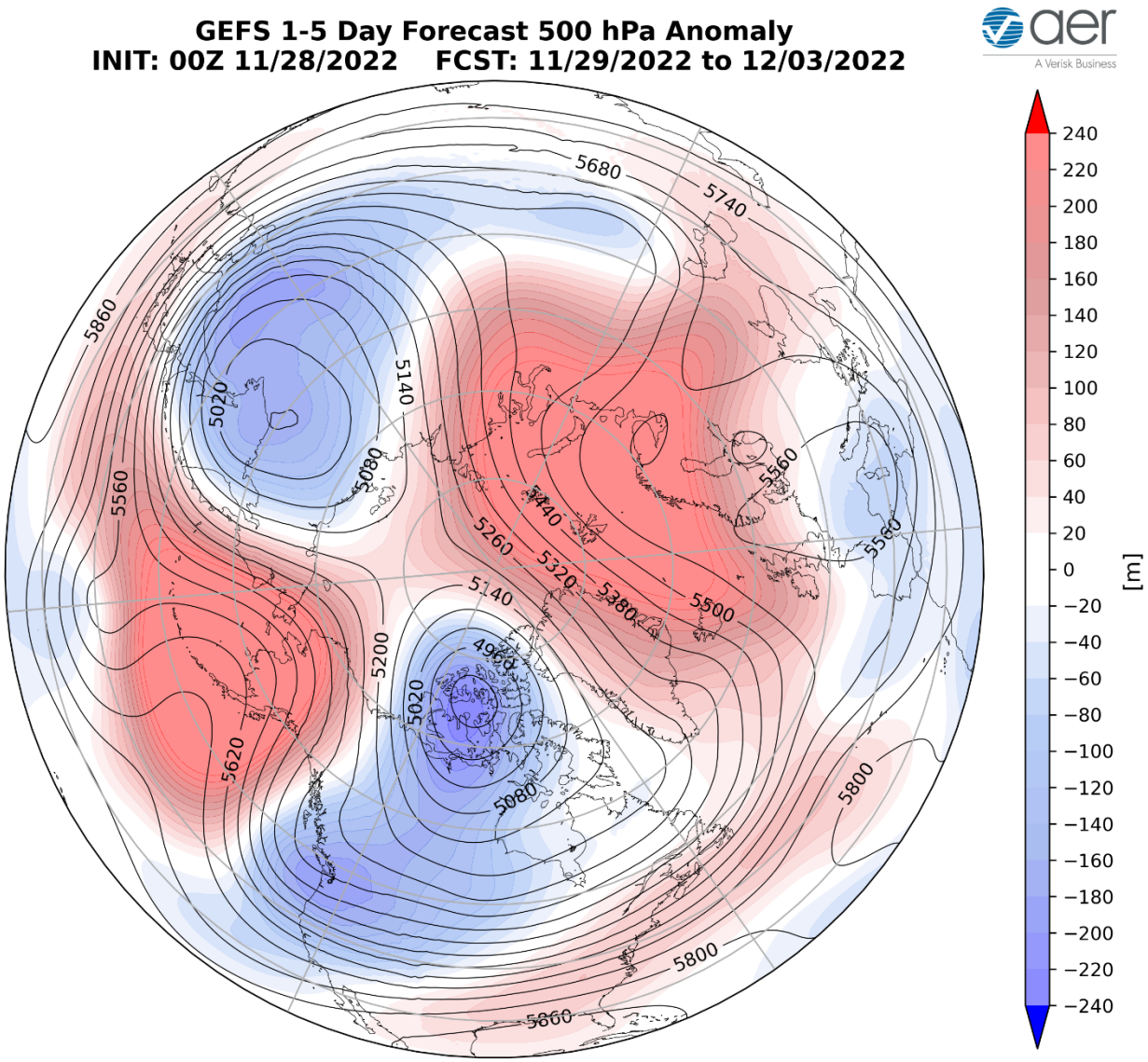


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 29 November – 3 December 2022. The forecasts are from the 00z 28 November 2022 GFS ensemble.

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 the Eastern 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 Canada and the Northwestern US **(Figure 3).**

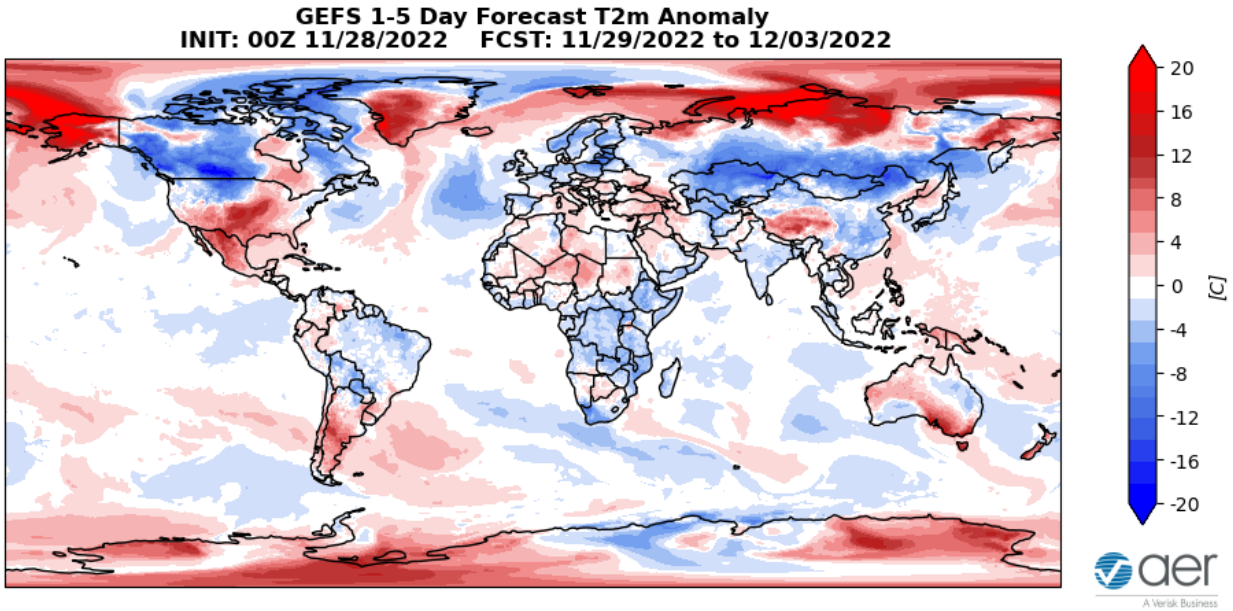


Figure 3. Forecasted surface temperature anomalies (°C; shading) from 29 November – 3 December 2022. The forecast is from the 00Z 28 November 2022 GFS ensemble

Troughing and/or cold temperatures will support new snowfall across Siberia and Central Asia while mild temperatures will support snowmelt in Eastern Europe (**Figure 4**). Troughing and/or cold temperatures will support new snowfall across northern Alaska, Northern, Western, Central and Eastern Canada while mild temperatures will support snowmelt across the Northern New England and the Canadian Maritimes (**Figure 4**).

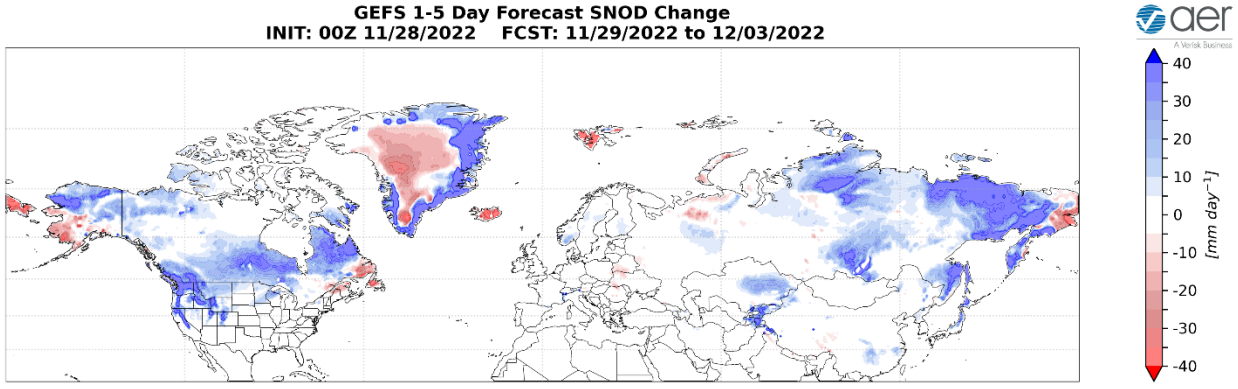


Figure 4. Forecasted snow depth changes (mm/day; shading) from 29 November – 3 December 2022. The forecast is from the 00Z 28 November 2022 GFS ensemble.

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.

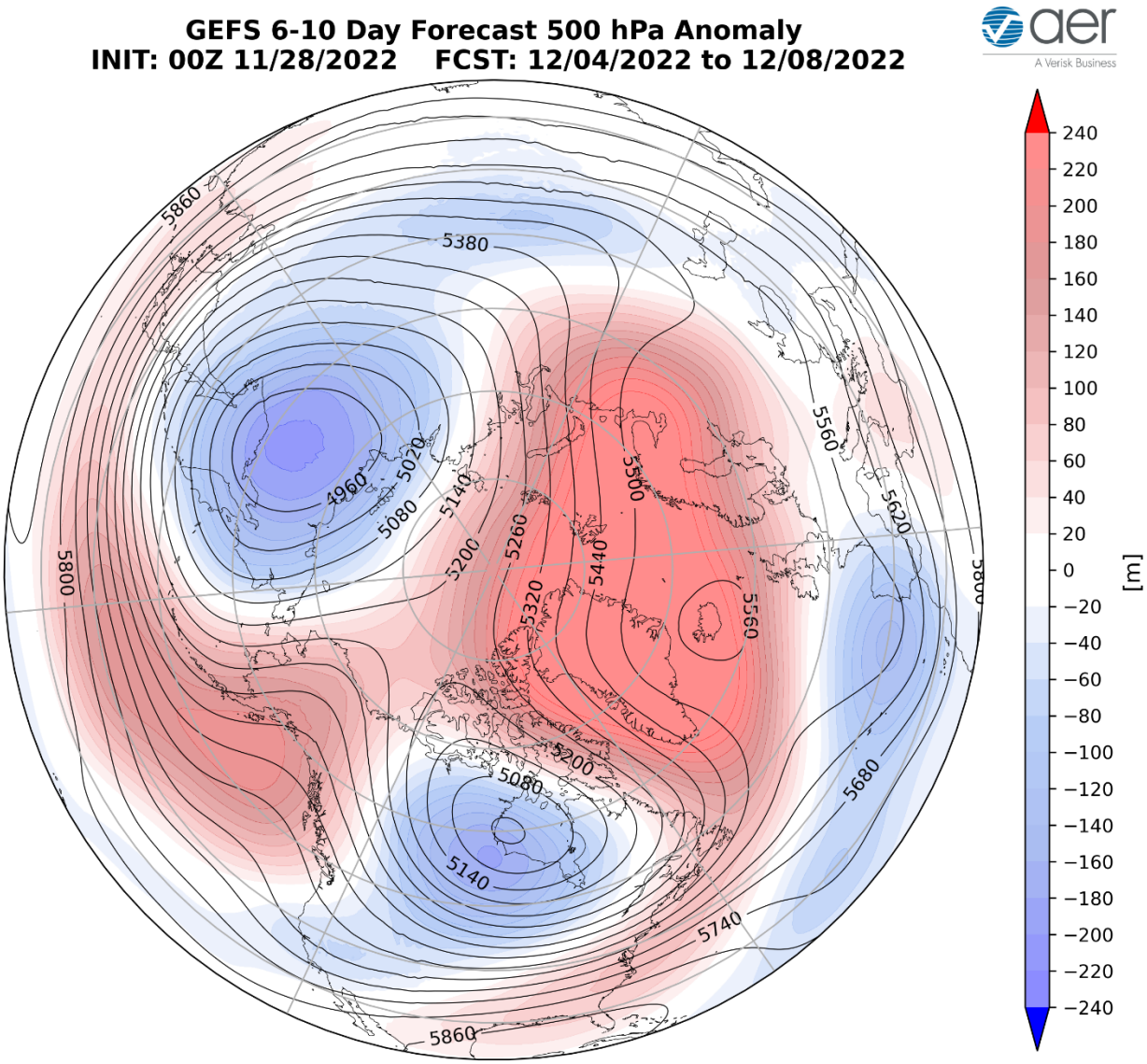


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 4 – 8 December 2022. The forecasts are from the 00z 28 November 2022 GFS ensemble.

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

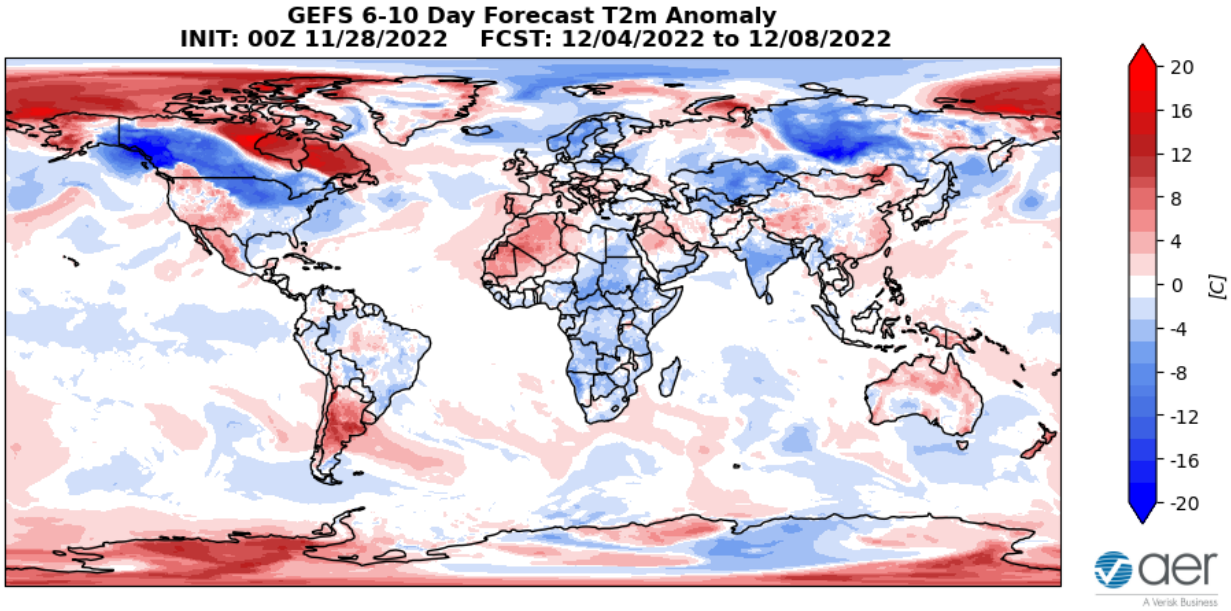


Figure 6. Forecasted surface temperature anomalies (°C; shading) from 4 – 8 December 2022. The forecast is from the 00Z 28 November 2022 GFS ensemble.

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

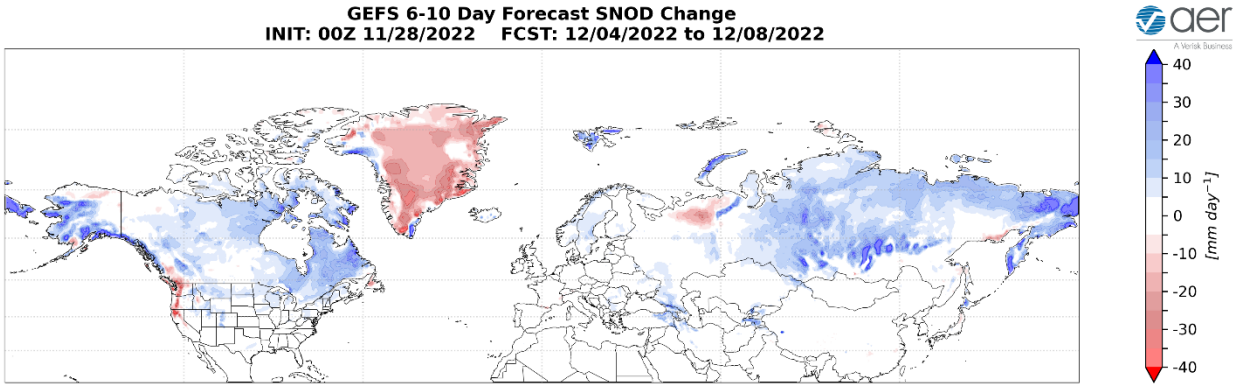


Figure 7. Forecasted snow depth changes (mm/day; shading) from 4 – 8 December 2022. The forecast is from the 00Z 28 November 2022 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Scandinavia, Northern and Central Asia while mild temperatures will support snowmelt in the Urals (**Figure 7**). Troughing and/or cold temperatures will support new snowfall across Alaska, Canada and the Northern US while mild temperatures will support snowmelt in coastal mountains of the Western US (**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 could also remain negative this period.

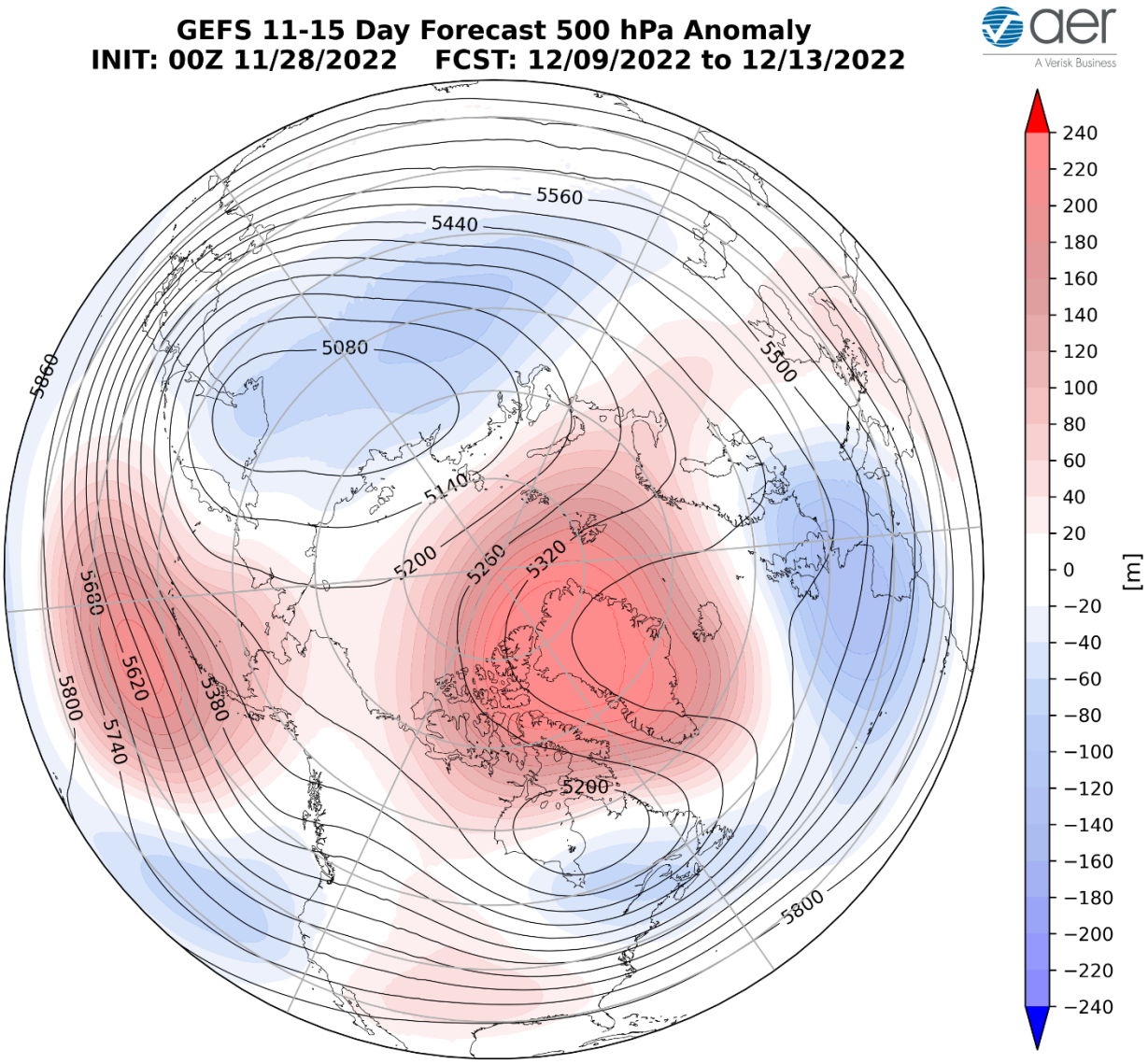


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 9 – 13 December 2022. The forecasts are from the 00z 28 November 2022 GFS ensemble.

Predicted ridging/positive geopotential height anomalies centered on Greenland will continue to favor troughing/negative geopotential height anomalies across Europe this period (**Figure 8**). This pattern favors a classical negative NAO pattern of normal to above normal temperatures across Northern Europe including the UK with normal to below normal temperatures across Southern Europe (**Figures 9**). Predicted ridging/positive geopotential height anomalies centered across Greenland will help to anchor troughing/negative geopotential height anomalies across Siberia that extend southwestward into Central Asia with ridging/positive geopotential height anomalies persisting in Southern Asia (**Figure 8**). This pattern favors widespread normal to below

normal temperatures across much of Northern and Central Asia with normal to above normal temperatures across Southern Asia (**Figure 9**).

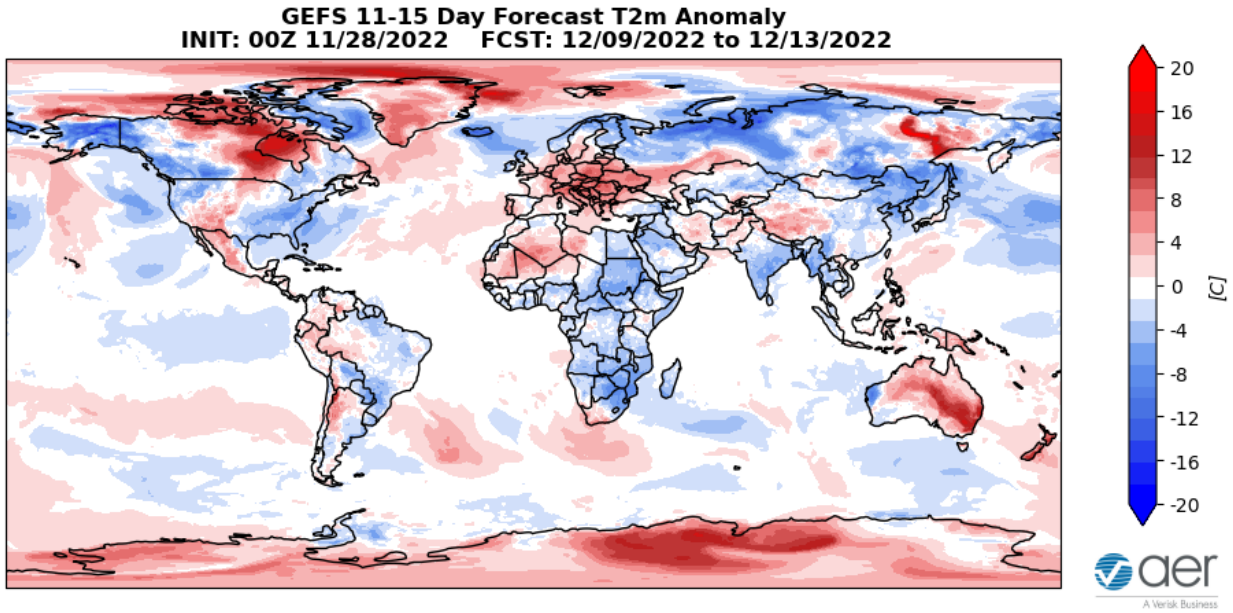


Figure 9. Forecasted surface temperature anomalies (°C; shading) from 9 – 13 December 2022. The forecast is from the 00Z 28 November 2022 GFS ensemble.

Predicted persistent ridging/positive geopotential height anomalies near the Aleutians will force troughing/negative geopotential height anomalies across Alaska, Western Canada and the Western US while ridging/positive geopotential height anomalies over Greenland will force troughing/negative geopotential height anomalies in eastern North America this period (**Figure 8**). This pattern favors widespread normal to below normal temperatures across Alaska, much of Canada and the US with normal to above normal temperatures limited to Northeastern Canada and the Southwestern and Southeastern US (**Figure 9**).

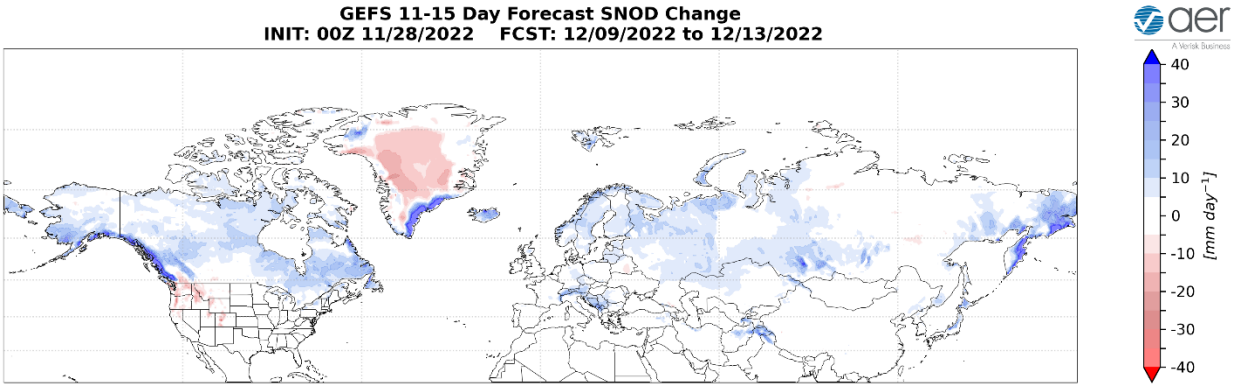


Figure 10. Forecasted snow depth changes (mm/day; shading) from 9 – 13 December 2022. The forecast is from the 00Z 28 November 2021 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Scotland, Norway, the Alps, Eastern Europe, Western Asia, Eastern Siberia and the Tibetan Plateau (**Figure 10**). Troughing and/or cold temperatures will support new snowfall across Alaska and much of Canada 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 to mid stratosphere with warm/positive PCHs in the lower stratosphere and the troposphere (**Figure 11**). Little change in this overall pattern is expected over the next two weeks (**Figure 11**).

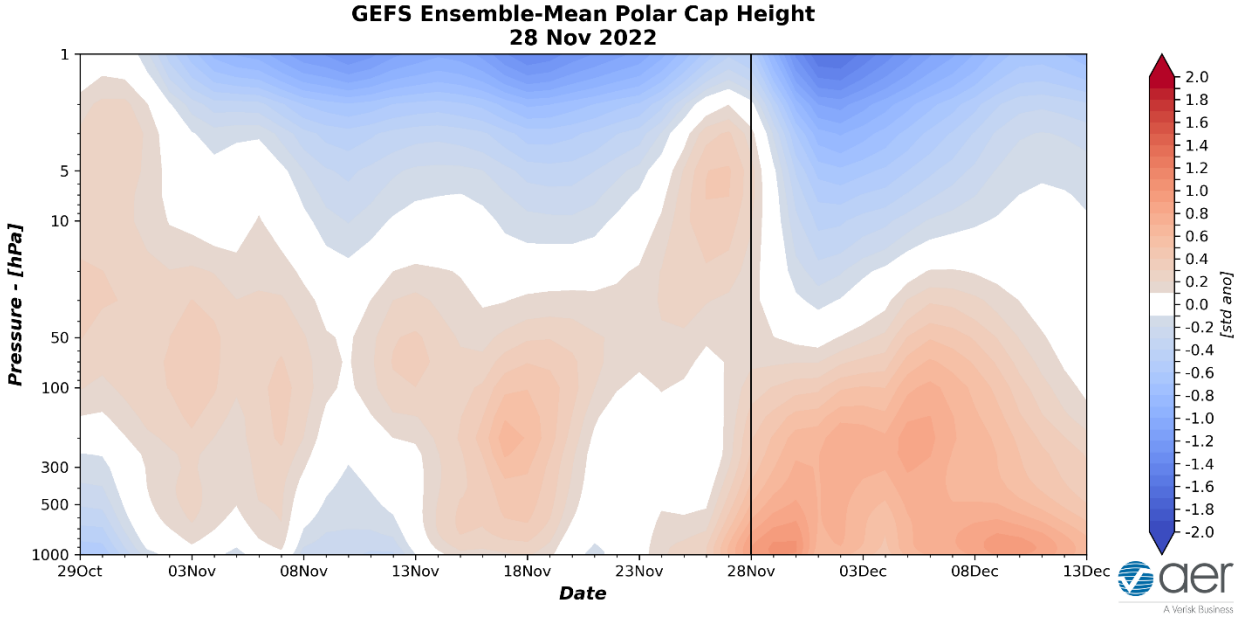


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 28 November 2022 GFS ensemble.

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**), therefore the surface AO is predicted to turn more strongly negative (**Figure 1**).

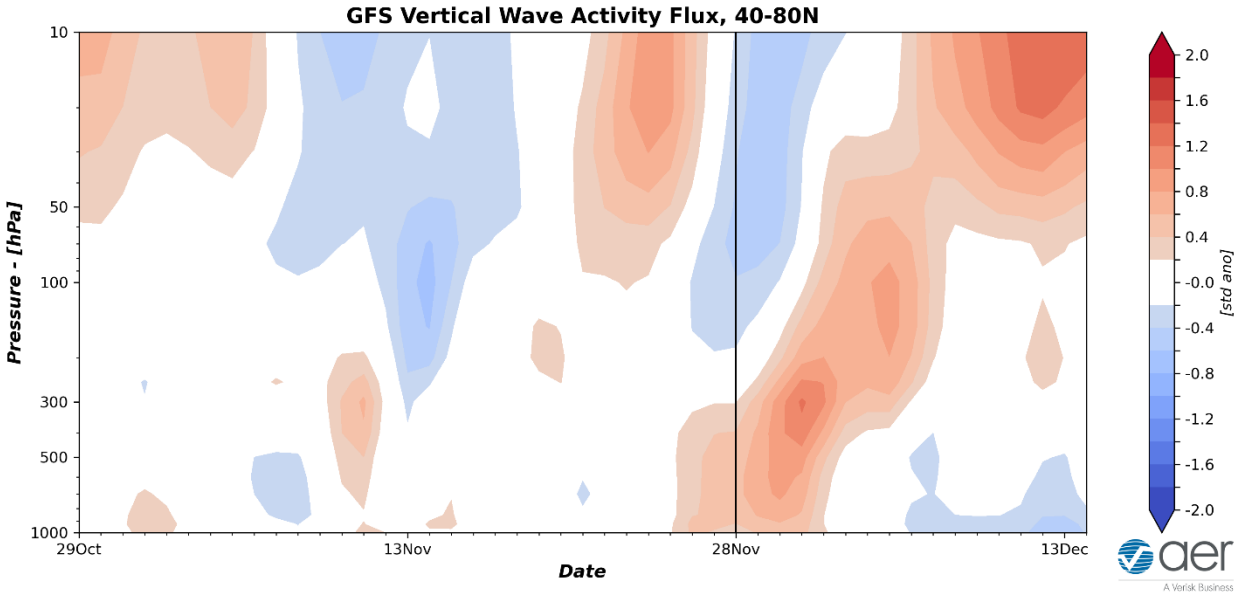


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 28 November 2022 GFS ensemble.

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 allowed the mid to upper stratospheric PCHs to remain relatively cold (**Figure 11**). The GFS is predicting a possible more active period of WAFz (**Figure 12**), resulting in mid stratospheric PCHs to warm before cooling again (**Figure 11**).

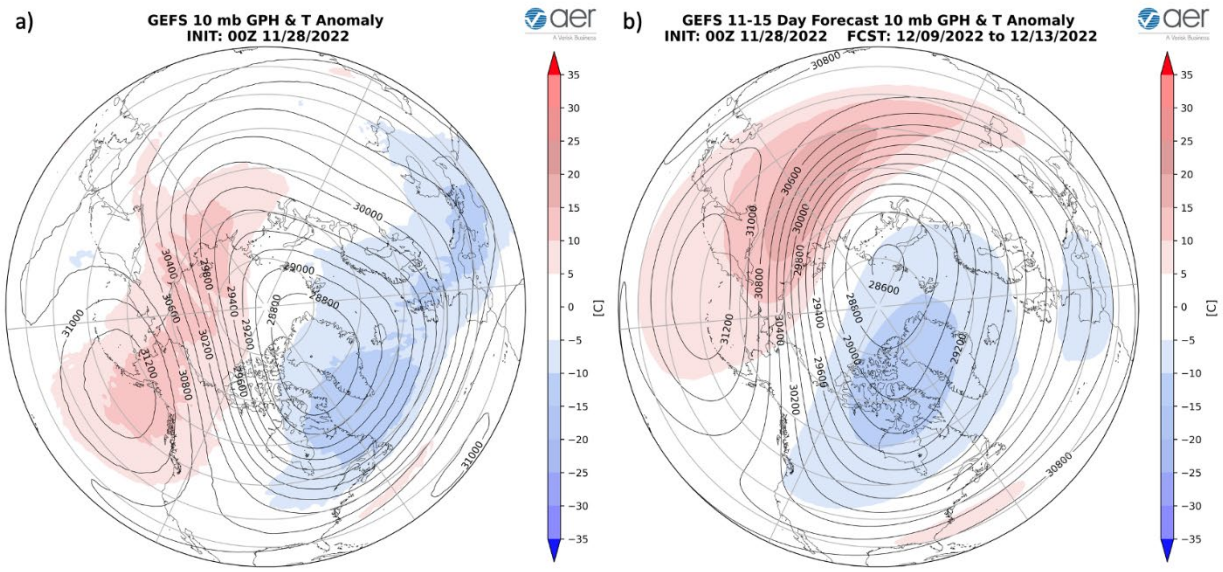


Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 28 November 2022. (b) Same as (a) except forecasted averaged from 9 – 13 December 2022. The forecasts are from the 00Z 28 November 2020 GFS model ensemble.

Still the near normal WAFz has caused a minor perturbation of the stratospheric PV with the PV center displaced towards Greenland **(Figure 13**). Also, the PV is elongated (**Figure 13**) extending from Siberia to Hudson Bay with ridging near the Aleutians. The configuration of the PV is consistent with a stretched PV. The predicted active WAFz could force another stretched PV the second week of December **Figure 13**). However, the PV is predicted to be normal to stronger than normal over the next two weeks despite the elongated configuration (**Figure 13**). Therefore, the stratospheric AO is predicted to remain neutral to positive over the next two weeks **(Figure 1**).

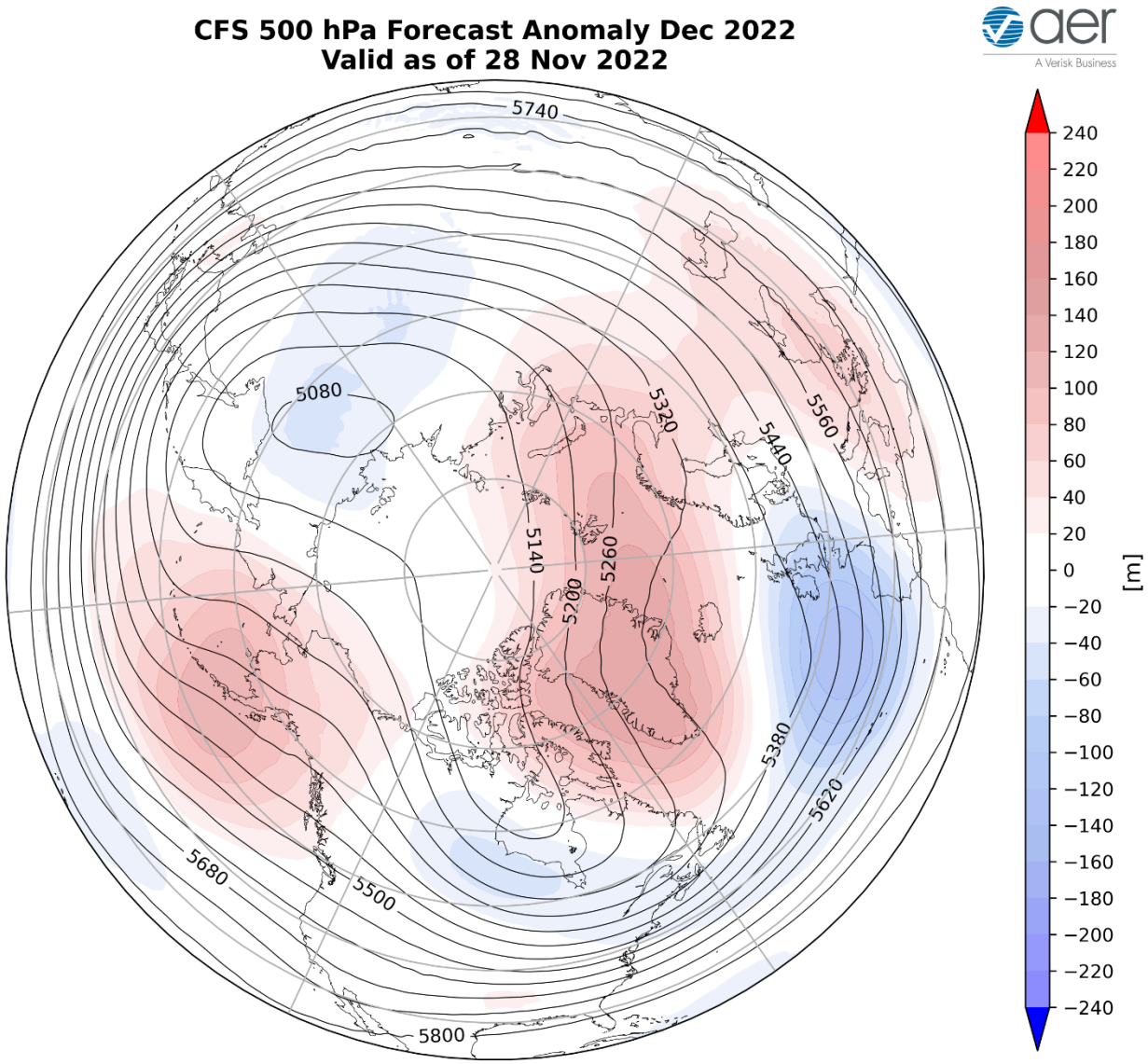


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for December 2022. The forecasts are from the 00Z 28 November 2022 CFS.

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

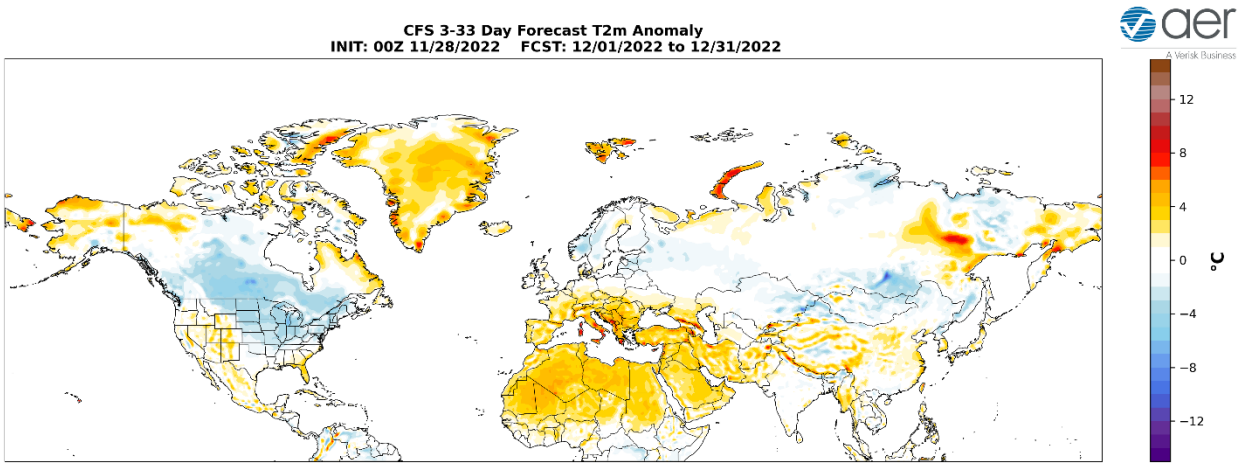


Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for December 2022. The forecasts are from the 00Z 28 November 2022 CFS.

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 but approaching normal. So it could be Arctic sea ice is

increasingly favoring high latitude blocking in the Barents-Kara Seas region and PV disruptions.

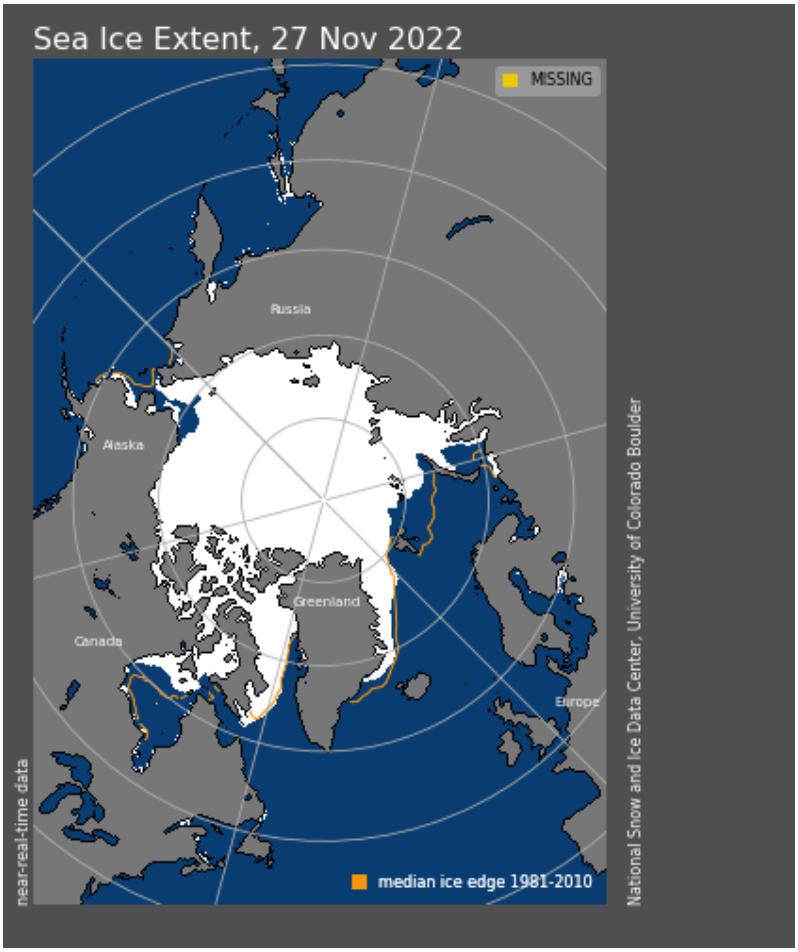


Figure 16. Observed Arctic sea ice extent on 27 November 2022 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC).

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.

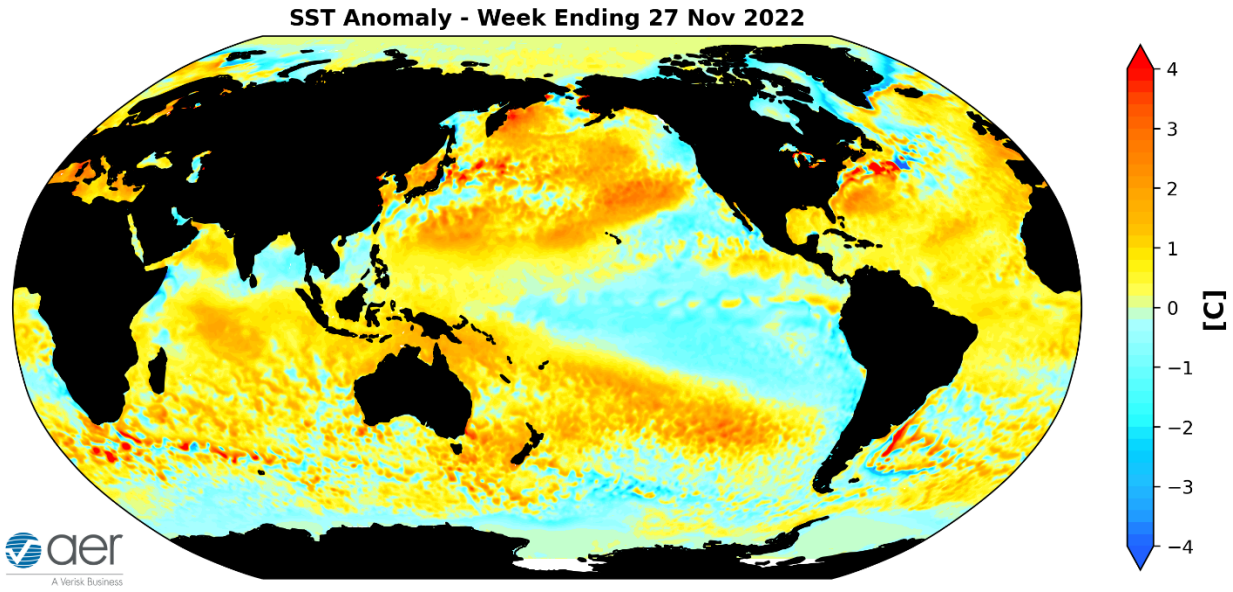


Figure 17. The latest weekly-mean global SST anomalies (ending 27 November 2022). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently the Madden Julian Oscillation (MJO) is in phase seven (**Figure 18**). The forecasts are for the MJO to quickly move into phase eight and then weaken to where no phase is favored. MJO phase eight favors ridging in the Northeastern Canada with a deep Aleutian low. The MJO could be having some influence on the weather across North America in the short term. But admittedly this is outside of my expertise.

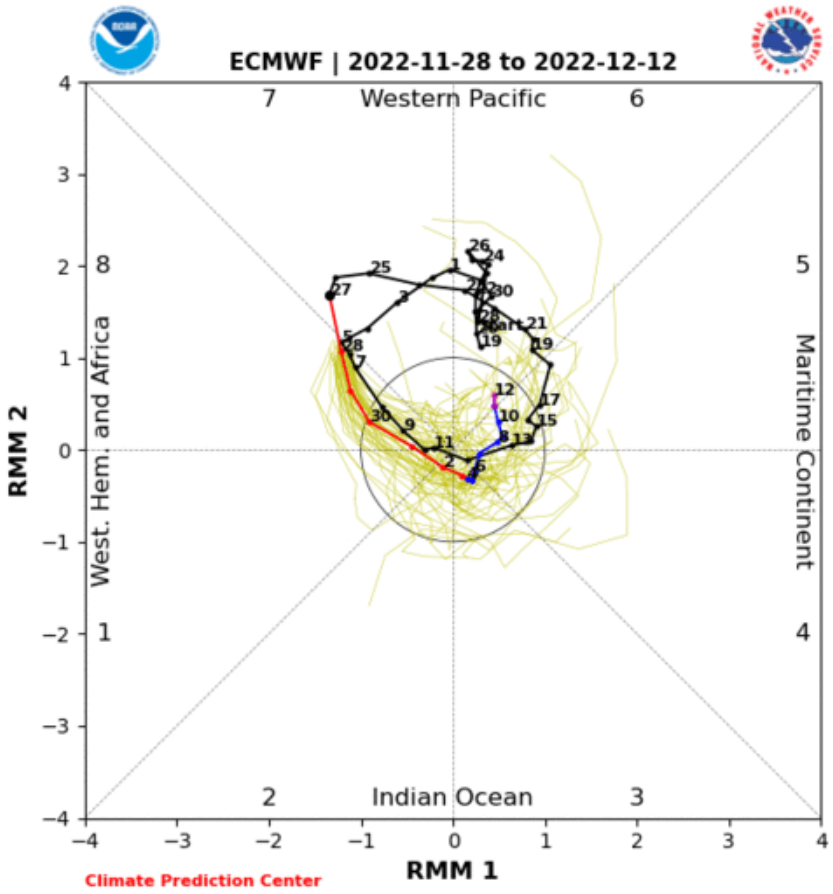


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 28 November 2022 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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 melted back this week from near decadal highs (see **Figure 19**) and now is near decadal means. With the predicted negative NAO, I expect snow cover to advance again in the coming weeks.

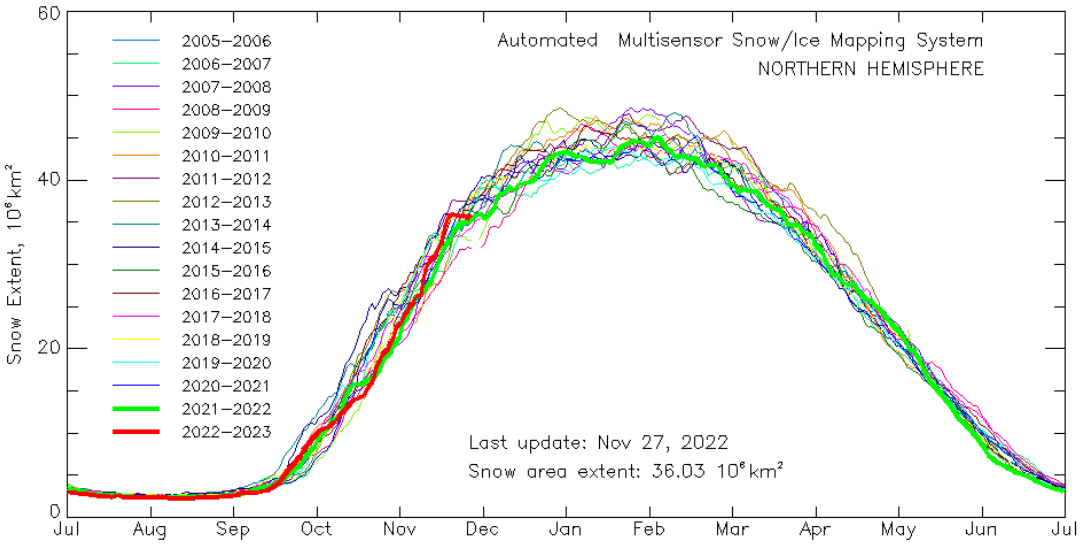


Figure 19. Observed North American snow cover extent through 27 November 2022. Plot from https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_monitor.html