

Arctic Oscillation and Polar Vortex Analysis and Forecasts

January 22, 2024

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

During the winter schedule the blog is updated once every week. Snow accumulation forecasts replace precipitation forecasts. Also, there is renewed emphasis on ice and snow boundary conditions and their influence on hemispheric weather. In late Spring, we transition to a spring/summer schedule, which is once every two weeks. Snow accumulation forecasts will be replaced by precipitation forecasts. Also, there will be less emphasis on ice and snow boundary conditions and their influence on hemispheric weather

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Summary

- The Arctic Oscillation (AO) is currently positive and is predicted to remain positive to neutral the next two weeks as pressure/geopotential height anomalies across the Arctic are currently mostly negative and are predicted to remain mostly negative over the next two weeks. The North Atlantic Oscillation (NAO) is currently positive with negative pressure/geopotential height anomalies across Greenland and the NAO is predicted to remain positive the next two weeks as pressure/geopotential height anomalies remain negative across Greenland.
- The next two weeks, troughing/negative geopotential height anomalies across Greenland will support mostly ridging/positive geopotential height anomalies across Europe. This pattern will support a classic +NAO temperature pattern with normal to above normal temperatures across much of Europe including the United Kingdom (UK). One exception

will be regional troughing/negative geopotential height anomalies across Southeastern Europe with normal to below normal temperatures across Southeastern Europe including Turkey.

- The general predicted pattern across Asia the next two weeks is an omega block pattern with ridging/positive geopotential height anomalies in the Urals-Western Siberia region bookended by troughing/negative geopotential height anomalies across Northwestern and Northeastern Asia. This pattern favors widespread normal to above normal temperatures across with normal to below normal temperatures regionally in Western and Eastern Asia but mostly Southern Siberia.
- The general predicted pattern across North America the next two weeks is troughing/negative geopotential height anomalies across Alaska and the Gulf of Alaska forcing troughing/negative geopotential height anomalies across the interior of North America. This pattern favors normal to above normal temperatures across much of Canada and United States (US) with the exception of normal to below normal temperatures across Alaska this week spreading into Western Canada and the Western US next week.
- In the Impacts section I discuss the strengthening polar vortex (PV) with possible minor PV disruptions similar to December with a Canadian warming and a stretched PV and the impacts to our weather.

Plain Language Summary

As I start off the Impact section it seems like “Déjà vu all over again” with the behavior of the polar vortex (PV) and associated weather in late January and into early February is reminiscent of what was observed in late November and into December. After last week’s major disruption of the PV more minor disruptions are likely in the coming weeks. The first is a Canadian warming with a side of a stretched PV to be followed by a more robust stretched PV. This combination of minor PV disruptions is likely to reinforce temperature patterns observed so far this winter (see **Figure**).

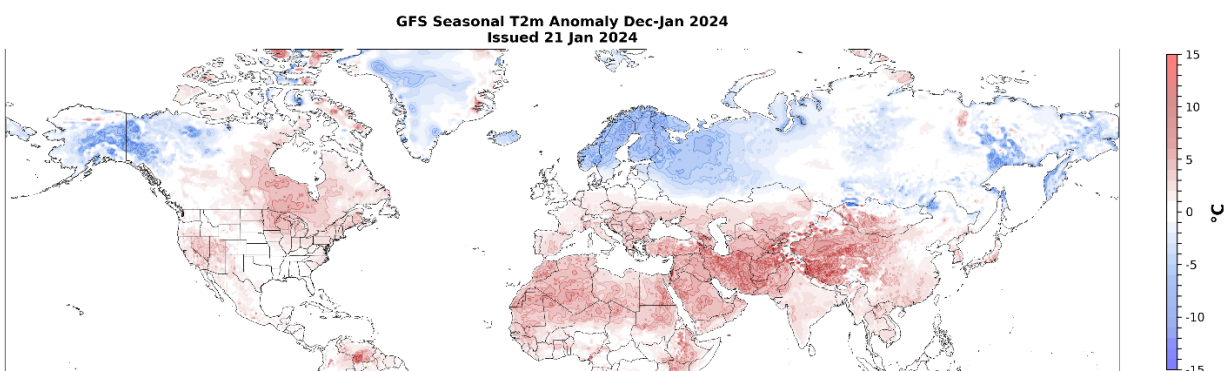


Figure. Estimate of the observed surface temperatures (°C; shading) from 1 December 2023 – 6 February 2024 based on GFS initializations and the GFS forecast from the 21 January 2024 forecast.

It seems to me, what you see is what you'll get. Cold in the short term across Northern Asia, with then cold spreading to Northern Europe. These are the locations where cold has been most consistent this winter. At least in the near-term cold is likely across Alaska, the region most consistently cold so far this winter in North America. Cold is likely to return to eastern North America in mid-February, a region where cold has been more ephemeral.

Impacts

In the immortal words of the twentieth century's greatest philosopher, Yogi Bera, looking at the PV forecasts it's "Déjà vu all over again." Cross currents, rapid and overlapping transitions of the polar vortex (PV) have made understanding exactly what is going on with the behavior of the PV and its impact on the weather challenging but I do think that PV behavior and its influence has become clearer, and it reminds me of the events of December.

Returning to sea level and finally getting sufficient oxygen to my lungs has helped lift the "hazy shades of winter" from last week when I was suffering from altitude sickness.

In December, a Canadian warming seemed to be the most influential behavior of the PV on the Northern Hemisphere (NH) weather with cold across Northern Eurasia but record mild in North America and record low snow cover. The ridging in Siberia with troughing near the Urals has indeed allowed the PV to quickly recover from the major warming (a reversal in the zonal mean zonal wind at 60°N and 10hpa from westerly to easterly/from positive to negative) of just last week. In **Figure 13b** you can see a nice tightly wound and circular PV, characteristic of a strong PV. However, the PV center is displaced off the North Pole towards Eurasia with a ridge of high pressure over Hudson Bay and the strongest warming over Greenland in the polar stratosphere. This does resemble a Canadian warming as I discussed in earlier blogs including the [11 December 2023](#) blog. In **Figure i**, I include a figure of different PV clusters and associated surface temperature anomalies from [Kretschmer et al. 2018](#) and highlight the middle cluster or the Canadian warming which does resemble **Figure 13b**. (I showed this figure in the 27 November 2023 blog but it didn't get saved to the archive.) Surface temperatures are quite warm across North America especially Canada with cold temperatures across Northern Eurasia. Warm temperatures (and likely record warm) are predicted for North America (see **Figure 6**) with cold temperatures across Northern Asia. For once Scandinavia is predicted to be mild but if geopotential heights lower in the polar stratosphere over Scandinavia as predicted, I do expect temperatures to cool over Scandinavia with time.

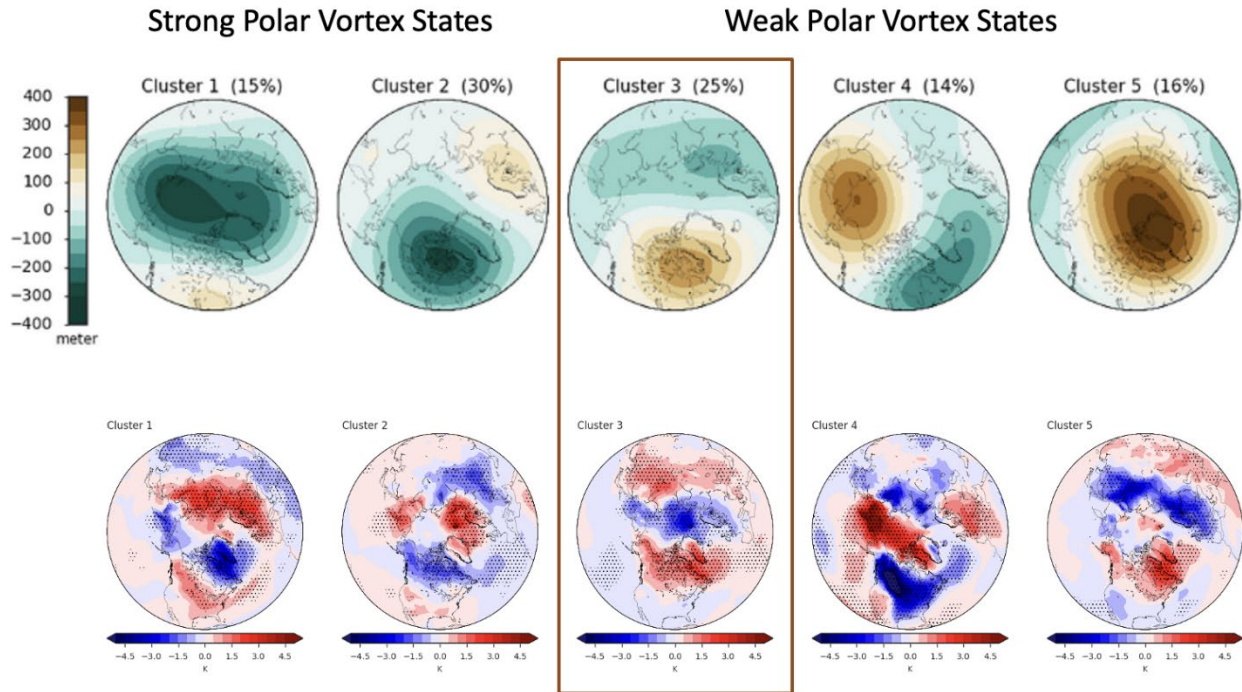


Figure i. Composites of geopotential height anomalies at 100 hPa in winter (JF) from 1979 to 2018 for days assigned to the same cluster. The number in brackets gives the total occurrence (in percent) over all winter days (top). Cluster 3 is a Canadian warming. Northern Hemisphere surface temperature anomalies in °C associated coincident with each cluster (bottom).

But I have also been highlighting in this time frame wave reflection where wave energy goes up emanating from ridging in Eastern Siberia/western North Pacific, boomerangs off the PV and goes back down over far eastern North America and the North Atlantic (see **Figure ii**). This wave reflection is both relatively shallow and shifted east of more typical wave reflections associated with stretched PVs.

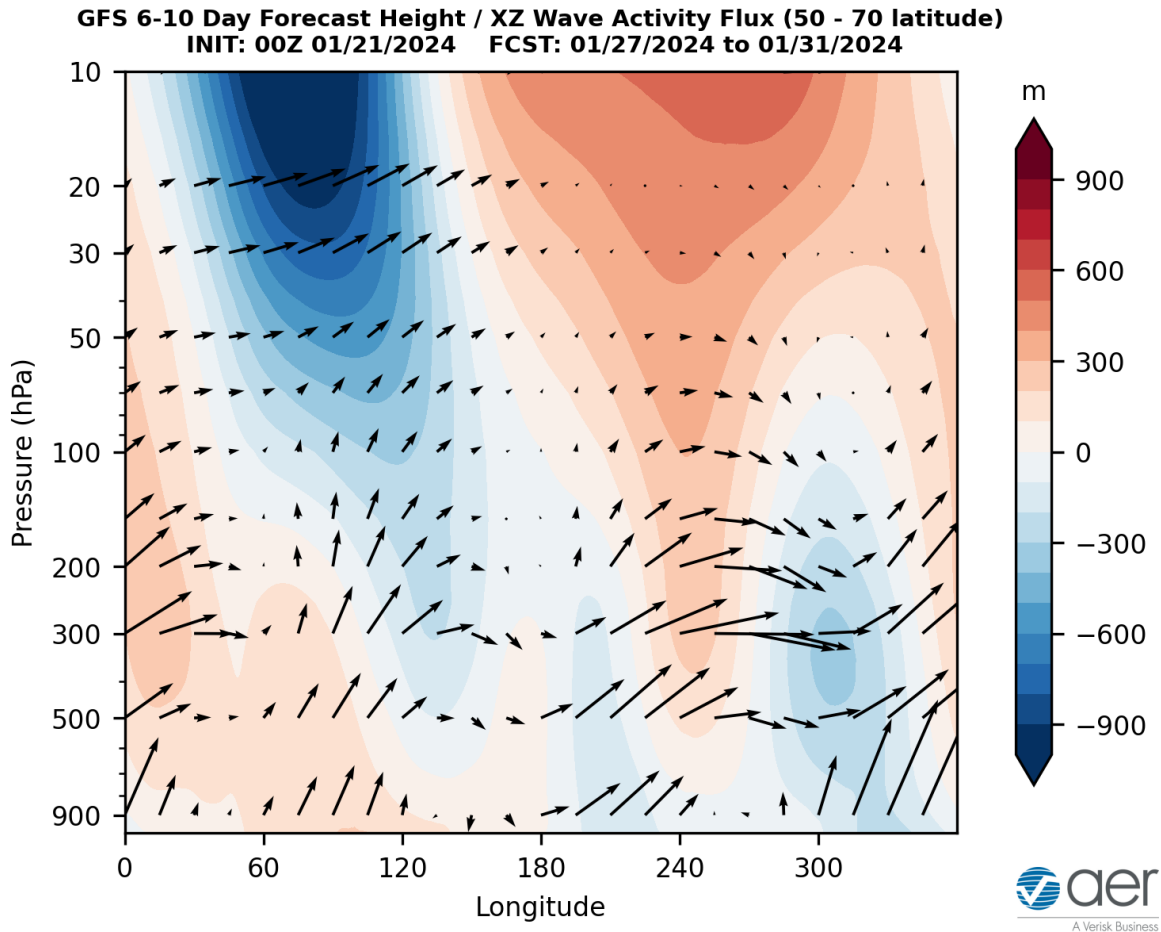


Figure ii. Longitude-height cross section of geopotential eddy height anomalies (shading) and wave activity flux (vectors) forecasted for 27 – 31 January 2024. The forecasts are from the 00z 21 January 2024 GFS ensemble.

So even though a stretched PV is not really apparent at 10hPa it does show up in the lower stratosphere at 100 hPa (see **Figure iii**). A trough is visible over far Eastern Canada, Greenland and the North Atlantic (though I admit that unfortunately it is hard to make out the features in this plot). A trough in a similar location can also be observed at 500 hPa (see **Figure 5**). Something very similar happened at the end of December where most of the cold air spilled out into the North Atlantic. Here too it looks like most of the cold air will be directed to Atlantic Canada and the North Atlantic, but some cold air could backdoor its way into the Northeastern US. So even though snow was a no show in December, it still may be possible next week in the Northeastern US.

mid-February a stretched PV is becoming more likely. This should help end the very mild pattern in place across North America. The intensity and duration of cold weather associated with the stretched PV is yet to be determined.

I want to end with one wild card. As usual I show the latest polar cap geopotential height anomalies (PCHs) plot in **Figure 11**, but occasionally I have also included the North Atlantic regional version of the plot, with the most recent in **Figure iv**. In **Figure 11** one cannot observe the typical “drip” of warm/positive PCHs from the stratosphere to the troposphere often on a timescale of two weeks. Instead, the warm/positive PCHs in the stratosphere associated with last week’s major warming come to an abrupt end and independently warm/positive PCHs appear or emerge in the troposphere in early February. But looking at the North Atlantic regional PCHs a different understanding is suggested. Warm/positive PCHs in the mid to upper stratosphere associated with last week’s major warming first “drip” or descend into the mid to lower stratosphere this week. This first leg down can be seen in **Figure 13b** with the polar stratospheric warming centered over Greenland. Then “drip” further into the troposphere in early February. Since this is only the North Atlantic regional plot, it is strongly suggestive of the return of Greenland blocking, though for now I don’t see much evidence of this in the weather model forecasts. But this possibility is something that I am monitoring. Greenland blocking favors colder weather across Europe but is also often a precursor to stretched PVs and eventually colder weather across North America east of the Rockies.

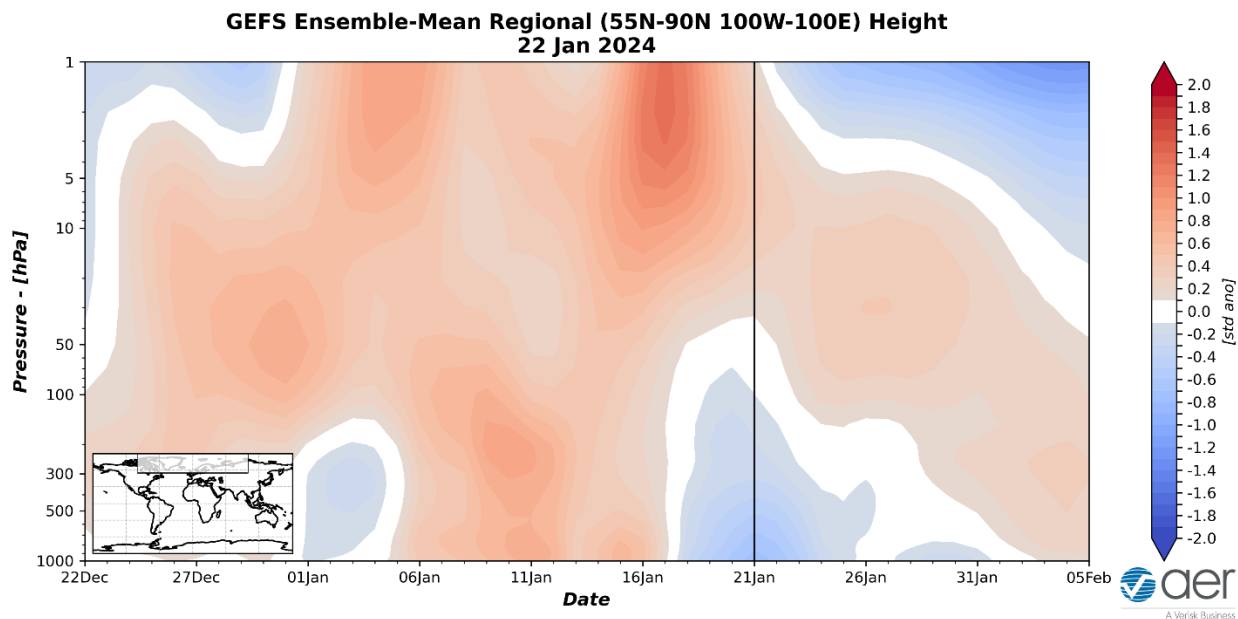


Figure iv. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies over the North Atlantic sector only (see insert). The forecast is from the 00Z 22 January 2024 GFS ensemble.

So, in summary, in the short-term mild in Europe and very mild for much of North America with the biggest exception being the North American Arctic including Alaska. Cold air for the remainder of the month is mostly limited to parts of Asia especially Siberia. Cold is then likely to return to Scandinavia in early February associated with lowering heights as the PV center edges closer to the region in reaction to the beginning of more active period of WAFz (see **Figure 12**). If Greenland blocking does materialize, the cold across Northern Europe could deepen and become more widespread. Greenland blocking could bring more seasonable temperatures to the Northeastern US but may also signal an increasing likelihood of another stretched PV as early as the second week of February. If a stretched PV does happen, which seems to me is increasingly likely, then cold in eastern North America would likely return as well.

I like to keep a tally or score of snowfall anomalies across the Northern Hemisphere. Last time that I showed the plot there were large deficits in snowfall especially across North America. Large areas of above normal snowfall exist in Northern Asia, Scandinavia, the Baltics, Northern Canada but especially Western Russia and Southeastern Alaska. Deficits exist in Western and Southern Europe, parts of the US, including the I95 corridor (despite the end of the snow drought) and especially the mountains of California and the Pacific Northwest (see **Figure v**).

ERA5 Cumulative Snowfall Anomaly Nov 2023 - Jan 2024

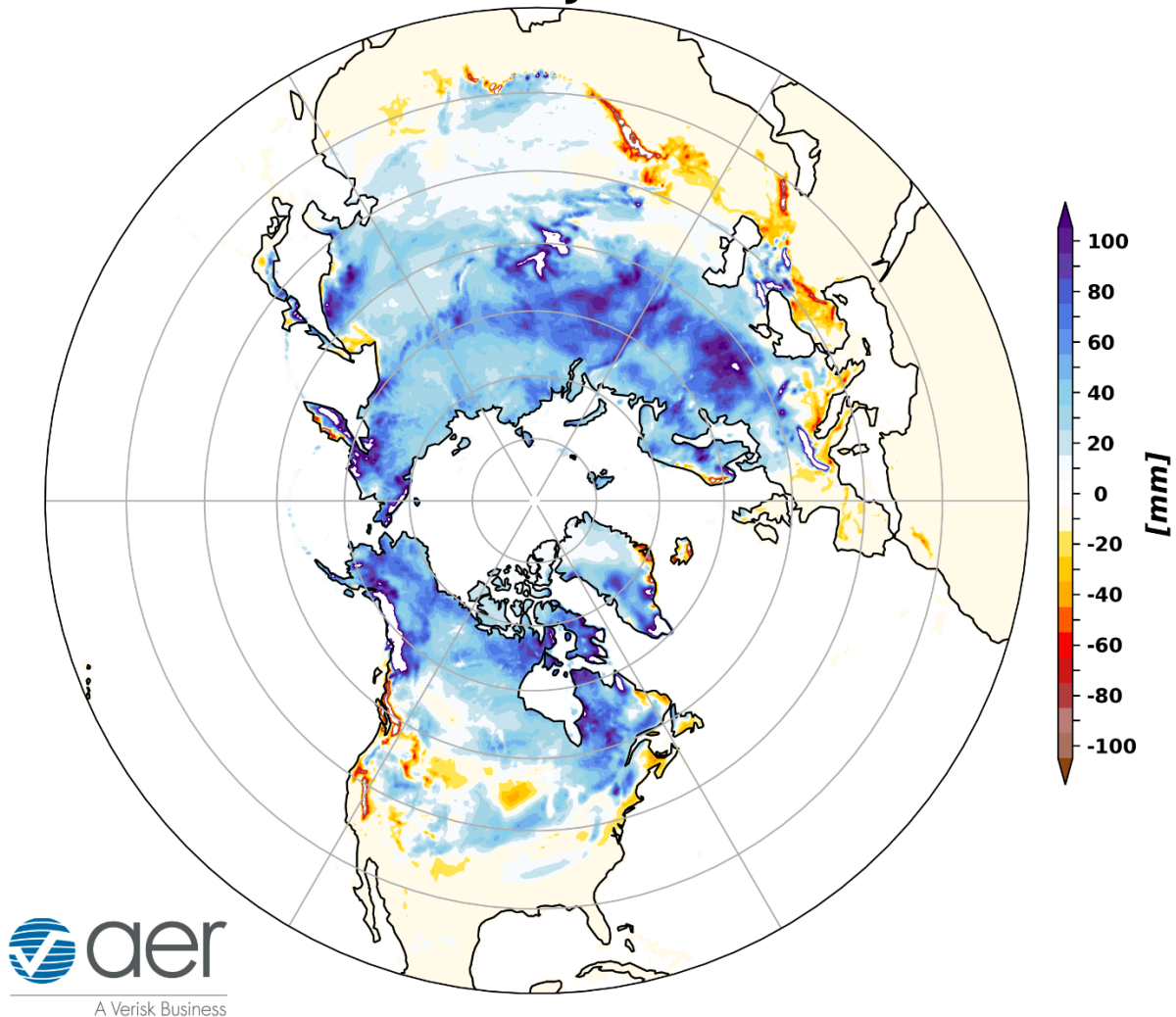


Figure v. Estimate of the observed snowfall anomalies (snow water equivalent in mm; shading) from 1 December 2023 – 6 February 2024 based on ERA5.

Near-Term

This week

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

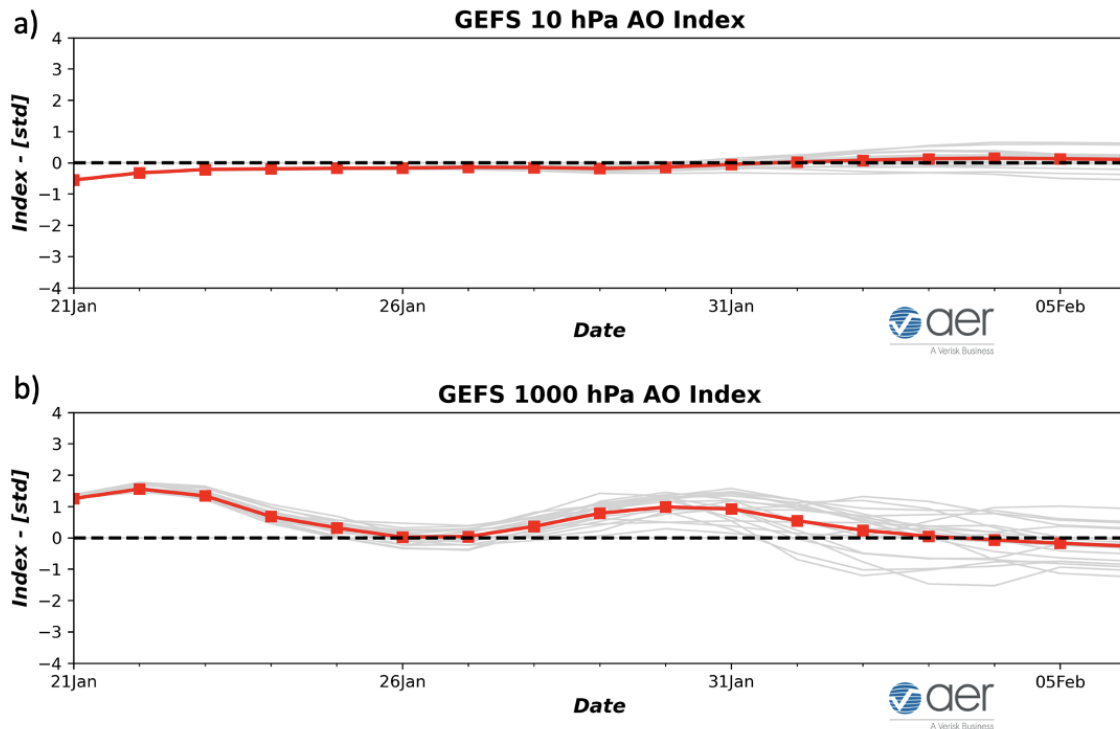


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 22 January 2024 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 22 January 2024 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Trouching/negative geopotential height anomalies centered over Greenland will favor ridging/positive geopotential height anomalies across much of Europe with some weak trouching/negative geopotential height anomalies across Southeastern Europe this week (**Figure 2**). The pattern favors widespread normal to above normal temperatures across Europe including the UK with normal to below normal temperatures limited to the Balkans and Turkey (**Figure 3**). Predicted ridging/positive geopotential height anomalies centered in the Barents-Kara Seas and the Urals will be sandwiched by trouching/negative geopotential height anomalies across Western and Northeastern Asia this period (**Figure 2**). This pattern favors widespread normal to above normal temperatures across Southern and Central Asia with normal to below normal temperatures across parts of Western and Eastern Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 hPa Anomaly
INIT: 00Z 01/22/2024 FCST: 01/23/2024 to 01/27/2024

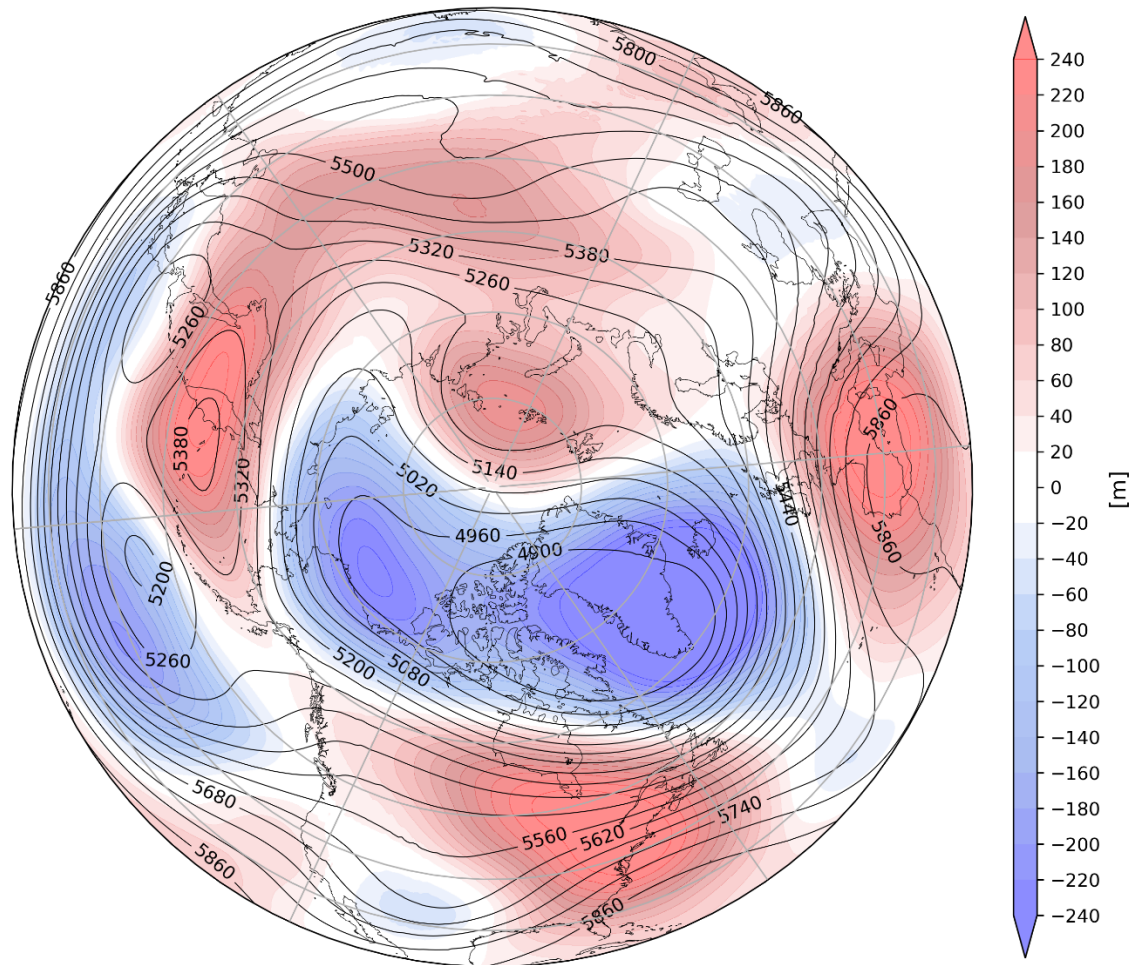


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 23 – 27 January 2024. The forecasts are from the 00z 22 January 2024 GFS ensemble.

The pattern this week across North America is troughing/negative geopotential height anomalies across Alaska and Northern Canada with ridging/positive geopotential height anomalies across Southern Canada and the Eastern US (**Figure 2**). This pattern will favor normal to below normal temperatures across Alaska and Northern Canada with normal to above normal temperatures across Southern Canada and much of the US (**Figure 3**).

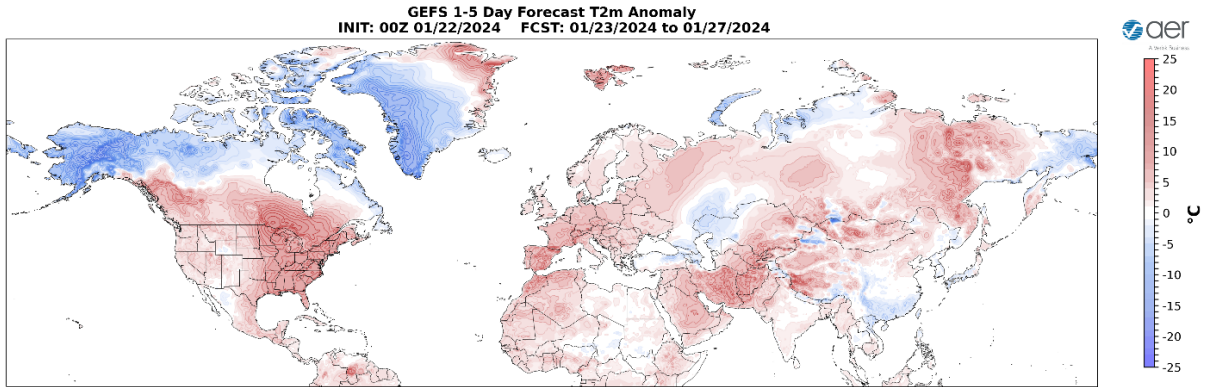


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 23 – 27 January 2024. The forecast is from the 00Z 22 January 2024 GFS ensemble.

Trouthing and/or cold temperatures will support new snowfall across Southern Scandinavia, eastern Turkey, Siberia and the Tibetan Plateau while mild temperatures will support snowmelt across Eastern Europe, Western Russia and Southern Siberia this week (**Figure 4**). Trouthing and/or cold temperatures will support new snowfall across Southeastern Alaska and Central Canada while mild temperatures will support snowmelt across the higher elevations of the Western US and the Northeastern US this week (**Figure 4**).

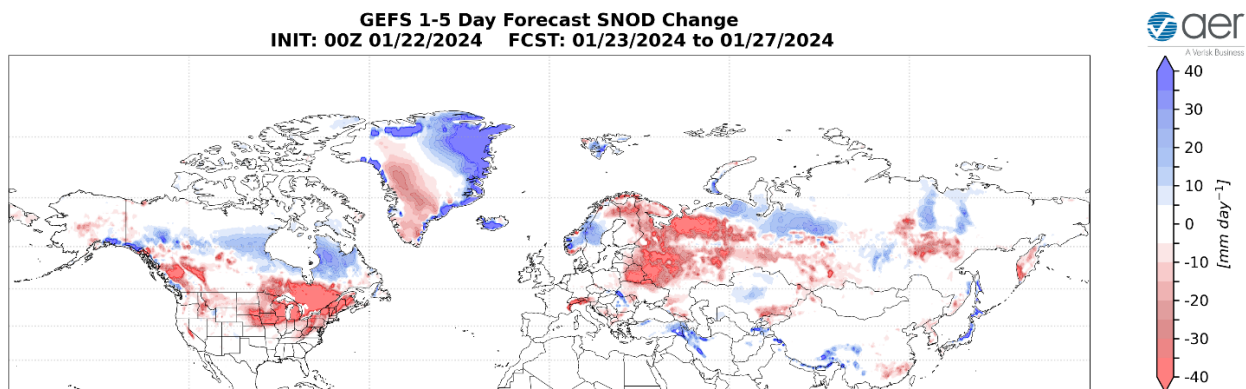


Figure 4. Forecasted snow depth changes (mm/day; shading) from 23 – 27 January 2024. The forecast is from the 00Z 22 January 2024 GFS ensemble.

Near-Mid Term

Next week

With geopotential height anomalies remaining mostly negative across the Arctic and with mixed geopotential height anomalies across the mid-latitudes this period (**Figure 5**), the AO will persist positive this period (**Figure 1**). With pressure/geopotential height

anomalies across Greenland also remaining negative (**Figure 5**), the NAO should persist in positive territory as well this period.

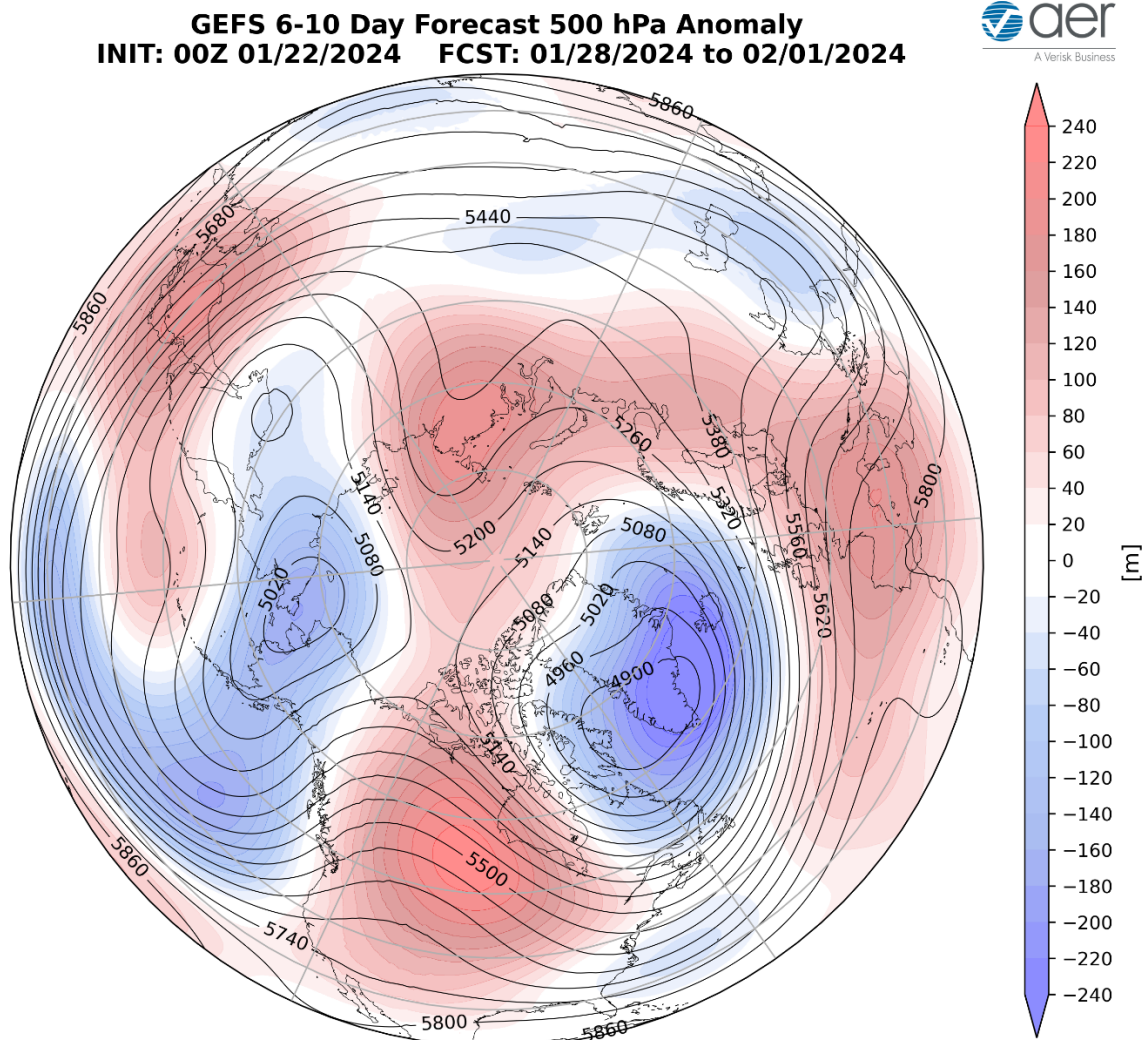


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 28 January – 1 February 2024. The forecasts are from the 00z 22 January 2024 GFS ensemble.

Trouching/negative geopotential height anomalies centered near Greenland will anchor ridging/positive geopotential height anomalies across Europe with the exception of trouching/negative geopotential height anomalies across Southeastern Europe this period (**Figure 5**). This pattern will favor widespread normal to above normal temperatures across much of Europe including the UK with normal to below normal temperatures limited to Turkey (**Figures 6**). The omega block pattern across Asia is predicted to persist with trouching/negative geopotential height anomalies across Northeastern and Northwestern

bookending ridging/positive geopotential height anomalies centered in Western Siberia this period (**Figure 5**). This pattern favors widespread normal to above normal temperatures across Asia with normal to below normal temperatures limited to Southwestern Asia, Northeastern Asia and Southern and Eastern Siberia this period (**Figure 6**).

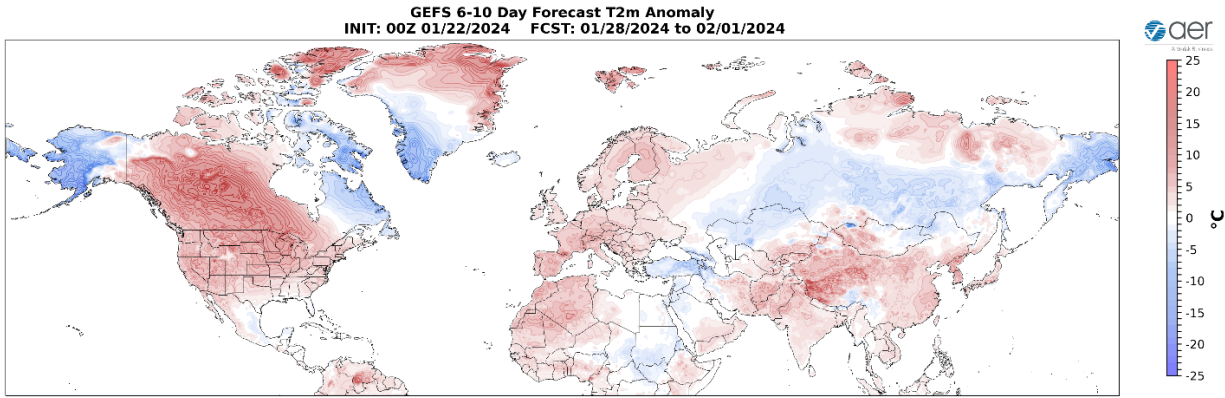


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 28 January – 1 February 2024. The forecasts are from the 00z 22 January 2024 GFS ensemble.

The overall pattern of troughing/negative geopotential height anomalies across Alaska and the Gulf of Alaska forcing ridging/positive geopotential height anomalies across much of North America is predicted to persist with additional troughing/negative geopotential height anomalies centered in Baffin Bay this period (**Figure 5**). This pattern favors normal to above normal temperatures across much of Canada, and the US with normal to below normal temperatures limited to Alaska, much of Quebec and the Canadian Maritimes (**Figure 6**).

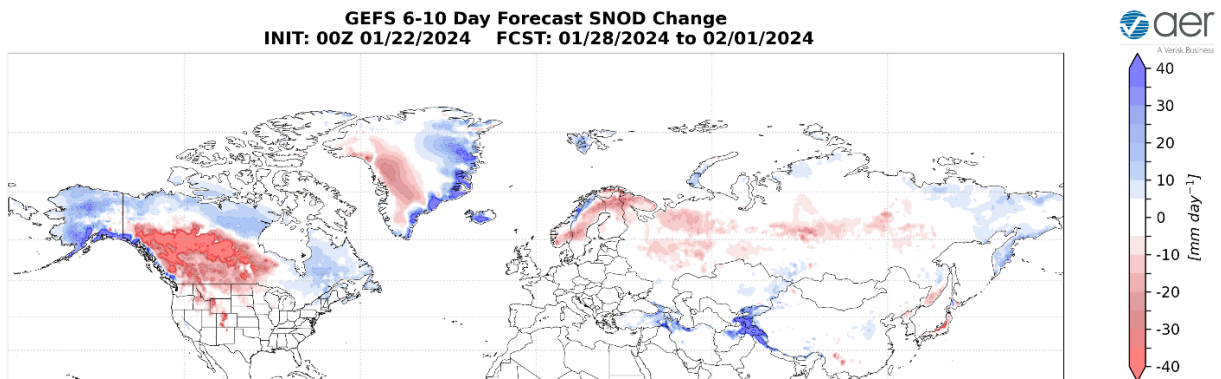


Figure 7. Forecasted snow depth changes (mm/day ; shading) from 28 January – 1 February 2024. The forecast is from the 00Z 22 January 2024 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Norway, Turkey, the Tibetan Plateau and Eastern Siberia while mild temperatures will support snowmelt in Sweden,

Finland and parts of Siberia this period (**Figure 7**). Troughing and/or cold temperatures will support new snowfall across Alaska, Northern and Eastern Canada, while mild temperatures will support snowmelt in Southwestern Canada and the higher elevations of the Western US this period (**Figure 7**).

Mid Term

Week Two

With more mixed geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes this period (**Figure 8**), the AO will likely remain close to neutral this period (**Figure 1**). With weak and mixed pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO should return to neutral as well this period.

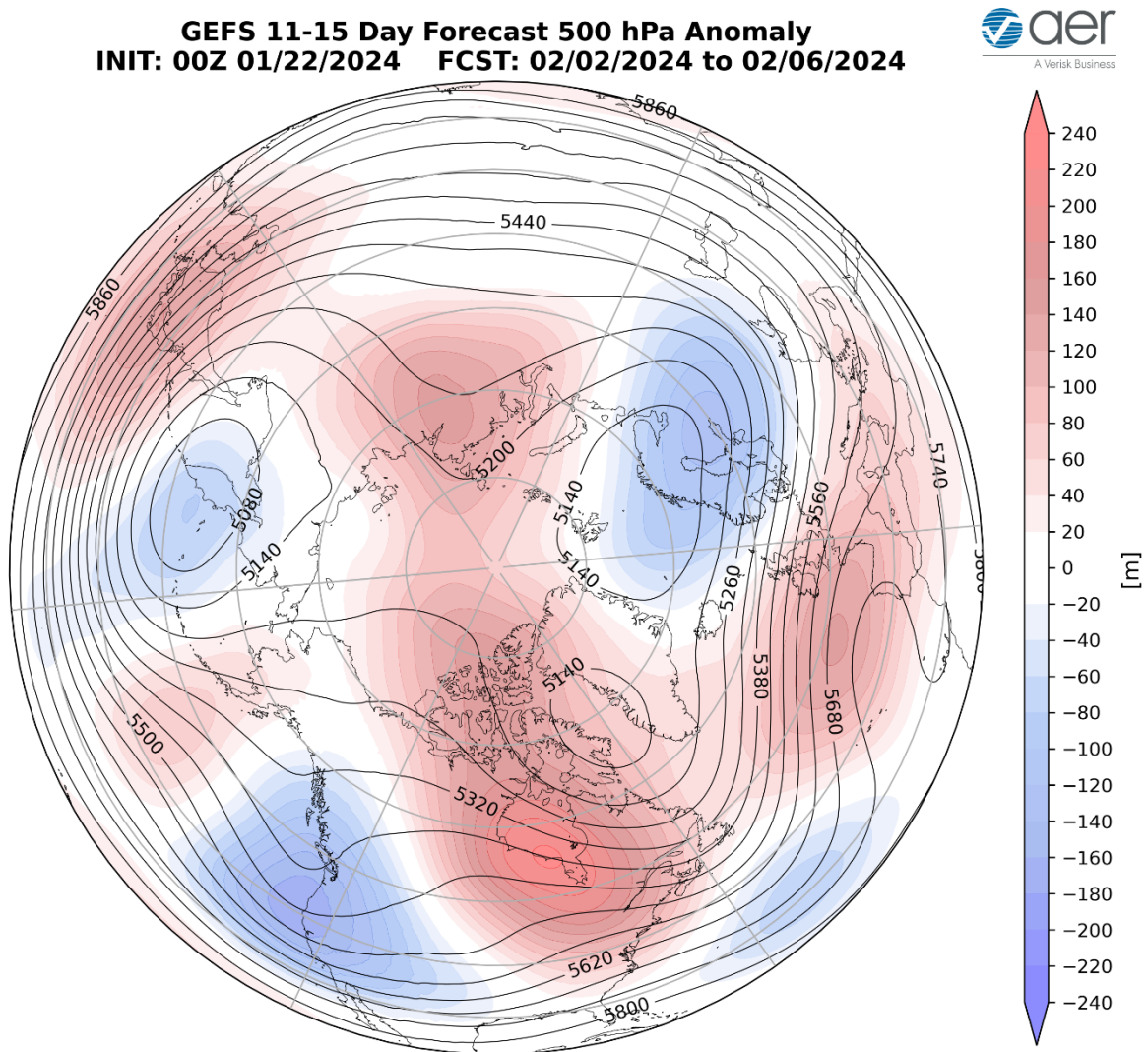


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 2 – 6 February 2024. The forecasts are from the 00z 22 January 2024 GFS ensemble.

Predicted persistent troughing/negative geopotential height anomalies across Greenland should continue to support mostly ridging/positive geopotential height anomalies across Europe with the exception of troughing/negative geopotential height anomalies across Scandinavia this period (**Figure 8**). This pattern should favor normal to above normal temperatures widespread across most of Europe including the UK with the exception of normal to below normal temperatures across Scandinavia this period (**Figures 9**). The omega block pattern across Asia is predicted to persist with troughing/negative geopotential height anomalies across Northeastern and Northwestern bookending ridging/positive geopotential height anomalies centered in Western Siberia yet again this period (**Figure 8**). The predicted pattern favors widespread normal to above normal temperatures across Asia with normal to below normal temperatures limited to Southern Siberia this period (**Figure 9**).

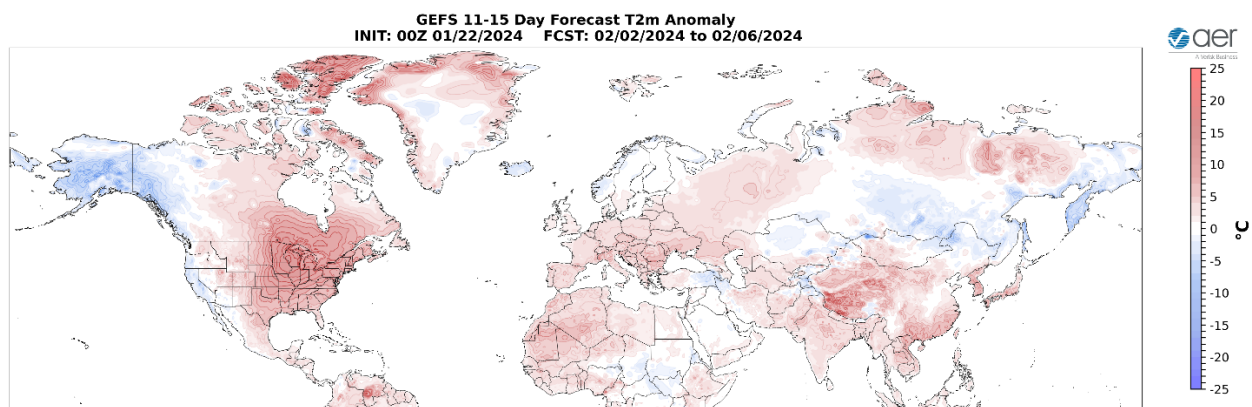


Figure 9. Forecasted surface temperature anomalies (°C; shading) from 2 – 6 February 2024. The forecasts are from the 00z 22 January 2024 GFS ensemble.

Troughing/negative geopotential height anomalies in the Gulf of Alaska and now expanding into the west coast of North America will continue to support ridging/positive geopotential height anomalies in eastern North America this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures Canada and the US east of the Rockies with normal to below normal temperatures across Alaska and the West Coasts of Canada and the US this period (**Figure 9**).

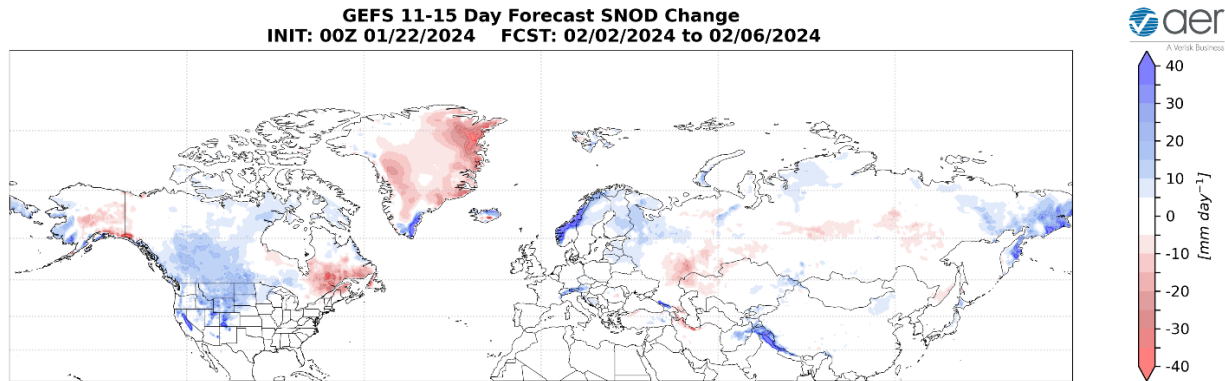


Figure 10. Forecasted snow depth changes (mm/day; shading) from 2 – 6 February 2024. The forecast is from the 00Z 22 January 2024 GFS ensemble.

Trouging and/or cold temperatures will support new snowfall across Scandinavia, the Balkans, the Alps, the Tibetan Plateau and Eastern Siberia while mild temperatures will support snowmelt in Central Siberia this period (**Figure 10**). Trouging and/or cold temperatures will support new snowfall across western Alaska, Western Canada and the Western US. Mild temperatures will support snowmelt in Southeastern Canada and New England this period (**Figure 10**).

Longer Term

30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows warm/positive PCHs throughout the stratosphere and cold/negative PCHs in the troposphere (**Figure 11**). Warm/positive in the mid-stratosphere will end this week and instead become increasingly cold/negative as the PV strengthens (**Figure 11**). At the same time tropospheric PCHs are predicted to reverse to warm/positive in early February.

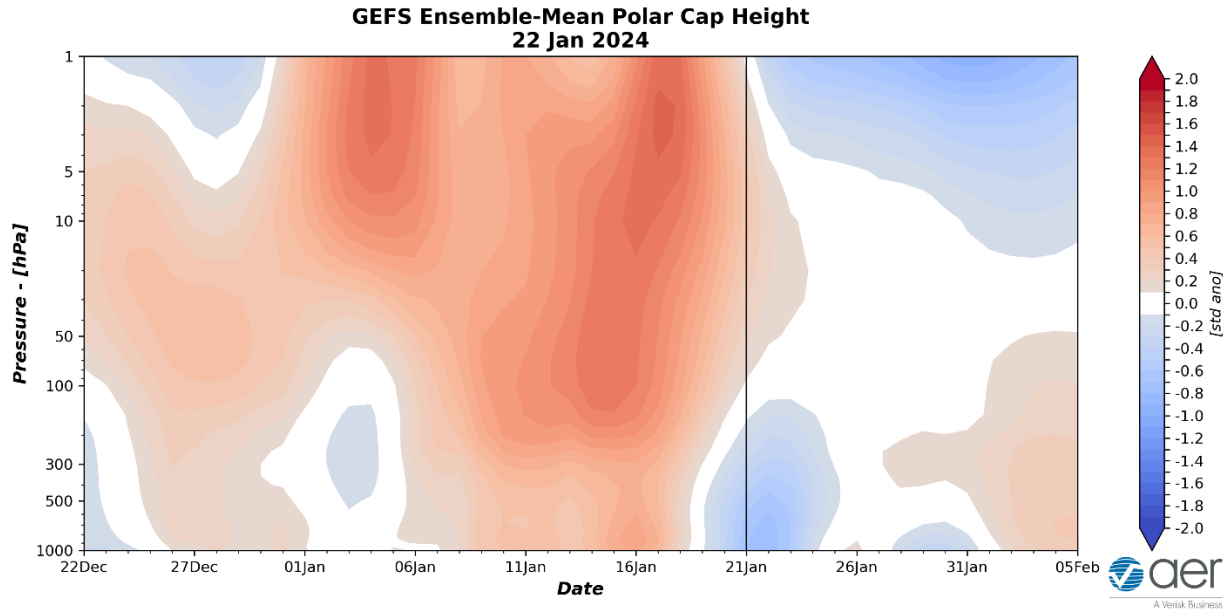


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 22 January 2024 GFS ensemble.

The predicted cold/negative PCHs in the lower troposphere this week (**Figure 11**) are consistent with the predicted positive surface AO this week (**Figure 1**). Then next week the predicted warm/positive PCHs in the lower troposphere (**Figure 11**) are consistent with the predicted surface AO becoming neutral. If the warm/positive PCHs in the lower troposphere are stronger than predicted then the AO could dip into negative AO territory.

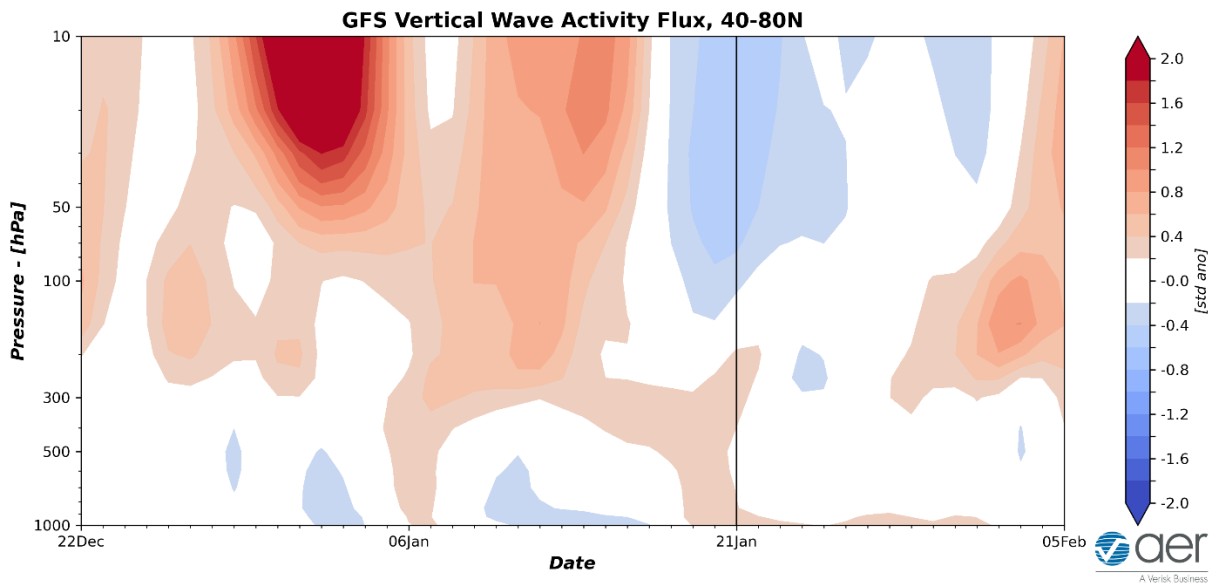


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 22 January 2024 GFS ensemble.

Also shown in **Figure 1** is the stratospheric AO. The stratospheric AO is currently negative but is predicted to trending towards neutral for much of the next two weeks. This is consistent with increasingly cold/negative stratospheric PCHs in the mid-stratosphere. The forecast of cooling PCHs in the stratosphere signals a strengthening PV.

Vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere or poleward heat transport in the stratosphere has been active since mid-November and peaked the first week of January I snow much less active (**Figure 12**). The predicted quieter WAFz activity next week (**Figure 12**), should result in a strengthening PV, at least temporarily. Another pulse of WAFz predicted in early February and could signal at least another minor PV disruption.

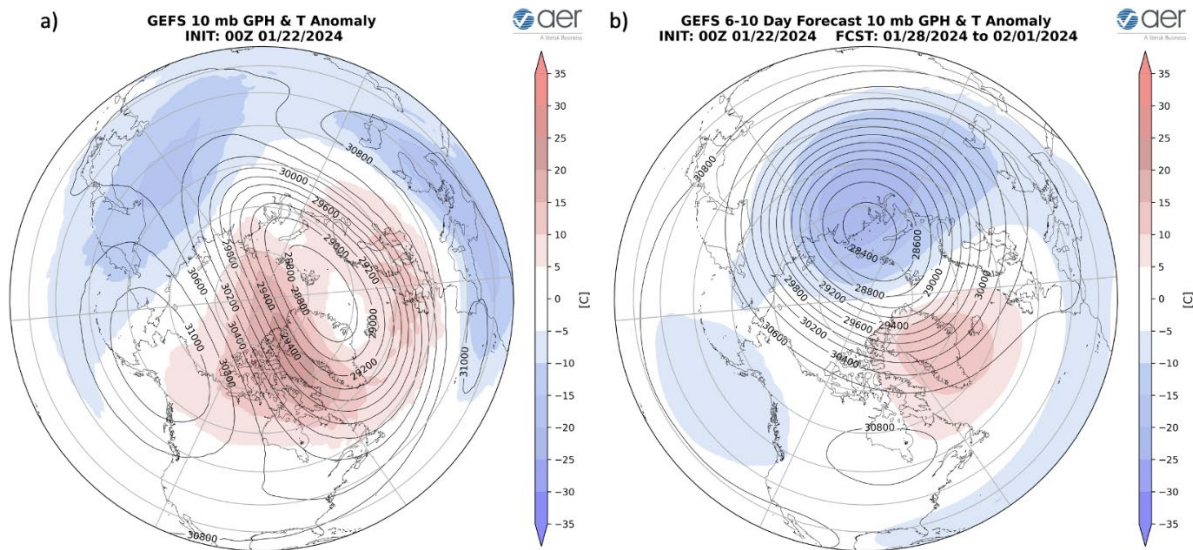


Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 22 January 2024 . (b) Same as (a) except forecasted averaged from 28 January – 1 February 2024. The forecasts are from the 00Z 22 January 2024 GFS model ensemble.

This week the polar vortex (PV) is elongated in shape with the PV center shifted south of the North Pole centered over Svalbard (**Figure 13a**). This elongated PV configuration is oriented along an axis from Western Siberia to Eastern Canada. Ridging in the polar stratosphere is centered over the Dateline with the strongest warming aimed at Baffin Bay. This PV configuration is consistent with a stretched PV that favors colder temperatures across Siberia and eastern North America. This configuration of the PV is predicted to quickly fade with the PV becoming centered over the Laptev Sea and more circular in shape next week, a sign of a strong PV (**Figure**

13b). However, there is also predicted to be ridging centered over Hudson Bay with the greatest warming over Greenland. This is characteristic of a Canadian warming.

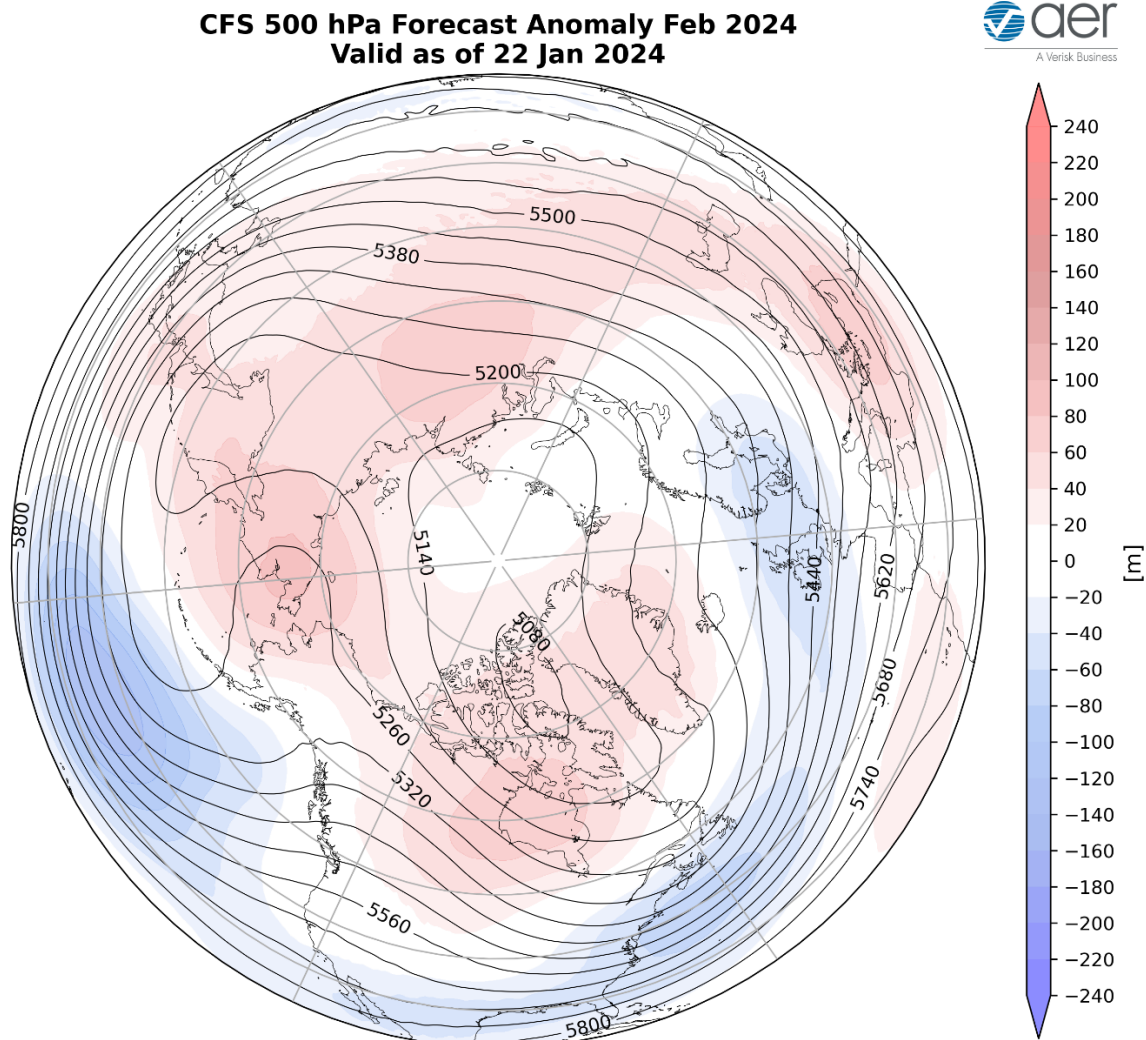


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for February 2024. The forecasts are from the 00Z 22 January 2024 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and surface temperatures for February (**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 Greenland, Western Siberia, Eastern Siberia, Alaska and Hudson Bay with troughing in Northern Europe, Northeast Asia, south of the Aleutians and the Eastern US (**Figure 14**). This pattern favors seasonable to relatively warm temperatures across Southern Europe, Western and Northern Asia, much of Canada and the Western US with seasonable to relatively

cold temperatures across Northern Europe, Siberia, Northeast Asia, Alaska and the Southern and Eastern US (**Figure 15**).

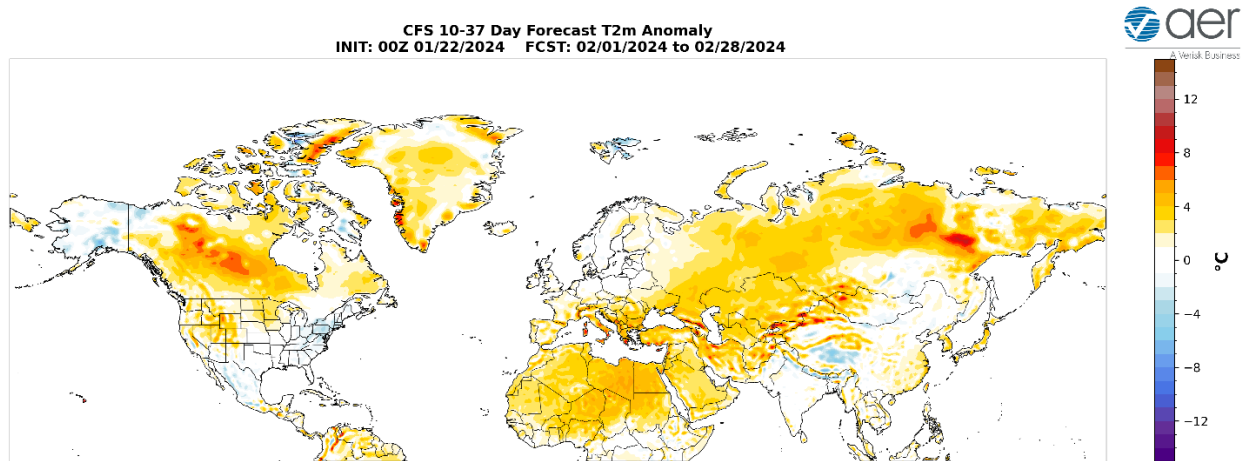


Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for February 2024. The forecasts are from the 00Z 22 January 2024 CFS.

Arctic sea ice extent

Arctic sea ice extent plateaued this week and after actually getting into a range that can be considered normal has pulled back. I continue to expect that the negative sea ice anomalies will become more focused in the North Atlantic sector, which is currently the case. Though sea ice extent is below normal as well as in the Bering Sea. Blocking in the Barents-Kara sea region is critical for weakening the PV that is favorable for widespread and meaningful cold in Northern Eurasia and eastern North America, which can persist for weeks.

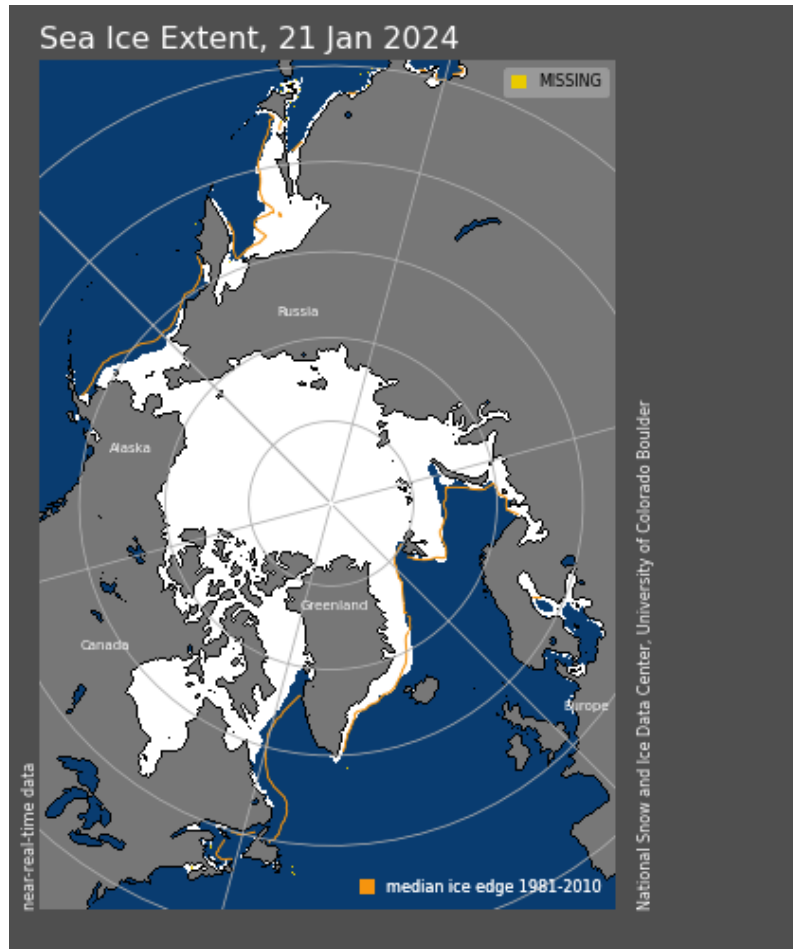


Figure 16. Observed Arctic sea ice extent on 21 January 2024 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are well above normal, especially along the South America coast, indicating that and El Niño remains strong (**Figure 17**) and El Niño conditions are expected through the end of the winter. Observed SSTs across the NH remain well above normal especially in the central North Pacific (west of recent years), the western North Pacific, the eastern North Atlantic and offshore of eastern North America though below normal SSTs exist regionally especially in the South and North Pacific and the North Atlantic.

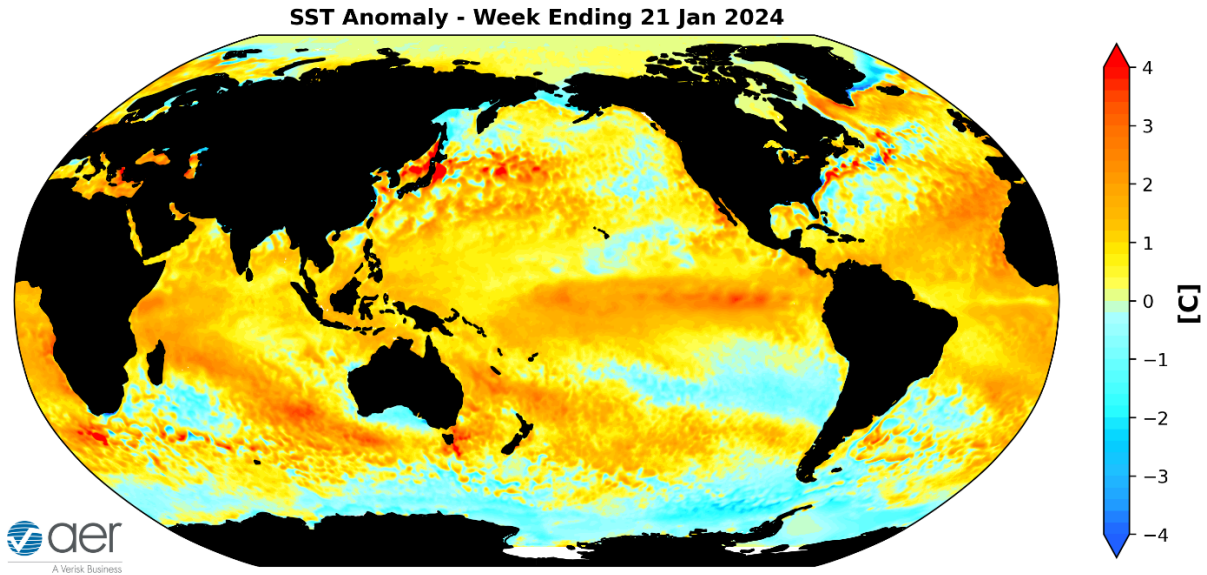


Figure 17. The latest weekly-mean global SST anomalies (ending 21 January 2024). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently the Madden Julian Oscillation (MJO) is in phase five (**Figure 18**). The forecasts are for the MJO to move rapidly into phases five through seven. Phases five through seven favor ridging near the Aleutians forcing troughing in western North America with ridging in the Eastern US. Therefore it seems that the MJO may be influencing the weather across North America weather this week and next week. But admittedly this is outside of my expertise.

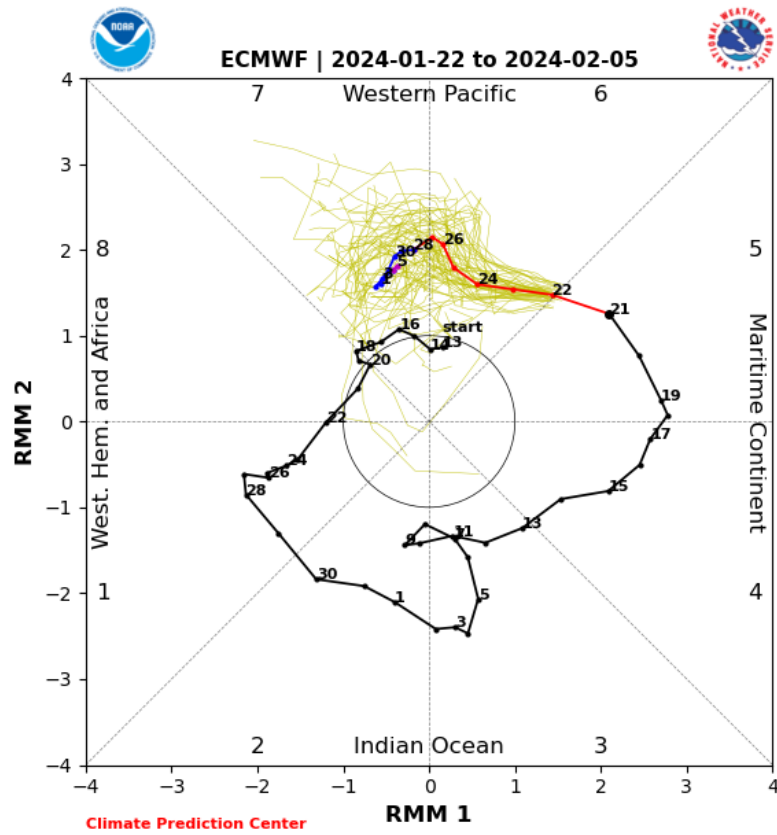


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 22 January 2024 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate the phase of the MJO, with geographical labels indicating where anomalous convection occurs during that phase. Image source:

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar_wh.shtml

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