Arctic Oscillation and Polar Vortex Analysis and Forecasts

January 16, 2023

Dear AO/PV blog readers:

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

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

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

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

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

Summary

- The Arctic Oscillation (AO) is currently negative and is predicted to trend positive over the next two weeks as pressure/geopotential height anomalies across the Arctic are currently mostly positive but are predicted to become increasingly

negative. The North Atlantic Oscillation (NAO) is currently positive and is predicted to straddle neutral the next two weeks as pressure/geopotential height anomalies are currently mostly negative but are predicted to remain mostly mixed across Greenland the next two weeks.

- This week strengthening ridging/positive geopotential height anomalies in Northeastern Canada and the western North Atlantic will force deepening troughing/negative geopotential height anomalies across Western Europe with ridging/positive geopotential height anomalies in Eastern Europe. But as troughing/negative geopotential height anomalies deepen over eastern North America, ridging/positive geopotential height anomalies are predicted to return to much of Europe next week. This pattern will generally favor normal to below normal temperatures across Western and Central Europe including the United Kingdom (UK) with normal to above normal temperatures across Eastern Europe.
- The next two weeks predicted ridging/positive geopotential height anomalies in the Laptev-Barents-Kara Seas and in Western Asia will force troughing/negative geopotential height anomalies across Siberia and Northeast Asia with more ridging/positive geopotential height anomalies in Southeast Asia. This pattern favors normal to above normal temperatures across Western and Southern Asia with normal to below normal temperatures across Central, Northern and Eastern Asia the next two weeks.
- The predicted pattern this week across North America is troughing/negative geopotential height anomalies in western North America with ridging/positive geopotential height anomalies across eastern North America. However next week strengthening ridging/positive geopotential height anomalies in the Gulf of Alaska will force deepening troughing/negative geopotential height anomalies in eastern North America. This pattern favors this week widespread normal to above normal across Alaska, Canada and the Central and Eastern United States (US) with normal to below normal temperatures limited to the Western US. However next week normal to above normal temperatures will continue across Alaska and the Southeastern US while normal to below normal temperatures will spread across much of Canada and the US.
- I discuss what we can expect in the coming weeks with the polar vortex (PV), which is predicted to undergo disruptions the next two weeks. However, my struggles identifying a stretched PV from a larger sudden stratospheric warming (SSW) continue and how they may impact Northern Hemisphere (NH) surface temperatures.

Plain Language Summary

One thing seems to be coming clearer, another stretched polar vortex (PV) that favors a cold pattern east of the Rockies in North America is likely to begin this week, but the cold arrives the last week of January. Really cold air has built up in Siberia which will take aim first at East Asia and then eastern North America. Following the stretched PV,

a larger PV disruption is likely that could bring a return of the cold to North America, Asia and/or Europe following an interlude of milder weather.

Impacts

Happy Cohen's official first day of winter in the era of climate change. At least here in Boston it finally snowed more than an inch. In the blog from the week of 2 January 2023 I said I wanted to see something from a possible US East Coast snow threat for MLK weekend, otherwise I think best to lower expectations for the remainder of the winter in regards to wintry weather. Far from a blockbuster but at least it is something, so I won't put a fork in winter 2022/23 just yet.

Prior to the winter I shared a meme where I am with Greenland blocking but Ural blocking has caught my attention. At least for the Eastern US, I continue to believe that Ural blocking is the critical feature of this winter. But for Ural blocking to most impactful, on the polar vortex (PV) and subsequently on Northern Hemisphere weather, it needs to remain nearly stationary and persist. But all winter it has been a shifty character. Present in November, it slid over to Greenland in early December. It did bring some colder weather and snow to Europe but really did nothing for the Eastern US. And Greenland blocking doesn't have much impact on the PV, it seems to me. It returned to the Urals (just long enough to trigger a stretched PV (that yielded an historic cold air outbreak east of the Rockies in mid-December) but then quickly slid east into Siberia. High pressure/blocking in Siberia is highly supportive of strengthening the PV. The PV strengthened and the polar stratosphere became record cold setting up a very mild pattern across the NH. In late December and early January.

But Ural blocking returned in very late December and into early January and has strengthened in mid-January and could persist until the end of the month. The forecasts are for the weakest PV in two winters and a minor sudden stratospheric warming (SSW; (where the winds fail to reverse at 60°N and 10 hPa but there is warming of the polar stratosphere. At least according to Wikipedia, a warming of 25°C within a week) is predicted by all the weather models and a major SSW (where the zonal-mean zonal wind winds at 60°N and 10 hPa) is possible.

But first I still think that the Ural blocking is initiating a fairly classic stretched PV/reflection event that will transpire over the next two weeks). I show in **Figure i** the predicted WAF in the vertical and latitudinal directions. You can easily make out WAF that is upward and eastward over Asia and the North Pacific and then eastward and downward over North America. In my most recent paper, Cohen et al. 2022 Figure 10) I provided a revised schematic shown below in **Figure ii** to illustrate the six step model for stretched PV/reflective events.

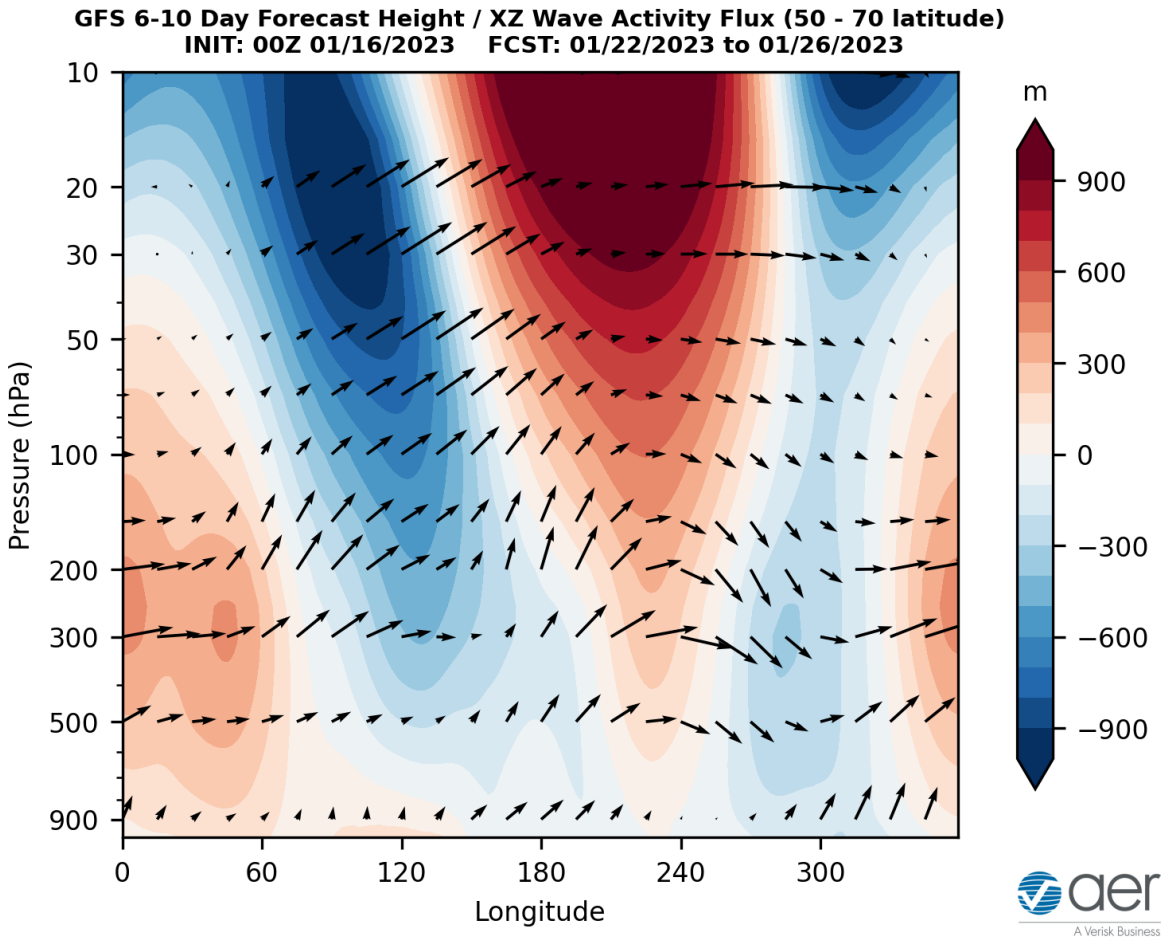

Figure i. Longitude-height cross section of geopotential eddy height anomalies (shading) and wave activity flux (vectors) forecasted for 22-26 January 2023. The forecasts are from the initialized 0z 16 January 2023 GFS ensemble.

Siberia has been impressively cold with temperatures reaching lower than -62°C/-80°F. I stick with my idea cold that starts in Siberia can spread to lower latitudes. We are already observing cold temperatures coupled with snow spread south across China. Snow cover extent is currently well above normal across China (see **Figure 19**). I saw on Twitter temperatures between -40 and -50°C observed/predicted in China. Cold and snow that starts in China often is a precursor to cold and snow across North America east of the Rockies with stretched PV events (a recent nice example of this was February 2021). Based on the weather models, the cold temperature anomalies and positive anomalous snow cover extent anomalies are most impressive in Asia currently, but that should transfer to North America east of the Rockies by the end of January.

I see that the weather models are predicting the trough that tries to get established in the Eastern US quickly starts shifting west as a Southeastern US strengthens. Still, I do think that it can be colder in the Eastern US than predicted by the models.

Identifying and anticipating the impacts from a stretched PV is the relatively easier part. However, in addition to the stretched PV we do have a predicted SSW, the impacts of which are still unknown. Conflating the stretched PV with the SSW and separating out the impacts on our weather has admittedly given me fits. But as I already did I think best to separate out the stretched PV, anticipate fairly textbook impacts and then deal later with the SSW.

But given that the models are fairly certain about an SSW, I think that it is time to break out my schematic of the six-step process of how snow cover extent in Siberia can force an SSW followed by a period of high latitude blocking, a negative AO (though not necessarily) and a period of severe winter weather (potentially weeks in duration) in three preferred regions but rarely simultaneously – East Asia, Europe and the US (typically east of the Rockies) shown in **Figure ii** and is taken from Cohen et al. 2007. I think the SSW (minor or major that we are likely to observe) is in part forced by both above normal Siberian snow depth this winter coupled with low sea ice in the Barents-Kara Seas observed in the fall and winter so far, has been favorable for initiating and maintaining step two - the northwestward expansion of the Siberian high into the Urals/Scandinavian region that is often referred to as Ural/ Scandinavian blocking. Strong Ural/ Scandinavian blocking is likely to dominate the month of January after wondering around the Arctic in December.

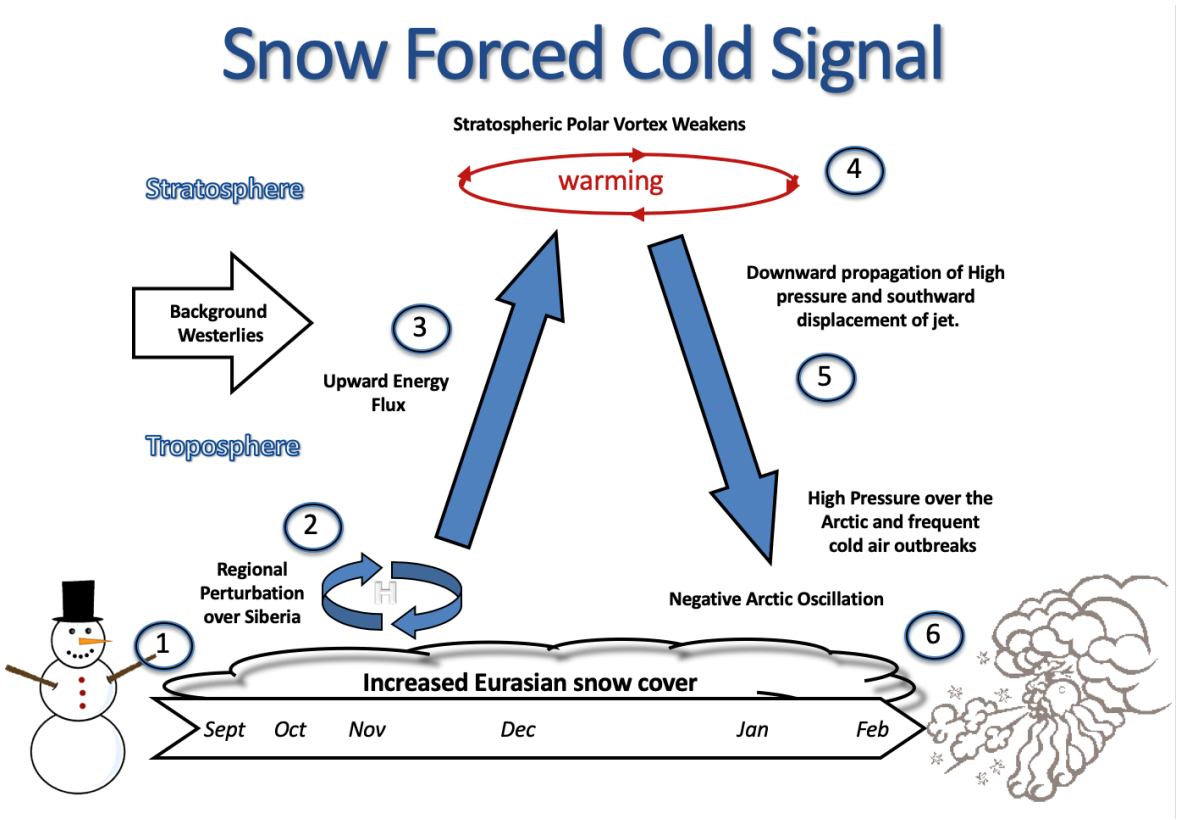

Figure ii. Conceptual model for how fall snow cover modifies winter circulation in both the stratosphere and the troposphere; case for extensive snow cover illustrated: 1. Snow cover increases rapidly in the fall across Siberia, when snow cover is above normal diabatic cooling helps 2. to strengthen the Siberian high and leads to below normal temperatures. 3. Snow forced diabatic cooling in proximity to high topography of Asia increases upward flux of energy in the troposphere, which is absorbed in the stratosphere.4. Strong convergence of wave activity flux (WAF) indicates higher geopotential heights, a weakened polarvortex and warmer temperatures in the stratosphere. 5.Anomalous geopotential heights and winds appear to propagate down from the stratosphere into the troposphere all the way to the surface.6. Dynamic pathway culminates with strong negative phase of the Arctic Oscillation at the surface.

I am attributing at least partially the SSW to Arctic forcings but as an aside not sure how much tropical forcing is contributing to the upcoming SSW. La Niña and a westerly quasi-biennial oscillation are not thought to favor an SSW. Also seems hard to me to make a clear connection between the Madden-Julian Oscillation and the upcoming SSW. But admittedly my expertise is much more on Arctic than tropical forcing.

The third step is the initiation of positive anomalous Wave Activity Flux in the vertical direction (or z coordinate; WAFz). WAFz is the vertical transfer of energy from waves in the atmosphere and is directly proportional to the poleward transport or advection of heat. Only the largest or Rossby waves (wavenumbers 1-2) across the Northern

Hemisphere (NH) produce energy strong enough to escape the troposphere into the stratosphere. When the vertical energy is absorbed in the polar stratosphere it leads to warming of the polar stratosphere or a weakening of the stratospheric PV. If it is of sufficient amplitude, it will result the fourth step of the model or in a sudden stratospheric warming (SSW).

From **Figure 12** below you can see the most active WAFz of the winter is predicted in the next couple of weeks, following the alternating positive and negative WAFz characteristic of stretched PV/reflective events.

When an SSW occurs, the PV vacates its perch near the North Pole and besides being anomalously warm across much of the polar stratosphere, the vacuum created by the absence of the PV center is filled by relatively high pressure. Meanwhile across the mid-latitudes anomalous low pressure occurs and in the most extreme cases the PV center itself will reach into the mid-latitudes accompanied by relatively cold temperatures. For now the weather models are predicting that the PV center will be displaced towards Europe. In addition, the belt of strongest zonal (west to east) winds is shifted south or equatorward. The fifth step is the downward propagation of the circulation anomalies from the stratosphere to the troposphere and ultimately to the surface. The climax or culmination of the whole event is relatively high pressure in the Arctic coupled with anomalous warmth, relative low pressure in the mid-latitudes, especially in the ocean basins and an equatorward shifted Jet Stream. A southward shifted Jet Stream increases the probabilities of both cold air outbreaks and snowstorms across the mid-latitude continents including Europe, East Asia and the US east of the Rockies. It can be in one or two of those regions but rarely all three.

Sometimes I will refer to the six-step model or process in a more abbreviated three step troposphere-stratosphere-troposphere (T-S-T) coupling event with a troposphere precursor (same as step two in **Figure ii** or Ural/ Scandinavian blocking) followed by a stratospheric PV disruption (same as step four or an SSW) and culminating with an extended period of high-latitude blocking/negative AO (same as step six).

What will be the impacts if any from the SSW and will they occur? These may well depend on how far south the PV will be displaced, will it split and will winds reverse at 60°N and 10 hPa are still open questions. However, I do believe, maybe in contrast to many of my colleagues, that a major SSW is not necessary to have a meaningful and long-lasting impact on NH weather. I expect that the upcoming PV disruption to have an impact on NH weather. Regardless of the weather model forecasts, I think a major SSW has a fairly high probability if the Ural/Scandinavian blocking can persist long enough. But there is often a delay between the SSW and impacts on the weather. Often in the interim the AO could flip positive, and the weather turns milder across parts of the NH before cold temperatures and snow expand across parts of the NH. A trough and cold is in parts of Europe currently but ridging is predicted to return next week, which is

also consistent with a stretched PV. So after the cold and snow first in Asia and then North America, an overall milder pattern can spread across the NH.

With SSWs I do believe that there are both immediate impacts and delayed impacts. This is completely speculative on my part, but all the models are consistent in predicting that the PV center will be displaced towards Europe. So, I do think a possible trough and cold could return to Europe possibly coupled with Greenland blocking in early February. Again, there is little to support my assertion but a thought. One thing I am much more certain about – that the weather models currently cannot resolve the pattern that will follow the SSW, it's just too soon.

Wednesday Update

First it seems that the cold in Siberia and China just keep getting more impressive, at least from what I read on Twitter (@Ventuskycom and @yangyubin1998). I have never done an analysis on what is the probability that extreme cold in Siberia/China is a reliable precursor for extreme cold in Europe and/or North America but my experience tells me that the probability is higher than when Siberia is relatively mild.

Interesting times with the PV look to continue. I included the six-step snow model in Monday's blog because I have not shown it since 2020 and I thought possibly many new readers of the blog have not seen it before and seems very relevant for the upcoming period. Still looks to me like a stretched PV followed by an SSW, either minor or major. In **Figure iii** I show the seasonal PCH plot where steps 2, 3 and 4 are clearly visible and the question mark remains steps 5 and 6 and therefore how much impact will the SSW have on the NH weather. I don't think that the weather model or I know the answer just yet.

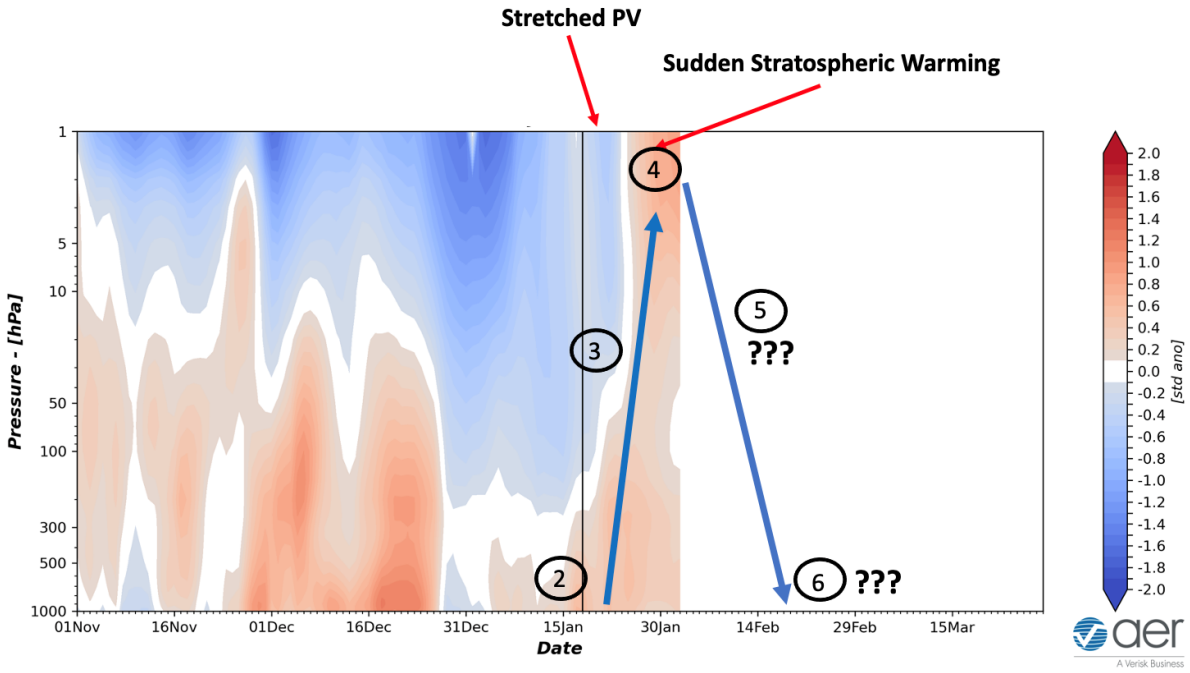

Figure iii. Observed (since 1 November 2022) and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 18 January 2023 GFS ensemble. Arrows indicate upcoming T-S-T coupling event (meant to represent blue arrows in **Figure ii**) and numbers represent the steps from schematic also shown in **Figure ii**.

There seems to be a lot of drama whether it will be a minor or major SSW. I don't think whether it is a minor or major SSW is really that important on the eventual impact on the weather; my impression is that I am in the minority on this or even unique in my opinion compared to my colleagues. Not the time now but I am happy to explain my reasoning. I know that most weather models predict that a major SSW is not the most likely outcome, but I have to ask - what is going to prevent a major SSW? All models predict the PV center will be displaced towards Scandinavia. The displacement coupled with a favorable wave pattern in the troposphere should keep allowing more heat or relatively warm air from lower latitudes to wrap in towards the North Pole more until a major SSW is achieved. This is speculative on my part without a lick of support, but we shall see.

I see the Tonga volcano remains in the news and many have asked me will it favor a stronger NH PV this winter. The truth is that I don't know. Tonga's most remarkable feat was injecting an incredible amount of water vapor into the stratosphere more so than sulfur dioxide. Water vapor is a very effective greenhouse gases and though greenhouse gases warm the troposphere, they cool the stratosphere. So, it makes sense that the Tonga eruption should strengthen the PV and make it more resilient to disruptions. I think this reasoning is solid for the Southern Hemisphere where the PV is

dynamically (relatively) inert or inactive but much less so than the NH PV that is dynamically active. The NH polar stratosphere is cooling in all seasons (presumably due to increasing greenhouse gases) but not in winter when WAF is most active, and I would argue an increase in upward WAF in the era of Arctic amplification is offsetting any radiative forced cooling. So maybe the Tonga eruption has made the PV more resilient to PV disruptions but at the end of the day WAF activity will dominate.

Recent and Very Near Term Conditions

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

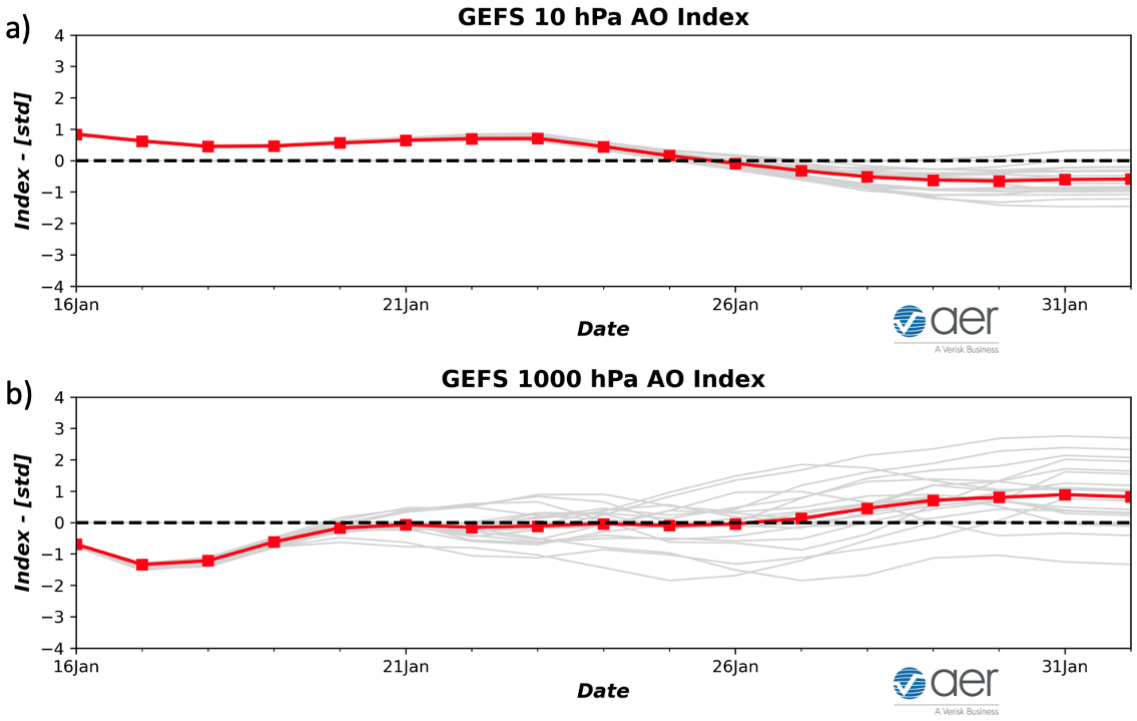

Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 16 January 2023 GFS ensemble. (b)The predicted daily-mean near-surface AO from the 00Z 16 January 2023 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Predicted ridging/positive geopotential height anomalies centered across Northeastern Canada and the western North Atlantic will force troughing/negative geopotential height anomalies across Western and Central Europe with ridging/positive geopotential height

anomalies across Eastern Europe (**Figure 2).** This pattern will favor normal to below normal temperatures across Western and Central Europe including the UK with normal to above normal temperatures across Eastern Europe (**Figure 3**). Ridging/positive geopotential height anomalies centered in the Laptev Sea and the Urals will favor troughing/negative geopotential height anomalies across Siberia, Central and Northeastern Asia with more ridging/positive across Southeastern Asia (**Figure 2**). This pattern favors normal to below normal temperatures across Siberia, Central and Northeastern Asia with normal to above normal temperatures across Western and Southeastern Asia **(Figure 3**).

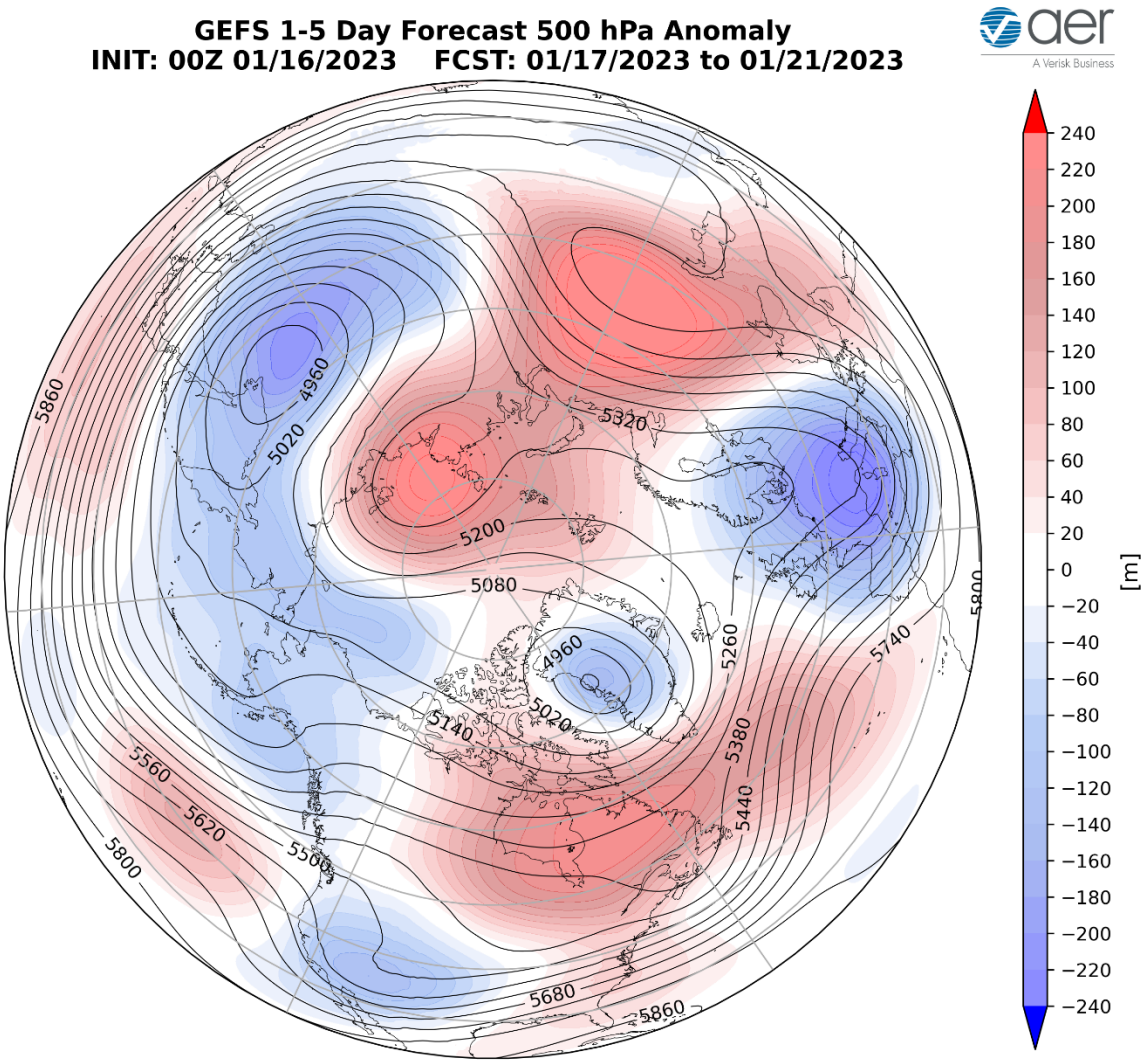

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 17 – 21 January 2023. The forecasts are from the 00z 16 January 2023 GFS ensemble.

The predicted pattern across North America this week is troughing/negative geopotential height anomalies across western North America with ridging/positive geopotential height anomalies across eastern North America **(Figure 2).** The pattern will favor normal to above normal temperatures across much of North America except for normal to below normal temperatures for parts of Alaska, across parts of the West Coast of Canada and the Western US **(Figure 3).**

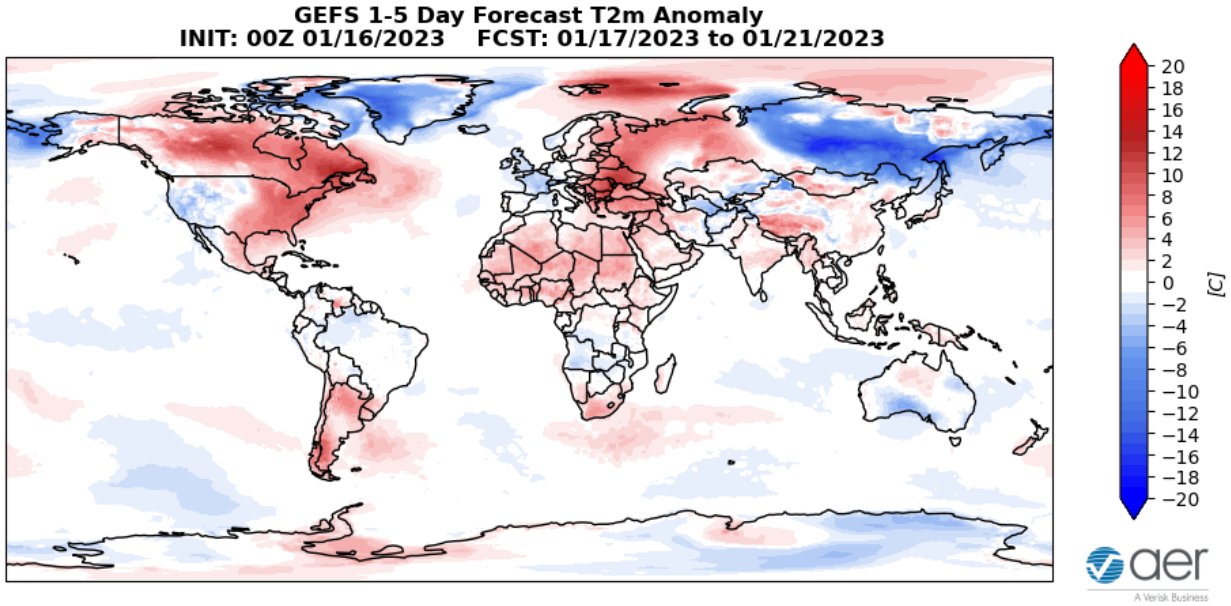

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 17 – 21 January 2023. The forecast is from the 00Z 16 January 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across parts of Scandinavia, the Alps, Northwestern, Central and East Asia while mild temperatures will support snowmelt across the Baltics and Southwestern Asia (**Figure 4**). Troughing and/or cold temperatures will support new snowfall across southern Alaska, Western and Southeastern Canada, Hudson Bay, the Western US and New England while mild temperatures will support snowmelt across the US Plains (**Figure 4**).

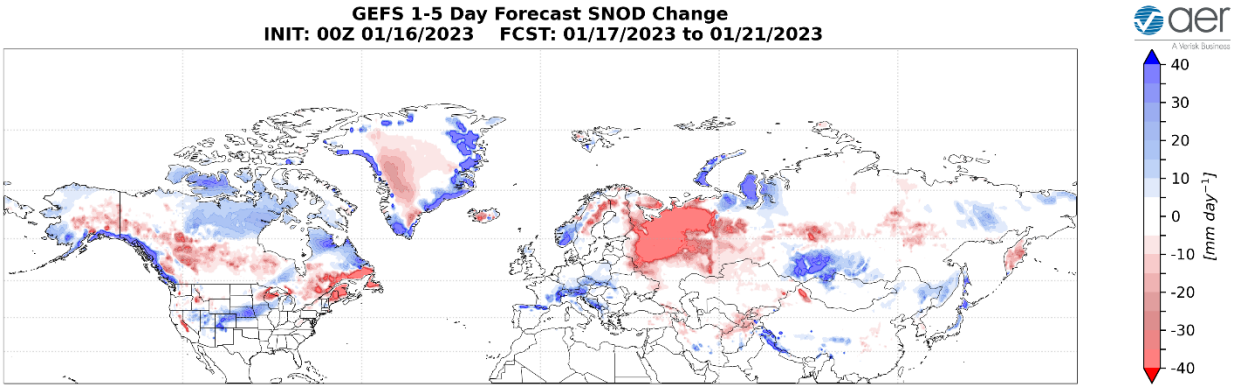

Figure 4. Forecasted snow depth changes (mm/day; shading) from 17 – 21 January 2023. The forecast is from the 00Z 16 January 2023 GFS ensemble.

Near-Term

1-2 week

The AO is predicted to remain close to neutral this period **(Figure 1**) as geopotential height anomalies continue mixed across the Arctic and mixed across the mid-latitudes (**Figure 5**). With mostly troughing albeit weak geopotential height anomalies across Greenland (**Figure 5**), the NAO is predicted to remain weakly positive this period.

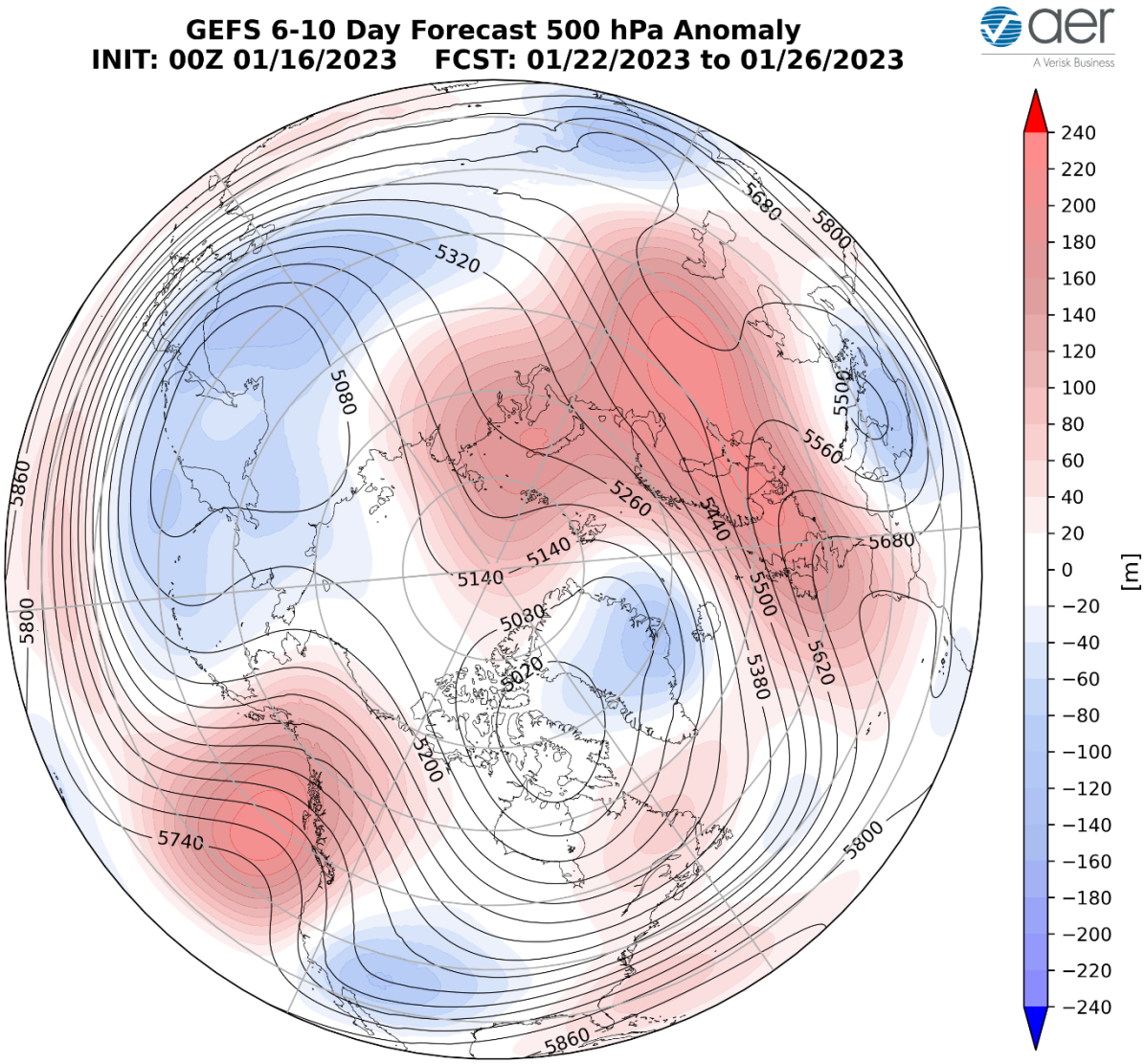

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 22 – 26 January 2023. The forecasts are from the 00z 16 January 2023 GFS ensemble.

Developing troughing/negative geopotential height anomalies across eastern North America and over towards Greenland favor strengthening ridging/positive geopotential height anomalies across much of Europe with the exception of troughing/negative geopotential height anomalies centered in the Adriatic Sea (**Figures 5).** This pattern favors normal to above normal temperatures across Northern and Eastern Europe including the UK with normal to below normal temperatures across Western and Southern Europe (**Figure 6**). Persistent ridging/positive geopotential height anomalies centered in the Laptev Sea and across the Urals are predicted to anchor troughing/negative geopotential height anomalies across Siberia and Northeastern Asia that extends southwestward into Central Asia with more ridging/positive geopotential

height anomalies across Southeastern Asia this period (**Figure 5**). This pattern favors normal to below normal temperatures across much of Siberia, Northeastern and Central Asia with normal to above normal temperatures across Western and Southern Asia **(Figure 6**).

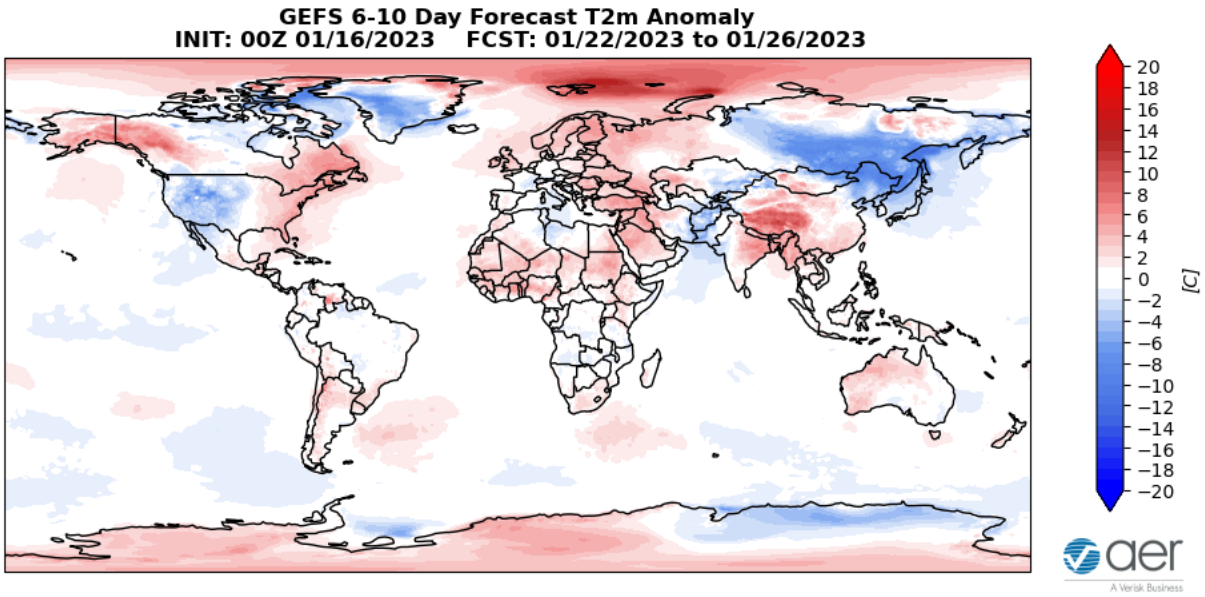

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 22 – 26 January 2023. The forecast is from the 00Z 16 January 2023 GFS ensemble.

Developing ridging/positive geopotential height anomalies centered in the Gulf of Alaska will support deepening troughing/negative geopotential height anomalies centered in the interior of North America with more ridging/positive geopotential height anomalies across the east coast of North America this period **(Figure 5).** This pattern will favor widespread normal to above normal temperatures across eastern North America with normal to below normal temperatures across parts of Alaska, Western Canada and especially the Western US **(Figure 6).**

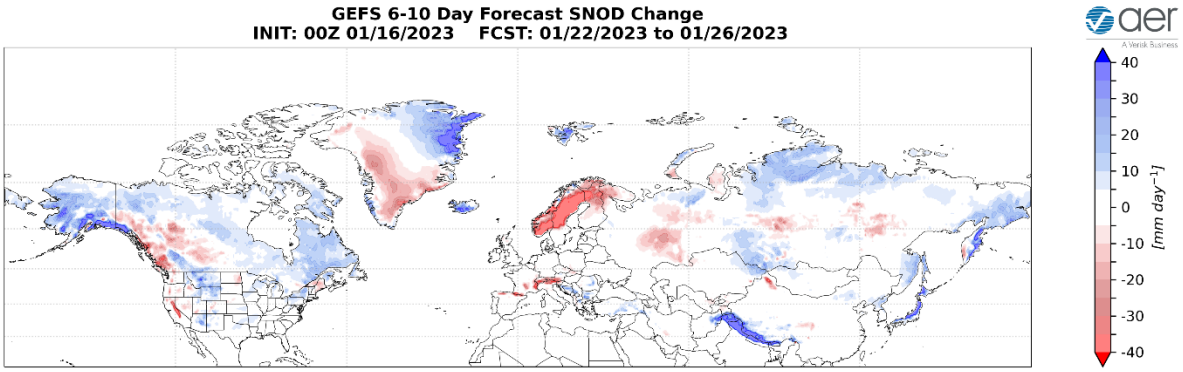

Figure 7. Forecasted snow depth changes (mm/day; shading) from 22 – 26 Janaury 2023. The forecast is from the 00Z 16 January 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Scandinavia, the Alps, Eastern Europe, Northern and Central Asia while mild temperatures will support snowmelt in Northwestern Asia (**Figure 7**). Troughing and/or cold temperatures will support new snowfall across Southern Alaska, Western and Southeastern Canada and the Northwestern and Northeastern US while mild temperatures will support snowmelt in California (**Figure 7**).

3-4 week

With continued mixed to negative geopotential height anomalies across the Arctic and with mixed geopotential height anomalies across the mid-latitudes this period (**Figure 8**), the AO should pop positive this period (**Figure 1**). With weak and mixed pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO will trend to neutral this period.

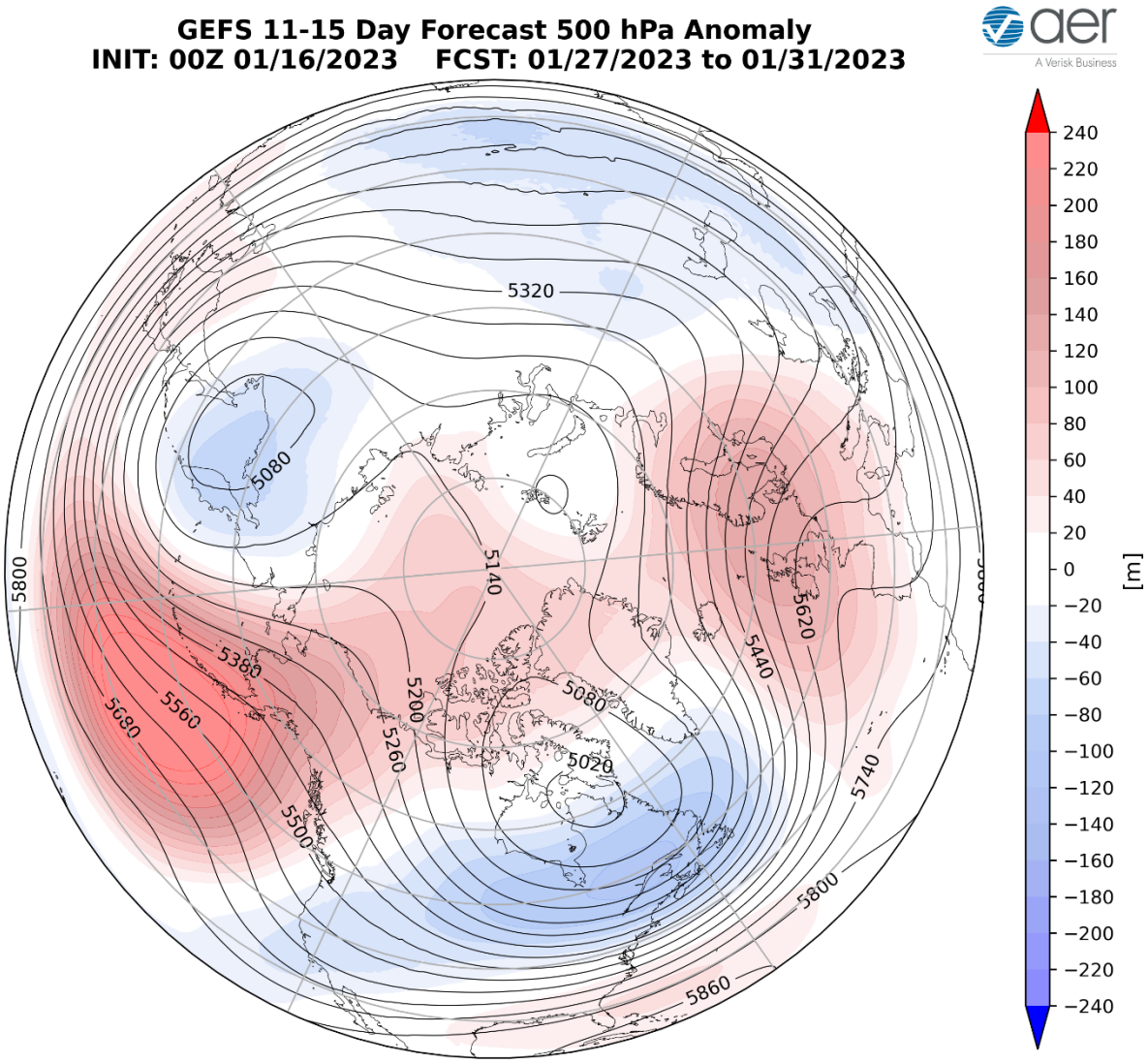

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 27 – 31 January 2023. The forecasts are from the 00z 16 January 2023 GFS ensemble.

Continued deepening of troughing/negative geopotential height anomalies across eastern North America will favor ridging/positive geopotential height anomalies across with Northern Europe with troughing/negative geopotential height anomalies across Southern Europe this period (**Figure 8**). This pattern favors normal to above normal temperatures across Northern and Eastern Europe including the UK with normal to below normal temperatures across Western and Southern Europe (**Figures 9**). Predicted coalescing ridging/positive geopotential height anomalies across Northern Europe will help to anchor troughing/negative geopotential height anomalies across Northern and Central Asia (**Figure 8**). This pattern favors widespread normal to

below normal temperatures across Central, Northern and Eastern Asia with normal to above normal temperatures across Western and Southern Asia (**Figure 9**).

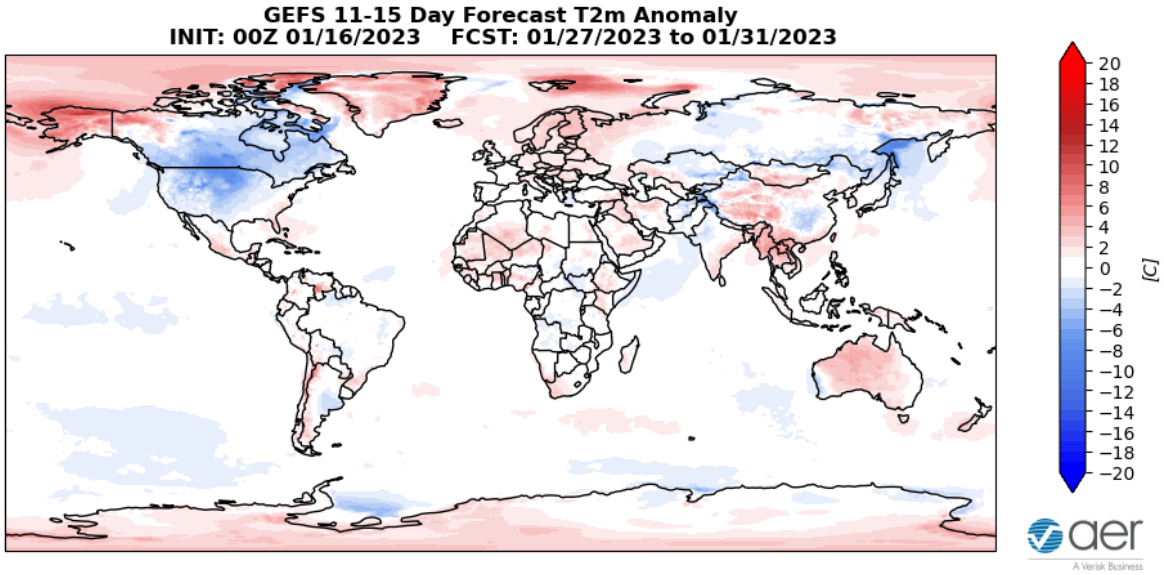

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 27 – 31 January 2023. The forecast is from the 00Z 16 January 2023 GFS ensemble.

Predicted ridging/positive geopotential height anomalies previously in the Gulf of Alaska extending north into the Beaufort Sea will anchor troughing/negative geopotential height anomalies across eastern North America this period (**Figure 8**). This pattern favors widespread normal to below normal temperatures across Canada and the US with normal to above normal temperatures limited to Alaska, Northwestern Canada and the Southeastern US (**Figure 9**).

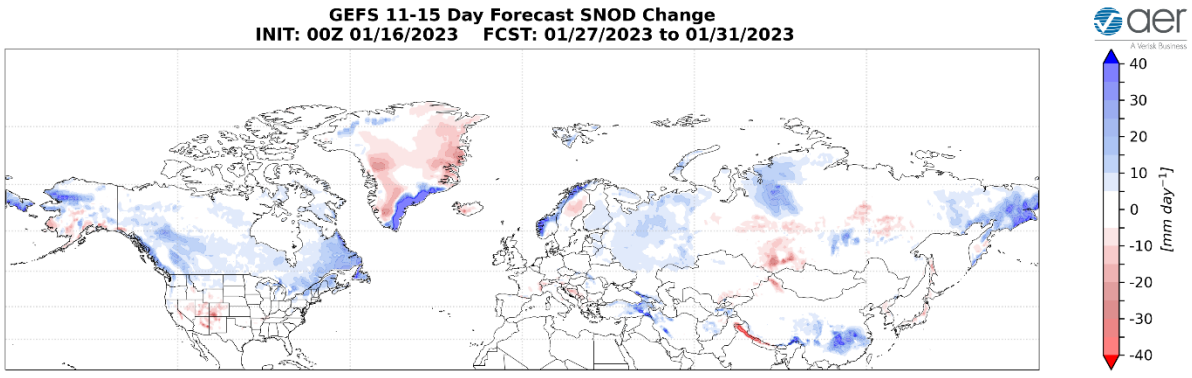

Figure 10. Forecasted snow depth changes (mm/day; shading) from 27 – 31 January 2023. The forecast is from the 00Z 16 January 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Norway, Turkey, Northwestern, Central and Eastern Asia while mild temperatures will support snowmelt in Sweden, the Alps and Central Asia (**Figure 10**). Troughing and/or cold temperatures will support new snowfall across western Alaska, Southern and Eastern Canada and the Central and Northern US while mild temperatures will support snowmelt in Southwestern Canada and the US West Coast (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows cold/negative PCHs throughout the stratosphere with warm/positive PCHs in the low to mid-troposphere (**Figure 11**). However, the cold/negative PCHs in the stratosphere are predicted to weaken and turn warm/positive while warm/positive PCHs in the troposphere are predicted to strengthen and extend into the upper troposphere starting this week into next (**Figure 11**).

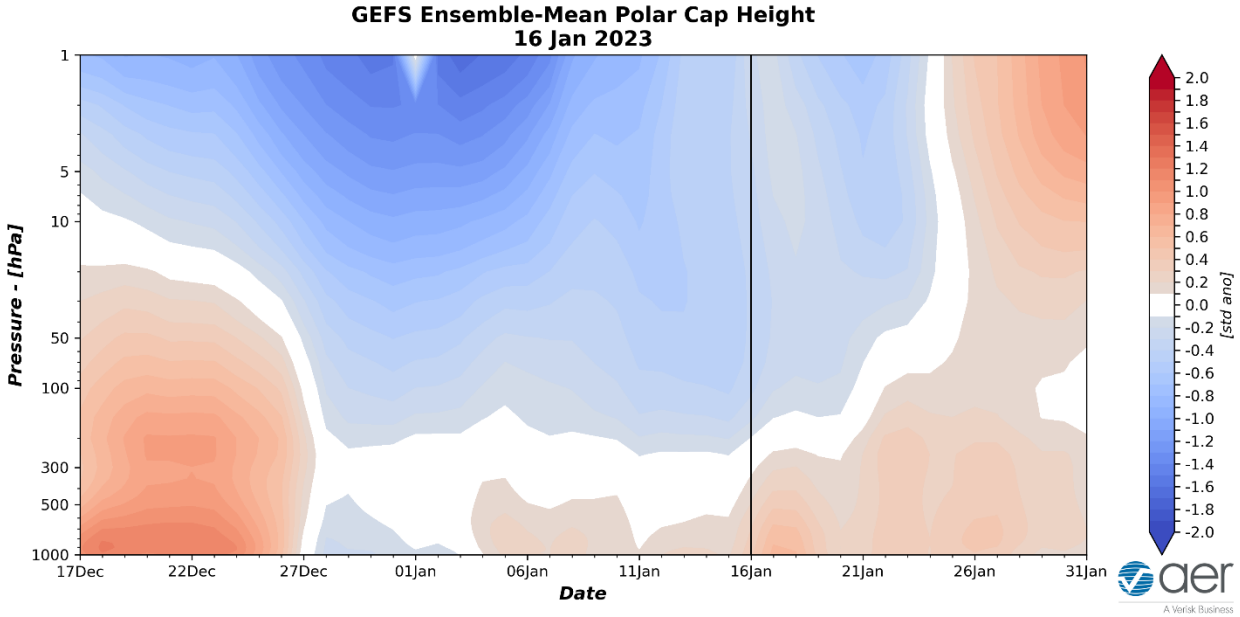

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 16 January 2023 GFS ensemble.

The mostly warm/positive PCHs in the lower troposphere over the next two weeks (**Figure 11**) are consistent with the predicted negative to neutral surface AO (**Figure 1**). However next week when the warm/positive PCHs in the lower troposphere are predicted to weaken (**Figure 11**), the AO could become more positive (**Figure 1**).

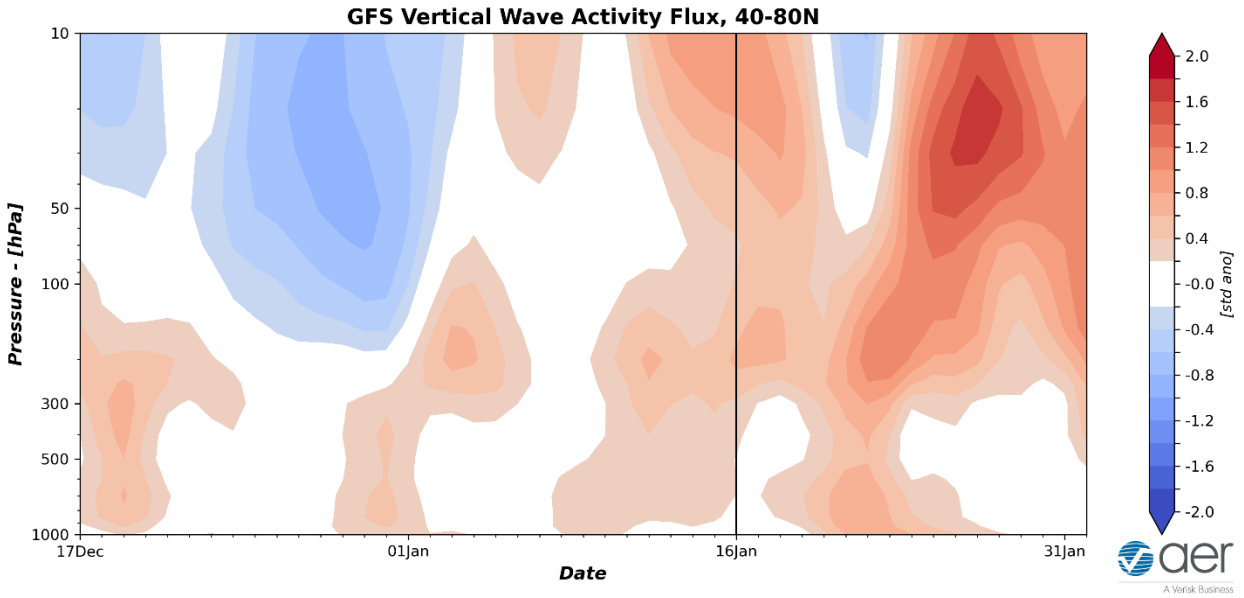

Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 16 January 2023 GFS ensemble.

Vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere or poleward heat transport in the stratosphere became more active the past two weeks (**Figure 12**) which has resulted in warming of the very cold/negative stratospheric PCHs from record and near record cold to just weakly cold (**Figure 11**). The GFS is predicting that the WAFz will become even more active in the next two weeks (**Figure 12**), resulting in continued overall warming of the stratospheric PCHs through late January that should result in at least a minor sudden stratospheric warming (SSW) and could potentially achieve major SSW status (**Figure 11**).

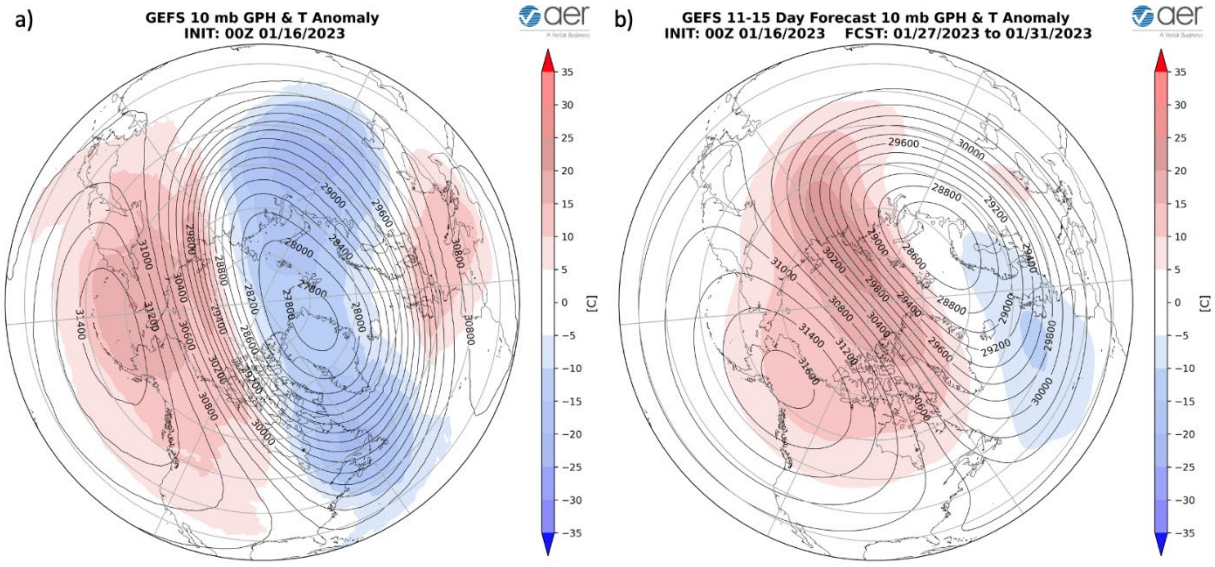

Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 16 January 2023. (b) Same as (a) except forecasted averaged from 27 – 31 January 2023. The forecasts are from the 00Z 9 January 2023 GFS model ensemble.

The more active WAFz has shifted the still strong stratospheric PV center over towards northeastern Greenland and has caused it to stretch or elongate **(Figure 13**). Coupled with the elongated PV is ridging and warming centered near the Dateline in the polar stratosphere (**Figure 13**). The above normal WAFz predicted for the next two weeks will continue to perturb the PV, with the PV shape remaining oblong but shifted into the Barents-Kara Seas with additional warming/ridging exiting from Siberia (**Figure 13**). These are all signs of a stretched PV that favor cold in eastern North America. However, the PV disruption could transition to one more consistent with an SSW. The stratospheric AO is predicted to remain positive over the next week or so before finally dipping negative **(Figure 1**).

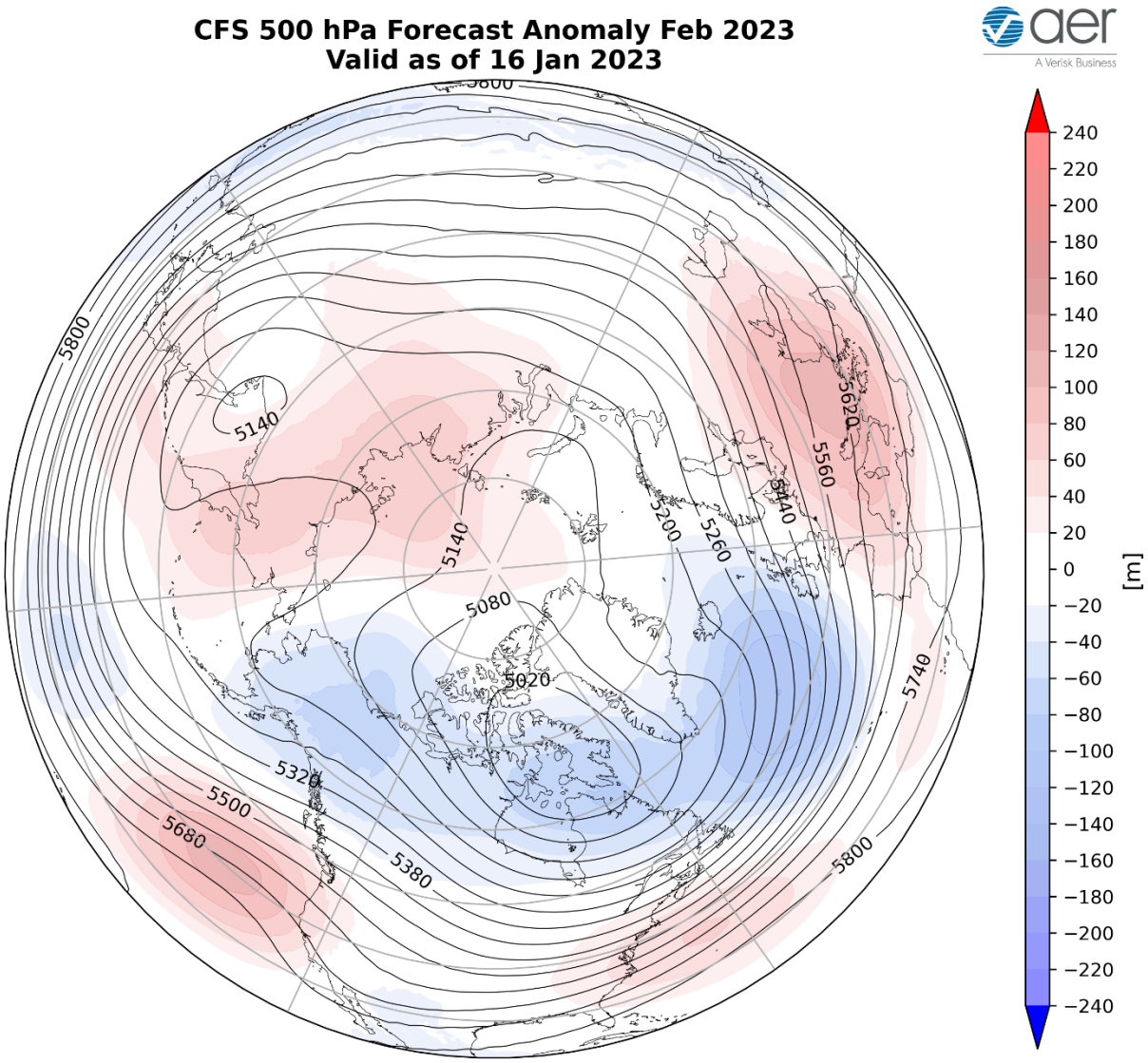

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for February 2023. The forecasts are from the 00Z 16 January 2023 CFS.

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 extending across Europe and stretching across the Barents-Kara Seas, Alaska and the Bering Sea with troughing across Central and Eastern Canada across Greenland and the North Atlantic, Northern and Eastern Asia (**Figure 14).** This pattern favors seasonable to relatively warm temperatures across Europe, Western and Northern Asia, Alaska and the Western US with seasonable to relatively cold temperatures across Central and Eastern Asia, much of Canada and the US (**Figure 15**).

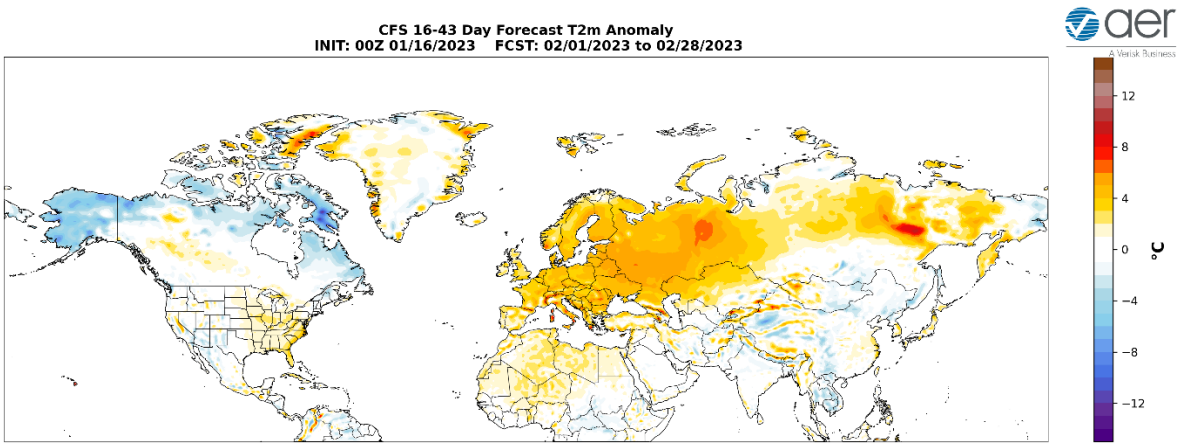

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for February 2023. The forecasts are from the 00Z 16 January 2023 CFS.

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. The greatest concentration of below normal remains in the Barents-Kara Seas, which I believe favors high latitude blocking. So it could be Arctic sea ice is increasingly favoring high latitude blocking in the Barents-Kara Seas region and PV disruptions.

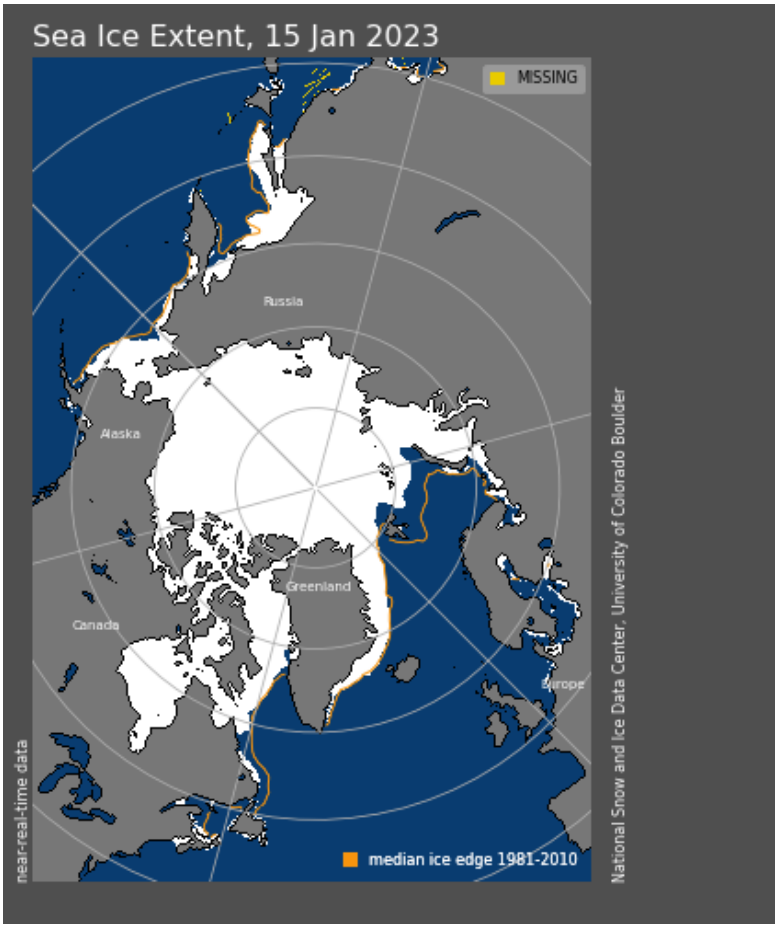

Figure 16. Observed Arctic sea ice extent on 15 January 2023 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC).

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 spring. 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.

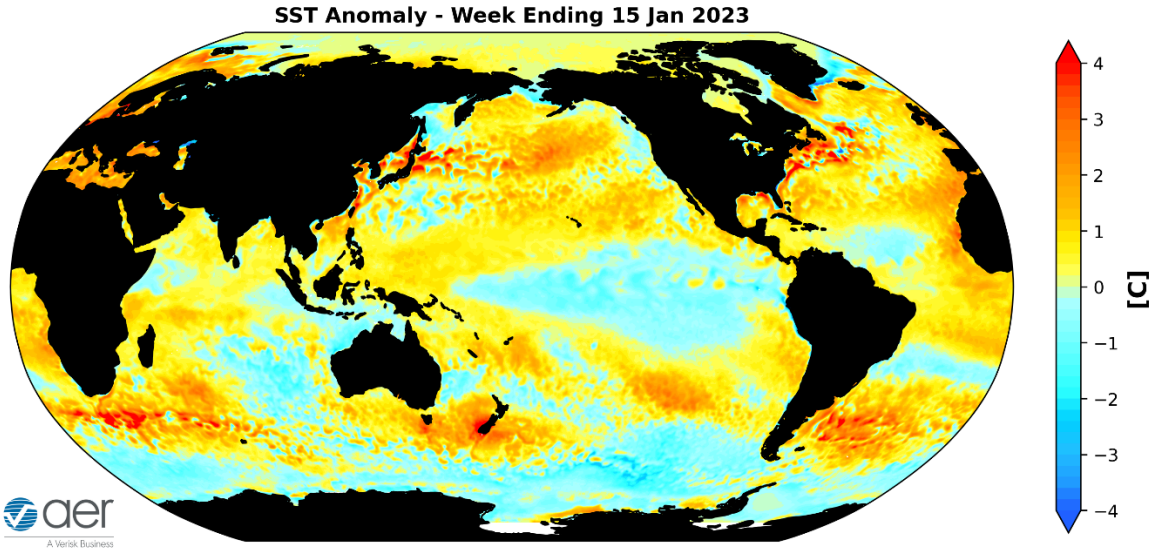

Figure 17. The latest weekly-mean global SST anomalies (ending 15 January 2023). Data from NOAA OI High-Resolution dataset.

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. The MJO is eventually predicted to emerge into phase three. Phase three favors troughing over Alaska, Western Canada and the Western US with ridging across eastern North America. Seems that the MJO is having little influence on the weather across North America in the short term. But admittedly this is outside of my expertise.

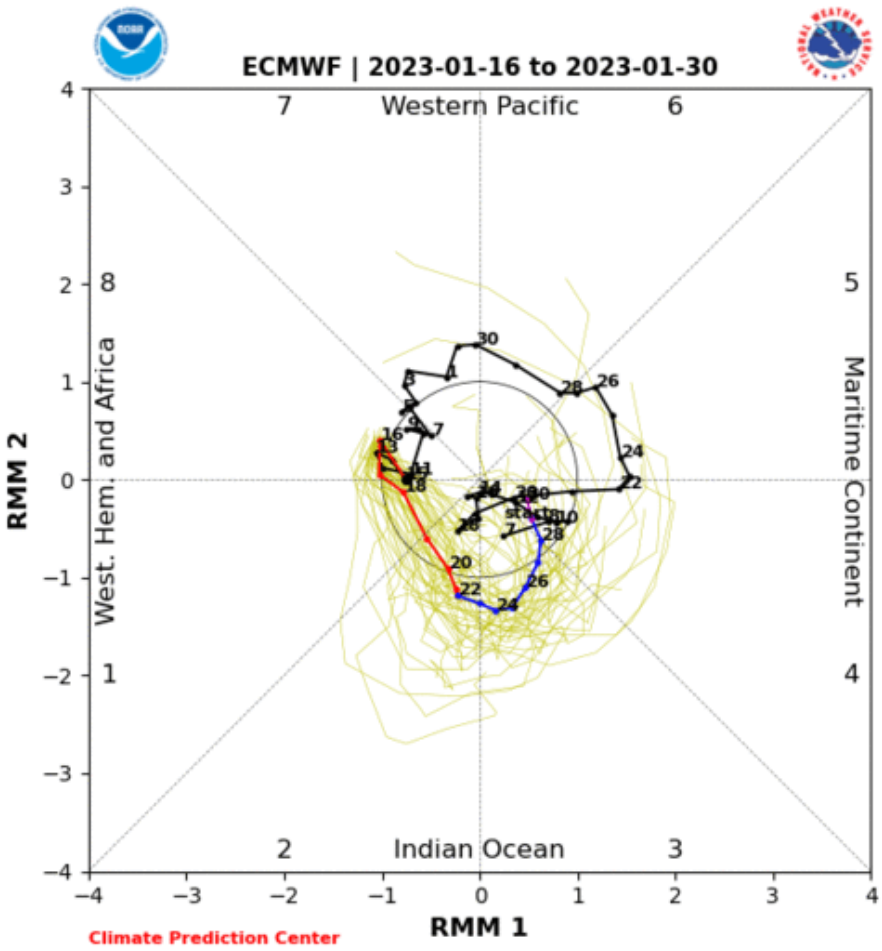

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 16 January 2023 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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) anomalies across the NH has advanced this past week due to cold temperatures mostly in Asia (see **Figure 19**). Snow cover is particularly extensive across China but below normal in Europe and the Eastern US. I expect snow cover to advance in the coming weeks.

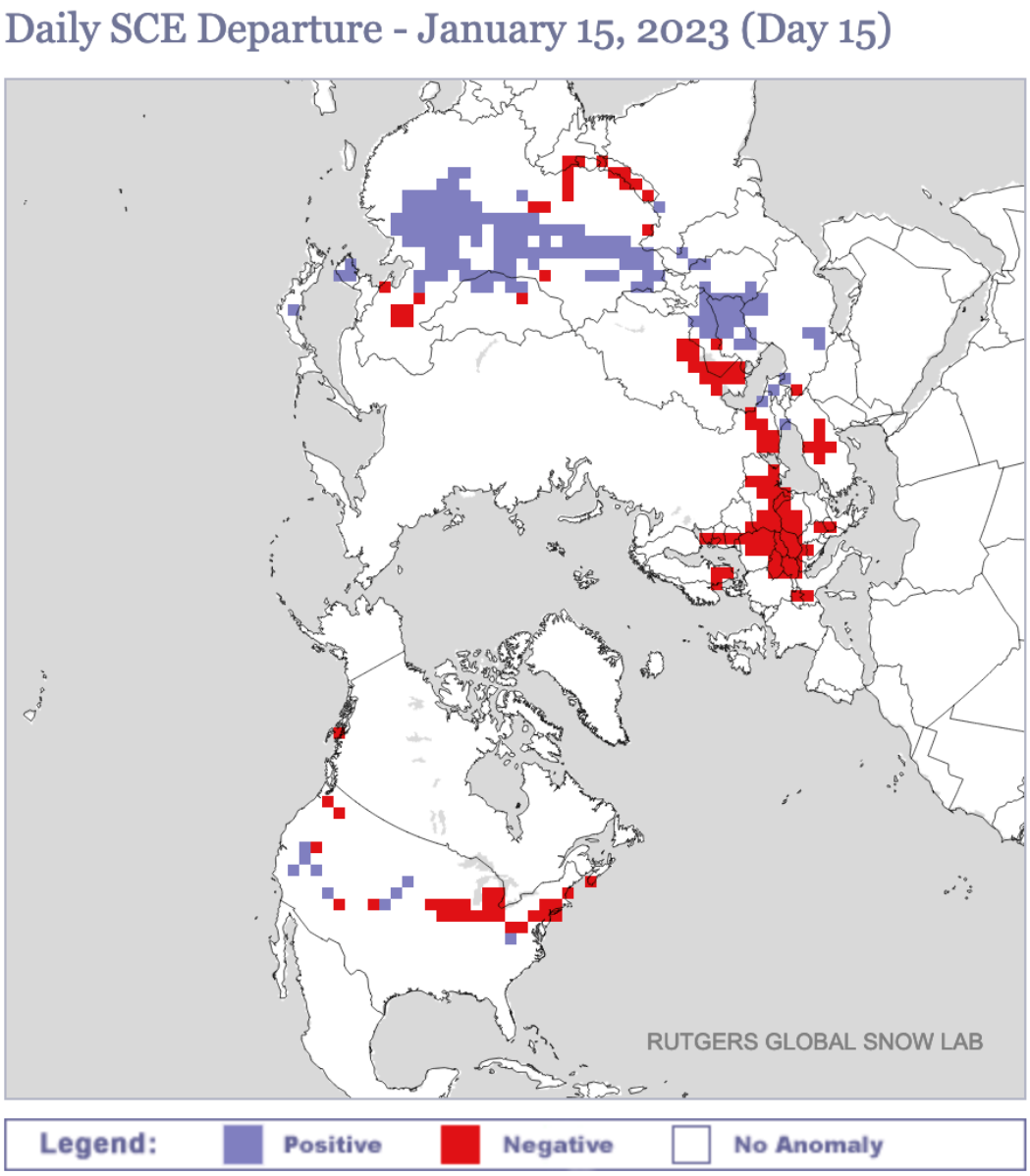

Figure 19. Observed North Hemisphere snow cover anomalies on 15 January 2023. Plot from https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_monitor.html

Get Detailed Seasonal Weather Intelligence with sCast

We appreciate your taking the time to read the public Arctic Oscillation blog from Dr. Judah Cohen and the AER Seasonal Forecasting team.

Dr. Cohen's detailed monthly seasonal forecast, sCast, is also available for purchase. sCast provides a monthly 30-60-90-180-day outlook into temperature and precipitation, solar flux and wind anomalies across the globe, and regional population weighted cooling and heating degree forecasts for the US.

Our sCast principal engineer, Karl Pfeiffer, can help you use sCast and other AER seasonal forecast products to deliver important, long-lead time weather intelligence to your business. Please reach out to Karl today!