Arctic Oscillation and Polar Vortex Analysis and Forecasts

February 6, 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 positive and is predicted to remain positive over the next two weeks as pressure/geopotential height anomalies across the Arctic are currently and are predicted to remain mostly negative. The

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

- The next two weeks predicted troughing/negative geopotential height anomalies across Greenland will favor this week ridging/positive geopotential height anomalies across Northern Europe with troughing/negative geopotential height anomalies across Southern but by next week the ridging/positive geopotential height anomalies will expand across most of Europe. This pattern favors this week normal to above normal temperatures across Northern Europe including the United Kingdom (UK) with normal to below normal temperatures across Southern Europe including Turkey. However next week normal to above normal temperatures will become more widespread across much of Europe with cold temperatures lingering the longest across Turkey.
- The predicted pattern this week across Asia is troughing/negative geopotential height anomalies across Siberia that trails southwestward into Central and Southwest Asia with ridging/positive geopotential height anomalies centered near the Urals and East Asia. However next week ridging/positive geopotential height anomalies will become centered over Siberia and dominate much of Asia. This pattern favors this week normal to above normal temperatures across Northwestern and Eastern Asia with normal to below normal temperatures across Siberia, Central and Southwestern Asia. However next week normal to above normal temperatures will become more widespread across Asia.
- The general pattern predicted across North America the next two weeks is troughing/negative geopotential height anomalies across much of Alaska, Western Canada and the Western United States (US) with ridging/positive geopotential height anomalies across Eastern Canada and the Eastern US. This pattern favors the next two weeks normal to below normal across Alaska, Western Canada and the Western US with normal to above normal temperatures across Eastern Canada and the Eastern US. However, for the second half of February, ridging/positive geopotential height anomalies are predicted to build south of the Aleutians deepening troughing in the interior of North America and more widespread cold.
- I discuss the predicted polar vortex (PV) disruption and its potential impacts on Northern Hemisphere (NH) surface temperatures. Large uncertainties remain however, and I expect forecasts to remain volatile the next two weeks.
- My Twitter account is down. There was one last idea I wanted to share which I did at the very end of the Wednesday Update section

Plain Language Summary

A major disruption of the polar vortex is increasingly likely based on weather model forecasts referred to as sudden stratospheric warmings (SSWs). Often following SSWs,

more severe wintry weather becomes more widespread across the Northern Hemisphere (NH). But as I show in **Figure ii,** there are many possible scenarios.

Impacts

It has been both a winter of not only weather whiplash but also large emotional swings that I think are consistent with ideas that I have advocated but also frustrating with a lack of recognizable winter weather here in Southern New England punctuated by historic but brief cold. And to be honest emotionally I am ready to move on to the warmer half of the year but rationally I still cannot with a possible significant disruption of the polar vortex (PV) possibly peaking next week. I do think that there remains a wide range of possible outcomes from a minor sudden stratospheric warming (SSW) with limited impacts on the Northern Hemisphere (NH) weather to a major SSW, either a displaced or split PV, with large and widespread impacts on the NH winter.

The purpose of the blog is not to respond to criticism on Twitter, but I did receive two criticisms on Twitter yesterday that I do want to address. I put a lot of effort into the blog where I try to present a well thought out and reasoned expectation of how I see the atmospheric circulation and weather unfolding in the coming weeks and maybe even to months (I always present our winter and summer forecasts) and to present the different possibilities and not just one possible outcome. Twitter is much more limiting but very rapid dissemination. I use Twitter to share what is top of mind and may be very fleeting. And at times I will tweet something provocative, but I try to signal the context of what is being shared.

First one person criticized me for not predicting the extreme cold in the Northeastern US this weekend. I raised the possibility of extreme cold in Eastern Canada/the Eastern US for the period of late January and early February in two consecutive blogs dated 16 January 2023 and 23 January 2023. That is one to two weeks before it started showing up (I believe the ECMWF model first) among the dynamical models. Two notable records were the coldest temperature in Boston since 1957 and lowest wind chill ever. Also, a record cold for the month of February in New Hampshire and the lowest wind chill ever recorded in the US on Mount Washington (see Washingtonpost northeast record cold). I include some notable wind chill records because I do think that we are seeing more dynamic or advective cold and less radiative cold with climate change. This would manifest as more impressive wind chills than absolute temperature records. And I believe that we have traded warm advection snow for dynamic snow for similar reasons. But that is based on my experience and not on any of my own analysis and needs to be left for another time. Also feel free to place that idea in the highly speculative bin.

Then I was criticized for posting the GFS 384 hour forecast for a PV split. I saw it yesterday and thought that it was worth a share. I don't think that this is for now the most probable outcome, but the probability is not negligible, and it could be a high

impact event. I didn't claim it would have any impact on our weather and I ended the tweet on a very skeptical note of its outcome (Tweet 5 Feb 2023). This is not analogous to posting a +384 hour forecast of a Northeastern US snowstorm. The stratosphere has many fewer degrees of freedom than the troposphere. All models agree on an SSW minor or major and where this event eventually ends up the models and meteorologists alike don't truly know in my opinion. Even the less impressive SSW of late January produced a split PV of sorts that I tweeted about more than once. If nothing else, it was of curious or academic interest, even if a tangible connection to our weather is difficult at the moment.

The GFS seems to be the most bullish model on a major SSW but from what I can see the ECMWF and Canadian models are awfully close. (After I wrote the blog I see that the EPS weeklies are all in on a major SSW). But as I tweeted on 3 Feb 2023, for now a displacement seems most likely based on the ensembles. However, I did mention in my tweet that a PV split is supported by the ensembles not because I looked at individual ensemble members but because there is this feature of the PV center in all the model forecasts of a log tail extending from Europe to the Eastern US (I drew a rectangle in **Figure 13b** highlighting the tail). It is my experience that this feature will eventually develop into a separate PV center. But admittedly even if a separate PV center develops over the US, the significance is of unknown importance. Another reason why I feel that a PV split is credibly possible because the dominant wave structure in the troposphere seems to me to be wave-2, which tends to favor PV splits.

Of course, whatever PV disruption occurs it is all academic unless it couples with the troposphere and influences the weather at least in parts of the NH. Usually, the impacts are most widespread when downward propagation of either a negative AO and/or warm positive polar cap geopotential height anomalies (PCHs) from the upper stratosphere to the lower stratosphere and then the troposphere and all the way to the surface referred to as the "dripping paint". This should result in relatively high pressure over the Arctic with a suppressed Jet Stream and relatively cold temperatures in Northern Europe, Asia and/or eastern North America but rarely all three. It does look to me that the latest PCHs shown in **Figure 11** is very suggestive of coupling from the stratosphere to the troposphere just beyond the forecast period. But whether that is true or not, the forecast can be very volatile, and it can be predicted one day and gone the next. But I think that there will be some attributable impacts even without obvious downward propagation though then the impacts may be more limited or regional.

I can remember very well robust model forecasts of a major SSW that busted even fairly close to the event so we are still a ways off of being confident about a major SSW, probably at least a week away. But if we have a PV displacement, what weather impacts may we expect? **Figure i** includes the recent displacements at 10hPa that I tweeted on 3 Feb 2023 and I included also 2 January 2002. I also include the GEFS forecast in **Figure 13b**. They all kind of look similar with the possible exception of January 2002.

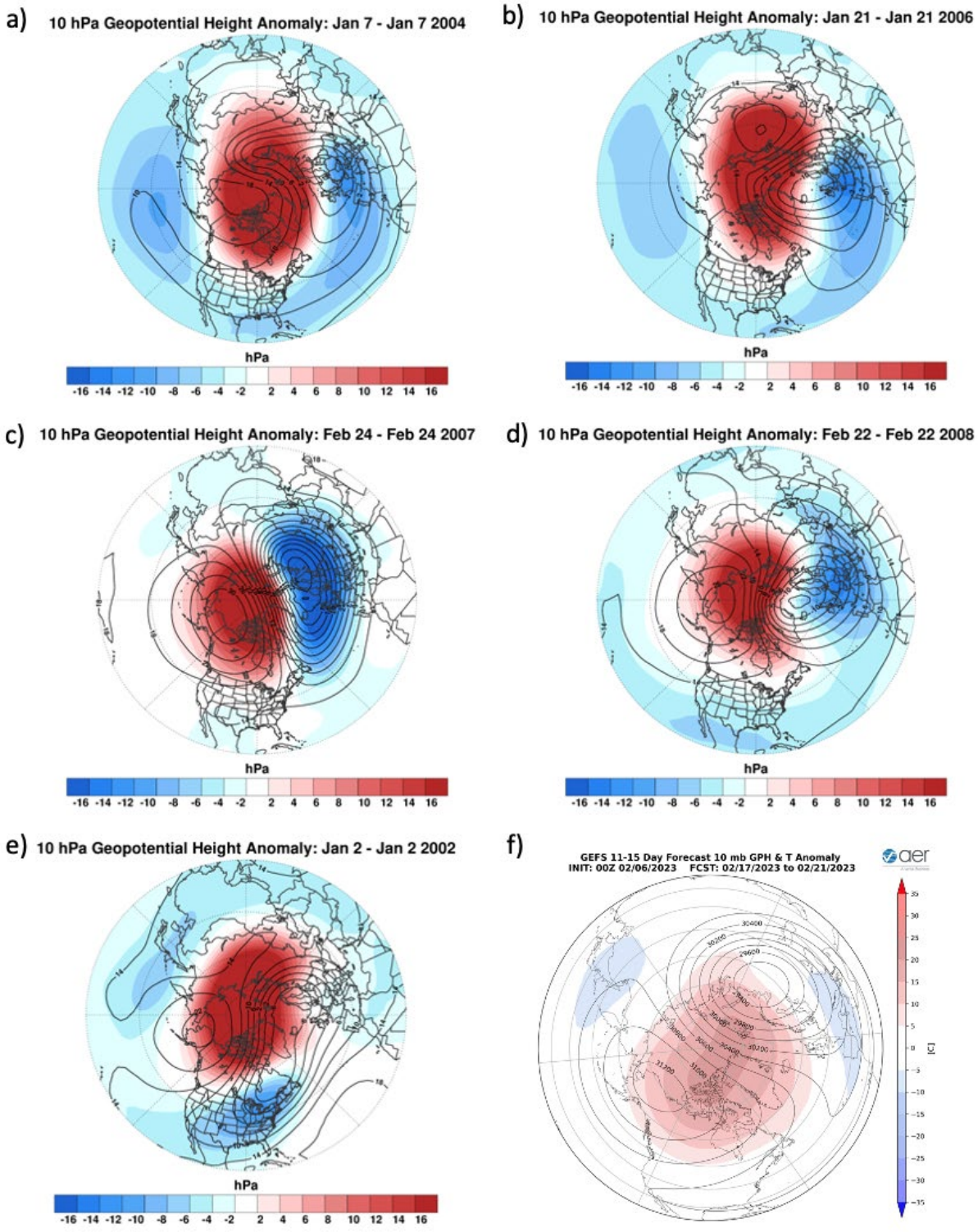

Figure i. Observed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere on (a) 7 January 2004, (b) 21 Janaury 2006, (c) 24 February 2007, (d) 24 February 2008, (e) 2 January 2002 and (f)

forecasted from 17 – 21 February 2023. The forecast is from the 00Z 6 February 2023 GFS ensemble.

Then in **Figure ii** I show the surface temperature anomalies for about six weeks after the central date of the SSW. You can see patterns that can be described as cold North America/warm Eurasia, warm North America/cold Eurasia and warm North America/warm Eurasia. I am sure that you can find an example of cold North America and at least cold Asia. This occurred as recently as January 2021. However, that was really a unique SSW that came in three parts, a displacement followed by a split followed by a stretched PV and lasted a full month! I don't want to sue that event as a paradigm for the current situation. At least from that sample even if a major SSW verifies, to me (and probably you) it still seems to be a crap shoot as to what weather actually follows.

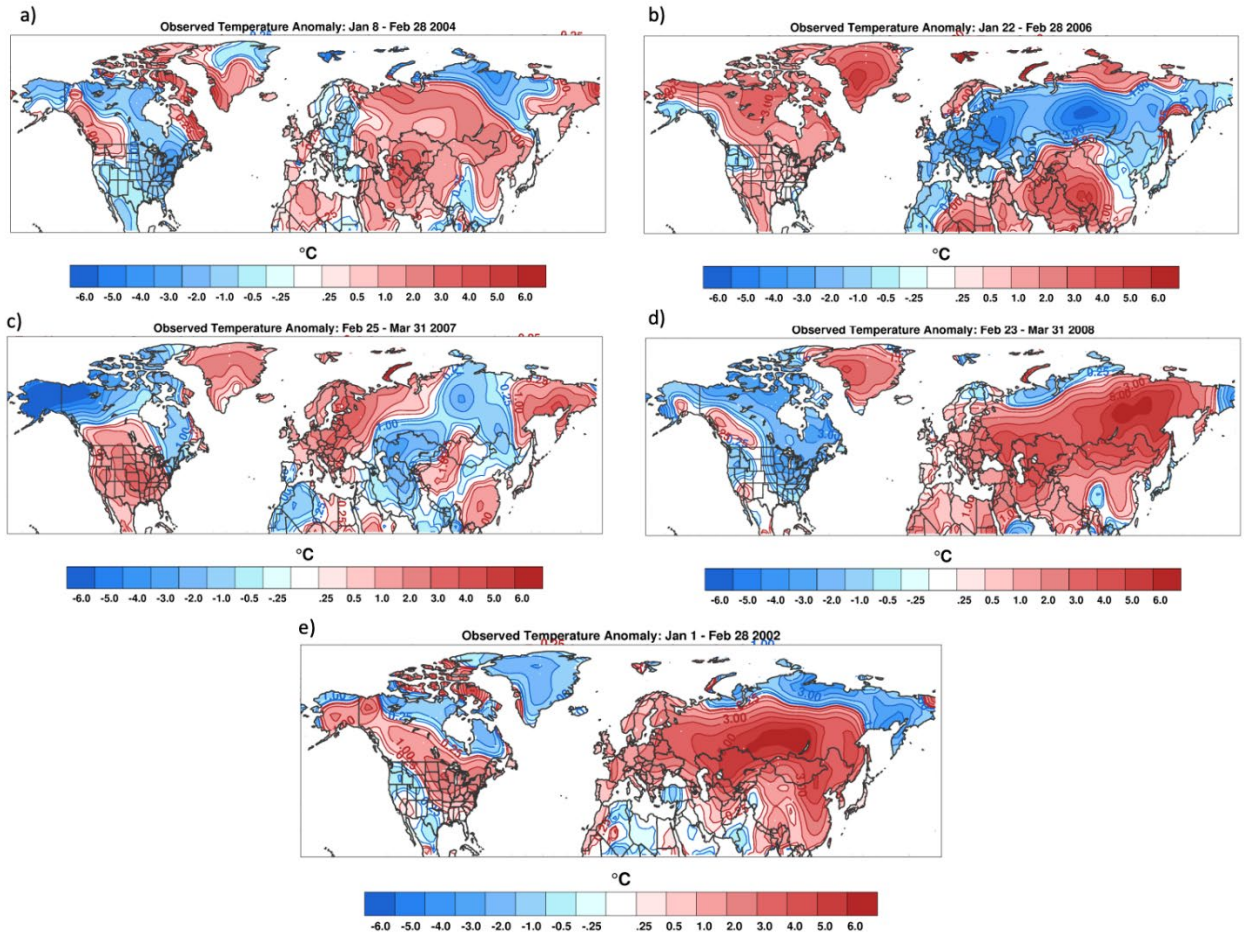

Figure ii. Observed surface temperature trend (°C; shading) for the NH from (a) 8 January – 28 February 2004, (b) 22 January – 28 February 2006, (c) 25 February – 31 March 2007, (d) 23 February – 31 March 2008, (e) 1 January – 28 February 2002 based on NCEP/NCAR reanalysis data

But leading up to the central date of the SSW, the models seem to be pretty strongly suggesting a warm Eurasia/cold North America pattern. Could the SSW simply lock that pattern in? Maybe but if the main PV center is bodily over Eurasia that could setup easterly flow across northern Eurasia and a cold pattern. That started to happen in January 2019 but then quickly flipped over to a cold North America/warm Eurasia pattern (see winter-2019-recap).

Another possibility is a PV split, which I maintain should be seriously considered. If that does happen that sets up a whole different set of analogs. If that scenario becomes more likely, then I will share those analogs as well. But for the impatient, in the meantime you can read my winter-2018-recap.

I think that I have not kept it a secret that this winter has been challenging for me and maybe the cliché "it is a riddle, wrapped in a mystery, inside an enigma" best describes how I find this winter. In winter 2019/20, I told folks winter was over by the second week of January. The PV had gone into beast mode (record strong), there was no high latitude blocking and the AO was on steroids. It seemed like a mutually reinforcing cycle that I saw no exit from. Maybe I am just a hopeless romantic but winter 2022/23 is not that winter. There has been good high latitude blocking. Yes, the PV was record strong in late December but ever since, it has been undergoing repeated disruptions. Also, true there has been impressive winter weather in parts of the NH but here in the Eastern US, remove two days and there has been no resemblance of winter weather. It just feels like something must give. Maybe I am just Charlie Brown expecting Lucy to actually hold the football in place this time just to be fooled yet again and kick nothing but air. Maybe we will get a winter pattern in April and May that deliver nothing more than a cold rain and days on end with no sun (maybe not too different from spring 2016). But there is still time until the end of March for some meaningful winter weather. But no matter what, by March the strength of the sun is a dominant factor, there is no escaping that truth.

I checked and I could not find another recent winter where a minor SSW was so quickly followed by a major SSW (with the big assumption that the GFS and ECMWF will ultimately be correct, but even another minor SSW would be unique). This to me is emblematic of the strangeness of this winter. Our experimental PV forecast model did show weakening of the PV in late January, strengthening of the PV in early February then another weakening in the second and third weeks of February with the PV weakest on February 19th. There are a lot of issues with the model but does seem to have at least caught the trends correctly.

One last caveat that I strongly believe that the weather models should not be relied on until the signal from the SSW reaches the stratosphere-troposphere boundary or the tropopause. I could be wrong, but I am prepared not only for weather whiplash but forecast whiplash as well.

I thought with the models now converging on a major SSW that my ongoing struggles this winter with predicting the weather would improve but instead they continue. It seems there are those that are bothered by my expressing my uncertainty (at least on Twitter), but I do think there is value and importance to expressing that uncertainty. I would much prefer to express a definitive outcome with great confidence, but I really don't think that I, the models or anyone else really knows the full impacts of the SSW in the coming weeks. To illustrate that point I really thought the analysis that @WorldClimateSvc Tweeted on 7 Feb 2023 was very informative. It showed that even though the ECMWF model has high accuracy predicting the circulation in the polar stratosphere by week two, it is quite poor in the polar troposphere. Predicting how the SSW will couple with the troposphere and the weather is still very challenging. So, when I see predictions that the SSW will bring cold to Europe and warmth to the US or warmth to Europe and cold to the US or any other possible permutation, my reaction is I don't really think you can draw those conclusions just yet. And I hope my discussion from Monday illustrates that very similar looking PV disruptions can be followed by very different looking surface temperature anomaly patterns.

Wednesday Update

But even given the inherent uncertainties predicting the weather after a generic SSW, I think there are additional complicating factors for this upcoming event. First, I have learned from past experiences even if the models are predicting a major SSW in 7-10 days it doesn't necessarily have to verify (but from what I can tell the probability of verifying seems to be only increasing). Second, I still think that both a PV split or PV displacement are possible even if the models are clearly favoring a PV displacement. Third, there is also a question of when the SSW will peak in the mid stratosphere (10 hPa) and how quickly it will propagate from there to the tropopause and the troposphere. It could be the greatest PV disruption on record but if the large anomalies associated with the SSW remain in the stratosphere it will have limited impacts on the weather.

The updated PCHs forecast from today (**see Figure iii**) shows some interesting additional information compared to what is shown in **Figure 11**. The GFS is still predicting that the PV disruption will peak at 1 hPa around 17 February. But at 10 hPa there are further disruptions predicted (this seems to me consistent across all the models) and will peak after 23 February on some heretofore unknown date. I am scratching my head on this because I would think the possibility of wave reflection and/or ridging/high pressure centered on Siberia would shut down any further disruptions of the stratospheric PV. But even if we assume that the model forecasts are correct and that the SSW will peak in two weeks or later, that makes anticipating the weather impacts even more complicated. In my opinion the models really won't resolve the surface impacts until the signal hits the tropopause, so the longer the PV disruption does aerial acrobatics in the stratosphere, the longer it will take for it to influence the weather and the longer it will take to accurately anticipate those impacts. Also, winter

is clearly running out of runway. If the SSW spins up a coastal storm for example in late February or early March that would be very different if it happens instead in late March and early April or even later. A societally disruptive snowstorm in early Mach could turn into a nuisance cold rain in early April.

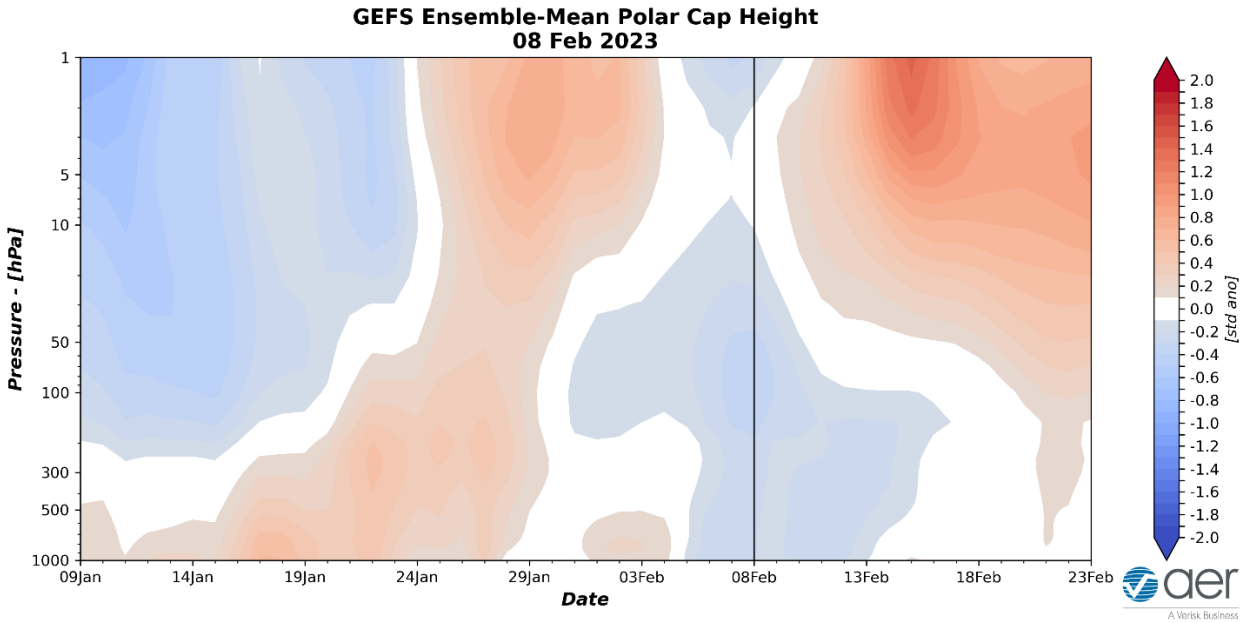

Figure iii. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 8 February 2023 GFS ensemble.

The PCHs forecast even suggests downward influence reaching the surface by 21 February. Something to watch but on this plot it does look strange.

The final head scratcher for me is the predicted surface temperature anomaly pattern at the time of the SSW. The predicted cold North America/warm Eurasia pattern is somewhat strange for any PV disruption but a lot less strange for a stretched PV event. The strongest surface temperature signal coinciding with an SSW is cold temperature anomalies spread across Northern Eurasia with a much weaker and mixed signal across North America. In **Figure iv**, I support this assertion with a modified figure from Kretschmer et al. 2018 but you can see this also in Figure 1 from Cohen et al. 2021, from Figure 4 in Butler et al. 2017 and even Figure 1 from Domeisen and Butler 2020. I am not saying that the model temperature forecasts are necessarily incorrect but when a particular event, while it may not be a unicorn event, certainly deviates from historical precedent, I do believe that It further complicates our ability to correctly predict the influence or impact on our weather. Or maybe I am over thinking the whole thing and the smart money would say we have a pretty good precedent in February 2019

(and ignoring the inconvenient fats that the SSW occurred in early January, it was a PV split and the PV was relatively strong in February 2019).

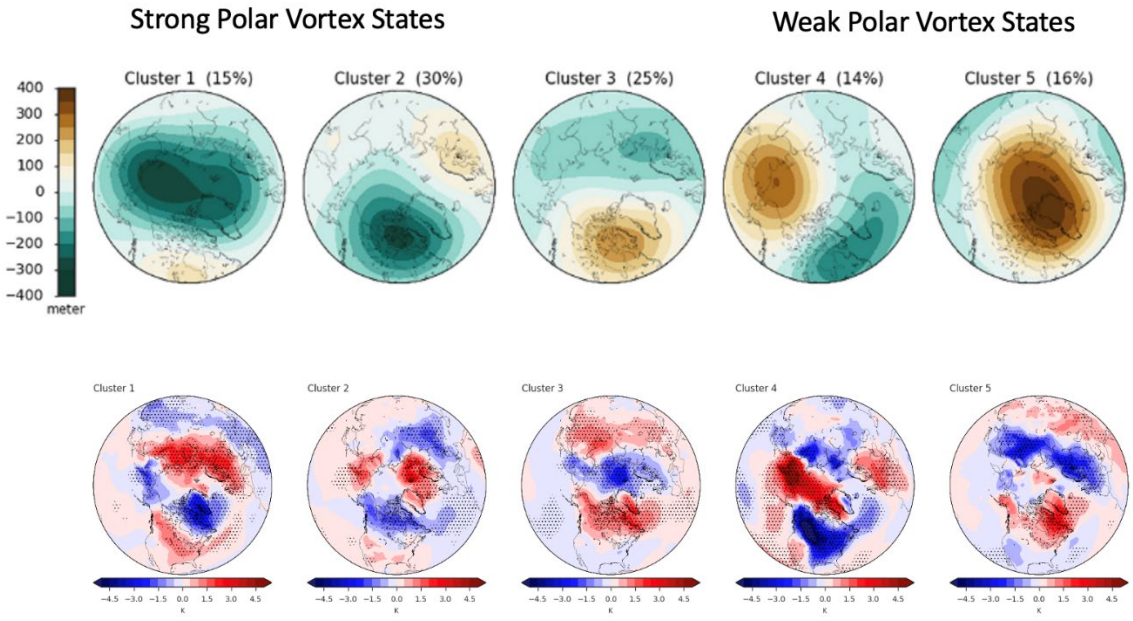

Figure iv. Composites of geopotential height anomalies at 100 hPa in winter (JF) from 1979 to 2018 for days assigned to the same cluster. The number in brackets gives the total occurrence (in percent) over all winter days (top). Cluster 4 is the stretched PV and cluster 5 is a sudden stratospheric warming (SSW). Northern Hemisphere surface temperature anomalies in °C associated coincident with each cluster (bottom).

The models are all consistent predicting that the PV center moving bodily into Asia and setting up easterly flow across Northern Asia and into Northern Europe (see **Figure v**). If this same circulation were to set up in the mid-troposphere it would potentially bring very cold weather to Europe. However so far there are no indications of this in the models and just the opposite is predicted, the model consensus is for well above normal temperatures across all of Northern Asia and Northern Europe. Often, I do believe a reflection of the PV center does develop in the troposphere beneath the stratospheric PV center. Right now, there is only an open trough under the PV center predicted in the models (see **Figure 8**). I do speculate whether over time this could develop into a closed low setting up a colder easterly flow. But the emphasis is on “speculate” and none of this speculating could come to fruition but something to keep an eye on.

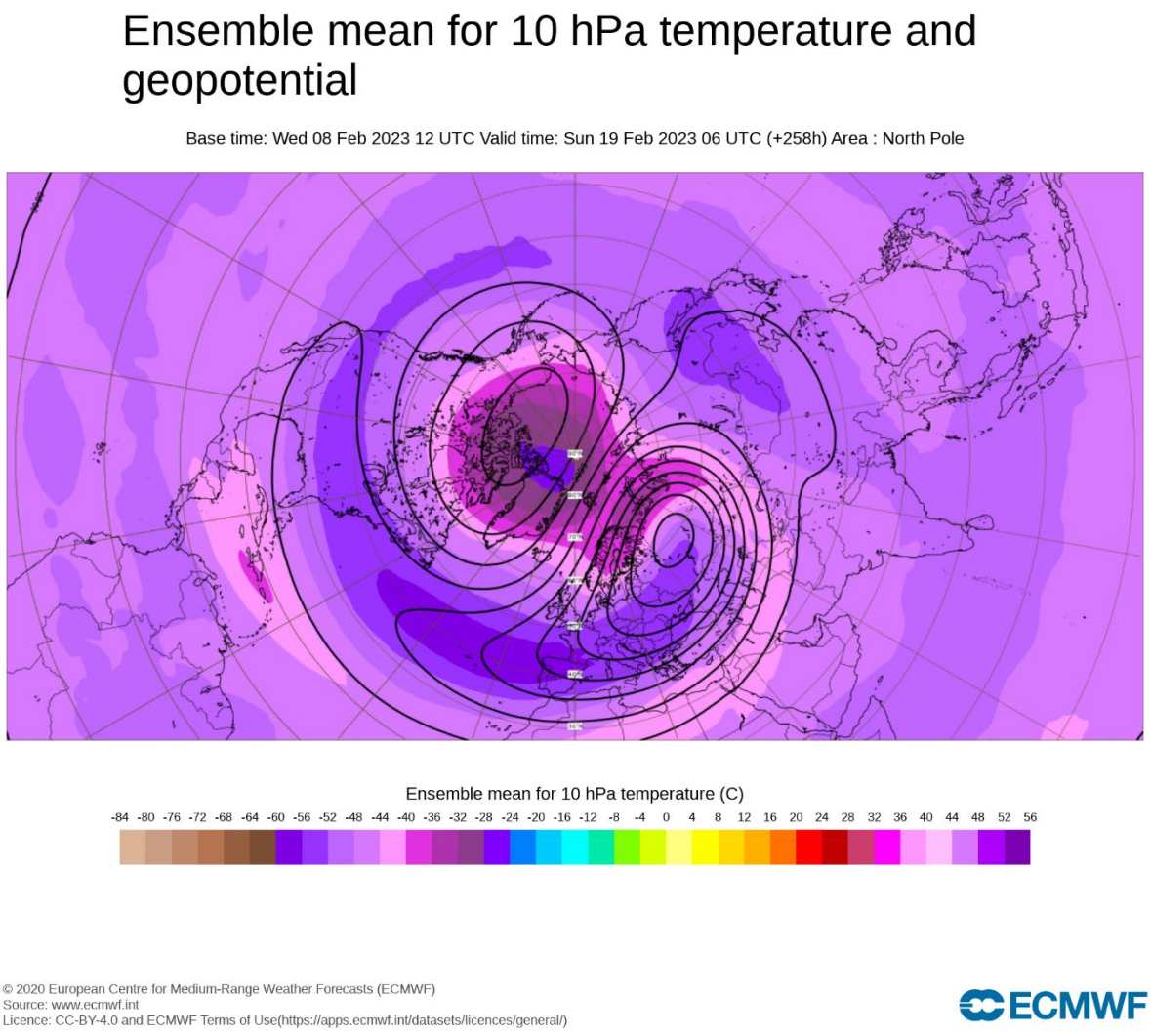

Figure v. Predicted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 19 February 2023. The forecast is from the 12Z 8 February 2023 ECMWF model ensemble. Chart from https://charts.ecmwf.int/

Recent and Very Near Term Conditions

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

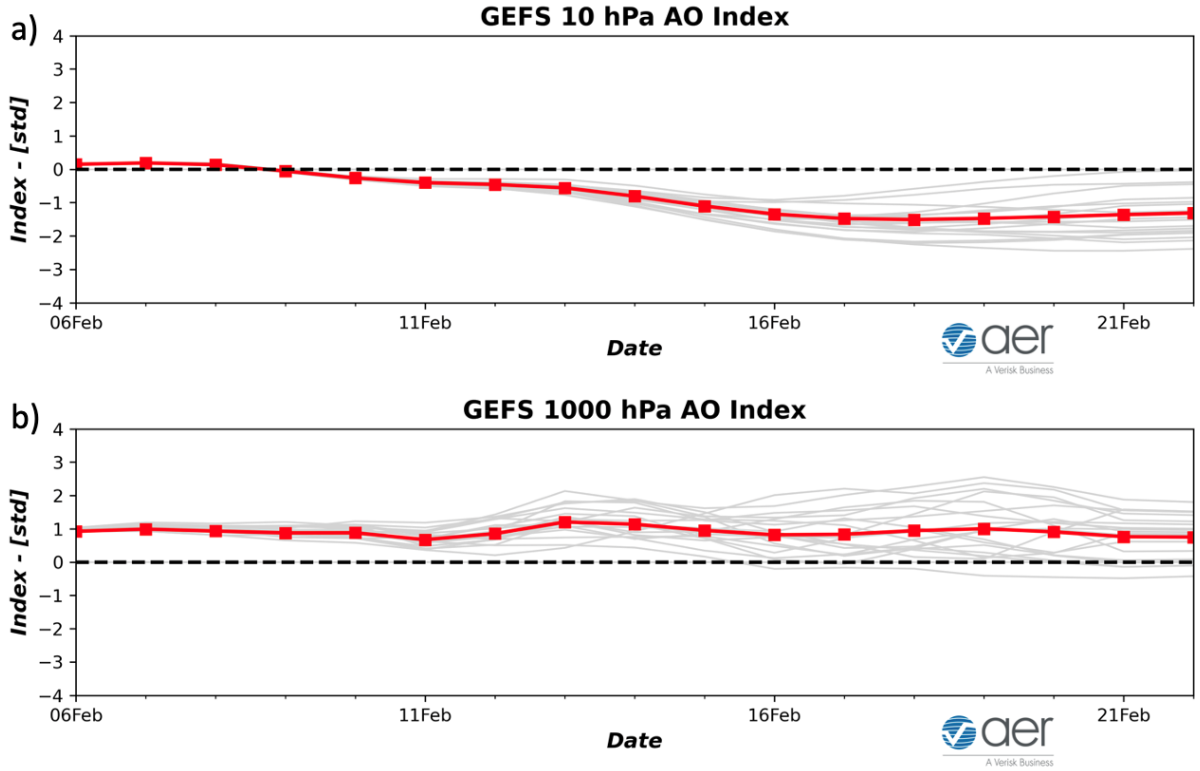

Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 6 February 2023 GFS ensemble. (b)The predicted daily-mean near-surface AO from the 00Z 6 February 2023 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Predicted troughing/negative geopotential height anomalies across Greenland will favor ridging/positive geopotential height anomalies across Northern Europe with troughing/negative geopotential height anomalies across Southern Europe this period (**Figure 2).** This pattern will favor normal to above normal temperatures across much of Northern Europe including the UK with normal to below normal temperatures across Southern Europe including Turkey (**Figure 3**). Ridging/positive geopotential height anomalies centered near the Urals will favor troughing/negative geopotential height anomalies across Siberia that extend southwestward to Central and Southwestern Asia with more ridging/positive geopotential height anomalies across Eastern Asia (**Figure 2**). This pattern favors normal to below normal temperatures across Siberia and parts of Central and Southwestern Asia with normal to above normal temperatures across Northwestern and Eastern Asia **(Figure 3**).

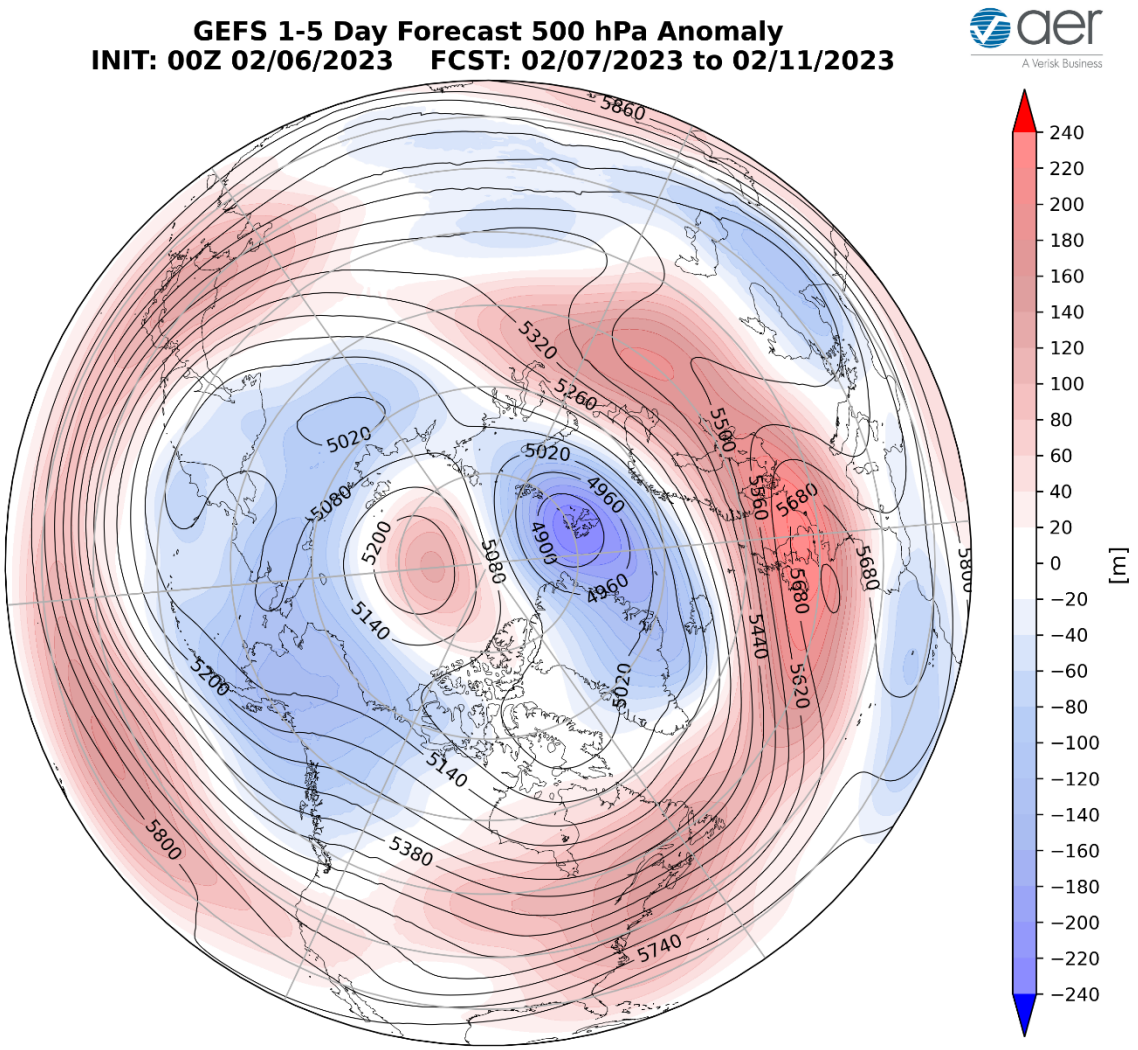

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 7 – 11 February 2023. The forecasts are from the 00z 6 February 2023 GFS ensemble.

Predicted troughing/negative geopotential height anomalies across Alaska, Western Canada and the Western US will force ridging/positive geopotential height anomalies across the eastern North America **(Figure 2).** The pattern will favor normal to below normal temperatures across Alaska, Northern Canada and the Western US with normal to above normal temperatures across Southern Canada and the Eastern US **(Figure 3).**

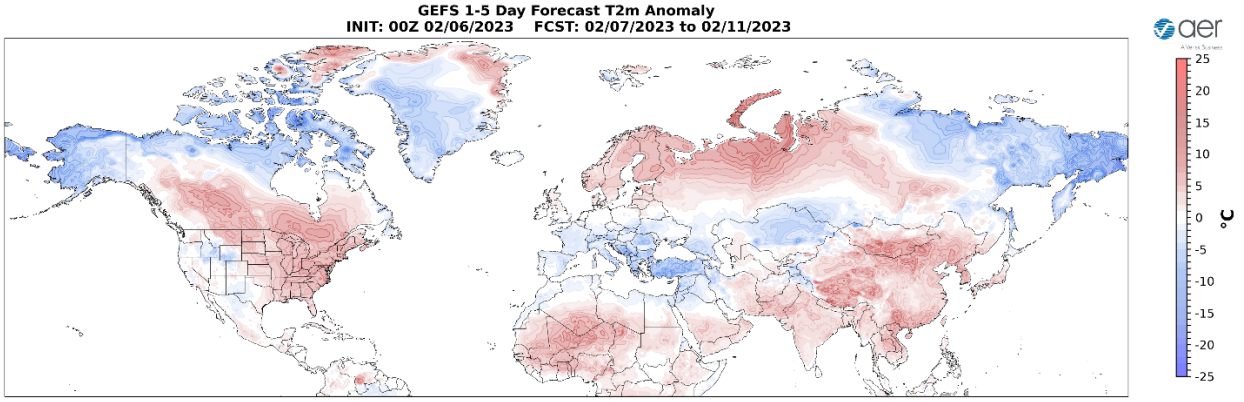

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 7 – 11 February 2023. The forecast is from the 00Z 6 February 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall to Norway, Turkey, Western Siberia, the Tibetan Plateau and Central Asia while mild temperatures will support snowmelt across the Alps, Central Europe, Sweden and Finland and Northwestern Russia (**Figure 4**). Troughing and/or cold temperatures will support new snowfall across Western Canada and the Canadian Maritimes while mild temperatures will support snowmelt across the Western US and New England (**Figure 4**).

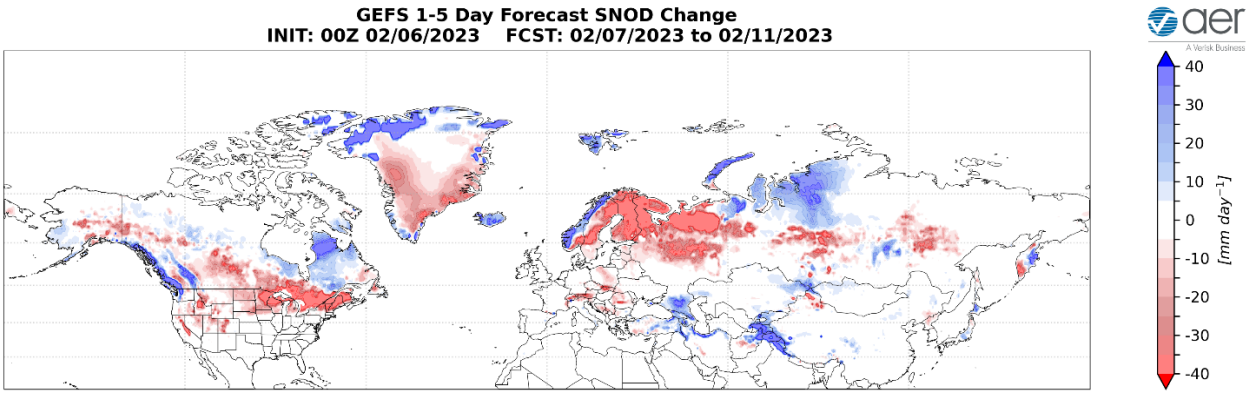

Figure 4. Forecasted snow depth changes (mm/day; shading) from 7 – 11 February 2023. The forecast is from the 00Z 6 February 2023 GFS ensemble.

Near-Term

1-2 week

The AO is predicted to remain positive this period **(Figure 1**) as geopotential height anomalies continue to be mostly negative across the Arctic and mixed across the mid-

latitudes (**Figure 5**). With negative geopotential height anomalies across Greenland (**Figure 5**), the NAO is predicted to remain positive this period.

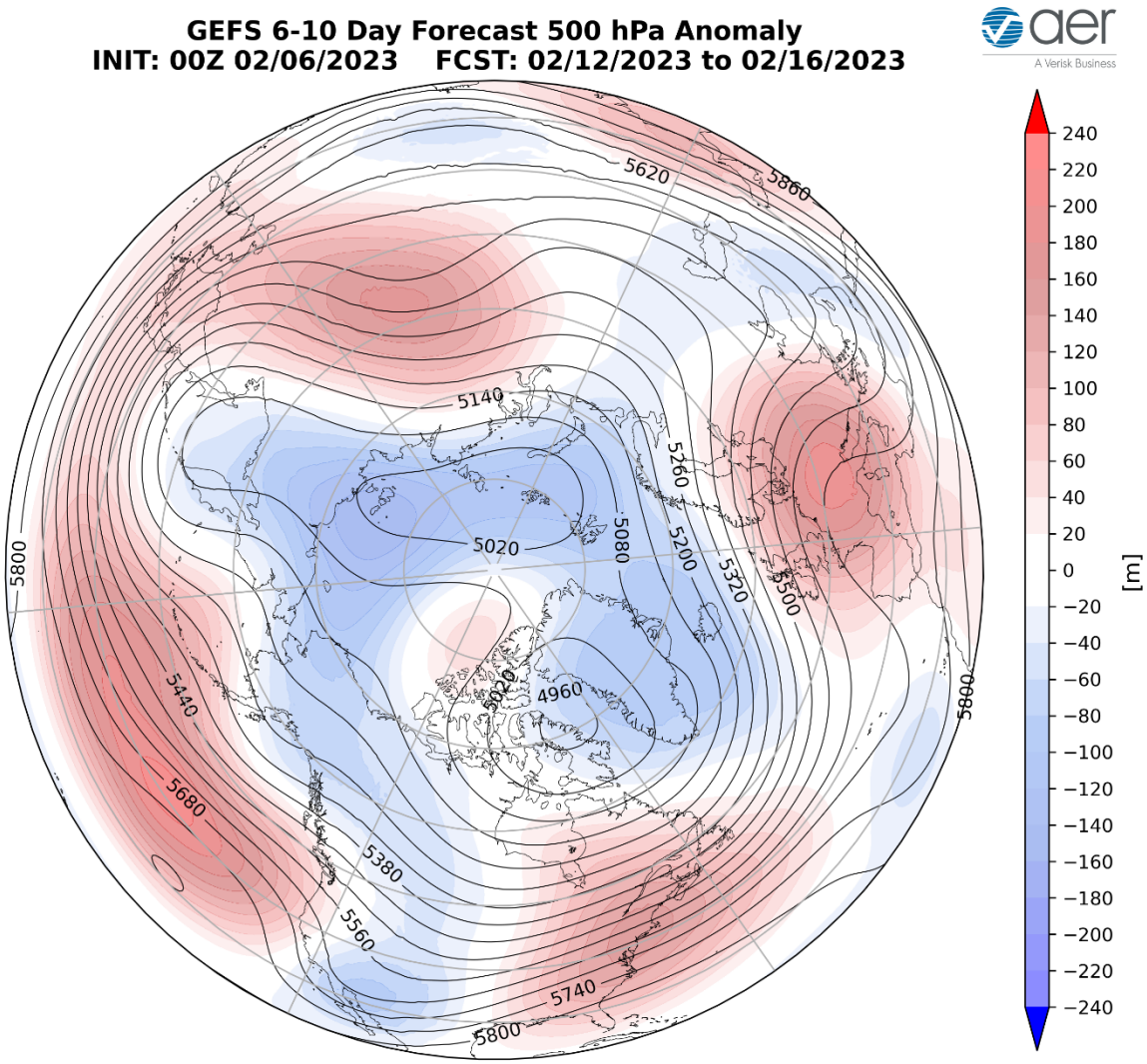

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 12 – 16 February 2023. The forecasts are from the 00z 6 February 2023 GFS ensemble.

Persistent troughing/negative geopotential height anomalies centered over Greenland will support ridging/positive geopotential height anomalies over most of Europe with troughing/negative geopotential height anomalies across the Eastern Mediterranean (**Figures 5).** This pattern favors normal to above normal temperatures across much of Europe including the UK with normal to below normal temperatures limited to the Adriatic Sea region including Turkey (**Figure 6**). Ridging/positive geopotential height anomalies are predicted to settle over Siberia with troughing/negative geopotential height anomalies mostly limited to Eastern Siberia and Southwestern Asia this period

(**Figure 5**). This pattern favors normal to above normal temperatures widespread across Asia but focused in Western Siberia with normal to below normal temperatures mostly limited to Eastern Siberia and Southwestern Asia **(Figure 6**).

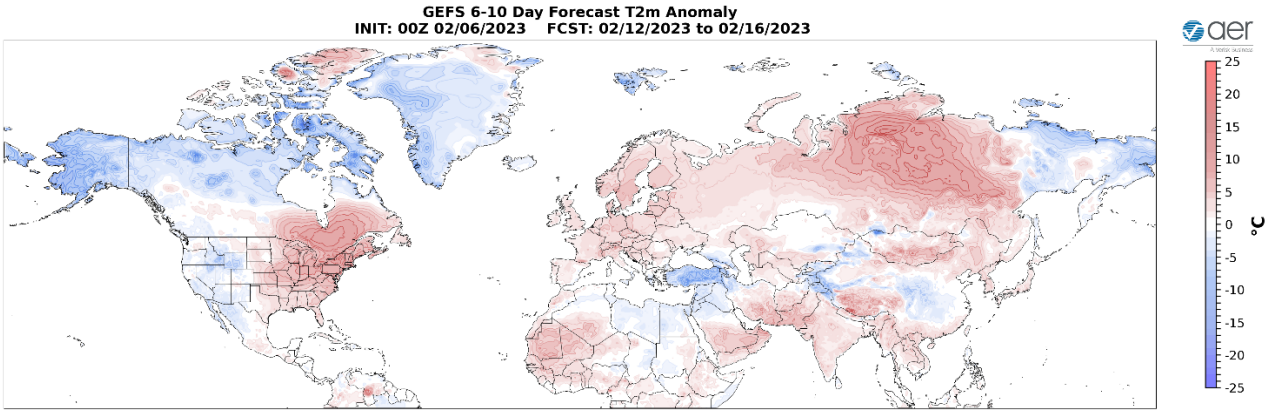

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 12 – 16 February 2023. The forecast is from the 00Z 6 February 2023 GFS ensemble.

Strengthening ridging/positive geopotential height anomalies south of the Aleutians will force deepening troughing/negative geopotential height anomalies across Alaska, Western Canada and the Western US with more ridging/positive geopotential height anomalies centered in the Eastern US this period **(Figure 5).** This pattern will favor normal to below normal temperatures across Alaska, Northern and Western Canada and the Western US with normal to above normal temperatures across Southeastern Canada and the Eastern US **(Figure 6).**

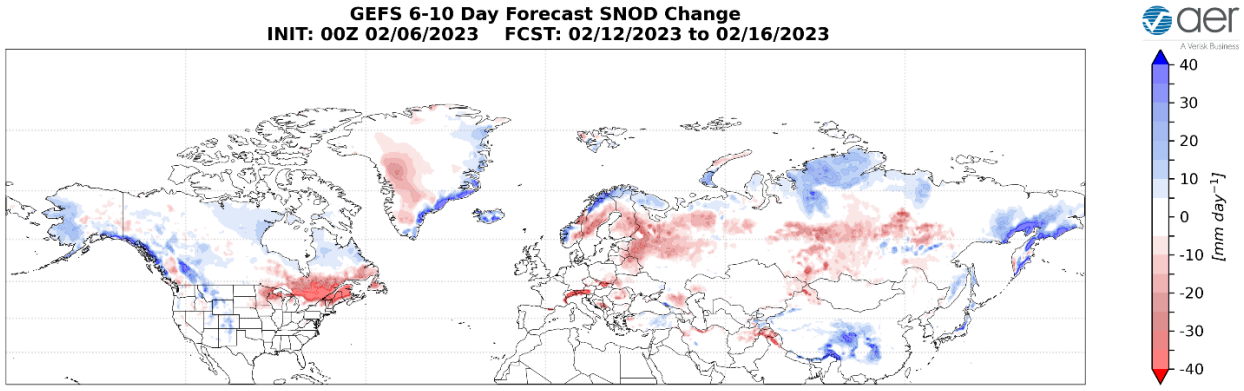

Figure 7. Forecasted snow depth changes (mm/day; shading) from 12 – 16 February 2023. The forecast is from the 00Z 6 February 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Northern Scandinavia, Northern and Eastern Siberia and parts of Central Asia while mild temperatures will support snowmelt in Sweden, Finland, the Baltics, the Alps, Northwestern Russia, Siberia and Central Asia (**Figure 7**). Troughing and/or cold temperatures will support new snowfall across western Alaska, the West Coast of Canada, Northeastern Canada and the Northwestern US while mild temperatures will support snowmelt in the Canadian Maritimes, Great Lakes and New England (**Figure 7**).

3-4 week

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

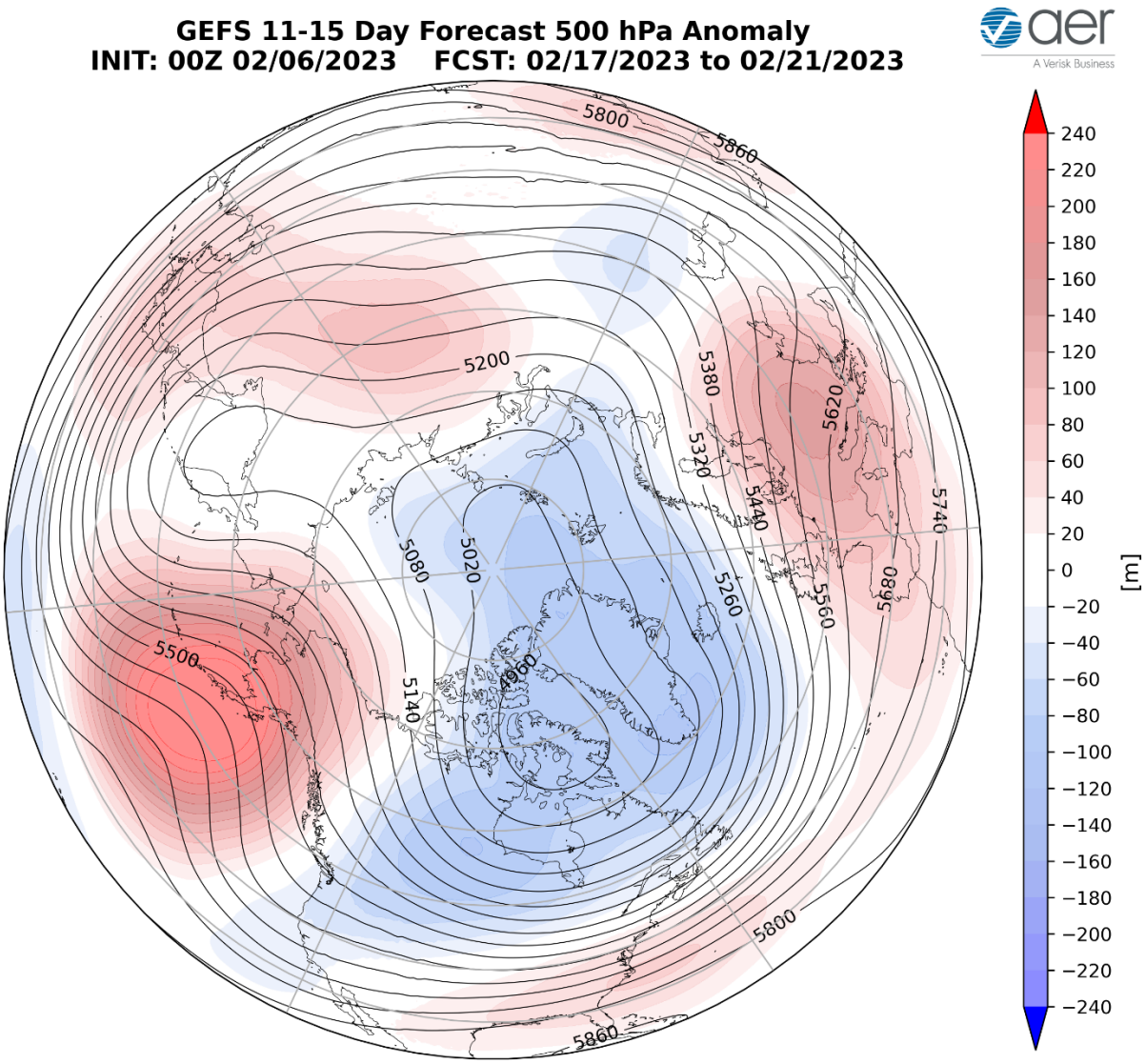

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 17 – 21 February 2023. The forecasts are from the 00z 6 February 2023 GFS ensemble.

Persistent troughing/negative geopotential height anomalies across Greenland will anchor ridging/positive geopotential height anomalies across Europe with some residual troughing/negative geopotential height anomalies in the Eastern Mediterranean this period (**Figure 8**). This pattern favors normal to above normal temperatures across much of Europe including the UK with normal to below normal temperatures mostly limited to Turkey (**Figures 9**). Persistent ridging/positive geopotential height anomalies are predicted to remain centered on Siberia with troughing/negative geopotential height anomalies limited to Eastern Siberia and Southwestern Asia (**Figure 8**). This pattern favors widespread normal to above normal temperatures across much of Asia with

normal to below normal temperatures mostly limited to Southwestern Asia and to the interior of China (**Figure 9**).

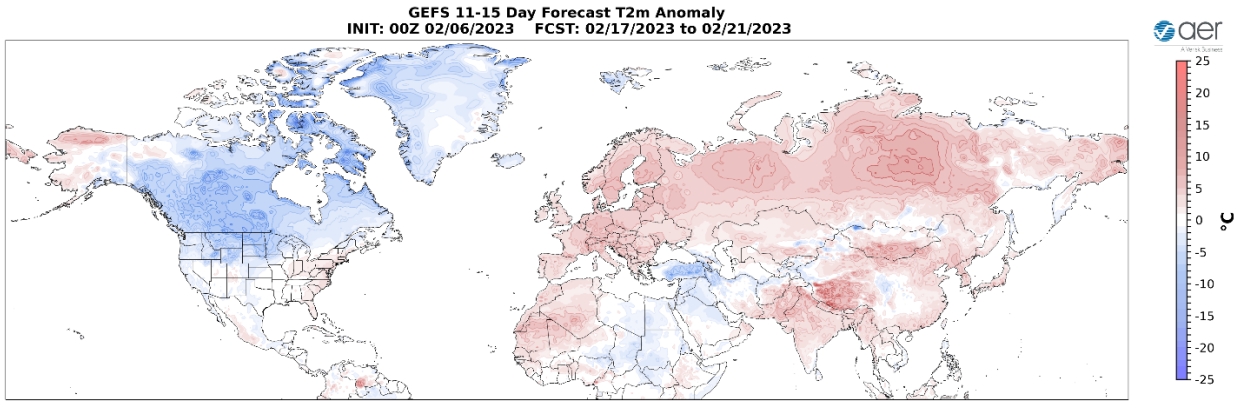

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 17 – 21 February 2023. The forecast is from the 00Z 6 February 2023 GFS ensemble.

Predicted strengthening ridging/positive geopotential height anomalies south of the Aleutians will continue to deepen troughing/negative geopotential height anomalies across much of Canada and the Western US with more ridging/positive geopotential height anomalies centered in the Southeastern US this period (**Figure 8**). This pattern favors widespread normal to below normal temperatures across Alaska, Canada and the Western US with normal to above normal temperatures mostly limited to the Eastern US (**Figure 9**).

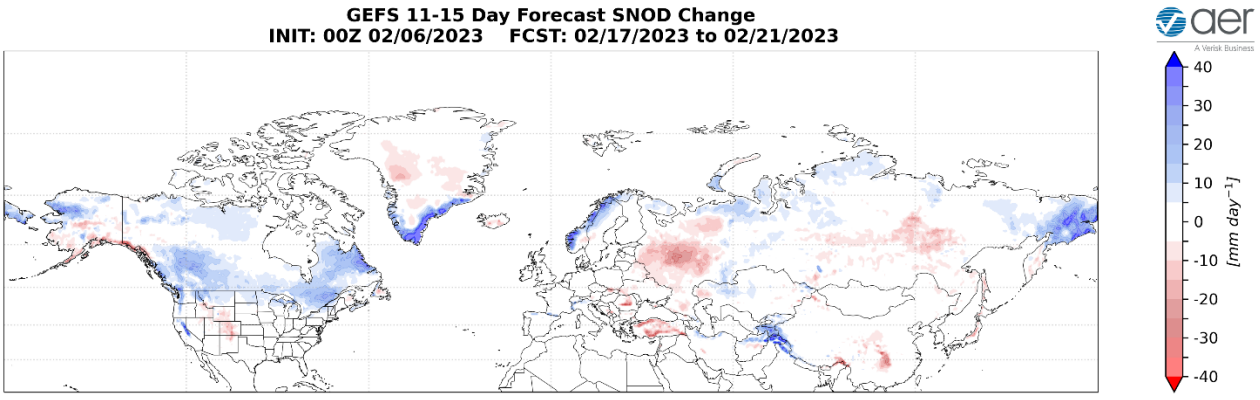

Figure 10. Forecasted snow depth changes (mm/day; shading) from 17 – 21 February 2023. The forecast is from the 00Z 6 February 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Norway, Northern Siberia and Central Asia while mild temperatures will support snowmelt in Turkey, Western Russia and Southern Siberia (**Figure 10**). Troughing and/or cold temperatures

will support new snowfall across western Alaska, Southern Canada, the Cascades, the Sierras and the Northern US while mild temperatures will support snowmelt in the Central Rockies (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to cold/negative PCHs throughout the stratosphere and the troposphere (**Figure 11**). However, the cold/negative PCHs in the stratosphere are predicted to turn warm/positive starting later this week and peaking next week while the normal to cold/negative PCHs in the troposphere are predicted to persist the next two weeks (**Figure 11**). The current warm/positive PCHs in the stratosphere are a result of a minor or possibly major sudden stratospheric warming (SSW). I don't want to read too much from the plot, but it is suggestive of downward propagation of the warm/positive PCHs from the upper to lower stratosphere and then possibly into the troposphere but admittedly speculative at this point.

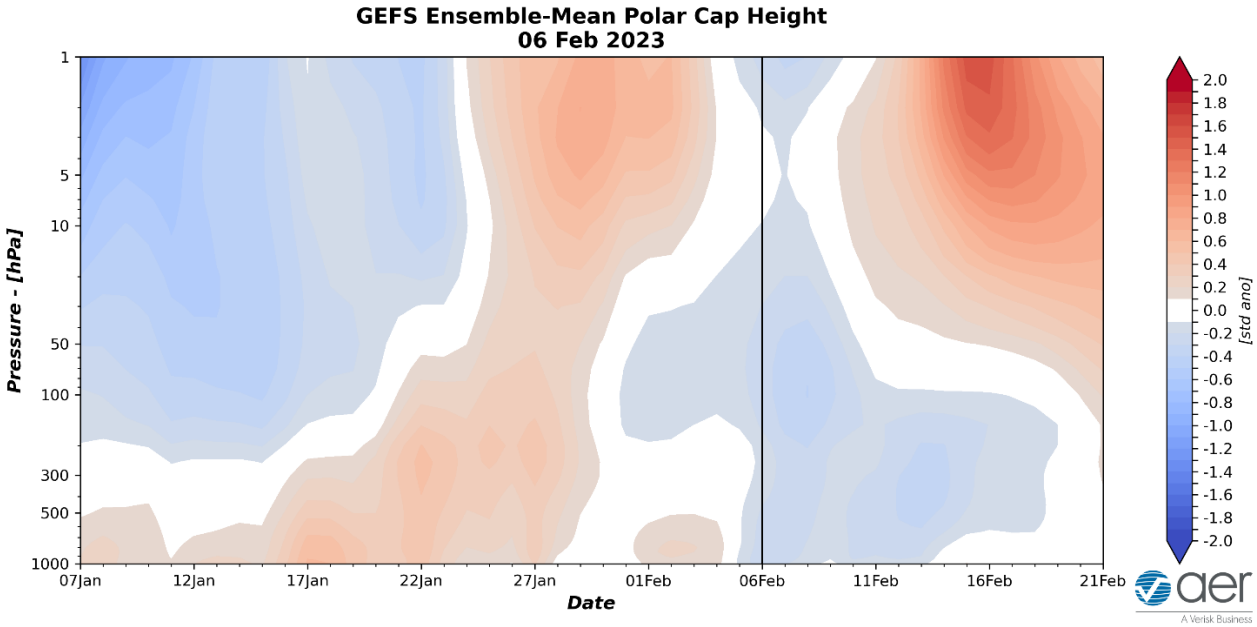

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 6 February 2023 GFS ensemble.

The mostly cold/negative PCHs in the lower troposphere over the next two weeks (**Figure 11**) are consistent with the predicted positive surface AO (**Figure 1**). However,

the third week of February when the cold/negative PCHs in the lower troposphere are predicted to weaken (**Figure 11**), the AO could become more neutral (**Figure 1**).

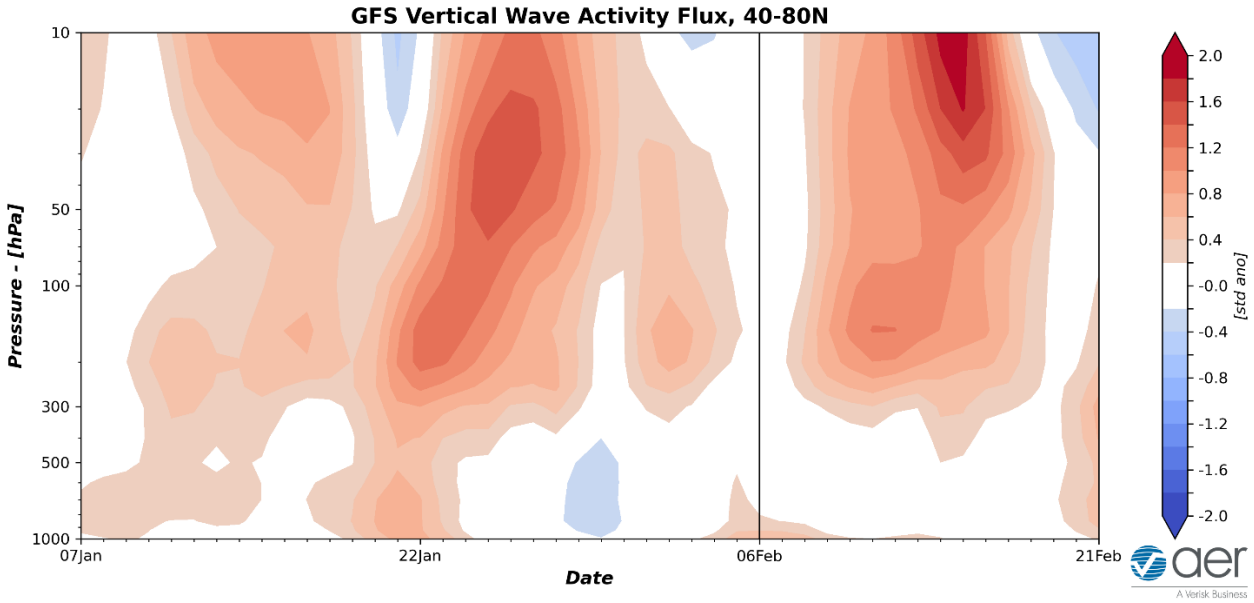

Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 6 February 2023 GFS ensemble.

Vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere or poleward heat transport in the stratosphere has been active since the beginning of the year and peaked the last week of January (**Figure 12**) which has resulted in warming of the polar stratosphere at the end of January (**Figure 11**). The GFS is predicting that the WAFz will become active again this week and peaking next week (**Figure 12**), resulting in warming of the polar stratosphere in mid-February (**Figure 11**) and could lead to another SSW minor or major.

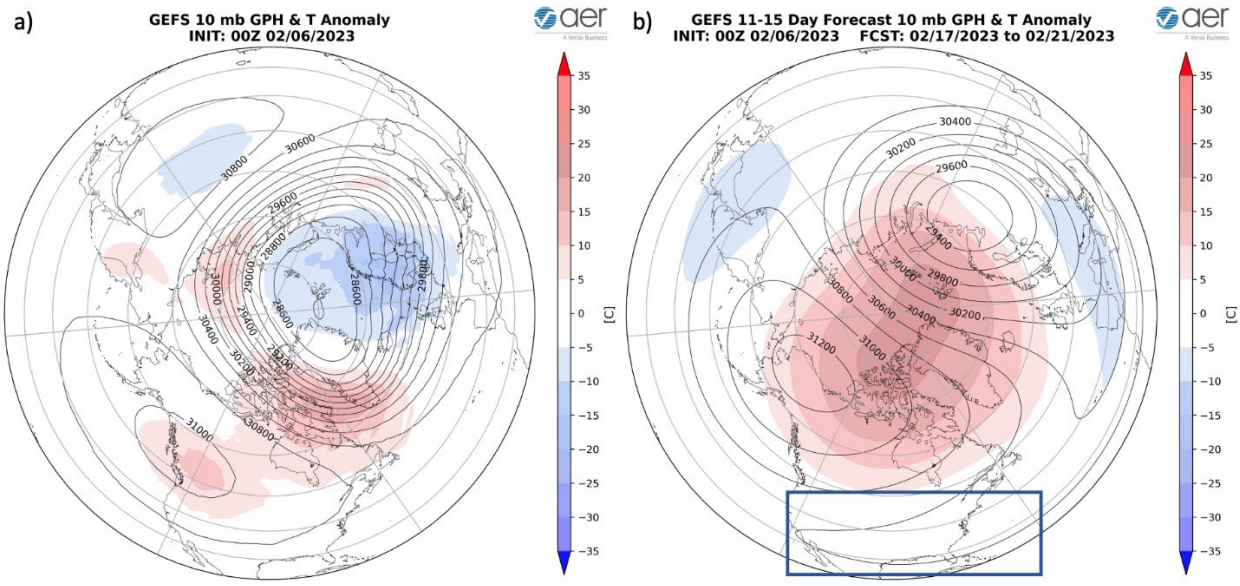

Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 6 February 2023. (b) Same as (a) except forecasted averaged from 17 – 21 February 2023. The forecasts are from the 00Z 6 February 2023 GFS model ensemble.

The more active WAFz has shifted the already weakened stratospheric PV center over towards Scandinavia and centered over Svalbard **(Figure 13a**) with the coldest temperature anomalies across Scandinavia and Northern Europe. Coupled with the shifted PV is ridging and warming centered over Western Canada in the polar stratosphere (see **Figure 13a**). The persistent active WAFz predicted for the next week to ten days will continue to weaken the PV, with the PV shape shifted further south to a position over Northwestern Russia with the coldest relative temperatures across Southern Europe (see **Figure 13b**). Meanwhile ridging and warming will strengthen with the ridge centered over Alaska and the peak warming centered near the North Pole (see **Figure 13**). With the ongoing weakening of the PV, the stratospheric AO is predicted to slide from near neutral to negative the next two weeks **(Figure 13**).

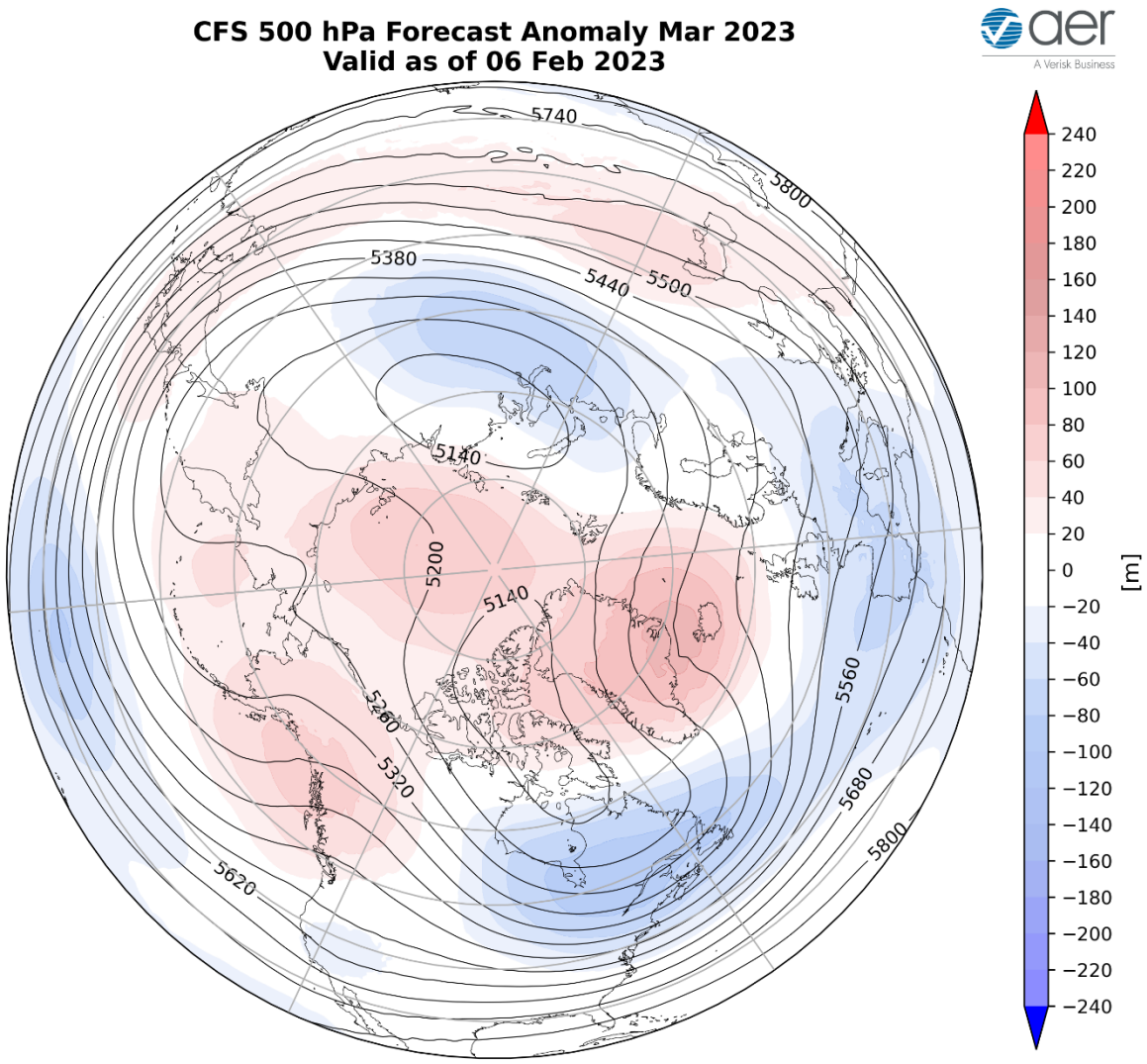

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for March 2023. The forecasts are from the 00Z 6 February 2023 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and surface temperatures for March (**Figure 15**) from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging across Greenland and Iceland, Eastern Siberia into the Central Arctic and the Gulf of Alaska and across Alaska with troughing across Europe, Northern and Eastern Asia, Eastern Canada and the Eastern US (**Figure 14).** This pattern favors seasonable to relatively warm temperatures across much of Southern Europe and Southern Asia, Eastern Siberia Alaska, Western Canada and the Western US with seasonable to relatively cold temperatures across Northern and Western Europe, Northern and Eastern Asia, Eastern Canada and the Eastern US (**Figure 15**)**.** For what it's worth this temperature pattern is consistent with a negative AO forced by a major

SSW.

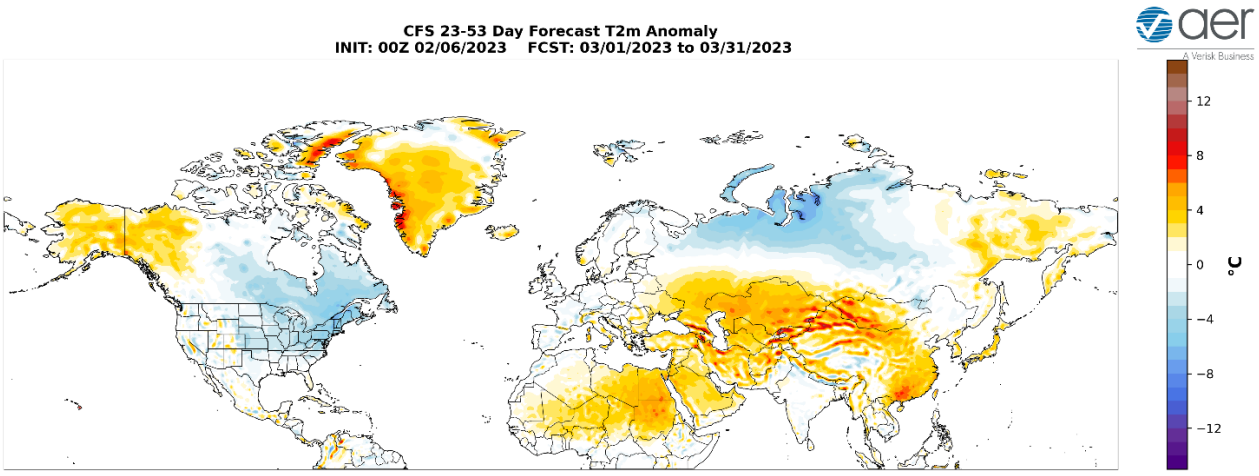

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for March 2023. The forecasts are from the 00Z 6 February 2023 CFS.

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 than 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.

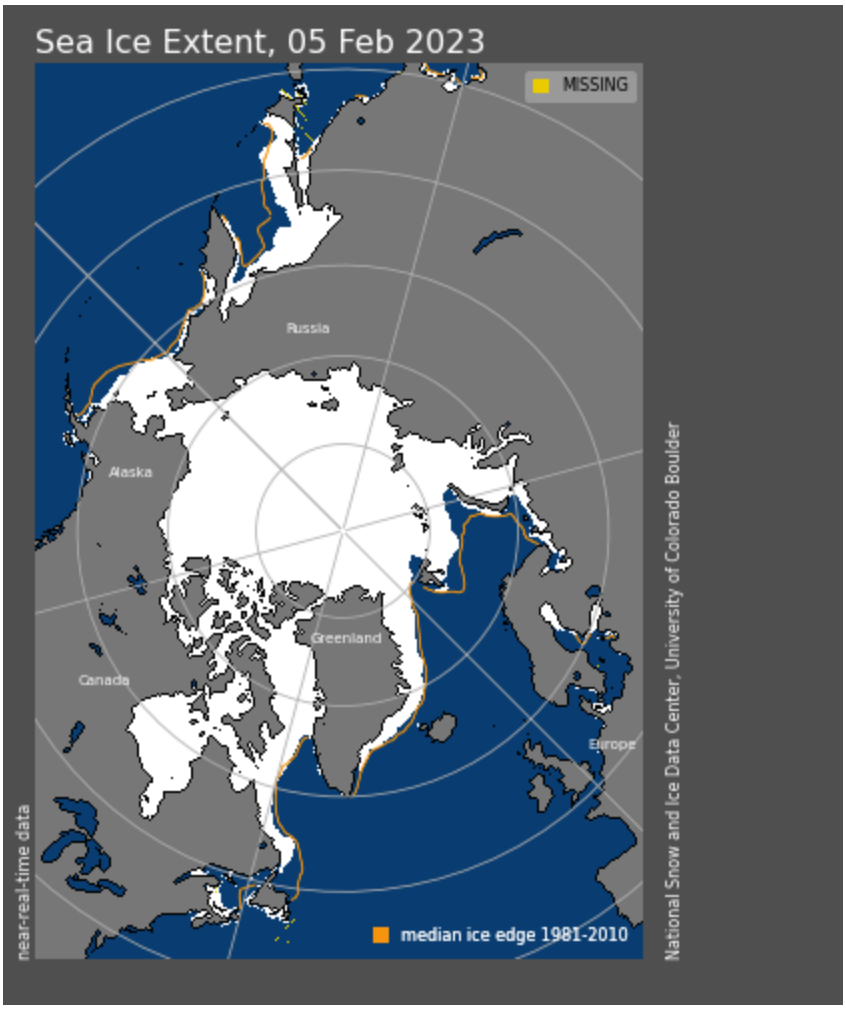

Figure 16. Observed Arctic sea ice extent on 5 February 2023 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC).

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.

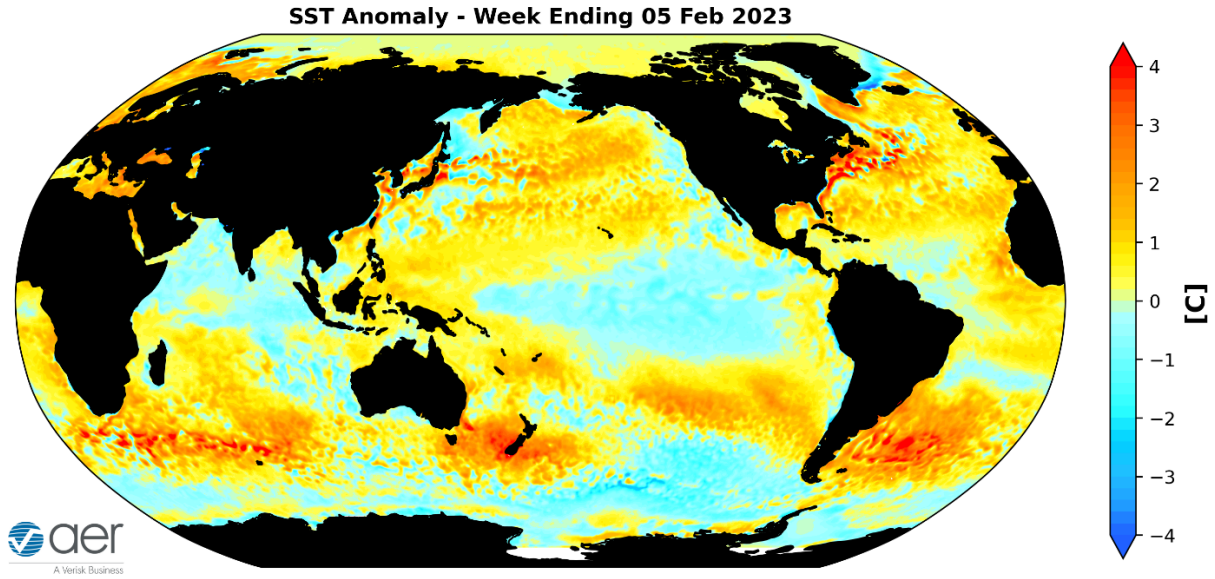

Figure 17. The latest weekly-mean global SST anomalies (ending 5 February 2023). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently the Madden Julian Oscillation (MJO) is in phase three (**Figure 18**). The forecasts are for the MJO to quickly rifle through phases 3, 4, 5, 6 and into 7. Phases three through six favor troughing over Alaska, Canada and the Western US with ridging across eastern North America. In phase 7 favors high latitude blocking with troughing over the US. Seems that the MJO is having an influence and possibly strong influence on the weather across North America in the short term. In addition, phase 3 is thought to favor an SSW two weeks later. But admittedly this is outside of my expertise.

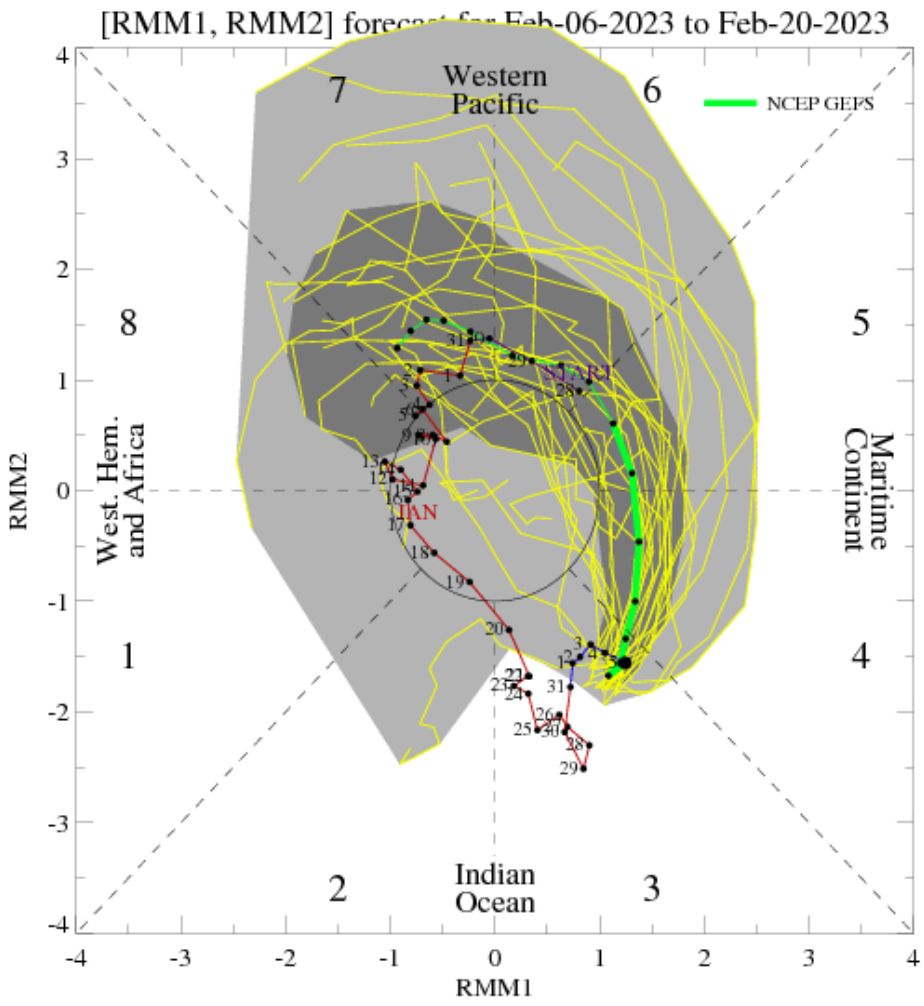

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 6 February 2023 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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 remained stable this past week. In North America snow cover is normal to slightly above (see **Figure 19**). Snow cover is near normal across East Asia, but snow cover extent is below normal in Eastern and Central Europe and Western Asia and below normal across all of Eurasia. I expect snow cover to remain stable in the coming weeks, especially across the US. However with widepread warming predicted across Eurasia, SCE could decline further.

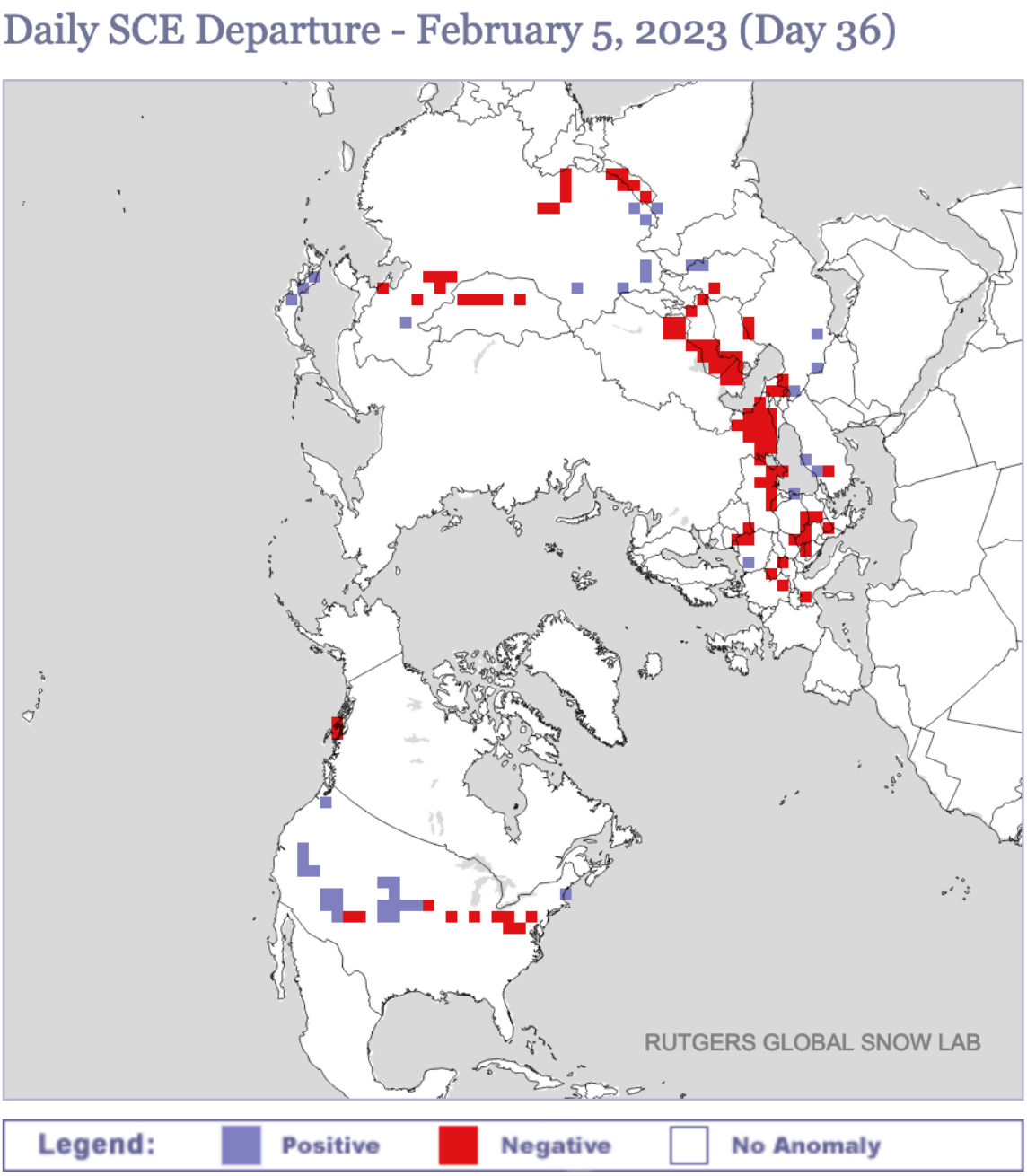

Figure 19. Observed North Hemisphere snow cover anomalies on 5 February 2023. Plot from http://climate.rutgers.edu/snowcover/index.php

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.

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