Arctic Oscillation and Polar Vortex Analysis and Forecasts

February 13, 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 centered on Central Europe with troughing/negative geopotential height anomalies across far Eastern Europe but by next week the ridging/positive geopotential height anomalies will be centered on Western Europe with troughing/negative geopotential height anomalies across Northeastern Europe. This pattern favors this week normal to above normal temperatures across much of Europe including the United Kingdom (UK) with normal to below normal temperatures across far Eastern Europe including Turkey. However next week normal to above normal temperatures will become more widespread across much of Europe with cold temperatures limited to northern Scandinavia.
- The predicted general pattern across Asia the next two weeks is troughing/negative geopotential height anomalies across Western and Eastern Asia with ridging/positive geopotential height anomalies centered across Central Asia. This pattern favors this week normal to above normal temperatures across much of Asia with normal to below normal temperatures limited across far Western Asia and Eastern Siberia. 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 amplifying ridging/positive geopotential height anomalies south of the Aleutians forcing troughing/negative geopotential height anomalies across much of Canada and the Western United States (US) with more ridging/positive geopotential height anomalies across the Southeastern US. This pattern favors the next two weeks normal to below normal across Alaska, much of Canada and the Western US with normal to above normal temperatures across Southeastern Canada and the Eastern US. However, next week the relatively cold temperatures will slowly slide eastward.
- I discuss the predicted large polar vortex (PV) disruption and its potential impacts on Northern Hemisphere (NH) surface temperatures. It does appear that coupling between the stratosphere and troposphere will hold off until March. Large uncertainties remain.

Plain Language Summary

A major disruption of the polar vortex (PV) 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 Europe and Asia. But instead, the models are predicting colder temperatures widespread across North America with well above normal temperatures in Europe and Asia (see **Figure 9**). However, I do think an unusual PV disruption is occurring and more classical

impacts are likely in March that include colder temperatures across Northern Europe and/or Asia.

Impacts

Nothing has come easy this winter. And it has been in many ways a frustrating winter. I don't think that this is a news flash to anyone who reads the blog or follows me on Twitter, I love snow and the lack of snow has been very disappointing and it has been even difficult at times writing the blog (or certainly my enthusiasm was not high) knowing the prospect of winter weather, but especially snow, were grim. But I also think that even if this winter was disappointing because of the snow drought, it was an intellectual challenge and productive as to my ideas on the relationship of Arctic variability and change, the polar vortex, severe winter weather and weather whiplash. But today is one of those days the words flowed from my head to my fingertips and on to the blog page. Today was one of those days I envisioned as the raison d'etre of the blog where I can both contribute to advancing the science and weather forecasting.

I think that it will not surprise anyone that I am focused on the ongoing large polar vortex (PV) disruption that is predicted to achieve major sudden stratospheric warming (SSW; defined as zonal mean zonal winds reversing from westerly to easterly or from positive to negative at 60°N and 10hPa) status this week around February 16th. So many studies have shown that the surface temperature pattern associated with a major SSW is relatively cold across northern Eurasia with weak and mixed signals across North America. But instead, the model forecasts have been steadfast for impressive and widespread cooling across North America and widespread and well above normal temperatures across northern Eurasia. So pretty much the opposite of historical precedent for a major SSW.

I have been writing for weeks now that if nothing else the weakening of the zonal mean zonal winds in the mid to upper stratosphere are conducive to wave energy reflection that are associated with stretched PVs. It certainly seems to me that the predicted surface temperature anomaly pattern is more consistent with wave reflection/stretched PV than a major SSW. The strong ridging/high pressure between the Dateline and the west coast of North America, the deep troughing/low pressure over Canada that extends into the North Atlantic (see **Figure 5**), the positive surface N/AO (see **Figure 1**) and the relatively cold North America and mild Europe (see **Figure 9**) are all consistent with the tropospheric response to a stretched PV/wave reflection event. And looking at the wave energy diagnostics for early next week the characteristic signature of upward Vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere is positive or upward over Eurasia but downward over North America (see **Figure i**). The convergence of the WAF east of the Dateline is strengthening ridging/high pressure between the Dateline and the west coast of North America (orange shading between 180-240°E) while deepening troughing/low pressure over North America (blue shading

between 240-300°E) all below 150 hPa in **Figure i**. Therefore at least in the short term the major SSW is a red herring or a distraction and instead just think of it as stretched PV/wave reflection event despite how you might interpret what is shown in **Figure 13**. And it is pretty much a done deal to understand the weather of winter 2022/23, like the previous winter 2021/22, an alternating strong and stretched PV is most important for understanding the resultant weather, at least in my opinion.

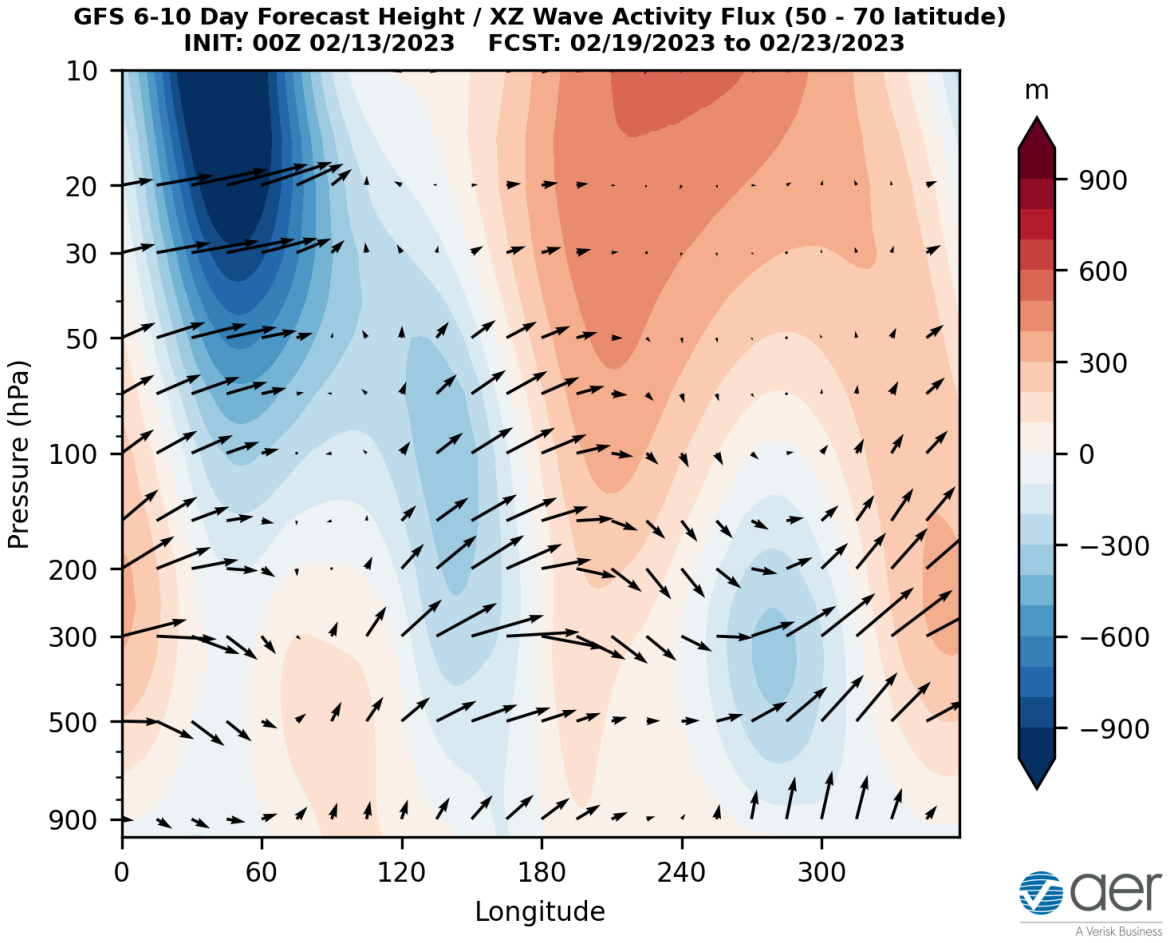

Figure i. Longitude-height cross section of geopotential eddy height anomalies (shading) and wave activity flux (vectors) forecasted for 19 – 23 February 2023. The forecast is from the 00Z 13 February 2023 operational GFS.

Mystery solved and all is well and good, right? Well, no actually. An early pioneer on the work of stretched PVs/wave reflection events is Kunihiko Kodera (and to be honest he almost exclusively worked on this phenomenon until my collaboration with Marlene Kretschmer (see Kretschmer et al. 2018). (There are other related papers from Judith Perlwitz, Nili Harnik and others [e.g., Perlwitz and Harnik 2003] on wave reflection events that are considered the same but I don't agree.). Kodera's earliest paper on the subject (see Kodera et al. 2008) discusses a stretched PV/wave reflection event that

piggybacked onto a major SSW. A good recent example of this type of stretched PV/wave reflection event is February 2021. In a later paper Kodera distinguishes between two different SSWs one that is reflective, where the SSW does not couple to the surface and a negative surface NAO does not follow and one that is absorptive, where the SSW does couple to the surface and is followed by a negative surface NAO (see Kodera et al. 2016). The one through line that connects both papers is that wave reflection ends the major SSW and extinguishes classical stratosphere-troposphere coupling. And from **Figure ii**, at least the GFS is predicting that upwelling wave energy will reach the PV even after the wave reflection.

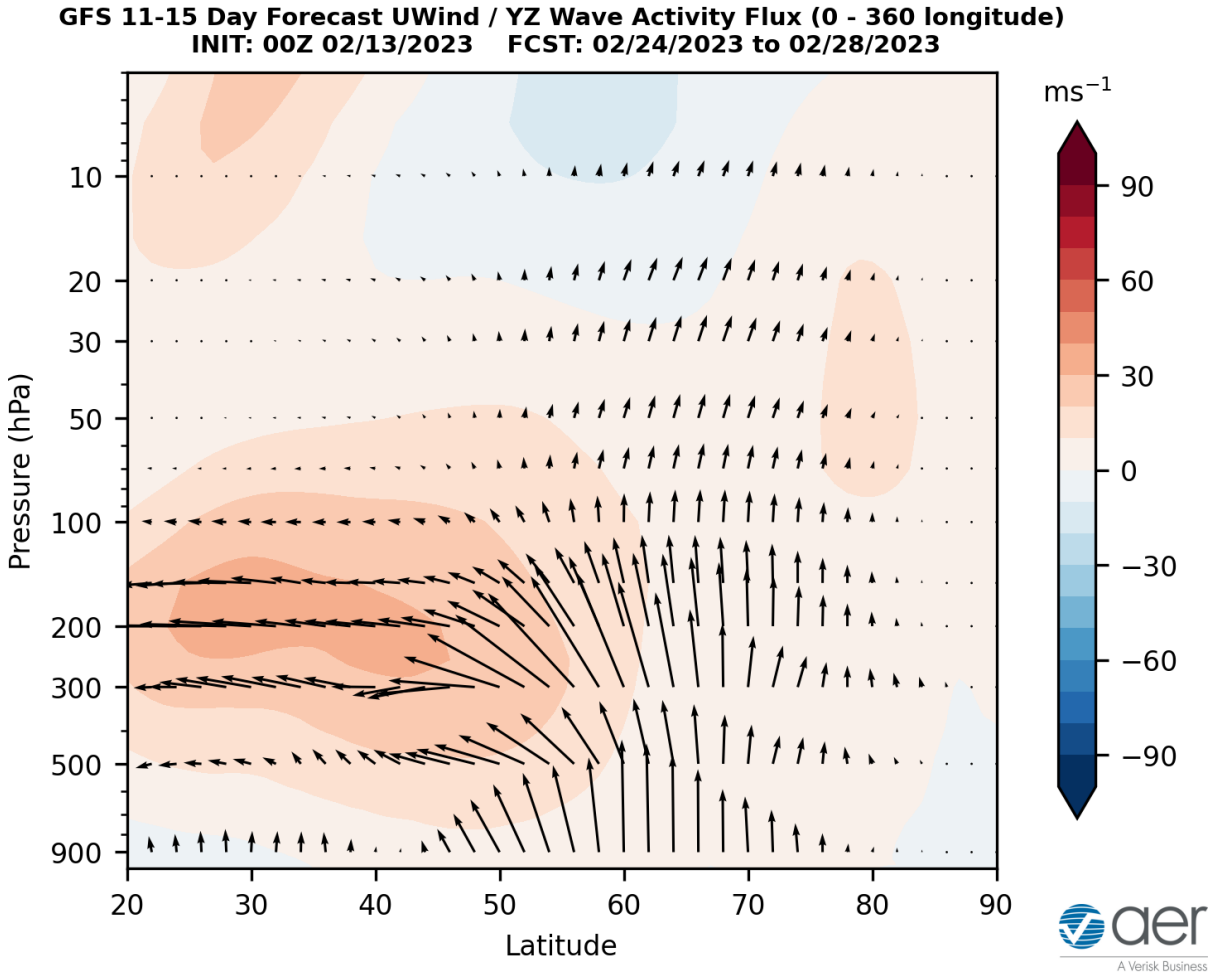

Figure ii. Latitude-height cross section of zonal-mean zonal wind (shading) and wave activity flux (vectors) forecasted for 24 – 28 February 2023. The forecast is from the 00Z 13 February 2023 operational GFS.

Here is the interesting part of the upcoming SSW. The wave reflection predicted in the next week or so is not protecting the PV from upwelling wave energy (something that puzzled me in last week's blog) and the PV is predicted to become continuously weaker

even during and after the wave reflection. It did also strike me as odd how long in duration this upcoming SSW is predicted to be. And though there is still no evidence of downward propagation and stratosphere-troposphere coupling from the polar cap geopotential height anomalies (PCHs) plot in **Figure 11**, the models are growing more confident that it will occur. The GFS, CFS (see **Figures 14** and **15**) and the ECWMF longer range forecasts (I will be curious to see the lates EPS forecasts later today) into March all predict Greenland blocking and a negative NAO. Also, the models are growing more confident that the SSW will evolve into a PV split (something that I have been emphasizing as a possibility because of the predicted wave-2 structure in the troposphere) which is thought to favor stronger coupling to the surface a negative surface NAO. Finally looking at the North Atlantic regional PCHs in **Figure iii** (compare to **Figure 11)**, it is more strongly suggestive of downward propagation that would be related to Greenland blocking and a negative surface NAO more so than high pressure in the Central Arctic and a negative surafce AO.

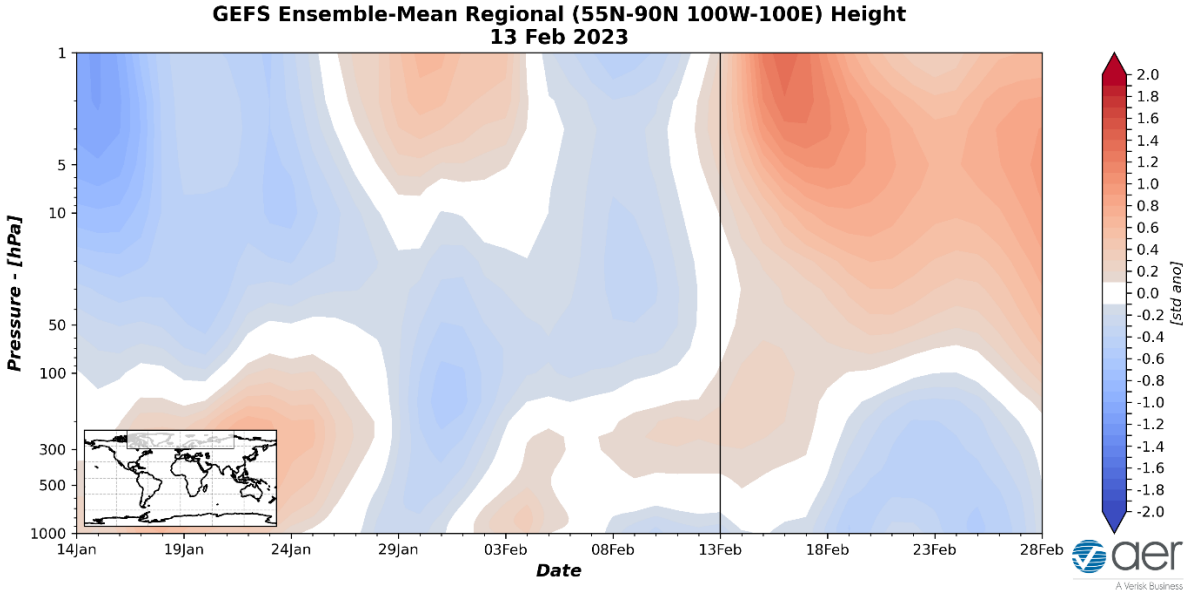

Figure iii. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) but limited to the North Atlantic region (see insert) standardized anomalies. The forecast is from the 00Z 13 February 2023 GFS ensemble.

So, if the model forecasts are correct (always a big if beyond a week) then the upcoming major SSW of late February and early March 2023 would be as far as I know the first documented hybrid SSW where first there is wave reflection and then followed by further absorption and downward influence or stratosphere-troposphere coupling in the classical sense. This understanding is not trivial in my estimation because wave reflection was thought to protect the PV from upwelling wave energy and allow a relatively quick recovery and according to Kodera prevent coupling to the surface. But here we (the readers of the blog) might be witnessing in real time something that I

believe Kodera did not consider - a reflecting SSW (using his terminology) that evolves into an absorbing SSW with full stratosphere-troposphere coupling. Of course, it hasn't happened yet but from what I can tell every model is predicting this very scenario.

So what are the tangible impacts to our weather if I am correct. The general warm Eurasia/cold North America pattern seems to be of fairly high confidence to me, though I do wonder if the warm Eurasia might be overdone. Then if the longer-range models are correct, then the SSW should make its influence on the tropospheric circulation more strongly felt. This would likely include Greenland blocking with lower geopotential heights across the mid-Atlantic North Atlantic sector extending from the Eastern US to Europe. Temperatures should turn colder in Europe and even possibly the Eastern US, though the Southeastern US ridge seems to have become a permanent feature of the atmosphere. So if the winter is all about the PV stretch, the spring could be all about the major SSW.

But even without seeing a direct line of the negative NAM or positive PCH anomalies from the stratosphere to the surface we can already see the influence of the PV disruption or stratosphere-troposphere coupling. The PV center in the mid-stratosphere is predicted to slide over towards northwest Russia and underneath the PV center the models are predicting a trough in the mid-troposphere, something I refer to in the past as a tropospheric reflection of the PV center above. If more classical stratosphere coupling does occur including Greenland blocking, it will be interesting to see if that trough deepens and even becomes a closed mid-troposphere low associated with a turn to more wintry weather conditions across Northern Europe and/or Western Asia.

The fun part will be to see in real-time how well my presented paradigm and revelation of the PV evolution and its coupling with our weather does in the coming weeks.

Wednesday Update

Tomorrow is predicted to be the central date of our first major sudden stratospheric warming (SSW) since 2021. Seems to be an event that garners excitement, though it's actual impact on our weather is a bit nebulous. The SSW in February 2018 was followed by subsequent impactful winter weather in Europe (the "Beast from the East") and the Eastern US (four nor'easters in a row) that pique many weather-enthusiasts' interest on both sides of the Atlantic. But the 2018 SSW was followed by the two major SSWs in 2019 and 2021, that were impactful (especially 2021) but less so in Europe and the Eastern US.

In addition, I was excited to share the blog where I discuss that the SSW begins as a reflective event and then is predicted to morph or transition into an absorptive event and I would appreciate receiving feedback from readers. At least based on my experience and recollection this seems to be an unusual event and begs for an explanation. The implication of such an understanding is that though clearly the relative

cold temperatures are predicted to be focused at first mostly in Canada and the Western US, the cold could eventually spread to Europe and/or the Eastern US. Though like I joked on Monday, the resilience of the Southeastern US ridge, certainly this winter but even the previous two, is impressive. And just maybe it will take El Niño to finally get an Eastern US. trough that can last more than a day.

The classical impact of a major SSW is probably most closely associated with Greenland blocking and a negative NAO. In trying to anticipate whether that will happen, I am focused on the daily PCH forecasts. The largest positive PCHs need to reach the tropopause and eventually into the troposphere to have a full impact on the NH weather. I already tweeted the North Atlantic regional PCHs GFS forecast from today (same as **Figure iii**: see Tweet 15Feb2023am), which clearly shows robust downward propagation of significant positive PCHs to the tropopause and even punching all the way down to the surface. While this does not guarantee Greenland blocking, I do believe that it greatly increases the likelihood of Greenland blocking. So, in **Figure iv**, I show the more traditional PCHs (includes the entire Arctic). Though it does not show the full downward propagation of positive PCHs to the surface like the North Atlantic regional plot, it does show downward progress at least to the tropopause something that is not apparent in **Figure 11** from Monday. These plots are volatile and still far from predicting something conclusive, but all the PCH forecasts and trends suggest a period, and possibly a persistent period, of Greenland blocking and negative NAO associated with more wintry weather for Europe and/or the Eastern US in March.

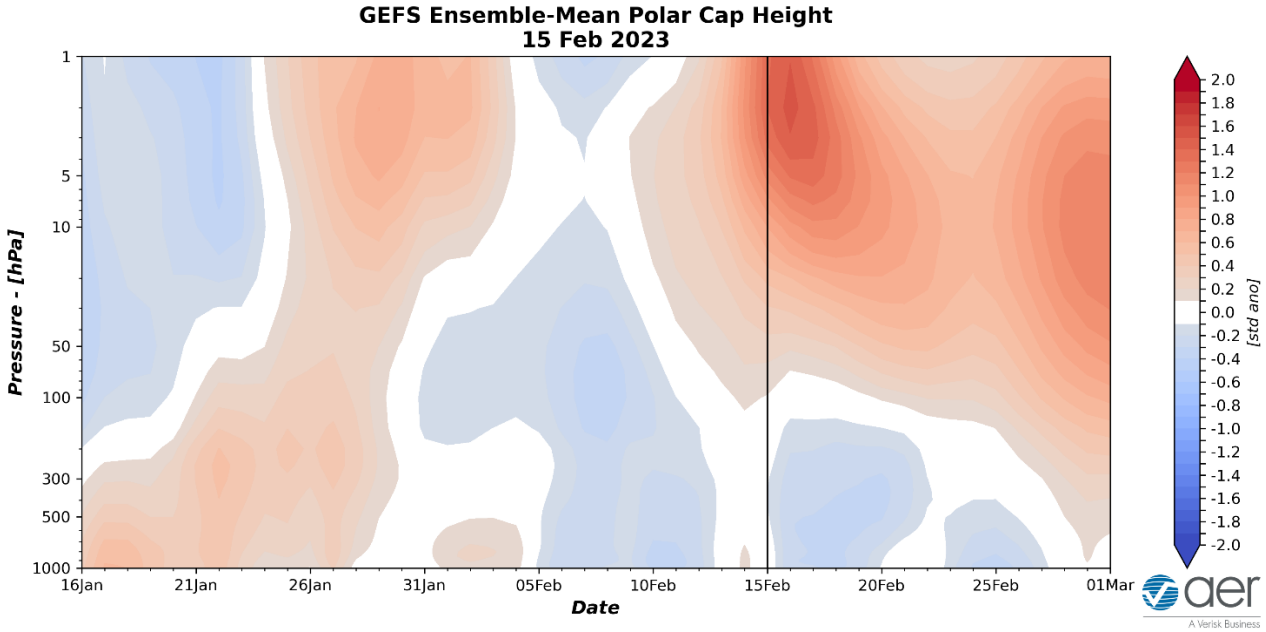

Figure iv. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 15 February 2023 GFS ensemble.

All the models are predicting a very impressive and long duration SSW. But one feature that has caught my attention is - two distinct PV centers (for the record I am not predicting a technical PV split but I do think it is a strong possibility) with a major PV center over northwestern Eurasia and a minor PV center over the Northeastern US (see **Figure v**). What I am about to write is highly speculative but something that intrigues me none the less, can this low center in the stratosphere be a precursor to a mid-tropospheric closed low center later in March that spawns one or more US East Coast Winter Storms (ECWS)? I would argue this was the case in 2018 but one data point isn't much to go on. For now, something to put a pin in but not much more.

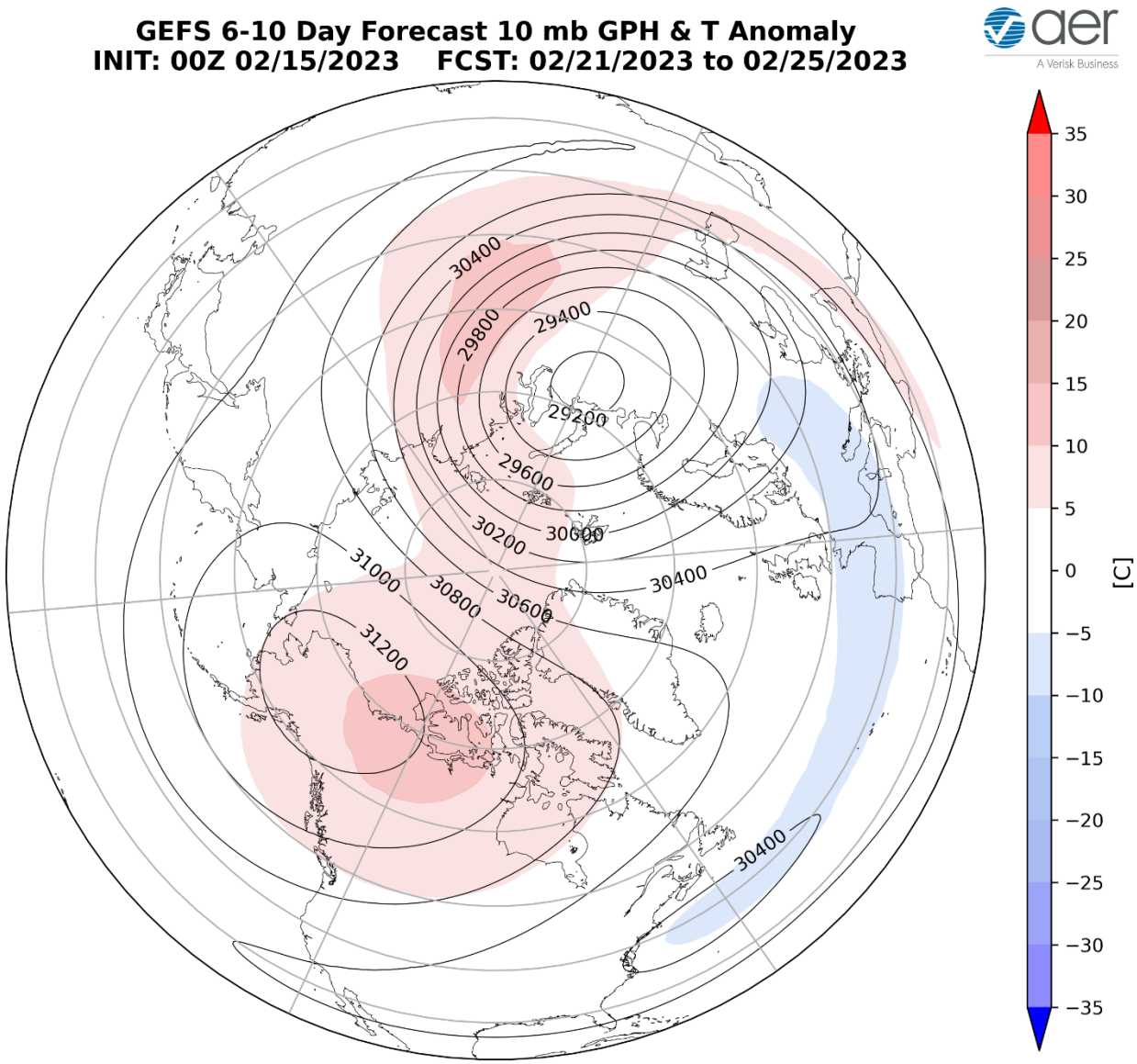

Figure 13. Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere from 21 – 25 February 2023. The forecasts are from the 00Z 15 February 2023 GFS model ensemble.

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**).

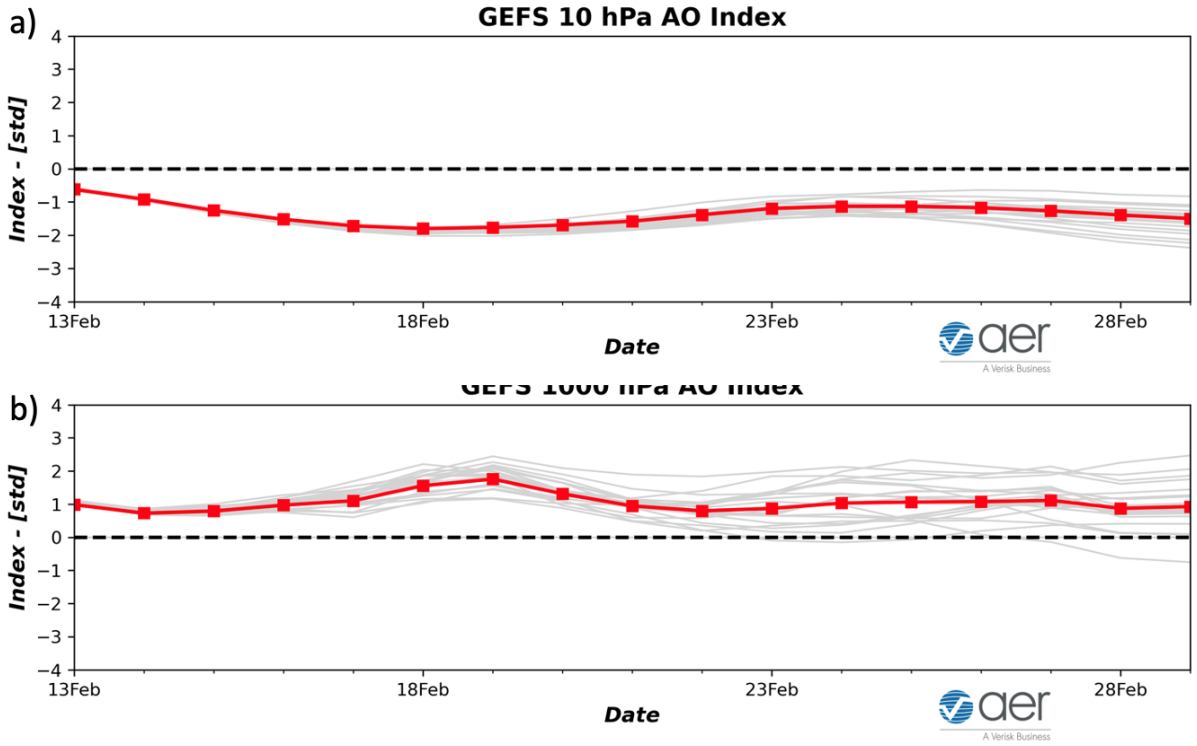

Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 13 February 2023 GFS ensemble. (b)The predicted daily-mean near-surface AO from the 00Z 13 February 2023 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Predicted troughing/negative geopotential height anomalies across Greenland will favor ridging/positive geopotential height anomalies across much of Europe centered on Central Europe with troughing/negative geopotential height anomalies across far Eastern Europe this period (**Figure 2).** This pattern will favor normal to above normal temperatures across much of Europe including the UK with normal to below normal temperatures limited to European Russia and Turkey (**Figure 3**). Troughing/negative geopotential height anomalies across far Western Asia and Eastern Siberia are predicted to sandwich ridging/positive geopotential height anomalies centered just east of the Urals (**Figure 2**). This pattern favors normal to below normal temperatures

limited to parts of Western Asia and Eastern Siberia with normal to above normal temperatures widespread across much of Asia (**Figure 3**).

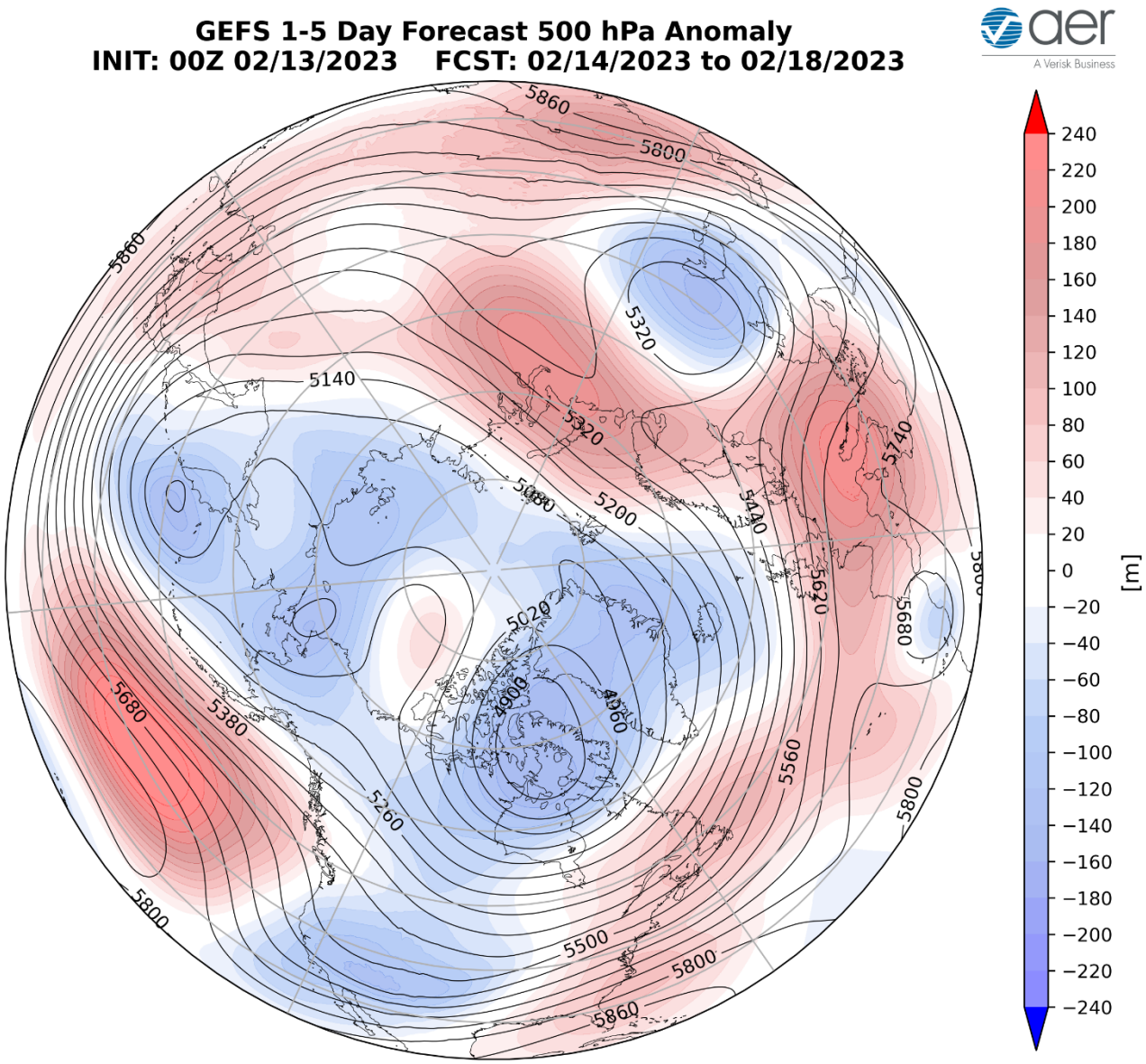

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 14 – 18 February 2023. The forecasts are from the 00z 13 February 2023 GFS ensemble.

Predicted ridging/positive geopotential height anomalies south of the Aleutians favor troughing/negative geopotential height anomalies across Alaska, Western and Central Canada and the Western US with more ridging/positive geopotential height anomalies across the Eastern US **(Figure 2).** The 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 Eastern and Southern Canada and the Eastern US **(Figure 3).**

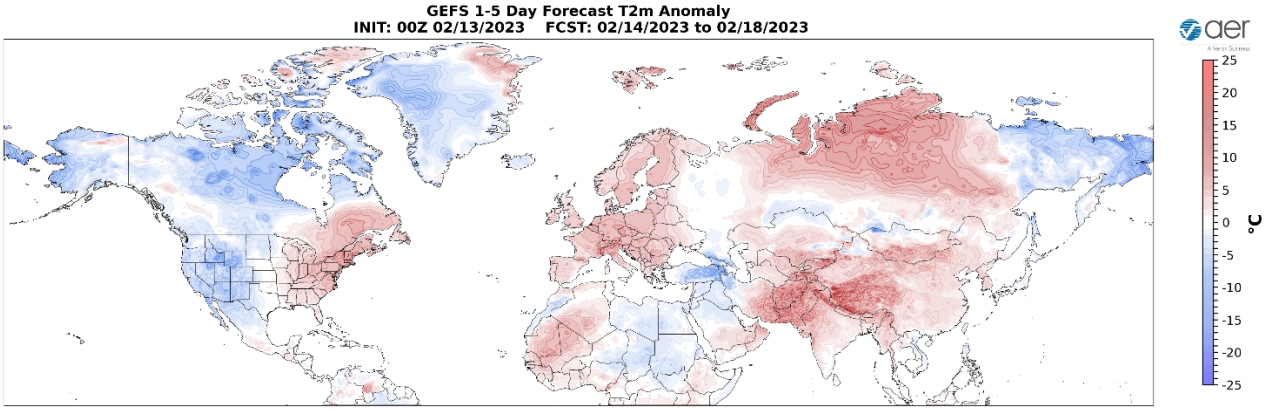

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 14 – 18 February 2023. The forecast is from the 00Z 13 February 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall to Norway, east of the Urals, the Tibetan Plateau and Southwestern Asia while mild temperatures will support snowmelt across the Alps, Southeastern Europe, Sweden and Finland, Northwestern Russia and Southern Siberia (**Figure 4**). Troughing and/or cold temperatures will support new snowfall across western Alaska, the west coast of Canada, around Hudson Bay and the US Continental Divide while mild temperatures will support snowmelt across the Great Lakes, Southeastern Canada and New England (**Figure 4**).

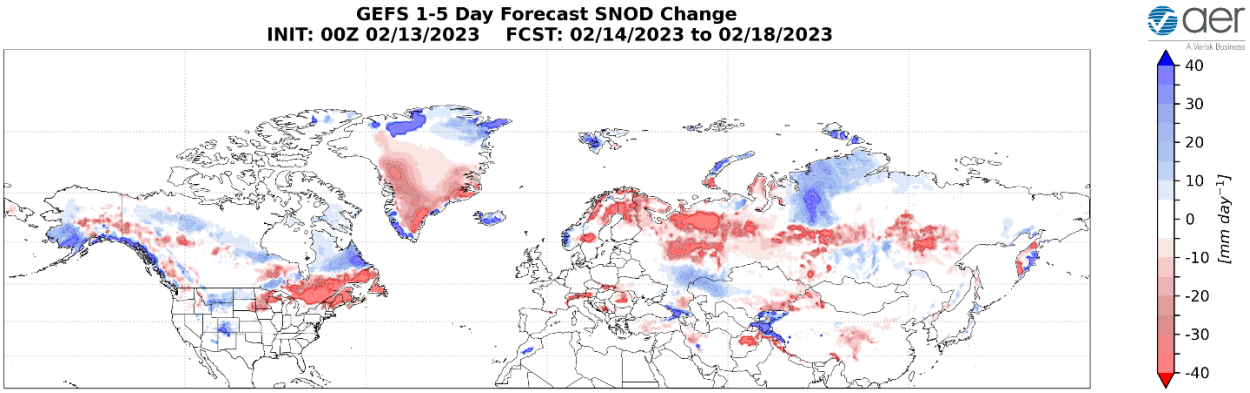

Figure 4. Forecasted snow depth changes (mm/day; shading) from 14 – 18 February 2023. The forecast is from the 00Z 13 February 2023 GFS ensemble.

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.

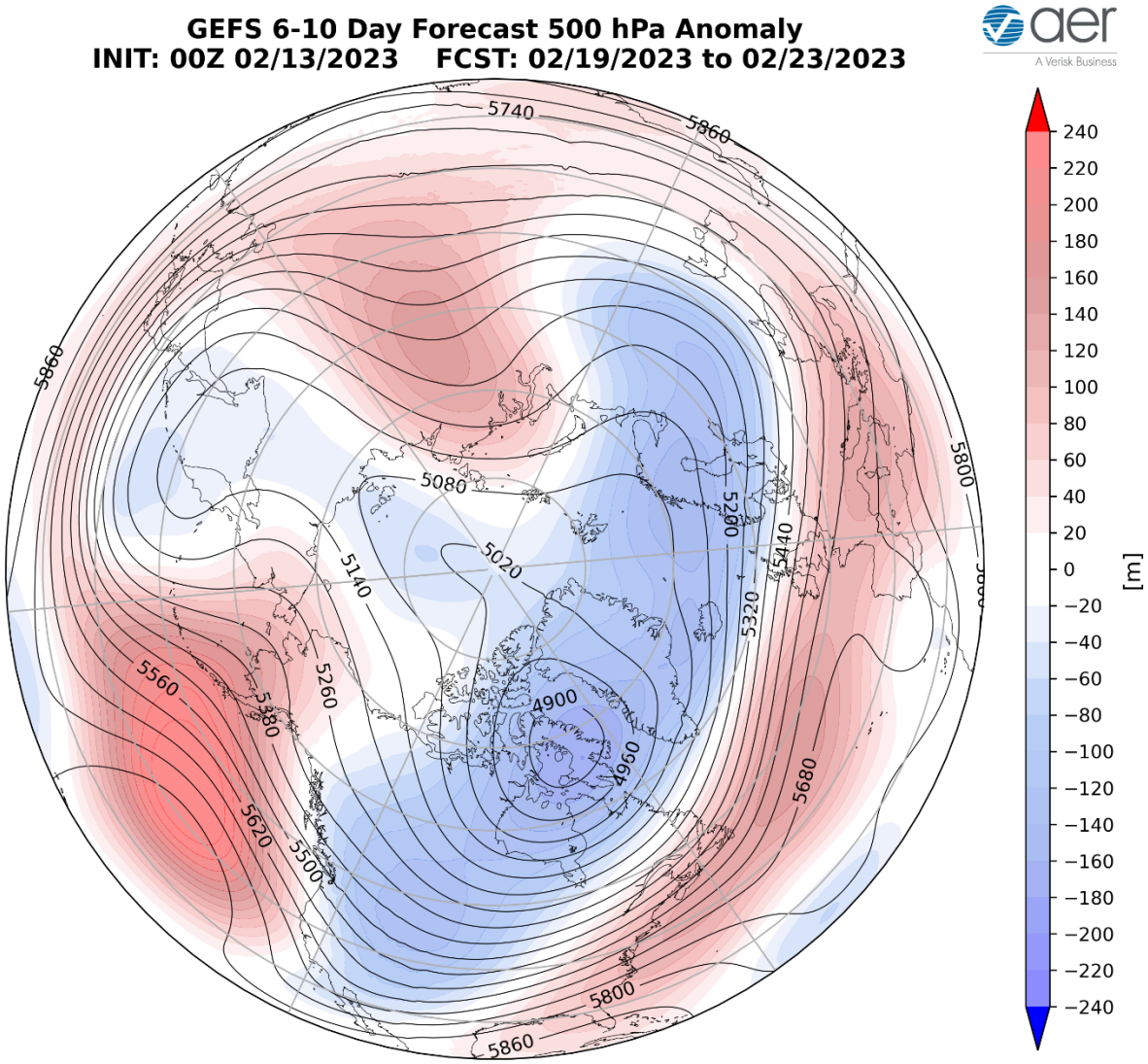

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 19 – 23 February 2023. The forecasts are from the 00z 13 February 2023 GFS ensemble.

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 Scandinavia and Northeastern Europe (**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 northern Scandinavia (**Figure 6**). Troughing/negative geopotential height anomalies in Northwestern Asia and Eastern Siberia are predicted to continue to bookend ridging/positive geopotential height anomalies centered on Western Siberia this period (**Figure 5**). This pattern favors widespread 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 Northwestern Asia **(Figure 6**).

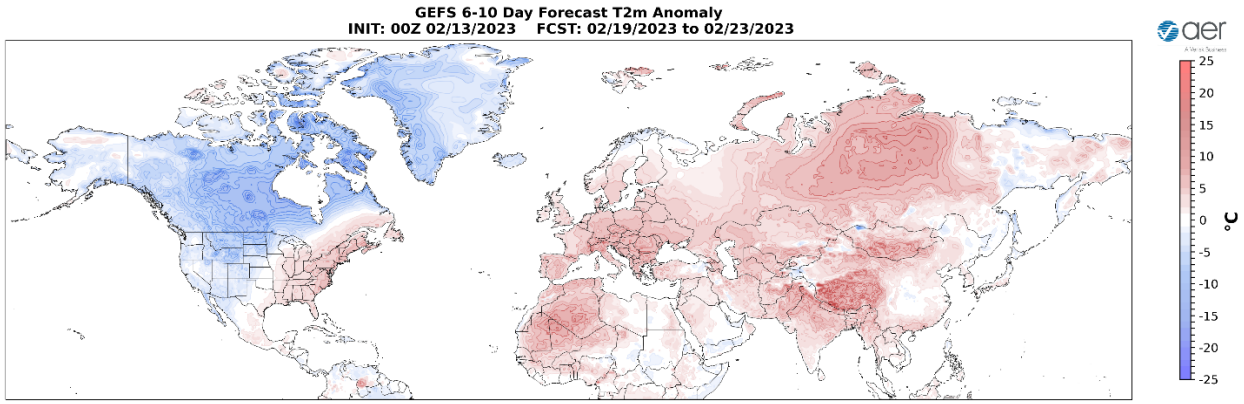

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 19 – 23 February 2023. The forecast is from the 00Z 13 February 2023 GFS ensemble.

Strengthening ridging/positive geopotential height anomalies south of the Aleutians will push north into Alaska and force deepening troughing/negative geopotential height anomalies across Western Canada and the Western US with more ridging/positive geopotential height anomalies centered along the US East Coast 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 far Southeastern Canada and the Eastern US **(Figure 6).**

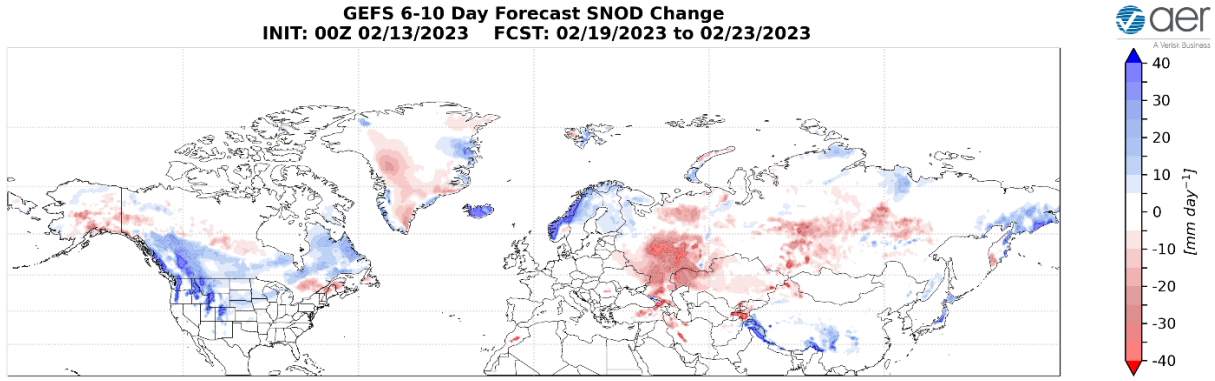

Figure 7. Forecasted snow depth changes (mm/day; shading) from 19 – 23 February 2023. The forecast is from the 00Z 13 February 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Norway, Eastern Siberia and the Tibetan Plateau while mild temperatures will support snowmelt in Western Russia and Southern Siberia (**Figure 7**). Troughing and/or cold temperatures will support new snowfall across Southern Canada, the higher elevations of the Western US and the Northern Plains while mild temperatures will support snowmelt in Southern Alaska, the Canadian Maritimes and Northern 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.

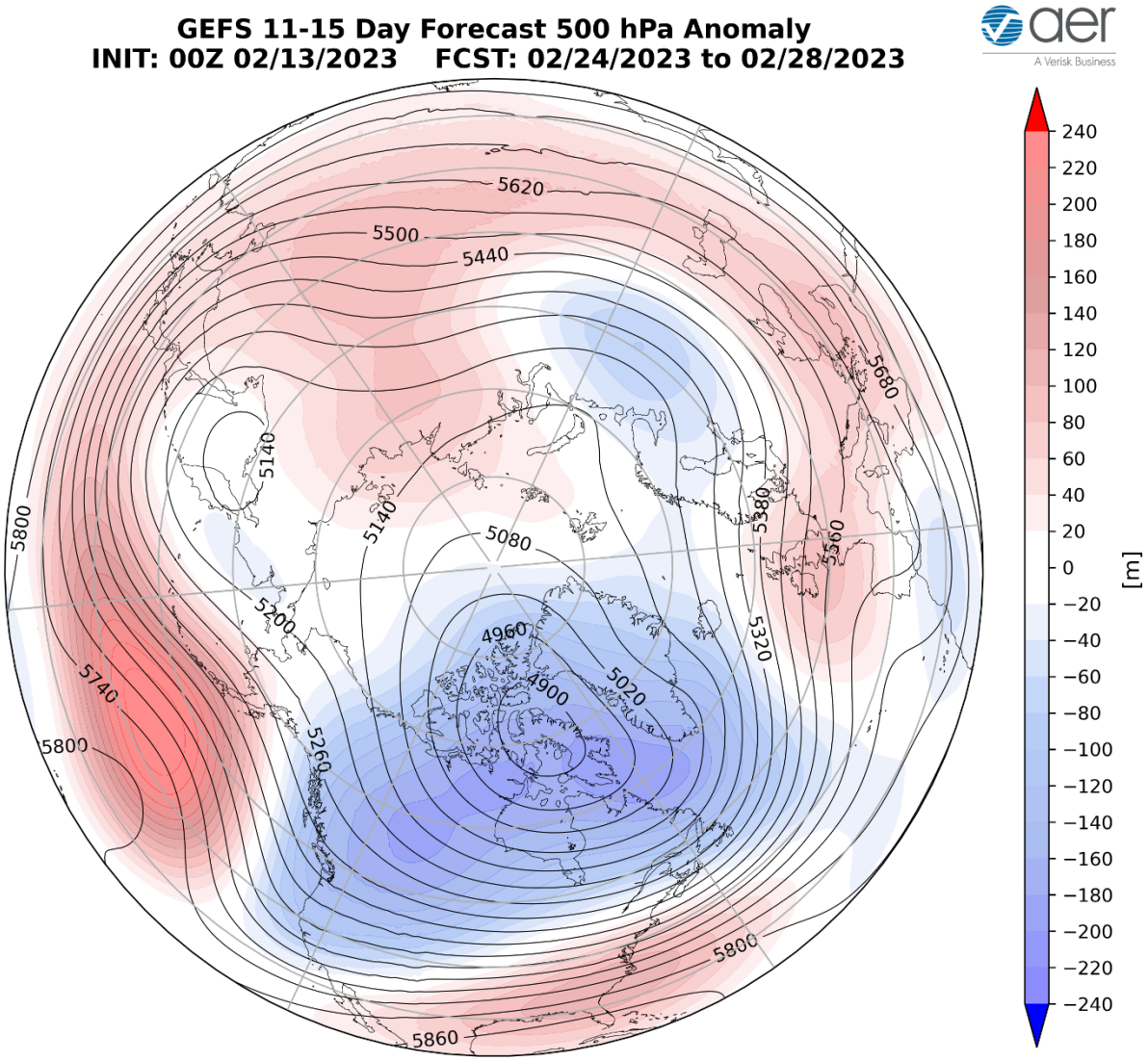

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 24 – 28 February 2023. The forecasts are from the 00z 13 February 2023 GFS ensemble.

Persistent troughing/negative geopotential height anomalies across Greenland will anchor ridging/positive geopotential height anomalies across Western Europe with troughing/negative geopotential height anomalies across Scandinavia and Northeastern Europe 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 northern Scandinavia (**Figures 9**). The omega pattern is predicted to persist across Asia with ridging/positive geopotential height anomalies centered in Western Siberia bookended with troughing/negative geopotential height anomalies limited to Eastern Siberia and Northwestern 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 Northwestern Asia and Eastern Siberia, even if it is not appearing in forecast plots (**Figure 9**).

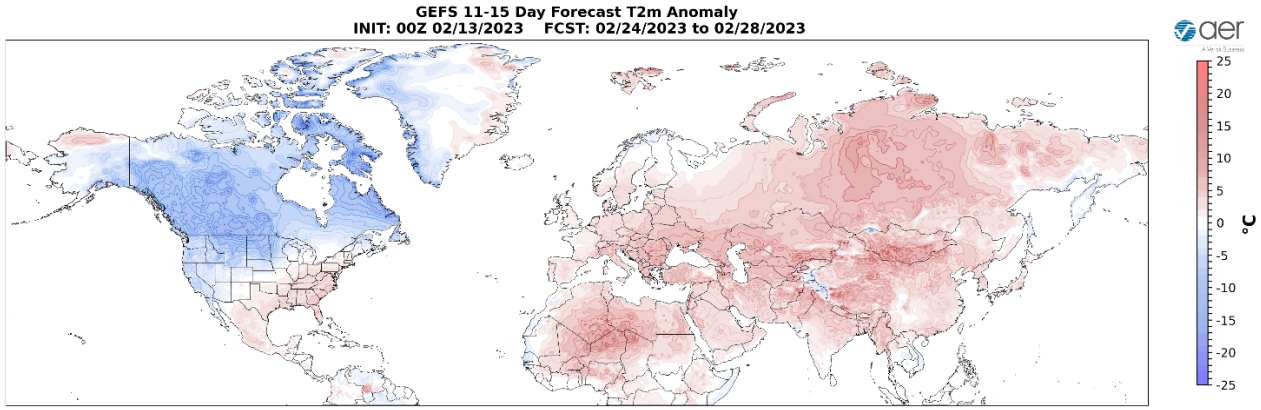

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 24 – 28 February 2023. The forecast is from the 00Z 13 February 2023 GFS ensemble.

Strong ridging/positive geopotential height anomalies south of the Aleutians will continue to anchor deep 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 and Central US with normal to above normal temperatures mostly limited to the Southern and Eastern US (**Figure 9**).

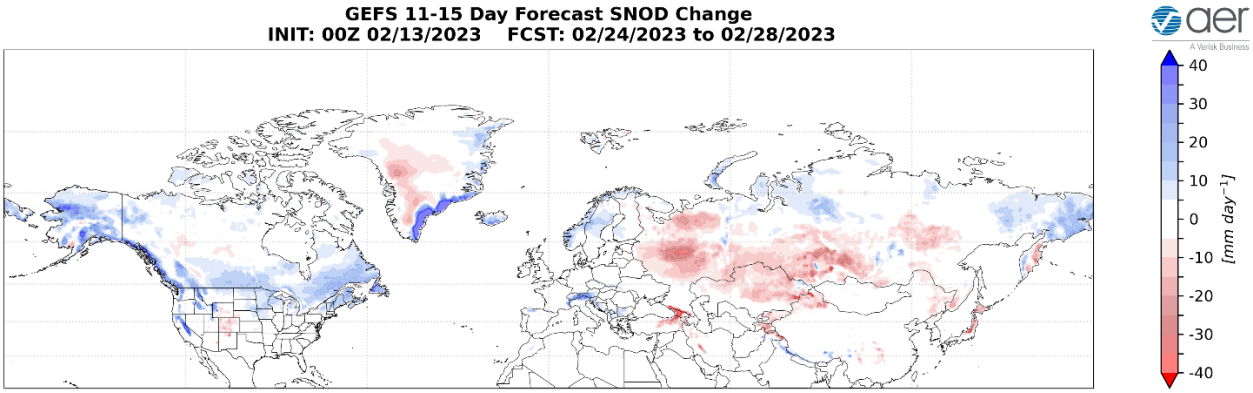

Figure 10. Forecasted snow depth changes (mm/day; shading) from 24 – 28 February 2023. The forecast is from the 00Z 13 February 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Scandinavia, the Alps and Northern Siberia 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 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 warm/positive PCHs throughout the stratosphere and the troposphere (**Figure 11**). However, the warm/positive PCHs in the stratosphere are predicted to strengthen this week and peaking this week in the upper stratosphere and maybe next week in the mid-stratosphere (**Figure 11**). Meanwhile the normal PCHs in the troposphere are predicted to turn mostly cold/negative over the next two weeks (**Figure 11**). The predicted strong warm/positive PCHs in the stratosphere are a result of a likely major sudden stratospheric warming (SSW). The plot is shows downward propagation of the warm/positive PCHs from the upper to mid stratosphere this month and for now only suggestive then possibly into the troposphere in March.

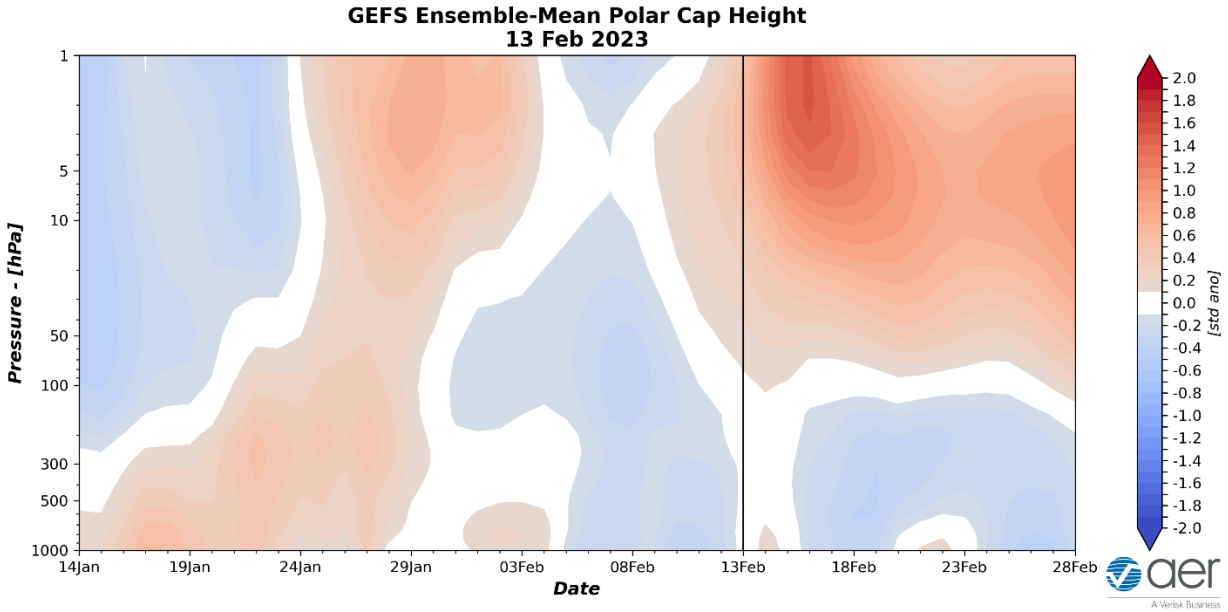

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 13 February 2023 GFS ensemble.

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 AO is predicted to peak the third week of February when the cold/negative PCHs in the lower troposphere are predicted to strengthen (**Figure 11**), with no signs for now of a negative AO (**Figure 1**).

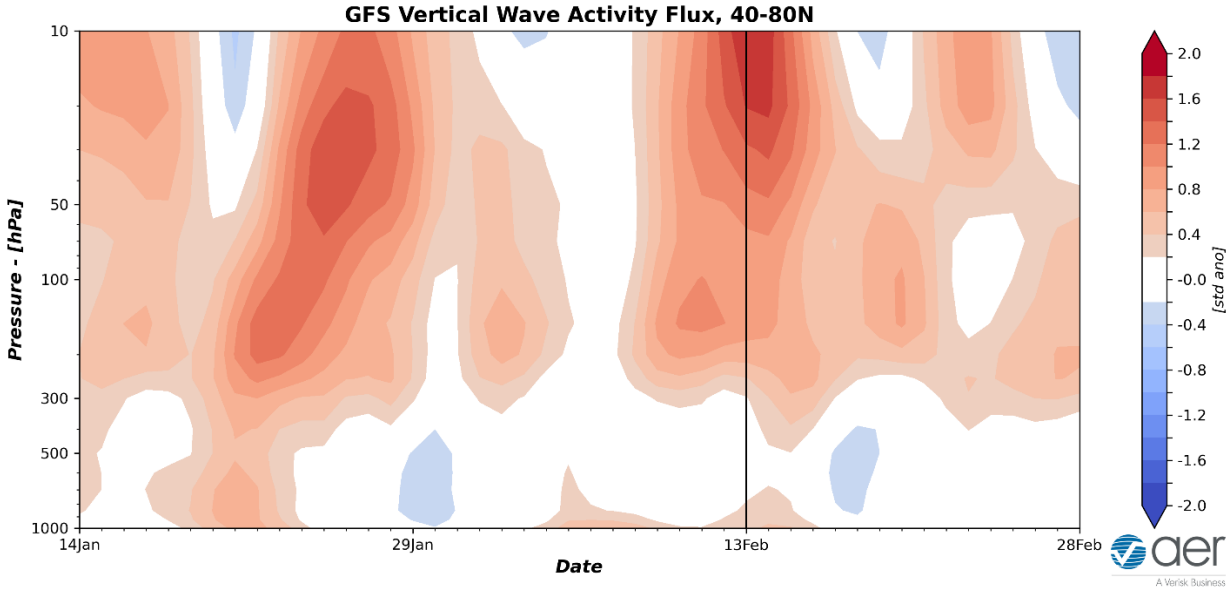

Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 13 February 2023 GFS ensemble.

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 with one peak the last week of January and another peak early this week (**Figure 12**) which has resulted in warming of the polar stratosphere since the end of January (**Figure 11**). The GFS is predicting that the WAFz will remain mostly active this week and next week (**Figure 12**), resulting in warming of the polar stratosphere through the end of February (**Figure 11**).

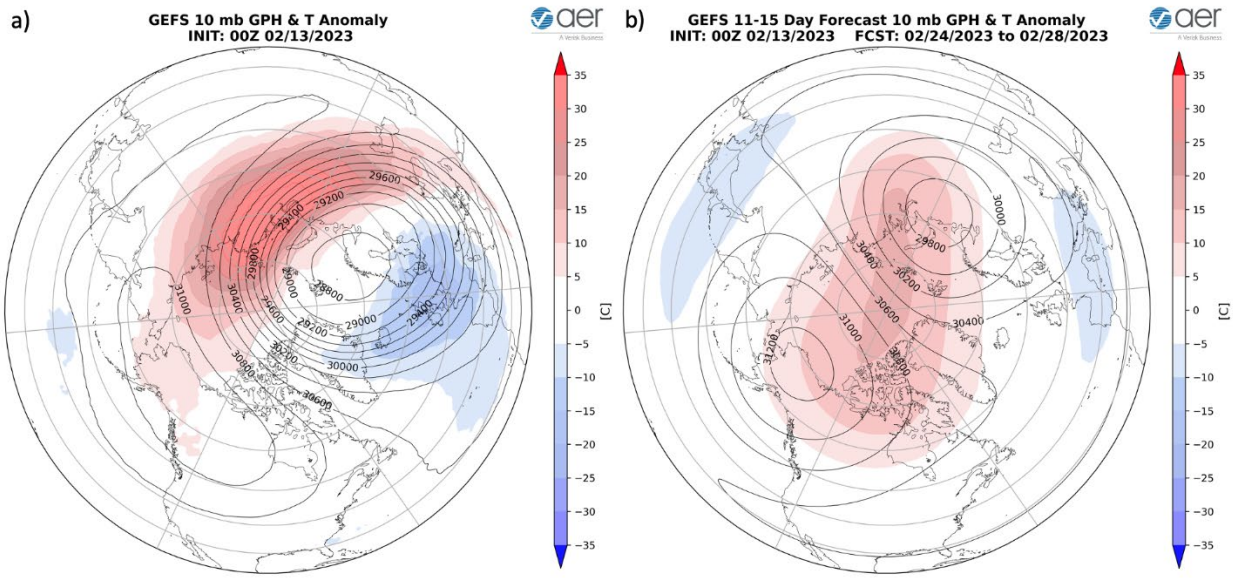

Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 13 February 2023. (b) Same as (a) except forecasted averaged from 24 – 28 February 2023. The forecasts are from the 00Z 13 February 2023 GFS model ensemble.

The more active WAFz has shifted the already weakened stratospheric PV center over towards Scandinavia **(Figure 13a**) with the relatively coldest temperature anomalies across Europe. Coupled with the shifted PV is ridging centered over Alaska and the relatively warmest temperatures across Western Russia aimed at the North Pole in the polar stratosphere (see **Figure 13a**). The persistent active WAFz predicted for the next two weeks will continue to weaken the PV, with the PV shape shifted further south to a position over the Urals with the coldest relative temperatures across Southern Europe and East Asia (see **Figure 13b**). Meanwhile ridging and warming will strengthen with the ridge still 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 remain negative the next two weeks **(Figure 13**).

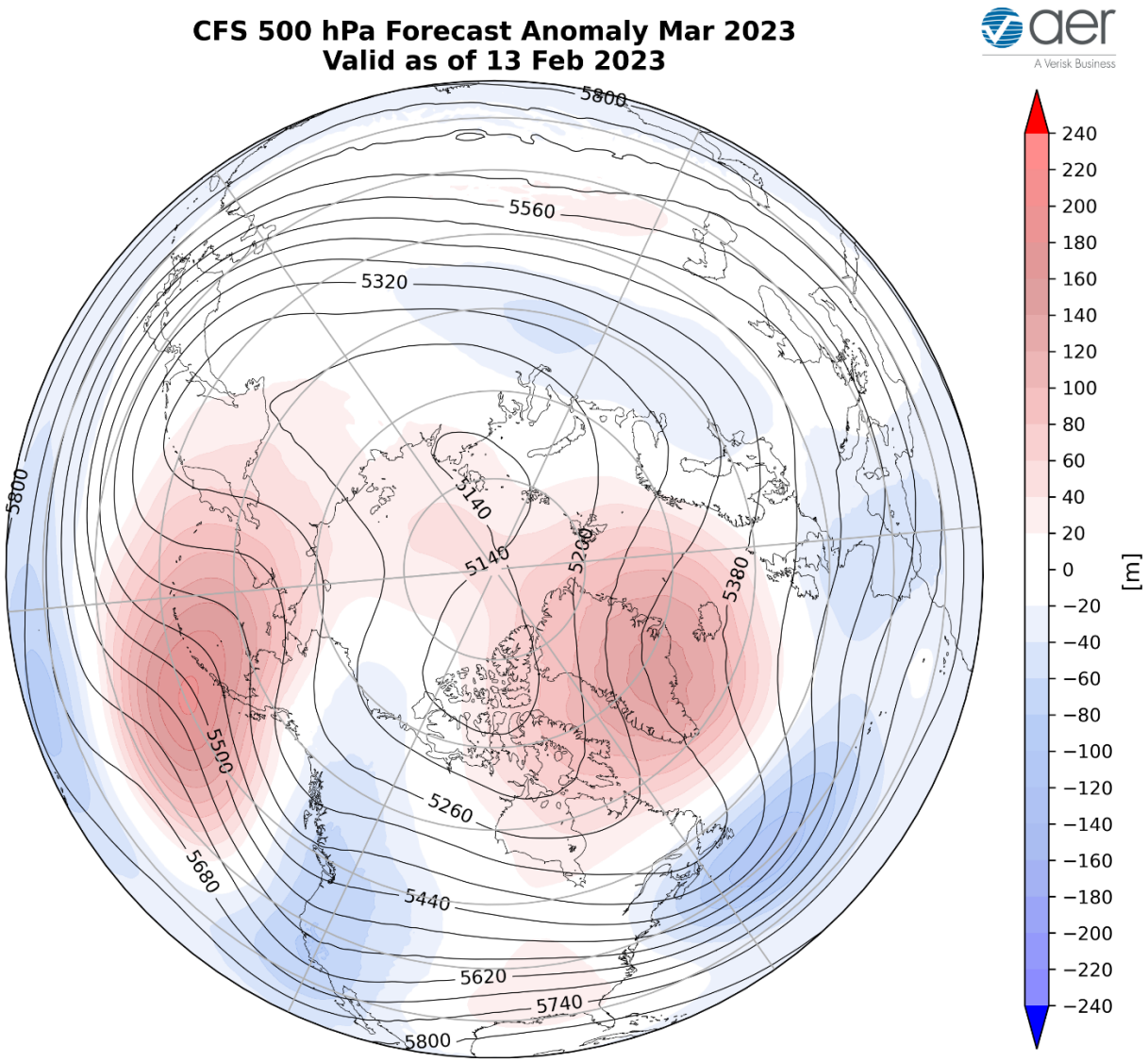

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for March 2023. The forecasts are from the 00Z 13 February 2023 CFS.

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 centered on the Aleutians with troughing across Europe, Northern and Eastern Asia, much of Canada and the Western US (**Figure 14).** This pattern favors

seasonable to relatively warm temperatures across much of Southern Europe and Southern Asia, Eastern Siberia, Northeastern Canada and the Southeastern US with seasonable to relatively cold temperatures across Northern Europe, Northern and Eastern Asia, Alaska, Western and Southern Canada and the Western and Northern US (**Figure 15**)**.**For what it's worth the CFS continues to predict a mid-troposphere and surface temperature pattern which is consistent with a negative NAO forced by a major SSW, though modified by a negative Pacific-North America pattern.

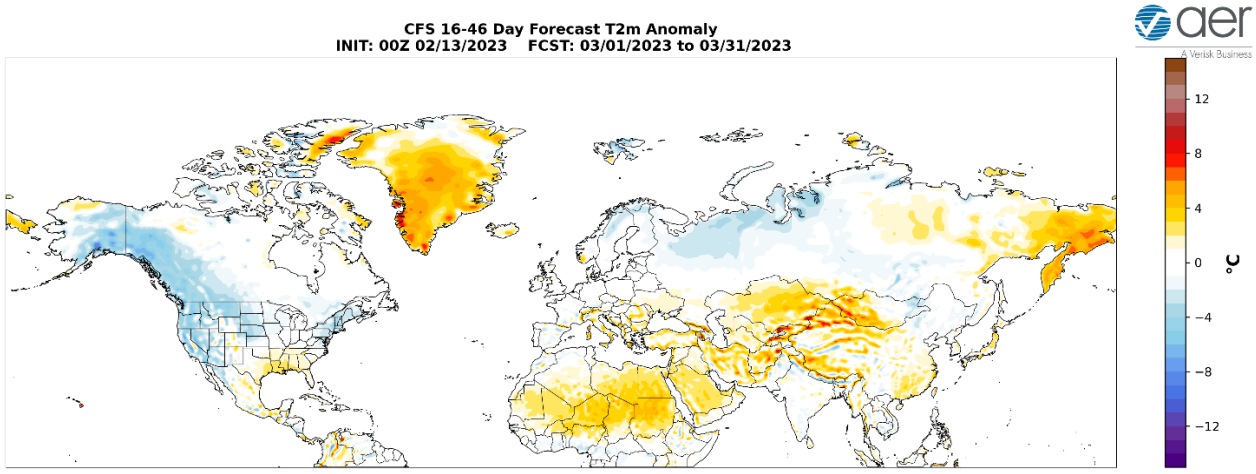

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for March 2023. The forecasts are from the 00Z 13 February 2023 CFS.

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. Certainly the PV has been unusually disrupted in January and February.

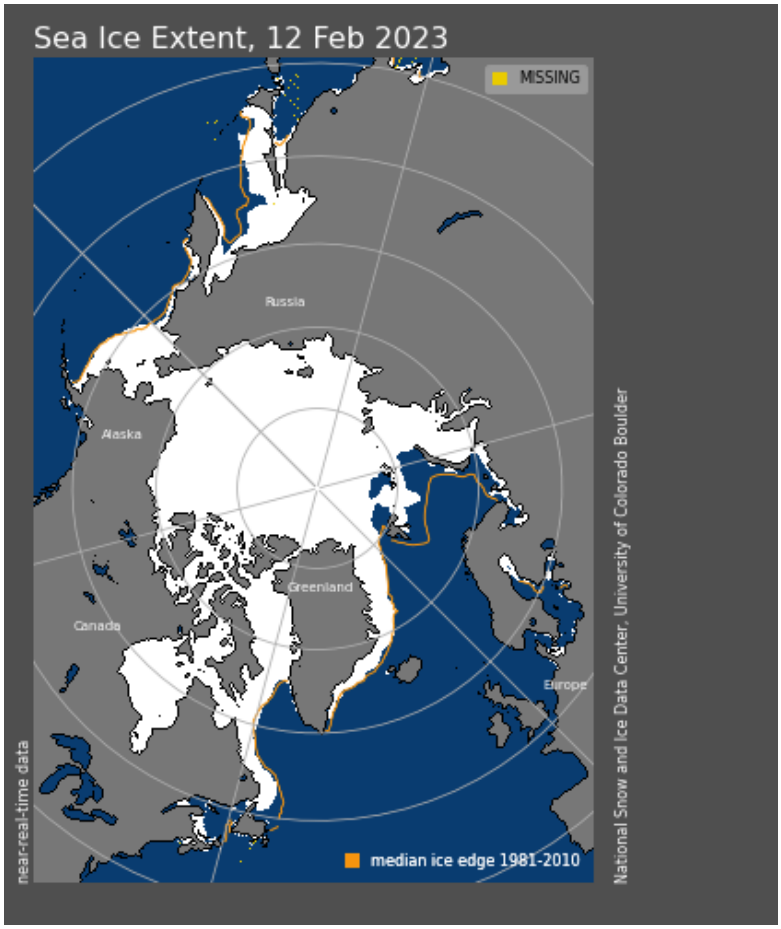

Figure 16. Observed Arctic sea ice extent on 12 February 2023 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC).

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.

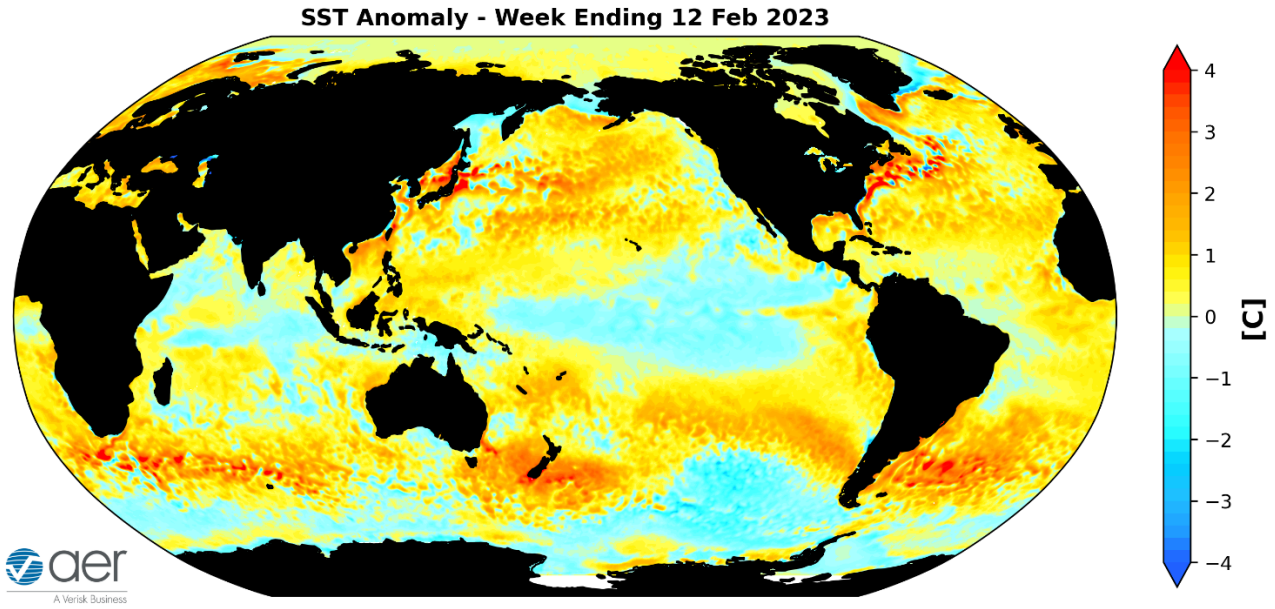

Figure 17. The latest weekly-mean global SST anomalies (ending 12 February 2023). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently the Madden Julian Oscillation (MJO) is in phase six (**Figure 18**). The forecasts are for the MJO to quickly rifle through phases 6, 7 and 8. Phase six favors ridging near the Aleutians, troughing over Alaska, Canada and the Western US with ridging across eastern North America. In phases 7 and 8 favor 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. So far the weather models are not predicting high latitude blocking but that could change. But admittedly this is outside of my expertise.

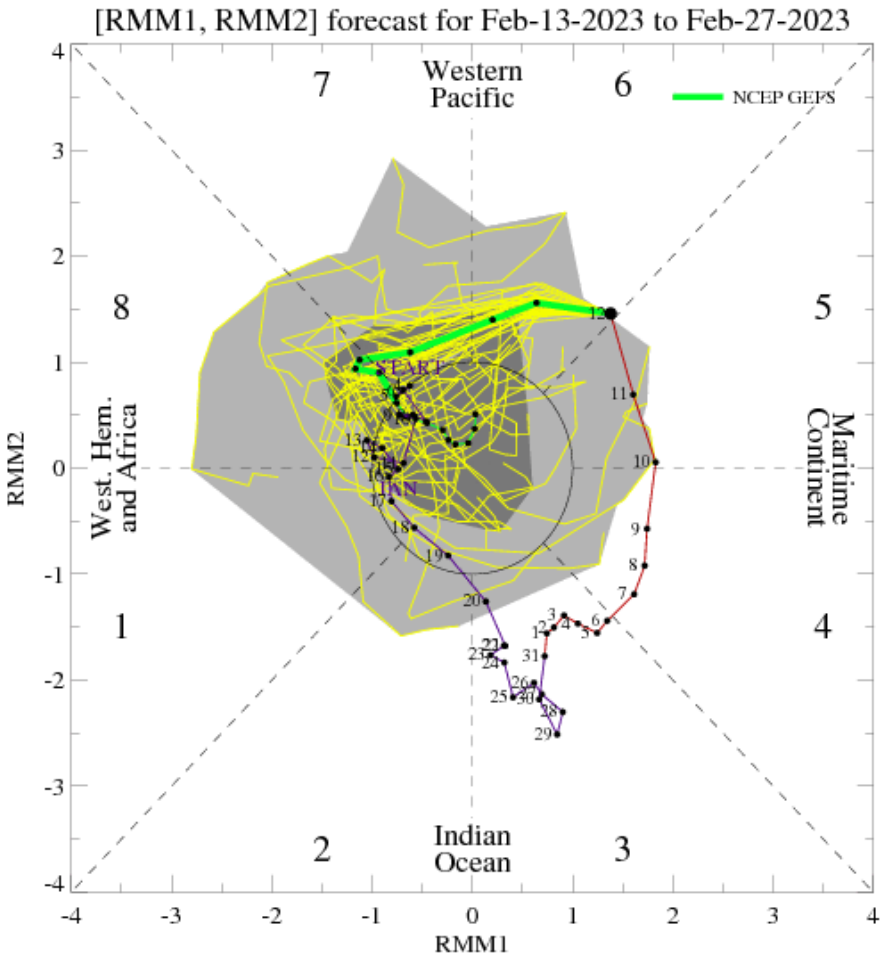

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 13 February 2023 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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 increased this past week mostly across Eurasia with above normal snow cover focused in China. Meanwhile North American snow cover is now below normal (see **Figure 19**). Snow cover is above normal across East Asia, but snow cover extent is below normal in Central Europe and below normal the Eastern US. I expect snow cover to remain stable in the coming weeks but could pick up across the US with predicted colder weather.

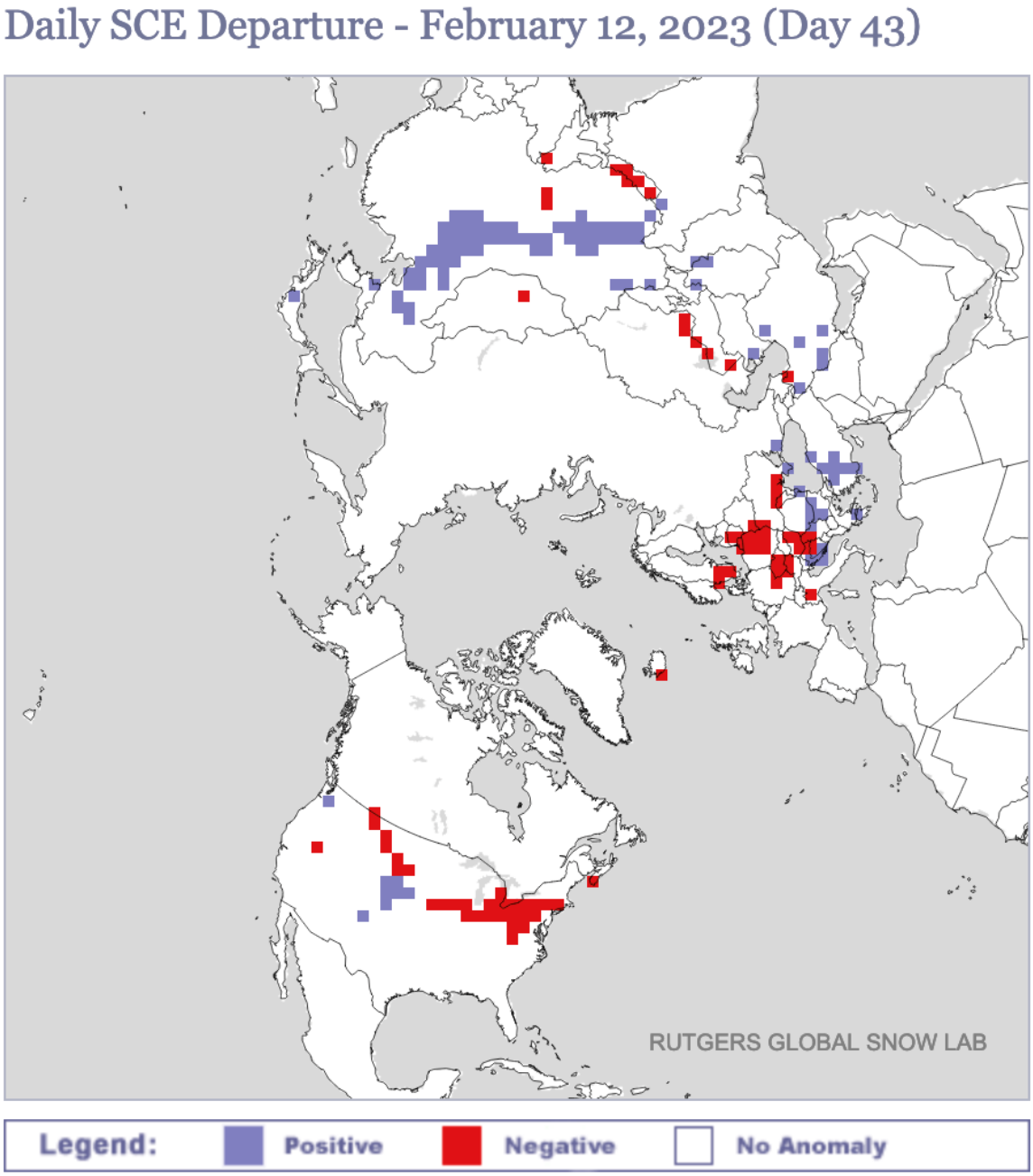

Figure 19. Observed North Hemisphere snow cover anomalies on 12 February 2023. Plot from http://climate.rutgers.edu/snowcover/index.php

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.

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!