

Arctic Oscillation and Polar Vortex Analysis and Forecasts

February 28, 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 slightly positive and is predicted to straddle either side of neutral the next two weeks as pressure/geopotential height anomalies across the Arctic are currently mostly negative and are predicted to remain mostly mixed the next two weeks. The North Atlantic Oscillation (NAO) is currently negative and is predicted to remain negative the next two weeks as pressure/geopotential height anomalies are currently positive and are predicted to remain positive across Greenland the next two weeks.
- This week predicted ridging/positive geopotential height anomalies centered near Iceland will favor troughing/negative geopotential height anomalies across Western Europe with ridging/positive geopotential height anomalies across Eastern Europe. However next week ridging/positive geopotential height anomalies previously centered near Iceland will become centered near Greenland favoring troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height anomalies across Southern Europe. This pattern favors this week normal to below normal temperatures across Western Europe including the United Kingdom (UK) with normal to above normal temperatures across Northern and Eastern Europe. However next week normal to above normal temperatures will become more widespread across Southern Europe with normal to below normal temperatures across Northern Europe including the UK.
- The predicted general pattern across Asia the next two weeks is troughing/negative geopotential height anomalies across Northern Asia with ridging/positive geopotential height anomalies centered across Southern Asia. The induced strong zonal or westerly flow the next two weeks favors normal to above normal temperatures across much of Asia with normal to below normal temperatures limited across far Northwestern Asia and far Northern Siberia.
- The general pattern predicted across North America the next two weeks is ridging/positive geopotential height anomalies centered 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. However, during early March the ridging/positive geopotential height anomalies from Greenland will begin to spread into Northeastern Canada while the ridging south of the Aleutians amplifies and pushes north and west towards the Bering Strait allowing troughing to expand across much of the US. This pattern generally favors this week 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, next week Alaska will transition to mostly above normal temperatures as the Aleutian ridging pushes north into Alaska while the below normal temperatures will push into Eastern Canada and the Eastern US.
- 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 is underway but the coupling is far from textbook and therefore large uncertainties remain.

Plain Language Summary

A major disruption of the polar vortex (PV) is ongoing with no end in sight and is referred to as a major sudden stratospheric warming (SSW; see **Figure 13**). Often following SSWs, more severe wintry weather becomes more widespread across Northern Europe and Asia. Though Europe is trending colder much of Asia is quite mild with colder temperatures spreading across North America (see **Figures 6 and 9**). And though the Eastern US has been mild for much of the winter, during the first half March the colder temperatures should sweep into the Eastern US. Though the classical response to SSWs including high pressure across Greenland and colder temperatures across Northern Europe are predicted they are predicted to be transitory (see **Figure 8 and Figure ii**).

Impacts

Today is the last day of meteorological winter. I think that it is no secret that I have struggled trying to understand the dynamics of the atmosphere, the behavior of the polar vortex (PV) and the relationship to the weather. But my intellectual struggles don't impact the winter forecast and I will share shortly the winter temperature anomaly observations with the temperature anomaly forecasts posted in the [28 November 2022](#) blog. I will provide my own perspective about the forecasts, and everyone can make their own judgments.

The long duration and what I consider impressive PV disruption, that began in late January continues at least into early March. In **Figure i**, I once again present the polar cap geopotential height anomalies (PCHs) limited to the North Atlantic sector. It shows downward propagation or drip of warm/positive PCHs from the stratosphere through the troposphere to the surface this week (see **Figure 11**). The warm/positive PCHs for the full Arctic are predicted to make it to the surface next week so following the North Atlantic touchdown by about a week. Not sure the reason for the delay in the downward propagation of the PCHs between the North Atlantic sector only and the full Arctic by about a week but you can see the impact in the sensible weather. High latitude blocking this week is limited to Iceland and Greenland (see **Figure 2**) but stretches across all of the North American Arctic next week (see **Figure 5**). High pressure across the North American Arctic looks to finally force a colder pattern in the Eastern US.

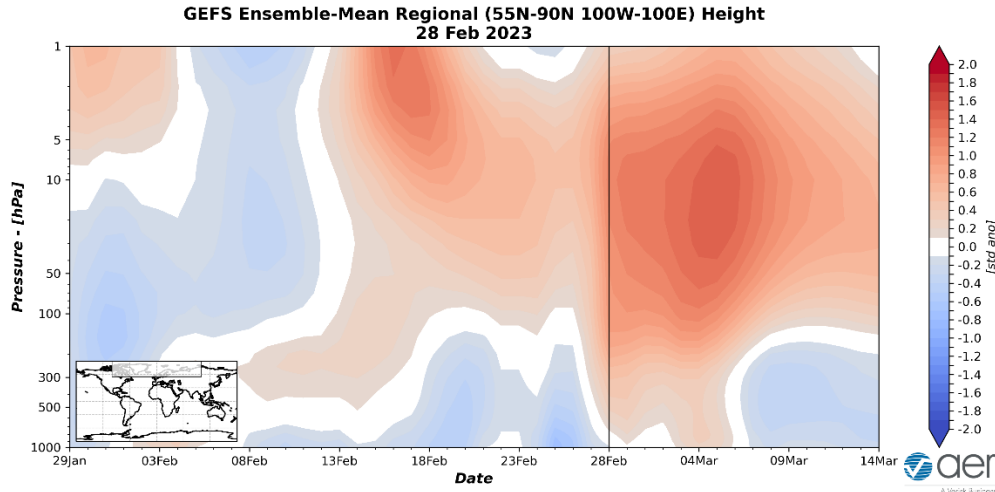


Figure i. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) but limited to the North Atlantic region (see insert) standardized anomalies. The forecast is from the 00Z 20 February 2023 GFS ensemble.

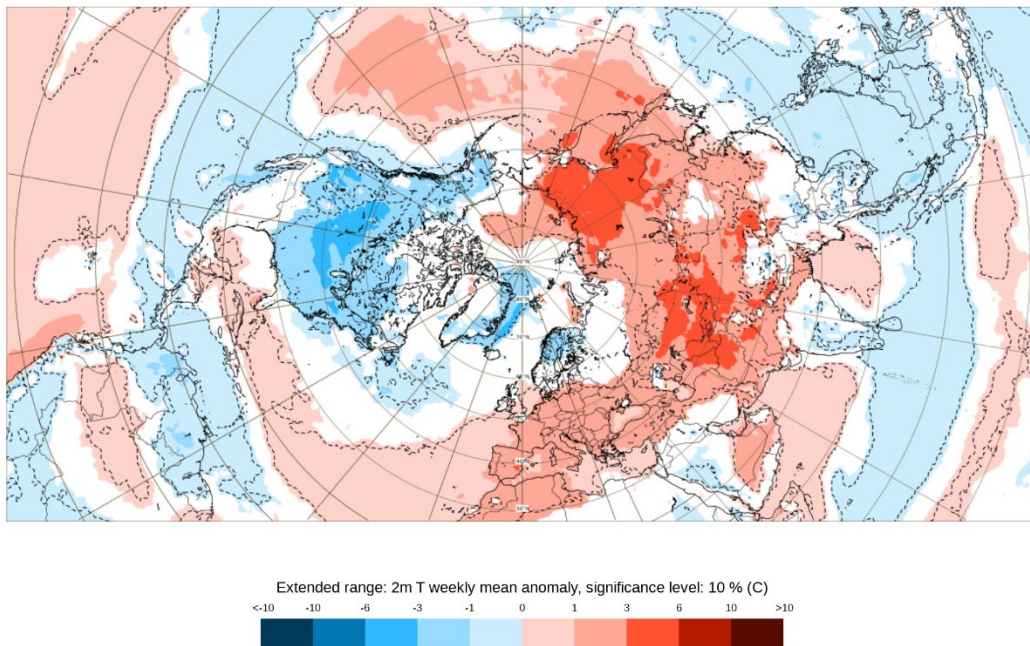
I am sure readers come to the blog to find answers and not more questions but the questions that I have are more interesting than my answers. For now, I am going to ignore the elephant in the room, what is the physical mechanism responsible for downward propagation of warm/positive PCHs of the of negative AO? There are several educated guesses, but I don't think that we really fully understand the mechanism. I was hoping this event was going to help provide an answer but so far, I remain as puzzled or possibly even more so than before the event. My first question is what is the cause of the time delay or separation in downward propagation between the PCHs limited to the North Atlantic and that of the pan or full Arctic? The second question is why even following the pan-Arctic downward propagation of warm/positive PCHs, why are the resultant high latitude blocking/high pressure limited to the North American sector of the Arctic while the Eurasian sector of the Arctic remains dominated by troughing/low pressure (see **Figure 5**)? Or in other words why doesn't the high latitude blocking in the troposphere include the entire Arctic as it does in the stratosphere (see **Figure 13**)? The strong low pressure along the Eurasian North Slope is forcing a mild westerly flow across Northern Asia rather than a colder northerly or easterly flow more typical post a major SSW.

And related to this why is this now the third major sudden stratospheric warming (SSW) in a row (2019, 2021 and 2023) where the cold surface temperature response has been focused in North America with a weak or tepid response in Eurasia? As I have been saying for several weeks now, the classical surface temperature response to a major SSW are widespread cold temperatures across Northern Eurasia yet for the third time in a row that really hasn't happened with 2018, the last time there was the textbook or classical temperature response. Yes, relatively cold temperatures are predicted across Northern Europe in the coming week or so but overall impressive warmth is predicted

across Europe and especially Asia (see **Figures 6** and **9**). And this seems to me a continuation of a recent trend where spring arrives more aggressively across Eurasia than North America. I am usually skeptical of ECMWF weekly forecasts beyond week two but here is the ECMWF ensemble temperature forecast for mid-March (see **Figure ii**). It really strikes me how cold (relative to normal, not absolute cold) the forecast is for North America (it rarely is this cold) and in contrast how warm the forecast is for Eurasia post the SSW? Why the lopsidedness especially typically the lopsidedness should be the other way following an SSW?

2 m temperature: Weekly mean anomalies

Base time: Mon 27 Feb 2023 Valid time: Mon 13 Mar 2023 - Mon 20 Mar 2023 (+504h) Area : North Pole



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Source: www.ecmwf.int
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Figure ii. Forecasted surface temperature anomalies (°C; shading) from 13 – 20 March 2023. The forecast is from the 00Z 27 February 2023 ECMWF ensemble. Chart downloaded from <https://charts.ecmwf.int/>

I do think one reason North America is cold because wave reflection that started earlier in February continues. In **Figure iii**, I show this week's forecast for the Vertical Wave Activity Flux (WAFz) in the vertical and longitudinal directions and as I have been

showing all winter it shows upward WAF over Eurasia and downward WAF over the eastern North Pacific and North America that helps maintain the ridging near the Aleutians with downstream troughing across Canada.

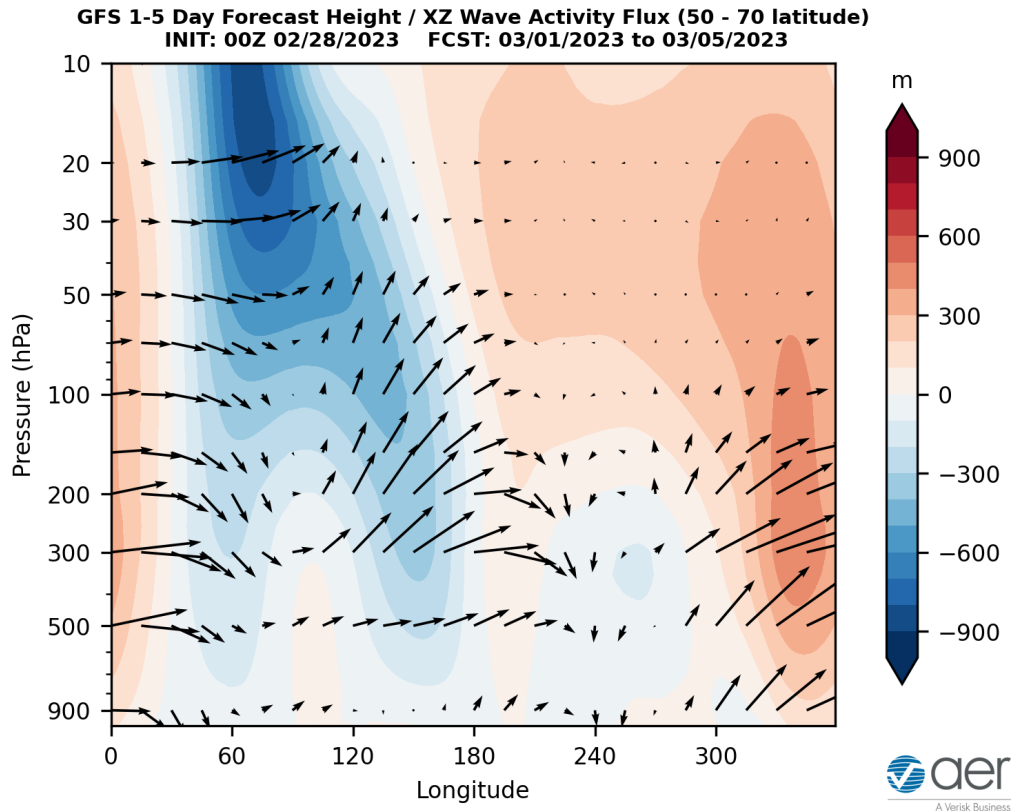


Figure iii. Longitude-height cross section of geopotential eddy height anomalies (shading) and wave activity flux (vectors) forecasted for 1 – 5 March 2023. The forecast is from the 00Z 28 February 2023 operational GFS.

I will close with next week's forecast for the WAF in the vertical and latitudinal directions (see **Figure iv**). It is showing downward WAF throughout the high latitudes. This is the signature of the more classical wave reflection as described early on by Judith Perlwitz, Nili Harnik and others [e.g., [Perlwitz and Harnik 2003](#)]. When the WAF becomes downward in the zonal mean this tends to spin up the stratospheric PV, tends to negate any high latitude blocking and supports a positive AO. So, I do wonder if this could prevent or weaken future drips of warm/positive PCHs after next week. But at this point Eurasia doesn't need much of an excuse to remain warm.

GFS 6-10 Day Forecast UWind / YZ Wave Activity Flux (0 - 360 longitude)
INIT: 00Z 02/28/2023 FCST: 03/06/2023 to 03/10/2023

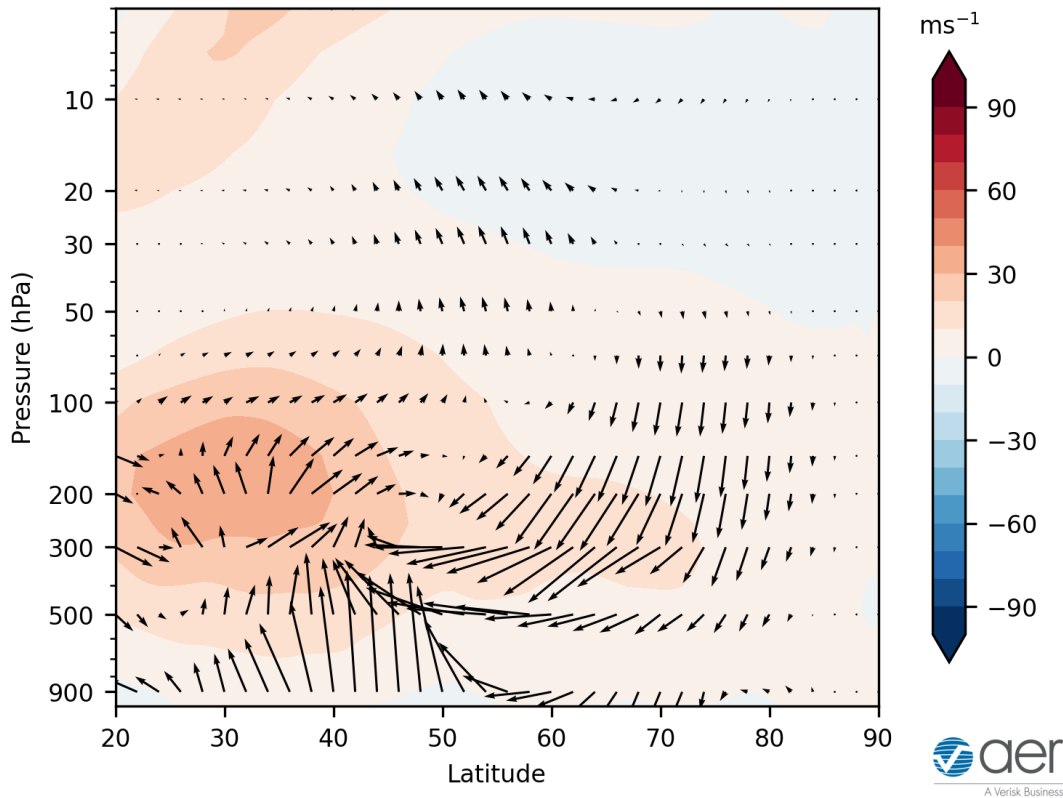


Figure iv. Latitude-height cross section of zonal-mean zonal wind (shading) and wave activity flux (vectors) forecasted for 6 – 10 March 2023. The forecast is from the 00Z 28 February 2023 operational GFS.

Wednesday Update

Just a couple of additional thoughts from yesterday. Today's pan-Arctic PCHs forecast from the GFS still shows the downward propagation from the stratosphere making it to the surface starting this weekend and through next week (see **Figure v**). This is important because as I have argued in the blog and in papers these full atmospheric column downward propagation or "drips" coincide with an increase in the probability of severe winter weather across the NH. Of course, it is all relative but next week some impressive cold possible across Northern Europe but especially across North America (see **Figures 6** and **9**). Also, it does look like a nice snowstorm for Central New England this weekend and then next week snow possibilities increase for Europe and the Plains of the US and Canada. Also **Figure v** does suggest another downward propagation or drip of warm/positive PCHs is possible after March 15th.

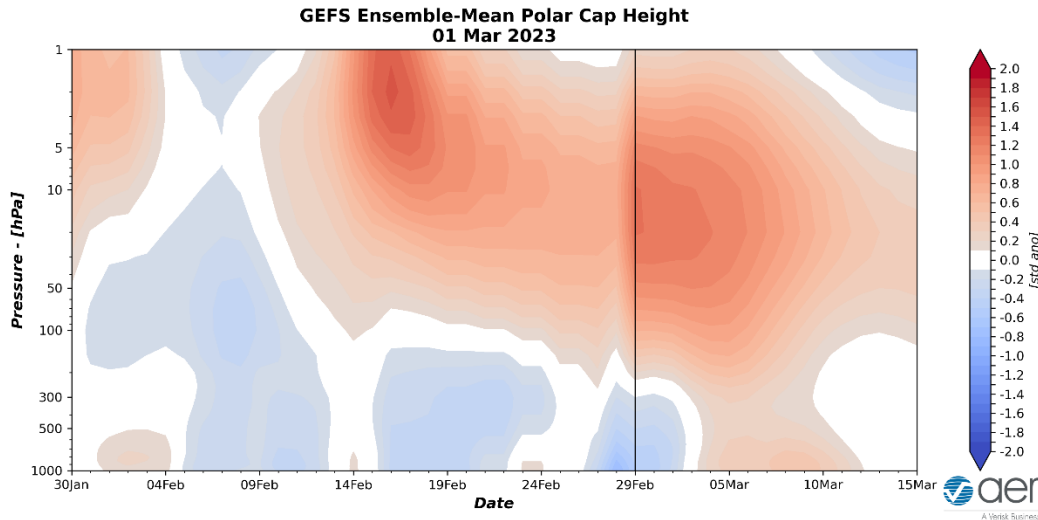


Figure v. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 1 March 2023 GFS ensemble.

Yesterday I did discuss the downward WAFz predicted for next week associated with the more classical wave reflection, a strengthening PV and positive AO. But I did notice today that the downward WAFz does coincide with the downward propagation or “drip” predicted for next week. So, I am very curious to see how everything plays out.

Finally the reason why I initially got excited by the GFS forecast from February 5th of a PV split, which I [tweeted](#) about is because it is my experience that there is a reflection of the PV low center in the mid-troposphere that can help generate not only cold air but snowstorms. To be fair the PV center that closer to the US Northeast coast is weaker so far than predicted but it did form (see **Figure via**). I already discussed the mid-tropospheric low center over Western Russia that was not well predicted and contributed to colder conditions for the region (and I assume snowier). But now we are seeing similar impacts for the Northeastern US. A closed low is forming in the mid-troposphere (see **Figure vib**), without which there would be no snowstorm in New England this weekend. So though I don’t know if this major SSW will be classified as a PV displacement or split but in my opinion in practical terms it is a PV split. That feature is predicted to strengthen next week, and it will be interesting to see if it can

generate more snow in the Northeastern US or simply spawn fish storms.

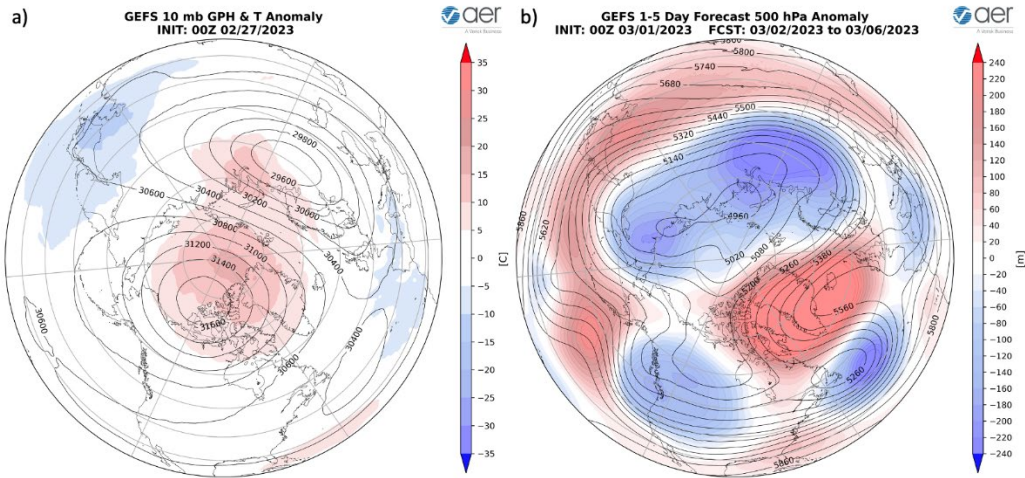


Figure vi. (a) Initialized 500 mb geopotential heights (dam; contours) and anomalies (m; shading) across the Northern Hemisphere for 27 February 2023. (b) 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere forecasted averaged from 2 – 6 March 2023. The forecasts are from the 00Z 1 March 2023 GFS model ensemble.

Recent and Very Near Term Conditions

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

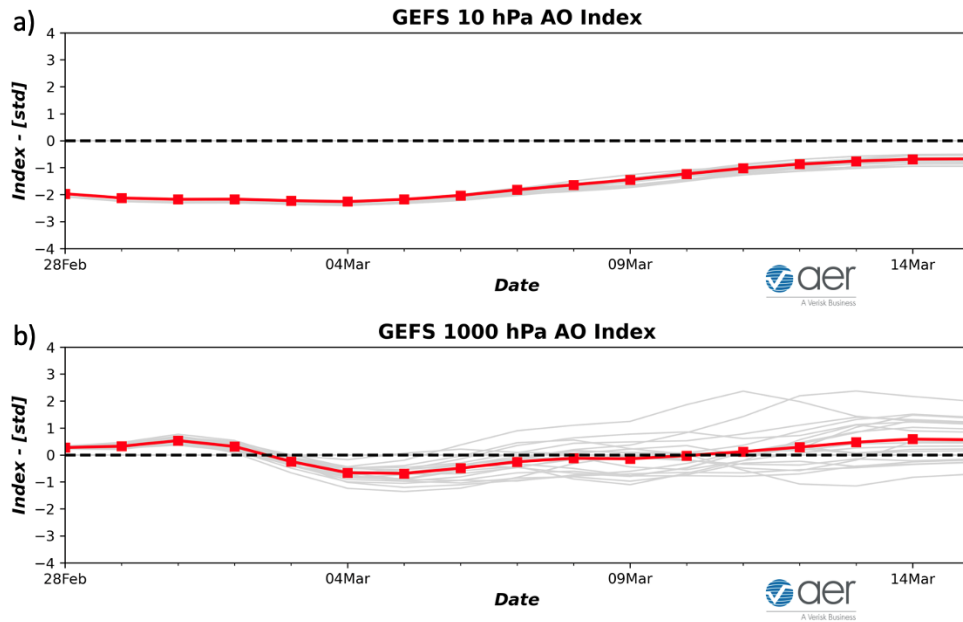


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 28 February 2023 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 28 February 2023 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Predicted ridging/positive geopotential height anomalies centered near Iceland will favor troughing/negative geopotential height anomalies across Western Europe with more ridging/positive geopotential height anomalies across Eastern Europe this period (**Figure 2**). This pattern will favor normal to below normal temperatures across Western Europe including the UK with normal to above normal temperatures across Northern and Eastern European (**Figure 3**). Troughing/negative geopotential height anomalies across Northwestern Asia and Eastern Siberia are predicted to bookend ridging/positive geopotential height anomalies centered in Central Asia and across much of Southern Asia (**Figure 2**). This pattern favors normal to below normal temperatures limited to Northwestern Asia and Eastern Siberia with normal to above normal temperatures widespread across much of Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 hPa Anomaly
INIT: 00Z 02/28/2023 FCST: 03/01/2023 to 03/05/2023

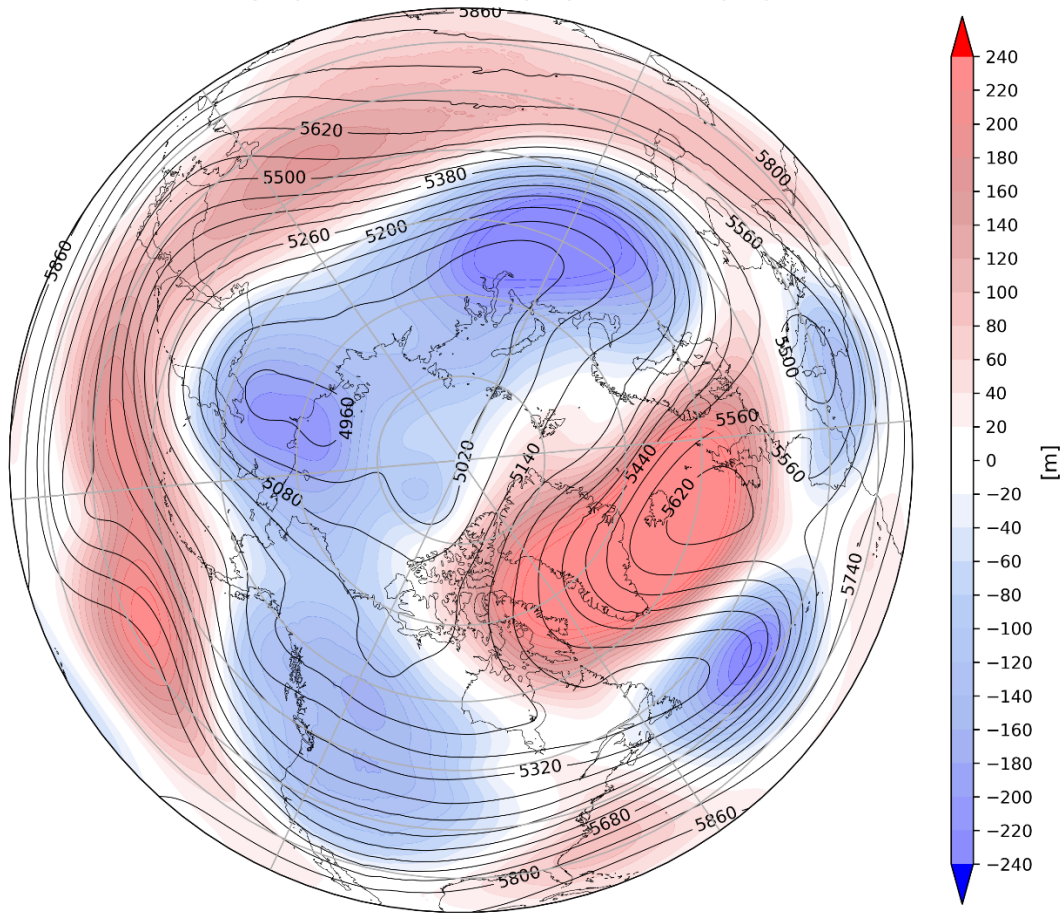


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 1 – 5 March 2023. The forecasts are from the 00z 28 February 2023 GFS ensemble.

Predicted ridging/positive geopotential height anomalies centered south of the Aleutians will favor troughing/negative geopotential height anomalies across Alaska, Western Canada and the Western US with more ridging/positive geopotential height anomalies across Eastern Canada and the Eastern US (**Figure 2**). The pattern will favor normal to below normal temperatures across Alaska, Western Canada and the Western US with normal to above normal temperatures across Eastern Canada and the Eastern US (**Figure 3**).

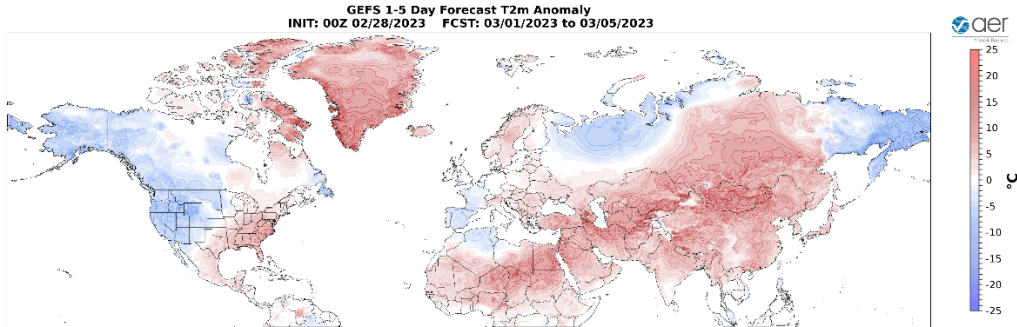


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 1 – 5 March 2023. The forecast is from the 00Z 28 February 2023 GFS ensemble.

Trouging and/or cold temperatures will support new snowfall to Norway, Northern Siberia and the Tibetan Plateau while mild temperatures will support snowmelt across the Alps, the Pyrenes, Eastern Europe, Western Russia, Central Asia and Southern Siberia (**Figure 4**). Trouging and/or cold temperatures will support new snowfall across Alaska, Western Canada and the Great Lakes while mild temperatures will support snowmelt across Southwest Alaska, Central and Southeastern Canada, the Canadian Maritimes, California and Northern New England (**Figure 4**).

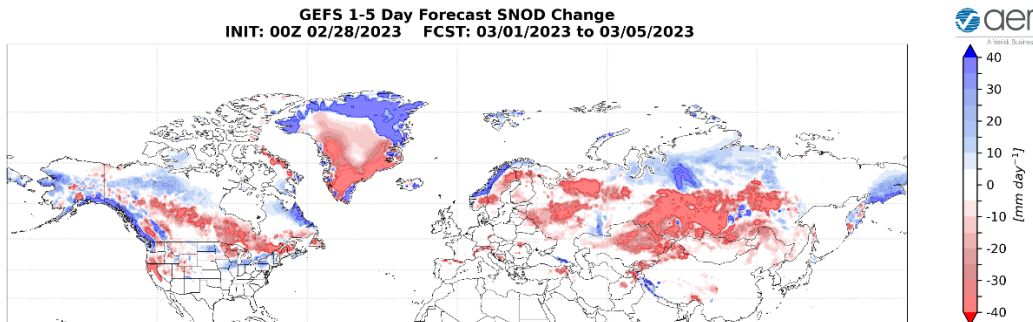


Figure 4. Forecasted snow depth changes (mm/day ; shading) from 1 – 5 March 2023. The forecast is from the 00Z 28 February 2023 GFS ensemble.

Near-Term

1-2 week

The AO is predicted to trend towards neutral or even negative this period (**Figure 1**) as geopotential height anomalies become increasingly positive across the North American sector of the Arctic and negative across the Eurasian sector of the Arctic (**Figure 5**). With positive geopotential height anomalies across Greenland (**Figure 5**), the NAO is predicted to remain negative this period.

GEFS 6-10 Day Forecast 500 hPa Anomaly
INIT: 00Z 02/28/2023 FCST: 03/06/2023 to 03/10/2023

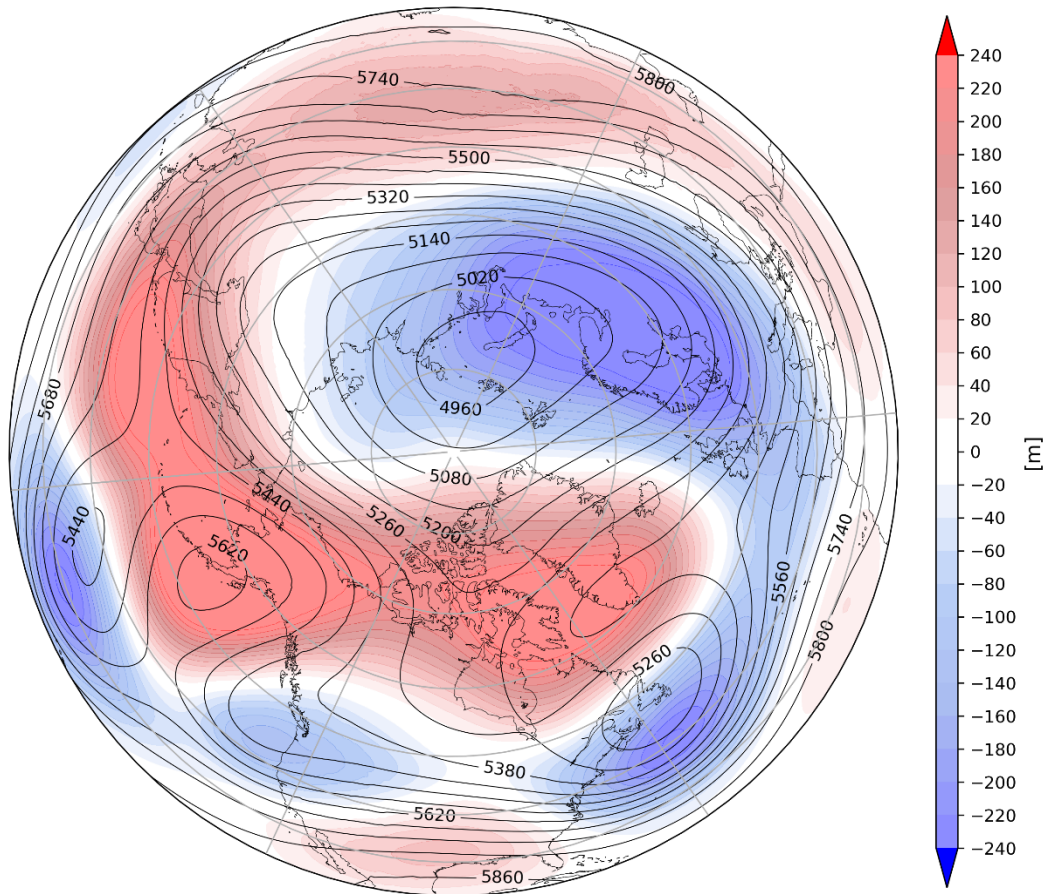


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 6 – 10 March 2023. The forecasts are from the 00z 28 February 2023 GFS ensemble.

Amplifying ridging/positive geopotential height anomalies across Greenland will support widespread troughing/negative geopotential height anomalies across much of Europe (**Figure 5**). This favors a classical negative NAO pattern with normal to below normal temperatures across Northern Europe including the UK with normal to above normal temperatures across Southern Europe (**Figure 6**). Ridging/positive geopotential height anomalies across Greenland favors troughing/negative geopotential height anomalies across Northern Asia with ridging/positive geopotential height anomalies across Southern Asia this period (**Figure 5**). The resultant strong zonal or westerly flow pattern still favors widespread normal to above normal temperatures across Asia but focused in Central Asia with normal to below normal temperatures mostly limited to Northwest Russia and Northern Siberia (**Figure 6**).

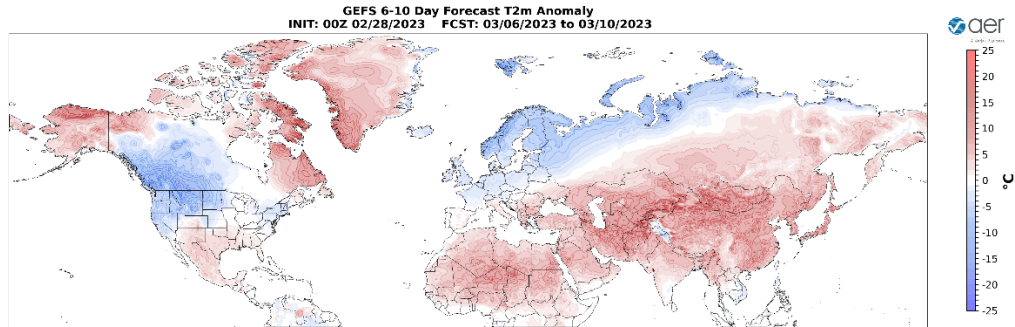


Figure 6. Forecasted surface temperature anomalies (°C; shading) from 6 – 10 March 2023. The forecast is from the 00Z 28 February 2023 GFS ensemble.

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

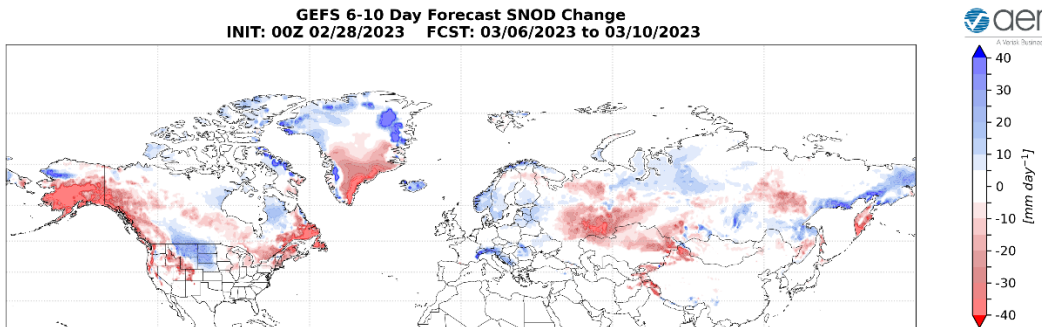


Figure 7. Forecasted snow depth changes (mm/day; shading) from 6 – 10 March 2023. The forecast is from the 00Z 28 February 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Scandinavia, the Baltics, the Alps and parts of Siberia while mild temperatures will support snowmelt in Northwestern Russia, Central and Northeast Asia (**Figure 7**). Troughing and/or cold temperatures will support new snowfall across Northern Alaska, across the Canadian Southern Plains and the US Northern Plains while mild temperatures will support snowmelt in Southern Alaska, the West Coast of Canada, Southeastern Canada, the Western US, the Great Lakes and the Northeastern US (**Figure 7**).

3-4 week

With mixed geopotential height anomalies across the Arctic and with mixed geopotential height anomalies across the mid-latitudes this period (**Figure 8**), the AO should remain near neutral this period (**Figure 1**). With mostly positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO will likely remain slightly negative to neutral this period.

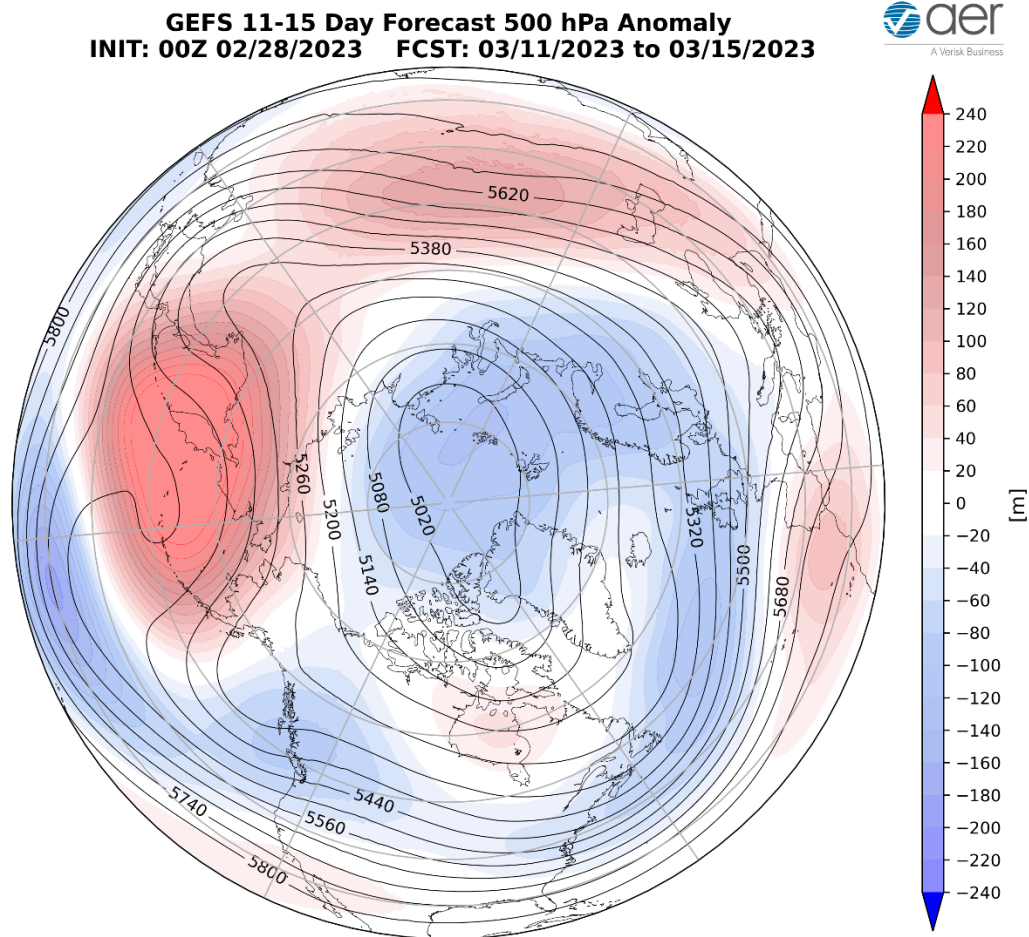


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 11 – 15 March 2023. The forecasts are from the 00z 28 February 2023 GFS ensemble.

Ridging/positive geopotential height anomalies centered across Greenland will continue to support widespread troughing/negative geopotential height anomalies across Europe with the exception of ridging/positive geopotential height anomalies across Spain this period (**Figure 8**). This pattern should continue to favor a classic negative NAO pattern with normal to below normal temperatures across Northern Europe including the UK with normal to above normal temperatures across Southern Europe (**Figures 9**). A deep trough/negative geopotential height anomalies center is predicted to persist over Western Russia with widespread ridging/positive geopotential height anomalies spread

across Central Asia and Eastern Siberia this period (**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 (**Figure 9**) this period.

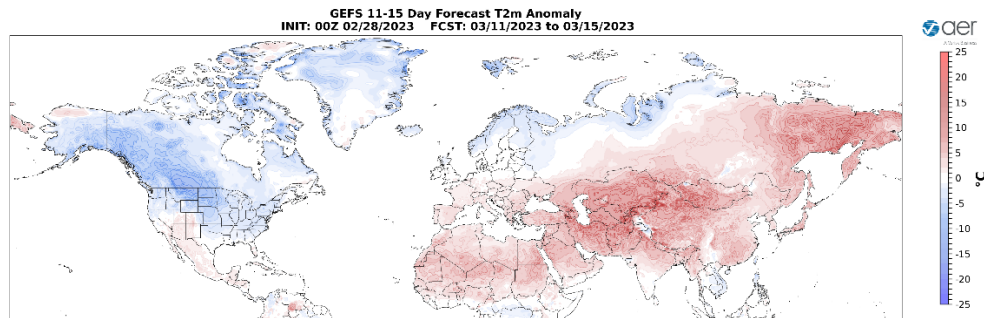


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 11 – 15 March 2023. The forecast is from the 00Z 28 February 2023 GFS ensemble.

Persistent ridging/positive geopotential height anomalies south of the Aleutians will continue to push northwestward into Eastern Siberia while anchoring troughing/negative geopotential height anomalies across Canada and the Northern US with more ridging/positive geopotential height anomalies centered in the Southwestern US 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 northern Alaska and in the Southwestern US (**Figure 9**).

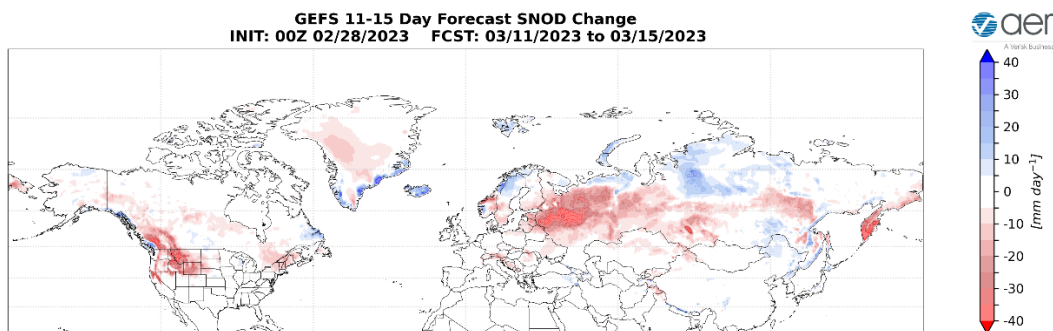


Figure 10. Forecasted snow depth changes (mm/day ; shading) from 11 – 15 March 2023. The forecast is from the 00Z 28 February 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across northern Scandinavia and parts of Siberia while mild temperatures will support snowmelt scattered throughout Europe and Asia (**Figure 10**). Troughing and/or cold temperatures will support new snowfall along both coasts of Canada while mild temperatures will support snowmelt scattered throughout Alaska, Canada and the Northern US (**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 upper troposphere with cold/negative PCHs in the mid to low-troposphere (**Figure 11**). However, the warm/positive PCHs in the mid stratosphere are predicted to strengthen this week and then weaken next week (**Figure 11**). Meanwhile the cold/negative PCHs in the troposphere are predicted to turn mostly warm/positive next week as warm/positive PCHs “drip” downs from the stratosphere into the troposphere commonly observed following a major sudden stratospheric warming (SSW; **Figure 11**). As long as warm/positive PCHs persist in the lower stratosphere more “drips” into the troposphere are possible in the coming weeks.

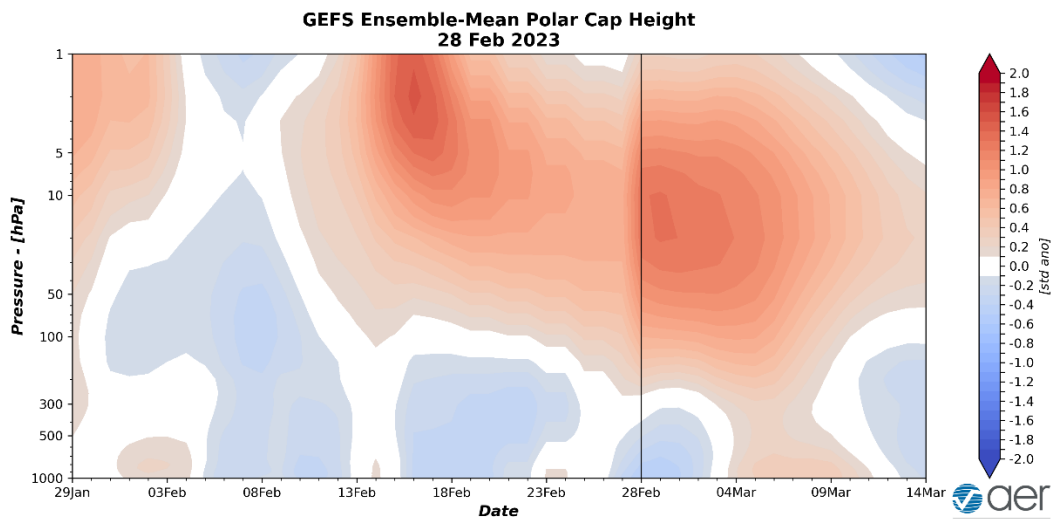


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 28 February 2023 GFS ensemble.

The mostly cold/negative PCHs in the lower troposphere this week (**Figure 11**) are consistent with the predicted weakly positive surface AO (**Figure 1**). However, the AO is predicted to become more mixed to negative next week (**Figure 1**) coinciding when warm/positive PCHs in the lower stratosphere are predicted to “drip” into the troposphere (**Figure 11**).

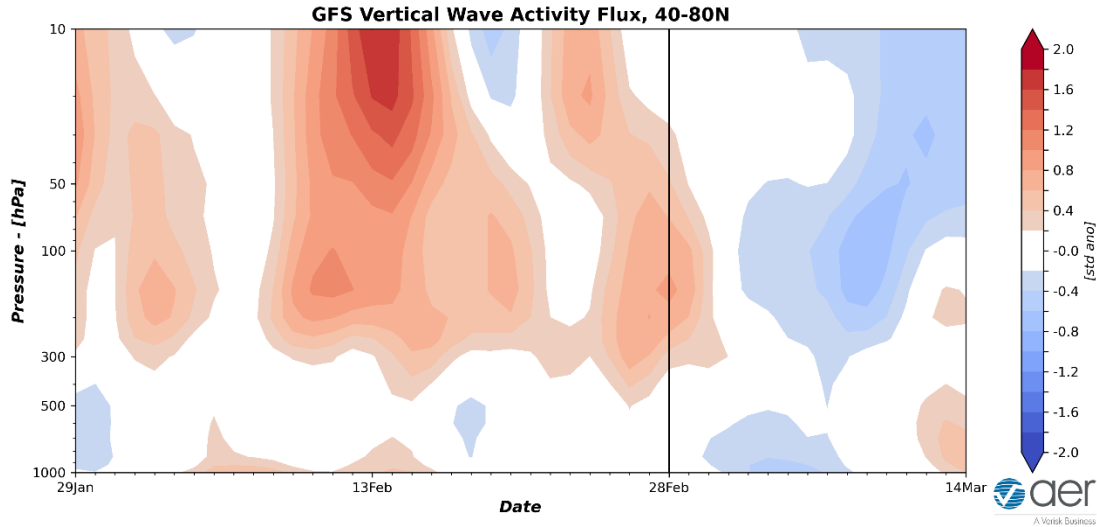


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 28 February 2023 GFS ensemble.

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 in mid-February (**Figure 12**) which has resulted in warming of the polar stratosphere since the end of January and now a major SSW the last two weeks of February (**Figure 11**). The GFS is predicting that the WAFz will remain mostly active this week (**Figure 12**), resulting in a second peak of the major SSW in the mid- stratosphere this week (**Figure 11**). However next week the WAFz is predicted to become strongly negative.

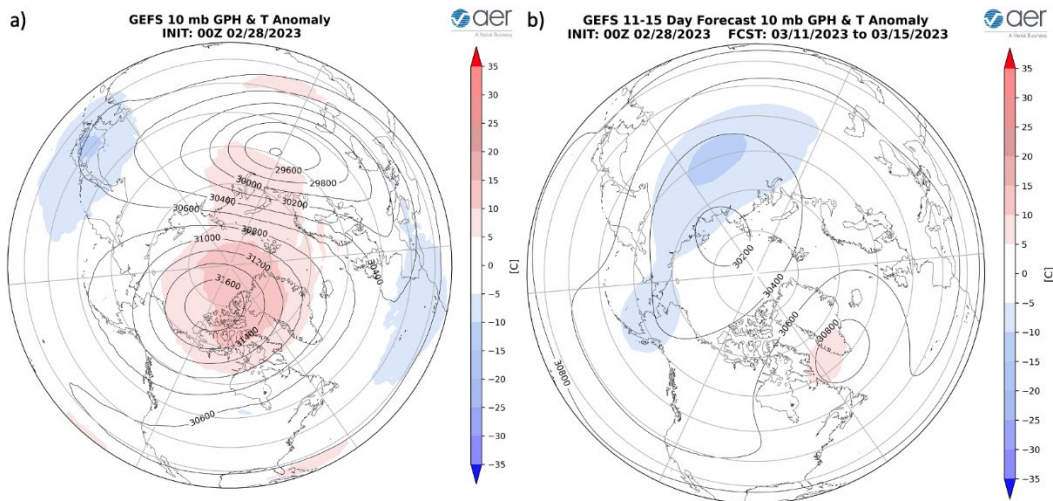


Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 28 February 2023. (b) Same as (a) except forecasted averaged from 11 – 15 March 2023. The forecasts are from the 00Z 28 February 2023 GFS model ensemble.

The more active WAFz has shifted the already weakened stratospheric major PV center over towards Northwestern Russia (**Figure 13a**) with the relatively coldest temperature anomalies across mid latitudes centered on Europe and East Asia. Coupled with the shifted PV, is ridging centered across the Canadian Archipelagos and with warming extending from the Urals across the North Pole and into Northern Canada with the relatively warmest temperatures centered over the North Pole in the polar stratosphere this week (see **Figure 13a**). There is also a predicted minor PV center off the US East Coast (see **Figure 13a**). The persistent active WAFz predicted this week will continue to weaken the PV, with the major PV center shifted to a position over East Asia with the coldest relative temperatures across Siberia and Alaska in the polar stratosphere (see **Figure 13b**). Meanwhile ridging and warming will become centered across Greenland (see **Figure 13b**). With the ongoing weakening of the PV, the stratospheric AO is predicted to remain negative the next two weeks (**Figure 13**).

**CFS 500 hPa Forecast Anomaly Mar 2023
Valid as of 28 Feb 2023**

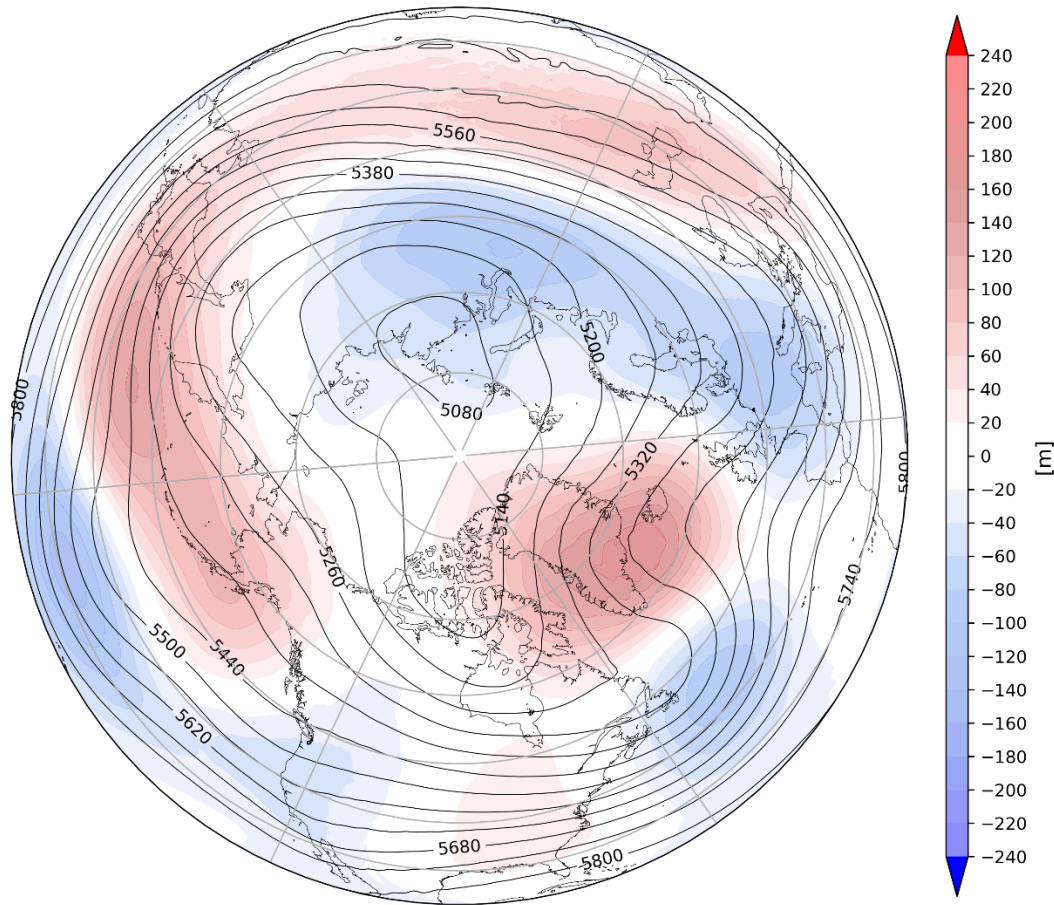


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for March 2023. The forecasts are from the 00Z 28 February 2023 CFS.

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 Iceland, Greenland across Northern Canada, Alaska, Eastern Siberia and over to Central Asia with troughing across Europe, Northern Asia, much of Canada and the Western US (**Figure 14**). This pattern favors seasonable to relatively warm temperatures across much of Southern Europe, Southern, Central and Eastern Asia, much of Siberia, Alaska, Northern Canada and the Eastern US with seasonable to relatively cold temperatures across Northern Europe, Northwestern Asia, Western and Southern Canada and the Western US (**Figure 15**). For what it's worth the CFS continues to predict a mid-tropospheric circulation and surface temperature pattern which is mostly consistent with a pattern forced by a major SSW, though modified by a negative Pacific-North America pattern and an overall warmer pattern

across Northern Eurasia than shown in historical composites of the temperature response to major SSWs. This forecast may or may not be correct.

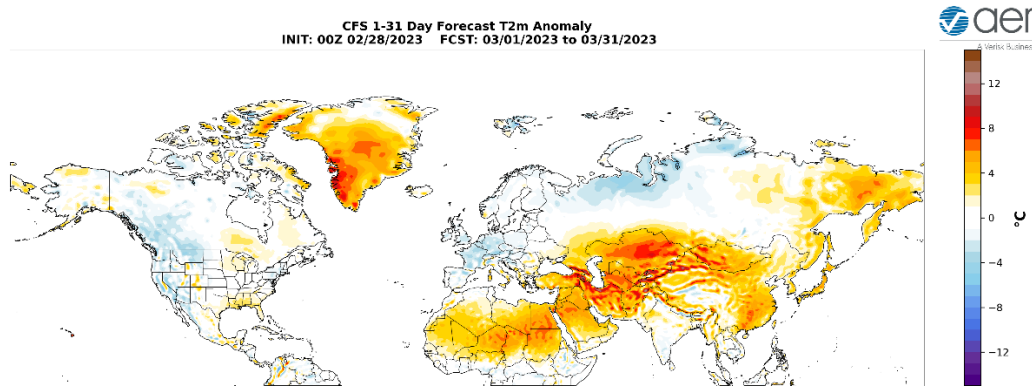


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for March 2023. The forecasts are from the 00Z 28 February 2023 CFS.

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.

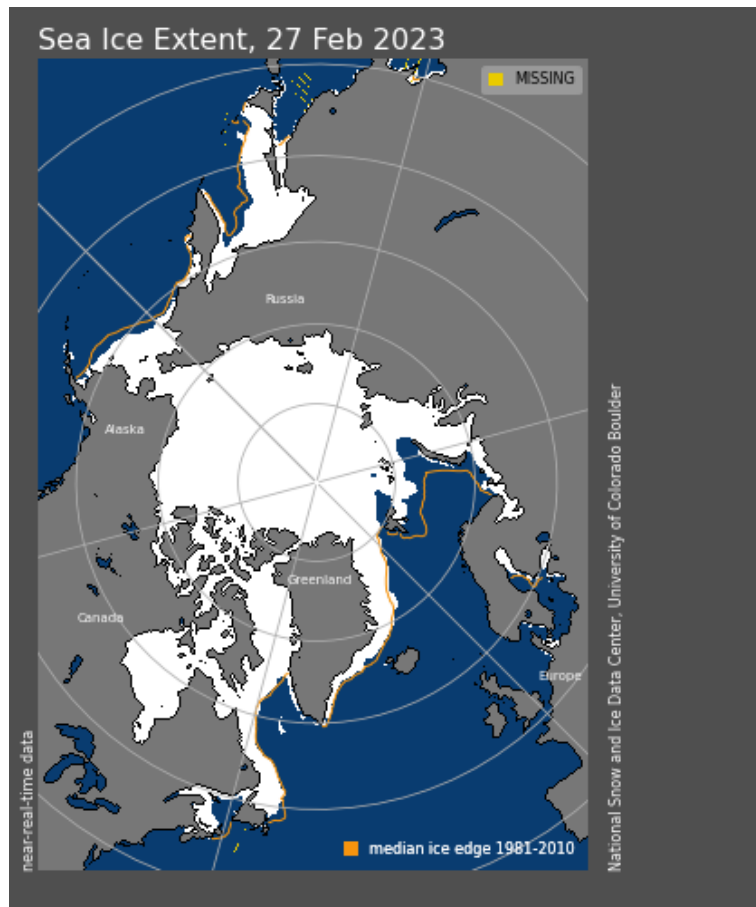


Figure 16. Observed Arctic sea ice extent on 27 February 2023 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC).

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.

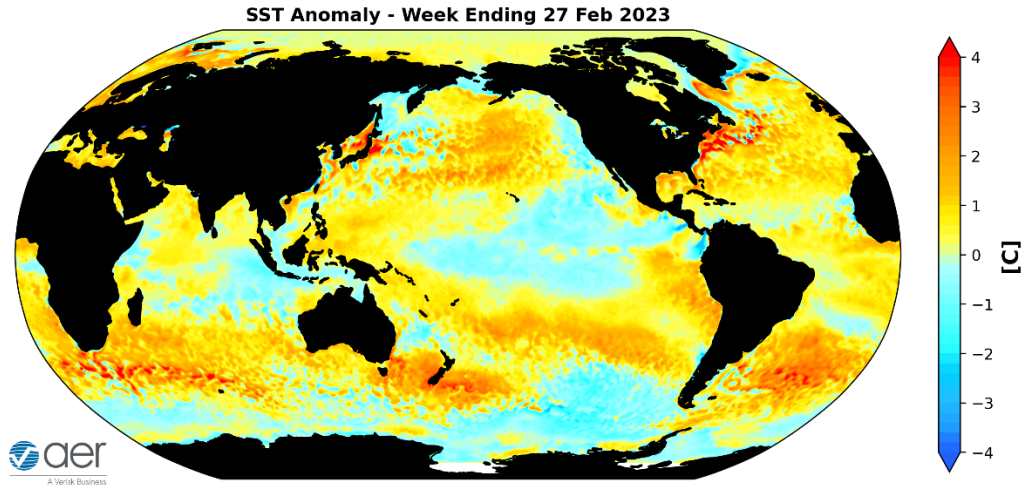


Figure 17. The latest weekly-mean global SST anomalies (ending 27 February 2023). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 18**). The forecasts are for the MJO to strengthen into phases 7 and 8. Phases 7 and 8 favor high latitude blocking with troughing over the US. Seems that the MJO is having some influence on the weather across North America in the short term but there are also large scale atmospheric features not consistent with MJO phases 7 and 8. So far the weather models are not predicting widespread high latitude blocking but that could change. But admittedly this is outside of my expertise.

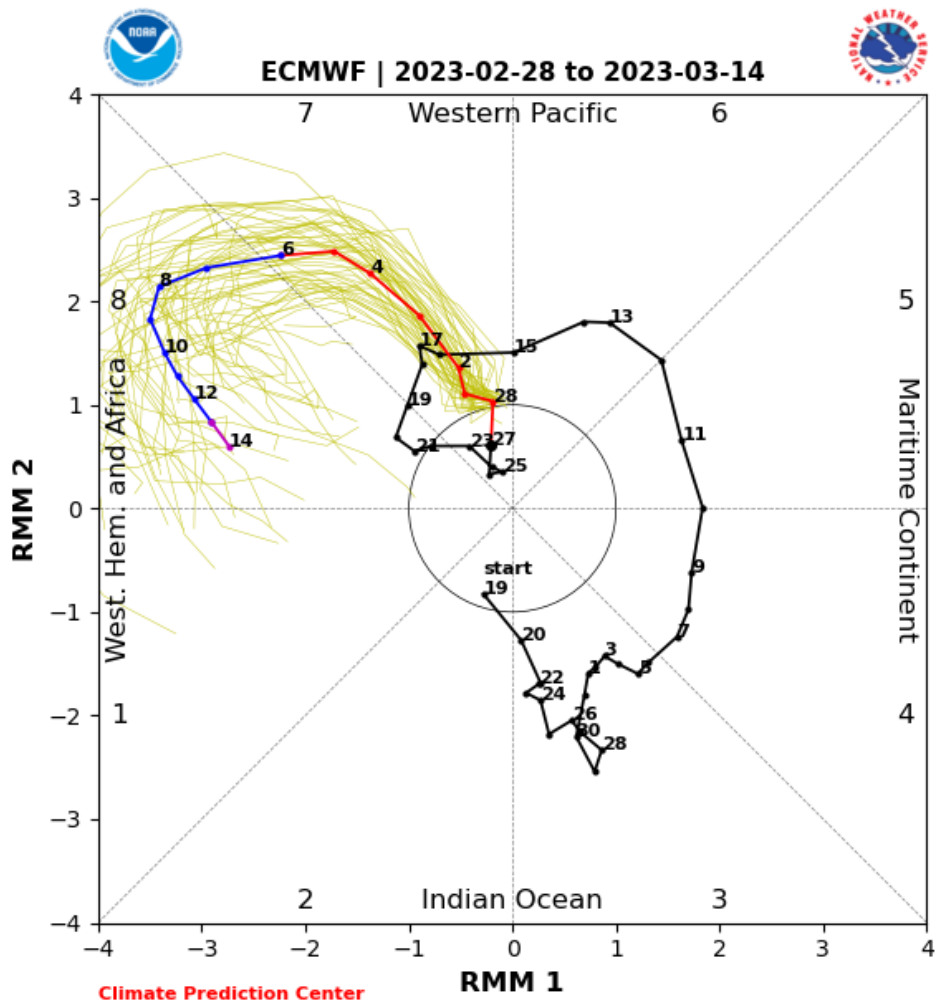


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 13 February 2023 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate the phase of the MJO, with geographical labels indicating where anomalous convection occurs during that phase. Image source:

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

Snow Cover

Snow cover extent (SCE) anomalies across the NH has decreased slightly this past week mostly across Eurasia with above normal snow cover focused in China and the Western US. Meanwhile Eurasian 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. Snow cover is above normal in North America. I expect snow cover to

decrease in the coming weeks, but more slowly across the US with predicted colder weather.

Daily SCE Departure - February 27, 2023 (Day 58)

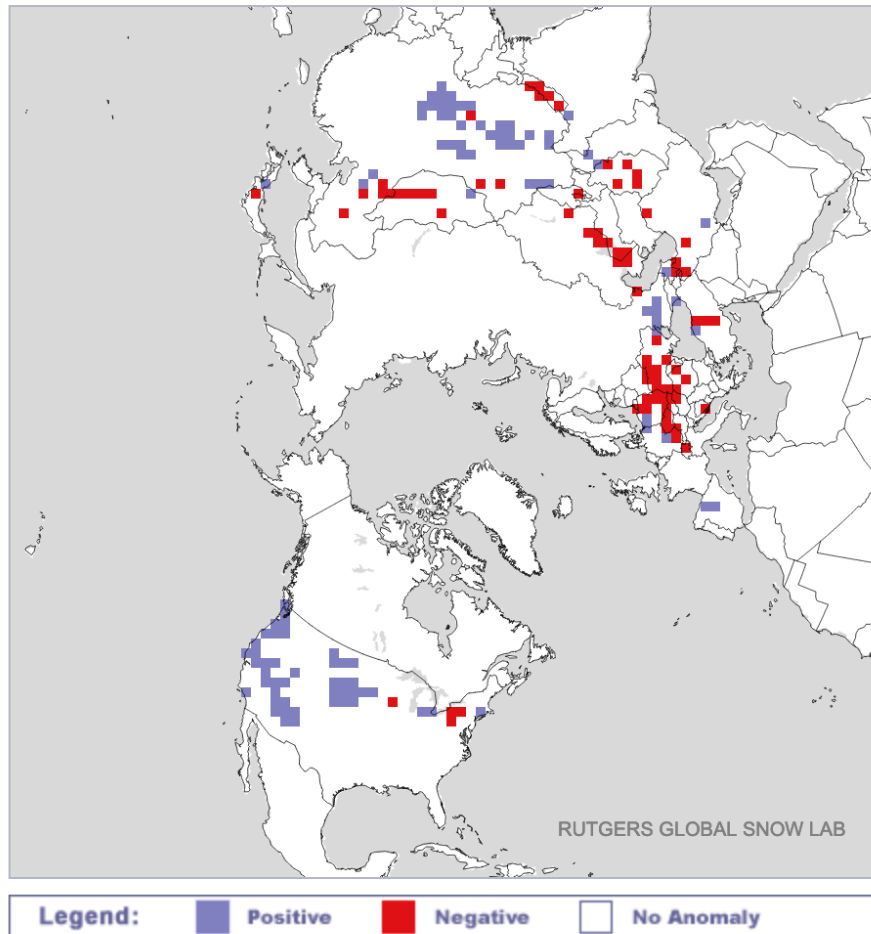


Figure 19. Observed North Hemisphere snow cover anomalies on 27 February 2023. Plot from <http://climate.rutgers.edu/snowcover/index.php>