

# Arctic Oscillation and Polar Vortex Analysis and Forecasts

March 18, 2024

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

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

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

## Summary

- The Arctic Oscillation (AO) is currently neutral and is predicted to remain fairly close to neutral this week as pressure/geopotential height anomalies across the Arctic are currently mixed but then trend negative next week as pressure/geopotential height anomalies across the Arctic turn more positive. The North Atlantic Oscillation (NAO) is currently positive with negative pressure/geopotential height anomalies across Greenland and the NAO is predicted to remain positive this week but then trend negative as pressure/geopotential height anomalies turn more positive across Greenland.
- Troughing/negative geopotential height anomalies across Greenland will support ridging/positive geopotential height anomalies across much of Europe this week but then next week as geopotential height anomalies across Greenland turn more positive will support troughing/negative geopotential height anomalies across Western Europe. This pattern will support normal to above normal temperatures across much of Europe

including the United Kingdom (UK) this week with normal to below normal temperatures spreading across Western Europe including the UK next week.

- The general predicted pattern across Asia the next two weeks is troughing/negative geopotential height anomalies across Northern and Western Asia with ridging/positive geopotential height anomalies dominating Southern and Eastern Asia. This pattern favors widespread normal to above normal temperatures across much of Asia with the exception of normal to below normal temperatures across the Urals and Western Siberia this week. The next week the troughing across Northern Asia will become more widespread along with below normal temperatures.
- The predicted pattern general pattern across North America the next two weeks is strengthening ridging/positive geopotential height anomalies centered over Alaska and the Gulf of Alaska forcing deepening troughing/negative geopotential height anomalies across Central Canada and the Central United States (US) with more ridging/positive geopotential height anomalies along the US East Coast. This pattern favors normal to above normal temperatures across Alaska, Western Canada and the Western US and the US East Coast with normal to below normal temperatures beginning in Central Canada and spreading into Eastern Canada and the Central and Eastern US.
- In the Impacts section I discuss the ongoing large disruption of the polar vortex (PV) and the possible impacts to Northern Hemisphere (NH) weather even though we are well into spring.
- **There will be no blog next week and I will be transitioning to the summer schedule of a bi-weekly publication.**

## Plain Language Summary

The forecast for the next week to ten days of building cold in Canada that extends into the US while most of Europe remains mild (see **Figures 3** and **6**) are consistent with a stretched polar vortex (PV). Europe could turn colder if the more traditional impacts occur from a sudden stratospheric warming (SSW) in very late March but more likely in April (see **Figure ii** last row).

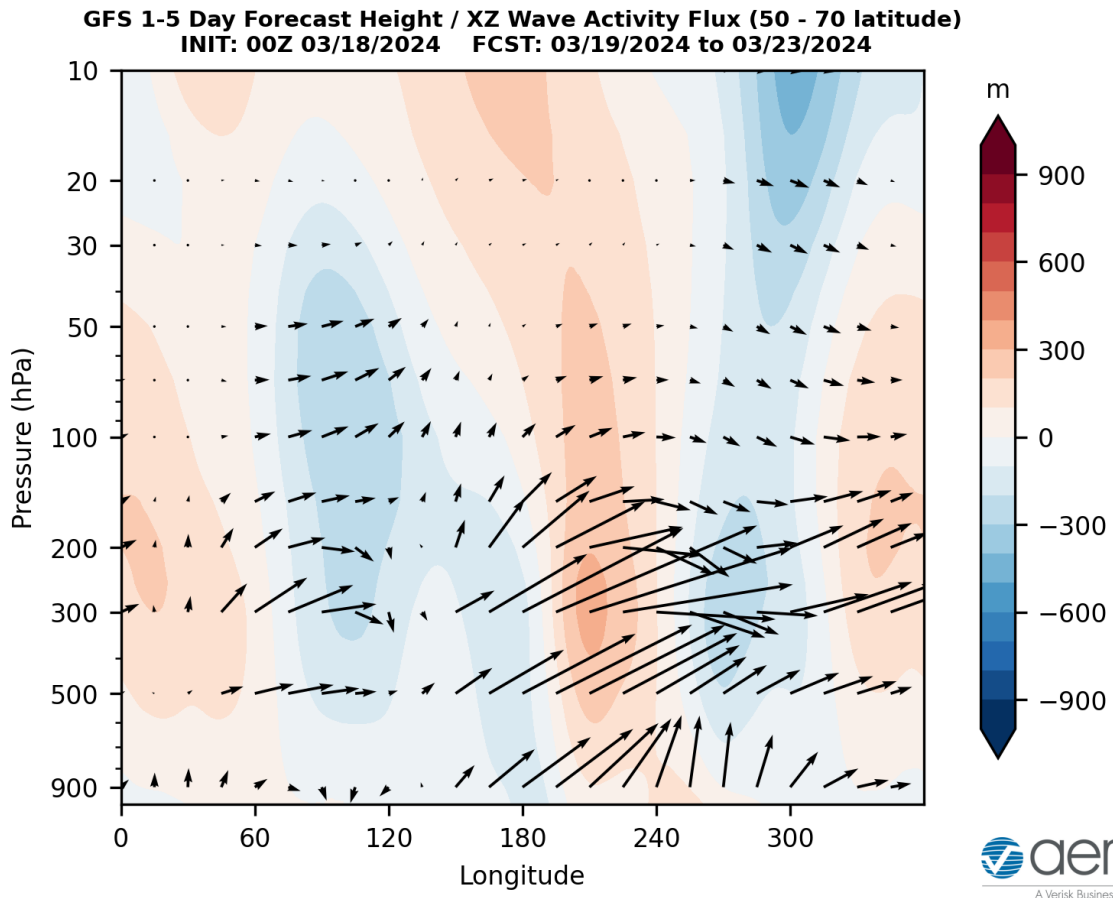
Who isn't excited for some spring snow? Based on the weather model forecasts snow is possible along the Northern US but especially in the Plains (see **Figures 4**).

## Impacts

Probably just mostly repeating myself this week, though some clarity has emerged since last week. They say timing is everything. Here we have this impressive polar vortex (PV) disruption/sudden stratospheric warming (SSW), that is now very clearly split (see **Figure 13a**), and I can't help but think how things could have been different this winter had this occurred in December or January. At least across North America including the US some impressive cold and snow are possible but with the caveat - for spring, this following a winter that was mostly absent except for a part of January.

The easy part is in the near-term where it appears to me, we have a pretty classical wave reflection occurring.

Wave reflection is showing up nicely in the Wave Activity Flux (WAF) vectors in the vertical and latitudinal direction with upward and eastward WAF over Asia and downward and eastward WAF over North America (see **Figure i**). This wave reflection is quite shallow. Also, the trough over North America tilts to the east with height. This is resulting in the build-up of cold air first across Canada this week (see **Figure 3**) that clearly extends into the center of the US next week (see **Figure 6**). And it is not limited to cold, snow is also predicted with the models most confident in the US Plains but could include the Great Lakes and New England (see **Figure 3** and **6**). In contrast the forecast for Europe is quite mild, especially this week also consistent with wave reflection/PV stretching.



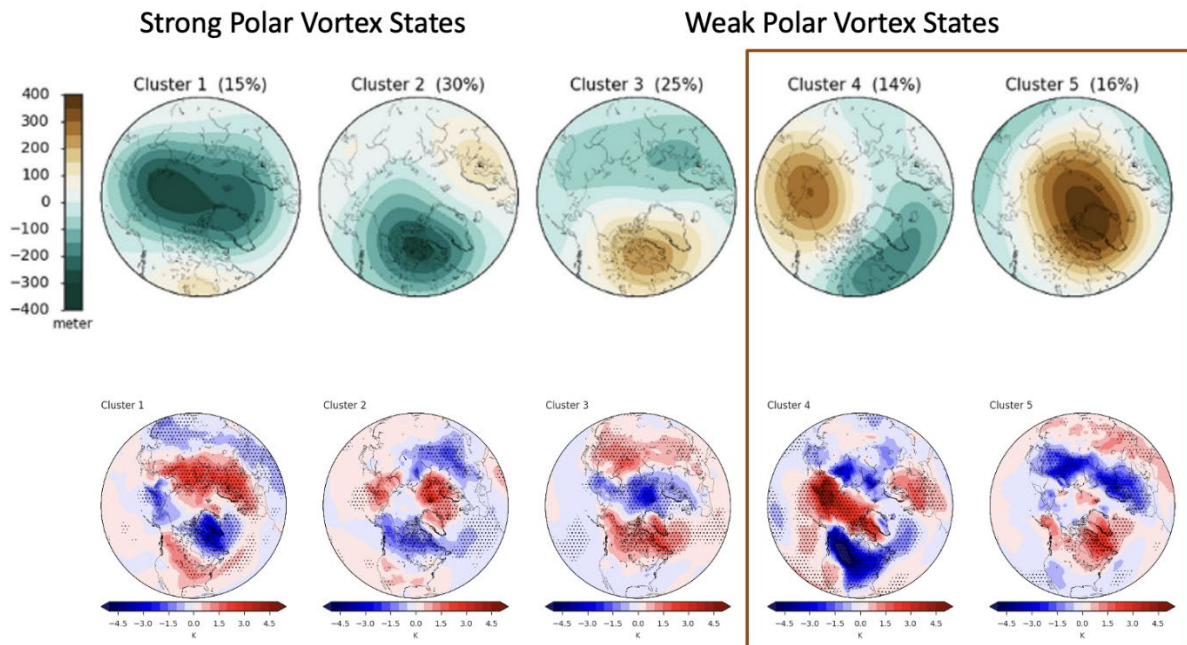
**Figure i.** Longitude-height cross section of geopotential eddy height anomalies (shading) and wave activity flux (vectors) forecasted for 19 – 23 March 2024. The forecasts are from the 00z 18 March 2024 GFS ensemble.

For me (and I am willing to bet the weather models) the challenge is, what is the impact to the Northern Hemisphere weather from the SSW? Seems to me it is no longer a question of if the signal of the SSW will reach the troposphere but when and in what form or character. The GFS is predicting that the downward influence from the SSW will reach the surface 28 March through 2 April (see **Figure 11**) with more impacts or drips likely to follow. And as I tweeted, the best evidence that the downward influence is coming are the cold temperatures predicted for Siberia (see **Figure 9**).

As far as I can tell the weather models are predicting varying amounts of high latitude blocking with the most likely region being Greenland. But so far, the forecasts are underwhelming with no exceptionally cold temperatures with the possible exception of Siberia. Across Europe there is residual ridging from during the wave reflection that separates Europe from the deepest pool of cold NH surface temperatures in Siberia (see **Figure 8**). So, it might turn seasonably cold across Western Europe but there is no tap between Europe and Siberia to usher unseasonably cold air into Northern Europe.

Based on **Figure 11** the latest polar cap geopotential height anomalies (PCHs) currently shows the largest warm/positive PCHs are still in the mid-stratosphere. They are not predicted to reach the lower stratosphere until the end of the week. I feel then that weather model forecasts will have a hard time finding consensus around a forecast and expect volatility in the forecasts until at least the end of the week.

I will conclude with **Figure ii** taken from [Kretschmer et al. \(2018\)](#) that I have showed many times previously. The top row shows the different PV clusters and the bottom row the associated surface temperature anomalies. The two right-most clusters, highlighted by a box, are the two weakest clusters and are the ones of greatest interest currently. The fourth cluster is that of wave reflection/stretched PV of this week. The coldest anomalies are in Canada that extend into the US with more cold in Siberia, but Europe is mild. This pattern is consistent with this week's and even into next week's temperature forecasts (see **Figures 3 and 6**). The fifth cluster is that of an SSW with the coldest temperatures spread across northern Eurasia, including Northern Europe with mixed temperatures across the US. The weather models are predicting cold in Siberia, consistent with the pattern shown in the figure but not Europe. I do wonder if the weather models will eventually converge to the temperature pattern associated with an SSW bringing colder temperatures to Northern Europe. Far from guaranteed but something to monitor.

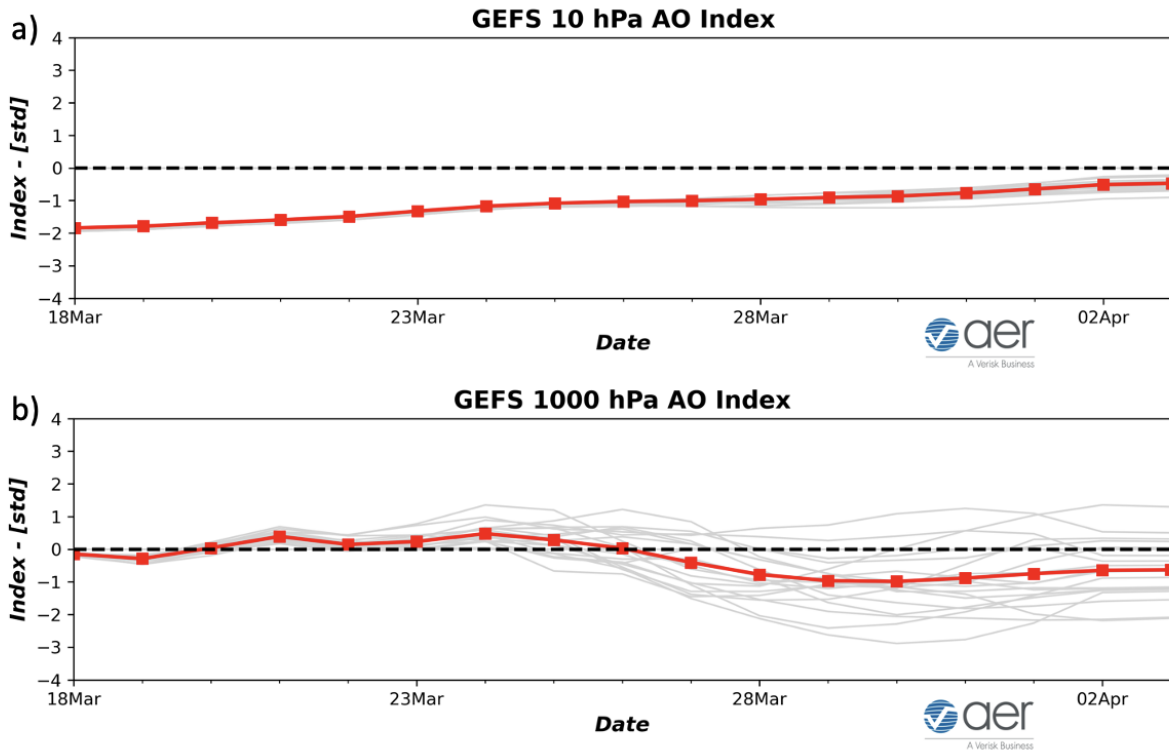


**Figure ii.** Composites of geopotential height anomalies at 100 hPa in winter (JF) from 1979 to 2018 for days assigned to the same cluster. The number in brackets gives the total occurrence (in percent) over all winter days (top). Cluster 4 is the stretched PV and cluster 5 is a sudden stratospheric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

## Near-Term

### *This week*

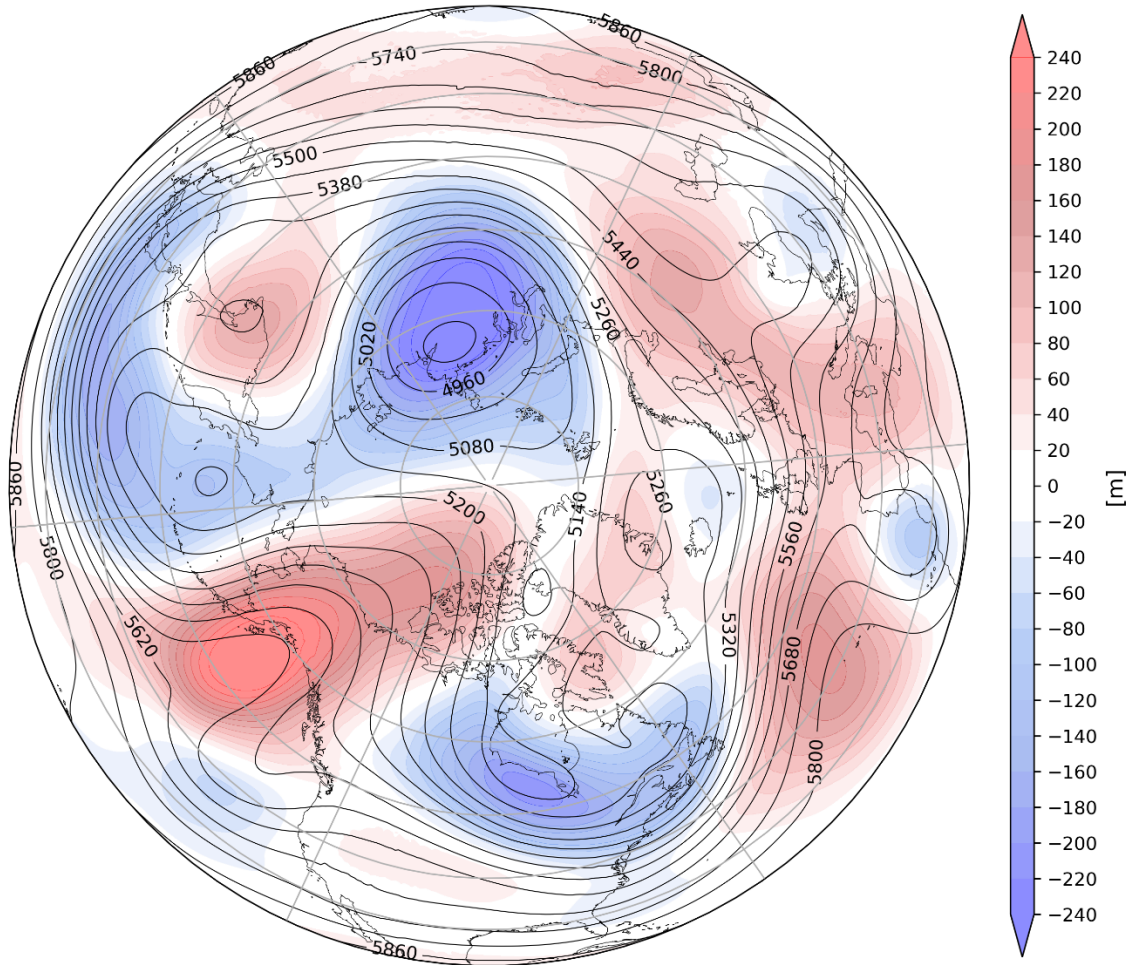
The AO is predicted to be neutral this week (**Figure 1**) with mixed geopotential height anomalies across the Arctic and with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). With predicted negative geopotential height anomalies across Greenland (**Figure 2**),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



**Figure 1.** (a) The predicted daily-mean AO at 1000 hPa from the 00Z 18 March 2024 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 18 March 2024 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

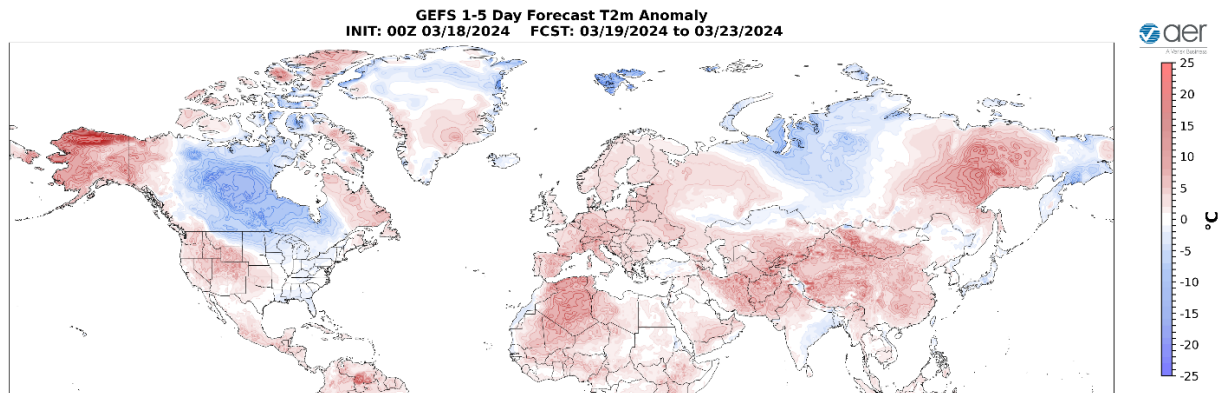
This week, troughing/negative geopotential height anomalies across Greenland will force ridging/positive geopotential height anomalies across much of Europe with the exception of troughing/negative geopotential height anomalies across Turkey (**Figure 2**). This pattern favors normal to above normal temperatures across much of Europe including the UK with the exception of normal to below normal temperatures across Turkey (**Figure 3**). Predicted ridging/positive geopotential height anomalies across Europe will support troughing/negative geopotential height anomalies across Western and Northern Asia with more ridging/positive geopotential height anomalies across Eastern Asia this period (**Figure 2**). This pattern favors widespread normal to above normal temperatures across much of Asia but focused in Central and Eastern Asia with normal to below normal temperatures centered across the Urals and Western Siberia (**Figure 3**).

**GEFS 1-5 Day Forecast 500 hPa Anomaly**  
**INIT: 00Z 03/18/2024 FCST: 03/19/2024 to 03/23/2024**



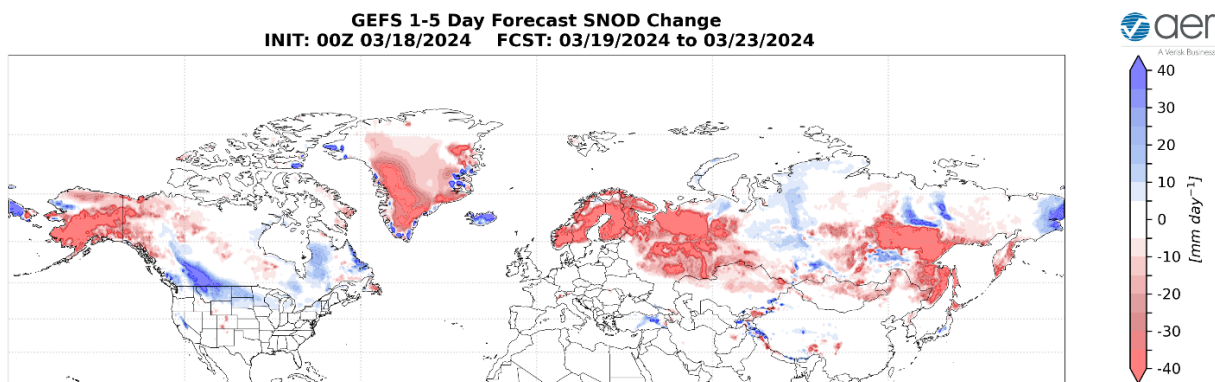
**Figure 2.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 19 – 23 March 2024. The forecasts are from the 00z 18 March 2024 GFS ensemble.

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



**Figure 3.** Forecasted surface temperature anomalies (°C; shading) from 19 – 23 March 2024. The forecast is from the 00Z 18 March 2024 GFS ensemble.

Trounging and/or cold temperatures will support new snowfall across Siberia and Turkey, while mild temperatures will support snowmelt across Scandinavia, the Alps and widespread across Western Russia, Southern Siberia and Northeastern Asia this week (**Figure 4**). Trounging and/or cold temperatures will support new snowfall across the Pacific Northwest, California, Quebec, the Canadian and Northern US Plains, the Great Lakes and New York while mild temperatures will support snowmelt across Alaska, and Northwestern Canada this week (**Figure 4**).



**Figure 4.** Forecasted snow depth changes (mm/day; shading) from 19 – 23 March 2024. The forecast is from the 00Z 18 March 2024 GFS ensemble.

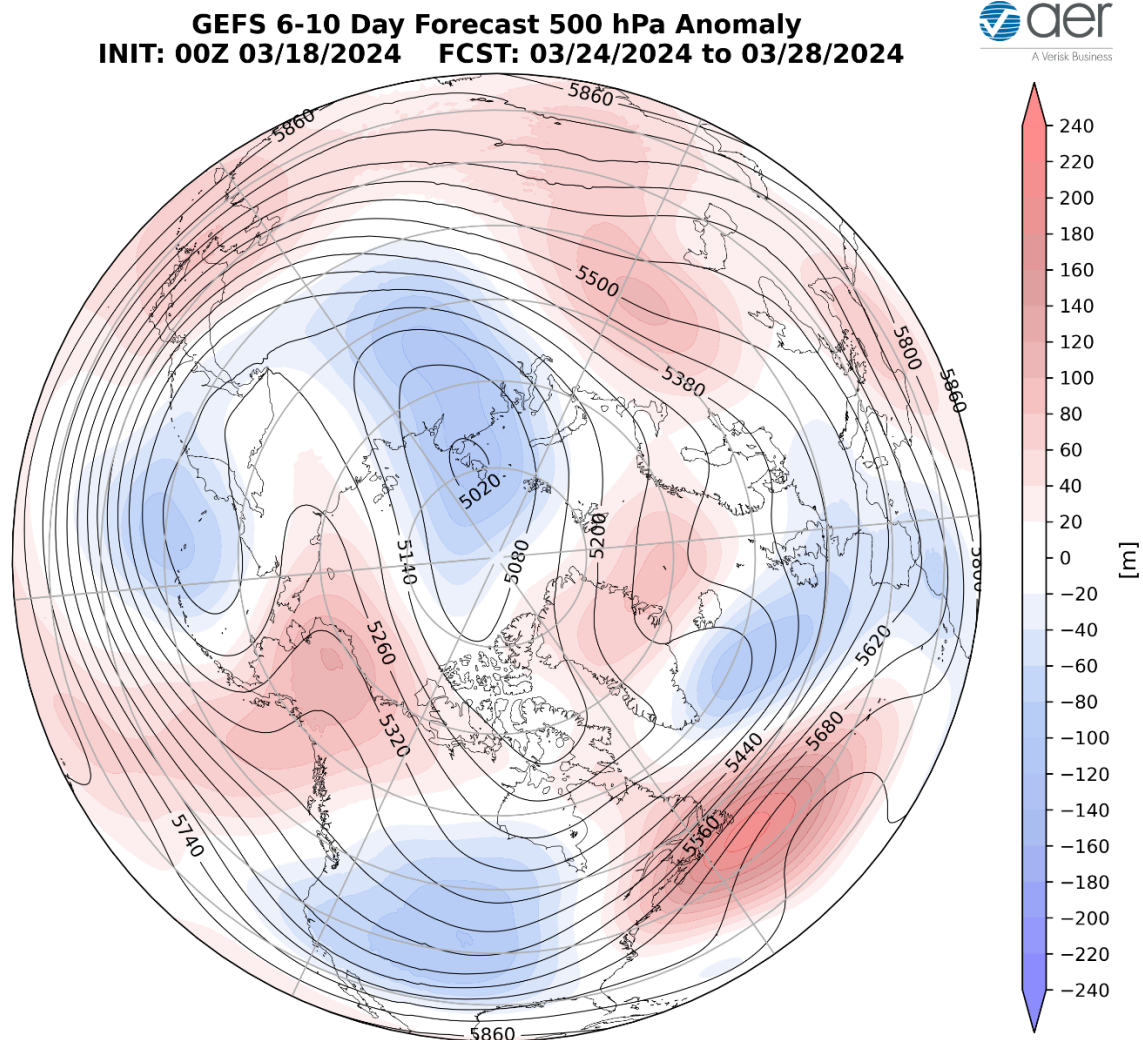
## Near-Mid Term

### *Next week*

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



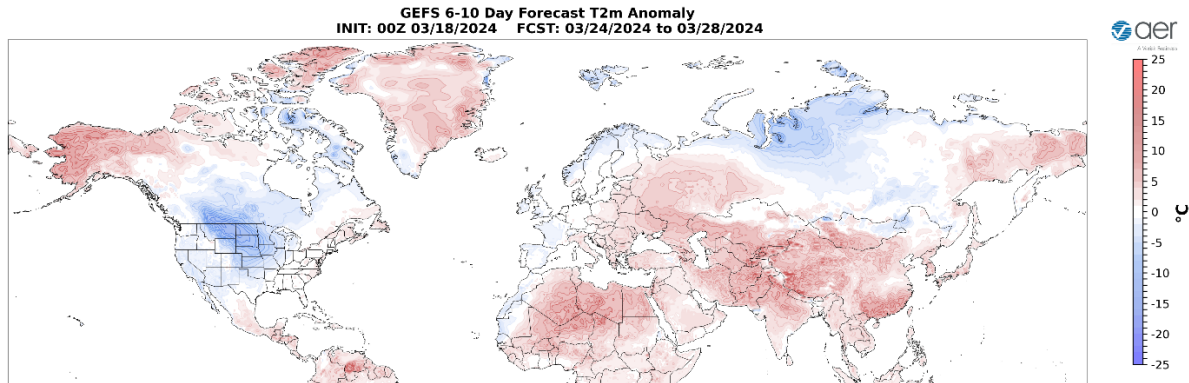
anomalies across Greenland turning more positive (**Figure 5**), the NAO will be close to neutral as well this period.



**Figure 5.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 24 – 28 March 2024. The forecasts are from the 00z 18 March 2024 GFS ensemble.

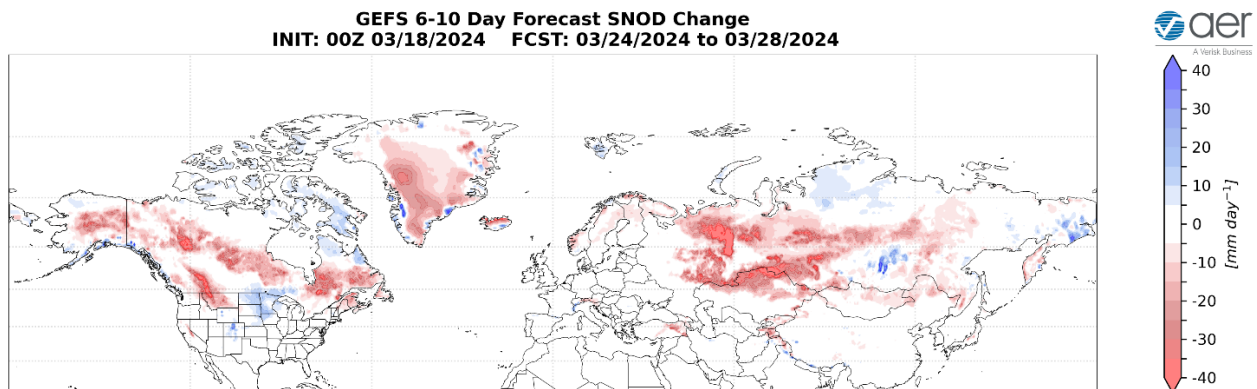
With increasing ridging/positive geopotential height anomalies across Greenland will support deepening troughing/negative geopotential height anomalies across Western Europe with more ridging/positive geopotential height anomalies across Eastern Europe this period (**Figure 5**). This pattern will favor normal to above normal temperatures across Southern and Eastern Europe with normal to below normal temperatures across Western and Northern Europe including the UK (**Figures 6**). Predicted ridging/positive geopotential height anomalies across Greenland, Eastern Europe and Western Russia will support troughing/negative geopotential height anomalies across Northern Asia with more

ridging/positive geopotential height anomalies across Southern Asia this period (**Figure 5**). This pattern favors widespread normal to above normal temperatures across much of Asia including Eastern Siberia with the exception of normal to below normal temperatures limited to Western and Central Siberia this period (**Figure 6**).



**Figure 6.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 24 – 28 March 2024. The forecasts are from the 00z 18 March 2024 GFS ensemble.

Predicted ridging/positive geopotential height anomalies across Alaska and the Gulf of Alaska will support troughing/negative geopotential height anomalies across much of Canada and the US with more ridging/positive geopotential height anomalies near New England and the Canadian Maritimes this period (**Figure 5**). This pattern favors normal to above normal temperatures across Alaska, Northwestern Canada, the Canadian Maritimes and New England with normal to below normal temperatures across much of Canada and the US (**Figure 6**).



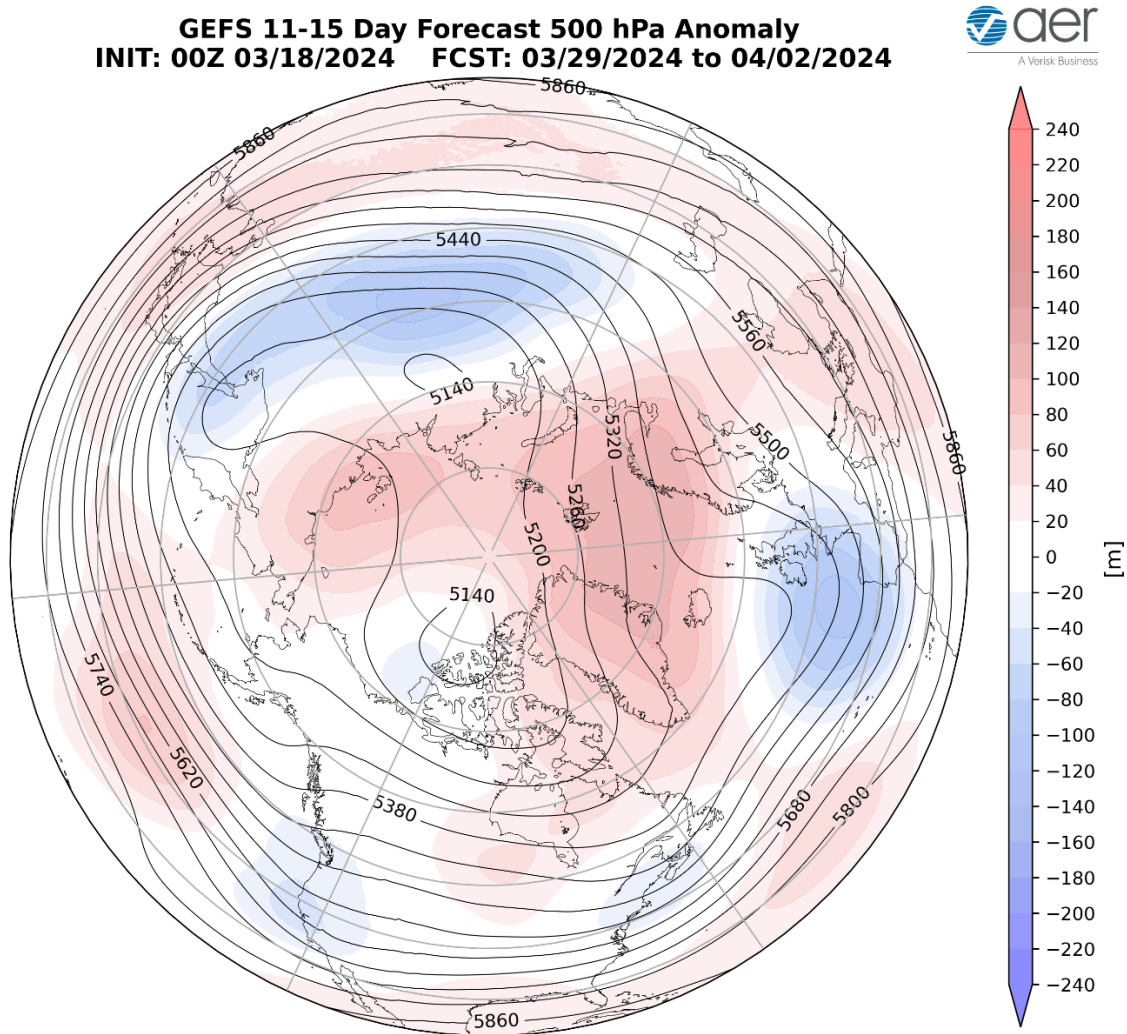
**Figure 7.** Forecasted snow depth changes ( $\text{mm}/\text{day}$ ; shading) from 24 – 28 March 2024. The forecast is from the 00Z 18 March 2024 GFS ensemble.

Trouching and/or cold temperatures will support new snowfall across parts of Northern Siberia while mild temperatures will support widespread snowmelt across Scandinavia, the Alps, Northern Asia and the Tibetan Plateau this period (**Figure 7**). Trouching and/or cold temperatures will support new snowfall across Northern and Eastern Canada and the Upper Midwest while mild temperatures will support snowmelt across central Alaska, widespread across Canada, the Northwestern US and New England this period (**Figure 7**).

## Mid Term

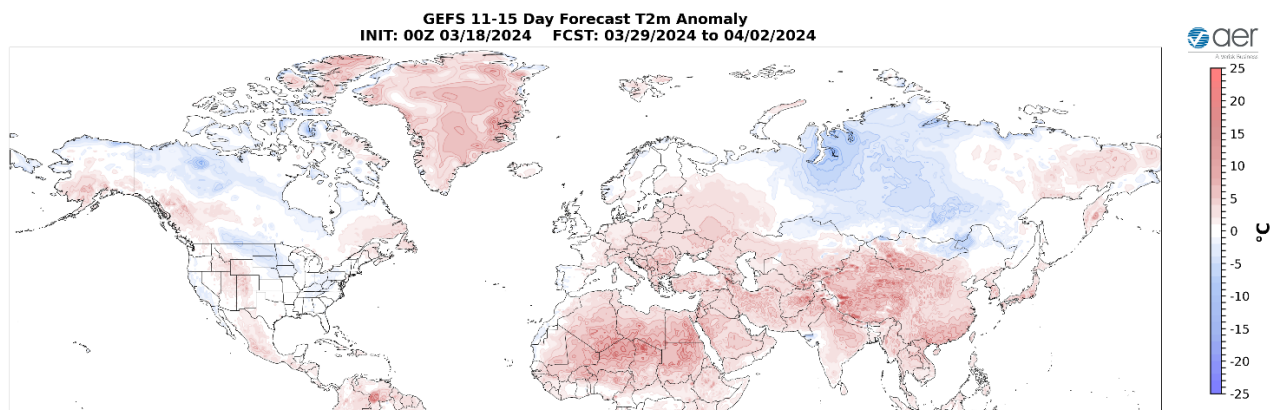
### Week Two

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



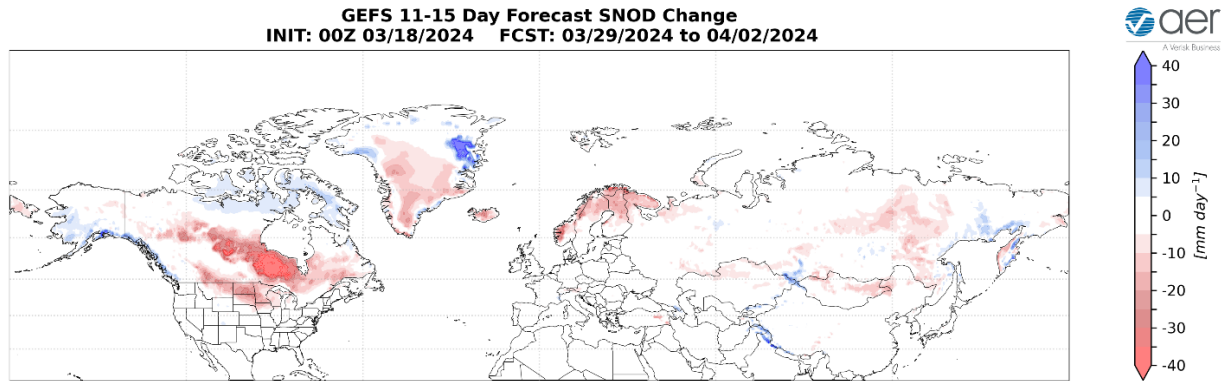
**Figure 8.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 29 March – 2 April 2024. The forecasts are from the 00z 18 March 2024 GFS ensemble.

Ridging/positive geopotential height anomalies across Greenland will continue to support troughing/negative geopotential height anomalies across Western Europe with more ridging/positive geopotential height anomalies across Eastern Europe this period (**Figure 8**). This pattern should favor normal to above normal temperatures across much of Europe with normal to below normal temperatures limited to Western Europe including the UK due to low geopotential heights this period (**Figures 9**). Ridging/positive geopotential height anomalies across the Eurasian side of the Arctic will continue to support troughing/negative geopotential height anomalies across Northern Asia with more ridging/positive geopotential height anomalies across Southern Asia this period (**Figure 8**). The predicted pattern favors widespread normal to above normal temperatures across Western, Southern and Eastern Asia with normal to below normal across Western and Central Siberia this period (**Figure 9**).



**Figure 9.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 29 March – 2 April 2024. The forecasts are from the 00z 18 March 2024 GFS ensemble.

Ridging/positive geopotential height anomalies is predicted to persist south of Alaska and Northern Canada forcing weak troughing/negative geopotential height anomalies across Southern Canada and the US this period (**Figure 8**). This pattern favors normal to above normal temperatures across Alaska, Western Canada, the Western US and New England with normal to below normal temperatures across Central Canada and the Central and Eastern US this period (**Figure 9**).



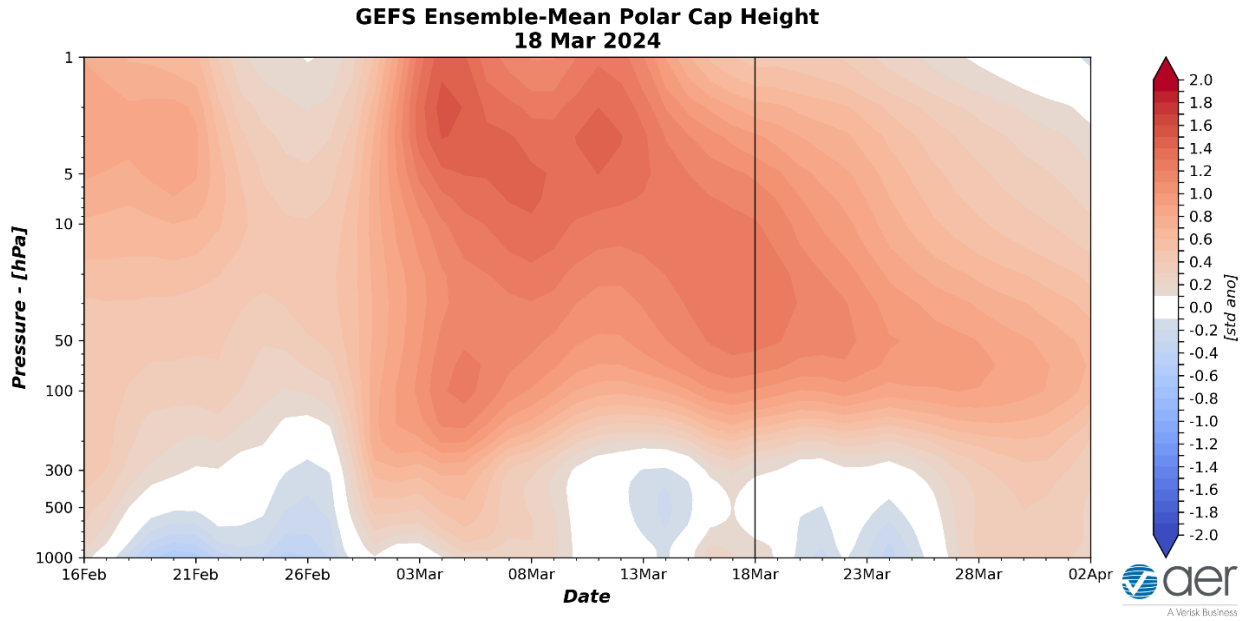
**Figure 10.** Forecasted snow depth changes (mm/day; shading) from 29 March – 2 April 2024. The forecast is from the 00Z 18 March 2024 GFS ensemble.

Trouging and/or cold temperatures will support new snowfall across parts of Siberia and the Tibetan Plateau while mild temperatures will support snowmelt across much of Scandinavia and Northern Asia this period (**Figure 10**). Trouging and/or cold temperatures will support new snowfall across Southern Alaska and Northern Canada. Mild temperatures will support snowmelt across Central and Southern Canada and the Northern US this period (**Figure 10**).

## Longer Term

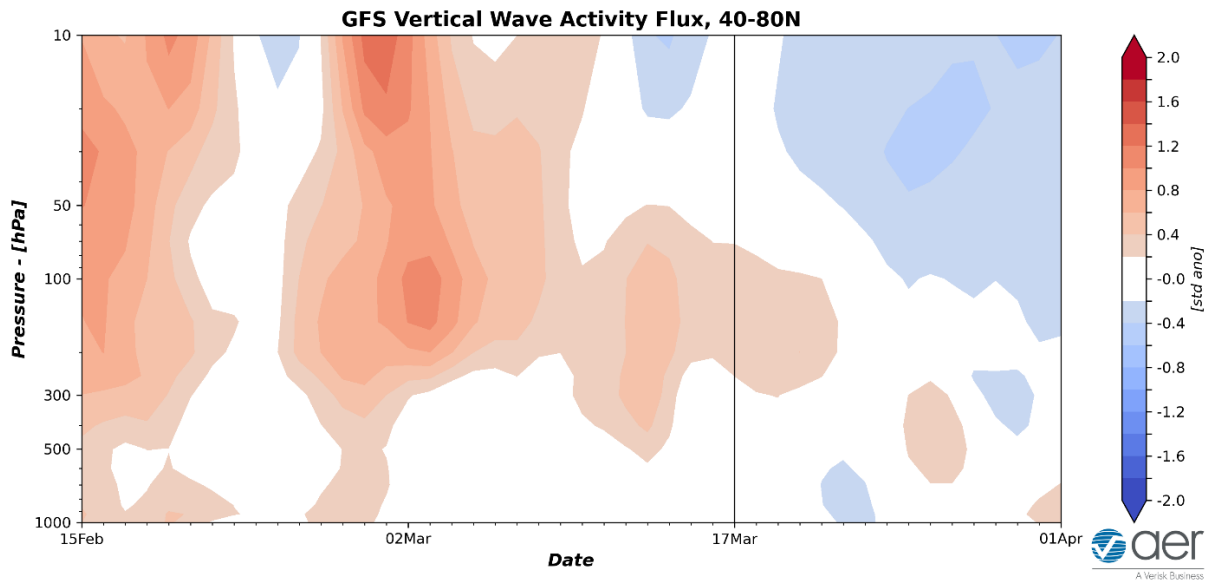
### *30-day*

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows warm/positive PCHs throughout the stratosphere and near neutral PCHs in the troposphere (**Figure 11**). Then for the next two weeks warm/positive PCHs will dominate the stratosphere with neutral to cold/negative PCHs in the troposphere this week but turning warm/positive PCHs next week (**Figure 11**). The warm/positive PCHs throughout the stratosphere (**Figure 11**) with the descent of the maximum warming/positive PCHs anomalies into the lower stratosphere are associated with the PV disruption/SSW. We should have a better idea of the impact to our weather once the maximum warm/positive PCHs reach the lower stratosphere.



**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 18 March 2024 GFS ensemble.

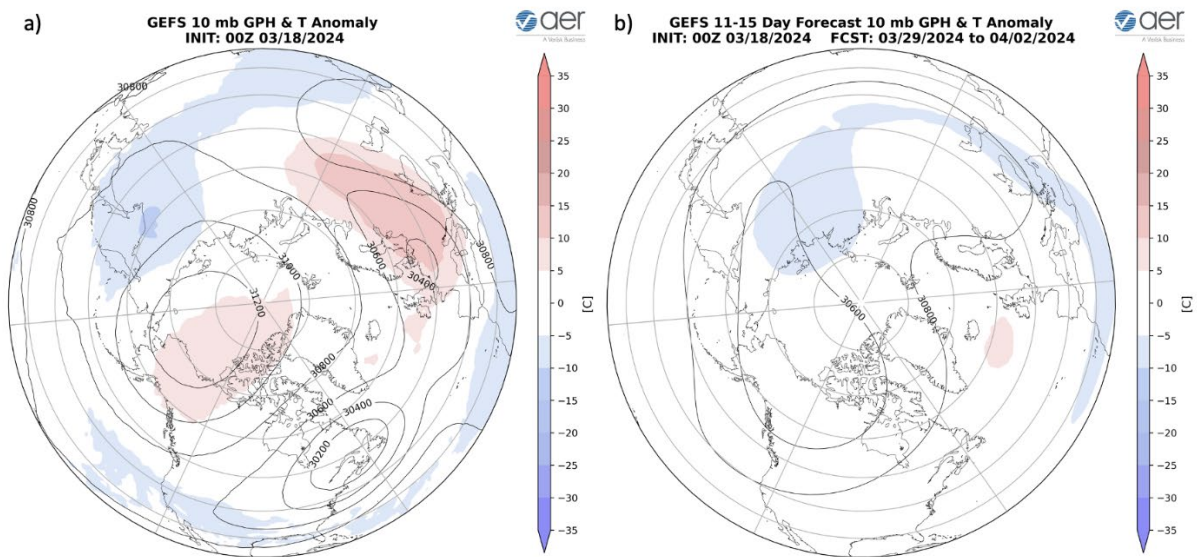
The predicted neutral to weakly cold/negative PCHs in the lower troposphere for this week (**Figure 11**) are consistent with the predicted neutral surface AO this week (**Figure 1**). However, as the neutral to weak cold/negative PCHs flip to warm/positive PCHs in the troposphere, the surface AO is more likely to dip into negative territory.



**Figure 12.** Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 18 March 2024 GFS ensemble.

Also shown in **Figure 1** is the stratospheric AO. The stratospheric AO is currently negative and is predicted to remain negative for the next two weeks. This is consistent with the warm/positive stratospheric PCHs in the mid-stratosphere associated with the weak PV that is dynamically consistent with a sudden stratospheric warming.

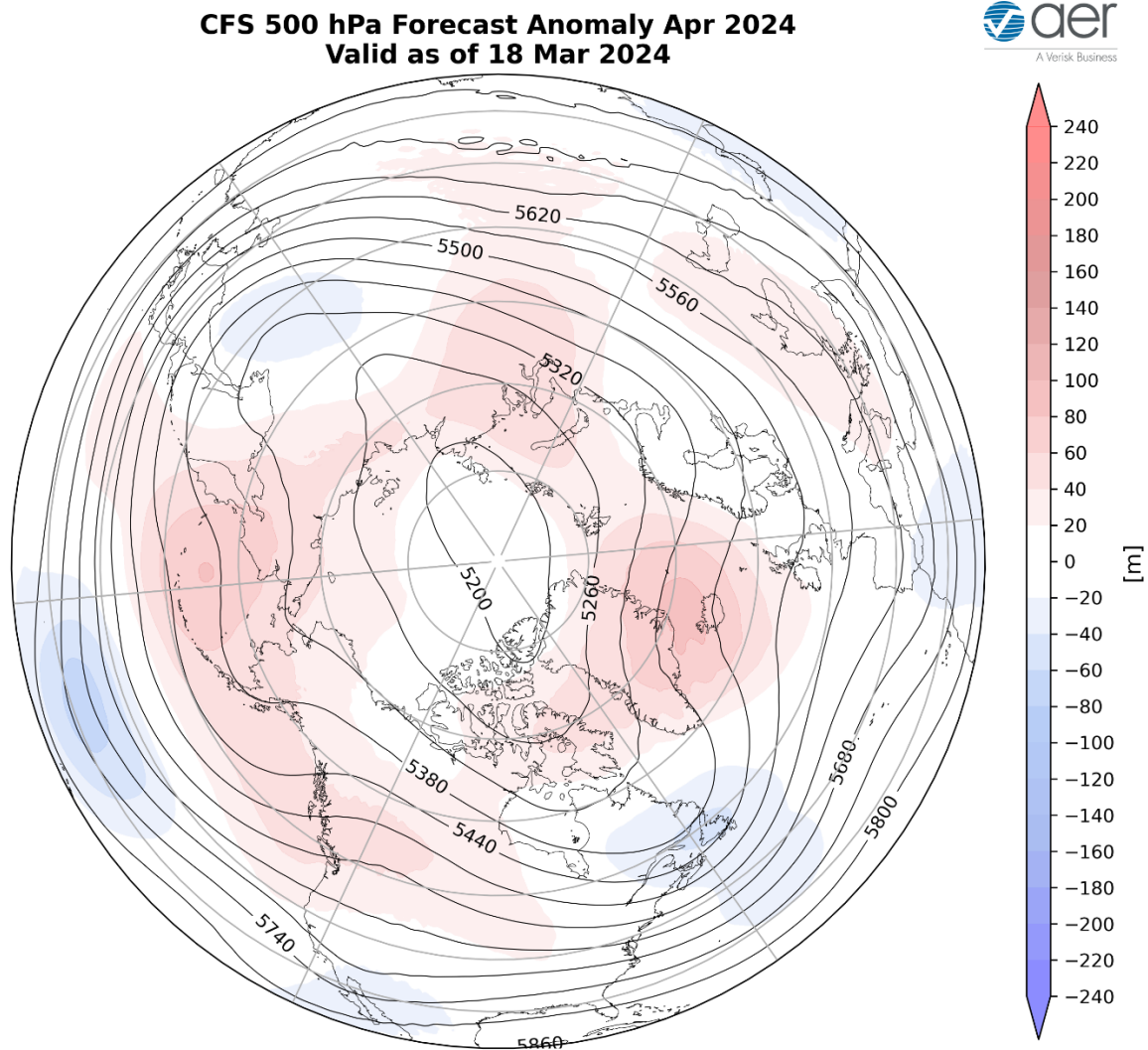
Active vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere or poleward heat transport in the stratosphere since the second week of February is finally turning quieter (**Figure 12**). The active WAFz has resulted in an impressive major SSW. The below normal WAFz predicted the next two weeks is consistent with an SSW but may also be characteristic of wave reflection.



**Figure 13.** (a) Observed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere from 18 March 2024 . (b) Same as (a) except forecasted averaged from 29 March – 2 April 2024. The forecasts are from the 00Z 18 March 2024 GFS model ensemble.

This week the polar vortex (PV) is predicted to be shifted way south of the North Pole, spread across the North Atlantic sector with two PV centers one over Europe and the second over Southeastern Canada and the Northeastern US (**Figure 13a**). The ridging in the polar stratosphere is centered near the North Pole Sea with the greatest warming centered across Europe. This is consistent with an evolving SSW while it is transitioning from a PV displacement to a PV split. For the monthly transition from March to April the PV center is predicted to consolidate over the

North Pacific sector of the Arctic with ridging predicted over the North Atlantic (**Figure 13b**). This is the PV trying to re-constitute right before the Final warming.

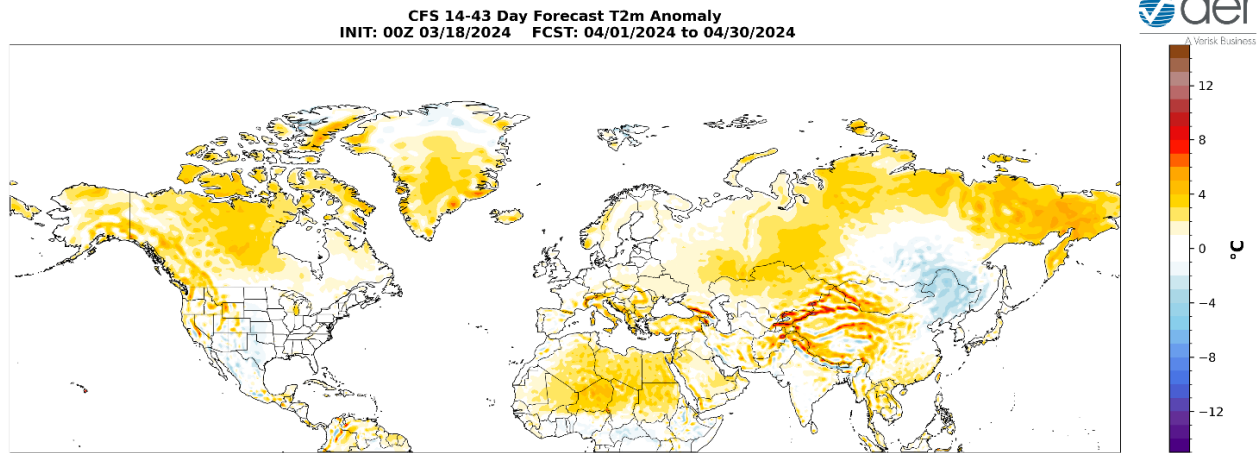


**Figure 14.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for April 2024. The forecasts are from the 00Z 18 March 2024 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and surface temperatures for April (**Figure 15**) from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging centered across Greenland and Iceland, Southern Europe, the Eurasian Arctic, the Dateline, Alaska, the Gulf of Alaska and Western Canada with troughing in Northern Europe, East Asia, the Southwestern US, Eastern Canada and the Northeastern US (**Figure 14**). This pattern favors seasonable to relatively warm temperatures across Southern Europe, Southern and Central Asia, Siberia, Alaska, Western Canada and the Western US with seasonable to relatively cold temperatures



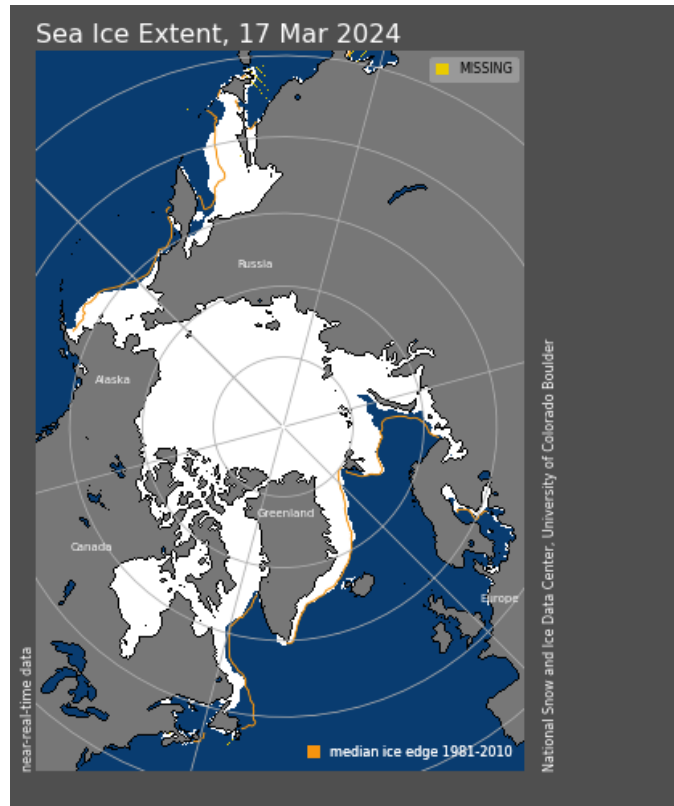
across Northern Europe, Northern and Eastern Asia, Southeastern Canada and the Eastern US (Figure 15).



**Figure 15.** Forecasted average surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) across the Northern Hemisphere for April 2024. The forecasts are from the 00Z 18 March 2024 CFS.

#### *Arctic sea ice extent*

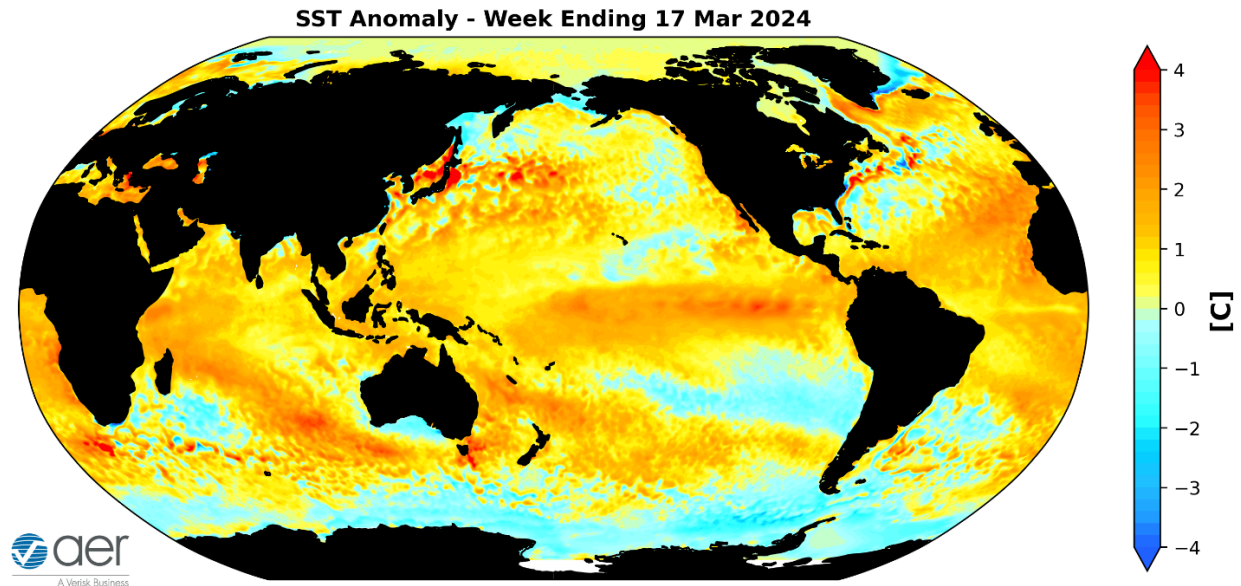
Arctic sea ice extent grew a little this week and is likely near its annual peak. I continue to expect that the negative sea ice anomalies will remain focused in the North Atlantic sector, which is currently more so than previously this winter. Blocking in the Barents-Kara sea region is critical for weakening the PV that is favorable for widespread and meaningful cold in Northern Eurasia and eastern North America, which can persist for weeks.



**Figure 16.** Observed Arctic sea ice extent on 17 March 2024 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

### *SSTs/El Niño/Southern Oscillation*

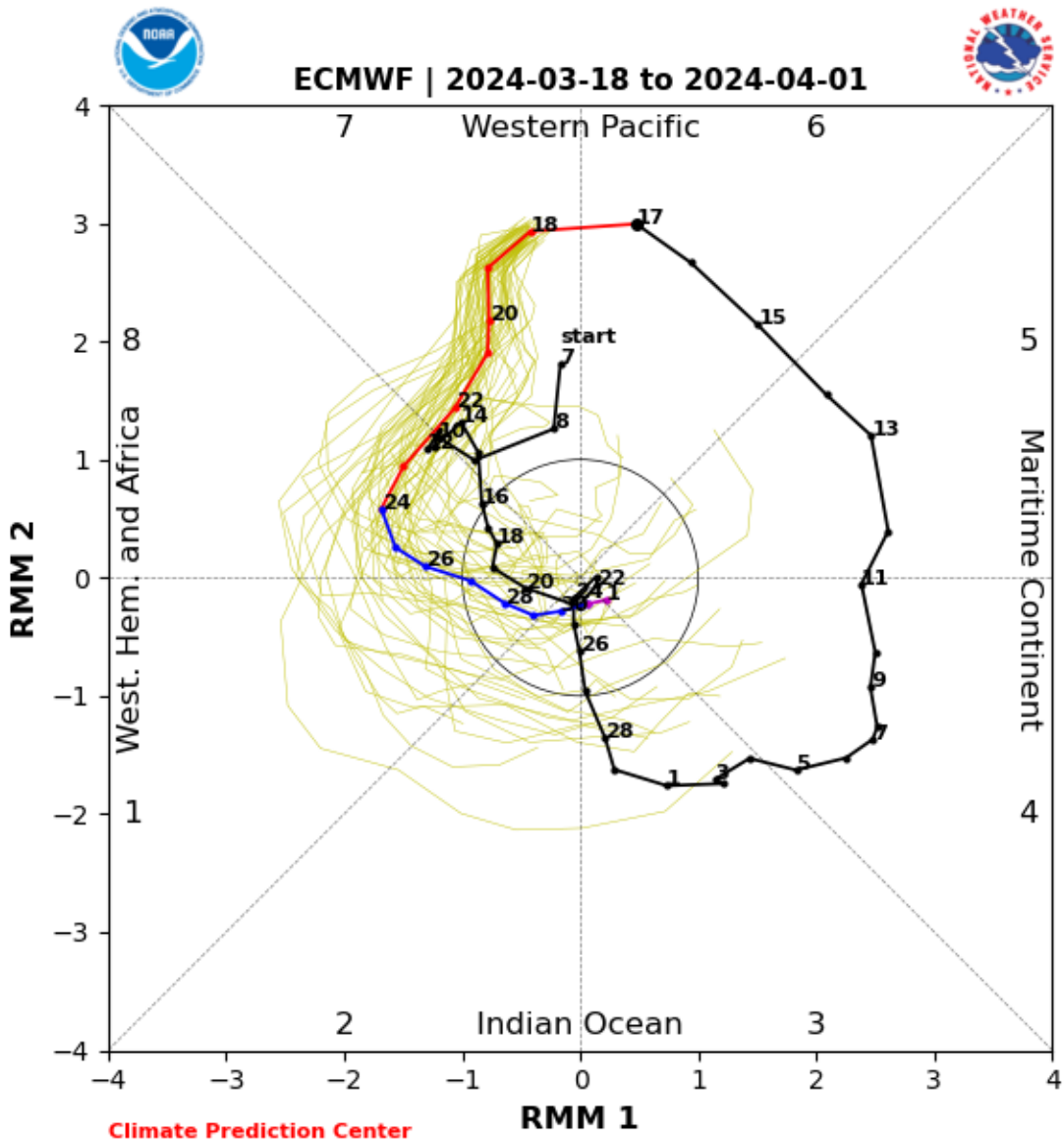
Equatorial Pacific sea surface temperatures (SSTs) anomalies are well above normal, especially along the South America coast, indicating that and El Niño remains strong (**Figure 17**) and El Niño conditions are expected through the the spring. Observed SSTs across the NH remain well above normal especially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



**Figure 17.** The latest weekly-mean global SST anomalies (ending 17 March 2024). 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 move quickly into phases seven, eight and then weaken to where no phase is favored. Phase six favors ridging in the Gulf of Alaska and the Eastern US with troughing in Alaska, Northern and Western Canada and the Western US. Phases seven and eight favor ridging across Canada with troughing in the US. Therefore the MJO could be having an influence on the weather across North America weather this week into next week. But admittedly this is outside of my expertise.



**Figure 18.** Past and forecast values of the MJO index. Forecast values from the 00Z 18 March 2024 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate the phase of the MJO, with geographical labels indicating where anomalous convection occurs during that phase. Image source: [https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar\\_wh.shtml](https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar_wh.shtml)

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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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