

Arctic Oscillation and Polar Vortex Analysis and Forecasts

March 1, 2021

Special blog on winter 2018/2019 retrospective can be found here
- <http://www.aer.com/winter2019>

Special blog on winter 2017/2018 retrospective can be found here
- <http://www.aer.com/winter2018>

Special blog on winter 2016/2017 retrospective can be found here
- <http://www.aer.com/winter2017>

Special blog on winter 2015/2016 retrospective can be found here
- <http://www.aer.com/winter2016>

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 briefly dip negative the end of the week and into the weekend and then remain positive through mid-March. Pressure/geopotential height anomalies are predicted to remain mostly negative pressure/geopotential height anomalies across the Arctic with mixed pressure/geopotential height anomalies across the mid-

latitudes the next two weeks. However, at the end of the week pressure/geopotential height anomalies across Greenland and Iceland are predicted to turn positive forcing both the AO and North Atlantic Oscillation (NAO) into negative territory. Other than this week, the NAO is predicted to remain neutral to positive as pressure/geopotential height anomalies are predicted to turn negative across Greenland next week.

- This week ridging/positive geopotential height anomalies is predicted to dominate Europe favoring normal to above normal temperatures across Europe, though the United Kingdom (UK) could be closer to seasonable temperatures due to northerly flow. However, a brief return of positive geopotential height anomalies across Greenland the end of this week will force troughing/negative geopotential height anomalies and relatively cooler temperatures across Europe next week before a strong westerly flow of maritime air returns milder temperatures for all of Europe mid-March.
- Continuous troughing/negative geopotential height anomalies coupled with relatively cold temperatures will persist for one more week across Northern Asia. However, by next week the troughing/negative geopotential height anomalies are predicted to migrate into the Central Arctic allowing normal to above normal temperatures to become widespread across Asia with the exception of troughing/negative geopotential height anomalies with regional normal to below normal temperatures in Western Asia.
- Troughing/negative geopotential height anomalies coupled with normal to below temperatures are predicted across Alaska, Northern and Eastern Canada and into the Eastern United States (US) with ridging/positive geopotential height anomalies coupled with normal to above normal temperatures across Southern and Western Canada and the Western US are predicted for this week. However next week troughing/negative geopotential height anomalies coupled with normal to below temperatures will become focused in western North America while ridging/positive geopotential height anomalies coupled with normal to above normal temperatures becomes widespread across Eastern Canada and the Eastern US.
- In the Impacts section I discuss the impacts/influence from the strengthening polar vortex (PV) on the weather across the Northern Hemisphere (NH).

Impacts

First happy first day of meteorological spring! Today's blog will be relatively short and I may not issue a new blog next Monday March 8th depending on my schedule.

Second, I should have stayed in Captain Obvious character the entire blog last week when presenting my expectations for March, I would be looking much better a week later! I believed that widespread cold temperatures and the record extensive snow cover at least across North America were going to make it difficult for mild weather to become widespread in March even despite a strengthening stratospheric PV. The latest

GFS is predicting a canonical positive AO by mid-March with low pressure/geopotential heights focused in the Central Arctic surrounded by high pressure/geopotential heights across the mid-latitudes forming an annulus in the NH circulation pattern. And though the stratospheric PV is often circular in shape it is rare to see the tropospheric PV as circular as predicted in the 11-15 day period (**Figure 8**) and is reminiscent of last winter. I commented how I was surprised how cold temperatures in Siberia seemed immune to the strong PV/positive AO but now even Siberia is predicted to turn much milder (**Figure 9**).

Though before the mild pattern really takes hold there is a respite or interlude from the overall mild pattern due to transitory high pressure over Greenland. High pressure over Greenland favors the return of troughing with more seasonable temperatures across Europe and at least temporarily blocks milder air from getting into the Eastern US. I showed this plot last week but using a North Atlantic regional plot of the polar cap geopotential height anomalies (PCHs) seems to suggest that high pressure over Greenland originated in the stratosphere and is one last vestige of the stratospheric PV disruption from January (**Figure i**). Whether this is real or apparent I don't know and is a very interesting question to me.

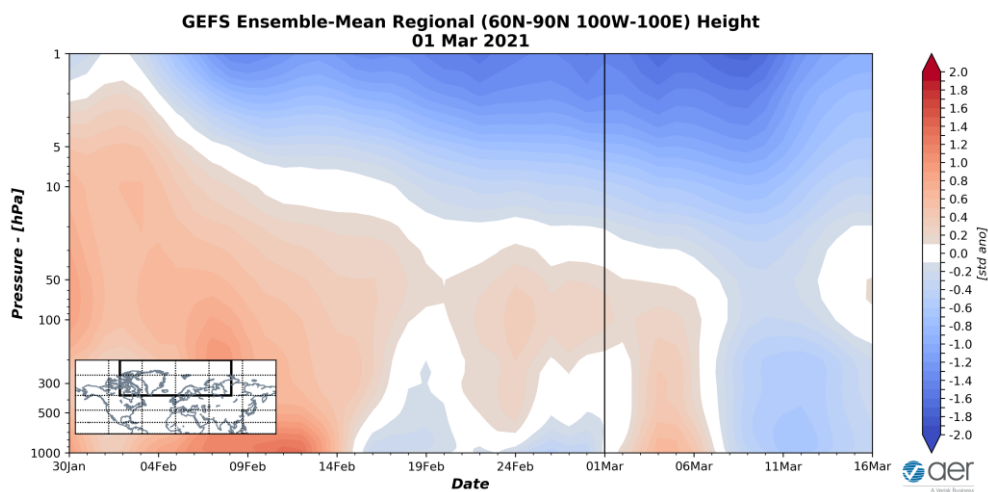


Figure i. Observed and predicted daily geopotential height standardized anomalies area-averaged over the North Atlantic region (see insert). The forecast is from the 00Z 1 March 2021 GFS ensemble.

Once that transitory spike in PCHs limited to the North Atlantic sector fades it is all cold/negative PCHs all the time. This favors a positive AO and a mild pattern across the NH mid-latitudes. And as is typical in strong positive AO regimes the two regions most likely to experience troughing and relatively cold temperatures in mid-March and into the foreseeable future are Western Asia and western North America.

There is still a chance of winter to cling on for dear life across North America more so than Eurasia. A strong PV favors cold air pooling across the North American Arctic that could overspread much of Canada and even make it into the Eastern US especially if there is even a minor disruption of the PV.

1-5 day

The AO is currently positive (**Figure 1**) but will trend negative this week as positive pressure/geopotential height anomalies build across Greenland with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with predicted positive geopotential height anomalies across Greenland later this week (**Figure 2**), the NAO is predicted to trend negative this week as well.

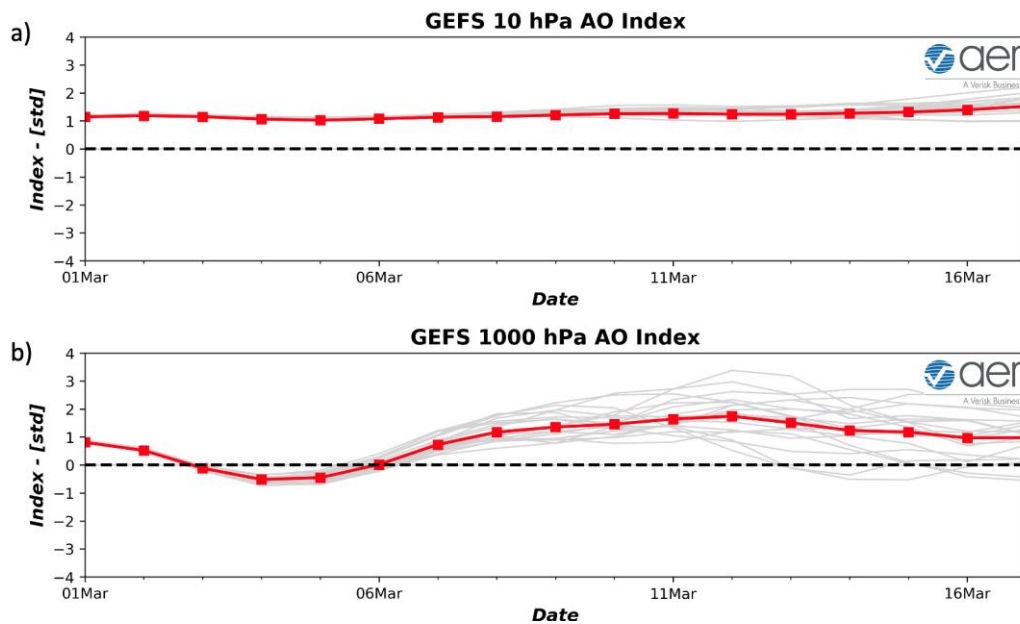


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 1 March 2021 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 1 March 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies are predicted to be widespread across Europe (**Figure 2**). This pattern favors normal to above normal temperatures across all of Europe with the exception of the UK (**Figure 3**) where northerly flow will bring relatively colder temperatures. This week, ridging/positive geopotential height anomalies centered over Europe and over towards Greenland will anchor troughing/negative geopotential height anomalies across Northern and Western Asia with ridging/positive geopotential height anomalies across Southern and Eastern

Asia (**Figure 2**). This pattern favors normal to below normal temperatures for Northern Asia with normal to above normal temperatures for Southern Asia (**Figure 3**).

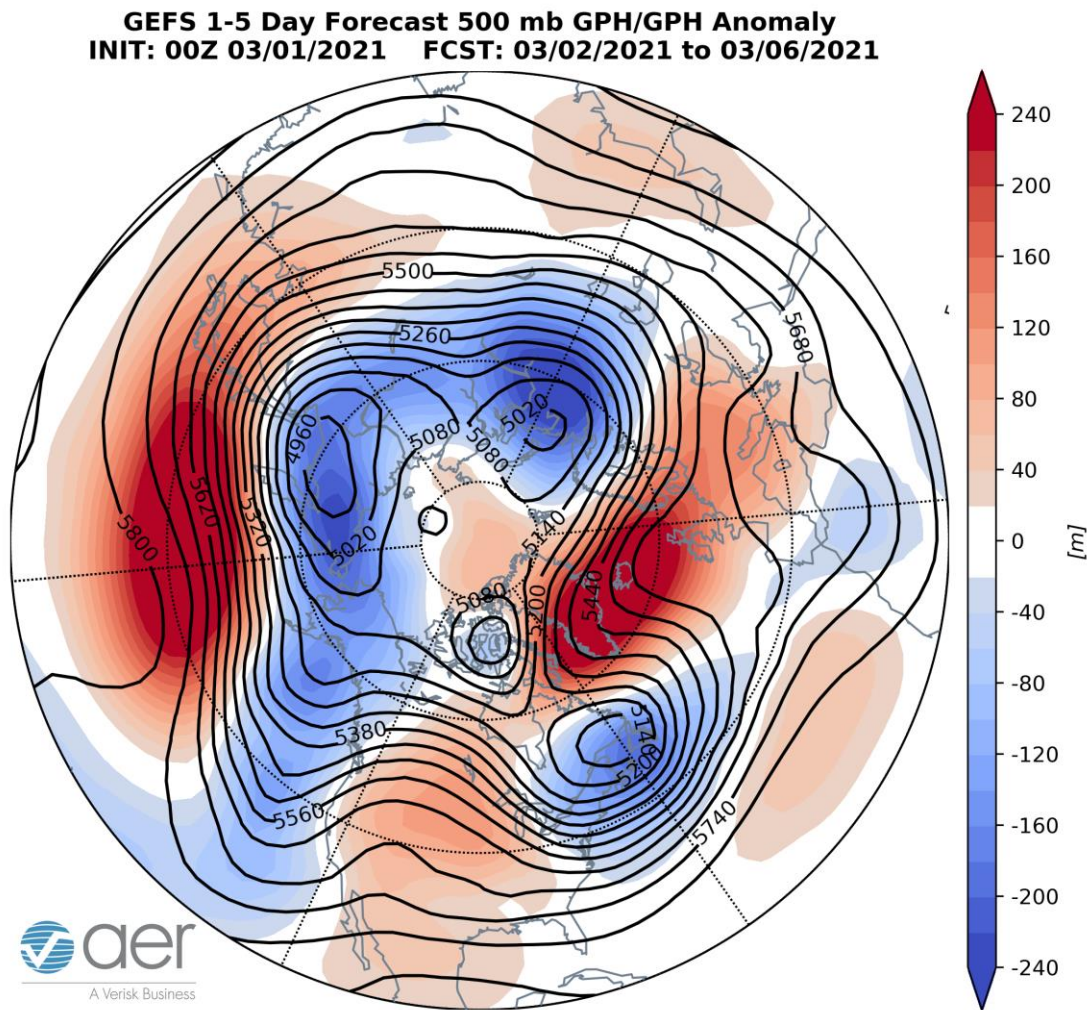


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 2 – 6 March 2021. The forecasts are from the 00z 1 March 2021 GFS ensemble.

This week troughing/negative geopotential height anomalies will extend from Alaska across Northern and Eastern Canada into the Northeastern US with ridging/positive geopotential height anomalies centered across Central Canada and the Central US (**Figure 2**). This pattern is predicted to bring normal to below normal temperatures across Alaska, Northern and Eastern Canada and the Eastern US with normal to above normal temperatures across Southwestern Canada, Central and Western US (**Figure 3**).

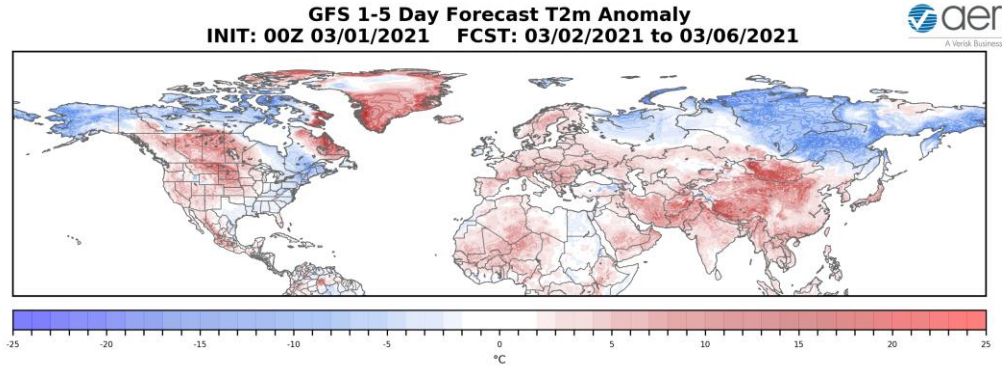


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 2 – 6 March 2021. The forecast is from the 00Z 1 March 2021 GFS ensemble.

Trouching and/or colder temperatures are predicted to support new snowfall across Northwestern Eurasia and Eastern Siberia, while warmer temperatures will cause snow melt in Central and Eastern Asia (**Figure 4**). Trouching and/or colder temperatures are predicted to support new snowfall across western Alaska, Northern and Eastern Canada, while warmer temperatures will cause snow melt in Western Canada and the Western US (**Figure 4**).

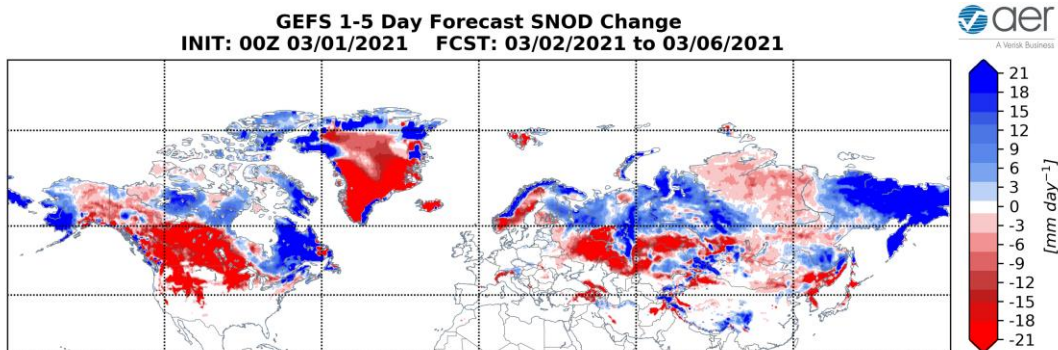


Figure 4. Forecasted snow depth changes (mm/day ; shading) from 2 – 6 March 2021. The forecast is from the 00Z 1 March 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to turn positive again next week (**Figure 1**) as negative geopotential height anomalies dominate the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with mixed geopotential height anomalies predicted across Greenland (**Figure 5**), the NAO is predicted to turn neutral to positive as well.

GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 03/01/2021 FCST: 03/07/2021 to 03/11/2021

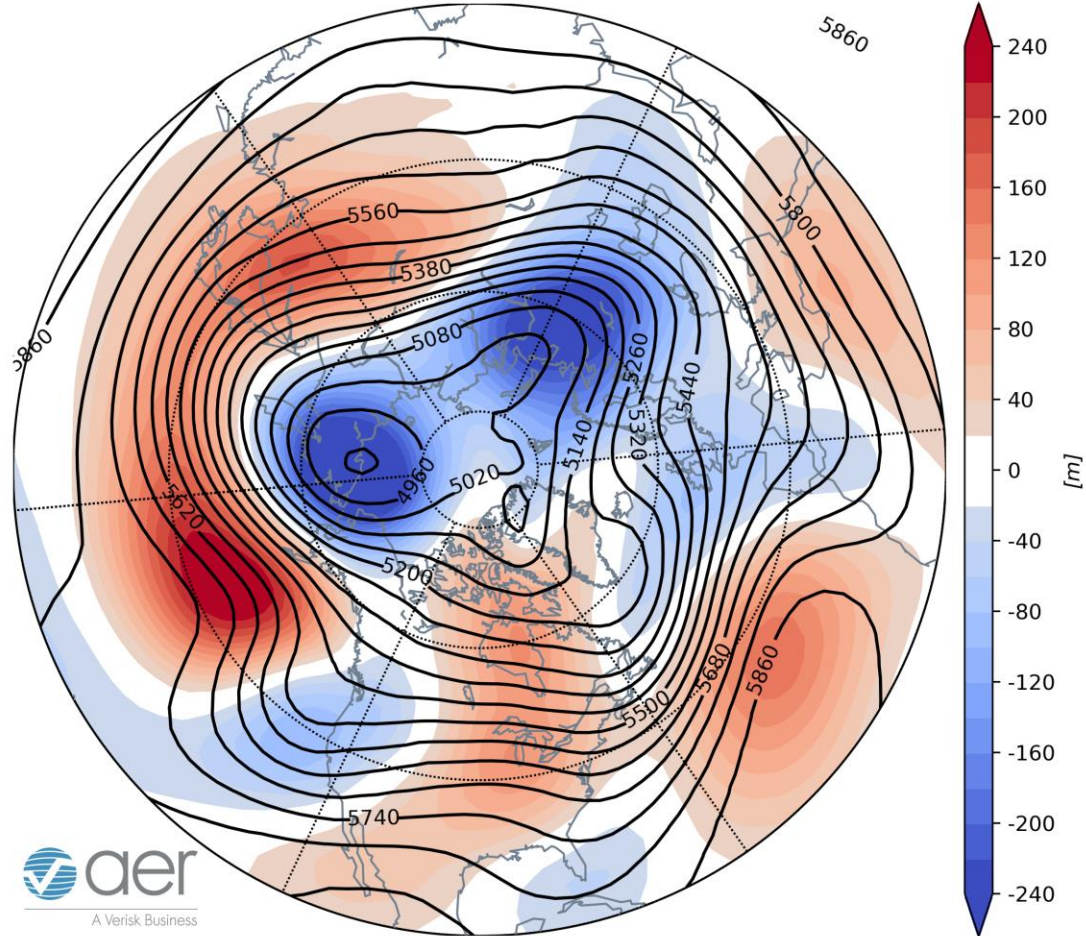


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 7 – 11 March 2021. The forecasts are from the 00z 1 March 2021 GFS ensemble.

Transient ridging/positive geopotential height anomalies predicted across Greenland will contribute to troughing/negative geopotential height anomalies across Europe this period (**Figures 5**). This will favor normal to below normal temperatures across much of Europe including the UK except for normal to above normal temperatures across the Mediterranean region where westerly flow will persist normal to above normal temperatures (**Figure 6**). Persistent troughing/negative geopotential height anomalies across Northern Asia is predicted to become more regionalized to Eastern Siberia and the Urals with ridging/positive geopotential height anomalies across Southern and Eastern Asia this period (**Figure 5**). This is predicted to favor normal to below normal temperatures across much of Western Asia and Eastern Siberia with normal to above normal temperatures to become more widespread across the remainder of Asia (**Figure 6**).

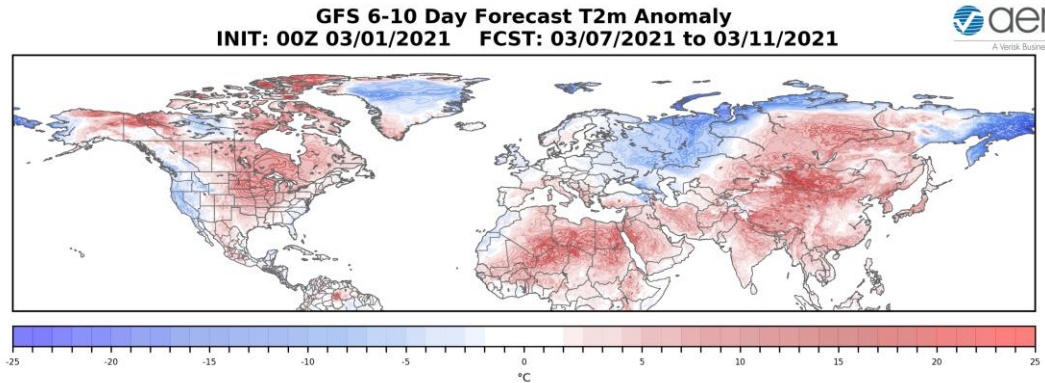


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 7 – 11 March 2021. The forecasts are from the 00Z 1 March 2021 GFS ensemble.

Trounging/negative geopotential height anomalies are predicted to become focused in western North America while ridging/positive geopotential height anomalies will overspread Eastern Canada and the Eastern US this period (**Figure 5**). This pattern is predicted to bring normal to below normal temperatures across Alaska and the West Coasts of Canada and the US with normal to above normal temperatures across Eastern Canada and the Eastern US (**Figure 6**).

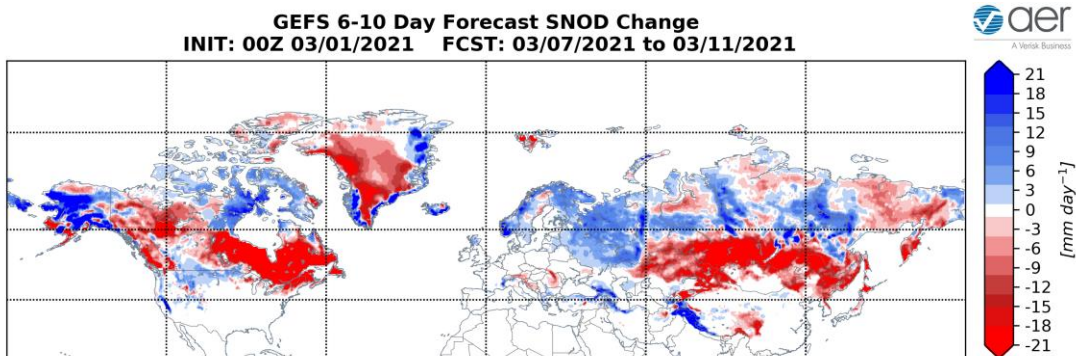


Figure 7. Forecasted snow depth changes (mm/day ; shading) from 7 – 11 March 2021. The forecasts are from the 00Z 1 March 2021 GFS ensemble.

Trounging and/or colder temperatures are predicted to potentially support new snowfall across Northwestern Eurasia and Siberia while warmer temperatures will cause regionalized snow melt in Central and Eastern Asia (**Figure 7**). Trounging and/or colder temperatures are predicted to support the potential for new snowfall across Alaska, Northern Canada and the West Coasts of Canada and the US while warmer temperatures will cause snow melt in Eastern Canada and New England (**Figure 7**).

11-15 day

As geopotential height anomalies are predicted to remain negative across much of the Arctic with mostly positive geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO should remain positive to strongly positive this period (**Figure 1**). With negative pressure/geopotential height anomalies spread across Greenland (**Figure 8**), the NAO is predicted to remain positive this period as well.

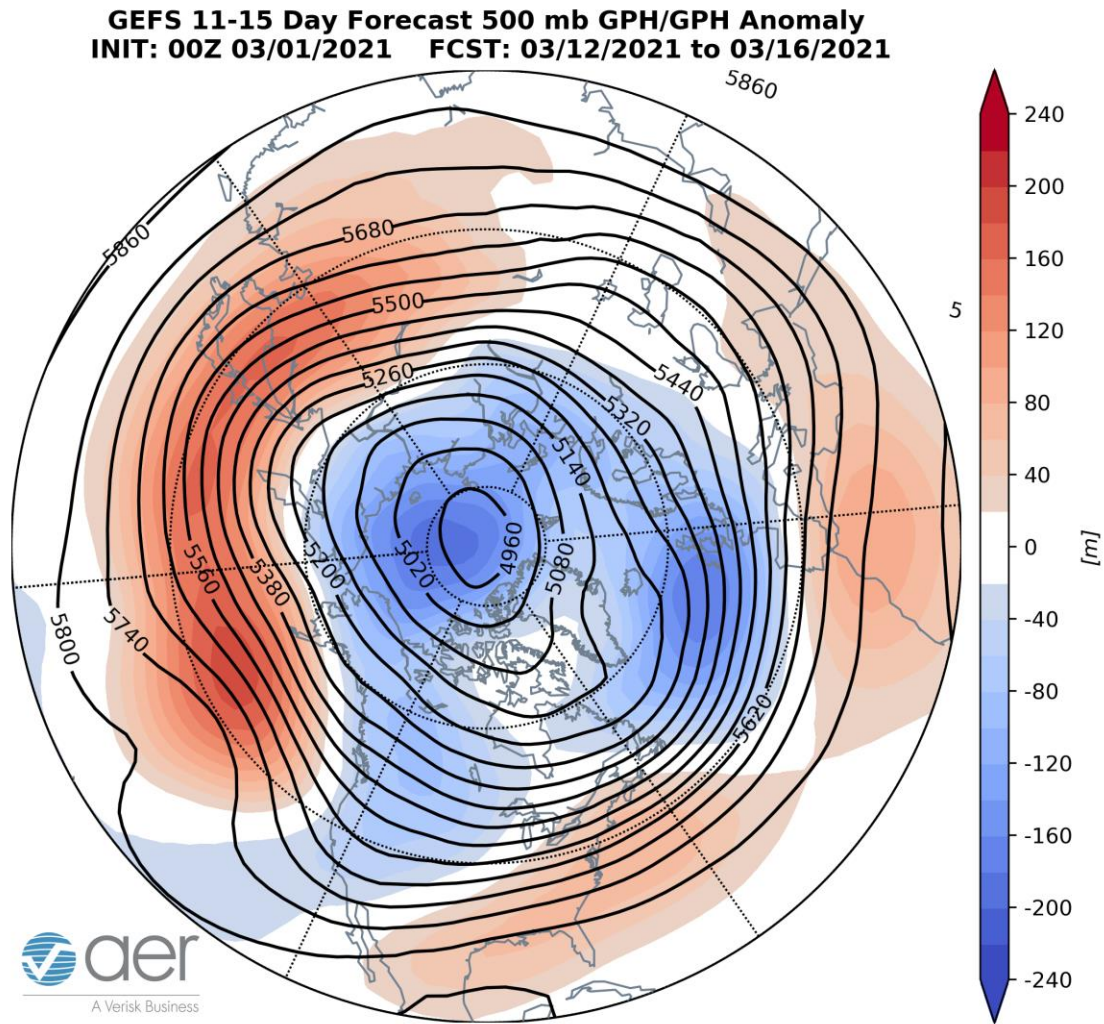


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 12 – 16 March 2021. The forecasts are from the 00z 1 March 2021 GFS ensemble.

A strong positive AO pattern with low pressure centered over the North Pole and high pressure strung across the mid-latitudes will force a fast-westerly flow of maritime air across Europe this period (**Figure 8**). This favors widespread normal to above normal temperatures across Europe including the UK this period (**Figure 9**). Similarly, across Asia a strong westerly flow of air with low pressure to the north and high pressure to the south will favor normal to above normal temperatures widespread across Asia with the

exception of regional normal to below normal temperatures across parts of Western Asia where weak troughing is predicted (**Figure 9**).

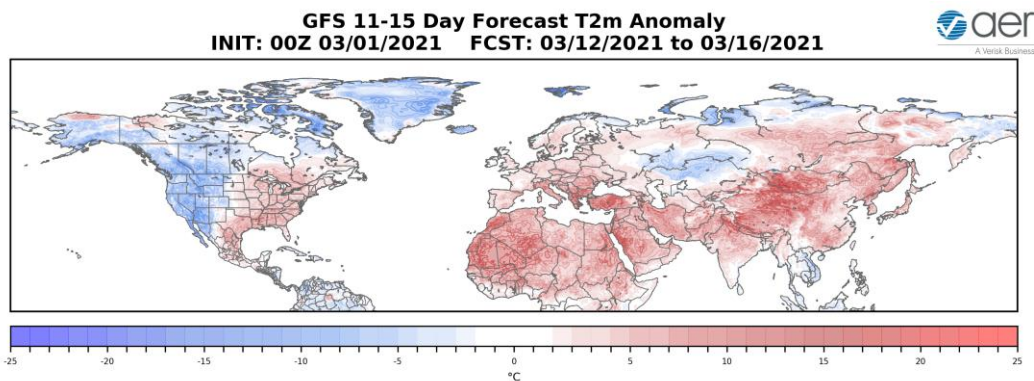


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 12 – 16 March 2021. The forecasts are from the 00z 1 March 2021 GFS ensemble.

Deepening troughing/negative geopotential height in the Central Arctic will focus troughing in western North America with ridging/positive geopotential height anomalies in eastern North America this period (**Figure 8**). This pattern favors widespread normal to below normal temperatures for Alaska, Western Canada and the Western US with normal to above normal temperatures across much of Eastern Canada and the Eastern US (**Figure 9**).

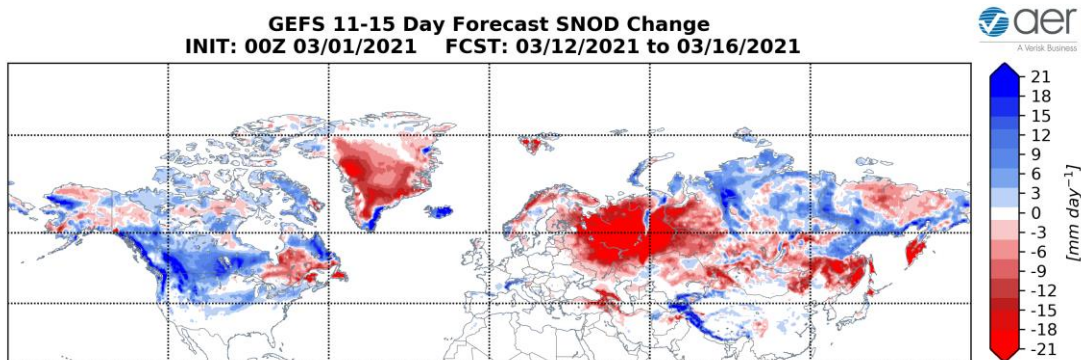


Figure 10. Forecasted snow depth changes (mm/day ; shading) from 12 – 16 March 2021. The forecasts are from the 00z 1 March 2021 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across Siberia and the Himalayas while warmer temperatures will cause snowmelt in Northeastern Europe and Northwestern Asia (**Figure 10**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, much of Northern and Western Canada, the Western US and even possibly the Northeastern US while warmer temperatures will result in snowmelt in Southeastern Canada (**Figure 10**).

Longer Term

30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to cold/negative PCHs throughout the troposphere and stratosphere for the next two weeks (**Figure 11**). The only exception is predicted warm/positive PCHs in the lower troposphere the end of this week. The deeper cold/negative PCHs currently in the upper stratosphere are predicted to descend through the stratosphere and troposphere all the way to the surface next week (**Figure 11**).

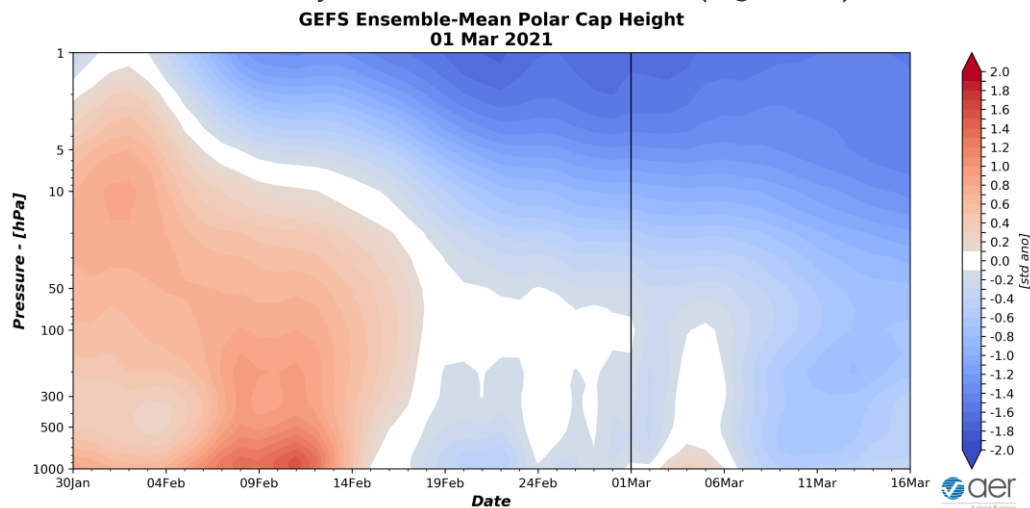


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 1 March 2021 GFS ensemble.

The overall cold/negative PCHs in the lower troposphere are consistent with the predicted positive surface AO the next two weeks (**Figure 1**). The one exception is later this week when the warm PCHs in the lower troposphere will coincide with a brief period of a negative surface AO (**Figure 1**). Similarly, the cold/negative PCHs in the mid-stratosphere are consistent with the positive stratospheric AO (at 10 hPa) the next two weeks (**Figure 1**). The descent of the more negative/cold PCHs in the stratosphere into the troposphere could force a period of a strongly positive AO in mid-March.

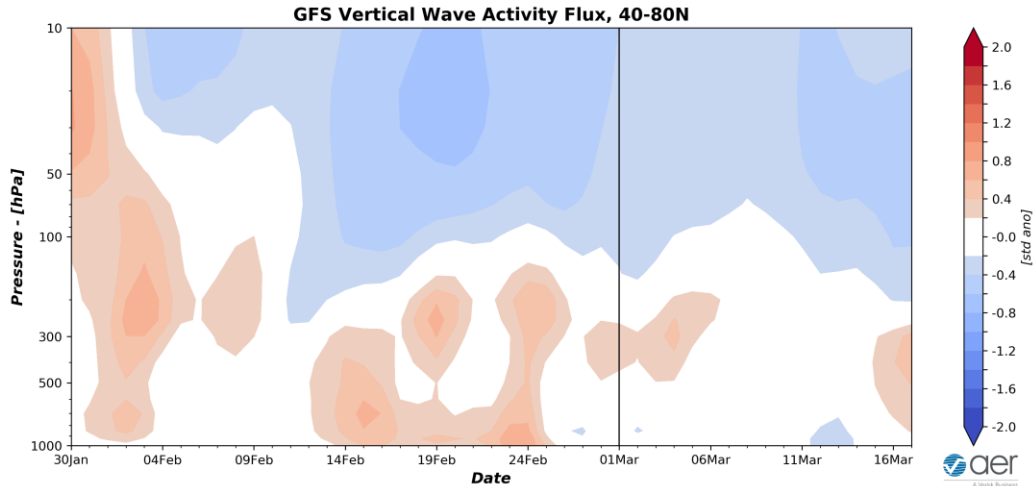


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 1 March 2021 GFS ensemble.

The plot of the Wave Activity Flux (WAFz and is proportional to poleward heat transport) forecast is showing currently below normal WAFz in the stratosphere but closer to normal WAFz in the troposphere (**Figure 12**). Still overall, the WAFz is predicted to be quiet, consistent with forecasts of a strong stratospheric PV.

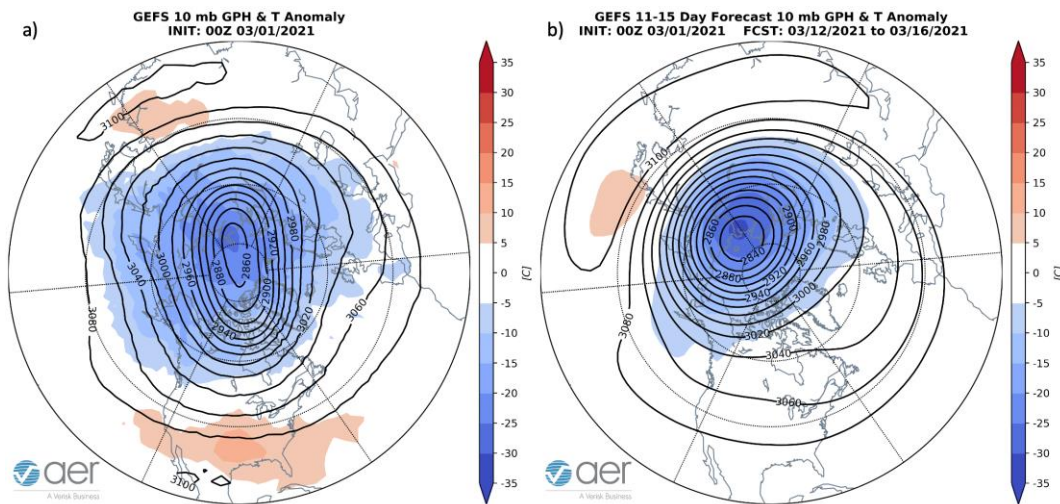


Figure 13. (a) Observed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 1 March 2021. (b) Same as (a) except forecasted averaged from 12 – 16 March 2021. The forecasts are from the 00Z 1 March 2021 GFS model ensemble.

The PV continues to strengthen with the vortex centered over the Laptev Sea (**Figure 13**). The PV is also a bit elongated possibly allowing some colder air into North

America (**Figure 13**). The PV center is predicted to migrate over towards Siberia mid-month and become more circular in shape (**Figure 13**). I believe that the PV center over Siberia may be a sign of some sort of minor PV disruption something to watch but nothing obvious at the moment.

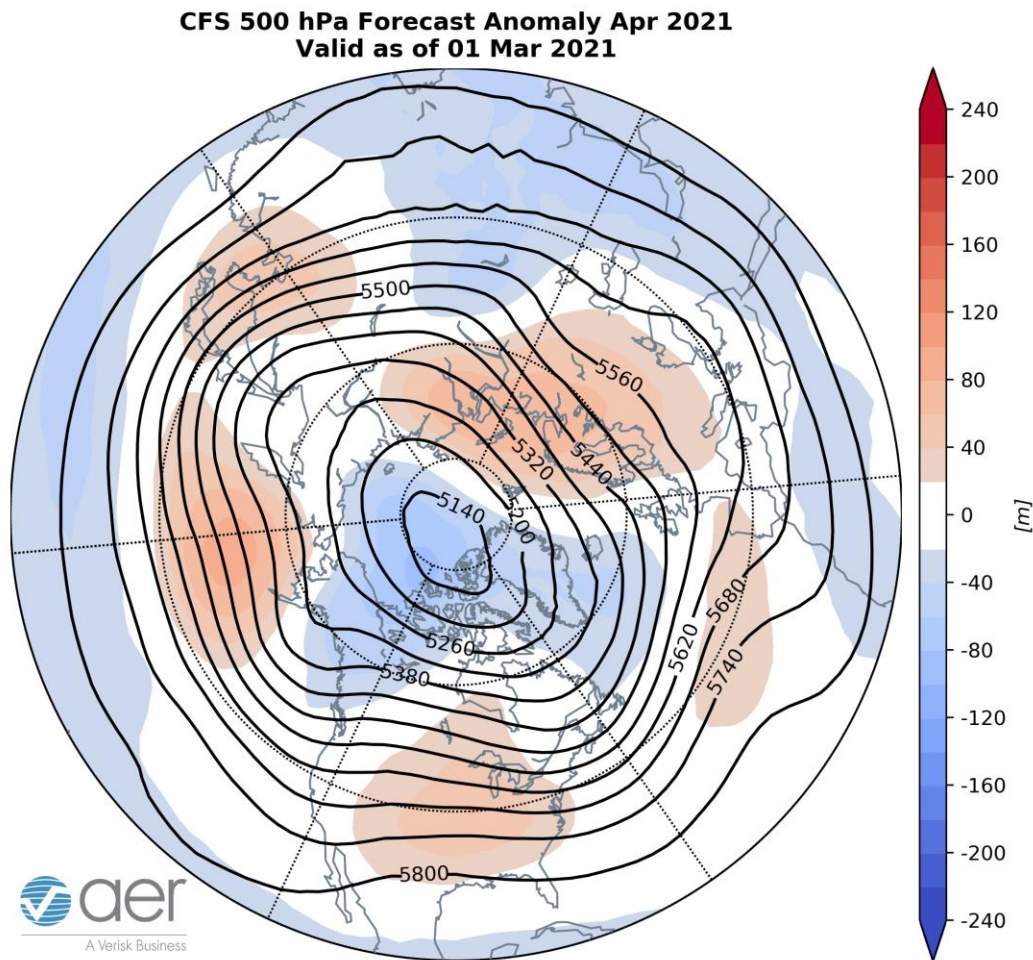


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for April 2021. The forecasts are from the 00Z 1 March 2021 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) forecast for April from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging across Scandinavia and the Urals, near the Dateline and eastern North America with troughing in Southern Europe, East Asia and western North America (**Figure 14**). This pattern favors relatively cold temperatures for Western and Southern Europe and East Asia with seasonable to relatively warm temperatures for Northern Europe, Central Asia and much of Canada and the US (**Figure 15**).

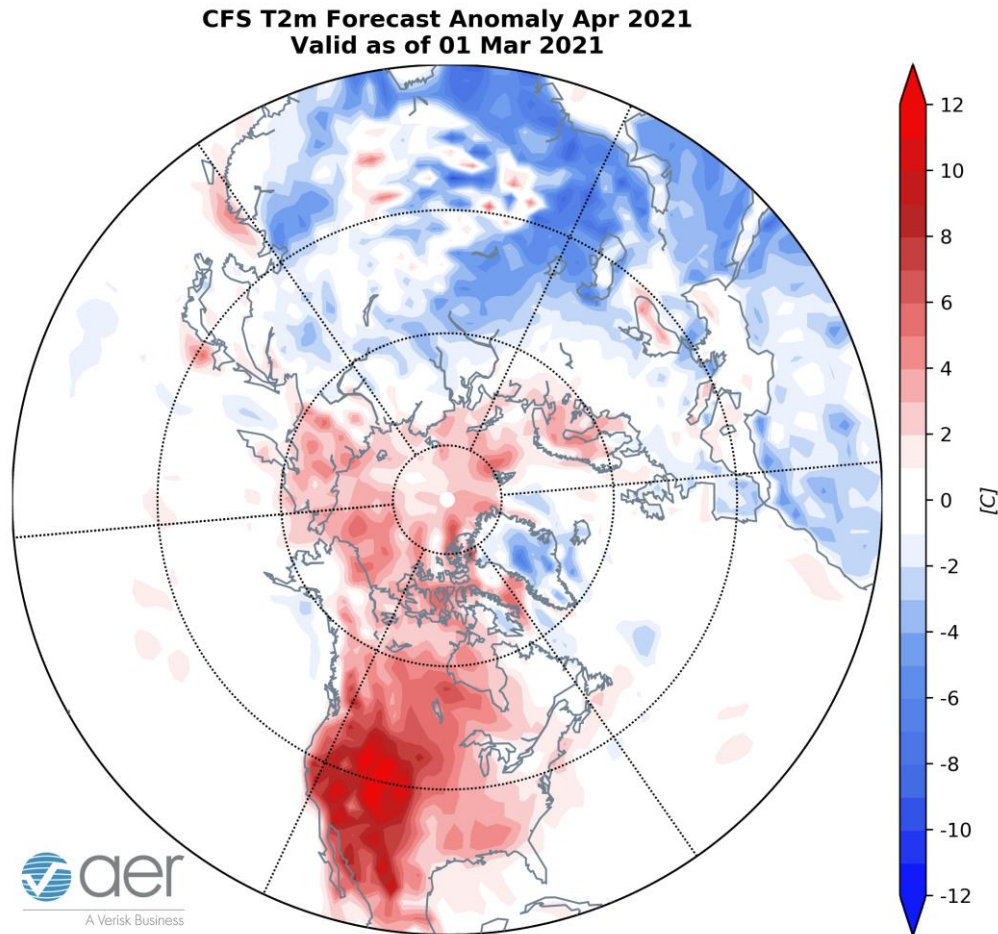


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for April 2021. The forecasts are from the 00Z 1 March 2021 CFS.

Surface Boundary Conditions

Arctic sea ice extent (not updated due to data issues)

Arctic sea ice is likely near its seasonal maximum and remains below normal but more extensive than recent winters. Negative sea ice anomalies exist mostly in Baffin Bay and the Sea of Okhotsk (**Figure 16**). Below normal sea ice in the Barents-Kara seas favor Ural blocking and cold temperatures in Central and East Asia, however this topic remains controversial. Recent research has shown that the regional anomalies that are most highly correlated with the strength of the stratospheric PV are across the Barents-Kara seas region where low Arctic sea ice favors a weaker winter PV. Low sea ice in the Chukchi and Bering seas may favor colder temperatures across North America but have not been shown to weaken the PV. Sea ice should continue to grow in this region based on the forecast.

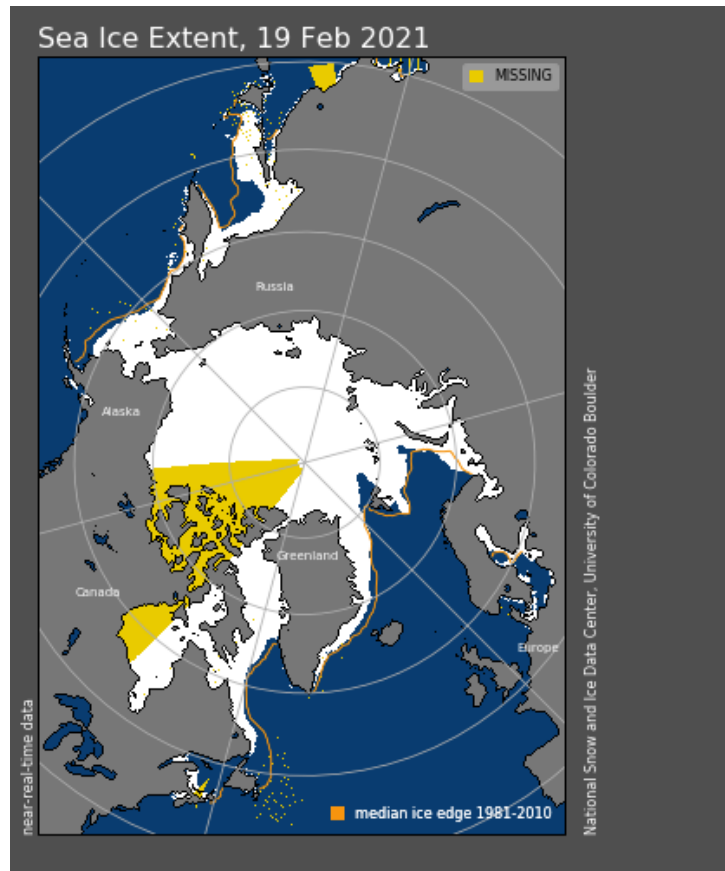


Figure 16. Observed Arctic sea ice extent on 19 February 2021 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies remain negative and we continue to observe a weak La Niña conditions (**Figure 17**) and La Niña is expected to persist and remain weak through the winter and into the spring. Observed SSTs across the NH remain well above normal especially near Alaska and in the Gulf of Alaska, the western North Pacific and offshore of eastern North America though below normal SSTs exist regionally especially in the Southern Hemisphere and south of Iceland. Warm SSTs in the Gulf of Alaska may favor mid-tropospheric ridging in the region.

SST Anomaly - Week Ending 28 Feb 2021

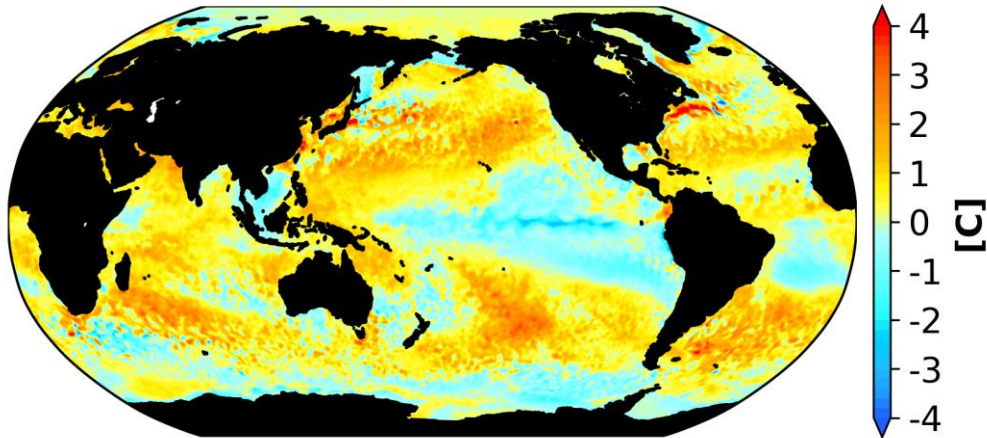


Figure 17. The latest weekly-mean global SST anomalies (ending 28 February 2021). Data from NOAA OI High-Resolution dataset.

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 18**). The forecasts are for the MJO to emerge into phase eight and then phase one. MJO phases eight and one favor blocking across Northern Canada and troughing in the Eastern US. The MJO does not seem to be contributing much to the predicted weather pattern across North America but admittedly this is outside of my expertise.

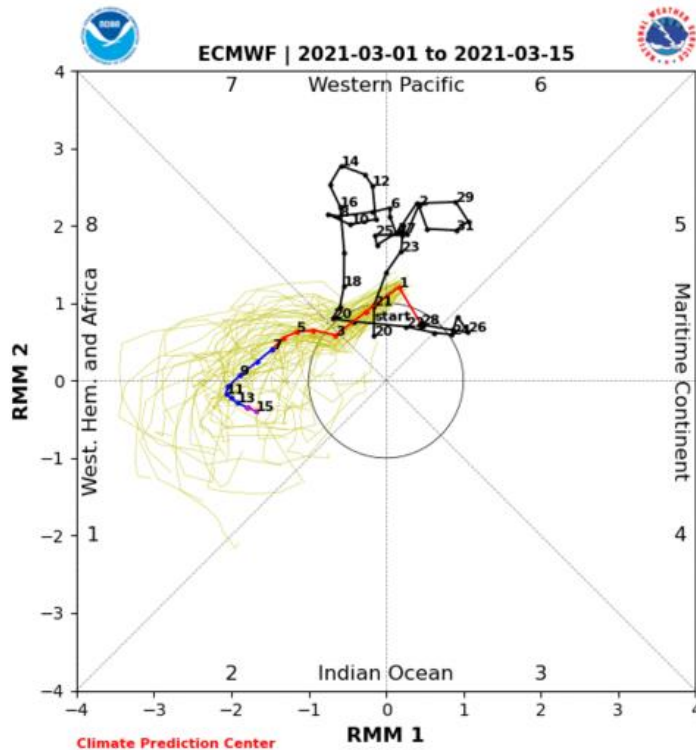


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 1 March 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>

Northern Hemisphere Snow Cover

Snow cover extent declined over the past week across Eurasia and remains near decadal lows. Snow cover advance is likely in its seasonal decline. Above normal snow cover extent in October, favors a strengthened Siberian high, cold temperatures across northern Eurasia and a weakened polar vortex/negative AO this upcoming winter followed by cold temperatures across the continents of the NH.

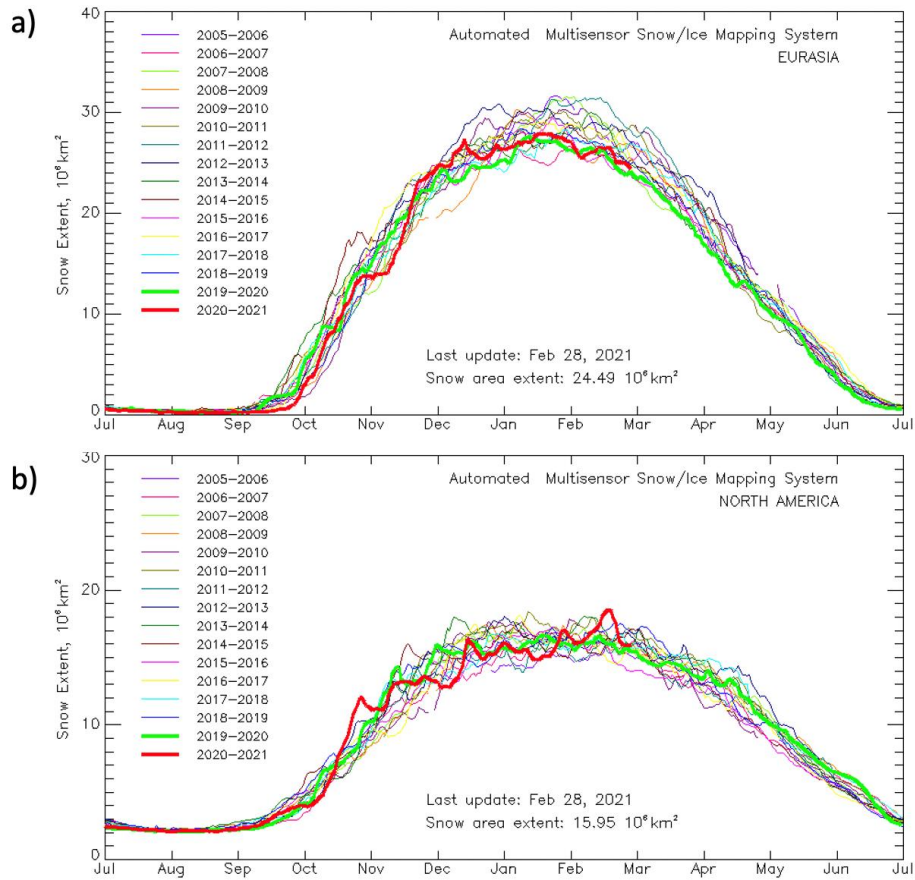


Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 28 February 2021. Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover declined from its record extent over the past week and is now at decadal means. Snow cover is now likely in its seasonal decline.