

Arctic Oscillation and Polar Vortex Analysis and Forecasts

March 15, 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 remain neutral to positive the next two weeks as 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. The North Atlantic Oscillation (NAO) is also

predicted to remain neutral to positive the next two weeks as persistent negative pressure/geopotential height anomalies are predicted across Greenland and Iceland.

- This week ridging/positive geopotential height anomalies centered between Iceland and the United Kingdom (UK) are predicted to force troughing/negative geopotential height anomalies and relatively colder temperatures across much of Europe, though the UK which is closest to the ridging is predicted to experience normal to above normal temperatures. However, starting next week, the ridging/positive geopotential height anomalies now in the eastern North Atlantic are predicted to overspread across Europe favoring normal to above normal temperatures across much of Europe.
- Ridging/positive geopotential height anomalies coupled with normal to above normal temperatures are predicted to dominate Southern and Eastern Asia while troughing/negative geopotential height anomalies coupled with normal to below temperatures will persist across parts of Northern and Western Asia the next two weeks
- Over the next two weeks, troughing/negative geopotential height anomalies coupled with normal to below temperatures are predicted to deepen across Alaska, Western and Northern Canada and the Western United States (US) while ridging/positive geopotential height anomalies are predicted to build, coupled with normal to above normal temperatures, across Eastern Canada and the Eastern US.
- In the Impacts section I discuss the influence of the strong polar vortex (PV) on the weather across the Northern Hemisphere (NH).

Impacts

The lesson from this week's blog is that almost never bet against the polar vortex (PV). I thought that persistence of the cold February would win the day but, in the end, it looks like instead the strong PV will rule the day for the month of March. Though Siberia does look like it will have an overall cold month and here in Boston it has been a great example of weather whiplash – either super cold or record warm.

Nothing terribly profound for me to write this week. The forecasts are for a positive AO, a strong stratospheric PV and cold/negative polar cap geopotential height anomalies (PCHs) for the foreseeable future. All these favor relatively mild temperatures for the Eastern US, Europe and East Asia and for the most part this is consistent with the forecasts. The one exception is this week with relatively high pressure/heights in the northern North Atlantic will force troughing in Europe accompanied by relatively cool temperatures this week. It will also force just enough troughing in the Northeastern US to eke out one last snowfall in the Northeast this winter season. In **Figure i**, I show the

regional North Atlantic PCHs where there is one last spike in PCHs in the troposphere and lower stratosphere associated with high pressure near Greenland.

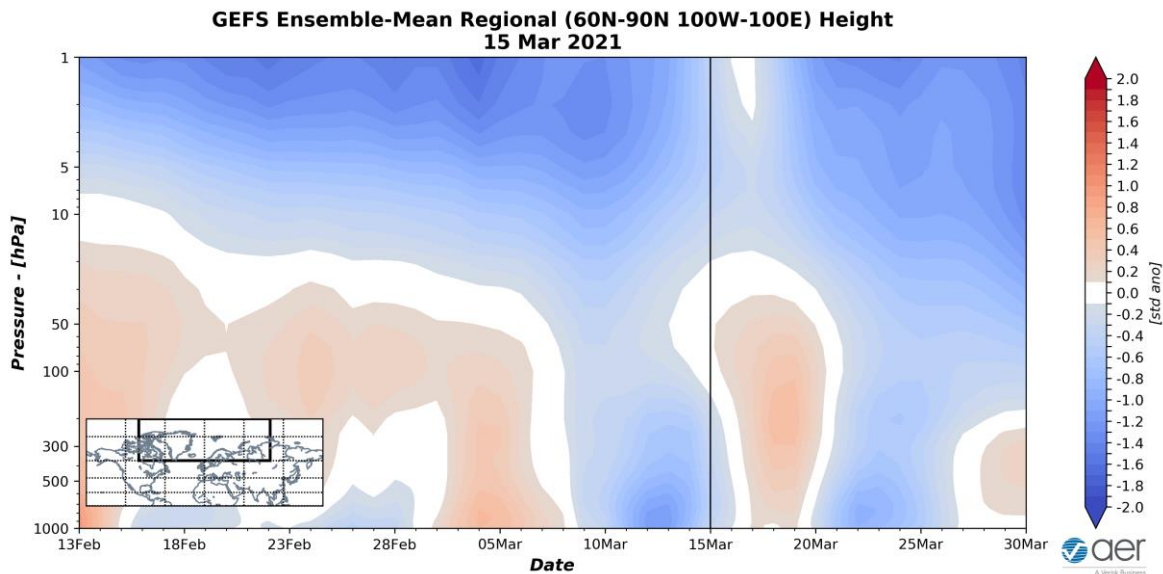


Figure i. Observed and predicted daily geopotential height standardized anomalies area-averaged over the North Atlantic region (see insert). The forecast is from the 00Z 15 March 2021 GFS ensemble.

Looking at the forecasts of the stratospheric PV, still looks like a minor PV stretching event is possible that favors relatively cold temperatures in the Eastern US. I have been saying this for a while and it keeps getting pushed off, so even I am skeptical. Also, it is getting so late in the season, I am unsure how much of an impact it could have on the weather regardless.

1-5 day

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

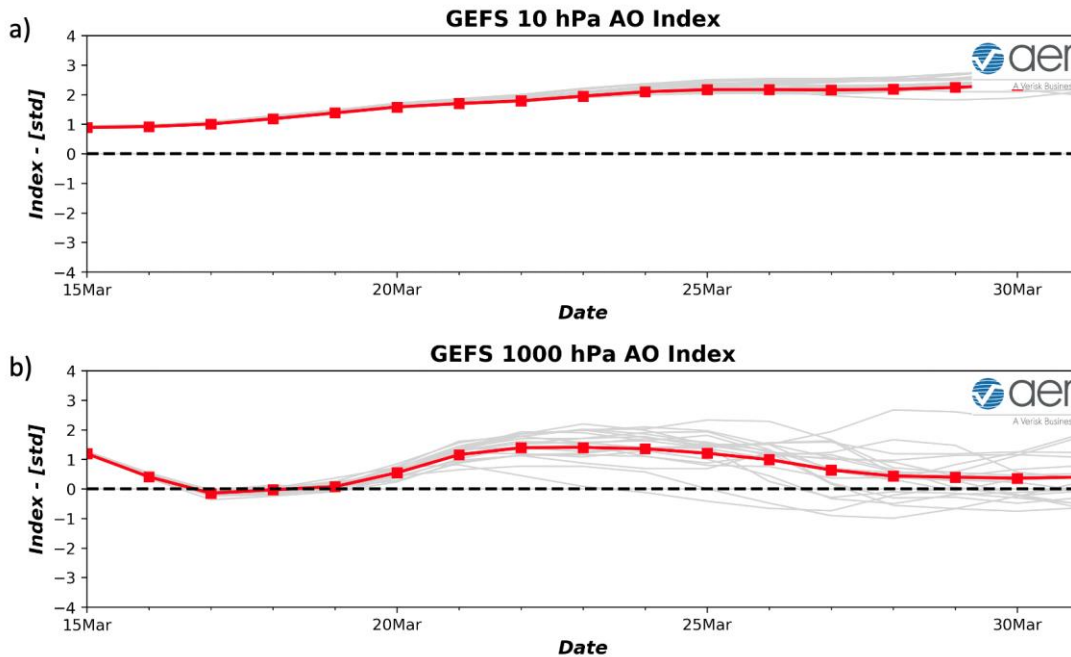


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 15 March 2021 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 15 March 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Ridging/positive geopotential height anomalies predicted centered between Iceland and the UK is predicted to force troughing/negative geopotential height anomalies across much of Europe this week (**Figures 2**). **This will favor** normal to below normal temperatures across much of Europe though one exception will be the UK **with** normal to above normal temperatures due to high heights across the region (**Figure 3**). Persistent troughing/negative geopotential height anomalies across Northern Asia is predicted to become more regionalized to the North Slope of Siberia and Northwest Russia with ridging/positive geopotential height anomalies across Southern and Eastern Asia this period (**Figure 2**). This is predicted to favor normal to below normal temperatures across far Northern and western Asia with normal to above normal temperatures widespread across the remainder of Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 03/15/2021 FCST: 03/16/2021 to 03/20/2021

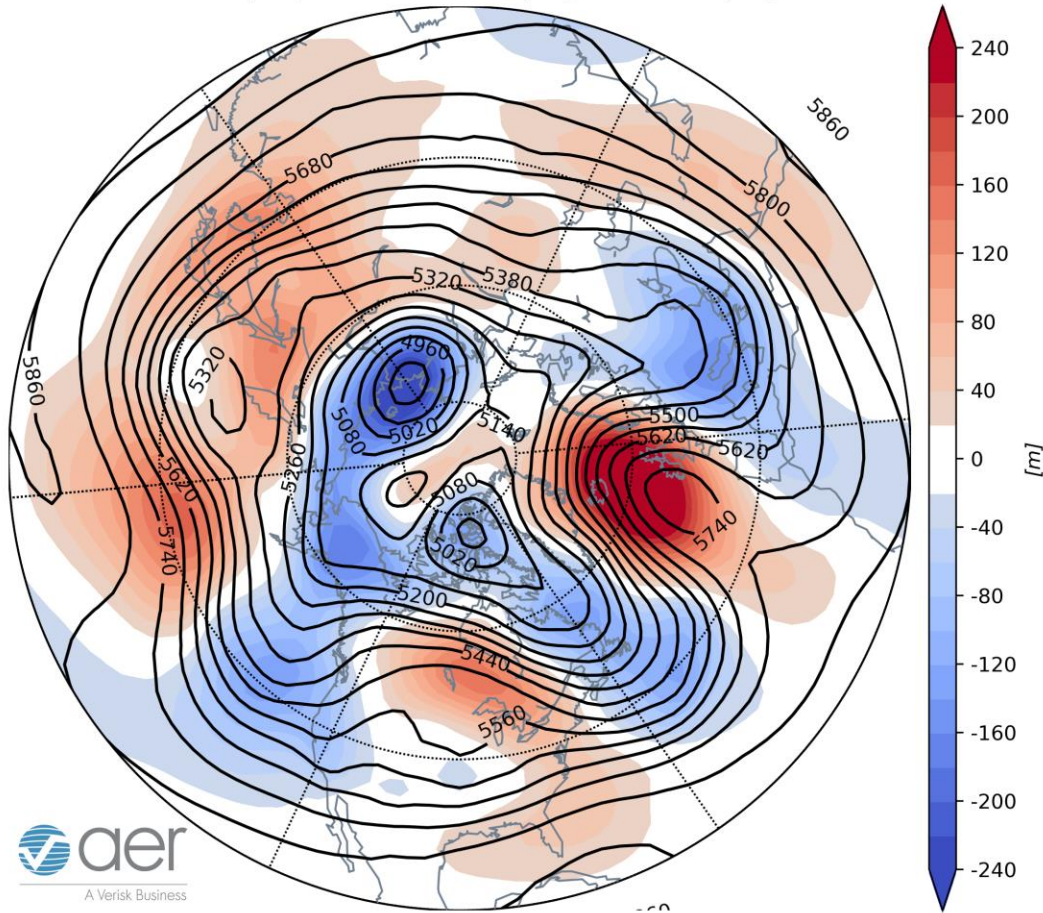


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 16 – 20 March 2021. The forecasts are from the 00z 15 March 2021 GFS ensemble.

This week, troughing/negative geopotential height anomalies are predicted to be focused along the west coast of North America and the Canadian Maritimes while ridging/positive geopotential height anomalies will overspread Central Canada and the Eastern US this period (**Figure 2**). This pattern is predicted to bring normal to below normal temperatures across Alaska, the West Coasts of Canada and the US and the Canadian Maritimes with normal to above normal temperatures across Central Canada and the Eastern US (**Figure 3**).

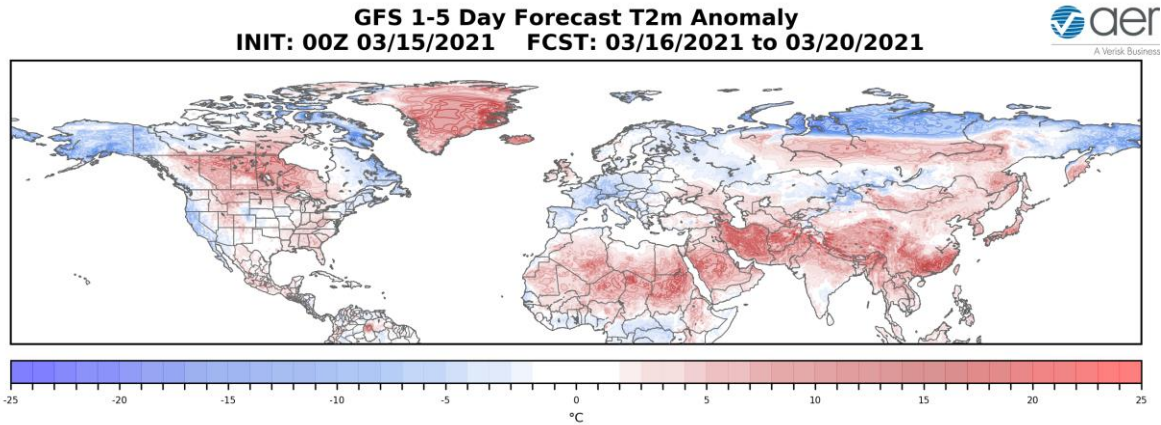


Figure 3. Forecasted surface temperature anomalies (°C; shading) from 16 – 20 March 2021. The forecast is from the 00Z 15 March 2021 GFS ensemble.

Trouching and/or colder temperatures are predicted to support regional snowfall across Europe, Asia and North America (**Figure 4**) while warmer temperatures will cause widespread snow melt in Asia, Canada and the US (**Figure 4**).

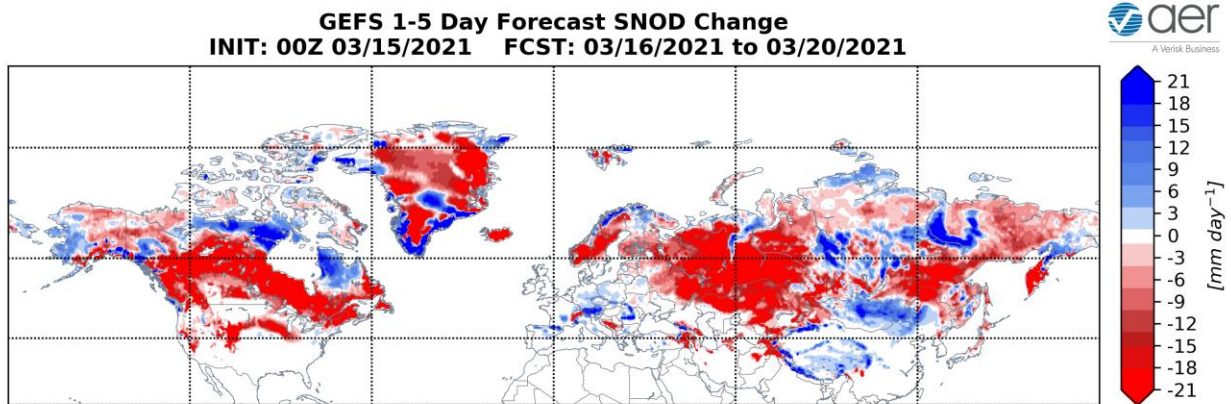


Figure 4. Forecasted snow depth changes (mm/day; shading) from 16 – 20 March 2021. The forecast is from the 00Z 15 March 2021 GFS ensemble.

Mid-Term

6-10 day

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

**GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 03/15/2021 FCST: 03/21/2021 to 03/25/2021**

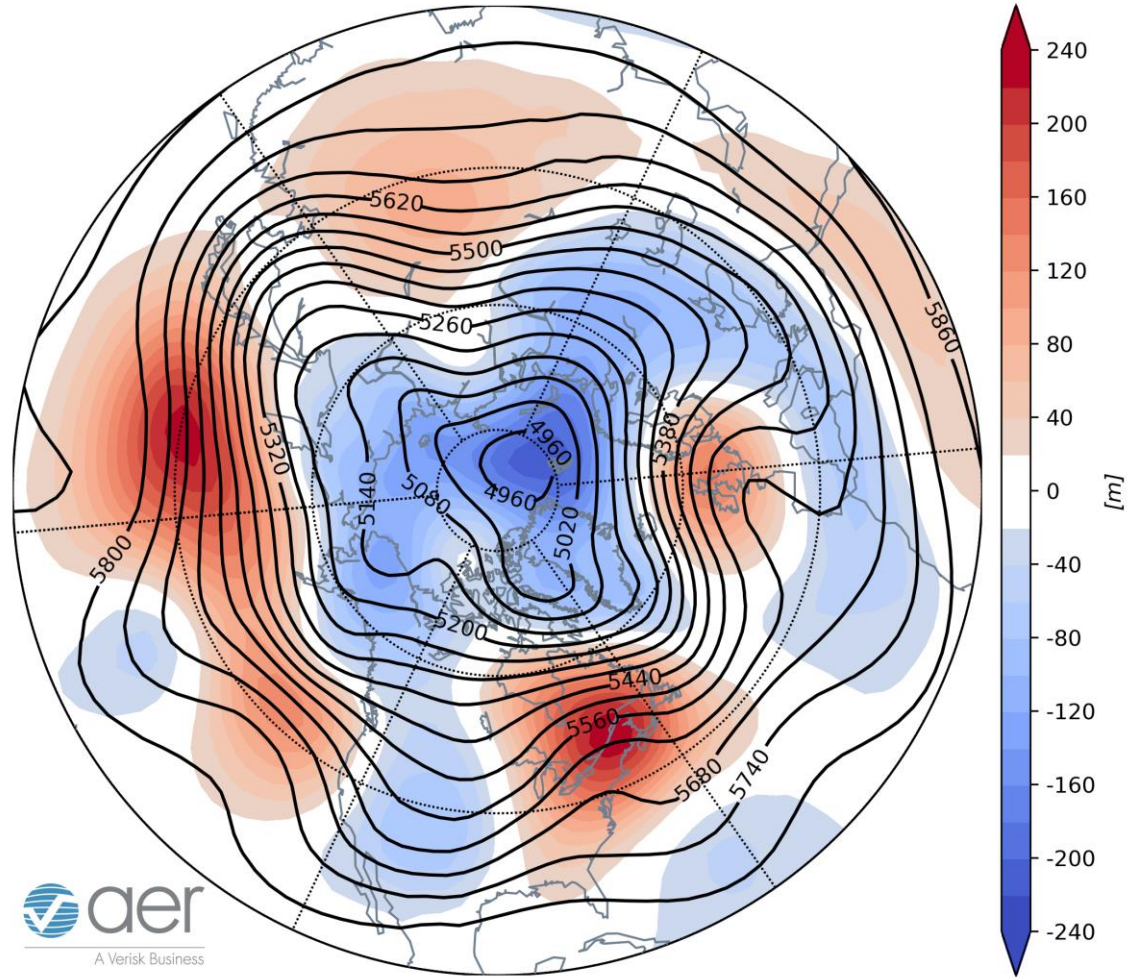


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 21 – 25 March 2021. The forecasts are from the 00z 15 March 2021 GFS ensemble.

Ridging/positive geopotential height anomalies previously in the eastern North Atlantic are predicted to overspread Northwestern Europe this week while troughing/negative geopotential height anomalies persist across Southern Europe (**Figure 5**). **This will favor** normal to above normal temperatures across Northwestern Europe including the UK **with** normal to below normal temperatures across Southern and even into Eastern Europe (**Figure 6**). Troughing/negative geopotential height anomalies across Northern and Western Asia with ridging/positive geopotential height anomalies across Southern and Eastern Asia are predicted to persist however the ridging is predicted to push further north (**Figure 5**). This pattern favors normal to below normal temperatures across much of Western Asia and Eastern Siberia with normal to above normal temperatures widespread across Southern, Central and Eastern Asia (**Figure 6**).

GFS 6-10 Day Forecast T2m Anomaly
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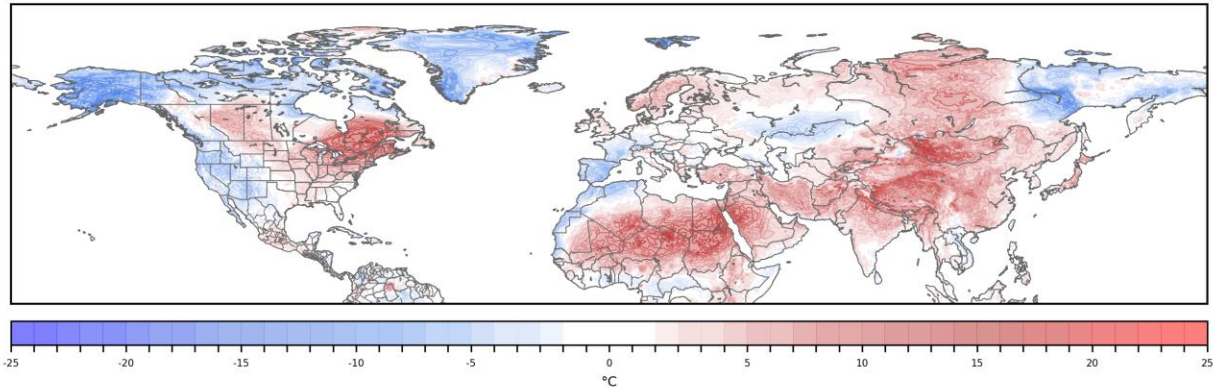


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 21 – 25 March 2021. The forecasts are from the 00Z 15 March 2021 GFS ensemble.

Trounging/negative geopotential height anomalies are predicted to become more widespread across western North America while ridging/positive geopotential height anomalies remain entrenched across Eastern Canada and the Eastern US this period (**Figure 5**). This pattern is predicted to bring normal to below normal temperatures across Alaska, Western Canada and the Western US while normal to above normal temperatures persists across Eastern Canada and the Eastern US (**Figure 6**).

GEFS 6-10 Day Forecast SNOD Change
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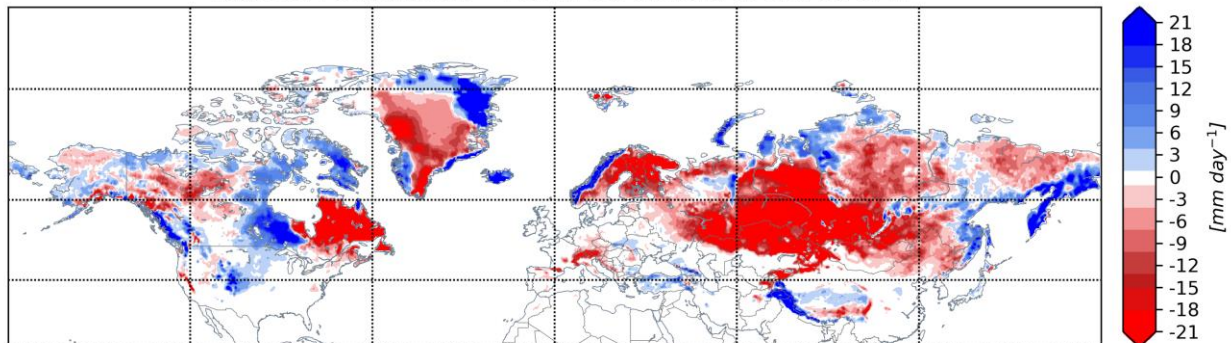


Figure 7. Forecasted snow depth changes (mm/day; shading) from 21 – 25 March 2021. The forecasts are from the 00Z 15 March 2021 GFS ensemble.

Trounging and/or colder temperatures are predicted to support regional snowfall across Europe, Asia but especially Central Canada and the Central US (**Figure 7**) while warmer temperatures will cause widespread snow melt in Europe, Asia and Canada (**Figure 7**).

11-15 day

As geopotential height anomalies are predicted to remain negative for much of the Arctic with mixed positive geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO should remain 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.

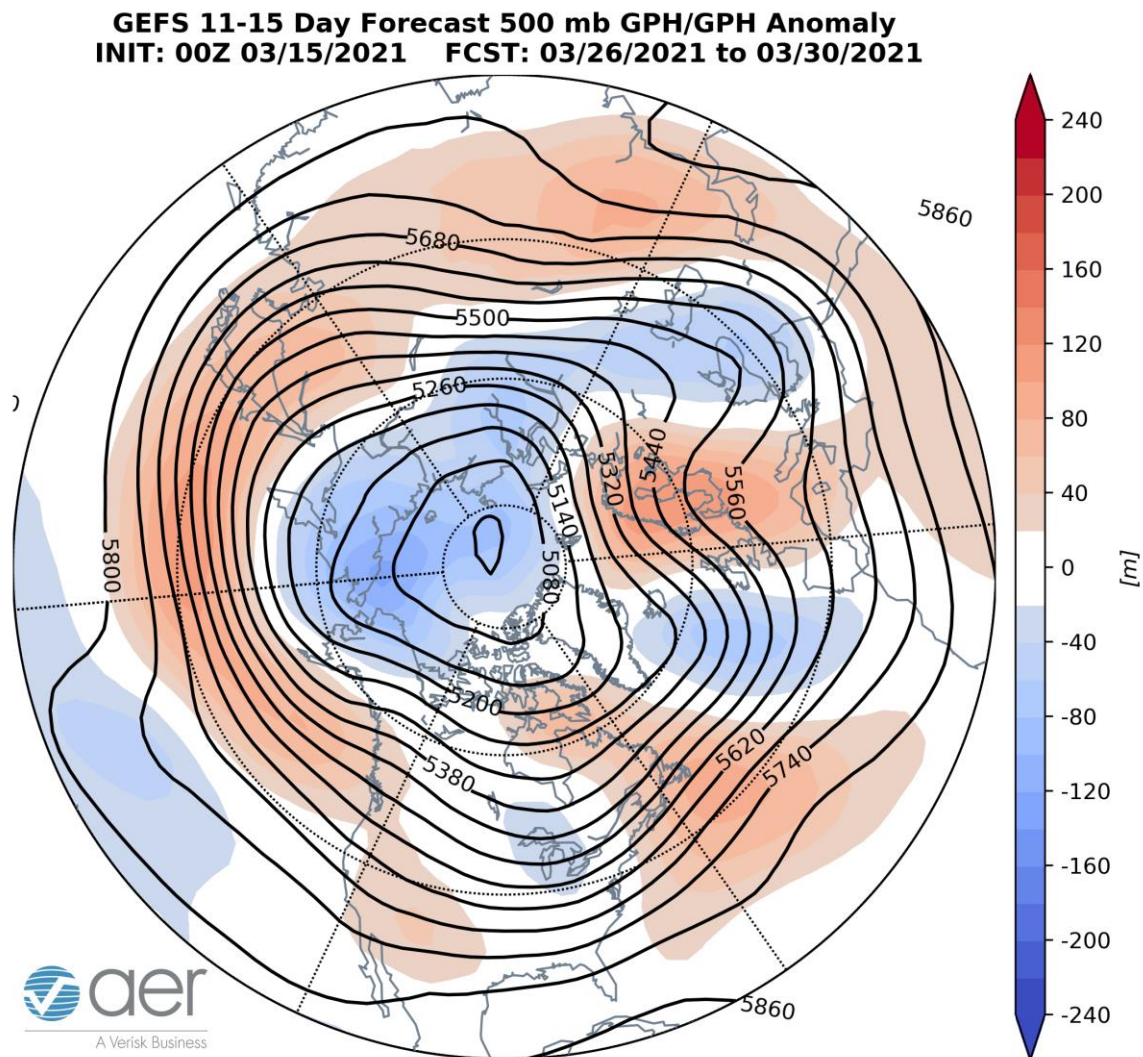


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 26 – 30 March 2021. The forecasts are from the 00z 15 March 2021 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to become widespread across Europe this period (**Figure 8**). This favors widespread normal to above normal temperatures across Europe including the UK (**Figures 9**). European ridging/positive

geopotential height anomalies will help persist troughing/negative geopotential height anomalies across Northern and Western Asia while ridging/positive geopotential height anomalies persist across Southern and Eastern Asia (**Figure 8**). This pattern favors normal to below normal temperatures across Northern and Western Asia with normal to above normal temperatures across Southern and Eastern Asia (**Figure 9**).

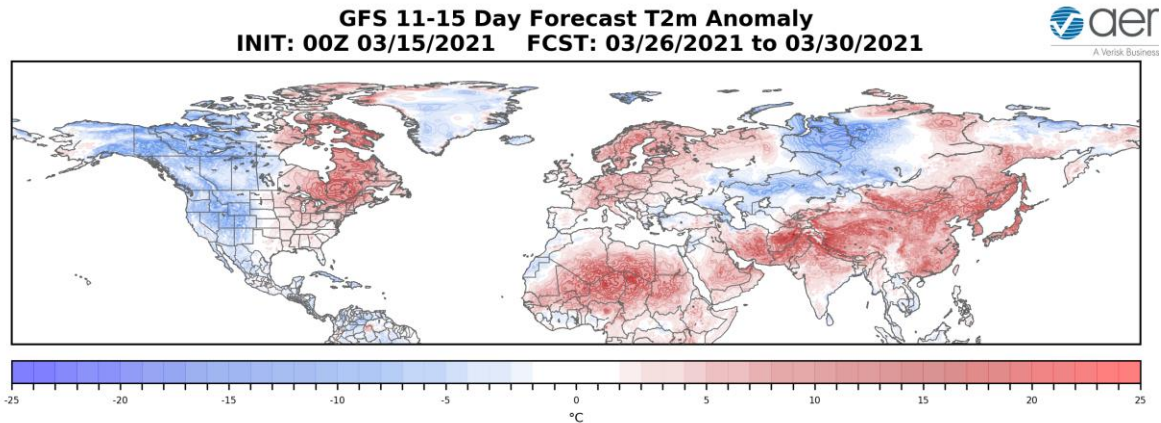


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 26 – 30 March 2021. The forecasts are from the 00z 15 March 2021 GFS ensemble.

Troughing/negative geopotential height anomalies in western North America are predicted to slide east into the interior with weak ridging/positive geopotential height anomalies along the west and east coasts of North America this period (**Figure 8**). This pattern favors widespread normal to below normal temperatures for Alaska, much of Western Canada and the Western US with normal to above normal temperatures across the Eastern Canada and the Eastern US (**Figure 9**).

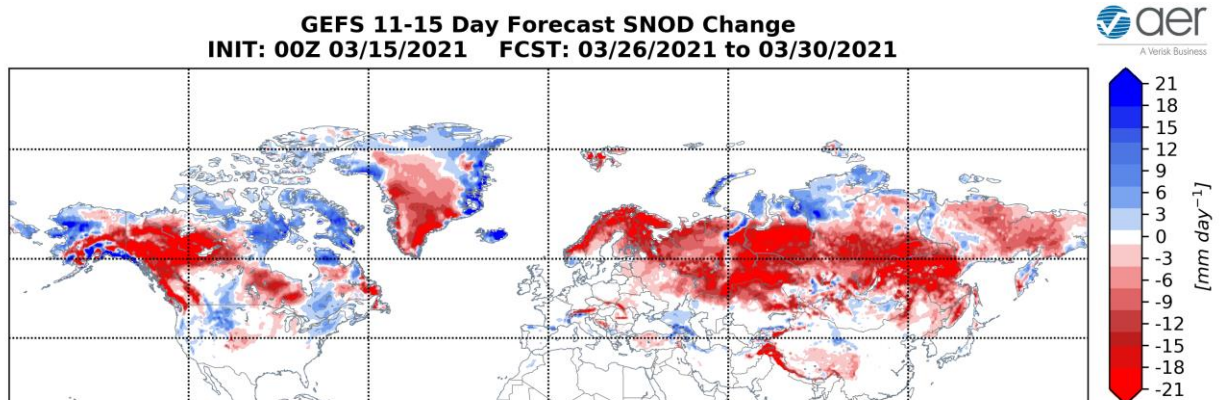


Figure 10. Forecasted snow depth changes (mm/day ; shading) from 26 – 30 March 2021. The forecasts are from the 00z 15 March 2021 GFS ensemble.

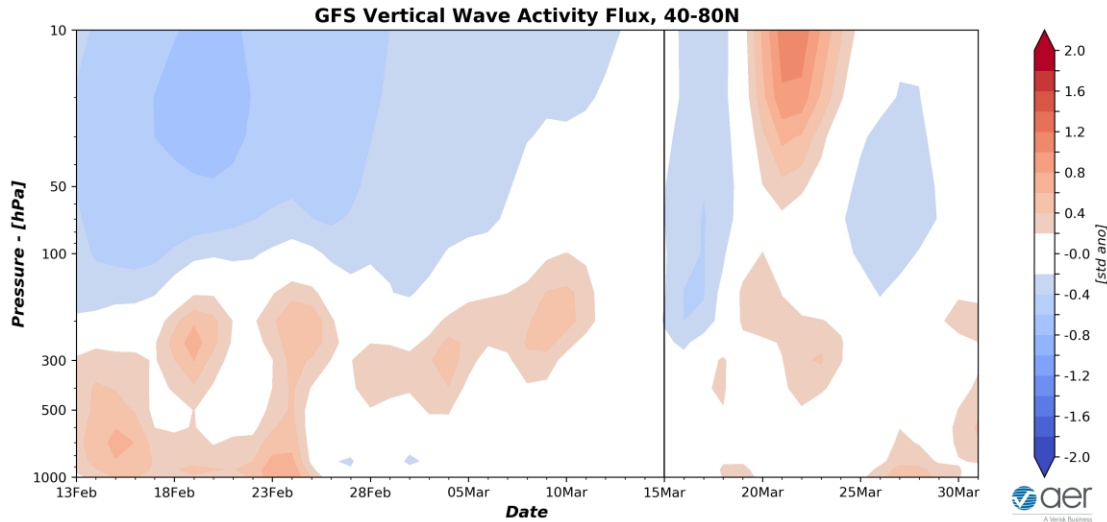


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 15 March 2021 GFS ensemble.

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 near normal WAFz in the troposphere (**Figure 12**). The WAFz forecast is predicted to get more active at the end of the week. It looks to me that this new pulse could force a minor disruption of the PV with it being stretched while high pressure builds near Alaska.

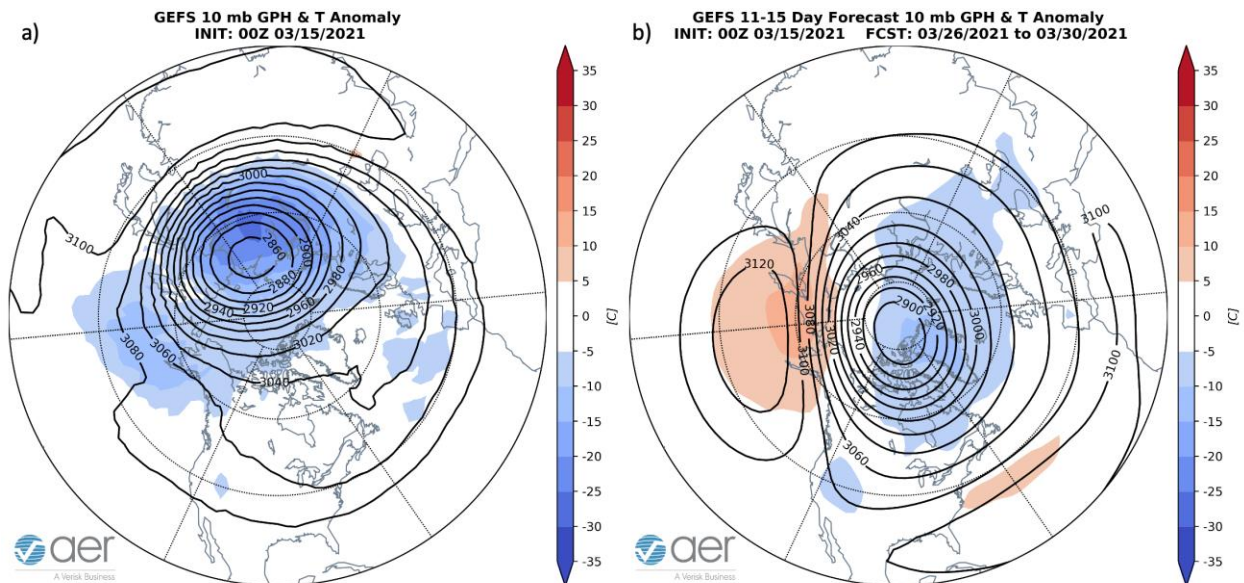


Figure 13. (a) Observed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 15 March 2021. (b) Same

as (a) except forecasted averaged from 26 – 30 March 2021. The forecasts are from the 00Z 8 March 2021 GFS model ensemble.

The PV continues to remain relatively strong with the vortex centered over Central Siberia (**Figure 13**). The PV is fairly circular, a sign of a strong PV (**Figure 13**). The PV center is predicted to migrate closer to the North Pole and become elongated in shape with an axis from Siberia to Western Canada (**Figure 13**). I believe that the elongated or stretched PV center may be a sign of a minor PV disruption that favors cold temperatures in East Asia and North America east of the Rockies. I have been anticipating this for much of March and so far it has not happened. It still could but not sure how impactful it would be on our weather so late in the season.

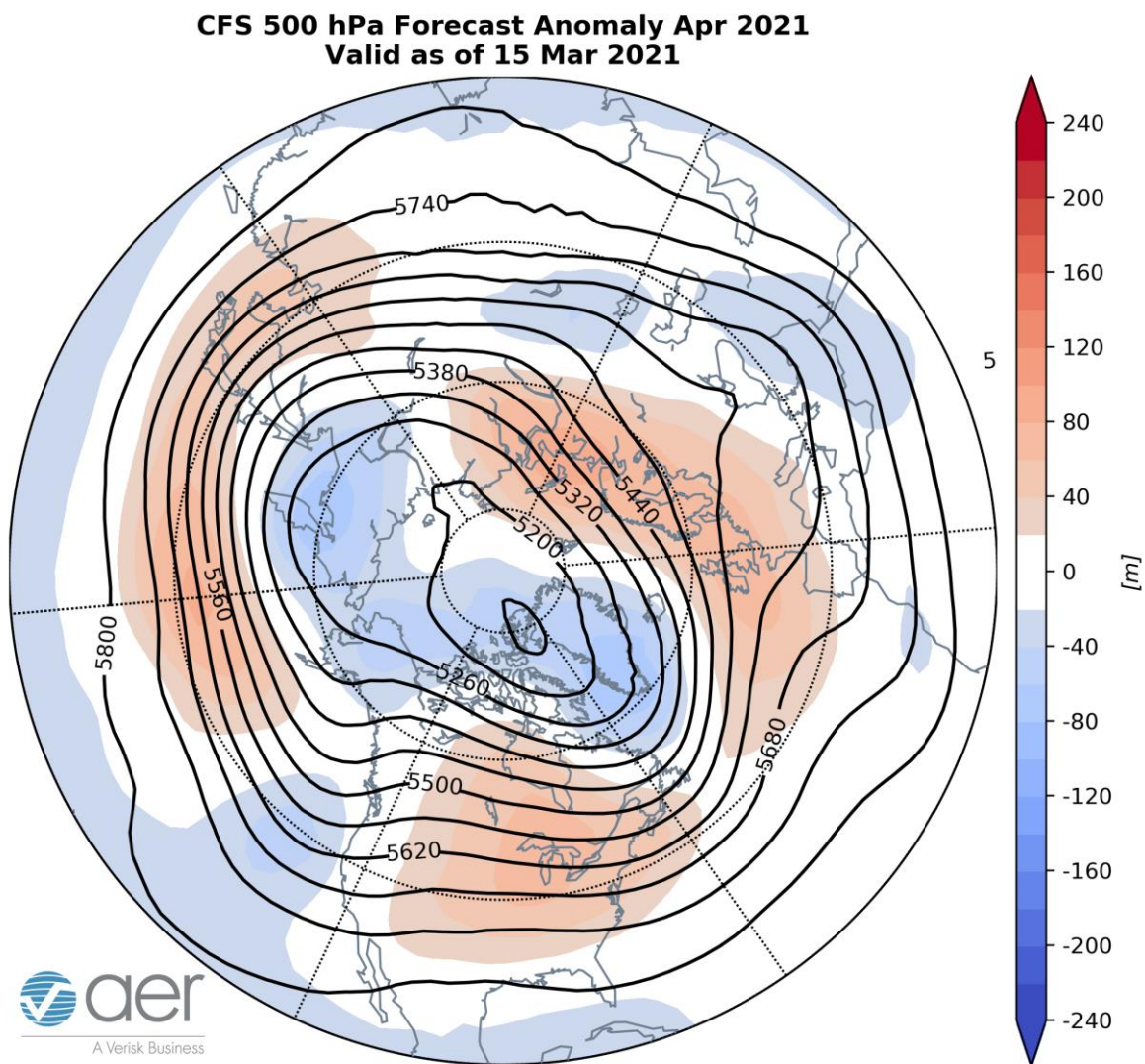


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for April 2021. The forecasts are from the 00Z 15 March 2021 CFS.

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 Northern Europe, Urals and Barents-Kara Seas, near the Dateline and eastern North America with troughing in Southern Europe, East Asia, Gulf of Alaska and western North America (**Figure 14**). This pattern favors relatively cool temperatures for Southern Europe and East Asia, with seasonable to relatively warm temperatures for Northern Europe, Western Asia and much of North America but especially Western Canada and the Western US (**Figure 15**).

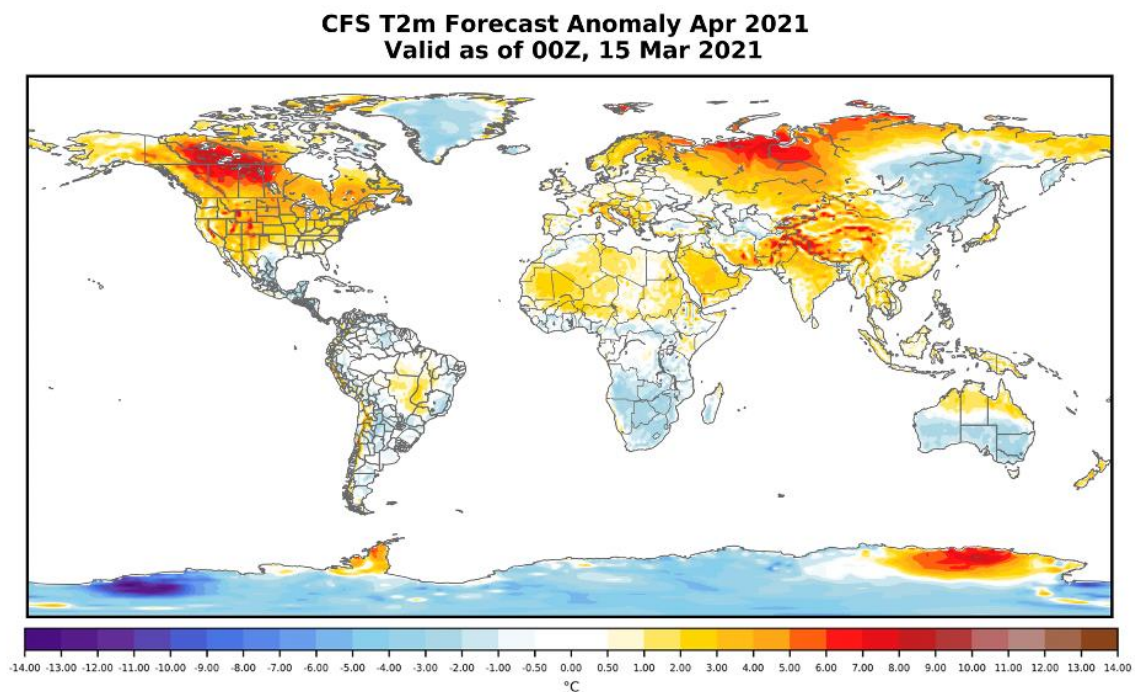


Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for April 2021. The forecasts are from the 00Z 15 March 2021 CFS.

Surface Boundary Conditions

Arctic sea ice extent

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 Bering Sea (**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.

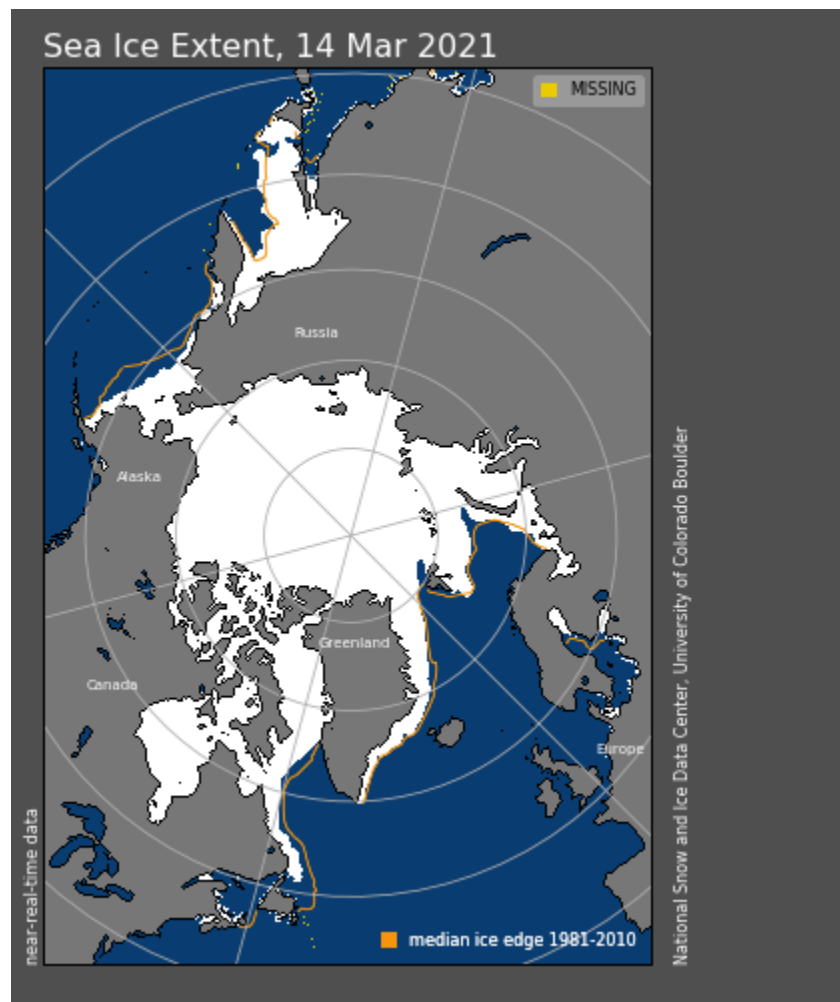


Figure 16. Observed Arctic sea ice extent on 7 March 2021 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC).

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 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.

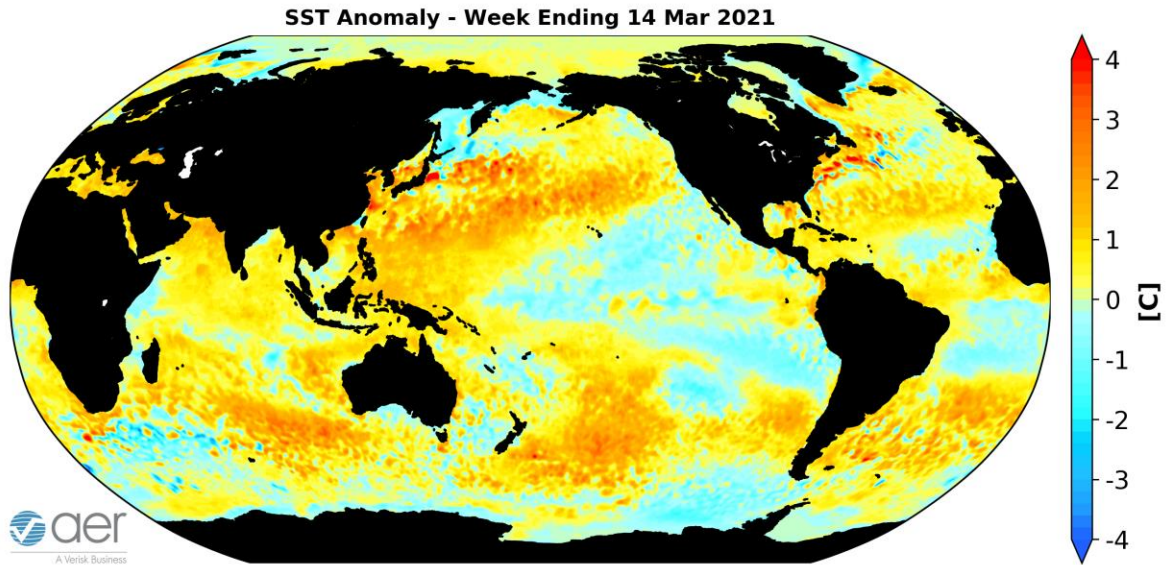


Figure 17. The latest weekly-mean global SST anomalies (ending 14 March 2021). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase eight (**Figure 18**). The forecasts are for the MJO to transition from phase eight to phase one and then weaken to where no phase is favored. 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.

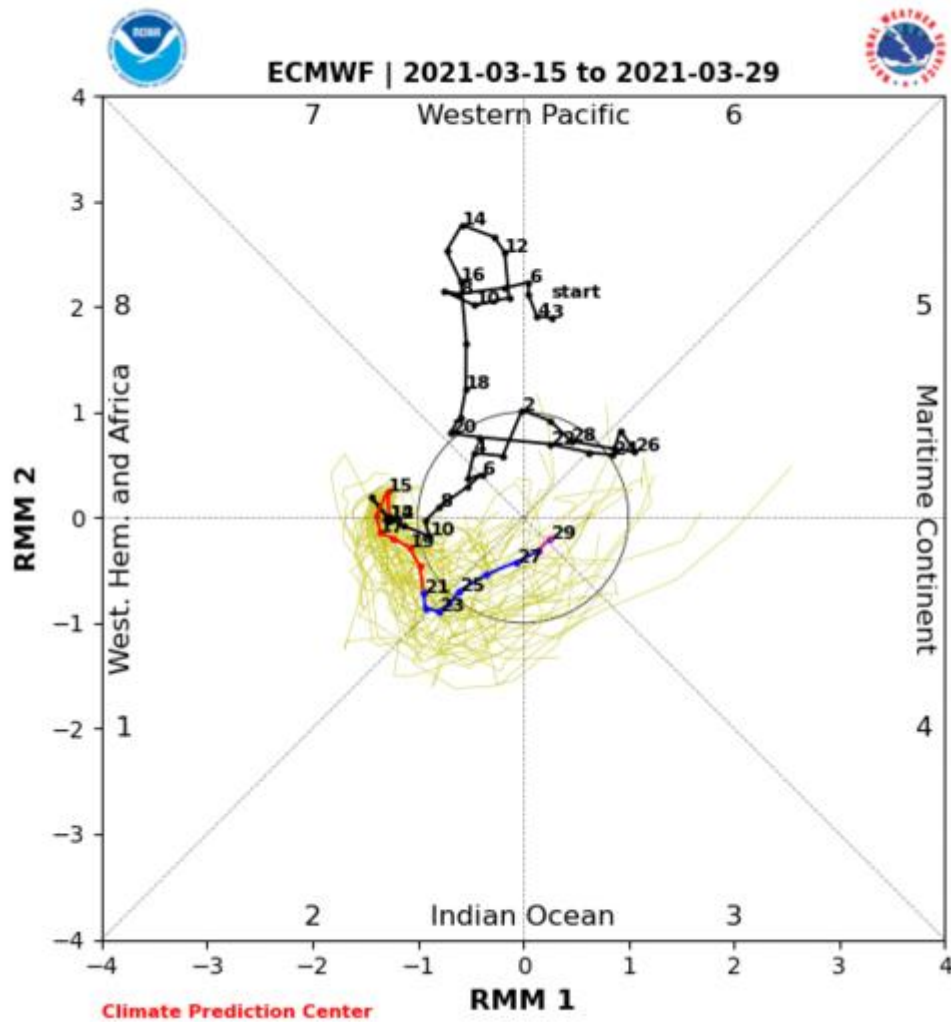


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 15 March 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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 extent is in its seasonal decline.

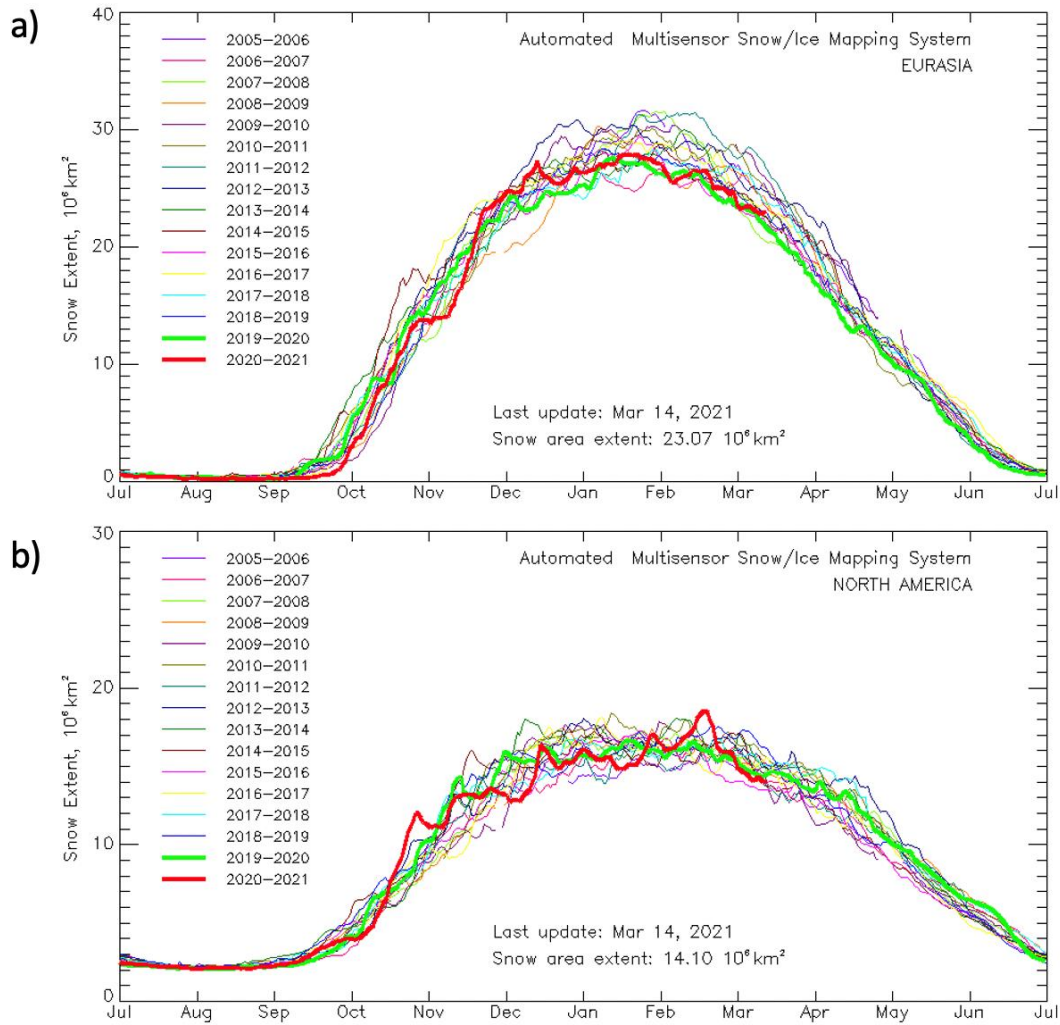


Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 14 March 2021. Image source:

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 near decadal lows. Snow cover is in its seasonal decline.