

Arctic Oscillation and Polar Vortex Analysis and Forecasts

February 22, 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 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 currently neutral to positive with weak and mixed pressure/geopotential height anomalies across Greenland and Iceland; and the NAO is predicted to remain neutral to positive as mixed pressure/geopotential height anomalies are predicted to persist across Greenland the next two weeks.
- Over the next two weeks ridging/positive geopotential height anomalies is predicted to remain widespread across Europe favoring normal to above normal temperatures across Europe including the United Kingdom (UK).
- Over the next two weeks, persistent ridging/positive geopotential height anomalies centered on Europe will anchor troughing/negative geopotential height anomalies across Northern and Western Asia with more ridging/positive geopotential height anomalies to the south and east. This pattern favors normal to below normal temperatures across Northern and Western Asia but especially Siberia with normal to above normal temperatures across Southern and Eastern Asia.
- Over the next two weeks troughing/negative geopotential height anomalies are predicted across Northern Canada and western North America with ridging/positive geopotential height anomalies across southern and eastern North America. This pattern favors normal to below normal temperatures widespread across Alaska, Northern and Western Canada and the Western United States (US) with normal to above normal temperatures across Southeastern Canada and the Southern and 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

What Captain Obvious playing the part of Judah Cohen would say is - the stratosphere is stronger than normal, the strong PV has coupled to the surface, contributing to low pressure/heights across the Arctic and all this favors relatively mild temperatures across the mid-latitudes. Besides these obvious facts there really is not much else. What is good for the goose is good for the gander. If I have been focused on the idea that a weak PV coupled to the surface favors an increase in severe winter weather, then a strong PV coupled to the surface favors the likelihood of mild winter weather. Based on the latest polar cap geopotential height anomalies (PCHs) plot (**Figure 11**) a stratosphere-troposphere coupling event with a strong PV and positive AO is already underway and is expected to continue for the foreseeable future. This coupling favors milder weather for the Eastern US, Europe and East Asia with possibly colder weather in Western Asia and western North America. And based on the figures below the forecast is consistent with this expectation. Though one aspect of the forecast is puzzling – the region whose temperatures are most sensitive to the strength of the PV and the phase of the AO is Siberia. And despite a strong PV and a positive AO, Siberia is predicted to experience relatively cold temperatures into the foreseeable future. One answer that I

can think of is that Siberia has had the most consistent snowfall and cold temperatures of any region across the NH this winter and thermal inertia is winning out.

I admit that I expected March to moderate after a cold February but still mostly remain below normal for Northern Europe and especially the Northeastern US given the more impressive snow cover. I am going to stick with that forecast though the likelihood of colder than normal March in the Eastern US and especially Europe is quickly dwindling. The GFS forecasts were suggesting a return of Greenland blocking even as the PV strengthens but even that forecast is fading. In **Figure i**, I show the North Atlantic regional PCH plot and it looks less impressive than the plot that I tweeted out on [February 17, 2021](#) and currently looks mostly like a non-event. The weather models struggle with stratosphere-troposphere coupling. In late January and early February, the models struggled with predicting the full impact of the PV disruption on the weather, with the observed weather in the end much colder than first predicted. Now too the models seem to be struggling with the full impact of the strong PV and are playing catch up with how quickly the pattern is turning milder.

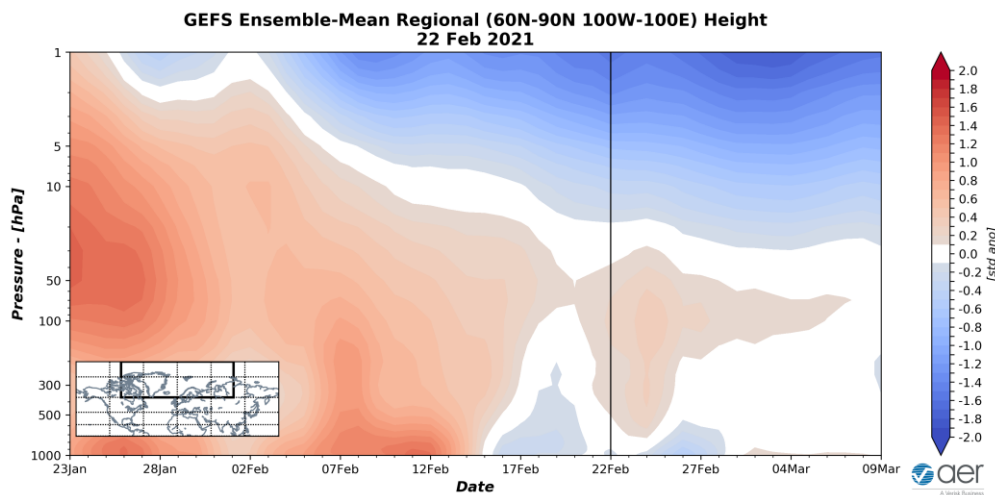


Figure i. Observed and predicted daily geopotential height standardized anomalies area-averaged over the North Atlantic region (see insert). The forecast is from the 00Z 22 February 2021 GFS ensemble.

It is not like I didn't notice the strengthening PV, I did. But typically, the most severe winter weather occurs while the PV is recovering and even when the PV turns stronger than normal. In addition, I kept in mind winter 2010, which had a very cold and snowy January related to a strong Greenland block and a negative AO. Yet in February the circulation pattern reversed, and a strong stratospheric PV coupled to the surface forcing a positive AO in early February for the rest of the winter (see **Figure ii**). And yet despite the strong PV and positive AO, the remainder of the winter (February and March)

was relatively cold for much of North America and Europe (see **Figure ii**). I did expect something similar for this winter but admittedly it is not looking terribly likely.

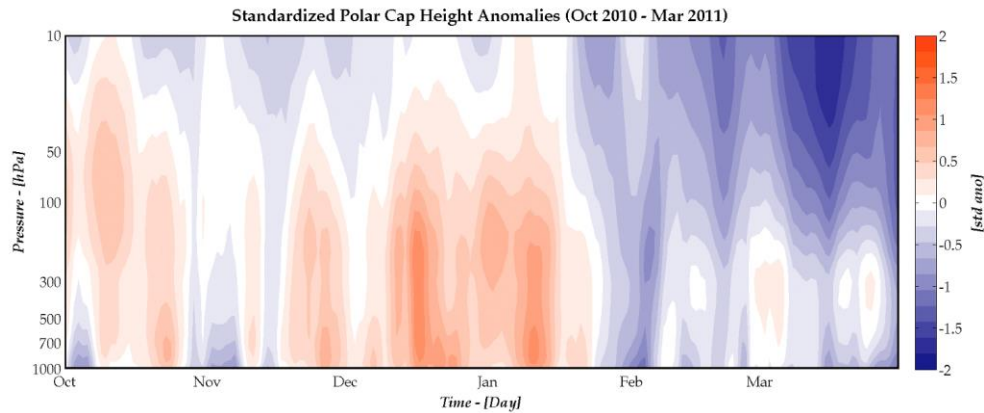


Figure ii. Observed daily polar cap (i.e., area-averaged geopotential heights poleward of 60°N) geopotential height standardized anomalies from October 1, 2010 through March 31, 2011.

It has been an unusual PV disruption this winter and it appears the unusual nature of the event will continue right to the end with a more abrupt end to its impacts on the NH weather compared to other similar PV disruptions. But I am sticking with my expectations despite the increasingly confident weather model forecasts to the contrary. I am sure I said this earlier, if I am afraid to fail then I don't think I am any longer providing a service of value and the goal of the blog is not to simply repackage or regurgitate the weather model forecasts but to argue otherwise or contrary when historical evidence warrants. If my expectations/forecast fail it is a new and valuable datapoint for the next event. Captain Obvious or captain by any other name, this captain is going down with the ship.

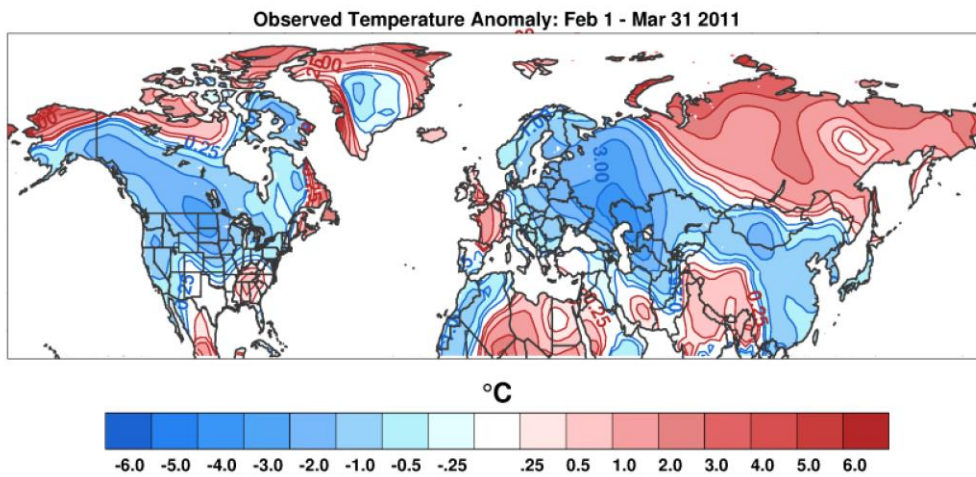


Figure iv. (a) Observed NH surface temperatures from February and March 2011.

1-5 day

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

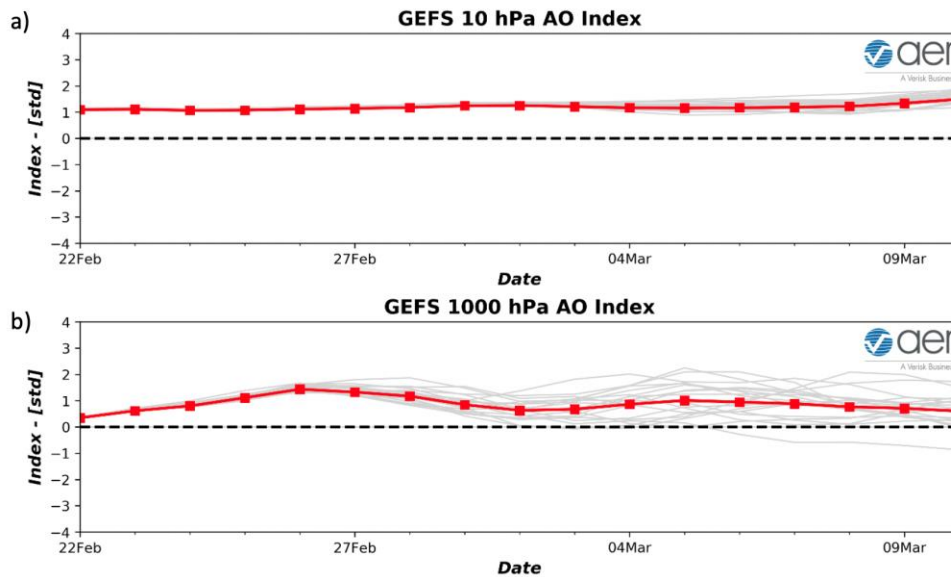


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 22 February 2021 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 22 February 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies are predicted to be centered on and widespread across Europe (**Figure 2**). This pattern favors normal to above normal temperatures across all of Europe including the UK (**Figure 3**). This week, ridging/positive geopotential height anomalies centered over Europe 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 and Western Asia with normal to above normal temperatures for Eastern and Southern Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 02/22/2021 FCST: 02/23/2021 to 02/27/2021

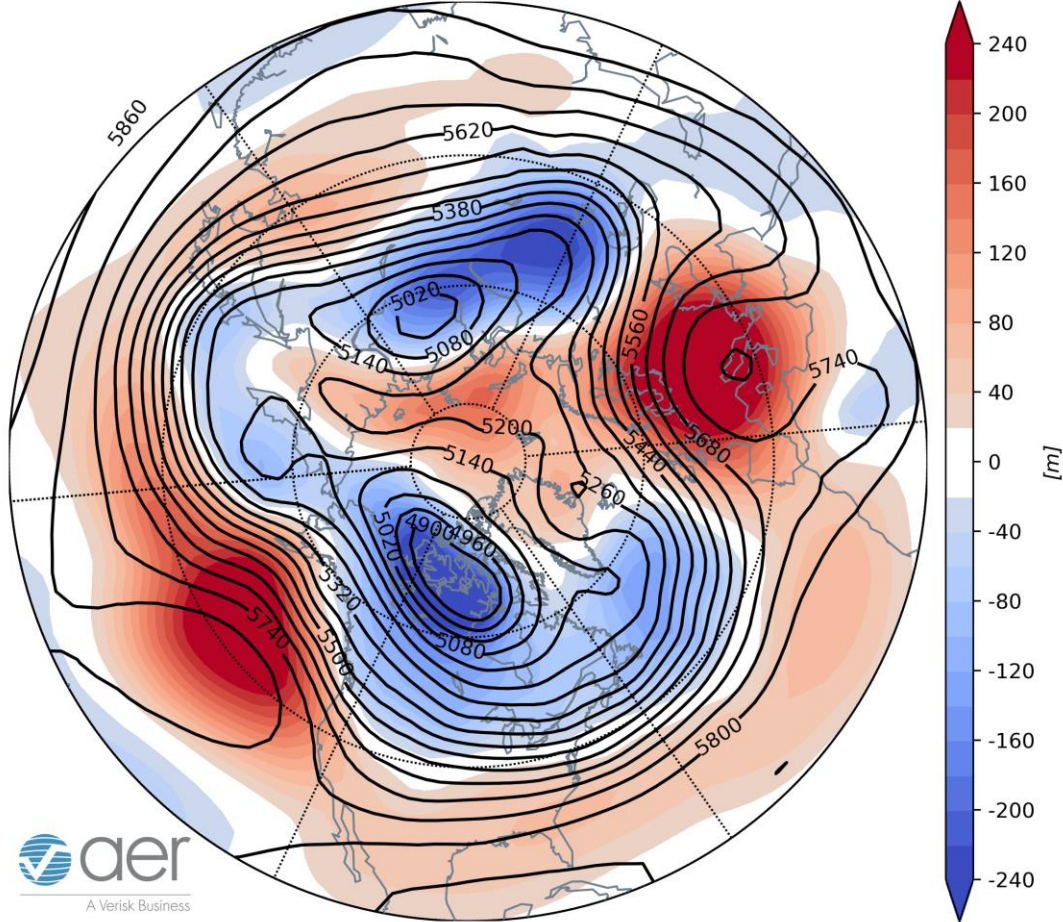


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 23 – 27 February 2021. The forecasts are from the 00z 22 February 2021 GFS ensemble.

This week ridging/positive geopotential height anomalies centered south of the Aleutians will favor broad troughing/negative geopotential height anomalies across Canada with more ridging/positive geopotential height anomalies in the Southeastern US (**Figure 2**). This pattern is predicted to bring widespread normal to below normal temperatures across Alaska, Northern and Western Canada and the Northwestern US with normal to above normal temperatures across Southeastern Canada, Southern and Eastern US (**Figure 3**).

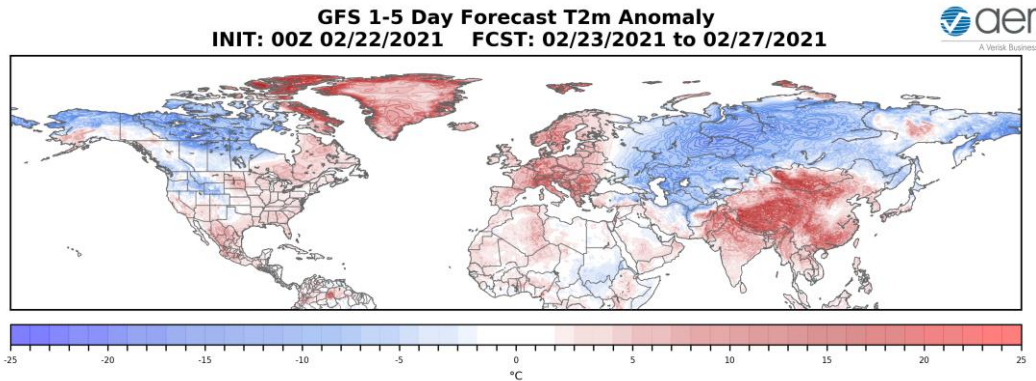


Figure 3. Forecasted surface temperature anomalies (°C; shading) from 23 – 27 February 2021. The forecast is from the 00Z 22 February 2021 GFS ensemble.

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

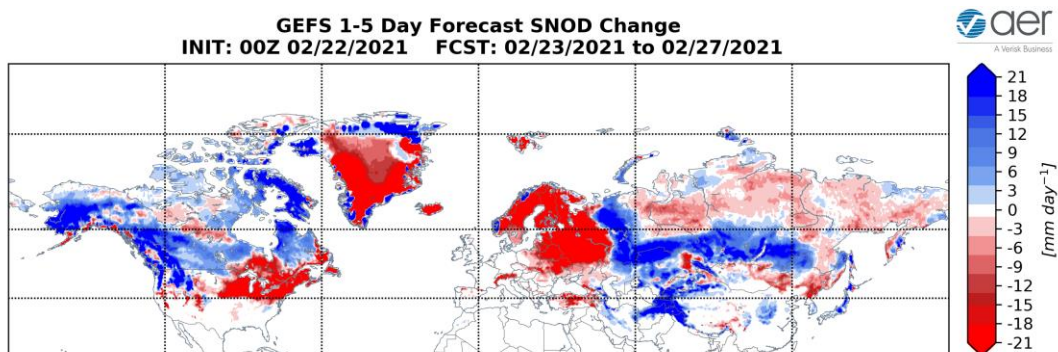


Figure 4. Forecasted snow depth changes (mm/day; shading) from 23 – 27 February 2021. The forecast is from the 00Z 22 February 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain positive next 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 mixed geopotential height anomalies predicted across Greenland (**Figure 5**), the NAO is predicted to remain neutral to positive.

GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
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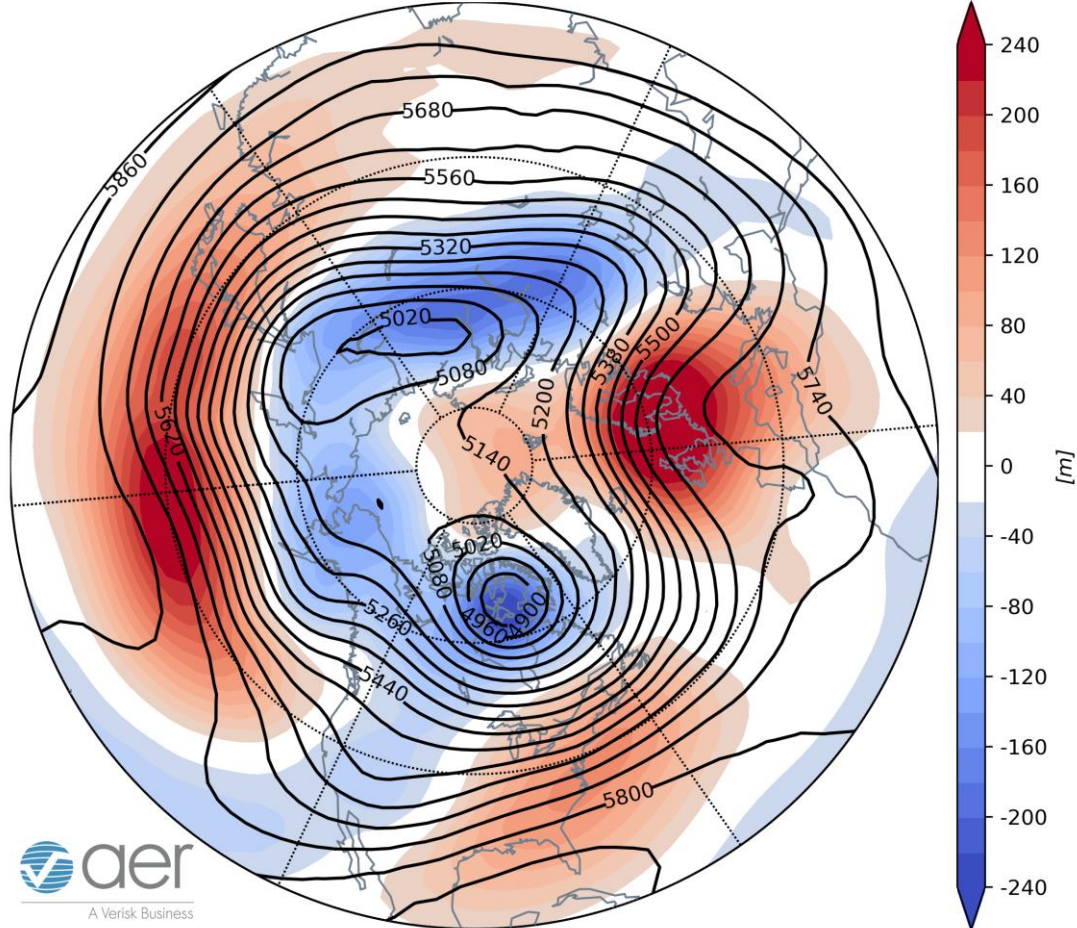


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 28 February – 4 March 2021. The forecasts are from the 00z 22 February 2021 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to persist across Europe this period (**Figure 5**). **This will favor** normal to above normal temperatures to remain widespread across Europe including the UK (**Figure 6**). Persistent ridging/positive geopotential height anomalies centered over Europe will anchor troughing/negative geopotential height anomalies across Northern and Western Asia with ridging/positive geopotential height anomalies across Southern and Eastern Asia this period (**Figure 5**). This is predicted to favor widespread normal to below normal temperatures across much of Northern and Western Asia with normal to above normal temperatures in Southern and Eastern Asia (**Figure 6**).

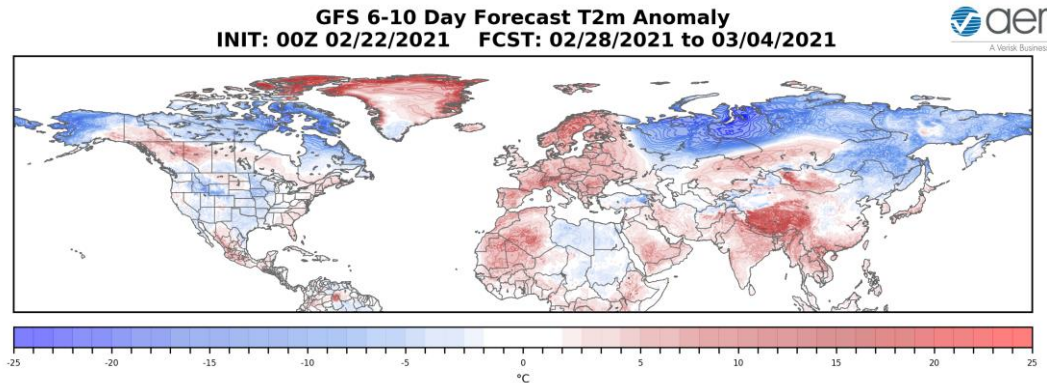


Figure 6. Forecasted surface temperature anomalies (°C; shading) from 28 February – 4 March 2021. The forecasts are from the 00Z 22 February 2021 GFS ensemble.

Trouching/negative geopotential height anomalies are predicted to persist across Northern Canada and western North America while ridging/positive geopotential height anomalies will strengthen across the Southeastern US this period (**Figure 5**). This pattern is predicted to bring widespread normal to below normal temperatures across Alaska, much of Northern and Western Canada and the Western US with normal to above normal temperatures across the Southern and Eastern US (**Figure 6**).

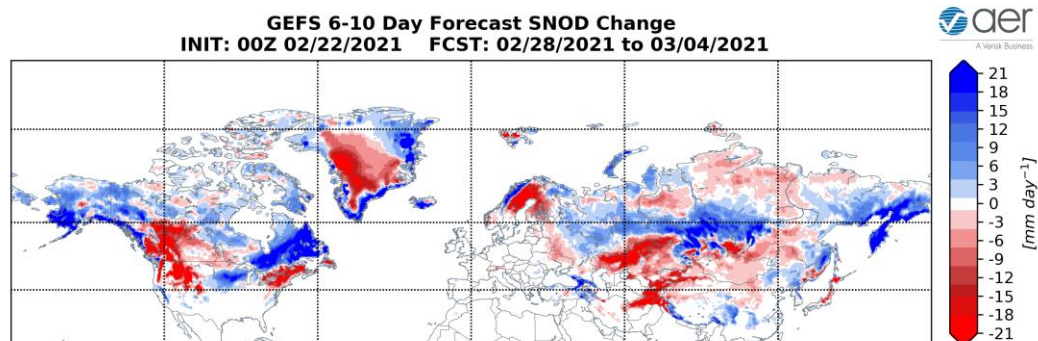


Figure 7. Forecasted snow depth changes (mm/day; shading) from 28 February – 4 March 2021. The forecasts are from the 00Z 22 February 2021 GFS ensemble.

Trouching and/or colder temperatures are predicted to potentially support new snowfall across Lapland, the Himalayas, Central Asia and Eastern Siberia while warmer temperatures will cause regionalized snow melt in Eastern Europe and Central Asia (**Figure 7**). Trouching and/or colder temperatures are predicted to support the potential for new snowfall across Alaska, Northern and Eastern Canada while warmer temperatures will cause possible snow melt in the Northeastern US, Southwestern Canada and the Northwestern US (**Figure 7**).

11-15 day

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

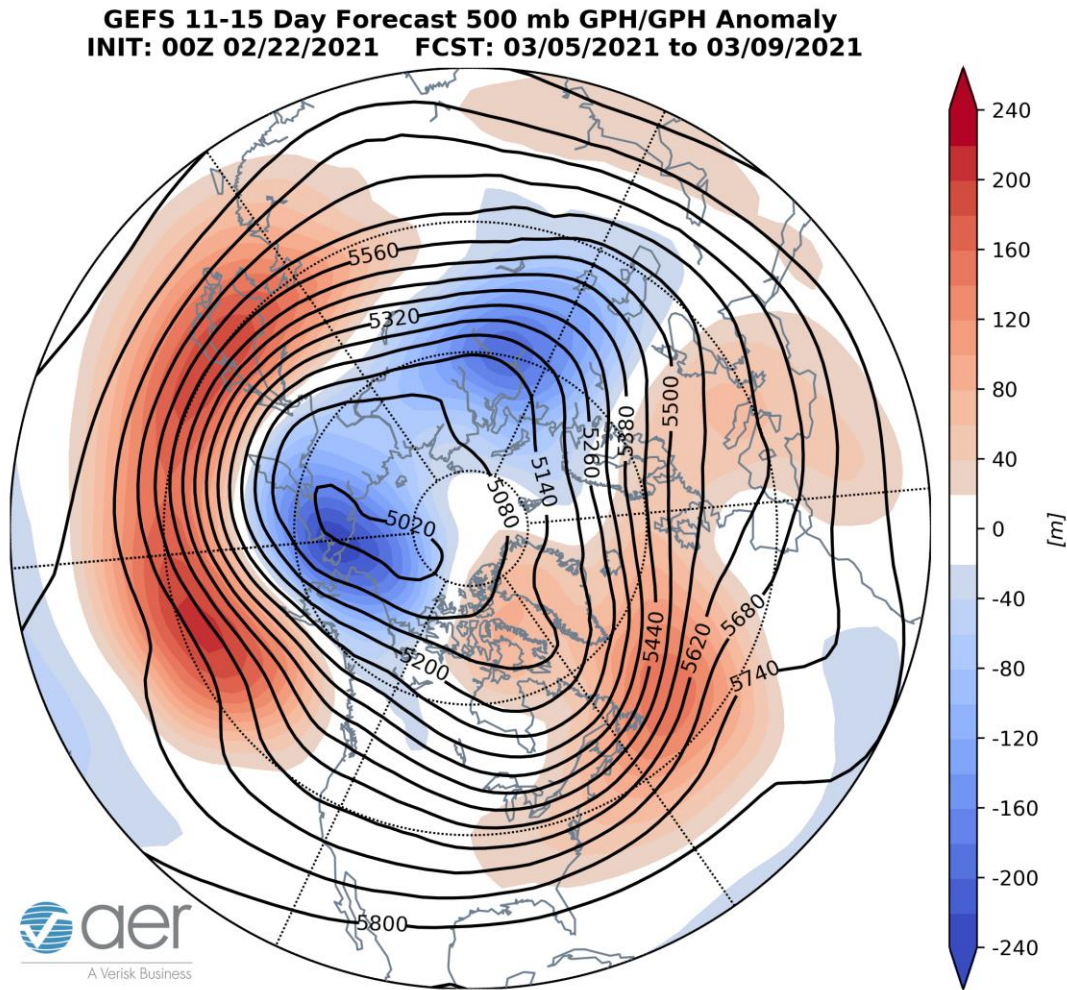


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 5 – 9 March 2021. The forecasts are from the 00z 22 February 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies across Europe are predicted to weaken this period (**Figures 8**). The forecast remains for widespread normal to above normal temperatures across Europe, though a return to more seasonable temperatures is possible across Western Europe this period (**Figures 9**). Ridging/positive geopotential height anomalies across Europe will help persist troughing/negative geopotential height anomalies across Northern and Western Asia with ridging/positive geopotential height anomalies across Southern and Eastern Asia

this period (**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**).

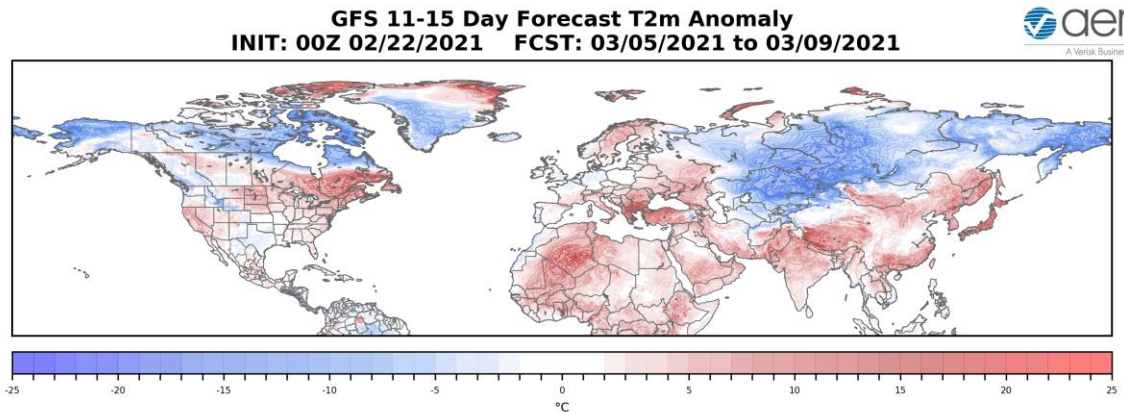


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 5 – 9 March 2021. The forecasts are from the 00z 22 February 2021 GFS ensemble.

Deepening troughing/negative geopotential height in the Bering Sea will promote a mostly zonal flow across North America with more ridging/positive geopotential height anomalies off the East Coast and centered south of Greenland this period (**Figure 8**). This pattern favors widespread normal to below normal temperatures for Alaska and Northern Canada with normal to above normal temperatures across much of Southern Canada and the US (**Figure 9**).

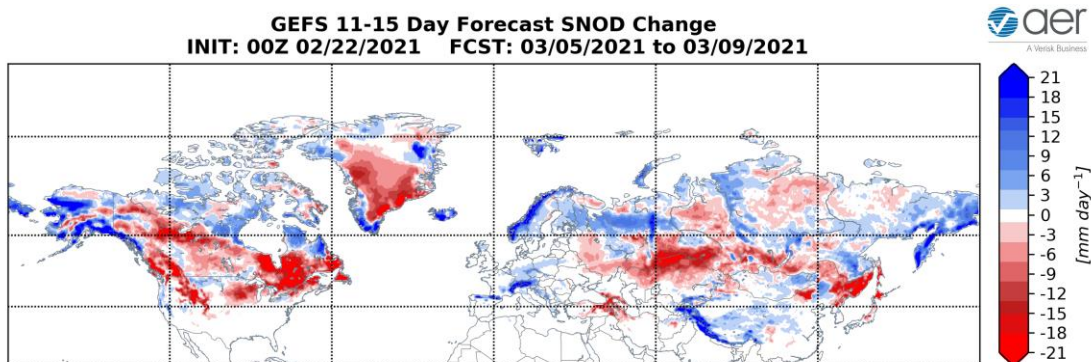


Figure 10. Forecasted snow depth changes (mm/day ; shading) from 5 – 9 March 2021. The forecasts are from the 00z 22 February 2021 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across the higher elevations of Europe, Northern Asia and the Himalayas while warmer temperatures will cause snowmelt in Eastern Europe and Central Asia (**Figure 10**). Troughing and/or colder temperatures are predicted to support new snowfall

across Alaska and much of Northern Canada while warmer temperatures will result in snowmelt in Southern 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 cold/negative PCHs throughout the troposphere and stratosphere (**Figure 11**). The cold/negative began in the upper stratosphere, intensified, descended through the stratosphere and troposphere and have made it all the way to the surface (**Figure 11**). Warm/positive PCHs are not predicted to return to the stratosphere or troposphere in the foreseeable future.

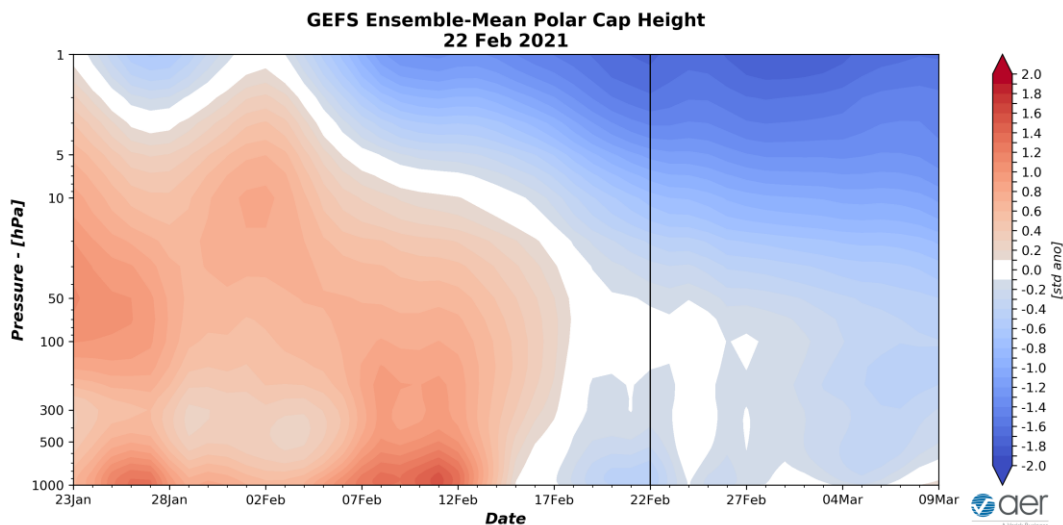


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 22 February 2021 GFS ensemble.

The overall cold/negative PCHs in the lower troposphere are consistent with the predicted positive surface AO the next two weeks (**Figure 1**). 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**).

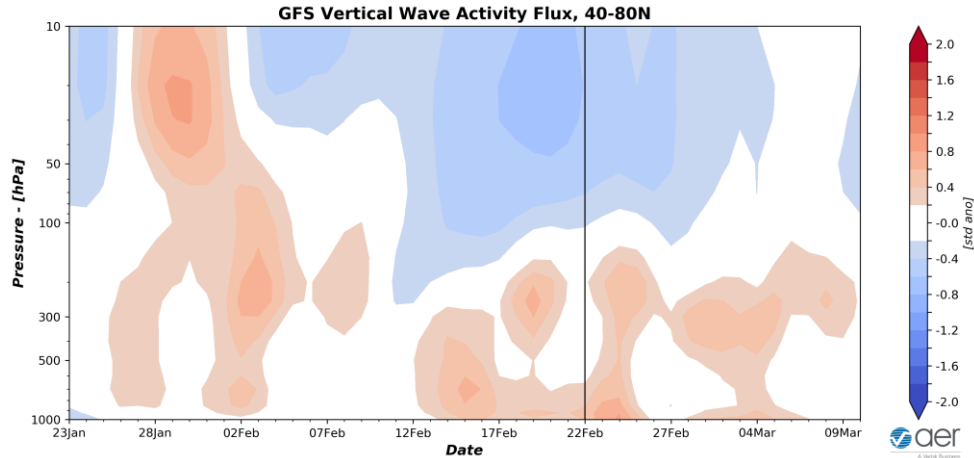


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 22 February 2021 GFS ensemble.

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 more active WAFz in the troposphere (**Figure 12**). Still overall, the WAFz is predicted to be quiet, consistent with forecasts of a strengthening stratospheric PV.

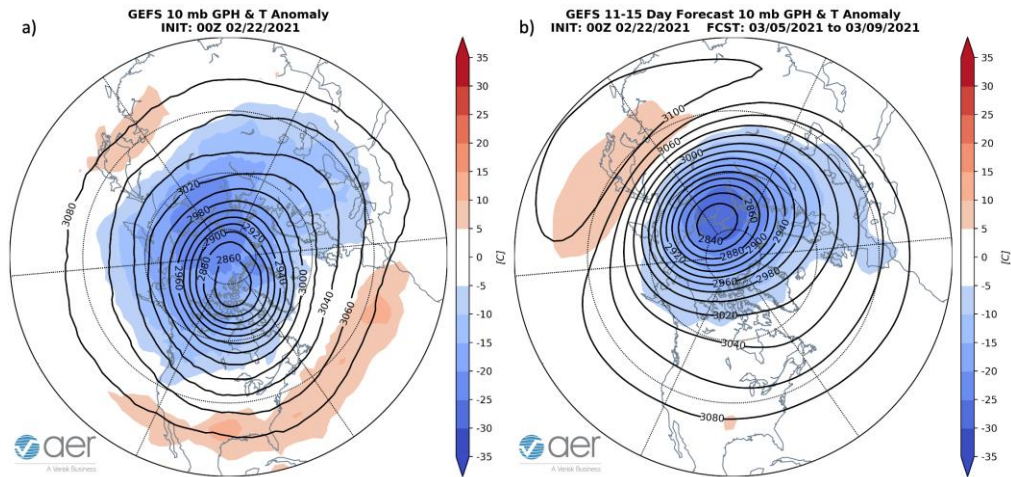


Figure 13. (a) Observed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 22 February 2021. (b) Same as (a) except forecasted averaged from 5 – 9 March 2021. The forecasts are from the 00Z 22 February 2021 GFS model ensemble.

The PV continues to strengthen with the vortex centered over the Canadian Archipelagos (**Figure 13**). The PV is also mostly circular in shape, a signature of a strong PV (**Figure 13**). The PV center is predicted to migrate over towards Siberia at the

end of the month (**Figure 13**). I believe that the PV center over Siberia may be a sign of some sort of minor PV disruption (**Figure 13**). But for now, I don't read much into it other than temperatures are likely to remain cold in Siberia.

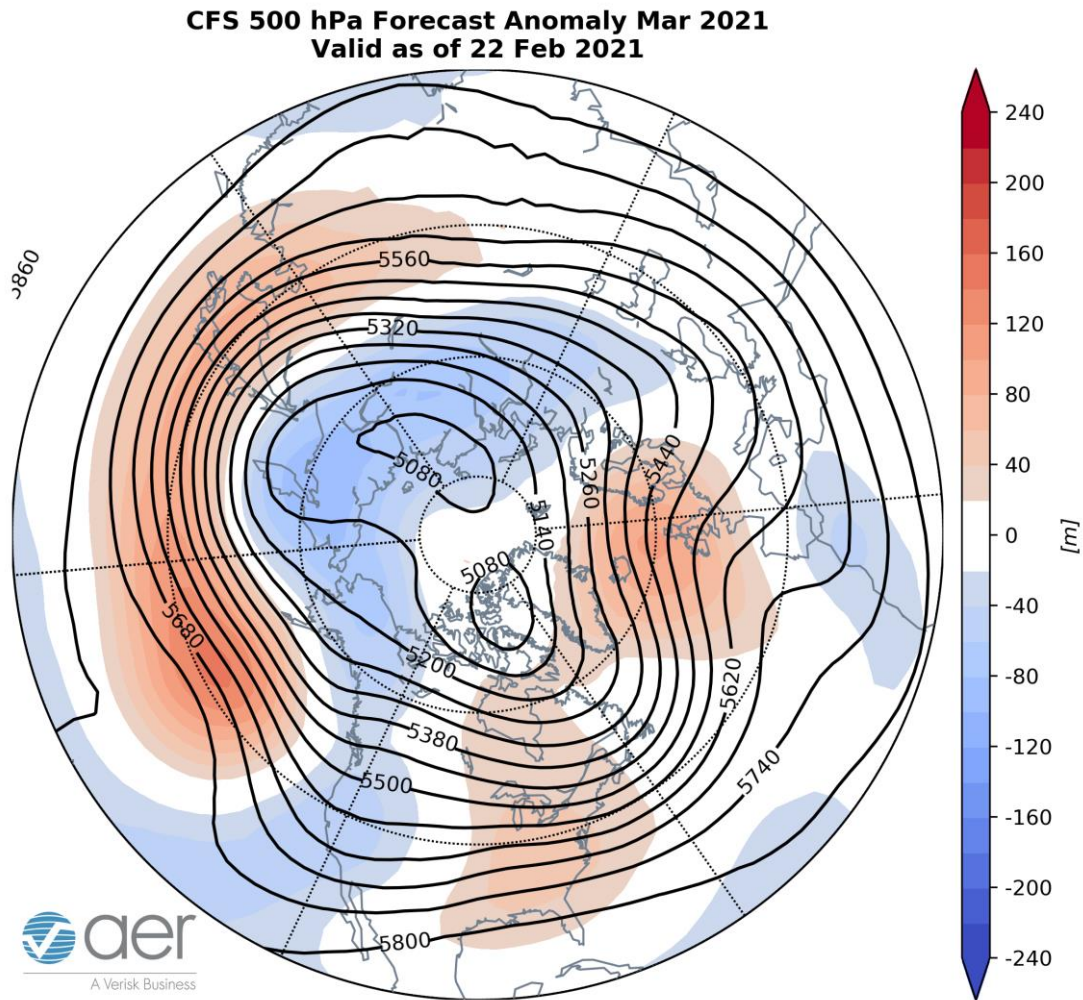


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for March 2021. The forecasts are from the 00Z 22 February 2021 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) forecast for March from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging between Iceland and the UK, south of the Aleutians and eastern North America with troughing in Southern Europe, Northern and Western Asia and western North America (**Figure 14**). This pattern favors relatively cold temperatures for Western and Southern Europe, Northern and Western Asia with

seasonable to relatively warm temperatures for Northern Europe, Central Asia, East Asia and much of Canada and the US (**Figure 15**).

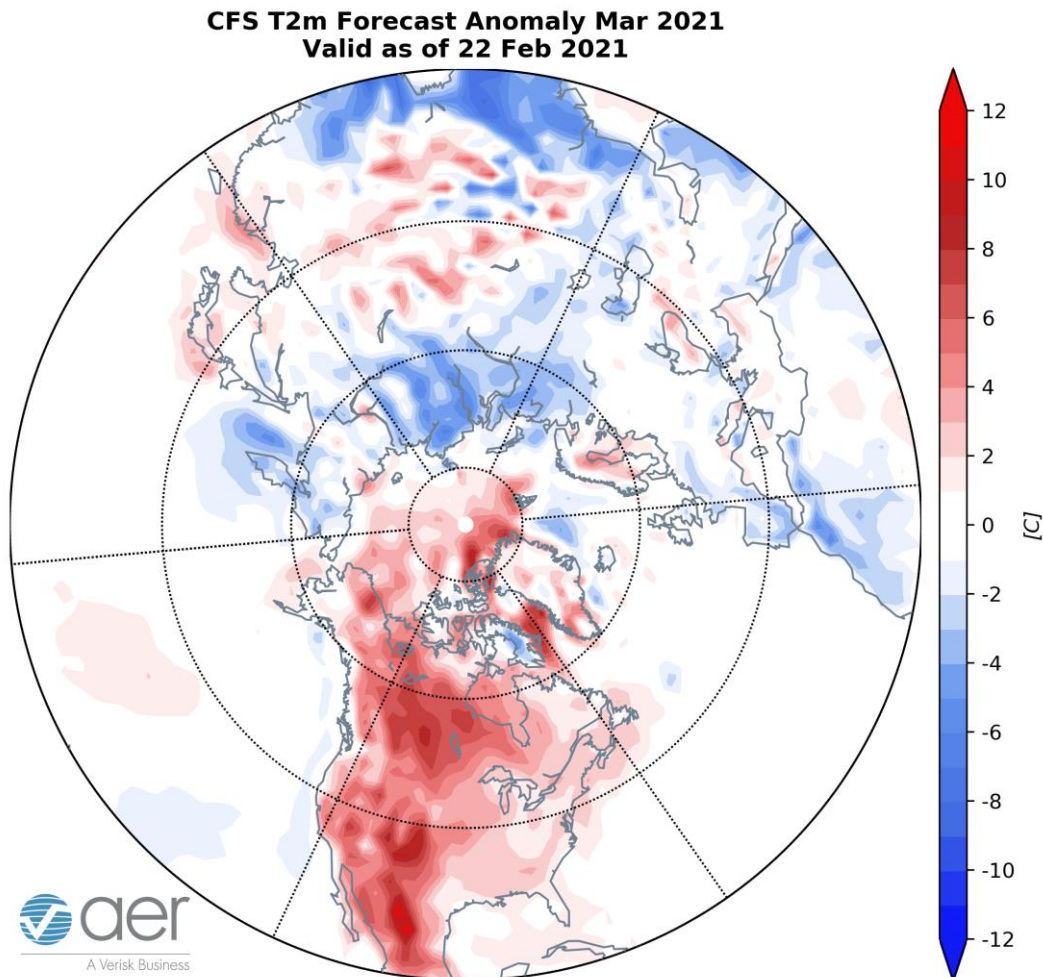


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for March 2021. The forecasts are from the 00Z 22 February 2021 CFS.

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 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.

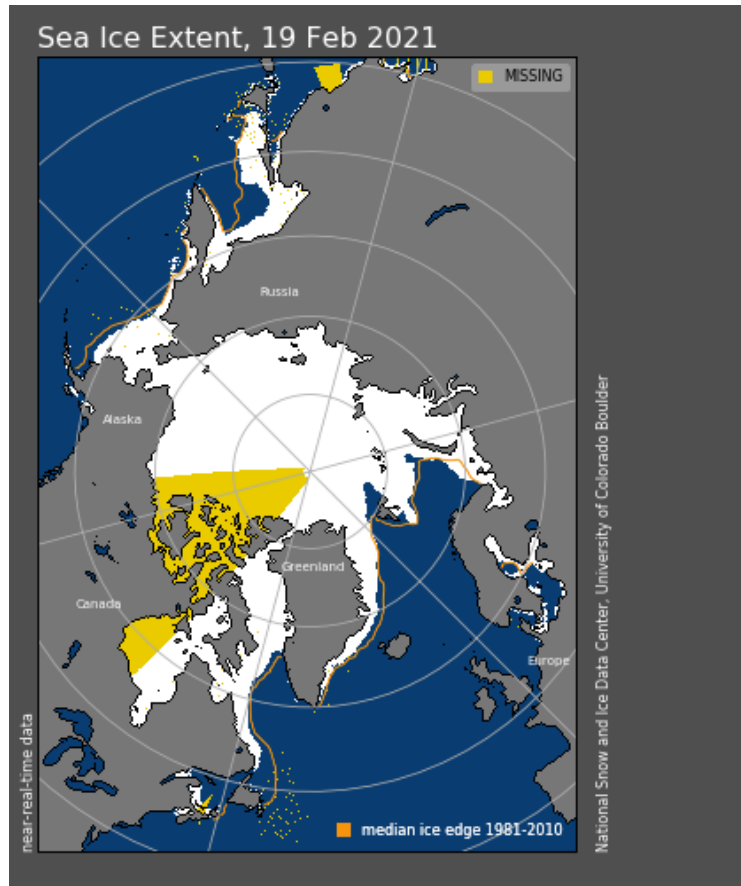


Figure 16. Observed Arctic sea ice extent on 19 February 2021 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC).

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 21 Feb 2021

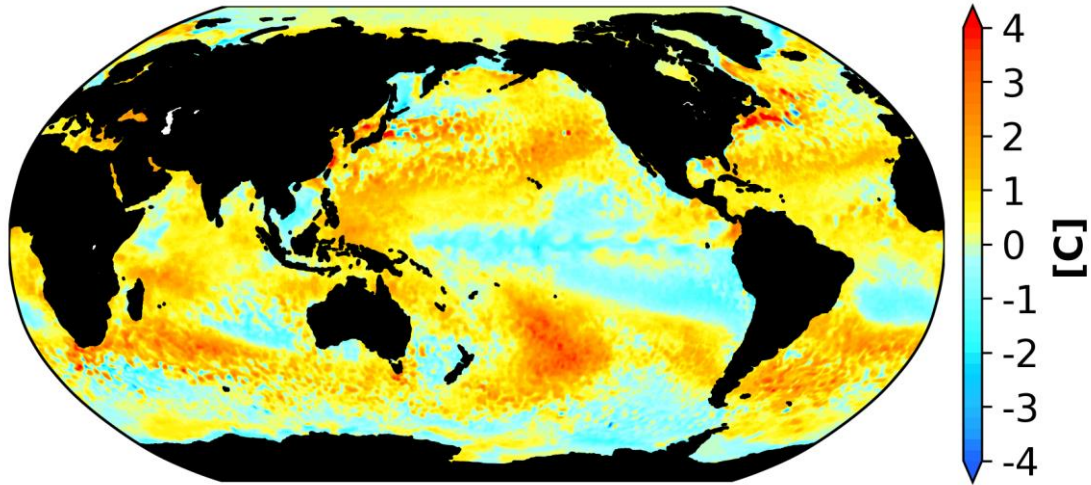


Figure 17. The latest weekly-mean global SST anomalies (ending 21 February 2021). Data from NOAA OI High-Resolution dataset.

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 18**). The forecasts are for the MJO to remain weak. The MJO does not seem to be contributing much to the weather pattern across North America but admittedly this is outside of my expertise.

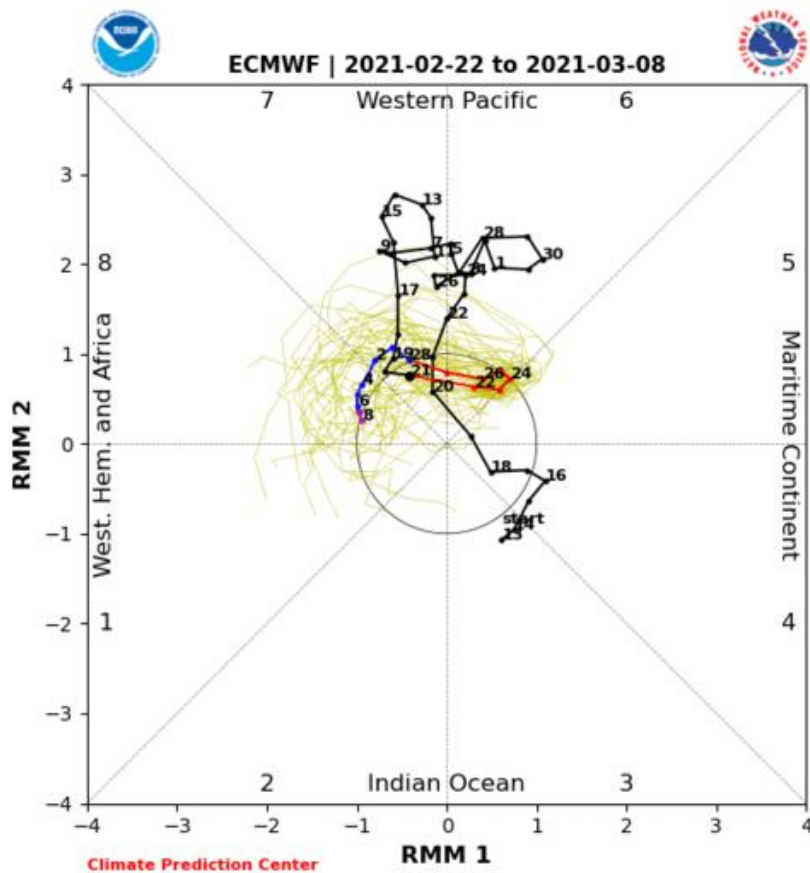


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 22 February 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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.

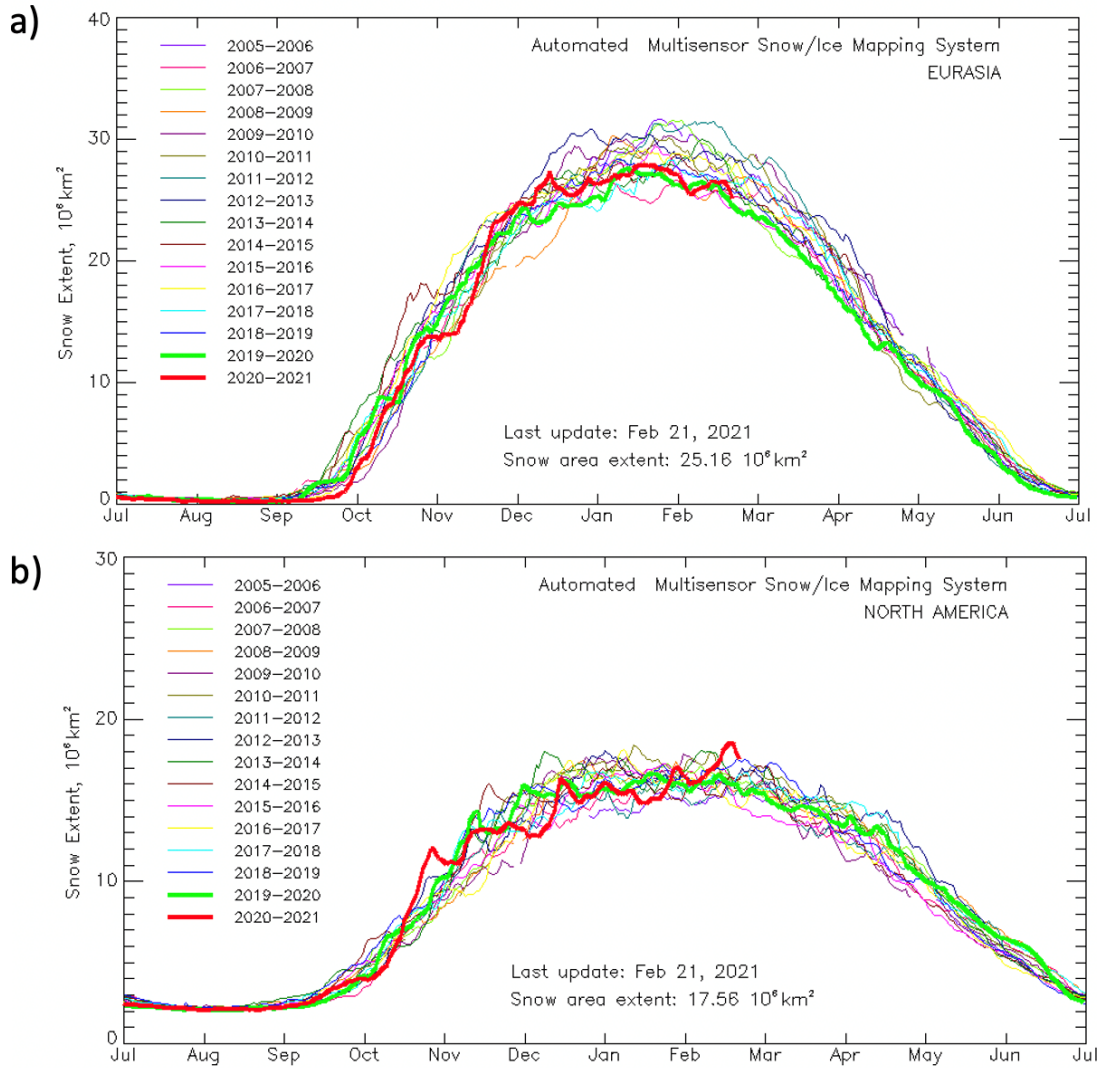


Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 21 February 2021. Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover advanced strongly over the past week and is at decadal highs. Snow cover is probably near its high-water mark and is now likely in its seasonal decline. The advance of snow cover will help amplify colder temperatures across North America.