Arctic Oscillation and Polar Vortex Analysis and Forecasts

January 18, 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.

Subscribe to our email list or follow me on Twitter (@judah47) for notification of updates.

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

Summary

- The Arctic Oscillation (AO) is currently negative and is predicted to remain neutral to negative the next two weeks as pressure/geopotential height anomalies are predicted to remain positive across the North Atlantic side of the Arctic the next two weeks.

- The current negative AO is reflective of positive pressure/geopotential height anomalies across the North Atlantic side of the Arctic with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently negative with positive pressure/geopotential height anomalies across Greenland and Iceland; and the NAO is predicted to remain neutral to negative the next two weeks as pressure/geopotential height anomalies are predicted to remain positive across Greenland.
- For the next two weeks ridging/positive geopotential height anomalies near Greenland will anchor troughing/negative geopotential height anomalies across Europe. However, as the Greenland high pressure drifts west this will allow a less amplified flow across Europe with a strong westerly component bringing in milder, maritime air across the continent with widespread normal to above normal temperatures for much of Europe including the United Kingdom (UK). The exceptions will be Scotland and Scandinavia which will remain north of the westerly belt of winds and where low heights favor normal to below temperatures.
- Over the next two weeks, persistent ridging/positive geopotential height anomalies in the Arctic, coupled briefly with ridging near the Urals, and troughing/negative geopotential height anomalies across Northern Asia in the stratosphere will help to maintain similar troughing/negative geopotential height anomalies in the mid-troposphere with ridging/positive geopotential height anomalies to the south. This pattern favors normal to below normal temperatures across Northern Asia, including much of Siberia, with normal to above normal temperatures across Southern Asia.
- Across North America, ridging/positive geopotential height anomalies across Greenland and in the Gulf of Alaska will help to develop troughing/negative geopotential height anomalies across Canada. However, as the whole pattern retrogrades west, the troughing will be increasingly focused across western North America. Currently widespread normal to above normal temperatures cover Canada and the United States (US), however over the next two weeks normal to below normal temperatures will build across Western Canada and the Western US with normal to above normal temperatures in Eastern Canada and the Eastern US.
- In the Impacts section I discuss the possible influence from the ongoing and complex polar vortex (PV) disruption on the weather across the Northern Hemisphere (NH).

Impacts

There is a Yiddish saying that probably many of you are familiar with - “Mann Tracht, Un Gott Lacht” which means “Man Plans, and God Laughs.” This is not the blog that I had planned but the cold, hard reality is leaving me no choice. I did think that I had troposphere-stratosphere-troposphere/PV weather coupling all figured out (this is of

course an exaggeration – I think I know the broad strokes but the devil is in the details and there is a lot that I don't know) and now Mother Nature serves up an event that I am unfamiliar with and struggling to understand and anticipate the implications for our weather. As I have discussed on Twitter, it is very puzzling to me to have strong/active vertical Wave Activity Flux (WAFz and is proportional to poleward heat transport) after a significant weakening of the PV (see **Figure 12**), especially one that crosses the threshold for a major mid-winter warming (MMW where the zonal winds reverse from westerly to easterly at 60°N and 10 hPa). As I showed in Figure 4 from Cohen and Jones (2011) and shown earlier by Polvani and Waugh (2004) as I show in **Figure i**, positive WAFz comes to an abrupt end at the Central Date (when the winds reverse from westerly to easterly in the stratosphere) and in fact is negative for an extended period. According to Polvani and Waugh the negative WAFz can last up to two months. But as seen in **Figure 12**, the WAFz continues to remain active following the initial wind reversal in the polar stratosphere the first week of January and will remain active right through the end of the month. I do have the winter season daily WAFz for every winter going back to 1969 and I cannot find another example of active WAFz following an MMW. To just show how unprecedented this may be, there is the possibility of two separate MMWs this winter separated by about a week based on the most recent EPS weeklies. There have been two MMWs in one winter before but usually they are separated by months and not a week or two. As far as I know this has never happened before.

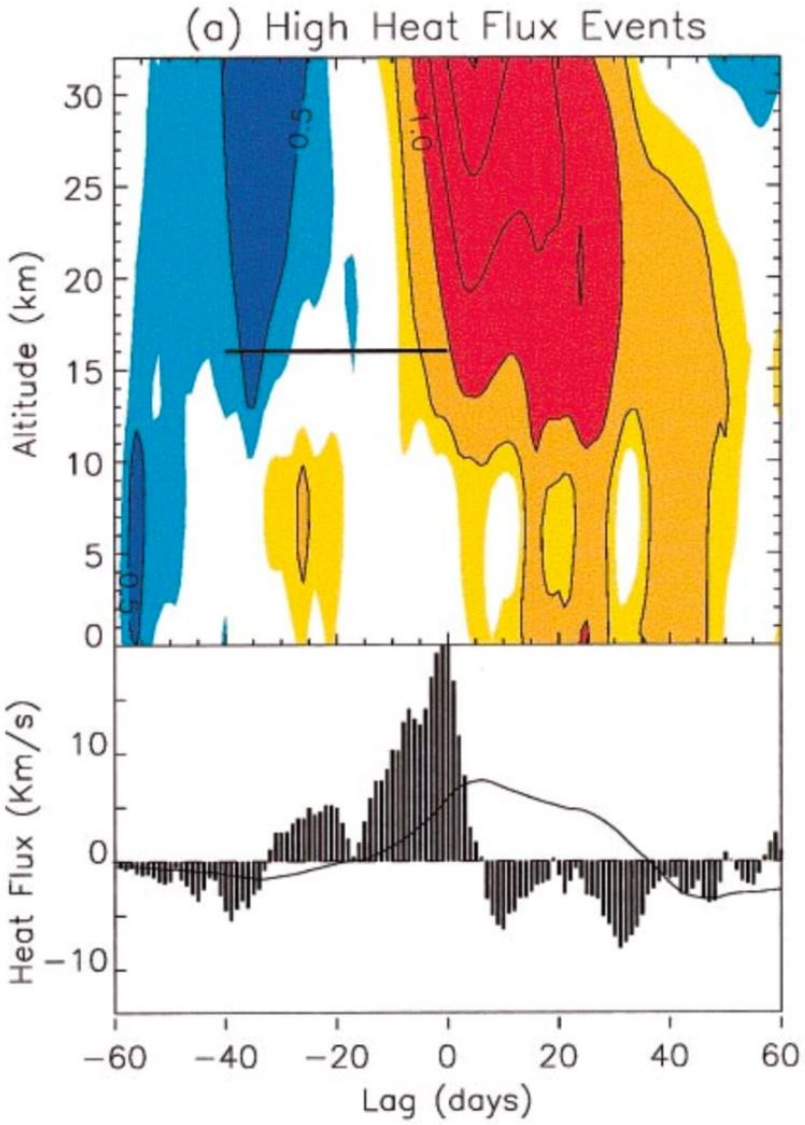

Figure i. (top) Composites of height–time development of the NAM index for (a) 25 high heat flux events. The horizontal line marks the 40-day period over which the averaged heat flux is anomalous. Values greater than 0.25 and smaller than −0.25 are shaded, and values greater (smaller) than 0.5 (−0.5) contoured, with a contour interval of 0.5. (bottom) Temporal evolution of composite mean daily (bars) and 40-day averaged (curves) heat flux anomalies at 100 hPa. From Polvani and Waugh (2004).

I provided a summary of anticipated generalized temperature anomalies through the life cycle of PV disruptions in Table 1 of the December 7, 2020 blog (see middle row). My expectation or assumption was that each column was offset in time and there was no overlap. But here we are, and the weather models are predicting the two occurring simultaneously. We are almost two weeks since the PV disruption, so looking forward the last column (five) should apply ("Weather 2-4 weeks after PV disruption" or last column). But complicating the story, WAFz is also active so column two also applies but

they describe different temperature anomalies. When WAFz is active (second column "active energy transfer") it is relatively cold in East Asia and western North America but relatively mild in the Eastern US and Europe. Two to four weeks post the PV disruption it is likely to be relatively cold in the Eastern US and Europe while the cold in East Asia and western North America eases and both cannot be simultaneously true. Does the active WAFz cancel the impacts to the weather from the PV disruption, is the opposite true or are both impacts operating simultaneously.

It seems to me that what the models are predicting is that partial weather patterns from both the active WAFz and the PV disruption will exist simultaneously. We can see from **Figure 5**, Ural ridging/blocking with troughing in East Asia and western North America giving the predicted temperature anomalies in **Figure 9**; relatively cold in East Asia and western North America but relatively mild in Europe and eastern North America. But we can also see the signature influences from the PV disruption with Greenland and Central Arctic high pressure/blocking and an overall negative AO/NAO. Typically, we do not observe Ural blocking post a PV disruption but rather Greenland blocking but this is exactly what the GFS is predicting. The resultant pattern is a hybrid or a mutt of both active WAFz and the downward influence of a PV disruption. I think for both eastern North America and Europe it is mild, consistent with active WAFz but the mild weather is moderated or damped by the influence of Greenland blocking and high pressure in the Central Arctic.

Some people over Twitter have been saying it can't get cold in the Eastern US while the only or major PV center is in Eurasia. I would argue that previous analysis disagrees as I have argued many times in the blog and most recently in the blog from December 28, 2020 **Figure iv** from the blog shows the temperatures anomalies the three weeks following a significant weakening of the stratospheric PV or PV cluster seven in Kretschmer et al. (2018). The weakest PV consists of high pressure over the Central Arctic with the weakened PV center in Eurasia. During the immediate week of the PV disruption the most robust negative temperature departures are across Northern Asia and Northern Europe. There are also negative temperature departures in the Western US in weeks one and two but by week three, the largest negative temperature departures stretch from Central Canada into the Eastern US. Throughout the three weeks the North American Arctic is warm. Based on this analysis, even if it is not cold initially in the Eastern US following an SSW/MMW, the odds for cold weather do increase with time. A similar analysis was shown in Zhang et al. (2016). In their paper they argue that below normal sea ice in the Barents Kara Seas and increased snow across Eurasia (similar to conditions this past fall) favor a displacement of the stratospheric PV towards Eurasia in February. During February there are relatively cold temperatures in both Eurasia and North America but by March all the relatively cold temperatures are limited to eastern North America (see **Figure ii**).

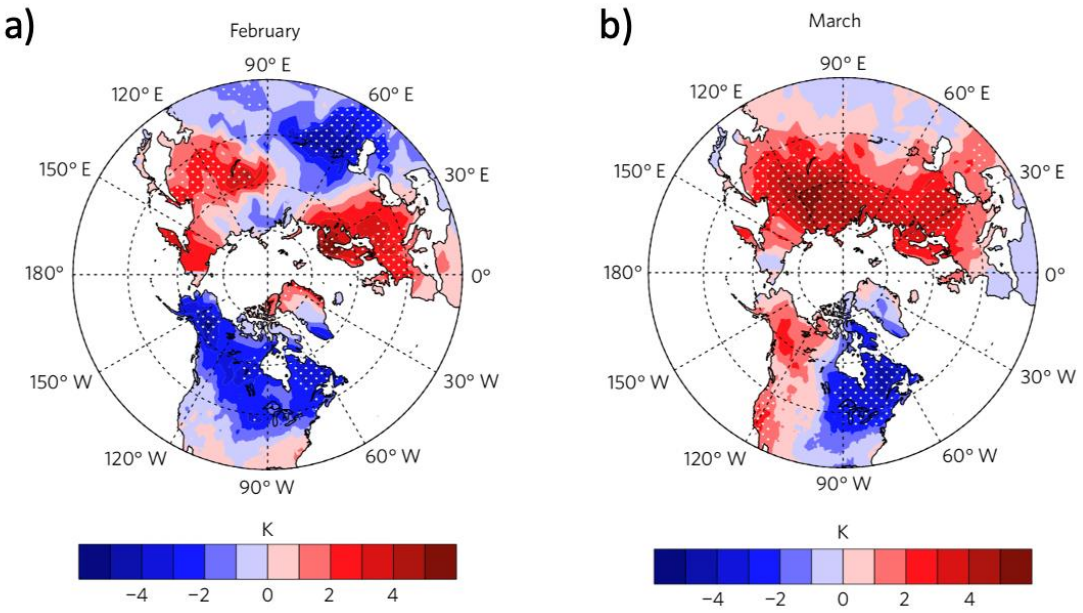

Figure ii. Composite differences in surface temperature (**a**,**b**) in February and March between high and low February-mean stratospheric PV index. The composited differences over the dotted regions are statistically significant at the 90% confidence level according to the Student's *t*-test. From Zhang et al. (2016).

It is complicated and we are in unchartered waters (at least for me) with this PV disruption. Through the end of January we have competing influences from both active energy transfer and the impacts following a PV disruption as summarized in columns two and five in **Table 1** from the December 7, 2020 blog (see middle row below). I showed the table last week but for convenience I bring it one more time. The resultant pattern will be a blend or mix of the two and though I don't trust the models during active energy transfer and immediately following a PV disruption, I have no precedence to offer as an alternative to the model forecasts though confidence should remain low to any forecast.

Table 1. Expected weather during and after three different vertical energy transfer scenarios described in the December 7, 2020 blog. But for today's blog the middle row is most relevant.

Vertical atmospheric energy transfer type	Weather during energy transfer	Duration of induced weather	Main impact on weather during PV disruption	Weather 2-4 weeks after PV disruption
reflective	N/A	days	Cold eastern North America/Central Asia	N/A
Absorptive polar region	Mild Eastern US/Europe & cold East Asia/western North America	2-4 weeks	Cold northern Eurasia can also cause cold in western North America	Consistent with negative AO, displacement favors cold eastern North America while split favors cold in Europe and/or US
Absorptive equatorial region then transitioning to absorptive polar region	Mild for entire Northern Hemisphere transitioning to Mild Eastern US/Europe & cold East Asia/western North America	4-6 weeks (or possibly more if it does not culminate in large PV disruption)	Cold northern Eurasia can also cause cold in western North America	Consistent with negative AO, displacement favors cold eastern North America while split favors cold in Europe and/or US

What about the period once WAFz becomes quieter probably sometime in early February (this is based on our speculative PV forecast model that showed a disrupted PV for all of January and finally strengthens in early February)? Unfortunately, further complicating the situation we have multiple PV splits and PV displacements so what are the combined impacts that we should expect. For that I think best to anticipate **Figure i** from the blog January 4, 2021 and **Figure iii** from the blog December 28, 2020. The region most likely to experience relatively cold temperatures is Siberia with increased chances of relatively cold temperatures for the Eastern US and/or Europe. Though if the last PV disruption is the most influential and the models are correct with a displaced PV in the North Atlantic side of the Arctic and high pressure in the North Pacific side of the Arctic and northerly flow into North America, then starting in mid-February I would expect a colder pattern in eastern North America. I still anticipate a turn to colder weather in the Eastern US but given the context this is speculative, and I don't have any past history to draw upon to guide me to predict the next two months.

I will also quickly mention that the GFS is still predicting a spike in polar cap geopotential heights, which is a good proxy for temperatures in the lower troposphere

for the very end of January. I haven't seen anything out of the ordinary from the weather models, but still I think the very end of January and early February is a period to watch for possible severe winter weather.

One thing I have wanted to mention for a while now but have kept running out of room in the blog so I will mention it today. Last year was brutal about the future prospects of winter weather as we expect. Siberia was off the charts warm that lead to a quick retreat of spring snow cover, an unprecedented June heat wave and unprecedented sea ice melt just north of Siberia over the summer. As I discussed in the blog from December 7, 2020 what I consider the most important outcome from this winter, a sign that "winter is healing" would be observed cold temperatures in Siberia. The PV disruption did what it is supposed to do – it made winter great again in Siberia. In **Figure iii**, I show the NH surface temperature anomalies from last winter and from this winter through January 13, 2021. Asia is experiencing a much colder winter so far and based on the forecasts below, that should continue for the foreseeable future. I believe if you are playing the long game on winter this is the most important outcome this winter more so than cold and snow in your backyard. I am frustrated by the lack of snow and cold the past month here in the Northeastern US, but I do believe that the longer-term prospects improved greatly for both with the winter temperature anomalies in Siberia. As I like to say Siberia is the refrigerator of the NH, and if the refrigerator breaks down permanently there are poor prospects for winter across the entire NH going forward and that includes your and my backyard.

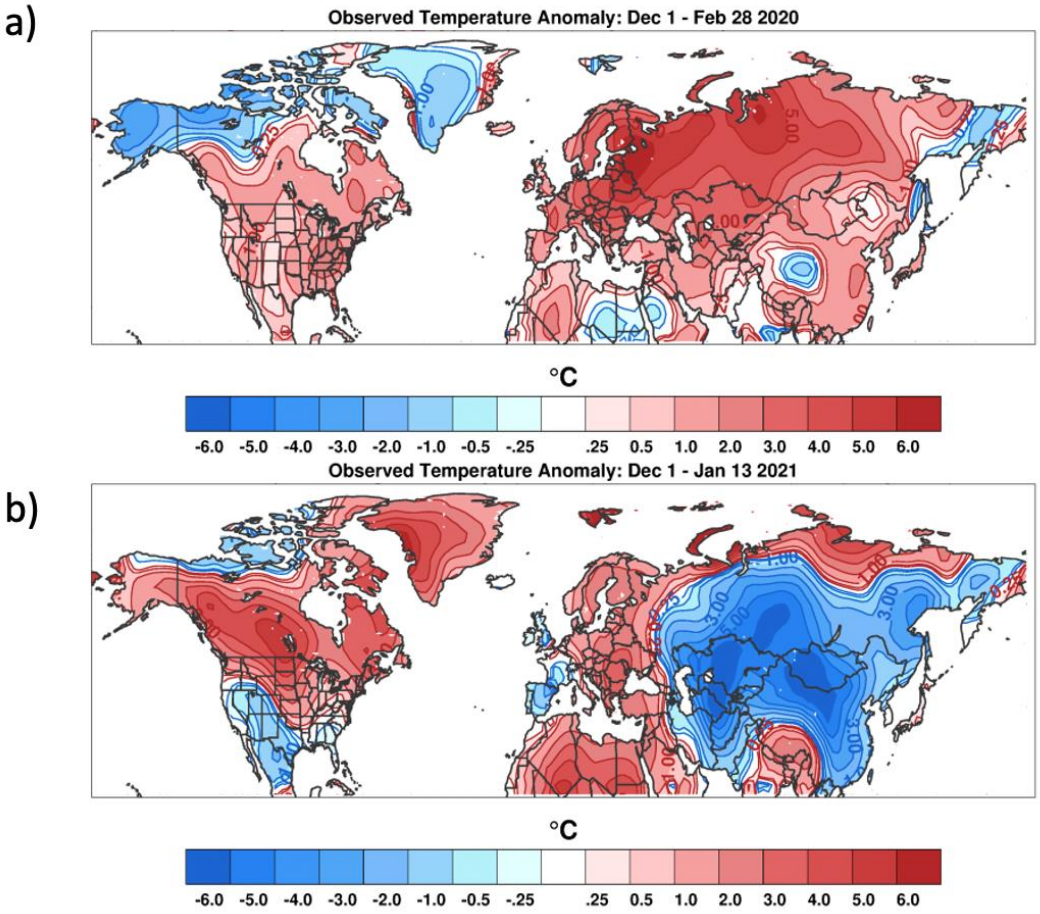

Figure iii. **a**) Observed surface temperature anomalies °C; shading) December 1. 2019 through February 28, 2020. **a**) Observed surface temperature anomalies °C; shading) December 1. 2020 through January 13, 2021.

Finally, once when I did an empirical orthogonal analysis of NH surface temperatures and one of the dominant patterns was a seesaw in temperatures between Eurasia and North America. If it was cold in Eurasia it was warm in North America and vice-versa. From 2000/01-2012/13, winter cold was focused in Eurasia relative to North America. But then from 2013/14-2019/20 the cold became focused in North America relative to Eurasia. This can be seen at looking at computed trends in my two review papers on Arctic mid-latitude linkages and I wonder if this winter is the start of the pendulum swinging back to a new period where the cold is once again shifted from North America to Eurasia. But we will not know the answer to this for at least a few more years.

1-5 day

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

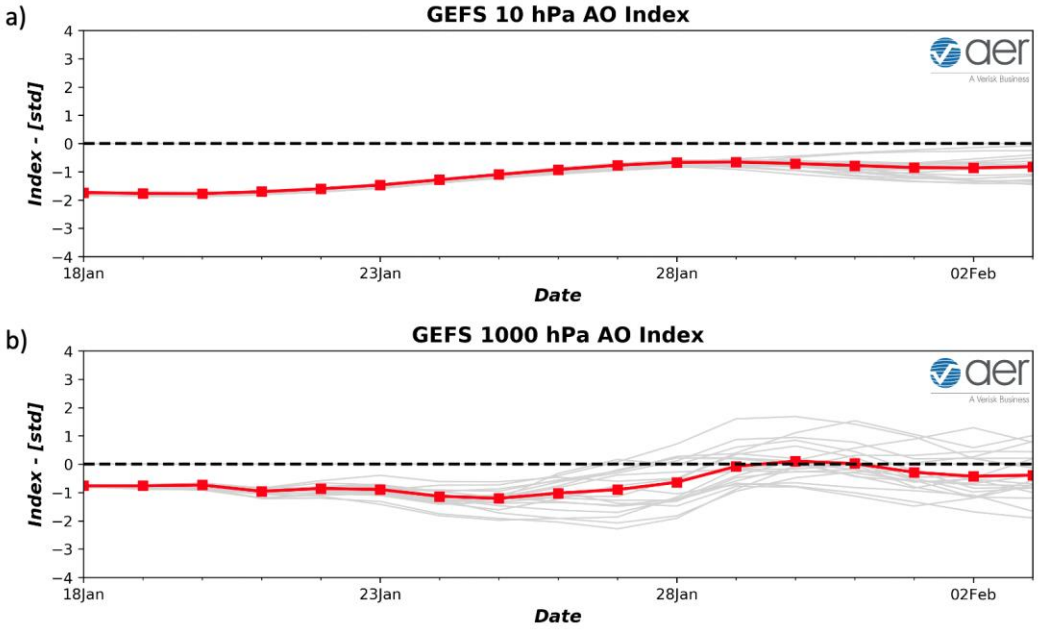

Figure 1. (**a**) The predicted daily-mean AO at 10 hPa from the 00Z 18 January 2021 GFS ensemble. (**b**)The predicted daily-mean near-surface AO from the 00Z 18 January 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies centered over Greenland are predicted to force downstream troughing/negative geopotential height anomalies across Europe (**Figure 2**). However, as the Greenland high pressure/blocking drifts west, this will allow an increasing westerly component to the winds across Europe introducing milder, maritime air. This pattern favors normal to below normal temperatures across Northern Europe including the northern UK as heights remain low but across the remainder of Europe including the southern UK, a mild westerly flow will favor normal to above normal temperatures (**Figure 3**). This week, troughing/negative geopotential height anomalies across much of Northern Asia in the stratosphere will help to anchor troughing/negative geopotential height anomalies across much of Northern Asia in the mid-troposphere with ridging/positive geopotential height anomalies across Southern Asia (**Figure 2**). This pattern favors normal to below normal temperatures **for much of** Northern Asia with normal to above normal temperatures for Southern Asia **(Figure 3**).

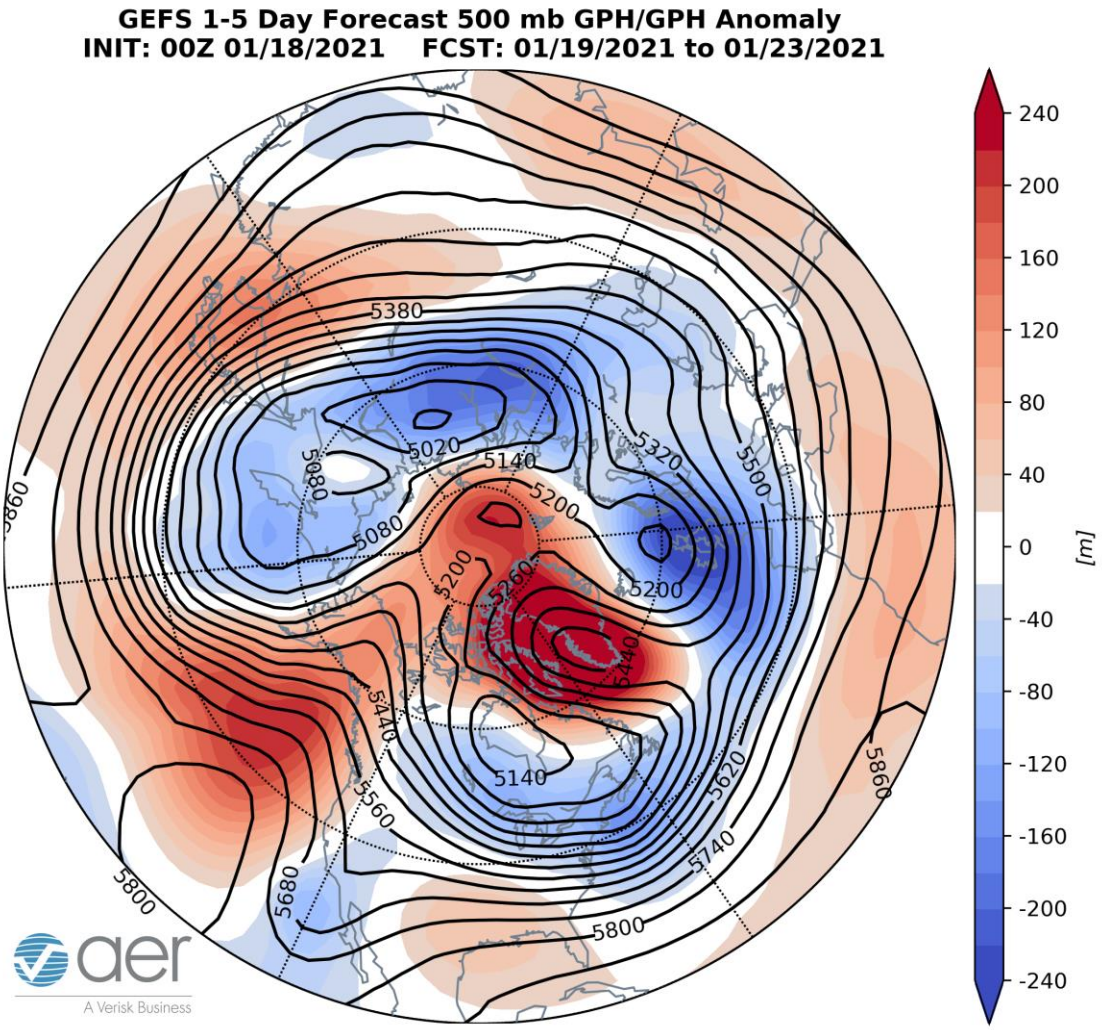

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 19 – 23 January 2021. The forecasts are from the 00z 18 January 2021 GFS ensemble.

This week ridging/positive geopotential height anomalies across Greenland and the Gulf of Alaska will force troughing/negative geopotential height anomalies across most of Canada and the Western US with more ridging/positive geopotential height anomalies in the Southeastern US **(Figure 2).** This pattern is predicted to bring widespread normal to above normal temperatures across much of Alaska, Northern Canada and the US with normal to below normal temperatures developing across Southern Canada **(Figure 3).**

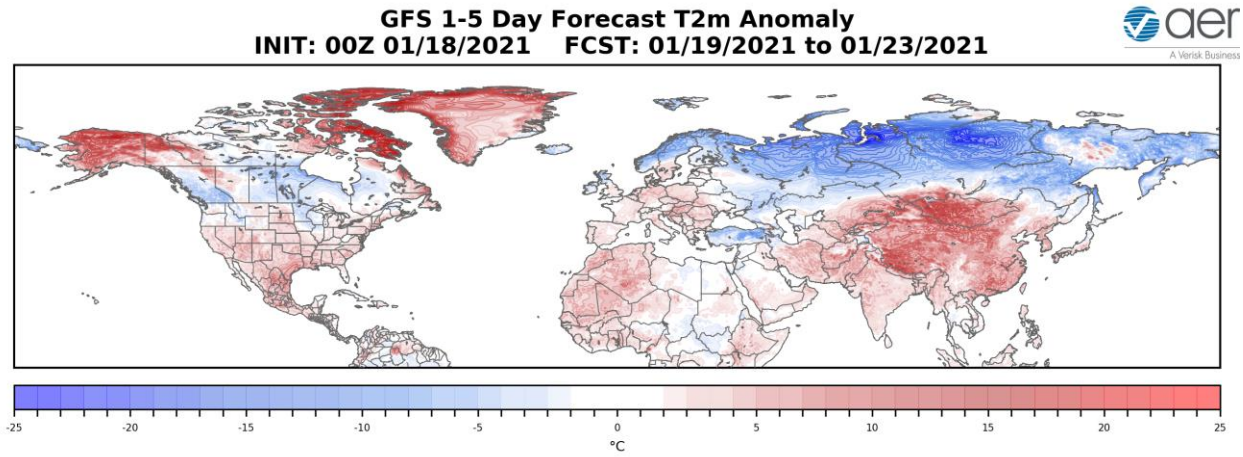

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 19 – 23 January 2021. The forecast is from the 00Z 18 January 2021 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across Scotland, Scandinavia, Central and Northern Asia while warmer temperatures will cause snow melt in Central and Eastern Europe, Korea and Japan (**Figure 4**). Troughing and/or colder temperatures are predicted to support new snowfall across parts of Alaska, Northern and Eastern Canada while warmer temperatures will cause snow melt in parts of Western Canada and the US Great Lakes (**Figure 4**).

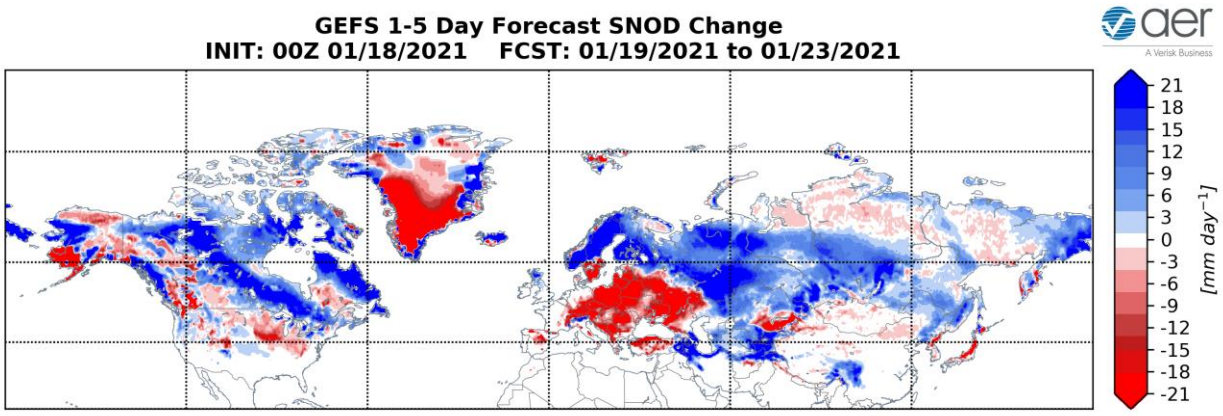

Figure 4. Forecasted snow depth changes (mm/day; shading) from 19 – 23 January 2021. The forecast is from the 00Z 18 January 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain negative next week **(Figure 1**) as positive geopotential height anomalies persist across the North Atlantic side of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with positive geopotential height anomalies predicted across Greenland (**Figure 5**), the NAO is predicted to also remain negative.

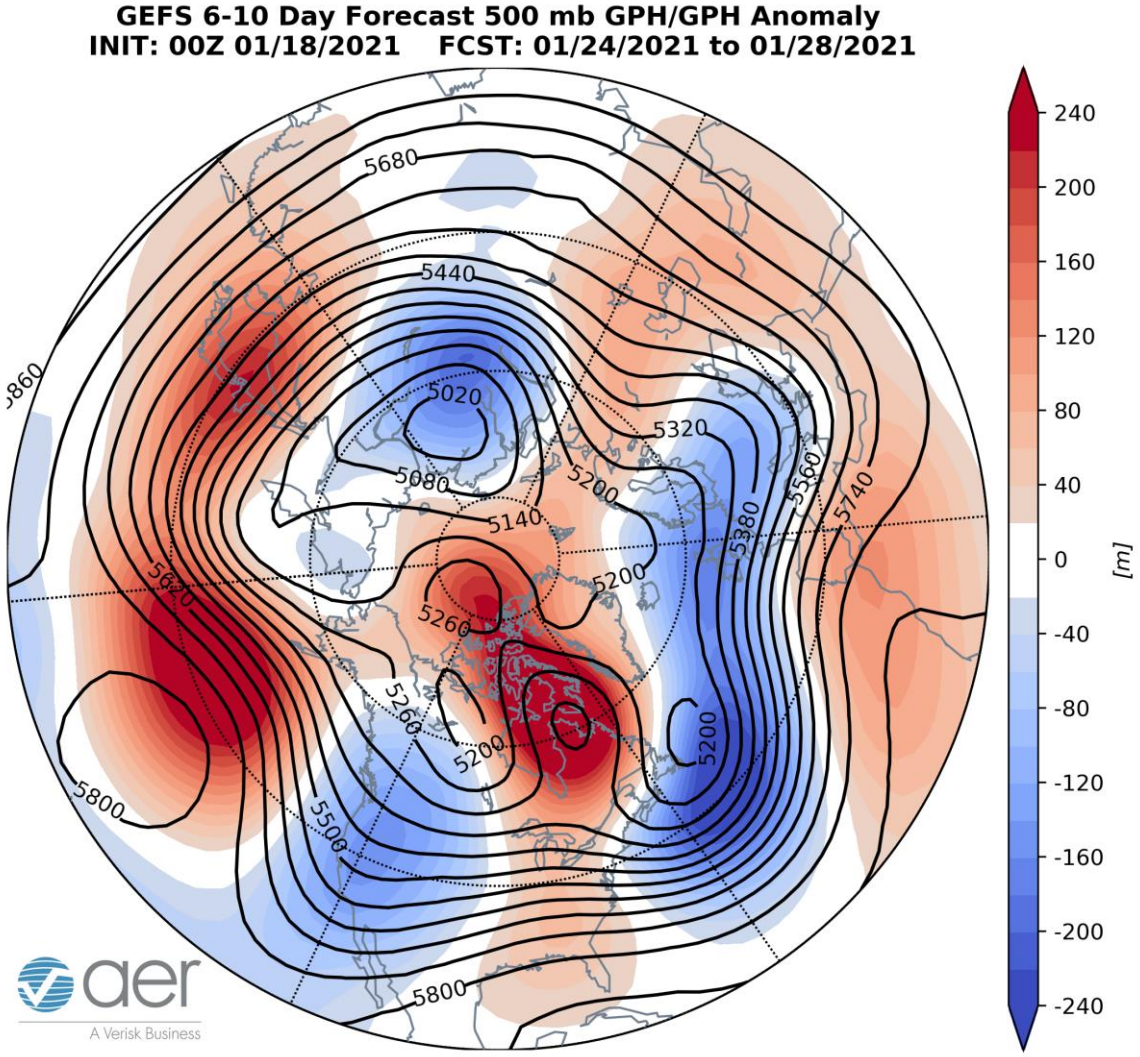

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 24 – 28 January 2021. The forecasts are from the 00z 18 January 2021 GFS ensemble.

As ridging/positive geopotential height anomalies previously centered across Greenland drifts west, troughing/negative geopotential height anomalies will dominate Europe however the flow will remain mostly from the west this period (**Figures 5).** A predominantly maritime flow of air across Europe favors normal to above normal temperatures across most of Europe including the UK with normal to below normal

temperatures limited to Scotland and Scandinavia where heights are low and are north of the westerly flow (**Figure 6**). Persistent troughing/negative geopotential height anomalies across Northern Asia in the stratosphere coupled with ridging over the Urals will help persist troughing/negative geopotential height anomalies in the mid-troposphere across Siberia and Central Asia with ridging/positive geopotential height anomalies across Southwestern and Southeastern Asia this period (**Figure 5**). This is predicted to favor widespread normal to below normal temperatures across much of Northern and Central Asia with normal to above normal temperatures in Southeastern and Southwestern Asia **(Figure 6**).

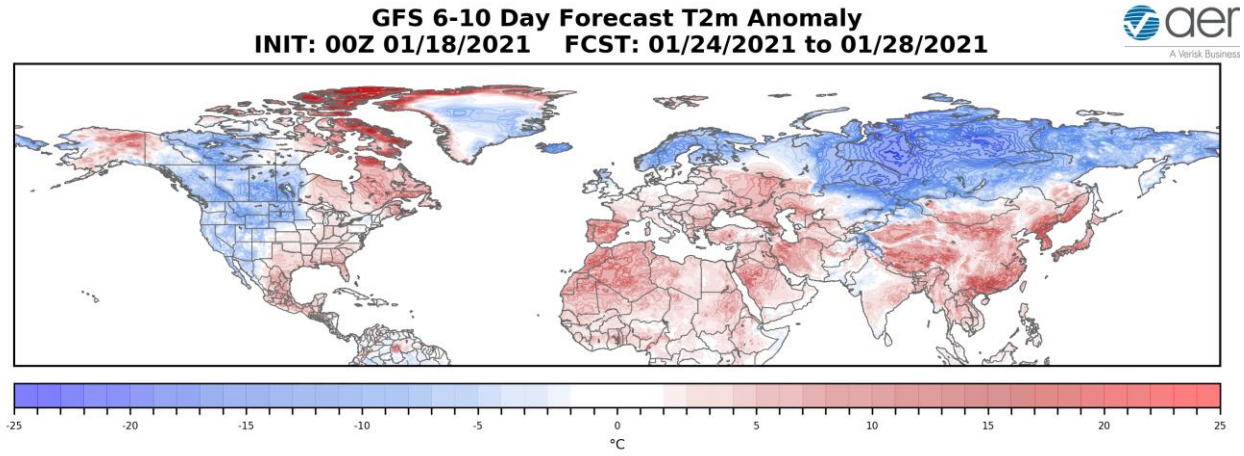

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 24 – 28 January. The forecasts are from the 00Z 18 January 2021 GFS ensemble.

Ridging/positive geopotential height anomalies south of the Aleutians will promote troughing/negative geopotential height anomalies across western North America with more ridging/positive geopotential height anomalies across eastern North America this period **(Figure 5).** This pattern is predicted to bring normal to above normal temperatures across Alaska, Eastern Canada and the Eastern US with normal to below normal temperatures across the Eastern US and Eastern Canada **(Figure 6).**

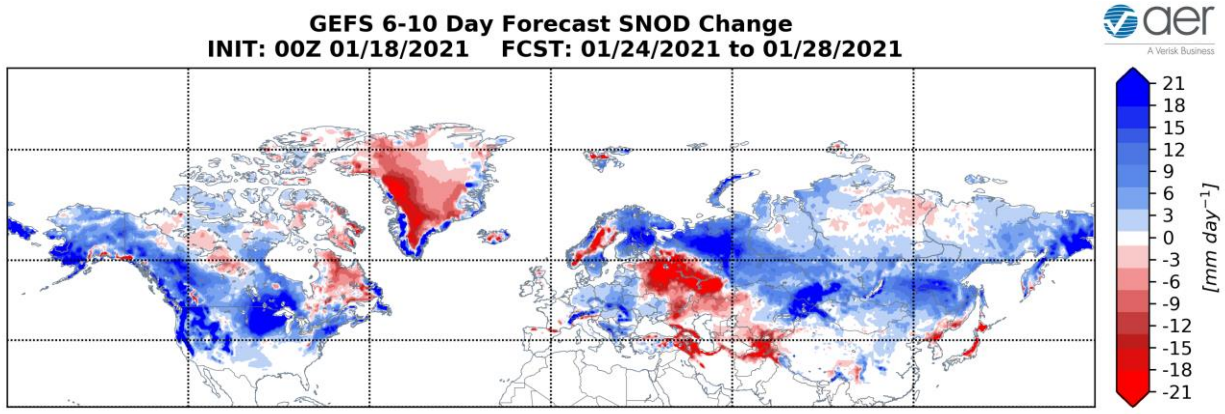

Figure 7. Forecasted snow depth changes (mm/day; shading) from 24 – 28 January. The forecasts are from the 00Z 18 January 2021 GFS ensemble.

Troughing and/or colder temperatures are predicted to potentially support new snowfall across the Alps, the Baltics, Southeastern Europe, Northern and Central Asia while warmer temperatures will cause regionalized snow melt in Eastern Europe, Southwestern Asia, Korea and Japan (**Figure 7**). Troughing and/or colder temperatures are predicted to support new snowfall across much of Alaska, Canada and the Northern, Western and even Northeastern US while warmer temperatures will cause possible snow melt in Eastern Canada (**Figure 7**).

11-15 day

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

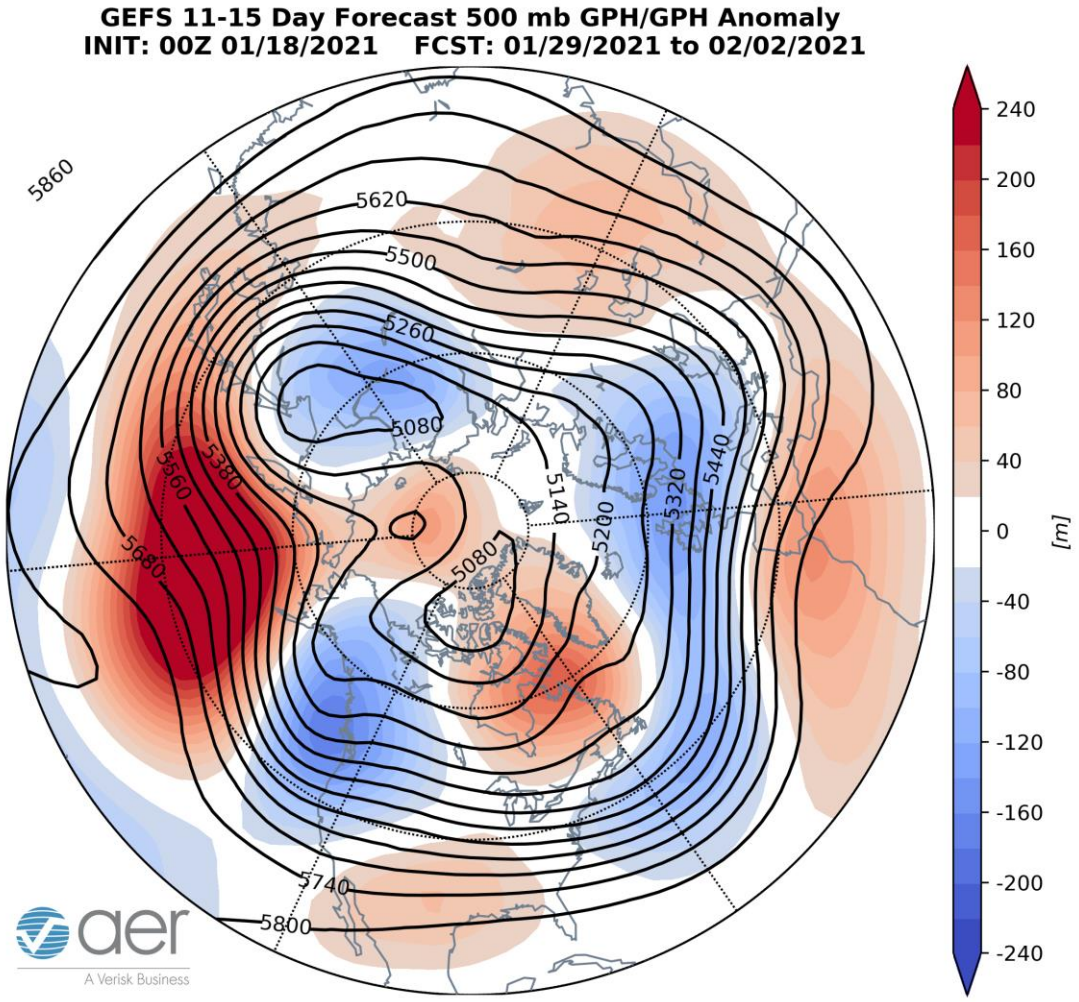

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 29 January – 2 February 2021. The forecasts are from the 00z 18 January 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies centered near Greenland are predicted to continue to anchor troughing/negative geopotential height anomalies across Europe this period (**Figures 8**). However, with the Greenland ridging centered over Baffin Bay the troughing will be shallow with mostly westerly flow across the continent, favoring widespread normal to above normal temperatures across Europe including the UK with only regional normal to below normal temperatures across Scandinavia, north of the westerly flow (**Figures 9**). Ridging/positive geopotential height anomalies troughing/negative geopotential height anomalies across the Arctic and near the Dateline will help persist troughing/negative geopotential height anomalies across Northern Asia with ridging/positive geopotential height anomalies across Southern Asia this period (**Figure 8**). This pattern favors normal to below normal temperatures across

Northern and Eastern Asia with normal to above normal temperatures across Western and Southern Asia (**Figure 9**).

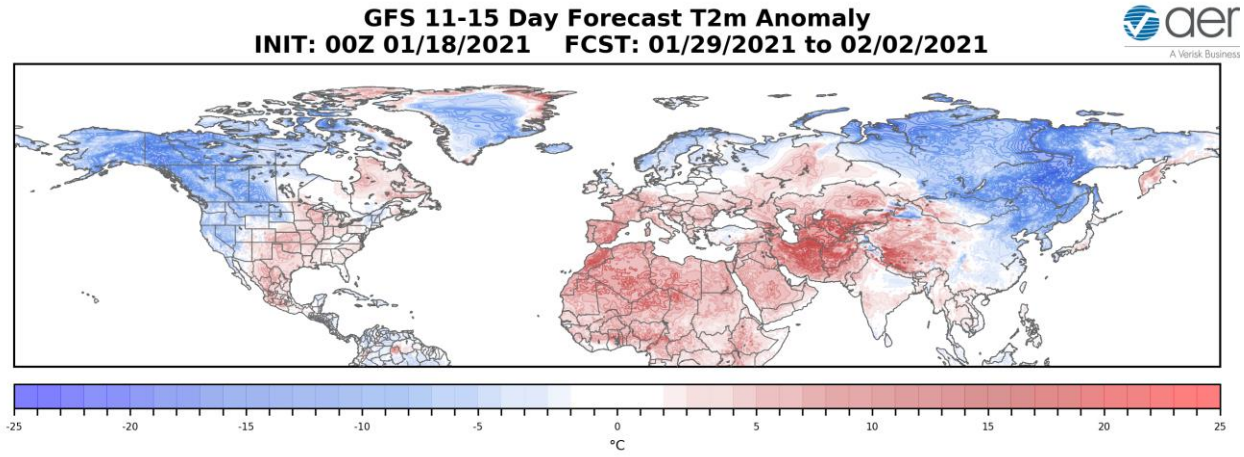

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 29 January – 2 February 2021. The forecasts are from the 00z 18 January 2021 GFS ensemble.

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

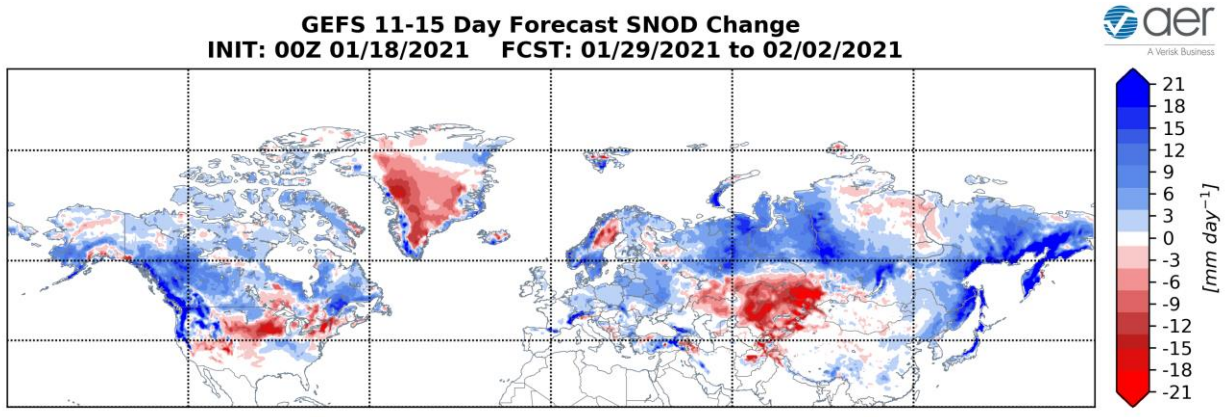

Figure 10. Forecasted snow depth changes (mm/day; shading) from 29 January – 2 February 2021. The forecasts are from the 00z 18 January 2021 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across the Pyrenees, the Alps, Central and Eastern Europe, Northern and Eastern Asia while warmer

temperatures will cause snowmelt in Southwestern and Central Asia (**Figure 10**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, much of Canada and the Northwestern US and possibly the Tennessee Valley and Southern Appalachians while warmer temperatures will result in snowmelt in the Central and Northeastern US (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows warm/positive normal PCHs throughout the troposphere and stratosphere for much of the next two weeks (**Figure 11**). Briefly the upper stratosphere will turn cold/negative the last week of January as the PV tries to recover before the next PV disruption.

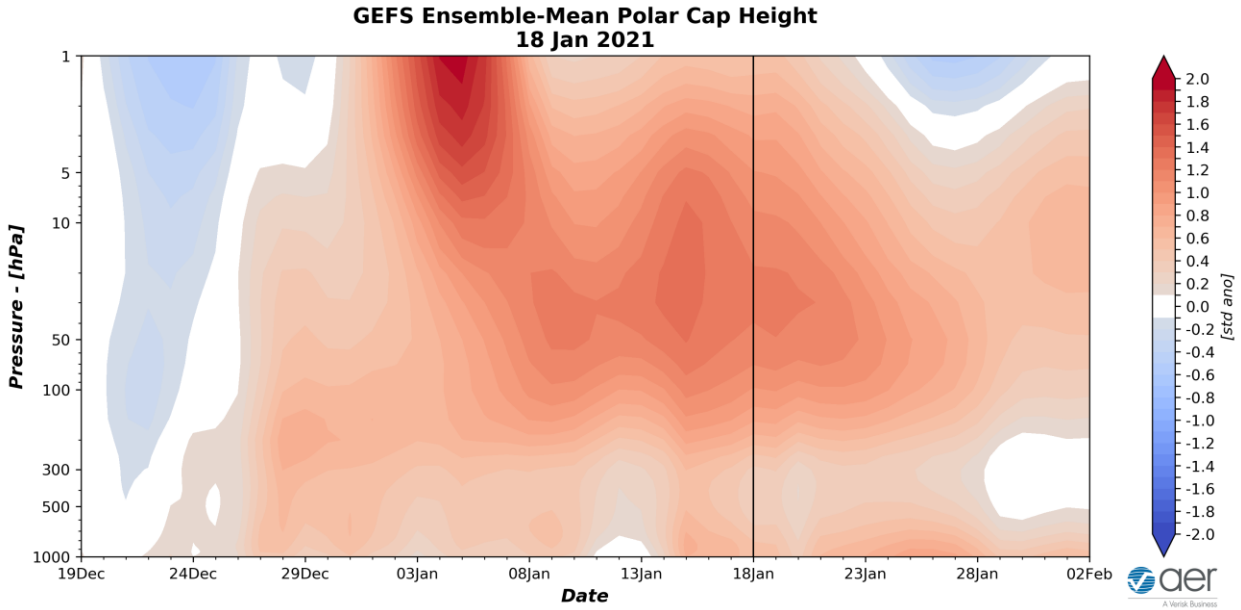

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 18 January 2021 GFS ensemble. Please note that the PCH plot now extends to 1 hPa.

Normal to warm/positive PCHs in the lower troposphere are consistent with the predicted negative surface AO the next two weeks (**Figure 1**). Warm/positive PCHs in the stratosphere are consistent with the negative stratospheric AO the next two weeks (**Figure 1**).

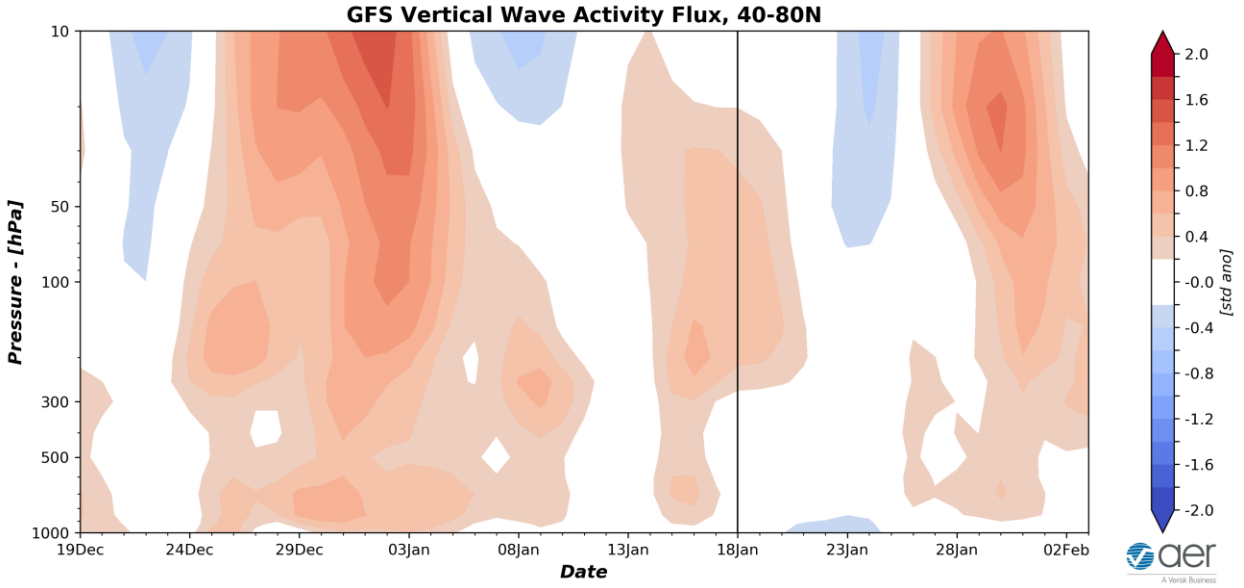

Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 18 January 2021 GFS ensemble.

The plot of Wave Activity Flux (WAFz and is proportional to poleward heat transport) forecasts is showing currently above normal WAFz throughout the atmospheric column (**Figure 12**). Though a major mid-winter warming (MMW where the zonal winds reverse from westerly to easterly at 60°N and 10 hPa) has already occurred a new pulse of WAFz is ongoing. Yet another stronger pulse is predicted for the end of January. These two pulses will continue to perturb the PV and delay its recovery.

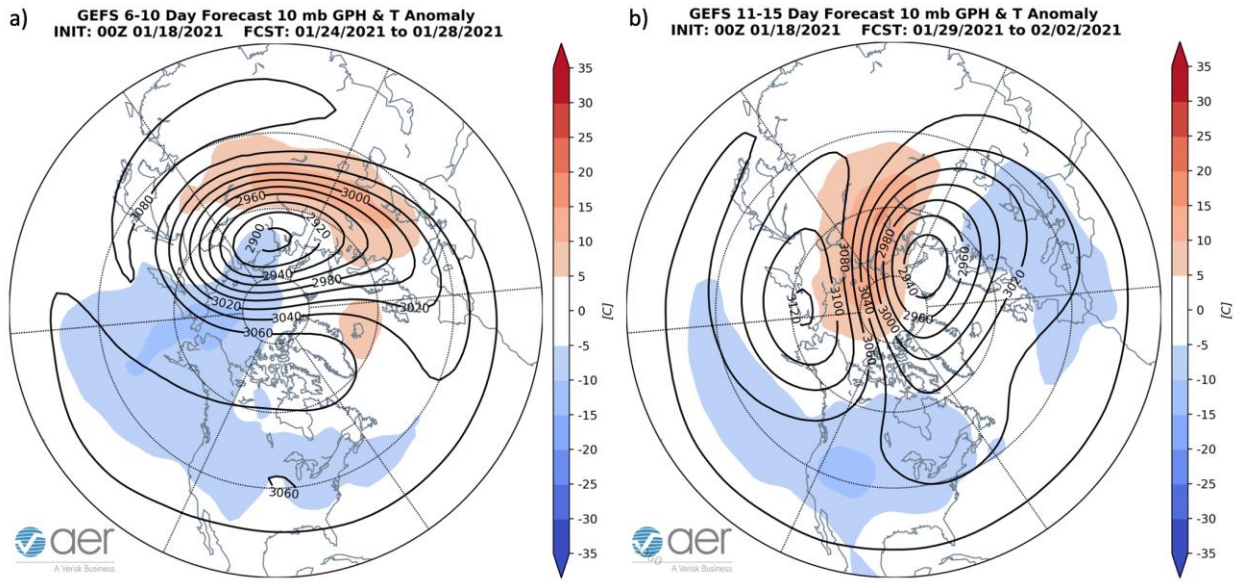

Figure 13. (**a**) Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 24 - 28 January 2021. (**b**) Same as (a) except forecasted averaged from 29 January – 2 February 2021. The forecasts are from the 00Z 11 January 2021 GFS model ensemble.

The PV has coalesced into one center yet again after the most recent split, over the Barents-Kara Seas. However, the increased WAFz activity this week is predicted to result in a third PV spit with two daughter vortices, one major vortex over Western Siberia and a minor vortex over the Central US (**Figure 13**). The increased WAFz activity at the end of January is predicted to perturb the PV further but changing the PV's orientation from east to west across Northern Eurasia to one north south from Western Asia to Eastern Canada with high pressure centered near the Dateline (**Figure 13**).

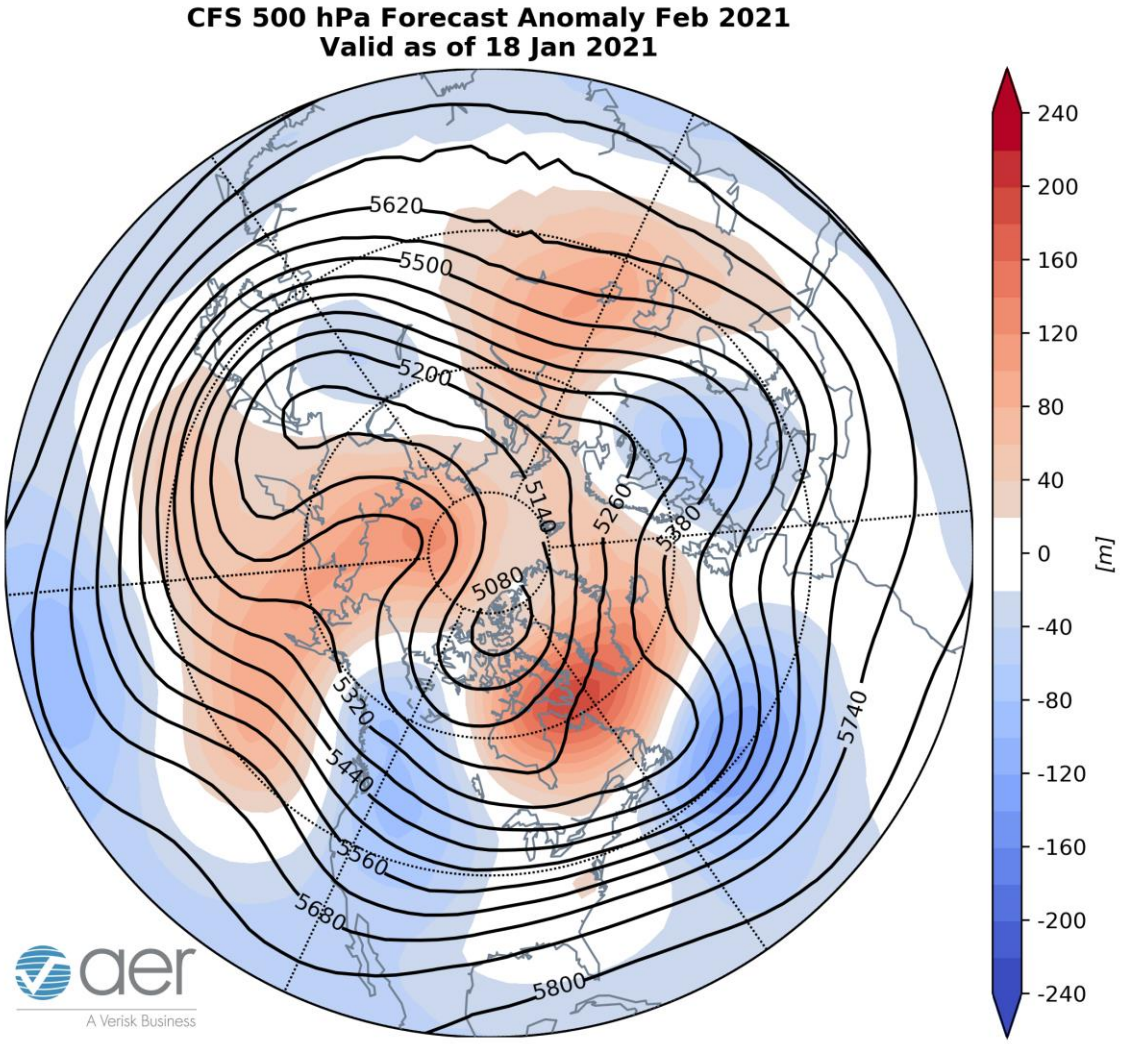

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for February 2021. The forecasts are from the 00Z 18 January 2021 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) forecast for February from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging stretching from Hudson Bay across Greenland and Iceland and then down the Urals, and from south of the Aleutians across Alaska and into the Beaufort Sea with troughing in Europe, Siberia, East Asia and western North America (**Figure 14).** This pattern favors relatively cold temperatures for much of Europe, Northern and Eastern Asia, Alaska, Western Canada and into the Northcentral US with seasonable to relatively warm temperatures for Southeastern Europe, Western Asia, the Southwestern US, Eastern Canada and along the Southern US and the East Coast (**Figure 15**)**.**I consider the forecast to be of low confidence.

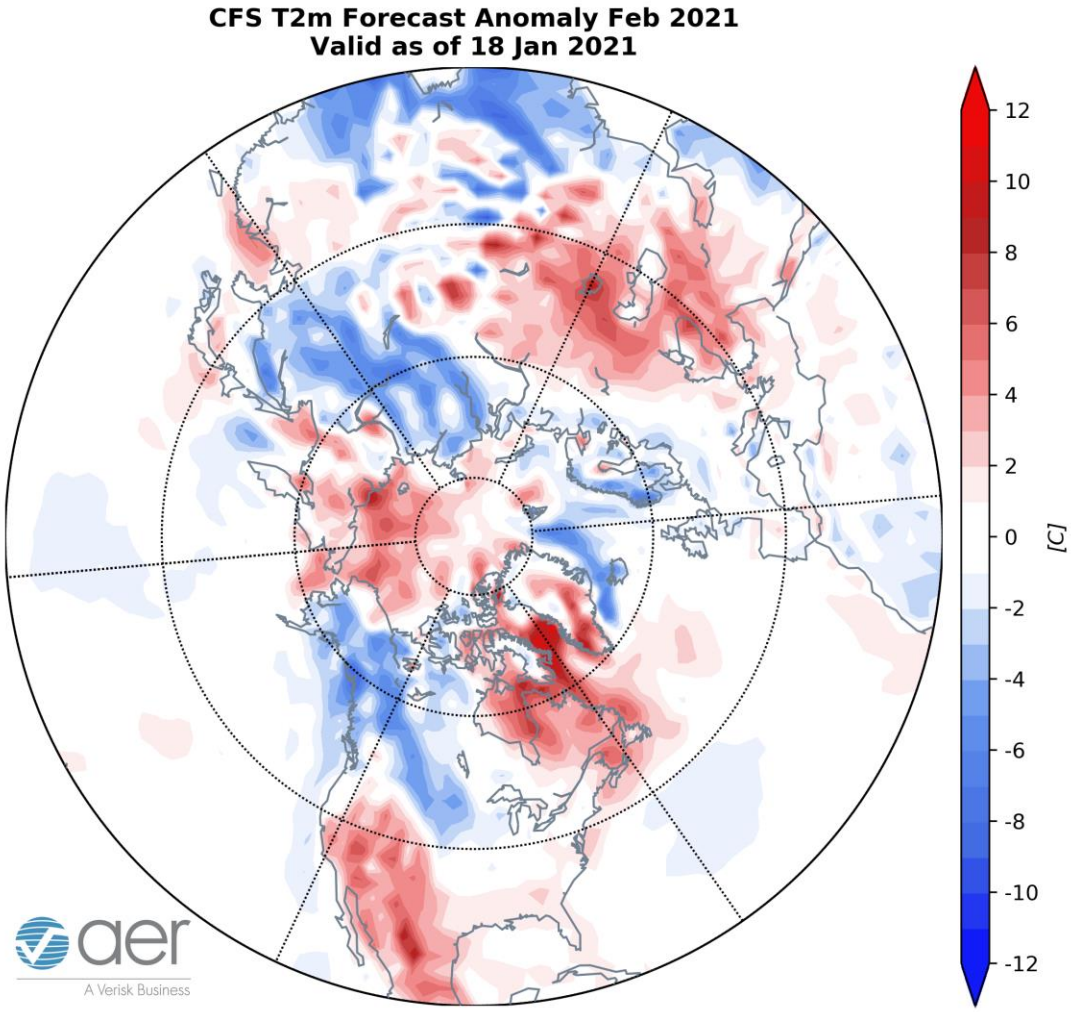

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for February 2021. The forecasts are from the 00Z 18 January 2021 CFS.

Surface Boundary Conditions

Arctic sea ice extent

Arctic sea ice continues to grow but currently remains below normal. Negative sea ice anomalies exist in the Bering Sea but especially in the Barents-Kara Seas (**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.

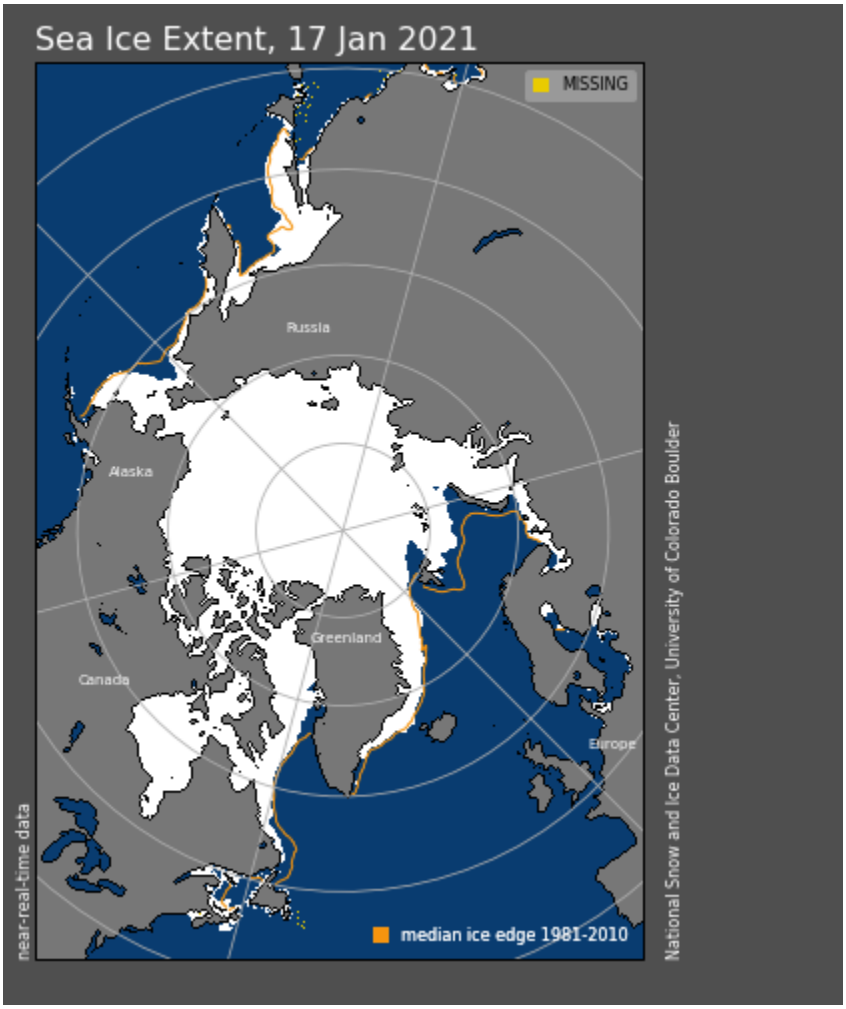

Figure 16. Observed Arctic sea ice extent on 10 January 2021 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies remain negative and we continue to observe moderate to weak La Niña conditions (**Figure 17**) and La Niña is expected to persist through the winter and remain moderate to weak the remainder of the winter. 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.

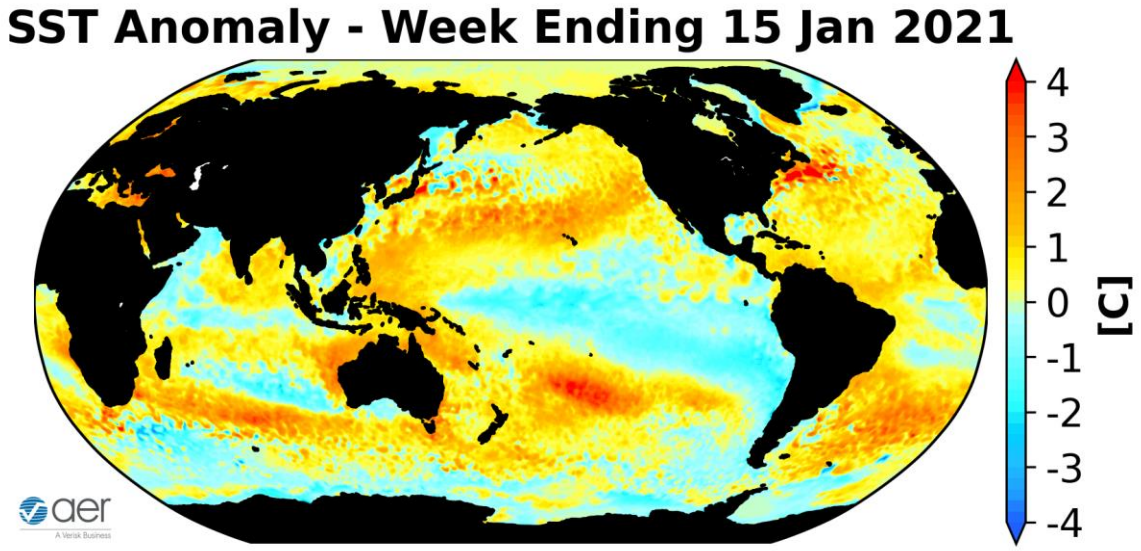

Figure 17. The latest weekly-mean global SST anomalies (ending 8 January 2021). Data from NOAA OI High-Resolution dataset.

Currently the no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 18**). The forecasts are for the MJO to remain weak where no phase is favored but could eventually emerge into phases 6 and seven. Phases six and seven favor ridging in eastern North America but eventually favors blocking across Northern Canada and troughing in the Eastern US. The MJO could eventually contribute to a colder pattern across eastern North America but admittedly this is outside of my

expertise.

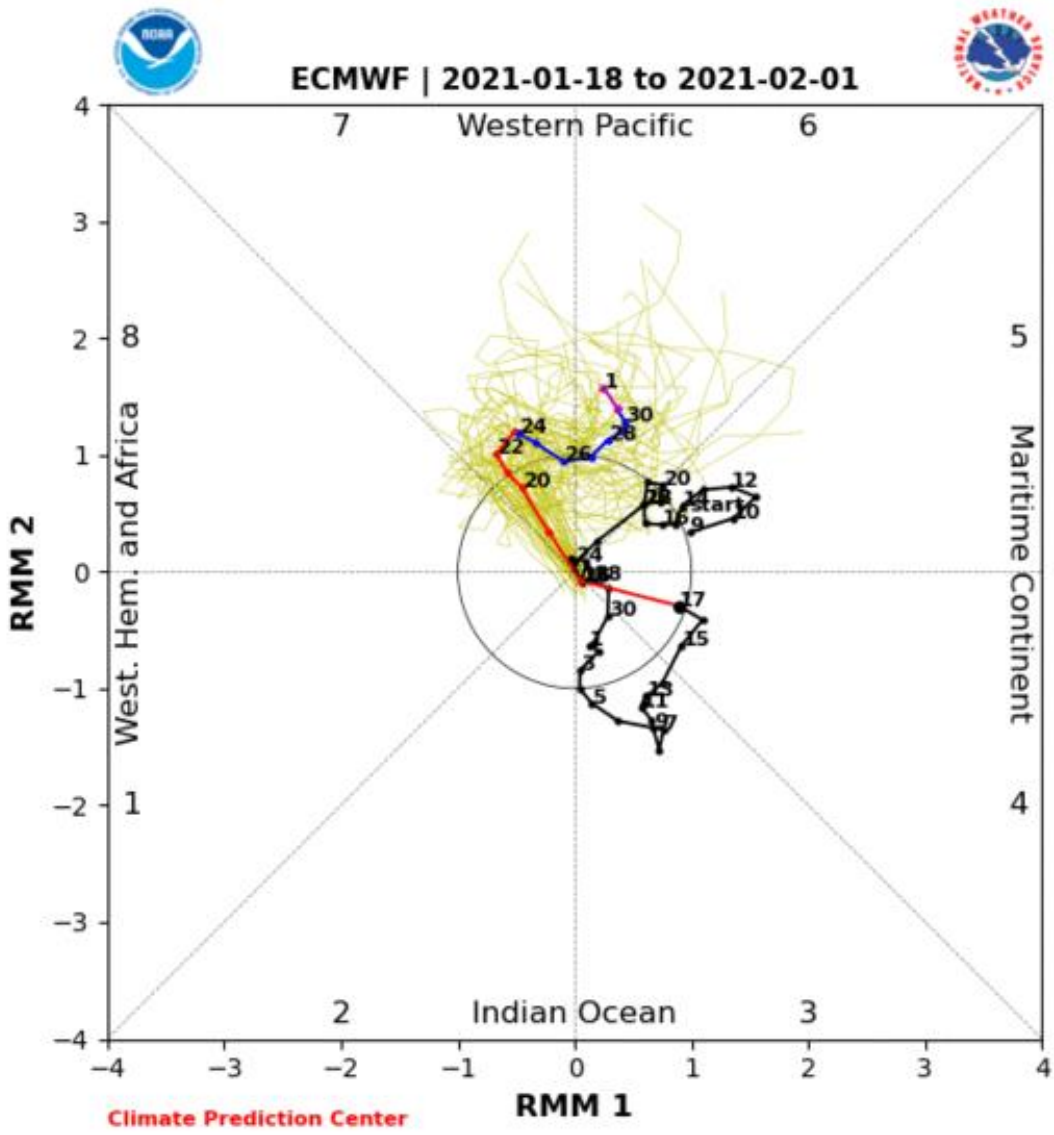

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 18 January 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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 advanced slightly over the past week across Eurasia and is now near decadal means. Snow cover advance will likely continue to increase especially across

East Asia but in the short term could retreat across Europe the next week. 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.

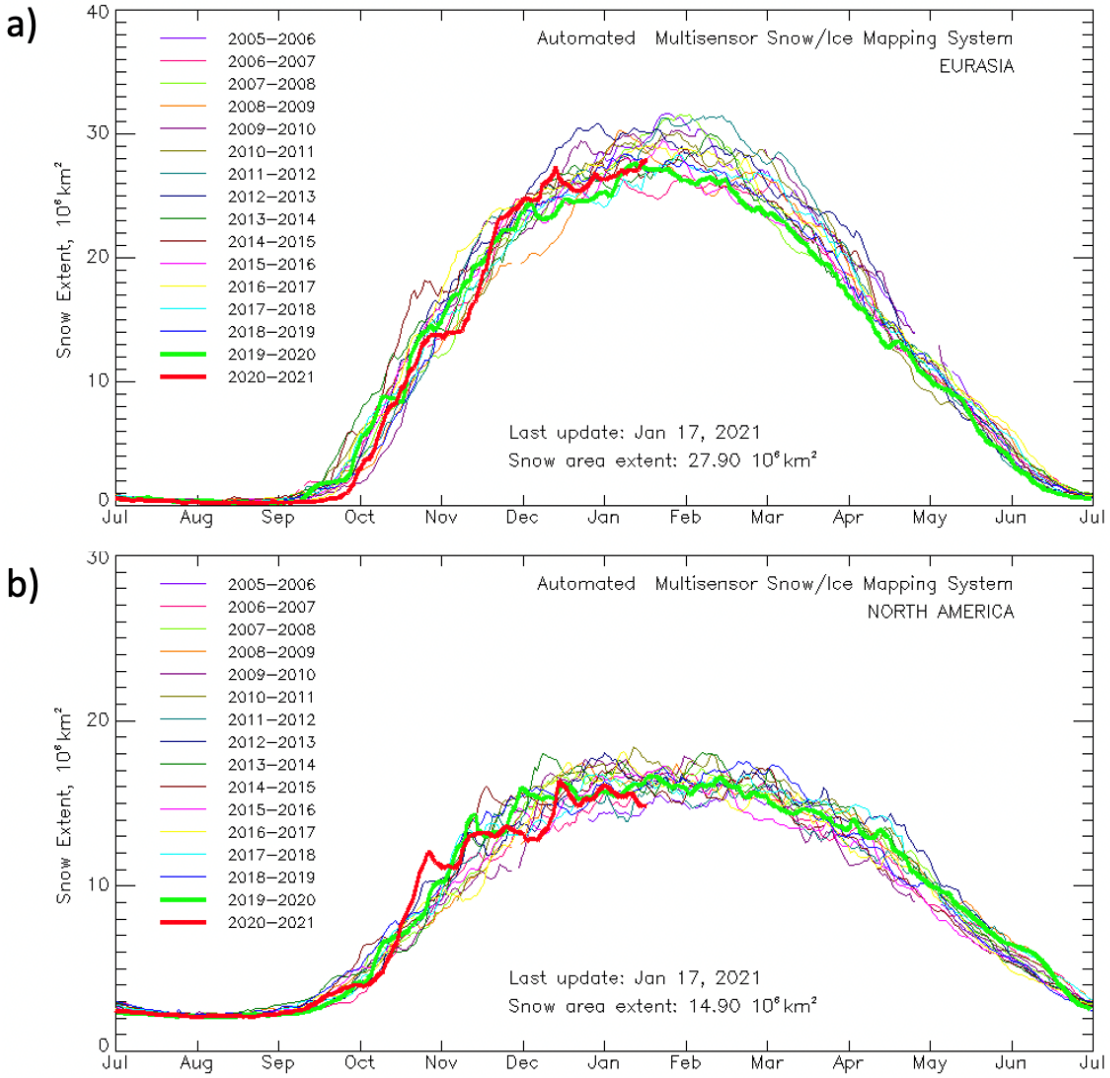

Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 17 January 2021. Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover declined over the past week and is near decadal lows. The early advance of snow cover across Canada this fall, has likely contributed to an early start of cold temperatures across the Central and Eastern US but the lack of snow cover is now likely contributing to milder temperatures.