Arctic Oscillation and Polar Vortex Analysis and Forecasts

December 28, 2020

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 negative and is predicted to remain 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 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 coupled with normal to below normal temperatures for much of Western Europe including the United Kingdom (UK). However, southwesterly flow will persist widespread normal to above normal temperatures across Eastern Europe.
- Over the next two weeks persistent ridging/positive geopotential height anomalies with normal to above normal temperatures centered near the Urals and Barents-Kara Seas are predicted to force troughing/negative geopotential height anomalies coupled with normal to below normal temperatures downstream across Central Asia, much of Siberia and East Asia.
- The predicted general trend across North America the next two weeks is ridging/positive geopotential height anomalies with normal to above normal temperatures across Greenland expanding across Eastern Canada and the Eastern United States (US), while troughing/negative geopotential height anomalies coupled with normal to below normal temperatures deepen across western North America.
- In the Impacts section I discuss the possible influence from a significant polar vortex (PV) disruption on the weather across the Northern Hemisphere (NH).

Impacts

A significant weakening of the PV is looking nearly certain and I believe even a major mid-winter warming (MMW where the zonal winds reverse from westerly to easterly at 60°N and 10 hPa) is likely in January. I would put the best chance for the winds around the PV to reverse from westerly to easterly the end of the first week of January. But if not the first week of January, then I think the chances are still good over the following two and even three weeks.

Even if an MMW does occur not all have a robust influence on the weather. It has been shown the tropospheric response/influence on the weather from an (Arctic forced) MMW is much weaker when the quasi-biennial oscillation (QBO) is in its westerly phase as this winter (e.g. Labe et al. 2019; Peings et al. 2017). Also not all MMWs are followed by a robust tropospheric response (e.g., Gerber et al. 2009; Hitchcock and Simpson 2014). A recent example where the tropospheric response was certainly not classical and some might even consider not robust is January 2019. You can see in **Figure 8** from my winter-2019-recap there is only one weak “drip” or coupling to the

surface in late January following the MMW in early January (though it did produced record cold in the Eastern US).

From looking at the polar cap geopotential height anomalies (PCHs; **Figure 11**) it is hard see how the stratosphere and troposphere aren't going to be coupled following the MMW given how coupled they are already heading into the event. It is typical that the tropospheric precursor (positive PCHs) leading up to the MMW (positive PCHs in the stratosphere) is well separated from the MMW itself. In **Figure i**, I show the PCHs from February 2018, which is a more classical appearance of the PCHs leading up to and following an MMW. The tropospheric precursor can be seen the very end of January and very early February. The first day of the MMW is February 12th and the first coupling to the surface is February 18th. The first "drip" or coupling to the surface initiated the "Beast from the East" or the record cold and snow across Europe in late February and early March 2018 and the second drip or coupling the first week of March initiated the four nor'easters for the Eastern US. The tropospheric precursor, the MMW and the tropospheric response are all well separated over a period of about six weeks.

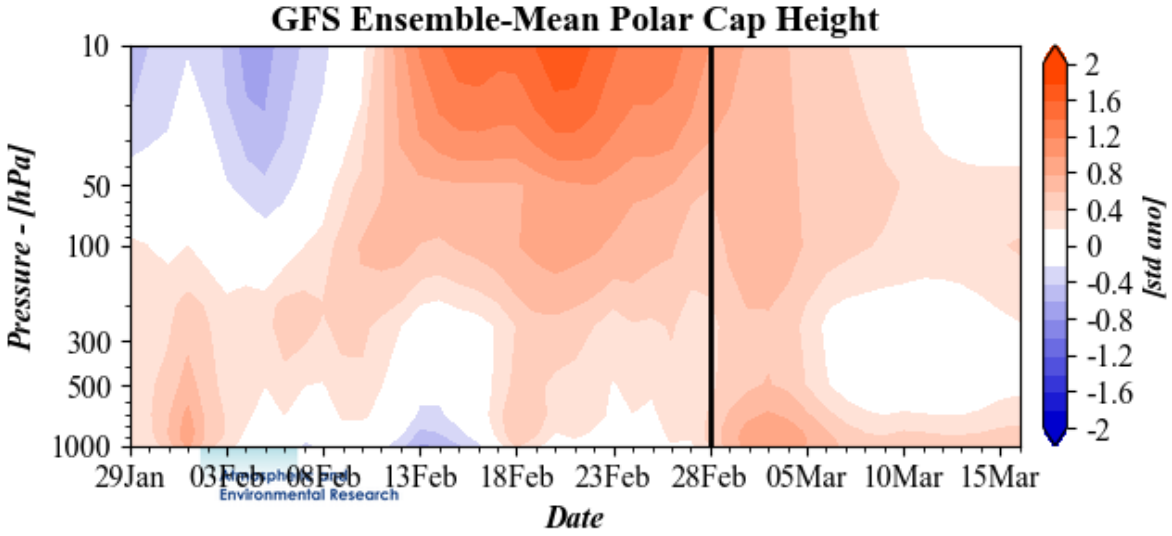

Figure i.Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 28 February 2018 GFS ensemble.

One exception that I know of to the classical "dripping paint" paradigm is the MMW of February 9, 2010. That winter is the record for the most negative winter AO observed in the reanalysis period. I wrote a paper about it because of the very active troposphere-stratosphere coupling (Cohen et al. 2010). There were two distinct events, the first a more classical look with a well separated troposphere precursor (late October), a sudden stratospheric warming (SSW in November as it didn't cross the threshold needed to be considered an MMW) and the tropospheric response

(December). However, in February there was a second troposphere-stratosphere coupling event where the troposphere precursor, the MMW and the tropospheric response are all compressed into one column of positive PCHs in the month of February and the three individual components are almost indistinguishable. And if the comparison to February 2010 is not close enough, I also include in **Figure ii** the observed 10 hPa geopotential heights from early February 2010 and the predicted 10 hPa geopotential heights for early January 2021 from the GFS. They look uncannily similar and the later GFS runs even more so (see tropicaltidbits). Who had winter 2009/2010 as the best analog on your winter 2020/2021 bingo card? But before anyone gets too excited (especially those in the Mid-Atlantic and the UK) hard to see a repeat of the winter of 2009/10 but an increased risk of high impact weather seems likely in Europe and/or Eastern US.

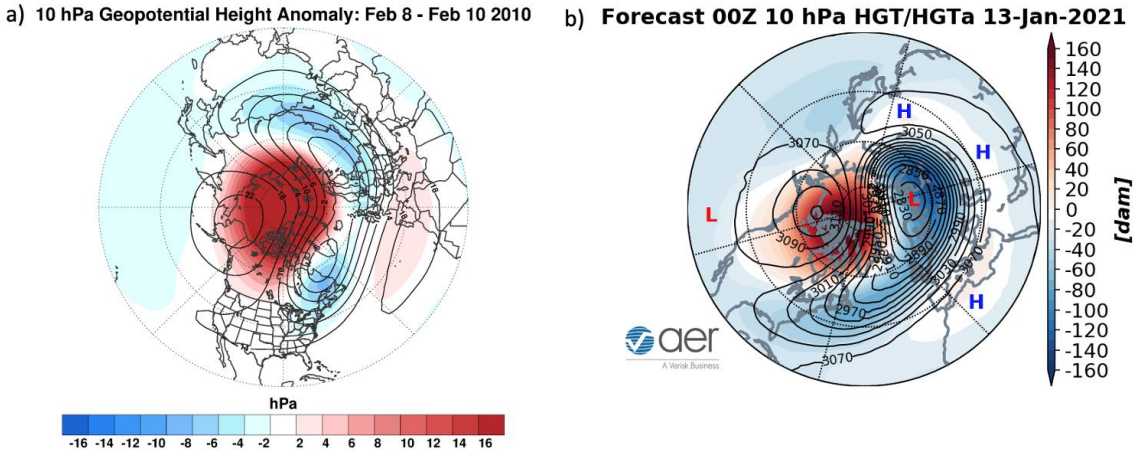

Figure ii. **a)** Observed 10 mb geopotential heights (dam; contours) and anomalies (shading) across the Northern Hemisphere for 8 – 10 February 2010. **b)** Forecasted 10 mb geopotential heights (dam; contours) and anomalies (shading) across the Northern Hemisphere for 13 January 2021. The forecast is from the 00Z 28 December 2020 GFS model ensemble.

Given the high likelihood (but I will not say certain until the event occurs) of a PV disruption, I thought to use today's blog to try to understand what the impact of the event on the NH surface temperatures will be in the weeks following the PV disruption. There have been a number of recent studies looking at the surface temperature following large PV disruptions. In **Figure iii**, I show the NH surface temperature anomalies for the period following an MMW from four different analysis in this order – a) from Domeisen et al. (2019) for days 15 through 28, b) from the sudden stratospheric warming compendium for days 0 through 30, c) Domeisen and Butler (2020) for days 1 through 30 and d) my new paper (in press) first authored by my colleague Jason Furtado for days 15 through 45 all following the first day an MMW is observed. All of the composites are based on the Era-Interim reanalysis except b) which is based on the JRA reanalysis.

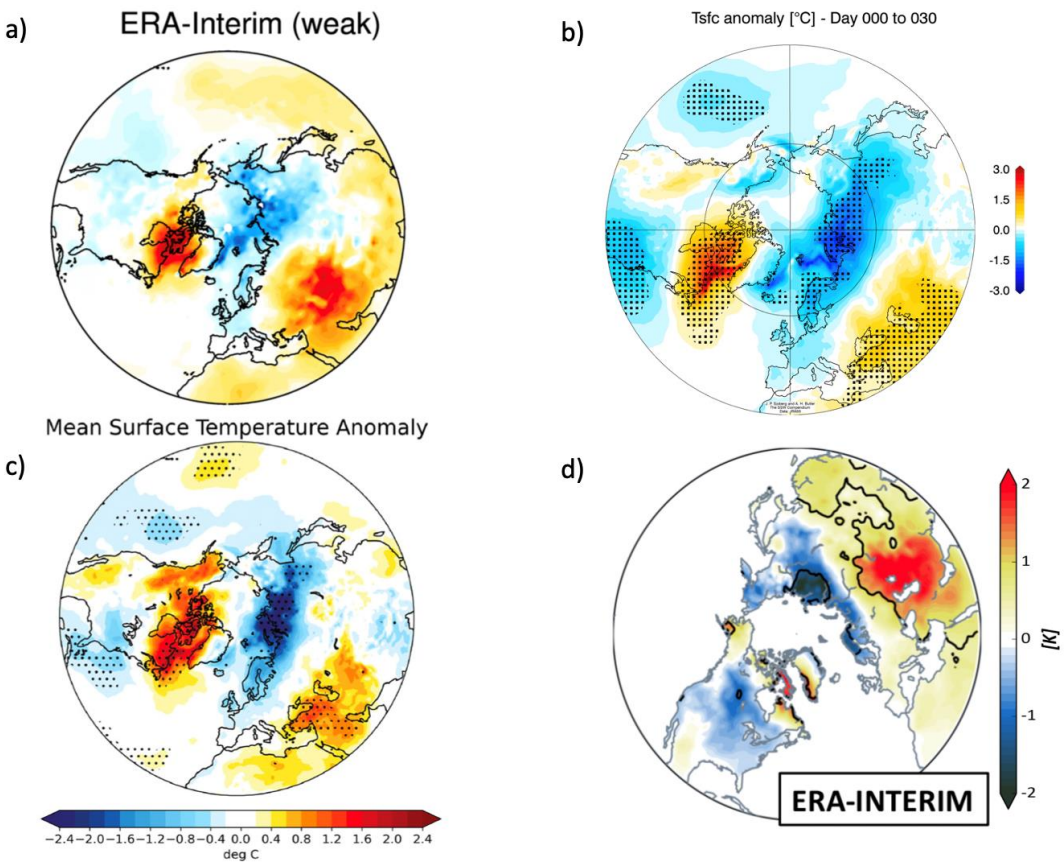

Figure iii. Composite of surface temperature analyses following a major mid winter warming from four different analyses. The different analyses are explained in the text.

All the analyses are fairly consistent with each other and can broadly be described as the surface temperature anomaly pattern in the weeks following an MMW is consistent with a canonical negative AO/NAO surface temperature anomaly pattern with relatively cold temperatures across Northern Asia, Northern Europe and the Eastern US with relatively warm temperatures across Southern Asia, the Middle East, North Africa and Northeastern Canada. This pattern is sometimes called the quadrupole pattern. The three most robust regions of temperature anomalies are the cold temperatures in Siberia and the warm temperatures in Northeastern Canada and the Middle East. Across the US the exact region of cold temperatures does vary across the different analyses and can be in the Eastern US, Western US and even sometimes include Western and Central Canada.

I show in **Figure iv**, a plot that I have shown before in the blog. It is the weekly surface temperature anomaly plot following a significant PV disruption using cluster analysis in Kretschmer et al. (2018a). During the 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

and 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.

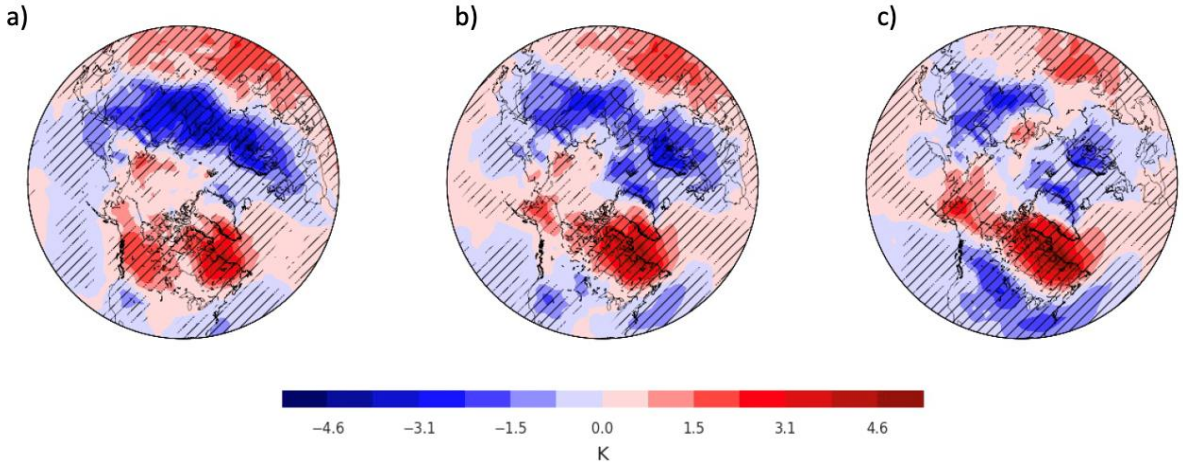

Figure iv.Composite mean of detrended lagged near surface temperature for significant PV disruptions **a)** a lag of 0-7 days; **b)** a lag of 7-14 days; **c)** a lag of 14-21 days. In all panels significant values (P<0.05) are indicated with dots.

In addition, there are two upcoming synoptic events that I believe are consistent with an impending PV disruption. A warm, wet and windy storm here in the Eastern US. This event reminds me of December 2003 and January 2006, both ahead of an MMW. The second is an anomalous cold surge in East Asia. One of the most famous was in January 2008 and more recently there was one in January 2018.

My only hesitation to being even more bullish about an imminent MMW is that the tropics broadly are more hostile to an MMW including La Niña and the westerly quasi-biennial oscillation (QBO). However, as I discussed in the October 19, 2020 blog, there have been several MMWs in recent years with both a La Niña and a westerly QBO including just three years ago in 2018.

In the follow up paper of Kretschmer et al. (2018b) we had one cluster of the PV, cluster three that also resembles the forecast for the PV in early January which I include in **Figure v** along with the accompanying surface temperature anomalies. The temperature pattern does resemble the pattern composite following an MMW with relatively cold temperatures across Northern Asia and Northern Europe with relatively very warm temperatures across Canada. I think with the center of the warm high pressure in the polar stratosphere predicted to be near Northern Canada, a cluster three solution (referred to as a Canadian warming) should be at least considered.

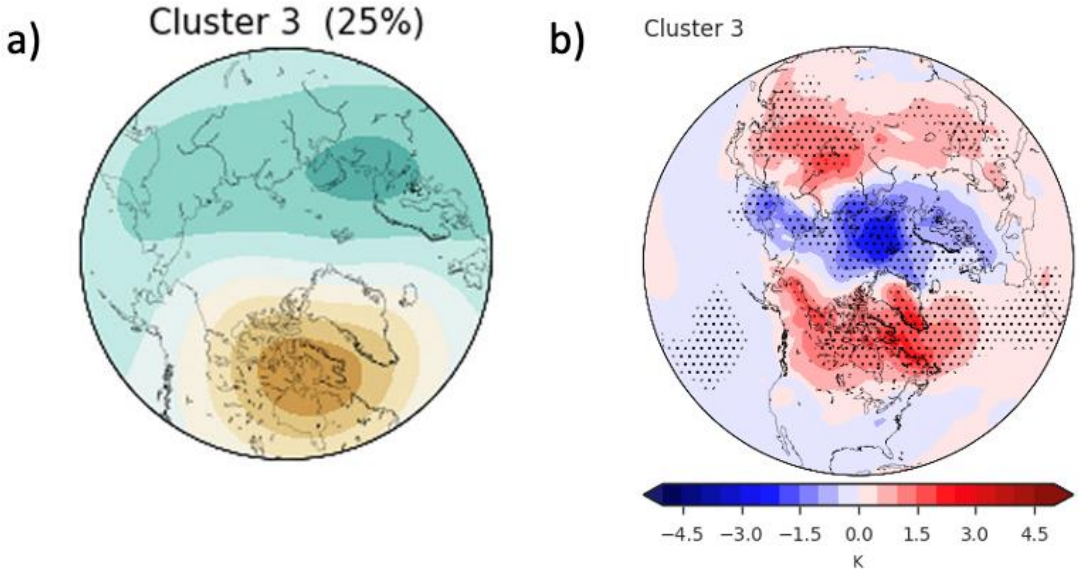

Figure v. **a)** Polar vortex cluster three based on geopotential height anomalies from Kretschmer et al. 2018b. **b)** Composite mean of detrended lagged near surface temperature for cluster three at a lag of 0-7 days.

One question is - will the upcoming PV disruption be a displacement (one PV center that is displaced from the North Pole) or a split (two distinct daughter vortices). The GFS can't seem to make up its mind while the ECMWF seems to be more solidly in the split camp. Every significant PV disruption since 2009 has been a split and that for me "the trend is your friend" is a compelling reason to expect the same in January. This despite that the strong wave one in the troposphere is thought to favor PV displacements that could still rule the day. In **Figure vi,** I show the ECMWF forecast of the PV in early January. The ECMWF has the North American daughter vortex further west than the GFS (when it predicts a split). I think the ECMWF solution favors any cold temperatures shifted west across North America relative to the GFS forecast.

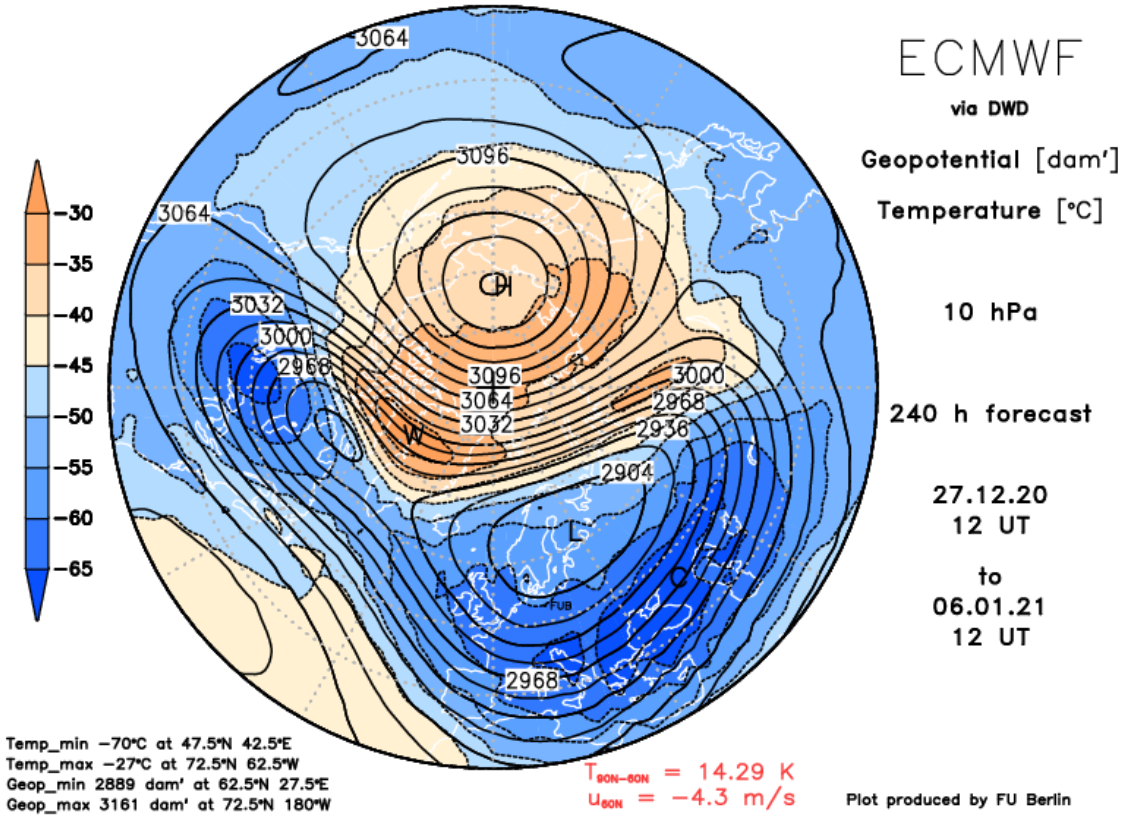

Figure vi. Forecasted 10 mb geopotential heights (dam; contours) and temperatures (°C; shading) across the Northern Hemisphere for 6 January 2021. The forecast is from the 00Z 27 December 2020 ECMWF operational model.

I conclude with my, for now speculative, expectations for NH temperatures, with the significant PV disruption I expect the best chance of below normal temperatures to occur across Northern Asia and Northern Europe. At least initially the major daughter vortex is predicted to be in Eurasia (in contrast to the most recent PV splits in 2018 and 2019 where the major daughter vortex was in North America). I would expect that the tropospheric PV, predicted to be near the Dateline leading into the MMW, will get pulled west closer to the stratospheric PV near Scandinavia. That would increase the risk of severe winter weather for Europe as easterly flow develops across Europe in the troposphere but not guarantee it. With the major tropospheric PV no longer in the North Pacific that would increase the possibility of ridging/high pressure across North America. If it resembles cluster three in **Figure v**, then Canada could be relatively quite warm, however it could also be a favorable pattern for snowstorms across the US with so much blocking to the north, not unlike 2010. However, if the North America ridging becomes focused across western North America/Gulf of Alaska/Aleutians that could leave open for much colder weather across North America.

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.

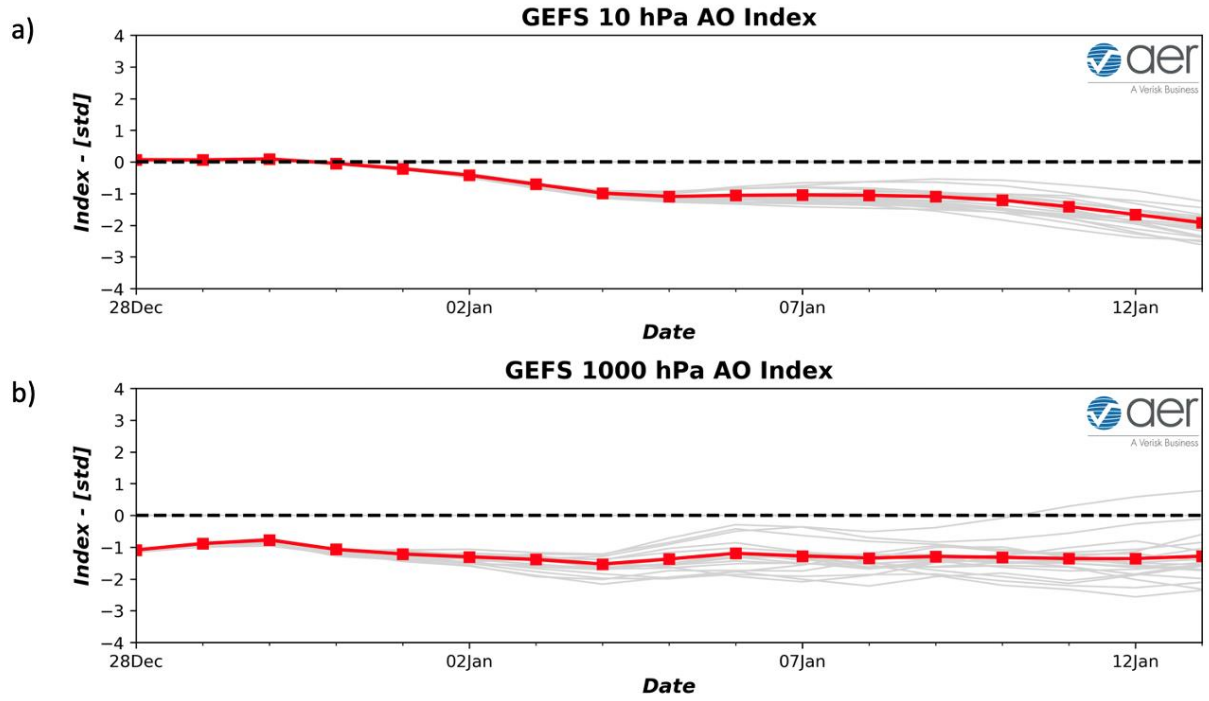

Figure 1. (**a**) The predicted daily-mean AO at 10 hPa from the 00Z 28 December 2020 GFS ensemble. (**b**)The predicted daily-mean near-surface AO from the 00Z 28 December 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies centered south of Greenland are predicted to force downstream troughing/negative geopotential height anomalies across Europe (**Figure 2**). This pattern favors normal to below normal temperatures across Western Europe including the UK while a mild southwesterly flow will favor widespread normal to above normal temperatures across Eastern Europe (**Figure 3**). This week, ridging/positive geopotential height anomalies centered near the Urals are predicted to force downstream troughing/negative geopotential height anomalies across much of Siberia, Eastern and Central Asia (**Figure 2**). This pattern favors normal to below normal temperatures for much of Siberia, Central and Eastern Asia with normal to above normal temperatures for far Western Asia **(Figure 3**).

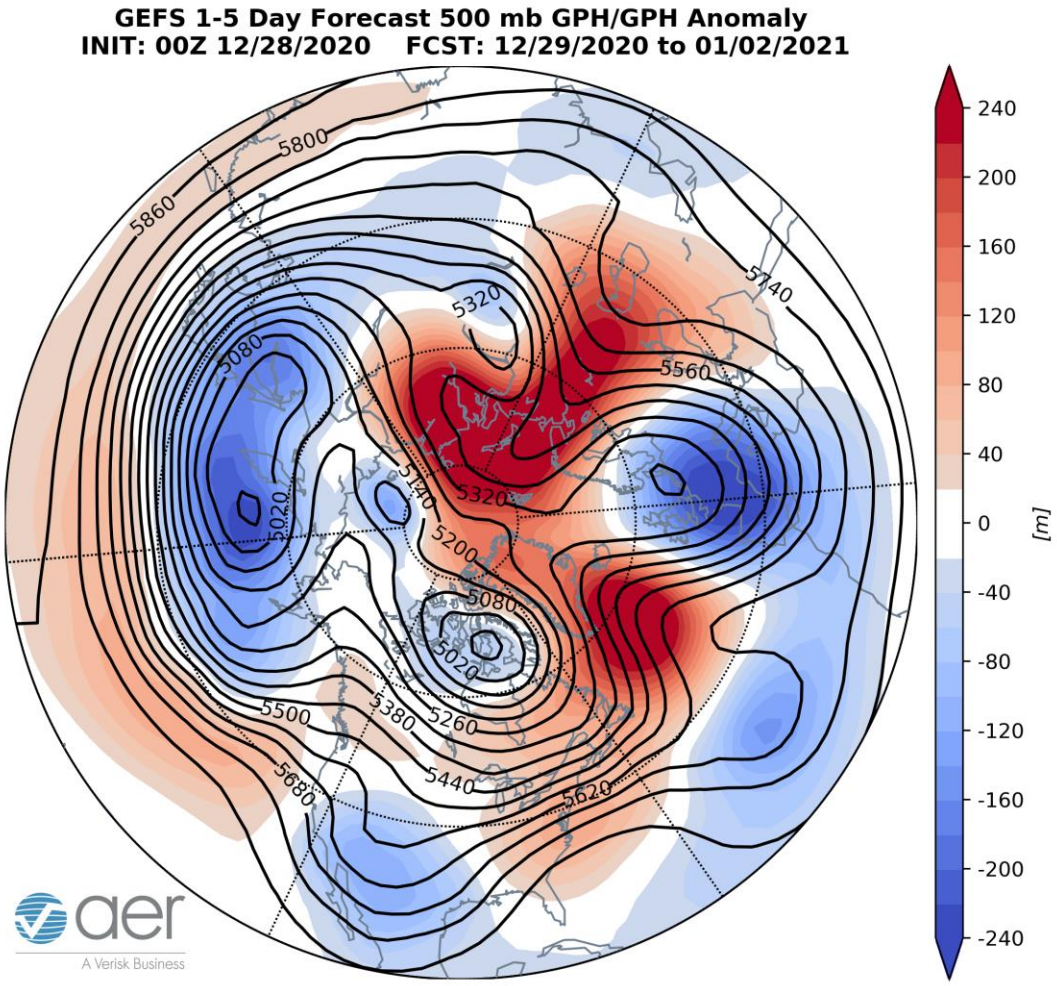

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 29 December 2020 – 2 January 2021. The forecasts are from the 00z 28 December 2020 GFS ensemble.

This week, ridging/positive geopotential height anomalies are predicted for Eastern North America and Western Canada with troughing/negative geopotential height anomalies in Northern Canada and the Western US **(Figure 2**). This pattern is predicted to bring widespread normal to above normal temperatures across much of Alaska, Southern Canada, the Canadian Maritimes and the Eastern US with normal to below normal temperatures for Northern Canada and in the Western US **(Figure 3).**

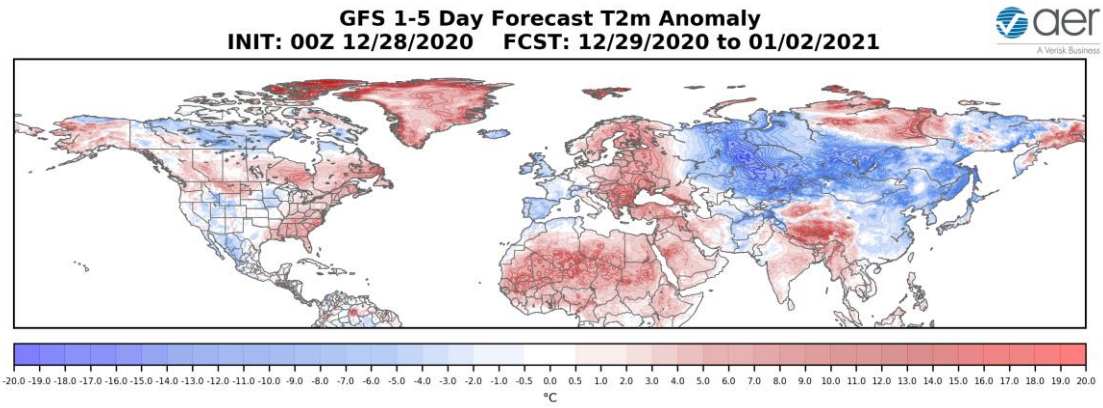

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 29 December 2020 – 2 January 2021. The forecast is from the 00Z 28 December 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across parts of Scandinavia, the Alps, the Pyrenees and Northern and Central Asia while warmer temperatures will cause regional snow melt in the Baltic States (**Figure 4**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, much of Canada, the Northwestern US, the Plain States into the Great Lakes and New England while warmer temperatures will cause snow melt in parts of the Western US and the Appalachians (**Figure 4**).

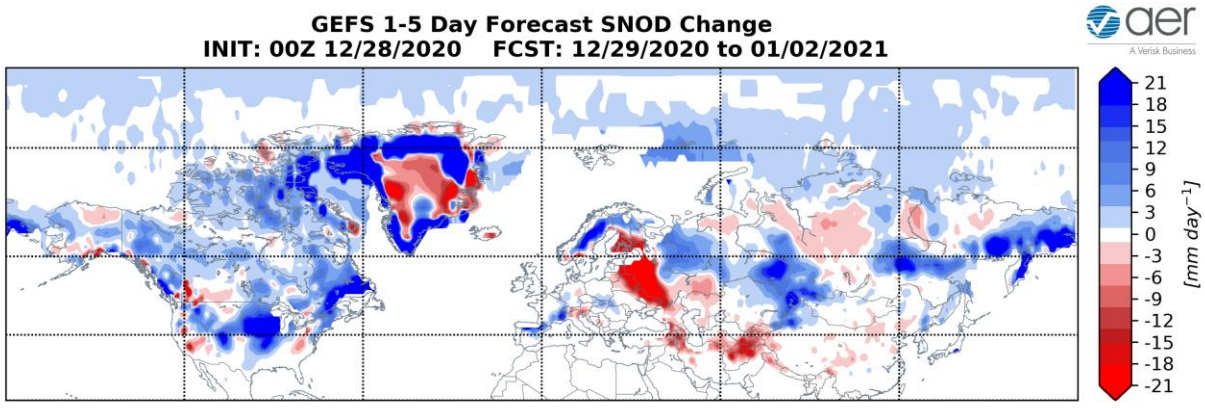

Figure 4. Forecasted snow depth changes (mm/day; shading) from 29 December 2020 – 2 January 2021. The forecast is from the 00Z 28 December 2020 GFS ensemble.

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.

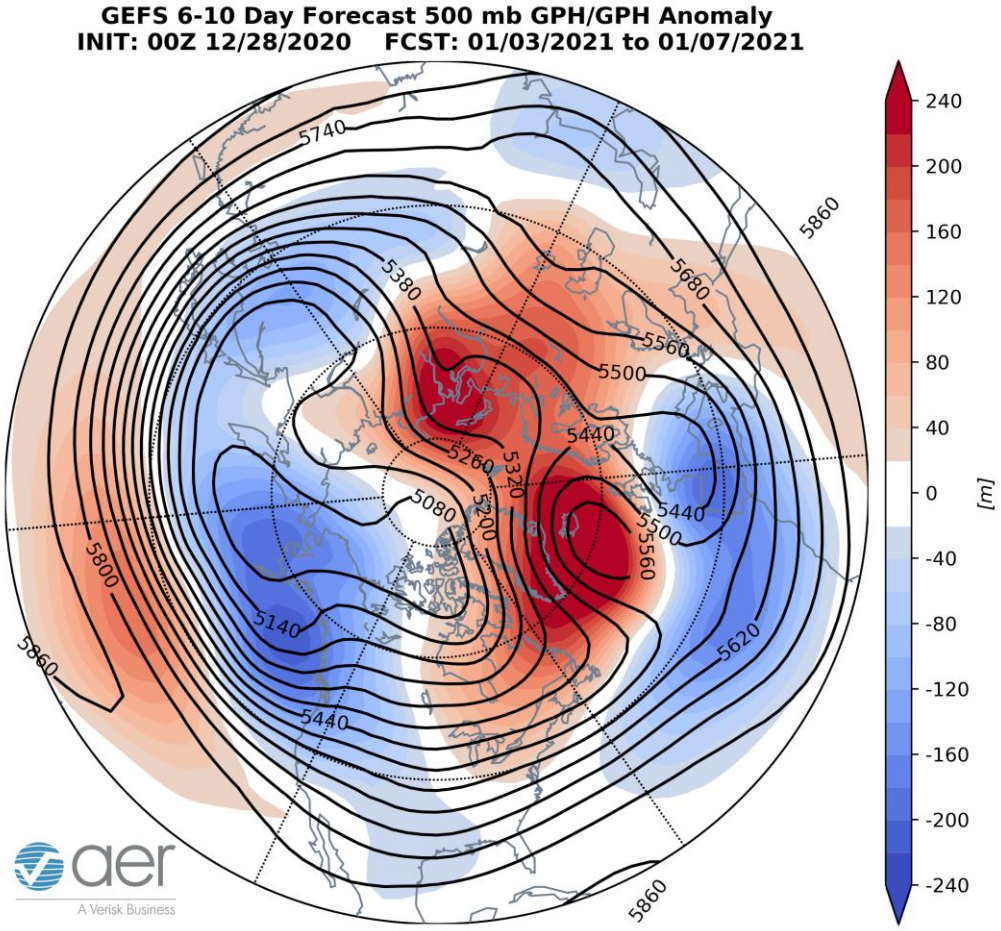

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 3 – 7 January 2021. The forecasts are from the 00z 28 December 2020 GFS ensemble.

Ridging/positive geopotential height anomalies centered near Iceland are predicted to anchor downstream troughing/negative geopotential height anomalies across Western Europe this period (**Figures 5). T**his pattern favors normal to below normal temperatures across Western Europe including the UK while southwesterly flow of mild air will persist normal to above normal temperatures across Eastern Europe (**Figure 6**). Persistent ridging/positive geopotential height anomalies centered near the Urals and Barents-Kara Seas will continue to force downstream troughing/negative geopotential height anomalies across Siberia and Central and East Asia this period (**Figure 5**). This is predicted to favor widespread normal to below normal temperatures

across much of Siberia, Central and East Asia with normal to above normal temperatures in Western and Southern Asia **(Figure 6**).

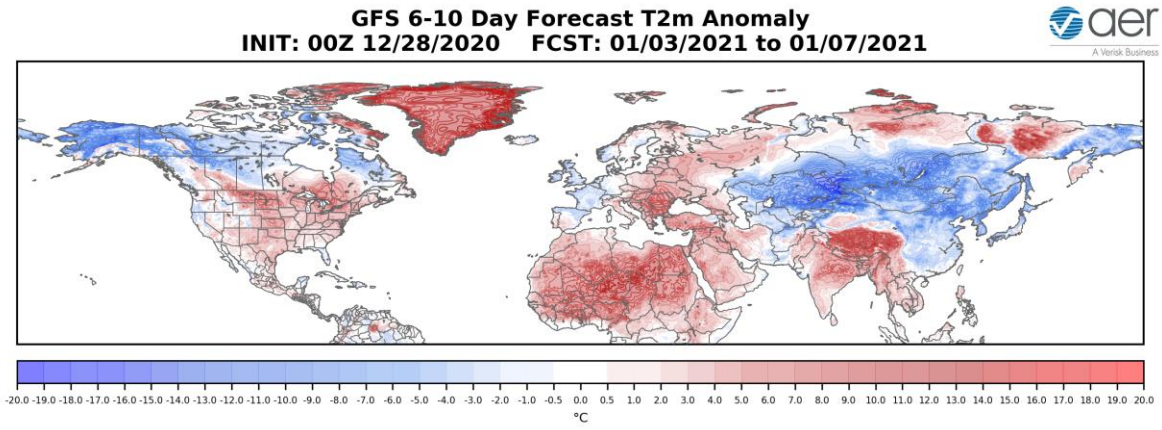

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 3 – 7 January. The forecasts are from the 00Z 28 December 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to persist across Eastern Canada and the Eastern US with deepening troughing/negative geopotential height anomalies across western North America **(Figure 5).** This pattern is predicted to bring normal to above normal temperatures across Southern Canada and the Central and Eastern US with normal to below normal temperatures across Alaska, Northern Canada and the Western US **(Figure 6).**

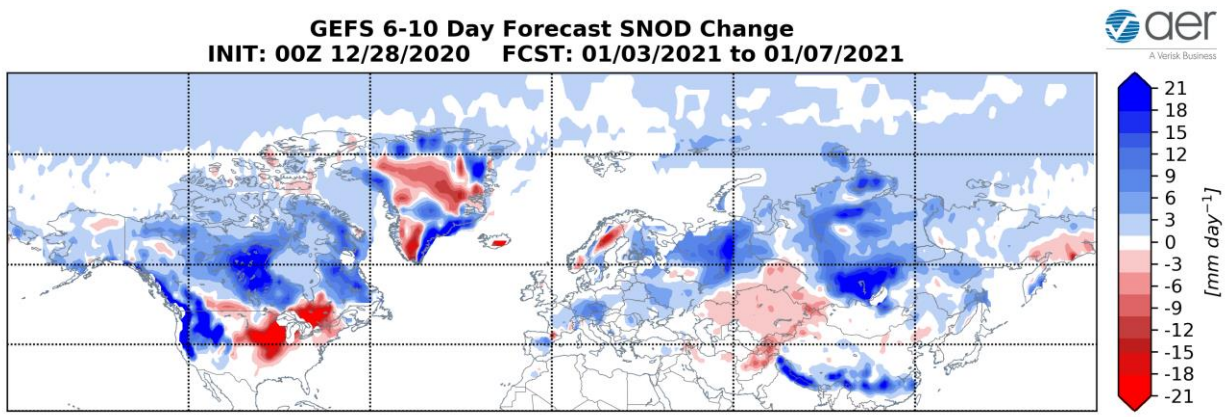

Figure 7. Forecasted snow depth changes (mm/day; shading) from 3 – 7 January. The forecasts are from the 00Z 28 December 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to potentially support new snowfall across large areas of Europe, Northwestern Asia, Siberia and possibly Southern China while warmer temperatures will cause regionalized snow melt including Scandinavia

and Central Asia (**Figure 7**). Troughing and/or colder temperatures are predicted to support new snowfall across much of Canada and the Western US while warmer temperatures will cause possible snow melt in the US Plains and into the Great Lakes (**Figure 7**).

11-15 day

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

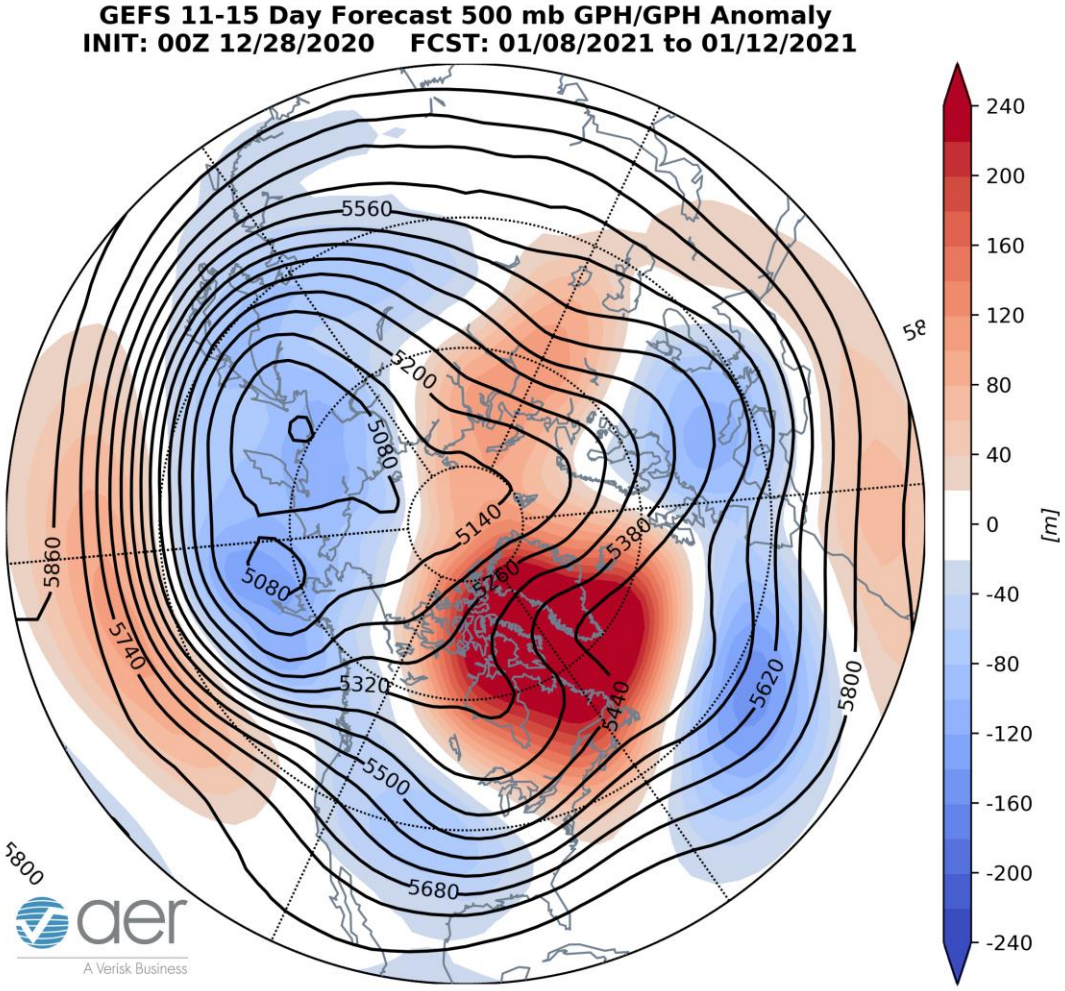

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 8 – 12 January 2021. The forecasts are from the 00z 28 December 2020 GFS ensemble.

Persistent ridging/positive geopotential height anomalies centered near Greenland coupled with ridging centered near the Urals are predicted to lock in troughing/negative geopotential height anomalies over Western and Central Europe this period (**Figures 8**). The forecast is for a more classical negative NAO pattern with normal to below normal temperatures across Northern Europe including the UK and normal to above normal temperatures for Southern Europe this period (**Figures 9**). Predicted persistent ridging/positive geopotential height anomalies focused near the Urals will continue to support downstream troughing/negative geopotential height anomalies across Siberia that extends south to Eastern and Central Asia this period (**Figure 8**). This pattern favors normal to above normal temperatures across Northern Siberia and Southwestern Asia with normal to below normal temperatures across much of Central and Eastern Asia (**Figure 9**).

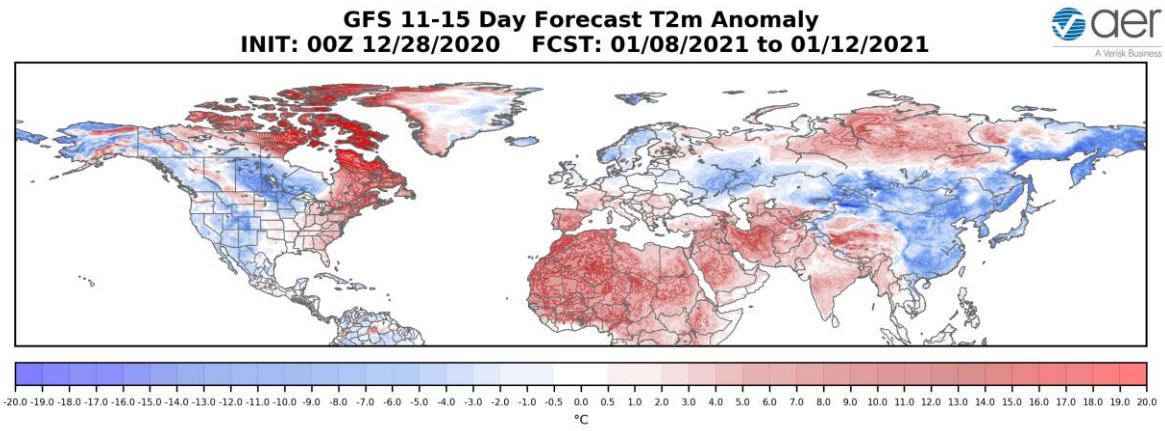

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 8 – 12 January 2021. The forecasts are from the 00z 28 December 2020 GFS ensemble.

The general pattern of ridging/positive geopotential height anomalies across eastern North America and troughing/negative geopotential height anomalies across western North America is predicted to persist this period (**Figure 8**). This pattern favors normal to above normal temperatures for Eastern Canada, and the Eastern US with normal to below normal temperatures for Alaska, Western and Central Canada and the Western US and into the US Upper Midwest (**Figure 9**).

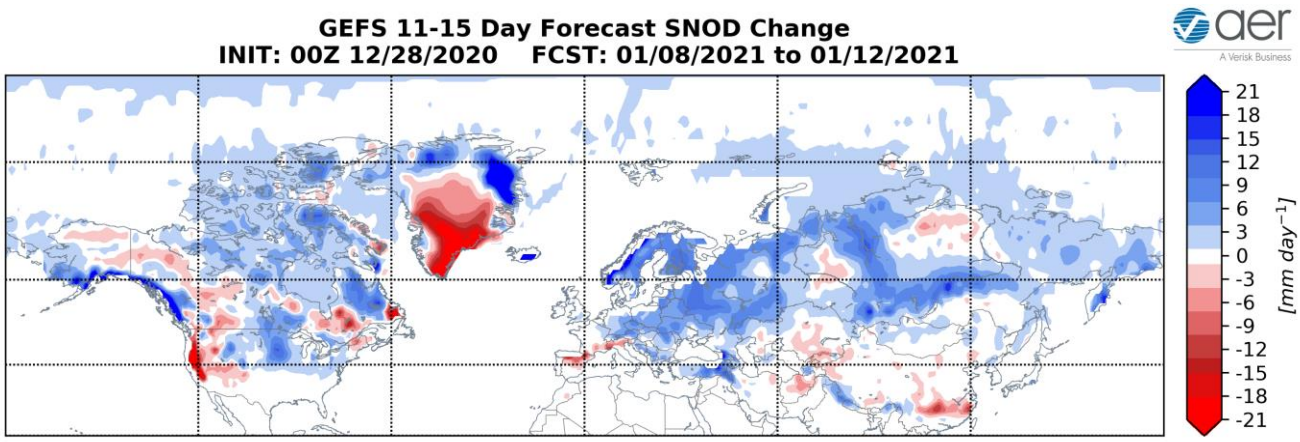

Figure 10. Forecasted snow depth changes (mm/day; shading) from 8 – 12 January 2021. The forecasts are from the 00z 28 December 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across much of Central and Eastern Europe and Northern Asia while warmer temperatures will cause snowmelt in Southern China and Southern Europe (**Figure 10**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, much of Canada and possibly the Northcentral US and the Great Lakes (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows warm/positive normal PCHs in the low to mid stratosphere and throughout the troposphere with cold/negative PCHs in the upper stratosphere for this week (**Figure 11**). However, by the end of the week the PCHs are predicted to turn warm/positive throughout the troposphere and stratosphere (**Figure 11**).

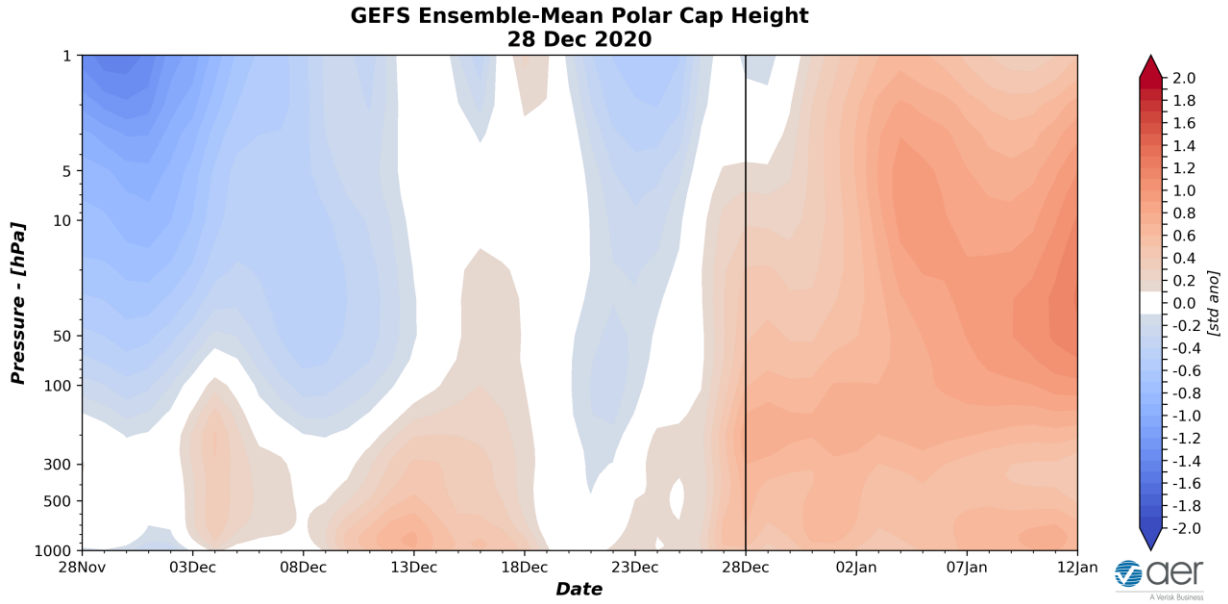

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 28 December 2020 GFS ensemble. Please note that the PCH plot now extends to 1 hPa.

Normal to warm/positive PCHs in the lower troposphere are consistent with the predicted negative surface AO the next two weeks (**Figure 1**). Mixed PCHs in the stratosphere are consistent with the neutral stratospheric AO this week while the warming/increasingly positive PCHs next week are consistent with the predicted negative stratospheric AO (**Figure 1**). I still believe there could be volatility in the PCH forecast that have important long-term implications for troposphere-stratosphere coupling.

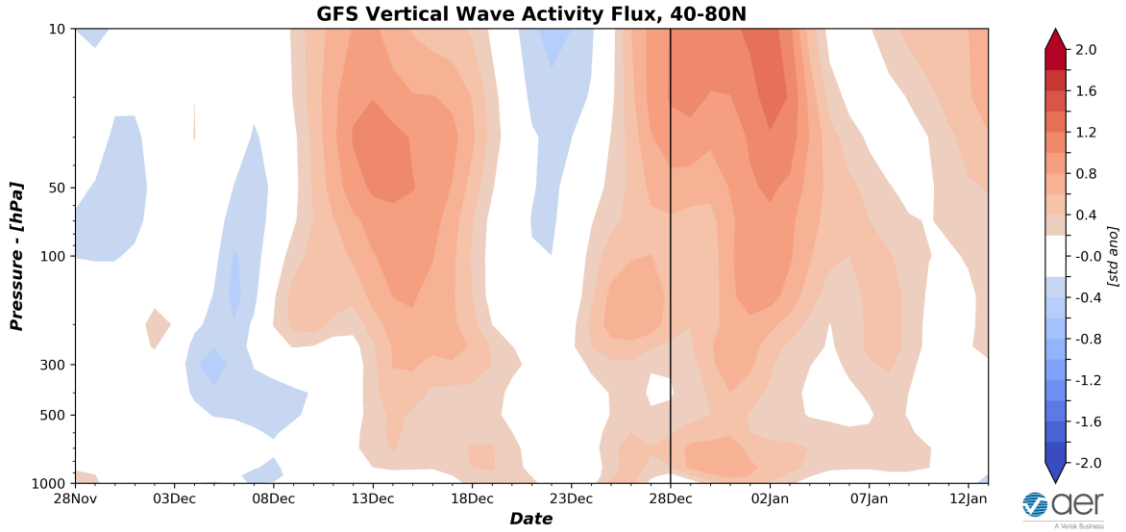

Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 28 December 2020 GFS ensemble.

The plot of Wave Activity Flux (WAFz and is proportional to poleward heat transport) forecasts is showing currently a strong WAFz pulse that will continue for most of the next two weeks (**Figure 12**). The first pulse of WAFz in mid-December did weaken the stratospheric PV just enough to precondition the PV for a more significant PV weakening to end the month and into early January. I do believe that the ongoing PV weakening will eventually meet the threshold of a major mid-winter warming (MMW where the zonal winds reverse from westerly to easterly at 60°N and 10 hPa) as suggested by the forecast of increasingly negative stratospheric AO over the next two weeks (**Figure 1**).

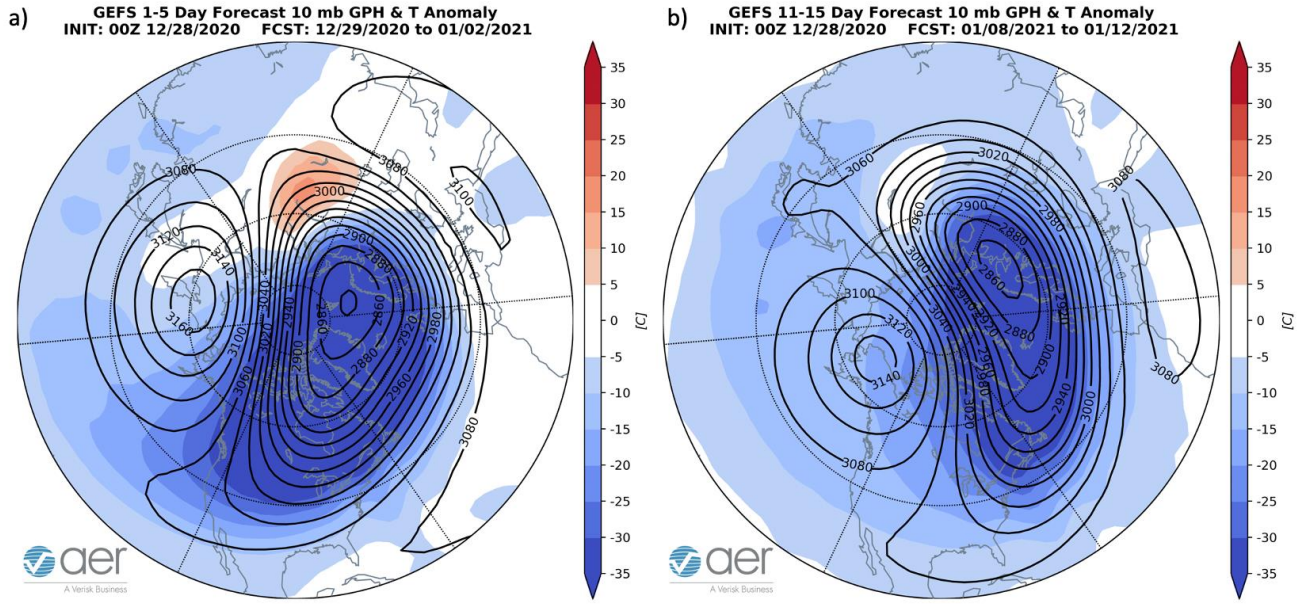

Figure 13. (**a**) Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 29 December 2020 – 2 January 2021. (**b**) Same as (a) except forecasted averaged from 8 – 12 January 2021. The forecasts are from the 00Z 28 December 2020 GFS model ensemble.

The PV is predicted to remain strong and centered near Svalbard this week (**Figure 13**). The PV is east of the North Pole and stretched due to high pressure centered near the Dateline. The high pressure near the Dateline is predicted to strengthen and drift towards Alaska while the PV is predicted to weaken and drift towards Scandinavia (**Figure 13**). The PV weakening is an absorptive event, which is most closely associated with cold temperatures in Northern Eurasia.

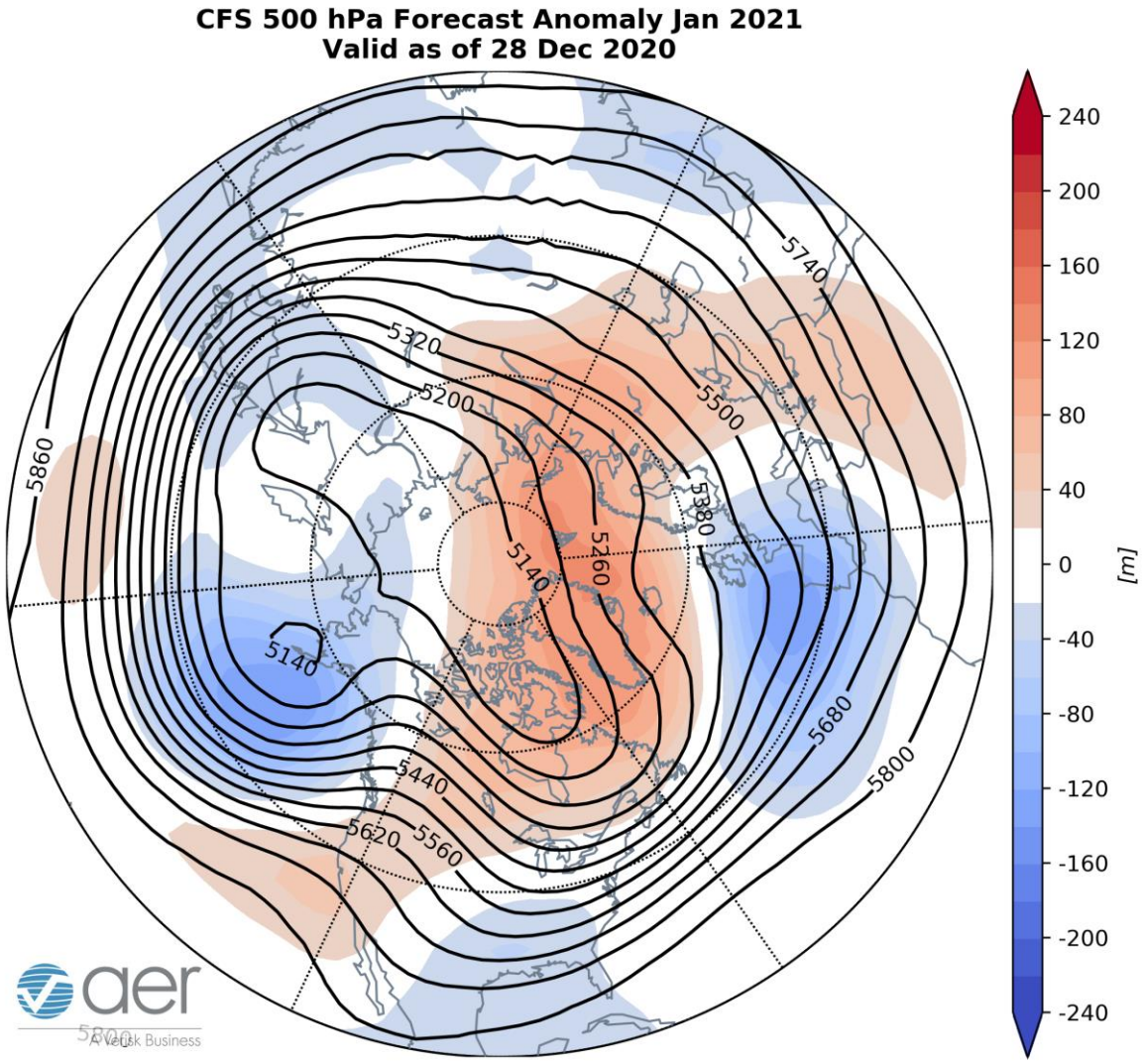

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for January 2021. The forecasts are from the 00Z 28 December 2020 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) forecast for January from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging on the North Atlantic side of the Arctic, the Urals/Barents-Kara Seas and western North America with troughing in Western Europe, much of Asia but especially Siberia, the Aleutians, Eastern Canada and the Eastern US (**Figure 14).** This pattern favors relatively warm temperatures for Eastern Europe, Western Asia and western North America with seasonable to relatively cold temperatures for Western Europe, Central and Eastern Asia and the Eastern US (**Figure 15**)**.** I don't believe the CFS can accurately predict the response to a significant PV disruption and the CFS forecast for January is of low confidence.

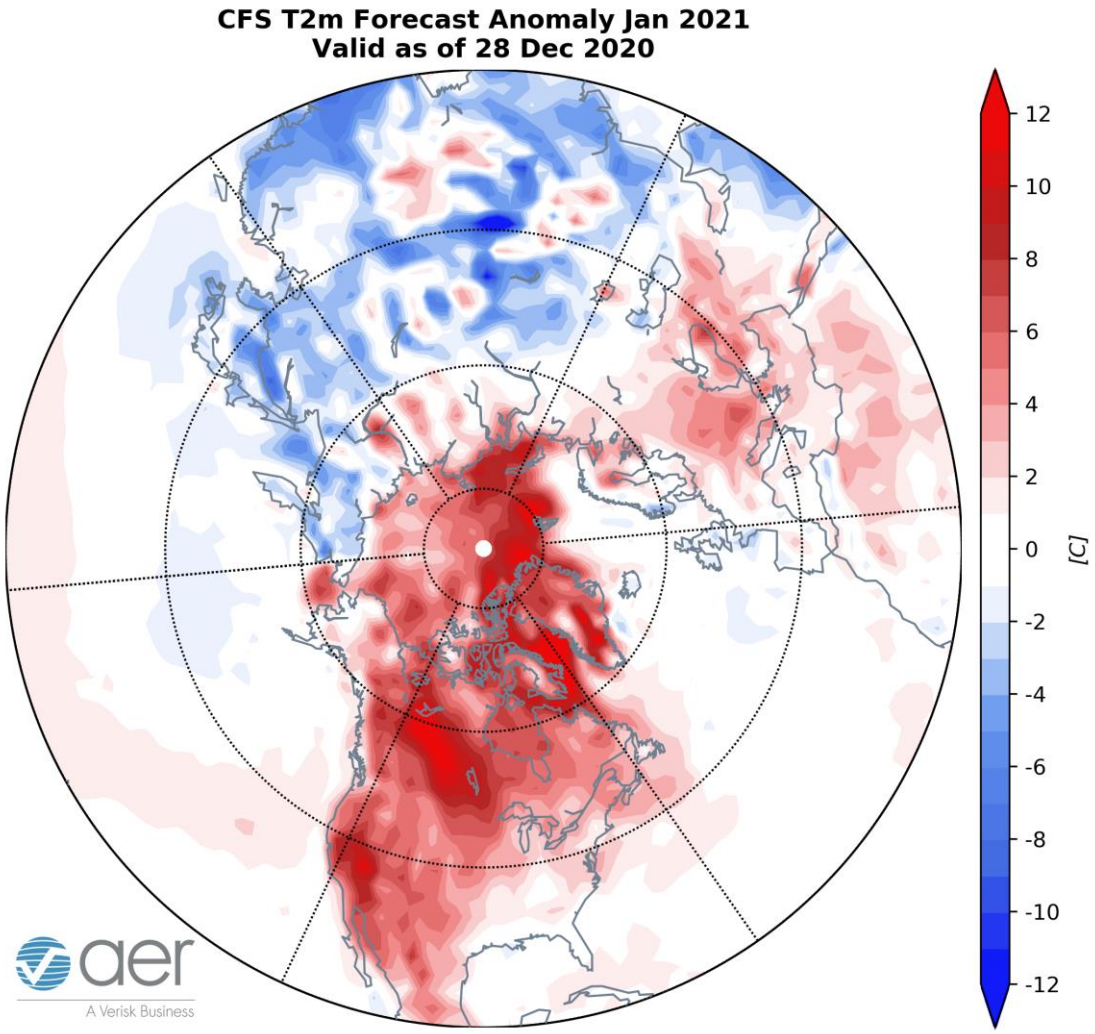

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for January 2021. The forecasts are from the 00Z 28 December 2020 CFS.

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 and 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.

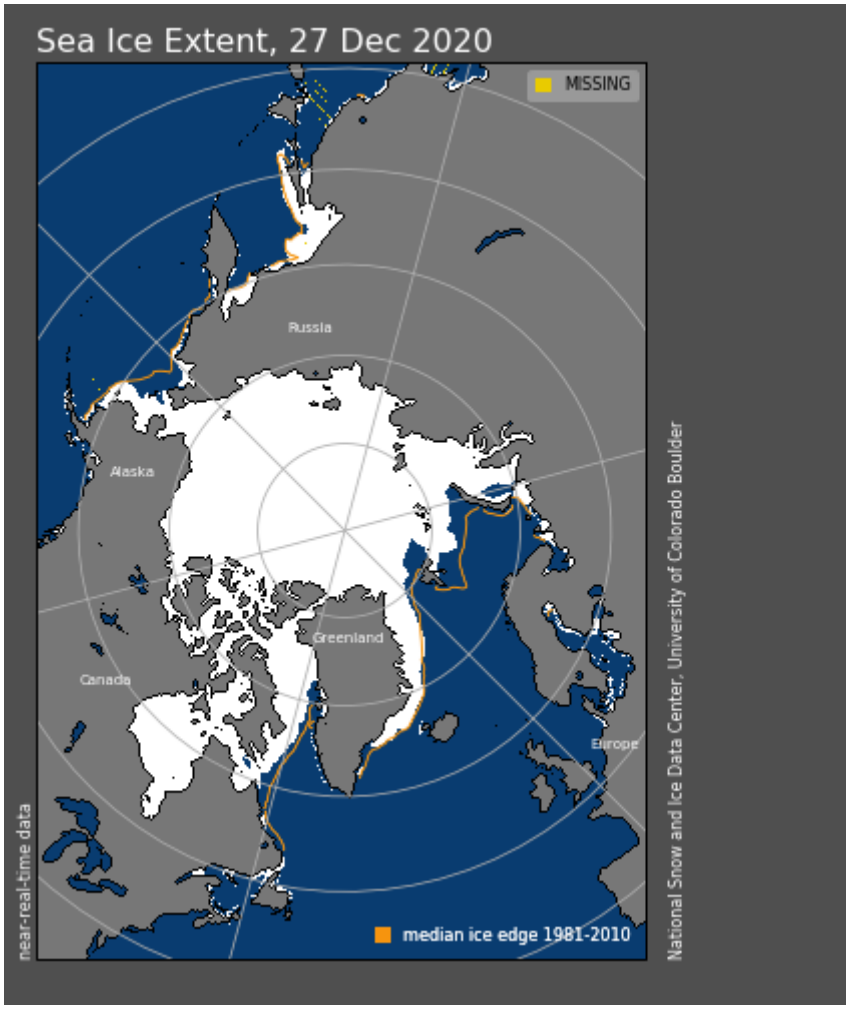

Figure 16. Observed Arctic sea ice extent on 27 December 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

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

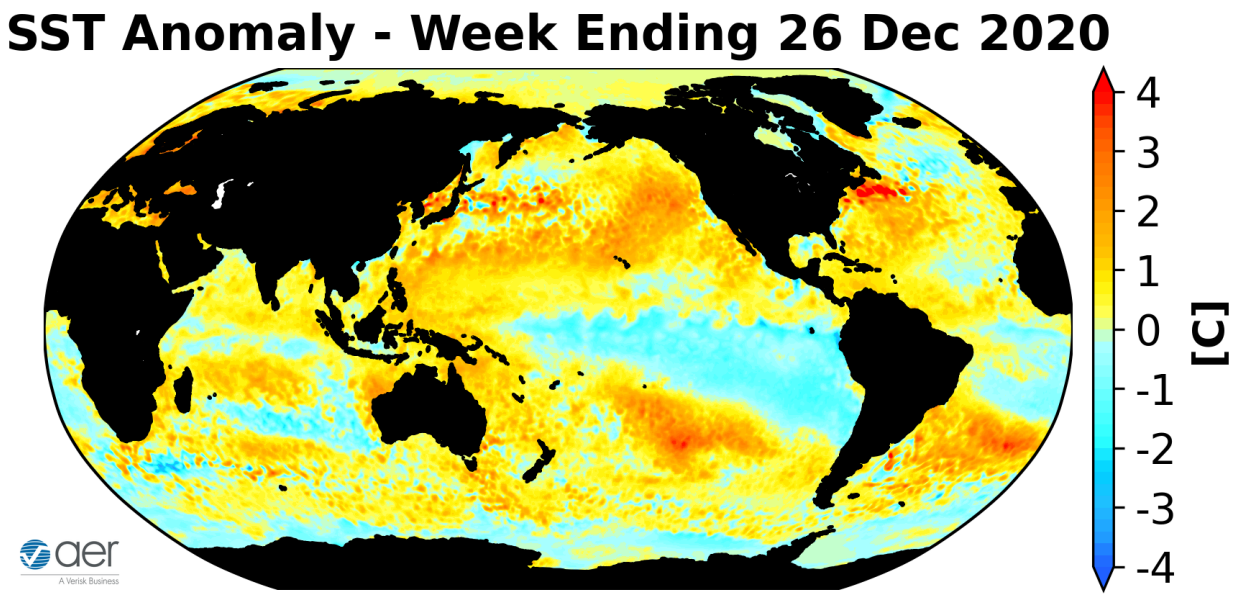

Figure 17. The latest weekly-mean global SST anomalies (ending 26 December 2020). Data from NOAA OI High-Resolution dataset.

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 18**). The forecasts are for the MJO to remain where no phase is favored for the next two weeks. Therefore it doesn't appear to me that the MJO is contributing to the pattern across North America but admittedly this is outside of my expertise.

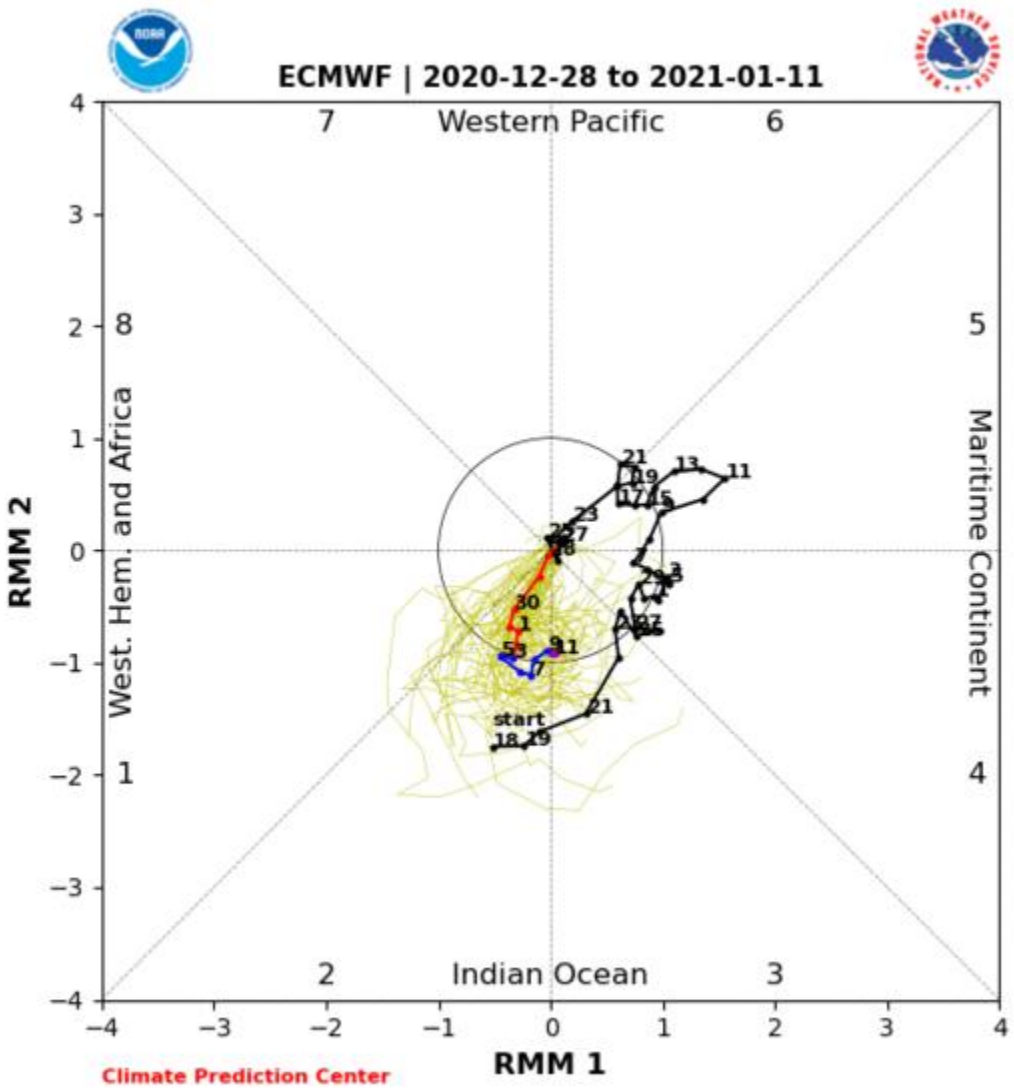

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 28 December 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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 over the past week across Eurasia but remains near decadal means. Snow cover advance will likely continue to increase especially across East Asia and likely into Europe the next two weeks. 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.

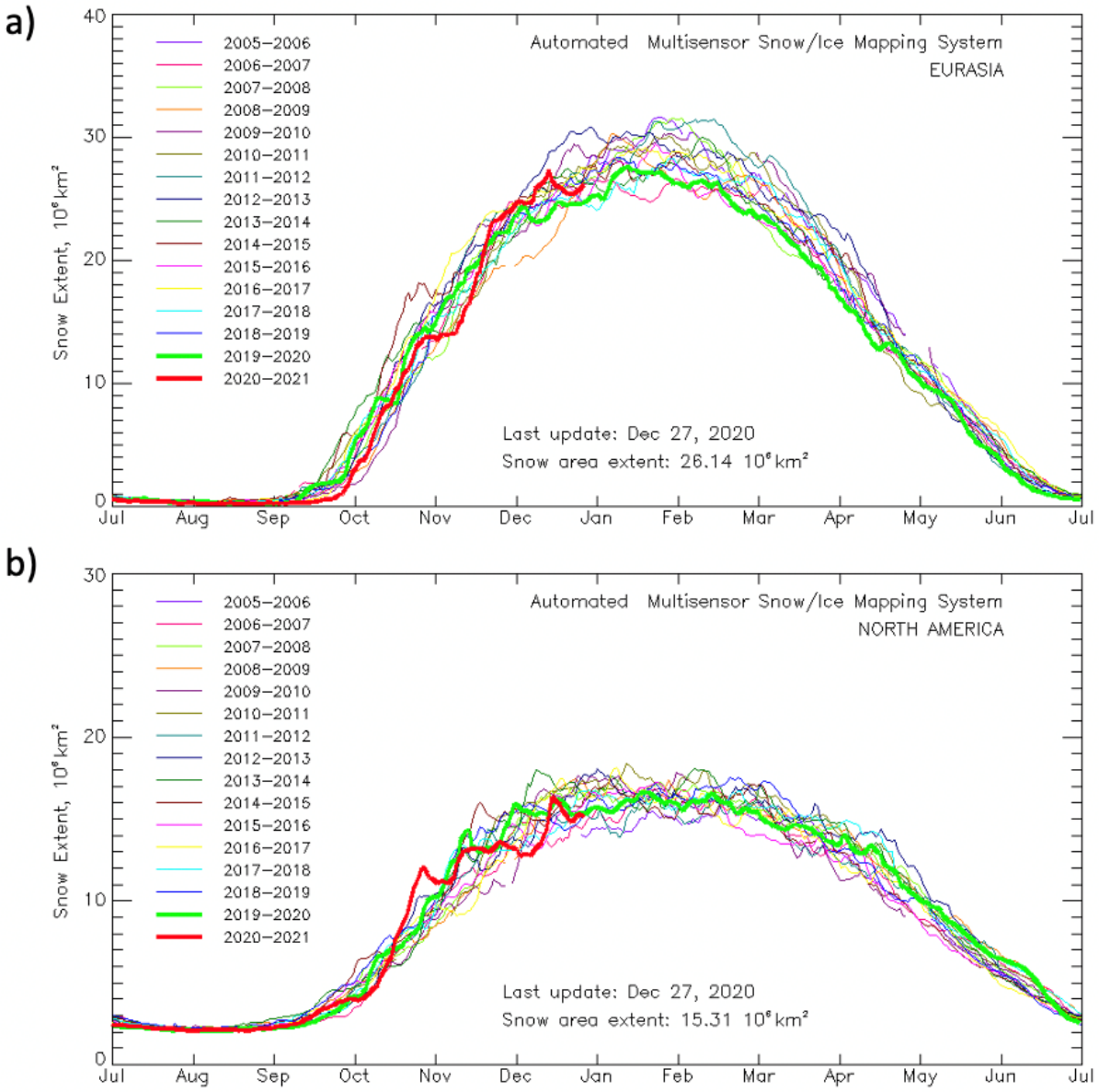

Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 27 December 2020. Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover remained steady over the past week and is near decadal means. 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.