Arctic Oscillation and Polar Vortex Analysis and Forecasts

December 14, 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.

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.
- The current negative AO is reflective of mostly positive pressure/geopotential height anomalies on 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.

- This week, ridging/positive geopotential height anomalies are predicted to dominate Europe coupled with normal to above normal temperatures for much of Europe including the United Kingdom (UK). However during the last week of December ridging/positive geopotential height anomalies building across Greenland are predicted to begin forcing downstream troughing/negative geopotential height anomalies coupled with normal to below normal temperatures across Northern and Western Europe while southwesterly flow will persist widespread normal to above normal temperatures across Southern and Eastern Europe.
- Over the next two weeks persistent ridging/positive geopotential height anomalies with normal to above normal temperatures centered near the Urals/Scandinavia/Barents-Kara Seas coupled with a second center over the Eastern Siberian/Laptev Seas are predicted to force troughing/negative geopotential height anomalies coupled with normal to below normal temperatures downstream cross Central Asia and much of Siberia into East Asia.
- The predicted general pattern across North America the next week is mostly zonal with ridging/positive geopotential height anomalies with normal to above normal temperatures across the United States (US) and Southern Canada with troughing/negative geopotential height anomalies coupled with normal to below normal temperatures across Alaska and Northern Canada. However, during the last week of December strengthening ridging/positive geopotential height anomalies coupled with normal to above normal temperatures across western North America will force deepening troughing/negative geopotential height anomalies coupled with normal to below normal temperatures across eastern North America.
- *In the Impacts section I continue to discuss the polar vortex (PV) and the implications for the weather in the coming weeks and months.*

Impacts

It wouldn't be officially winter if I didn't post in the blog the six-step model of how above normal October Siberian snow cover extent can force a PV disruption/sudden stratospheric warming followed by a period of high latitude blocking, a negative AO (though not necessarily) and a period of severe winter weather (potentially weeks in duration) in three preferred regions but rarely simultaneously – East Asia, Europe and the US (typically east of the Rockies) shown in **Figure I** and is taken from Cohen et al. 2007. Siberian snow cover was slightly above normal and I did not think initially it necessarily favored triggering the six step process but snow cover in November advanced more robustly across Eurasia and with the predicted Rex block (high pressure

to the north and low pressure to the south) across Siberia is favorable for heavy snowfall across Siberia. I would argue heavy snowfall across Siberia October, but maybe more importantly November and December, coupled with low sea ice in the Barents-Kara Seas this entire fall has been favorable for initiating and maintaining step two - the northwestward expansion of the Siberian high into the Urals/Scandinavian region that is often referred to as Ural/ Scandinavian blocking. We have observed strong Ural/ Scandinavian blocking in November and now persisting into December, though the high heights/pressures have begun wandering around the Arctic but is predicted to return to the Ural/ Scandinavian region later this month.

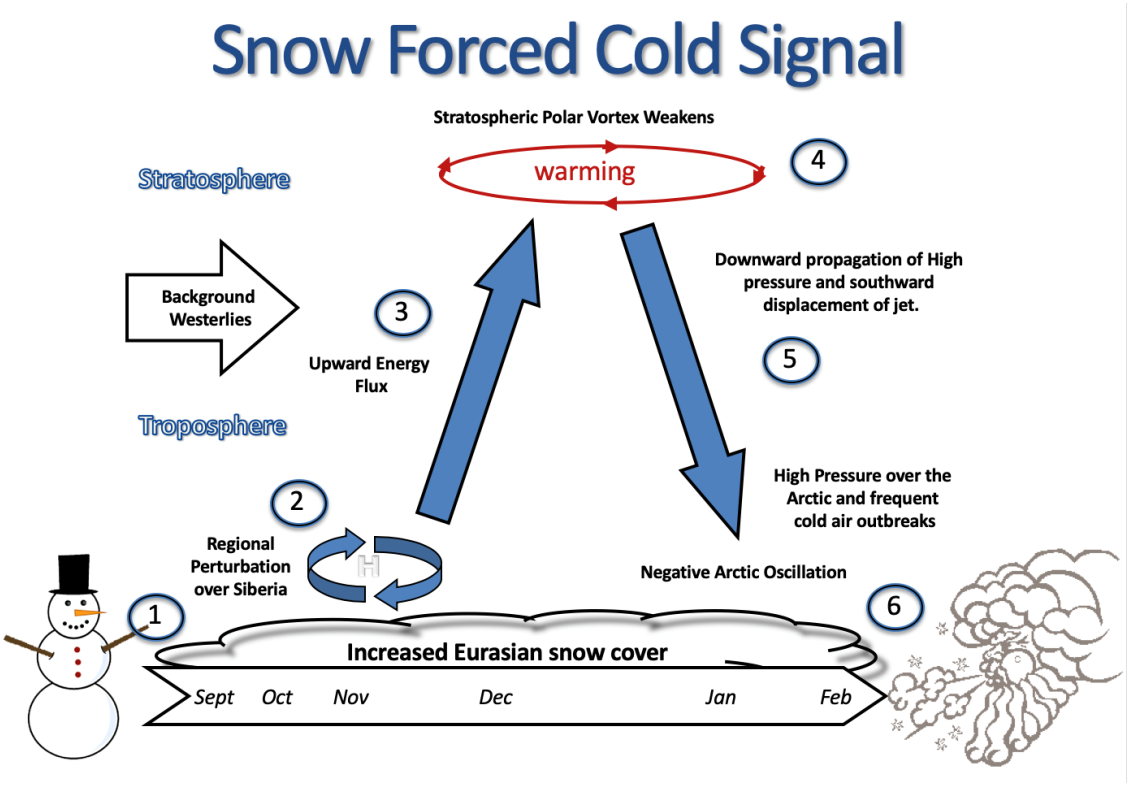

Figure i. Conceptual model for how fall snow cover modifies winter circulation in both the stratosphere and the troposphere; case for extensive snow cover illustrated: 1. Snow cover increases rapidly in the fall across Siberia, when snow cover is above normal diabatic cooling helps 2. to strengthen the Siberian high and leads to below normal temperatures. 3. Snow forced diabatic cooling in proximity to high topography of Asia increases upward flux of energy in the troposphere, which is absorbed in the stratosphere.4. Strong convergence of wave activity flux (WAF) indicates higher geopotential heights, a weakened polar vortex and warmer temperatures in the stratosphere. 5.Anomalous geopotential heights and winds appear to propagate down from the stratosphere into the troposphere all the way to the surface.6. Dynamic pathway culminates with strong negative phase of the Arctic Oscillation at the surface.

The third step is the initiation of positive anomalous Wave Activity Flux in the vertical direction (or z coordinate; WAFz). WAFz is the vertical transfer of energy from waves in the atmosphere and is directly proportional to the poleward transport or advection of heat. Only the largest or Rossby waves (wave numbers 1-2) across the Northern Hemisphere (NH) produce energy strong enough to escape the troposphere into the stratosphere. When the vertical energy is absorbed in the polar stratosphere it leads to warming of the polar stratosphere or a weakening of the stratospheric PV. If it is of sufficient amplitude it will result in the fourth step of the model or in a sudden stratospheric warming (SSW).

When an SSW occurs, the PV vacates its perch near the North Pole and besides being anomalously warm across much of the polar stratosphere, the vacuum created by the absence of the PV center is filled by relatively high pressure. Meanwhile across the mid-latitudes anomalous low pressure occurs and in the most extreme cases the PV center itself will reach into the mid-latitudes accompanied by relatively cold temperatures. In addition, the belt of strongest zonal (west to east) winds is shifted south or equatorward. The fifth step is the downward propagation of the circulation anomalies from the stratosphere to the troposphere and ultimately to the surface. The climax or culmination of the whole event is relatively high pressure in the Arctic coupled with anomalous warmth, relative low pressure in the mid-latitudes, especially in the ocean basins and an equatorward shifted Jet Stream. A southward shifted Jet Stream increases the probabilities of both cold air outbreaks and snowstorms across the mid-latitude continents including Europe, East Asia and the US east of the Rockies. It can be in one or two of those regions but rarely all three.

Sometimes I will refer to the six-step model or process in a more abbreviated three step troposphere-stratosphere-troposphere (T-S-T) coupling event with a troposphere precursor (same as step two in **Figure i** or Ural/ Scandinavian blocking) followed by a stratospheric PV disruption (same as step four or an SSW) and culminating with an extended period of high-latitude blocking/negative AO (same as step six).

I show in **Figure ii** the regression of October snow cover extent with both WAFz (top) and the AO or Northern Annular Mode (NAM; bottom) at all atmospheric levels from the surface to the mid-stratosphere. The NAM is analogous to the PCH plot I typically show in **Figure 11**. These figures were created with my former colleague Jason Furtado. I also include in Figure the representation of the six steps. I show Figure ii as an example of possible timing to help gauge timing for this winter. Step two first is observed in the latter half of November (positive values in the tropospheric NAM/PCH) and is often an indication of high-latitude blocking often in the Ural/ Scandinavian region.

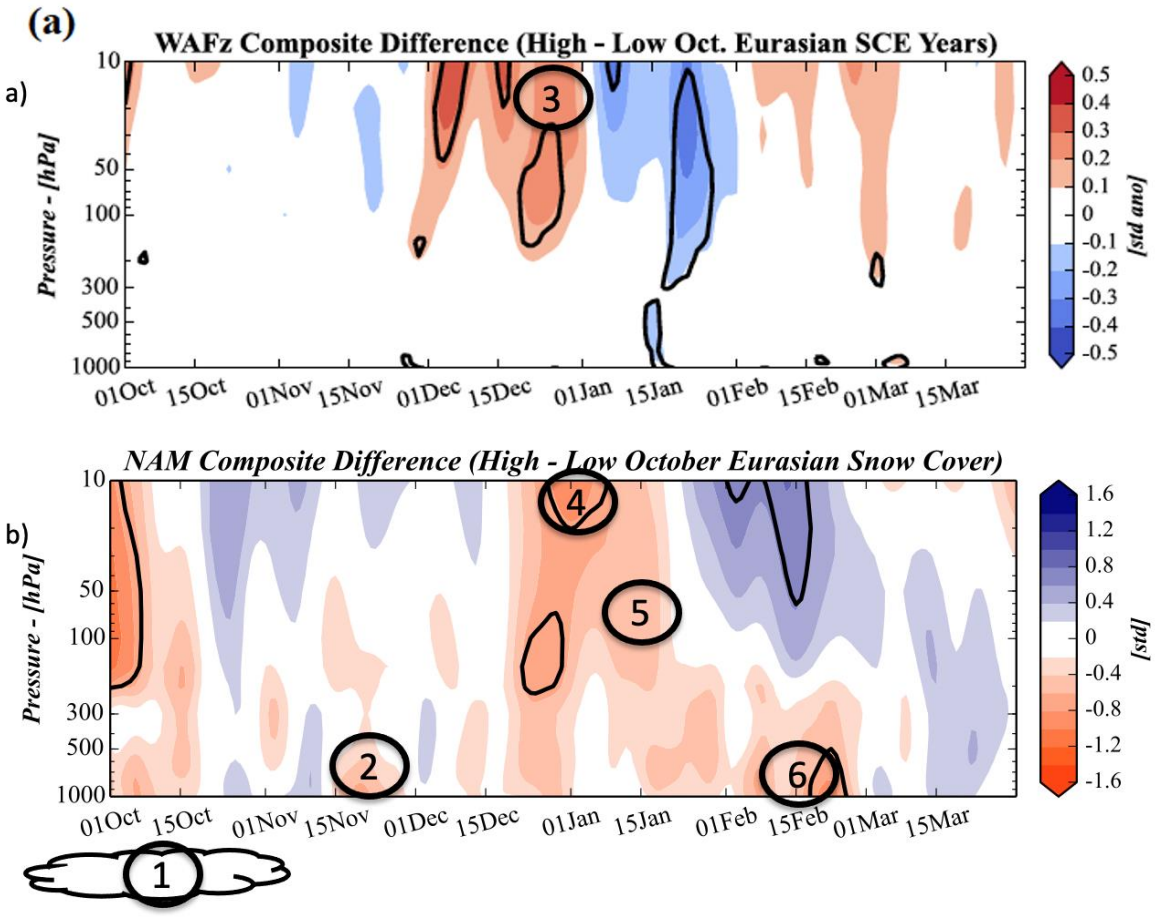

Figure ii. **a)** composite of WAFz from October 1 through March 31 for winters when October Eurasian snow cover extent is high minus low. **b)** composite of the Northern Annular Mode (NAM) from October 1 through March 31 for winters when October Eurasian snow cover extent is high minus low. Black contours delineate those differences that are statistically significant.

There is variability in the blocking with it weakening and strengthening until the end of December, when it on average peaks. Looking at **Figure 11**, the timing and variability or vacillations in the high-latitude blocking matches very well what is shown in **Figure ii**. So far this fall and early winter, Ural blocking initiated in late November has waxed and waned and could peak in late December.

The commencement of Ural/Scandinavian blocking the last two weeks of November initiates positive anomalous WAFz or poleward heat transport in the stratosphere starting in late November on average and continuing through the end of December. This is consistent with what I discussed in last week's blog; it typically takes four to six weeks of positive anomalous WAFz pulses to initiate a PV disruption/SSW. If we compare **Figure ii** with **Figure 12**, the observed/predicted WAFz this late fall and early winter is delayed by about two weeks compared to historical averages. I don't

have an answer as to why despite Ural blocking being on time compared with historical analysis the WAFz is delayed by about two weeks. However, I have been trying to draw attention to Siberia/East Asia temperature anomalies for many weeks now. Despite a favorable atmospheric circulation, it has taken a long time for widespread below normal temperatures to appear across Siberia. Mika Rantane was kind enough to provide me with a January through November temperature anomaly plot (**Figure iii**) for the Arctic and all year long it has been ridiculously warm in Siberia. This year there was clearly much more thermal inertia that favored relatively warm temperatures compared to previous years. As you can see below (**Figures 3, 6** and **9**) that has finally changed with relatively cold temperatures being observed and are predicted for Siberia over the next two weeks. I don't have proof to offer but I am guessing that the delay in cold temperatures in Siberia, despite a favorable atmospheric circulation, has contributed to the delay or gap from the formation Ural blocking to positive anomalies in WAFz.

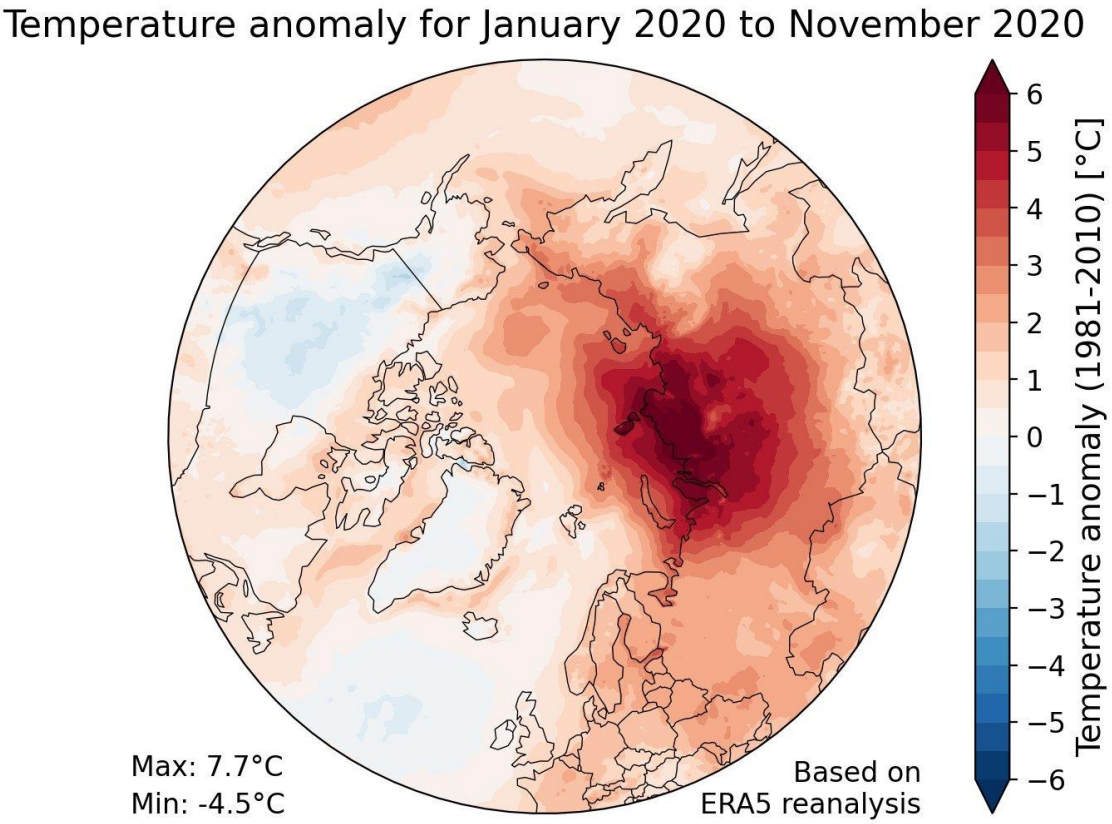

Figure iii. Observed winter surface temperature anomalies for January through November 2020 based on ERA5 from https://climatereanalyzer.org/.

The next step, a PV disruption/SSW on average begins in very late December and peaks in early January. However, we know from **Figure 12** there is a two-week delay in the WAFz response this year compared to historical averages and therefore if we are to observe a significant PV disruption/SSW, it is more likely to occur early to mid-January

or possibly even later. The downward propagation of circulation anomalies on average occur in mid-January followed by an extended period of a negative AO/NAM from late January through February. Similarly, the downward propagation and extended negative AO/NAM, too could be delayed.

In my own head, I think of a troposphere-stratosphere-troposphere (T-S-T) coupling event as cold-mild-cold across the NH continents. The tropospheric precursor features Ural blocking which favors cold downstream across Siberia. Europe and the US can be relatively mild or cold depending on other atmospheric features, but it based on my observations the Eastern US is often also cold. In **Figure ii** the mild period would be when the negative NAM weakens and the WAFz peaks at the end of December and into early January. I think based on **Figure 11**, with the positive PCH predicted to strengthen the last week of December and multi-week mild period will likely hold off until sometime in January.

From **Figure i**, there are, to use an American football analogy, five different handoffs that need to be executed successfully to go from surface or boundary forcings that favor a cold winter (or at least for a substantial period) to having a cold winter/period. I think the surface-atmosphere successfully completed one of those five handoffs, so we have four more to go. If any of the next four handoffs are fumbled, an extended cold period is unlikely to happen. There are obviously many different scenarios and like snowflakes, no two winters are alike. I will just mention one scenario for now, always a bridesmaid never a bride (where a large PV disruption is the bride). The winter consists of only tropospheric precursors and no large PV disruptions. Such a winter was 1995/96 but it is rare.

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 weak positive geopotential height anomalies across Greenland (**Figure 2**), the NAO is predicted to also be neutral to negative this week.

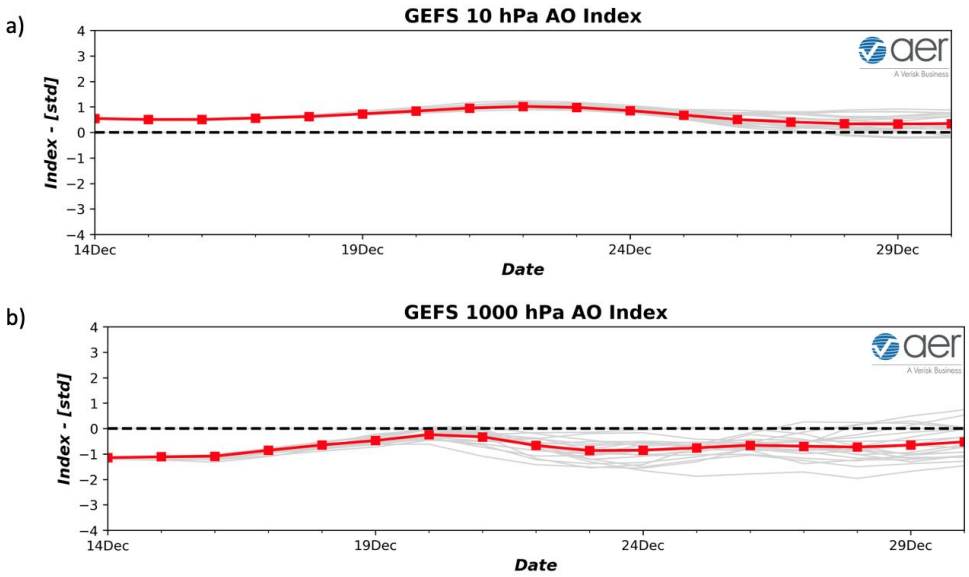

Figure 1. (**a**) The predicted daily-mean AO at 10 hPa from the 00Z 14 December 2020 GFS ensemble. (**b**)The predicted daily-mean near-surface AO from the 00Z 14 December 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies are predicted to dominate much of Europe (**Figure 2**). This pattern favors normal to above normal temperatures across Europe including the UK (**Figure 3**). This week, European/Western Russia ridging/positive geopotential height anomalies coupled with another positive height centered in the East Siberian Sea 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 above normal temperatures **for** Western and Southern Asia with normal to below normal temperatures for Siberia, Central and Eastern Asia **(Figure 3**).

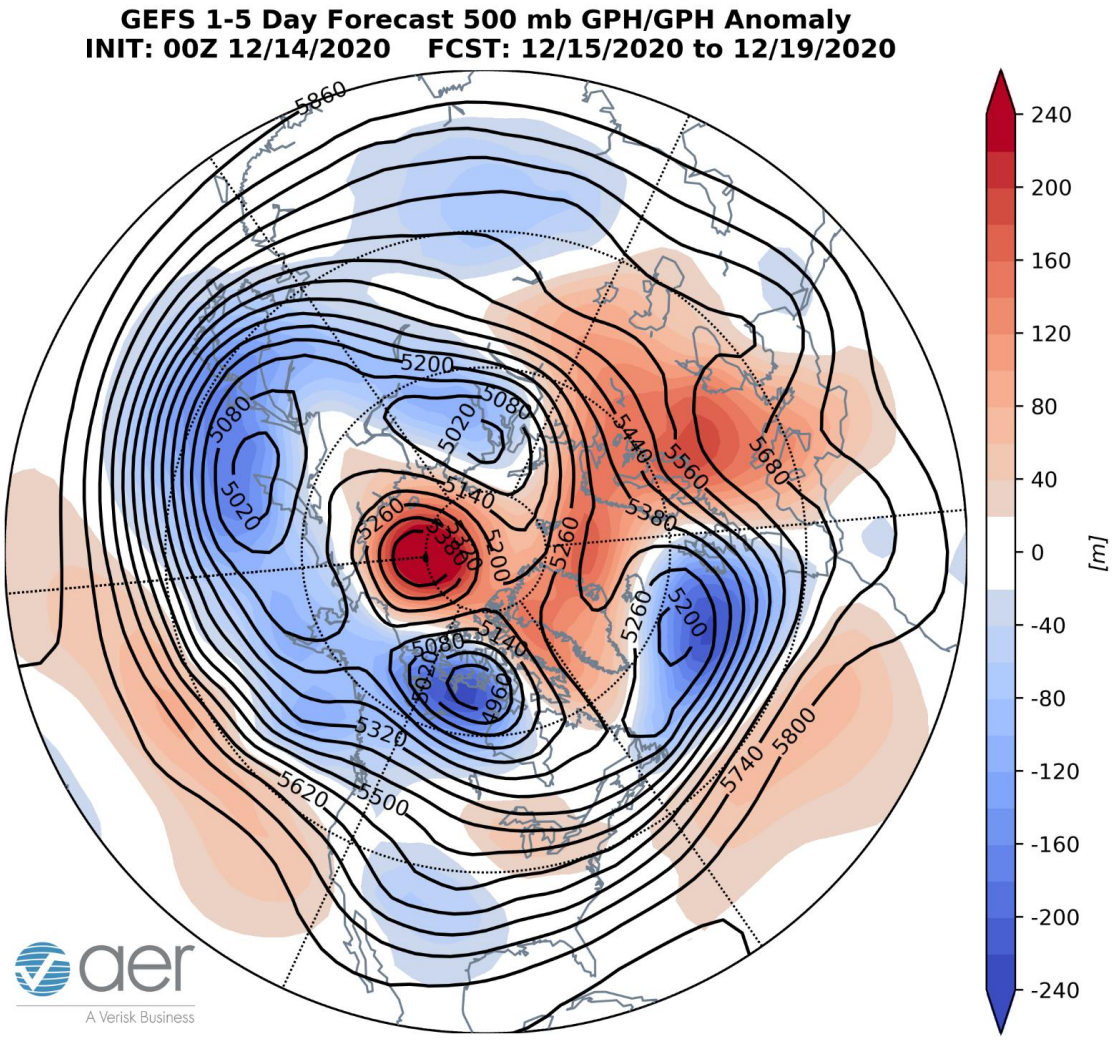

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 15 – 19 December 2020. The forecasts are from the 00z 14 December 2020 GFS ensemble.

This week, zonal flow is predicted across North America with ridging/positive geopotential height anomalies for the Western United States (US) and into the Great Lakes and troughing/negative geopotential height anomalies for Alaska, Canada and the Southcentral US **(Figure 2).** This pattern is predicted to bring widespread normal to above normal temperatures across much of the Western US and Canada/US border with normal to below normal temperatures for Alaska, Northern and Eastern Canada and in the Southern and Eastern US **(Figure 3).**

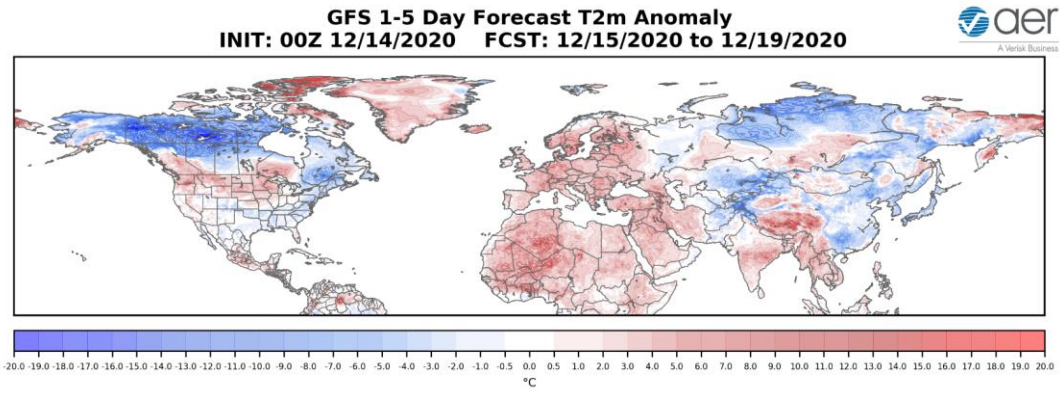

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 15 – 19 December 2020. The forecast is from the 00Z 14 December 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across parts of Scandinavia, Siberia, Western and Central Asia and Western China while warmer temperatures will cause regional snow melt in the Alps, Eastern Europe and Southwestern Asia (**not shown**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, Northern, Western and Central Canada, Quebec, the Northwestern US and the US Mid-Atlantic and Northeast while warmer temperatures will cause snow melt in parts of the Plains and Ontario (**Figure 4**).

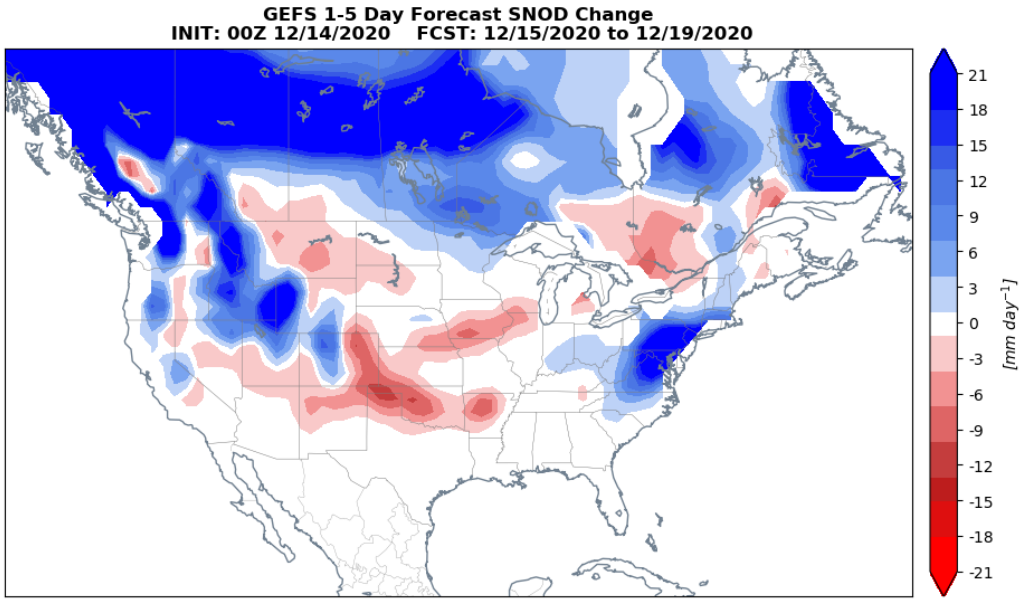

Figure 4. Forecasted snow depth changes (mm/day; shading) from 15 – 19 December 2020. The forecast is from the 00Z 14 December 2020 GFS ensemble. I only show the US to focus on the upcoming Nor'easter this week.

Mid-Term

6-10 day

The AO is predicted to remain slightly negative to neutral 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 mostly negative.

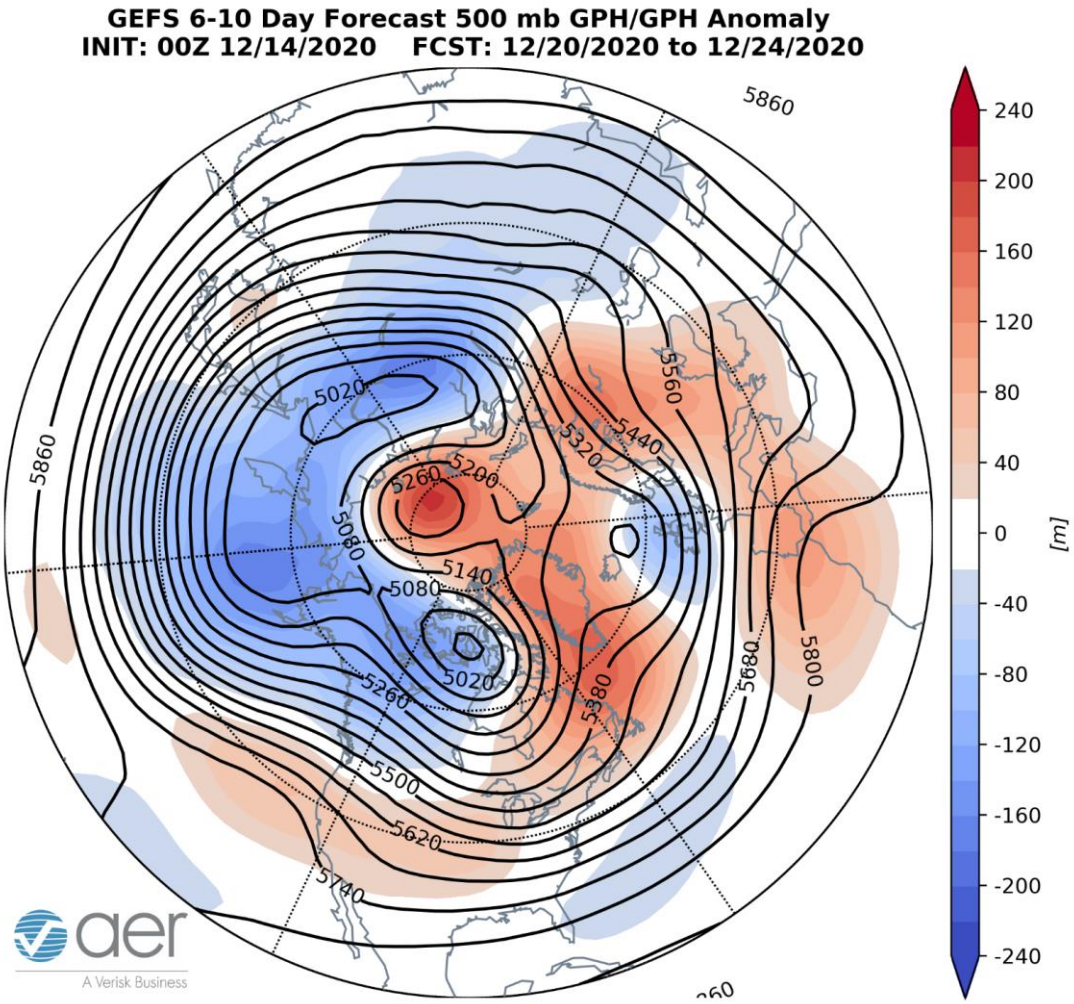

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 20 – 24 December 2020. The forecasts are from the 00z 14 December 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to dominate Europe with the exception of troughing/negative geopotential height anomalies across the UK this

period (**Figures 5).** This pattern favors normal to above normal temperatures across much of Europe with the possible exception of normal to below normal temperatures in the UK (**Figure 6**). Persistent ridging/positive geopotential height anomalies centered between the Urals and Scandinavia coupled with another positive height center in the Laptev Sea are predicted to anchor troughing/negative geopotential height anomalies downstream across Central Asia and Siberia that extends south across East Asia this period (**Figure 5**). This is predicted to favor widespread normal to below normal temperatures across much of Northern, Central and East Asia with normal to above normal temperatures in the Ural region and Southern Asia **(Figure 6**).

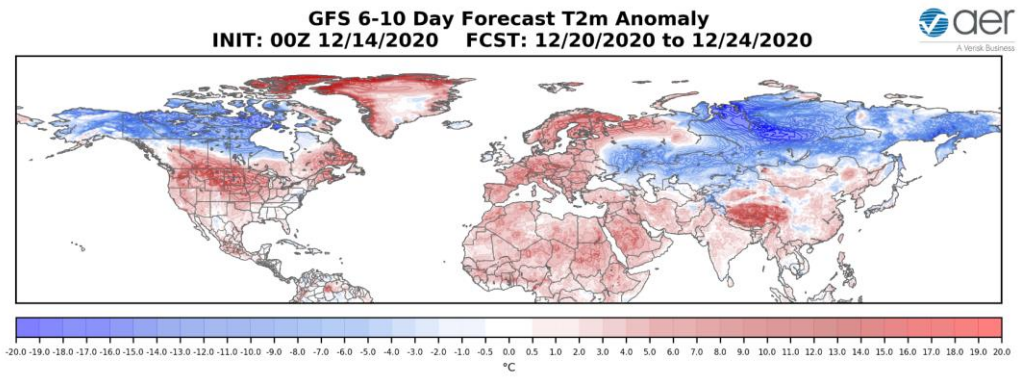

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 20 – 24 December 2020. The forecasts are from the 00Z 14 December 2020 GFS ensemble.

Zonal flow is predicted to mostly persist this period with ridging/positive geopotential height anomalies across much of the US and Eastern Canada with troughing/negative geopotential height anomalies across Alaska, Western Canada and the Southeastern US **(Figure 5).** This pattern is predicted to bring widespread normal to above normal temperatures across the US and Southern Canada with normal to below normal temperatures across Alaska, much of Northern Canada and the Southeastern US **(Figure 6).**

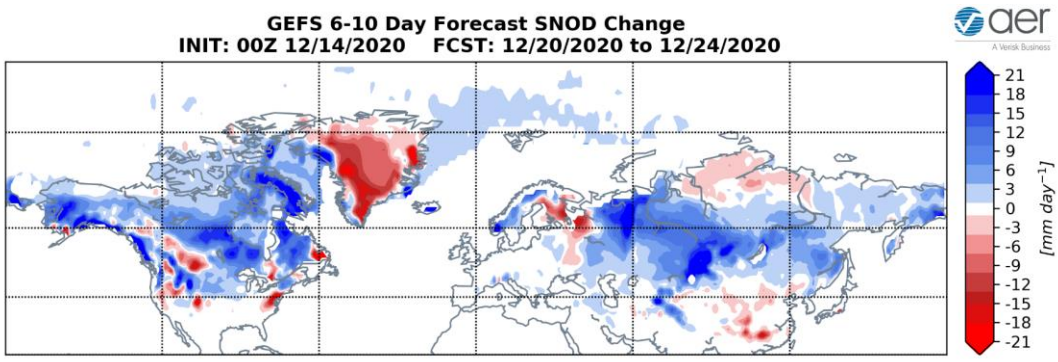

Figure 7. Forecasted snow depth changes (mm/day; shading) from 20 – 24 December 2020. The forecasts are from the 00Z 14 December 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across Scandinavia, Northern Asia and the Himalayas while warmer temperatures will cause regionalized snow melt including the Baltic States and China (**Figure 7**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, much of Canada and possibly the Northern US while warmer temperatures will cause possible snow melt in the US Rockies and Mid-Atlantic States (**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.

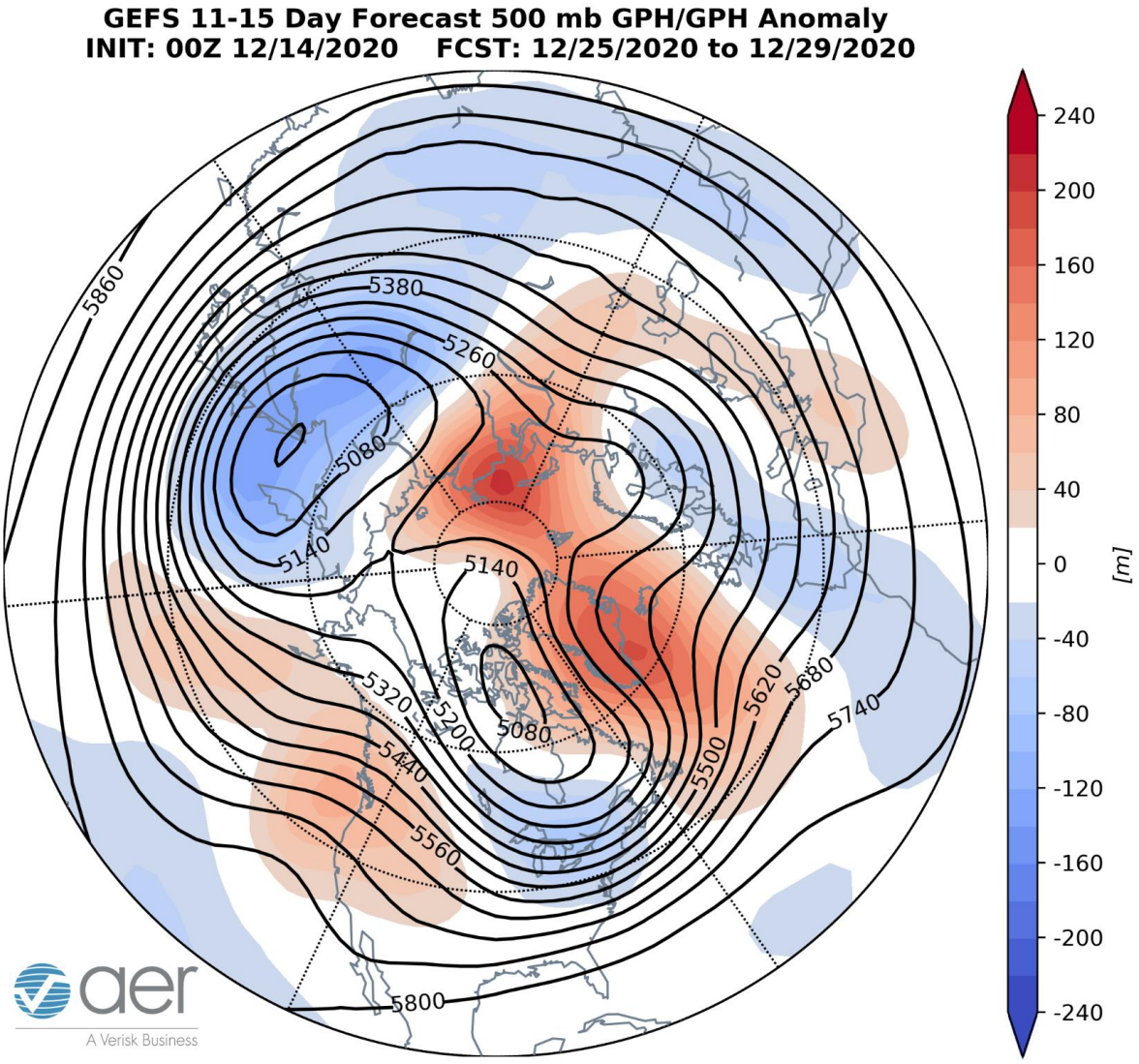

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 25 – 29 December 2020. The forecasts are from the 00z 14 December 2020 GFS ensemble.

Ridging/positive geopotential height anomalies in the northern North Atlantic are predicted to become more focused over Greenland forcing new troughing/negative geopotential height anomalies over Western and Northern Europe this period (**Figures 8**). The forecast is for normal to below normal temperatures across Northern and Western Europe including the UK while Southwesterly flow persists with normal to above normal temperatures for Southern and Eastern Europe this period (**Figures 9**). Predicted persistent ridging/positive geopotential height anomalies focused in the Laptev Sea and the Urals this period 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 the Western and Southern Asia with normal to below normal temperatures across much of Siberia and into East Asia (**Figure 9**). The movement of the cold air southeastwards out of Siberia this period suggests to me an increased risk of a cold air outbreak into East Asia.

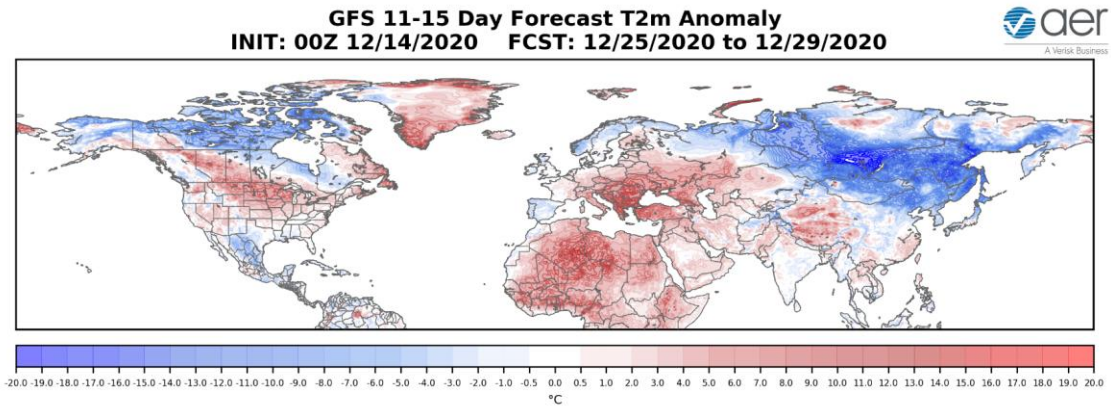

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 25 – 29 December 2020. The forecasts are from the 00z 14 December 2020 GFS ensemble.

Predicted building ridging/positive geopotential height anomalies across western North America will force troughing/negative geopotential height anomalies across eastern North America and the Gulf of Alaska this period (**Figure 8**). This predicted pattern is mostly a continuation from the previous period with normal to above normal temperatures for much of the US and Southern Canada with normal to below normal temperatures for Alaska and Northern Canada (**Figure 9**). However cold air should be on the move south across Central and Eastern Canada and eventually into the US if the pattern verifies.

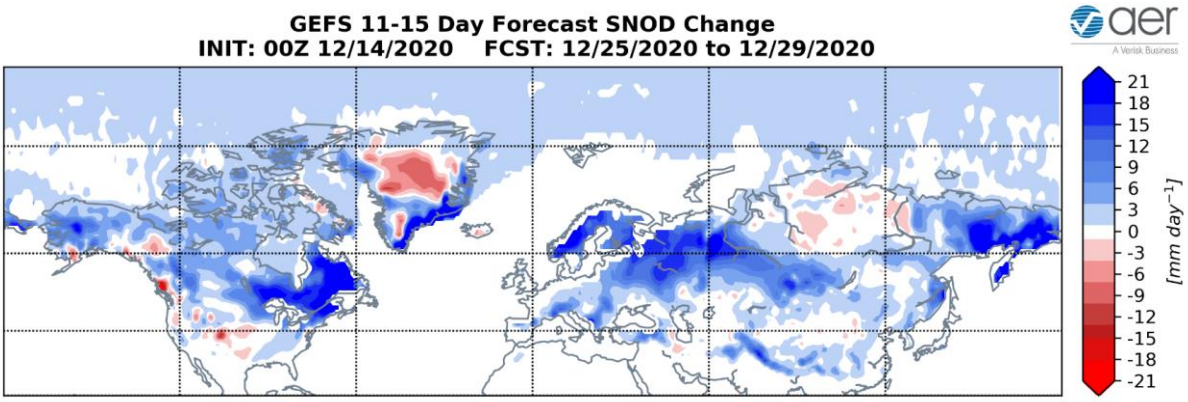

Figure 10. Forecasted snow depth changes (mm/day; shading) from 25 – 29 December 2020. The forecasts are from the 00z 14 December 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across Scandinavia and much of Northern and Central Eurasia and even Europe (**Figure 10**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, much of Canada but especially eastern Canada and New England while warmer temperatures will cause possible snow melt in the Central US (**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 troposphere and into the lower stratosphere but near normal PCHs in the mid to upper stratosphere (**Figure 11**). The stratospheric PCHs are predicted to briefly turn cold/negative the next two weeks (**Figure 11**). **Please note that the PCH plot now extends to 1 hPa and previously it stopped at 10 hPa.**

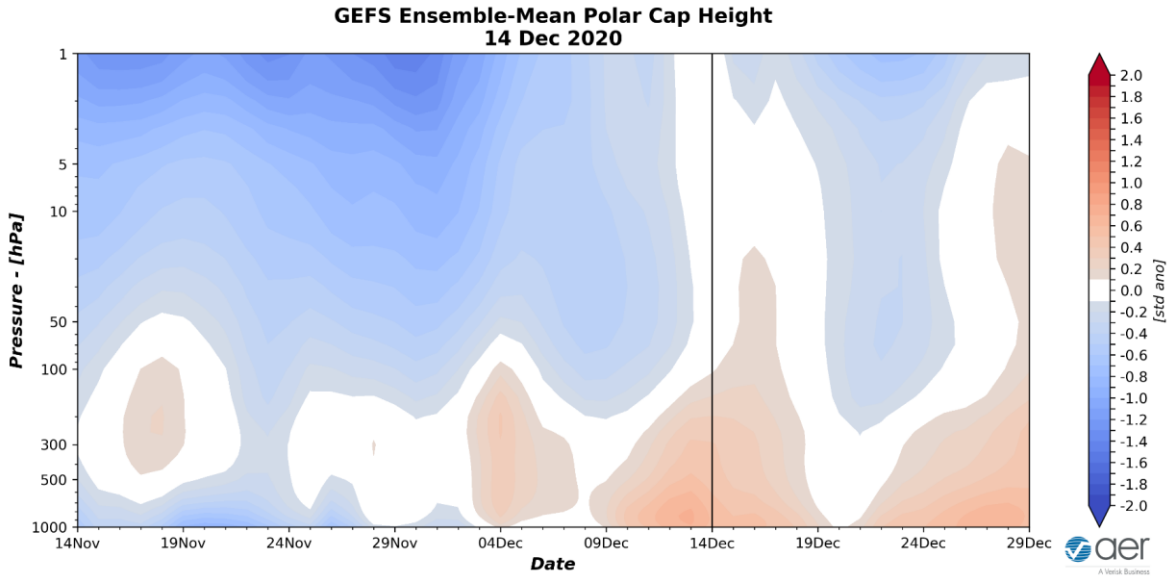

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 14 December 2020 GFS ensemble. Please note that the PCH plot now extends to 1 hPa.

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

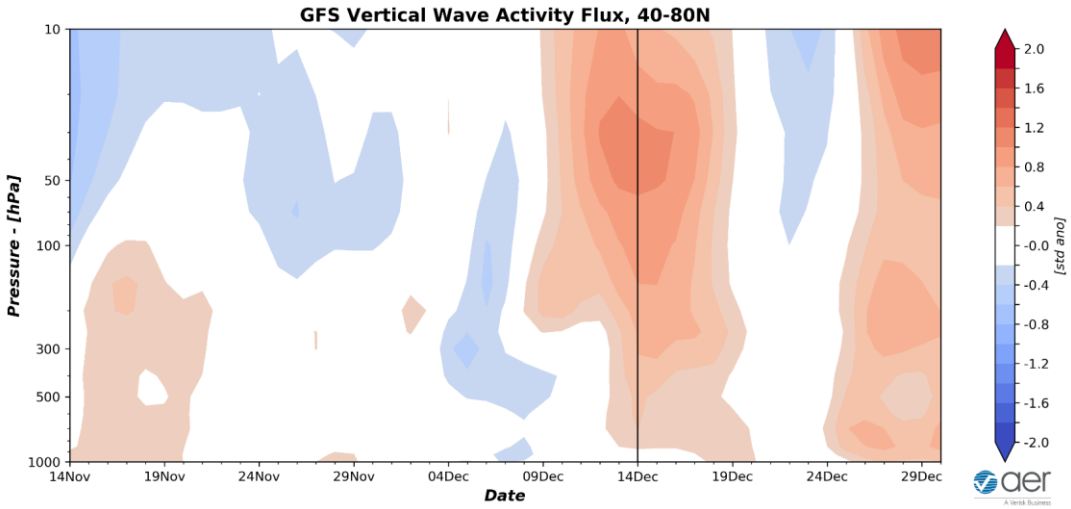

Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 14 December 2020 GFS ensemble.

The plot of Wave Activity Flux (WAFz) is proportional to poleward heat transport forecasts is showing a current active period of WAFz in the troposphere but especially the stratosphere this week (**Figure 12**). There is a predicted distinct second pulse of WAFz during the holidays (**Figure 12**). The lack of active WAFz much of the fall has allowed the stratospheric PV to become anomalously strong. But weakening of the PV is looking more likely with the upcoming active period of WAFz but especially with the predicted second pulse.

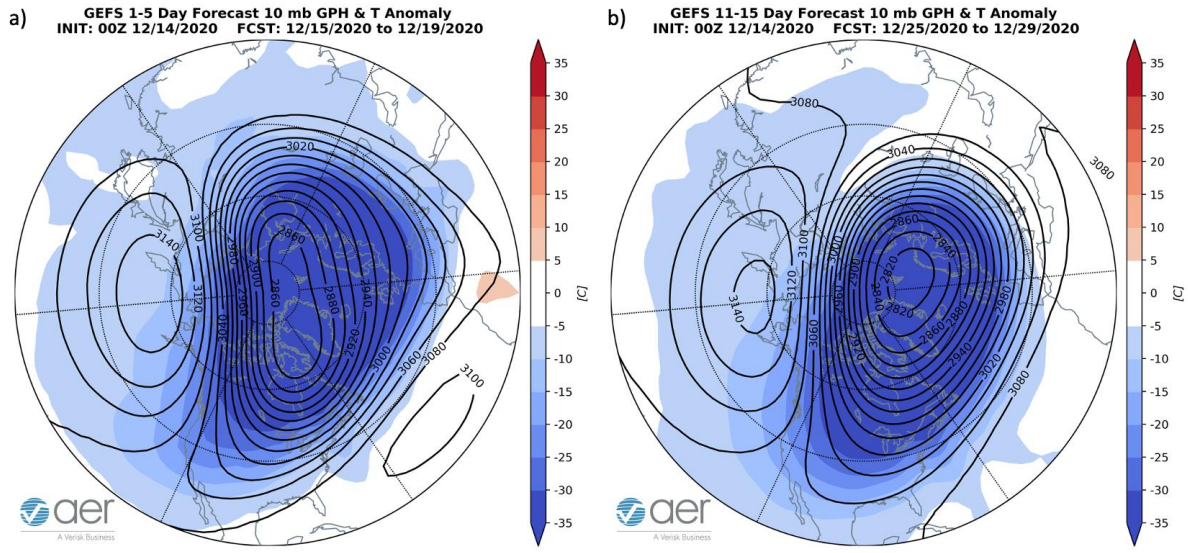

Figure 13. (**a**) Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 15 – 19 December 2020.

(**b**) Same as (a) except forecasted averaged from 25 – 29 December 2020. The forecasts are from the 00Z 14 December 2020 GFS model ensemble.

The PV is predicted to remain strong and centered near Greenland and Svalbard this week (**Figure 13**). The PV is east of the North Pole and stretched due to high pressure centered near the Dateline. This a sign of some perturbation of the PV and could be suggestive of an upcoming disruption of the PV that is looking more like an absorptive event, which is most closely associated with cold temperatures in Northern Eurasia.

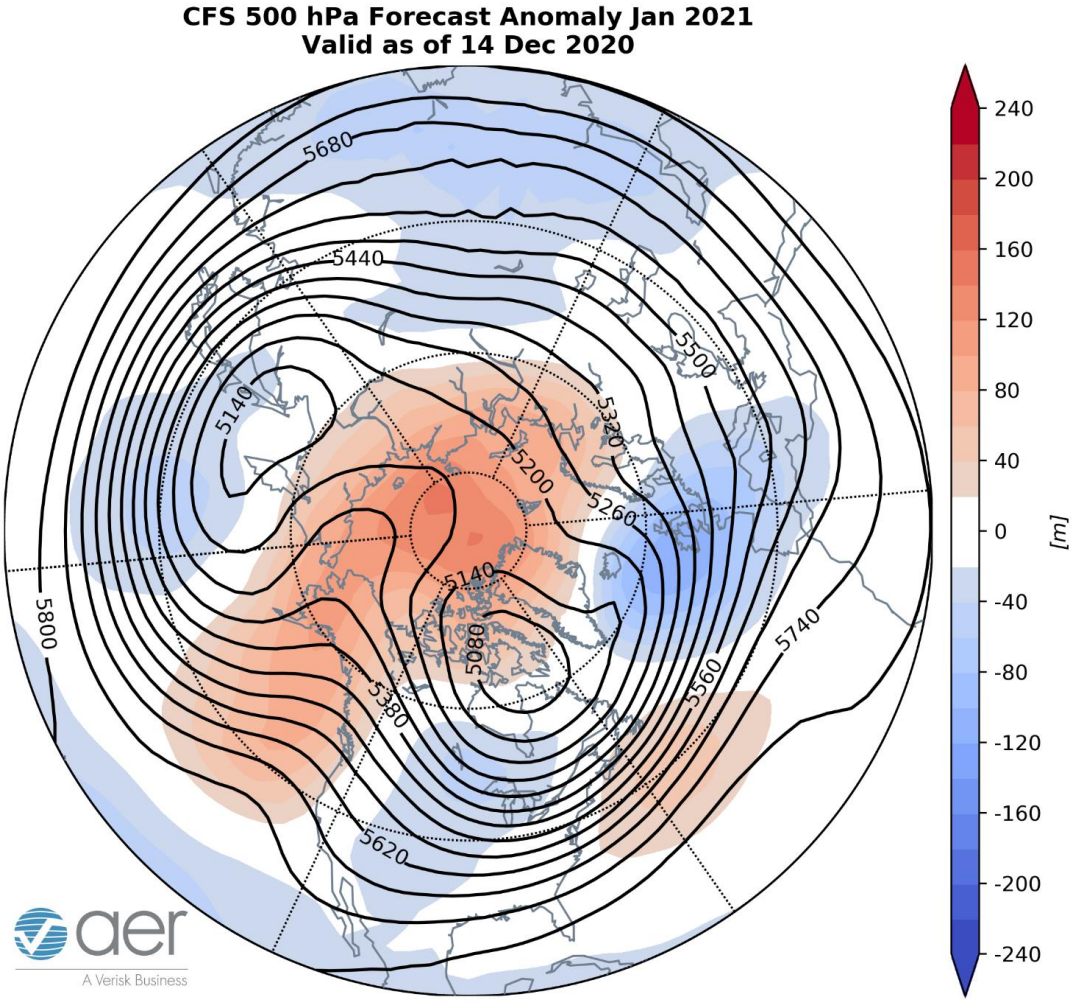

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for January 2021. The forecasts are from the 00Z 14 December 2020 CFS.

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 in the Central Arctic, Gulf of Alaska, Alaska and the western North Atlantic with troughing in Europe, East Asia, Central Canada into the Central US (**Figure 14).** This pattern favors relatively warm temperatures for Southeast Europe, the North Slope of Asia and western North America with seasonable to relatively cold temperatures for Northern and Western Europe, Central and Eastern Asia, Eastern Canada and the Eastern US (**Figure 15**).

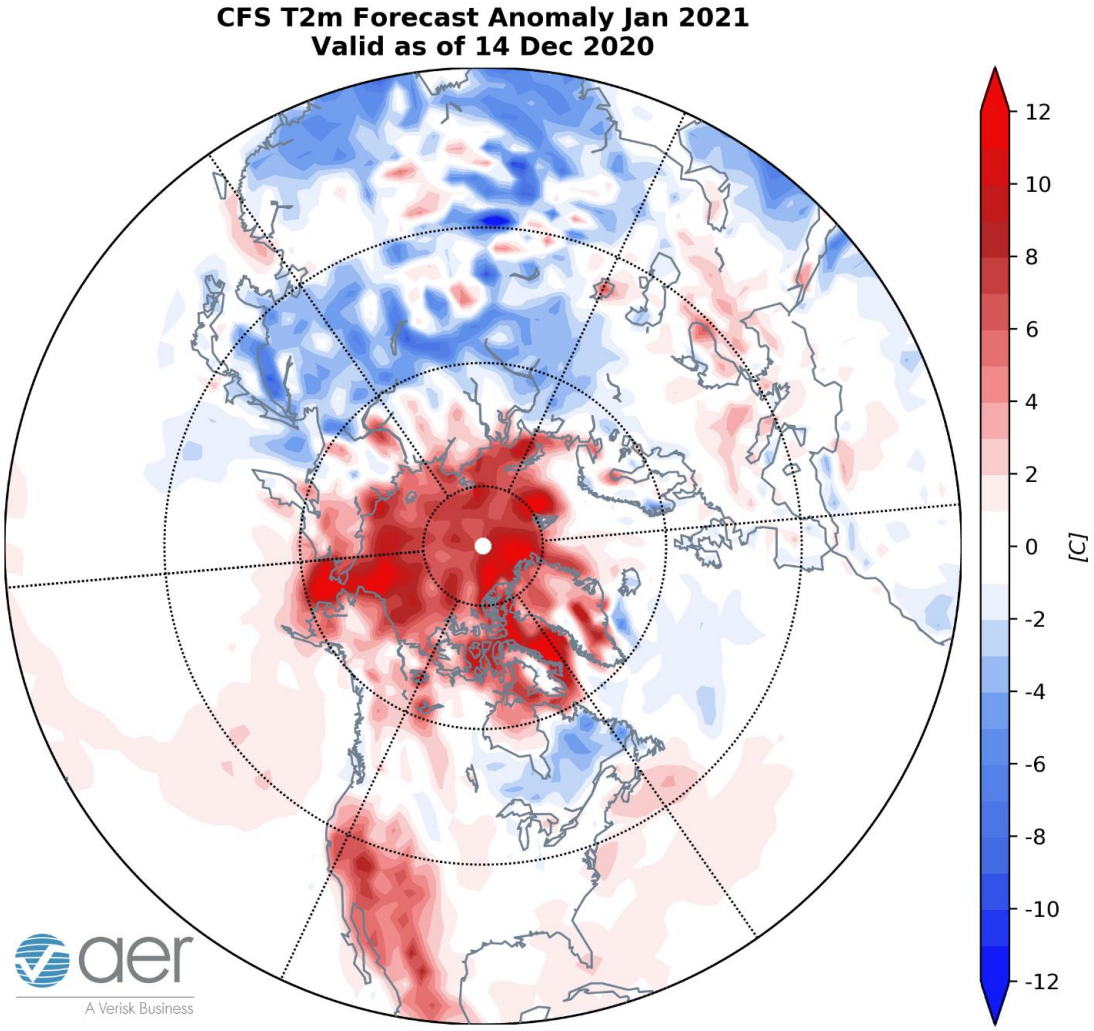

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for January 2021. The forecasts are from the 00Z 14 December 2020 CFS.

Surface Boundary Conditions

Arctic sea ice extent

Arctic sea ice continues to grow but currently remains well below normal. Negative sea ice anomalies are filling in the Bering and Chukchi Seas (**Figure 16**). Therefore the largest negative sea anomalies are mostly focused in the Barents-Kara Seas. 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.

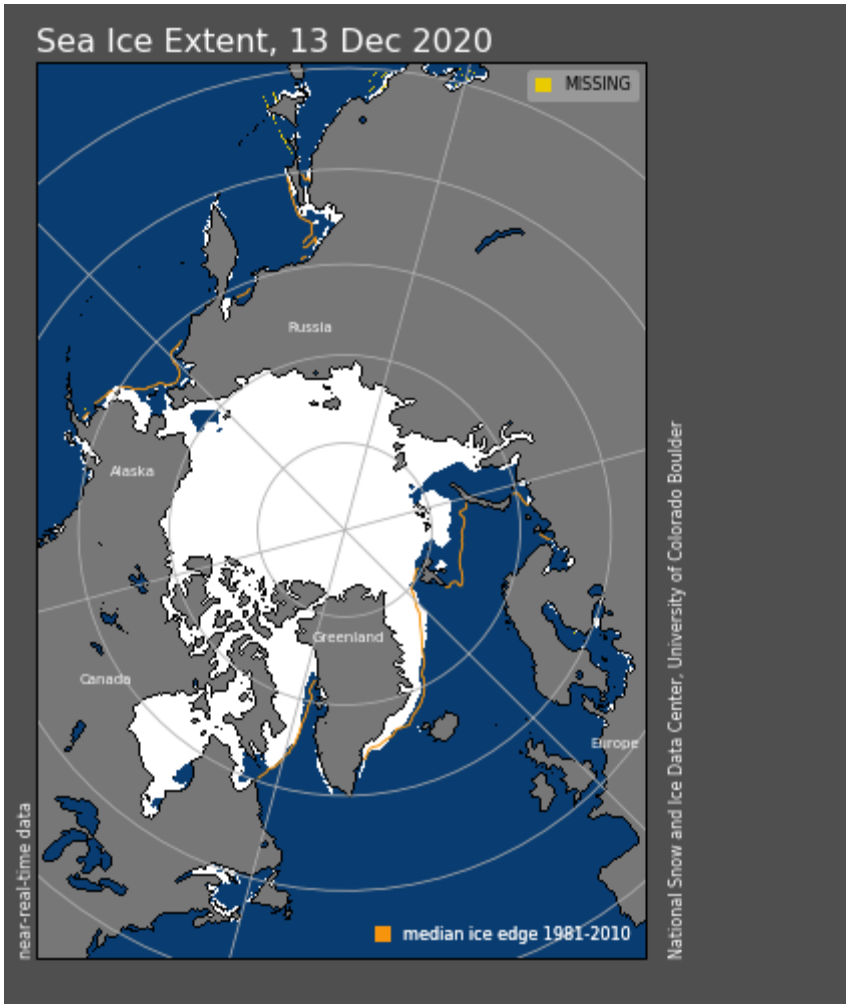

Figure 16. Observed Arctic sea ice extent on 13 December 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies remain negative and we continue to observe moderate La Niña conditions (**Figure 14**) and La Niña is expected to persist through the winter and remain moderate. 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.

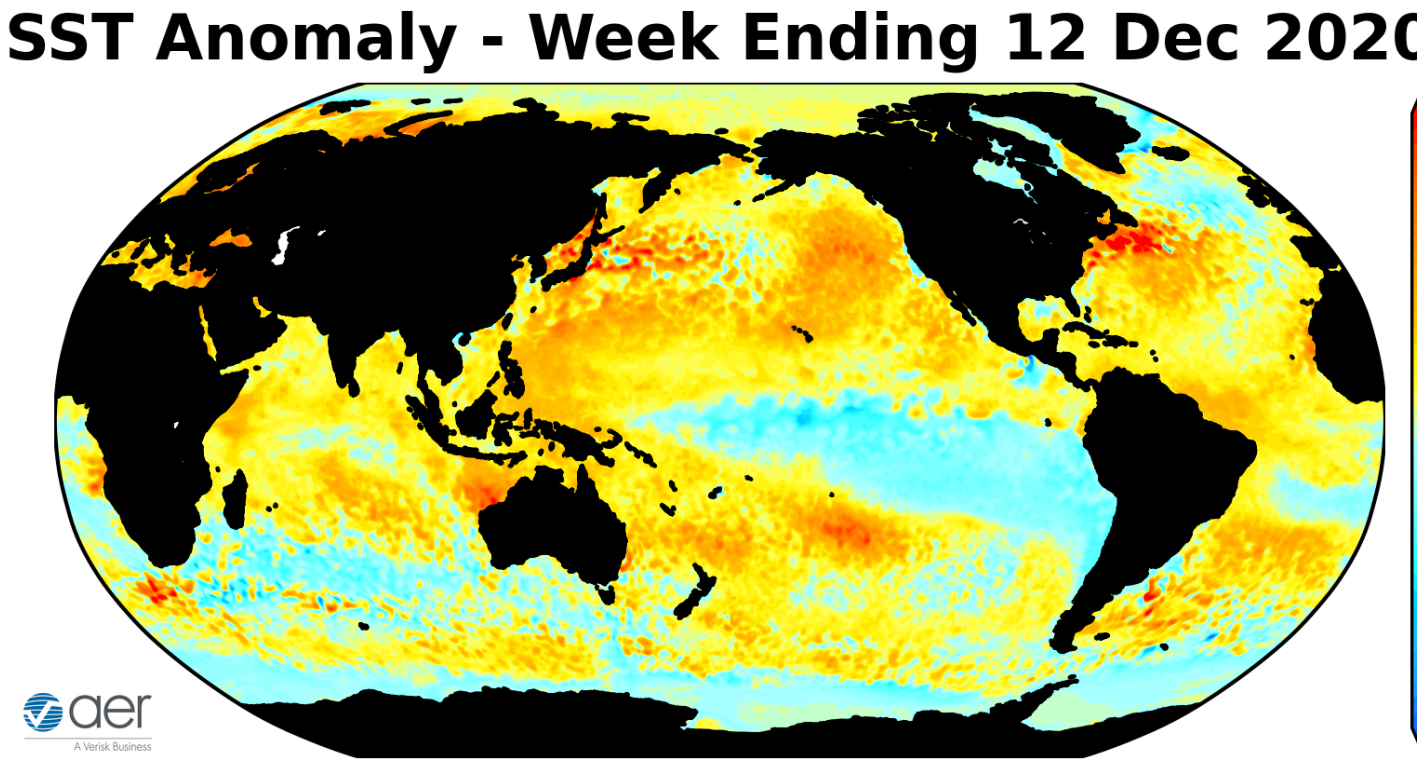

Figure 17. The latest weekly-mean global SST anomalies (ending 12 December 2020). Data from NOAA OI High-Resolution dataset.

Currently Madden Julian Oscillation (MJO) is in phase five (**Figure 15**). The forecasts are for the MJO to quickly weaken where no phase is favored for the next two weeks. Phase five does favor a zonal flow across North America and may be contributing to the near-term weather across North America. However it doesn't appear to me that the MJO is contributing to the pattern across North America beyond a few days but admittedly this is outside of my expertise.

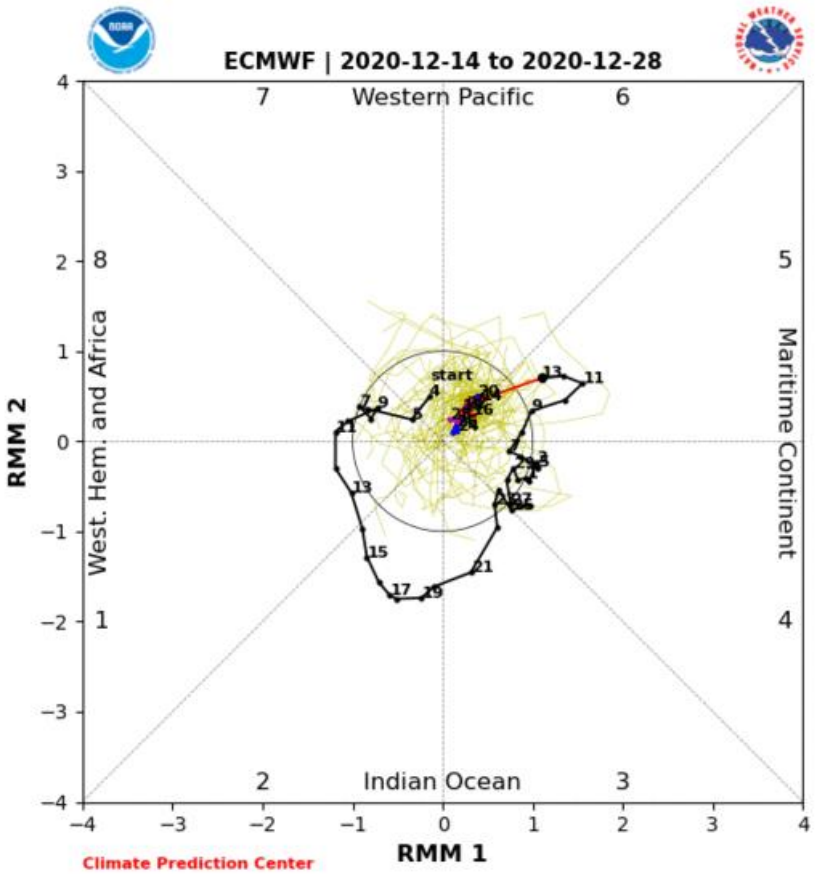

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 14 December 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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 more quickly over the past week across Eurasia and remains near decadal highs. Snow cover advance will likely continue to increase especially across East Asia and possibly 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.

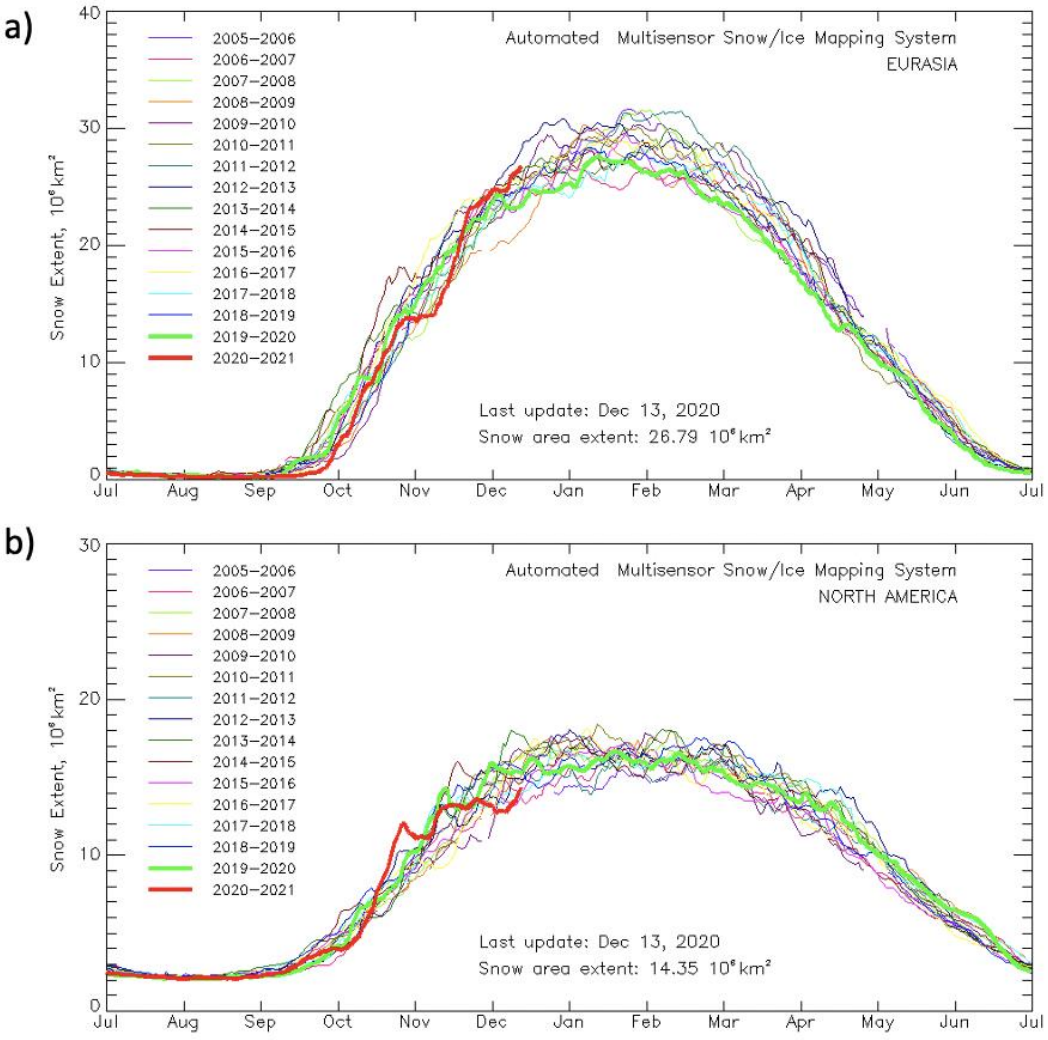

Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 13 December 2020. Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover advance finally got off the matt. Snow cover advance has mostly stalled since October and remains 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.