

Arctic Oscillation and Polar Vortex Analysis and Forecasts

November 23, 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 positive and is predicted to trend towards neutral the next two weeks.
- The current positive AO is reflective of mostly negative pressure/geopotential height anomalies across the Arctic especially 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 positive with negative pressure/geopotential height anomalies spread across Greenland and Iceland; and the NAO is predicted to also remain positive this week before turning neutral next week as pressure/geopotential height anomalies are predicted to trend close to zero next week.

- This week, ridging/positive geopotential height anomalies with normal to above normal temperatures are predicted to dominate Europe including the United Kingdom (UK). However next week the ridging/positive geopotential height anomalies are predicted to push far enough north to allow some troughing/negative geopotential height anomalies with normal to below normal filter into Central and Southern Europe.
- The predicted general pattern the next two weeks across Asia is ridging/positive geopotential height anomalies with normal to above normal temperatures becoming centered near the Urals by week two with troughing/negative geopotential height anomalies with near seasonable to even below normal temperatures in Southwestern Asia and Eastern Siberia with some of the colder temperatures filtering into East Asia.
- The predicted pattern this week across North America is a mostly zonal flow with ridging/positive geopotential height anomalies with normal to above normal temperatures across the United States (US) with troughing/negative geopotential height anomalies coupled with normal to below normal temperatures for Alaska and Northern Canada. However next week the ridging/positive geopotential height anomalies with normal to above normal temperatures will become focused in western North America with troughing/negative geopotential height anomalies coupled with normal to below normal temperatures mostly limited to the Eastern US.
- In the Impacts section I discuss what I am watching for hints of a possible future polar vortex (PV) disruption.

Impacts

In next week's blog I will post the AER winter temperature anomaly forecast for the Northern Hemisphere (NH).

Earlier in the month I did think that we were about to go over a metaphorical cliff where a very mild start to the winter was all but inevitable across much of the Northern Hemisphere mid-latitudes probably through at least mid-January. In last week's blog I described taking one step back from the abyss and I think this week we have taken another step back but overall; we are still not that far from the cliff's edge.

The polar cap geopotential height anomalies (PCHs) in the stratosphere remain negative/cold with no signs of that reversing in the foreseeable future. The vertical energy transfer from the troposphere to the stratosphere remains relatively quiet for the

next couple of weeks (see **Figure 12**) at least ensuring no meaningful disruptions of the polar vortex in the near future.

But I am struck by how despite the persistent anomalously strong stratospheric PV and at times the negative/cold PCHs near the surface there has not yet been a robust troposphere-stratosphere-troposphere (T-S-T) coupling event that includes both a strong stratospheric PV and a positive AO that in combination contribute to widespread relatively mild temperatures across the NH. It kind of reminds me of last year at this time when we were observing a T-S-T coupling event that included both a weak stratospheric PV and a negative AO. But the event was relatively weak and of short duration. The almost failed event setup a quickly strengthening PV that coupled to the surface resulting in a strongly positive AO and very mild temperatures across the NH mid-latitudes for the remainder of the winter. I do believe the longer that the stratosphere and troposphere fail to fully couple the more likely for the tropospheric PCHs to turn positive/warm that will begin to disrupt the stratospheric PV. Looking back at the past two decades of winters or so, this scenario only occurred once in 2013/14. So though I am not expecting a repeat of winter 2013/14, the upcoming winter could share some similarities.

One plausible reason in my opinion that the negative cold PCHs have not fully coupled in the troposphere to the stratosphere is the extremely low Arctic sea ice and resultant relatively very mild temperatures in the Arctic. The persistently warm Arctic has acted as a resistor to the tropospheric PCHS turning fully negative/cold, though of course this could change. Also the lack of sea ice particularly in the Barents-Kara Seas region (see **Figure 16**) could potentially act as a magnet of sorts attracting positive geopotential height anomalies to the region. High pressure/blocking near the Urals/Scandinavia region is the atmospheric feature most favorable for disrupting the stratospheric PV. In addition, sea surface temperatures remain elevated in the Gulf of Alaska (see **Figure 17**) that could also act like a magnet attracting positive geopotential height anomalies to the Gulf of Alaska and western North America. The models are suggesting more and more that high pressure/blocking in the western hemisphere will become focused across western North America in early December. I think that the combination of ridging near the Urals and Gulf of Alaska/western North America greatly increases the risk of below normal to well below normal temperatures in central and eastern North America and less so for Europe. Though as is often the case when the NAO is positive some more active winter weather is possible across Southern and maybe even Central Europe.

I do believe that the strong stratospheric PV centered near the North Pole is supporting a reflection of the deep low pressure in the mid-troposphere as well. If the stratospheric PV can get knocked off its perch near the North Pole, that could facilitate a mid-tropospheric circulation more favorable for more active winter weather.

I did peek at the 12z GFS ensembles and they seem to have lost the ridging near the Urals but strengthened the ridging across western North America. That would increase the cold risk in the short term across eastern North America but lower it longer term. It is only one run so I would want to see more consistency in the forecast before becoming confident in that outcome. I find it a bit ironic that despite the very robust ongoing La Niña, winter is looking to kick off with a canonical El Niño pattern across North America with deep troughing/low geopotential heights near the Aleutians, ridging/high heights across western North America with more troughing/low geopotential heights in the Eastern US especially the Southeast (see **Figure 8**). December is often the odd winter-month out so I am not going to make too much of it but will think differently if the same pattern occurs in January.

Finally, I have been harping about the lack of relatively cold temperatures in Eurasia but especially East Asia. Still no cold of note, but quite stealthily it seems - Eurasian snow cover has experienced an impressive advance (see **Figure 19**). Where North America snow cover put on quite the show in October while Eurasia was lackluster, the roles have reversed for November. Now that snow cover extent is above normal across Eurasia, it should be more favorable for more extensive relatively cold temperatures. If a large pool of cold temperatures can develop across Northern Asia, then I do believe that it will be more favorable for disrupting the stratospheric PV.

1-5 day

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

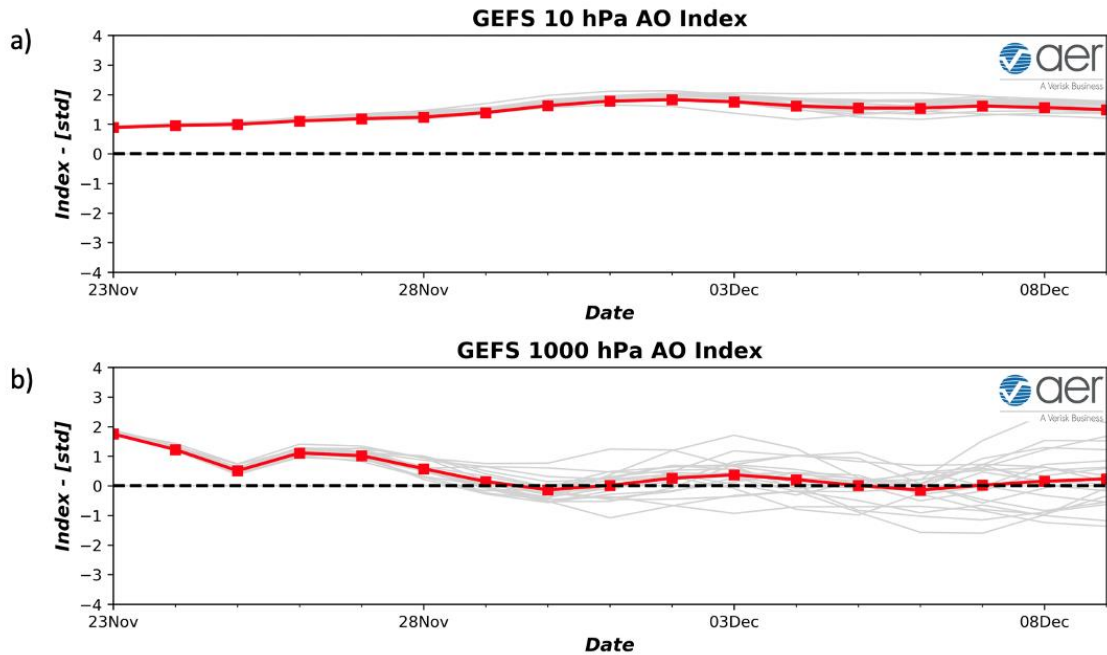


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 23 November 2020 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 23 November 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the 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 for much of Europe including the UK (**Figure 3**). This week, ridging/positive geopotential height anomalies will dominate Asia but centered in Western Siberia with troughing/negative geopotential height anomalies in Western Asia and Eastern Siberia that extends south into East Asia (**Figure 2**). This pattern favors widespread normal to above normal temperatures for Northern and far Southern Asia with near normal to slightly below normal temperatures in Southwestern, Central and East Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 11/23/2020 FCST: 11/24/2020 to 11/28/2020

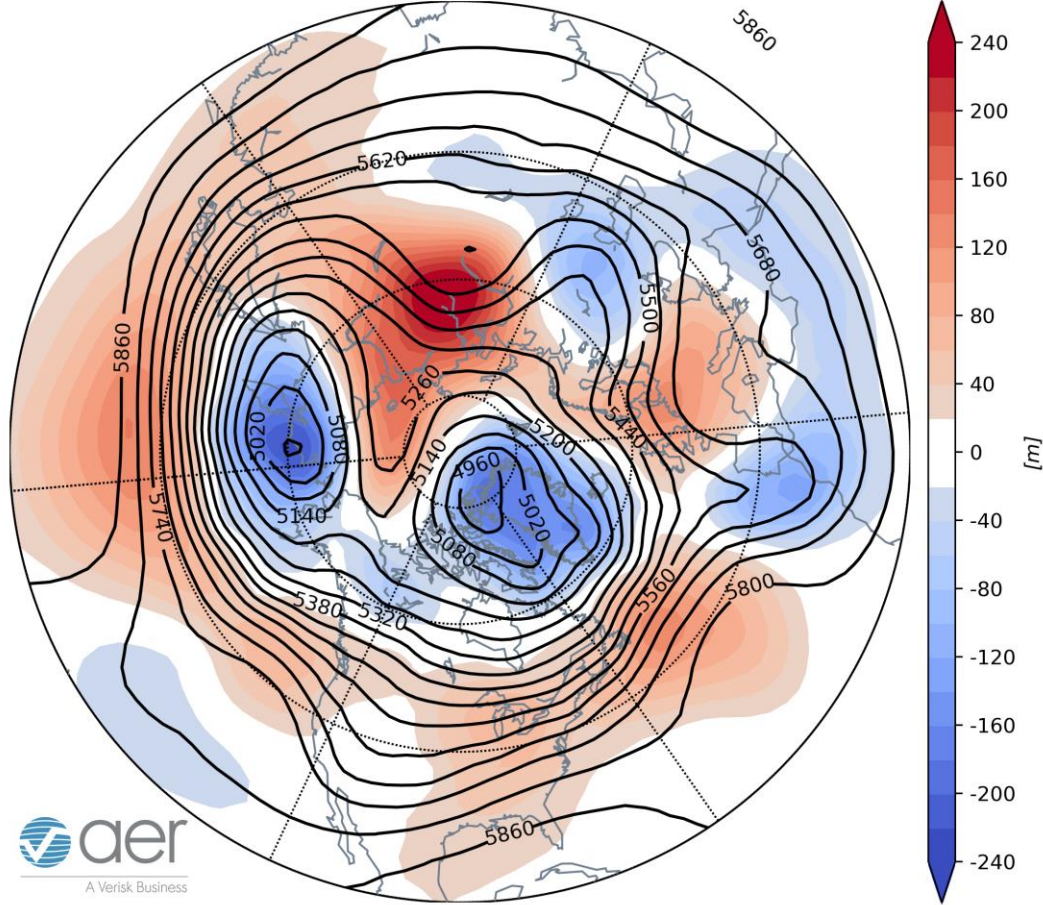


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 24 – 28 November 2020. The forecasts are from the 00z 23 November 2020 GFS ensemble.

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

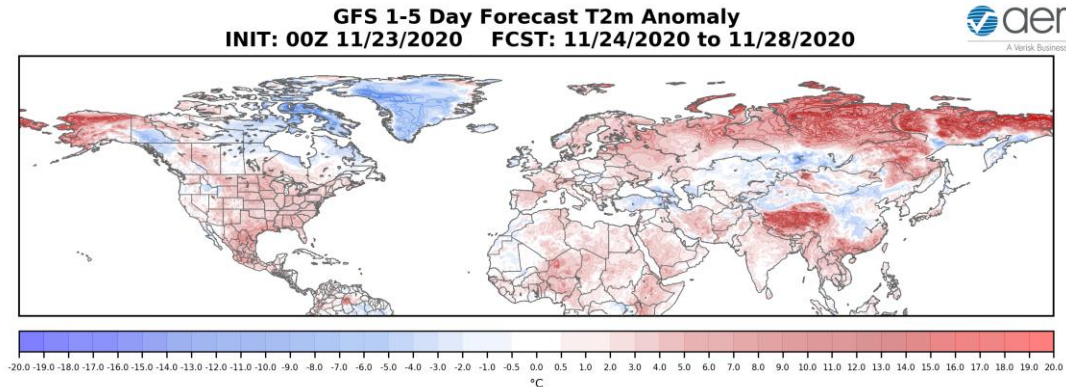


Figure 3. Forecasted surface temperature anomalies (°C; shading) from 24 – 28 November 2020. The forecast is from the 00Z 23 November 2020 GFS ensemble.

Trouching and/or colder temperatures are predicted to support new snowfall across Northern Scandinavia, Northern and parts of East Asia and the Himalayas while warmer temperatures will cause snow melt in Central Asia (**Figure 4**). Trouching and/or colder temperatures are predicted to support new snowfall across Alaska, Northern and Western Canada and the US Rockies while warmer temperatures will cause snow melt in parts of Southern Canada (**Figure 4**).

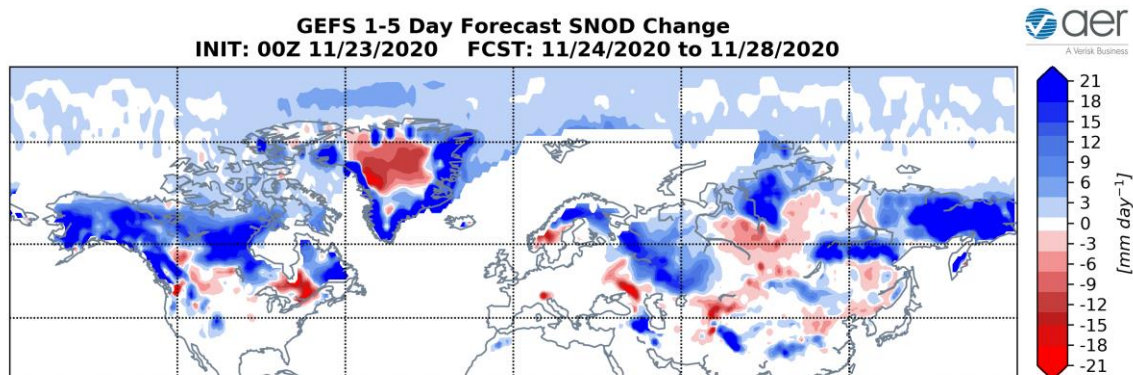


Figure 4. Forecasted snow depth changes (mm/day; shading) from 24 – 28 November 2020. The forecast is from the 00Z 23 November 2020 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to trend towards neutral next week (**Figure 1**) as geopotential height anomalies begin to rise across the North Atlantic side of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with

the persistent negative geopotential height anomalies predicted across Greenland (Figure 5), the NAO is predicted to remain positive.

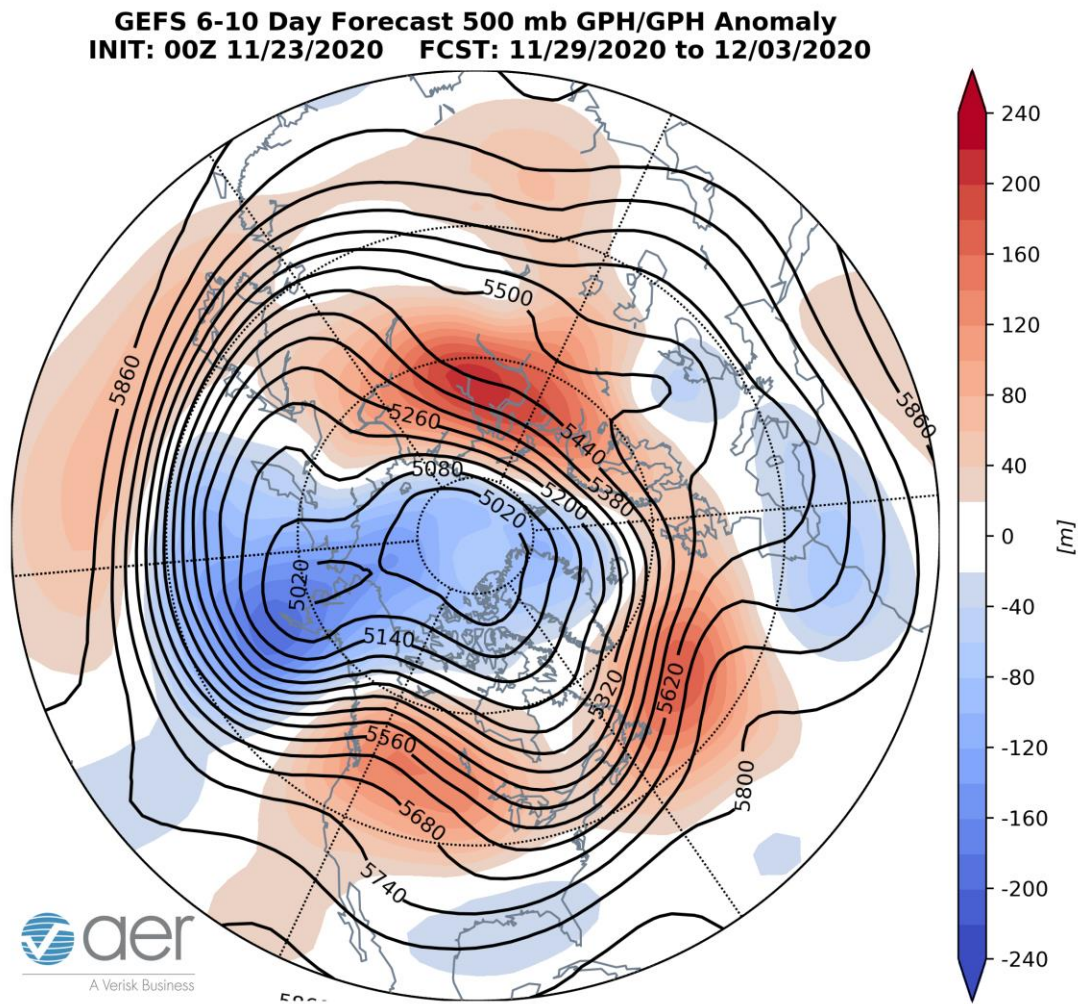


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 29 November – 3 December 2020. The forecasts are from the 00z 23 November 2020 GFS ensemble.

Persistent ridging/positive geopotential height anomalies are predicted to dominate Northern Europe with troughing/negative geopotential height anomalies in Southern Europe (Figures 5). This pattern favors normal to above normal temperatures across much of Northern Europe with normal to below normal temperatures in Northwestern and Central Europe including the UK (Figure 6). Persistent ridging/positive geopotential height anomalies centered in Western Siberia are predicted to dominate Asia with only localized troughing/negative geopotential height anomalies in Southwestern Asia and Eastern Siberia this period (Figure 5). This is predicted to favor widespread normal to

above normal temperatures across much of Asia but especially Northern Asia with normal to below normal temperatures limited to parts of Western, Central and Eastern Asia and Eastern Siberia (**Figure 6**).

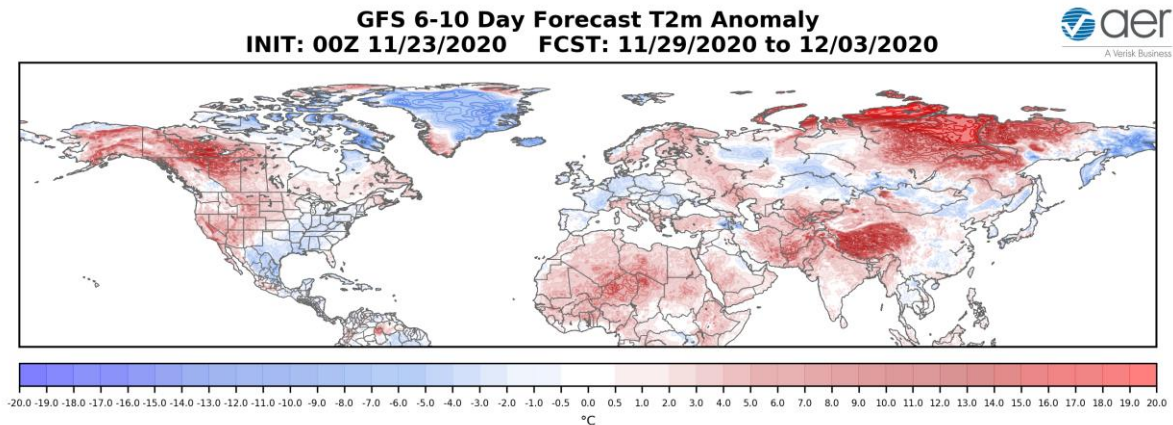


Figure 6. Forecasted surface temperature anomalies (°C; shading) from 29 November – 3 December 2020. The forecasts are from the 00Z 23 November 2020 GFS ensemble.

Predicted deepening troughing/negative geopotential height anomalies near the Aleutians will force ridging/positive geopotential height anomalies across western North America with more troughing/negative geopotential height anomalies in the Eastern US this period (**Figure 5**). This pattern is predicted to bring widespread normal to above normal temperatures across Alaska, Canada and the Western US with normal to below normal temperatures across the Eastern US (**Figure 6**).

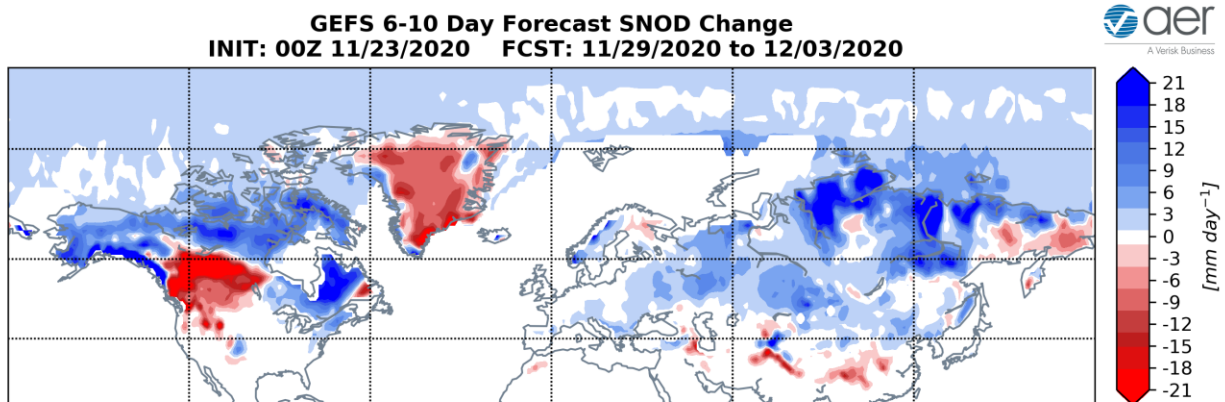


Figure 7. Forecasted snow depth changes (mm/day; shading) from 29 November – 3 December 2020. The forecasts are from the 00Z 23 November 2020 GFS ensemble.

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

temperatures will cause regionalized snow melt including the Himalayas (**Figure 7**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, much of Northern and Eastern Canada and possibly New England while warmer temperatures will cause possible snow melt in Western Canada (**Figure 7**).

11-15 day

As geopotential height anomalies are predicted to slowly rise 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 straddle neutral this period (**Figure 1**). With rising pressure/geopotential height anomalies spreading across Greenland (**Figure 8**), the NAO is predicted to finally drift back to neutral this period.

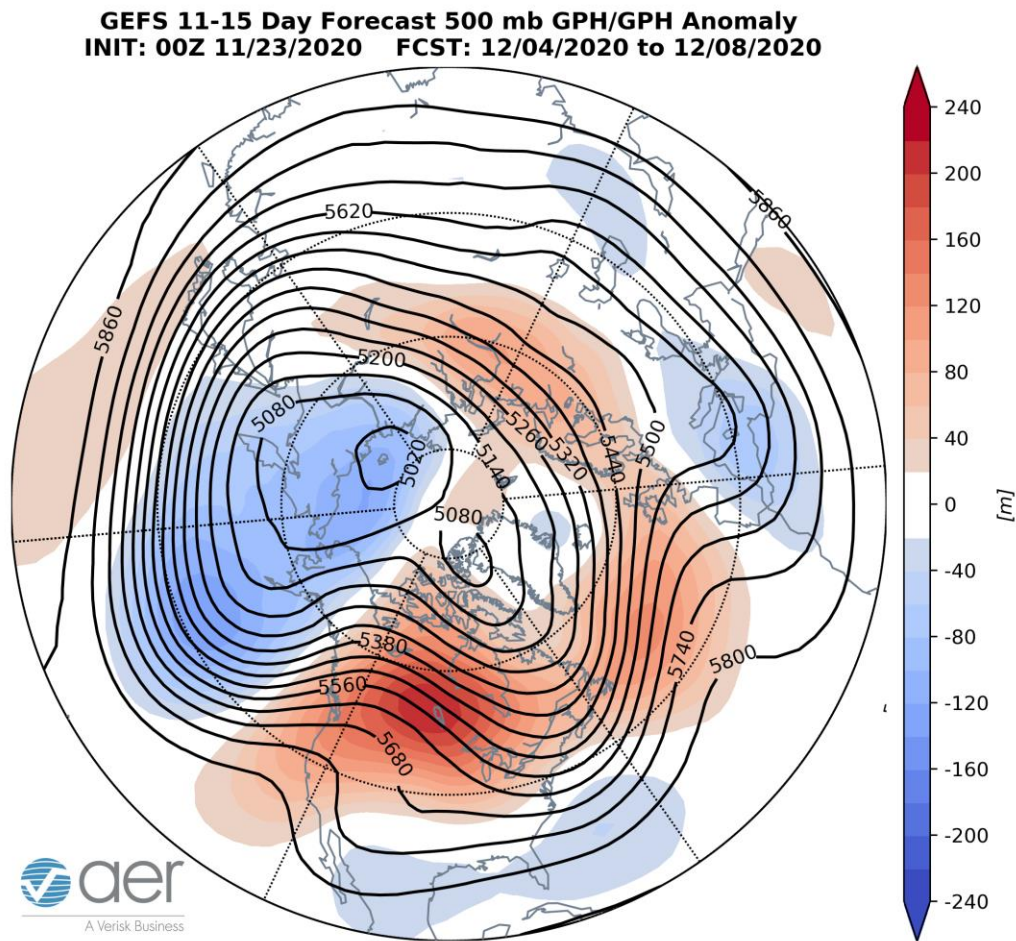


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 4 – 8 December 2020. The forecasts are from the 00z 23 November 2020 GFS ensemble.

European ridging/positive geopotential height anomalies are predicted to remain across Northern Europe allowing troughing/negative geopotential height anomalies to undercut the ridging across Southern Europe this period (**Figures 8**). The forecast is for normal to above normal temperatures across Northern Europe including the UK with seasonable temperatures across Southern Europe this period (**Figures 9**). Predicted persistent ridging/positive geopotential height anomalies focused over Northern Asia is predicted to become focused on the Urals this period continuing to support troughing/negative geopotential height anomalies across Southwestern Asia and Eastern Siberia that extends south to East Asia this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across most of Northern and Central Asia with normal to below normal temperatures in Western Asia and Eastern Siberia that bleeds into East Asia (**Figure 9**).

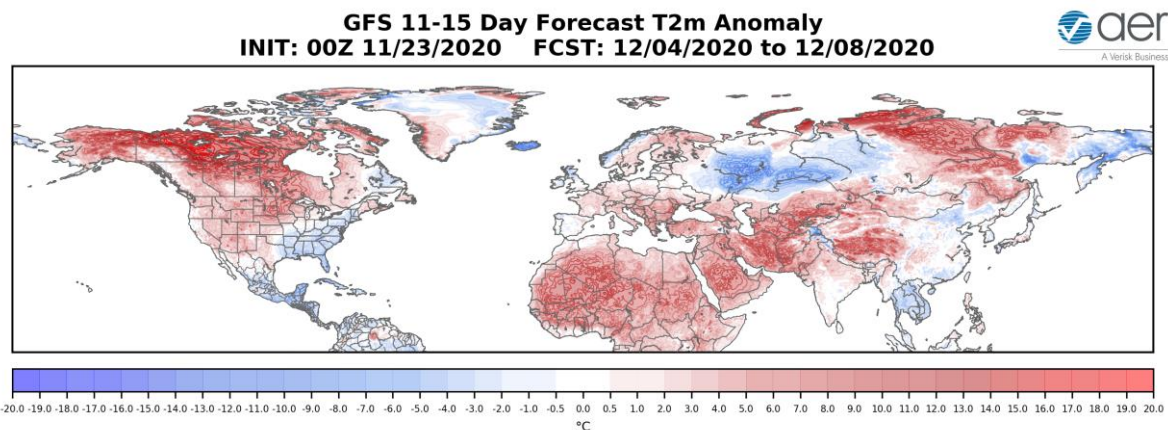


Figure 9. Forecasted surface temperature anomalies (°C; shading) from 4 – 8 December 2020. The forecasts are from the 00z 23 November 2020 GFS ensemble.

Predicted persistent troughing/negative geopotential height anomalies near the Aleutians will force ridging/positive geopotential height anomalies across western and central North America with more troughing/negative geopotential height anomalies in the Eastern US this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures for Alaska, Canada and the Western US with normal to below normal temperatures for the Eastern US and the Canadian Maritimes (**Figure 9**).

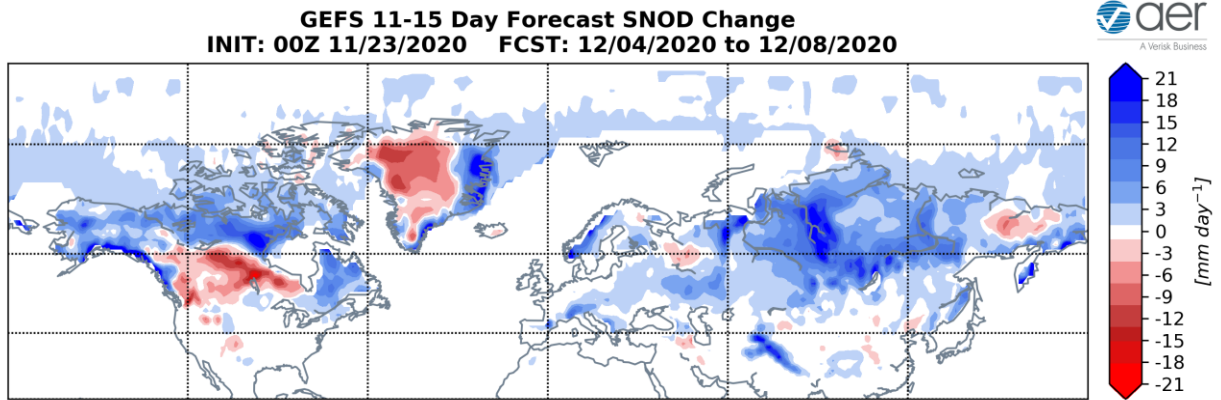


Figure 10. Forecasted snow depth changes (mm/day; shading) from 4 – 8 December 2020. The forecasts are from the 00z 23 November 2020 GFS ensemble.

Trouching and/or colder temperatures are predicted to support new snowfall across much of Northern Eurasia, the Alps and even possibly Eastern Europe (**Figure 10**). Trouching and/or colder temperatures are predicted to support new snowfall across Alaska, Northern and Eastern Canada and possibly New England while warmer temperatures will cause possible snow melt in Southwestern Canada (**Figure 10**).

Longer Term

30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal PCHs in the mid to upper troposphere but cold/negative PCHs in the stratosphere and lower troposphere (**Figure 11**). The cold/negative stratospheric PCHs are predicted to continually strengthen in the stratosphere through late-November but could weaken in early December (**Figure 11**).

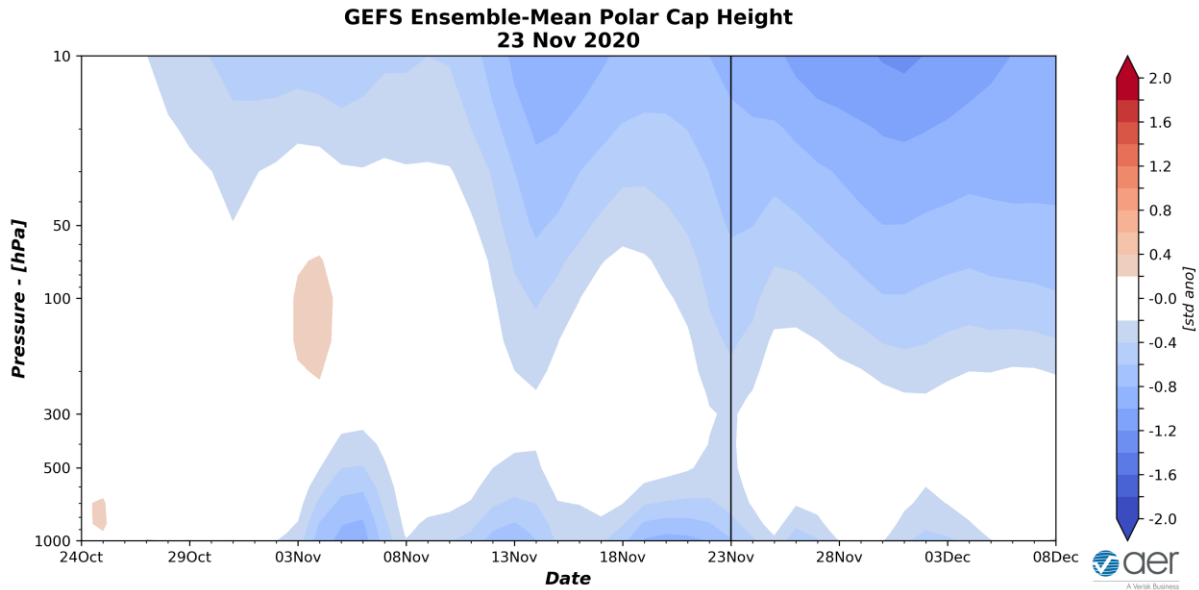


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 23 November 2020 GFS ensemble.

Cold/negative PCHs in the lower troposphere are predicted to persist through the end of November consistent with the predicted positive AO this week (**Figure 1**). However, the forecast for the first week of December is for the lower troposphere PCHs to turn normal and could signal a return to neutral AO next week. I still believe there could be volatility in the PCH forecast that have important long-term implications for troposphere-stratosphere coupling.

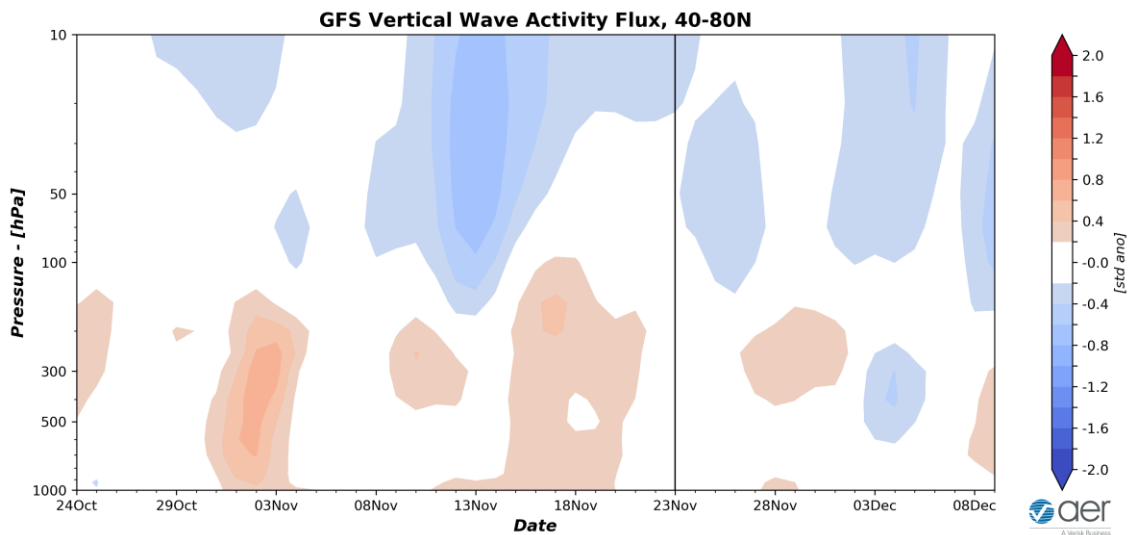


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 23 November 2020 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport forecasts are showing quiet period of WAFz in the troposphere but especially the stratosphere over the next two weeks (**Figure 12**). The lack of active WAFz is allowing the stratospheric PV to remain anomalously strong.

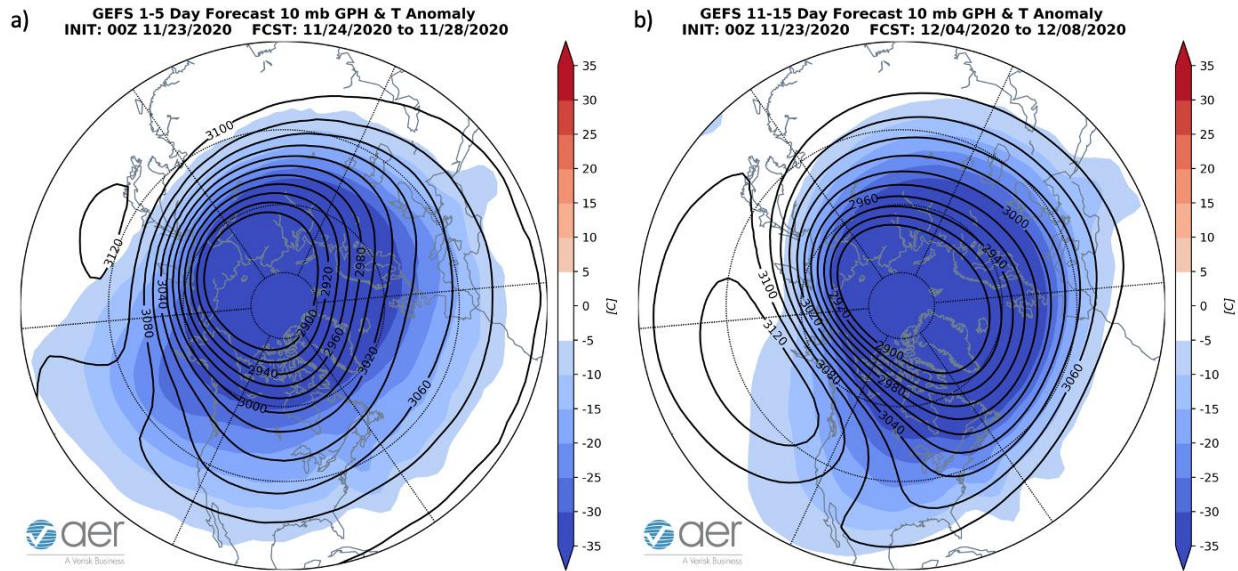


Figure 13. (a) Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 24 –28 November 2020. (b) Same as (a) except forecasted averaged from 4 – 8 December 2020. The forecasts are from the 00Z 23 November 2020 GFS model ensemble.

The PV is currently centered near the North Slope of Siberia but is predicted to slowly drift back to near the North Pole (**Figure 13**). Currently there are no signs of any weakening of the PV, however, the GFS for next week is predicting a stretching of the PV and could be suggestive of some upcoming minor disruption of the PV.

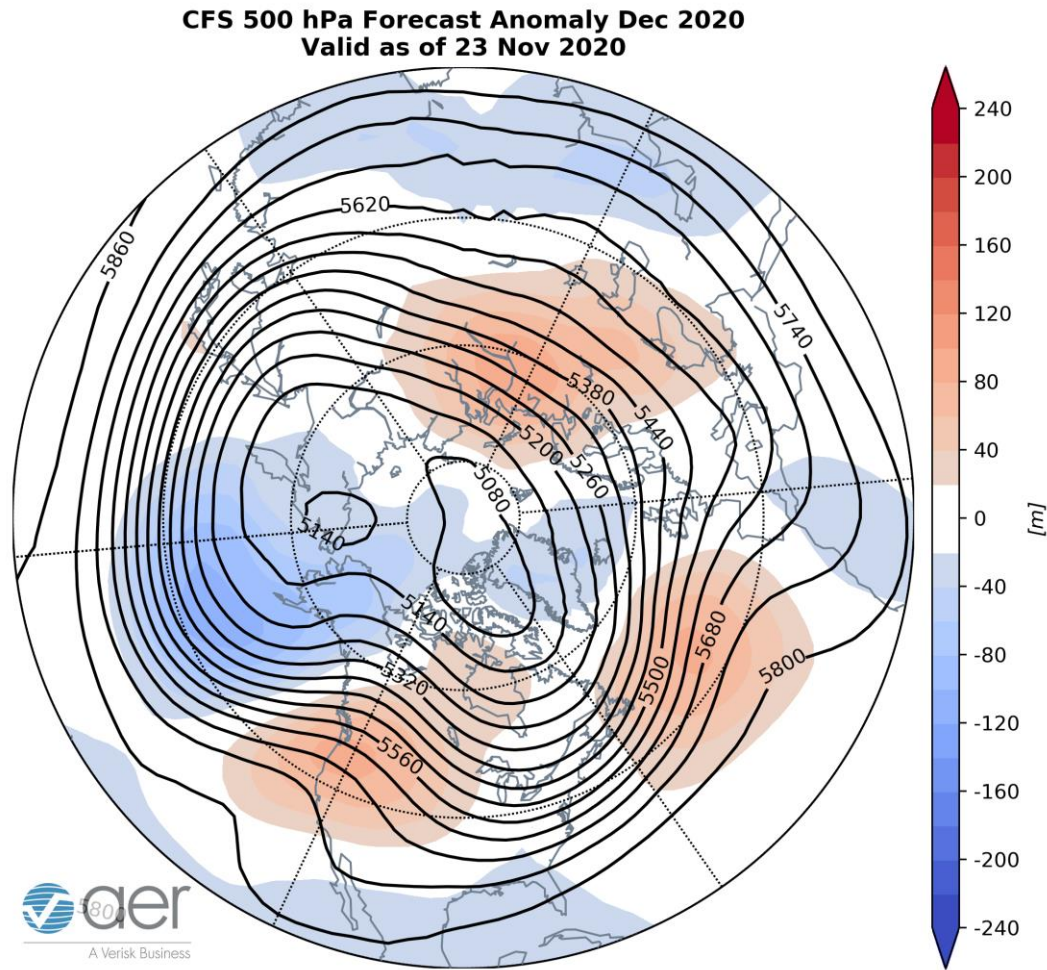


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for December 2020. The forecasts are from the 00Z 23 November 2020 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) forecast for December from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging in the central North Atlantic, the Urals and western North America with troughing in Western Europe, East Asia, the Dateline, Alaska and the Eastern US (**Figure 14**). This pattern favors relatively warm temperatures for Northern and Eastern Europe, Northern and Western Asia and much of North America with seasonable to relatively cold temperatures for Western Europe, Eastern Siberia, Southern and Eastern Asia and the Southeastern US (**Figure 15**). This is a big if, but if the CFS forecast for December is close to being correct there is increasing risk for more anomalous cold in central and eastern North America.

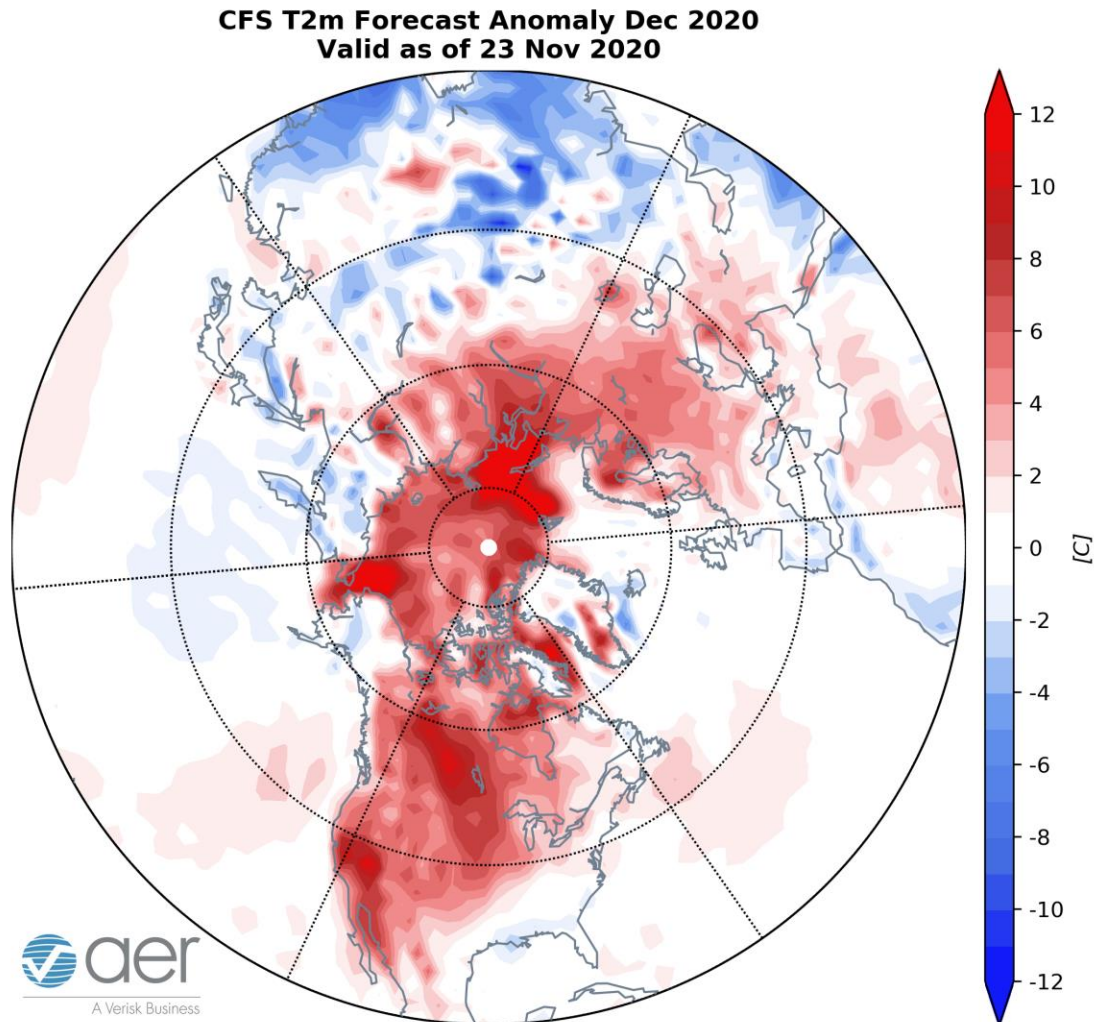


Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for December 2020. The forecasts are from the 00Z 23 November 2020 CFS.

Surface Boundary Conditions

Arctic sea ice extent

Arctic sea ice continues to grow but currently remains well below normal. Negative sea ice anomalies exist continuously from Alaska to East Siberia (**Figure 16**). However the largest negative sea anomalies are now focused in the Barents-Kara Seas. Below normal sea ice in the Barents-Kara seas favor 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, Beaufort and Bering seas may favor colder temperatures across North America but has not been shown to weaken the PV.

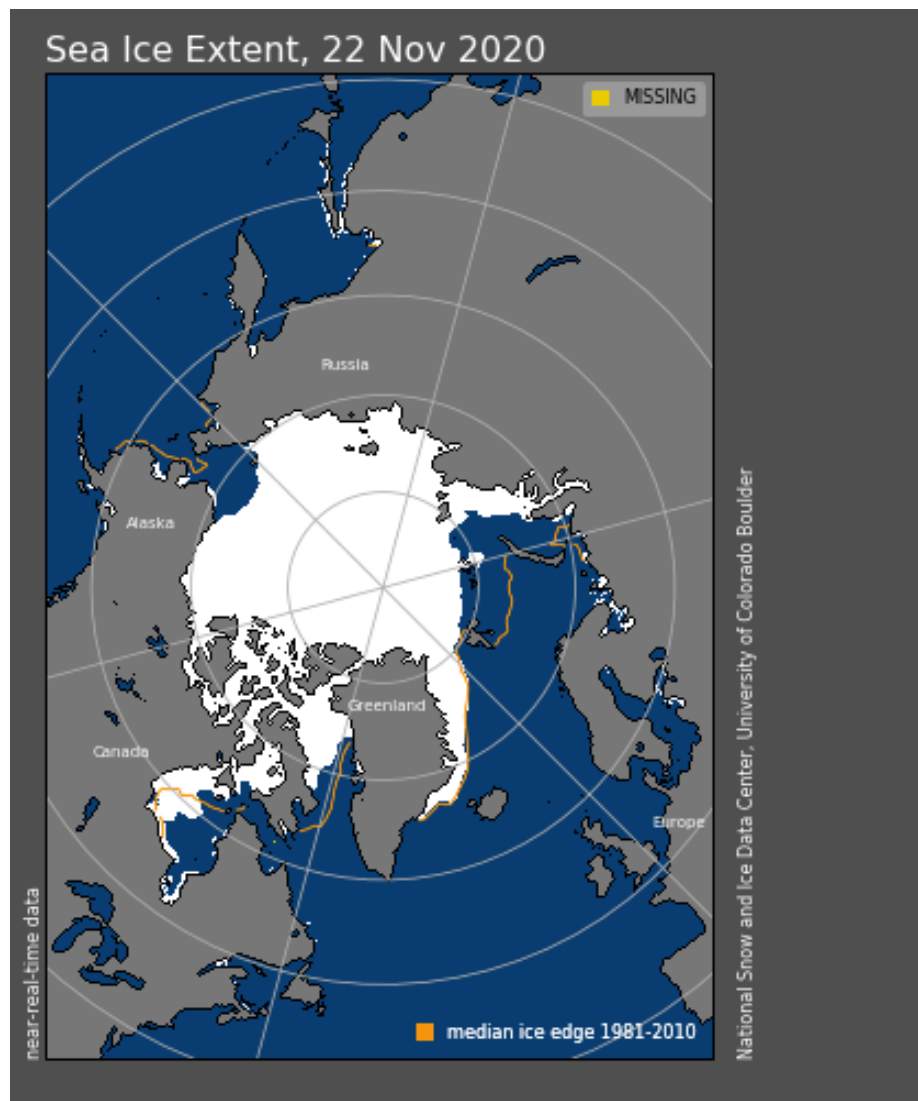


Figure 16. Observed Arctic sea ice extent on 22 November 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies remain negative and we have now entered moderate La Niña conditions (**Figure 14**) and La Niña is expected to persist through the fall and could even be moderate to strong this 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.

SST Anomaly - Week Ending 21 Nov 2020

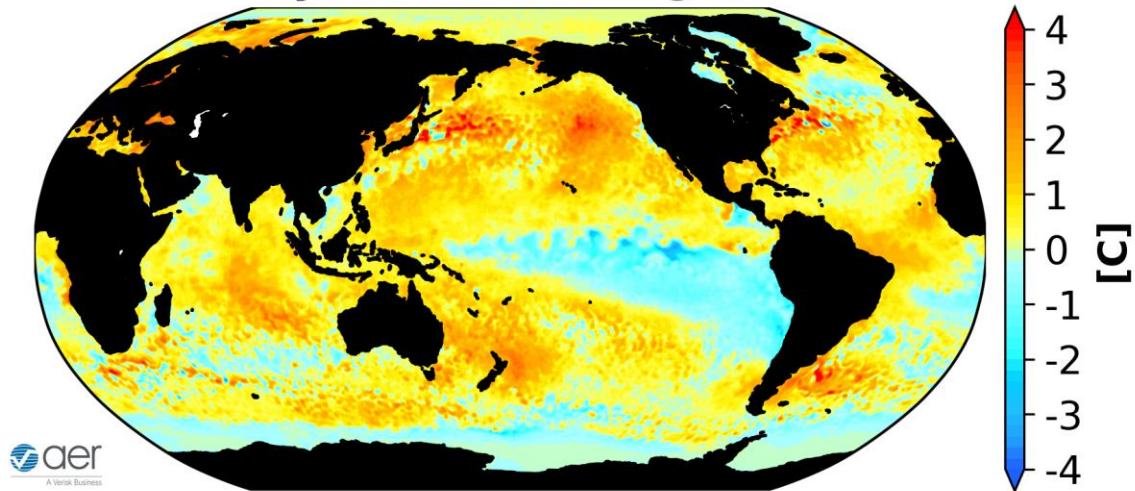


Figure 17. The latest weekly-mean global SST anomalies (ending 21 November 2020). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase three (**Figure 15**). The forecasts are for the MJO to quickly weaken where no phase is favored. MJO phase three favors troughing across Alaska and Northern Canada with ridging across the US. The MJO could be contributing to the short term pattern across North America.

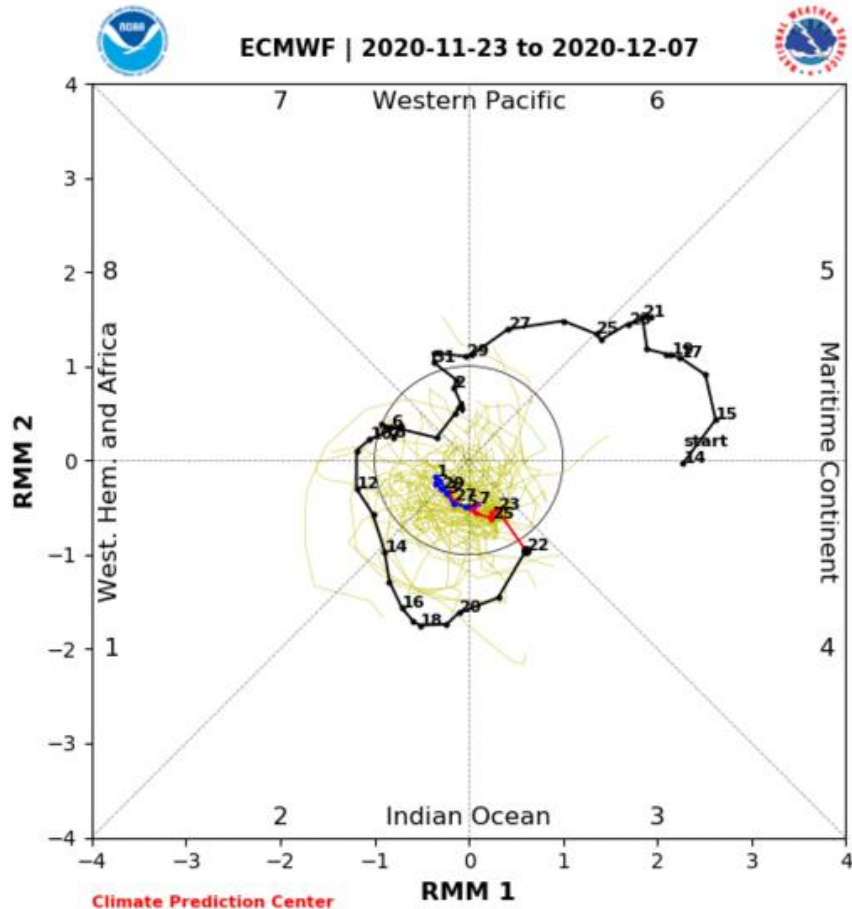


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 23 November 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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 rapidly over the past week across Eurasia and is currently 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.

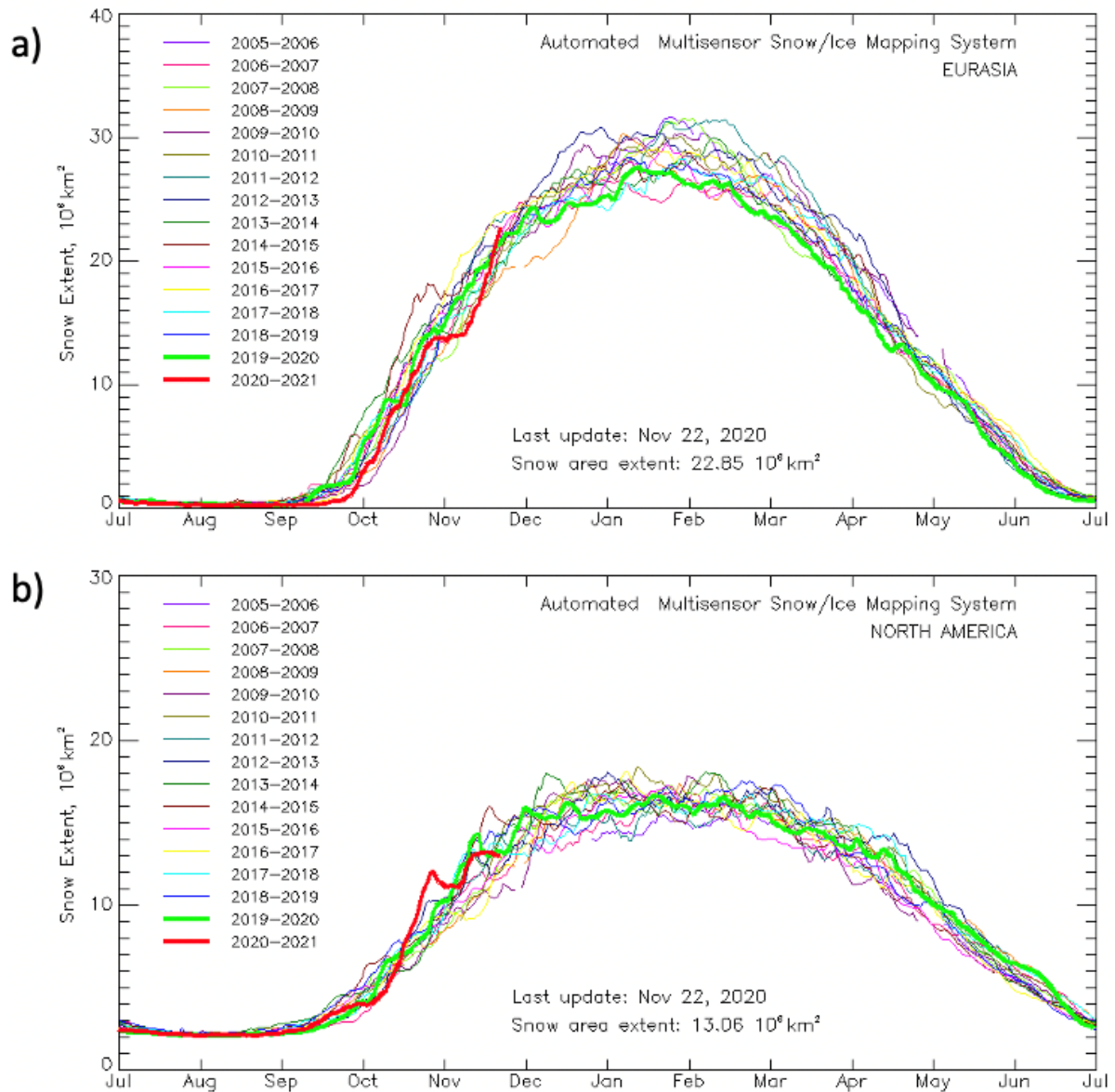


Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 22 November 2020. Image source:

https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover has stalled and is now 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.