Arctic Oscillation and Polar Vortex Analysis and Forecasts

November 16, 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 remain positive over the next week before turning neutral to slightly negative next week.
- The current positive AO is reflective of mostly negative pressure/geopotential height anomalies across the Arctic especially in the Central 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 to negative next week as pressure/geopotential height anomalies are predicted to trend more positive the next two weeks.

- This week, ridging/positive geopotential height anomalies with normal to above normal temperatures are predicted to dominate Europe including the United Kingdom (UK). However during week two 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 temperatures from Central and Western Asia to filter into Eastern Europe.
- The predicted general pattern the next two weeks across Asia is ridging/positive geopotential height anomalies with normal to above normal temperatures centered near the Urals and extending east across much of Northern and Eastern Asia with troughing/negative geopotential height anomalies with near seasonable to even below normal temperatures in Southwestern Asia. Next week the forecast is for the colder temperatures to filter into Eastern Asia as well.
- The predicted general pattern the next two weeks 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 Canada.
- In the Impacts section I discuss what I am watching for hints in the future behavior of the polar vortex (PV).

Impacts

If you are interested in winter weather this is crunch time and if you are a winter weather enthusiast, at least in my mind things are looking up (and if you are a meteorologist that is something you should be doing often anyway).

I do think that we are entering a very critical period for the winter, but the signals are mixed at best and I expect quite a bit of volatility from the numerical weather prediction models in the coming weeks. The polar cap geopotential height anomalies (PCHs) with negative/cold PCHs in the lower troposphere and the same in the stratosphere into the foreseeable future are close to completing a 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 for an extended period. However, since last week I think we have taken at least a small step back from the abyss (and if you like mild weather then the abyss is a good thing). That is because the GFS long range forecasts of a complete absence of high latitude blocking (high pressure) have so far failed to materialize this fall. And as I have mused previously, this could be related to the GFS not properly simulating the

atmosphere coupling to the Arctic ocean surface where lack of sea ice and the transfer of heat favor higher geopotential heights/pressure through the mid-troposphere.

Most importantly the GFS is predicting that the focus of high latitude blocking/high pressure will be near the Urals and Scandinavia (see **Figure 8**). This is the ideal location for exciting vertical energy transfer from the troposphere to the stratosphere necessary for perturbing the stratospheric PV. The GFS forecasts for the vertical energy transfer (or WAFz) is so far underwhelming but I believe that there is a good chance that will change in the coming days and weeks if the GFS ensembles are close to being correct.

Some recent GFS runs have shown a stretching of the stratospheric PV with elongation towards North America at 10hPa (see **Figure i**). These events develop relatively quickly and are relatively short lived but can deliver anomalous cold weather east of the Rockies across North America. However, we defined these events at 100hPa (Kretschmer et al. 2018) and looking at ECMWF forecasts 100hPa do not suggest such a stretching event (see Frei Berlin 100hPa). Still, I think the risk of such an event remains, but it is far from obvious.

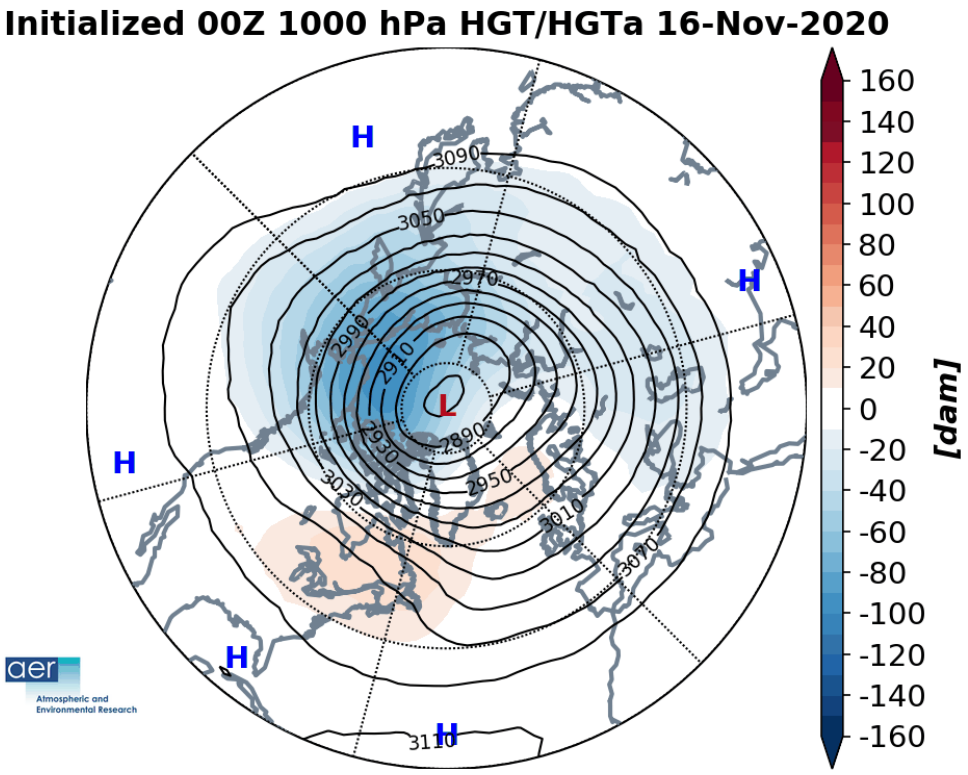

Figure i. Forecasted 10 mb geopotential heights (dam; contours) and anomalies (°C; shading) across the Northern Hemisphere for 16 –2 December 2020.

Looking instead at the longer range 500 hPa, that pattern is looking much more favorable for a more substantial disruption of the PV rather than exciting a PV stretching. By the end of November, the two main features across the Northern Hemisphere (NH) consist of ridging/high pressure centered near Scandinavia and troughing/low pressure near the Dateline. There is also a more minor feature of troughing/low pressure in the North Atlantic. This is either a wave one or wave two pattern that is also reminiscent of the tripole pattern in Figure 1 of Cohen and Jones 2012. Both wave one and wave two can have a lasting impact on the stratospheric PV with wave one favoring a displacement and wave two a split. The impacts from a stretched PV are more localized with the cold focused in eastern North America but especially a PV split can have impacts on a much larger and persistent scale delivering severe winter weather to East Asia, Europe and the US.

There are lots of caveats – first the GFS has to be correct in its forecast and the pattern needs to persist. And as I discuss below the EPS offers a different scenario but I consider all forecasts beyond a week, forecasts of low confidence regardless of the model. But if at a minimum those two conditions verify then a meaningful disruption of the PV becomes increasingly likely. Also keep in mind that this is a drawn-out process and the weather impacts will not be felt for many weeks even months to come.

I know many people especially in the UK that get most excited about Greenland blocking/high pressure, but Greenland blocking is not known for disrupting the PV and development now of Greenland blocking will help to maintain a strong PV in the long run. I do believe the development of the Greenland blocking last fall contributed to the spin up of the PV last winter.

I did look at the latest EPS (ECMWF ensembles) out to day ten and the forecast is for ridging in Siberia. That is not the pattern you want to see for a disruption of the PV bit it is one run of one model. But the latest EPS is just one more data point of - what is going on in Siberia! I do believe that cold temperatures are conducive to disrupting the PV and I still can't wrap my head around how warm this year has been across much of Eurasia but especially Siberia. This temperature time series tweeted from Robert Rhode of Berkeley Earth is mind boggling (see **Figure ii**). You have to wonder if it is a tipping point of sorts. So far this year, blocking in the Arctic has been suggestive of a cold pattern across Siberia and the GFS keeps predicting cold for Siberia but it is like "Waiting for Godot" and never actually happens. If widespread cold across Siberia ever does return, I will be much more bullish of a more substantial disruption of the PV.

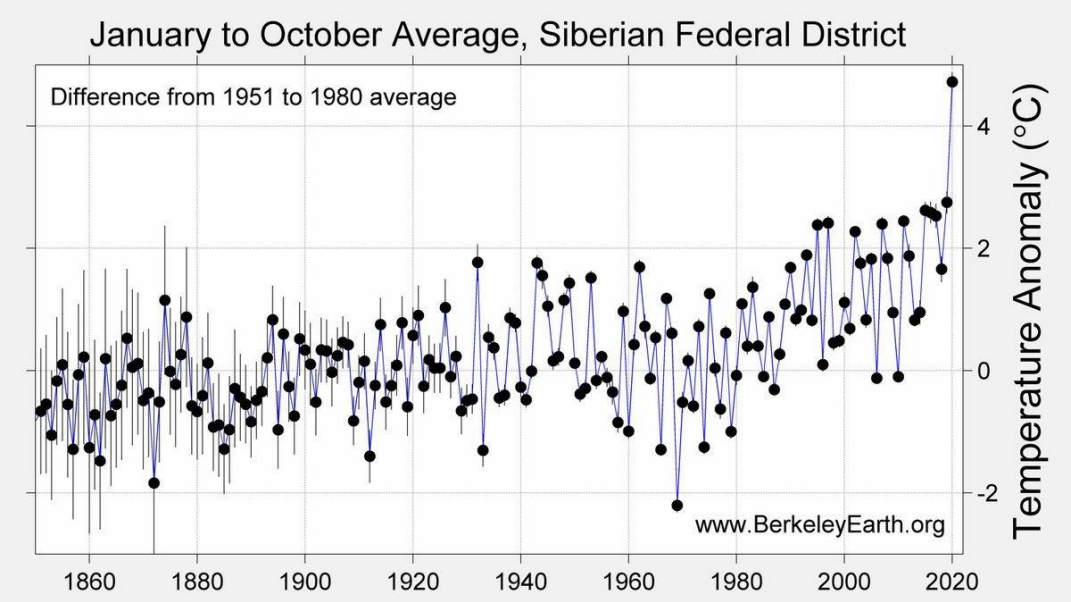

Figure ii. Time series of Siberian temperature anomalies for the calendar year from January to October from 1851 through 2020. Analysis from http://berkeleyearth.org/.

1-5 day

The AO is currently positive **(Figure 1**) with mostly negative geopotential height anomalies in 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.

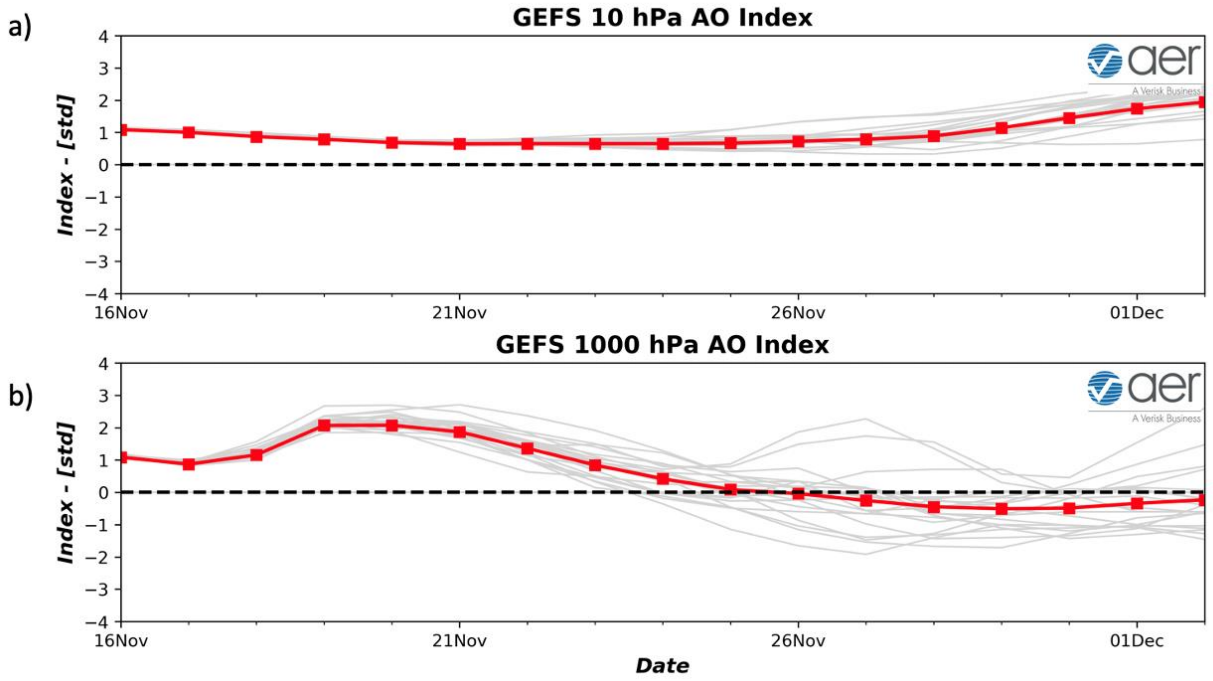

Figure 1. (**a**) The predicted daily-mean AO at 10 hPa from the 00Z 16 November 2020 GFS ensemble. (**b**)The predicted daily-mean near-surface AO from the 00Z 16 November 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given 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 in Europe centered near the Urals will support troughing/negative geopotential height anomalies in Central Asia and Eastern Siberia with more ridging/positive geopotential height anomalies in Eastern Asia (**Figure 2**). This pattern favors widespread normal to above normal temperatures for Western and Eastern Asia with near normal to slightly below normal temperature in Central Asia and parts of Eastern Siberia **(Figure 3**).

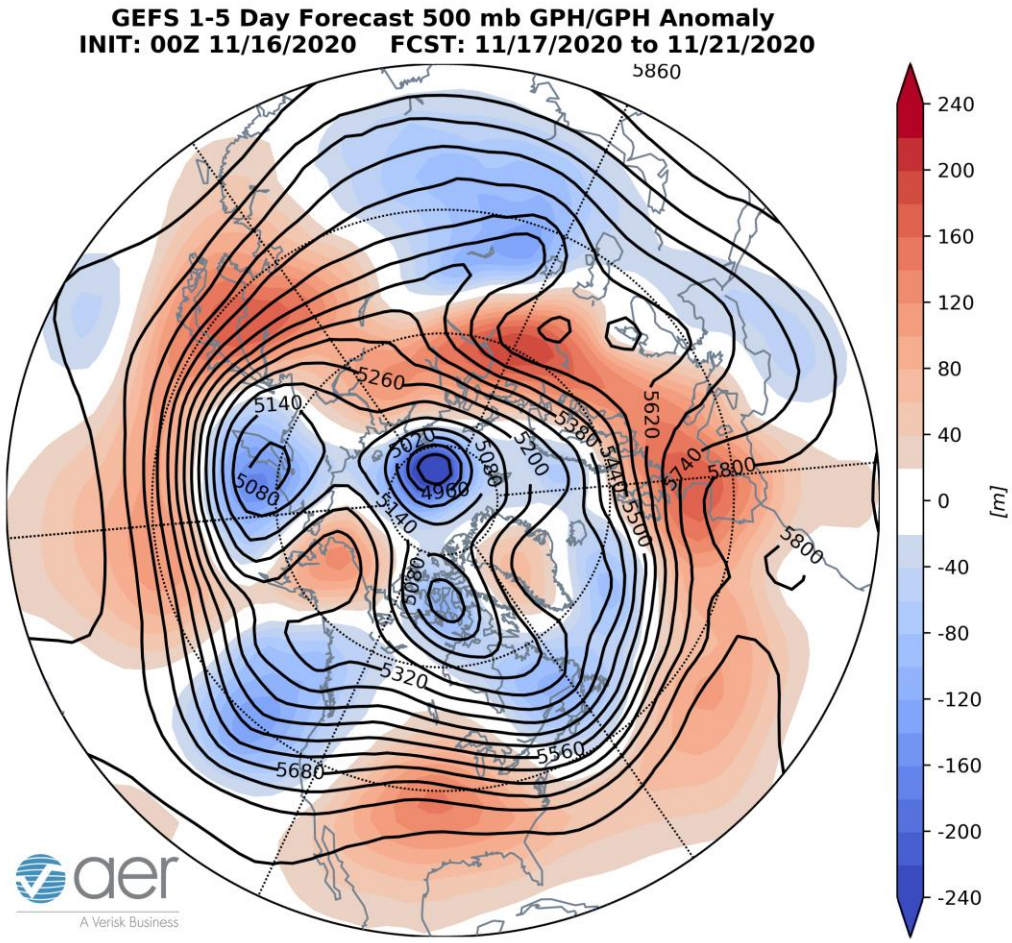

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 17 – 21 November 2020. The forecasts are from the 00z 16 November 2020 GFS ensemble.

This week ridging/positive geopotential height anomalies are predicted to stretch across Alaska, and the US lower 48 with troughing/negative geopotential height anomalies across Western and Eastern Canada and the US West Coast **(Figure 2).** This pattern is predicted to bring normal to above normal temperatures across Northern Alaska and the interior of the US Canada with normal to below normal temperatures for much of Canada, the US West and East Coasts **(Figure 3).**

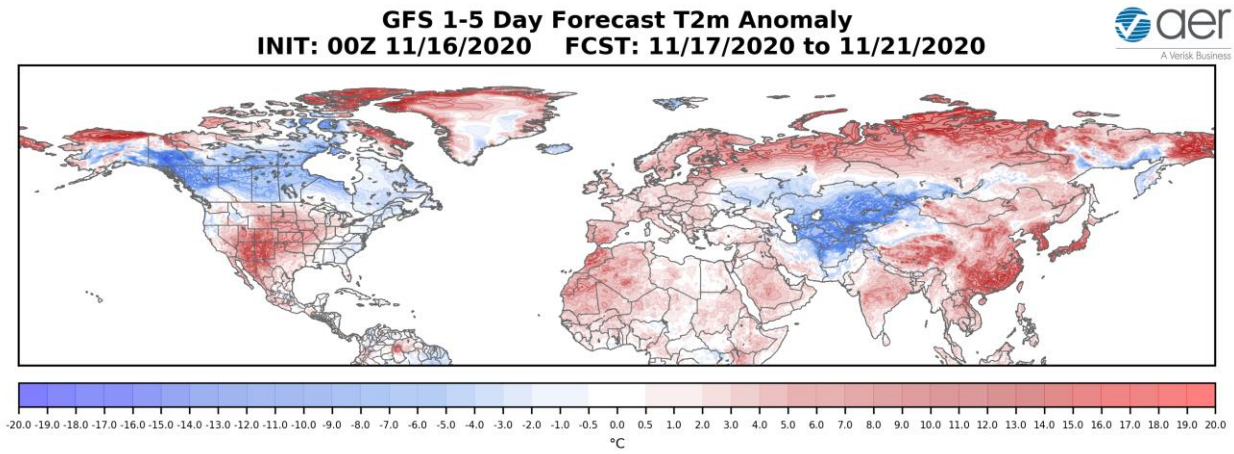

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 17 – 21 November 2020. The forecast is from the 00Z 16 November 2020 GFS ensemble.

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

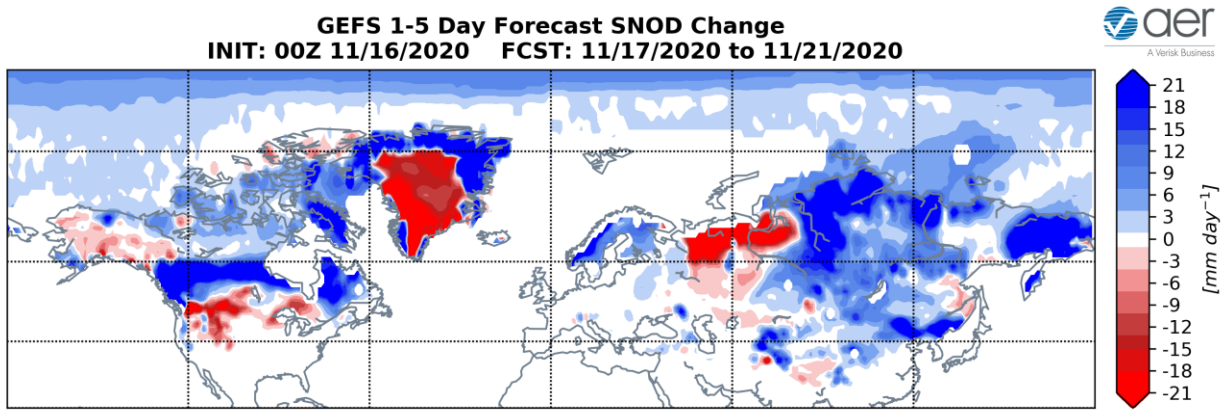

Figure 4. Forecasted snow depth changes (mm/day; shading) from 17 – 21 November 2020. The forecast is from the 00Z 16 November 2020 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to trend towards neutral next week **(Figure 1**) as positive geopotential height anomalies from northwest Eurasia spill into 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.

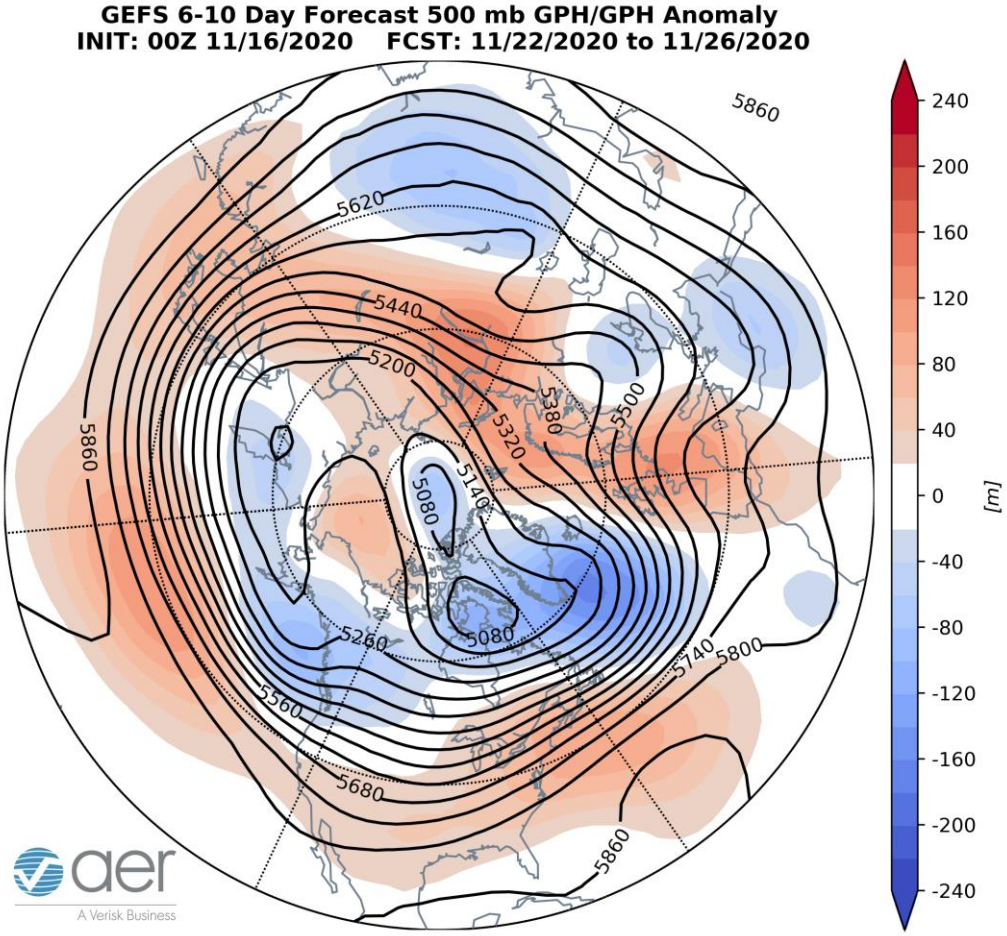

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 22 – 26 November 2020. The forecasts are from the 00z 16 November 2020 GFS ensemble.

Persistent ridging/positive geopotential height anomalies are predicted to dominate Central and Western Europe with troughing/negative geopotential height anomalies in Southeastern Europe (**Figures 5).** This pattern favors normal to above normal temperatures across much of Europe including the UK except for normal to below normal temperatures in Southeastern Europe (**Figure 6**). Persistent ridging/positive geopotential height anomalies centered near the Urals are predicted to anchor troughing/negative geopotential height anomalies in Central Asia and Eastern Siberia with more ridging/positive geopotential height anomalies in Eastern Asia this period

(**Figure 5**). This is predicted to favor widespread normal to above normal temperatures across Northern Western and Eastern Asia with normal to below normal temperatures limited to Central Asia and Kamchatka **(Figure 6**).

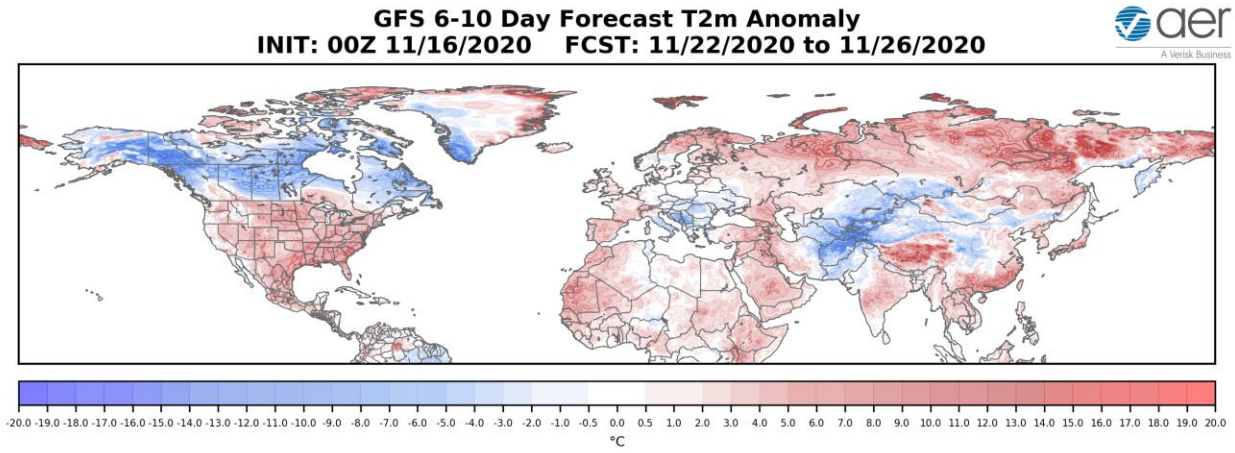

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 22 – 26 November 2020. The forecasts are from the 00Z 16 November 2020 GFS ensemble.

A zonal pattern is predicted this period with troughing/negative geopotential height anomalies across Alaska and Canada with ridging/positive geopotential height anomalies across the US but focused in the Eastern US this period **(Figure 5).** This pattern is predicted to bring widespread normal to below normal temperatures across Alaska and Canada with normal to above normal temperatures across the US **(Figure 6).**

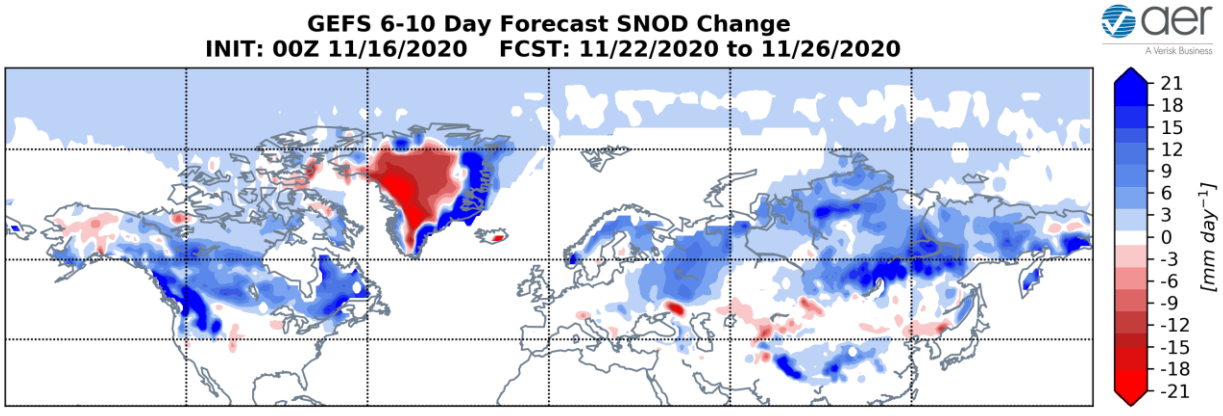

Figure 7. Forecasted snow depth changes (mm/day; shading) from 22 – 26 November 2020. The forecasts are from the 00Z 16 November 2020 GFS ensemble.

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

11-15 day

As positive geopotential height anomalies from Europe are predicted to push north into the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO should straddle neutral to slightly negative this period (**Figure 1**). With positive pressure/geopotential height anomalies spreading from Europe across Greenland (**Figure 8**), the NAO is predicted to finally drift into negative territory this period.

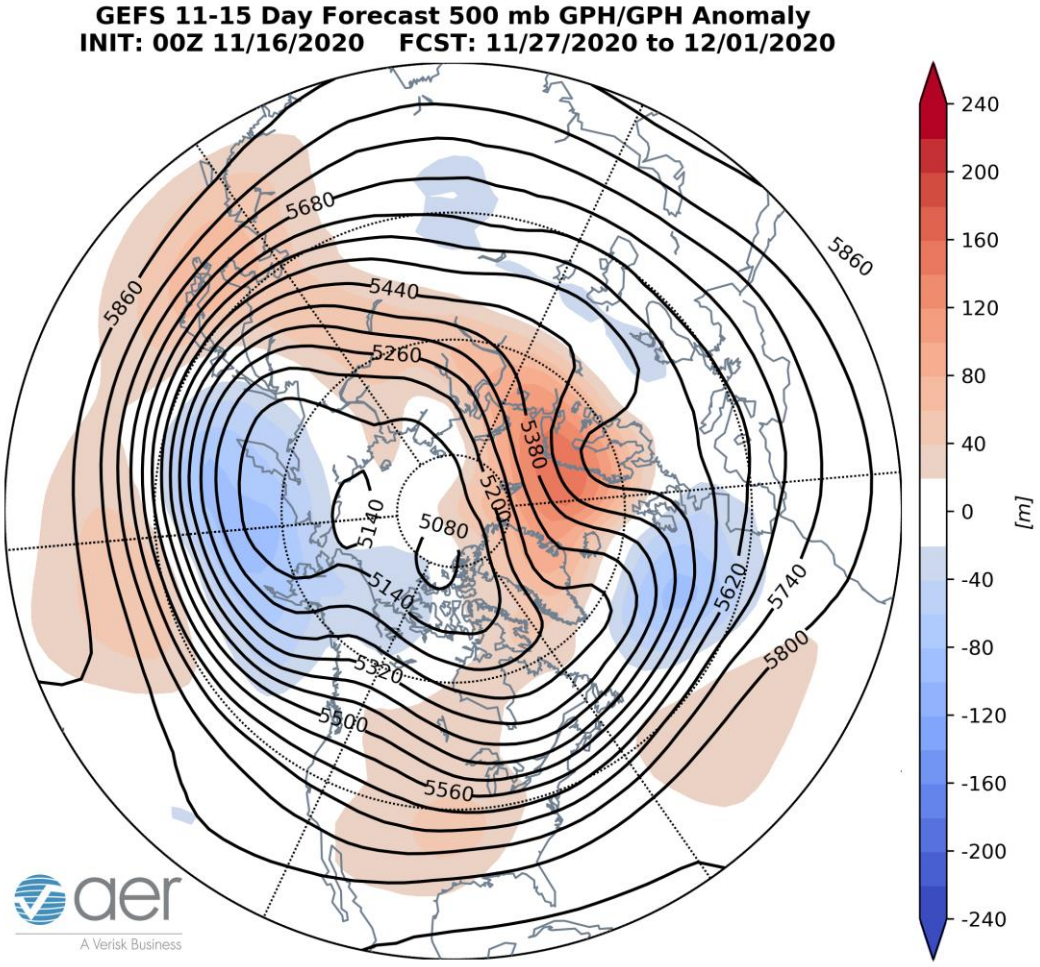

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 27 November – 1 December 2020. The forecasts are from the 00z 16 November 2020 GFS ensemble.

European ridging/positive geopotential height anomalies are predicted to push north towards the northern North Atlantic allowing some 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 normal to below normal temperatures bleeding into Southeastern Europe from Asia this period (**Figures 9**). Predicted persistent ridging/positive geopotential height anomalies focused over Northwest Asia will continue to support troughing/negative geopotential height anomalies across Central and Western Asia and Eastern Siberia with more ridging/positive geopotential height anomalies in East Asia this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across most of Northern and Western Asia with normal to below normal temperatures in Eastern Siberia and Central Asia that bleeds into East Asia (**Figure 9**).

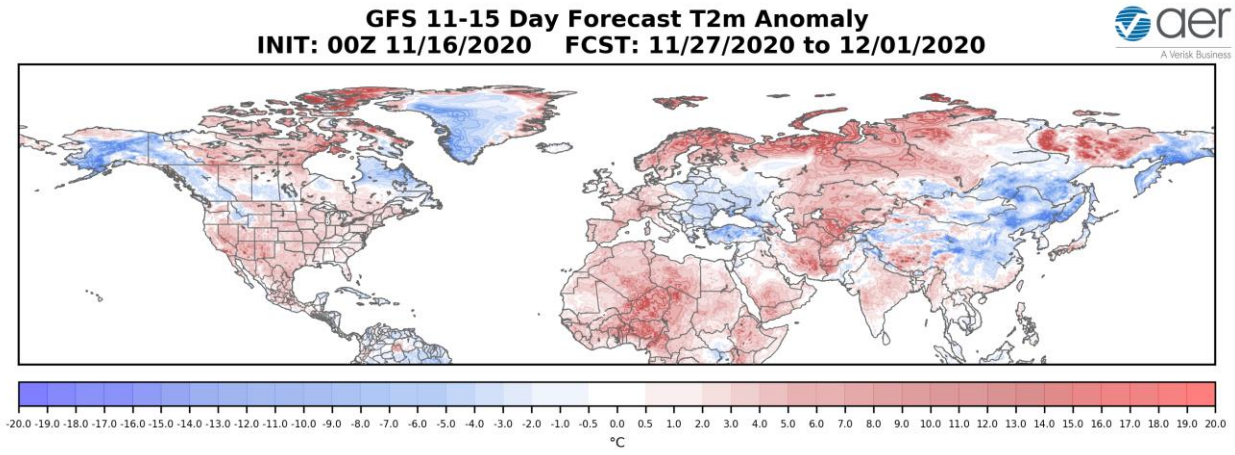

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 27 November – 1 December 2020. The forecasts are from the 00z 16 November 2020 GFS ensemble.

A mostly zonal flow is predicted to persist this period with ridging/positive geopotential height anomalies previously across the US Lower 48 with troughing/negative geopotential height anomalies across Alaska and Canada this period (**Figure 8**). This pattern favors normal to below normal temperatures for Alaska, Western and Eastern Canada with normal to above normal temperatures for much of the US and Central Canada (**Figure 9**).

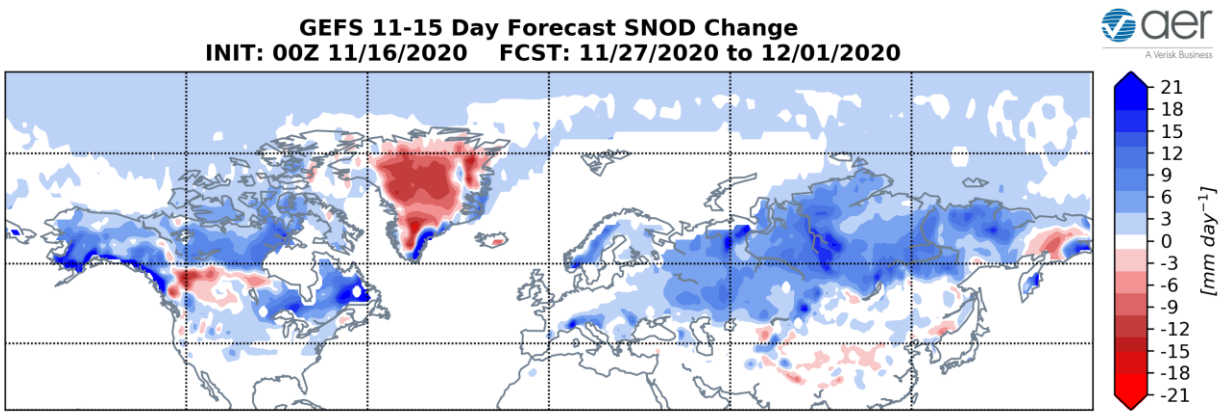

Figure 10. Forecasted snow depth changes (mm/day; shading) from 27 November – 1 December 2020. The forecasts are from the 00z 16 November 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across much of Northern Eurasia, the Alps and even possibly Eastern Europe (**Figure 10**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, much of Canada and possibly New England and the US Northern Plains 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 (**Figure 11**).

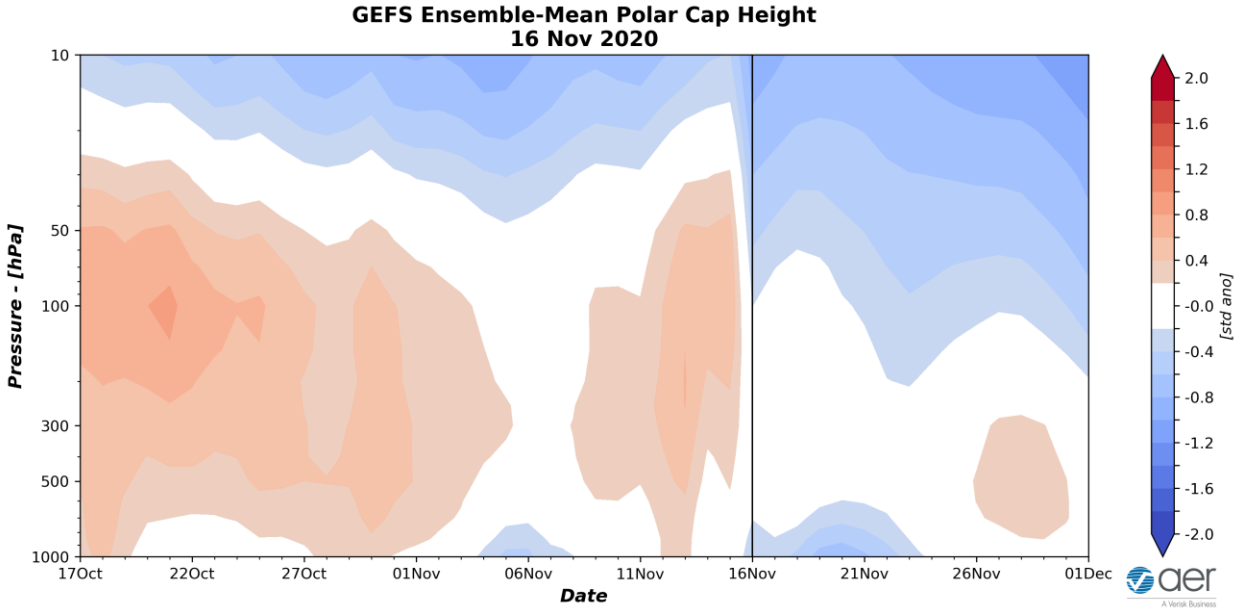

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 16 November 2020 GFS ensemble.

Cold/negative PCHs in the lower troposphere are predicted to spike this week consistent with the predicted positive AO this week (**Figure 1**). However, the forecast for next week is neutral to possibly weakly positive PCHs in the troposphere 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.

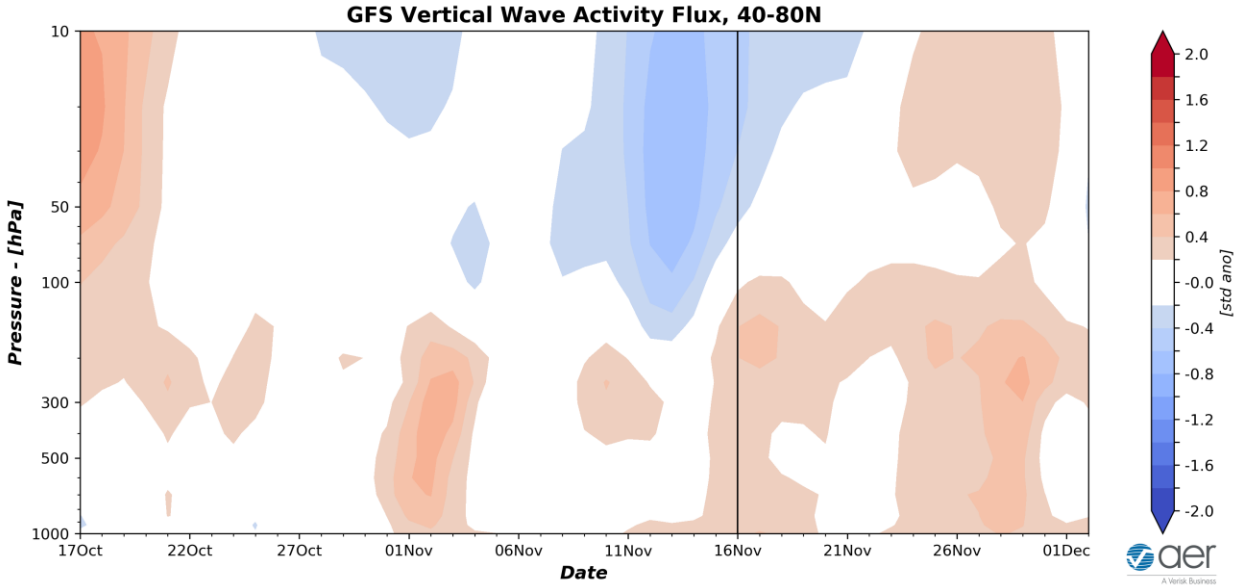

Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 9 November 2020 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows forecasts are finally showing more active WAFz in the troposphere and possibly the stratosphere over the next two weeks (**Figure 12**). If WAFz does enter the stratosphere later this month, it may begin to perturb the stratospheric PV.

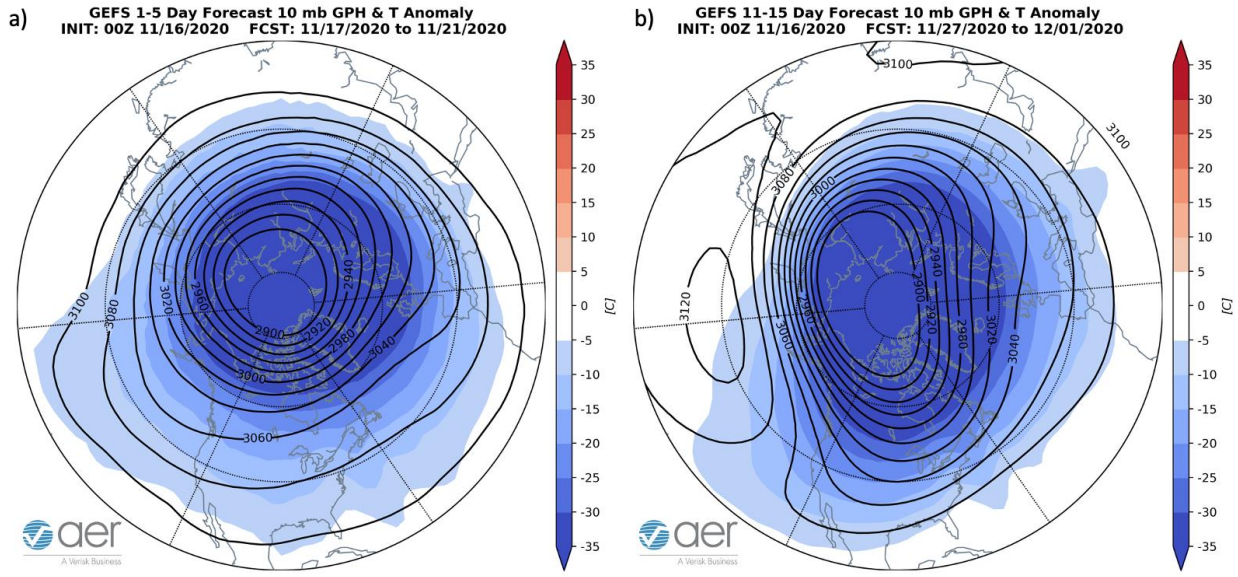

Figure 13. (**a**) Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 17 –21 November 2020. (**b**) Same as (a) except forecasted averaged from 27 November – 1 December 2020. The forecasts are from the 00Z 16 November 2020 GFS model ensemble.

However, in the meantime, the overall upcoming quieter period of WAFz in the stratosphere (**Figure 12**) will continue to support a strengthening PV. The PV is currently centered near the North Pole but is predicted to take up a position on the North Pacific side of the Arctic (**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 cold air pooling in North America.

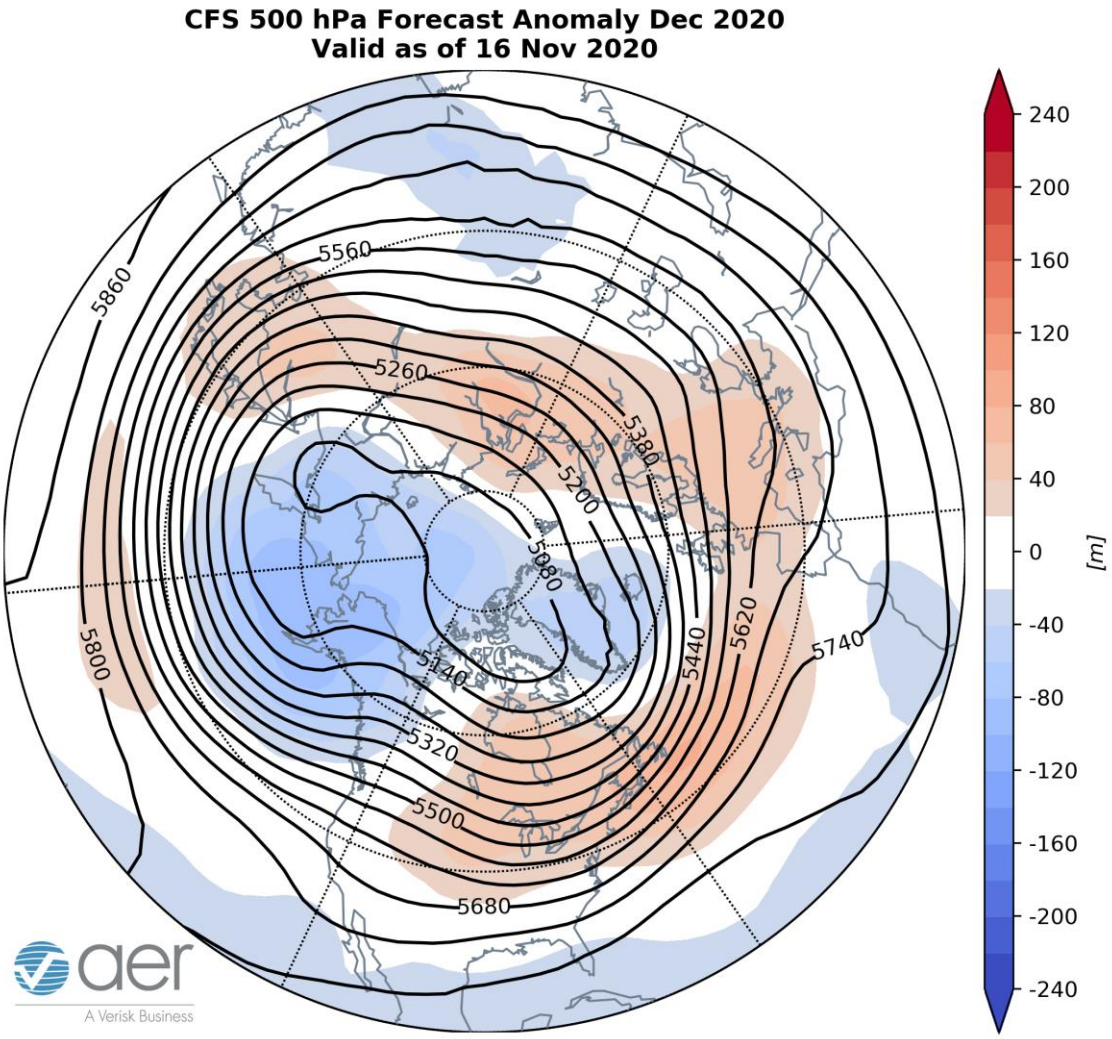

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for December 2020. The forecasts are from the 00Z 16 November 2020 CFS.

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 across Europe, East Asia and eastern North America with troughing in the eastern Mediterranean, Central Asia, Eastern Siberia, Alaska and Western Canada (**Figure 14).** This pattern favors relatively warm temperatures for much of Europe centered on Scandinavia, Northern and Eastern Asia and much of North America with seasonable to relatively cold temperatures for Southern Europe, Eastern Siberia, Southern Asia, Alaska, Northwestern Canada and the Canadian Maritimes (**Figure 15**).

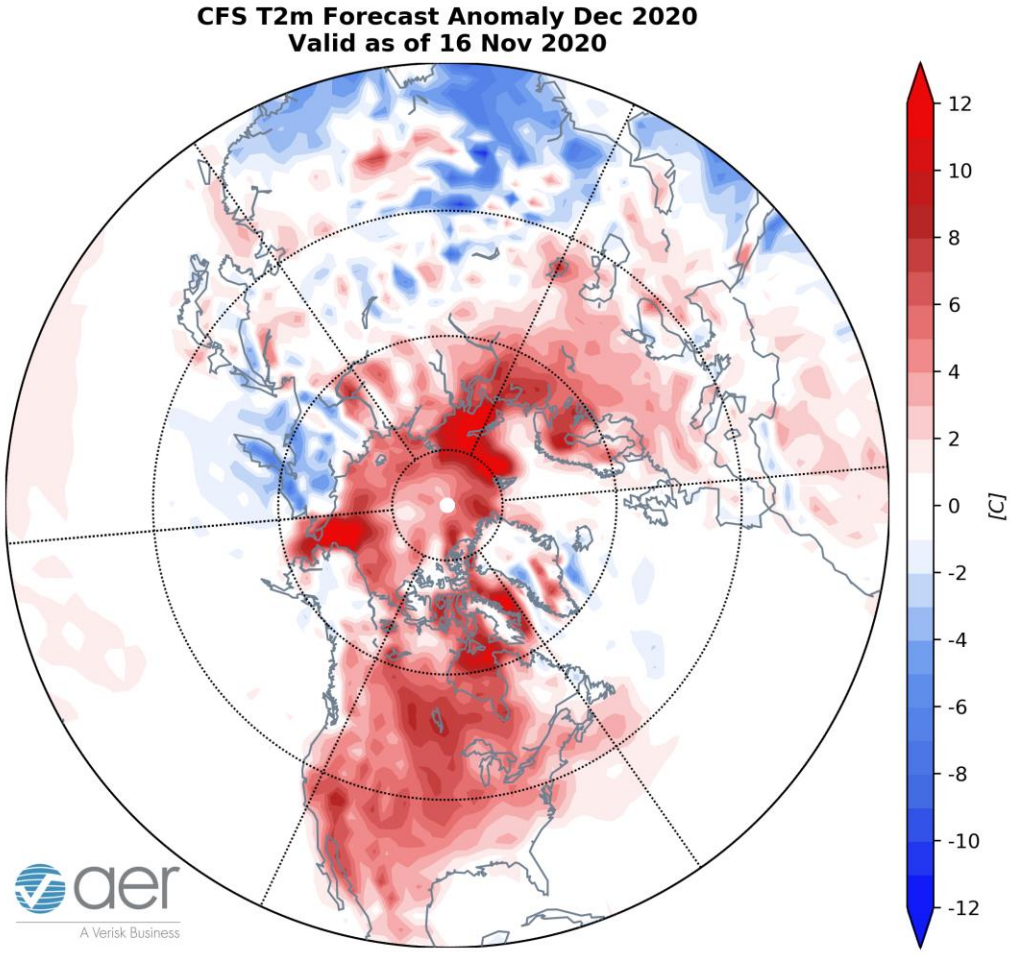

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for December 2020. The forecasts are from the 00Z 16 November 2020 CFS.

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.

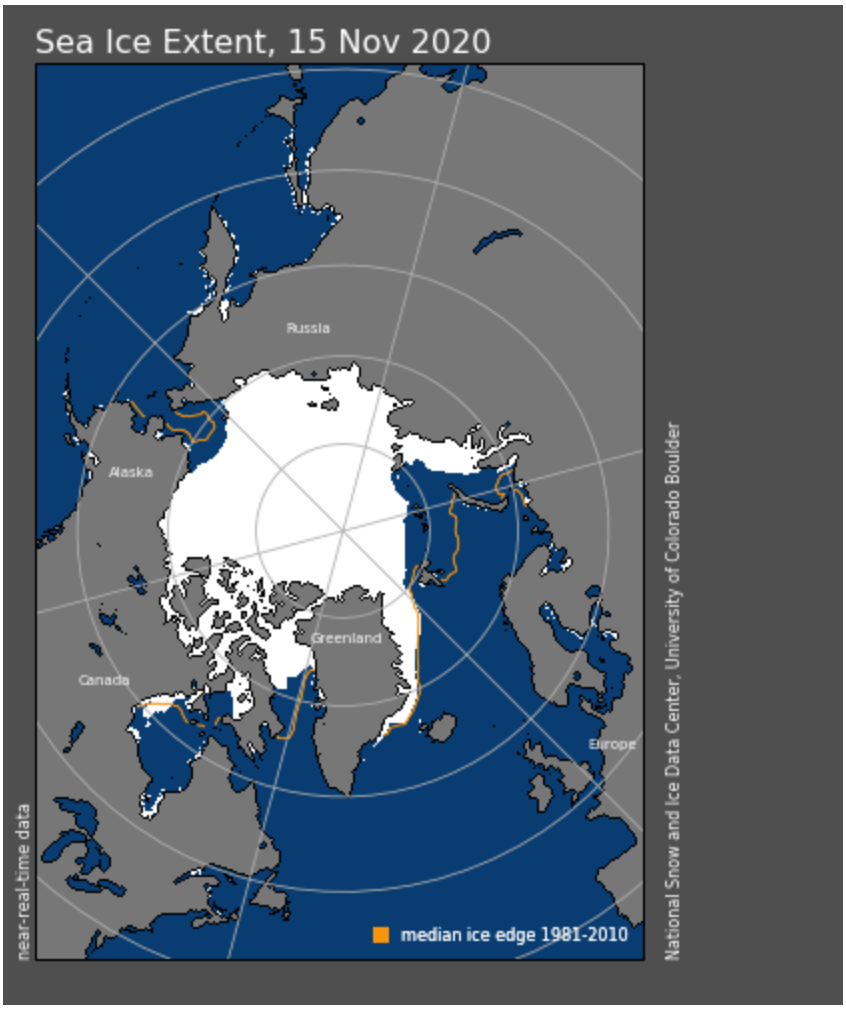

Figure 16. Observed Arctic sea ice extent on 15 November 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

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.

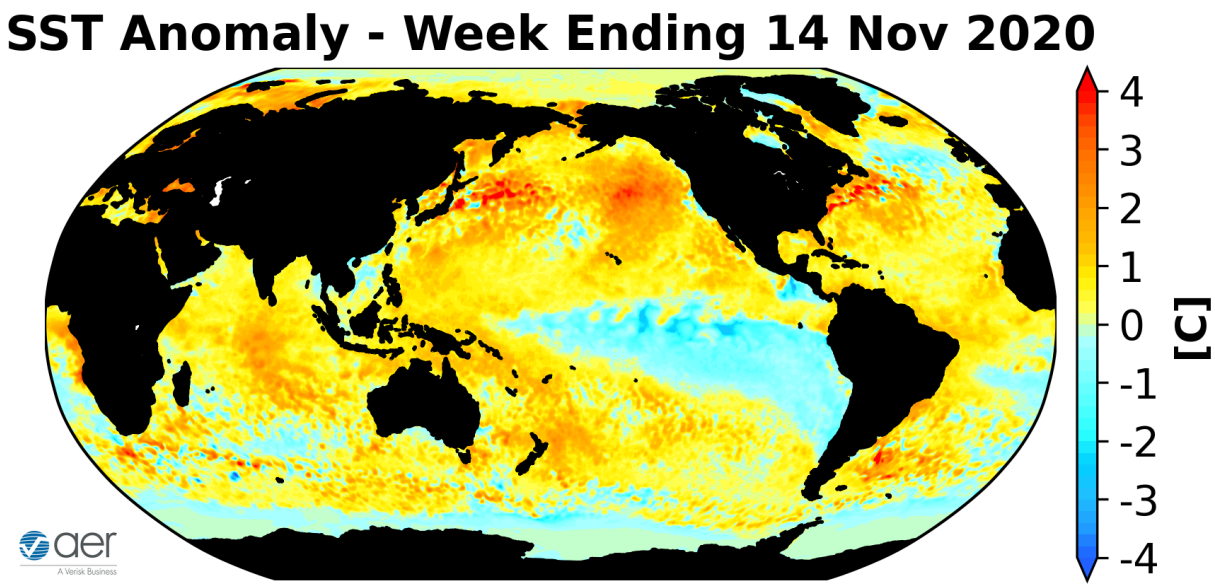

Figure 17. The latest weekly-mean global SST anomalies (ending 14 November 2020). Data from NOAA OI High-Resolution dataset.

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

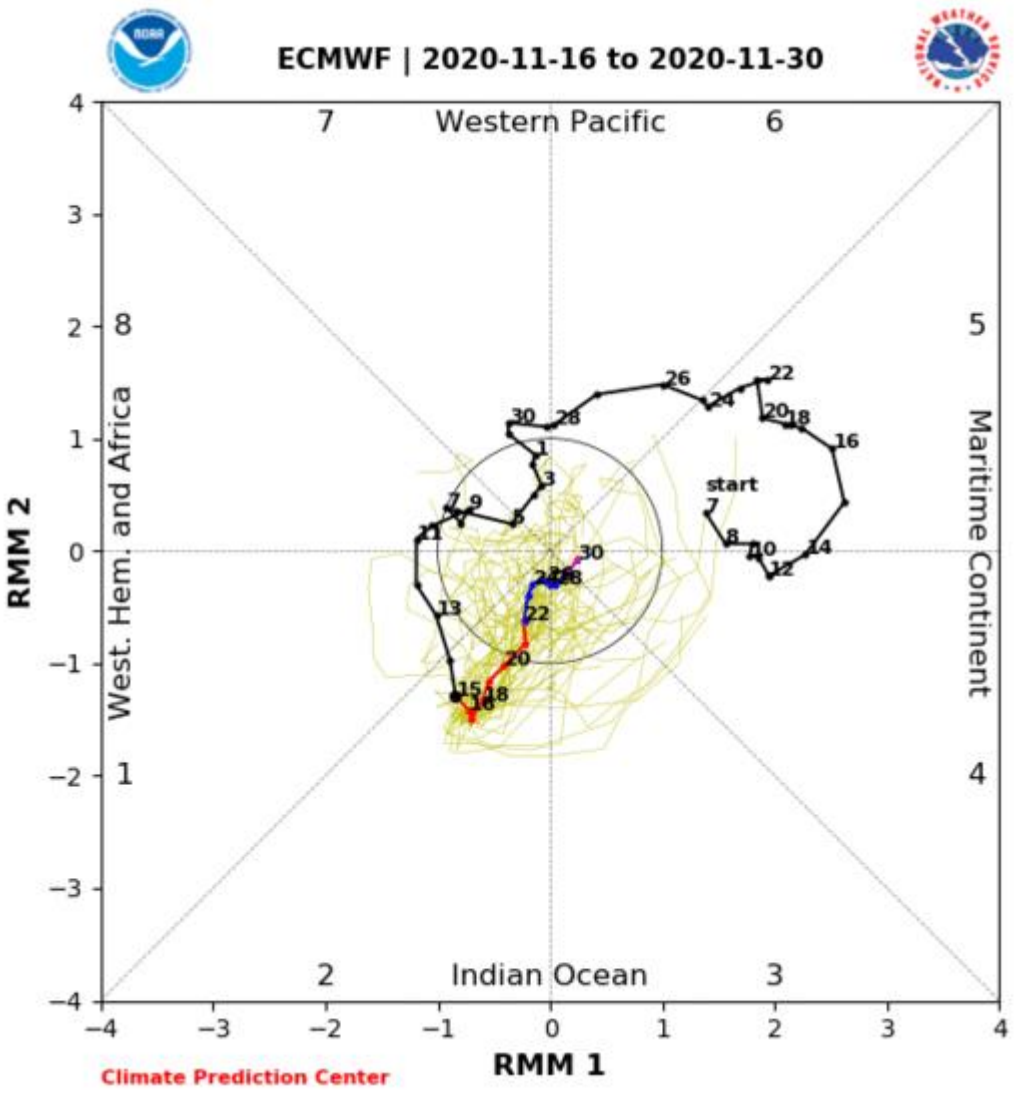

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 16 November 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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 advance has resumed over the past week across Eurasia but remains at the low end of decadal values for the date. Snow cover advance will likely continue to increase especially across Asia the next two weeks. Above normal snow cover extent in October, favors a strenghtened 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.

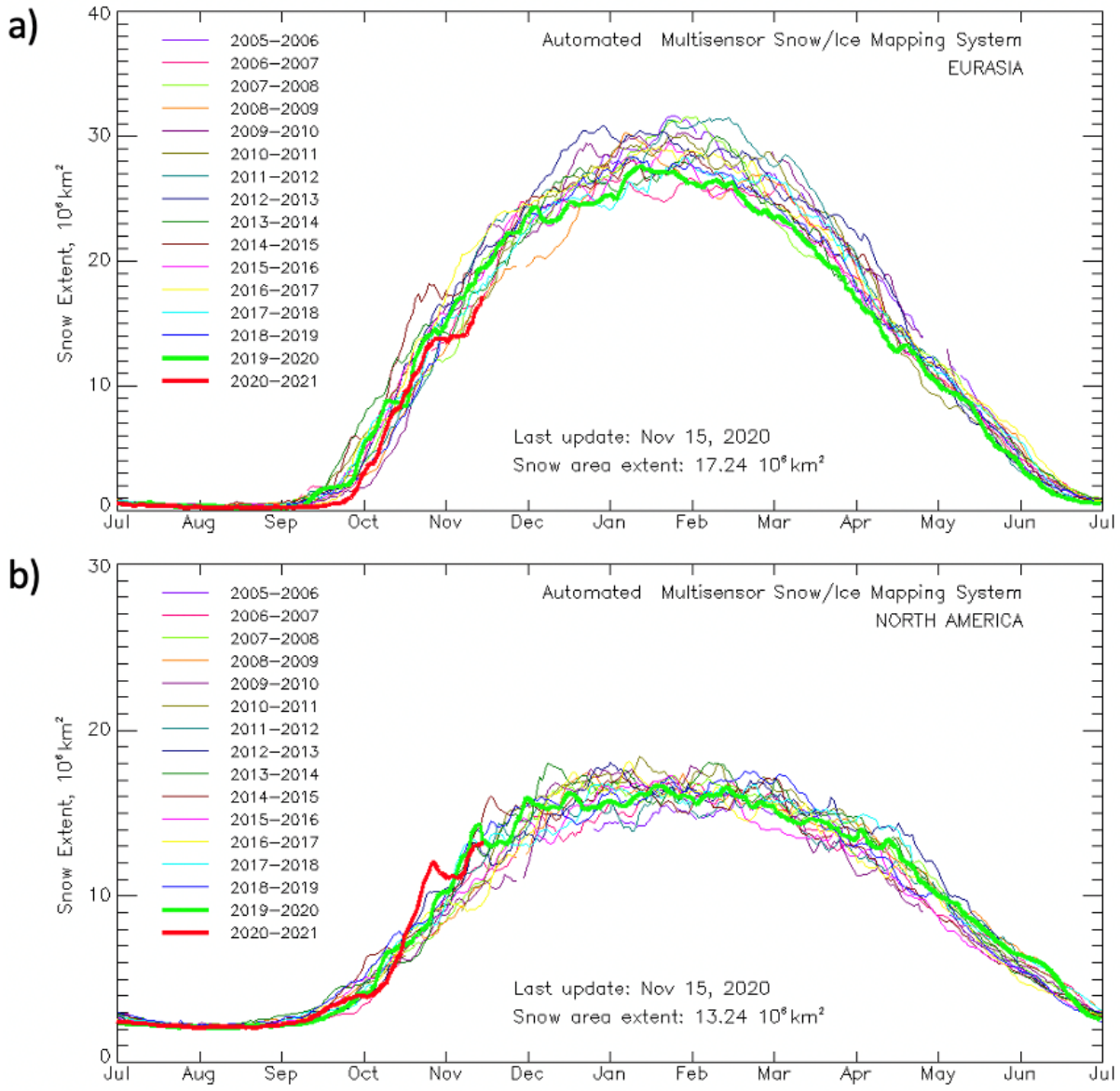

Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 15 November 2020. Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover resumed and remains near decadal highs. 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.