

Arctic Oscillation and Polar Vortex Analysis and Forecasts

November 2, 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 spike strongly positive this week and then drift to neutral and possibly 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 spike positive this week and then drift back to neutral next week as pressure/geopotential height anomalies are predicted to become mixed next week.

- The next two weeks, 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 will push far enough north to allow some undercutting of the ridging with troughing/negative geopotential height anomalies with normal to below normal temperatures from Central and Western Asia filtering into Eastern Europe.
- This week the predicted pattern is ridging/positive geopotential height anomalies with normal to above normal temperatures in Western Asia with troughing/negative geopotential height anomalies with near seasonable temperatures in East Asia. However next week, as European ridging/positive geopotential height anomalies pushes into the Barents-Kara Seas this is predicted to support increasing troughing/negative geopotential height anomalies with normal to below normal temperatures in Central and even into Western Asia with more ridging/positive geopotential height anomalies and normal to above normal temperatures in East Asia.
- This week ridging/positive geopotential height anomalies with normal to above normal temperatures are predicted to dominate the United States (US) and Southern Canada with troughing/negative geopotential height anomalies coupled with normal to below normal temperatures for Alaska and Northern Canada. However next week strong ridging/positive geopotential height anomalies in Alaska and the Gulf of Alaska will support deepening troughing/negative geopotential height anomalies accompanied by normal to below normal temperatures in Western North America with more ridging/positive geopotential height anomalies with normal to above normal temperatures in eastern North America.
- In the Impacts section I discuss the potential influence of October Eurasian snow cover, La Niña, record low Arctic sea ice on the upcoming winter.

Impacts

It is crunch time as far as issuing a winter forecast and it never is easy or gets easier. I have discussed this previously but to me it is pretty amazing how much more improvement and progress there has been achieved for short term weather prediction compared to longer term subseasonal to seasonal weather or climate prediction. Still I do think that we are aware of more potential forcing mechanisms or indicators today compared with initially just one - El Niño/Southern Oscillation (ENSO) of a couple of decades ago. Today there is research demonstrating the utility of Eurasian snow cover,

Arctic sea ice, the quasi-biennial oscillation and after last winter I would include the Indian Ocean dipole, the Pacific Decadal Oscillation and the Atlantic Multi-decadal Oscillation. The last two I don't pay too much attention simply as their names suggests they are of the wrong timescale. But with greater potential predictors comes increased degrees of freedom and what to focus on is challenging. And I have said before the only guarantee in long term weather/climate prediction is to be humbled.

That was the case last year when at this time I believed all the ingredients were present that favored a weak stratospheric polar vortex (PV) in the winter months including high Eurasian snow cover, record low Arctic sea ice, including in the Barents-Kara Seas, and high latitude blocking. There was a weakening of the PV in late November and very early December but that quickly reversed, and the PV remained strong through the entire winter.

So, I am trying my best this winter to keep a more open mind about what could be important for the upcoming winter. But keeping an open mind also introduces greater doubt and balancing the two is challenging.

One indicator that is different from last fall is Eurasian October snow cover extent (SCE). In **Figure i** I show the daily SCE for this October and all Octobers back to 2009. October 2020 is near the low end of recent Octobers and at the end of the month is just above 2010 for lowest extent. Every year shown is above normal except 2011 which was slightly below normal, so it gives a skewed impression. I expect this October will be close to normal and very close to 2011. I computed a monthly value of 9.5 million squared kilometers, but my values tend to be lower than those of Rutgers. I also compute the snow advance index (SAI; see [Cohen and Jones 2011](#)) and that came in slightly below normal. My conclusion from both the October SCE and SAI – there isn't much of a signal so far this year not for the strength of the PV, the winter AO or the severity of the winter across the Northern Hemisphere (NH). If anything, relative to just the most recent Octobers it might be taken as a signal that favors a stronger PV and a milder winter. And to be honest in recent years snow cover has not been a reliable predictor for the winter. However more consistently there have been a weakening of the PV following a rapid advance of Eurasian snow cover, however not all those PV weakening's had a large and lasting impact on the large-scale weather. To be clear I still believe that the mechanism of how snow cover can influence the behavior of the PV and subsequently NH weather is robust but has likely been complicated by rapid Arctic change.

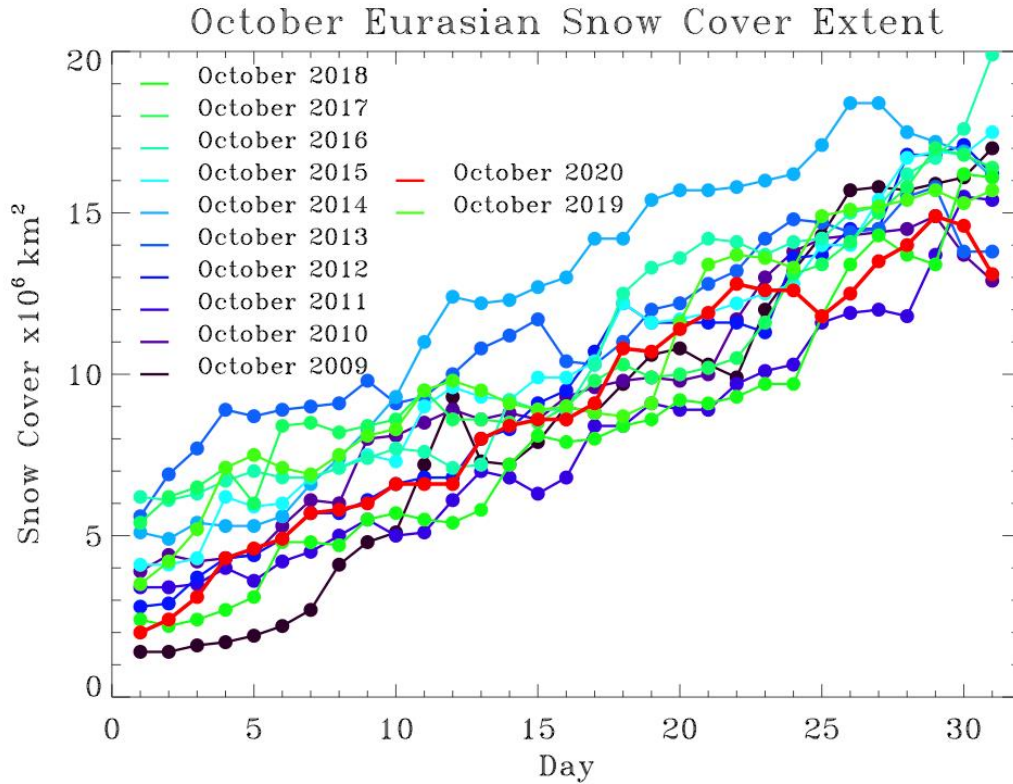


Figure i. Daily Eurasian snow cover extent in millions of squared kilometers for October 2009-2020.

I have mused as well as others that there are some eerie similarities between fall 2020 and 2011. In **Figure ii** I compare the sea level pressure anomalies observed from November 2011 and an early estimate of November 2020. To be honest I generated the figure to argue how much the two differ but looking at the figure they do share many common features including high pressure west of the Urals and south of the Aleutians and low pressure in the Arctic basin, Siberia and Canada. Still I believe there is potential for high pressure near the Urals/Scandinavia to be more impressive in November 2020 compared to 2011.

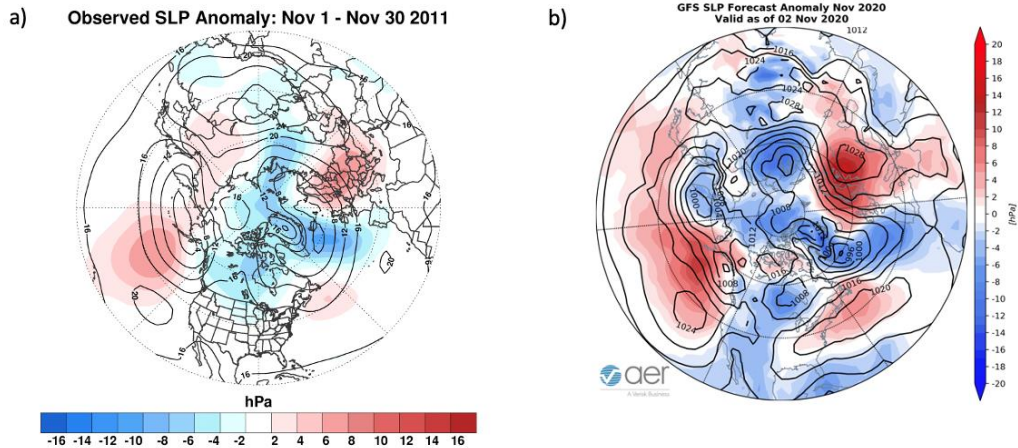


Figure ii. Plot of Northern Hemisphere sea level pressure (contours) and anomalies (shading) (a) observed for November 2011 and (b) projected from the GFS for November 2020.

Arctic sea ice continues to be at record low extent with large negative departures all along Eurasia and over to Alaska (see **Figure 16**). But the sea ice has begun and will continue to rapidly spread along the Siberian coast and over to Alaska. The remaining negative sea ice anomalies will likely be heavily focused in the Barents-Kara Seas within a week or two. And I believe that it is plausible that high pressure near Scandinavia and Urals could couple with the open waters of the Barents-Kara Seas where low sea ice supports high pressure and high pressure supports low sea ice. If high pressure/blocking persists in the Urals/Scandinavian/Barents-Kara Seas for multiple weeks and even longer than one month it will likely weaken the PV, so this is something I think that bears watching.

Though it seems more and more likely that the eight-hundred-pound gorilla this winter will be the ever growing La Niña. Just a short while ago it was questionable whether there would be a La Niña at all and now it is potentially a strong event. The two strongest La Niña events were 1973/74 and 1988/89. Both those winters were mild in the Eastern US and in fact all strong ENSO events were accompanied by mild winters in the Eastern US. La Niña winters also seem to favor cold winters in Central Asia with only a weak signal in Europe (see the blog post from October 19, 2020).

One potentially important difference from November 2011 and 2020 are the sea surface temperatures (SSTs). SSTs were much colder in the North Pacific in November 2011 (**Figure iii**) compared to current SSTs (see **Figure 17**). As I discussed previously this could favor an eastward shift in the North Pacific ridging that could force troughing and cold temperatures east relative to a canonical La Niña. But for now, this is a speculative assumption.

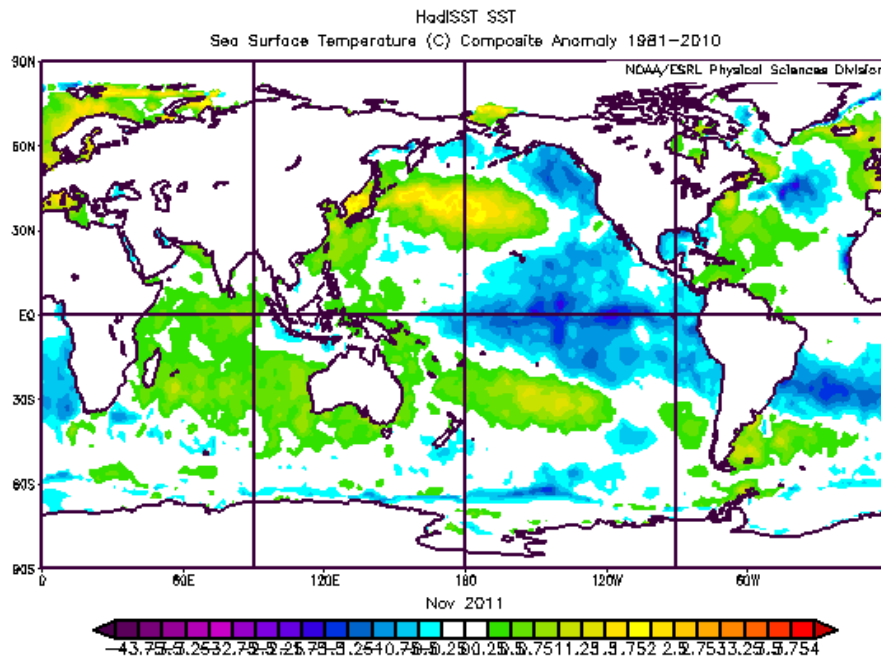


Figure iii. Sea surface temperature from November 2011. Plotted from NOAA ESRL https://psl.noaa.gov/cgi-bin/gcos_wgsp/printpage.pl.

In November 2011 a strong PV coupled with a positive AO to give a mild start to the winter across the NH. With the predicted strong PV over the next two weeks there is a risk something similar could occur in the coming weeks. So far, the GFS is not predicting coupling, but this is something to watch. It seems to me that the GFS is starting to suggest a movement of the PV center from the North Pole to the North Slope of Siberia. This could be a very early sign of an eventual disruption of the PV of unknown magnitude. Again, something to watch.

Finally the large sea ice anomalies in the Barents-Kara seas seems to favor colder temperatures not only in the interior of Eurasia but also North America, which would reinforce the La Niña temperature anomaly pattern with relatively cold in Central Asia, central North America, mild along the US East Coast and with only a weak signal for Europe. And if as I expect negative sea ice anomalies become focused in the Barents-Kara Seas, I will include in the blog the temperature pattern associated with negative Barents-Kara Seas sea ice anomalies. It is convenient to assume the upcoming winter will be cold in the interior and mild on the coasts given the strong emerging La Niña and sea ice signals. But the newly reformed and wiser forecaster in me is trying better to expect the unexpected.

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.

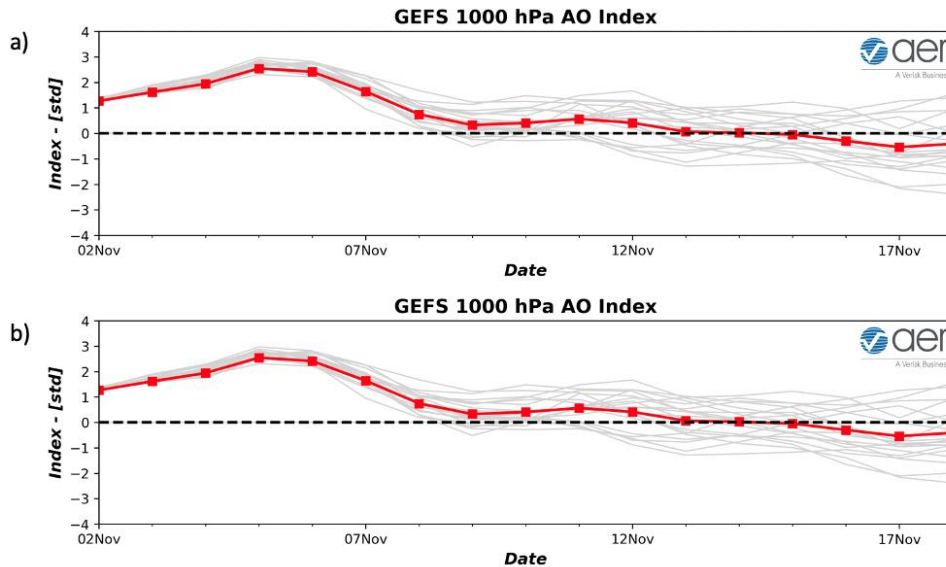


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 2 November 2020 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 2 November 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies are predicted to dominate much of Europe with troughing/negative geopotential height anomalies limited to far western Europe including the UK (**Figure 2**). This pattern favors normal to above normal temperatures for much of Europe with more seasonable temperatures in far Western Europe including the UK (**Figure 3**). Across Asia this week, ridging/positive geopotential height anomalies are predicted to dominate Western Asia with troughing/negative geopotential height anomalies in Eastern Asia (**Figure 2**). This pattern favors widespread normal to above normal temperatures for Western Asia with near normal temperatures in Eastern Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 11/02/2020 FCST: 11/03/2020 to 11/07/2020

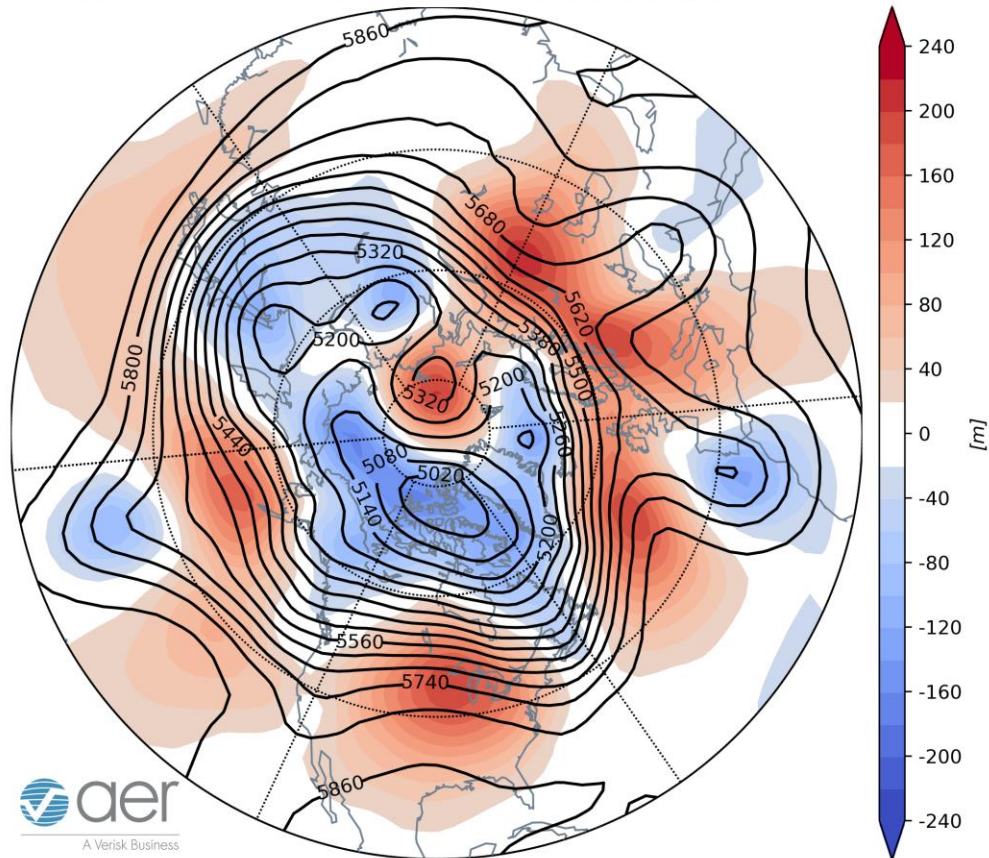


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 3 – 7 November 2020. The forecasts are from the 00z 2 November 2020 GFS ensemble.

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

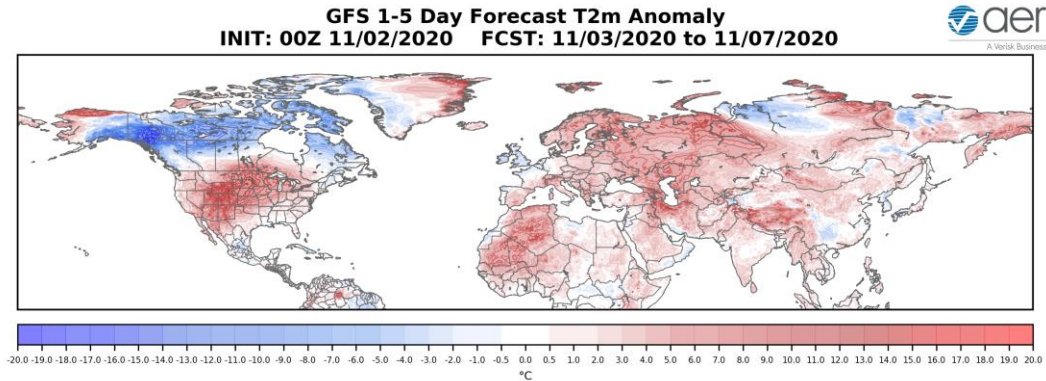


Figure 3. Forecasted surface temperature anomalies (°C; shading) from 3 – 7 November 2020. The forecast is from the 00Z 2 November 2020 GFS ensemble.

Trouging and/or colder temperatures are predicted to support new snowfall across Siberia and the Himalayas while warmer temperatures will cause snow melt in Scandinavia and Western Russia (**Figure 4**). Trouging and/or colder temperatures are predicted to support new snowfall across Alaska, Western Canada and the Northwestern US while warmer temperatures will cause snow melt in Southeastern Canada and the Northeastern US (**Figure 4**).

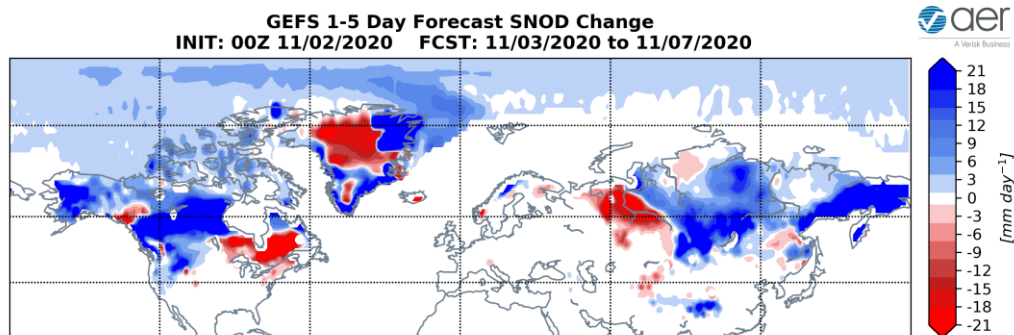


Figure 4. Forecasted snow depth changes (mm/day; shading) from 3 – 7 November 2020. The forecast is from the 00Z 2 November 2020 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to drift back towards neutral next week (**Figure 1**) as positive geopotential height anomalies filter into the Central 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.

GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 11/02/2020 FCST: 11/08/2020 to 11/12/2020

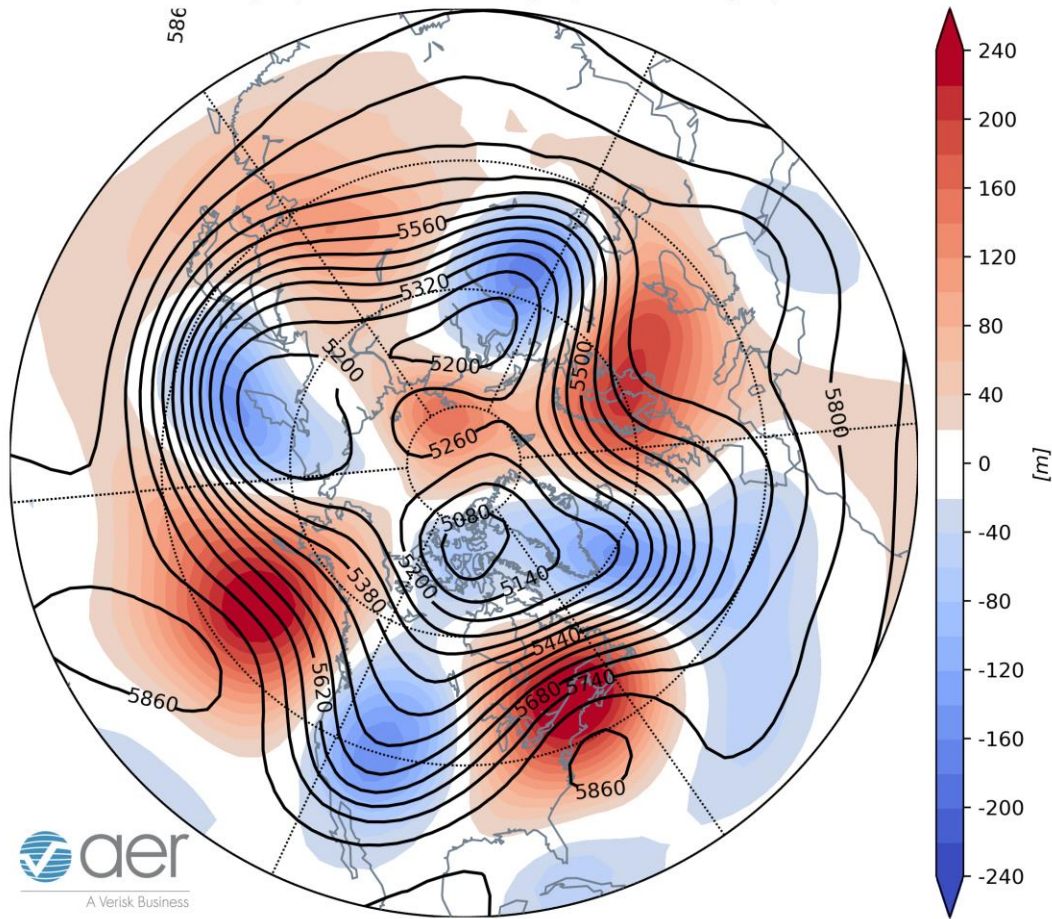


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 8 – 12 November 2020. The forecasts are from the 00z 2 November 2020 GFS ensemble.

Persistent ridging/positive geopotential height anomalies are predicted to dominate all of Europe (**Figure 5**). This pattern favors normal to above normal temperatures across all of Europe including the UK (**Figure 6**). Strengthening European ridging/positive geopotential height anomalies are predicted to initiate troughing/negative geopotential height anomalies in Central Asia 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 Asia with normal to below normal temperatures limited to localized pockets in Siberia (**Figure 6**).

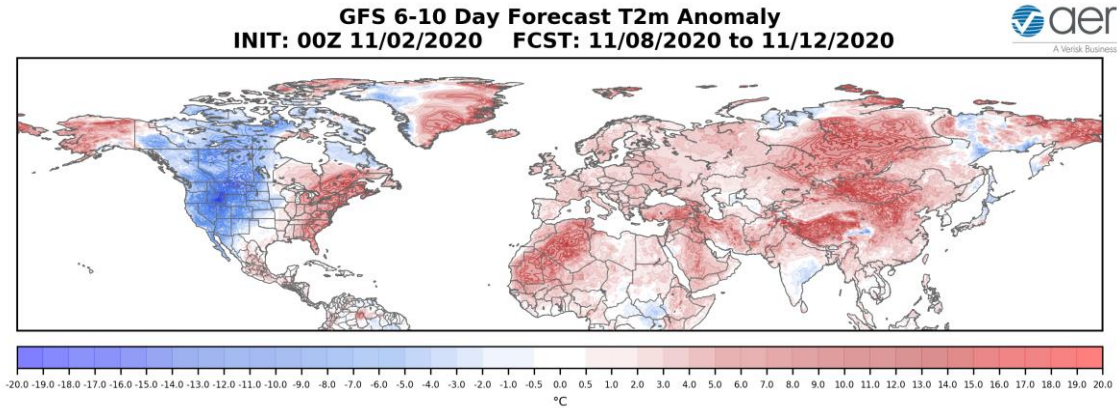


Figure 6. Forecasted surface temperature anomalies (°C; shading) from 8 – 12 November 2020. The forecasts are from the 00Z 2 November 2020 GFS ensemble.

Ridging/positive geopotential height anomalies previously near the Aleutians are predicted to slide into the Gulf of Alaska forcing deepening troughing/negative geopotential height anomalies in western North America with more ridging/positive geopotential height anomalies in eastern North America this period (**Figure 5**). This pattern is predicted to bring widespread normal to below normal temperatures across Western Canada and the Western US with normal to above normal temperatures across Alaska, Eastern Canada and the Eastern US (**Figure 6**).

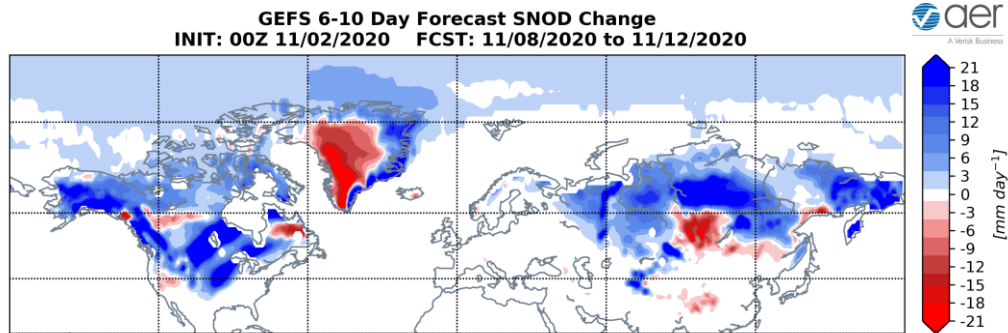


Figure 7. Forecasted snow depth changes (mm/day; shading) from 8 – 12 November 2020. The forecasts are from the 00Z 2 November 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across Northern and Central Asia while warmer temperatures will cause snow melt in Southcentral Siberia (**Figure 7**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, much of Canada, the Northwestern and Central US while warmer temperatures will cause snow melt in Quebec (**Figure 7**).

11-15 day

Predicted consolidation of positive geopotential height anomalies in the Barents-Kara Seas with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), will keep the AO tethered to neutral or possibly weakly negative this period (**Figure 1**). With mixed pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is predicted to also straddle neutral.

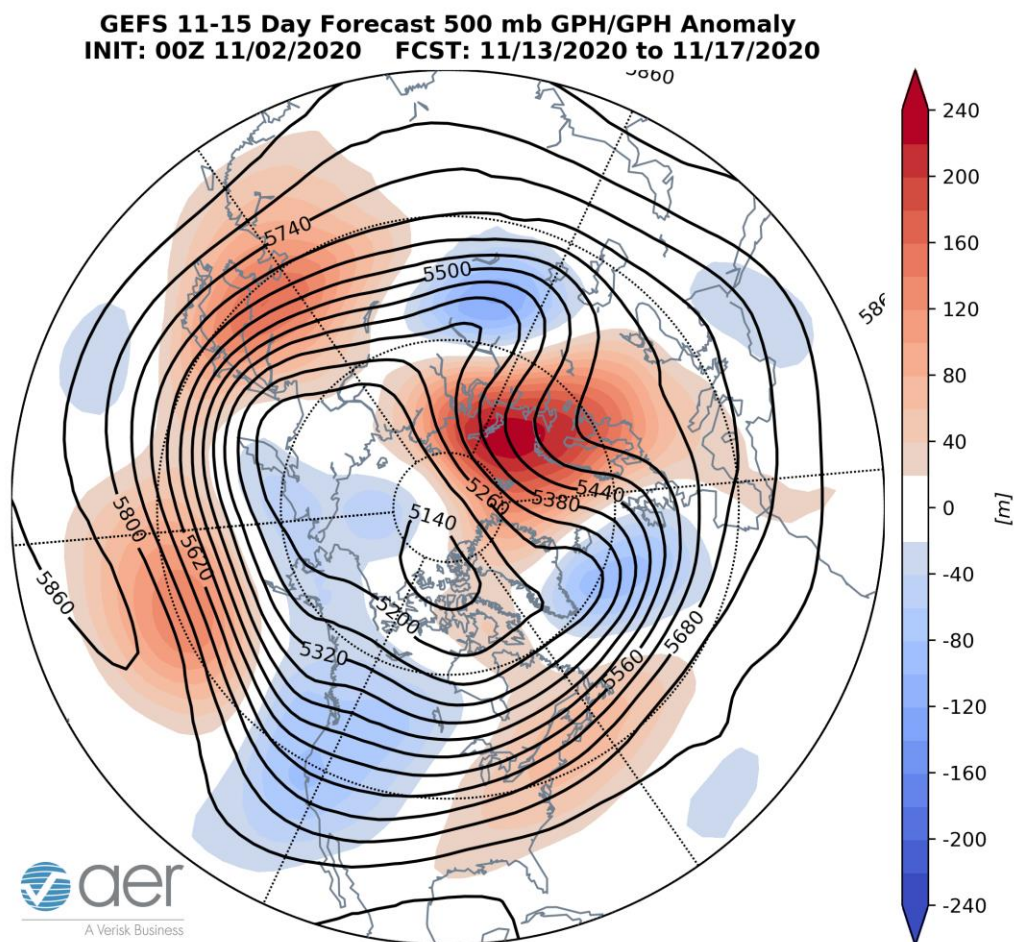


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 13 – 17 November 2020. The forecasts are from the 00z 2 November 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to still dominate Europe but centered over Scandinavia and the Barents-Kara Seas allowing some backdoor troughing/negative geopotential height anomalies from Western Asia to trail southwestward towards Southeastern Europe this period (**Figures 8**). The forecast is for normal to above normal temperatures across most of Europe including the UK with normal to below normal temperatures bleeding into Eastern Europe from Central Asia this period (**Figures 9**). Predicted ridging/positive geopotential height anomalies focused over Scandinavia and the Barents-Kara Seas will support deepening

troughing/negative geopotential height anomalies across Central Asia 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 Asia with normal to below normal temperatures in Central Asia and into Southwestern Asia (**Figure 9**).

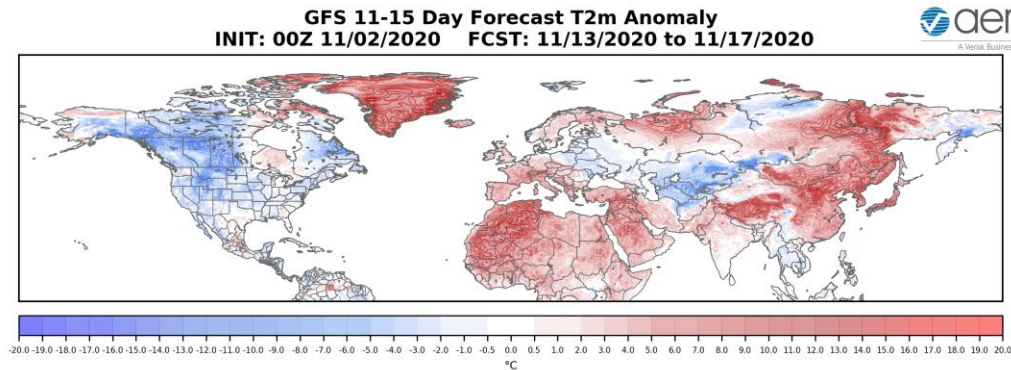


Figure 9. Forecasted surface temperature anomalies (°C; shading) from 13 – 17 November 2020. The forecasts are from the 00z 2 November 2020 GFS ensemble.

Ridging/positive geopotential height anomalies previously in the Gulf of Alaska are predicted to drift towards the Aleutians anchoring troughing/negative geopotential height anomalies across western North America with persistent ridging/positive geopotential height anomalies in eastern North America this period (**Figure 8**). This pattern favors widespread normal to below normal temperatures for Alaska, Western Canada and Western US with some of the colder temperatures filtering into Eastern Canada and even into the Eastern US this period (**Figure 9**).

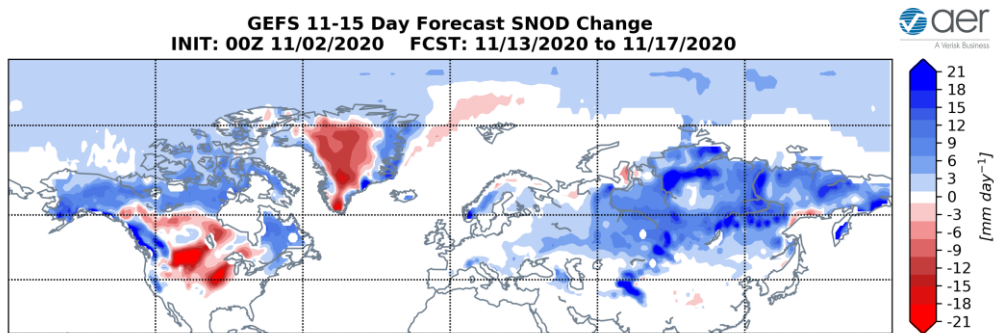


Figure 10. Forecasted snow depth changes (mm/day; shading) from 13 – 17 November 2020. The forecasts are from the 00z 2 November 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across much of Northern Eurasia and even possibly Southeastern Europe (**Figure 10**). Troughing and/or colder temperatures are predicted to support new snowfall

across Alaska, Western and Northern Canada, Quebec and possibly New England while warmer temperatures will cause snow melt in the Plains of Canada and the US (**Figure 10**).

Longer Term

30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows near normal PCHs in the troposphere but cold/negative PCHs in the stratosphere (**Figure 11**). The cold/negative PCHs are predicted to continually strengthen in the stratosphere through mid-November (**Figure 11**).

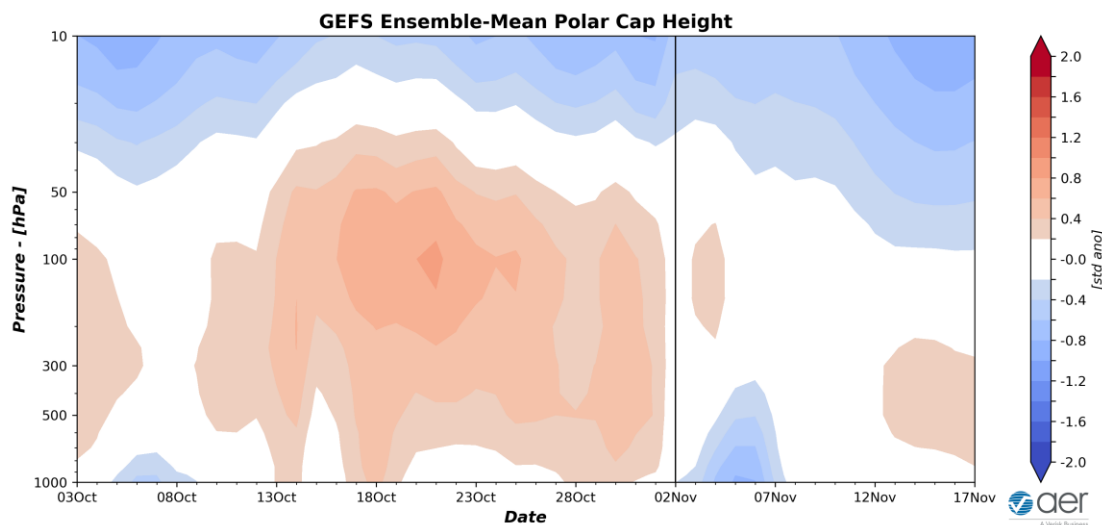


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 2 November 2020 GFS ensemble.

Cold/negative PCHs in the lower troposphere are predicted to spike this week consistent with the predicted positive in the AO this week (**Figure 1**). However, the forecast for next week is neutral to weakly positive PCHs in the troposphere consistent with a return to neutral to slightly negative AO next week. I still believe there could be volatility in the PCH forecast that have important long-term implications for troposphere-stratosphere coupling.

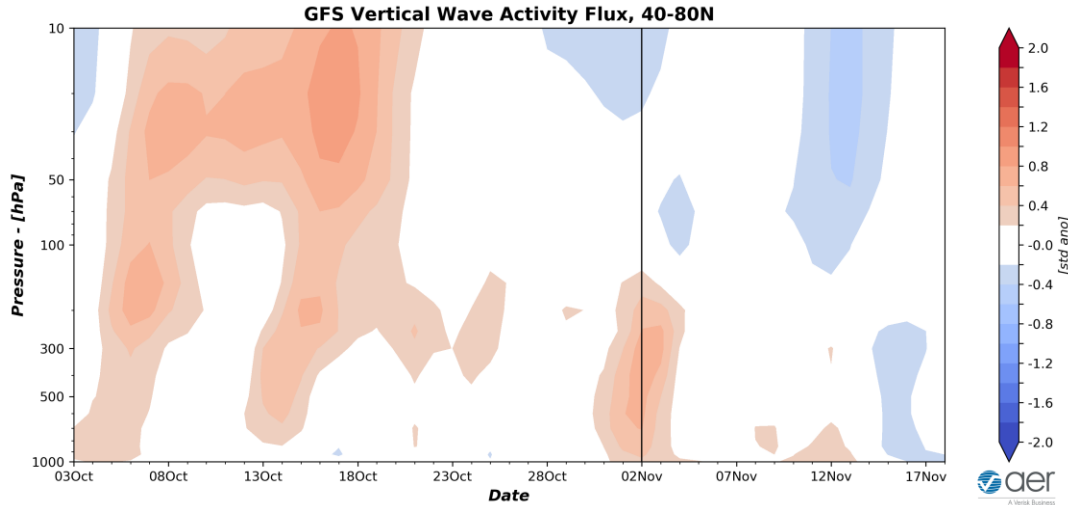


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 2 November 2020 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows currently some active WAFz in the troposphere that is not predicted to enter the stratosphere (**Figure 12**). Other than the current troposphere-only pulse, the GFS is predicting a relatively quiet period of WAFz (**Figure 12**).

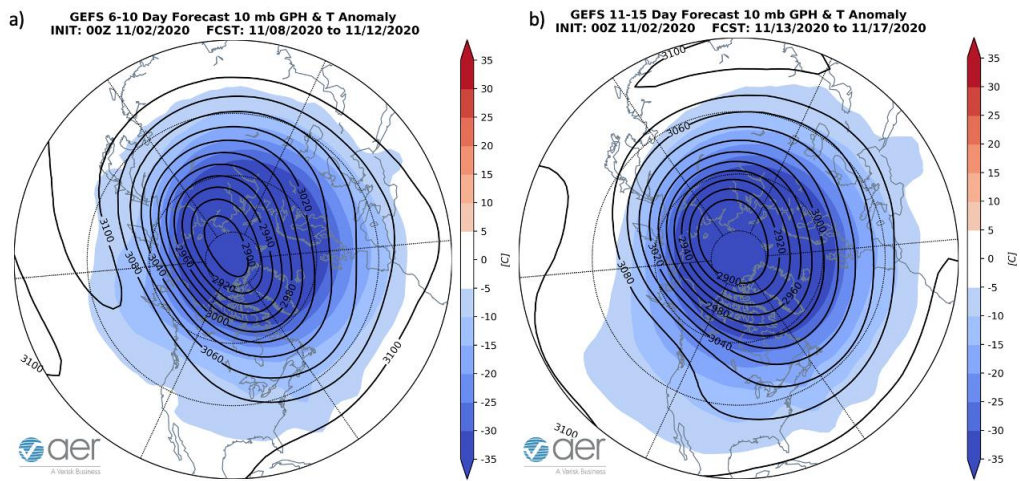


Figure 13. (a) Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 8 – 12 November 2020. (b) Same as (a) except forecasted averaged from 13 – 17 November 2020. The forecasts are from the 00Z 2 November 2020 GFS model ensemble.

The upcoming quieter period of WAFz (**Figure 12**) will support a strengthening PV. The PV is predicted to take up a position near the North Pole and deepen (**Figure 13**).

Currently there are no signs of any weakening of the PV, however, the GFS at the end of the two-week period is predicting a drift of the PV center towards Eurasia. This could be an initial sign of eventual PV weakening.

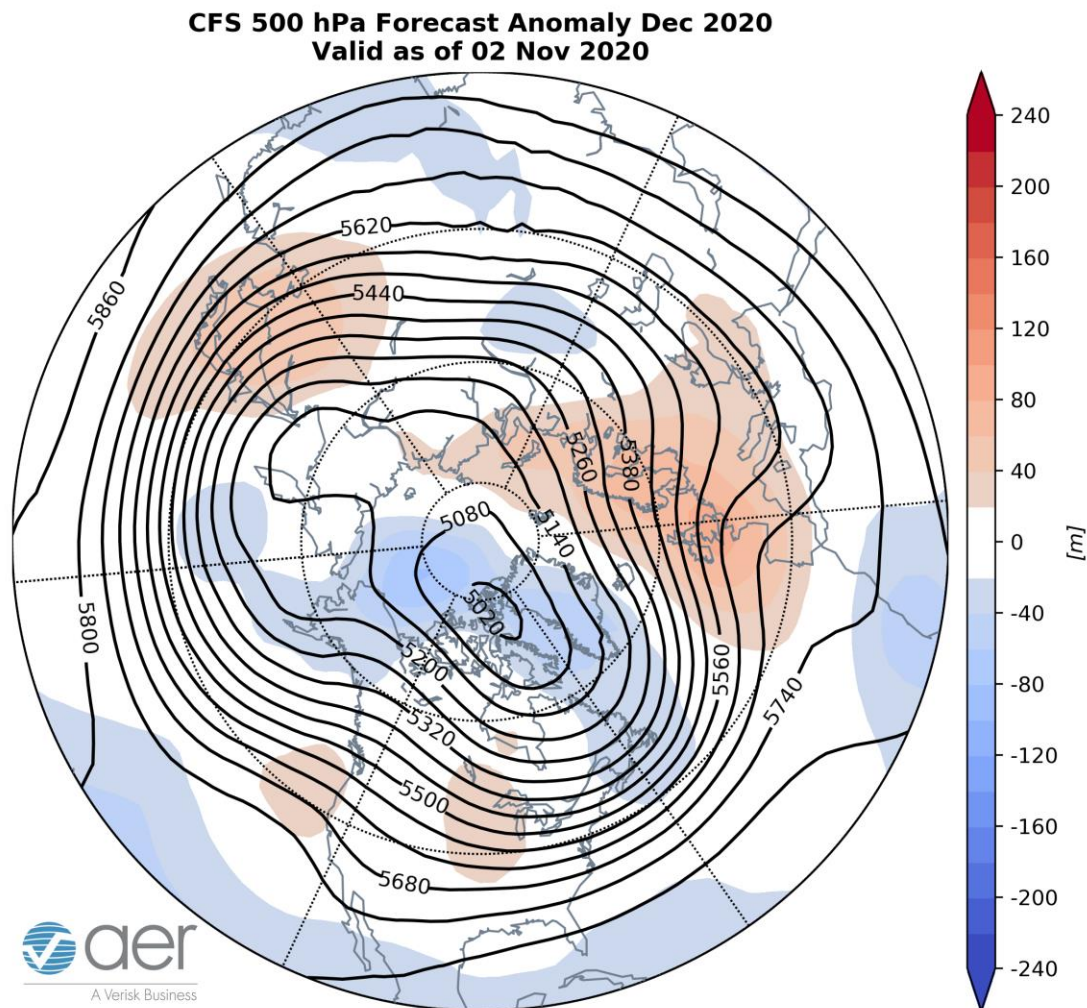


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for December 2020. The forecasts are from the 00Z 2 November 2020 CFS.

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 Northwest Europe, East Asia, and along the US West Coast with troughing in Southeastern Europe, Central Asia, Siberia, Alaska and the Canadian Maritimes and into New England (**Figure 14**). This pattern favors relatively warm temperatures for much of Europe centered on Scandinavia, Northern Asia and

much of North America with seasonable to relatively cold temperatures for Southern Europe, Southern Asia, the Canadian Maritimes and New England (**Figure 15**).

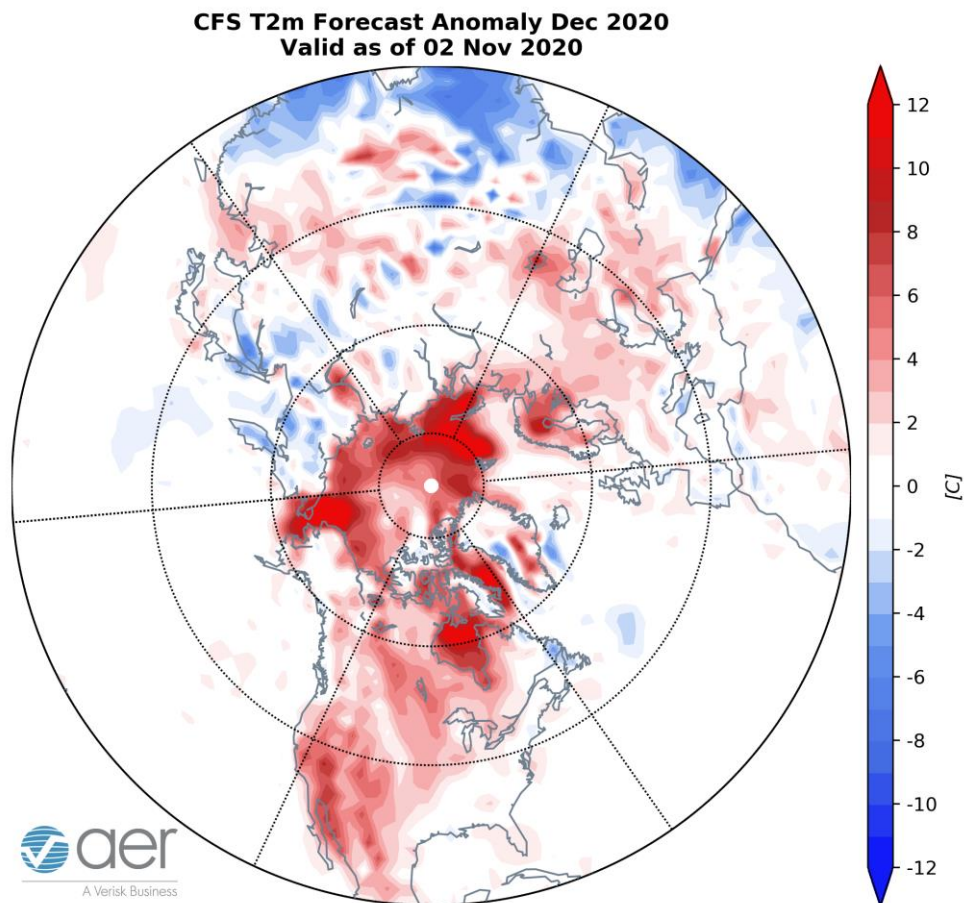


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for December 2020. The forecasts are from the 00Z 2 November 2020 CFS.

Surface Boundary Conditions

Arctic sea ice extent

Arctic sea ice continues to grow at a record slow rate and is currently well below any previous year on this date. Large negative sea ice anomalies exist continuously from Alaska to the Barents-Kara Seas (**Figure 16**). However I do expect sea ice to grow rapidly north of Siberia and in the next week or so negative sea anomalies will become 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.

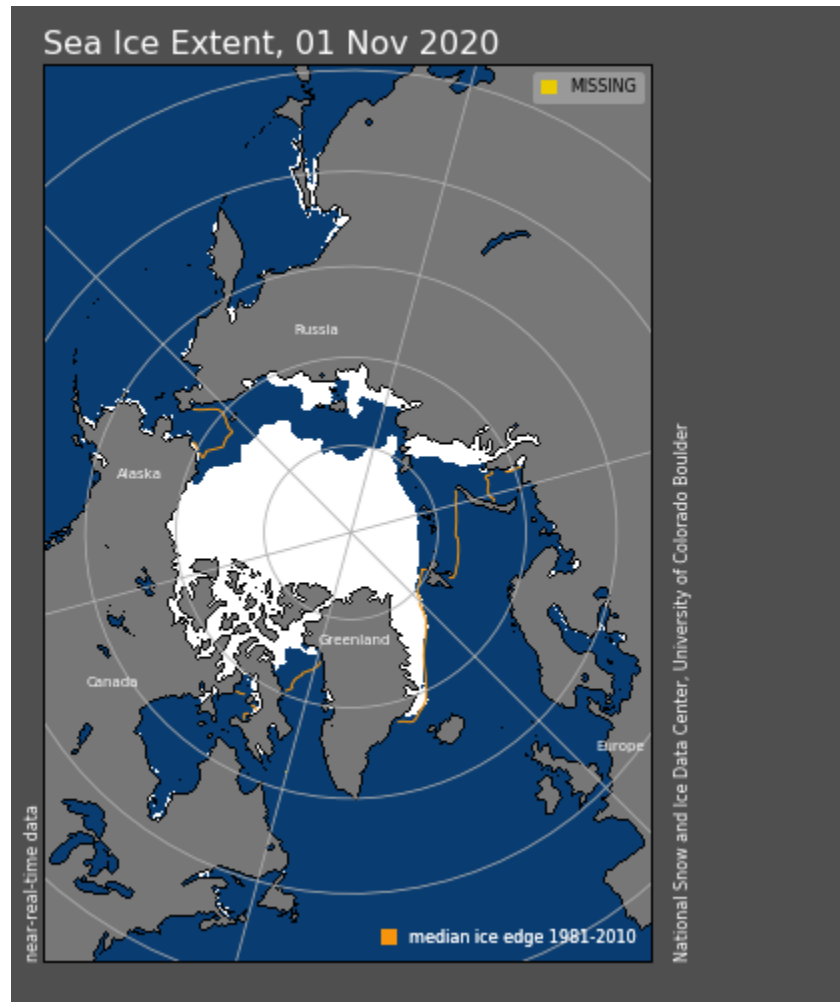


Figure 16. Observed Arctic sea ice extent on 1 November 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies continue to cool slowly 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. 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 31 Oct 2020

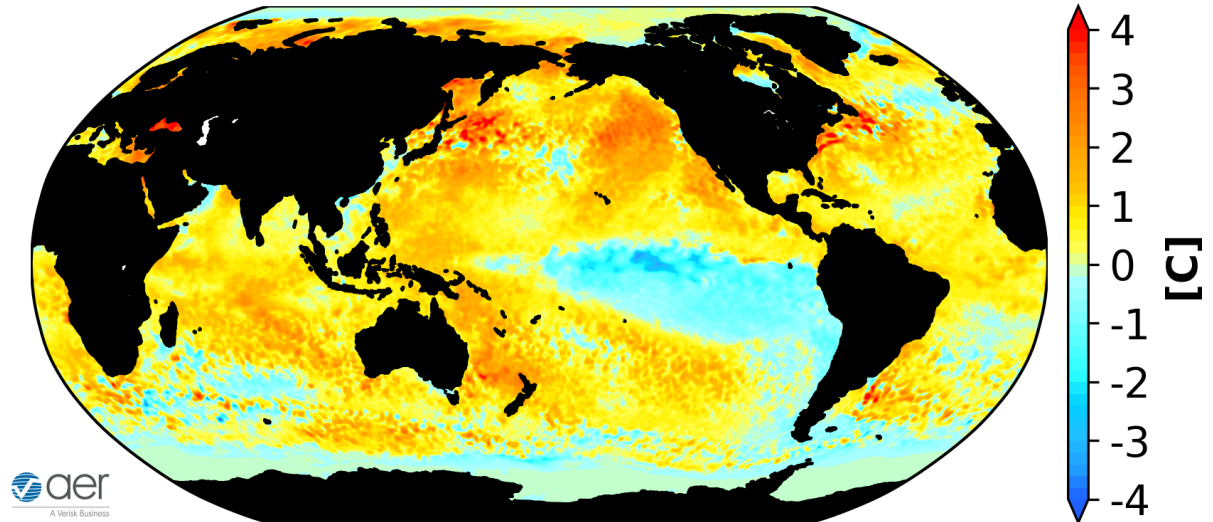


Figure 17. The latest weekly-mean global SST anomalies (ending 31 October 2020). Data from NOAA OI High-Resolution dataset.

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 15**). The forecasts are for the MJO to emerge into phases eight and one and then once again weaken where no phase is favored. MJO phases eight and one favor troughing across western North America with ridging in Eastern Canada. The MJO could be contributing to the short term pattern across North America.

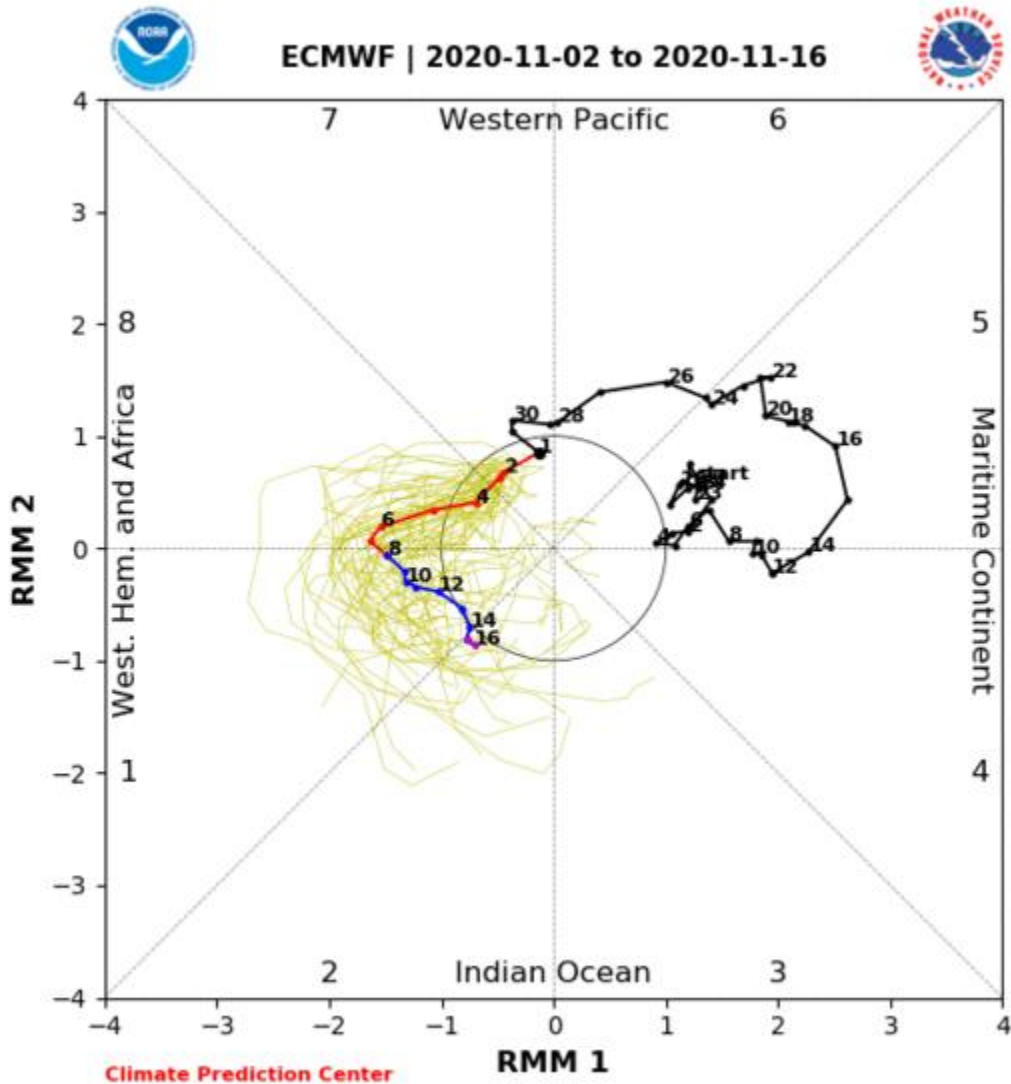


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 22 November 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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 stalled the past week across Eurasia and is currently on the low end of decadal means. Snow cover advance will likely continue to advance especially across East Asia the next two weeks as troughing and cold temperatures spread east across the region. 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.

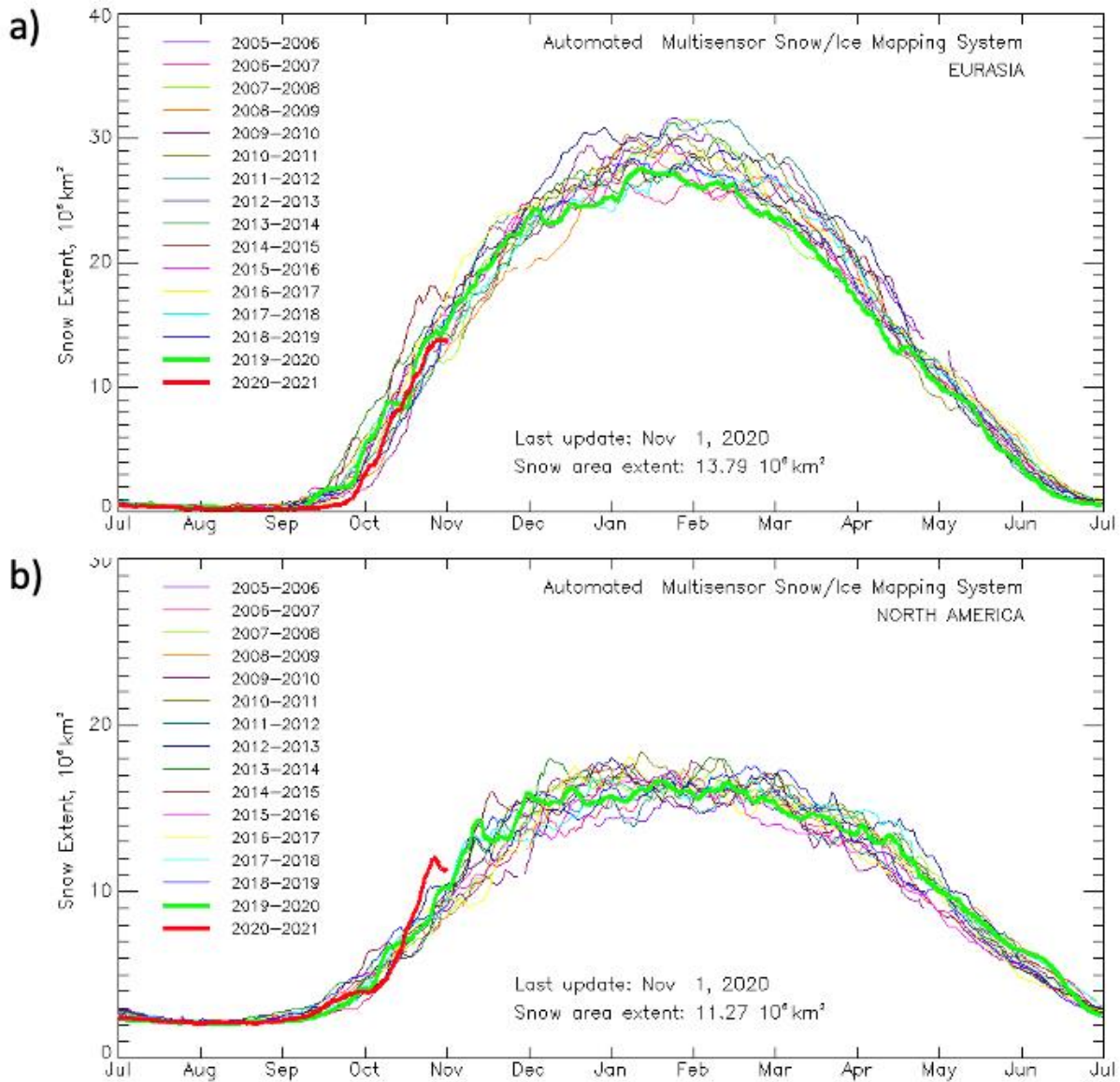


Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 1 November 2020. Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover retreated but remains at 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.

