November 4, 2019

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) recently 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.

With the start of spring we transitioned 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 negative for the next two weeks.
- The current negative AO is reflective of mostly positive pressure/geopotential height anomalies across the Arctic and mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is near neutral with weak positive pressure/geopotential height anomalies spread across Greenland and Iceland; and the NAO is predicted to remain near neutral as geopotential height anomalies remain weak across Greenland.
- Troughing/negative pressure/geopotential height anomalies over Western Europe are predicted to be sandwiched by ridging/positive geopotential height anomalies in the central North Atlantic and Western Asia. Normal to below

normal temperatures are predicted for Western Europe including the United Kingdom (UK) under northerly flow while normal to above normal temperatures are predicted for Eastern Europe under southerly flow.

- Currently temperatures are mostly above normal across Asia as ridging/positive geopotential height anomalies dominate the continent. However, over the next two weeks, ridging/positive geopotential height anomalies centered on the Caspian Sea and eventually extending north to the North Pole will force downstream troughing/negative geopotential height anomalies with below normal temperatures across East Asia especially across much of Siberia.
- Over the next two weeks a fairly stable pattern of ridging/positive geopotential height anomalies across western North America with normal to above normal temperatures for Alaska and the West Coasts of Canada and the United States will force downstream troughing/negative geopotential height anomalies over eastern North America with normal to below normal temperatures east of the Rockies both in Canada and the US.
- In the Impacts section I discuss the next steps to watch now that October snow cover extent is now in the books.

Impacts

It's one again that time of year when winter is approaching, and I dust off the six-step model how October Siberian snow cover extent can influence the weather across the Northern Hemisphere (NH) in winter. The first step is the advance of snow cover across Siberia during the month of October. If the snow cover advance is sluggish then the next anticipated step is a weakened and more contracted Siberian high and mild temperatures across Siberia. Alternatively, if Siberian snow cover advances more rapidly then the next anticipated step is a strengthened and more expansive Siberian high and cold temperatures across Siberia.

The advance of snow cover across Siberia was relatively fast, with a very fast start right at the beginning, a long stall in the middle and a fast end. The snow cover extent (SCE) time series since in 1979 is shown in **Figure i**. As I tweeted the snow advance index (SAI) was also positive but not as large as the SCE.

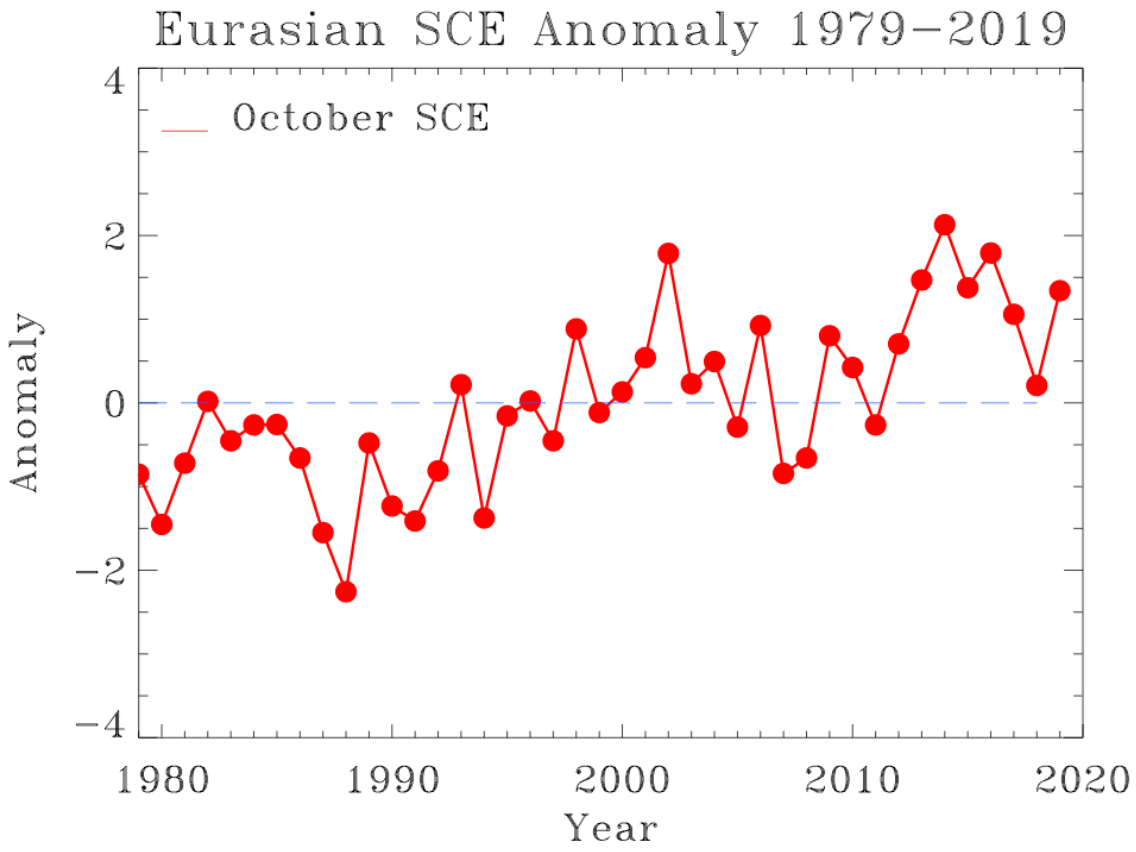

Figure i. October Eurasian snow cover extent 1979 through 2018 with 2019 estimated. I expect 2019 to be comparable to 2013.

After discovering the strong statistical relationship between October Siberian snow cover extent and winter weather in the Eastern US (though admittedly since then the relationship has weakened), I focused, with the help of many collaborators, my research on trying to understand the physical mechanism of this empirical relationship which is summarized in **Figure ii**. As it turns out for step two, the Siberian high response, is not just any generic contraction or expansion but the response in the northwest quadrant is most important. If rapid snow cover advance yields a northwest expansion of the Siberian this favors increased vertical transfer of energy from the troposphere to the stratosphere while a more anemic advance of snow cover yields a retreat of the Siberian High in its northwest quadrant which then favors decreased vertical transfer of energy from the troposphere to the stratosphere or step three in the model. The northwestward expansion of the Siberian high often but not always resembles Scandinavian blocking.

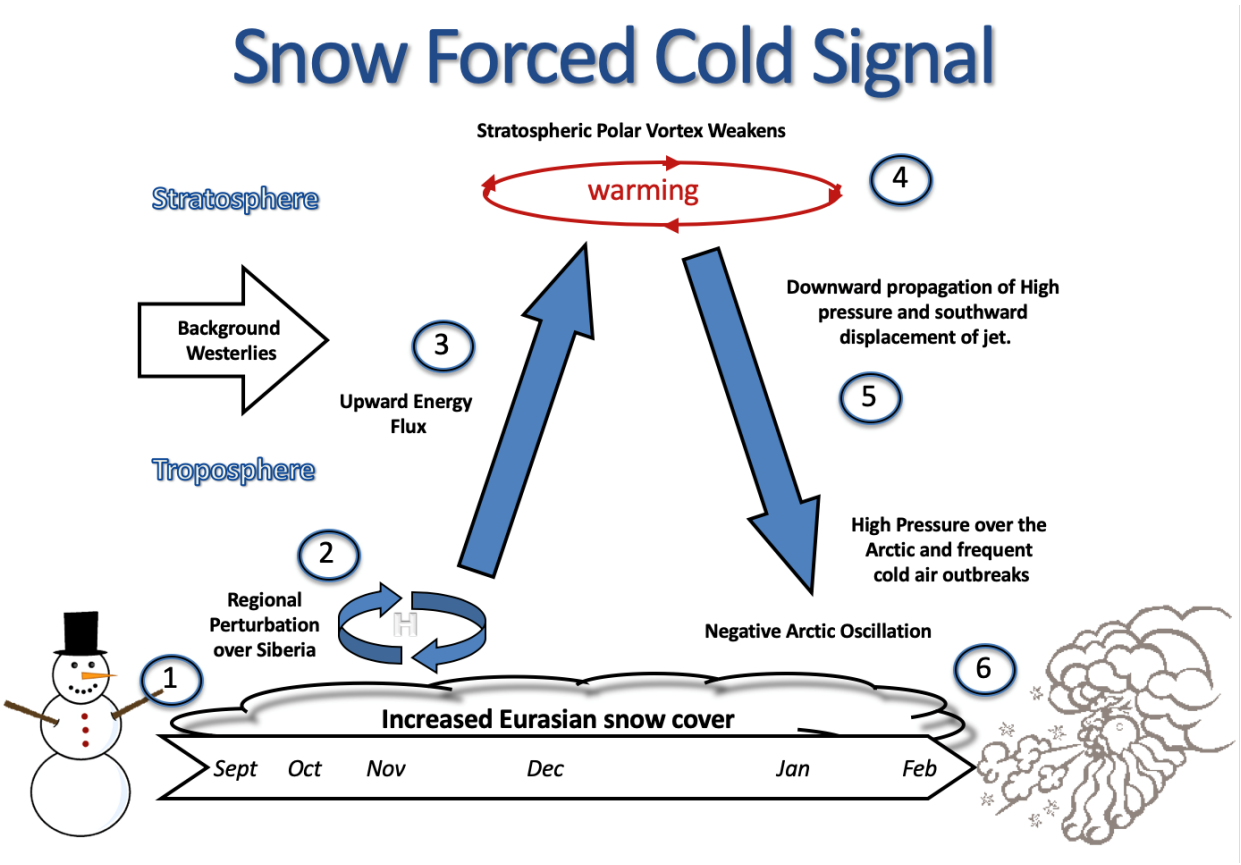

Figure ii. Conceptual model for how fall snow cover modifies winter circulation in both the stratosphere and the troposphere; case for extensive snow cover illustrated: 1. Snow cover increases rapidly in the fall across Siberia, when snow cover is above normal diabatic cooling helps 2. to strengthen 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.

One way we represented this northwestward expansion of the Siberian high in Cohen et al. 2014 was by regressing October snow cover extent anomalies on to November sea level pressure (SLP) anomalies and regressing December anomalies of vertical energy transfer from the troposphere to the stratosphere on to November SLP anomalies. If snow cover advances more rapidly in October this favors the northwestward expansion of the Siberian high in November and more active vertical energy transfer in December. This would then lead to a sudden stratospheric warming/weakened polar vortex (PV) most likely in January and eventually a negative AO/NAO and widespread severe winter weather across the NH.

I recently came across a similar analysis but instead of SLP with 500 hPa geopotential heights. I show in **Figure iii** the CFS estimation of monthly mean November 2019 500 hPa geopotential heights and anomalies from today. Also included is a regression of October SCE and November 500 hPa anomalies from my colleague Jason Furtado. As you can see from the figure the resemblance is quite strong with troughing from East Asia to south of the Aleutians and in the North Atlantic with ridging in Western Asia/Urals and Alaska/Western Canada in both figures. This coupled with the predicted wide expanse of cold temperatures suggest to me that the atmosphere is responding to the rapid advance of snow cover as demonstrated in Jason's analysis. Not sure though that I would call it "textbook" as far as the potential to disrupt the PV. The models seem to be struggling with the forecast of where exactly the blocking sets up in the high latitudes, which is critical for disrupting the PV. I do believe because sea ice loss is so skewed to the North Pacific sector it might inhibit blocking closer to Scandinavia, which is the region most favorable in disrupting the PV. Still I do I expect some disrupting of the stratospheric PV. But if I am wrong and the vertical transfer of energy from the troposphere to the stratosphere goes quiet, then eventually I would expect the strong stratospheric PV to couple with the troposphere favoring an overall mild pattern.

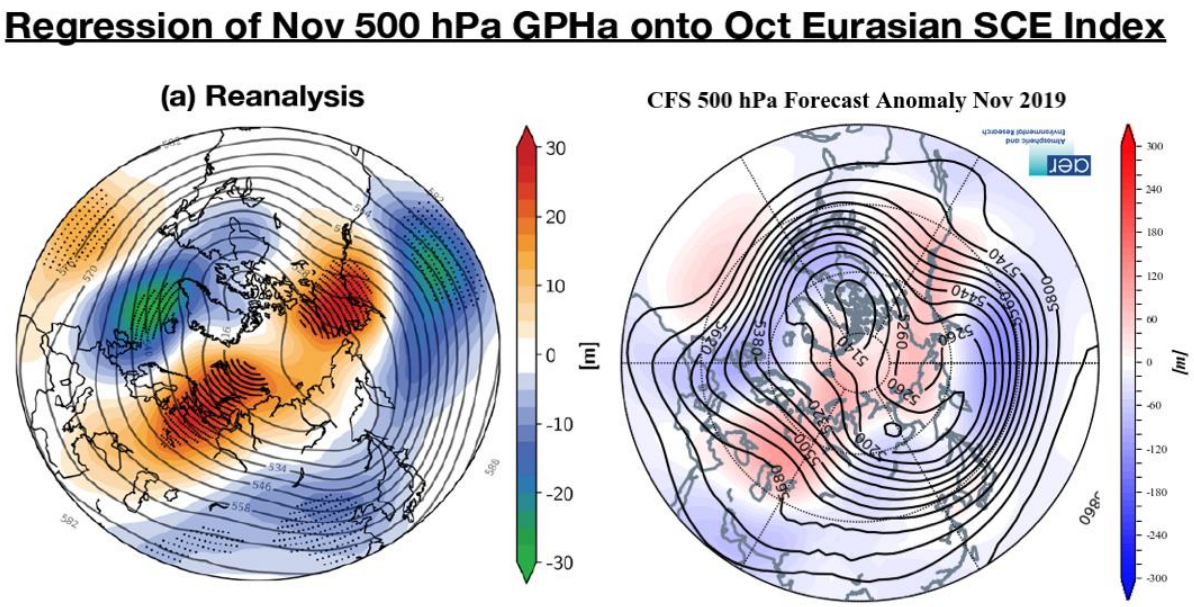

Figure iii. a) Regression of Eurasian snow cover extent onto 500 hPa geopotential heights. **b)** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for November 2019. The forecasts are from the 4 November 2019 CFS.

Occasionally I get asked to explain my tweets in simpler language or to recommend reading to better understand the concepts discussed in the blog. I did find this lecture on You Tube that I presented at Penn State on my forecast ideas and methodology. It is an hour long but hopefully worth the investment.

Near Term Conditions

1-5 day

The AO is currently negative **(Figure 1**) with mostly positive geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with only weak positive geopotential height anomalies across Greenland (**Figure 2**), the NAO is neutral.

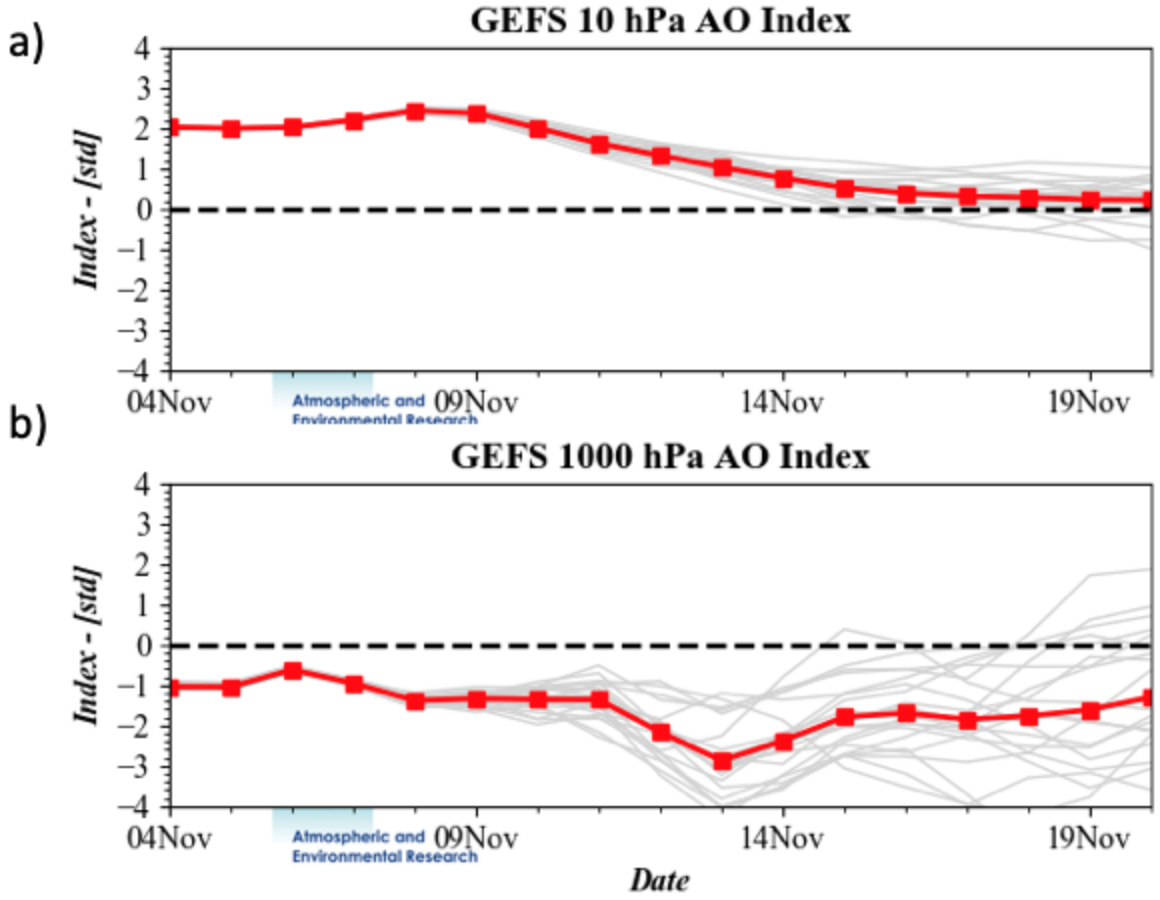

Figure 1. (**a**) The predicted daily-mean AO at 10 hPa from the 00Z 4 November 2019 GFS ensemble. (**b**)
The predicted daily-mean near-surface AO from the 00Z 4 November 2019 GFS ensemble. Gray lines
indicate the AO index from each individual ensemble member, with the ensemble-mean AO index
given by the red line with squares.

Ridging/positive geopotential height anomalies anchored in the central North Atlantic are forcing downstream troughing/negative geopotential height anomalies across

Western Europe with more ridging/positive geopotential height in Western Asia (**Figure 2**). This will result in normal to below temperatures across Western Europe including the UK and Scandinavia under northerly flow and normal to above normal temperatures across Eastern Europe under southwesterly flow (**Figure 3**). This week ridging/positive geopotential height anomalies are predicted to dominate much of Asia with normal to above normal temperatures including the Middle East and Southeast Asia (**Figure 2**). Exceptions are the north slope of Asia, Northeast Asia and part of Southwest Asia where troughing/negative geopotential height anomalies will bring normal to below normal temperatures **(Figure 3**).

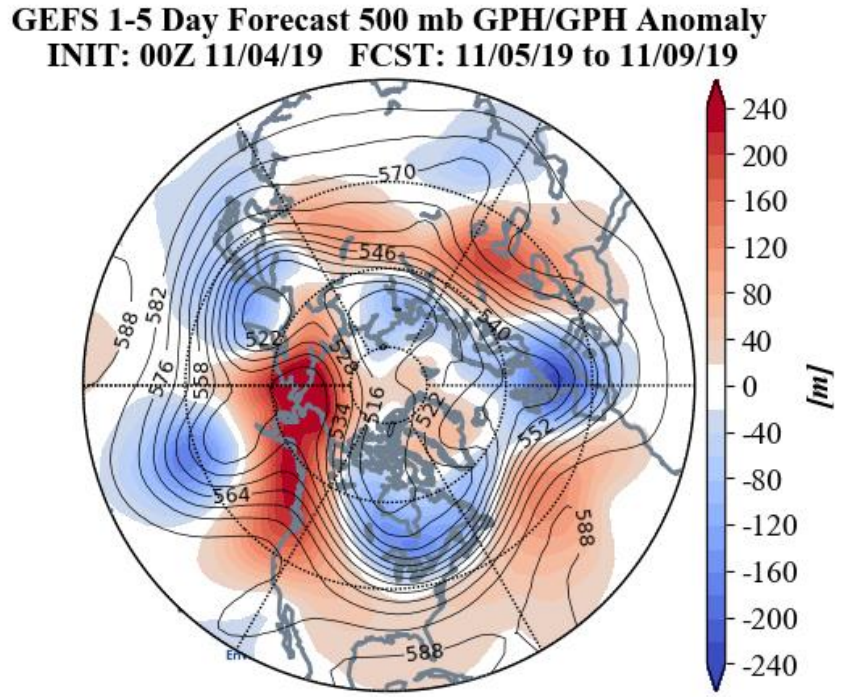

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 5 – 9 November 2019. The forecasts are from the 4 November 00z GFS ensemble.

This week ridging/positive geopotential height anomalies stretching from Alaska to California with normal to above normal temperatures will force downstream troughing/negative geopotential height anomalies with normal to below normal temperatures across Canada and the US east of the Rockies **(Figures 2 and 3). One exception is Florida** where ridging/positive geopotential height anomalies will result in normal to above normal temperatures **(Figures 2 and 3).**

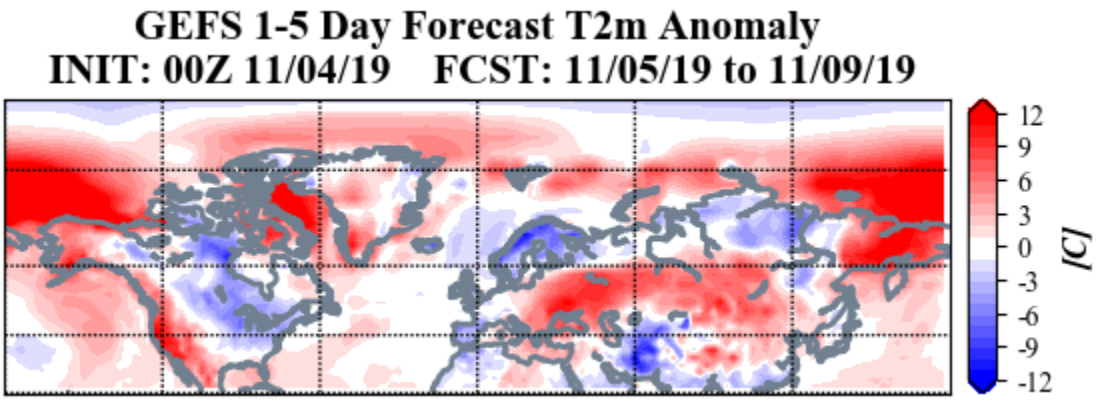

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 5 – 9 November 2019. The forecast is from the 00Z 4 November 2019 GFS ensemble.

Troughing and/or cold temperatures are predicted to bring new snowfall across Siberia, Northwestern Russia, Central Asia, Scandinavia, the Alps and the Pyrenees (**Figure 4**). However, intrusion of warm air on southerly winds will melt snow in Western Russia (**Figure 4**). Troughing and cold temperatures are predicted to bring new snowfall to Canada and possibly the Northern US (**Figure 4**). Warm temperatures will bring some melting to Alaska and the intermountain plateau of the US (**Figure 4**).

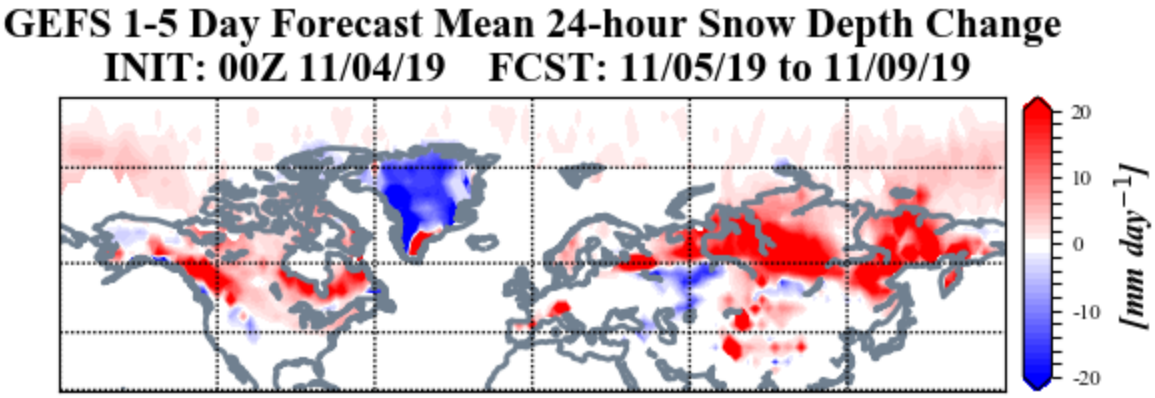

Figure 4. Forecasted snowdepth anomalies (mm/day; shading) from 5 – 9 November 2019. The forecast is from the 00Z 4 November 2019 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain negative **(Figure 1**) with mostly positive geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the

mid-latitudes of the NH (**Figure 5**). And with only weak positive geopotential height anomalies persisting across Greenland (**Figure 2**), the NAO is predicted to remain near neutral.

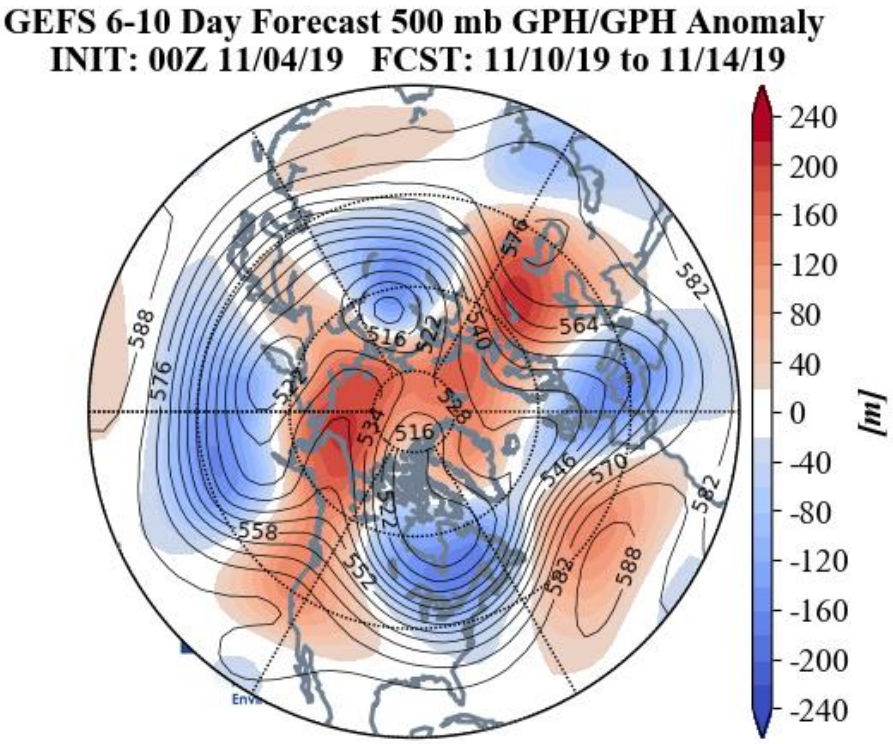

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 10 – 14 November 2019. The forecasts are from the 4 November 00z GFS ensemble.

Nearly stationary ridging/positive geopotential height anomalies in the central North Atlantic are predicted to continue to force downstream troughing/negative geopotential height anomalies across Western Europe with more ridging/positive geopotential height in Western Asia (**Figure 5**). This will result in normal to below temperatures across Western Europe including the UK and Scandinavia under northerly flow and normal to above normal temperatures across Eastern Europe under southwesterly flow (**Figure 6**). Strengthening ridging/positive geopotential height anomalies in western Asia is predicted to force downstream deepening troughing/negative geopotential height anomalies across Siberia (**Figure 5**). This is predicted to yield more widespread normal to above normal temperatures for Western Asia, the Middle East and much of Southern and East Asia **(Figure 6**). Deepening troughing will bring normal to below temperatures to Siberia that will bleed southwesterly into Central Asia **(Figure 6**).

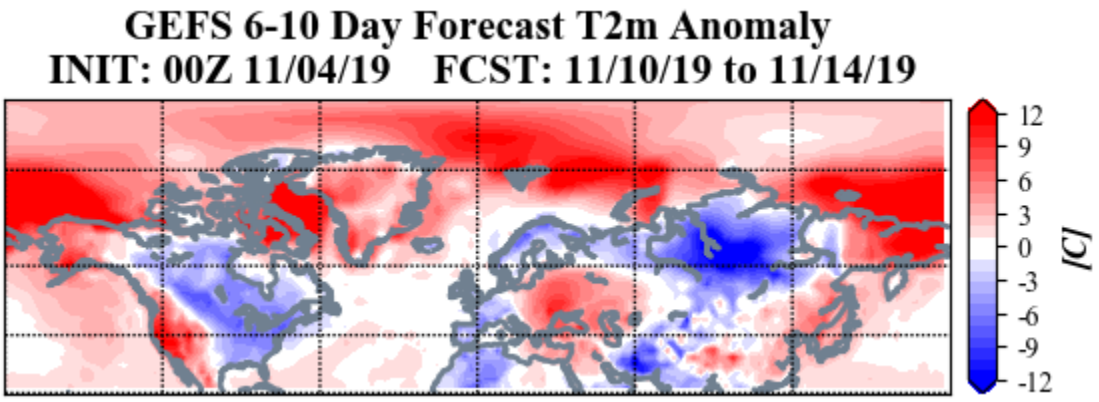

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 10 – 14 November 2019. The forecasts are from the 00Z 4 November 2019 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to remain across Alaska, the Gulf of Alaska and along the west coast of North America forcing downstream troughing/negative geopotential height anomalies in Canada and the US east of the Rockies (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across Alaska, the West Coasts of the US and Canada with normal to below normal temperatures stretching across Canada and the US east of the Rockies **(Figure 6).**

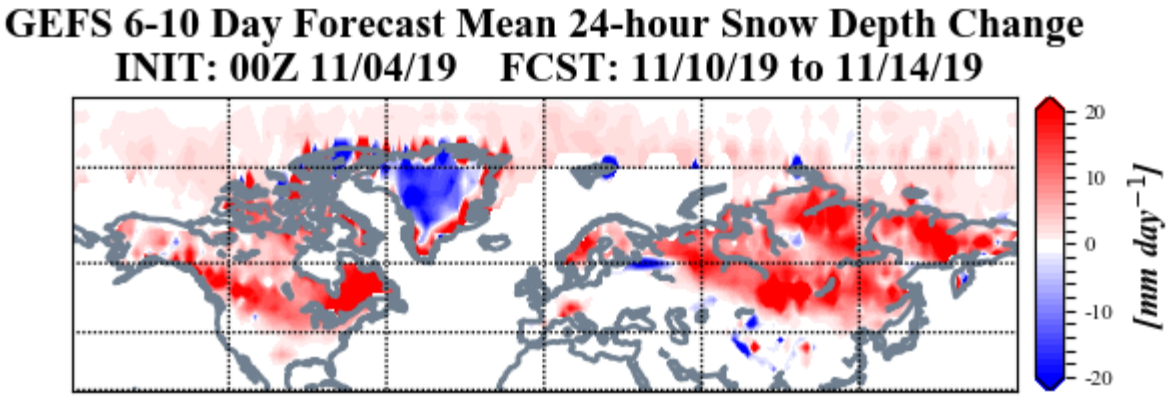

Figure 7. Forecasted snowdepth changes (mm/day; shading) from 10 – 14 November 2019. The forecasts are from the 00Z 4 November 2019 GFS ensemble.

Troughing and/or cold temperatures will support the potential for new snowfall across much of Siberia, Scandinavia, Northwest Russia, the Tibetan Plateau, Alaska and much of Canada (**Figure 7**). Some snowmelt is predicted in Western Siberia and the Northcentral US (**Figure 7**).

11-15 day

With positive geopotential height anomalies predicted for the Arctic especially on the Asian side (**Figure 8**), the AO is predicted to remain negative yet again this period (**Figure 1**). With predicted weak positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is likely to remain close to neutral this period.

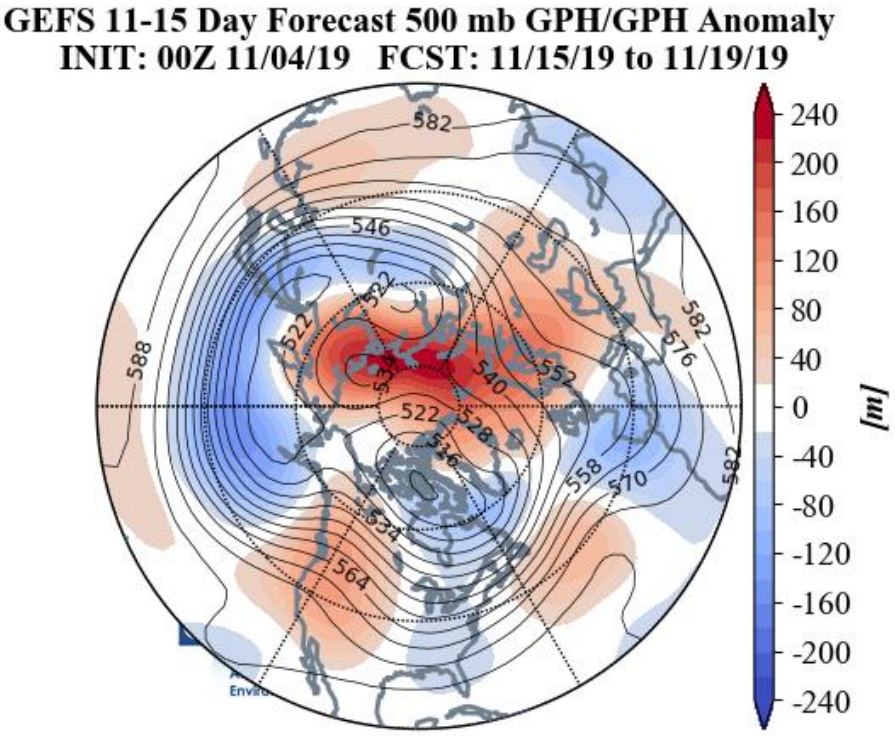

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 15 – 19 November 2019. The forecasts are from the 4 November 00z GFS ensemble.

Little change is predicted for Europe this period as ridging/positive geopotential height anomalies in the central North Atlantic are predicted to continue to force downstream troughing/negative geopotential height anomalies across Western Europe with more ridging/positive geopotential height in Eastern Europe and Western Asia (**Figure 8**). This pattern is predicted to result in seasonable to below normal temperatures for Western Europe including the UK and Scandinavia with seasonable to above normal temperatures across Eastern Europe (**Figure 9**). Ridging/positive geopotential height anomalies in Western Asia are predicted to expand over the top of Asia forcing troughing/negative geopotential height anomalies across much of Siberia and Northeast Asia (**Figure 8**). This pattern favors normal to above normal temperatures across Southern, Western and Southeast Asia including the Middle East and the Indian

subcontinent with normal to below normal temperatures widespread across Siberia, Northeast Asia and parts of Central Asia (**Figure 9**).

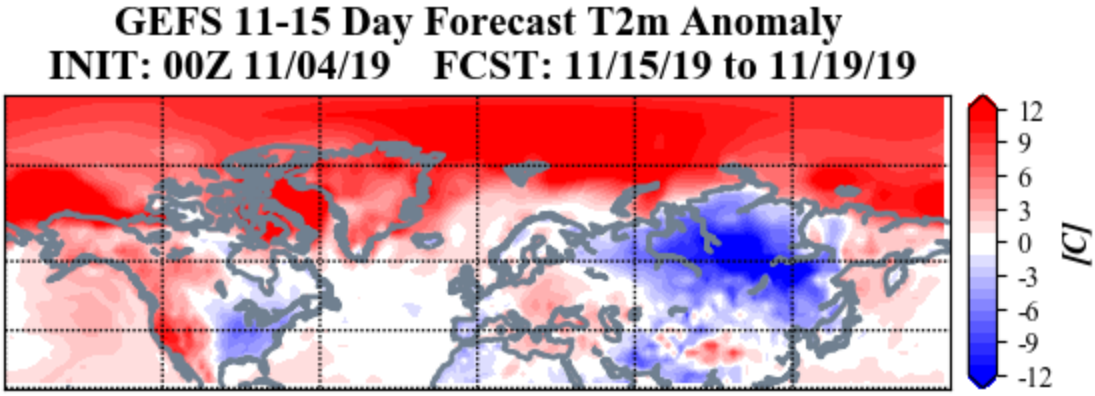

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 15 – 19 November 2019. The forecasts are from the 4 November 00z GFS ensemble.

The overall pattern across North America is predicted to persist with ridging/positive geopotential height anomalies stretching from Alaska into the Gulf of Alaska and along the West Coasts of Canada and the US with downstream troughing/negative geopotential height anomalies in eastern North America (**Figure 8**). This will favor normal to above normal temperatures across Alaska, the West Coasts of Canada and the US with normal to below normal temperatures across much of Canada and the US east of the Rockies (**Figure 9**).

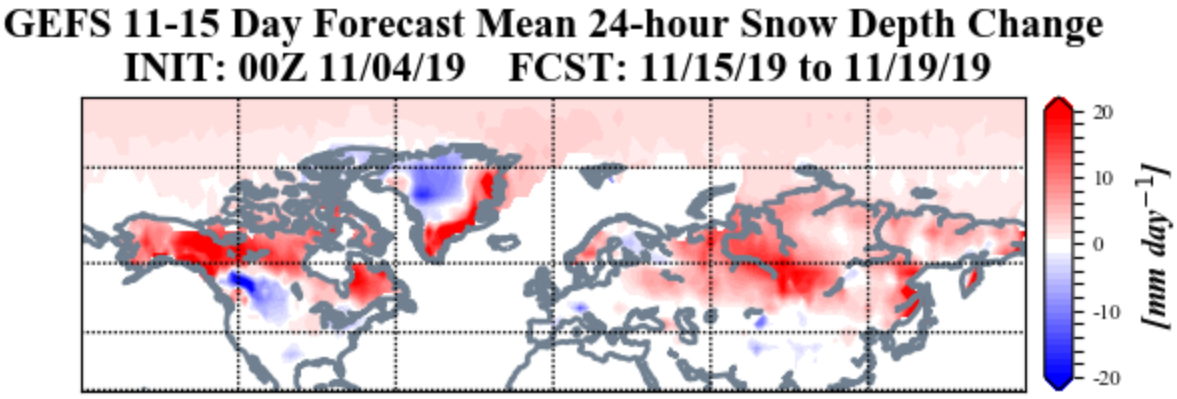

Figure 10. Forecasted snow depth changes (mm/day; shading) from 15 – 19 November 2019. The forecasts are from the 00z 4 November GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across much of Siberia, Northwest Russia, Northeast Asia, possibly parts of Eastern Europe, Alaska, much of

Canada and even possibly the western Great Lakes (**Figure 10**). Milder temperatures could result in snowmelt in parts of Europe and Southwestern Canada (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to below normal PCHs in the stratosphere and normal to above normal PCHs in the troposphere (**Figure 11**). Currently the lower troposphere PCHs are above normal, and are predicted to peak in amplitude mid-month, when the AO could possibly turn strongly negative (**Figure 1**).

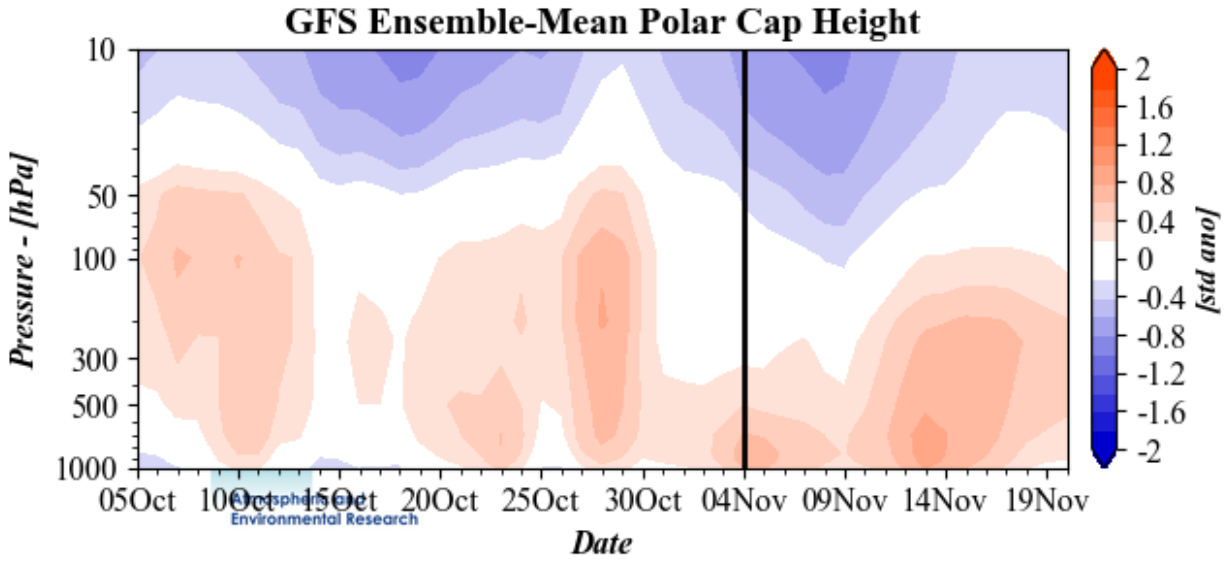

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 4 November 2019 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows a relatively quiet upcoming period (**Figure 12**). There is a weak positive pulse of WAFz predicted for mid-month. This pulse could be observed to be stronger than currently predicted leading to some minor disruptions of the stratospheric PV (**Figure 1**).

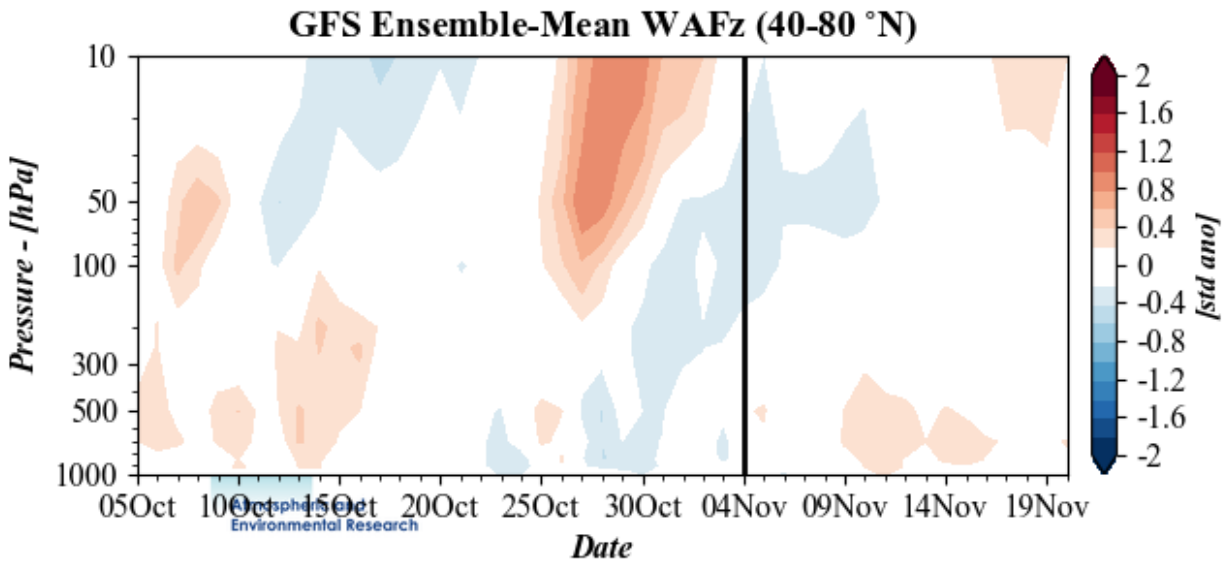

Figure 12. Observed and predicted daily vertical component of the wave activity Wux (WAFz)
standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 4 November 2019
GFS ensemble.

The stratospheric AO is strongly positive (**Figure 1**) reflective of a strong PV. I have seen much chatter about the strong PV and is it influencing NH weather. Normally a strong PV would bring relatively mild temperatures to the NH mid-latitudes. However, despite the strong circulation around the PV center and relatively low heights, the PV is not circular in shape but rather elongated (**Figure 13**). The counterclockwise low around the PV center is bringing northerly flow to North America rather than westerly flow more common with a strong PV with a more circular configuration (**Figure 13)**.

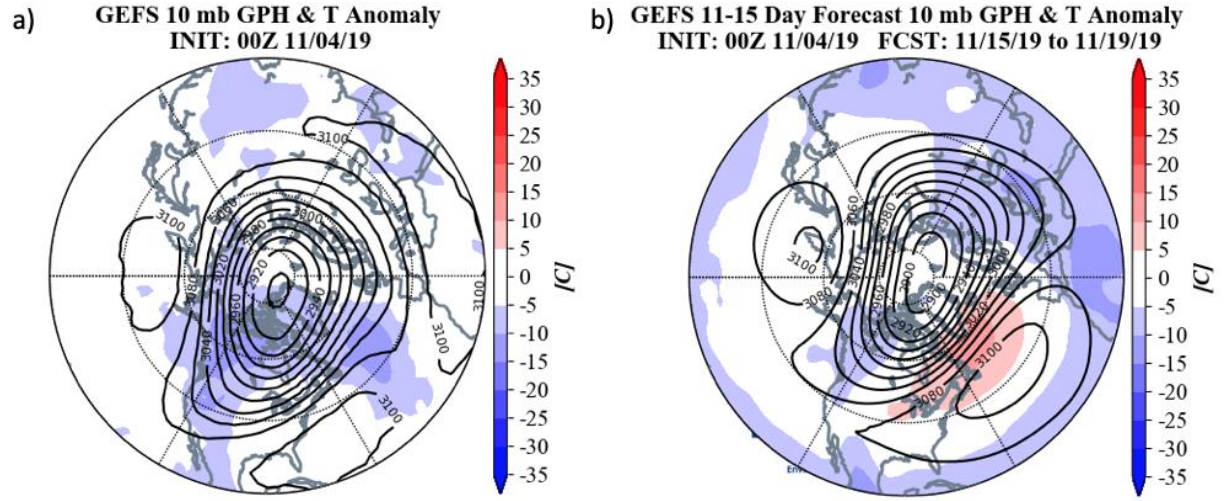

Figure 13. (**a**) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C;
shading) across the Northern Hemisphere for 4 November 2019. (**b**) Same as (a) except forecasted
averaged from 15 – 19 November 2019. The forecasts are from the 00Z 4 November 2019 GFS operational
model.

Currently there is one ridge in the North Pacific sector but interestingly enough the GFS predicts a second warming in the northern North Atlantic sector (**Figure 13)**. The two warmings will likely maintain the PV in its current elongated shape and continue to drive cold air into North America, at least in the short term. It could have important implications for the NH weather whether the PV maintains an elliptical shape supportive of cold temperatures or becomes circular with time more supportive of relatively mild temperatures.

This scenario of warming first in the North Pacific sector followed by warming in the North Atlantic sector is a classic precursor of a stratospheric PV split. This is not yet predicted by the GFS but could evolve in the model forecasts in the coming days and weeks. A major PV split is highly unusual before January, so if a PV split does occur, I expect it to be minor and of short duration. Still it could be sufficient to kick off some early winter weather across the NH.

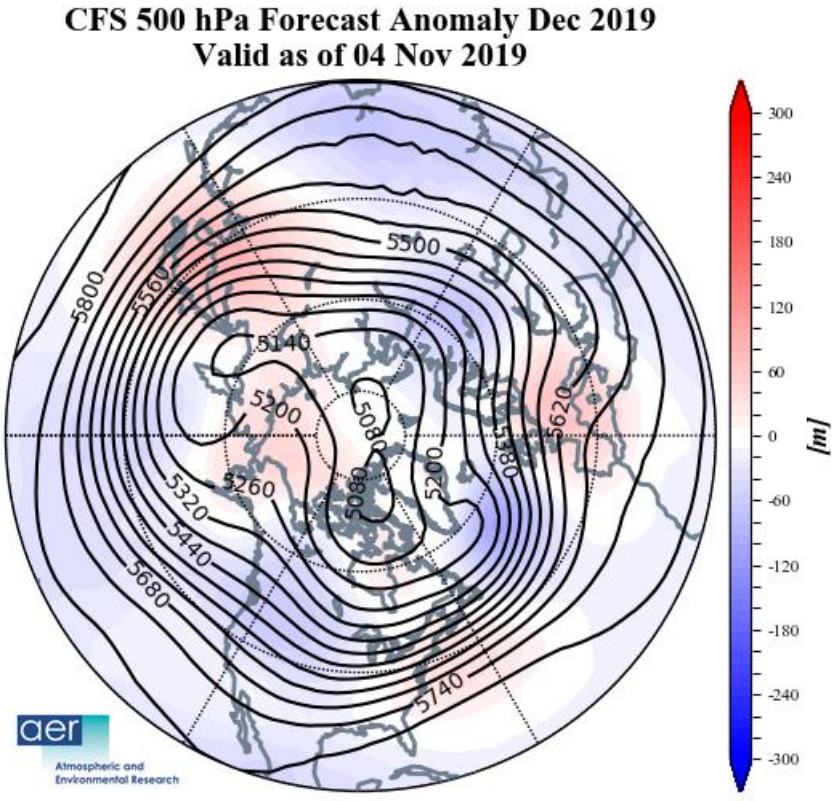

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for December 2019. The forecasts are from the 4 November 2019 CFS.

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 centered across the Western Europe, East Asia, Alaska and the US East Coast with troughs south of Greenland and Iceland, Western Asia, Eastern Siberia, the Dateline, Western Canada and the Western US (**Figure 14).** This pattern favors relatively warm temperatures for much of Europe and Asia, Eastern Canada and the US with seasonable to relatively cold temperatures for Siberia, Western Canada and Eastern Alaska (**Figure 15**)**.** The CFS has shown little consistency from run to run.

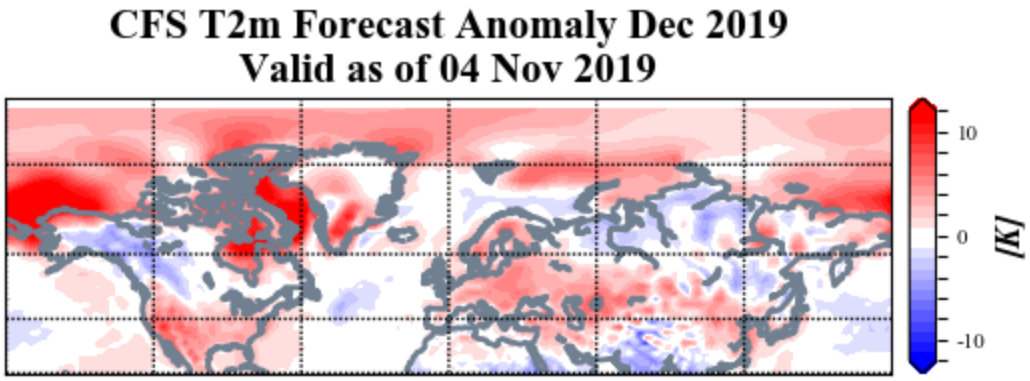

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for December 2019. The forecasts are from the 4 November 2019 CFS.

Surface Boundary Conditions

Arctic sea ice extent

Arctic sea ice growth rate has accelerated but remains well below normal. Large negative sea ice anomalies exist in two regions: the Chukchi-Beaufort and Barents-Kara Seas, however the anomalies in the North Pacific sector have emerged as the most well below normal (**Figure 16**). Below normal sea ice also exists in and around Greenland and the Canadian Archipelagos, which may favor a negative winter NAO. Based on recent research low sea ice anomalies in the Chukchi and Bering seas favors cold temperatures in central and eastern North America while low 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 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. However so far this fall coupling with the atmosphere has been stronger in the Chukchi, Beaufort and Bering seas, possibly since the negative anomalies are greater there.

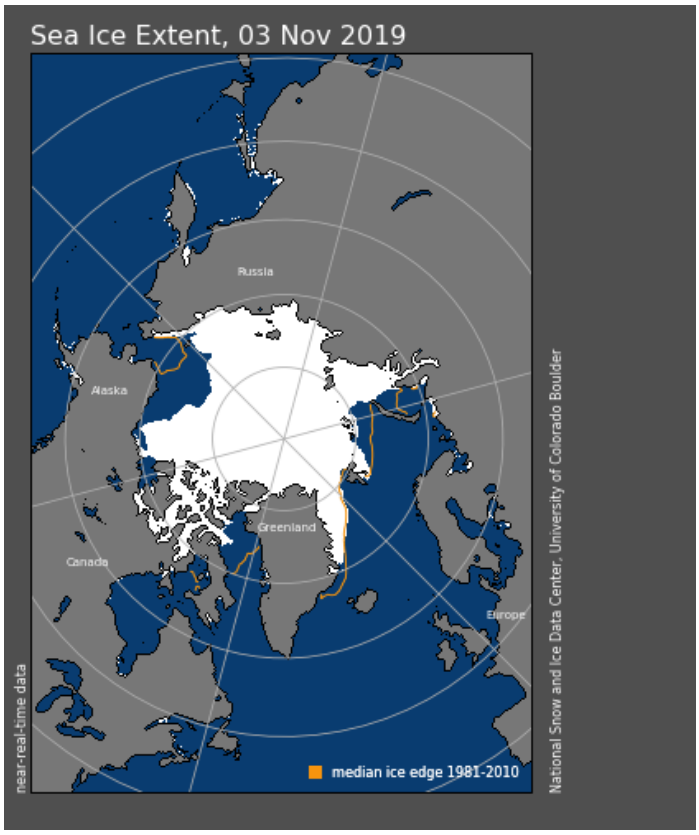

Figure 16. Observed Arctic sea ice extent on 3 November 2019 (white). Orange line shows
climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and
Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies have cooled and Neutral El Niño/Southern Oscillation (ENSO) conditions seem most likely (**Figure 17**). Observed SSTs across the NH remain well above normal especially near Alaska and along the north slope of Asia though below normal SSTs exist regionally especially west of South America. Warm SSTs around Alaska may favor mid-tropospheric ridging in the region this upcoming winter.

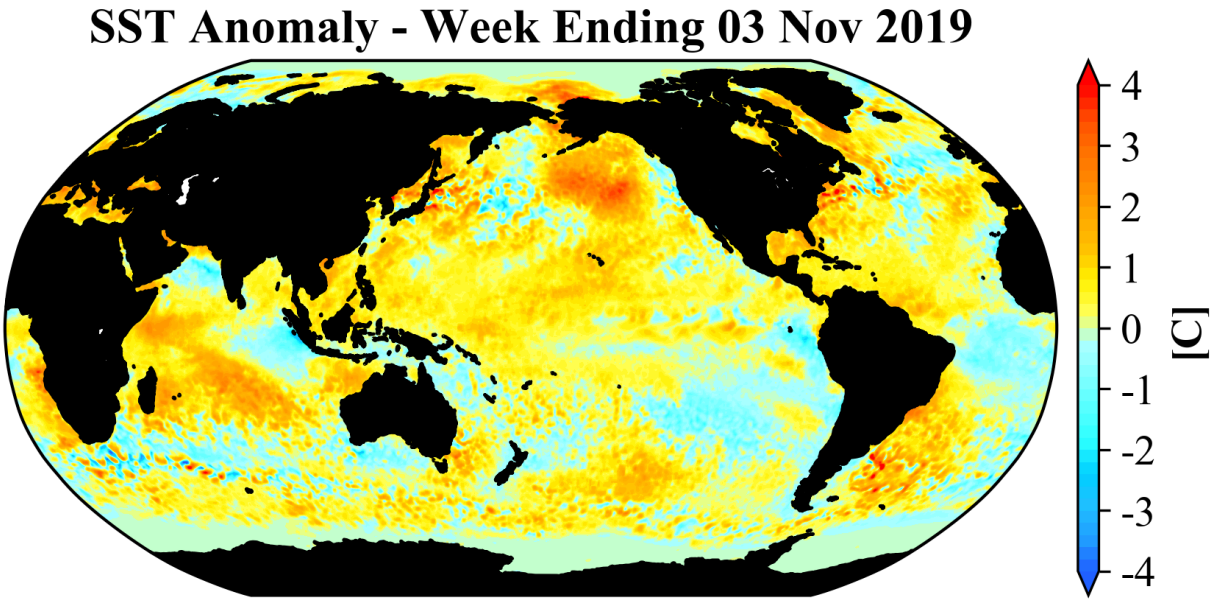

Figure 17. The latest weekly-mean global SST anomalies (ending 3 November 2019). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase 5 (**Figure 18**). The forecasts are for the MJO to rifle through phases 5-8 and possibly 1 over the next two weeks. Some MJO influence is possible across North American weather over the next two weeks as theses phases favor high latitude blocking and troughing in the US.

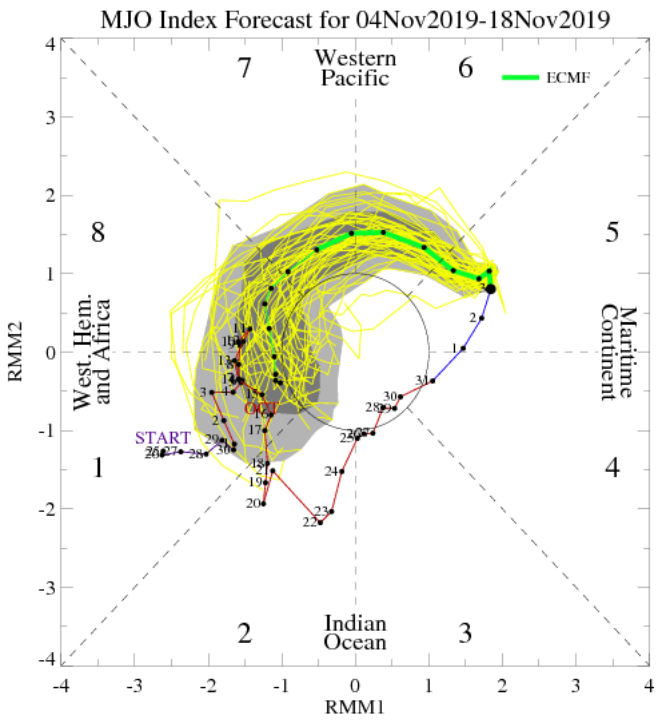

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 3 November 2019 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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 continues its climb across Eurasia and is currently near decadal averages. Snow cover will likely continue to advance especially across East Asia next week as troughing and cold temperatures spread across the region. 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.

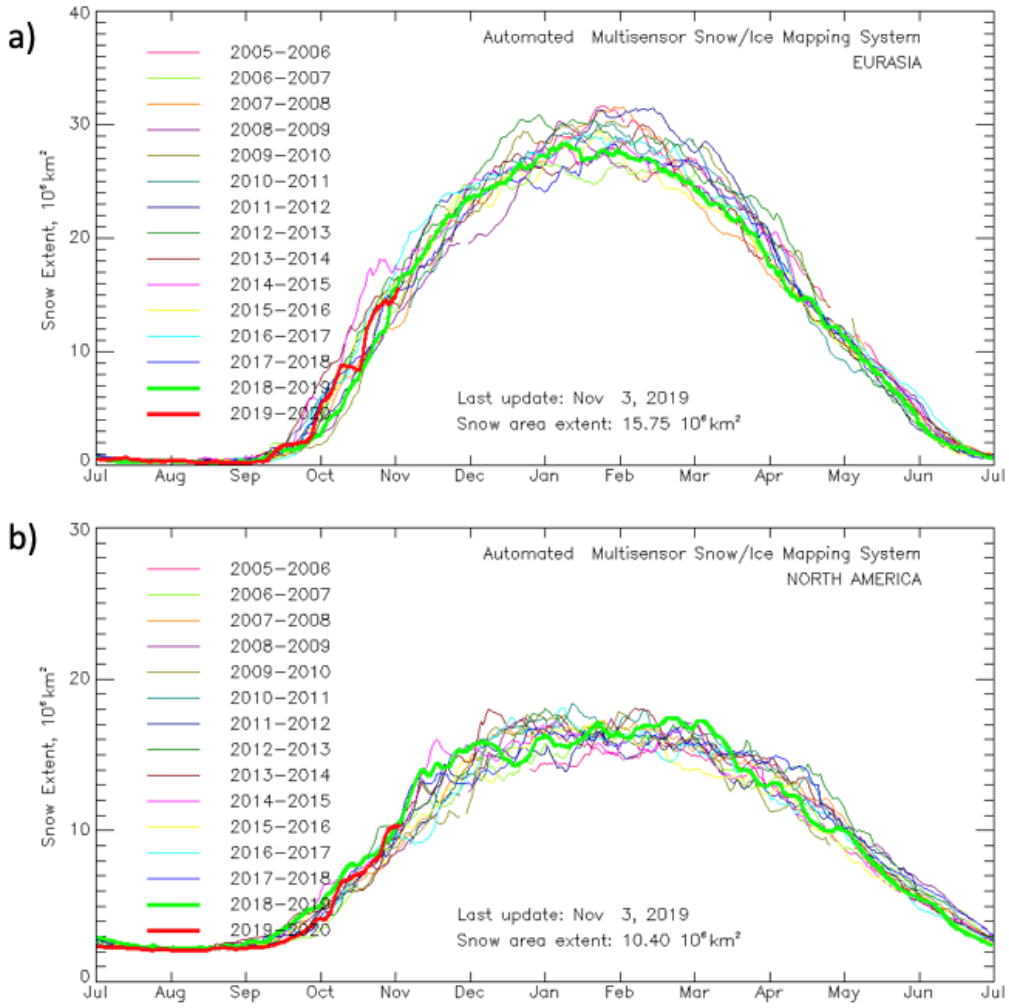

Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 3
November 2019. Image source:
https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover is also steadily advancing to near decadal highs and is comparable to last year at this time. The early advance of snow cover across Canada this fall, has likely contributed to an early start of cold temperatures across the Western US and now Eastern US.