

Arctic Oscillation and Polar Vortex Analysis and Forecasts

October 25, 2021

Dear AO/PV blog readers:

Starting this week, we shift the public release of the Arctic Oscillation/Polar Vortex blog to Wednesdays weekly through the winter season.

For those who would like an early look on Mondays, we will be offering at a nominal price a PDF version of the upcoming blog, and we will be rolling out in the coming weeks access to the datasets used in the production of this blog. At present we plan to make available in comma-separated values the timeseries of the Polar Cap Height and the timeseries of the Wave Activity Flux (vertical component), though we would love to hear your suggestions for additional data of interest to you all.

Starting on Monday, 25 Oct 2021, we will announce the availability of the AO/PV report for the week with links to the report and attendant datasets. The content of the report will be publicly available on Wednesday, 27 Oct, on our web site.

Special blog on winter 2018/2019 retrospective can be found here - <http://www.aer.com/winter2019>

Special blog on winter 2017/2018 retrospective can be found here - <http://www.aer.com/winter2018>

Special blog on winter 2016/2017 retrospective can be found here - <http://www.aer.com/winter2017>

Special blog on winter 2015/2016 retrospective can be found here - <http://www.aer.com/winter2016>

Dr. Judah Cohen from Atmospheric and Environmental Research (AER) embarked on an experimental process of regular research, review, and analysis of the Arctic Oscillation (AO) and Polar Vortex (PV). This analysis is intended to provide researchers and practitioners real-time insights on one of North America's and Europe's leading drivers for extreme and persistent temperature patterns.

During the winter schedule the blog is updated once every week. Snow accumulation forecasts replace precipitation forecasts. Also, there is renewed emphasis on ice and snow boundary conditions and their influence on hemispheric weather. With the start of spring we transition to a spring/summer schedule, which is once every two weeks. Snow accumulation forecasts will be replaced by precipitation forecasts. Also, there will be less emphasis on ice and snow boundary conditions and their influence on hemispheric weather.

Subscribe to our email list or follow me on Twitter (@judah47) for notification of updates.

The AO/PV blog is partially supported by NSF grant AGS: 1657748.

Summary

- The Arctic Oscillation (AO) is currently neutral and is predicted to straddle neutral over the next two weeks with mixed pressure/geopotential height anomalies across the Arctic and mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently negative and is predicted to remain negative as pressure/geopotential height anomalies are predicted to remain mostly positive across Greenland the next two weeks.
- This week Europe will be dominated by ridging/positive geopotential height anomalies coupled with normal to above normal temperatures. However, beginning next week strengthening ridging/positive geopotential height anomalies across Greenland will promote troughing/negative geopotential height anomalies coupled with normal to below temperatures across Western Europe including the United Kingdom (UK) as ridging/positive geopotential height anomalies coupled with normal to above normal temperatures persist across Eastern Europe.
- Much of Asia will be dominated by ridging/positive geopotential height anomalies coupled with normal to above normal temperatures over the next two weeks. However, one exception is troughing/negative geopotential height anomalies coupled with normal to below temperatures that begins over northwest Asia this week that slides eastward into Central Asia and then East Asia and deepens. Deepening troughing in Central and extending into East Asia could have longer term implications for North American weather.
- The pattern across North America this week is troughing/negative geopotential height anomalies coupled with normal to below normal temperatures along the west coast of North America including Alaska and the Eastern United States (US) with ridging/positive geopotential height anomalies coupled with normal to above temperatures in Eastern Canada. However, next week strengthening ridging/positive geopotential height anomalies coupled with normal to above temperatures in western North America will contribute to deepen troughing/negative geopotential height anomalies coupled with normal to below temperatures in the Eastern US.
- In the *Impacts* section I once again discuss Siberian snow cover extent and the possibility of a stretched stratospheric polar vortex (PV) second week of November and the implication for North American weather.

Plain Language Summary of Impacts

I use October Eurasian snow cover extent (SCE) as one of our main predictors for winter temperature anomalies across the Northern Hemisphere (NH). Eurasian SCE is likely to be slightly above normal for the month of October so not a strong indicator. But I will continue to monitor the snow cover extent into November and December for further clues. This is speculative but changes in the atmospheric circulation suggest to me the beginnings of troposphere-stratosphere coupling that cause the polar vortex to stretch like a rubber band or taffy. The important weather implications for this coupling are for

colder weather first in East Asia and then North America east of the Rockies likely starting in mid-November.

Impacts

With my focus intently on the upcoming winter I will begin with the latest plot of daily Eurasian snow cover extent (SCE). In **Figure i**, I present my estimate of the observed daily snow cover extent for October 2021 compared with other Octobers dating back to 2009. The more extensive the snow cover the greater probability of an impactful PV disruption during winter and colder weather across the NH with a less extensive snow cover extent favoring a strong PV and milder weather across the NH.

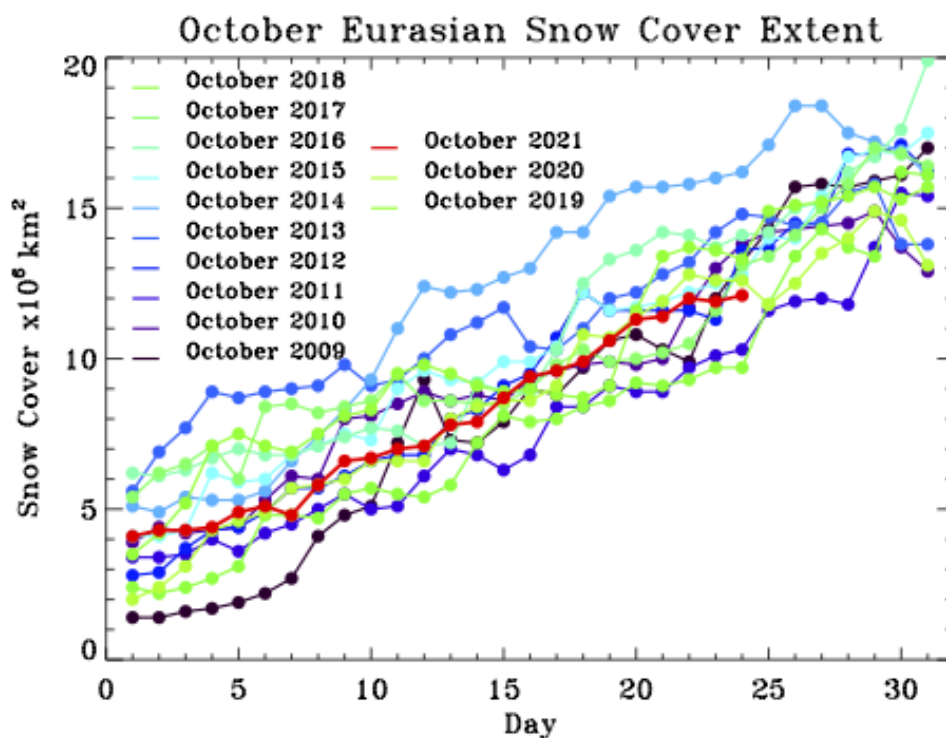


Figure i. Observed Eurasian daily snow cover extent in km^2 throughout the month of October from 2009 through 2020. Also show on red is the snow cover extent 1 – 24 October 2021.

Again as a reminder, the vast majority of those Octobers, the SCE was above normal, so the graph is a bit skewed, but so far the SCE in October 2021 is in the lower end of the pack. And with a week remaining in the month, I expect Eurasian snow cover extent to come in on the low end of recent years. The lowest year over the past decade was 2011. 2011 was also the second La Niña winter in row, as is predicted for this winter. I think this October will come in higher than 2011 and more in line with 2018 and even last year of 2020. All Octobers discussed preceded La Niña winters. It does seem to

me that El Niño is more favorable for the rapid advance in Eurasian snow cover during October and La Niña favors a slower advance; 2021 seems to be consistent with this personal observation.

I used to only pay attention to Eurasian SCE during October but now pay attention to November and even during the winter months in part thanks to recent studies such as [Wegmann et al. 2020](#) and [Gastineau et al. 2017](#). And in large part due to the study of [Lv et al. 2020](#), I will watch snowfall across Siberia even in December and January for clues about a possible PV disruption. And therefore, I am intrigued that the predicted atmospheric pattern does seem conducive for a more rapid increase in SCE across Eurasia heading into November.

I also continue to monitor the snow advance index (SAI; see [Cohen and Jones 2011](#)). It continues to be negative which is suggestive of a strong PV and milder weather. Though in more recent years I have thought of it as a better indicator to the timing of a possible PV disruption. A positive value suggests an earlier PV disruption and a negative value suggests a later PV disruption. If the SCE south of 60°N were to experience a jump in area towards the end of the month, it could turn positive.

In last week's blog I did mention the possibility of a stretched polar vortex event (for background see [Kretschmer et al. 2018](#)). In our recent paper [Cohen et al. 2021](#), some of the analysis suggested that Greenland high pressure/blocking was a long lead precursor to a stretched PV. Also, the predicted tropospheric and stratospheric circulations predicted by the CFS for November were consistent with a stretched polar vortex event. The forecast for the stratosphere still looks consistent with a stretched polar vortex event (see **Figure ii**) with a stretched PV from Siberia to eastern North America, ridging near Alaska and warming on the North Pacific side of the polar stratosphere. Though the tropospheric circulation doesn't look like much of anything (see **Figure 14**).

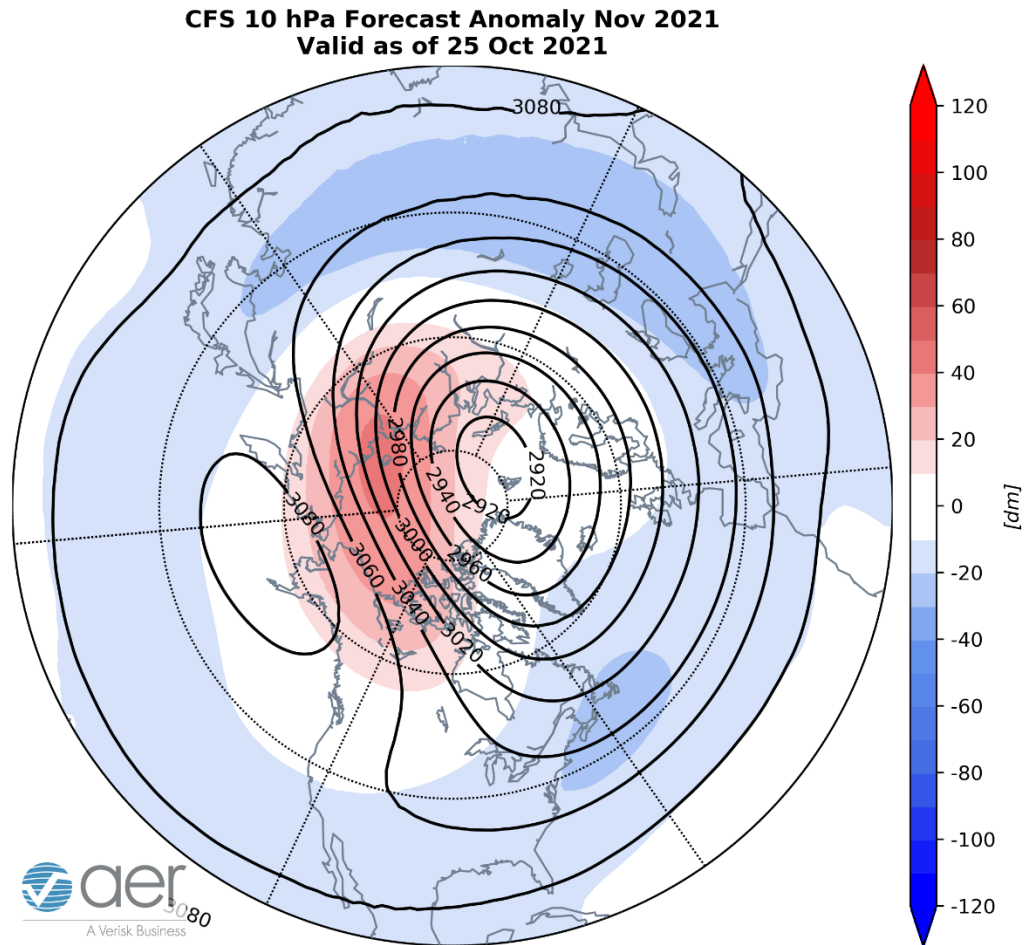


Figure ii. Forecasted average 10 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for November 2021. The forecasts are from the 00Z 25 October 2021 CFS.

The GFS tropospheric forecast of Ural ridging with downstream troughing (see **Figure 8**), the spreading of colder temperatures in Central Asia and extending into East Asia (see **Figure 9**) are reminiscent of precursors to a stretched polar vortex event. There is also a positive pulse of vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere or poleward heat transport in the stratosphere that is predicted for next week (**Figure 12**). We would still need to see reflection of the WAFz or downward over North America for a stretched polar vortex event to materialize, which is beyond the two-week forecast period. If a stretched polar vortex event does occur, the main tropospheric response is ridging over western North America into the Gulf of Alaska with downstream troughing across eastern North America likely in mid-November. This general pattern is already predicted beginning next week but following the wave reflection this pattern should become more amplified with deeper and more widespread cold. Our analysis does suggest that the stretched polar vortex event does not initiate the pattern but rather amplifies it. This is all very speculative, but a stretched polar

vortex could result in a reversal from October with a rapid expanse of snow cover accompanied by much colder weather across North America.

Now going even further down the speculative spectrum - the stratospheric PV could rapidly strengthen following a reflective or stretched polar vortex event (since reflection indicates that WAFz is blocked from reaching the stratospheric PV allowing it to strengthen). This could setup the US for a relatively mild December, something that seems consistent with recent trends with a cold November followed by a mild December. But of course, we need to observe the stretched polar vortex event first before predicting what might follow.

I typically don't post the AER winter temperature forecast to the blog until the very last few days of November. But, if possible, I will post to the blog a preliminary forecast either next week or the following week.

1-5 day

The AO is predicted to be mostly positive this week (**Figure 1**) as geopotential height anomalies are predicted to be mostly negative across the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). However, with mostly positive geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to be negative (**Figure 1**).

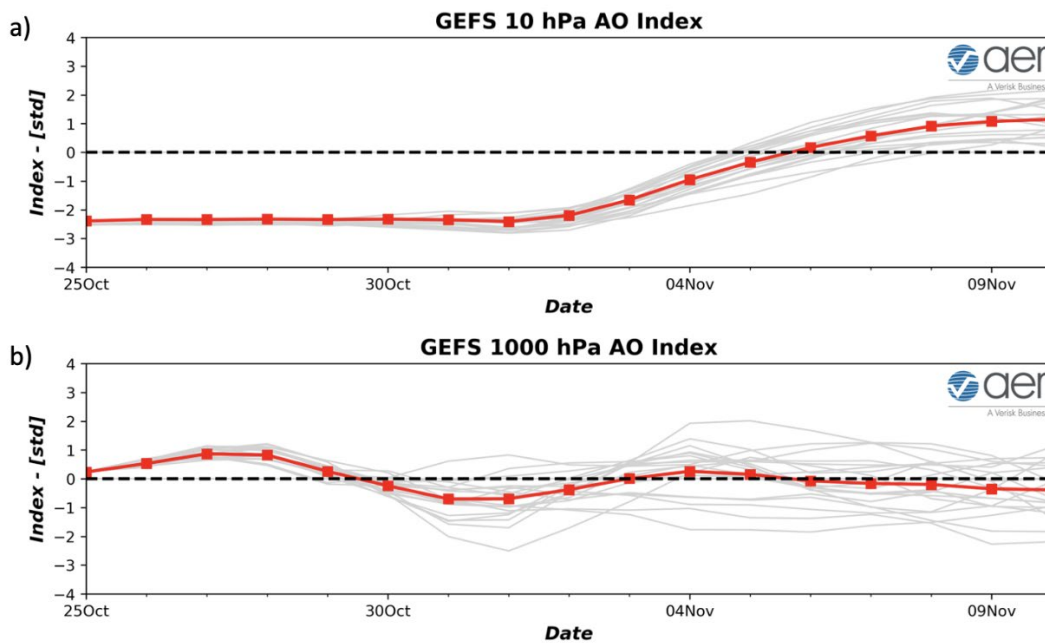


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 25 October 2021 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 25 October

2021 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 be widespread across Europe (**Figures 2**). This will favor widespread normal to above normal temperatures across Europe including the UK (**Figure 3**). The general pattern across Asia this period is ridging/positive geopotential height anomalies centered over East Asia except for troughing/negative geopotential height anomalies in Western Asia that extends eastward across the north Slope of Siberia (**Figure 2**). This pattern favors normal to above normal temperatures widespread across much of Asia with normal to below normal temperatures limited to Northwest Asia, the north slope of Siberia and Eastern Siberia (**Figure 3**).

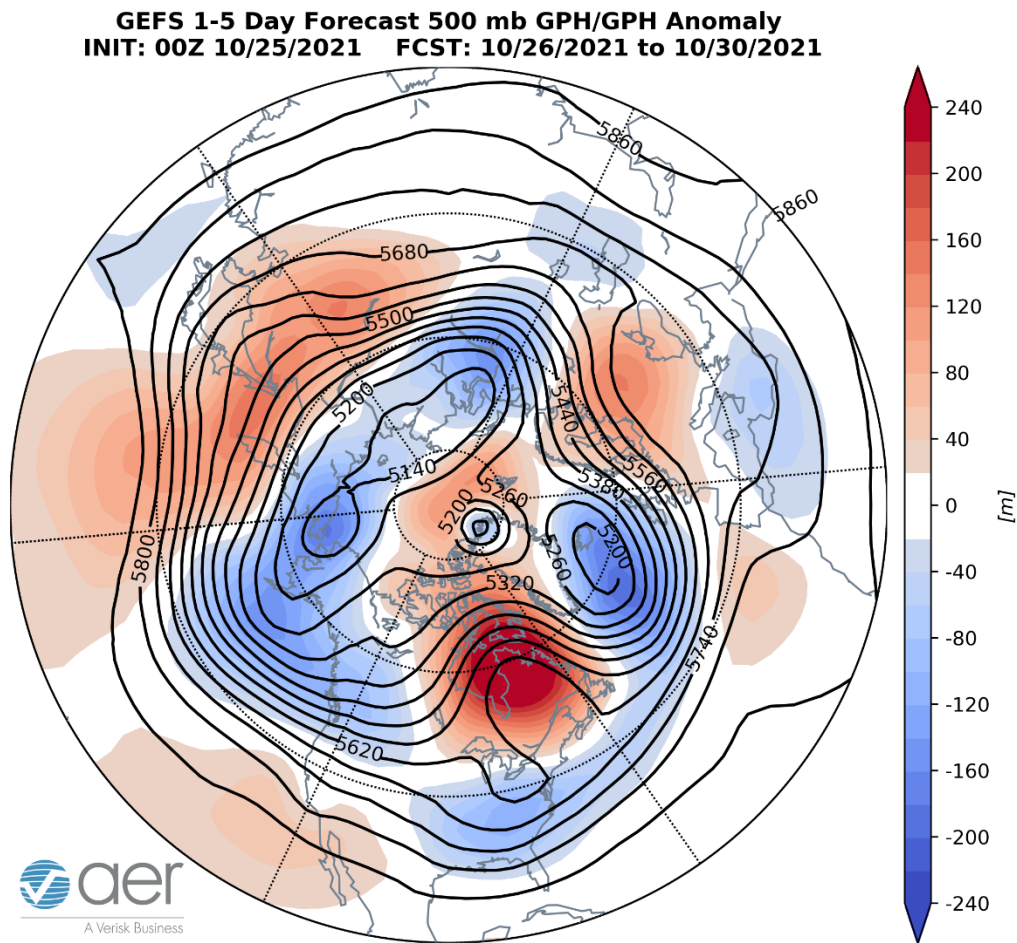


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 26 – 30 October 2021. The forecasts are from the 00z 25 October 2021 GFS ensemble.

The general pattern this week across North America is troughing/negative geopotential height anomalies centered in the Gulf of Alaska extending into western North America including Alaska forcing downstream ridging/positive geopotential height anomalies across Eastern Canada with more troughing/negative geopotential height anomalies in the Eastern US (**Figure 2**). This pattern is predicted to bring normal to below normal temperatures across the West Coasts of Canada and the US and parts of the Eastern US with normal to above normal temperatures across much of Alaska, Canada and the Western and Central US (**Figure 3**).

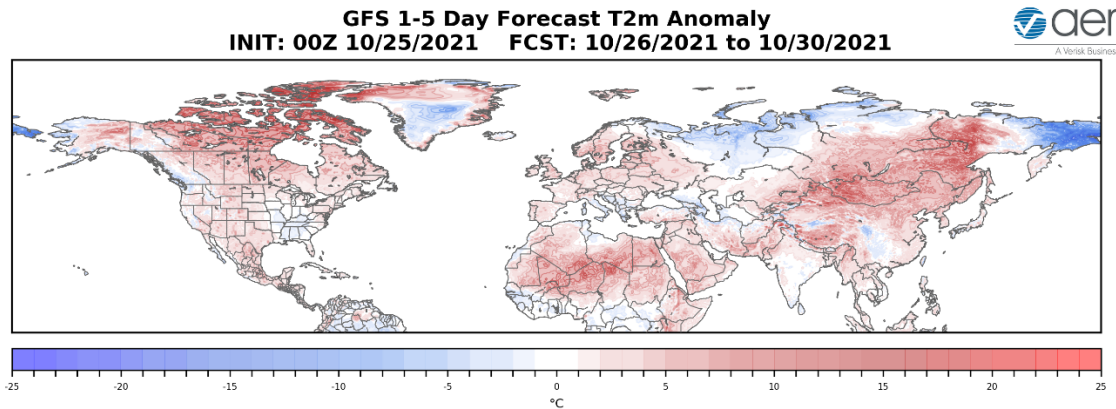


Figure 3. Forecasted surface temperature anomalies (°C; shading) from 26 – 30 October 2021. The forecast is from the 00Z 25 October 2021 GFS ensemble.

Troughing and/or cold temperatures are predicted to support new snowfall across Siberia while mild temperatures promote snowmelt in Scandinavia (**Figure 4**). Troughing and/or cold temperatures are predicted to support new snowfall across Alaska and far Northern and Western Canada while mild temperatures promote snowmelt in northwestern Hudson Bay (**Figure 4**).

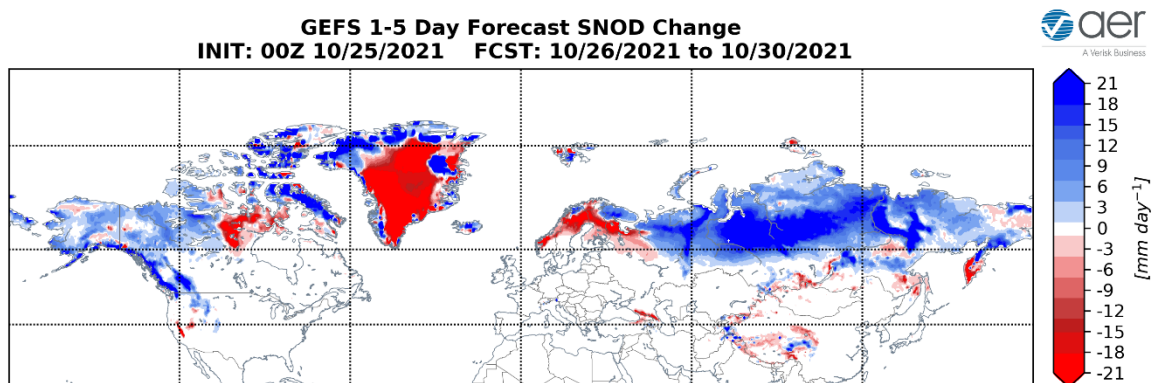
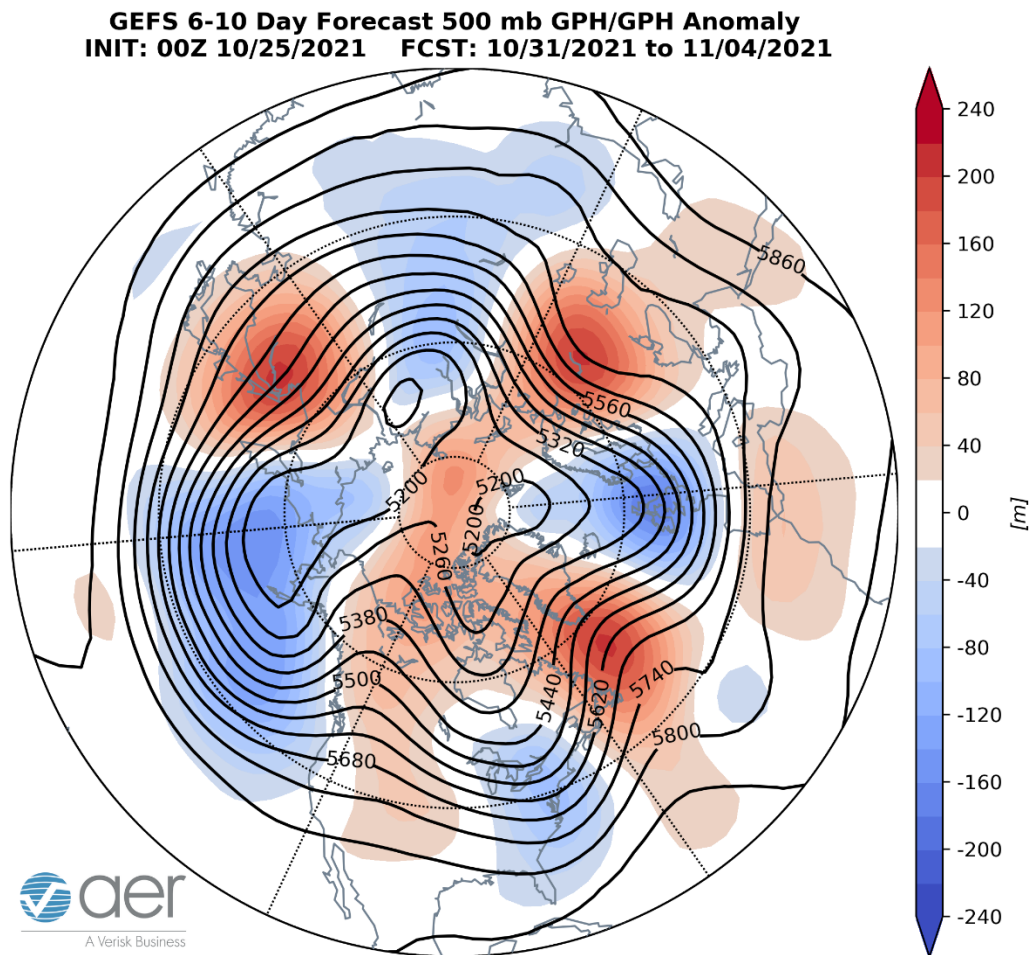


Figure 4. Forecasted snow depth changes (mm/day; shading) from 26 – 30 October 2021. The forecast is from the 00Z 25 October 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to dip into negative territory this period (**Figure 1**) as geopotential height anomalies turn positive across the Central Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with positive geopotential height anomalies continuing across the North Atlantic side of the Arctic (**Figure 5**), the NAO is predicted to remain negative this period.



Strengthening ridging/positive geopotential height anomalies across Greenland will force the return of troughing/negative geopotential height anomalies across Western

Europe including the UK with downstream ridging/positive geopotential height anomalies across Eastern Europe with this period (**Figures 5**). This will result in normal to above normal temperatures across Northwestern Europe including the UK with normal to below normal temperatures across Southern and Eastern Europe (**Figure 6**). Ridging/positive geopotential height anomalies in East Asia will persist while troughing/negative geopotential height anomalies previously in Western Asia will slide into Central Asia and deepen this period (**Figure 5**). This pattern favors normal to above normal temperatures widespread across West and East Asia with normal to below normal temperatures in Central Asia and Eastern Siberia (**Figure 6**).

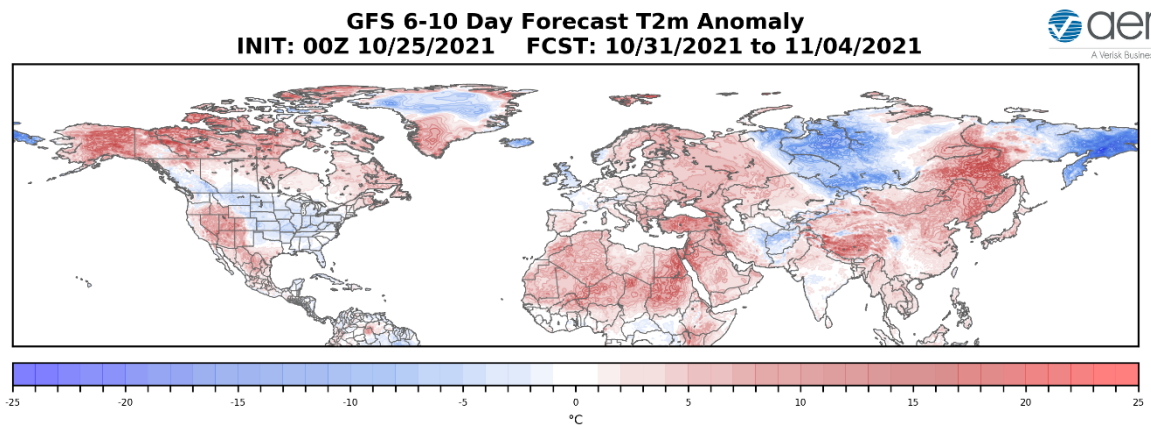


Figure 6. Forecasted surface temperature anomalies (°C; shading) from 31 October – 4 November 2021. The forecasts are from the 00Z 25 October 2021 GFS ensemble.

Troughing/negative geopotential height anomalies previously in the Gulf of Alaska are predicted to retrograde towards the Aleutians contributing to building ridging/positive geopotential height anomalies across western North America and much of Canada with troughing/negative geopotential height anomalies in the Eastern US (**Figure 5**). The widespread ridging is predicted to bring normal to above normal temperatures across much of Canada, Alaska, and the Western US with normal to below normal temperatures in Southwestern Canada, the Central and Eastern US (**Figure 6**).

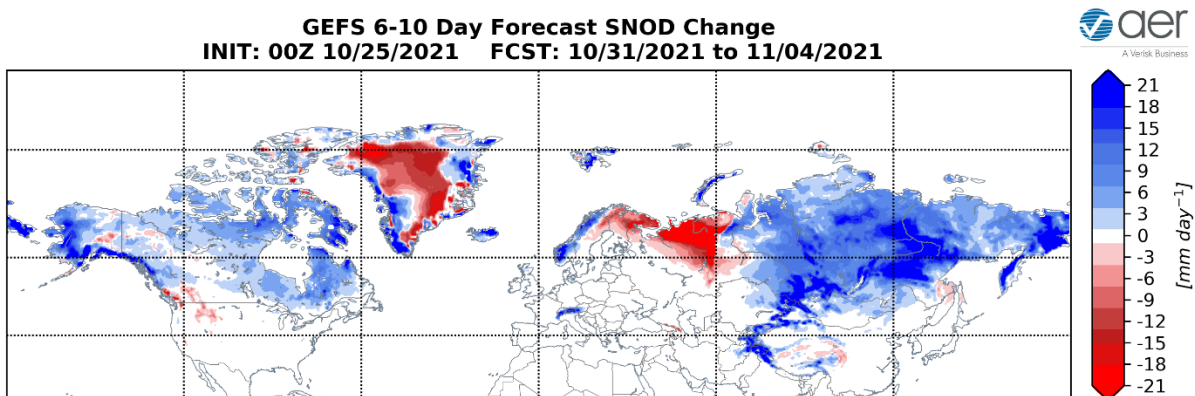


Figure 7. Forecasted snow depth changes (mm/day; shading) from 31 October – 4 November 2021. The forecast is from the 00Z 25 October 2021 GFS ensemble.

Trouging and/or cold temperatures are predicted to support new snowfall across Northern and Central Asia and the Tibetan Plateau while milder temperatures promote snowmelt across Scandinavia and Northwestern Asia (**Figure 7**). Trounging and/or cold temperatures are predicted to support new snowfall across Alaska, Northern and Eastern Canada while milder temperatures promote snowmelt across the Northwestern US (**Figure 7**).

11-15 day

With mostly positive geopotential height anomalies predicted across the Central Arctic and Greenland but negative on the North Pacific and Eurasian sides of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO should remain near neutral before dipping into negative territory this period (**Figure 1**). With predicted weak positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is forecasted to remain neutral to negative this period.

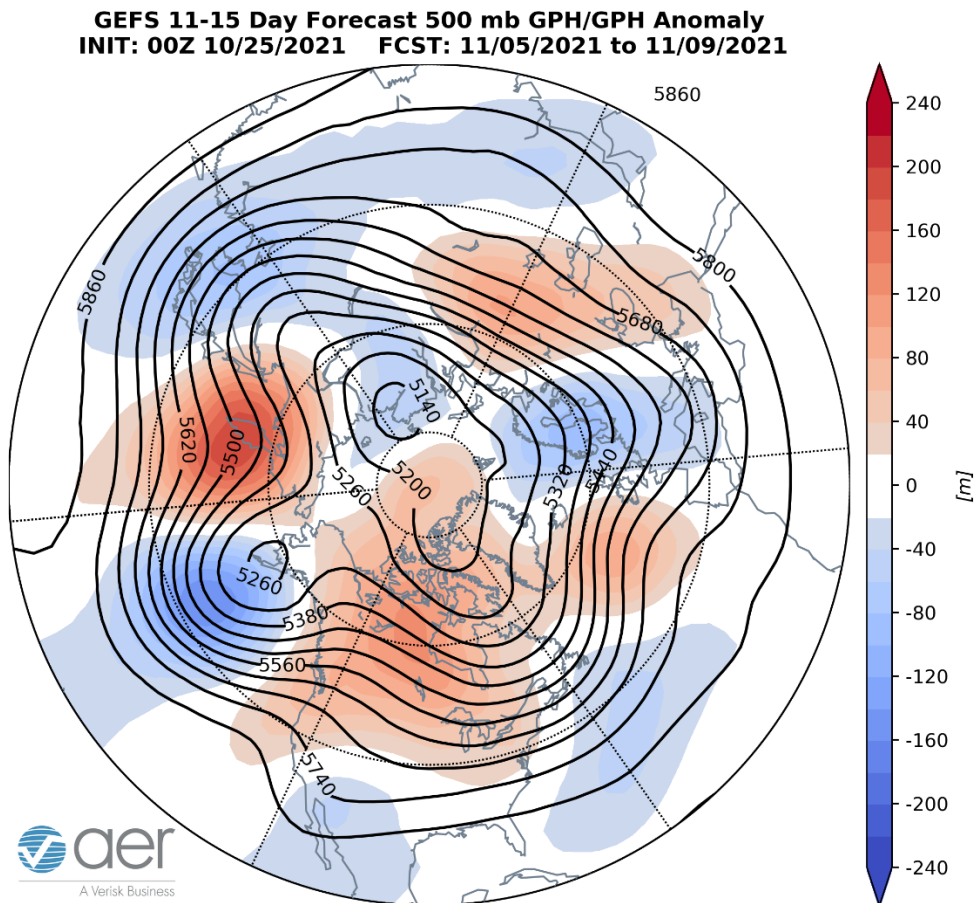


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 5 – 9 November 2021. The forecasts are from the 00z 25 October 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies across Greenland will anchor troughing/negative geopotential height anomalies across Western Europe with ridging/positive geopotential height anomalies across Eastern Europe this period (**Figure 8**). This pattern favors widespread normal to below normal temperatures across Western Europe including the UK with normal to above normal temperatures across Eastern Europe this period (**Figures 9**). Ridging/positive geopotential height anomalies are predicted across much of Western Asia and Eastern Siberia with troughing/negative geopotential height anomalies in Central Asia that extends southeastward into East Asia this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across much of Western Asia and parts of Eastern Siberia with normal to below normal temperatures in Western and Central Siberia that begins to filter into East Asia this period (**Figure 9**).

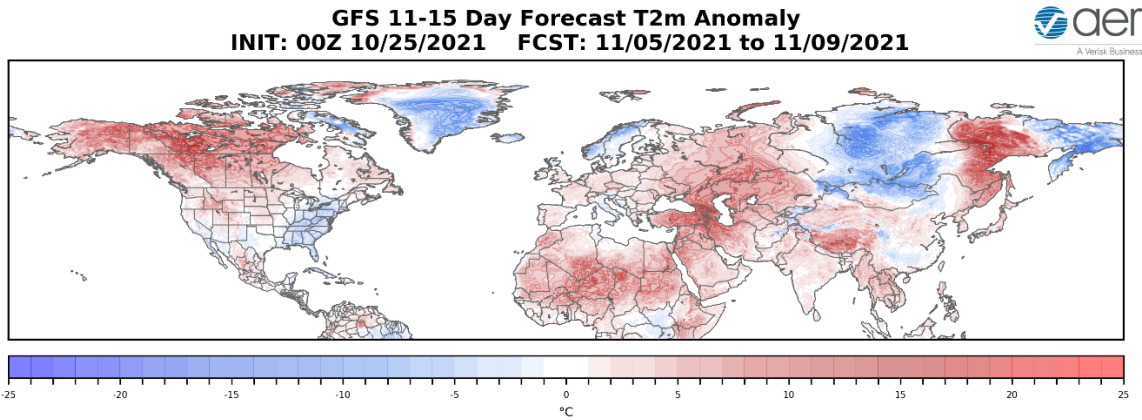


Figure 9. Forecasted surface temperature anomalies (°C; shading) from 5 – 9 November 2021. The forecasts are from the 00z 25 October 2021 GFS ensemble.

Deepening troughing/negative geopotential height anomalies near the Aleutians will favor downstream ridging/positive geopotential height anomalies across the Western US and much of Canada with more troughing/negative geopotential height anomalies in the Eastern US this period (**Figure 8**). This pattern favors normal to above normal temperatures widespread across much of Alaska, Canada, and the Western US with normal to below normal temperatures limited to the Eastern US (**Figure 9**).

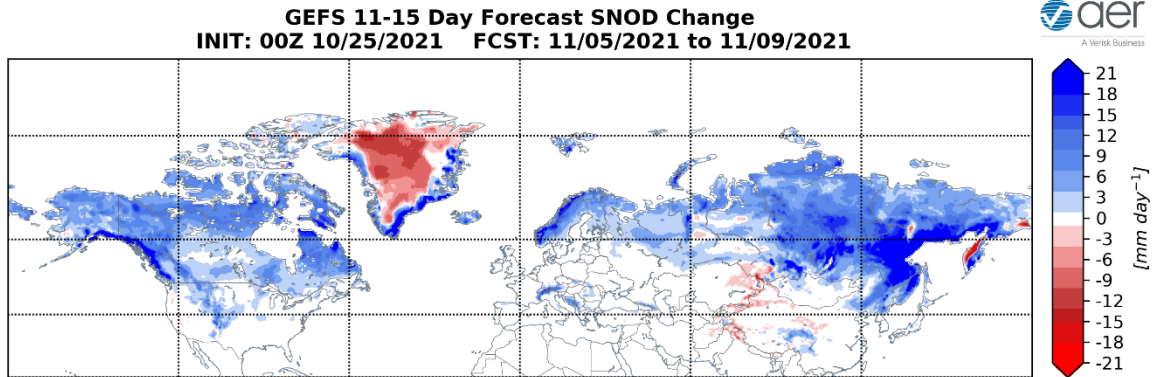


Figure 10. Forecasted snow depth changes (mm/day; shading) from 5 – 9 November 2021. The forecast is from the 00Z 25 October 2021 GFS ensemble.

Trouging and/or cold temperatures are predicted to support possible new snowfall across Scandinavia, Northern and Eastern Asia (**Figure 10**). Trouging and/or cold temperatures are predicted to support possible new snowfall across Alaska, much of Canada and the US Rockies (**Figure 10**).

Longer Term

30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to warm/positive PCHs in the upper troposphere and especially the stratosphere (**Figure 11**). The PCHs in the lower troposphere are cold/negative while the maximum of warm/positive PCHs in the stratosphere are predicted to descend this week into next causing the cold/negative PCHS in the lower troposphere to warm next week (**Figure 11**).

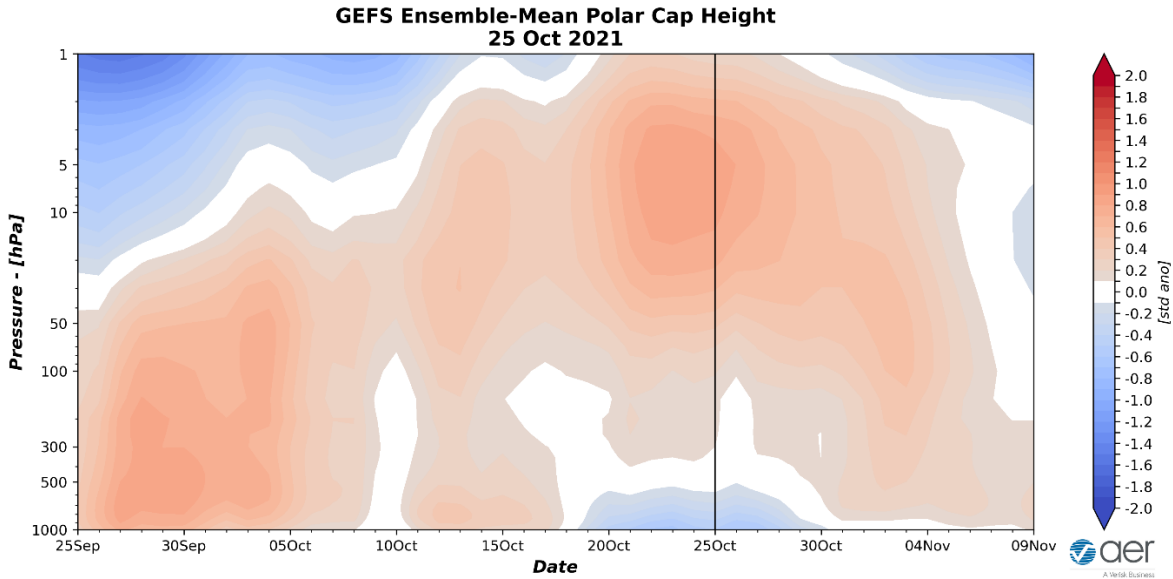


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 25 October 2021 GFS ensemble.

The current cold/negative lower tropospheric PCHs are consistent with the predicted slightly positive surface AO this week (**Figure 1**). However, as PCHs transition to neutral to warm in the lower troposphere next week, the surface AO will slowly drop to neutral and then negative next week (**Figure 1**).

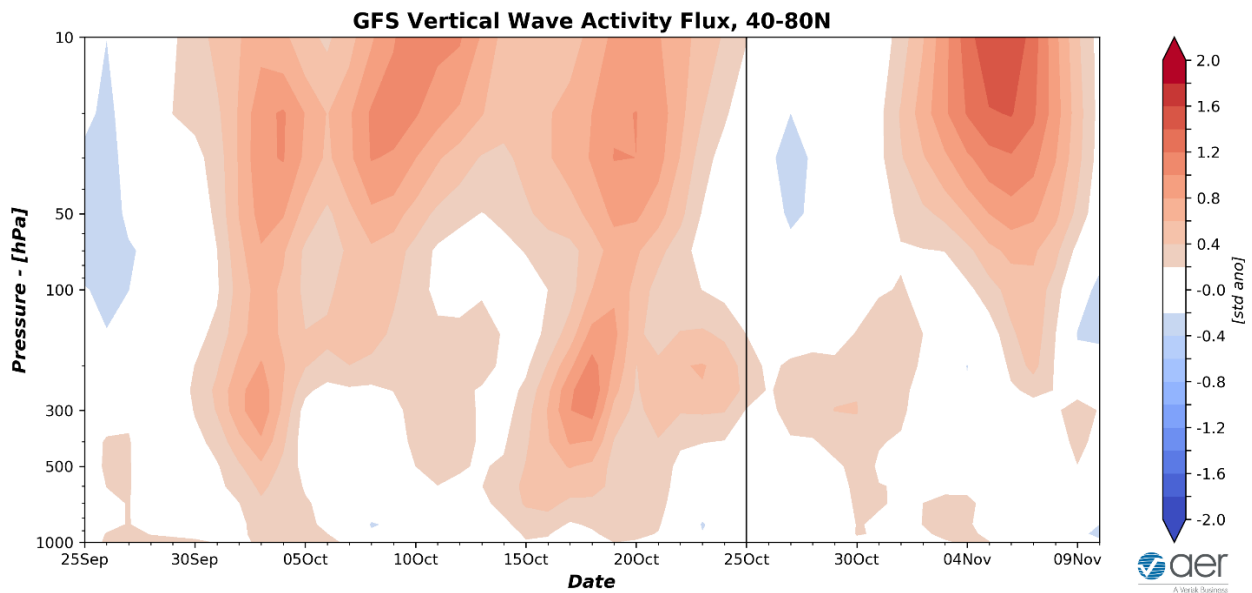


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 25 October 2020 GFS ensemble.

The positive WAFz this month perturbed the stratospheric PV, with the PV displaced towards the Barents-Kara Seas and with weak warming on the North Pacific and American sides of the polar stratosphere (**Figure 13**). The perturbed PV is resulting in a strongly negative stratospheric AO (**Figure 11**). With a break in the positive WAFz, the PV is predicted to recover and return to being centered near the North Pole (**Figure 13**) and a return to a positive stratospheric AO in early November (**Figure 11**).

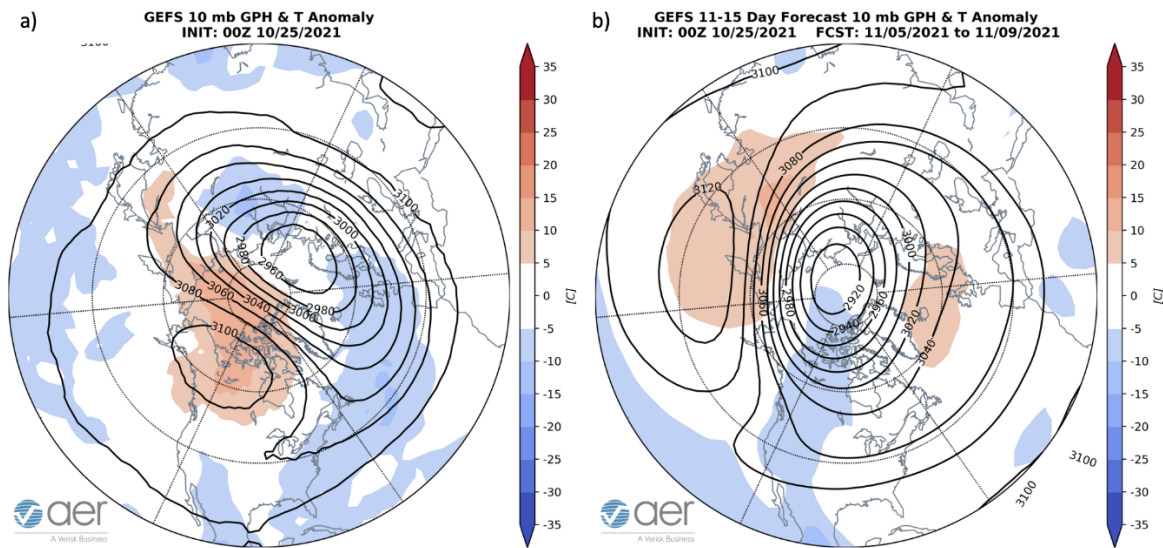


Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 25 October 2021. (b) Same as (a) except forecasted averaged from 5 – 9 November 2021. The forecasts are from the 00Z 25 October 2021 GFS model ensemble.

However, a new pulse of WAFz is predicted for next week (**Figure 12**). This is speculative but there are predicted anomalies in both the troposphere and stratosphere including ridging in the polar stratosphere centered near the Dateline and new warming coming out of East Asia towards Alaska (**Figure 13**) suggestive of a stretched polar vortex event. A stretched polar vortex is associated with cold temperatures first in Central and East Asia and then across Canada and the US east of the Rockies.

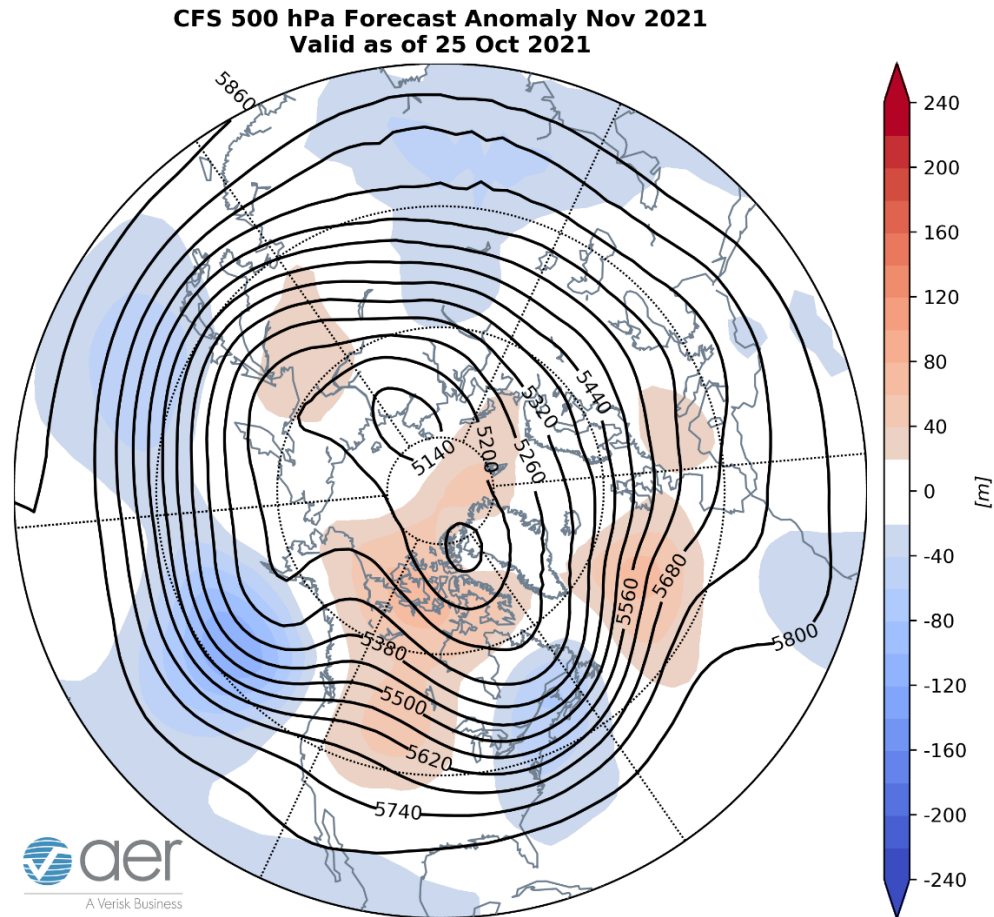


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for November 2021. The forecasts are from the 00Z 25 October 2021 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and surface temperatures for November (**Figure 15**) from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging south of Iceland, the Barents-Kara Seas, Eastern Siberia, Alaska, and Western Canada with troughing in Western Europe, Central Asia, Central Asia, from Japan through the Dateline and into the Gulf of Alaska and the Eastern US (**Figure 14**). This pattern favors seasonable to relatively warm temperatures widespread across Eastern Europe, West and East Asia, much of Alaska, Canada, and the Western US with seasonable to relatively cold across Western Europe, Central Asia, and the Eastern US (**Figure 15**). The anomalies are fairly weak and I would rate the forecast one of low confidence.

CFS 7-36 Day Forecast T2m Anomaly
INIT: 00Z 10/25/2021 FCST: 11/01/2021 to 11/30/2021

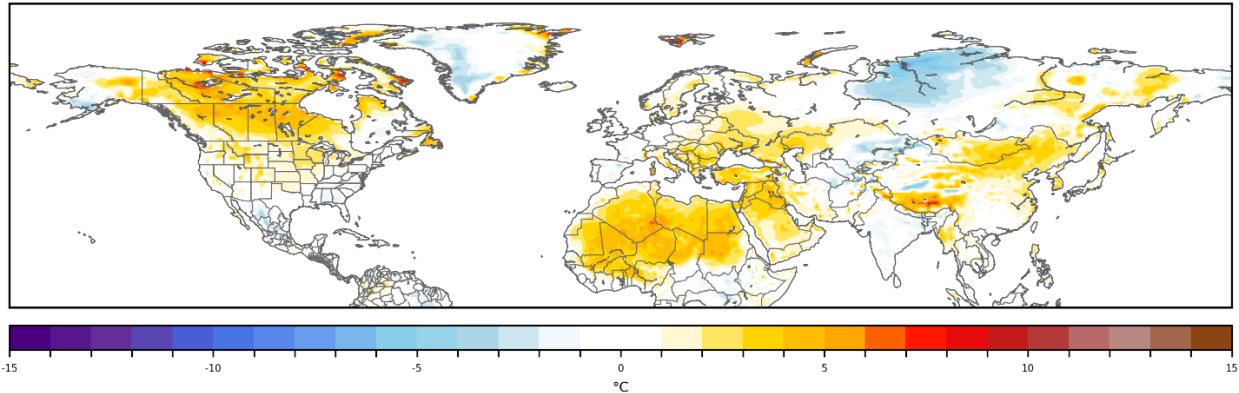


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for November 2021. The forecasts are from the 00Z 25 October 2021 CFS.

Surface Boundary Conditions

Arctic Sea ice

Arctic sea ice is growing but remains well below normal east of Greenland, along the Eurasian coast and in the Barents-Kara Seas. Sea ice is close to normal in the Canadian Archipelagos and in the Chukchi Sea. Sea ice is advancing in the Laptev and East Siberian seas and soon the largest negative anomalies should be focused in the Barents-Kara seas. Below normal sea ice in the Barents-Kara seas favors 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.

Northern Hemisphere, October 20, 2021

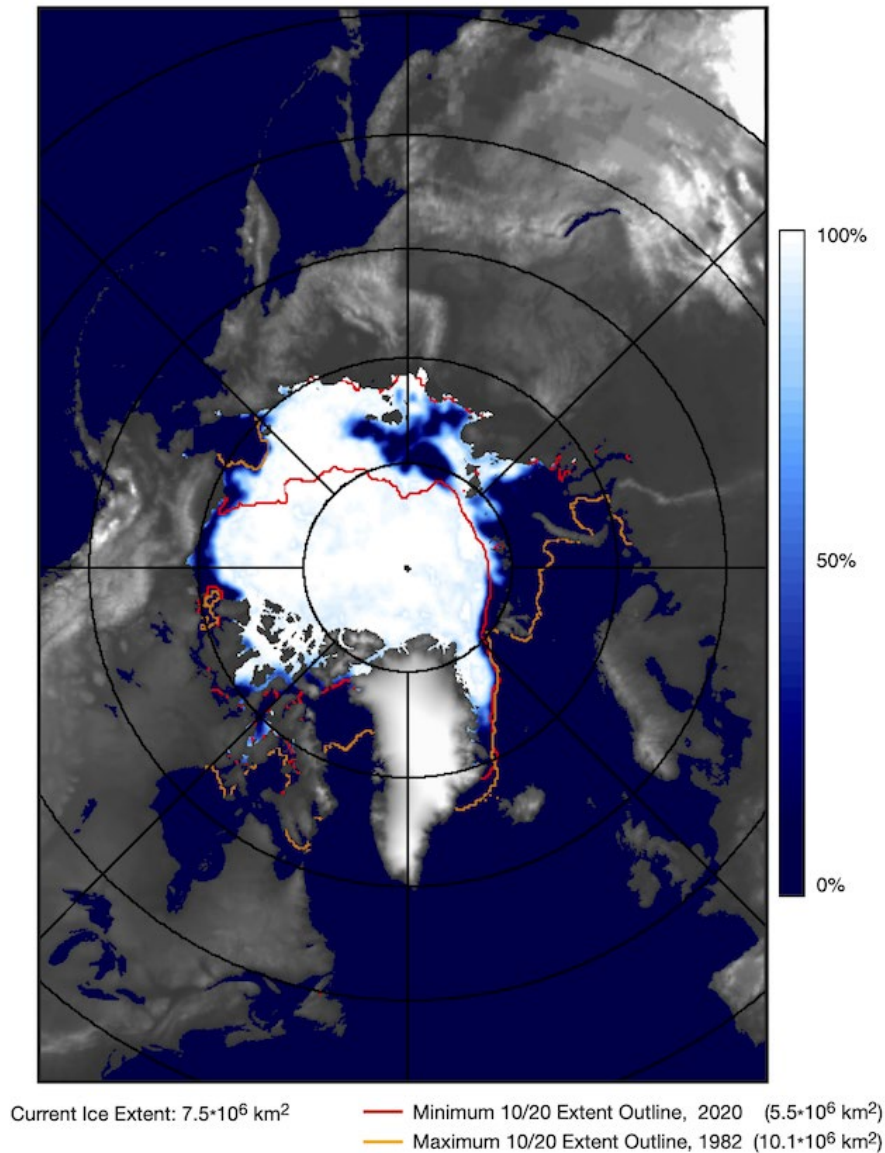


Figure 16. Observed Arctic sea ice extent on 20 October 2021 (white). Orange line shows minimum extent and red line shows maximum extent of sea ice based on the years 1981-2020. Image courtesy of <https://earth.gsfc.nasa.gov/cryo/data/current-state-sea-ice-cover>. The normal plot from NSIDC is missing.

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are below normal and we continue to observe neutral to weak La Niña conditions (**Figure 17**) and La Niña

conditions are expected through the fall. Observed SSTs across the NH remain well above normal especially in the Baltic Sea, central North Pacific (west of recent years), the western North Pacific and offshore of eastern North America though below normal SSTs exist regionally especially in the Southern Hemisphere. Not my expertise but the SST pattern in the North Pacific is starting to resemble a negative Pacific Decadal Oscillation (PDO) pattern that favors colder temperatures across northwestern North America and milder temperatures across southeastern North America.

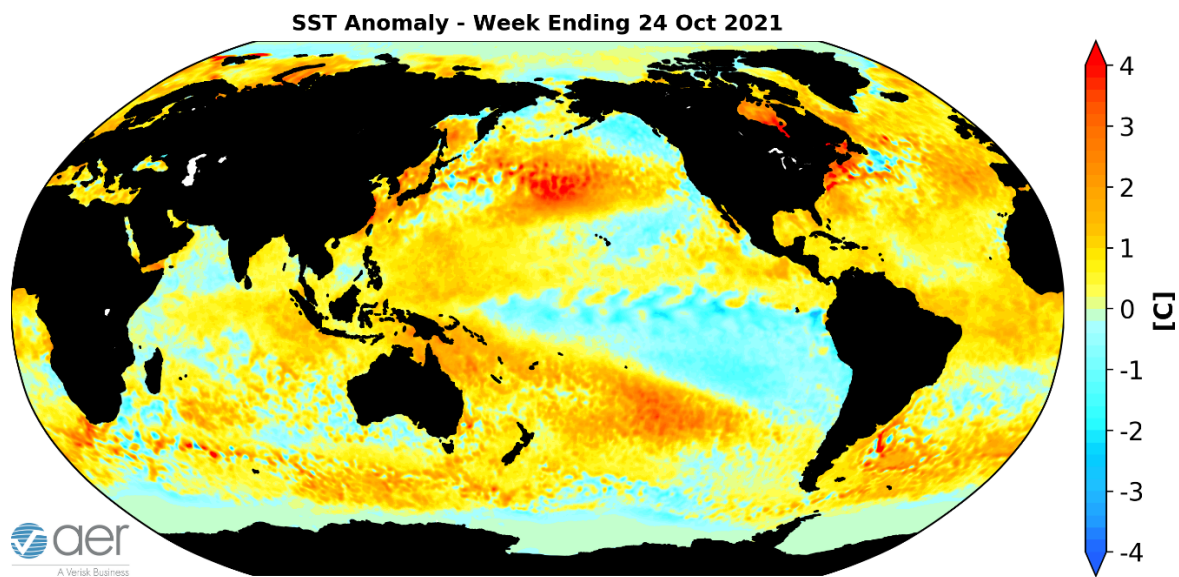


Figure 17. The latest weekly-mean global SST anomalies (ending 24 October 2021). Data from NOAA OI High-Resolution dataset.

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 18**). The forecasts are for the MJO to remain weak where no phase is favored for much of the next two weeks with the exception of a brief excursion into phase one later this week. Therefore it seems unlikely that the MJO is contributing significantly to the predicted weather pattern across North America over the next two weeks but admittedly this is outside of my expertise.

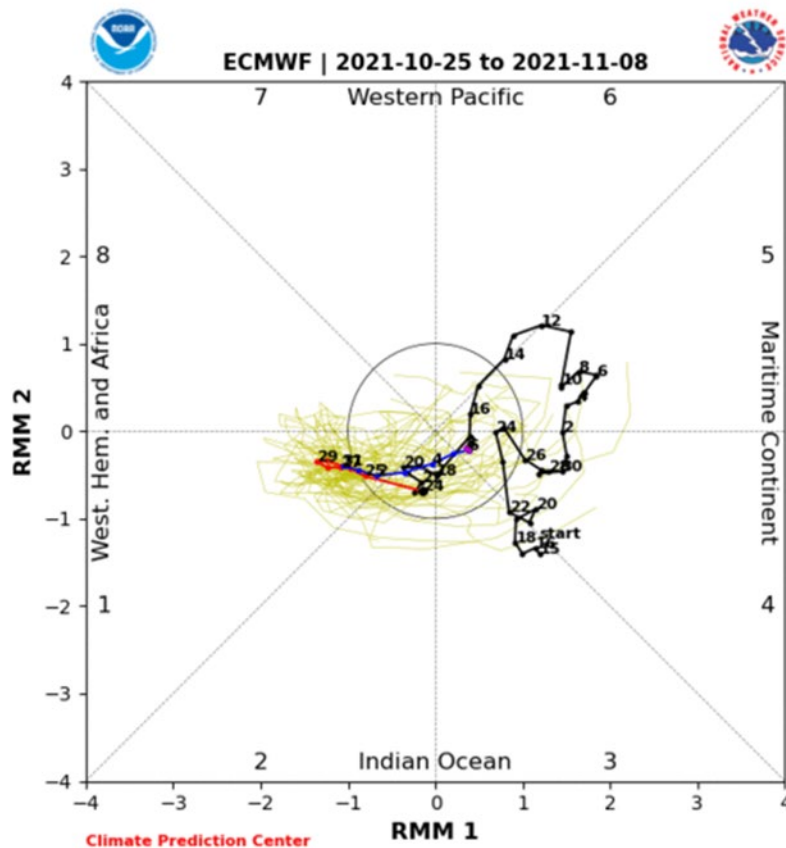


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 25 October 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>

Get Detailed Seasonal Weather Intelligence with [sCast](#)

We appreciate your taking the time to read the public Arctic Oscillation blog from Dr. Judah Cohen and the AER Seasonal Forecasting team.

Dr. Cohen’s detailed monthly seasonal forecast, sCast, is also available for purchase. [sCast](#) provides a monthly 30-60-90-180-day outlook into temperature and precipitation, solar flux and wind anomalies across the globe, and regional population weighted cooling and heating degree forecasts for the US.

Our sCast principal engineer, [Karl Pfeiffer](#), can help you use sCast and other AER seasonal forecast products to deliver important, long-lead time weather intelligence to your business. Please reach out to Karl today!