Arctic Oscillation and Polar Vortex Analysis and Forecasts

October 19, 2022

Dear AO/PV blog readers:

We have shifted the public release of the Arctic Oscillation/Polar Vortex blog to every other Wednesday through the summer season.

For those who would like an early look on Mondays, we will be offering at a nominal price (US $25) a PDF version of the upcoming blog, and we will be rolling out 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 appreciate to hear your suggestions for additional data of interest to you all.

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 neutral and is predicted to trend positive this and is predicted to remain neutral to positive the next two weeks as pressure/geopotential height anomalies are currently mixed across the Arctic but then become increasingly negative the next two weeks with mixed pressure/geopotential height anomalies across the mid-latitudes. The North

Atlantic Oscillation (NAO) is currently negative and is predicted to trend positive towards neutral the next two weeks as pressure/geopotential height anomalies are currently mostly positive across Greenland but then weaken and possibly turn negative the next two weeks.

- Over the next two weeks troughing/negative geopotential height anomalies in the eastern North Atlantic will favor ridging/positive geopotential height anomalies across much of Europe. This pattern will favor normal to above normal temperatures across much of Europe including the United Kingdom (UK) however towards the very end of the month the North Atlantic troughing will extend far enough east to bring normal to below normal temperatures across Western Europe including the UK and a trough on the upstream side of the Scandinavian block will pull cold temperatures from Western Russia into Eastern Europe.
- Over the next two weeks, the predicted general pattern is ridging/positive geopotential height anomalies centered in Western Siberia and extending into East Asia bookended by troughing/negative geopotential height anomalies in Eastern Siberia and Western Asia. This pattern favors widespread normal to above normal temperatures across Asia with normal to below normal temperatures mostly limited to Eastern Siberia and Western Asia the next two weeks.
- The general pattern this week across North America is ridging/positive geopotential height anomalies in the Gulf Alaska forcing troughing/negative geopotential height anomalies in Western Canada and the United States (US) with more ridging along the North Atlantic coast. This pattern favors widespread normal to above normal temperatures across Alaska, Western and Eastern Canada, the Western and Eastern US with normal to below normal temperatures across Central Canada and the Central US. However, starting next week the troughing in the Gulf of Alaska will push into the west coast of North America favoring strengthening ridging/positive geopotential height anomalies in eastern North America. This will favor cooling temperatures across Western Canada and the Western US with relatively milder temperatures across eastern North America.
- In the *Impacts* section I continue to discuss how the current and evolving anomalies in snow and ice across the Arctic how they might portend the behavior of the polar vortex (PV) and the Northern Hemisphere (NH) winter.
- *Impacts* section I continue to discuss how the current and evolving anomalies in snow and ice across the Arctic might portend for the polar vortex (PV) and the Northern Hemisphere (NH) winter.

Plain Language Summary

I discuss the current state of two fall Arctic predictors that I use for our winter forecast. The first is snow cover extent which despite a fast start has basically crashed and burned and for now is limping along. Second is Arctic sea ice, which is well below

normal but regional anomalies are very important. The overall pattern for the next two weeks is looking mild and increasingly favorable for a strong PV in the short-term.

Impacts

I still expect to return to the regular schedule of early release for a nominal fee on Monday and then fully public on Wednesday next week. Given the short time between blogs, I will keep today's blog short and hope to discuss more on Monday.

Despite the Snow cover extent across Siberia beginning the month with a fast start it has basically flatlined for much of the month (see **Figure i**). Please note that earlier versions of the plot had one erroneous data point, which has been corrected. Currently snow cover advance has since fallen back towards the bottom of pack rivaling 2011 and 2018 for the least amount of snow cover for this date (see **Figure i**). Interestingly enough, those winters were very different and there is enough variability in those two winters to make most everyone happy to consider as plausible. The persistent ridging centered over Siberia is hostile to rapid advancement of snow cover which has been the dominant pattern this month. The pattern is starting to look better but still far from ideal if you believe the dynamical model forecasts. I still think that the monthly average will be above normal but not by much and mostly because of the fast start.

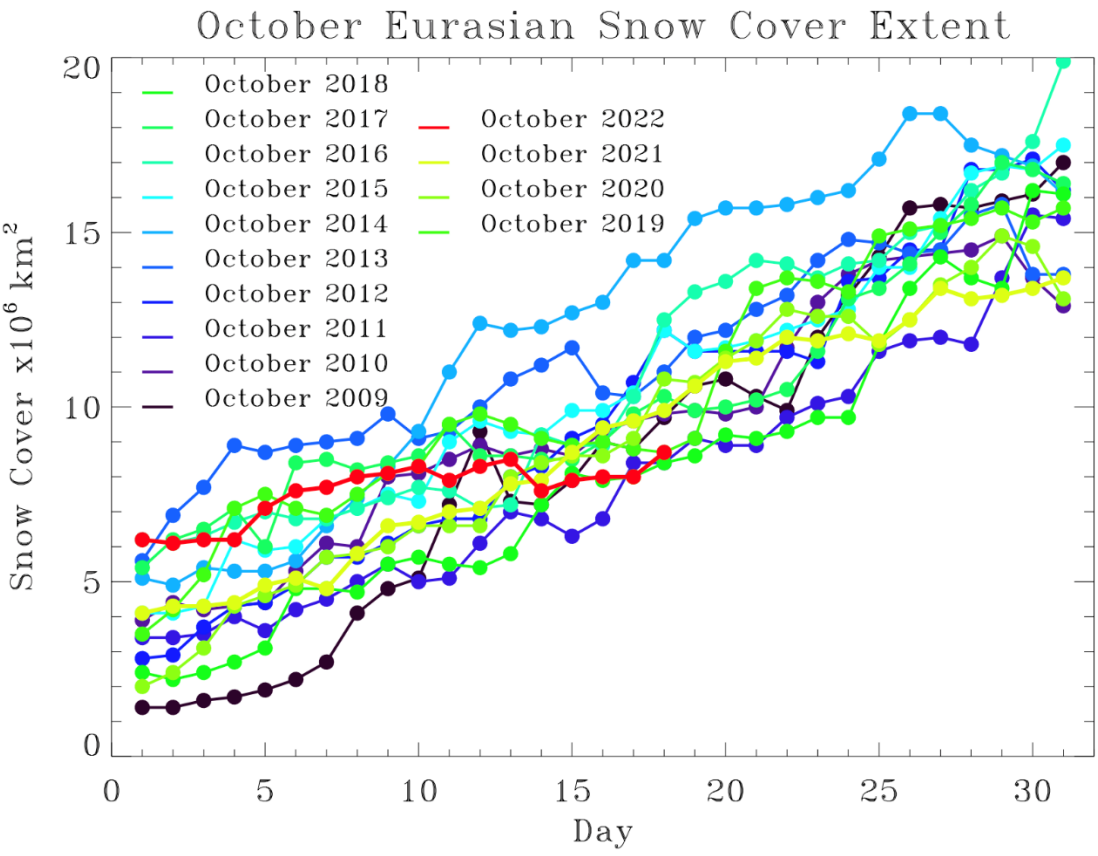

Figure i. Observed Eurasian daily snow cover extent in km2 throughout the month of October from 2009 through 2021. Also shown on red is the snow cover extent 1 – 18 October 2022.

Extensive Siberian snow cover (and likely deep but much harder to measure) favors an overall more disrupted PV and colder temperatures across parts of the Northern Hemisphere (NH). But if the value is only slightly above normal, then I would consider October snow cover as not a strong factor or a reliable predictor of the behavior of the PV later this winter.

In addition to using SCE as a predictor for the winter, I have also tried to incorporate Arctic sea ice anomalies in predicting the behavior of the PV. However, the region of below sea ice is important, with below normal sea ice in the Barents-Kara seas (near the Urals and Scandinavia) more influential in disrupting the PV than other Arctic regions. Sea ice growth is in full swing, and it does seem to me that the ice is growing faster in the North Pacific sector than in the North Atlantic sector (see **Figure ii**). If this trend continues it could favor a weaker PV in the winter months.

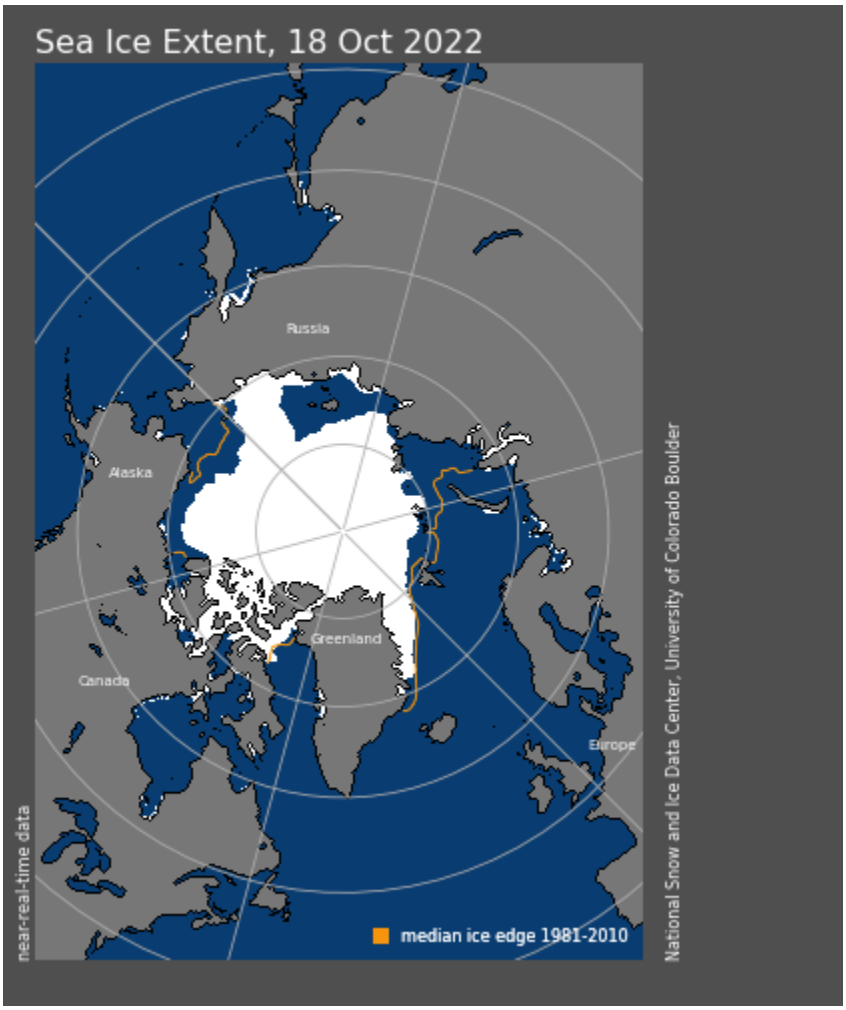

Figure ii. Observed Arctic sea ice extent on 18 October 2022 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC).

I did tweet about the recent troposphere-stratosphere-troposphere (T-S-T) coupling event that recently completed (see **Figure 11**) but the leg of the event (the downward propagation from the stratosphere to the troposphere was initially missed by the Global Forecast System (GFS) even in the short range. I think that this has strong ramifications for forecasts with time horizons of weeks to months because it is a challenge for all dynamical models to predict the correct impacts of a PV disruption even as little as a week in advance and certainly two weeks and longer. Though a highly anomalous event, I do think that it illustrates this point more clearly than most but then adding in the tweet a "classic tropospheric response" was likely a questionable statement. Yes, it did result in a deep trough in eastern North America with record cold and snow as is often observed with a stretched PV but "classic" does most often refer to a negative AO and/or NAO (which was my intention) and the GFS has backed off that forecast.

At least I am having a hard time getting excited by the predicted pattern (e.g. **Figure 5**). Deep troughing near the Urals and in the Gulf of Alaska with ridging in East Asia and eastern North America is not only an overall mild pattern it is very favorable for strengthening the PV. If you are a winter weather enthusiast, be thankful it is only October. If you are concerned about energy shortages and prefer to dampen heating demand, this pattern is as good as it gets if it can persist into winter.

Recent and Very Near Term Conditions

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

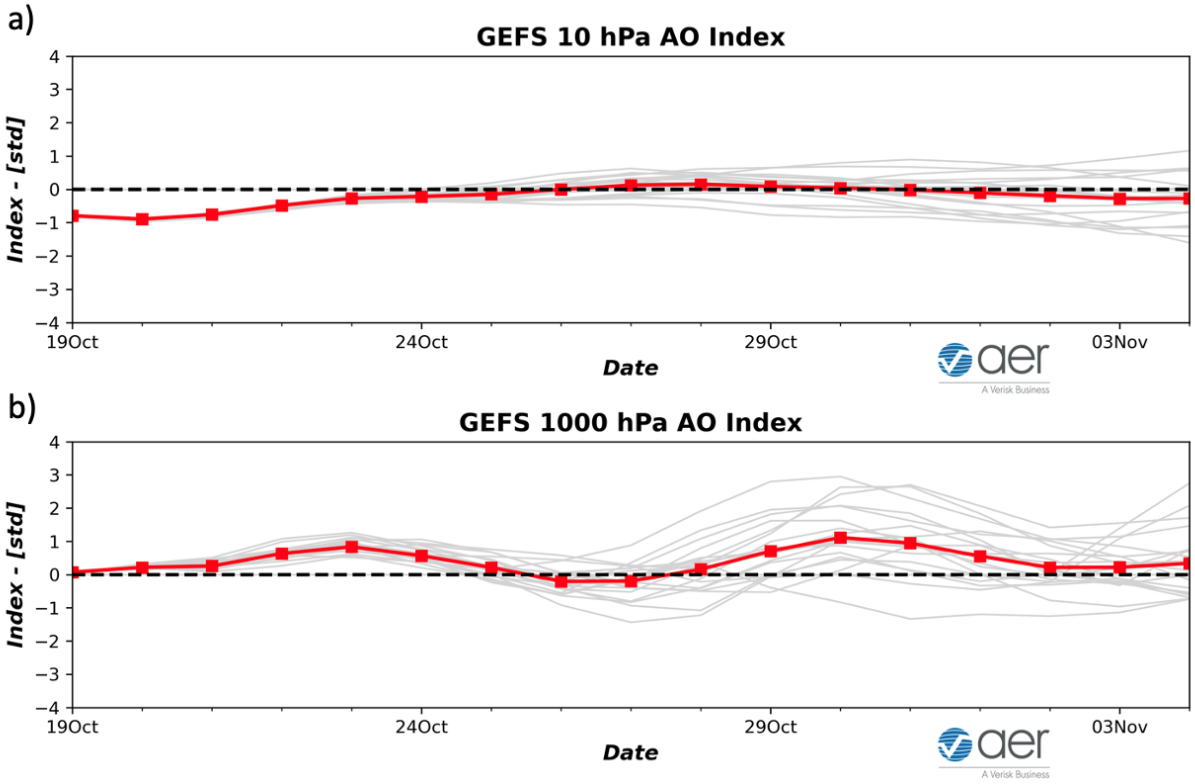

Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 19 October 2022 GFS ensemble. (b)The predicted daily-mean near-surface AO from the 00Z 19 October 2022 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Predicted troughing/negative geopotential height anomalies in the eastern North Atlantic will force ridging/positive geopotential height anomalies across much of Europe with troughing/negative geopotential height anomalies limited to Scandinavia and Turkey (**Figure 2).** This will favor normal to above normal temperatures across much of Europe including the UK except for normal to below normal temperatures across Scandinavia and Turkey (**Figure 3**). An omega block pattern is predicted across Asia with ridging/positive geopotential height anomalies centered across Western Siberia bookended by troughing/negative geopotential height anomalies in Eastern Siberia and Western Asia (**Figure 2**). This pattern favors widespread normal to above normal temperatures across most of Asia with normal to below normal temperatures mostly limited to Eastern Siberia and Western Asia **(Figure 3**).

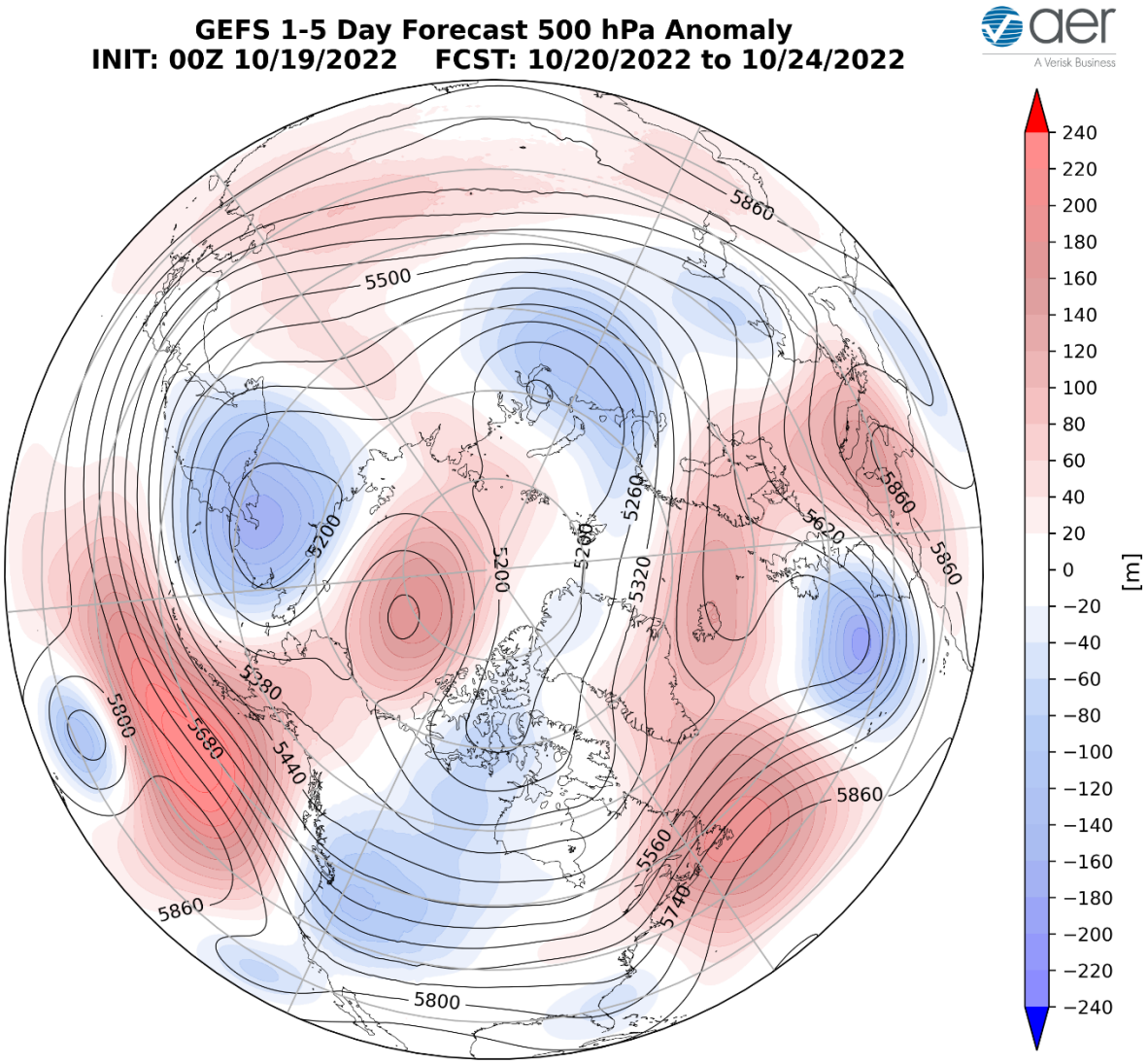

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 20 – 24 October 2022. The forecasts are from the 00z 19 October 2022 GFS ensemble.

Ridging/positive geopotential height anomalies in the Gulf of Alaska and Alaska favors troughing/negative geopotential height anomalies extending from Northern Canada to the Western US with more ridging/positive geopotential height anomalies centered in the Canadian Maritimes **(Figure 2).** The pattern will favor widespread normal to above normal temperatures across Alaska, Western and Eastern Canada, and the Eastern US with normal to below normal temperatures across Northern and Central Canada and the Western US **(Figure 3).**

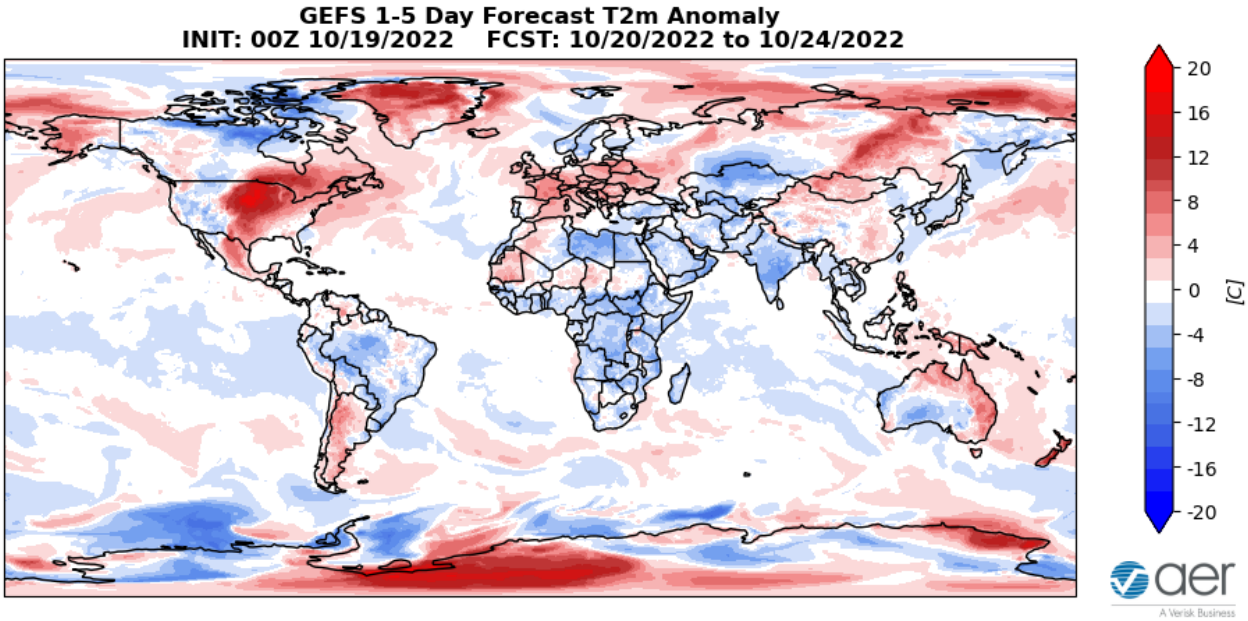

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 20 – 24 Octobe 2022. The forecast is from the 00Z 19 October 2022 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across northern Scandinavia and Siberia while mild temperatures will support snowmelt in the Tibetan Plateau (**Figure 4**). Troughing and/or cold temperatures will support new snowfall across Alaska and Northern and Western Canada while mild temperatures will support snowmelt in southern Hudson Bay (**Figure 4**).

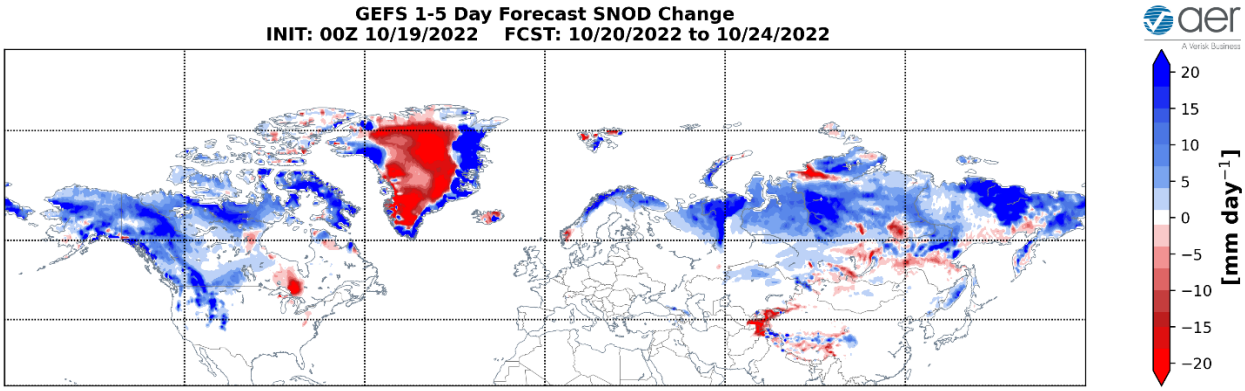

Figure 4. Forecasted snow depth changes (mm/day; shading) from 20 – 24 October 2021. The forecast is from the 00Z 19 October 2021 GFS ensemble.

Near-Term

1-2 week

The AO is predicted to straddle neutral this period **(Figure 1**) as geopotential height anomalies turn mixed across the Arctic and the mid-latitudes (**Figure 5**). With weaker and mixed geopotential height anomalies across Greenland (**Figure 5**), the NAO is predicted to straddle neutral this period as well.

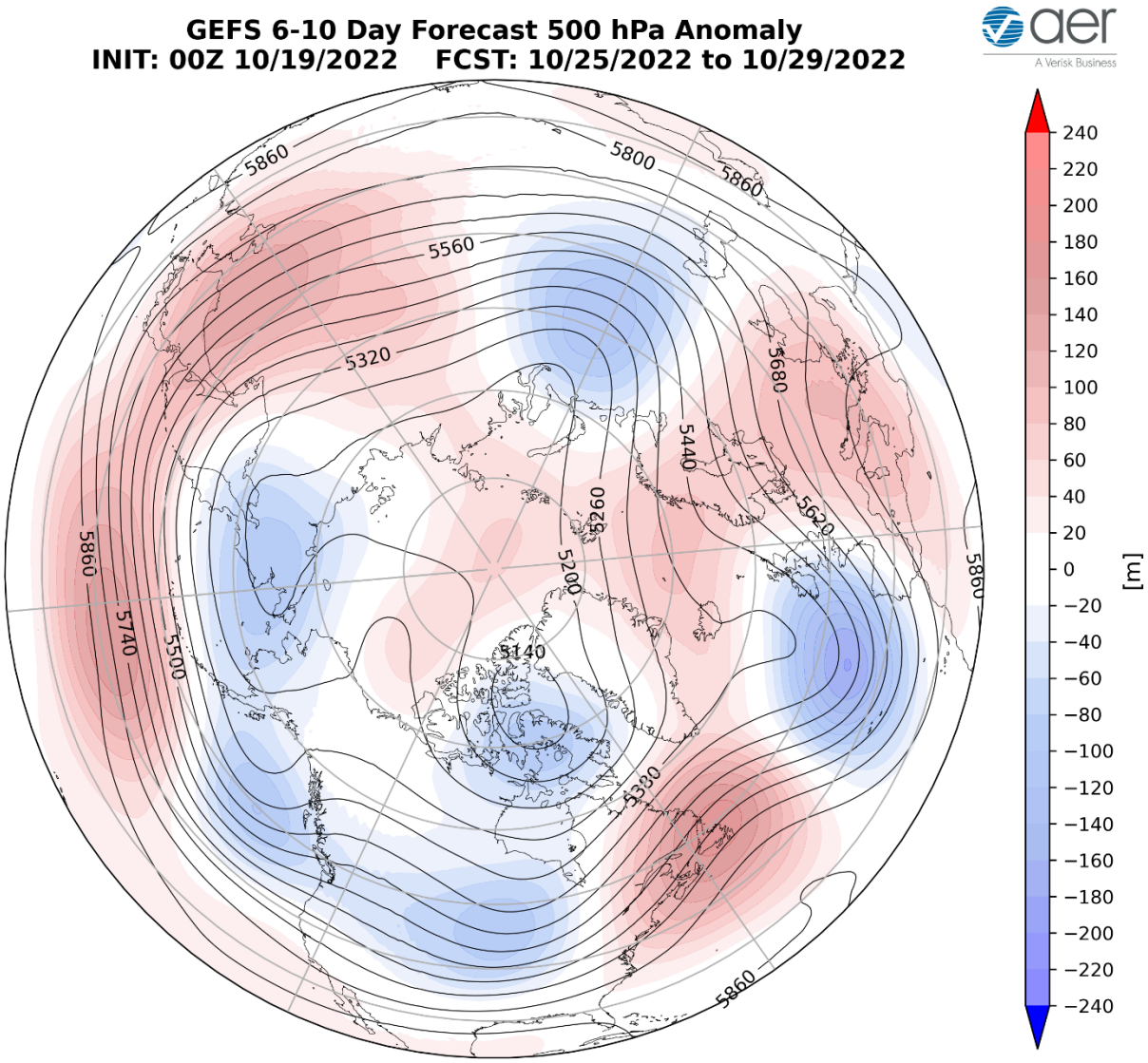

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 25 – 29 October 2022. The forecasts are from the 00z 19 October 2022 GFS ensemble.

Predicted troughing/negative geopotential height anomalies in the eastern North Atlantic will continue to support widespread ridging/positive geopotential height

anomalies persisting across Europe (**Figures 5). T**he pattern is predicted to result in widespread normal to above normal temperatures across Europe including the UK (**Figure 6**). Ridging/positive geopotential height anomalies are predicted to persist across Western Siberia extending into Eastern Asia with troughing/negative geopotential height anomalies centered in Eastern Siberia and the Urals this period (**Figure 5**). This pattern favors widespread normal to above normal temperatures across Asia with normal to below normal temperatures limited to Eastern Siberia and Western Asia **(Figure 6**).

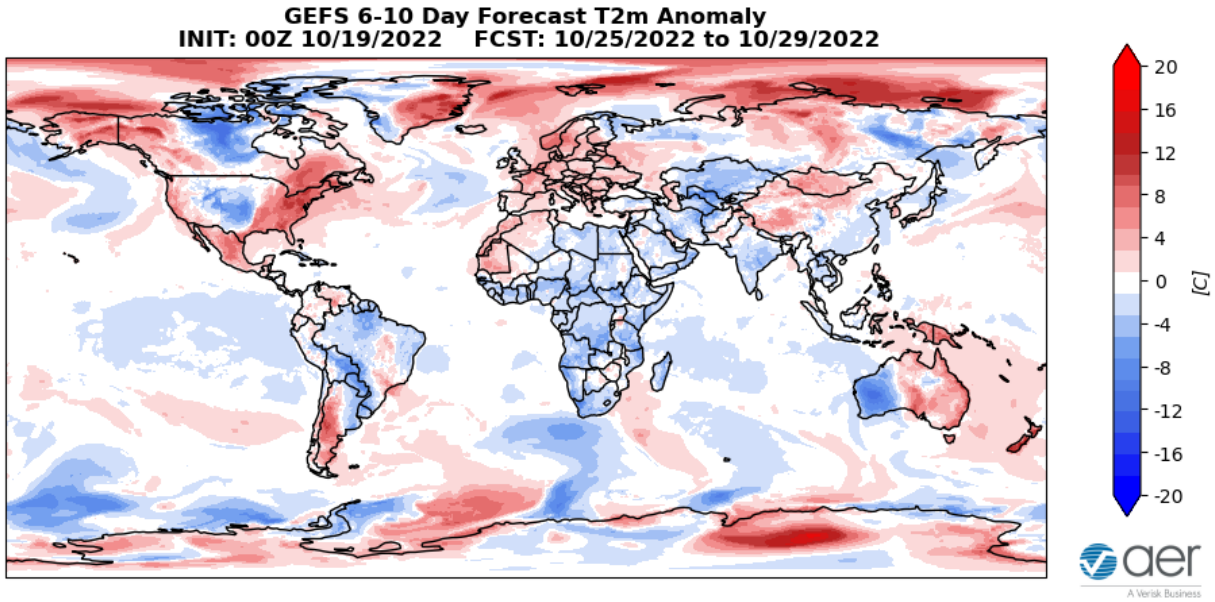

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 25 – 29 October 2022. The forecast is from the 00Z 19 October 2022 GFS ensemble.

Troughing/negative geopotential height anomalies previously in the Western US will slide east into the Central US and Central Canada with ridging/positive geopotential height anomalies along the west and east coasts of North America **(Figure 5).** This pattern will favor normal to above normal temperatures widespread across Alaska, Western and Eastern Canada and the Western and Eastern US with normal to below normal temperatures across Central Canada and the Central US **(Figure 6).**

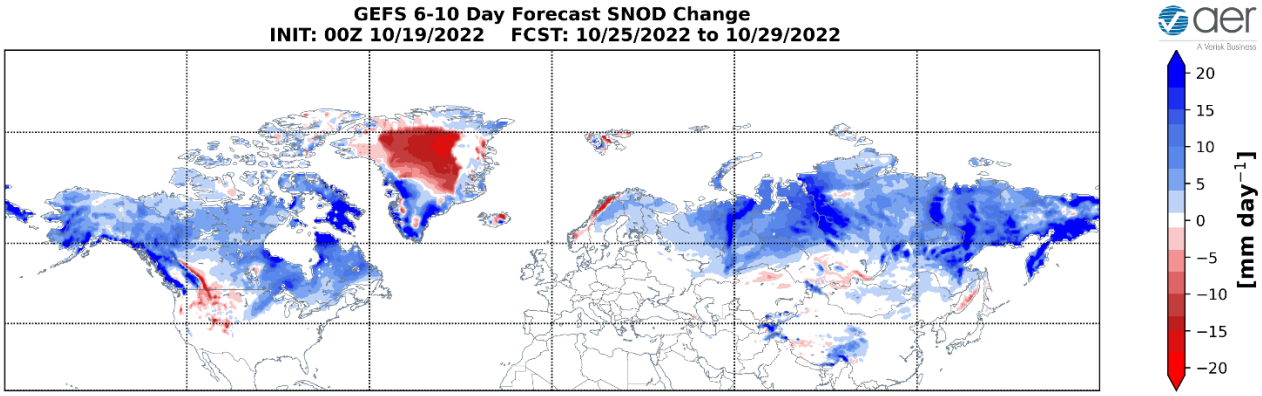

Figure 7. Forecasted snow depth changes (mm/day; shading) from 25 – 29 October 2021. The forecast is from the 00Z 19 October 2021 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across parts of Scandinavia and Northern Asia while mild temperatures will support snowmelt in Norway (**Figure 7**). Troughing and/or cold temperatures will support new snowfall across Alaska and Canada while mild temperatures will support snowmelt along the Front Range of the Rockies (**Figure 7**).

3-4 week

Geopotential height anomalies are predicted to turn mostly negative but weak across the Arctic this period (**Figure 8**), therefore the AO should remain on the positive side of neutral (**Figure 1**). With predicted weak negative pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is predicted to remain weakly positive this period.

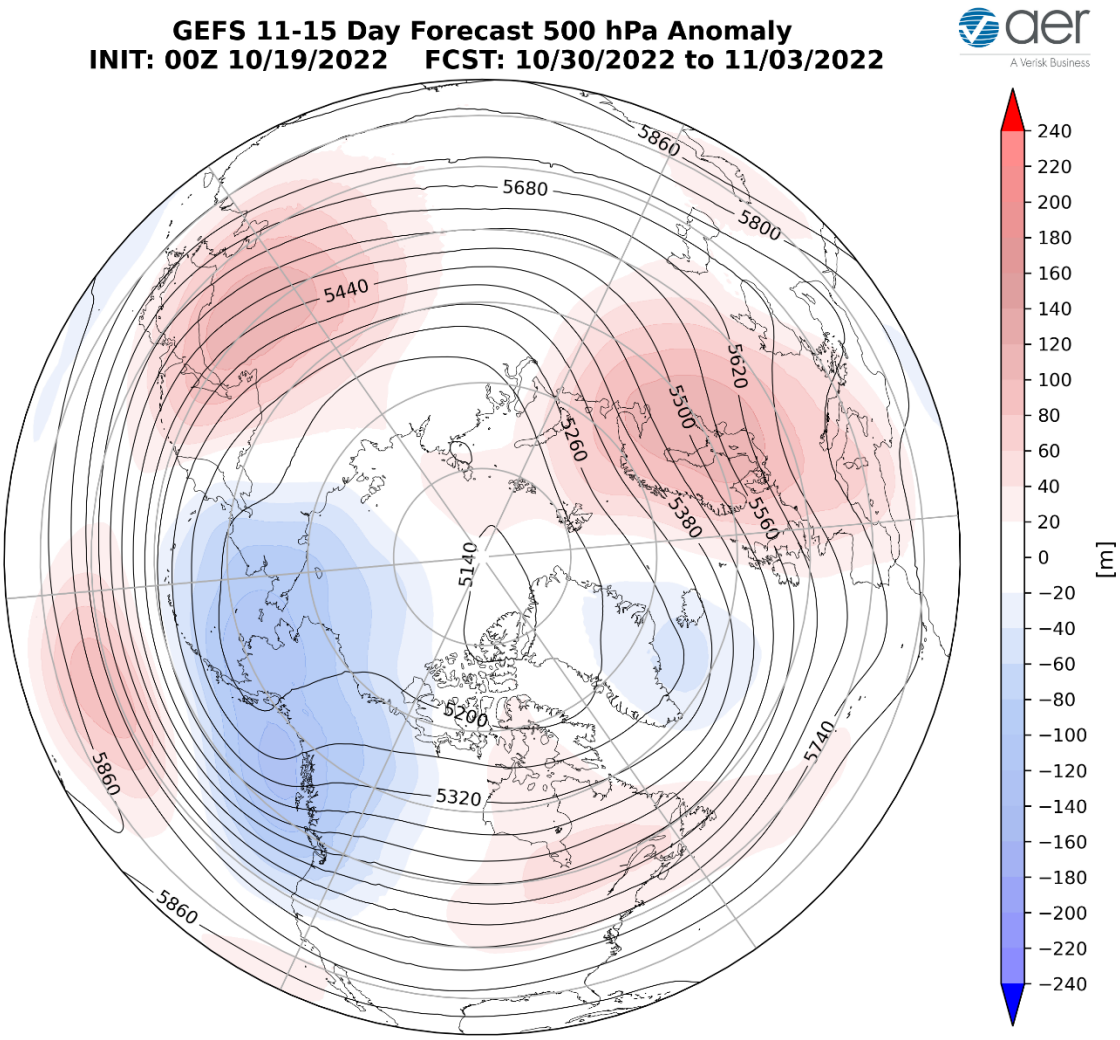

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 30 October – 3 November 2022. The forecasts are from the 00z 19 October 2022 GFS ensemble.

Troughing/negative geopotential height anomalies are predicted to extend into Western Europe Europe forcing ridging/positive geopotential height anomalies across Central Europe this period (**Figure 8**). This pattern favors normal to above normal temperatures across Central Europe with normal to below normal temperatures across Western Europe including the UK under the trough and Eastern Europe where the winds will turn northerly (**Figures 9**). Strengthening ridging/positive geopotential height anomalies centered across Scandinavia will contribute to deepening troughing/negative geopotential height anomalies centered near the Urals but extending into Siberia with more ridging/positive geopotential height anomalies in East Asia (**Figure 8**). This pattern favors widespread normal to below normal temperatures across Western Asia

and much of Siberia with normal to above normal temperatures across the North Slope of Siberia and Central and East Asia (**Figure 9**).

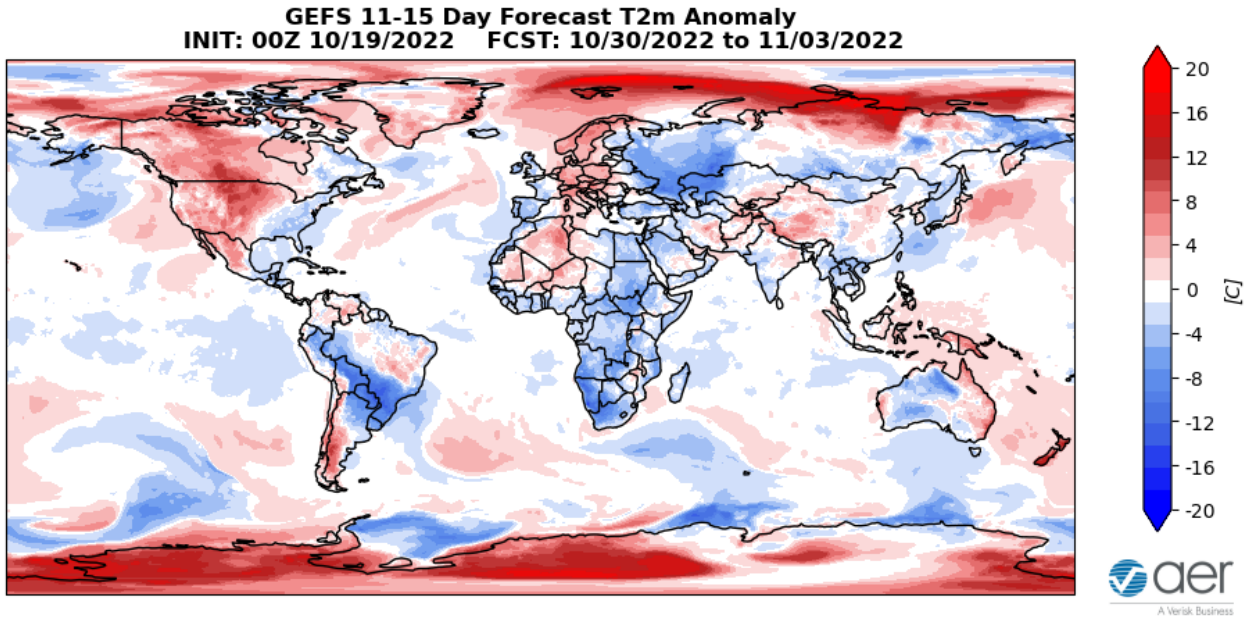

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 30 October – 3 Nofember 2022. The forecast is from the 00Z 19 October 2022 GFS ensemble.

Deep troughing/negative geopotential height anomalies is predicted to develop across western North America with ridging/positive geopotential height anomalies expanding across eastern North America this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across much of Canada and much of the US with normal to below normal temperatures spreading across the West Coasts of Canada and the US (**Figure 9**).

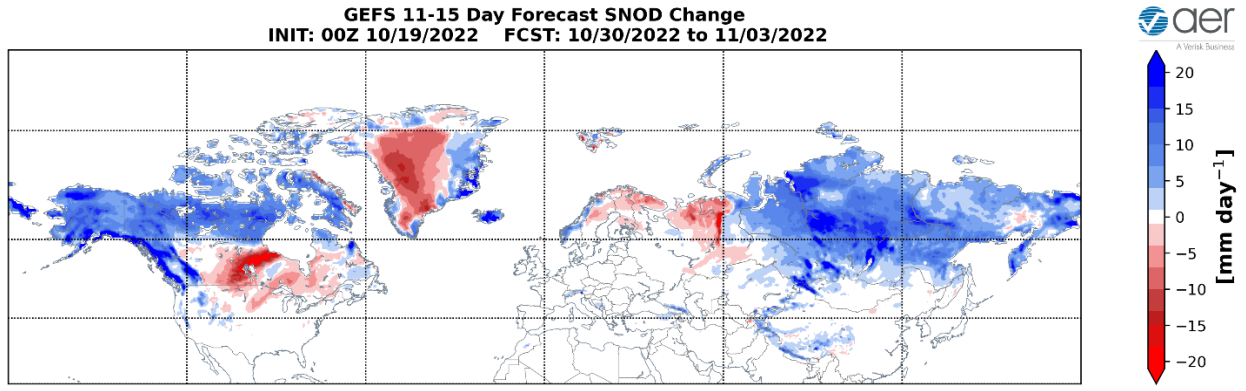

Figure 10. Forecasted snow depth changes (mm/day; shading) from 30 October – 3 November 2021. The forecast is from the 00Z 19 October 2021 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Norway, Siberia and the Tibetan Plateau and Northern Asia while mild temperatures will support snowmelt west of the Urals (**Figure 10**). Troughing and/or cold temperatures will support new snowfall across Alaska, Western and Northern Canada and the higher elevations of the Western US while mild temperatures will support snowmelt in the Canadian Prairies (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows cold/negative PCHs in the upper stratosphere and the lower troposphere with warm/positive PCHs in the mid to mid to lower stratosphere and the mid to upper troposphere (**Figure 11**). However, the cold/negative PCHs currently observed in the lower troposphere are predicted to become mixed as warm/positive PCHs descend from above (**Figure 11**).

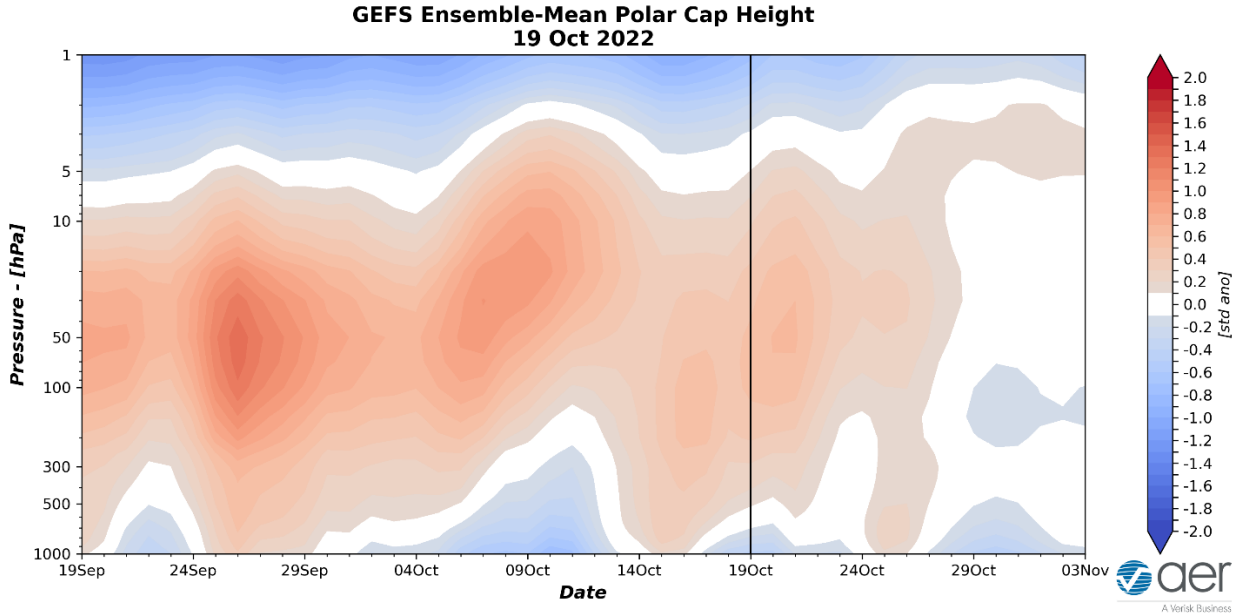

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 19 October 2022 GFS ensemble.

The cold/negative PCHs in the lower troposphere (**Figure 11**) are consistent with the predicted positive surface AO predicted for this week (**Figure 1**). However as lower stratospheric warm/positive PCHs descend into the troposphere next week (**Figure 11**),

the surface AO is predicted to become more tethered to neutral with a bias towards negative (**Figure 1**).

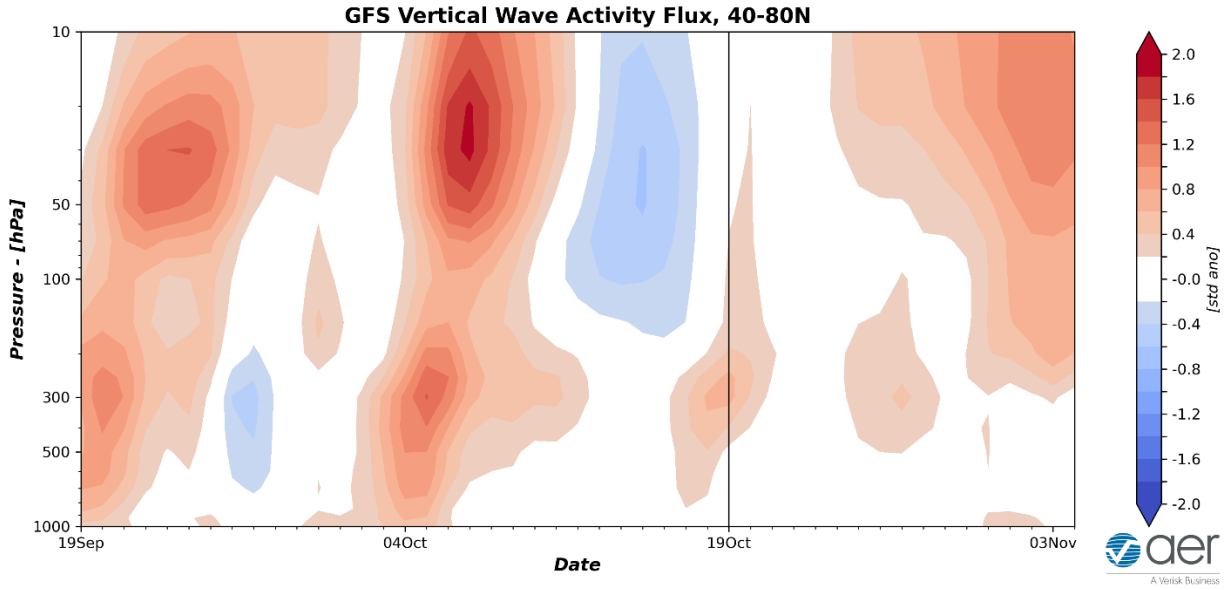

Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 19 October 2022 GFS ensemble.

The cold PCHs in the stratosphere are a result of strong vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere or poleward heat transport in the stratosphere earlier this month (**Figure 12**). The WAF has been less active recently but is predicted to possibly become more active towards the end of the month (**Figure 12**).

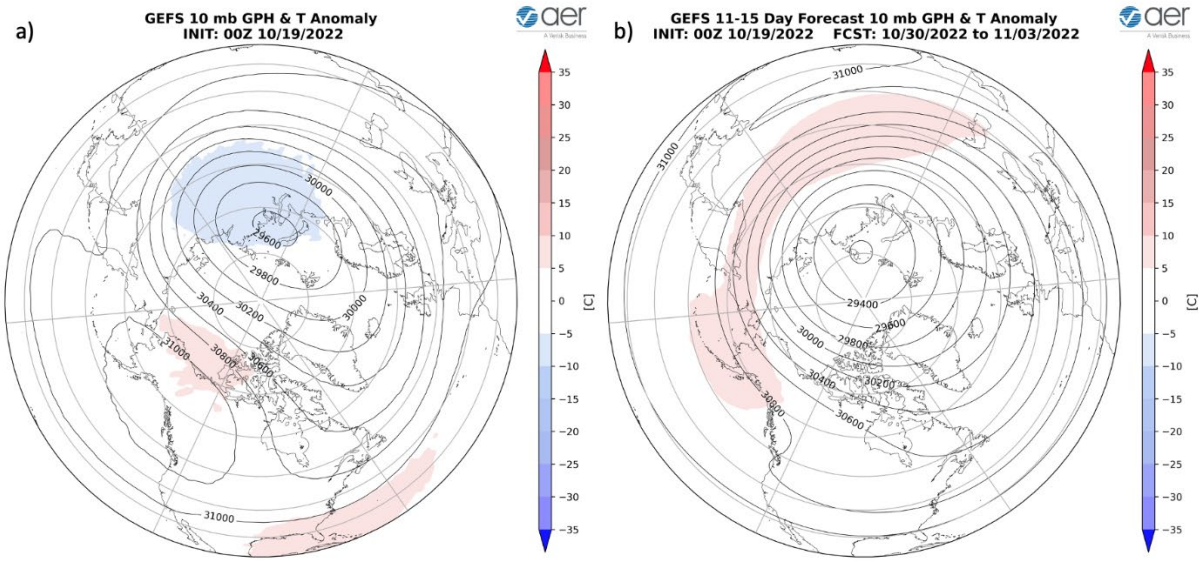

Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 19 October 2022. (b) Same as (a) except forecasted averaged from 30 October – 3 November 2020. The forecasts are from the 00Z 19 October 2020 GFS model ensemble.

The active WAFz has perturbed the stratospheric PV **(Figure 13**). The PV is currently displaced towards the Kara Sea coupled with ridging centered near Alaska and western Canada (**Figure 13**). I would argue this is the tail end of a stretched PV that favors colder temperatures in East Asia and especially eastern North America but not Europe (**Figure 13**). The recent less active WAFz is allowing the PV to strengthen and inch its way back towards the North Pole (**Figure 13**) and is consistent with the stratospheric AO returning to neutral next week **(Figure 1**).

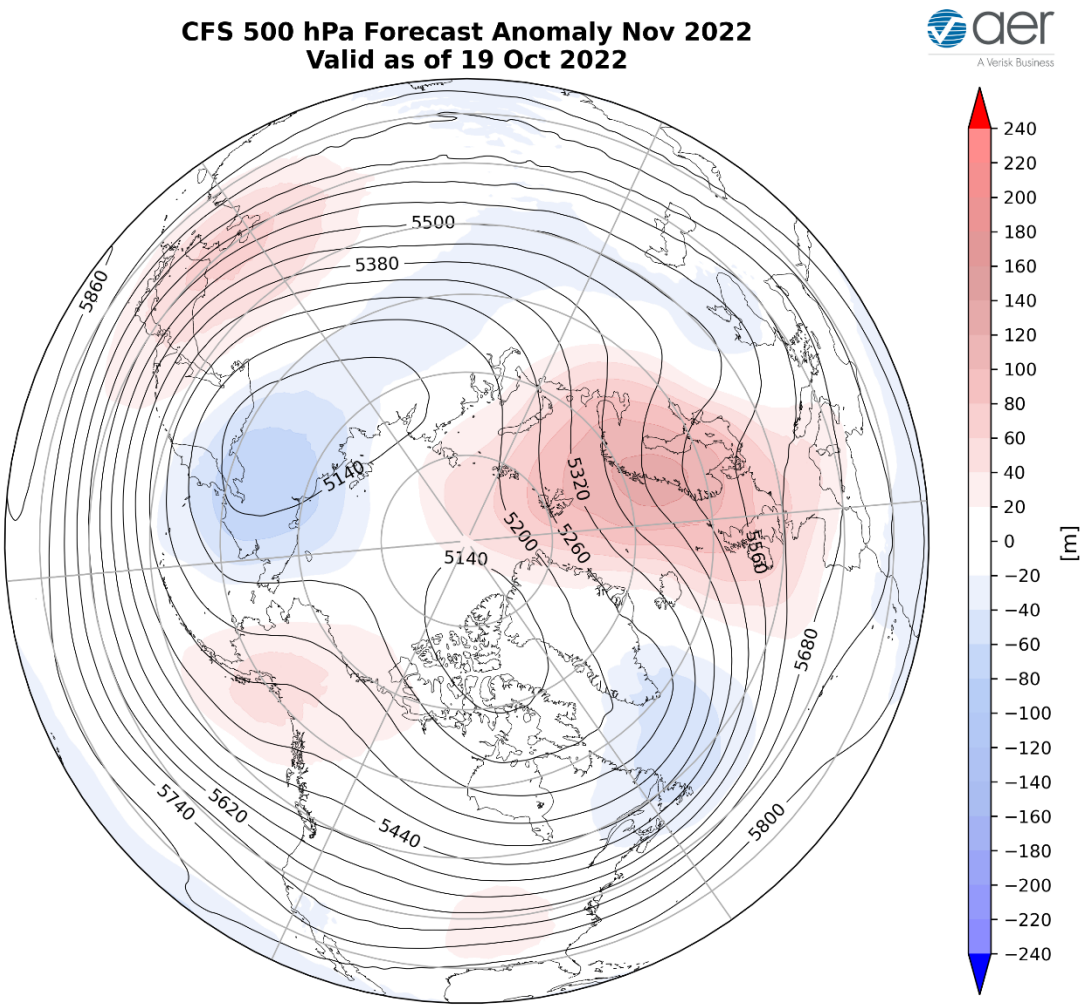

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for November 2022. The forecasts are from the 00Z 19 October 2022 CFS.

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 centered across Scandinavia, East Asia, Alaska and the Southern US with troughing across Southeastern Europe, Siberia and the Eastern Canada (**Figure 14).** This pattern favors seasonable to relatively warm temperatures across Northern Europe, East Asia Alaska, Northern Canada and the Western and Southern US with seasonable to relatively cool temperatures across Southeastern Europe, the Middle East, Eastern Canada and the Northeastern US (**Figure 15**).

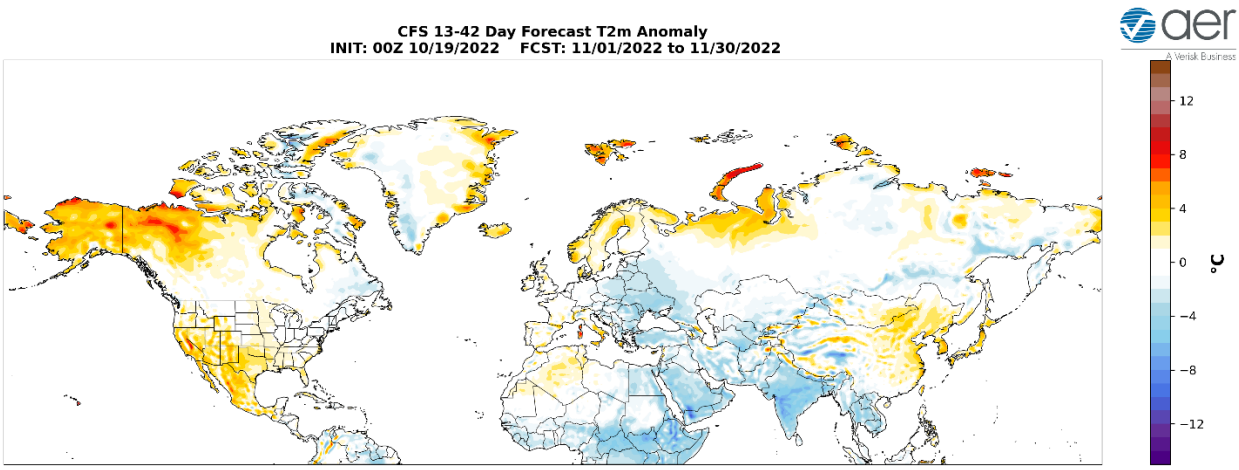

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for November 2022. The forecasts are from the 00Z 19 October 2022 CFS.

Boundary Forcings

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are below normal and we continue to observe weak La Niña conditions (**Figure 16)** and La Niña conditions are expected through the fall. Observed SSTs across the NH remain well above normal especially in the 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 South Pacific.

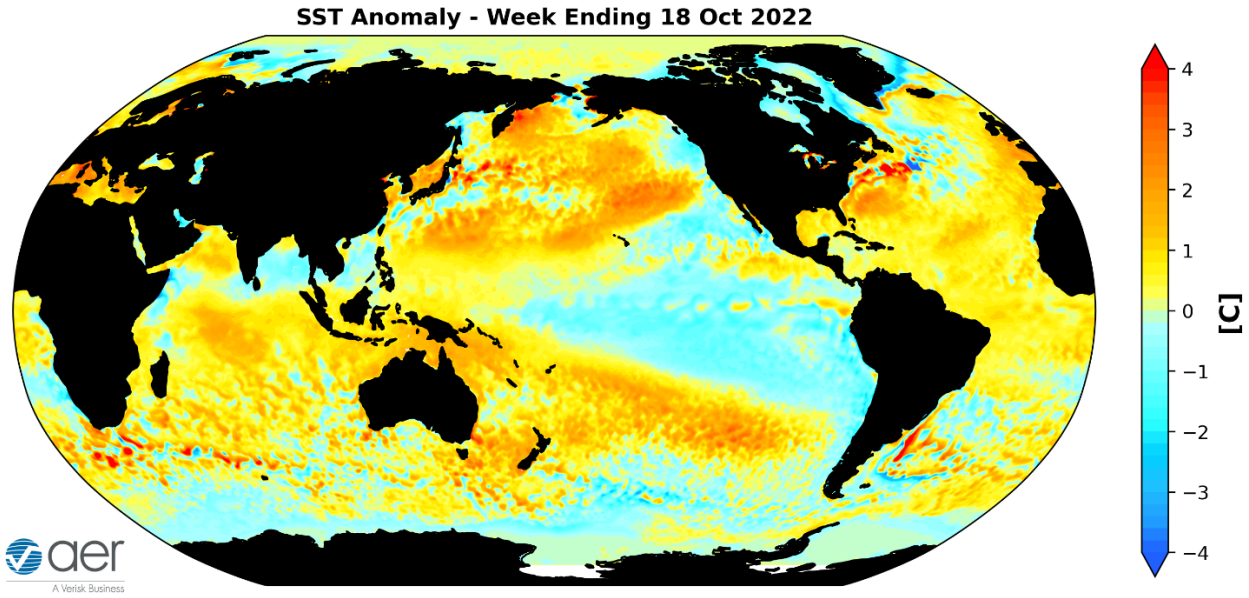

Figure 16. The latest weekly-mean global SST anomalies (ending 18 October 2022). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently the Madden Julian Oscillation (MJO) is in phase six (**Figure 17**). The forecasts are for the MJO to quickly move to phase seven and remain there for the next two weeks. MJO phase seven longer term favors ridging in eastern North America with troughing in western North America and could therefore the MJO could be an influence on the mid term weather across North America. But admittedly this is outside of my expertise.

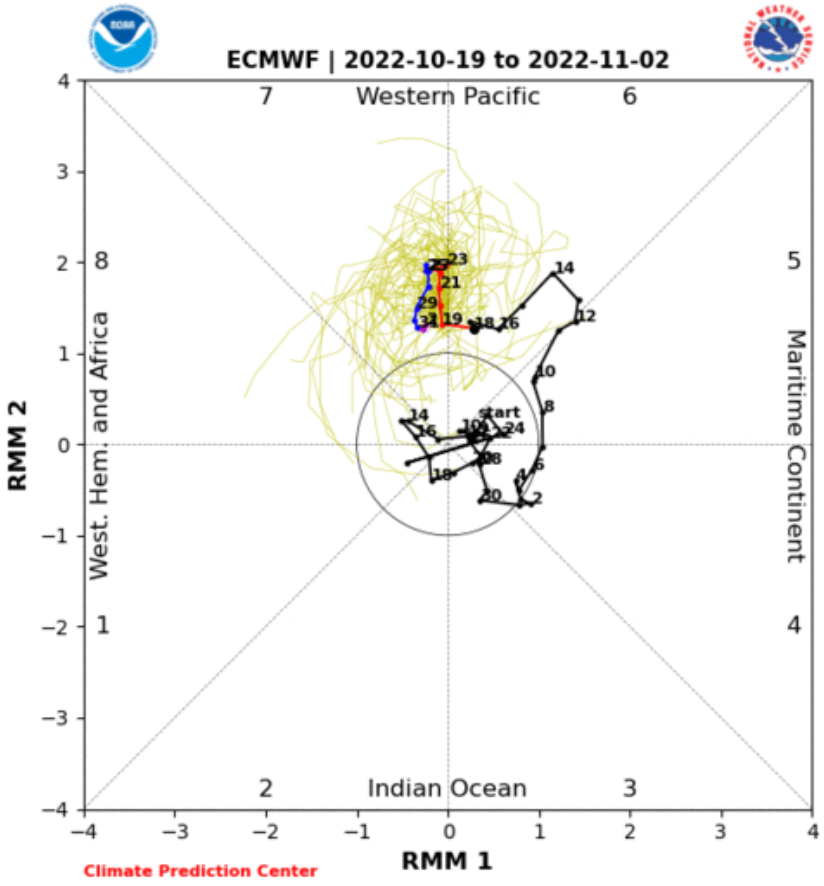

Figure 17. Past and forecast values of the MJO index. Forecast values from the 00Z 19 October 2022 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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