Arctic Oscillation and Polar Vortex Analysis and Forecasts

October 12, 2022

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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Summary

- The Arctic Oscillation (AO) is currently positive and is predicted to trend negative this week towards neutral and then is predicted to straddle neutral next week as pressure/geopotential height anomalies are mostly negative across the Arctic this week but then next week pressure/geopotential height anomalies are predicted to become more mixed with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently slightly positive and is predicted to sink into negative territory later this week and into next week as pressure/geopotential height anomalies are negative this week and then turn positive across Greenland next week.

- The general predicted pattern across Europe the next two weeks is troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height anomalies across Southern Europe. However next week ridging will temporarily strengthen across much of Europe. This pattern will favor normal to below normal temperatures across Northern Europe including the United Kingdom (UK) with normal to above normal temperatures across Central and Southern Europe.

- Over the next two weeks, ridging/positive geopotential height anomalies centered in Western Siberia will dominate much of Asia with troughing/negative geopotential height anomalies limited to far Eastern Asia and the Urals. This pattern favors widespread normal to above normal temperatures across Asia with normal to below normal temperatures mostly limited to Eastern Siberia this week and then becoming more widespread across Eastern and Northwestern Asia next week.

- The general pattern the next ten days across North America is ridging/positive geopotential height anomalies across Western Canada and the Western United States (US) with troughing/negative geopotential height anomalies in Eastern Canada and the Eastern US. This pattern favors widespread normal to above normal temperatures across Alaska, Western Canada and the Western US with normal to below normal temperatures across Eastern Canada and the Eastern US. However, late next week the ridging will become centered across Northern Canada with troughing centered along the west coast of North America favoring widespread relative warm temperatures across the continent with relatively cool temperatures limited to the west coast of North America.

- In the *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 off to an overall fast start but is now experiencing a mid-month stall. Second is Arctic sea ice, which is well below normal but regional anomalies are very important. But an unexpected third factor is the unusually early polar vortex disruption that could have very important implications for the upcoming winter.

Impacts

My apologies for the erratic publication of the blog but I expect to publish next Wednesday and then the following week return to the regular schedule of early release for a nominal fee on Monday and then fully public on Wednesday.

It is October and given that I am probably best known for arguing that the advance of Siberian snow cover in the fall can portend the behavior of the polar vortex (PV) during the winter months and can also portend the surface temperature anomaly pattern across the Northern Hemisphere (NH) continents during the winter, I begin with the state of Siberian snow cover advance this month. Snow cover extent across Siberia was off to a rip-roaring start and the fastest since 2009, when I started to compute the daily values (see **Figure i**). But snow cover advance has slowed down considerably and has since fallen back into the middle of the pack (see **Figure i**). Ridging centered over

Siberia is hostile to rapid advancement of snow cover which is the predicted pattern this week and snow cover will likely find strong resistance to advancing at more than a snail's pace over the next week or so. After that the pattern looks better but still not great if you believe the dynamical model forecasts. However, I do think that there is potential for the pattern to become more conducive to the advancement of snow cover than the models are currently predicting.
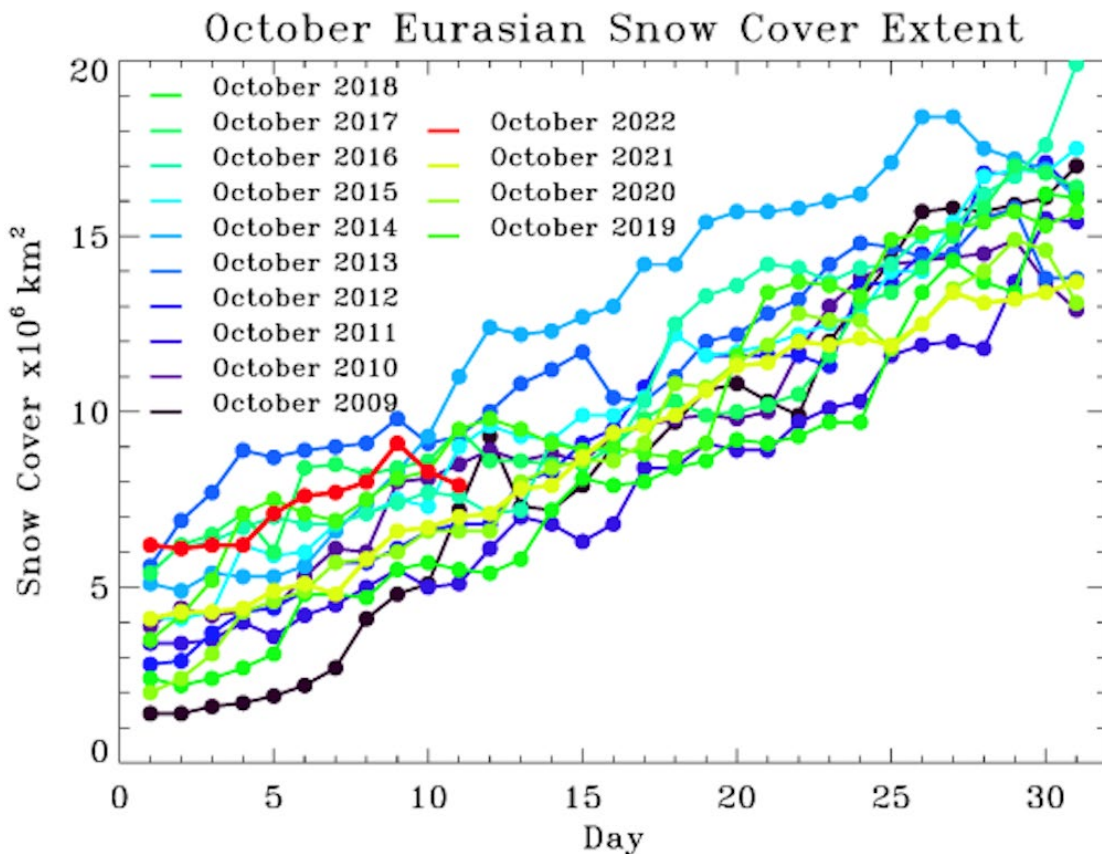

Figure i. Observed Eurasian daily snow cover extent in km2 throughout the month of October from 2009 through 2021. Also show on red is the snow cover extent 1 – 11 October 2022.

Despite the stall in snow cover advance, I fully expect that Eurasian snow cover extent (SCE) for the month of October to be above normal both given the fast start to the month and that almost every year now, October SCE is above normal. I think the more important question is whether it will be just slightly above normal or well above normal. Given the current pattern, it is hard to see it being well above normal but with a more favorable circulation pattern to end the month higher totals are still possible. Extensive (and likely deep but much harder to measure) favors an overall

more disrupted PV and colder temperatures across parts of the Northern Hemisphere (NH).

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 and winter temperatures across the NH. I have tried to argue (as well as many others) that below normal sea ice also favors a more disrupted PV and overall colder temperatures. 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. Looking at the current sea ice extent in **Figure ii**, it does seem to me that the ice deficit (compared to climatology) in the Barents-Kara Seas is growing relative to a month ago. I still think it is hard to know what the impact of sea ice will be to the winter pattern but right now I would score it biasing a weaker PV and therefore some colder weather.
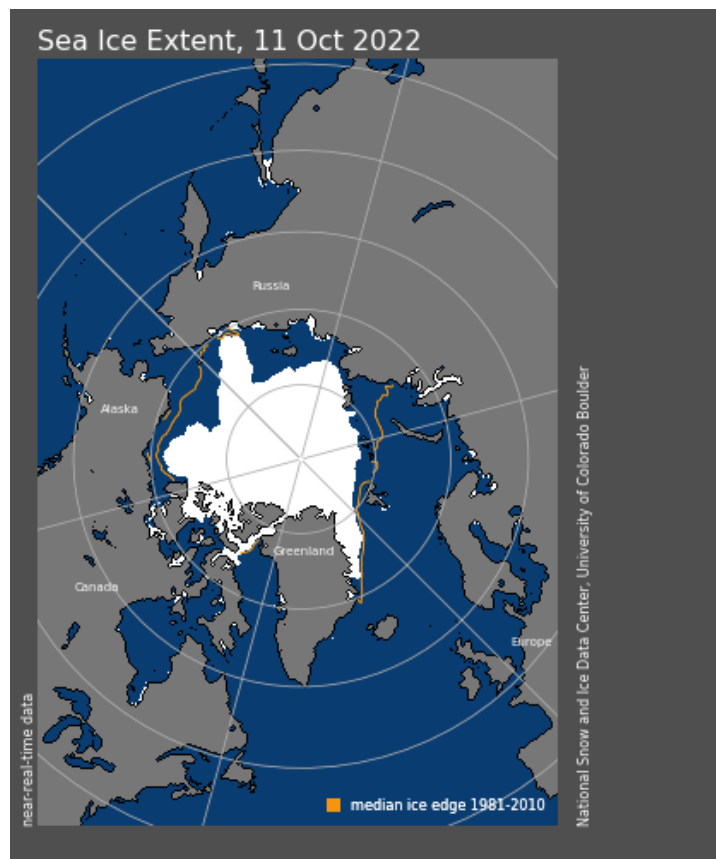

Figure ii. Observed Arctic sea ice extent on 11 October 2022 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC).

What is very interesting and potentially an important wrinkle in the forecast is a troposphere-stratosphere-troposphere (T-S-T) coupling event currently halfway through

the cycle (see **Figure 11**). On Twitter I have been posting how the Global Forecast System (GFS) model has been teasing that this event may cycle through to completion, and based on **Figure 11**, this scenario is looking much more likely. This is the earliest such complete T-S-T event that I can find since 1979, when reliable stratospheric data first became available. The other two falls that come close are 2006 and 2016 and even those spanned October and November while this will occur fully in October (if the forecast is correct). If winters 2006/07 and 2016/17 don't exactly jump out at you, they probably shouldn't. Certainly, from a PV perspective they were relatively unremarkable winters. The main event both those seasons was the unusually early PV disruption with the winter months characterized by uninspiring PV behavior (at least from my perspective). In addition, they were not characterized as particularly cold and snowy winters. Two data points are too few to draw strong generalizations but certainly there is a lack of evidence that an unusually early PV disruption signals a more impressive disruption in the winter months when it is much more impactful.

Often following a PV disruption, the PV strengthens and that seems like the most reasonable expectation for the PV heading into November. How soon to expect a subsequent PV disruption is in my opinion one of the most important unanswered questions for the upcoming winter. I think it will depend on the nature of the high latitude blocking (high pressure ridging) that follows the PV disruption. If high latitude blocking can persist for at least multiple weeks post the PV disruption and settle in a favorable location that can further disrupt the PV, then another PV disruption can occur relatively quickly. I would argue that the longer the time between PV disruptions, the greater the likelihood that the winter is overall mild. In contrast, the shorter the time between PV disruptions the greater the likelihood that the winter is overall cold in favored locations.

Recent and Very Near Term Conditions

The AO is predicted to be positive this week **(Figure 1)** with mostly positive geopotential height anomalies predicted across the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with predicted negative geopotential height anomalies this week across Greenland (**Figure 2**), the NAO is predicted to be positive this week (**Figure 1**).
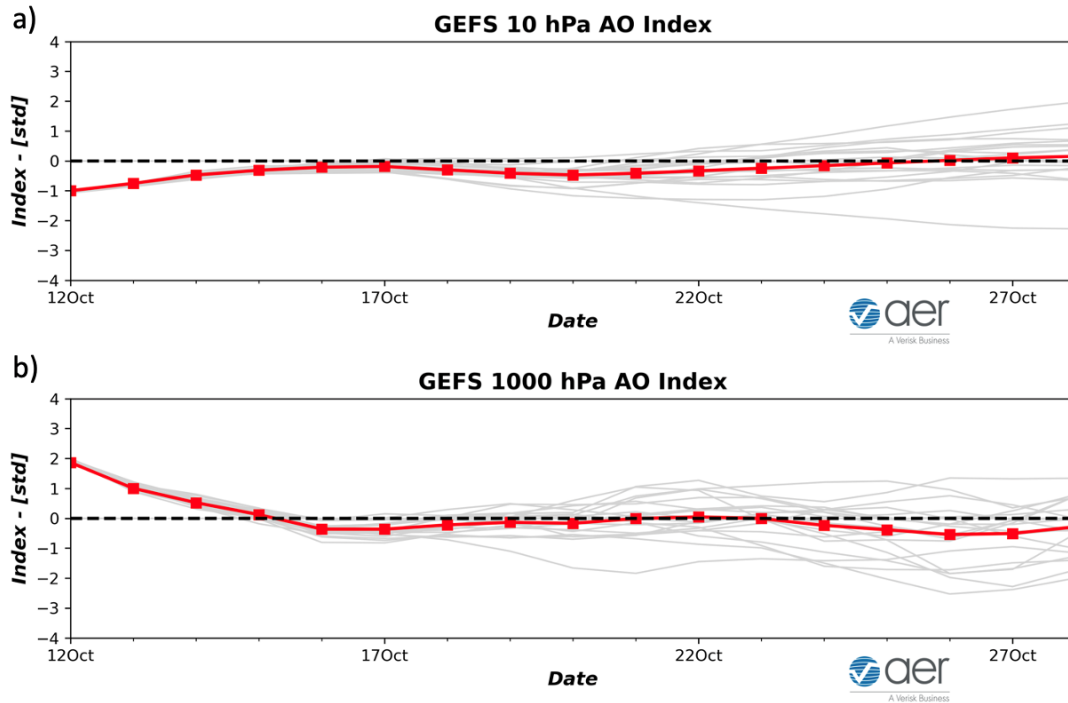
Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 12 October 2022 GFS ensemble. (b)The predicted daily-mean near-surface AO from the 00Z 12 October 2022 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Predicted ridging/positive geopotential height anomalies centered in Baffin Bay will force troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height anomalies across Northern Europe (**Figure 2**). **This will favor** normal to above normal temperatures across much of Europe except for normal to below normal temperatures across the UK and Norway (**Figure 3**). Strong ridging/positive geopotential height anomalies centered across Western Siberia will dominate Asia except for troughing/negative geopotential height anomalies focused across Eastern Siberia (**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 (**Figure 3**).
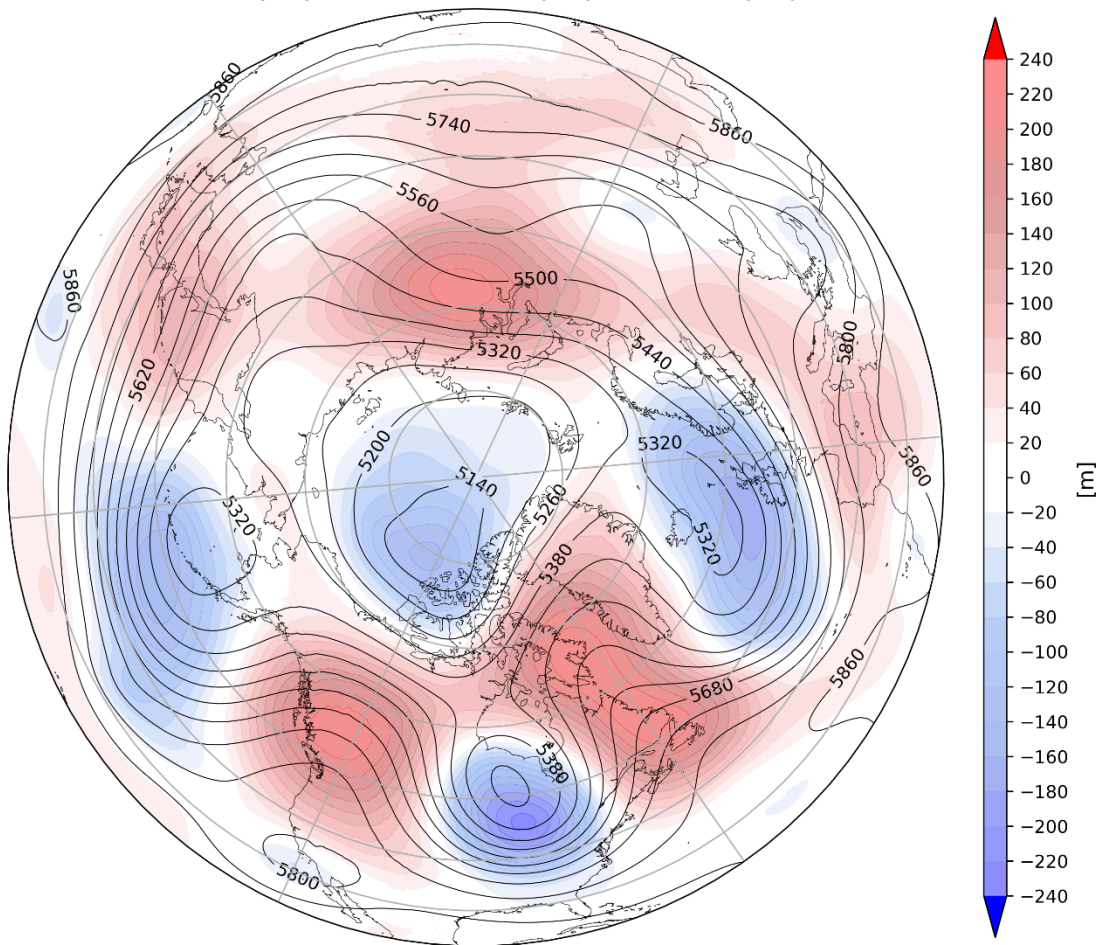
Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 13 – 17 October 2022. The forecasts are from the 00z 12 October 2022 GFS ensemble.

Troughing/negative geopotential height anomalies near the Dateline will contribute to ridging/positive geopotential height anomalies across western North America with troughing/negative geopotential height anomalies across eastern North America centered in lower Hudson Bay **(Figure 2).** The pattern will favor widespread normal to above normal temperatures across Alaska, Western Canada, the Western US and along the North Atlantic coast with normal to below normal temperatures across Central Canada and the US Great Lakes **(Figure 3).**
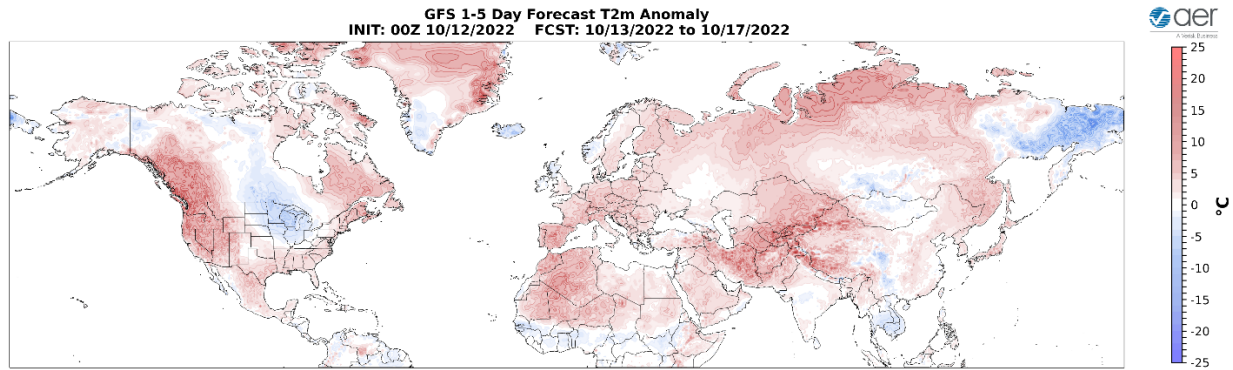
Figure 3. Forecasted surface temperature anomalies (°C; shading) from 13 – 17 October 2022. The forecast is from the 00Z 12 October 2022 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Norway and Eastern Siberia while warm temperatures will support snowmelt in Central Siberia (**Figure 4**). Troughing and/or cold temperatures will support new snowfall across Alaska and Northern and Central Canada (**Figure 4**).
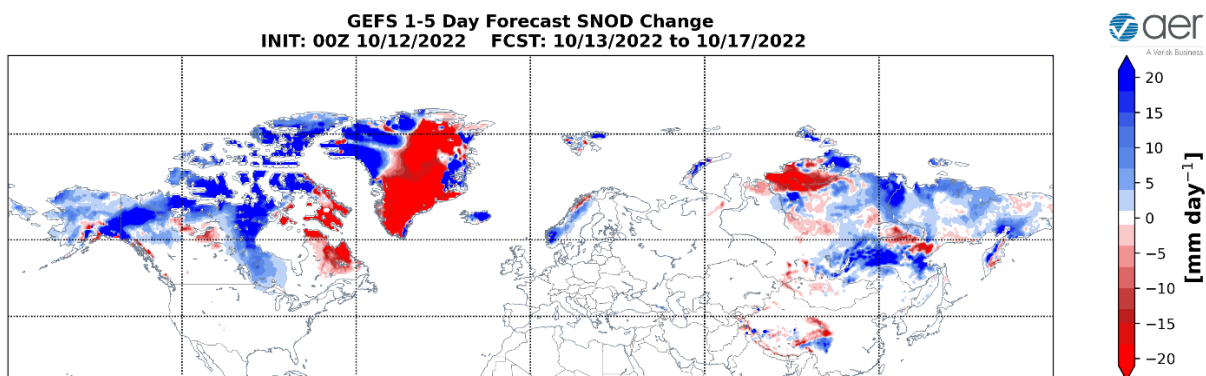

Figure 4. Forecasted snow depth changes (mm/day; shading) from 13 – 17 October 2021. The forecast is from the 00Z 12 October 2021 GFS ensemble.

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 mostly positive geopotential height anomalies across Greenland (**Figure 5**), the NAO is predicted to turn negative this period.
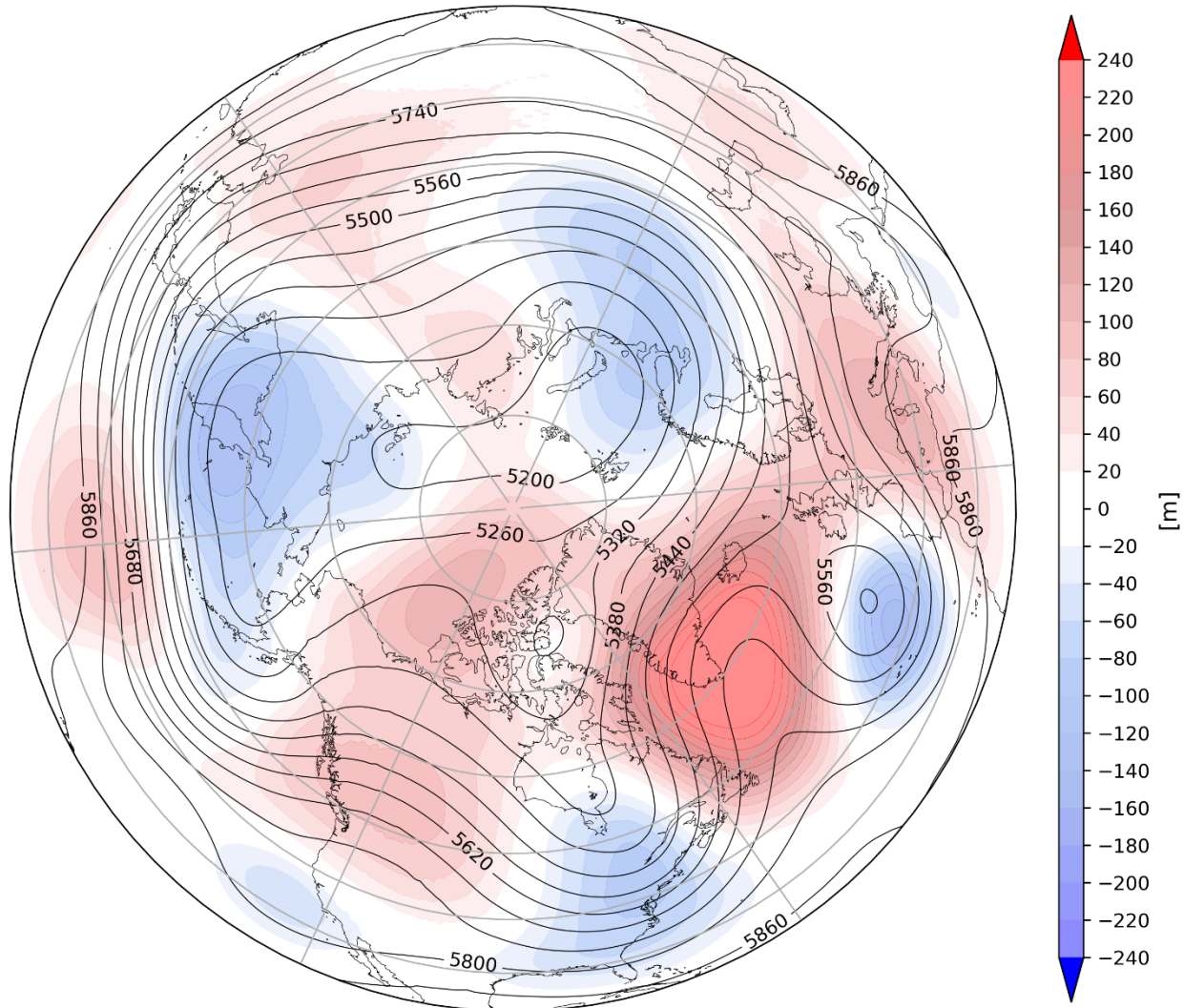
Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 18 – 22 October 2022. The forecasts are from the 00z 12 October 2022 GFS ensemble.

Ridging/positive geopotential height anomalies centered across southern Greenland will support troughing/negative geopotential height persisting across Northern Europe while ridging/positive geopotential height anomalies dominates much of Europe (**Figures 5**). The pattern is predicted to result in widespread normal to above normal temperatures across Central and Southern Europe with normal to below normal temperatures across Northern Europe including the UK (**Figure 6**). Ridging/positive geopotential height anomalies are predicted to persist across Western Siberia extending into Southeastern Asia with deepening troughing/negative geopotential height anomalies in Northeastern and Northwestern Asia 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 Northwestern Russia **(Figure 6)**.
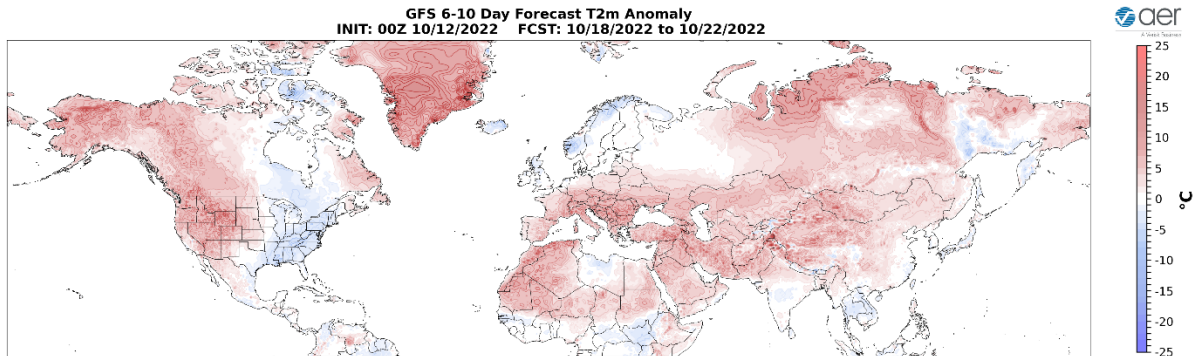

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 18 – 22 October 2022. The forecast is from the 00Z 12 October 2022 GFS ensemble.

Rdging/positive geopotential height anomalies are predicted to continue to dominate much of western North America with troughing/negative geopotential height anomalies across Eastern Canada and the Eastern US **(Figure 5)**. This pattern will favor normal to above normal temperatures widespread across Alaska, Western Canada and the Western US with normal to below normal temperatures across Eastern Canada and the Eastern US **(Figure 6)**.
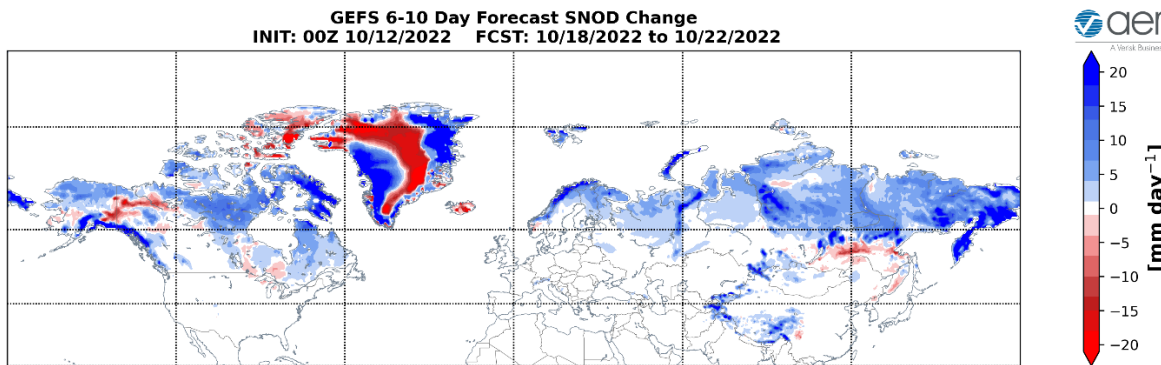

Figure 7. Forecasted snow depth changes (mm/day; shading) from 18 – 22 October 2021. The forecast is from the 00Z 12 October 2021 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across parts of Scandinavia and Northern Asia while warm temperatures will support snowmelt in Southern Siberia **(Figure 7)**. Troughing and/or cold temperatures will support new snowfall across Alaska, the West Coast of Canada and Northern and Eastern Canada **(Figure 7)**.

3-4 week

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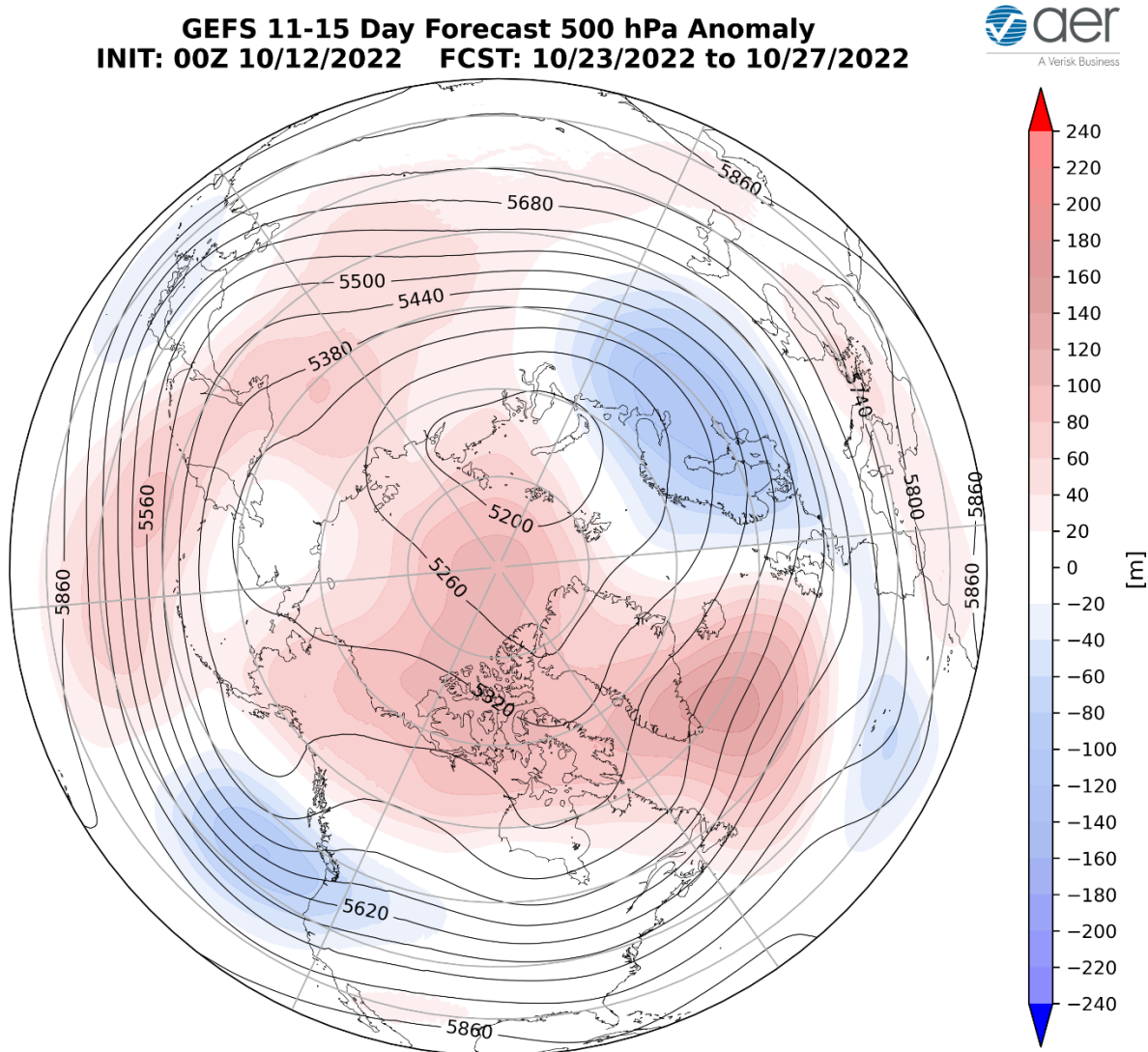

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 23 – 27 October 2022. The forecasts are from the 00z 12 October 2022 GFS ensemble.

Ridging/positive geopotential height anomalies across southern Greenland will continue to support troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height anomalies across Southern Europe this period

(**Figure 8**). This pattern favors normal to above normal temperatures across Southern Europe with normal to below normal temperatures across Northern Europe including the UK (**Figures 9**). Persistent ridging/positive geopotential height anomalies centered across Western Siberia bookended by troughing/negative geopotential height anomalies in Northeastern and Northwestern Asia are predicted (**Figure 8**). This pattern favors widespread normal to below normal temperatures across Asia with normal to below normal temperatures limited to Eastern Siberia, parts of East Asia and Northwest Russia (**Figure 9**).
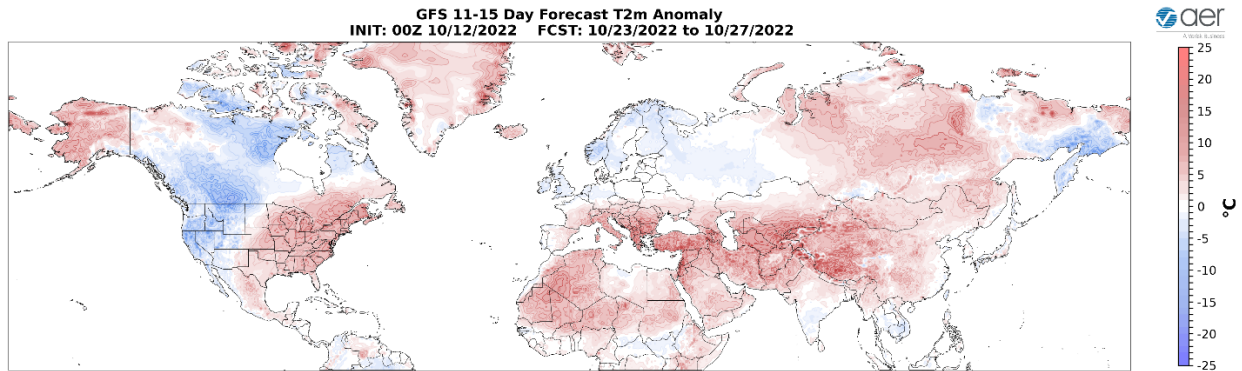

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 23 – 27 October 2022. The forecast is from the 00Z 12 October 2022 GFS ensemble.

The pattern is predicted to become rearrange across North America this period with ridging/positive geopotential height anomalies draped across northern North America with troughing/negative geopotential height anomalies spreading across the west coast of North America this period (**Figure 8**).   This pattern favors widespread normal to above normal temperatures across Alaska, much of Canada and much of the US with normal to below normal temperatures limited to the West Coasts of Canada and the US (**Figure 9**).
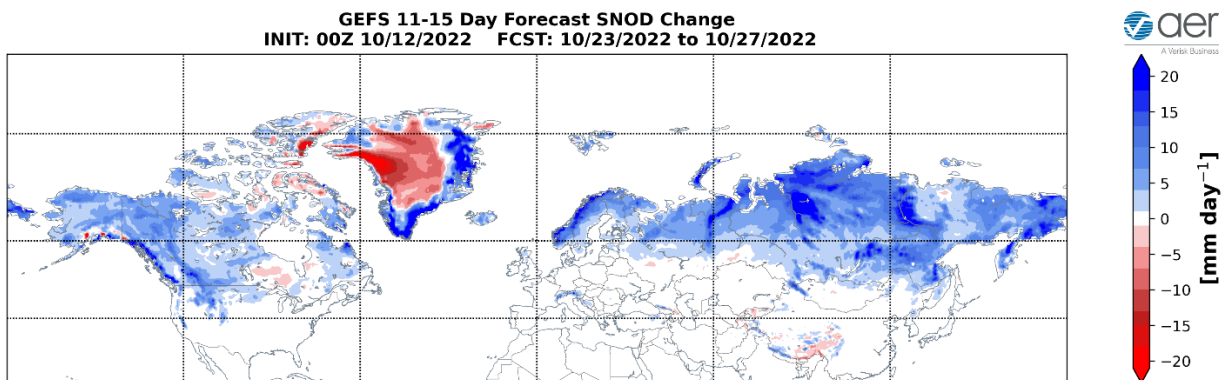
Figure 10. Forecasted snow depth changes (mm/day; shading) from 23 – 27 October 2021. The forecast is from the 00Z 12 October 2021 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across parts of Scandinavia, the Alps and Northern Asia while warm temperatures will support snowmelt in the Tibetan Plateau (**Figure 10**). Troughing and/or cold temperatures will support new snowfall across Alaska, Canada and the higher elevations of the Western US (**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 mid to lower troposphere with warm/positive PCHs in the mid to mid to lower stratosphere and the 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**).
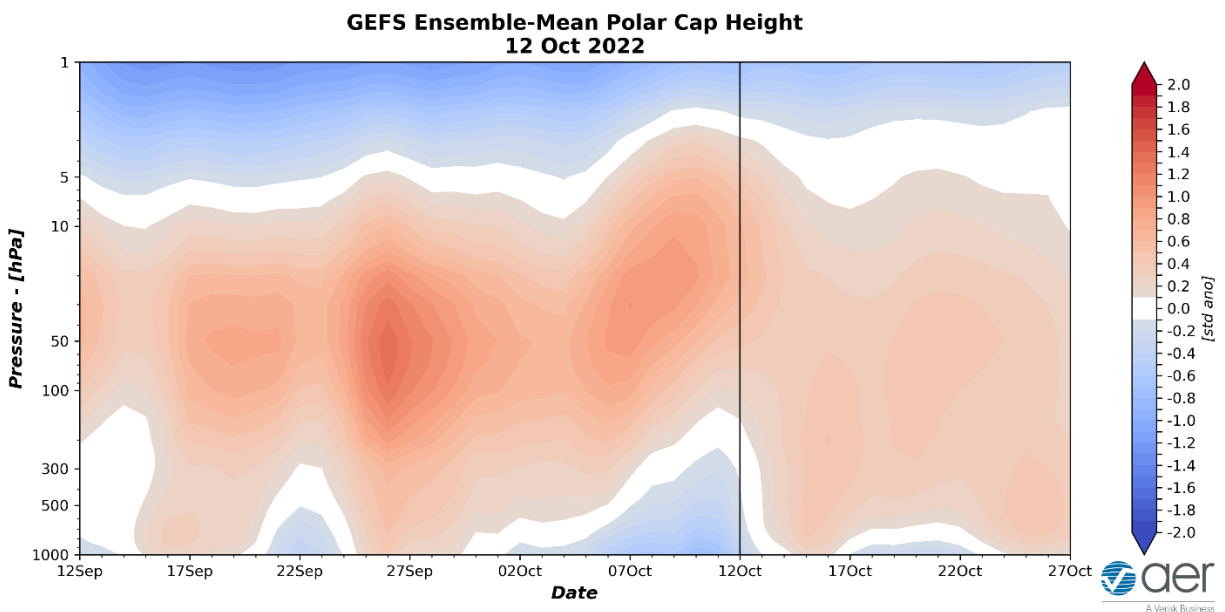

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 12 October 2022 GFS ensemble.

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**).
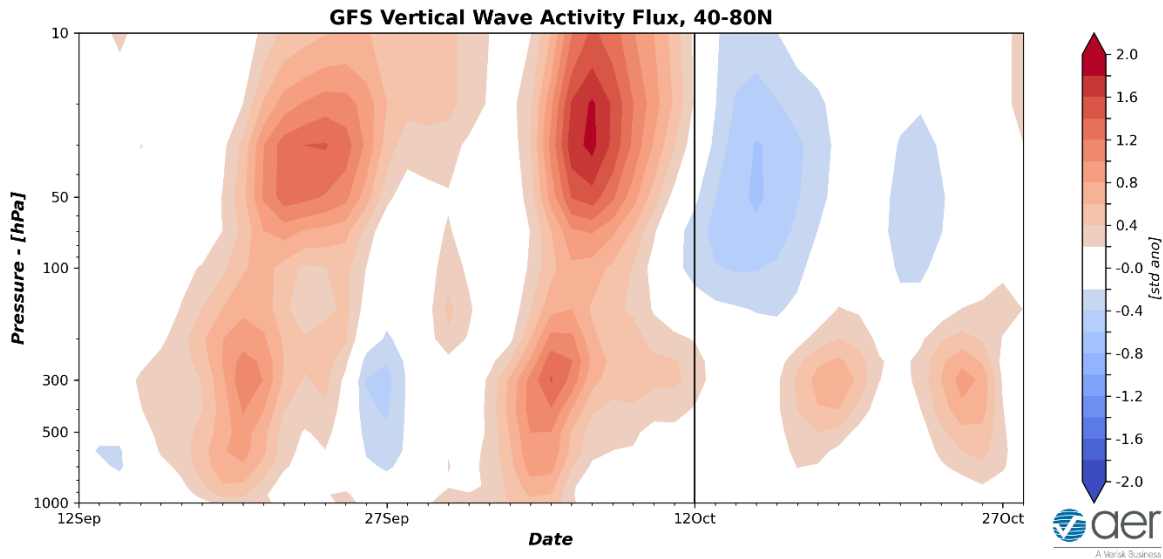

Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 12 October 2022 GFS ensemble.

The cold PCHs in the troposphere and warming of 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 that has been observed since mid-September (**Figure 12**).
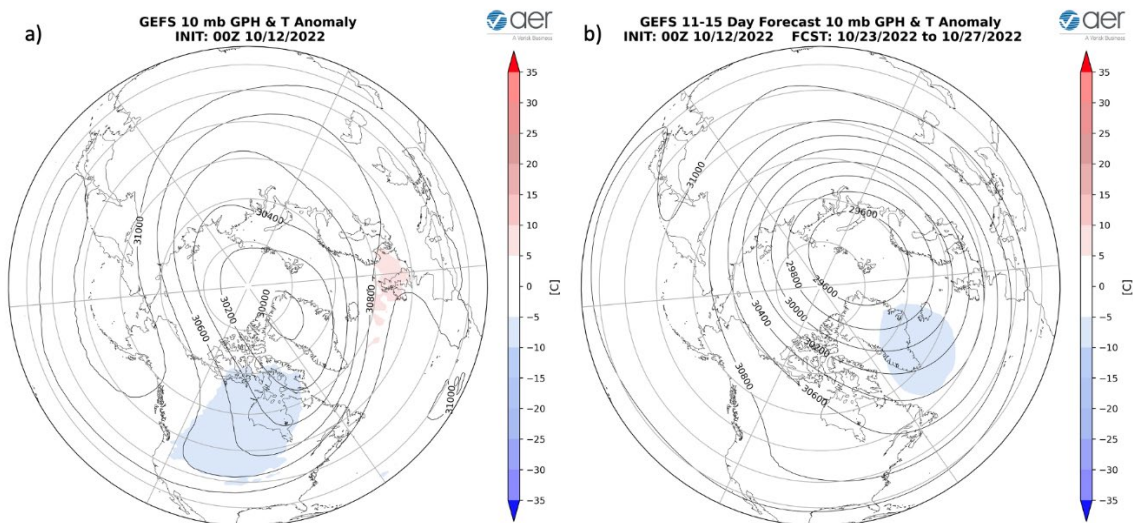
Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 12 October 2022. (b) Same as (a) except forecasted averaged from 23 – 27 October 2020. The forecasts are from the 00Z 12 October 2020 GFS model ensemble.

The active WAFz has perturbed the stratospheric PV (Figure 13), in fact last week it was record weak for the date. The PV is currently displaced towards Greenland coupled with ridging centered near the Dateline (**Figure 13**). I would argue this is a fairly textbook case of a stretched PV that favors colder temperatures in East Asia and especially eastern North America but not Europe (**Figure 13**). The WAFz is predicted to be less active over the next two weeks allowing the PV to strengthen back towards normal and is consistent with the stratospheric AO returning to neutral next week (Figure 1). However, the stratospheric PV is predicted to remain displaced towards the Barents-Kara Seas towards the end of October (**Figure 13**).
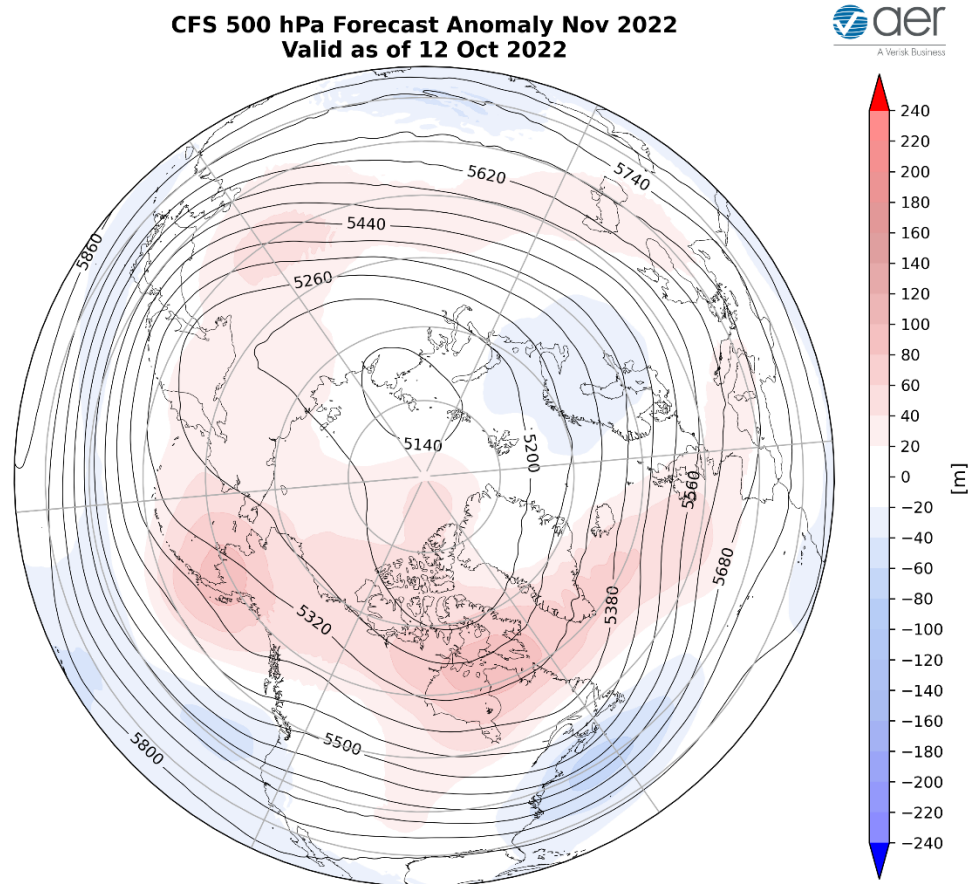

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for November 2022. The forecasts are from the 00Z 12 October 2022 CFS.I

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 stretching from Hudson Bay across southern Greenland, Iceland, and the British Isles, East Asia, Alaska and Northern Canada with troughing across Scandinavia, Eastern Siberia and the West and East Coasts of the US (**Figure 14**).   **T**his pattern favors seasonable to relatively warm temperatures across Southern Europe, much of Northern Asia including Siberia, Alaska, Northern Canada and the Western two thirds of the US with seasonable to relatively cool temperatures across Northern Europe, the Middle East, Southern Asia and the Eastern US (**Figure 15**).
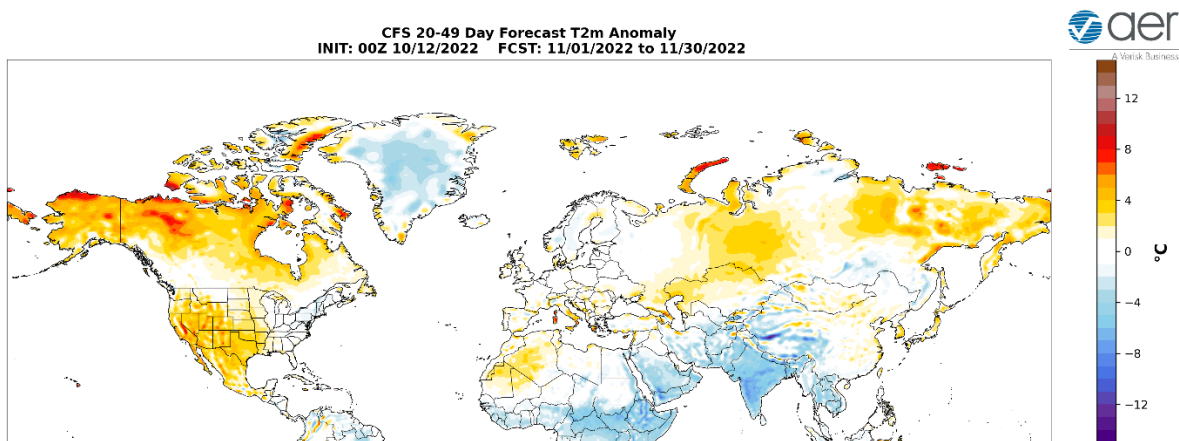

Figure 15.   Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for November 2022. The forecasts are from the 00Z 12 October 2022 CFS.

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.
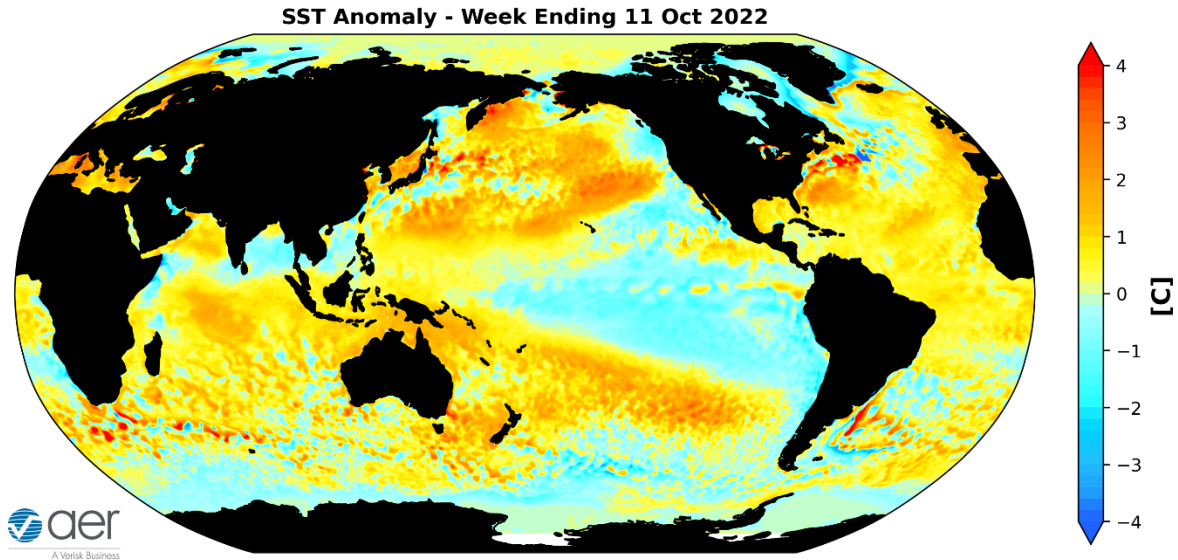
SST Anomaly - Week Ending 11 Oct 2022

Figure 16. The latest weekly-mean global SST anomalies (ending 11 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 remain in phase six for the next two weeks. MJO phase six at least initally favors ridging in western North America with troughing in the Eastern US and could therefore the MJO could be an influence on the near a term weather across North America. But admittedly this is outside of my expertise.
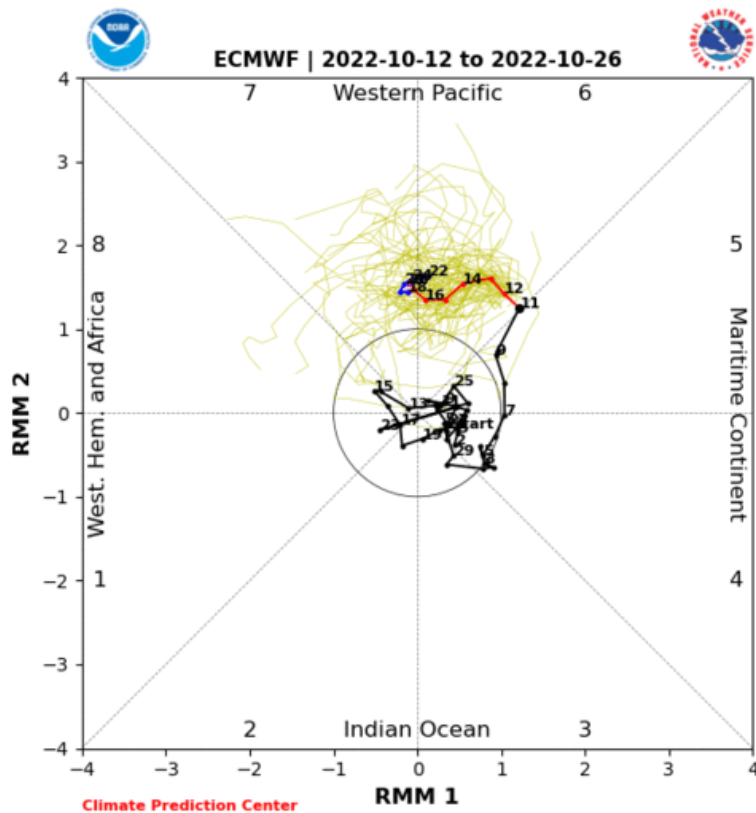
Figure 17. Past and forecast values of the MJO index. Forecast values from the 00Z 12 October 2022 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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