Arctic Oscillation and Polar Vortex Analysis and Forecasts

September 23, 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 neutral and is predicted to trend negative this week and then is predicted to straddle neutral next week as pressure/geopotential height anomalies are mostly positive 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 neutral and is predicted to trend negative this week and then return to neutral next week as pressure/geopotential height anomalies are positive this week and then trend weaker across Greenland next week.
- This week, ridging/positive geopotential height anomalies across Greenland will favor troughing/negative geopotential height anomalies across Europe except for ridging/positive geopotential height anomalies across Scandinavia. However as ridging across Greenland weakens ridging will strengthen across Europe. This pattern will favor this week normal to below normal temperatures across much of Europe including the United Kingdom (UK) with normal to above normal temperatures limited to Scandinavia. However next week normal to above normal temperatures will become more widespread across Europe.
- Over the next two weeks, ridging/positive geopotential height anomalies centered in the region of the Barents-Kara Seas and the Urals will favor troughing/negative geopotential height anomalies across Northern and Central Asia with more ridging/positive geopotential height anomalies across Southern Asia. This pattern favors normal to below

normal temperatures across Northern Asia with normal to above normal temperatures across Southern Asia.
- The general pattern the next two weeks 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, in early October the ridging and warm temperatures are predicted to spread eastward.
- In the *Impacts* section I 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

Two fall predictors that I use for our winter forecast are starting to take shape. The first is snow cover extent which off to a fast start. Second is Arctic sea ice, which is well below normal but regional anomalies are very important. It is excruciatingly early but below I discuss why from the very earl signs I see a higher cold risk for Asia and the US more so than Europe.

Imapcts

My apologies but publishing of the blog will continue to be erratic in the coming weeks.

It is only September, but I wanted to share some thoughts on the upcoming winter based on anomalies that I see in the Arctic in late September. It is very early and that must be weighed heavily when considering what I share below.

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 have focused on the month of October, but subsequently other studies have focused on November. As I discussed in the previous blog in early September, the weather pattern across Asia looked favorable for an early advance of snow cover this month. It does look like snow cover extent across Siberia is off to a gangbuster start, possibly the fastest in at least 25 years. Extensive (and likely deep but much harder to measure) favors an overall more disrupted PV and colder temperatures. Temperatures are still marginal so much of the snow could melt but as you can read below it does seem that that the pattern is supportive of the further advance of snow cover across Siberia in the next two weeks (see **Figure i**).

GEFS 6-10 Day Forecast SNOD Change
INIT: 00Z 09/23/2022   FCST: 09/29/2022 to 10/03/2022
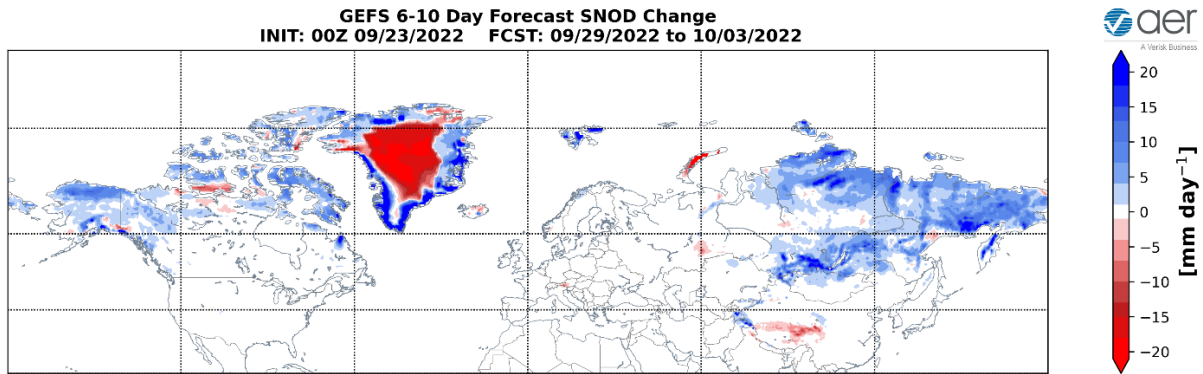
Figure i. Forecasted snow depth changes (mm/day; shading) from 29 September – 3 October 2022. The forecast is from the 00Z 23 September 2022 GFS ensemble.

More recently I have tried to incorporate Arctic Sea ice anomalies in predicting the behavior of the PV and winter temperatures across the NH. It does look like the Arctic Sea ice extent has put in a minima very close to last year but still well below normal. I have tried to argue 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 **Figure ii**, sea ice in the North Pacific sector is more extensively melted relative to normal than in the North Atlantic sector. Sea ice in the Barents-Kara Seas is relatively extensive compared to recent years.
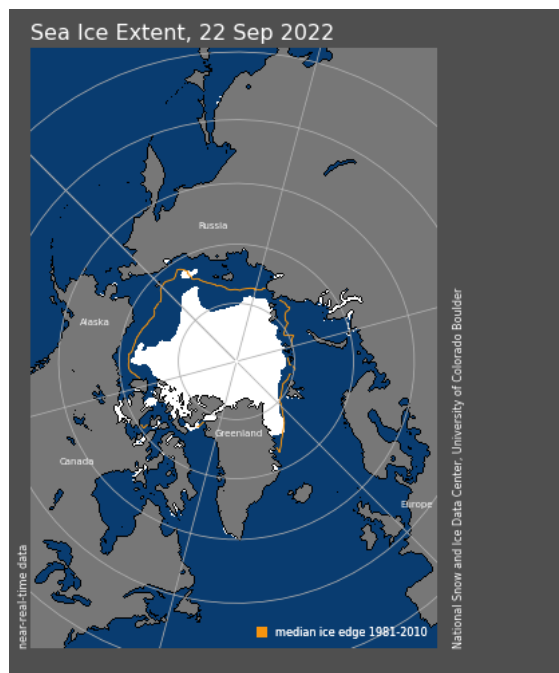
Figure ii. Observed Arctic Sea ice extent on 22 September 2022 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC).

As I have been discussing for a few years now in the blog there are two types of PV disruptions. The first is a major disruption where the PV becomes very weak and can even disappear known as sudden stratospheric warmings (SSWs). These types of disruptions occur when upwelling energy from the troposphere is absorbed in the core of the PV. Following SSWs the coldest departure from normal temperatures tend to be focused across Northern Asia and Europe. The second type of PV disruption is a more minor disruption where the PV stretches or elongates but remains intact. This type of disruption occurs when upwelling energy from the troposphere is reflected off of the PV back down into the troposphere. Following stretched PV events, the coldest departure from normal temperatures tends to be focused across Asia and especially North America east of the Rockies.

Based on our recent paper, Cohen et al. 2021, extensive snow cover across Siberia coupled with relatively extensive sea ice in the Barents-Kara seas would favor a stretched PV over an SSW. For now, a note of interest and will revise as anomalies in the Arctic evolve.

Looking at tropical forcings both La Niña and a westerly quasi-biennial oscillation or QBO (both expected this winter) are thought to inhibit SSWs. If upwelling tropospheric energy is active in the coming months, this could also favor a stretched or elongated PV rather than an SSW.

Of course snow and ice cover can be very favorable for disrupting the PV but that alone is not sufficient to disrupt the PV. They need to force or be coupled with high latitude blocking (essentially high-pressure ridges). Predicted high latitude blocking to end the month and even into early October looks impressive. So at least it is in place, but it will need to persist for many more months before it is a strong influence on the winter weather.

So, in summary all the pieces are in place to disrupt the PV, extensive snow cover, low sea ice and high latitude blocking. However near normal sea ice in the Barents-Kara Seas, La Niña and a westerly QBO, I believe all favor stretched PV disruptions compared with SSWs and that is what I will be watching for this fall. Stretched PVs favor relatively cold temperatures in Central to East Asia and North America east of the Rockies but not Europe.

There are of course many caveats. First snow and sea ice anomalies will vary greatly in the coming months. I would argue it is plausible that September foreshadows the upcoming winter but will not influence the upcoming winter. What happens in November is much more important on the circulation of the upcoming winter than what happens in September. Second though I feel fairly confident we will see more stretched PV events this fall, there are very different transitions from a stretched PV as we approach winter. The environment that initiates a stretched PV can subsequently shield the PV from further disruptions leading to a strong and stable PV as happened in winter 2019/20. Another is where stretched PV events happen repeatedly as happened last winter but maybe the best example of this phenomenon is winter 2013/14. Another plausible scenario is that a stretched PV eventually transitions to an SSW as happened in winter 2017/18. These three winters had very different sensible weather across the NH though they all started with stretched PVs in the fall and early winter. Of course, there are other possible scenarios but those three are the most likely from this very early and truthfully premature vantage point.

Recent and Very Near Term Conditions

The AO is predicted to be negative 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 positive geopotential height anomalies this week across Greenland (**Figure 2**), the NAO is predicted to be negative this week (**Figure 1**).
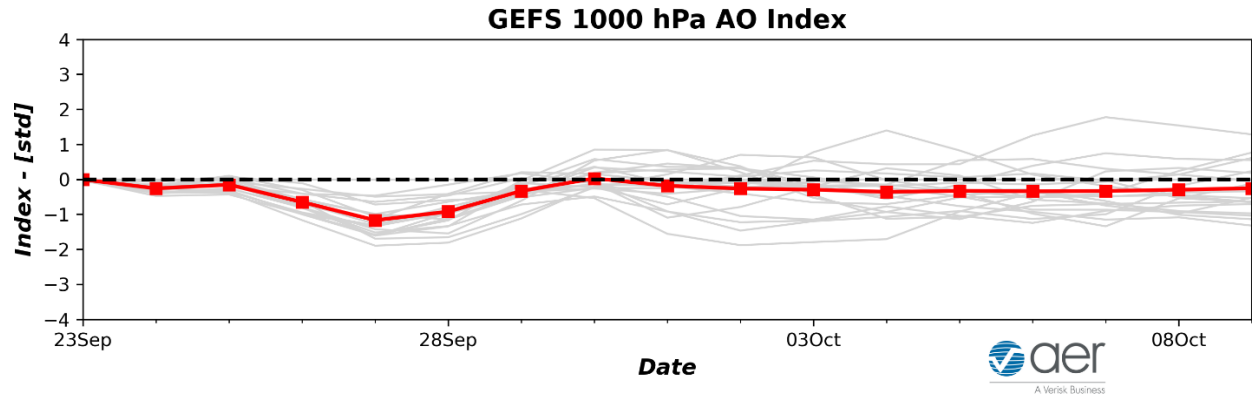
Figure 1. The predicted daily-mean AO at 1000 hPa from the 00Z 23 September 2022 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares

Predicted ridging/positive geopotential height anomalies across Greenland will force troughing/negative geopotential height anomalies across much of Europe except for ridging/positive geopotential height anomalies across Scandinavia (**Figure 2**). This will favor normal to below normal temperatures across much of Europe including the UK with normal to above normal temperatures mostly limited to Scandinavia (**Figure 3**). Strong ridging/positive geopotential height anomalies across the Barents-Kara Seas and the Urals are predicted to contribute to troughing/negative geopotential height anomalies focused across Northern Asia with ridging/positive geopotential height anomalies across Southern Asia (**Figure 2**). This pattern favors widespread normal to below normal temperatures across Northern Asia with normal to above normal temperatures across Southern Asia (**Figure 3**).
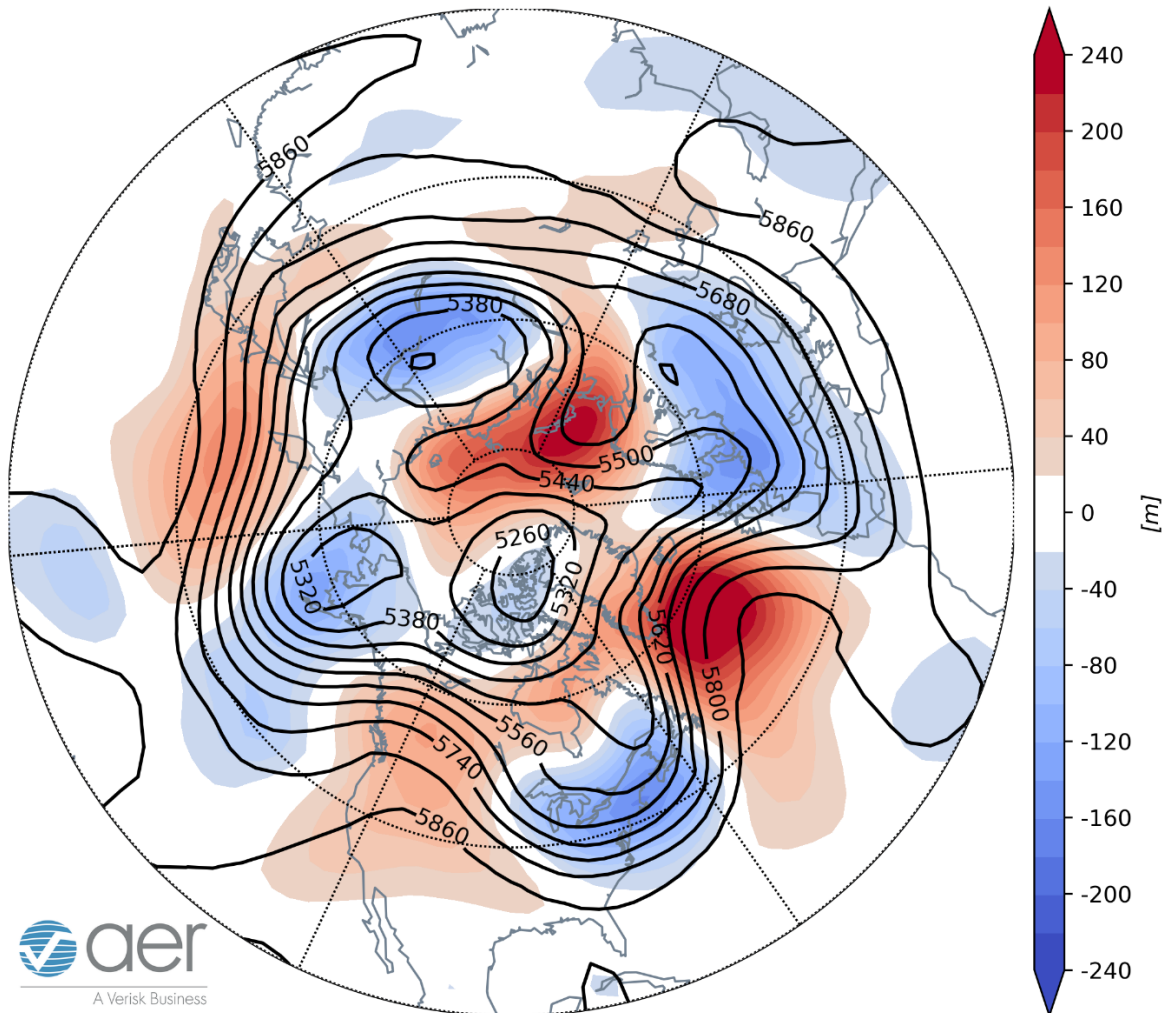
Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 24 – 28 September 2022. The forecasts are from the 00z 23 September 2022 GFS ensemble.

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 **(Figure 2).** The pattern will favor 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 **(Figure 3).**
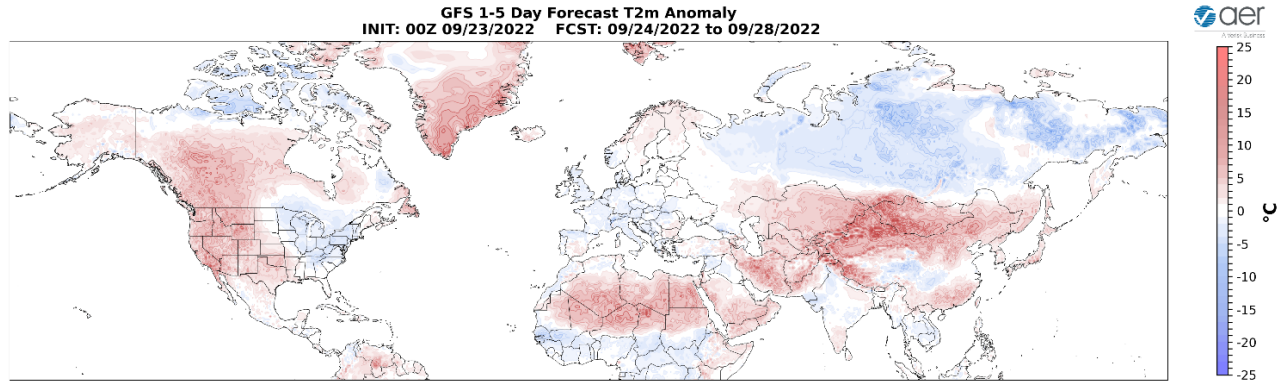
Figure 3. Forecasted surface temperature anomalies (°C; shading) from 24 – 28 September 2022. The forecast is from the 00Z 23 September 2022 GFS ensemble.

Mostly below normal precipitation is predicted across Eurasia with above normal precipitation predicted for parts of Scandinavia, Southern Europe, Southern and Eastern Asia (**Figure 4**). Mostly below normal precipitation is predicted across North America with above normal precipitation predicted across Southeastern Alaska, and parts of the Canadian Archipelagos (**Figure 4**).
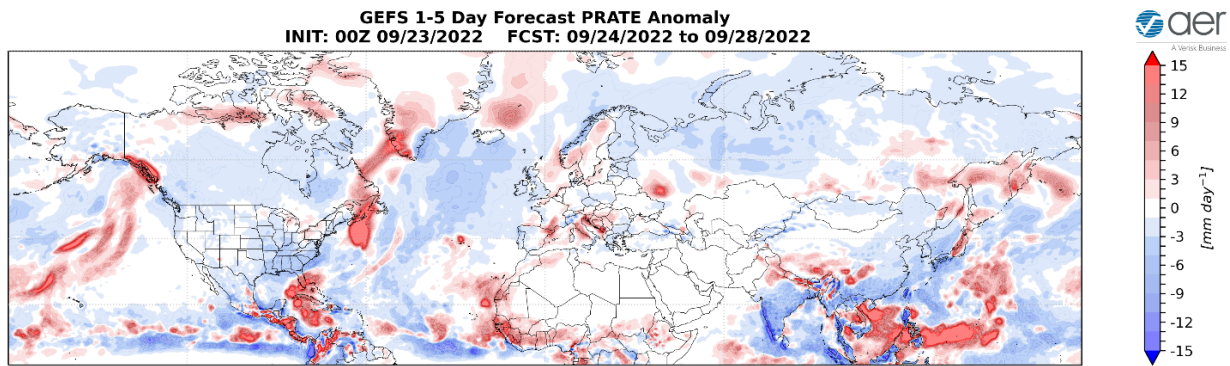
Figure 4. Forecasted precipitation rate (mm/day; shading) from 24 – 28 September 2022. The forecast is from the 00Z 23 September 2022 GEPS ensemble.

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 weak but mostly positive geopotential height anomalies across Greenland (**Figure 5**), the NAO is predicted to remain near neutral to slightly negative this period.
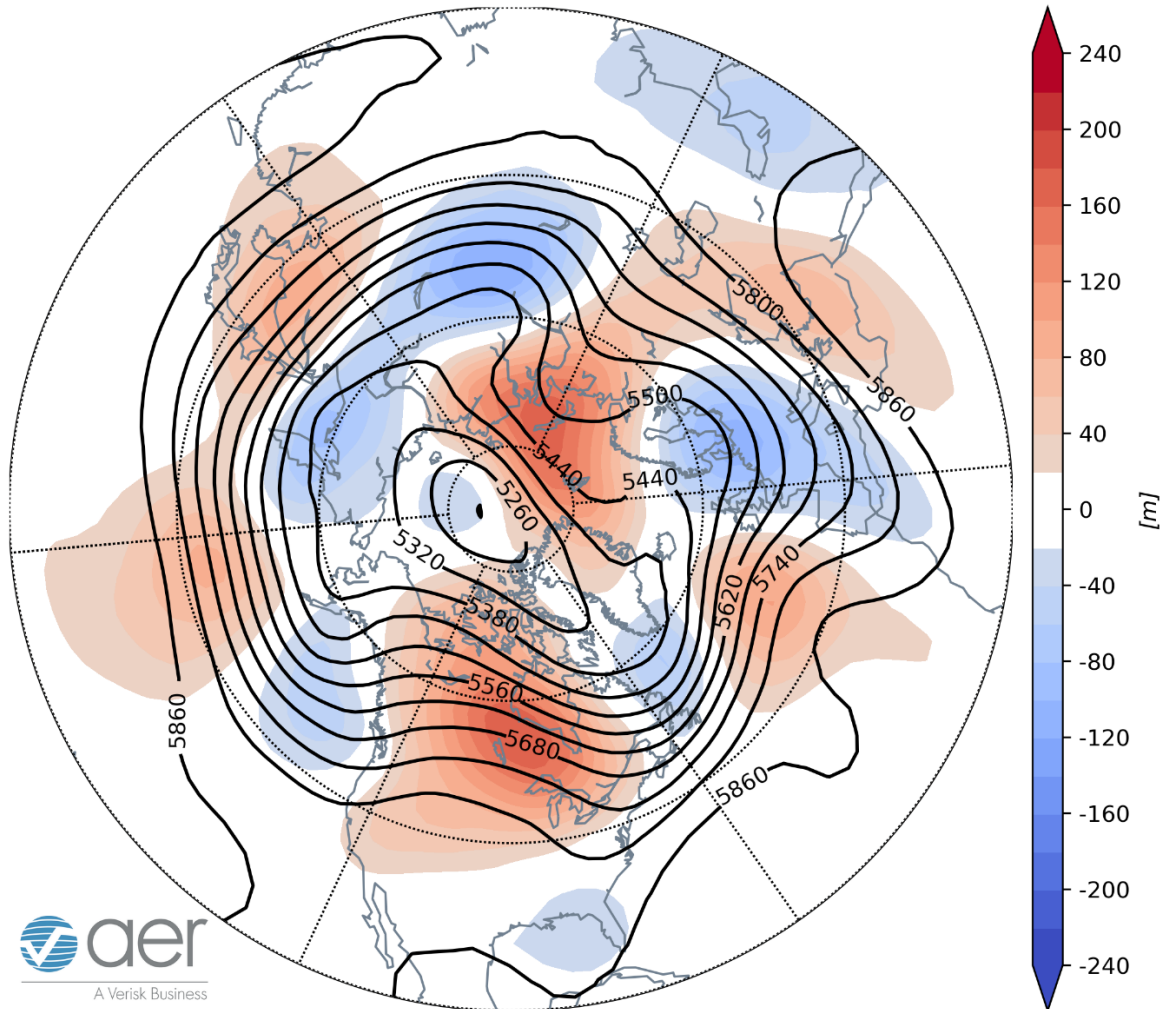
Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 29 September – 3 October 2022. The forecasts are from the 00z 23 September 2022 GFS ensemble.

With weakening ridging/positive geopotential height anomalies across Greenland troughing/negative geopotential height across Europe will persist but weaken (**Figures 5**). The pattern is predicted to result in more widespread normal to above normal temperatures across Europe including the UK (**Figure 6**). Ridging/positive geopotential height anomalies are predicted to persist across the Barents-Kara Seas and the Urals and will continue to favor troughing/negative geopotential height anomalies in Northern and Central Asia with ridging/positive geopotential height anomalies across Southern Asia this period (**Figure 5**). This pattern favors widespread normal to below normal temperatures across Northern Asia with normal to above normal temperatures across Southern Asia (**Figure 6**).
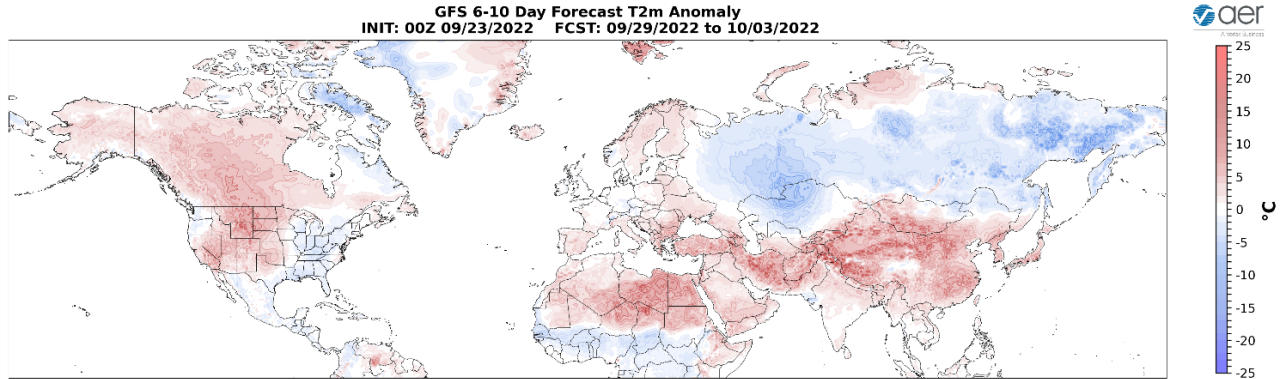
Figure 6. Forecasted surface temperature anomalies (°C; shading) from 29 September – 3 October 2022. The forecast is from the 00Z 23 September 2022 GFS ensemble.

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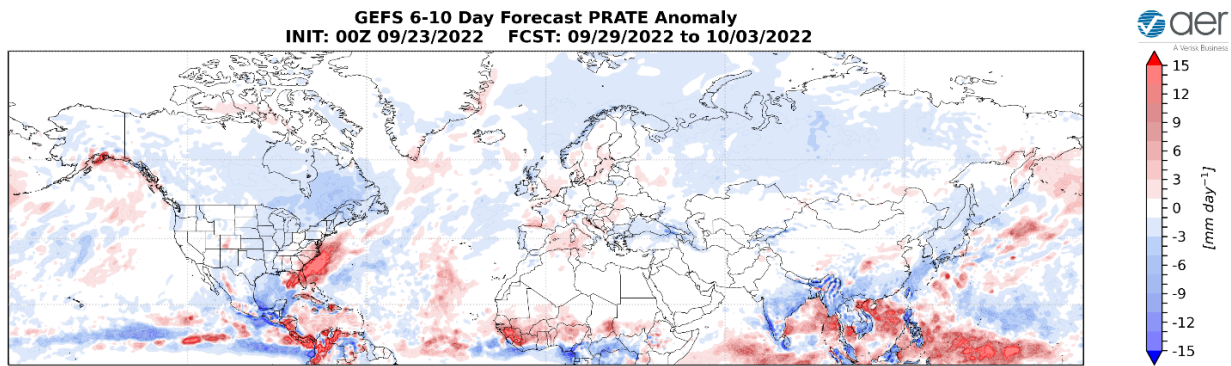

Figure 7. Forecasted precipitation rate (mm/day; shading) from 29 September – 3 October 2022. The forecast is from the 00Z 23 September 2022 GFS ensemble.

Mostly below normal precipitation is predicted across Eurasia with above normal precipitation predicted regionally across Europe and parts of Southern and Eastern Asia (**Figure 7**). Mostly below normal precipitation is predicted across North America with above normal precipitation predicted across the Southeastern US (**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 neutral (**Figure 1**). With predicted weak positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is predicted to remain neutral to weakly negative this period.

GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
**INIT: 00Z 09/23/2022   FCST: 10/04/2022 to 10/08/2022**
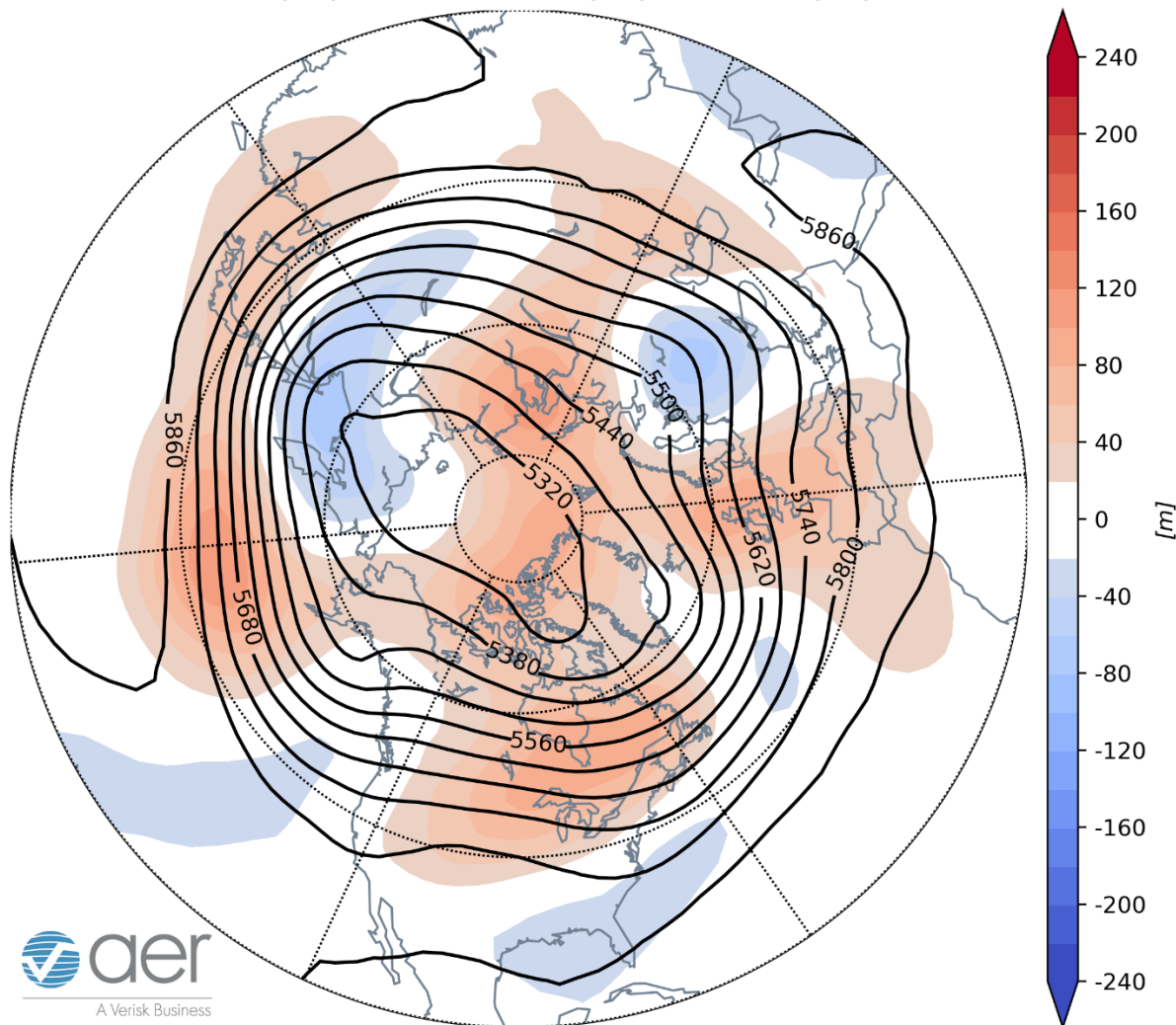
Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 4 – 8 October 2022. The forecasts are from the 00z 23 September 2022 GFS ensemble.

Weakened ridging/positive geopotential height anomalies across Greenland will continue to support strengthening ridging/positive geopotential height anomalies across Europe with some remnant weak troughing across Western Europe this period (**Figure 8**). This pattern favors normal to above normal temperatures across much of Europe with normal to below normal temperatures limited to Northwestern Europe including the UK (**Figures 9**). Persistent albeit weakening ridging/positive geopotential height anomalies centered across the Barents-Kara Seas and the Urals will continue to support troughing/negative geopotential height anomalies in Northern and Central Asia with ridging/positive geopotential height anomalies across Southern Asia (**Figure 8**). This pattern favors widespread normal to below normal temperatures across Northern and Central Asia with normal to above normal temperatures across Southern Asia (**Figure 9**).
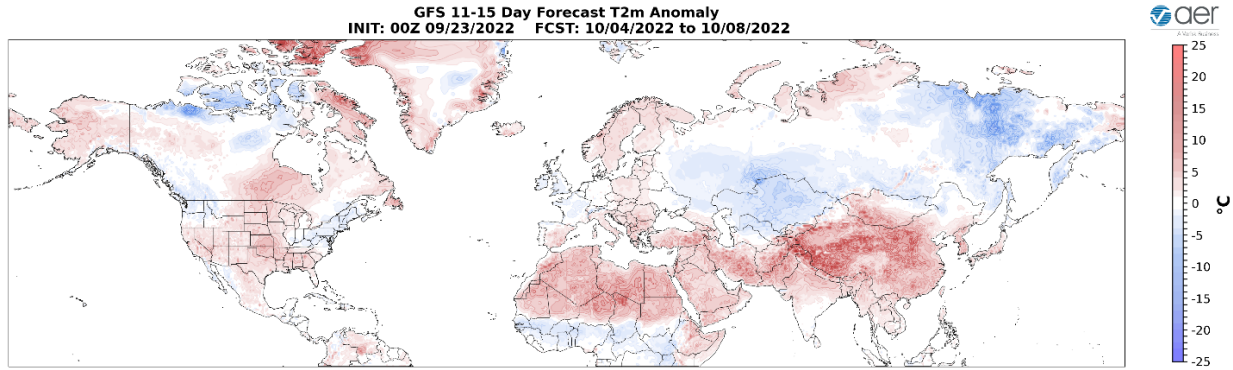
Figure 9. Forecasted surface temperature anomalies (°C; shading) from 4 – 8 October 2022. The forecast is from the 00Z 23 September 2022 GFS ensemble.

The predicted pattern across North America this period is weak troughing/negative geopotential height anomalies in the Gulf of Alaska and along the west coast of North America that will help nudge ridging/positive geopotential height anomalies eastward across much of North America with more weak troughing/negative geopotential height anomalies across the Southeastern US 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 Ethe West Coast of Canada, the North-western and -eastern US (**Figure 9**).
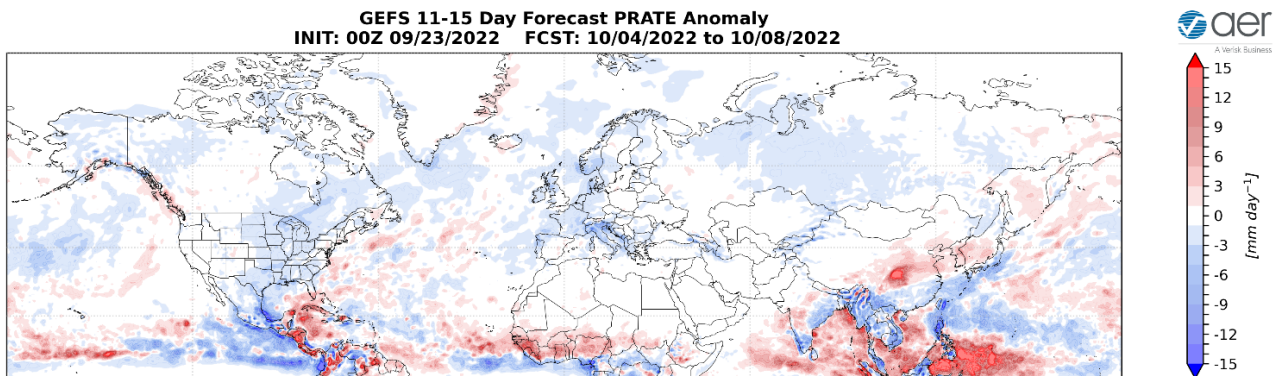

Figure 10. Forecasted precipitation rate (mm/day; shading) from 4 – 8 October 2022. The forecast is from the 00Z 23 September 2022 GFS ensemble.

Mostly below normal precipitation is predicted across Eurasia with above normal precipitation predicted for parts of Southern and Eastern Asia (**Figure 10**). Mostly below normal precipitation is predicted across North America except for the west cost of Canada (**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 with warm/positive PCHs in the mid to lower stratosphere and the troposphere (**Figure 11**). One exception is cold/negative PCHs are currently observed in the lower troposphere (**Figure 11**).
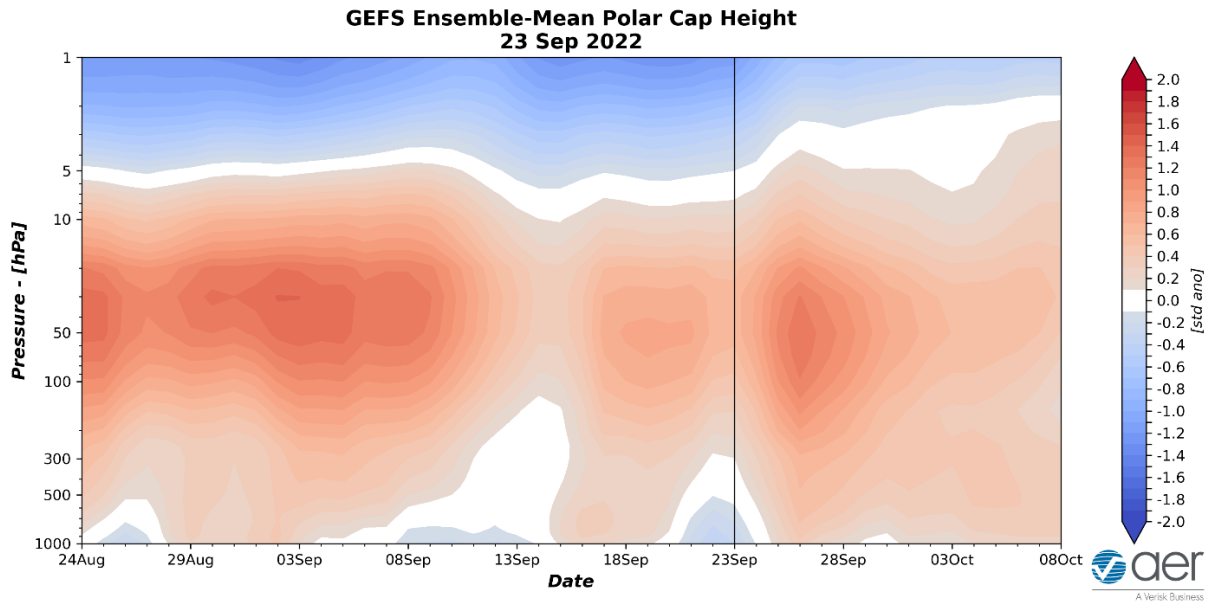

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 23 September 2022 GFS ensemble.

The warm/positive PCHs in the lower troposphere (**Figure 11**) are consistent with the predicted negative surface AO predicted for this week (**Figure 1**). However as lower tropospheric PCHs weaken next week (**Figure 11**), the surface AO is predicted to become more tethered to neutral (**Figure 1**).
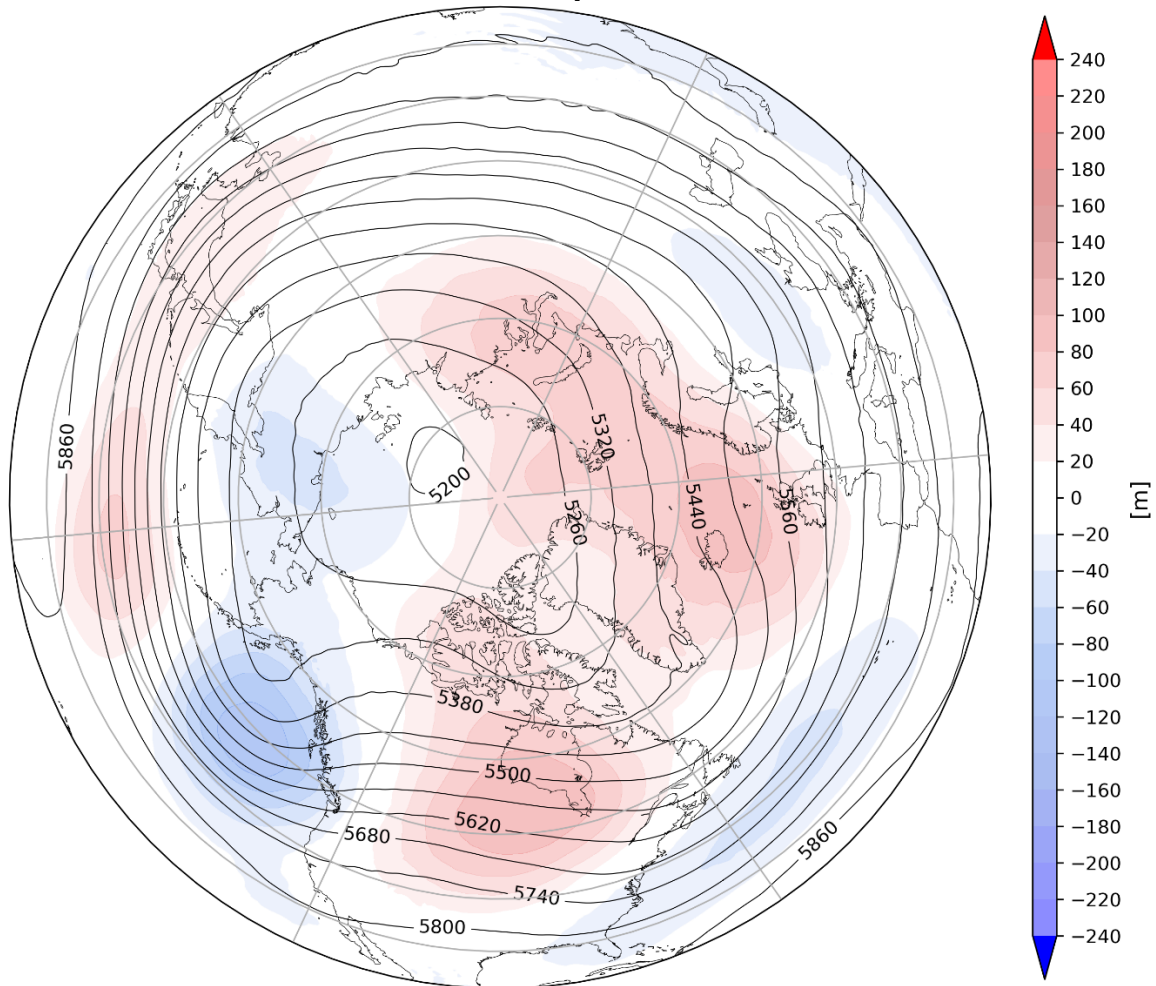
Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for October 2022. The forecasts are from the 00Z 23 September 2022 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and surface temperatures for October (**Figure 13**) 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 Greenland, Iceland, Scandinavia to the Barents-Kara Seas and the Urals and one more region of ridging near the Dateline with troughing across Eastern Europe, Western Asia, Siberia, the Gulf of Alaska and the Southeastern US (**Figure 12).** This pattern favors seasonable to relatively warm temperatures across Northern Europe, the north slope of Siberia, Alaska, much of Canada and the Western and Central US with seasonable to relatively cool temperatures across Central and Eastern Europe, the Middle East, Northern and Central Asia and the Eastern US (**Figure 13).**
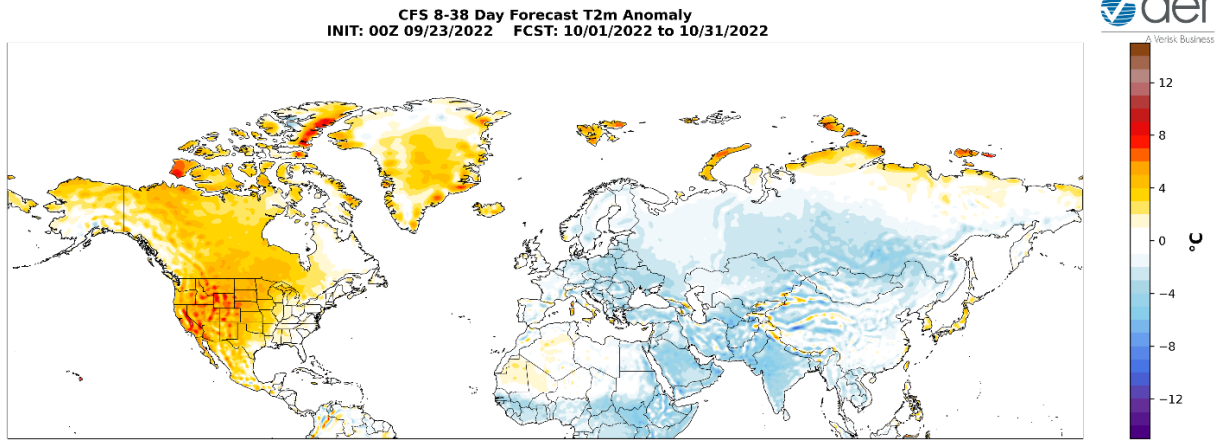
Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for October 2022. The forecasts are from the 00Z 23 September 2022 CFS.

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 14) 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 North Pacific.
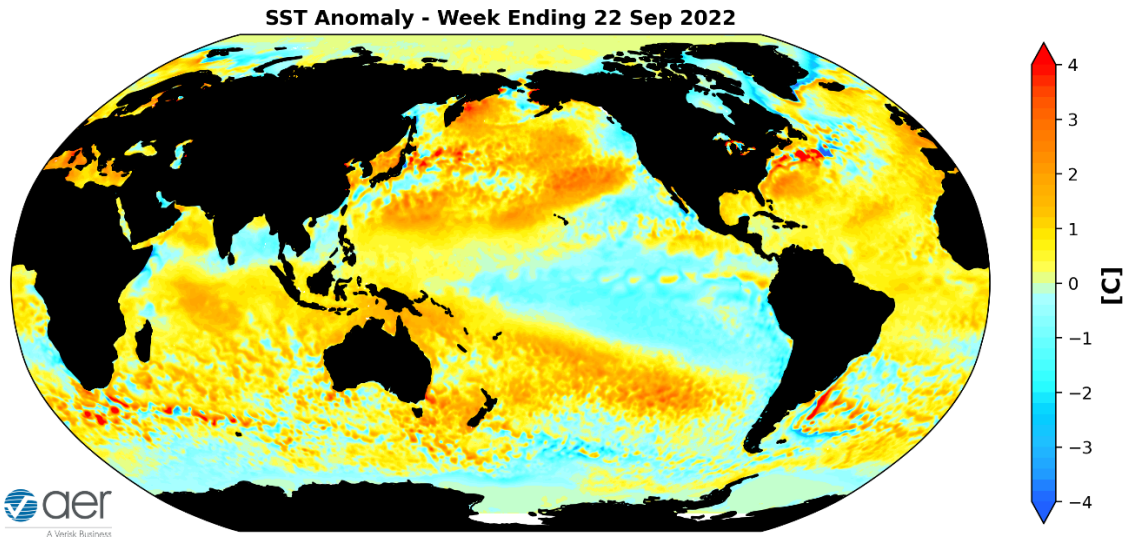
Figure 14. The latest weekly-mean global SST anomalies (ending 22 September 2022). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently the Madden Julian Oscillation (MJO) is weak where no phase is favored (Figure 15). The forecasts are for the MJO to remain weak where no phase is favored and then possibly emerge into Phase 6. Therefore there seems to be little MJO influence in the near and long term weather across North America. But admittedly this is outside of my expertise.
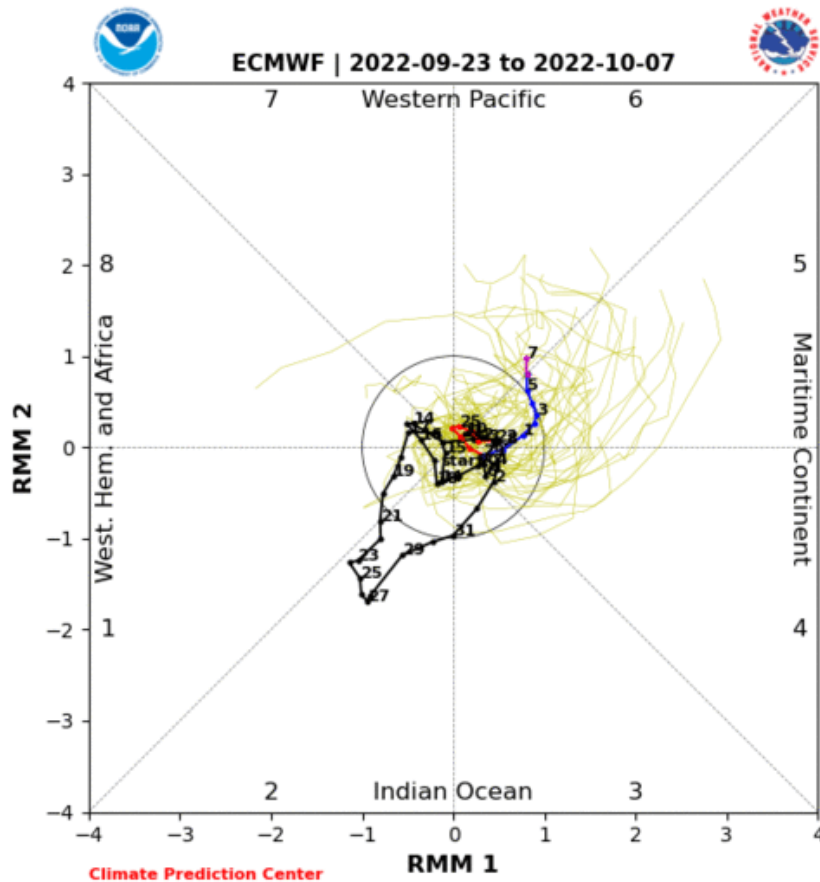
Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 23 September 2022 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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