

Arctic Oscillation and Polar Vortex Analysis and Forecasts

September 27, 2021

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.

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

Summary

- The Arctic Oscillation (AO) is currently negative and is predicted to remain negative to neutral over the next two weeks with mostly positive pressure/geopotential height anomalies across the North Atlantic side of the Arctic and mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently negative and is

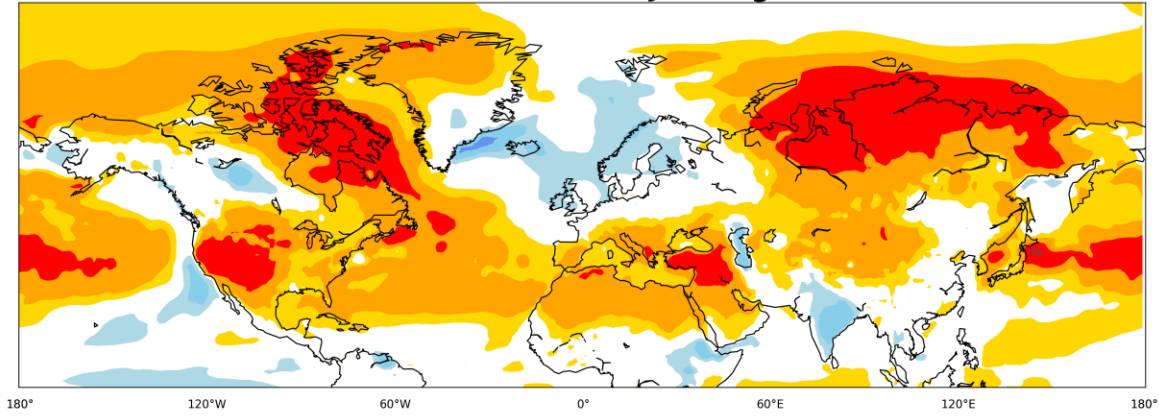
predicted to remain negative to neutral as pressure/geopotential height anomalies are predicted to remain mostly positive across Greenland the next two weeks.

- The next two weeks, ridging/positive geopotential height anomalies across Greenland will favor troughing/negative geopotential height anomalies coupled with normal to below temperatures in Northwestern Europe including the United Kingdom (UK) while ridging/positive geopotential height anomalies coupled with normal to above normal temperatures are predicted to dominate much of Southern and Eastern Europe.
- Over the next two weeks persistent ridging/positive geopotential height anomalies coupled with normal to above normal temperatures centered near the Urals will force downstream troughing/negative geopotential height anomalies coupled with normal to below temperatures first in Central and then in Northeastern Asia.
- This general pattern across North America the next two weeks is troughing/negative geopotential height anomalies coupled with normal to below normal temperatures across the west coast of North America including Alaska forcing downstream ridging/positive geopotential height anomalies coupled with normal to above temperatures in much of Canada and the United States (US) from the Rockies eastward. However, one exception is the Northeastern US where troughing/negative geopotential height anomalies coupled with normal to below temperatures are predicted to linger much of this week.

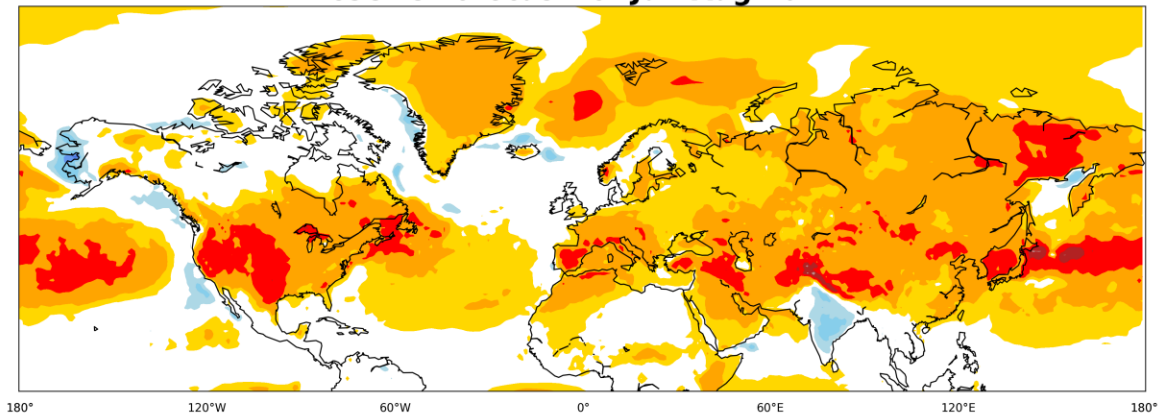
Impacts

With the end of meteorological summer at the beginning of the month and now astronomical summer last week, we can assess the summer season which features widespread above to well above normal temperatures across the Northern Hemisphere (NH) and compare with the summer forecasts from this past spring as shown in **Figure i**. Regions that experienced exceptional warmth include Southwestern Canada, the Western US, Eastern Europe, North Africa, the Middle East, Siberia and East Asia. Regional exceptions to the overall warmth that experienced a relatively cool summer are the Western Alaska, Northern Canada, the Southeastern US, Western Europe and parts of Central Asia. Overall, the AER summer temperature anomaly forecast performed well but especially across Eurasia. The AER model performed better across Eurasia than the dynamical model forecasts. Across much of North America the AER performed well except for Alaska, where the forecast was too warm. Across North America the C3S (ensemble of European models) probably performed the best, though all forecasts missed the relatively cool temperatures across the Southeastern US.

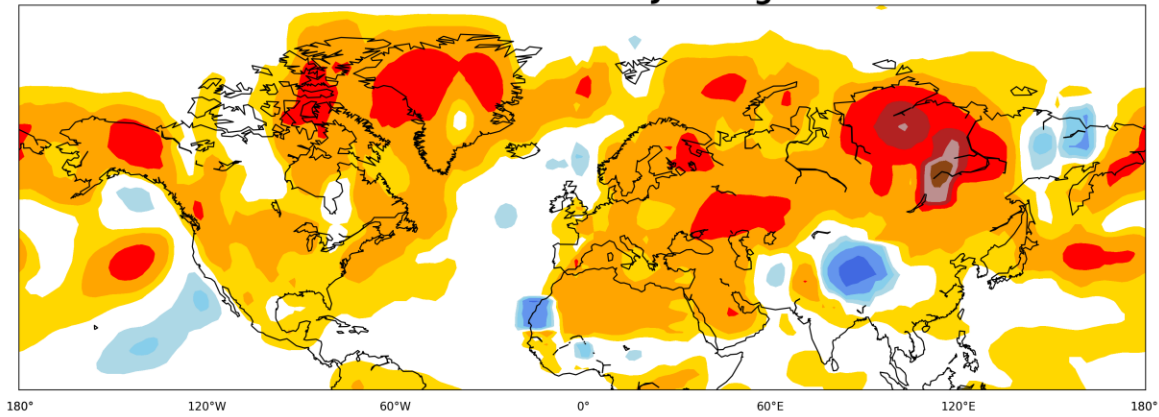
NMME Ts Forecast for Jun-Aug 2021



C3S Ts Forecast for Jun-Aug 2021



AER Forecast of Ts for Jun-Aug 2021



Observed Ts for Jun-Aug 2021

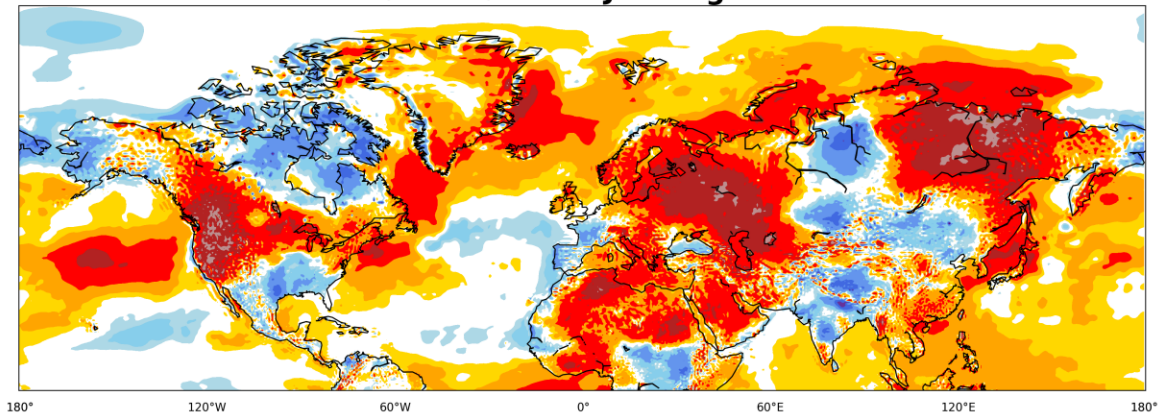


Figure i. Forecasted surface temperature anomalies for June-August 2021 from the NMME (top), C3S (second row) AER (third row) models and observed surface temperature anomalies ($^{\circ}\text{K}$; shading) over the NH for 1 June through 31 August 2021 based on GFS analysis.

Also, now that the summer is over, I turn my attention much more closely to surface boundary conditions in the Arctic. The sea ice annual minimum was reached two weeks ago at 4.72 million squared kilometers according to the National Snow and Ice Data Center <https://nsidc.org/arcticseaicenews/> (see **Figure ii**). The sea ice extent minimum is above the past two years and more in line with the years 2015-2018. Sea ice is near normal on the North Pacific side of the Arctic and well below normal on the Eurasian to North Atlantic side of the Arctic. I think this is an interesting anomaly pattern that is conducive to perturb the polar vortex (PV) with below normal sea ice weighted towards the North Atlantic side of the Arctic most favorable for perturbing the PV (see **Figure iii**).

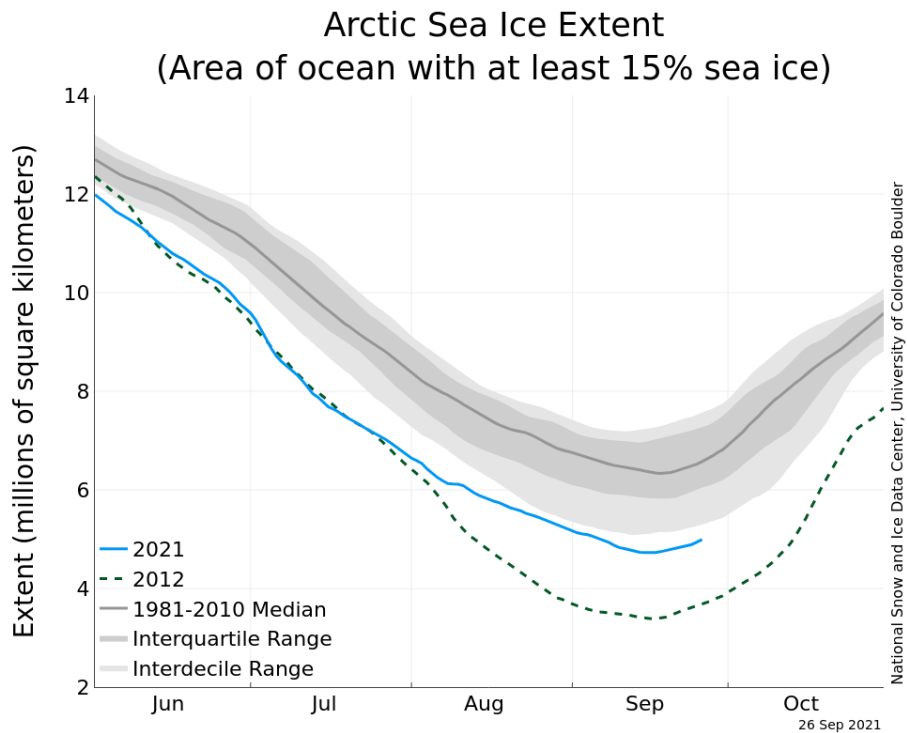


Figure ii. Observed Arctic sea ice extent through 26 September 2021 (blue). Gray shading and line shows climatological extent of sea ice based on the years 1981-2010 while green dashed shows the extent for 2012. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

I am also watching Eurasian snow cover extent. It is very early, and it seems that snow cover is above normal both across North America and Eurasia. The persistent Ural

blocking predicted by the weather models should be favorable for a rapid advance of snow cover especially across Siberia. The GFS has been advertising for a while a rapid advance of Siberian snow cover (as a recent example see **Figure iv**) but the models do struggle with snow forecasts in Siberia, so I am taking a wait and see attitude.

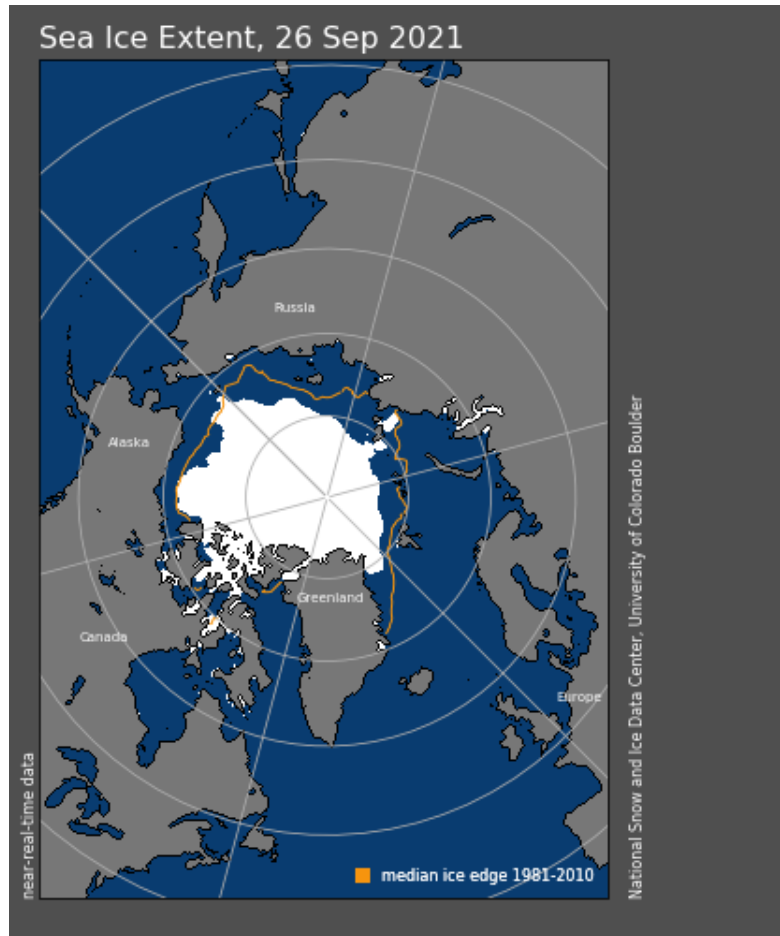


Figure iii. Observed Arctic sea ice extent on 26 September 2021 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

Below normal sea ice especially in the Barents-Kara seas favors a sudden stratospheric warming type PV disruption that is related to relatively cold temperatures in the eastern US, but especially Northern Europe and Northeast Asia. In contrast, I believe that above normal snow cover across Siberia in October also favors a disrupted polar vortex but more of the stretched PV variety that favors cold temperatures in East Asia and eastern North America. The different regional expectations between snow and ice are related to the analysis in our recent [Science paper](#).

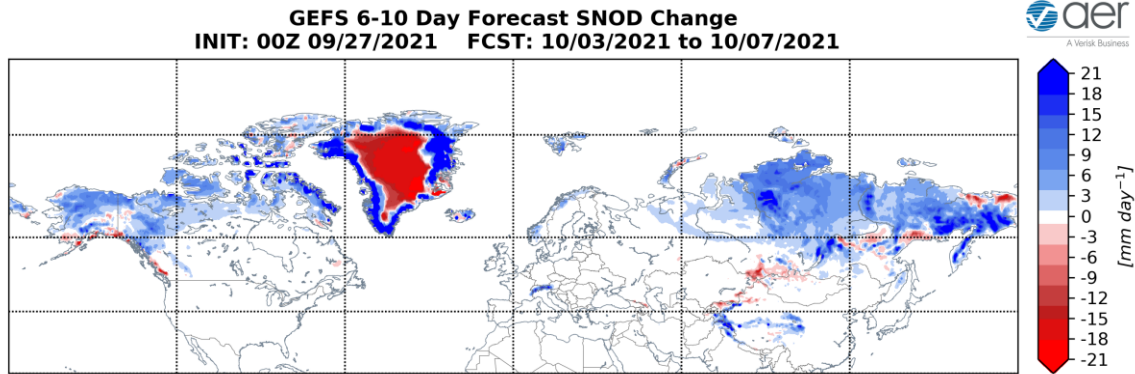


Figure iv. Forecasted precipitation anomalies (mm/day; shading) from 3 – 7 October 2021. The forecasts are from the 00z 27 September 2021 GFS ensemble.

Finally, I am very intrigued by the persistent Scandinavian/Urals region blocking predicted by the weather models. This is the atmospheric feature that I believe is most conducive to disrupting the PV but it is very early. If the tendency for Scandinavian/Urals region blocking can persist into November and especially December, a significant disruption of the polar vortex this winter is almost inevitable.

1-5 day

The AO and NAO are predicted to be negative this week (**Figure 1**) as geopotential height anomalies are predicted to be positive across the North Atlantic side of the Arctic including Greenland with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**).

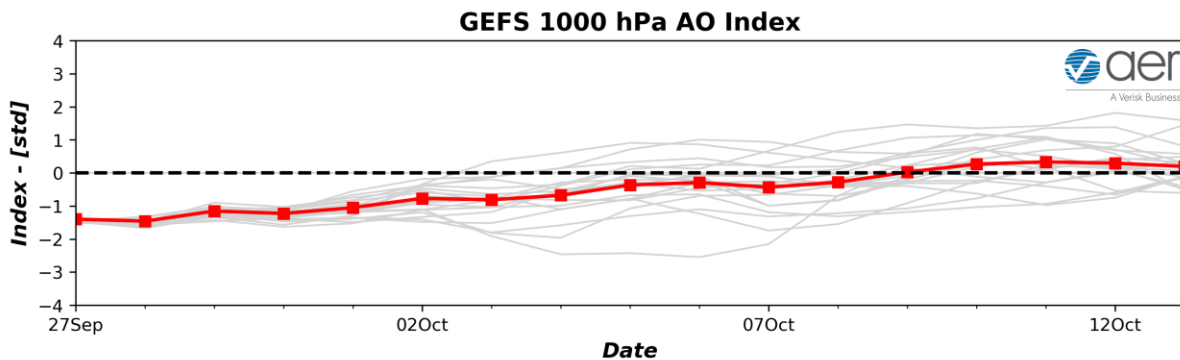


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 27 September 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Ridging/positive geopotential height anomalies across Greenland will promote troughing/negative geopotential height anomalies across Northwestern Europe with ridging/positive geopotential height anomalies in Southern and Eastern Europe (Figures 2). This will favor widespread normal to above normal temperatures across much of Europe except for normal to below normal temperatures across Northwestern Europe including the UK (Figure 3). The general pattern across Asia this period is ridging/positive geopotential height anomalies across Western Asia that will force downstream troughing/negative geopotential height anomalies in Central Asia that extends into Northeastern Asia (Figure 2). This pattern favors normal to above normal temperatures across much of Western and Southern Asia with normal to below normal temperatures in Central Asia that extends eastward into Siberia (Figure 3).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 09/27/2021 FCST: 09/28/2021 to 10/02/2021

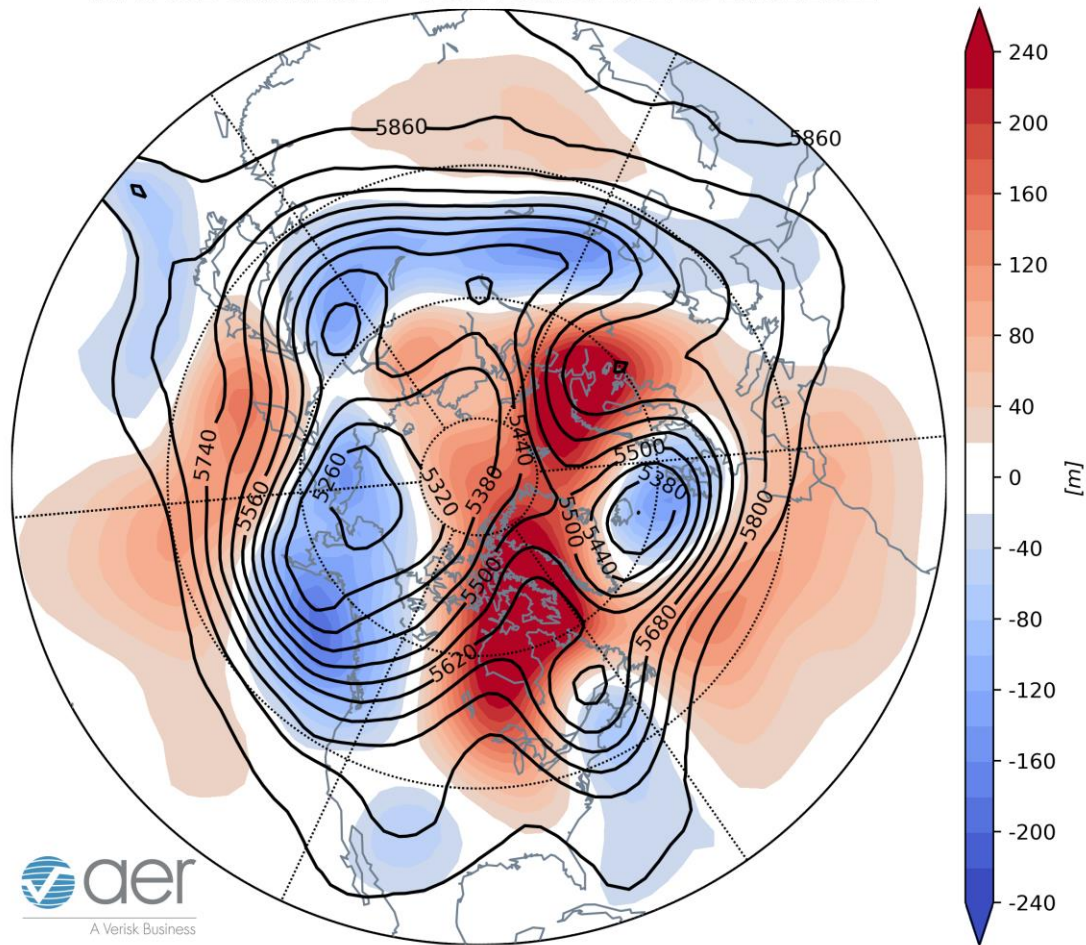


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 28 September – 2 October 2021. The forecasts are from the 00z 27 September 2021 GFS ensemble.

The general pattern this week is troughing/negative geopotential height anomalies across the west coast of North America including Alaska forcing downstream ridging/positive geopotential height anomalies across much of North America east of the Rockies except for regional troughing/negative geopotential height anomalies across the Northeastern US (**Figure 2**). This pattern is predicted to bring normal to below normal temperatures across much of Alaska, Western Canada, the Western US and the Northeastern US, with normal to above normal temperatures across much of Canada and the US east of the Rockies (**Figure 3**).

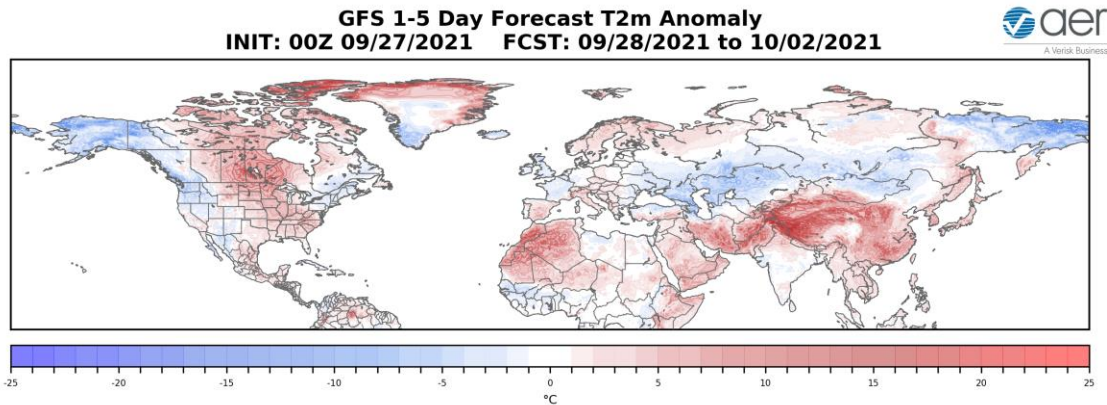


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 28 September – 2 October 2021. The forecast is from the 00Z 27 September 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia with the exceptions of above normal precipitation across the British Isles, Southern Norway, Southern and Eastern Asia (**Figure 4**). Normal to below normal precipitation is predicted for much of North America with the exceptions of normal to above normal precipitation along the West Coast of Canada, the US Pacific Northwest, the western Gulf of Mexico and the Canadian Maritimes (**Figure 4**).

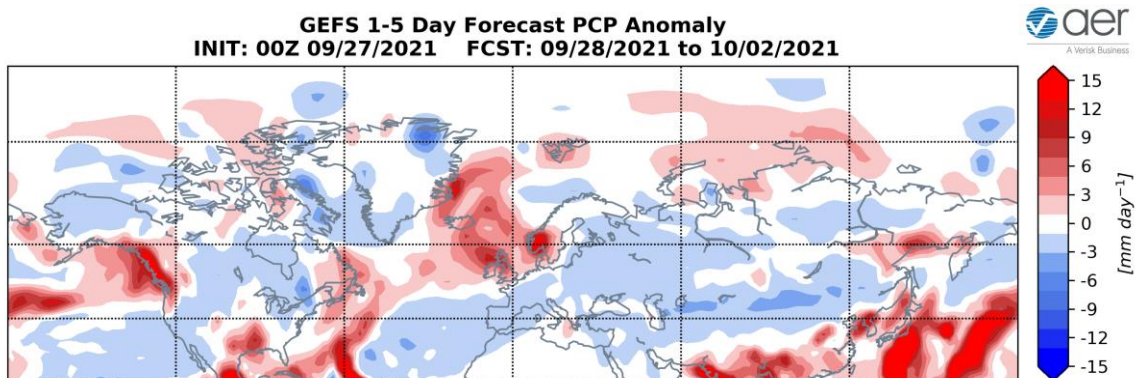


Figure 4. Forecasted precipitation anomalies (mm/day; shading) from 28 September – 2 October 2021. The forecast is from the 00Z 27 September 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to continue to remain negative to neutral this period (**Figure 1**) as geopotential height anomalies remain positive across the North Atlantic side of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with mostly positive geopotential height anomalies continuing across Greenland (**Figure 5**), the NAO is predicted to be negative this period.

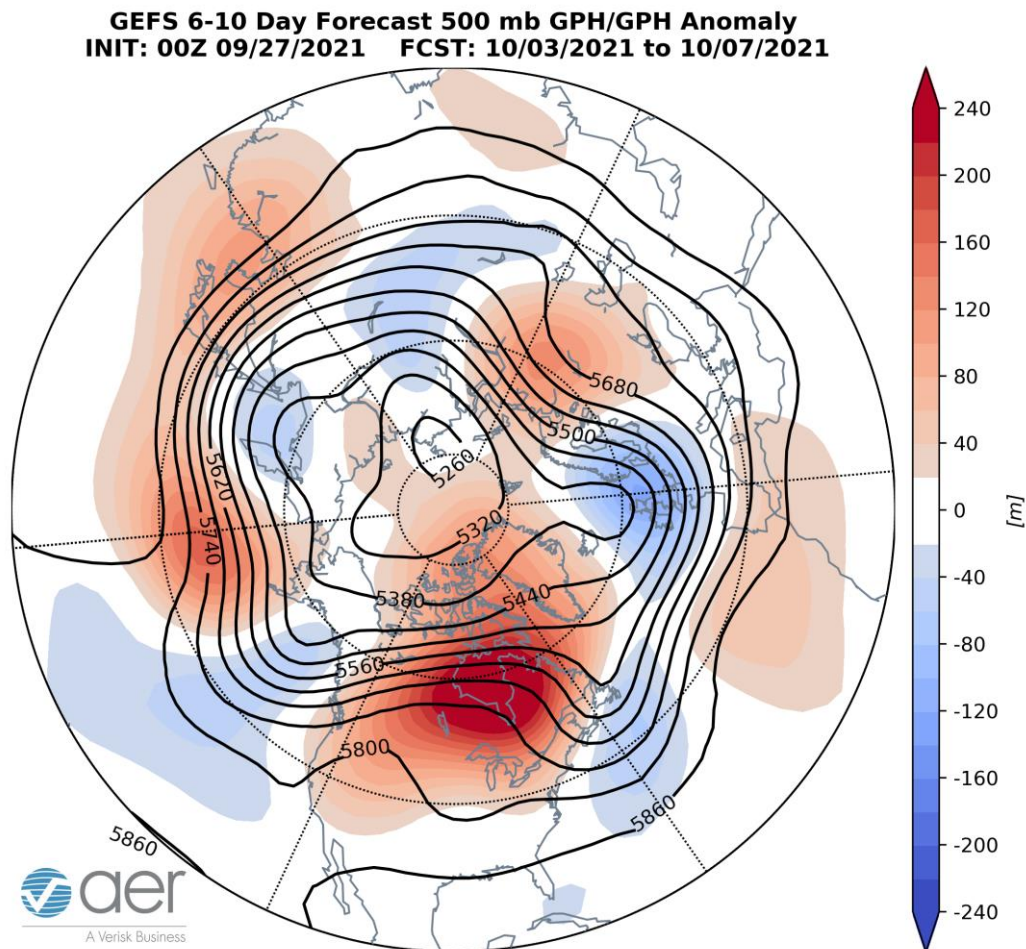


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 3– 7 October 2021. The forecasts are from the 00z 27 September 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies are predicted across Greenland favoring troughing/negative geopotential height anomalies across Northwestern Europe including the UK with ridging/positive geopotential height anomalies across Eastern Europe this period (**Figures 5**). This will result in widespread

normal to below normal temperatures across Western Europe including the UK with normal to above normal temperatures across Eastern Europe (**Figure 6**). Ridging/positive geopotential height anomalies are predicted across to persist across Western Asia that will continue to favor troughing/negative geopotential height anomalies across Central and Eastern Asia this period (**Figure 5**). This pattern favors normal to above normal temperatures widespread across Western and Southern Asia with normal to below normal temperatures in Central and Northeastern Asia (**Figure 6**).

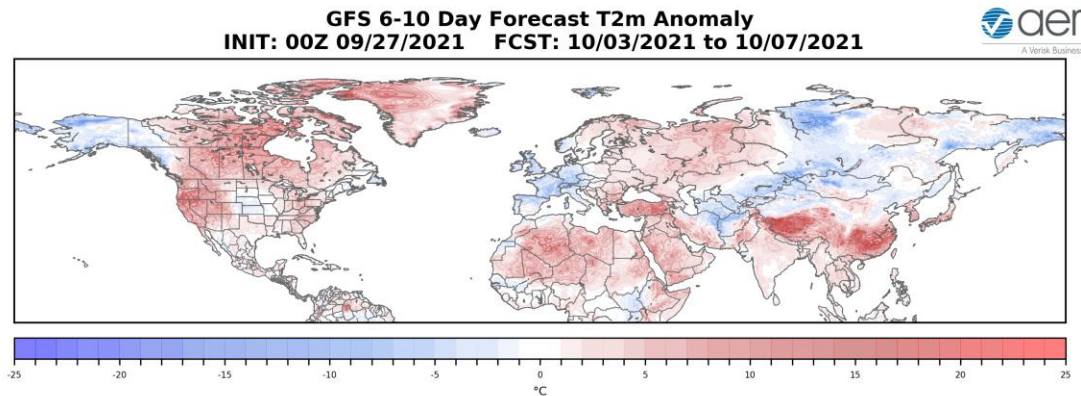


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 3– 7 October 2021. The forecasts are from the 00Z 27 September 2021 GFS ensemble.

Troughing/negative geopotential height anomalies are predicted across Alaska and the Gulf of Alaska contributing to ridging/positive geopotential height anomalies widespread across much of North America except for weak troughing/negative geopotential height in the US Plains (**Figure 5**). The widespread ridging is predicted to bring normal to above normal temperatures across much of Canada and the US with the exception of normal to below normal temperatures Alaska, Northwestern Canada and the US Plains (**Figure 6**).

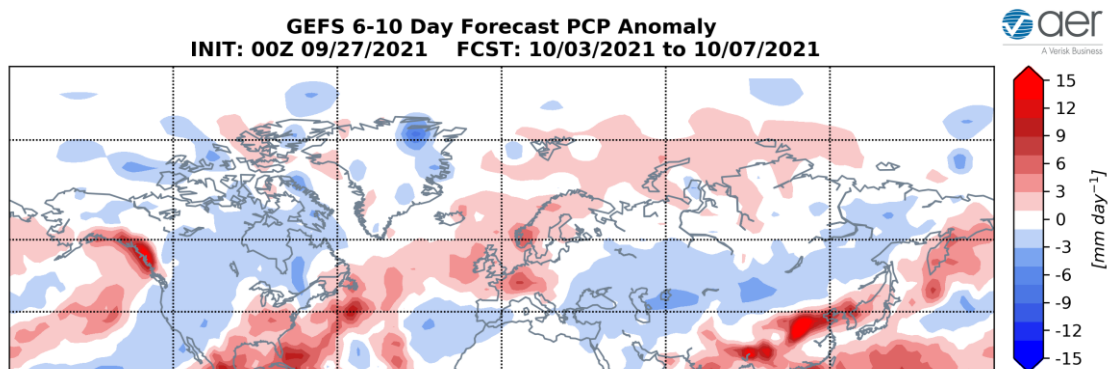


Figure 7. Forecasted precipitation anomalies (mm/day ; shading) from 3– 7 October 2021. The forecasts are from the 00Z 27 September 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia with the exceptions of above normal precipitation across Northwestern and Central Europe, Southern and Eastern Asia (**Figure 7**). Normal to below normal precipitation is predicted for much of North America except for normal to above normal precipitation in Southern Alaska, the West Coast of Canada, the Eastern US and the Canadian Maritimes (**Figure 7**).

11-15 day

With mostly positive geopotential height anomalies predicted across the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO should remain near neutral this period (**Figure 1**). With predicted negative pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is forecasted to remain neutral to negative this period.

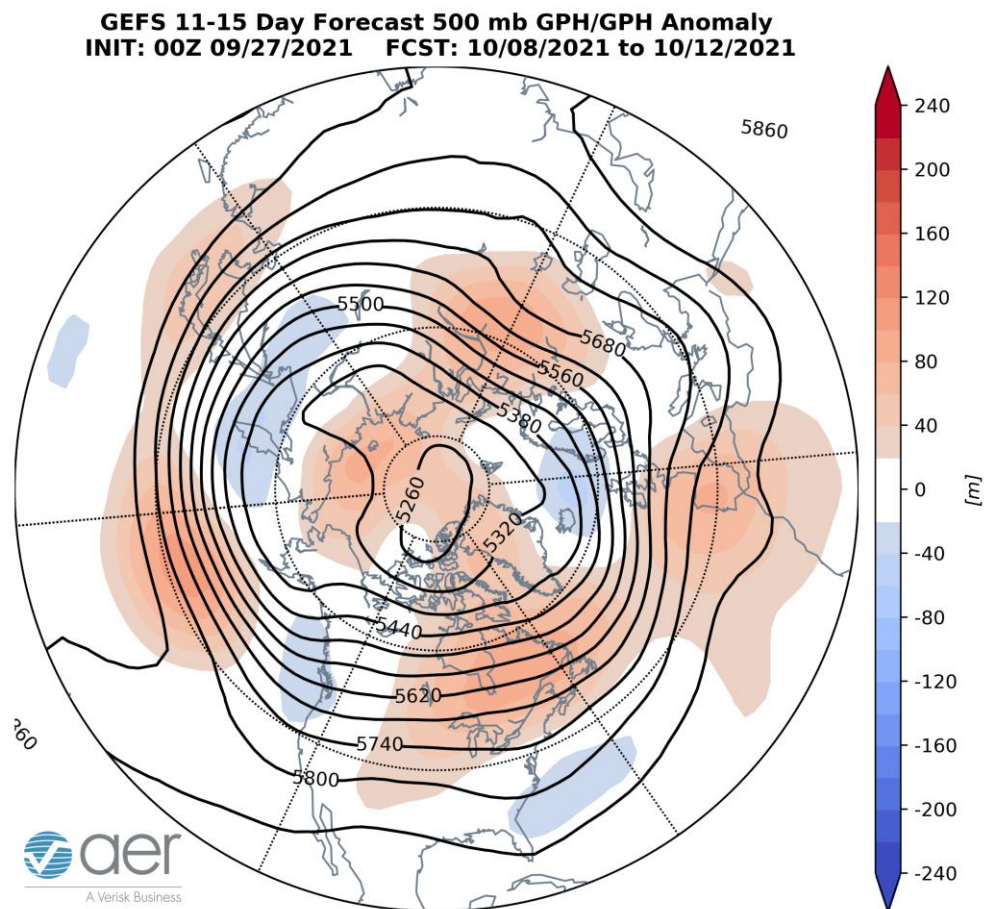


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 8 – 12 October 2021. The forecasts are from the 00z 27 September 2021 GFS ensemble.

Ridging/positive geopotential height anomalies across Greenland will continue to favor troughing/negative geopotential height anomalies across Northwestern Europe with ridging/positive geopotential height anomalies across Southern and Eastern Europe this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across much of Southern and Eastern Europe with normal to below normal temperatures across Western and Central Europe including the UK this period (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to remain anchored across Western Asia favoring troughing/negative geopotential height anomalies in Northeastern Asia this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across much of Western and Southern Asia with normal to below normal temperatures across Northeastern Asia including much of Siberia (**Figure 9**).

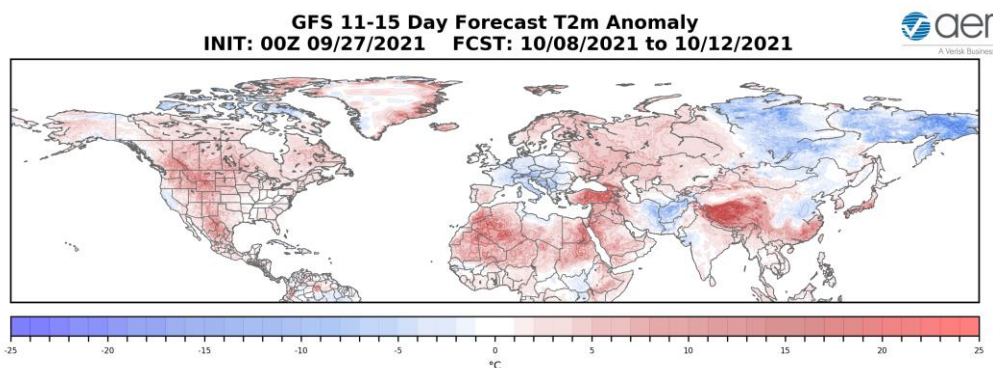


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 8 – 12 October 2021. The forecasts are from the 00z 27 September 2021 GFS ensemble.

The general pattern of troughing/negative geopotential height anomalies along the west coast of North America with downstream ridging/positive geopotential height anomalies across the US and Canada east of the Rockies this period (**Figure 8**). This pattern favors normal to above normal temperatures widespread across much of the US and Canada with normal to below normal temperatures limited to Alaska and the West Coasts of Canada and the US (**Figure 9**).

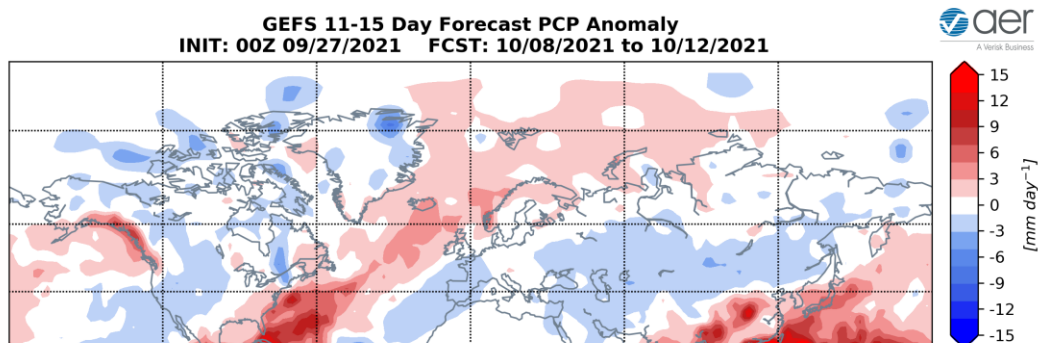


Figure 10. Forecasted precipitation anomalies (mm/day; shading) from 8 – 12 October 2021. The forecasts are from the 00z 27 September 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia except for above normal precipitation across Scandinavia and Southeast Asia (**Figure 10**). Normal to above normal precipitation is predicted for much of North America with normal to above normal precipitation in the Alaska Panhandle, the West Coast of Canada, the Eastern US and the Canadian Maritimes (**Figure 10**).

Longer Term

30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to cold/negative PCHs in the upper to mid-stratosphere with warm/positive PCHs in the lower stratosphere and all of the troposphere with the positive anomalies peaking later this week (**Figure 11**).

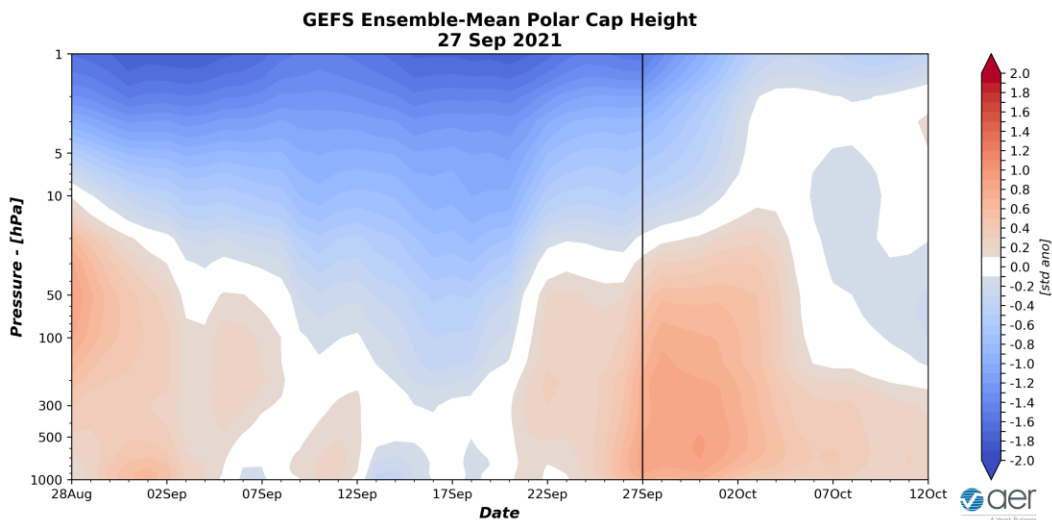


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 27 September 2021 GFS ensemble.

The overall predicted cold/negative PCHs in the upper stratosphere are predicted to weaken the next two weeks (**Figure 11**) due to upward energy transfer from the troposphere. Persistent warm/positive PCHs in the lower troposphere are consistent with the predicted neutral to negative AO this week and into next week (**Figure 1**).

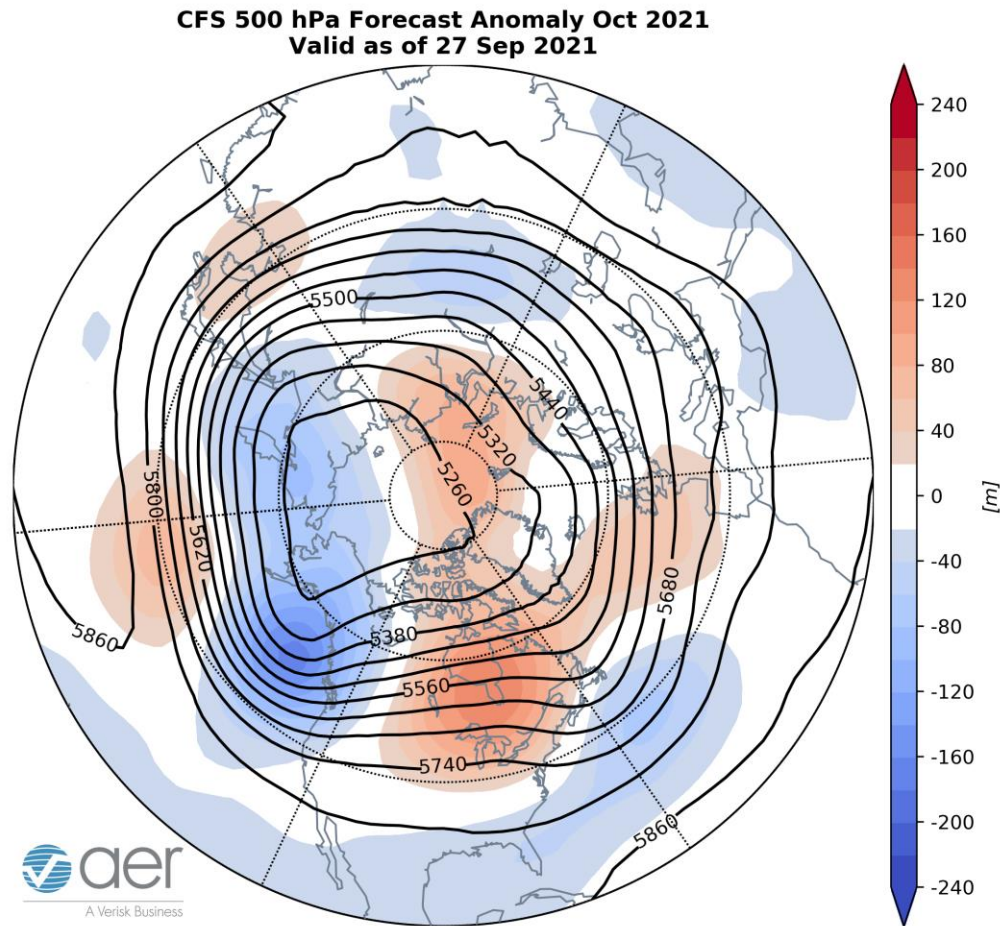


Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for October 2021. The forecasts are from the 00Z 27 September 2021 CFS.

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 from Eastern Canada across the North Atlantic side of the Arctic into the Barents-Kara Seas and the Dateline with troughing in Eastern Europe, Central Asia, Eastern Siberia, Alaska and the Gulf of Alaska into the west coast of North America (**Figure 12**). This pattern favors seasonable to relatively cool temperatures for Central and Northeastern Asia, Eastern Siberia and western North America with seasonable to relatively warm temperatures for Europe, Western and Southern Asia, Eastern Canada and much of the Eastern US (**Figure 13**).

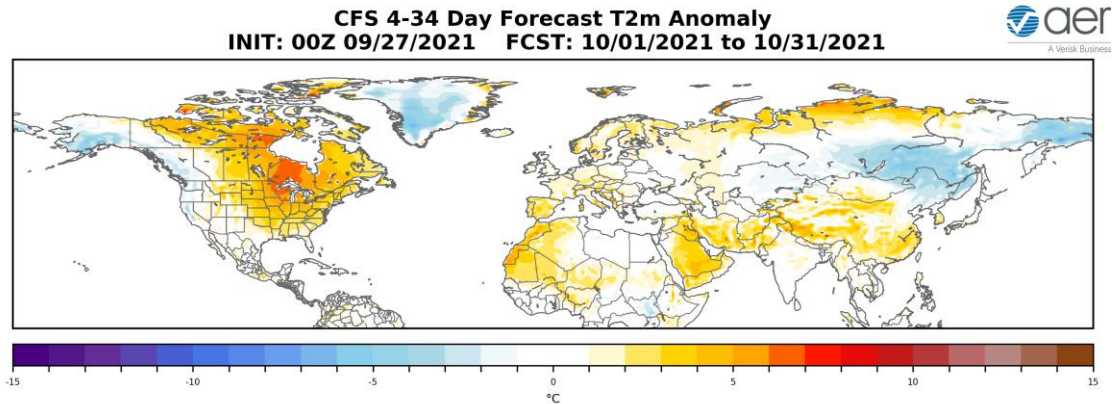


Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for October 2021. The forecasts are from the 00Z 27 September 2021 CFS.

Surface Boundary Conditions

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 14**) and La Niña conditions are expected through the fall. Observed SSTs across the NH remain well above normal especially in the Baltic Sea, Gulf of Alaska, the western North Pacific and offshore of eastern North America though below normal SSTs exist regionally especially in the Southern Hemisphere. Warm SSTs in the Gulf of Alaska may favor mid-tropospheric ridging in the region.

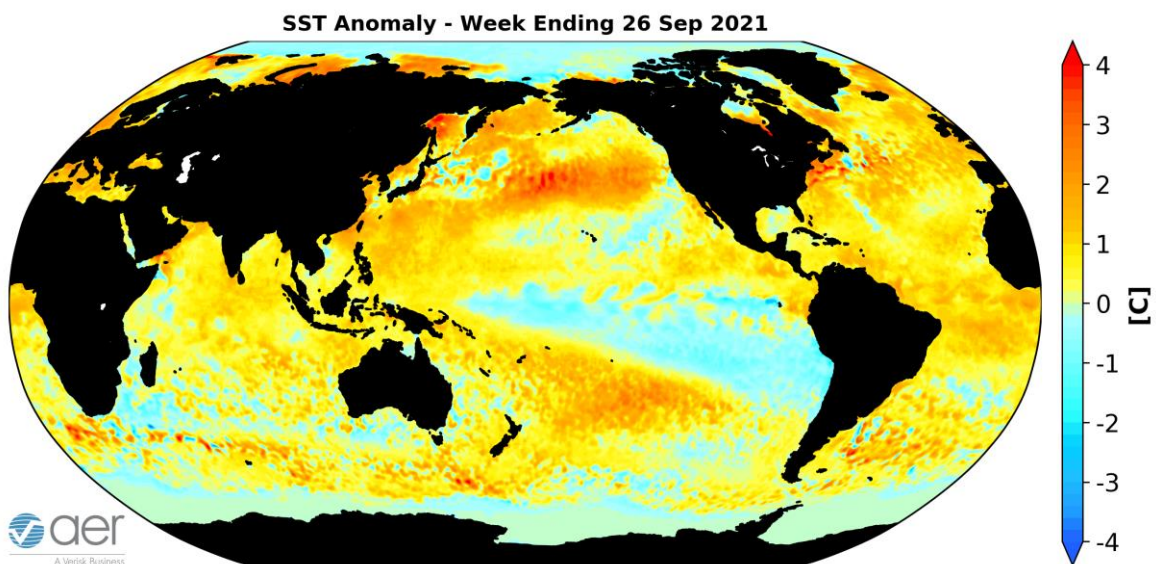


Figure 14. The latest weekly-mean global SST anomalies (ending 26 September 2021). Data from NOAA OI High-Resolution dataset.

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 15**). The forecasts are for the MJO to remain weak where no phase is favored over the next two weeks. 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.

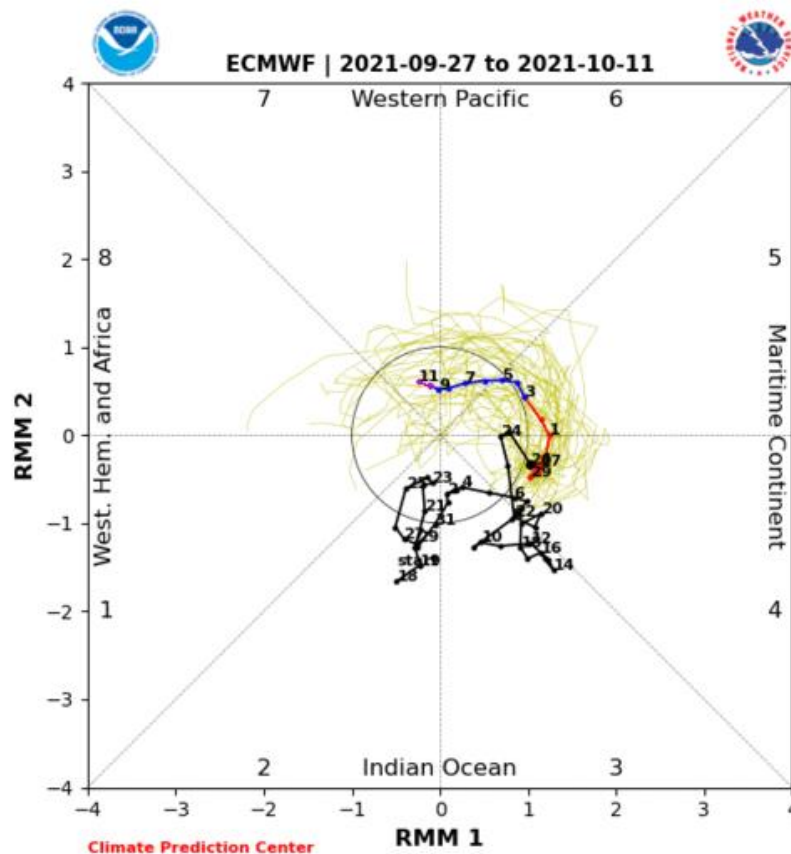


Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 27 September 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>