Arctic Oscillation and Polar Vortex Analysis and Forecasts

September 14, 2020

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) recently 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 briefly turn positive next week but otherwise straddle neutral over the next two weeks.
- The current neutral AO is reflective of mixed pressure/geopotential height anomalies across the Arctic with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently positive

with negative pressure/geopotential height anomalies spread across Greenland and Iceland; and the NAO is predicted to remain positive through the end of next week as pressure/geopotential height anomalies remain negative across Greenland before turning positive the last week of September.

- Europe including the United Kingdom (UK) are predicted be dominated by ridging/positive geopotential height anomalies with normal to above normal temperatures. A couple of exceptions are Eastern Europe next week when northerly flow will bring normal to below normal temperatures and Western Europe the last week of September when predicted troughing/negative geopotential height anomalies could bring normal to below normal temperatures.
- The predicted general pattern for Asia the next two weeks is widespread ridging/positive geopotential height anomalies with normal to above normal temperatures. A couple of exceptions are Western Asia and East Asia where troughing/negative geopotential height anomalies will result in regional normal to below normal temperatures in Central Asia.
- The general pattern for North America the next two weeks, is for ridging/positive geopotential height anomalies coupled with normal to above normal temperatures in western North America and troughing/negative geopotential height anomalies accompanied by normal to below normal temperatures in eastern North America including the Eastern United States (US). One exception will be next week when ridging/positive geopotential height anomalies coupled with normal to above normal temperatures will be more widespread.
- In the Impacts section I discuss the end of Northern Hemisphere (NH) summer in relation to the forecasts and the end of the Arctic sea ice melt season.

Impacts

As promised, I provide a comparison of the Northern Hemisphere surface temperature anomalies for the entire summer with the forecasts included in the blog on May 27, 2020 in **Figure i**. It does seem that “observed” temperature plot may have a cool bias in the Central US but otherwise seems fairly accurate across the NH. I did substitute our plot for the C3S forecast system with one downloaded from Copernicus since our plot seemed to have a cool bias and I apologize for the different projection that makes the comparison more difficult.

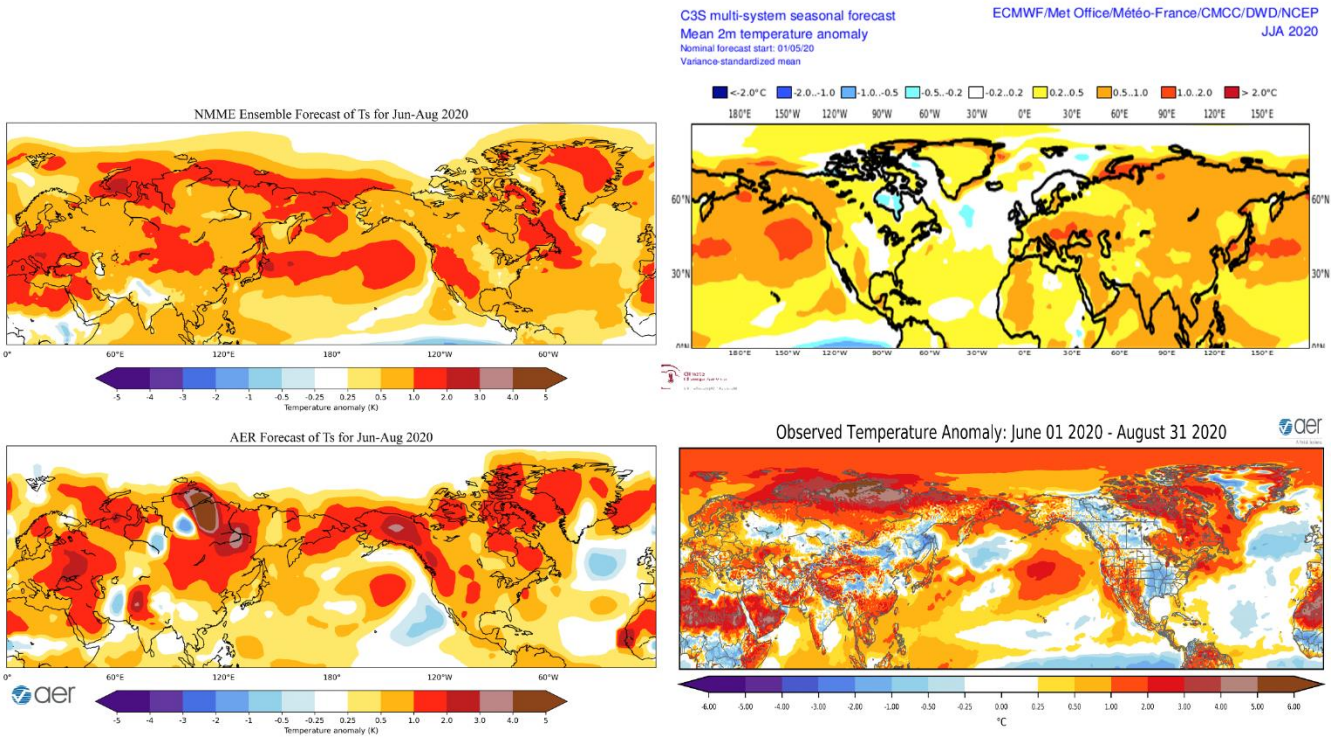

Figure i. The temperature anomaly forecast for June, July and August 2020 from the NMME ensembles (top left), the C3S ensembles (top right) and the AER model (bottom left) and observed surface temperature anomalies for June, July and August 2020 based on the GFS daily analysis (bottom right). Climatology is 1981-2010 from CFSR.

Overall all the model systems did well with the predicted widespread relatively warm temperatures. From the figure, I would argue the AER model compares favorably with the two major dynamical model ensembles from North America (North American multi-Model Ensemble or NMME; https://www.cpc.ncep.noaa.gov/products/NMME/) and Europe (ECMWF, UK Met Office and Meteo France or C3S; https://climate.copernicus.eu/charts/c3s_seasonal/). The biggest miss of the AER model was predicted temperatures too warm for Alaska. The model correctly predicted regions of more amplified warming in the Western US, Eastern Canada and the Northeastern US with more damped warm anomalies in the interior of the continent. Across Eurasia the temperature anomaly pattern was possibly even a better match to the observations, correctly predicting the largest positive departures across Siberia that extend across northern Asia over towards Scandinavia. Also correct was the west to east gradient of amplified warming across Europe and extending into the Middle East. Finally, the model did predict more amplified warming across North Africa over towards the Arabian Peninsula. I will repeat what I wrote last week, I am really surprised by the magnitude of the warm anomalies across the Sahara, an already very hot region. Finally, something that I would never have expected, the AER model even did a good job predicting the sea surface temperature pattern across the extratropics.

Of the two dynamical model systems, it does appear that the North American suite of models outperformed the European suite of models. The C3S system missed the large warm anomalies in Siberia and in Eastern Canada. The NMME also correctly limited the more amplified warm anomalies to the Western US and did not extend them north into Alaska as the AER model did. However, the NMME probably did the poorest with Europe incorrectly focusing the heat across Western Europe.

The one region warm anomaly missed by all three forecasts was in the Central Arctic. The warm summer in the Arctic was a departure from recent summers where temperatures where close to normal. The warm Arctic summer was related to high pressure in the region and a negative AO, in contrast to recent summers that were dominated by low pressure in the Arctic. The warm Arctic summer has resulted in the second lowest sea ice extent ever measured in the Arctic, just behind 2012.

The melt season is just about over in the Arctic and the weather pattern is looking more conducive to preserving and even building sea ice, especially next week. From the chart on the NSIDC website of Arctic sea ice extent, it looks like it is forming a bottom just missing a new record minimum (see **Figure ii**). When so much ice missing in the Arctic basin relative to climatology, large amounts of heat will be released from the ocean to the atmosphere in the coming months as the atmosphere cools faster than the ocean. Though still a matter of debate, large release of heat in the Arctic region could promote high pressure/blocking in the Arctic region. So far there are no signs of high latitude blocking but it is still very early.

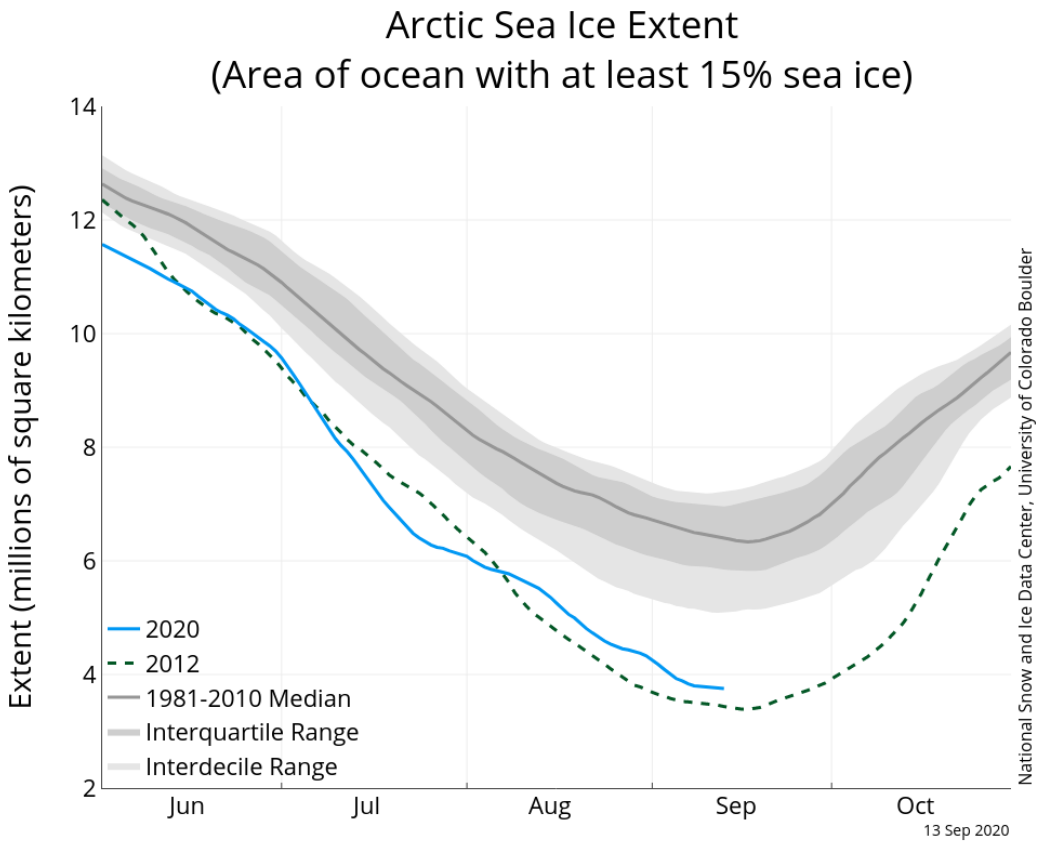

Figure ii. Observed Arctic sea ice extent for the current year and 2012 (https://nsidc.org/arcticseaicenews/).

Soon will commence the snowfall season across the NH. Both Siberia and Canada have experienced a fast start to the snowfall season in recent years. But I do wonder if this fall might be different, at least across Siberia. It has probably been the warmest year on record across Siberia so far and there are still no signs of the well above normal temperatures dissipating anytime soon.

1-5 day

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

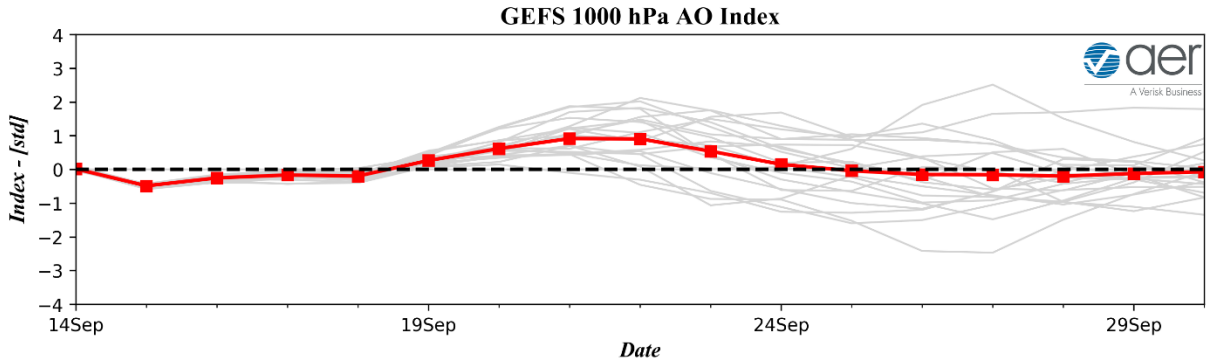

Figure 1. The predicted daily-mean AO at 1000 hPa from the 00Z 14 September 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies will dominate much of Europe with the exception of troughing/negative geopotential height anomalies with northerly flow across northern Scandinavia (**Figure 2**) resulting in normal to above normal temperatures **f**or much of Europe including the UK with normal to below normal temperatures for northern Scandinavia (**Figure 3**). Across Asia this week, ridging/positive geopotential height anomalies will dominate much of Asia with the exception of regional troughing/negative geopotential height anomalies in Western and East Asia (**Figure 2**). This pattern favors widespread normal to above normal temperatures for much of Asia with the exceptions of normal to below normal temperatures in Western Asia and Eastern China **(Figure 3**).

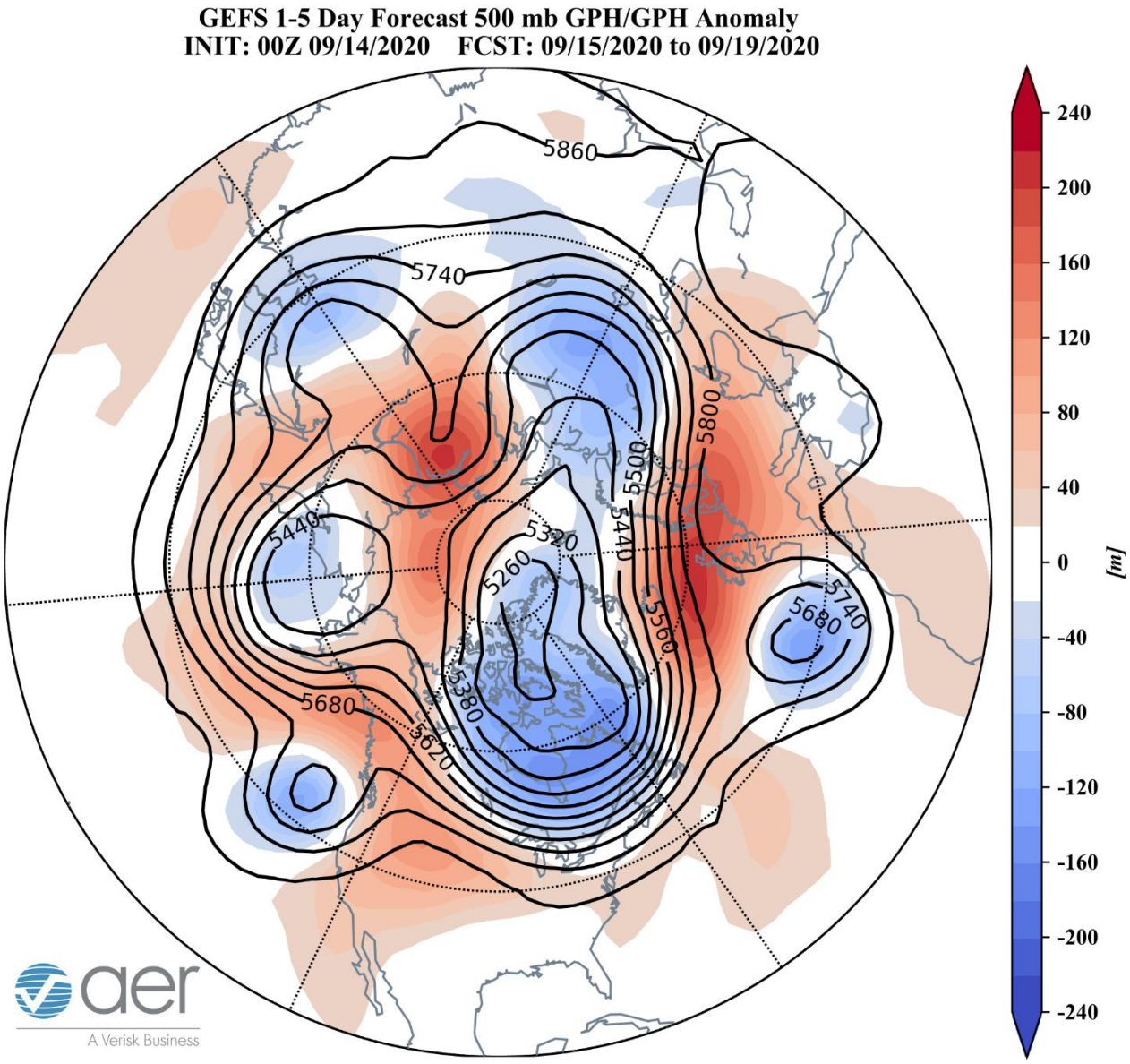

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 15 – 19 September 2020. The forecasts are from the 00z 14 September 2020 GFS ensemble.

This week predicted ridging/positive geopotential height anomalies in western North America will force deepening troughing/negative geopotential height anomalies in eastern North America **(Figure 2). T**his pattern is predicted to bring normal to above normal temperatures across Alaska, Western Canada and the Western US with normal to below normal temperatures for much of Central and Eastern Canada and the Eastern US with the exception of along the US Gulf Coast **(Figure 3).**

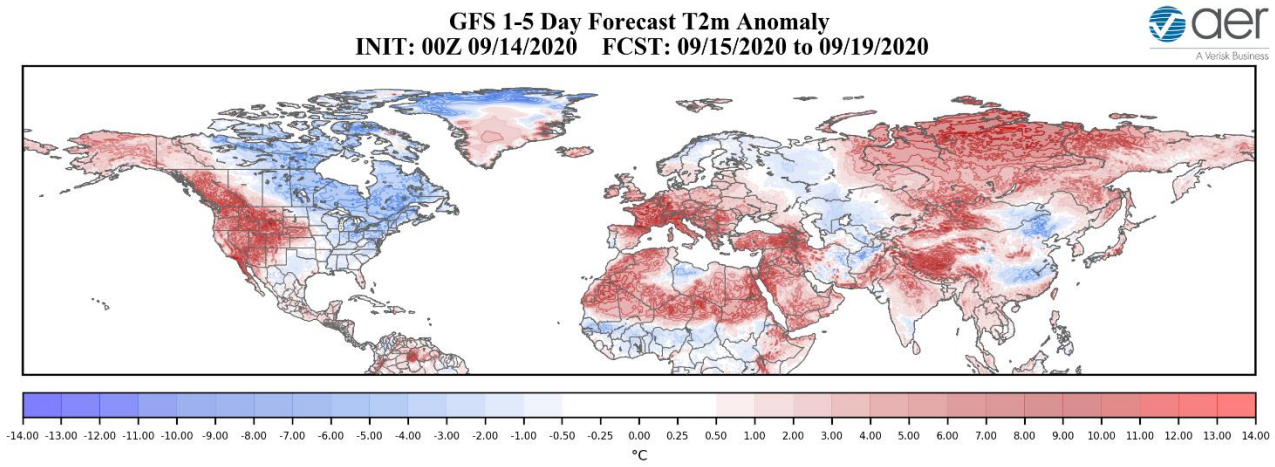

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 15 – 19 September 2020. The forecast is from the 00Z 14 September 2020 GFS ensemble.

Below normal precipitation is predicted for much of Europe and Asia with the exceptions of above normal precipitation in Spain, Scandinavia, Southern and East Asia (**Figure 4**). Below normal precipitation is predicted for much of North America with above normal precipitation for western Alaska, Northeastern Canada and along the eastern Gulf of Mexico related to hurricane Sally (**Figure 4**).

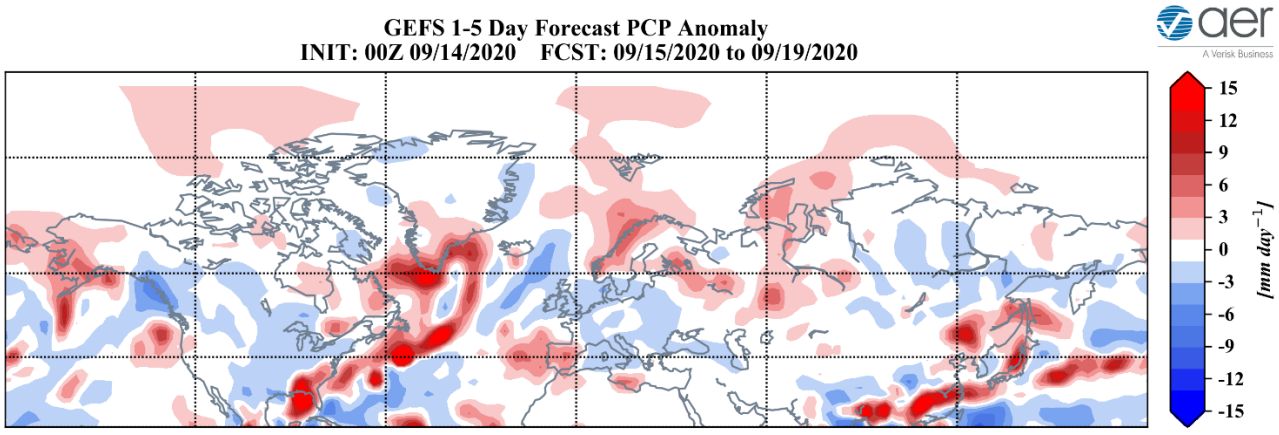

Figure 4. Forecasted precipitation anomalies (mm/day; shading) from 15 – 19 September 2020. The forecast is from the 00Z 14 September 2020 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to briefly turn positive this week **(Figure 1**) with mostly negative geopotential height anomalies across the Central and North Atlantic side of the Arctic

and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with negative geopotential height anomalies predicted across Greenland (**Figure 5**), the NAO is predicted to remain positive.

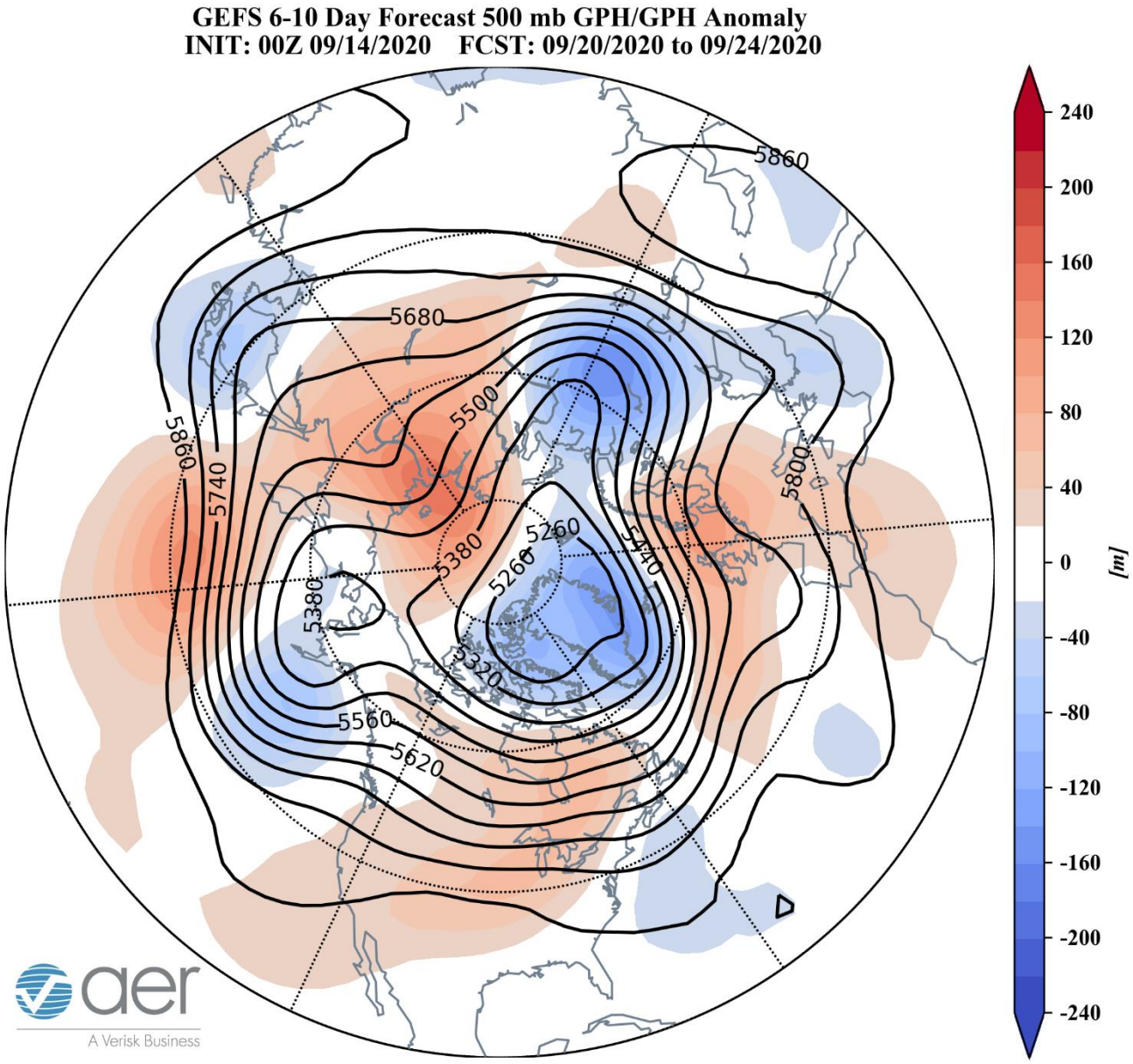

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 20 – 24 September 2020. The forecasts are from the 00z 14 September 2020 GFS ensemble.

Once again ridging/positive geopotential height anomalies are predicted to dominate Europe (**Figures 5).** This pattern favors normal to above normal temperatures across

Western and Central Europe including the UK, however northerly flow between European ridging and troughing/negative geopotential height anomalies in Western Asia will usher normal to below normal temperatures across Eastern Europe (**Figure 6**). Ridging/positive geopotential height anomalies are predicted to dominate Central Asia bookended by troughing/negative geopotential height anomalies in Western and East Asia this period (**Figure 5**). This is predicted to yield widespread normal to above normal temperatures in Central and Northern Asia with normal to below temperatures In Western Asia and Eastern China **(Figure 6**).

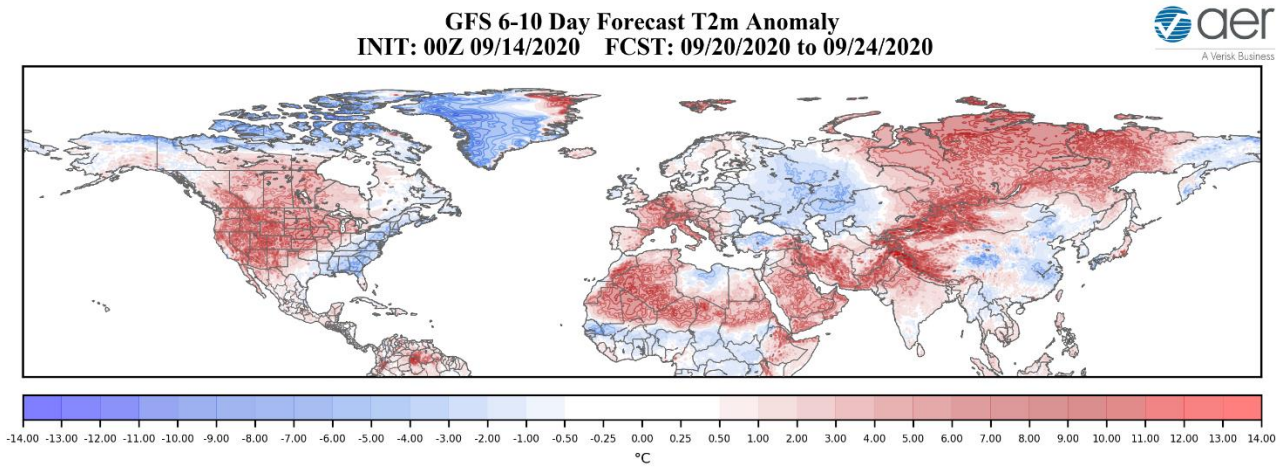

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 20 – 24 September 2020. The forecasts are from the 00Z 14 September 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to spread across much of North America with the exception of troughing/negative geopotential height anomalies in Alaska, the West Coast of Canada and the US East Coast this period **(Figure 5).** This pattern is predicted to bring widespread normal to above normal temperatures across Southern Alaska, much of Canada, the Western and Central US with normal to below normal temperatures for Northern Alaska, Northwestern Canada and the US East Coast **(Figure 6).**

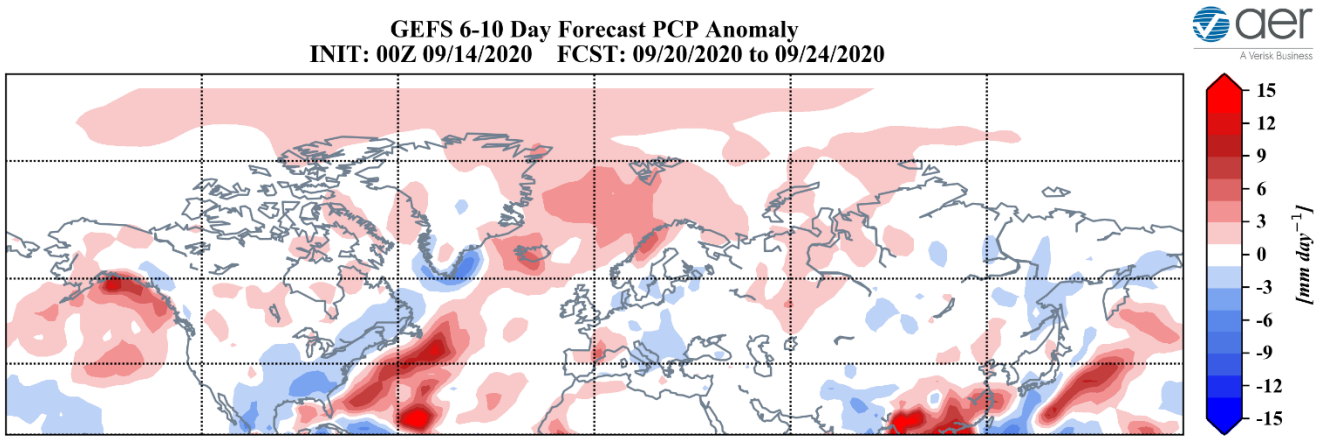

Figure 7. Forecasted precipitation anomalies (mm/day; shading) from 20 – 24 September 2020. The forecasts are from the 00Z 14 September 2020 GFS ensemble.

Normal to below normal precipitation is predicted for much of Eurasia with the exceptions of above normal precipitation across Spain, Norway and Southeast Asia (**Figure 7**). Normal to below normal precipitation is predicted for much of North America with above normal precipitation predicted for the Panhandle of Alaska (**Figure 7**).

11-15 day

With mostly weak and mixed geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO is predicted to return to neutral this period (**Figure 1**). With weak positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is likely to turn negative.

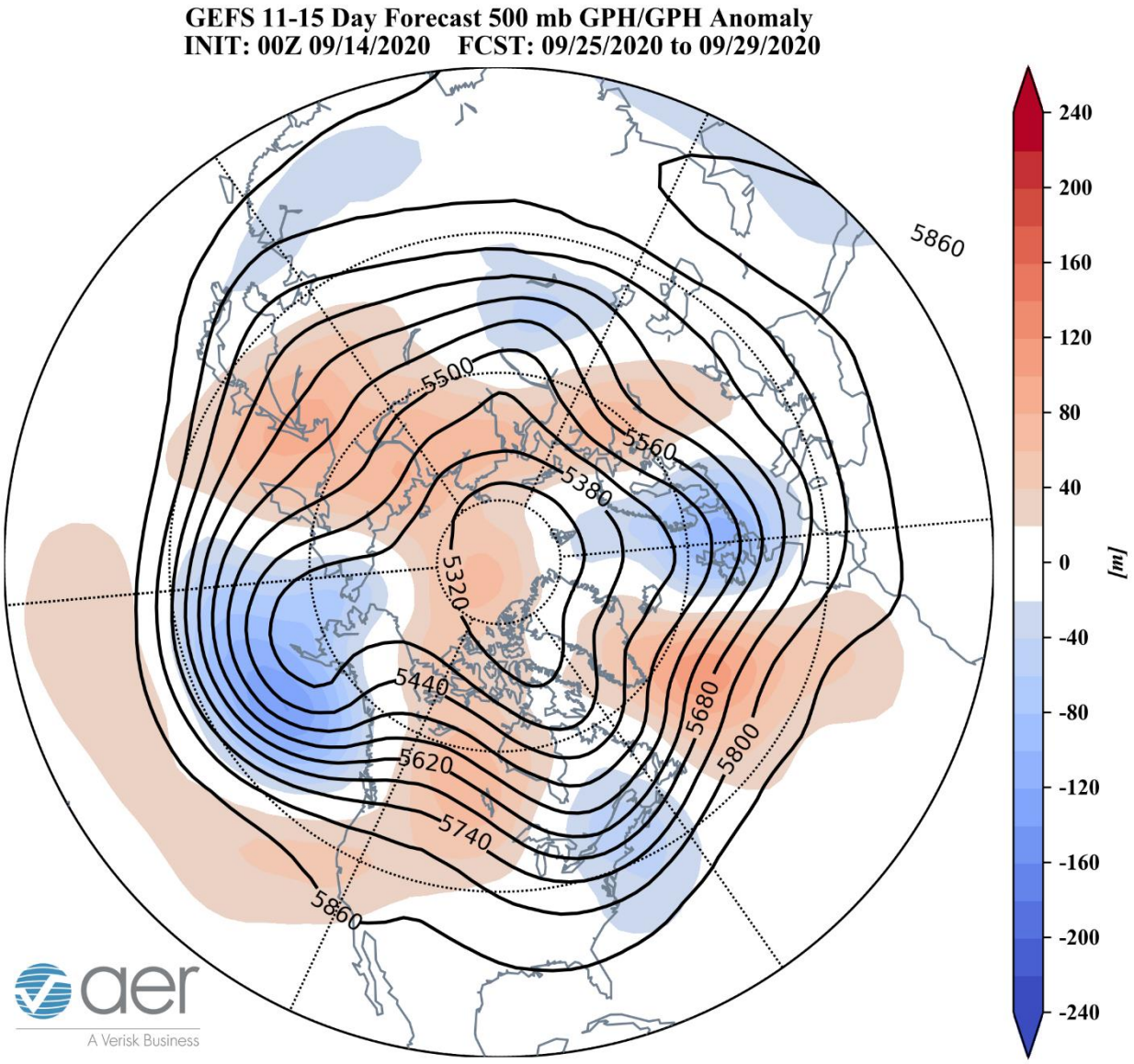

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 25 – 29 September 2020. The forecasts are from the 00z 14 September 2020 GFS ensemble.

Weak troughing/negative geopotential height anomalies in the eastern North Atlantic are predicted to slide into Western Europe forcing ridging/positive geopotential height anomalies across into Central and Eastern Europe this period (**Figures 8**). The forecast is for normal to above normal temperatures across most of Europe with the exception of normal to below normal temperatures across far Western Europe including the UK this period (**Figures 9**). For Asia, the general predicted pattern is for ridging/positive geopotential height anomalies especially Northern Asia with only weak troughing/negative geopotential height anomalies in Central and Southeast Asia this

period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across Asia with only regional normal to below normal temperatures centered on Kazakhstan and Southeast Asia (**Figure 9**).

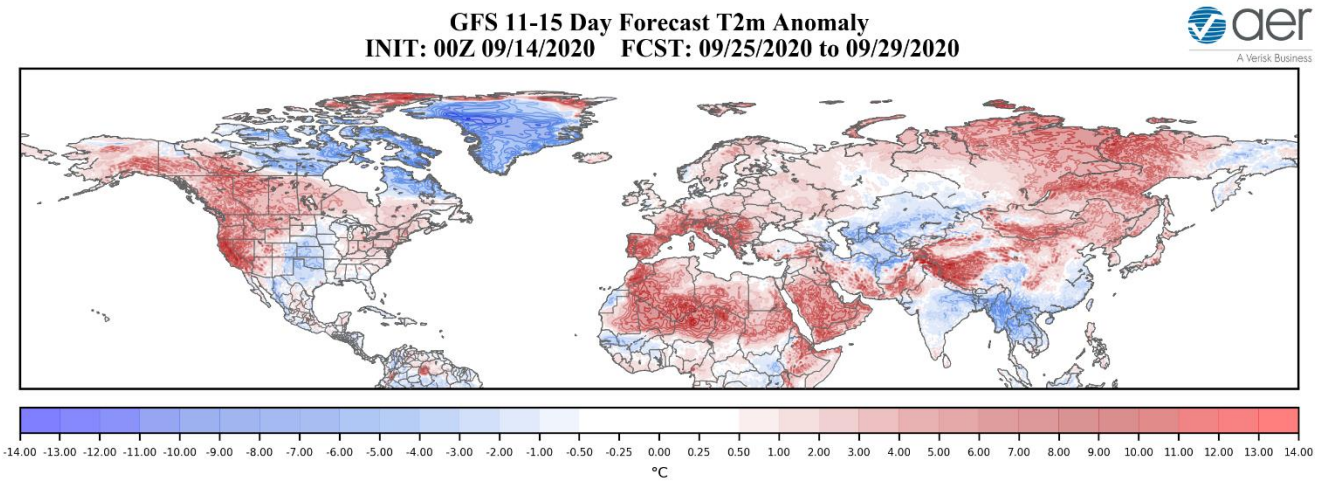

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 25 – 29 September 2020. The forecasts are from the 00z 14 September 2020 GFS ensemble.

Troughing/negative geopotential height anomalies are predicted to deepen in the Aleutians forcing ridging/positive geopotential height anomalies downstream across western North America with more troughing/negative geopotential height anomalies in the Northeastern US and the Canadian Maritimes this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across Alaska and much of Western Canada and the Western US with normal to below normal temperatures for the Northeastern US and Southeast Canada (**Figure 9**).

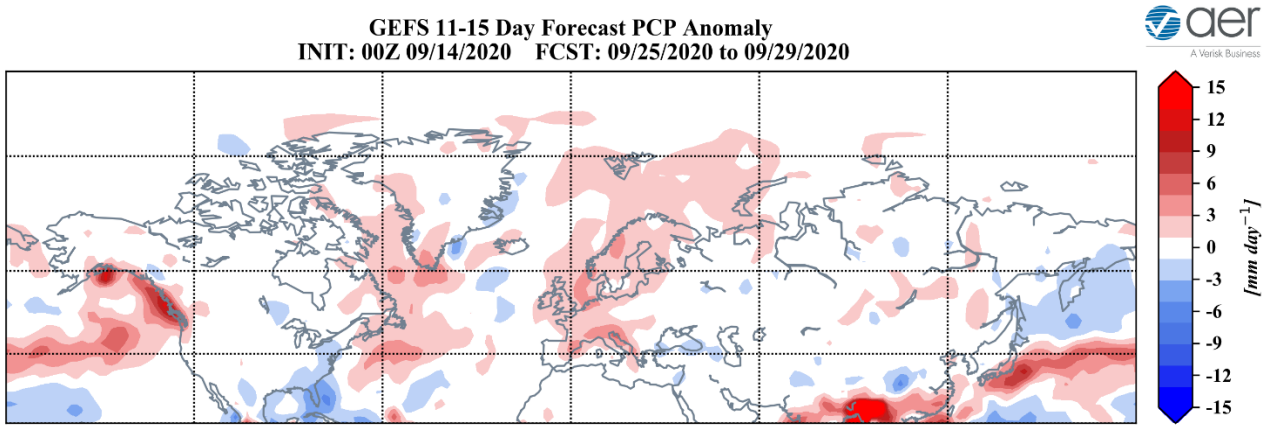

Figure 10. Forecasted precipitation anomalies (mm/day; shading) from 25 – 29 September 2020. The forecasts are from the 00z 14 Spetember 2020 GFS ensemble.

Normal to below normal precipitation is predicted for much of Eurasia except for normal to above normal precipitation for Western Europe and parts of Southern and Far East Asia (**Figure 10**). Normal to below normal precipitation is predicted for much of North America except for above normal precipitation for southern Alaska, the West Coast of Canada and the Canadian Maritimes (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows near normal PCHs in the troposphere but normal to below normal PCHs in the stratosphere (**Figure 11**). PCHs are predicted to cool further in the stratosphere and the cold stratospheric PCHs could couple with the surface for a brief period next week (**Figure 11**).

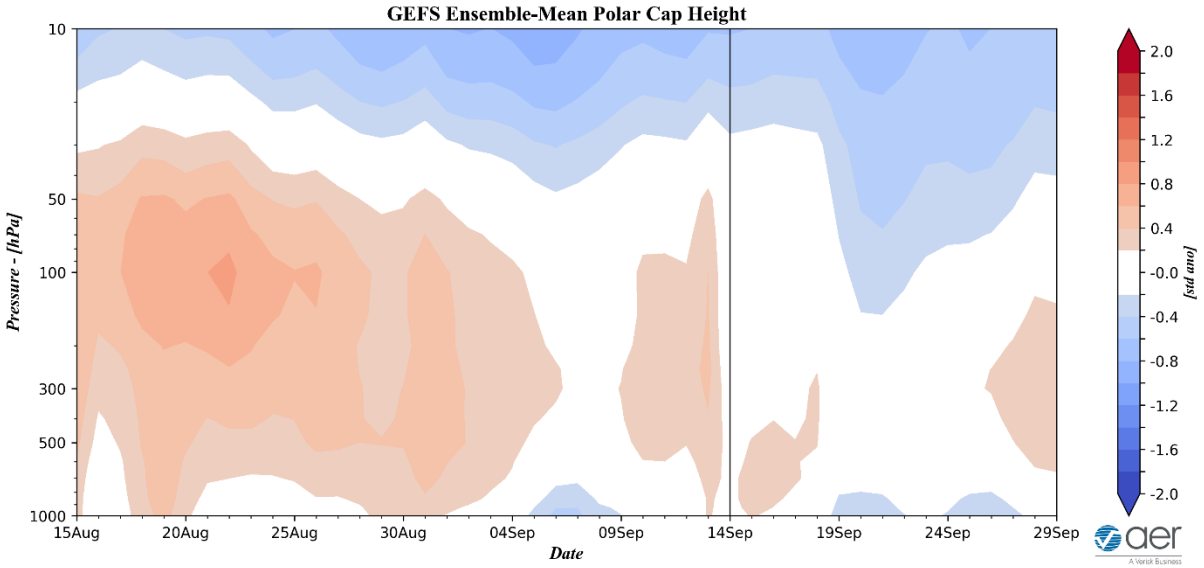

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 14 September 2020 GFS ensemble.

The current near normal PCHs in the troposphere are consistent with the predicted neutral AO this week (**Figure 1**). However, the forecast is for the PCHs to turn briefly negative/cold consistent with a brief jump of the AO into positive territory. Now that the stratospheric polar vortex has formed, coupling with the surface is possible. The PCHs plot suggests that the jump in the AO is related to a brief coupling between the polar vortex and the surface.

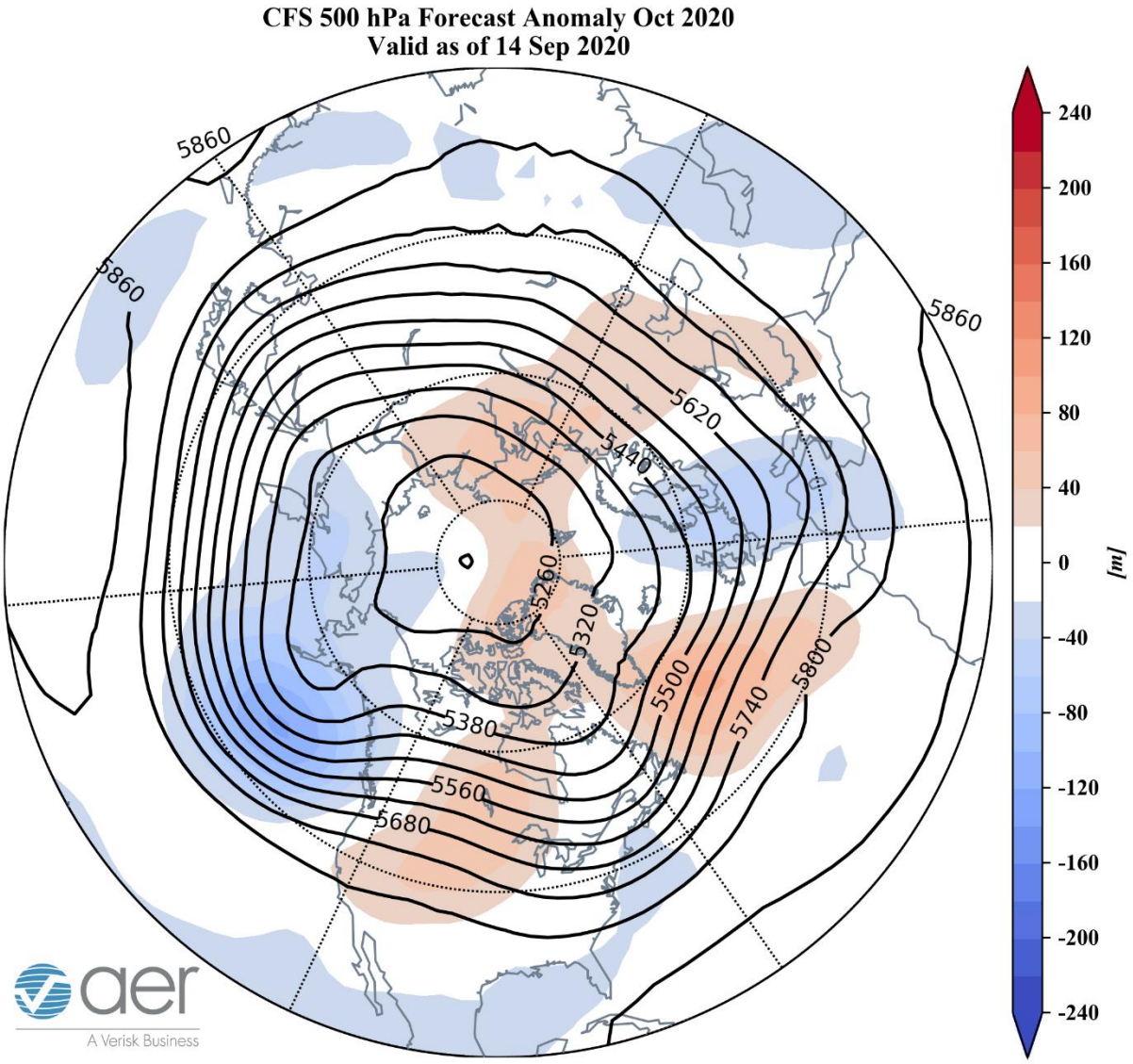

Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for October 2020. The forecasts are from the 00Z 14 September 2020 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and the surface temperatures (F**igure 13**) forecast for October from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging south of Greenland and Iceland, Western Asia, Central Canada and the Western US with troughing in Western Europe, East Asia, Alaska, the Gulf of Alaska, the Canadian West Coast and the US East Coast (**Figure 12**). This pattern favors relatively warm temperatures for Scandinavia, Northern and Western Asia and western North America with seasonable to relatively cool temperatures for Western Europe, Southern and East Asia and the US East Coast **(Figure 13).**

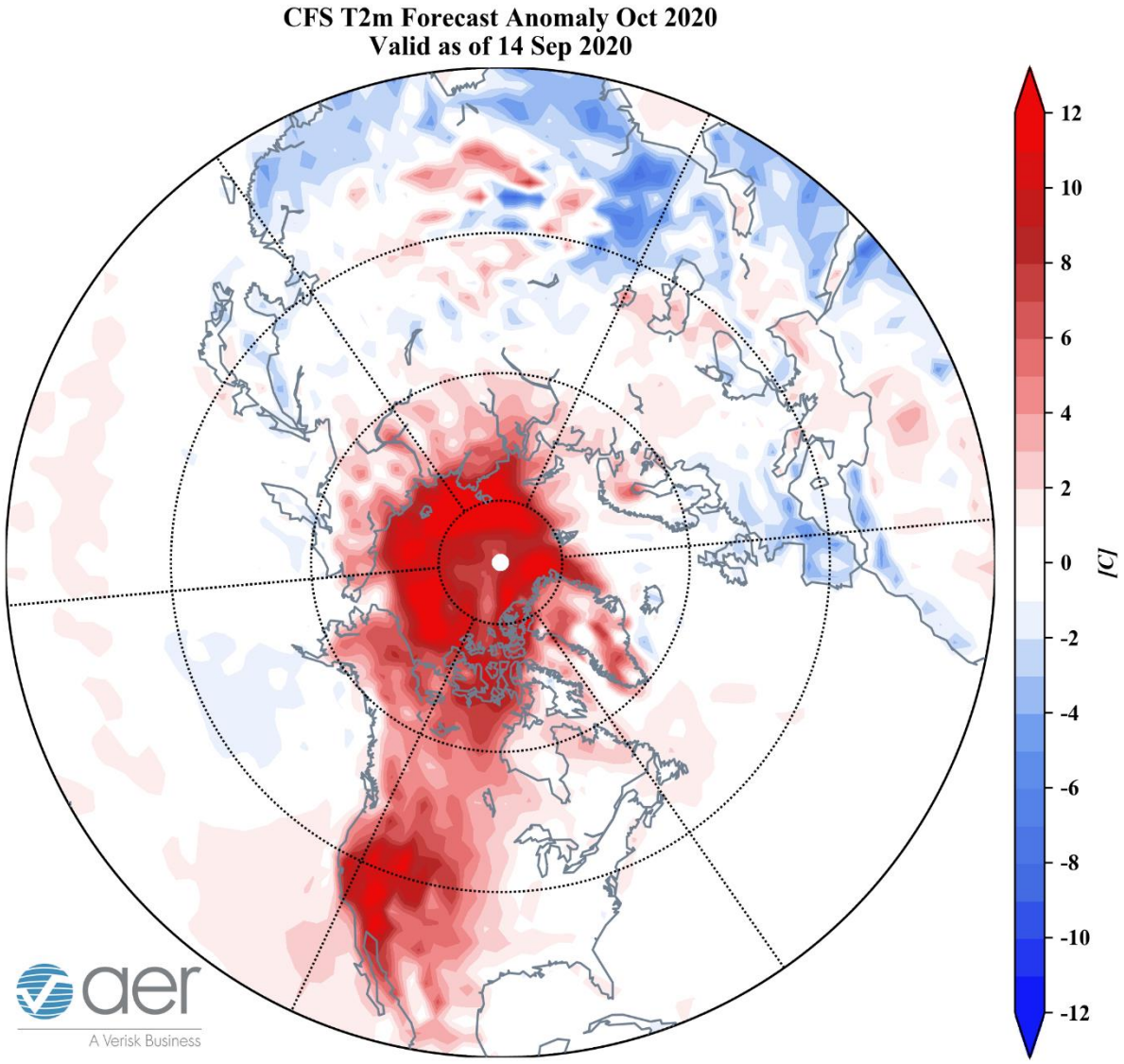

Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for October 2020. The forecasts are from the 00Z 14 September 2020 CFS.

Surface Boundary Conditions

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies continue to cool slowly, and we have now entered weak La Niña conditions (**Figure 14**) and La Niña is expected to persist through the fall. Observed SSTs across the NH remain well above normal especially near Alaska and in the Gulf of Alaska, the western North Pacific and offshore of eastern North America though below normal SSTs exist regionally especially in the

Southern Hemisphere and south of Iceland. Warm SSTs in the Gulf of Alaska may favor mid-tropospheric ridging in the region.

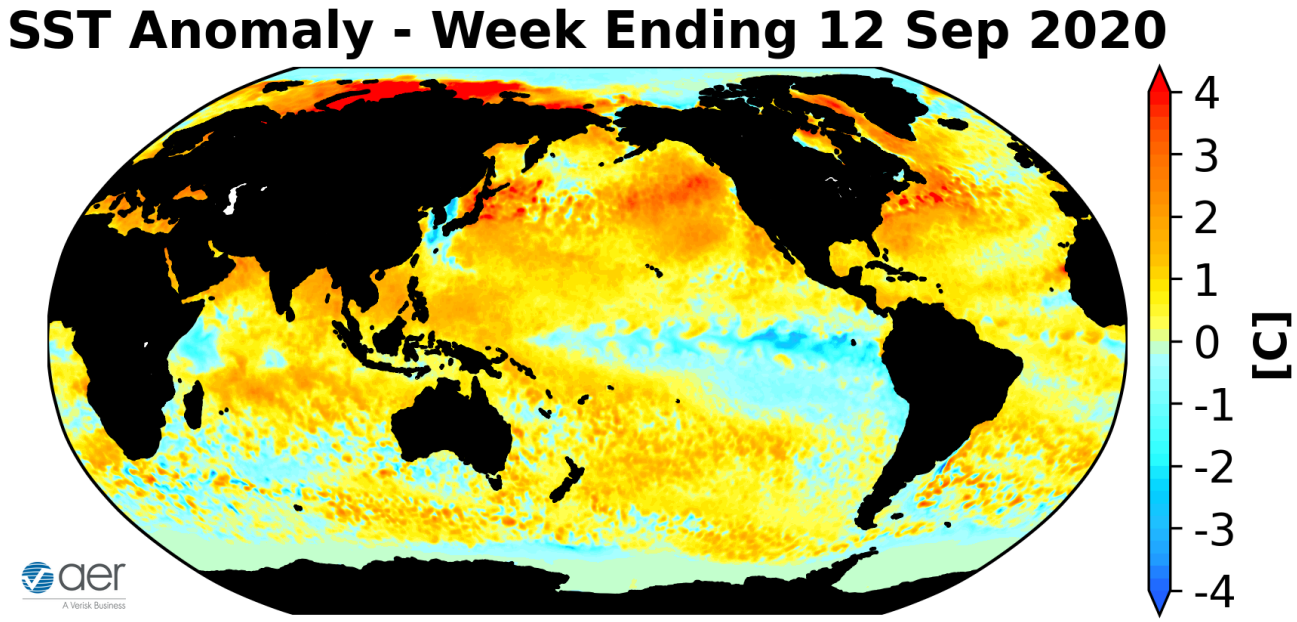

Figure 14. The latest weekly-mean global SST anomalies (ending 12 September 2020). Data from NOAA OI High-Resolution dataset.

Currently no phase is favored for the Madden Julian Oscillation (MJO) (**Figure 15**). The forecasts are for the MJO to briefly emerge into phase four and then weaken again where no phase is favored. MJO phase four in the short-term favor troughing in the Western US and much of Canada with ridging across the Eastern US. The MJO does not seem to be contributing to the short-term pattern across North America.

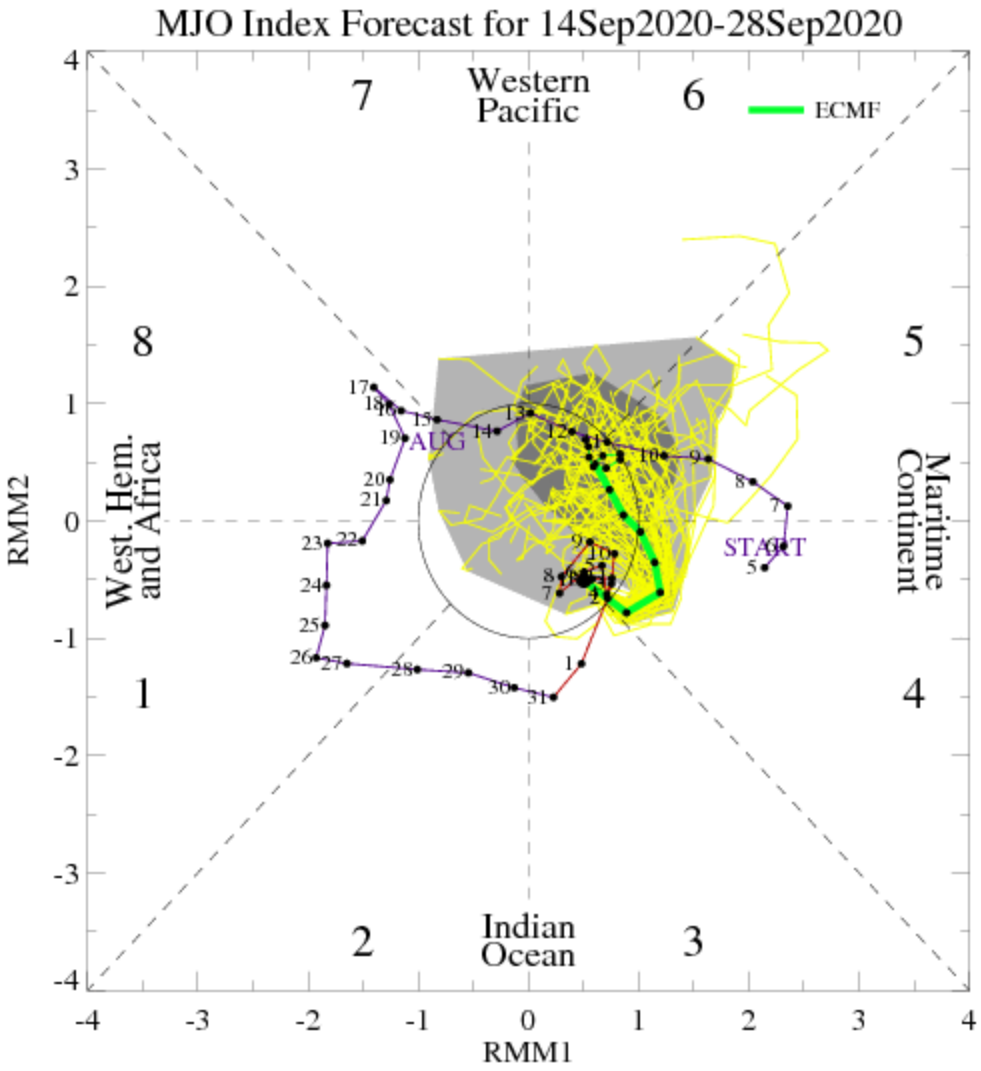

Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 14 September 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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