Arctic Oscillation and Polar Vortex Analysis and Forecasts

September 29, 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 turn negative this week and continue into next week.
- 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 neutral with weak pressure/geopotential height anomalies spread across Greenland and Iceland; and the NAO is predicted to turn negative this week and continue into next week as pressure/geopotential height anomalies turn positive across Greenland the next two weeks.

- The general pattern for Europe the next two weeks is ridging/positive geopotential height anomalies centered across Eastern Europe and extending across Scandinavia and eventually across Greenland that will force troughing/negative geopotential height anomalies in Western Europe. This pattern favors normal to above normal temperatures across Eastern Europe and Scandinavia with normal to below normal temperatures across Western Europe including the United Kingdom (UK).
- The predicted general pattern for Asia the next two weeks is strengthening ridging/positive geopotential height anomalies in Western Asia that forces deepening troughing/negative geopotential height anomalies in Central Asia with more ridging/positive geopotential height anomalies in Eastern Siberia. This pattern favors normal to above normal temperatures in Western and Southern Asia and Eastern Siberia normal to below normal temperatures in Central and East Asia especially Western and Central Siberia.
- 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 forcing troughing/negative geopotential height anomalies accompanied by normal to below normal temperatures in eastern North America including the Eastern United States (US).
- In the Impacts section I do one last wrap up of the Northern Hemisphere (NH) summer temperatures and I then turn my attention to winter.

Impacts

I just thought to begin today's discussion tying up some loose ends in regard to the observed temperatures this past summer. In the past two blogs, I posted the observed summer surface temperature anomalies for the NH using the GFS analysis. In the past I have used NCEP/NCAR reanalysis for observed temperatures, which I include in **Figure i**. It has a clear error and cold bias in Asia. The Siberian heat this summer made the international news so to show below normal temperatures seemed strange. However, in the NCEO/NCAR reanalysis, the US temperatures exhibit normal to above normal temperatures throughout the US. This seems more accurate than the GFS analysis when compared with station data (look at the two most recent blog posts). I do consider reanalysis products as "observations" but the comparison of the two temperature plots show that assumption to have limits.

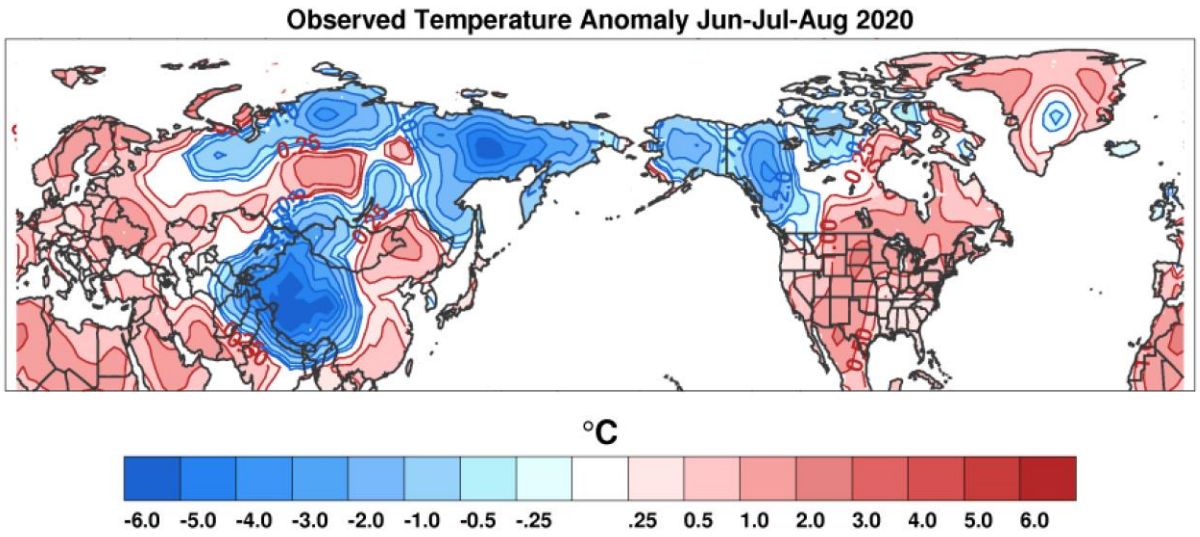

Figure i. The observed surface temperature anomalies for June, July and August 2020 based on the NCEP/NCAR reanalysis. Climatology is 1981-2010.

If one of the most notable features of this past summer was Siberian heat, based on today's weather graphics included in the blog, then with a changing season comes a changing weather pattern across Siberia. An impressive ridge of high pressure or block currently centered near the Urals is expected to extend north towards the North Pole and displace the tropospheric polar vortex (TPV) into Siberia. The dropping down of the TPV from near the North Pole into Siberia should bring an extended period of cold and snow to Siberia. At least in my opinion, an extensive snowfall across Siberia in the month of October has implications for NH winter weather with extensive snow cover favoring a relatively cold winter across the NH mid-latitude continents. This pattern for early October does seem to favor more extensive snow cover rather than a sparse snow cover. But it is early, and the snow cover can have dramatic swings in the fall.

The current blocking in the Urals that is predicted to expand towards Scandinavia and then eventually Greenland is impressive. And if this pattern is still around in 4-6 weeks and beyond, I would have a hard time containing myself in the blog and on Twitter. This pattern is not only favorable for active winter weather in Western Europe and the Eastern US, but I believe is a strong precursor to weakening of the stratospheric polar vortex (SPV). But it is very early in the season and how much impact it ultimately has on the winter season is an open question. To use a baseball analogy, you would rather see your team get hot in September and October than May. I doubt you will be making plans to attend the World Series just because your team had a strong May. Still you would rather see your team do better than worse in May and a strong May could create enough momentum to lead to a strong overall season. Same with this pattern, it is not going to have an impact on our winter weather by itself, but the pattern could create momentum that eventually has a strong influence on the winter. As a cautionary tale, this pattern of strong blocking in early October reminds me of the fall of 2016. That October Eurasian

snow cover was also quite extensive. Strong blocking resulted in a relatively weak SPV in October and November. But the SPV disruptions fell short of major sudden stratospheric warming (SSW) criteria and eventually the SPV recovered and strengthened in December and into January resulting in overall mild weather across the NH for the first half of the winter (see **Figure ii** and https://www.aer.com/science-research/climate-weather/winter2017/). There was also very strong Ural blocking in October 1987 (see **Figure ii**) that did force one of the earliest major SSW in the observational record in early December, but it seemed to have limited impact on the troposphere for much of the winter. So early impressive blocking and a weak early SPV does not necessarily translate into an active winter season. In both winters the quasi-biennial oscillation was westerly, which may have played a role.

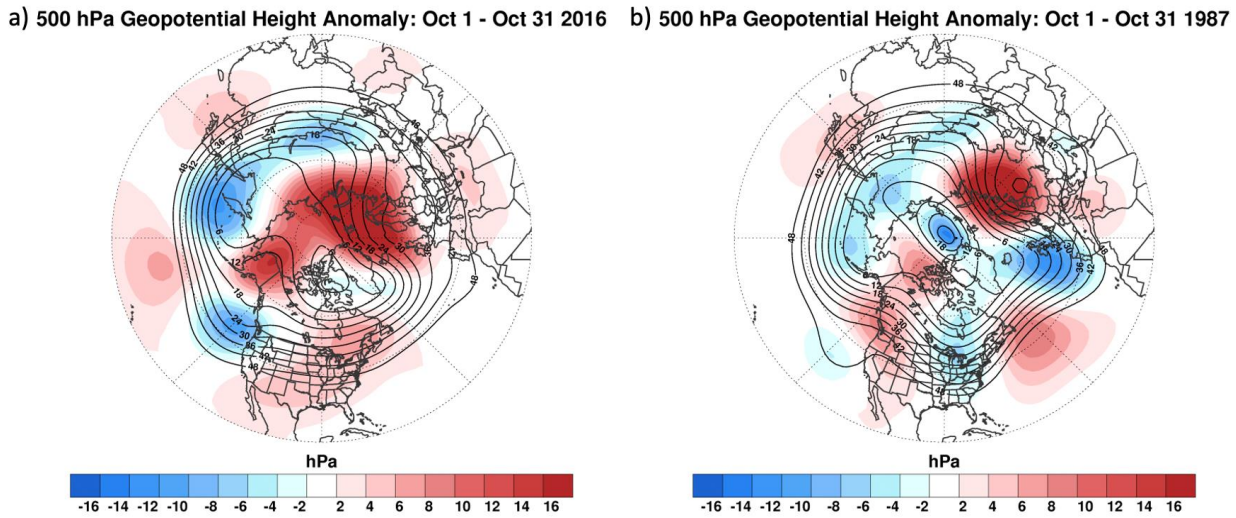

Figure i. The observed 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from **a**) 1 – 31 October 2016 and **b**) 1 – 31 October 1987.

The sea ice minimum is in the record books as the second lowest on record. I believe that the low sea ice will both favor a rapid advance of snow cover both across Eurasia and North America and high latitude blocking in the coming months. Typically in early October, the blocking is on the North Pacific side of the Arctic and the rapid increase in snow cover is in Eastern Siberia. So far, this fall is a little different with early blocking in the North Atlantic side of the Arctic and the predicted rapid advance in snow cover more in Western and Central Siberia. I do think key will be how long the blocking can persist in the Urals/Scandinavia region in the coming weeks. The blocking will most likely need to persist into much of November to have more than a short-term impact. If the blocking does become centered near Greenland that can make for some interesting weather in the Eastern US and Western Europe in the short term but would likely have less impact on the SPV.

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 weak geopotential height anomalies across Greenland (**Figure 2**), the NAO is predicted to be neutral this week.

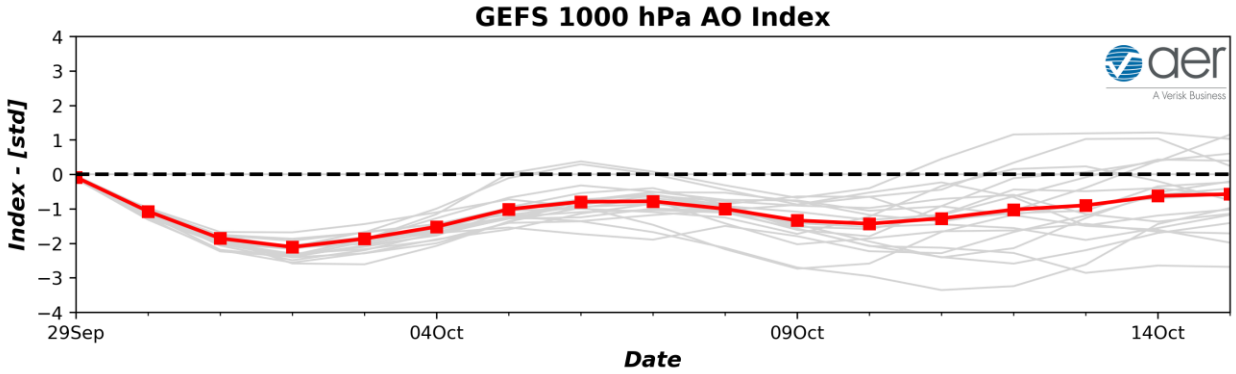

Figure 1. The predicted daily-mean AO at 1000 hPa from the 00Z 29 September 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies will dominate much of Western Asia, Eastern Europe and Scandinavia will help to lock in troughing/negative geopotential height anomalies across Western Europe (**Figure 2**) resulting in normal to above normal temperatures for much of Eastern Europe and Scandinavia with normal to below normal temperatures for Western Europe including the UK (**Figure 3**). Across Asia this week, strengthening ridging/positive geopotential height anomalies centered across Western Asia will contribute to deepening troughing/negative geopotential height anomalies in Central and East Asia with more ridging/positive geopotential height anomalies in Eastern Siberia (**Figure 2**). This pattern favors widespread normal to above normal temperatures for much of Western Asia and Eastern Siberia with normal to below normal temperatures in Central and East Asia **(Figure 3**).

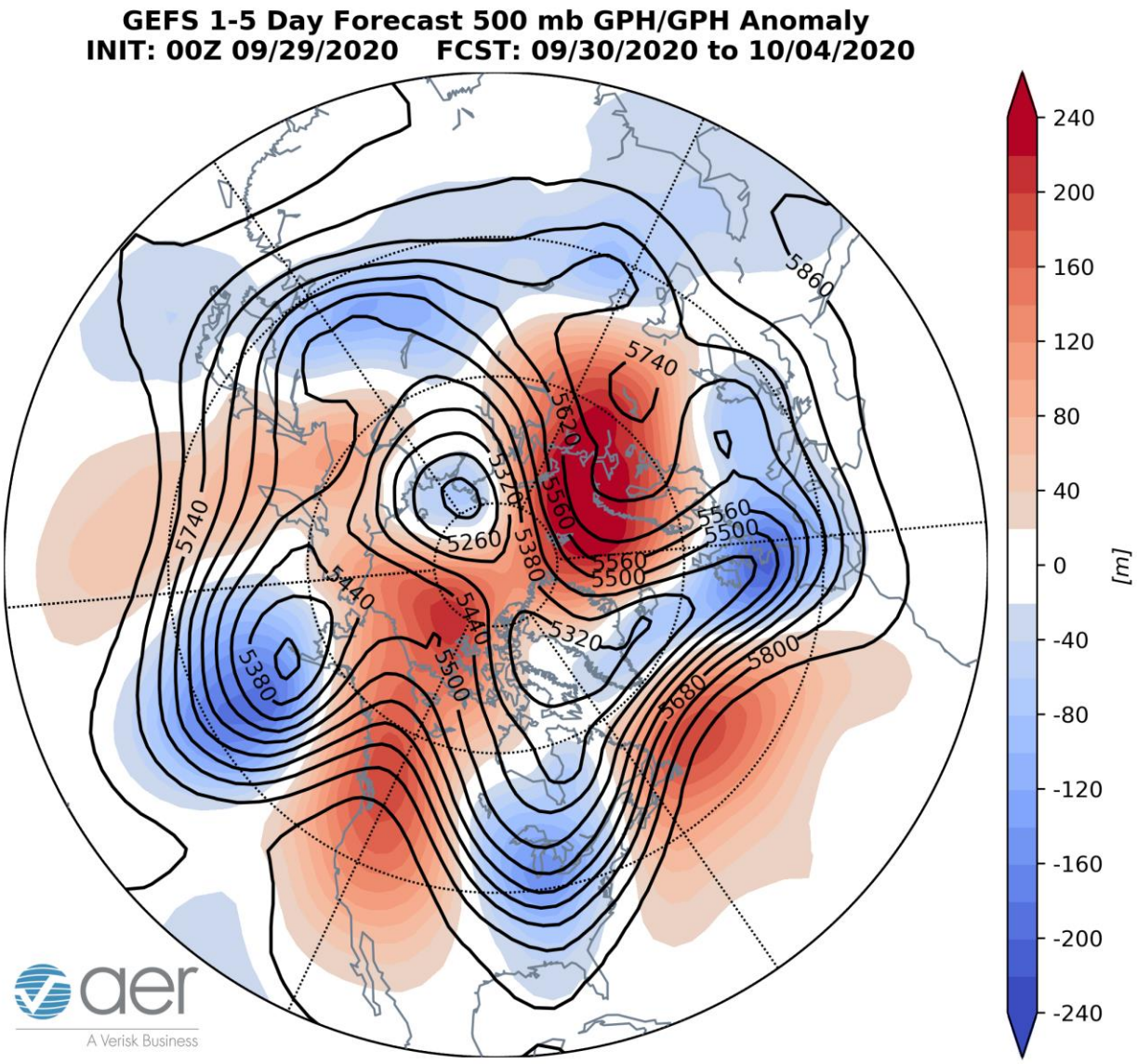

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 30 September – 4 October 2020. The forecasts are from the 00z 29 September 2020 GFS ensemble.

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**). This 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 exceptions of New England and the Canadian Maritimes **(Figure 3).**

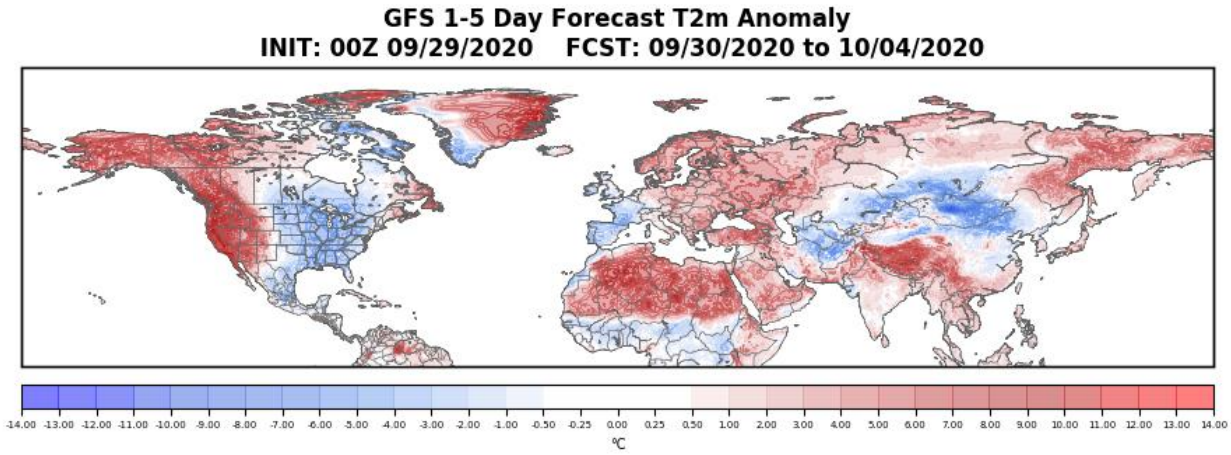

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 30 September – 4 October 2020. The forecast is from the 00Z 29 September 2020 GFS ensemble.

Below normal precipitation is predicted for much of Europe and Asia with the exceptions of above normal precipitation Western Europe, Southeast Asia and Western Siberia in the form of snow (**Figure 4**). Below normal precipitation is predicted for much of North America with above normal precipitation for southern Alaska, Northeastern Canada and along the US East Coast (**Figure 4**).

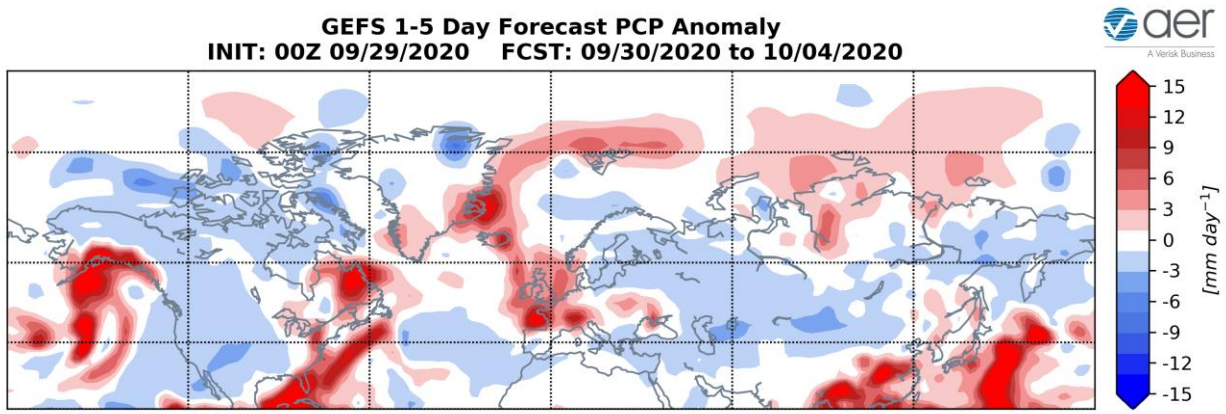

Figure 4. Forecasted precipitation anomalies (mm/day; shading) from 30 September – 4 October 2020. The forecast is from the 00Z 29 September 2020 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to turn negative this week into next week **(Figure 1**) with mostly positive geopotential height anomalies across the Arctic but especially across the

Central and the North Atlantic side of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with positive geopotential height anomalies predicted across Greenland (**Figure 5**), the NAO is predicted to turn negative as well.

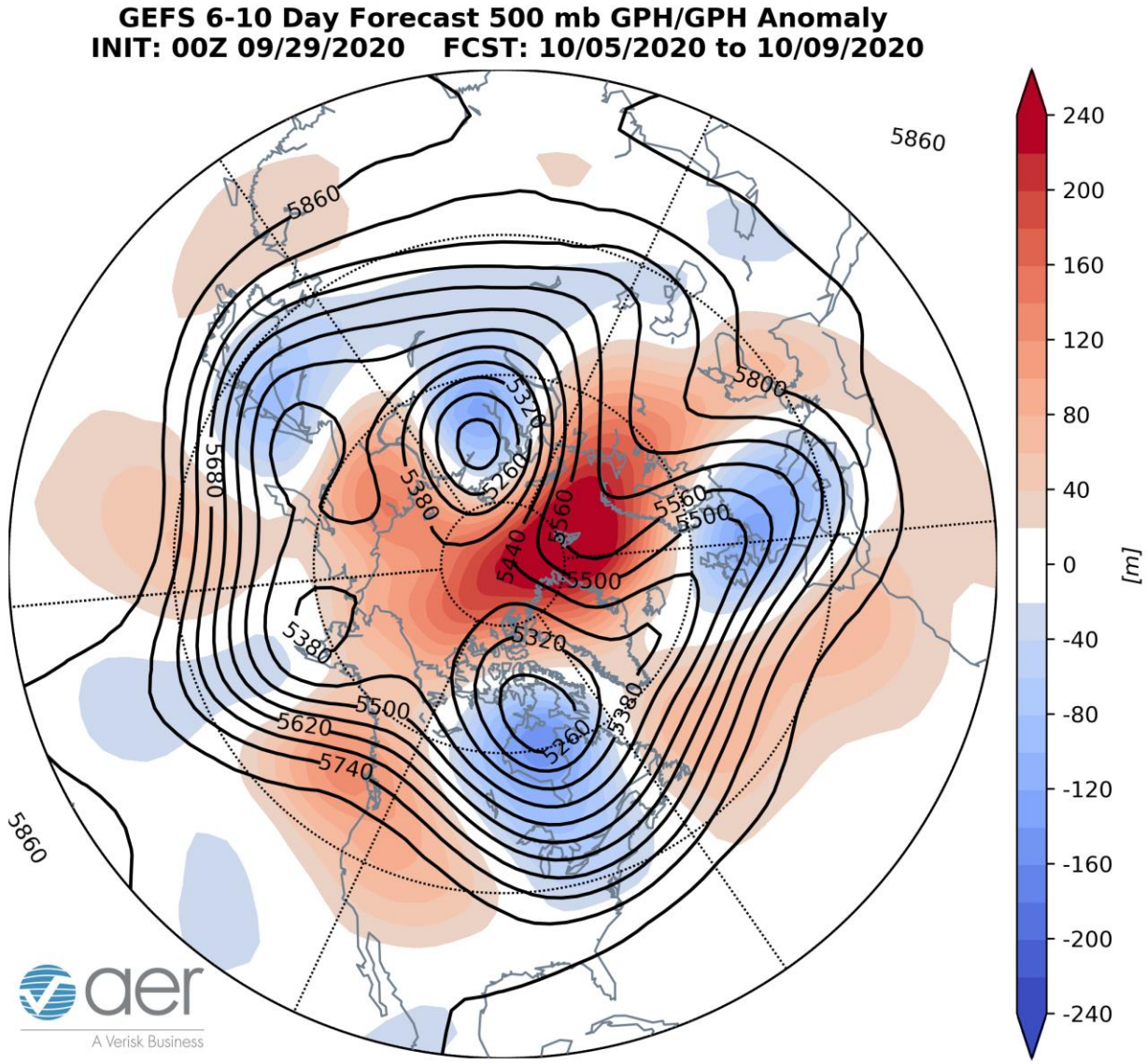

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 5 – 9 October 2020. The forecasts are from the 00z 29 September 2020 GFS ensemble.

Once again strong ridging/positive geopotential height anomalies are predicted to dominate Eastern Europe and Scandinavia forcing troughing/negative geopotential height anomalies across Western Europe (**Figures 5).** This pattern favors normal to above normal temperatures across Eastern Europe and Scandinavia with normal to

below normal temperatures across Western Europe including the UK (**Figure 6**). Strong ridging/positive geopotential height anomalies in Western Asia are predicted to contribute to troughing/negative geopotential height anomalies in Central Asia into East Asia with more ridging/positive geopotential height anomalies in Eastern Siberia this period (**Figure 5**). This is predicted to yield widespread normal to above normal temperatures in Western and Southern Asia and Eastern Siberia with normal to below temperatures In Central and East Asia **(Figure 6**).

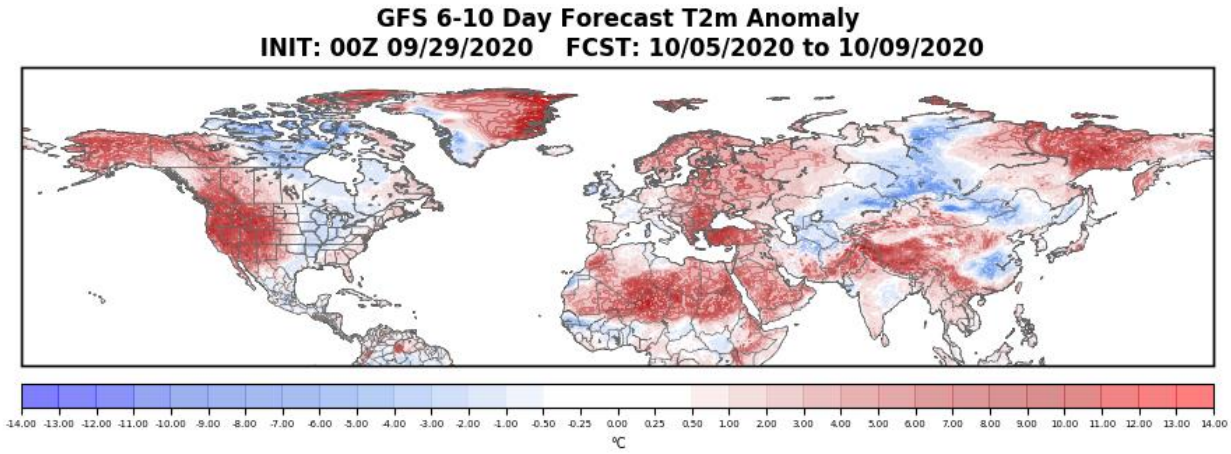

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 5 – 9 October 2020. The forecasts are from the 00Z 29 September 2020 GFS ensemble.

Persistent ridging/positive geopotential height anomalies in western North America will anchor troughing/negative geopotential height anomalies in eastern North America this period **(Figure 5).** This pattern is predicted to bring widespread normal to above normal temperatures across Alaska, Western Canada, the Western and Central US with normal to below normal temperatures for Eastern Canada and the Eastern US **(Figure 6).**

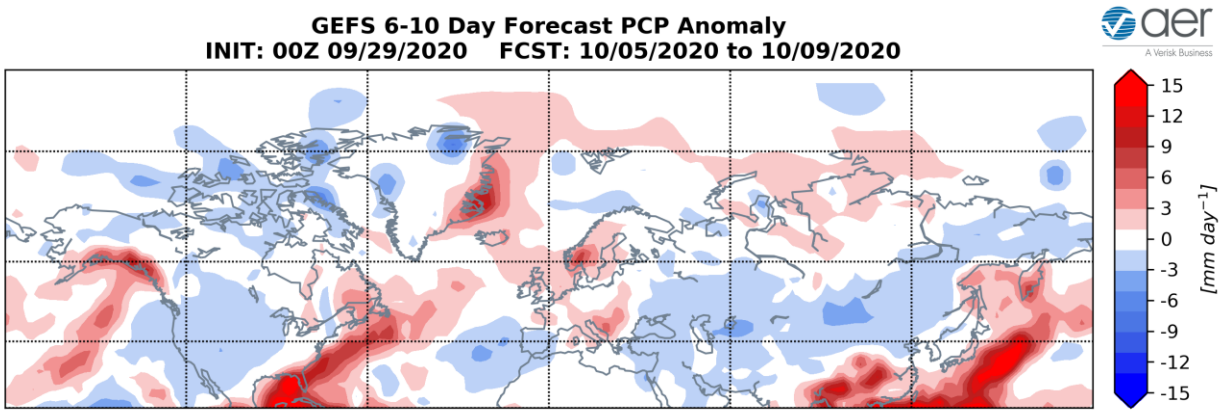

Figure 7. Forecasted precipitation anomalies (mm/day; shading) from 5 – 9 October 2020. The forecasts are from the 00Z 29 September 2020 GFS ensemble.

Normal to below normal precipitation is predicted for much of Eurasia with the exceptions of above normal precipitation across the Balkans, 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, the West Coast of Canada, the eastern Gulf of Mexico and the Canadian Maritimes (**Figure 7**).

11-15 day

With mostly positive 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 remain negative this period (**Figure 1**). With positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is predicted to remain negative.

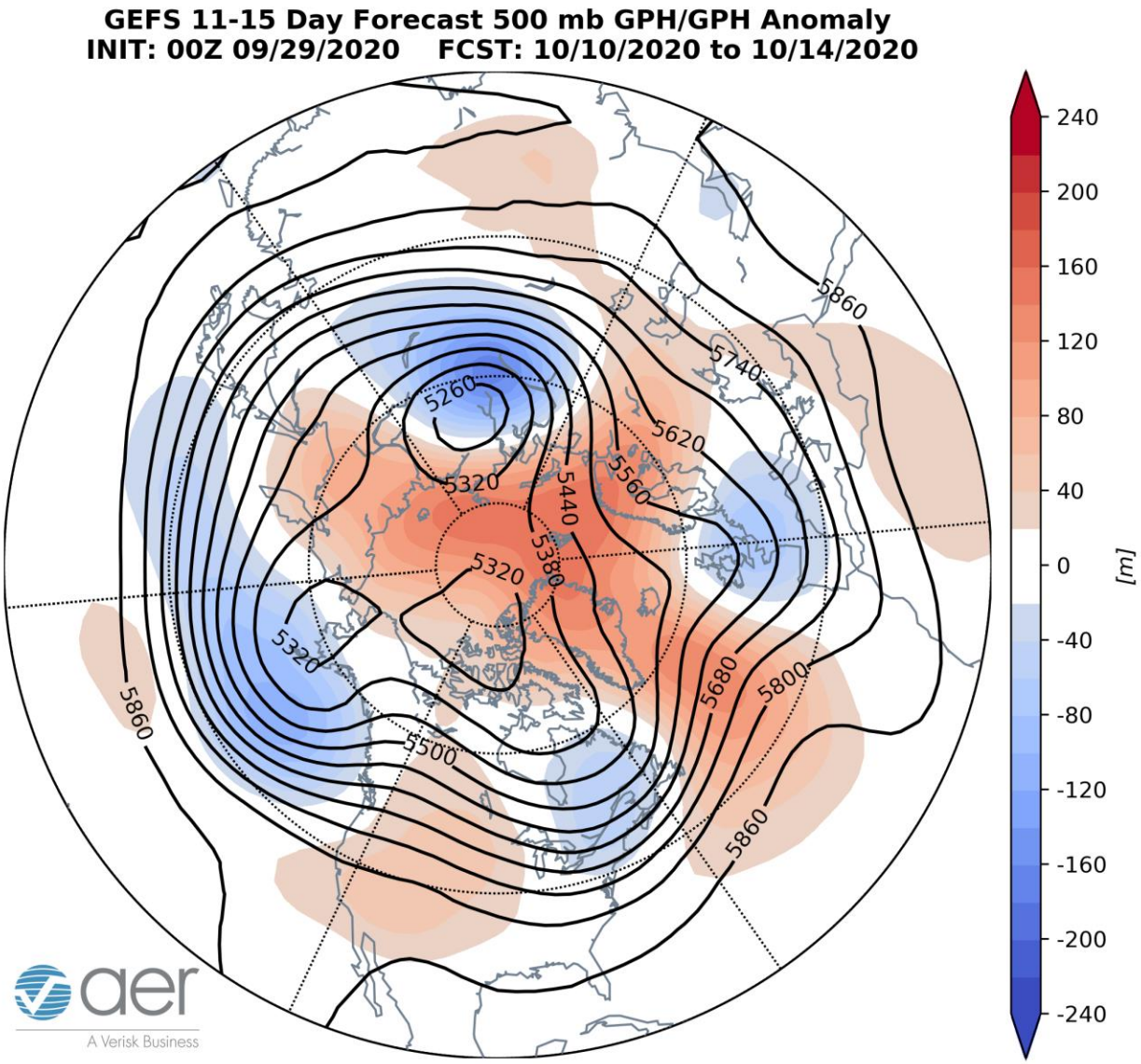

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 10 – 14 October 2020. The forecasts are from the 00z 29 September 2020 GFS ensemble.

Persistent ridging/positive geopotential height anomalies across Eastern Europe, Scandinavia and including Greenland will continue to favor troughing/negative geopotential height anomalies in Western Europe forcing this period (**Figures 8**). The forecast is for normal to above normal temperatures across Eastern Europe and Scandinavia with normal to below normal temperatures across Western Europe including the UK this period (**Figures 9**). For Asia, the general predicted pattern is for continued ridging/positive geopotential height anomalies in Western Asia and Eastern Siberia with troughing/negative geopotential height anomalies in Central and East Asia this period (**Figure 8**). This pattern favors widespread normal to above normal

temperatures across Western and Southern Asia and Eastern Siberia with normal to below normal temperatures in Central and East Asia (**Figure 9**).

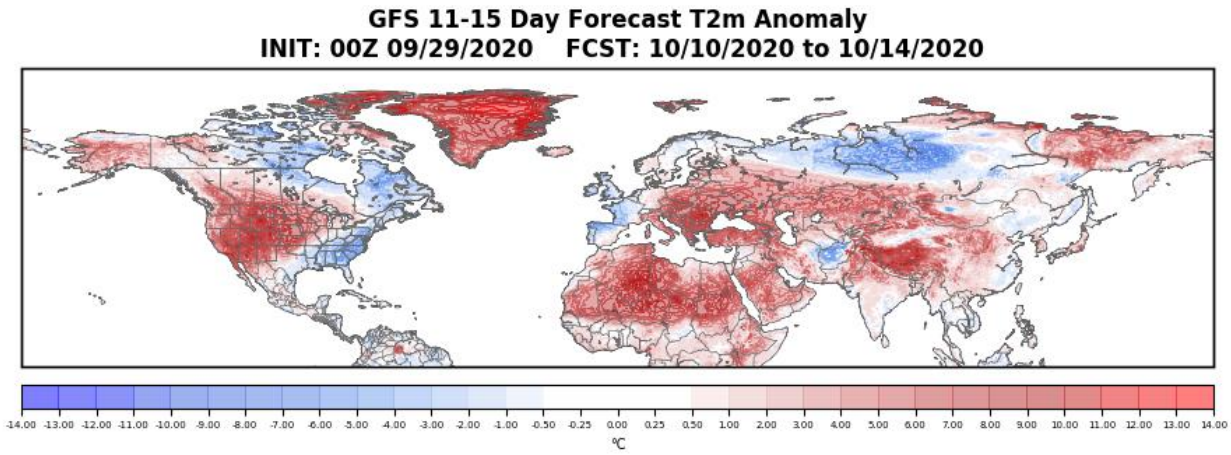

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 10 – 14 October 2020. The forecasts are from the 00z 29 September 2020 GFS ensemble.

Troughing/negative geopotential height anomalies are predicted to deepen that may signal a pattern change but for this period ridging/positive geopotential height anomalies across western North America will continue to force troughing/negative geopotential height anomalies in eastern North America (**Figure 8**). This pattern favors widespread normal to above normal temperatures across Alaska, Western Canada and the Western US with normal to below normal temperatures for the Eastern US and Eastern Canada (**Figure 9**).

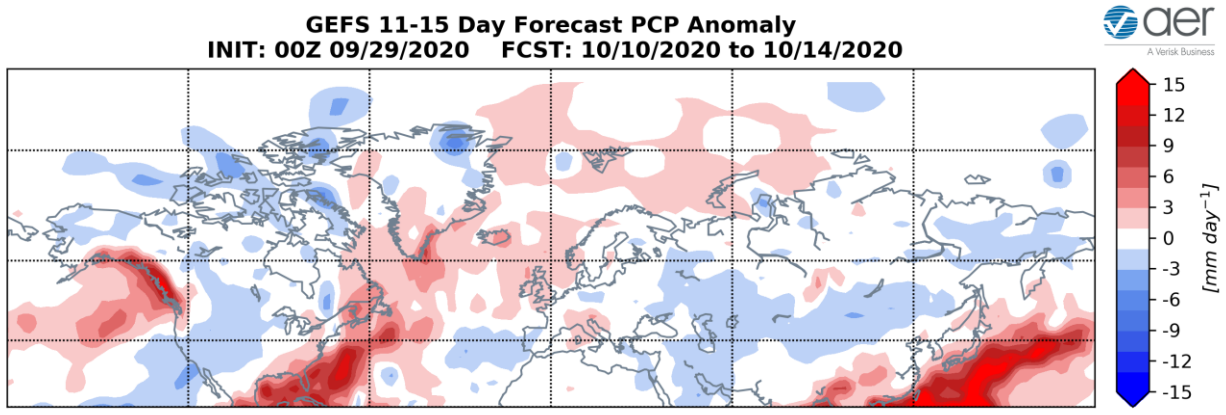

Figure 10. Forecasted precipitation anomalies (mm/day; shading) from 10 – 14 October 2020. The forecasts are from the 00z 29 September 2020 GFS ensemble.

Normal to below normal precipitation is predicted for much of Eurasia except for normal to above normal precipitation for Northwestern 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, the Southeastern US and the Canadian Maritimes (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows above normal PCHs in the troposphere that extend into the stratosphere (**Figure 11**). The warm/positive PCHs are predicted to peak this week in the troposphere with gradual weakening into next week and even cold/negative PCHS in the stratosphere next week (**Figure 11**).

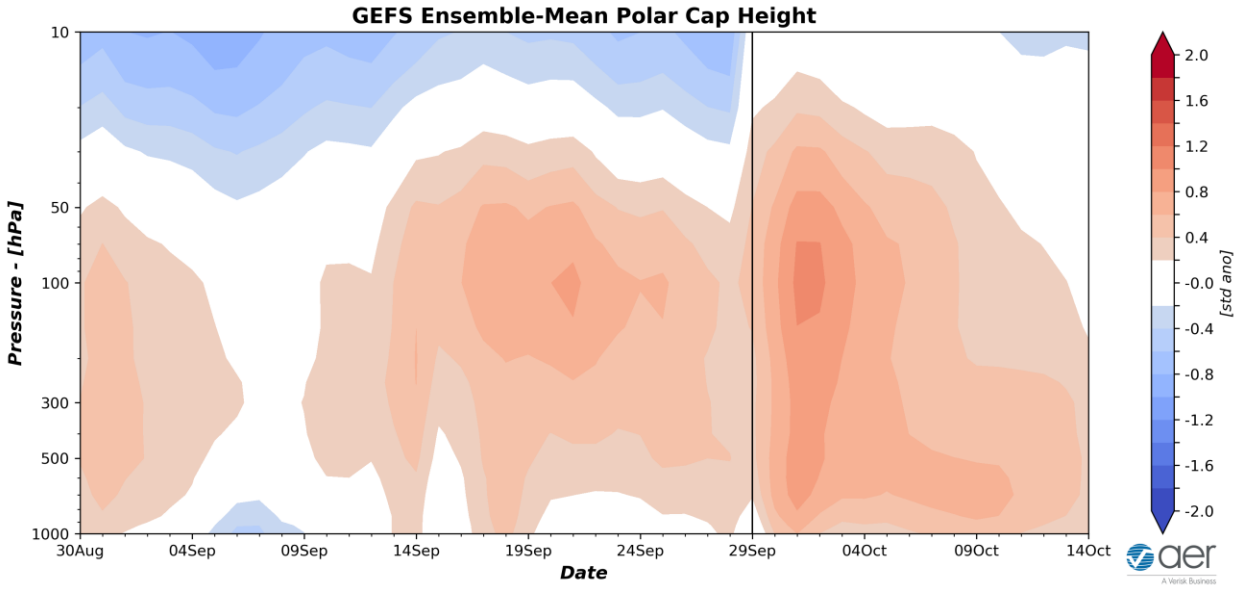

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 29 September 2020 GFS ensemble.

The current above normal PCHs in the troposphere are consistent with the predicted negative AO the next two weeks (**Figure 1**). The forecast is for the warm PCHs to dampen over time and the negative AO to weaken as well. However, the strength of the PCH typically vacillates even if it remains the same sign so further strengthening is possible as long as there isn't a strong increase in vertical energy from the troposphere to the stratosphere. If this vertical energy increases the tropospheric PCHs could turn negative.

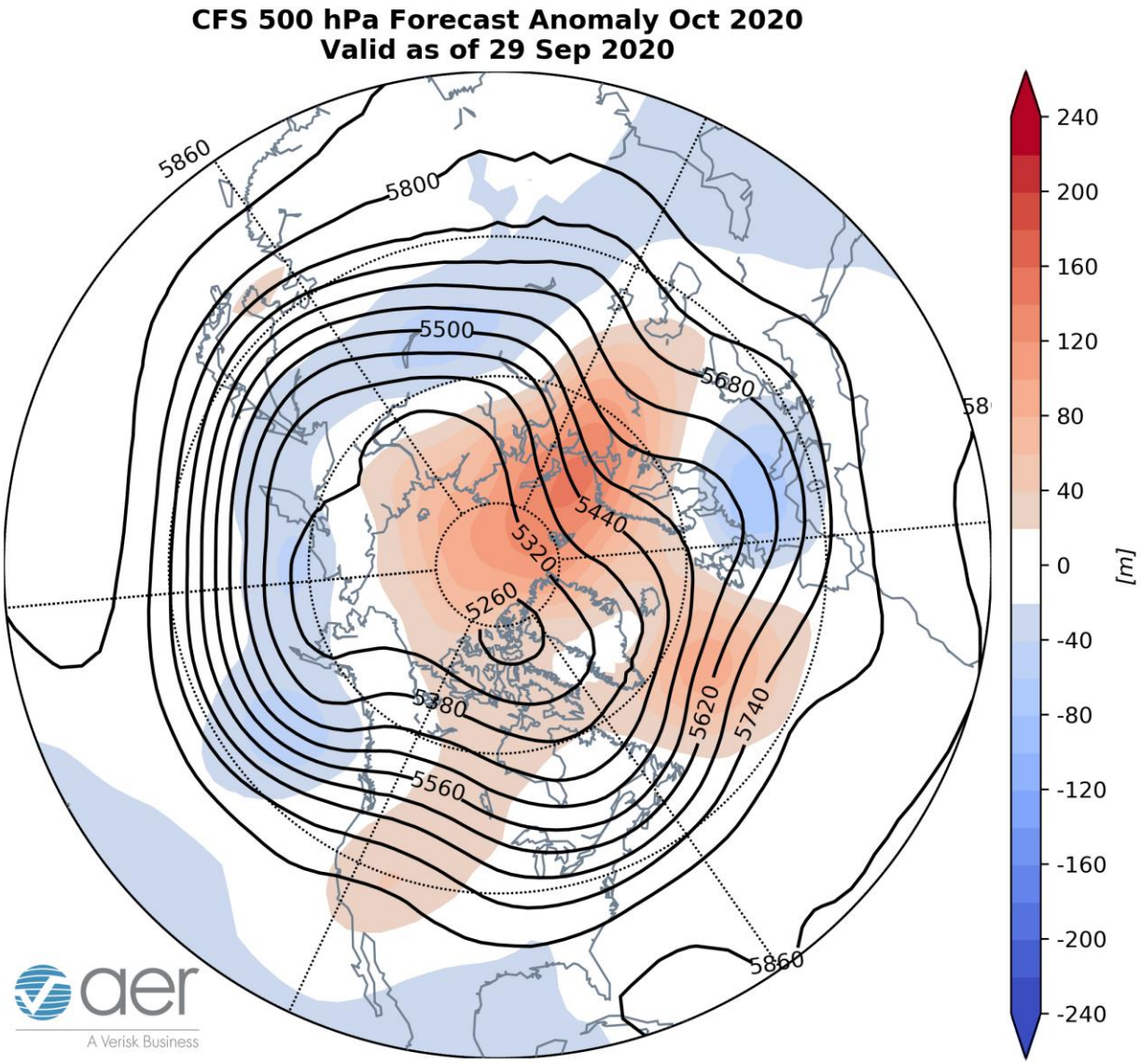

Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for October 2020. The forecasts are from the 00Z 29 September 2020 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and the surface temperatures (**Figure 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 across the Central Arctic, Scandinavia, Eastern Europe, Western Asia, Central Canada and the Western US with troughing in Western Europe, Central and 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, Eastern Europe, Western Asia the North Slope of Siberia and western North

America with seasonable to relatively cool temperatures for Western Europe, Central and East Asia and the Eastern US **(Figure 13).**

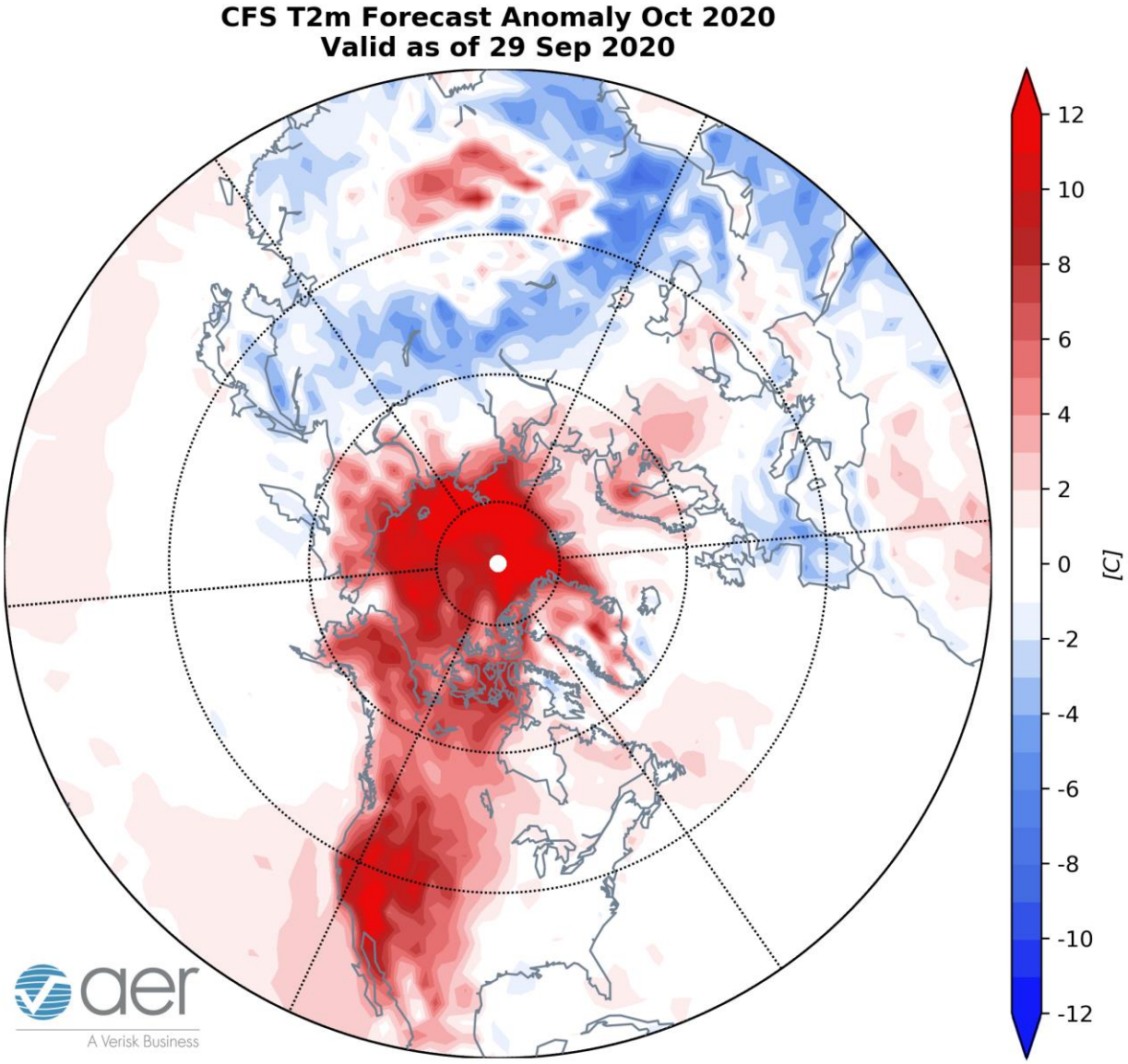

Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for October 2020. The forecasts are from the 00Z 29 September 2020 CFS.

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.

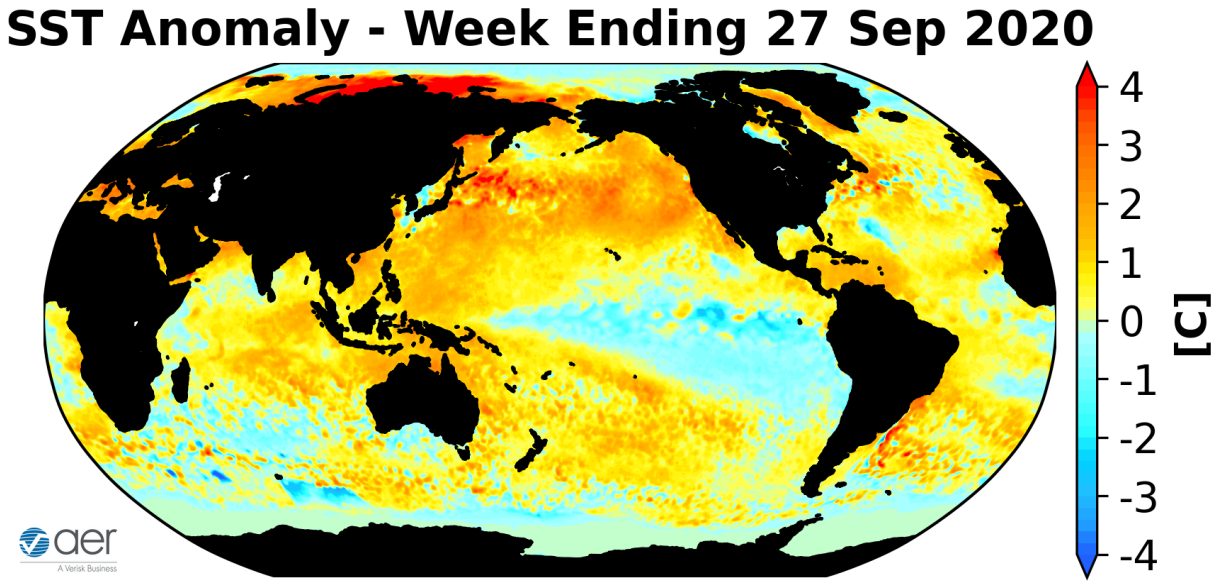

Figure 14. The latest weekly-mean global SST anomalies (ending 27 September 2020). Data from NOAA OI High-Resolution dataset.

Currently no phase is favored for the Madden Julian Oscillation (MJO) (**Figure 15**). The forecasts are for the MJO to briefly emerge into phase five and then weaken again where no phase is favored. MJO phase five in the short term favors troughing across the US with ridging in Canada and then transitioning to troughing in western North America with ridging in eastern North America. The MJO does not seem to be contributing to the short term pattern across North America.

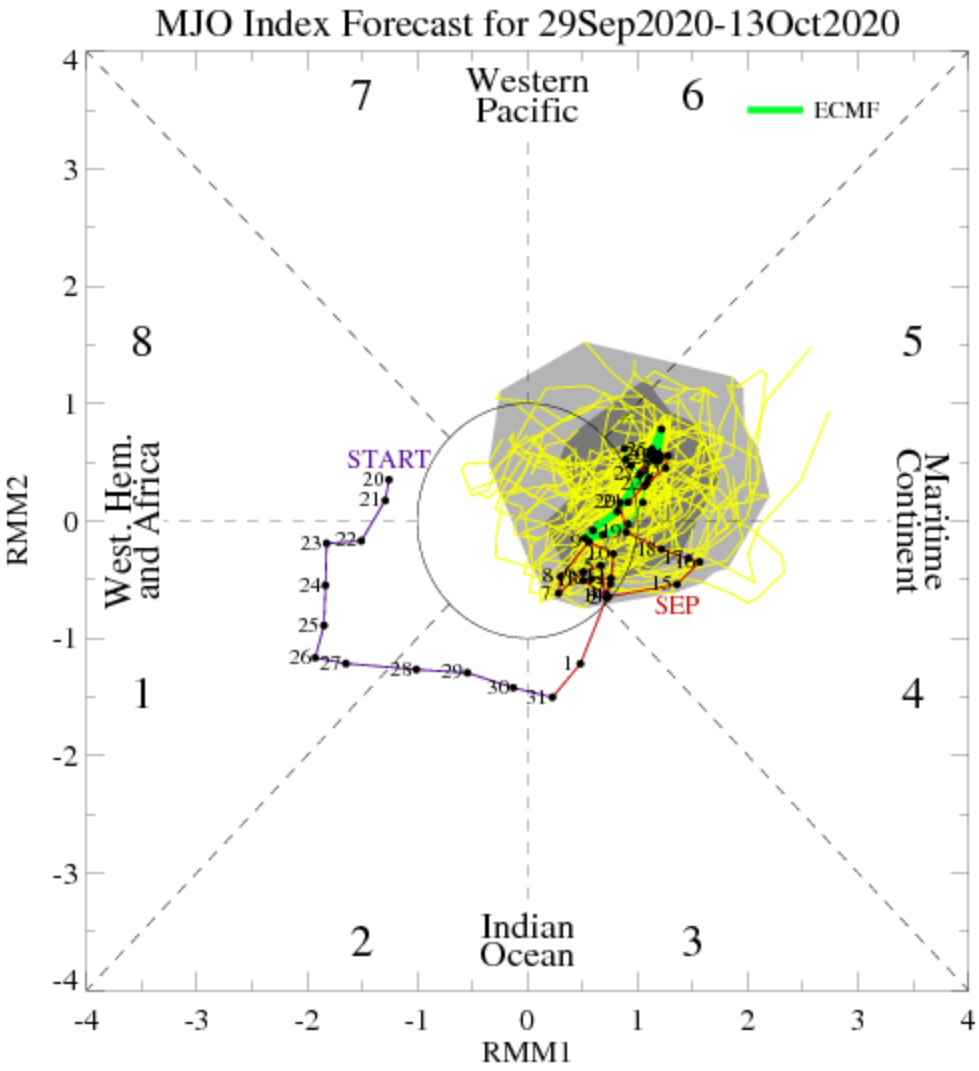

Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 29 September 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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