Arctic Oscillation and Polar Vortex Analysis and Forecasts

October 12, 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 negative with positive pressure/geopotential height anomalies spread across Greenland and Iceland; and the NAO is predicted to remain negative this week and continue into next week as pressure/geopotential height anomalies are predicted to remain positive across Greenland the next two weeks.

- Persistent ridging/positive geopotential height anomalies centered near Greenland and over towards the North Pole will favor troughing/negative geopotential height anomalies across Europe especially Northern and Western Europe including the United Kingdom (UK). This pattern favors normal to below normal temperatures for much of Europe. One exception will be Southeastern Europe where general west to southwest winds transport episodically relatively mild temperatures into the region.
- The predicted general pattern for Asia this week is ridging/positive geopotential height anomalies in Western Asia forcing troughing/negative geopotential height anomalies in Eastern Asia. However next week, ridging/positive geopotential height anomalies are predicted to migrate to a position near the North Pole, which will favor troughing/negative geopotential height anomalies across all of Northern Asia. This pattern favors normal to above normal temperatures in Western and Southern Asia and Eastern Siberia with normal to below normal temperatures in East Asia this week and normal to below normal temperatures across much of Northern Asia with normal to above normal temperatures in Southern Asia and Eastern 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 fully turn my attention toward anticipating the upcoming Northern Hemisphere (NH) winter. As a result, I am transitioning the blog from summer to winter format.

Impacts

Over the past several winters, periods with strong blocking/high pressure centered near the North Pole have been a rare commodity in the winter months. Such a pattern favors severe winter weather widespread across the NH continents in the months December through March. So, if you are a winter weather enthusiast like me, you might be tempted to think “why waste such a good pattern of limited supply in the relatively innocuous month of October?” But I will try to argue that without this anomalous pattern a mild winter would be much more likely.

As @ZLabe has consistently tweeted, Siberia has had a record warm year so far and has been the warmest region relative to normal across the entire globe. **Figure i**, is a

recent plot of Arctic temperature anomalies so far this year through September highlighting the incredible warmth observed across Siberia from @ZLabe.

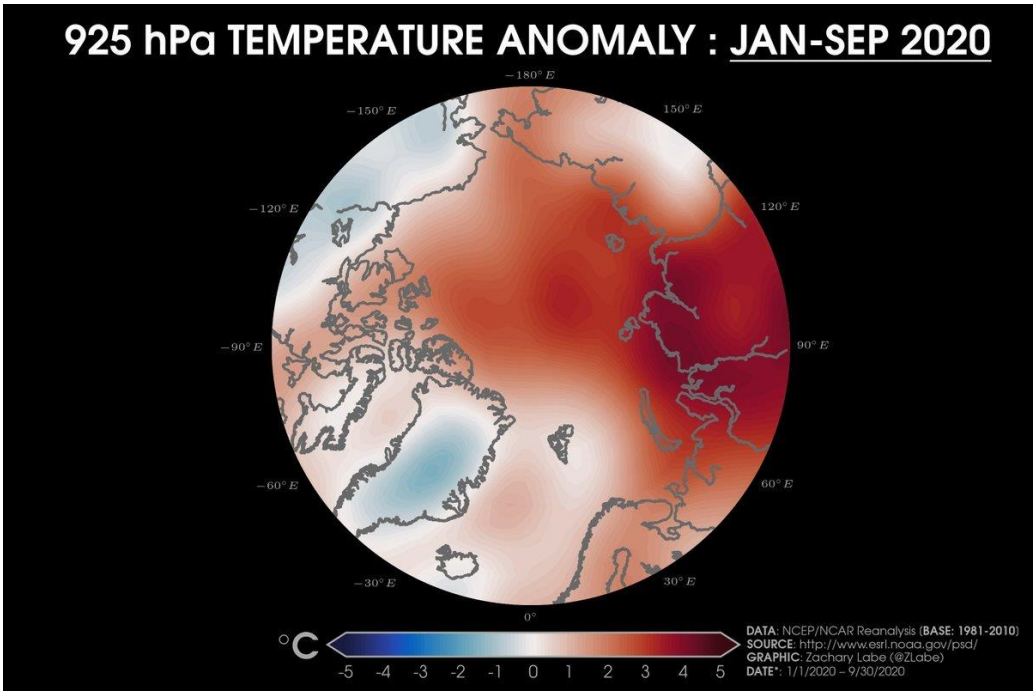

Figure i. The observed Arctic temperature anomalies at 925 hPa (near the surface for January through Spetember, 2020 based on the NCEP/NCAR reanalysis. Climatology is 1981-2010. Plot created by Zachary Labe.

But the record warm streak is likely to end in October attributable to an amplified pattern in the troposphere that favors high latitude blocking or high pressure. The high latitude blocking started the month centered near the Ural Mountains. The center of the high latitude blocking is predicted to shift from the Urals to the North Pole over the next week or so. High latitude blocking both centered near the Urals and the North Pole favor relatively cold temperatures and heavy snowfall across Siberia. However, the favorable pattern for a rapidly expanding snow cover is meeting resistance from the strong inertial warming established the entirety of this year.

I show in **Figure ii** the daily snow cover extent across Eurasia for October going as far back as 2009 and including this year through yesterday. I apologize for the less than optimal color scheme and at some point, I hope to improve the graphic. But I think the plot is best used to get a sense of the relative advance of snow cover extent to date rather than comparing the extent to any individual year. While the total areal extent is shown, where the snow cover is present or absent regionally is not shown and that is likely even more important. So far snow cover extent is relatively sparse compared to recent years despite the favorable pattern and likely related to the large reservoir of heat stored in the region. But the pattern looks to favor for the continued expansion of snow

cover through the end of October. And an expanding snow cover will be increasingly supportive of more widespread below normal temperatures across Northern Asia and possibly into Northern Europe.

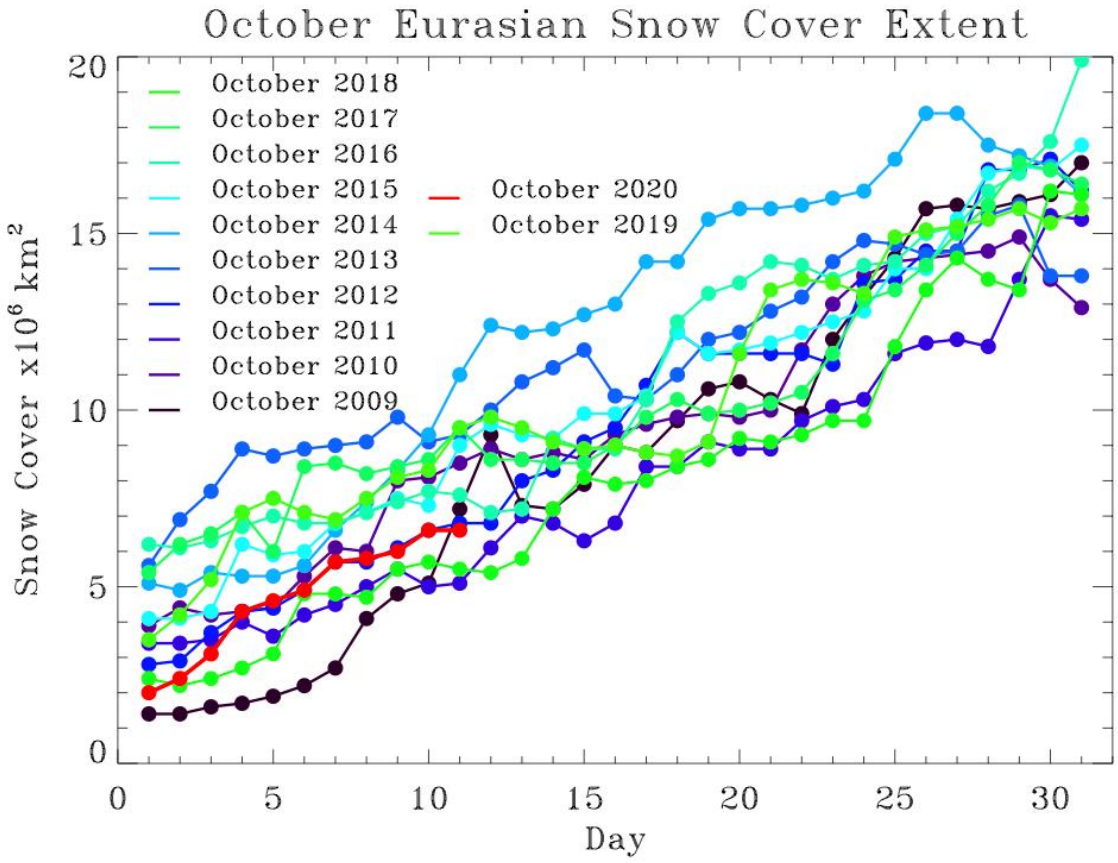

Figure ii. Daily Eurasian snow cover extent in millions of squared kilometers for October 2009-2020.

For the AER winter forecast we rely on the October Eurasian snow cover extent (SCE) as one of our main predictors. Expansive SCE favors a more severe winter in Northern Asia, Europe and the Eastern US while a sparser SCE favors a milder winter in those same regions. Based on the forecasts, I expect the SCE to be above normal once again this year, but I would be more confident if October had not been preceded by record warmth for so many consecutive months. I have focused on SCE for the month of October but there have been some recent studies that argue that November is the key month (e.g. Wegmann et al. 2020). So I will continue to pay attention to SCE into the month of November this year.

Two other predictors we use in our winter forecast are Arctic sea ice extent (SIE) and high latitude blocking in the fall. Sparse Arctic SIE and increased high latitude blocking, especially in the Eurasian sector favor a more severe winter in Northern Asia, Europe

and the Eastern US while more extensive Arctic SIE and decreased high latitude blocking favor a milder winter in those same regions. It is my opinion (mostly based on observational analysis) that sparse Arctic SIE favors increased high latitude blocking as heating from the open waters cause the atmospheric column to expand leading to high pressure (really geopotential heights, which is basically what I refer to when I use the term “blocking”). There is likely an unprecedented amount of heat storage this fall in the Arctic Ocean that will try to escape the ocean into the atmosphere in the coming months that will increase the probability of high latitude blocking for the reminder of the fall and into the winter.

Consistent with these expectations, the polar cap geopotential height anomalies (PCHs) forecast (**Figure 11**) shows impressive positive/warm values in the troposphere and extending into the stratosphere for the next week and a half and possibly beyond. The strong positive values are indicative of strong high latitude blocking. I would argue that near record and soon to be record low Arctic SIE is supportive of the strong blocking so far this fall. Additionally, the high latitude blocking centered near the Urals, has contributed to a weak stratospheric polar vortex so far this month. Ridging near the Urals with downstream troughing across East Asia and into the North Pacific is the most favorable atmospheric wave pattern for disrupting the stratospheric PV (e.g. Cohen and Jones 2012).

The past two falls that were characterized by strong high latitude blocking in October and a weak PV in the fall were then followed by a strong winter PV and relatively mild temperatures across the continents of the mid-latitudes in 2019 and prior to that in 2016. This scenario is certainly plausible once again especially given the anticipated westerly Quasi Biennial Oscillation and La Niña. But the strong positive PCHs and high latitude blocking this October and/or weak PV are also reminiscent of 2002, 2003, 2009, 2010 and 2012. All the ensuing winters were characterized by strong high latitude blocking and all but 2010 were followed by a major sudden stratospheric warming and a highly disrupted PV in the winter months.

2019 and 2016 demonstrated that high latitude blocking and a weak PV are no guarantee that this circulation behavior will persist into the winter, though I can recall more examples where it did than did not. Also, I believe if it were not for the unusually amplified pattern this early in the season there would be a diminished probability of high latitude blocking but especially a weakened PV in the winter months. Without the amplified pattern, SCE would likely be well below normal this October and temperatures would continue to remain above to most likely well above normal temperatures across Siberia. And with continued widespread relative warmth across the hemisphere but especially Eurasia, SCE would likely remain below normal into November. And it is my opinion that a sparse SCE and nearly coast to coast relative warmth across the Eurasian continent favor a strong PV in the winter months.

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

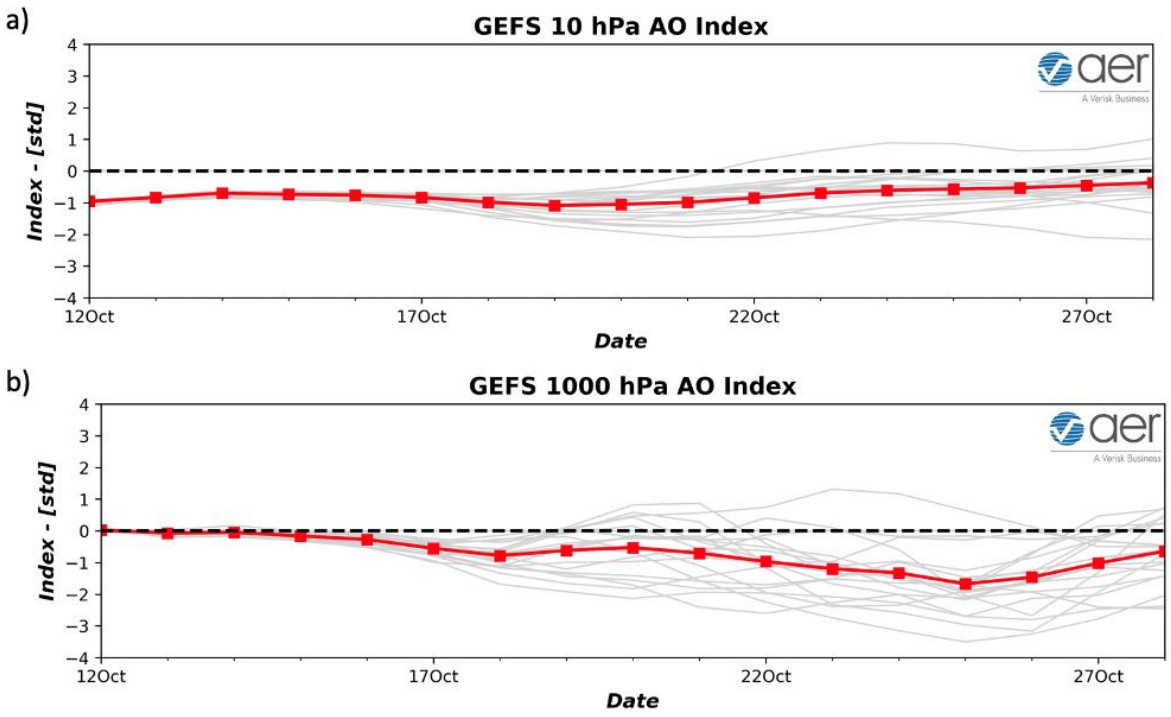

Figure 1. (**a**) The predicted daily-mean AO at 10 hPa from the 00Z 12 October 2020 GFS ensemble. (**b**)The predicted daily-mean near-surface AO from the 00Z 12 October 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies centered near Greenland will help to anchor troughing/negative geopotential height anomalies across much of Europe (**Figure 2**). This pattern favors in normal to below normal temperatures **f**or much of Europe including the UK with the exception of Southeastern Europe where southwesterly winds will usher across the region normal to above normal temperatures (**Figure 3**). Across Asia this week, predicted ridging/positive geopotential height anomalies centered across Western Asia will force downstream troughing/negative geopotential height anomalies across East Asia with more ridging/positive geopotential height anomalies in Eastern Siberia (**Figure 2**). This pattern favors widespread normal to above normal temperatures **f**or much of Western Asia and Eastern Siberia with normal to below normal temperatures for East Asia **(Figure 3**).

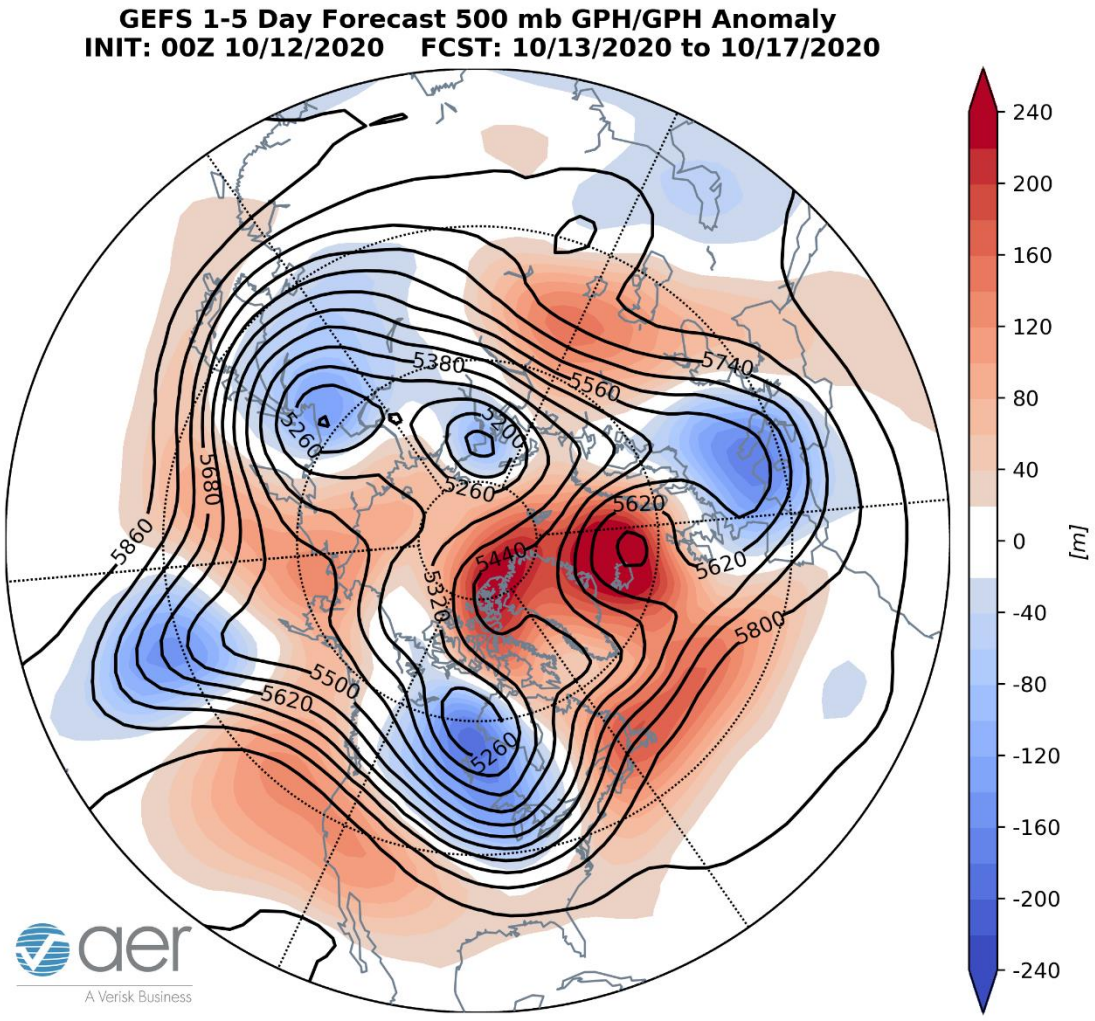

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 13 – 17 October 2020. The forecasts are from the 00z 12 October 2020 GFS ensemble.

This week predicted fractured ridging/positive geopotential height anomalies in the Bering Sea and in the Gulf of Alaska will force deepening troughing/negative geopotential height anomalies centered in Central Canada and the Central US with more ridging/positive geopotential height anomalies along the North American east coast (**Figure 2**). This pattern is predicted to bring normal to above normal temperatures across Southern Alaska, the Western US, the Canadian Maritimes and the US East Coast with normal to below normal temperatures for Northern Alaska, Central and Western Canada and the Central US **(Figure 3).**

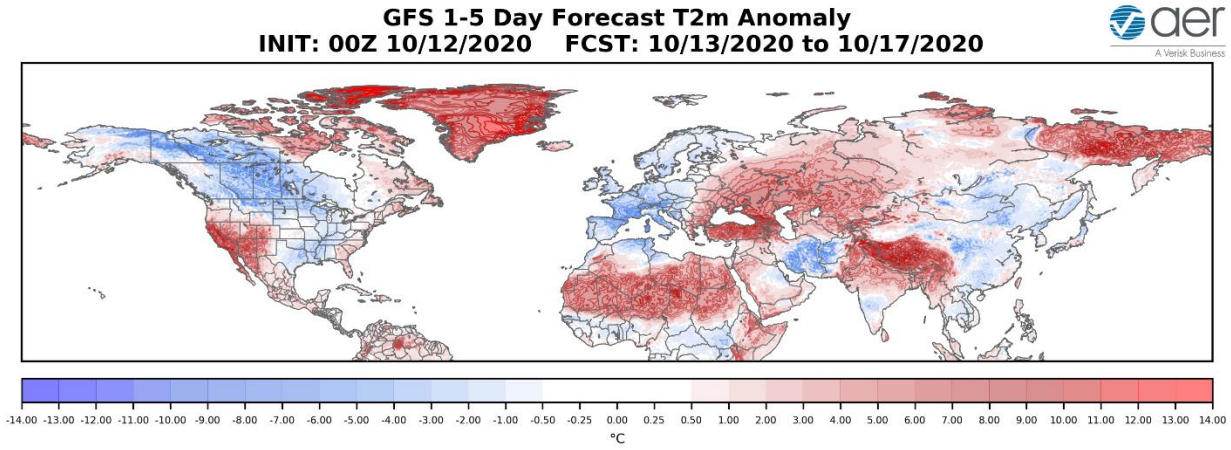

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 13 – 17 October 2020. The forecast is from the 00Z 12 October 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across Central and Eastern Siberia while warmer temperatures will cause snow melt in Western Siberia (**Figure 4**). Troughing and/or colder temperatures are predicted to support new snowfall across Southeastern Alaska, Western and Central Canada while warmer temperatures will cause snow melt in eastern Quebec (**Figure 4**).

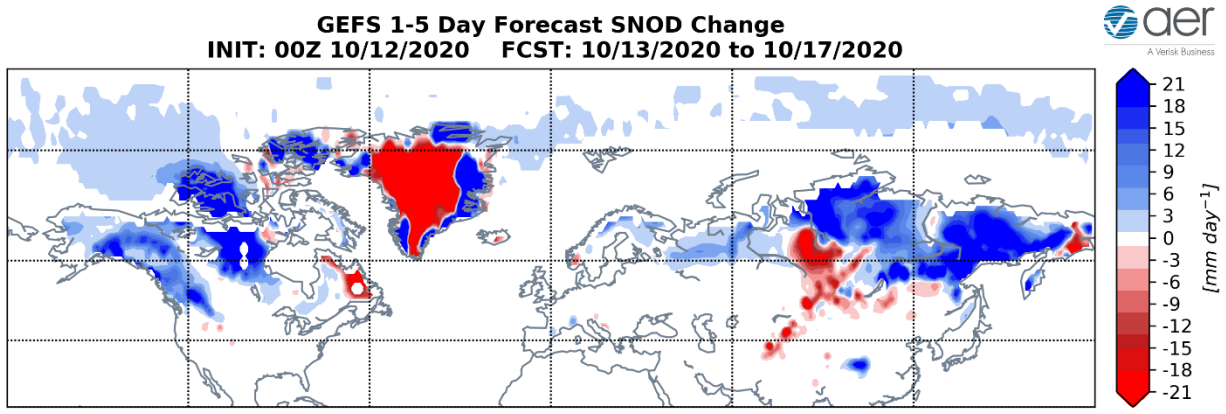

Figure 4. Forecasted snowfall (mm/day; shading) from 13 – 17 October 2020. The forecast is from the 00Z 12 October 2020 GFS ensemble.

Mid-Term

6-10 day

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

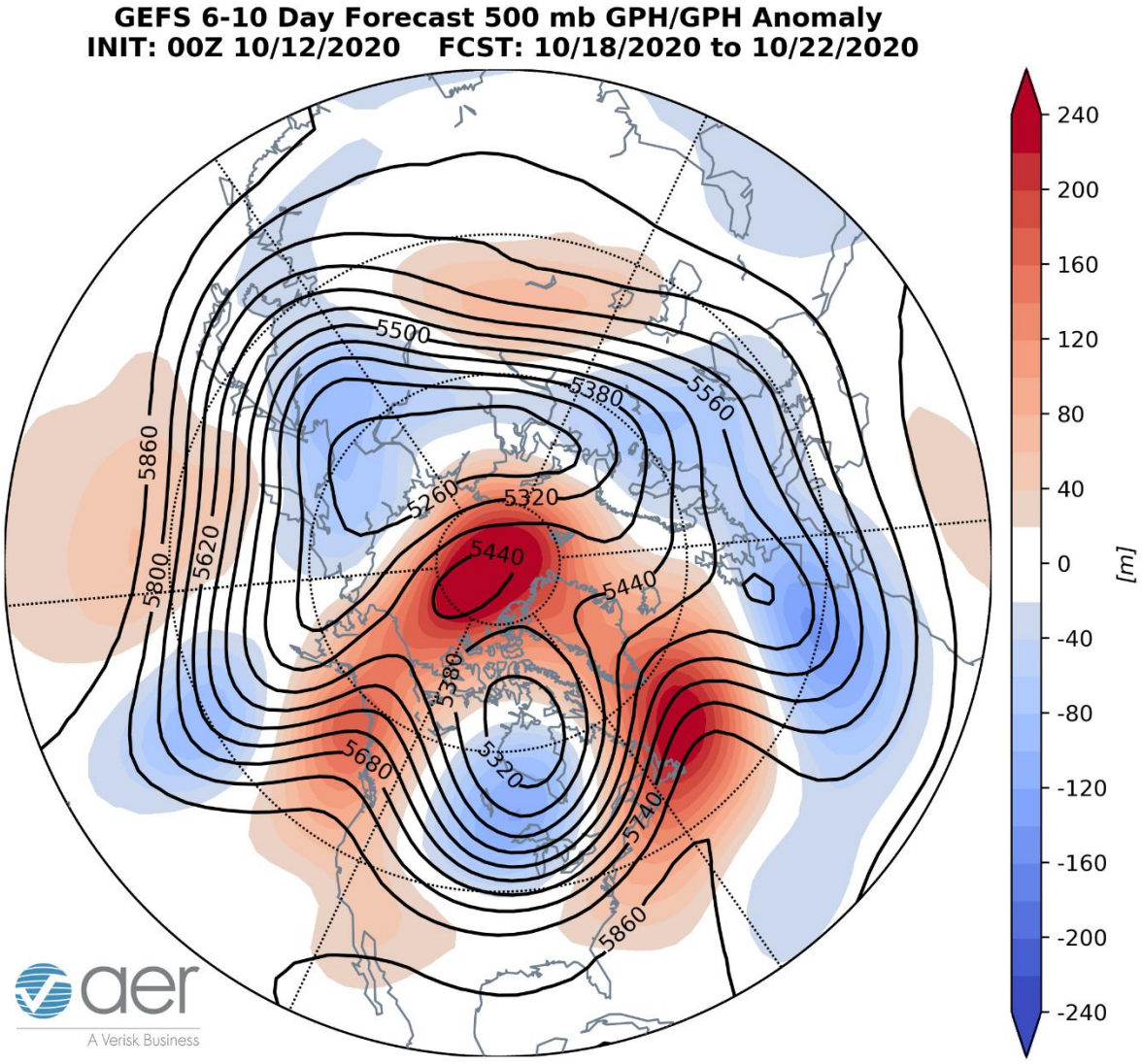

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 18 – 22 October 2020. The forecasts are from the 00z 12 October 2020 GFS ensemble.

Once again ridging/positive geopotential height anomalies across Greenland but focused in the Central Arctic are predicted to favor troughing/negative geopotential height anomalies across much of Europe (**Figures 5).** This pattern favors normal to below normal temperatures across Northern Europe including the UK with normal to above normal temperatures across Southern Europe as westerly flow favors relatively mild temperatures (**Figure 6**). Strong ridging/positive geopotential height anomalies

centered near the North Pole will favor troughing/negative geopotential height anomalies expansive across Northern Asia and 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 below normal temperatures in Northern and East Asia with normal to above temperatures In Southwestern and Central Asia and Eastern Siberia **(Figure 6**).

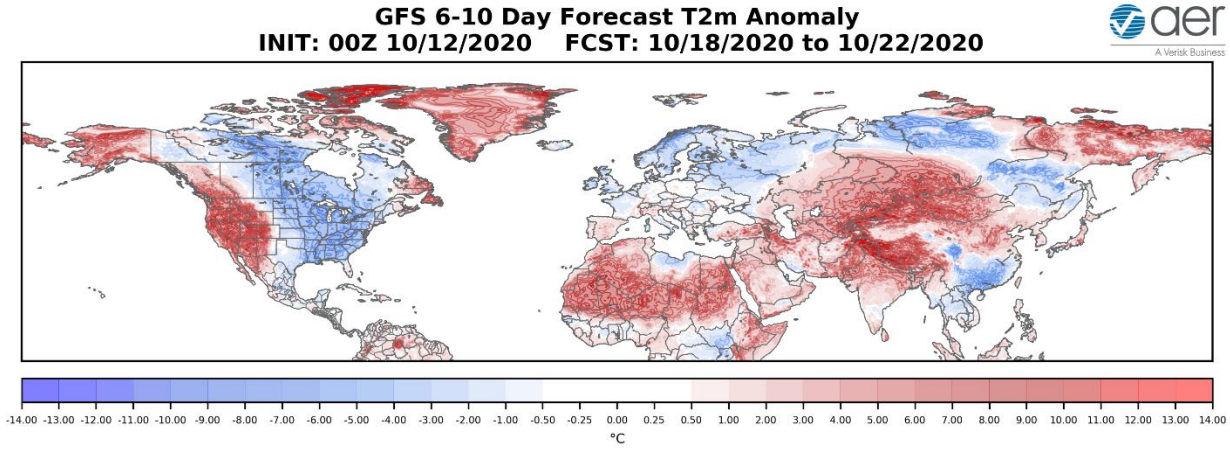

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 18 – 22 October 2020. The forecasts are from the 00Z 12 October 2020 GFS ensemble.

Ridging/positive geopotential height anomalies all along the west coast of North America will force troughing/negative geopotential height anomalies in central North America with more ridging/positive geopotential height anomalies along the North American east coast this period **(Figure 5).** This pattern is predicted to bring widespread normal to above normal temperatures across Alaska, Western Canada, the Western US and the Canadian Maritimes with normal to below normal temperatures for Central and Eastern Canada and the Eastern US **(Figure 6).**

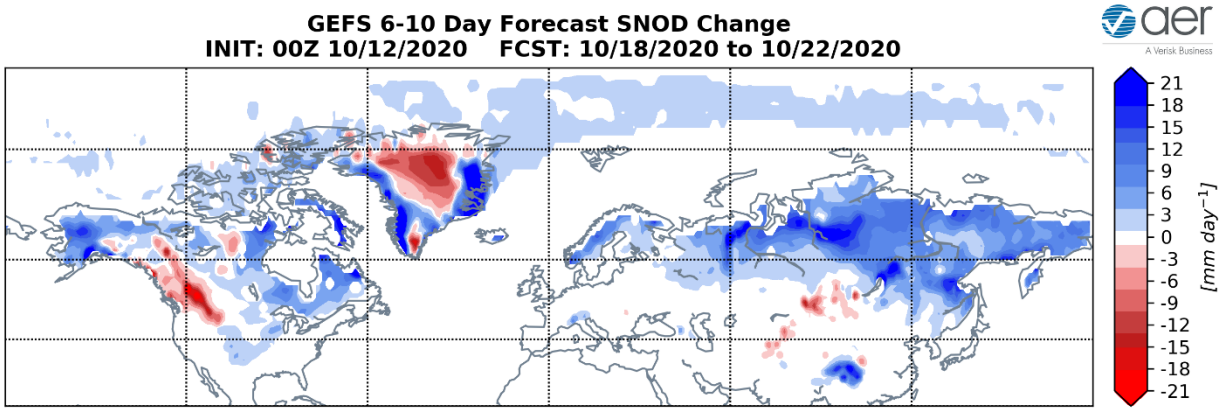

Figure 7. Forecasted precipitation anomalies (mm/day; shading) from 5 – 9 October 2020. The forecasts are from the 00Z 12 October 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across much of Northern Eurasia including Scandinavia, the Alps and the Himalayas while warmer temperatures will cause snow melt in Central Asia (**Figure 7**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, Central and Eastern Canada and even possibly the Central US while warmer temperatures will cause snow melt in Western Canada (**Figure 7**).

11-15 day

With mostly positive geopotential height anomalies across the Arctic centered near the North Pole 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 also predicted to remain negative.

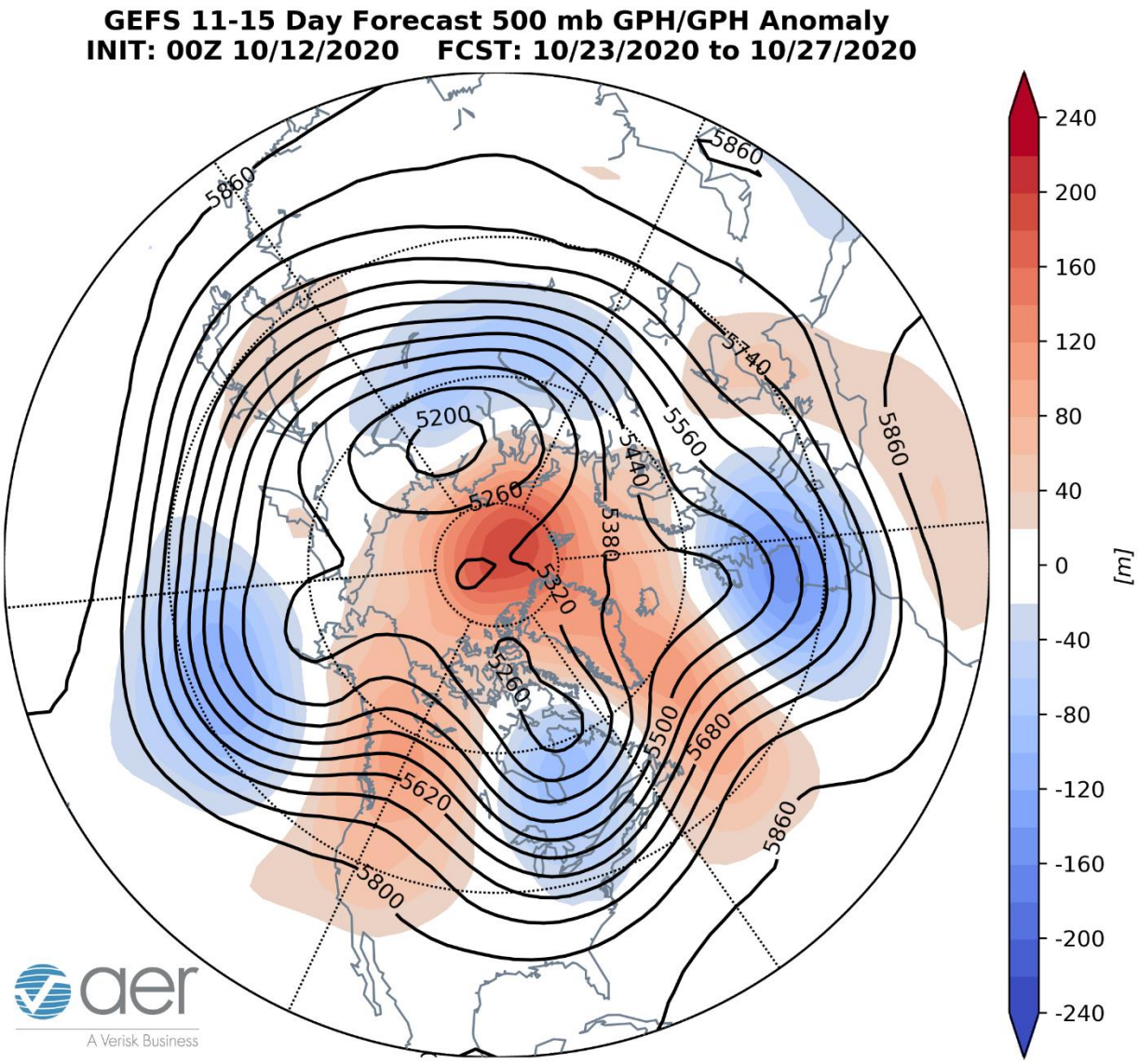

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 23 – 27 October 2020. The forecasts are from the 00z 12 October 2020 GFS ensemble.

Persistent ridging/positive geopotential height anomalies across the Arctic including Greenland will continue to favor troughing/negative geopotential height anomalies across much of Europe but especially Western Europe this period (**Figures 8**). The forecast is for normal to below normal temperatures across Western and Northern Europe including the UK, however a mild, southwesterly flow will favor normal to above normal temperatures across Southern and Eastern Europe this period (**Figures 9**). Predicted persistent ridging/positive geopotential height anomalies centered near the North Pole will support expansive troughing/negative geopotential height anomalies across Northern Asia this period (**Figure 8**). This pattern favors widespread normal to

below normal temperatures widespread across Northern Asia while a mild westerly and/or southwesterly flow will favor normal to above normal temperatures across Southern Asia and Eastern Siberia (**Figure 9**).

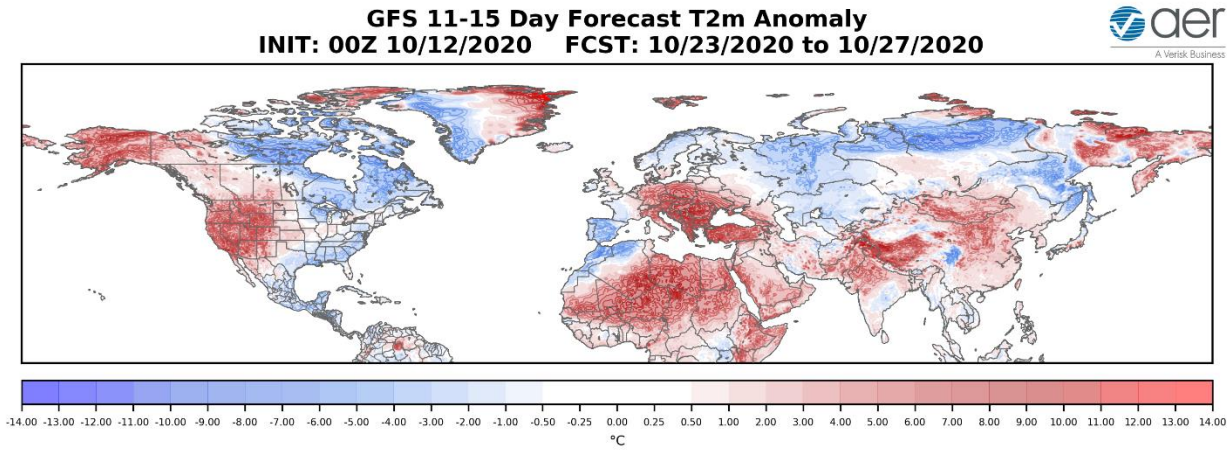

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 10 – 14 October 2020. The forecasts are from the 00z 12 October 2020 GFS ensemble.

Predicted persistent 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**).

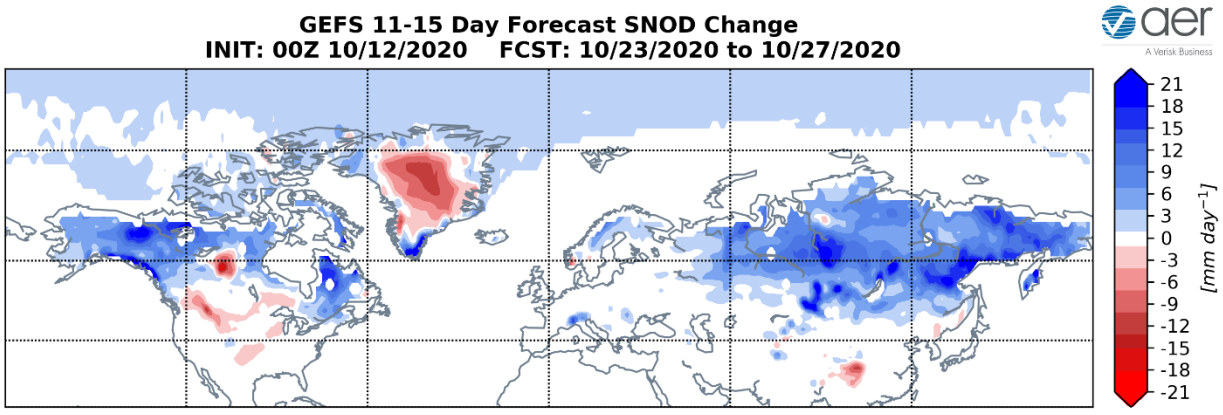

Figure 10. Forecasted precipitation anomalies (mm/day; shading) from 23 – 27 October 2020. The forecasts are from the 00z 12 October 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across much of Northern Eurasia including Scandinavia and the Alps while warmer

temperatures will cause snow melt in and the Himalayas (**Figure 10**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, Northern and Eastern Canada and even possibly New England while warmer temperatures will cause snow melt in Western Canada, the US Northern Rockies and possibly the Plains (**Figure 10**).

Longer Term

30–day

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

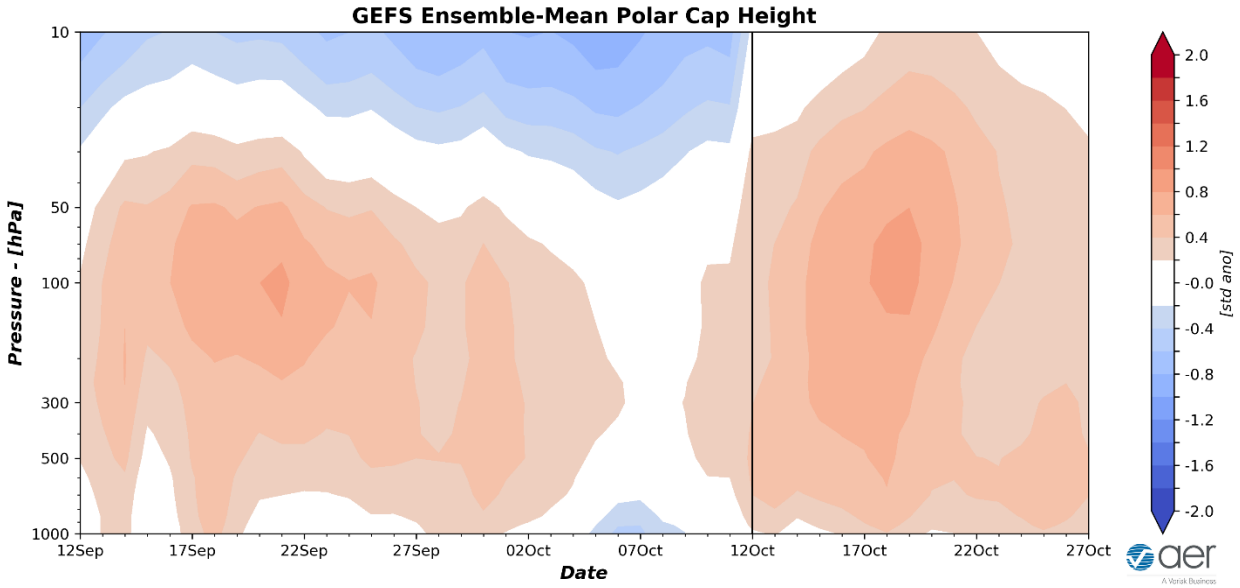

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 12 October 2020 GFS ensemble.

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 the end of next week 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.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows active WAFz for this week but quieter for next week (**Figure 12**). The weak pulse of WAFz this week is predicted to cause a minor disruption of the PV as seen by the warming of stratospheric PCHs and the negative stratospheric AO for the next two weeks (**Figure 1**).

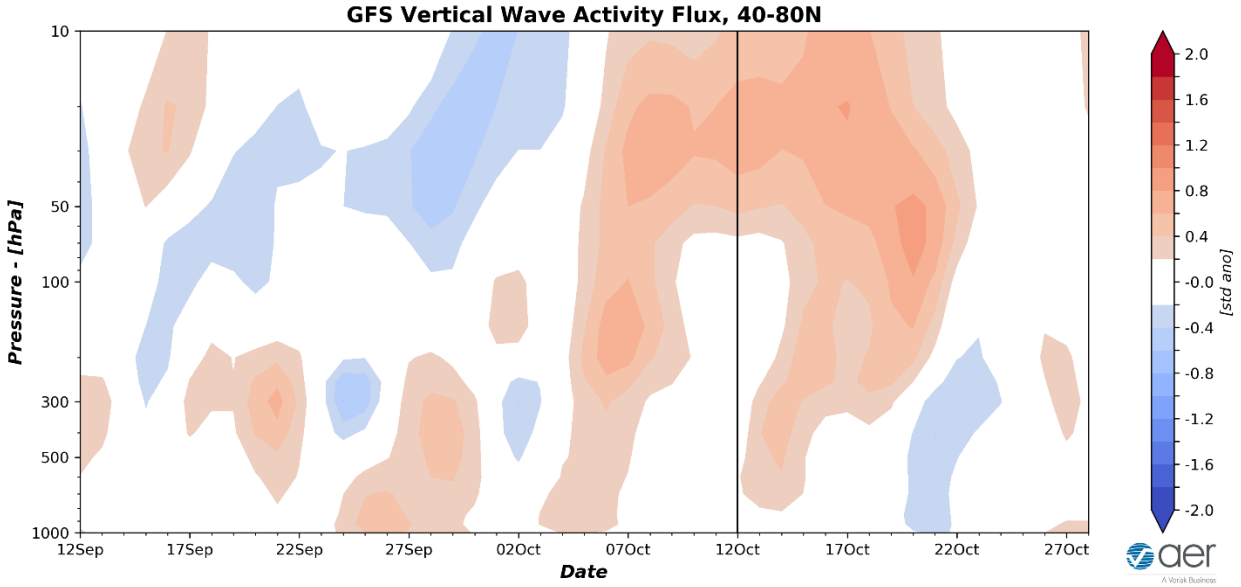

Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 12 October 2020 GFS ensemble.

The minor perturbation of the PV looks to be a reflective event which is characterized by warming and ridging in the northern North Pacific sector and an elongation of the PV. At first the PV is displaced towards the Barents-Kara Seas and then closer to Greenland (**Figure 13**).

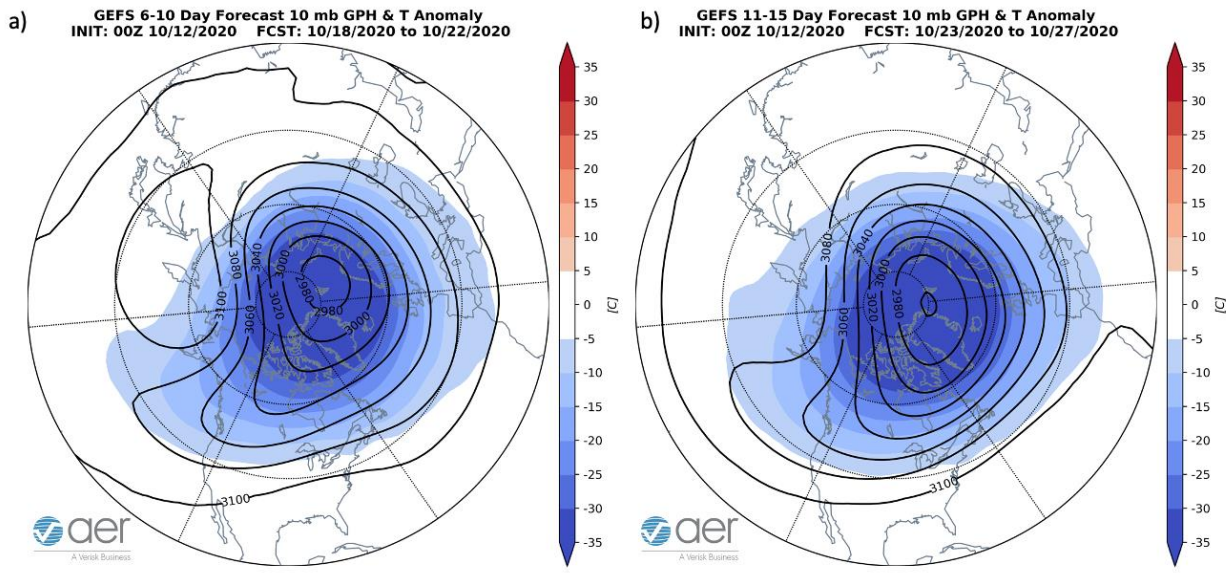

Figure 13. (**a**) Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 18 –22 October 2020. (**b**) Same as (a) except forecasted averaged from 23 – 27 October 2020. The forecasts are from the 00Z 12 October 2020 GFS model ensemble.

The forecast of a PV position towards Greenland coupled with an elongation of the PV (**Figure 13**) could support relatively cold temperatures in eastern North America as a mirror circulation sets up in the troposphere with northerly flow driving Arctic air south.

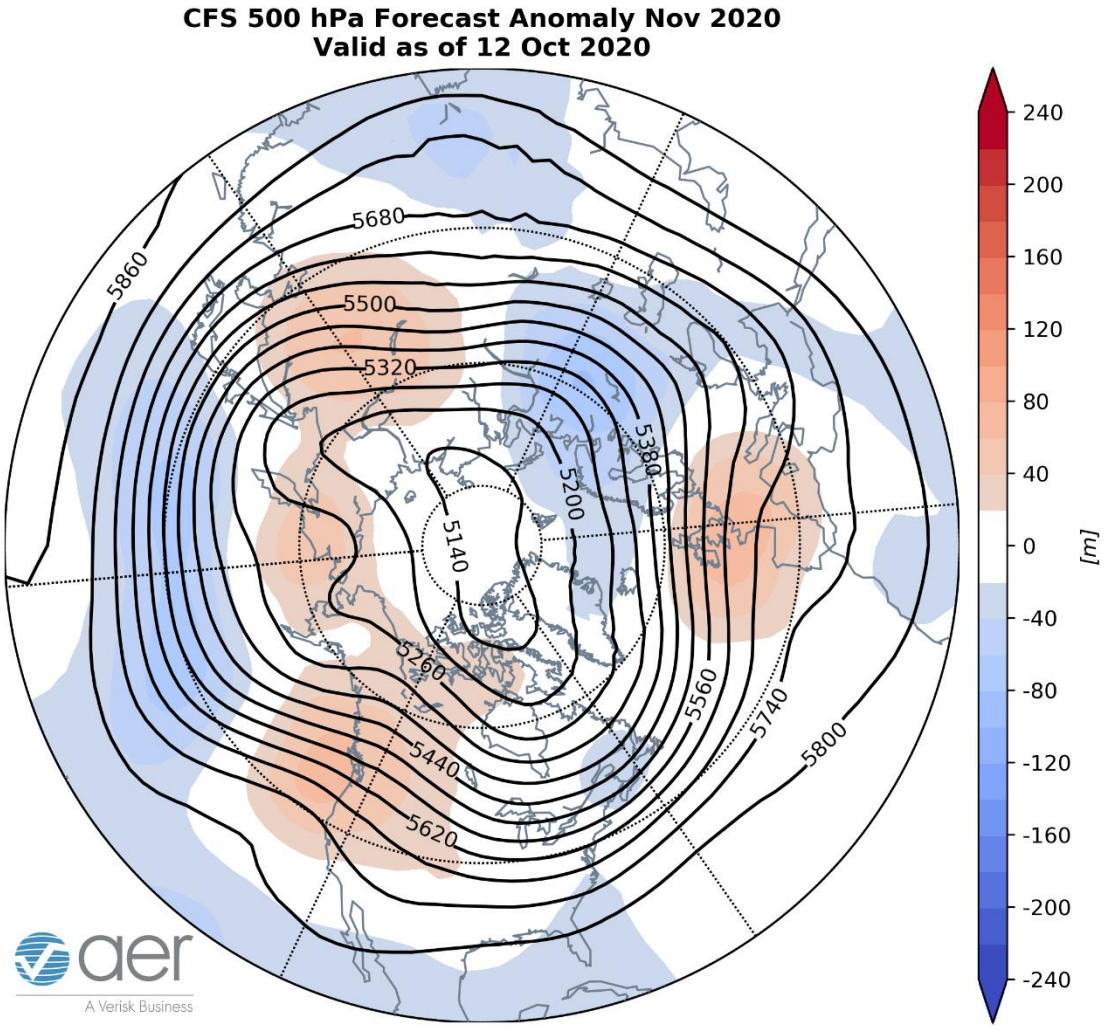

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for November 2020. The forecasts are from the 00Z 12 October 2020 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) forecast for November from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging across Western Europe, Eastern Asia, the Bering Sea, Western Canada and the Western US with troughing in Scandinavia, Western Asia, Eastern Canada and the Eastern US (**Figure 14).** This pattern favors relatively warm temperatures for Northern Europe, Northern Asia and western North America with seasonable to relatively cool temperatures for Southern Europe, Southern Asia and the Eastern US(**Figure 15**)**.**

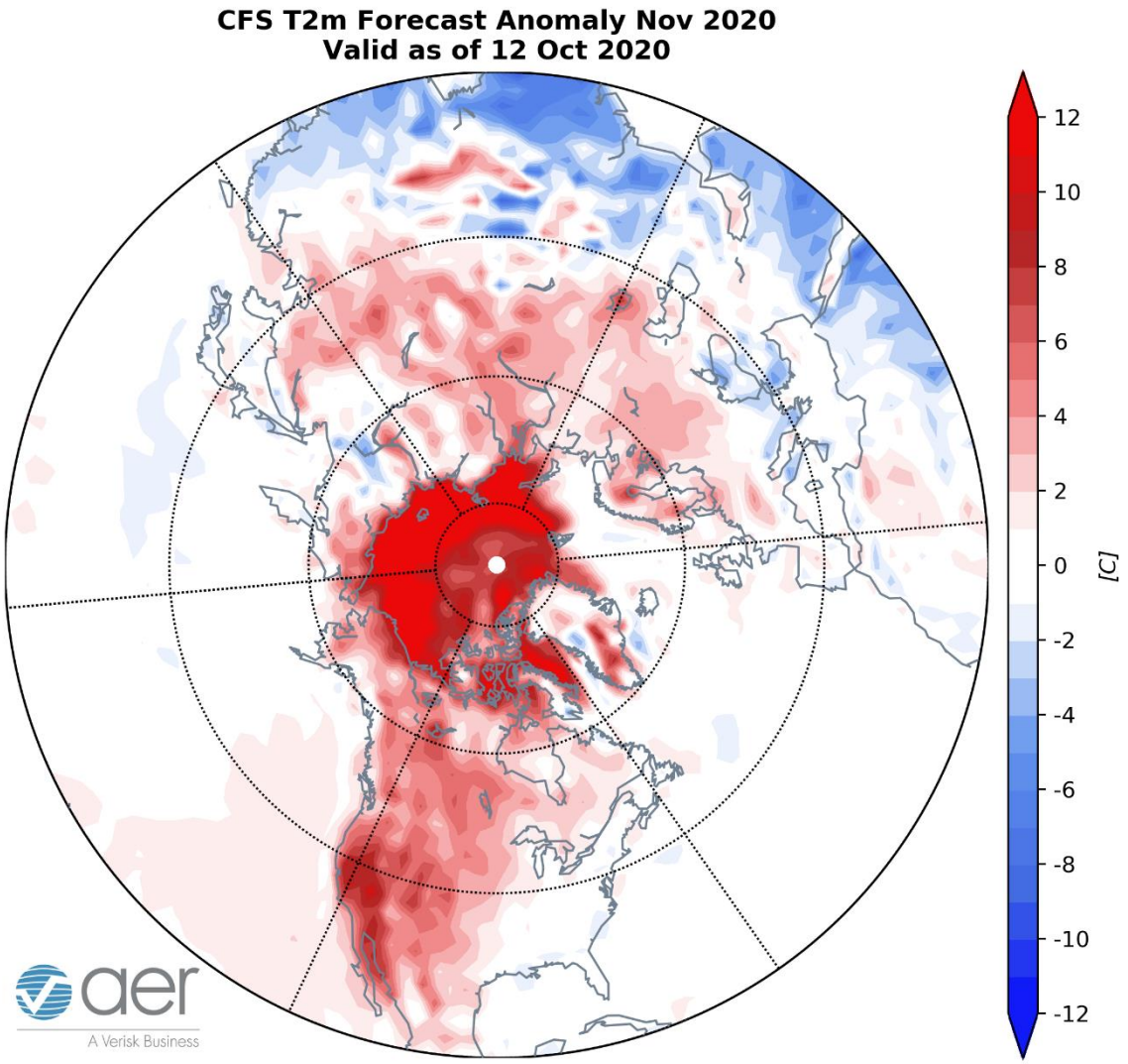

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for November 2020. The forecasts are from the 00Z 12 October 2020 CFS.

Surface Boundary Conditions

Arctic sea ice extent

Arctic sea ice growth rate continues at a slow rate and remains well below normal. Large negative sea ice anomalies exist continuously from Alaska to the Barents-Kara Seas (**Figure 16**). Sea ice extent is currently comparable to 2012 but will likely drop below 2012 this week to new record lows. Below normal sea ice in the Barents-Kara seas favor cold temperatures in Central and East Asia, however this topic remains controversial. Recent research has shown that the regional anomalies that are most highly correlated with the strength of the stratospheric PV are across the Barents-

Kara seas region where low Arctic sea ice favors a weaker winter PV. Low sea ice in the Chukchi, Beaufort and Bering seas may favor colder temperatures across North America but has not been shown to weaken the PV.

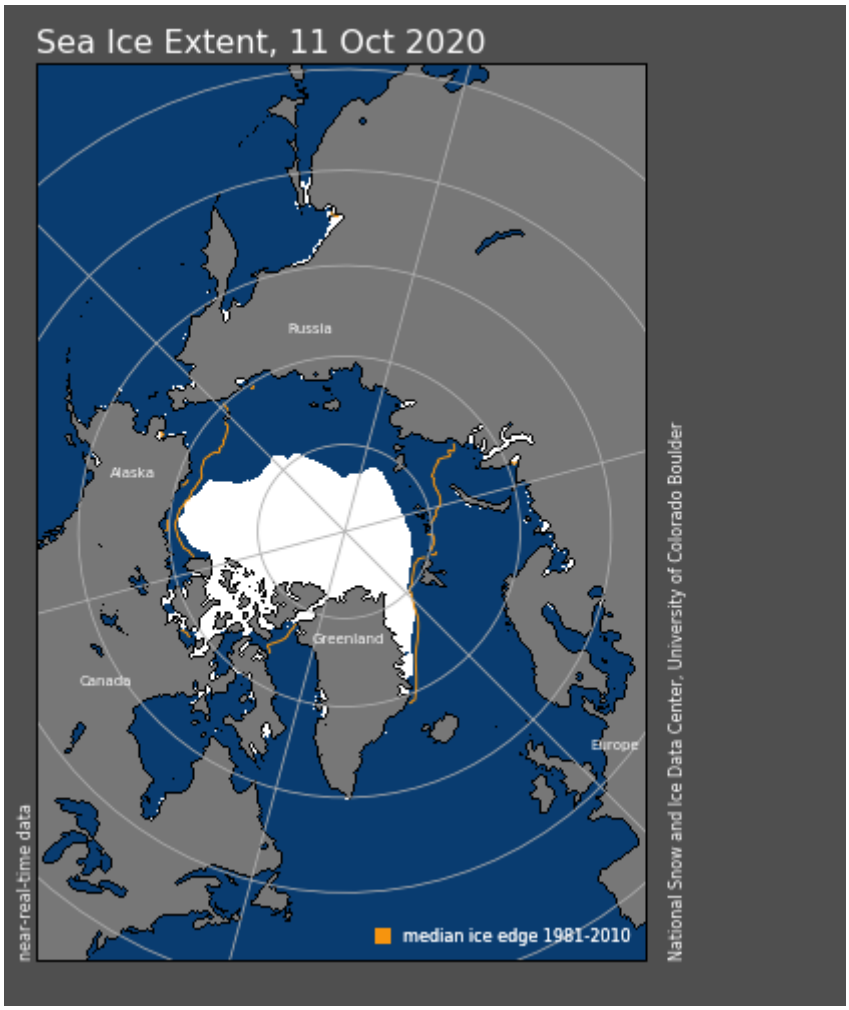

Figure 16. Observed Arctic sea ice extent on 11 October 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

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.

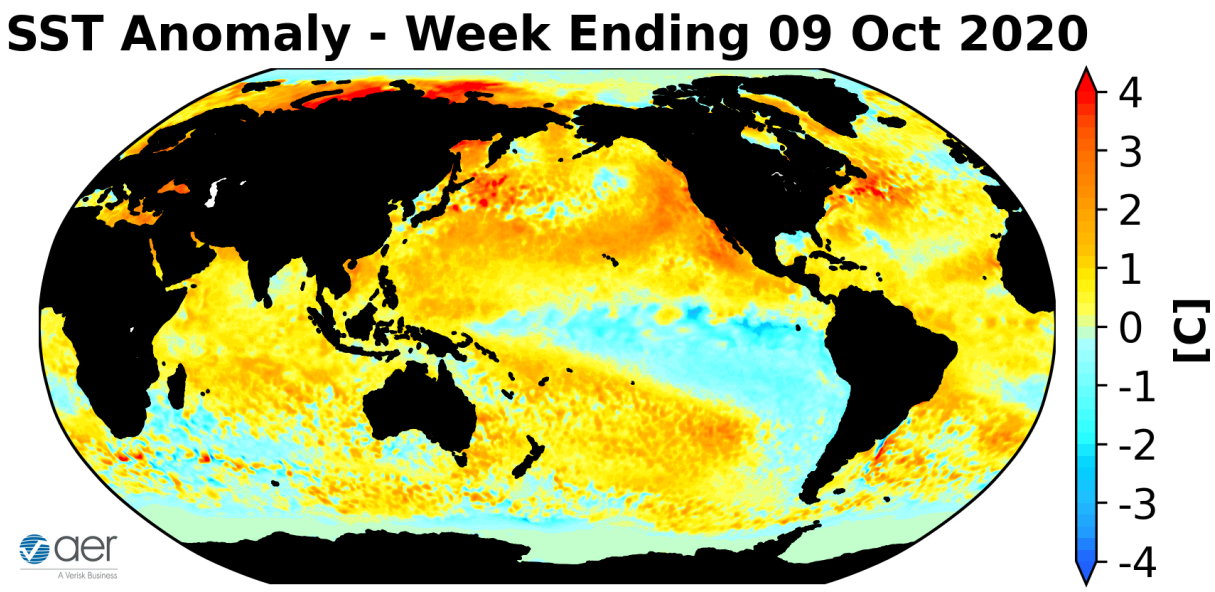

Figure 14. The latest weekly-mean global SST anomalies (ending 9 October 2020). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase four (**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.

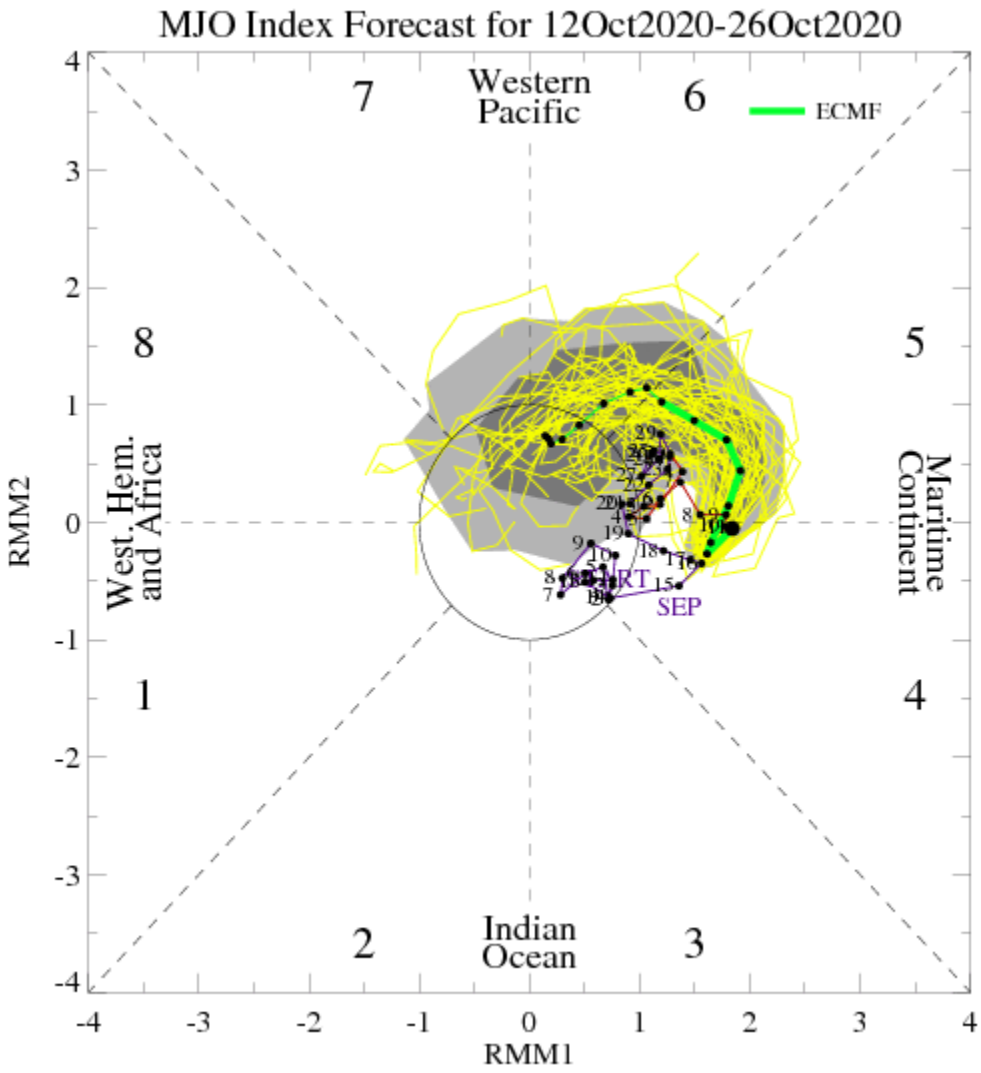

Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 12 October 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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