Arctic Oscillation and Polar Vortex Analysis and Forecasts

October 26, 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 positive and is predicted to straddle neutral to mostly positive over the next two weeks.
- The current positive AO is reflective of mostly negative pressure/geopotential height anomalies across the Arctic especially in the Central 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 this week and continue into next week as pressure/geopotential height anomalies are predicted to remain negative across Greenland the next two weeks.

- This week and into the middle of next week ridging/positive geopotential height anomalies with normal to above normal temperatures are predicted to become widespread across Europe including the United Kingdom (UK). However beginning in the middle of next week deepening troughing/negative geopotential height anomalies with normal to below normal temperatures in Western Russia will allow colder temperatures to bleed west into Eastern Europe from Siberia with ridging/positive geopotential height anomalies with normal to above normal temperatures for the remainder of Europe including the UK.
- Asia is predicted to be dominated this week by ridging/positive geopotential height anomalies with normal to above normal temperatures and troughing/negative geopotential height anomalies with normal to below normal temperatures limited to Western and Central Siberia. However next week, troughing/negative geopotential height anomalies with normal to below normal temperatures are predicted to become more widespread across Northern Asia.
- Currently strong ridging/positive geopotential height anomalies in the Gulf of Alaska are forcing deep troughing/negative geopotential height anomalies coupled with normal to below normal temperatures in most of Canada and the Western and Central United States (US) with more ridging/positive geopotential height anomalies and normal to above normal temperatures along the US Southeast Coast. However starting this week the Gulf of Alaska ridging/positive geopotential height anomalies with normal to above normal temperatures are predicted to spread east into the Western US forcing troughing/negative geopotential height anomalies accompanied by normal to below normal temperatures into eastern North America including the Eastern US.
- In the Impacts section I discuss the North American record cold and snow in contrast to the paucity of Eurasian snow and the strengthening polar vortex (PV).

Impacts

If you follow the weather, it is hard not to be impressed by the record cold and/or snow in Canada and the US. And talk about fire and ice – while Colorado is experiencing record wildfires, they also got hit by record cold and a foot and a half of snow! And some of the record cold in the Western US are not only daily records but even all-time monthly records. Maybe to me the most impressive chart is the rapid advance of North American snow cover this month (see **Figure 19**), which is likely unprecedented. And if you juxtapose the record cold and snow in the context of the continuous record warmth observed throughout the Northern Hemisphere (NH) this past spring and summer, the

record cold is even more impressive (**Figure i)**. In addition, the source region of NH cold – the Arctic, continues to experience record warmth and record low sea ice that is continuously heating the atmosphere from below.

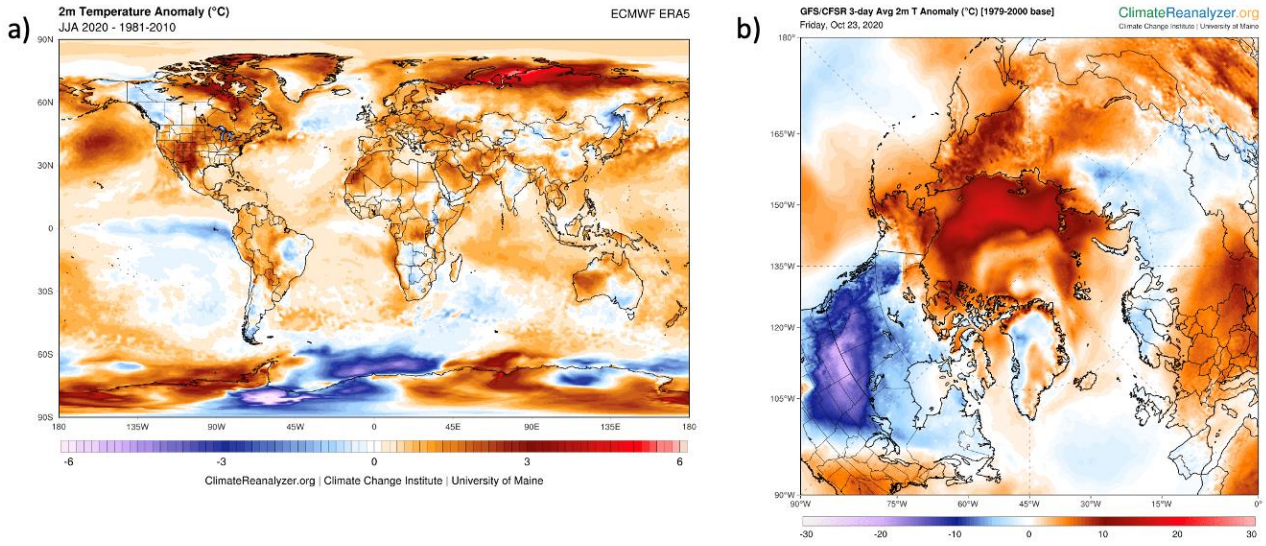

Figure i. (**a**) Observed surface temperature anomalies for June, July and August 2020 from the ERA5 reanalysis. (**a**) Observed surface temperature anomalies for three days ending on October 23, 2020. Plots are from https://climatereanalyzer.org/.

I saw on Twitter that climate change is understood to result in greater variability or large swings in the weather (and who doesn't believe what they read on Twitter?). But this Is not what the models predict with climate change but rather the opposite with damped variability or a decrease in weather volatility (e.g. Screen 2014). So how to contextualize the weather whiplash from record heat to record cold is not simple or straightforward. So what changed from September when warmth was nearly universal and snow and ice were at record lows to October where snow is record extensive and cold is intense and expansive (across North America at least)? Prior to September heating in the Arctic went into the Arctic ocean but after September the heating reverses and is currently out of the ocean. To my eye it is Occam's Razor the record warmth in the Arctic is related to the record cold across North America from looking at **Figure ib.** Of course, this is a controversial topic and the opinion I express here is probably the minority opinion where the majority opinion is that a warm Arctic contributes to a warmer and not colder mid-latitudes.

The record extensive snow cover across North America this month is a continuation of an impressive increasing trend in NH snow cover extent (**Figure ii)**. This observed increasing trend was not predicted by our climate models and I believe is hard to explain without invoking some external forcing and to me - accelerated Arctic warming

is as good as a source as any other forcing that comes to mind including natural variability.

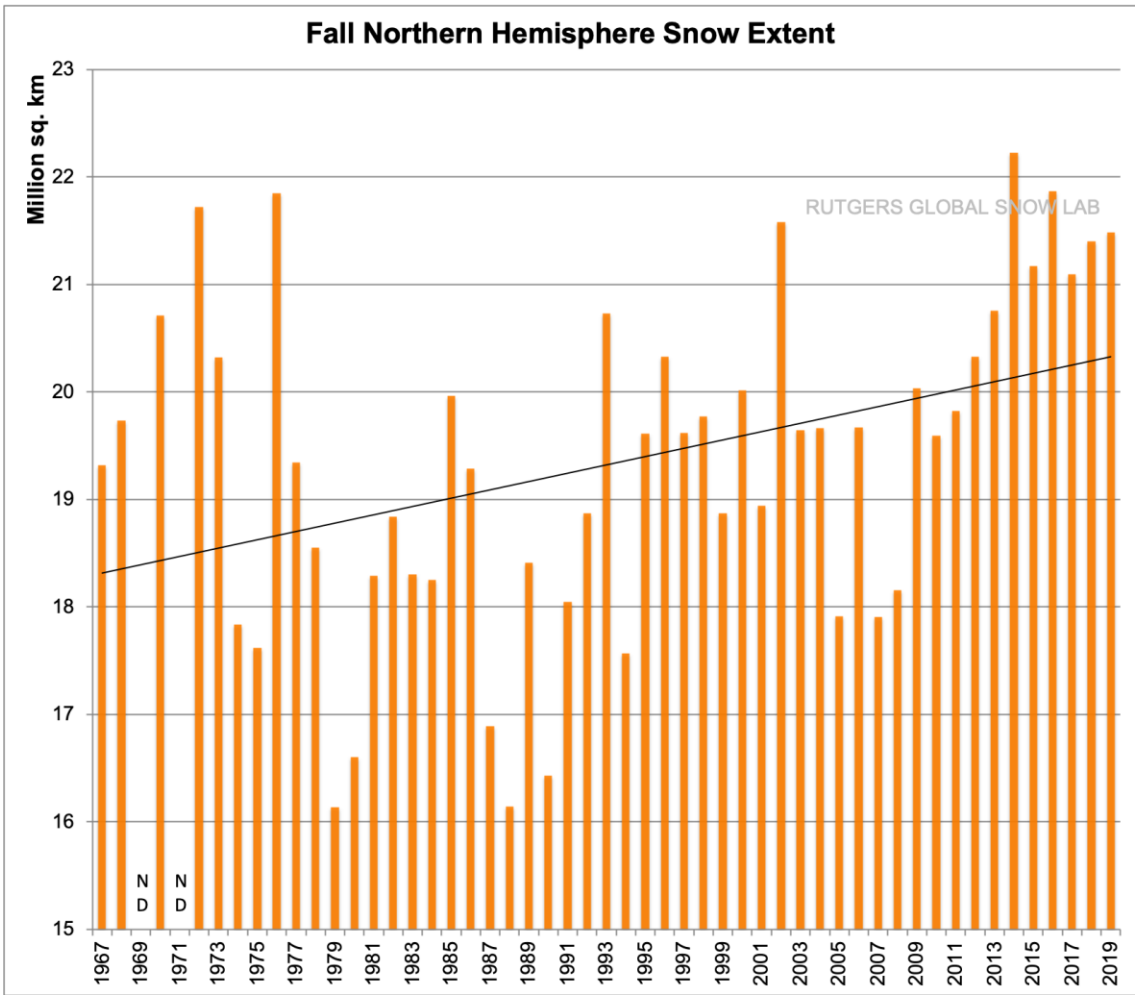

Figure ii. Plot of Northern Hemisphere fall snow cover extent including the trend line. Plot available from https://climate.rutgers.edu/snowcover/.

The increasing snow cover extent (SCE) trend is not limited to North America but includes Eurasia. I focus on the month of October, which is the pivotal fall month and over the past two decades only a handful of years has SCE been normal to slightly below normal with only 2007 and 2008 being close to one standard deviation below normal. This year it does seem that the record SCE across North America has come at the expense of Eurasia with a relatively anemic advance this month. In **Figure iii** I show the daily Eurasian SCE for October for the past fifteen years and on this date 2020 currently shares the bottom two spots with 2011. 2011 was also a La Niña fall and winter and I did find the Eurasian SCE tends to be lower in La Niña relative to El Niño falls. The snow advance index (SAI; Cohen and Jones 2011) is also currently below

normal. Below normal SCE and SCE and SAI suggest a stronger winter PV and subsequently relatively mild temperatures across the mid-latitudes of the NH.

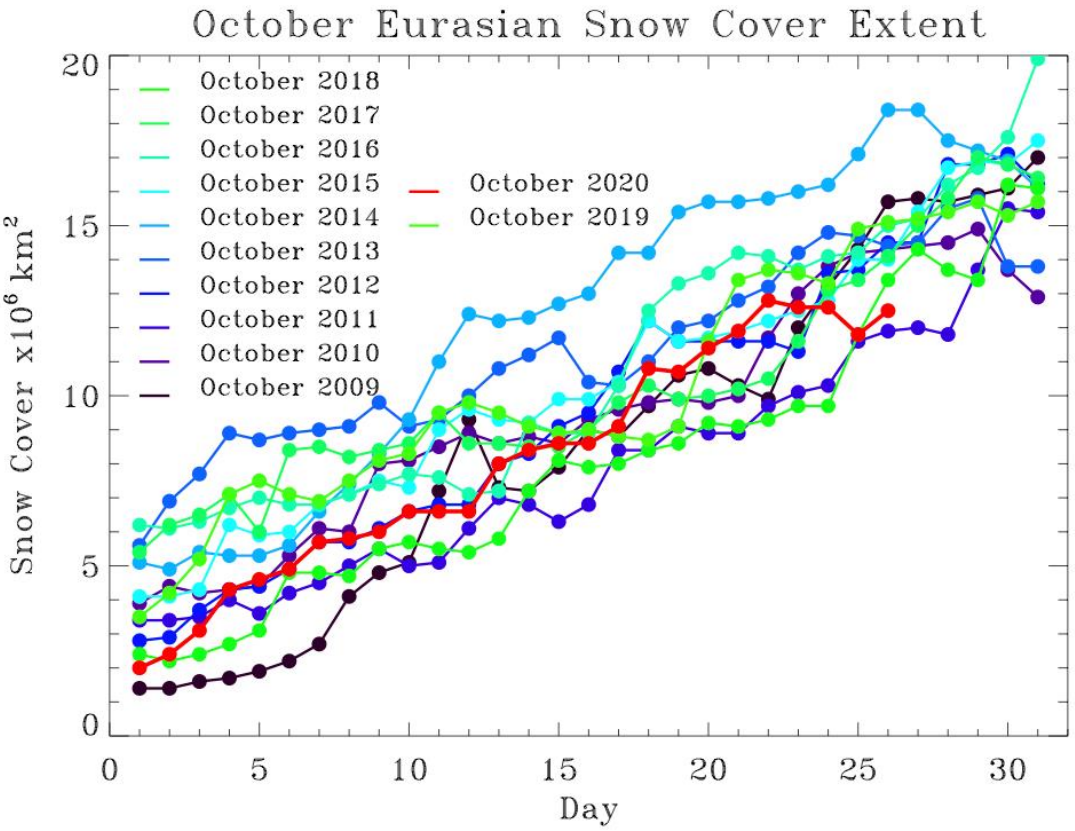

Figure iii. Daily Eurasian snow cover extent from 2005 through 2020.

Speaking of the PV, it is looking very healthy over the next two weeks. It is predicted to be centered near the North Pole with lowering geopotential heights and mostly zonal or straight west to east flow counterclockwise around the center of low pressure (**Figure iv**). There is the risk that the strong PV couples with the troposphere all the way to the surface (as happened for much of last winter) in the coming weeks, resulting in an overall mild pattern across the mid-latitudes of the NH. That the stratospheric PV is relatively strong in the fall is not that unusual in recent years but if the cold/negative stratospheric polar cap geopotential height anomalies (PCHs) couple with the troposphere, cold/negative PCHs in the troposphere is unusual in the fall. It last happened in 2015 and before that 2013 but especially 2011. Comparisons to 2011 seem to keep coming up and if it snows the end of the month here in Southern New England, that will be yet another eerie similarity to 2011. There was no significant weakening of the PV that winter and North America was very mild that winter, though Eurasia experienced widespread below normal temperatures. Though to be clear I am not expecting a repeat of the 2011/12 winter, at least not yet.

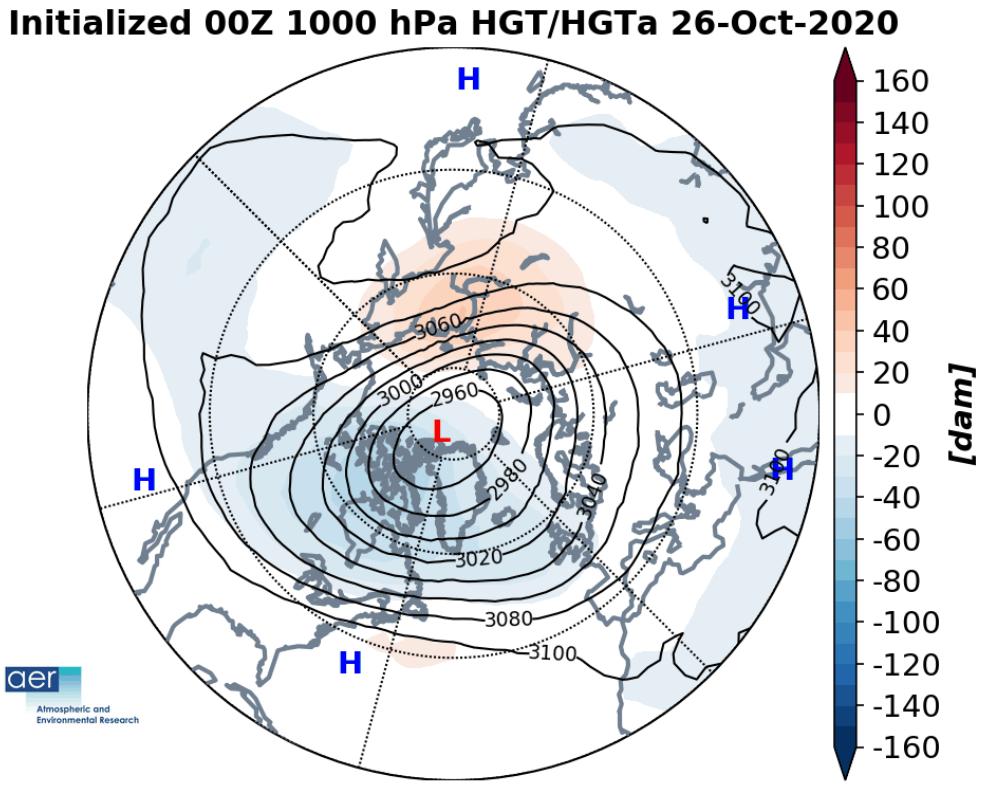

Figure iv. Animation of 10 mb geopotential heights (dam; contours) and anomalies (decameters; shading) from 26 October - 11 November 2020.

The atmospheric feature most likely to weaken the PV over the coming weeks and even months is Ural/Scandinavian high pressure or blocking. The end of last week, the GFS was not predicting any high latitude blocking including near the Urals/Scandinavia, but the ECMWF model was. I don't know how to explain the model differences but circling back to whether the Arctic can influence our weather, if the lack of sea ice and the release of heat from the ocean to the atmosphere can heat up not only the boundary layer but the atmospheric column through at least the mid-troposphere, seems reasonable to lean towards the ECMWF solution. I will be interested to see which model is correct in the end. According to the GFS solution there is little reason to expect any meaningful weakening of the PV in the foreseeable. However, based on the ECMWF forecasts an eventual weakening of the PV seems more likely.

1-5 day

The AO is currently positive **(Figure 1**) with mostly negative 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.

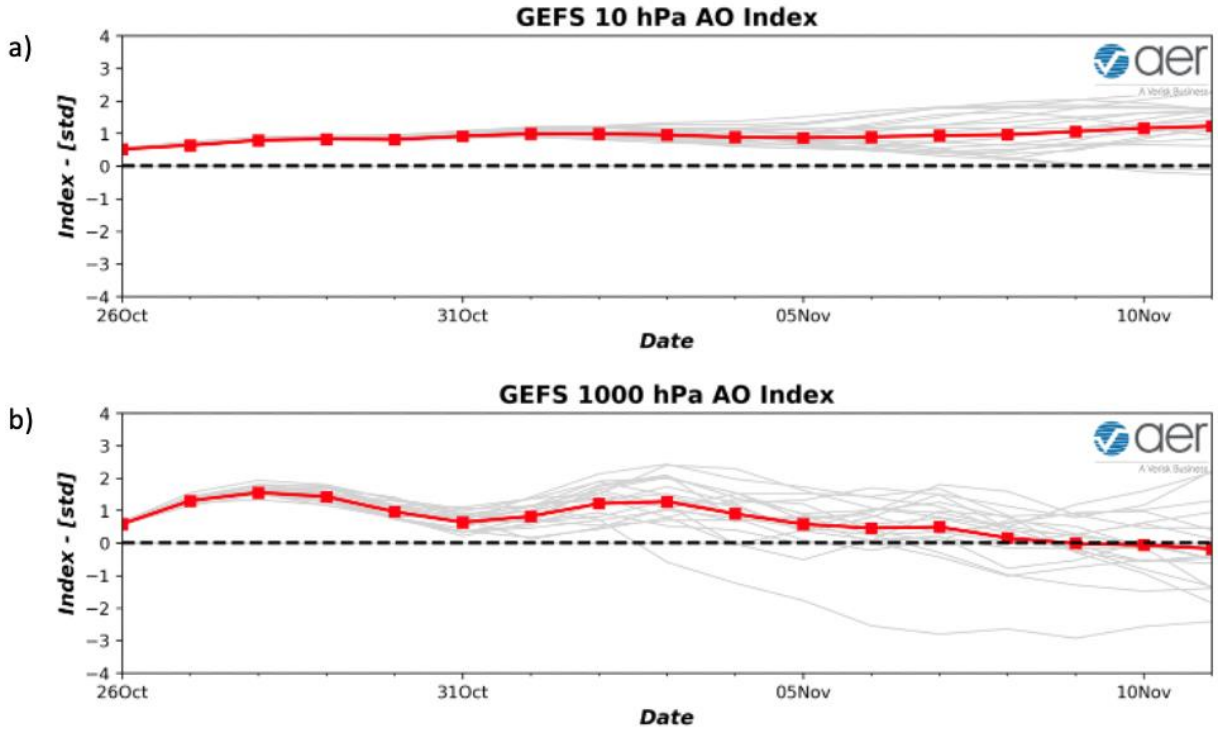

Figure 1. (**a**) The predicted daily-mean AO at 10 hPa from the 00Z 26 October 2020 GFS ensemble. (**b**)The predicted daily-mean near-surface AO from the 00Z 26 October 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies are predicted to dominate much of Europe with troughing/negative geopotential height anomalies limited to Northwestern Europe (**Figure 2**). This pattern favors normal to above normal temperatures for much of Europe with more seasonable temperatures in Western Europe including the UK (**Figure 3**). Across Asia this week, ridging/positive geopotential height anomalies are predicted to be widespread with troughing/negative geopotential height anomalies limited to Central Asia (**Figure 2**). This pattern favors widespread normal to above normal temperatures for much of Asia with normal to below normal temperatures mostly limited to Western and Central Siberia and parts of Central Asia **(Figure 3**).

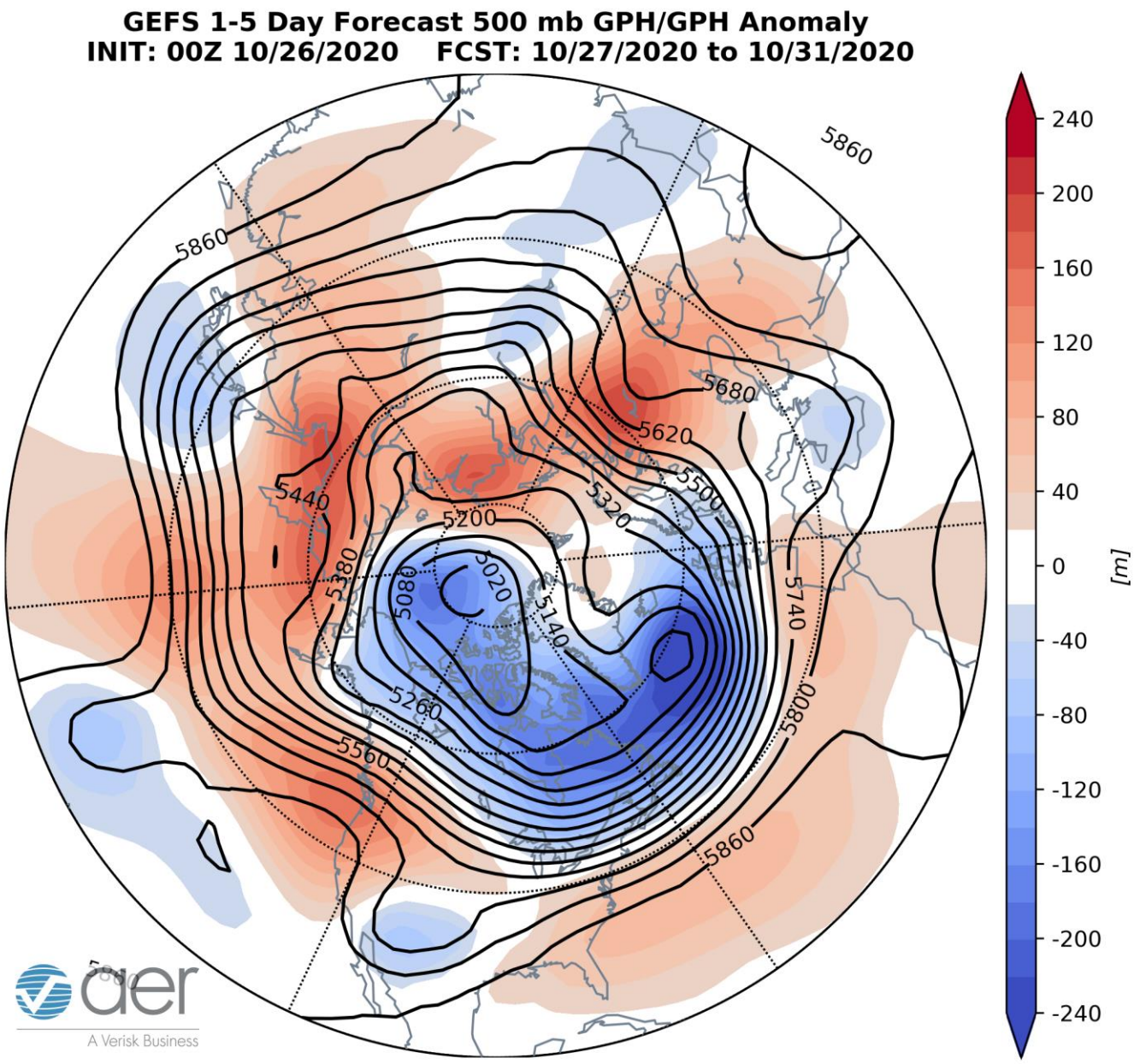

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 27 – 31 October 2020. The forecasts are from the 00z 26 October 2020 GFS ensemble.

This week predicted strong ridging/positive geopotential height anomalies in the Gulf of Alaska will force troughing/negative geopotential height anomalies downstream across much of Canada and the Central US with more ridging/positive geopotential height anomalies in the Southeastern US **(Figure 2).** This pattern is predicted to bring normal to above normal temperatures across Alaska, the Southwestern US and the

Southeastern US with normal to below normal temperatures for much of Canada and the Central and Northeastern US **(Figure 3).**

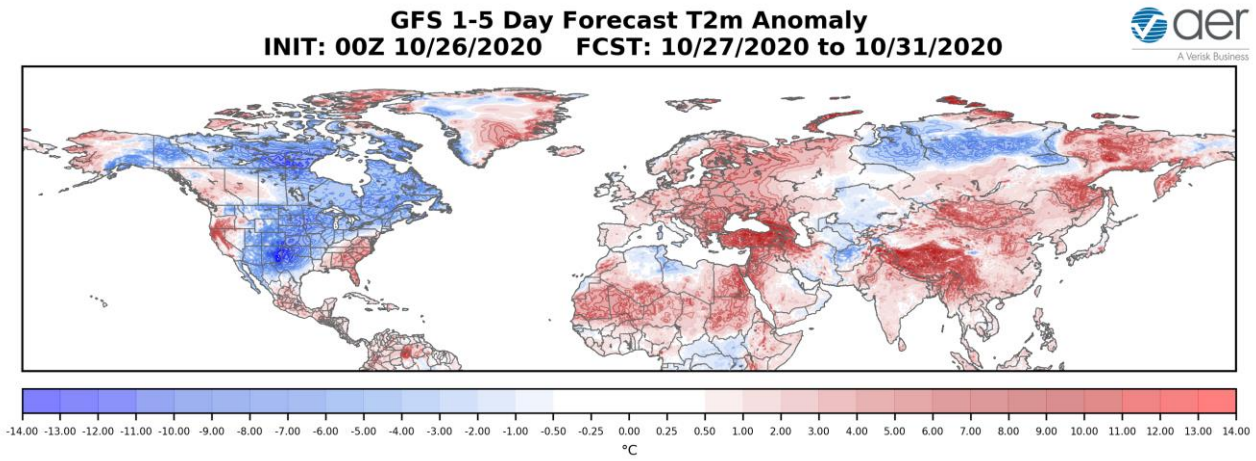

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 27 – 31 October 2020. The forecast is from the 00Z 26 October 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across Siberia while warmer temperatures will cause snow melt in Scandinavia and Northwestern Asia (**Figure 4**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, Northern and Eastern Canada and possibly New England while warmer temperatures will cause snow melt in Southwestern Canada and the US Plains (**Figure 4**).

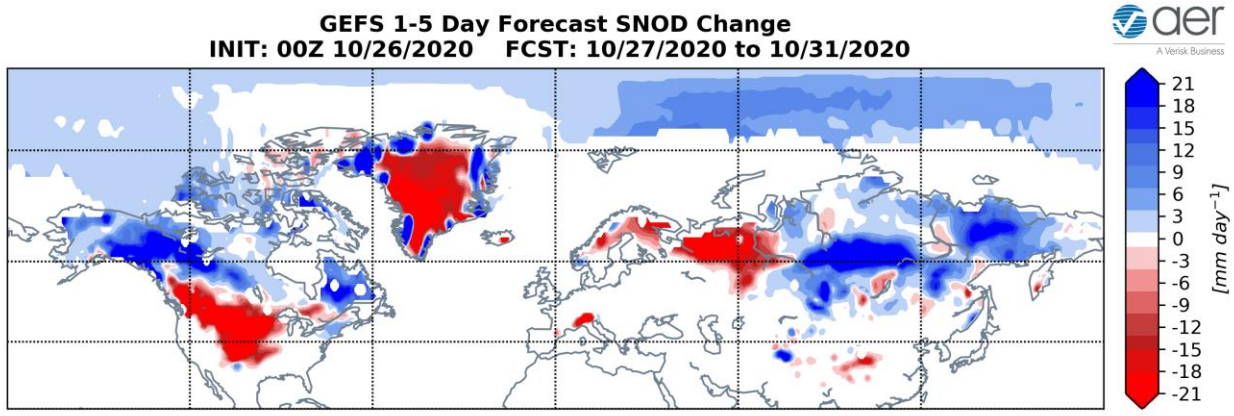

Figure 4. Forecasted snow depth changes (mm/day; shading) from 27 – 31 October 2020. The forecast is from the 00Z 26 October 2020 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain positive next week (**Figure 1**) as negative geopotential height anomalies dominate the Arctic especially the Canadian Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with the persistent negative geopotential height anomalies predicted across Greenland (**Figure 5**), the NAO is predicted to remain positive as well.

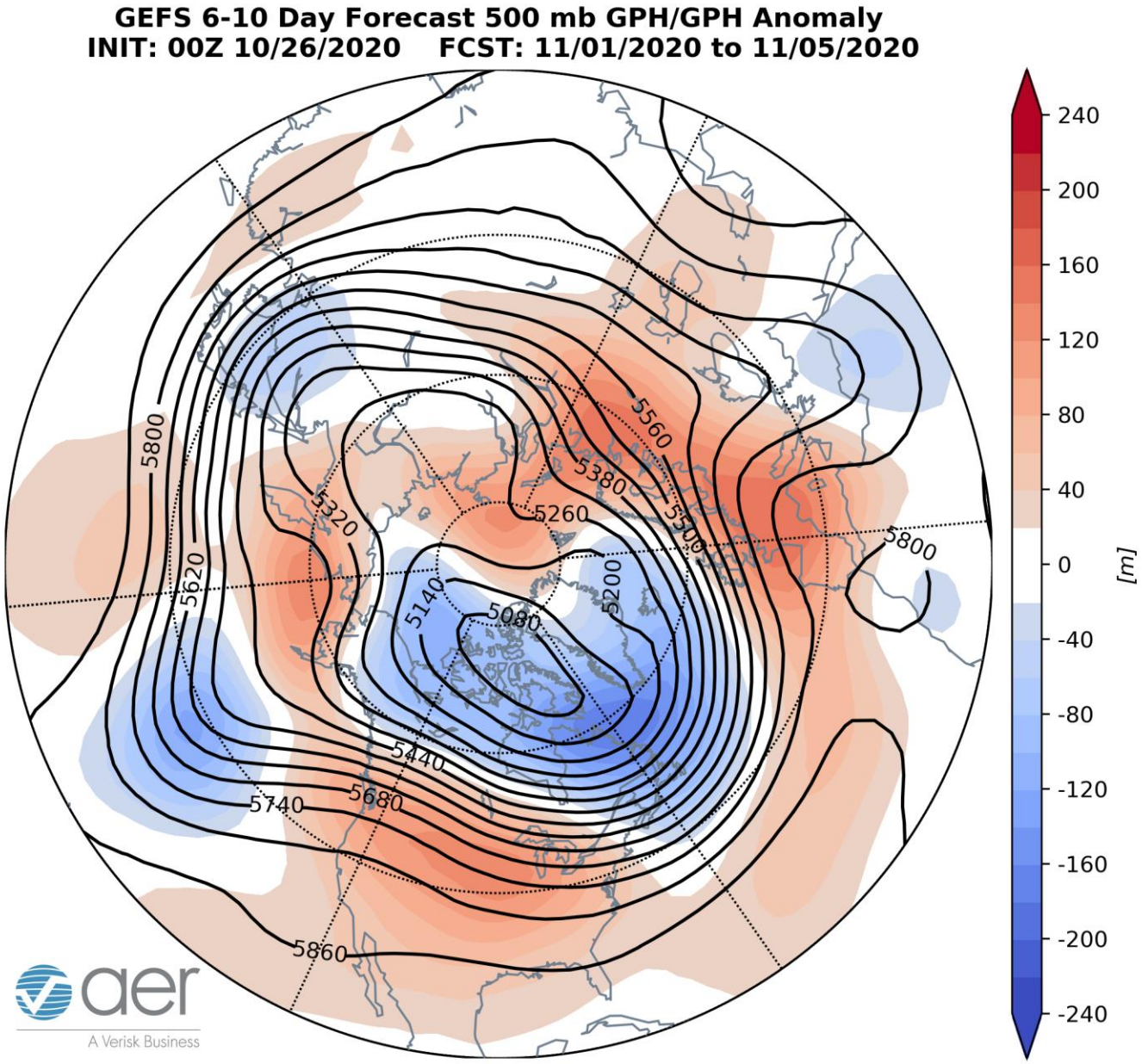

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 1 – 5 November 2020. The forecasts are from the 00z 26 October 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to dominate all of Europe (**Figures 5).** This pattern favors normal to above normal temperatures across all of Europe including the UK (**Figure 6**). Ridging/positive geopotential height anomalies are predicted to persist across Western Asia with previous troughing/negative geopotential height anomalies in Central Asia expanding into Eastern Asia this period (**Figure 5**). This is predicted to expand normal to below normal temperatures in Siberia into parts of East Asia but most of Asia will continue to experience normal to above temperatures **(Figure 6**).

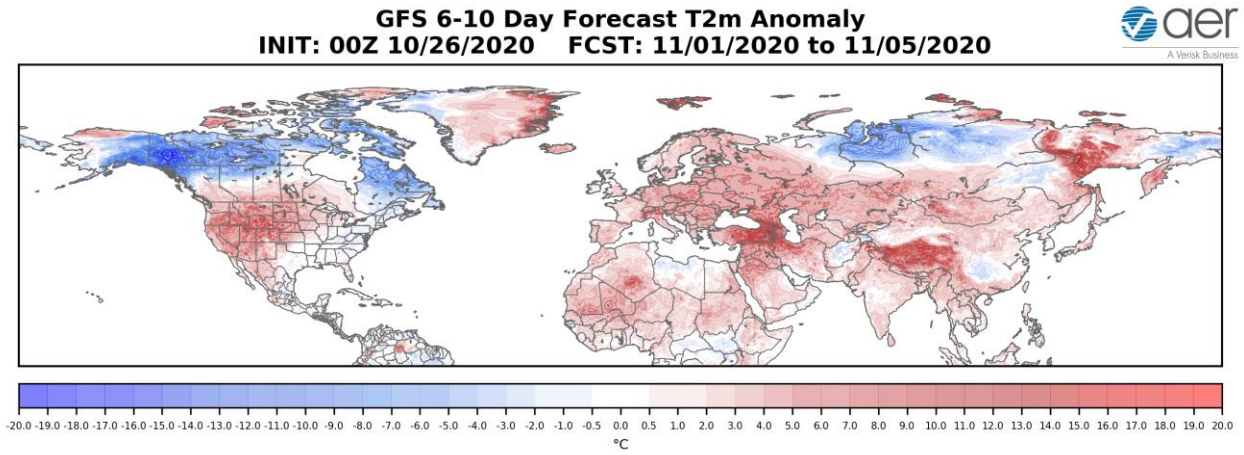

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 1 – 5 November 2020. The forecasts are from the 00Z 26 October 2020 GFS ensemble.

Ridging/positive geopotential height anomalies previously in the Gulf of Alaska are predicted to move bodily over the US and become centered over the Central US with troughing/negative geopotential height anomalies in Alaska, Northern and Eastern Canada this period **(Figure 5).** This pattern is predicted to bring widespread normal to below normal temperatures across Alaska, Northern and Eastern Canada and possibly New England with normal to above normal temperatures across Western and Southern Canada and the Western and Central US **(Figure 6).**

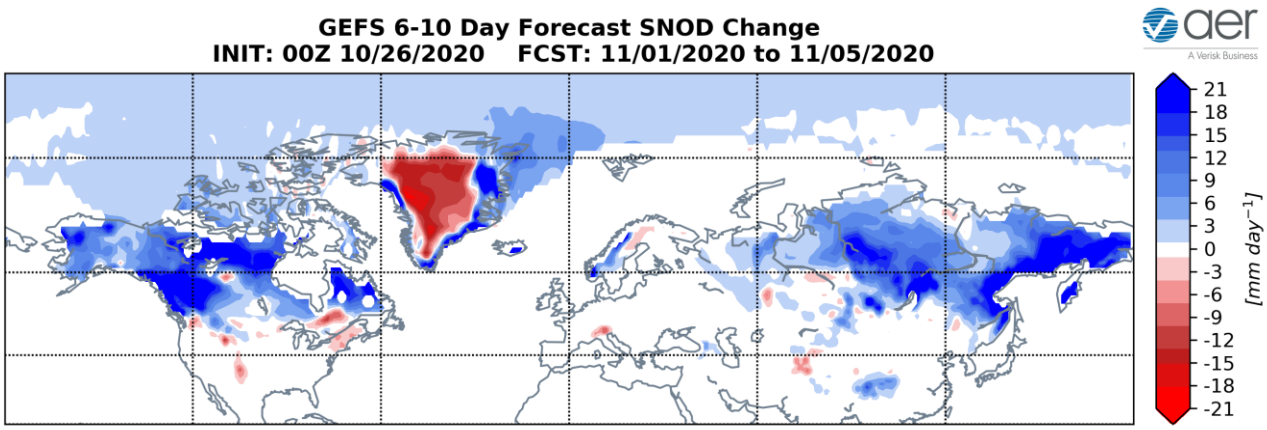

Figure 7. Forecasted snow depth changes (mm/day; shading) from 1 – 5 November 2020. The forecasts are from the 00Z 26 October 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across Scandinavia, Siberia, Northeast Asia and the Himalayas (**Figure 7**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska and much of Canada while warmer temperatures will cause snow melt in Southeastern Canada and New England (**Figure 7**).

11-15 day

With the return of some positive geopotential height anomalies across the Eurasian Arctic and North Pole with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO is predicted to trend neutral this period (**Figure 1**). With mostly negative pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is predicted to remain positive.

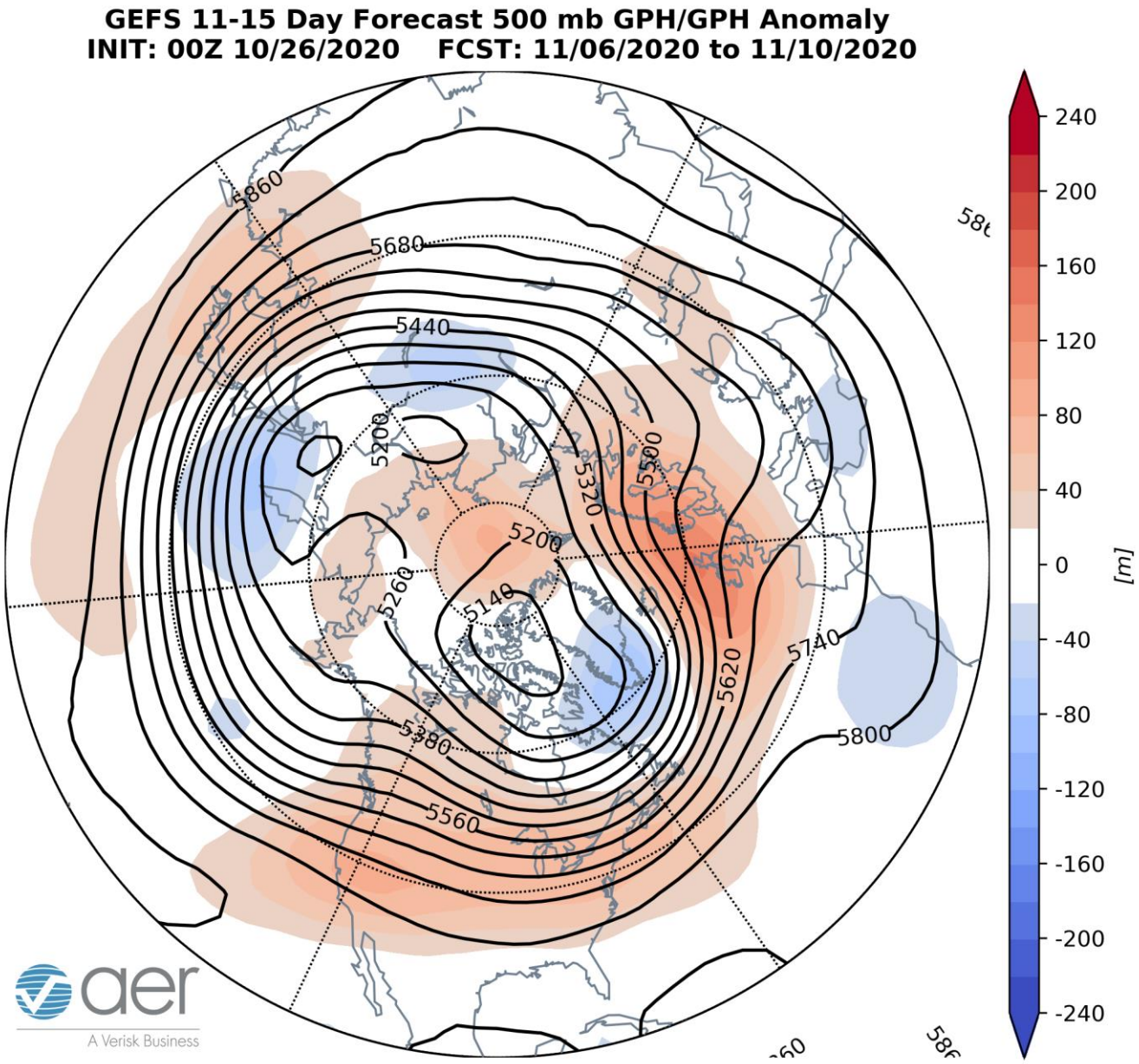

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 6 – 10 November 2020. The forecasts are from the 00z 26 October 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to still dominate Europe but centered over Scandinavia, however troughing/negative geopotential height anomalies in Western Asia are predicted to trail southwestward towards Southeastern Europe this period (**Figures 8**). The forecast is for normal to above normal temperatures across most of Europe including the UK with normal to below normal temperatures bleeding into Eastern Europe from Siberia this period (**Figures 9**). Predicted ridging/positive geopotential height anomalies over Scandinavia will support

expanding troughing/negative geopotential height anomalies across Central and East Asia this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across most of Asia with normal to below normal temperatures in Northern Asia but mostly in Siberia (**Figure 9**).

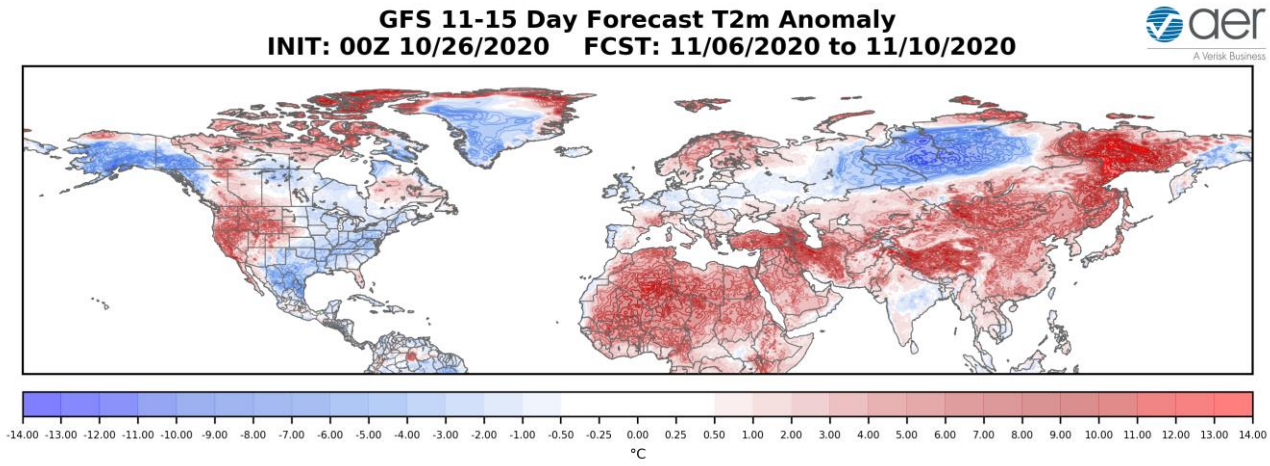

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 6 – 10 November 2020. The forecasts are from the 00z 26 October 2020 GFS ensemble.

Ridging/positive geopotential height anomalies previously in the Gulf of Alaska are predicted to become widespread across North America with troughing/negative geopotential height anomalies confined to Alaska and Eastern Canada (**Figure 8**). This pattern favors widespread normal to above normal temperatures across Western Canada and the Western US with normal to below normal temperatures for Eastern Canada with some of those colder temperatures filtering into the Eastern US (**Figure 9**).

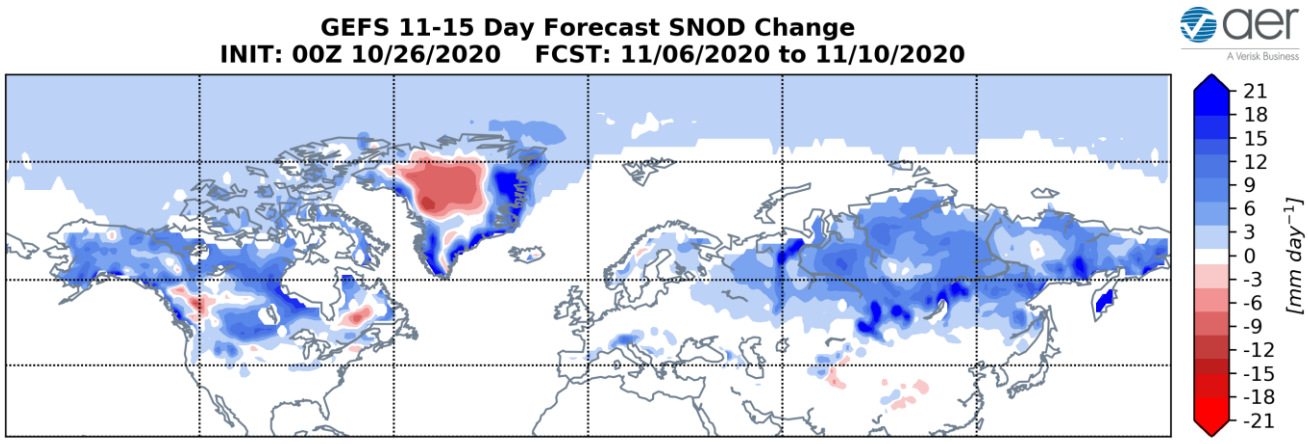

Figure 10. Forecasted snow depth changes (mm/day; shading) from 6 – 10 November 2020. The forecasts are from the 00z 26 October 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across much of Northern Eurasia and the Alps (**Figure 10**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, the Northern Rockies and much of Canada while warmer temperatures will cause snow melt in Southwestern Canada and Quebec (**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 cold/negative PCHs in the stratosphere over the next two weeks (**Figure 11**). The cold/negative PCHs are predicted to continually strengthen in the stratosphere through early November (**Figure 11**).

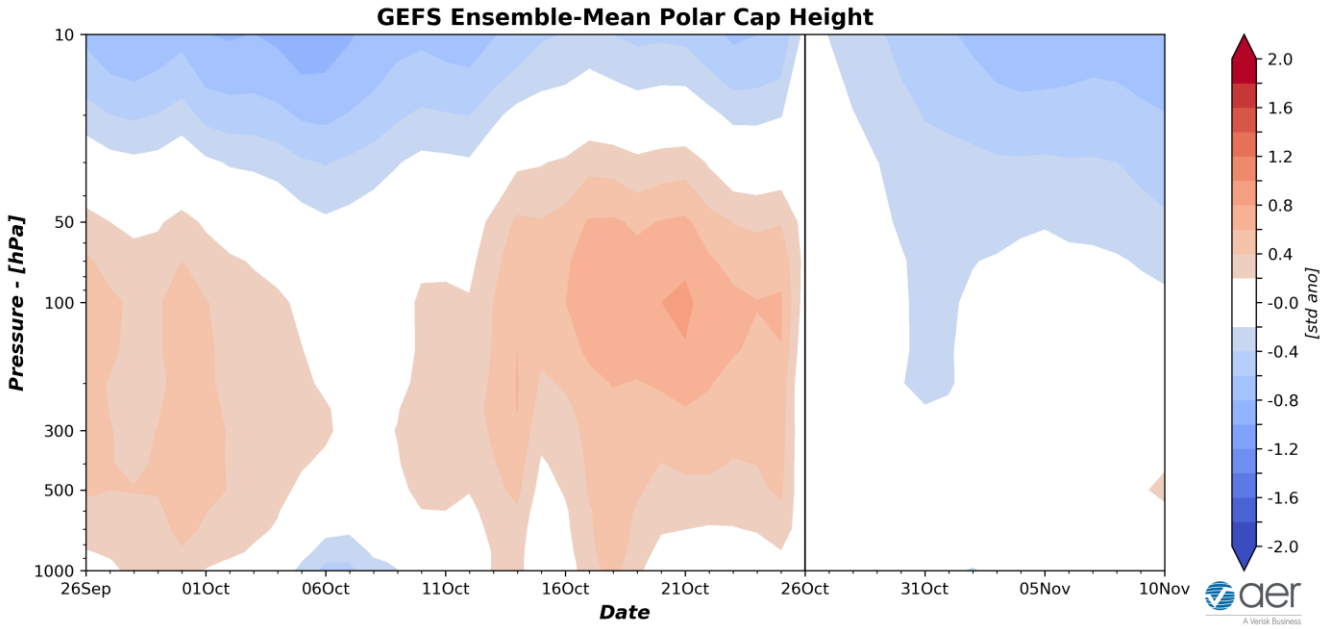

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 26 October 2020 GFS ensemble.

The current weak PCHs in the lower troposphere are consistent with the predicted near neutral to positive AO the next couple of weeks (**Figure 1**). The forecast of neutral PCHs in the troposphere for the entire two weeks, is likely a sign of low confidence in the forecast and a possibly volatile forecast.

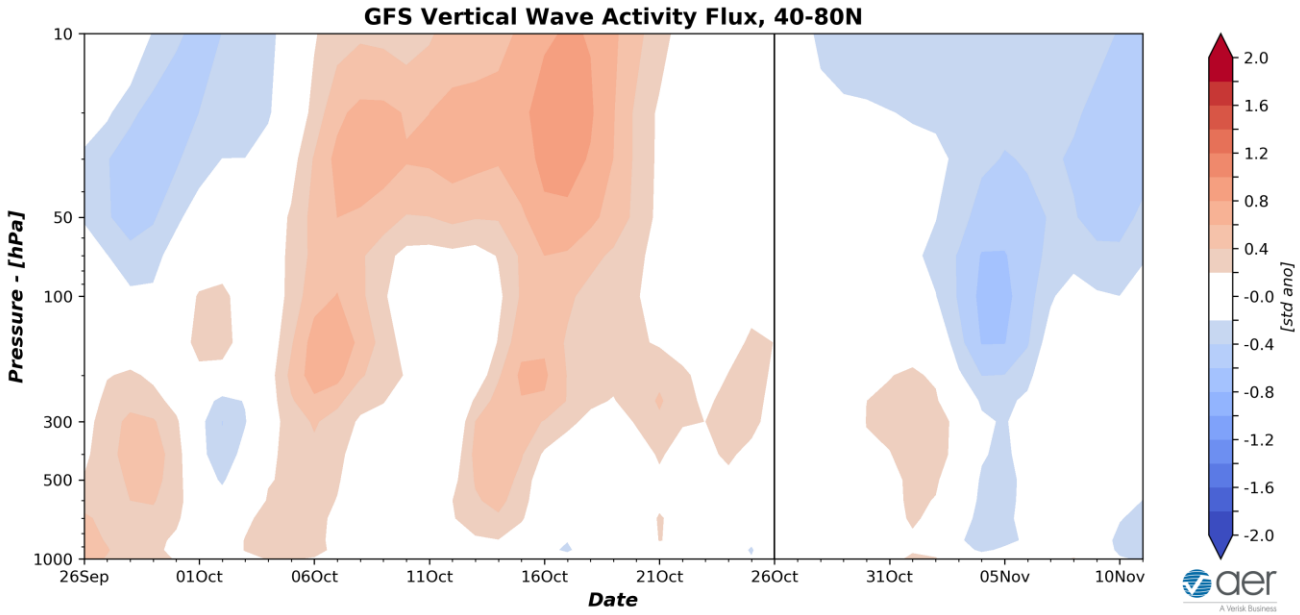

Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 26 October 2020 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows the active WAFz of October to be followed by a much quieter early November (**Figure 12**). I still believe that the active WAFz of mid-October resulted in a minor disruption of the PV in the form of stretching that is related to the record cold weather across North America. The predicted quieter period of WAFz could result in an upcoming milder period for North America.

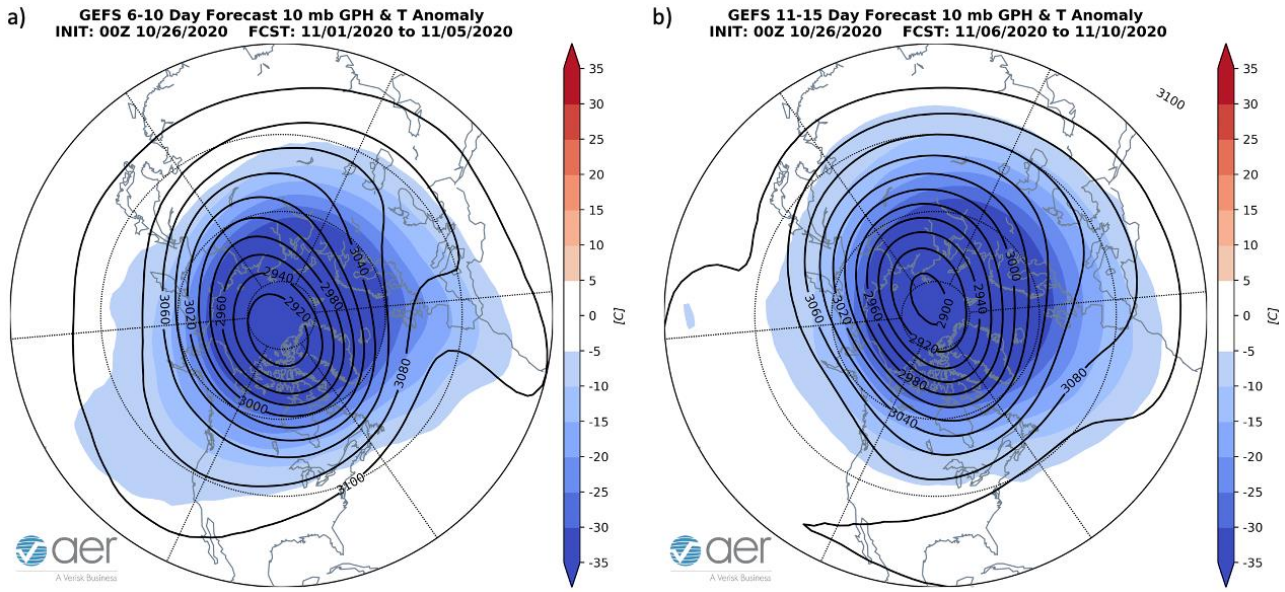

Figure 13. (**a**) Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 1 –5 November 2020. (**b**) Same as (a) except forecasted averaged from 6 – 10 November 2020. The forecasts are from the 00Z 26 October 2020 GFS model ensemble.

The upcoming quieter period of WAFz (**Figure 12**) will support a strengthening PV. The PV is predicted to take up a position near the North Pole and deepen (**Figure 13**). Currently there are no signs of any weakening of the PV.

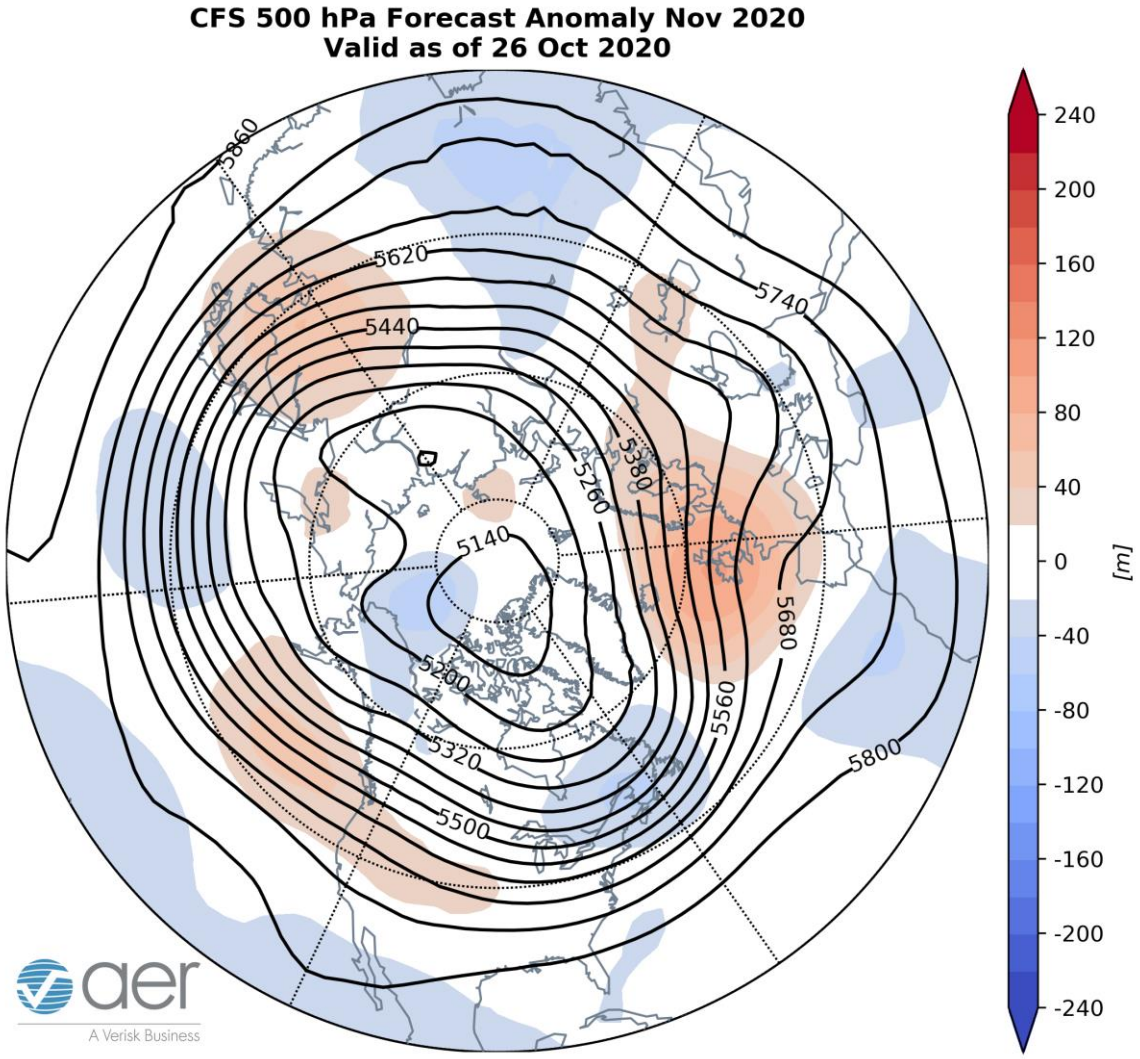

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for November 2020. The forecasts are from the 00Z 26 October 2020 CFS.

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 Northwest Europe, East Asia, and the Gulf of Alaska with troughing in Southeastern Europe, Central Asia, Siberia, Alaska and the Canadian Maritimes and into New England (**Figure 14).** This pattern favors relatively warm temperatures for much of Europe centered on Scandinavia, Northern Asia and much of North America with seasonable to relatively cold temperatures for Southern Europe, Southern Asia, the Canadian Maritimes and New England (**Figure 15**).

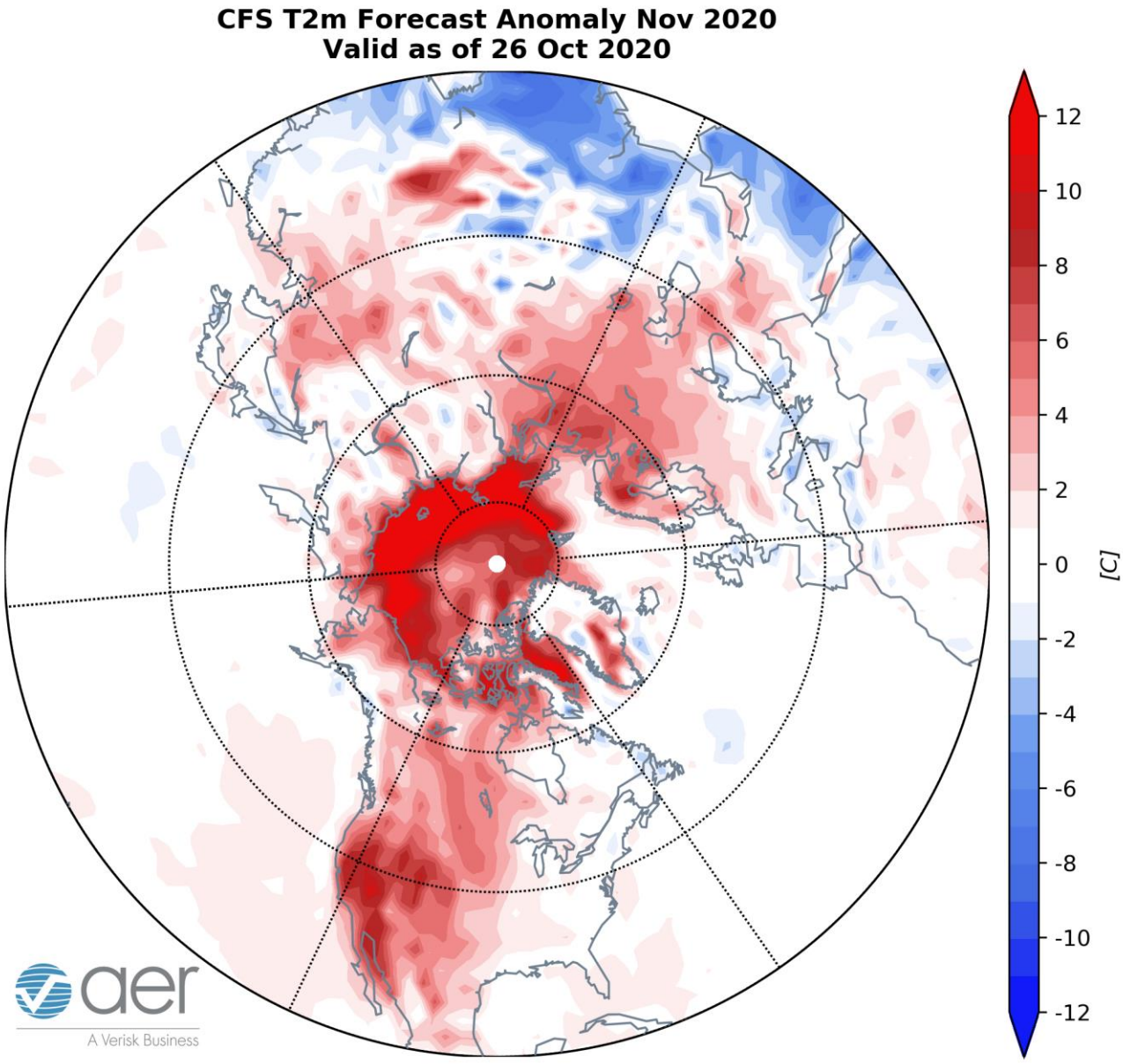

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for November 2020. The forecasts are from the 00Z 26 October 2020 CFS.

Surface Boundary Conditions

Arctic sea ice extent

Arctic sea ice continues to grow at a record slow rate and is currently well below any previous year on this date. Large negative sea ice anomalies exist continuously from Alaska to the Barents-Kara Seas (**Figure 16**). 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.

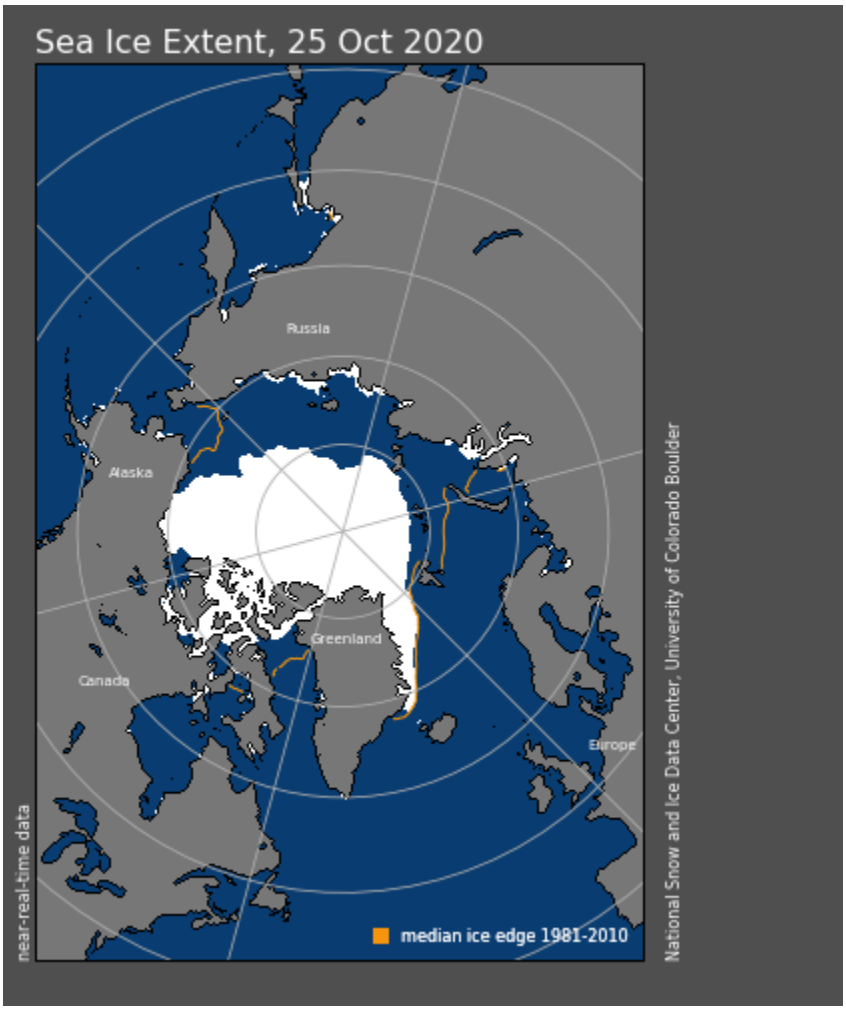

Figure 16. Observed Arctic sea ice extent on 25 October 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies continue to cool slowly and we have now entered weak to moderate 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.

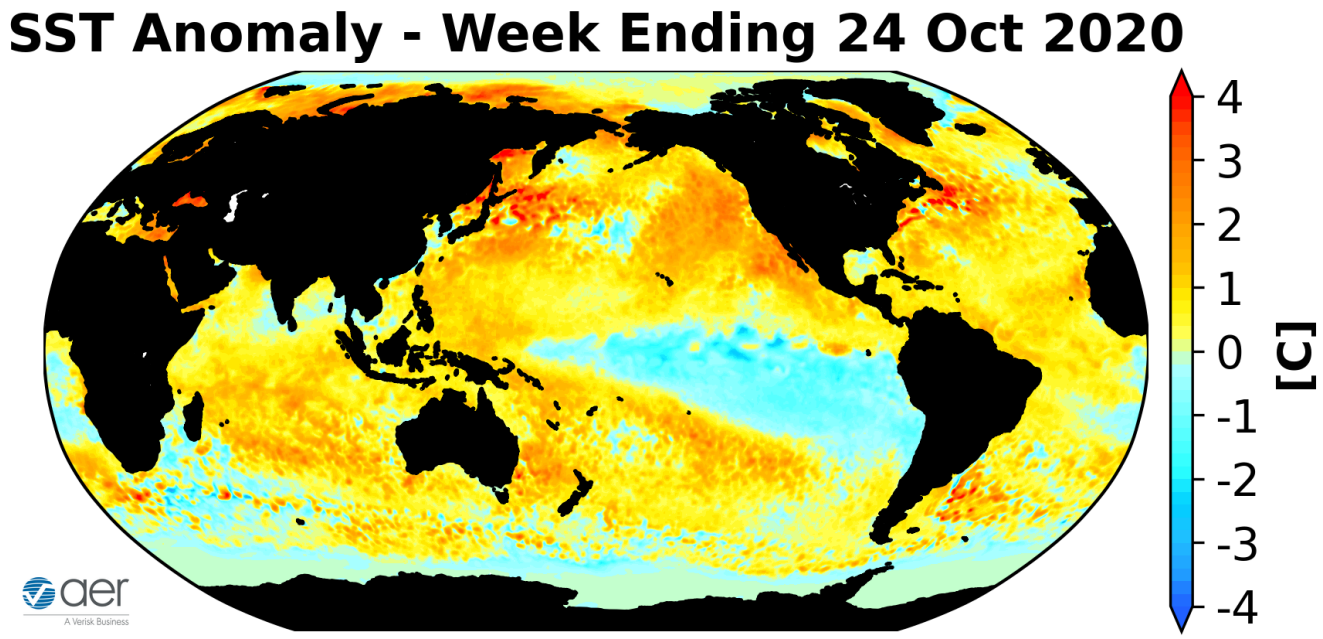

Figure 17. The latest weekly-mean global SST anomalies (ending 24 October 2020). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase five (**Figure 15**). The forecasts are for the MJO to weaken 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.

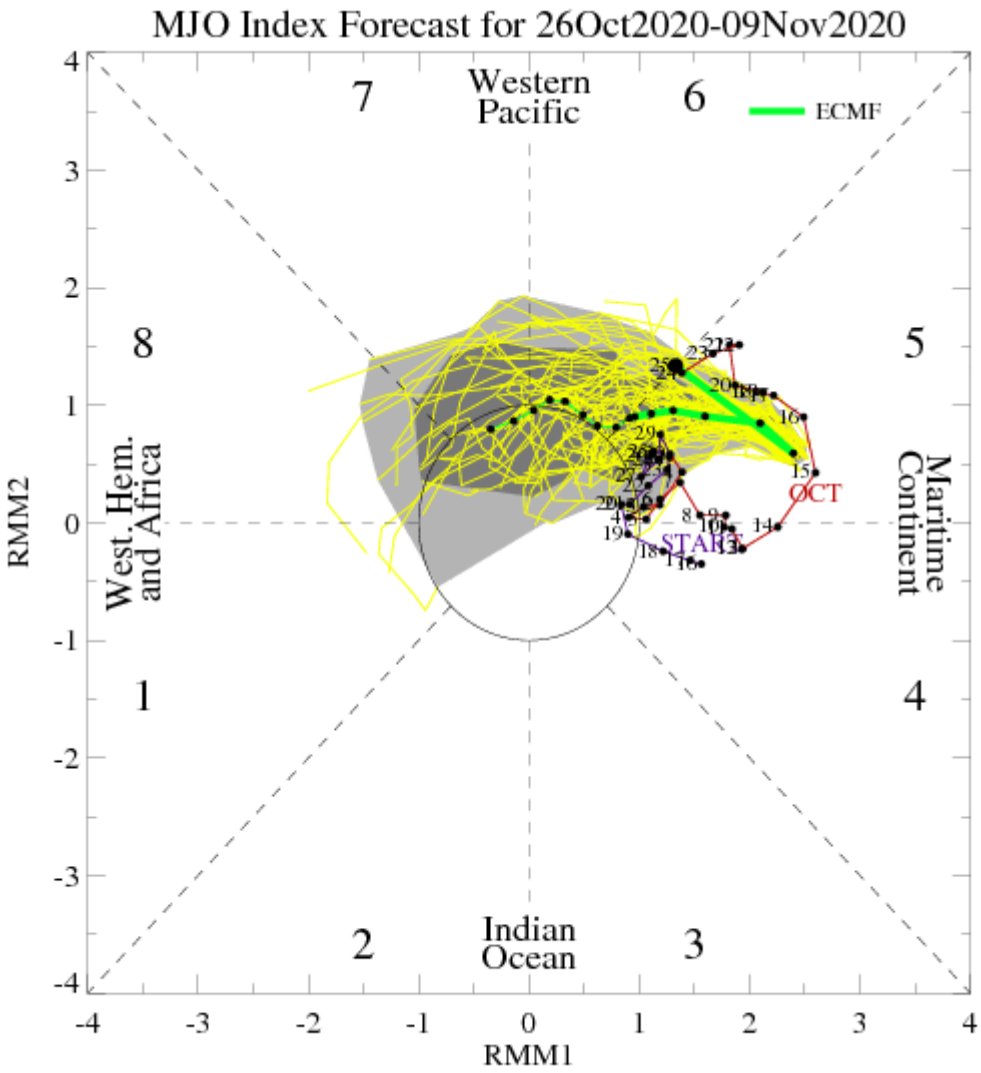

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 26 October 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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

Northern Hemisphere Snow Cover

Snow cover advance continues its climb across Eurasia and is currently on the low end of decadal means. Snow cover advance will likely continue to advance especially across East Asia the next two weeks as troughing and cold temperatures spread across east across the region. Above normal snow cover extent in October, favors a strengthened Siberian high, cold temperatures across northern Eurasia and a weakened polar

vortex/negative AO this upcoming winter followed by cold temperatures across the continents of the NH.

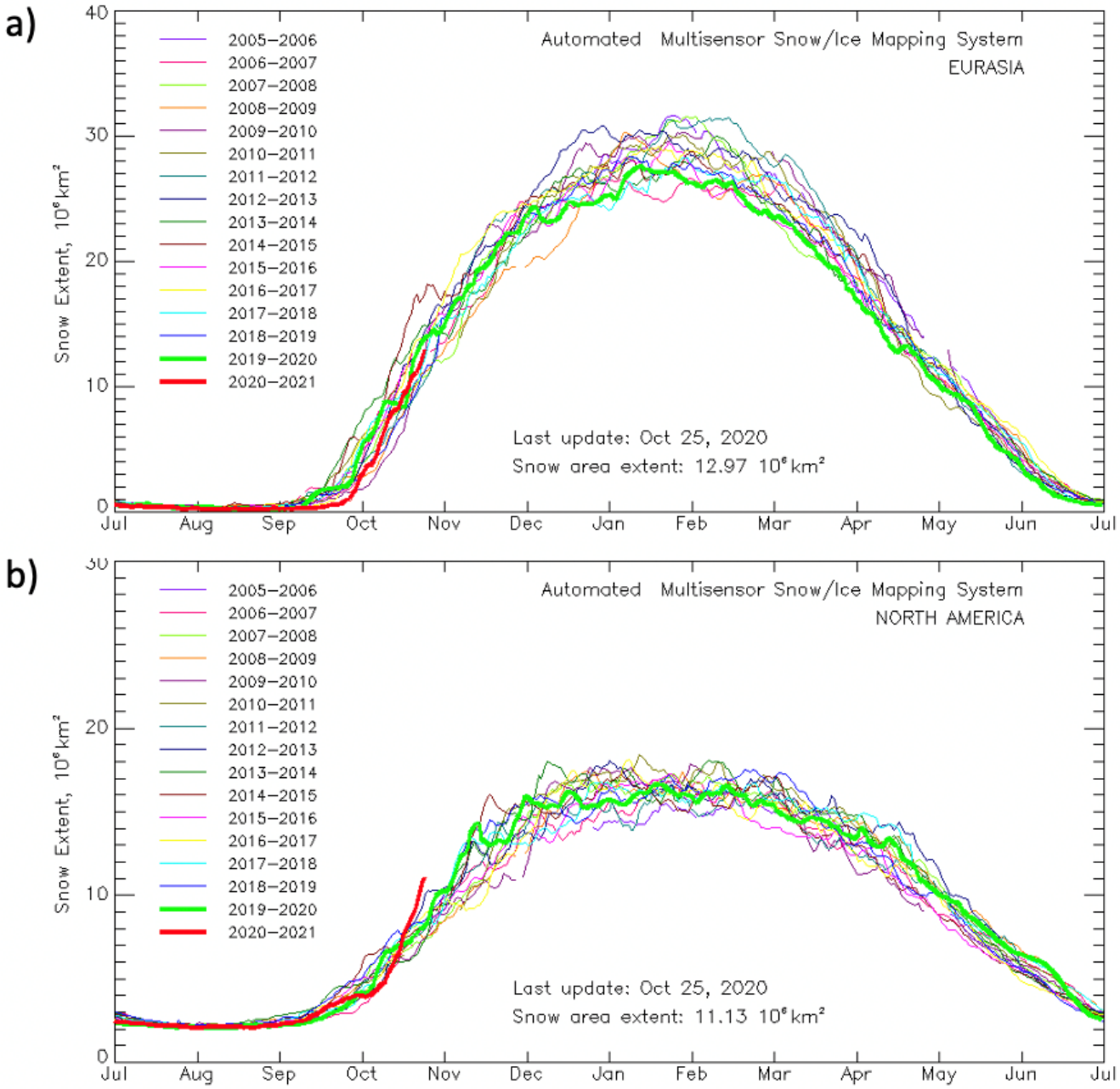

Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 25 October 2020. Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover experienced explosive advance to likely record highs. The early advance of snow cover across Canada this fall, has likely contributed to an early start of cold temperatures across the Central US.