October 17, 2019

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.

With the start of spring we transitioned 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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Summary

- The Arctic Oscillation (AO) is currently weakly negative and is predicted to remain mostly negative for the next two weeks.
- The current negative AO is reflective of mostly positive pressure/geopotential height anomalies across the Arctic and mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is negative with mostly positive pressure/geopotential height anomalies spread across Greenland and Iceland; and the NAO is predicted to remain negative as geopotential height anomalies are predicted to remain positive across Greenland over the next two weeks.
- Ridging/negative geopotential height anomalies with seasonable to above normal temperatures currently dominate much of Europe with troughing/negative

geopotential height anomalies and below normal temperatures limited to far Western Europe including the United Kingdom (UK) and Scandinavia. However, the forecast is for troughing/negative geopotential height anomalies with normal to below normal temperatures to eventually dominate much of Western Europe as Greenland blocking strengthens.

- This week, ridging/positive geopotential height anomalies with above normal temperatures are predicted to dominate much of Asia with troughing/negative geopotential height anomalies and below normal temperatures in Central Asia. Over the next two weeks, ridging/positive geopotential height anomalies and above normal temperatures will become even more widespread across Asia with troughing/negative geopotential height anomalies with below normal temperatures mostly confined to Northwest Russia.
- The general pattern predicted across North America for the upcoming week is for troughing/negative geopotential height anomalies with normal to below normal temperatures for western North America and ridging/positive geopotential height anomalies with normal to above normal temperatures for eastern North America. However, a strong area of low pressure that is slow to depart the Northeastern United States (US) will depress temperatures in the Eastern US through the end of the week.
- Eventually the pattern across North America will transition to troughing/negative geopotential height anomalies with normal to below normal temperatures for eastern North America and ridging/positive geopotential height anomalies with normal to above normal temperatures for western North America as a minor polar vortex (PV) interacts with the troposphere.
- In the Impacts section I share my initial thoughts about the upcoming pattern and the Northern Hemisphere (NH) winter.

Impacts

In the blog I have not discussed the stratospheric PV very much since the fall began as I had little expectation that the stratospheric PV was coupling with the troposphere in a meaningful way. There is some indication that it did couple briefly last week when cold polar cap geopotential heights coupled from the stratosphere to the surface resulting in a positive AO.   The GFS is now predicting a minor perturbation of the PV where warming in the northern North Pacific sector helps to stretch the PV across the Pole resulting in cross polar flow from Siberia into Canada. A similar pattern happens in the troposphere driving cold air south, east of the Rockies. As the models have better resolved this perturbation, the forecasts have become increasing colder in the Central and Eastern US.

The impacts on the weather from these minor perturbations are focused across central and eastern North America and typically last up to two weeks. If the model forecasts are accurate then this would contribute to colder temperatures in early November likely followed by a milder trend. However, these minor disruptions of the PV often repeat,

and I think that will be important for the month of November. The largest expanse of warm sea surface temperature (SST) anomalies across the globe is currently located in the eastern North Pacific from the Chukchi Sea to Hawaii. There is the possibility that the predicted ridging in the eastern North Pacific becomes phase locked with the warm SSTs forcing troughing with cold temperatures downstream across parts of North America. November seems too early in the season for that type of scenario but something to watch for later in the winter.

As I wrote in my previous blog, in producing a winter forecast the predictors that I most heavily rely on are the El Niño/Southern Oscillation (ENSO), October Siberian snow cover extent, November Arctic sea ice extent and high latitude blocking.

Even CPC in their release of the winter forecast didn't believe that ENSO would be a factor this winter and I expect to discuss only very little if any the influence of ENSO on winter weather.

At the time of the last blog October Siberian snow cover extent was off to a fast start but as can be seen from **Figure i**, the October Eurasian, but focused mostly in Siberia, snow cover extent has experienced a prolong pause in advancing. Still I expect that Eurasian snow cover extent will be above normal for the month of October. But the magnitude of the positive anomaly does not look to be impressive at this point. Slightly above normal snow cover extent is an indicator of a cold winter in the Eastern US, East Asia and Northern Europe but not a strong indication.
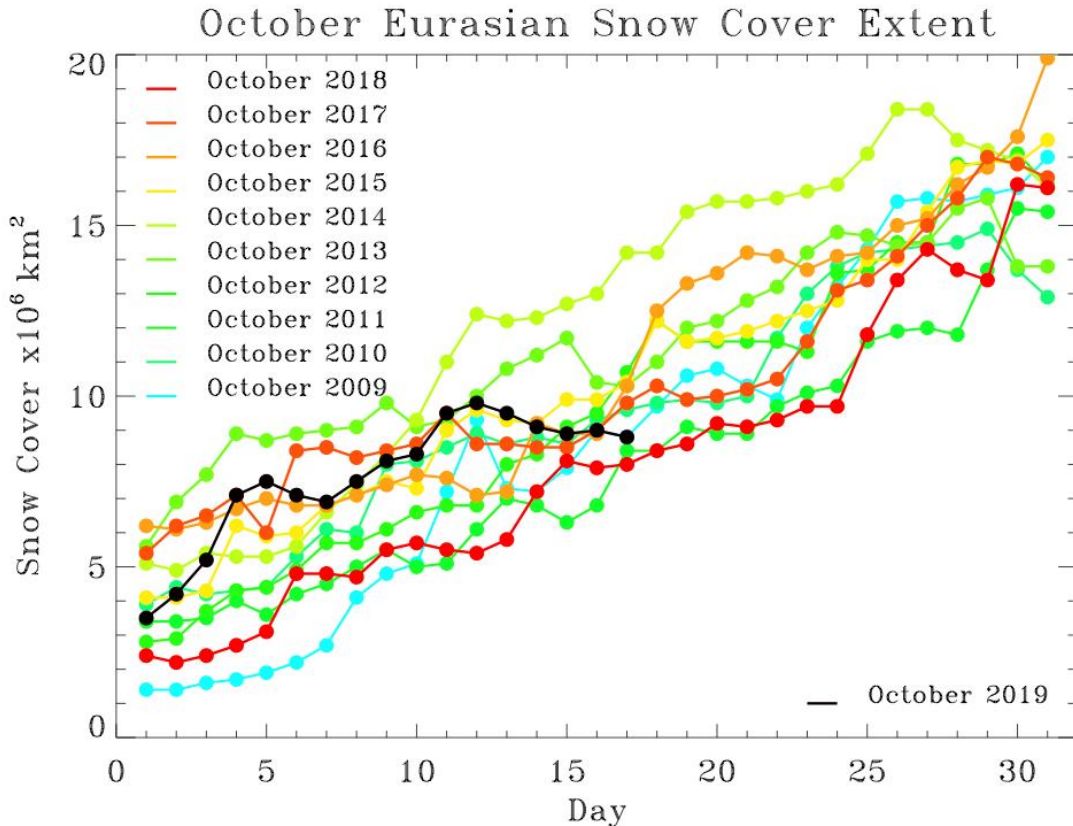
Figure i. Observed Eurasian daily snow cover extent in km² throughout the month of October from 2009 through 2019.

I also compute the snow advance index (SAI; see Cohen and Jones 2011), which computes the relative rate of advance of snow cover extent south of 60°N across Eurasia. This is almost certainly going to be a negative number this year. I interpret this that a major PV disruption is more likely in the late winter relative to the early winter. There is time for this to change but it would take a lot at this point.

Myself and my colleagues have outlined a six-step process from the snow cover advance in Europe until severe winter weather across the NH. The second step is the northwest expansion of the Siberian high that is often referred to as Scandinavian/Ural blocking. The short-range weather models are predicting just the opposite. With deep low pressure in the Barents Kara Seas and adjoining land areas. This is not conducive to a major disruption of the PV. The low pressure in this region seems to be a reflection of the stratospheric PV which is predicted to move into this region.   But as the PV gets stretched and pulled away from the Barents Kara Seas, might allow for high pressure to return. Something that I will be watching.

Arctic sea ice extent is well below normal and that is not going to change for the remainder of the fall and the winter. In fact, it might even be at a record low for the

date. I think it is still a question is where the largest negative anomalies will be focused on the North Atlantic or the North Pacific side of the Arctic. However, it is looking more and more likely that it will be on the North Pacific side. As seen from **Figure ii**, sea ice extent is below normal on the North Atlantic side but much more so on the North Pacific side. That coupled with the very warm SSTs in the eastern North Pacific, I believe favors blocking/ridging on the North Pacific side relative to the North Atlantic side. This would favor colder temperatures across North America relative to Eurasia similar to last winter, in my opinion. Still, even if the ridging materialized near Alaska, I am uncertain whether this would favor cold temperatures in western or eastern North America.
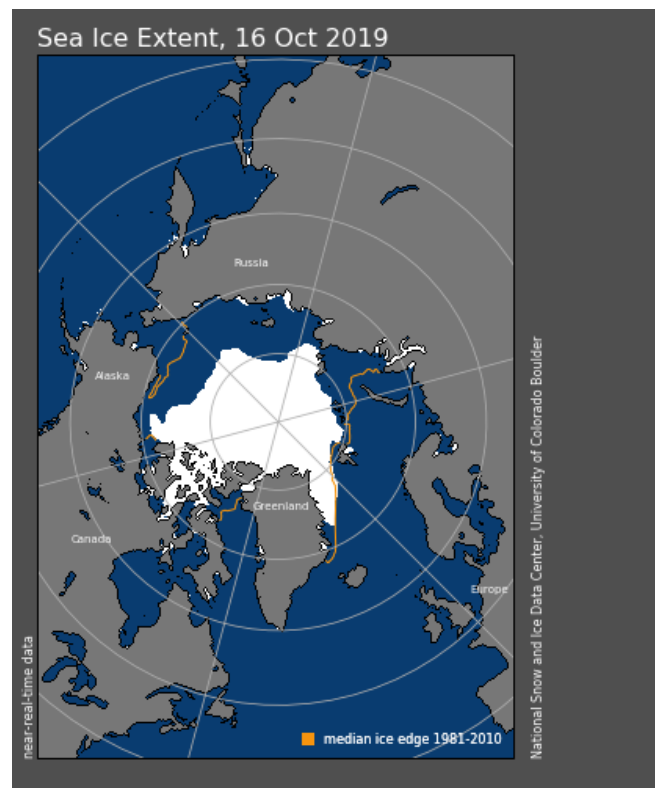
Figure ii. Observed Arctic sea ice extent on 16 October 2019 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

In **Figure iii,** I present an update estimate of the sea level pressure (SLP) anomalies for the month of October for the NH. Earlier in the month the strongest positive SLP anomalies were in the Barents-Kara Seas region but have been migrating over time towards Greenland. Blocking near Greenland might favor minor disruptions of the PV similar to the predicted disruption at the end of the month but not more significant disruptions. In contrast blocking in the Barents-Kara Seas region is more favorable for major disruptions of the PV. It is still very early and though the blocking is focused across Greenland to end the month, I expect that to change quite a bit over the coming weeks and months.

GFS SLP Forecast Anomaly Oct 2019
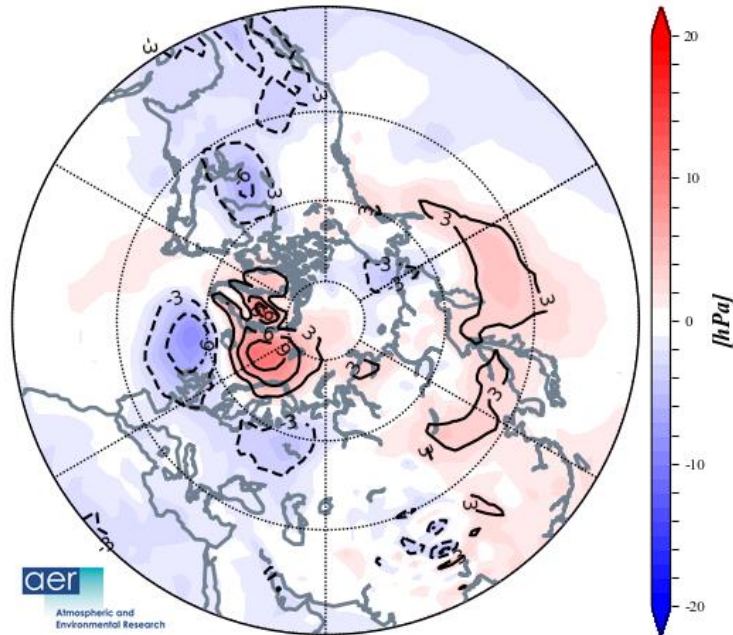**Valid as of 17 Oct 2019**

Figure iii. Observed sea level pressure anomalies through 17 October 2019 from the 00Z GFS analysis and the predicted sea level pressure anomalies from the 16-day forecast (18 October through 31 October 2019) from from the 00Z 17 October 00z GFS.

Near Term Conditions

1-5 day

The AO is currently slightly negative **(Figure 1)** with mostly positive geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with mostly positive geopotential height anomalies across Greenland (**Figure 2**), the NAO is negative.
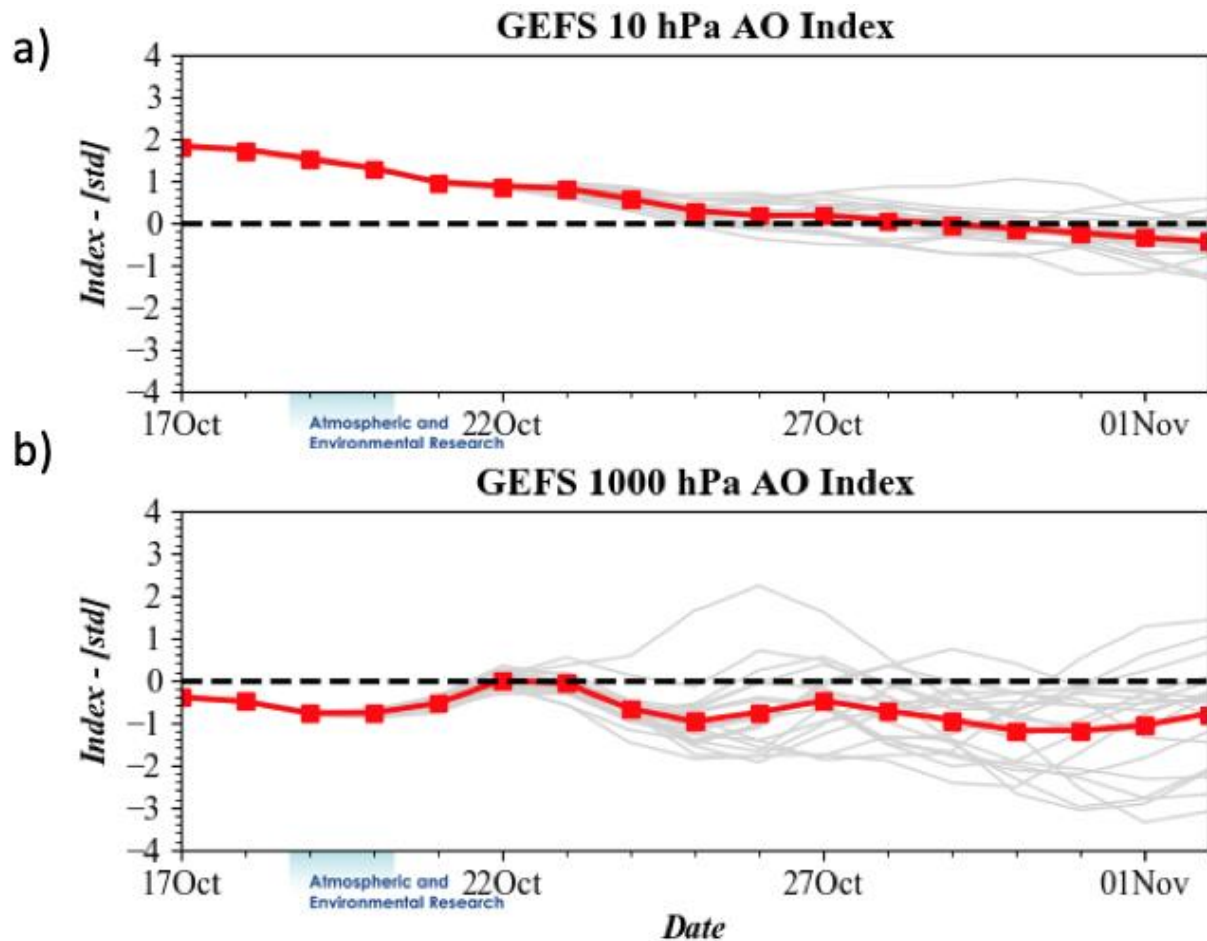
Figure 1. (**a**) The predicted daily-mean AO at 10 hPa from the 00Z 17 October 2019 GFS ensemble. (**b**)
The predicted daily-mean near-surface AO from the 00Z 17 October 2019 GFS ensemble. Gray lines
indicate the AO index from each individual ensemble member, with the ensemble-mean AO index
given by the red line with squares.

Currently ridging/positive geopotential height anomalies dominate much of Europe with troughing/negative geopotential height anomalies predicted to be confined across far Western Europe and Northern Scandinavia during the week (**Figure 2**). This will result in normal to above temperatures across much of Europe with the exception of normal to below normal temperatures across far Western Europe including the UK and Northern Scandinavia (**Figure 3**). This week ridging/positive geopotential height anomalies are predicted to dominate Western and Eastern Asia with troughing/negative geopotential height anomalies confined to Central Asia especially Western Siberia (**Figure 2**). This is predicted to yield normal to above normal temperatures for much of Asia including the Middle East and East Asia with normal to below normal temperatures confined to parts of Central Asia especially Western Siberia (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
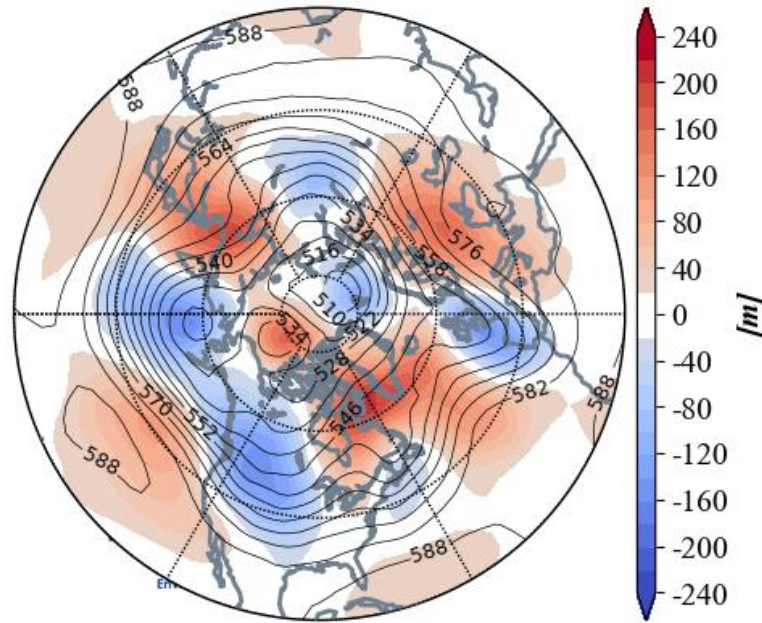**INIT: 00Z 10/17/19   FCST: 10/18/19 to 10/22/19**

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 18 – 22 October 2019. The forecasts are from the 17 October 00z GFS ensemble.

This week troughing/negative geopotential height anomalies stretching from the Bering Sea southwest across Alaska, Western Canada and the Western US are predicted to force downstream ridging/positive geopotential height anomalies in Eastern Canada **(Figure 2).** However, a deep storm across the Northeastern US will be slow to depart helping to suppress geopotential heights across the Eastern US **(Figure 2).** This pattern is predicted to deliver normal to above normal temperatures in Alaska and Eastern Canada with normal to below normal temperatures for Western Canada, the Western US and the US East Coast **(Figure 3).**

GEFS 1-5 Day Forecast T2m Anomaly
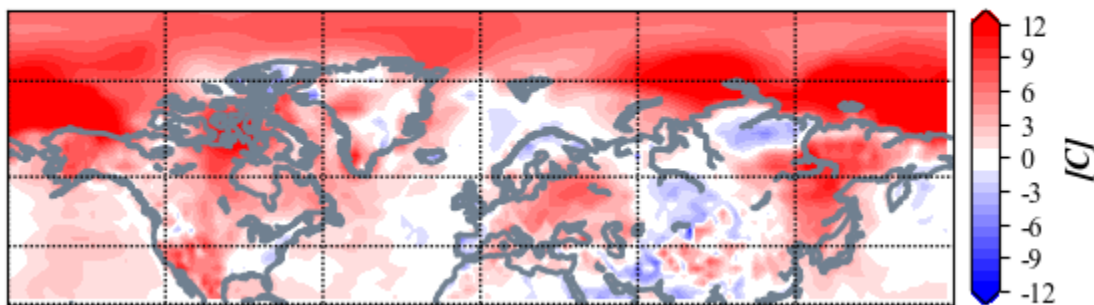**INIT: 00Z 10/17/19   FCST: 10/18/19 to 10/22/19**

Troughing is predicted to bring new snowfall across Siberia, Northwestern Russia and Northern Scandinavia (**Figure 4**). However, intrusion of warm air on southerly winds will melt snow in southeastern Siberia (**Figure 4**). Troughing and cold temperatures are predicted to bring new snowfall to Western Canada and the Northwestern US (**Figure 4**).
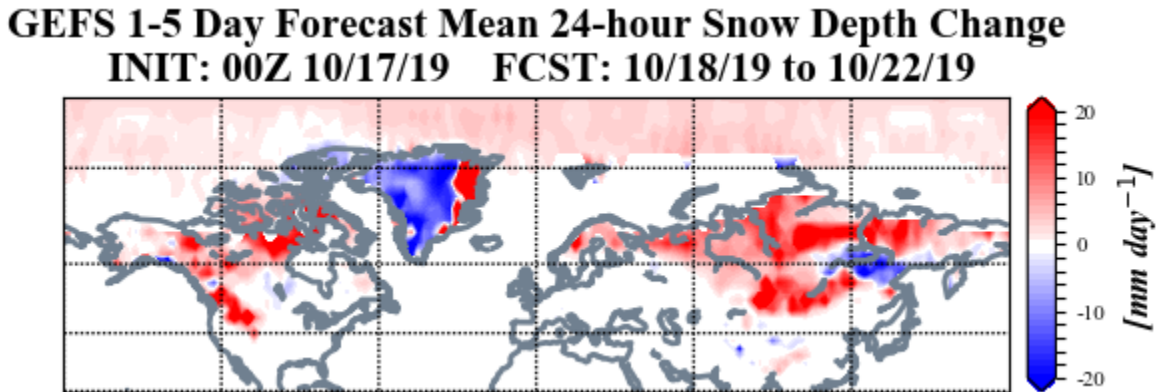

Figure 4. Forecasted snowdepth anomalies (mm/day; shading) from 18 – 22 October 2019. The forecast is from the 00Z 7 October 2019 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain mostly negative this period (**Figure 1**) with mostly positive geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with strengthening positive geopotential height anomalies across Greenland (**Figure 5**), the NAO will likely turn even more negative.
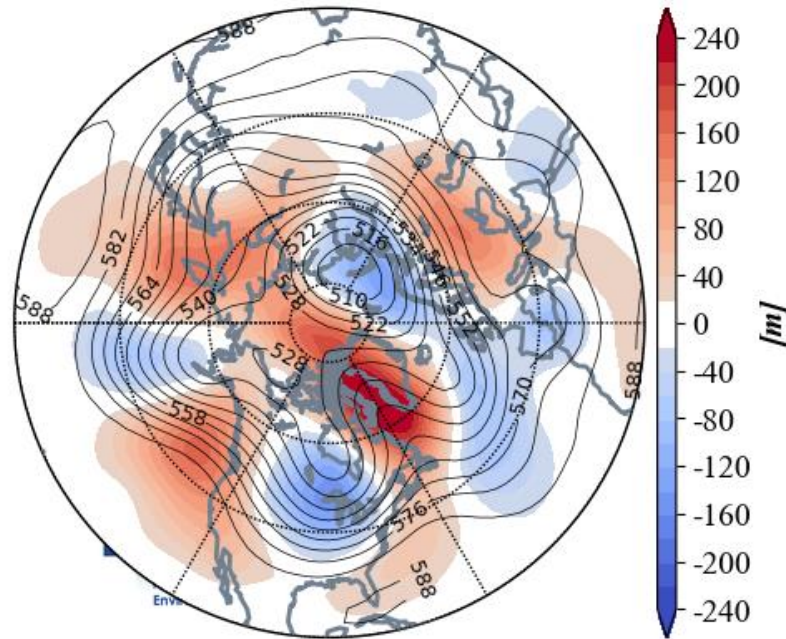
Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 23 – 27 October 2019. The forecasts are from the 17 October 00z GFS ensemble.

Troughing/negative geopotential height anomalies from the previous across far Western Europe will only slowly push eastward with ridging/positive geopotential height anomalies entrenched across Central and Eastern Europe (**Figure 5**). This pattern favors normal to above normal temperatures across much of Europe with normal to below normal temperatures confined to far Western Europe including the UK and Scandinavia (**Figure 6**). Ridging/positive geopotential height anomalies are predicted to become more widespread across Asia with troughing/negative geopotential height anomalies confined to Northwest Russia and Northeast Asia (**Figure 5**). This is predicted to yield widespread normal to above normal temperatures for much of Asia including the Middle East and Southeast Asia with normal to below normal temperatures confined to the Northern Urals, Mongolia and Northern China (**Figure 6**).

GEFS 6-10 Day Forecast T2m Anomaly
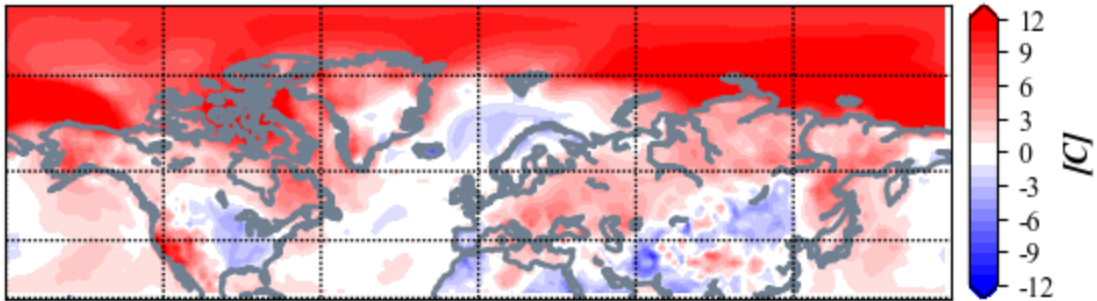**INIT: 00Z 10/17/19   FCST: 10/23/19 to 10/27/19**

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 23 – 27 October 2019. The forecasts are from the 00Z 17 October 2019 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to build in the Gulf of Alaska and long the west coast of North America including Alaska with downstream troughing/negative geopotential height anomalies in Eastern Canada and the Eastern US (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across Alaska, the US West coast and Northeastern Canada with normal to below normal temperatures in stretching from Western Canada through the Central US and into the Southeastern US **(Figure 6).**

GEFS 6-10 Day Forecast Mean 24-hour Snow Depth Change
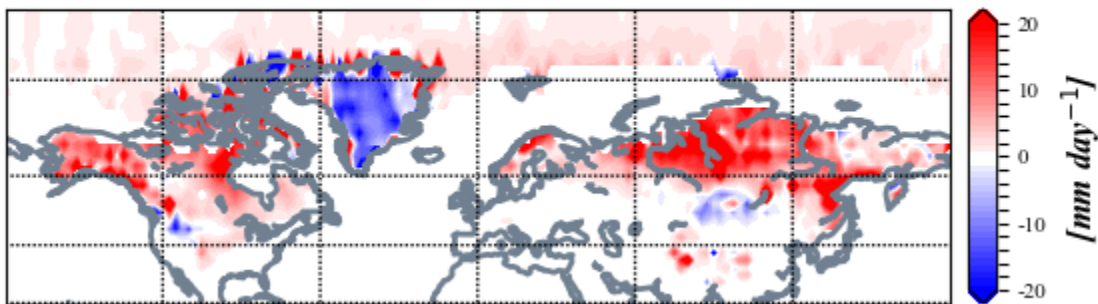**INIT: 00Z 10/17/19   FCST: 10/23/19 to 10/27/19**

Figure 7. Forecasted snowdepth changes (mm/day; shading) from 23 – 27 October 2019. The forecasts are from the 00Z 17 October 2019 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across much of Siberia, Northern Scandinavia, Alaska and Northern and Western Canada (**Figure 7**). Some snowmelt is predicted in Southern Siberia and the Northwestern US (**Figure 7**).

11-15 day

With mostly positive geopotential height anomalies predicted for the Arctic (**Figure 8**), the AO is likely to remain negative this period (**Figure 1**). With predicted strong positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is likely to remain negative this period as well.

GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
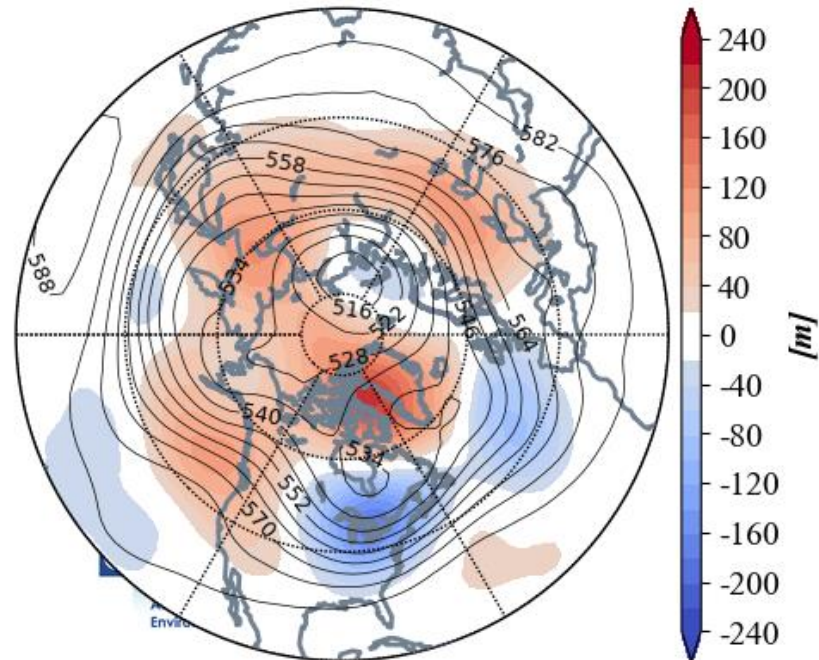**INIT: 00Z 10/17/19   FCST: 10/28/19 to 11/01/19**

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 28 October – 1 November 2019. The forecasts are from the 17 October 00z GFS ensemble.

Troughing/negative geopotential height anomalies are predicted to continue to slowly move east across Western Europe this period with ridging/positive geopotential height anomalies retreating into Eastern Europe (**Figure 8**). This pattern is predicted to result in seasonable to above normal temperatures for Eastern Europe with seasonable to below normal temperatures across Western Europe including the UK and Scandinavia (**Figure 9**). Ridging/positive geopotential height anomalies are predicted to dominate Asia with troughing/negative geopotential height anomalies confined to Northwestern Russia (**Figure 8**). This pattern favors normal to above normal temperatures widespread across Asia with normal to below normal temperatures mostly limited to Northwestern Russia (**Figure 9**).

GEFS 11-15 Day Forecast T2m Anomaly
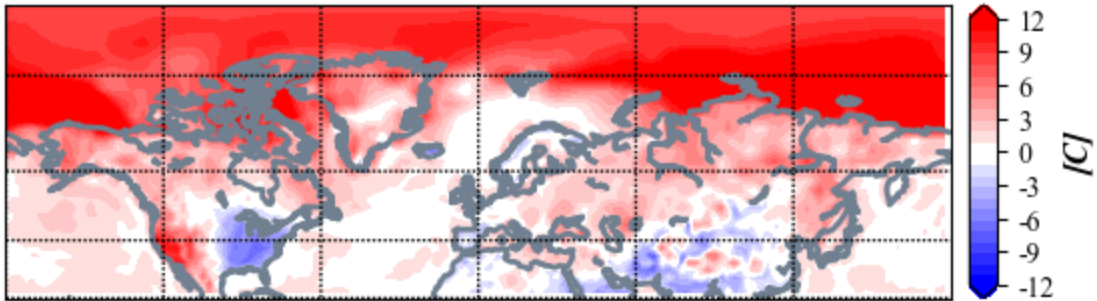**INIT: 00Z 10/17/19   FCST: 10/28/19 to 11/01/19**

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 28 October – 1 November 2019. The forecasts are from the 00Z 17 October 2019 GFS ensemble.

The overall pattern across North America is predicted to persist with ridging/positive geopotential height anomalies stretching from Alaska into the Gulf of Alaska and the west coasts of Canada and the US with downstream troughing/negative geopotential height anomalies in eastern North America (**Figure 8**).   This will favor normal to above normal temperatures across Alaska, the West Coasts of Canada and the US with normal to below normal temperatures across Southcentral and Southeastern Canada and the Eastern US (**Figure 9**).

GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change
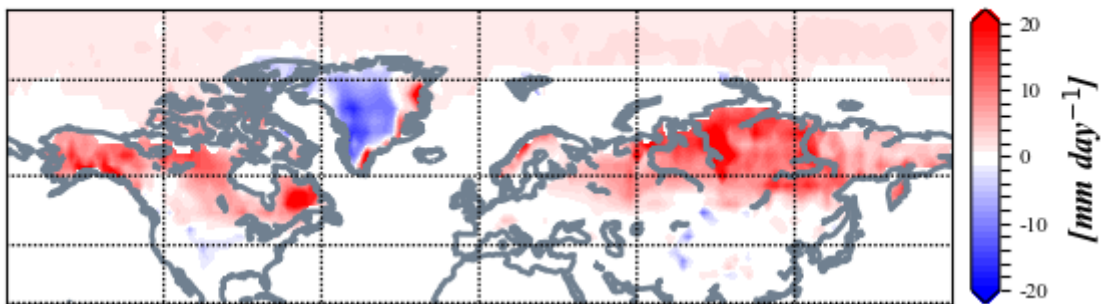**INIT: 00Z 10/17/19   FCST: 10/28/19 to 11/01/19**

Figure 10. Forecasted snowdepth changes (mm/day; shading) from 28 October – 1 November 2019. The forecasts are from the 00Z 17 October 2019 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across much of Siberia, Norway, Alaska, Northern and Eastern Canada (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to below normal PCHs in the stratosphere and normal to above normal PCHs in the mid to upper troposphere (**Figure 11**). Currently the lower troposphere PCHs are near normal, but are predicted to turn positive, consistent with the predicted negative AO (**Figure 1**).
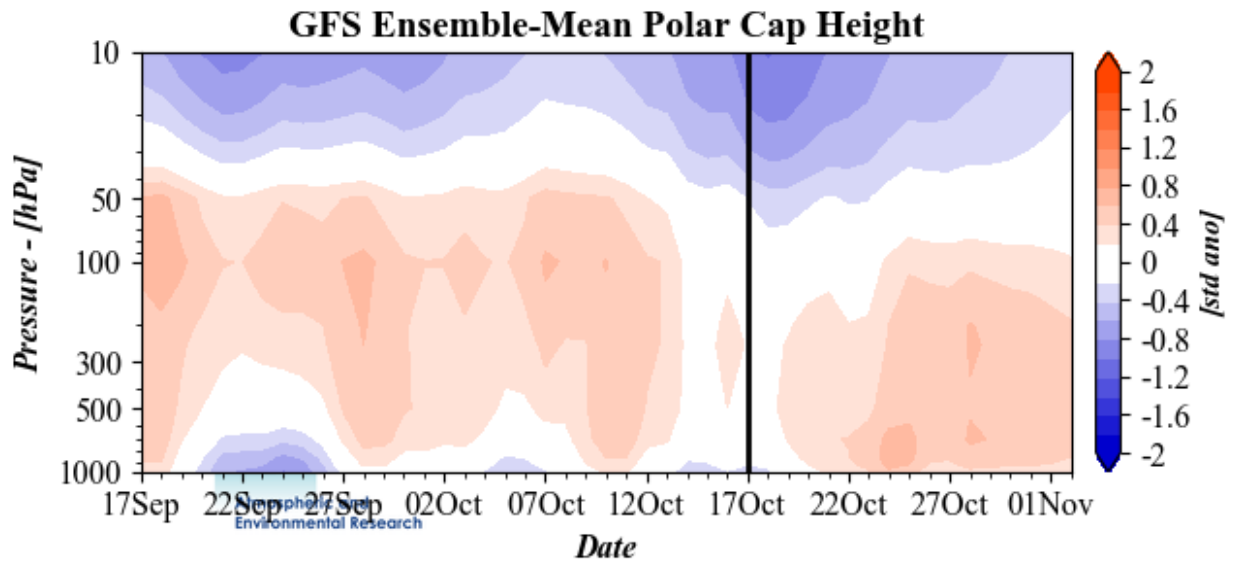

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 17 October 2019 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows mostly normal WAFz for this week but a new weak pulse is predicted for the last week of October (**Figure 12**). The weak pulse of WAFz the end of October is predicted to cause a minor disruption of the PV as seen by the warming of stratospheric PCHs and the negative trend in the stratospheric AO (**Figure 1**).
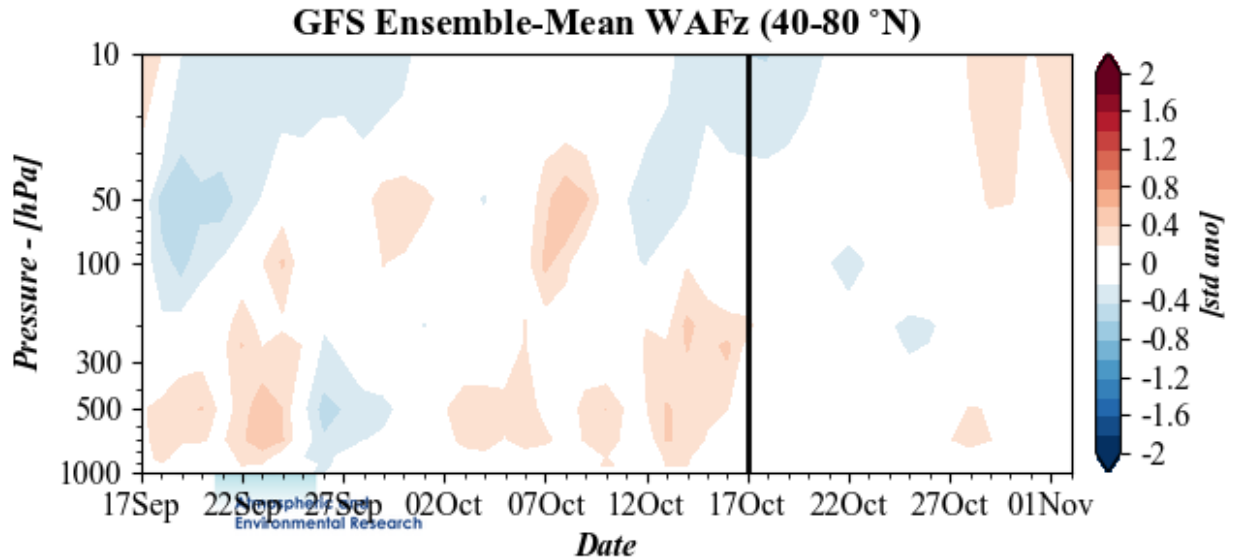
Figure 12. Observed and predicted daily vertical component of the wave activity Wux (WAFz)
standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 17 October 2019
GFS ensemble.

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 (**Figure 13**). This is then followed in the 11-15 day forecast by an elongation of the PV (**Figure 13**). Though warming in the northern North Pacific sector is not apparent in **Figure 13**, the warming can be seen in the PV animation that I tweeted out earlier today.
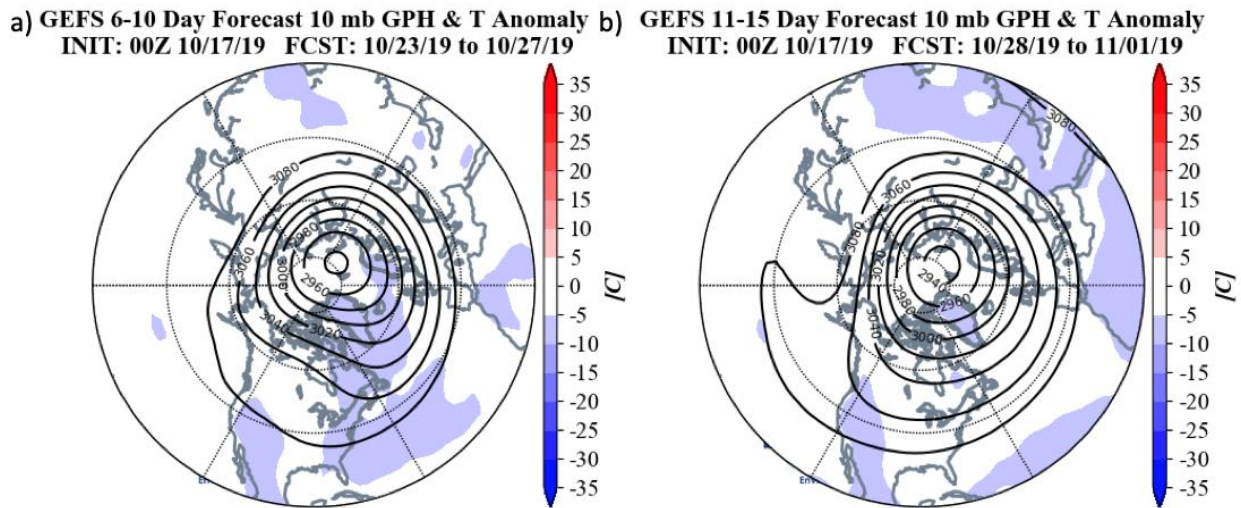
Figure 13. (a) Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C;
shading) across the Northern Hemisphere for 23 – 27 October 2019. (b) Same as (a) except forecasted
averaged from 28 October – 1 November 2019. The forecasts are from the 00Z
17 October 2019 GFS operational
model.

During these reflective PV perturbations, the pattern couples quickly with the troposphere with ridging near Alaska and downstream troughing across central and eastern North America as seen in the 11-15 day 500 hPa geopotential height forecast (**Figure 8**). This drives cold air south across North America east of the Rockies.
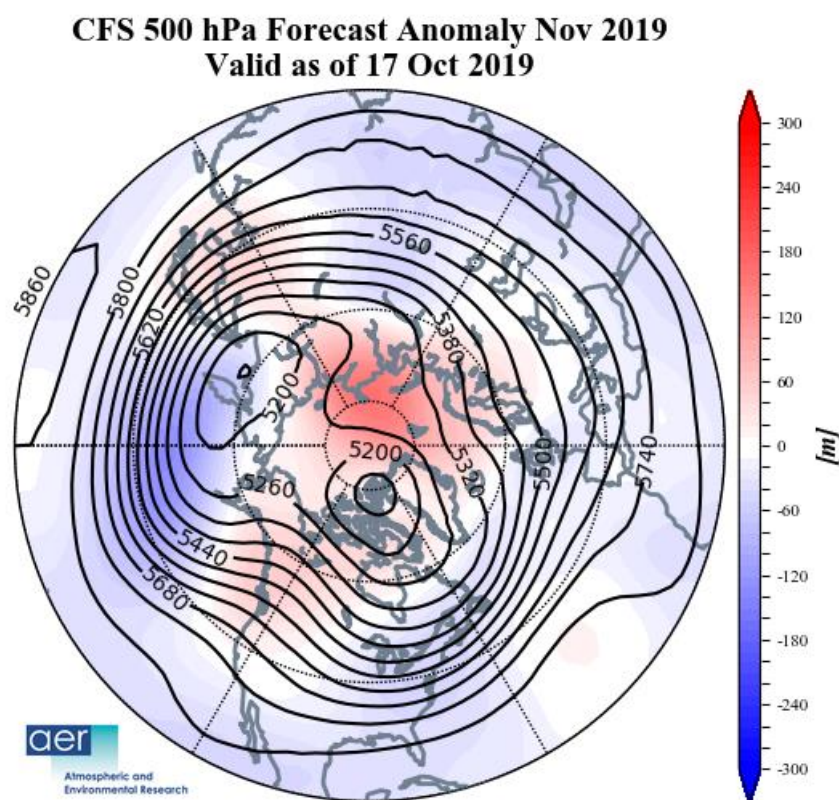

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for November 2019. The forecasts are from the 17 October 2019 CFS.

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 centered across Scandinavia, the Urals, Barents and Laptev Seas and Western Canada with troughs in Western Europe, Central and East

Asia, Eastern Siberia, the Aleutians, Eastern Canada and the Eastern US (**Figure 14**). This pattern favors relatively warm temperatures for Northern Europe, Western Asia, Alaska, Western Canada and the Western US with seasonable to relatively cold temperatures for Southern Europe, Central and East Asia, Southeast Canada and the Northeastern US **(Figure 15).**
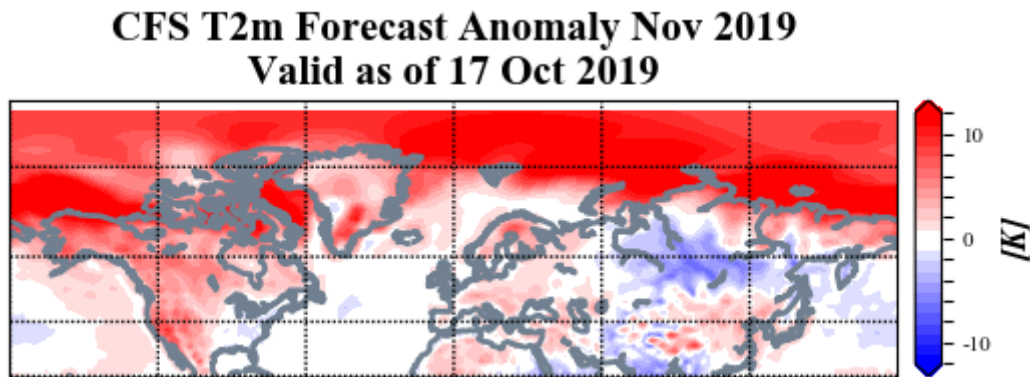

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for November 2019. The forecasts are from the 17 October 2019 CFS.

Surface Boundary Conditions

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies have cooled and whether El Niño conditions will continue has become questionable especially now that that SSTs in the eastern equatorial Pacific are cool to normal (**Figure 16**). Observed SSTs across the NH remain well above normal especially near Alaska and along the north slope of Asia though below normal SSTs exist regionally especially west of South America.
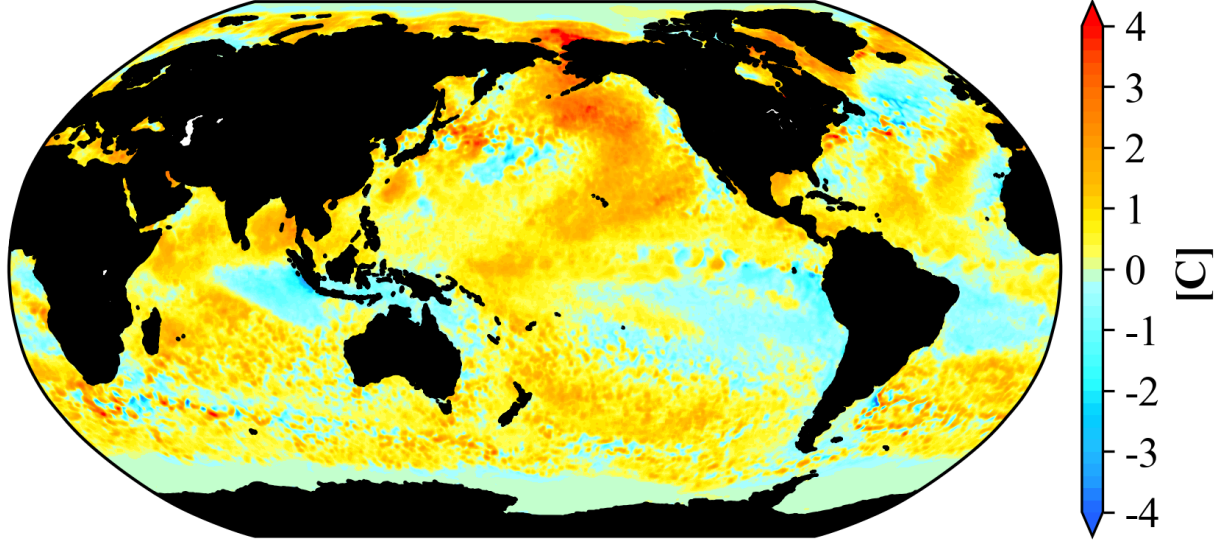
Figure 16. The latest weekly-mean global SST anomalies (ending 15 October 2019). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase one (**Figure 17**). The forecasts are for the MJO to transition to phase two and then weaken to where no phase is favored over the next two weeks. Phase one favors ridging in the Eastern US and toughing in western North America, consistent with the forecast for this week but phase 2 favors a similar pattern which is inconsistent with the forecast weather pattern across North America. This is suggestive of a waning MJO influence on North American weather.
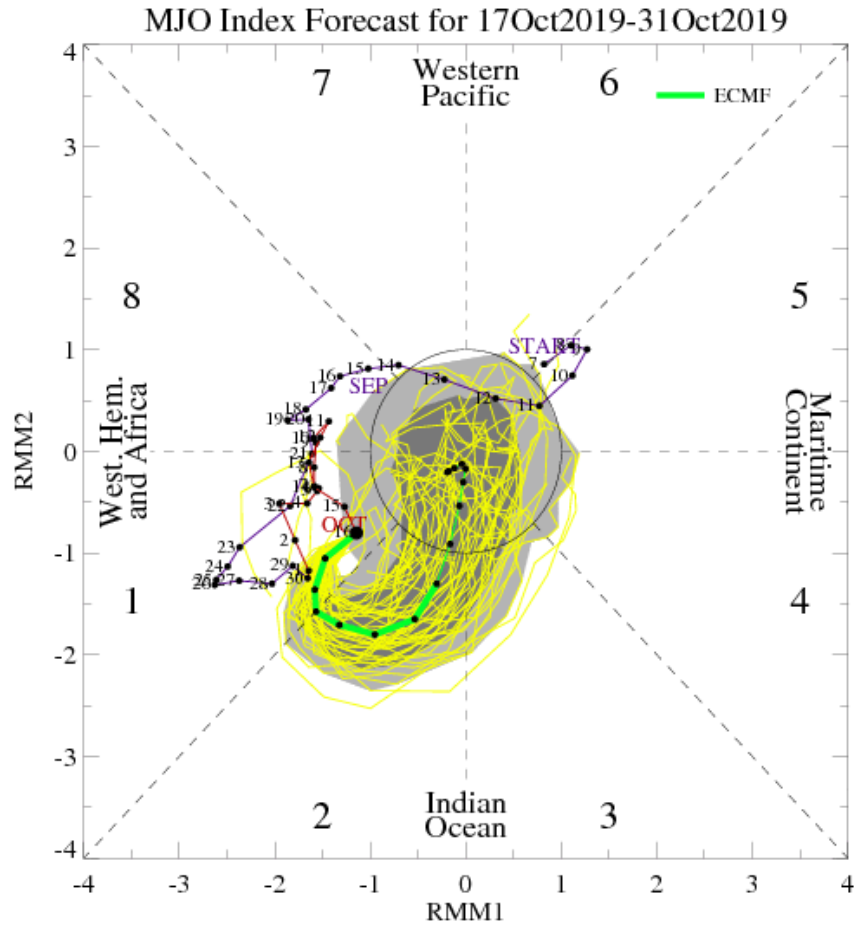
Figure 17. Past and forecast values of the MJO index. Forecast values from the 00Z 7 October 2019 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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