

Arctic Oscillation and Polar Vortex Analysis and Forecasts

October 7, 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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The AO/PV blog is partially supported by NSF grant AGS: 1657748.

Summary

- The Arctic Oscillation (AO) is currently positive and is predicted to remain positive this week before returning to neutral.
- The current positive AO is reflective of mixed pressure/geopotential height anomalies across the Arctic and mostly positive pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is neutral with mixed pressure/geopotential height anomalies spread across Greenland and Iceland; and the NAO is predicted to turn negative as

geopotential height anomalies are predicted to turn mostly positive across Greenland over the next two weeks.

- Troughing/negative geopotential height anomalies with seasonable to below normal temperatures currently dominate much of Europe with ridging/positive geopotential height anomalies and above normal temperatures limited to far Western Europe including the United Kingdom (UK). However, the forecast is for ridging/positive geopotential height anomalies with normal to above normal temperatures to eventually dominate much of Europe mid to late October.
- 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 parts of East Asia and Western Russia. 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 Eastern Siberia.
- The general pattern predicted across North America for the next two weeks 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. One exception is a strong area of low pressure that is predicted to form over the Central United States (US) this upcoming weekend and will sweep some colder air through eastern North America early next week.
- In the Impacts section I share my initial thoughts about the upcoming winter.

Impacts

As I have written about previously in the 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. To monitor how well the forecast is performing I will closely follow the vertical energy transfer from the troposphere to the stratosphere and the behavior of the polar vortex (PV).

Currently the ENSO forecasts predict a neutral winter and in the coming months I expect to discuss only very little the influence of ENSO on winter weather. Next up is Siberian snow cover extent during the month of October. As can be seen from **Figure i**, the October Eurasian, but focused mostly in Siberia, snow cover extent got off to a fast start but pulled back with snow melt over the weekend. But even with the melt, it is still far ahead of last October at this time. Last fall North American snow cover extent was far more impressive than Eurasian snow cover extent. In fact, last fall North American snow cover was record extensive. I would argue this was a foreshadowing of the following winter where cold anomalies during the winter were more impressive across North America than Eurasia. So far, the snow cover advance across Eurasia has been more impressive. But it is early, and the forecast of an extended period of positive AO is not conducive to a rapid advance of snow cover across Eurasia and in the next two

weeks and North American snow cover extent could catch up with Eurasian snow cover extent.

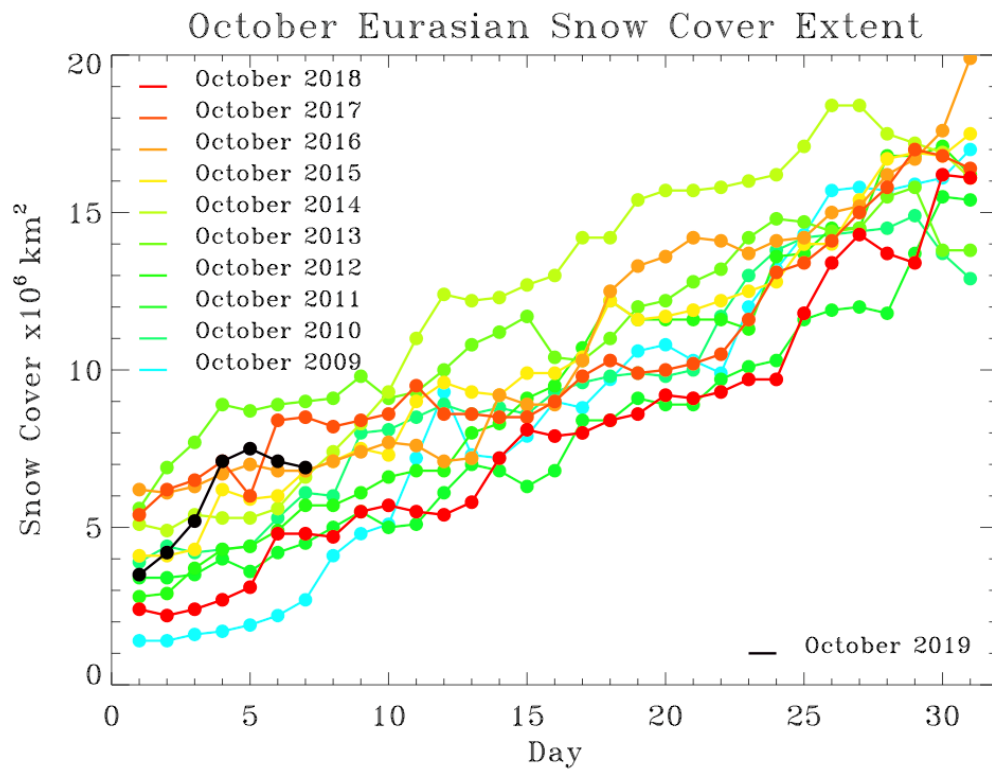


Figure i. Observed Eurasian daily snow cover extent in km^2 throughout the month of October from 2009 through 2019.

The early indication from Eurasian snow cover extent is that for the month of October it will be above normal. But the next week or so will be critical, and an extended stall is possible based on the positive AO forecasts. Still I anticipate the monthly value to be above normal which favors a cold winter in East Asia, Northern Europe and the Eastern US.

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. With this weekend's melt, the SAI is off to a slow start and with the forecast of a positive AO, I don't expect that to change for at least the next week or so. For the past couple winters, I have been using the SAI mostly to predict the timing a PV disruption with higher SAI values favoring a PV disruption earlier in the winter and lower values of the SAI favoring a delayed disruption of the PV. The early indications of the SAI favor a delayed PV disruption.

Arctic sea ice extent is well below normal and that is not going to change for the remainder of the fall and the winter. What is a question is where will the largest

negative anomalies be focused on the North Atlantic or the North Pacific side of the Arctic? 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. The predicted atmospheric circulation over the Arctic for the next two weeks, seems favorable to me for sea ice growth on the North Pacific side of the Arctic so the situation remains fluid. I do expect that negative Arctic sea extent anomalies to be favorable for high latitude blocking with downstream troughing and cold temperatures across the continents and probably for disrupting the PV, but the details remain unclear.

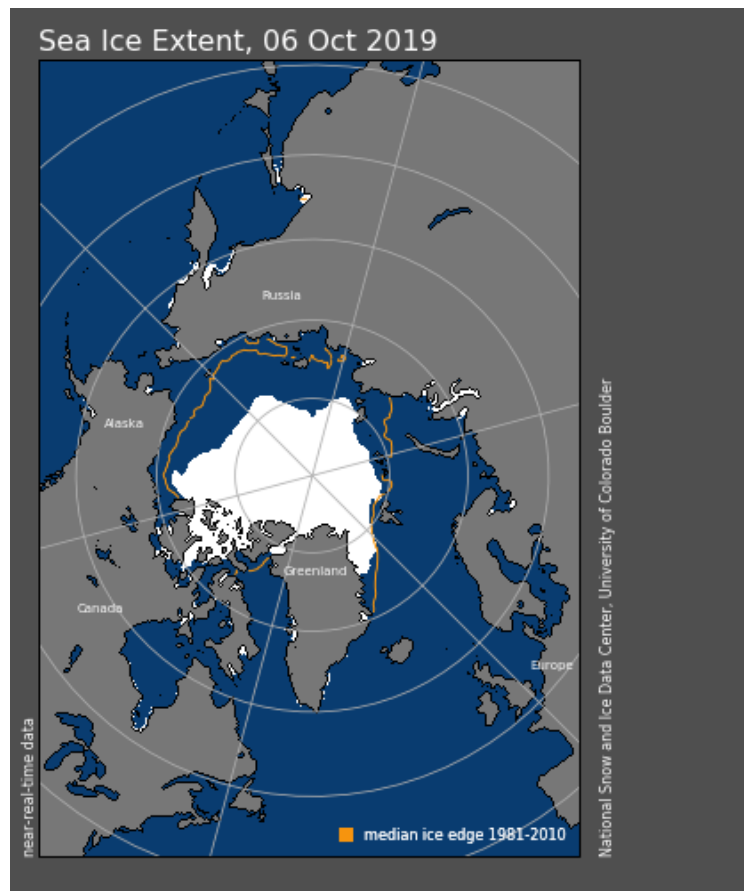


Figure ii. Observed Arctic sea ice extent on 6 October 2019 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

In **Figure iii**, I present an estimate of the sea level pressure anomalies for the month of October for the Northern Hemisphere (NH). Nothing really jumps out at me currently. At high latitudes there is generally high SLP in the North Atlantic and low SLP in the North Pacific. If over time the high SLP in the North Atlantic sinks south this could force a negative NAO pattern with cold temperatures both for Northern Europe and the Eastern US. Or if it migrates towards the Urals/Scandinavia region coupled with the low SLP in the North Pacific also sinking south near the Aleutians, this pattern would be very favorable for disrupting the PV. The most impressive positive SLP anomalies are

in the Gulf of Alaska in the region of the very warm sea surface temperatures (SSTs) in the eastern North Pacific and it will be interesting to see if during the upcoming winter the warm SSTs and positive SLP anomalies couple to form persistent ridging in the region. If the ridging remains offshore close to the Aleutians, this would favor cold temperatures over western North America like last winter. However, if the ridging is further east along the west coast of North America this would favor colder temperatures further east over the Central and Eastern US. I think though it is too early to predict one or neither of these scenarios.

**GFS SLP Forecast Anomaly Oct 2019
Valid as of 07 Oct 2019**

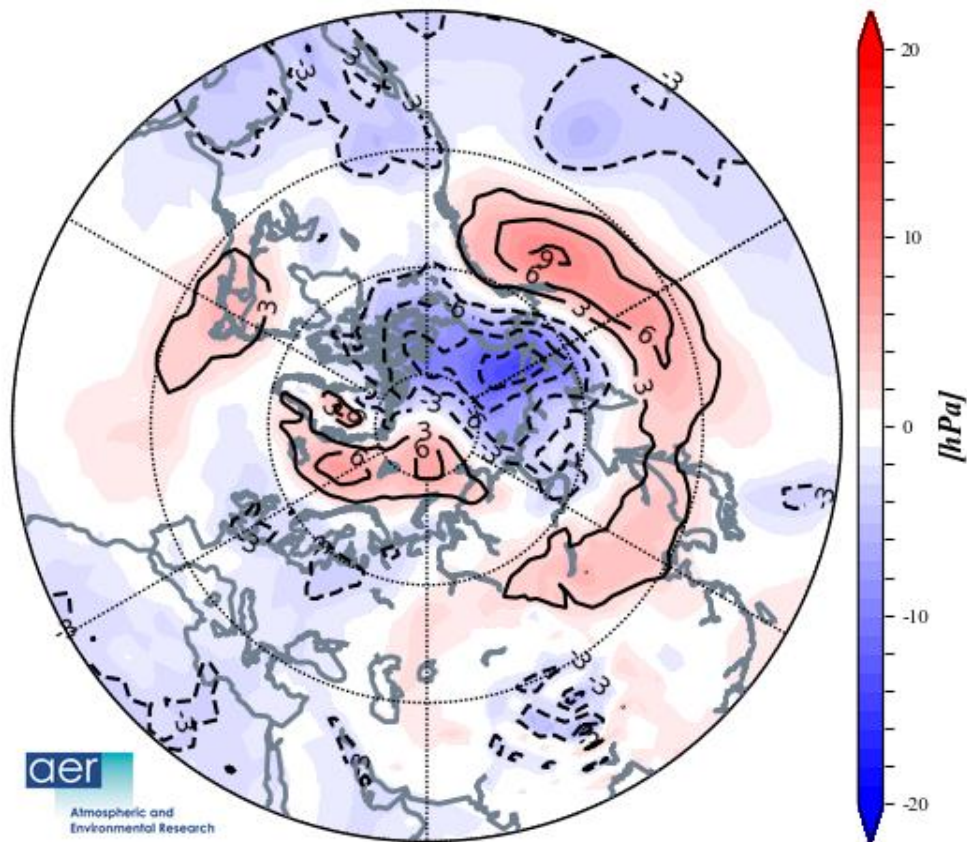


Figure iii. Observed sea level pressure anomalies through 7 October 2019 from the 00Z GFS analysis and the predicted sea level pressure anomalies from the 16-day forecast (8 October through 23 October 2019) from from the 00Z 7 October 00z GFS.

Finally, I do think that Mother Nature likes to foreshadow the character of the upcoming weather season. We are about to have our second very impressive snowstorm in the Northwestern US and Southwestern Canada. That coupled with the summer like ridge and hot temperatures in the Eastern US is very reminiscent of last winter. So, is the weather of September and early October portending a repeat of winter 2018/19 for North America? I actually believe it is more likely a head fake than anything else, but I

could be totally off on this early prediction. Across Eurasia if the snow cover advance continues at a pace more impressive than last fall, then I would read this as a sign of the likelihood of a harsher winter than last year.

Near Term Conditions

1-5 day

The AO is currently positive (**Figure 1**) with mixed geopotential height anomalies across the Arctic and mostly positive geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with mixed geopotential height anomalies across Greenland (**Figure 2**), the NAO is neutral.

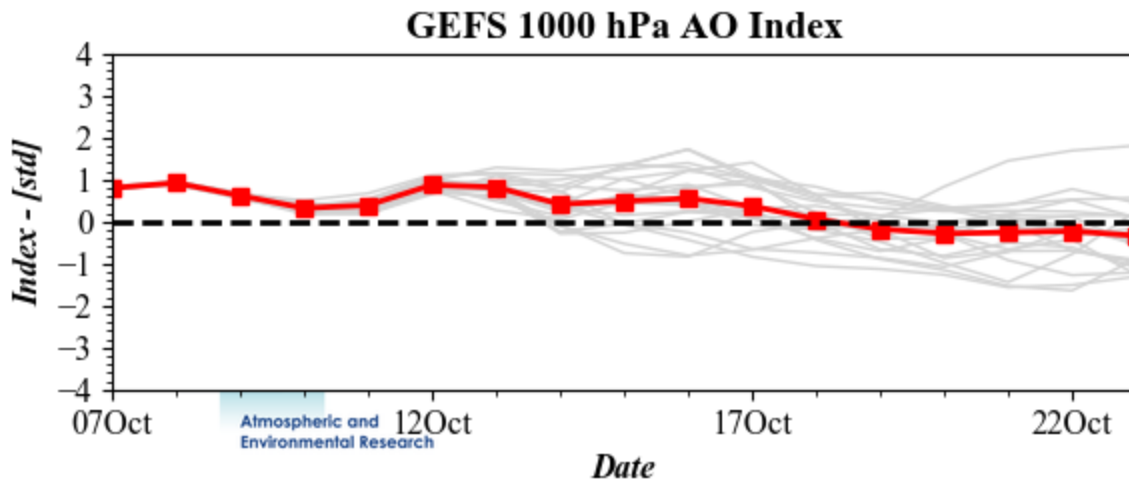


Figure 1. The predicted daily-mean AO at 10 hPa from the 00Z 7 October 2019 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

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

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 10/07/19 FCST: 10/08/19 to 10/12/19

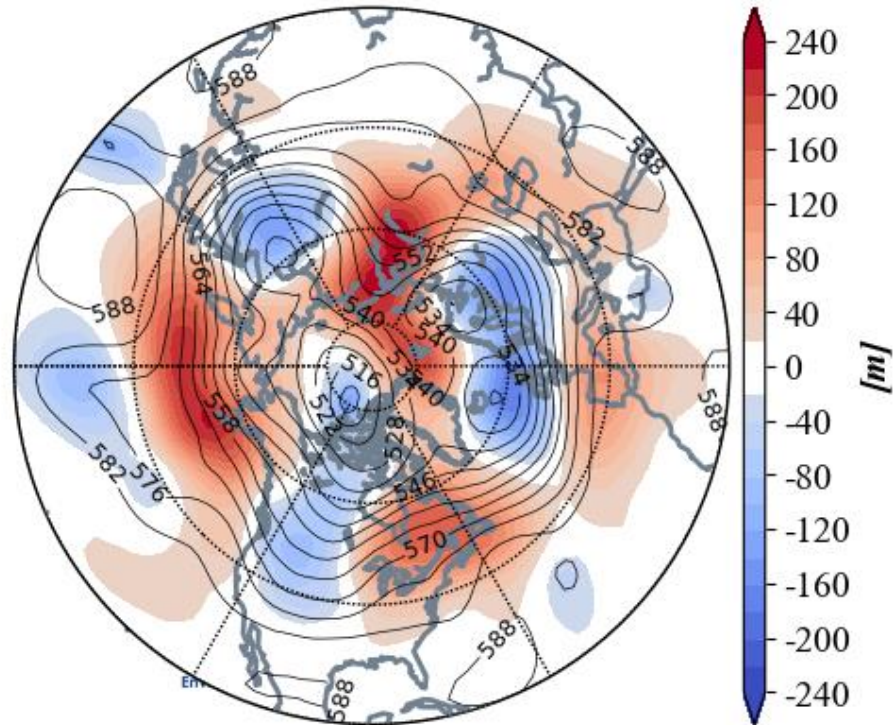


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 8 – 12 October 2019. The forecasts are from the 7 October 00z GFS ensemble.

This week ridging/positive geopotential height anomalies stretching from Alaska south into the Gulf of Alaska are predicted to force downstream troughing/negative geopotential height anomalies in Western Canada and the Western US with more ridging/positive geopotential height anomalies for eastern North America (**Figure 2**). This pattern is predicted to deliver normal to above normal temperatures in Alaska, Eastern Canada and the Eastern US with normal to below normal temperatures for Western Canada and the Western US (**Figure 3**).

GEFS 1-5 Day Forecast T2m Anomaly
INIT: 00Z 10/07/19 FCST: 10/08/19 to 10/12/19

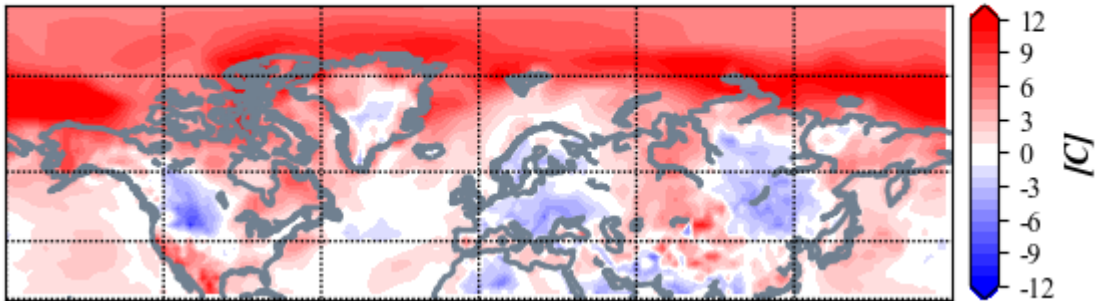


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 8 – 12 October 2019. The forecast is from the 00Z 7 October 2019 GFS ensemble.

Trouching is predicted to bring new snowfall to Central and Eastern Siberia and Northern Scandinavia (**Figure 4**). Trouching and cold temperatures are predicted to bring new snowfall to Alaska and Western Canada (**Figure 4**). And an unusually strong storm for this time of year will bring heavy snowfall to the Northcentral US (**Figure 4**).

GEFS 1-5 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 10/07/19 FCST: 10/08/19 to 10/12/19

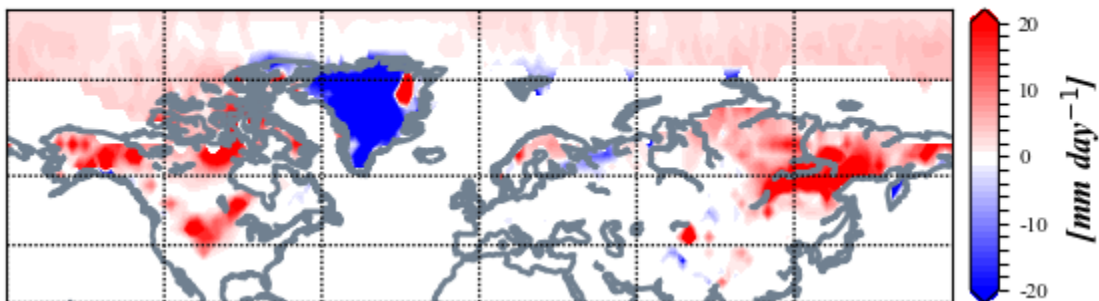


Figure 4. Forecasted snowdepth anomalies (mm/day ; shading) from 8 – 12 October 2019. The forecast is from the 00Z 7 October 2019 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain positive this period (**Figure 1**) with mostly negative geopotential height anomalies across the Arctic and mostly positive geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with mostly positive geopotential height anomalies across Greenland (**Figure 5**), the NAO will likely turn negative.

GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 10/07/19 FCST: 10/13/19 to 10/17/19

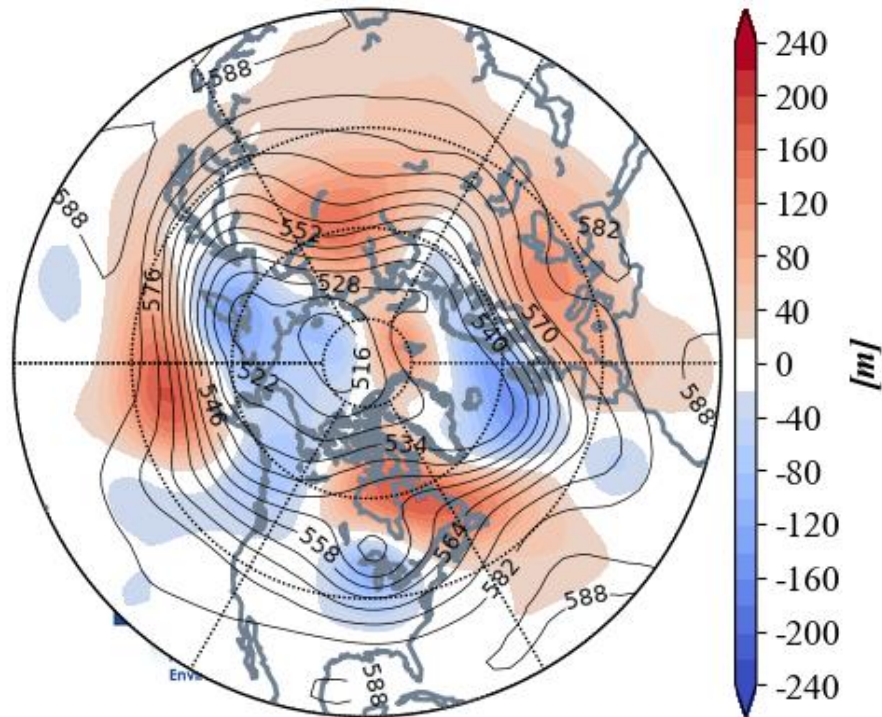


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 13 – 17 October 2019. The forecasts are from the 7 October 00z GFS ensemble.

Trouching/negative geopotential height anomalies from the previous across Northern and Eastern Europe will continue to retreat northward as ridging/positive geopotential height anomalies across Southern Europe expand northward (**Figure 5**). This pattern favors normal to above normal temperatures across much of Europe including the UK with normal to below normal temperatures confined to Scandinavia (**Figure 6**). Ridging/positive geopotential height anomalies are predicted to become more widespread across Asia with troughing/negative geopotential height anomalies mostly confined to Eastern Siberia (**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 Eastern Siberia with some of the colder air bleeding into Northeast Asia (**Figure 6**).

GEFS 6-10 Day Forecast T2m Anomaly
INIT: 00Z 10/07/19 FCST: 10/13/19 to 10/17/19

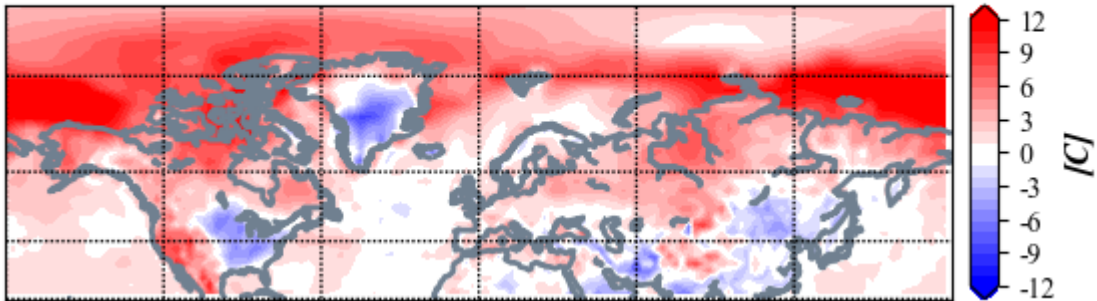


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 13 – 17 October 2019. The forecasts are from the 00Z 7 October 2019 GFS ensemble.

Trouging/negative geopotential height anomalies are predicted to persist in western North America now including Alaska with downstream ridging/positive geopotential height anomalies in Northeastern Canada, however, a deep storm will sweep lower geopotential heights across Southeastern Canada and the Eastern US (**Figure 5**). This pattern is predicted to bring normal to below normal temperatures across eastern Alaska Western Canada, the Western US and the Eastern US with normal to above normal temperatures in Eastern Canada (**Figure 6**).

GEFS 6-10 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 10/07/19 FCST: 10/13/19 to 10/17/19

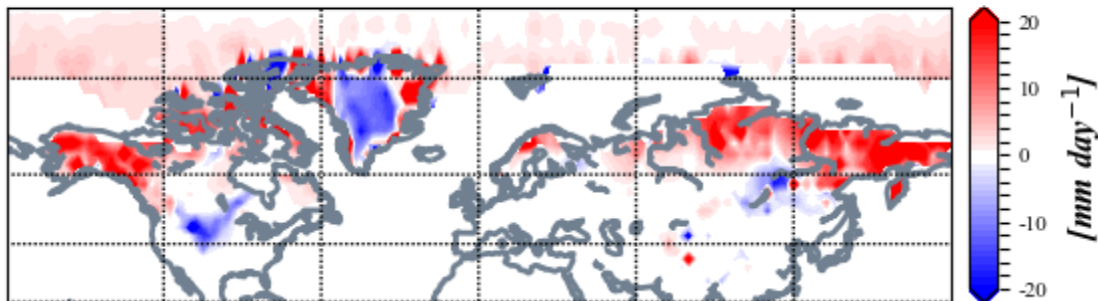


Figure 7. Forecasted snowdepth changes (mm/day ; shading) from 13 – 17 October 2019. The forecasts are from the 00Z 7 October 2019 GFS ensemble.

Trouging and/or cold temperatures will support new snowfall across Northern Siberia, Northern Scandinavia, Alaska and Northwestern Canada (**Figure 7**).

11-15 day

With weak geopotential height anomalies predicted for the Arctic (**Figure 8**), the AO is likely to drift back to near neutral this period (**Figure 1**). With predicted weak positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is likely to remain negative this period.

GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 10/07/19 FCST: 10/18/19 to 10/22/19

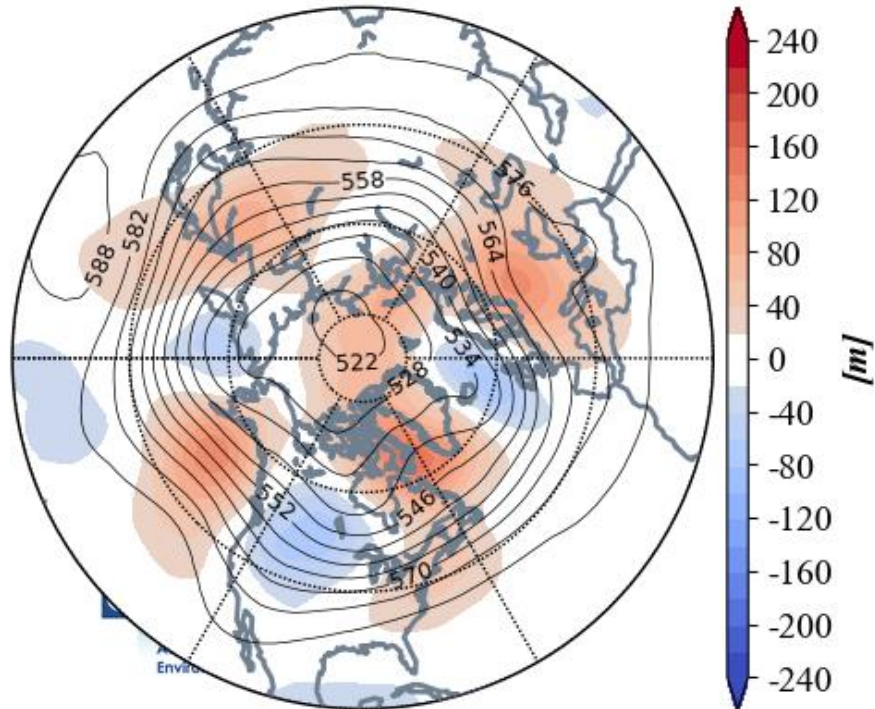


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 18 – 22 October 2019. The forecasts are from the 7 October 00z GFS ensemble.

Ridging/positive are predicted to dominate almost of Europe this period with troughing/negative geopotential height anomalies confined to the British Isles and Western Scandinavia (**Figure 8**). This pattern is predicted to result in seasonable to above normal temperatures for almost all of Europe with normal to below normal temperatures confined to the UK and Western Scandinavia (**Figure 9**). Ridging/positive geopotential height anomalies are predicted to dominate Asia with troughing/negative geopotential height anomalies limited to Western and Eastern Siberia (**Figure 8**). This pattern favors normal to above normal temperatures widespread across Asia with normal to below normal temperatures limited to parts of Western and Eastern Siberia (**Figure 9**).

GEFS 11-15 Day Forecast T2m Anomaly
INIT: 00Z 10/07/19 FCST: 10/18/19 to 10/22/19

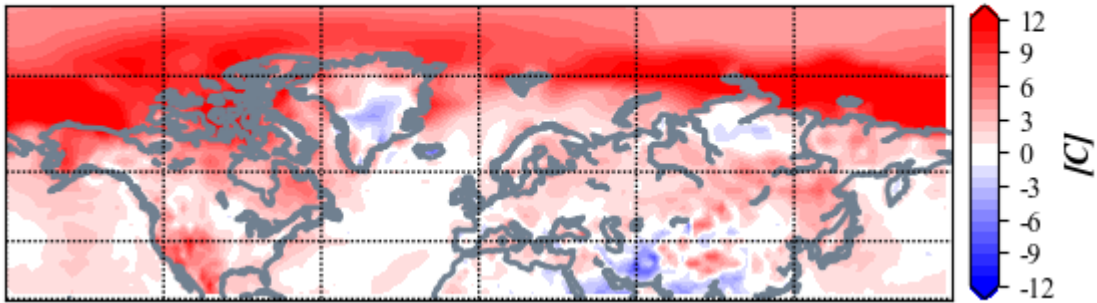


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 18 – 22 October 2019. The forecasts are from the 00Z 7 October 2019 GFS ensemble.

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

GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 10/07/19 FCST: 10/18/19 to 10/22/19

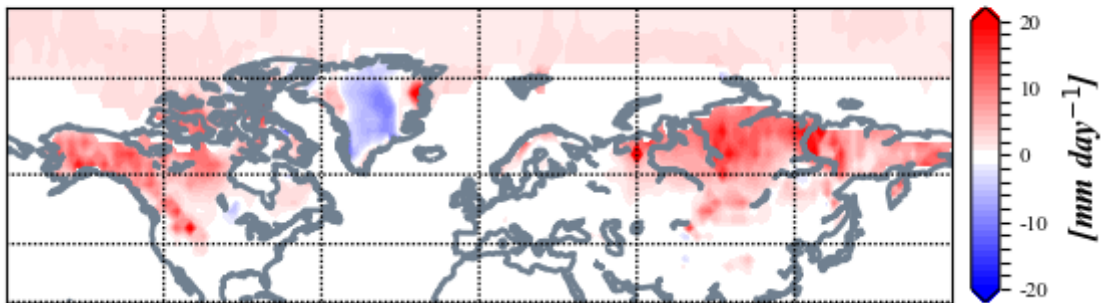


Figure 10. Forecasted snowdepth changes (mm/day ; shading) from 18 – 22 October 2019. The forecasts are from the 00Z 7 October 2019 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across much of Siberia, Northern Scandinavia, Alaska, Western Canada and the Northwestern US (**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**). In the lower troposphere PCHs are below normal, consistent with the positive AO (**Figure 1**).

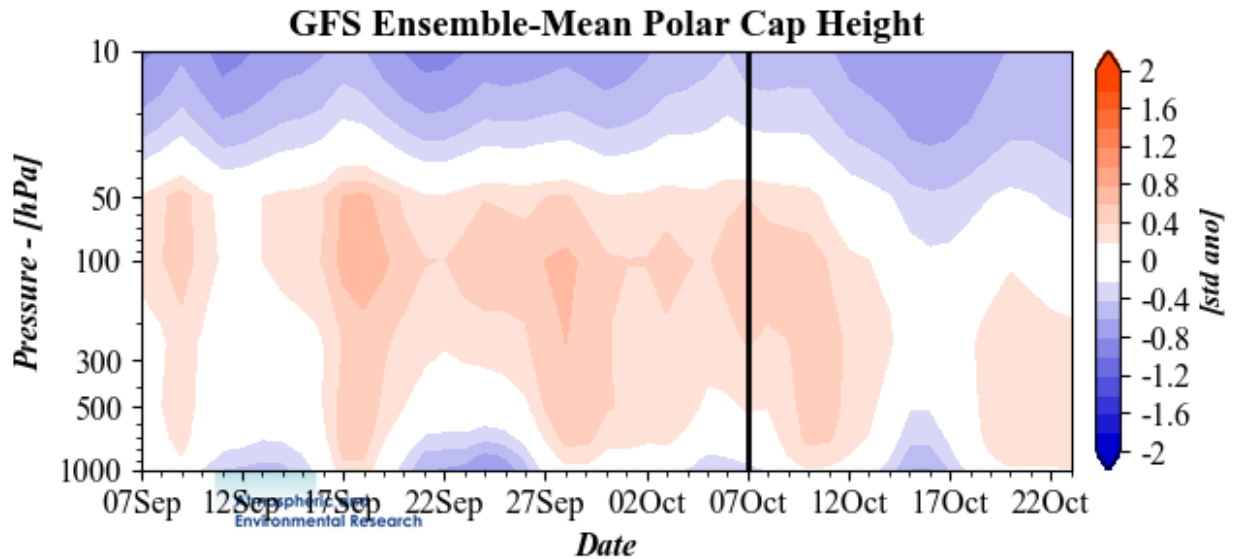


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 7 October 2019 GFS ensemble.

In the middle of the month the negative/cold PCHs are predicted to extend throughout the atmosphere (**Figure 11**), possibly representing the first troposphere-stratosphere coupling of the season. However, this coupling is predicted to be short-lived with a return of positive/warm to the troposphere in late October (**Figure 11**).

CFS 500 hPa Forecast Anomaly Nov 2019
Valid as of 07 Oct 2019

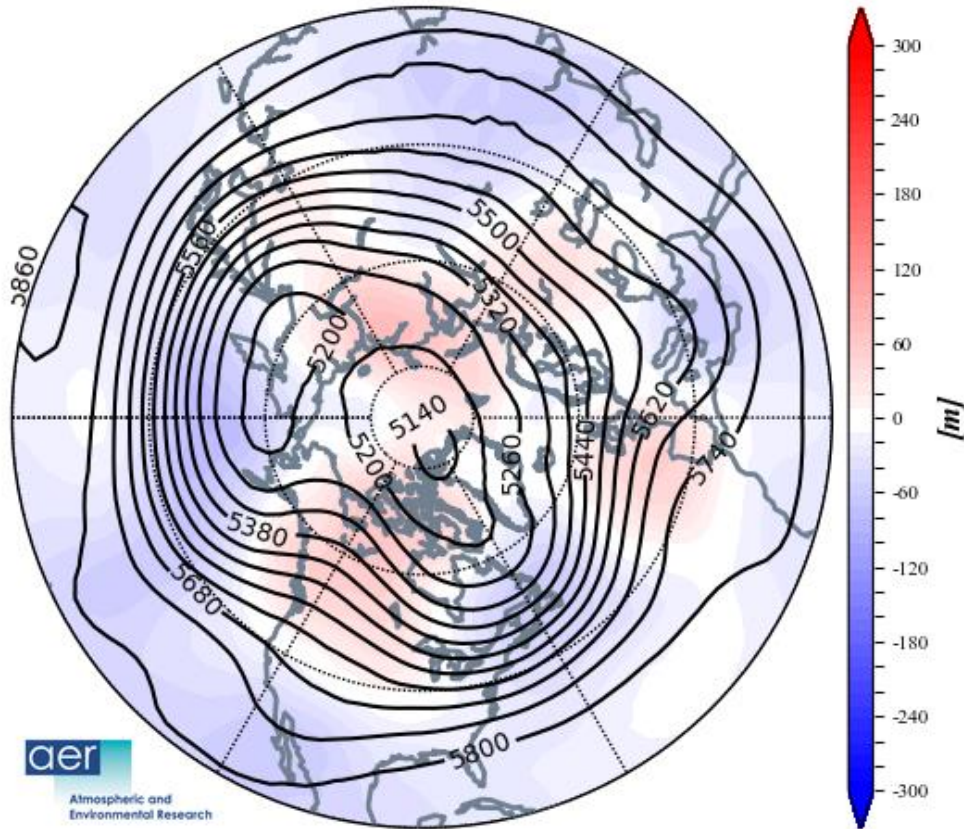


Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for November 2019. The forecasts are from the 7 October 2019 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and the surface temperatures (**Figure 13**) 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 Western Europe, the Urals and Laptev Sea and Western Canada with troughs in Southern Europe, Central and East Asia, Eastern Siberia, the Aleutians, Eastern Canada and the Northeastern US (**Figure 12**). 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 13**).

CFS T2m Forecast Anomaly Nov 2019 Valid as of 07 Oct 2019

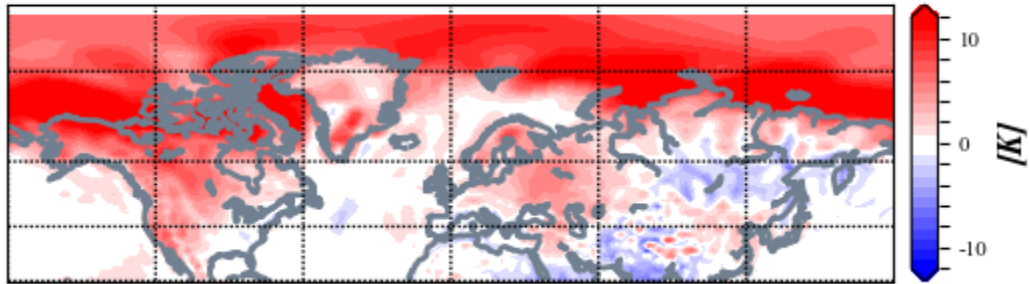


Figure 13. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for November 2019. The forecasts are from the 7 October 2019 CFS.

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 14**). 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.

SST Anomaly - Week Ending 06 Oct 2019

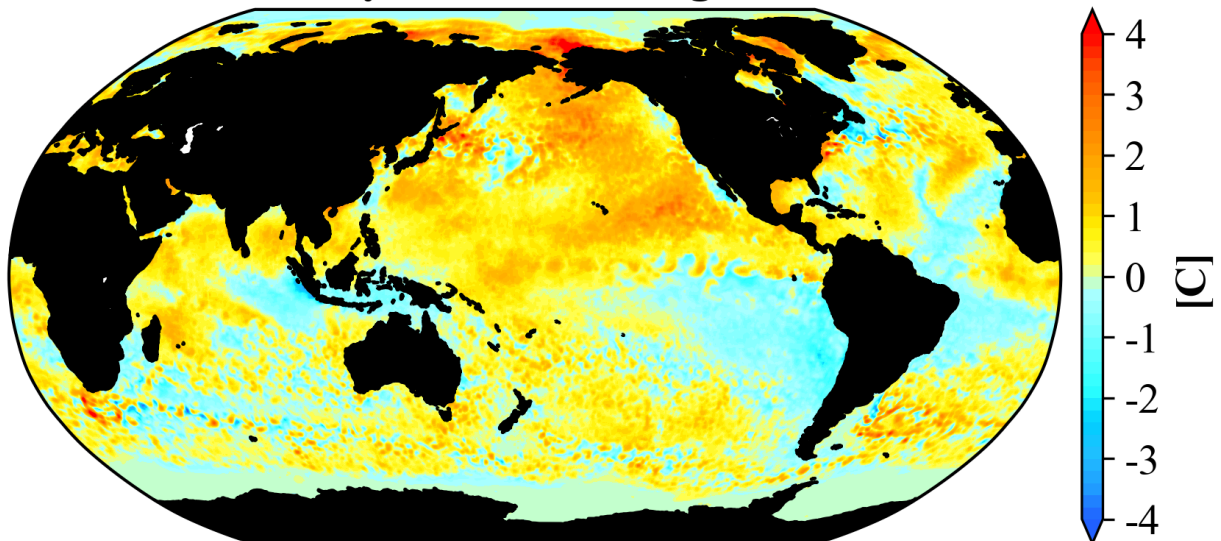


Figure 14. The latest weekly-mean global SST anomalies (ending 22 September 2019). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase eight (**Figure 13**). The forecasts are for the MJO to remain in phase one for the next two weeks. Phase one favors ridging in the Eastern US and toughing in western North America, consistent with the forecast and supportive of a strong MJO influence on the weather across North America.

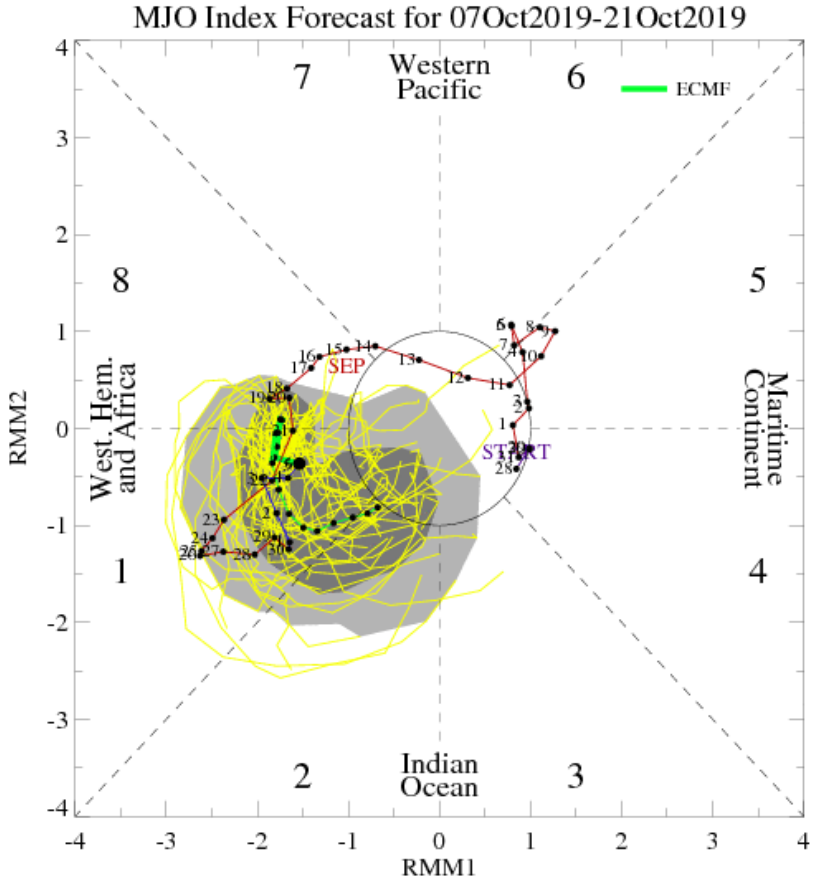


Figure 13. Past and forecast values of the MJO index. Forecast values from the 00Z 7 October 2019 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>