September 9, 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 through the middle of next week before turning negative.
- The current positive AO is reflective of mostly negative pressure/geopotential height anomalies across the Arctic and mostly positive pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is also positive as negative pressure/geopotential height anomalies are spread across Greenland and Iceland; and the NAO is predicted to remain positive to neutral over the next two weeks as geopotential height anomalies are predicted to remain negative or weak across Greenland over the next two weeks.
- Troughing/negative geopotential height anomalies with seasonable to below normal temperatures currently dominate Western Europe including the United

Kingdom (UK) with ridging/positive geopotential height anomalies and above normal temperatures dominating much of Eastern Europe. However, the forecast is for ridging/positive geopotential height anomalies and above normal temperatures to eventually dominate much of Europe after mid-month.

- This week, ridging/positive geopotential height anomalies with above normal temperatures are predicted to dominate Western and East Asia with troughing/negative geopotential height anomalies and below normal temperatures across Siberia. However, the pattern is predicted to flip with troughing/negative geopotential height anomalies and below normal temperatures across Western and East Asia and ridging/positive geopotential height anomalies with above normal temperatures for Siberia for the following week.
- The general pattern predicted across North America for the next two weeks is troughing/negative geopotential height anomalies along the west coast and ridging/positive geopotential height anomalies with normal to above normal temperatures from the Rockies to the east coast.

Impacts

Now that meteorological summer (June 1-August 31) is over, I thought to look back at the summer forecast from both AER and from the large government forecast centers. In **Figure i** are included the Northern Hemisphere (NH) surface temperature anomalies from the North American Multi-Model ensemble (NMME), the EUROSIP super ensemble, including the ECMWF, UK Met Office, Meteo France and the Climate Forecast System (CFS) from NCEP (referred to as the International Multi-Model ensemble (IMME) or in the plot the MMA) and the AER forecast. Also included are the observed NH summer surface temperature anomalies. Overall all the modeling systems performed relatively well with a general relatively warm summer across the NH.

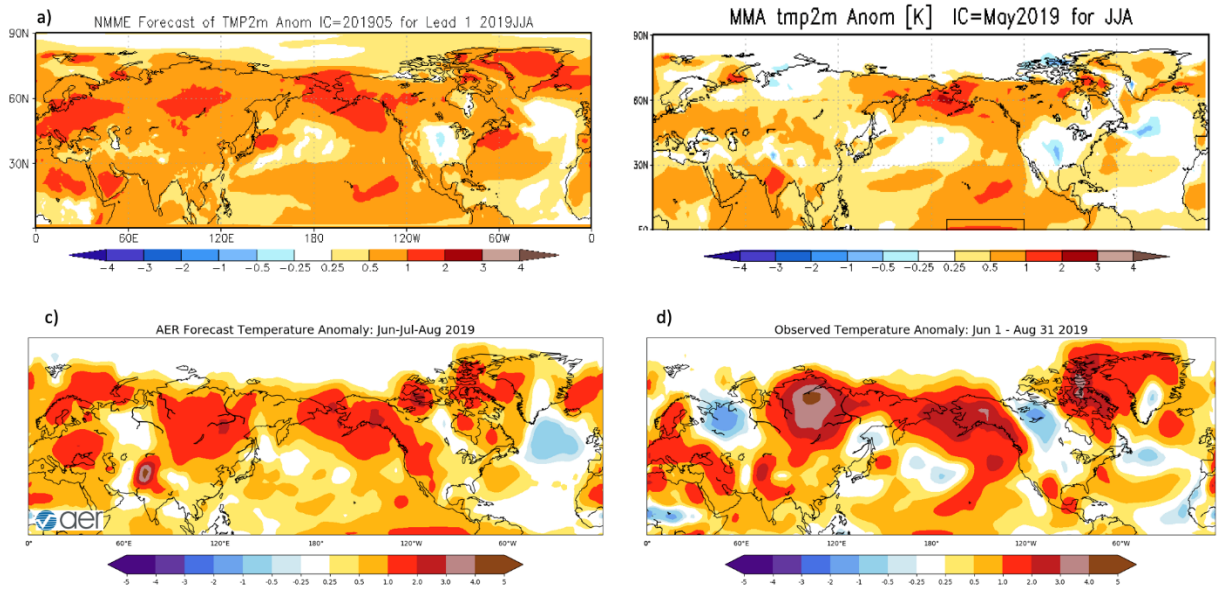

Figure i. Predicted surface temperature anomalies (°C; shading) across the Northern Hemisphere from 1 June – 31 August 2019 from the a) NMME ensemble b) IMME ensemble and c) the AER model. d) Observed surface temperature anomalies (°C; shading) across the Northern Hemisphere from 1 June – 31 August 2019.

It is my opinion that the AER model best predicted the general anomaly pattern across the NH correctly predicting the regions of local temperature anomaly maximums in Siberia, Alaska and the North American West Coast, Greenland and Europe. Temperature anomaly minimums existed in the interior of the continents in Central Canada and Western Russia sandwiched in between the heat ridges on the edges of the continents. Though as is often the case the model underpredicted both the temperature anomaly maximums and minimums.

Based on **Figure i**, the NMME seemed to have the best forecast for the US. In **Figure ii**, I include the surface temperature anomaly from station data from NOAA, and the warmth was more widespread than shown from my plot in **Figure i.**

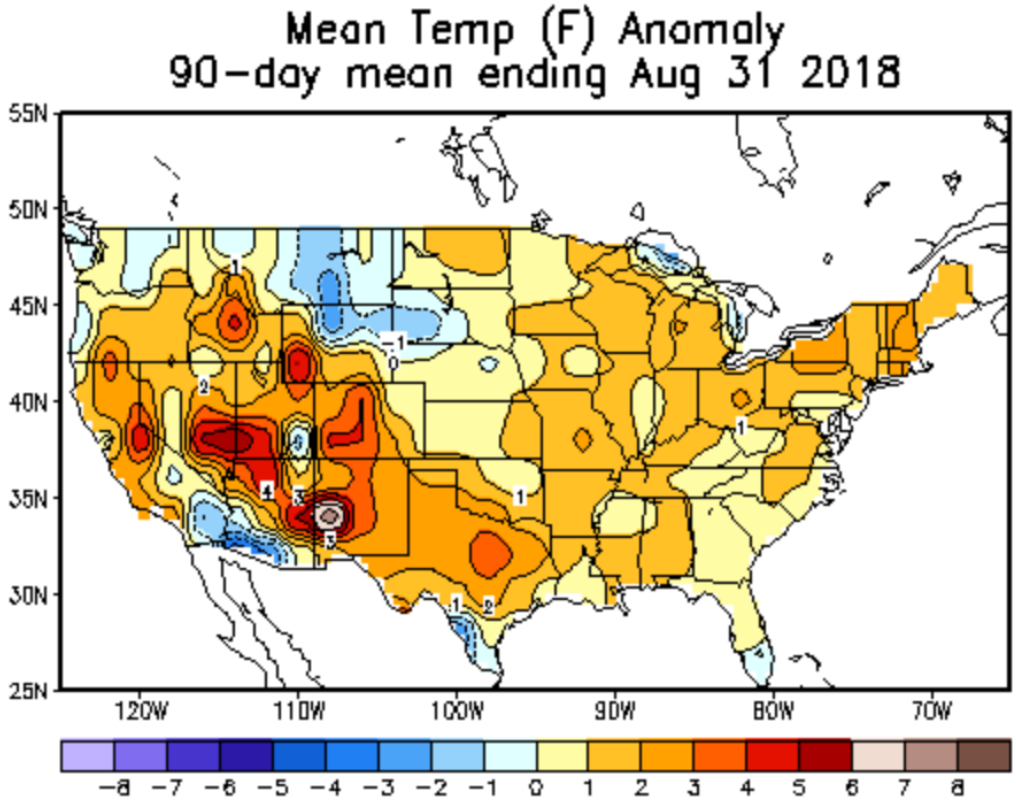

Figure i. Observed surface temperature anomalies (°C; shading) across the US from 3 June – 31 August 2019 from https://www.cpc.ncep.noaa.gov/products/tanal/temp_analyses.php

In **Figure iii,** I show the 500 hPa geopotential heights and anomalies for the summer months June through August. The summer was characterized by high latitude blocking and a negative AO. There three were main high height centers in the high latitudes, near Greenland, Alaska and Siberia. These are the same regions with the greatest temperature anomalies. Downstream of the high height centers in Alaska and Greenland are troughs in Central Canada and Western Russia. These are the regions with the relatively coolest temperature anomalies. Finally, in the mid-latitudes the strongest ridge or positive height center is over Europe, which also experienced a very hot summer. During the summer I did discuss one argument for the warm-cool-warm pattern from west to east across the Eurasian continent that involved snow depth and soil moisture.

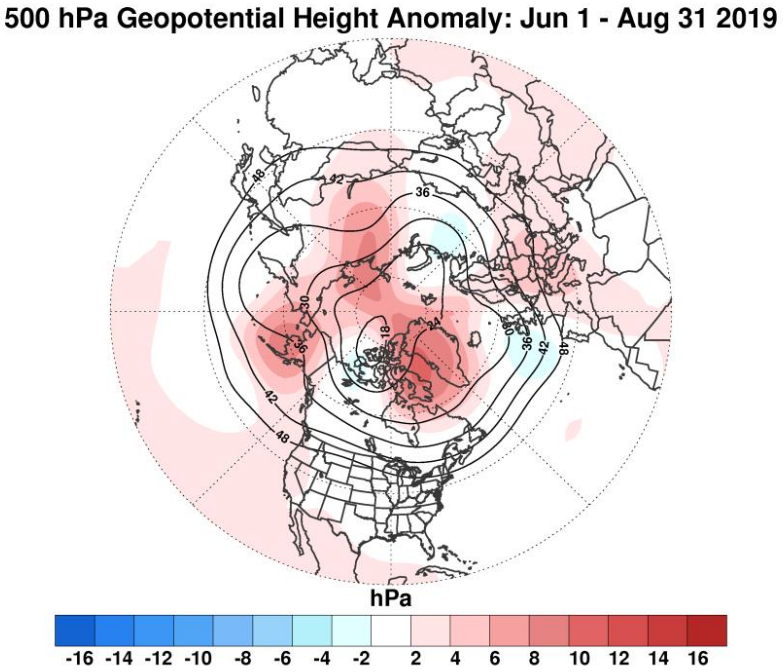

Figure 2. Observed average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 1 June – 31 August 2019.

Why was the high latitude blocking focused near Greenland, Alaska and Siberia? I don't have an answer, but I would guess it is related to lack of snow cover in spring and early summer and Arctic sea ice melt. Certainly, sea ice around Alaska had a record melt. This idea has support in the scientific literature, but this answer is probably still overly simplistic.

Now that summer is in the rear-view mirror, what lies ahead. Similar to summer, NH surface temperatures have been experiencing a robust warming trend and I see little reason to expect any significant deviations from the overall trend. One region that has bucked the warming trend is Siberia and the early signs are this trend too may continue for 2019, but it is early. Winter is more difficult to predict, and I would argue this is related to the behavior of the polar vortex. As I have argued in many scientific articles over my career, low Arctic sea ice and extensive Eurasian snow cover favor a disrupted or perturbed polar vortex. I think a new record low Arctic sea ice minimum is probably out of reach given that the sea ice minimum is usually observed in mid-September. Instead it looks like it will be close for second place between 2019 and 2007. There is a slight chance it could come in close to the extent observed in 2016 if sea ice melt ends soon. Regardless Arctic sea extent will be far below normal in Fall 2019.

From **Figure iv**, sea ice extent is more retracted or below normal on the North Pacific side of the Arctic compared to the North Atlantic side. Last winter the opposite was true, and I will be watching closely if sea ice anomalies on the North Pacific side continue to outpace negative anomalies on the North Atlantic side. I believe a focus of sea ice anomalies on the North Pacific side could favor the interior of North America for cold air outbreaks.

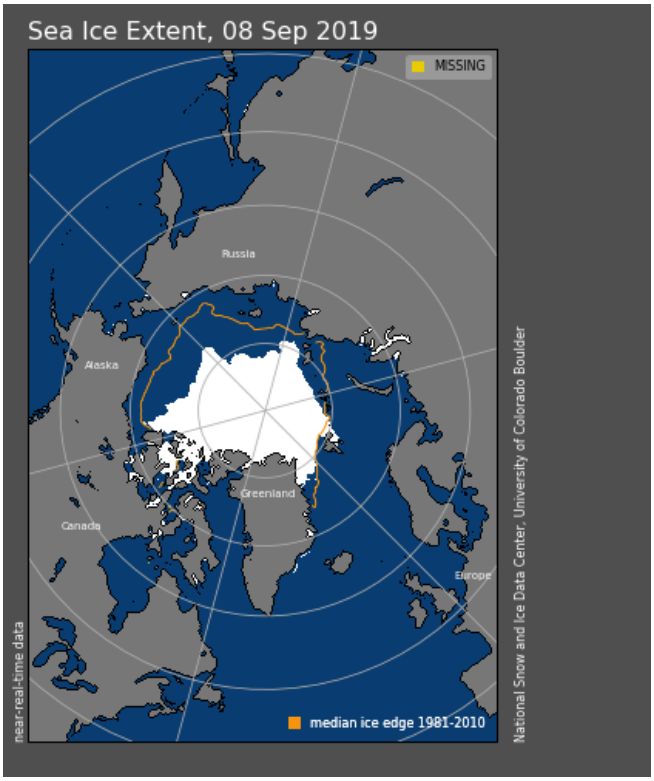

Figure iv. Observed Arctic sea ice extent on 8 September 2019 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

Way too early to tell if Eurasian snow cover will be above normal in October 2019 but according to the GFS forecasts, September snow cover advance across Siberia could get off to a fast start (see **Figure iv**). Still much can change and the exact relationship between snow cover and sea ice extent and winter weather in general and the polar vortex in particular remains controversial. El Niño/Southern Oscillation remains the dominant predictor in seasonal forecasting but with many winter ENSO forecasts trending towards neutral, any signal from ENSO looks to be limited for the upcoming winter.

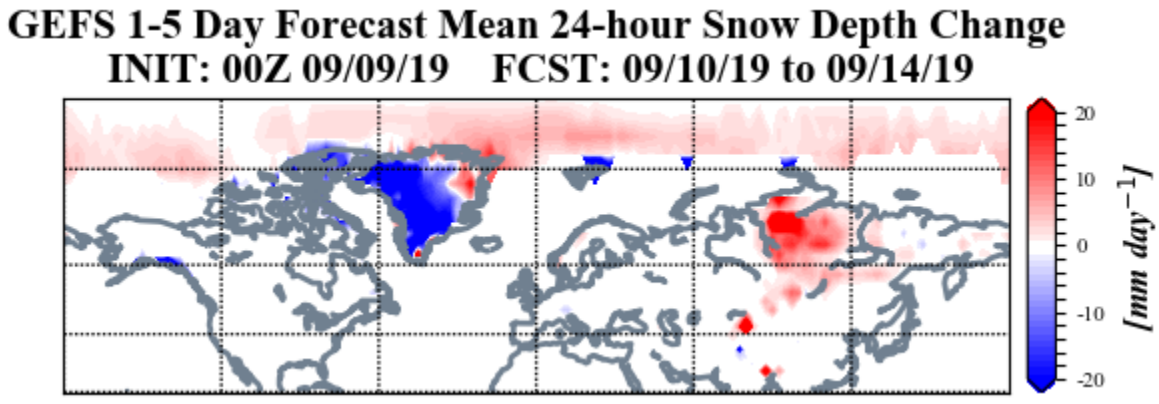

Figure v. Forecasted snow depth anomalies (mm/day; shading) from 10 – 14 September 2019. The forecast is from the 00Z 9 September 2019 GFS ensemble.

Near Term Conditions

1-5 day

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

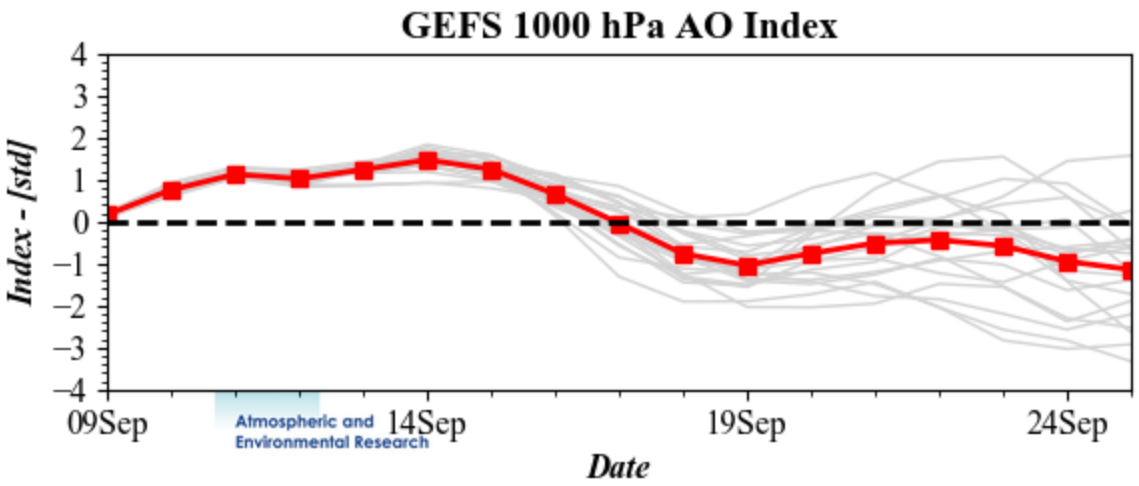

Figure 1. The predicted daily-mean AO at 10 hPa from the 00Z 9 September 2019 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Current troughing/negative geopotential height anomalies over Western Europe will become isolated to Spain this week with ridging/positive geopotential height anomalies across Eastern Europe (**Figure 2**) resulting in normal to below temperatures across much Western Europe including the UK and normal to above normal temperatures across Eastern Europe (**Figure 3**). This week troughing/negative geopotential height anomalies across Siberia are predicted to be bookended by ridging/positive geopotential height anomalies across Western and East Asia (**Figure 2**). This is predicted to yield normal to above normal temperatures for much of Western and East Asia with normal to below normal temperatures for Siberia **(Figure 3**). The troughing in Siberia is predicted to extend southwestward towards the Middle East allowing for colder temperatures to bleed into Central Asia and Iran.

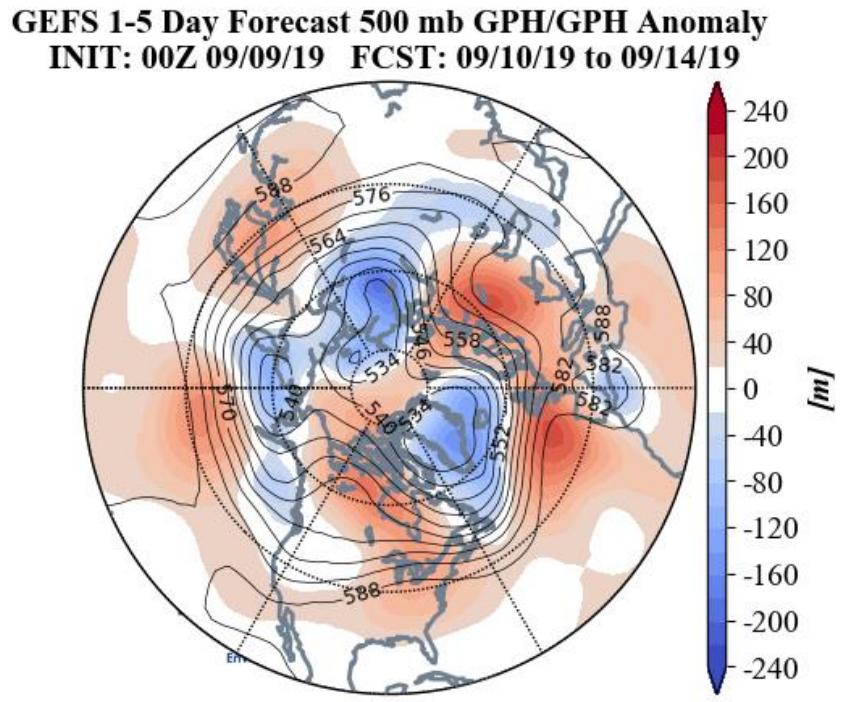

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 10 – 14 September 2019. The forecasts are from the 9 September 00z GFS ensemble.

Troughing/negative geopotential height anomalies are predicted to stretch from Alaska down along the west coast of North America with downstream ridging/positive geopotential height anomalies for Canada and the US east of the Rockies (**Figure 2**). This pattern is predicted to deliver normal to above normal temperatures in Alaska, Northern Canada and the Southern US (**Figure 3**). Residual troughing/negative geopotential height anomalies normal are predicted to result in below normal temperatures for Southern Canada and the Northern US **(Figure 3).**

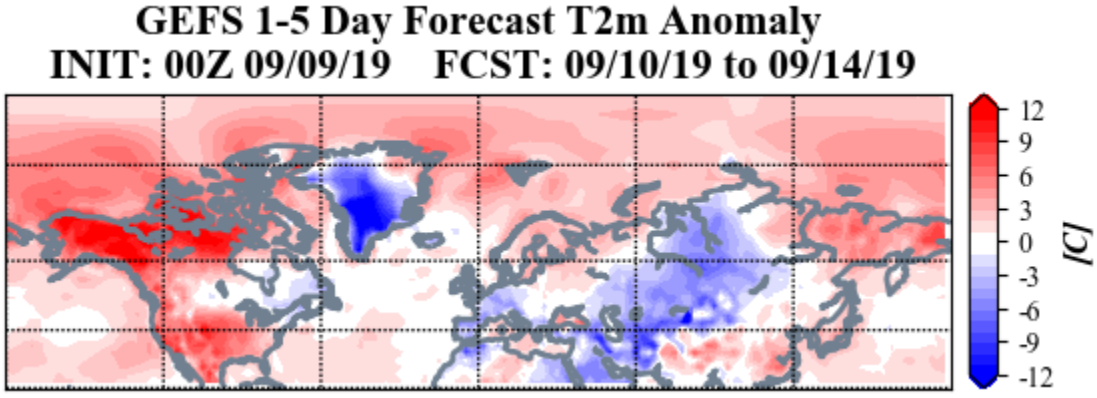

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 10 – 14 September 2019. The forecast is from the 00Z 9 September 2019 GFS ensemble.

Much of Europe is predicted to receive below normal precipitation (**Figure 4**). Troughing is predicted to bring above normal rainfall/snowfall to Siberia, the monsoon regions of India, East Asia and Mexico (**Figure 4**). Troughing will bring above normal precipitation to parts of the Northern US (**Figure 4**).

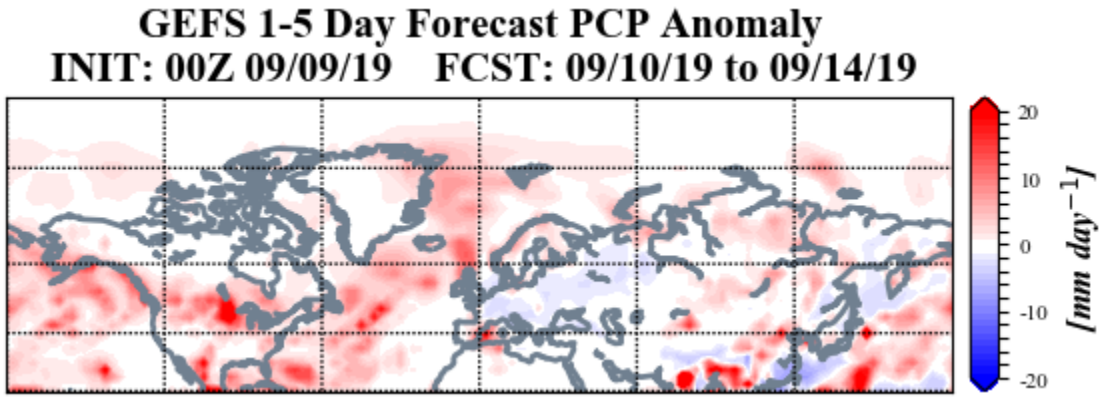

Figure 4. Forecasted precipitation anomalies (mm/day; shading) from 10 – 14 September 2019. The forecast is from the 00Z 9 September 2019 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to start off the period positive but then dip negative this period **(Figure 1**) as positive geopotential height anomalies return to the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with weak negative geopotential height anomalies across Greenland (**Figure 5**), the NAO will likely remain positive.

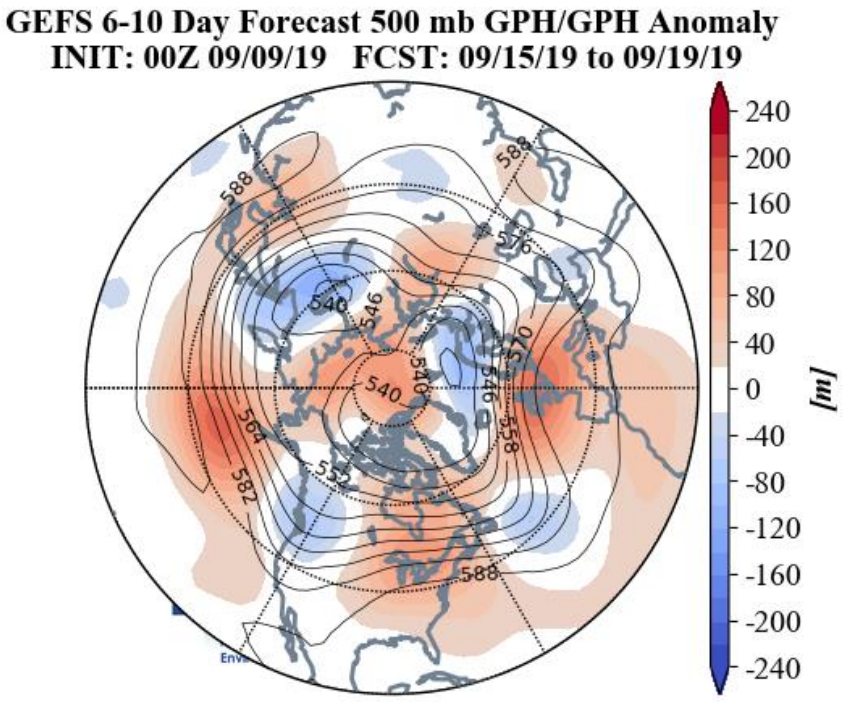

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 15 – 19 September 2019. The forecasts are from the 9 September 00z GFS ensemble.

Troughing/negative geopotential height anomalies from the previous period centered near Greenland and Iceland are predicted to move across Northern Europe and drop into Eastern Europe this period with ridging/positive geopotential height anomalies now focused in Western Europe (**Figure 5**). This pattern favors normal to above normal temperatures across Western Europe including the UK with normal to below normal temperatures in Eastern Europe (**Figure 6**). The pattern from the previous period is predicted to persist this period across Asia with troughing/negative geopotential height anomalies in Siberia that extends southwestward towards the Tibetan Plateau with ridging/positive geopotential height anomalies in Western and East Asia (**Figure 5**). This is predicted to yield widespread normal to above normal temperatures for much of Western and East Asia including the Middle East with normal to below normal temperatures for much of Siberia and the Tibetan Plateau **(Figure 6**).

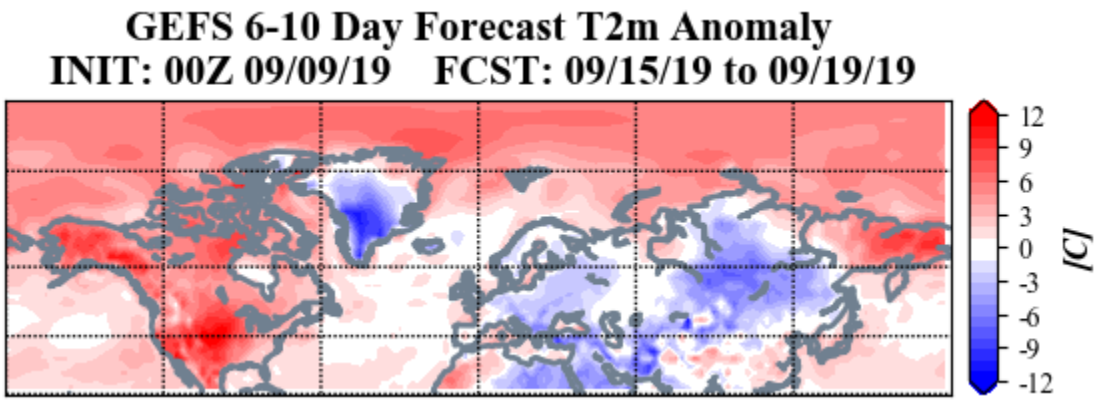

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 15 – 19 September 2019. The forecasts are from the 00Z 9 September 2019GFS ensemble.

Troughing/negative geopotential height anomalies are predicted to persist along the west coast of North America with downstream ridging/positive geopotential height anomalies in Eastern Canada and in the Eastern US (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across Alaska, much of Canada and the US from the Rockies to the East Coast with normal to below normal temperatures confined to southern British Columbia and the US West Coast **(Figure 6).**

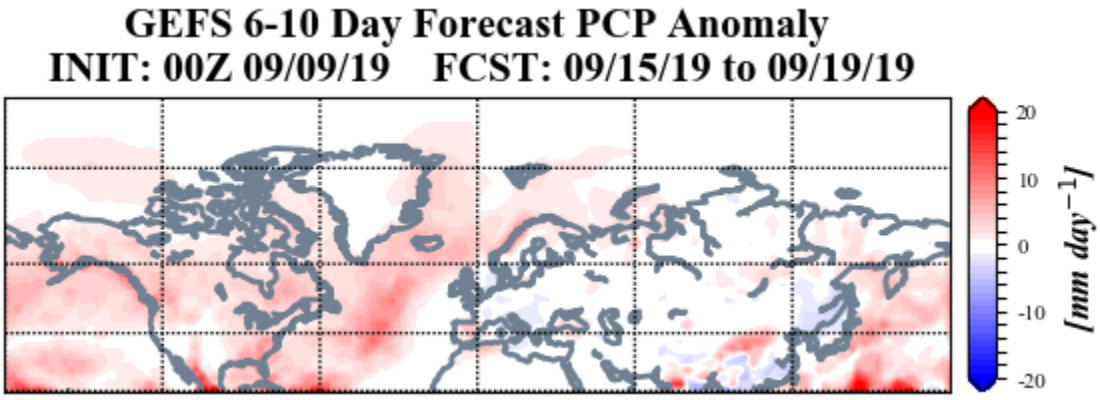

Figure 7. Forecasted precipitation anomalies (mm/day; shading) from 15 – 19 September 2019. The forecasts are from the 00Z 9 September 2019 GFS ensemble.

Much of Eurasia is predicted to receive near normal precipitation with above normal precipitation confined to Spain and the Tibetan Plateau (**Figure 7**). Troughing is predicted to bring above normal rainfall to the monsoon region of Mexico and the Southeastern US (**Figure 7**).

11-15 day

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

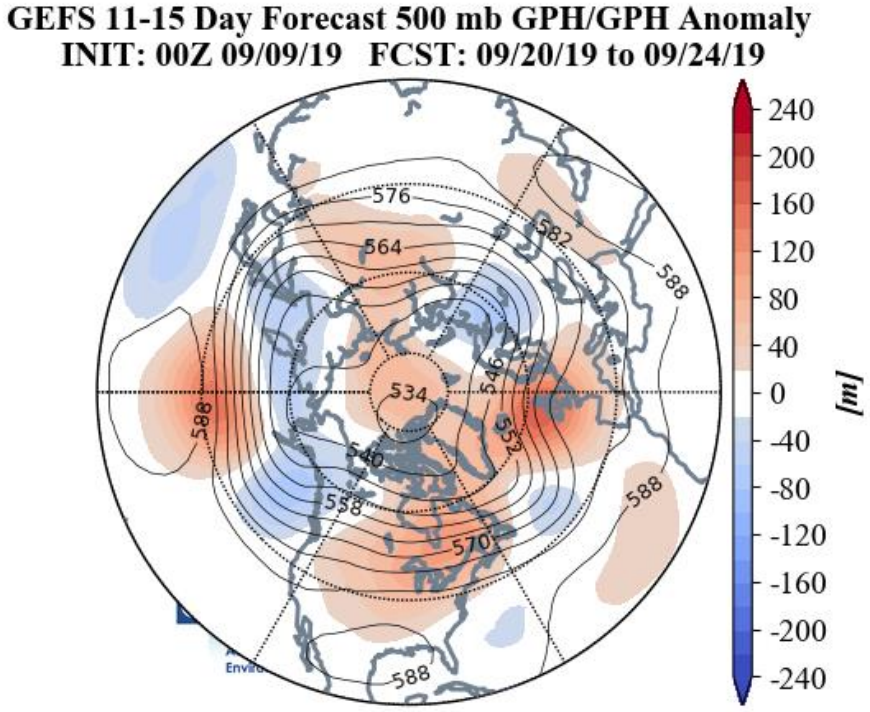

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 20 – 24 September 2019. The forecasts are from the 9 September 00z GFS ensemble.

Ridging/positive are predicted to persist this period across Western Europe with troughing/negative geopotential height anomalies across Eastern Europe (**Figure 8**). This pattern is predicted to result in more seasonable to above normal temperatures for Western Europe including the UK with normal to below normal temperatures for Eastern Europe (**Figure 9**). The predicted pattern across Asia this period is predicted to flip with ridging/positive geopotential height anomalies in Siberia with troughing/negative geopotential height anomalies in Western and Northeast Asia (**Figure 8**). This pattern favors normal to below normal temperatures for Western but especially East Asia with normal to above normal temperatures for Siberia, the Middle East and Southeast Asia (**Figure 9**).

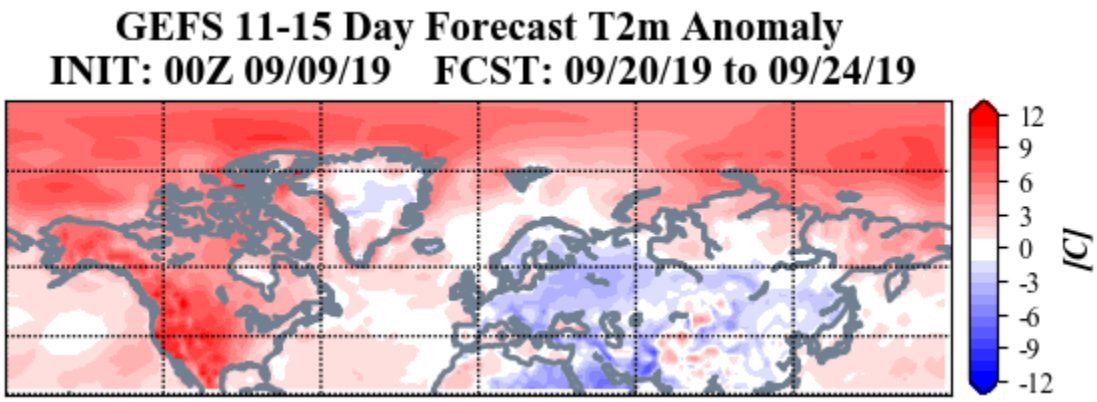

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 20 – 24 September 2019. The forecasts are from the 00Z 9 September 2019 GFS ensemble.

Troughing/negative geopotential height anomalies are predicted to remain confined to western North America including Alaska with downstream ridging/positive geopotential height anomalies in both Canada and the US east of the Rockies (**Figure 8**). This will favor normal to above normal temperatures to be widespread across North America with the possible exception of normal to below normal temperatures along the US West Coast (**Figure 9**).

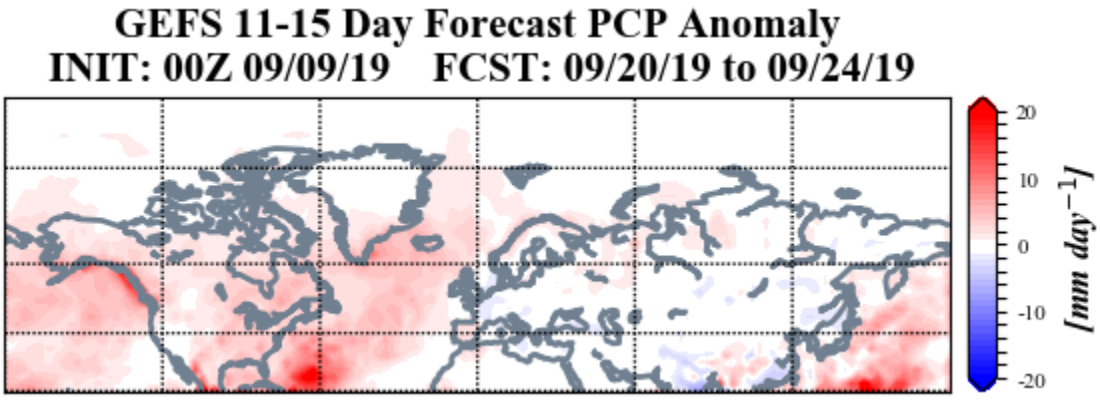

Figure 10. Forecasted precipitation anomalies (mm/day; shading) from 20 – 24 September 2019. The forecasts are from the 00Z 9 September 2019 GFS ensemble.

Much of Eurasia and North America are predicted to receive near normal precipitation (**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 lowest troposphere PCHs are weakly below normal, consistent with the positive AO (**Figure 1**).

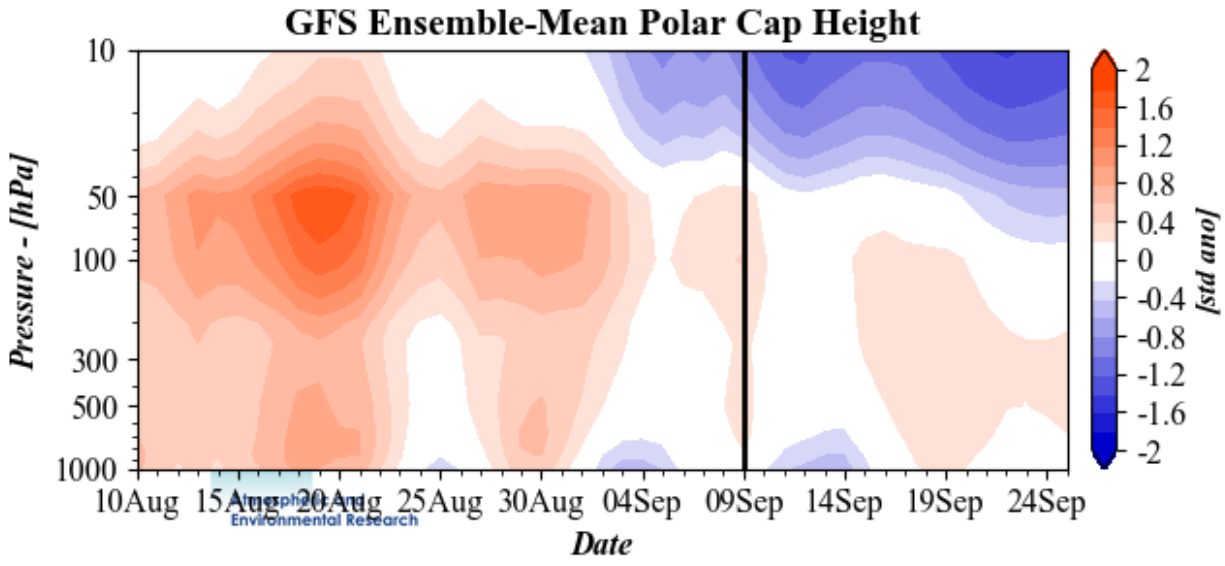

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 9 September 2019 GFS ensemble.

Positive PCHs in the mid to upper troposphere are predicted to descend into the lower troposphere end of next week (**Figure 11**). This should cause the AO to trend negative and into negative territory after mid-month. Given how weak the predicted anomalies are, I would consider this a low confidence forecast.

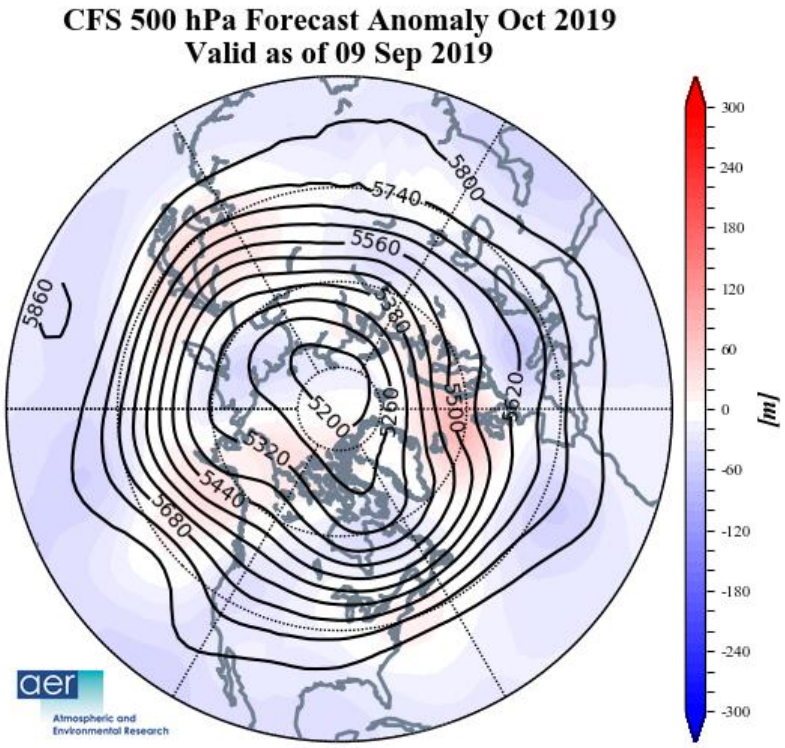

Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for October 2019. The forecasts are from the 9 September 2019 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and the surface temperatures (**Figure 13**) forecast for October from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging centered across Northern Europe, East Asia and the Gulf of Alaska with troughs in Southern Europe, Southwest Asia, Siberia, the Western US and Eastern Canada (**Figure 12**). This pattern favors relatively warm temperatures for Northern Europe, East Asia, Western Canada and the Western US with seasonable to relatively cool temperatures for Southern Europe, Southwest Asia, Southeast Canada and the Northeastern US **(Figure 13).** I am skeptical of the latest CFS forecast.

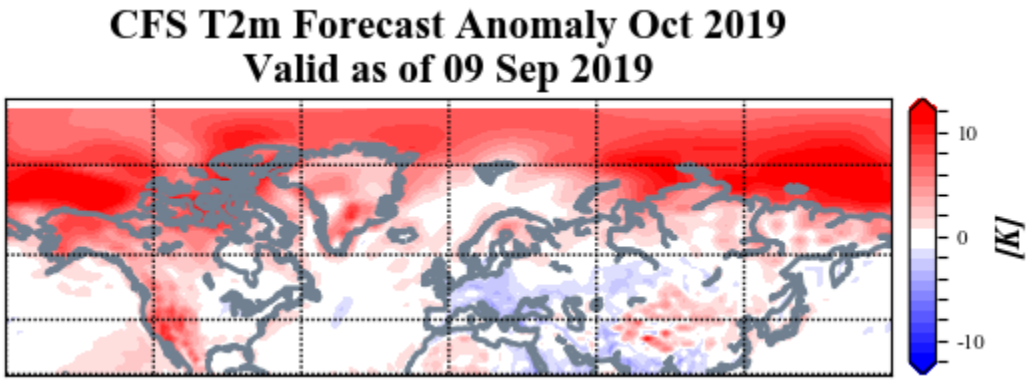

Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for October 2019. The forecasts are from the 9 September 2019 CFS.

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.

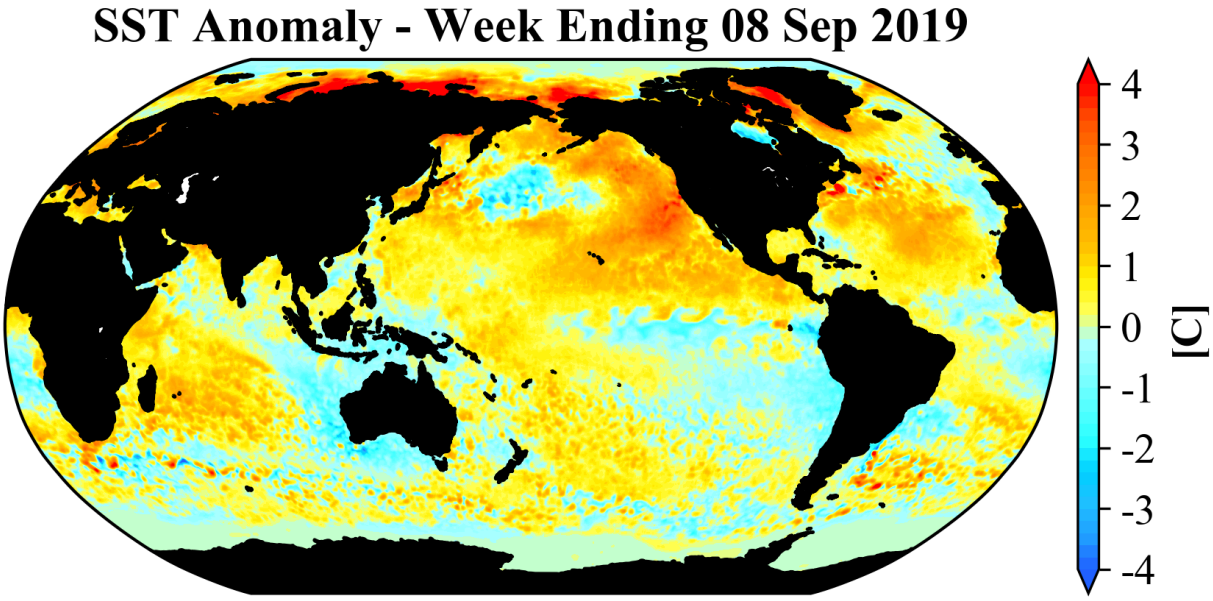

Figure 14. The latest weekly-mean global SST anomalies (ending 8 September 2019). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase six (**Figure 13**). However the forecasts are for no phase of the MJO to be favored over the next two weeks before emerging into phase eight. Little influence from the MJO is expected over the upcoming two weeks.

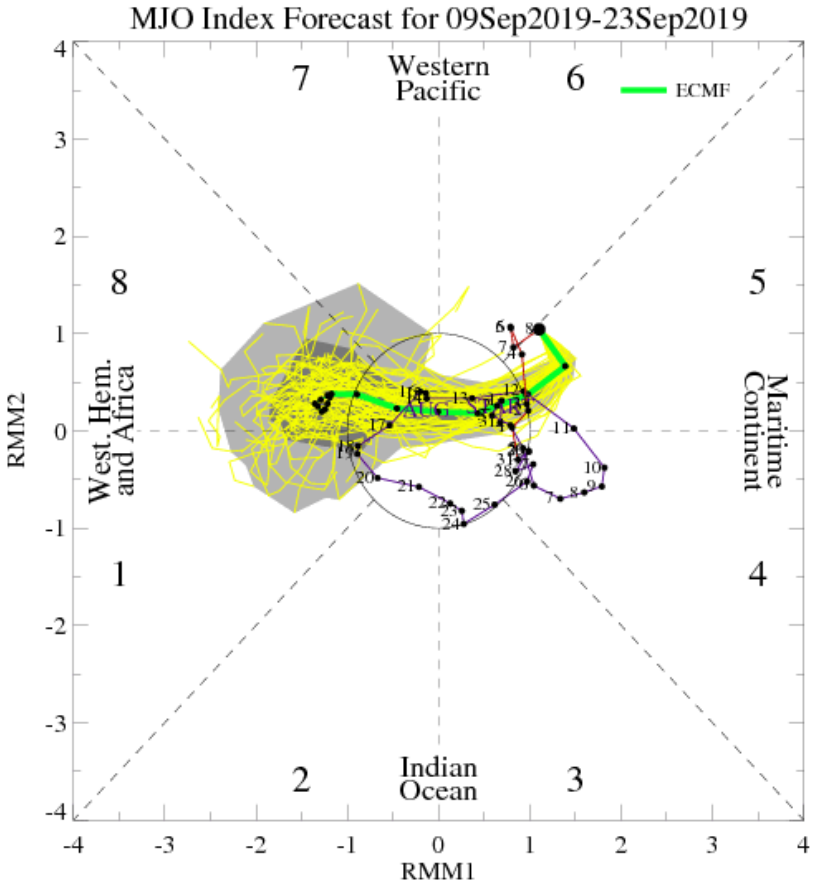

Figure 13. Past and forecast values of the MJO index. Forecast values from the 00Z 9 September 2019 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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