

Arctic Oscillation and Polar Vortex Analysis and Forecasts

July 26, 2021

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) embarked on an experimental process of regular research, review, and analysis of the Arctic Oscillation (AO) and Polar Vortex (PV). This analysis is intended to provide researchers and practitioners real-time insights on one of North America's and Europe's leading drivers for extreme and persistent temperature patterns.

During the winter schedule the blog is updated once every week. Snow accumulation forecasts replace precipitation forecasts. Also, there is renewed emphasis on ice and snow boundary conditions and their influence on hemispheric weather. With the start of spring we transition to a spring/summer schedule, which is once every two weeks. Snow accumulation forecasts will be replaced by precipitation forecasts. Also, there will be less emphasis on ice and snow boundary conditions and their influence on hemispheric weather.

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

Summary

- The Arctic Oscillation (AO) is currently neutral and is predicted to drop into negative territory this week and slowly trend positive into next week as positive pressure/geopotential height anomalies dominate the Central Arctic and Greenland this week and then are predicted to slowly weaken next week with mixed pressure/geopotential height anomalies across the mid-latitudes. The

North Atlantic Oscillation (NAO) is currently also neutral and is predicted to drop into negative territory and then slowly trend positive as pressure/geopotential height anomalies are predicted to be positive this week across Greenland and then weaken next week.

- This week, ridging/positive geopotential height anomalies across Greenland favor troughing/negative geopotential height anomalies coupled with normal to below temperatures in Western Europe including the United Kingdom (UK) with ridging/positive geopotential height anomalies coupled with normal to above normal temperatures in Eastern Europe. Next week, troughing/negative geopotential height anomalies coupled with normal to below temperatures will spread from Western Europe into Eastern Europe.
- Over the next two weeks much of Asia will be dominated by an omega block pattern with troughing/negative geopotential height anomalies coupled with normal to below temperatures in Western and Eastern Asia sandwiching ridging/positive geopotential height anomalies coupled with normal to above normal temperatures in Central Asia.
- This general pattern across North America over the next two weeks is ridging/positive geopotential height anomalies coupled with normal to above normal temperatures in western North America and troughing/negative geopotential height anomalies coupled with normal to below temperatures across eastern Canada and the Eastern United States (US) but mostly the Northeastern US.
- In the Impacts section I share some more thoughts on the summer pattern across the Northern Hemisphere (NH).

Impacts

For winter weather enthusiasts like myself the predicted circulation pattern across the NH is more reminiscent of mid-winter much more so than mid-summer. A healthy negative AO associated with troughs and relatively cool temperatures simultaneously across Northern Europe, East Asia and eastern North America is more common in winter than in summer and even in winter is rare. And from looking at the polar cap geopotential height anomalies (PCHs) in **Figure 11**, it appears that the source of the negative AO is descent of warm/PCHS from the lower stratosphere to the surface just as occurs when the stratospheric polar vortex (SPV) is highly disrupted. The NH SPV is in summer hibernation, so this clearly is not happening. The fact that we can observe “dripping paint” or dripping positive values of the PCH from the stratosphere to the surface in summer probably just highlights more than anything else that we don’t really understand the dynamic coupling of the stratosphere and the troposphere in winter.

In **Figure i**, I include the observed temperature anomalies for summer 2021 so far. As I discussed in the previous blog, overall, the NH is experiencing widespread warmer than normal temperatures, but three regions stand out for more amplified warming relative to normal: The Western US and Southwestern Canada, Northeastern Europe and

Siberia. Also exceptionally hot are the Middle East into Central Asia, especially centered near Iran and North Africa. It is interesting how northern Eurasia is experiencing a much warmer summer relative to normal than northern North America. It is hard to anticipate how long the negative AO pattern will persist but there could be some changes to the regions of warm anomalies in the second half of the summer.

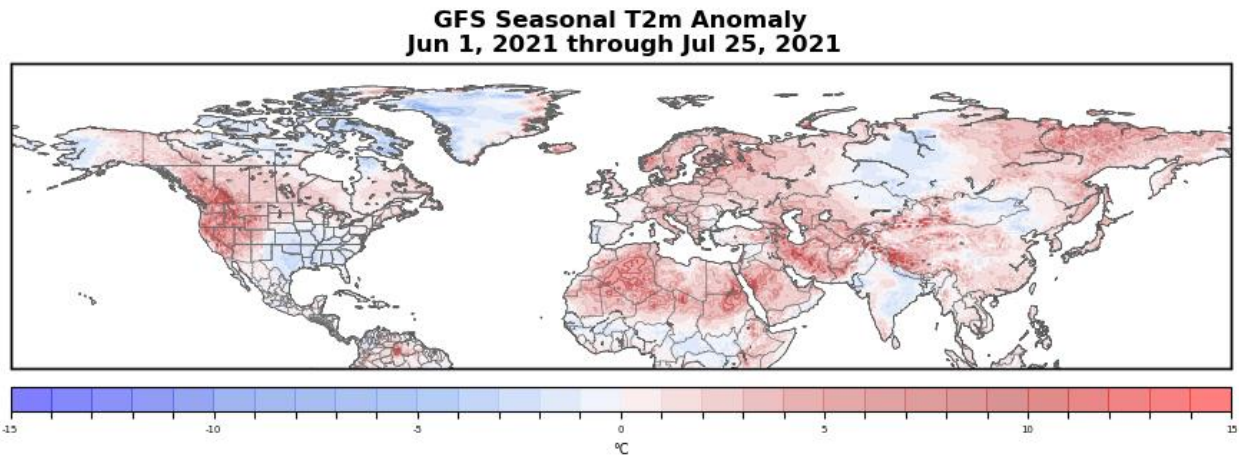


Figure i. Observed surface temperature anomalies (°C; shading) over the NH for June and July 1-25, 2021 based on GFS analysis.

Besides the cooler weather in Europe, East Asia and Eastern Canada and US, the negative AO is associated with relatively high pressure and more sunshine over Greenland and the Central Arctic. In Greenland this could lead to increased land ice melt and in the Central Arctic could result in more sea ice melt. So far in summer 2021 (see **Figure ii**), Arctic sea ice extent is near daily record lows comparable to 2007 and 2012 but slightly higher at this time of year than in 2020. The upcoming period of negative AO should help to melt Arctic sea ice at a good clip and keep 2021 near a record pace of low extent. I still think 2012 will be hard to beat but certainly a possibility and the extent minimum will likely be close to 2007, 2012 and 2020.

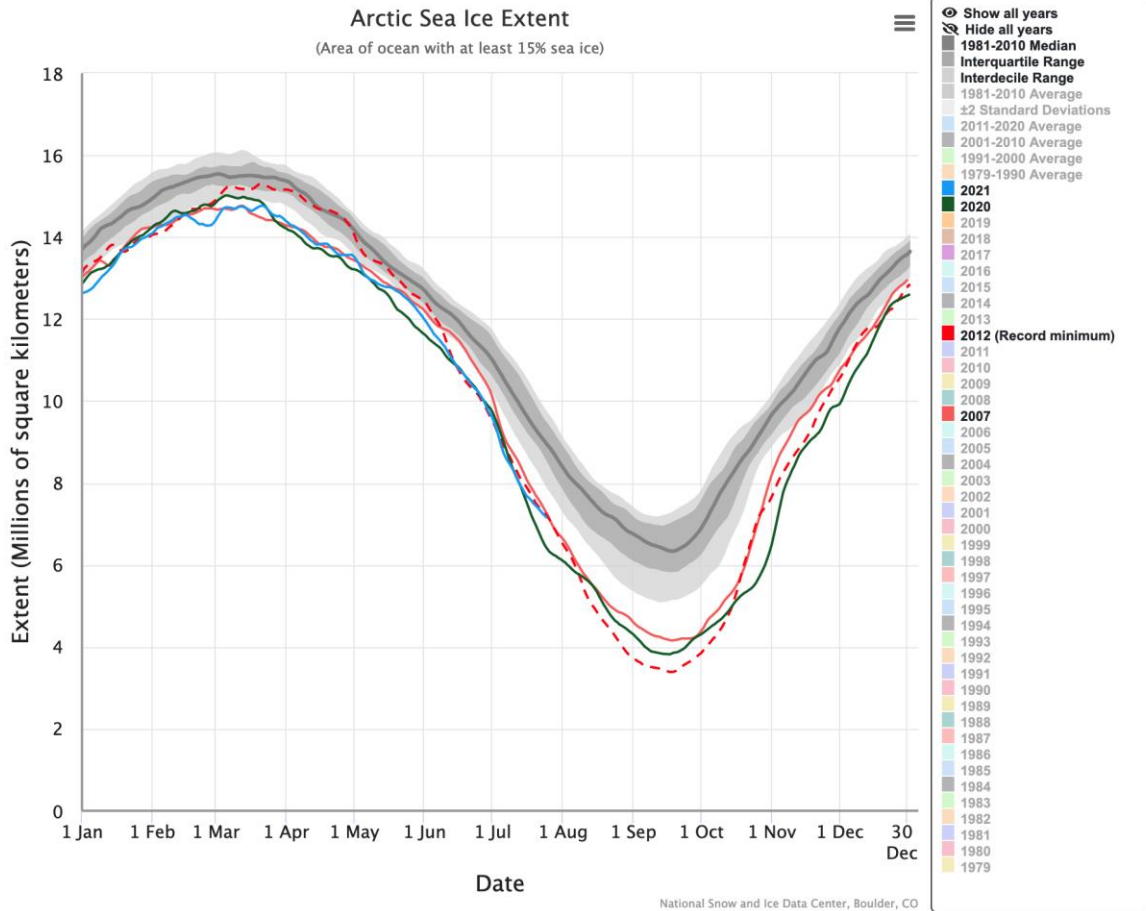


Figure ii. Daily observed Arctic sea ice extent 25 July 2021 (blue). Also shown are 2007 (orange) 2012 (red dashed) and 2020 (green). Image courtesy of National Snow and Ice Data Center (NSIDC).

1-5 day

The AO and NAO are predicted to be negative this week (**Figure 1**) as geopotential height anomalies are predicted to be mostly positive in the Central Arctic and across Greenland with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**).

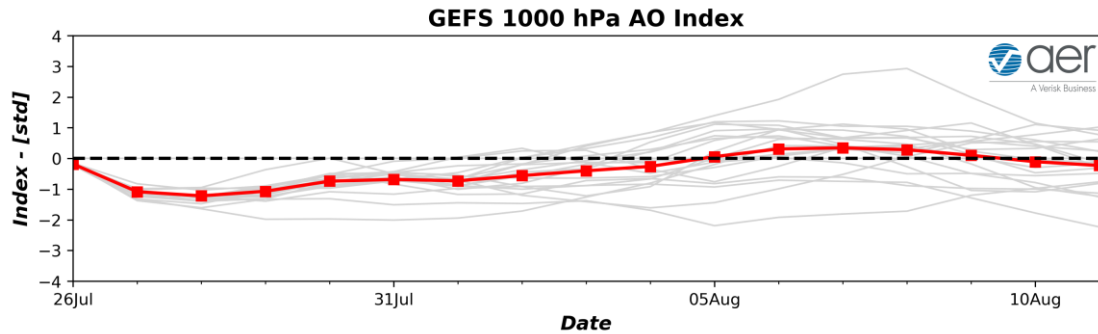


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 26 July 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Ridging/positive geopotential height anomalies across Greenland are predicted to favor troughing/negative geopotential height anomalies across Western Europe especially across the UK with ridging/positive geopotential height anomalies across Eastern Europe (**Figures 2**). This will favor normal to below normal temperatures across much of Western Europe including the UK with normal to above normal temperatures across Eastern Europe (**Figure 3**). The general pattern across Asia this period is ridging/positive geopotential height anomalies across Central Asia bookended by troughing/negative geopotential height anomalies in Western and Eastern Asia (**Figure 2**). This pattern favors normal to above normal temperatures across much of Central Asia with normal to below normal temperatures in much of Western and Eastern Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 07/26/2021 FCST: 07/27/2021 to 07/31/2021

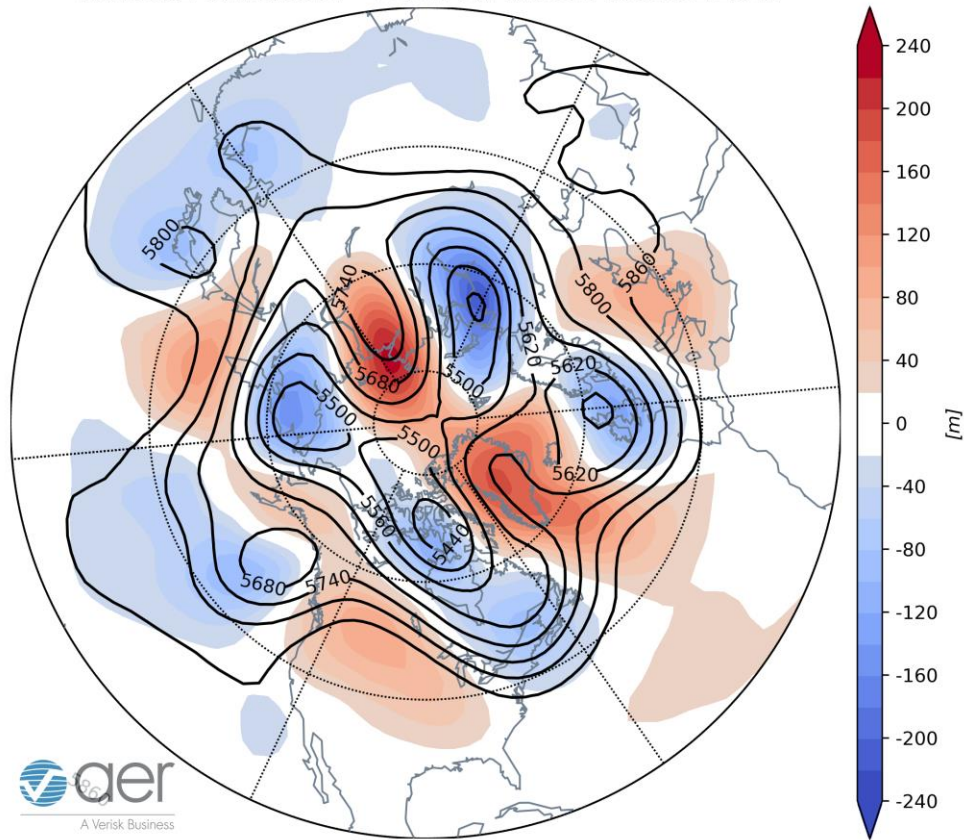


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 27–31 July 2021. The forecasts are from the 00z 26 July 2021 GFS ensemble.

The general pattern this week is ridging/positive geopotential height anomalies across much of western North America with troughing/negative geopotential height anomalies across eastern North America (**Figure 2**). This pattern is predicted to bring normal to above normal temperatures across much of Eastern Alaska, Western Canada, the Western and Southeastern US with normal to below normal temperatures across Western Alaska, Eastern Canada and the Northeastern US (**Figure 3**).

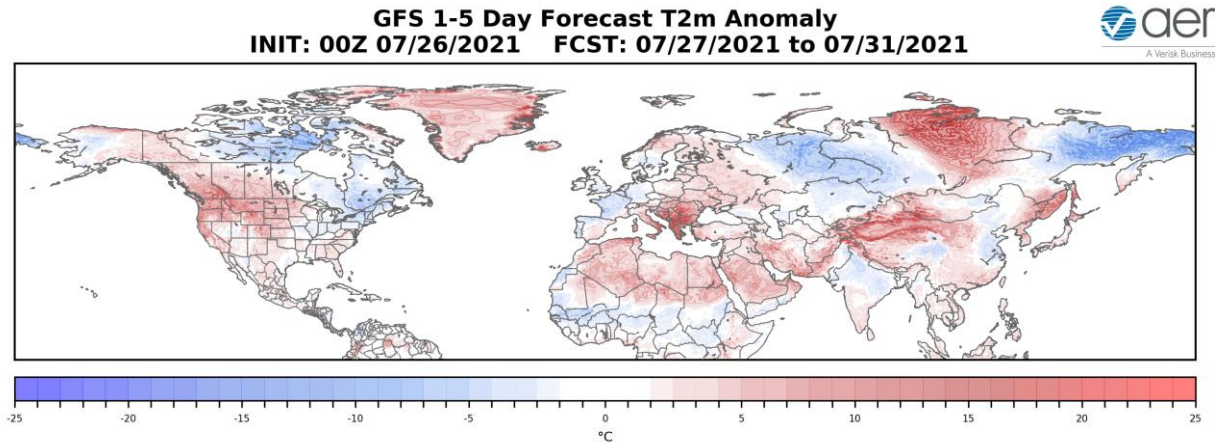


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 27– 31 July 2021. The forecast is from the 00Z 26 July 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia with the exceptions of above normal precipitation across Northern and Central Europe, the Baltic States, Southern and Eastern Asia (**Figure 4**). Normal to below normal precipitation is predicted for much of North America with the exceptions of normal to above normal precipitation in Western Alaska, Florida, eastern New England and the Canadian Maritimes (**Figure 4**).

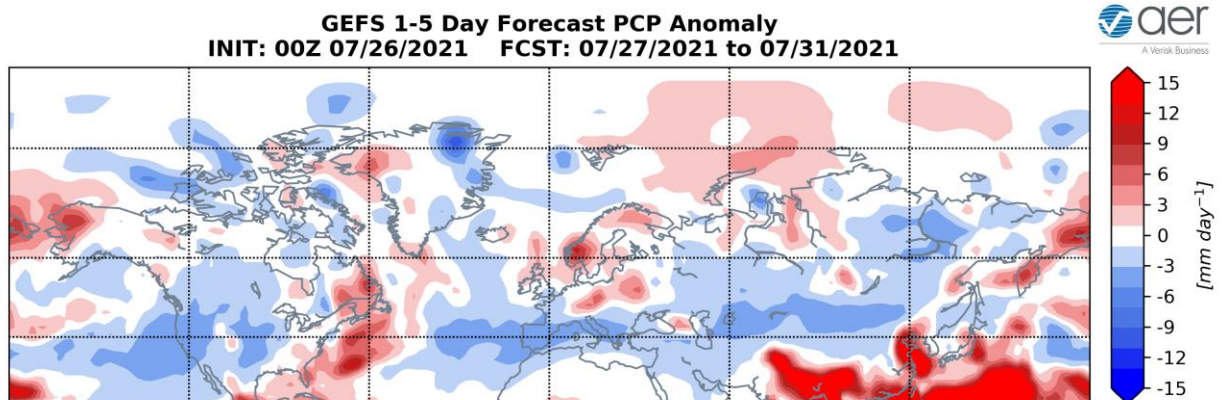


Figure 4. Forecasted precipitation anomalies (mm/day; shading) from 27– 31 July 2021. The forecast is from the 00Z 26 July 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to transition from negative to positive this period (**Figure 1**) as geopotential height anomalies remain normal to above normal but weakened across the Central Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with normal to above normal geopotential height anomalies continuing across Greenland (**Figure 5**), the NAO is predicted to also remain negative this period.

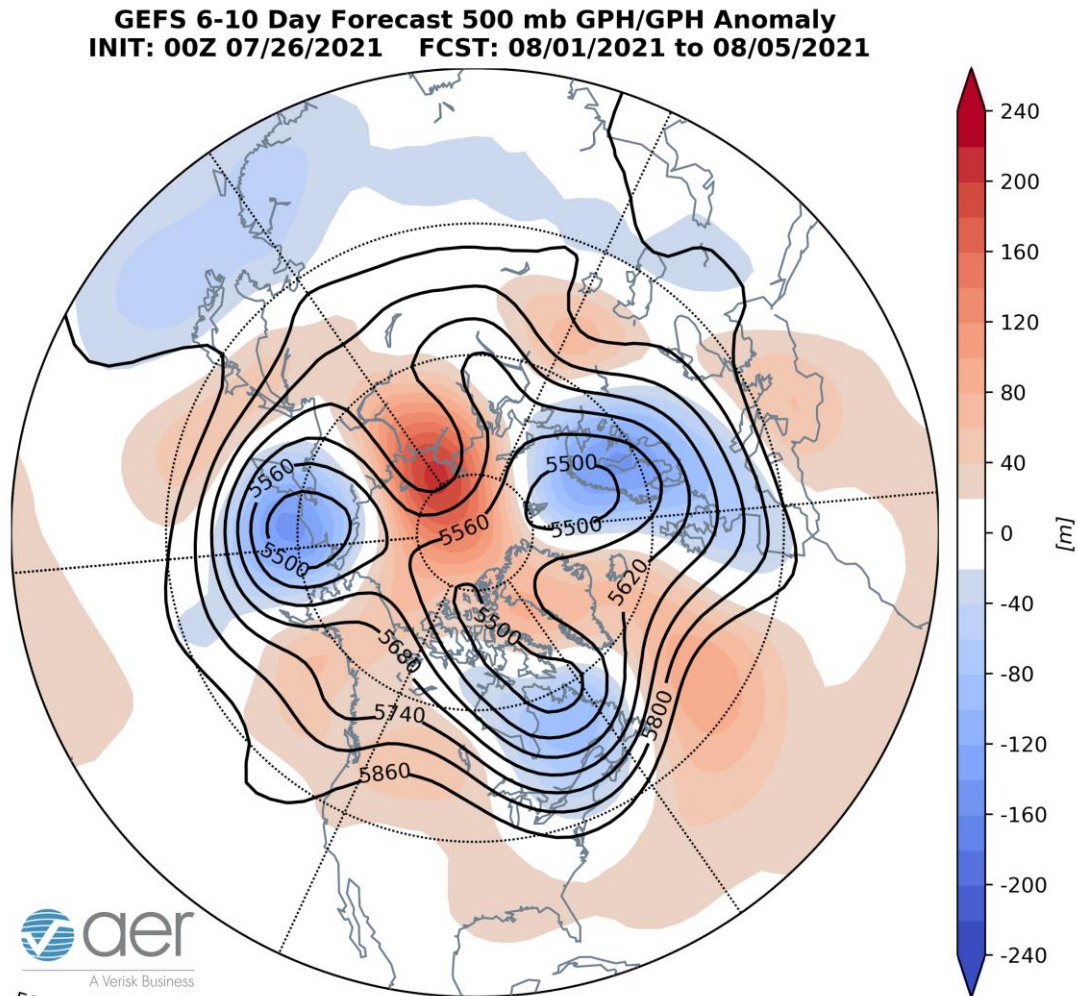


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 1 – 5 August 2021. The forecasts are from the 00z 26 July 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies across Greenland will contribute to persistent troughing/negative geopotential height anomalies across Europe especially Northern Europe with ridging/positive geopotential height anomalies suppressed into Southeastern Europe (**Figures 5**). This will favor widespread normal to below normal temperatures across much of Europe including the UK with the exception of normal to above normal temperatures confined across Southern Italy and into the

Balkans (**Figure 6**). The omega block pattern is predicted to persist across Asia with ridging/positive geopotential height anomalies over Central Asia bookended by troughing/negative geopotential height anomalies across Eastern Asia and Western Asia, though the Western Asia node will weaken from the previous period (**Figure 5**). This pattern favors normal to above normal temperatures across much of Western and Central Asia with normal to below normal temperatures in East Asia (**Figure 6**).

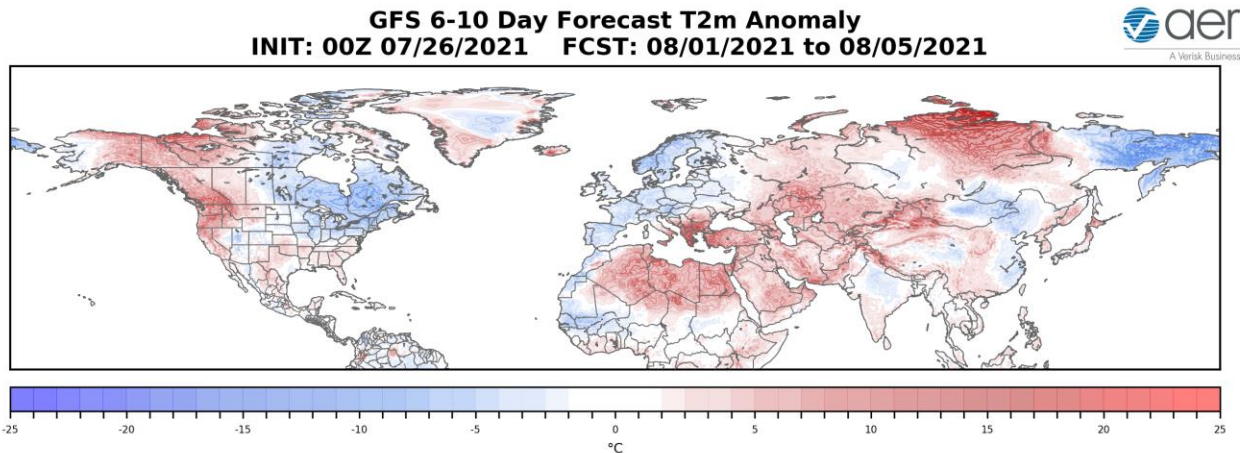


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 1 – 5 August 2021. The forecasts are from the 00Z 26 July 2021 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to continue to dominate western North America with 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 much of Alaska, Western Canada, the Western and Southern US with normal to below normal temperatures across Eastern Canada and the Northeastern US (**Figure 6**).

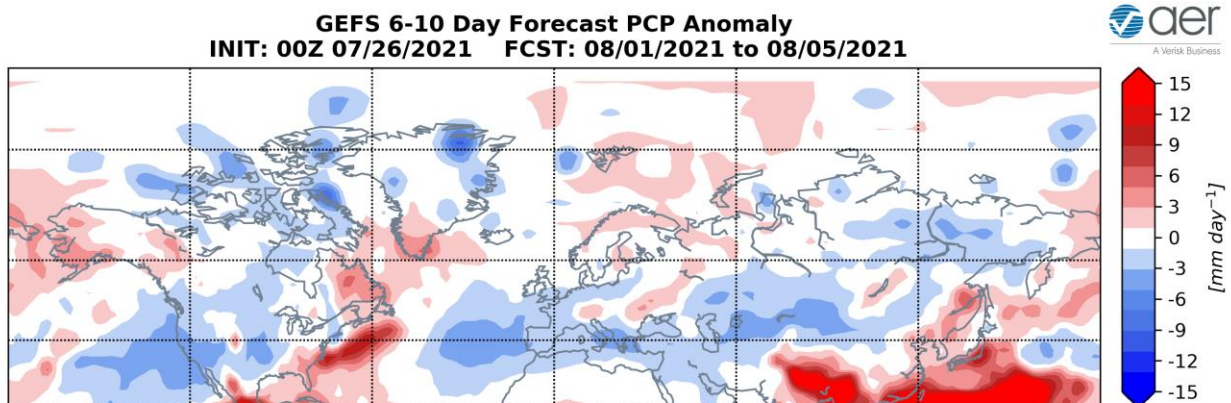


Figure 7. Forecasted precipitation anomalies (mm/day; shading) from 1 – 5 August 2021. The forecasts are from the 00Z 26 July 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia with the exceptions of above normal precipitation in Eastern Europe and Southern and Eastern Asia (**Figure 7**). Normal to below normal precipitation is predicted for much of North America except for normal to above normal precipitation in Western Alaska, Northwest Canada, the Southeastern US and the Canadian Maritimes (**Figure 7**).

11-15 day

With persistent but weak normal to above normal geopotential height anomalies across the Central Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO should remain near neutral this period (**Figure 1**). With weak pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is predicted to remain near neutral this period as well.

GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 07/26/2021 FCST: 08/06/2021 to 08/10/2021

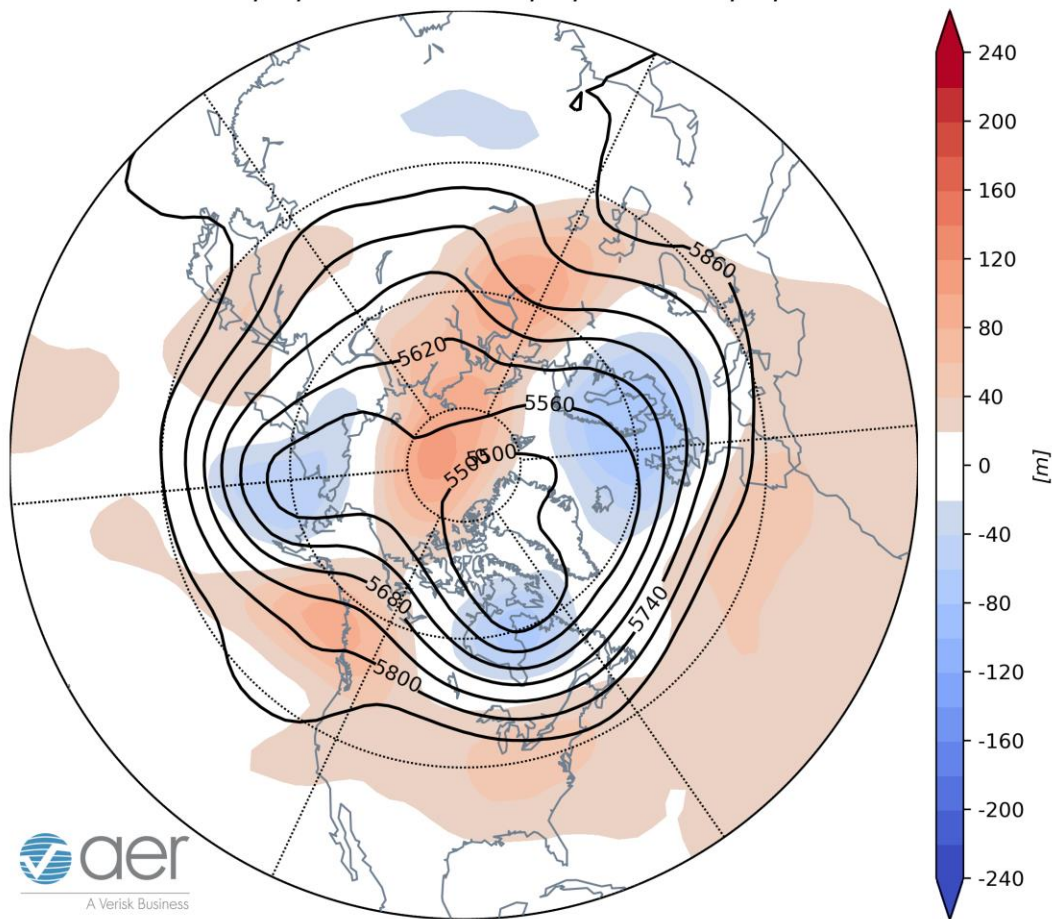


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 6 – 10 August 2021. The forecasts are from the 00z 26 July 2021 GFS ensemble.

Recent ridging/positive geopotential height anomalies are predicted to continue to favor troughing/negative geopotential height anomalies across much of Europe this period except for ridging/positive geopotential height anomalies across Spain (**Figure 8**). This pattern favors widespread normal to below normal temperatures across much of Europe including the UK except for normal to above normal temperatures across Portugal, Spain and the southern Balkans (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to become more widespread across Asia except for weak troughing/negative geopotential height anomalies in Siberia that extends southwestward into Mongolia and Central China this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across much of Asia but especially Western and Central Siberia except for normal to below normal temperatures across Eastern Siberia, Mongolia and Central China (**Figure 9**).

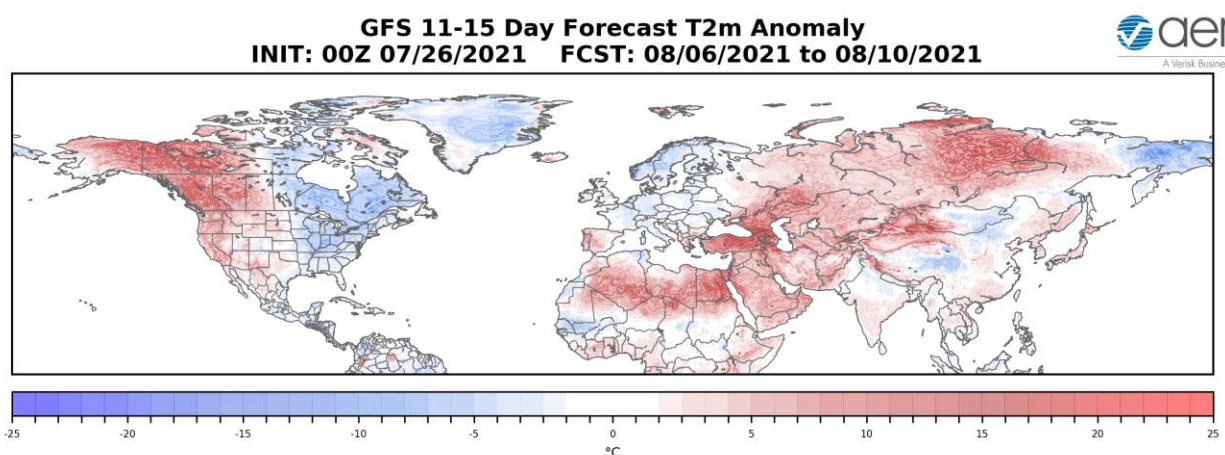


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 6 – 10 August 2021. The forecasts are from the 00z 26 July 2021 GFS ensemble.

The general pattern of ridging/positive geopotential height anomalies across western North America, with troughing/negative geopotential height across Eastern Canada are predicted to persist this period (**Figure 8**). One change is the expansion of Western US ridging into the Eastern US (**Figure 8**). This pattern favors normal to above normal temperatures Alaska, Western Canada, the Western US with normal to below normal temperatures across Eastern Canada, and much of the Eastern US (**Figure 9**).

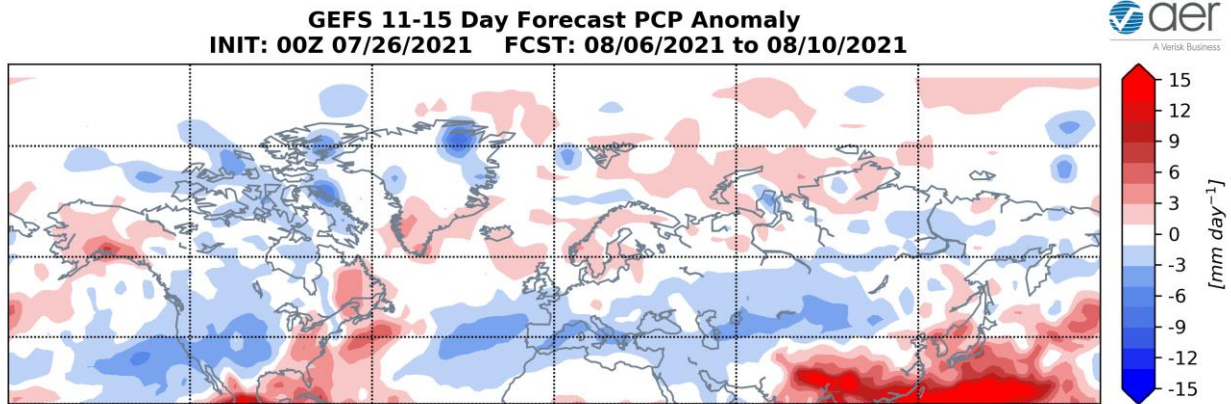


Figure 10. Forecasted precipitation anomalies (mm/day; shading) from 6 – 10 August 2021. The forecasts are from the 00z 26 July 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia except for above normal precipitation across Scandinavia and Southeast Asia (**Figure 10**). Normal to below normal precipitation is predicted for much of North America except for normal to above normal precipitation in Alaska, Northwest Canada, the Eastern US and the Canadian Maritimes (**Figure 10**).

Longer Term

30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to cold/negative PCHs in the upper stratosphere and low to mid troposphere with warm/positive PCHs in the mid to low stratosphere and upper troposphere (**Figure 11**).

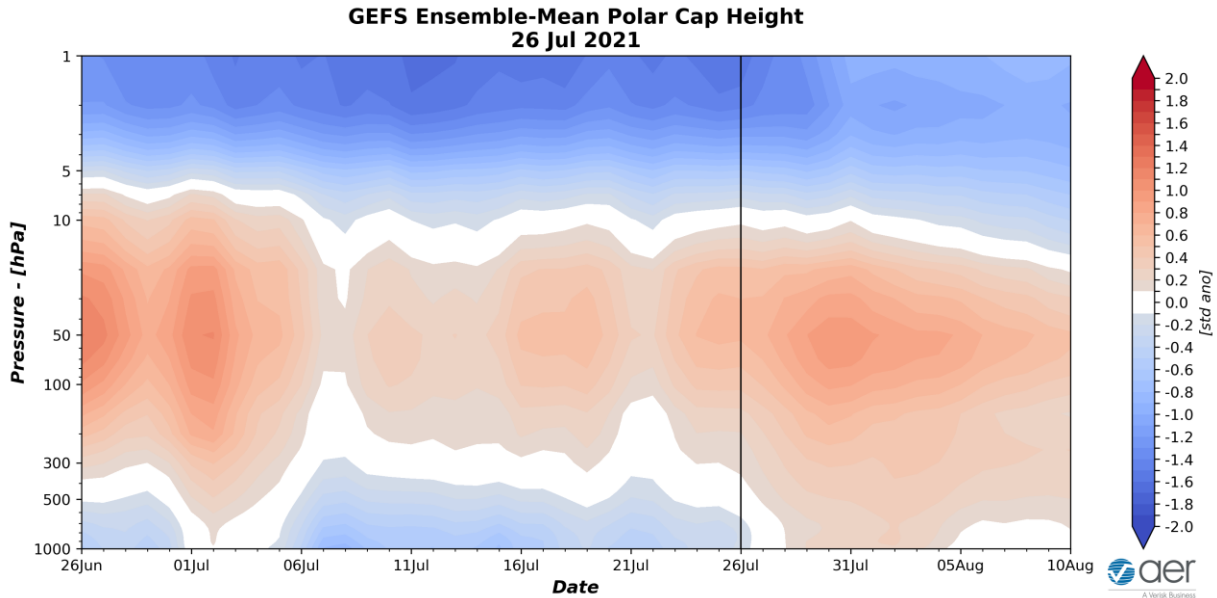


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 26 July 2021 GFS ensemble.

The overall predicted warm/positive PCHs in the upper troposphere are predicted to descend to the surface early this week (**Figure 11**). Predicted warm/positive PCHs in the lower troposphere are consistent with the predicted negative surface AO this week and into next week (**Figure 1**).

**CFS 500 hPa Forecast Anomaly Aug 2021
Valid as of 26 Jul 2021**

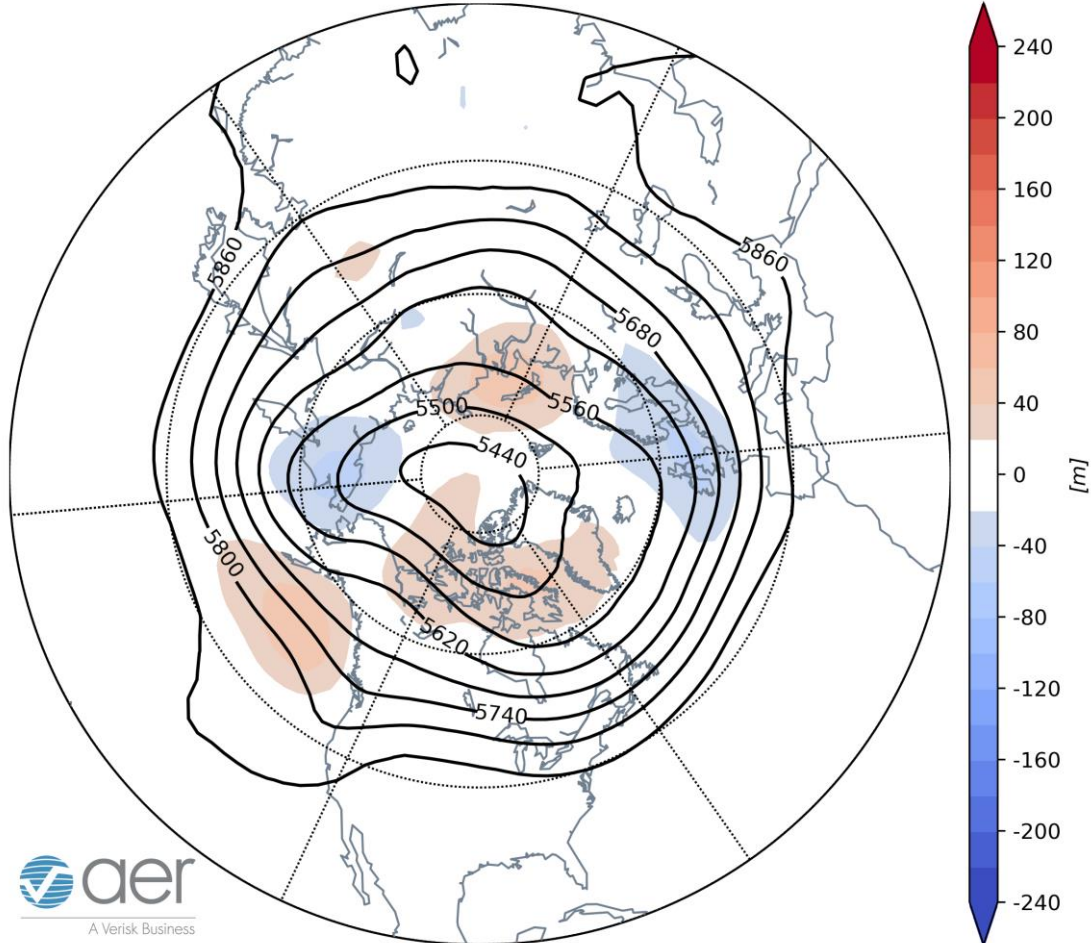


Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for August 2021. The forecasts are from the 00Z 26 July 2021 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and the surface temperatures (**Figure 13**) forecast for August from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging in near the Urals, Eastern Asia, the Gulf of Alaska and the Canadian Arctic Archipelagos with troughing in Northern Europe, Eastern Siberia, along the US West Coast and Eastern Canada (**Figure 12**). This pattern favors seasonable to relatively cool temperatures for Western and Northern Europe, Western Asia, Eastern Siberia, Western Alaska, Western Canada and the Central US with seasonable to relatively warm temperatures for Northern, Central and East Asia, much of Northern and Eastern Canada and the Eastern US (**Figure 13**).

CFS 6-36 Day Forecast T2m Anomaly
INIT: 00Z 07/26/2021 FCST: 08/01/2021 to 08/31/2021

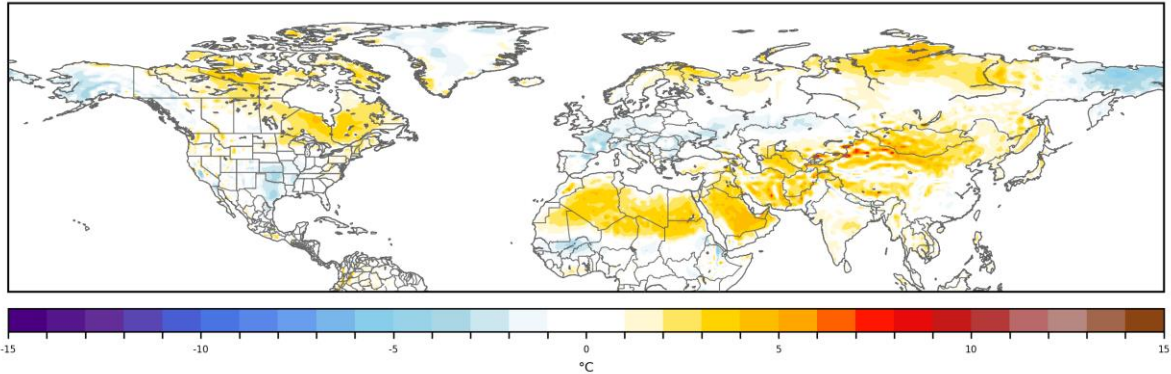


Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for August 2021. The forecasts are from the 00Z 26 July 2021 CFS.

Surface Boundary Conditions

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are close to normal and we continue to observe neutral conditions (**Figure 14**) and neutral conditions are expected through the summer. Observed SSTs across the NH remain well above normal especially in the Baltic Sea, Gulf of Alaska, the western North Pacific and offshore of eastern North America though below normal SSTs exist regionally especially in the Southern Hemisphere. Warm SSTs in the Gulf of Alaska may favor mid-tropospheric ridging in the region.

SST Anomaly - Week Ending 25 Jul 2021

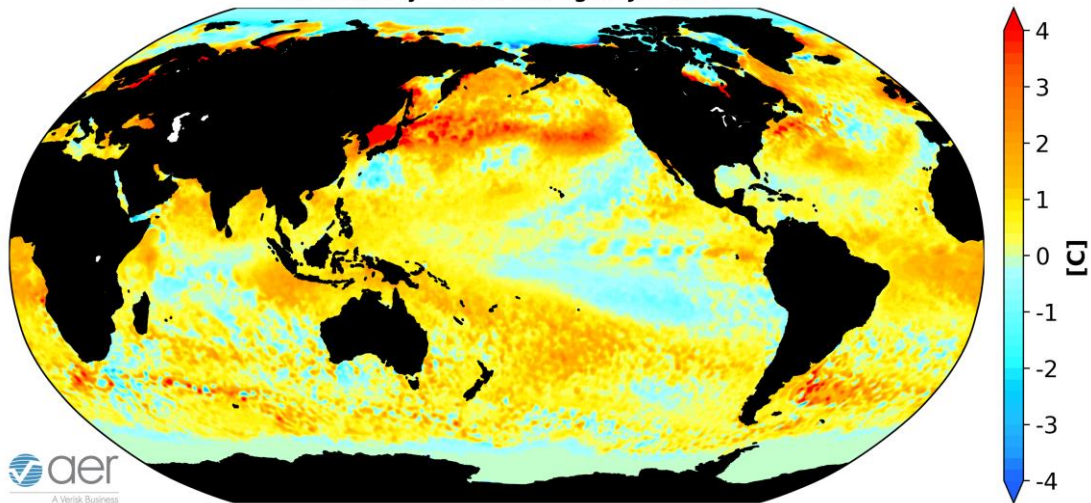


Figure 14. The latest weekly-mean global SST anomalies (ending 25 July 2021). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase six (**Figure 15**). The forecasts are for the MJO to quickly weaken to where no phase is favored. Phase six is related to ridging in western North America and troughing in eastern North America. Therefore it is possible that the MJO is contributing in the short term to the predicted weather pattern across North America but admittedly this is outside of my expertise.

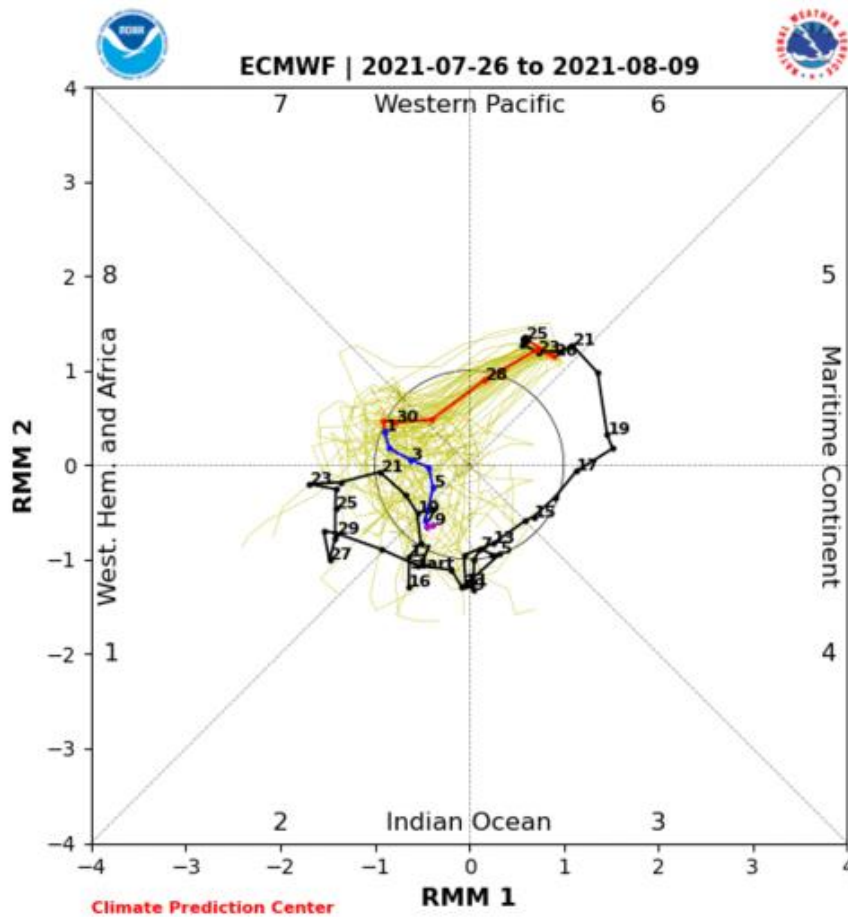


Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 26 July 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>

