

Arctic Oscillation and Polar Vortex Analysis and Forecasts

May 3, 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 negative and is predicted to be slowly trend positive the next two weeks as strongly positive pressure/geopotential height anomalies across Greenland are predicted to turn be mostly negative with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is also currently negative and is predicted to

trend positive the next two weeks as pressure/geopotential height anomalies are predicted to be reverse from positive to negative across Greenland.

- Currently strong ridging/positive geopotential height anomalies across Greenland are forcing deep troughing/negative geopotential height anomalies across Europe with below normal and even well below normal temperatures across much of Europe including the United Kingdom (UK). However, as geopotential heights lower across Greenland, geopotential heights and temperatures are predicted to rise across Europe over the next two weeks.
- The next two weeks, ridging/positive geopotential height anomalies coupled with widespread normal to above normal temperatures are predicted to dominate much of Asia. This week the exception will be troughing/negative geopotential height anomalies coupled with normal to below temperatures in East Asia, however as European troughing fades next week, troughing/negative geopotential height anomalies will deepen across Western Asia coupled with normal to below temperatures.
- The predicted general pattern for much of the next two weeks across North America is ridging/positive geopotential height anomalies coupled with normal to above normal temperatures across western North America, which will force troughing/negative geopotential height anomalies across eastern North America favoring normal to below temperatures east of the Rockies both in Canada and the United States (US).
- In the Impacts section I discuss some early indications for the summer.

Impacts

As I discussed in last week's blog, strong Greenland blocking during April has resulted in a cool month across much of Europe, I believe the coolest in a while (the cold in the UK seems to be especially impressive: [coldest UK April since 1922](#)). This bucks recent trends where Europe is one of the regions warming the fastest across the globe in the warmer months of the spring and summer. I have expressed my puzzlement many times in the blog as to why Europe is one of the regions experiencing accelerated warming in the summer months. I would have thought proximity to the ocean would have resulted in just the opposite, cooling sea breezes would have moderated warming experienced in the interior of the Eurasian continent. Instead, the region that has seen the least amount of warming across the Eurasian continent is Western Asia during summer. That region has often been under the influence of anomalous troughing, especially in the early summer months that has shielded it from the anomalous warmth observed elsewhere across Eurasia.

Could this summer differ from recent trends? Certainly, the tendency for troughing across Europe during April is conducive to preserving soil moisture. The relatively warm and dry springs of late have been favorable for desiccating the soils and fostering summer heat. So far this spring that has not be a factor. But based on the forecast below from the latest GFS, the answer is looking increasingly no. As summer

approaches the atmospheric circulation is resorting to old habits with ridging in Europe and East Asia bookending troughing across Western Asia. This pattern would once again favor amplified warming across Europe and East Asia with closer to normal temperatures in Western Asia. But it is early and certainly too early to assume that the summer circulation pattern has settled in.

The tag team of Greenland blocking and ridging across western North America has also delivered some cooler weather to eastern North America the second half of April. Possibly analogous to Eurasia the trend of recent summers is for accelerated heating especially across western North America but also eastern North America with more tempered warming in the interior of the continent, sometimes referred to as the US "warming hole." The GFS is predicting that the ridging in North America will persist even after the Greenland blocking has faded. So whether the Northeastern US have a cooler summer relative to recent summers is more of an open question, at least based on the latest GFS forecasts.

The latest July CFS forecast shows a circulation pattern reminiscent of recent circulation trends (see **Figure i**). Ridging is centered on Northern Europe and to a lesser degree East Asia with anomalous troughing in Western Asia. Across North America anomalous ridging is focused in western North America with downstream troughing in eastern North America and overall is more amplified than is typical for summer. The largest geopotential height anomalies are centered over the North Pole, a break from recent summers but did occur last summer that helped accelerate sea ice melt. I still think that an anomalous high center over the North Pole is a low confidence forecast for now.

**CFS 500 hPa Forecast Anomaly Jul 2021
Valid as of 03 May 2021**

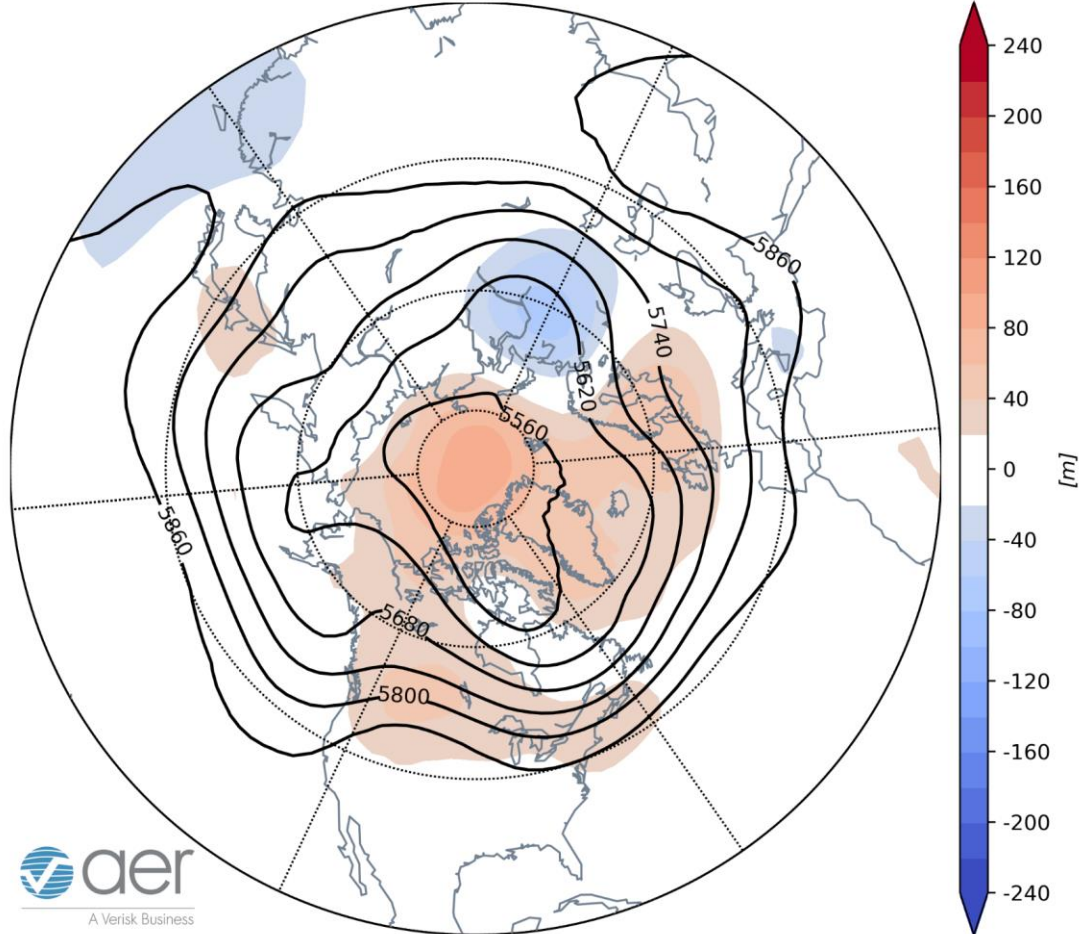


Figure i. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for July 2021. The forecasts are from the 00Z 3 May 2021 CFS.

The CFS July temperature surface forecast does suggest a cooler summer across at least parts of Europe are possible (see **Figure ii**). Some of the cooler temperatures in Western Asia expand westward into Eastern Europe and relatively cool temperatures are predicted for Western Europe as well. Across North America relatively warm temperatures are predicted for western North America and the Northeastern US with the best chance of seasonable to even cool temperatures in the interior. But the CFS is most confident in the warmest temperatures in the Arctic across Siberia and Northern Canada.

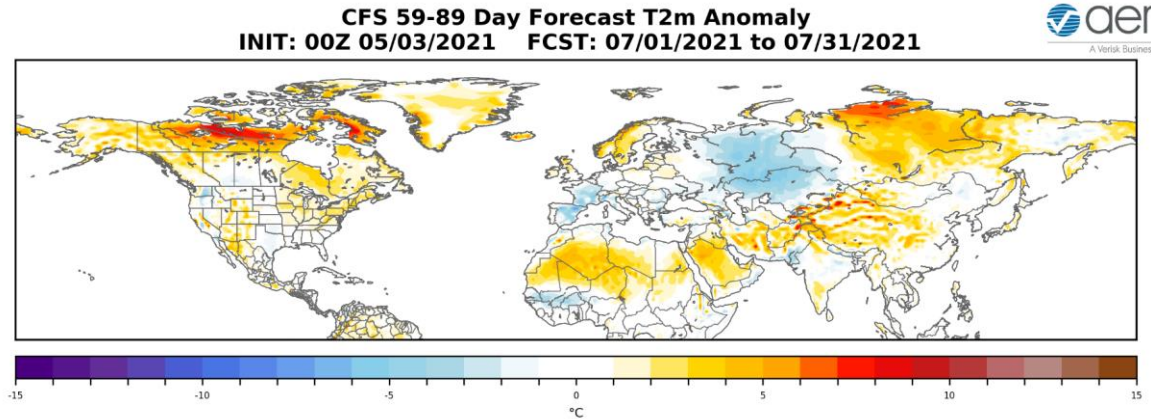


Figure ii. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for July 2021. The forecasts are from the 00Z 3 May 2021 CFS.

1-5 day

The AO is predicted to be negative this week (**Figure 1**) as positive geopotential height anomalies stretch across Greenland with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with positive geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to remain negative as well this week.

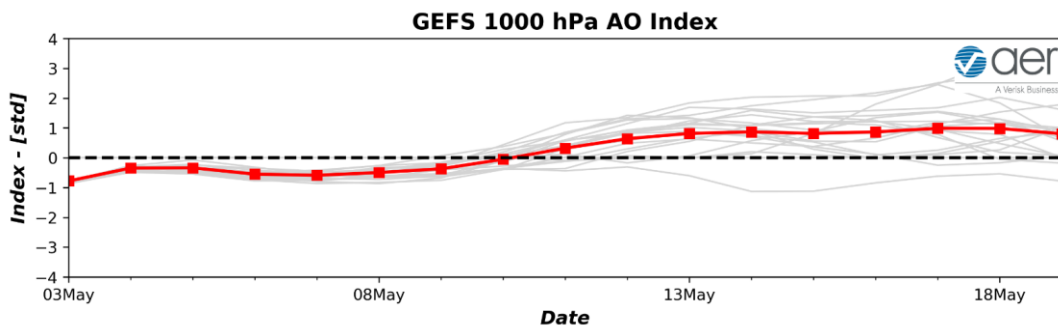


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 3 May 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Ridging/positive geopotential height anomalies across Greenland are predicted to persist deep troughing/negative geopotential height anomalies across Europe this week (**Figures 2**). **This will favor** normal to below normal temperatures across Northern and Central Europe including the UK with normal to above normal temperatures across Southern Europe under mid-tropospheric ridging (**Figure 3**). Much of Asia will be dominated by ridging/positive geopotential height anomalies with the main center over

Western Asia with troughing/negative geopotential height anomalies focused in East Asia (**Figure 2**). This is predicted to favor widespread normal to above normal temperatures across much of Asia except for normal to below normal temperatures across East Asia (**Figure 3**).

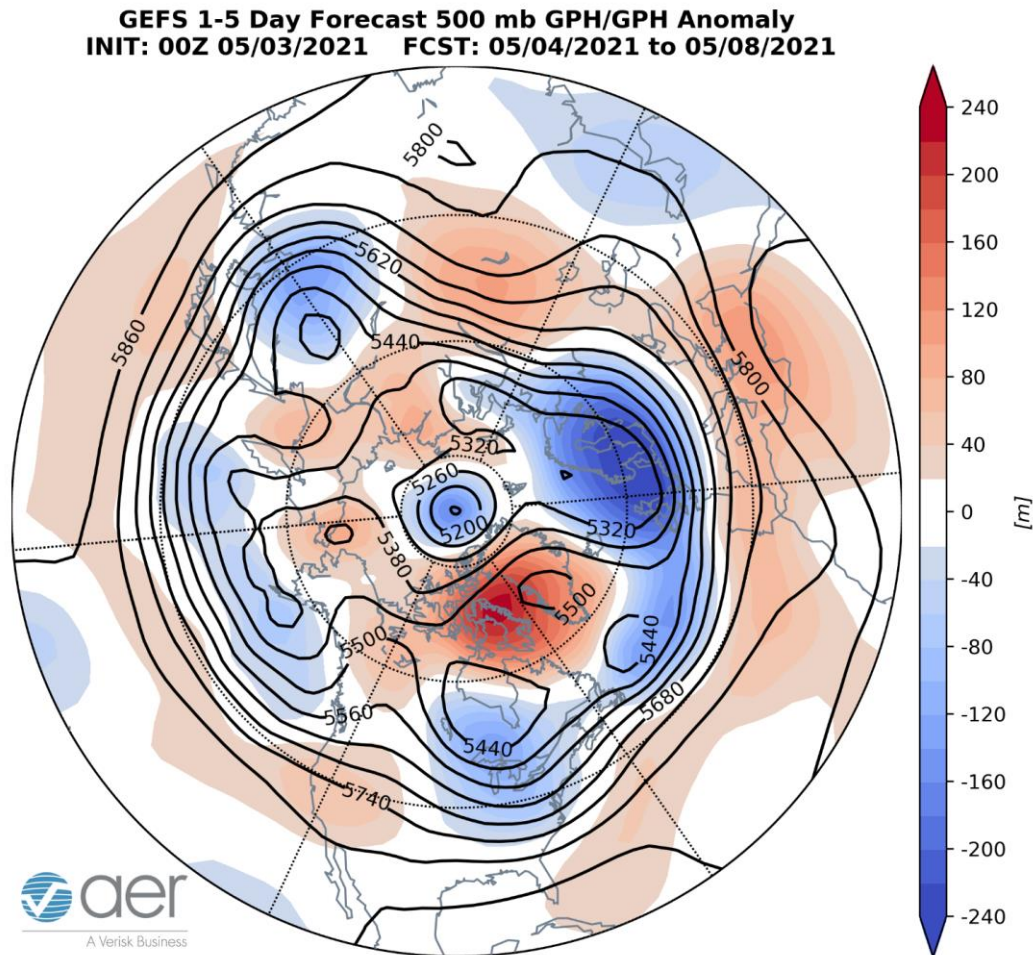


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 4 – 8 May 2021. The forecasts are from the 00z 3 May 2021 GFS ensemble.

This week, the predicted dominant circulation pattern is ridging/positive geopotential height anomalies that will stretch from Alaska east to Greenland and south to California locking in troughing/negative geopotential height anomalies centered over southern Hudson Bay but widespread east of the Rockies (**Figure 2**). This pattern is predicted to bring normal to above normal temperatures across Alaska, Northern Canada and the West Coasts of Canada and the US with normal to below normal temperatures east of the Rockies in Canada and the US with the exception of the Canadian Maritimes (**Figure 3**).

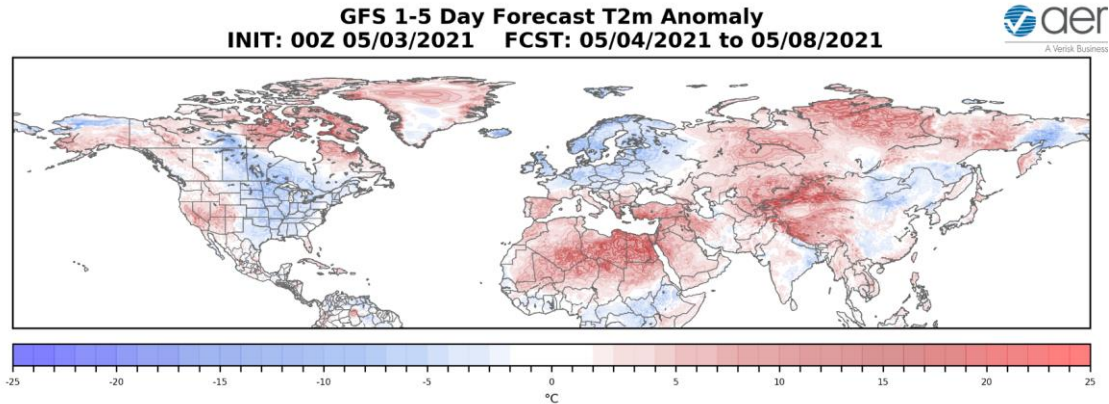


Figure 3. Forecasted surface temperature anomalies (°C; shading) from 4 – 8 May 2021. The forecast is from the 00Z 3 May 2021 GFS ensemble.

Normal to below normal precipitation are predicted for Eurasia with the exceptions of above normal precipitation in Northern Europe and East Asia (**Figure 4**). Normal to below normal precipitation are predicted for North America except for the Eastern US and the Canadian Maritimes (**Figure 4**).

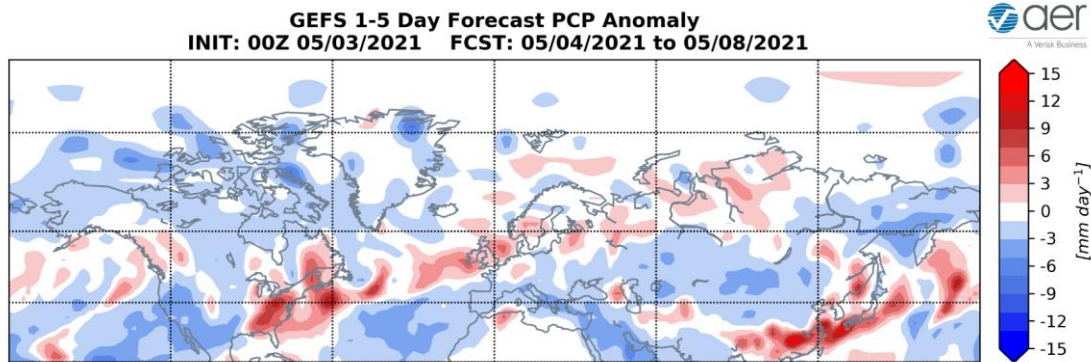


Figure 4. Forecasted precipitation anomalies (mm/day; shading) from 4 – 8 May 2021. The forecast is from the 00Z 3 May 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to transition from negative to positive next week (**Figure 1**) as strong positive geopotential height anomalies are replaced with negative anomalies across Greenland with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with positive geopotential height anomalies predicted to switch to negative across Greenland (**Figure 5**), the NAO is predicted to flip positive as well.

GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 05/03/2021 FCST: 05/09/2021 to 05/13/2021

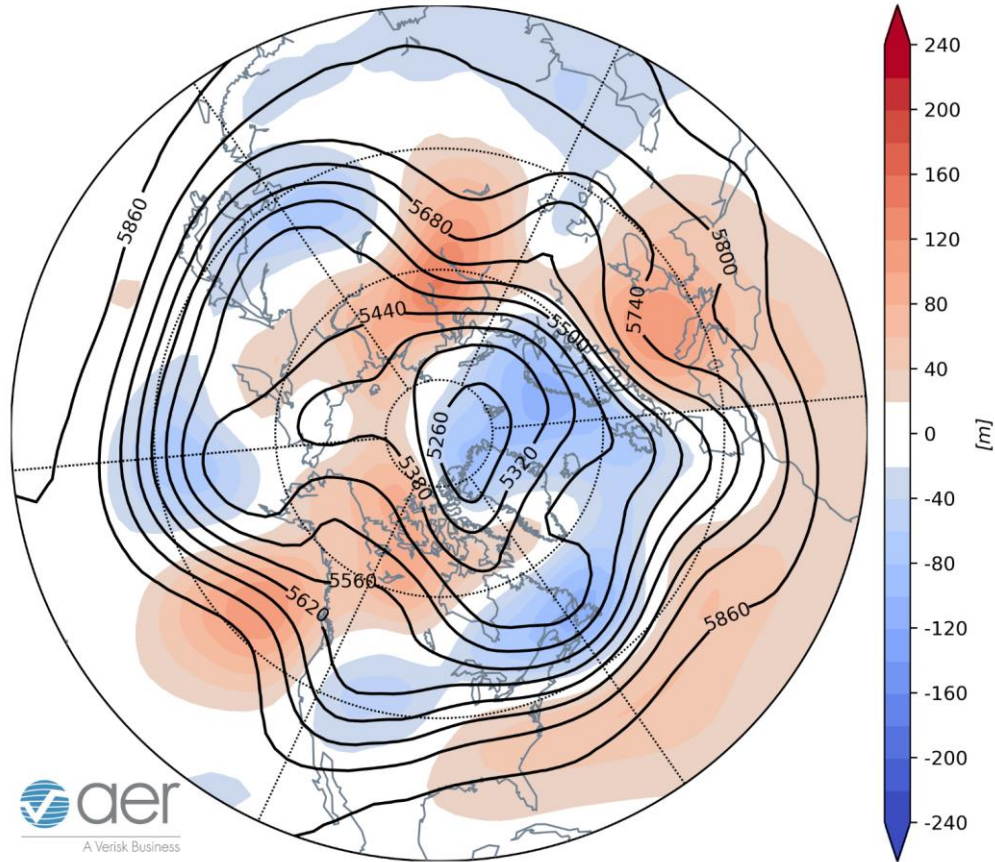


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 9 – 13 May 2021. The forecasts are from the 00z 3 May 2021 GFS ensemble.

Ridging/positive geopotential height anomalies across Greenland are predicted to fade this week allowing ridging/positive geopotential height anomalies previous confined to Southern Europe to expand northward into Central Europe next week, though troughing/negative geopotential height anomalies will persist across Northern Europe (**Figures 5**). This will favor normal to above normal temperatures across much of Southern and Central Europe with normal to above normal temperatures confined to Northern Europe including the UK (**Figure 6**). Ridging/positive geopotential height anomalies will persist across much of Asia, centered across Western Asia, with more regional troughing/negative geopotential height anomalies in East Asia, but this pattern is showing signs of transition (**Figure 5**). This pattern favors widespread normal to above normal temperatures across much of Asia with normal to below normal temperatures limited to East Asia (**Figure 6**).

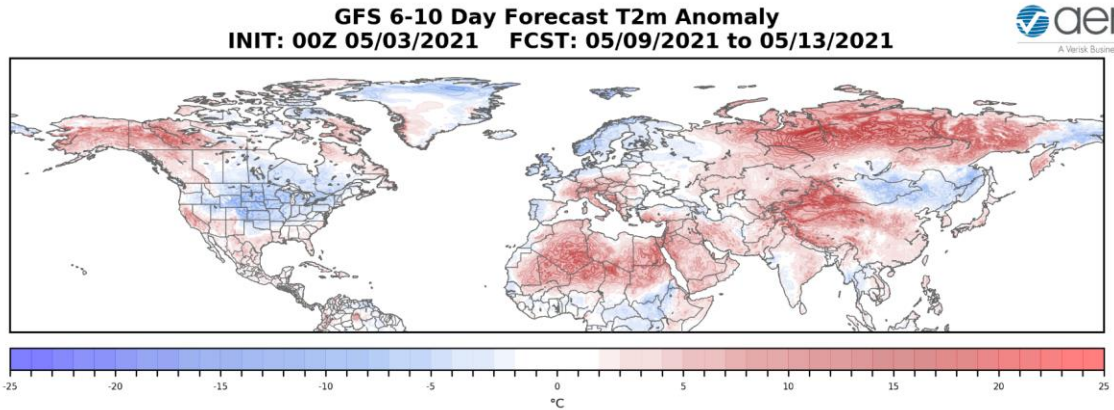


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 9 – 13 May 2021. The forecasts are from the 00Z 3 May 2021 GFS ensemble.

Ridging/positive geopotential height anomalies will persist across Alaska and Northern Canada but further south the ridging will retrograde westward into the Gulf of Alaska favoring downstream troughing/negative geopotential height anomalies in the Western US and in the Eastern Canada this period (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across Alaska, Western and Northern Canada and the deep Southern US with normal to below normal temperatures across Central and Southeastern Canada and much of the Northern US (**Figure 6**).

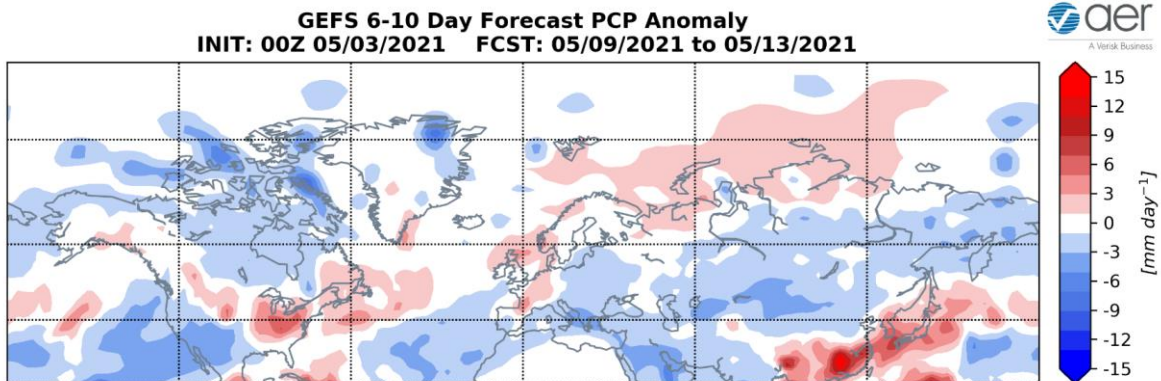


Figure 7. Forecasted precipitation anomalies (mm/day; shading) from 9 – 13 May 2021. The forecasts are from the 00Z 3 May 2021 GFS ensemble.

Normal to below normal precipitation are predicted for Eurasia with the exceptions of above normal precipitation in Western Europe and East Asia (**Figure 7**). Normal to below normal precipitation are predicted for North America except for US Northern Rockies, the Eastern US and the Canadian Maritimes (**Figure 7**).

11-15 day

With predicted mostly negative geopotential height anomalies across Greenland and the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO should remain positive this period (**Figure 1**). With negative pressure/geopotential height anomalies persisting across Greenland (**Figure 8**), the NAO is predicted to remain positive this period as well.

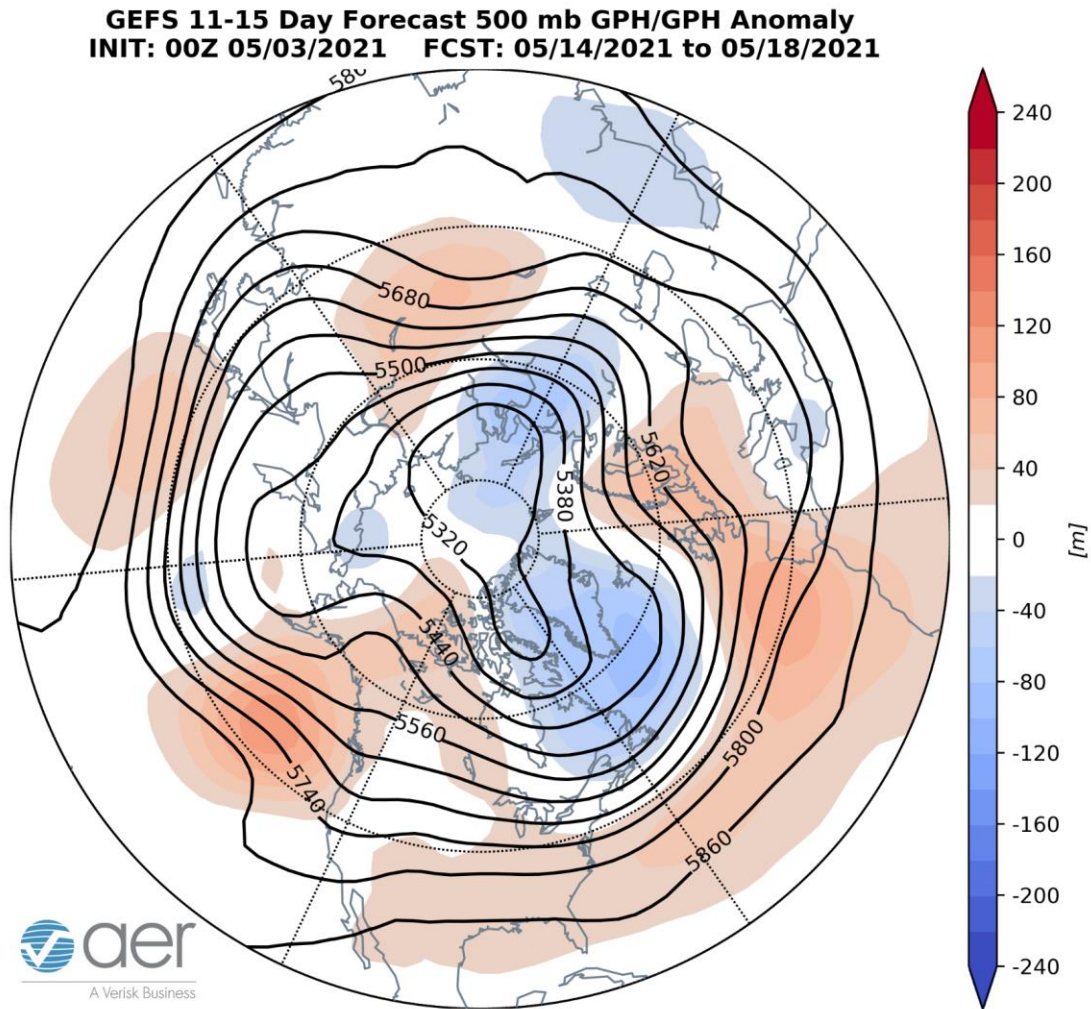


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 14 – 18 May 2021. The forecasts are from the 00z 3 May 2021 GFS ensemble.

Deepening troughing/negative geopotential height anomalies across Greenland will continue to allow ridging/positive geopotential height anomalies to continue to push northward into Northern Europe this period with troughing/negative geopotential height anomalies mostly confined to Eastern Europe (**Figure 8**). This pattern favors widespread normal to above normal temperatures across much of Europe with normal to below normal temperatures across far Western and far Eastern Europe (**Figures**

9). Troughing/negative geopotential height anomalies previously in Europe are predicted to push into Western Asia displacing ridging/positive geopotential height anomalies previously in Western Asia and into Eastern Asia this period (**Figure 8**). This pattern favors normal to above normal temperatures across much of Asia with normal to below normal temperatures across Western Asia (**Figure 9**).

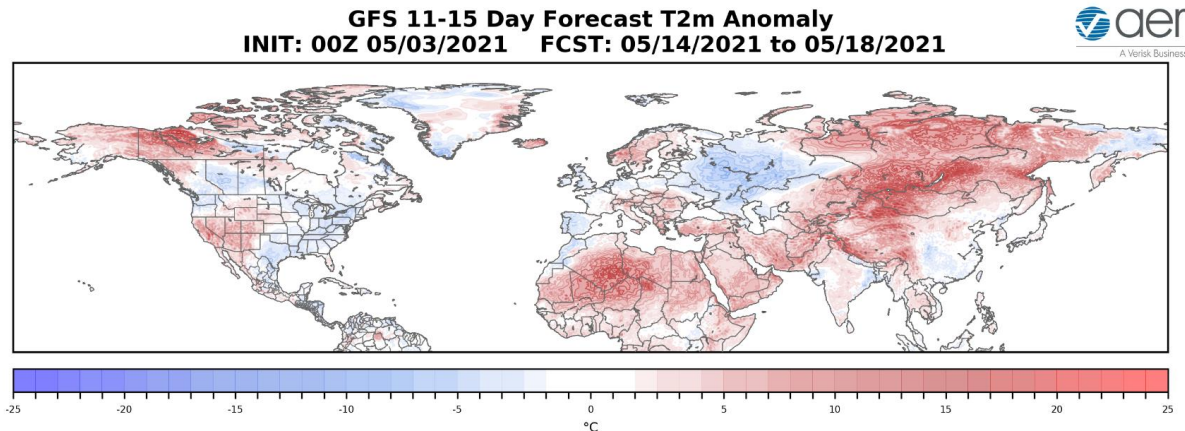


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 14– 18 May 2021. The forecasts are from the 00z 3 May 2021 GFS ensemble.

Predicted persistent ridging/positive geopotential height anomalies across Alaska and the Gulf of Alaska will continue to favor downstream troughing/negative geopotential height anomalies across Eastern Canada east of the Rockies this period (**Figure 8**). This pattern favors normal to above normal temperatures for Alaska, Northern Canada and the Western US with normal to below normal temperatures across Southern Canada and the Eastern US (**Figure 9**).

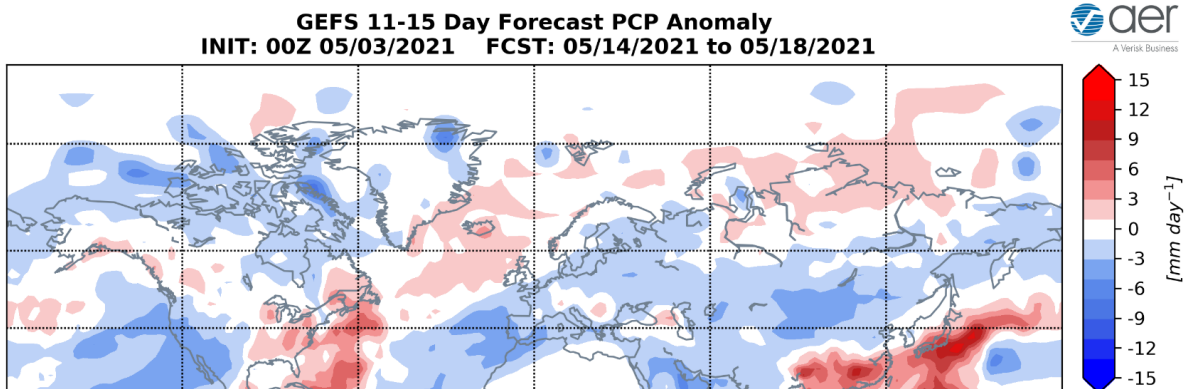


Figure 10. Forecasted precipitation anomalies (mm/day; shading) from 14– 18 May 2021. The forecasts are from the 00z 3 May 2021 GFS ensemble.

Normal to below normal precipitation are predicted for Eurasia with the exception of above normal precipitation in Southeast Asia (**Figure 10**). Normal to below normal precipitation are predicted for much of North America except for above normal precipitation for the coastal mountains of Alaska and Western 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 mid to lower stratosphere and upper troposphere but warm/positive PCHs in the mid to low troposphere this week (**Figure 11**). However next week PCHs are predicted to be normal to cold/negative in throughout the troposphere and stratosphere (**Figure 11**).

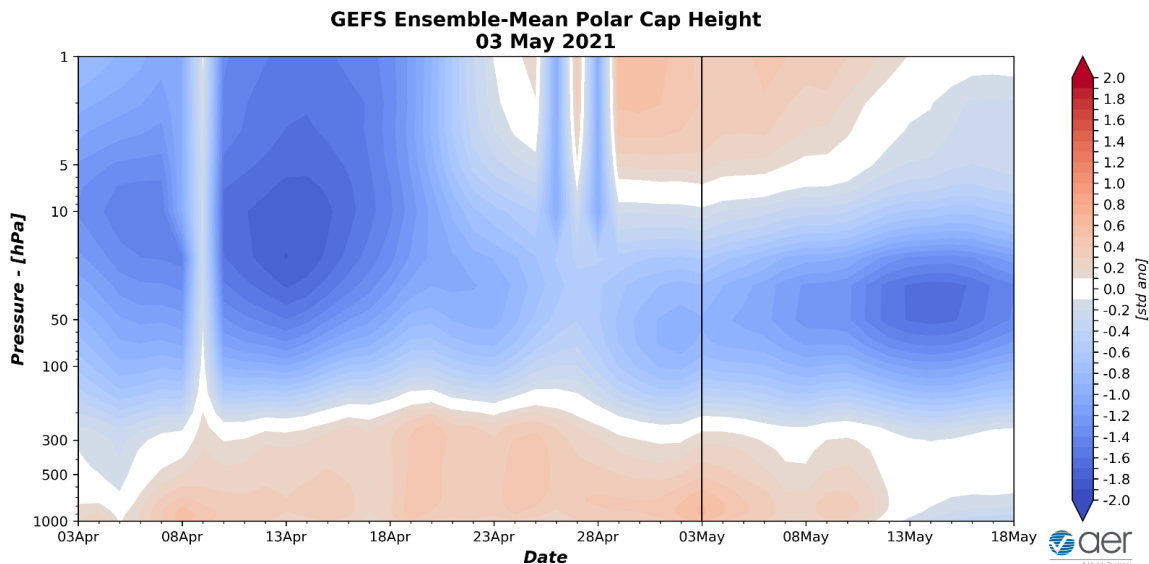


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 3 May 2021 GFS ensemble.

The overall warm/positive PCHs in the lower troposphere are consistent with the predicted neutral to negative surface AO this week while the positive AO next week is consistent with the predicted cold/negative PCHs in the lower troposphere next week (**Figure 1**).

The Final Warming occurred last week (where the stratospheric polar vortex (PV) completely disappears) therefore I will no longer discuss the vertical Wave Activity Flux (WAFz and is proportional to poleward heat transport) and the PV until next fall.

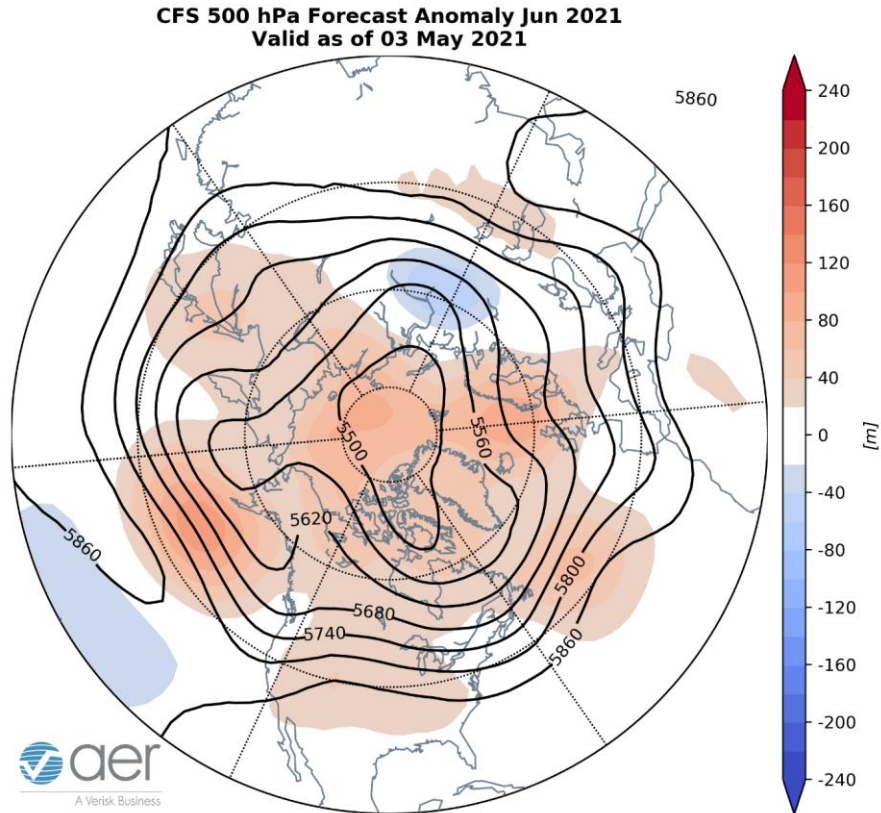


Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for June 2021. The forecasts are from the 00Z 3 May 2021 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and the surface temperatures (**Figure 13**) forecast for June from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging across Northwestern Europe, East Asia, south of the Aleutians and the Central US with troughing in Eastern Europe/Western Asia, Eastern Siberia, the North American west coast and Eastern Canada (**Figure 12**). This pattern favors relatively cool temperatures for Eastern Europe/Western Asia, the US West Coast, Southeastern Canada and the Northeastern US with seasonable to relatively warm temperatures for Northwestern Europe, the Middle East, Central and East Asia, Alaska, much of Northern and Western Canada and the Western US (**Figure 13**).

CFS 29-58 Day Forecast T2m Anomaly
INIT: 00Z 05/03/2021 FCST: 06/01/2021 to 06/30/2021

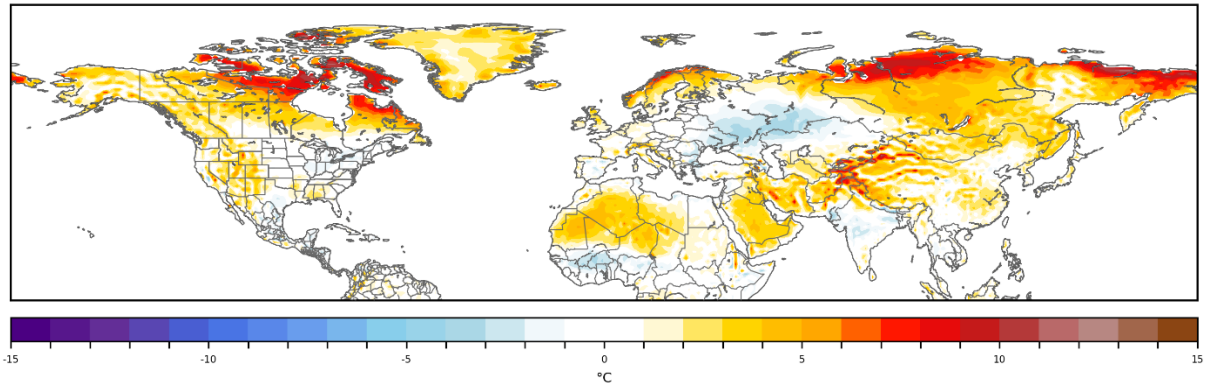


Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for June 2021. The forecasts are from the 00Z 3 May 2021 CFS.

Surface Boundary Conditions

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies remain negative and we continue to observe a weak La Niña or possibly neutral conditions (**Figure 14**) and La Niña is expected to remain weak or transition to neutral through the spring. Observed SSTs across the NH remain well above normal especially in the Gulf of Alaska, the western North Pacific and offshore of eastern North America though below normal SSTs exist regionally especially in the Southern Hemisphere and south of Iceland. Warm SSTs in the Gulf of Alaska may favor mid-tropospheric ridging in the region.

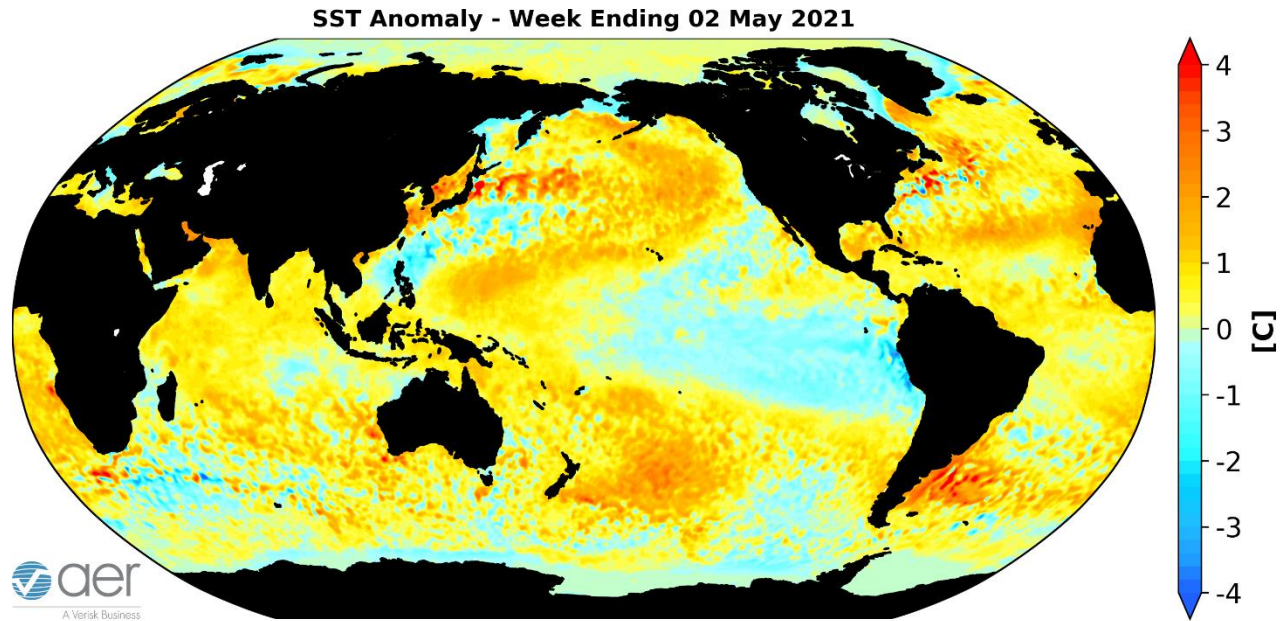


Figure 14. The latest weekly-mean global SST anomalies (ending 2 May 2021). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase one (**Figure 15**). The forecasts are for the MJO to transition to phase two and then where no phase is favored. MJO phases one and two overall favor blocking across Alaska and Northern Canada with troughing across the US. Therefore, it does appear that the MJO is contributing to the predicted weather pattern across North America but admittedly this is outside of my expertise.

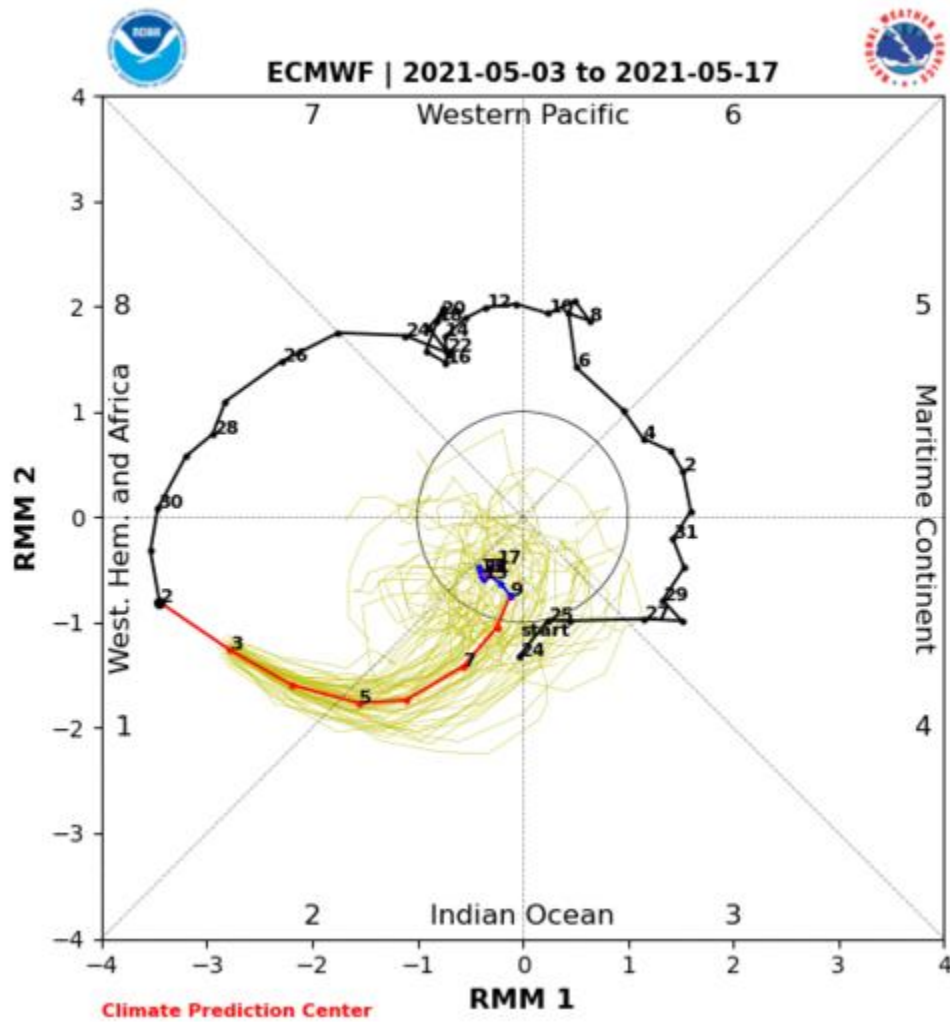


Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 3 May 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>