

Arctic Oscillation and Polar Vortex Analysis and Forecasts

April 5, 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 positive and is predicted to trend negative this week as pressure/geopotential height anomalies are predicted turn strongly positive across Greenland with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is also predicted to

transition from positive to negative as pressure/geopotential height anomalies are predicted to turn strongly positive across Greenland.

- This week strengthening ridging/positive geopotential height anomalies predicted to overspread Greenland this week will force deepening troughing/negative geopotential height anomalies across much of Europe this week, bringing with it normal to below normal temperatures across much of Europe including the United Kingdom (UK) with the exception of Southwestern Europe due to lingering ridging and parts of Scandinavia under southerly flow. Next week the troughing and below normal temperatures are predicted to mostly persist.
- Deep European troughing will favor widespread Asian ridging/positive geopotential height anomalies centered over the Urals coupled with widespread normal to above normal temperatures across Asia. And as is typical with Ural blocking, cooler temperatures will begin to expand across Northeast Asia. However next week, as the polar vortex weakens and meanders towards Northern Asia, likely a sign of the Final Warming, this will promote more widespread troughing/negative geopotential height anomalies coupled with normal to below temperatures across parts of Northern and Eastern Asia.
- This week much of North America will be dominated by ridging/positive geopotential height anomalies coupled with normal to above normal temperatures with the exception of troughing/negative geopotential height anomalies coupled with normal to below temperatures across Alaska and Northwestern Canada. However beginning next week, predicted ridging/positive geopotential height anomalies coupled with above normal temperatures across Greenland and Northern Canada will force troughing/negative geopotential height anomalies across the United States (US) and cooler temperatures.
- In the Impacts section I discuss the possible influence on the weather across the Northern Hemisphere (NH) of a dynamic Final Warming where the stratospheric polar vortex (PV) disappears for the remainder of the spring and summer.

Impacts

In recent years, the warm season has advanced aggressively across the NH regardless of the winter, whether it has been mild or cold, especially across Eurasia. Looking at the forecasts from both the GFS and CFS relatively mild temperatures are predicted to dominate the NH continents. However, there are signs that the warmth may not be as aggressive across Eurasia this spring as in recent springs. First as I mentioned in the last blog, snow cover is not melting as quickly across Eurasia as in previous springs and the development of a Greenland block could even result in an advance in snow cover across parts of Europe this week (see **Figure i**). Second the development of the Greenland block will bring unseasonably cold temperatures to Europe this week and recent model forecasts have been trending for the Greenland block to be more persistent, which will prolong the cool spell. The Greenland block is predicted to drift west, which will also eventually favor cooler temperatures in the Eastern US.

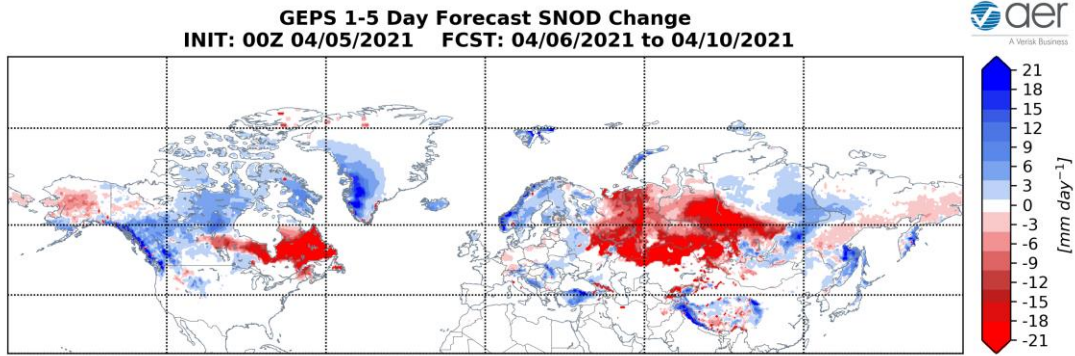


Figure i. Forecasted snow depth changes (mm/day; shading) from 6 – 10 April 2021. The forecast is from the 00Z 5 April 2021 Canadian or GEM ensemble.

Even beyond the lifetime of the Greenland block, there are signs of a dynamic Final Warming. The stratospheric PV always disappear in the spring due to the increasing solar radiation in the polar stratosphere. However, during some springs in addition to the radiative warming of the polar stratosphere, there is also dynamic warming of the polar stratosphere due to the absorption of upwelling Wave Activity Flux (WAFz) from the troposphere. This occurred last spring, which did result in a cool May and even some rare snowfall in the Northeastern US. The predicted return of Ural blocking coupled with Northeast Asia/northern North Pacific troughing is conducive to more active WAFz. The latest PV animation (see **Figure ii**) shows the stratospheric PV filling (weakening) and meandering over the northern Asia in response to the more active WAFz. This could be the beginning of a dynamically assisted Final Warming that could result in a period of cooler temperatures in parts of the mid-latitudes.

Initialized 00Z 10 hPa HGT/HGTa 05-Apr-2021

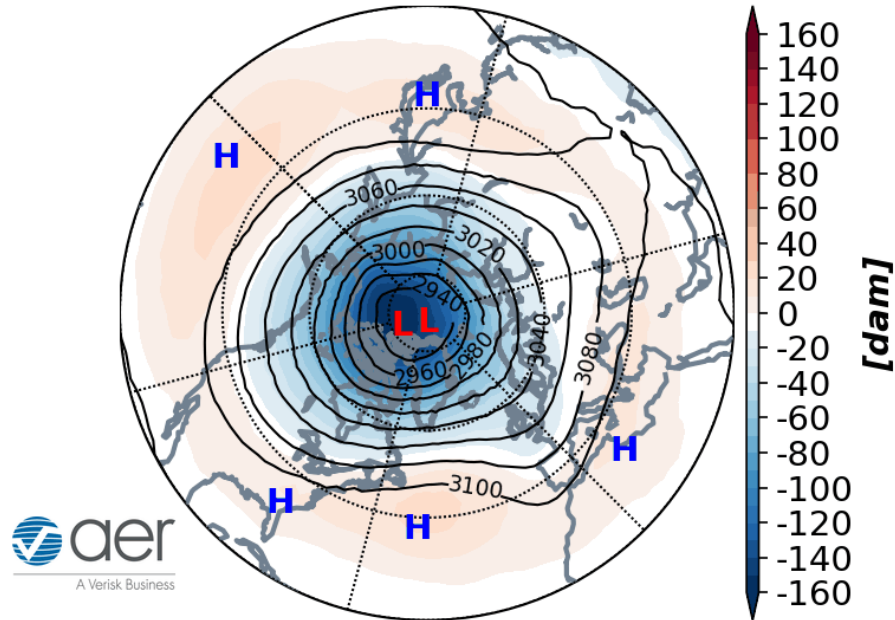


Figure ii. Observed and predicted daily geopotential heights (dam; contours) and anomalies (shading) through April 21, 2021. The forecast is from the 00Z 5 April 2021 GFS ensemble.

Last year's dynamical Final Warming did result in much cooler temperatures across eastern North America but more limited cooling in Eurasia (mostly western Russia). The anticipation of a dynamic Final Warming is still speculative but based on snow cover and the predicted position of the PV over Siberia, I would expect a dynamic Final Warming to bring more widespread cool temperatures to Eurasia relative to last spring. For now, something to monitor.

1-5 day

The AO is predicted to begin the week positive but then turn negative (**Figure 1**) as positive geopotential height anomalies build across Greenland with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with building positive geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to transition from positive to negative as well this week.

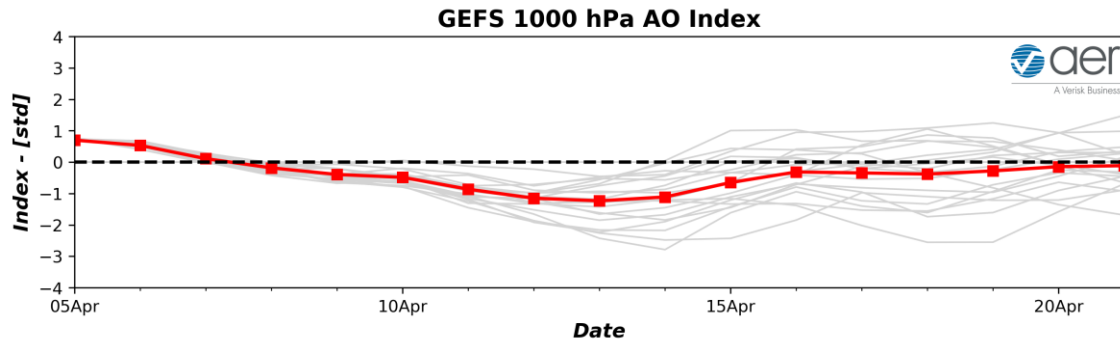


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 5 April 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Building ridging/positive geopotential height anomalies across Greenland this week are predicted to force deepening troughing/negative geopotential height anomalies across much of Europe this week (**Figures 2**). **This will favor** normal to below normal temperatures across much of Europe though a couple of exceptions are Spain and Portugal due to lingering ridging and Sweden and Finland due to a mild southerly flow (**Figure 3**). Much of Asia will be dominated by ridging/positive geopotential height anomalies centered on the Urals except for troughing/negative geopotential height anomalies across Northeastern 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 Northeastern Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 04/05/2021 FCST: 04/06/2021 to 04/10/2021

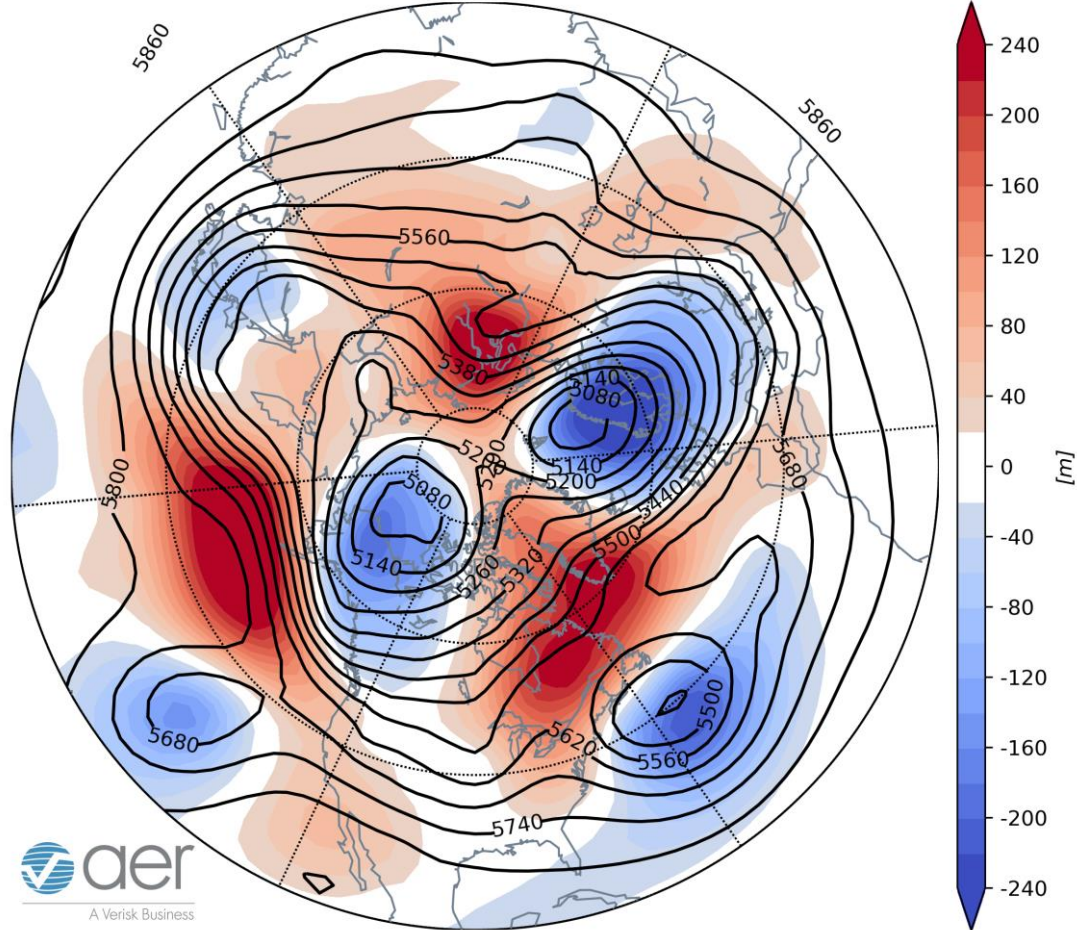


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 6 – 10 April 2021. The forecasts are from the 00z 5 April 2021 GFS ensemble.

This week, ridging/positive geopotential height anomalies will dominate much of North America except for troughing/negative geopotential height anomalies in Alaska and Northwestern Canada this period (**Figure 2**). This pattern is predicted to bring normal to above normal temperatures across much of Canada and the US with normal to below normal temperatures across Alaska and Northwest Canada (**Figure 3**).

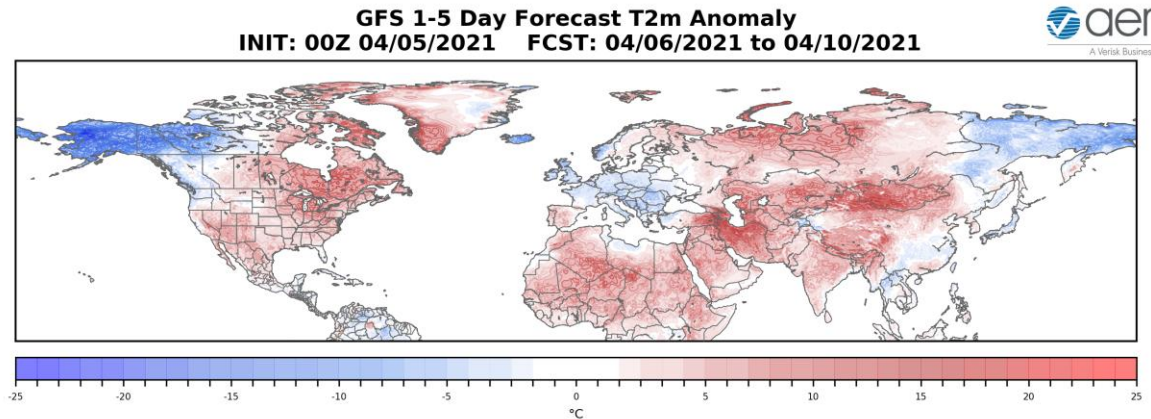


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 6 – 10 April 2021. The forecast is from the 00Z 5 April 2021 GFS ensemble.

Normal to below normal precipitation are predicted for Eurasia with the exception of above normal precipitation in Southeast Asia (**Figure 4**). Normal to below normal precipitation are predicted for North America except for the West Coast of Canada and the Eastern US (**Figure 4**).

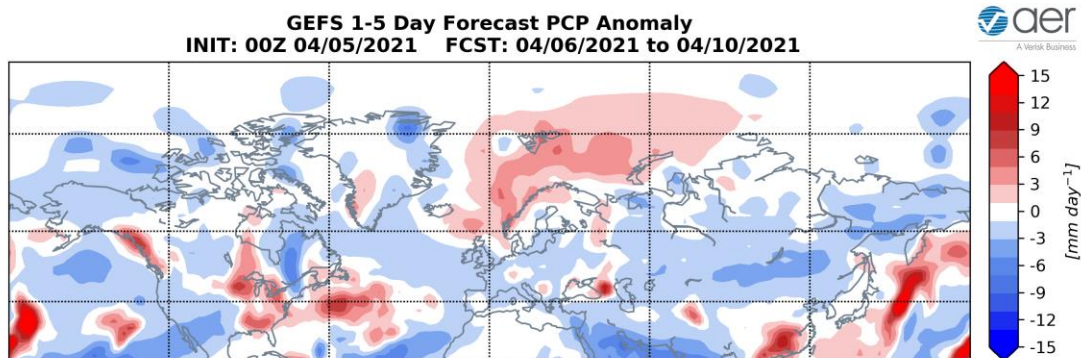


Figure 4. Forecasted precipitation anomalies (mm/day ; shading) from 6 – 10 April 2021. The forecast is from the 00Z 5 April 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain negative next week (**Figure 1**) as strong positive geopotential height anomalies continue to be widespread across Greenland with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with positive geopotential height anomalies predicted across Greenland (**Figure 5**), the NAO is predicted to remain negative as well.

GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
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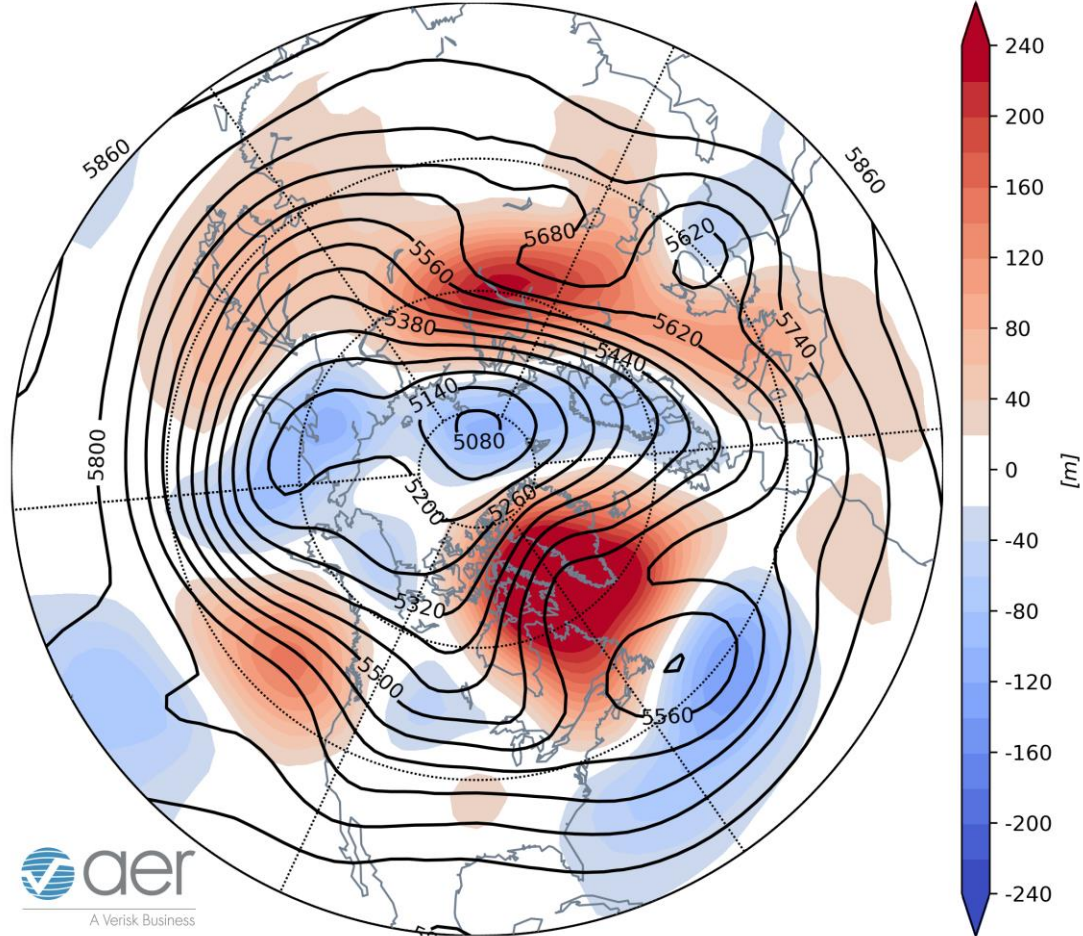


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 11 – 15 April 2021. The forecasts are from the 00z 5 April 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies will continue to favor troughing/negative geopotential height anomalies across Europe except for ridging in Southeastern Europe next week (**Figures 5**). This will favor normal to below normal temperatures across much of Europe including the UK except for normal to above normal temperatures in Southeastern Europe (**Figure 6**). Ridging/positive geopotential height anomalies centered on the Urals will continue to dominate Asia except for troughing/negative geopotential height anomalies in the Middle East and Eastern Siberia (**Figure 5**). This pattern favors widespread normal to above normal temperatures across much of Asia and with normal to below normal temperatures in the Middle East and Eastern Siberia (**Figure 6**).

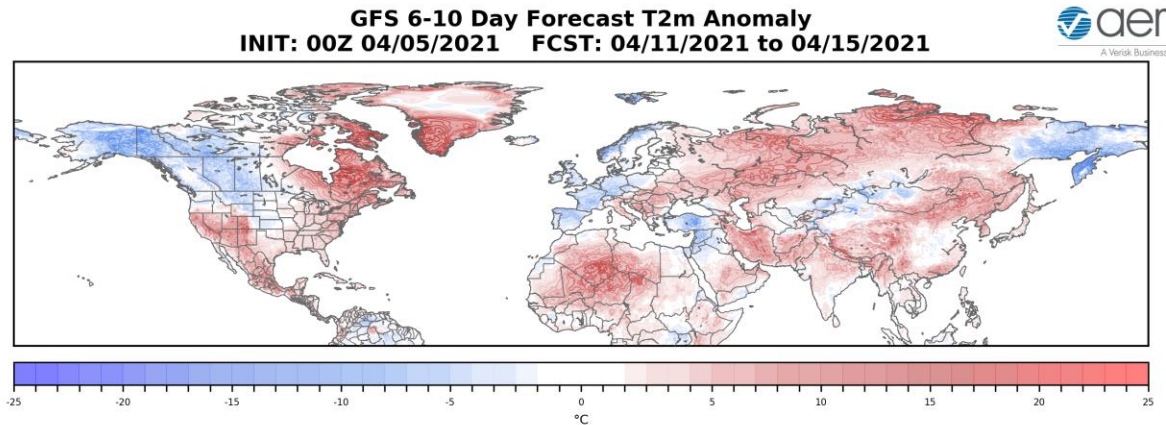


Figure 6. Forecasted surface temperature anomalies (°C; shading) from 11 – 15 April 2021. The forecasts are from the 00Z 5 April 2021 GFS ensemble.

Predicted ridging/positive geopotential height anomalies across Greenland and the Gulf of Alaska will force troughing/negative geopotential height anomalies in Western Canada and the Central US this period (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across Eastern Canada and the Southwestern and Eastern US with normal to below normal temperatures across Alaska, Western Canada and the Northwestern US (**Figure 6**).

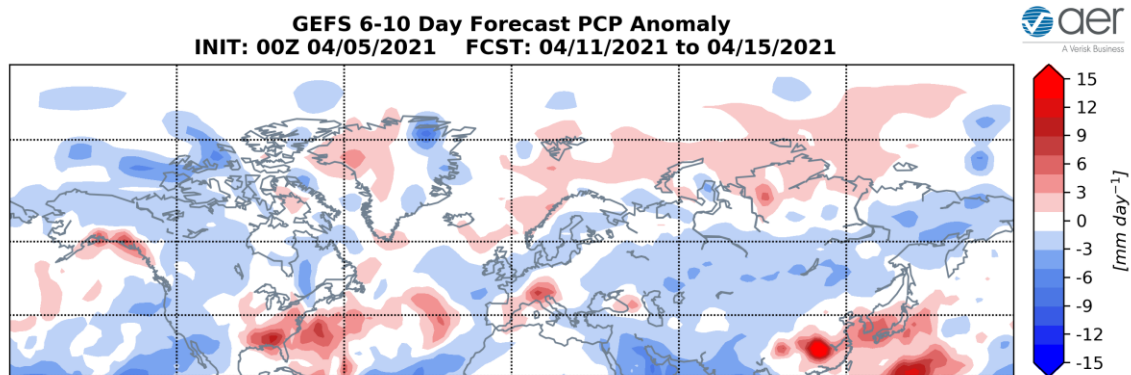


Figure 7. Forecasted precipitation anomalies (mm/day; shading) from 11 – 15 April 2021. The forecasts are from the 00Z 5 April 2021 GFS ensemble.

Normal to below normal precipitation are predicted for Eurasia with the exception of above normal precipitation in the Alps and Southeast Asia (**Figure 7**). Normal to below normal precipitation are predicted for North America except for Southern Alaska, the West Coast of Canada and the Eastern US (**Figure 7**).

11-15 day

With geopotential height anomalies predicted to be positive on the North American side of the Arctic but negative on the Eurasian side of the Arctic (**Figure 8**), the AO should remain negative to neutral this period (**Figure 1**). With positive pressure/geopotential height anomalies persisting across Greenland (**Figure 8**), the NAO is predicted to remain negative this period.

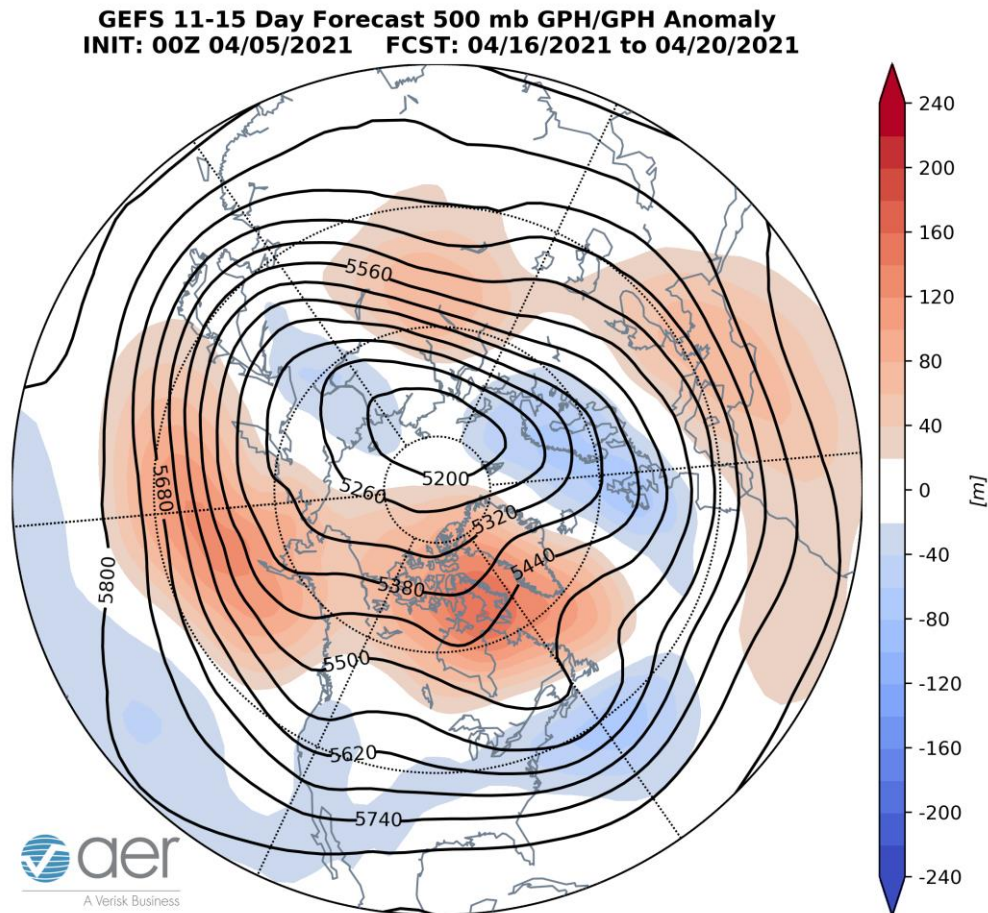


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 16 – 20 April 2021. The forecasts are from the 00z 5 April 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies will continue to favor troughing/negative geopotential height anomalies across Europe once again this period (**Figure 8**). This pattern favors widespread normal to below normal temperatures across Europe including the UK with the exception of Southeastern Europe due to southwesterly flow of milder air (**Figures 9**). Troughing/negative geopotential height anomalies are predicted to become more widespread across Northern and Eastern Asia due to the stratospheric PV moving over the region while ridging/positive geopotential height anomalies persist across Southern Asia (**Figure 8**). This pattern favors normal to

below normal temperatures across much of East Asia with normal to above normal temperatures across Western and Central Asia (**Figure 9**).

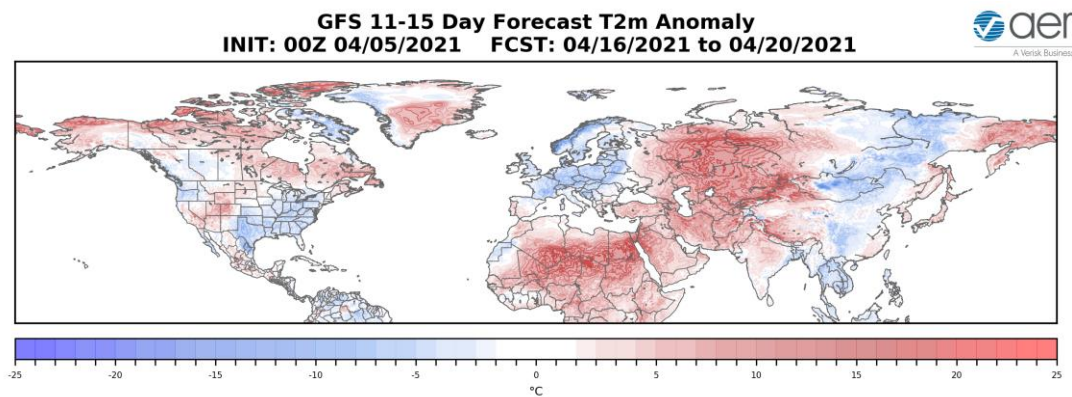


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 16 – 20 April 2021. The forecasts are from the 00z 5 April 2021 GFS ensemble.

Trouging/negative geopotential height anomalies are predicted to become increasingly widespread across the US as ridging/positive geopotential height anomalies build across all of Northern Canada and Alaska this period (**Figure 8**). This pattern favors normal to above normal temperatures for Alaska, Northern and Eastern Canada and the Southwestern US with normal to below normal temperatures across the Southwestern Canada and the Northern and Eastern US (**Figure 9**).

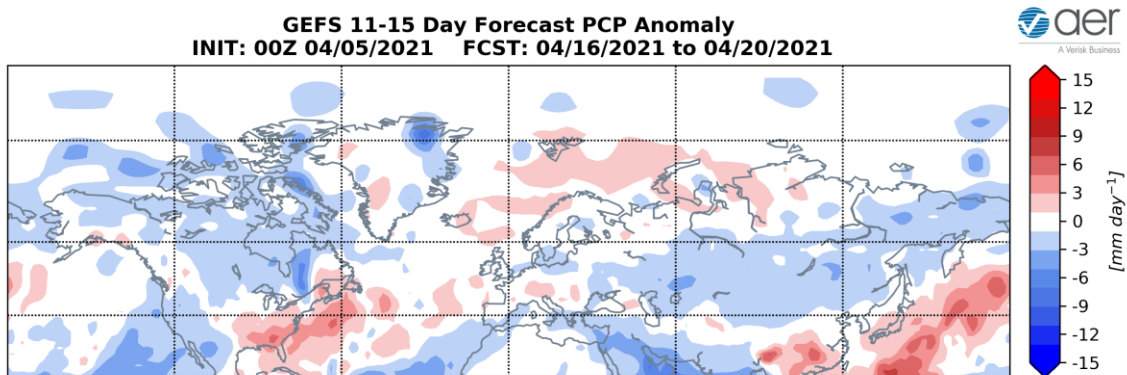


Figure 10. Forecasted precipitation anomalies (mm/day ; shading) from 16 – 20 April 2021. The forecasts are from the 00z 5 April 2021 GFS ensemble.

Normal to below normal precipitation are predicted for Eurasia with the exception of above normal precipitation in the Alps and Southeast Asia (**Figure 10**). Normal to below normal precipitation are predicted for North America except the Eastern US (**Figure 10**).

Longer Term

30-day

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

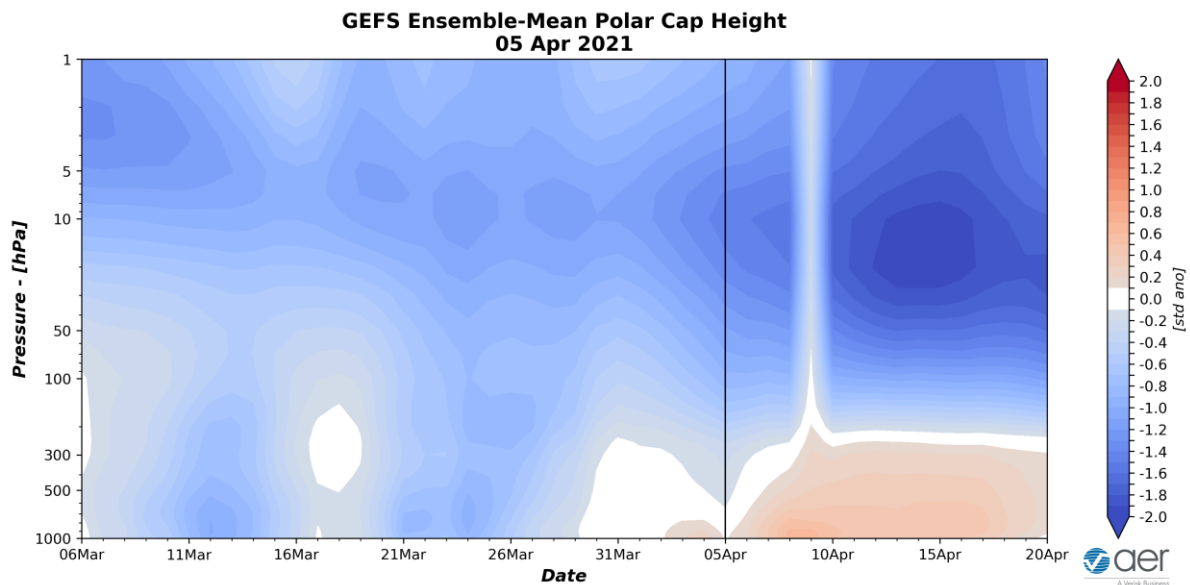


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 5 April 2021 GFS ensemble.

The overall warm/positive PCHs in the lower troposphere are consistent with the predicted neutral to negative surface AO the next two weeks (**Figure 1**).

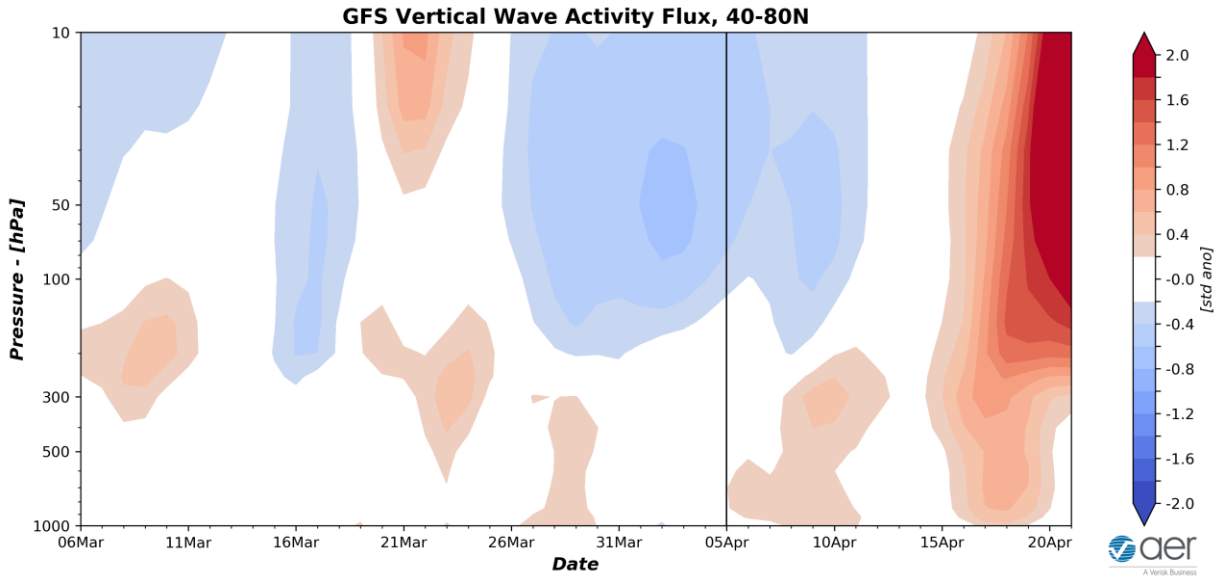


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 5 April 2021 GFS ensemble.

The plot of the Wave Activity Flux (WAFz and is proportional to poleward heat transport) forecast is showing currently normal to below normal WAFz especially in the stratosphere over the next week (**Figure 12**). However, starting next week, the WAFz is predicted to become much more active. It looks to me that this new pulse has the potential to result in a dynamic Final Warming (where the stratospheric PV disappears until the fall). A dynamic Final Warming can have a similar influence on the weather analogous to PV disruptions or weakenings (though usually on a smaller scale) that results in cooler weather across the mid-latitudes.

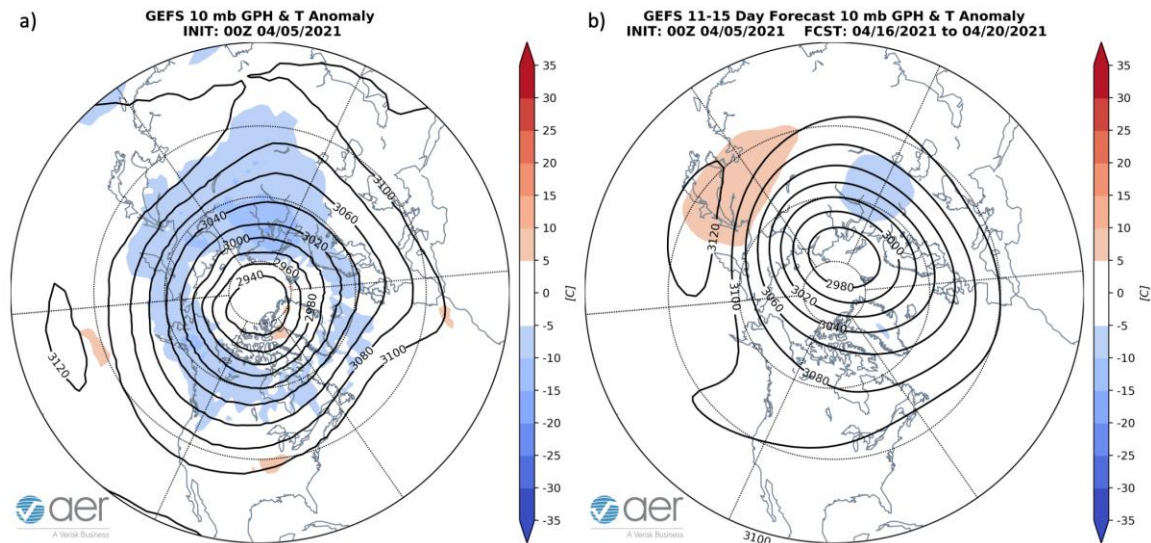


Figure 13. (a) Observed 10 mb geopotential heights (dam; contours) and temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for 5 April 2021. (b) Same as (a) except forecasted averaged from 16 – 20 April 2021. The forecasts are from the 00Z 5 April 2021 GFS model ensemble.

The PV continues to remain relatively strong with the vortex centered over the North Pole and is circular in shape (**Figure 13**). However, the PV center is predicted to migrate closer to the North Slope of Asia and fill (**Figure 13**). This is a sign of weakening and could be the beginning stages of the PV Final Warming.

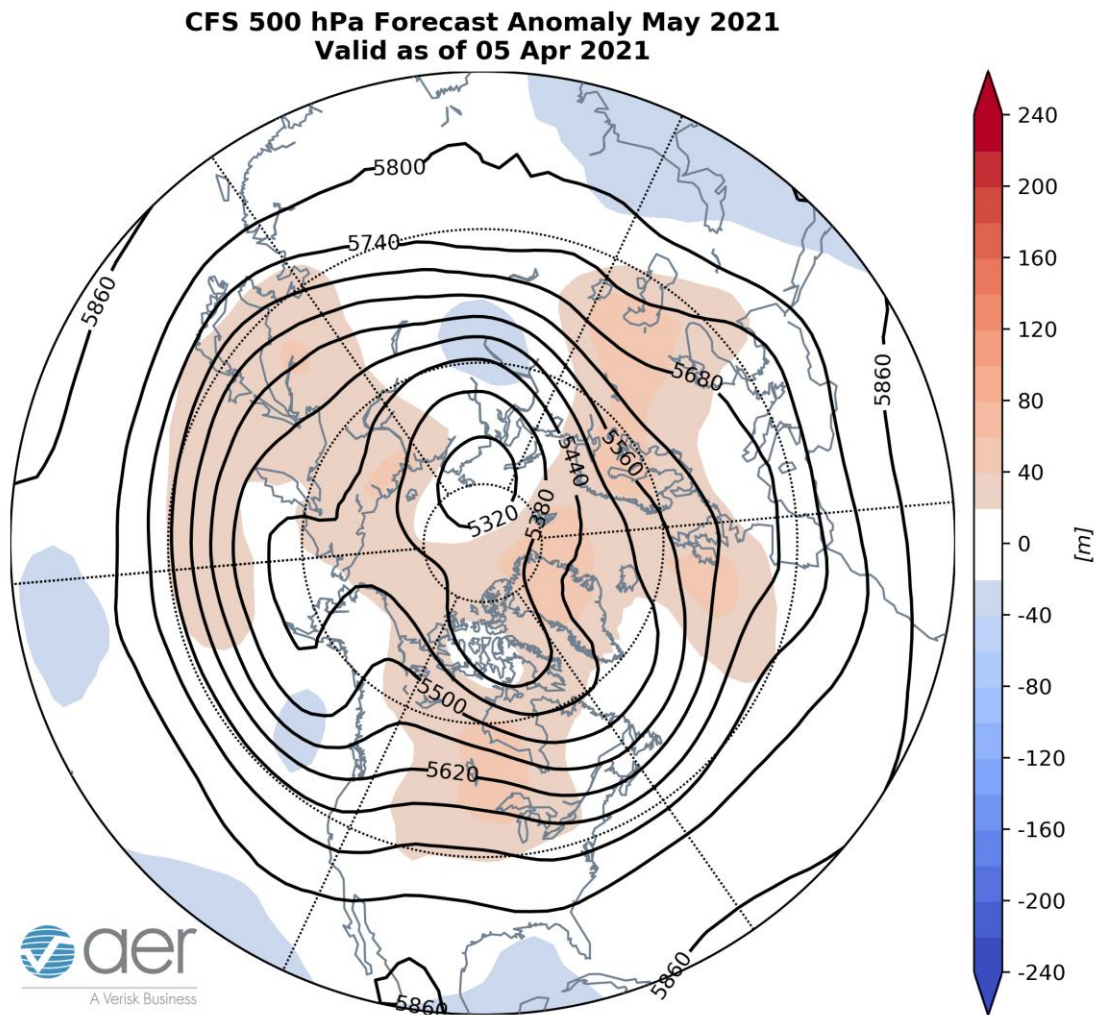


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for May 2021. The forecasts are from the 00Z 5 April 2021 CFS.

I include in this week’s blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) forecast for May from the Climate Forecast

System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging across Northwestern Europe, Eastern Siberia, western North America and Greenland with troughing in Western Asia, East Asia, near the Aleutians and eastern North America (**Figure 14**). This pattern favors relatively cool temperatures for Western Asia, East Asia, Central Canada and the Central US with seasonable to relatively warm temperatures for Western Europe, Central Asia and much of Northern and Eastern Canada and the Western US (**Figure 15**).

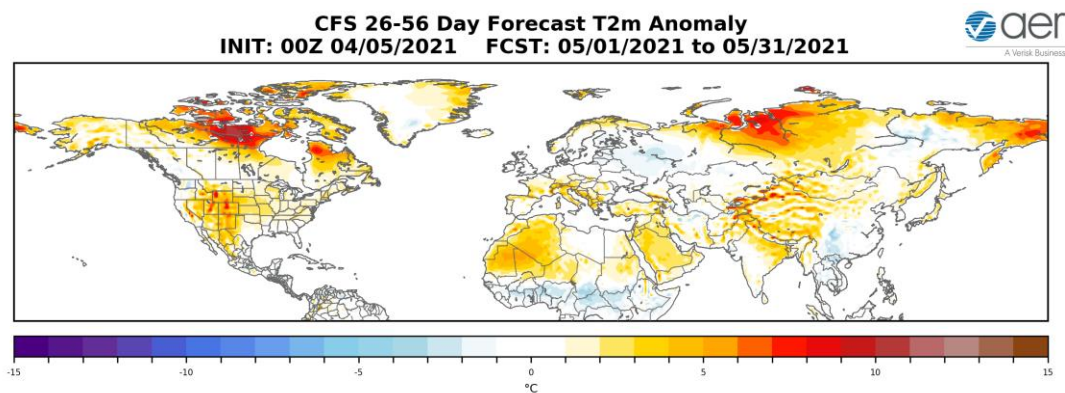


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for May 2021. The forecasts are from the 00Z 5 April 2021 CFS.

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 conditions (**Figure 17**) 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.

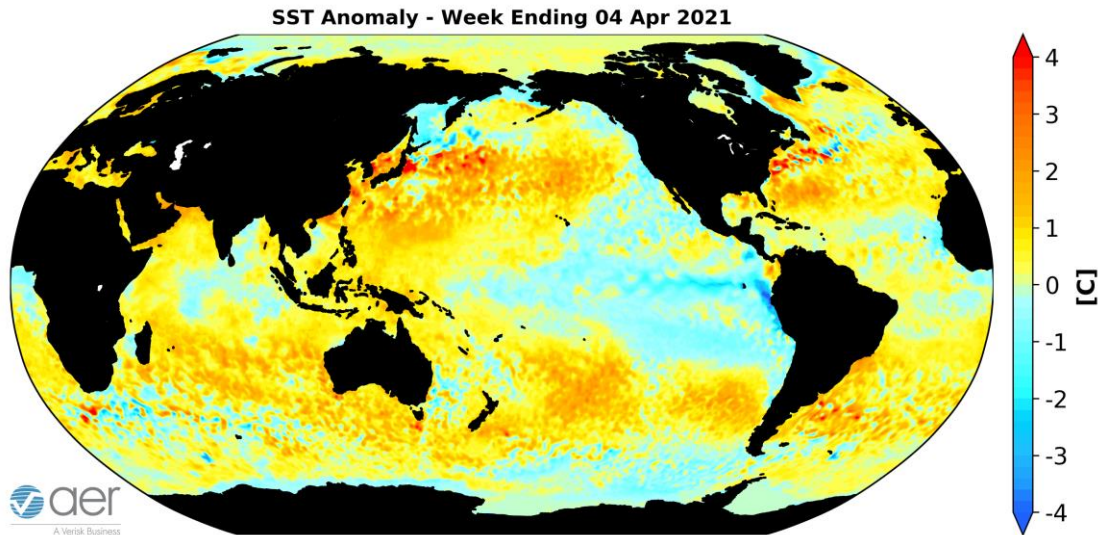


Figure 17. The latest weekly-mean global SST anomalies (ending 4 April 2021). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase five (**Figure 18**). The forecasts are for the MJO to quickly transition to phases six and then seven. MJO phases six and seven initially favor ridging in the Eastern US but eventually blocking near Greenland and Northern Canada with troughing in the Eastern 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.

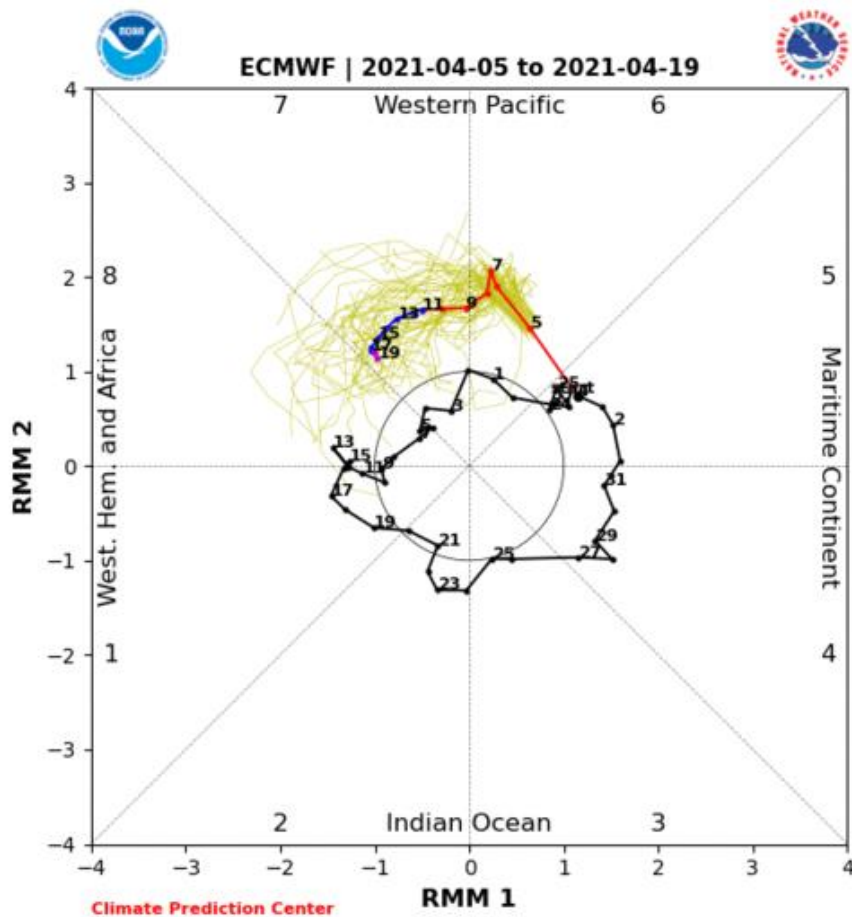


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 5 April 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>