Arctic Oscillation and Polar Vortex Analysis and Forecasts

April 19, 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 be neutral to negative the next two weeks as pressure/geopotential height anomalies are predicted to be mostly positive in the Arctic but especially across Greenland with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is also predicted to be neutral to negative the

next two weeks as pressure/geopotential height anomalies are predicted to be mostly positive across Greenland.

- This week and into next, predicted strengthening ridging/positive geopotential height across Greenland will force deepening troughing/negative geopotential height anomalies across much of Europe this week and into next week, bringing with it normal to below normal temperatures across much of Europe including the United Kingdom (UK) with the exception of parts of Southern Europe where above normal temperatures are common during periods of negative NAO.
- European troughing will favor ridging/positive geopotential height anomalies centered over the Urals and into Siberia coupled with widespread normal to above normal temperatures across Northern Asia. Ural and Siberian blocking, in turn will force troughing/negative geopotential height anomalies coupled with normal to below temperatures to the south across Central and Eastern Asia.
- For much of the next two weeks, ridging/positive geopotential height anomalies coupled with normal to above normal temperatures first across Alaska and then Greenland will combine to force troughing/negative geopotential height anomalies across the interior of 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 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. I also look ahead to the summer.

Impacts

The PV is in its waning days of the 2020/21 cold season and will likely be nearly or completely disappeared by the next blog update. This seems to me to be a clear dynamically assisted Final Warming as vertical Wave Activity Flux (WAFz and is proportional to poleward heat transport) has been active for at least a week now and is predicted to remain active for the next two weeks. A dynamic Final Warming can result in some cooler weather across the mid-latitudes; and in my opinion the snow and possibly record cold temperatures predicted for the Eastern US this week is related to the dynamic Final Warming. The PV is being stretched from Siberia to Canada that creates cross polar flow from Siberia to North America that drives cold air south across Canada and the US east of the Rockies. I do believe that this is a short-term impact only and will not have an influence on the summer weather across North America.

Europe has had an impressively cool April, relative to recent Aprils (probably the coolest April since 2013 and maybe even since 2003), which is directly attributable to Greenland blocking that has also extended into the North Atlantic for much of the month. There are no strong signs that the Greenland blocking will disappear any time soon, and as long as it persists, Europe can experience relatively cool temperatures. I see no obvious signs that the Greenland blocking is tied to PV variability and it is therefore more challenging for me to anticipate how long it will last. But it is likely that the streak of

cool weather is dependent on the persistence of the Greenland blocking. If and when the Greenland blocking abates, European temperatures could start to climb.

As I mentioned in the last blog, 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. Melting of Arctic sea ice and snow cover across the Eurasian and North American Arctic tends to amplify summer warming and rises in geopotential heights along the northern continental edges (which border the Arctic ocean). I just note that the latest CFS forecast for June is consistent with this idea. The June CFS forecast shows the lowest geopotential heights centered over the North Pole but is then ringed by positive geopotential height anomalies across Northern Eurasia and Northern Canada (see **Figure i**). The CFS June temperature forecast predicts amplified warming across Northern Asia and Northern Canada and more moderate warming across the mid-latitudes (see **Figure ii**). Parts of Europe and the US are more seasonable.

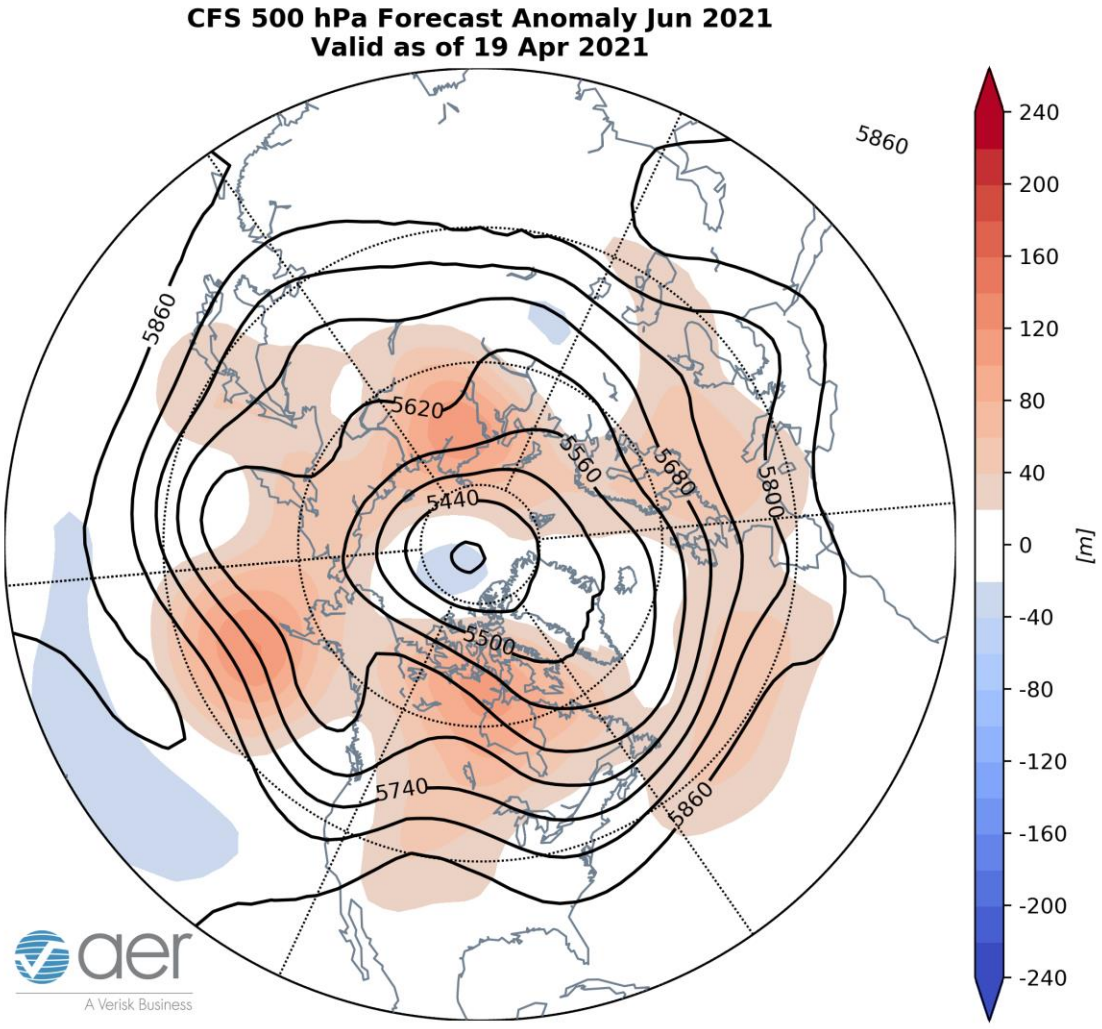

Figure i. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for June 2021. The forecasts are from the 00Z 19 April 2021 CFS.

So far this year, spring seems to be less aggressive than recent years especially across Europe and this could be a harbinger of the summer. There is no reason not to expect an overall hot summer for the NH but there could be regions of relatively cooler temperatures relative to normal. But as exemplified in the latest CFS forecast, if high latitude blocking sets up just so, it could contribute to keeping summer temperatures close to seasonable or even seasonably cool across Europe and/or the US.

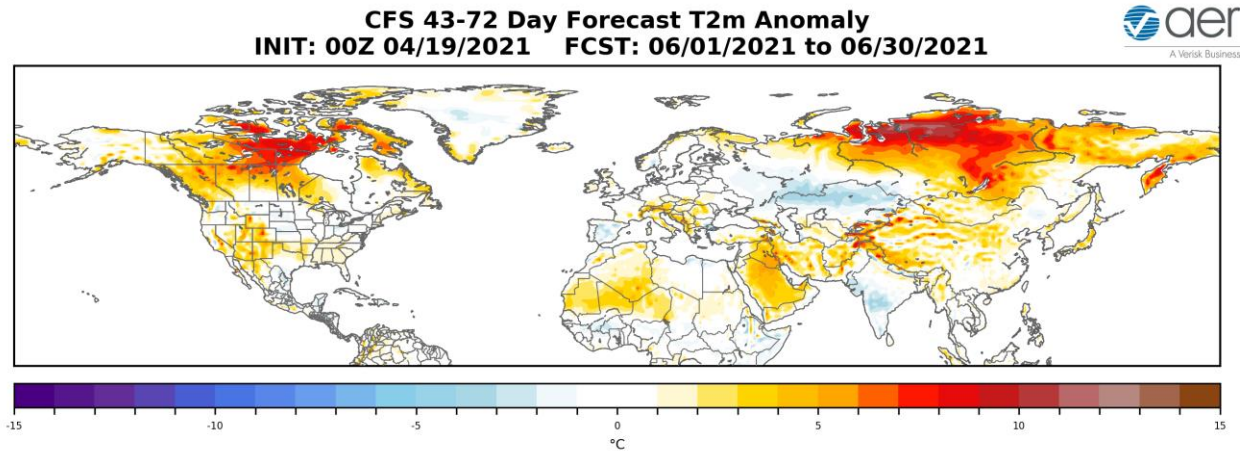

Figure ii. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for June 2021. The forecasts are from the 00Z 19 April 2021 CFS.

1-5 day

The AO is predicted to begin the week neutral 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 neutral to negative as well this week.

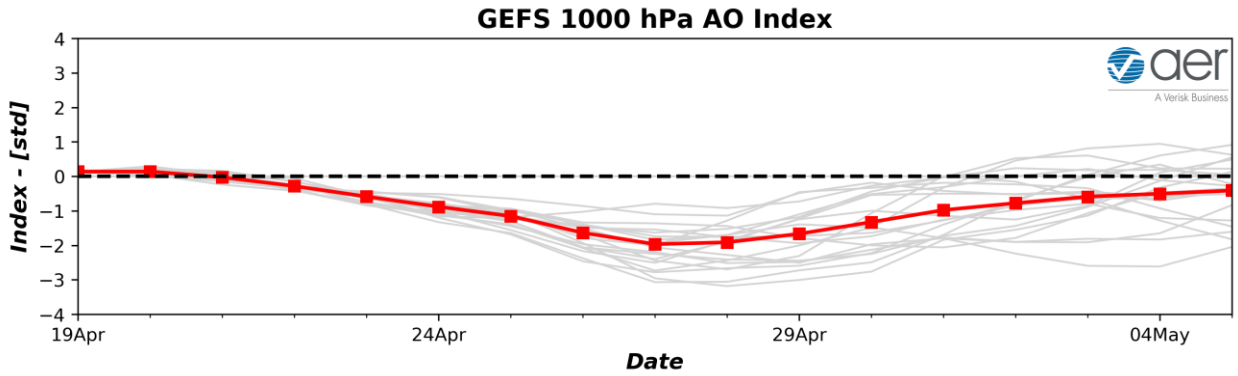

Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 19 April 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Building ridging/positive geopotential height anomalies across Greenland are predicted to force deepening troughing/negative geopotential height anomalies across Europe this week (**Figures 2). This will favor** normal to below normal temperatures across Central and Eastern Europe including the UK though normal to above normal temperatures will linger longer across Northern Europe under mid-tropospheric ridging (**Figure 3**). Much of Asia will be dominated by ridging/positive geopotential height anomalies with two centers, one over the Urals and the other over East Asia with troughing/negative geopotential height anomalies focused in Central 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 Central Asia **(Figure 3**).

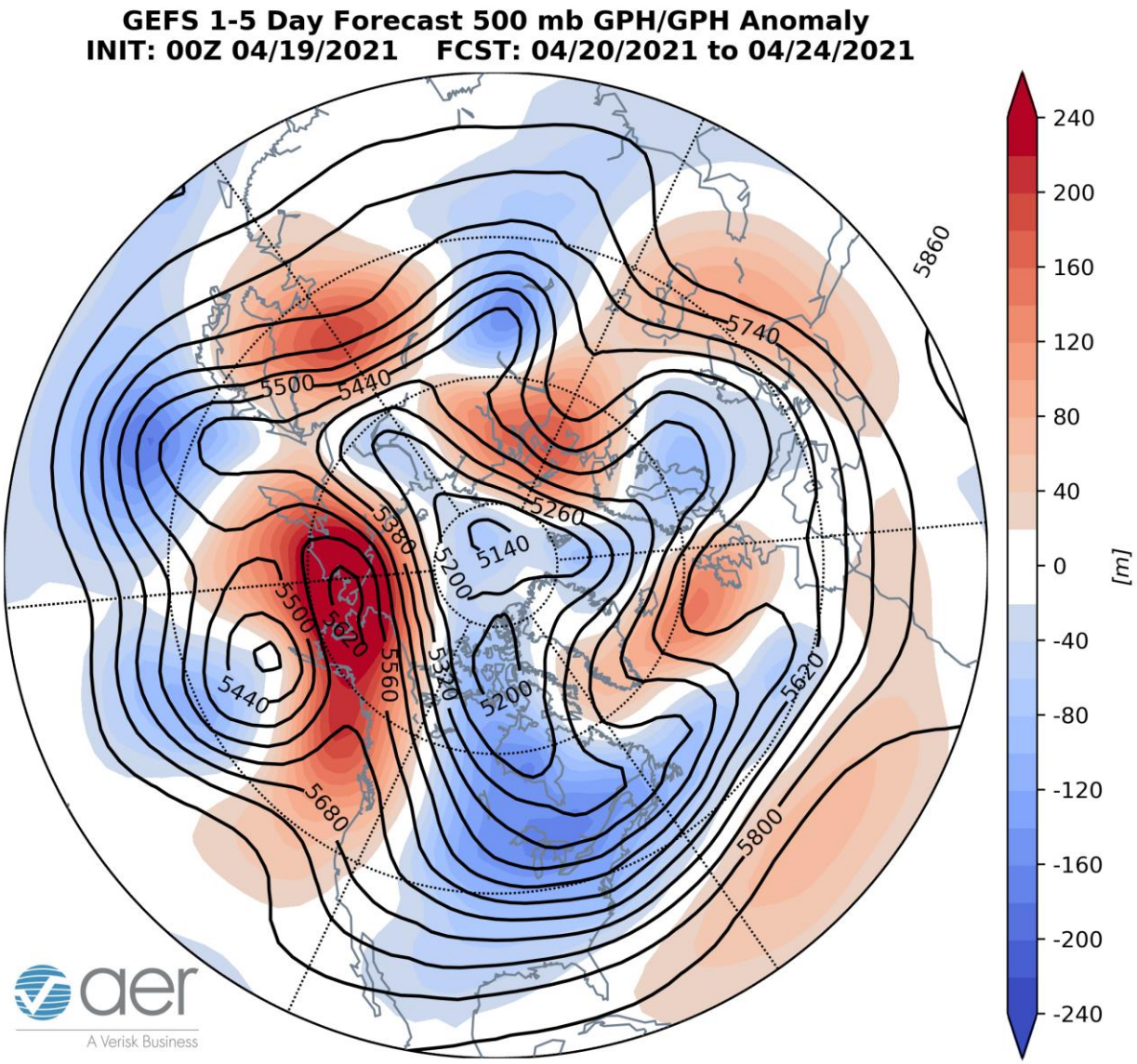

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 20 – 24 April 2021. The forecasts are from the 00z 19 April 2021 GFS ensemble.

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

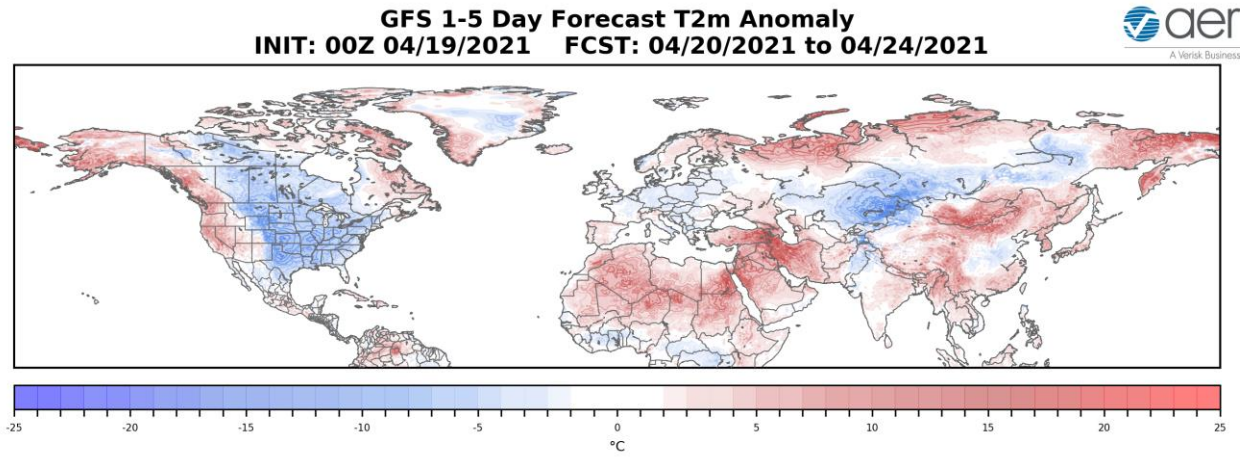

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 20 – 24 April 2021. The forecast is from the 00Z 19 April 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia with the exception of above normal precipitation in Southeast Asia (**Figure 4**). Normal to below normal precipitation is predicted for North America except for the Mississippi River Valley, the Great Lakes, New England and the Canadian Maritimes (**Figure 4**).

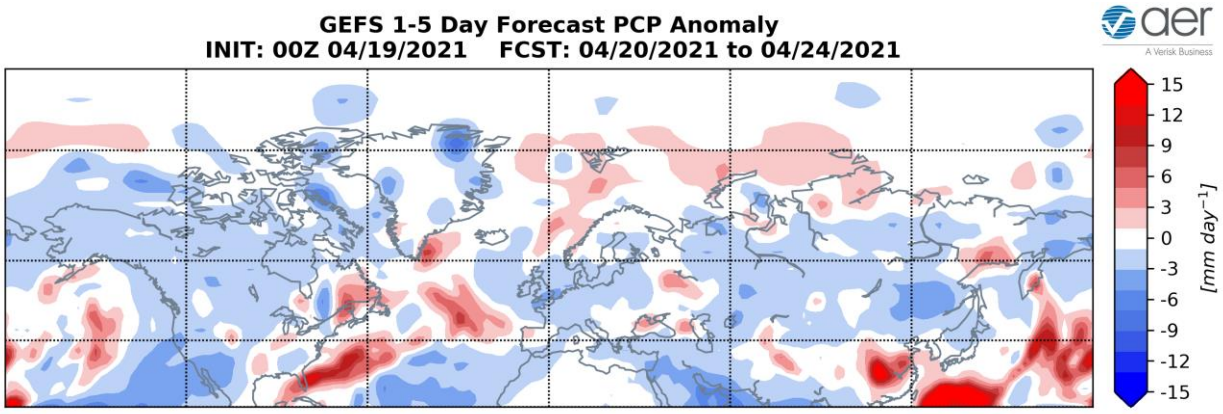

Figure 4. Forecasted precipitation anomalies (mm/day; shading) from 20 – 24 April 2021. The forecast is from the 00Z 19 April 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain negative even possibly strongly 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.

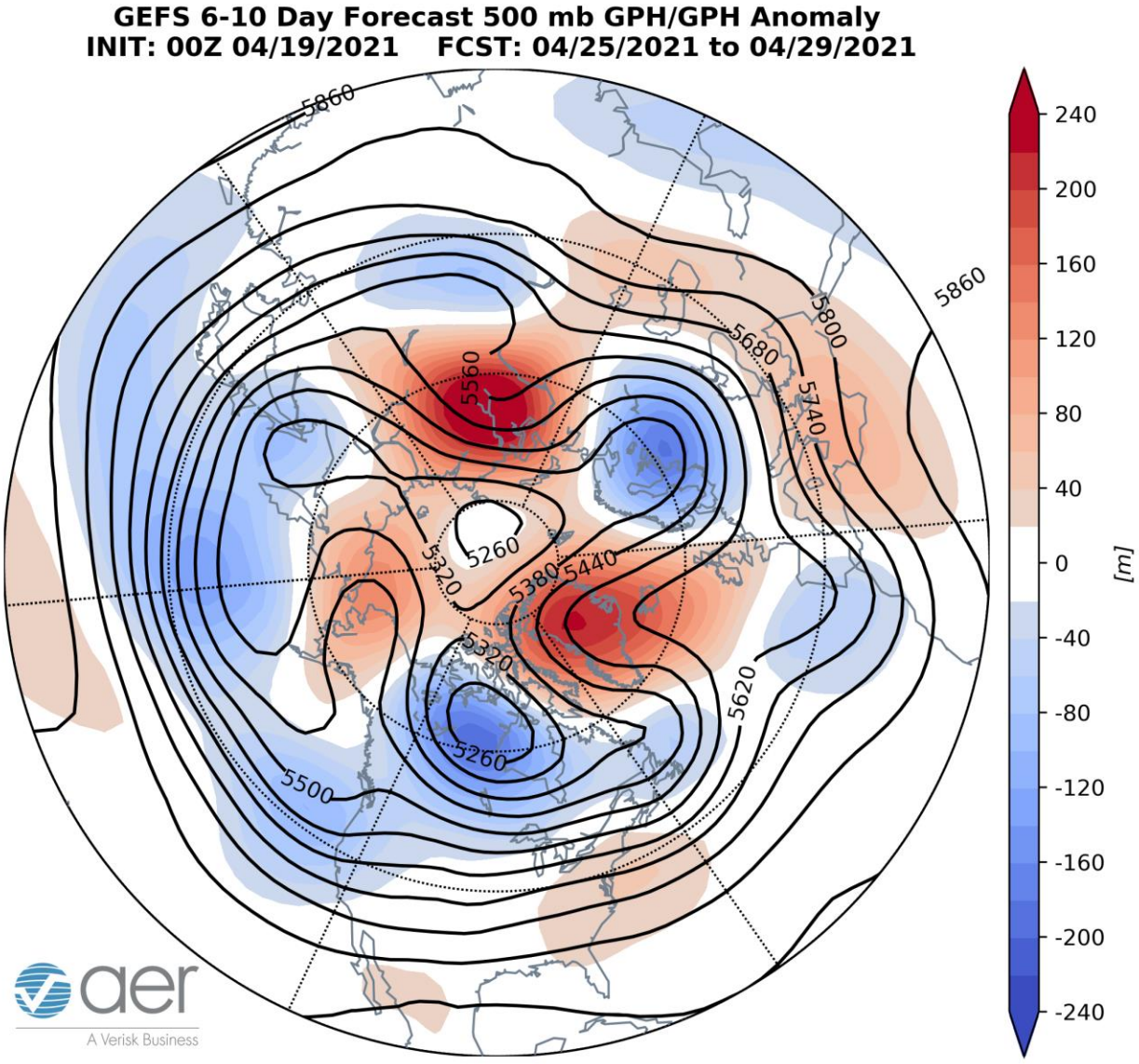

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 25 – 29 April 2021. The forecasts are from the 00z 19 April 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies across Greenland 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 Western Siberia will

continue to dominate Northern Asia forcing troughing/negative geopotential height anomalies in Central Asia (**Figure 5**). This pattern favors widespread normal to above normal temperatures across much of Asia with normal to below normal temperatures in Central Asia **(Figure 6**).

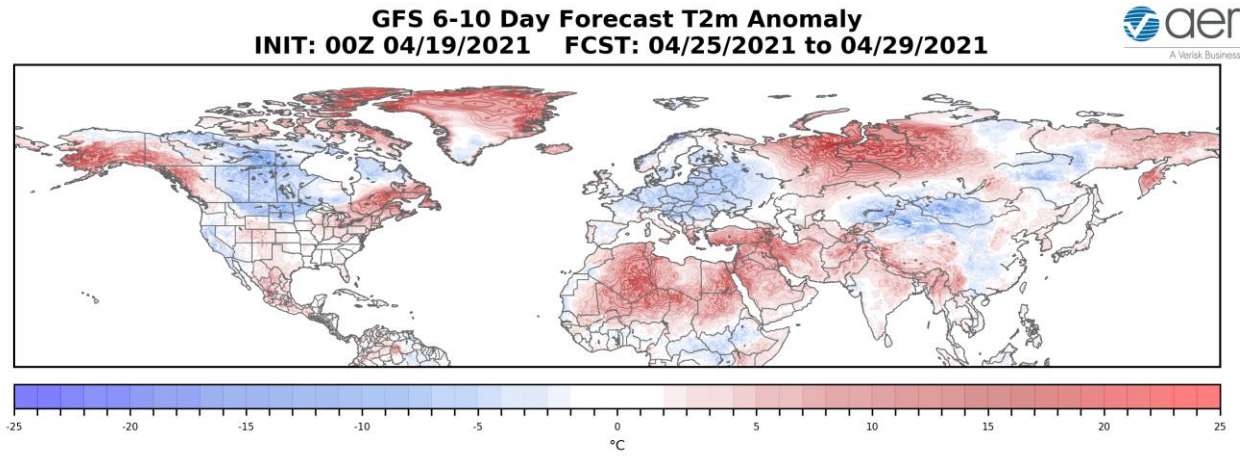

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 25 – 29 April2021. The forecasts are from the 00Z 19 April 2021 GFS ensemble.

Predicted continued ridging/positive geopotential height anomalies across Alaska but especially Greenland will continue to force troughing/negative geopotential height anomalies in Central Canada which trails back into the Western US this period **(Figure 5).** This pattern is predicted to bring normal to above normal temperatures across Alaska, Western and Eastern Canada and the Northeastern US with normal to below normal temperatures across Central Canada and the Northcentral and Western US **(Figure 6).**

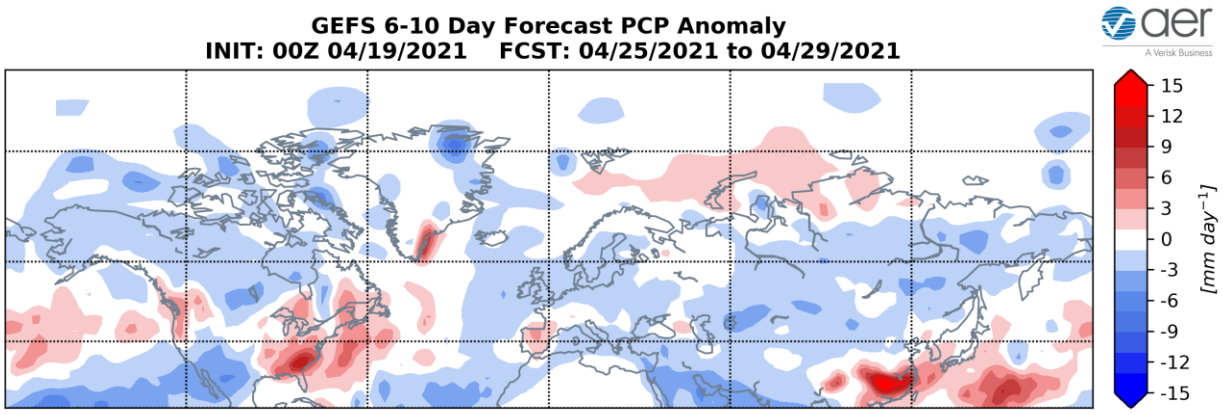

Figure 7. Forecasted precipitation anomalies (mm/day; shading) from 25 – 29 April 2021. The forecasts are from the 00Z 19 April 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia with the exception of above normal precipitation in Spain and Southeast Asia (**Figure 7**). Normal to below normal precipitation is predicted for North America except for US Pacific Northwest, the Eastern US and the Canadian Maritimes (**Figure 7**).

11-15 day

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

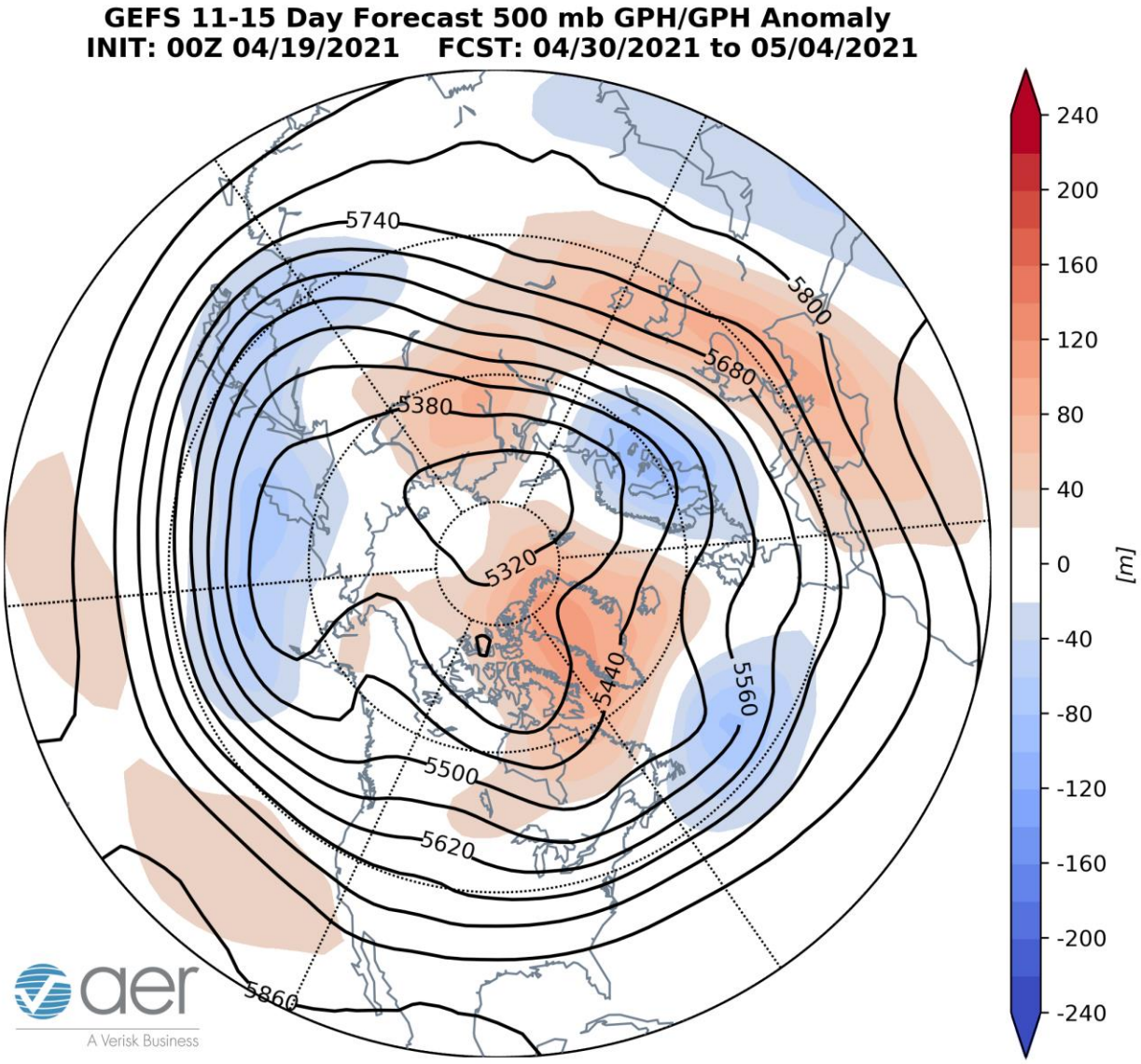

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 30 April – 4 May 2021. The forecasts are from the 00z 19 April 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies across Greenland will continue to favor troughing/negative geopotential height anomalies across Northern Europe with more ridging/positive geopotential height anomalies strung across Southern Europe this period (**Figure 8**). This pattern favors widespread normal to below normal temperatures across Northern Europe including the UK with normal to above normal temperatures across Southern Europe (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to persist across Northern Asia though troughing/negative geopotential height anomalies previously in Central Asia are predicted to slide east into Eastern Asia this period (**Figure 8**). This pattern favors normal to below normal temperatures across much of East Asia with normal to above normal temperatures across much of the remainder of Asia (**Figure 9**).

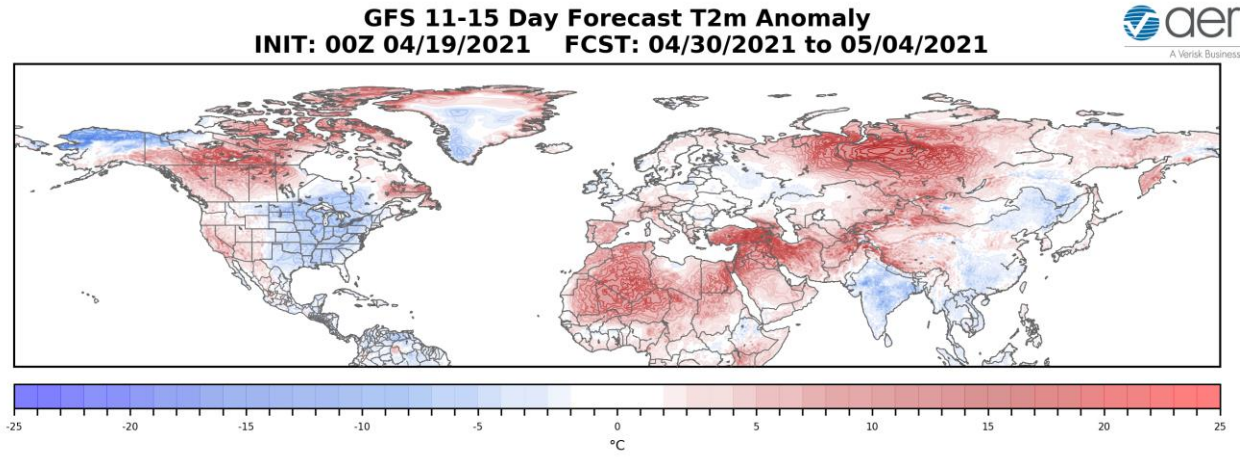

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 30 April – 4 May 2021. The forecasts are from the 00z 19 April 2021 GFS ensemble.

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

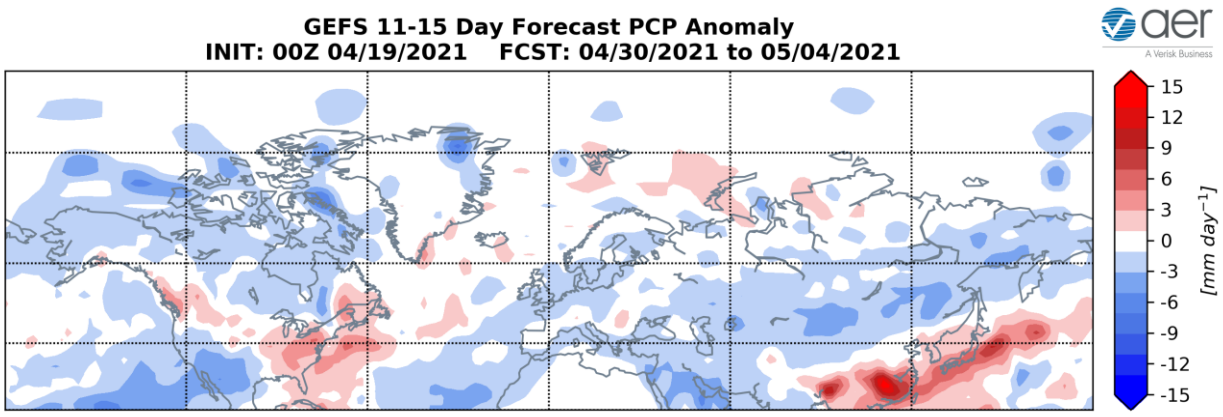

Figure 10. Forecasted precipitation anomalies (mm/day; shading) from 30 April – 4 May 2021. The forecasts are from the 00z 19 April 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia with the exception of above normal precipitation in Southeast Asia (**Figure 10**). Normal to below normal precipitation is predicted for North America except for the Pacific Northwest and 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 in the mid to lower stratosphere and upper troposphere but warm/positive PCHs in the mid to low troposphere for the next two weeks (**Figure 11**).

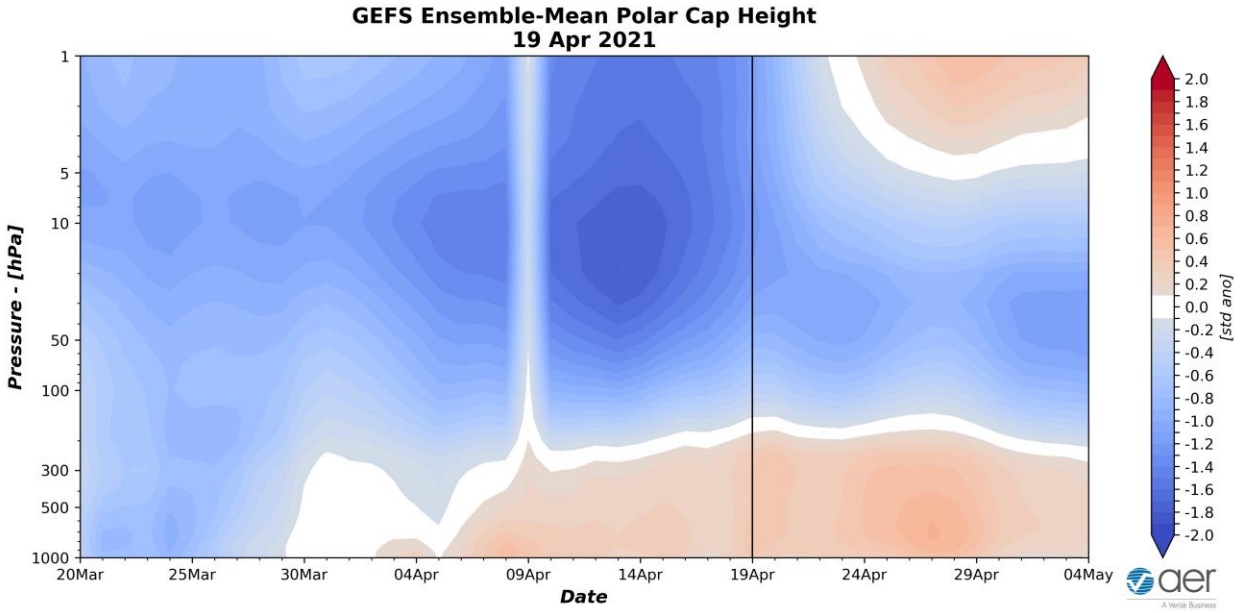

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 19 April 2021 GFS ensemble.

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**).

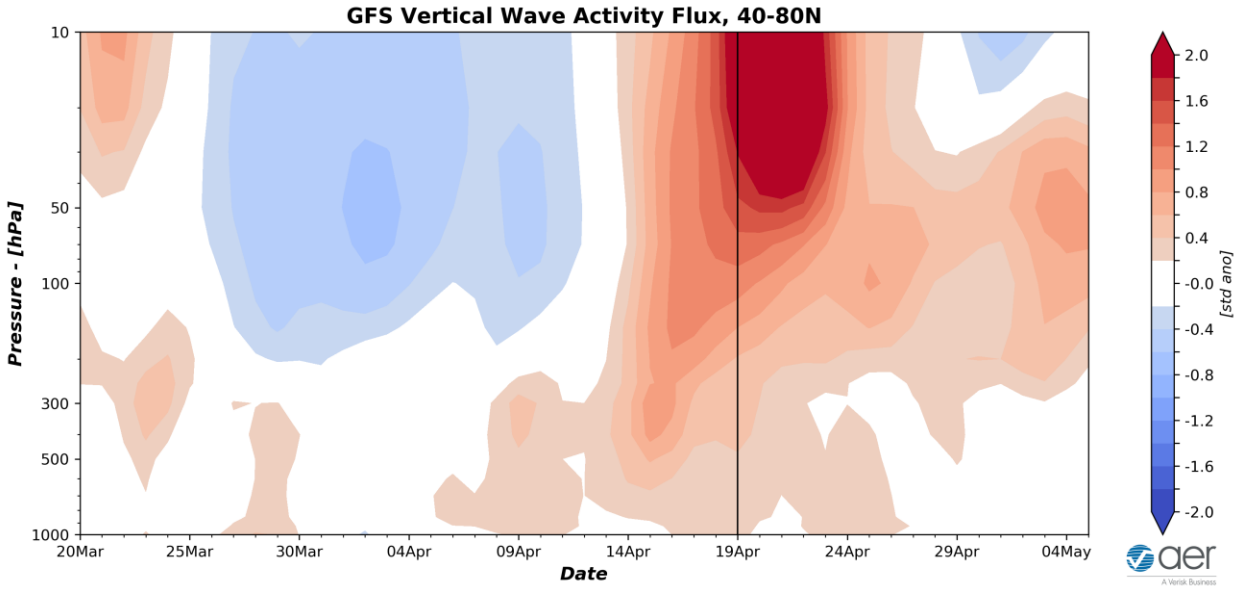

Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 19 April 2021 GFS ensemble.

The plot of the vertical Wave Activity Flux (WAFz and is proportional to poleward heat transport) forecast is showing currently very active WAFz. The WAFz is predicted to remain active especially in the stratosphere over the next week (**Figure 12**). It is highly likely that this WAFz activity will 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. Though admittedly it is not obvious, I do think that the dynamic Final Warming is contributing to the forecasts of cooler weather in Europe and the Eastern US.

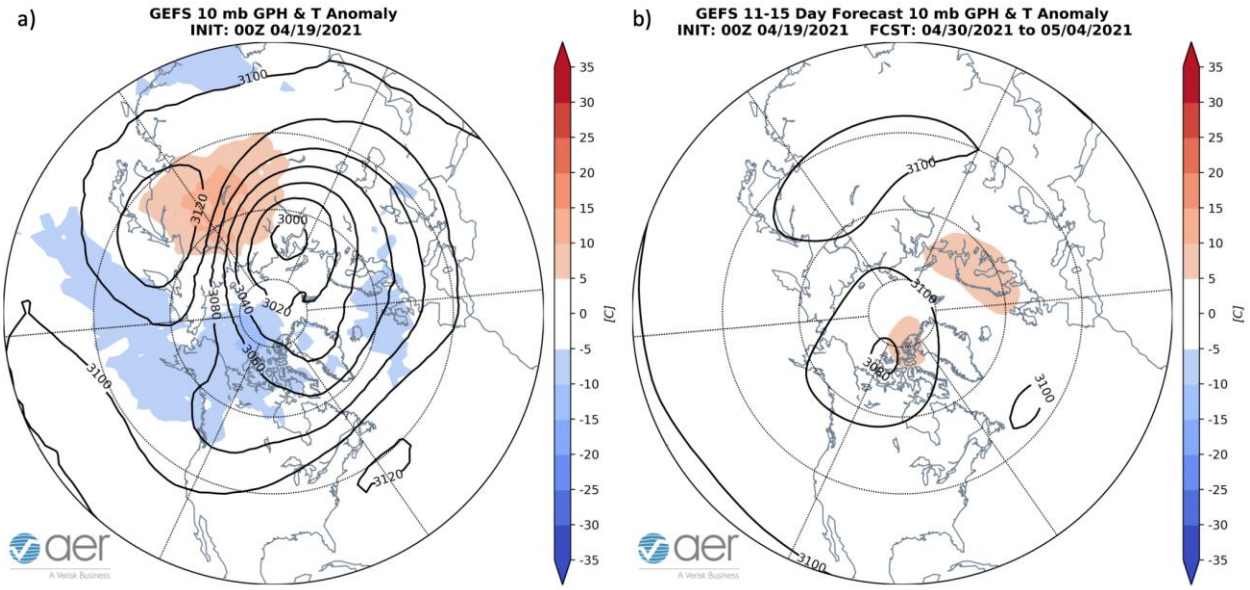

Figure 13. (**a**) Observed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 19 April 2021. (**b**) Same as (a) except forecasted averaged from 30 April – 4 May 2021. The forecasts are from the 00Z 19 April 2021 GFS model ensemble.

The PV continues to remain relatively strong with the vortex centered near the Urals and is stretched in shape (**Figure 13**). This is a sign of the PV weakening and is the beginning stages of the PV Final Warming. By the end of April and early May, the PV is predicted to be very weak (**Figure 13**) and may even disappear completely by that time period.

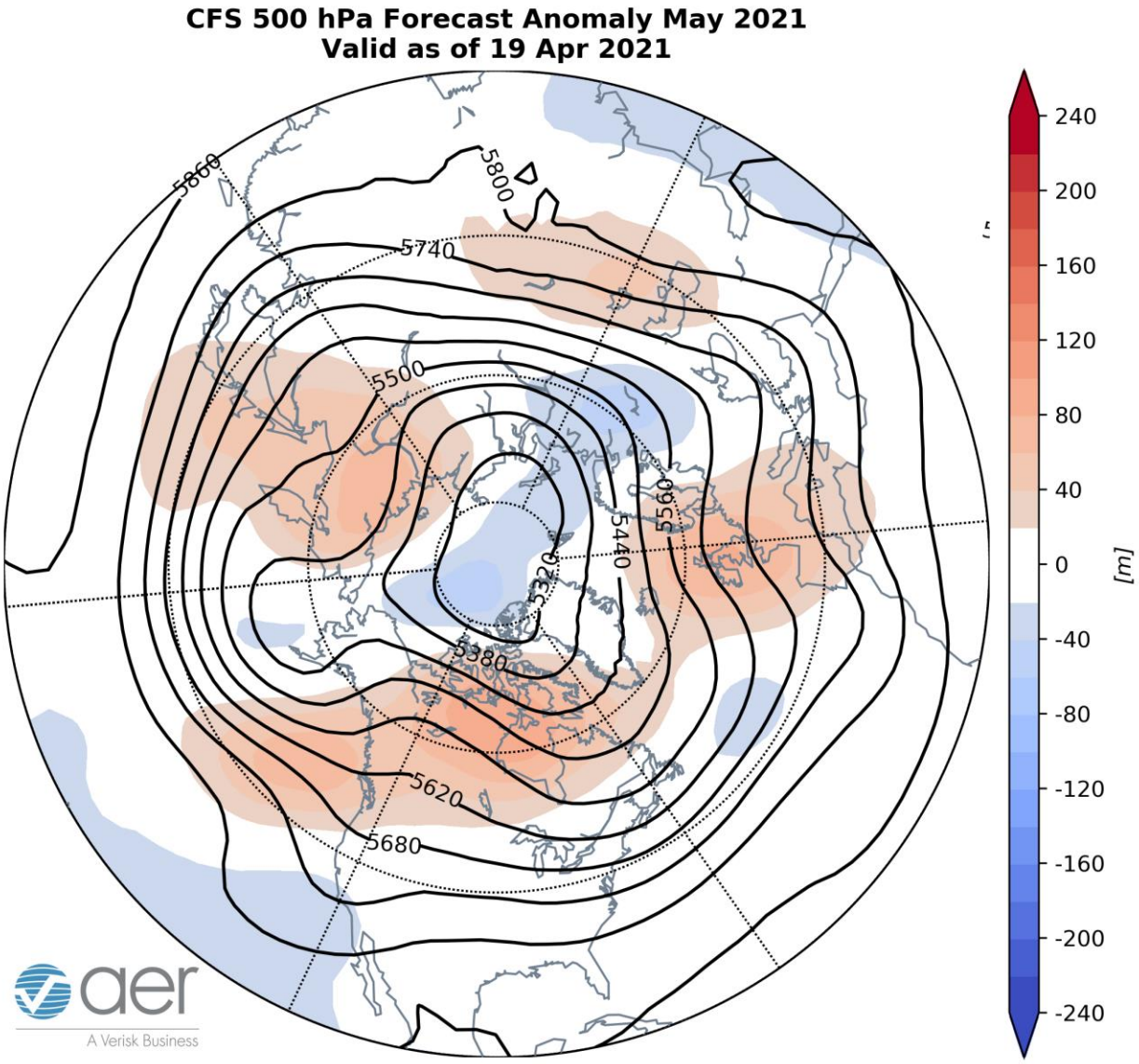

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for May 2021. The forecasts are from the 00Z 19 April 2021 CFS.

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, Gulf of Alaska, Western and Northern Canada with troughing in Eastern Europe/Western Asia, East Asia, near the Aleutians, the US West Coast and eastern North America (**Figure 14**). This pattern favors relatively cool temperatures for Eastern Europe/Western Asia, East Asia and the US West Coast with seasonable to relatively warm temperatures for

Northern Europe, the Middle East, Central Asia, Alaska and much of Canada and the Eastern US **(Figure 15).**

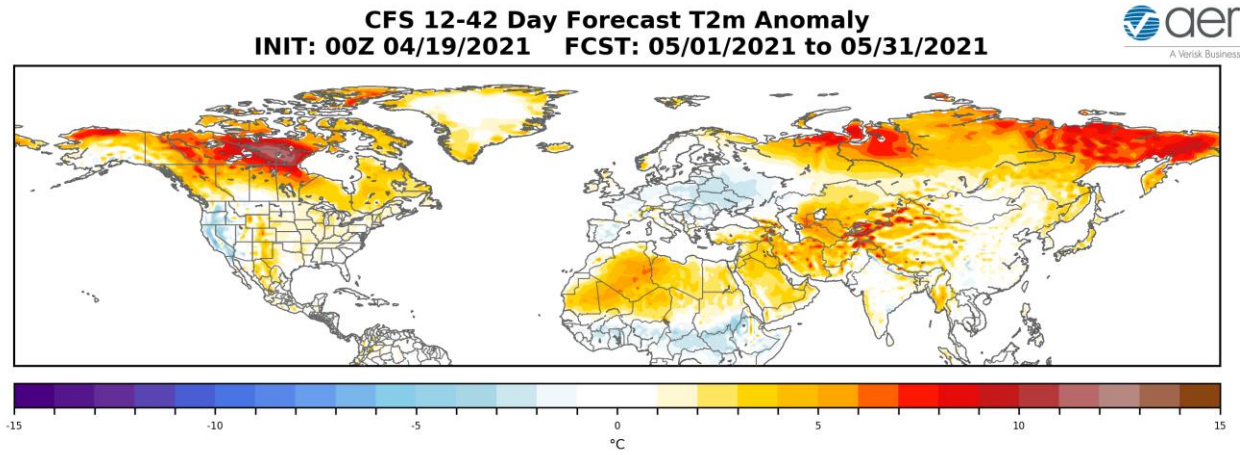

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for May 2021. The forecasts are from the 00Z 19 April 2021 CFS.

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 or possibly neutral 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.

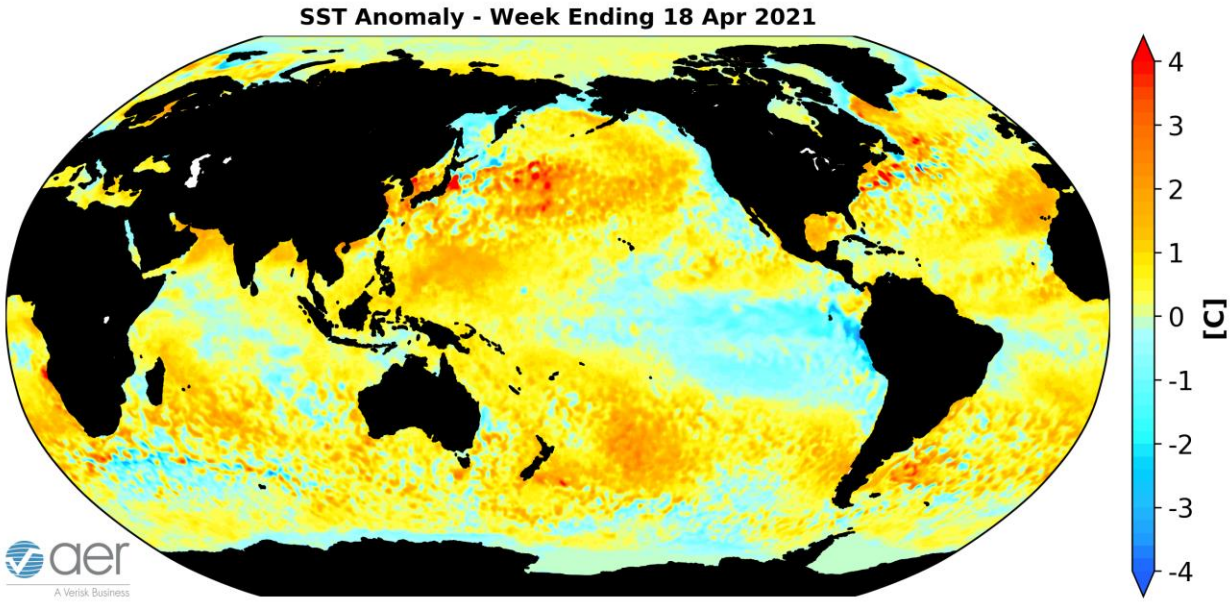

Figure 17. The latest weekly-mean global SST anomalies (ending 18 April 2021). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase seven (**Figure 18**). The forecasts are for the MJO to quickly transition to phases eight and then one. MJO phases seven through one 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.

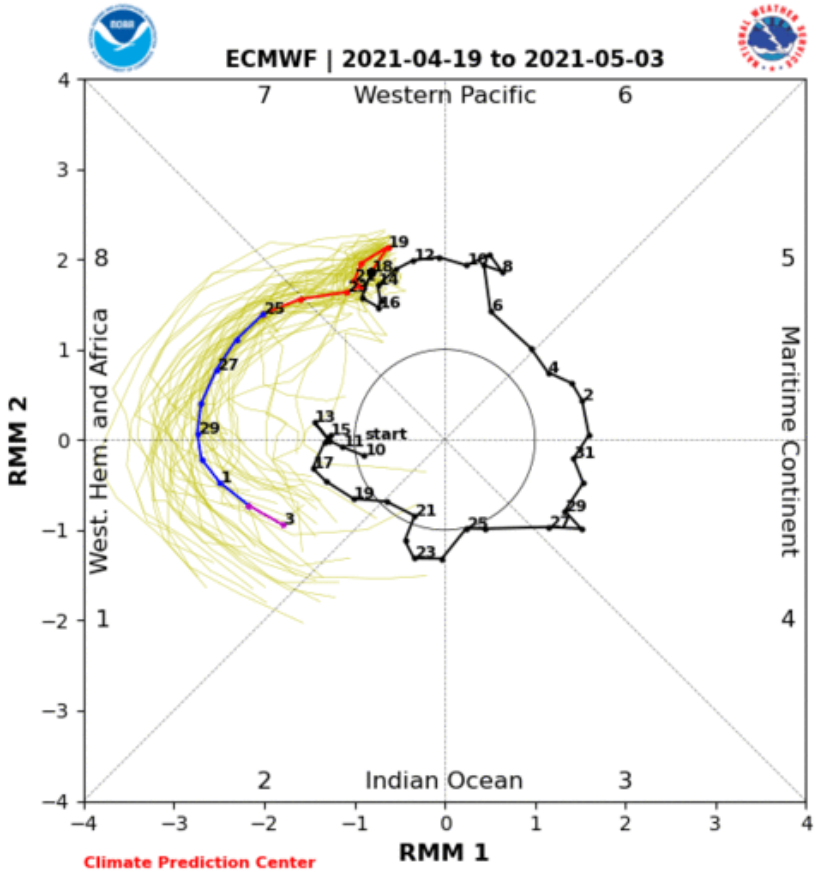

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 19 April 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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