

Arctic Oscillation and Polar Vortex Analysis and Forecasts

May 14, 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 remain neutral to negative over the next two weeks as pressure/geopotential height anomalies across the Arctic are mixed but are predicted to become positive across the Central Arctic with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently

negative and is predicted to remain neutral to negative over the next two weeks as pressure/geopotential height anomalies are predicted to remain predominately positive across Greenland.

- Predicted ridging/positive geopotential height anomalies across Greenland favor troughing/negative geopotential height anomalies across Europe with below normal temperatures across much of Europe including the United Kingdom (UK) over the next two weeks. However, across Southern Europe predicted above normal geopotential heights will favor normal to above normal temperatures especially across Spain over the next two weeks.
- The next two weeks, European troughing will help to anchor a wave train across Asia with ridging/positive geopotential height anomalies coupled with widespread normal to above normal temperatures across Western Asia with troughing/negative geopotential height anomalies coupled with normal to below temperatures in Central Asia and finally ridging/positive geopotential height anomalies coupled with normal to above temperatures in East Asia.
- Currently across North America the pattern is ridging/positive geopotential height anomalies coupled with normal to above normal temperatures across western North America with troughing/negative geopotential height anomalies across eastern North America coupled with normal to below temperatures east of the Rockies both in Canada and the United States (US). However, geopotential heights are predicted to rise across eastern North America coupled with rising temperatures with troughing coupled with normal to below normal temperatures in Central Canada that are predicted to spread into Western Canada and the Western US over the next two weeks.
- In the Impacts section I discuss some late season troposphere-stratosphere coupling and some thoughts on summer.

Impacts

Since I am unable to post the blog on Monday May 17 at its normal scheduled time, I posted the blog today, Friday May 14 instead.

I have been fascinated by the relatively cool spring in Europe this year, as I am sure many others, most of whom actually live in Europe. The cool weather across Europe is related to in large part unusually active Greenland blocking. Greenland blocking is a feature more commonly associated with winter weather and what is the source of the Greenland blocking is an interesting question.

In the previous blog the GFS forecasts were suggesting that Greenland blocking was fading, and European temperatures were on the rise. In today's blog that is no longer the case with a return of Greenland blocking predicted. And with more ridging/high pressure predicted in and around Greenland, troughing and seasonably cool weather could be anticipated for large parts of Europe into the foreseeable future.

Another circulation feature more reminiscent of winter than late spring is Ural blocking. And the Ural blocking looks to have an impact on the hemispheric circulation. Ural blocking is predicted to trigger vertically propagating wave energy into the stratosphere. On Twitter I have also been fascinated by the predicted troposphere-stratosphere coupling post the Final Warming. Maybe my fascination is misplaced because even though the winds in the polar stratosphere have reversed from westerly to easterly in the mid to upper stratosphere the winds remain westerly in the lower stratosphere. So even though the Ural blocking is exciting vertical energy that is blocked from reaching the upper stratosphere due to easterly winds, it can still reach the lower stratosphere where the winds remain westerly.

Still as far as I know troposphere-stratosphere coupling is not discussed post a Final Warming and the upcoming event does look to have an impact on the weather. Amplitudes are much more modest in the spring compared to winter, but the NASA model is predicting record poleward heat flux in the lower stratosphere (see **Figure i**) resulting in the zonal winds going from record strong to below normal in a very short period of time (see **Figure i**). So though what seems to be a sudden stratospheric warming or a Final Warming (winds reverse from westerly to easterly) on a more miniature scale and at lower levels, I just wonder could it have an impact on the troposphere including higher pressure over the Arctic especially near Greenland.

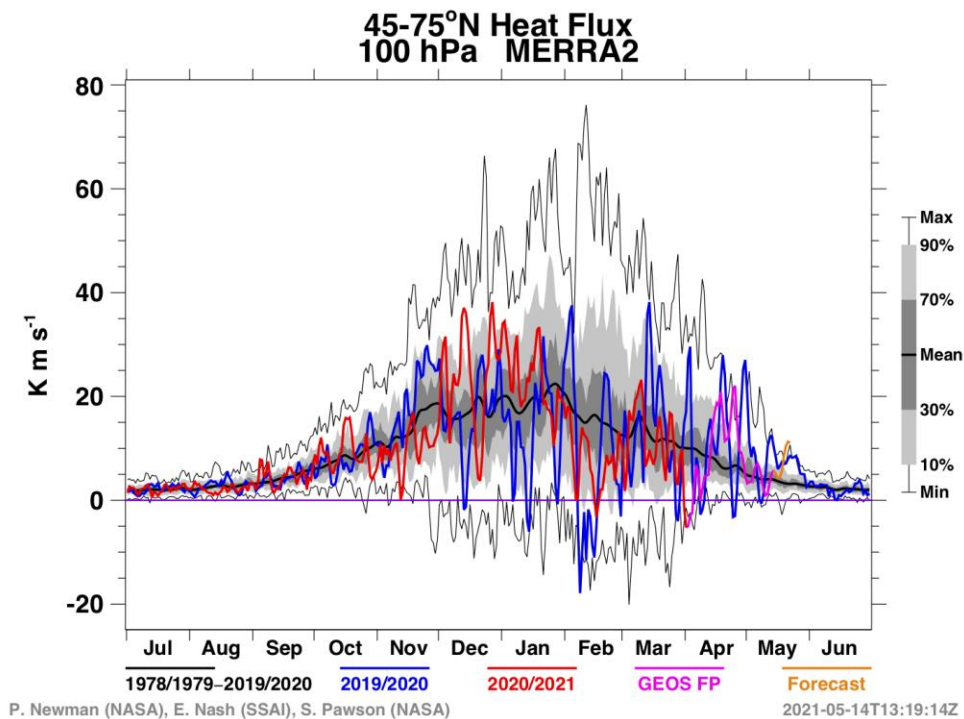


Figure i. Observed and forecasted poleward heat flux at 100 hPa. The forecasts are from 14 May 2021. Plot from: https://acd-ext.gsfc.nasa.gov/Data_services/met/ann_data.html

It seems to me the warming of geopotential heights in the lower stratosphere is related to increasing ridging/high pressure in the Central Arctic in the troposphere the second half of May. But could rising geopotential heights in the lower stratosphere contribute to either amplifying or even persisting the predicted ridging/high pressure across Greenland? I don't know but if yes then the cool spring in Europe could linger into early summer and the trend of European summers heating up could take a pause this year. Greenland blocking can also result in cooler weather in the Eastern US. Unusually strong summer high latitude blocking can bring record temperatures to the Arctic but can also force some cooler and/or wetter downstream.

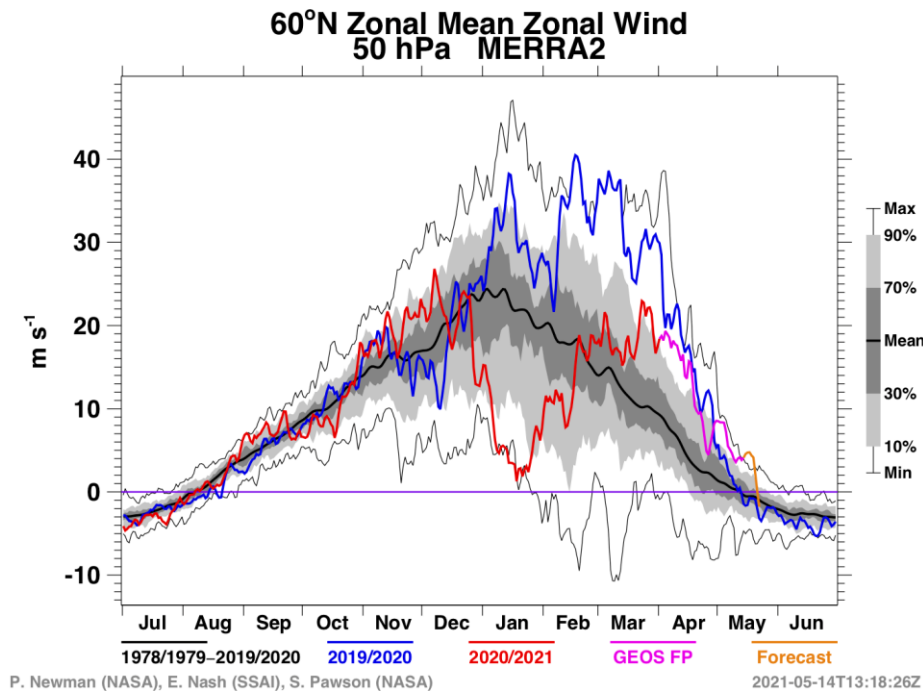


Figure ii. Observed and forecasted zonal-mean zonal wind at 60°N 50 hPa. The forecasts are from 14 May 2021. Plot from: https://acd-ext.gsfc.nasa.gov/Data_services/met/ann_data.html

So even though recent summers have been almost universally relatively warm, I do see risks for at least a regionally cool summer. The latest CFS is suggestive of this as well. The latest June surface temperature forecast is shown in **Figure 13**, and I include

July in **Figure iii**. So, though the CFS is predicting a relatively warm summer for the high latitudes of the Northern Hemisphere including much of Russia and Canada, the CFS is less certain of a warm summer in Europe and the Central and Eastern US.

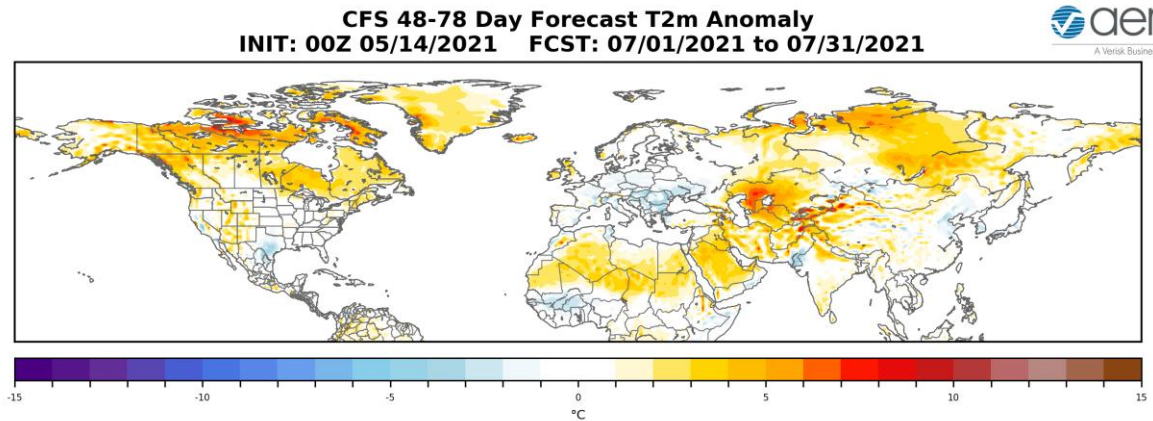


Figure iii. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for July 2021. The forecasts are from the 00Z 14 May 2021 CFS.

1-5 day

The AO is predicted to be neutral this period (**Figure 1**) with mixed geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with mostly positive geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to remain negative this period.

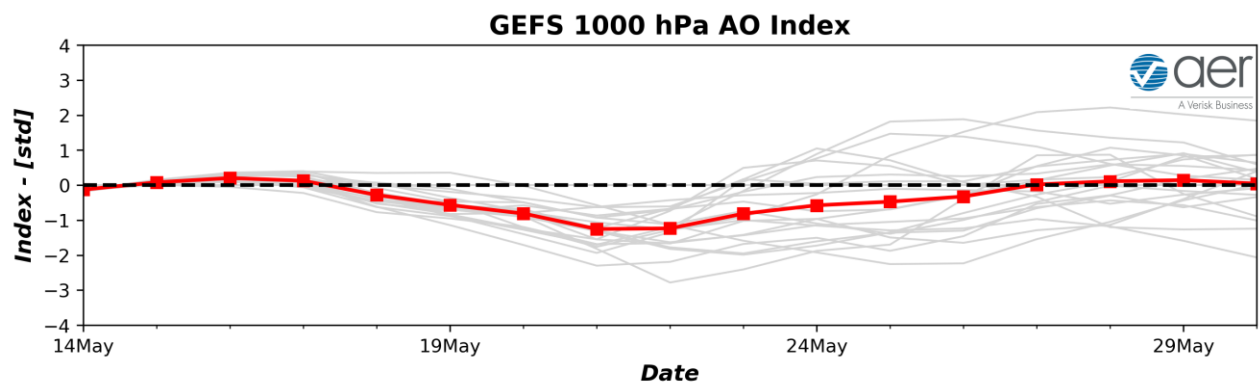


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 14 May 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Ridging/positive geopotential height anomalies across Greenland are predicted to persist troughing/negative geopotential height anomalies across Europe this period (**Figure 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 as geopotential heights remain above normal (**Figure 3**). Western Asia will be dominated by ridging/positive geopotential height anomalies forcing troughing/negative geopotential height anomalies in Central Asia with more ridging/positive geopotential height anomalies in East Asia (**Figure 2**). This is predicted to favor widespread normal to above normal temperatures across Western and Eastern Asia with normal to below normal temperatures across Central Asia especially Western Siberia (**Figure 3**).

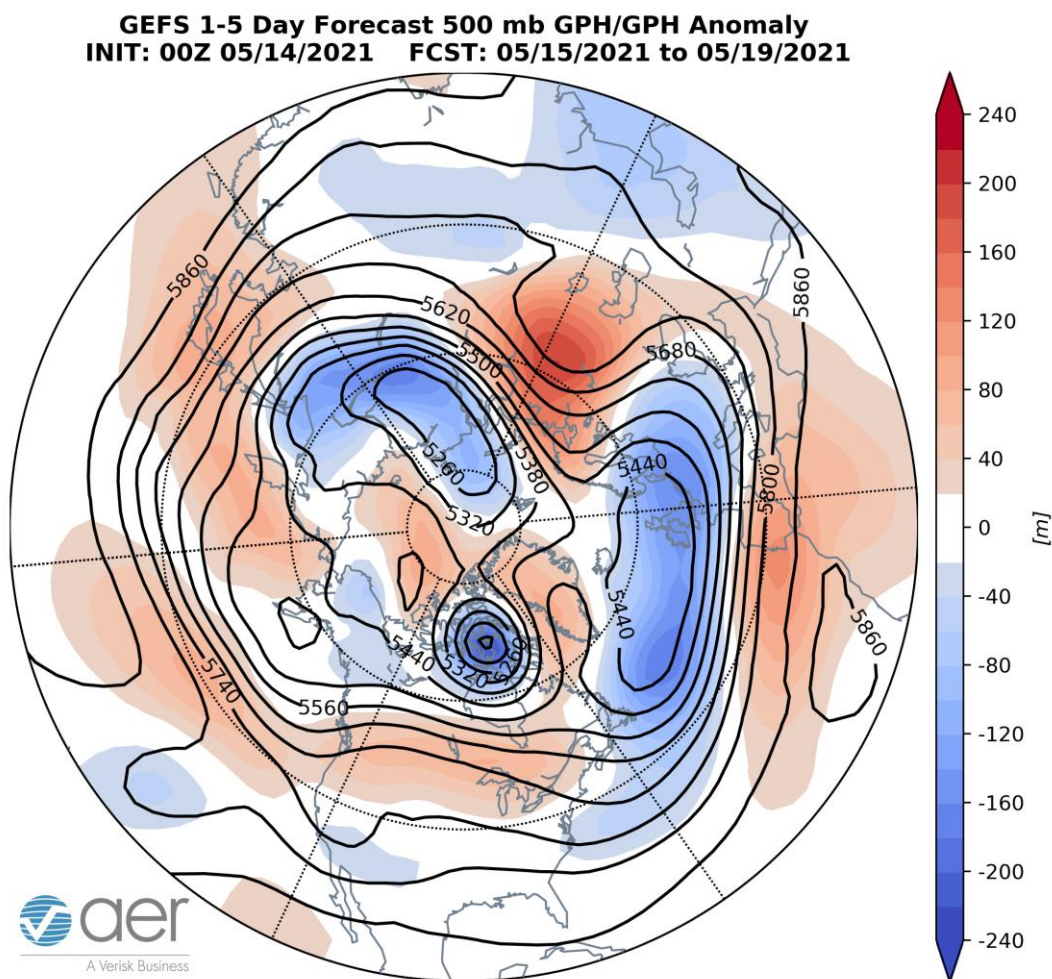


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 15 – 19 May 2021. The forecasts are from the 00z 14 May 2021 GFS ensemble.

The predicted dominant circulation pattern across North America is a mostly zonal flow with ridging/positive geopotential height anomalies focused on the US-Canadian border with troughing/negative geopotential height anomalies over Northern Canada and the Southern US (**Figure 2**). This pattern is predicted to bring normal to above normal temperatures across Alaska, Southern Canada and the Northern US with normal to below normal temperatures across Northern Canada and the Southern US (**Figure 3**).

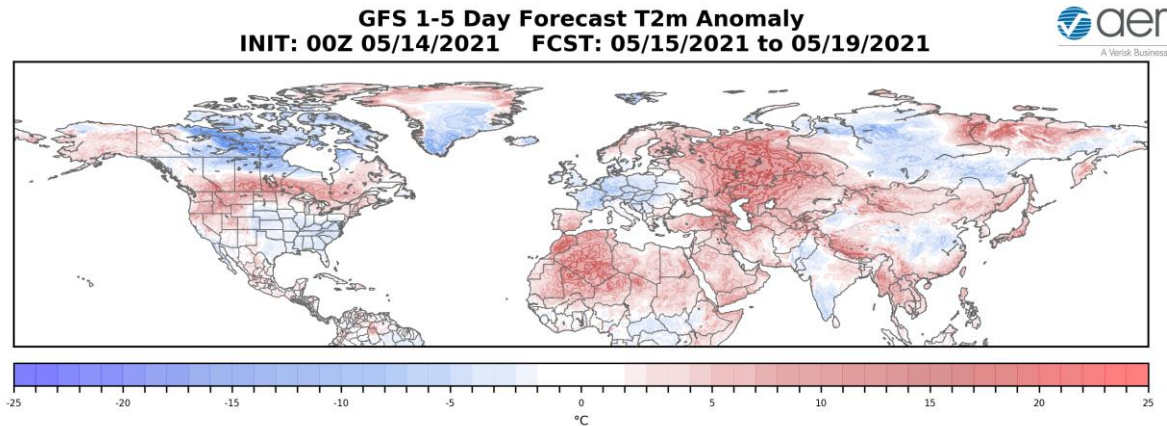


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 15 – 19 May 2021. The forecast is from the 00Z 14 May 2021 GFS ensemble.

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 Central and Eastern US, Northwest Canada and the Canadian Maritimes (**Figure 4**).

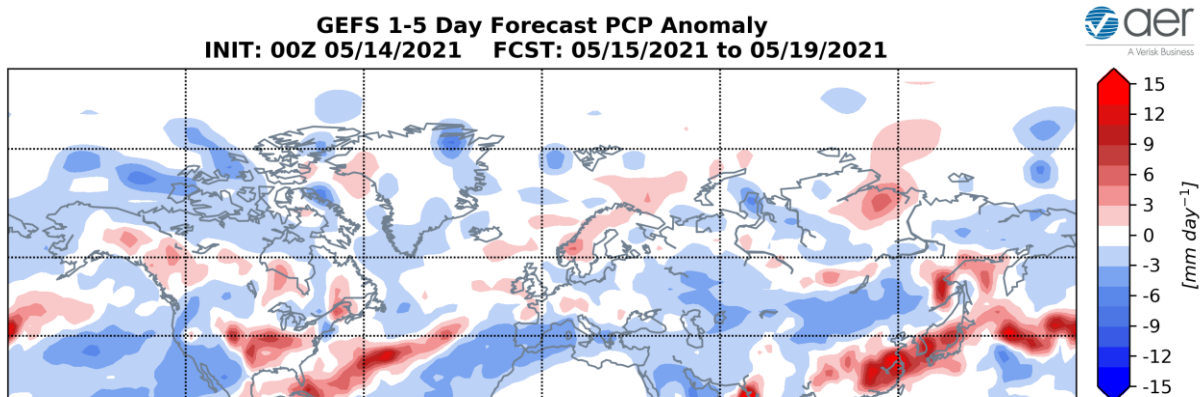


Figure 4. Forecasted precipitation anomalies (mm/day ; shading) from 15 – 19 May 2021. The forecast is from the 00Z 14 May 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to turn more negative this period (**Figure 1**) as positive geopotential height anomalies spread across much of the North Atlantic side of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with positive geopotential height anomalies spread across Greenland (**Figure 5**), the NAO is predicted to remain negative as well.

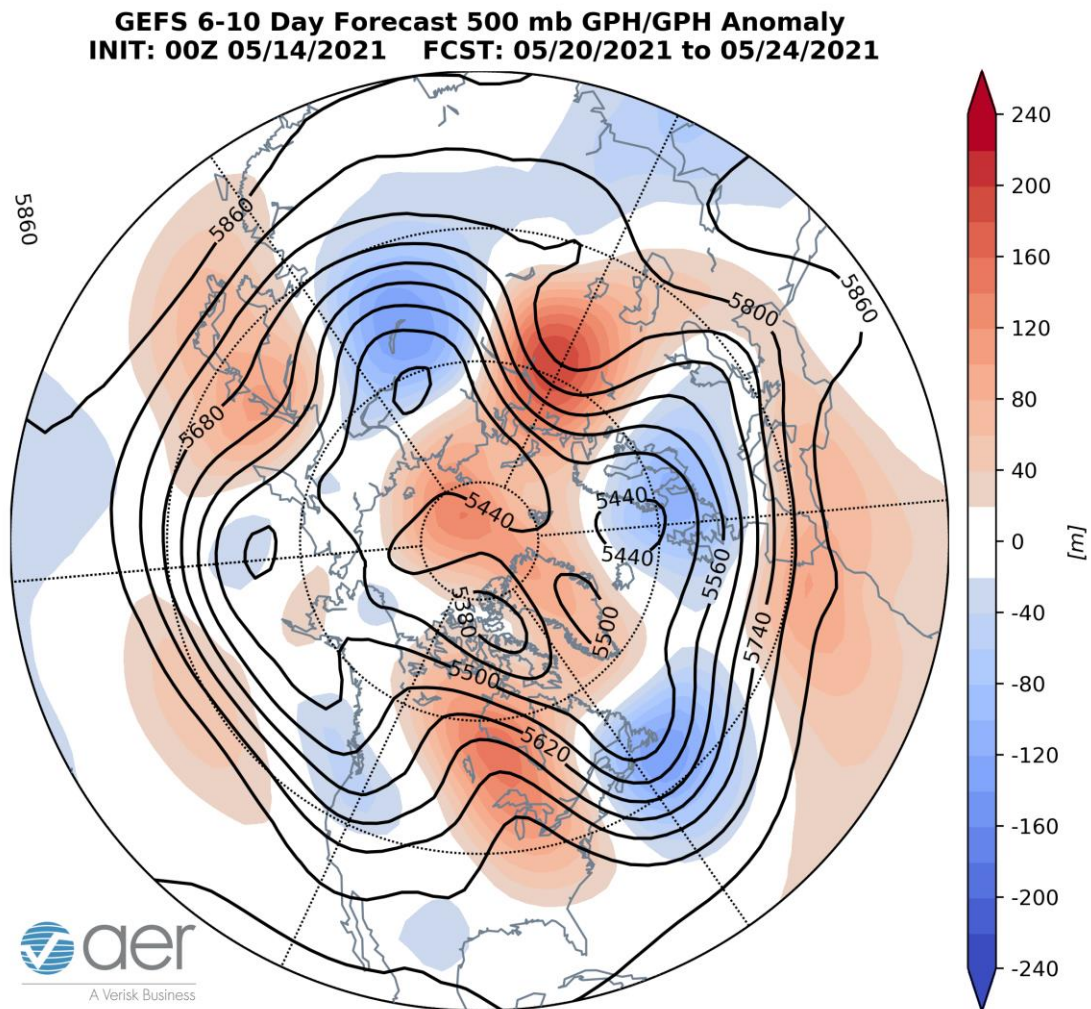


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 20 – 24 May 2021. The forecasts are from the 00z 14 May 2021 GFS ensemble.

Ridging/positive geopotential height anomalies across Greenland are predicted to strengthen this period favoring ongoing troughing/negative geopotential height anomalies across Northern and Central Europe while ridging/positive geopotential height anomalies will persist across Southern Europe (**Figures 5**). This will favor normal

to below normal temperatures across much of Northern and Central Europe including the UK with normal to above normal temperatures confined to far Southern Europe (**Figure 6**). Ridging/positive geopotential height anomalies will persist across Western Asia, with troughing/negative geopotential height anomalies in Central Asia with more ridging/positive geopotential height anomalies in East Asia (**Figure 5**). This pattern favors widespread normal to above normal temperatures across Western and Eastern Asia with normal to below normal temperatures limited to Central Asia (**Figure 6**).

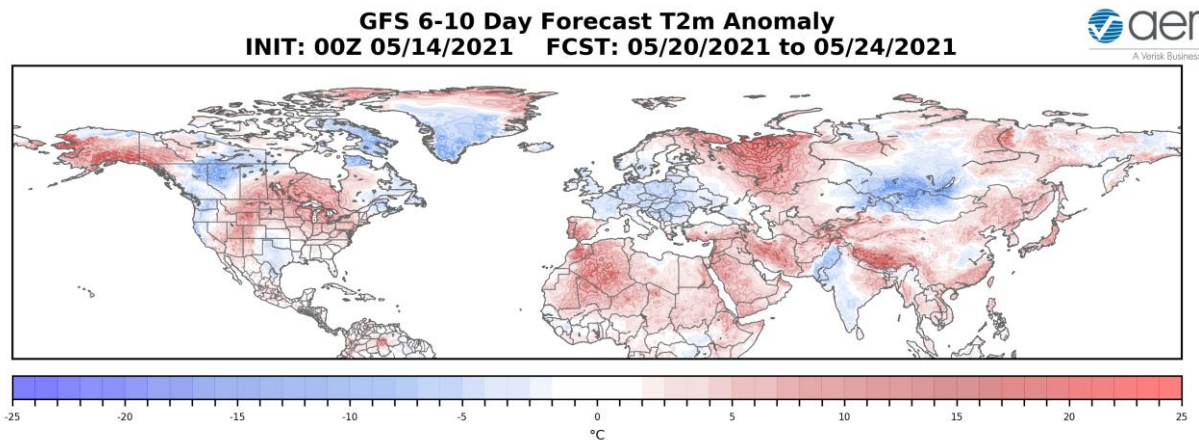


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 20 – 24 May 2021. The forecasts are from the 00Z 14 May 2021 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to become more amplified in Central Canada and the Eastern US with troughing/negative geopotential height anomalies on either side of the ridging in Western Canada, the Western US and the Canadian Maritimes this period (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across Alaska, Central and Eastern Canada and much of the US from the Rockies eastward with normal to below normal temperatures across Western Canada, the US West Coast, the Gulf of Mexico states and the Canadian Maritimes (**Figure 6**).

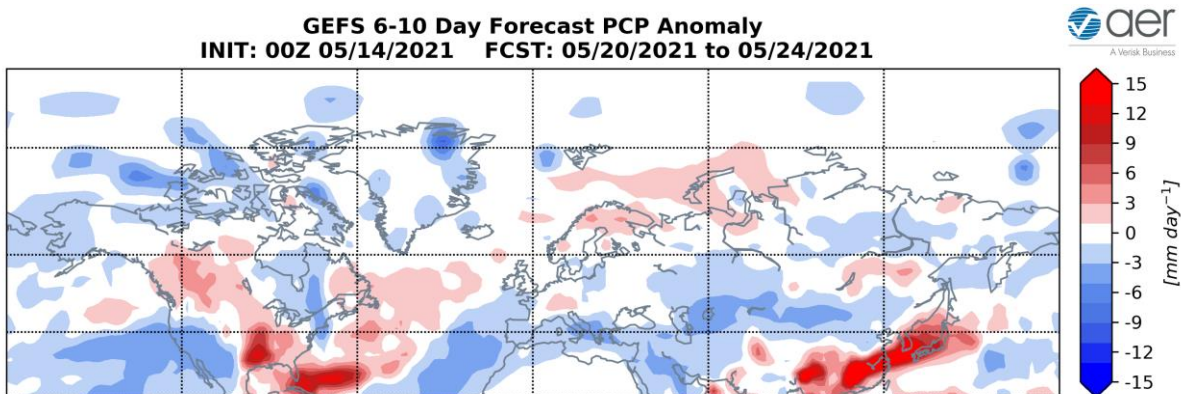


Figure 7. Forecasted precipitation anomalies (mm/day; shading) from 20 – 24 May 2021. The forecasts are from the 00Z 14 May 2021 GFS ensemble.

Normal to below normal precipitation are predicted for Eurasia with the exceptions of above normal precipitation in Northern and Central Europe and East Asia (**Figure 7**). Normal to below normal precipitation are predicted for Alaska, the Western US, Eastern Canada and New England with normal to above normal precipitation in Western Canada, the Eastern US, especially the Southern Plains and the Canadian Maritimes (**Figure 7**).

11-15 day

With predicted mostly negative 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 neutral to negative this period (**Figure 1**). With mostly negative pressure/geopotential height anomalies persisting across Greenland (**Figure 8**), the NAO is predicted to remain neutral to negative this period as well.

GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 05/14/2021 FCST: 05/25/2021 to 05/29/2021

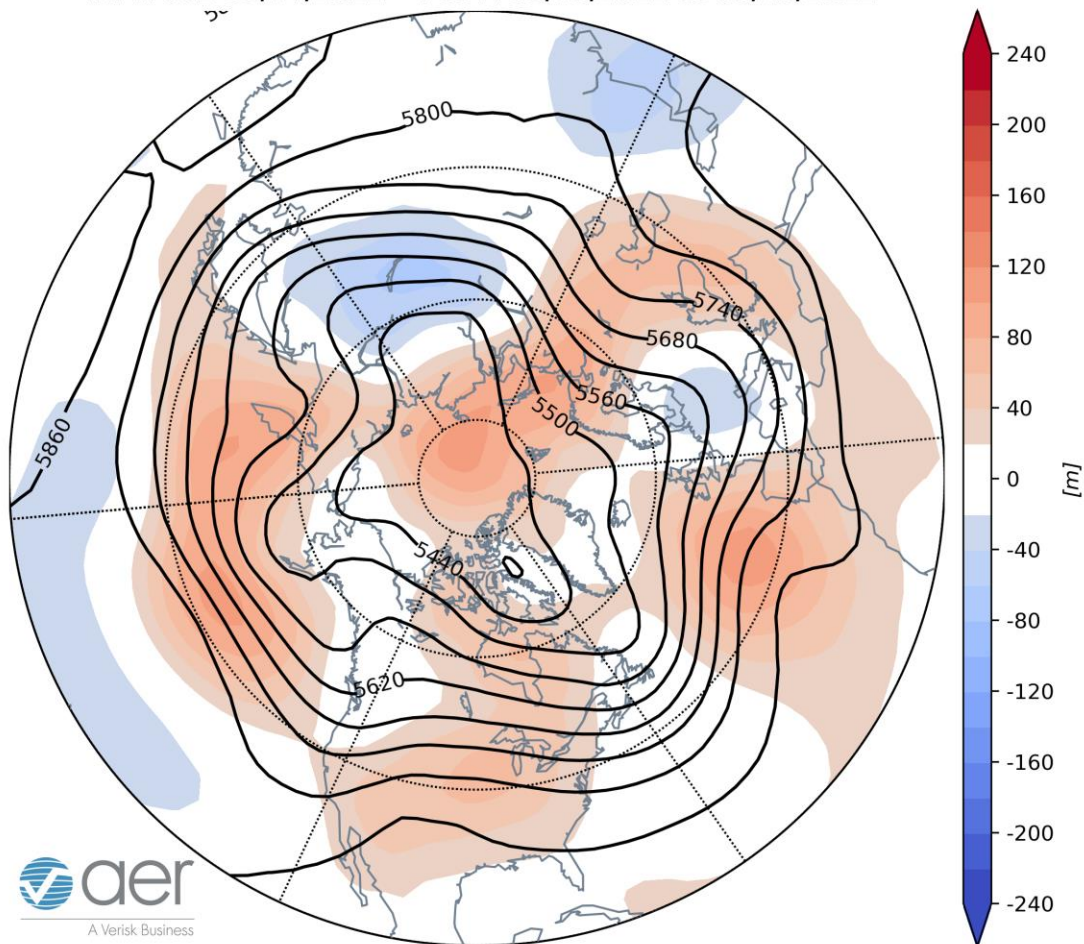


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 25 – 29 May 2021. The forecasts are from the 00z 14 May 2021 GFS ensemble.

Ridging/positive geopotential height anomalies previously near Spain and the Azores will push north into the UK this period persisting troughing/negative geopotential height anomalies in Central and Eastern Europe (**Figure 8**). This pattern favors normal to above normal temperatures across much of Western Europe with normal to below normal temperatures across Central and Eastern Europe (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to persist in Western Asia forcing troughing/negative geopotential height anomalies in Central Asia that extends into East Asia with ridging/positive geopotential height anomalies persisting in Eastern Siberia this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across much of Western Asia and much of Siberia with normal to below normal temperatures across Central and East Asia (**Figure 9**).

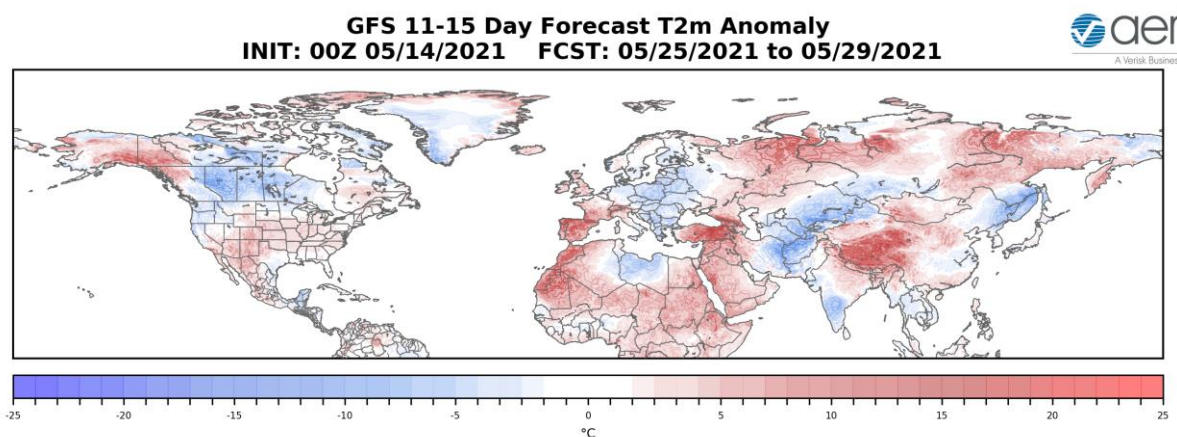


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 25 – 29 May 2021. The forecasts are from the 00z 14 May 2021 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to continue expanding across much of North America with troughing/negative geopotential height anomalies mostly confined to Western Canada and the Western US this period (**Figure 8**). This pattern favors normal to above normal temperatures for Alaska, Eastern Canada and much of the US with normal to below normal temperatures across Western Canada and the US West Coast (**Figure 9**).

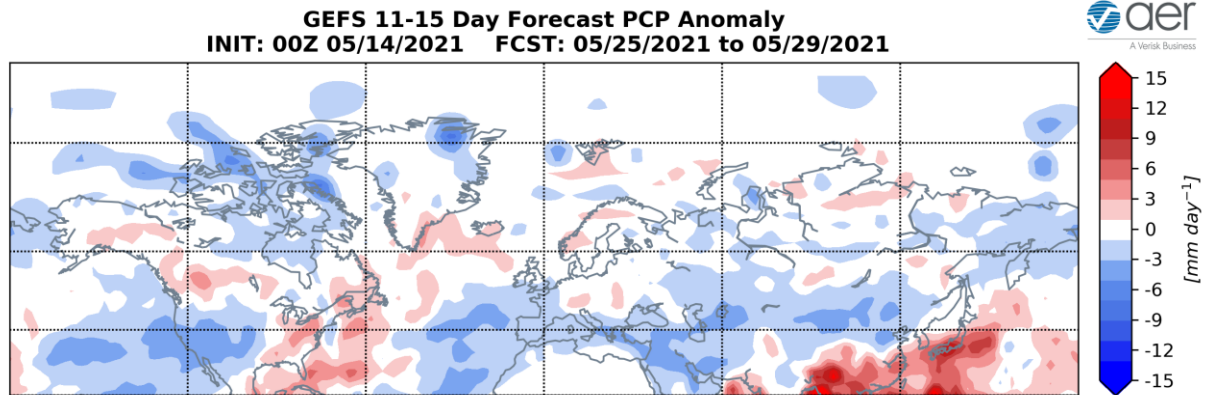


Figure 10. Forecasted precipitation anomalies (mm/day; shading) from 25 – 29 May 2021. The forecasts are from the 00z 14 May 2021 GFS ensemble.

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 with the exception of normal to above normal precipitation in 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, starting late next week PCHs are predicted to warm with normal to warm/positive throughout the troposphere and even the stratosphere (**Figure 11**). As I have been tweeting out this week, the warming of the polar stratosphere is fascinating to me. The Final Warming (where the polar vortex disappears until the fall) took place at the end of April. As far as I know we don't consider troposphere coupling post the Final Warming, yet it seems obvious to me upwelling energy from the troposphere is warming the polar stratosphere. And this seems to also be impacting the weather across the Northern Hemisphere.

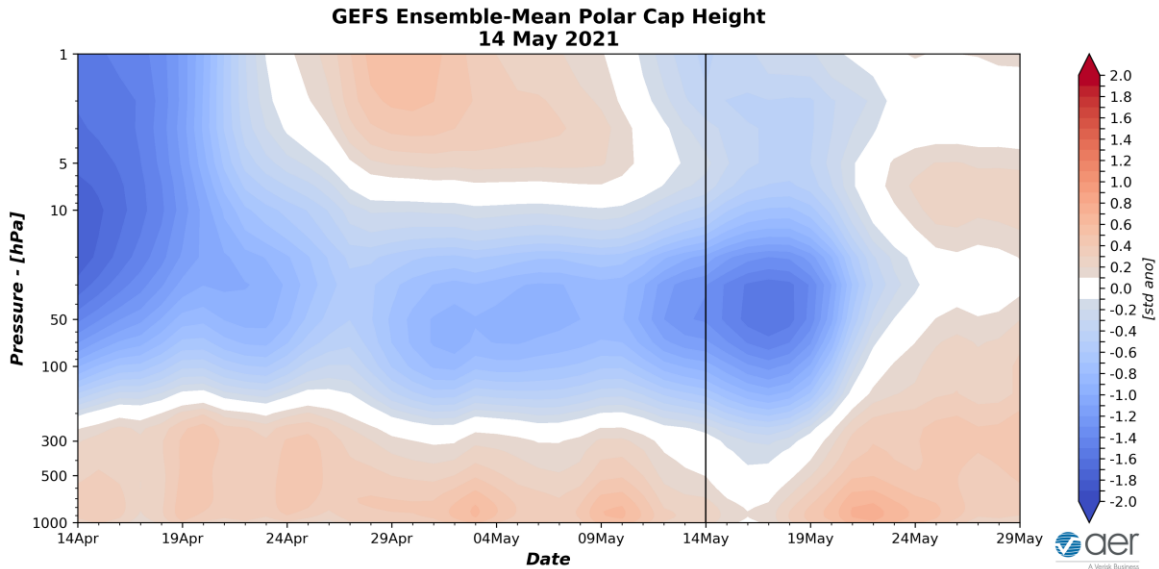


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 14 May 2021 GFS ensemble.

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

**CFS 500 hPa Forecast Anomaly Jun 2021
Valid as of 14 May 2021**

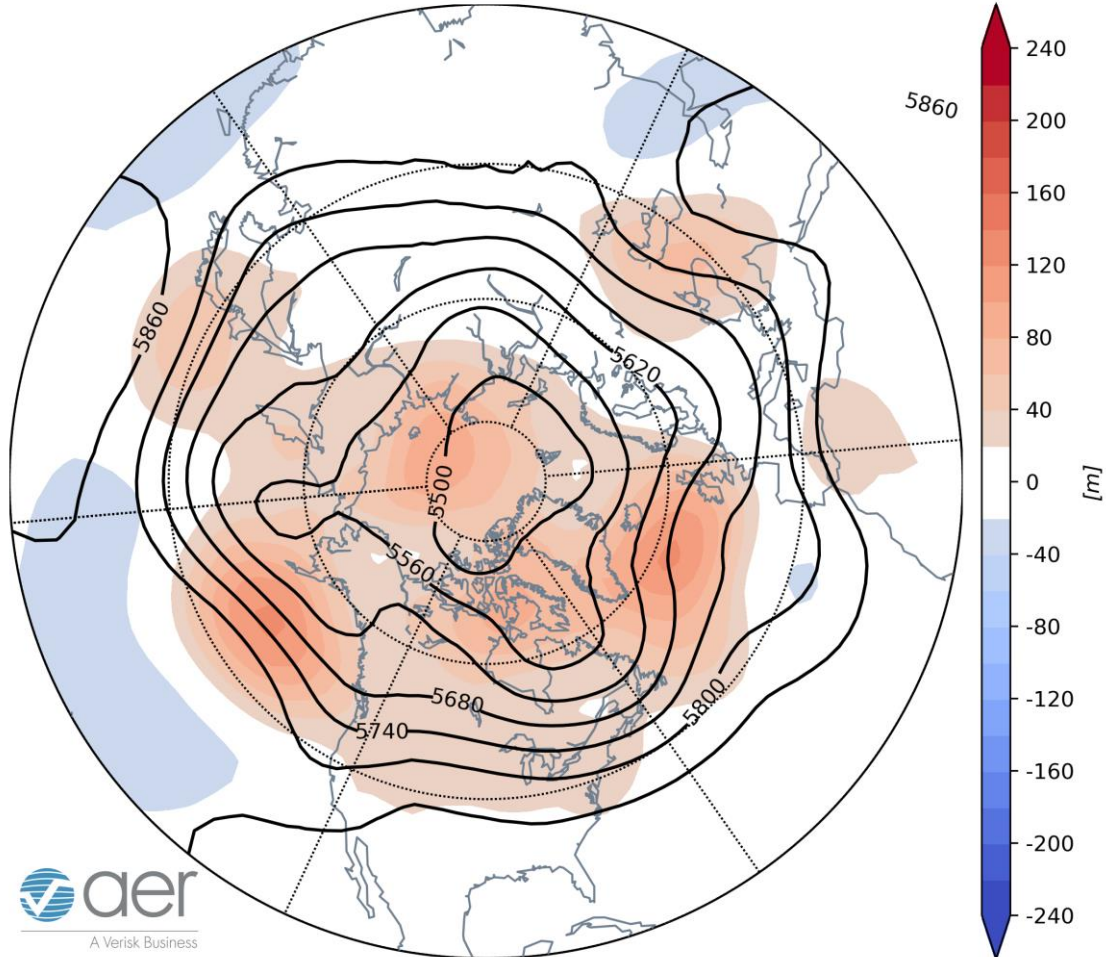


Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for June 2021. The forecasts are from the 00Z 14 May 2021 CFS.

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 in the northern North Atlantic centered between Iceland and the UK, the Middle East, south of the Aleutians and near Baffin Bay with troughing in Europe, East Asia, the US West Coast and Eastern Canada (**Figure 12**). This pattern favors seasonable to relatively cool temperatures for Europe and into Western Asia, East Asia and the Central US with seasonable to relatively warm temperatures for far Northern Europe, the Middle East, Central Asia, Siberia, Alaska, much of Northern and Western Canada, the Canadian Maritimes and the Western US (**Figure 13**).

CFS 18-47 Day Forecast T2m Anomaly
INIT: 00Z 05/14/2021 FCST: 06/01/2021 to 06/30/2021

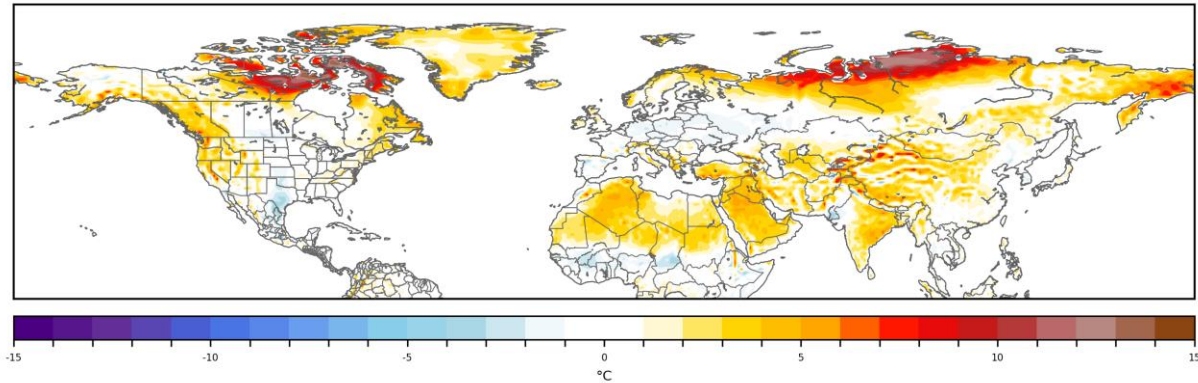


Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for June 2021. The forecasts are from the 00Z 14 May 2021 CFS.

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 and into the summer. 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.

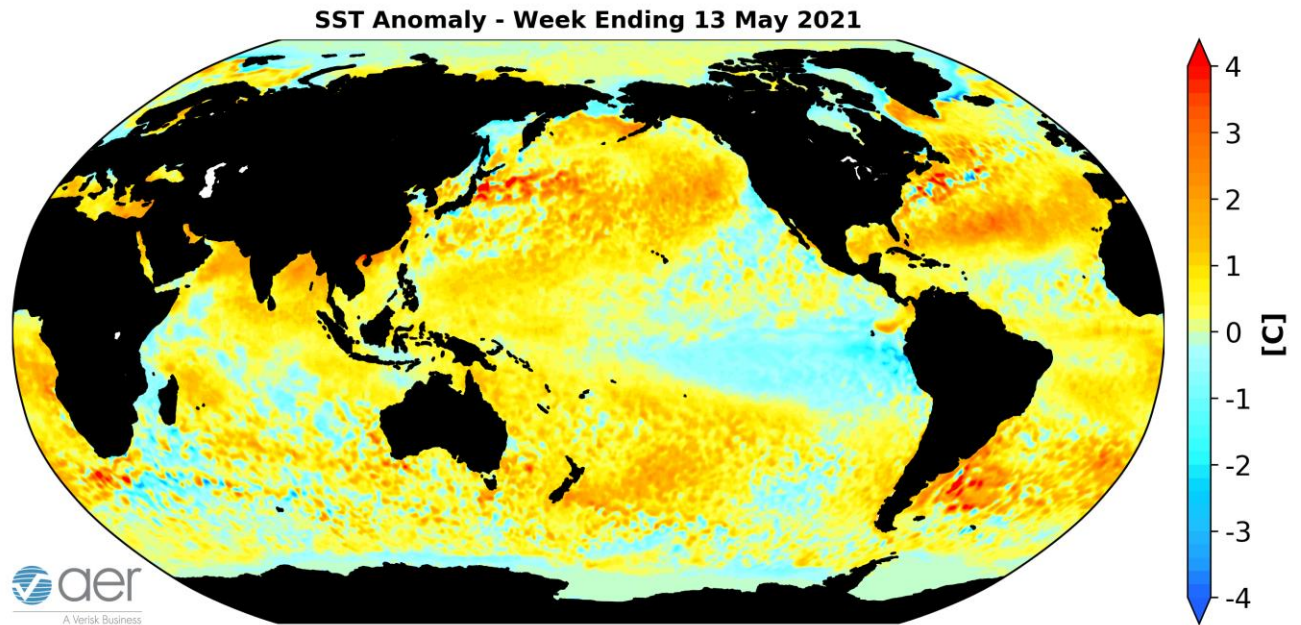


Figure 14. The latest weekly-mean global SST anomalies (ending 13 May 2021). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is weakly in phase two (**Figure 15**). The forecasts are for the MJO to transition to overall remain weak where no phase is really favored. MJO phase two overall favors ridging across eastern North America with troughing across western North America. Therefore it does appear 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.

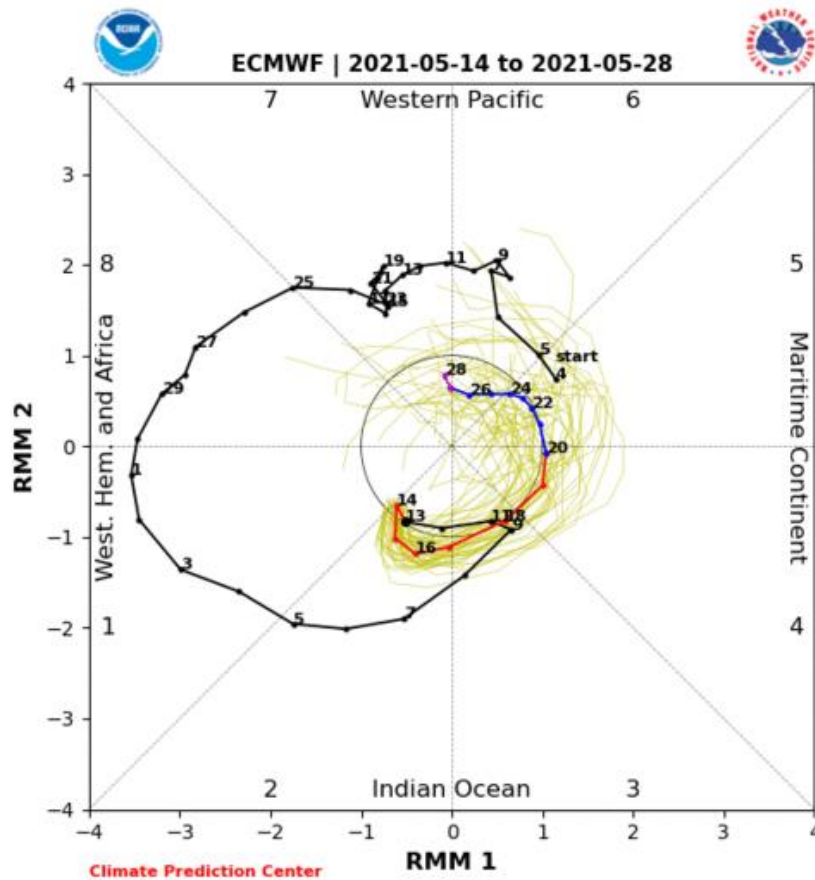


Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 14 May 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>