

Arctic Oscillation and Polar Vortex Analysis and Forecasts

May 23, 2022

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 and turn negative over the weekend through early June as mostly negative pressure/geopotential height anomalies across the Arctic including the North Atlantic side of the Arctic transition to mostly positive with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently positive and is predicted to trend negative as pressure/geopotential height anomalies are predicted to become increasingly positive across Greenland over the next two weeks.
- Troughing/negative geopotential height anomalies across Greenland will support ridging/positive geopotential height anomalies across Southern Europe and strong zonal flow this week but then transition to troughing/negative geopotential height anomalies covering much of Europe next week. This pattern favors widespread normal to above normal temperatures across much of Europe including the United Kingdom (UK) this week with normal to below normal temperatures widespread across Europe including the UK next week.

- The general pattern across Asia the next two weeks is an omega block pattern with troughing/negative geopotential height anomalies across West and East Asia bookending ridging/positive geopotential height anomalies centered across Central Asia. This pattern favors widespread normal to above normal temperatures across much of Asia, especially Central Asia with normal to below normal temperatures focused across Western Asia this week but across Eastern Asia next week.
- The general pattern this week across North America is ridging/positive geopotential height anomalies centered near the Dateline forcing widespread troughing/negative in the interior of North America with ridging/positive geopotential height anomalies along both coasts of the United States (US). However, next week the ridging/positive geopotential height anomalies near the Dateline will retrograde westward favoring troughing/negative geopotential height anomalies across Western Canada and the Western US with ridging/positive geopotential height anomalies across the Eastern US and Southeastern Canada. The pattern favors this week normal to below normal temperatures across much of Canada and the US with normal to above normal temperatures across Alaska, and the US West and East Coasts. Then next week normal to above normal temperatures will become widespread across Alaska, Northern and Eastern Canada and the Central and Eastern US with normal to below normal temperatures limited to southwestern Canada and the Western US.
- In the *Impacts* section I discuss how the transitioning to a summer pattern and the emergence of troughing/low pressure in the Central Arctic but ridging/high pressure and relatively warm temperatures across the continents.

Plain Language Summary

Today's weather forecasts are consistent with my expectations for the summer pattern across the Northern Hemisphere. This includes low pressure with relatively seasonable to cool temperatures in the Central Arctic surrounded by a "ring of fire" across the northern continents. I hope to post the official AER summer forecast at the end of the month.

Impacts

I have returned from my two weeks of traveling and besides learning about recent discoveries about Arctic change I got to experience a large variety of weather. It was summery with warm and dry conditions in Germany, fall and winter with heavy snow in Aspen, Colorado and full-on mid-summer heat with severe storms nearby when I returned to Boston yesterday. What I experienced this weekend can best be described as "weather whiplash," which was pretty extreme (Denver alone went from near 90°F to 31°F and snow in just one day). It does seem that the weather pattern has been unusually amplified this month, but I will stop about drawing more longer-term conclusions about the weather and climate from my two-week experience.

I think the circulation pattern across the Northern Hemisphere (NH) has settled into a summer pattern. Last week I tongue-in-cheek tweeted about predicted stratosphere-troposphere coupling between a strong polar vortex and a positive surface AO, which can clearly be seen in today's polar cap geopotential height anomalies (PCHs) forecast (**Figure 11**). This is thought of as a purely winter phenomenon and it is a puzzle to explain it a full month and a half after the polar vortex has gone on its summer hiatus. I probably raise this question every spring or early summer but still do not have an answer. But the forecast is for the PCHs in the troposphere to transition from cold/negative to warm/positive at the end of the week (**Figure 11**) and I expect warm/positive to be the dominant phase of tropospheric PCHs this summer as disappearing snow cover and maybe to a lesser degree sea ice support a warmer than normal atmospheric column in the high latitudes.

The warm/positive tropospheric PCHs will likely not be forced by high pressure and ridging centered near the North Pole as is typical of winter but rather along the periphery of the Arctic along the northern boundaries of the continents. In the mid troposphere this will be characterized by low heights/pressures in the Central Arctic ringed by high heights/pressures across the continents at mid- to high-latitudes (e.g. **Figures 8** and **12**). This pattern will likely be the dominant pattern for the summer. The current surface boundary anomalies in the high latitudes seem to be conducive to this pattern. Despite the historic snow in Colorado, snow cover extent across the NH is well below normal especially in Siberia (see **Figure i**). In contrast, Arctic sea ice is on the high end of the envelop of recent years with ice extent near normal across the Arctic Ocean (see **Figure ii**). This anomaly pattern of boundary conditions in the high latitudes should help support low pressure/heights centered near the North Pole ringed by high pressure/heights across the northern continents and the circulation pattern would in turn reinforce the surface anomalies; the predicted circulation is conducive to slowing the melt of Arctic Ocean sea ice but hasten the demise of continental snow cover and could also favor heat domes over the continents supporting heat waves and wildfires. Since 2012 I have been waiting for a new record sea ice extent minimum, but the odds don't look good for 2022 as we stand at the precipice of summer. But it is certainly possible, especially, as I learned this week, if strong Arctic cyclones develop later this summer.

Daily SCE Departure - May 22, 2022 (Day 142)

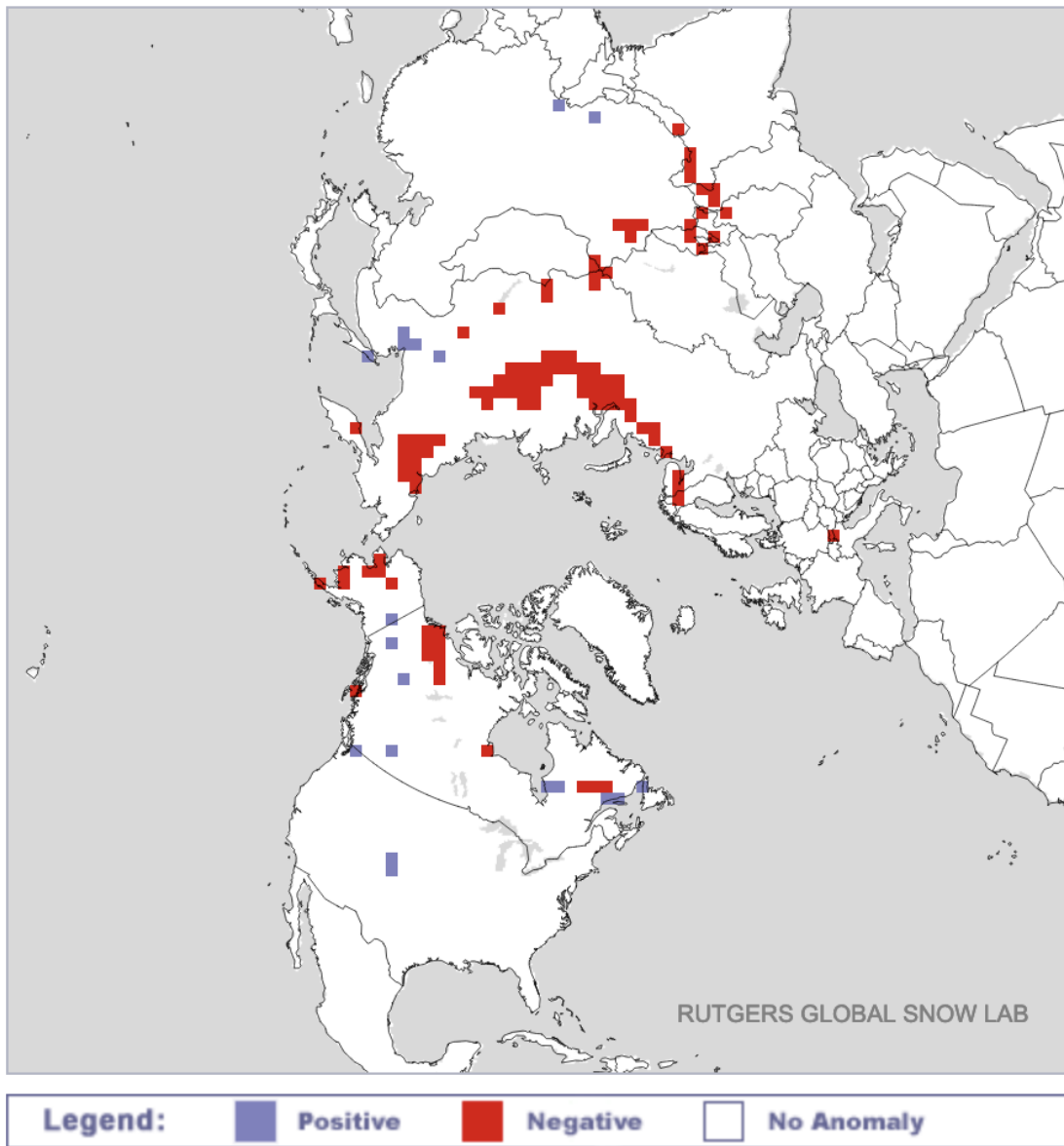


Figure i. Observed Northern Hemisphere snow cover extent anomalies from 22 May 2022 from <http://climate.rutgers.edu/snowcover/index.php>

It has been an overall warm May in Siberia and I expect that to continue with high pressure/ridging being the dominant weather feature of the summer across much of Siberia. Another consistent feature of recent summers has been low pressure/troughing in Western Asia. In the coming two weeks this feature is predicted but shifted west of its typical location encompassing Eastern Europe as well. We will have to see if this trough slides east with time or bucks the trend of recent summers and sets up far enough west to bring a cooler summer to Eastern Europe relative to recent

summers. Another region to watch is western North America, which has been dominated by troughing this month. I fully expect a heat dome over North America, but it could be shifted east relative to recent summers, bringing warm temperatures to central North America and possibly cooler temperatures to both coasts relative to recent summers. The trend as a predictor for summer temperatures has worked well recently so I say don't bet against it but certainly something to watch. I do hope to post the AER summer temperature forecast for the NH by month's end along with the dynamical model forecasts from the leading government forecast centers.

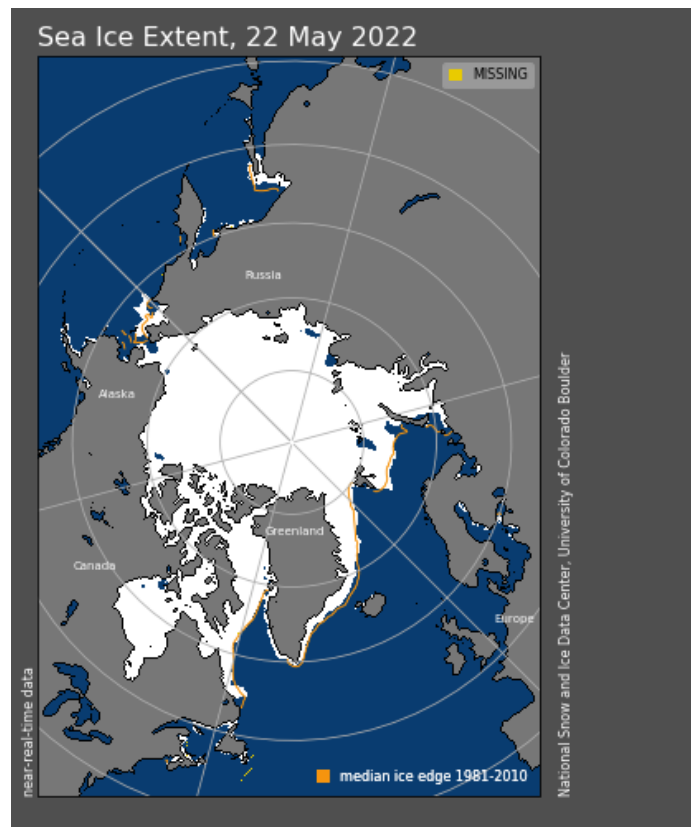


Figure ii. Observed Arctic Sea ice extent on 22 May 2022 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC).

1-5 day

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

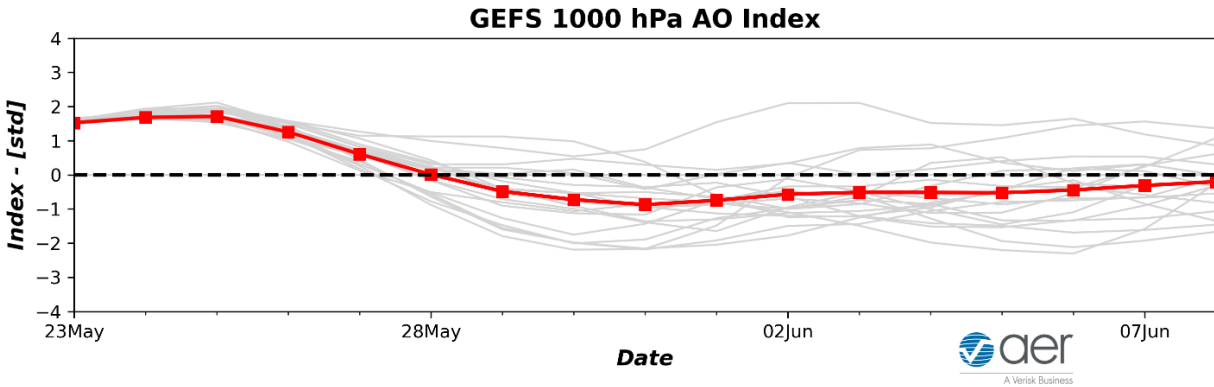


Figure 1. The predicted daily-mean AO at 1000 hPa from the 00Z 23 May 2022 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Trouching/negative geopotential height anomalies across Greenland will support ridging/positive geopotential height anomalies across Southern Europe with trouching/negative geopotential height anomalies across Northern Europe (**Figures 2**). This resultant zonal flow will favor widespread normal to above normal temperatures across most of Europe including the UK with normal to below normal temperatures mostly limited to far Eastern Europe (**Figure 3**). Trouching/negative geopotential height anomalies is predicted across Western and Eastern Asia with ridging/positive geopotential height anomalies across Central Asia this period (**Figure 2**). This pattern favors normal to below normal temperatures across Western and Eastern Asia with normal to above normal temperatures across Central and much of Southern Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 05/23/2022 FCST: 05/24/2022 to 05/28/2022

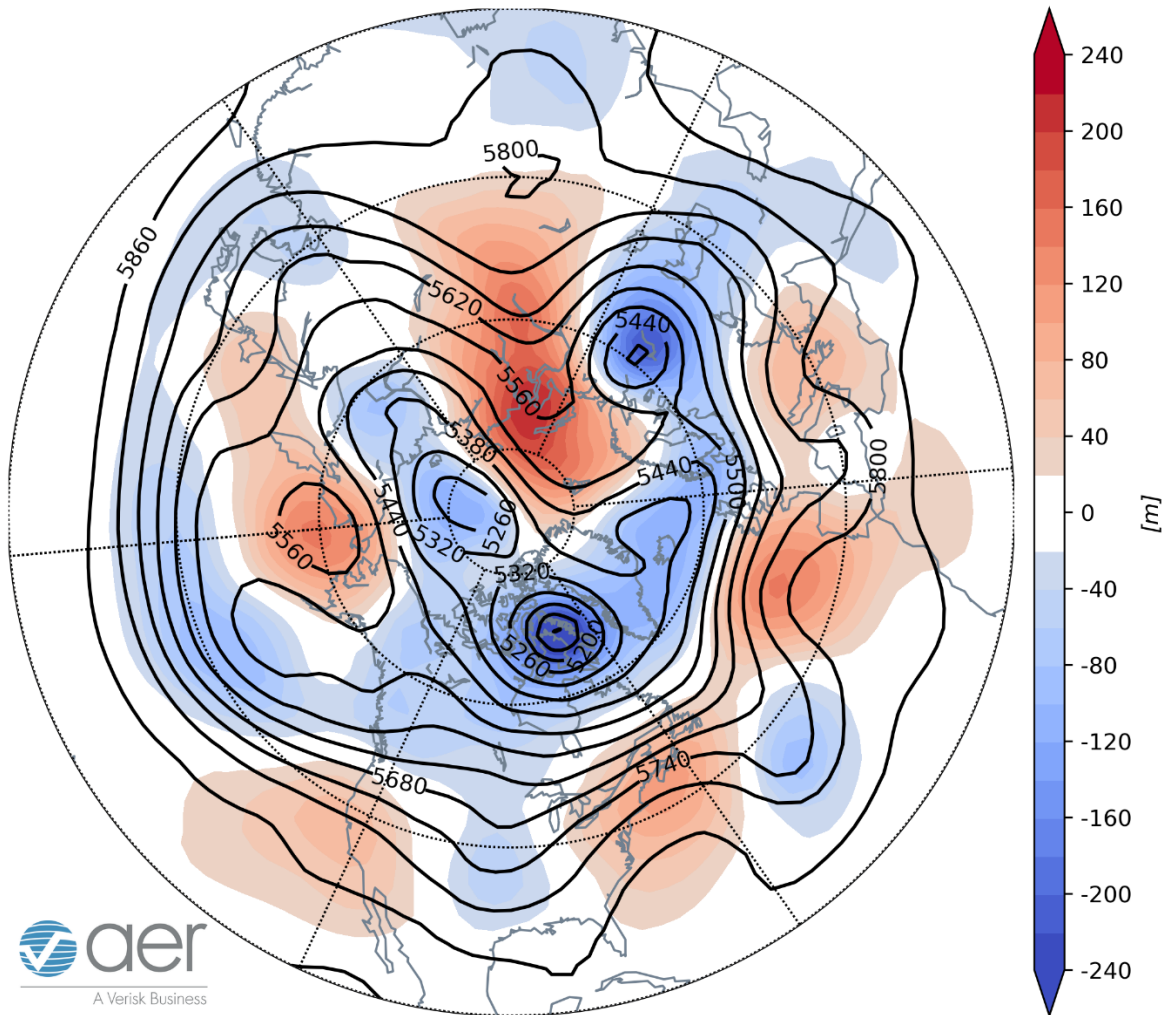


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 24 – 28 May 2022. The forecasts are from the 00z 23 May 2022 GFS ensemble.

Ridging/positive geopotential height anomalies centered near the Dateline will force troughing/negative geopotential height anomalies across the interior of North America with ridging/positive geopotential height anomalies along both coasts of the US (**Figure 2**). The pattern will favor normal to below normal temperatures across much of Canada and the Central US normal to above normal temperatures across Alaska, Southeastern Canada and the Western and Eastern US (**Figure 3**).

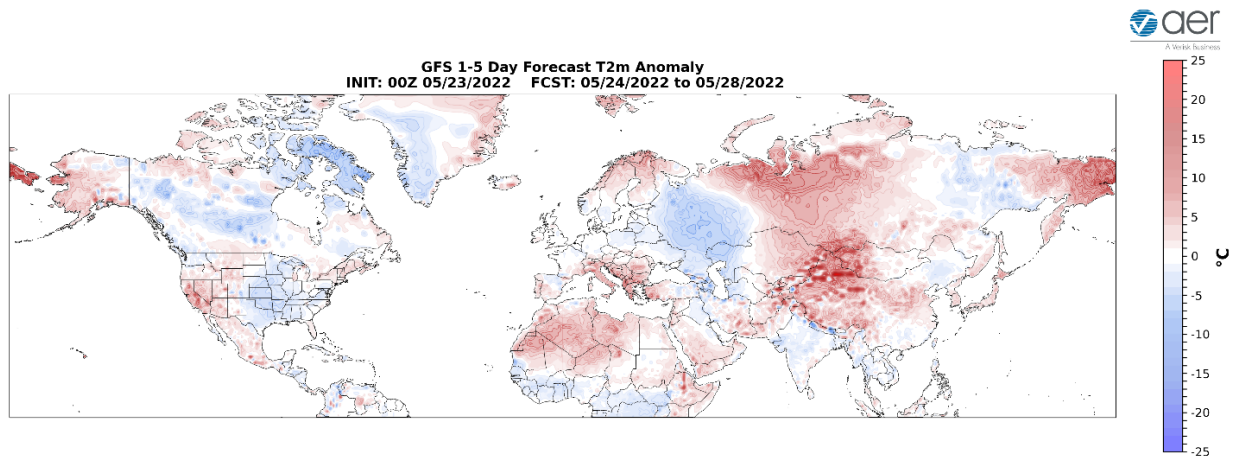


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 24 – 28 May 2022. The forecast is from the 00Z 23 May 2022 GFS ensemble.

Mostly below normal precipitation is predicted across Eurasia with above normal precipitation predicted for parts of Central Europe and Southeast Asia (**Figure 4**). Mostly below normal precipitation is predicted across North America with above normal precipitation predicted for Western and Southeastern Canada and the Southeastern US (**Figure 4**).

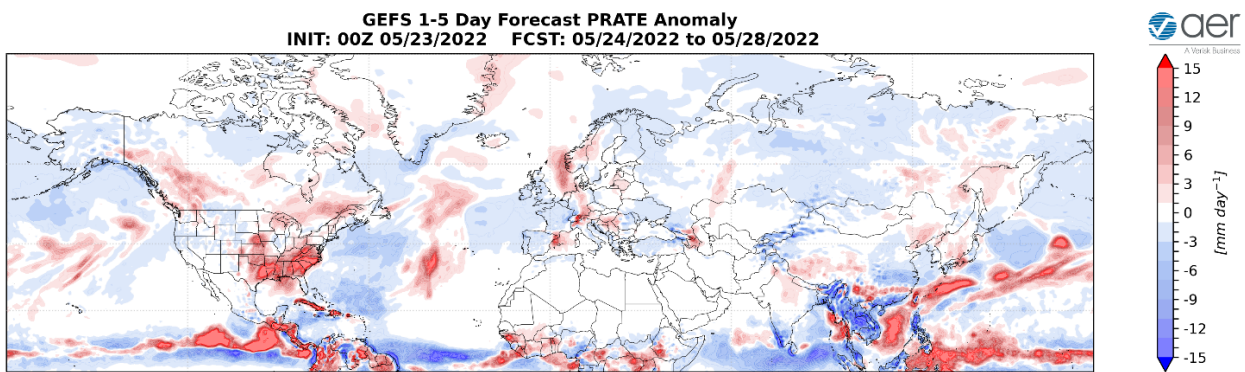


Figure 4. Forecasted precipitation rate (mm/day; shading) from 24 – 28 May 2022. The forecast is from the 00Z 23 May 2022 GEPS ensemble.

Mid-Term

6-10 day

The AO is predicted to reverse to negative this period (**Figure 1**) as geopotential height anomalies turn mostly positive across the Arctic, especially the North Atlantic side of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And as geopotential height anomalies also reverse to positive across

Greenland and Iceland (**Figure 5**), the NAO is predicted to turn negative this period as well.

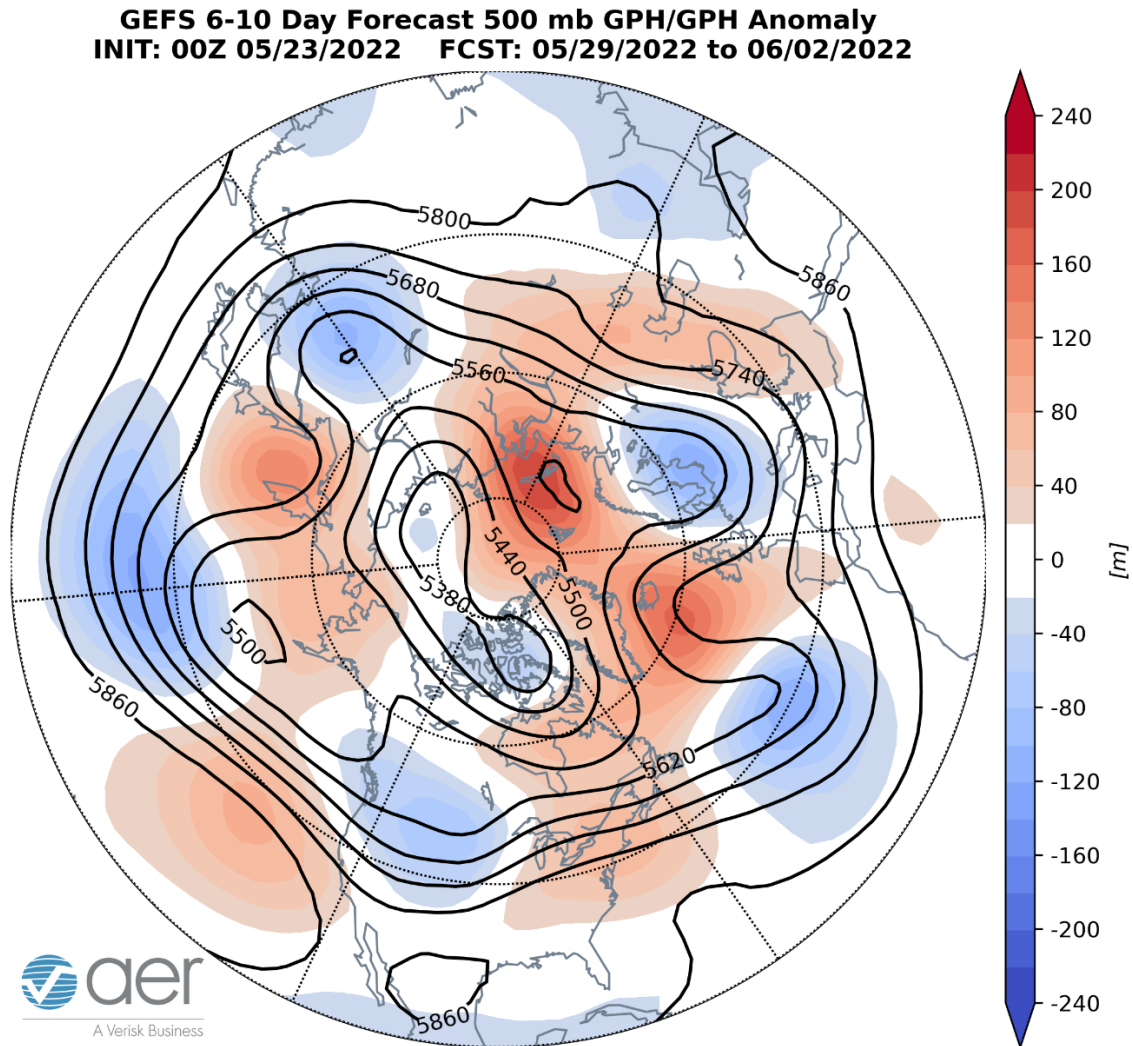


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 29 May – 2 June 2022. The forecasts are from the 00z 23 May 2022 GFS ensemble.

Predicted ridging/positive geopotential height anomalies centered near Iceland will force troughing/negative geopotential height anomalies centered across Central Europe with more ridging/positive geopotential height anomalies across Southeastern Europe this period (**Figures 5**). This will result in normal to below normal temperatures across much of Europe including the UK with normal to above normal temperatures across northern Scandinavia and Southern Europe (**Figure 6**). The omega block pattern across Asia is predicted to persist with troughing/negative geopotential height anomalies across Western and Eastern Asia sandwiching ridging/positive geopotential height anomalies across Central Asia this period (**Figure 5**). This pattern favors normal

to below normal temperatures across much of Northwestern and Northeastern Asia with normal to above normal temperatures across Siberia and Central and Southern Asia (**Figure 6**).

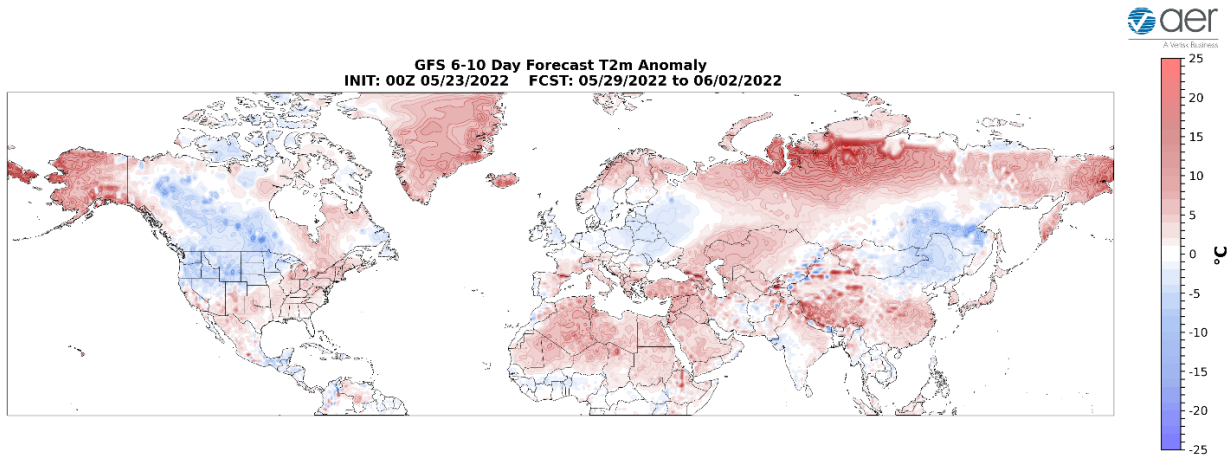


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 29 May – 2 June 2022. The forecasts are from the 00Z 23 May 2022 GFS ensemble.

With the ridging/positive geopotential height anomalies previously centered near the Dateline predicted to retrograde towards Eastern Siberia, previous troughing/negative geopotential height anomalies in central North America will get pulled into western North America with ridging/positive geopotential height anomalies becoming more widespread across Eastern Canada and the Eastern US (**Figure 5**). This will favor normal to below normal temperatures across Western Canada and the Northwestern US with normal to above normal temperatures across Eastern Canada and the Southern and Eastern US (**Figure 6**).

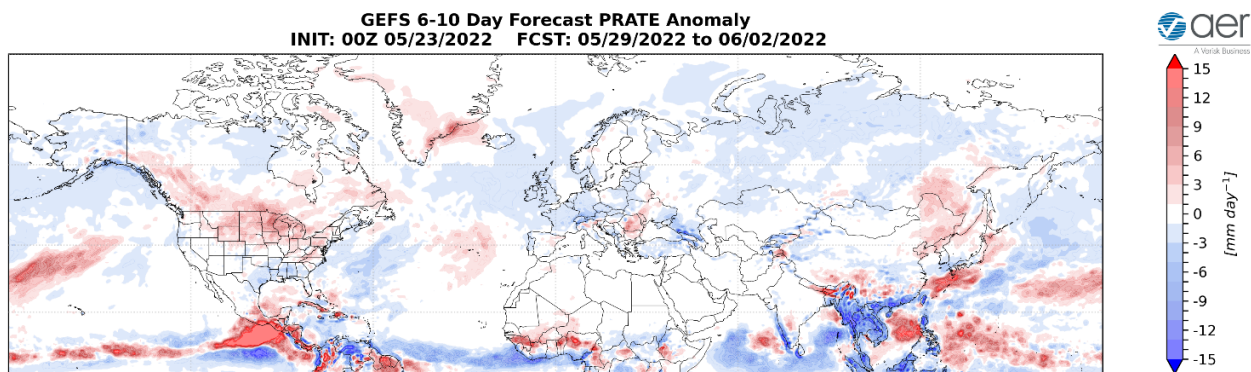


Figure 7. Forecasted precipitation rate (mm/day; shading) from 29 May – 2 June 2022. The forecast is from the 00Z 23 May 2022 GEFS ensemble.

Mostly below normal precipitation is predicted across Eurasia with above normal precipitation predicted for the Balkans and Southern and Eastern Asia (**Figure 7**). Mostly below normal precipitation is predicted across North America with above normal precipitation predicted along the US-Canadian border (**Figure 7**).

11-15 day

Geopotential height anomalies are predicted to remain mostly positive across the Arctic this period (**Figure 8**), therefore the AO should remain negative (**Figure 1**). With predicted persistent positive pressure/geopotential height anomalies across Greenland and Iceland (**Figure 8**), the NAO is predicted to also remain negative this period.

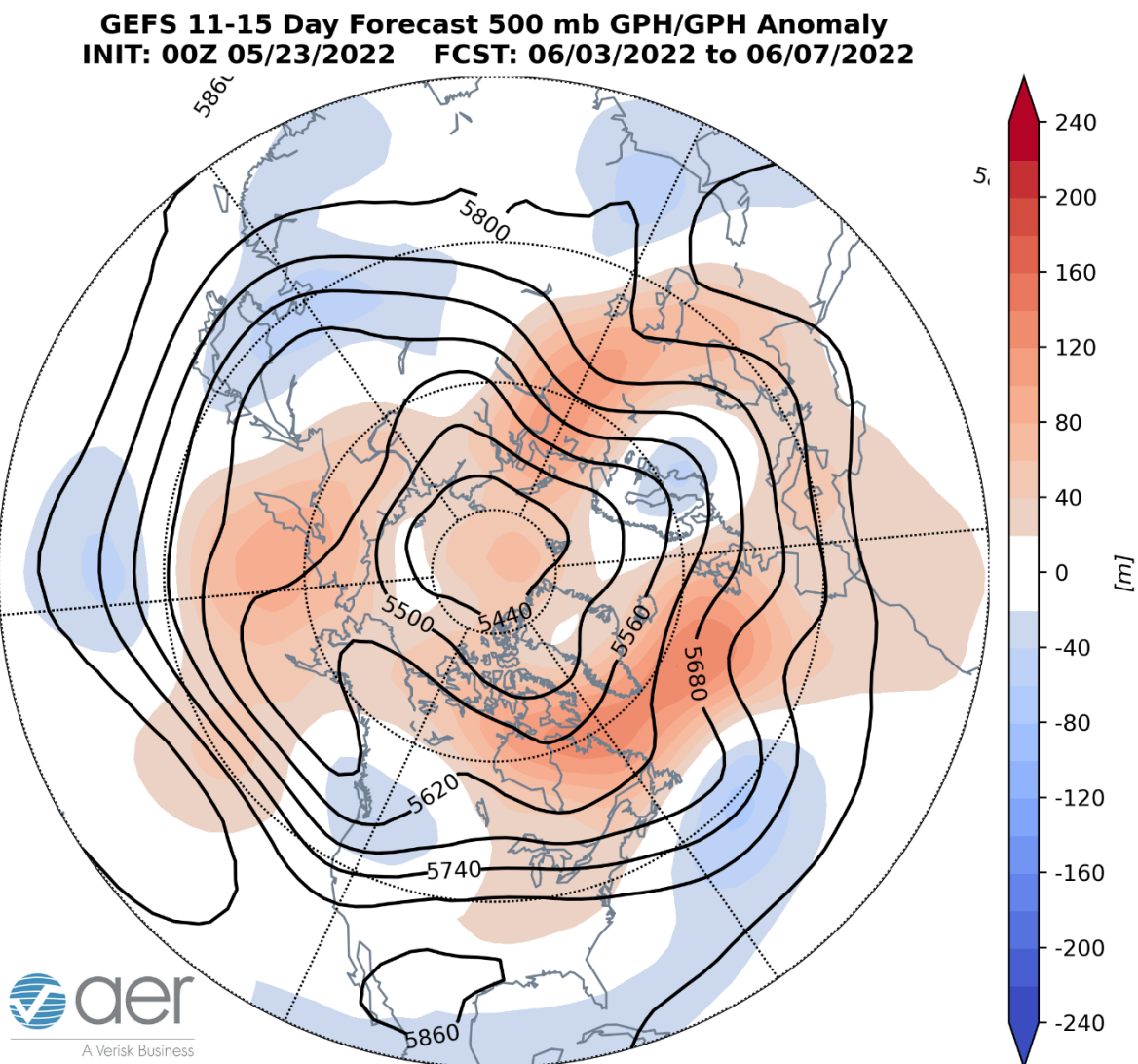


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 3 – 7 June 2022. The forecasts are from the 00z 23 May 2022 GFS ensemble.

Persistent ridging/positive geopotential height anomalies will continue to favor troughing/negative geopotential height anomalies across Central Europe with ridging/positive geopotential height anomalies across Western Europe this period (**Figure 8**). This pattern favors normal to above normal temperatures across Western and Southern Europe including the UK with normal to below normal temperatures across Northern and Eastern Europe (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to become more widespread across Asia but still centered in Central Asia this period with troughing/negative geopotential height anomalies mostly limited to Northeast Asia (**Figure 8**). This pattern favors widespread normal to above normal temperatures across much of Asia with normal to below normal temperatures mostly limited to Northeastern Asia and northwestern Russia (**Figure 9**).

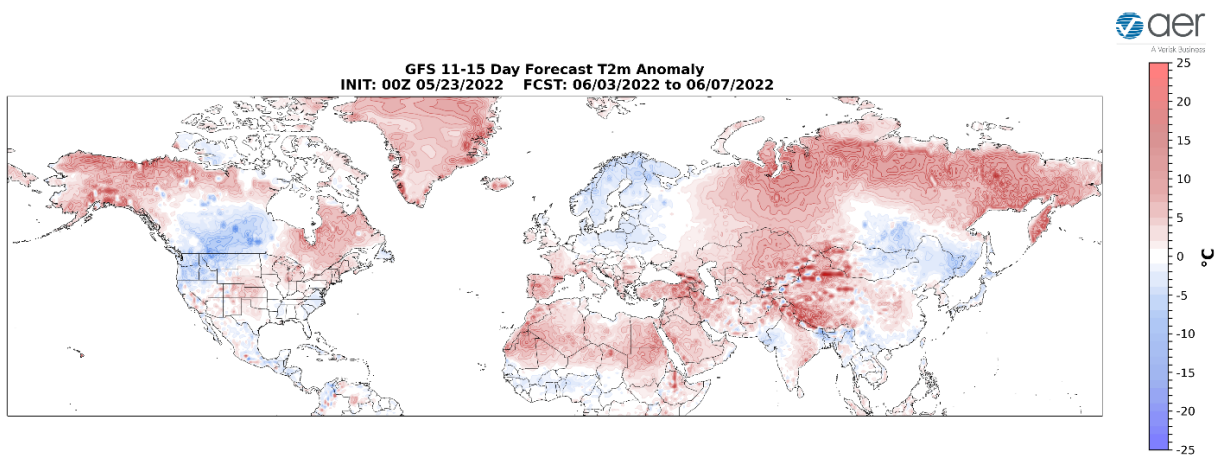


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 3 – 7 June 2022. The forecasts are from the 00z 23 May 2022 GFS ensemble.

Ridging/positive geopotential height anomalies predicted to stretch from Eastern Siberia to Alaska will continue to support troughing/negative geopotential height anomalies across western North America with ridging/positive geopotential height anomalies across eastern North America this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across Alaska, much of Northern and Eastern Canada and the Southern and Eastern US with normal to below normal temperatures across Southern and Western Canada and the Northwestern US (**Figure 9**).

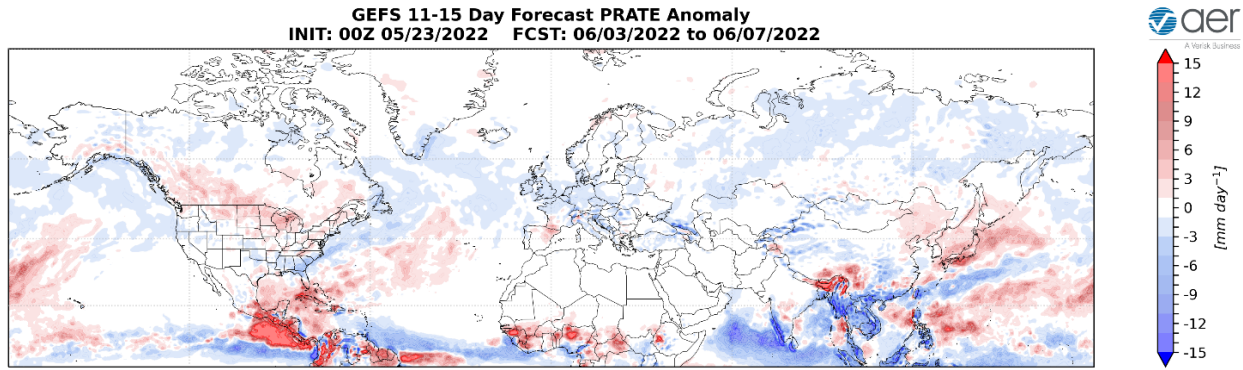


Figure 10. Forecasted precipitation rate (mm/day; shading) from 3 – 7 June 2022. The forecast is from the 00Z 23 May 2022 GEPS ensemble.

Mostly below normal precipitation is predicted across Eurasia with above normal precipitation predicted for the Pyrenees and Southern and Eastern Asia (**Figure 10**). Mostly below normal precipitation is predicted across North America with above normal precipitation predicted for the US-Canadian border (**Figure 10**).

Longer Term

30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows cold/negative PCHs throughout the stratosphere and the troposphere. Cold/negative PCHs are predicted to persist in the upper and middle stratosphere the next two weeks (**Figure 11**).

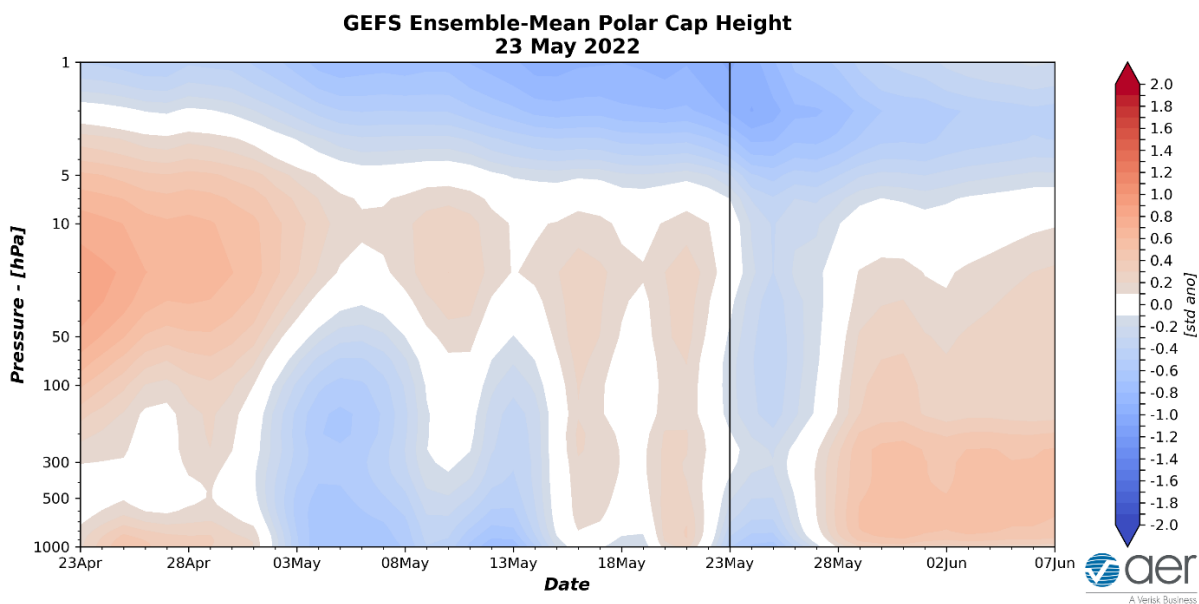


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 23 May 2022 GFS ensemble.

The cold/negative PCHs predicted this week in the troposphere are predicted to turn warm/positive at the end of the week and then remain warm/positive through the first week of June (**Figure 11**). The cold/negative PCHs transitioning to warm/positive are consistent with the surface AO starting positive this week and then reversing negative this weekend and through the first week of June (**Figure 1**).

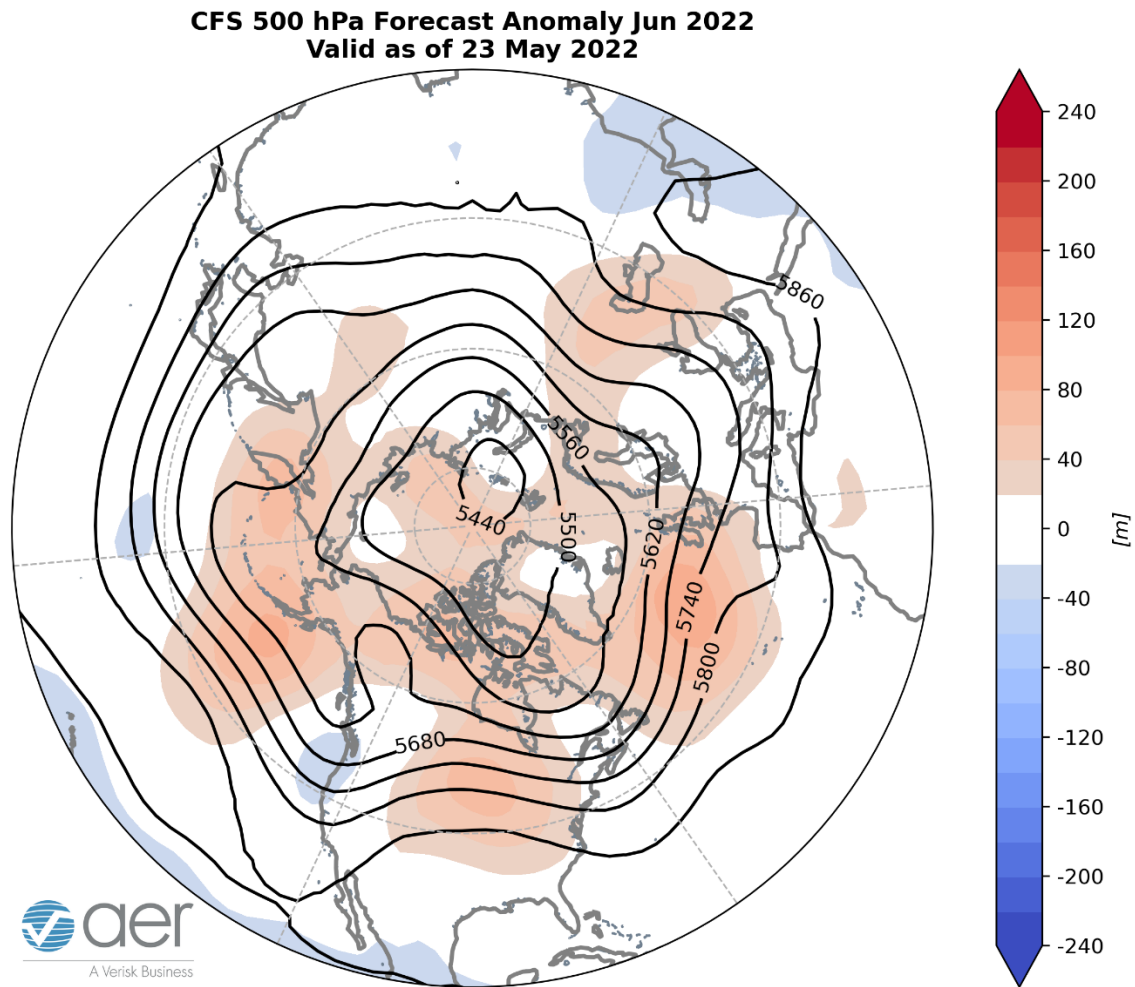


Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for June 2022. The forecasts are from the 00Z 23 May 2022 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and surface temperatures for June (**Figure 13**) from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere

is ridging centered just west of Western Europe, Western Asia, Eastern Siberia, the Gulf of Alaska, Northern Canada and central North America with troughing across Eastern Europe, Central and East Asia, the Western US, Eastern Canada and the Northeastern US (**Figure 12**). This pattern favors seasonable to relatively warm temperatures across Western and Northern Europe, much of Asia but especially Siberia, Alaska, Northern Canada and the Western and Northern US with seasonable to relatively cool temperatures across Eastern Europe, East Asia, Southern Canada and the Central and Southeastern US (**Figure 13**).

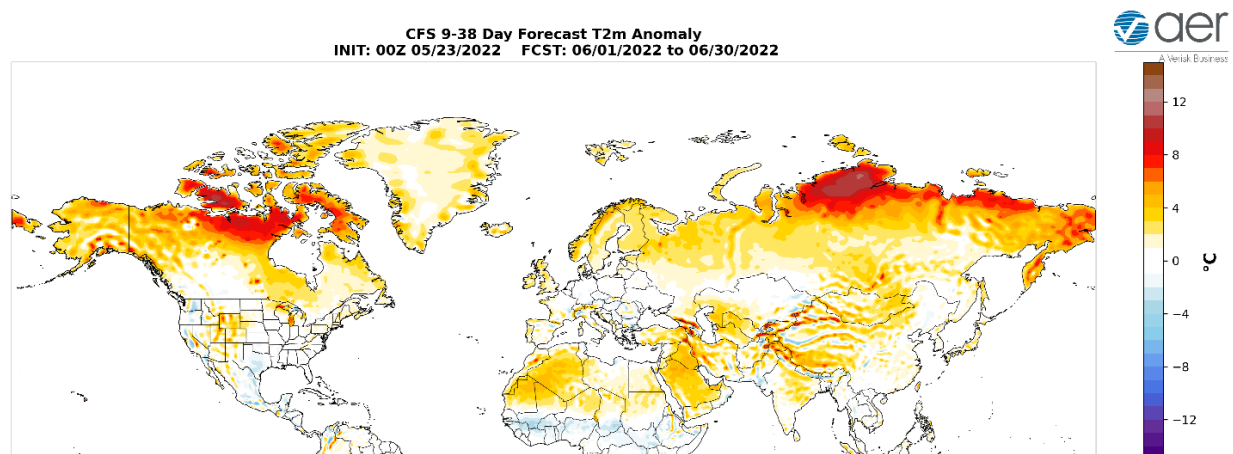


Figure 13. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for June 2022. The forecasts are from the 00Z 23 May 2022 CFS.

Surface Boundary Conditions

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are below normal and we continue to observe weak La Niña conditions (**Figure 14**) and La Niña conditions are expected through the summer. La Niña could favor a North America heat dome during the summer months and a more active North Atlantic hurricane season. Observed SSTs across the NH remain well above normal especially in the central North Pacific (west of recent years), the western North Pacific and offshore of eastern North America though below normal SSTs exist regionally especially in the North Pacific.

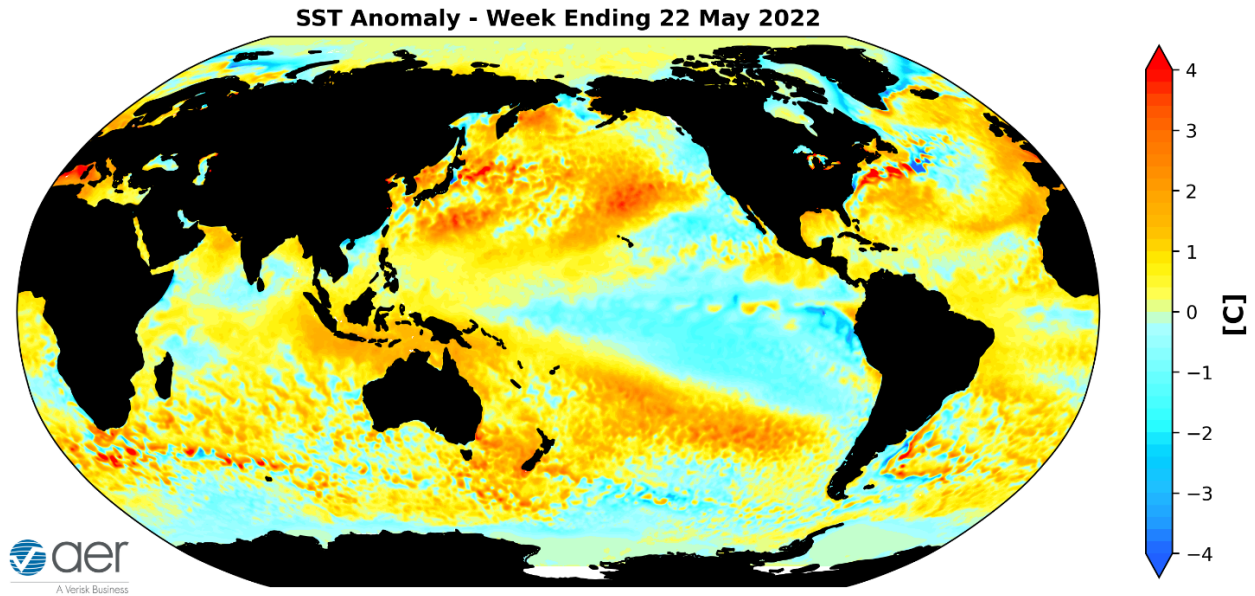


Figure 14. The latest weekly-mean global SST anomalies (ending 22 May 2022). Data from NOAA OI High-Resolution dataset.

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 15**). The forecasts are for the MJO to remain weak where no phase is favored and then emerge in phase 7 at the end of the week and then slide into phase 8. Phases 7 and 8 favor ridging and relatively warm temperatures in Western Canada with troughing and relatively cool temperatures in the Eastern US. Therefore it is hard for me to see that the MJO is likely influencing the weather across North America. But admittedly this is outside of my expertise.

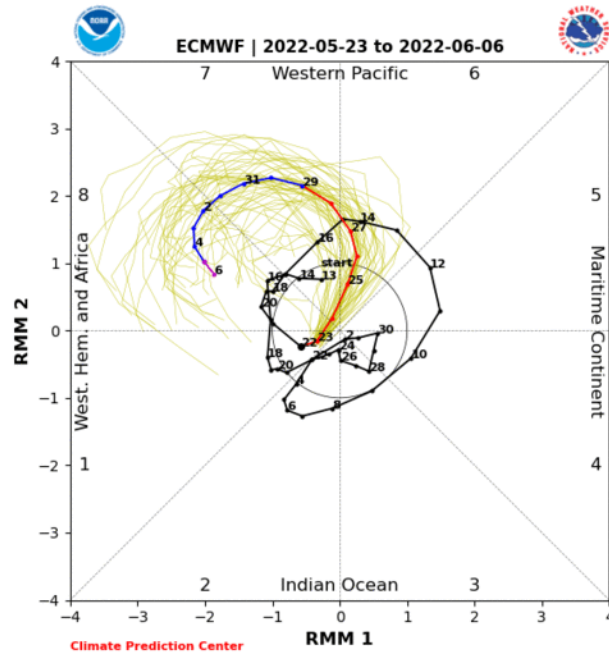


Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 23 May 2022 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>

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We appreciate your taking the time to read the public Arctic Oscillation blog from Dr. Judah Cohen and the AER Seasonal Forecasting team.

Dr. Cohen’s detailed monthly seasonal forecast, **sCast**, is also available for purchase. **sCast** provides a monthly 30-60-90-180-day outlook into temperature and precipitation, solar flux and wind anomalies across the globe, and regional population weighted cooling and heating degree forecasts for the US.

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