Arctic Oscillation and Polar Vortex Analysis and Forecasts

May 19, 2025

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. In late 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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Summary

- The Arctic Oscillation (AO) is currently slightly negative and is predicted to trend positive as pressure/geopotential height anomalies across the Arctic are currently mostly positive and are predicted to turn more negative over the next two weeks. The North Atlantic Oscillation (NAO) is currently negative as positive pressure/geopotential height anomalies dominate across Greenland and the NAO is predicted to trend positive the next two weeks as pressure/geopotential height anomalies are predicted to become increasingly negative across Greenland.
- This week, ridging/positive geopotential height anomalies centered between Iceland and Greenland will force troughing/negative geopotential height anomalies across much of Europe and then next week deepening troughing across Greenland will favor strengthening ridging across Europe. This pattern will support widespread normal to below normal temperatures across most of Europe including the UK except for normal to above normal temperatures across Portugal and the Balkans this week and then next week normal to above normal temperatures will become more widespread across Europe.
- Over the next two weeks, ridging/positive geopotential height anomalies will dominate Asia with the exceptions of troughing/negative geopotential height anomalies centered in East Asia this week and Central Asia next week. This pattern favors normal to above normal temperatures widespread across much of Asia the next two weeks with the exceptions of

normal to below normal temperatures across India the next two weeks, far Northwestern Russia and East Asia this week and Kazakhstan, Southern Siberia and Mongolia next week.

- The general pattern across North America the next two weeks is ridging/positive geopotential height anomalies centered near northern Hudson Bay supporting troughing/negative geopotential height anomalies near Alaska and the Eastern United States (US). This patten will favor widespread normal to above normal temperatures across Canada and the far Southern US the next two weeks and the Western US next week with normal to below normal temperatures across Alaska, and the Central and Eastern US this week into next week.
- The polar vortex (PV) is gone until next fall, but its influence continues this week. The starting in June, I expect a more typical summer pattern across the Northern Hemisphere to take shape.

Plain Language Summary

Widespread warmth dominated the land areas of the Northern Hemisphere (NH) this spring especially across Eurasia (see **Figure**). The warmth occurred despite the large polar vortex (PV) disruption of early March. However, the biggest exception has been Canada and close to the Dateline (see **Figure**). Here the episodic influence from the PV disruption and the resultant high latitude blocking delivered cooler weather. The last gasps of the PV disruption are predicted to bring high-latitude blocking to the Asian side of the Arctic and Northern Canada resulting in relatively cool temperatures to Central Asia and the Eastern US for late May in Europe (see **Figures 6** and **9**). The PV influence will end in time for the start of meteorological summer when I expect a summer pattern consistent with recent summers to emerge.

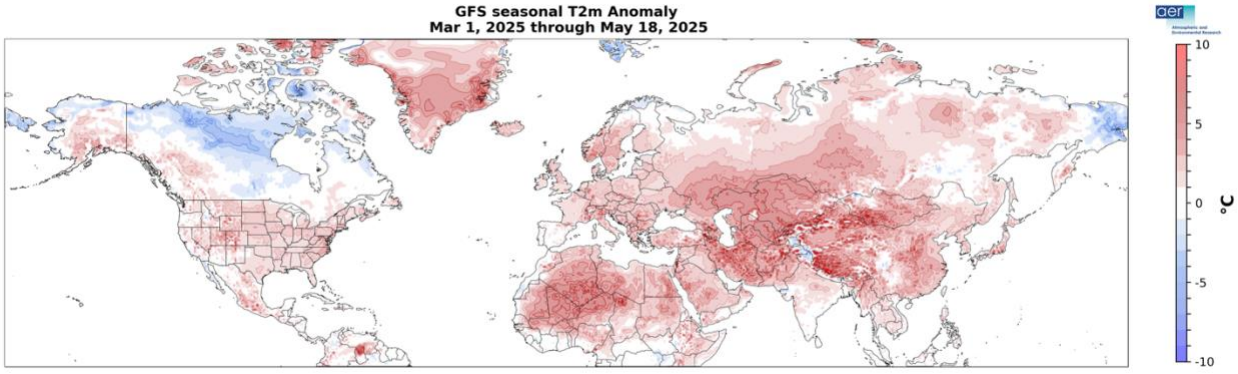

Figure. Estimate of the observed surface temperatures (°C; shading) from 01 Mar to 18 May 2025 based on GFS initializations and the GFS forecast from the 19 May 2025 run.

Impacts

It remains my opinion that the relatively cool weather in Europe this week and the Eastern US the next two weeks is related to the sudden stratospheric warming (SSW and is defined to occur when the zonal-mean zonal wind at 10 hPa and 60°N drops below zero m/s or easterly) but will be defined as a Final warming (PV does not return until next fall). I can see from social media many disagree with me. But I have been repeating this idea or forecast for over two months now from even before the SSW officially began. As early the blog from 10 March 2025, I anticipated the main impact from the SSW will not arrive until late April the earliest and likely in May. And this quote from the blog in both the 3 March 2025 and repeated in the 10 March 2025 blogs turned out to be very prescient:

"But given that it is already the second week of March, the SSW is more likely to result in chilly and wet weather rather than cold and snowy weather, outside of higher elevations and higher latitudes."

I strongly believe that a successful long-range forecast should be given a lot of weight, especially a forecast shared multiple months in advance. (As an aside, I am sure I have written this many times, it never ceases to amaze me how little credit is given for correct forecasts!)

Had the SSW or large polar vortex (PV) disruption happened two or more months earlier, the blog would be obsessing about the long duration cold and heavy snowfall in the Northeastern US (maybe Europe as well) rather than unusually chilly weather and multiple day rainfalls as summer rapidly approaches. The nor'easter predicted for the end of the week would have produced a crippling blizzard in Southern New England, that may have exceeded the seasonal snowfall totals that were observed this and even the three past winters. This echoes the frustration as a snow lover that I expressed in the 10 March 2025 blog of what was and what could have been.

I have consistently referred to the large PV disruption as an SSW, because the impacts to the troposphere and the weather seem to closely follow what we might expect following an SSW even earlier in the winter when the PV does recover. We can follow the long and unbroken journey of the largest warm/positive polar cap geopotential height anomalies (PCHs) from the upper stratosphere in early March to the lower troposphere in late May (see **Figure 11**). One could argue that the impacts to the tropospheric circulation (most notably high latitude blocking and relatively cold temperatures across the mid-latitudes) were not large or of long duration, but that is not uncommon with other SSWs that occur earlier in the winter. Understanding why some SSWs have larger impacts to our weather than other SSWs, has been a vexing question for the climate community for decades.

Waiting for notable Greenland blocking following the SSW has been like "Waiting for Godot." Greenland blocking is predicted for this week (see **Figure i**), which results relatively cool weather for Europe and the Eastern US over the next two weeks (see **Figures 3, 6** and **9**). But consistent with all winter, any Greenland blocking seems to be ephemeral. The blocking slides west to

Hudson Bay, allowing temperatures to turn warmer in Europe but anchoring damp and chilly weather to plague the Northeastern US for the next two weeks.

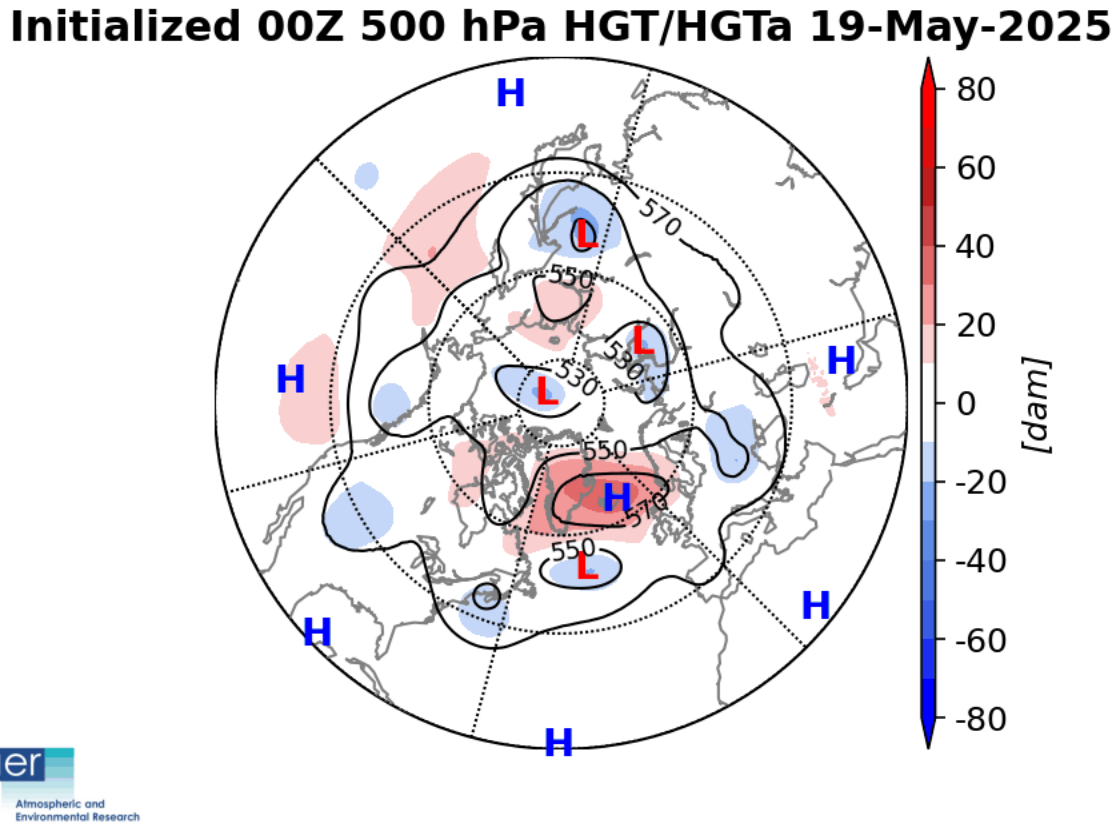

Figure i. Initialized 500 mb geopotential heights (dam; contours) and decameter anomalies (dam; shading) across the Northern Hemisphere for 19 May 2025 and forecasted from 20 May to 03 Jun 2025. The forecasts are from the 00Z 19 May 2025 GFS model ensemble.

But it does seem to me from the PCHs plot shown in **Figure 11** that the influence from the large PV disruption in March comes to a complete end next week and the atmosphere is ready to turn the page to a pattern more reminiscent of summer pattern of the recent past. Looking at the PCH plot, I think that we will see alternating or striations of PCHs from warm/positive to cold/negative for the remainder of the summer.

As far as the mid-tropospheric circulation, I expect a pattern that I have labeled the "ring of fire." This pattern is characterized by low pressure centered over the Central Arctic and it is ringed by ridging/high pressure across the northern continents, many of which will be associated with heat domes. In between the heat domes are areas of lower geopotential heights and relatively cooler temperatures. There are favored regions for the heat domes and the weakness in the mid-tropospheric ridging or even respectable troughing but I will leave that for the next blog to start sorting it out.

Near-Term

This week

The AO is predicted to start negative and end positive this week **(Figure 1**) with mostly negative geopotential height anomalies currently across the Arctic but become increasingly negative with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). With predicted positive geopotential height anomalies across Greenland (**Figure 2**), the NAO is predicted to be negative this week as well.

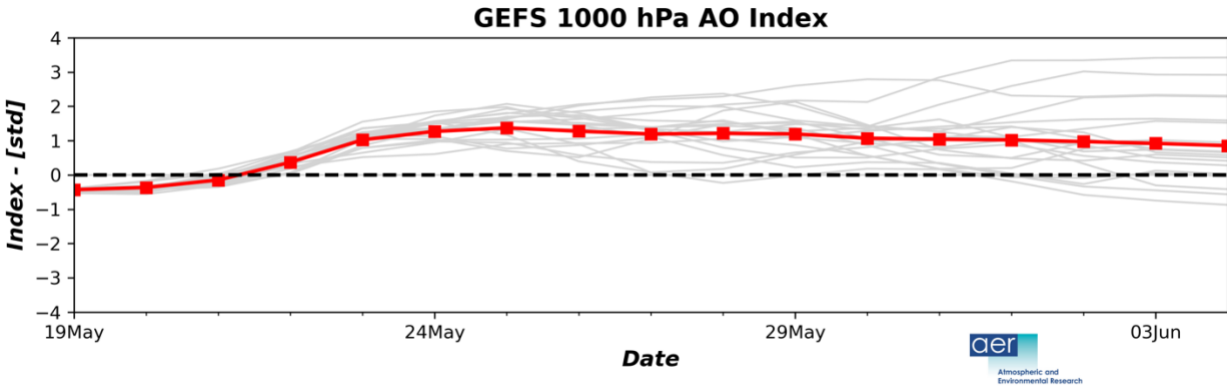

Figure 1. The predicted daily-mean AO at 1000 hPa from the 00Z 19 May 2025 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble mean AO index given by the red line with squares.

This week predicted ridging/positive geopotential height anomalies centered between Iceland and Greenland will favor troughing/negative geopotential height anomalies across much of Europe (**Figure 2).** This pattern will favor widespread normal to below normal temperatures across Europe including the UK with exceptions of normal to above normal temperatures limited to Portugal, Ireland and the Balkan States this period (**Figure 3**). This week a quasi-omega block pattern is predicted across Asia with ridging/positive geopotential height anomalies centered in Central Asia bookended troughing/negative geopotential height anomalies across Northwestern Russia and in East Asia (**Figure 2**). This pattern favors normal to above normal temperatures widespread across much of Asia with normal to below normal temperatures limited to Northwestern Russia, parts of East Asia and India **(Figure 3**).

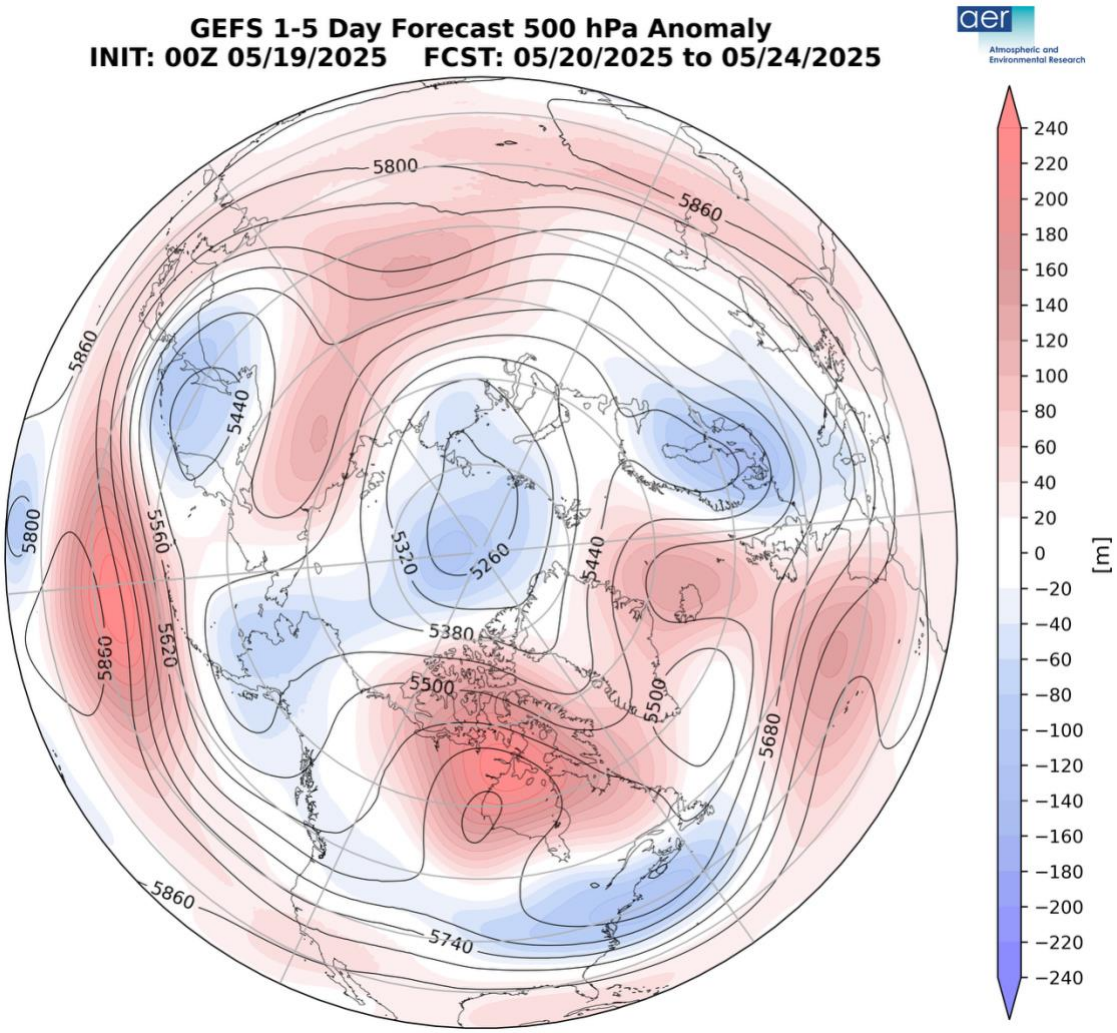

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 20 May to 24 May 2025. The forecasts are from the 00Z 19 May 2025 GFS ensemble.

This week ridging/positive geopotential height anomalies centered over Hudson Bay will support troughing/negative geopotential height anomalies across Alaska and the Northern US with more ridging/positive geopotential height anomalies across the Southern US (**Figure 2**). This pattern favors normal to above normal temperatures across much of Canada and the Southern US with normal to below normal temperatures across Alaska, Southeastern Canada and the Northern US. (**Figure 3**).

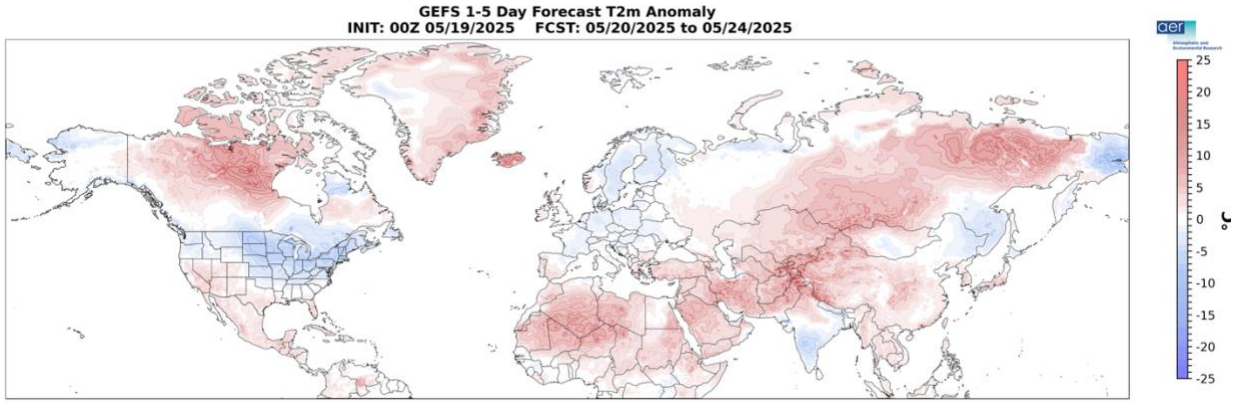

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 20 May to 24 May 2025. The forecasts are from the 00Z 19 May 2025 GFS ensemble.

Troughing will support new rainfall across Scandinavia, Southeastern Europe, Southeast Asia, western India and the Tibetan Plateau with otherwise mostly dry conditions widespread across Europe and Asia this week (**Figure 4**). Troughing will support new rainfall across the Central and Northeastern US and parts of Alaska and Western Canada with otherwise mostly dry conditions widespread across Canada and the US this week (**Figure 4**).

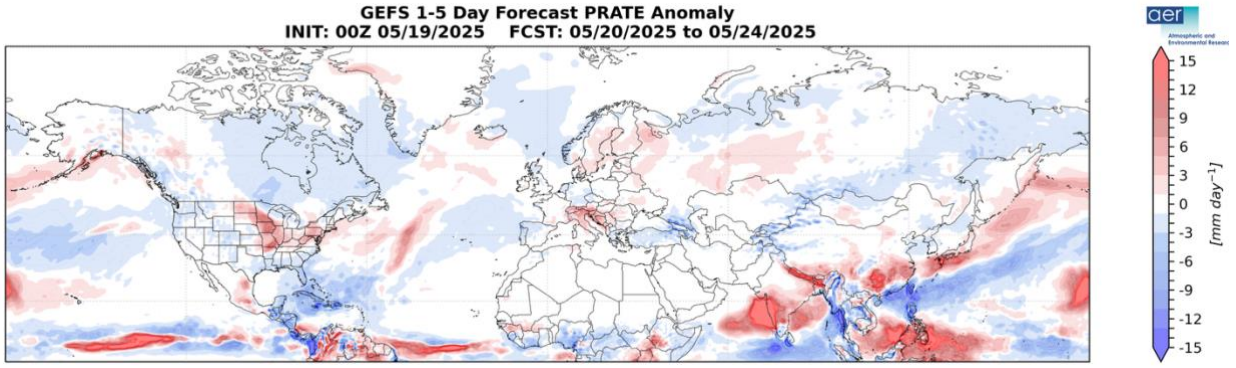

Figure 4. Forecasted rainfall (mm/day; shading) from 20 May to 24 May 2025. The forecasts are from the 00Z 19 May 2025 GFS ensemble.

Near-Mid Term

Next week

With geopotential height anomalies becoming mostly negative across the Arctic and with mixed geopotential height anomalies across the mid-latitudes this period (**Figure 5**), the AO will likely turn positive this period (**Figure 1**). With predicted weak but negative pressure/geopotential height anomalies across Greenland (**Figure 5**), the NAO will likely be positive this period.

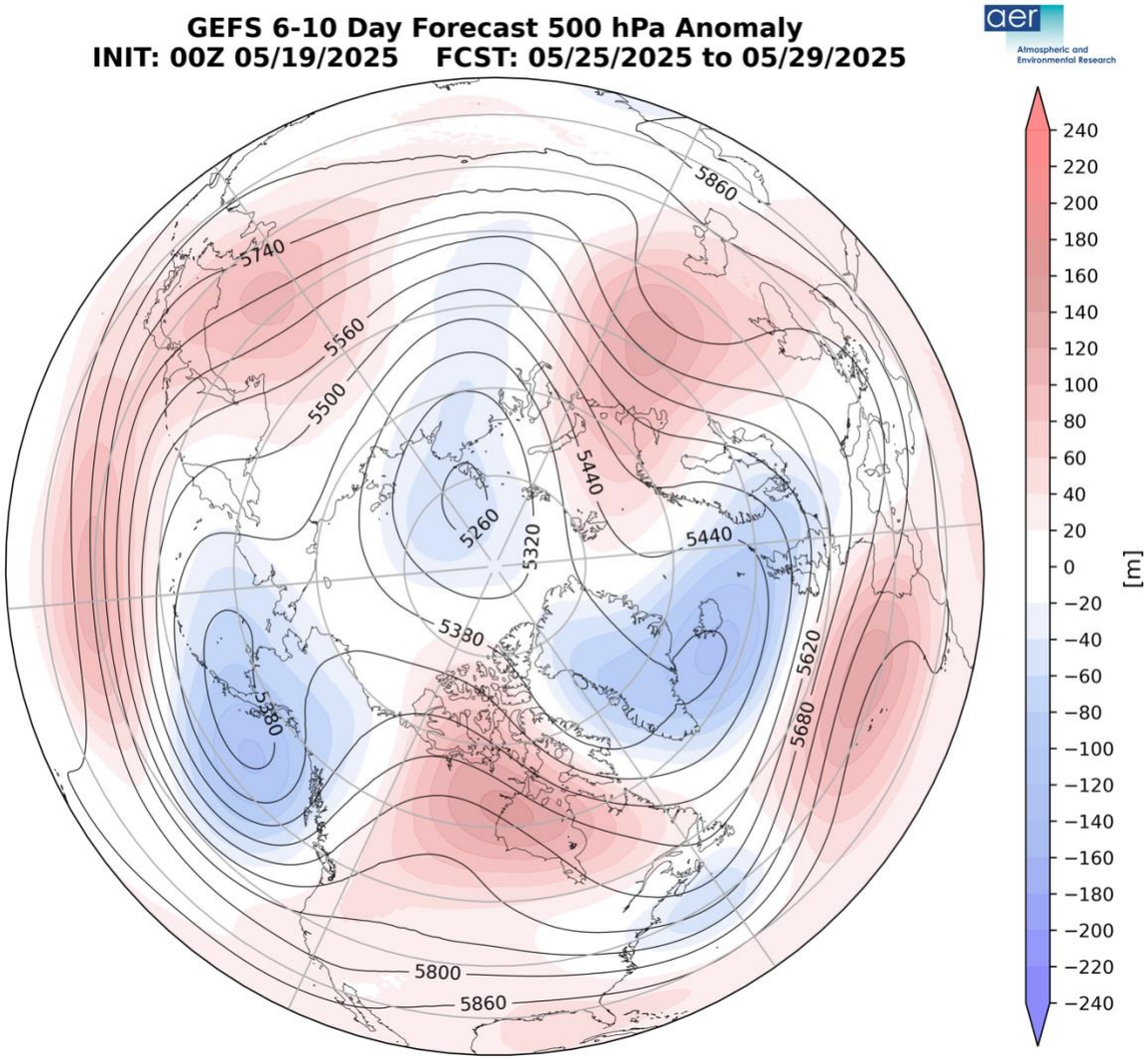

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 25 May to 29 May 2025. The forecasts are from the 00Z 19 May 2025 GFS ensemble.

Deepening troughing/negative geopotential height anomalies are predicted to extend from Greenland to Northwest Europe with ridging/positive geopotential height anomalies elsewhere across Europe (**Figure 5**). This pattern will favor normal to below normal

temperatures across Northwestern Europe including the UK with normal to above normal temperatures spreading across the rest of Europe this period (**Figure 6**). Ridging/positive geopotential height anomalies will continue to dominate Western and Eastern Asia with troughing/negative geopotential height anomalies in Central Asia this period (**Figure 5**). This pattern favors widespread normal to above normal temperatures across most of Asia with normal to below normal temperatures limited to eastern Kazakhstan, Southern Siberia and India this period (**Figure 6**).

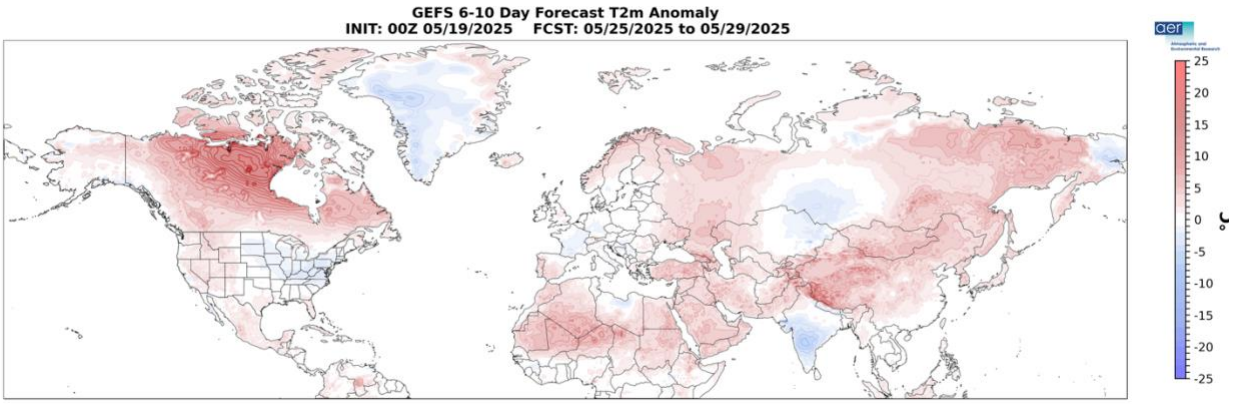

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 25 May to 29 May 2025. The forecasts are from the 00Z 19 May 2025 GFS ensemble.

The predicted pattern across North America is ridging/positive centered over Hudson Bay supporting troughing/negative geopotential height anomalies centered near the Aleutians and the eastern US this period (**Figure 5**). This pattern will favor normal to above normal temperatures across much of Alaska, Canada and the Western US with normal to below normal temperatures across the Eastern US (**Figure 6**).

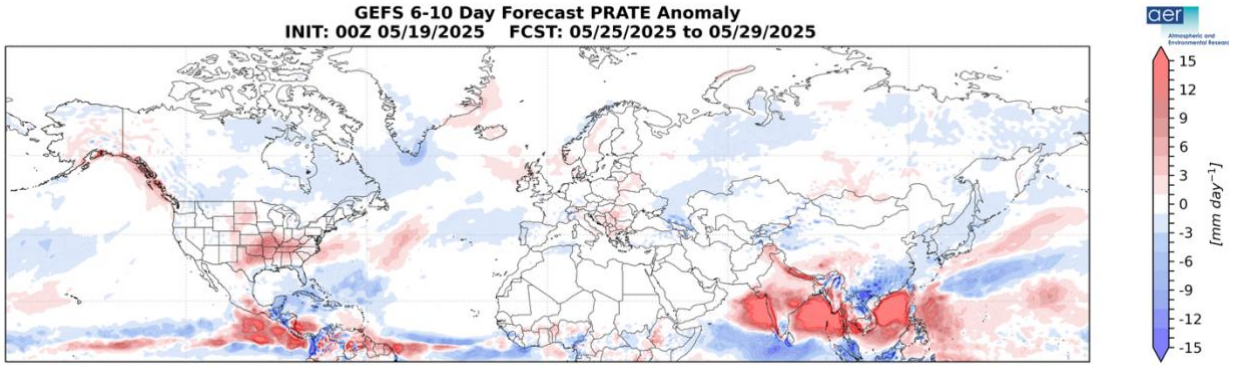

Figure 7. Forecasted precipitation rate (mm/day; shading) from 25 May to 29 May 2025. The forecasts are from the 00Z 19 May 2025 GFS ensemble.

Troughing will support new rainfall across Southeastern Europe, Southern Siberia, western India, Southeast Asia and the Tibetan Plateau with otherwise mostly dry conditions widespread across Europe and Asia this week (**Figure 7**). Troughing will support new rainfall across the parts of

Alaska, Plains of the US and the Eastern US with otherwise mostly dry conditions widespread across Canada and the US this week (**Figure 7**).

Mid Term

Week Two

With predicted persistent mostly mixed to negative geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes this period (**Figure 8**), the AO will likely remain positive this period (**Figure 1**). With predicted weak but mostly negative pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO will likely be near neutral to positive this period.

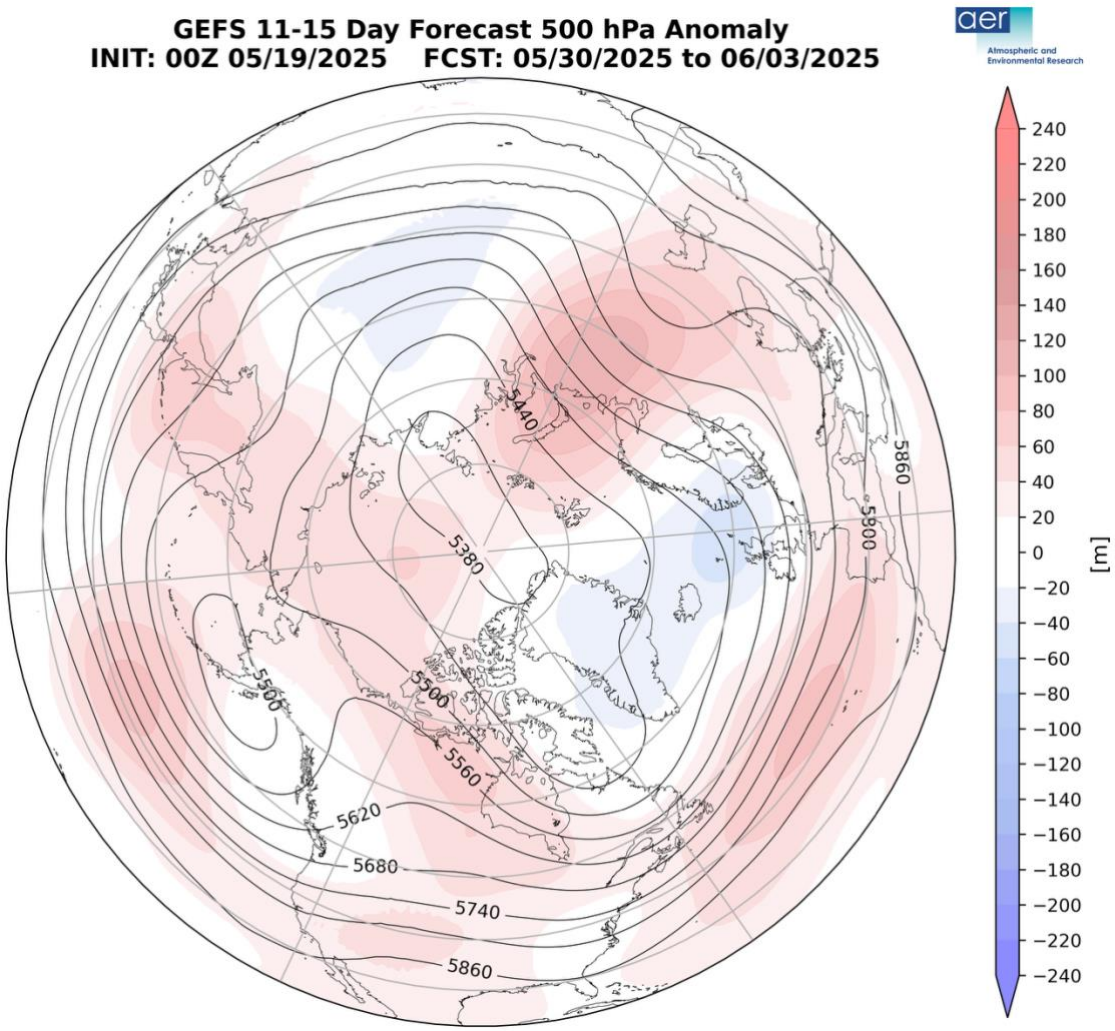

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 30 May to 03 Jun 2025. The forecasts are from the 00Z 19 May 2025 GFS ensemble.

Persistent troughing/negative geopotential height anomalies across Greenland will support increasing ridging/positive geopotential height anomalies across Europe this period (**Figure 8**). This pattern should favor widespread normal to above normal temperatures across most of Europe with the exception of lingering normal to below normal temperatures across Northwestern Europe including the UK this period (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to dominate Asia with the exception of persistent troughing/negative geopotential height anomalies across Central Asia this period (**Figure 8**). The predicted pattern favors widespread normal to above normal temperatures across most of Asia with normal to below normal temperatures mostly limited to eastern Kazakhstan, Southern Siberia, Mongolia and India this period (**Figure 9**).

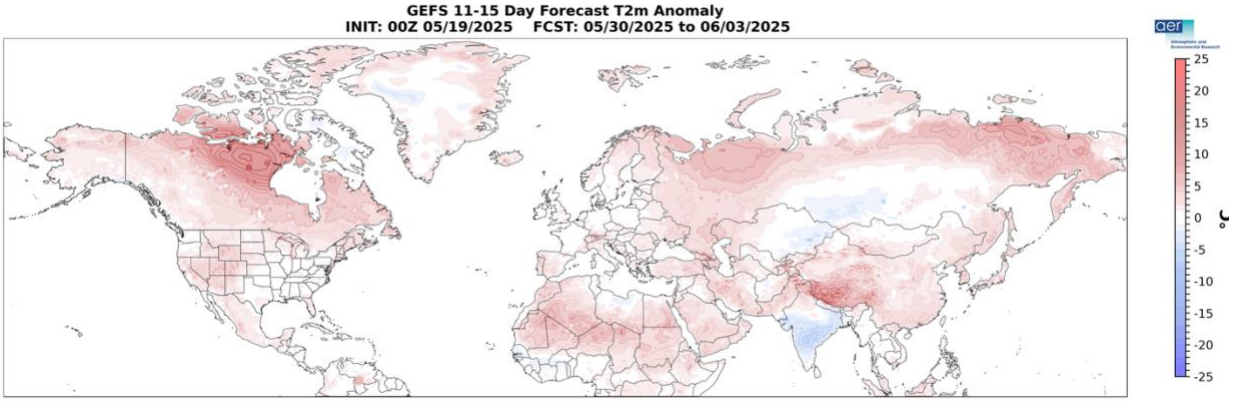

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 30 May to 03 Jun 2025. The forecasts are from the 00Z 19 May 2025 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to dominate much of Alaska, Canada and the US with weak troughing/negative geopotential height anomalies persisting across the Eastern US this period (**Figure 8**). This pattern supports normal to above normal temperatures across Alaska, Canada and the Western US with normal to below normal temperatures limited to the Eastern US this period (**Figure 9**).

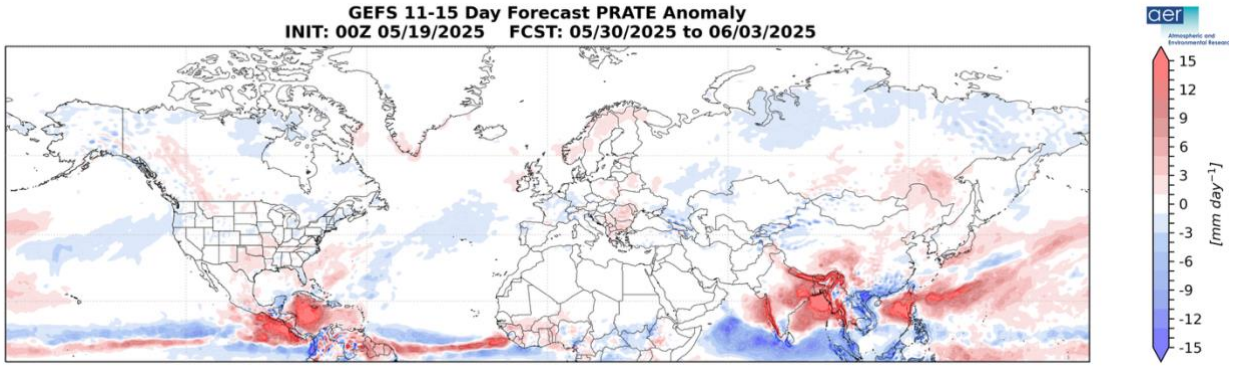

Figure 10. Forecasted precipitation rate (mm/day; shading) from 30 May to 03 Jun 2025. The forecasts are from the 00Z 19 May 2025 GFS ensemble.

Troughing will support new rainfall across Southeastern Europe, Northeast Asia, India and the Tibetan Plateau with otherwise mostly dry conditions widespread across Europe and Asia this period (**Figure 10**). Troughing will support new rainfall across Western Canada and the Central US with otherwise mostly dry conditions widespread across Canada and the US this period (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows warm/positive PCHs throughout the mid to low stratosphere and the troposphere with cold/negative PCHs in the upper stratosphere (**Figure 11**). The cold/negative PCHs in the upper stratosphere are predicted to descend all the way to the surface the last week of May. I do think that the warm/positive PCHs in the troposphere this week is the final impact from the PV disruption in March before the atmosphere flips into summer mode.

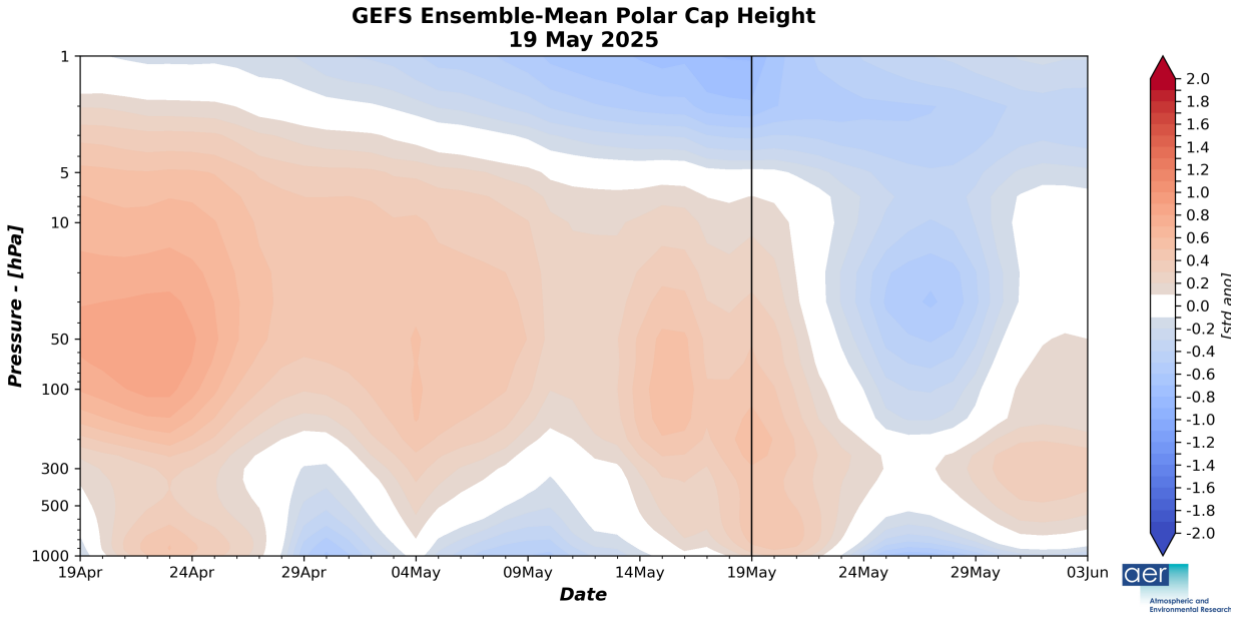

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 19 May 2025 GFS ensemble.

The predicted warm/positive PCHs in the lower troposphere for this week (Figure 11) are consistent with the predicted slightly negative surface AO this week (**Figure 1**). Then next week predicted descent of cold/negative PCHs into the lower troposphere (**Figure 11**) are consistent with the predicted turn to positive surface AO starting next week (**Figure 1**).

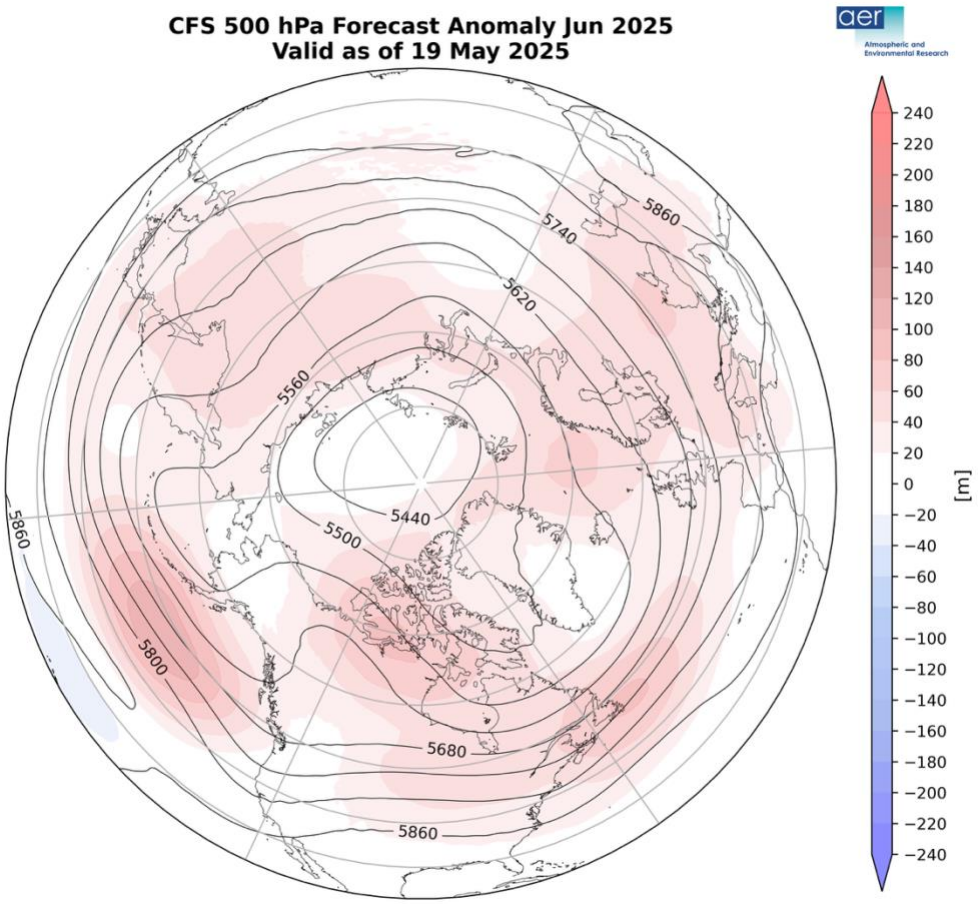

Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for June 2025. The forecasts are from the 00Z 19 May 2025 CFS.

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 between Greenland and Scandinavia, Eastern Europe, East Asia, south of the Aleutians, Western Canada and the Eastern US with troughing across Greenland, Central Asia, centered around the Dateline, the US West Coast and Eastern Canada (**Figure 12**). This pattern favors seasonable to relatively warm temperatures across Europe, much of Asia, especially Northern Siberia and the Tibetan Plateau, Alaska, Canada, especially Northern Canada and the Western and Eastern US with seasonable to relatively cool temperatures across Central Asia centered on Kazakhstan, the Plains of Southern Canada and the US (**Figure 13**).

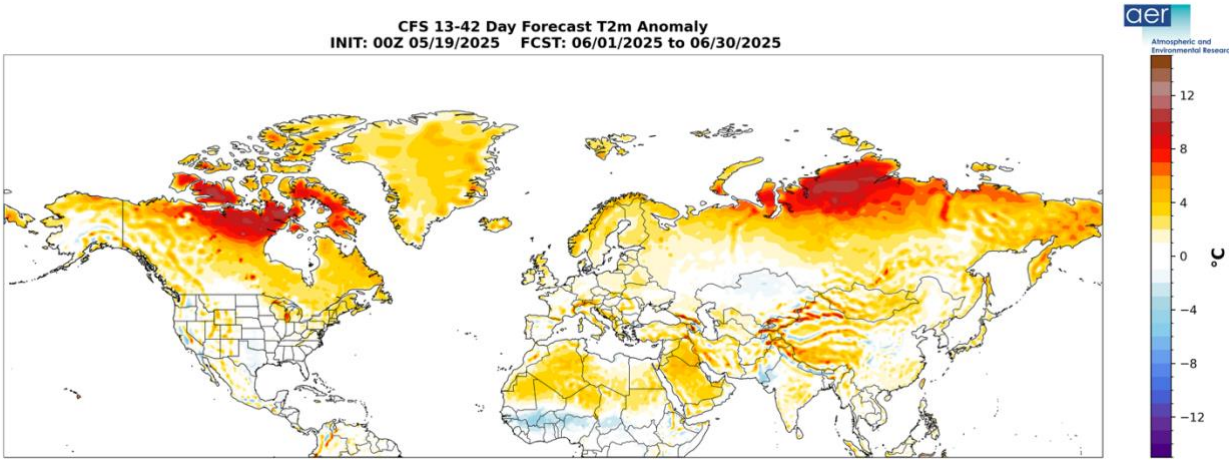

Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for Jun 2025. The forecasts are from the CFS 00Z 19 May 2025.

Boundary Forcings

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are slightly below normal, on either side of the Dateline, indicating that the winter La Niña event is waning (**Figure 14**) and neutral conditions are expected through the spring and into early summer. Warming of SSTs along the equator near South America are suggestive of an emerging El Niño. However current forecasts show large spread and plenty of uncertainty. Observed SSTs across the NH remain well above normal especially in the central North Pacific centered on the Dateline and the western North Pacific and much of the North Atlantic with the exception near the Canadian Maritimes though below normal SSTs exist regionally especially in the South Pacific.

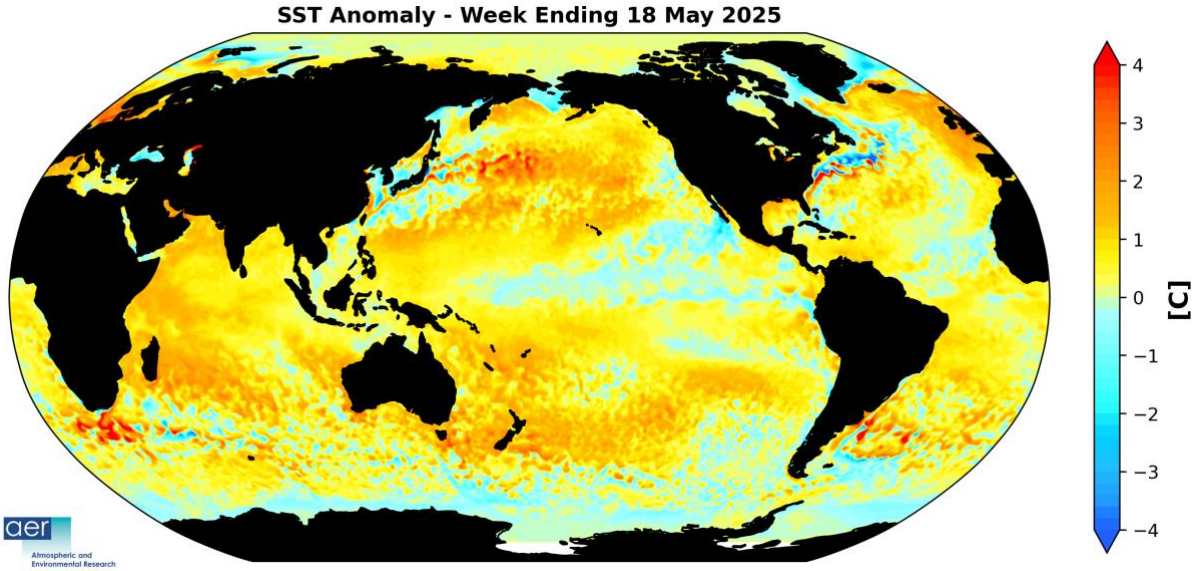

Figure 14. The latest daily-mean global SST anomalies (ending 17 May 2025). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently the Madden Julian Oscillation (MJO) is weak where no phase is favored (**Figure 15**). The forecasts are for the MJO to remain overall weak where no phase is favored through the end of May. Therefore, it seems to me that the MJO is having little to no obvious influence on North American weather for the next two weeks. But admittedly this is outside of my expertise.

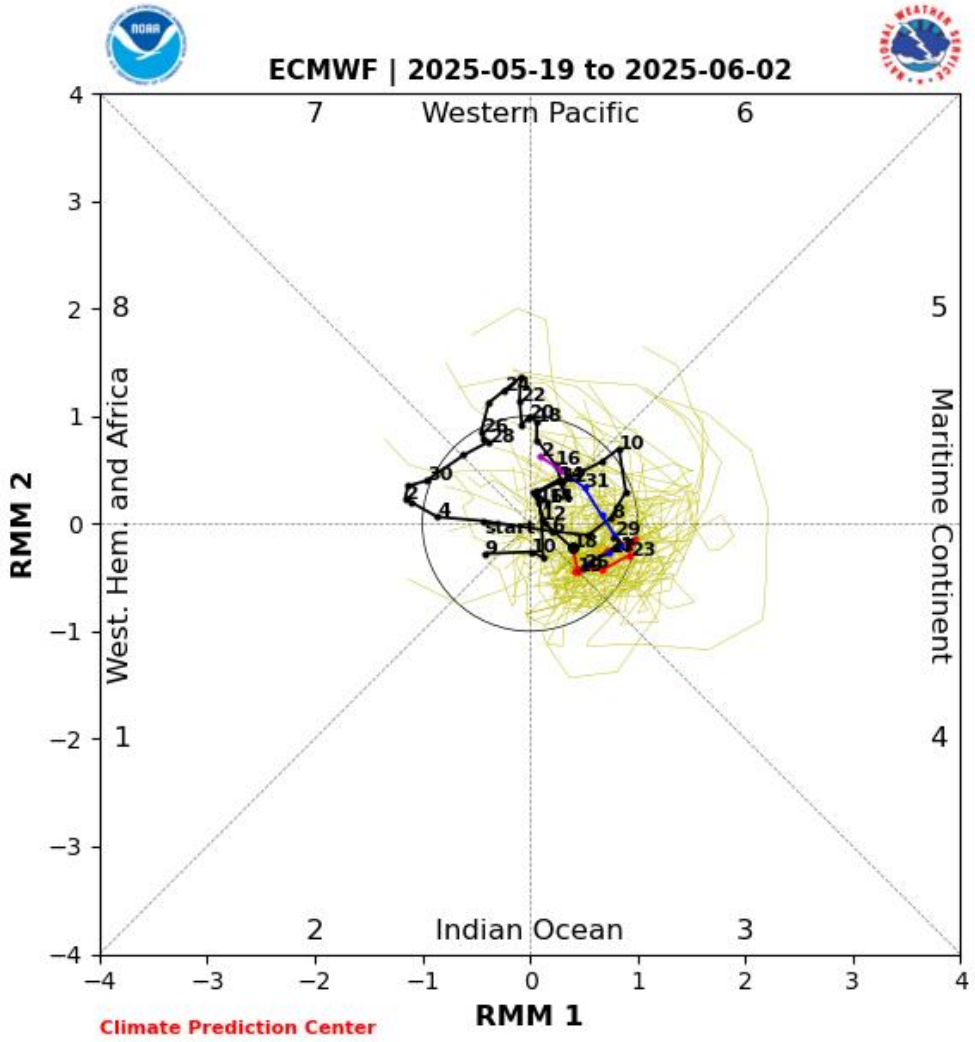

Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 18 May 2025 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model 'spread' is denoted by the gray shading. Sector numbers indicate the phase of the MJO, with geographical labels

indicating where anomalous convection occurs during that phase. Image source https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/ecmf.shtml

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