Arctic Oscillation and Polar Vortex Analysis and Forecasts

April 21, 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 neutral and is predicted to remain near neutral to slightly negative as pressure/geopotential height anomalies across the Arctic are currently mixed and are predicted to remain mixed to slightly positive over the next two weeks. The North Atlantic Oscillation (NAO) is currently neutral with weak but mostly positive pressure/geopotential height anomalies across Greenland and the NAO is predicted to remain neutral to slightly negative the next two weeks as pressure/geopotential height anomalies are predicted to remain weak but mostly positive across Greenland.
- Over the next two weeks, Europe is predicted to be mostly dominated by ridging/positive geopotential height anomalies with the main exception of troughing/negative geopotential height anomalies across Northeastern Europe next week. This pattern will support widespread normal to above normal temperatures across Europe including the United Kingdom (UK) with the biggest exception of normal to below normal temperatures across Northern and Eastern Europe next week.
- Over the next two weeks, Asia is predicted to be mostly dominated by ridging/positive geopotential height anomalies with the exception of troughing/negative geopotential height anomalies centered across Northwestern Asia and extending southeastward into Central and East Asia. This pattern favors this week normal to above normal temperatures widespread across Asia with normal to below normal temperatures across Northwestern

Asia and extending into parts of Central and East Asia.

- The general pattern across North America the next two weeks is ridging/positive geopotential height anomalies across much of Canada and the United States (US) with the exceptions of troughing/negative geopotential height anomalies across Alaska and the Northwestern US this week and into next week and then eventually the Eastern US. This patten will favor widespread normal to above normal temperatures across Canada and the US with normal to below normal temperatures across Alaska and the Northwestern US this week into next week and then starting next week in the Eastern US.
- A long duration sudden stratospheric warming (SSW) continues with episodic influence on the weather across the Northern Hemisphere is winding down but influences on the weather can still be felt into early May as discussed below.

Plain Language Summary

Despite the large polar vortex (PV) disruption of early March and the clear influence albeit episodic, surface temperatures across much of the Northern Hemisphere (NH) are above normal so far this April with the one exception being Eastern Canada and the Northeastern US (see **Figure**). Another episodic influence from the PV disruption is predicted to bring cooler weather to Northeastern Europe, Northwestern Asia and eventually the Eastern US (see **Figures 6** and **9**).

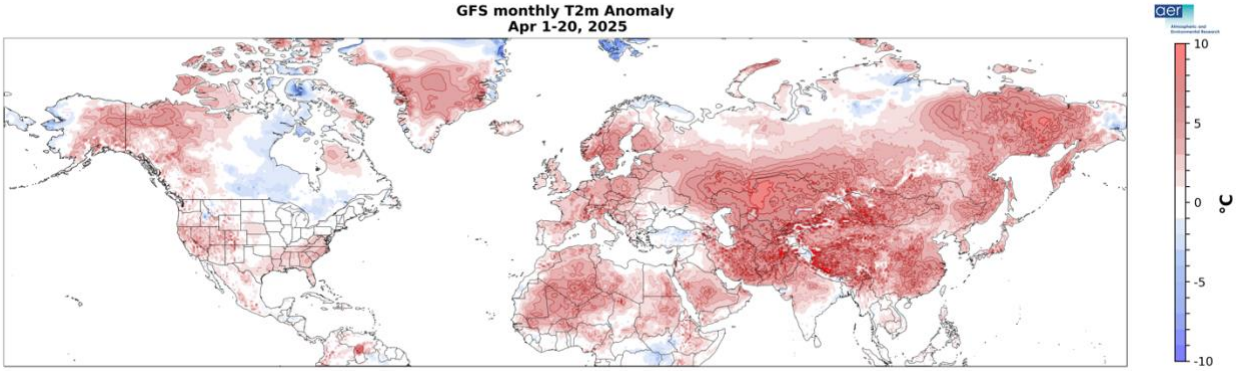

Figure. Estimate of the observed surface temperatures (°C; shading) from 01 Apr to 20 Apr 2025 based on GFS initializations and the GFS forecast from the 21 Apr 2025 run.

Impacts

It is not often that one discusses a 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) and even a Final warming (PV will not return until next fall) having influence on the weather in early May but here we are. The polar vortex is alive and kicking and currently over the Urals/western Russia and is predicted to continue its westward journey in the prevailing easterly flow and eventually to once more end up over the Northeastern US (see **Figure i**).

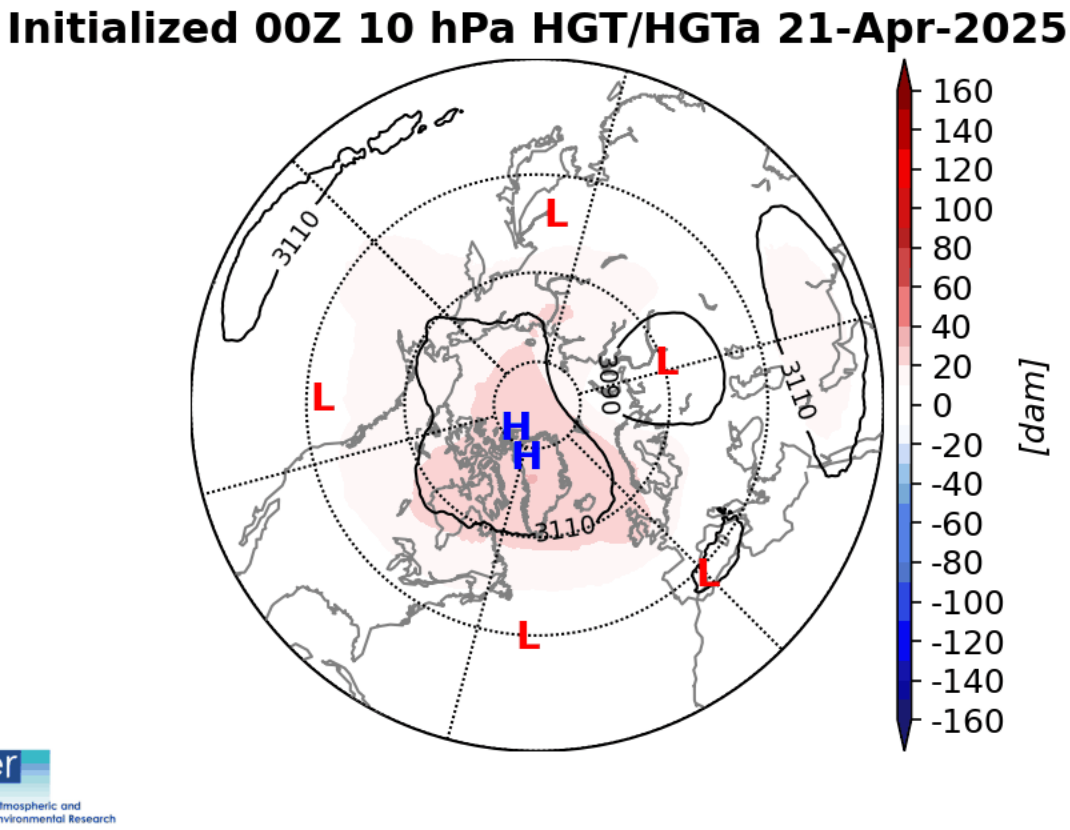

Figure ii. Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 21 Apr 2025 and forecasted from 22 Apr to 06 May 2025. The forecasts are from the 00Z 21 Apr 2025 GFS model ensemble.

In my opinion the PV center is related to some relatively cool weather in western Russia this week and into next week (see **Figure ii**). I do think there is potential that when the PV center makes its way to the northeastern US, it could also be related to relatively cool weather in the Northeastern US the first week and into the second week of May. The GFS is not really predicting any cool weather in the 11-15 day time period, but the ECMWF does show some seasonably cool weather starting in the middle of the first week of May. I do think that there is the possibility that the forecasts cool with time for early May in the Eastern US, especially the Northeastern US.

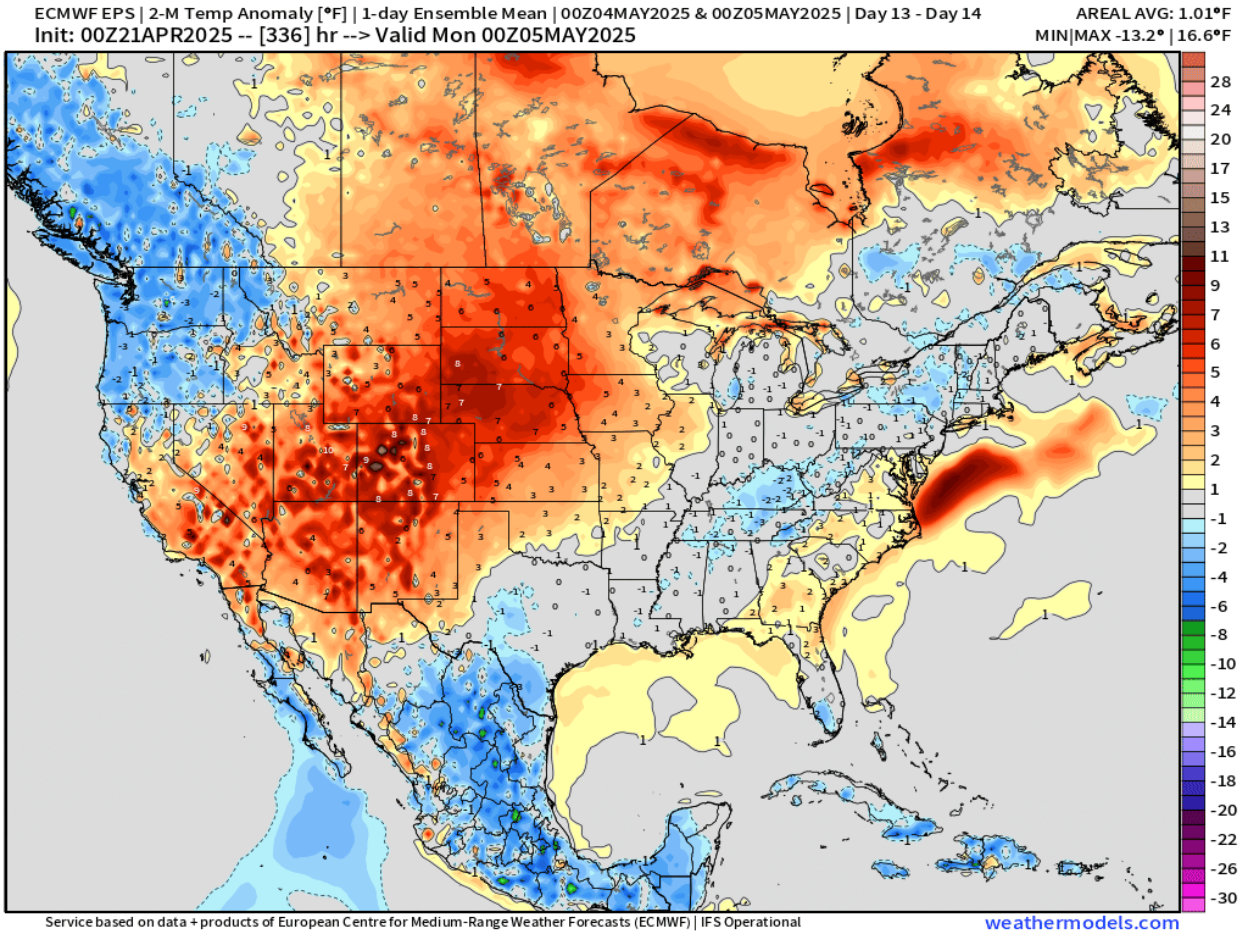

Figure ii. Forecasted surface temperature anomalies (°C; shading) for 4 May 2025. The forecasts are from the 00Z 21 Apr 2025 ECMWF ensemble. Plot downloaded from https://weathermodels.com/.

The PV center has passed over the Northeastern US earlier this spring in association with the large PV disruption from early March with no discernible large impact to the weather. However, this time may be different as the main signal from the PV disruption is now clearly lower in the atmosphere (see **Figure 11**). But timing is everything and the impact from an SSW in early May could be considered bringing benign or pleasant weather more so than hazardous weather. But if a cutoff low forms in the mid-troposphere, heavy rain could be a risk.

Looking at the forecast from the mid-tropospheric circulation from the GFS, early on, the GFS is predicting a closed relatively deep low over western Russia (see **Figure iii**), underneath the PV center and associated with the cool weather predicted for the region (see **Figure 6**). As the main signal from the PV disruption makes its way to the troposphere, Greenland blocking could form and or strengthen (not that visible from **Figure iii** but showing up in the ensemble forecasts e.g., **Figure 8**). And I do think both the PV center finding its way back to the Northeastern US and the possibility of Greenland blocking could result in a cutoff low over the Northeastern US in early May. Greenland blocking could also bring cool temperatures to Western Europe.

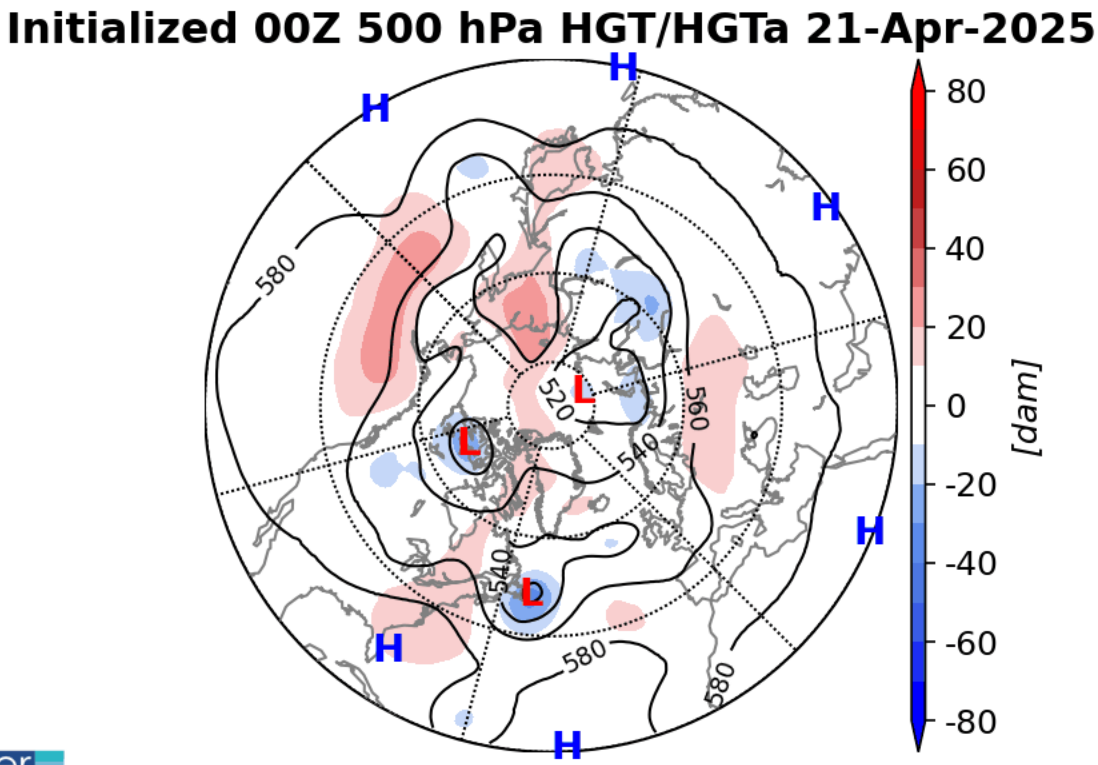

Figure iii. Initialized 500 mb geopotential heights (dam; contours) and decameter anomalies (dam; shading) across the Northern Hemisphere for 21 Apr 2025 and forecasted from 22 Apr to 06 May 2025. The forecasts are from the 00Z 21 Apr 2025 GFS model ensemble.

Otherwise, it has been a relatively mild spring across the NH, and I expect that the overall relatively warm temperatures for the NH to continue.

Near-Term

This week

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

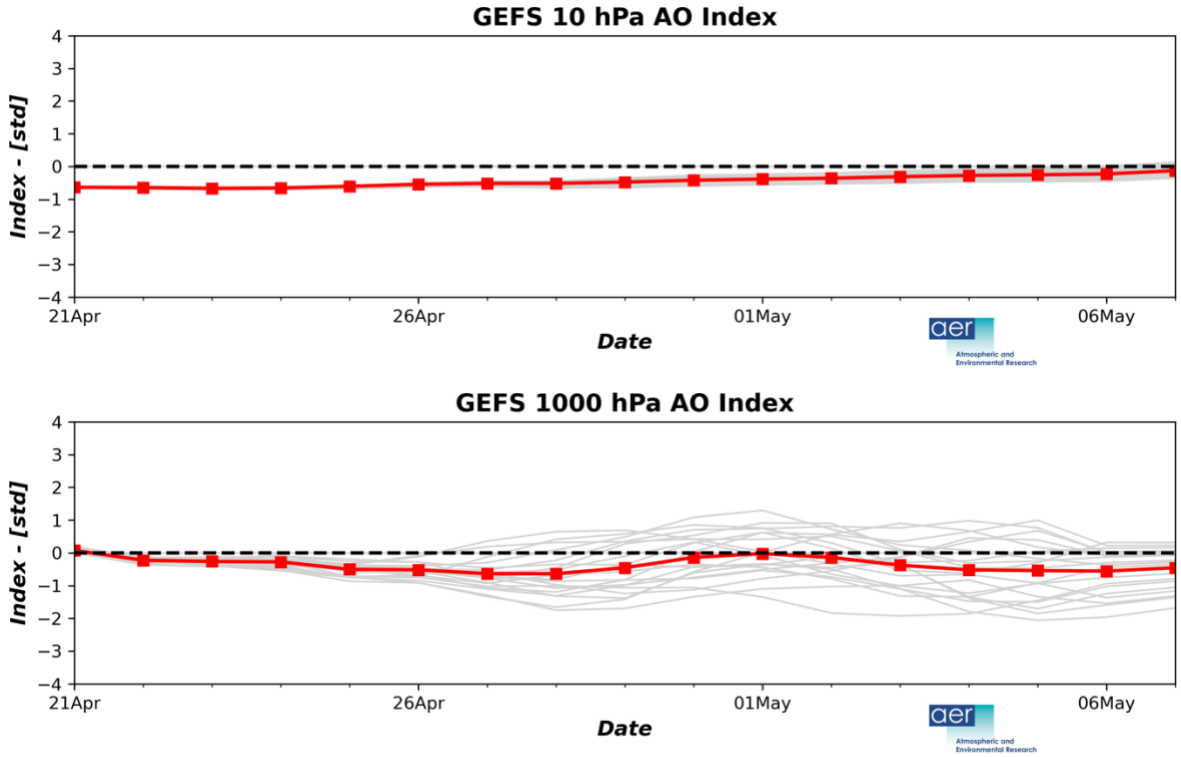

Figure 1. a) The predicted daily-mean AO at 10 hPa from the 00Z 21 Apr 2025 GFS ensemble. b) The predicted daily-mean AO at 1000 hPa from the 00Z 21 Apr 2025 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble mean AO index given by the red line with squares.

This week predicted ridging/positive geopotential height anomalies across Greenland will favor troughing/negative geopotential height anomalies centered in the Barents-Kara Seas but also including Scandinavia with ridging/positive geopotential height anomalies dominating much of the rest of Europe (**Figure 2).** This pattern will favor widespread normal to above normal temperatures across Europe including the UK with normal to below normal temperatures limited to Scandinavia this period (**Figure 3**). This week ridging/positive geopotential height anomalies are predicted to dominate most of Asia with troughing/negative geopotential height anomalies limited to far Northwestern Asia but extending southeastward all the way to East Asia (**Figure 2**). This pattern favors normal to above normal temperatures widespread across Asia with normal to below normal temperatures limited to Northwestern Russia and parts of Southern Siberia and Northeast Asia **(Figure 3**).

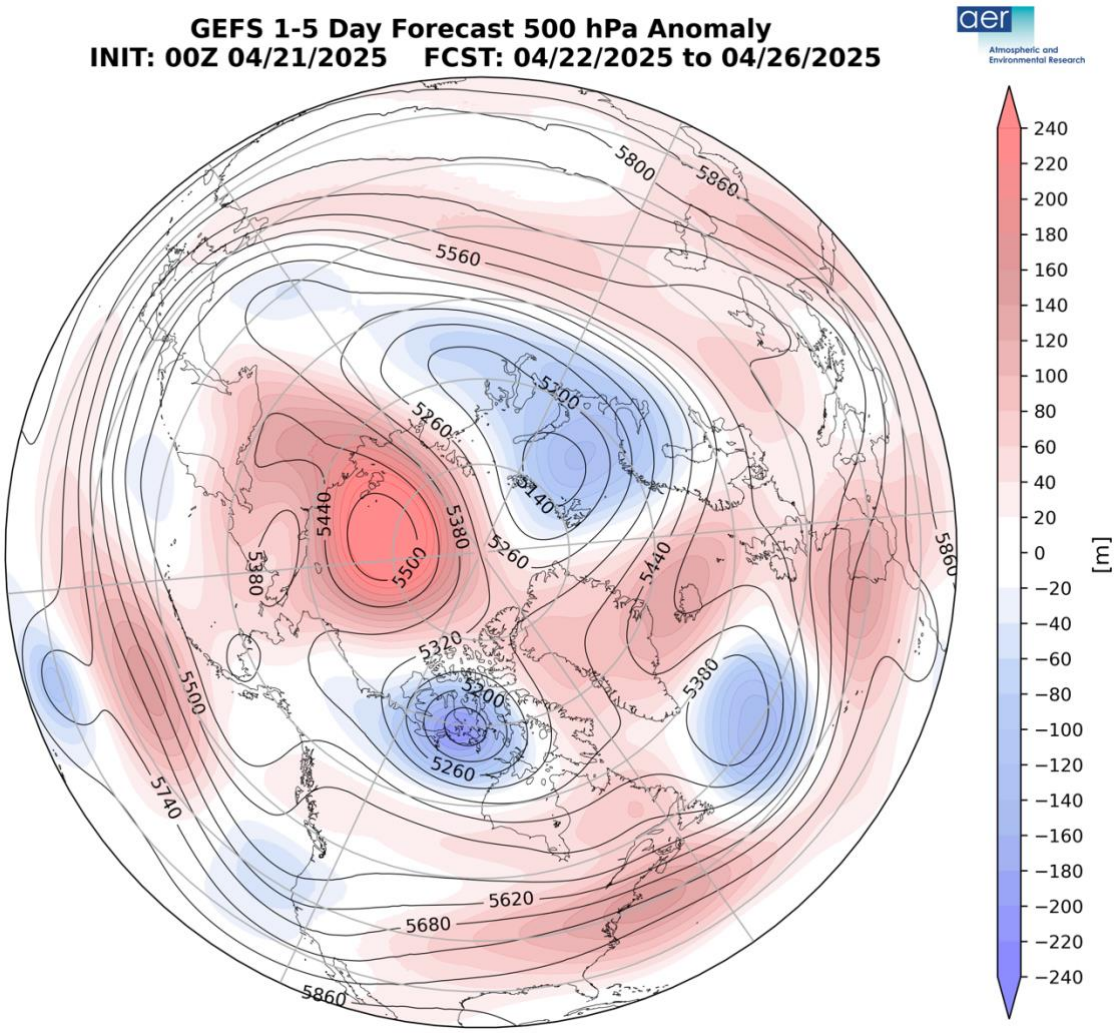

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 22 Apr to 26 Apr 2025. The forecasts are from the 00Z 21 Apr 2025 GFS ensemble.

This week ridging/positive geopotential height anomalies are predicted to dominate Canada and the US with the exceptions of troughing/negative geopotential height anomalies across Alaska, Northwestern Canda and the Northwestern US (**Figure 2**). This pattern favors normal to above normal temperatures across eastern much of Canada and the US with normal to below normal temperatures across western Alaska, Northwestern Canda and the Northwestern US. (**Figure 3**).

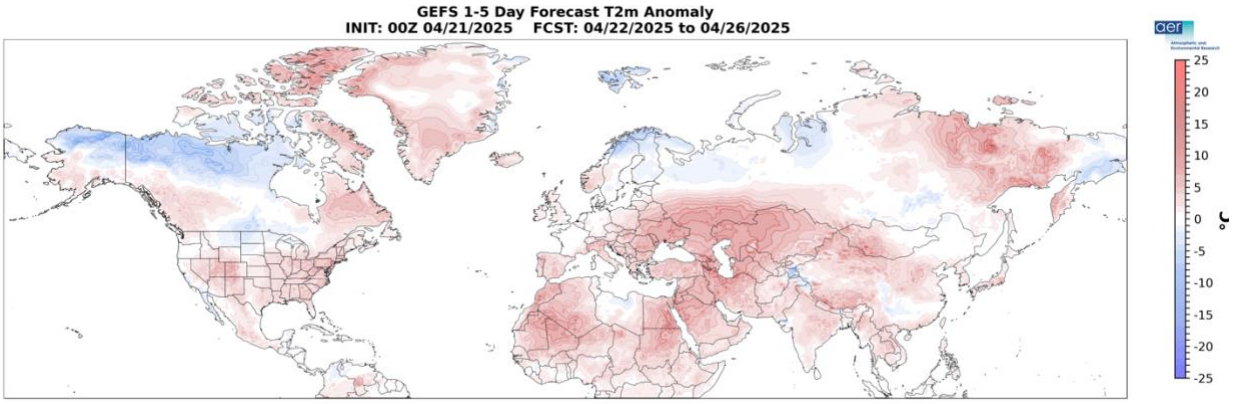

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 22 Apr to 26 Apr 2025. The forecasts are from the 00Z 21 Apr 2025 GFS ensemble.

Troughing will support new rainfall across Central Europe, Southeast Asia 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 Southeastern US with otherwise mostly dry conditions widespread across Canada and the US this week (**Figure 4**).

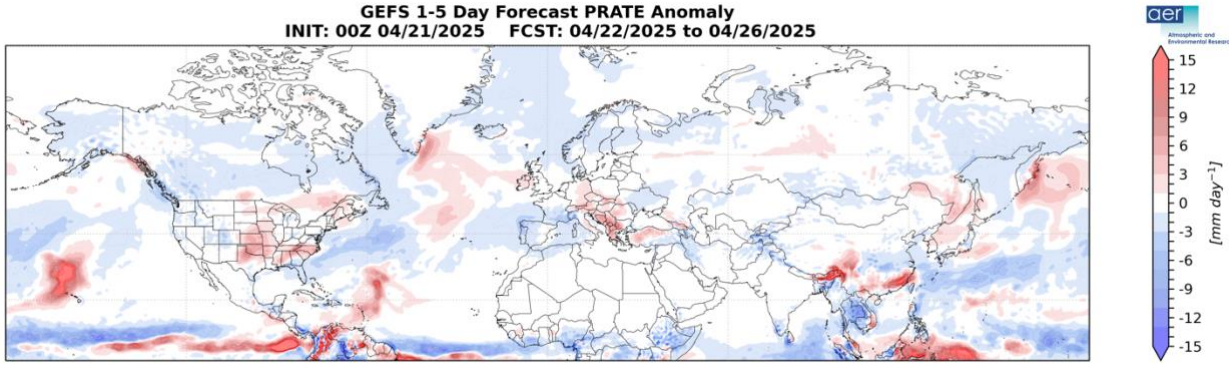

Figure 4. Forecasted rainfall (mm/day; shading) from 22 Apr to 26 Apr 2025. The forecasts are from the 00Z 21 Apr 2025 GFS ensemble.

Near-Mid Term

Next week

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

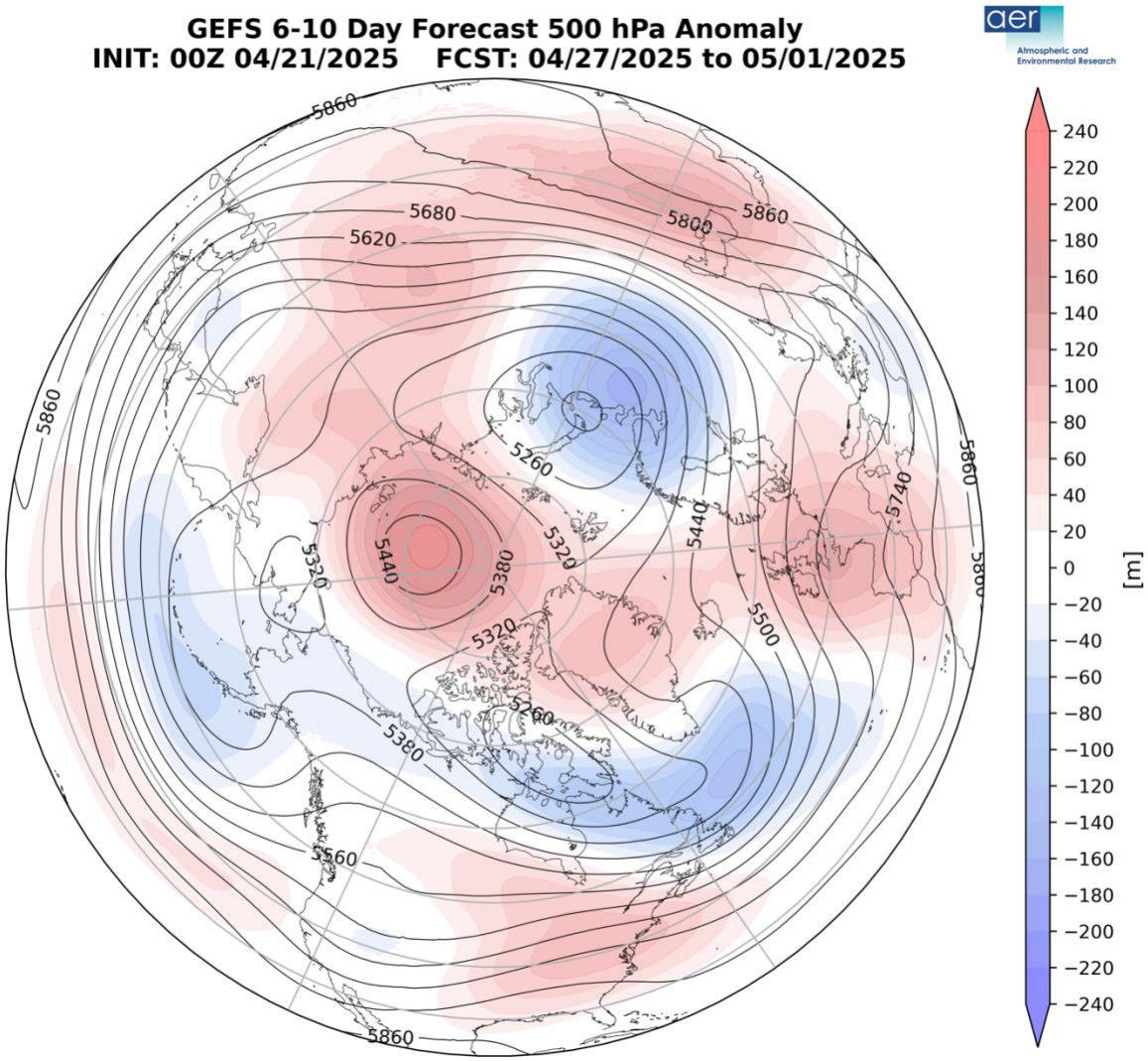

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 27 Mar to 01 May 2025. The forecasts are from the 00Z 21 Apr 2025 GFS ensemble.

Once again ridging/positive geopotential height anomalies are predicted to dominate Western Europe with troughing/negative geopotential height anomalies across

Northeastern Europe (**Figure 5**). This pattern will favor widespread normal to above normal temperatures across Western and Southern Europe including the UK with normal to below normal temperatures across Northern and Eastern Europe this period (**Figure 6**). Ridging/positive geopotential height anomalies will continue to dominate Asia with the amin exception of troughing/negative geopotential height anomalies centered on the Urals and a weak into extension into East Asia (**Figure 5**). This pattern favors widespread normal to above normal temperatures across most of Asia with normal to below normal temperatures limited to Western Russia and Northeast China this period (**Figure 6**).

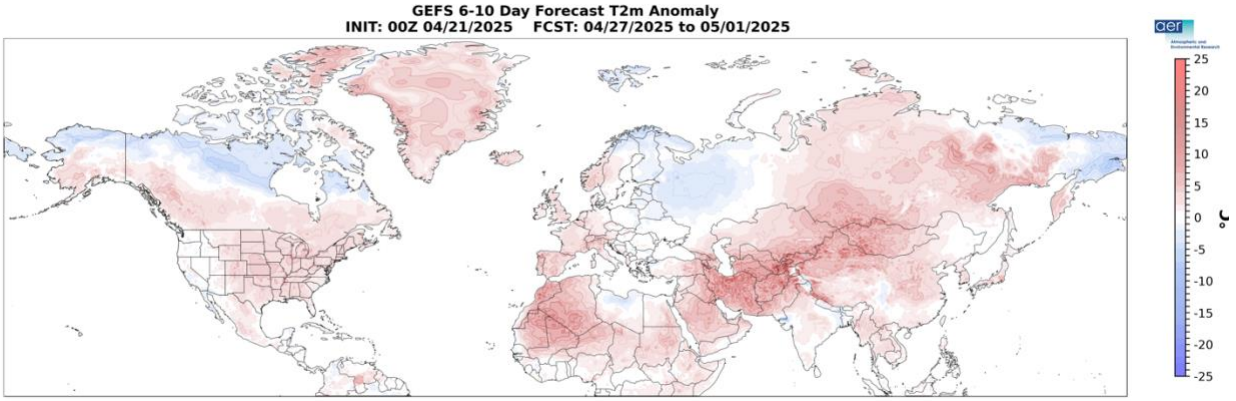

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 27 Apr to 01 May 2025. The forecasts are from the 00Z 21 Apr 2025 GFS ensemble.

The pattern across North America is with ridging/positive geopotential height anomalies dominating Southern Canada and the US with troughing/negative geopotential height anomalies across Alaska, Northern Canada and the Western US this period (**Figure 5**). This pattern will favor normal to below normal temperatures widespread across Southern Canada and the US with normal to below normal temperatures across Alaska, Northern Canada and the Western US (**Figure 6**).

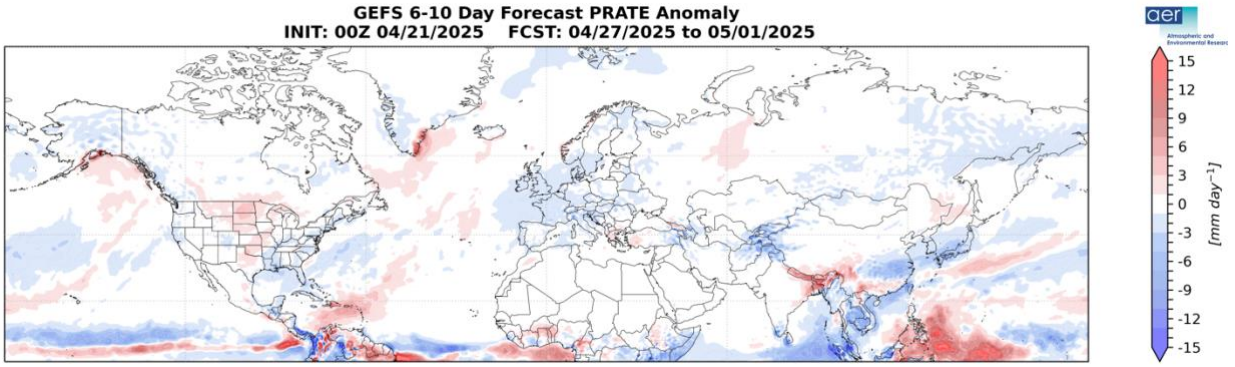

Figure 7. Forecasted snow depth changes (mm/day; shading) from 27 Apr to 01 May 2025. The forecasts are from the 00Z 21 Apr 2025 GFS ensemble.

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

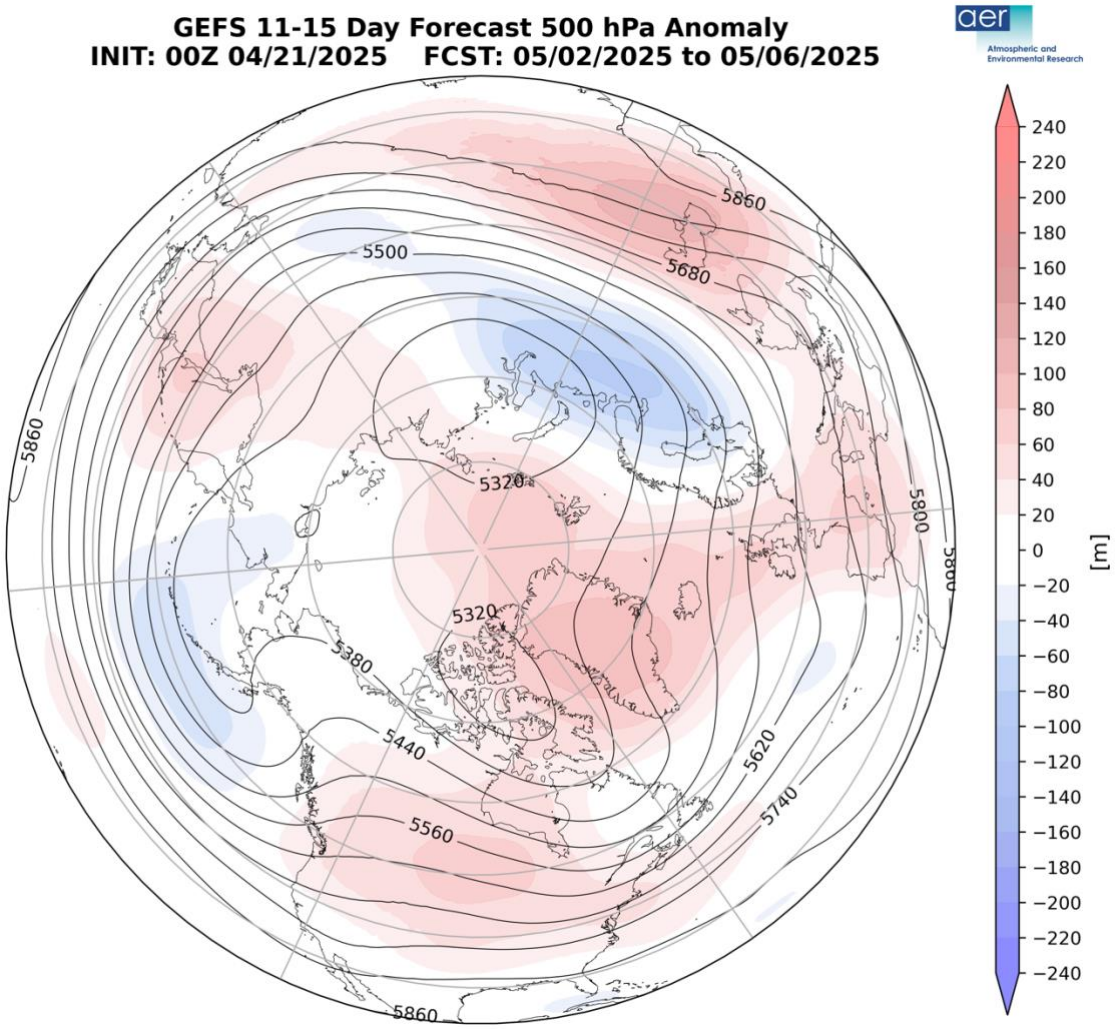

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 02 May to 06 May 2025. The forecasts are from the 00Z 21 Apr 2025 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to continue to dominate much of Western Europe with troughing/negative geopotential height anomalies across Northeastern Europe this period (**Figure 8**). This pattern should favor normal to above normal temperatures widespread across Western and Southern Europe including the UK with normal to below normal temperatures across Northern and Eastern Europe this period (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to dominate Asia with persistent troughing/negative geopotential height anomalies centered over the Urals and extending into East 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 Western Russia, Mongolia and Northeastern China this period (**Figure 9**).

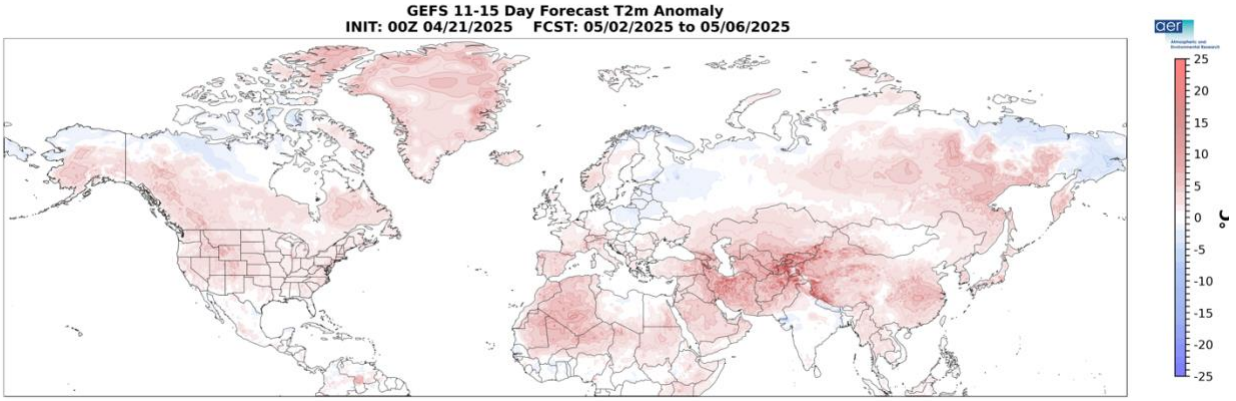

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 02 May to 06 May 2025. The forecasts are from the 00Z 21 Apr 2025 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to dominate North America with weak troughing/negative geopotential height anomalies across northern Alaska, Northern Canada and the Eastern US this period (**Figure 8**). This pattern supports normal to above normal temperatures across southern Alaska, Southern Canada and the much of the US with normal to below normal temperatures across northern Alaska, Northern Canada and the Eastern US (as predicted by the ECMWF but not showing up in the GFS forecasts) this period (**Figure 9**).

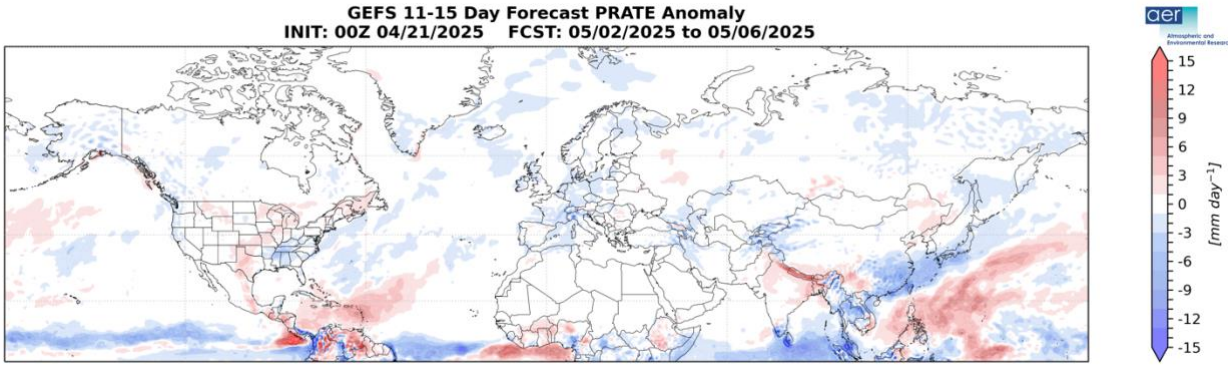

Figure 10. Forecasted snow depth changes (mm/day; shading) from 02 May to 06 May 2025. The forecasts are from the 00Z 21 Apr 2025 GFS ensemble.

Troughing will support new rainfall across Southeast Asia and the Tibetan Plateau with otherwise mostly dry conditions widespread across Europe and Asia this week (**Figure 10**). Troughing will support new rainfall across the Central and Northeastern US with otherwise mostly dry conditions widespread across Canada and the US this week (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows warm/positive PCHs throughout the stratosphere and the troposphere (**Figure 11**). The strongest warm/positive PCHs are currently in the lower stratosphere and are predicted to descend all the way to the surface this week. This is likely the climactic impact from the PV disruption in March, though given that it is late April, the resultant weather will be far less dramatic than had it occurred two months earlier. Then the warm/positive PCHs in the lower troposphere are predicted to weaken next week and then possibly strengthen again in early May but not by much. The warm/positive PCHs in the stratosphere represent a sudden stratospheric warming (SSW) but will be defined as a Final Warming. The influence from the SSW is clearly waning.

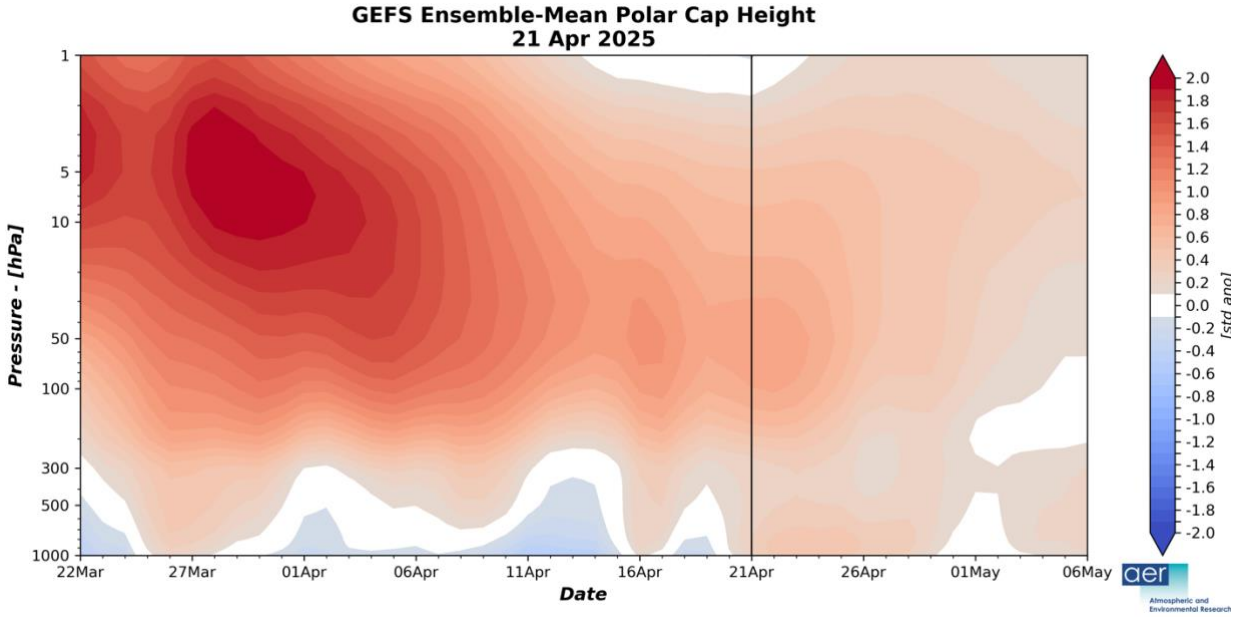

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 21 Apr 2025 GFS ensemble.

The predicted warm/positive PCHs in the lower troposphere for most of the next two weeks (**Figure 11**) are consistent with the predicted neutral to slightly negative surface AO the next two weeks (**Figure 1**).

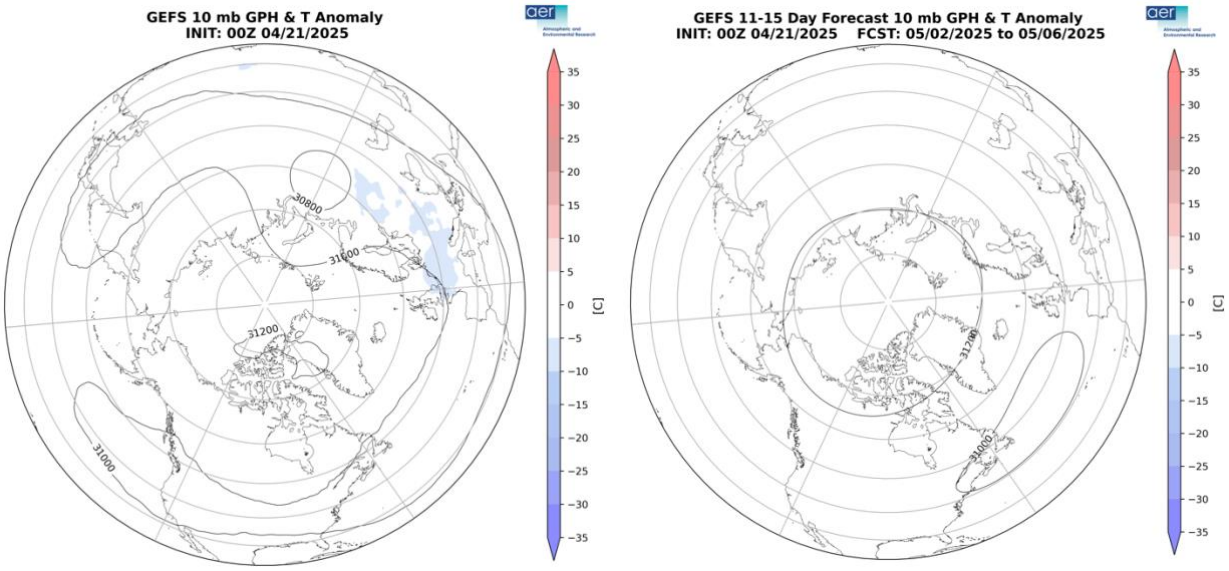

Figure 12. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 21 Apr 2025. (b) Same as (a) except forecasted averaged from 02 May to 06 May 2025. The forecasts are from the 00Z 21 Apr 2025 GFS model ensemble.

Yes, the polar vortex (PV) is still alive and kicking centered over the Urals with relatively coldest temperatures across Europe with high pressure over the central Arctic and the relatively warmest temperatures across the Arctic Ocean in the polar stratosphere (**Figure 13a**). This is consistent with an ongoing SSW. Then in early May the PV is predicted to slide close to the Northeastern US in the polar stratosphere. The relatively coldest temperatures are predicted across mid-latitudes and the warmest temperatures spread across the Arctic Ocean in the stratosphere (**Figure 13b**). This is consistent with an SSW or Final Warming. The stratospheric AO in **Figure 1** this week and next week will be persistently negative, but climbing towards neutral ad the whole cycle of the PV disruption winds down.

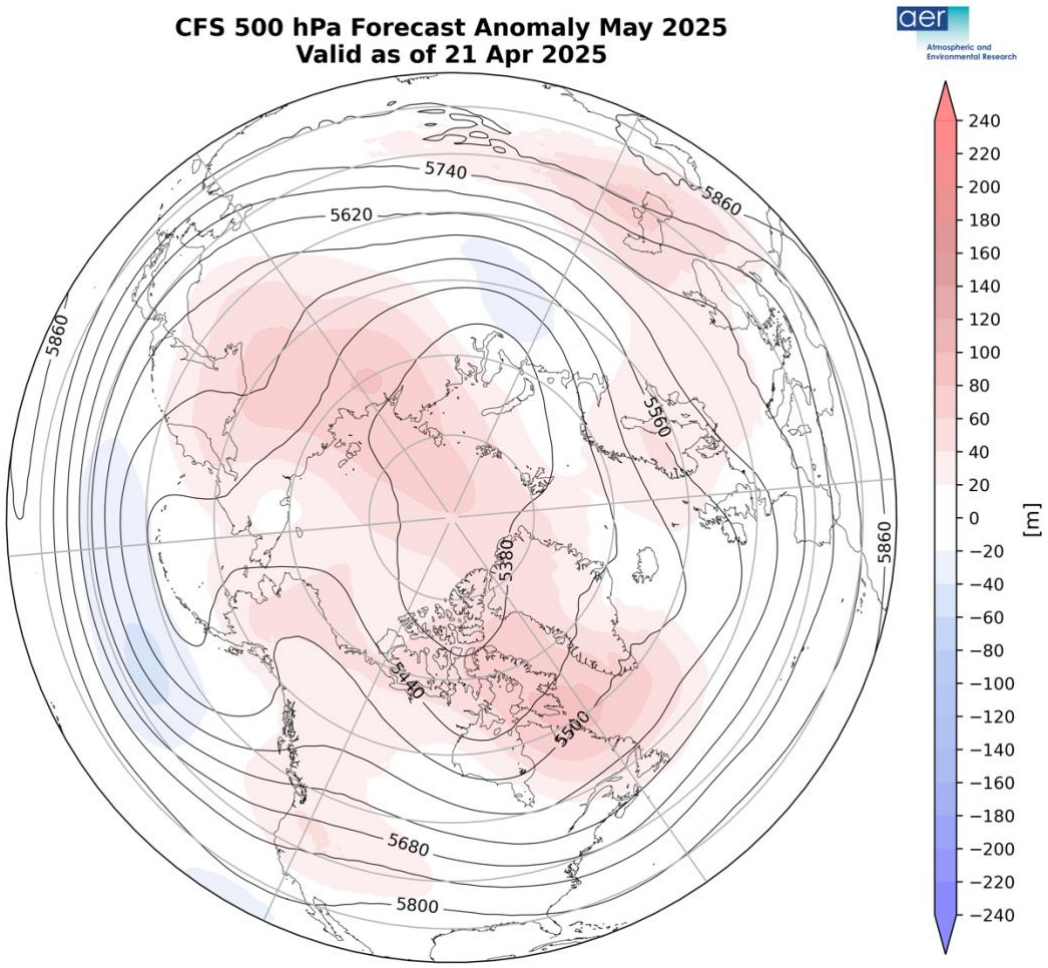

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for May 2025. The forecasts are from the 00Z 21 Apr 2025 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and surface temperatures for May (**Figure 15**) from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging centered south in Baffin Bay, Scandinavia, the Laptev Sea into Siberia, Southwest Asia, Alaska, Western Canada and the Western US with troughing across Western Europe, the Urals, centered around the Dateline and near the Aleutians, Eastern Canada and the Northeastern US (**Figure 14**). This pattern favors seasonable to relatively warm temperatures across Northern and Eastern Europe, much of Asia, especially Southern Asia and Siberia, Alaska, Western and Northern Canada and the Western US with seasonable to relatively cool temperatures across Western Europe, Southern Siberia and Kazakhstan, parts of East Asia, Southeastern Canada and the Eastern US (**Figure 15**). You can almost convince yourself that the pattern resembles the tropospheric response to an SSW.

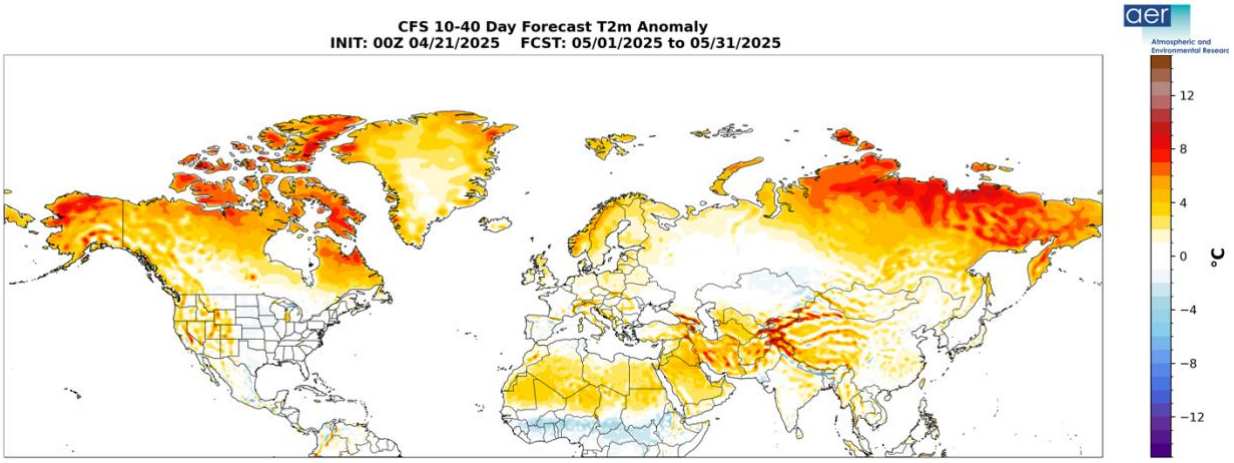

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for May 2025. The forecasts are from the CFS 00Z 21 Apr 2025.

Boundary Forcings

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are below normal, between the Dateline and Indonesia, indicating that the winter La Niña event is waning (**Figure 17**) and neutral conditions are expected through the spring. 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 off of the US Mid-Atlantic coast though below normal SSTs exist regionally especially in the South Pacific.

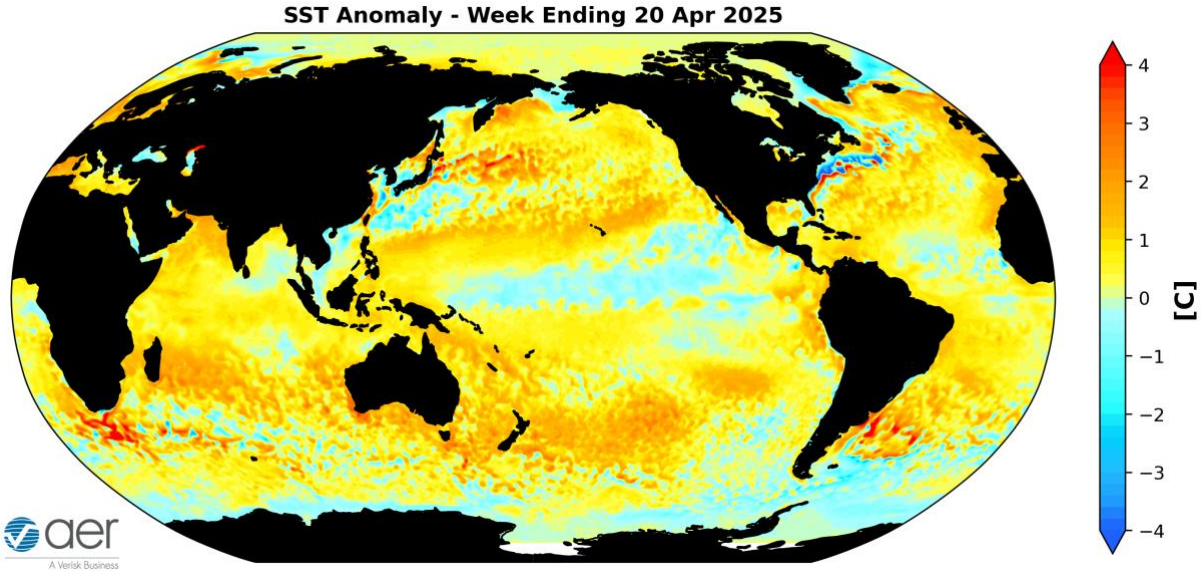

Figure 17. The latest daily-mean global SST anomalies (ending 20 Apr 2025). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently the Madden Julian Oscillation (MJO) is weak where no phase is favored (**Figure 18**). The forecasts are for the MJO to remain overall weak but to emerge in phase seven and eight in late April and early May. Phases seven and eight favor ridging in the western North America and troughing in the Eastern US. Therefore, it seems to me that the MJO may have some but not obvious influence on North American weather for the next two weeks. But admittedly this is outside of my expertise.

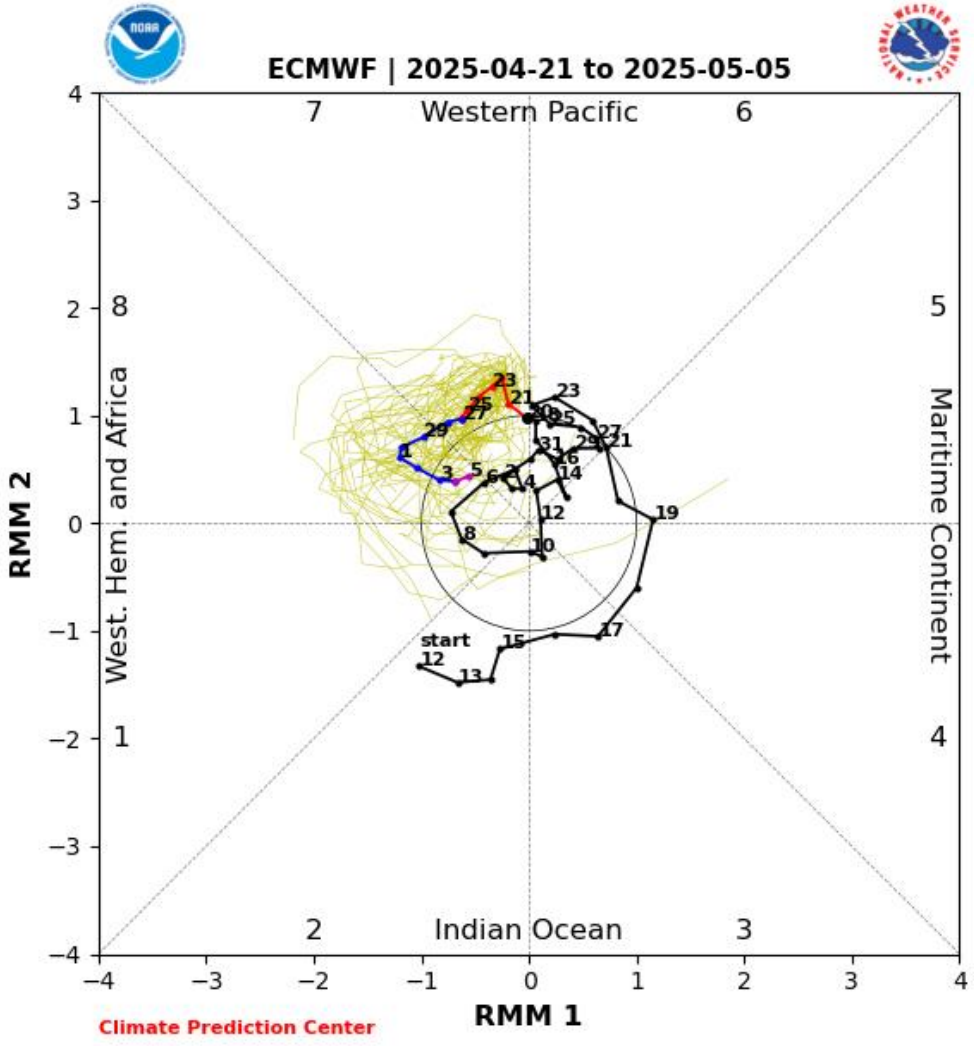

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 21 Apr 2025 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model 'spread' is denoted by the gray shading. Sector numbers indicate 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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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. 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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