Arctic Oscillation and Polar Vortex Analysis and Forecasts

May 5, 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 positive and is predicted to slowly trend negative as pressure/geopotential height anomalies across the Arctic are currently mostly negative and are predicted to slowly turn more positive over the next two weeks. The North Atlantic Oscillation (NAO) is currently positive as negative pressure/geopotential height anomalies dominate across Greenland and the NAO is predicted to trend negative the next two weeks as pressure/geopotential height anomalies are predicted to become increasingly positive across Greenland.
- Over the next two weeks, ridging/positive geopotential height anomalies strung from west to east from the United Kingdom (UK) to the Laptev Sea will force troughing/negative geopotential height anomalies across much of Europe. This pattern will support widespread normal to below normal temperatures across most of Europe including the UK this week and into next week with the biggest exceptions of normal to above normal temperatures across the Balkans this week and Scandinavia and the UK next week as ridging north of Europe sags south.
- Over the next two weeks, ridging/positive geopotential height anomalies centered in the Laptev Sea will favor troughing/negative geopotential height anomalies centered across Northwestern Russia and Siberia extending southeastward into East Asia. This pattern favors normal to above normal temperatures widespread across Asia with normal to below

normal temperatures across Northwestern Russia and Southern Siberia extending into parts of East Asia.

- The general pattern across North America the next two weeks is troughing/negative geopotential height anomalies across Alaska and the Gulf of Alaska slowly making its way to the West Coast and will force ridging/positive geopotential height anomalies across the Western United States (US) and into Southern Canada with more troughing/negative geopotential height anomalies across the Eastern US and Northeastern Canada. This patten will favor widespread normal to above normal temperatures across Southern Canada and the Western US with normal to below normal temperatures across Alaska, Northeastern Canada and the Eastern US this week into next week and then starting next week in the Western US.
- The polar vortex (PV) is ending its world tour over Southeastern Canada and the Northeastern US until next fall. This should be followed by the more typical summer pattern across the Northern Hemisphere eventually but does the second half of May still have one more surprise.

Plain Language Summary

Widespread warmth dominated the land areas of the Northern Hemisphere (NH) in April especially across Eurasia (see **Figure**). The warmth occurred despite the large polar vortex (PV) disruption of early March. However, the biggest exception was in Eastern Canada and the Northeastern US (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 North Atlantic side of the Arctic resulting in a much cooler relative to normal first half May in Europe (see **Figures 3, 6** and **9**). A pair of cutoff lows in the mid-troposphere in the Eastern US, that I would argue are related to the last dying remnants of the PV will also bring cooler weather to the Eastern US in early May (see **Figures 3** and **6**).

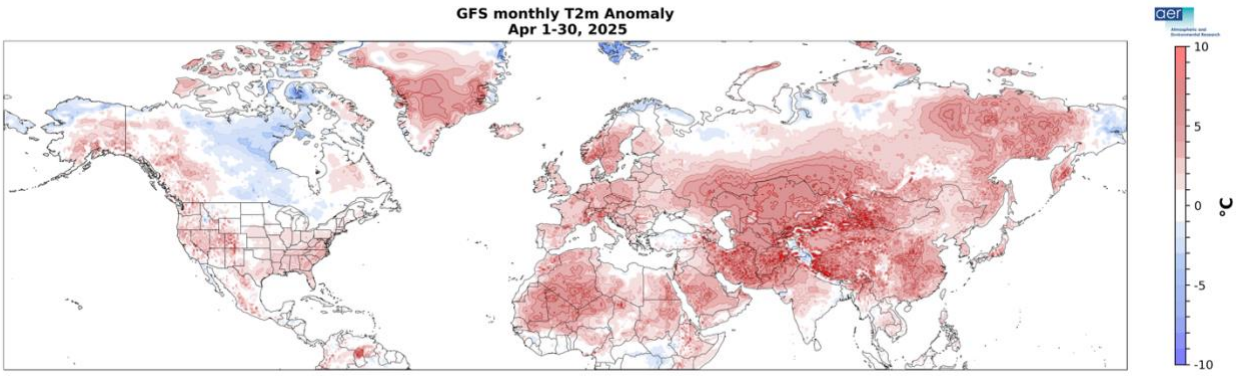

Figure. Estimate of the observed surface temperatures (°C; shading) from 01 Apr to 30 Apr 2025 based on GFS initializations and the GFS forecast from the 01 May 2025 run.

Impacts

Maybe like all good addicts, I tell myself I need just one last fix of the polar vortex (PV). The PV is currently over Southeastern Canada and the Northeastern US (see **Figure i**). In the previous blog I did discuss the possibility of cooler weather than predicted two weeks ago for early May and the formation of cutoff lows in the Eastern US related to the arrival of the PV to the region and both have materialized. This week and into next week, two cutoff lows in the Eastern US are predicted (see **Figure ii**) and cooler temperatures (see **Figures 3** and **6**). I thought that the relatively coolest temperatures would show up in the Northeastern US but instead are to the west and south from the lower Great Lakes into the Southeastern US. This makes sense as the coolest temperatures tend to result in the northerly flow to the west and south of the low center.

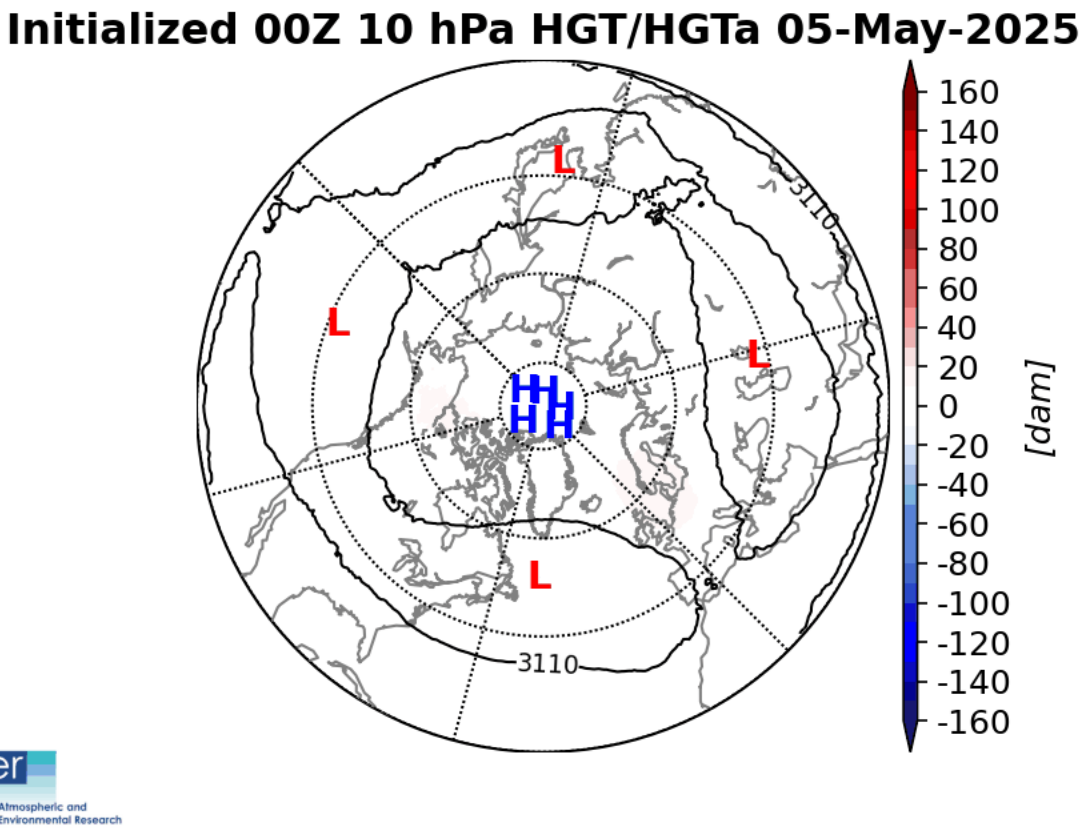

Figure ii. Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 05 May 2025 and forecasted from 06 May to 20 May 2025. The forecasts are from the 00Z 05 May 2025 GFS model ensemble.

I also thought that Greenland blocking could put an exclamation mark to the climatic end of the PV disruption in early May but so far that has not happened. Instead, high latitude blocking has formed closer to Europe stretching from the United Kingdom (UK) to the Laptev Sea (see **Figure ii**). Though the blocking is close to Europe, because it is sufficiently far north, it allows for a cool

easterly flow into Europe and similar to Greenland blocking, will result in a much cooler first half of May relative to normal than observed in April across much of Europe (see **Figures 3, 6** and **9**).

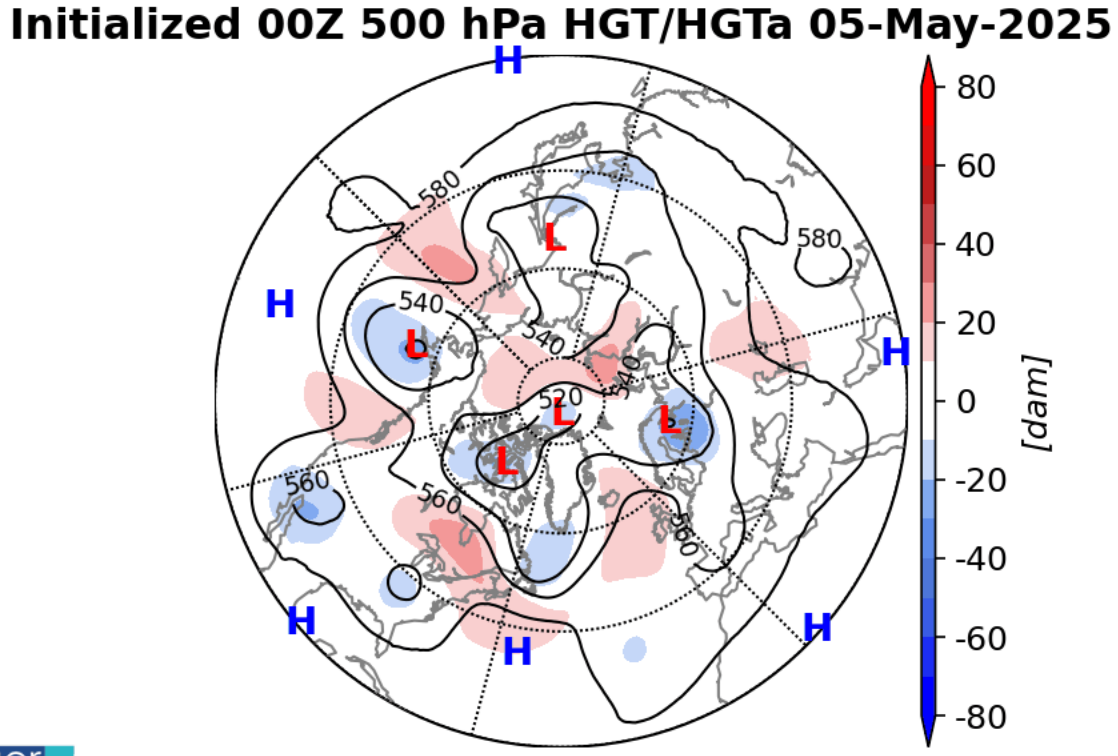

Figure ii. Initialized 500 mb geopotential heights (dam; contours) and decameter anomalies (dam; shading) across the Northern Hemisphere for 05 May 2025 and forecasted from 06 May to 20 May 2025. The forecasts are from the 00Z 05 May 2025 GFS model ensemble.

At the end of the mid-tropospheric animation shown in **Figure ii**, Greenland blocking is predicted. If correct, then the overall relatively cool weather in Europe could persist into the second half of May. Relatively warm temperatures are predicted for now in mid to late May in the Eastern US (see **Figure 9**) but here too, maybe temperatures turn cooler with the onset of Greenland blocking. From the polar cap geopotential height anomalies (PCHs) plot shown in **Figure 11**, it is not obvious that the predicted Greenland blocking is connected to the PV disruption from back in early March. However, the regional version of the PCH plot, limited to the North Atlantic sector, more strongly suggests the connection (see **Figure iii**). As seen in **Figure iii**, the warm/positive PCHs in the lower stratosphere descend to the surface for the second half of May. Also, the warm/positive PCHs show a continuous connection to the much greater in magnitude warm/positive PCHs in the stratosphere back in early April and before that back to the start of the PV disruption in early March.

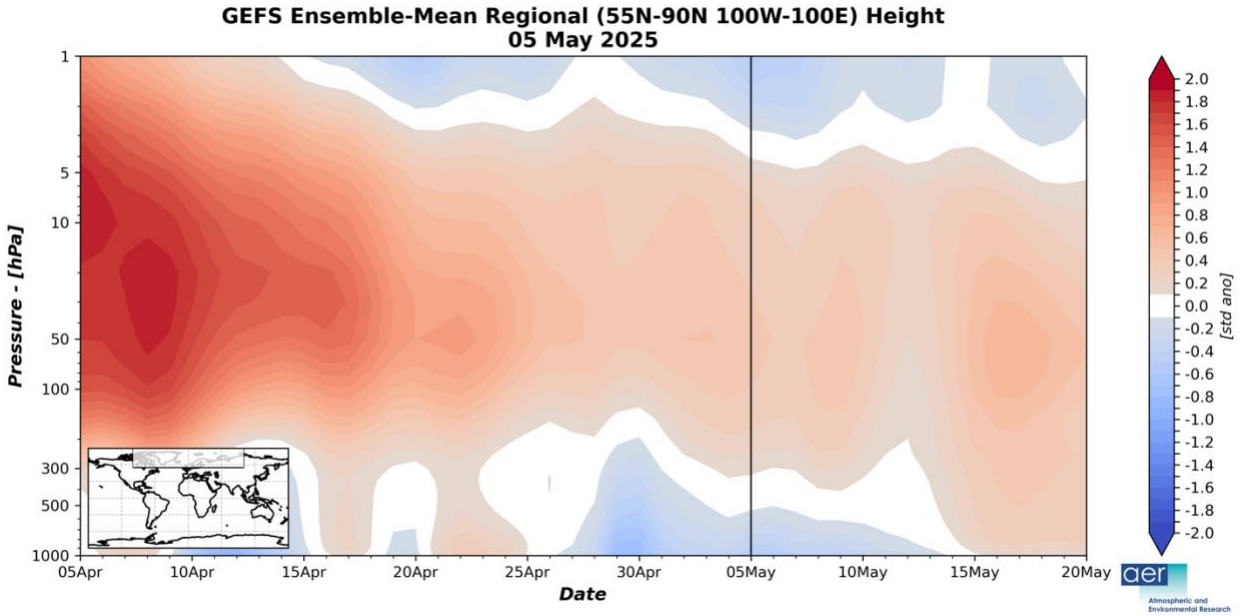

Figure iii. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies for the North Atlantic sector only (see insert). The forecast is from the 00Z 05 May 2025 GFS ensemble.

Finally, the pan Arctic PCHs plot shown in **Figure 11** reminds me of what we observed last summer with this bizarre PCH sandwich with warm/positive PCHs in the mid to lower stratosphere and upper troposphere with warm/positive PCHs in the upper stratosphere and lower troposphere. In this configuration, warmth across the NH was widespread but when the warm/positive PCHs descended to the surface high latitude blocking formed and relatively cooler temperatures at least regionally. This resulted in a relatively cooler summer in parts of East Asia, Northwest Europe and especially the Central and Eastern US. The PCH sandwich seemed strange to me last summer and may have been related to Hong Tonga water vapor in the stratosphere absorbing sunlight and heating the upper atmosphere. Of course, it disappeared once the sun set over the Arctic in fall. It will be interesting to see if it can possibly repeat itself.

Near-Term

This week

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

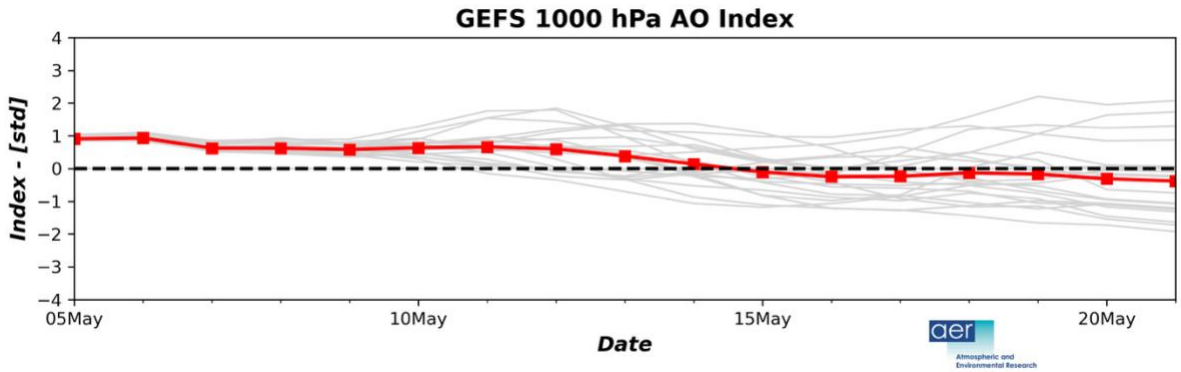

Figure 1. The predicted daily-mean AO at 10 hPa from the 00Z 05 May 2025 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble mean AO index given by the red line with squares.

This week predicted ridging/positive geopotential height anomalies spread across the UK to the Laptev Sea will favor troughing/negative geopotential height anomalies across much of Europe with the exception of ridging/positive geopotential height anomalies across Southeastern Europe (**Figure 2).** This pattern will favor widespread normal to below normal temperatures across Europe including the UK with normal to above normal temperatures limited to the Balkan States this period (**Figure 3**). This week ridging/positive geopotential height anomalies centered in the Laptev Sea will favor troughing/negative geopotential height anomalies across Northwestern Russia and in Siberia and extending into East Asia with more ridging in Central 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 and parts of Southern Siberia and into East Asia **(Figure 3**).

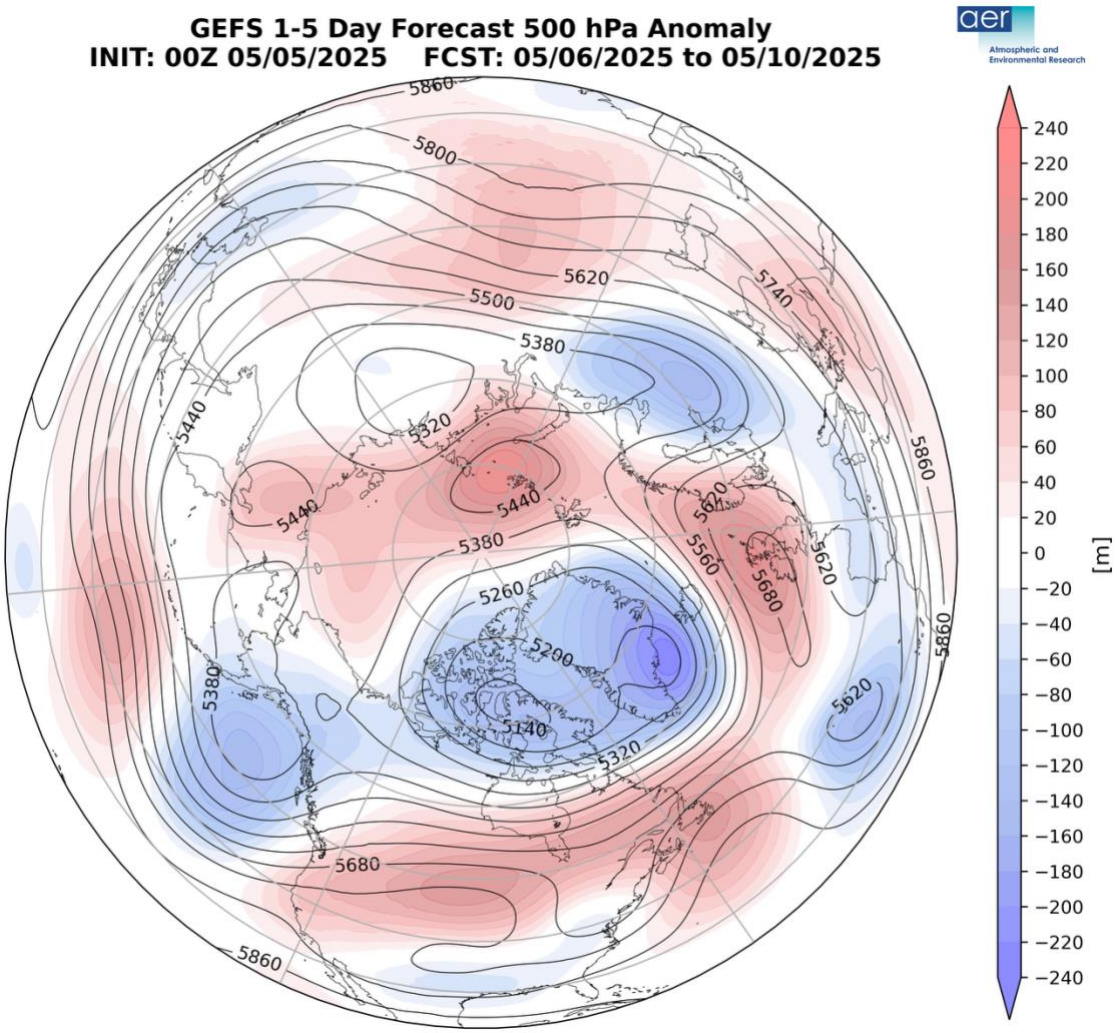

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 06 May to 10 May 2025. The forecasts are from the 00Z 05 May 2025 GFS ensemble.

This week troughing/negative geopotential height anomalies across Alaska and the Gulf of Alaska will force ridging/positive geopotential height anomalies across the Western US and Southern Canada with more troughing/negative geopotential height anomalies across Northern Canda and the Eastern US (**Figure 2**). This pattern favors normal to above normal temperatures across Southern Canada and the Western US with normal to below normal temperatures across Alaska, Northern Canda and the Eastern US. (**Figure 3**).

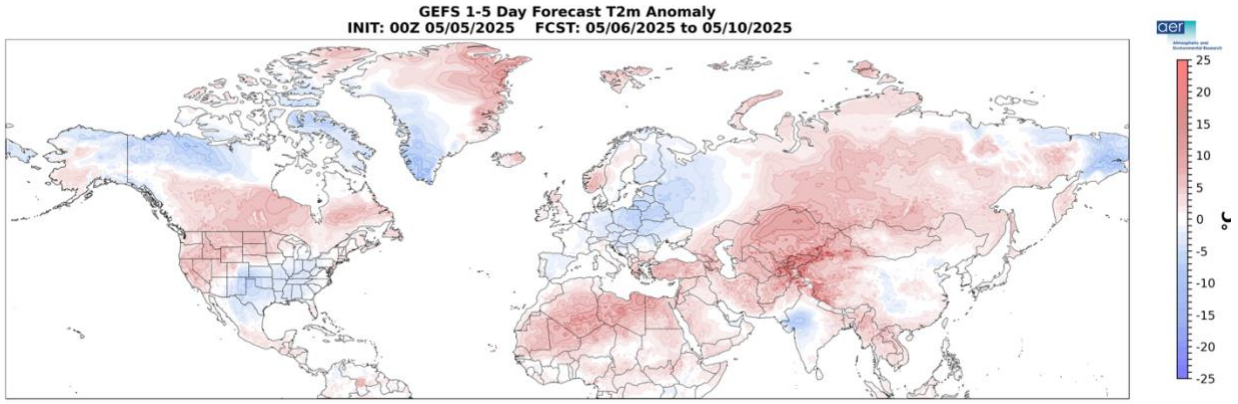

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 06 May to 10 May 2025. The forecasts are from the 00Z 05 May 2025 GFS ensemble.

Troughing will support new rainfall across 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 Southeastern US and New England with otherwise mostly dry conditions widespread across Canada and the US this week (**Figure 4**).

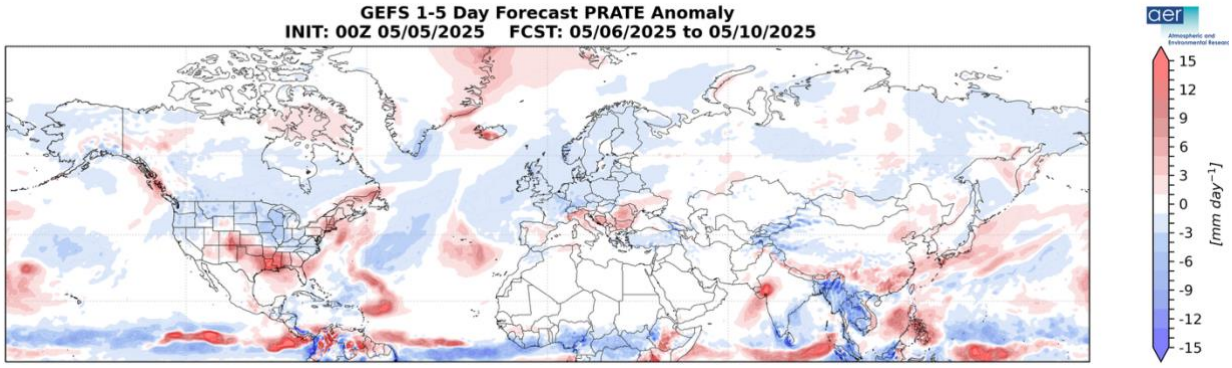

Figure 4. Forecasted rainfall (mm/day; shading) from 06 May to 10 May 2025. The forecasts are from the 00Z 05 May 2025 GFS ensemble.

Near-Mid Term

Next week

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

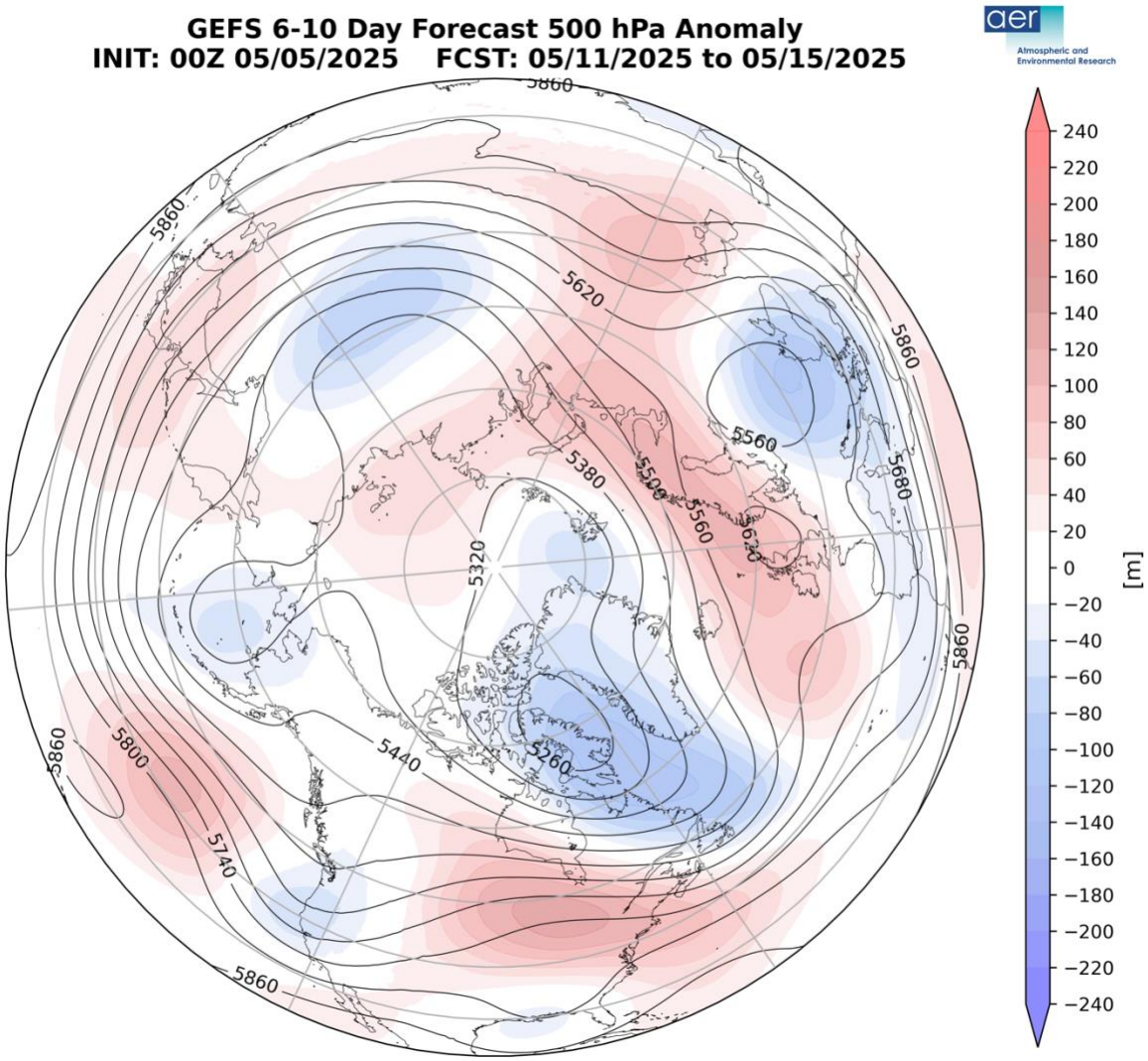

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 11 May to 15 May 2025. The forecasts are from the 00Z 05 May 2025 GFS ensemble.

Once again ridging/positive geopotential height anomalies are predicted to extend from Northern Europe to the Laptev Sea forcing troughing/negative geopotential height anomalies

across much of Europe (**Figure 5**). This pattern will favor normal to above normal temperatures across Scandinavia and the UK with normal to below normal temperatures across Central and Southern Europe this period (**Figure 6**). Ridging/positive geopotential height anomalies will continue to dominate Northern and Southern Asia with troughing/negative geopotential height anomalies in Central Asia centered across Southern Siberia with 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 Southern Siberia this period (**Figure 6**).

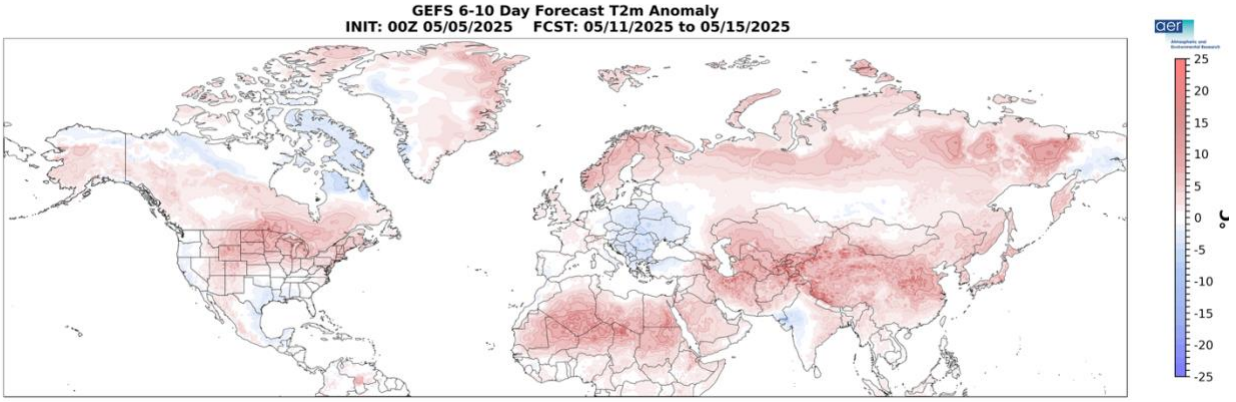

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 11 May to 15 May 2025. The forecasts are from the 00Z 05 May 2025 GFS ensemble.

The predicted pattern across North America is troughing/negative geopotential height anomalies along the West coasts of Canada and the US, which will force ridging/positive geopotential height anomalies dominating Southern Canada and the Northern US with more troughing/negative geopotential height anomalies across Northern Canada and the Southeastern US this period (**Figure 5**). This pattern will favor normal to below normal temperatures widespread across Alaska, Southern Canada and the Northern US with normal to below normal temperatures across Northern Canada, the US West Coast and the Southeastern US (**Figure 6**).

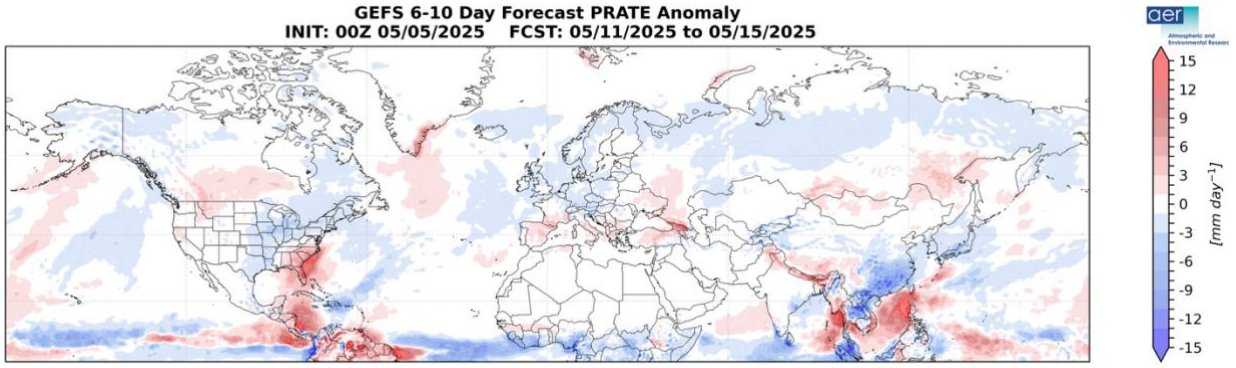

Figure 7. Forecasted snow depth changes (mm/day; shading) from 11 May to 15 May 2025. The forecasts are from the 00Z 05 May 2025 GFS ensemble.

Troughing will support new rainfall across Southwestern and Eastern Europe, Southern Siberia, 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 Plains of Canada and the Northern US and the Southeastern 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 negative this period.

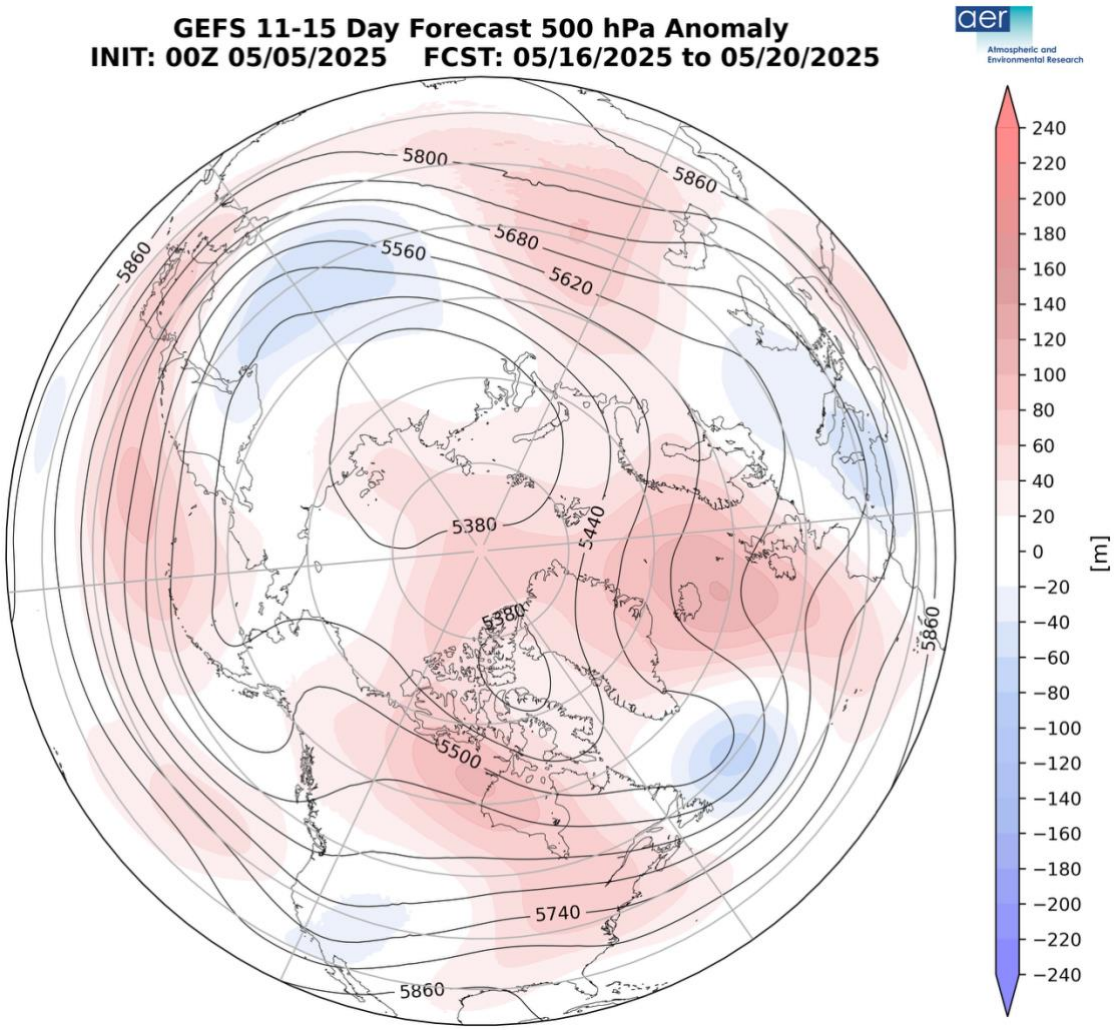

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 16 May to 20 May 2025. The forecasts are from the 00Z 05 May 2025 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to consolidate across Northwestern Europe with troughing/negative geopotential height anomalies across Central and Southern Europe this period (**Figure 8**). This pattern should favor normal to above normal temperatures across Scandinavia the UK with normal to below normal temperatures across Central and Southern Europe this period (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to remain in the Laptev Sea and strengthen across Western Asia forcing troughing/negative geopotential height anomalies across Siberia 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 Southern Siberia, Mongolia and Northeastern China this period (**Figure 9**).

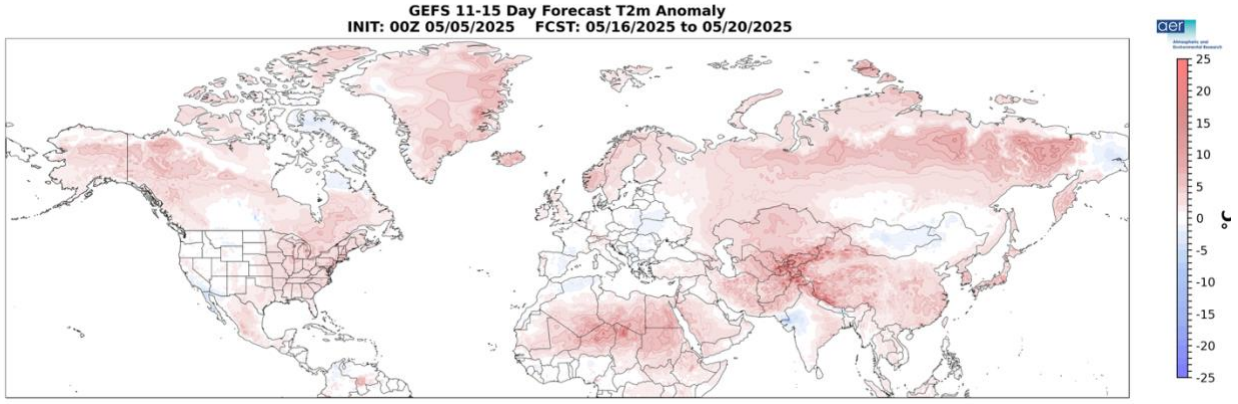

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 16 May to 20 May 2025. The forecasts are from the 00Z 05 May 2025 GFS ensemble.

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

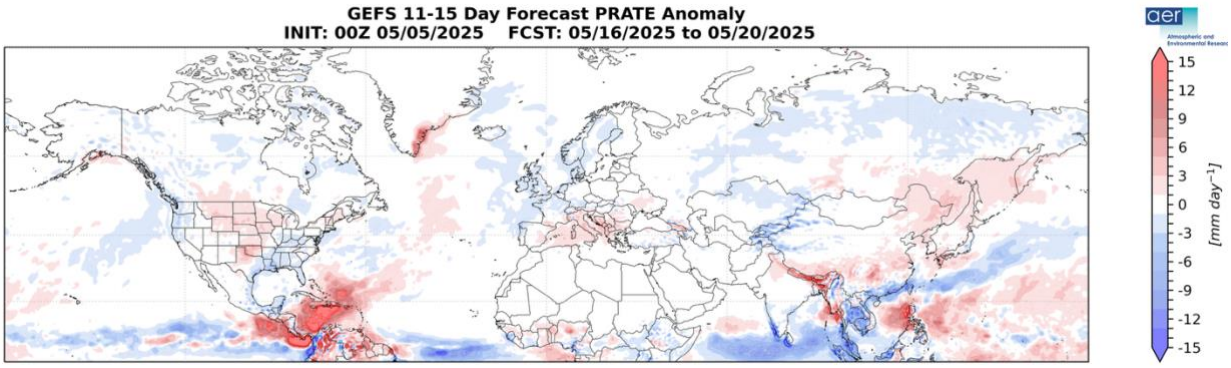

Figure 10. Forecasted snow depth changes (mm/day; shading) from 16 May to 20 May 2025. The forecasts are from the 00Z 05 Apr 2025 GFS ensemble.

Troughing will support new rainfall across Southern Europe, Northeast 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 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 mid to low stratosphere and the upper and mid-troposphere with cold/negative PCHs in the upper stratosphere and lower troposphere (**Figure 11**). The warm/positive PCHs are predicted to descend all the way to the surface the third week of May. Hard to know if this is the final impact from the PV disruption (but see Impacts section) in March or just the atmosphere flipping into summer mode. For those who remember last summer was dominated by a similar PCH sandwich with warm/positive PCHs in the mid to lower stratosphere and upper troposphere with warm/positive PCHs in the upper stratosphere and lower troposphere. The long duration warm/positive PCHs in the stratosphere represent a sudden stratospheric warming (SSW) but defined as a Final Warming from back in March. The influence from the SSW is clearly waning.

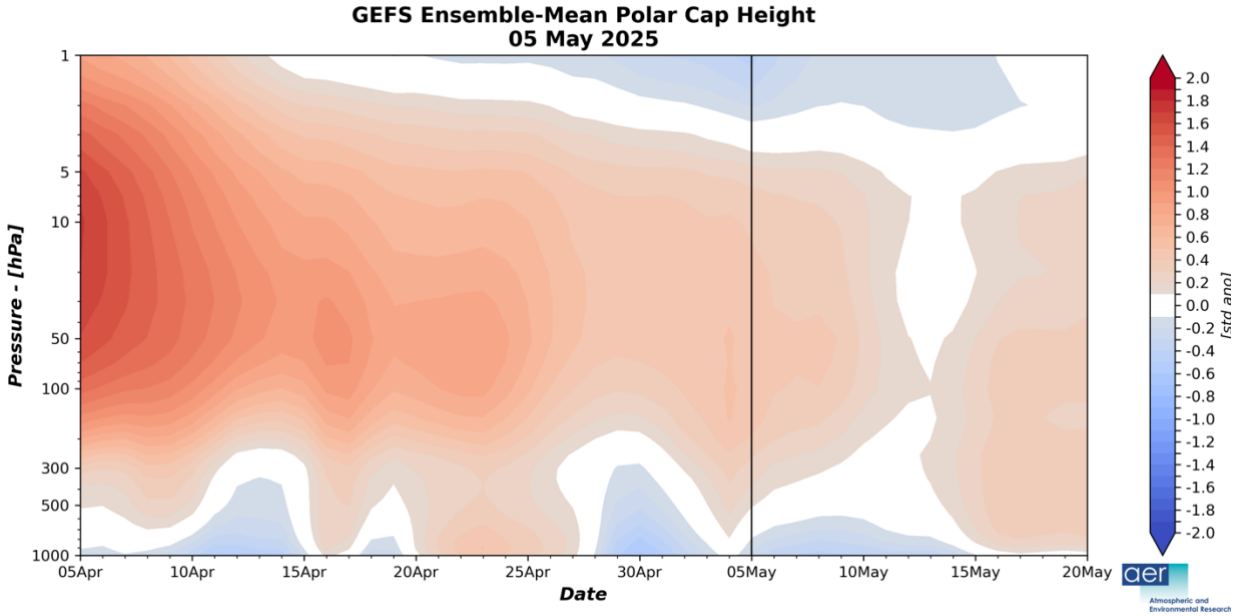

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 05 May 2025 GFS ensemble.

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

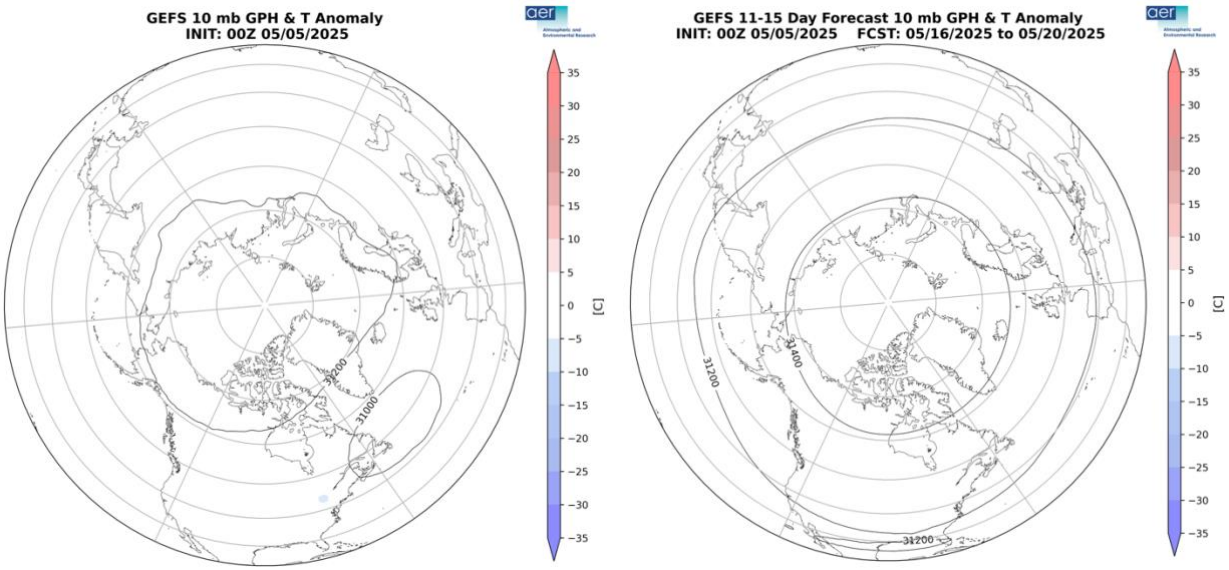

Figure 12. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 05 May 2025. (b) Same as (a) except forecasted averaged from 16 May to 20 May 2025. The forecasts are from the 00Z 05 May 2025 GFS model ensemble.

The polar vortex (PV) is on life support and over Southeastern Canada and the Northeastern US with high pressure dominating the Arctic (**Figure 13a**). This is consistent with an ongoing SSW/Final Warming. Then in mid-May the PV is predicted to completely disappear with no discernable low center and only high pressure in the polar stratosphere (**Figure 13b**). This is consistent with the summer mode of the polar stratosphere until the return of the PV in early fall.

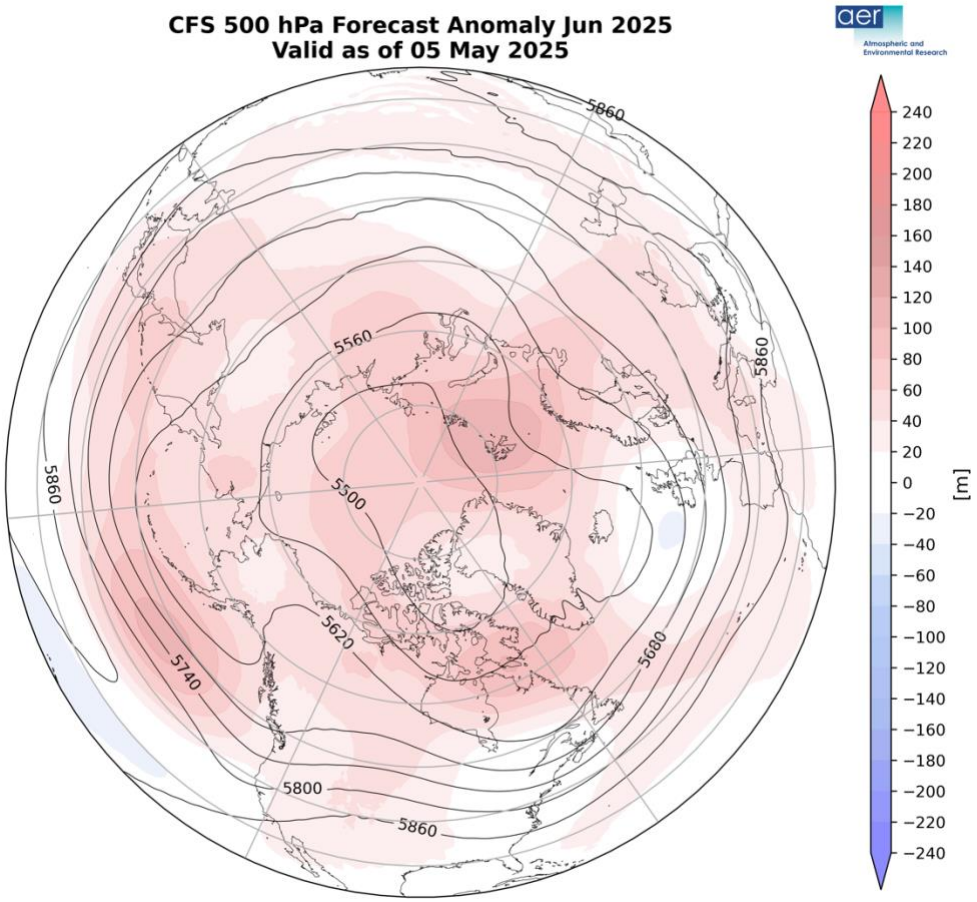

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for June 2025. The forecasts are from the 00Z 05 May 2025 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and surface temperatures for June (**Figure 15**) from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging centered in Baffin Bay, Barents, Kara and Laptev Seas, East Asia, Alaska, Western Canada and the Western US with troughing across Western Europe, Central Asia, centered around the Dateline and near the Aleutians, the US West Coast, 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 Northern Siberia and the Tibetan Plateau, Alaska, Alaska, Western and Northern Canada and the Western US with seasonable to relatively cool temperatures across Western Europe, Central Asia centered on Kazakhstan, Southeastern Canada and the Eastern US (**Figure 15**).

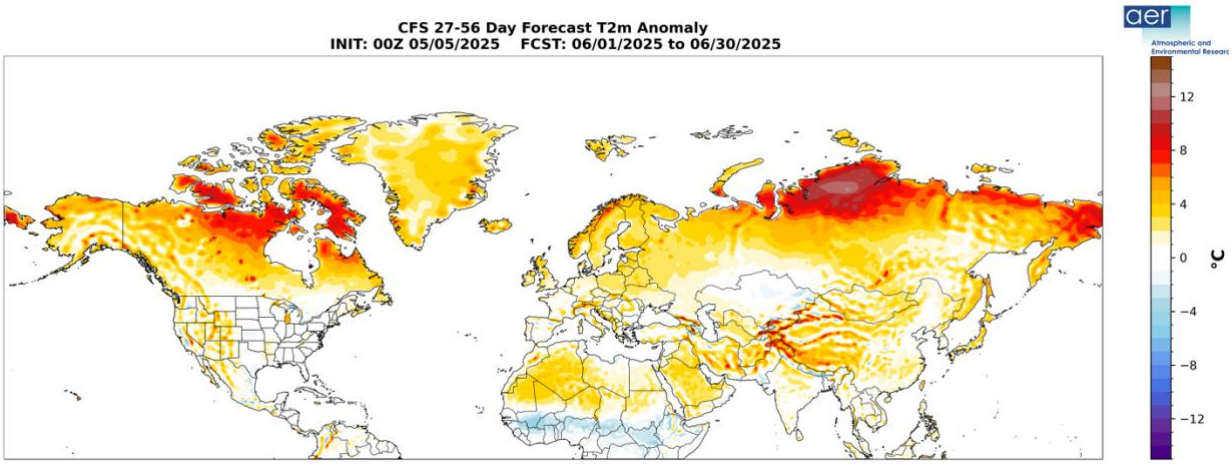

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for May 2025. The forecasts are from the CFS 00Z 05 May 2025.

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 17**) 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 off of the Canadian Maritimes though below normal SSTs exist regionally especially in the South Pacific.

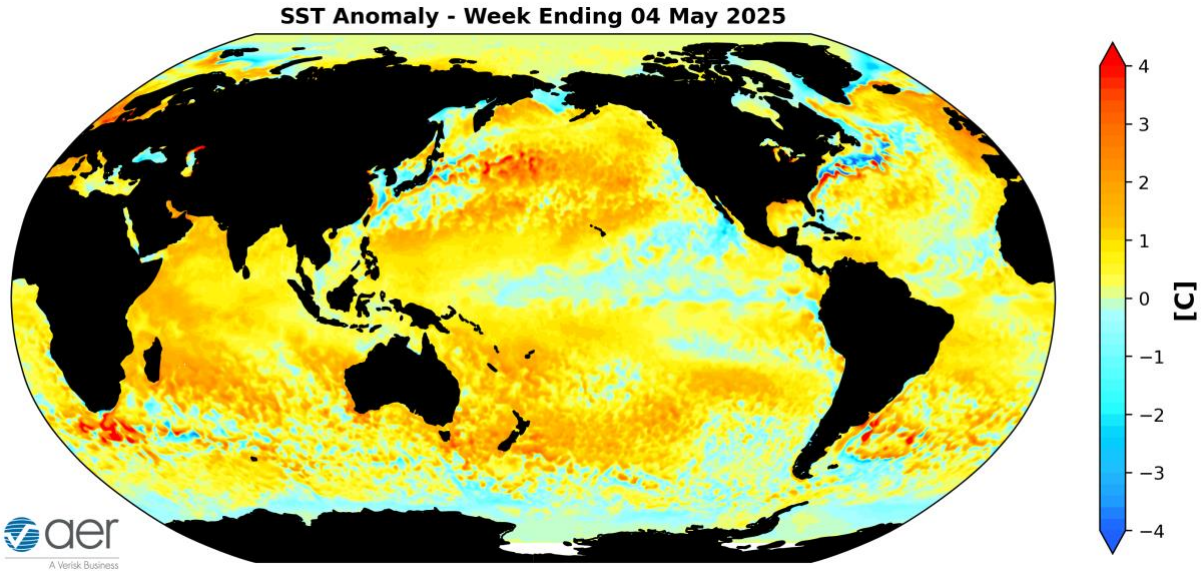

Figure 17. The latest daily-mean global SST anomalies (ending 4 May 2025). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently the Madden Julian Oscillation (MJO) is weak where no phase is favored (**Figure 18**). The forecasts are for the MJO to remain overall weak where no phase is favored through mid-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.

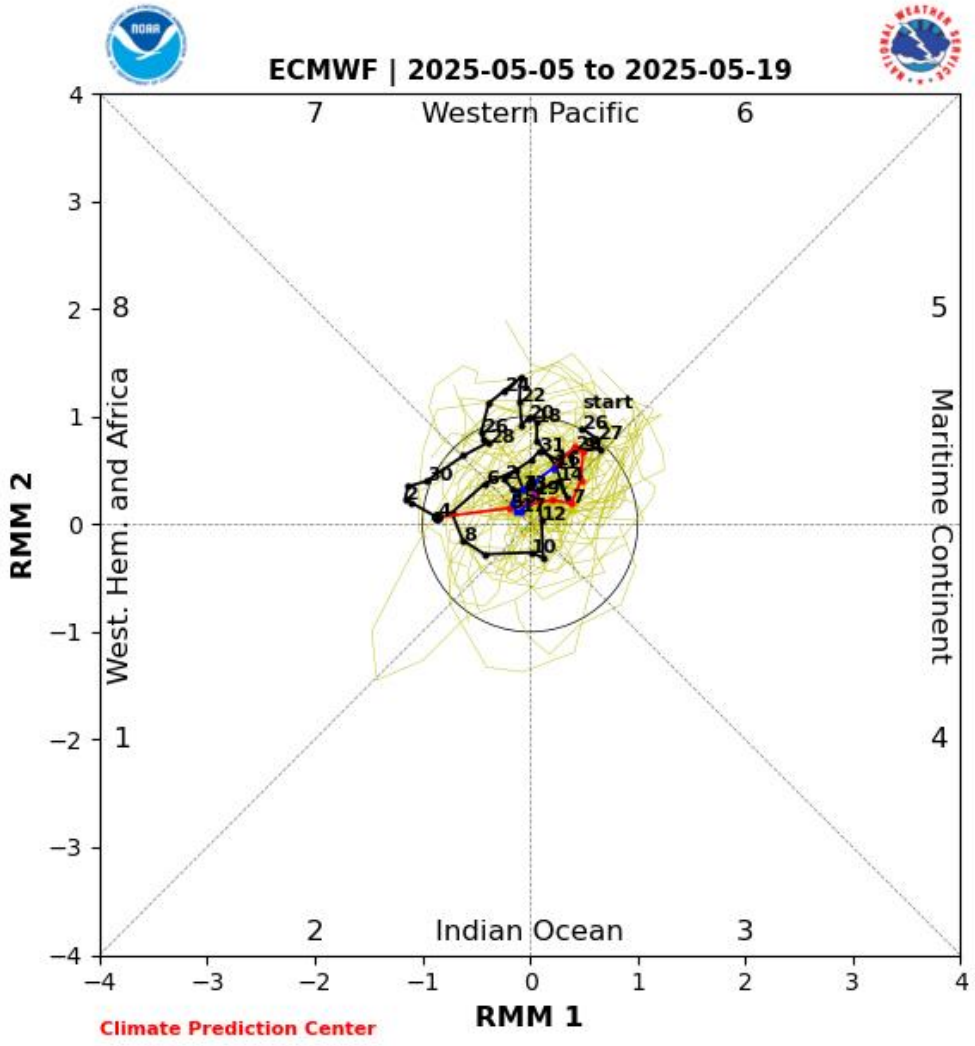

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 05 May 2025 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model 'spread' is denoted by the gray shading. Sector numbers indicate 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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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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