Arctic Oscillation and Polar Vortex Analysis and Forecasts

Jun 23, 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 strongly positive and is predicted to remain positive the next two weeks as pressure/geopotential height anomalies across the Arctic are currently mostly negative and are predicted to remain mostly negative 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 remain positive the next two weeks as pressure/geopotential height anomalies are predicted to remain mostly negative across Greenland.
- The next two weeks, troughing/negative geopotential height anomalies across Greenland will extend across the North Atlantic into Northern and Eastern Europe with ridging/positive geopotential height anomalies across Southern and Central Europe. This pattern will support widespread normal to above normal temperatures across Southern, Western and Central Europe including the UK with normal to below normal temperatures across far Northern and Eastern Europe the next two weeks.
- The general pattern across Asia the next two weeks is troughing/negative geopotential height anomalies across Western Asia and Siberia with ridging/positive geopotential height anomalies across Southern and Eastern Asia. This pattern favors normal to below normal temperatures across Western Asia, extending into the Indian subcontinent and Siberia with normal to above normal temperatures across much of Southern, Central and Eastern Asia.

- Ridging/positive geopotential height anomalies are predicted to dominate North America the next two weeks centered over the Eastern United States (US) with troughing/negative geopotential height anomalies across the Alaska and the Western US this week and then Eastern Canada and the Eastern US next week. This patten will favor widespread normal to above normal temperatures across Canada and the Eastern US with normal to below normal temperatures across Alaska and the Western US this week and then next week normal to above normal temperatures will become focused in western North America with cooler temperatures filtering into Southeastern Canada and the Eastern US.
- I discuss the Northern Hemisphere (NH) early summer circulation and temperature forecast in this week's blog.

Plain Language Summary

Widespread warmth dominated the land areas of the Northern Hemisphere (NH) so far this early summer especially across Eurasia (see **Figure**). Warmth has dominated western North America, Western and Southern Europe, Central and East Asia. The biggest exceptions have been relatively cool temperatures in Central Canada and parts of Siberia and with close to seasonable temperatures in Scandinavia and Eastern Europe (see **Figure**). For the upcoming week the hot temperatures will slide east across North America bringing the first heat wave of the summer to the Eastern US (see **Figure 3**) before snapping back to the early June pattern (see **Figure 9**). Across Eurasia it is more of what you see is what you get (see **Figures 3, 6** and **9**).

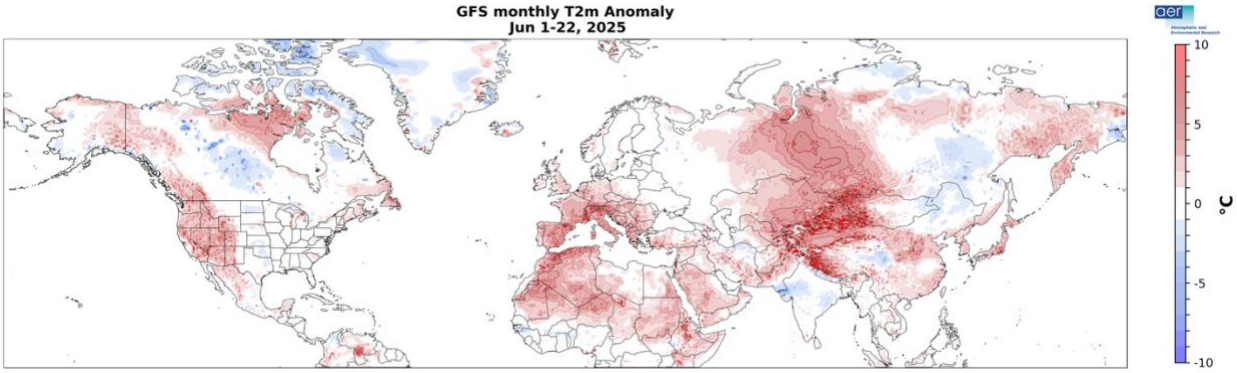

Figure. Estimate of the observed surface temperatures (°C; shading) from 01 Jun to 22 Jun 2025 based on GFS initializations and the GFS forecast from the 23 June 2025 run.

Impacts

As a heads up, on Monday July 7, I will be in transit to Germany so there will be a delay in the next blog.

Nothing profound in today's blog. As I have been describing in general, the two-week forecast for the mid-tropospheric circulation is characterized by low pressure centered near the North Pole and high latitude ridging along the periphery of the Arctic (see **Figure i**). This pattern generally favors widespread warmth across both the Eurasian and North American continents (see **Figures 3, 6** and **9**). A pattern that I am fond as referring to as the "ring of fire" summer pattern. As can be seen in the animation of **Figure i**, the heat domes will be focused in Europe, Central and possibly East Asia and fairly broad across North America. So far this summer, the ridging across North America has been focused in western North America but this week will cover the Eastern US, bringing with-it record-breaking heat but then in early July, the heat dome is predicted to slide back towards western North America.

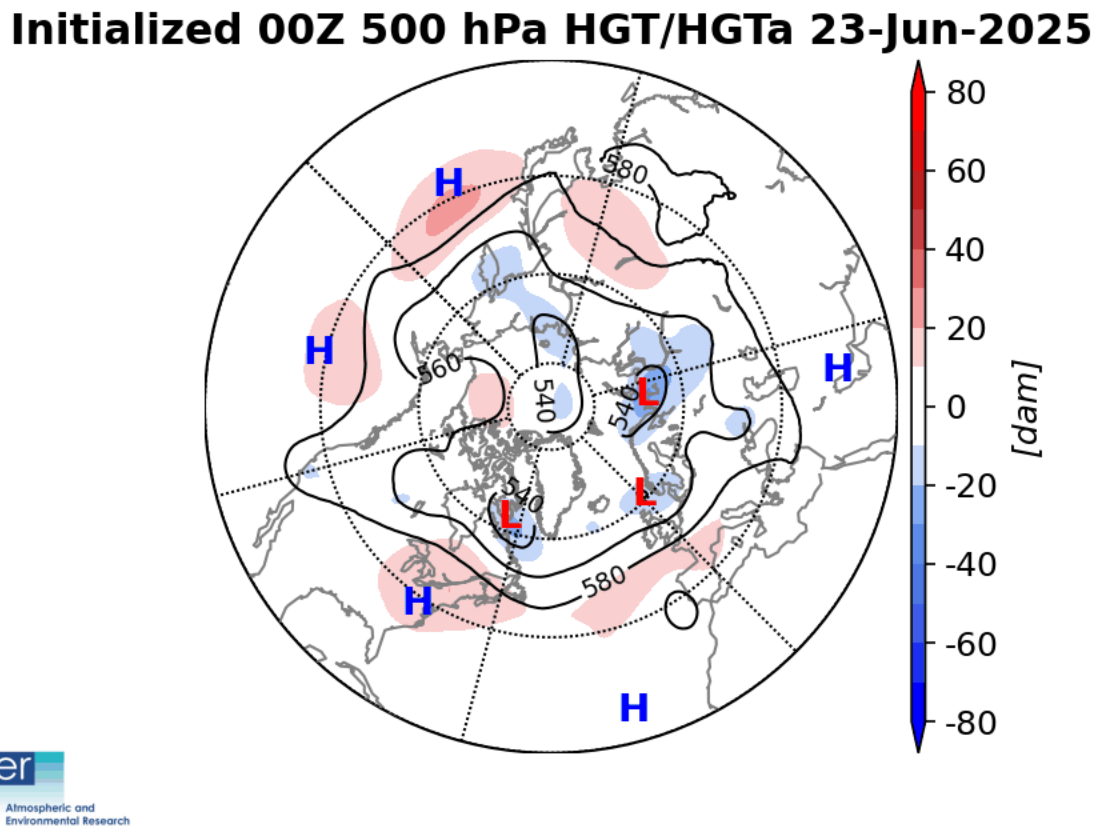

Figure i. Initialized 500 mb geopotential heights (dam; contours) and decameter anomalies (dam; shading) across the Northern Hemisphere for 23 Jun 2025 and forecasted from 24 Jun to 08 Jul 2025. The forecasts are from the 00Z 23 Jun 2025 GFS model ensemble.

All of last summer I commented in the blog the strange sandwich pattern of warm/postive polar cap geopotential height anomalies (PCHs) in most of the stratosphere and troposphere except

for the upper stratosphere and often in the lower troposphere. However episodically the warm/postive PCHs in the upper troposphere would descend to the surface triggering or associated with high-latitude blocking that did result in cooler temperatures in the Central and Eastern US, Western Europe and East Asia. I did not have a good answer for the unusal pattern of PCHs last summer but did postulate that it could be related to the Honga-Tonga volcanic eruption. Looking at **Figure 11**, it would appear we will not observe a repeat of that pattern this summer. Currently cold/negative PCHs dominate both the stratosphere and troposphere and I would expect PCHs in the tropopshere to alternate between warm/postive and cold/negative while in the stratopshere I would expect that the PCHs to be predmoniately cold/negative.

Given that at least based on the early summer pattern so far we might expect temperature anomalies to more closely follow recent decadal trends. I showed the June, July and August surface temperature trend from 1991 through 2023 a year ago and include here in **Figure ii**. The most notable feature of the plot is the widespread warming trend. Warming is strongest in the Western US, Eastern Europe and Western Russia and parts of Siberia. Some more muted warming in the Great Lakes, Western Europe and east of the Urals. I am skeptical of the widespread cooling in western China.

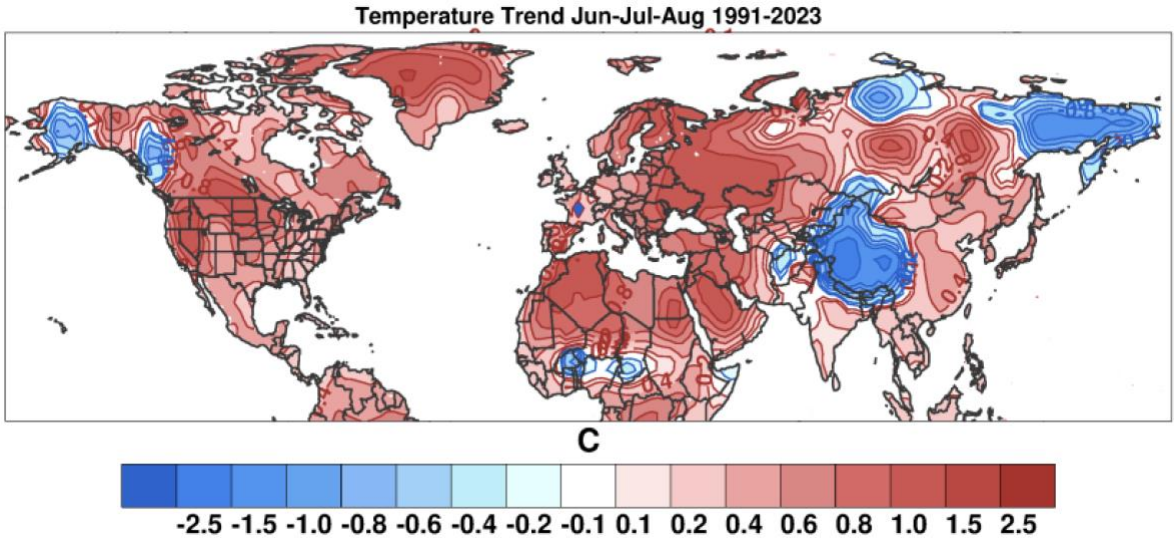

Figure ii. Observed surface temperature anomalies (°C; shading) across the Northern Hemisphere for June, July and August 1991 through 2023 from the NCEP/NCAR reanalysis.

Comparing the decadal trends with what has been observed so far the first three weeks of summer 2025 and keeping in mind the two-week forecast, summer 2025 will likely see the trends continue in certain regions but not in others. Despite this week's cool temperatures, western North America is on track for a hot summer. The secondary maximum in warming trends along the US East Coast could easily repeat in summer 2025 with the Plains of the US and Canada and maybe even into the Southeastern US see the most muted warming or even below normal temperatures. This region is referred to as the "warming hole." In western Eurasia, decadal warming has been focused in Eastern Europe and Western Russia. So far that is not the case with

warming focused more in Western and Southern Europe. Unless the NAO turns negative and Greenland blocking returns for an extended period, this temperature dipole pattern could dominate this summer. The observed trend of muted warming over the Urals and Western Siberia might be shifted west this summer. A relatively warm East Asia and a relatively cool Siberia or at least Eastern Siberia also looks on track.

I think the "ring of fire" NH pattern looks in place with heat domes circling the NH. But the domes are not stationary as we see this week with the Western North America heat dome sloshing east over the Central and Eastern US before it is predicted to return to its "home" base next week. Where these heat domes spend most of the summer will play a large role in the summer temperature pattern. And if the "ring of fire" does remain in place for much of the summer, Arctic sea ice will be well below normal but not likely to achieve a record low.

Near-Term

This week

The AO is predicted to be strongly positive this week **(Figure 1**) with mostly negative geopotential height anomalies currently across the Arctic and 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.

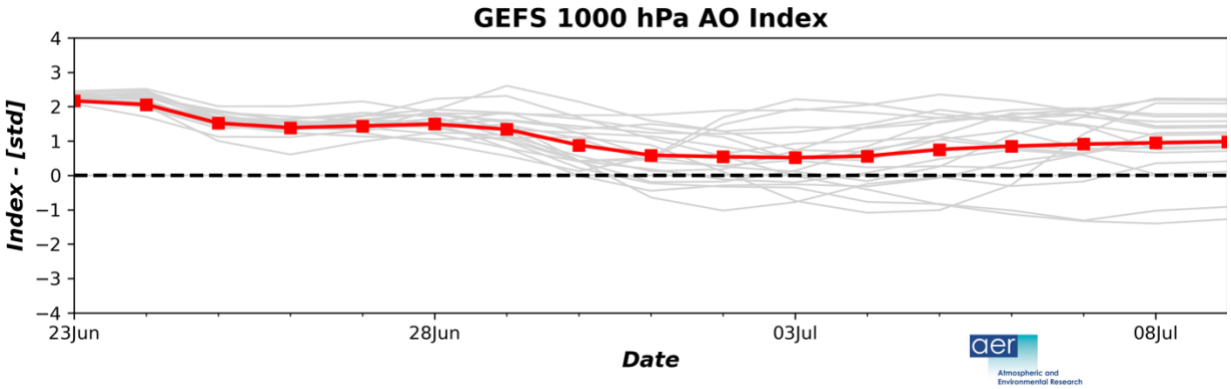

Figure 1. The predicted daily-mean AO at 1000 hPa from the 00Z 23 Jun 2025 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble mean AO index given by the red line with squares.

This week predicted troughing/negative geopotential height anomalies across Greenland will extend into Northern and Eastern Europe with ridging/positive geopotential height anomalies across Western and Southern Europe (**Figure 2).** This pattern will favor 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 3**). This week the

predicted pattern across Asia is troughing/negative geopotential height anomalies across Western Asia and Siberia with ridging/positive geopotential height anomalies across Southern and Eastern Asia (**Figure 2**). This pattern favors normal to above normal temperatures widespread across Southern, Central and Eastern Asia including Pakistan and Afghanistan with normal to below normal temperatures across Western Asia, Siberia, central China and northern India **(Figure 3**).

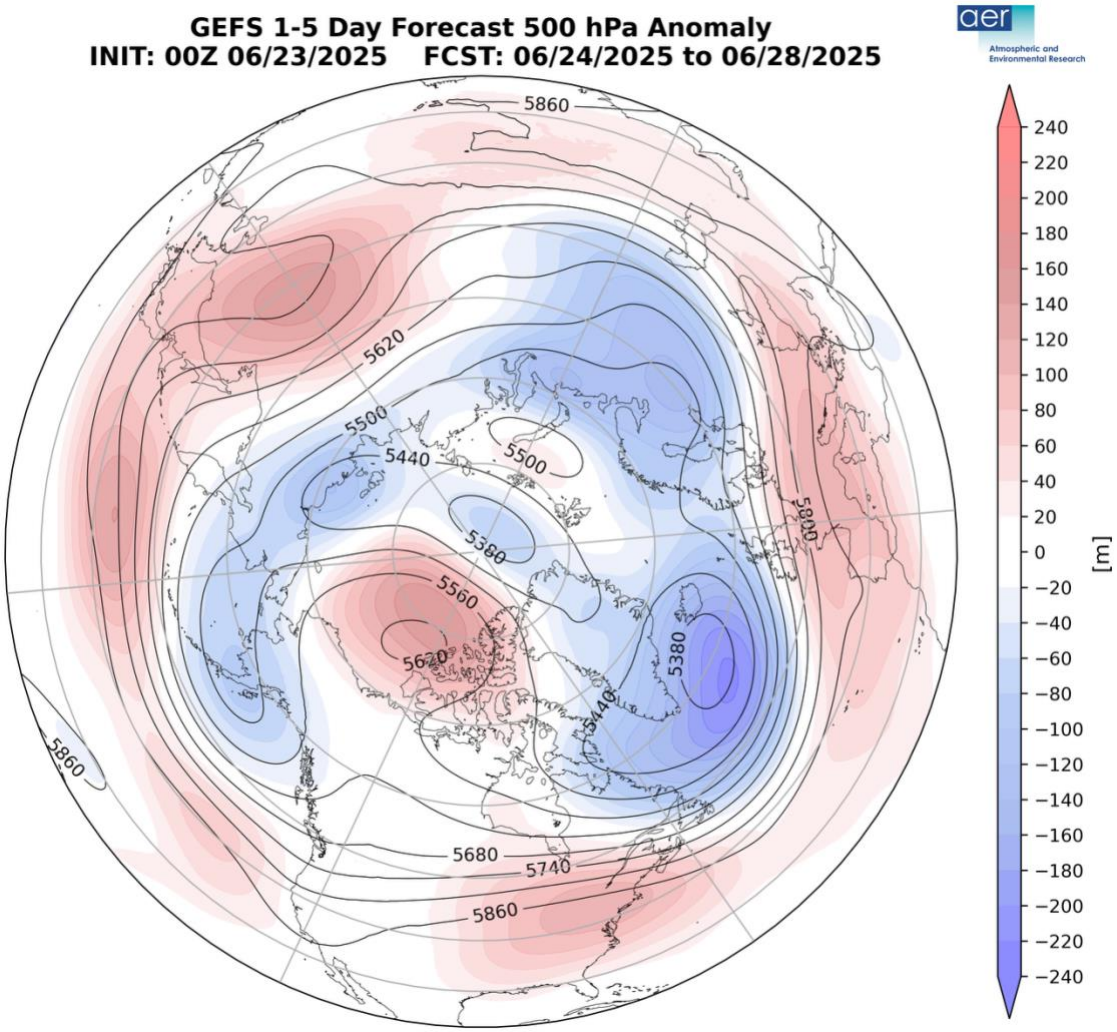

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 24 Jun to 28 Jun 2025. The forecasts are from the 00Z 23 Jun 2025 GFS ensemble.

This week ridging/positive geopotential height anomalies are predicted to be centered in the Beaufort Sea and the Eastern US with troughing/negative geopotential height anomalies across Alaska and the Western US (**Figure 2**). This pattern favors normal to above normal temperatures across much of Canada and the Eastern US with normal to below normal temperatures limited to Alaska into the Western US. (**Figure 3**).

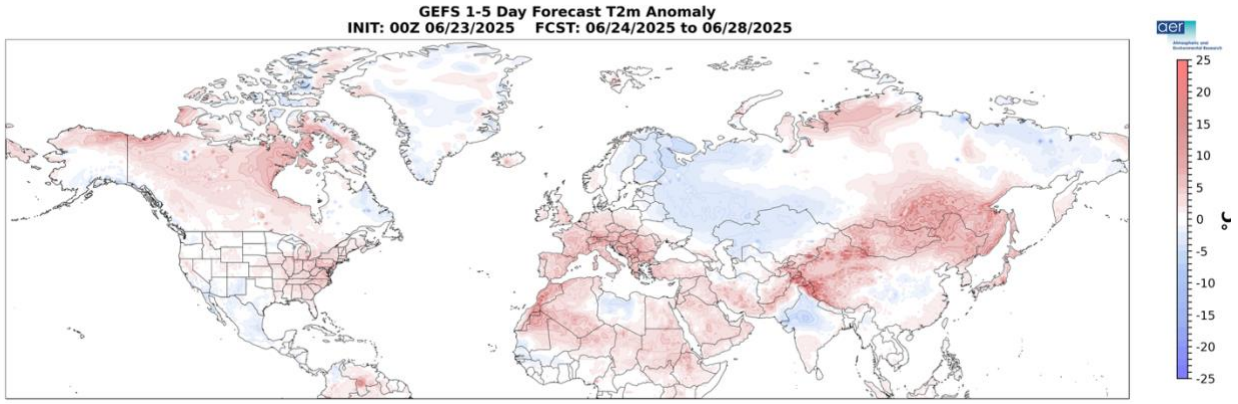

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 24 Jun to 28 Jun 2025. The forecasts are from the 00Z 23 Jun 2025 GFS ensemble.

Troughing will support new rainfall across Western Russia, Siberia, parts of Southeast Asia and the Tibetan Plateau with otherwise mostly dry conditions widespread across Europe and Asia, in particular across Central Europe and Southeastern China this week with near normal precipitation across Afghanistan and Pakistan (**Figure 4**). Troughing will support new rainfall across Alaska, parts of Western Canada and the Central US with otherwise mostly dry conditions widespread across Canada and the US this week (**Figure 4**).

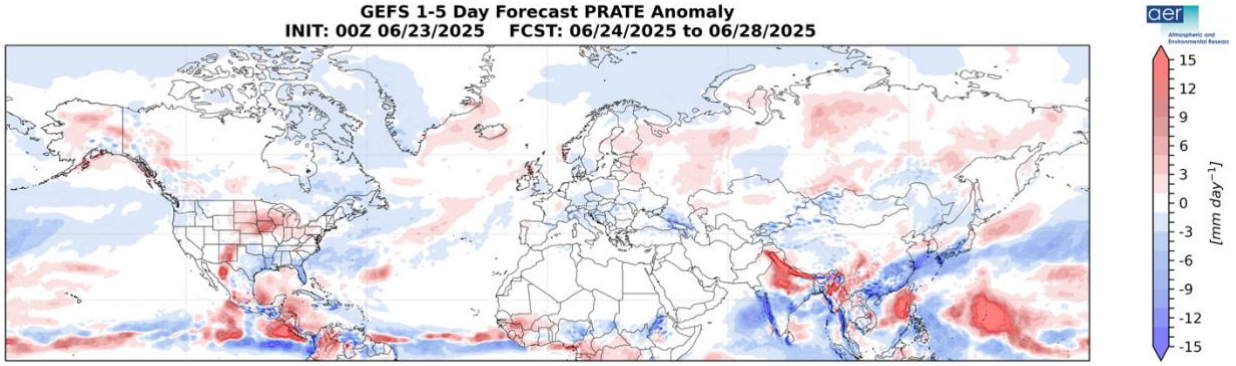

Figure 4. Forecasted rainfall (mm/day; shading) from 24 Jun to 28 Jun 2025. The forecasts are from the 00Z 23 Jun 2025 GFS ensemble.

Near-Mid Term

Next week

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

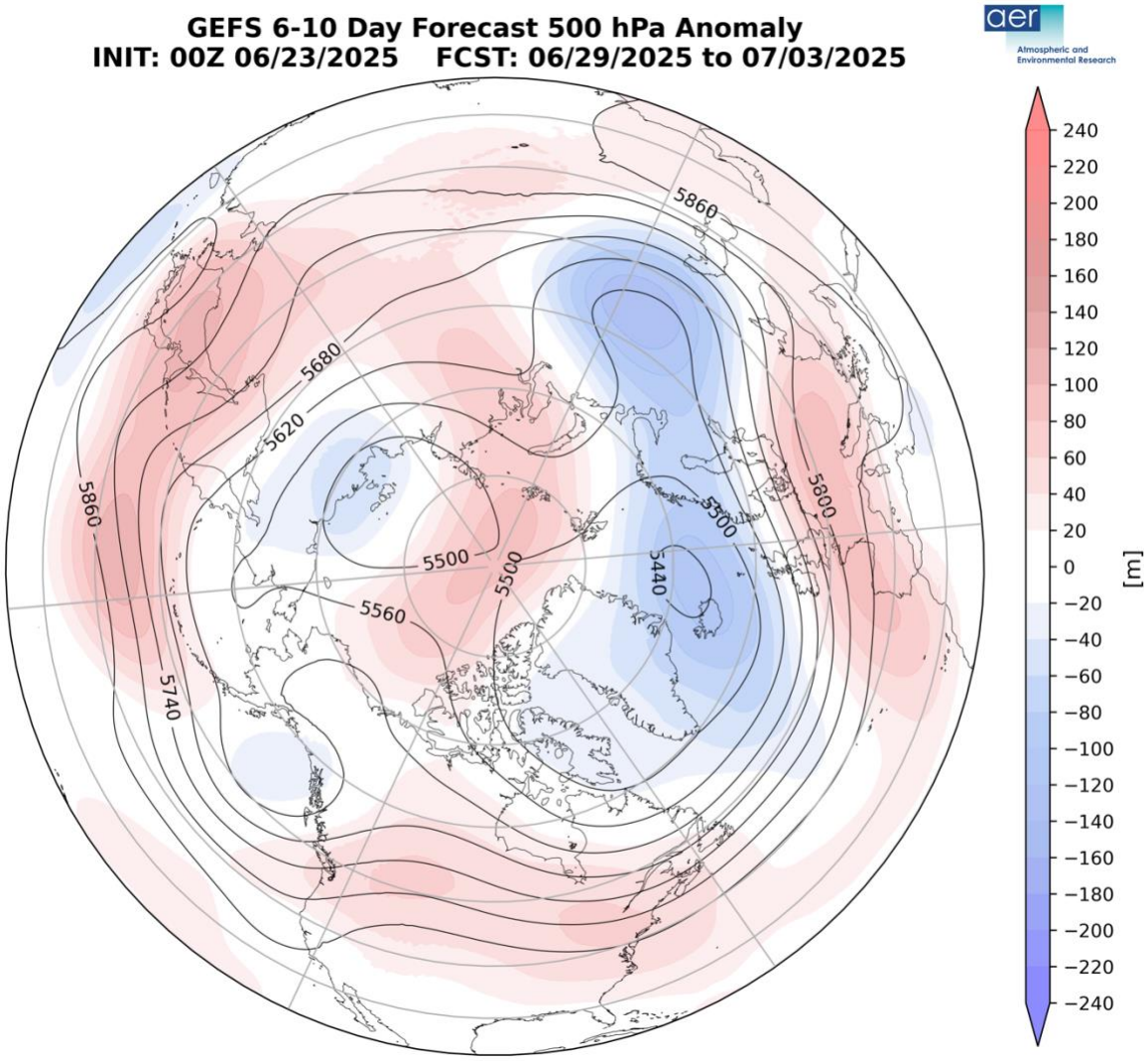

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 29 Jun to 03 Jul 2025. The forecasts are from the 00Z 23 Jun 2025 GFS ensemble.

Persistent troughing/negative geopotential height anomalies across Greenland will extend into Northern and Eastern Europe with ridging/positive geopotential height anomalies across Southern and Central Europe this period (**Figure 5**). This pattern will favor 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 across Europe will support troughing/negative geopotential height anomalies in Western Asia extending into Siberia with ridging/positive geopotential height anomalies Central and East Asia this period (**Figure 5**). This pattern favors widespread normal to above normal temperatures across Central and Southern Asia including Afghanistan and Pakistan with normal to below normal temperatures Western Russia, western Kazakhstan, northern India and Siberia this period (**Figure 6**).

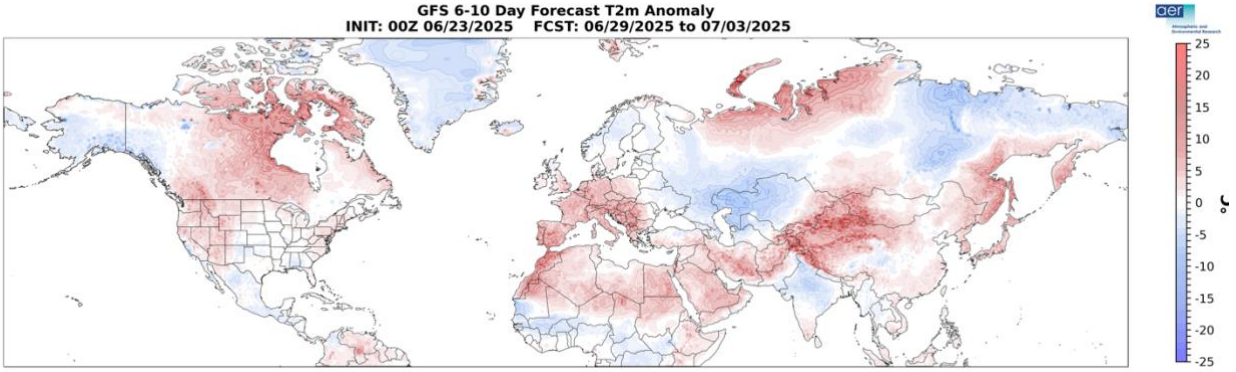

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 29 Jun to 03 Jul 2025. The forecasts are from the 00Z 23 Jun 2025 GFS ensemble.

The predicted pattern across North America is widespread ridging/positive geopotential height anomalies centered over the US with troughing/negative geopotential height anomalies limited to Alaska and the South-central US this period (**Figure 5**). This pattern will favor normal to above normal temperatures across much of Canada and the US with normal to below normal temperatures limited to Alaska and the US Southern Plains (**Figure 6**).

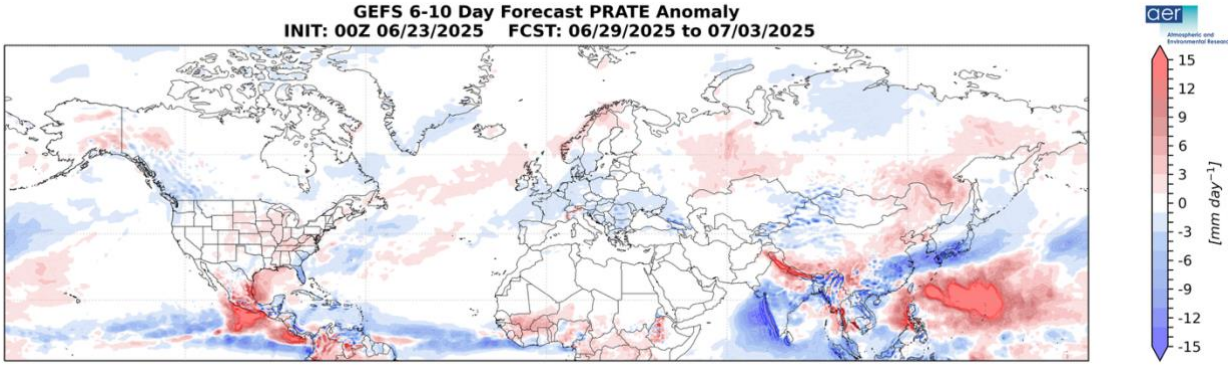

Figure 7. Forecasted precipitation rate (mm/day; shading) from 29 Jun to 03 Jul 2025. The forecasts are from the 00Z 23 Jun 2025 GFS ensemble.

Troughing will support new rainfall near the Urals, Eastern Siberia, Northeastern Asia, parts of Southeast Asia and the Tibetan Plateau with otherwise mostly dry conditions widespread across

Europe and Asia and near normal across Afghanistan and Pakistan this week (**Figure 7**). Troughing will support new rainfall across parts of Alaska and the Eastern US with otherwise mostly dry conditions widespread across Canada and the Western 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 positive this period as well.

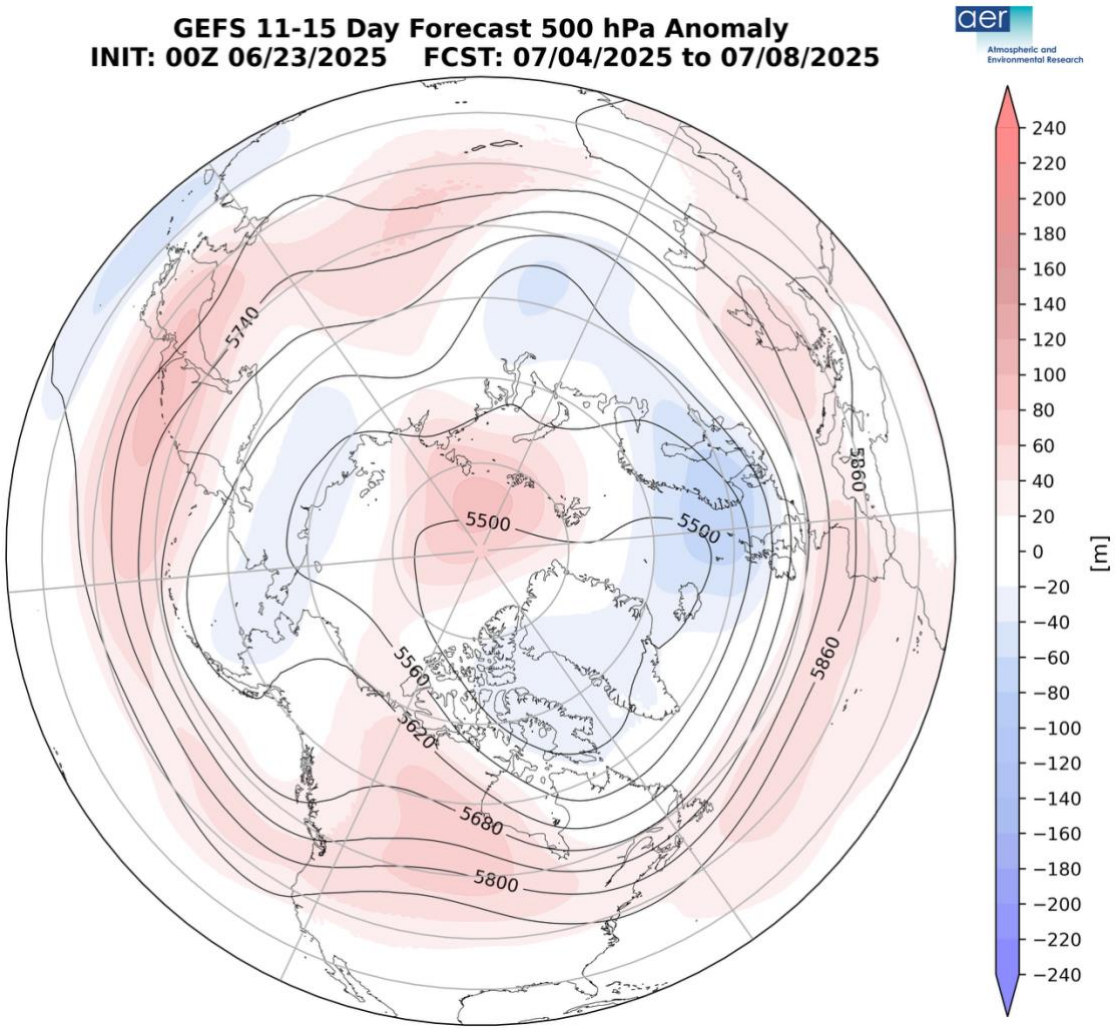

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 04 Jul to 08 Jul 2025. The forecasts are from the 00Z 23 Jun 2025 GFS ensemble.

Once again, persistent troughing/negative geopotential height anomalies across Greenland will extend into Northern and Eastern Europe with ridging/positive geopotential height anomalies across Southern Europe this period (**Figure 8**). This pattern should favor 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 (**Figures 9**). Ridging/positive geopotential height anomalies in Europe and near the North Pole will support persistent troughing/negative geopotential height anomalies across Western Asia and extending into Siberia with ridging/positive geopotential height anomalies across Central and Southern Asia this period (**Figure 8**). The predicted pattern favors normal to below normal temperatures across Western Russia, western Kazakhstan, Siberia and northern India with normal to above normal temperatures across Central, Southern and Eastern Asia including Pakistan and Afghanistan with this period (**Figure 9**).

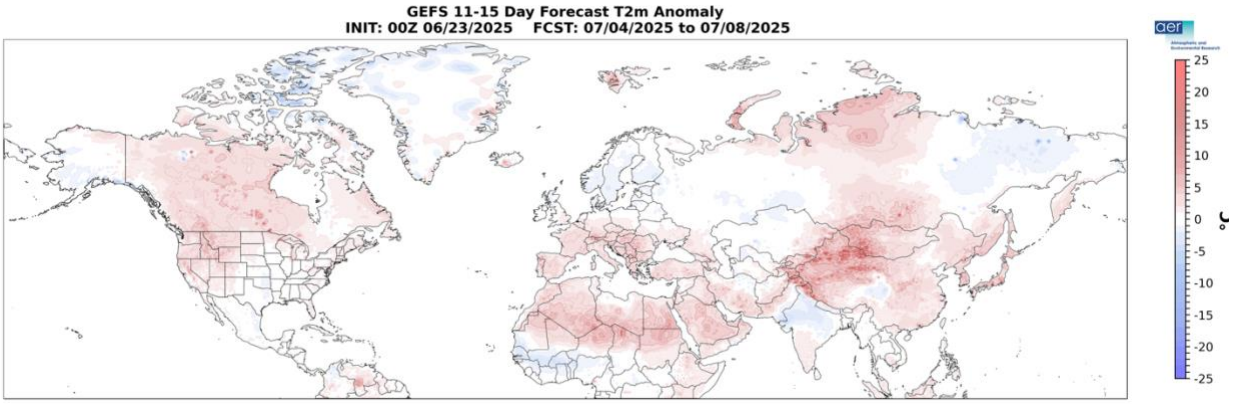

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 04 Jul to 08 Jul 2025. The forecasts are from the 00Z 23 Jun 2025 GFS ensemble.

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

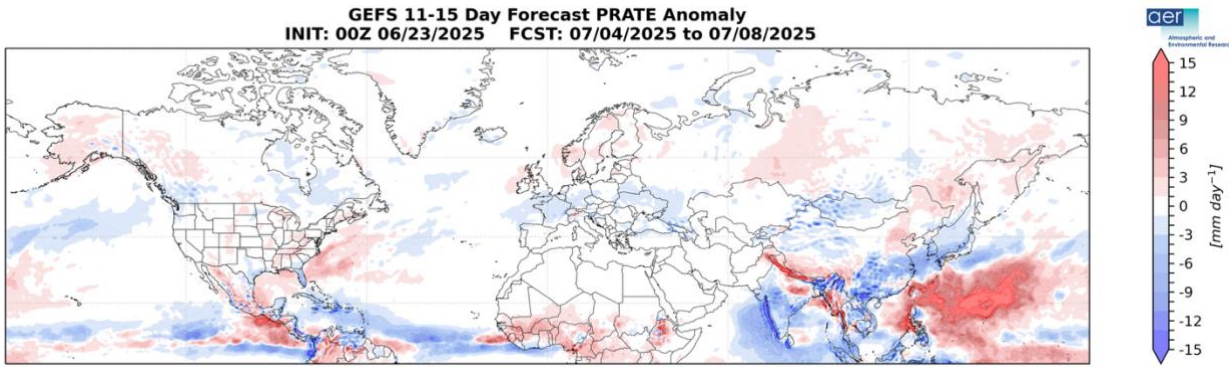

Figure 10. Forecasted precipitation rate (mm/day; shading) from 04 Jul to 08 Jul 2025. The forecasts are from the 00Z 23 Jun 2025 GFS ensemble.

Troughing will support new rainfall across Scandinavia, Western Siberia, parts of Northeast, Northern India and the Tibetan Plateau with otherwise mostly dry conditions widespread across Europe and Asia and near normal precipitations in Pakistan and Afghanistan this period (**Figure 10**). Troughing will support new rainfall across Alaska, Western Canada and the Central and Eastern 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 cold/negative PCHs throughout the stratosphere and the troposphere (**Figure 11**). The cold/negative PCHs are predicted to persist in the stratosphere and the lower troposphere over the next two weeks with warm/positive PCHs developing in the upper troposphere in early July.

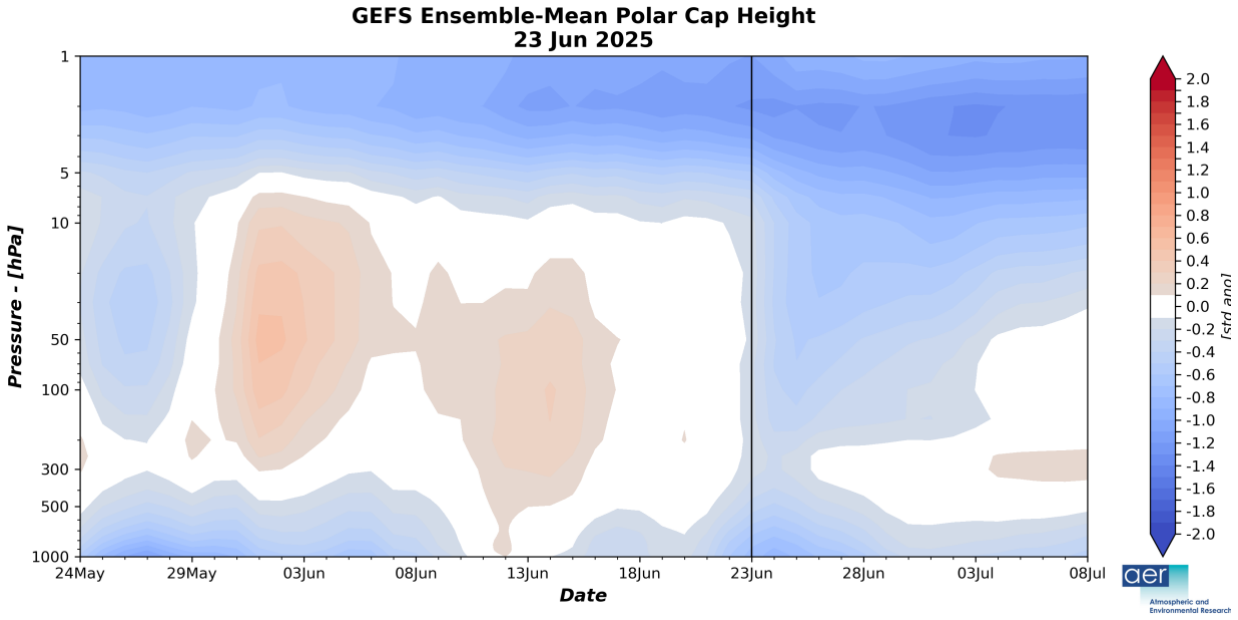

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 23 Jun 2025 GFS ensemble.

The predicted cold/negative PCHs in the lower troposphere for the next two weeks (**Figure 11**) are consistent with the predicted positive surface AO the next two weeks (**Figure 1**). For now, no signs of a change in this pattern.

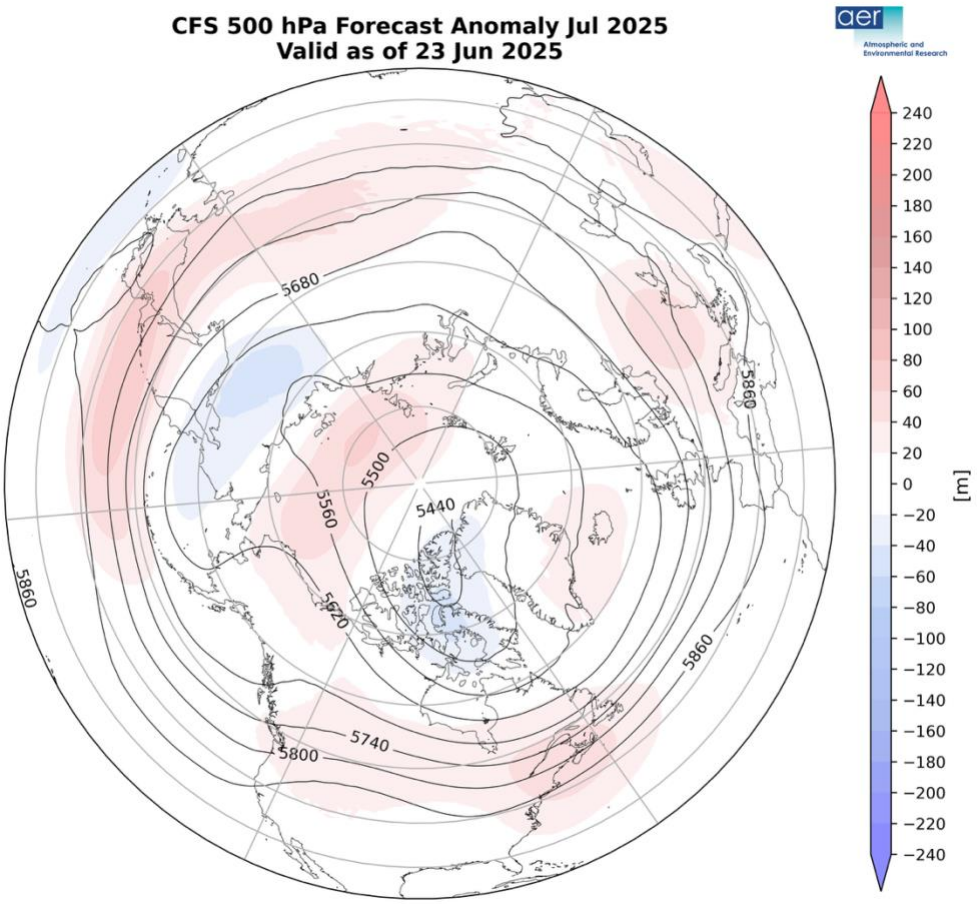

Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for July 2025. The forecasts are from the 00Z 23 Jun 2025 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and surface temperatures for July (**Figure 13**) from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging centered over Iceland, Eastern Europe, Southern and Eastern Asia the Laptev Sea and along the US-Canadian border, with troughing across Western Europe, Western Asia, Siberia, the Gulf of Alaska and the Central US (**Figure 12**). This pattern favors seasonable to relatively warm temperatures across Eastern Europe, much of Asia, especially Central Asia and the Tibetan Plateau, Pakistan and Afghanistan**,** Alaska, much of Canada, especially Western Canada, the Western and Northeastern US with seasonable to relatively cool temperatures across Western Europe, Western Russia and Kazakhstan, the US Plains and into the Southeastern US (**Figure 13**).

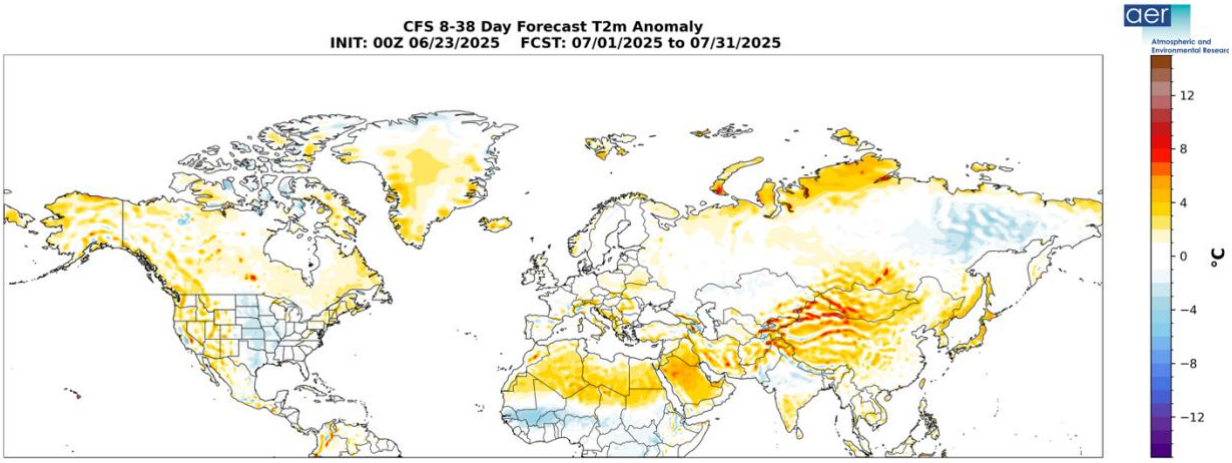

Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for July 2025. The forecasts are from the CFS 00Z 23 Jun 2025.

Boundary Forcings

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are now slightly above normal, on either side of the Dateline, indicating that the winter La Niña event is gone (**Figure 14**) and neutral conditions are expected through the 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 and mostly favor a continuation of neutral conditions. 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 and the Northeastern US though below normal SSTs exist regionally especially in the South Pacific.

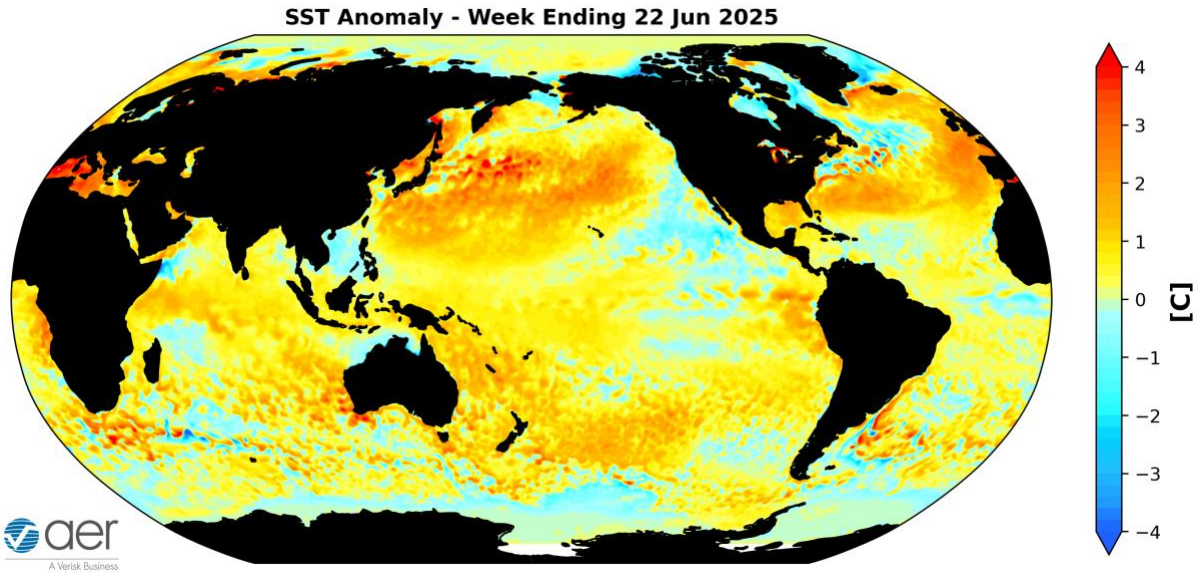

Figure 14. The latest daily-mean global SST anomalies (ending 22 Jun 2025). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently the Madden Julian Oscillation (MJO) is currently weak where no phase is favored (**Figure 15**). The forecasts are for the MJO to remain overall weak for most of the next two weeks before emerging into phase six the end of the first week of July. 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.

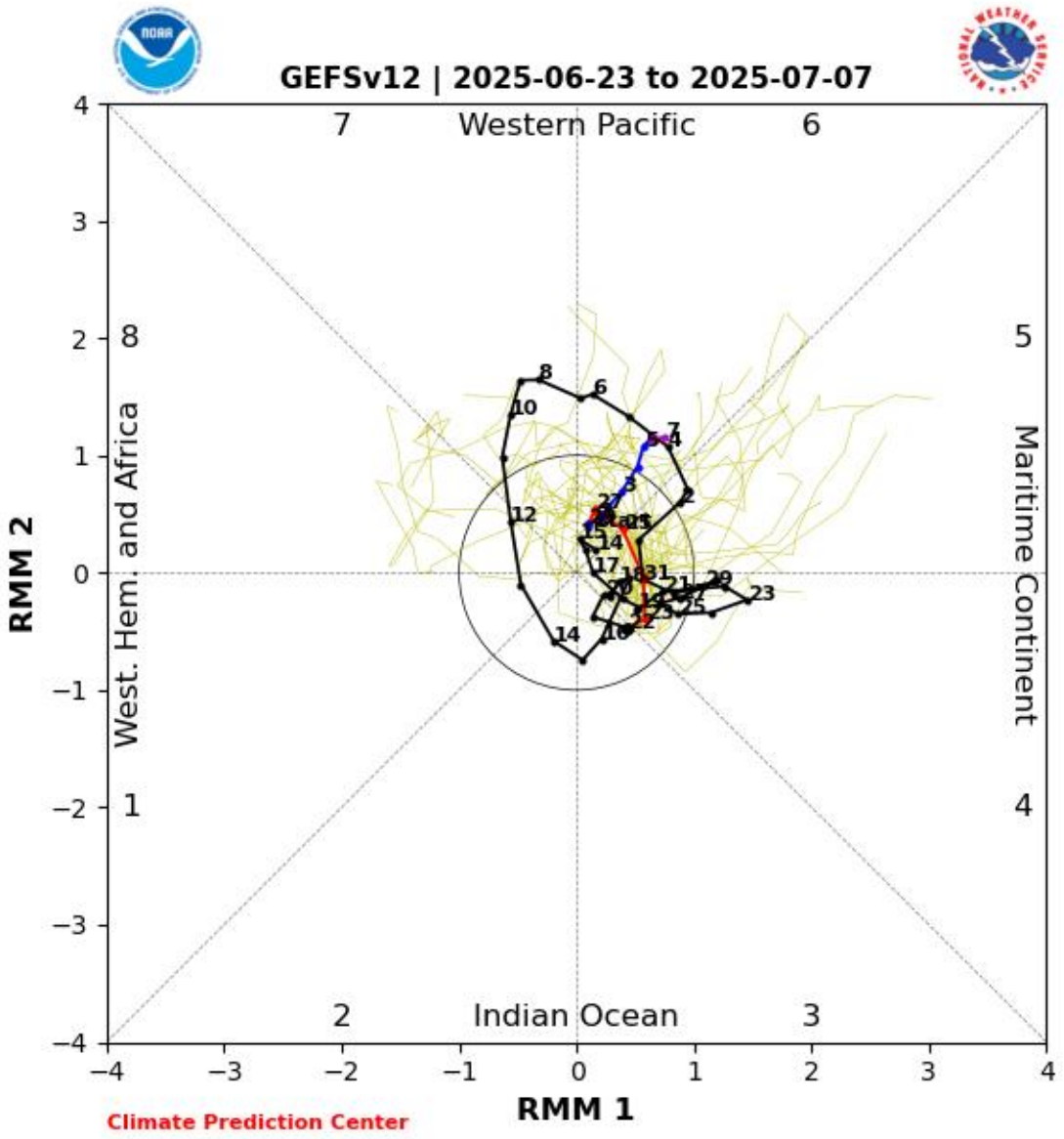

Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 23 Jun 2025 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model 'spread' is denoted by the gray shading. Sector numbers indicate 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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