Arctic Oscillation and Polar Vortex Analysis and Forecasts

September 08, 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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The AO/PV blog is partially supported by NSF grant AGS: 1657748

Summary

- The Arctic Oscillation (AO) is currently positive and is predicted to slowly trend negative the next two weeks as pressure/geopotential height anomalies across the Arctic are currently mostly negative and are predicted to become mostly mixed over the next two weeks. The North Atlantic Oscillation (NAO) is currently slightly negative as positive pressure/geopotential height anomalies dominate across Greenland, and the NAO is predicted to remain near neutral the next two weeks as pressure/geopotential height anomalies are predicted to remain mostly mixed across Greenland.
- This week and into next week, deep troughing/negative geopotential height anomalies centered south of Greenland and Iceland will support a strong jet and troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height anomalies across Southern Europe. The mostly zonal flow pattern will support widespread normal to above normal temperatures across much of Europe with the biggest exception of normal to below normal temperatures across far Western Europe especially the United Kingdom (UK) the next two weeks.
- The general pattern across Asia the next two weeks is strong ridging/positive geopotential height anomalies centered Western Asia forcing troughing/negative geopotential height anomalies across Western and Central Siberia with the southern end of the troughing swinging eastward from Kazakhstan to Northeast Asia. This pattern favors normal to above

normal temperatures across much of Asia with the exceptions of normal to below normal temperatures across Western Siberia and Kazakhstan this week and much of Siberia and Northeast Asia next week.

- The general predicted pattern the next two weeks across North America is expanding ridging/positive geopotential height anomalies across the continent with the exceptions of troughing/negative geopotential height anomalies across western Alaska, Eastern Canada, the Eastern United States (US) and the US West Coast this week. This patten will favor widespread normal to above normal temperatures across the US and Canada the next two weeks with the biggest exceptions of normal to below normal temperatures in western Alaska, Eastern Canada, the Eastern US and US West Coast this week.
- I discuss the Northern Hemisphere (NH) summer observed and predicted surface temperature anomalies and start discussing the upcoming winter.

Plain Language Summary

The first week of fall is in the books and as we saw in summer, widespread warmth dominated the land areas of the Northern Hemisphere (NH) in particular across Eastern Europe, Central Asia and especially Western Canada (see **Figure**). The biggest exception has been the extensive and relatively cool temperatures in Central Canada, the Central and Eastern US (see **Figure**). Also, some regionally cool temperatures in Siberia and East Asia. Kind of reminiscent of last winter, is it some foreshadowing from Mother Nature? Looking ahead over the next two weeks, overall looks warm where most people live (see **Figure 9**). Though some cool or even cold temperatures predicted for Siberia. And if you are a winter weather enthusiast, that is a trend you would like to see to continue through the fall.

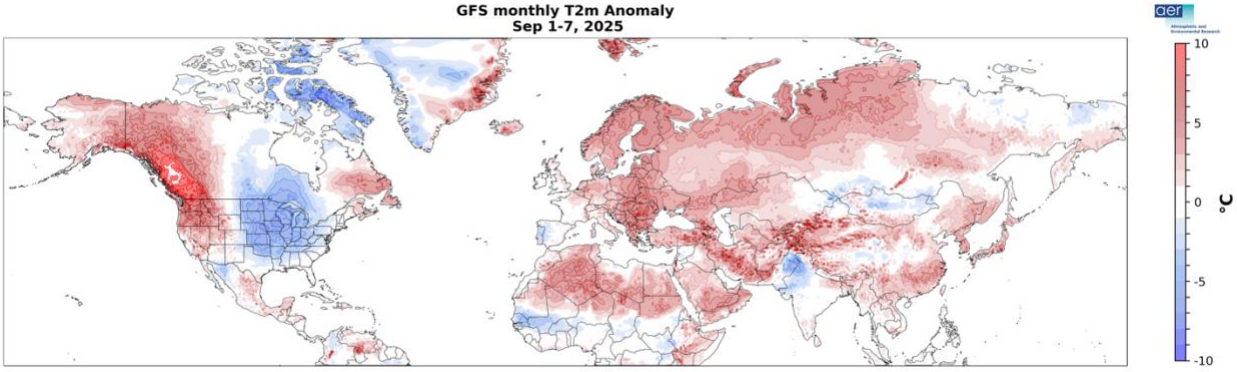

Figure. Estimate of the observed surface temperatures (°C; shading) from 01 Sep to 07 Sep 2025 based on GFS initializations and the GFS forecast from the 8 September 2025 run.

Impacts

Now that the Northern Hemisphere (NH), summer has ended I will begin discussing the observed temperatures and how the various forecasts performed (see **Figure i**). Europe is one of the fastest warming regions on earth and so not surprising overall Europe was warm yet again this summer. However, in somewhat of a departure from recent summers, the core of the relative warmth is shifted west in Western Europe and not Eastern Europe. It was also a warm summer in Scandinavia thanks to an impressive heat wave in July. East Asia was warm, though Siberia doesn't seem to be as warm as some recent summers with some localized areas even showing up as below normal. It was near normal in Western Russia, west of the Urals, which again I feel is consistent with recent summers. Finally, it seems that overall North America experienced a warm summer but not as warm as might be expected from recent summers, but the pattern is familiar - warm on both coasts and normal to relatively cool down the middle. The seasonable to relatively cool temperatures down the middle of the continent are consistent with the much talked about US "warming hole." I have not seen other summaries of the summer surface temperature anomalies so it will be interesting to compare our estimate with other estimates from government agencies.

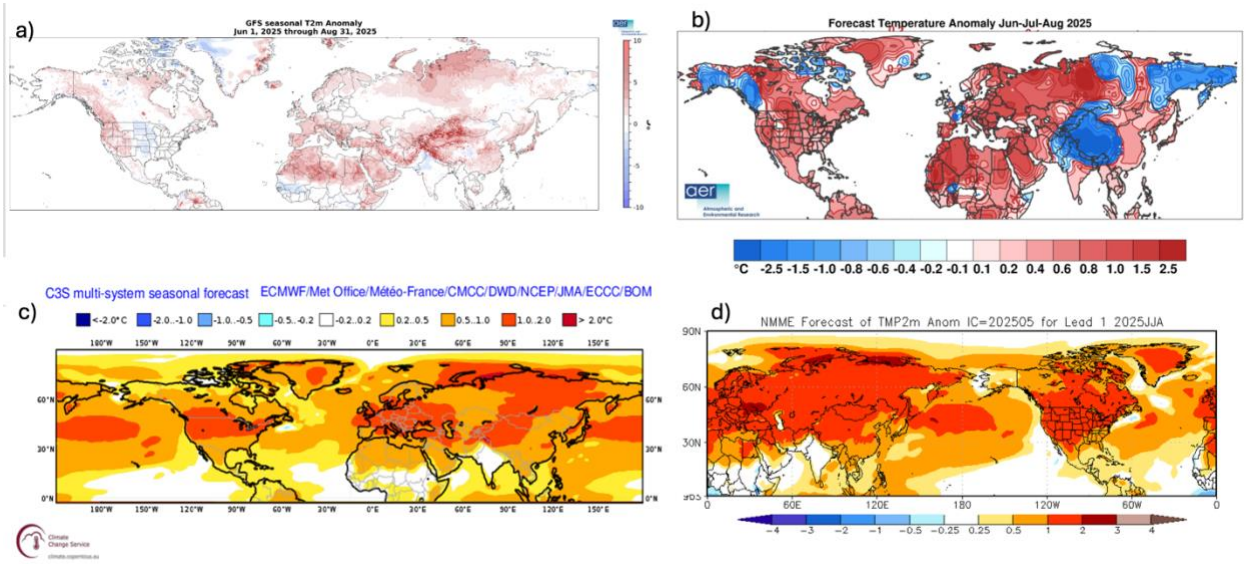

Figure i. a) Observed surface temperature anomalies (°C; shading) across the Northern Hemisphere for June, July and August 2025 from the daily initialized GFS forecast. Predicted surface temperature anomalies (°C; shading) across the Northern Hemisphere for June, July and August 2025 from the b) AER model, c) the C3S suite of models and td) the NMME suite of models The C3S forecast was downloaded from: https://climate.copernicus.eu/charts/packages/c3s_seasonal/ and the NMME forecast was downloaded from: https://www.cpc.ncep.noaa.gov/products/NMME/.

I also include the AER summer forecast, the C3S summer forecast (an ensemble of European models) and the NMME forecast (an ensemble of North American models) in **Figure i**. Though all the forecasts are correctly overall warm, I don't think that any of the three forecasts performed

exceptionally well. The dynamical models had a broad-brush warm forecast that that missed the variability and the regions of where temperatures were normal to below normal. At least the AER forecast had some regions of below normal and wasn't bad in Siberia. However, the below normal temperature forecast in northwestern North America was wrong. The below normal temperatures in central Asia, should be ignored as I mentioned when the forecast was posted, I believe it is an error in the data. All the forecasts missed the regional variations in Europe and the "warming hole" in North America.

Once again 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 ii**). Two dominant high-pressure centers are predicted over the next two weeks, the first over Western Russia and then over Hudson Bay (see **Figure ii**). The high-pressure center over Hudson Bay is even predicted to punch north towards the North Pole. These high-pressure centers favor widespread warmth for Europe and especially North America.

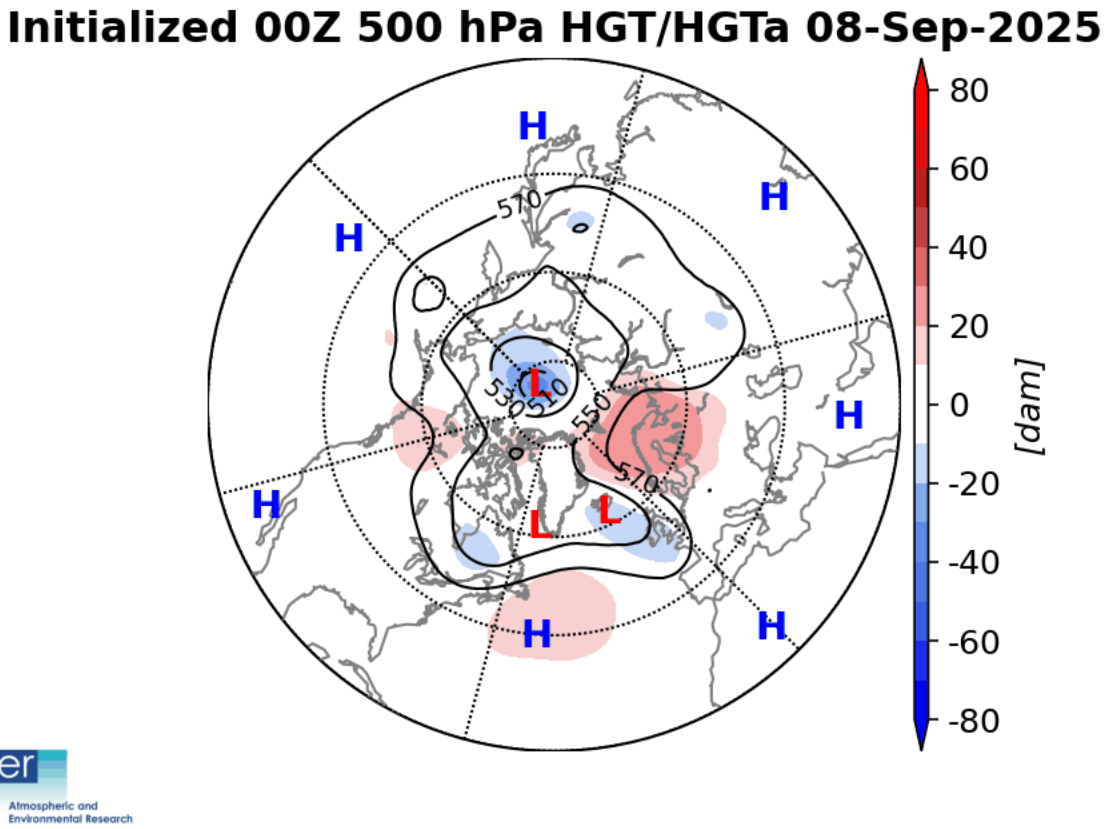

Figure ii. Initialized 500 mb geopotential heights (dam; contours) and decameter anomalies (dam; shading) across the Northern Hemisphere for 08 Sep 2025 and forecasted from 09 Sep to 23 Sep 2025. The forecasts are from the 00Z 08 Sep 2025 GFS model ensemble.

However, on the flip side, the high-pressure center over Western Russia and even over towards the Urals will usher in northerly flow downstream over Siberia and eventually into East Asia. And

some of that air will be cold enough to support snow in parts of Siberia (see **Figure iii**), and so it begins. If you are rooting for a weak polar vortex this winter this is pattern you would like to see persist for the fall but especially be dominant in November and December. But too early to teel if this is truly a sign of things to come after the first week of September. But the right sea ice and snow cover anomalies can reinforce this pattern.

Certainly, Siberian snow cover is something that I follow closely in trying to predict the upcoming winter weather where high snow favors an overall colder winter and low snow favors an overall milder winter. Fall Siberian snow cover seems to have gotten a bad rap the past several years, but I think it is not deserved. I remain confident that it should be used as an important predictor for the upcoming winter. I hope to discuss more in the coming months, why that is but like any predictor it is far from perfect.

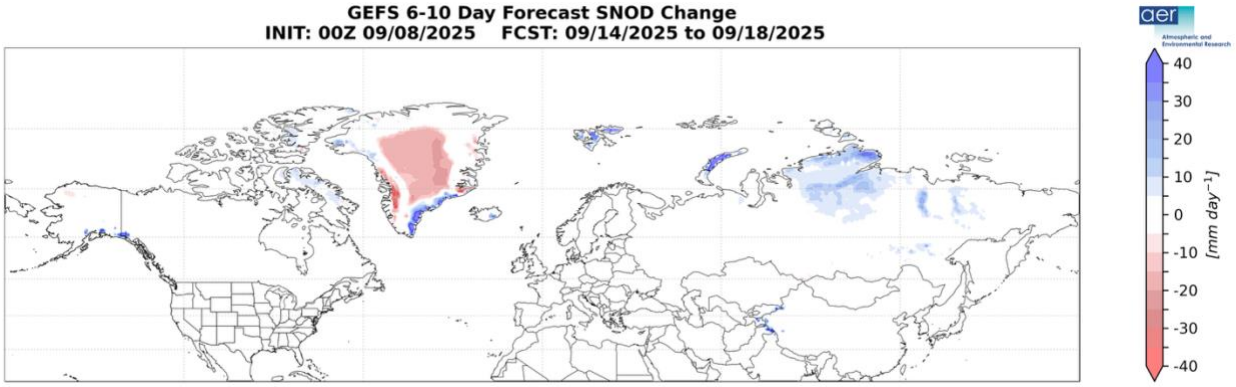

Figure ii. Forecasted snow depth change (mm/day; shading) from 14 Sep to 18 Sep 2025. The forecasts are from the 00Z 08 Sep 2025 GFS ensemble.

Ultimately, I use snow cover to try to predict the behavior of the winter polar vortex (PV) with high snow cover favoring a weak/stretched PV and low snow cover favoring a strong/circular PV. I have seen on social media some excitement how the PV is starting off this fall weak even close to record weak. Well, I am old enough to remember fall 2024 when the PV was weak even record weak all of September and October and then from November through February was relatively strong continuously thoughout those entire four months including the entire winter. So, for now I am keeping my excitement in check.

Once again, I will end with the imminent Arctic sea ice minimum, which is rapidly approaching and should occur in the next week or so. Arctic sea is well below normal, but the decline has started to slow down and is now well off the rapid sea ice decline of 2012 and is in line with the past two summers and those from 2017 and 2018 (see **Figure iv**). As I discussed in the previous blogs, a record low sea ice minimum is highly unlikely. And based on the four summers shown in **Figure iv** looks to come in the 4.4-4.8 million squared kilometers range.

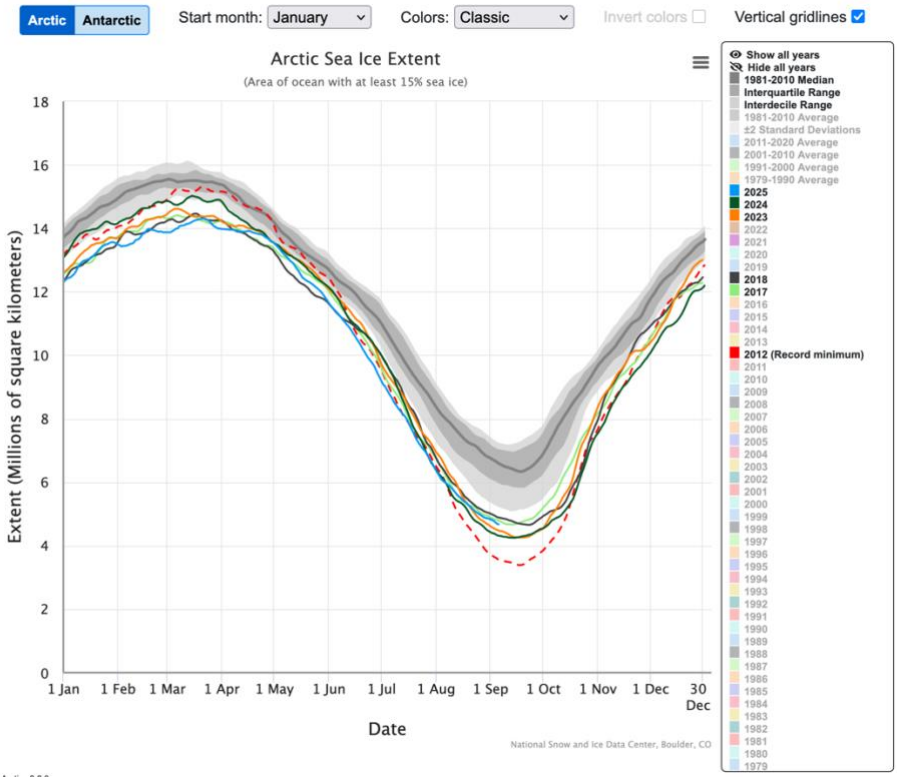

Figure iv. Daily sea ice extent for 2025 and I also included 2024, 2023, 2018 and 2017. 2012 is shown in the red dashed line. 1981-2010 average is shown in dark gray line.

It has been shown that less sea ice in the North Atlantic sector of the Arctic weakens the polar vortex while less sea ice in the North Pacific sector strengthens the polar vortex. Since sea ice is currently low in both the North Atlantic and the North Pacific sectors, I think best to follow the evolution of sea ice melt and growth this fall before trying to infer what could be the possible impact on the fall and winter PV. And that is something that I will be following closely in the coming months.

Near-Term

This week

The AO is predicted to be 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 weak but positive geopotential height anomalies across Greenland (**Figure 2**), the NAO is predicted to be negative this week.

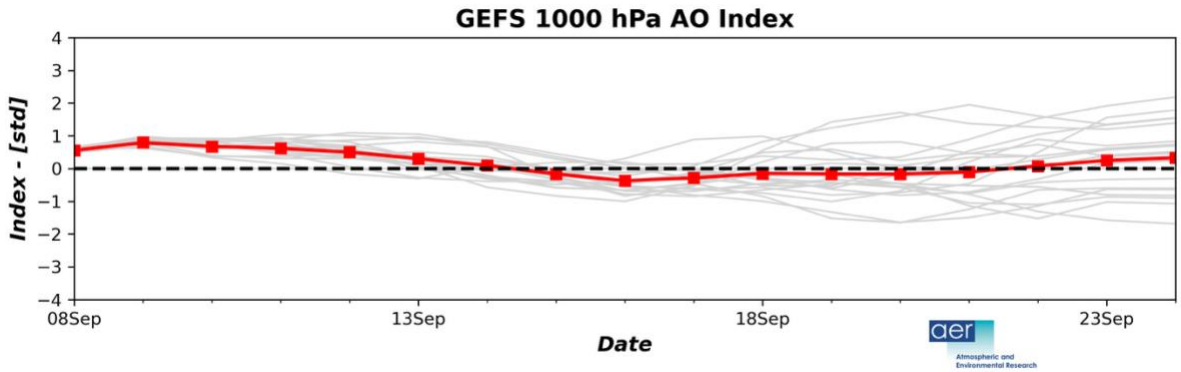

Figure 1. The predicted daily-mean AO at 1000 hPa from the 00Z 08 September 2025 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble mean AO index given by the red line with squares.

This week predicted deep troughing/negative geopotential height anomalies centered south of Greenland and Iceland will support a strong jet and troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height anomalies across Southern Europe (**Figure 2).** The mostly zonal flow pattern will support widespread normal to above normal temperatures across much of Europe with the biggest exception of normal to below normal temperatures across far Western Europe including the UK this period (**Figure 3**). This week the predicted pattern across Asia is strong ridging/positive geopotential height anomalies centered Western Asia forcing troughing/negative geopotential height anomalies across Western and Central Siberia with the southern end of the troughing swinging through Kazakhstan (**Figure 2**). This pattern favors widespread normal to above normal temperatures across much of Asia with the exceptions of normal to below normal temperatures across Western Siberia and Kazakhstan this period **(Figure 3**).

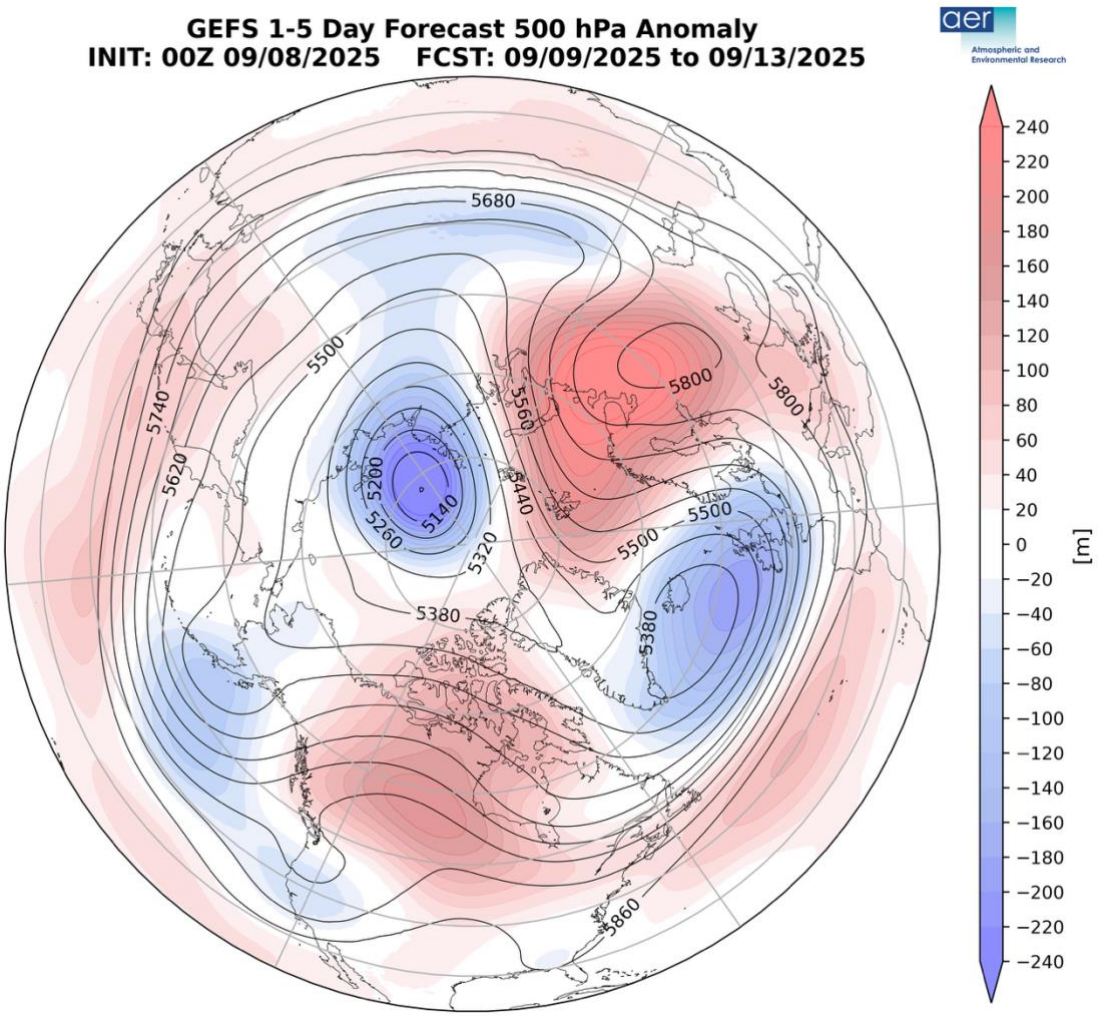

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 09 Sep to 13 Sep 2025. The forecasts are from the 00Z 08 Aug 2025 GFS ensemble.

This week expanding ridging/positive geopotential height anomalies is predicted to expand across the continent with the exceptions of troughing/negative geopotential height anomalies across western Alaska, Eastern Canada, the Eastern United States (US) and the US West Coast this week (**Figure 2**). This patten will favor widespread normal to above normal temperatures across the US and Canada with the exceptions of normal to below normal temperatures in western Alaska, Eastern Canada, the Eastern US and US West Coast (**Figure 3**).

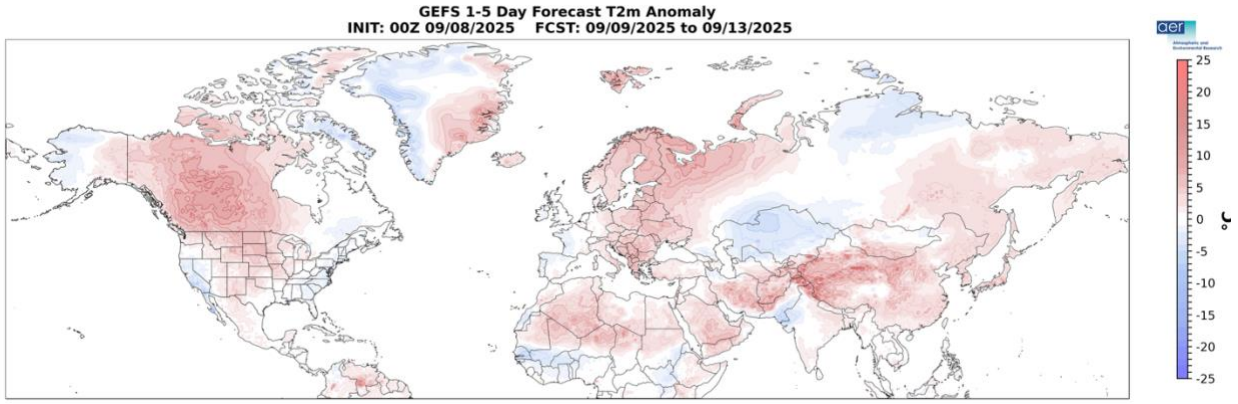

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 09 Sep to 13 Sep 2025. The forecasts are from the 00Z 08 Sep 2025 GFS ensemble.

Troughing will support new rainfall across the UK, Central Europe including the Alps, Southern Siberia, parts of East Asia and the Tibetan Plateau with otherwise mostly dry conditions widespread across Europe and Asia, with near normal precipitation across Afghanistan this week (**Figure 4**). Troughing will support new rainfall across northern and southern Alaska and the Western US with otherwise mostly dry conditions widespread across Canada and the US this week (**Figure 4**).

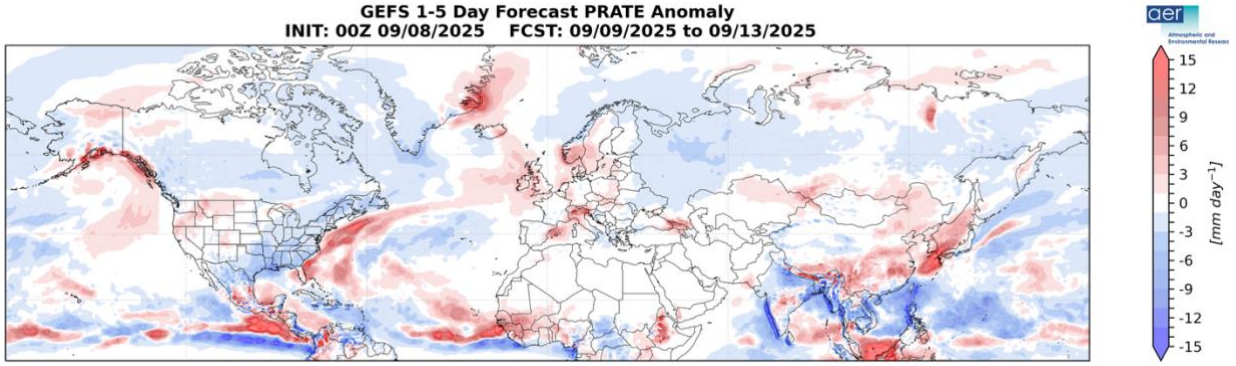

Figure 4. Forecasted rainfall (mm/day; shading) from 09 Sep to 13 Sep 2025. The forecasts are from the 00Z 08 Sep 2025 GFS ensemble.

Near-Mid Term

Next week

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

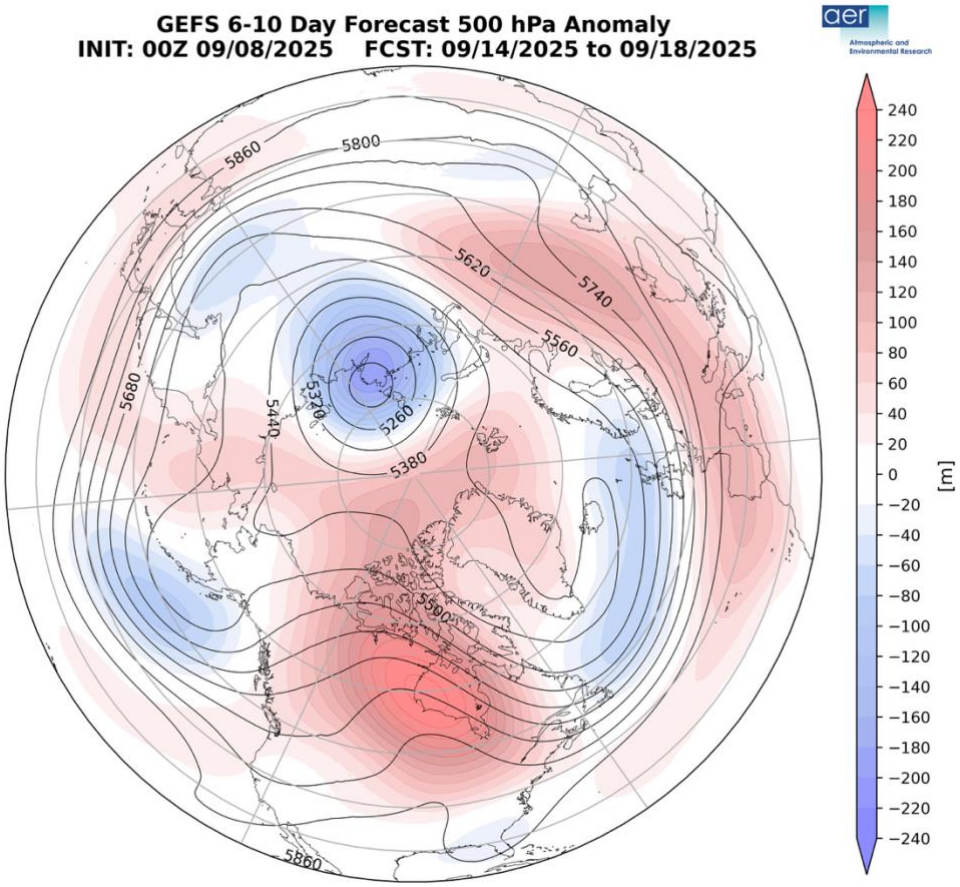

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 14 Sep to 18 Sep 2025. The forecasts are from the 00Z 08 Sep 2025 GFS ensemble.

Persistent troughing/negative geopotential height anomalies centered south of Greenland and Iceland will support a strong jet and troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height anomalies across Southern Europe (**Figure 5**). The mostly zonal flow pattern will support widespread normal to above normal temperatures across much of Europe with the biggest exception being the UK this period (**Figure 6**). Persistent ridging/positive geopotential height anomalies will remain centered over Western Asia will support troughing/negative geopotential height

anomalies centered in Western Siberia and into Central and East Asia this period (**Figure 5**). This pattern favors widespread normal to above normal temperatures across most of Asia including Pakistan with normal to below normal temperatures Western and Central Siberia and parts of Central and East Asia including Kazakhstan, Mongolia and northern Pakistan this period (**Figure 6**).

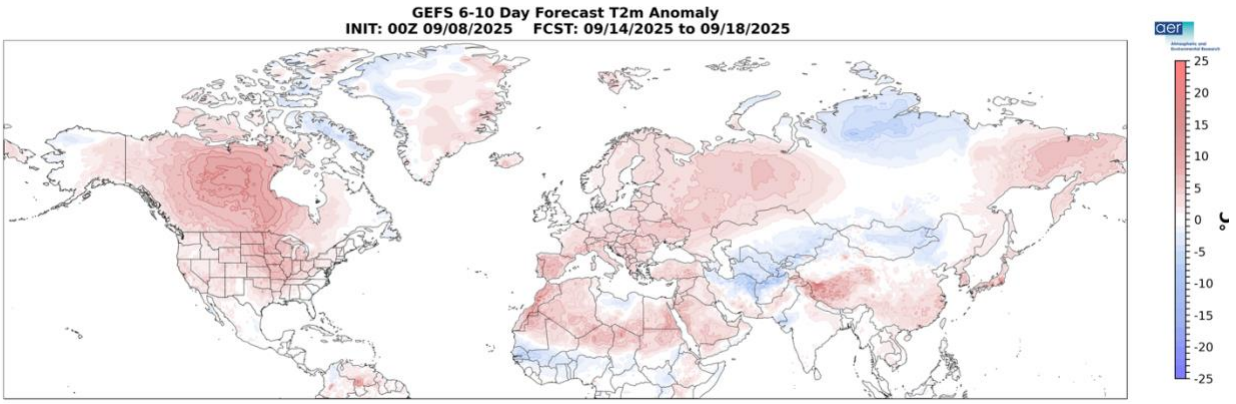

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 14 Sep to 18 Sep 2025. The forecasts are from the 00Z 08 Sep 2025 GFS ensemble.

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

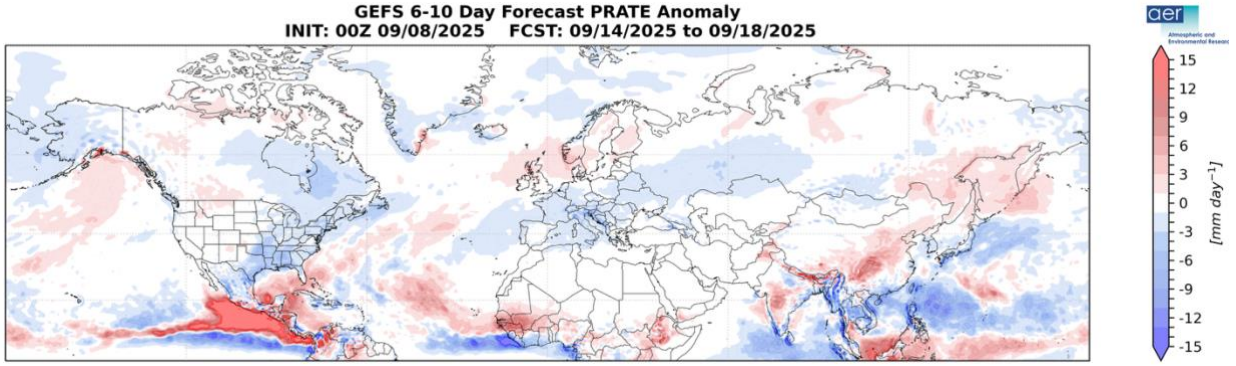

Figure 7. Forecasted precipitation rate (mm/day; shading) from 14 Sep to 18 Sep 2025. The forecasts are from the 00Z 08 Sep 2025 GFS ensemble.

Troughing will support new rainfall across the UK, Scandinavia, India, Southwestern and Northeastern China, parts of Southeast Asia and the Tibetan Plateau including northern Pakistan with otherwise mostly dry conditions widespread across Europe and Asia and near normal across Afghanistan and Pakistan this period (**Figure 7**). Troughing will support new rainfall

across the Canadian and Northern US Rockies with otherwise mostly dry conditions widespread across Canada and the US this period (**Figure 7**).

Mid Term

Week Two

With predicted mostly mixed 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 this period (**Figure 1**). With predicted weak and mixed pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO will likely be near neutral this period.

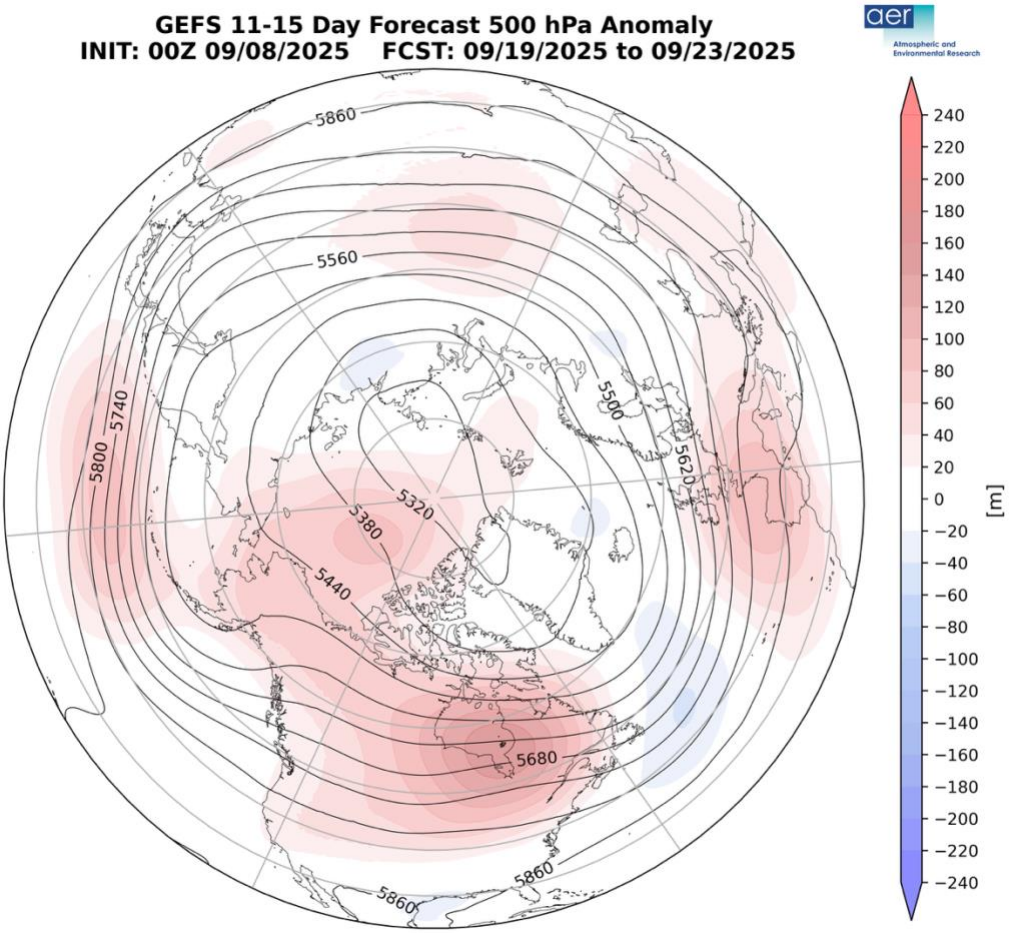

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 19 Sep to 23 Sep 2025. The forecasts are from the 00Z 08 Sep 2025 GFS ensemble.

The persistent pattern of troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height anomalies across Southern Europe is predicted to continue this period (**Figure 8**). This quasi-zonal pattern should favor normal to above normal

temperatures across much of Europe with the possible exception of normal to below temperatures across the UK this period (**Figures 9**). Persistent ridging/positive geopotential height anomalies are predicted weaken across Asia with residual weak troughing/negative geopotential height anomalies across Siberia and into Eastern Asia this period (**Figure 8**). The predicted pattern favors normal to above normal temperatures widespread across Asia including Pakistan with normal to below normal temperatures across Western and Central Siberia, Eastern China, Afghanistan and India this period (**Figure 9**).

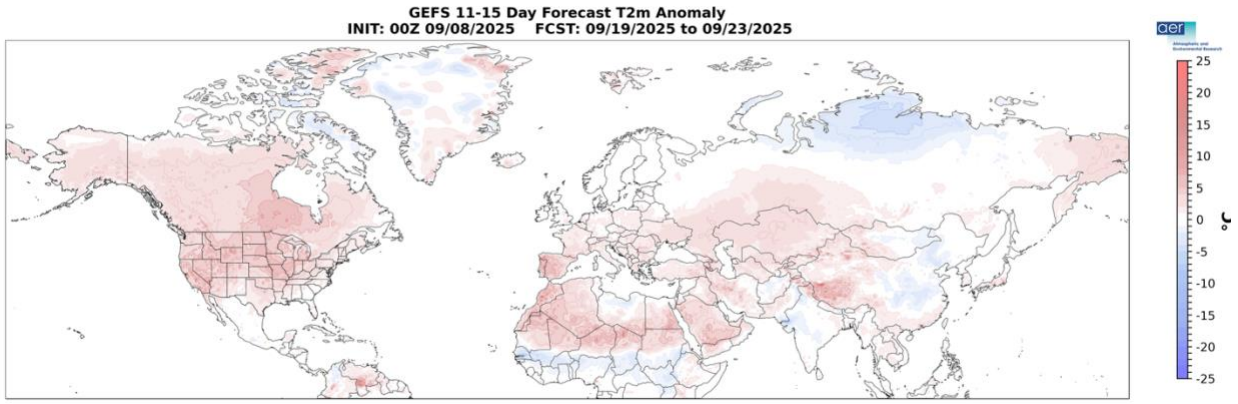

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 19 Sep to 23 Sep 2025. The forecasts are from the 00Z 08 Sep 2025 GFS ensemble.

Ridging/positive geopotential height anomalies centered Hudson Bay are predicted to dominate North America with weak troughing/negative geopotential height anomalies across the Southeastern US this period (**Figure 8**). This pattern supports widespread normal to above normal temperatures across Alaska, Canada and the US with normal to below normal temperatures mostly limited to the Southeastern US this period (**Figure 9**).

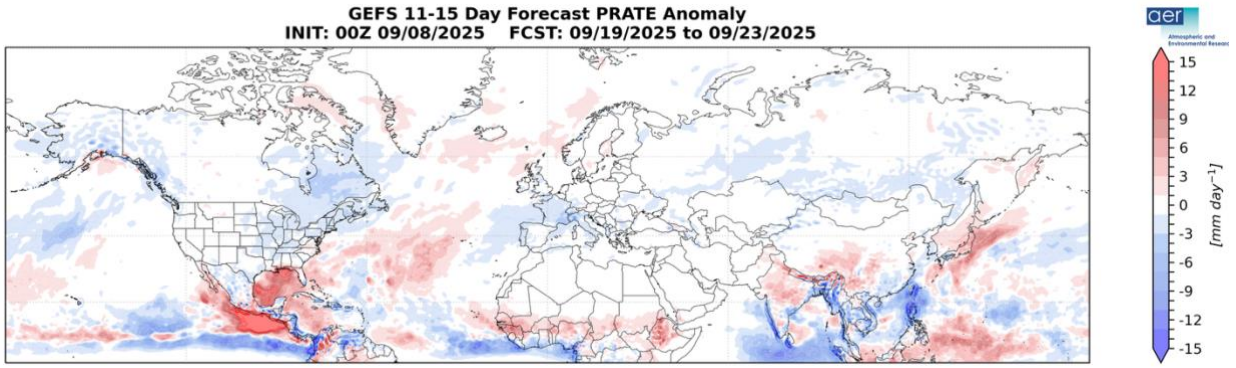

Figure 10. Forecasted precipitation rate (mm/day; shading) from 19 Sep to 23 Sep 2025. The forecasts are from the 00Z 08 Sep 2025 GFS ensemble.

Troughing will support new rainfall across parts of Northeast Asia, Central China, Northern India and the Tibetan Plateau with otherwise mostly dry conditions widespread across Europe and

Asia and near normal precipitation in Afghanistan and Pakistan this period (**Figure 10**). Troughing will support new rainfall along the Gulf of Mexico 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 in the upper stratosphere with warm/positive PCHs in the lower stratosphere and throughout the troposphere (**Figure 11**). The cold/negative PCHs are predicted to persist in the stratosphere over the next two weeks with warm/positive PCHs weakening in the lower stratosphere and upper troposphere but possibly reversing in late September.

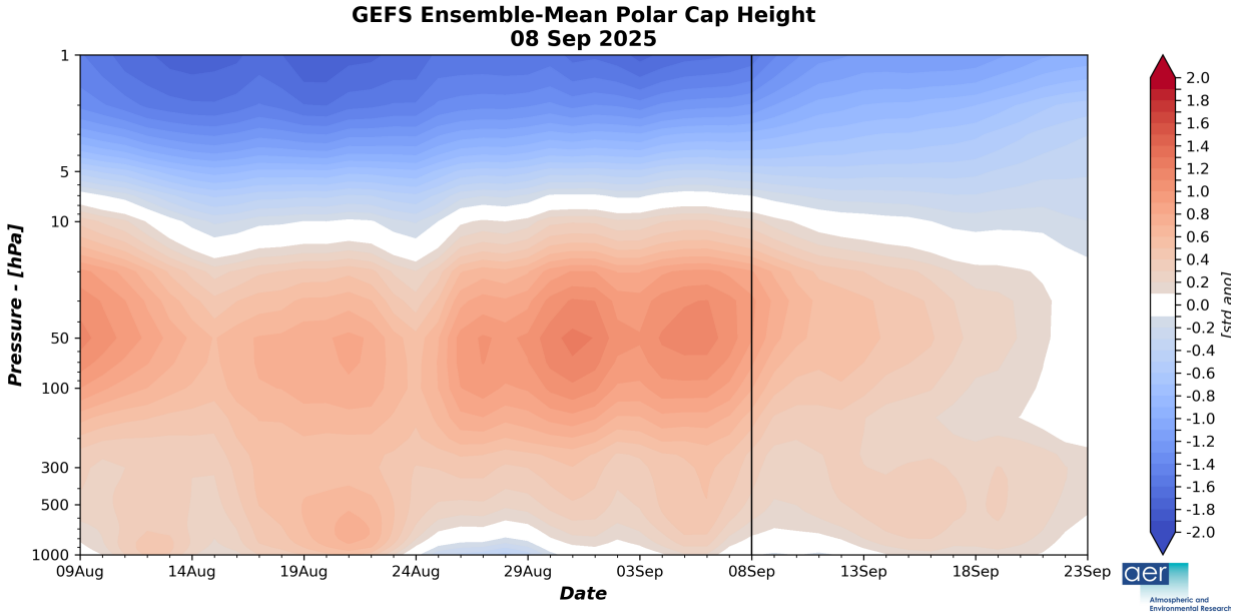

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 08 Aug 2025 GFS ensemble.

The predicted near neutral PCHs in the lower troposphere this week (**Figure 11**) are consistent with the predicted near neutral surface AO this week (**Figure 1**). Then heading towards the end of the month, the predicted increasing relaxing warm/positive PCHs in the troposphere (**Figure 11**) should start to bias the surface AO positive (**Figure 1**).

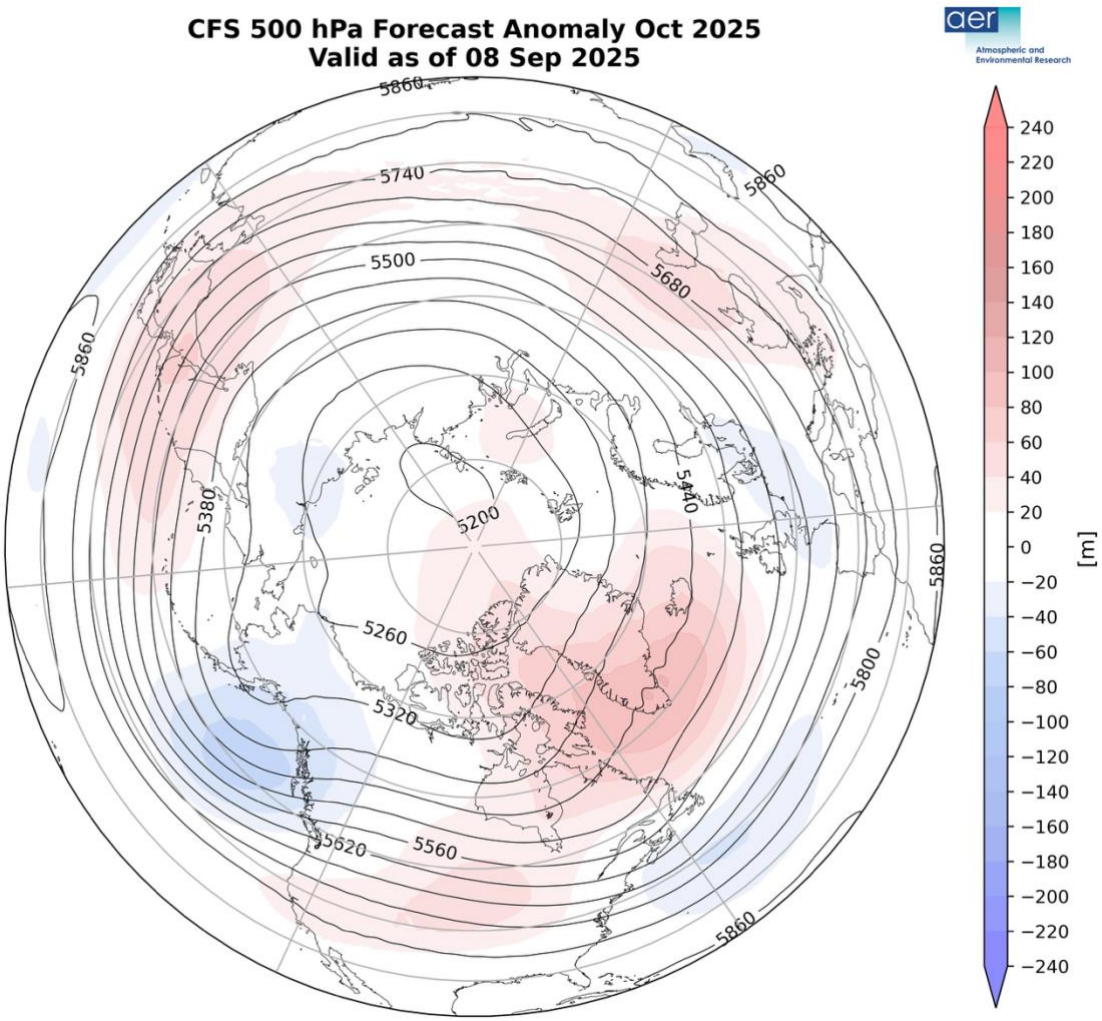

Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for October 2025. The forecasts are from the 00Z 08 Sep 2025 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and surface temperatures for September (**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 southern Greenland, Western Asia and Central Canada and the US, with troughing across Northern Europe, Siberia, the Gulf of Alaska and the Northeastern US (**Figure 12**). This pattern favors seasonable to relatively warm temperatures across Southern and Eastern Europe, Western and Central Asia, the Tibetan Plateau, Pakistan, Afghanistan, much of Canada and the US with seasonable to relatively cool temperatures across Northern Europe, Siberia, parts of Eastern Asia, Alaska, Western Canada, the Canadian Maritimes and New England (**Figure 13**).

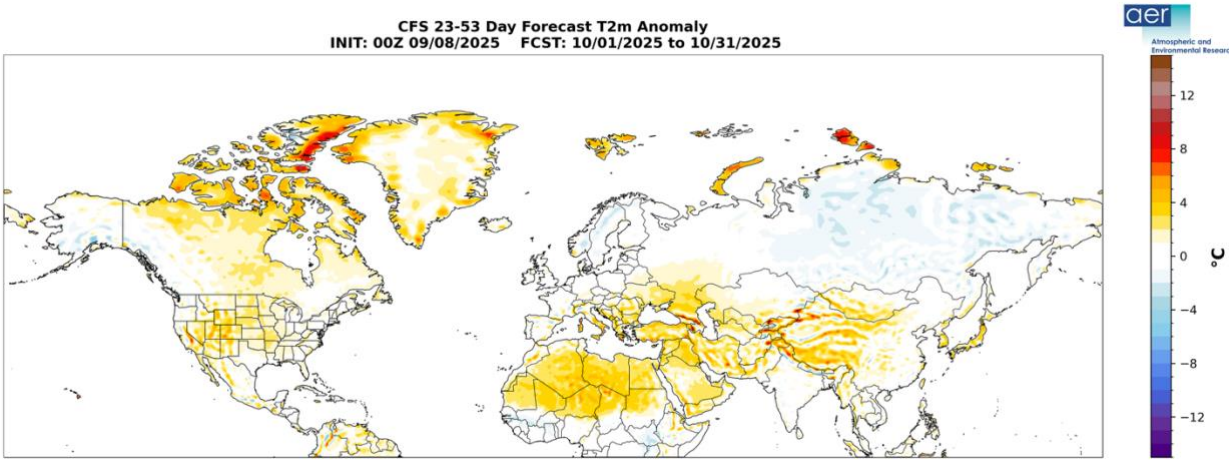

Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for October 2025. The forecasts are from the CFS 00Z 08 Sep 2025.

Boundary Forcings

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are slightly below normal, east of the Dateline (**Figure 14**) consistent with neutral conditions but suggestive that La Niña could return once again this winter and 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 North Pacific (not sure if this plot is accurate but is eye popping!) and much of the North Atlantic with the exception near the Canadian Maritimes and the Northeastern US and extending south of Iceland, though below normal SSTs exist regionally especially in the South Pacific.

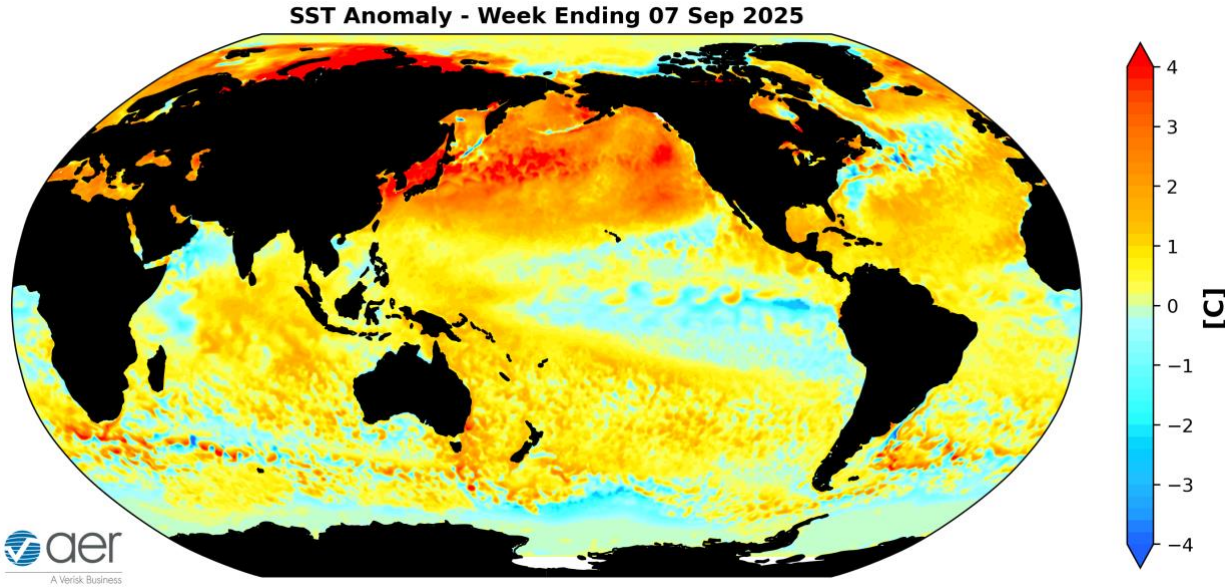

Figure 14. The latest daily-mean global SST anomalies (ending 07 Sep 2025). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently the Madden Julian Oscillation (MJO) is in phase two and is predicted to weaken to where no phase is favored (**Figure 15**). Phase two favors ridging centered in the center of North America and with troughing in the Gulf of Alaska, therefore, it seems to me that the MJO could be having some influence on North American weather this week. But admittedly this is outside of my expertise.

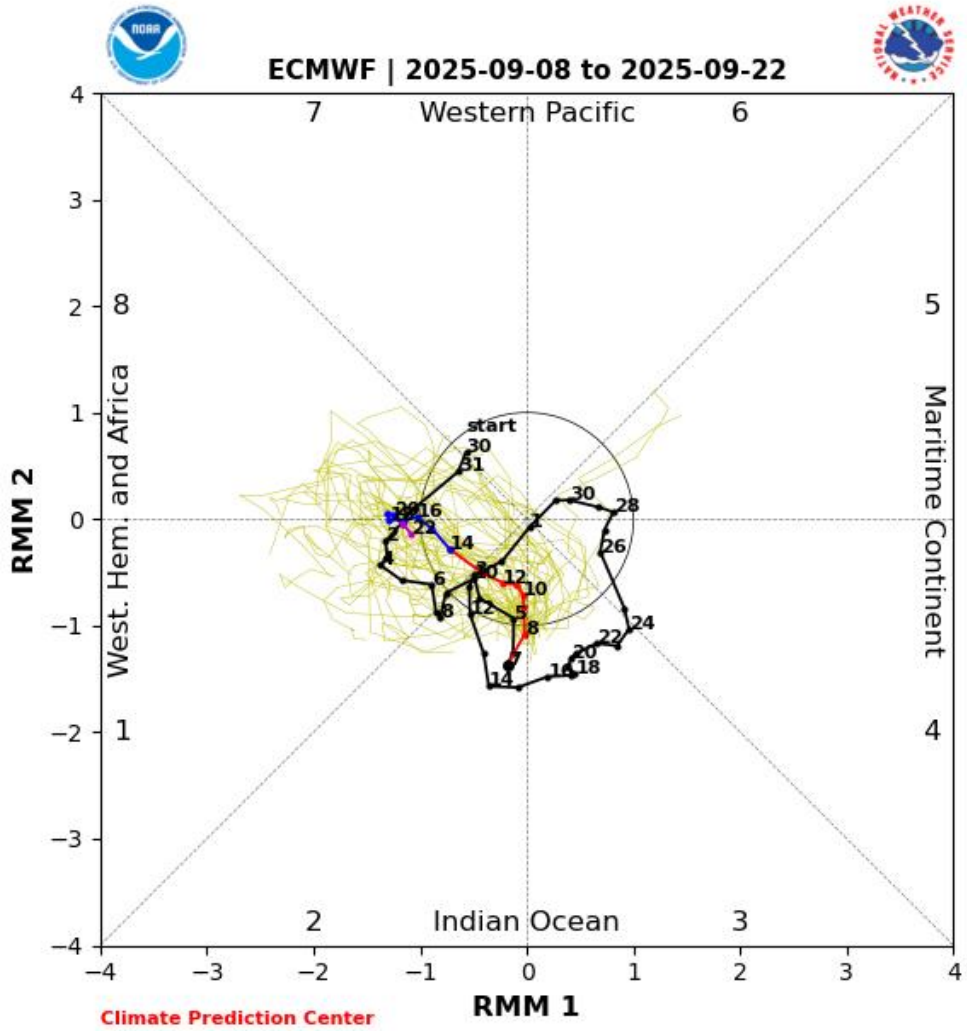

Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 08 Sep 2025 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model 'spread' is denoted by the gray shading. Sector numbers indicate 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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