

Arctic Oscillation and Polar Vortex Analysis and Forecasts

May 28, 2021

Special blog on winter 2018/2019 retrospective can be found here
- <http://www.aer.com/winter2019>

Special blog on winter 2017/2018 retrospective can be found here
- <http://www.aer.com/winter2018>

Special blog on winter 2016/2017 retrospective can be found here
- <http://www.aer.com/winter2017>

Special blog on winter 2015/2016 retrospective can be found here
- <http://www.aer.com/winter2016>

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. With the start of 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 neutral and is predicted to straddle neutral over the next two weeks as pressure/geopotential height anomalies across the Arctic are predicted to remain mixed across the Arctic with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently negative and is predicted to first pop

positive this upcoming week as pressure/geopotential height anomalies are predicted to turn negative across Greenland and then trend negative as pressure/geopotential height anomalies rise the second week of June.

- Recent ridging/positive geopotential height anomalies across Greenland will favor troughing/negative geopotential height anomalies across Europe with below normal temperatures across much of Europe including the United Kingdom (UK) over the next week. However, as geopotential heights fall over Greenland this will favor rising pressure/geopotential height anomalies across Europe and a warming trend the second week of June.
- This week, the predicted pattern across Asia is troughing/negative geopotential height anomalies coupled with normal to below temperatures in Western and Eastern Asia with ridging/positive geopotential height anomalies coupled with normal to above normal temperatures across Central Asia. However, troughing/negative geopotential height anomalies are predicted to weaken with ridging/positive geopotential height anomalies become more expansive across Asia favoring widespread normal to above temperatures across Asia the second week of June.
- This week across North America the predicted pattern is ridging/positive geopotential height anomalies coupled with normal to above normal temperatures across western North America and Eastern Canada with troughing/negative geopotential height anomalies coupled with normal to below temperatures across the Eastern United States (US). However, for the following week geopotential heights are predicted to rise in the Gulf of Alaska forcing troughing/negative geopotential height anomalies coupled with normal to below temperatures first in Western Canada and then in the Central US while ridging/positive geopotential height anomalies coupled with normal to above normal temperatures overspread the west and east coasts of North America.
- In the Impacts section I present the AER summer temperature forecast for the Northern Hemisphere (NH) and compare with the ensemble from the American and European dynamical models.

Impacts

I am posting in today's blog the AER summer temperature anomaly forecast for the NH in **Figure i**. I also included the ensemble mean from the North American Multi-Model Ensemble (NMME) and from the C3S, which is the ensemble of the UK Met Office, ECMWF and Meteo France. There is a consistent theme from all three forecasts – above normal temperatures can be expected across most of the mid-latitude continents. Regions where the models are most confident of experiencing above normal temperatures are the Western US, Siberia and the Middle East into Central Asia.

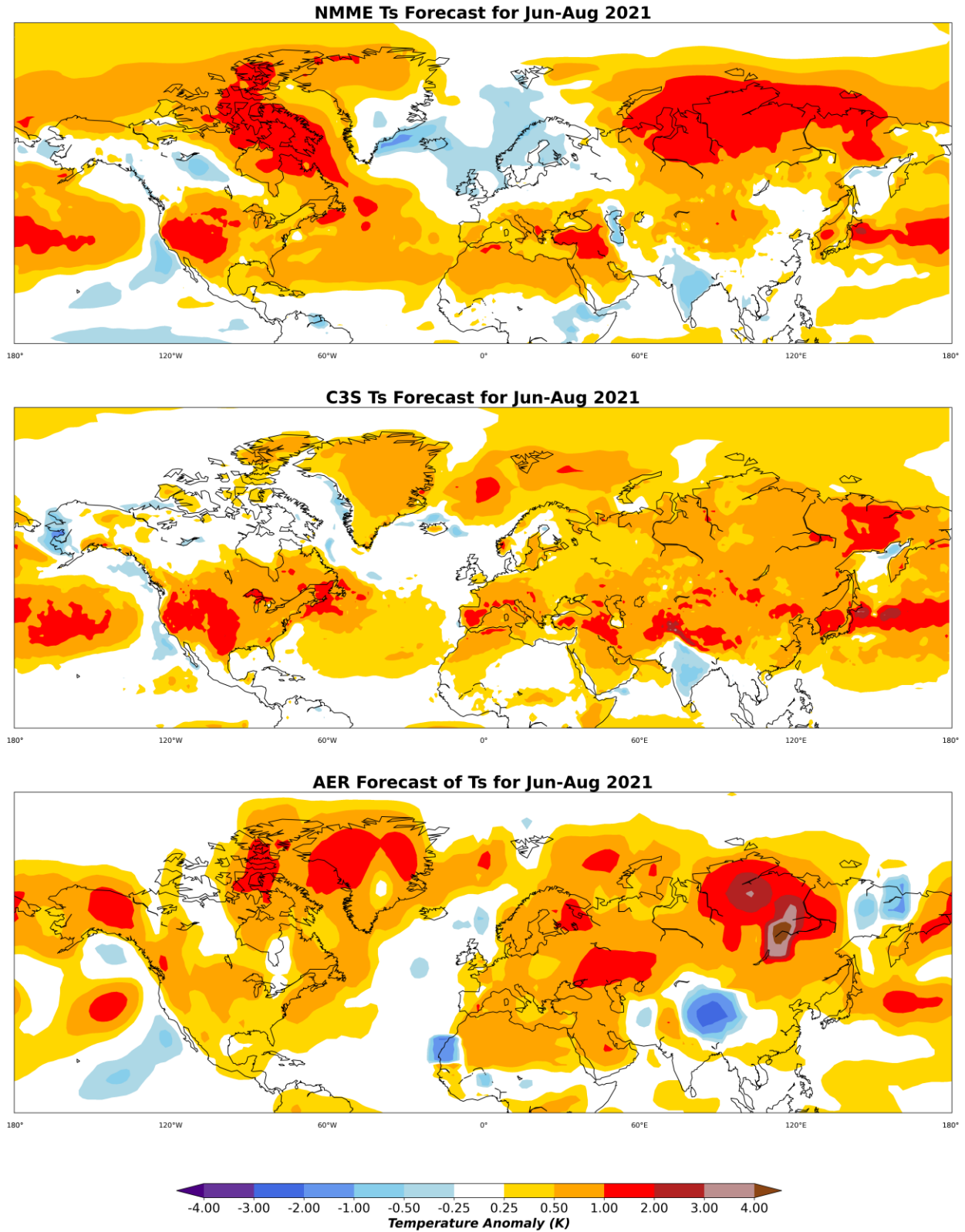


Figure i. Forecasted surface temperature anomalies for June-August 2021 from the NMME (top), C3S (middle) and AER (bottom) models.

A couple of factors thought to be important for summer weather are El Niño/Southern Oscillation (ENSO) and soil moisture. ENSO is predicted to be neutral so not much signal there, but perhaps soil moisture provides more interesting information. Wet soil is thought to favor cooler temperatures and dry soil warmer temperatures. That is because when the soils are wet incoming sunlight is used to evaporate moisture from the soil rather than heat the soil. If the soil is dry much more of the sunlight is converted into heating. Though soil moisture is often argued as influential on summer temperatures, it does seem to me the relationship is tenuous at best.

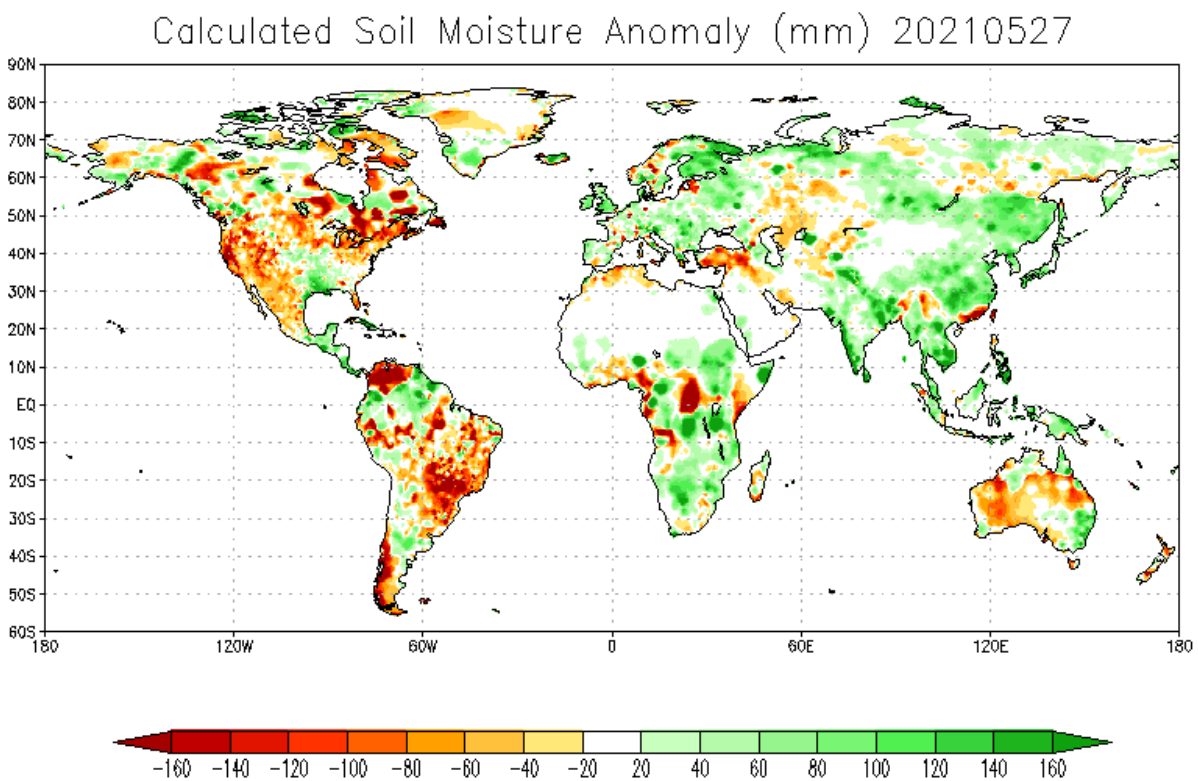


Figure ii. Observed soil moisture anomalies in mm. Plot from: https://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/GLB/glb_s.shtml

In **Figure ii**, I present recent global soil moisture anomalies from NOAA's Climate Prediction Center. In the NH, the US stands out for being dry especially in the Western and Northern US. With little chance of erasing this deficit in the summer months, the Western US will likely stay dry all summer, supporting a relatively hot summer. There is a better chance that the dryness in the Northeastern US moderates over the summer and I don't consider it as strong as an indicator. Europe looks relatively wet, in part due

to a cold spring that inhibits evaporation. Also, in many locations the cool weather was accompanied by plenty of rainfall. This spring, Europe was cooler and wetter than most recent springs and could be a harbinger of a cooler summer than many recent summers. Europe has been one of the regions warming the fastest in summer, but this summer may be an exception.

Finally, it is my impression that there has been a tendency for high latitude blocking/high pressure this spring and that could persist for much of the summer. If high latitude blocking persists in a certain region it could contribute to cool and/or wet weather downstream. An example from this spring is Greenland blocking contributing to the cool spring across Europe. Blocking near Alaska/Gulf of Alaska could not only bring warm temperatures to the west coast of North America but cooler weather to the interior of North America. In **Figure iii**, I include an animation of 500 hPa geopotential heights from the most recent GFS. Towards the end of the animation the GFS is predicting episodes of high pressure both for Greenland and the Gulf of Alaska. I have low confidence in this particular forecast, but I do think that it highlights the need to monitor for episodes of high latitude blocking during the summer months.

Initialized 00Z 500 hPa HGT/HGTa 28-May-2021

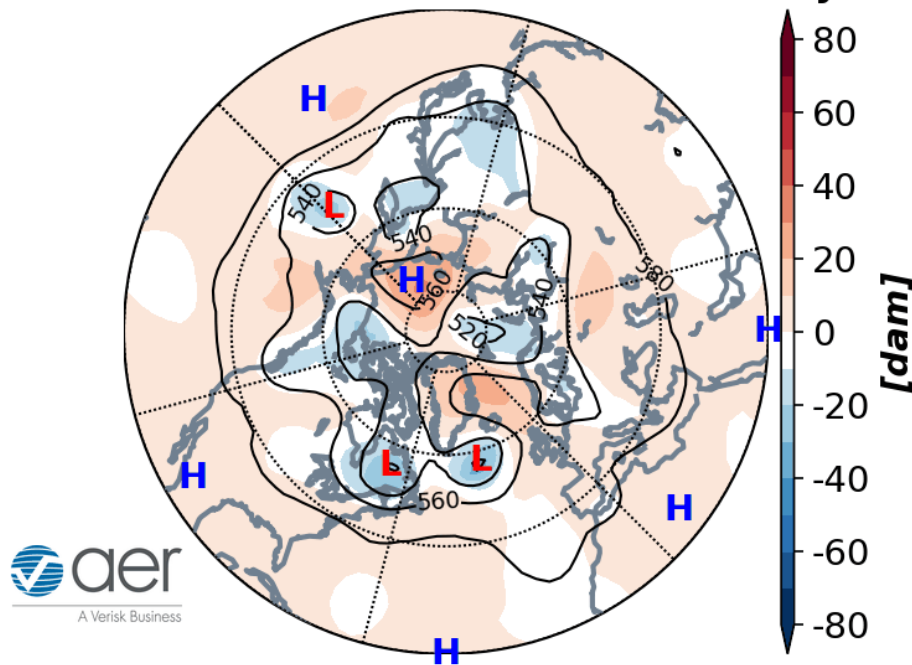


Figure iii. Observed and forecasted 500 hPa geopotential height anomalies (decameters; shading) from 28 May - 13 June 2021. The forecasts are from the 00Z 28 May 2021 GFS operational run.

1-5 day

The AO is predicted to remain near neutral this period (**Figure 1**) as geopotential height anomalies remain mixed across the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with negative geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to jump positive this period.

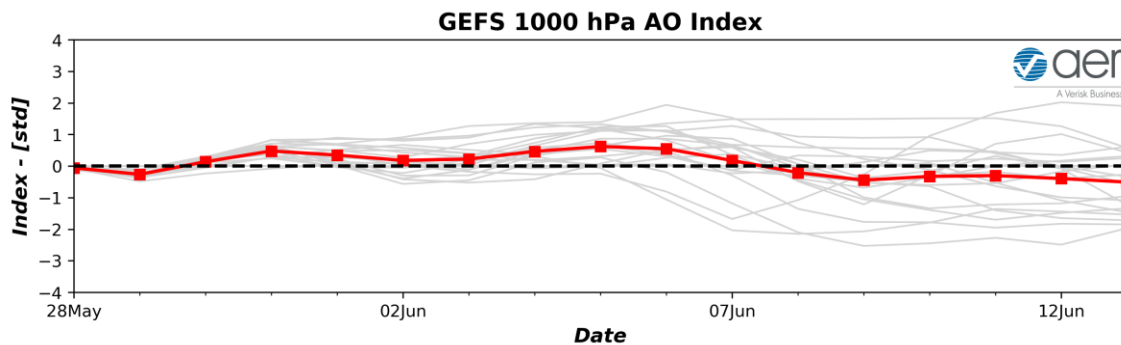


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 28 May 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Trouching/negative geopotential height anomalies across Greenland are predicted to force ridging/positive geopotential height anomalies across Europe especially across Northern Europe with residual troughing/negative geopotential height anomalies across Southeastern Europe (**Figures 2**). This will favor normal to above normal temperatures across much of Northern and Western Europe including the UK with normal to below normal temperatures across Eastern and Southern Europe (**Figure 3**). Eastern European troughing/negative geopotential height anomalies are predicted to extend into Western Asia with ridging/positive geopotential height anomalies in Central Asia, with more troughing/negative geopotential height anomalies in East Asia (**Figure 2**). This pattern favors normal to below normal temperatures across Western and Eastern Asia with normal to above normal temperatures in Central Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 05/28/2021 FCST: 05/29/2021 to 06/02/2021

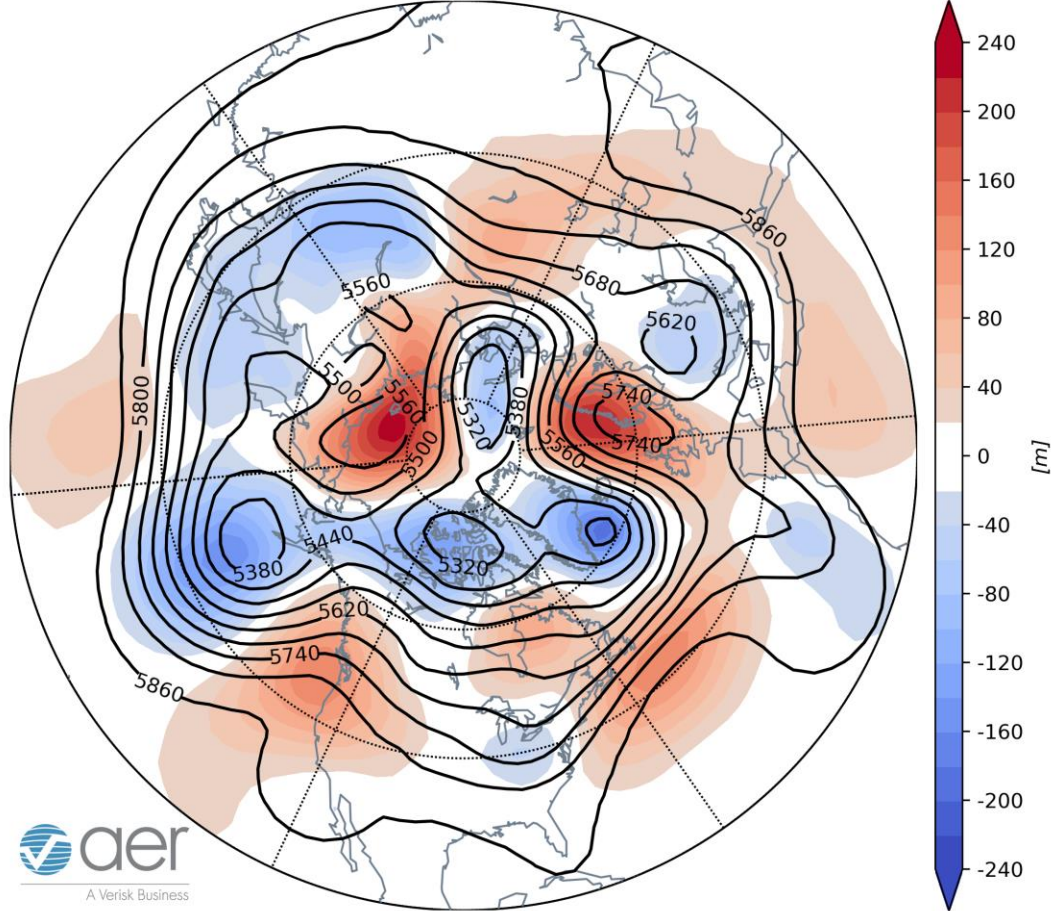


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 29 May – 2 June 2021. The forecasts are from the 00z 28 May 2021 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted across western North America and much of Canada with troughing/negative geopotential height anomalies mostly confined to Alaska and the Eastern US (**Figure 2**). This pattern is predicted to bring normal to above normal temperatures across much of Canada and the Western US with normal to below normal temperatures across Alaska and the US east of the Rockies (**Figure 3**).

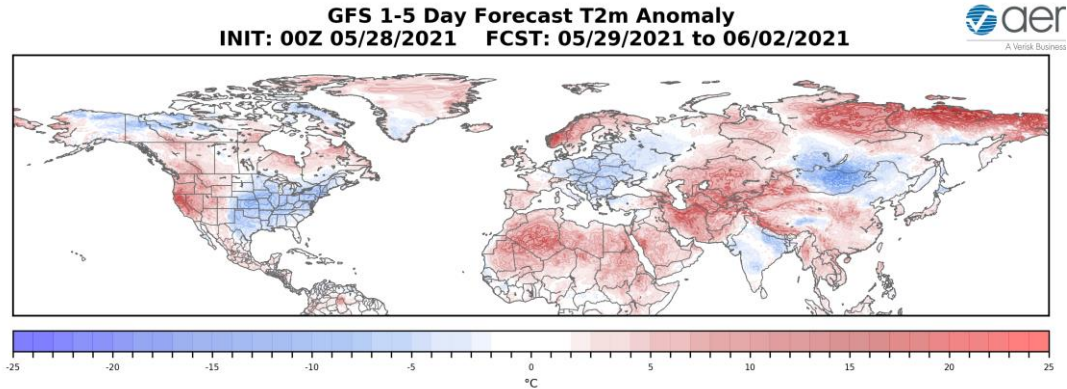


Figure 3. Forecasted surface temperature anomalies (°C; shading) from 29 May – 2 June 2021. The forecast is from the 00Z 28 May 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia with the exceptions of above normal precipitation across northwest Russia and East Asia (**Figure 4**). Normal to below normal precipitation is predicted for much of North America with the exceptions of normal to above normal precipitation in southeastern Alaska, the West Coast of Canada, the US Central Plains, the Northeastern US and the Canadian Maritimes (**Figure 4**).

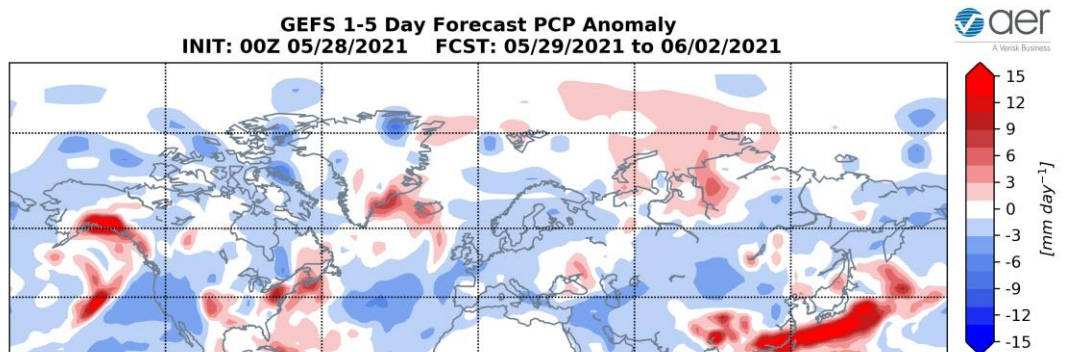


Figure 4. Forecasted precipitation anomalies (mm/day; shading) from 29 May – 2 June 2021. The forecast is from the 00Z 28 May 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to still remain near neutral this period (**Figure 1**) as geopotential height anomalies remain mixed across the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with geopotential height

anomalies predicted to rise across Greenland to slightly positive (**Figure 5**), the NAO is predicted to drop towards neutral or even slightly negative this period.

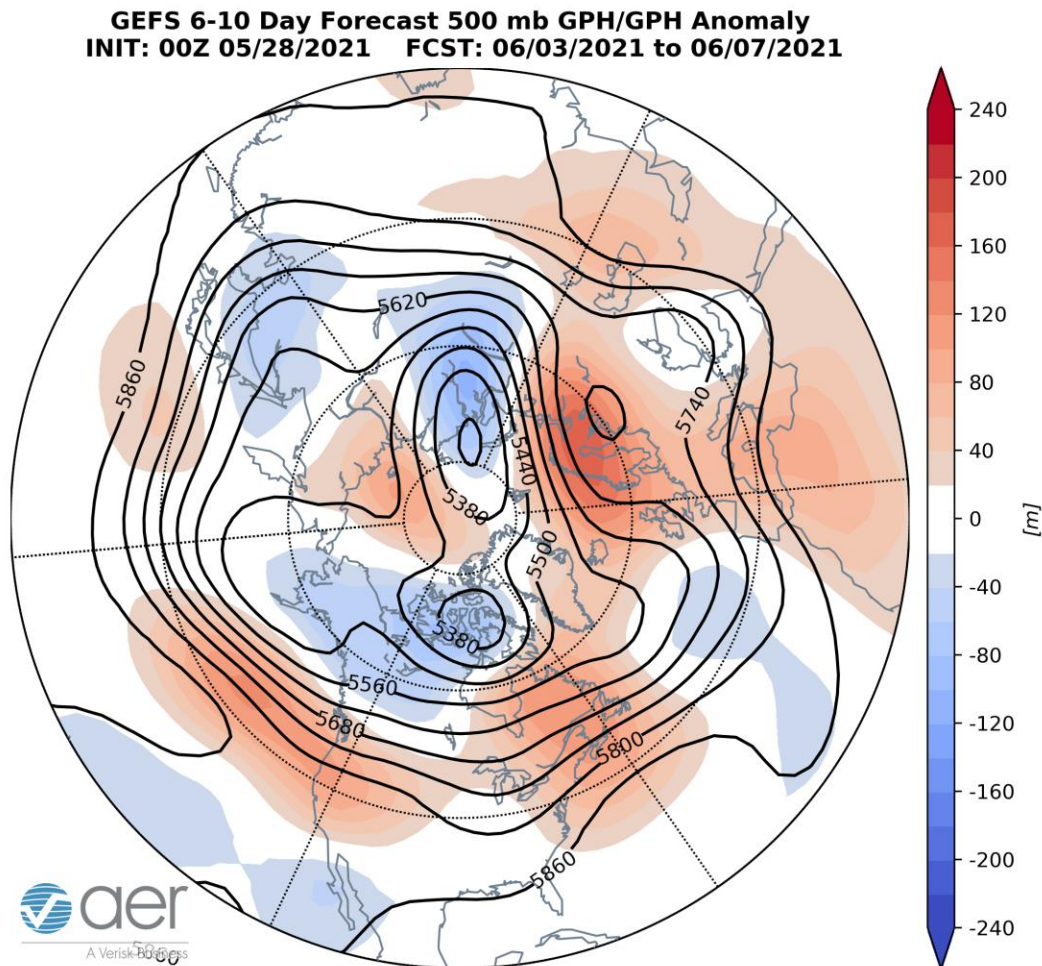


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 3 – 7 June 2021. The forecasts are from the 00z 28 May 2021 GFS ensemble.

Ridging/positive geopotential height anomalies previously confined across Northern Europe are predicted to become more widespread this period across Europe with still some stubborn residual troughing/negative geopotential height anomalies across Southeastern Europe (**Figures 5**). This will favor normal to above normal temperatures across much of Northern and Western Europe including the UK with normal to below normal temperatures confined across Southeastern Europe (**Figure 6**). Troughing/negative geopotential height anomalies previously in Northwestern Russia will slide into Western Siberia this period as ridging/positive geopotential height anomalies become more widespread in Asia, with some residual troughing/negative geopotential height anomalies in East Asia (**Figure 5**). This pattern favors normal to

above normal temperatures across much of Asia with normal to below normal temperatures confined to Western Siberia and Northeast Asia (**Figure 6**).

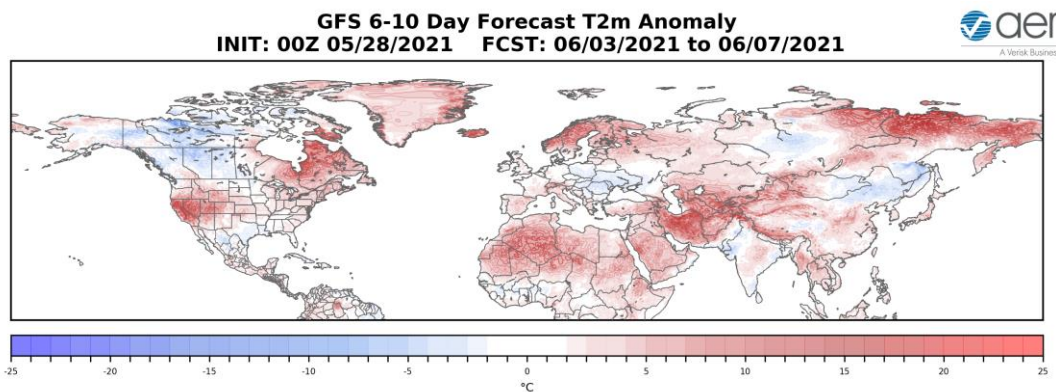


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 3 – 7 June 2021. The forecasts are from the 00Z 28 May 2021 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to become more widespread across North America with troughing/negative geopotential height anomalies mostly confined to Alaska and Northwestern Canada (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across much of Eastern Canada and the US with normal to below normal temperatures across Alaska and Western Canada (**Figure 6**).

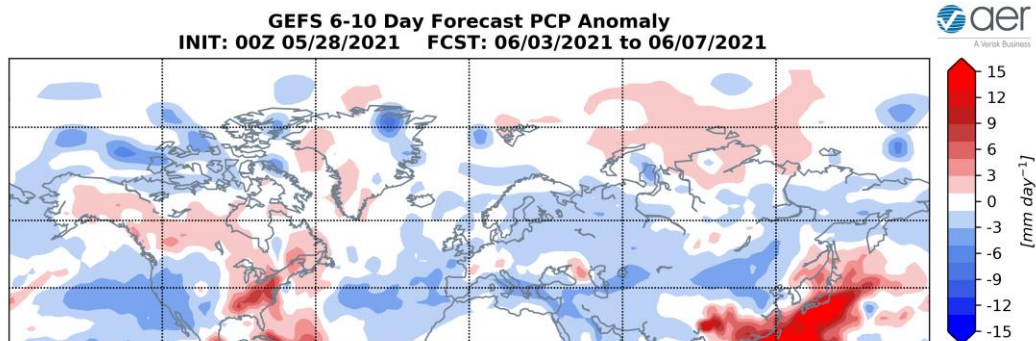


Figure 7. Forecasted precipitation anomalies (mm/day; shading) from 3 – 7 June 2021. The forecasts are from the 00Z 28 May 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia with the exceptions of above normal precipitation across East Asia (**Figure 7**). Normal to below normal precipitation is predicted for much of North America except for normal to above normal precipitation in the Eastern US (**Figure 7**).

11-15 day

With predicted mostly weak positive geopotential height anomalies across the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO should remain neutral to possibly negative this period (**Figure 1**). With possibly weak positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is predicted to remain neutral to negative this period as well.

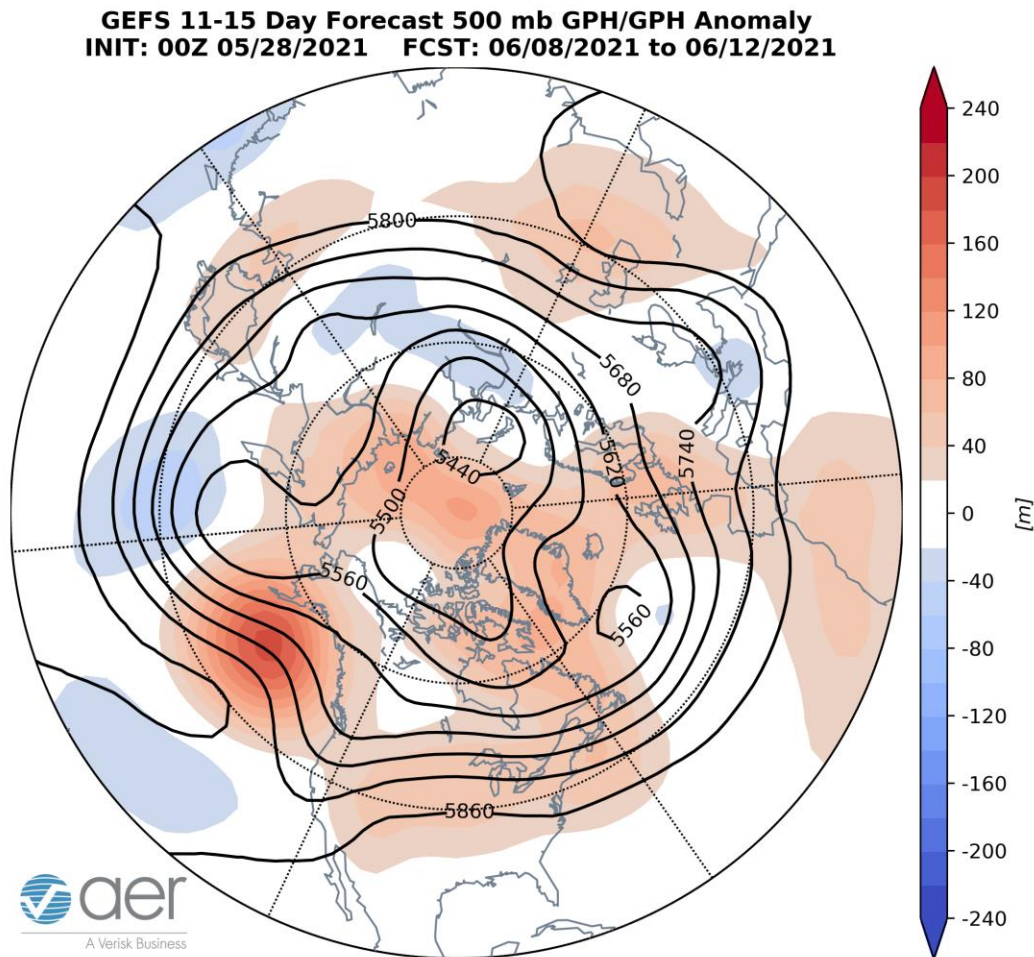


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 8 – 12 June 2021. The forecasts are from the 00z 28 May 2021 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to continue to dominate Europe with the exception of residual troughing/negative geopotential height anomalies in Southeastern Europe (**Figure 8**). This pattern favors normal to above normal temperatures across much of Europe including the UK with normal to below normal temperatures confined to parts of Eastern Europe (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to dominate much of Asia but especially Southcentral Asia with only some weak troughing/negative geopotential height anomalies in Western Siberia this period (**Figure 8**). This pattern favors widespread

normal to above normal temperatures across much of Asia but especially from Iran across to Western China with normal to below normal temperatures limited to parts of Western Siberia and Southeast Asia (**Figure 9**).

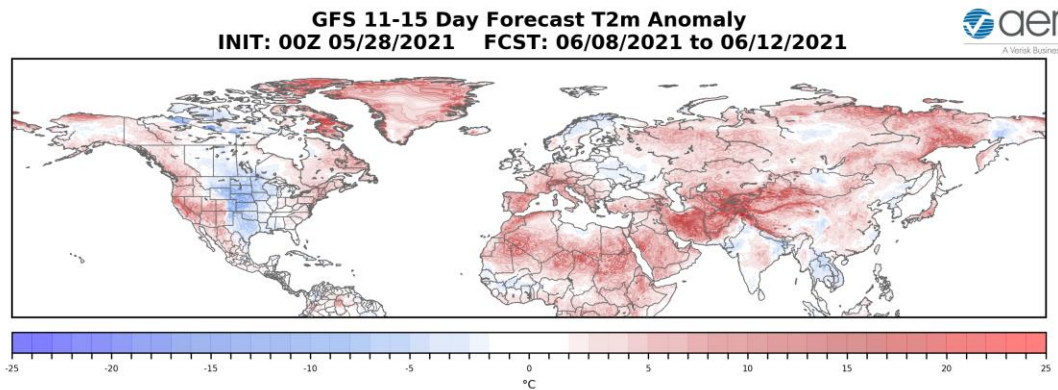


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 8 – 12 June 2021. The forecasts are from the 00z 28 May 2021 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to continue expanding across much of North America. However with the main center of ridging becoming focused in the Gulf of Alaska, this will help to promote troughing/negative geopotential height in the interior of North America this period (**Figure 8**). This pattern favors normal to above normal temperatures for Alaska, Western and Eastern Canada and the Western and Eastern US with normal to below normal temperatures across Central Canada and the Central US (**Figure 9**).

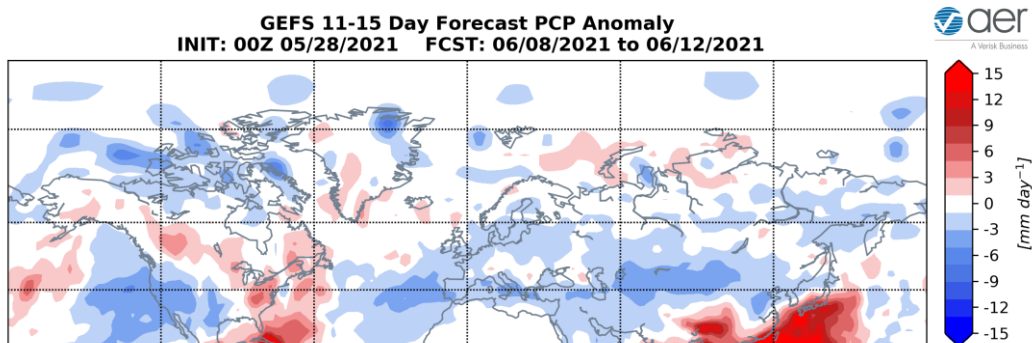


Figure 10. Forecasted precipitation anomalies (mm/day ; shading) from 8 – 12 June 2021. The forecasts are from the 00z 28 May 2021 GFS ensemble.

Normal to below normal precipitation is predicted for Eurasia except for above normal precipitation in Southeast Asia (**Figure 10**). Normal to below normal precipitation is predicted for much of North America except for normal to above normal precipitation in Western Canada, Great Lakes, the Eastern US and the Canadian Maritimes (**Figure 10**).

Longer Term

30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to cold/negative confined to the upper stratosphere with warm/positive PCHs in the mid to low stratosphere and troposphere with the exception of neutral PCHs near the surface this week (**Figure 11**). However, starting late next week cold/negative PCHs in the stratosphere are predicted expand while warm/positive descend and extend throughout the troposphere (**Figure 11**).

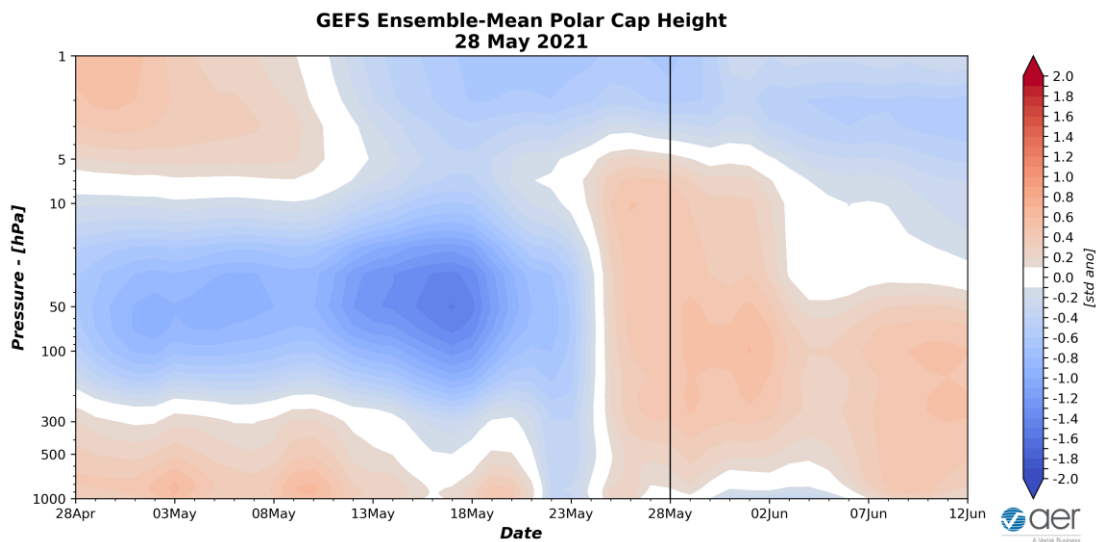


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 28 May 2021 GFS ensemble.

The overall neutral PCHs in the lower troposphere are consistent with the predicted neutral surface AO predicted for next week (**Figure 1**). However, the expansion of warm/positive PCHs to the surface predicted for the end of next week (**Figure 1**) suggests an increasing probability of a negative surface AO heading into the second week of June.

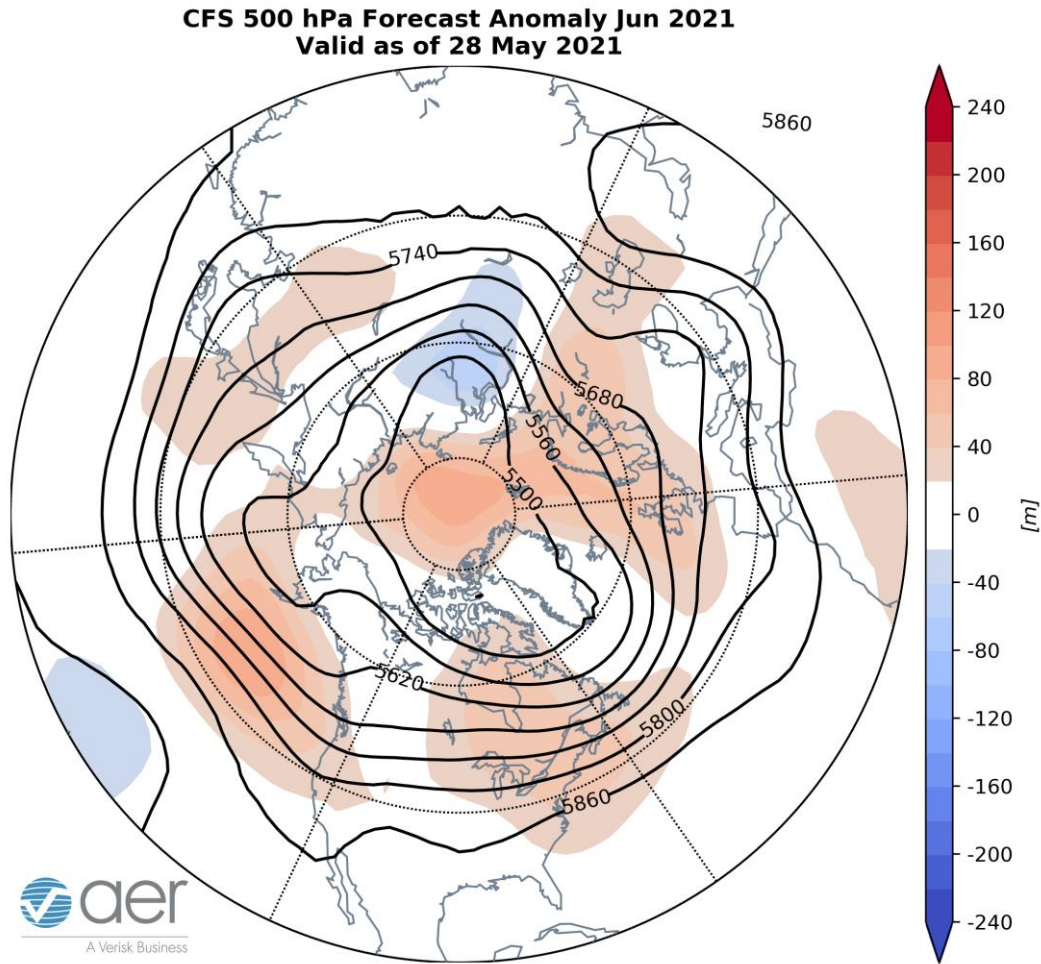


Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for June 2021. The forecasts are from the 00Z 28 May 2021 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and the surface temperatures (**Figure 13**) forecast for June from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging across Northern Europe, Western Asia, Eastern Asia, Gulf of Alaska and eastern North America with troughing in Spain, Southeastern Europe, Western Siberia and near the Dateline (**Figure 12**). This pattern favors seasonable to relatively warm temperatures for Northern Europe, much of Asia but especially Central Asia and the north slope of Siberia, much of Alaska, Canada the Western and Eastern US with seasonable to relatively cool temperatures for Southwestern Europe, Western Siberia and the Central US (**Figure 13**).

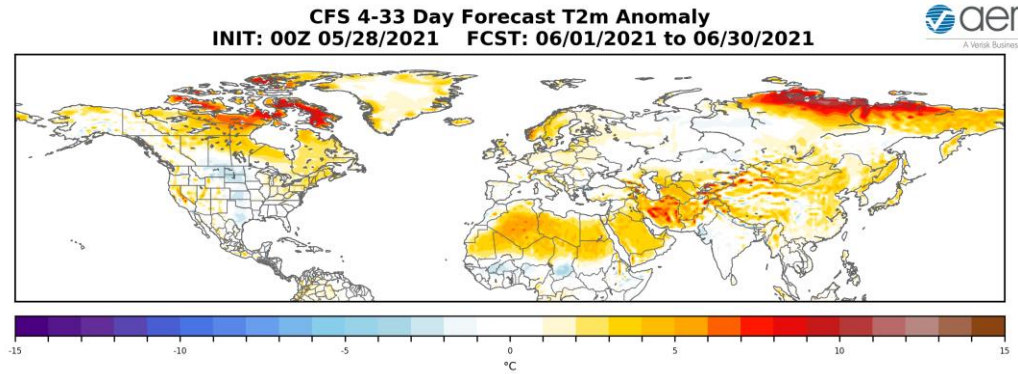


Figure 13. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for June 2021. The forecasts are from the 00Z 28 May 2021 CFS.

Surface Boundary Conditions

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies remain negative and we continue to observe neutral conditions (**Figure 14**) and neutral conditions are expected through the summer. Observed SSTs across the NH remain well above normal especially in the Gulf of Alaska, the western North Pacific and offshore of eastern North America though below normal SSTs exist regionally especially in the Southern Hemisphere and south of Iceland. Warm SSTs in the Gulf of Alaska may favor mid-tropospheric ridging in the region.

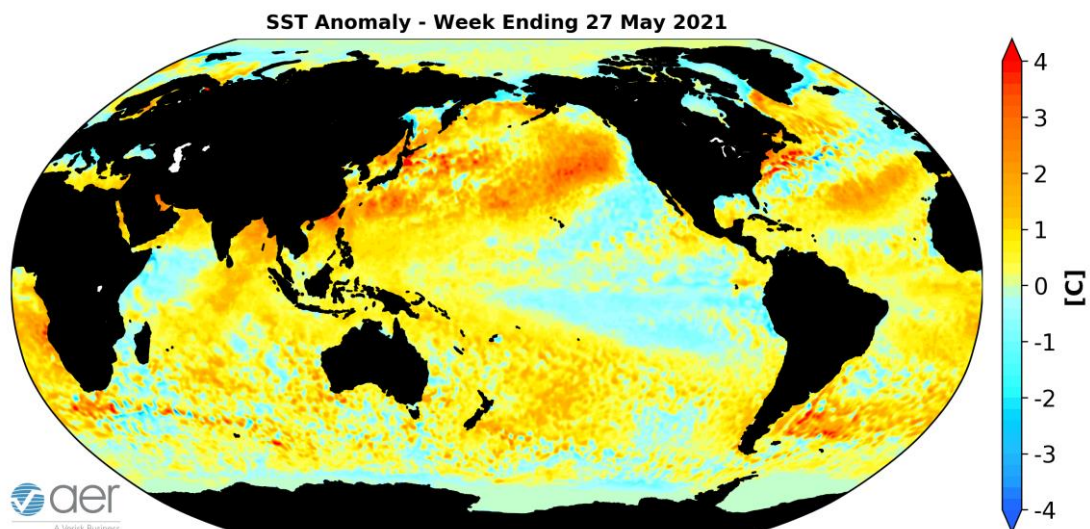


Figure 14. The latest weekly-mean global SST anomalies (ending 27 May 2021). Data from NOAA OI High-Resolution dataset.

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 15**). The forecasts are for the MJO to overall remain weak where no phase is really favored with the possible exception of a brief period in phase seven. MJO phase seven overall favors ridging across Canada with troughing across the Eastern US. Therefore it does not appear that the MJO is contributing much to the predicted weather pattern across North America but admittedly this is outside of my expertise.

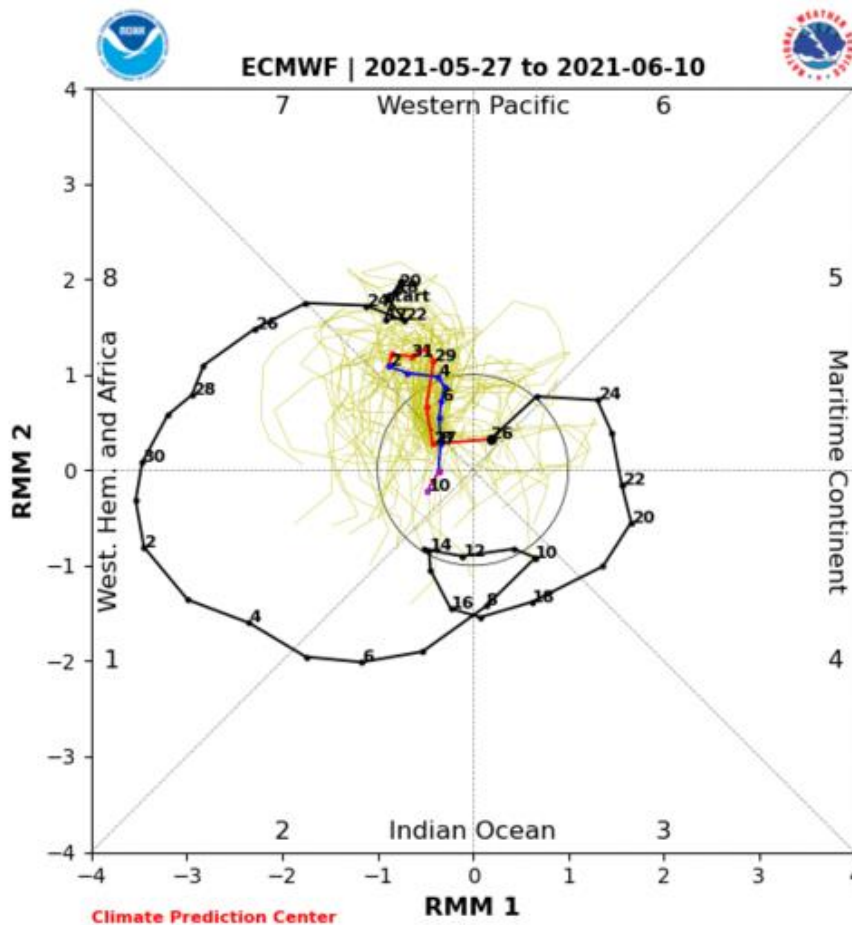


Figure 15. Past and forecast values of the MJO index. Forecast values from the 00Z 27 May 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate the phase of the MJO, with geographical labels indicating where anomalous convection occurs during that phase. Image source: <http://www.atmos.albany.edu/facstaff/roundy/waves/phasediags.html>