# Arctic Oscillation and Polar Vortex Analysis and Forecasts

**May 27, 2020**

***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) recently 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 positive and is predicted to remain positive this week and then trend to neutral to slightly negative next week.
- The current positive AO is reflective of mostly negative pressure/geopotential height anomalies on the North Atlantic side of Arctic with mixed

pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently positive with negative pressure/geopotential height anomalies spread across Greenland; and the NAO is predicted to remain positive this week but turn negative this week as pressure/geopotential height anomalies rise across Greenland and Iceland.

- This week, ridging/positive geopotential height anomalies with normal to above normal temperatures across Western Europe including the United Kingdom (UK) will favor troughing/negative geopotential height anomalies with normal to below normal temperatures across Eastern Europe. However next week rising geopotential height anomalies near Iceland and Scandinavia will favor troughing/negative geopotential height anomalies with normal to below normal temperatures in Western Europe with rising geopotential heights and temperatures in Eastern Europe.
- The predicted general pattern for Asia this week is ridging/positive geopotential height anomalies with normal to above normal temperatures in Western Asia forcing troughing/negative geopotential height anomalies with normal to below normal temperatures across Central Asia. However next week ridging/positive geopotential height anomalies with normal to above normal temperatures will become more widespread across Asia. Some regional exceptions are troughing/negative pressure/geopotential height anomalies with normal to below normal temperatures across the northern Indian subcontinent, Japan and Korea.
- Over the next two weeks ridging/positive geopotential height anomalies with normal to above normal temperatures will dominate North America. One exception is troughing/negative geopotential height anomalies accompanied by normal to below normal temperatures in the US Southern Plains the next two weeks. A second exception is troughing/negative geopotential height anomalies with below normal temperatures in Northern Canada this week swinging through Eastern Canada and the Northeastern US next week.
- Once again, in the Impacts section I discuss an apparent and very curious troposphere-stratosphere-troposphere coupling event and the implications for the Northern Hemisphere (NH) circulation pattern.
- The AER summer forecast is included below.

***Impacts***

We had an issue with generating the normal blog plots so please excuse the mostly revised plots.

In **Figure i**, I include the Northern Hemisphere temperature anomaly forecast for June, July and August 2020. Besides the AER statistical model forecast, I include the dynamical forecast from the from nine models, which participate in the North American Multi-Model Ensemble (NMME). The NMME system includes coupled models from a number of US and Canadian modeling centers in an ensemble of opportunity supporting

seasonal forecasting experiments (Kirtman et al. 2014). The individual models that make up the NMME forecast can be found on the NOAA website, which manages the NMME project. In addition, I also compare to the real-time forecasts from an international suite of models the European Centre for Medium-range Weather Forecasting (ECMWF) model, the UK Met Office Hadley Center Unified Model and the MeteoFrance model. These three models are referred to as the C3S and can be found on the Copernicus website. I am confident that my plotting of the NMME forecast is correct but less so of the C3S forecast. The general pattern seems to be correct, but I am surprised by the relatively cool temperatures predicted in eastern North America and Scandinavia and if anyone can provide a check on my plot please let me know. I don't beleive that this plot is publicly available.

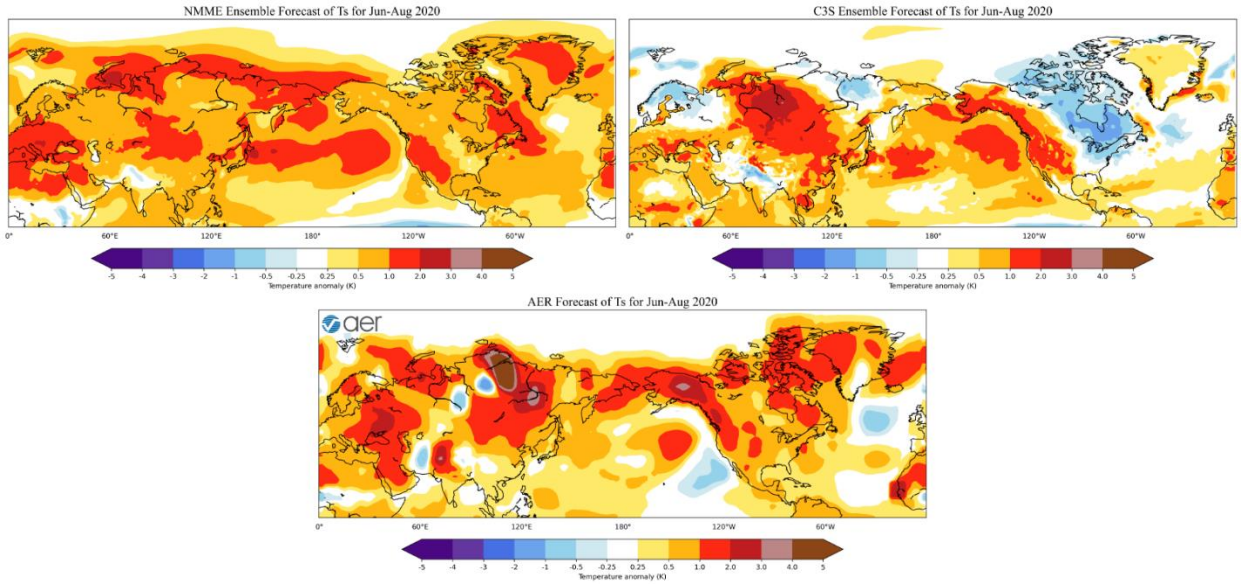


**Figure i**. The temperature anomaly forecast for June, July and August 2020 from the NMME ensembles (top left), the C3S ensembles (top right) and the AER model (bottom).

The general theme from all three model systems is the prevalence of above normal temperatures across the Northern Hemisphere with some regional or localized exceptions. Of the three forecasts, the AER forecast is the warmest. There are four regions of where temperatures are predicted to be the warmest – Siberia, western North America (especially Alaska), Eastern and Northern Europe extending into western Russia and eastern North America. These regions are likely to be dominated by ridging/high pressure or heat domes. Of the four regions, the model is most confident of well above normal temperatures in Siberia followed by western North America. Siberia has had an exceptionally warm spring so far (see CWG article on early Siberian heat) and is likely creating favorable conditions for a hot summer. The only regions that are predicted to experience below normal temperatures are localized areas in western Asia. As I have discussed in the blog previously, there has been a tendency in recent

summers for troughing in Western Asia keeping temperatures closer to normal while most other regions across the NH experience above normal temperatures.

Of the two dynamical systems the C3S, is most similar to the AER forecast also predicting regional temperature anomaly maximums in western Siberia and western North America with a third more localized maximum in Southeastern Europe. The NMME is similar to the AER forecast in forecasting a fourth temperature anomaly maximum in eastern North America, which is absent in the C3S ensemble. The NMME is predicting a warmer summer in Western Europe relative to either the C3S system or the AER forecast. I have been puzzled by the recent streak of European summer heatwaves some of which has been truly spectacular. And though I don't fully understand the reason it seems to me the possibility of the streak continuing this summer is high.

Below is the discussion from Monday but it does have some implications for the summer forecast. The late season troposphere-stratosphere-troposphere (T-S-T) coupling event has reversed negative/cold polar cap geopotential height anomalies (PCHs) to positive/warm in the troposphere, at least episodically. And now that the tropospheric PCHs are normal to positive, the likely warm Arctic summer should continue to favor positive/warm PCHs.

The above normal temperatures should be greatest not in the Central Arctic but on the periphery of the Arctic Ocean in part due to early snow melt and drying of the tundra. So, the T-S-T coupling event in May could trigger at least episodic high latitude blocking/high pressure that persists through the summer months. If that high latitude blocking sets up over Greenland, then that could favor troughing relatively cool and possibly wet weather for Europe and/or Eastern North America. If Greenland blocking does impact European weather, its impacts are probably more likely to be felt in Western Europe, I believe more so than Eastern Europe. As far as the Central Arctic, I think there remains a strong likelihood that it will be dominated by low pressure and close to normal as predicted by all three forecasts shown. However, if the forecasts are wrong and high pressure dominates the Central Arctic, expect rapid melting of Arctic sea ice and a run at a new record sea ice extent minimum (end of summer forecast discussion).

I remain fascinated by the troposphere-stratosphere-troposphere (T-S-T) coupling event seen so clearly in the polar cap geopotential height anomalies (PCHs) plot (**Figure 11**). High latitude blocking or a tropospheric precursor back in early May forces a stratospheric polar vortex (PV) weakening in mid-May followed by possible multiple downward propagations of positive/warm PCHs accompanied by a negative AO in mid-May and predicted for early June. From **Figure 11** the T-S-T coupling event looks classic to me creating the illusion of dripping paint. And each of these "drips" seems to have important implications for the weather. These drips are accompanied by a period of increased high latitude blocking in the northern North Atlantic and/or near Alaska

forcing downstream troughing and cooler weather in Europe and/or eastern North America.

The most recent “drip” was the third week of May. This was accompanied by a negative AO and relatively cold weather in eastern North America and mostly Northern and Eastern Europe. Since then the positive/warm PCHs have retreated back to the upper troposphere and the stratosphere allowing for a turn to negative/cold PCHs in the lower troposphere and a positive AO and a turn to milder weather. The next predicted drip is for the very end of May or the first week of June. This again looks to be accompanied by cooler weather in eastern North America and Europe by this time more focused in Western and Southern Europe.

If this were winter, these drips could continue for four to six weeks and it will be interesting to see how long the drips of positive/warm PCHs continue now in the summer months instead. And as I discussed last week, I really don’t understand how this T-S-T coupling event is happening at all post a Final Warming (where the stratospheric PV disappears until the fall). What is even more incredible to me this “summer” T-S-T coupling event seems more robust than the T-S-T coupling event related to the very impressive stratospheric PV split that occurred in January 2019. The positive/warm PCHs and deeply negative stratospheric AO almost completely failed to descend into the troposphere, yet this one is doing so with surprisingly ease. To me it just seems to illustrate we really lack a good understanding of T-S-T coupling events especially the downward propagation component.

*1-5 day*

The AO is currently positive **(Figure 1**) with negative geopotential height anomalies focused mostly on the North Atlantic side of the Arctic and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with predicted negative geopotential height anomalies across Greenland (**Figure 2**), the NAO is predicted to be positive as well.

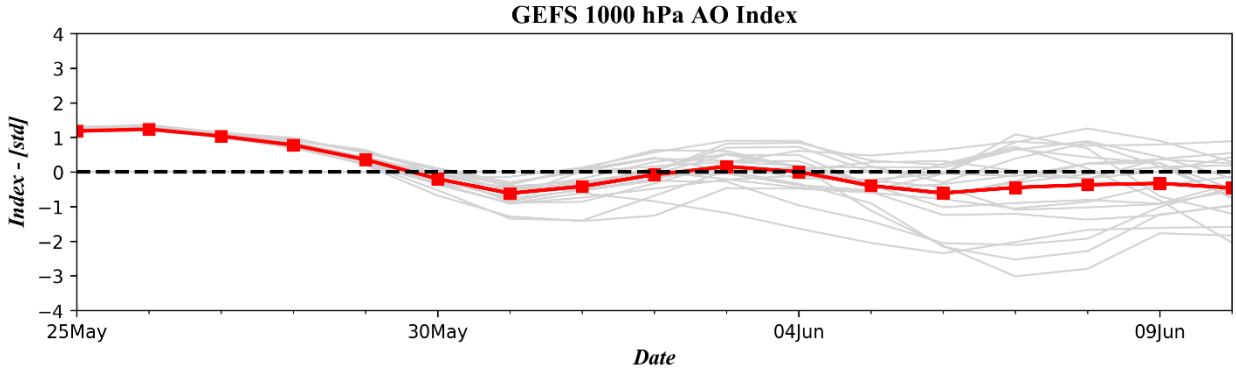

**Figure 1**. The predicted daily-mean AO at 10 hPa from the 00Z 25 May 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies with normal to above normal temperatures across Northern and Western Europe including the UK will favor troughing/negative geopotential height anomalies and normal to below normal temperatures for much of Southern and Eastern Europe (**Figures 2 and 3**). Ridging/positive geopotential height anomalies in Western Asia, will help to anchor troughing/negative geopotential height anomalies widespread across Eastern Asia this week (**Figure 2**). This pattern favors normal to above normal temperatures across Western and Northern Asia with normal to below normal temperatures in Central and Eastern Asia and the Northern Indian subcontinent **(Figure 3**).

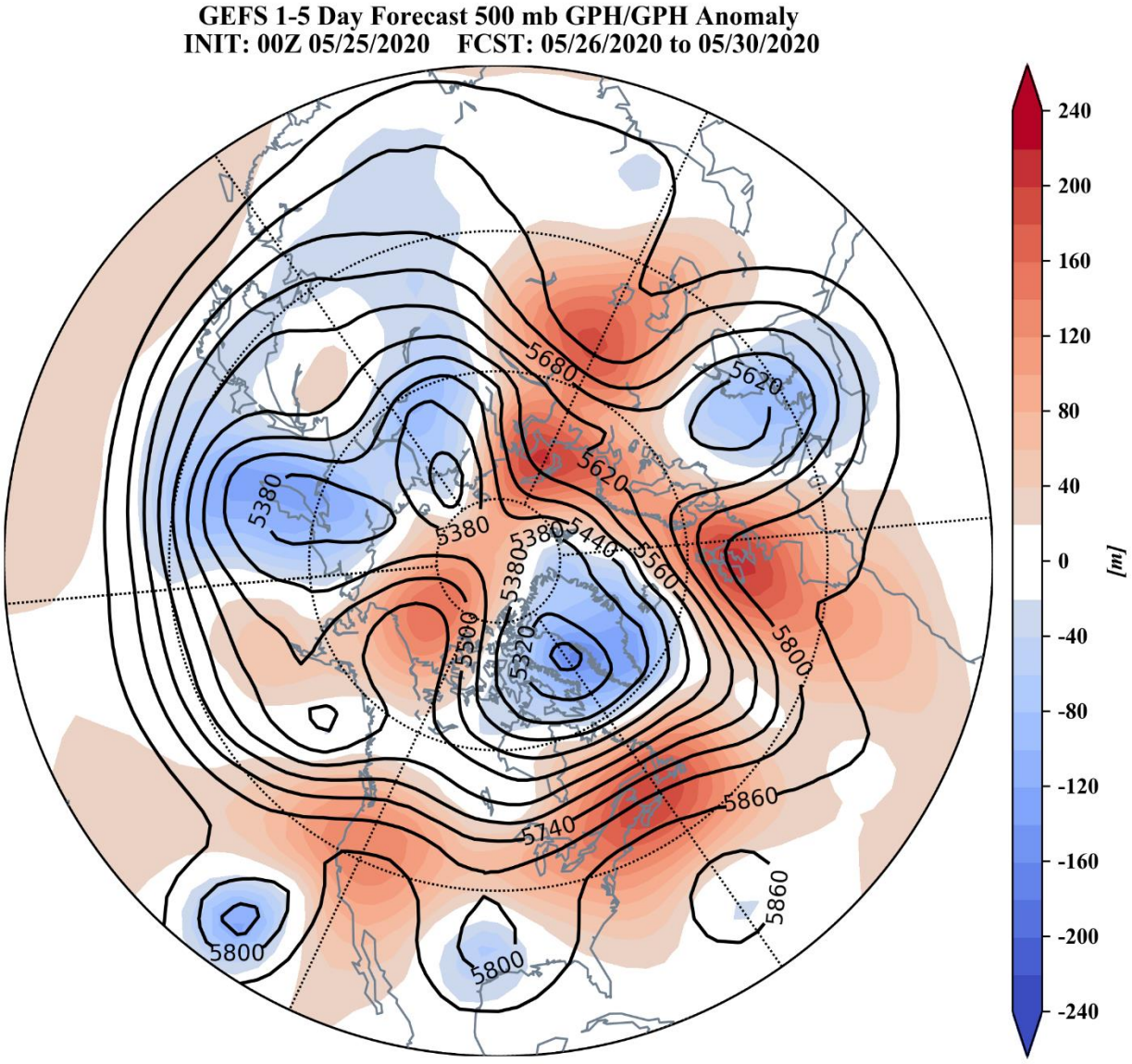

**Figure 2.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 26 – 30 May 2020. The forecasts are from the 00z 25 May 2020 GFS ensemble.

This week, ridging/positive geopotential height anomalies are predicted to dominate North America with the exceptions of regional troughing/negative geopotential height anomalies in Northern Canada and the US Southern Plains **(Figure 2).** This pattern is predicted to bring normal to above normal temperatures across much of Canada and the US with normal to below normal temperatures in Northcentral Canada and the US Southern Plains **(Figure 3).**

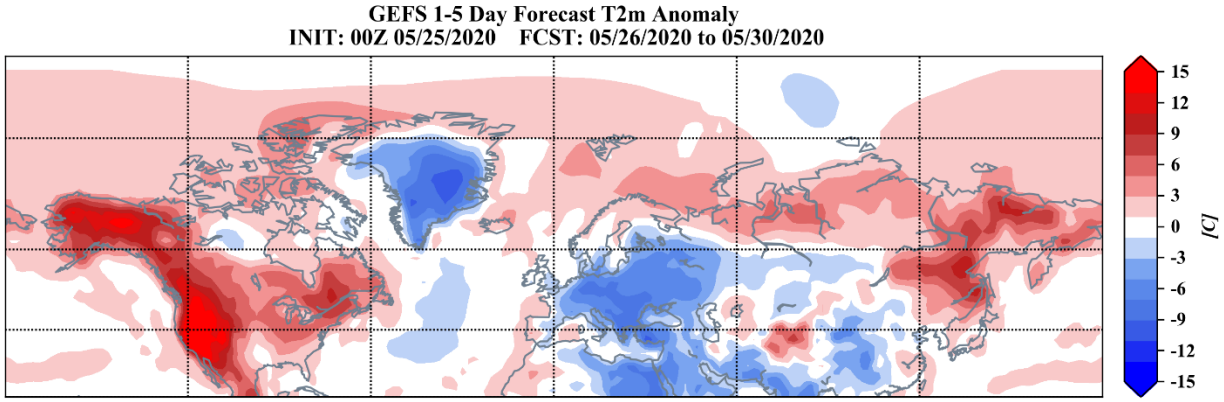


**Figure 3**. Forecasted surface temperature anomalies (°C; shading) from 26 – 30 May 2020. The forecast is from the 00Z 25 May 2020 GFS ensemble.

Below normal precipitation is predicted for much of Europe and Asia with the exceptions of above normal precipitation for Siberia and Southeast Asia (**Figure 4**). Below normal precipitation is predicted for western North America with above normal precipitation across the Southern and Eastern US (**Figure 4**).

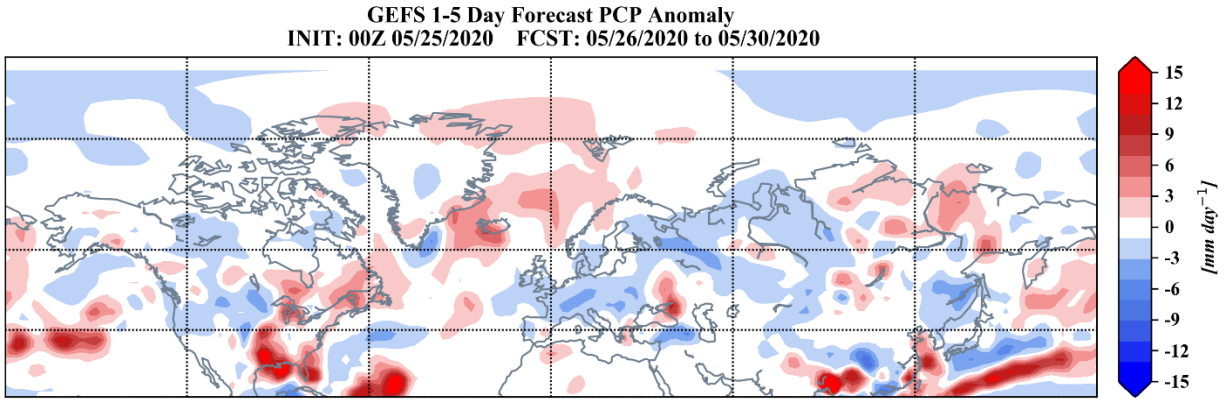

**Figure 4**. Forecasted precipitation anomalies (mm/day; shading) from 26 – 30 May 2020. The forecast is from the 00Z 25 May 2020 GFS ensemble.

*Mid-Term*

*6-10 day*

The AO is predicted to trend to neutral **(Figure 1**) or weakly negative as positive geopotential height anomalies become more widespread across the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with weak geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to straddle neutral.

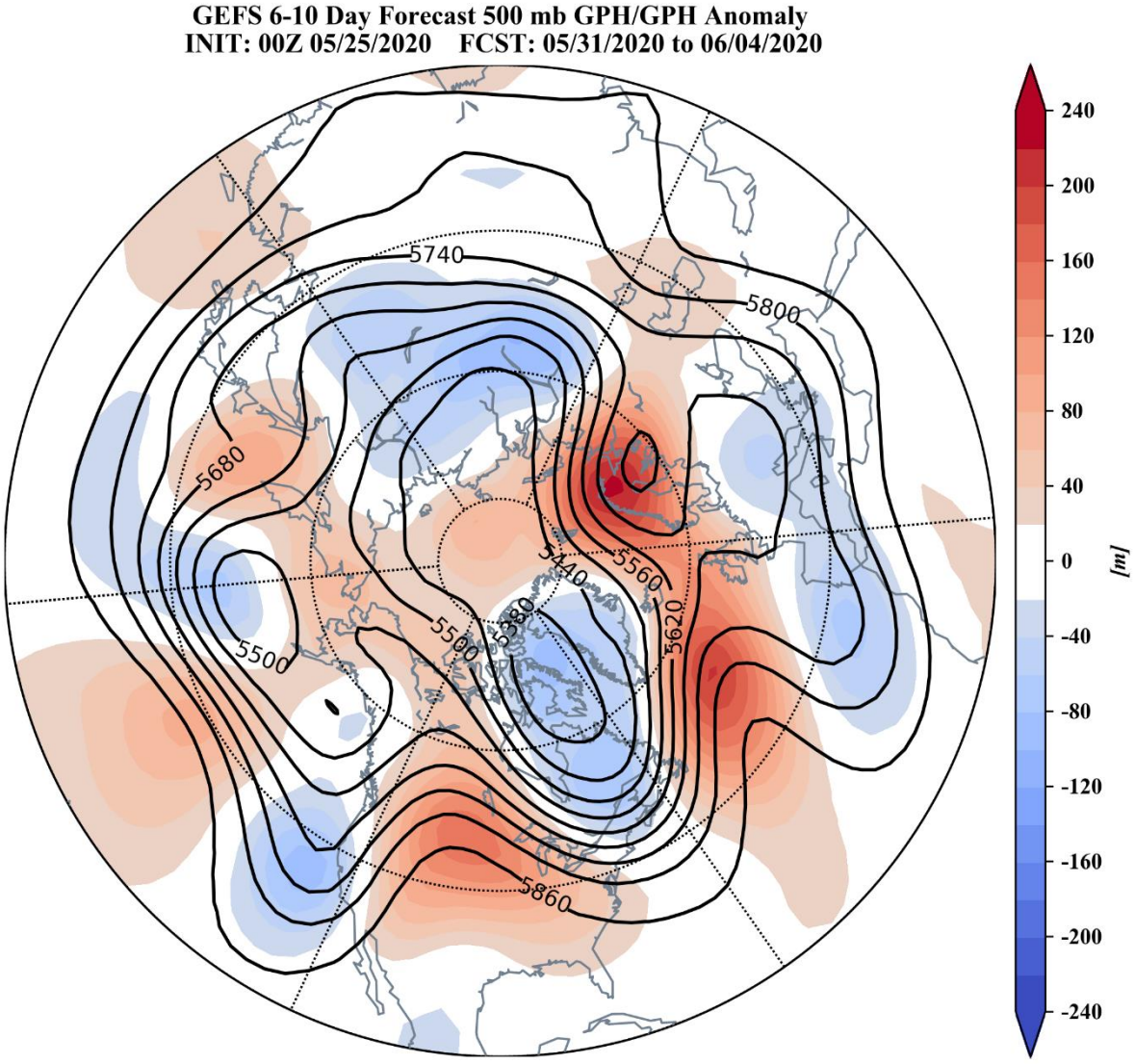

**Figure 5.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 31 May – 4 June 2020. The forecasts are from the 00z 25 May 2020 GFS ensemble.

Ridging/positive geopotential height anomalies stretching from south of Greenland across to Scandinavia will help to anchor troughing/negative geopotential height anomalies across Southern and Western Europe while ridging/positive geopotential height anomalies persist across Northern Europe (**Figures 5). This pattern will favor** normal to below normal temperatures across Western and Southern Europe with normal to above normal temperatures across Northern and Southeastern Europe including the UK (**Figure 6**). Persistent ridging/positive geopotential height anomalies in Western Asia will help to anchor troughing/negative geopotential height anomalies in Central Asia with more ridging/positive geopotential height anomalies in East Asia (**Figure 5**). This is predicted to yield normal to above normal temperatures in Western and Eastern Asia **with** normal to below temperatures In Central Asia **(Figure 6**). Some weak troughing/negative geopotential height anomalies across the Northern Indian subcontinent will favor normal to below normal temperatures across that region (**Figures 5 and 6**).

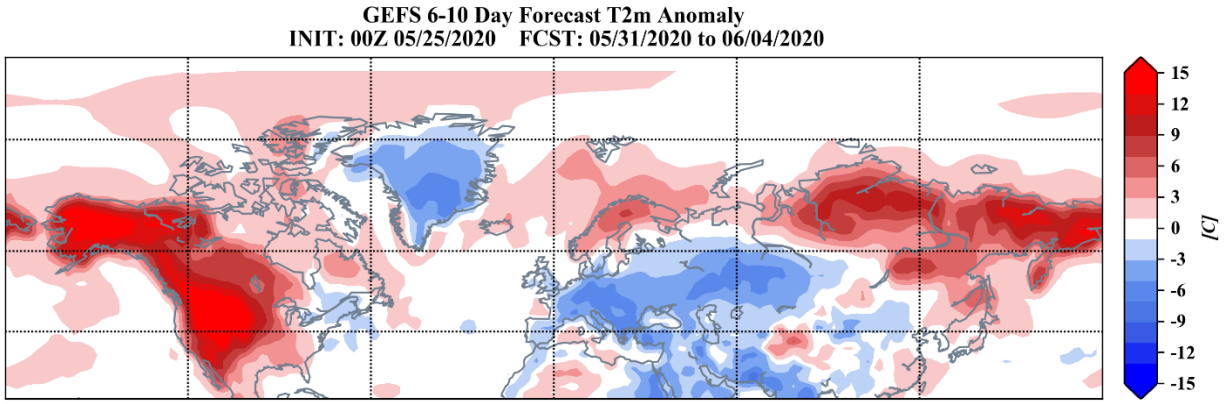


**Figure 6**. Forecasted surface temperature anomalies (°C; shading) from 31 May – 4 June 2020. The forecasts are from the 00Z 25 May 2020 GFS ensemble.

Persistent ridging/positive geopotential height anomalies will stretch across Alaska Western Canada and the Western and Southern US, with troughing/negative geopotential height anomalies across Eastern Canada and the Northeastern US this period (**Figure 5**). This pattern is predicted to bring widespread normal to above normal temperatures across Alaska, Western Canada and the Western US with normal to below normal temperatures for Eastern Canada and the Northeastern US (**Figure 6**). Some weak troughing in the Southern Plains (**Figure 5**) could bring normal to below normal temperatures to much of Texas **(Figure 6).**

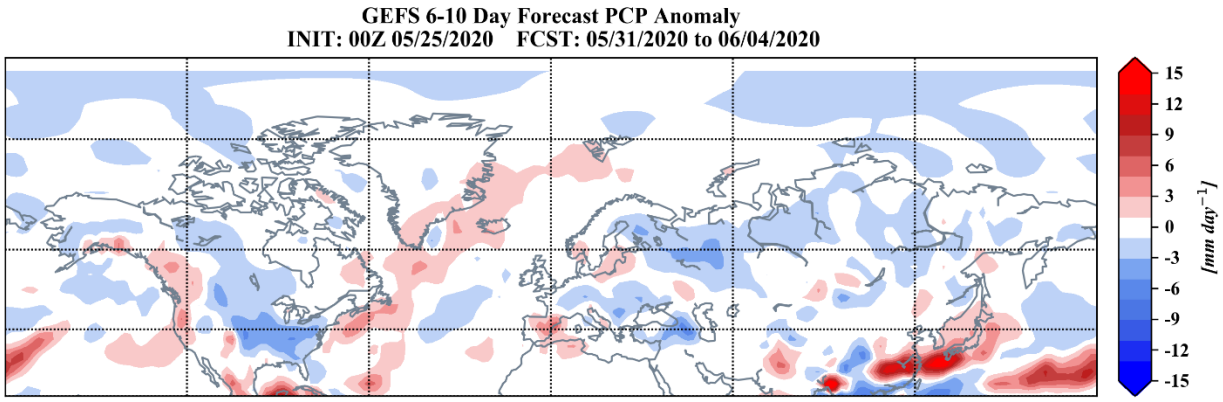


**Figure 7**. Forecasted precipitation anomalies (mm/day; shading) from 31 May – 4 June 2020. The forecasts are from the 00Z 25 May 2020 GFS ensemble.

Normal to below normal precipitation is predicted for much of Eurasia with the exceptions of above normal precipitation in Spain and Southeastern Asia (**Figure 7**). Normal to below normal precipitation is predicted for much of North America with above normal precipitation predicted for the west coast of North America (**Figure 7**).

*11-15 day*

With predicted continued increasing positive geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO is predicted to remain weakly negative this period (**Figure 1**). With weak pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is likely to be neutral to slightly negative as well.

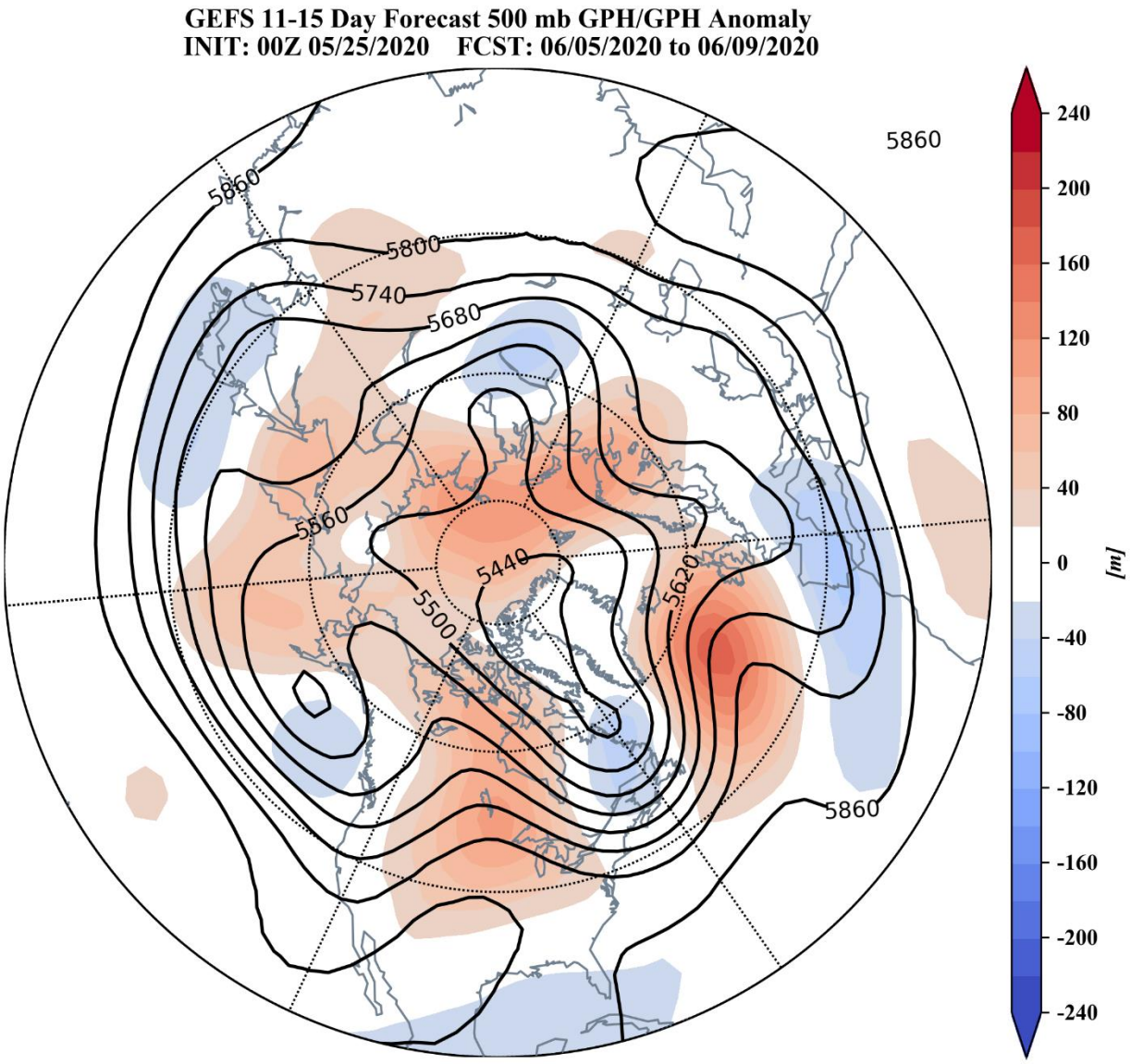


**Figure 8.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 5 – 9 June 2020. The forecasts are from the 00z 25 May 2020 GFS ensemble.

Persistent ridging/positive geopotential height anomalies south of Greenland across to Northern Europe are predicted once again to favor downstream troughing/negative geopotential height anomalies across Western Europe and Southern Europe (**Figures 8**). The forecast is for normal to below normal temperatures across Western and Southern Europe with normal to above normal temperatures across Northern and Eastern Europe including the UK this period (**Figures 9**). Once again, ridging/positive geopotential height anomalies are predicted to dominate Western and now Northern Asia with troughing/negative pressure/geopotential height anomalies in Central and far Eastern Asia this period (**Figure 8**). This pattern favors widespread normal to above

normal temperatures across Asia especially in Northern and Eastern Asia with normal to below normal temperatures for parts of Central Asia (**Figure 9**). Some weak troughing/negative geopotential height anomalies across the Northern India subcontinent will favor normal to below normal temperatures in the region (**Figures 8 and 9**).

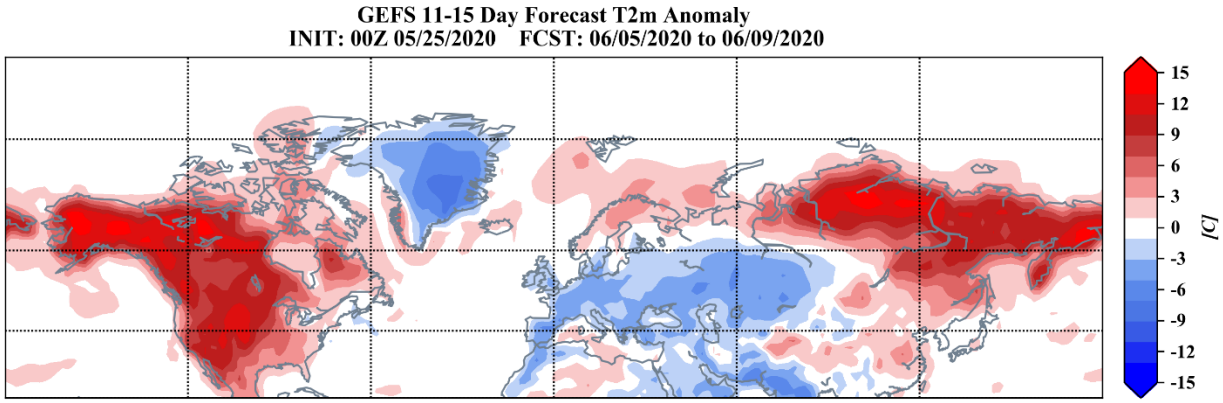


**Figure 9**. Forecasted surface temperature anomalies (°C; shading) from 5 – 9 June 2020. The forecasts are from the 00z 25 May 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to dominate North America with regional troughing/negative geopotential height anomalies in Eastern Canada, the Northeastern US, along the US Gulf Coast and the US West Coast (**Figure 8**). This pattern favors normal to above normal temperatures across Alaska, Western Canada and the Western US with normal to below normal temperatures for Eastern Canada, the Northeastern US, Texas and the US West Coast (**Figure 9**).

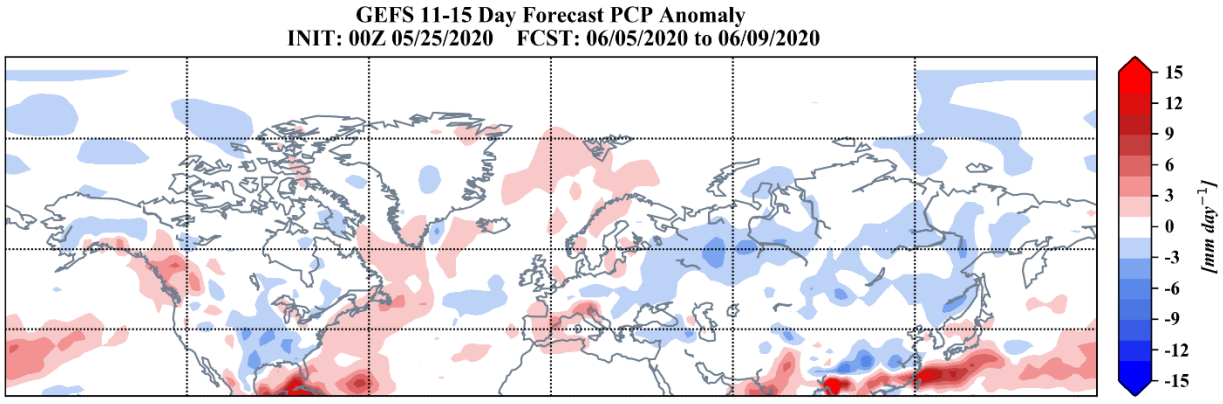


**Figure 10**. Forecasted precipitation anomalies (mm/day; shading) from 5 – 9 June 2020. The forecasts are from the 00z 25 May 2020 GFS ensemble.

Normal to below normal precipitation is predicted for much of Eurasia except for normal to above normal precipitation for Southwestern Europe and Southeast Asia (**Figure 10**). Normal to below normal precipitation is predicted for much North America except for above normal precipitation in Western Canada (**Figure 10**).

*Longer Term*

*30–day*

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to below normal PCHs in the lower troposphere with normal to above normal PCHs throughout much of the troposphere and stratosphere (**Figure 11**). However, PCHs in the stratosphere are predicted to reverse to normal to below normal next week while PCHs in the lower troposphere are predicted to turn mostly positive (**Figure 11**). The below normal PCHs in the lower troposphere are consistent with the predicted positive AO this week and the above normal PCHs in the lower troposphere are consistent with the predicted negative AO next week (**Figure 1**).

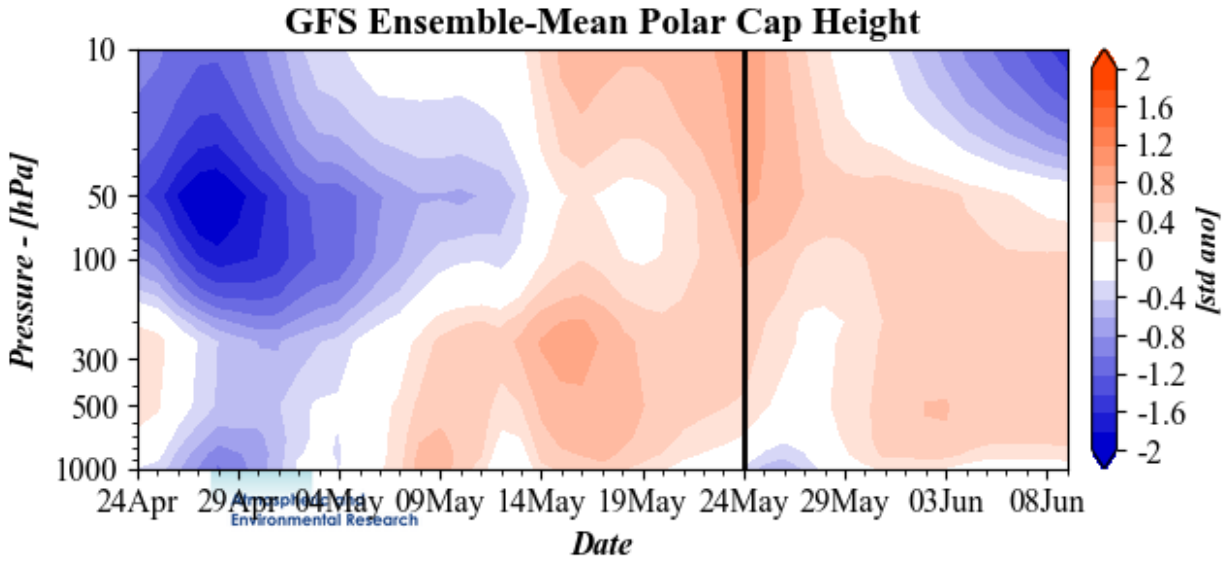


**Figure 11**. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 24 May 2020 GFS ensemble.

The plot of vertical Wave Activity Flux (WAFz) or poleward heat transport forecast shows a strong positive anomaly pulse for this week followed by normal WAFz next week (**Figure 12**). The recent active positive WAFz anomalies are responsible for reversing the negative/cold PCHs in the stratosphere to positive/warm for much of May (**Figure 11**).

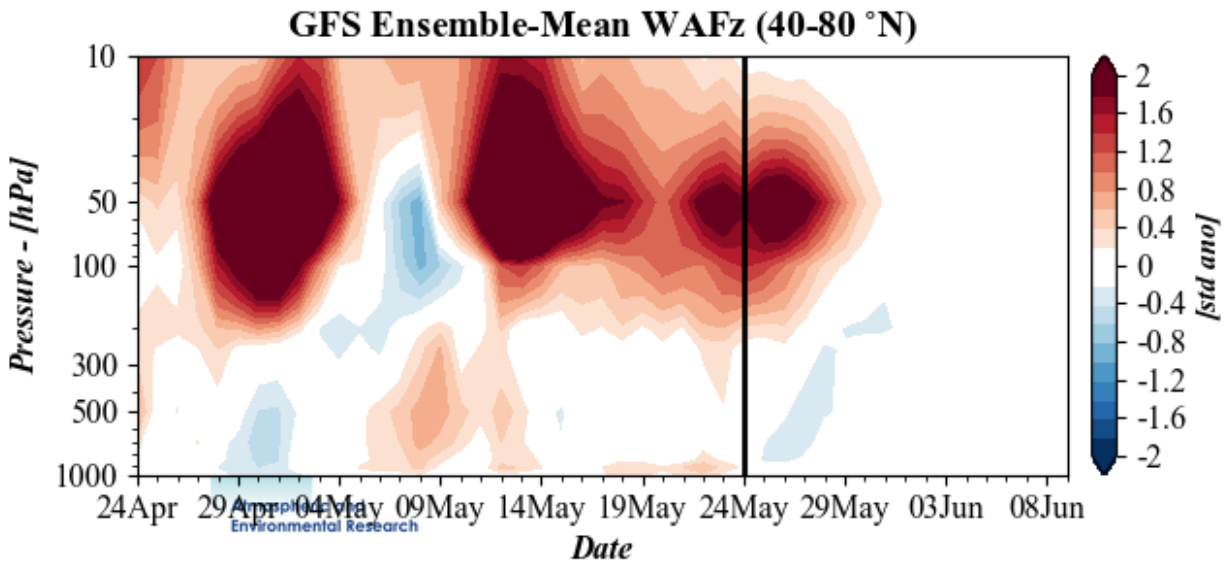


**Figure 12**. Observed and predicted daily vertical component of the wave activity flux (WAFz)
standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 24 May 2020 GFS ensemble.

The Final Warming has taken place (where the stratospheric PV disappears until the fall). But the recent strong pulses of WAFz suggest to me that this is a dynamically induced Final Warming rather than a passive or radiatively forced Final Warming. The implications of a dynamically forced Final Warming relative to a radiatively-only forced Final Warming is that it is more likely to have an impact on the weather. I believe that the dynamic Final Warming has contributed to the warm stratospheric PCHs that continue to "drip" down into the troposphere that has contributed to periods of below normal temperatures across eastern North America and Europe.

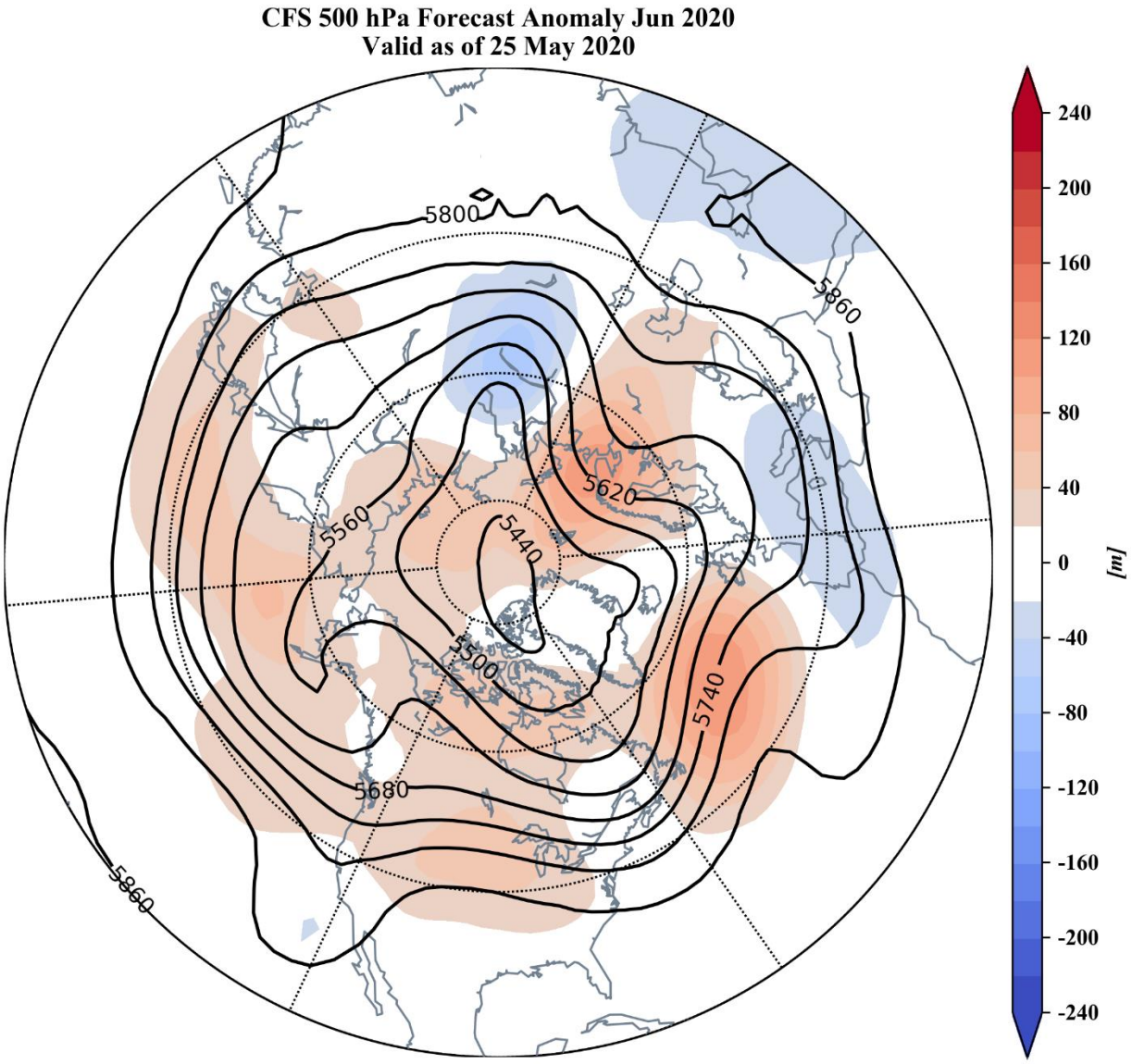


**Figure 14**. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for June 2020. The forecasts are from the 00Z 25 May 2020 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) 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, Alaska and the interior of North America with troughing in Western and Southern Europe, the Arabian Gulf, the Dateline, Eastern Canada, the Northeastern US and the US West Coast (**Figure 14**). This pattern favors relatively mild temperatures for Northern Europe, much of Northern and Eastern Asia, western North America and Northern Canada with

seasonable to relatively cool temperatures for Southern and Western Europe, Western and Southern Asia, Southeastern Canada and the Northeastern US **(Figure 15).**

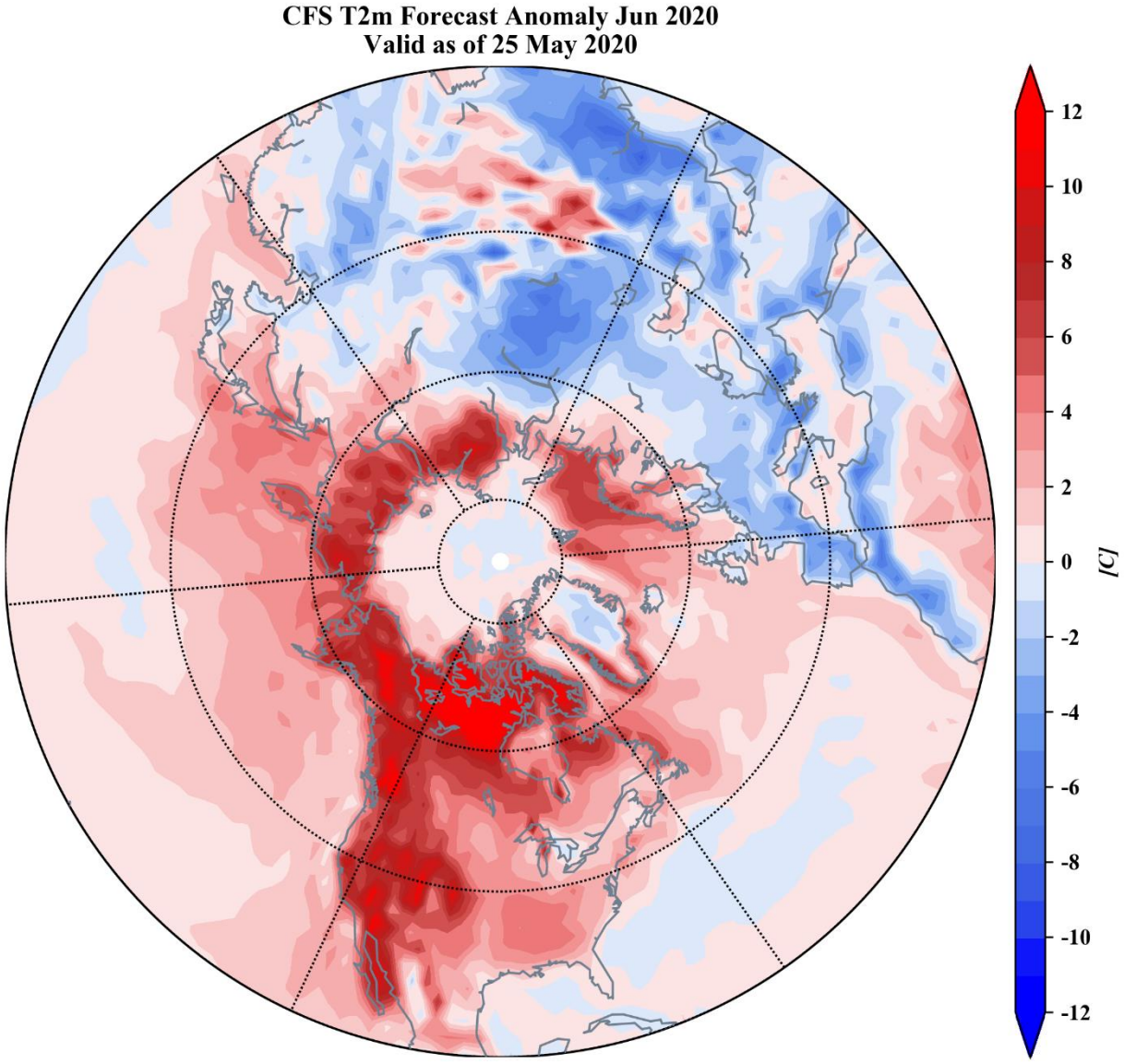


**Figure 15**. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for June 2020. The forecasts are from the 00Z 25 May 2020 CFS.

*Surface Boundary Conditions*

*SSTs/El Niño/Southern Oscillation*

Equatorial Pacific sea surface temperatures (SSTs) anomalies continue to cool slowly but neutral El Niño/Southern Oscillation (ENSO) conditions seem most likely this

summer (**Figure 17**). Observed SSTs across the NH remain well above normal especially near Alaska and in the Gulf of Alaska and the western North Pacific though below normal SSTs exist regionally especially west of South America and south of Iceland. Warm SSTs in the Gulf of Alaska may favor mid-tropospheric ridging in the region.

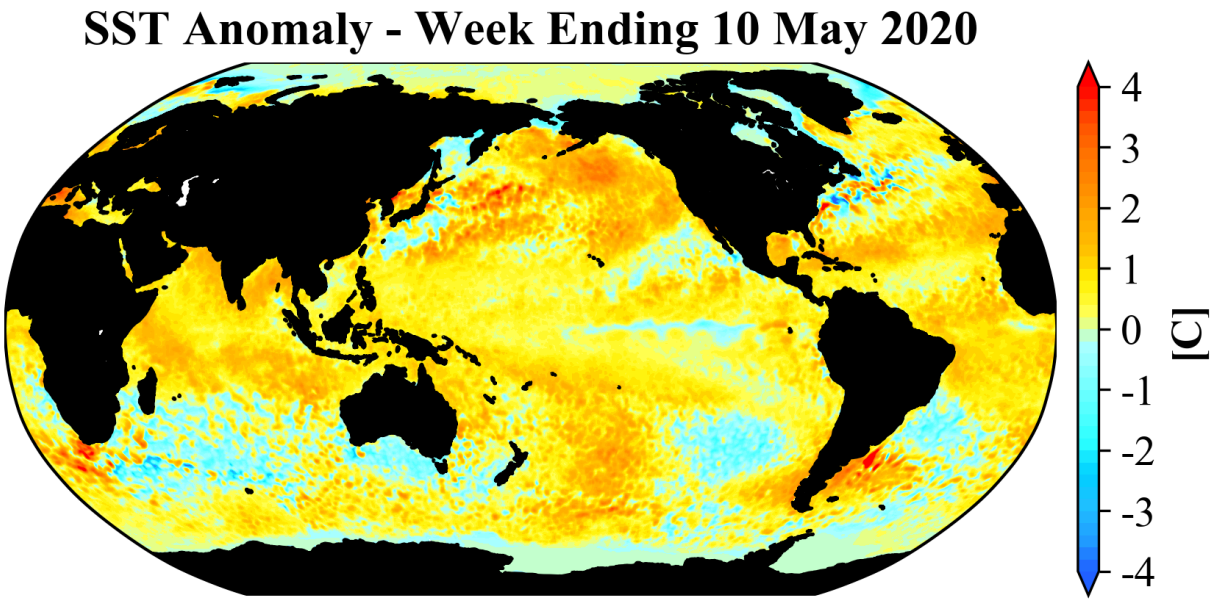


**Figure 17**. The latest weekly-mean global SST anomalies (ending 26 April 2020 not updated). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase six (**Figure 18**). The forecasts are for the MJO to quickly transition to phases seven eight and one. MJO phases 6, 7, 8 and 1 do favor ridging across Canada and Alaska and could be contributing to the weather patterns across North America in the next two weeks.

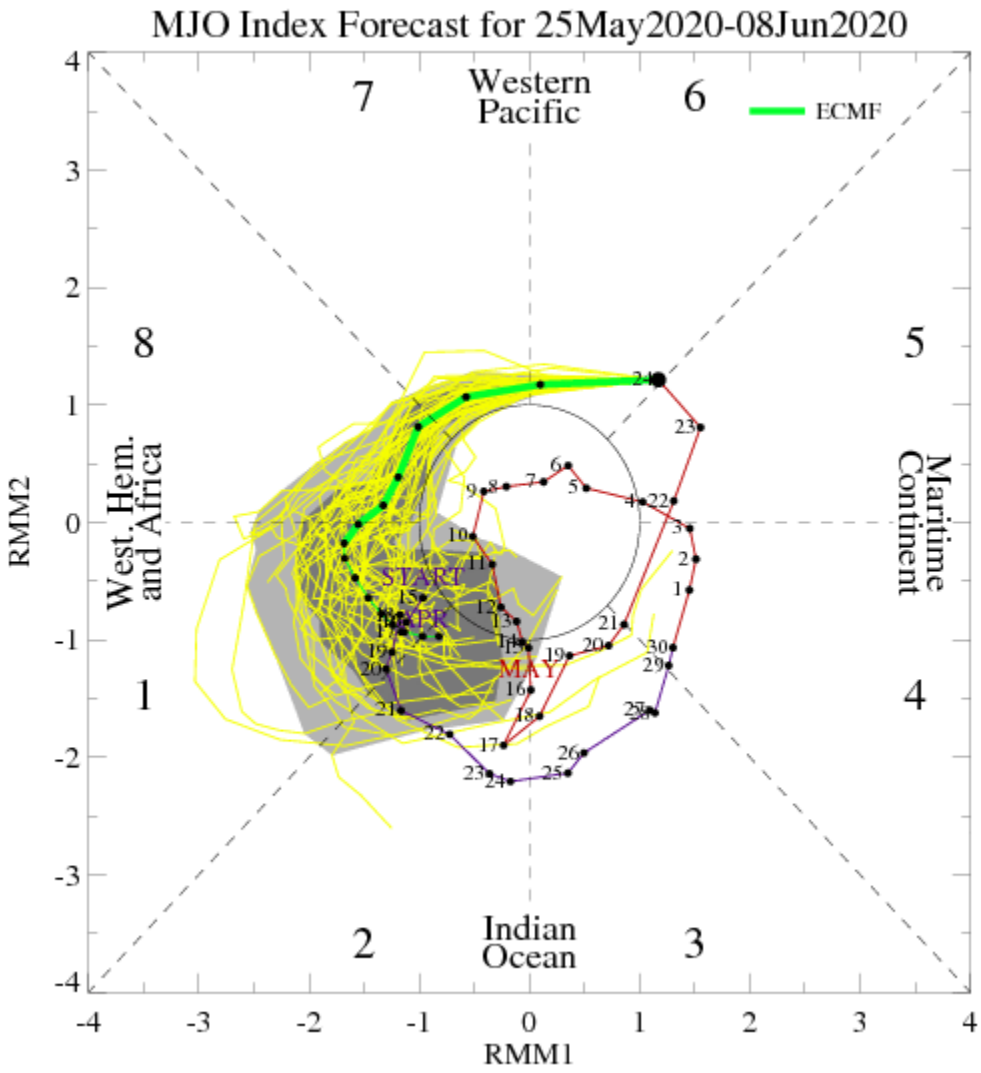


**Figure 18**. Past and forecast values of the MJO index. Forecast values from the 00Z 25 May 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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