

Arctic Oscillation and Polar Vortex Analysis and Forecasts

May 13, 2019

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.

With the start of spring we transitioned 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 slightly negative and is predicted to remain neutral to negative over the next two weeks.
- The current negative AO is reflective of mostly positive pressure/geopotential height anomalies across the Arctic especially on the North Atlantic side of the Arctic and mostly negative pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is negative as positive

pressure/geopotential height anomalies are spread across Greenland and Iceland and is predicted to remain mostly negative over the next two weeks.

- Ridging/positive geopotential height anomalies across the high latitudes of the North Atlantic and Northern Europe are predicted to force troughing/negative geopotential height anomalies to the south across Southern Europe. This pattern favors seasonable to warm temperatures across Northern Europe including the United Kingdom (UK) and seasonable to cool temperatures across Southern Europe.
- Currently ridging/positive geopotential height anomalies across the Arctic are forcing troughing/negative geopotential height anomalies with normal to below normal temperatures across Central Siberia. However, over the next two weeks the troughing and its associated relatively cool air is predicted to retrograde west into Western Siberia and northwest Russia. Elsewhere ridging/positive geopotential height anomalies and normal to above normal temperatures are predicted to dominate much of Asia over the next two weeks. One possible exception is the region of northwest India and Pakistan where some weak troughing may support relatively cool temperatures.
- Currently ridging/positive geopotential height anomalies with relatively mild temperatures dominate western North America and troughing/negative geopotential height anomalies with relatively cool temperatures dominate eastern North America especially the Eastern United States (US). However, over the next week the pattern is predicted to flip with troughing/negative geopotential height anomalies and relatively cool temperatures in western North America with ridging/positive geopotential height anomalies and relatively warm temperatures across the Eastern US. For the last week of May, the pattern could reverse once again.
- In the Impacts section I continue to discuss the surprising troposphere-stratosphere-troposphere coupling of late April and May.

Impacts

In my previous blog I focused on the potential impacts from what I considered a highly anomalous troposphere-stratosphere-troposphere (T-S-T) coupling event that began with strong Scandinavian blocking/high pressure in April that accelerated a Final Warming in the stratosphere (defined as when the stratospheric PV disappears for the summer and winds are persistently easterly at 60°N and 10 hPa). This Final Warming was accompanied by a record weak stratospheric polar vortex (PV) and has been followed by strong Greenland blocking/high pressure now in May. This has resulted in anomalous cold and even snow both in Europe and the US. A similar event appeared to have occurred in 1997.

The impacts from the 1997 event lasted about a month and therefore I thought the most likely expectation for the current event is a similar length duration of about a month and therefore any impacts should end by early June. But as I have discussed

numerous times in the blog and in my two most recent winter retrospectives the impacts, or at least the cold anomalies, from similar PV disruptions, first appear in Eurasia and then only later in North America. However, the cold anomalies do seem to persist longer in North America. So, though the models seem to be indicating moderation in temperatures for Europe, it is not as obvious to me for the US. Therefore, I am now wondering if the overall cool pattern could linger longer in the US and into June consistent with wintertime T-S-T coupling events.

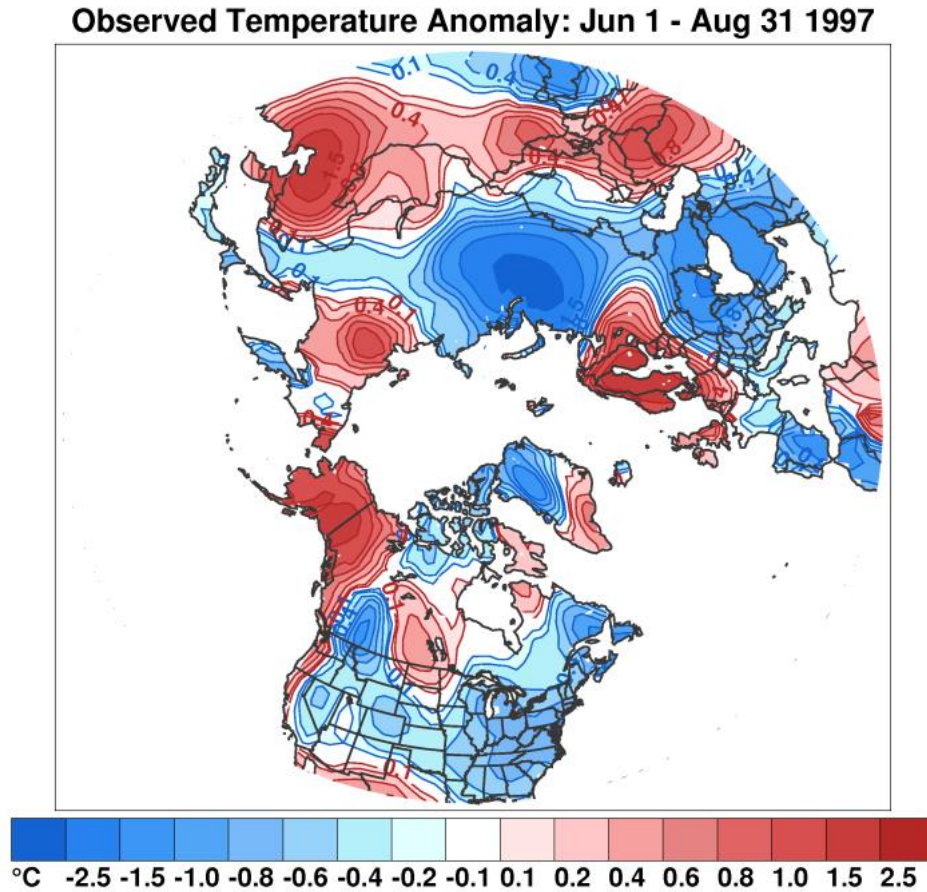


Figure i. Observed surface temperature anomalies (°C; shading) from 1 June – 31 August 1997.

I include in **Figure i**, the surface temperature anomalies from June, July and August 1997. Many locations in the US, Southern Europe, North Asia experienced a cool summer. How much can be attributed to the T-S-T coupling event is hard to know but can something similar happen this summer? I highly doubt it. I include in **Figure ii**, the surface temperature anomalies from June, July and August 2018 and nearly the entire

continents of the North Hemisphere experienced above normal temperatures with highly localized and disperse exceptions. It just seems to me it is much more difficult to observe wide spread relatively cool summer temperatures in the late 2010's compared to the late 1990's.

Observed Temperature Anomaly: Jun 1 - Aug 31 2018

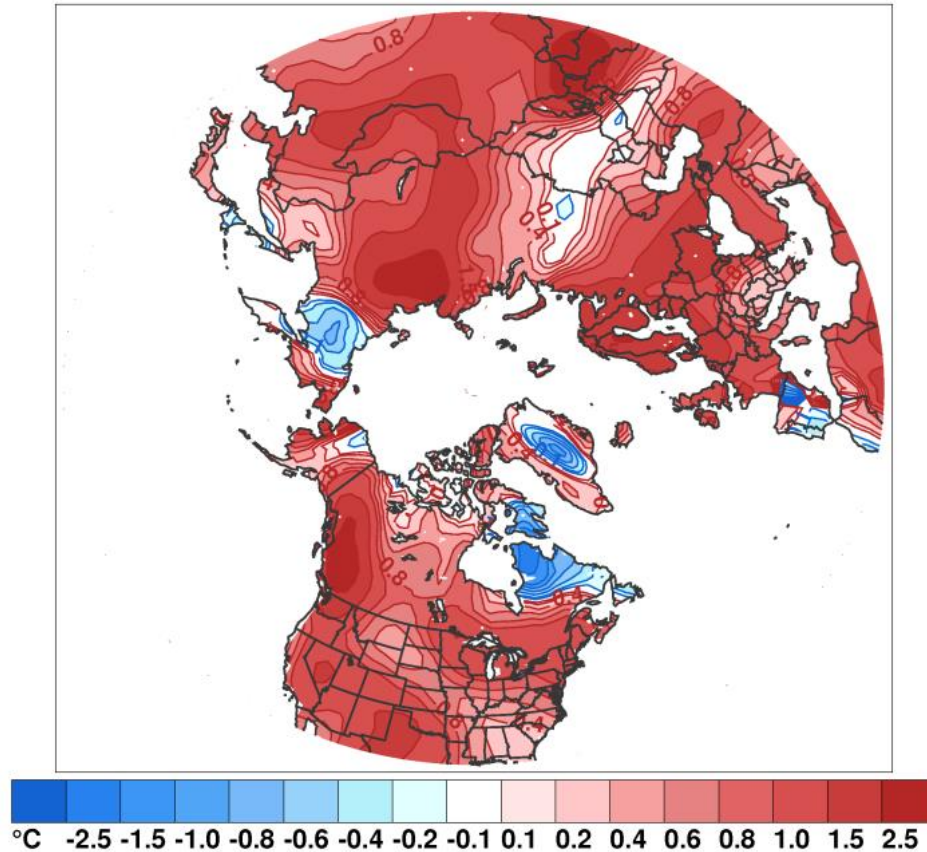


Figure ii. Observed surface temperature anomalies (°C; shading) from 1 June – 31 August 2018.

In **Figure iii**, I show the polar cap geopotential height anomalies (PCHs) for this day in 2018. The PCHs in the stratosphere but even in the troposphere were dominated by cold/negative PCHs whereas currently they are dominated by warm/positive PCHs (see below **Figure 10**). To me this should be interpreted as very different atmospheric circulations in May 2018 compared to May 2019 with the circulation in May 2018 more favorable for mid-latitude ridging and warm temperatures. And last May ridging dominated both Europe and the US, preconditioning the regions for a hot summer. How

much summer 2019 will differ from 2018 is hard to know but I expect significant differences.

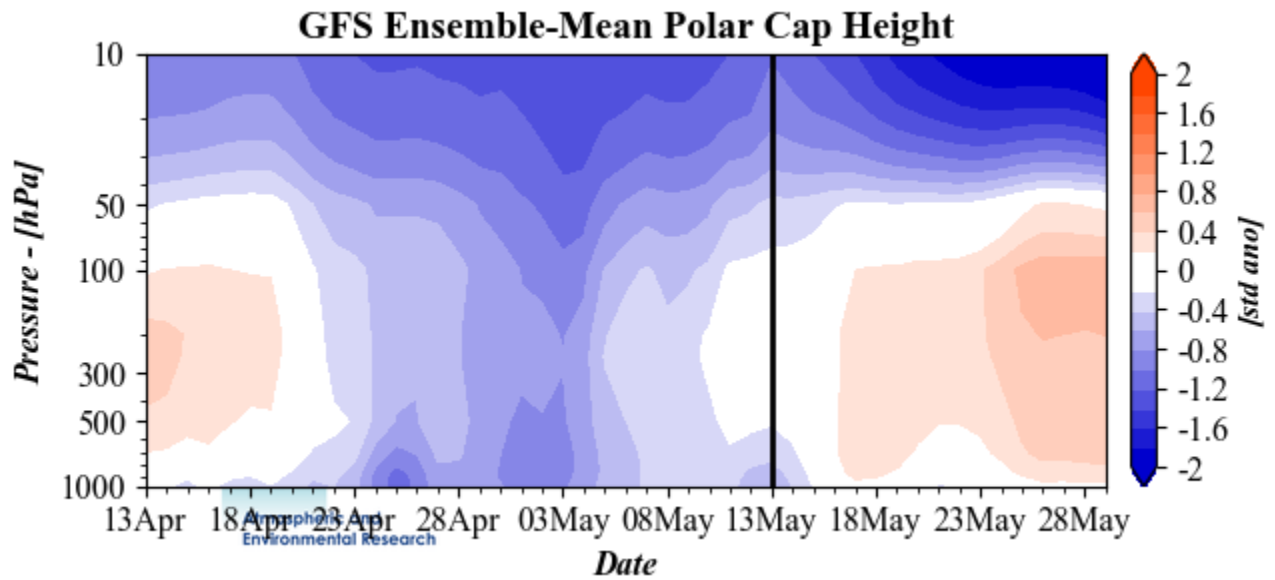


Figure iii. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 13 May 2018 GFS ensemble.

Near Term Conditions

1-5 day

The AO is currently negative and is predicted to remain negative over the next week (**Figure 1**) as positive geopotential height anomalies dominate the North Atlantic side of the Arctic with mostly positive geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with strong geopotential height anomalies across Greenland and Iceland (**Figure 2**), the NAO will likely remain negative this week as well.

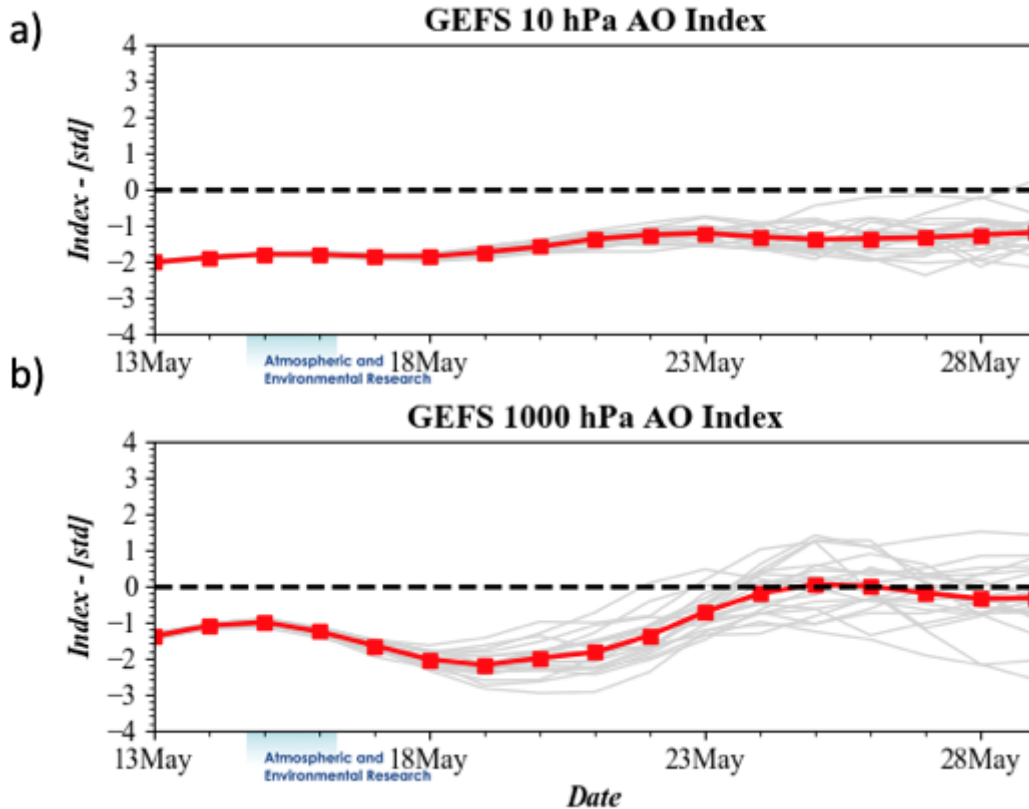


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 13 May 2019 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 13 May 2019 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Ridging/positive geopotential height anomalies between Iceland and Scandinavia and covering Western Europe as well are predicted to force troughing/negative geopotential height anomalies across Southern Europe centered on Italy this week (**Figure 2**). This pattern is predicted to result in normal to below normal temperatures across Central and Southern Europe with normal to above temperatures across the UK, Spain and Scandinavia underneath mid-tropospheric ridging (**Figure 3**). More ridging/positive geopotential height anomalies centered on the Laptev Sea will force troughing/negative geopotential height anomalies across Central Siberia and Mongolia bookended by ridging in Eastern and Western Asia including the Middle East (**Figure 2**). This is predicted to yield normal to below normal temperatures for Western and Central Siberia and Mongolia with normal to above normal temperatures across Western Asia including the Middle East and East Asia (**Figure 3**). Weak troughing in northwest India and Pakistan (**Figure 2**) will likely support relatively cool temperatures (**Figure 3**).

GEFS 500 mb GPH/GPH Anomaly
INIT: 00Z 05/13/19

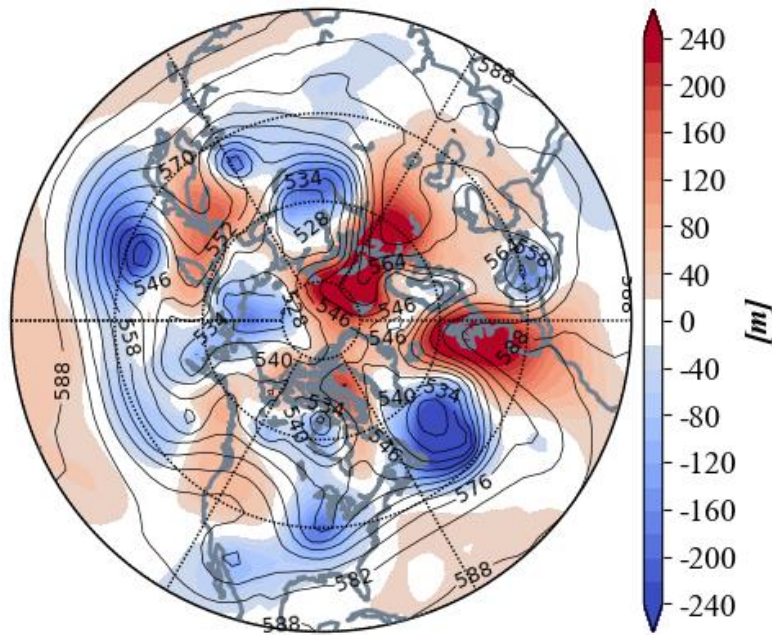


Figure 2. Observed 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) for 00Z 13 May 2019.

Ridging/positive geopotential height anomalies between Greenland and Alaska but centered on the Canadian Archipelagos are predicted to force troughing/negative geopotential height anomalies along the North American West Coast and the Eastern US with ridging/positive geopotential height anomalies in between centered over the Rockies (**Figure 2**). This pattern is predicted to bring normal to below normal temperatures in the Eastern US and the US West Coast with normal to above normal temperatures for Alaska, the Central US and much of Canada (**Figure 3**).

GEFS 1-5 Day Forecast T2m Anomaly
INIT: 00Z 05/13/19 FCST: 05/14/19 to 05/18/19

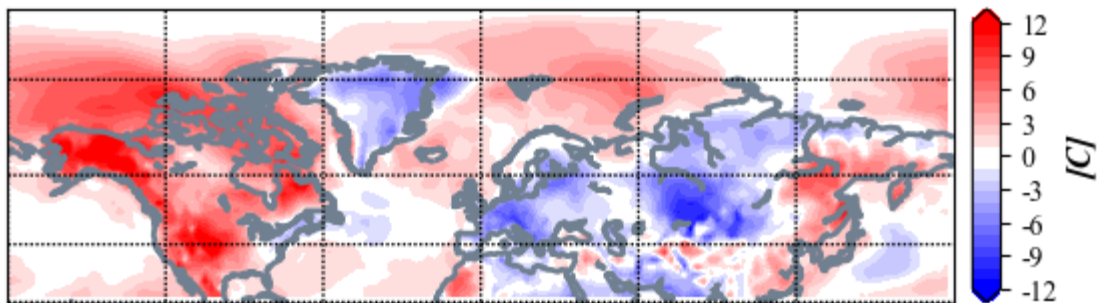


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 14 – 18 May 2019. The forecast is from the 00Z 13 May 2019 GFS ensemble.

Trouging is predicted to bring above normal rainfall to Southeastern Europe, Mongolia, the Northern US and Southern Canada (**Figure 4**).

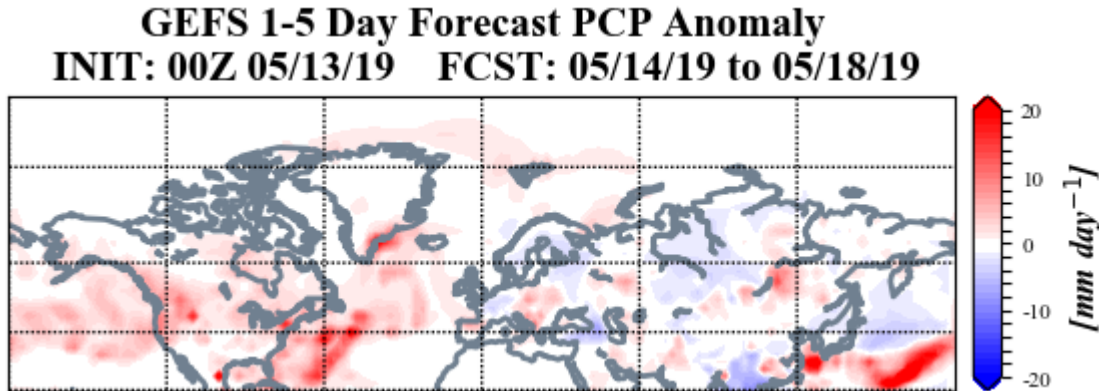


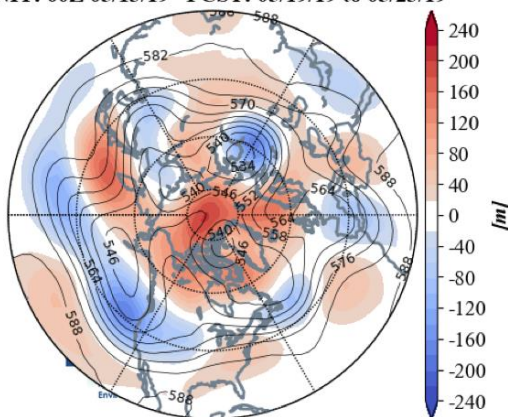
Figure 4. Forecasted rainfall anomalies (mm/day; shading) from 14 – 18 May 2019. The forecast is from the 00Z 13 May 2019 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain negative next week (**Figure 1**) as positive geopotential height anomalies are predicted to dominate the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5a**). And with persistent positive geopotential height anomalies across Greenland (**Figure 5a**), the NAO will likely remain negative next week as well.

a) GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 05/13/19 FCST: 05/19/19 to 05/23/19



b) GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 05/13/19 FCST: 05/24/19 to 05/28/19

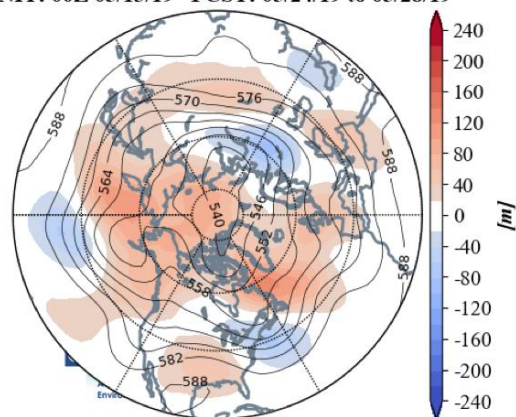


Figure 5. (a) Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 19 – 23 May 2019. (b) Same as (a) except averaged from 24 – 28 May 2019. The forecasts are from the 13 May 00z GFS ensemble.

Continued ridging/positive geopotential height anomalies between Greenland and Scandinavia are predicted to favor troughing/negative geopotential height anomalies south across Southwestern Europe next week with more ridging to the east across Eastern Europe (**Figure 5a**). This pattern is predicted to result in widespread normal to above normal temperatures across Europe including the UK except for normal to below temperatures across Spain, Portugal and France underneath mid-tropospheric troughing (**Figure 6**). The trough/negative geopotential height anomalies previously across Central Siberia will split into two with one piece sliding westward into northwest Russia and a second piece propagating to the east into East Asia, separated by ridging/positive geopotential height anomalies in Central Siberia (**Figure 5a**). This is predicted to yield widespread normal to above normal temperatures for most of Asia including the Middle East with normal to below normal temperatures across Mongolia, Eastern China and Western Russia (**Figure 6**).

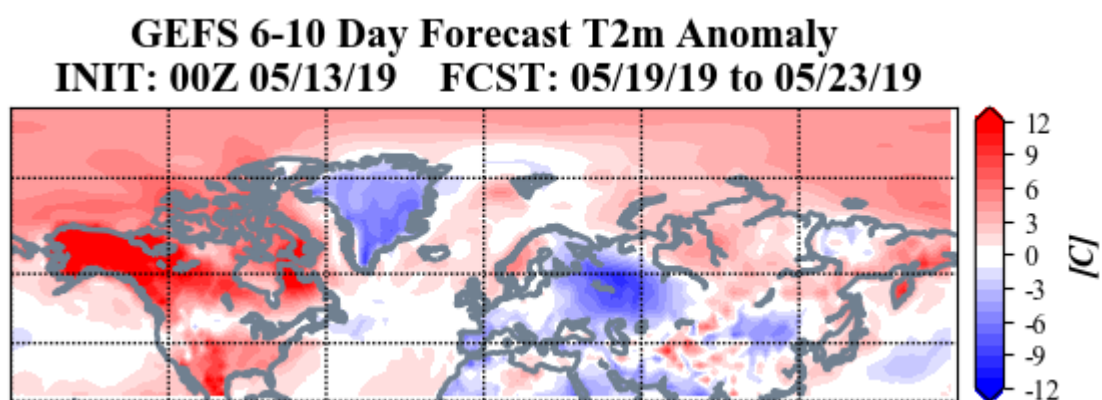


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 19 – 23 May 2019. The forecasts are from the 00Z 13 May 2019GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to cover much of the North American Arctic and most of Canada and the Eastern US while unusually deep troughing/negative geopotential height anomalies for this time of year enters the Western US from the Gulf of Alaska (**Figure 5a**). This pattern is predicted to bring normal to below normal temperatures across much of the Western Canada US with normal to above normal temperatures for Alaska, most of Canada and the Eastern US (**Figure 6**).

GEFS 6-10 Day Forecast PCP Anomaly
INIT: 00Z 05/13/19 FCST: 05/19/19 to 05/23/19

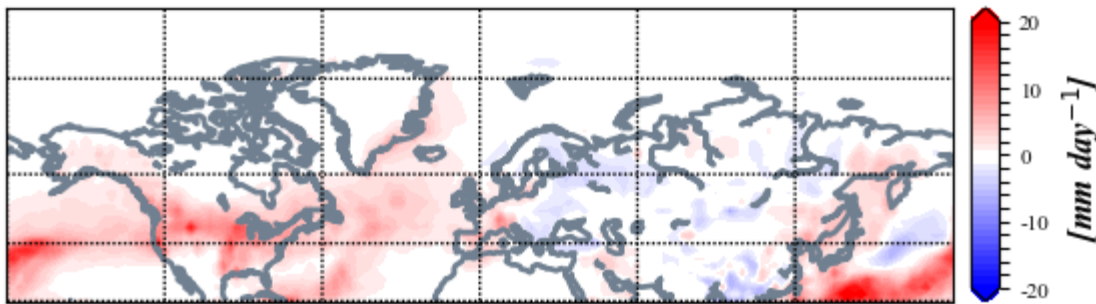


Figure 7. Forecasted rainfall anomalies (mm/day; shading) from 19 – 23 May 2019. The forecasts are from the 00Z 13 May 2019 GFS ensemble.

Trouthing is predicted to bring above normal rainfall to Southwestern Europe, East Asia, the Northwestern US and Southern Canada (**Figure 7**).

11-15 day

With mostly positive height anomalies predicted for the Arctic (**Figure 5b**), the AO is likely to remain neutral to negative this period (**Figure 1**). With predicted mostly positive pressure/geopotential height anomalies across Greenland (**Figure 1**), the NAO is likely to be neutral to negative this period as well.

Previous troughing/negative geopotential height anomalies across Southern Europe is predicted to weaken leaving mostly ridging/positive geopotential height anomalies across Europe (**Figure 5b**). This pattern is predicted to result in normal to above normal temperatures for most of Europe including the UK except for normal to below normal temperatures for the Baltic states as some cooler air bleeds west from northwest Russia (**Figure 8**). Little change is predicted for the circulation across Asia with ridging/positive geopotential height anomalies covering much Asia with troughing/negative geopotential height anomalies mostly confined to Western Russia and northwestern India and Pakistan (**Figure 5b**). This pattern favors normal to above normal temperatures for most of Asia including for East Asia and the Middle East with normal to below normal temperatures confined to Western Russia and northwest India and Southern Pakistan (**Figure 8**).

GEFS 11-15 Day Forecast T2m Anomaly
INIT: 00Z 05/13/19 FCST: 05/24/19 to 05/28/19

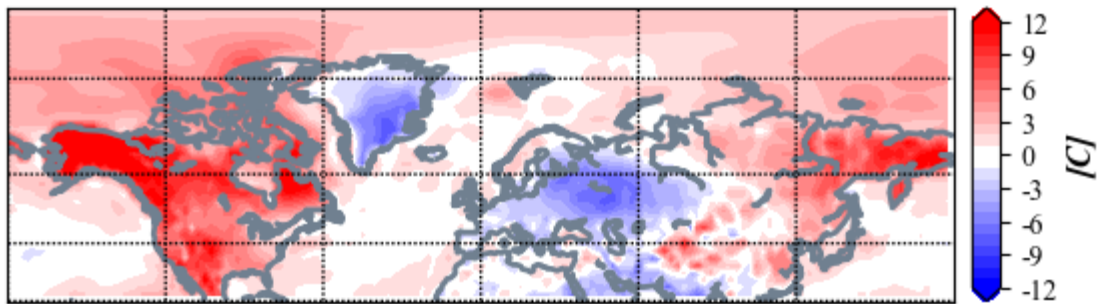


Figure 8. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 24 – 28 May 2019. The forecasts are from the 00Z 13 May 2019 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to dominate much of North America with troughing/negative geopotential height anomalies in the Southwestern and Northeastern US (**Figure 5b**). This will favor normal to above normal temperatures across Alaska, much of Canada, the Central and Southeastern US with normal to below normal temperatures for the Southwestern US and New England (**Figure 8**).

GEFS 11-15 Day Forecast PCP Anomaly
INIT: 00Z 05/13/19 FCST: 05/24/19 to 05/28/19

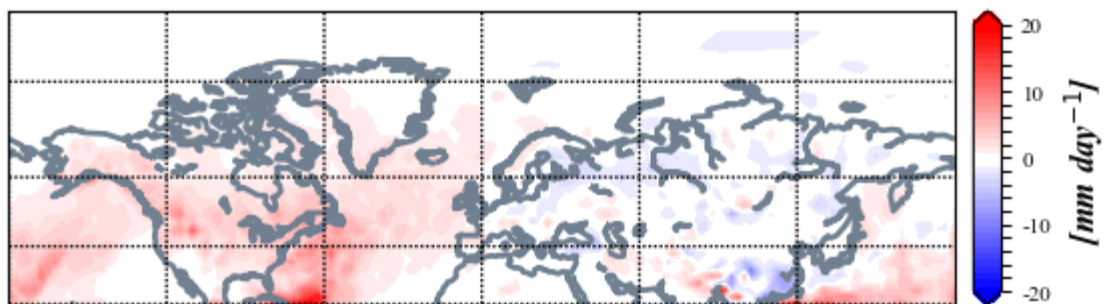


Figure 9. Forecasted rainfall anomalies (mm/day ; shading) from 24 – 28 May 2019. The forecasts are from the 00Z 13 May 2019 GFS ensemble.

Troughing is predicted to bring above normal rainfall to parts of Spain, Northern India and the Northeastern US (**Figure 9**). Ridging will bring dry conditions to Northern Europe (**Figure 9**).

Longer Term

30-day

The latest plot of the polar cap geopotential heights (PCHs) shows predicted normal to above normal PCHs throughout the stratosphere and the troposphere (**Figure 10**). The above normal PCHs in the stratosphere are consistent with a predicted negative stratospheric AO for the next two weeks (**Figure 1**) while the predicted above normal PCHs in the lower troposphere are consistent with a neutral to negative surface AO predicted for the next two weeks (**Figure 1**). The positive PCHs in the stratosphere appear to have descended into the troposphere in early May and will continue to dominate the troposphere for the next two weeks (**Figure 10**).

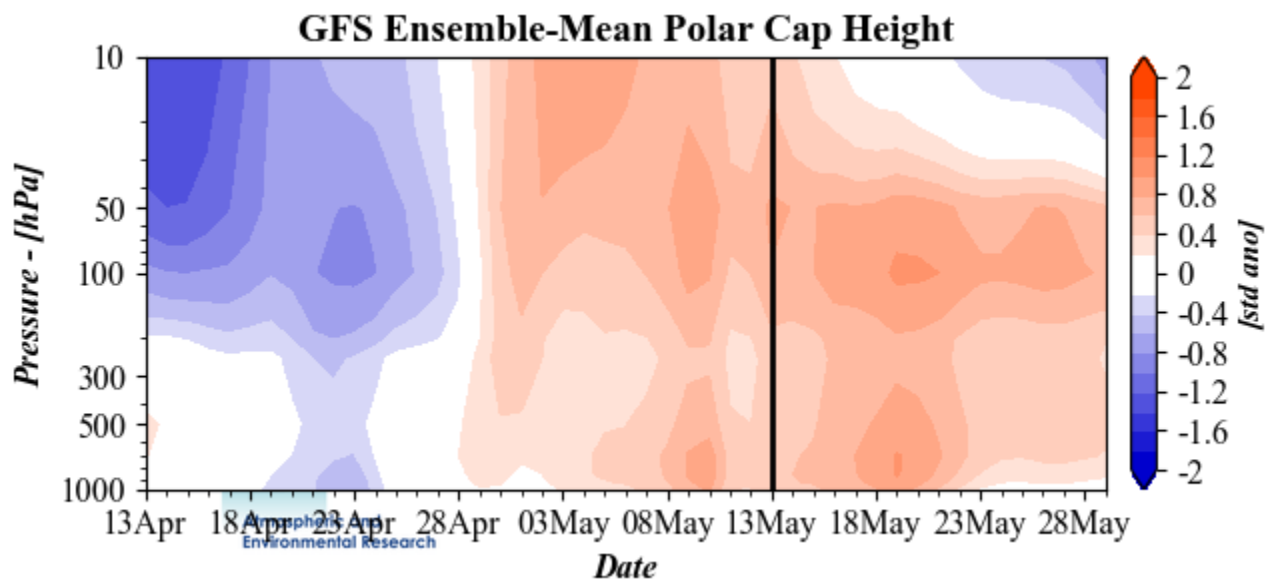


Figure 10. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 13 May 2019 GFS ensemble.

As discussed in the previous blog the positive PCHs and negative AO appear to be related an unusually dynamic stratospheric Final Warming (where the stratospheric PV disappears for the summer and winds are persistently easterly at 60°N and 10 hPa). This has resulted in a suppressed Jet Stream and relatively cool temperatures across the US and Europe in early May. There are signs the unusually south position and active Jet Stream may continue for a while longer across the US but less so across Europe.

**CFS 500 hPa Forecast Anomaly Jun 2019
Valid as of 13 May 2019**

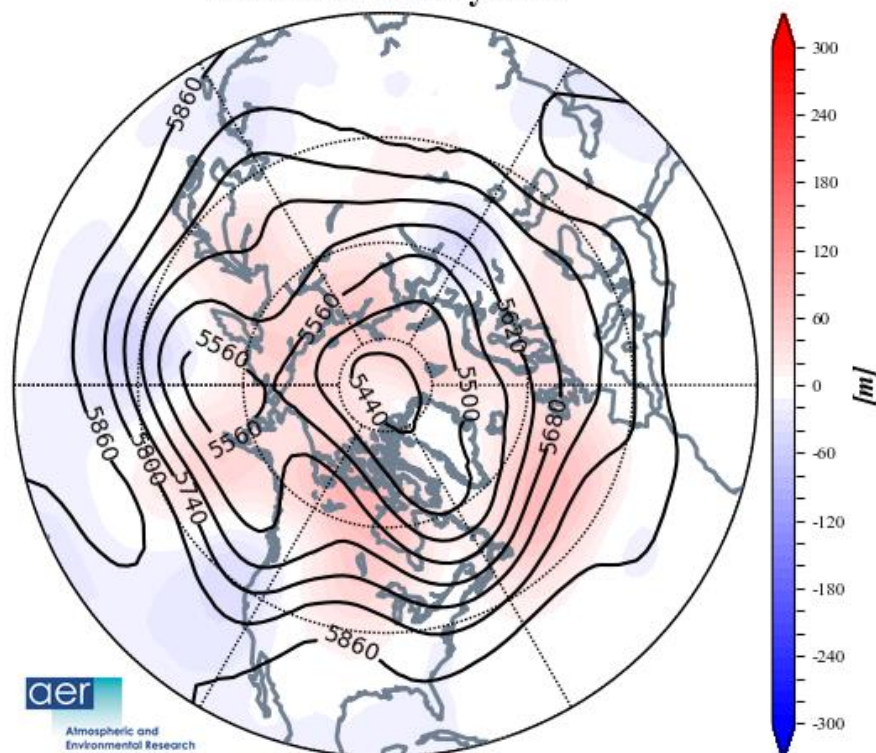


Figure 13. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for June 2019. The forecasts are from the 13 May 2019 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 11**) and the surface temperatures (**Figure 12**) forecast for June from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging centered across Northern Europe, Northeast Asia, Alaska, Western Canada and the Central US with troughs in Spain, Western Russia, Southeast Asia, the US West and East Coasts (**Figure 11**). This pattern favors cool temperatures for parts of Southern Europe, Western and Southeast Asia and possibly Eastern Canada and the US East Coast with relatively mild temperatures for Northern Europe, Northeast Asia and much of Western and Central North America (**Figure 12**).

CFS T2m Forecast Anomaly Jun 2019 Valid as of 13 May 2019

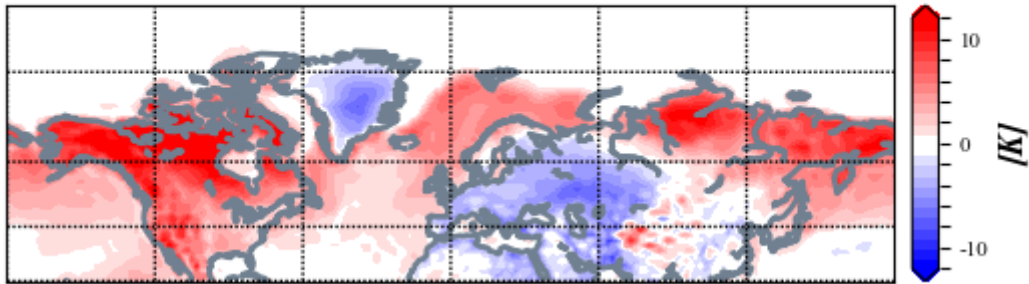


Figure 14. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for June 2019. The forecasts are from the 13 May 2019 CFS.

Surface Boundary Conditions

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies remain warm and El Niño conditions are expected for this summer (**Figure 13**). Observed SSTs across the NH remain well above normal though below normal SSTs exist regionally. Cold SSTs south of Iceland and in the subtropics of the North Atlantic with above normal SSTs in the mid-latitudes are thought to favor a positive NAO.

SST Anomaly - Week Ending 12 May 2019

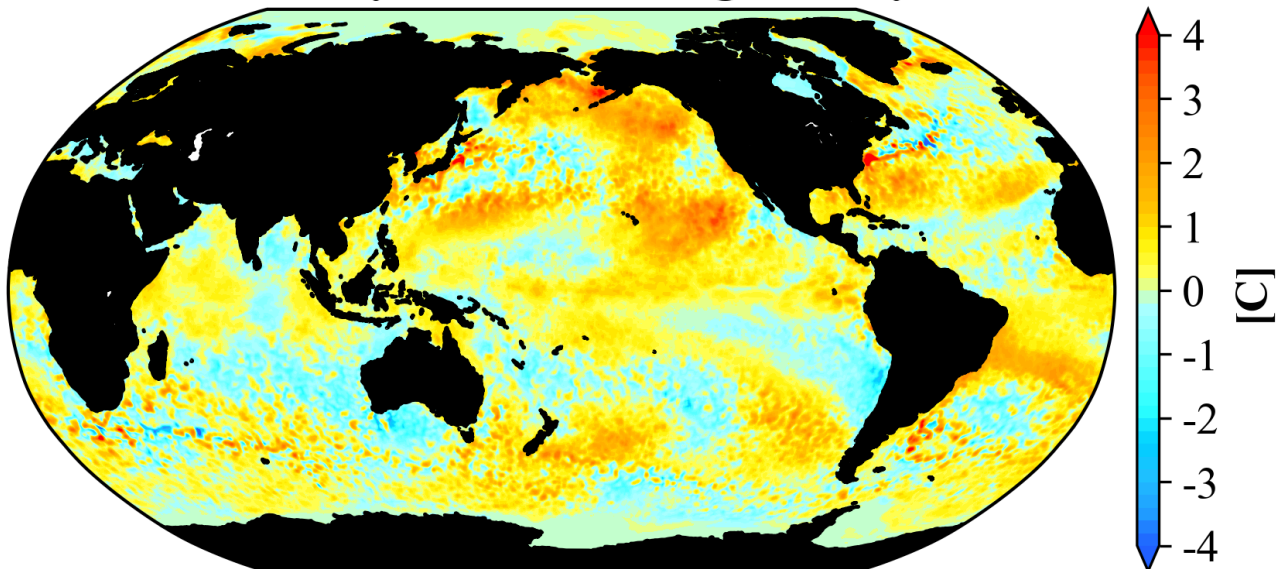


Figure 16. The latest weekly-mean global SST anomalies (ending 12 May 2019). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase seven (**Figure 14**). And the forecasts are for the MJO to then enter into phases 8 and 1. MJO phases 7-8-1 do favor ridging in Northern Canada and troughing in the Eastern US and could be contributing to the predicted pattern across North America.

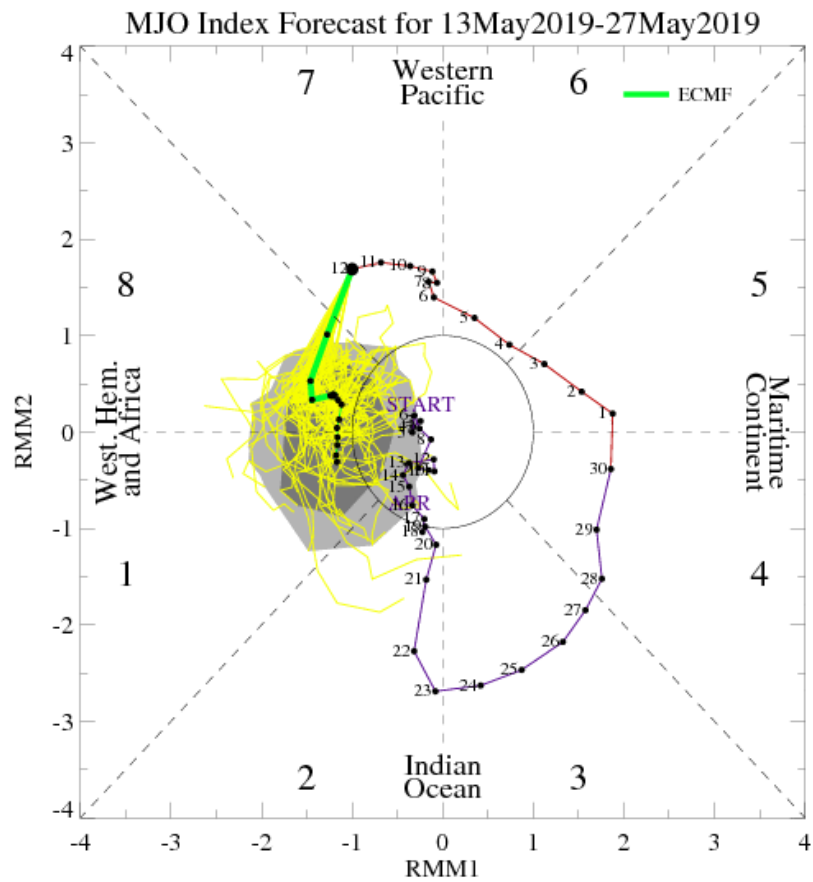


Figure 17. Past and forecast values of the MJO index. Forecast values from the 00Z 13 May 2019 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>