

Arctic Oscillation and Polar Vortex Analysis and Forecasts

April 13, 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.

Subscribe to our email list or follow me on Twitter (@judah47) for notification of updates.

The AO/PV blog is partially supported by NSF grant AGS: 1657748.

Summary

- The Arctic Oscillation (AO) is positive and is predicted to remain positive this week but then turn negative next week.
- The current positive AO is reflective of negative pressure/geopotential height anomalies in the Central Arctic and mixed pressure/geopotential height

anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently negative with positive pressure/geopotential height anomalies spread across Greenland and Iceland; and the NAO is predicted to flip briefly positive this week before returning to negative as height anomalies across Greenland are predicted to become negative this week and then positive next week.

- The predicted general circulation pattern over Europe including the United Kingdom (UK) is general ridging/positive geopotential height anomalies with normal to above normal temperatures this week followed by increasing troughing/negative geopotential height anomalies and cooling temperatures as Greenland blocking strengthens.
- The predicted general pattern for Asia over the next two weeks is ridging/positive geopotential height anomalies with normal to above normal temperatures in Central Asia bookended by troughing/negative pressure/geopotential height anomalies with normal to below normal temperatures in Western and Eastern Asia.
- The predicted general pattern for North America over the next two weeks is ridging/positive geopotential height anomalies with normal to above normal temperatures stretching from Alaska southward along the west coast of North America forcing troughing/negative geopotential height anomalies with normal to below normal temperatures in Central and Eastern Canada and the United States (US).
- In the Impacts section I discuss the predicted Final Warming of the polar vortex (PV) and the implications for the Northern Hemisphere (NH) circulation pattern.

Impacts

Though the stratospheric polar vortex took two very different paths last winter and this winter it does seem that the endings will be nearly identical. Last winter even though the PV was anomalously weak for all of January, it strengthened in February and was anomalously strong for all of March and into early April before strong vertical energy transfer in mid-April and forced by blocking in the northern North Atlantic brought about a dynamical Final Warming (where vertical energy transfer from the troposphere to the stratosphere contributes to the PV disappearing until the fall). This winter the PV has remained strong throughout the winter, but the ending looks to be nearly identical with another strong pulse of vertical energy transfer in mid-April (possibly even record strong for the date and almost to the day as in April 2019 see **Figure i**) forced by blocking in the northern North Atlantic bringing about a dynamical Final Warming.

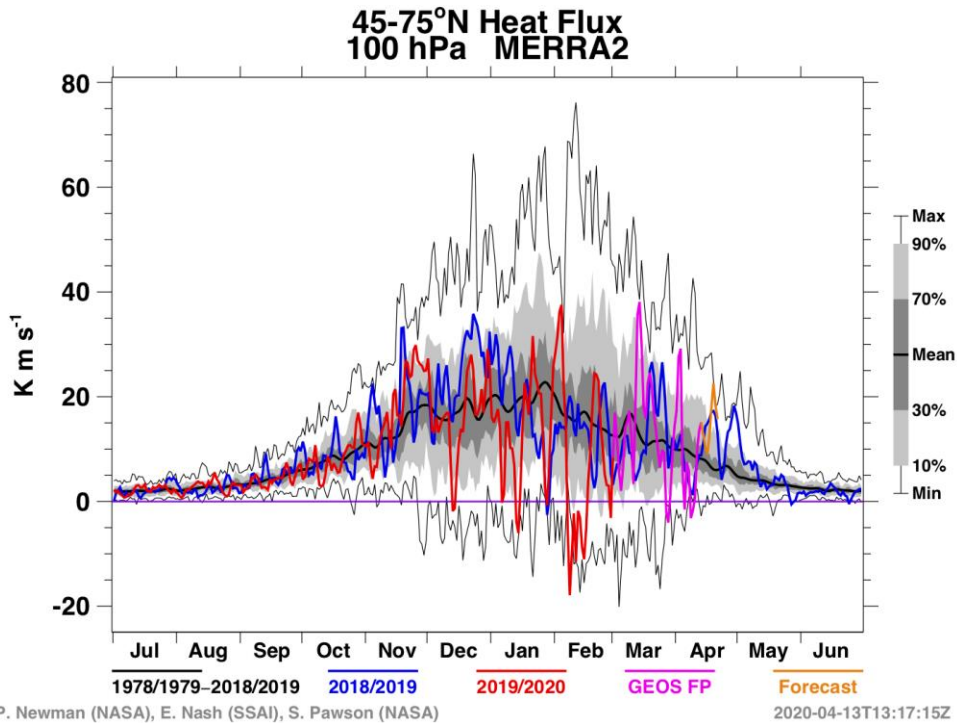


Figure i.

Poleward heat transport between 45 to 75°N at 100 hPa. Plot valid for 13 April 2020. Poleward heat transport is strongly related to WAFz. Plot downloaded from https://acd-ext.gsfc.nasa.gov/Data_services/met/ann_data.html

Last spring's dynamical Final Warming likely contributed to relatively cold temperatures in the Central US and to much of Canada that was favorable for an active period of severe weather in the US, especially in May. The GFS is predicting that for this year's dynamical Final Warming the PV center will be displaced into Western Asia and then likely into Europe (see **Figure ii**).

Initialized 00Z 10 hPa HGT/HGTa 13-Apr-2020

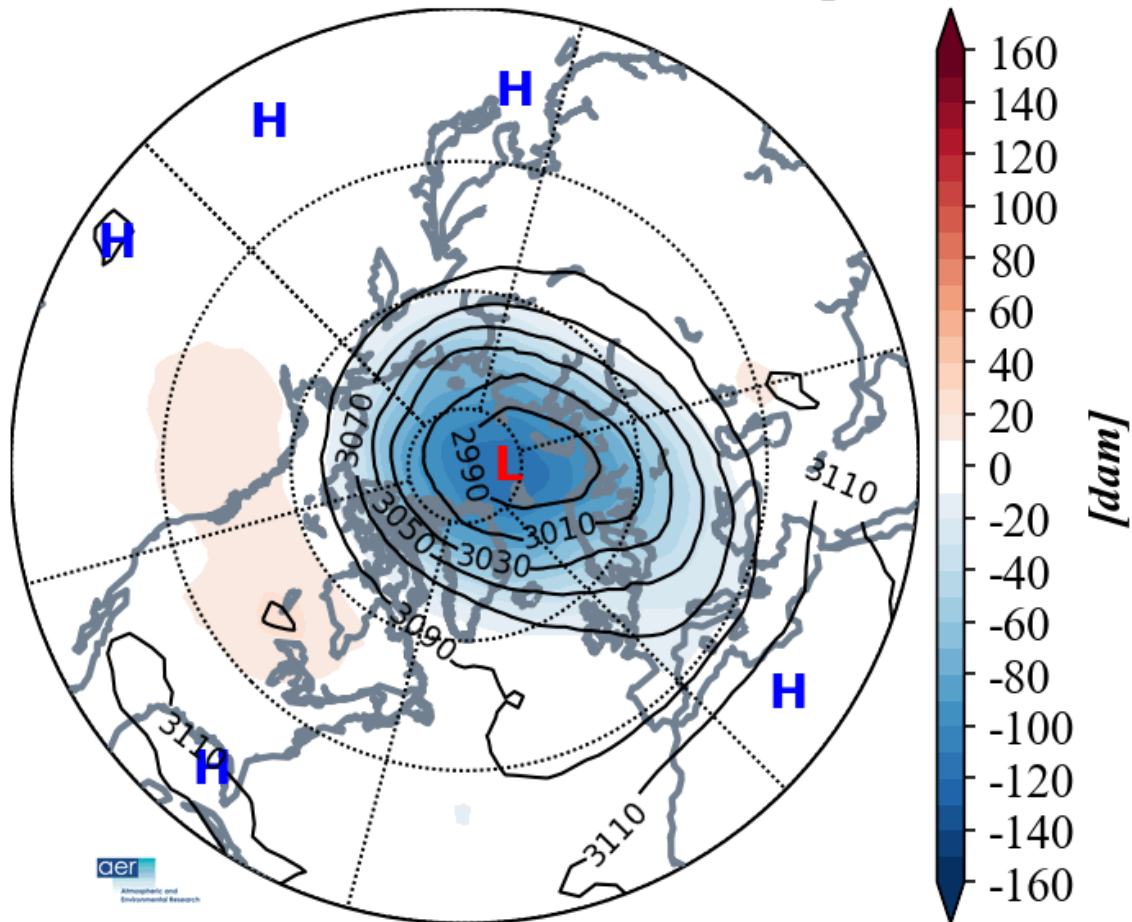


Figure ii. Analyzed and predicted 10 hPa geopotential heights (dam; contours) and anomalies (dam; shading) across the Northern Hemisphere from 13 – 29 April 2020. The forecasts are from the 00Z 13 April 2020 GFS operational model.

Induced low heights/troughing and easterly flow in the troposphere will favor below normal temperatures first in Western Asia and then Europe for much of the remainder of April based on the GFS (see **Figures 6** and **9**) and even for much of May based on the CFS forecast (see **Figure 15**). If the dynamical Final Warming may also be contributing to persistent Greenland blocking that not only favors relatively cool temperatures in Europe but also the Eastern US.

Any induced circulation patterns in the troposphere from the dynamical Final Warming are unlikely to persist past May though. The CFS forecast for June features a return of ridging/high heights to Europe (see **Figure iii**) with warmer temperatures. Though I would not consider a two-month CFS forecast very reliable, the predicted pattern of ridging in Europe, East Asia and western North America with troughing in Western Asia

has been the dominant circulation pattern of recent summers and I think is likely to repeat this summer.

**CFS 500 hPa Forecast Anomaly Jun 2020
Valid as of 13 Apr 2020**

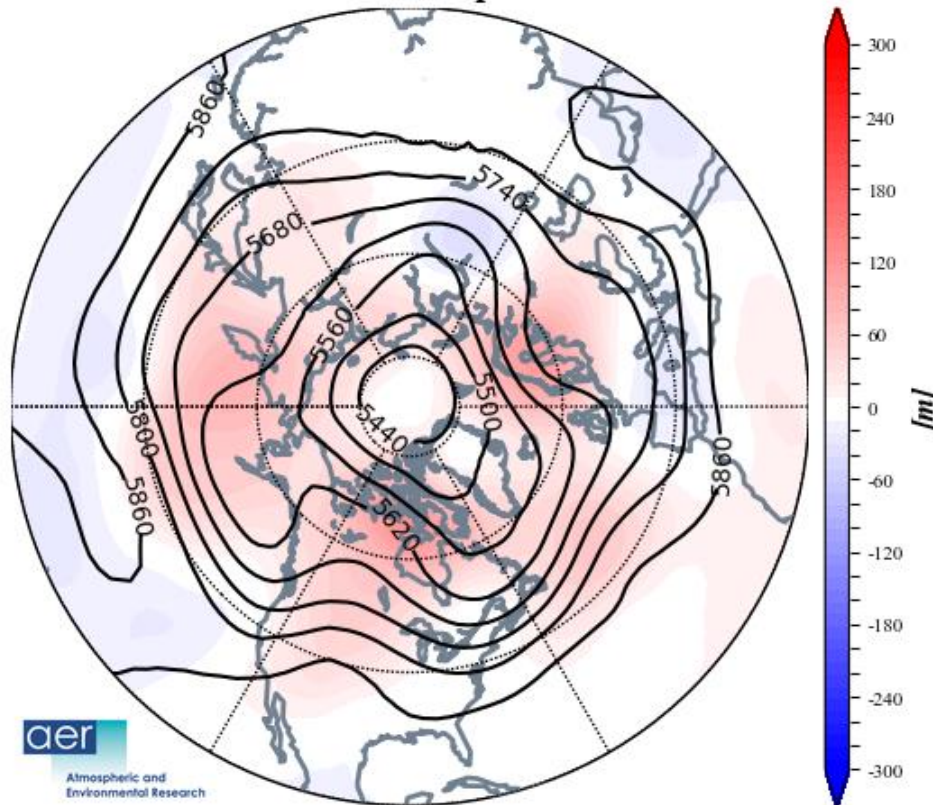


Figure iii. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for June 2020. The forecasts are from the 00Z 13 April 2020 CFS.

1-5 day

The AO is currently positive (**Figure 1**) with negative geopotential height anomalies in the Central Arctic and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with predicted negative geopotential height anomalies across Greenland and Iceland (**Figure 2**), the NAO is predicted to be positive.

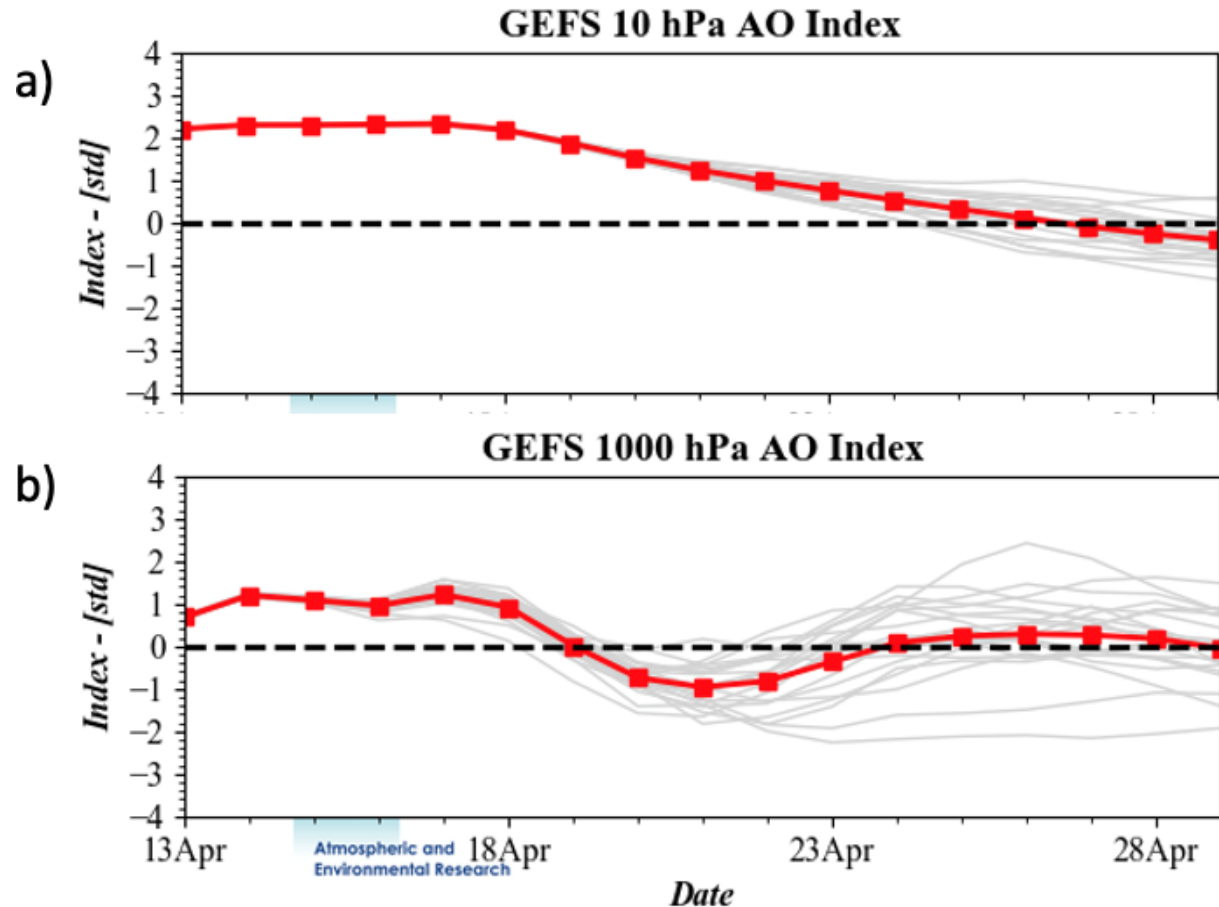


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 13 April 2020 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 13 April 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies with normal to above normal temperatures will dominate much of Europe including the UK (**Figures 2 and 3**). One exception is troughing/negative geopotential height anomalies with normal to below normal temperatures in Eastern Europe (**Figures 2 and 3**). Troughing/negative geopotential height anomalies are predicted for Western Asia and Eastern Siberia with ridging/positive geopotential height anomalies across Central and Eastern Asia this week (**Figure 2**). This pattern favors normal to below normal temperatures across Western Asia and Eastern Siberia with normal to above normal temperatures in Central and Eastern Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 04/13/20 FCST: 04/14/20 to 04/18/20

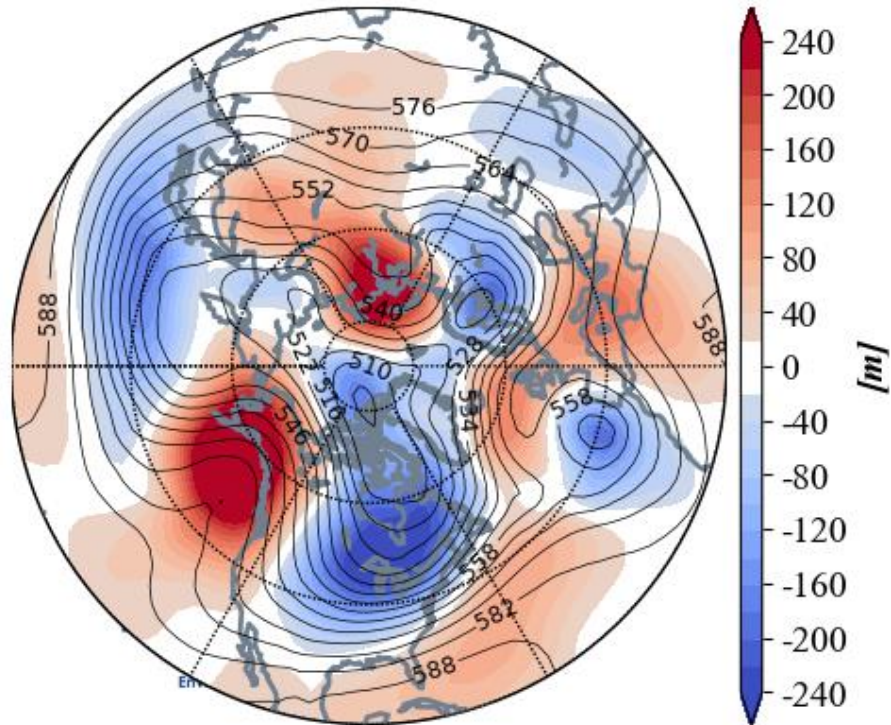


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 14 – 18 April 2020. The forecasts are from the 00z 13 April 2020 GFS ensemble.

This week, ridging/positive geopotential height anomalies are predicted to stretch from Alaska, the Gulf of Alaska and along the west coast of North America anchoring troughing/negative geopotential height anomalies downstream across North America east of the Rockies (**Figure 2**). This pattern is predicted to bring normal to above normal temperatures across Alaska and the West Coasts of Canada and the US with normal to below normal temperatures across Canada and the US from the Rockies to the Atlantic seaboard (**Figure 3**).

GEFS 1-5 Day Forecast T2m Anomaly
INIT: 00Z 04/13/20 FCST: 04/14/20 to 04/18/20

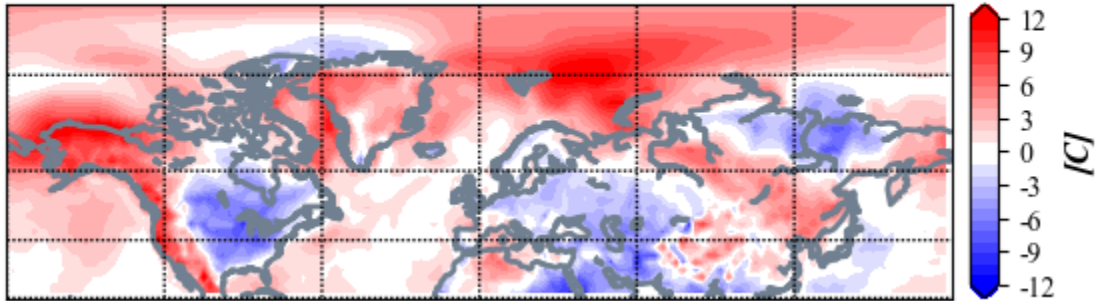


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 14 – 18 April 2020. The forecast is from the 00Z 13 April 2020 GFS ensemble.

Widespread normal to below normal precipitation is predicted across Eurasia except for normal to above normal precipitation in Spain, Eastern Europe and parts of the Middle East (**Figure 4**). Near normal precipitation is predicted for North America except for above normal precipitation in the Northeastern US and Eastern Canada (**Figure 4**).

GEFS 1-5 Day Forecast PCP Anomaly
INIT: 00Z 04/13/20 FCST: 04/14/20 to 04/18/20

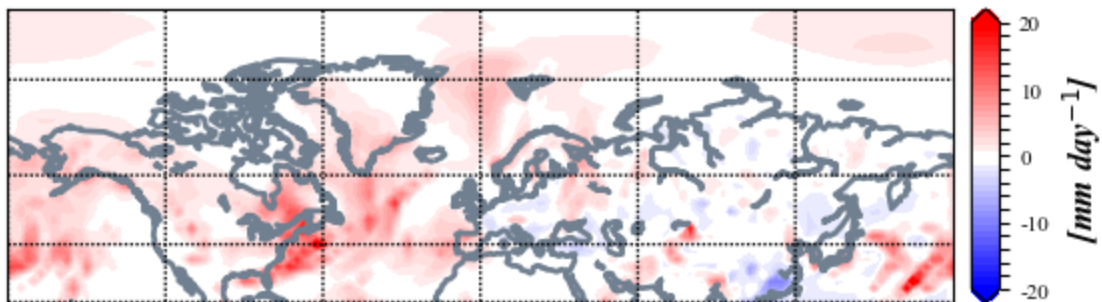


Figure 4. Forecasted precipitation anomalies (mm/day ; shading) from 14 – 18 April 2020. The forecast is from the 00Z 13 April 2020 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to turn negative (**Figure 1**) as positive geopotential height anomalies become more widespread across the North Atlantic side of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And

with positive geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to turn negative as well.

GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 04/13/20 FCST: 04/19/20 to 04/23/20

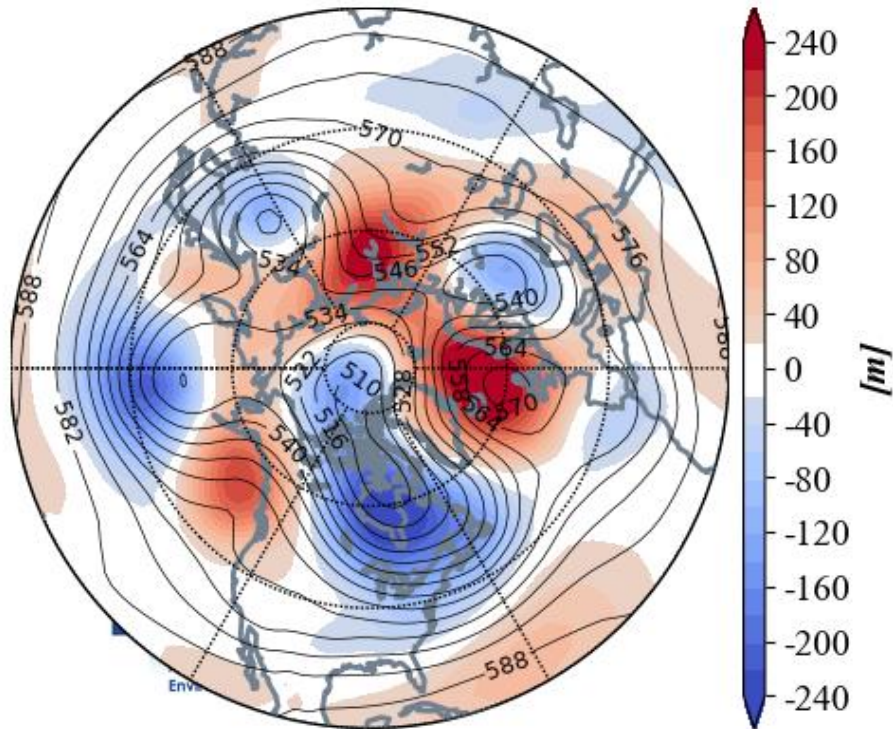


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 19 – 23 April 2020. The forecasts are from the 00z 13 April 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to become more widespread across the northern North Atlantic supporting increasing troughing/negative geopotential height anomalies in Europe, especially Eastern and Central Europe this period (**Figures 5**). **This pattern will favor** normal to above normal temperatures across Western Europe including the UK and Scandinavia with normal to below normal temperatures for Central and Eastern Europe (**Figure 6**). Persistent troughing/negative geopotential height anomalies in Western Asia will help to anchor ridging/positive geopotential height anomalies in Central Asia with more troughing/negative geopotential height anomalies in Eastern Asia (**Figure 5**). This is predicted to yield normal to below normal temperatures in far Western Asia and Eastern Asia **with** normal to above temperatures in Central Asia (**Figure 6**). Some weak troughing/negative geopotential height anomalies across Southern Asia will favor normal to below normal temperatures in the Tibetan Plateau (**Figures 5 and 6**).

GEFS 6-10 Day Forecast T2m Anomaly
INIT: 00Z 04/13/20 FCST: 04/19/20 to 04/23/20

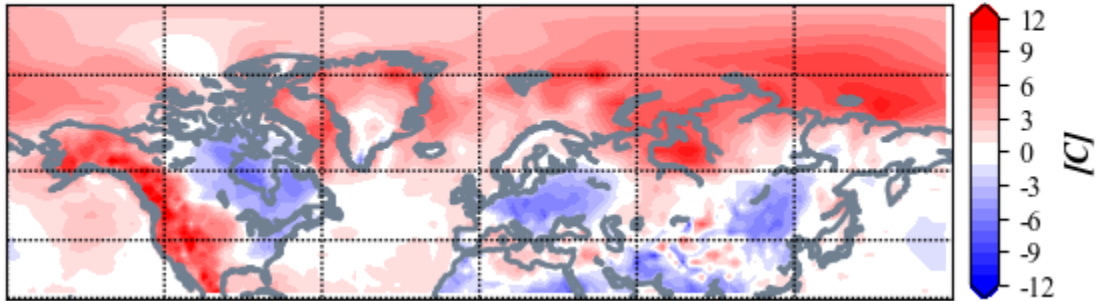


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 19 – 23 April 2020. The forecasts are from the 00Z 13 April 2020 GFS ensemble.

Again, persistent ridging/positive geopotential height anomalies across Alaska, the Gulf of Alaska and along the west coast of North America will force troughing/negative geopotential height anomalies downstream across North America east of the Rockies this period (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across Alaska, Western Canada and the Western US with normal to above normal temperatures for Eastern Canada and the Eastern US (**Figure 6**).

GEFS 6-10 Day Forecast PCP Anomaly
INIT: 00Z 04/13/20 FCST: 04/19/20 to 04/23/20

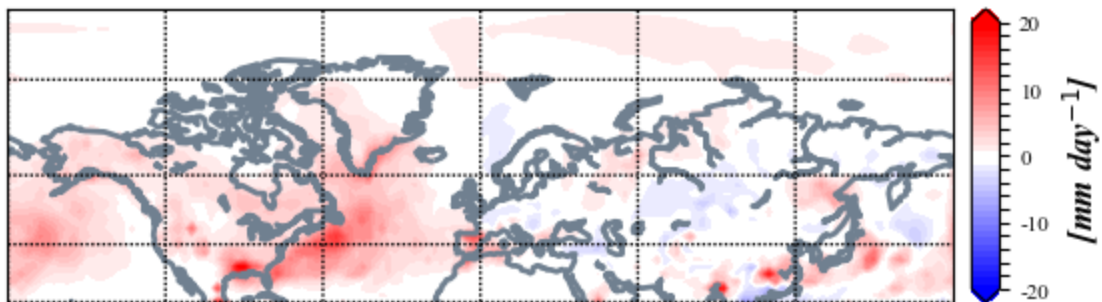


Figure 7. Forecasted precipitation anomalies (mm/day ; shading) from 19 – 23 April 2020. The forecasts are from the 00Z 13 April 2020 GFS ensemble.

Widespread normal to below normal precipitation is predicted across Eurasia except for normal to above normal precipitation in Spain, the north slope of Asia and parts of East Asia (**Figure 7**). Near normal precipitation is predicted for North America except for above normal precipitation along the Gulf of Mexico and parts of the Rockies (**Figure 7**).

11-15 day

With weak geopotential height anomalies predicted for the Arctic except for positive geopotential height anomalies in the North Atlantic side of the Arctic (**Figure 8**) and mixed geopotential height anomalies across the mid-latitudes of the NH, the AO is predicted to straddle neutral this period (**Figure 1**). With predicted positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is likely to remain negative.

GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 04/13/20 FCST: 04/24/20 to 04/28/20

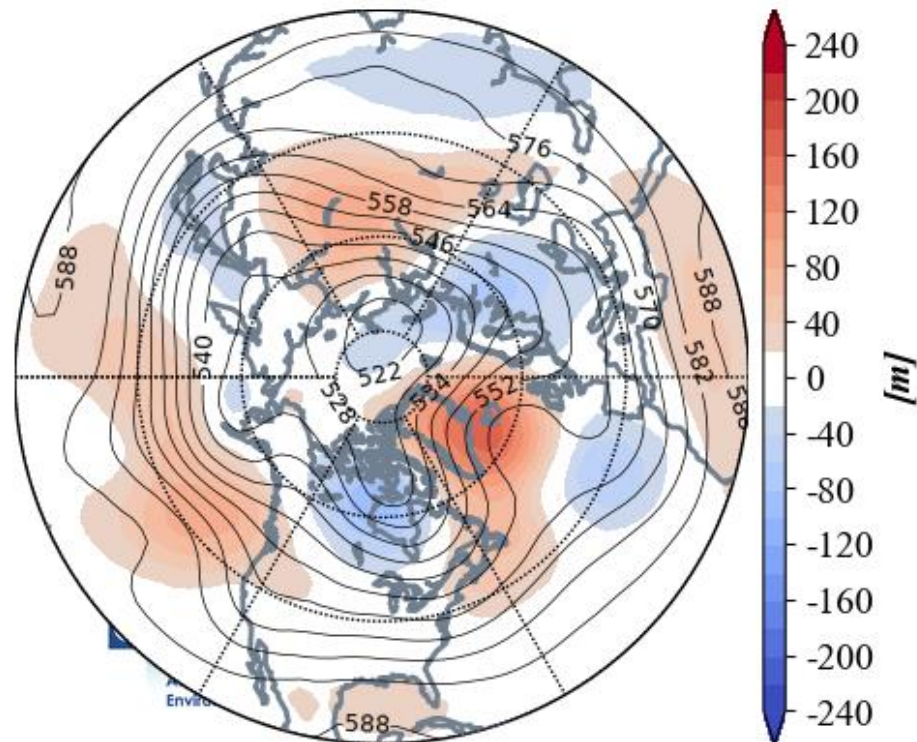


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 24 – 28 April 2020. The forecasts are from the 00z 13 April 2020 GFS ensemble.

Ridging/positive geopotential height anomalies anchored across Greenland will promote troughing/negative geopotential height anomalies widespread across Europe this period (**Figures 8**). The forecast is for widespread normal to below normal temperatures across Europe including the UK this period (**Figures 9**). Once again, ridging/positive geopotential height anomalies in Central Asia are predicted to be bookended by troughing/negative pressure/geopotential height anomalies in Western Asia and far East Asia this period (**Figure 8**). This pattern favors normal to below normal

temperatures for Western and Southeast Asia with normal to above normal temperatures for Central and Northeast Asia (**Figure 9**). Some weak troughing/negative geopotential height anomalies across Southern Asia will favor normal to below normal temperatures in the region (**Figures 8 and 9**).

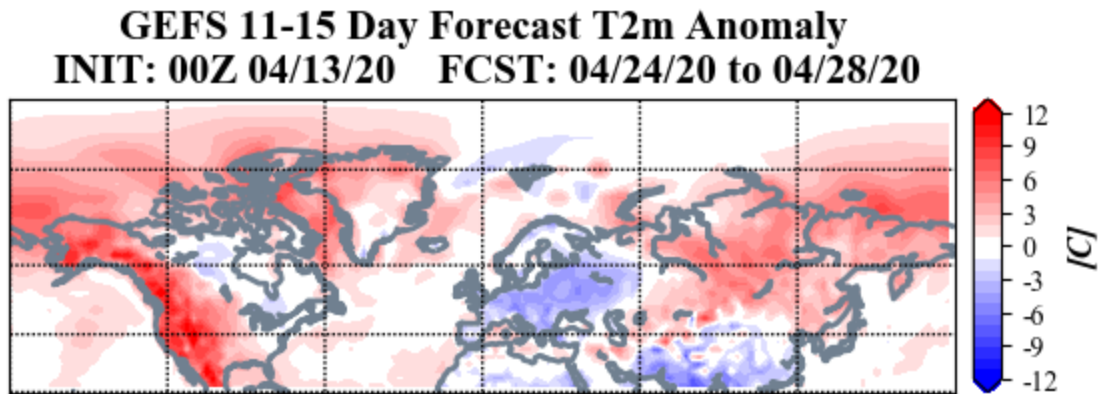


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 24 – 28 April 2020. The forecasts are from the 00z 13 April 2020 GFS ensemble.

Persistent ridging/positive geopotential height anomalies in the Gulf of Alaska will force downstream troughing/negative geopotential height anomalies in Eastern Canada this period (**Figure 8**). This pattern continues to favor normal to above normal temperatures across Western Canada and much of the Western and Central US with normal to below normal temperatures for Eastern Canada and the Eastern US (**Figure 9**).

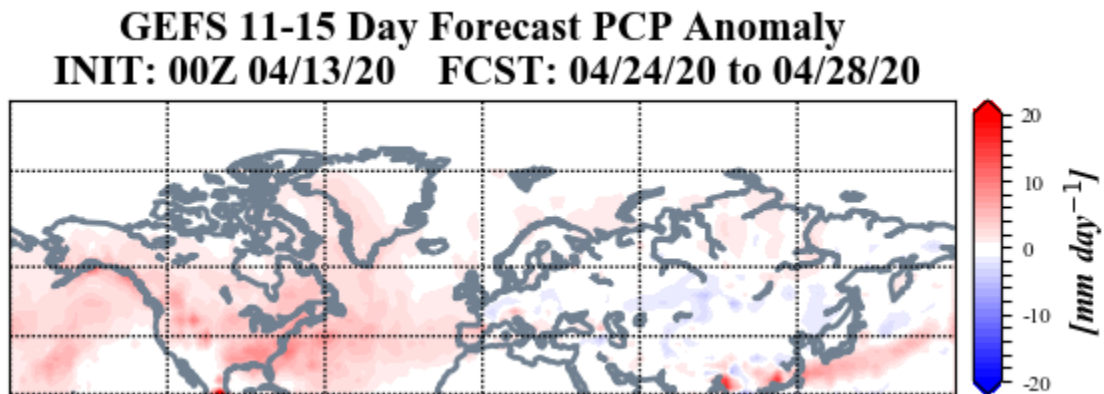


Figure 10. Forecasted precipitation anomalies (mm/day ; shading) from 24 – 28 April 2020. The forecasts are from the 00z 13 April 2020 GFS ensemble.

Widespread normal to below normal precipitation is predicted across Eurasia except for normal to above normal precipitation in Spain and Southeast Asia (**Figure 10**). Near normal precipitation is predicted for North America except for above normal precipitation in the Eastern US (**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 stratosphere over the next two weeks with the largest negative departures in the lower stratosphere (**Figure 11**). However, PCHs in the troposphere are predicted to be normal to above normal (**Figure 11**) consistent with the predicted negative to neutral AO (**Figure 1**) and negative NAO.

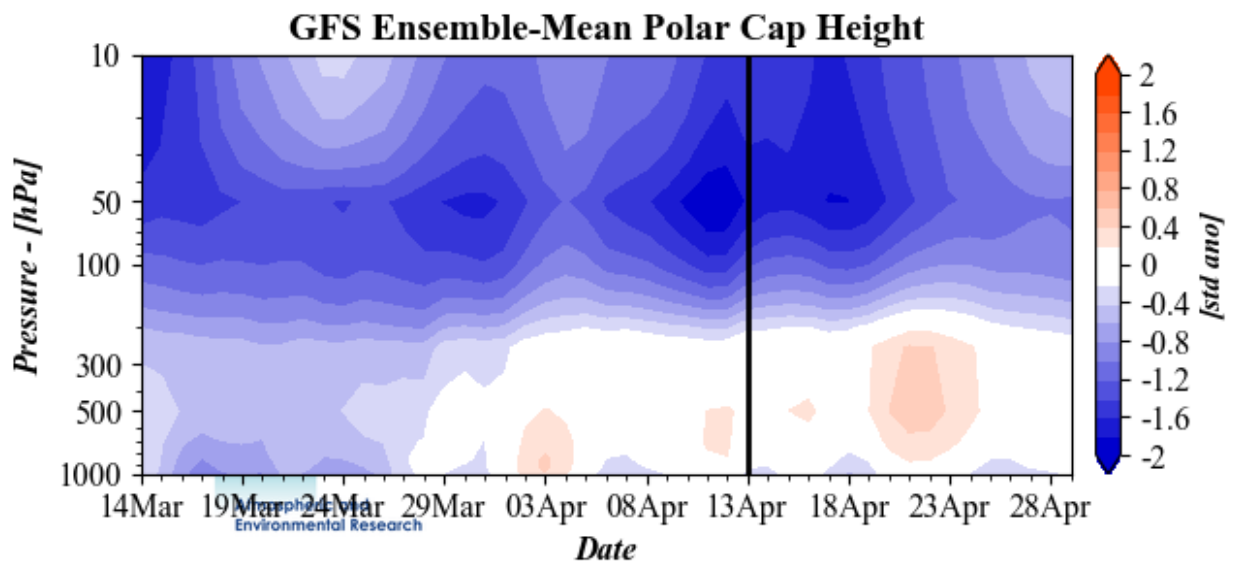


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 13 April 2020 GFS ensemble.

The plot of vertical Wave Activity Flux (WAFz) or poleward heat transport forecast shows a strong positive anomaly pulse for next week (**Figure 12**). The strong increase in positive WAFz anomalies are likely related to positive height anomalies predicted this week stretching from Greenland to Northern Europe and across Northern Asia (**Figure 5**).

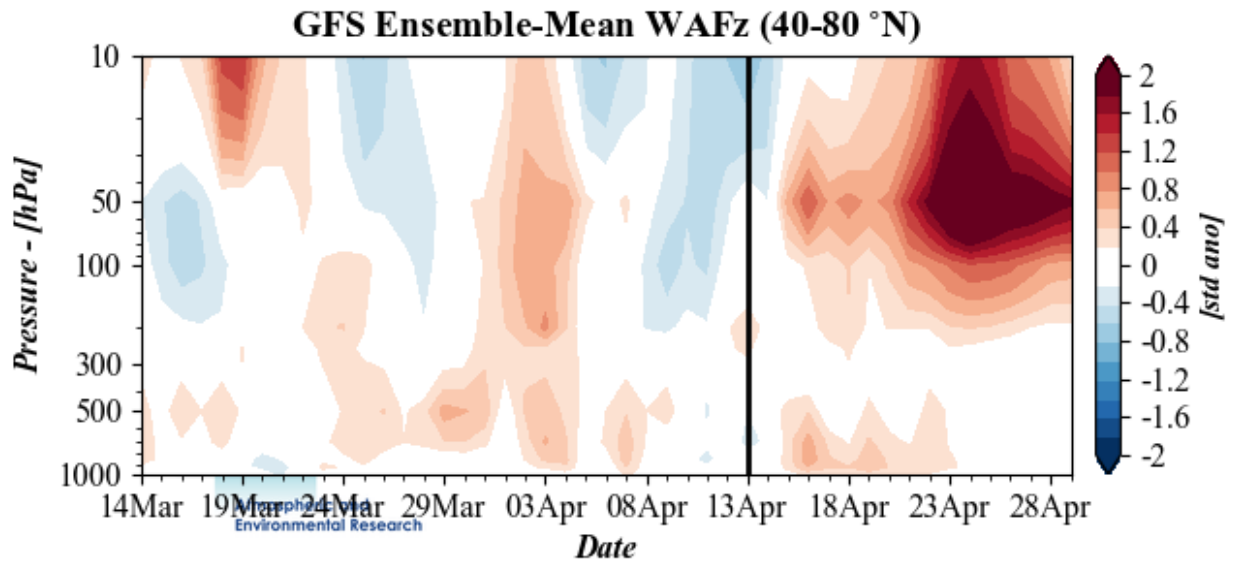


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 13 April 2020 GFS ensemble.

The positive WAFz anomalies are predicted to finally force the stratospheric AO from strongly positive back to neutral (**Figure 1**) consistent with a weakening PV (**Figure 1**). The GFS is predicting that the WAFz pulse will be sufficiently strong to induce the Final Warming (where the stratospheric PV disappears until the fall).

Currently the stratospheric PV center is centered over Franz Josef Land (**Figure 13**) with the largest positive temperature departures in the polar stratosphere located in the center of the PV (**Figure 13**). The PV is also elongated along an axis from the North Pole to Western Asia/Eastern Europe. This is likely related to the predicted troughing in the mid-troposphere in the same region (**Figure 2**).

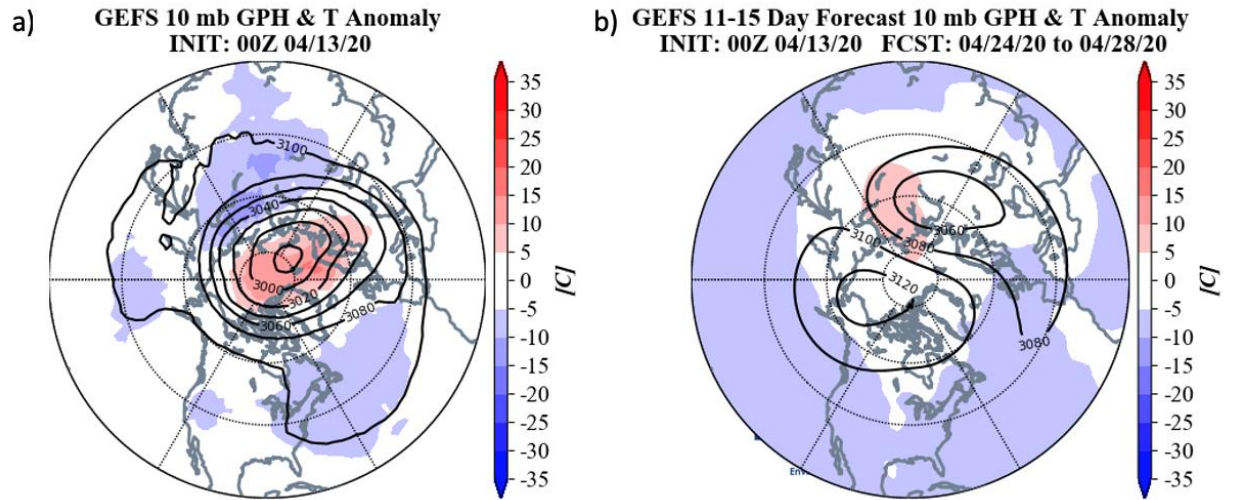


Figure 13. (a) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere at 00Z 13 April 2020. (b) Same as (a) except forecasted averaged from 24 – 28 April 2020. The forecasts are from the 00Z 13 April 2020 GFS operational model.

Over the next two weeks, the PV center is predicted to be displaced into western Asia and weakened as ridging spreads across the Central Arctic (**Figure 13**). The displacement and weakening of the PV are related to the strong WAFz pulse of next week and should result in the Final Warming.

CFS 500 hPa Forecast Anomaly May 2020
Valid as of 13 Apr 2020

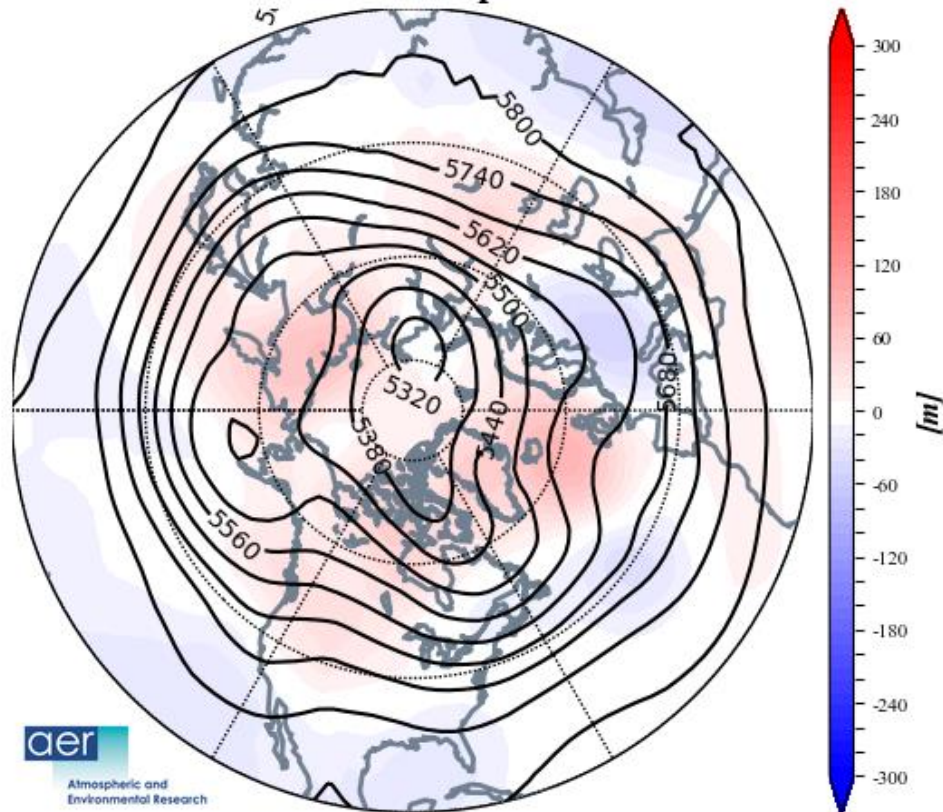


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for May 2020. The forecasts are from the 00Z 13 April 2020 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) forecast for May from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging in the northern North Atlantic, Western Asia, Eastern Siberia, Alaska and Western Canada with troughing in Europe into the Middle East, East Asia, Eastern Canada and the Southwestern US (**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 Central Europe, Western and Southern Asia, Southeastern Canada and the Eastern US (**Figure 15**).

CFS T2m Forecast Anomaly May 2020 Valid as of 13 Apr 2020

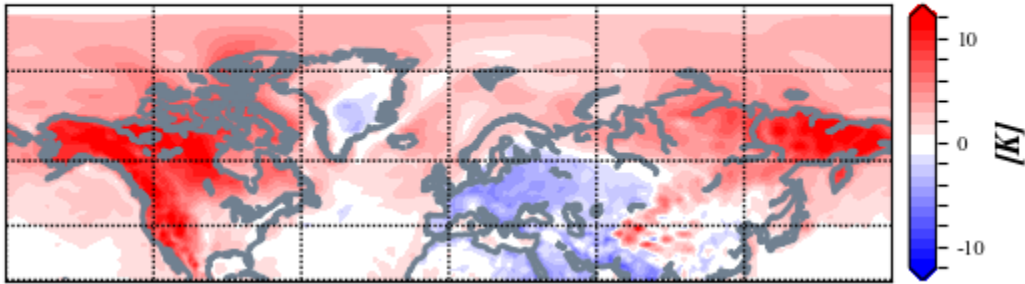


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for May 2020. The forecasts are from the 00Z 13 April 2020 CFS.

Surface Boundary Conditions

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are cooling slightly but neutral El Niño/Southern Oscillation (ENSO) conditions seem most likely this spring (**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.

SST Anomaly - Week Ending 12 Apr 2020

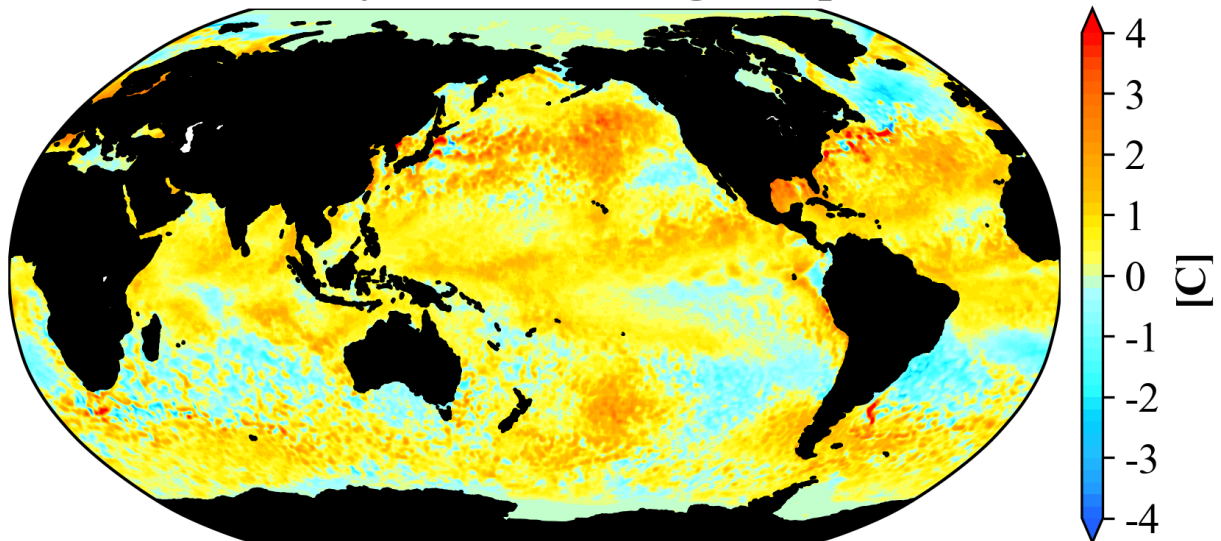


Figure 17. The latest weekly-mean global SST anomalies (ending 12 April 2020). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase eight (**Figure 18**). The forecasts are for the MJO to transition to phase one and two. MJO phases eight, one and two favor ridging in Canada with troughing in the US. The MJO could be partially contributing to the weather patterns across North America in the short term.

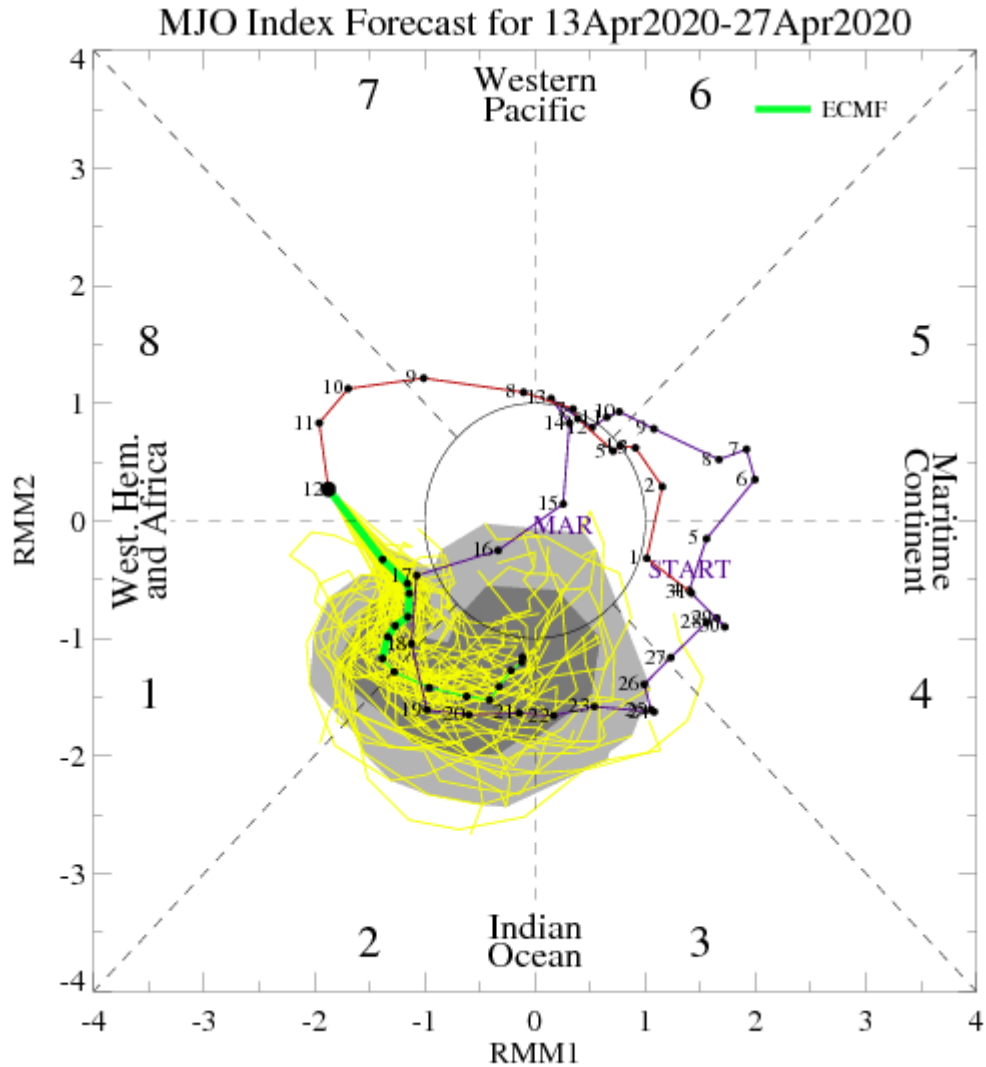


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 13 April 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>

