

March 25, 2019

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

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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](#)). 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 positive and is predicted to remain positive over the next week but turn negative in early April.
- The current positive AO is reflective of mostly negative pressure/geopotential height anomalies across the Arctic and positive pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is also positive as currently negative pressure/geopotential height anomalies are spread across Greenland and mostly positive pressure/geopotential height anomalies across the mid-latitudes of the North Atlantic and is predicted to remain positive over the next two weeks.
- Ridging/positive geopotential height anomalies is predicted to be generally positioned west and north of Europe with troughing/negative geopotential height anomalies across Eastern and Southern Europe. This pattern favors near seasonable temperatures across the continent including the United Kingdom (UK) with the best chances of below normal temperatures across Southern and Eastern Europe.
- Over the next two weeks, ridging/positive geopotential height anomalies are predicted to be centered on Central Asia with widespread normal to above

normal temperatures with troughing/negative geopotential height anomalies with normal to below normal temperatures confined to Eastern Siberia, Northeast Asia and Western Asia.

- This week ridging/positive geopotential height anomalies with relatively mild temperatures are predicted across western North America with troughing/negative geopotential height anomalies and relatively cold temperatures across Eastern Canada and the Eastern United States (US). However next week the ridging/positive geopotential height anomalies and relatively mild temperatures are predicted to become more widespread across North America with troughing/negative geopotential height anomalies and relatively cold temperatures confined to northern Canada. Though I do believe the GFS forecast of a warmup but may be premature.

Impacts

As I have written in several research papers, winter is the only season that widespread temperature anomalies that are closer to the 30-year average of let's say 1980-2010 are still observed (e.g. [Cohen et al. 2012](#)). Or in other words winter is the one season so far resistant to a robust warming trend, at least across the mid-latitude continents and that in the other three seasons a robust warming trend is observed. So, for me an interesting question is when will the transition occur from a winter regime, with persistent and widespread below normal temperatures to a spring and summer regime, when only regional and more episodic below normal temperatures will occur.

Over the past two winters we observed a highly anomalous polar vortex disruptions and a stratospheric polar vortex split. For reason that I don't fully understand the cold was more persistent across North America relative to Eurasia both winters. Last winter cold was widespread across both North America and Eurasia in March but in April the Eurasian continent quickly warmed while record cold persisted across large parts of North America. This winter below normal temperatures have been far more impressive across North America while in Eurasia the cold has been more regional and ephemeral.

One important difference between last winter and this winter is the timing of the PV disruption, which are separated by calendar dates of about six weeks. Last winter it occurred in mid-February while this winter it occurred in early January. I would argue that last year, the record cold April in North America was attributable to the PV disruption back in February. This winter I would argue that the cold in early March across North America was attributable to the PV disruption back in early January however the cold that followed after the first week in March is not related to the major PV disruption in January but rather to a subsequent more minor one in March. Therefore, I don't expect a repeat of last April across North America this year.

So, I do anticipate an aggressive transition to spring across the Northern Hemisphere (NH) at some point but there are still no signs of it in the near future. Across North

America the minor PV disruption spawned a strong blocking high centered near Alaska. I think this blocking high could be hard to dissipate. Sea ice is extremely low or even completely absent from the Bering Sea. I believe that heating from the open waters could help to anchor the ridge that has developed in the atmosphere above. The GFS does predict that the ridge drifts into Eastern Siberia the first week of April, which would remove the forcing for troughing and below normal temperatures in eastern North America, but I do believe the GFS may be premature in predicting a pattern change.

For Europe a spring warm up this year is so far not looking to keep pace with last year. The AO is predicted to turn negative next week (though some skepticism is warranted as many negative AO forecasts have not verified this winter). Also ridging centered first just west of Europe and then just north of Europe will keep much of Europe in weak northerly flow that is predicted to tether temperatures close to seasonable. If the ridging comes ashore and becomes centered over Europe, then temperatures could rise quickly but so far there are no signs of this. But such a scenario can develop quickly.

Near Term Conditions

1-5 day

The AO is positive (**Figure 1**), with mostly negative pressure/geopotential height anomalies across the Arctic with positive pressure/geopotential height anomalies across the mid-latitudes (**Figure 2**). Geopotential height anomalies are negative across Greenland and positive across the mid-latitudes of the North Atlantic (**Figure 2**) and therefore the NAO is positive.

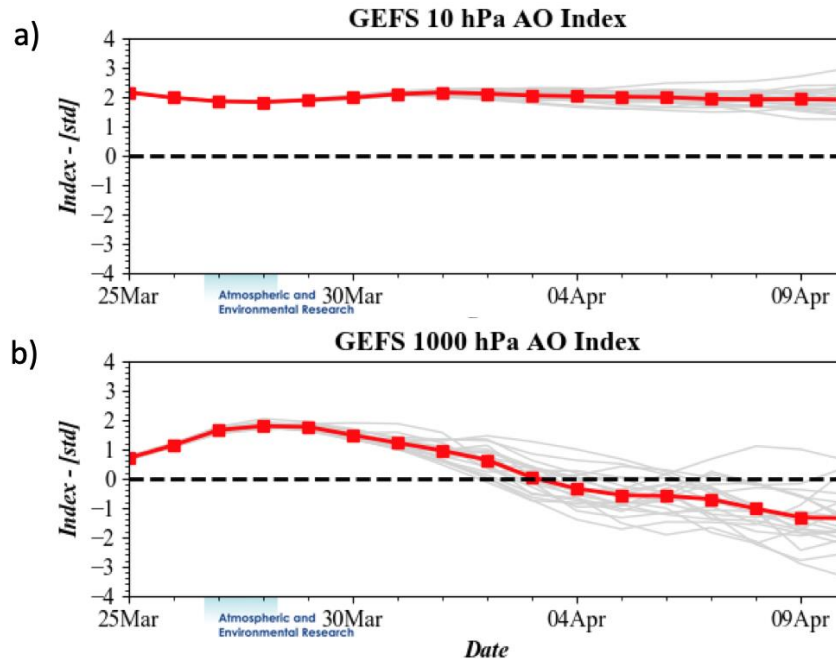


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 25 March 2019 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 25 March 2019 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Ridging/positive geopotential height anomalies spread across Western and Northern Europe with troughing/negative geopotential height anomalies spread across Eastern and Southern Europe (**Figure 2**) are predicted to result in mostly normal to above normal temperatures for Western and Northern Europe including the UK with normal to below normal temperatures across Eastern and Southern Europe (**Figure 3**). The forecast for Asia is ridging/positive geopotential height anomalies centered over Central Asia with troughing/negative geopotential height anomalies confined to Eastern Siberia, Northeast Asia and far western Asia (**Figure 2**). This pattern is predicted to yield widespread normal to above normal temperature for Asia with normal to below normal temperatures confined to Eastern Siberia, Northeast Asia, Western Russia and the Middle East (**Figure 3**).

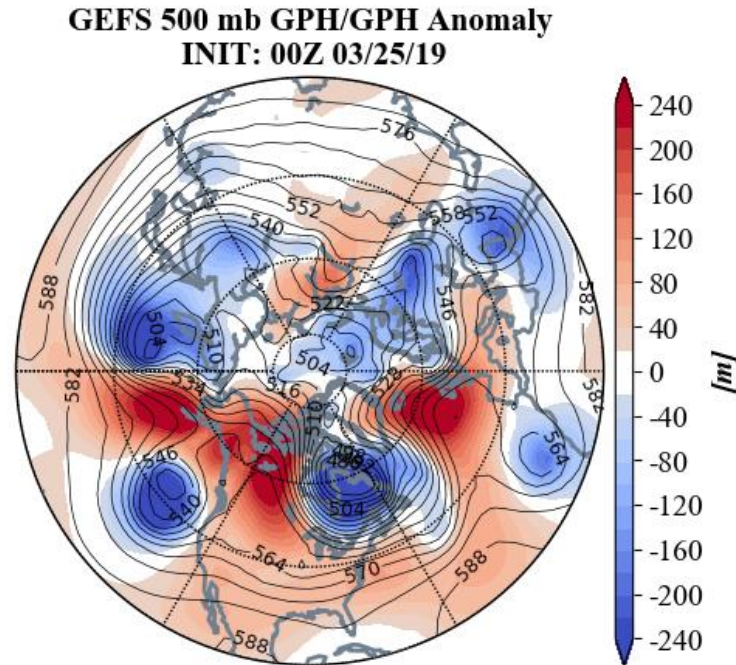


Figure 2. Observed 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) for 00Z 25 March 2019.

Ridging/positive geopotential height anomalies dominate western North with troughing/negative geopotential height anomalies in eastern North America but especially Eastern Canada (**Figure 2**). This pattern is predicted to result in normal to above normal temperatures for Alaska, Western Canada and the Western US with normal to below normal temperatures for Eastern Canada and the US East Coast (**Figure 3**).

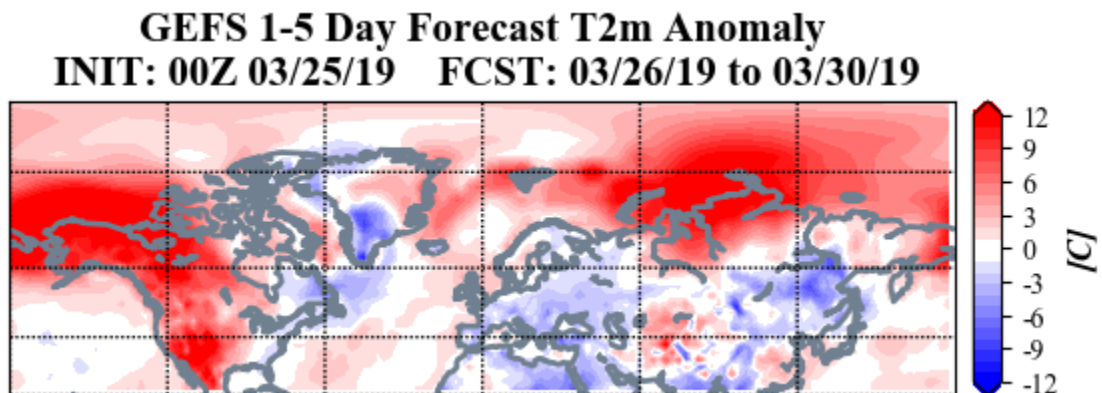


Figure 3. Forecasted surface temperature anomalies (°C; shading) from 26 – 30 March 2019. The forecast is from the 00Z 25 March 2019 GFS ensemble.

With the steady decline of snow cover across the NH, snowmelt will be widespread with the exception of new snowfall in parts of Turkey, Eastern Siberia, the Tibetan Plateau, Northeast Asia, Northern and Eastern Canada, the Northern US Rockies and the Central Plains of the US (Figure 4).

GEFS 1-5 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 03/25/19 FCST: 03/26/19 to 03/30/19

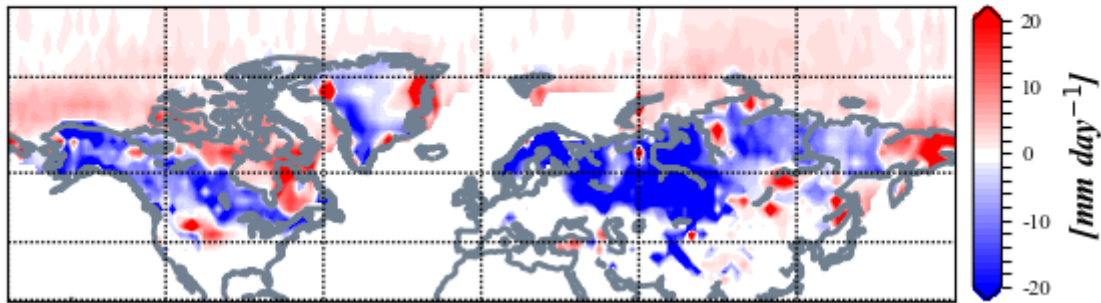


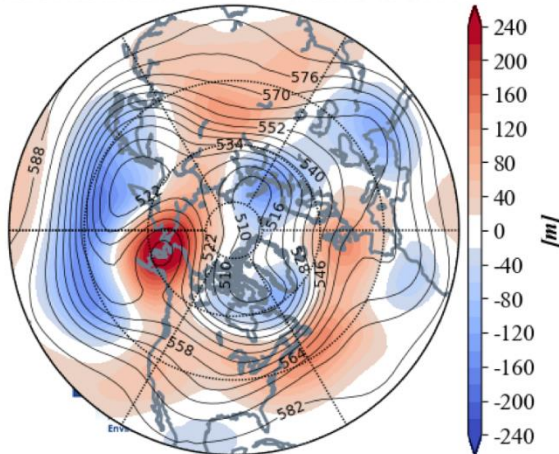
Figure 4. Forecasted snowfall anomalies (mm/day; shading) from 26 – 30 March 2019. The forecast is from the 00Z 25 March 2019 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to transition from positive to negative next week (Figure 1) as positive geopotential height anomalies become more widespread across the Eurasian side of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (Figure 5a). And with negative geopotential height anomalies across Greenland, the NAO will likely remain positive next week.

a) **GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly**
INIT: 00Z 03/25/19 FCST: 03/31/19 to 04/04/19



b) **GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly**
INIT: 00Z 03/25/19 FCST: 04/05/19 to 04/09/19

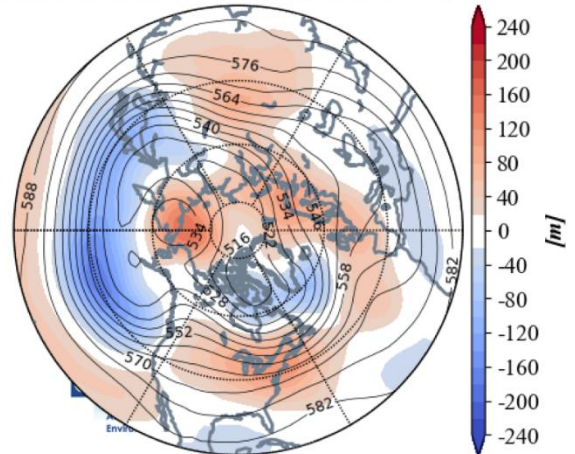


Figure 5. (a) Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 31 March – 4 April 2019. (b) Same as (a) except averaged from 5 – 9 April 2019. The forecasts are from the 25 March 2019 00z GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to become more focused near the British Isles allowing for weak northerly flow across much of Europe (**Figure 5a**). This pattern is predicted to result in widespread near seasonable temperatures including the UK with the best chance of normal to below temperatures across Southern and Eastern Europe (**Figure 6**). The overall pattern across Asia is predicted to persist with ridging/positive geopotential height anomalies anchored across Central Asia with troughing/negative geopotential height anomalies confined to Northeastern Asia and far Western Asia (**Figure 5a**). This is predicted to yield widespread normal to above normal temperatures for most of Asia with normal to above normal temperatures confined to Northeast Asia and Western Asia including the Middle East (**Figure 6**).

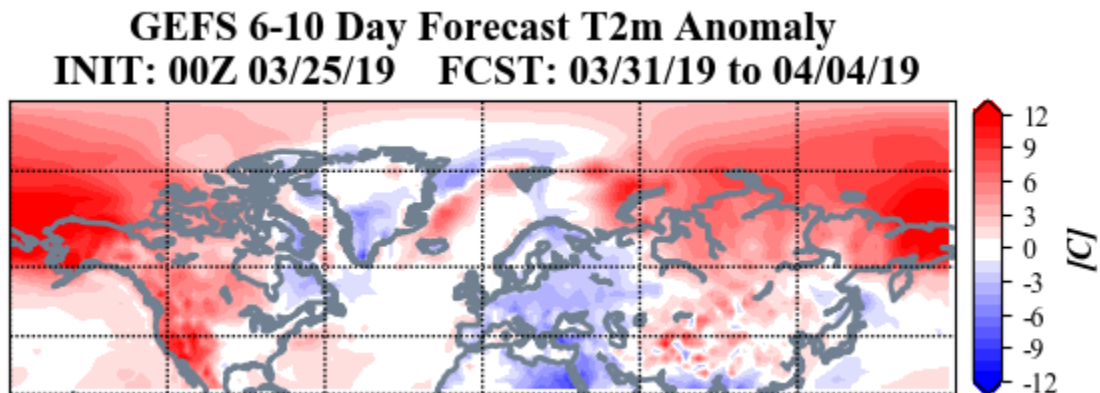


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 31 March – 4 April 2019. The forecasts are from the 00Z 25 March 2019 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to become more widespread across North America this period with troughing/negative geopotential height anomalies confined to Northern and Eastern Canada (**Figure 5a**). This pattern is predicted to bring normal to above normal temperatures across much of Alaska, Western Canada and the Western US with normal to below normal temperatures for Eastern Canada and close to seasonable temperatures for the Central and Eastern US (**Figure 6**). The European Center for Medium-range Weather Forecasting (ECMWF) is predicting cooler temperatures in the Central and Eastern US than the GFS and for now I favor the cooler ECMWF forecast.

GEFS 6-10 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 03/25/19 FCST: 03/31/19 to 04/04/19

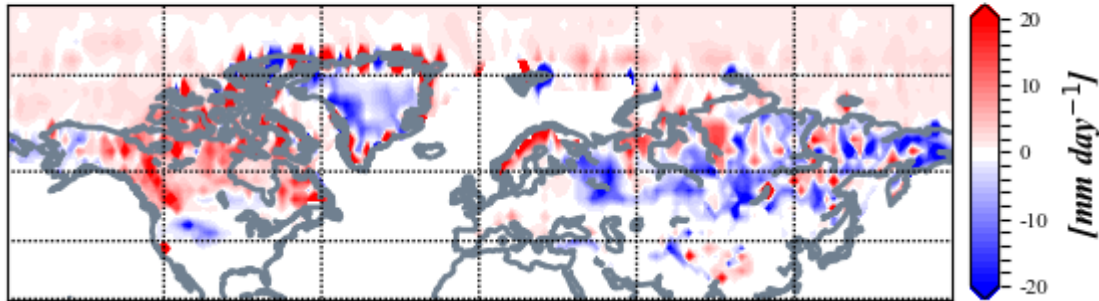


Figure 7. Forecasted snowfall anomalies (mm/day; shading) from 31 March – 4 April 2019. The forecasts are from the 00Z 25 March 2019 GFS ensemble.

Widespread snowmelt is predicted to continue with new snowfall confined to parts of Scandinavia, Siberia, the higher elevations of Southern Europe, the Tibetan Plateau, eastern Alaska and Canada (**Figure 7**).

11-15 day

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

Ridging/positive geopotential height anomalies are predicted to expand across Northern Europe this period with weak troughing/negative geopotential height anomalies confined to Southern Europe (**Figure 5b**). No strong anomalies are predicted with normal to above normal temperatures for Europe including the UK with normal to below normal temperatures for Southern Europe (**Figure 8**). Once again ridging/positive geopotential height anomalies are predicted to remain anchored across Central Asia with troughing/negative geopotential height anomalies confined to East Asia and southwestern Asia (**Figure 5b**). This pattern favors normal to above normal temperatures for much of Asia with normal to below normal temperatures for East Asia and southwestern Asia (**Figure 8**).

GEFS 11-15 Day Forecast T2m Anomaly
INIT: 00Z 03/25/19 FCST: 04/05/19 to 04/09/19

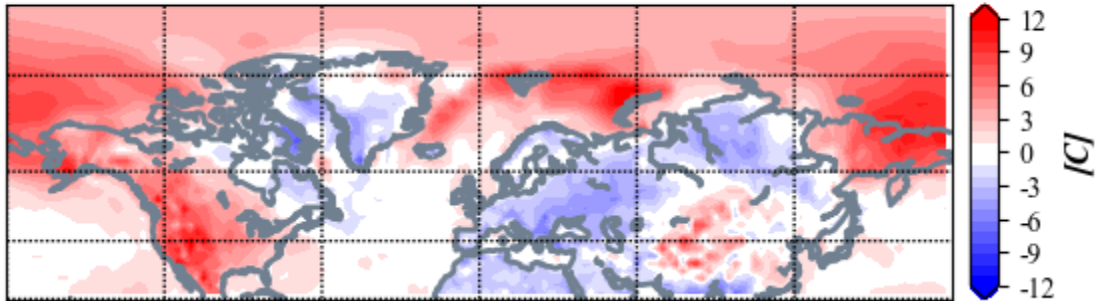


Figure 8. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 5 – 9 April 2019. The forecasts are from the 00Z 25 March 2019 GFS ensemble.

Ridging/negative geopotential height anomalies are predicted to persist across much of North America with troughing/negative geopotential height anomalies confined to Northern Canada (**Figure 5b**). This will favor normal to above normal temperatures across Alaska, Southern Canada and much of the US with normal to below normal temperatures for Northern and Eastern Canada (**Figure 8**). Again, the ECMWF is not as warm as the GFS with more seasonable temperatures in the Central and Eastern US and I am leaning towards the ECMWF solution over the GFS solution.

GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 03/25/19 FCST: 04/05/19 to 04/09/19

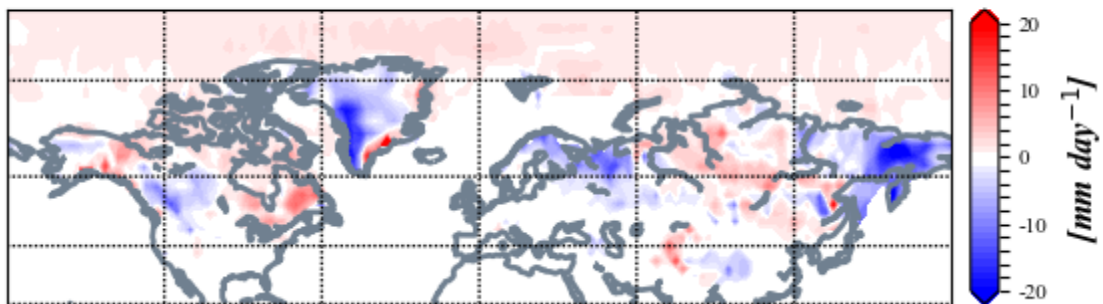


Figure 9. Forecasted snowfall anomalies (mm/day ; shading) from 5 – 9 April 2019. The forecasts are from the 00Z 25 March 2019 GFS ensemble.

Once again widespread snowmelt is predicted to continue with new snowfall confined to parts of Siberia, the Tibetan Plateau and Northern and Eastern Canada (**Figure 9**).

Longer Term

30-day

The latest plot of the polar cap geopotential heights (PCHs) currently shows normal to below normal PCHs in both the stratosphere and the lower troposphere with normal to above normal PCHs in the upper troposphere (**Figure 10**). The below normal PCHs in the stratosphere are consistent with a predicted positive stratospheric AO for the next two weeks (**Figure 1**) while the predicted below normal PCHs in the lower troposphere are consistent with a positive AO also predicted for next week (**Figure 1**). The positive PCHs in the upper troposphere are predicted to descend to the lower troposphere next week consistent with the predicted transition in the surface AO from positive to negative (**Figure 1**).

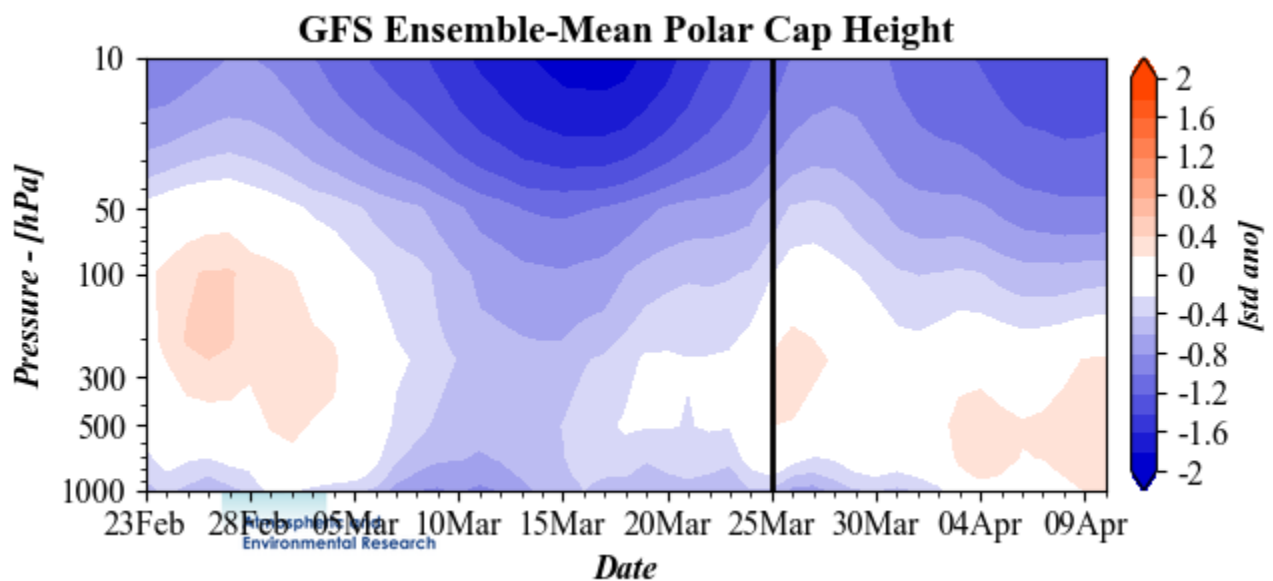


Figure 10. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 25 March 2019 GFS ensemble.

The negative PCHs throughout the stratosphere are a cumulative result of the lack of Wave Activity Flux (WAFz) or poleward heat transport since the sudden stratospheric warming (SSW) and a major mid-winter warming (MMW; where the zonal mean zonal wind reverses from westerly to easterly at 60°N and 10 hPa) back in early January. The negative PCHs in the stratosphere are likely to persist until at least next fall.

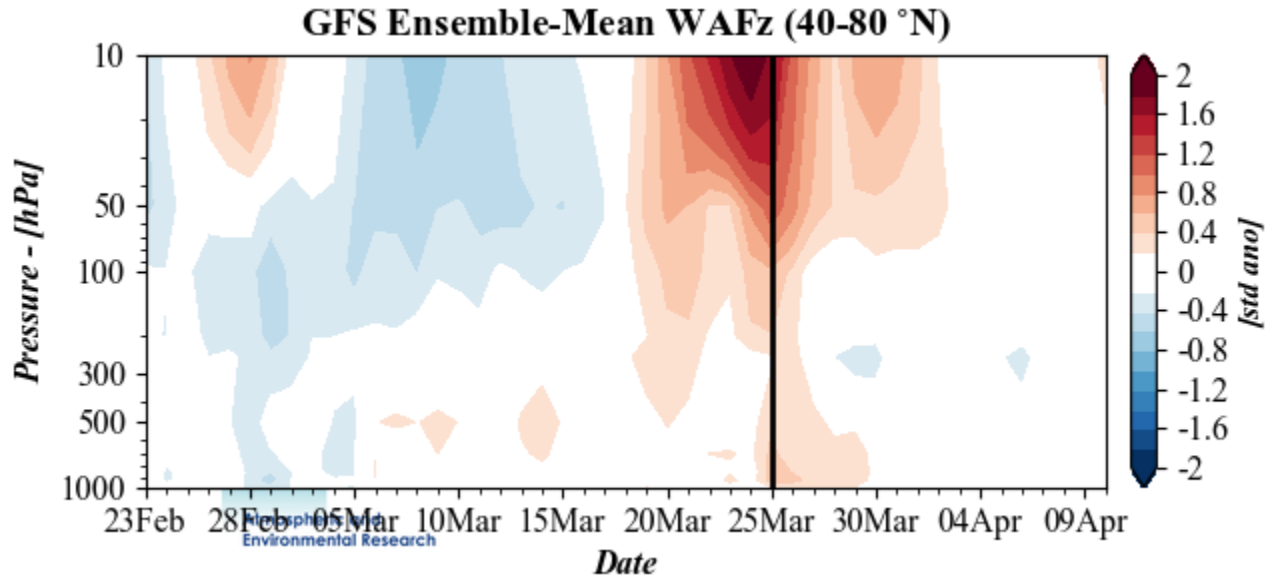
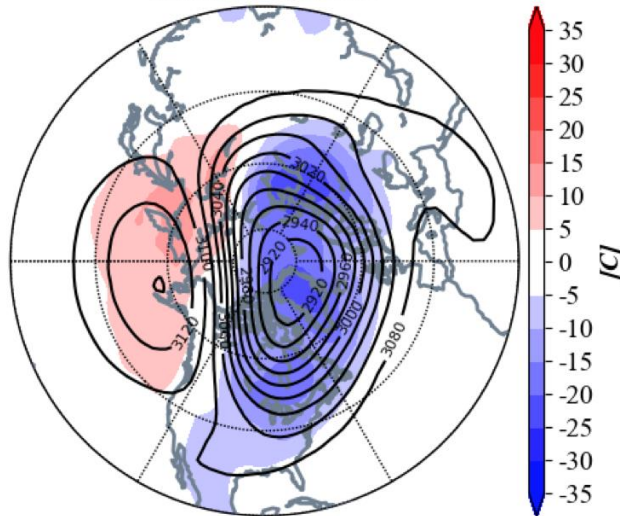


Figure 11. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 25 March 2019 GFS ensemble.

The plot of WAFz or poleward heat transport shows an ongoing pulse of WAFz for this week but near normal WAFz for next week (**Figure 11**). I would argue that the WAFz pulse last week and into this week is related to the strong ridging/positive geopotential height anomalies centered over Alaska not only in the stratosphere but also in the troposphere with troughing/negative geopotential height anomalies downstream across eastern North America and the relatively cold temperatures.

a) GEFS 10 mb GPH & T Anomaly
INIT: 00Z 03/25/19



b) GEFS 11-15 Day Forecast 10 mb GPH & T Anomaly
INIT: 00Z 03/25/19 FCST: 04/05/19 to 04/09/19

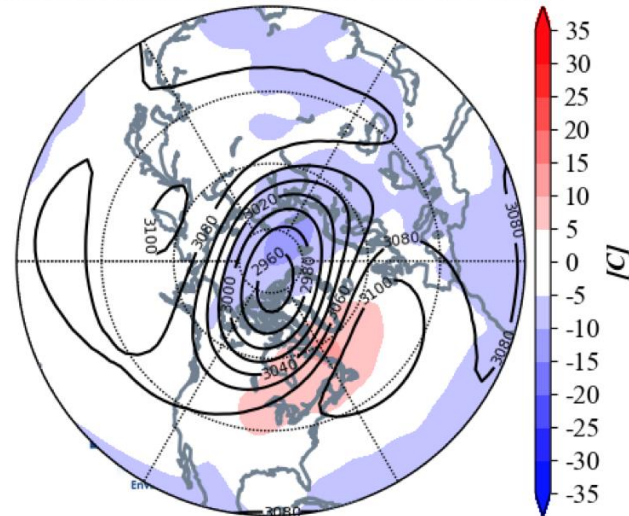


Figure 12. (a) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for 25 March 2019. **(b)** Same as **(a)** except forecasted averaged from 5 – 9 April 2019. The forecasts are from the 00Z 25 March 2019 GFS operational model.

The stratospheric PV is currently centered close to northern Greenland and is predicted to remain there over the next two weeks (**Figure 12**). The stratospheric PV is predicted to weaken over the next two weeks in part due to the strong WAFz pulse and also the increasing solar radiation. Eventually the increasing solar radiation will lead to the collapse of the stratospheric PV known as the Final Warming.

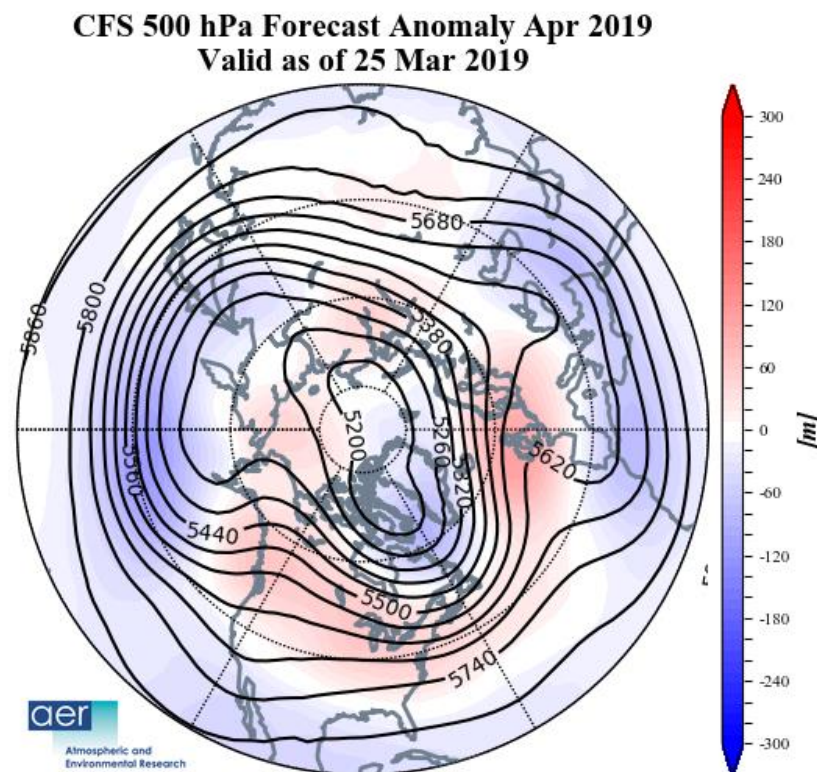


Figure 13. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for April 2019. The forecasts are from the 25 March 2019 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 13**) and the surface temperatures (**Figure 14**) forecast for April 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, Central Asia, the Gulf of Alaska and Western Canada with troughs in the Western US, Eastern Canada, the Mediterranean and East Asia (**Figure 13**). This pattern favors cold temperatures for Southern Europe, North Africa, the Middle East, East Asia and Eastern Canada and the

Northeastern US with relatively mild temperatures for Northern Europe, Central Asia and western North America (**Figure 14**).

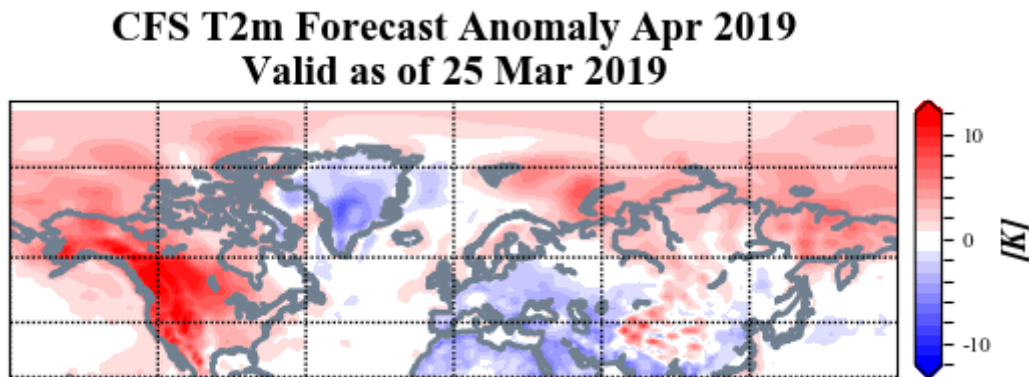


Figure 14. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for April 2019. The forecasts are from the 25 March 2019 CFS.

Surface Boundary Conditions

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies remain warm and NOAA has declared the return of El Niño conditions (**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 24 Mar 2019

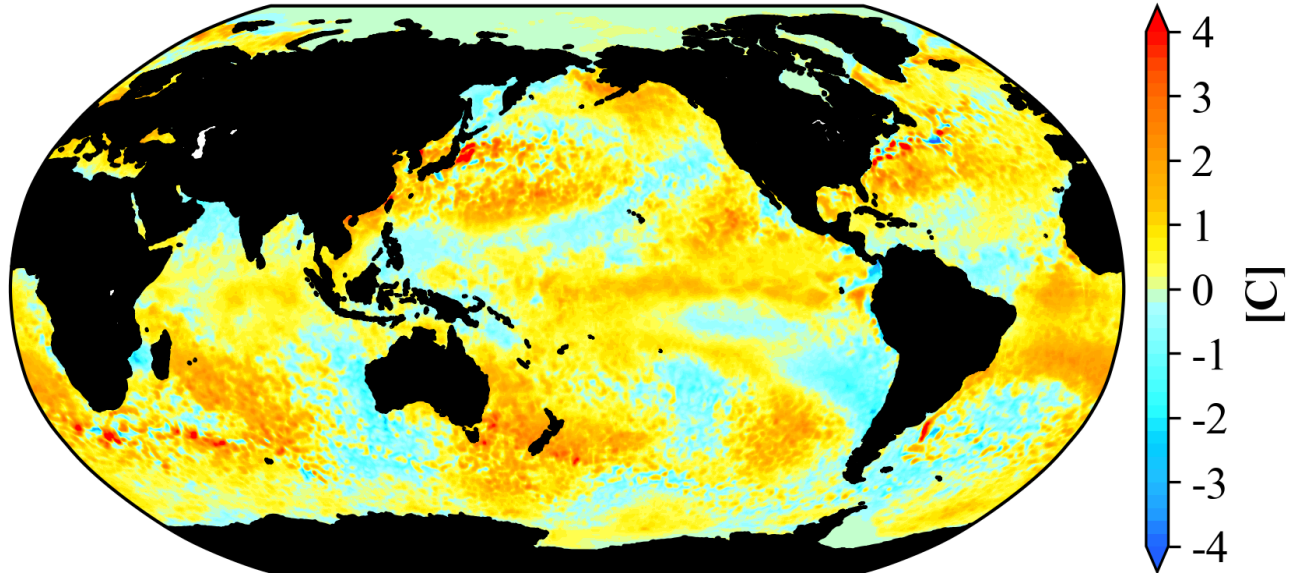


Figure 16. The latest weekly-mean global SST anomalies (ending 24 March 2019). Data from NOAA OI High-Resolution dataset.

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 14**). And the forecasts are for no phase of the MJO to be favored over the next two weeks. Little influence on North American weather is expected from the MJO in the near term.

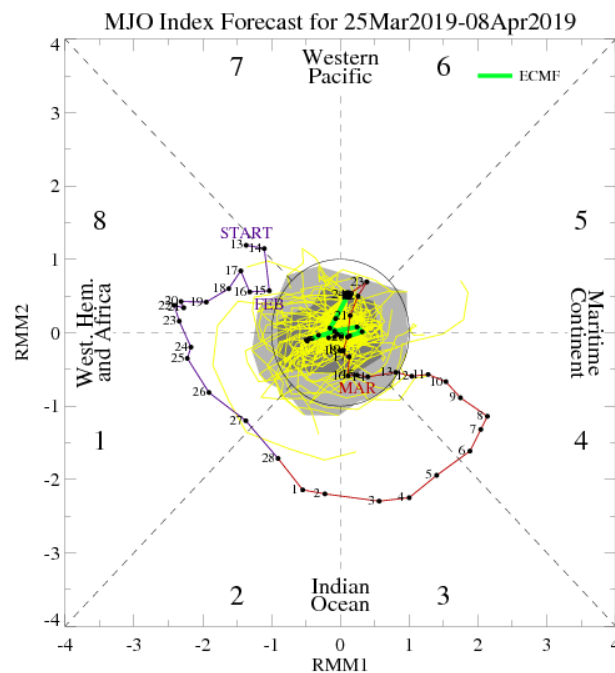


Figure 17. Past and forecast values of the MJO index. Forecast values from the 00Z 25 March 2019 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>