

Arctic Oscillation and Polar Vortex Analysis and Forecasts

March 23, 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.

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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 but then return to neutral over the weekend and next week.
- The current positive AO is reflective of negative pressure/geopotential height anomalies in the Arctic with mostly positive pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is also positive with negative pressure/geopotential height anomalies spread across Greenland and Iceland; and the NAO is predicted to remain positive this week

before returning to neutral or possibly negative as height anomalies are predicted to finally turn positive across Greenland next week.

- The predicted general circulation pattern over Europe the next two weeks is troughing/negative geopotential height anomalies across Southern Europe with ridging/positive geopotential height anomalies across Northern Europe. This pattern has allowed colder temperatures to filter across Central and Southern Europe including the United Kingdom (UK) with normal to above normal temperatures for Northern Europe.
- The predicted general pattern for Asia over the next two weeks is ridging/positive geopotential height anomalies on the western and eastern edge of Asia with troughing/negative pressure/geopotential height anomalies in the interior of Asia. This pattern favors normal to above normal temperatures across western and eastern Asia but especially Northwestern and Northeastern Asia with normal to below normal temperatures in the interior of Asia.
- The predicted pattern for North America this week is ridging/positive geopotential height anomalies in Alaska and eastern North America with normal to above normal temperatures and troughing/negative geopotential height anomalies with normal to below normal temperatures in western North America. Next week the troughing/negative geopotential height anomalies with normal to below normal temperatures will retreat to Alaska and Northwest Canada with ridging/positive geopotential height anomalies and normal above normal temperatures elsewhere across North America. However, in early April renewed troughing with relatively cool temperatures are predicted in the Southeastern US.
- In the Impacts section I discuss the Northern Hemisphere (NH) pattern change.

Impacts

The weather pattern across the Northern Hemisphere (NH) continues to evolve away from the dominant weather pattern of the winter, especially those associated with the positive AO. High pressure/ridging across Northern Europe has facilitated cold air to first become entrenched in Siberia that has spread out mostly to the west towards Europe. Similarly, high pressure/ridging near Alaska has helped to deliver some colder temperatures to Canada and even to the Northern US. The colder weather to Eurasia could potentially continue well into April as long as blocking/high pressure remains in place anywhere between Greenland and the Barents-Kara Seas. In contrast the cold weather across Canada and the US is looking more short-lived as low geopotential heights/troughing is predicted to return to Alaska and this could setup a relatively warm month of April for large parts of Canada and the US, especially east of the Rockies.

Though while there has been a relaxation in the positive AO, the strong polar vortex (PV) seems to be more resilient. The PV is slowly weakening heading into the Final Warming (where the PV disappears until the fall) but remains climatologically strong to possibly very strong. Though the weakening seems to be sufficient to allow the AO to drift

towards neutral. It does seem that the PV will break down later than usual this spring. A rare ozone hole does seem to be already developing over the Arctic this March (see **Figure i**) due to the very cold temperatures:

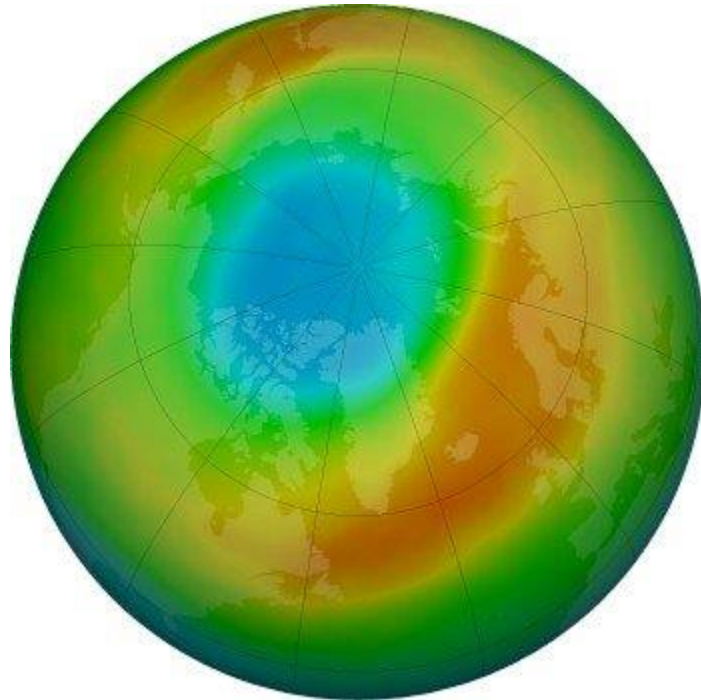


Figure i. Total ozone March 2020
from <https://ozonewatch.gsfc.nasa.gov/monthly/NH.html>.

There could be some support for colder weather across the NH if a dynamic Final Warming occurs. Development of high pressure in the northern North Atlantic is conducive for driving wave energy into the PV, though so far there are no signs of strong wave driving into the PV. Across North America signs are there for a warm spring, especially if snow melt accelerates. Across Eurasia widespread warming might be somewhat more delayed but I expect there as well a relatively quick warm up sometime in April.

1-5 day

The AO is currently positive (**Figure 1**) with negative geopotential height anomalies across the Arctic and mostly positive geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with mostly negative geopotential height anomalies across Greenland and Iceland (**Figure 2**), the NAO is positive as well.

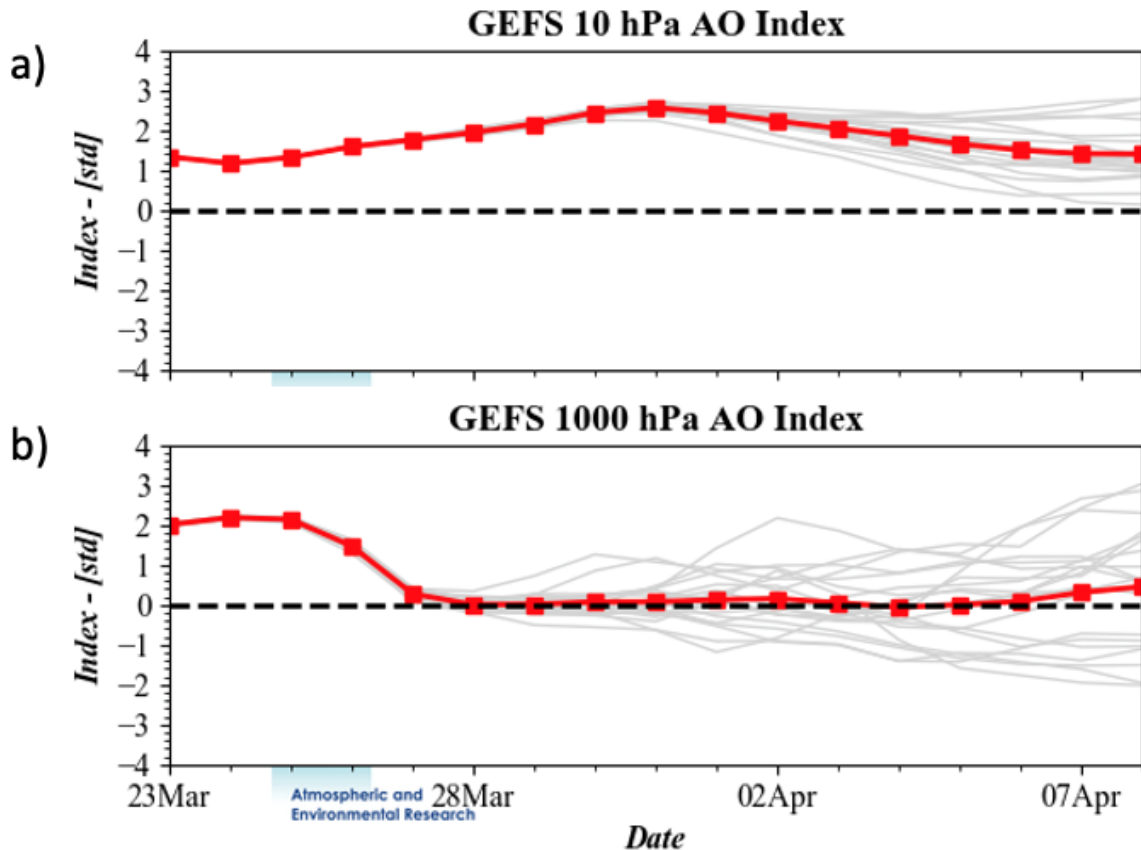


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 23 March 2020 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 23 March 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies with normal to above normal temperatures are predicted to spread across Northern Europe and troughing/negative geopotential height anomalies with normal to below normal temperatures across Central and Southern Europe including the UK (**Figures 2 and 3**). Across Asia, ridging/positive geopotential height anomalies focused across Northwestern and Northeastern Asia bookending troughing/negative geopotential height anomalies in the interior of the continent are predicted for this week (**Figure 2**). This pattern favors normal to above normal temperatures across Western and Eastern Asia with normal to below normal temperatures in Central Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 03/23/20 FCST: 03/24/20 to 03/28/20

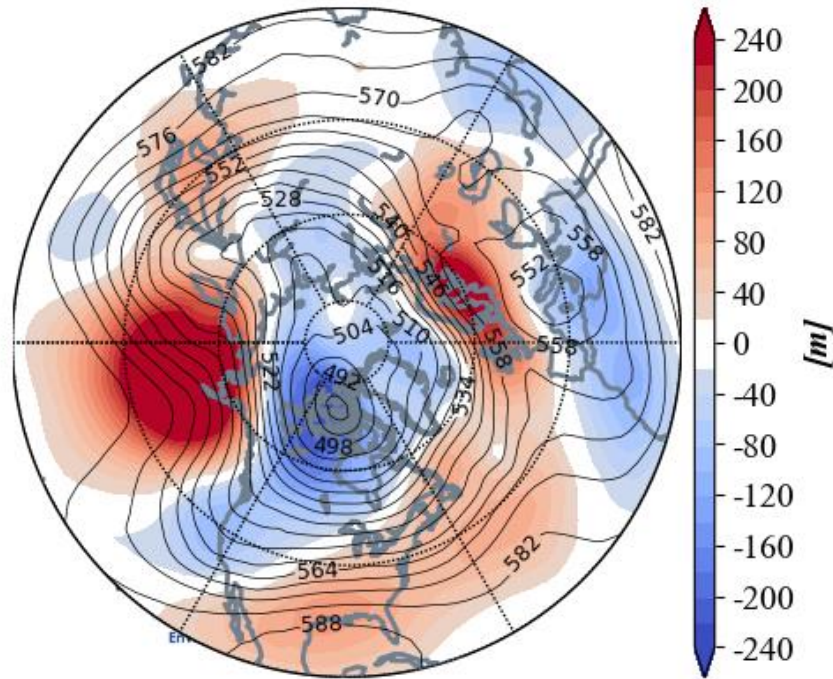


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 24 – 28 March 2020. The forecasts are from the 00z 23 March 2020 GFS ensemble.

This week, ridging/positive geopotential height anomalies are predicted for Alaska and eastern North America with troughing/negative geopotential height anomalies in western North America (**Figure 2**). This pattern is predicted to bring normal to above normal temperatures across Alaska, Eastern Canada and the Eastern US with normal to below normal temperatures across Western Canada and much of the Western US (**Figure 3**).

GEFS 1-5 Day Forecast T2m Anomaly
INIT: 00Z 03/23/20 FCST: 03/24/20 to 03/28/20

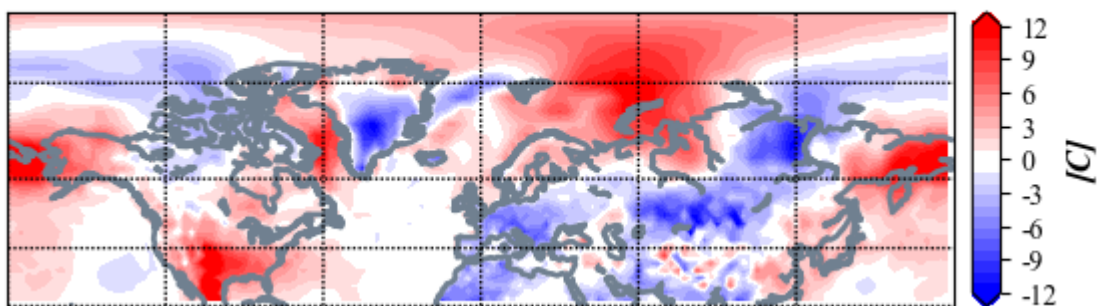


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 24 – 28 March 2020. The forecast is from the 00Z 23 March 2020 GFS ensemble.

Trouthing and/or cold temperatures are predicted to bring new snowfall to parts of Northern Asia, Northern and Eastern Canada and the US Northern Rockies (**Figure 4**). Warm temperatures are predicted to result in snowmelt for large swaths of Northern Europe, Northwestern Asia and Southeastern Canada (**Figure 4**).

GEFS 1-5 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 03/23/20 FCST: 03/24/20 to 03/28/20

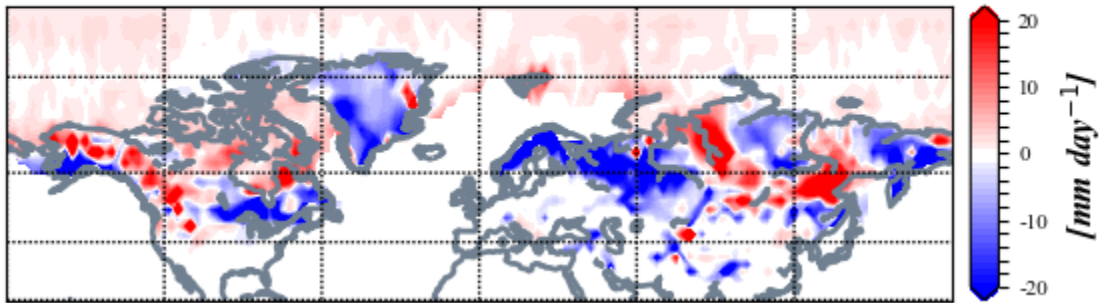


Figure 4. Forecasted snowdepth anomalies (mm/day ; shading) from 24 – 28 March 2020. The forecast is from the 00Z 23 March 2020 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to return to neutral (**Figure 1**) as positive geopotential height anomalies spread 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 return to neutral as well.

**GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 03/23/20 FCST: 03/29/20 to 04/02/20**

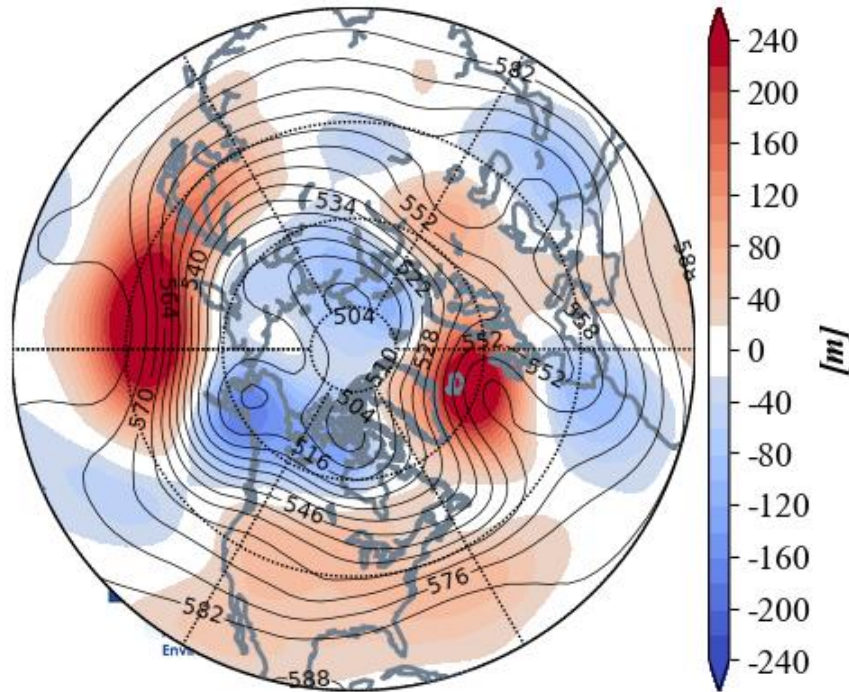


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 29 March – 2 April 2020. The forecasts are from the 00z 23 March 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to stretch across Northern and Eastern Europe forcing troughing/negative geopotential height anomalies to the south across Southern and Western Europe this period (**Figure 5**). This pattern will favor normal to above normal temperatures for much of Northern and Eastern Europe with normal to below normal temperatures for Western and Southern Europe including the UK (**Figure 6**). Troughing/negative geopotential height anomalies in Central Asia will extend to the southwest into Southwestern Asia with ridging/positive geopotential height anomalies in Northwestern and Eastern Asia (**Figure 5**). This is predicted to yield normal to below normal temperatures for most of Central and Southwestern Asia with normal to above temperatures in Northwestern and Eastern Asia (**Figure 6**).

GEFS 6-10 Day Forecast T2m Anomaly
INIT: 00Z 03/23/20 FCST: 03/29/20 to 04/02/20

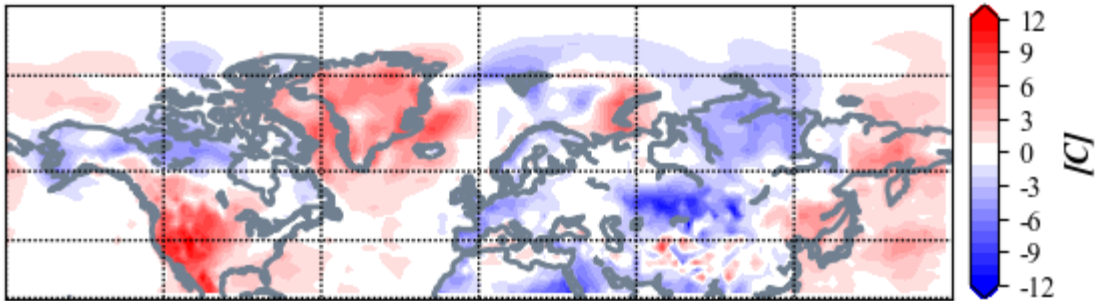


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 29 March – 2 April 2020. The forecasts are from the 00Z 23 March 2020 GFS ensemble.

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

GEFS 6-10 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 03/23/20 FCST: 03/29/20 to 04/02/20

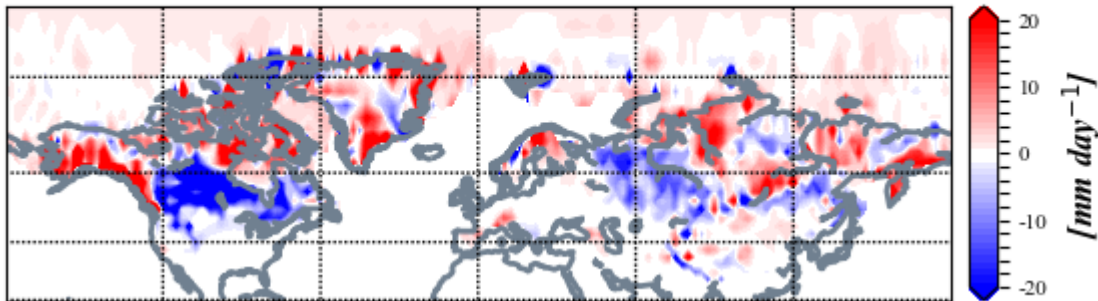


Figure 7. Forecasted snowdepth changes (mm/day ; shading) from 29 March – 2 April 2020. The forecasts are from the 00Z 23 March 2020 GFS ensemble.

Troughing and/or cold temperatures will support the potential for new snowfall in northern Scandinavia, the Alps, the Pyrenees, Northern Asia, Alaska, Northern and Western Canada (**Figure 7**). Snowmelt is predicted in Northwestern Asia, Southern and Eastern Canada and the US Northern Rockies (**Figure 7**).

11-15 day

With mostly negative geopotential height anomalies predicted for the North Pacific side of the Arctic but positive geopotential height anomalies across the North Atlantic side of the Arctic (**Figure 8**), the AO is predicted to be neutral this period (**Figure 1**). With predicted weak positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is likely to remain neutral as well or possibly even negative.

GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 03/23/20 FCST: 04/03/20 to 04/07/20

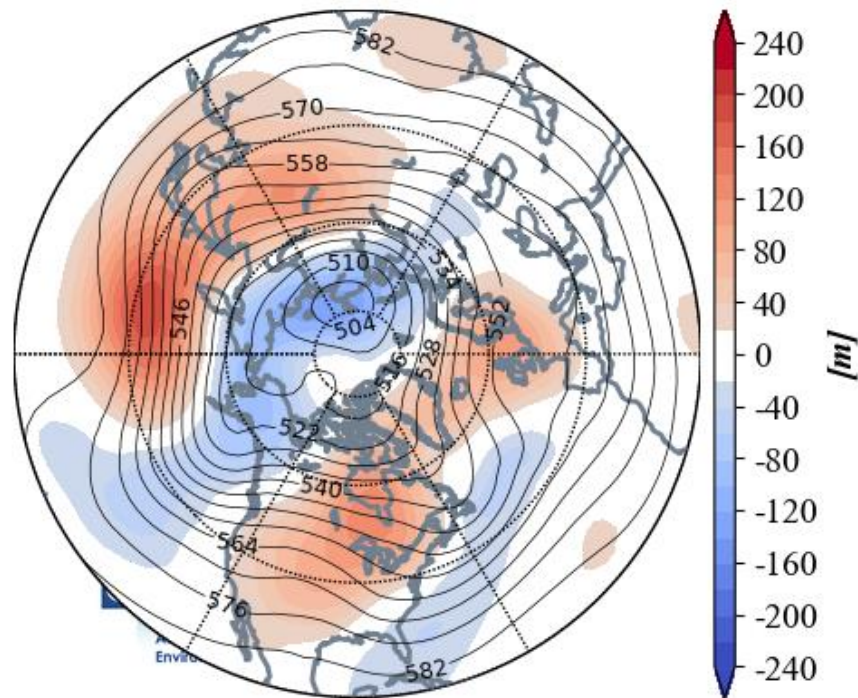


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 3 – 7 April 2020. The forecasts are from the 00z 23 March 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted across Northern and Western Europe with troughing/negative geopotential height anomalies across Southern and Eastern Europe this period (**Figures 8**). The forecast is for near seasonable temperatures including the UK with the best chance of normal to above normal temperatures in Southeastern Europe this period (**Figures 9**).

Troughing/negative geopotential height anomalies across Northern and Western Asia with ridging/positive geopotential height anomalies across Southern and Eastern Asia this period (**Figure 8**). This pattern favors normal to below normal temperatures for Siberia and Western Asia with normal to above normal temperatures for Southern and Eastern Asia (**Figure 9**).

GEFS 11-15 Day Forecast T2m Anomaly
INIT: 00Z 03/23/20 FCST: 04/03/20 to 04/07/20

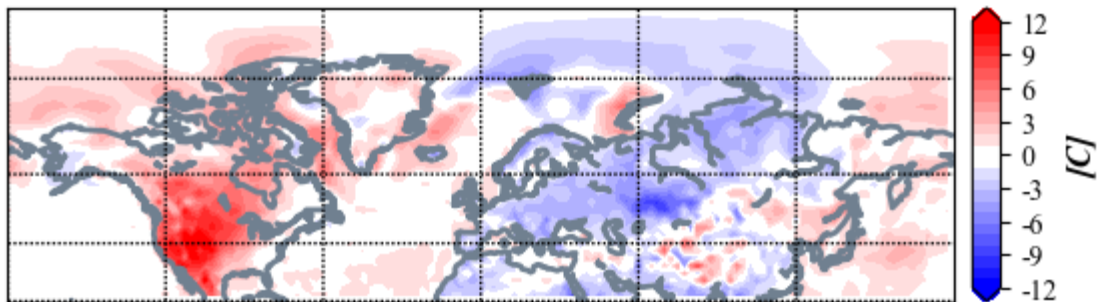


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 3 – 7 April 2020. The forecasts are from the 00z 23 March 2020 GFS ensemble.

Ridging/positive geopotential height anomalies is predicted to become more widespread across North America this period with troughing/negative geopotential height anomalies confined to Alaska, Northwestern Canada and the Southeastern US (**Figure 8**). This pattern is predicted to favor normal to above normal temperatures across most of Canada and the US with normal to below normal temperatures for Alaska, Northwest Canada and the Southeastern US (**Figure 9**).

GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 03/23/20 FCST: 04/03/20 to 04/07/20

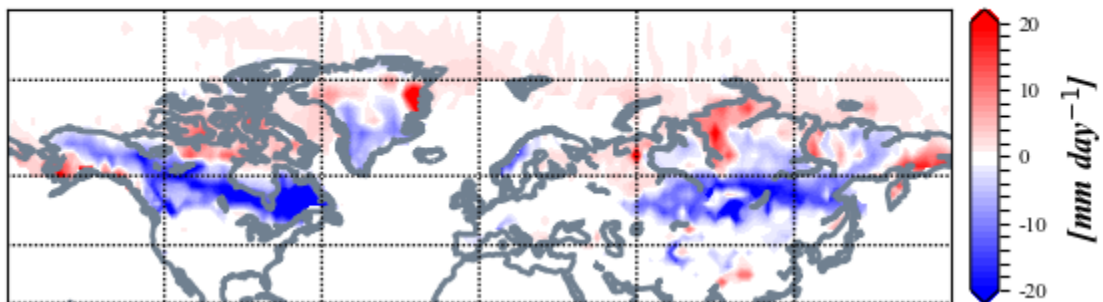


Figure 10. Forecasted snow depth changes (mm/day ; shading) from 3 – 7 April 2020. The forecasts are from the 00z 23 March 2020 GFS ensemble.

Troughing and/or cold temperatures could support new snowfall across parts of Northern Asia, the Tibetan Plateau, Alaska and the Canada archipelagos (**Figure 10**). Snowmelt is predicted for Central Asia, and much of 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 both the troposphere and stratosphere with the largest negative departures in the lower stratosphere (**Figure 11**). The predicted cold tropospheric PCHs are consistent with a predicted positive surface AO (**Figure 1**). Though predicted downward propagation of cold PCHs from the strong stratospheric PV to the surface is predicted to continue, this plot is suggestive that any downward propagation will be weak allowing the AO to return to neutral.

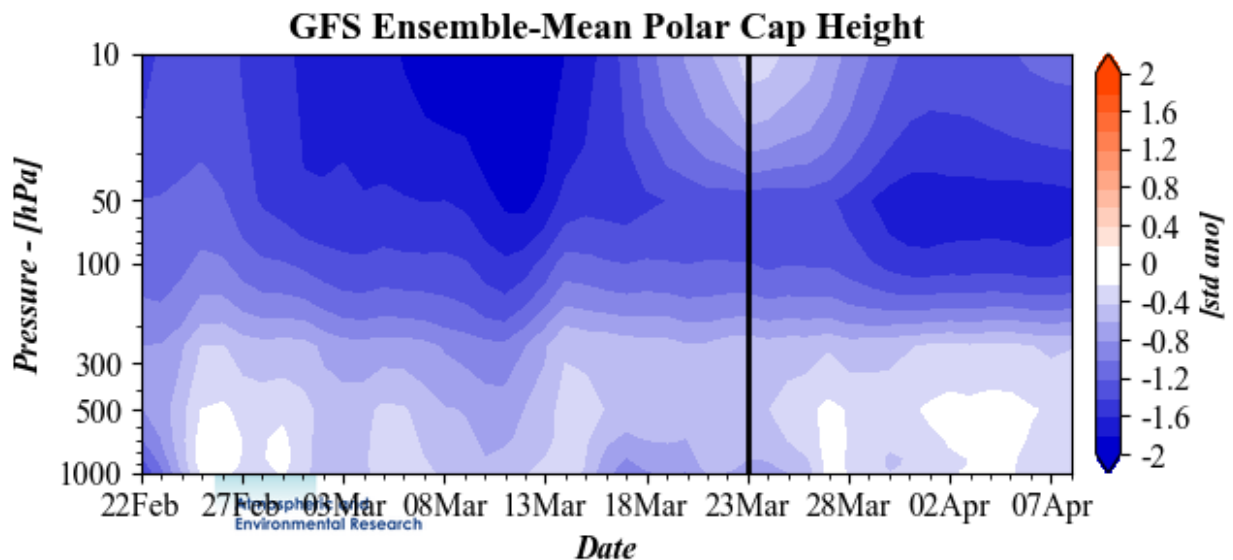


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 23 March 2020 GFS ensemble.

The plot of vertical Wave Activity Flux (WAFz) or poleward heat transport forecast shows only weak negative anomalies this week and weak positive anomalies for next week (**Figure 12**). Though positive height anomalies predicted for next week across Northern Europe (**Figures 5 and 8**) could eventually lead to stronger positive WAFz anomalies.

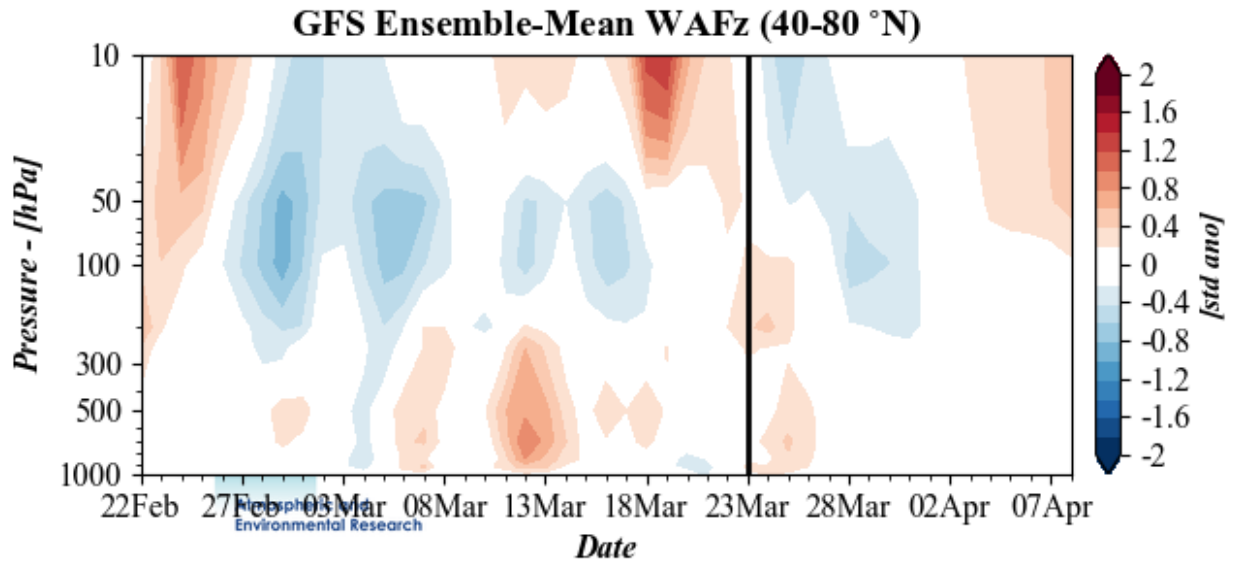


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 23 March 2020 GFS ensemble.

The stratospheric AO is currently positive (**Figure 1**) consistent with a relatively strong PV (**Figure 1**). The GFS predicts some relatively minor disrupting of the PV through early April with changes in the position of the PV and ongoing polar stratospheric warming though the stratospheric AO is predicted to remain positive to strongly positive over the next two weeks.

Currently the stratospheric PV is centered over the Canadian archipelagos (**Figure 13**) with the largest negative temperature departures in the polar stratosphere located over western North America (**Figure 13**) where temperatures are predicted to be coldest this week across North America. The PV is elongated along an axis from Siberia to Canada in part due to weak ridging centered on Scandinavia and Eastern Siberia. This is the same locations of ridging/high heights in the mid-troposphere.

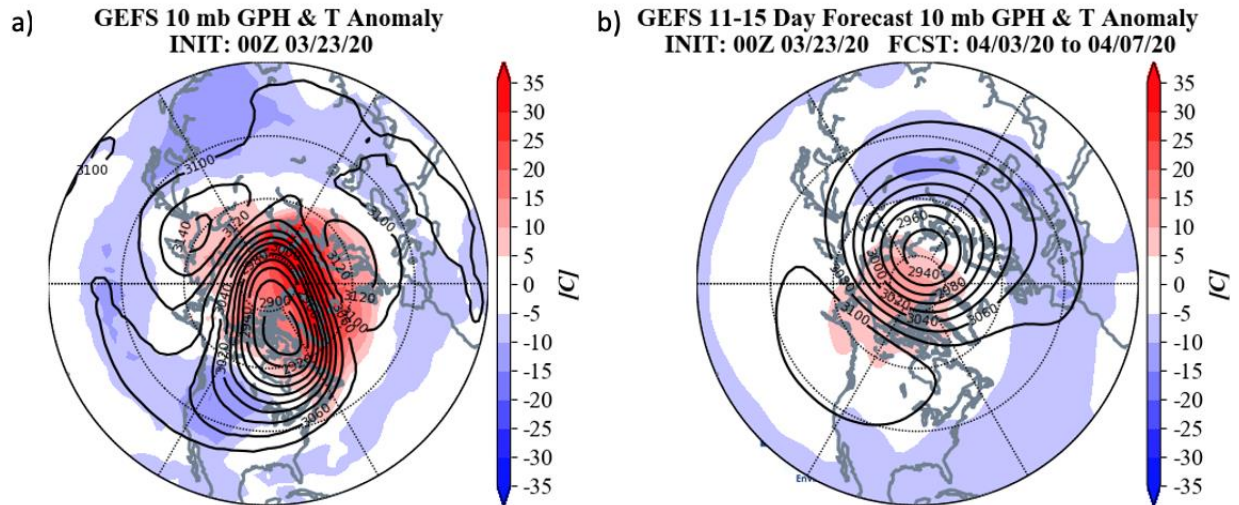


Figure 13. (a) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere at 00Z 23 March 2020 . (b) Same as (a) except forecasted averaged from 3 – 7 April 2020. The forecasts are from the 00Z 23 March 2020 GFS operational model.

Over the next two weeks, the PV center is predicted to drift from Canada and Greenland towards Siberia and slowly weaken (**Figure 13**). Warming currently spread across the polar stratosphere is predicted to weaken (**Figure 13**) with only weak positive WAFz predicted for next week.

CFS 500 hPa Forecast Anomaly Apr 2020
Valid as of 23 Mar 2020

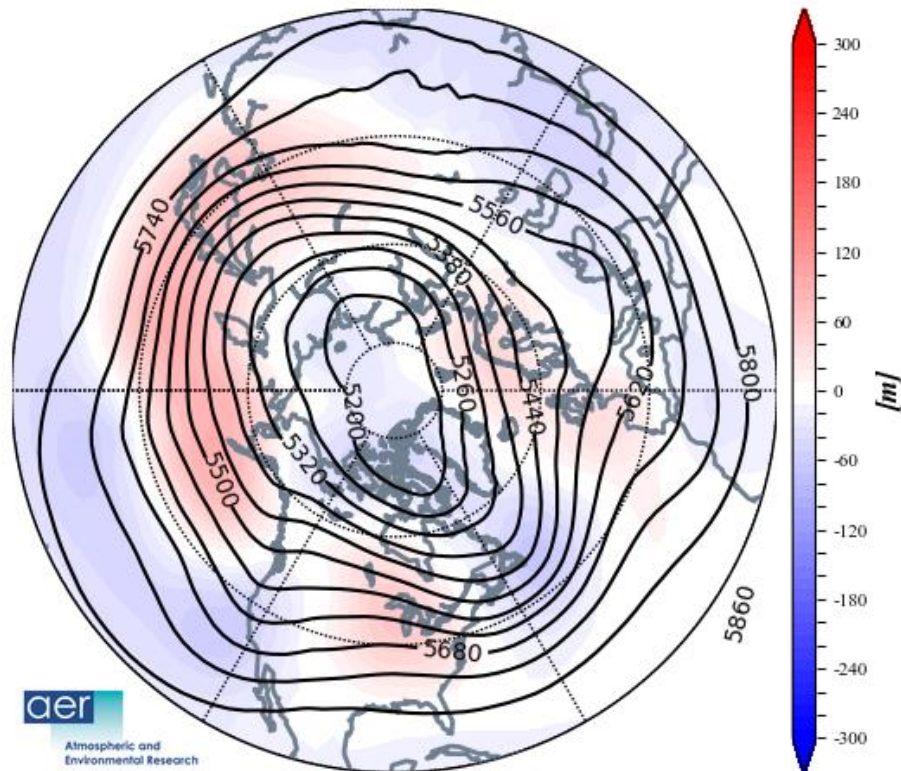


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for April 2020. The forecasts are from the 00Z 23 March 2020 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) forecast for April from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging across Northern Europe, from East Asia across the Dateline and into the Gulf of Alaska and central North America with troughing in Eastern and Southern Europe into the Middle East and Western Asia, Eastern Siberia, Eastern Canada and the Southwestern US (**Figure 14**). This pattern favors relatively mild temperatures for Northern Europe, much of Northern and Eastern Asia and western North America with seasonable to relatively cool temperatures for Central and Southern Europe, Western and Southern Asia, Southeastern Canada and the Northeastern US (**Figure 15**).

CFS T2m Forecast Anomaly Apr 2020 Valid as of 23 Mar 2020

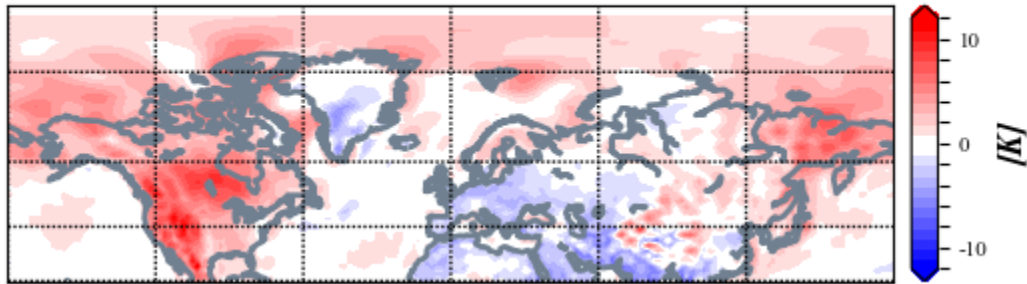


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for April 2020. The forecasts are from the 00Z 23 March 2020 CFS.

Surface Boundary Conditions

Arctic sea ice extent

The positive AO has been conducive to sea ice growth for much of the winter and Arctic sea ice extent remains higher than recent winters. We are likely very close to the seasonal maximum extent in Arctic sea ice and it should start to retreat and there are signs that is happening already. Overall sea ice extent is near normal though negative sea ice anomalies are showing up in the Bering Sea, still I don't expect a collapse similar to what happened last spring.

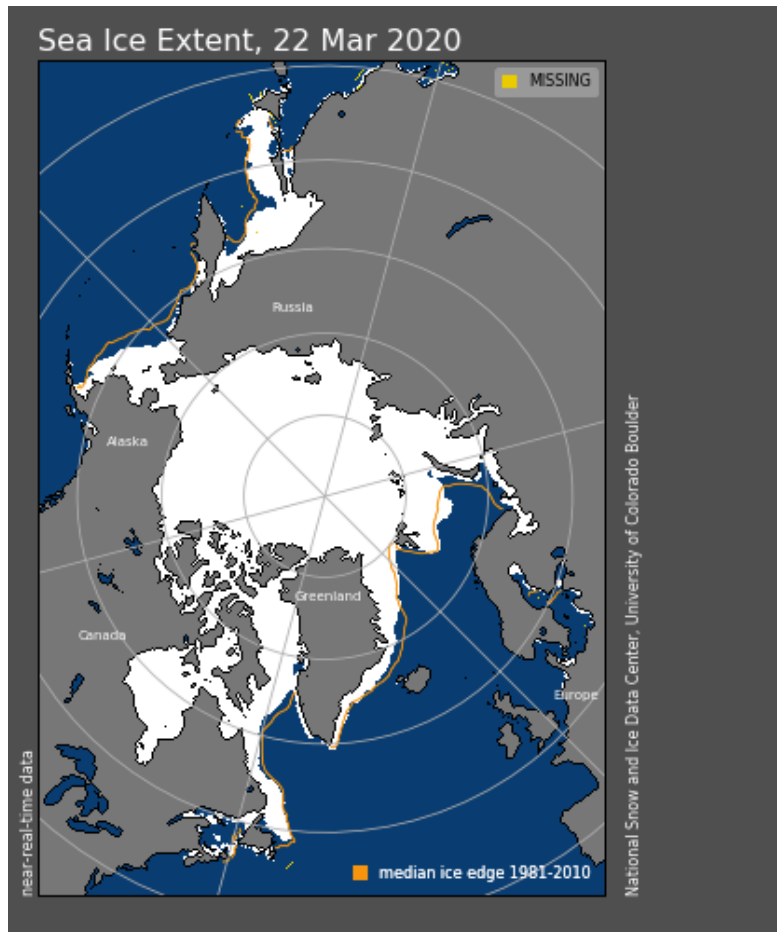


Figure 16. a) Observed Arctic sea ice extent on 22 March 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010.

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 22 Mar 2020

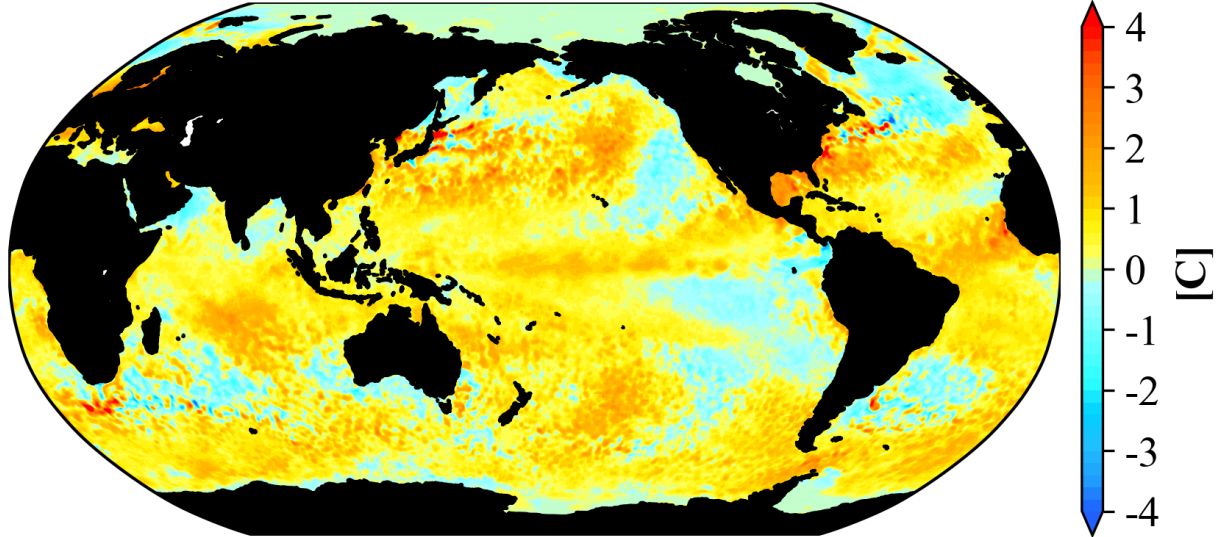


Figure 17. The latest weekly-mean global SST anomalies (ending 15 March 2020). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase three (**Figure 18**). The forecasts are for the MJO to weaken where no phase is favored. MJO phase three favors troughing throughout North America. MJO does not seem to be contributing to the weather patterns across North America in the short term.

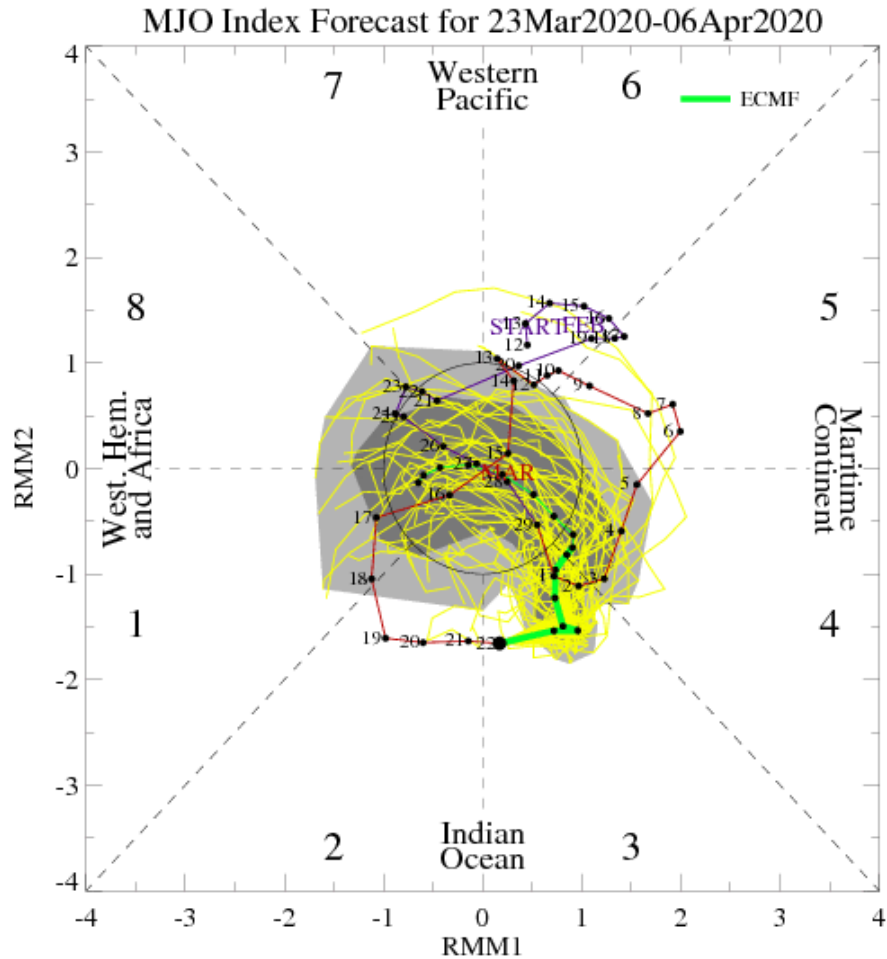


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 22 March 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>

Northern Hemisphere Snow Cover

Snow cover declined across Eurasia and remains near decadal lows. Snow cover extent is clearly in its seasonal decline. Relative low snow cover extent favors above normal temperatures.

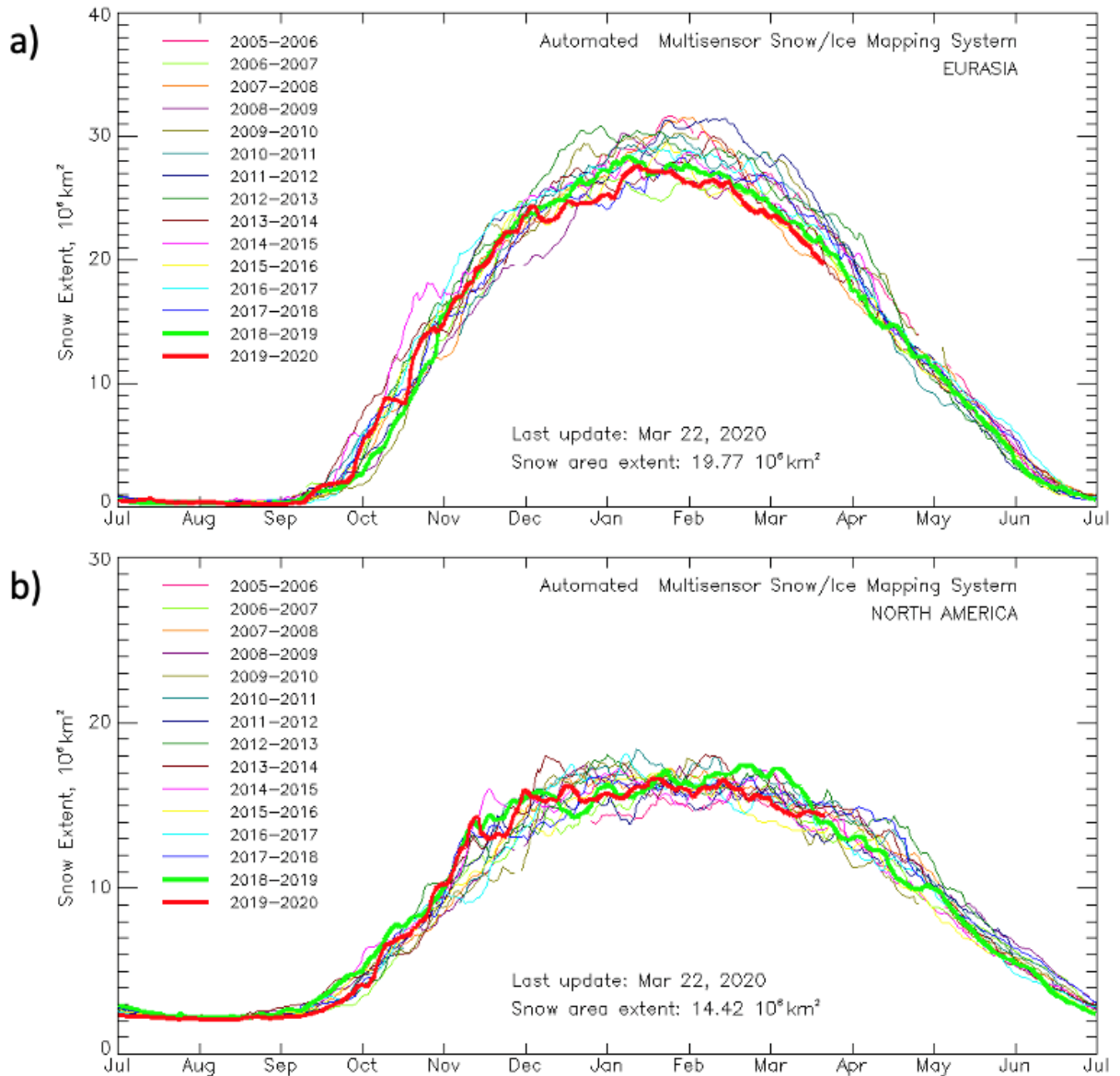


Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 22 March 2020 (not updated). Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover stayed nearly steady this week and remains near decadal means. Regardless snow cover extent is in its seasonal decline. If the melting accelerates this could contribute to a warm spring.