

Arctic Oscillation and Polar Vortex Analysis and Forecasts

March 30, 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 neutral and is predicted to remain near neutral this week but then return to positive values next week.
- The current neutral AO is reflective of mixed pressure/geopotential height anomalies in the 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 remain negative this week

before returning to neutral as height anomalies are predicted to become weak and mixed across Greenland next week.

- The predicted general circulation pattern over Europe including the United Kingdom (UK) is general troughing/negative geopotential height anomalies with normal to below normal temperatures this week followed by increasing ridging/positive geopotential height anomalies and warming temperatures from west to east starting this weekend.
- The predicted general pattern for Asia over the next two weeks is troughing/negative pressure/geopotential height anomalies in Western and far Northern Asia helping to anchor ridging/positive geopotential height anomalies in Central and extending into Eastern Asia. This pattern favors normal to below normal temperatures across Western Asia with normal to above normal temperatures in Central and Eastern Asia.
- The predicted pattern for North America this week is ridging/positive geopotential height anomalies with normal to above normal temperatures stretching from Greenland to Alaska forcing troughing/negative geopotential height anomalies with normal to below normal temperatures in western North America and along the United States (US) Eastern Seaboard. Next week troughing/negative geopotential height anomalies with normal to below normal temperatures will become more widespread across western North America with ridging/positive geopotential height anomalies and normal to above normal temperatures across eastern North America.
- In the Impacts section I discuss the Northern Hemisphere (NH) pattern and how it is reminiscent of recent summer patterns.

Impacts

This is the last blog in the winter format. There will be no blog next week and thereafter the blog will be published every two weeks in the spring format until next fall.

We have seen a temporary change in the Northern Hemisphere weather pattern with the AO slightly negative and the NAO more impressively negative for the first time since December. This pattern change is accompanied by relatively cold temperatures across Europe and Western Asia, a stark change from the record warmth experienced in this region most of the winter. Also, cold temperatures are filtering into New England and will spread throughout much of the Eastern US this week. Though much more impressive cold air is pooling in Western Canada, a sign the pattern of relatively cold temperatures in the Eastern US is unlikely to last for long.

However, this pattern change is only temporary and at least the AO is predicted to return solidly positive by next week. Also, the stratospheric polar vortex (PV), though clearly weakening is still quite strong from a climatological standpoint for this time of year. And a delayed Final Warming (where the PV disappears until the fall) seems all but inevitable. If the high pressure in the northern North Atlantic would persist longer it

might have been sufficient to drive wave energy into the stratospheric PV, enough so to bring its demise but that is not looking likely. Instead the PV will only slowly weaken in large part due to increasing solar radiation until it finally disappears.

The predicted weather pattern across Eurasia for the second week of April is reminiscent of recent summer patterns with ridging accompanied by above normal temperatures across Europe and Central and East Asia and in between the two ridges is troughing accompanied by more seasonable temperatures in Western Asia. I think there is a good probability that this pattern will once again be the dominant summer pattern across Eurasia, and it will be interesting to see if this pattern can hold (with of course some short-term variability) for the next several months. But the warm winter, the lack of snowfall certainly seems to be priming the continent for another hot summer.

Across North America the pattern is predicted to settle into a familiar recent winter pattern troughing in western North America and ridging in eastern North America. This is different from recent summer patterns that have been characterized by strong ridging in western North America, more ridging along the North American east coast and weak troughing in the central part of the continent. I am confident that there is a good chance that the predicted pattern of troughing in western North America will transition to a pattern of ridging in western North America by the summer. But then again, I was very confident of a warm to record warm winter in the Arctic including Alaska and at least one disruption of the stratospheric PV this winter and neither happened. So, confidence doesn't always translate into a verified forecast.

1-5 day

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

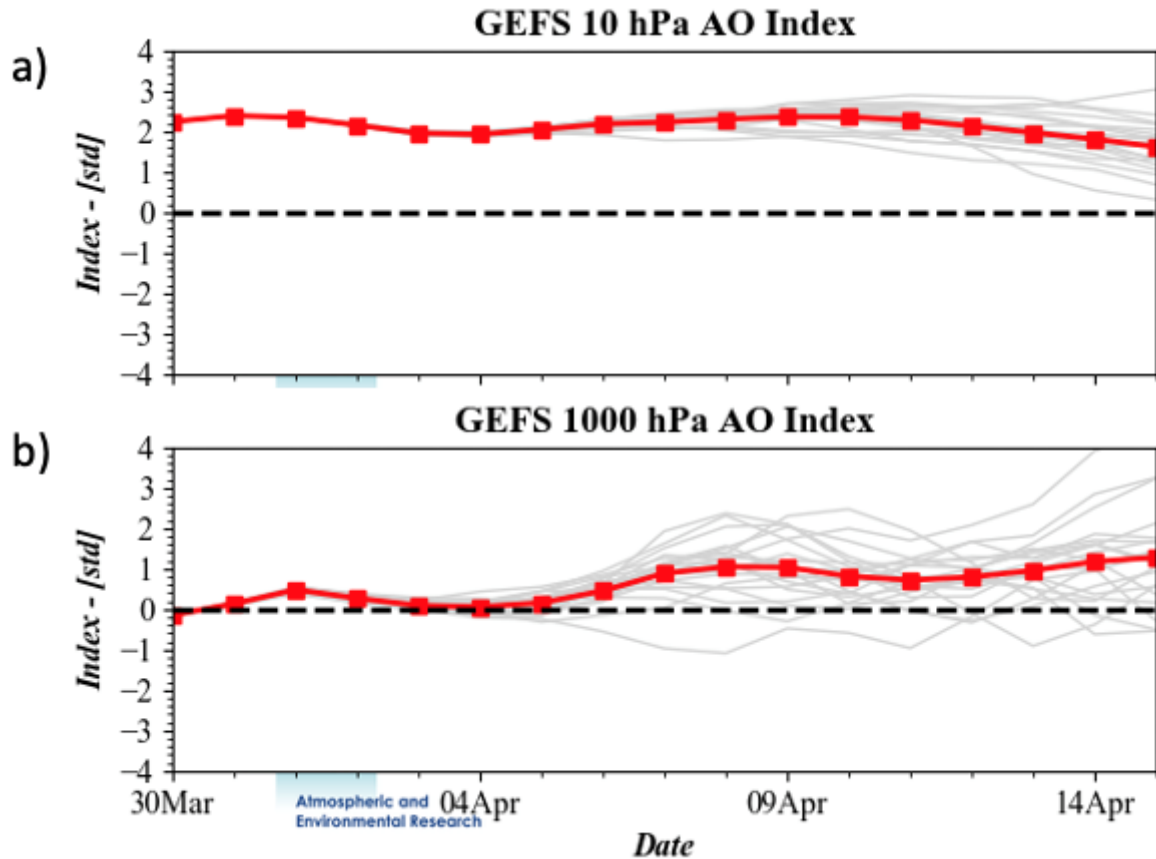


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 30 March 2020 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 30 March 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies stretching from Eastern Canada to the British Isles are predicted to force troughing/negative geopotential height anomalies with normal to below normal temperatures across much of Europe including the UK (**Figures 2 and 3**). Across Asia, troughing/negative geopotential height anomalies in Western Asia and along the North Slope will help to anchor 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 far Northern Siberia with normal to above normal temperatures in Central and Eastern Asia (**Figure 3**). Some weak troughing/negative geopotential height anomalies across Southern Asia will favor normal to below normal temperatures in the region (**Figures 2 and 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 03/30/20 FCST: 03/31/20 to 04/04/20

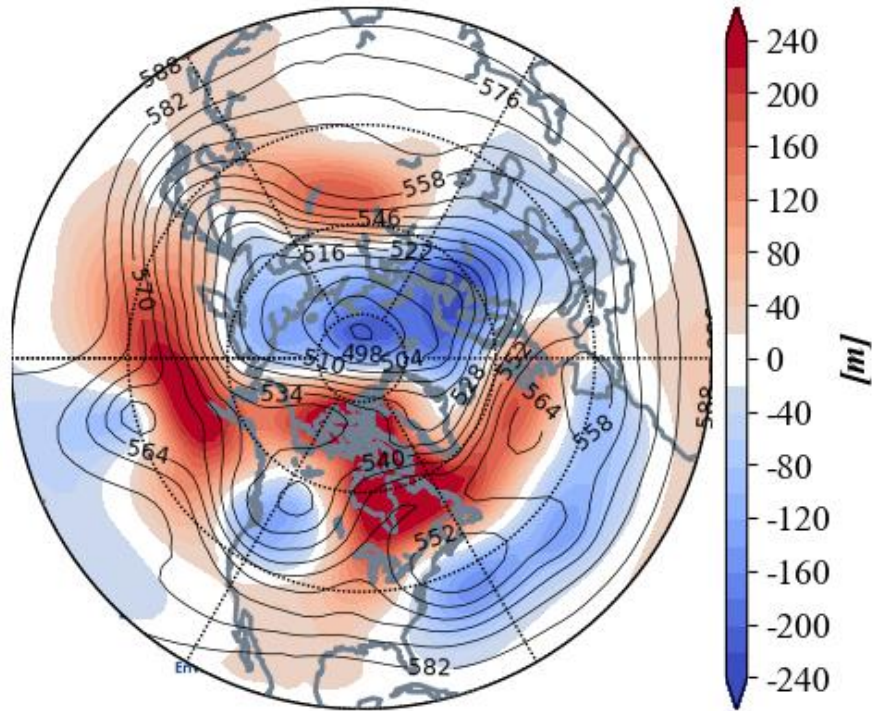


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 31 March – 4 April 2020. The forecasts are from the 00z 30 March 2020 GFS ensemble.

This week, ridging/positive geopotential height anomalies are predicted to stretch from Alaska to Greenland supportive of troughing/negative geopotential height anomalies in western North America and along the US Eastern Seaboard (**Figure 2**). This pattern is predicted to bring normal to above normal temperatures across Alaska, Northern and Eastern Canada and the Southern and Central US with normal to below normal temperatures across Western Canada, much of the Western US and US East Coast (**Figure 3**).

GEFS 1-5 Day Forecast T2m Anomaly
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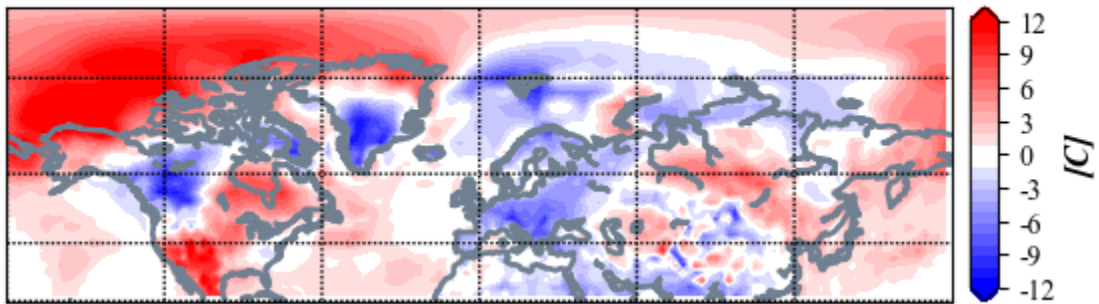


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 31 March – 4 April 2020. The forecast is from the 00Z 30 March 2020 GFS ensemble.

Widespread snowmelt is predicted across Eurasia and North America however troughing and/or cold temperatures are predicted to bring a large swath of new snowfall to Western Canada and the US Northern Rockies and Northern Plains (**Figure 4**).

GEFS 1-5 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 03/30/20 FCST: 03/31/20 to 04/04/20

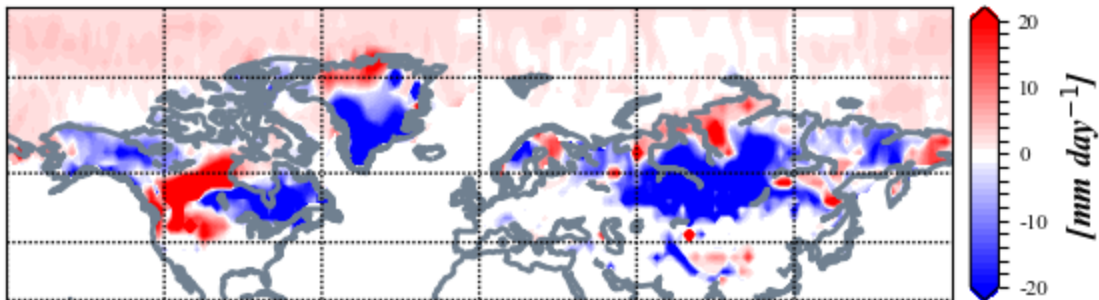


Figure 4. Forecasted snowdepth anomalies (mm/day ; shading) from 31 March – 4 April 2020. The forecast is from the 00Z 30 March 2020 GFS ensemble.

Mid-Term

6-10 day

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

positive geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to start negative but trend to neutral.

GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 03/30/20 FCST: 04/05/20 to 04/09/20

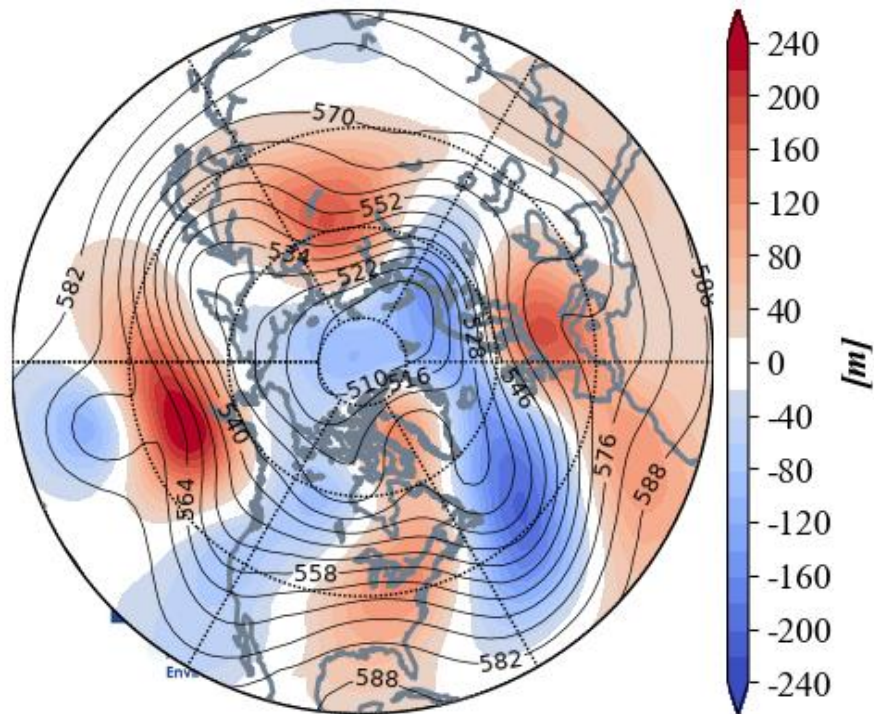


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 5 – 9 April 2020. The forecasts are from the 00z 30 March 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to become more widespread across Europe with troughing/negative geopotential height anomalies confined to Northern Scandinavia and Southeastern Europe this period (**Figures 5**). This pattern will favor normal to above normal temperatures widespread across Europe including the UK with normal to below normal temperatures for Northern Scandinavia and Southeastern Europe (**Figure 6**). Persistent troughing/negative geopotential height anomalies in Western Asia and along the North Slope favor ridging/positive geopotential height anomalies in Central and Eastern Asia (**Figure 5**). This is predicted to yield normal to below normal temperatures for Western Asia with normal to above temperatures in Central and Eastern 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 03/30/20 FCST: 04/05/20 to 04/09/20

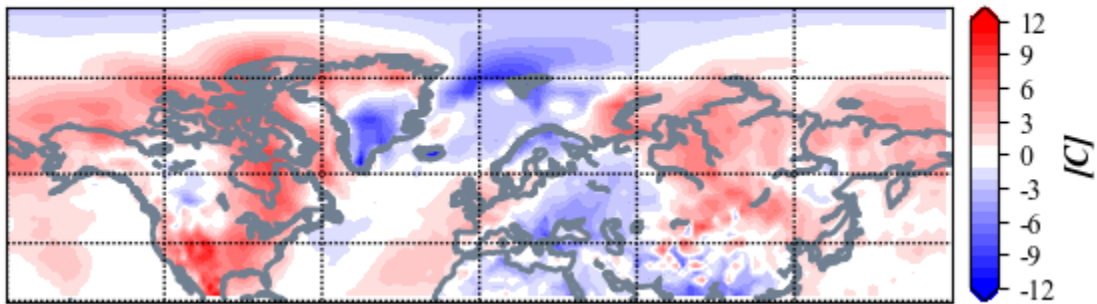


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 5 – 9 April 2020. The forecasts are from the 00Z 30 March 2020 GFS ensemble.

Trouching/negative geopotential height anomalies are predicted to become widespread across western North America forcing ridging/positive geopotential height anomalies in eastern North America this period (**Figure 5**). This pattern is predicted to bring normal to below normal temperatures across Alaska, Western Canada and much of the Western US with normal to above normal temperatures for Eastern Canada and the Eastern US (**Figure 6**).

GEFS 6-10 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 03/30/20 FCST: 04/05/20 to 04/09/20

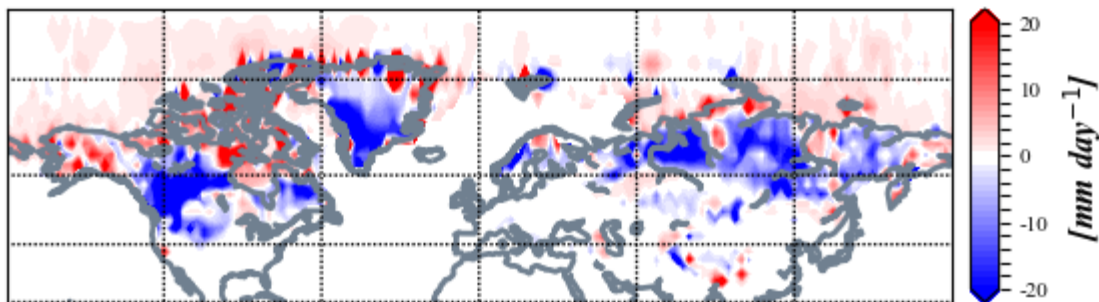


Figure 7. Forecasted snowdepth changes (mm/day ; shading) from 5 – 9 April 2020. The forecasts are from the 00Z 30 March 2020 GFS ensemble.

Widespread snowmelt is predicted across Eurasia and North America however troughing and/or cold temperatures are predicted to bring new snowfall to Alaska and Northern Canada (**Figure 7**).

11-15 day

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

GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
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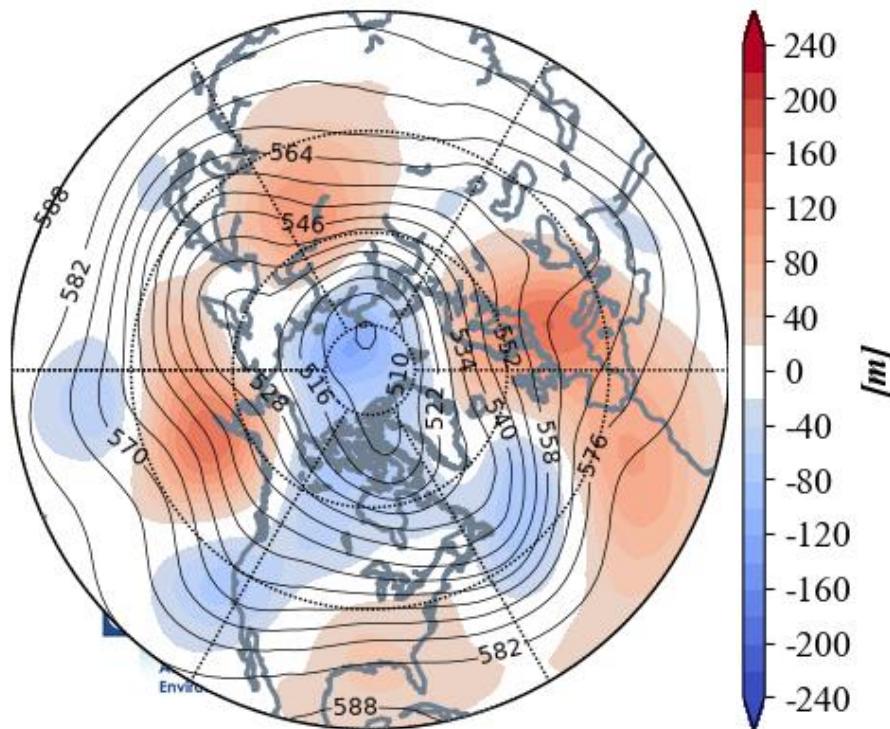


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 10 – 14 April 2020. The forecasts are from the 00z 30 March 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are to dominate Europe with troughing/negative geopotential height anomalies confined to extreme Southeastern Europe this period (**Figures 8**). The forecast is for widespread normal to above normal temperatures across Europe including the UK with normal to below normal temperatures confined to Northern Scandinavia and extreme Southeastern Europe this period (**Figures 9**). Once again, troughing/negative geopotential height anomalies across Northern and Western Asia favor ridging/positive geopotential height anomalies across Central and Eastern Asia this period (**Figure 8**). This pattern favors normal to below normal temperatures for Western and far Northern Asia with normal to above normal temperatures for Central and Eastern 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**).

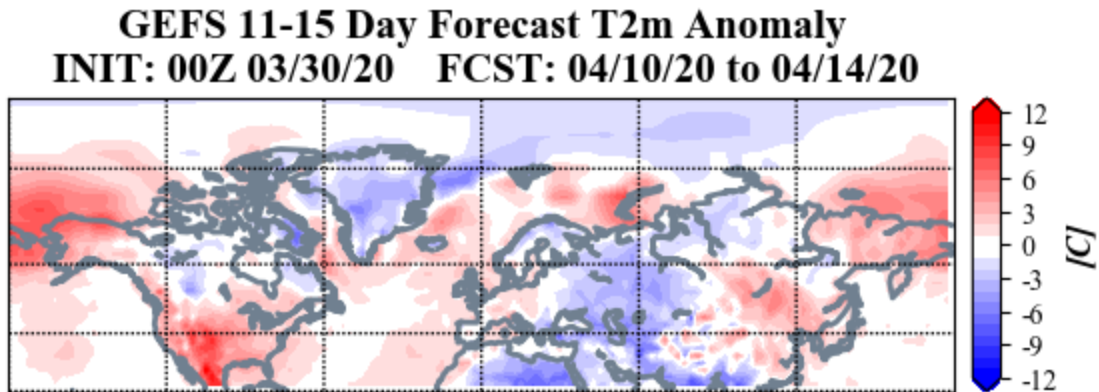


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 10 – 14 April 2020. The forecasts are from the 00z 30 March 2020 GFS ensemble.

Once again troughing/negative geopotential height anomalies are predicted for western North America but now spreading across Northern Canada with ridging/positive geopotential height in the Eastern US this period (**Figure 8**). This pattern is predicted to favor normal to below normal temperatures across Western and Northern Canada and much of the Western US with normal to above normal temperatures for Southeastern Canada and the Eastern US (**Figure 9**).

GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 03/30/20 FCST: 04/10/20 to 04/14/20

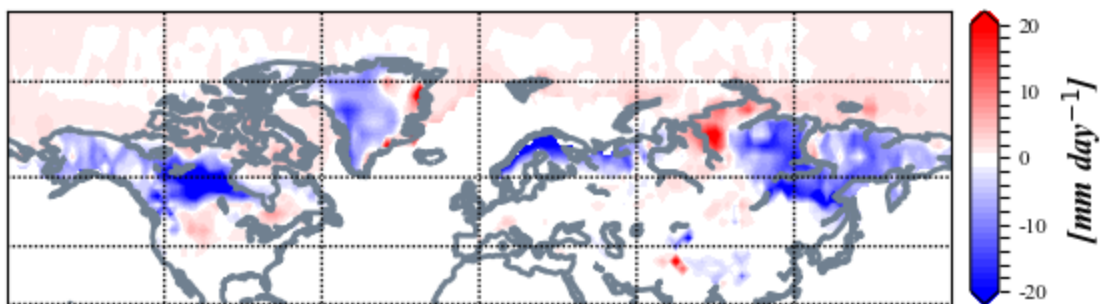


Figure 10. Forecasted snow depth changes (mm/day; shading) from 10 – 14 April 2020. The forecasts are from the 00z 30 March 2020 GFS ensemble.

Widespread snowmelt is predicted across Eurasia and North America however troughing and/or cold temperatures are predicted to bring possible new snowfall to parts of Siberia, Northern and Southern Canada and the Northwestern US (**Figure 7**).

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 over the next two weeks with the largest negative departures in the lower stratosphere (**Figure 11**). However, this week there are some weak above normal PCHs predicted in the lower troposphere (**Figure 11**) consistent with the current neutral AO (**Figure 1**) and negative NAO. If this verifies this will be the first positive PCHs in either the troposphere or stratosphere since December.

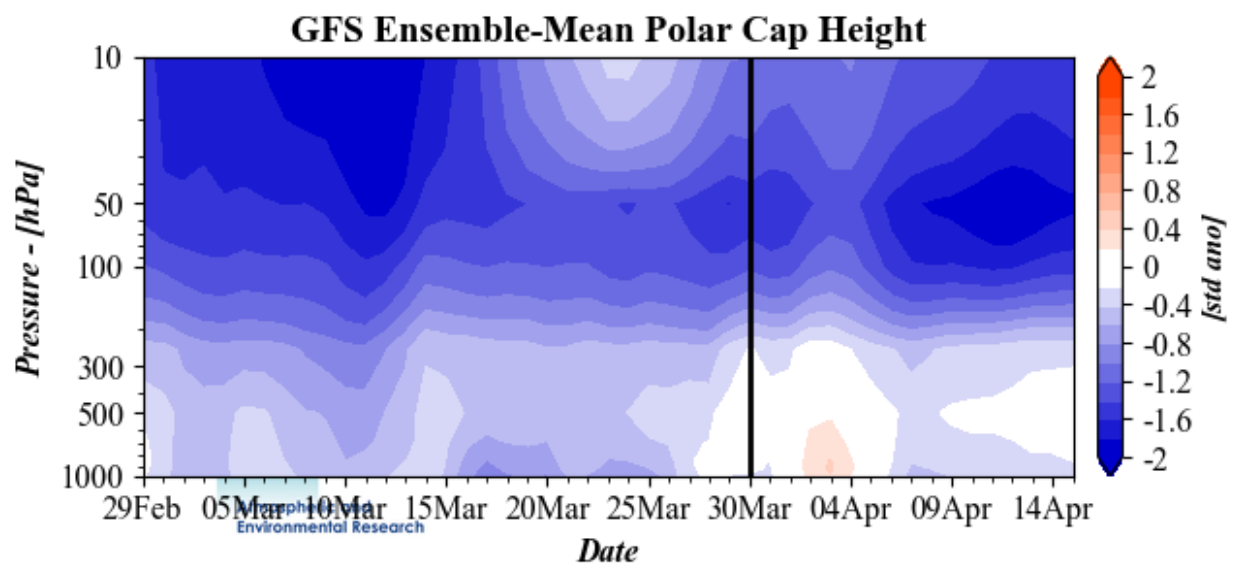


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 30 March 2020 GFS ensemble.

The plot of vertical Wave Activity Flux (WAFz) or poleward heat transport forecast shows one weak pulse of positive anomalies this week and a possibly stronger pulse of positive anomalies beginning next week (**Figure 12**). The slight increase in positive WAFz anomalies are likely related to positive height anomalies predicted this week stretching from Northern Europe to Eastern Canada (**Figure 2**).

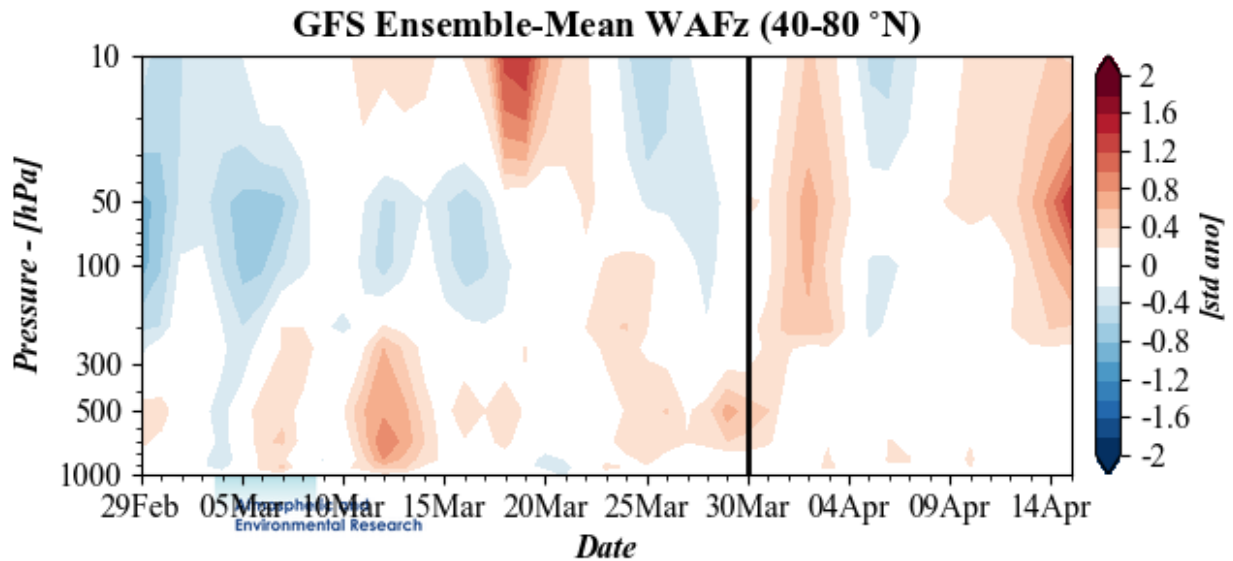


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 30 March 2020 GFS ensemble.

Despite the predicted positive WAFz anomalies, the stratospheric AO is strongly positive and is predicted to remain strongly positive (**Figure 1**) consistent with a relatively strong PV (**Figure 1**). The GFS predicts minor disrupting of the PV and slow weakening through mid-April with slight changes in the position of the PV and ongoing polar stratospheric warming. And though the PV is weakening relative to mid-winter values it remains strong relative to early spring values.

Currently the stratospheric PV center is diffuse and stretched along an axis from Svalbard to the Canadian archipelagos (**Figure 13**) with the largest negative temperature departures in the polar stratosphere located over Eurasia (**Figure 13**). The PV is also elongated along an axis from the Urals to Western Canada in part due to squeezing from two weak ridge centers one over the Eastern US and the other over Eastern Siberia.

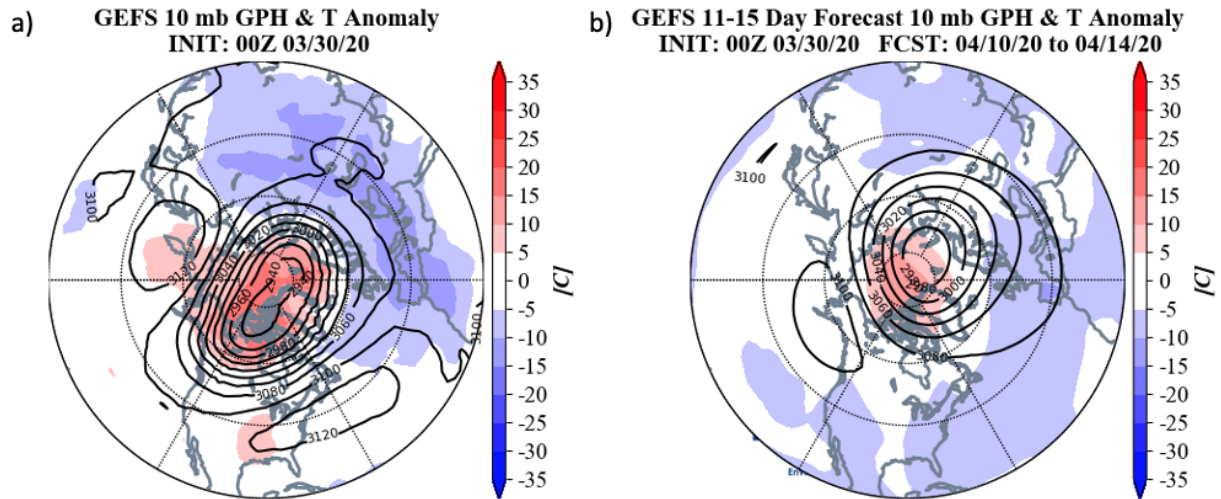


Figure 13. (a) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere at 00Z 30 March 2020 . (b) Same as (a) except forecasted averaged from 10 – 14 April 2020. The forecasts are from the 00Z 30 March 2020 GFS operational model.

Over the next two weeks, the PV center is predicted to remain centered near Svalbard and slowly weaken (**Figure 13**). Warming currently spread across the polar stratosphere is predicted to weaken (**Figure 13**) and become confined to near the North Pole. At this point a relatively late Final Warming (where the PV disappears until the fall) seems inevitable.

**CFS 500 hPa Forecast Anomaly Apr 2020
Valid as of 30 Mar 2020**

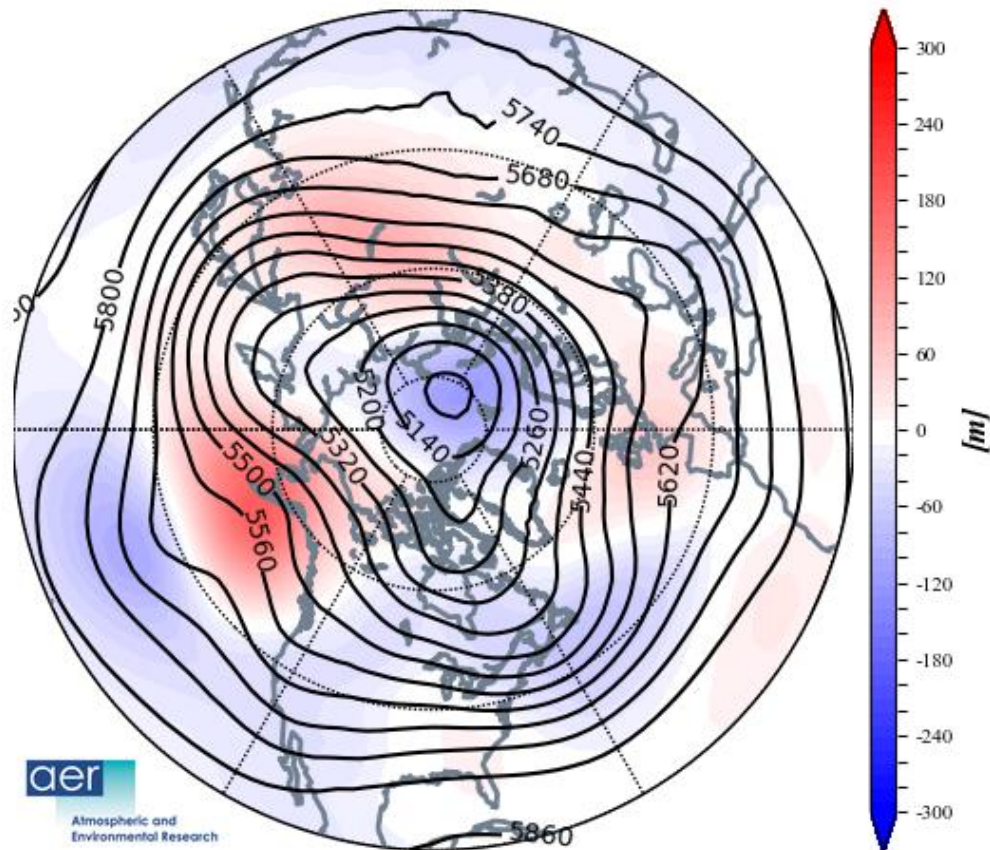


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for April 2020. The forecasts are from the 00Z 30 March 2020 CFS.

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 Western Europe, Central Asia, the Gulf of Alaska, Alaska and the Southeastern US with troughing in Eastern and Southern Europe into the Middle East, East Asia, Eastern Canada and the Southwestern US (**Figure 14**). This pattern favors relatively mild temperatures for Western Europe, much of Northern and Eastern Asia, western North America and the Southeastern US with seasonable to relatively cool temperatures for Southern and Eastern Europe, Western and Southern Asia, Southeastern Canada and the Northeastern US (**Figure 15**).

CFS T2m Forecast Anomaly Apr 2020
Valid as of 30 Mar 2020

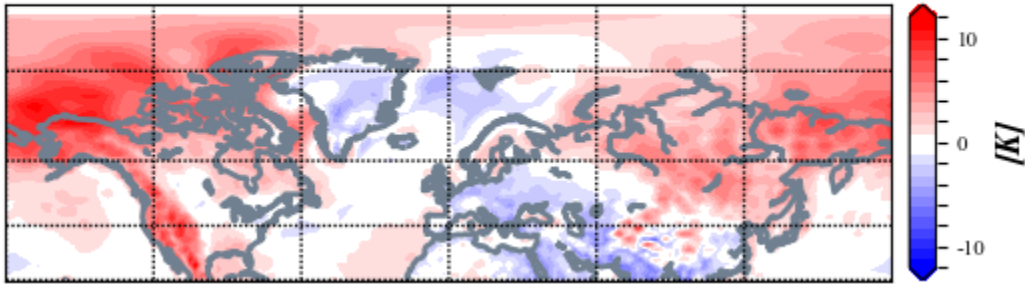


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for April 2020. The forecasts are from the 00Z 30 March 2020 CFS.

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. There was a dramatic drop in sea ice extent especially in the Bering Sea. I don't know the reason but suspect that it is due to mechanical break-up of the ice from the wind. With the recent dramatic drop in extent, we are likely past the seasonal maximum extent in Arctic sea ice for the year.

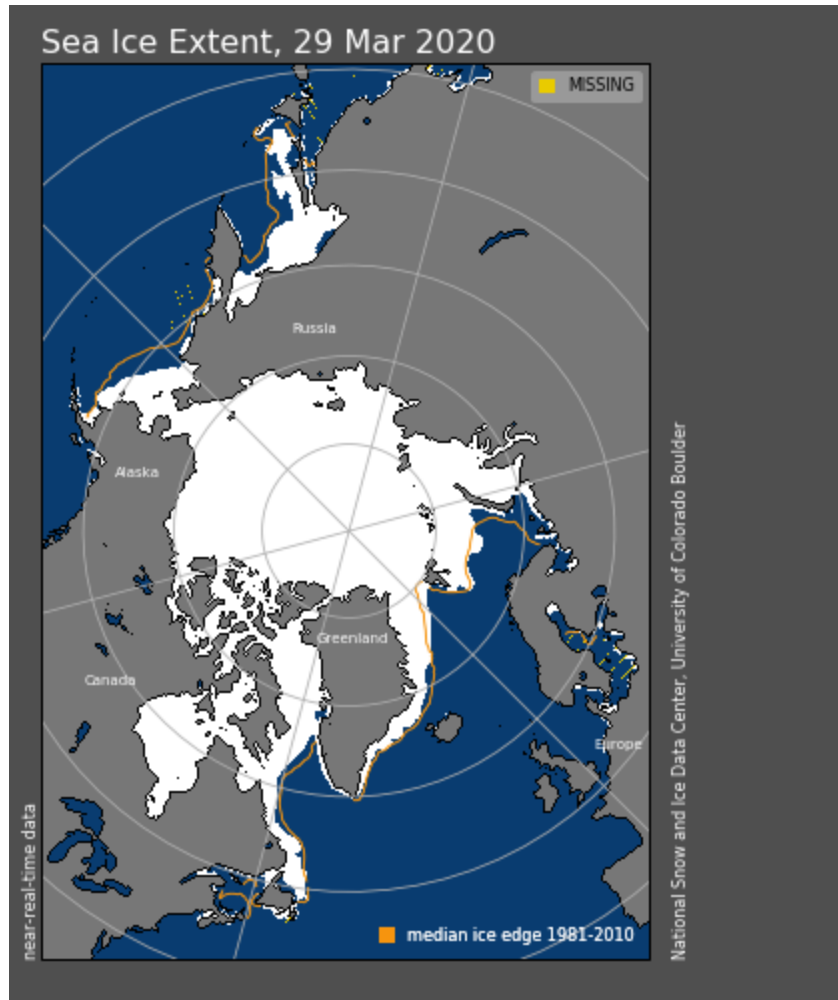


Figure 16. a) Observed Arctic sea ice extent on 29 March 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010.

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 26 Mar 2020

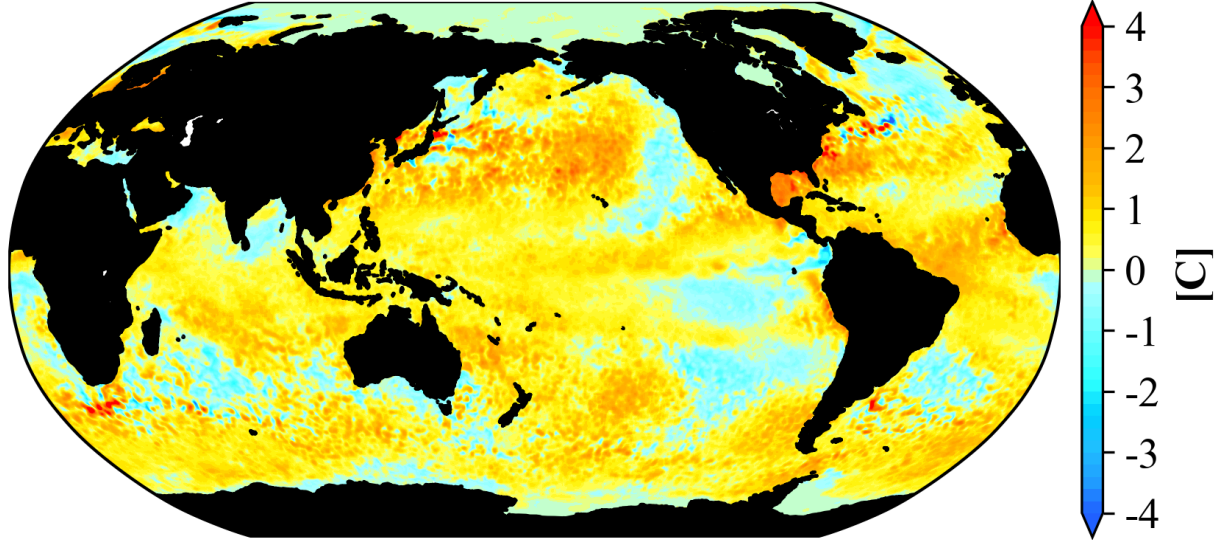


Figure 17. The latest weekly-mean global SST anomalies (ending 26 March 2020). Data from NOAA OI High-Resolution dataset.

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

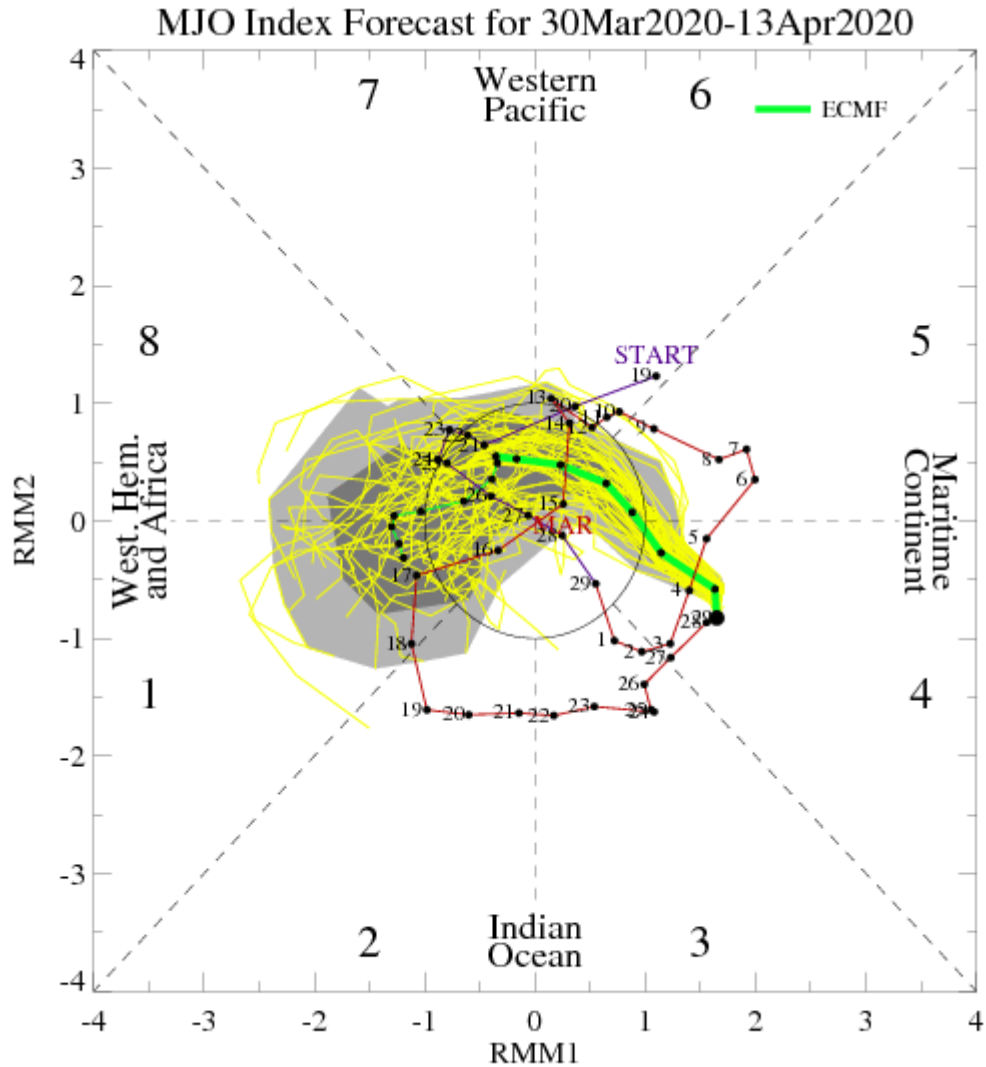


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 30 March 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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 continued to decline 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.

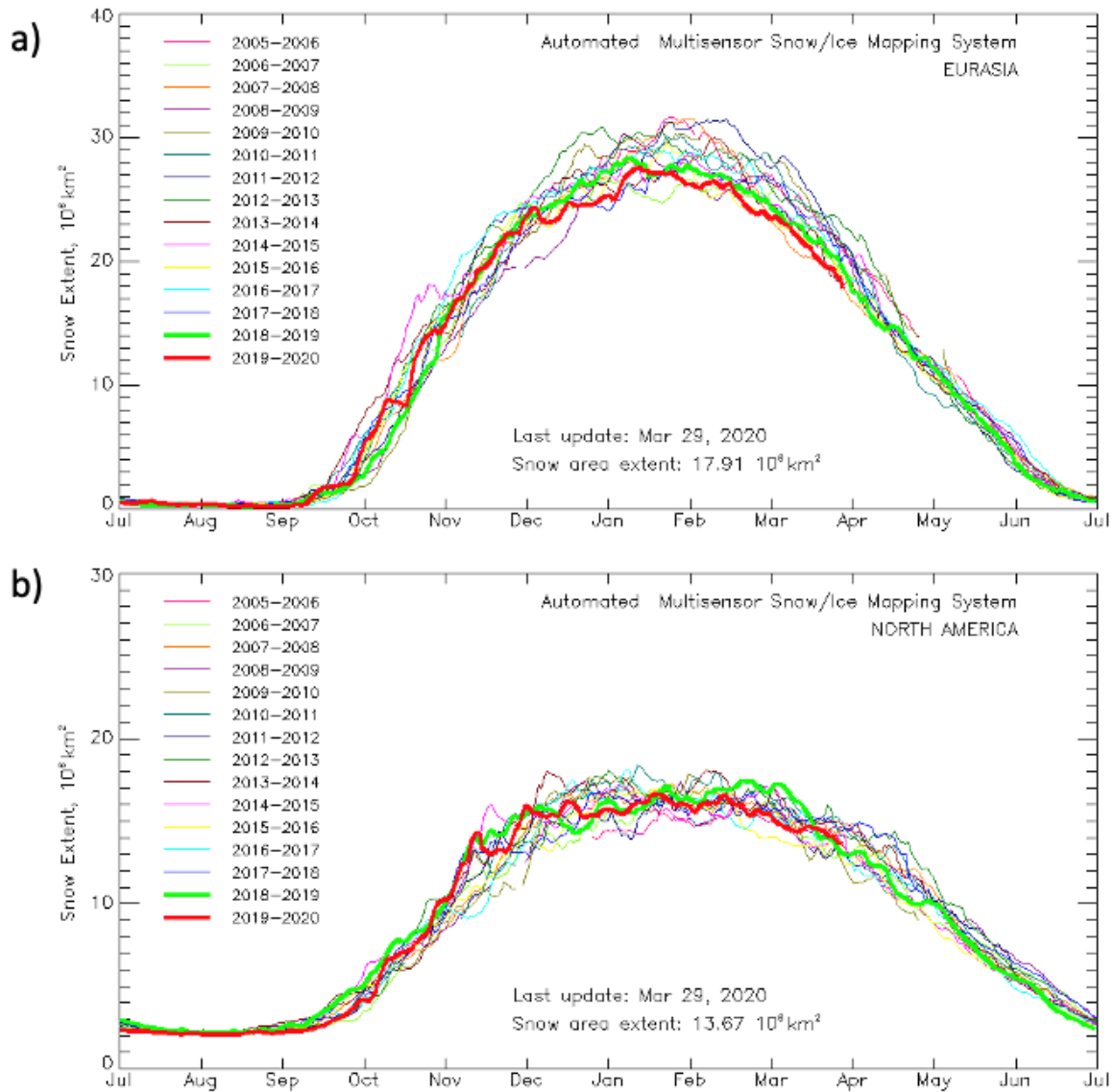


Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 29 March 2020 (not updated). Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover declined this week and remains near decadal means. Snow cover extent is now clearly in its seasonal decline. If the melting accelerates this could contribute to a warm spring.