

# Arctic Oscillation and Polar Vortex Analysis and Forecasts

March 9, 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 the next two weeks but slowly trend towards neutral.
- 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 over the next

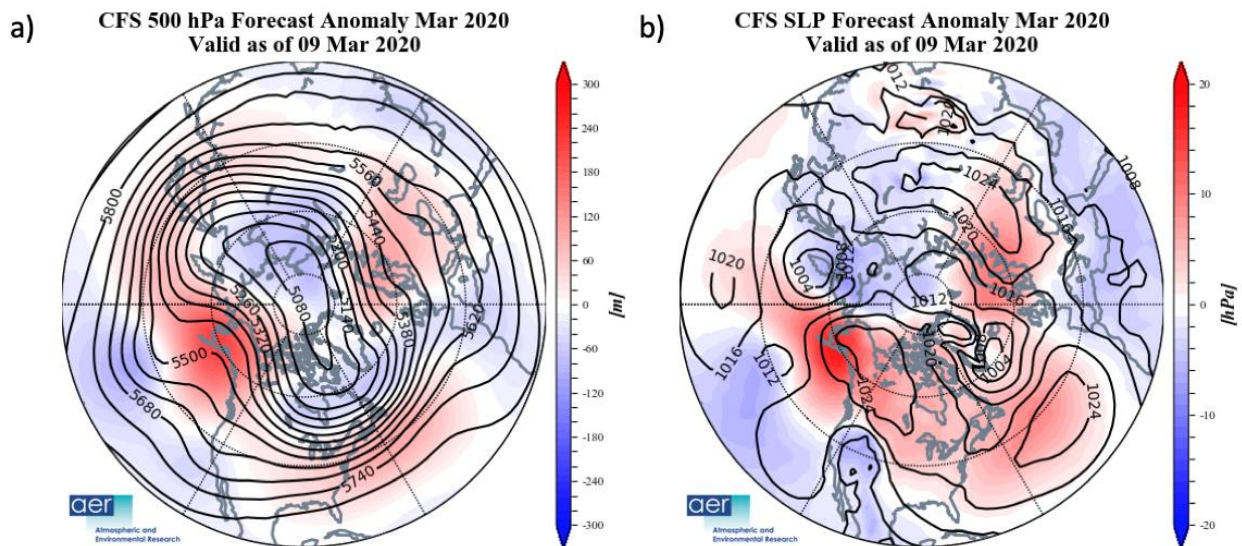
two weeks as height anomalies are predicted to remain negative across Greenland.

- The general circulation pattern over Europe this week is troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height anomalies across Southern Europe. Starting next week, ridging/positive geopotential height anomalies will become focused across Northern Europe with troughing/negative geopotential height anomalies beginning in Western Europe and expanding eastward. This pattern favors normal to above normal temperatures for much of Europe including the United Kingdom (UK) this week with normal to below normal temperatures in Western and Northern Europe next week and spreading into Central Europe by the end of next week.
- The predicted general pattern for Asia is ridging/positive geopotential height anomalies in Western and Central Asia with troughing/negative pressure/geopotential height anomalies limited to Eastern Asia. Next week ridging/positive geopotential height anomalies will become more widespread with troughing/negative pressure/geopotential height anomalies limited to Northern Asia. But by the end of next week troughing/negative pressure/geopotential height anomalies will become more widespread across Asia. This pattern favors normal to above normal temperatures across much of Asia except for normal to below normal temperatures in East Asia this week. Next week normal to above normal temperatures will become more widespread with normal to below normal temperatures limited to northern most Asia but then the cold temperatures will become more widespread across Asia. Also, persistent troughing/negative pressure/geopotential height anomalies across the northern Indian subcontinent will bring normal to below normal temperatures to the region.
- The predicted pattern for North America this week is troughing/negative geopotential height anomalies with normal to below temperatures across Alaska and much of Canada with ridging/positive geopotential height anomalies and above normal temperatures across the United States (US). However next week, ridging/positive geopotential height anomalies in the Gulf of Alaska and Alaska with normal to above normal temperatures will force troughing/negative geopotential height anomalies with normal to below normal temperatures in western North America and Eastern Canada with more ridging/positive geopotential height anomalies with normal above normal temperatures in the Eastern US.
- In the Impacts section I discuss the increasingly likely hemispheric pattern change.

### ***Impacts***

The signs that the dominant weather pattern of the winter with strong low pressure in the Barents-Kara Seas and northwestern Eurasia is finally changing are increasing this

week. The most important change is the predicted building of high pressure across Northern Europe and the northern North Atlantic starting next week (see **Figures 5 and 8**). Ridging/high pressure across Northern Europe is helping to force downstream troughing/low pressure in East Asia (**Figure i**). I believe the persistent low pressure across Northwest Eurasia, Barents-Kara Seas was the anchor of the positive AO and strong stratospheric PV this winter. Building of pressures/heights across Northwest Eurasia and into the northern North Atlantic will initially weaken the strong positive surface AO. But longer-term high heights and mild temperatures across northwestern Eurasia and low heights with cold temperatures in northeastern Eurasia are favorable for exciting vertical Wave Activity Flux (WAFz) or poleward heat transport that is necessary to weaken/disrupt the stratospheric PV. The stratospheric PV will weaken with time regardless due to the increasing solar radiation with the return of the sun's position to the Northern Hemisphere (NH) but I believe it will likely be abetted by WAFz pulses.



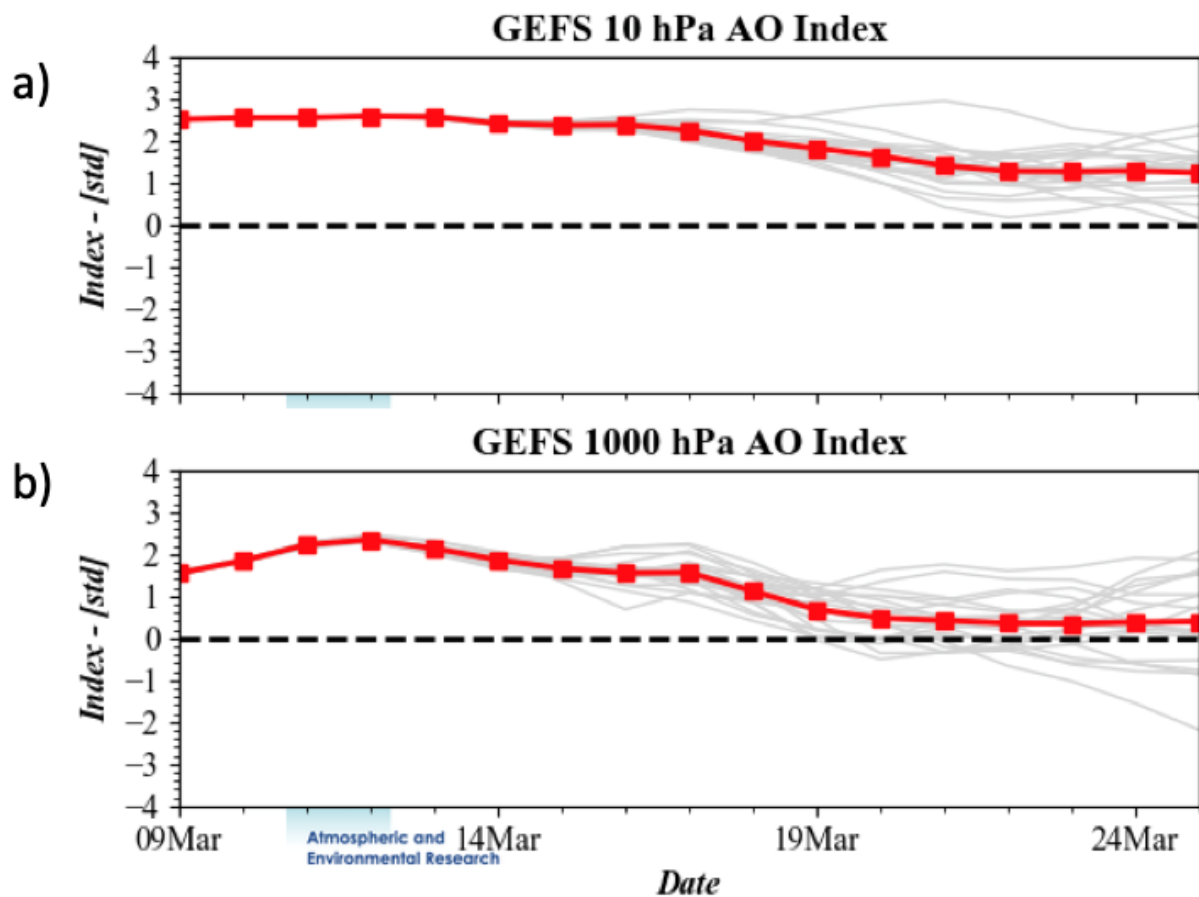
**Figure iv.** Predicted a) 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) and b) sea level pressure (hPa; contours) and sea level pressure (shading; hPa) anomalies for March 2020 from the 09 March 2020 CFS ensemble.

The immediate impact of the change from low to high pressure across Northern Europe is a supportive circulation for troughing and relatively cold temperatures for Europe (with the possible exception of Scandinavia but especially Siberia and East Asia). There is uncertainty from the model forecasts how quickly this new pattern will weaken the stratospheric PV but I feel that it inevitably will and probably sooner than later. Though the strong PV has had an incredible streak it can defy climatology for so long. Not sure if it is related, but in addition to the building of high heights with mild temperatures across Northern Europe the same is predicted for Alaska. In the short term this is

predicted to favor colder temperatures in Canada and the Western US but over time the colder air could move into the Eastern US. If a PV disruption does take place in the coming weeks this could help reinforce colder weather in Northern and Eastern Asia and eastern North America. However strong seasonal warming taking place across the NH with the arrival of boreal spring will be a dominating factor regardless, especially across North America if the predicted widespread snowmelt verifies (see **Figure 10**).

1-5 day

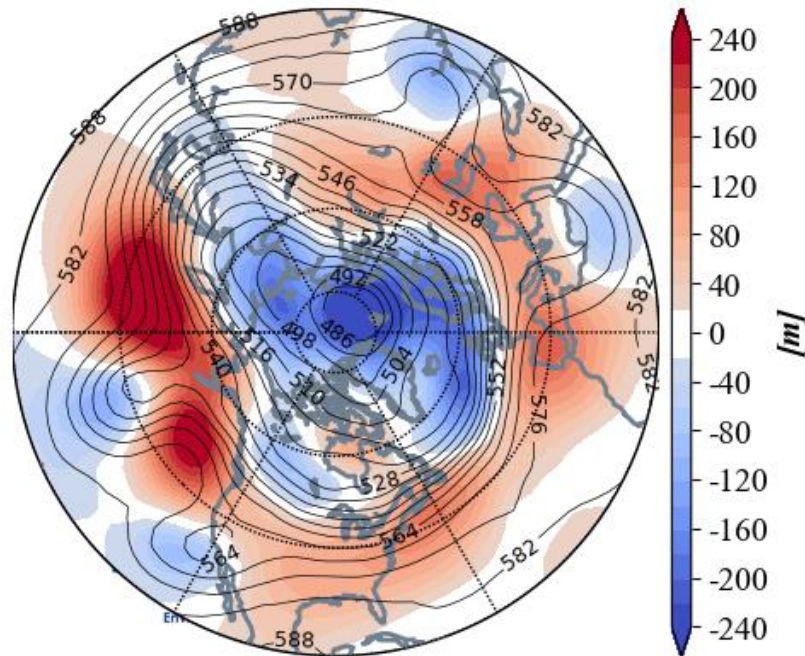
The AO is currently positive (**Figure 1**) with negative geopotential height anomalies across the Arctic and mostly positive geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with mostly negative geopotential height anomalies across Greenland and Iceland (**Figure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



**Figure 1.** (a) The predicted daily-mean AO at 10 hPa from the 00Z 9 March 2020 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 9 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 will dominate Europe including the UK (**Figures 2 and 3**). This week, ridging/positive geopotential height anomalies are predicted to dominate much of Asia with troughing/negative geopotential height anomalies confined to East Asia and the northern Indian subcontinent (**Figure 2**). This pattern favors normal to above normal temperatures across most of Asia with normal to below normal temperatures confined to Eastern Siberia, Northeast Asia, Pakistan and Afghanistan (**Figure 3**).

**GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly**  
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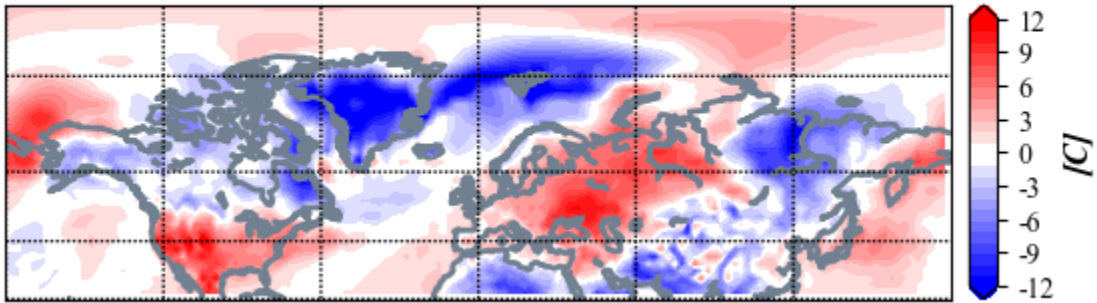


**Figure 2.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 10 – 14 March 2020. The forecasts are from the 00z 9 March 2020 GFS ensemble.

Troughing/negative geopotential height anomalies are predicted this week to stretch from Alaska across much of Canada with ridging/positive geopotential height anomalies across the US with the exception of a closed upper level low over the Desert Southwest (**Figure 2**). This is predicted to result in normal to below normal temperatures in Alaska and much of Canada with normal to above normal temperatures across much of the US (**Figure 3**).



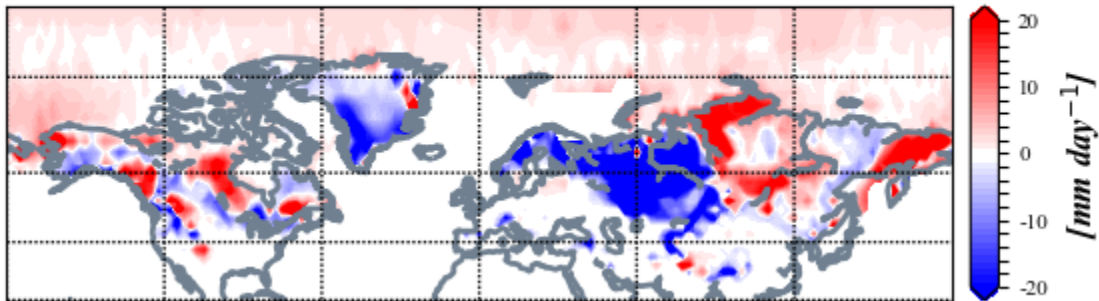
**GEFS 1-5 Day Forecast T2m Anomaly**  
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**Figure 3.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 10 – 14 March 2020. The forecast is from the 00Z 9 March 2020 GFS ensemble.

Trouching and/or cold temperatures are predicted to bring new snowfall to parts of Siberia and the Tibetan Plateau (**Figure 4**). Trouching and/or cold temperatures are predicted to bring new snowfall to parts of Alaska and Canada and possibly the Southern Rockies with the upper level low (**Figure 4**). Warm temperatures are predicted to result in snowmelt for a large swath of Western Asia, Northern Europe, the Alps, and scattered throughout North America (**Figure 4**).

**GEFS 1-5 Day Forecast Mean 24-hour Snow Depth Change**  
**INIT: 00Z 03/09/20 FCST: 03/10/20 to 03/14/20**



**Figure 4.** Forecasted snowdepth anomalies ( $\text{mm}/\text{day}$ ; shading) from 10 – 14 March 2020. The forecast is from the 00Z 9 March 2020 GFS ensemble.

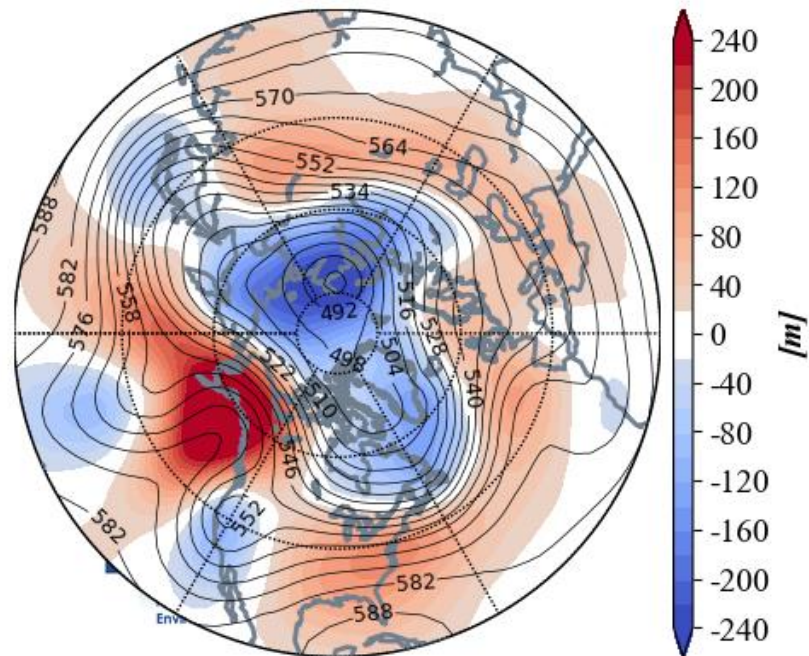
*Mid-Term*

*6-10 day*

The AO is predicted to remain positive (**Figure 1**) as negative geopotential height anomalies continue to dominate the Arctic with mostly positive geopotential height

anomalies across the mid-latitudes of the NH (**Figure 5**). And with negative geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to remain positive as well.

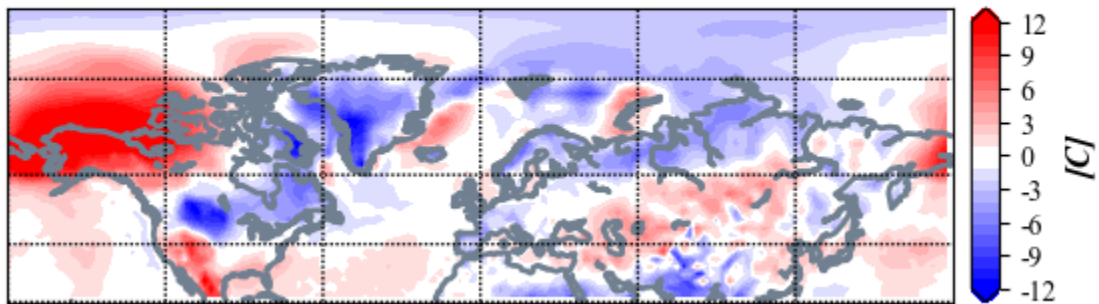
**GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly**  
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**Figure 5.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 15 – 19 March 2020. The forecasts are from the 00z 9 March 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to stretch across Northern and Eastern Europe with troughing/negative geopotential height anomalies beginning to develop across Western Europe this period (**Figures 5**). This pattern will favor normal to below normal temperatures for Western and Northern Europe including the UK with normal to above normal temperatures for Central and Eastern Europe (**Figure 6**). Persistent ridging/positive geopotential height anomalies are predicted to become even more widespread across Asia with troughing/negative geopotential height anomalies confined to Northern Asia (**Figure 5**). This is predicted to yield normal to above normal temperatures for most of Asia **with** normal to below temperatures limited to the North Slope of Asia (**Figure 6**). Northerly flow in East Asia (**Figure 5**) will help to filter some of the cold air from Eastern Siberia into Northeast Asia (**Figure 6**). Persistent troughing/negative geopotential height anomalies across the northern Indian subcontinent (**Figure 5**) favors normal to below normal temperatures for the Tibetan Plateau (**Figure 6**).

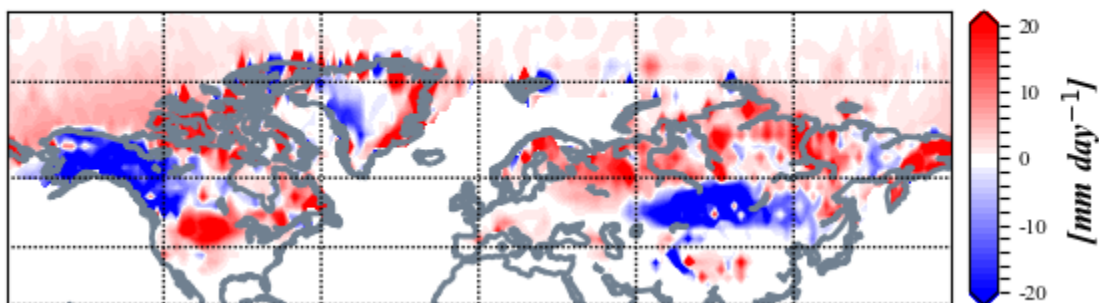
**GEFS 6-10 Day Forecast T2m Anomaly**  
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**Figure 6.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 15 – 19 March 2020. The forecasts are from the 00Z 9 March 2020 GFS ensemble.

Ridging/positive geopotential height anomalies in the Gulf of Alaska and Alaska are predicted to force troughing/negative geopotential height anomalies in Eastern Canada and western North America with more ridging/positive geopotential height anomalies in the Eastern US (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across Alaska, Northwestern Canada and the Eastern US with normal to below normal temperatures across Southwestern and Eastern Canada and much of the Western US (**Figure 6**).

**GEFS 6-10 Day Forecast Mean 24-hour Snow Depth Change**  
**INIT: 00Z 03/09/20 FCST: 03/15/20 to 03/19/20**



**Figure 7.** Forecasted snowdepth changes ( $\text{mm}/\text{day}$ ; shading) from 15 – 19 March 2020. The forecasts are from the 00Z 9 March 2020 GFS ensemble.

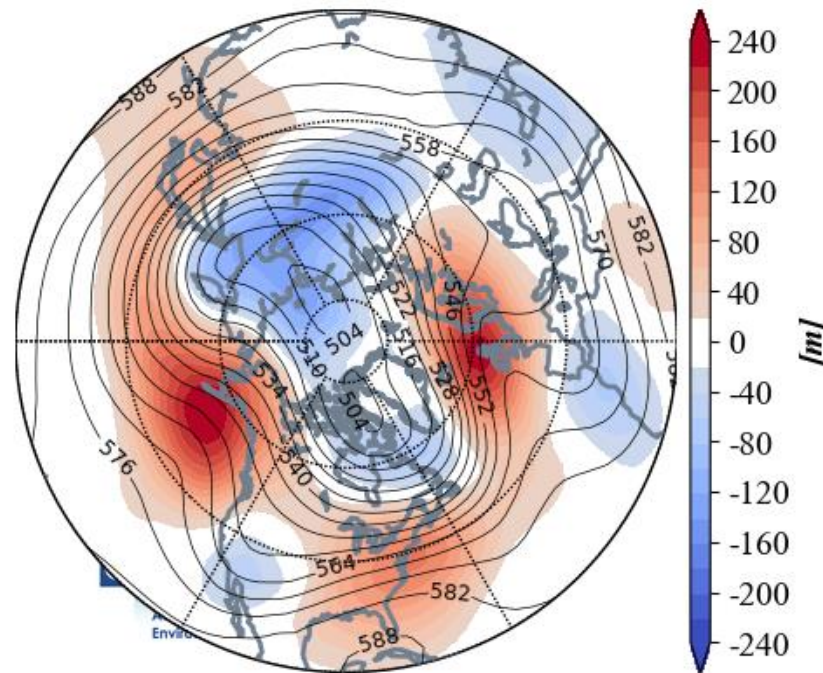
Troughing and/or cold temperatures will support the potential for new snowfall across Northern Europe and Asia, the higher elevations of Central Europe, the Tibetan Plateau, Eastern Canada and the Western US (**Figure 7**). Snowmelt is predicted in Central Asia, Alaska and Northwestern Canada (**Figure 7**).



11-15 day

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

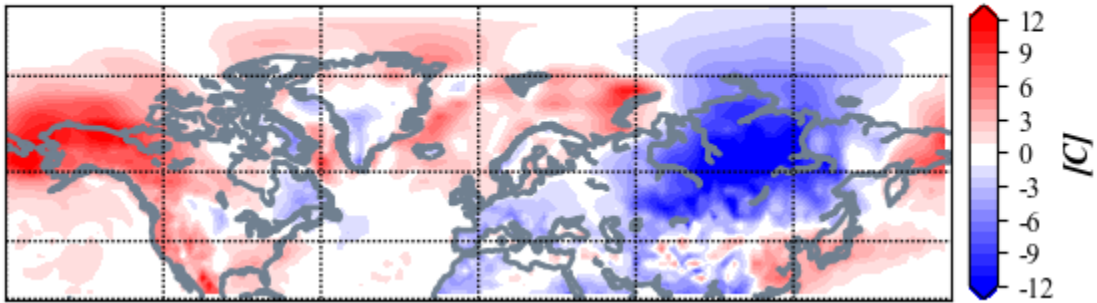
**GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly**  
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**Figure 8.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 20 – 24 March 2020. The forecasts are from the 00z 9 March 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to consolidate across Northern Europe with troughing/negative geopotential height anomalies becoming more widespread across Western and Central Europe this period (**Figures 8**). This pattern favors normal to above normal temperatures for Northern and Eastern Europe with normal to below normal temperatures in Western and Central Europe including the UK this period (**Figures 9**). Troughing/negative geopotential height anomalies will become more widespread this period likely related to a developing PV disruption with ridging/positive geopotential height anomalies confined to Southeast Asia (**Figure 8**). This pattern favors normal to below normal temperatures for Western and Northern Asia with normal to below normal temperatures for Southern and Eastern Asia (**Figure 9**).

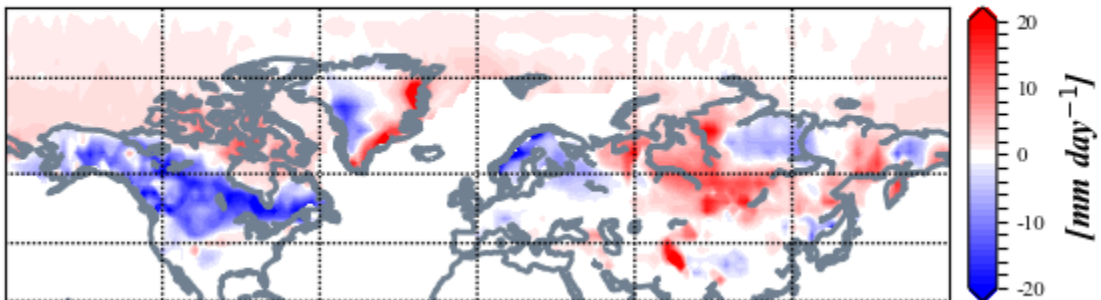
**GEFS 11-15 Day Forecast T2m Anomaly**  
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**Figure 9.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 20 – 24 March 2020. The forecasts are from the 00z 9 March 2020 GFS ensemble.

Little change is predicted in the pattern across North America as ridging/positive geopotential height anomalies in the Gulf of Alaska and Alaska continue to force troughing/negative geopotential height anomalies in Eastern Canada and western North America with more ridging/positive geopotential height anomalies in the Eastern US (**Figure 8**). This pattern is predicted to favor normal to above normal temperatures across Alaska, Northern and Western Canada and the Eastern US with normal to below normal temperatures for Southern and Eastern Canada and much of the Western US (**Figure 9**).

**GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change**  
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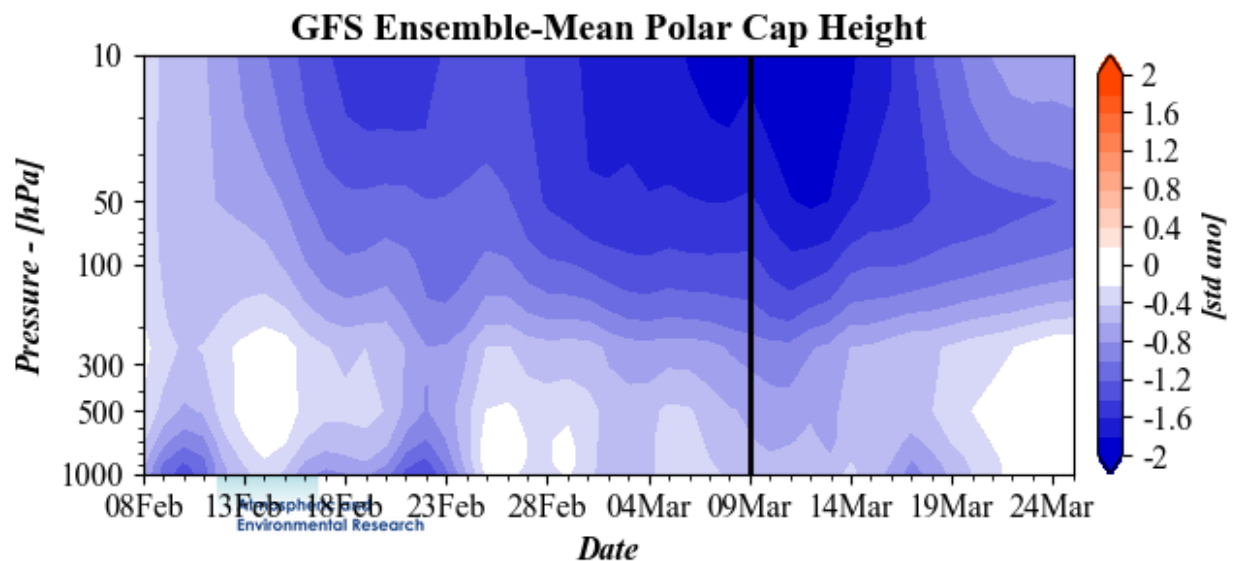
**Figure 10.** Forecasted snow depth changes ( $\text{mm}/\text{day}$ ; shading) from 20 – 24 March 2020. The forecasts are from the 00z 9 March 2020 GFS ensemble.

Troughing and/or cold temperatures could support new snowfall across parts of Northern and Eastern Asia, the Tibetan Plateau, and possibly Turkey and Iran (**Figure 10**). Snowmelt is predicted in Scandinavia, the Alps and widespread across North America (**Figure 10**).

Longer Term

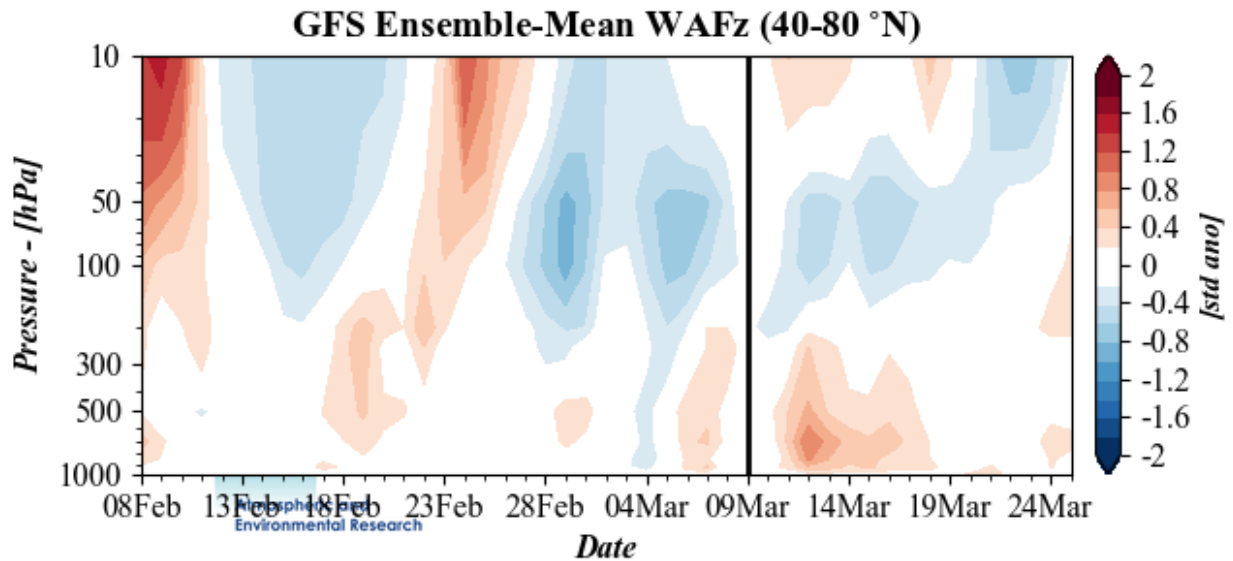
30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to below normal PCHs in both the troposphere and stratosphere (**Figure 11**). The cold PCHs in the middle stratosphere are related to a normal to strong PV since December that coupled to the troposphere for much of January, February and is predicted to continue to persist well into March (**Figure 11**). The predicted cold tropospheric PCHs are consistent with a predicted positive surface AO (**Figure 1**). Though the predicted downward propagation of cold PCHs from the strong stratospheric PV to the surface has been fairly consistent since late December, this plot is suggestive that it may finally end with the arrival of astronomical spring.



**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 9 March 2020 GFS ensemble.

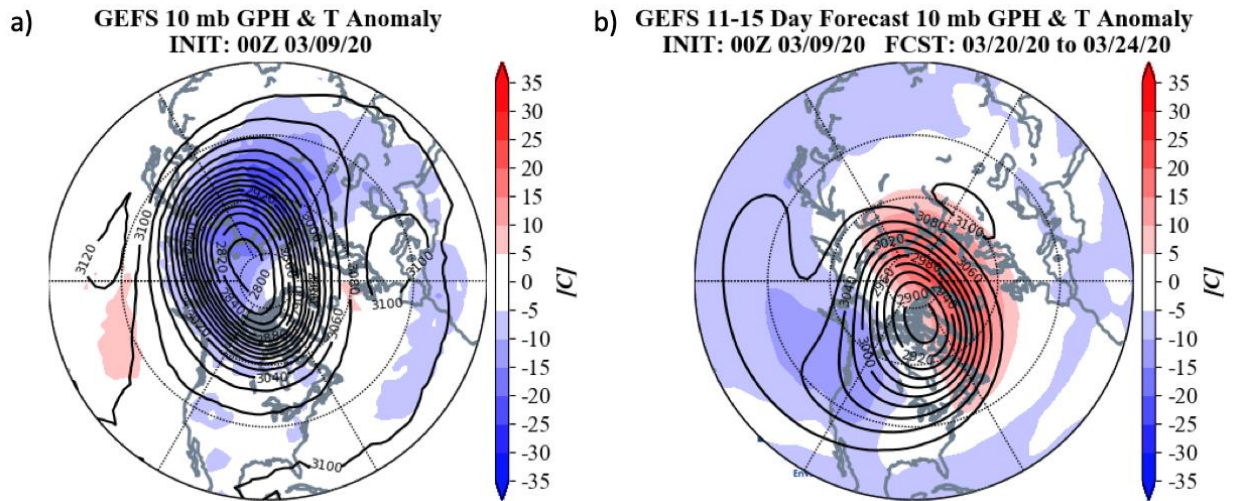
The plot of vertical Wave Activity Flux (WAFz) or poleward heat transport forecast shows only weak negative and positive anomalies over the next two weeks (**Figure 12**). Though the plot of ensemble spread of WAFz anomalies become large starting next week suggestive of increasing model uncertainty (**not shown**).



**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 9 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 mid-March with changes in the position of the PV and increased polar stratospheric warming with some decreases in the overall positive stratospheric AO starting next week.

Currently the stratospheric PV is centered over the Chukchi Sea (**Figure 13**) with the largest negative temperature departures in the polar stratosphere located over northern Eurasia (**Figure 13**). The PV is elongated along an axis from Siberia to Canada. This is the same axis of the coldest temperatures predicted at the surface the next week or so.

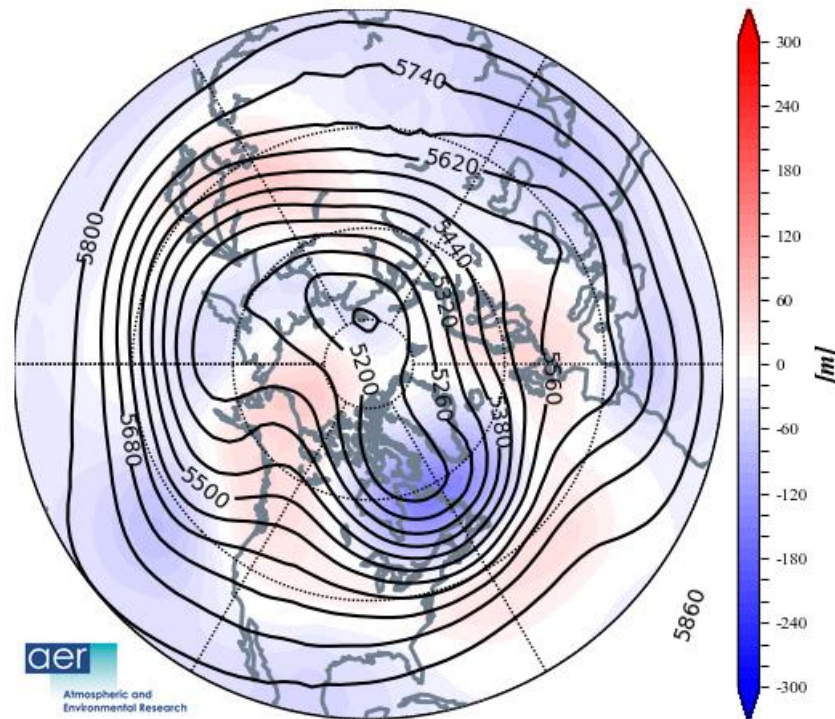


**Figure 13.** (a) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies ( $^{\circ}\text{C}$ ; shading) across the Northern Hemisphere at 00Z 9 March 2020 . (b) Same as (a) except forecasted averaged from 20 – 24 March 2020. The forecasts are from the 00Z 9 March 2020 GFS operational model.

Over the next two weeks, the PV center is predicted to drift from the Eurasian coast towards Canada (**Figure 13**). New ridging and warming are predicted to develop across the northern North Atlantic into Northwest Eurasia related to weak positive WAFz the next week or so (**Figure 13**). The tropospheric pattern is becoming more favorable for triggering positive WAFz pulses that are likely to continue to weaken the stratospheric PV.



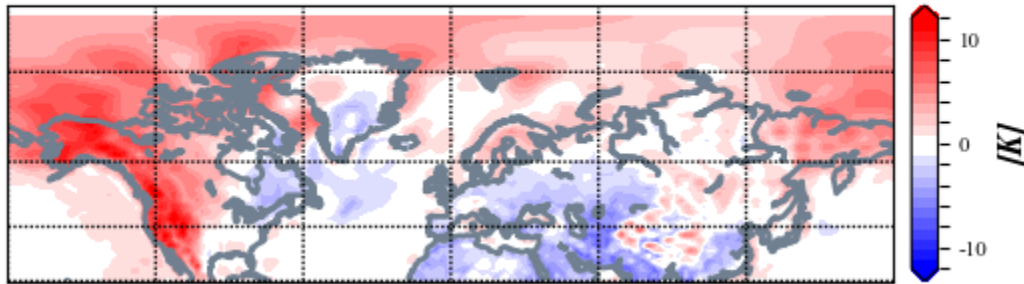
**CFS 500 hPa Forecast Anomaly Apr 2020  
Valid as of 09 Mar 2020**



**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 9 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 and western North America with troughing in Western and Southern Europe into the Eastern Mediterranean and Western Asia, Eastern Siberia and Eastern Canada (**Figure 14**). This pattern favors relatively mild temperatures for Northern Europe, much of East Asia and western North America with seasonable to relatively cold temperatures for Central and Southern Europe, Western and Southern Asia, Eastern Canada and the Northeastern US (**Figure 15**).

**CFS T2m Forecast Anomaly Apr 2020  
Valid as of 09 Mar 2020**

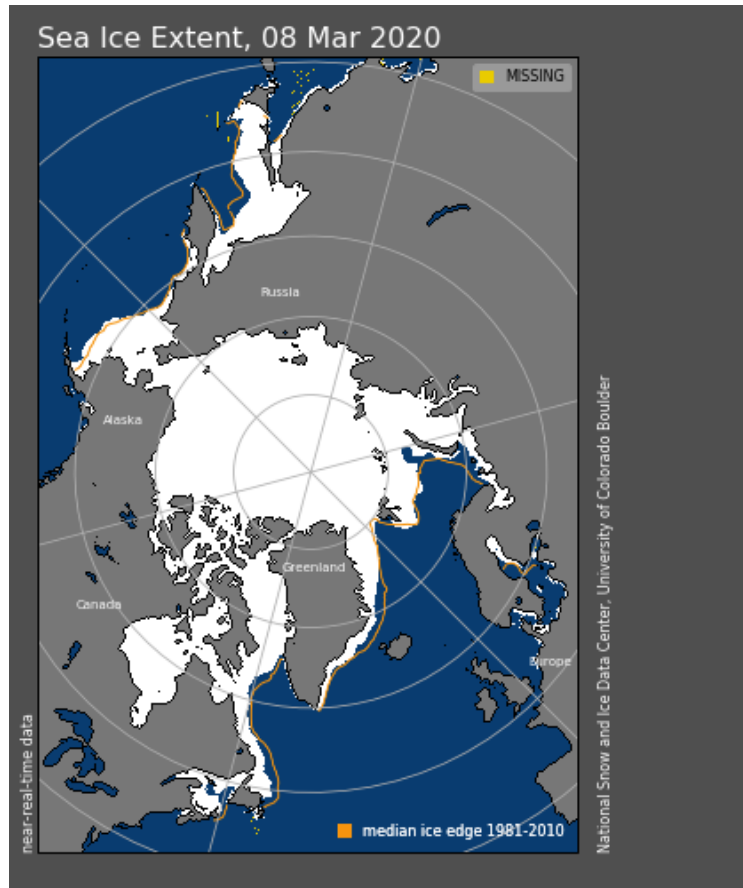


**Figure 15.** Forecasted average surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) across the Northern Hemisphere for April 2020. The forecasts are from the 00Z 9 March 2020 CFS.

*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. The predicted positive AO remains favorable for further sea ice growth, though we are likely close to the seasonal maximum extent in Arctic sea ice. Overall sea ice extent is near normal throughout the Arctic and negative anomalies exist mostly in seas outside of the Arctic.

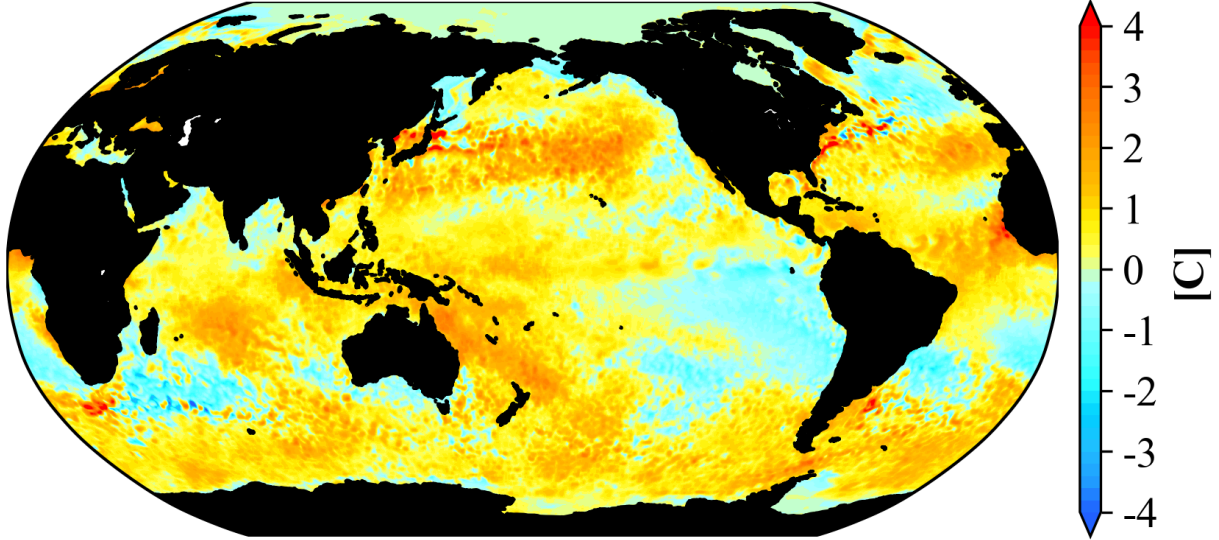


**Figure 16.** a) Observed Arctic sea ice extent on 8 March 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010.

### *SSTs/El Niño/Southern Oscillation*

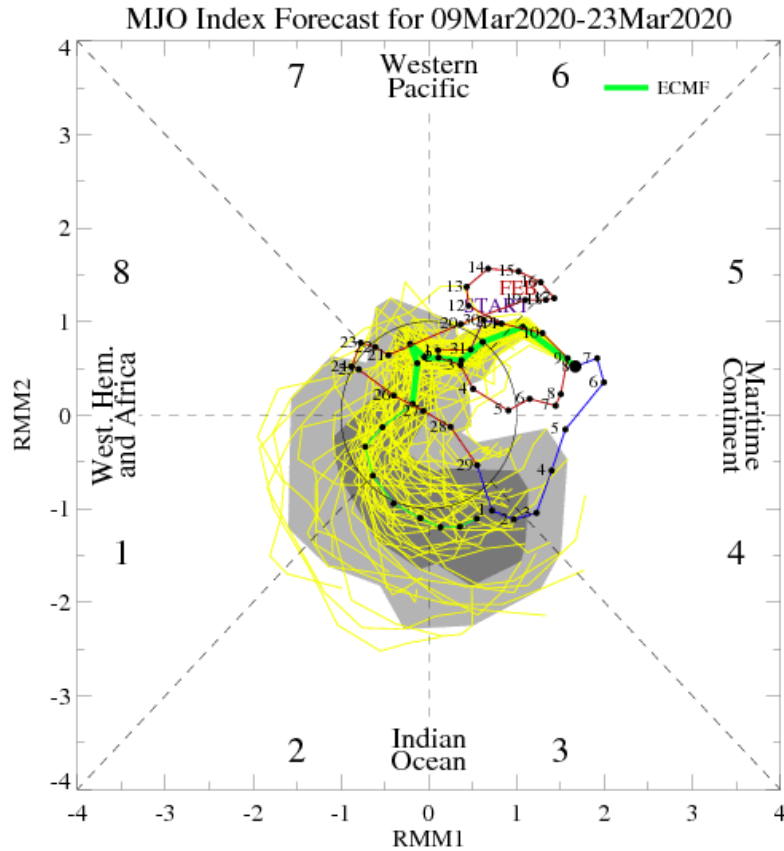
Equatorial Pacific sea surface temperatures (SSTs) anomalies are cooling slightly but neutral El Niño/Southern Oscillation (ENSO) conditions seem most likely this spring (**Figure 17**). Observed SSTs across the NH remain well above normal especially near Alaska and in the Gulf of Alaska and the western North Pacific though below normal SSTs exist regionally especially west of South America. Warm SSTs in the Gulf of Alaska may favor mid-tropospheric ridging in the region.

## SST Anomaly - Week Ending 08 Mar 2020



**Figure 17.** The latest weekly-mean global SST anomalies (ending 8 March 2020). Data from NOAA OI High-Resolution dataset.

Currently Madden Julian Oscillation (MJO) is in phase five (**Figure 18**). The forecasts are for the MJO to weaken to where no phase is favored. MJO phase five favor ridging in the Eastern US and troughing in Alaska. MJO is relatively weak but is likely contributing to the predicted pattern across North America this week.



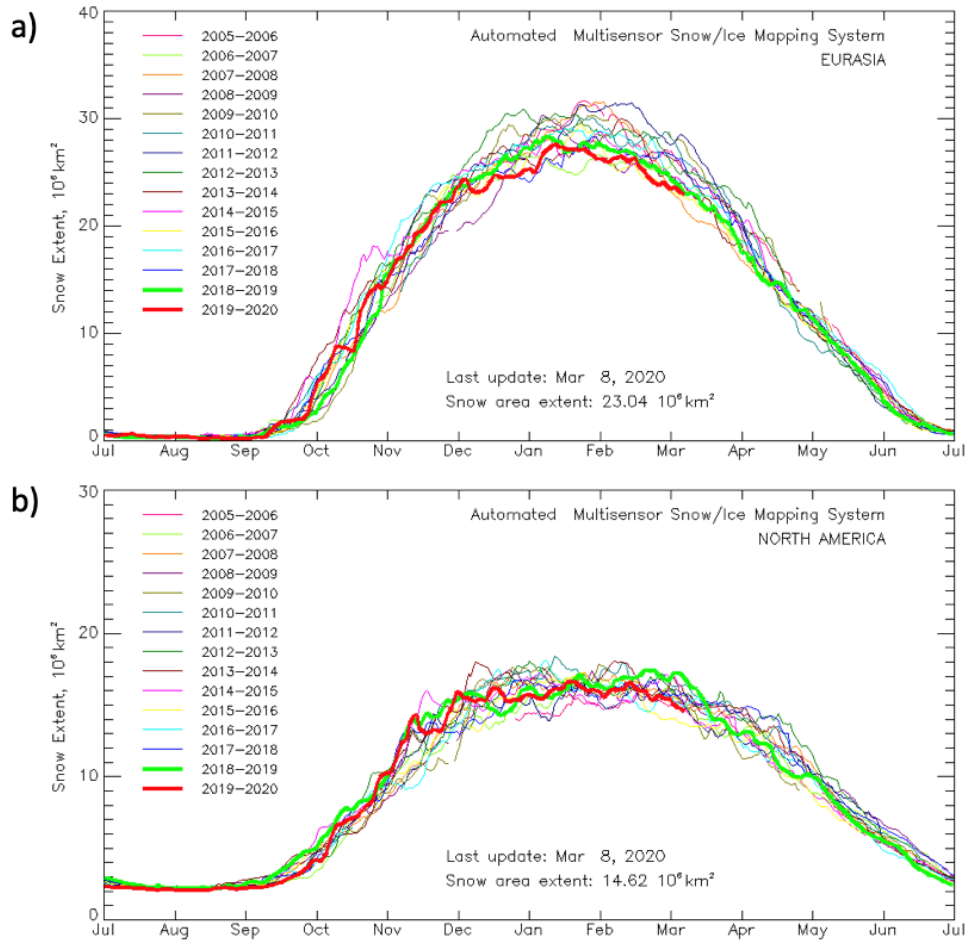
**Figure 18.** Past and forecast values of the MJO index. Forecast values from the 00Z 9 March 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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 (not updated)*

Snow cover declined across Eurasia and is 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 23 February 2020 (not updated). Image source: [https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow\\_extent\\_plots.html](https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html)

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