

# Arctic Oscillation and Polar Vortex Analysis and Forecasts

March 2, 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.
- 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

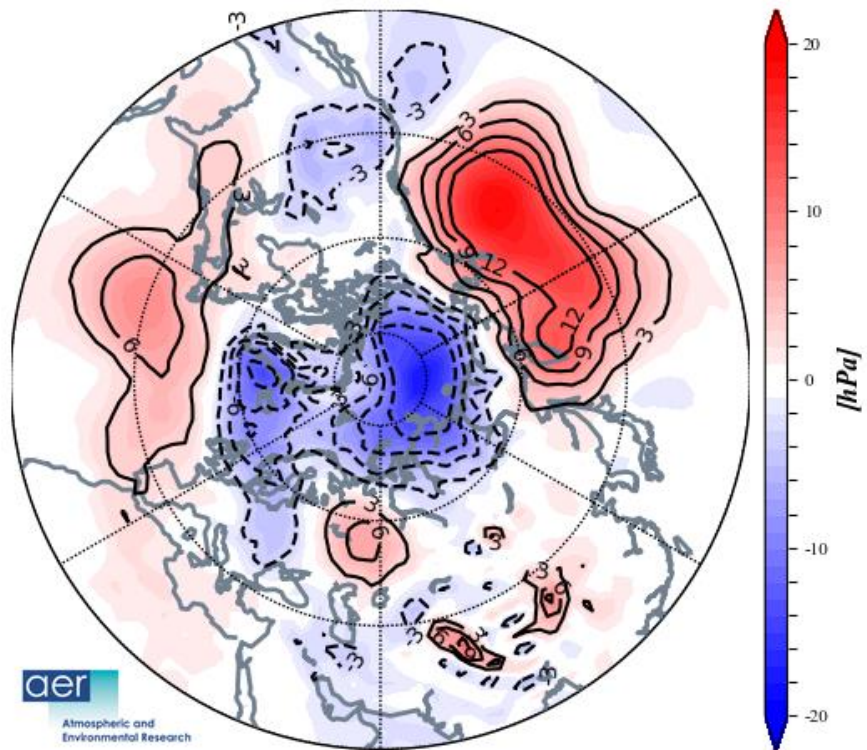
two weeks as height anomalies are predicted to remain mostly negative across Greenland.

- The general circulation pattern over Europe the next ten days or so is troughing/negative geopotential height anomalies across Western/Central Europe with ridging/positive geopotential height anomalies across Southern Europe followed by increasing geopotential heights across the entire continent. This pattern favors normal to below normal temperatures for much of Western and Central Europe including the United Kingdom (UK) with normal to above normal temperatures for Eastern Europe over the next ten days followed by a general warming trend.
- The predicted general pattern for Asia is ridging/positive geopotential height anomalies in Western and Eastern Asia with troughing/negative pressure/geopotential height anomalies beginning in Western Siberia and slowly propagating eastward and deepening. This pattern favors normal to above normal temperatures across much of Asia except for normal to below normal temperatures beginning in Western Siberia and becoming more widespread across Siberia over the next two weeks. 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 across Alaska, much of Canada and into the Eastern United States (US) with ridging/positive geopotential height anomalies across the Western and Central US into the Gulf of Mexico. However, with time, above normal geopotential heights will become more widespread across North America with troughing/negative geopotential height anomalies mostly confined to Alaska. This pattern favors widespread normal to above normal temperatures in Canada and the US with normal to below normal temperatures mostly confined to Alaska and Northern Canada. However, next week some of that colder air could filter out of Alaska into Western Canada.
- In the Impacts section I discuss the possibility of a hemispheric pattern change but any changes to the weather will be slow.

### ***Impacts***

There are some signs that the dominant weather pattern of the winter with strong low pressure in the Barents-Kara Seas and northwestern Eurasia is finally transitioning to one where the center of the low-pressure anomalies is moving to the Beaufort Sea (**Figure i**). This may allow high pressure to build in the Barents Kara Seas, Scandinavia, Urals that is conducive to generating vertical energy transfer from the troposphere to the stratosphere to finally weaken the stratospheric PV and send it the polar stratosphere into the Final Warming (where the PV disappears until the fall). But any changes appear to be happening slowly and any meaningful weakening of the PV appears to be weeks away.

**GFS SLP Forecast Anomaly Mar 2020  
Valid as of 02 Mar 2020**



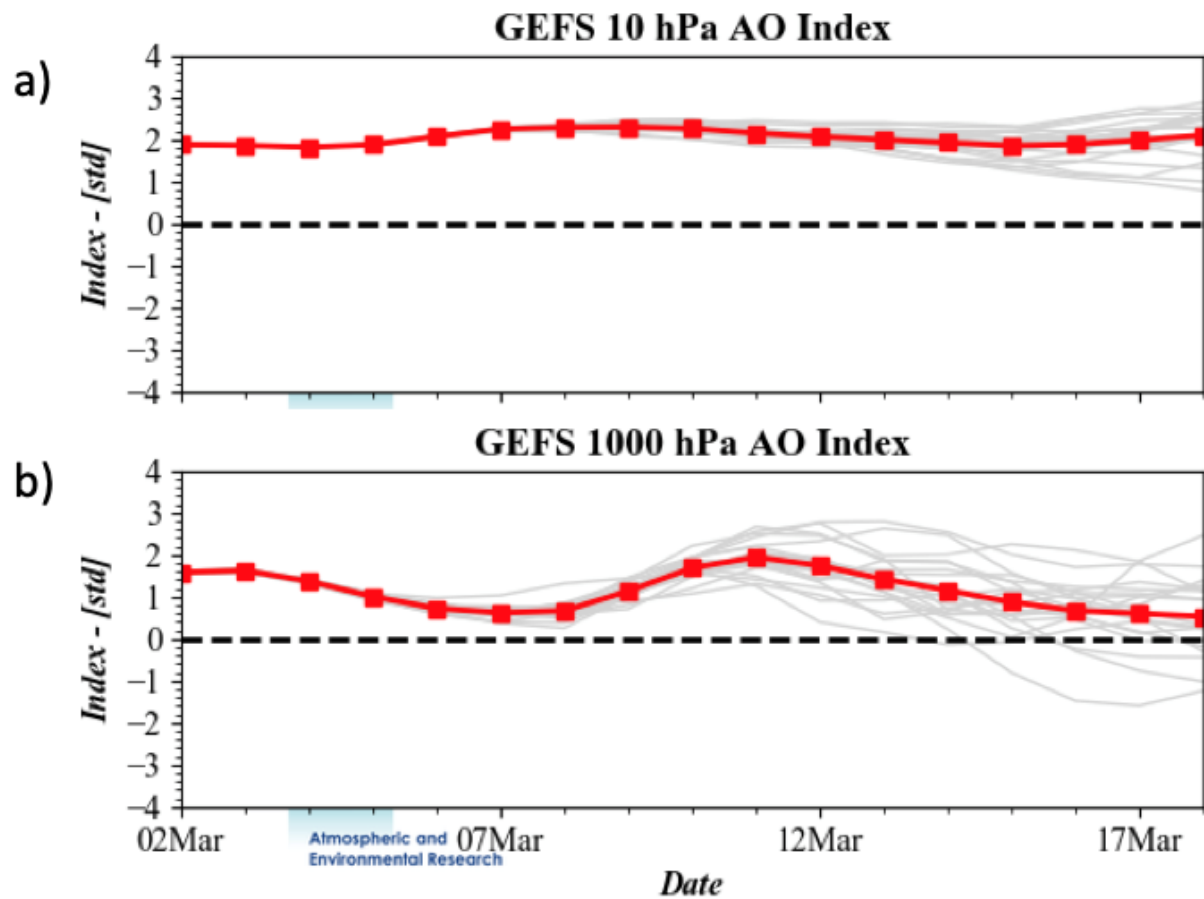
**Figure iv.** Estimate of sea level pressure anomalies for March 2020 from the 02 March 2020 GFS operational.

With the PV remaining strong (currently near record daily strong and defying the seasonal weakening typical of March) and the AO positive into the foreseeable future there is little reason to expect anything more than temporary and regional cooling across the mid-latitude continents. I do think that there is an ongoing PV reflective event that brought some colder weather to the Eastern US and now to Siberia but this seems to a relatively minor event and impacts last on the order from days to a week or two at most and for the Eastern US the cold is already in the past. With below normal snow cover and limited cold air outside of the Arctic, strongly favors a warm spring across the Northern Hemisphere.

*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-

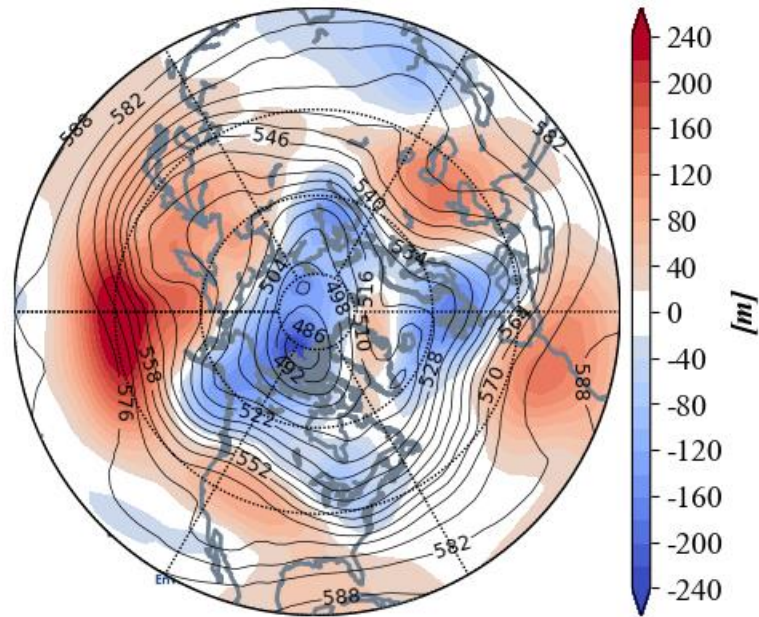
latitudes of the NH (**Figure 2**). And with mostly negative geopotential height anomalies across Greenland and Iceland (**Figure 2**), the NAO is positive as well.



**Figure 1.** (a) The predicted daily-mean AO at 10 hPa from the 00Z 2 March 2020 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 2 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 troughing/negative geopotential height anomalies are predicted for Western Europe with ridging/positive geopotential height anomalies across Eastern Europe (**Figure 2**). This will result in normal to below normal temperatures across Western and Northern Europe including the UK with normal to above normal temperatures in Eastern Europe (**Figure 3**). This week, ridging/positive geopotential height anomalies are predicted to dominate much of Asia with troughing/negative geopotential height anomalies confined to Western and Southeastern Siberia 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 Western and Southern Siberia and the Tibetan Plateau (**Figure 3**).

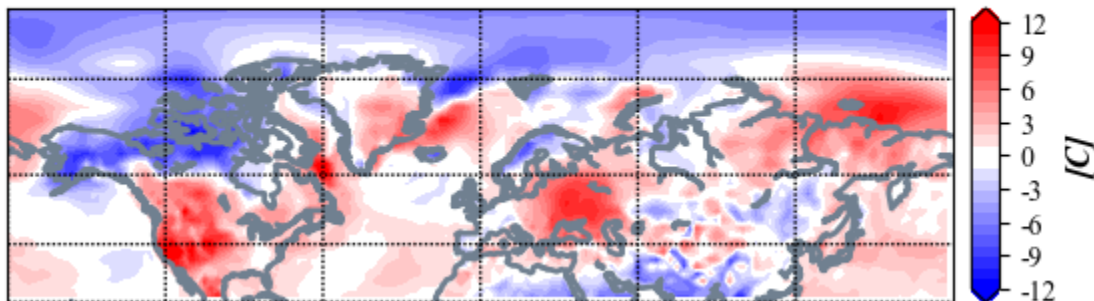
**GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly**  
**INIT: 00Z 03/02/20 FCST: 03/03/20 to 03/07/20**



**Figure 2.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 3 – 7 March 2020. The forecasts are from the 00z 2 March 2020 GFS ensemble.

This week, troughing/negative geopotential height anomalies ridging/positive geopotential height anomalies are predicted to extend from Alaska across much of Canada and into the Eastern US with ridging/positive geopotential height anomalies extending from the Western US across the Central US and into the Gulf of Mexico (**Figure 2**). This is predicted to result in normal to below normal temperatures in Alaska and Northwestern Canada with normal to above normal temperatures across much of Canada and the US (**Figure 3**).

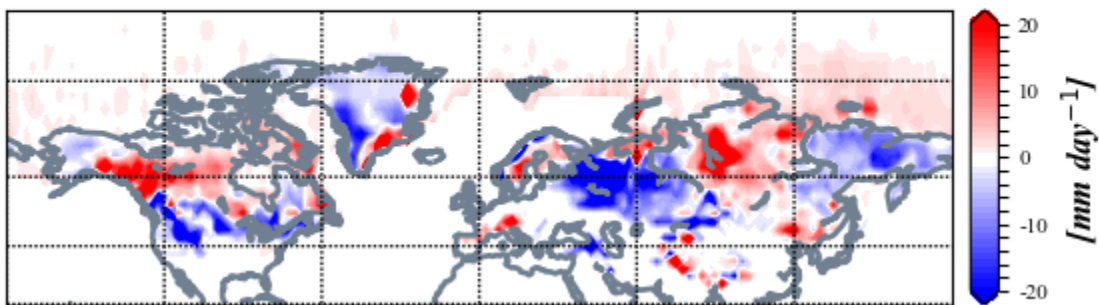
**GEFS 1-5 Day Forecast T2m Anomaly**  
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**Figure 3.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 3 – 7 March 2020. The forecast is from the 00Z 2 March 2020 GFS ensemble.

Trouthing and/or cold temperatures are predicted to bring new snowfall to parts of Siberia, the Tibetan Plateau, Northeast Asia, Scandinavia and possibly the higher elevations of Central and Western Europe (**Figure 4**). Trouthing and/or cold temperatures are predicted to bring new snowfall to Northern Canada (**Figure 4**). Warm temperatures are predicted to result in snowmelt for a large swath of Western Asia, Eastern Siberia, Southern Canada and the Pacific Northwest (**Figure 4**).

**GEFS 1-5 Day Forecast Mean 24-hour Snow Depth Change**  
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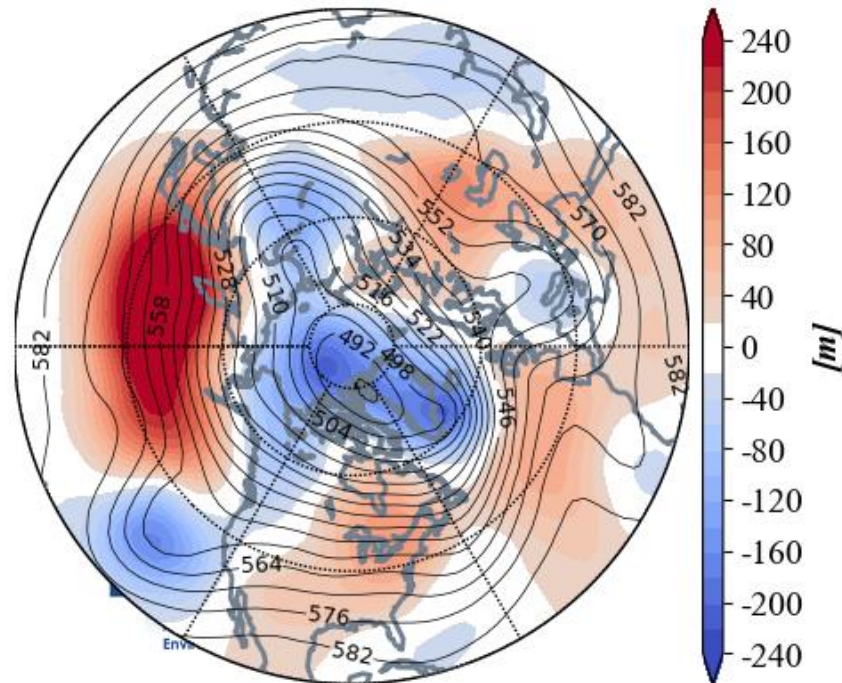
**Figure 4.** Forecasted snowdepth anomalies ( $\text{mm}/\text{day}$ ; shading) from 3 – 7 March 2020. The forecast is from the 00Z 2 March 2020 GFS ensemble.

*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.

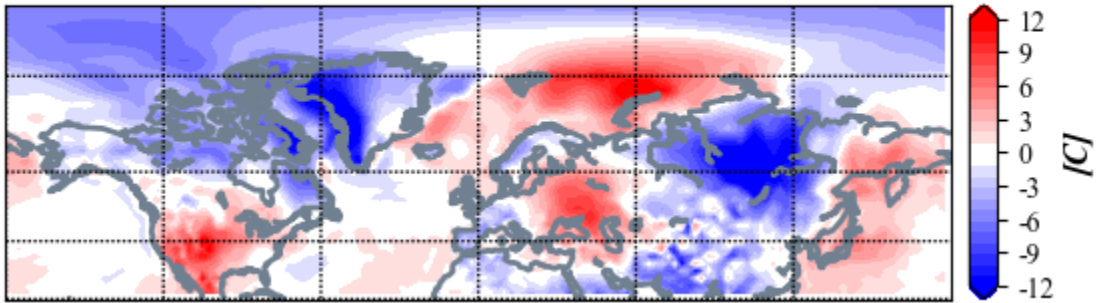
**GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly**  
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**Figure 5.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 8 – 12 March 2020. The forecasts are from the 00z 2 March 2020 GFS ensemble.

Trouching/negative geopotential height anomalies are predicted to stretch across Western Europe with ridging/positive geopotential height anomalies stretched across Eastern Europe this period (**Figure 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 Eastern Europe (**Figure 6**). Persistent ridging/positive geopotential height anomalies are predicted to persist across Western and Eastern Asia with troughing/negative geopotential height anomalies in between across much of Siberia (**Figure 5**). This is predicted to yield normal to above normal temperatures for most of Asia with normal to below temperatures widespread across Siberia (**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, Pakistan and Afghanistan (**Figure 6**).

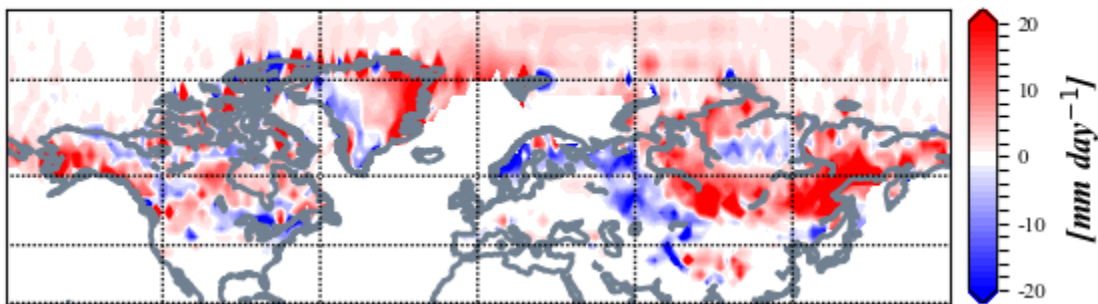
**GEFS 6-10 Day Forecast T2m Anomaly**  
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**Figure 6.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 8 – 12 March 2020. The forecasts are from the 00Z 2 March 2020 GFS ensemble.

Ridging/positive geopotential height anomalies will dominate much of North America with troughing/negative geopotential height anomalies mostly confined to Alaska and the West Coasts of Canada and the US (**Figure 5**). This pattern is predicted to bring normal to below normal temperatures across Alaska, Northern and Western Canada with normal to above normal temperatures across Southeastern Canada and much of the US (**Figure 6**). Northerly flow behind a coastal storm may bring close to seasonable temperatures to the Southeastern US (**Figure 6**).

**GEFS 6-10 Day Forecast Mean 24-hour Snow Depth Change**  
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**Figure 7.** Forecasted snowdepth changes (mm/day; shading) from 8 – 12 March 2020. The forecasts are from the 00Z 2 March 2020 GFS ensemble.

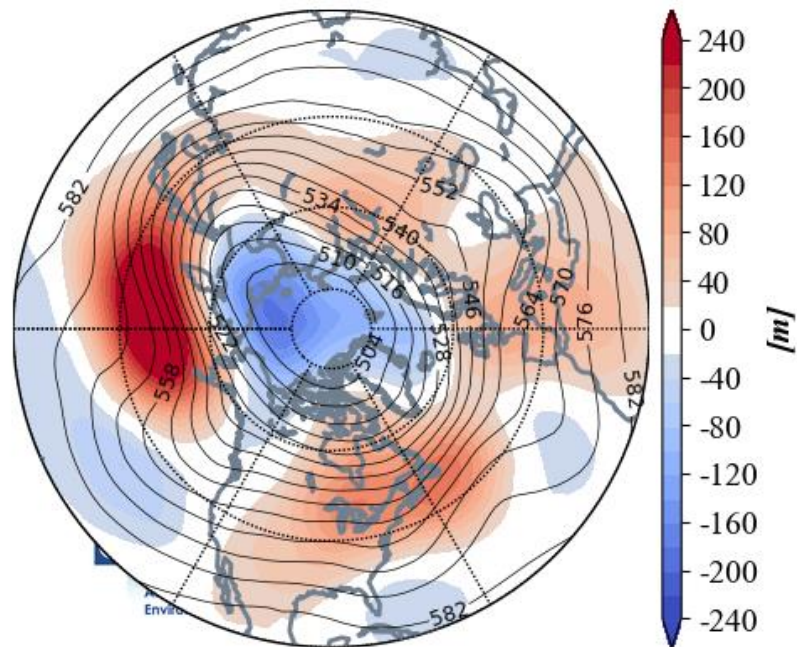
Troughing and/or cold temperatures will support the potential for new snowfall across Northern and Eastern Asia, the Tibetan Plateau, Alaska, and scattered across Canada and the Northwestern US (**Figure 7**). Some snowmelt is predicted in Western Asia, Southeastern Canada and New England (**Figure 7**). Right at the beginning of the period a coastal storm could bring snowfall to New England.



11-15 day

With continued 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 this period (**Figure 1**). With predicted negative pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is likely to remain positive as well.

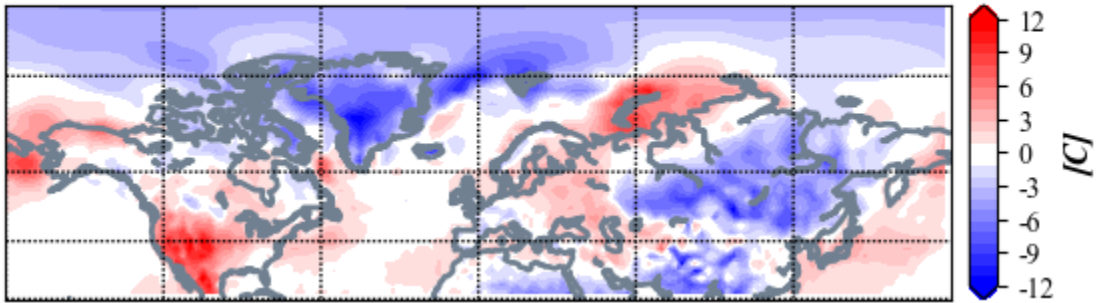
**GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly**  
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**Figure 8.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 13 – 17 March 2020. The forecasts are from the 00z 2 March 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are once again predicted to dominate much of Europe with troughing/negative geopotential height anomalies confined to Northern Scandinavia this period (**Figures 8**). This pattern favors normal to above normal temperatures across most of Europe except for more seasonable temperatures in Western Europe including the UK due to lingering cold temperatures from the previous period (**Figures 9**). Ridging/positive geopotential height anomalies will also once again dominate much of Asia with troughing/negative geopotential height anomalies confined to Central and Eastern Siberia and the northern Indian subcontinent (**Figure 8**). This pattern favors normal to above normal temperatures for Western and Central Asia with normal to below normal temperatures widespread across Siberia and the northern Indian subcontinent (**Figure 9**).

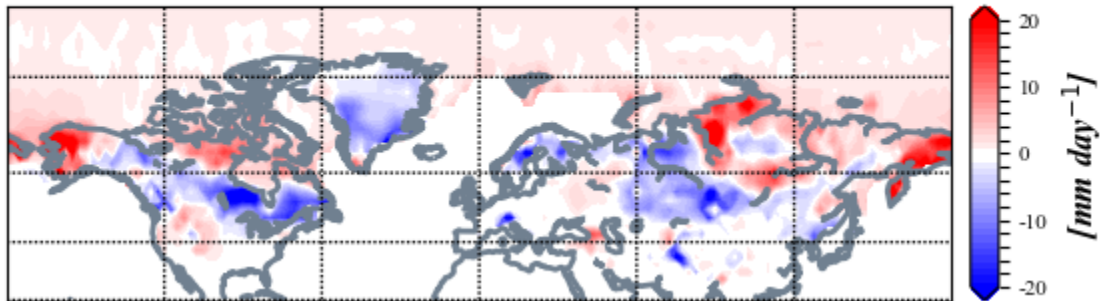
**GEFS 11-15 Day Forecast T2m Anomaly**  
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**Figure 9.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 13 – 17 March 2020. The forecasts are from the 00z 2 March 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to dominate much of North America with troughing/negative geopotential height anomalies confined to Western Alaska and Western Canada (**Figure 8**). This pattern is predicted to favor normal to below normal temperatures across Alaska, Northern and Western Canada with normal to above normal temperatures for Southeastern Canada and much of the US (**Figure 9**).

**GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change**  
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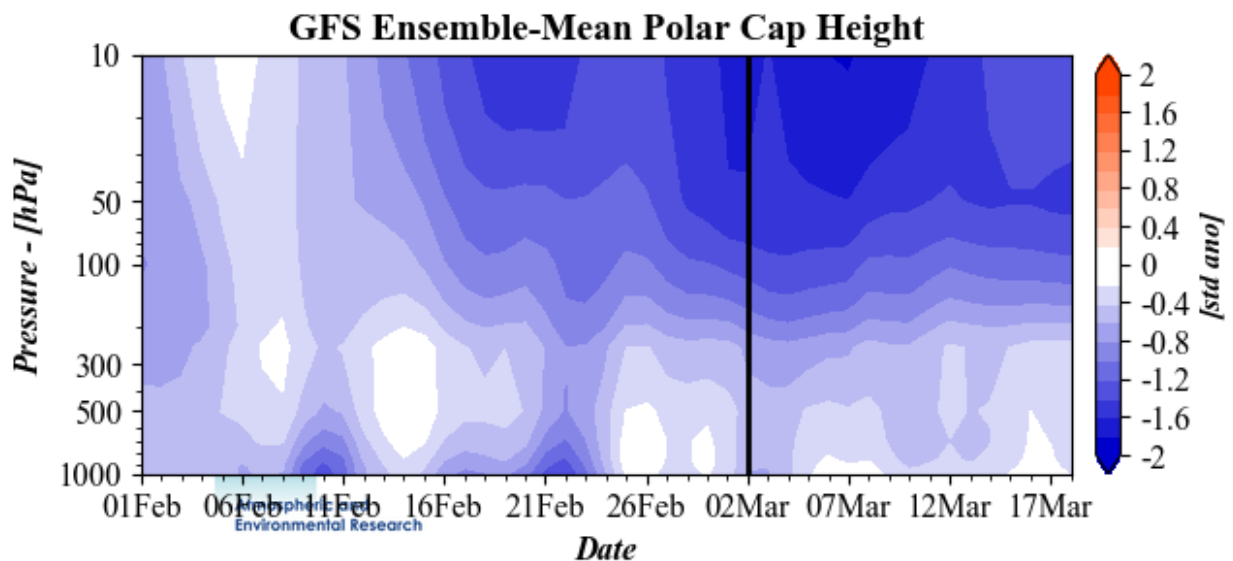
**Figure 10.** Forecasted snow depth changes ( $\text{mm}/\text{day}$ ; shading) from 13 – 17 March 2020. The forecasts are from the 00z 2 March 2020 GFS ensemble.

Troughing and/or cold temperatures could support new snowfall across parts of Northern and Eastern Asia, Turkey and Iran (**Figure 10**). New snowfall is possible across Alaska, Northern Canada and possibly the Western US (**Figure 10**). Snowmelt is possible in Western and Central Asia, Scandinavia, the Alps, Western and Southern Canada (**Figure 10**).

Longer Term

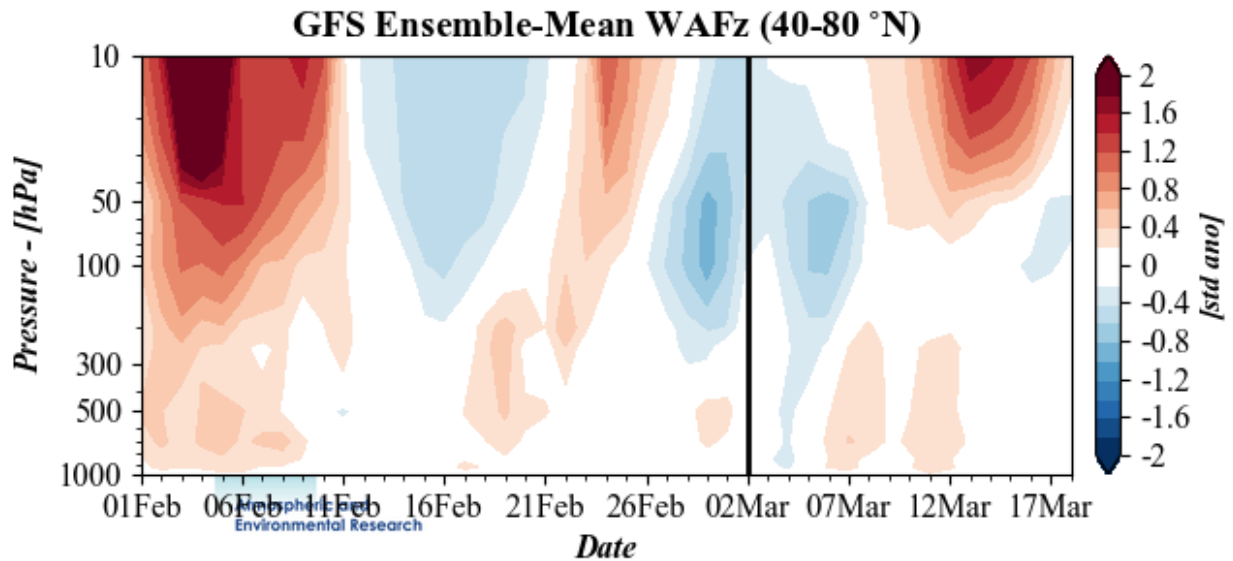
30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to below normal PCHs in both the troposphere and stratosphere (**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 is not as impressive as it was earlier in February.



**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 2 March 2020 GFS ensemble.

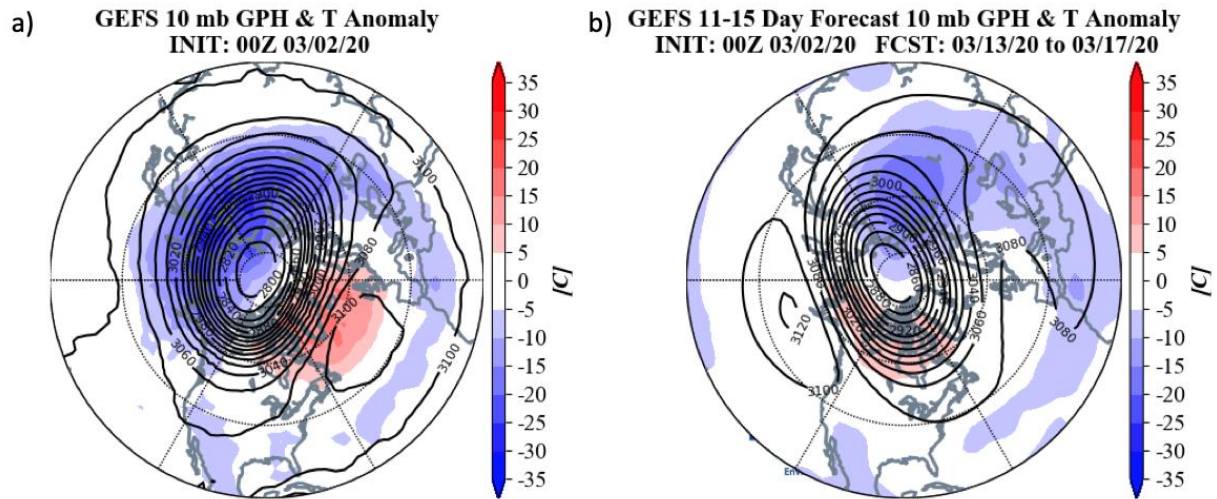
The plot of vertical Wave Activity Flux (WAFz) or poleward heat transport forecast shows negative anomalies over the next week (**Figure 12**). The WAFz anomalies are predicted to turn positive next week (**Figure 12**). If ridging can be sustained across northwest Eurasia WAFz may become more active.



**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 2 March 2020 GFS ensemble.

The stratospheric AO is currently positive (**Figure 1**) consistent with a relatively normal to strong PV (**Figure 1**). The GFS predicts some relatively minor disrupting of the PV mid-March with changes in shape and orientation of the PV but little change is predicted in the overall positive stratospheric AO over the next two weeks.

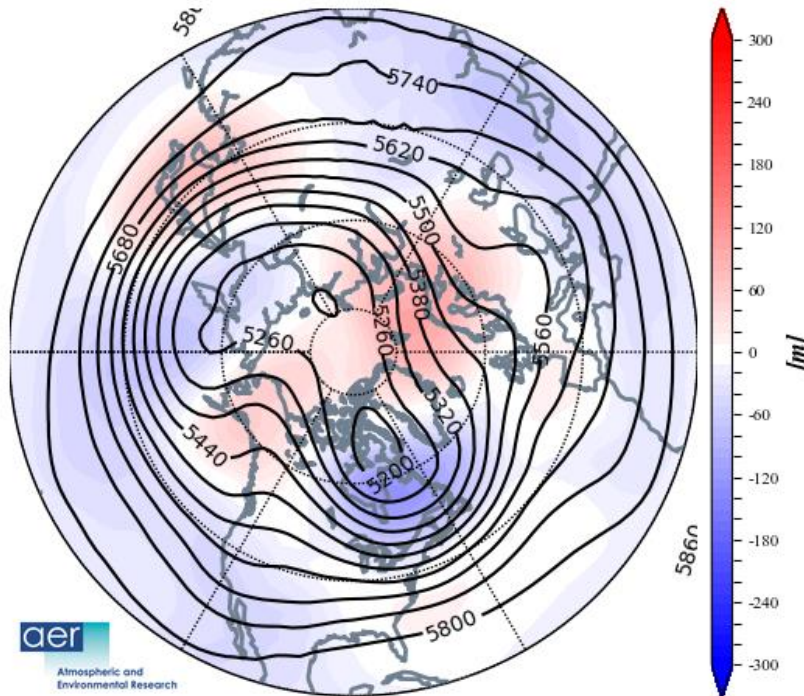
Currently the stratospheric PV is centered near the North Pole (**Figure 13**) with the largest negative temperature departures in the polar stratosphere located over northern Eurasia (**Figure 13**). The PV is elongated along an axis from Western Siberia to Alaska. This is the same axis of the coldest 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 2 March 2020. (b) Same as (a) except forecasted averaged from 13 – 17 March 2020. The forecasts are from the 00Z 2 March 2020 GFS operational model.

Over the next two weeks, the PV center is predicted to remain centered near the North Pole but then is predicted to wobble (**Figure 13**). New ridging and warming are predicted across Alaska and Canada probably related to the positive WAFz next week (**Figure 13**). The PV also is once again elongated but along a new axis from Eastern Siberia to Eastern Canada. This does remind me of a potential PV reflective event. Even though the forecasts are for a milder mid-month in eastern North America, with time the forecasts could become relatively colder.

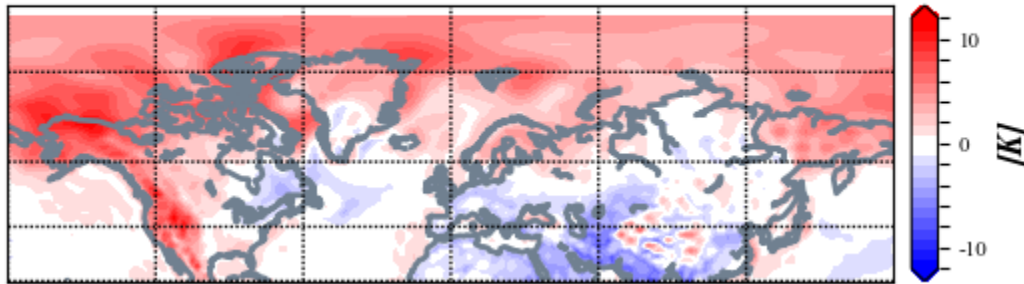
**CFS 500 hPa Forecast Anomaly Apr 2020  
Valid as of 02 Mar 2020**



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

**CFS T2m Forecast Anomaly Apr 2020  
Valid as of 02 Mar 2020**

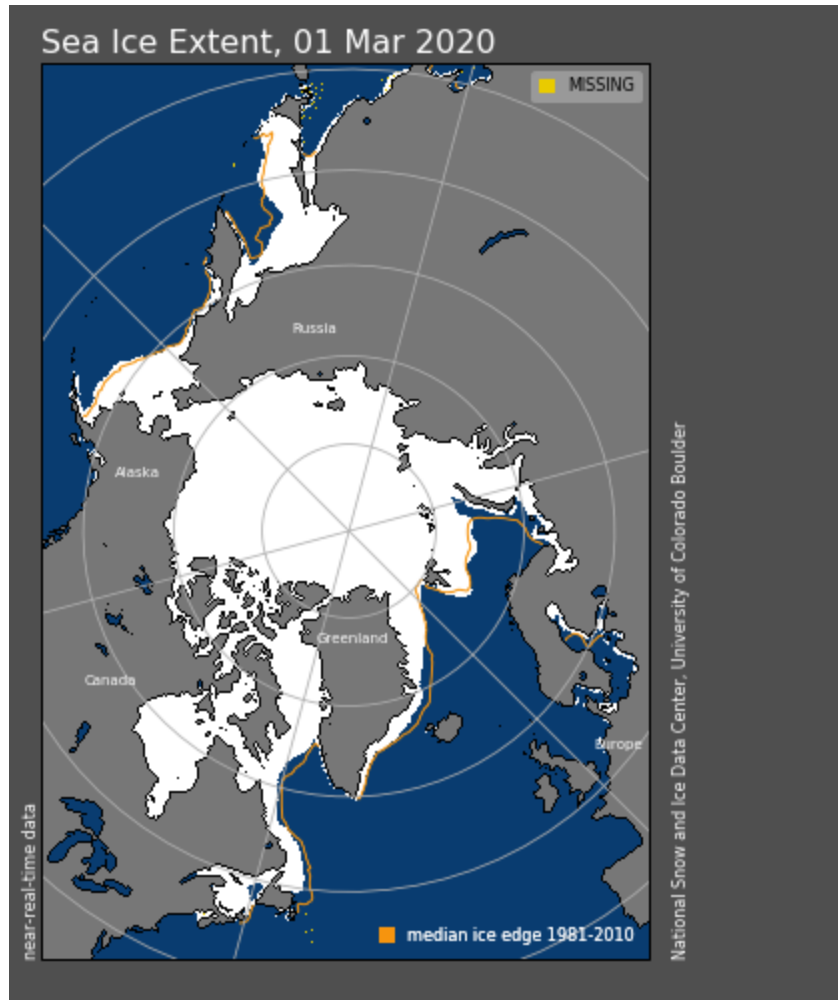


**Figure 15.** Forecasted average surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) across the Northern Hemisphere for April 2020. The forecasts are from the 00Z 2 March 2020 CFS.

*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. Overall sea ice extent is near normal throughout the Arctic and negative anomalies exist mostly in seas outside of the Arctic. Recent research has shown that regional anomalies that are most highly correlated with the strength of the stratospheric PV are across the Barents-Kara seas region where low Arctic sea ice favors a weaker winter PV. In contrast low sea ice in the Chukchi and Bering seas could favor a strong PV.



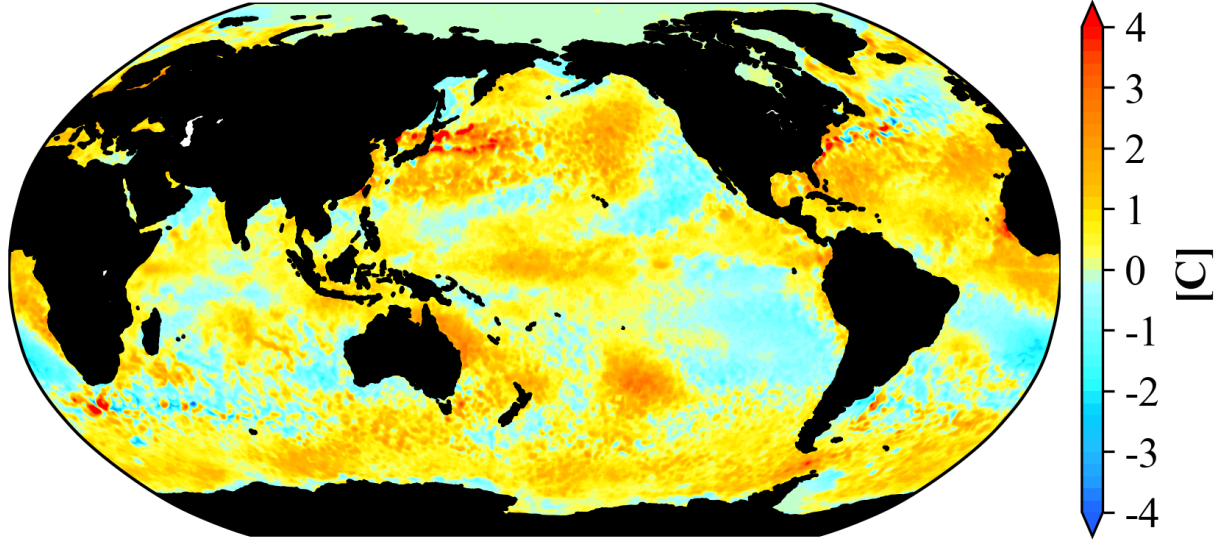
**Figure 16.** a) Observed Arctic sea ice extent on 1 March 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010.

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

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

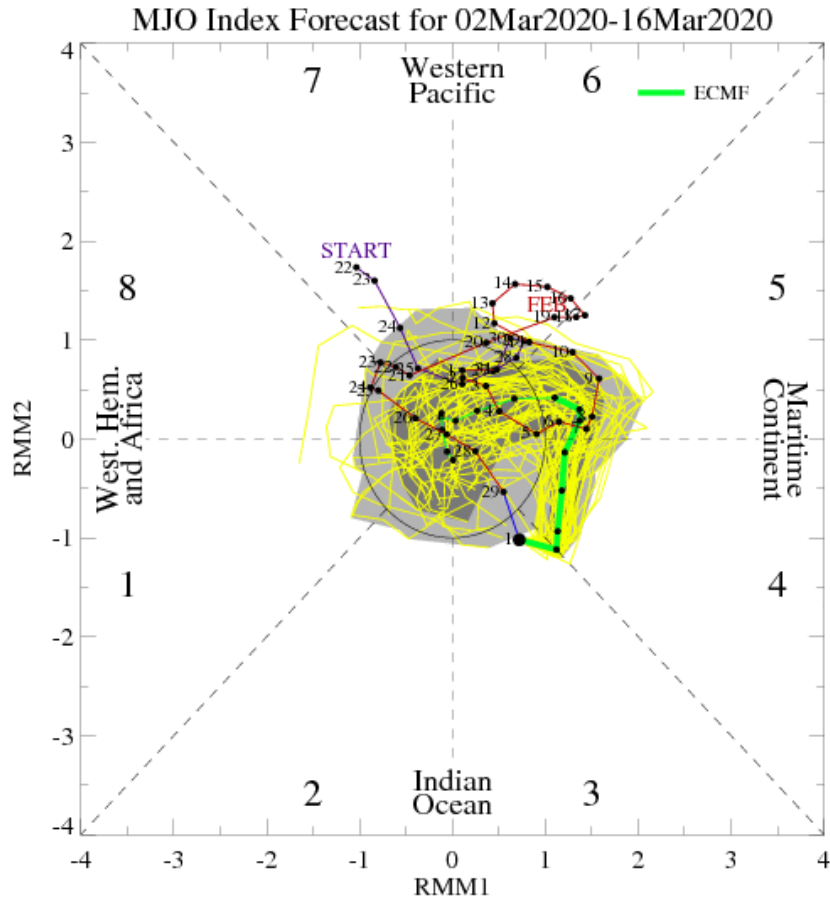


## SST Anomaly - Week Ending 23 Feb 2020



**Figure 17.** The latest weekly-mean global SST anomalies (ending 23 February 2020 not updated). Data from NOAA OI High-Resolution dataset.

Currently Madden Julian Oscillation (MJO) is in phase three (**Figure 18**). The forecasts are for the MJO to quickly move into phases four and five before weakening to where no phase is favored. MJO phases four and 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.

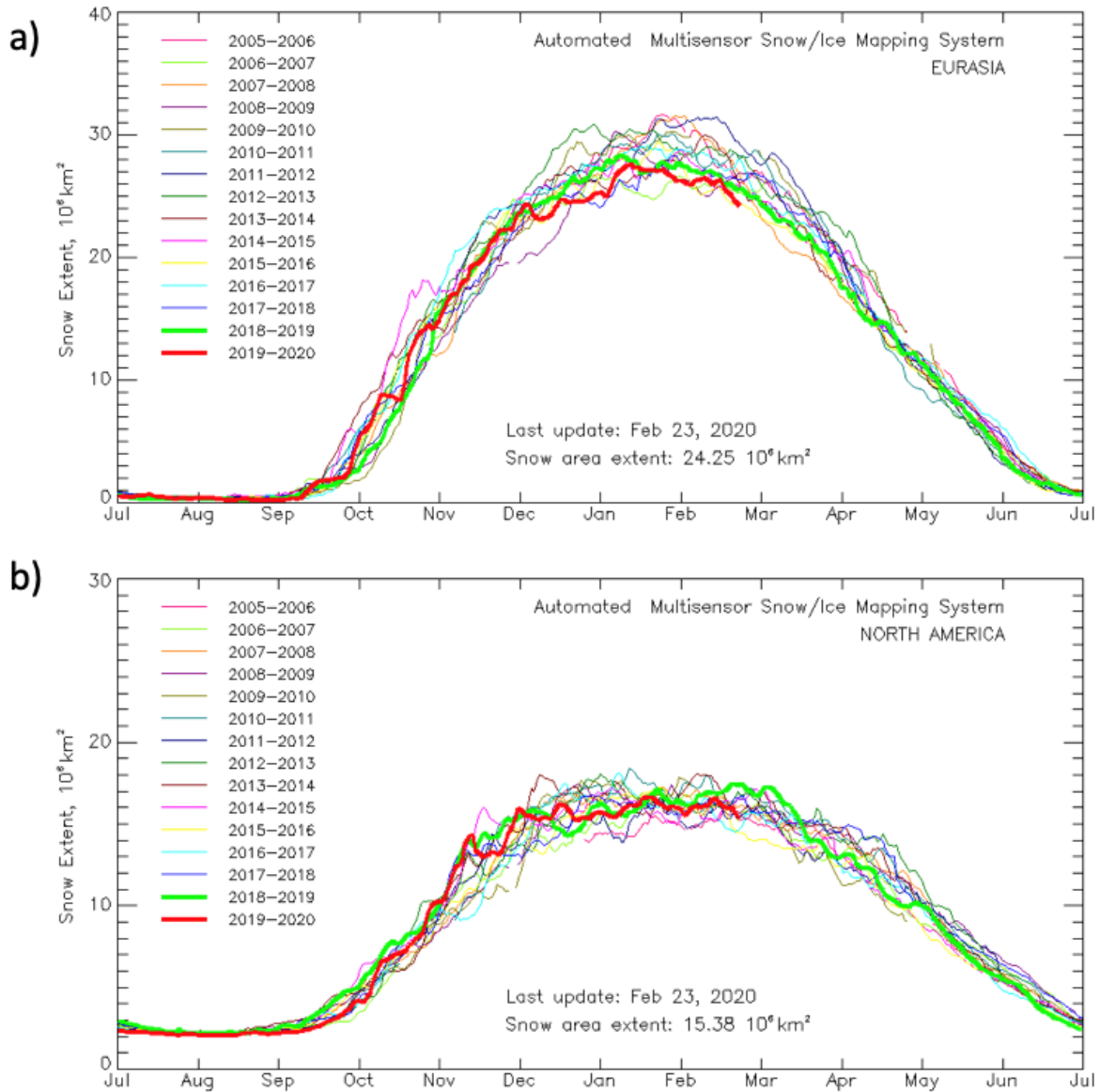


**Figure 18.** Past and forecast values of the MJO index. Forecast values from the 00Z 24 February 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers 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. With a predicted positive AO, I don't expect the snow cover to advance much in the coming week. 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 but remains near decadal means. Snow is predicted to remain fairly steady in the coming week. If the melting accelerates this could contribute to a warm spring.