

Arctic Oscillation and Polar Vortex Analysis and Forecasts

February 17, 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 strongly positive and is predicted to remain positive the next two weeks but is not predicted to be as strongly positive 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 over the next

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

- The general circulation pattern over Europe the next two weeks is troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height anomalies across Southern Europe forcing a mild, westerly, maritime flow of air across the continent. The high heights and/or westerly flow of maritime air favor above normal temperatures for much of Europe including the United Kingdom (UK) over the next two weeks. One possible exception is across Northern Scandinavia and possibly the northern British Isles as low/negative geopotential height anomalies result in normal to below normal temperatures week two.
- The predicted general pattern for Asia is an omega block pattern with ridging/positive geopotential height anomalies in Central Asia sandwiched between troughing/negative pressure/geopotential height anomalies on the edges in Western and Eastern Asia. This pattern favors normal to above normal temperatures across much of Asia except for normal to below normal temperatures in Eastern Siberia with some of that cold air bleeding into Northeastern Asia for the next two weeks.
- The predicted pattern for North America this week is ridging/positive geopotential height anomalies anchored over the Gulf of Alaska with troughing/negative geopotential height anomalies extending from Hudson Bay southwestward into the Western United States (US) with more ridging/positive geopotential height anomalies in the Eastern US. This pattern favors normal to below normal temperatures in Eastern Canada and the Northern and Western US with normal to above normal temperatures in Alaska and the Eastern US. However, a trough in the Western US is predicted to slide eastward with time while deepening in the Eastern US. This will favor cold temperatures in eastern North America with normal to above normal temperatures in Western North America including Alaska.
- In the Impacts section I discuss the same old, same old - the strong polar vortex (PV).

Impacts

I know I am dating myself but what comes to mind as I sit down to write another blog is "Tune in tomorrow—same Bat-time, same Bat-channel!" I could just as easily write tune in next week same positive AO same strong PV. The AO remains positive and the PV remains strong both even flirting with records with no real change in the foreseeable future (**Figures 1 & 11**). I did check historical winter polar cap geopotential height anomalies (PCHs), and the stretch of universally cold tropospheric and stratospheric PCHs that we observed this winter is extremely rare. The closest that I could find is the winter of 1975/76. When cold PCHs dominated the stratosphere and troposphere right through the end of March. In general, I don't like using data before 1979 but I could not find anything analogous since 1979 with 1989/90 being the closest. Though in

February 1990 there was a sudden stratospheric warming (see **Figure i**). So, there is precedent, though rare, for the positive AO/strong PV to continue right through March.

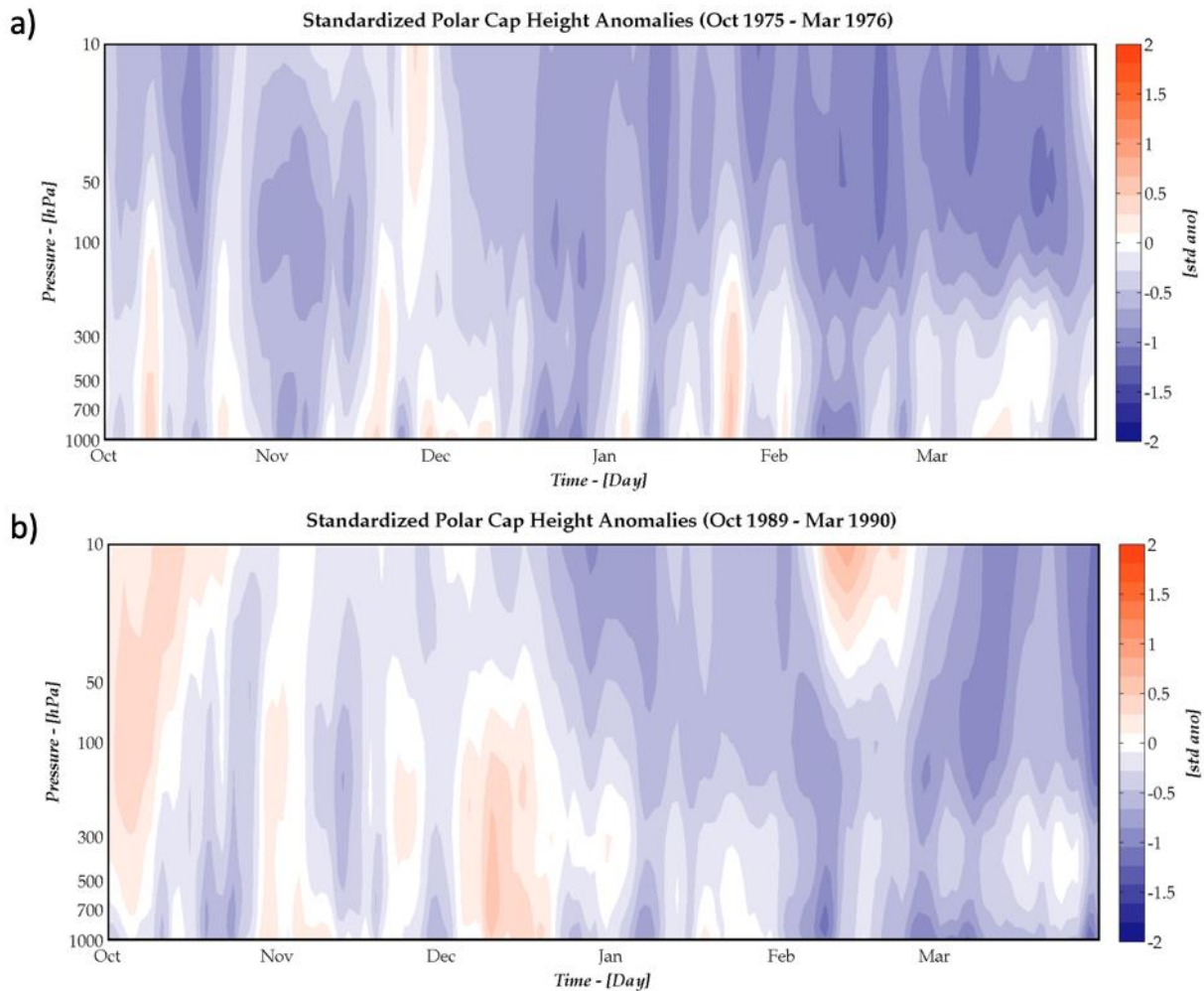


Figure i. a) Observed daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies from October 1, 1975 through March 31, 1976. b) Observed daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies from October 1, 1989 through March 31, 1990.

There are signs that the positive AO, though not a reversal, will weaken as positive geopotential height anomalies try to push towards the Arctic from the Gulf of Alaska. This will be sufficient to knock the AO out of record territory but for now the AO seems to remain safely positive. And with no predicted ridging/blocking predicted in the North Atlantic side of the Arctic, it is hard for me to envision any meaningful weakening of the PV in the foreseeable future. In the Wave Activity Flux (WAFz) or poleward heat transport forecast (**Figure 12**) the positive anomaly quickly followed by a

negative anomaly reminds me of the signature of a reflective PV event that favors cold temperatures in eastern Northern America. It is a relatively minor event but could be contributing to the predicted cold temperatures in eastern North America for early March while Europe remains mild. Though the cold temperatures related to a PV reflective event is relatively short-lived, typically a week or less.

Interestingly, sea ice has retreated in the Barents-Kara Seas this week likely in response to the strong North Atlantic storms. This could be more favorable for building high pressure in the region but more likely it is too little too late. Hard for me to see how Europe breaks out of the current mild pattern. Predicted building ridging in western North America will likely drive cold air into the Eastern US. If snow cover can accompany the cold temperatures the two can feedback on each other and a cold March is possible in the Eastern US. However, my attitude for now is skeptical of any meaningful pattern change and more of the same (positive AO, strong PV) seems to be the most logical expectation.

1-5 day

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

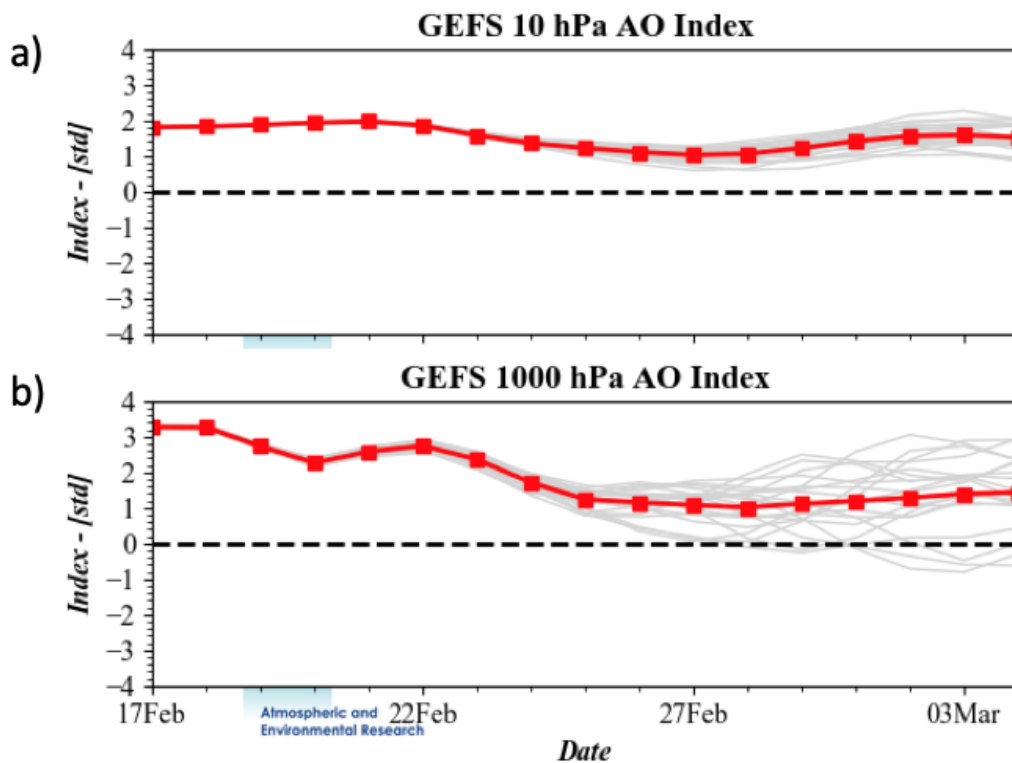


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 17 February 2020 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 17 February 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height across Southern Europe are predicted to force a westerly flow of maritime, relatively mild air across Europe (**Figure 2**). This will result in normal to above normal temperatures across much of Europe including the UK (**Figure 3**). This week, ridging/positive geopotential height anomalies are predicted to dominate Southern and Central Asia with troughing/negative geopotential height anomalies confined to Northwest and Northeast Asia (**Figure 2**). This pattern favors normal to above normal temperatures across most of Asia with normal to below normal temperatures confined to Eastern Siberia (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 02/17/20 FCST: 02/18/20 to 02/22/20

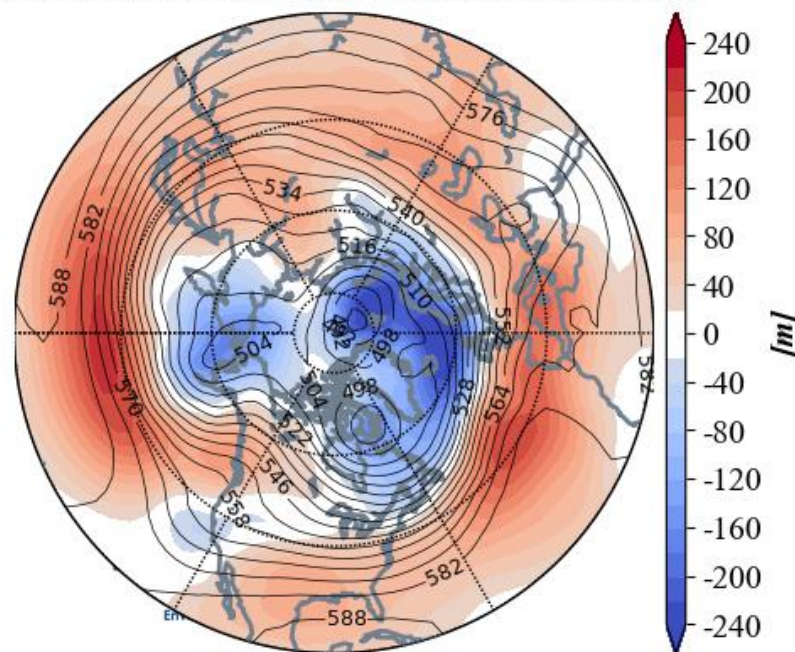


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 18 – 22 February 2020. The forecasts are from the 00z 17 February 2020 GFS ensemble.

This week, ridging/positive geopotential height anomalies in the Gulf of Alaska and Western Canada will force downstream troughing/negative geopotential height anomalies across Eastern Canada that extends southwestward into the Western US with more ridging/positive geopotential height anomalies in the Eastern US (**Figure**

2). This is predicted to result in normal to below normal temperatures in Eastern Canada and the Northern and Western US with normal to above normal temperatures across Alaska, Northwestern Canada and the Southern US (**Figure 3**).

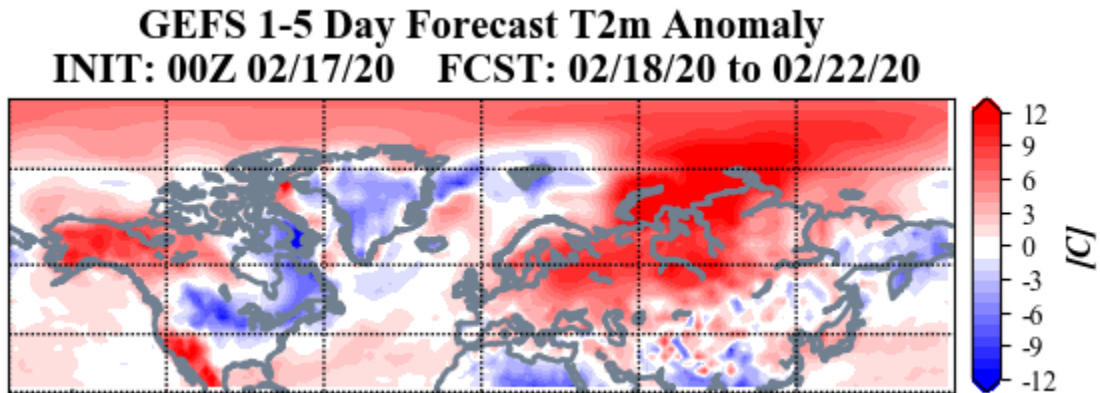


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 18 – 22 February 2020. The forecast is from the 00Z 17 February 2020 GFS ensemble.

Trouthing and/or cold temperatures are predicted to bring new snowfall across Northern and Eastern Asia (**Figure 4**). Trouthing and cold temperatures are predicted to bring new snowfall to western Alaska, Eastern Canada and possibly the US Central Plains (**Figure 4**). Warm temperatures are predicted to result in snowmelt for a large swath of Western Asia, Scandinavia, Western Canada and the Pacific Northwest (**Figure 4**).

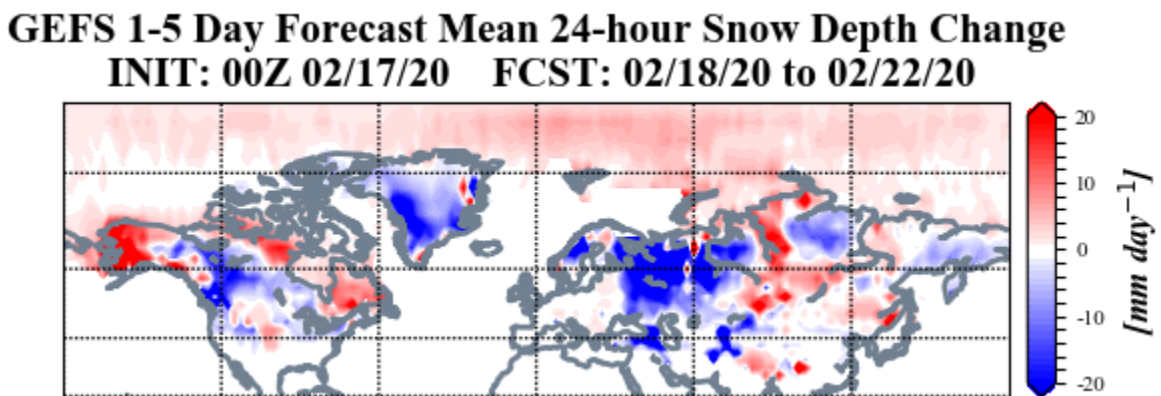


Figure 4. Forecasted snowdepth anomalies (mm/day ; shading) from 18 – 22 February 2020. The forecast is from the 00Z 10 February 2020 GFS ensemble.

Mid-Term

GEFS 6-10 Day Forecast T2m Anomaly
INIT: 00Z 02/17/20 FCST: 02/23/20 to 02/27/20

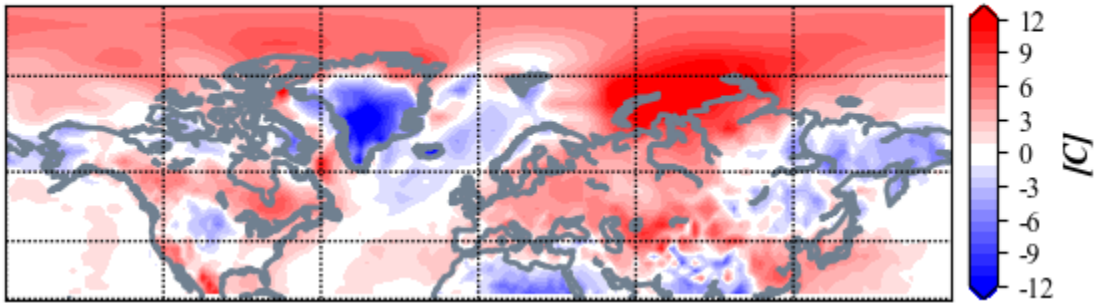


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 23 – 27 February 2020. The forecasts are from the 00Z 17 February 2020 GFS ensemble.

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

GEFS 6-10 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 02/17/20 FCST: 02/23/20 to 02/27/20

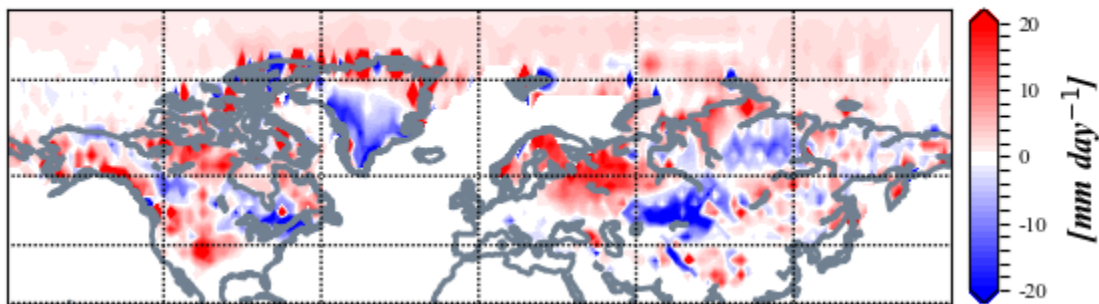


Figure 7. Forecasted snowdepth changes (mm/day ; shading) from 23 – 27 February 2020. The forecasts are from the 00Z 17 February 2020 GFS ensemble.

Troughing and/or cold temperatures will support the potential for new snowfall across Northwestern Asia, Scandinavia, the Baltic States, the Tibetan Plateau, possibly parts of East Asia, Alaska, the Canadian West Coast, Northern and Eastern Canada and the Western US (**Figure 7**). Some snowmelt is predicted in Central Asia, Southeastern Canadian and New England (**Figure 7**).

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, though not as strong (**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
INIT: 00Z 02/17/20 FCST: 02/28/20 to 03/03/20

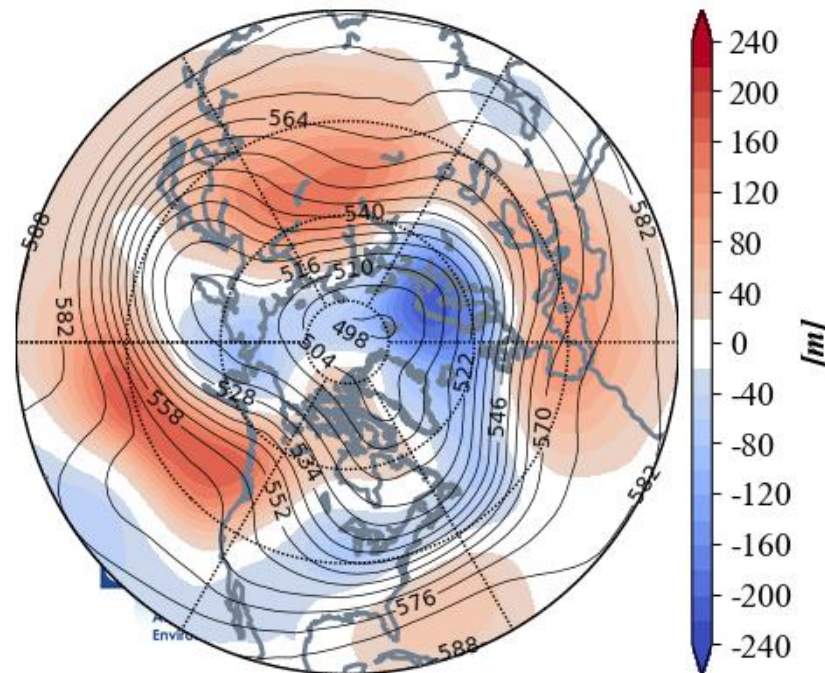


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 28 February – 3 March 2020. The forecasts are from the 00z 17 February 2020 GFS ensemble.

Ridging/positive geopotential height anomalies will dominate Southern Europe with troughing/negative geopotential height anomalies across Northern Europe this period (**Figures 8**). The strong pressure gradient across the continent will favor a mild westerly flow of air with normal to above normal temperatures across much of Europe including England (**Figures 9**). Low heights could result in normal to below normal temperatures for the northern British Isles and northern Scandinavia (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to dominate much of Asia with troughing/negative geopotential height anomalies persisting in Northwest Asia and Eastern Siberia (**Figure 8**). This pattern favors normal to above normal temperatures

widespread across Asia with normal to below normal temperatures confined to Eastern Siberia and parts of Northeast Asia (**Figure 9**). Predicted regionalized troughing/negative geopotential height anomalies in the Persian Gulf region (**Figure 8**) could result in normal to below normal temperatures for Saudi Arabia and other Persian Gulf countries (**Figure 9**).

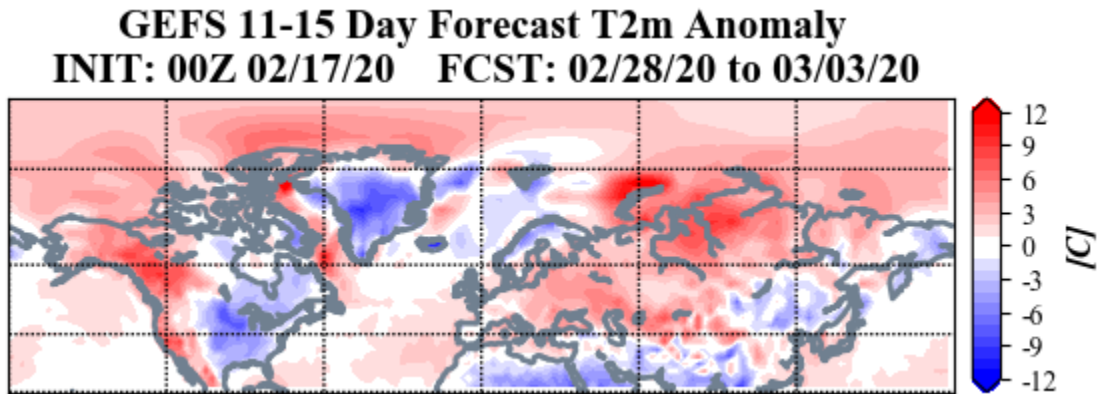


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 28 February – 3 March 2020. The forecasts are from the 00z 17 February 2020 GFS ensemble.

The troughing/negative geopotential height anomalies in the Western US from the previous period is predicted to slide east into eastern North America and deepen with ridging/positive geopotential height anomalies following in its wake across western North America (**Figure 8**). This pattern is predicted to favor normal to above normal temperatures across Alaska, Western Canada, the Western US and Florida with normal to above normal temperatures for Eastern Canada and the Eastern US (**Figure 9**).

GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 02/17/20 FCST: 02/28/20 to 03/03/20

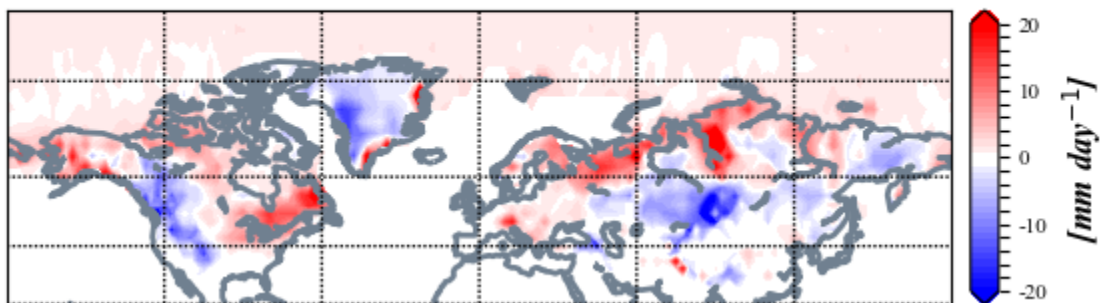


Figure 10. Forecasted snow depth changes (mm/day ; shading) from 28 February – 3 March 2020. The forecasts are from the 00z 17 February 2020 GFS ensemble.

No strong signals are evident but troughing and/or cold temperatures could support new snowfall across much of Northern Asia, Scandinavia, the Alps and Eastern Europe (**Figure 10**). New snowfall is possible across Alaska, Northern and Eastern Canada and possibly the Northeastern US (**Figure 10**). Some snowmelt is possible in Western and Central Asia, Western Canada and the Western US (**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 due to a normal to strong PV since December that coupled to the troposphere for much of January, early February and is predicted to persist for the foreseeable future (**Figure 11**). The predicted cold tropospheric PCHs are consistent with a predicted positive surface AO (**Figure 1**). The prediction of another possible record positive surface AO this weekend is due to another downward propagation of cold PCHs from the strong stratospheric PV.

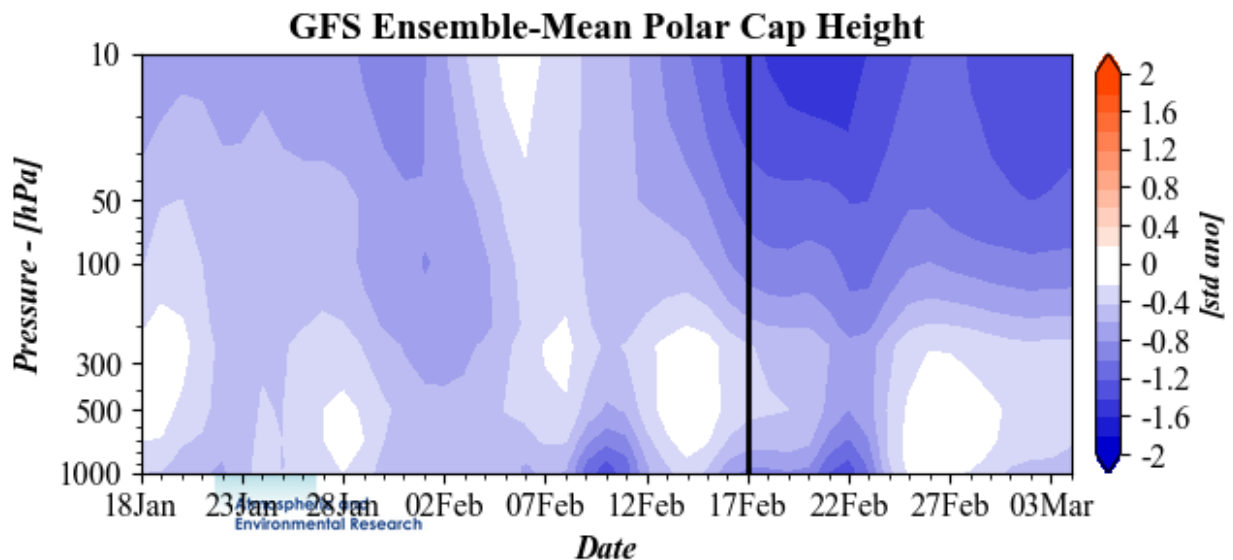


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 17 February 2020 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport forecast shows a relatively quiet two weeks (**Figure 12**). The negative WAFz anomalies this week will support a strengthening of the stratospheric PV to near record strength for the date this

week. There are no significant signs of a meaningful PV disruption through early March (Figure 12).

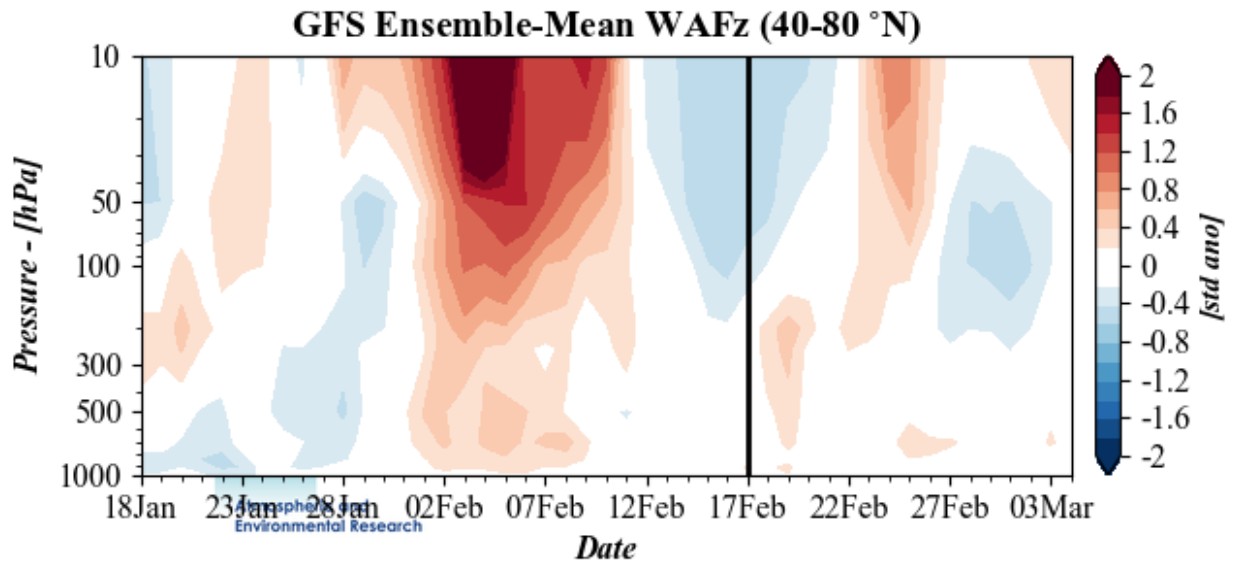


Figure 12. Observed and predicted daily vertical component of the wave activity W_{ux} (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 17 February 2020 GFS ensemble.

The stratospheric AO is currently positive (Figure 1) consistent with a relatively normal to strong PV (Figure 1). The GFS predicts some weakening during the last few days of February related to a small positive WAFz pulse but then predicts the stratospheric PV to strengthen again in early March.

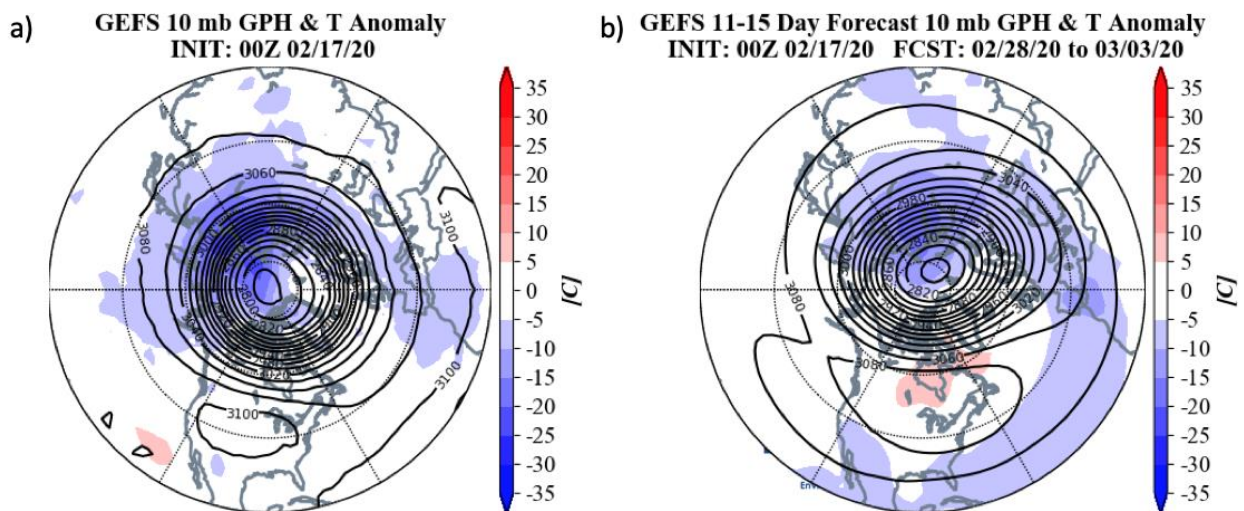


Figure 13. (a) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere at 00Z 17 February 2020. (b) Same as (a) except forecasted averaged from 28 February – 3 March 2020. The forecasts are from the 00Z 17 February 2020 GFS operational model.

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 circular in shape indicative of a strong, quiet stratospheric PV.

Over the next two weeks, the PV center is predicted to remain centered near the North Pole but then is predicted to drift towards the Barents-Kara Seas in early March (**Figure 13**). Some ridging and warming are predicted across Canada probably related to the weak, positive WAFz pulse at the end of February (**Figure 13**). A strong PV favors a cold Arctic and relatively mild temperatures widespread across the NH mid-latitude continents.

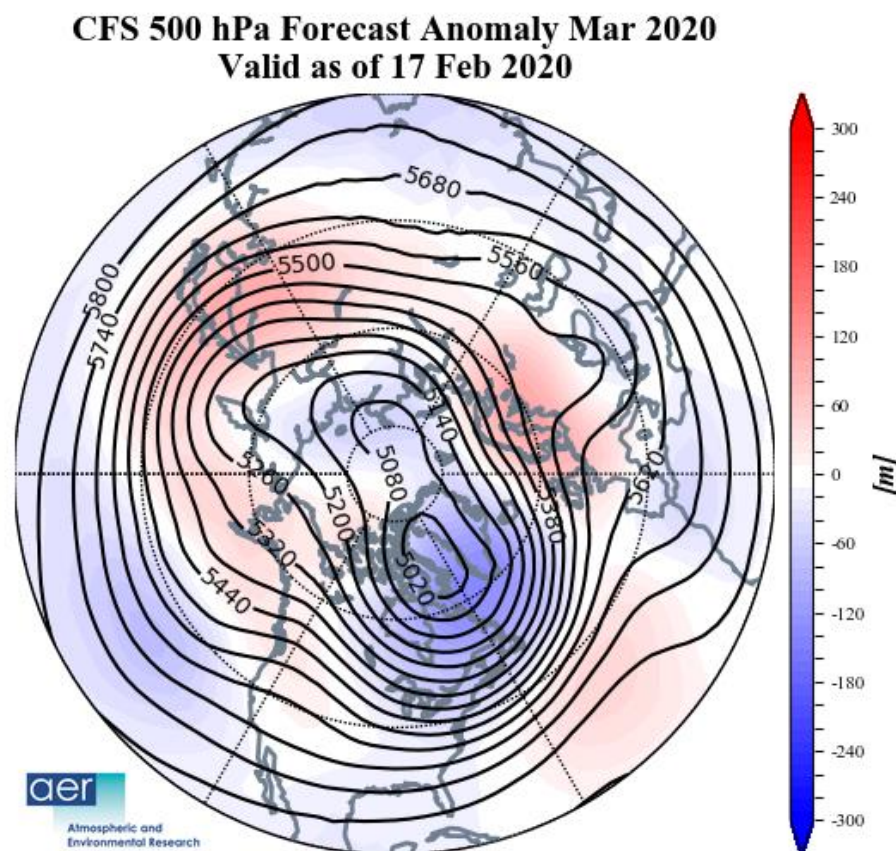


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for March 2020. The forecasts are from the 00Z 17 February 2020 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) forecast for March from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging across Europe, the western North Pacific and Alaska with troughing in Western Asia into the Eastern Mediterranean, Eastern Siberia, the eastern North Pacific and Eastern Canada into the Eastern US (**Figure 14**). This pattern favors relatively mild temperatures for Europe, Asia, Alaska, Western Canada and the Western US with seasonable to relatively cold temperatures for the Middle East, Eastern Canada and the Eastern US (**Figure 15**). Though the forecast has been showing some consistency, I have low confidence in the forecast.

CFS T2m Forecast Anomaly Mar 2020 Valid as of 17 Feb 2020

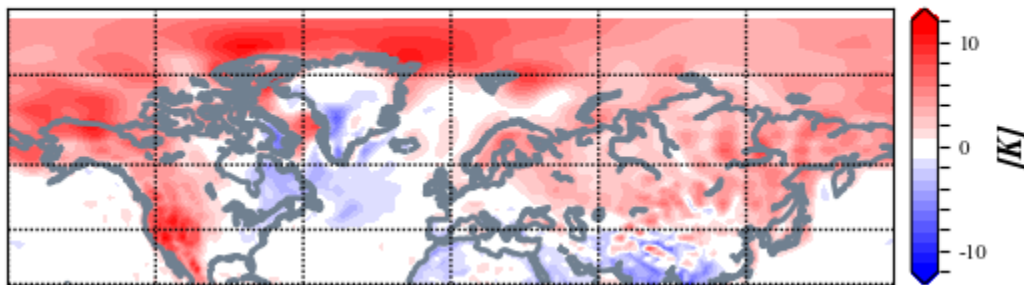


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for March 2020. The forecasts are from the 00Z 17 February 2020 CFS.

Surface Boundary Conditions

Arctic sea ice extent

The positive AO has been conducive to sea ice growth for much of the winter but the recent strong storms in the North Atlantic have caused sea ice to recede in the Barents-Kara Seas. Even with sea ice pulling back, 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.

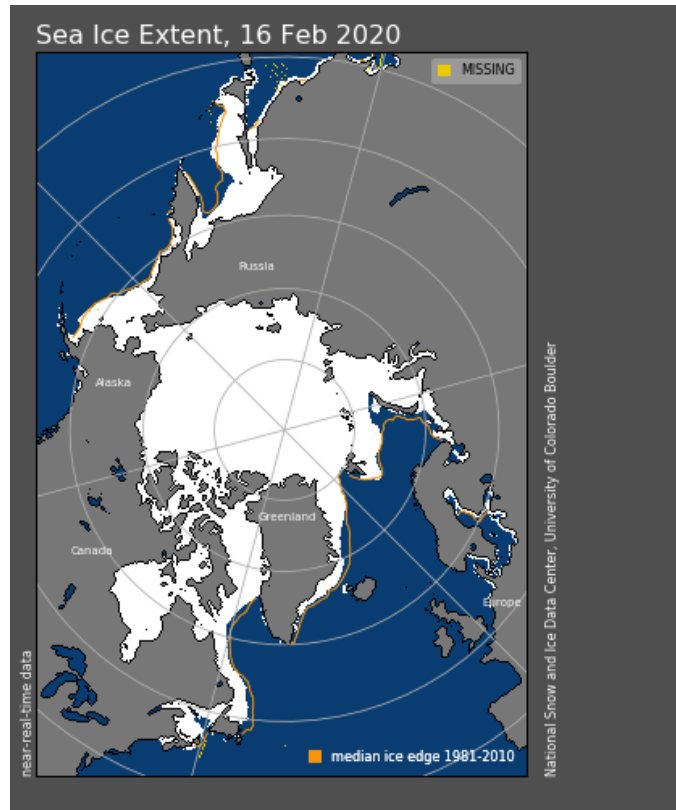


Figure 16. a) Observed Arctic sea ice extent on 16 February 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010.

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 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 16 Feb 2020

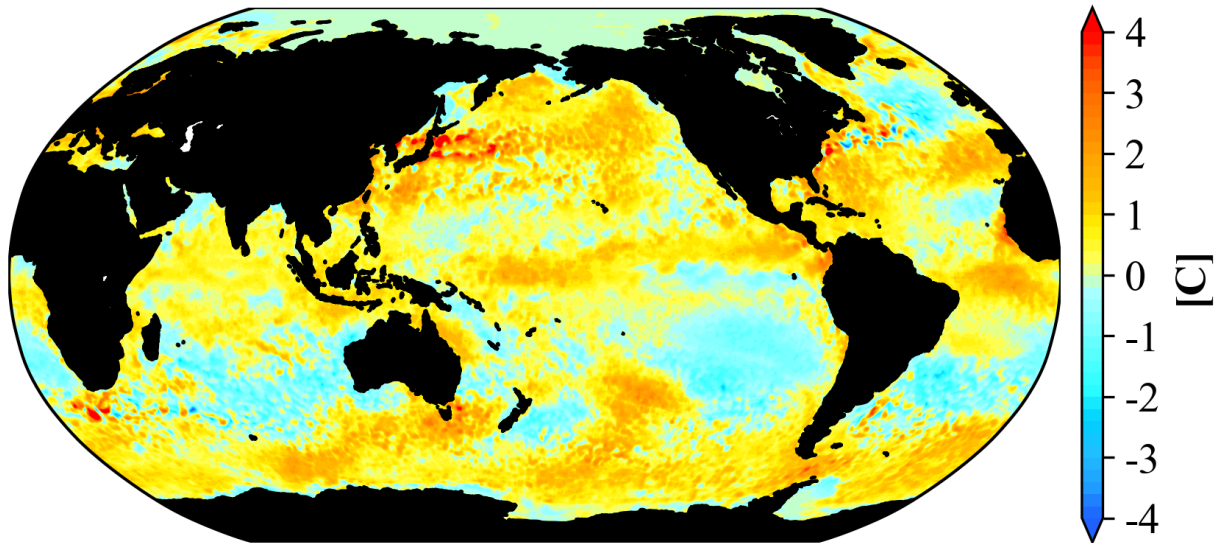


Figure 17. The latest weekly-mean global SST anomalies (ending 16 February 2020).
Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase six (**Figure 18**). The forecasts are for the MJO to quickly weaken where no phase is favored. MJO phase six mostly favors ridging in the Gulf of Alaska and troughing across Canada with more ridging in the Eastern US. This is consistent with the predicted pattern across North America this week but overall seems that the MJO is not contributing strongly to the predicted pattern across North America.

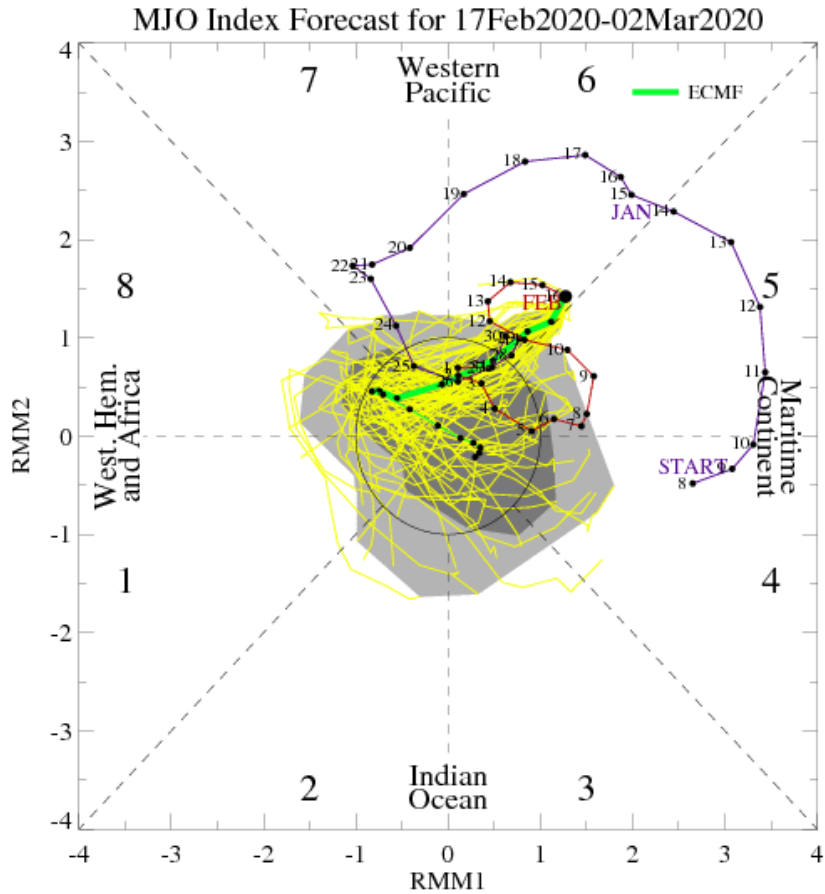


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 17 February 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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

Snow cover remained nearly steady 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.

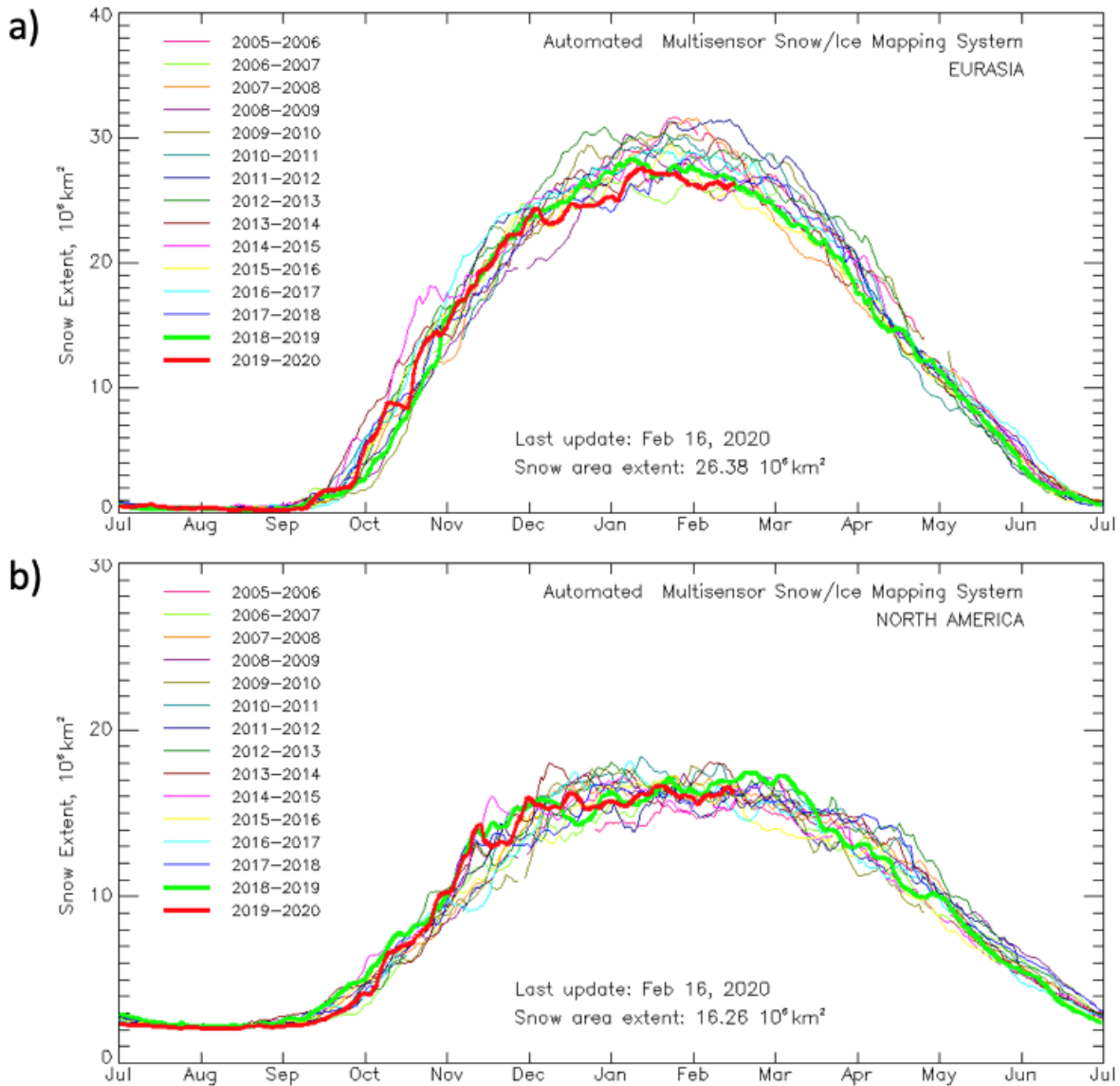


Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 16 February 2020. Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover remained nearly steady and 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.