

Arctic Oscillation and Polar Vortex Analysis and Forecasts

February 10, 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 could return to strongly positive early 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 most of the United Kingdom (UK) over the next two weeks. One exception is across Northern Scandinavia and possibly the northern British Isles as low/negative geopotential height anomalies result in normal to below normal temperatures.
- 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 the Middle East this week and Eastern Siberia and eventually 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 widespread normal to below normal temperatures across Alaska, Canada and the Western US with normal to above normal temperatures in the Eastern US. However, the Gulf of Alaska ridging is predicted to slide eastward with time while troughing deepens over Alaska. This will favor cold temperatures mostly confined to Alaska and northern-most Canada with normal to above normal temperatures across much of Canada and the US.
- In the Impacts section I share some thoughts on the strong polar vortex (PV).

Impacts

I know I sound like a broken record when I start every blog by how surprised I am by the stratospheric PV remains on the strong side of normal and even at times near or at record strong for the date. Today there has been some chatter/news about a record daily high for the AO today. But the incessant stretch of positive to strongly positive AO since late December, based on the polar cap geopotential height anomalies (PCHs) plot originated in the polar stratosphere with cold/negative PCHs/strong PV back in mid-December that propagated to the surface over a course of two weeks (see **Figure i**). And ever since, the two (strong PV – positive AO) have been locked in an infinite loop. Cold/negative PCHs/strong PV favor a positive AO and a positive AO with the lack of high latitude blocking/zonal (straight west to east) jet stream favor a strong PV. And to be honest there is no built-in circuit breaker to stop this infinite loop other than

internal/natural variability where wave breaking can help to disrupt the PV (for such an example see [Leet et al. 2019](#)). Interestingly poleward heat flux/Wave Activity Flux (WAFz) is currently and is predicted to remain negative or downward in the stratosphere for the rest of the week, a highly anomalous phenomenon. This is contributing to the near record strong PV but it should help to warm the tropospheric Arctic and build high pressure favoring a negative trend in the AO. I wonder if the models handle this well so I just wonder if the models are persisting the low heights/pressure in the tropospheric Arctic positive AO more than they should based on the heat flux anomalies. To be honest this not much more than pure conjecture on my part but something to watch in the coming days and weeks.

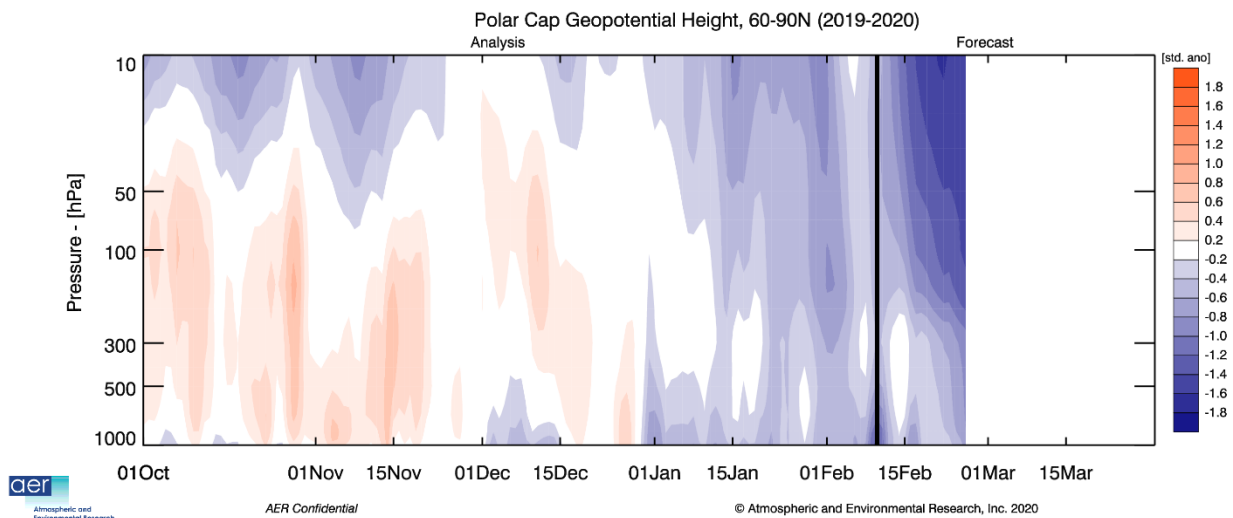


Figure i. Observed from October 1, 2019 and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 10 February 2020 GFS operational.

Arctic sea ice extent is also not conducive to disrupting the PV. For much of the winter the greatest negative extent anomalies have been on the North Pacific side of the Arctic and not the North Atlantic side. This asymmetry in sea ice anomalies favors a strengthened PV and not a weakened PV, at least based in some modeling experiments (e.g. [McKenna et al. 2017](#)). Please don't interpret this last point as trying to attribute the strong PV/positive AO solely to Arctic forcing. It seems highly plausible to me that the positive Indian Ocean dipole and strange behavior of the Madden Julian Oscillation (stuck in an infinite loop of its own between phases 4-6) have played an important role in the positive AO winter, especially given that it was predicted by the models this past fall. I simply want to make the point that the strong PV is not inconsistent with Arctic sea ice forcing.

Currently sea ice extent is near normal throughout the Arctic. Negative sea ice anomalies are mostly confined to outside the Arctic along the eastern boundaries of the

continents. And based on the latest model forecasts of more cold weather in the Bering Sea region, Bering sea ice extent could end the winter above normal! This is an incredible reversal of the past two winters where Bering sea ice collapsed in the late winter and early spring, wreaking havoc on the local ecology. I still believe the strong PV/positive AO has had a remedial impact on Arctic sea ice. Arctic sea ice extent has surged in recent weeks and is clearly above all recent winters on this date (see **Figure ii**). Of course, sea ice is thin and come the spring and summer will melt quickly but it will be interesting to see where the sea ice minimum falls next September.

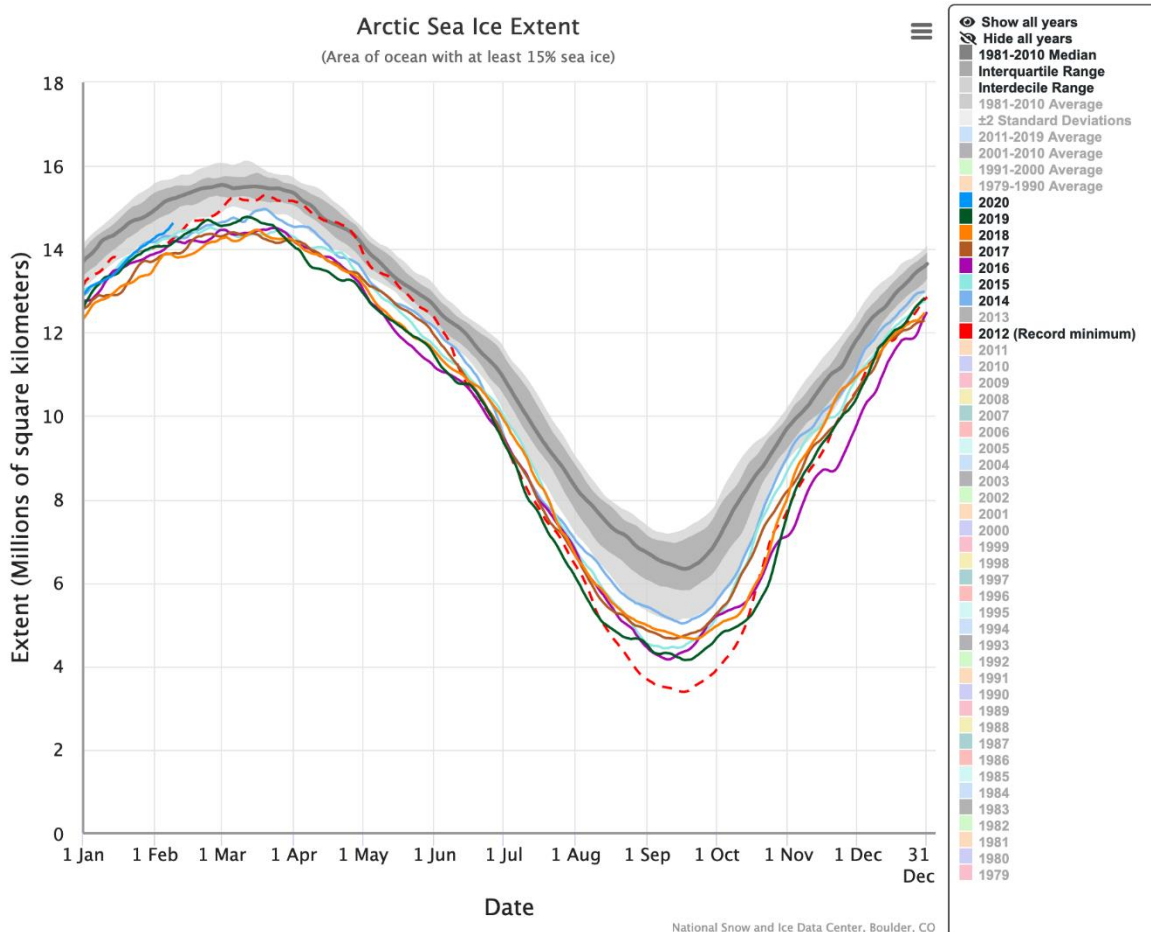


Figure ii. Arctic sea extent through February 9th, 2012, 2014 through 2020.

I have two early takeaways from what I have observed this winter. I have been arguing that sustained cold and snow is becoming increasingly difficult across the mid-latitudes without some type of PV disruption in the era of rapid climate change. Certainly, what I have observed this winter has only reinforced this idea for me. This winter will likely be the least disrupted PV winter since the 1990's and one of the mildest if not mildest winter across the mid-latitudes. The second is the relationship between accelerated Arctic warming or Arctic amplification (AA) and a strong polar vortex. Also keep in mind AA is mostly a winter phenomenon. Many model experiments support the idea that

favors a strong PV. But this winter has me wondering if to a large extent the two are mutually exclusive. Temperatures in the Arctic this winter are above normal but not any more so than in the mid-latitudes. I have a sense that AA is fairly negligible this winter much more so than we have observed over the past couple of decades; and in my mind this is directly attributable to the strong PV. The strong PV has deflected away from the Arctic any warming from lower altitudes. It seems to me that it is very difficult for AA to force a strong PV without a strong negative feedback in the cycle, where the strong PV erases AA in winter. In contrast AA and a weak PV would reinforce each other or in other words a weak PV would only act to amplify AA.

1-5 day

The AO is currently strongly 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 negative geopotential height anomalies across Greenland and Iceland (**Figure 2**), the NAO is positive as well.

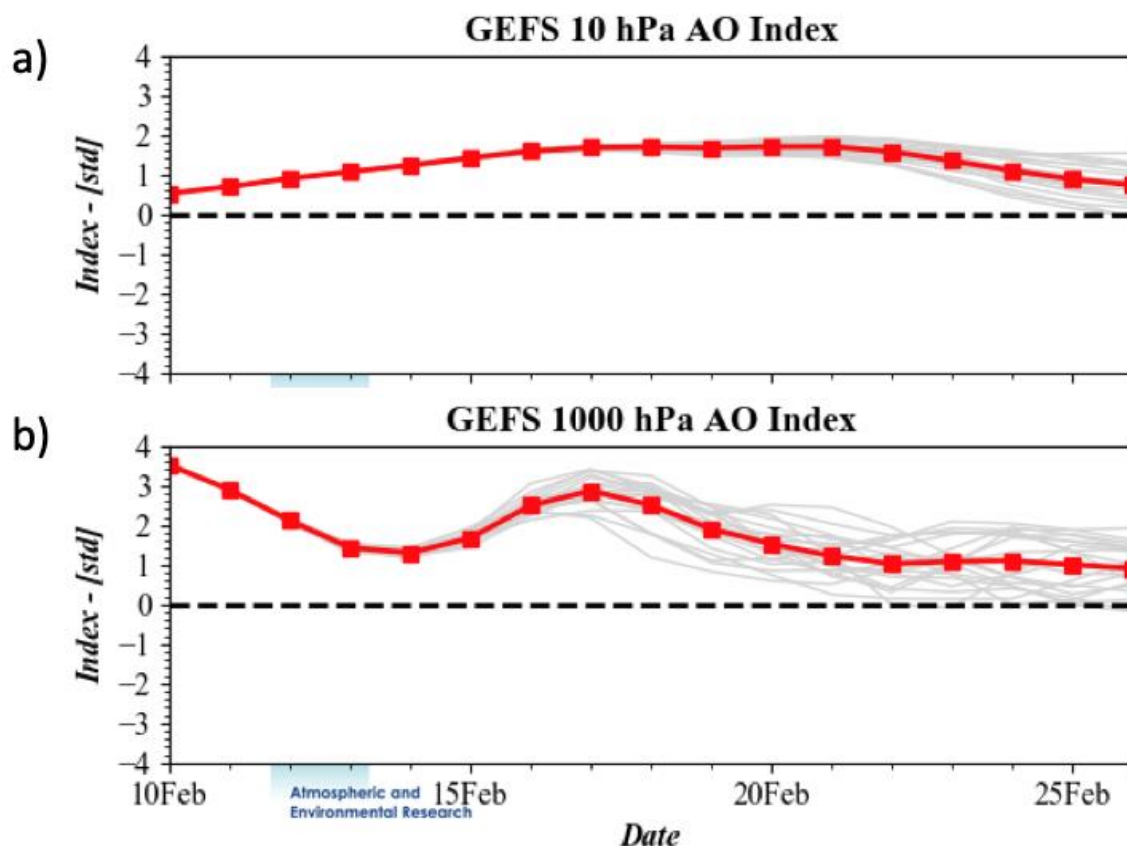


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 10 February 2020 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 10 February 2020

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 maritime, mild flow of westerly flow across Europe (**Figure 2**). This will result in normal to above normal temperatures across much of Europe including England (**Figure 3**). One exception could be Ireland, Scotland and Norway where low heights (**Figure 2**) could result in normal to below normal temperatures (**Figure 3**). This week, ridging/positive geopotential height anomalies are predicted to dominate Central Asia bookended by troughing/negative geopotential height anomalies in West and East Asia (**Figure 2**). This pattern favors normal to above normal temperatures across most of Asia with normal to below normal temperatures confined to the Middle East and Eastern Siberia (**Figure 3**). Residual troughing/negative geopotential height anomalies in the Tibetan Plateau (**Figure 2**) favor normal to below normal temperatures for the northern Indian subcontinent (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 02/10/20 FCST: 02/11/20 to 02/15/20

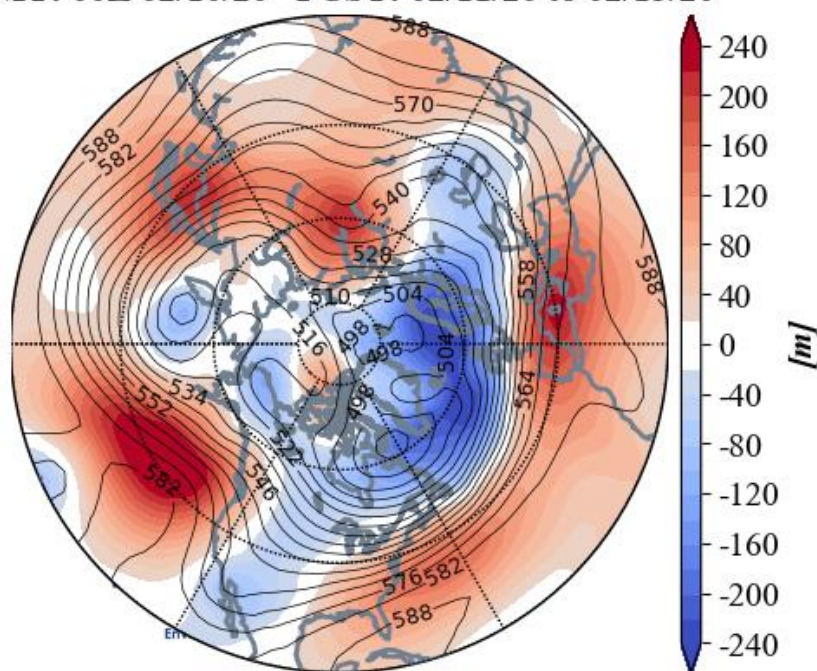


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 11 – 15 February 2020. The forecasts are from the 00z 10 February 2020 GFS ensemble.

This week, ridging/positive geopotential height anomalies in the Gulf of Alaska will force downstream troughing/negative geopotential height anomalies from Alaska,

across much of Canada and 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 stretching from Alaska to Central and Eastern Canada and the Central US with normal to above normal temperatures across the West Coasts of Canada and the US and the Eastern US (**Figure 3**).

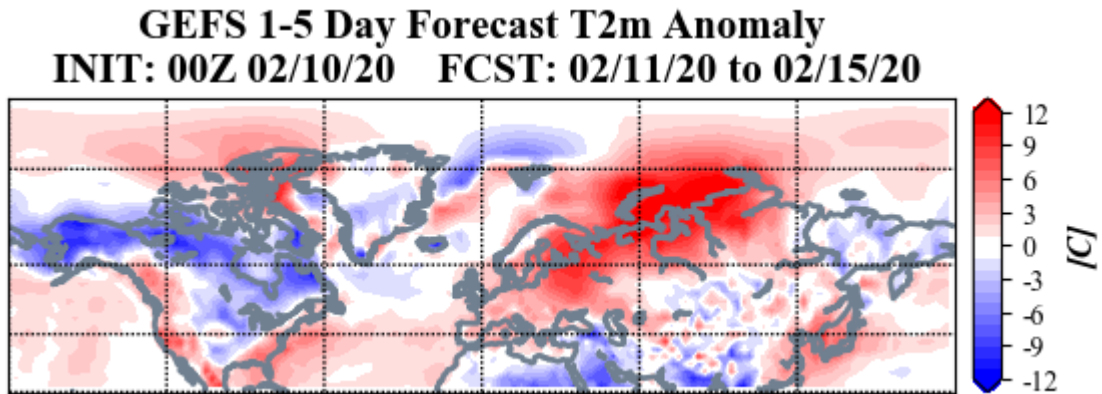


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 11 – 15 February 2020. The forecast is from the 00Z 10 February 2020 GFS ensemble.

Trouging and/or cold temperatures are predicted to bring new snowfall across Northern Asia and Southeastern Europe (**Figure 4**). Trouging and cold temperatures are predicted to bring new snowfall to much of Alaska, Canada and possibly along a stripe from the US South-Central Plains to the Great Lakes (**Figure 4**). Warm temperatures are predicted to result in snowmelt for Northwest Asia, Scandinavia and the Pacific Northwest (**Figure 4**).

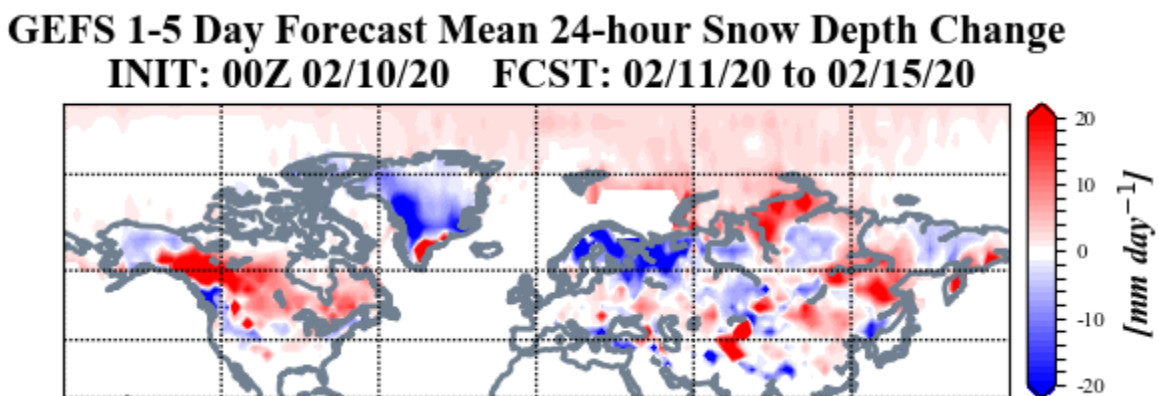


Figure 4. Forecasted snowdepth anomalies (mm/day; shading) from 11 – 15 February 2020. The forecast is from the 00Z 10 February 2020 GFS ensemble.

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
INIT: 00Z 02/10/20 FCST: 02/16/20 to 02/20/20

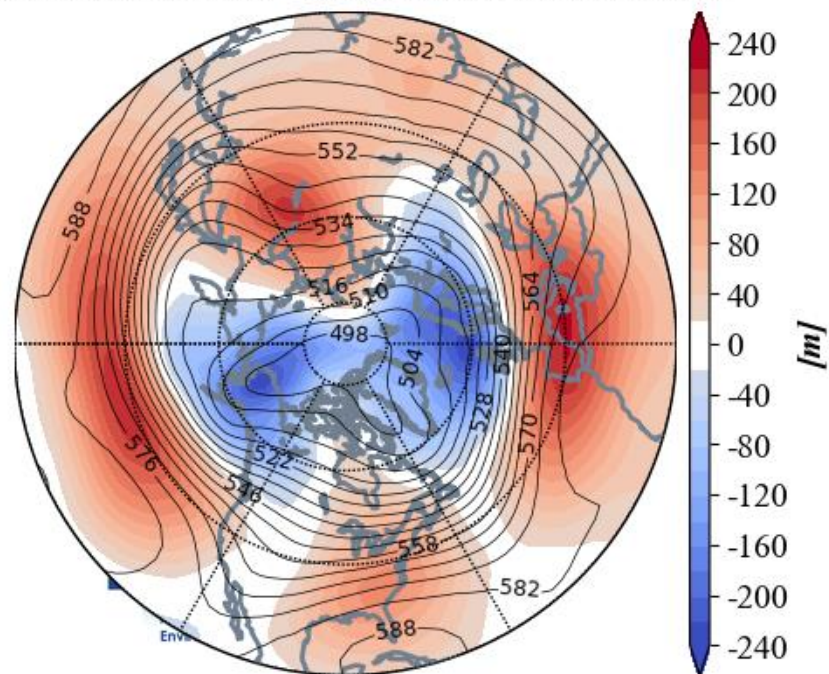


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 16 – 20 February 2020. The forecasts are from the 00z 10 February 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to stretch across Southern Europe with troughing/negative geopotential height anomalies stretched across Northern Europe this period (**Figures 5**). A strong westerly flow of maritime air will favor widespread normal to above normal temperatures for much of Europe including the UK (**Figure 6**). Persistent ridging/positive geopotential height anomalies will dominate Central Asia with troughing/negative geopotential height anomalies across West Asia and Eastern Siberia (**Figure 5**). This is predicted to yield normal to below normal temperatures for most of Asia with normal to below temperatures

confined to Eastern Siberia (**Figure 6**). Northerly flow in East Asia (**Figure 5**) will help to filter some of the cold air from Eastern Siberia into East Asia (**Figure 6**).

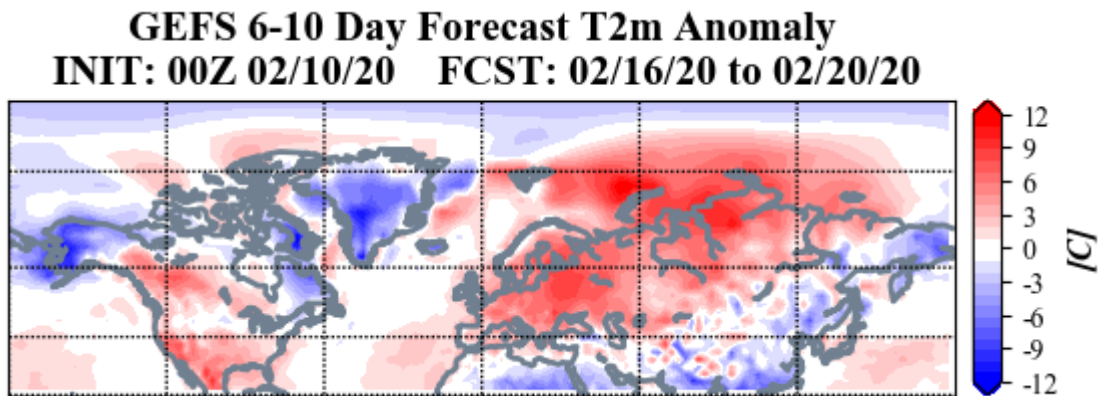


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 16 – 20 February 2020. The forecasts are from the 00Z 10 February 2020 GFS ensemble.

Ridging/positive geopotential height anomalies in the Gulf of Alaska are predicted to flatten out this period allowing ridging in the Eastern US to become more widespread with troughing/negative geopotential height anomalies now mostly confined to Alaska and northern-most Canada (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across much of Canada and the US with normal to below normal temperatures across Alaska, eastern-most Canada and New England (**Figure 6**).

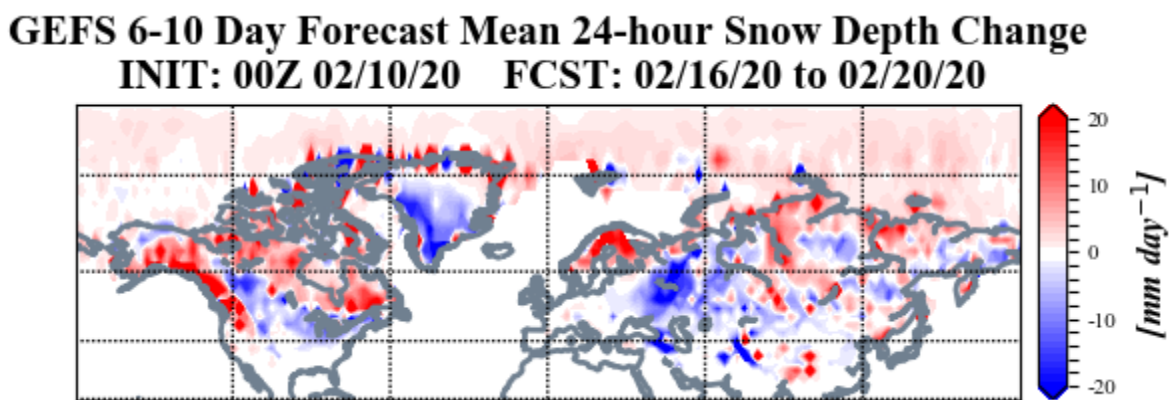


Figure 7. Forecasted snowdepth changes (mm/day ; shading) from 16 – 20 February 2020. The forecasts are from the 00Z 10 February 2020 GFS ensemble.

Troughing and/or cold temperatures will support the potential for new snowfall across Northern Asia, Scandinavia, the Tibetan Plateau, possibly parts of East Asia, Alaska, the Canadian West Coast, Northern and Eastern Canada and possibly the Northwestern US

(Figure 7). Some snowmelt is predicted in Western Russia, Eastern Europe, the Canadian and US Plains and the Northeastern US (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 (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 02/10/20 FCST: 02/21/20 to 02/25/20

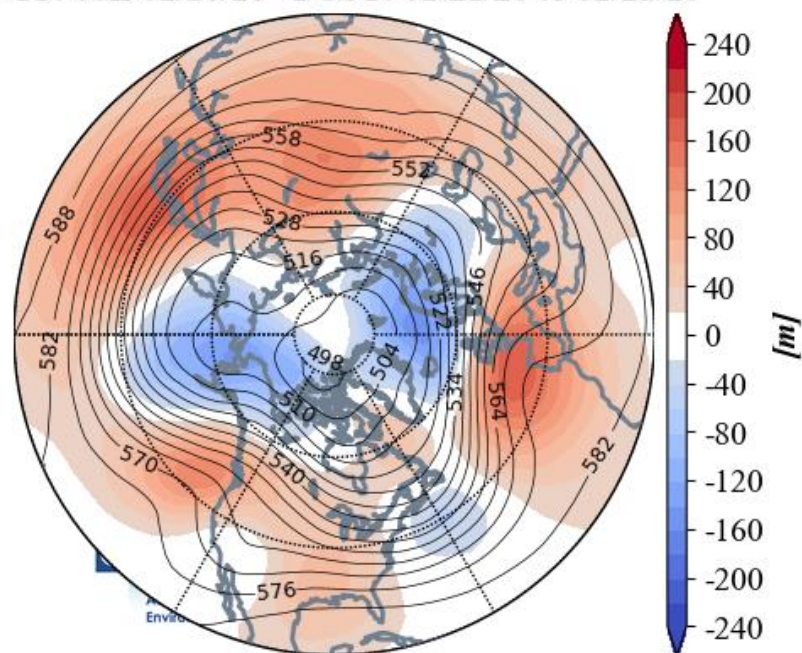


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 21 – 25 February 2020. The forecasts are from the 00z 10 February 2020 GFS ensemble.

Ridging/positive geopotential height anomalies will dominate much of Europe with troughing/negative geopotential height anomalies confined to Scandinavia and the Baltic States this period (Figures 8). High heights and below normal snow cover favor normal to above normal temperatures across much of Europe including the UK. Some suggested troughing in the Mediterranean could result in normal to below normal temperatures for parts of Southern Europe (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, parts of Northeast Asia and the Tibetan Plateau (**Figure 9**).

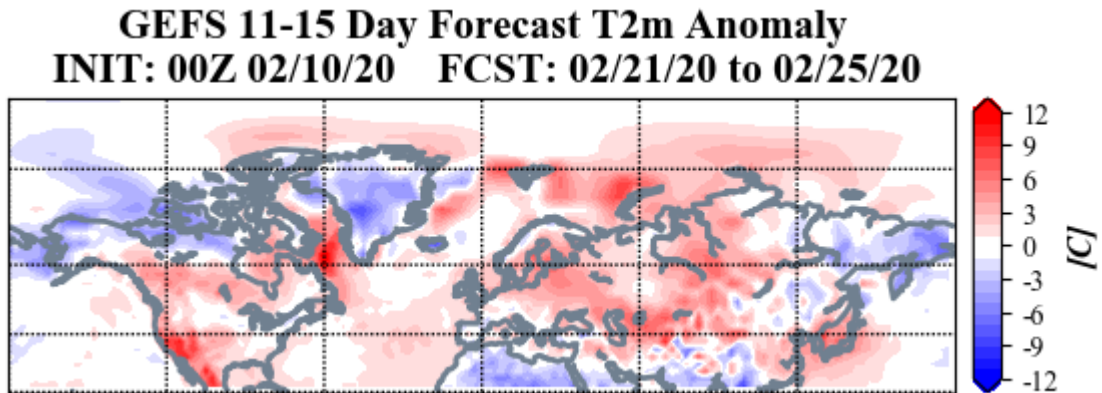


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 21 – 25 February 2020. The forecasts are from the 00z 10 February 2020 GFS ensemble.

Ridging/positive geopotential height anomalies in the Gulf of Alaska are predicted to persist but also to start spreading across Canada with troughing/negative geopotential height anomalies confined to Alaska and northern-most Canada (**Figure 8**). This pattern is predicted to favor normal to above normal temperatures across much of Canada and the US with normal to below normal temperatures confined to Alaska, northern-most Canada and possibly New England and adjacent Canada due to predicted northerly flow (**Figure 9**).

GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 02/10/20 FCST: 02/21/20 to 02/25/20

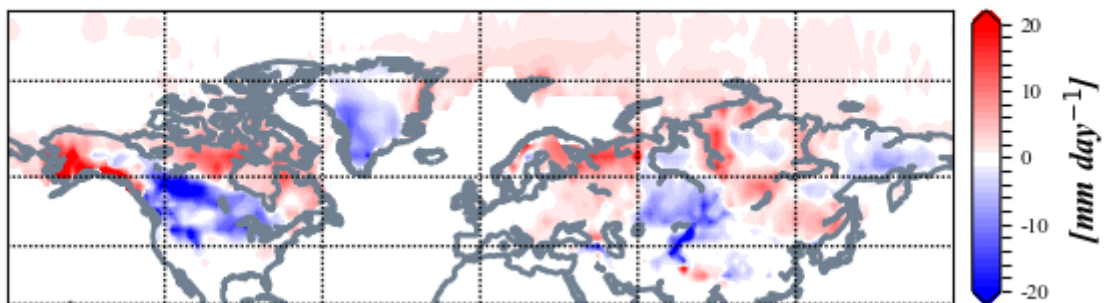


Figure 10. Forecasted snow depth changes (mm/day ; shading) from 21 – 25 February 2020. The forecasts are from the 00z 10 February 2020 GFS ensemble.

No strong signals are evident but troughing and/or cold temperatures could support new snowfall across much of Northern and possibly East Asia, Scandinavia and Eastern Europe (**Figure 10**). New snowfall is possible across Alaska, Northern and Eastern Canada and possibly New England (**Figure 10**). Some snowmelt is possible in Western Asia, Central and Southern Canada and the Northern 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 models have backed away from any reversal in the PCHs in both the stratosphere and the troposphere.

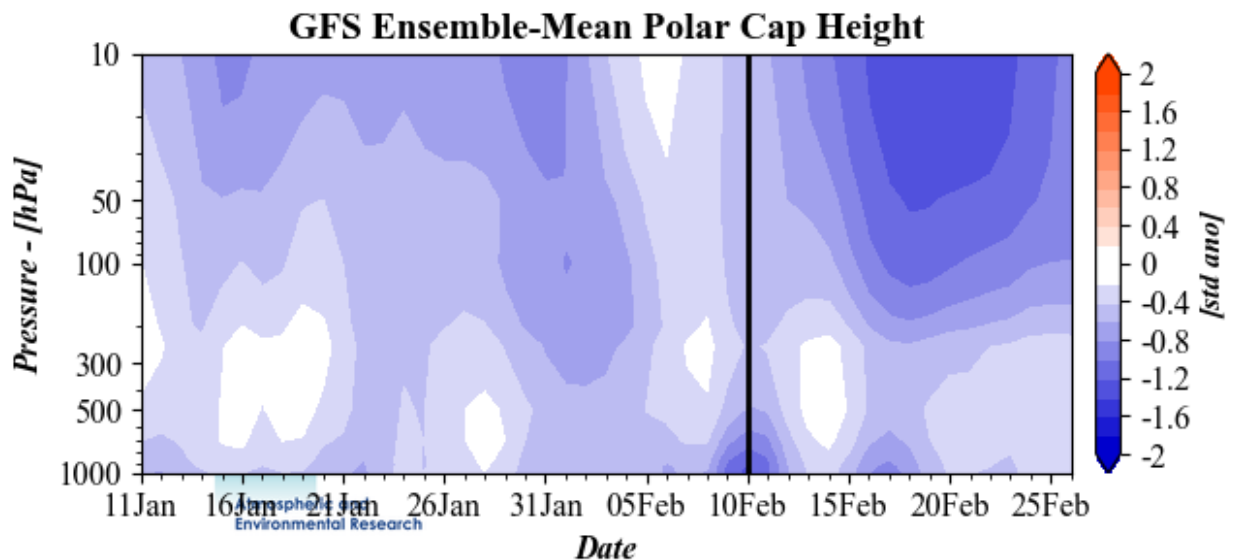


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 10 February 2020 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows a negative anomaly for the next ten days (**Figure 12**). The negative WAFz anomalies will support a strengthening of the stratospheric PV to near record strength for the date, the third

week of February. The next possible pickup in WAFz activity that could disrupt the PV is not until the last week of February (**Figure 12**).

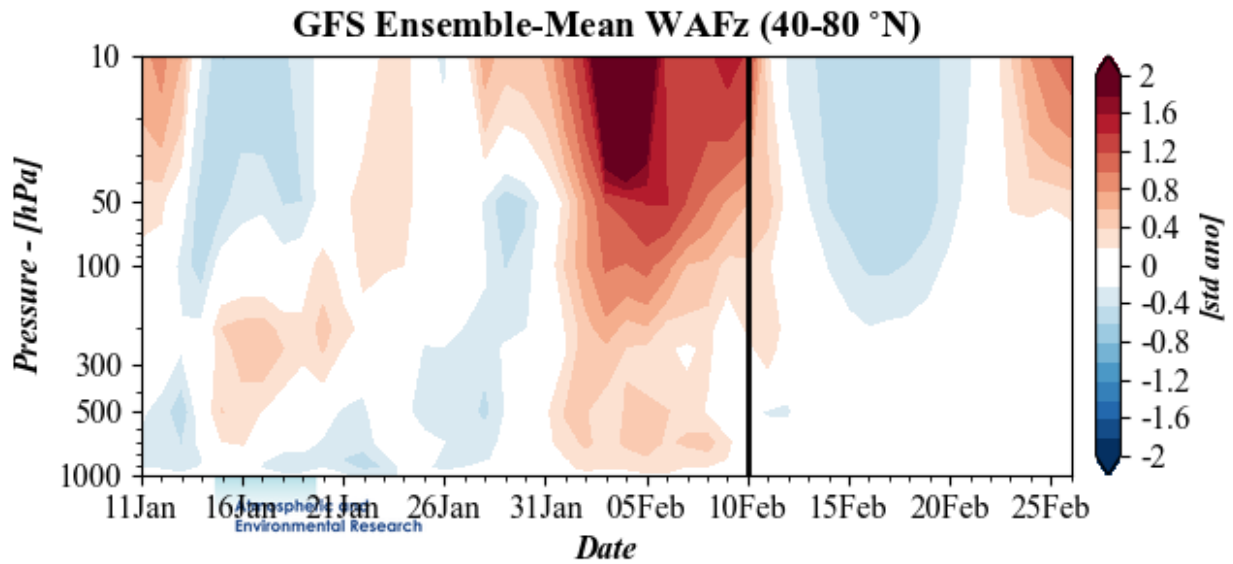


Figure 12. Observed and predicted daily vertical component of the wave activity W_{ux} (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 10 February 2020 GFS ensemble.

The stratospheric AO is currently positive (**Figure 1**) consistent with a relatively normal to strong PV and the stratospheric AO is predicted to become even more positive as the PV strengthens over the next ten days (**Figure 1**). The GFS predicts some weakening during the last week of February related to the predicted increase in WAFz but for now this remains highly uncertain.

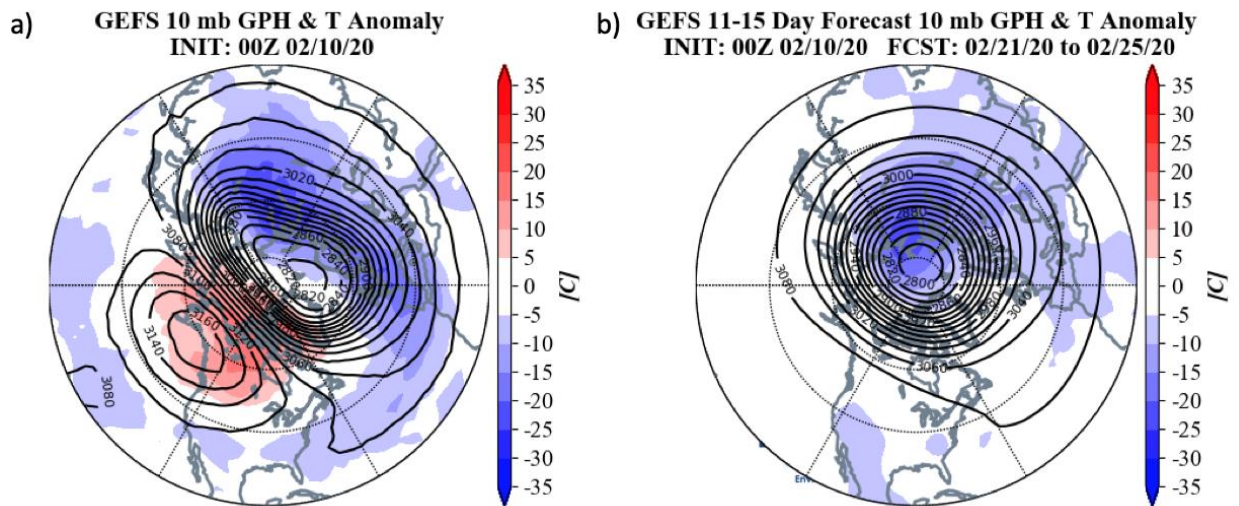


Figure 13. (a) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere at 00Z 10 February 2020. (b) Same as (a) except forecasted averaged from 21 – 25 February 2020. The forecasts are from the 00Z 10 February 2020 GFS operational model.

Currently the stratospheric PV is centered over the Barents Kara Seas (**Figure 13**) with the largest negative temperature departures in the polar stratosphere located over northern Eurasia (**Figure 13**). The PV is not circular in shape but rather elongated along an axis from Northeast Asia to the UK due to ridging and warming extending from Eastern Siberia to Alaska and Northern Canada. The northwest flow in the polar stratosphere from Eastern Siberia, across Canada and into New England is probably helping to support cold temperatures predicted from Eastern Siberia, across Canada and into New England over the next ten days to two weeks.

Over the next two weeks, the PV center is predicted to remain between the Barents-Kara Seas and the North Pole (**Figure 13**). However, the warming on the North Pacific side of the Arctic is predicted to fade and the PV is predicted to become more circular in shape (**Figure 13**). These are signs that the PV is strengthening further. A strong PV favors a cold Arctic and relatively mild temperatures widespread across the NH mid-latitude continents.

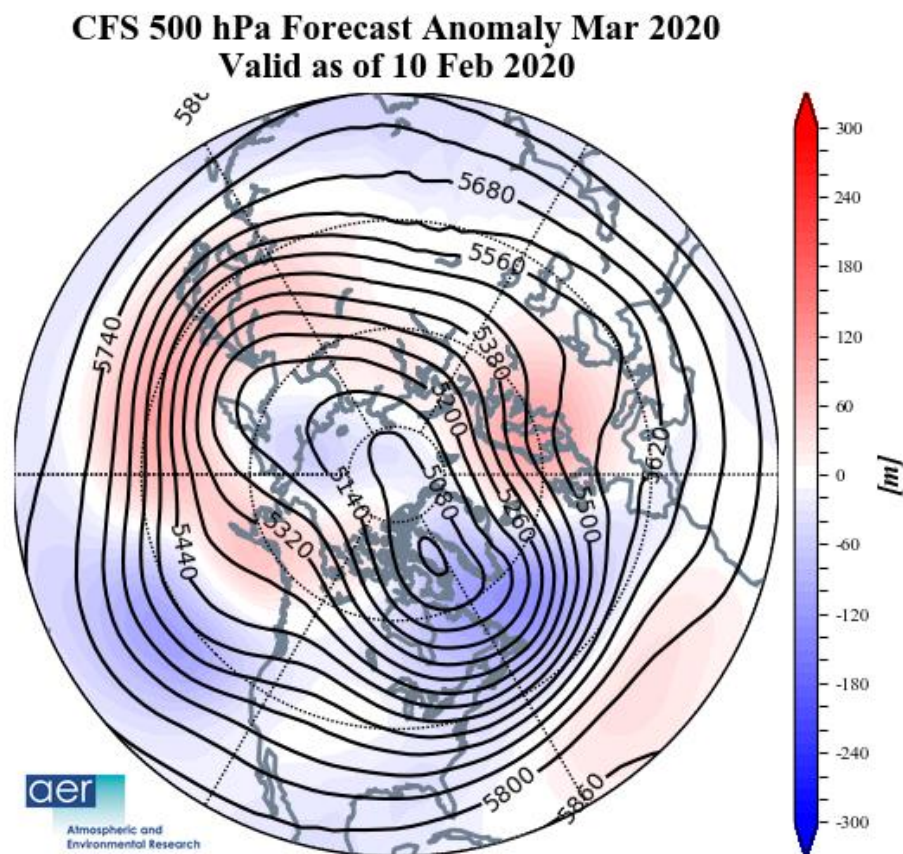


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for March 2020. The forecasts are from the 00Z 10 February 2020 CFS.

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, Eastern Asia, Alaska, Western Canada and the Western US with seasonable to relatively cold temperatures for Western Asia, the Middle East, Eastern Canada and the Northeastern 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 10 Feb 2020**

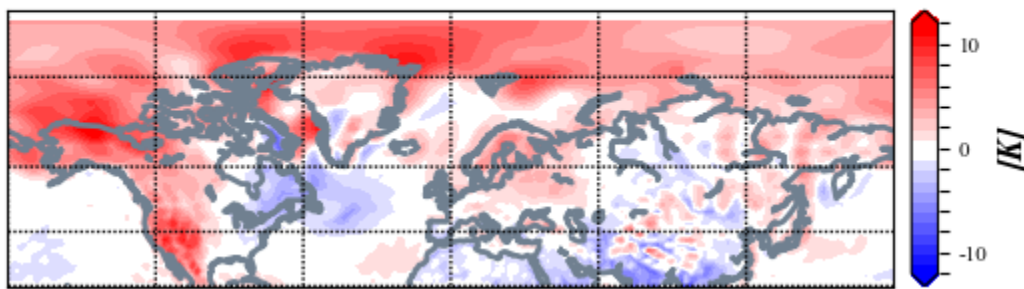


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for March 2020. The forecasts are from the 00Z 10 February 2020 CFS.

Surface Boundary Conditions

Arctic sea ice extent

The positive AO is conducive to sea ice growth and Arctic sea ice growth rate continues to grow slowly and remains below normal but higher than recent winters; the weather pattern remains favorable for further sea ice growth. 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.

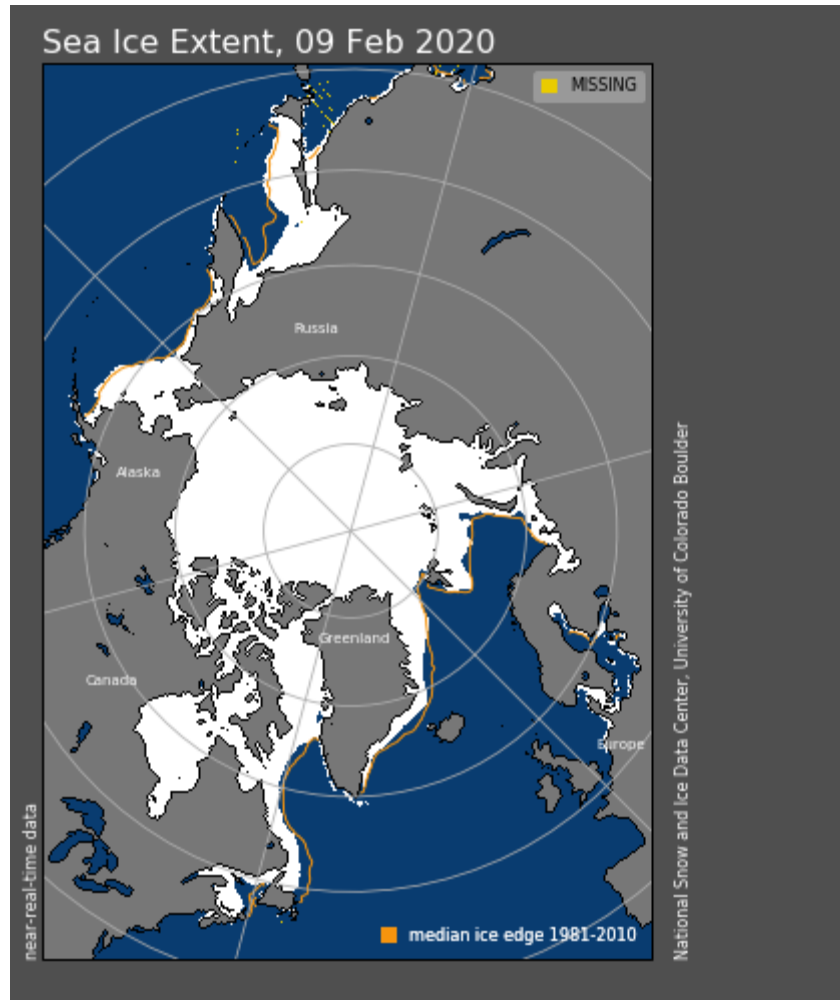


Figure 16. a) Observed Arctic sea ice extent on 9 February 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010.

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 09 Feb 2020

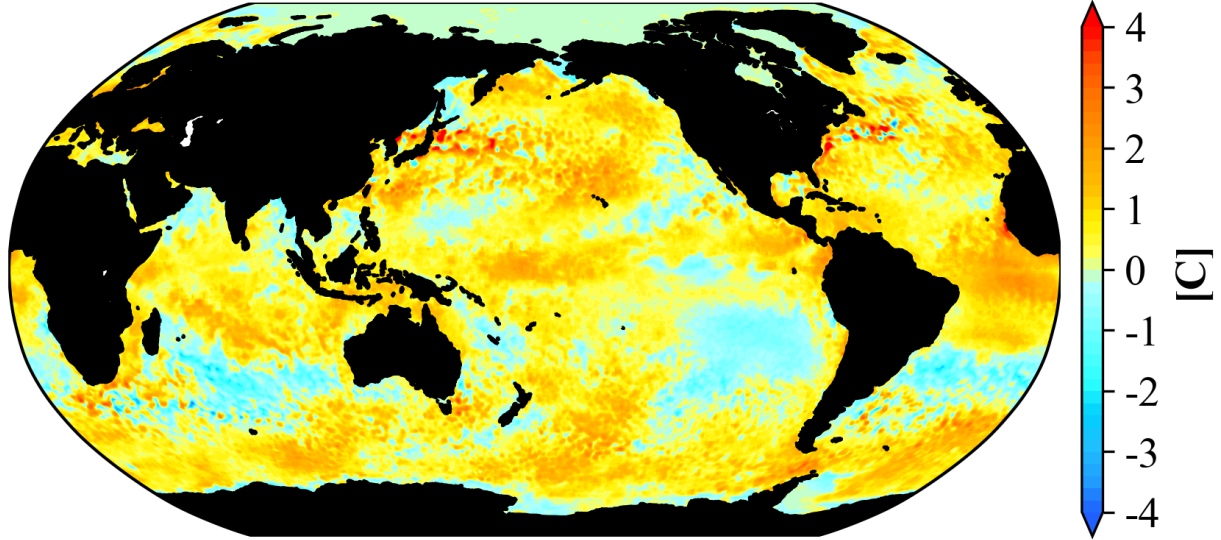


Figure 17. The latest weekly-mean global SST anomalies (ending 9 February 2020).
Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase five (**Figure 18**). The forecasts are for the MJO to briefly enter phases six this week before weakening where no phase is favored. MJO phases five and six mostly favor 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.

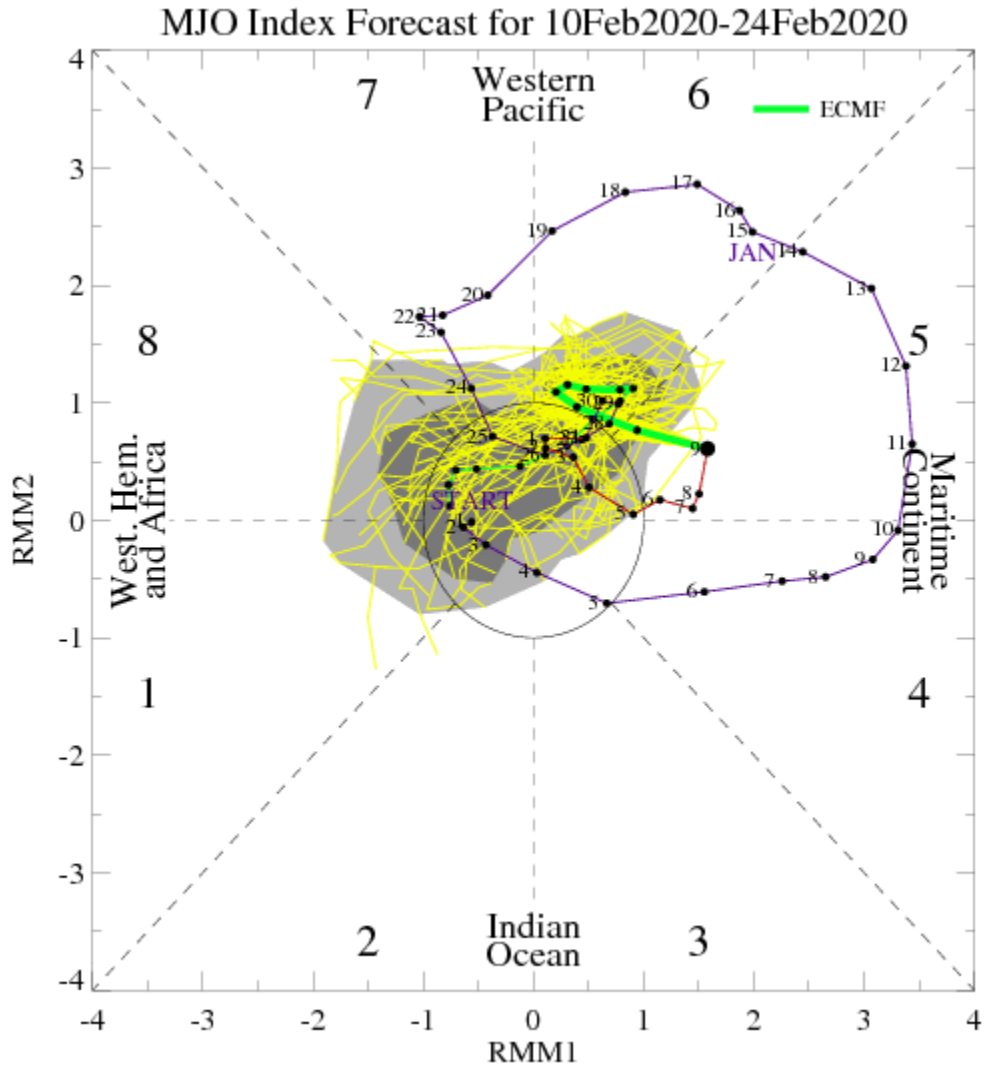


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 10 February 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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.

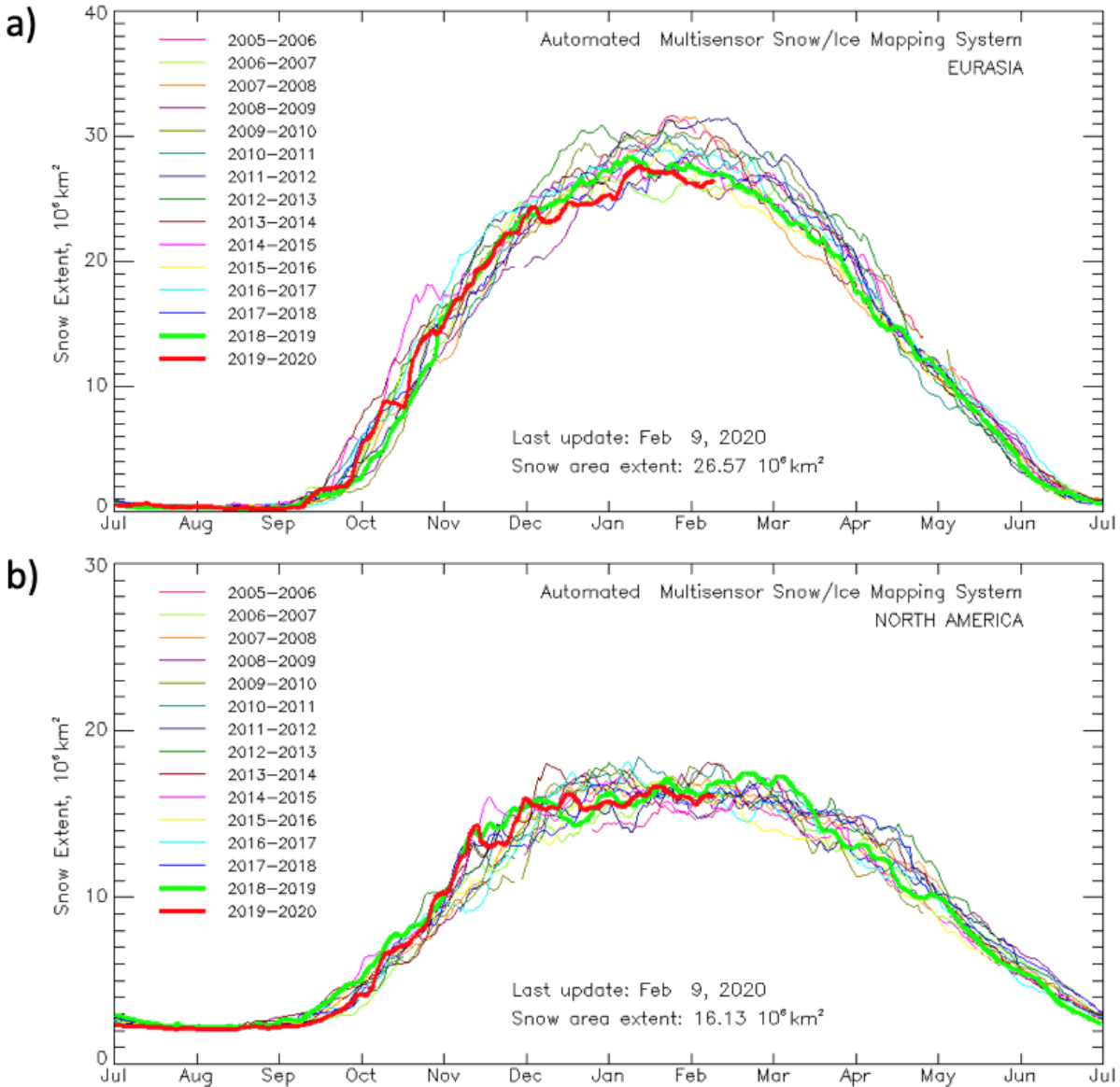


Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 2 February 2020. Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover remained nearly steady and remains near decadal means. Snow is predicted to mostly melt in the coming weeks. If the melting accelerates this could contribute to a warm spring.