

Arctic Oscillation and Polar Vortex Analysis and Forecasts

January 20, 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.
- The current positive AO is reflective of negative pressure/geopotential height anomalies in the Arctic with mixed 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 heights are predicted remain negative across Greenland.
- The general circulation pattern over the next two weeks is ridging/positive geopotential height anomalies over most of Europe with troughing/negative geopotential height anomalies confined to Northernmost Europe. The high heights and westerly flow of

maritime air favor above normal temperatures for much of Europe including the United Kingdom (UK) over the next two weeks. One exception is this week as a cutoff low/negative geopotential height anomaly will be centered over Spain bringing normal to below normal temperatures to Western Europe.

- With a positive AO this week the general predicted pattern for Asia is ridging/positive geopotential height anomalies with normal to above normal temperatures. Exceptions will be troughing/negative pressure/geopotential height anomalies and normal to below normal temperatures across Siberia this week and South-Central Asia the next two weeks.
- The predicted pattern for next two weeks across North America is ridging/positive geopotential height anomalies anchored over central Canada with troughing/negative geopotential height anomalies confined to Alaska and the Southeastern United States (US). This pattern favors widespread normal to above normal temperatures across Canada and the US with normal to below normal temperatures in Alaska and the Southeastern US.
- In the Impacts section I discuss my expectations for the polar vortex (PV) in the next month or so.

Impacts

As I discussed in last week's blog, I believed a troposphere-stratosphere-troposphere (T-S-T) coupling event with a strong PV/positive AO was likely. From this week's geopotential height anomalies (PCH) plot the cycle is now complete. The tropospheric precursor (positive AO) occurred for all of early January, the strong PV peaked last week, and the downward propagation has now reached the surface. When the PCH anomalies couple from the stratosphere to the troposphere this could lead to long lived surface AO anomalies consistent with the sign of the PCHs. In this case with coupling of cold PCHs, the AO could remain predominantly in the positive phase for up to two months. Positive AO favors relatively mild temperatures for the Eastern US, Northern Europe and East Asia but not necessarily all at the same time. Also, a positive AO most strongly favors mild temperatures across Northern Europe and especially Siberia.

Low pressure/geopotential heights near Scandinavia and the Urals observed most of January is not favorable for exciting the vertical transfer of atmospheric energy or Wave Activity Flux (WAFz). Relatively quiet WAFz has allowed the stratospheric PV to strengthen for the entire month of January. The vertical energy transfer/WAFz is predicted to become more active at the end of the month. This is predicted to result in a Canadian warming as seen in **Figure i** in the most recent PV animation.

Initialized 12Z 10 hPa HGT/HGTa 20-Jan-2020

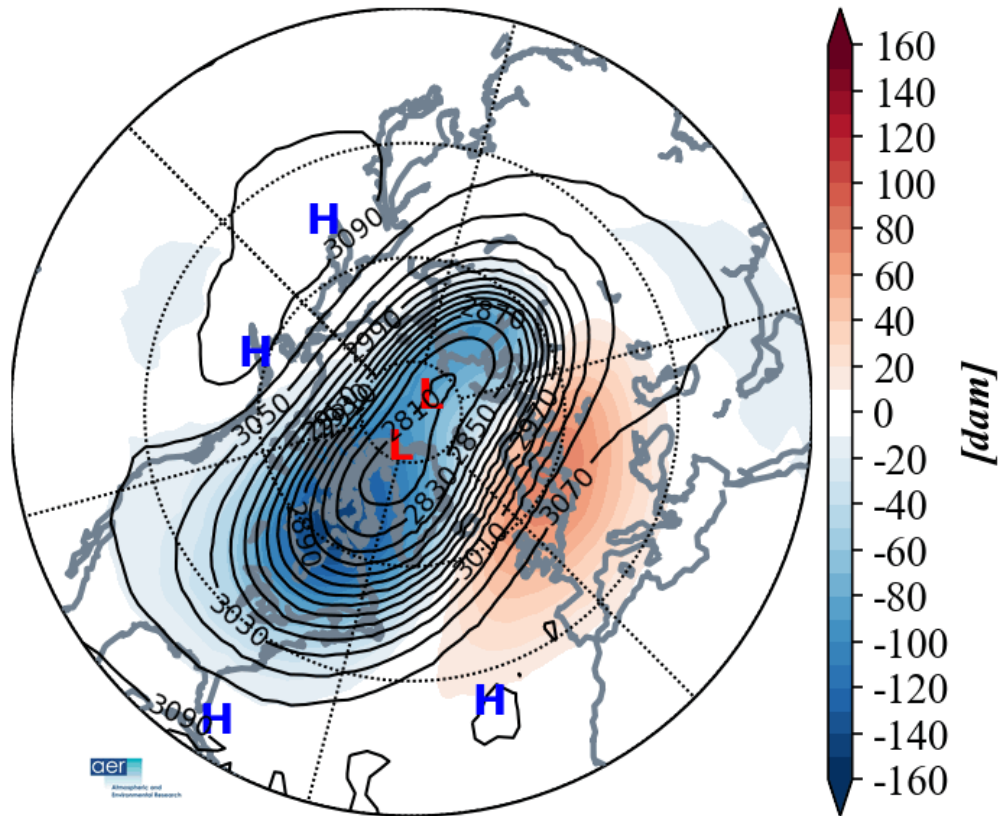


Figure i. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 13 January 2020 GFS operational.

In a Canadian warming the warmest temperatures in the polar stratosphere are centered over Canada and coldest along the north slope of Eurasia. A Canadian warming was one of the clusters found in [Kretschmer et al. \(2018\)](#). These events favor at the surface relative mild temperatures across much of Canada, cold temperatures in the Arctic and the north slope of Eurasia, warm across much of Asia and seasonable across the US (**Figure ii**). This is the pattern I would generally expect with the upcoming Canadian warming and seems consistent with the model forecasts, though I don't expect the pattern to be long lived.

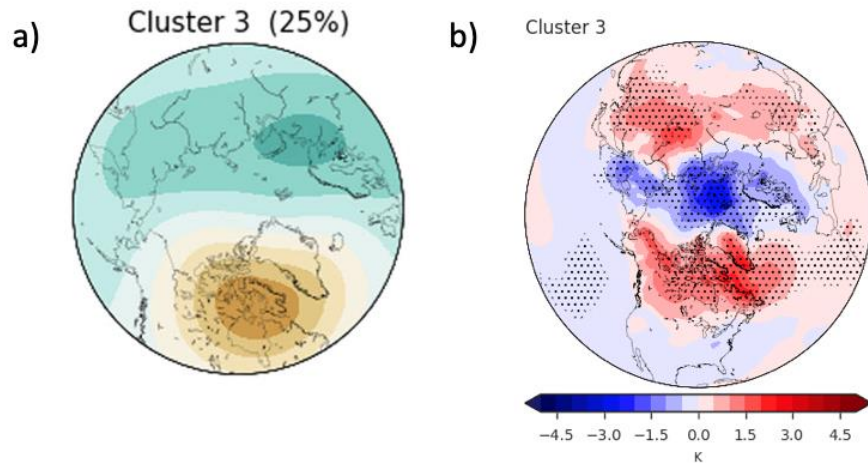


Figure ii. a) Composite of geopotential height anomalies at 100 hPa in winter (JF) from 1979 to 2018 for days assigned to cluster three from Kretschmer (2018). **b)** Surface temperature anomalies associated with cluster three.

As I have been saying for a while despite the strong PV I do expect in February and/or March a significant disruption. I looked back at historical PCHs and found that in the winters of 2006/07 and 2007/08 the late December and much of January periods of those winters featured a strong stratospheric PV, cold PCHs coupled to the surface and positive surface AO, similar to the current winter (**Figure iii**). In both those winters the stratospheric PV weakened in mid to late February. I do think those two winters can represent analogs for this winter with eventual weakening of the PV. Though a major warming was observed both February 2007 and 2008 and I am not expecting a major warming this winter and if one did occur it would be exceptional. In February 2007 blocking was observed across Scandinavia and in January 2008 blocking was observed centered on the Urals, both favorable for disrupting the PV and so far, not observed or predicted this winter. So, for any meaningful disruption of the PV blocking would likely need to develop in one of these two regions. Of course, as I have discussed in previous blogs the polar vortex could remain strong right up to the Final Warming, a scenario that is becoming more credible every week.

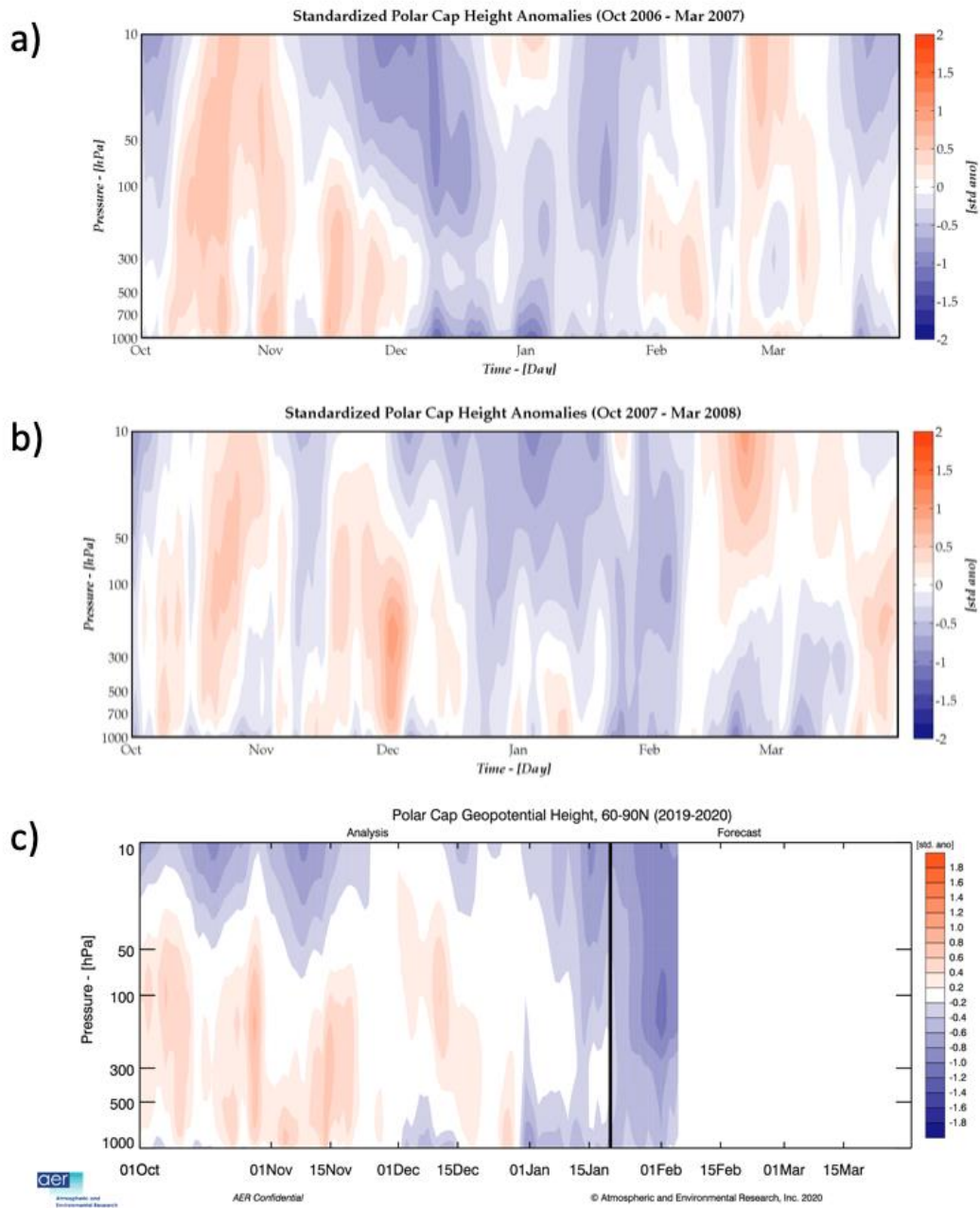


Figure iii. a) Observed predicted daily polar cap height standardized anomalies from October 1, 2006-March 31, 2007 b) Observed predicted daily polar cap height standardized anomalies from October 1, 2007-March 31, 2008 c) Observed from October 1, 2019 and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 20 January 2020 GFS ensemble.

Near Term Conditions

1-5 day

The AO is currently positive (**Figure 1**) with negative geopotential height anomalies across the Arctic and mixed 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.

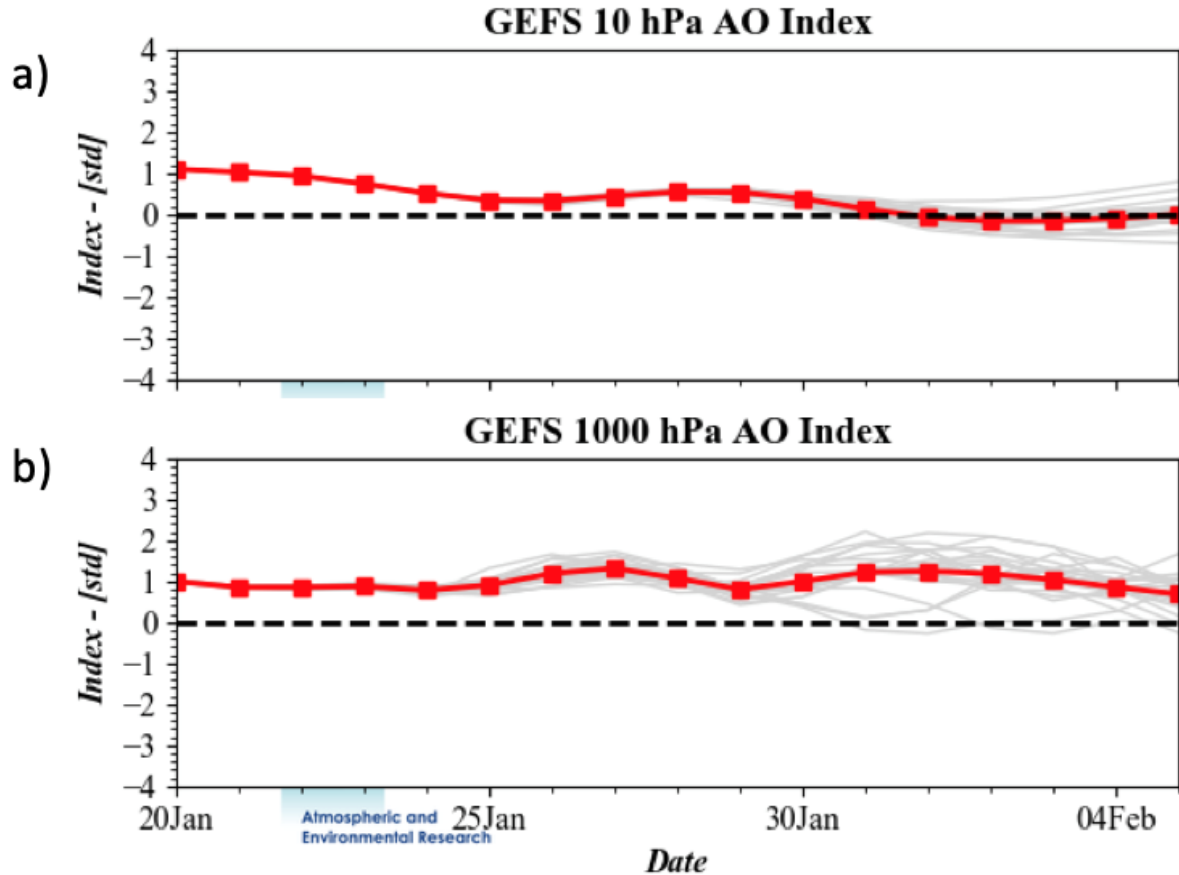


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 20 January 2020 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 20 January 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week ridging/positive geopotential height anomalies are predicted to dominate much of Europe with the exception of a cutoff low/negative geopotential height anomalies centered over Spain (**Figure 2**). General high heights and lack of snow cover will result in normal to above normal temperatures across much of Europe with the exception of normal to below normal temperatures across Western Europe including the UK due to low geopotential heights and northerly flow (**Figure 3**). This week, ridging/positive geopotential height anomalies are predicted to dominate much of Asia (**Figure 2**) favoring widespread normal to above normal temperatures **across much of Asia** (**Figure 3**). Exceptions are Siberia and South-Central Asia where regional troughing/negative geopotential height anomalies (**Figure 2**) are predicted to result in normal to below normal temperatures (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 01/20/20 FCST: 01/21/20 to 01/25/20

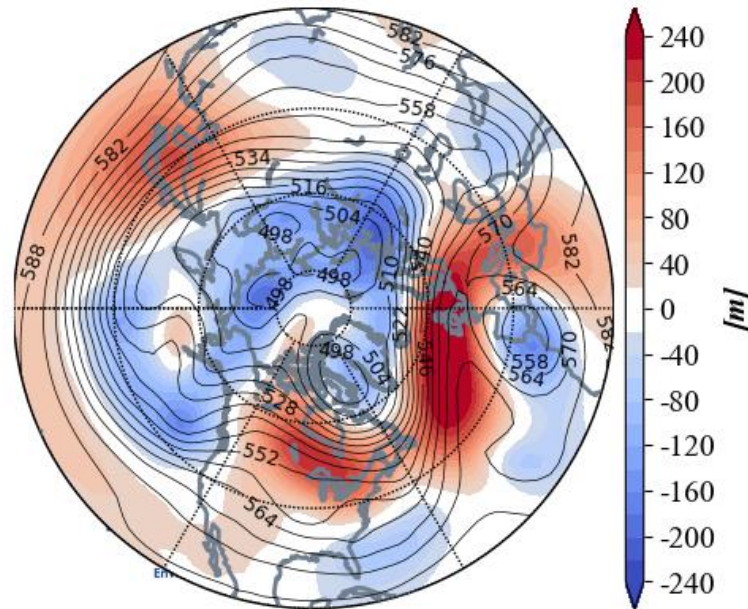


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 21 – 25 January 2020. The forecasts are from the 00z 20 January 2020 GFS ensemble.

This week, ridging/positive geopotential height anomalies are predicted to dominate North America anchored over interior Canada with troughing/negative geopotential height anomalies confined to Alaska and the Southeastern US (**Figure 2**). This is predicted to result in normal to above normal temperatures for much of Canada and the US with normal to below normal temperatures across Alaska and the Eastern US (**Figure 3**).

GEFS 1-5 Day Forecast T2m Anomaly
INIT: 00Z 01/20/20 FCST: 01/21/20 to 01/25/20

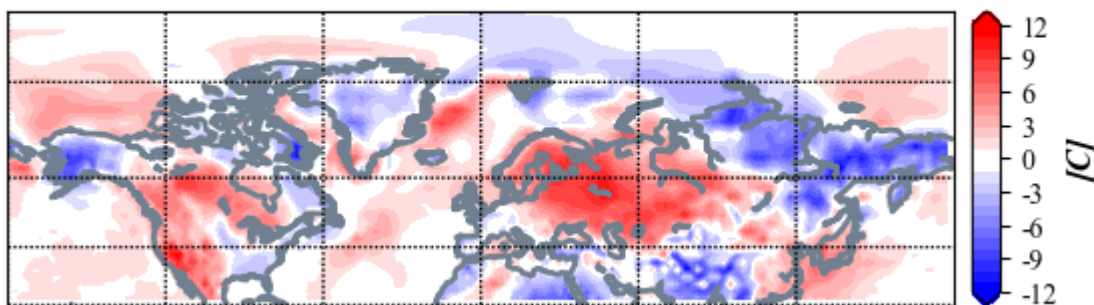


Figure 3. Forecasted surface temperature anomalies (°C; shading) from 21 – 25 January 2020. The forecast is from the 00Z 20 January 2020 GFS ensemble.

Trouging and/or cold temperatures are predicted to bring new snowfall across Northern and Western Asia (**Figure 4**). Trouging and cold temperatures are predicted to bring new snowfall to much of Northern Canada (**Figure 4**). Warmer temperatures are predicted to result in snowmelt for Northern Europe, Alaska, Western and Southeastern Canada and the Western and Northeastern US (**Figure 4**).

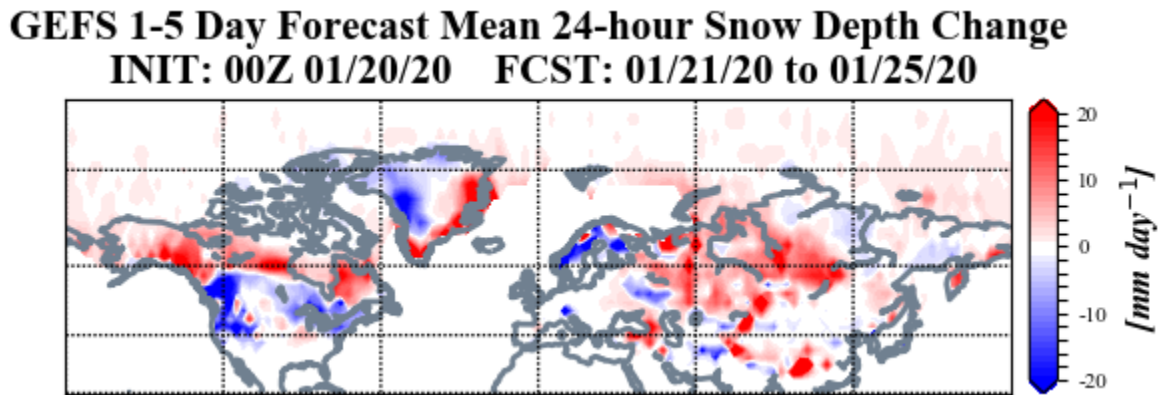


Figure 4. Forecasted snowdepth anomalies (mm/day; shading) from 21 – 25 January 2020. The forecast is from the 00Z 20 January 2020 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain positive and possibly even strengthen this period (**Figure 1**) as negative geopotential height anomalies dominate the Arctic with mixed 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 01/20/20 FCST: 01/26/20 to 01/30/20

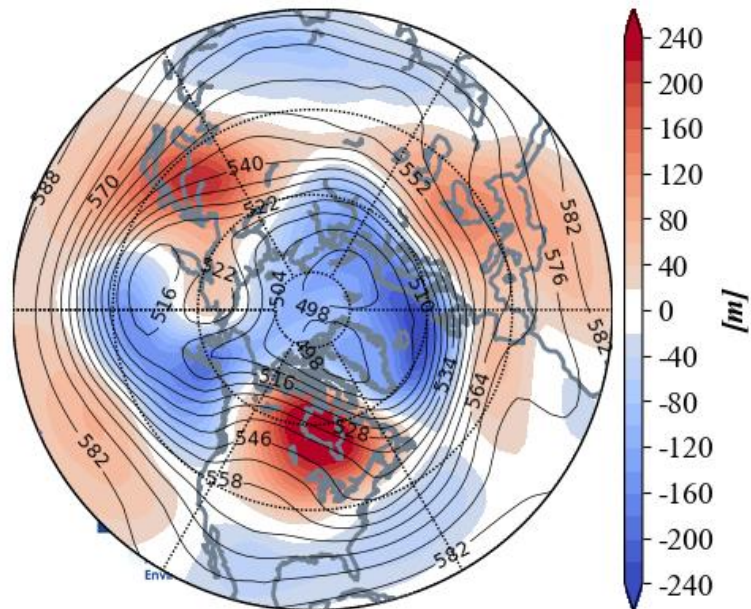


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 26 – 30 January 2020. The forecasts are from the 00z 20 January 2020 GFS ensemble.

This week ridging/positive geopotential height anomalies are predicted to stretch across Southern Europe with troughing/negative geopotential height anomalies stretched across Northern Europe this period (**Figure 5**). A strong westerly flow of maritime air will favor widespread normal to above normal temperatures for much of Europe including the UK with the possible exception of Spain where lingering cold temperatures from the previous period may persist (**Figure 6**). Ridging/positive geopotential height anomalies will dominate Western and East Asia with troughing/negative geopotential height anomalies across South - Central Asia and the Urals (**Figure 5**). This is predicted to yield normal to above normal temperatures for Western and Eastern Asia **with** normal to below temperatures for much of Southern Asia, the Urals and parts of Siberia (**Figure 6**).

GEFS 6-10 Day Forecast T2m Anomaly
INIT: 00Z 01/20/20 FCST: 01/26/20 to 01/30/20

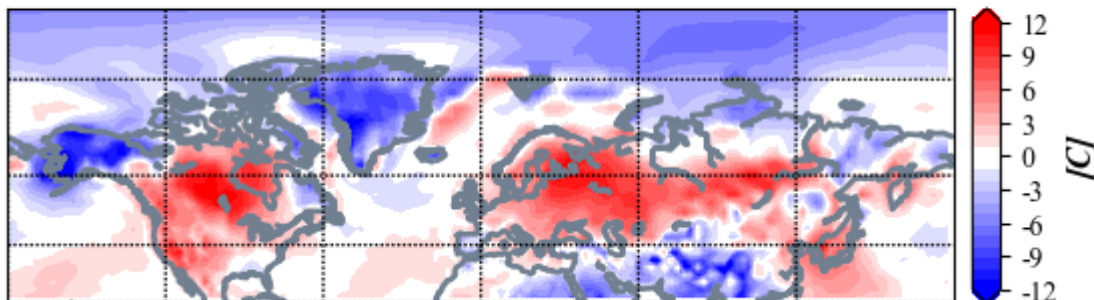


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 26 – 30 January 2020. The forecasts are from the 00Z 20 January 2020 GFS ensemble.

The overall pattern from the previous period is predicted to persist across North America with ridging/positive geopotential height anomalies dominating North America centered over the interior of Canada with troughing/negative geopotential height anomalies confined to Alaska and the Southern US (**Figure 5**). This pattern is predicted to bring widespread normal to above normal temperatures across much of Canada and the US with normal to below normal temperatures confined to Alaska and the Southeastern US (**Figure 6**).

GEFS 6-10 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 01/20/20 FCST: 01/26/20 to 01/30/20

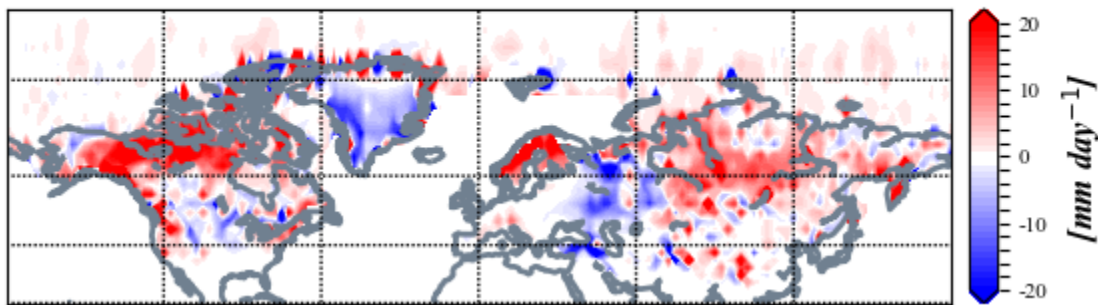


Figure 7. Forecasted snowdepth changes (mm/day; shading) from 26 – 30 January 2020. The forecasts are from the 00Z 20 January 2020 GFS ensemble.

Troughing and/or cold temperatures will support the potential for new snowfall across much of Northern Asia, Scandinavia and possibly the Alps and Tibetan Plateau, Alaska, Northwest Canada, the Western US and possibly Southeastern Canada and the Northeastern US (**Figure 7**). Some snowmelt is predicted in Western Russia and the North American Plains (**Figure 7**).

11-15 day

With continued negative geopotential height anomalies predicted for the Arctic (**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 this period as well.

GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 01/20/20 FCST: 01/31/20 to 02/04/20

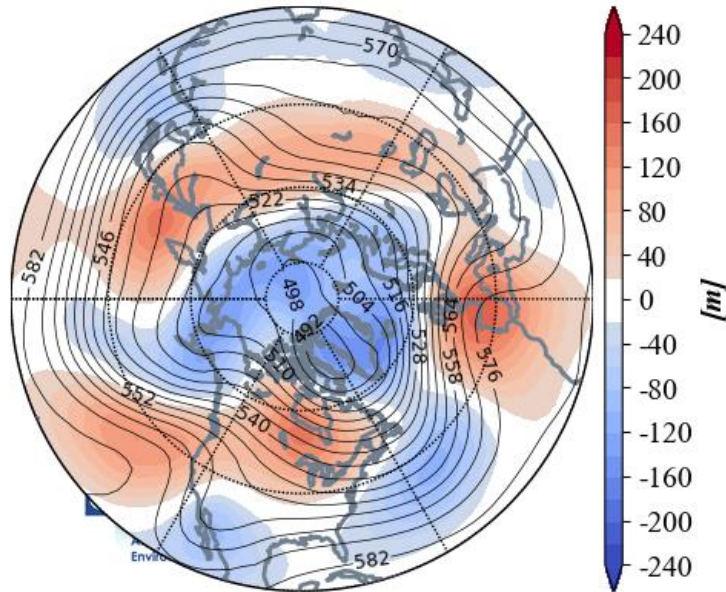


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 31 January – 4 February 2020. The forecasts are from the 00z 20 January 2020 GFS ensemble.

Ridging/positive geopotential height anomalies will dominate Europe with troughing/negative geopotential height anomalies confined to Northern Europe this period (**Figures 8**). High heights and lack of snow cover favor normal to above normal temperatures across much of Europe including the UK with normal to below normal temperatures confined to northern Scandinavia (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to dominate the interior of Asia with troughing/negative geopotential height anomalies confined to the edges over Northern Siberia and Southern Asia (**Figure 8**). This pattern favors normal to above normal temperatures across much of Asia with normal to below normal temperatures across northern Siberia and Southern Asia (**Figure 9**).

GEFS 11-15 Day Forecast T2m Anomaly
INIT: 00Z 01/20/20 FCST: 01/31/20 to 02/04/20

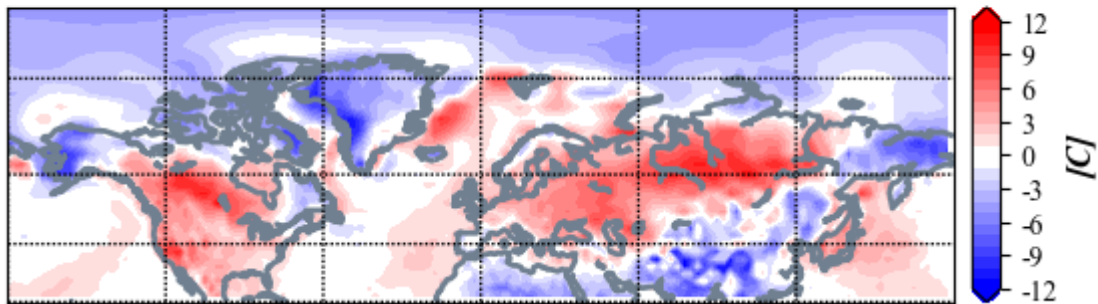


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 31 January – 4 February 2020. The forecasts are from the 00z 20 January 2020 GFS ensemble.

Persistent ridging/positive geopotential height anomalies are predicted to remain anchored over the interior of Canada with troughing/negative geopotential height anomalies confined to Alaska and the Southern US (**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 for Alaska and Northeastern Canada (**Figure 9**).

GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 01/20/20 FCST: 01/31/20 to 02/04/20

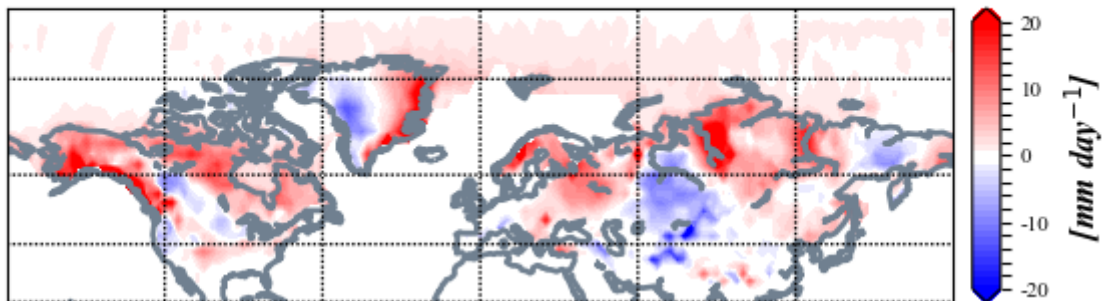


Figure 10. Forecasted snow depth changes (mm/day; shading) from 31 January – 4 February 2020. The forecasts are from the 00z 20 January 2020 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across much of Northern Asia and possibly Eastern Europe, Western Russia and the Tibetan Plateau (**Figure 10**). New snowfall is possible across much of Alaska, Western and Eastern Canada and possibly the Central and Northeastern US (**Figure 10**). Some snowmelt is possible in Central Asia, the Western US and the North American Plains (**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 early January have now coupled to the troposphere (**Figure 11**). The predicted cold tropospheric PCHs are consistent with a predicted positive surface AO (**Figure 1**). This completes a troposphere-stratosphere-troposphere coupling event with a strong stratospheric PV/positive AO.

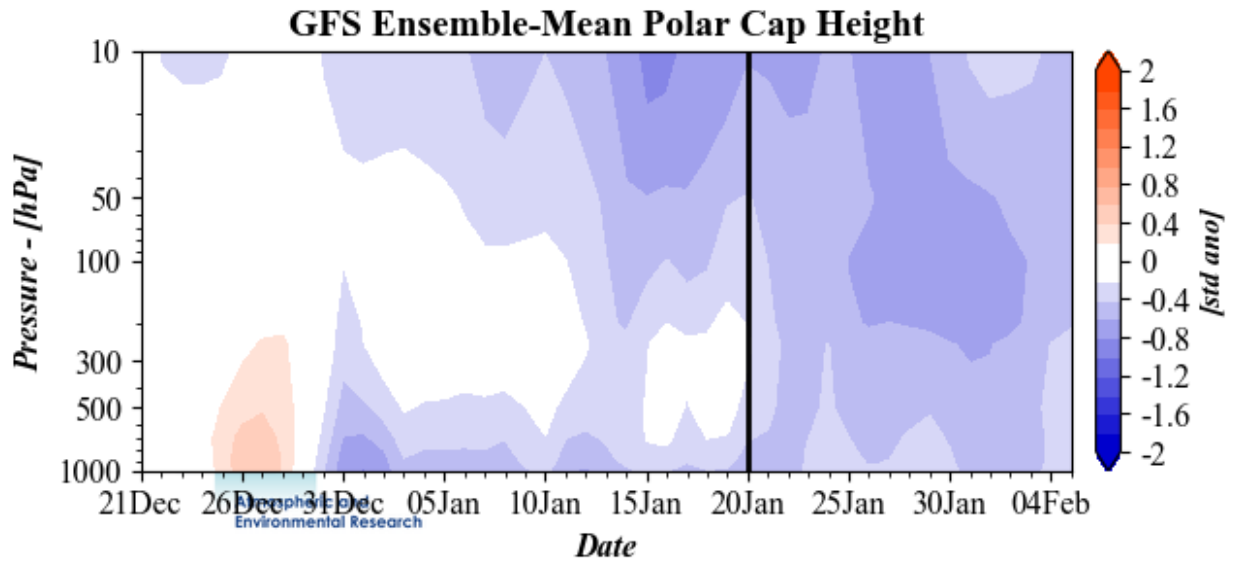


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 20 January 2020 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows a relatively quiet week with only weak positive WAFz anomalies (**Figure 12**). Next week a stronger pulse of positive anomalies is predicted (**Figure 12**). But for now, no significant WAFz pulses are predicted.

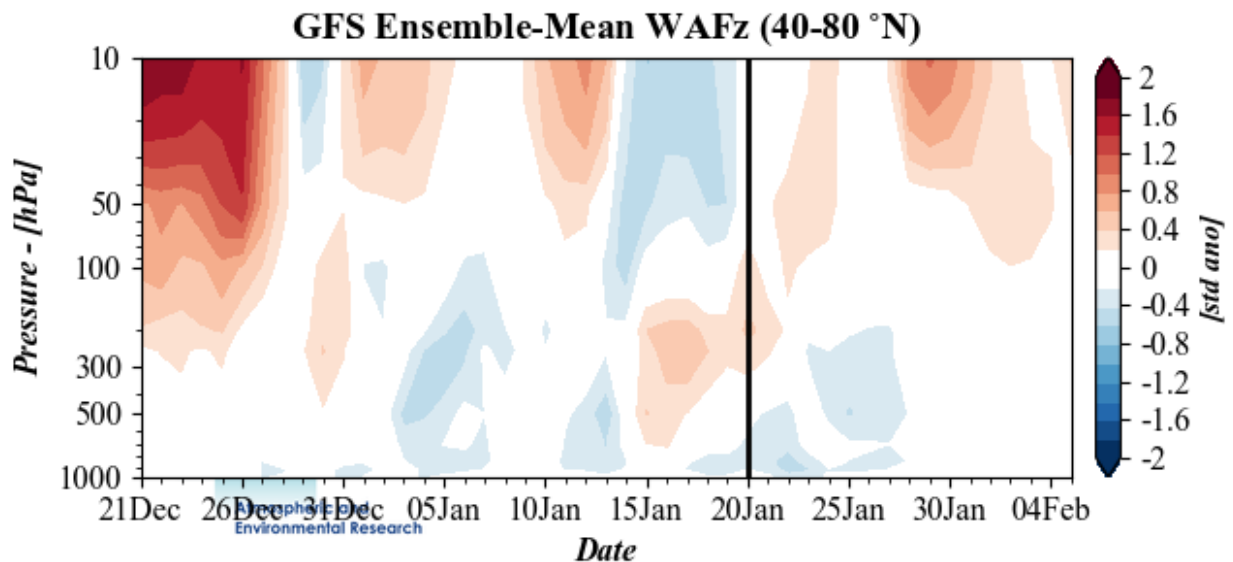


Figure 12. Observed and predicted daily vertical component of the wave activity W_{ux} (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 20 January 2020 GFS ensemble.

The stratospheric AO is currently positive (**Figure 1**) consistent with a relatively normal to strong PV and the stratospheric AO is predicted to slowly trend to neutral (**Figure 1**). The slight weakening of the stratospheric PV is probably related to the positive WAFz pulse predicted for next week.

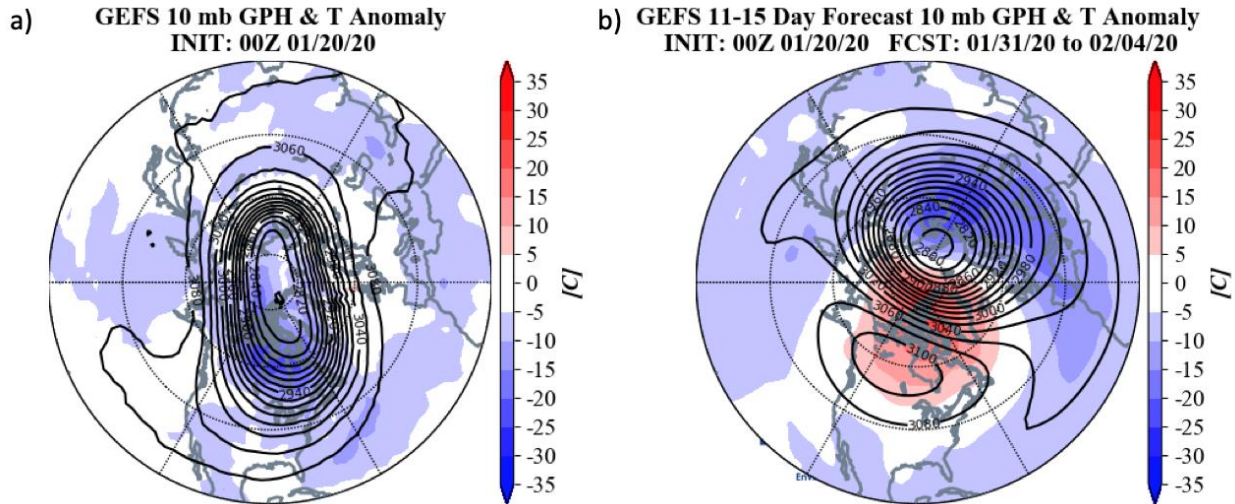


Figure 13. (a) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere at 00Z 20 January 2020. (b) Same as (a) except forecasted averaged from 31 January – 4 February 2020. The forecasts are from the 00Z 20 January 2020 GFS operational model.

Currently the stratospheric PV remains centered near the North Pole (**Figure 13**) with the largest negative temperature departures in the polar stratosphere located over Hudson’s Bay (**Figure 13**). The PV is elongated along an axis from Siberia to Canada and as I described last week, seems to be characteristic of a reflective PV event that favors cold in Siberia and eastern North America.

However, starting next week, the PV center is predicted to become displaced towards the northern Urals with the lowest heights in northern Eurasia (**Figure 13**). At the same time ridging develops over central Canada accompanied by warm temperatures (**Figure 13**). The displacement of the PV into northern Eurasia with ridging over Canada are characteristic of a “Canadian warming” in the stratosphere (**Figure 13**).

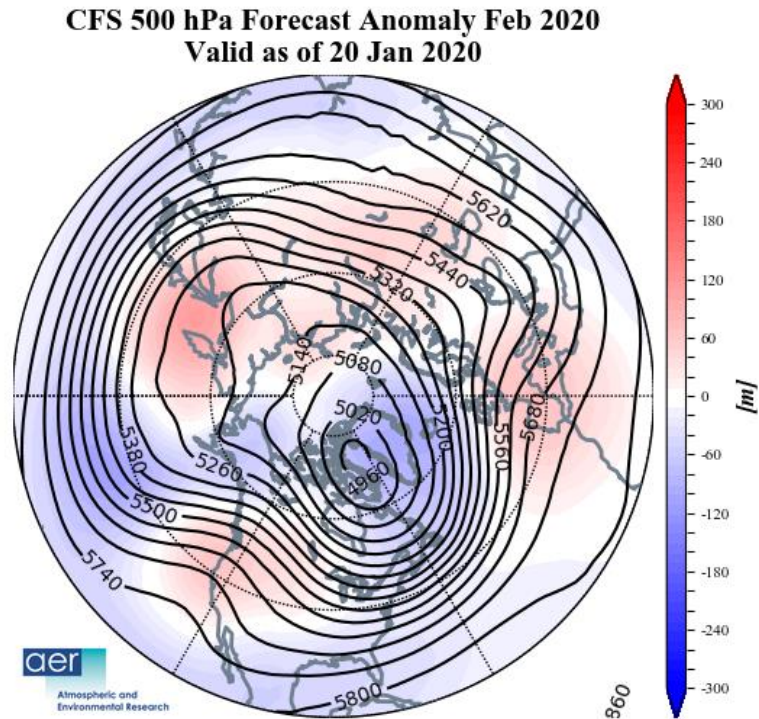


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for February 2020. The forecasts are from the 00Z 20 January 2020 CFS.

I include in this week’s blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) forecast for February from the Climate Forecast System (CFS; the plots represent yesterday’s four ensemble members). The forecast for the troposphere is ridging across Western Europe, Kamchatka and the Western US with troughing in Western and Eastern Asia and eastern North America (**Figure 14**). This pattern favors relatively mild temperatures for Europe, Western Asia, Western Canada and the Western US with seasonable to relatively cold temperatures for much of Central and Eastern Asia, Eastern Canada and the Eastern US (**Figure 15**). I have particularly low confidence in the forecast.

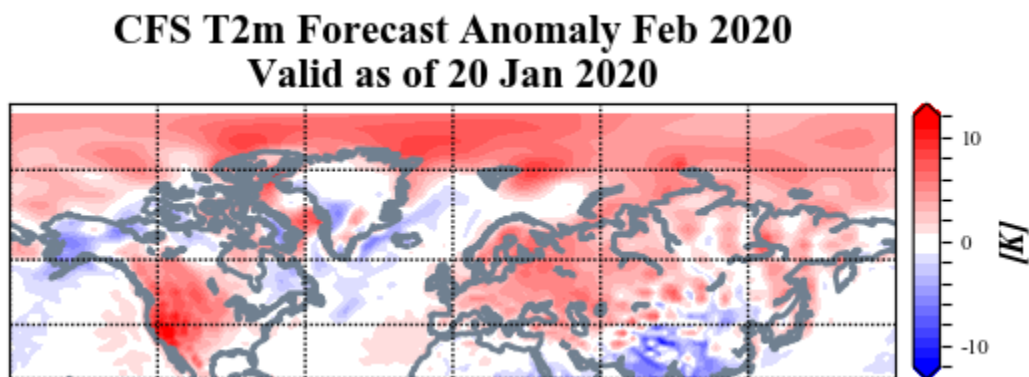


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for February 2020. The forecasts are from the 00Z 20 January 2020 CFS.

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 well below normal but higher than recent winters; the weather pattern remains favorable for further sea ice growth. Negative sea ice anomalies exist in three regions: the Bering Sea, around Greenland-Canadian Archipelagos and Barents-Kara Seas. The negative anomalies in the North Pacific still remain the greatest (**Figure 16**), though based on model forecasts negative sea ice anomalies in the Bering Sea can shrink further in the next two weeks. Below normal sea ice in and around Greenland and the Canadian Archipelagos may favor a negative winter NAO, though there are no signs of such a scenario. Based on recent research low sea ice anomalies in the Chukchi and Bering seas favors cold temperatures in central and eastern North America while low sea ice in the Barents-Kara seas favor cold temperatures in Central and East Asia, however this topic remains controversial. 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.

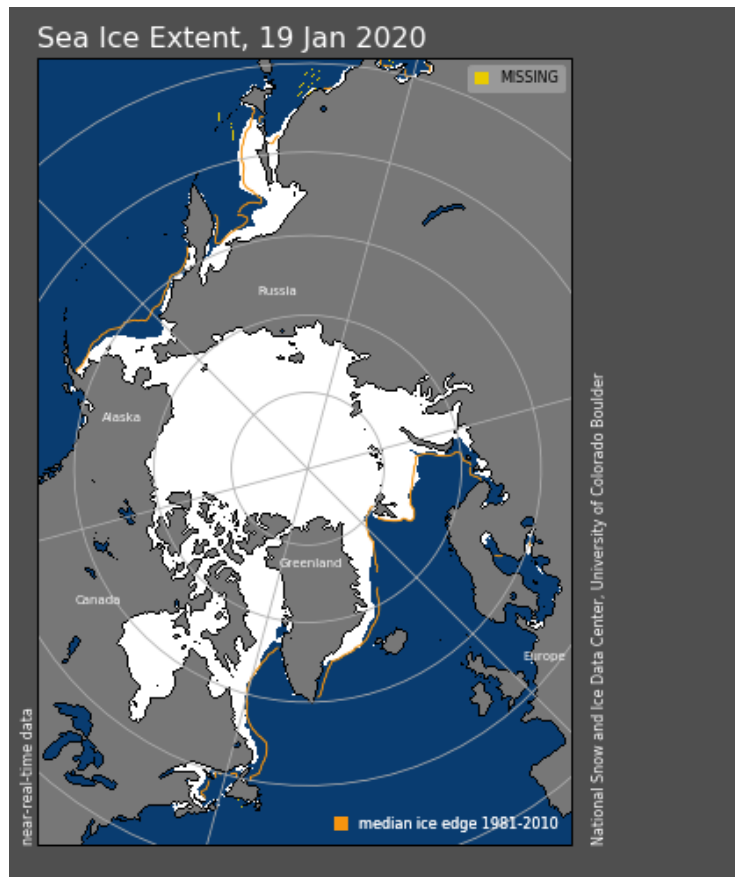


Figure 16. a) Observed Arctic sea ice extent on 19 January 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010.

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 19 Jan 2020

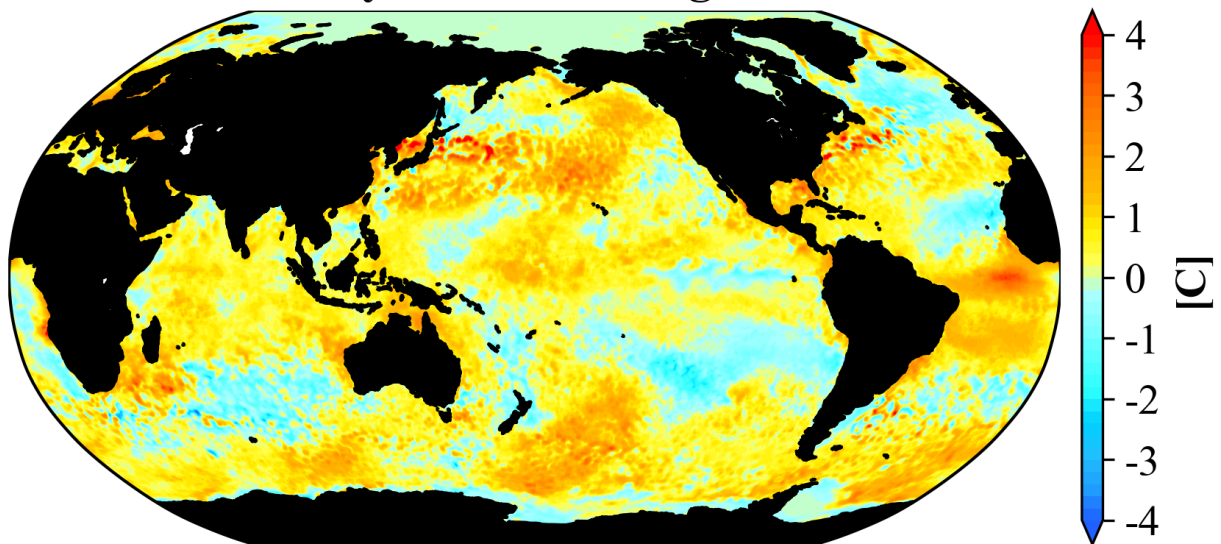


Figure 17. The latest weekly-mean global SST anomalies (ending 19 January 2020). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase six (**Figure 18**). The forecasts are for the MJO to quickly transition to phase seven this week before weakening where no phase is favored. MJO phase seven mostly favors troughing south of the Aleutians, ridging in Canada with more troughing across the US. This is consistent with the predicted pattern across North America and supports that the MJO is contributing to the predicted pattern across North America.

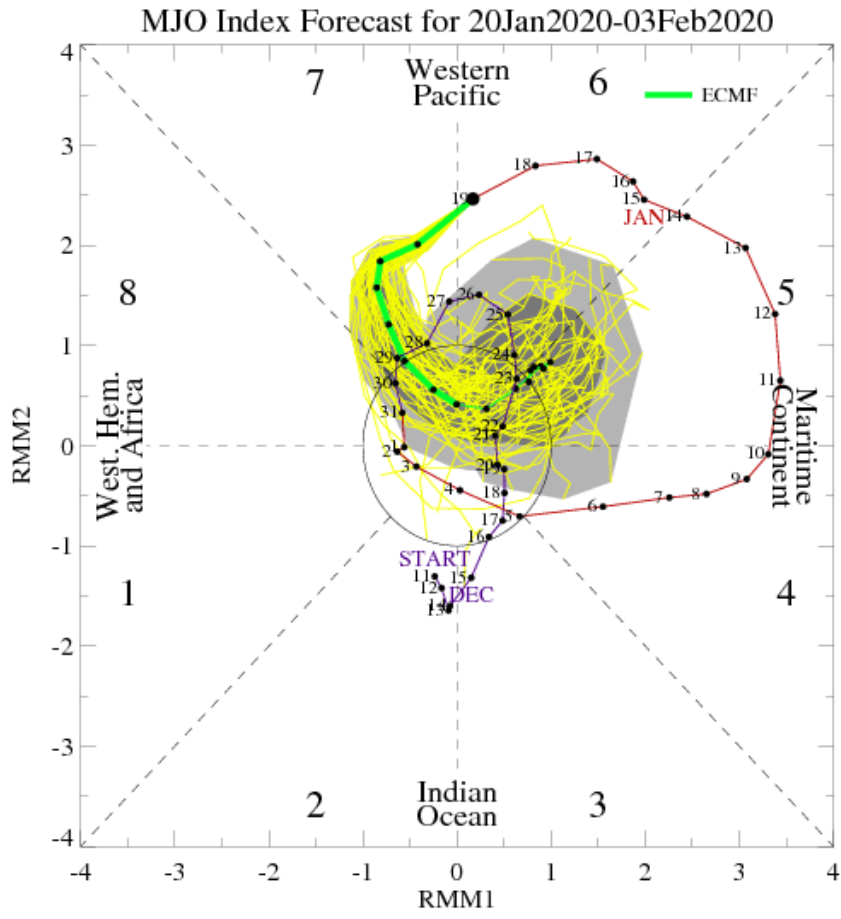


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 6 January 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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 has declined across Eurasia but remains near decadal means. With a predicted positive AO, I don't expect the snow cover to advance in the coming week. Above normal snow cover extent in October, favors a strengthened Siberian high, cold temperatures across northern Eurasia and a weakened polar vortex/negative AO this upcoming winter followed by cold temperatures across the continents of the NH.

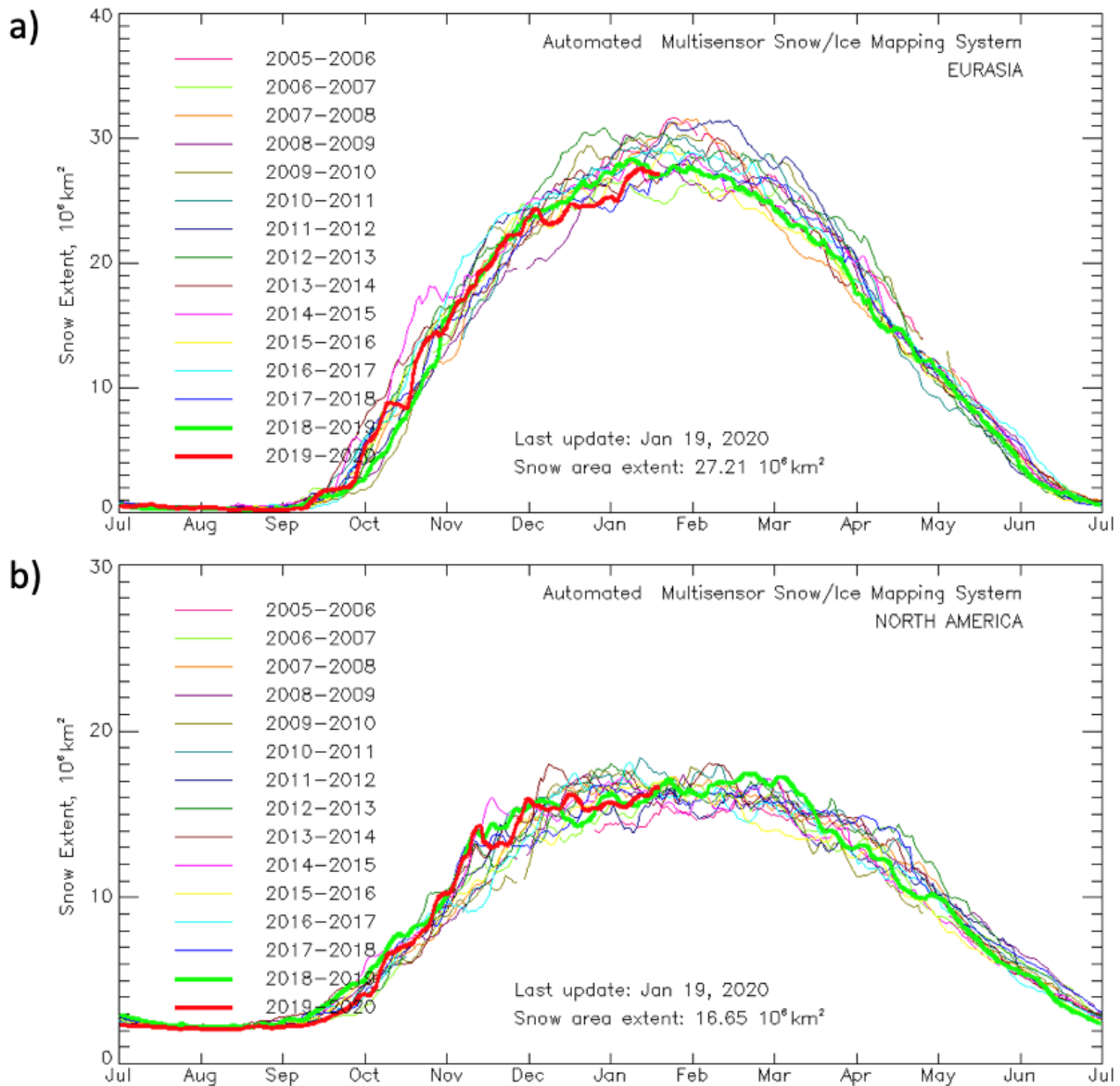


Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 5 January 2020 . Image source:

https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover advanced slightly and remains at the high end of decadal means. Snow is predicted to melt in regions but could advance if an East Coast snow storm materializes in this pattern. The early advance of snow cover across Canada this fall, has likely contributed to the expanse of cold temperatures across Canada.