Arctic Oscillation and Polar Vortex Analysis and Forecasts

February 3, 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.

Subscribe to our email list or follow me on Twitter (@judah47) for notification of updates.

The AO/PV blog is partially supported by NSF grant AGS: 1657748.

Summary

- The Arctic Oscillation (AO) is currently positive and is predicted to remain positive the next two weeks but could turn strongly positive early next week.
- 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 near neutral over the next two weeks as height anomalies are predicted to remain weak across Greenland.

- The general circulation pattern over the next two weeks is ridging/positive geopotential height anomalies and/or a mild westerly, maritime flow of air over most of Europe with troughing/negative geopotential height anomalies confined to Northernmost Europe. 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 pattern for Asia is transitory starting with ridging/positive geopotential height anomalies in Central Asia sandwiched between troughing/negative pressure/geopotential height anomalies on the edges transitioning to troughing in Western Asia and ridging in Eastern Asia back to a trough-ridge-trough pattern. This pattern favors normal to below normal temperatures across East Asia with normal to above normal temperatures in West Asia flipping to below normal temperatures in West Asia and above normal temperatures in East Asia before returning to above normal temperatures in West Asia with below normal temperatures in East Asia mid-month. The one constant over the next two weeks is troughing/negative pressure/geopotential height anomalies and normal to below normal temperatures in Eastern Siberia and the northern Indian subcontinent.
- The general predicted pattern the next two weeks for North America 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 Sates (US) with more ridging/positive geopotential height anomalies in the Eastern US. This pattern favors widespread normal to below normal temperatures across Canada and the Western US with normal to above normal temperatures in Alaska and much of the Eastern US.
- In the Impacts section I discuss whether the pattern will ever change this winter, especially the strong polar vortex (PV).

Impacts

Seems appropriate to be writing this blog the day after Groundhog's Day, with its perception changed with the movie of the same name where the actor Bill Murray repeated Groundhog Day over and over again.

We have been locked in a pattern where the PV is normal to even near record strong since mid-December and the AO is positive to near record positive since late December and from today's weather maps it is difficult to see how that changes. Right now, yesterday's weather is the best forecast for tomorrow's weather and the day after that and the day after that and so on.

I believe that the one large-scale circulation feature that is most consequential for disrupting the stratospheric PV is blocking/high pressure in the Scandinavian/Urals region. For January there has been strong relatively low pressure/geopotential heights in this region and the forecast is for this to continue into February for the foreseeable future. This coupled with high pressure/ridging in the North Pacific has been a very nurturing environment for a strong stratospheric PV or at least not triggering a significant disruption to the PV. The circulation pattern of relatively low pressure across northwest Eurasia and relatively high pressure in the North Pacific suppresses vertical energy transfer from the troposphere to the stratosphere that drives PV variability. The more (less) vertical energy that is absorbed in the polar stratosphere the weaker (stronger) the PV. And with a deficit of energy transfer from the troposphere to the polar stratosphere the PV strengthened, temperatures cooled, and geopotential heights lowered. Once the strong PV with cold/negative geopotential height anomalies coupled to the surface the AO has remained positive to even extremely positive.

A major warming has a built-in shut off valve because once the winds reverse from westerly to easterly, vertical energy from the troposphere can no longer enter the stratosphere allowing the PV to recover fairly quickly at least in the middle stratosphere. There is no such mechanism in reverse. There is no turn on switch for the vertical energy transfer to weaken a strong PV. Without a change in the tropospheric pattern that gave rise to the strong PV, the PV will remain strong. Or in other words a strong PV favors a positive AO and the low pressure/heights at high latitudes (or a lack of high latitude blocking) associated with a positive AO favor a strong PV and they both seem to be locked in an infinite loop. This loop is often broken when a positive NAO combines with Ural blocking that can weaken the PV but as of yet there are no signs of any Ural blocking.

As in recent winters, there is no assistance from below normal sea ice to force high pressure/blocking in the region of the Barents-Kara Seas as sea ice extent is fairly close to normal. Sea ice extent is reasonably close to normal in all of the Arctic seas including the Bering Sea. And at least for me the ability of sea ice to recover this winter off of record low extent this past fall is one of the feel-good stories of this otherwise uneventful winter.

The one region where an anomalously warm ocean surface may have been able to generate high pressure/ridging is in the North Pacific due to well above normal sea surface temperatures in the eastern North Pacific that seems to have supported persistent ridging in the region. Ridging in the Gulf of Alaska is predicted to amplify once again and should support colder temperatures downstream across Canada and the Northern and Western US.

Given the forecasts of an extreme positive AO for the first half of February the most surprising aspect might be why aren't predicted temperatures even warmer across the Northern Hemisphere continents. Widespread relatively cold temperatures are

predicted for North America and even Siberia for the next two weeks despite the record-breaking positive AO. I think part of the answer is because despite the strong PV, it is not predicted to be circular in shape but rather elongated from Siberia to Canada. This is consistent or maybe reminiscent of a reflective PV event that supports cold temperatures in Siberia and North America, though the axis of the cold temperatures is predicted to be shifted west across North America compared to typical reflective events.

I have been frustrated with the model forecasts of PV behavior which have been exaggerating for much of the winter any PV disruptions. But with that in mind, besides the relatively minor PV disruption this week, the most recent GFS operational run is predicting a second relatively minor PV perturbation where the PV center is displaced towards North America (see **Figure i**). If that verified it is suggestive to me of more potential cold weather in Siberia but especially western North America. I still see no reason for a change to more wintry weather across Europe. The pockets of cold in this overall mild winter seem to be East Asia and western North America. If we do get a PV disruption, then that would probably favor cold air shifting to the Eastern US before Europe.

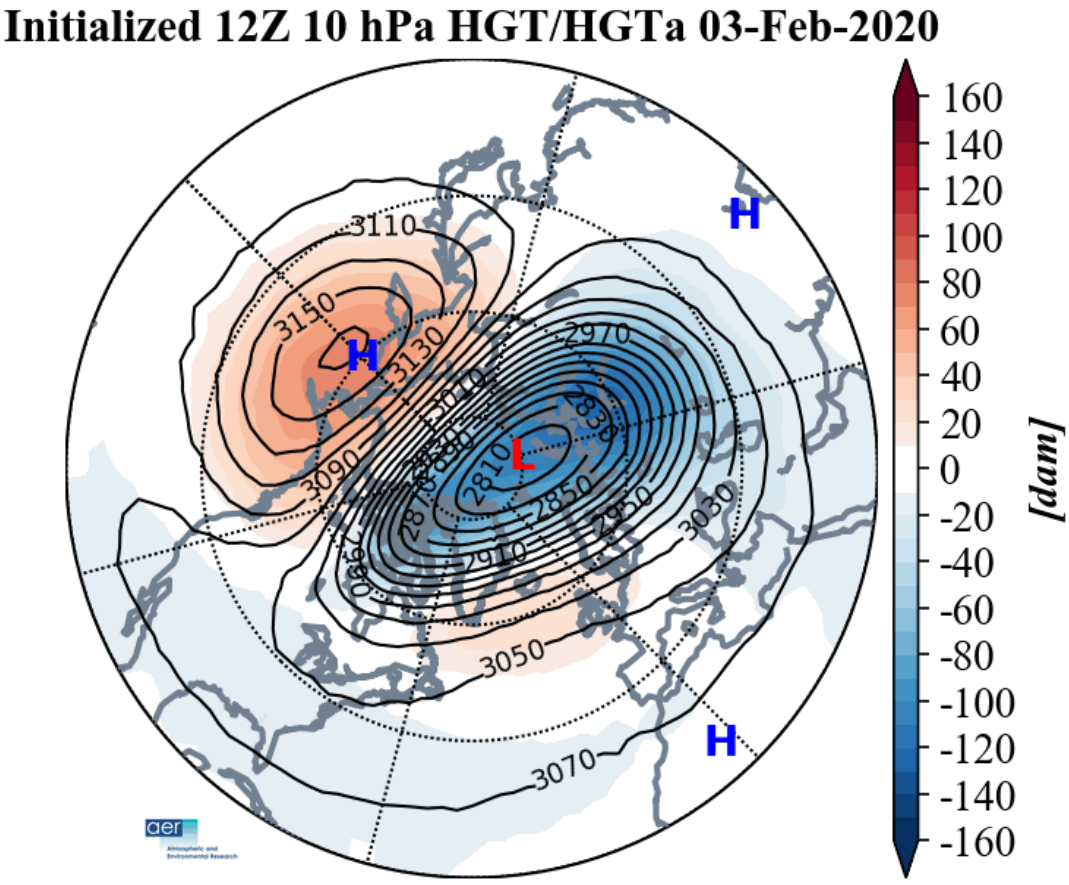

Figure i.

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 3 February 2020 GFS operational.

I am still expecting at least one PV disruption of greater magnitude that what we have seen so far since mid-December before the Final Warming but that is mostly based on what has occurred the past two decades in late winter more so than anything that I see in the current atmospheric circulation. In addition, there doesn't seem to be much assist from Arctic sea ice extent or warm Arctic temperatures. Temperatures in the Arctic are for the most part above normal but not extremely so like we have seen in past winters or even in early December 2019. But looking at today's weather forecasts I think the best chance of bringing any semblance of winter weather before spring blossoms in full is for one of two regions of ridging can make its way into the northern North Atlantic. So that either ridging in the Gulf of Alaska can bridge across from the North Pacific part of the Arctic to the North Atlantic part of the Arctic and/or alternatively ridging over Europe pushes north into the northern North Atlantic.

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.

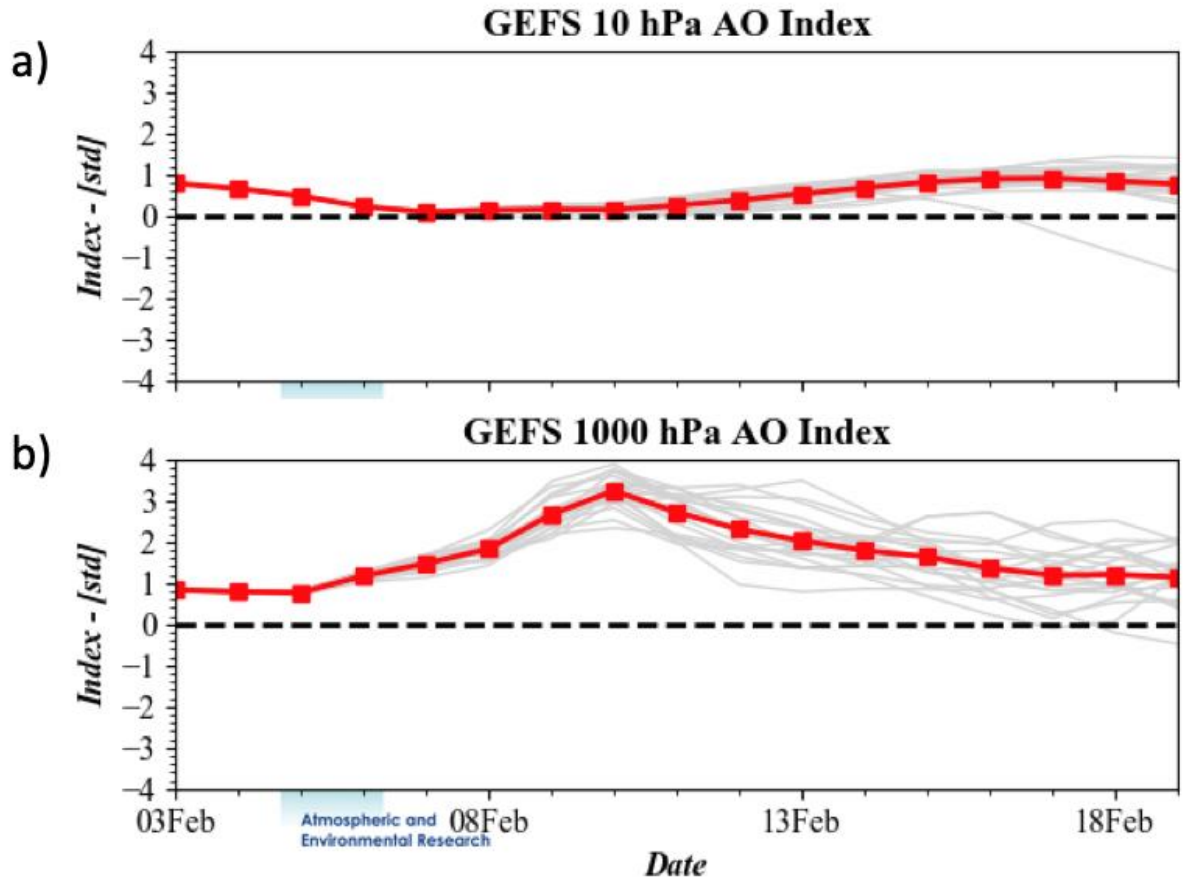

Figure 1. (**a**) The predicted daily-mean AO at 10 hPa from the 00Z 3 February 2020 GFS ensemble. (**b**) The predicted daily-mean near-surface AO from the 00Z 3 February 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week ridging/positive geopotential height anomalies are predicted to dominate much of Europe (**Figure 2**). General high heights and lack of snow cover will result in normal to above normal temperatures across much of Europe including the UK (**Figure 3**). One exception could be northern Scandinavia 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 West Asia with normal to below normal temperatures in East Asia and far northwestern Asia **(Figure 3**). Persistent troughing/negative geopotential height anomalies in the Tibetan Plateau (**Figure 2**) favor normal to below normal temperatures for the northern Indian subcontinent **(Figure 3).**

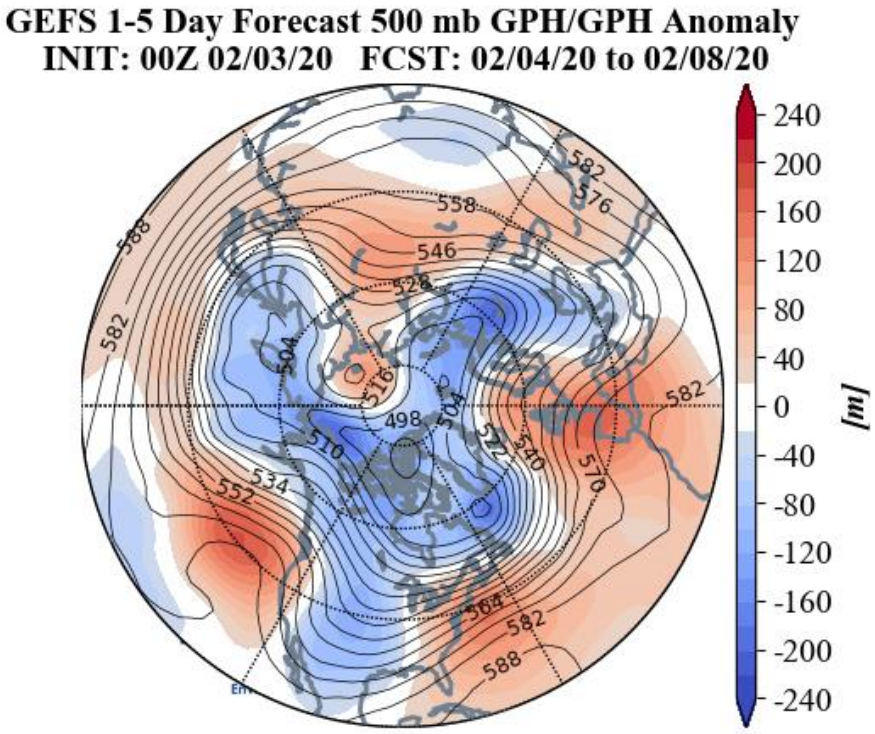

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 4 – 8 February 2020. The forecasts are from the 00z 3 February 2020 GFS ensemble.

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 northern Alaska to Central Canada and the Western US with normal to above normal temperatures across Southern Alaska parts of Western and Eastern Canada and the Eastern US **(Figure 3).**

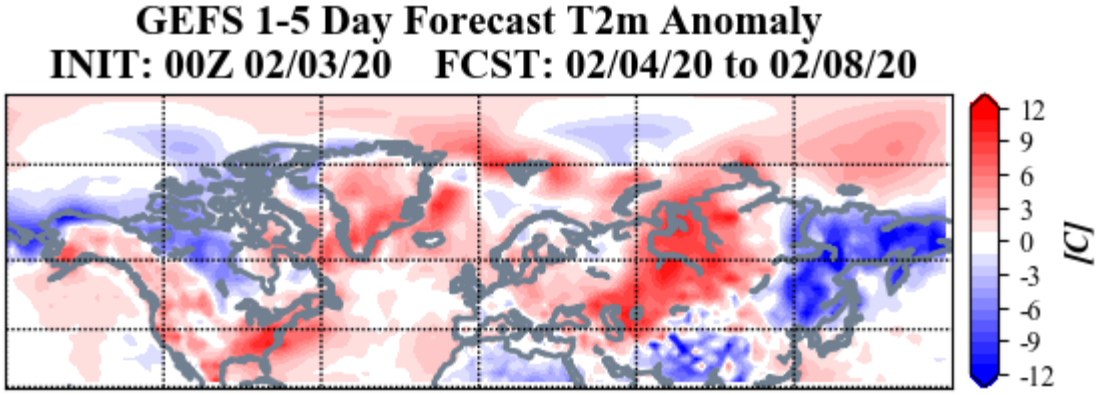

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 4 – 8 February 2020. The forecast is from the 00Z 3 February 2020 GFS ensemble.

Troughing and/or cold temperatures are predicted to bring new snowfall across Northern Asia and Eastern Europe (**Figure 4**). Troughing and cold temperatures are predicted to bring new snowfall to much of Alaska, Canada and along a stripe from the US South-Central Plains to New England (**Figure 4**). Warm temperatures are predicted to result in snowmelt for West Asia and the Pacific Northwest (**Figure 4**).

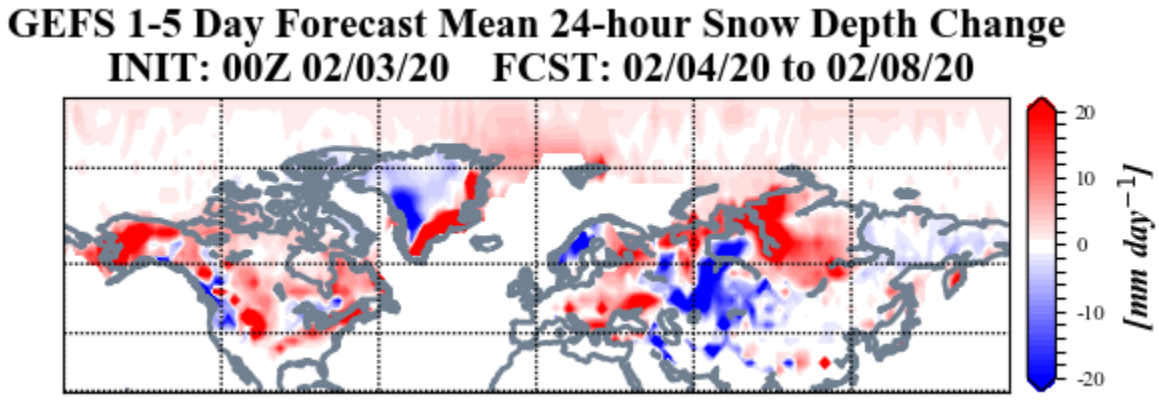

Figure 4. Forecasted snowdepth anomalies (mm/day; shading) from 4 – 8 February 2020. The forecast is from the 00Z 3 February 2020 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to turn strongly 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 strong negative geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to turn strongly positive as well.

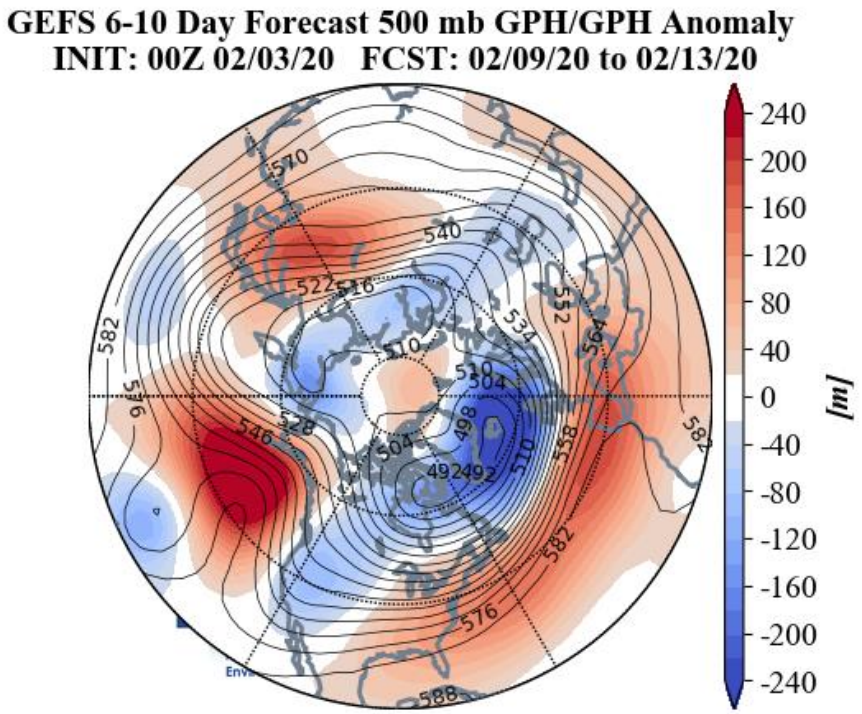

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 9 – 13 February 2020. The forecasts are from the 00z 3 February 2020 GFS ensemble.

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**). Ridging/positive geopotential height anomalies will dominate East Asia with troughing/negative geopotential height anomalies across Central South and West Asia (**Figure 5**). This is predicted to yield normal to below normal temperatures for Western Asia **with** normal to below temperatures for much of Southern and Eastern Asia and most of Siberia **(Figure 6**). Troughing/negative geopotential height anomalies across Northern and Eastern Siberia (**Figure 5**) will bring normal to below normal temperatures for these regions **(Figure 6**).

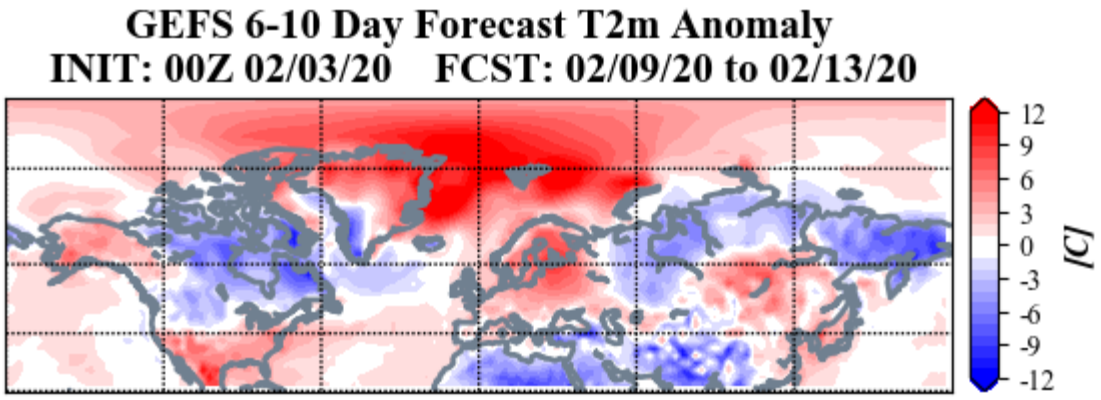

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 9 – 13 February 2020. The forecasts are from the 00Z 3 February 2020 GFS ensemble.

Ridging/positive geopotential height anomalies in the Gulf of Alaska are predicted to push north this period into Alaska forcing downstream troughing/negative geopotential height anomalies across much Canada and the Western US with more ridging/positive geopotential height anomalies in the Eastern US (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across Alaska and the Southwestern and Eastern US with normal to below normal temperatures across much of Canada and the Northwestern US **(Figure 6).**

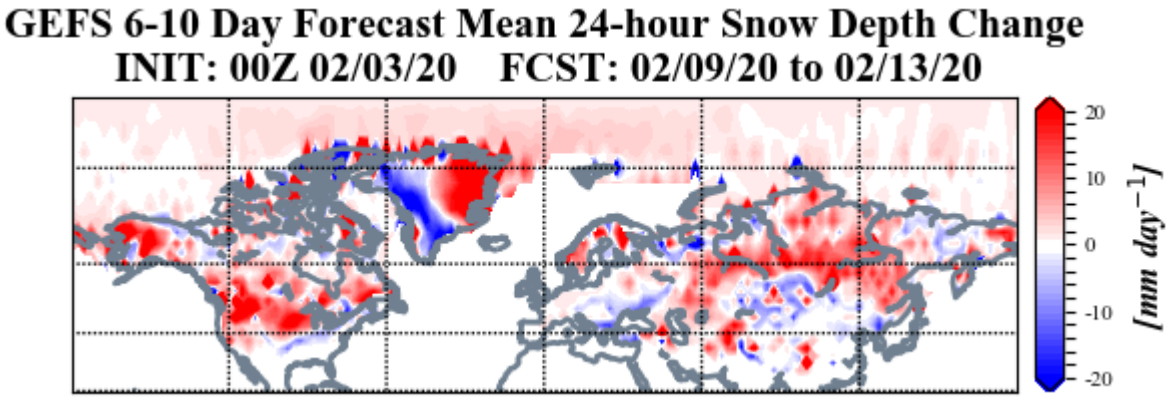

Figure 7. Forecasted snowdepth changes (mm/day; shading) from 9 – 13 February 2020. The forecasts are from the 00Z 3 February 2020 GFS ensemble.

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

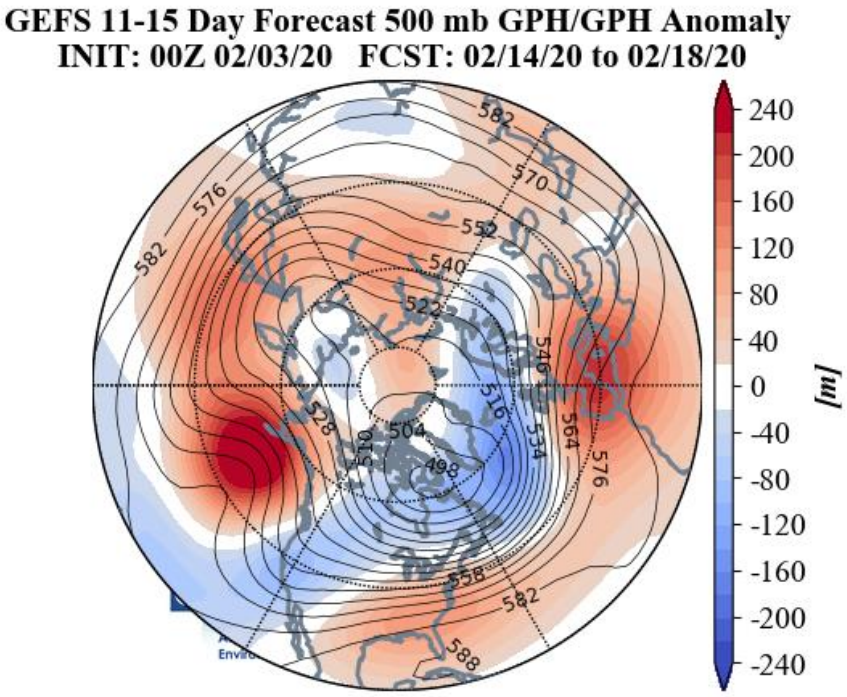

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 14 – 18 February 2020. The forecasts are from the 00z 3 February 2020 GFS ensemble.

Ridging/positive geopotential height anomalies will dominate Central and Southern Europe with troughing/negative geopotential height anomalies confined to Scandinavia 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 much of Asia with troughing/negative geopotential height anomalies persisting in East and South-Central Asia (**Figure 8**). This pattern favors normal to above normal temperatures across Western and Central Asia with normal to below normal temperatures across Siberia, Northeast Asia and the Tibetan Plateau (**Figure 9**).

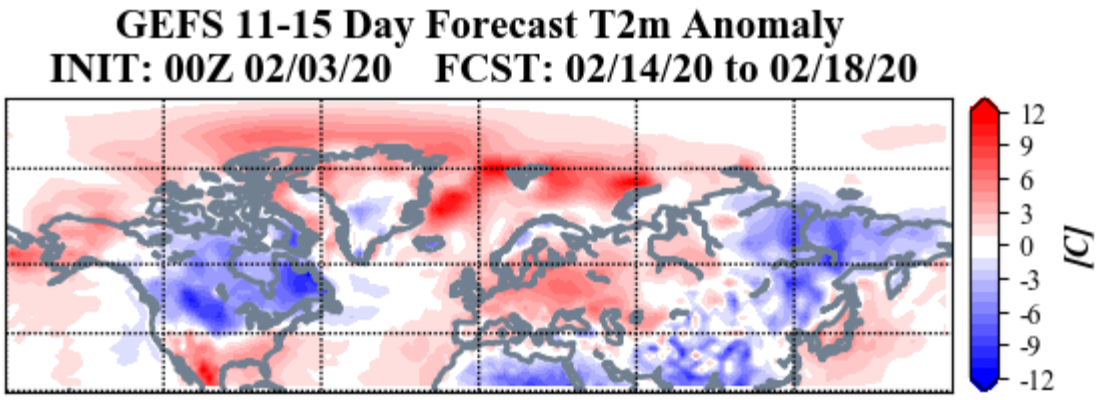

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 14 – 18 February 2020. The forecasts are from the 00z 3 February 2020 GFS ensemble.

Persistent ridging/positive geopotential height anomalies in the Gulf of Alaska and Alaska are predicted to force downstream troughing/negative geopotential height anomalies across much of Canada and the Western US with more ridging/positive geopotential height anomalies in the Southeastern US (**Figure 8**). This pattern is predicted to favor normal to below normal temperatures across much of Canada and the Northern and Western US with normal to above normal temperatures across Alaska and the Southern and Eastern US (**Figure 9**).

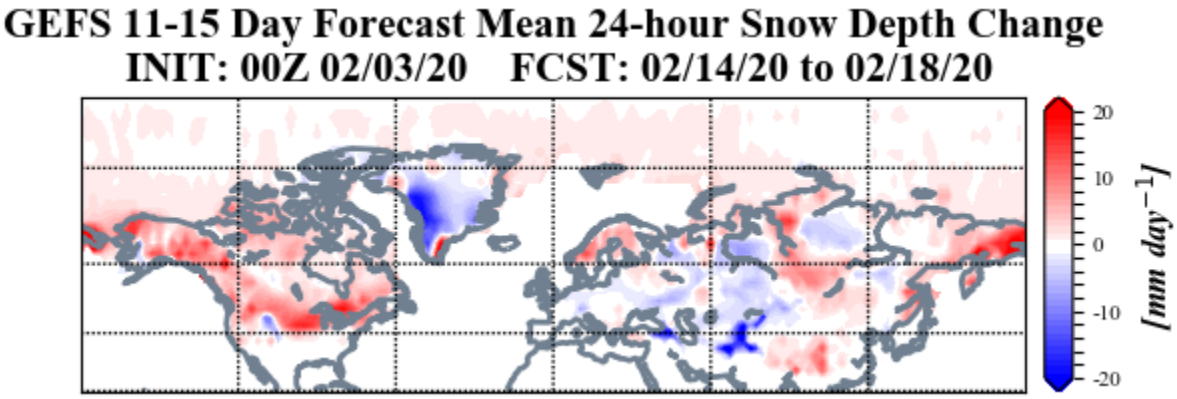

Figure 10. Forecasted snow depth changes (mm/day; shading) from 14 – 18 February 2020. The forecasts are from the 00z 3 February 2020 GFS ensemble.

No strong signals are evident but troughing and/or cold temperatures could support new snowfall across much of Northern and possibly Central Asia and Scandinavia (**Figure 10**). New snowfall is possible across Alaska, much of Canada and possibly the Northern US (**Figure 10**). Some snowmelt is possible in Western Asia and Eastern Europe (**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 that coupled to the troposphere for much of January and predicted to persist into mid-February at least (**Figure 11**). The predicted cold tropospheric PCHs are consistent with a predicted positive surface AO (**Figure 1**). Last week the coupled event was predicted to come to a complete end the first week of February, but the models have now backed away from that forecast. PCHs are predicted to return to normal in the troposphere but not in the stratosphere the third week of February.

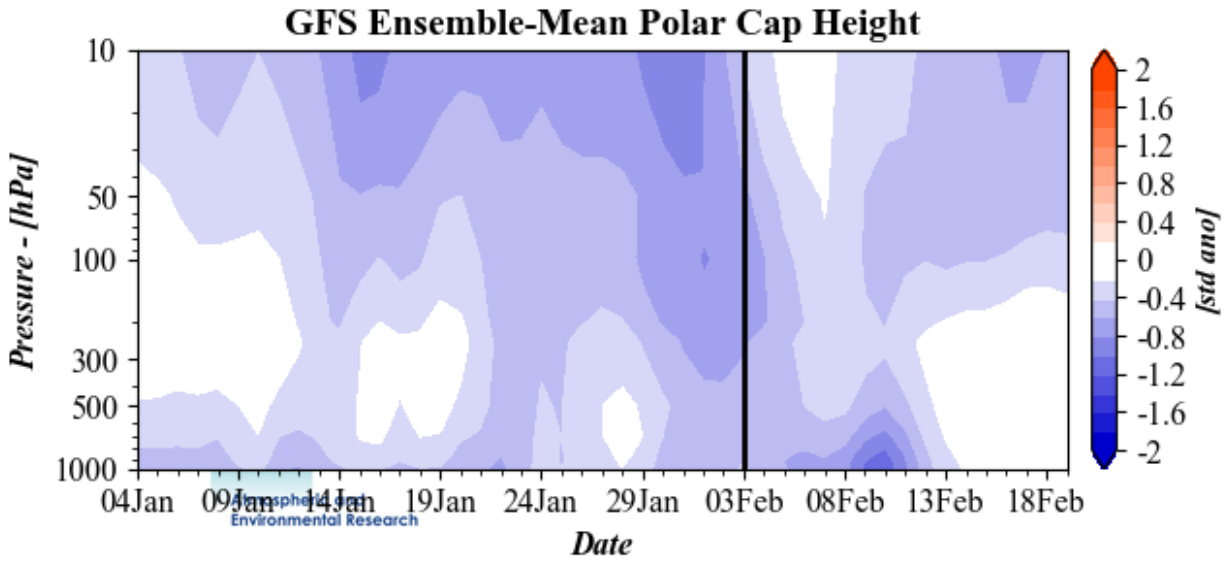

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 3 February 2020 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows a fairly strong pulse currently after a relatively quiet month with only weak positive WAFz anomalies (**Figure 12**). After this week's pulse there seems to be lots of model uncertainty with near normal activity predicted for next week (**Figure 12**).

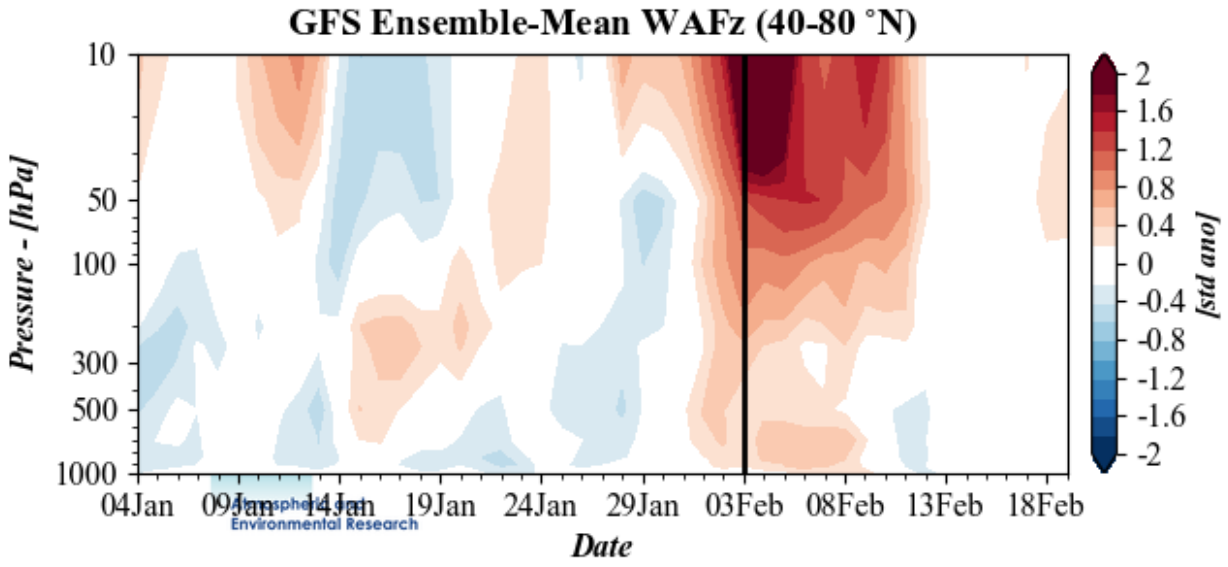

Figure 12. Observed and predicted daily vertical component of the wave activity Wux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 3 February 2020 GFS ensemble.

The stratospheric AO is currently positive (**Figure 1**) consistent with a relatively normal to strong PV and the stratospheric AO is predicted to slowly trend to neutral and then back to positive (**Figure 1**). The weakening of the stratospheric PV is related to the positive WAFz pulse predicted for this week. Further WAFz pulses could weaken the stratospheric PV but for now there are no meaningful indications of this.

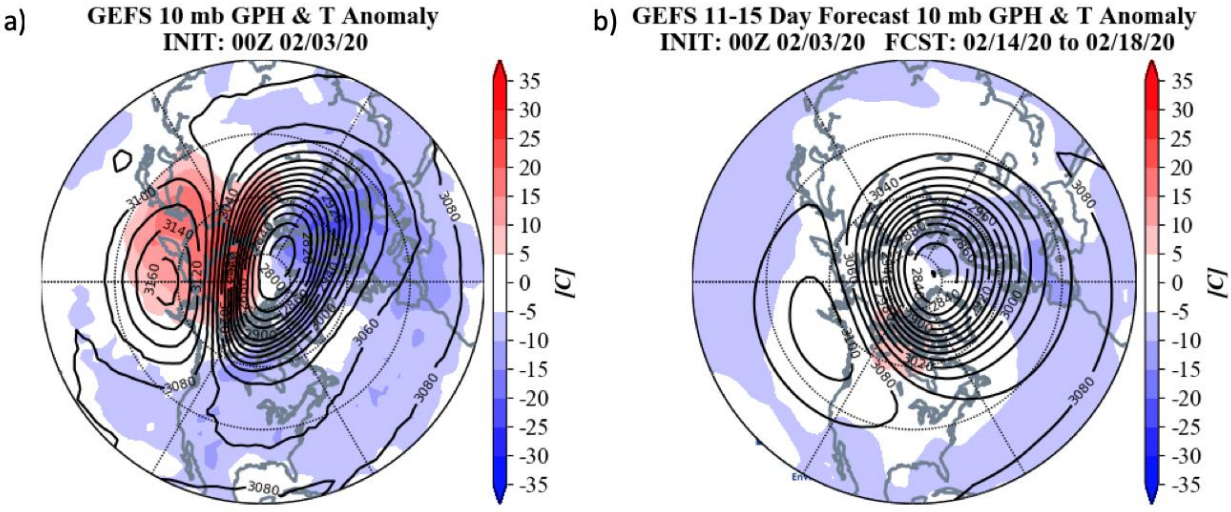

Figure 13. (**a**) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere at 00Z 3 February 2020. (**b**)

Same as (a) except forecasted averaged from 14 – 18 February 2020. The forecasts are from the 00Z 3 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 northwest Eurasia (**Figure 13**). The PV is not circular in shape but rather elongated along an axis from the Urals into Western Canada due to ridging and warming extending from Eastern Siberia to Alaska. The elongated PV is probably helping to support cold temperatures from Siberia to Canada despite the strongly positive AO.

Over the next two weeks, the PV center is predicted to remain displaced over the Barents-Kara Seas (**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 and returning to stronger than normal. Though the most recent suite of runs are somewhat suggestive of a new relatively minor disruption.

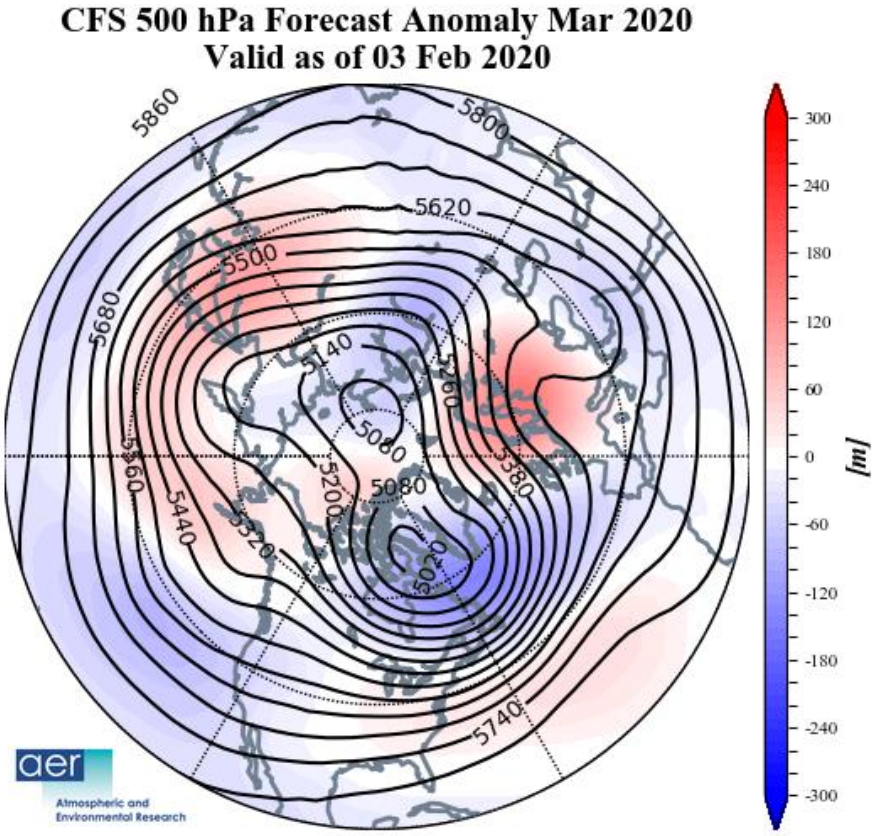

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for March 2020. The forecasts are from the 00Z 3 February 2020 CFS.

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, East Asia and the Beaufort Sea with troughing in Western Asia, the Eastern Mediterranean. Eastern Canada and the Western 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**). I have low confidence in the forecast.

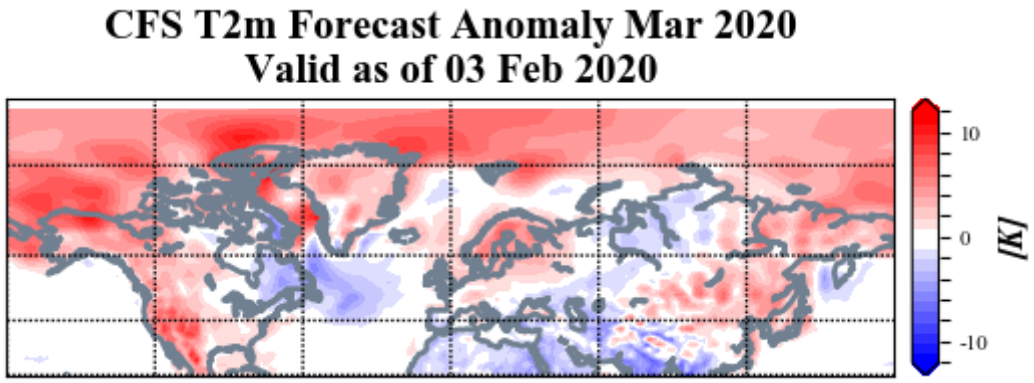

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for March 2020. The forecasts are from the 00Z 3 February 2020 CFS.

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 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. Though currently no large negative extent anomalies exist in any of these regions. 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.

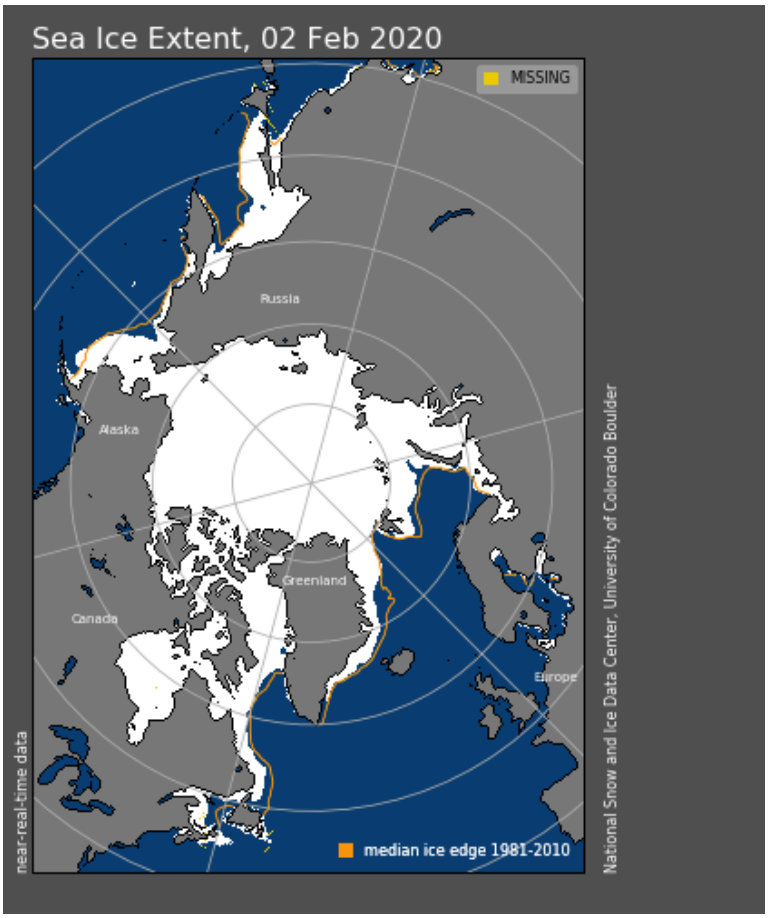

Figure 16. a) Observed Arctic sea ice extent on 2 February 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010.

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.

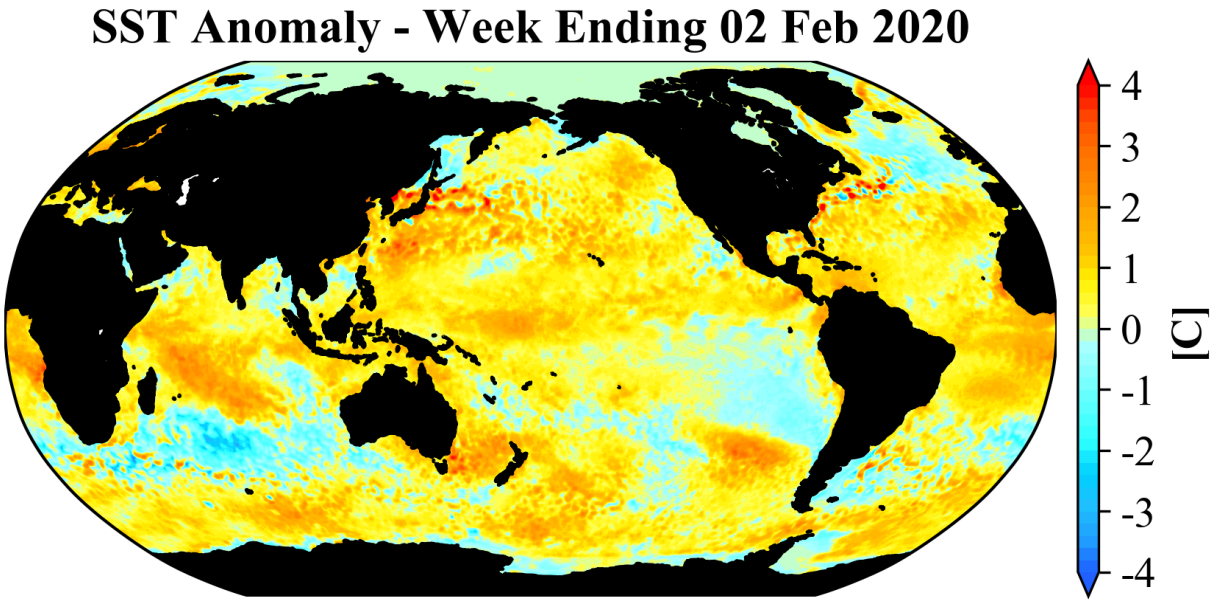

Figure 17. The latest weekly-mean global SST anomalies (ending 2 February 2020). Data from NOAA OI High-Resolution dataset.

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

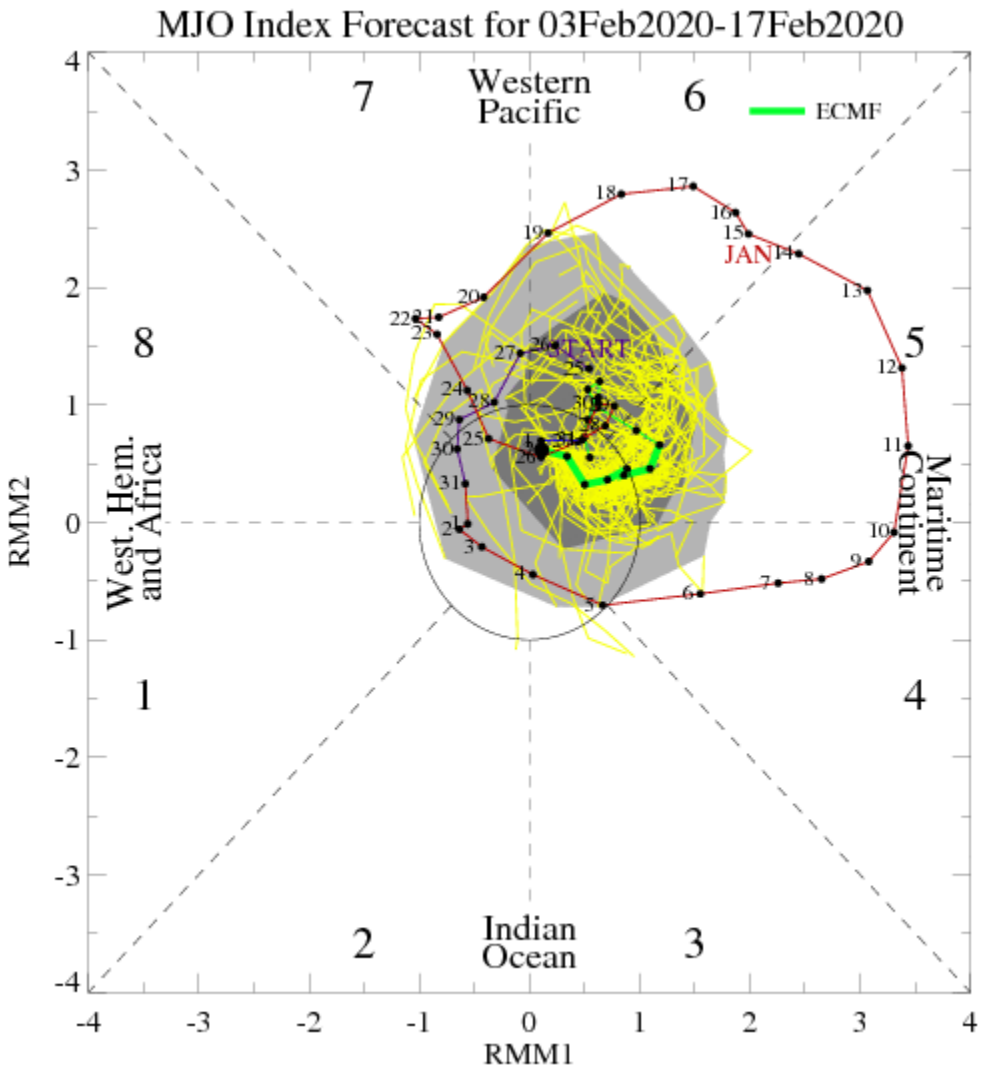

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 2 February 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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 declined across Eurasia and is near decadal lows. 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.

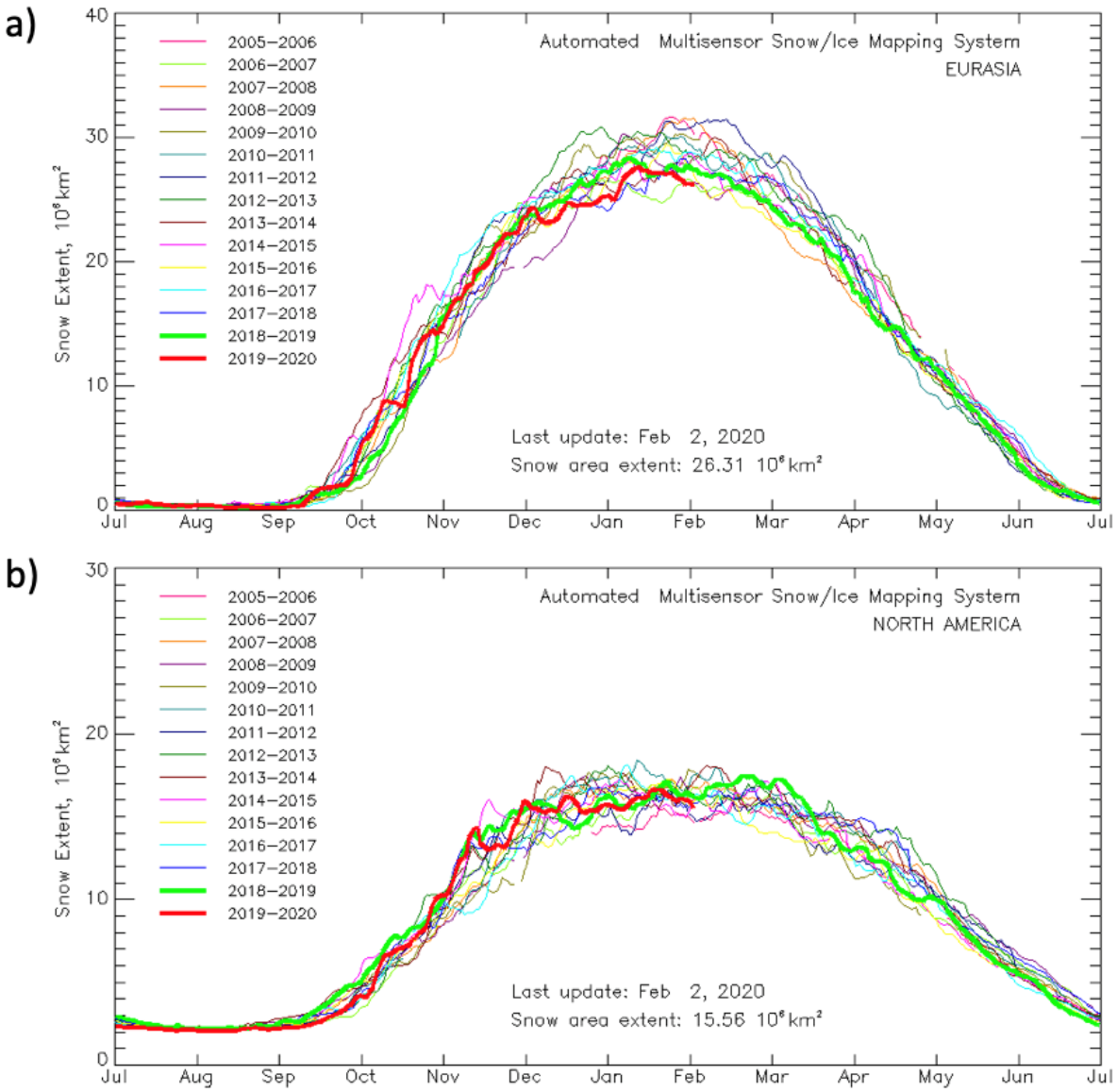

Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 2 February 2020 . Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover declined slightly and remains near decadal means. Snow is predicted to melt in regions but could advance if an East Coast snowfall 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.