

Arctic Oscillation and Polar Vortex Analysis and Forecasts

January 27, 2020

Special blog on winter 2018/2019 retrospective can be found here
- <http://www.aer.com/winter2019>

Special blog on winter 2017/2018 retrospective can be found here
- <http://www.aer.com/winter2018>

Special blog on winter 2016/2017 retrospective can be found here
- <http://www.aer.com/winter2017>

Special blog on winter 2015/2016 retrospective can be found here
- <http://www.aer.com/winter2016>

Dr. Judah Cohen from Atmospheric and Environmental Research (AER) recently embarked on an experimental process of regular research, review, and analysis of the Arctic Oscillation (AO) and Polar Vortex (PV). This analysis is intended to provide researchers and practitioners real-time insights on one of North America's and Europe's leading drivers for extreme and persistent temperature patterns.

During the winter schedule the blog is updated once every week. Snow accumulation forecasts replace precipitation forecasts. Also, there is renewed emphasis on ice and snow boundary conditions and their influence on hemispheric weather.

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

Summary

- The Arctic Oscillation (AO) is currently positive and is predicted to remain positive the next two weeks.
- The current positive AO is reflective of negative pressure/geopotential height anomalies in the Arctic with 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 during week two. 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 exception is next week across Northern Scandinavia as low/negative geopotential height anomalies result in normal to below normal temperatures.
- The general predicted pattern for Asia is ridging/positive geopotential height anomalies with normal to above normal temperatures in East Asia with troughing/negative pressure/geopotential height anomalies and normal to below normal temperatures across Western Asia this week and South-Central Asia the next two weeks. However, the troughing/negative pressure/geopotential height anomalies and normal to below normal temperatures in Western Asia this week are predicted to propagate into East Asia next week as ridging/positive geopotential height anomalies with normal to above normal temperatures move into Southwest Asia.
- The predicted pattern for this week 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 right along the Gulf of Mexico. However next week the low heights and below normal temperatures will slide southeastward across Canada and the US east of the Rockies downstream of ridging/positive geopotential height anomalies in the Gulf of Alaska.
- In the Impacts section I discuss my expectations for the polar vortex (PV) and its influence on the sensible weather across the Northern Hemisphere (NH) in the next month or so.

Impacts

I was pretty surprised when I tried to find the last time that the polar cap geopotential height anomalies (PCHs) were positive/warm in the mid-stratosphere (at 10 hPa at least in my plots) and found it was mid-August. The long stretch of normal to strong stratospheric PV has contributed to an overall mild winter so far across the Northern Hemisphere (NH) mid-latitudes.

In **Figure i**, I include the PCHs from the operational GFS analysis since October 1, 2019 and the forecast through February 11. So far, this cold season there seems to have been two troposphere-stratosphere-troposphere (T-S-T) coupling events the first was a weak PV/negative AO in November and December. This event was of weak amplitude and was relatively shallow. The second event was a strong PV/positive AO that dominated January and into early February. This event was of stronger magnitude and

deeper. I included in the plot red arrows to approximate the upward and downward propagation of the weak PV/negative AO and blue arrows to approximate the upward and downward propagation of the strong PV/positive AO.

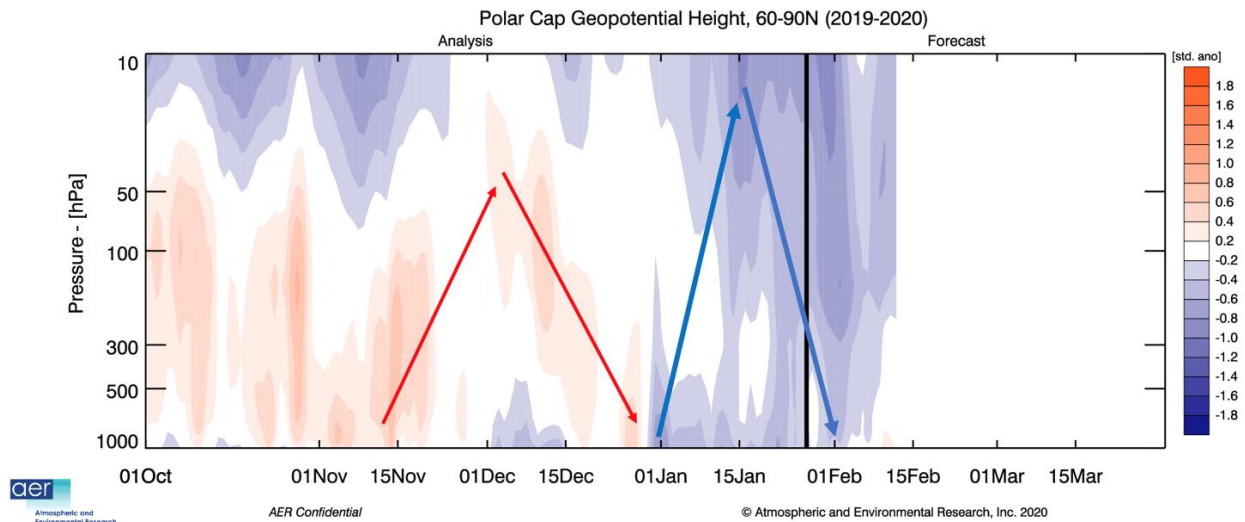


Figure i. Observed from October 1, 2019 and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 27 January 2020 GFS ensemble. Arrows show upward and downward propagation of weak (strong) PV/negative (positive) AO

It does seem from this week's geopotential height anomalies (PCH) plot based on the GFS ensembles (**Figure 11**) that the strong PV/positive AO cycle is now complete. Therefore, it seems reasonable to expect a new cycle possibly of the opposite sign but not necessarily.

I have and continue to anticipate a PV disruption in February and/or March for some time now and I do believe the conditions are becoming more favorable but certainly not ideal for a PV disruption. Surface temperatures have turned colder across Siberia and are predicted to turn colder still. There is a general pattern of increased high pressure across the northern North Atlantic and northwest Eurasia with low pressure in East Asia and over to the Dateline. Though admittedly some of the expectation of a perturbed PV was based on below normal sea ice extent in the Barents-Kara Seas and currently the sea ice extent in this region is very close to normal (**Figure 16**).

The dominant pattern for January was nearly the opposite with relative low pressure across the northern North Atlantic and northwest Eurasia with relatively high pressure across the North Pacific centered on the Dateline. This pattern is favorable for maintaining a stable and strong stratospheric PV or conversely is hostile to disrupting the stratospheric PV.

The models have been flip-flopping on whether the PV will become disrupted, but my expectations are for at least one or possibly two PV disruption of unknown magnitudes in February and March. I don't expect the PV to be as relatively strong in February and March as it was in January, but this forecast could very well be wrong. I also don't expect February and March to be as relatively warm across the NH as January was but again that forecast could easily be wrong. I expect East Asia (centered on Siberia) to be the region most favored for relatively cold temperatures followed by eastern North America. I still expect Europe to be the region least likely to turn cold if the PV becomes more perturbed. The one event that would make me consider a colder solution for Europe is a PV split but so far, I see no reason to anticipate a PV split. Also, a more disrupted PV is more favorable for snowfalls across the mid-latitudes.

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.

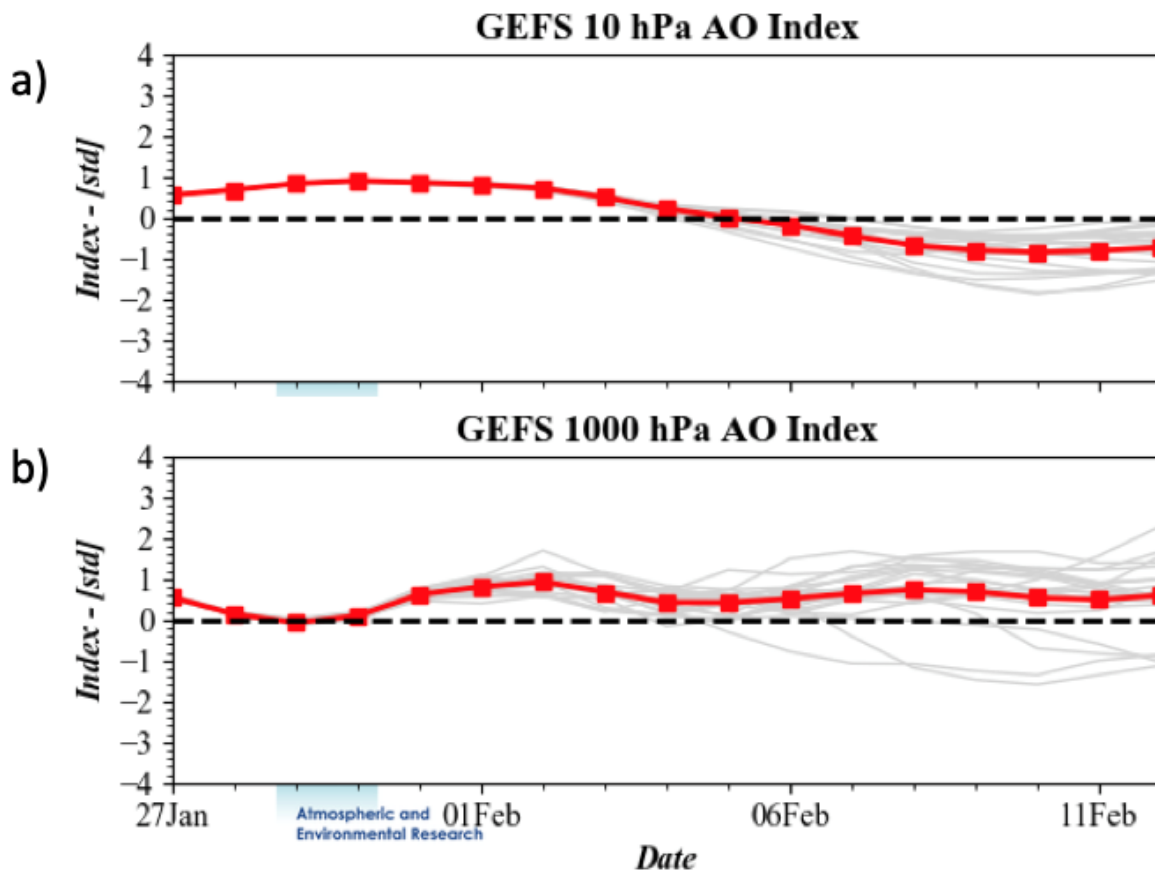


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 27 January 2020 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 27 January 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week ridging/positive geopotential height anomalies are predicted to dominate much of Europe (**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**). This week, ridging/positive geopotential height anomalies are predicted to dominate East Asia (**Figure 2**) favoring widespread normal to above normal temperatures across East Asia (**Figure 3**) while troughing/negative geopotential height anomalies in West and South Central Asia (**Figure 2**) favor normal to below normal temperatures for Western Asia and the Middle East, the northern Indian subcontinent and Southeast Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 01/27/20 FCST: 01/28/20 to 02/01/20

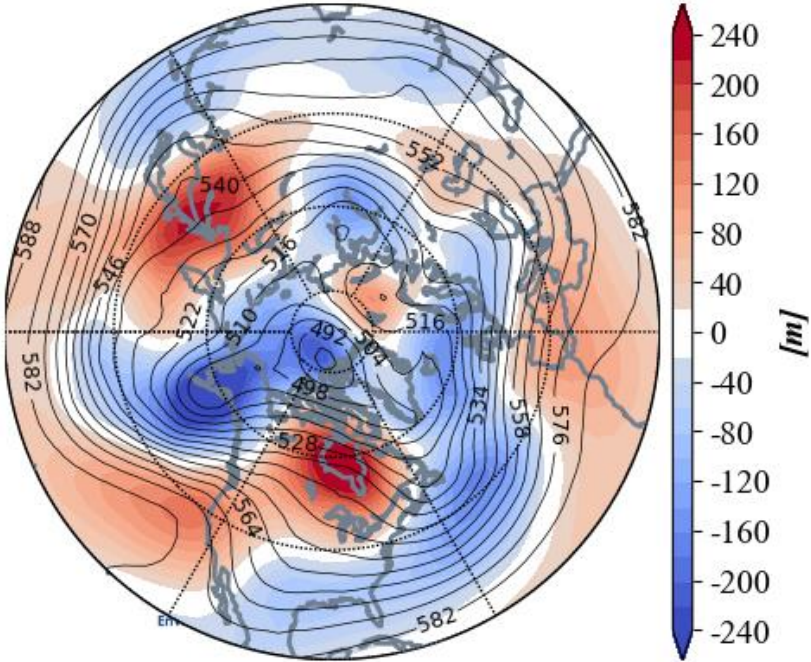


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 28 January – 1 February 2020. The forecasts are from the 00z 27 January 2020 GFS ensemble.

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 along the Gulf of Mexico (**Figure 3**).

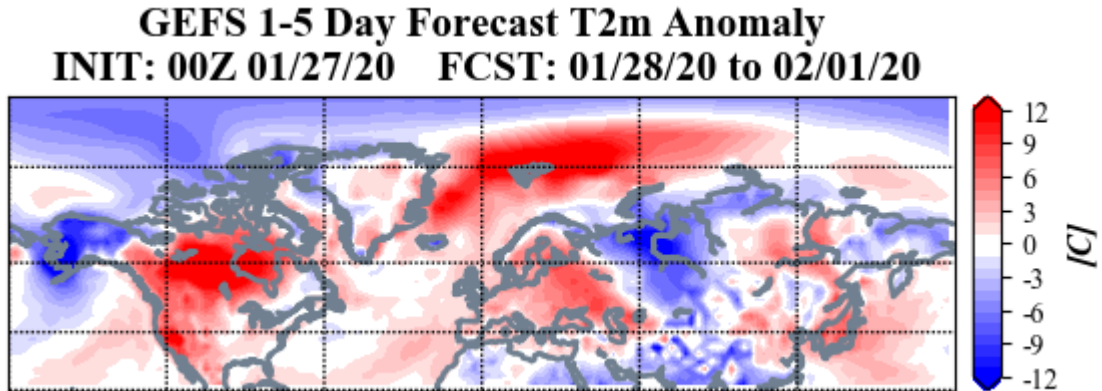


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 28 January – 1 February 2020. The forecast is from the 00Z 27 January 2020 GFS ensemble.

Trouching and/or cold temperatures are predicted to bring new snowfall across Northern and Western Asia, Scandinavia and Eastern Europe (**Figure 4**). Trouching and cold temperatures are predicted to bring new snowfall to much of Alaska and Northern Canada (**Figure 4**). Warm temperatures are predicted to result in snowmelt for Southwest Asia, interior Canada and the Northern US (**Figure 4**).

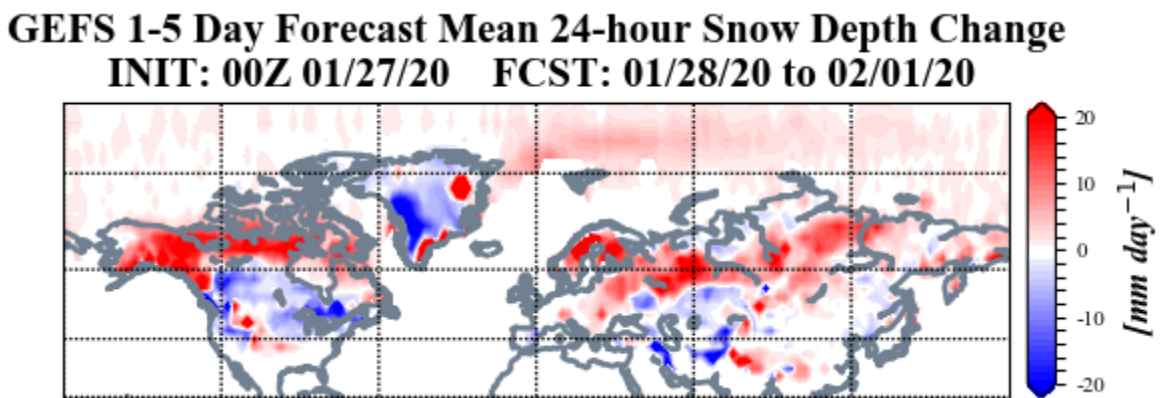


Figure 4. Forecasted snowdepth anomalies (mm/day ; shading) from 28 January – 1 February 2020. The forecast is from the 00Z 27 January 2020 GFS ensemble.

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 mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with only weak geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to remain near neutral.

GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 01/27/20 FCST: 02/02/20 to 02/06/20

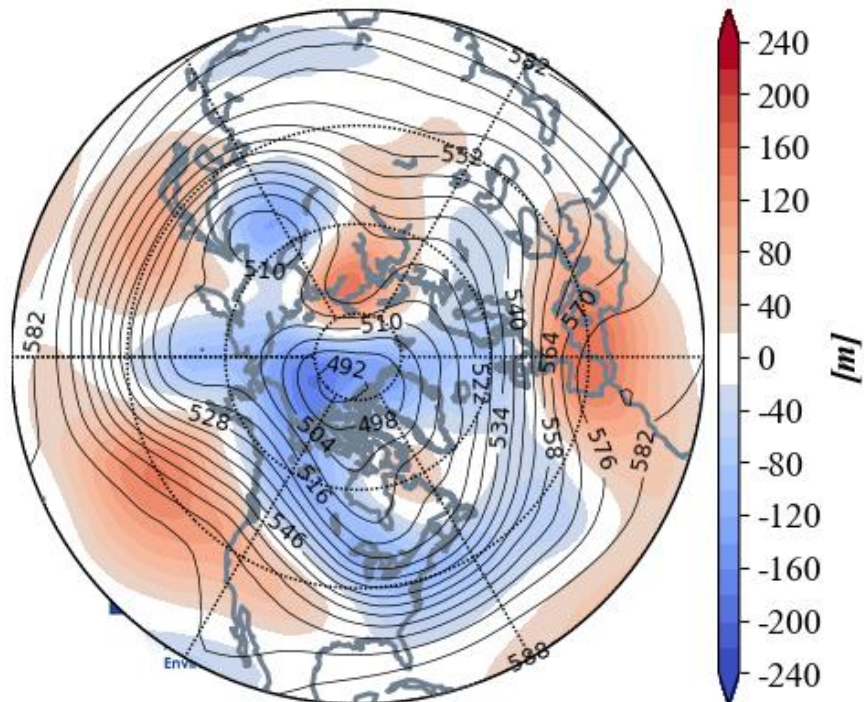


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 2 – 6 February 2020. The forecasts are from the 00z 27 January 2020 GFS ensemble.

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 Western Asia with troughing/negative geopotential height anomalies across East and South - Central Asia (**Figure 5**). This is predicted to yield normal to above normal temperatures for Western Asia with normal to below temperatures for much of Southern Asia and most of Siberia (**Figure 6**). The cold temperatures in Siberia this period and next, despite the positive AO, are likely related to the displacement of the PV close to Siberia accompanied by low heights and cold temperatures in the polar stratosphere.

GEFS 6-10 Day Forecast T2m Anomaly
INIT: 00Z 01/27/20 FCST: 02/02/20 to 02/06/20

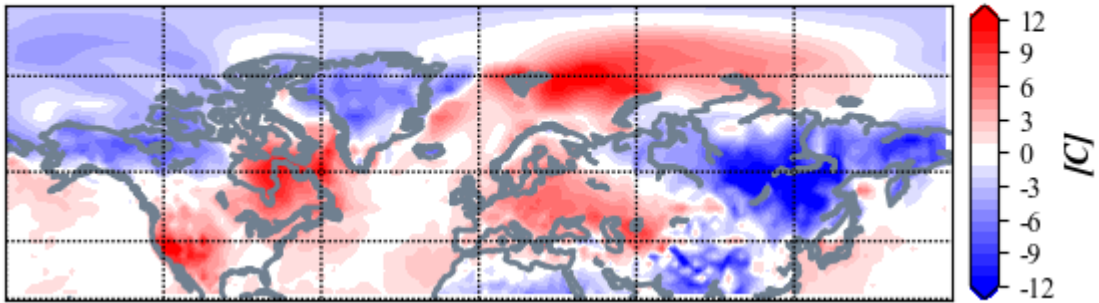


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 2 – 6 February 2020. The forecasts are from the 00Z 27 January 2020 GFS ensemble.

Ridging/positive geopotential height anomalies in the Gulf of Alaska will help dislodge troughing/negative geopotential height anomalies previously confined to Alaska and slide southeastward across Canada and the US east of the Rockies (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across Northeastern Canada, the Western and Northeastern US with normal to below normal temperatures in Alaska, Northwestern Canada and the Southeastern US (**Figure 6**).

GEFS 6-10 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 01/27/20 FCST: 02/02/20 to 02/06/20

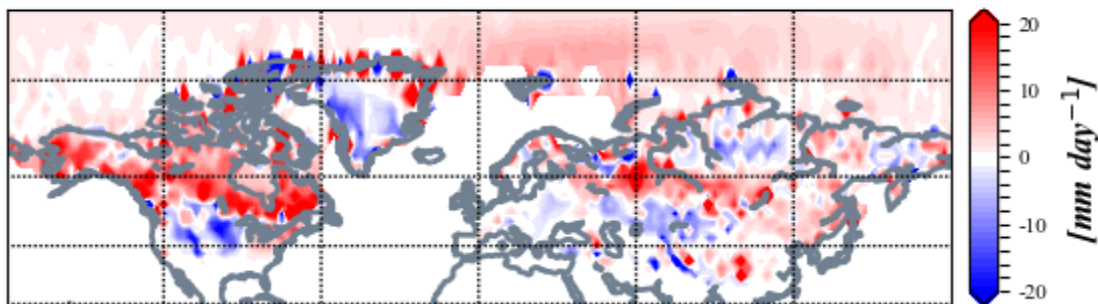


Figure 7. Forecasted snowdepth changes (mm/day ; shading) from 2 – 6 February 2020. The forecasts are from the 00Z 27 January 2020 GFS ensemble.

Troughing and/or cold temperatures will support the potential for new snowfall across Northern Asia and 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 intermountain West 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 weak pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is likely to remain near neutral this period.

GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 01/27/20 FCST: 02/07/20 to 02/11/20

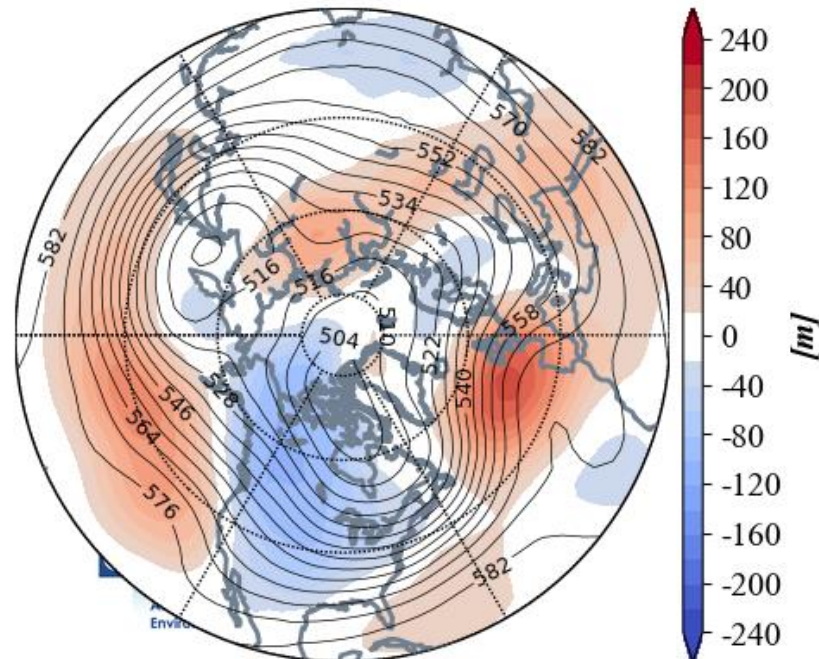


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 7 – 11 February 2020. The forecasts are from the 00z 27 January 2020 GFS ensemble.

Ridging/positive geopotential height anomalies will dominate Europe with troughing/negative geopotential height anomalies confined to Scandinavia and the Baltic States 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 Scandinavia (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to dominate Western 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 Asia with normal to below normal temperatures across the Urals, Siberia, Northeast Asia and the Tibetan Plateau (**Figure 9**).

GEFS 11-15 Day Forecast T2m Anomaly
INIT: 00Z 01/27/20 FCST: 02/07/20 to 02/11/20

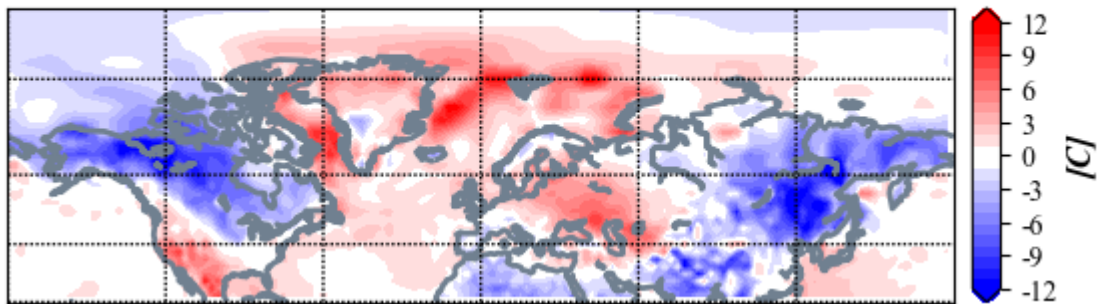


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 7 – 11 February 2020. The forecasts are from the 00z 27 January 2020 GFS ensemble.

Persistent ridging/positive geopotential height anomalies are predicted in the Gulf of Alaska forcing downstream troughing/negative geopotential height anomalies across much of North America (**Figure 8**). This pattern is predicted to favor normal to below normal temperatures across much of Canada and the US especially east of the Rockies with normal to above normal temperatures mostly confined to the Southwestern US (**Figure 9**).

GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 01/27/20 FCST: 02/07/20 to 02/11/20

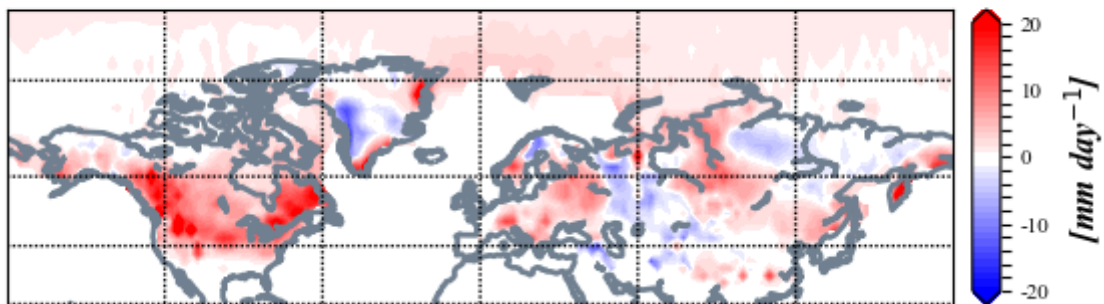


Figure 10. Forecasted snow depth changes (mm/day ; shading) from 7 – 11 February 2020. The forecasts are from the 00z 27 January 2020 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across much of Northern Asia and possibly Central and Eastern Europe, the Tibetan Plateau and Northeast Asia (**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 (**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 early February (**Figure 11**). The predicted cold tropospheric PCHs are consistent with a predicted positive surface AO (**Figure 1**). This coupled event is predicted to come to a complete end the first week of February. PCHs are predicted to be normal in the troposphere and in the stratosphere the second week of February. Slight positive/warm PCHs are even predicted in the mid-stratosphere. If this verifies, it would be the first positive PCHs in the mid-stratosphere since August!

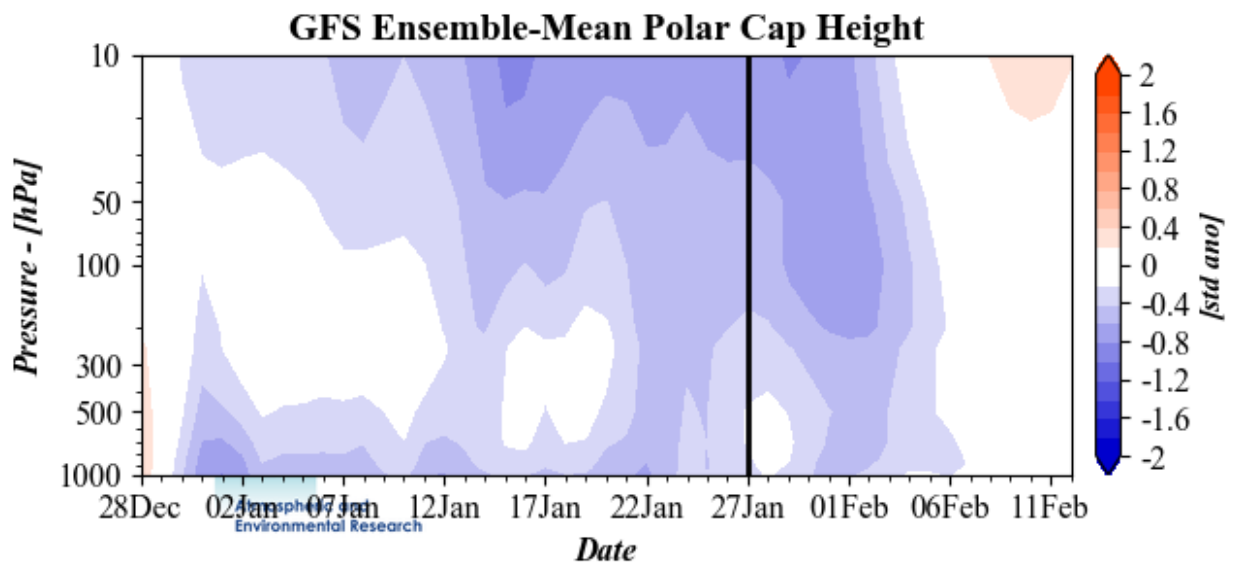


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 27 January 2020 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows an increase in activity after a relatively quiet month with only weak positive WAFz anomalies (**Figure 12**). Next week a stronger pulse of positive anomalies is predicted to begin and peak at the end of the first week of February (**Figure 12**). This is predicted to be the most significant WAFz pulse since mid-December.

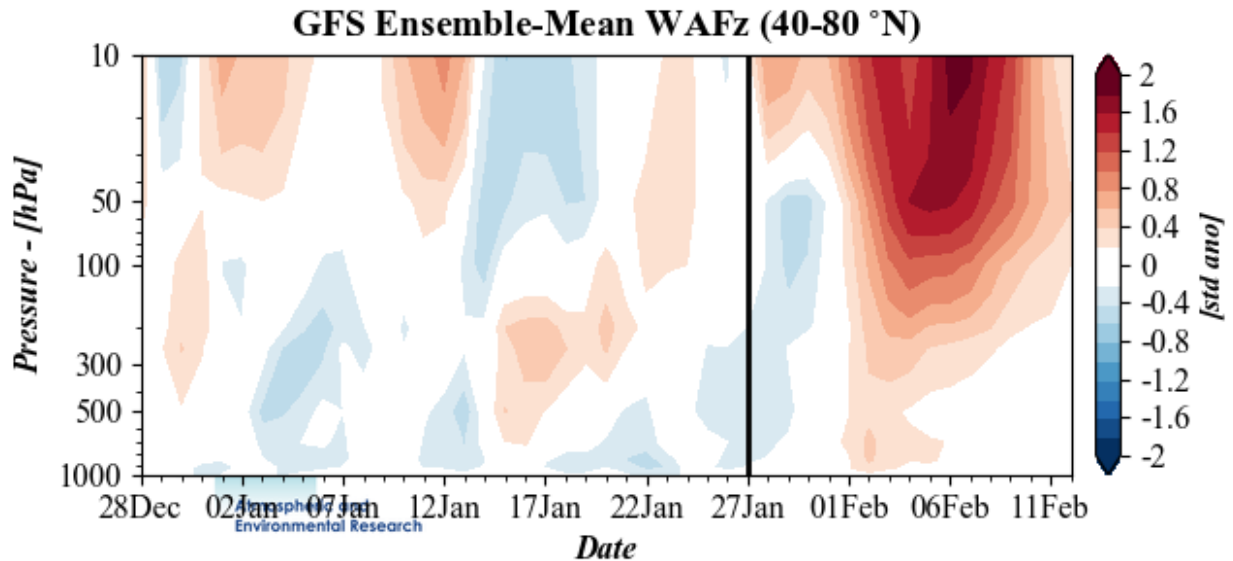


Figure 12. Observed and predicted daily vertical component of the wave activity W_{ux} (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 27 January 2020 GFS ensemble.

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 and then negative (**Figure 1**). The weakening of the stratospheric PV is related to the positive WAFz pulse predicted for next week. Further WAFz pulses could weaken the stratospheric PV further and force the stratospheric AO further into negative territory.

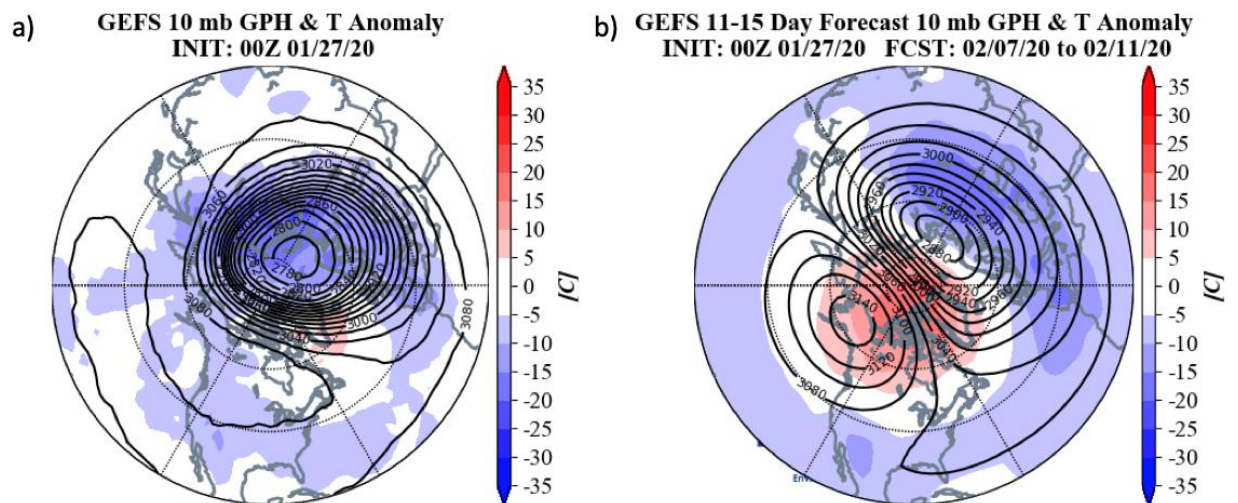


Figure 13. (a) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere at 00Z 27 January 2020 . (b)

Same as (a) except forecasted averaged from 7 – 11 February 2020. The forecasts are from the 00Z 27 January 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 Siberia (**Figure 13**). Though the PV is displaced it remains fairly circular in shape.

Starting next week, the PV center is predicted to remain displaced towards the northern Urals with the lowest heights in northern Eurasia but now the PV is predicted to become more elongated in shape rather than circular (**Figure 13**). At the same time ridging develops over central Alaska accompanied by warm temperatures spread across the Arctic but focused on the North American side in the stratosphere (**Figure 13**). The displacement of the PV into northern Eurasia with warming over Canada are characteristic of a “Canadian warming” in the stratosphere (**Figure 13**). But I do believe that as long as the PV center remains displaced towards the Eurasian sector, the stratospheric PV remains vulnerable to further disruptions.

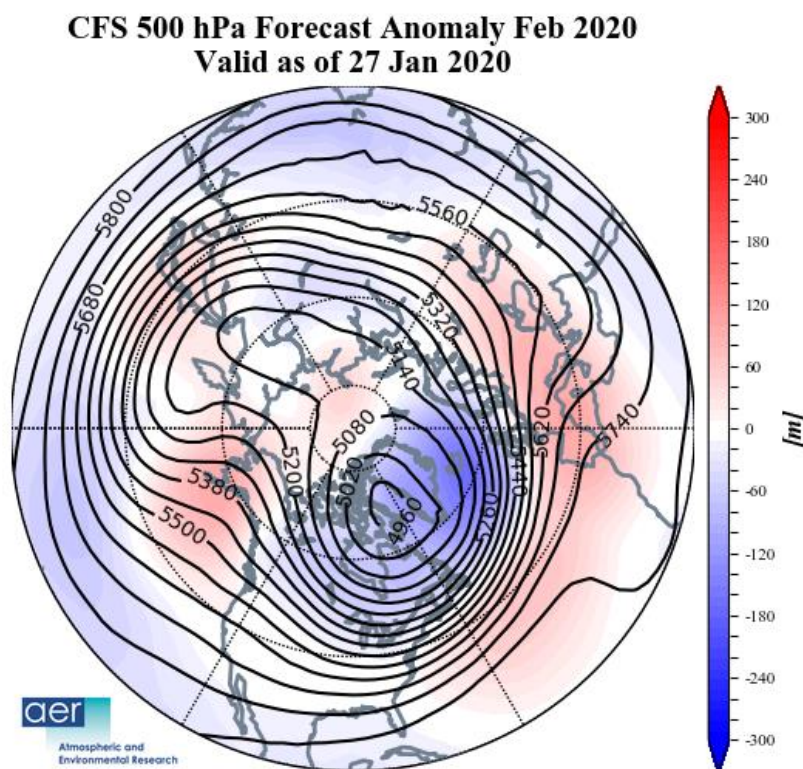


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for February 2020. The forecasts are from the 00Z 27 January 2020 CFS.

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 Southern and Central Europe, Kamchatka and the Gulf of Alaska with troughing in Western and Eastern Asia and eastern North America (**Figure 14**). This pattern favors relatively mild temperatures for Europe, Western Asia, Alaska, Western Canada and the Western US with seasonable to relatively cold temperatures for much of Central and Eastern Asia, Eastern Canada and the Northeastern US (**Figure 15**). I continue to have low confidence in the forecast.

CFS T2m Forecast Anomaly Feb 2020
Valid as of 27 Jan 2020

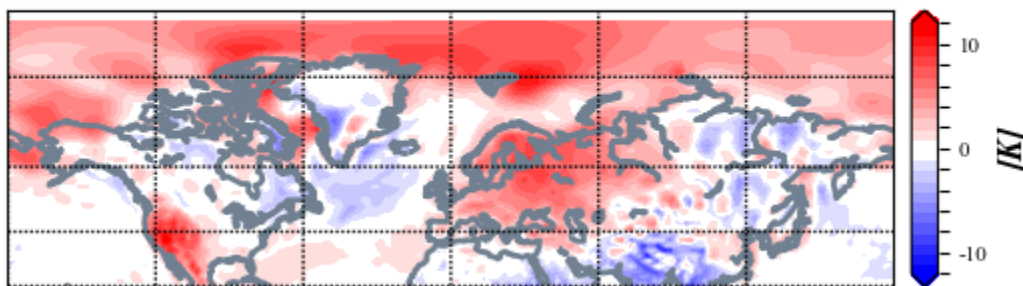


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for February 2020. The forecasts are from the 00Z 27 January 2020 CFS.

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 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.

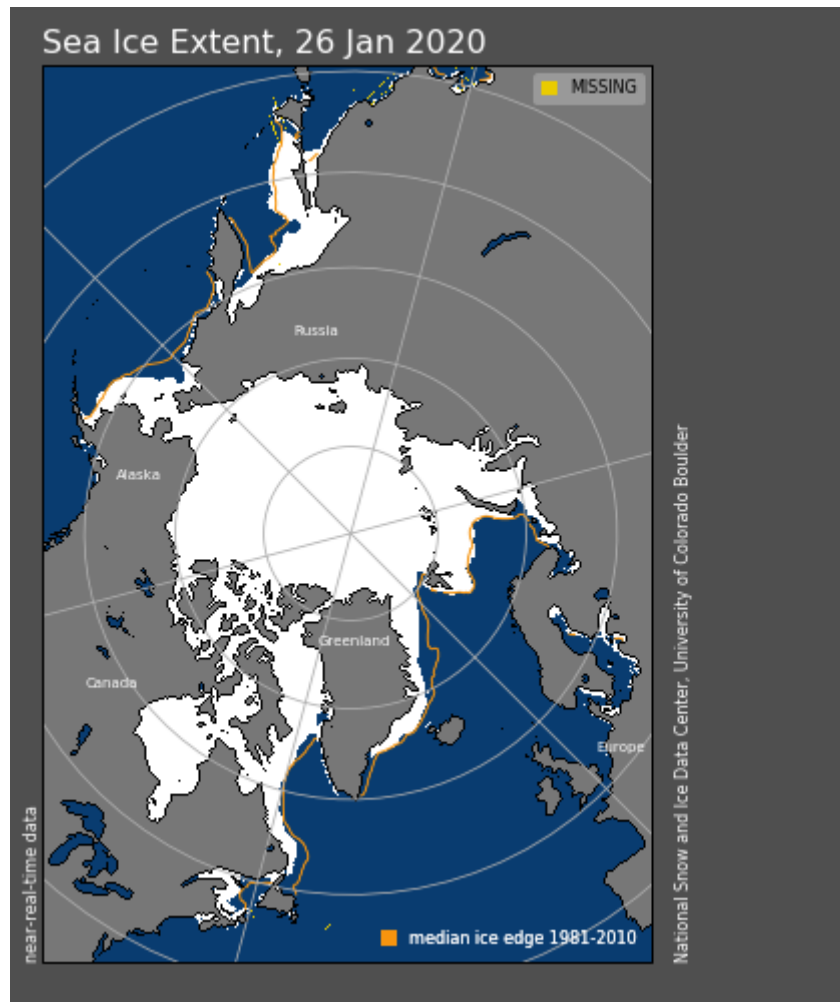


Figure 16. a) Observed Arctic sea ice extent on 26 January 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010.

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 26 Jan 2020

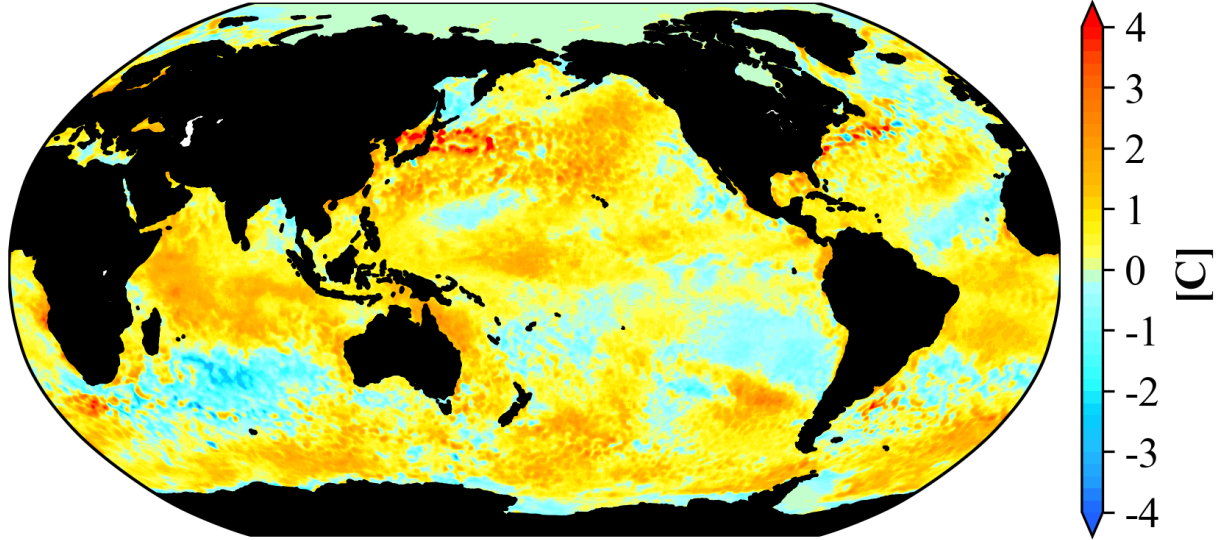


Figure 17. The latest weekly-mean global SST anomalies (ending 26 January 2020). Data from NOAA OI High-Resolution dataset.

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 18**). The forecasts are for the MJO to briefly emerge into phase six this week before weakening where no phase is favored. MJO phase six mostly favors ridging in the Gulf of Alaska and across the 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.

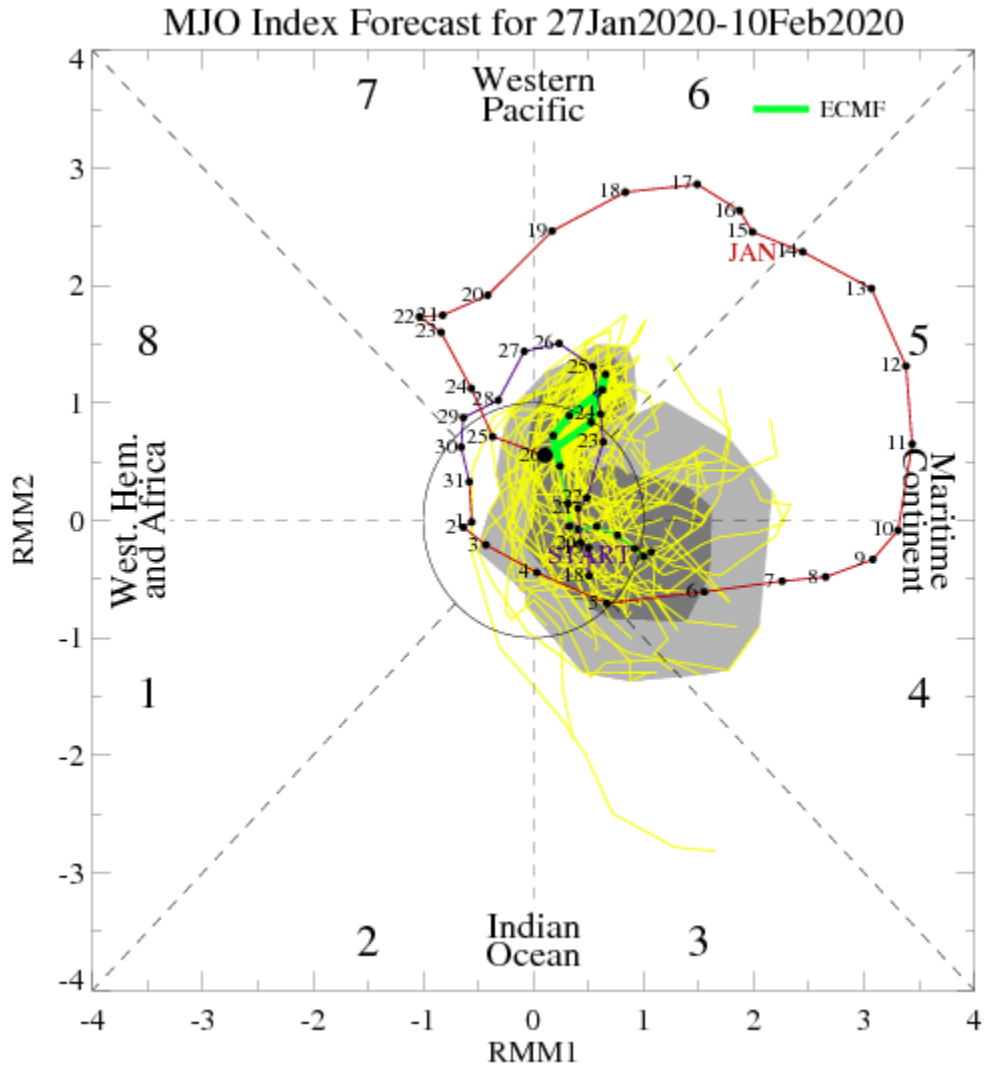


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 6 January 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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 remained steady 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.

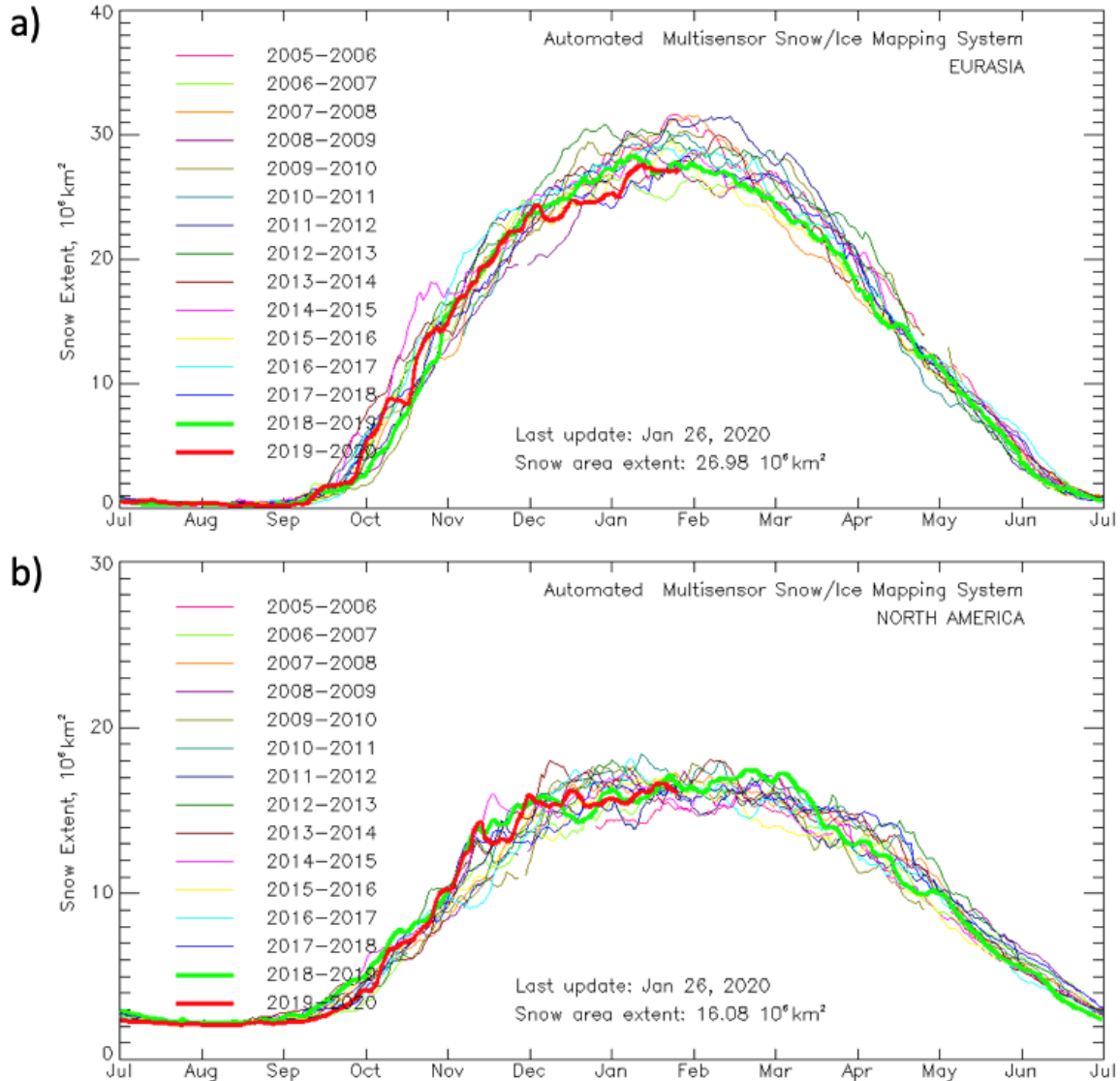


Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 5 January 2020. Image source:

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

North American snow cover declined slightly and remains near 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.