

Arctic Oscillation and Polar Vortex Analysis and Forecasts

January 13, 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 slowly trend negative towards neutral over 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 also slowly trend negative back towards

neutral over the next two weeks as heights slowly return close to normal across Greenland.

- This week ridging/positive geopotential height anomalies and normal to above normal temperatures will dominate Europe including the United Kingdom (UK). However, starting next week, the ridging/positive geopotential height anomalies will become focused between Iceland and the Greenwich Meridian promoting northerly flow first across Western Europe and then further east filtering in colder temperatures across 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 the northern Indian subcontinent and Eastern Siberia. However, starting next week increasing troughing across Central Asia will bring more widespread normal to below normal temperatures across Central and East Asia.
- The predicted pattern this week across North America is ridging/positive geopotential height anomalies anchored south of the Aleutians forcing downstream troughing/negative pressure/geopotential height anomalies in western North America with more ridging/positive geopotential height anomalies in the Eastern United States (US). This pattern favors normal to below normal temperatures in Alaska, the Western US and widespread across Canada with normal to above normal temperatures in the Eastern US. However, starting next week, the pattern is predicted to reverse with ridging/positive geopotential height anomalies in western North America and troughing/negative pressure/geopotential height anomalies in eastern North America. Next week below normal temperatures will be widespread across both Canada and the US with the exceptions of the Southwestern US and Florida. However, for the last week of January temperatures will moderate in western North America while eastern North America remains cold.
- In the Impacts section I discuss the pattern reversal and how long it may last.

Impacts

They say when you are a hammer the whole looks like a nail. I have over my career become more and more focused on the stratospheric polar vortex (PV) and admit that I do tend to see at least winter weather mostly through the PV prism or framework. But I try to be open minded and maybe what I write next does seem even to me a bit tenuous and I may be off. The GFS and the other models are predicting that the cold air in western North America will make its way into eastern North America starting next weekend and persist through the end of January. I don't take it as a given if it starts cold in western North America that it will eventually make its way to eastern North America; we had a great example of that last winter (mostly February), but I think other good examples are December 1983 and February 1989. So what is the mechanism triggering the pattern reversal or flip?

I have seen others and I even tweeted that the Madden Julian Oscillation (MJO) would switch the pattern across North America from western trough/eastern ridge to western ridge/eastern trough. But the timing seems off based on the NOAA CPC MJO composites: <https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjo.shtml#composite>. The MJO is predicted to enter phase 7 early next week. According to the composites initially for MJO phase 7 the Eastern US experiences ridging and mild temperatures with the troughing and colder temperatures not reaching the Eastern US for another 7-10 days. So at least based on the CPC analysis it seems challenging to attribute the pattern change to the MJO, though composites don't explain all the range of possible variability.

Consistent with my PV prism, it does seem that the pattern transition is consistent with a reflective PV event (you can read about reflective events here: [Kretschmer et al. 2018](#)). The vertical wave activity flux WAFz from the operational GFS (**Figure 12**) shows positive values quickly followed by negative values, an elongated stratospheric PV, ridging in the polar stratosphere centered near Alaska (**Figure 13**), an elongated tropospheric PV, mid-tropospheric ridging near Alaska and cold temperatures in Siberia and eastern North America (**Figures 8 and 9**). Also the WAFz timing coincides with the pattern reversal. I also believe that since this is something that I have been anticipating for the past two blogs is supportive that the pattern reversal is attributable to a PV reflection

Assuming the pattern reversal is related to a PV reflection what can we expect? The influence of a reflective PV reflection is relatively short-lived, on the order of one to two weeks. It could last longer if it gets an assist from the MJO (though it is currently predicted to weaken to the point where no phase is favored). But it is my impression that without a significant PV disruption any cold regime won't last much more than three weeks. Based on this idea alone I would expect the pattern to become milder in the Eastern US first or the latest second week of February.

I can see the pattern persisting longer if the atmospheric ridging could phase lock with the warm sea surface temperatures in eastern North Pacific, but this is something that I can't anticipate in advance. Though I think a more likely scenario is a repeat of another reflective event. I do think blocking in the North Atlantic could increase the chances of another reflective event. And though so far there are still no signs of this, I still believe a more significant PV disruption or a dynamic final warming in the Northern Hemisphere (NH) polar stratosphere is likely before the winter is over.

I tweeted about this earlier in the week, but I do believe that looking at the polar cap geopotential height anomalies (PCH) is suggestive of a troposphere-stratosphere-troposphere (T-S-T) coupling event with a strong PV/positive AO. The tropospheric precursor (positive AO) occurred for all of early January, the strong PV is occurring this week (the GFS ensembles shows it peaking this week while the operational GFS has it peaking later). The event would be completed by the downward propagation of the

cold/negative PCHs from the stratosphere to the surface triggering a potentially long-lasting positive AO regime that would favor mild temperatures across the NH continents. In **Figure i**, I show the PCHs for the operational GFS, which is already showing this scenario, though I believe it is likely overdone.

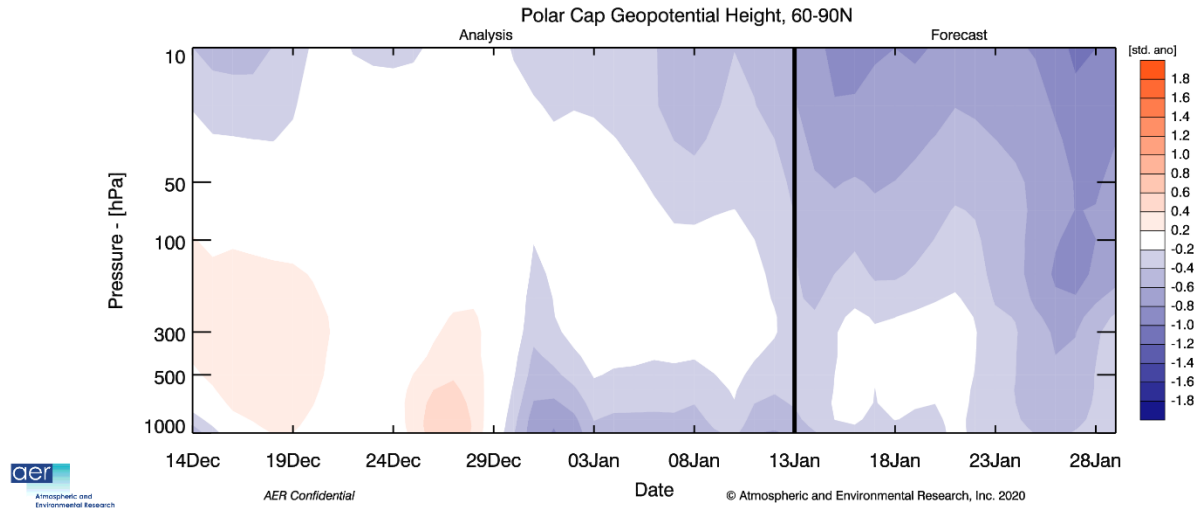


Figure i. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 13 January 2020 GFS operational.

But just as with a weak PV/negative AO T-S-T coupling event, the last phase can be of weak magnitude and/or short lived or not even propagate to the surface. But even with these caveats a return of much milder weather in February has to be strongly considered. I know if the PCH plot was shaded red instead of blue I would be pretty excited right now.

Near Term Conditions

1-5 day

The AO is currently strongly 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.

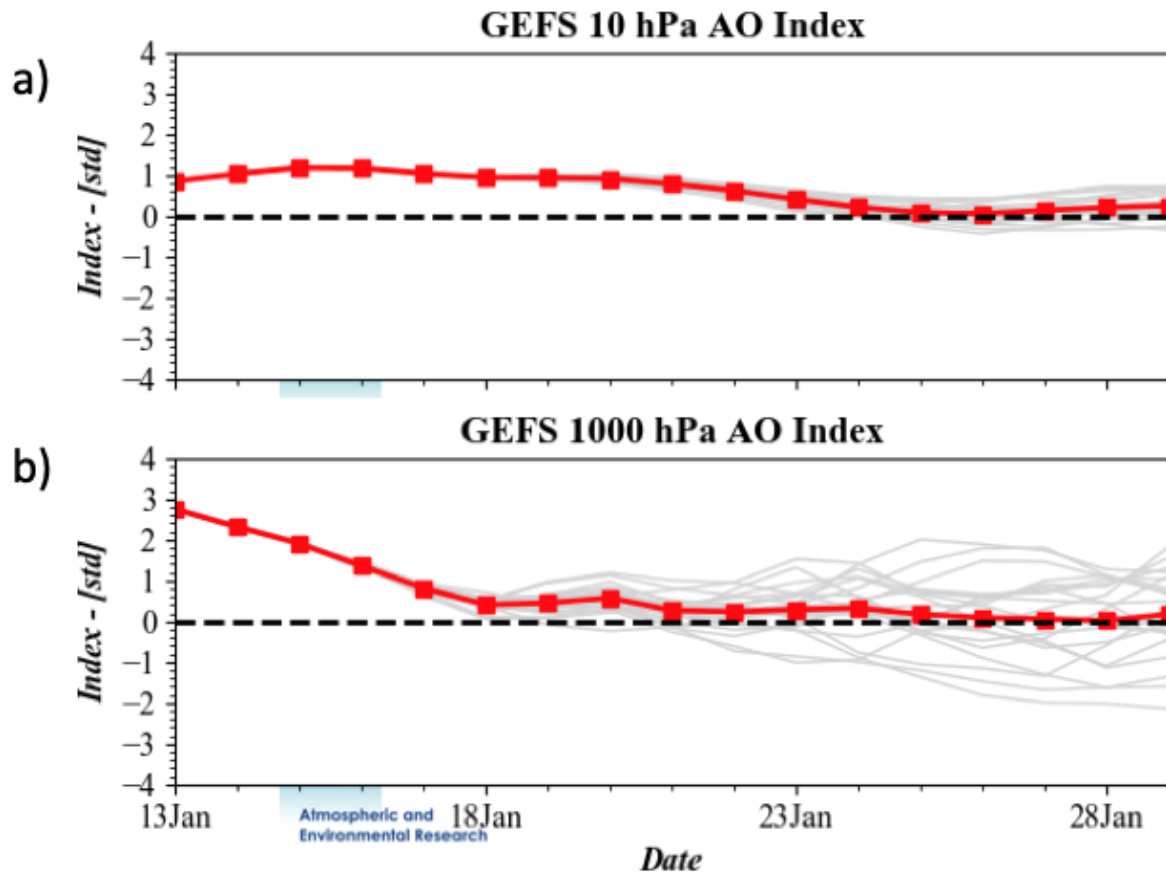


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 13 January 2020 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 13 January 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week ridging/positive geopotential height anomalies are predicted to dominate Europe with troughing/negative geopotential height anomalies mostly confined to the eastern Mediterranean (**Figure 2**). General high heights and lack of snow cover will result in normal to above normal temperatures across much of Europe including England with the possible exception of normal to below normal temperatures across Ireland and Scotland due to low geopotential heights (**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 the northern India subcontinent and Eastern Siberia into parts of Northeast 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 01/13/20 FCST: 01/14/20 to 01/18/20

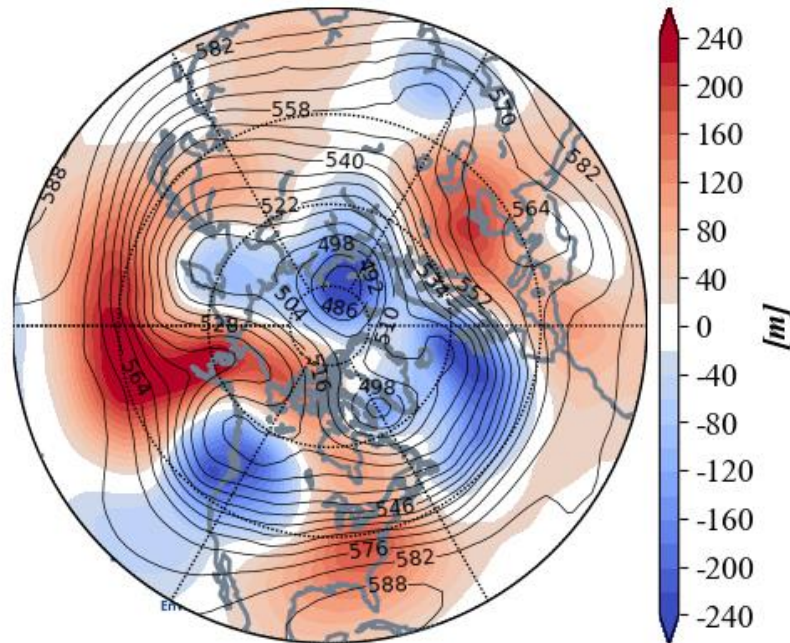


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 14 – 18 January 2020. The forecast is from the 00Z 13 January 2020 GFS ensemble.

Trouthing and/or cold temperatures are predicted to bring new snowfall across Central Asia and Eastern Siberia (**Figure 4**). Trouthing and cold temperatures are predicted to bring new snowfall to much of Southern Canada and the Northern US (**Figure 4**). Warmer temperatures are predicted to result in snowmelt for Western Russia, the Middle East, Alaska and Western Canada (**Figure 4**).

GEFS 1-5 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 01/13/20 FCST: 01/14/20 to 01/18/20

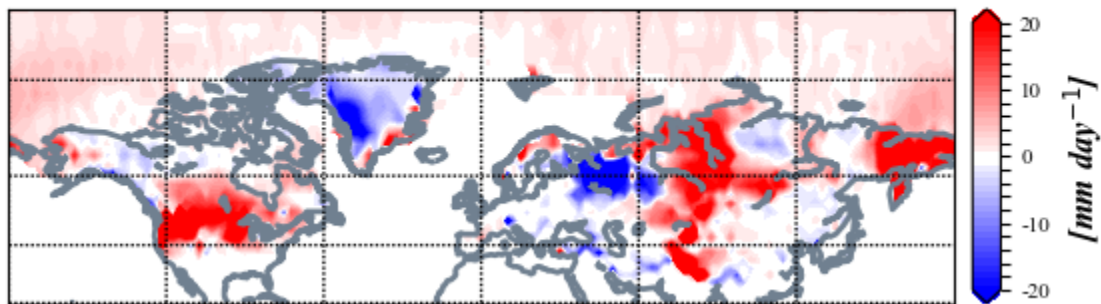


Figure 4. Forecasted snowdepth anomalies (mm/day; shading) from 14 – 18 January 2020. The forecast is from the 00Z 13 January 2020 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to trend towards neutral this period (**Figure 1**) as positive geopotential height anomalies enter the North American Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with weak geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to trend towards neutral as well.

GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 01/13/20 FCST: 01/19/20 to 01/23/20

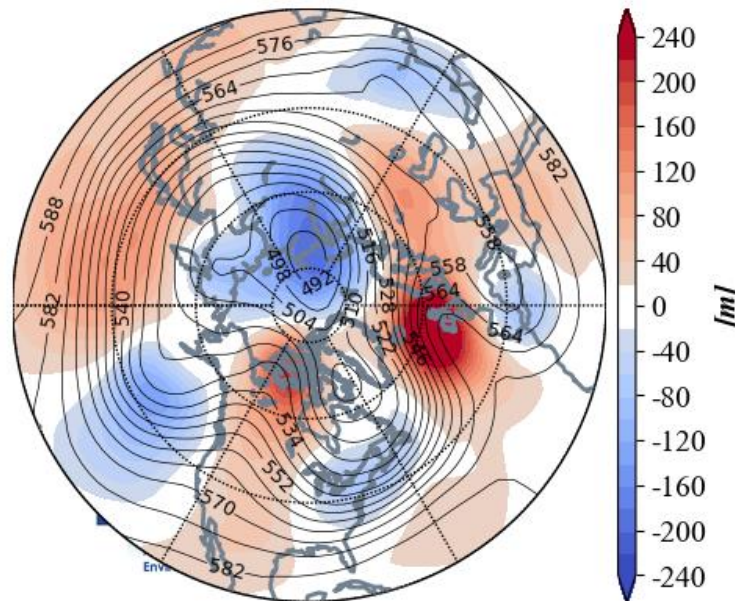


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 19 – 23 January 2020. The forecasts are from the 00z 13 January 2020 GFS ensemble.

This week ridging/positive geopotential height anomalies are predicted to become focused between Iceland and Norway with troughing/negative geopotential height anomalies to the south in the Western Mediterranean this period (**Figures 5**). Once again generally high geopotential heights and lack of snow cover will favor widespread normal to above normal temperatures for Eastern Europe, however northeasterly flow across Western Europe will usher in normal to below normal temperatures in Western Europe including the UK (**Figure 6**). Ridging/positive geopotential height anomalies will dominate Western and Southeast Asia with troughing/negative geopotential height anomalies widespread across Central Asia and Eastern Siberia (**Figure 5**). This is predicted to yield normal to above normal temperatures for Western and Southeastern Asia **with** normal to below temperatures for much of Central Asia and much of Siberia (**Figure 6**).

GEFS 6-10 Day Forecast T2m Anomaly
INIT: 00Z 01/13/20 FCST: 01/19/20 to 01/23/20

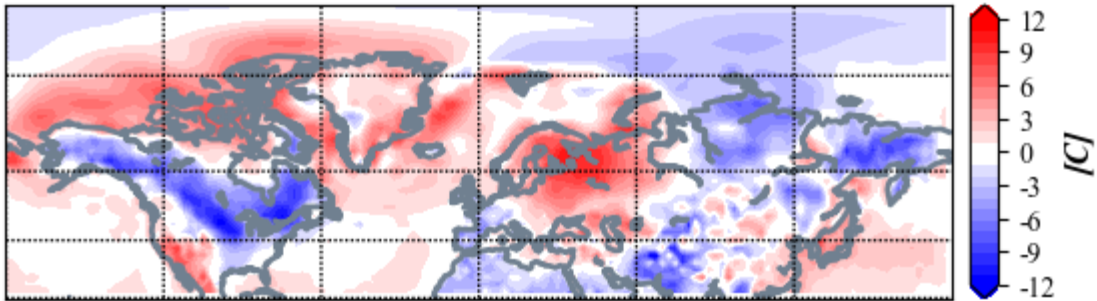


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 19 – 23 January 2020. The forecasts are from the 00Z 13 January 2020 GFS ensemble.

The pattern is predicted to reverse across North America this period with troughing/negative geopotential height anomalies south of the Aleutians forcing ridging/positive geopotential height anomalies across western North America with downstream troughing/negative geopotential height anomalies in eastern North America (**Figure 5**). This pattern is predicted to bring widespread normal to below normal temperatures across much of Canada and the US with normal to above normal temperatures confined to the Southwestern US and Florida (**Figure 6**).

GEFS 6-10 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 01/13/20 FCST: 01/19/20 to 01/23/20

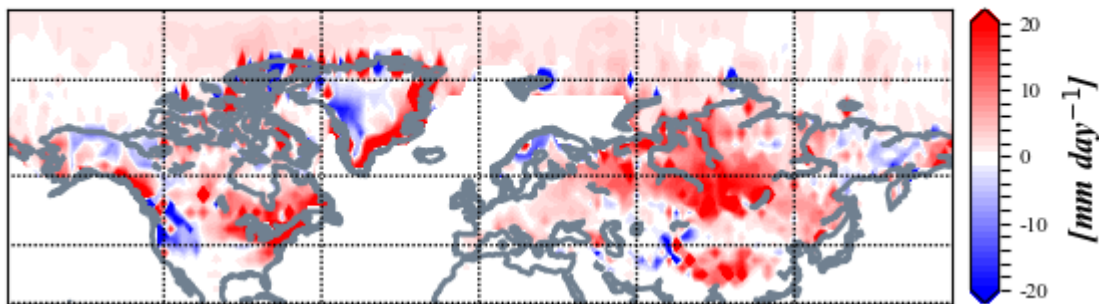


Figure 7. Forecasted snowdepth changes (mm/day ; shading) from 19 – 23 January 2020. The forecasts are from the 00Z 13 January 2020 GFS ensemble.

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

11-15 day

With mixed and weak geopotential height anomalies predicted for the Arctic (**Figure 8**), the AO is predicted to remain close to neutral this period (**Figure 1**). With predicted weak negative pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is likely to remain near neutral this period as well.

GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 01/13/20 FCST: 01/24/20 to 01/28/20

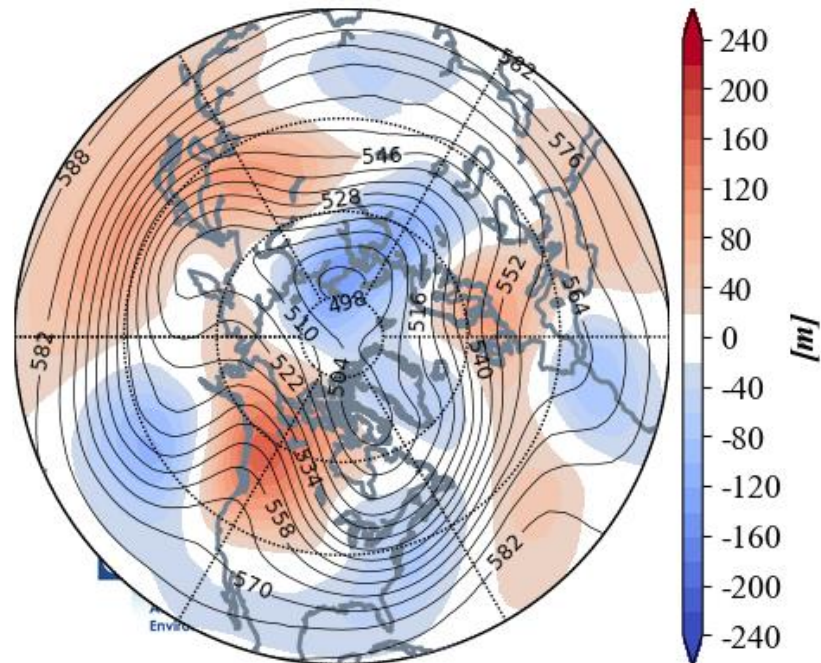


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 24 – 28 January 2020. The forecasts are from the 00z 13 January 2020 GFS ensemble.

Ridging/positive geopotential height anomalies will dominate Northern Europe with troughing/negative geopotential height anomalies to the south in the Western Mediterranean this period (**Figures 8**). This pattern favors normal to above normal temperatures across Northern and Eastern Europe with normal to below normal temperatures across Western and Southern Europe including the UK (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to be mostly confined to East Asia with troughing/negative geopotential height anomalies over Siberia, Western and much of Central Asia (**Figure 8**). This pattern favors normal to below normal temperatures across much of Siberia, Northeast Asia with mixed temperatures across Western and Central Asia and normal to above normal temperatures in Southeast Asia (**Figure 9**).

GEFS 11-15 Day Forecast T2m Anomaly
INIT: 00Z 01/13/20 FCST: 01/24/20 to 01/28/20

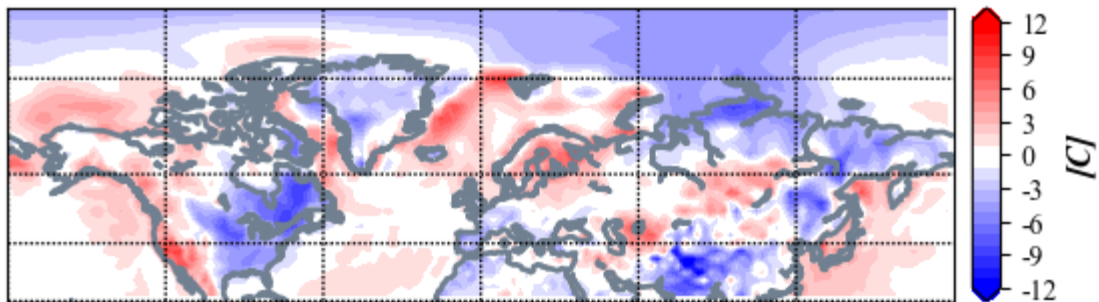


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 24 – 28 January 2020. The forecasts are from the 00z 13 January 2020 GFS ensemble.

Persistent troughing/negative geopotential height anomalies south of the Aleutians will continue to support downstream ridging/positive geopotential height anomalies across western North America with troughing/negative geopotential height anomalies in eastern North America (**Figure 8**). This pattern is predicted to favor normal to above normal temperatures across Alaska, much of Western Canada and the Western US with normal to above normal temperatures for much of Eastern Canada and the Eastern US (**Figure 9**).

GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 01/13/20 FCST: 01/24/20 to 01/28/20

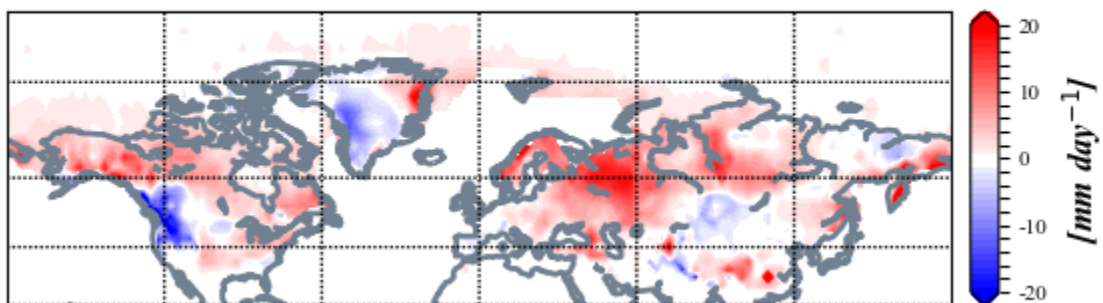


Figure 10. Forecasted snow depth changes (mm/day ; shading) from 24 – 28 January 2020. The forecasts are from the 00z 13 January 2020 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across much of Northern Asia but especially Western Russia, the Tibetan Plateau and possibly Eastern and Central Europe (**Figure 10**). New snowfall is possible across much of Alaska, Eastern Canada and possibly the Central and Northeastern US (**Figure 10**). Some snowmelt is possible in Central Asia, Southwestern Canada and the Northwestern 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 lower troposphere since the end of December appear to be coupled with and in response to downward propagation of cold PCHs in the middle stratosphere due to a normal to strong PV since mid-December (**Figure 11**). However, the tropospheric PCHs are predicted to become neutral starting next week consistent with a predicted neutral surface AO.

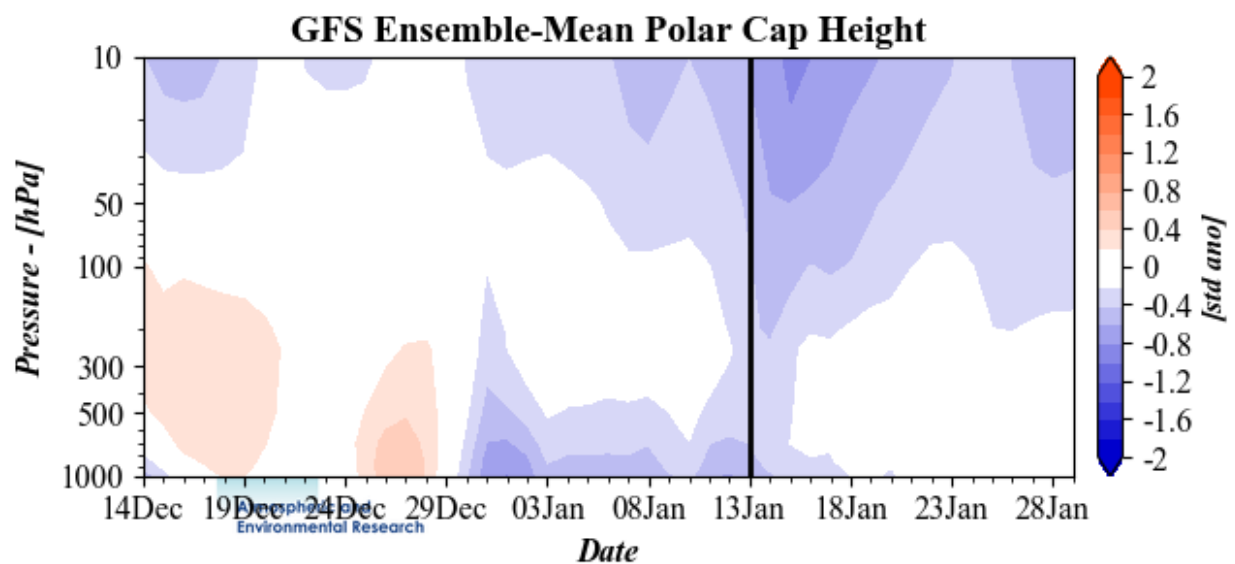


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 13 January 2020 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows a relatively quiet period this week with mostly negative WAFz anomalies (**Figure 12**). Next week one pulse of positive anomalies predicted is predicted (**Figure 12**). The predicted positive WAFz for the next week is predicted to be followed by weak negative anomalies in the troposphere. A positive pulse followed quickly by negative anomalies is characteristic of a reflective event that favors cold temperatures in Siberia and eastern North America.

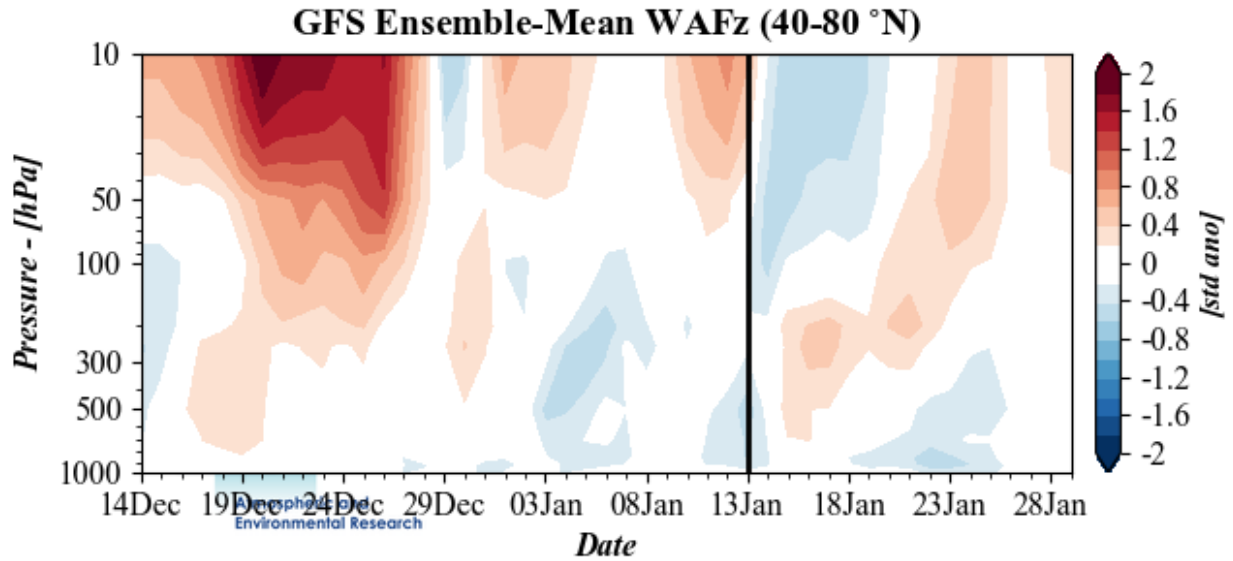


Figure 12. Observed and predicted daily vertical component of the wave activity W_{ux} (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 13 January 2020 GFS ensemble.

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.

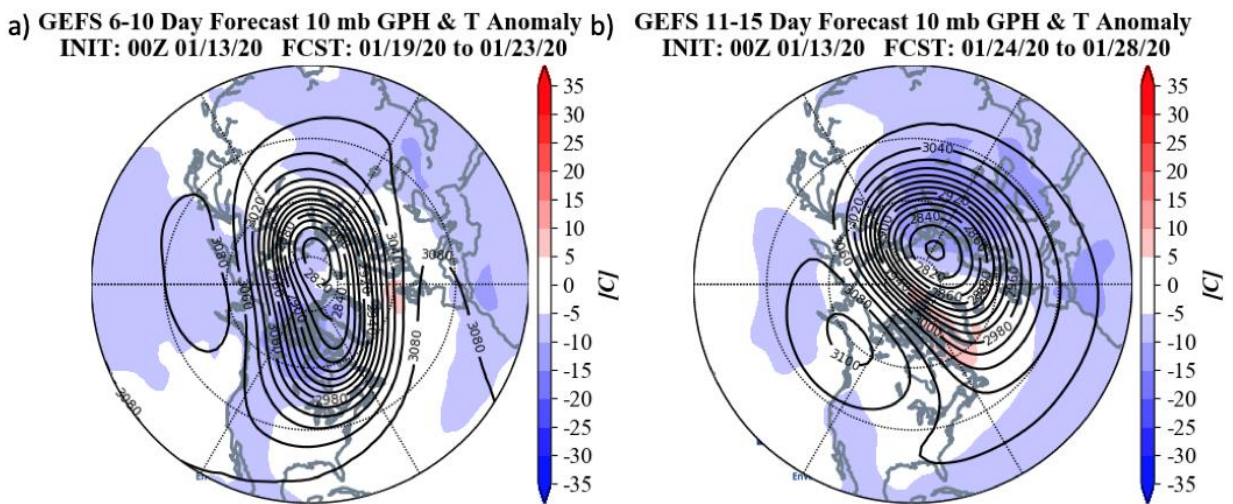


Figure 13. (a) Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere from 19 – 23 2020 . (b) Same as (a) except forecasted averaged from 24 – 28 January 2020. The forecasts are from the 00Z 13 January 2020 GFS operational model.

Currently the stratospheric PV remains centered near the Northeastern tip of Greenland (not shown) with the largest negative temperature departures in the polar stratosphere are over Northern Asia while the greatest positive temperature anomalies are over the North American Arctic (not shown).

However, starting next week, the PV is predicted to become more elongated with the PV center displaced towards the North Slope of Asia (**Figure 13**). At the same time ridging develops near the Dateline and propagates eastward and amplifies over Alaska (**Figure 13**). The elongation of the PV along an axis from Siberia into Canada with ridging near Alaska are characteristic of reflective PV disruptions (**Figure 13**).

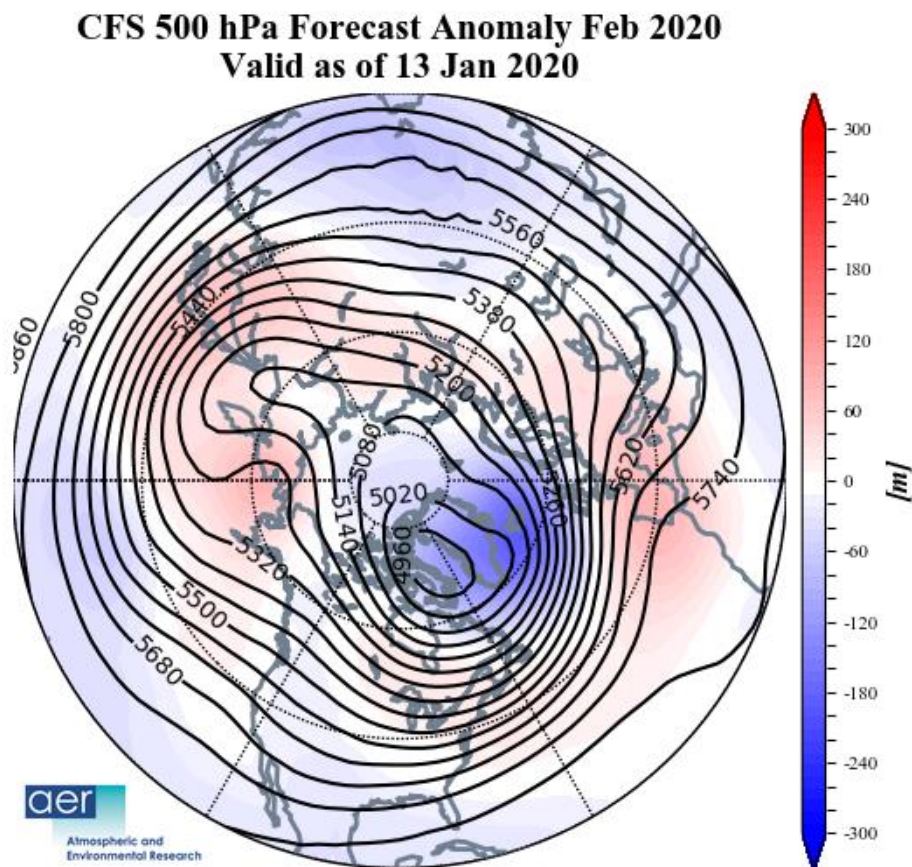


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for February 2020. The forecasts are from the 00Z 13 January 2020 CFS.

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, the Dateline and Alaska 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.

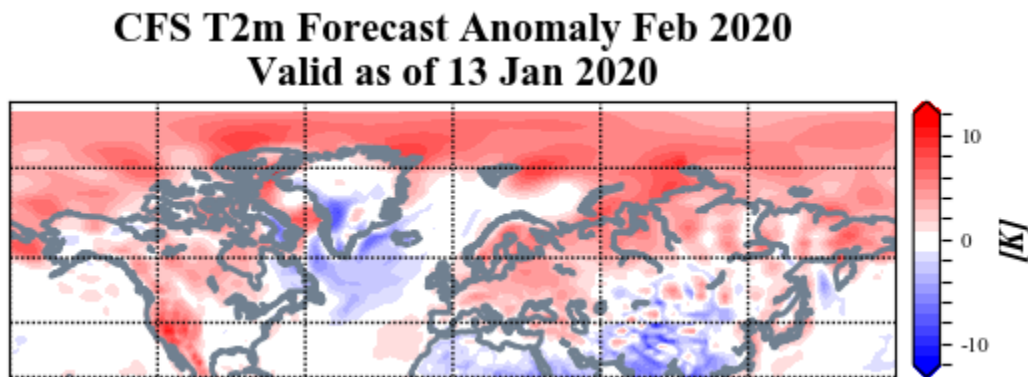


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for February 2020. The forecasts are from the 00Z 13 January 2020 CFS.

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 anomalies in the North Pacific sector have shrunk (**Figure 16**) and 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.

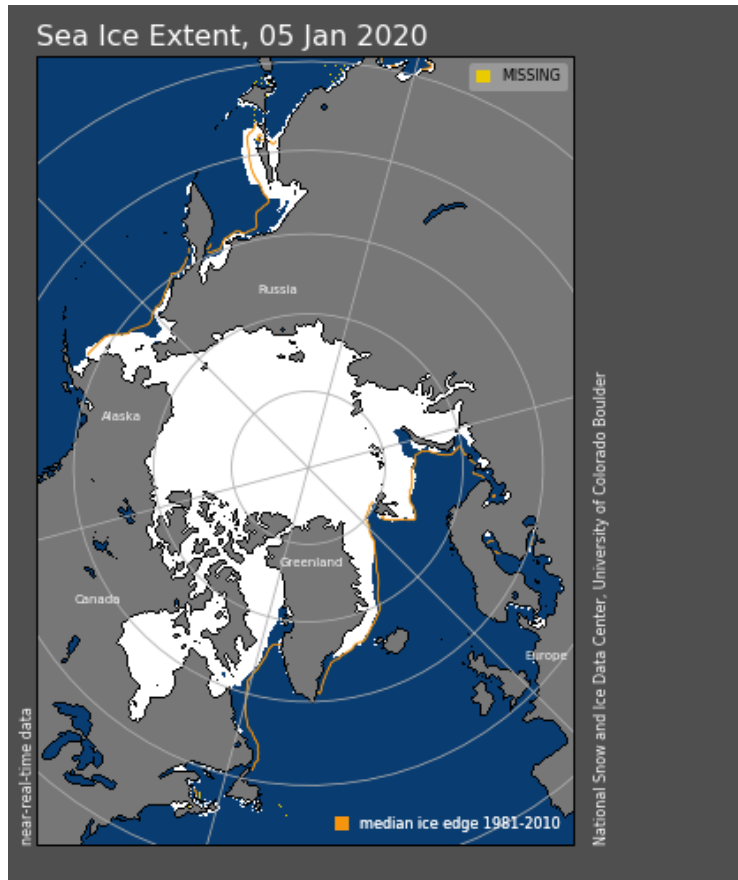


Figure 16. a) Observed Arctic sea ice extent on 5 January 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010.

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 05 Jan 2020

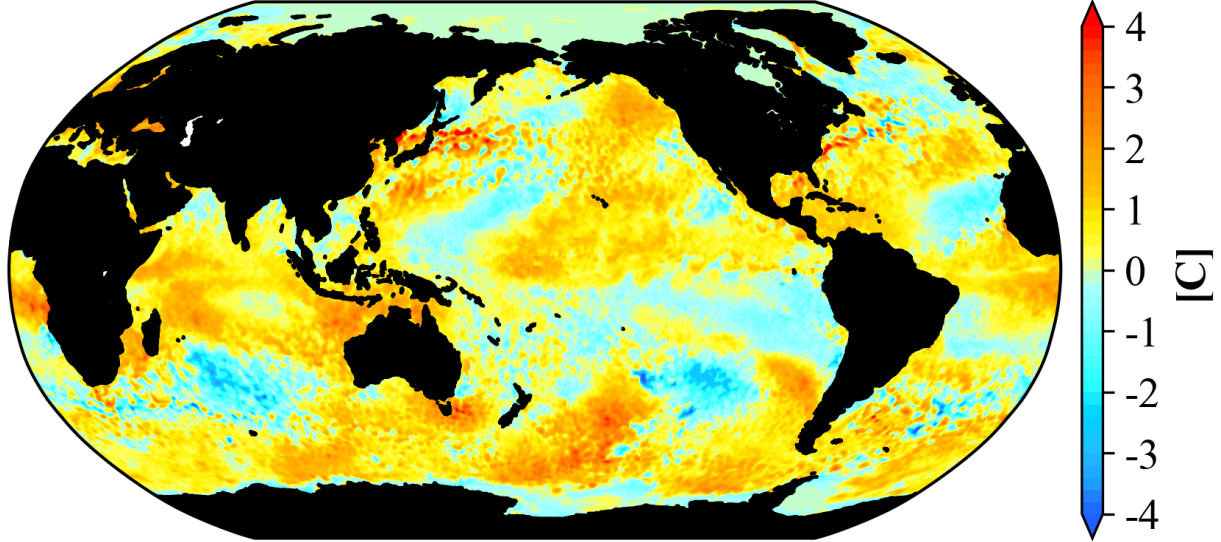


Figure 17. The latest weekly-mean global SST anomalies (ending 5 January 2020). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase five (**Figure 18**). The forecasts are for the MJO to transition to phases six this week and seven next week before weakening where no phase is favored. MJO phases five through seven mostly favor ridging south of the Aleutians, troughing in western North America with more ridging in the Eastern US. As I argue in the Impacts section, I don't see how MJO is contributing to the predicted pattern change across North America starting this weekend.

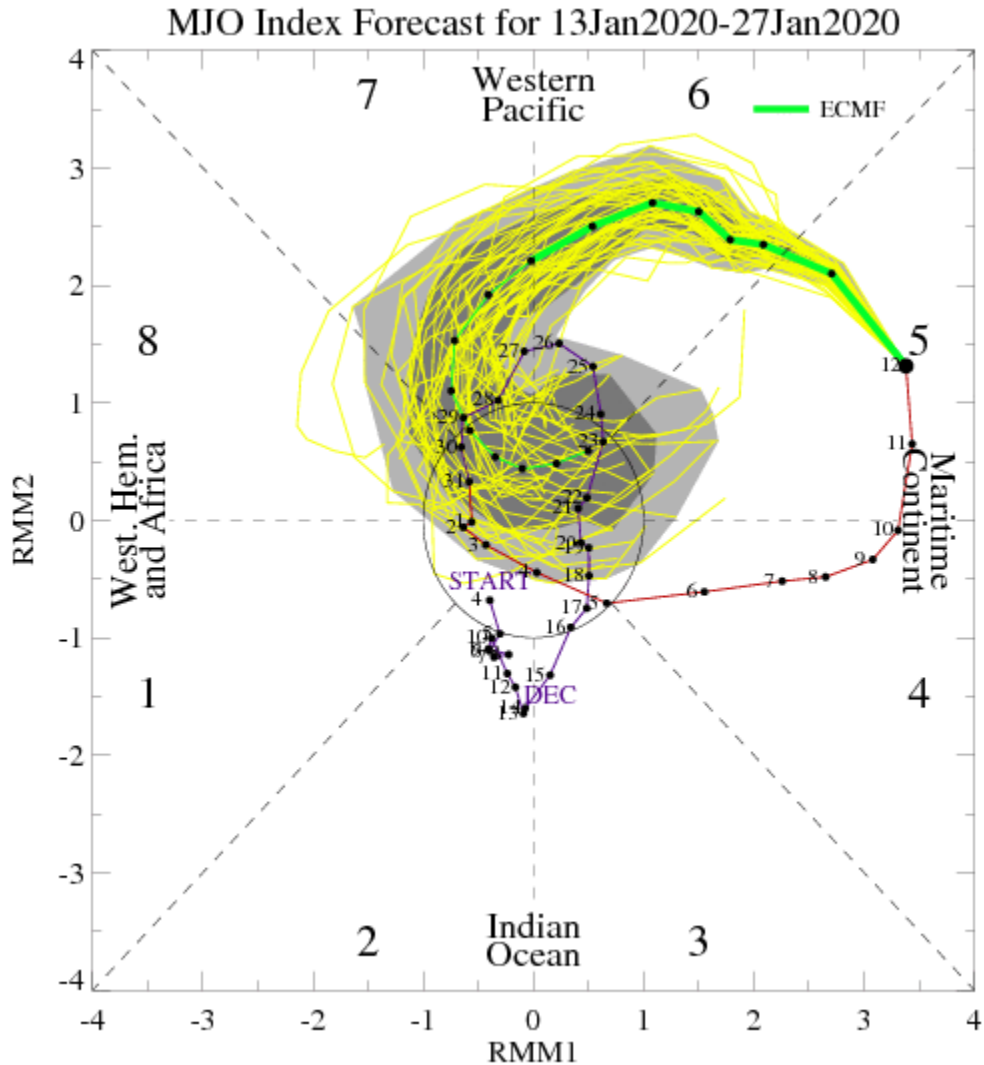


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 6 January 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate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

Despite a strongly positive AO snow cover has advanced across Eurasia and is now near decadal means. And if the snowfall forecasts for Europe ever verify it could advance further. 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.

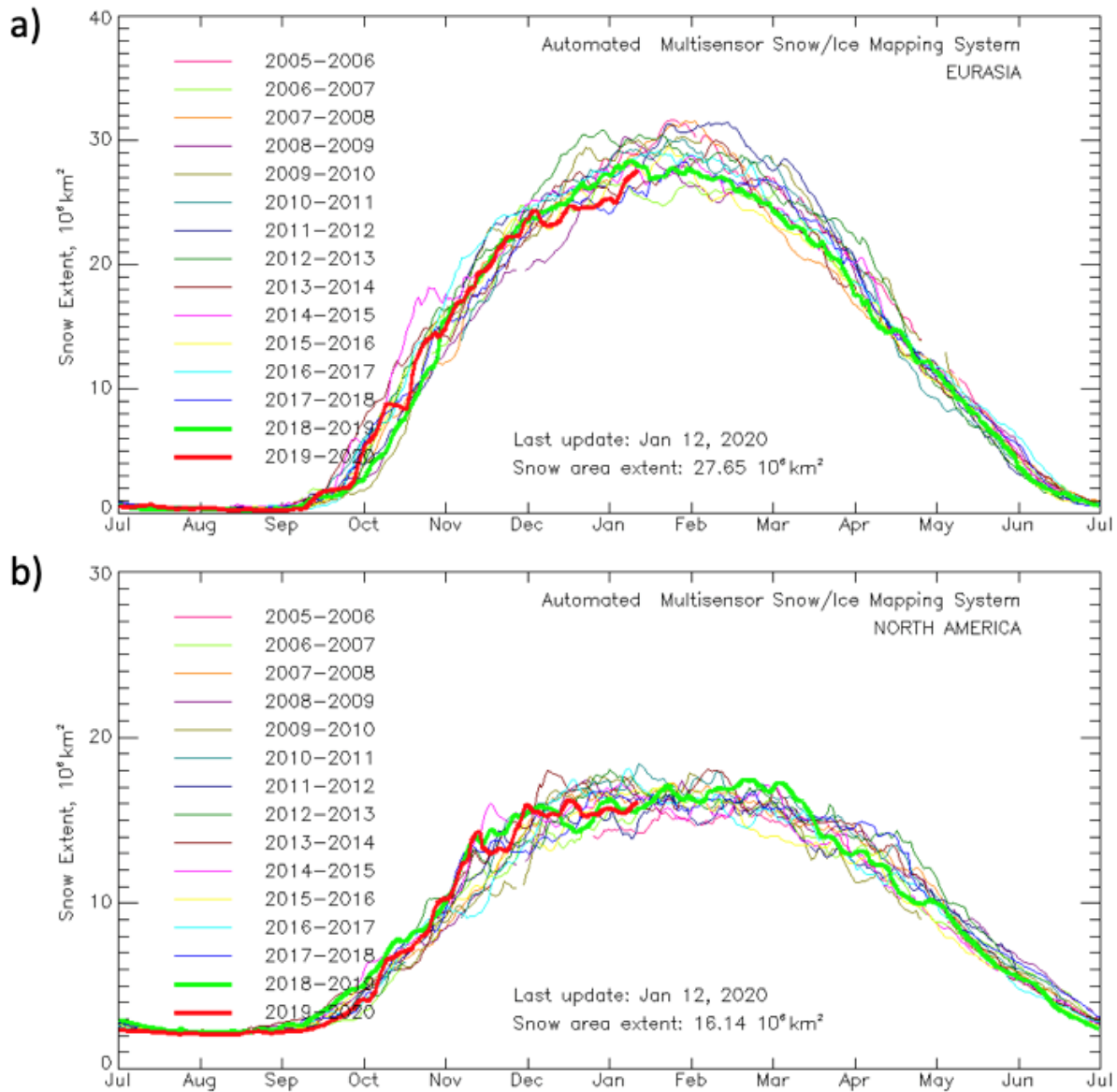


Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 5 January 2020. Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover advanced slightly and remains near decadal means, which is consistent with a negative Pacific/North American pattern. With forecasts of snow in the Northeast it could advance further. The early advance of snow cover across Canada this fall, has likely contributed to the expanse of cold temperatures across Canada.