Arctic Oscillation and Polar Vortex Analysis and Forecasts

December 21, 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) 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. With the start of spring we transition to a spring/summer schedule, which is once every two weeks. Snow accumulation forecasts will be replaced by precipitation forecasts. Also, there will be less 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 neutral and is predicted to remain neutral to negative the next two weeks as pressure/geopotential height anomalies are predicted to remain positive across the North Atlantic side of the Arctic the next two weeks.

- The current neutral AO is reflective of mixed pressure/geopotential height anomalies across the Arctic with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently neutral with weak positive pressure/geopotential height anomalies across Greenland and Iceland; and the NAO is predicted to remain neutral to negative the next two weeks as pressure/geopotential height anomalies are predicted to remain positive.
- This week, ridging/positive geopotential height anomalies are predicted to dominate Europe coupled with normal to above normal temperatures for much of Europe including the United Kingdom (UK). However, starting next week ridging/positive geopotential height anomalies building south of Greenland are predicted to begin forcing downstream troughing/negative geopotential height anomalies coupled with normal to below normal temperatures across Northern and Western Europe while southwesterly flow will persist widespread normal to above normal temperatures across Southern and Eastern Europe.
- Over the next two weeks persistent ridging/positive geopotential height anomalies with normal to above normal temperatures centered near the Urals/Scandinavia/Barents-Kara Seas coupled with a second center over the Laptev Sea are predicted to force troughing/negative geopotential height anomalies coupled with normal to below normal temperatures downstream cross Central Asia and much of Siberia and eventually into East Asia. The biggest Arctic outbreak of the season is looking increasingly likely across East Asia.
- The predicted general pattern across North America the next week is ridging/positive geopotential height anomalies with normal to above normal temperatures across Alaska and Western Canada forcing troughing/negative geopotential height anomalies coupled with normal to below normal temperatures across the Eastern United States (US). However, troughing/negative geopotential height anomalies coupled with normal to below normal temperatures will enter the Western US from the Gulf of Alaska. Meanwhile strengthening ridging/positive geopotential height anomalies coupled with normal to above normal temperatures south of Greenland will expand into Eastern Canada.
- In the Impacts section I continue to discuss the increasing likelihood of a significant polar vortex (PV) disruption based on observations and model forecasts.

Impacts

Happy first day of boreal (astronomical) winter! Certainly, plenty to discuss with predicted upcoming weakening of the stratospheric PV. I would like to discuss what we can expect from the PV weakening, timing and potential impacts on the Northern Hemisphere weather (NH). But I ran out of time and will focus on the arguments for and against a significant PV disruption. I will break up the discussion into observations/statistical analysis and dynamical model forecasts.

In my opinion the Arctic has been mostly favorable for disrupting the stratospheric PV. Arctic sea ice has been below normal to well below normal all fall and early winter. Sea ice has been especially below normal in the Barents-Kara Seas the region theorized to be most important for troposphere-stratosphere coupling. Though sea ice growth has had a good advance recently, including in the Barents Kara Seas, it still remains below normal. And most importantly temperatures remain well above normal in the Barents-Kara Seas/Euro region of the Arctic (see **Figure i**).

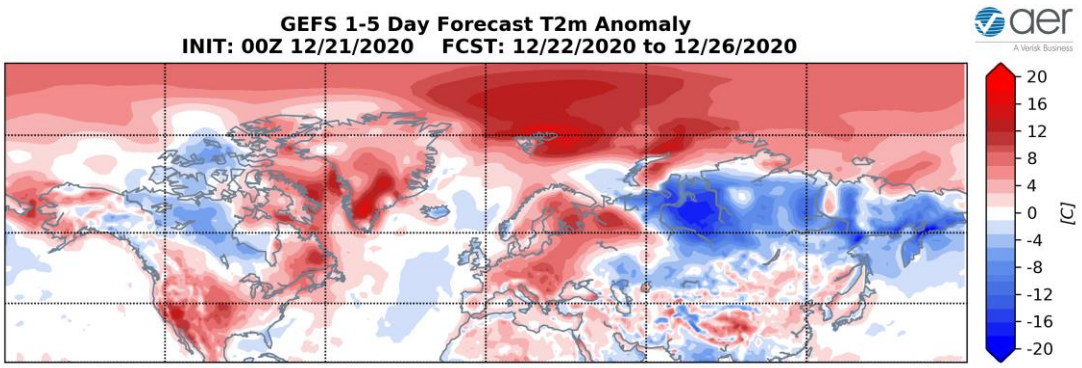

Figure I. Forecasted surface temperature anomalies (°C; shading) from 22 – 26 December 2020. The forecast is from the 00Z 21 December 2020 GFS ensemble. Same as Figure 3 below but is shown to highlight "warm Arctic/cold Asia pattern."

October Eurasian snow cover was slightly above normal, and I did not consider it a very compelling signal for a PV disruption. However, as I discussed in the November 9, 2020 blog, based on research from other groups, snow cover across Eurasia has been favorable for disrupting the PV in November and December. One of those groups, Lv et al. 2020 argue that snow depth across Siberia can weaken the PV even into January. In **Figure ii**, I show the NH snow depth analysis from Environment Canada and snow depth is above normal across much of Siberia and matches the region shown in Lv et al. Arctic sea ice and Eurasian snow cover anomalies are highly supportive for relative warmth on the North Atlantic side of the Arctic coupled with relatively cold temperatures across Siberia is also known as the "warm Arctic/cold Eurasia (really Asia) pattern" and is ideal for forcing a large-scale wave across the Eurasian continent characterized by ridging across northwestern Eurasia and troughing across northeastern Eurasia. It is my impression that the community has come to a consensus that amplifying this wave is most important in forcing PV disruptions. And there are no signs of that ridge-trough pattern across Eurasia breaking down into the foreseeable future based on the dynamical weather model forecasts. We also have an experimental and highly speculative PV forecast model and it predicts a weak PV and possibly a major mid-winter warming (MMW where the zonal winds reverse from westerly to easterly at 60°N and 10 hPa) during the late December and early January period. If one doesn't occur then, the next best chance is the third week of January.

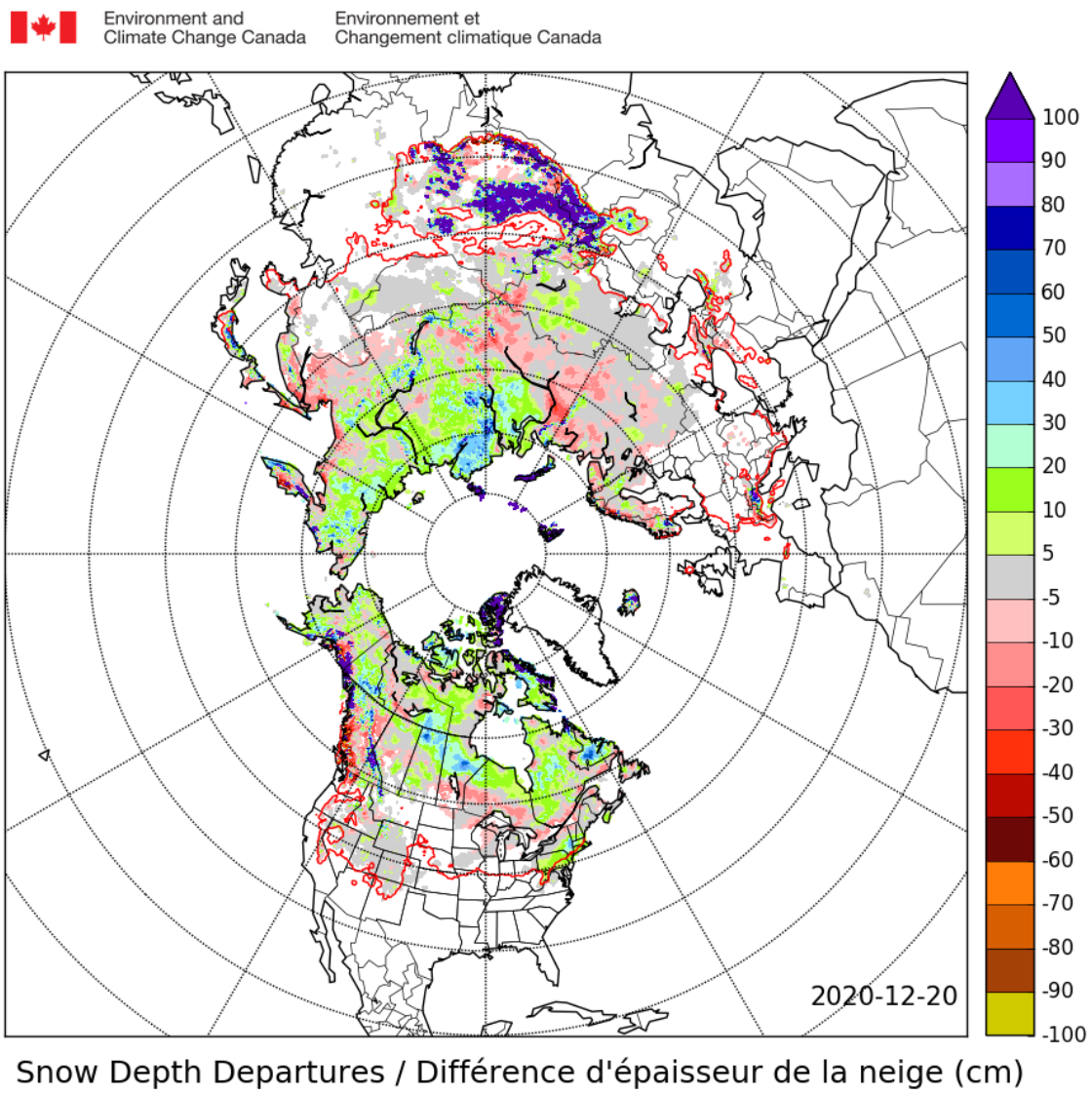

Figure ii. Snow depth anomalies across the Northern Hemisphere on 20 December 2020. From https://www.ccin.ca/ccw/snow/current.

I also have a new paper (in press) first authored by my colleague Jason Furtado. In the paper, we compare the tropospheric precursor to MMWs in the reanalysis and several different dynamical models (Furtado, J. C., J. Cohen, E. J. Becker and D. C. Collins. 2020: Evaluation of the predictability of the northern annular mode and sudden stratospheric warmings in the NMME Phase-2 models, Climate Dynamics, in press). In **Figure iii**, I show the precursor for the three weeks immediately prior to a MMW derived at 500 hPa from reanalysis. I also include two other similar analyses I published identifying the tropospheric precursor. All three plots share Ural ridging with

downstream troughing across Siberia and into the northern North Pacific. What is different in the new analysis is more ridging in the North Atlantic. I have often in the past described the tropospheric precursor as a tripole pattern but in the new analysis it resembles more of a dipole pattern broadly generalized as ridging in the North Atlantic sector and troughing in the North Pacific sector. But most importantly for today, the precursor pattern strongly resembles the forecast in the coming two weeks (e.g., Figures **5** and **8**). This is yet another observation suggestive of a potential MMW in the coming weeks. Just as an aside the differences in the North Atlantic are likely related to a small sample size, large internal variability and possibly the anomalies in the North Atlantic are not as a robust as across Asia and the North Pacific.

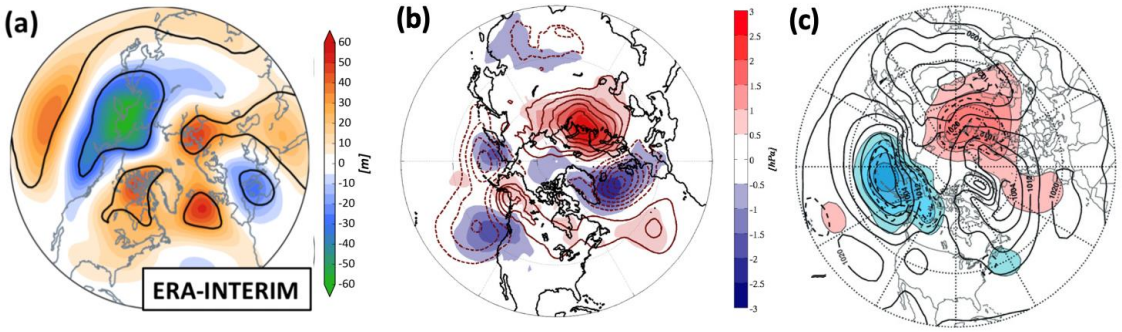

Figure iii. a) Lag composite of 500 hPa GPHa (m) from ERA-Interim averaged between 1 to 20 days before the start of a major mid-winter warming. b) Regression of November SLP anomalies (hPa) onto October monthly-mean Eurasian SCE (contouring) and onto December meridional heat flux anomalies at 100 hPa, averaged be-tween 40° and 80°N (shading). c) Sea level pressure (SLP) anomalies (hPa) averaged 45 to 0 days prior to vortex displacements.

The observed and predicted Wave Activity Flux (WAFz and is proportional to poleward heat transport) from today reminds me of the WAFz we analyzed the month leading up to PV splits. I show the analysis from Cohen and Jones 2012 in **Figure iv** and it looks strikingly similar to the WAFz plot below much more so than what we found for displacements (**Figure 12**). Also the PV tends to be stronger prior to a split than before a displacement.

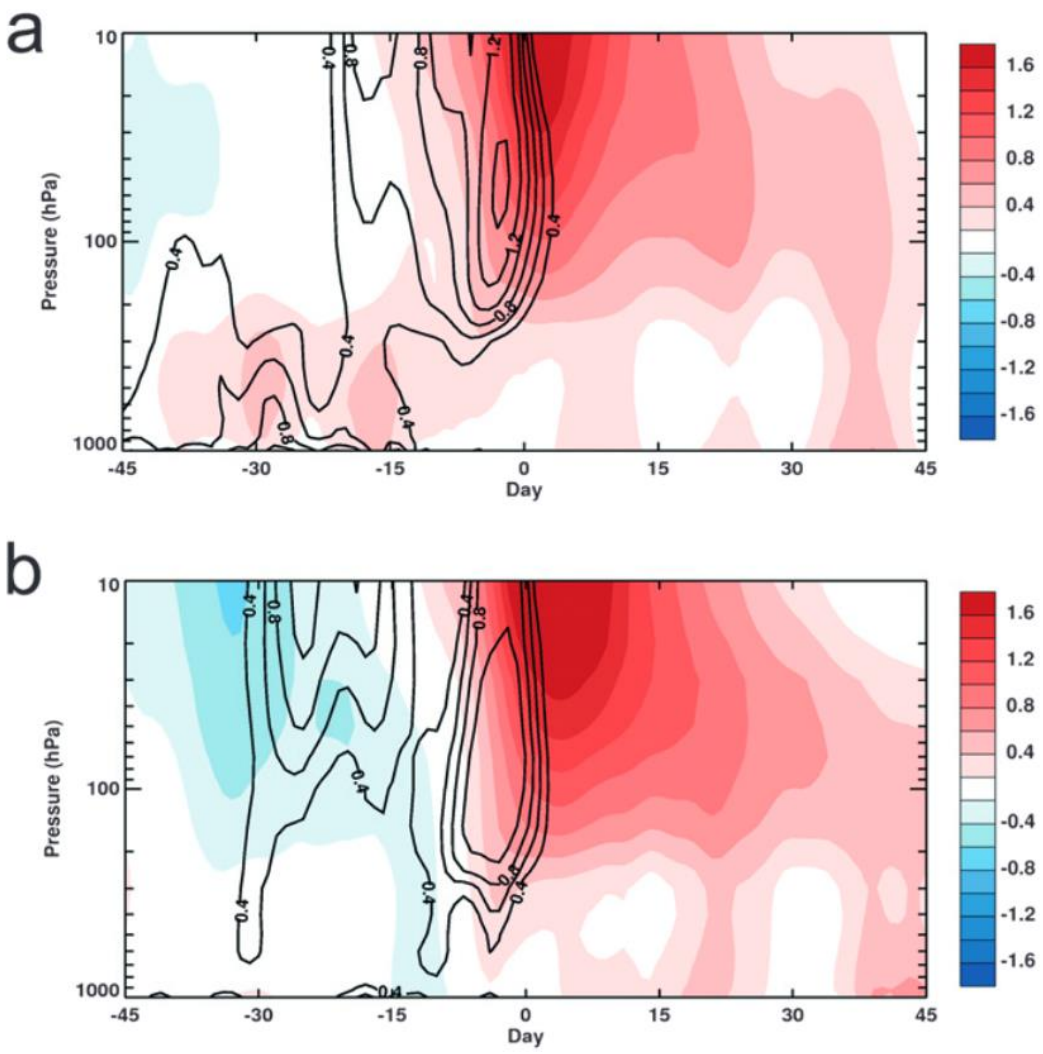

Figure iv. Polar cap geopotential height anomalies (shading) and WAF anomalies bounded by 40°–80°N, 30°E–180° (contouring) from 45 days prior until 45 days after **a)** vortex displacements and **b)** vortex splits.

In addition, there are two upcoming synoptic events that I believe are consistent with an impending PV disruption. A warm, wet and windy storm here in the Eastern US. This event reminds me of December 2003 and January 2006, both ahead of an MMW. The second is an anomalous cold surge in East Asia. One of the most famous was in January 2008 and more recently there was one in January 2018.

My only hesitation to being even more bullish about an imminent MMW is that the tropics broadly are more hostile to an MMW including La Niña and the westerly quasi-biennial oscillation (QBO). However, as I discussed in the October 19, 2020 blog, there have been several MMWs in recent years with both a La Niña and a westerly QBO including just three years ago in 2018.

The dynamical models are all on board with a disruption of the PV but of varying intensity. The GFS operational have recently been some of the more extreme solutions and I couldn't resist including the PV animation from this morning in **Figure v**. It shows a very nice PV split. I expect the models to struggle with the PV forecast in the coming days and even weeks. I recall a large divergence among models for the most recent MMW in early January 2019 even within a few days of the event and I expect something similar currently.

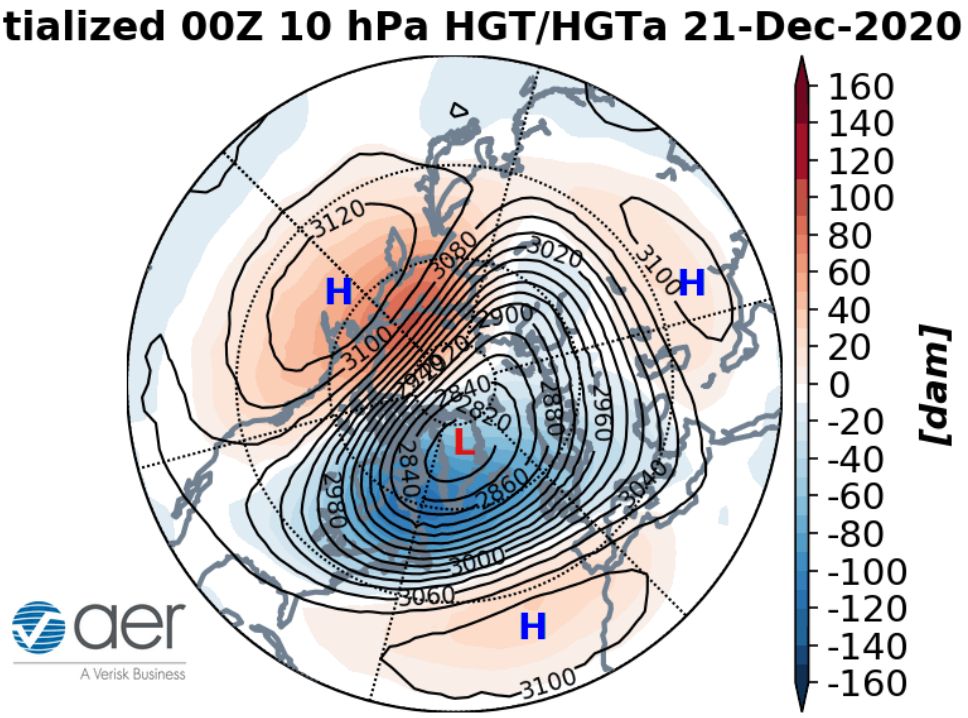

Figure v. Forecasted 10 mb geopotential heights (dam; contours) and anomalies (°C; shading) across the Northern Hemisphere for 21 December 2020 – 6 January 2021.

One other model forecast of interest is the divergence of WAFz in the polar stratosphere (in the zonal mean sense is referred to as Eliassen-Palm (EP) flux). As I have been discussing in recent blogs for the stratospheric PV to weaken the WAFz or EP flux needs to be absorbed or converge in the polar stratosphere. The GFS is predicting that an impressive amount of WAFz will be absorbed in or converge on the polar stratosphere (negative or blue values) the first week of January (**Figure vi**) and is comparable to the end of December 2018.

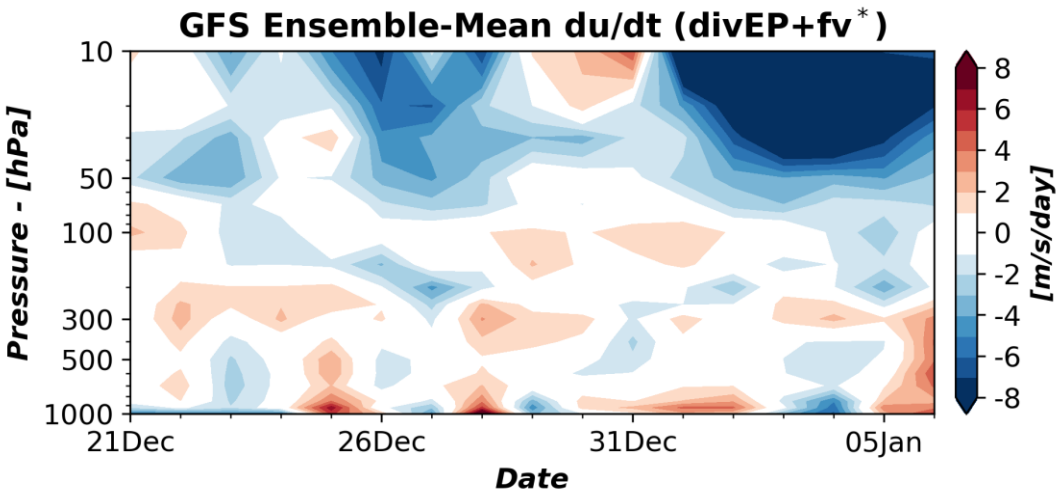

Figure vi. Forecast of the divergence (positive/red shading) and convergence of WAFz or EP flux (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 21 December 2020 GFS ensemble. Blue shading represents convergence and indicates a weakening of the PV.

I want to conclude though with a cautionary tale from last winter – what looks like a significant PV event in the models could end up being a non-event. In early December 2019 the GFS was also predicting a significant PV disruption. I present in **Figure vii** the 10 hPa geopotential forecast 11-15 days and then 1-5 days. What was predicted to be a robust sudden stratospheric warming turned out to be a fairly strong PV instead. And the stratospheric warming predicted by the GFS ensembles was more impressive last December than any warming this December so far.

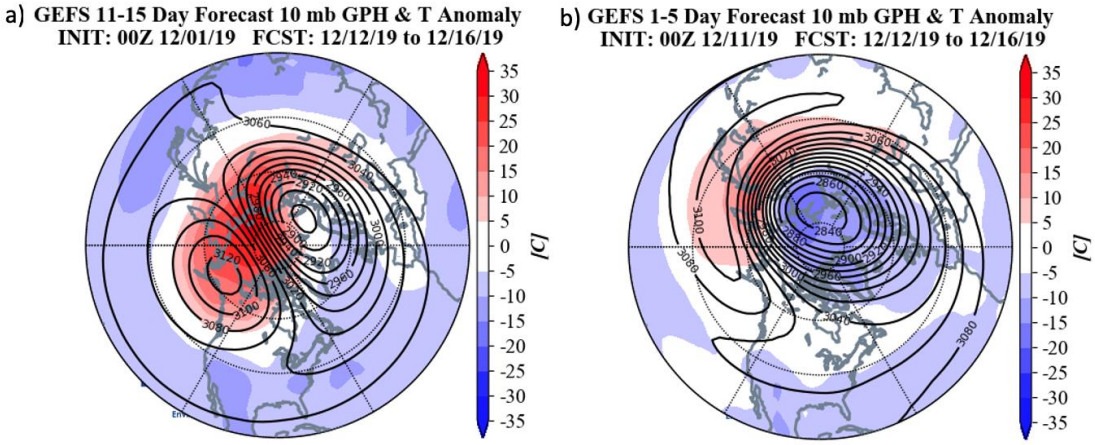

Figure vii.. (**a**) Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 12 – 16 December

2019. The forecast is from the 00Z 14December 2019 GFS model ensemble. (**b**) Same as (**a**) except from the 00Z 11 December 2019 GFS model ensemble.

I did want to discuss some of the impacts from the upcoming potential PV disruption but as usual there is so much to say, but I think that it is best to wrap it up here. When we grow more confident how the evolving PV disruption will evolve it will help focus possible implications for our weather. Also, I wanted to describe in layman terms how the PV forms and what is required to disrupt it. I think this was a suggestion from Tim Dunkerton (@tim_dunkerton) and whether it was his intention or not, seems like a good one. In the coming weeks I will try to make progress on it.

1-5 day

The AO is currently neutral **(Figure 1**) with mixed pressure/geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with predicted weak positive geopotential height anomalies across Greenland (**Figure 2**), the NAO is predicted to also be neutral this week.

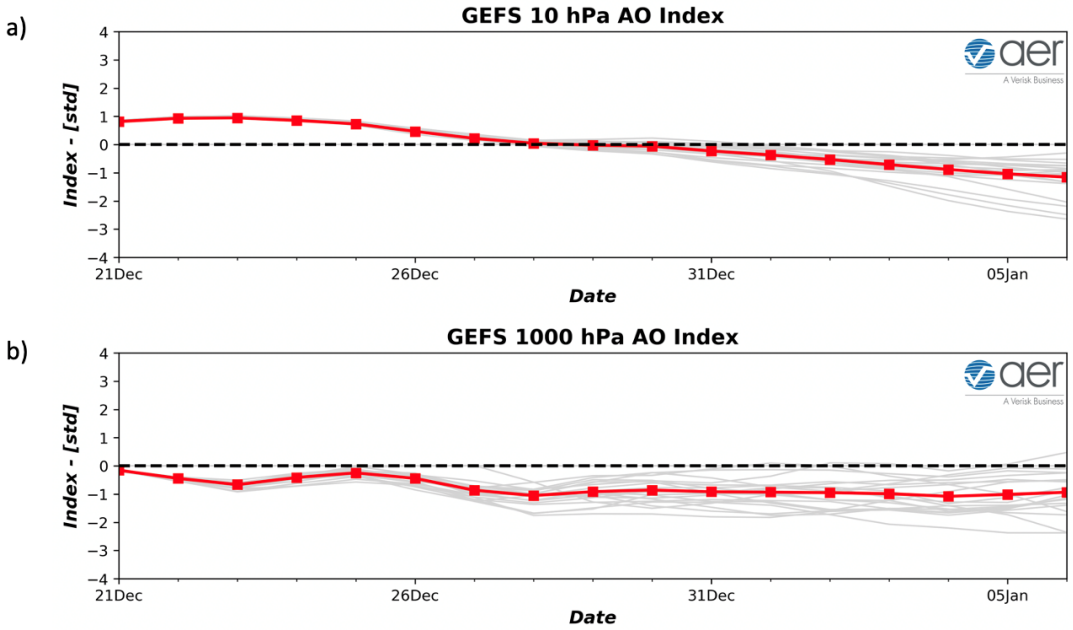

Figure 1. (**a**) The predicted daily-mean AO at 10 hPa from the 00Z 21 December 2020 GFS ensemble. (**b**)The predicted daily-mean near-surface AO from the 00Z 21 December 2020 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies are predicted to dominate much of Europe (**Figure 2**). This pattern favors normal to above normal temperatures

across Europe including the UK (**Figure 3**). This week, Western Russia ridging/positive geopotential height anomalies coupled with another positive height centered in the Laptev Sea are predicted to force downstream troughing/negative geopotential height anomalies across much of Siberia and Central Asia (**Figure 2**). This pattern favors normal to above normal temperatures **f**or Western, Southern and Eastern Asia with normal to below normal temperatures for Siberia and Central Asia **(Figure 3**).

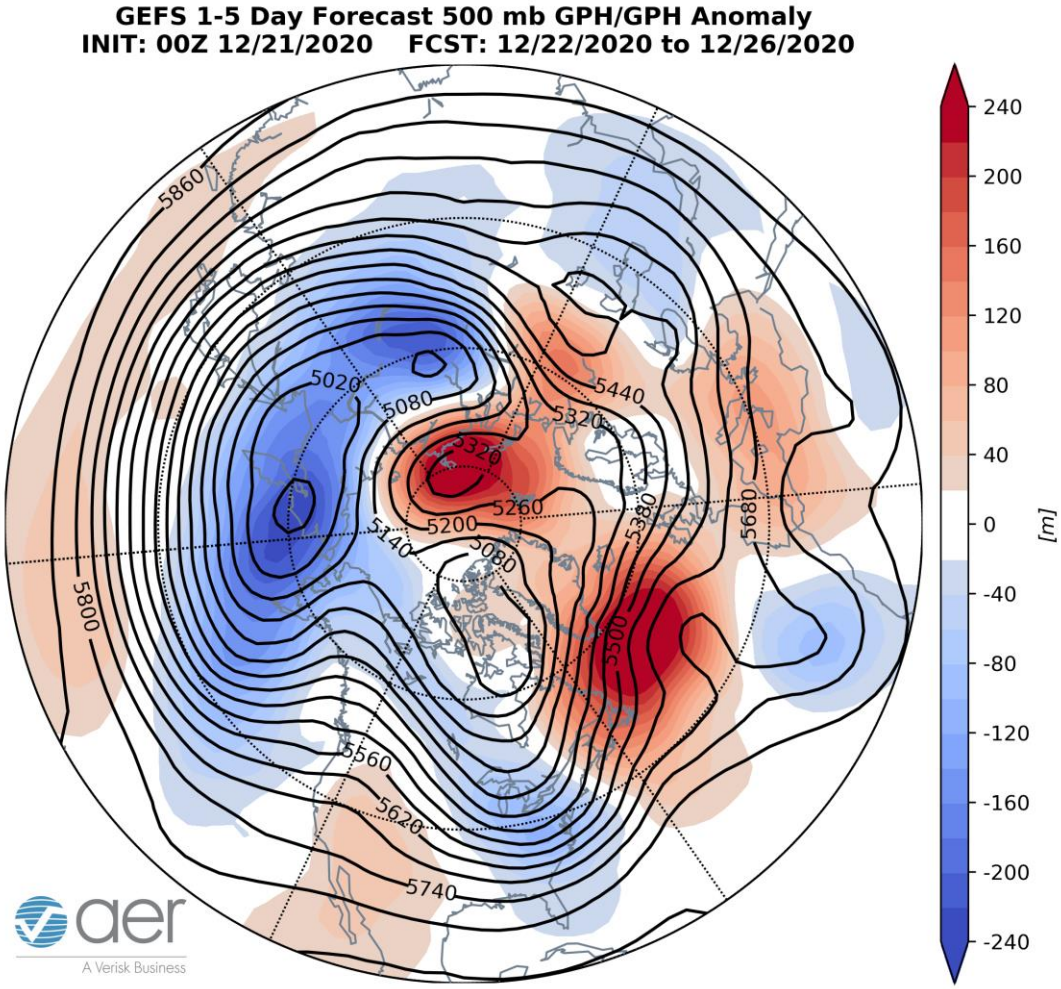

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 22 – 26 December 2020. The forecasts are from the 00z 21 December 2020 GFS ensemble.

This week, ridging/positive geopotential height anomalies are predicted for Western North America forcing troughing/negative geopotential height anomalies in Central Canada and the Eastern US with more ridging/positive geopotential height anomalies across the Canadian Maritimes **(Figure 2). T**his pattern is predicted to bring widespread normal to above normal temperatures across much of Alaska, Western

Canada, the Canadian Maritimes and the Western US with normal to below normal temperatures for Central Canada and in the Eastern US **(Figure 3).**

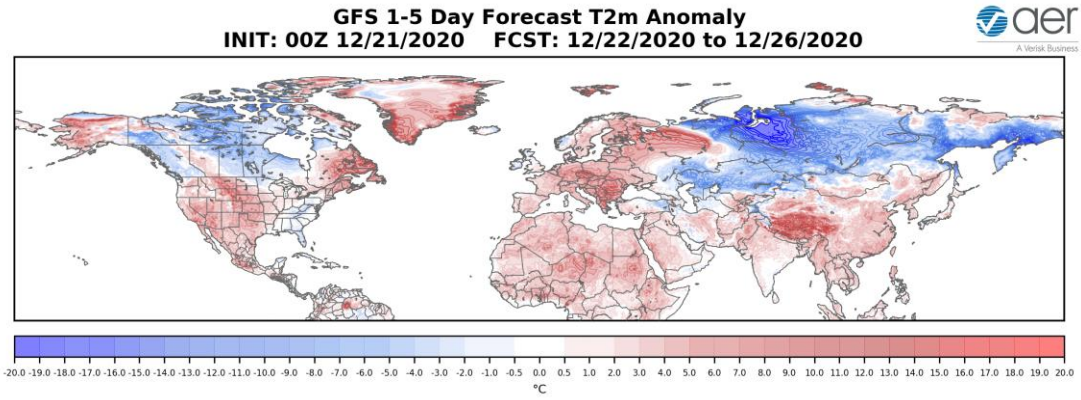

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 22 – 26 December 2020. The forecast is from the 00Z 21 December 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across parts of Scandinavia, the Alps, the Caucasus Mountains and Siberia while warmer temperatures will cause regional snow melt in Central Asia and China (**Figure 4**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, much of Canada, and the Ohio valley into the Great Lakes while warmer temperatures will cause snow melt in parts of the Plains, Northeastern US and the Canadian Maritimes (**Figure 4**).

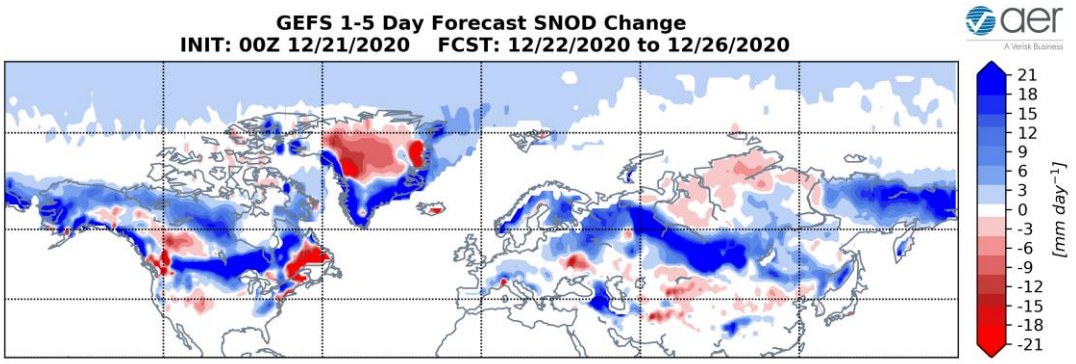

Figure 4. Forecasted snow depth changes (mm/day; shading) from 22 – 26 December 2020. The forecast is from the 00Z 21 December 2020 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain slightly negative to neutral next week **(Figure 1**) as positive geopotential height anomalies dominate the North Atlantic side of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with positive geopotential height anomalies predicted across Greenland (**Figure 5**), the NAO is predicted to also remain mostly negative.

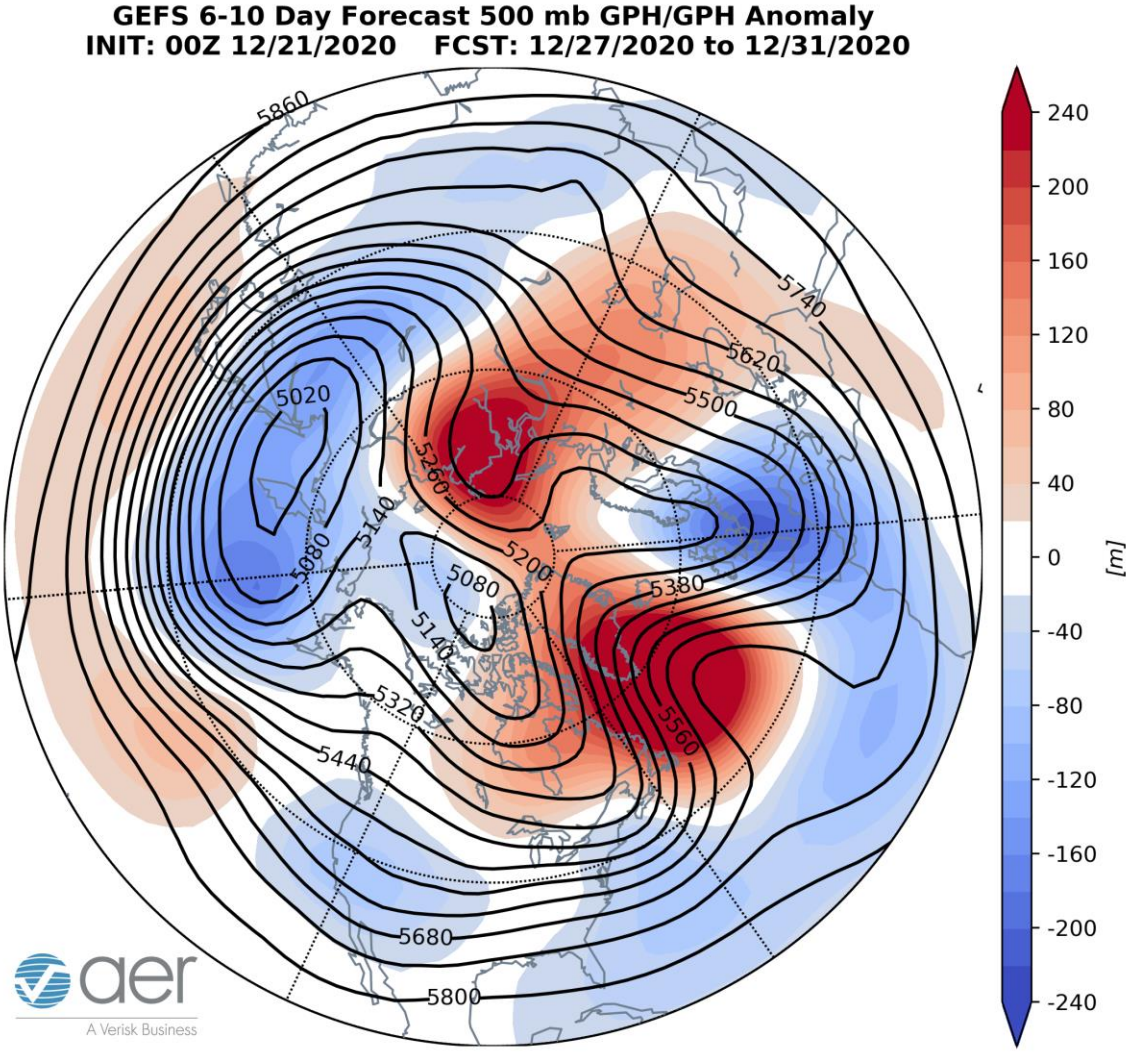

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 27 – 31 December 2020. The forecasts are from the 00z 21 December 2020 GFS ensemble.

Strengthening ridging/positive geopotential height anomalies south of Greenland are predicted to force downstream troughing/negative geopotential height anomalies across Western Europe this period (**Figure 5). T**his pattern favors normal to below normal temperatures across Western Europe including the UK while southwesterly flow of mild air will persist normal to above normal temperatures across much of Central

and Eastern Europe (**Figure 6**). Persistent ridging/positive geopotential height anomalies centered near the Urals will begin to merge another positive height center in the Laptev Sea and will continue to force downstream troughing/negative geopotential height anomalies across Central Asia and Siberia that extends south across East Asia this period (**Figure 5**). This is predicted to favor widespread normal to below normal temperatures across much of Siberia, Central and increasingly across East Asia with normal to above normal temperatures in Western and Southern Asia **(Figure 6**).

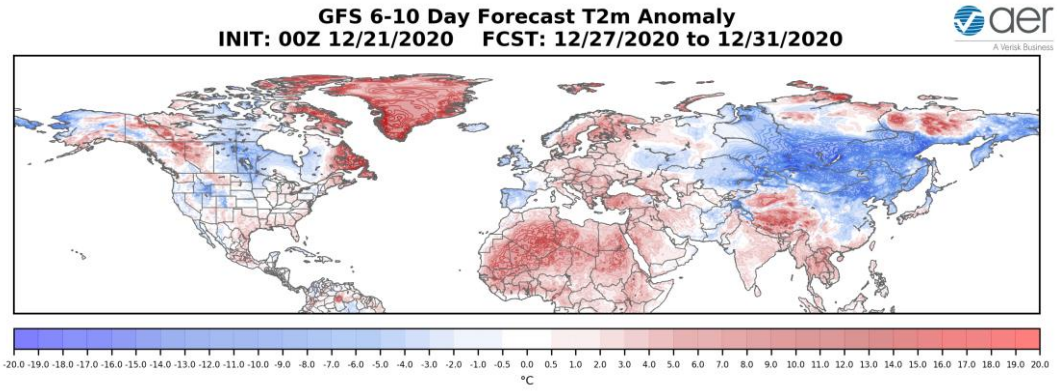

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 27 – 31 December 2020. The forecasts are from the 00Z 21 December 2020 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to persist across Alaska and Western Canada and the Canadian Maritimes forcing downstream troughing/negative geopotential height anomalies across the Eastern US (**Figure 5**). However, in addition troughing/negative geopotential height anomalies previously in the Gulf of Alaska will enter the Western US (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across Alaska, Western Canada, the Central US and the Canadian Maritimes with normal to below normal temperatures across Central Canada and the Western and Eastern US **(Figure 6).**

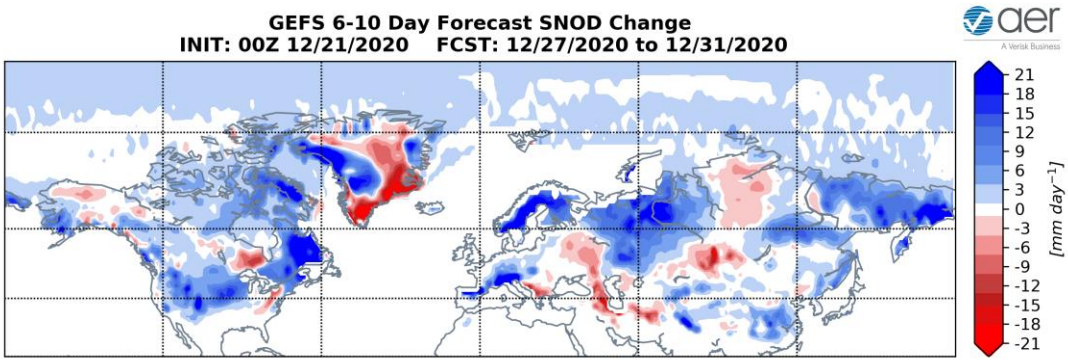

Figure 7. Forecasted snow depth changes (mm/day; shading) from 27 – 31 December 2020. The forecasts are from the 00Z 21 December 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across Scandinavia, the higher terrain of Europe, Western Asia, Siberia and possibly Eastern China, the Himalayas while warmer temperatures will cause regionalized snow melt including the Baltic States and the Caucasus Mountains (**Figure 7**). Troughing and/or colder temperatures are predicted to support new snowfall across much of Canada and the Western, Central and Northeastern US while warmer temperatures will cause possible snow melt in the US Appalachians (**Figure 7**). Though not obvious from the plot, blocking in the Canadian Maritimes does pose a risk of heavy snowfall in the Northeastern US this period and next.

11-15 day

As geopotential height anomalies are predicted to remain positive on the North Atlantic side of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO should remain negative this period (**Figure 1**). With continued positive pressure/geopotential height anomalies spread across Greenland (**Figure 8**), the NAO is predicted to remain negative this period as well.

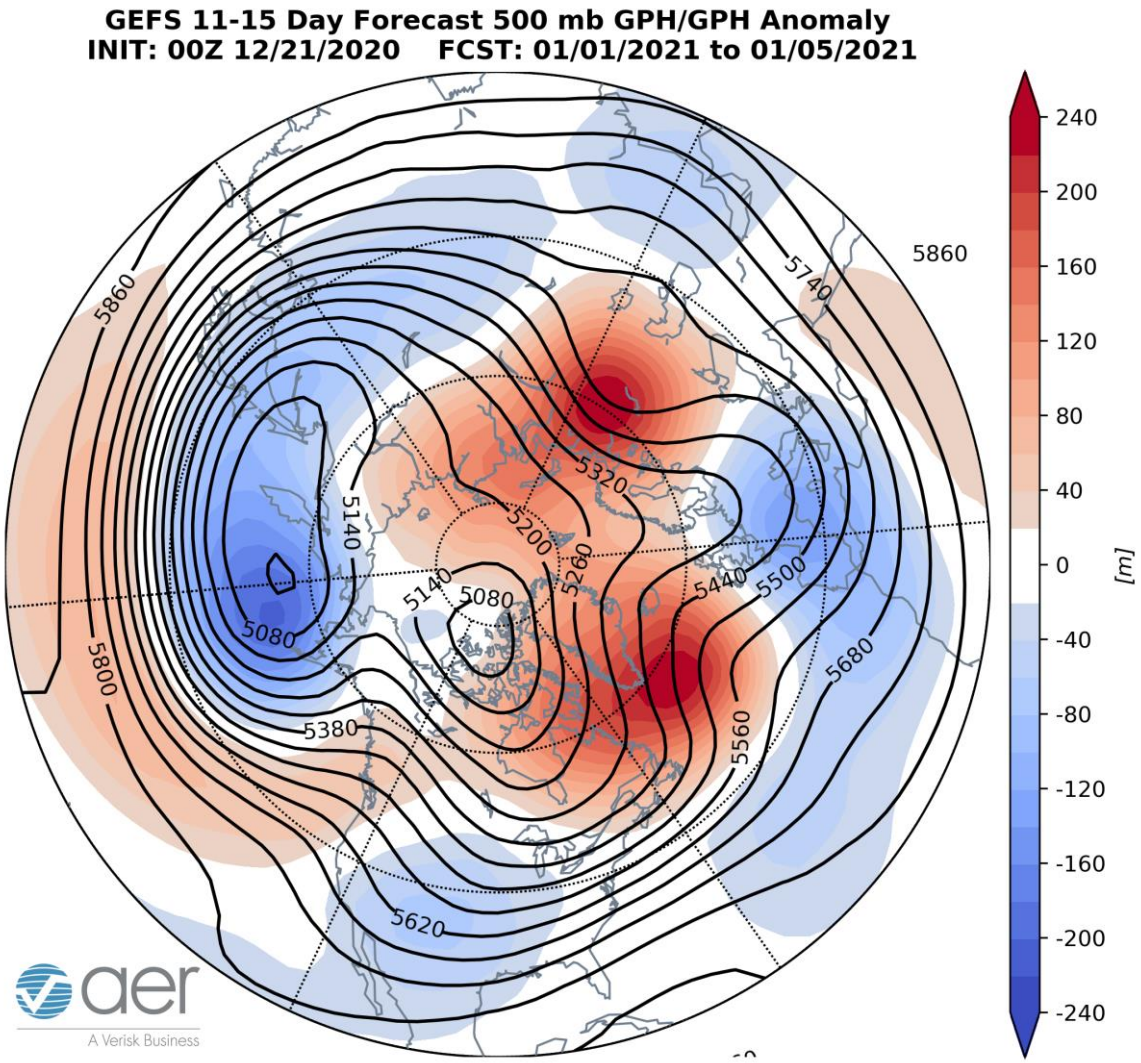

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 1 – 5 January 2021. The forecasts are from the 00z 21 December 2020 GFS ensemble.

Persistent ridging/positive geopotential height anomalies centered south of Greenland coupled with ridging centered near the Urals are predicted to lock in troughing/negative geopotential height anomalies over Western and Central Europe this period (**Figures 8**). The forecast is for normal to below normal temperatures across Northern and Western Europe including the UK while Southwesterly flow persists normal to above normal temperatures for Eastern Europe this period (**Figures 9**). Predicted persistent ridging/positive geopotential height anomalies focused near the Urals will continue to support downstream troughing/negative geopotential height anomalies across Siberia that extends south to Eastern and Central Asia this period (**Figure 8**). This pattern favors normal to above normal temperatures across the Western and Southcentral Asia with normal to below normal temperatures across much of Siberia and into East Asia

(**Figure 9**). The movement of the cold air southeastwards out of Siberia this period could extend anomalously south across China and Southeast Asia.

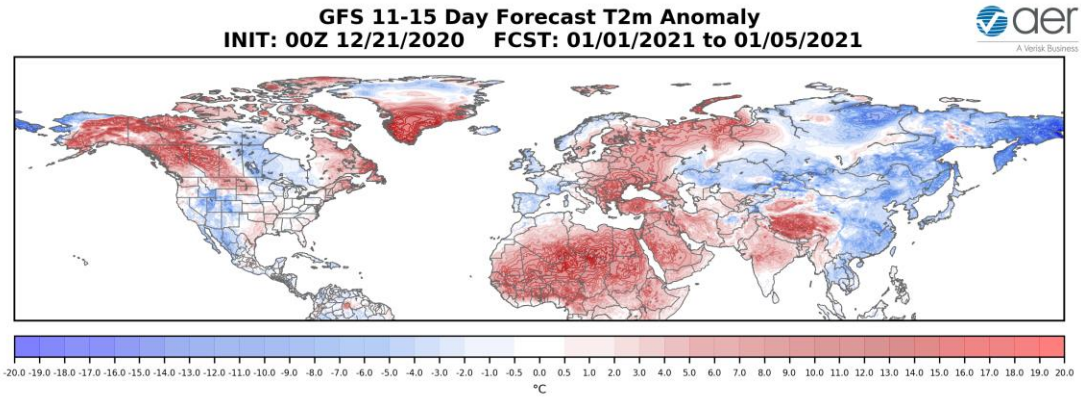

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 1 – 5 January 202. The forecasts are from the 00z 21 December 2020 GFS ensemble.

Persistent ridging/positive geopotential height anomalies across Alaska and Western Canada will force troughing/negative geopotential height anomalies across Central North America with ridging in the Canadian Maritimes persisting this period as well (**Figure 8**). This predicted pattern favors normal to above normal temperatures for Alaska, Western Canada, the Canadian Maritimes and the Eastern US with normal to below normal temperatures for Central Canada and the Western and Central US (**Figure 9**).

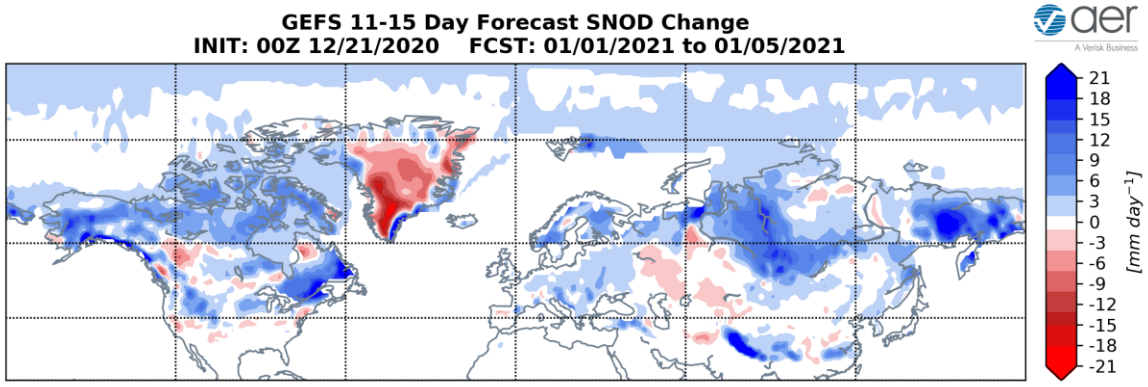

Figure 10. Forecasted snow depth changes (mm/day; shading) from 1 – 5 January 2021. The forecasts are from the 00z 21 December 2020 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across Scandinavia, the Himalayas, much of Northern and Eastern Asia and even possibly Central and Eastern Europe (**Figure 10**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, much of Northern but especially

Eastern Canada and possibly the Northwestern US, western Great Lakes and New England (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows warm/positive normal PCHs in the low to mid troposphere and cold/negative PCHs in the upper troposphere and extending throughout the stratosphere for this week (**Figure 11**). However, by next week the PCHs are predicted to turn warm/positive throughout the troposphere and stratosphere (**Figure 11**). **Please note that the PCH plot now extends to 1 hPa and previously it stopped at 10 hPa.**

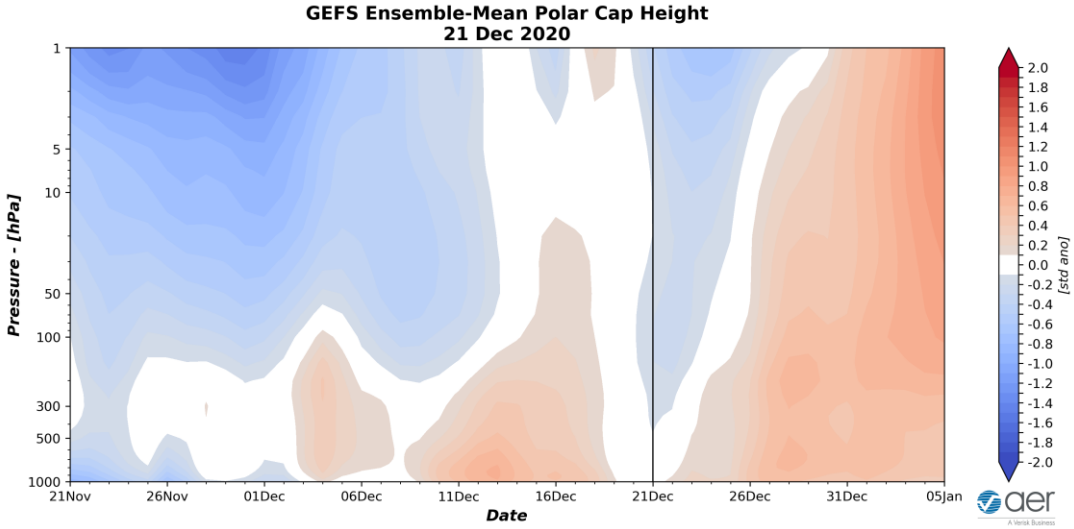

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 21 December 2020 GFS ensemble. Please note that the PCH plot now extends to 1 hPa.

Normal to warm/positive PCHs in the lower troposphere are consistent with the predicted neutral to negative surface AO the next two weeks (**Figure 1**). Cold/negative PCHs in the stratosphere are consistent with the positive stratospheric AO this week while the change to warm/positive PCHs next week are consistent with the predicted negative stratospheric AO (**Figure 1**). I still believe there could be volatility in the PCH forecast that have important long-term implications for troposphere-stratosphere coupling.

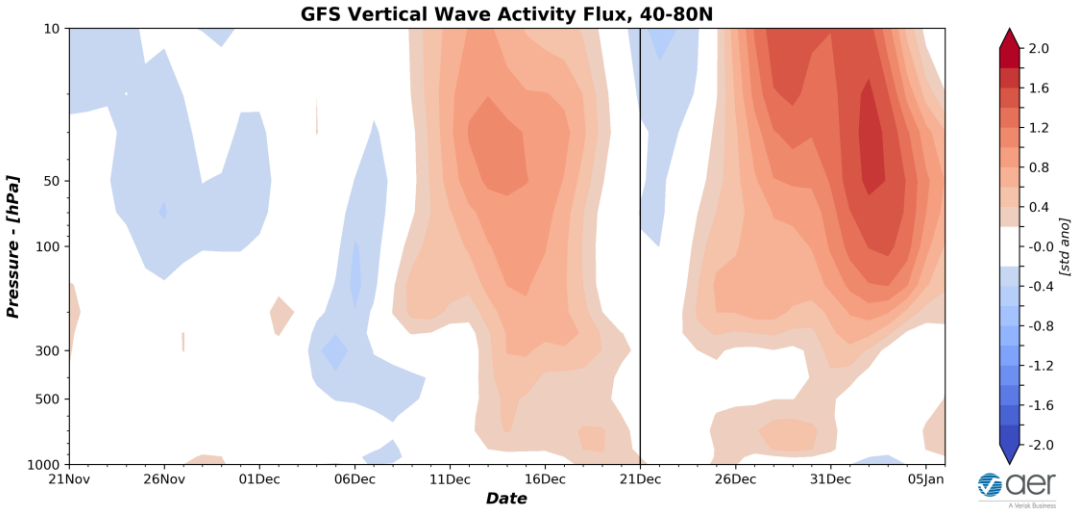

Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 21 December 2020 GFS ensemble.

The plot of Wave Activity Flux (WAFz and is proportional to poleward heat transport) forecasts is showing the first strong WAFz pulse of the winter has now ended with a relatively quiet upcoming first half of the week (**Figure 12**). There is a predicted second, stronger pulse of WAFz starting this week and continuing into early January (**Figure 12**). While the first pulse of WAFz did weaken the stratospheric PV just enough to precondition the PV for a more significant PV weakening to end the month and into early January. Too early to know if the PV weakening will meet the threshold of a major mid-winter warming (MMW where the zonal winds reverse from westerly to easterly at 60°N and 10 hPa) but it is likely that PCHs will reverse from cold to warm and the stratospheric AO from positive to negative (**Figure 1**).

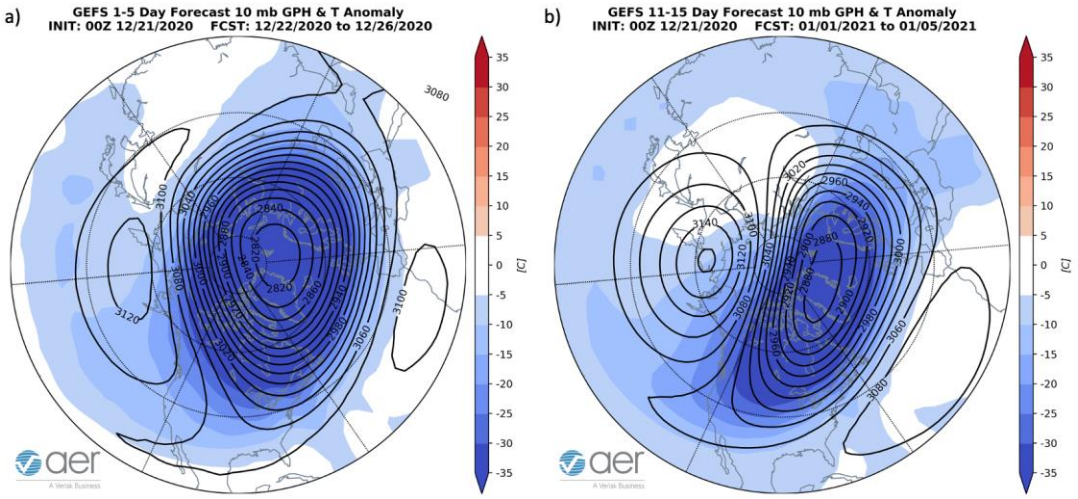

Figure 13. (**a**) Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 22 – 26 December 2020. (**b**) Same as (a) except forecasted averaged from 1 – 5 January 2021. The forecasts are from the 00Z 21 December 2020 GFS model ensemble.

The PV is predicted to remain strong and centered near Svalbard this week (**Figure 13**). The PV is east of the North Pole and stretched due to high pressure centered near the Dateline. The high pressure near the Dateline is predicted to strengthen while the PV is predicted to weaken in place near Greenland (**Figure 13**). The PV weakening is looking more like an absorptive event, which is most closely associated with cold temperatures in Northern Eurasia.

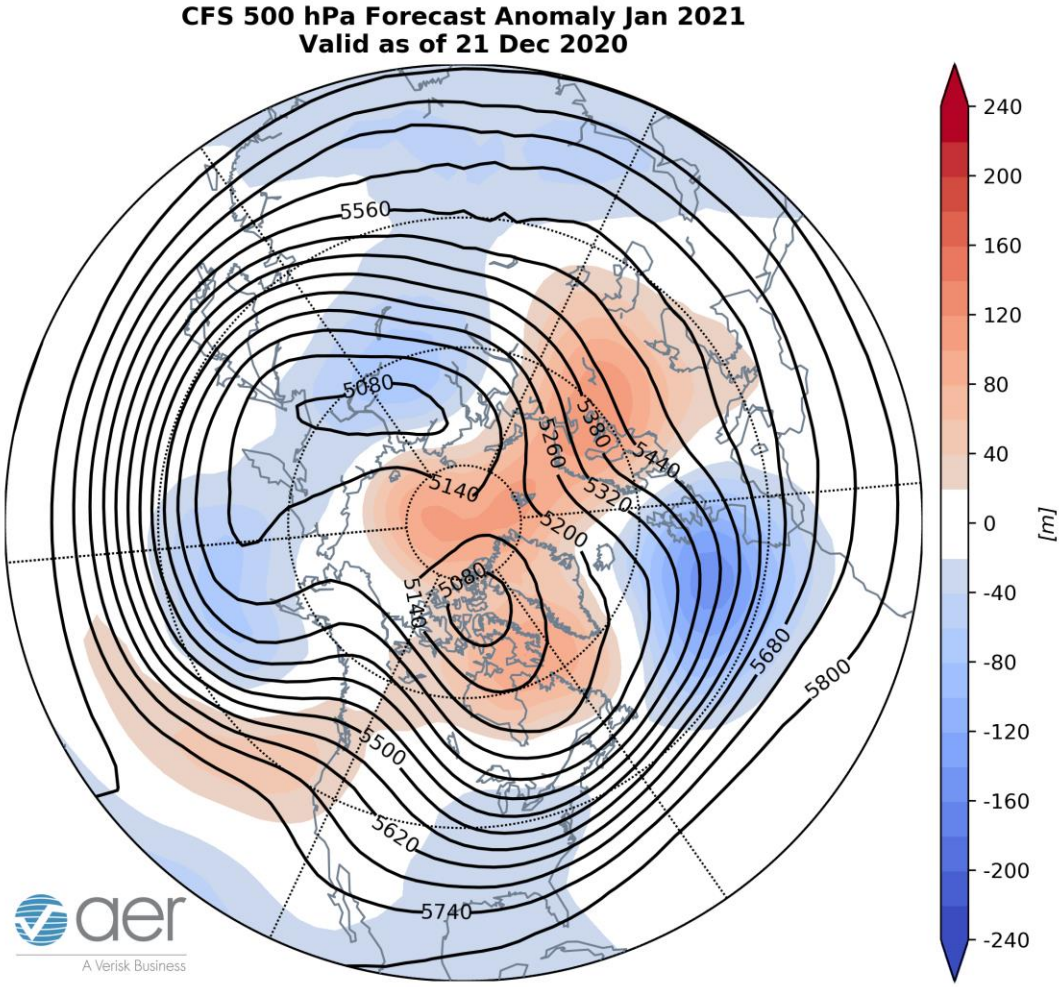

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for January 2021. The forecasts are from the 00Z 21 December 2020 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) forecast for January from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging in the Central Arctic, the Urals/Scandinavia, Gulf of Alaska, Alaska and the western North America and Greenland with troughing in Western Europe, much of Asia but especially Siberia, Central Canada into the Eastern US (**Figure 14).** This pattern favors relatively warm temperatures for Eastern Europe, Western Asia and western North America with seasonable to relatively cold temperatures for Western Europe, Central and Southeastern Canada and the Eastern US (**Figure 15**)**.** I don't believe the CFS can accurately predict the response to a significant PV disruption, but the January forecast is consistent with one.

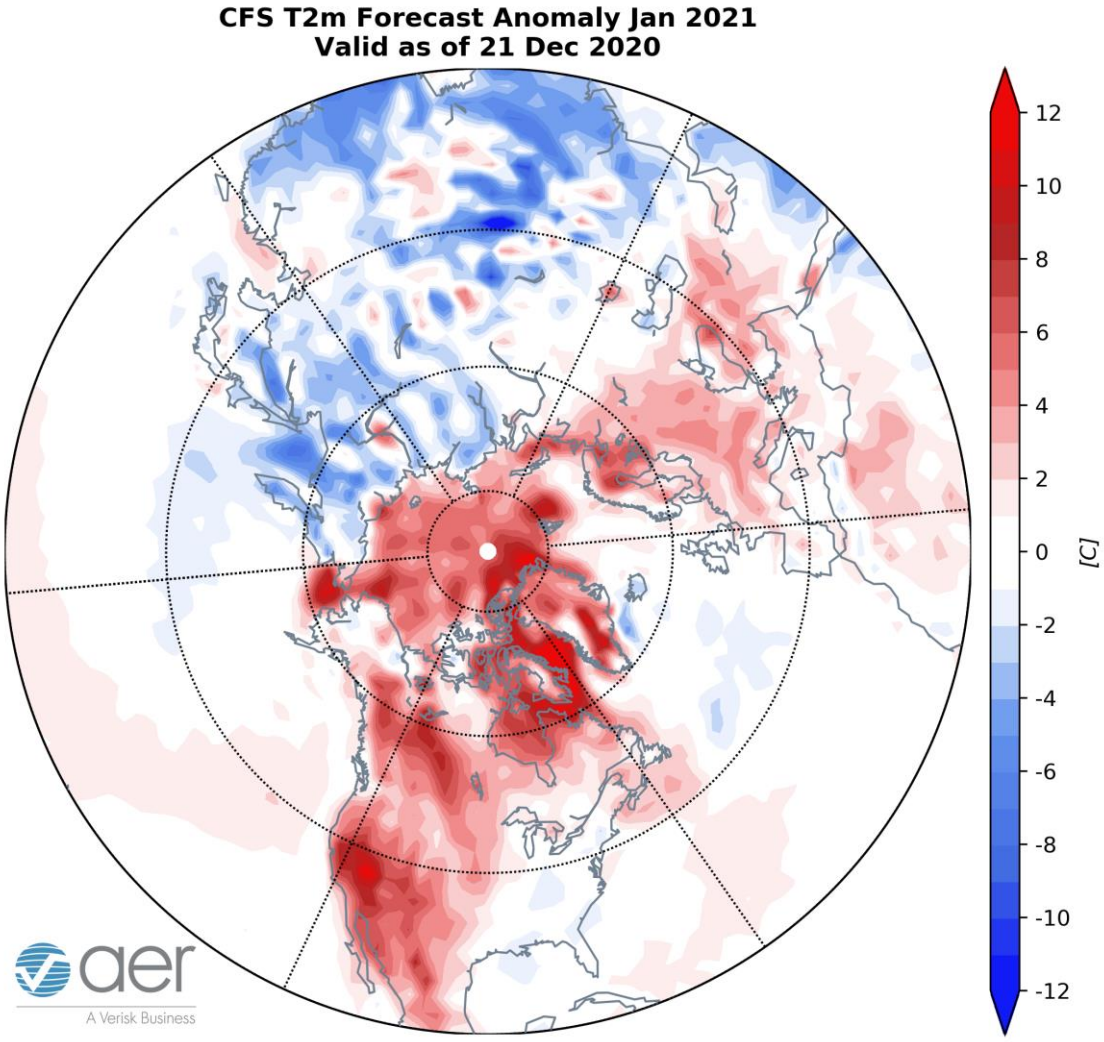

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for January 2021. The forecasts are from the 00Z 21 December 2020 CFS.

Surface Boundary Conditions

Arctic sea ice extent

Arctic sea ice continues to grow but currently remains below normal. Negative sea ice anomalies are filling in the Bering and Chukchi Seas and even in the Barents-Kara Seas (**Figure 16**). Below normal sea ice in the Barents-Kara seas favor Ural blocking and cold temperatures in Central and East Asia, however this topic remains controversial. Recent research has shown that the 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. Low sea ice in the Chukchi and Bering seas may favor colder temperatures across North America but have not been shown to weaken the PV. Sea ice should continue to grow in this region based on the forecast.

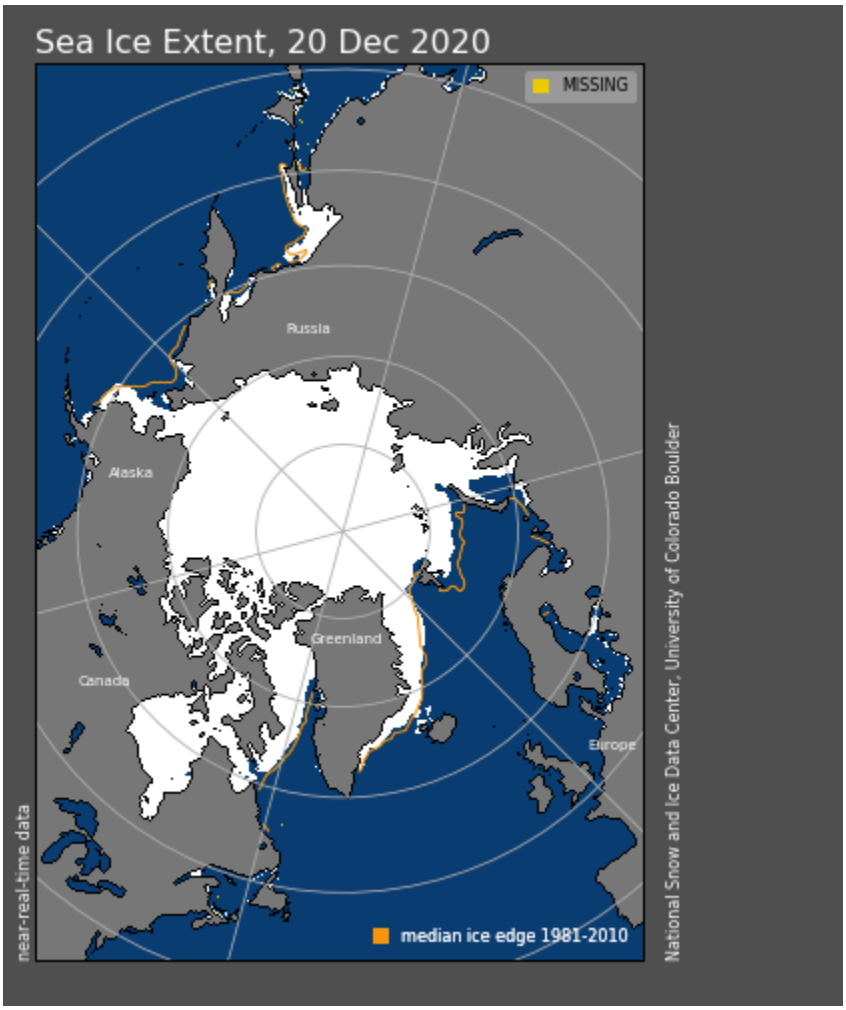

Figure 16. Observed Arctic sea ice extent on 20 December 2020 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies remain negative and we continue to observe moderate La Niña conditions (**Figure 17**) and La Niña is expected to persist through the winter and remain moderate. Observed SSTs across the NH remain well above normal especially near Alaska and in the Gulf of Alaska, the western North Pacific and offshore of eastern North America though below normal SSTs exist regionally especially in the Southern Hemisphere and south of Iceland. Warm SSTs in the Gulf of Alaska may favor mid-tropospheric ridging in the region.

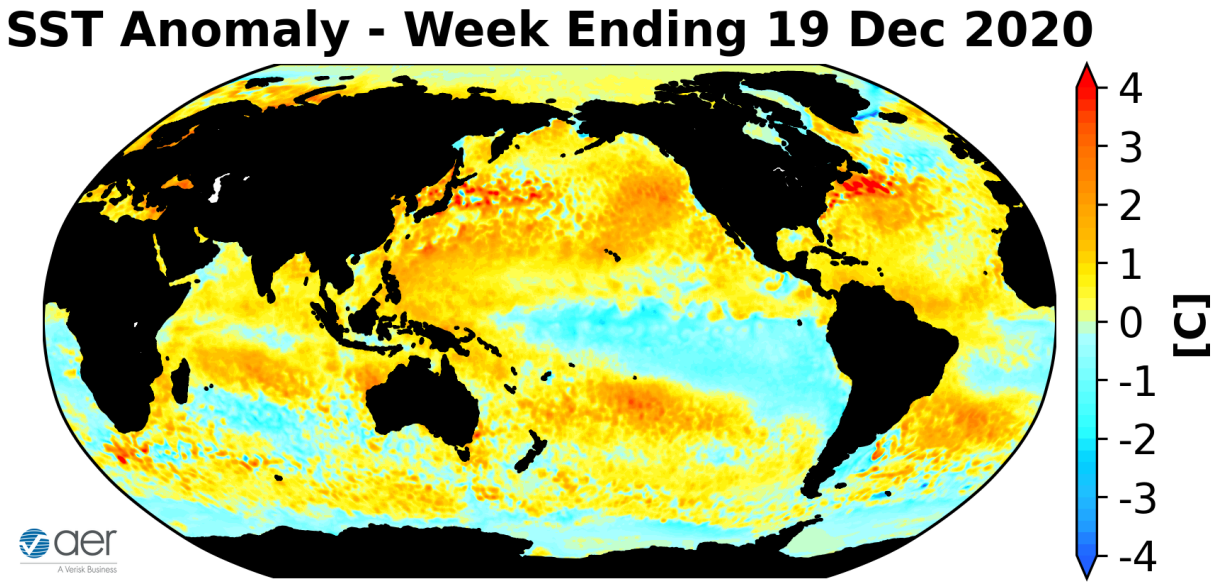

Figure 17. The latest weekly-mean global SST anomalies (ending 19 December 2020). Data from NOAA OI High-Resolution dataset.

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 18**). The forecasts are for the MJO to remain where no phase is favored for the next two weeks. Therefore, it doesn't appear to me that the MJO is contributing to the pattern across North America but admittedly this is outside of my expertise.

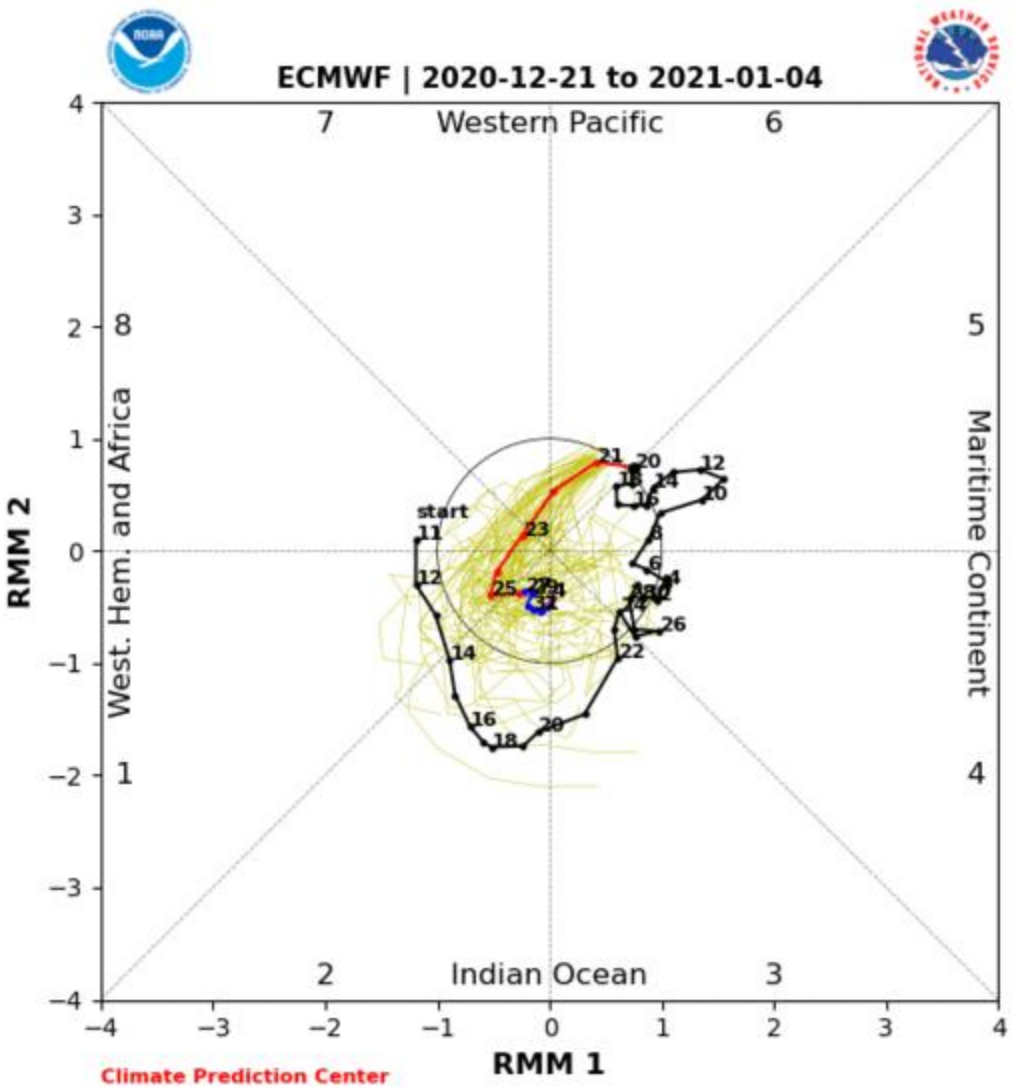

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 21 December 2020 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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 retreated over the past week across Eurasia and is now near decadal means. Snow cover advance will likely continue to increase especially across East Asia and possibly into Europe the next two weeks. 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.

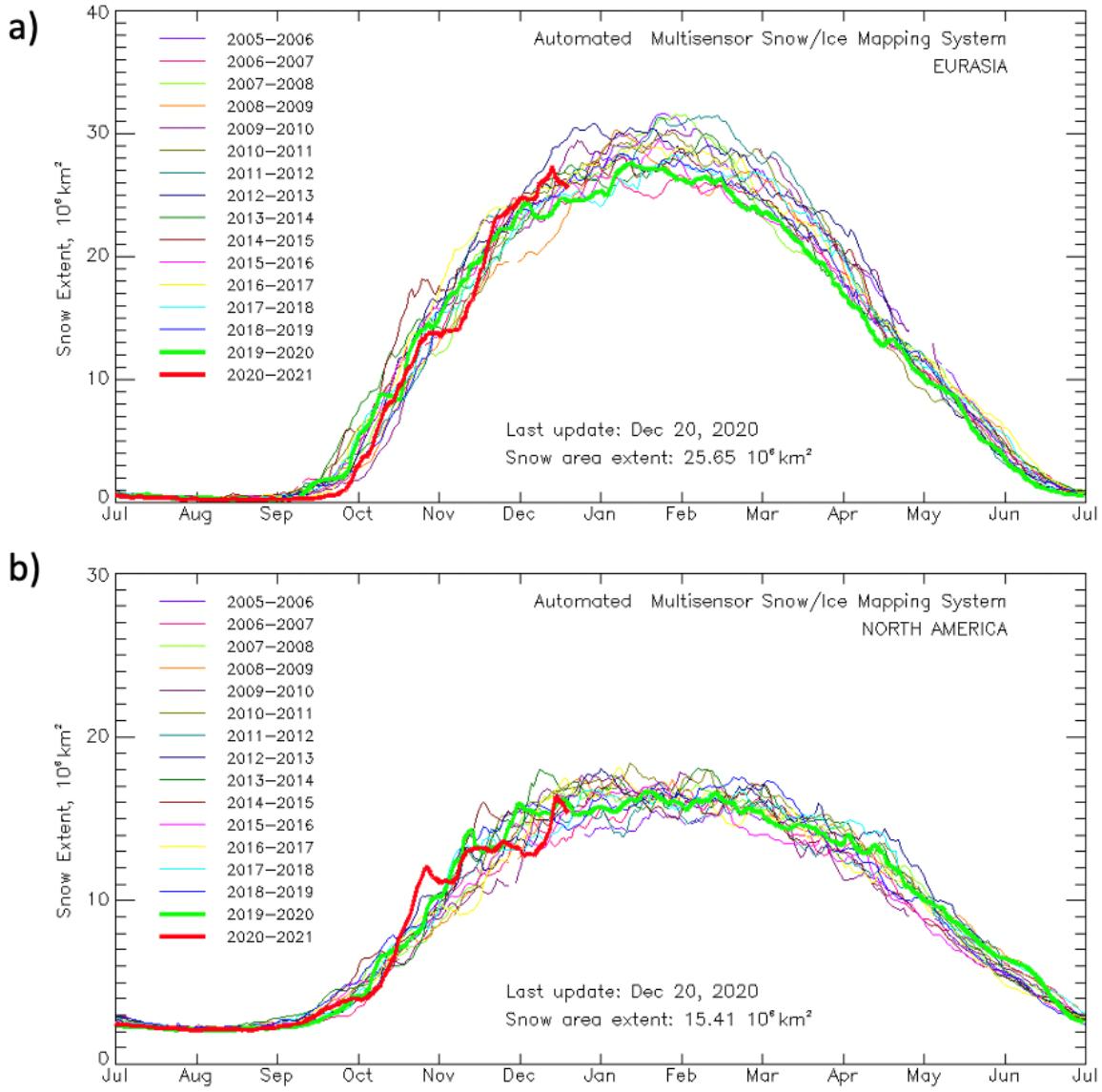

Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 20 December 2020. Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover advanced over the past week and now snow cover advance is near decadal means. The early advance of snow cover across Canada this fall, has likely contributed to an early start of cold temperatures across the Central and Eastern US but the lack of snow cover is now likely contributing to milder temperatures.