Arctic Oscillation and Polar Vortex Analysis and Forecasts

January 25, 2021

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.

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

Summary

- The Arctic Oscillation (AO) is currently negative and is predicted to remain 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 negative AO is reflective of positive pressure/geopotential height anomalies across the North Atlantic side of the Arctic and in the Central Arctic with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently negative with 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 across Greenland.
- For the next two weeks ridging/positive geopotential height anomalies near Greenland will anchor troughing/negative geopotential height anomalies across Europe. However, because the center of the high pressure remains over Baffin Bay, this will allow a less amplified flow across Europe with a strong westerly component bringing in milder, maritime air across the continent with widespread normal to above normal temperatures for much of Europe including the United Kingdom (UK). The exceptions will be Scotland and Scandinavia which will remain north of the westerly belt of winds and where low heights favor normal to below temperatures. Longer term the winds could turn more northerly allowing cold temperatures to expand.
- Over the next two weeks, persistent ridging/positive geopotential height anomalies in the Arctic, coupled with ridging near the Urals and troughing/negative geopotential height anomalies across Northern Asia in the stratosphere will help to maintain similar troughing/negative geopotential height anomalies in the mid-troposphere with ridging/positive geopotential height anomalies to the south. This pattern favors normal to below normal temperatures across Northern and Eastern Asia, including much of Siberia, with normal to above normal temperatures across Southern and Western Asia. Typically, Ural blocking is absent post a Polar Vortex (PV) disruption, however persistent Ural blocking will drive cold Siberian air into East Asia.
- Across North America, ridging/positive geopotential height anomalies across Greenland and in the Gulf of Alaska will help to maintain troughing/negative geopotential height anomalies in western North America and along the United States (US) East Coast. However, the Greenland ridging is predicted to extend south, increasingly focusing troughing across western North America. This week, normal to below normal temperatures cover much of western North America with seasonable temperatures along the US East Coast (though as I write the blog models are showing impressive cold air for the Northeast this weekend), however over the next two weeks normal to below normal temperatures will deepen and become more widespread across Alaska, Northern and Western Canada and the Western US with normal to above normal temperatures in Southeastern Canada and the Eastern US.
- In the Impacts section I discuss how this winter's polar vortex (PV) disruption is unusual and the possible influence from the ongoing and complex PV disruption on the weather across the Northern Hemisphere (NH).

Impacts

I want to continue last week's blog's theme that the current PV disruption at least in my opinion is unusual and maybe unique in the observational record. Long range prediction is challenging on the best of days and trying to anticipate the impacts of an unprecedented event or maybe as some like to say a "black swan" event (to be clear I am not suggesting there will be catastrophic consequences from the event just that it is rare and hard to have anticipated before it occurred) is many degrees more challenging.

There is consensus that in early January 2021 we observed a major mid-winter warming (MMW where the zonal winds reverse from westerly to easterly at 60°N and 10 hPa). The event was a double dip affair with the winds briefly going westerly before going even more negative about a week later. As I discussed last week, typically strong/active vertical Wave Activity Flux (WAFz and is proportional to poleward heat transport) should cease after a significant weakening of the PV, certainly an MMW. As seen in **Figure 12**, there have been two more positive pulses one centered on mid-January and now an even bigger pulse to end the month of January. It is not predicted by all models but at least by some models (and it seems to me most consistent by the ECMWF) have been predicting that this last pulse will result in yet another reversal of the winds from westerly to easterly at 60°N and 10 hPa.

This is very unusual and has resulted in observing two separate phenomena typically not seen together, almost like seeing Superman and Clark Kent or Batman and Bruce Wayne in the same room at the same time as I will try to demonstrate.

This follows a tweet from last week. I showed in last week's blog a composite of the pressure-time plot of the North Annular Mode (NAM) from Polvani and Waugh (2004) but today I show the original composite of the pressure-time plot of the NAM (the same as the AO but I prefer the AO since in the troposphere the AO is not annular) from Baldwin and Dunkerton (2001) in **Figure i**. This plot is comparable to the polar cap geopotential height anomalies (PCHs) shown in **Figure 11** every week. What the plot shows is that the negative NAM or AO propagates from the stratosphere to the surface with time and is often called the "dripping paint" plot for that very reason.

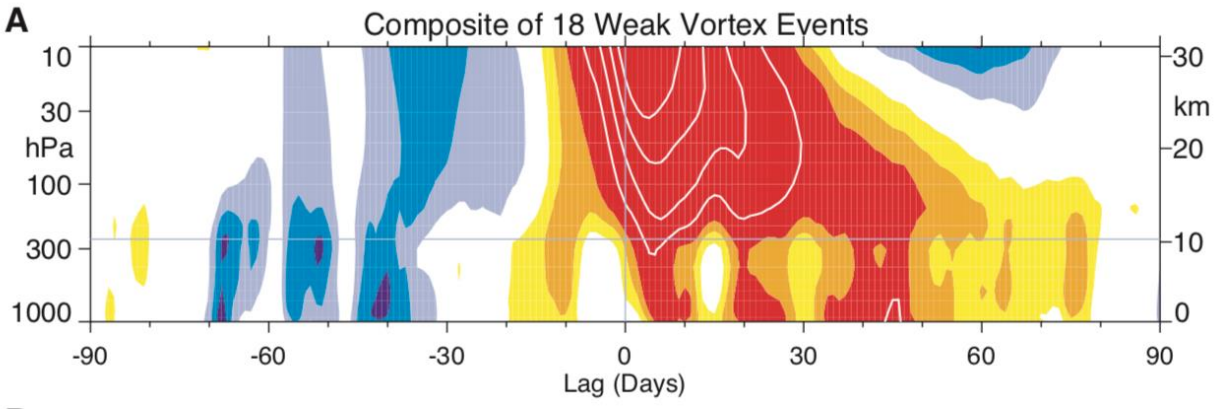

Figure i. Composites of time-height development of the northern annular mode for (**A**) 18 weak vortex events. The events are determined by the dates on which the 10-hPa annular mode values cross –3.0. The indices are nondimensional; the contour interval for the color shading is 0.25, and 0.5 for the white contours. Values between 0.25 and 0.25 are unshaded. The thin horizontal lines indicate the approximate boundary between the troposphere and the stratosphere. From Baldwin and Dunkerton (2001).

However, in **Figure ii** I show **Figure 11** with arrows clearly delineating where the PCHs (proxy for the AO/NAM) both dripping down and up or as I tweeted doing loop-de-loops or twirls in the stratosphere like the Blue Angels. Now at times it does appear as if the PCHs are propagating up but this is only during active WAFz prior to an MMW (and I include one at the end of December as an example) but not post an MMW. Having simultaneous upward and downward PCHs seems very strange and unusual to me. My explanation for the simultaneous upward and downward PCHs is we have the typically "dripping paint" phenomenon following an MMW simultaneous with active WAFz or vertical energy transfer as seen in **Figure 12**. And as I discussed last week, I could not find another example of active WAFz post an MMW dating back to 1969.

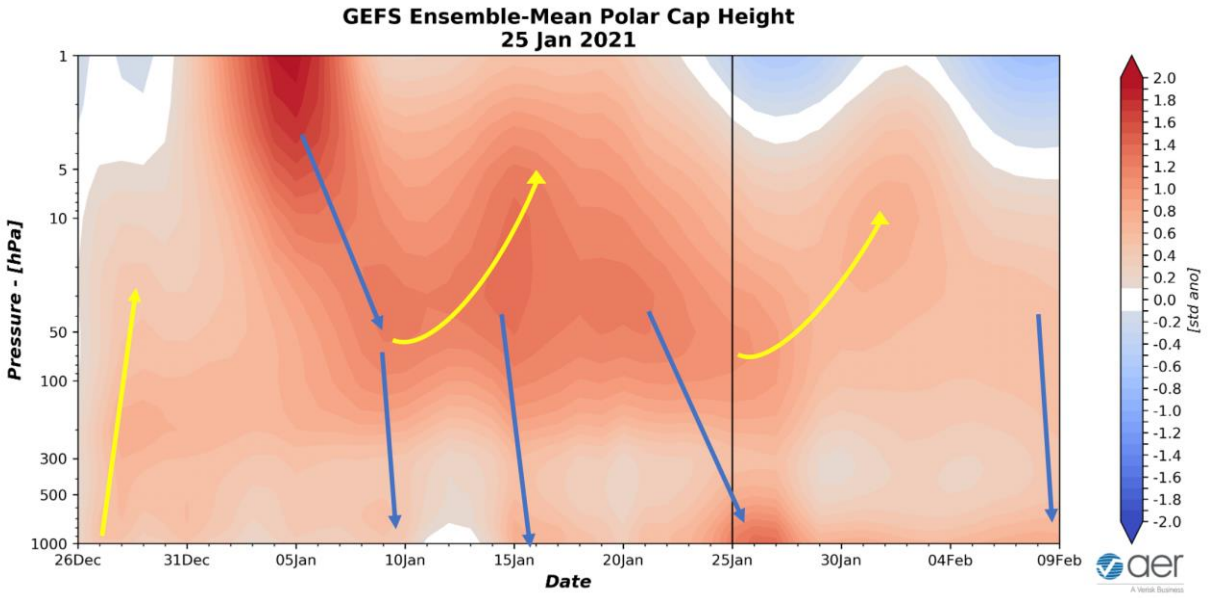

Figure ii. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 25 January 2021 GFS ensemble. Blue arrows show downward propagation of PCHs and yellow arrows show upward propagation of PCHs.

As I have discussed in previous blogs, we observe Ural blocking ahead of a PV disruption (it is the trigger for the event) and Greenland blocking after the PV disruption. I will admit that I don't fully understand the physics behind this very sequence of events: Ural blocking-PV disruption-Greenland blocking but it appears in every analysis. A cautionary tale of relying on empirical analysis without physical reasoning. In **Figure iii**, I include my analysis from Cohen and Jones (2012) but you can see the same result in Mitchell et al. (2013). Leading up the current PV disruption we observed strong Ural blocking (see for example the blog from 07 December 2020. But now post the PV disruption we observe Greenland blocking but oddly enough the Ural blocking is still there (see **Figure 3**), it is like the dinner guest that overstayed its welcome or like having Superman and Clark Kent in the same room at the same time, it's not supposed to happen. As an aside it is a great question what has led to the persistence of the Ural blocking this winter season? I have argued that below normal Barents Kara sea ice and above normal Siberian snow cover favor Ural blocking (see see http://rdcu.be/fJte but especially Box B2) both of which have been present in an impressive manner since the fall (see below **Figure 16** and current observed snow depth). But as much as I like to be provocative, even I won't venture to make a linkage based on one data point especially when including last winter. Excuse the bad pun but talk about polar opposites is comparing last winter when Ural blocking was nowhere to be found to this winter when Ural blocking just can't quit. So a good question without a good answer for now.

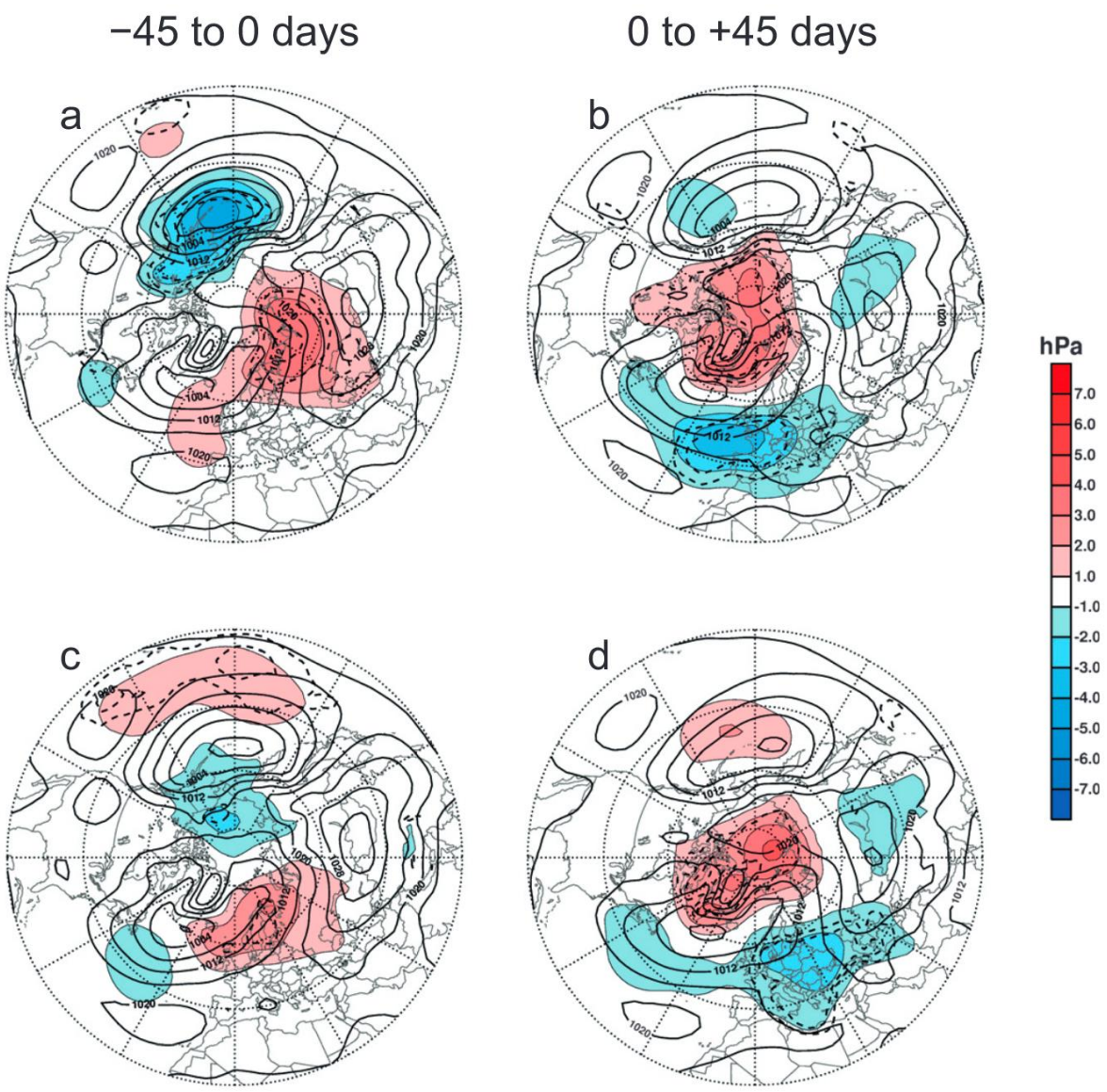

Figure iii. Sea level pressure (SLP) anomalies (hPa) (a) averaged 45 to 0 days prior to vortex displacements, (b)averaged 0 to 45 days after vortex displacements, (c) averaged 45 to 0 days prior to vortex splits, and (d) averaged 0 to 45 days after vortex splits. Colored shading represents anomalies, solid contours show the full values of the SLP field, and dashed contours represent 90% and 95% confidence levels. Mean values are computed daily over the reanalysis period 1948–2010. From Cohen and Jones (2012).

The PV split of January 2009 may just be the most impressive PV disruption that I can recall. The PV was completely obliterated. At the time, it set the record for strongest easterly winds ever observed at 60°N and 10 hPa and the winds remained easterly for a full month! In **Figure iv** I present an animation of the PV disruption. I want you to notice

that once the warm air rushes the Arctic with the commencement of the MMW, it does not happen again.

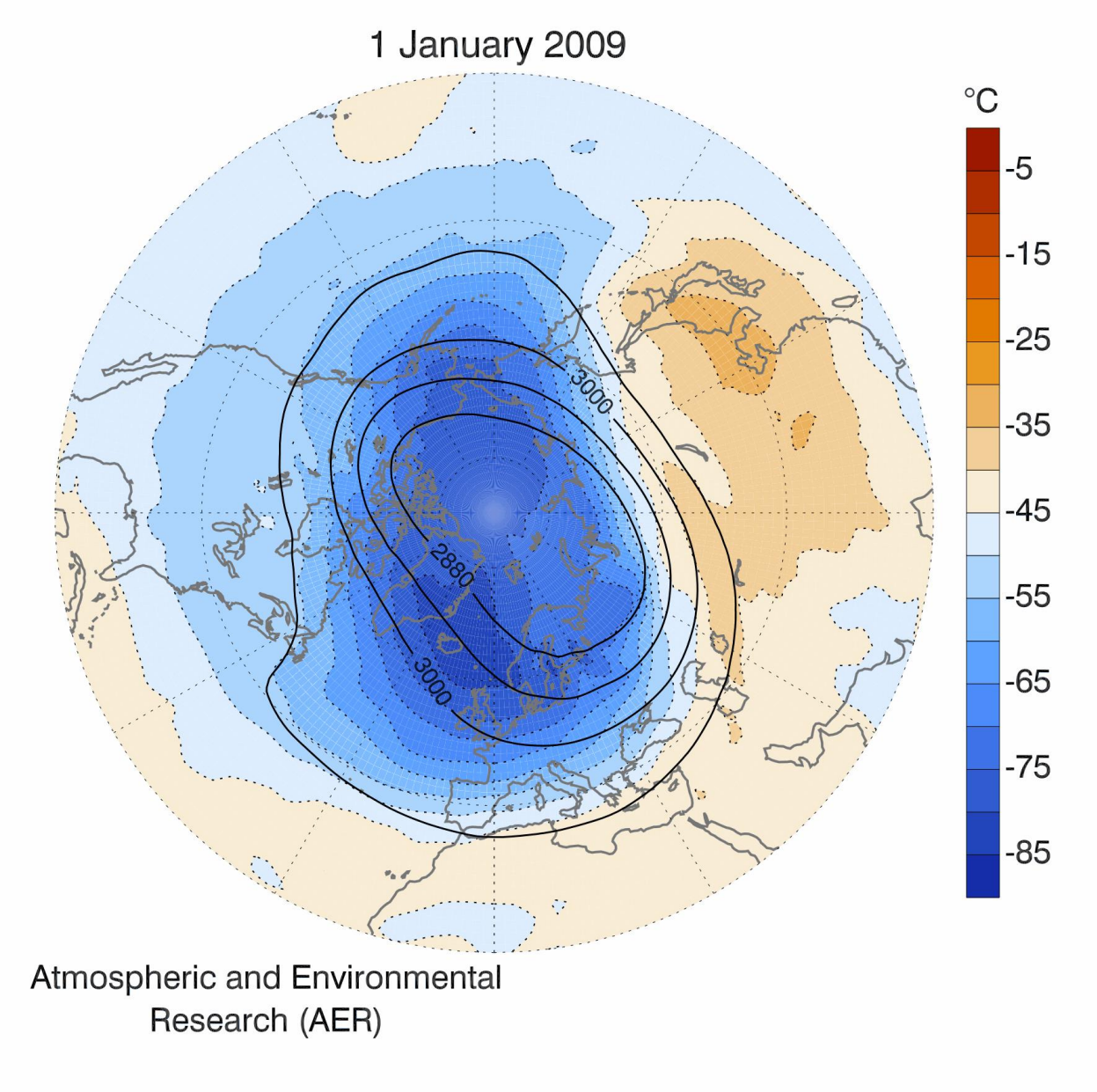

Figure iv. Observed 10 hPa geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 1 January - 28 February 2009. This is an older animation so please excuse the different shading.

The central date or the day the winds first turned easterly/negative at 60°N and 10 hPa is January 24, 2009. In **Figure v,** I include the WAFz from the entire winter of 2008/09. This incredibly intense and long-lasting PV disruption was triggered by one WAFz pulse at the end of January. Once the MMW commences, the spigot is shut off.

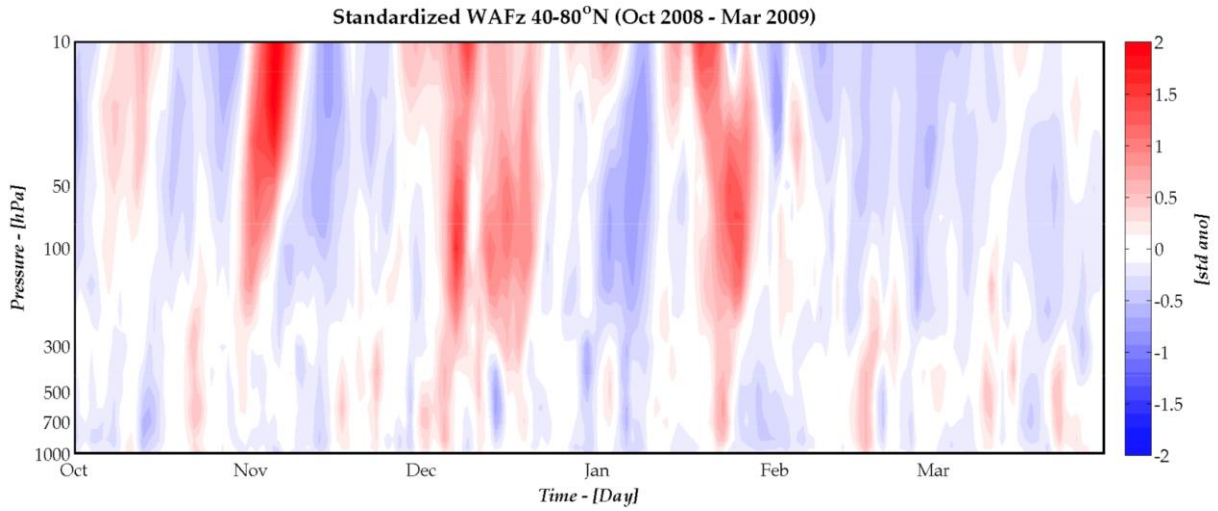

Figure v. Observed daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N from 1 October 2008 - 31 March 2009.

Now look at **Figure 12** below there are two more WAFz pulses after the MMW commences. I include a longer polar vortex animation of beginning on December 1, 2020 in **Figure vi**. The multiple WAFz pulses even post the MMW are creating a unique situation in the polar stratosphere this winter with polar stratospheric warmings on January 5th, January 15th and again February 2nd. I don't consider this "business as usual." I would argue that the sudden stratospheric warmings of January 5th and possibly February 2nd should be to some degree two separate dynamic events and not simply one protracted event. And as I will now explain considering them as two events helps us better understand the current weather and possibly better predict future weather, which cannot be done lumping everything as just one MMW with a central date of January 5th.

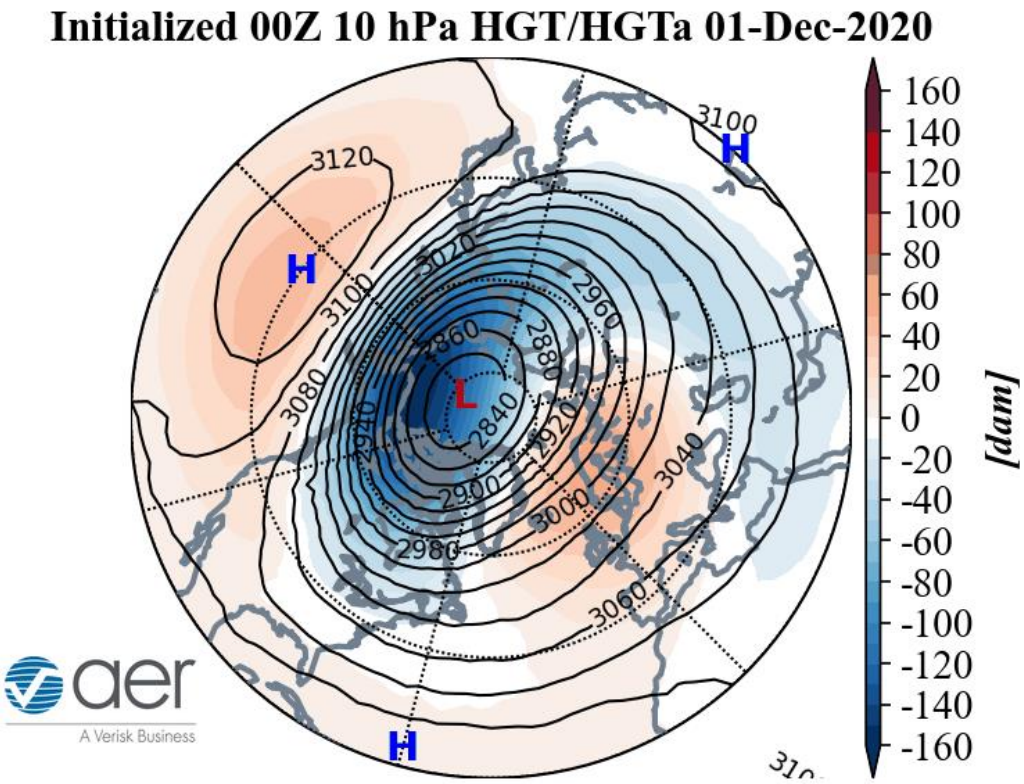

Figure vi. Observed 10 hPa geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 1 December 2020- 25 January 2021 and forecasted from 26 January – 9 February 2021.

I am sure at this point you are yelling at your computer screen "enough with the childlike wonderment and the academics" – let's get down to tachlis (don't get the wrong impression, I don't speak a lick of Yiddish) how does this impact me? As I tried to argue in last week's blog, we have a hybrid or amalgam of pre- and post- PV disruption weather all happening simultaneously. We have observed/forecasts consistent with pre-PV disruption weather characterized by Ural blocking forcing cold and snow in East Asia, also cold and snow in Western North America but mild in Europe and the Eastern US. But we have observed/forecasts consistent with a post-PV disruption (and more what might be expected following a PV split and not a PV displacement though both have occurred) with Greenland blocking, cold and snow for Europe (including the UK this week) and milder in East Asia. The one region that has cold and snow both before and after a PV disruption – Siberia has an exceptional cold streak so far this winter (see Philadelphia Inquirer). Also, in the era of climate change to see cold and snow in just one of the three target regions – East Asia, Europe, Eastern US associated with PV

disruptions is difficult enough, to see all three within a short time period is impressive in my opinion and again suggestive of an unusual weather pattern across the NH.

We don't expect or not trained to expect Superman and Clark Kent or Batman and Bruce Wayne in the same room at the same time but I think there are real world advantages to being open to the idea. I think we will continue to see this unusual mix or hybrid of pre- and post-PV disruption weather or Superman and Clark Kent or Batman and Bruce Wayne present together. It does seem from **Figure 12** that the heat flux may finally wane by early February, and the weather may finally follow a more common script following a PV disruption with more consistent cold in Europe and/or the Eastern US. I still maintain that the GFS forecast (and this is not consistent across models, so confidence is low) with the PV centered over Svalbard, high pressure over Alaska and northerly, cross polar flow from Asia into Canada suggests cold temperatures for North America. And as I argued in last week's blog, I do believe that over time the cold should make its way into eastern North America even with the major or single PV center over Eurasia. Also the latest CFS forecast for February (**Figure 14**) is consistent with my thinking but with the caveat the CFS has a checkered track record.

On Twitter and in last week's blog I highlighted amplified warm/positive PCHs for this week (see **Figure ii** with downward arrow ending January 26th) arguing that it raises the risk of severe winter weather across the mid-latitudes this week and into next despite absence of such expectations in the models. In **Figure ii**, I include another downward arrow for the second week of February. It does not look as impressive as this week's lower tropospheric spike in PCHs, but something to watch.

1-5 day

The AO is currently negative **(Figure 1**) with positive pressure/geopotential height anomalies across the North Atlantic side of the Arctic centered over Baffin Bay and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with predicted positive geopotential height anomalies across Greenland (**Figure 2**), the NAO is predicted to also be negative this week.

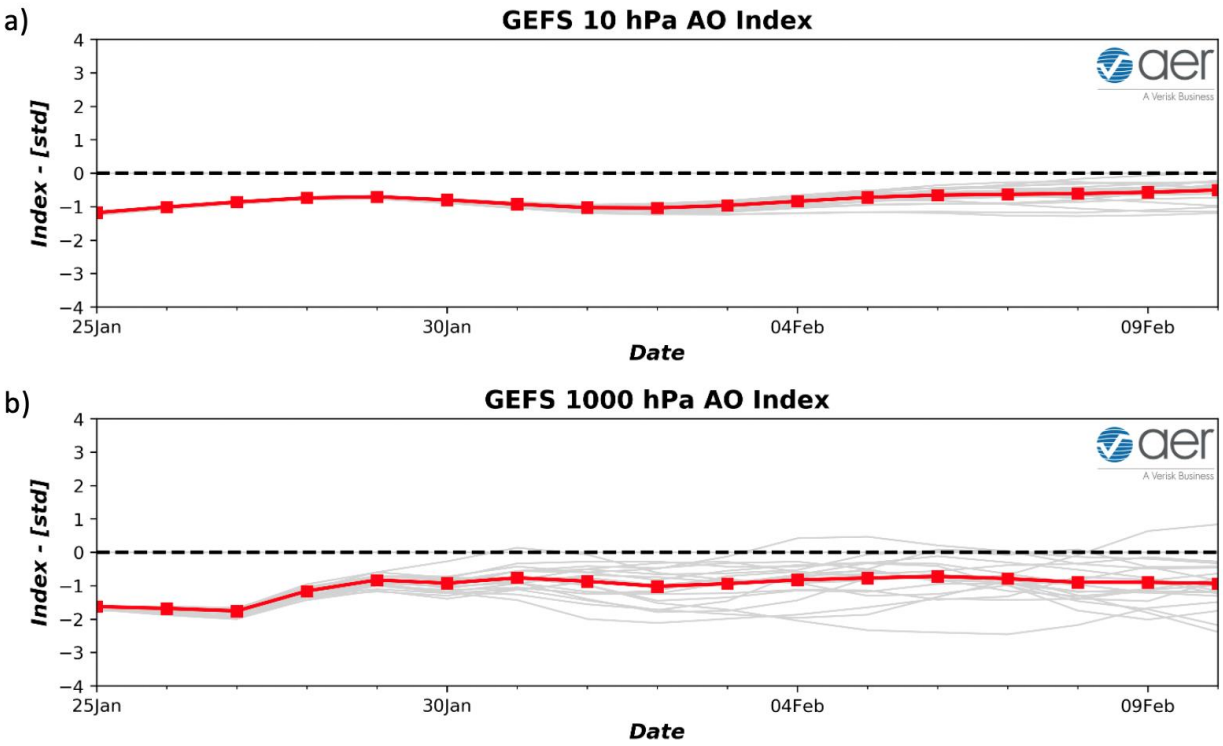

Figure 1. (**a**) The predicted daily-mean AO at 10 hPa from the 00Z 25 January 2021 GFS ensemble. (**b**)The predicted daily-mean near-surface AO from the 00Z 25 January 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies centered over Greenland are predicted to force downstream troughing/negative geopotential height anomalies across Europe (**Figure 2**). However, with Greenland high pressure/blocking centered in Baffin Bay will allow an increasing westerly component to the winds across Europe introducing milder, maritime air. This pattern favors normal to below normal temperatures across Northern Europe including the northern UK as heights remain low but across the remainder of Europe including the southern UK, a mild westerly flow will favor normal to above normal temperatures (**Figure 3**). This week, troughing/negative geopotential height anomalies across much of Northern Asia in the stratosphere coupled with ridging/positive geopotential height anomalies centered over the Urals will help to anchor troughing/negative geopotential height anomalies across much of Siberia and East Asia in the mid-troposphere with ridging/positive geopotential height anomalies across Western Asia (**Figure 2**). This pattern favors normal to below normal temperatures **for** Northern and Eastern Asia with normal to above normal temperatures for Western and Southern Asia **(Figure 3**).

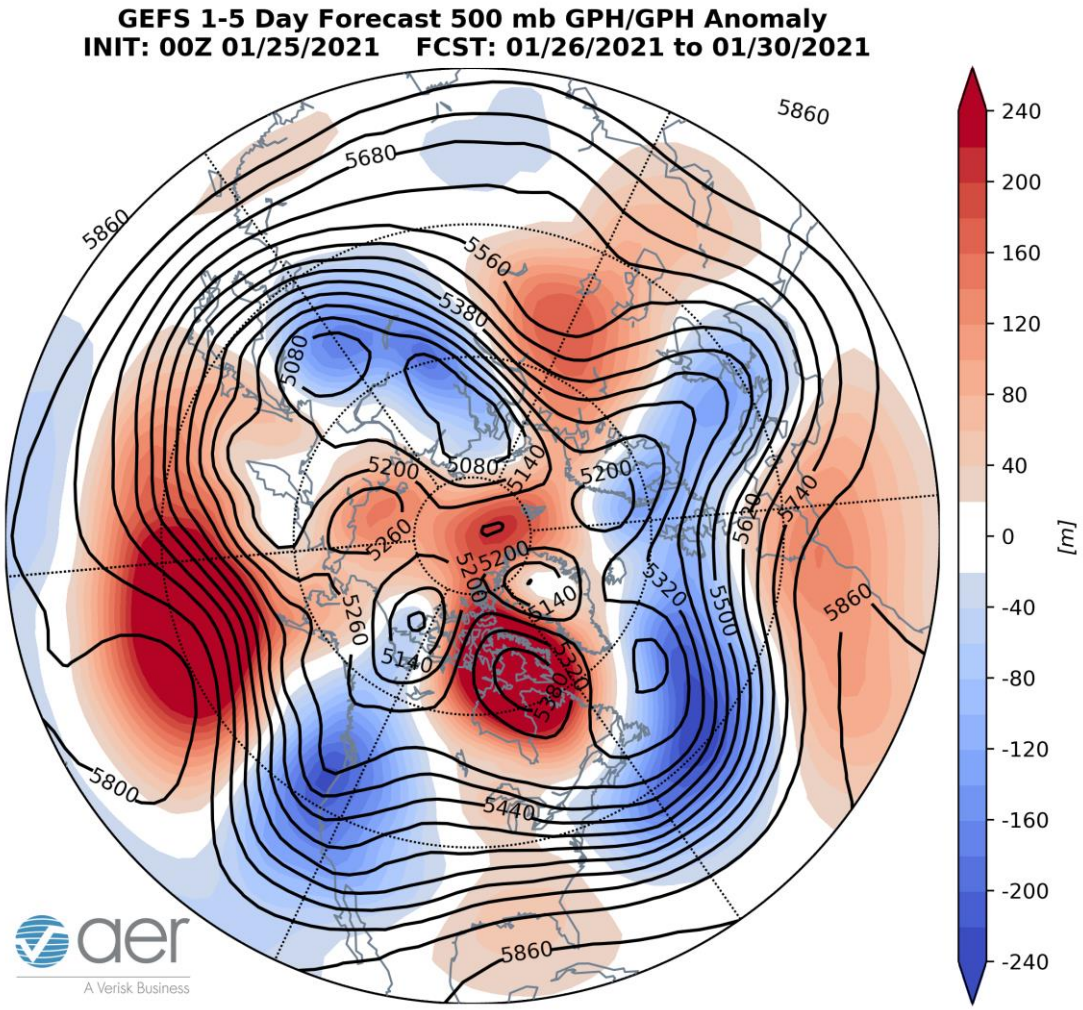

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 26 – 30 January 2021. The forecasts are from the 00z 25 January 2021 GFS ensemble.

This week ridging/positive geopotential height anomalies across Baffin Bay and the Gulf of Alaska will force troughing/negative geopotential height anomalies across most of Western Canada, the Western US and the Northeastern US with more ridging/positive geopotential height anomalies in the Southeastern US **(Figure 2).** This pattern is predicted to bring widespread normal to above normal temperatures across Northern and Eastern Canada and the Southeastern US with normal to below normal temperatures across Alaska, Southern and Western Canada, the Western and Northeastern US **(Figure 3).**

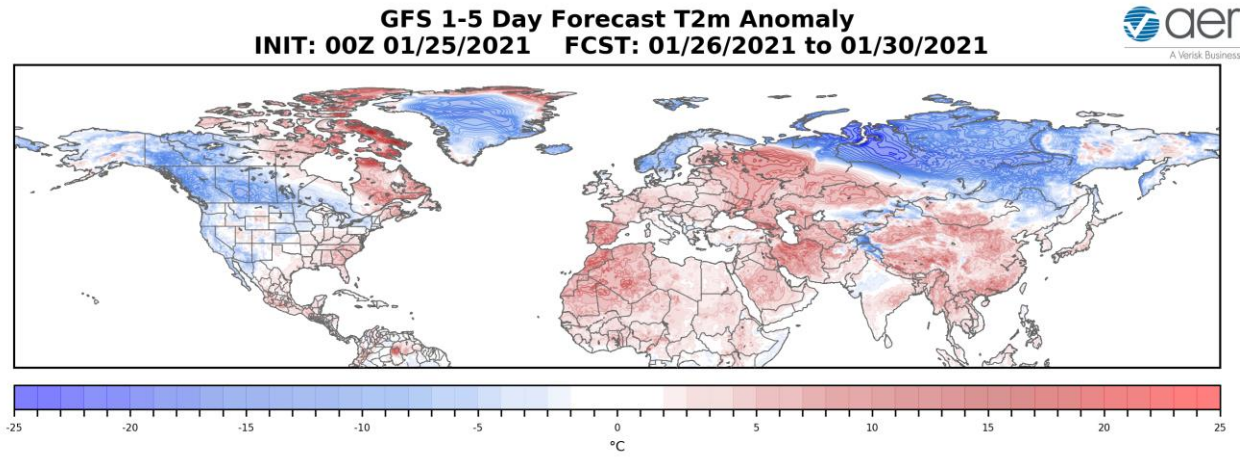

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 26 – 30January 2021. The forecast is from the 00Z 25 January 2021 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across Scandinavia, Eastern Europe, Turkey, Central and Northwestern Central and East Asia while warmer temperatures will cause snow melt in the UK, Central Europe, Southwestern Asia (**Figure 4**). Troughing and/or colder temperatures are predicted to support new snowfall across southwestern Alaska, Northern and Central Canada, the Great Lakes and into the Northeastern US while warmer temperatures will cause snow melt in parts of Western Canada and the Western US (**Figure 4**).

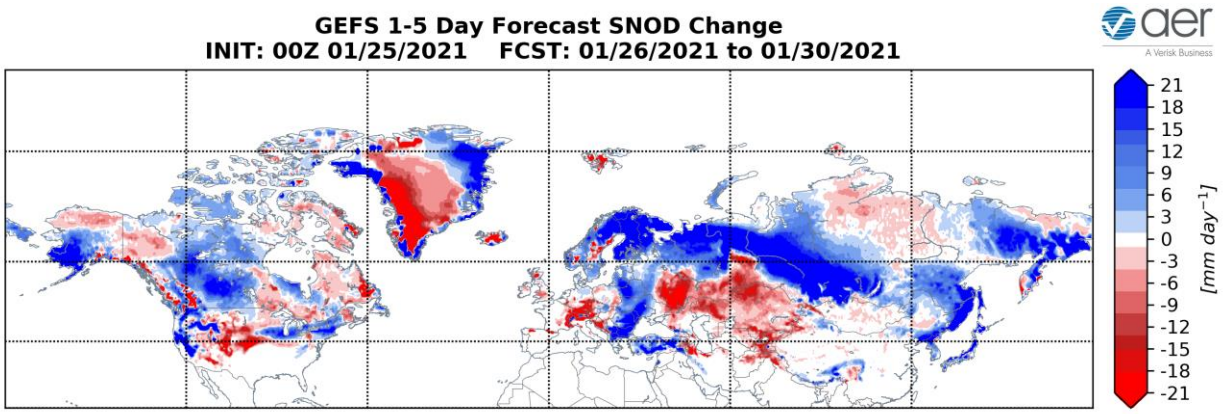

Figure 4. Forecasted snow depth changes (mm/day; shading) from 26 – 30 January 2021. The forecast is from the 00Z 25 January 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain negative next week **(Figure 1**) as positive geopotential height anomalies persist across the North Atlantic side of the Arctic and strengthen in the Central 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 negative to neutral.

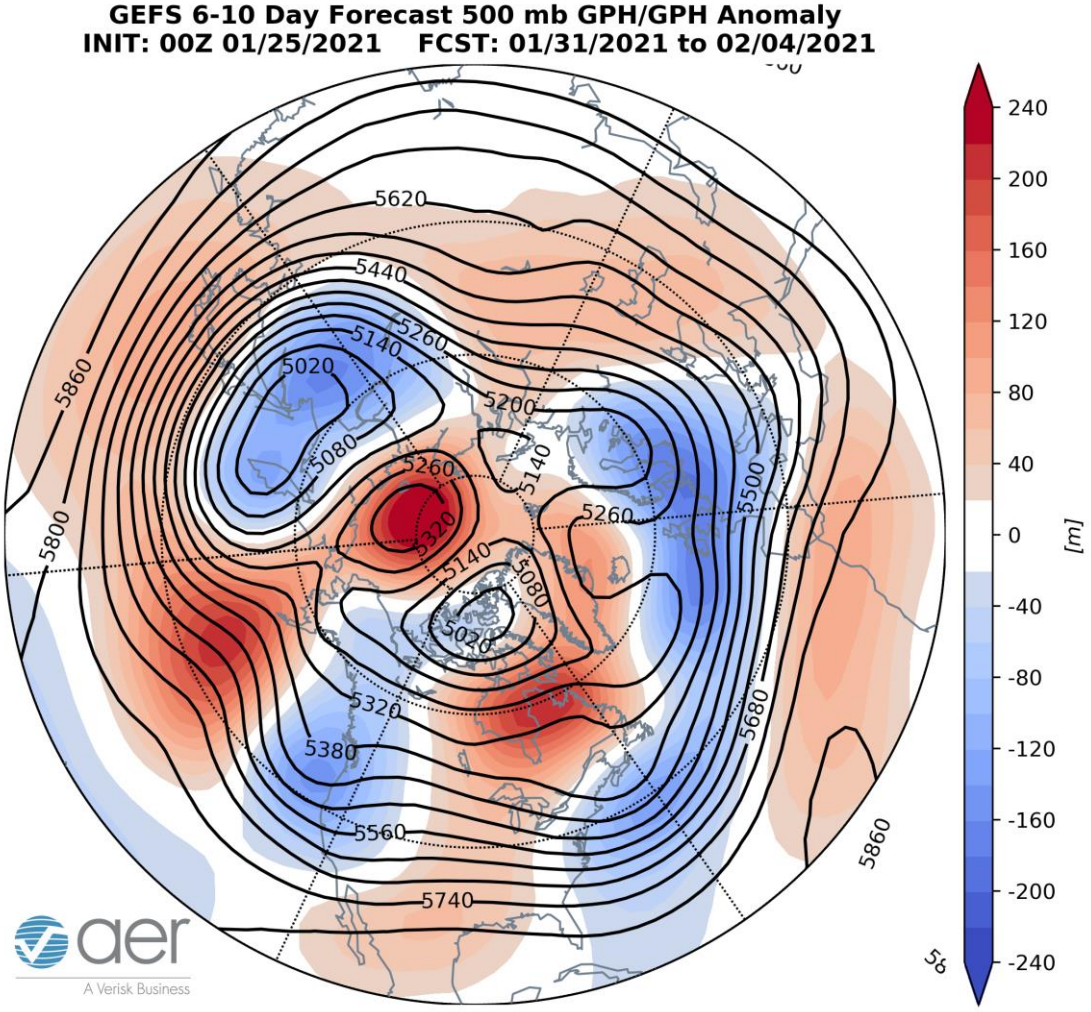

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 31 January – 4 February 2021. The forecasts are from the 00z 25 January 2021 GFS ensemble.

With ridging/positive geopotential height anomalies previously centered across Greenland are predicted to be mostly across Northeastern Canada, troughing/negative geopotential height anomalies will dominate Europe however the flow will remain mostly from the west this period (**Figures 5).** A predominantly maritime flow of air across Europe favors normal to above normal temperatures across most of Europe

including the UK with normal to below normal temperatures limited to Scotland and Scandinavia that are north of the westerly flow and where heights are low (**Figure 6**). Persistent ridging/positive geopotential height anomalies across the Urals will anchor troughing/negative geopotential height anomalies in the mid-troposphere across Siberia and East Asia with ridging/positive geopotential height anomalies across Western Asia this period (**Figure 5**). This is predicted to favor widespread normal to below normal temperatures across much of Siberia and East Asia with normal to above normal temperatures in Western and Southern Asia **(Figure 6**).

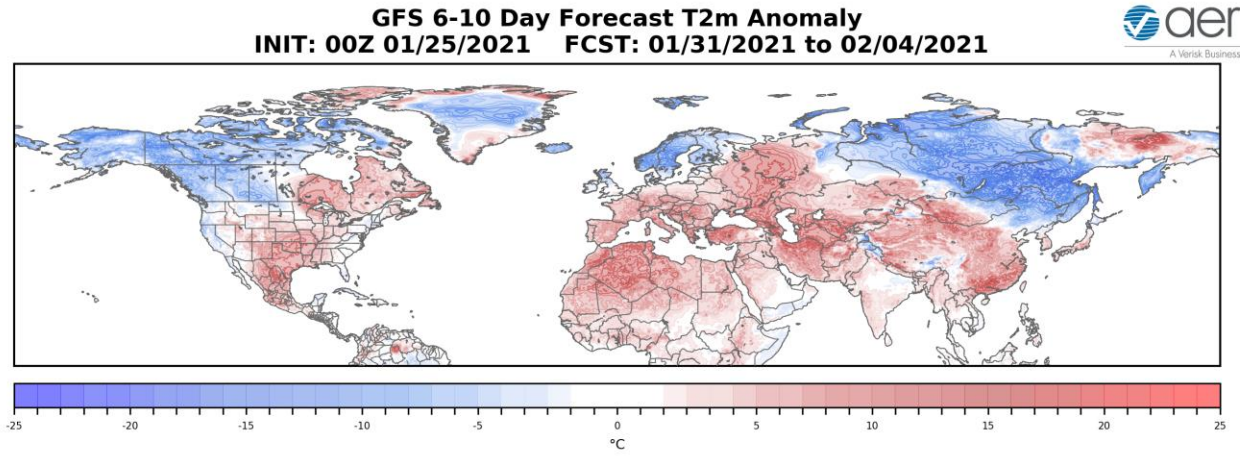

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 31 January – 4 February 2021. The forecasts are from the 00Z 25 January 2021 GFS ensemble.

Ridging/positive geopotential height anomalies south of the Aleutians will force troughing/negative geopotential height anomalies across western North America with more ridging/positive geopotential height anomalies across central North America while ridging/positive geopotential height anomalies across Hudson Bay will persist troughing/negative geopotential height anomalies along the US East Coast this period **(Figure 5).** This pattern is predicted to bring normal to below normal temperatures across Alaska, Western Canada, the Western US and the US East Coast with normal to above normal temperatures across the Central US and Eastern Canada **(Figure 6).**

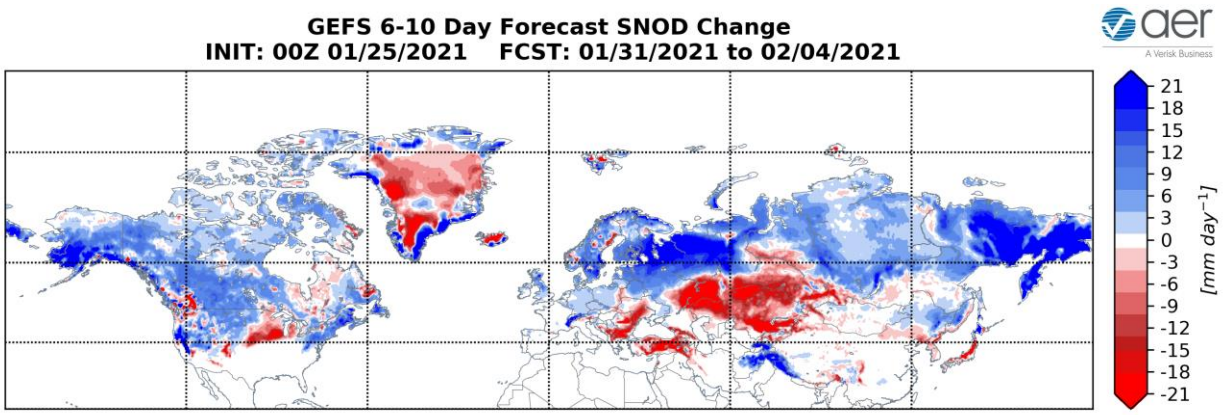

Figure 7. Forecasted snow depth changes (mm/day; shading) from 31 January – 4 February 2021. The forecasts are from the 00Z 25 January 2021 GFS ensemble.

Troughing and/or colder temperatures are predicted to potentially support new snowfall across parts of the UK, the Alps, Scandinavia, the Baltics, , Northern and Eastern Asia while warmer temperatures will cause regionalized snow melt in Southeastern Europe, Southwestern Asia, Korea and Japan (**Figure 7**). Troughing and/or colder temperatures are predicted to support new snowfall across much of Alaska, Canada and the Northern, Western and even Northeastern US while warmer temperatures will cause possible snow melt in the US Central Plains (**Figure 7**).

11-15 day

As geopotential height anomalies are predicted to remain positive on the North Atlantic side of the Arctic and in the Central 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 neutral to negative this period as well.

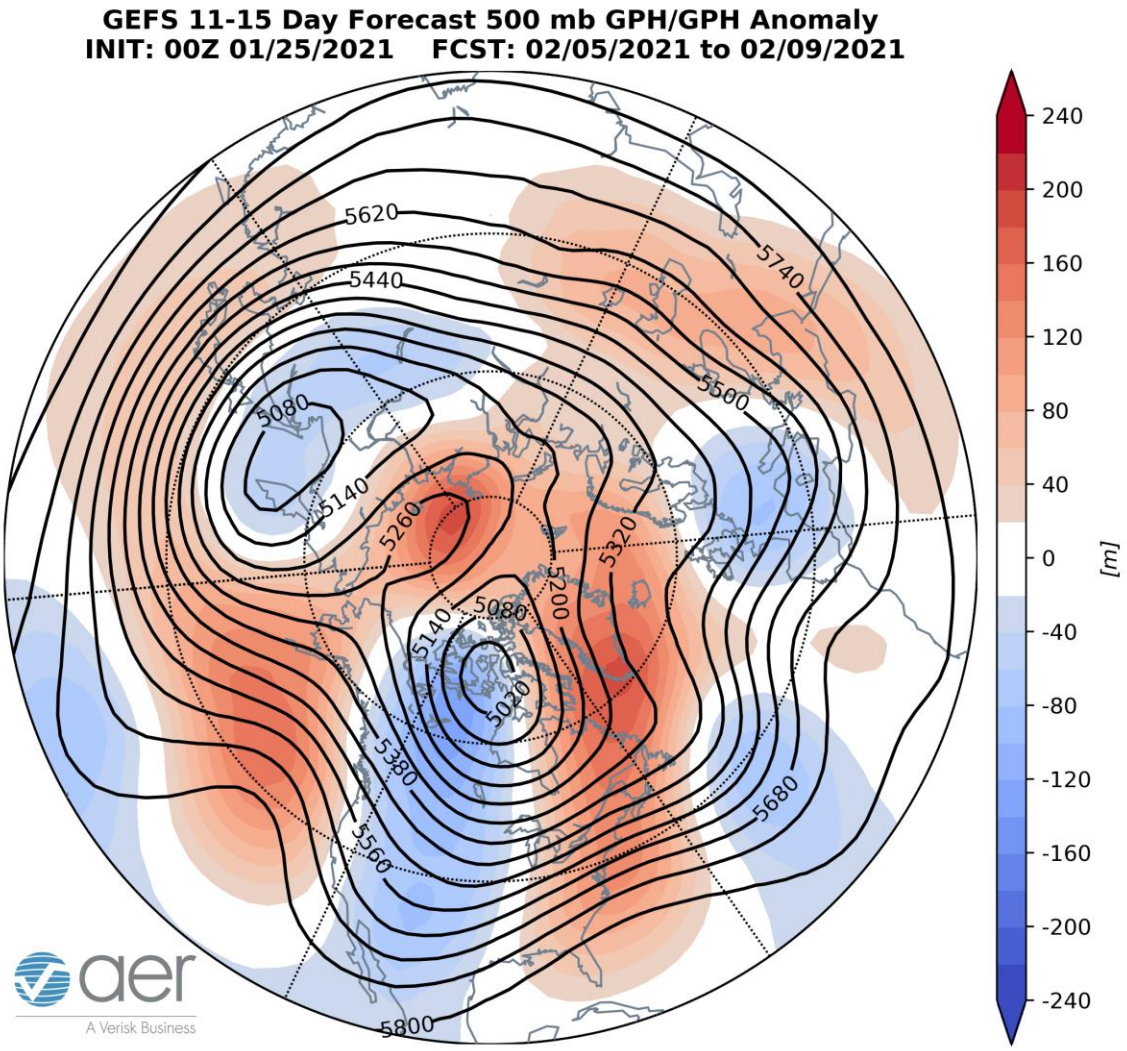

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 5 – 9 February 2021. The forecasts are from the 00z 25 January 2021 GFS ensemble.

With the center of ridging/positive geopotential height anomalies over Baffin Bay predicted to move back over Greenland, this will anchor troughing/negative geopotential height anomalies across Europe but also introduce a more northerly component across Europe this period (**Figures 8**). The forecast remains for widespread normal to above normal temperatures across Europe, however, normal to below normal temperatures across Scandinavia, and Scotland could begin to expand further south this period (**Figures 9**). Ridging/positive geopotential height anomalies troughing/negative geopotential height anomalies across the Arctic and over the Urals will help persist troughing/negative geopotential height anomalies across Siberia and East Asia with ridging/positive geopotential height anomalies across Western Asia this period (**Figure 8**). This pattern favors normal to below normal temperatures across Siberia and Eastern

Asia with normal to above normal temperatures across Western and Southern Asia (**Figure 9**).

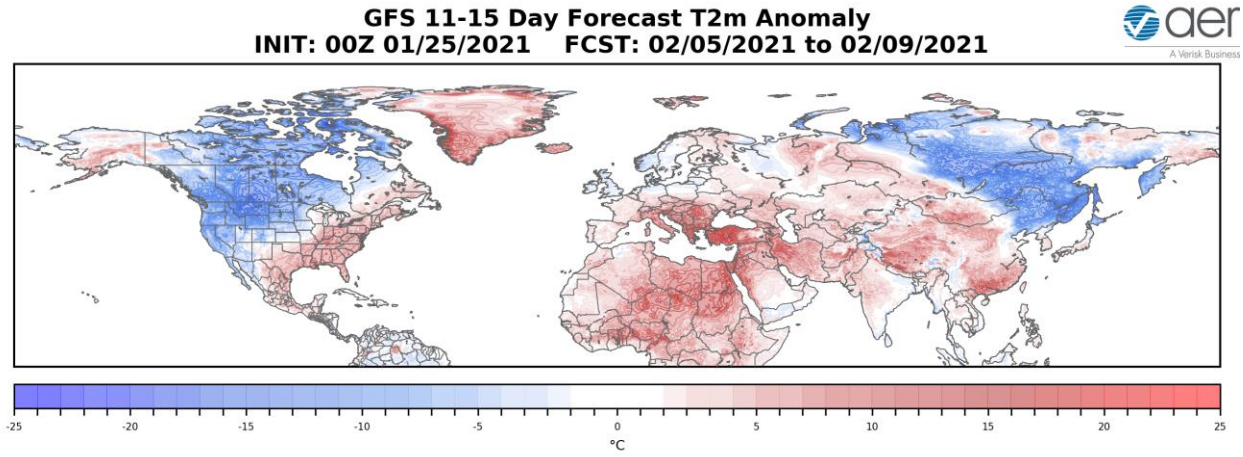

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 5 – 9 February 2021. The forecasts are from the 00z 25 January 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies south of the Aleutians will contribute to deepening troughing/negative geopotential height anomalies across western North America with more ridging/positive geopotential height anomalies across eastern North America this period (**Figure 8**). This pattern favors widespread normal to below normal temperatures for Western and Northern Canada, the Western and Northcentral US with normal to above normal temperatures for Southeastern Canada and the Southern and Eastern US (**Figure 9**).

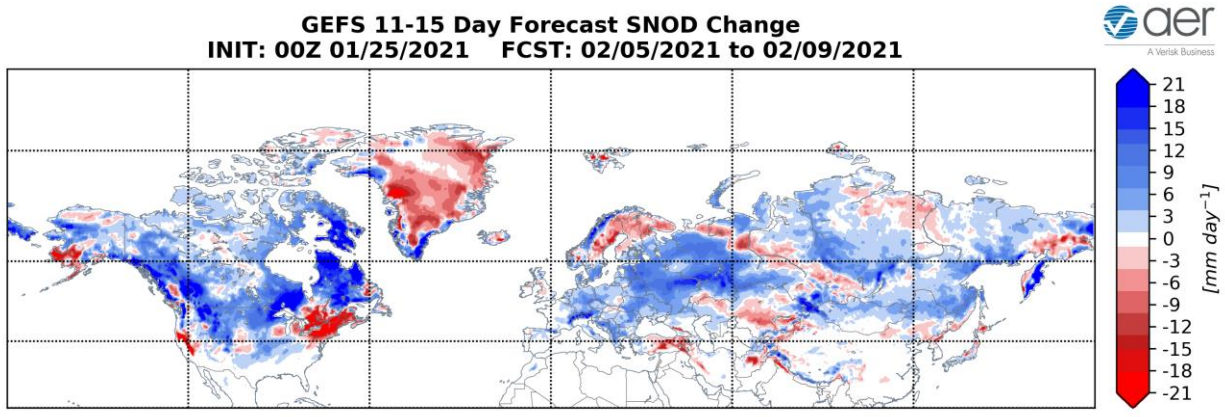

Figure 10. Forecasted snow depth changes (mm/day; shading) from 5 – 9 February 2021. The forecasts are from the 00z 25 January 2021 GFS ensemble.

Troughing and/or colder temperatures are predicted to support new snowfall across the Pyrenees, the Alps, Central and Eastern Europe, Northern and Central Asia while warmer temperatures will cause snowmelt in Turkey and Finland (**Figure 10**). Troughing and/or colder temperatures are predicted to support new snowfall across Alaska, much of Canada and the Northwestern and Central US and while warmer temperatures will result in snowmelt in California, Southeastern Canada and Northeastern US (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows warm/positive normal PCHs throughout the troposphere and mid to low stratosphere for the next two weeks (**Figure 11**). In contrast the upper stratosphere is predicted to be cold/negative for much of the next two weeks as the PV tries to recover from previous and ongoing PV disruptions.

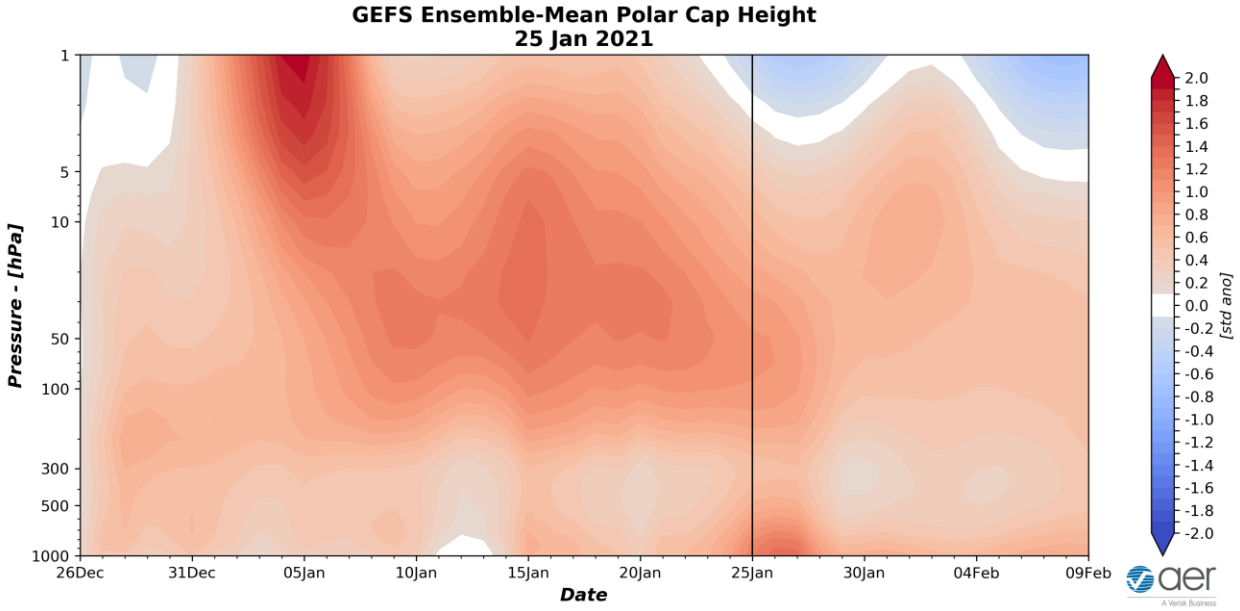

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 25 January 2021 GFS ensemble.

Normal to warm/positive PCHs in the lower troposphere are consistent with the predicted negative surface AO the next two weeks (**Figure 1**). Warm/positive PCHs in the mid-stratosphere are consistent with the negative stratospheric AO (at 10 hPa) the next two weeks (**Figure 1**).

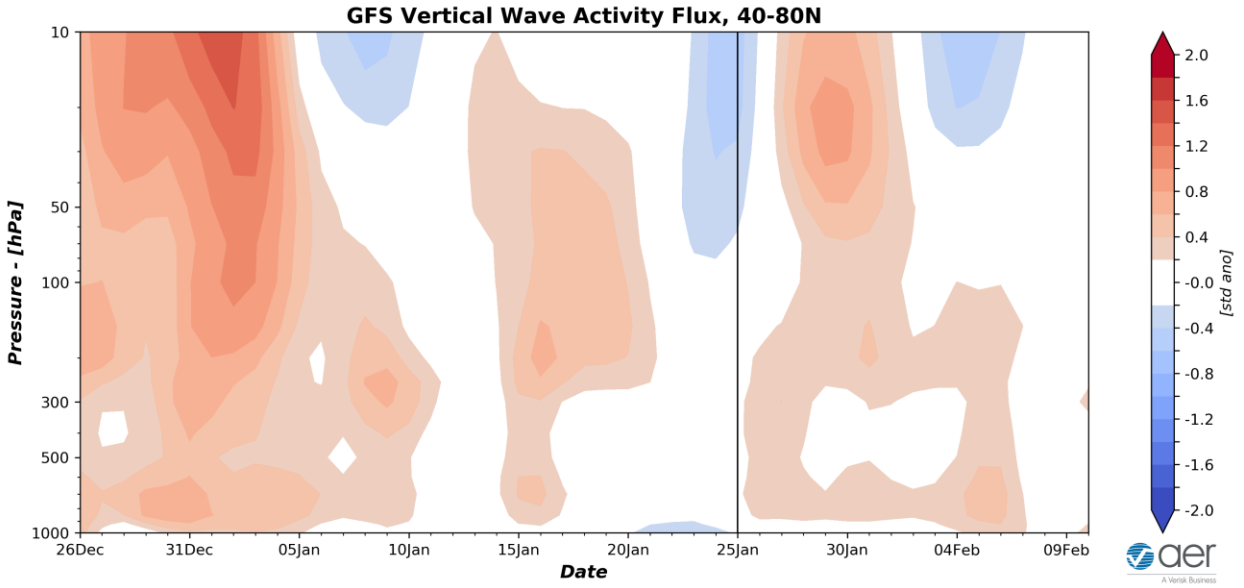

Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 25 January 2021 GFS ensemble.

The plot of the Wave Activity Flux (WAFz and is proportional to poleward heat transport) forecast is showing currently near normal WAFz in the troposphere but below normal WAFz in the stratosphere (**Figure 12**). Though a major mid-winter warming (MMW where the zonal winds reverse from westerly to easterly at 60°N and 10 hPa) has already occurred a new pulse of WAFz is predicted for this week. This new pulse is predicted to further perturb the PV (possibly causing a second MMW though if winds turn negative at 60°N and 10 hPa the stratospheric community will consider it one event, which I disagree with as discussed in the Impacts section) and delay its recovery.

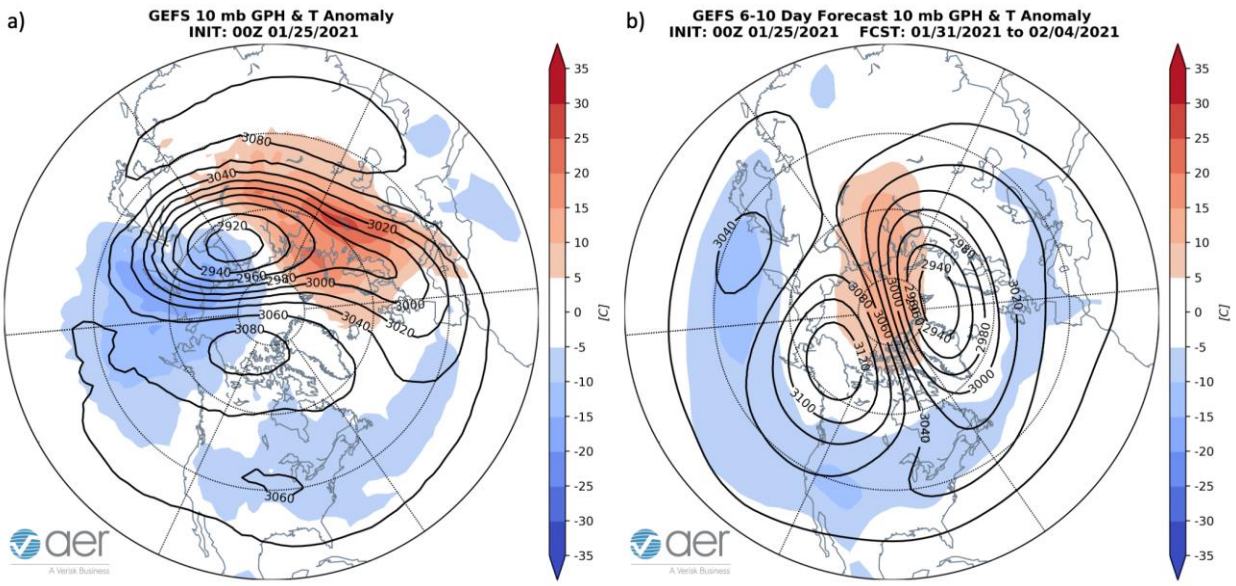

Figure 13. (**a**) Observed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 25 January 2021. (**b**) Same as (a) except forecasted averaged from 31 January – 4 February 2021. The forecasts are from the 00Z 25 January 2021 GFS model ensemble.

The PV has split yet again with the major daughter vortex over Siberia and the minor daughter vortex over the Central US (**Figure 13a**). The minor daughter vortex is predicted to quickly move westward to try to merge with the major daughter vortex over Asia (**Figure 13b**). However, the increased WAFz activity this week (**Figure 12**) is predicted to result in yet more warming of the polar stratosphere (**Figure 13b**). The increased WAFz activity at the end of the month will also change the PV's orientation from east to west across Northern Eurasia to one north south across the North Atlantic side of the Arctic from the Urals to Eastern Canada while high pressure strengthens near Alaska (**Figure 13b**).

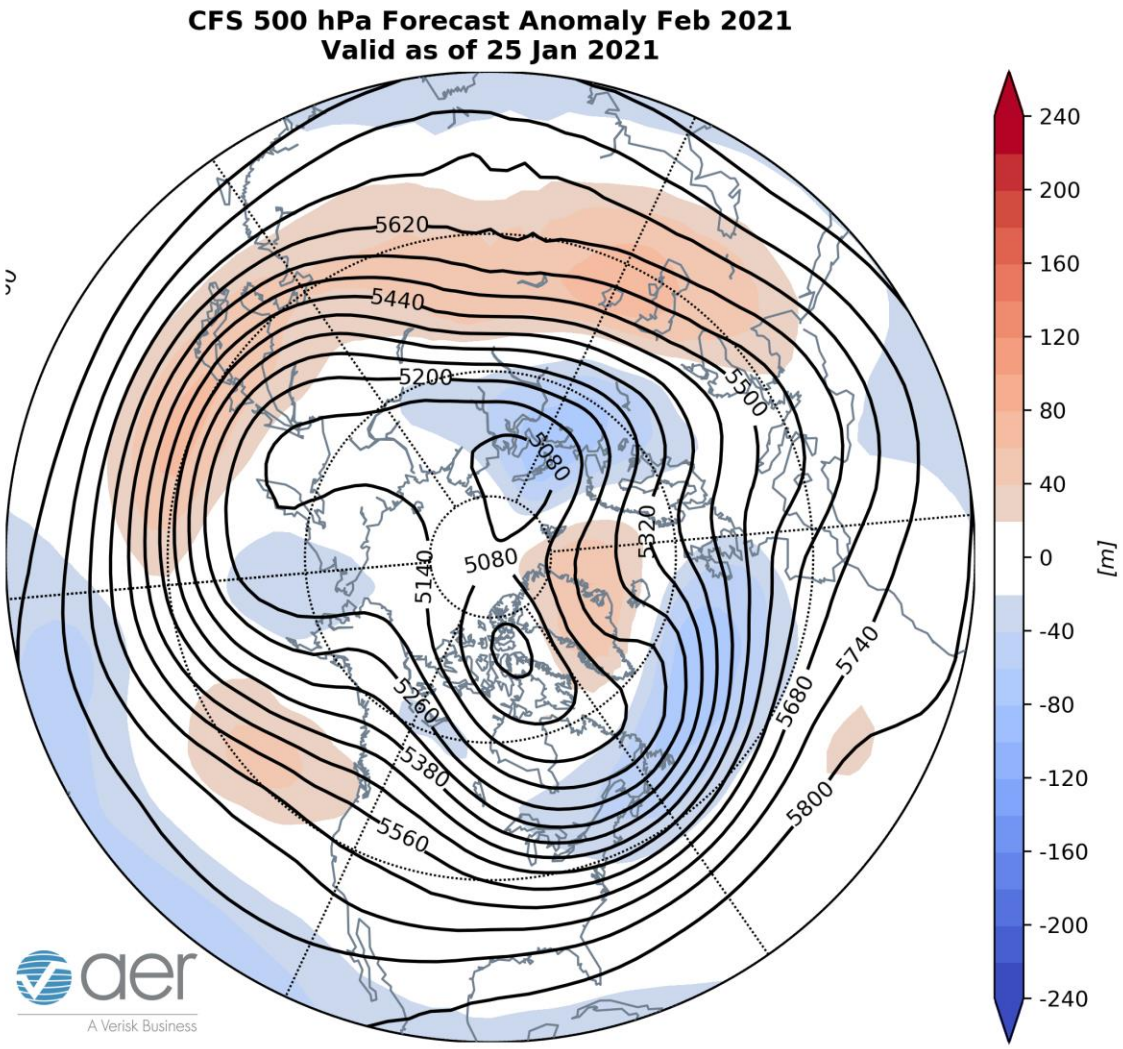

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for February 2021. The forecasts are from the 00Z 25 January 2021 CFS.

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 Greenland and Iceland, Southern Asia, the Gulf of Alaska and Alaska and into the Chukchi Sea with troughing in Northern Eurasia and eastern North America (**Figure 14).** This pattern favors relatively cold temperatures for Northern Europe, Northern and Eastern Asia, Eastern Canada and the Eastern US with seasonable to relatively warm temperatures for Southern Europe, Central and Southern Asia, Alaska, Western Canada and the Western US (**Figure 15**). Greenland blocking and cold in eastern North America is consistent with the period when the PV recovers

following a disruption, still I consider the forecast to be of low confidence given the volatility in recent model forecasts.

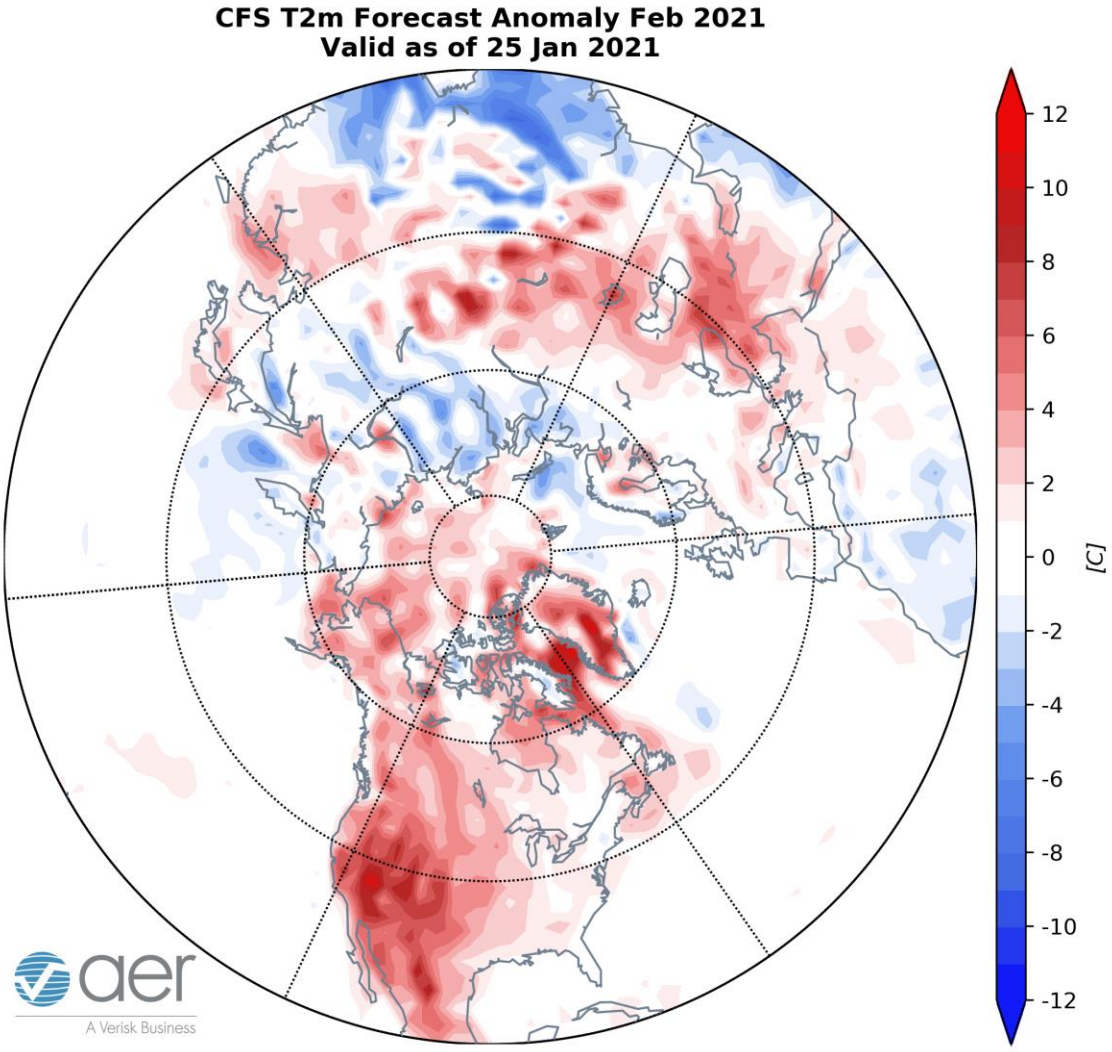

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for February 2021. The forecasts are from the 00Z 25 January 2021 CFS.

Surface Boundary Conditions

Arctic sea ice extent

Arctic sea ice continues to grow but currently remains below normal. Negative sea ice anomalies exist in the Bering Sea but especially in the Barents-Kara Seas (**Figure 16**). A cold winter in Siberia has resulted in above normal sea ice in the Sea of Okhotsk. 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.

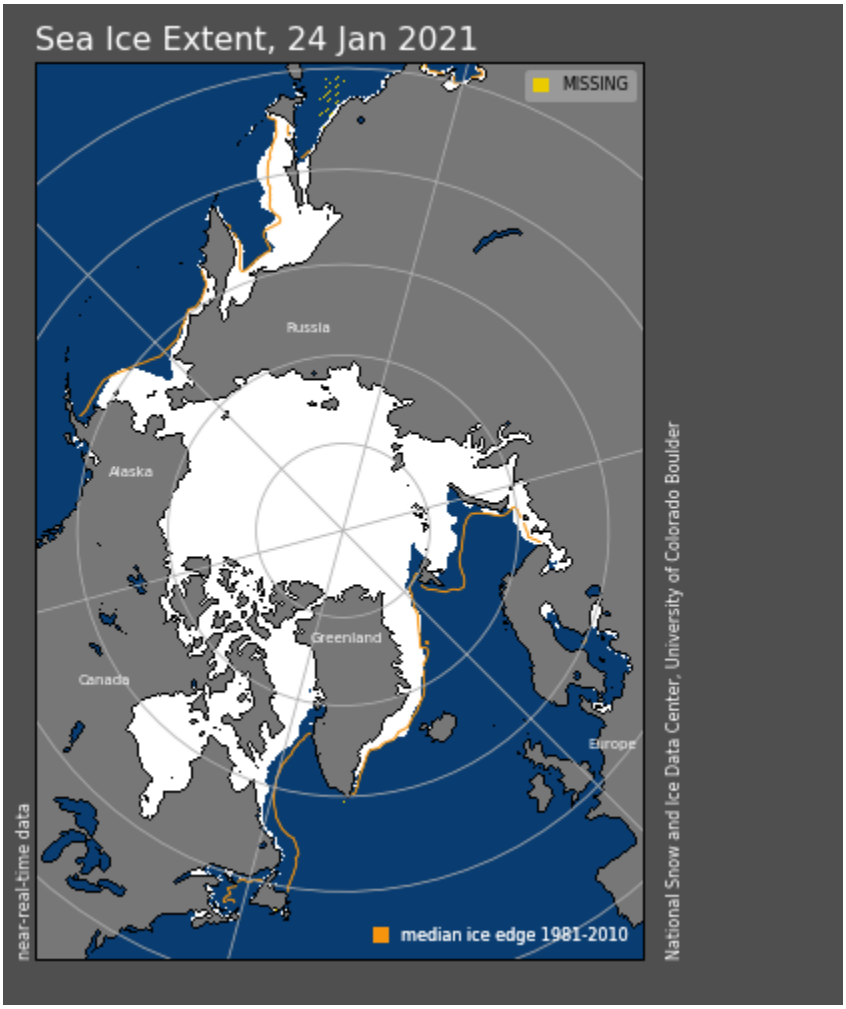

Figure 16. Observed Arctic sea ice extent on 24 January 2021 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies remain negative and we continue to observe moderate to weak La Niña conditions (**Figure 17**) and La Niña is expected to persist and remain moderate to weak through the winter. 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.

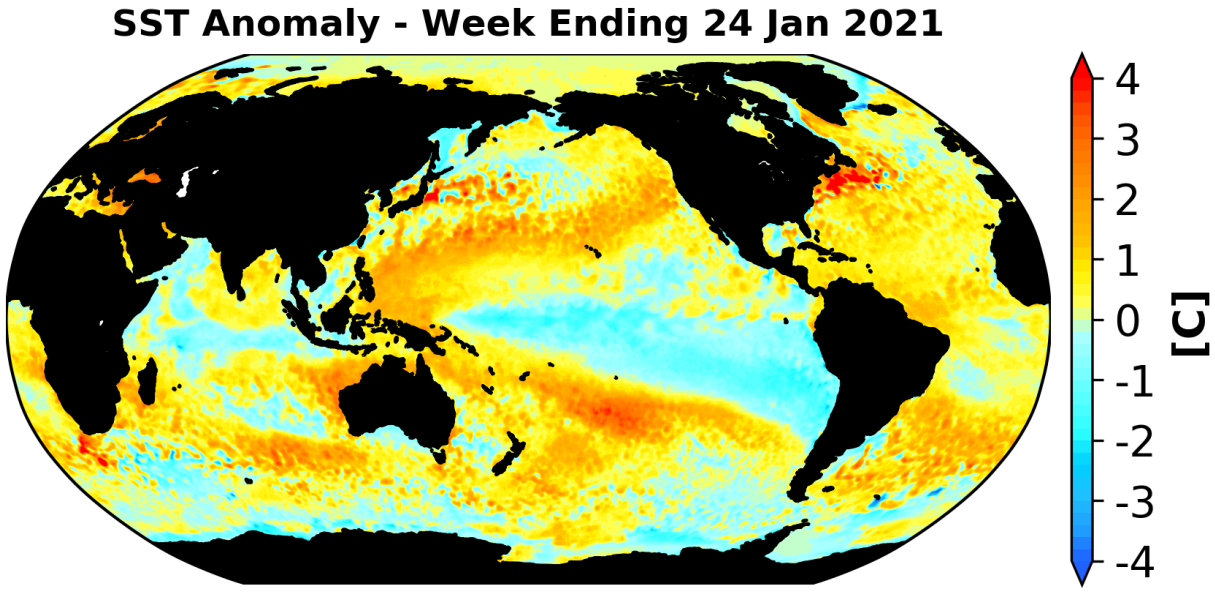

Figure 17. The latest weekly-mean global SST anomalies (ending 24 January 2021). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase six (**Figure 18**). The forecasts are for the MJO to remain in phase six and then move into phase seven. Phases six and seven favor ridging in eastern North America but eventually favors blocking across Northern Canada and troughing in the Eastern US. The MJO could eventually contribute to a colder pattern across eastern North America but admittedly this is outside of my expertise.

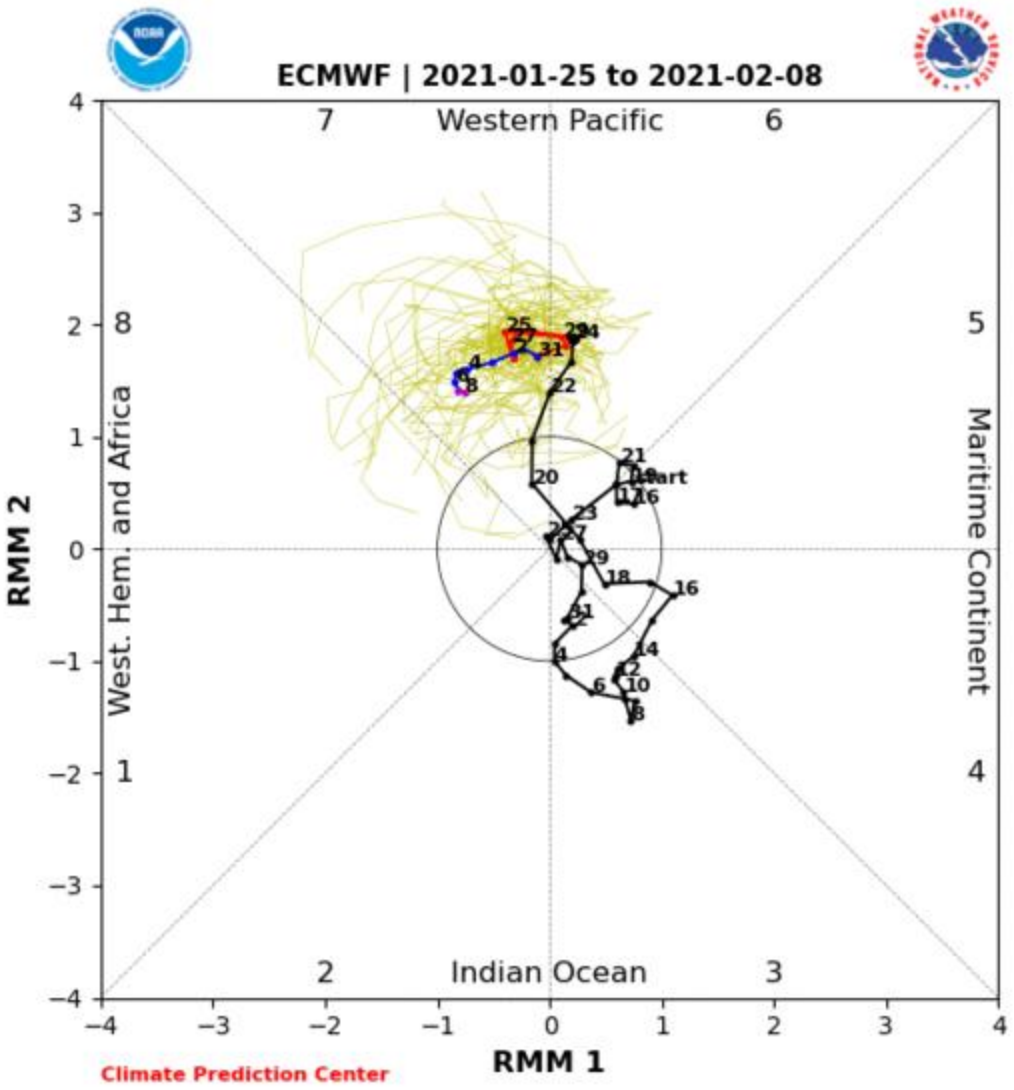

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 25 January 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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 advanced remained steady over the past week across Eurasia and is near decadal means. Snow cover advance will likely continue to increase especially across East Asia but in the short term could retreat across Europe the next week but could advance across Europe in February. 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.

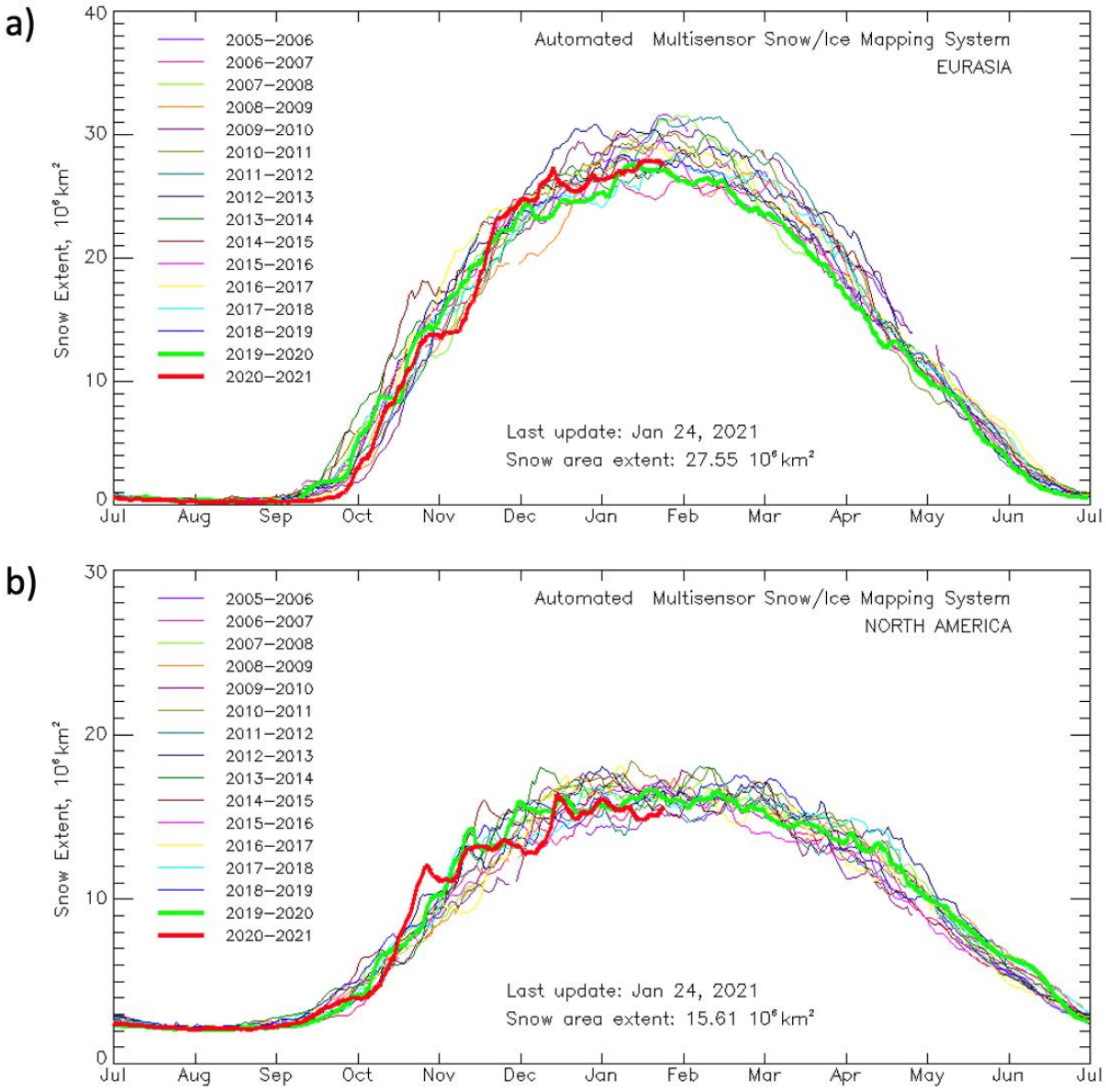

Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 17 January 2021. Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover remained steady over the past week and is near decadal lows. However snow cover could advance over the next two weeks. 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.