

Arctic Oscillation and Polar Vortex Analysis and Forecasts

December 13, 2021

Dear AO/PV blog readers:

We have shifted the public release of the Arctic Oscillation/Polar Vortex blog to Wednesdays weekly through the winter season.

For those who would like an early look on Mondays, we will be offering at a nominal price (US \$25) a PDF version of the upcoming blog, and we will be rolling out in the coming weeks access to the datasets used in the production of this blog. At present we plan to make available in comma-separated values the timeseries of the Polar Cap Height and the timeseries of the Wave Activity Flux (vertical component), though we would appreciate to hear your suggestions for additional data of interest to you all.

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 positive and is predicted to remain positive this week and then straddle neutral with mostly negative pressure/geopotential height anomalies across the Arctic this week but then oceanic ridges are predicted to push into the Arctic with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently positive but is then predicted to trend negative as negative pressure/geopotential height anomalies are predicted to become increasingly positive across Greenland.
- This week troughing/negative geopotential height anomalies across Greenland will favor ridging/positive geopotential height anomalies coupled with normal to above temperatures across much of Europe including the United Kingdom (UK) except for troughing/negative geopotential height anomalies coupled with normal to below normal temperatures in the Balkans. However next week the return of ridging/positive geopotential height anomalies across Greenland will support increasing troughing/negative geopotential height anomalies with normal to below normal temperatures across Eastern Europe with ridging/positive geopotential height anomalies coupled with normal to above temperatures across Western Europe including the UK.
- The predicted general pattern across Asia the next two weeks is strengthening ridging/positive geopotential height anomalies coupled with normal to above normal temperatures across Western Asia that slowly drifts westward into Europe with deepening troughing/negative geopotential height anomalies coupled with normal to below normal temperatures across much Northern and Eastern Asia.
- Persistent and nearly stationary ridging/positive geopotential height anomalies between the Dateline and the Aleutians will favor troughing/negative geopotential height anomalies in Alaska, Western Canada and the Western US with ridging/positive geopotential height anomalies anchored in the Southeastern US. This pattern favors normal to below normal temperatures across Alaska and Western Canada and normal to above temperatures for much of the US and Eastern Canada this week but limited to the Eastern US next week.
- In the *Impacts* section I discuss the unusual pattern predicted for the end of December and how it might impact the polar vortex (PV) and the remainder of the winter for the Northern Hemisphere (NH).

Plain Language Summary

I feel that we have approached a fork in the road for the winter. The first path includes a brief colder period as we close out the year and a resumption of relatively milder weather will return early in the new year. The second path means the overall mild winter is mostly winding down and much of the remainder of the winter will feature colder weather. Either path is possible at this point.

Impacts

Making a winter forecast is never easy but I am finding it particularly challenging this winter. I do think that Arctic sea ice has become an important factor over the past two decades but with sea ice relatively extensive compared to recent winters, I think it is providing less of a signal. Sea ice is near normal in much of the Arctic basin with the largest negative anomalies in Hudson Bay and I expect it will freeze over quickly for the remainder of December. If sea ice had been below normal in the Barents-Kara seas as is common over the past decade it would have helped ridging/high pressure in the region. Instead ridging/high pressure in the region seems more ephemeral. This week ridging/high pressure centered in Western Asia with troughing low pressure in Eastern Asia is a favorable pattern for disrupting the stratospheric PV. However, the ridging/high pressure unlike last year when it remained nearly stationary for multiple weeks in December this year it is predicted to slide west towards the Greenwich meridian and may make it to Greenland. Had the ridging/high pressure remained near the Urals, I would fully expect a significant disruption to the PV.

And to be completely honest not sure what to make of ridging/high pressure centered near the Greenwich meridian and how it will impact the PV. It is in the node of between it can strengthen and weaken the PV, so it is simply a wash? Latest GFS has been sliding the ridging/high pressure towards Greenland and Iceland where it will not weaken the PV substantially.

But the model trends seem to be converging on a solution with large and highly amplified mid-oceanic ridges and high pressure. The one in the North Pacific will support downstream troughing and cold temperatures across North America and the one in the North Atlantic will support downstream troughing and cold temperatures across a good chunk of Eurasia. And with the ridging continuing to slide west this will include Europe. But maybe more importantly it blocks or protects the respective continents from the moderating influence of westerly maritime air masses allowing the manufacture of cold polar masses above the snowpack. This pattern reminds me of winter 2010/11 but with some important differences and I included a 500 hPa geopotential height anomaly in **Figure i**. The ridging in the North Pacific was centered in the Gulf of Alaska, which is why it was so cold in the Eastern US and I had forgotten the strong Ural blocking. Right now there are no signs of the ridging moving bodily into the Gulf of Alaska.

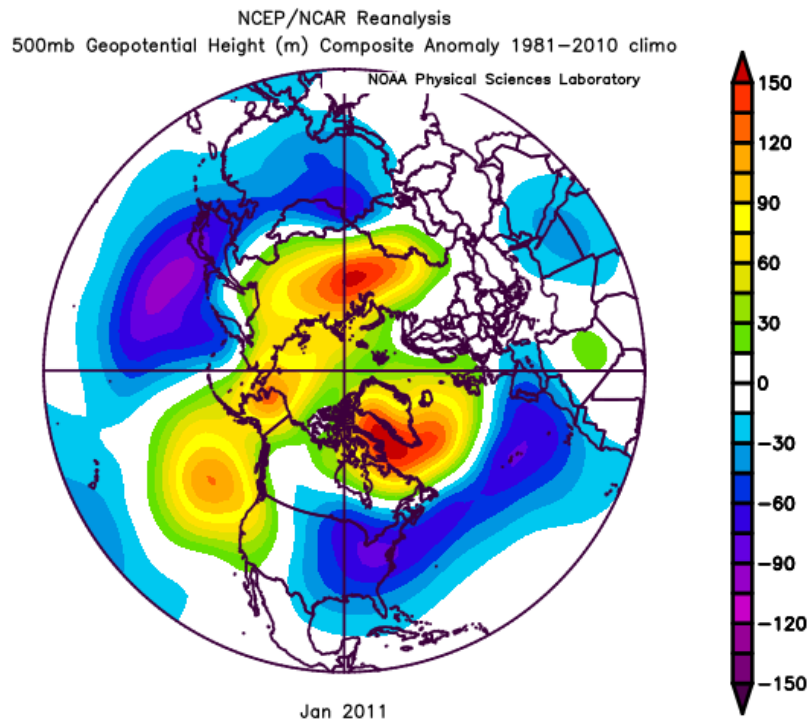


Figure i. Composite 500 hPa geopotential height anomaly for January 2011 from <https://psl.noaa.gov/cgi-bin/data/composites/printpage.pl>

The models seem to love to warmup Asia, especially Siberia without little justification and I am watching to see if a Siberian air mass forms of much greater expanse and deeper cold more so than any models have been predicting. For some reason the models have an easier time predicting cold for North America and is an interesting discussion for another time.

As far as I can tell the development of the mid-ocean ridges is independent of the polar vortex therefore and therefore the mid-ocean blocking can be expected to last as long as three weeks and would need to couple with the polar vortex for longer duration in my opinion. I do expect some disruption of the stratospheric PV but unless the ridging/high pressure slides east again, I don't see a large disruption such as a sudden stratospheric warming for now. I would also add, what I discussed last week with a troposphere-stratosphere-troposphere (T-S-T) coupling event that ends with an extended period of positive AO/NAO remains a strong possibility. If that coupling event goes the distance then the upcoming cold period across the continents will be the heart of winter, will be relatively brief and most of the winter will be dominated by relatively mild weather.

In conclusion I think we have reached a fork in the road. The first path is an overall mild winter with an ongoing T-S-T coupling that favors a positive AO, a strong stratospheric PV and relatively mild temperatures. We are currently entering a period that is an interruption to the overall mild pattern, it will likely last into the beginning of the year but much of January and February will be mild. The alternate path is that we are concluding our extensive mild period and the continuation of the mild period is being discontinued or disrupted by favorable placement of ridge/high pressure centers that in the short term is allowing the NH landmasses to cool significantly. But I do think for the relatively cold pattern to have longevity, it needs to involve the stratospheric PV either through a classical SSW or alternatively a stretched PV but in the former disruption, it would likely need to occur multiple times to have a discernable impact on the seasonal means. Again, I do think that the best plot to determine which path we are on the PCH and WAFz plots are critical.

1-5 day

The AO is predicted to be positive this week (**Figure 1**) as geopotential height anomalies are predicted to be mostly negative across the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with negative geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to be positive this week as well (**Figure 1**).

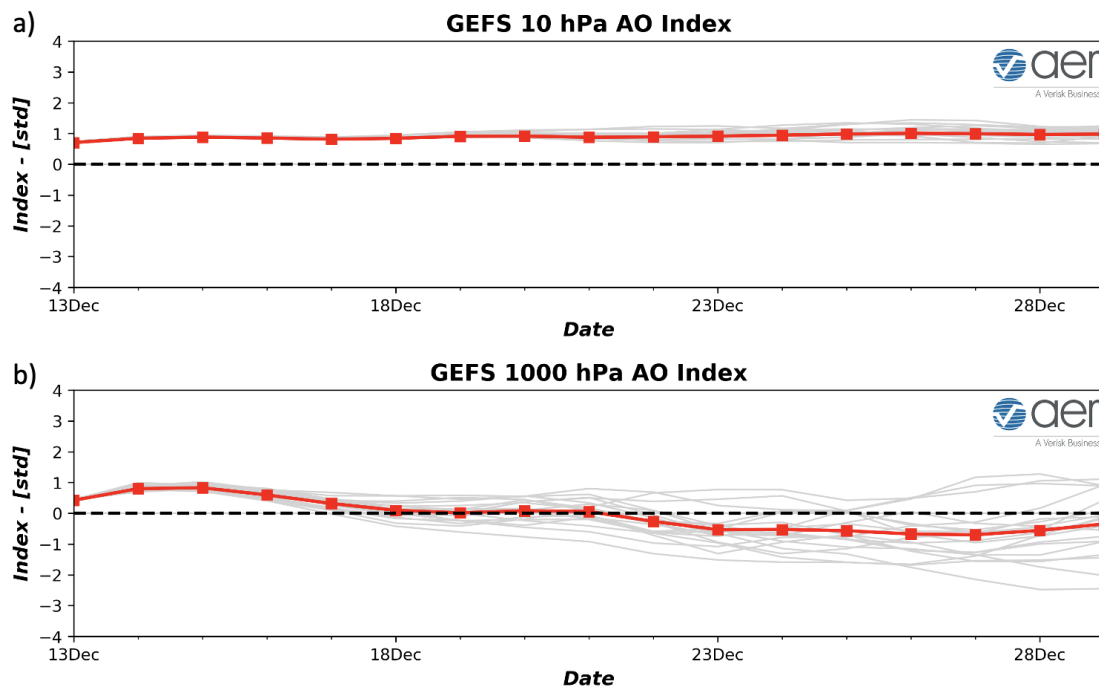


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 13 December 2021 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 13 December

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, troughing/negative geopotential height anomalies centered across Greenland will favor ridging/positive geopotential height anomalies across much of Europe including the UK this period except for troughing/negative geopotential height anomalies in the Balkans (**Figure 2**). This will result in normal to above normal temperatures across much of Europe including the UK with the exception of normal to below normal temperatures in the Balkans (**Figure 3**). Ridging/negative geopotential height anomalies are predicted to strengthen near the Urals contributing to deepening troughing/negative geopotential height anomalies across much of Siberia and East Asia this period (**Figure 2**). This pattern favors normal to above normal temperatures across much of Western and Southern Asia with normal to below normal temperatures across far Northern and Eastern Asia (**Figure 3**).

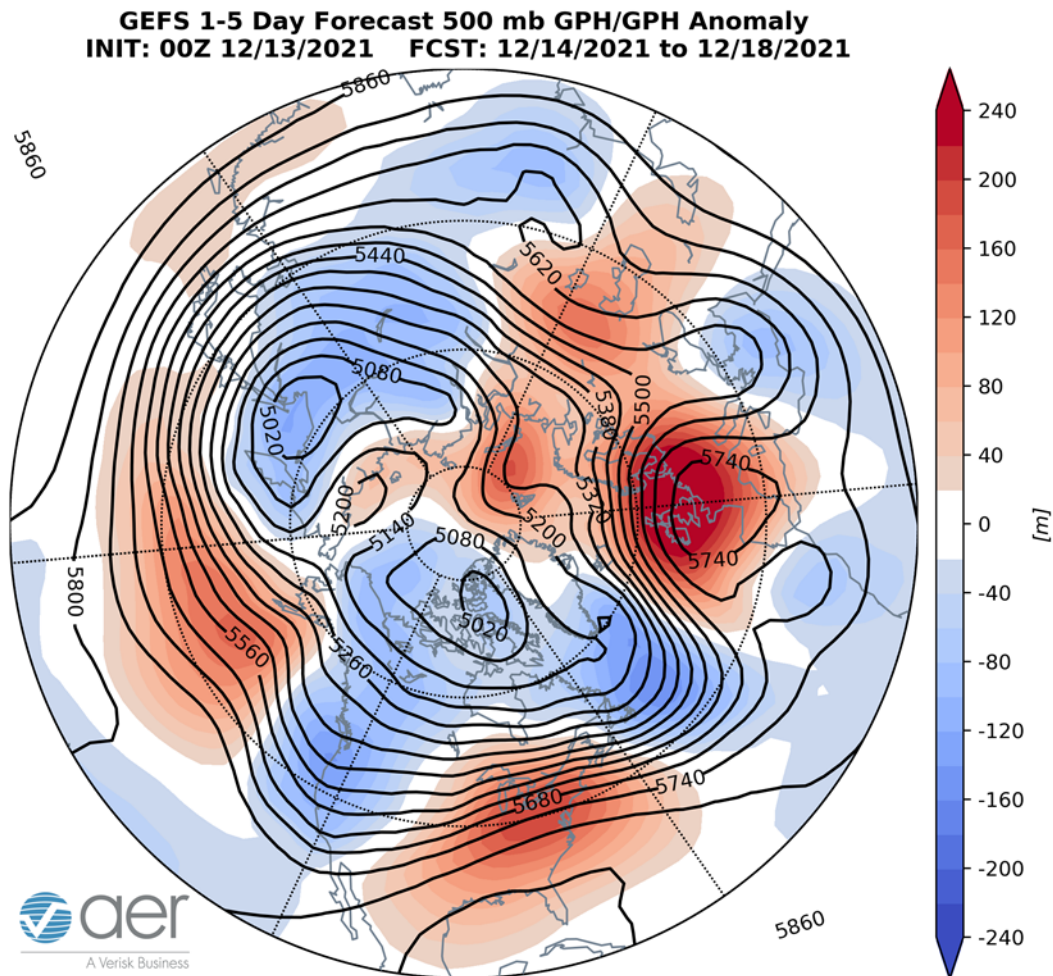


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 14 – 18 December 2021. The forecasts are from the 00z 13 December 2021 GFS ensemble.

Ridging/positive geopotential height anomalies between the Dateline and the Aleutians will contribute to deepening troughing/negative geopotential height anomalies in western North America with strengthening ridging/positive geopotential height anomalies across the US east of the Rockies centered near the Great Lakes this period (**Figure 2**). This will favor normal to below normal temperatures across Alaska much of Western Canada and the US West Coast with normal to above normal temperatures in Eastern Canada and much of the US from the Rockies eastward (**Figure 3**).

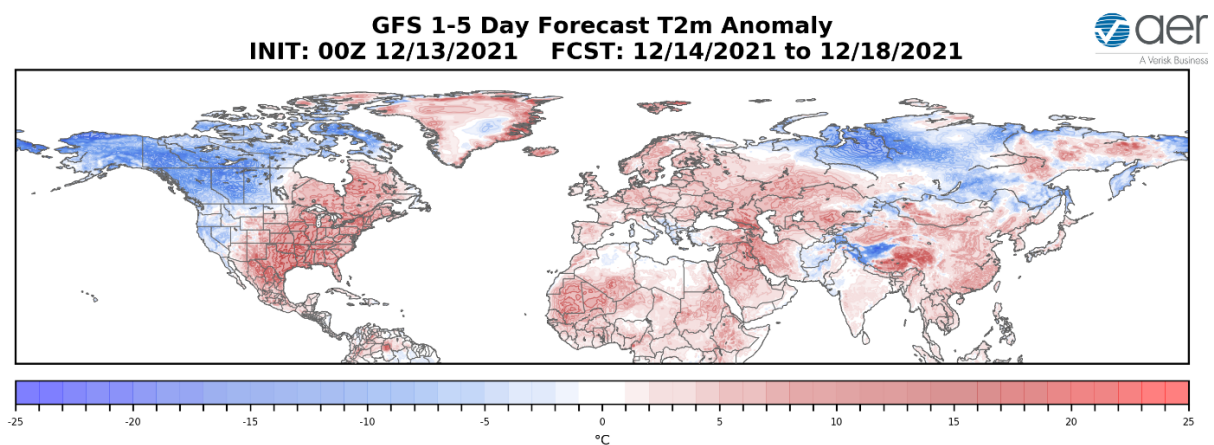


Figure 3. Forecasted surface temperature anomalies (°C; shading) from 14 – 18 December 2021. The forecast is from the 00Z 13 December 2021 GFS ensemble.

Troughing and/or cold temperatures are predicted to support new snowfall across Northern, Central and Eastern Asia while mild temperatures promote snowmelt in Central and Northeastern Europe (**Figure 4**). Troughing and/or cold temperatures are predicted to support new snowfall across Alaska, much of Western and Central Canada and the Western US while mild temperatures promote snowmelt in the Southeastern Canada and the US Upper Midwest (**Figure 4**).

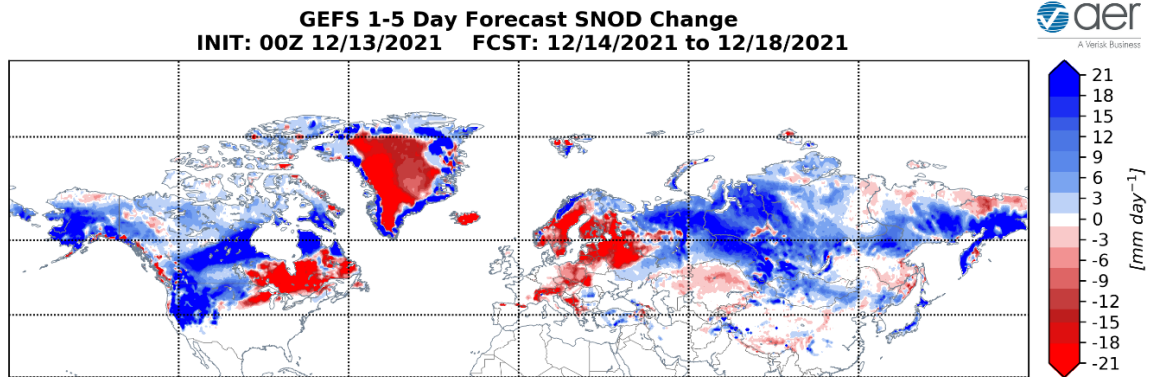


Figure 4. Forecasted snow depth changes (mm/day; shading) from 14 – 18 December 2021. The forecast is from the 00Z 13 December 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to trend negative this period towards neutral this period (**Figure 1**) as positive geopotential height anomalies from Northern Europe punch into the Arctic but especially Greenland with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with geopotential height anomalies rising across Greenland (**Figure 5**), the NAO is predicted to dip negative this period.

GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 12/13/2021 FCST: 12/19/2021 to 12/23/2021

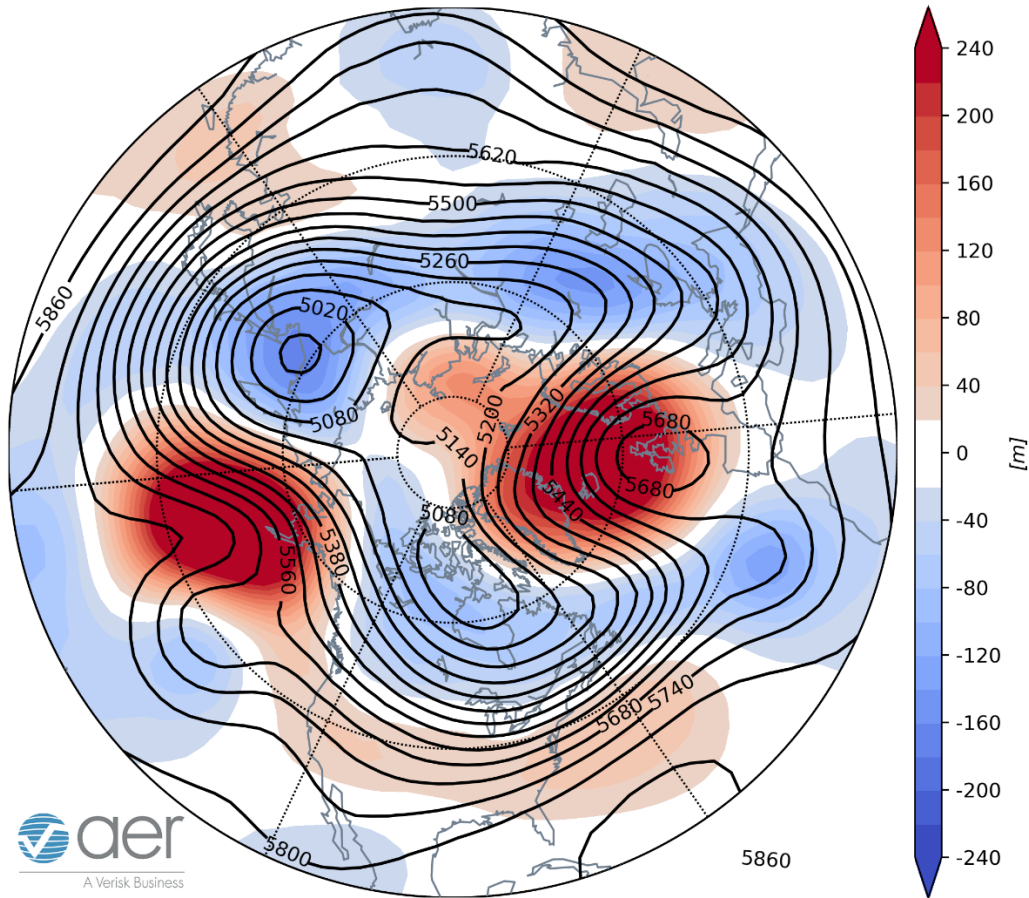


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 19 – 23 December 2021. The forecasts are from the 00z 13 December 2021 GFS ensemble.

Ridging/positive geopotential height anomalies previously widespread across Europe will consolidate across Northwestern Europe this period with troughing/negative geopotential height anomalies spreading from Western Asia into Eastern Europe (**Figures 5**). This will result in normal to below normal temperatures across eastern Europe including with normal to above normal temperatures across Western Europe including the UK (**Figure 6**). Ridging/positive geopotential height anomalies in Western Asia will retrograde westward into Europe allowing troughing/negative geopotential height anomalies to spread across all of Northern Asia with ridging/positive geopotential height anomalies confined to Southern Asia (**Figure 5**). This pattern favors normal to below normal temperatures across Northern Asia with normal to above normal temperatures across Southern Asia (**Figure 6**).

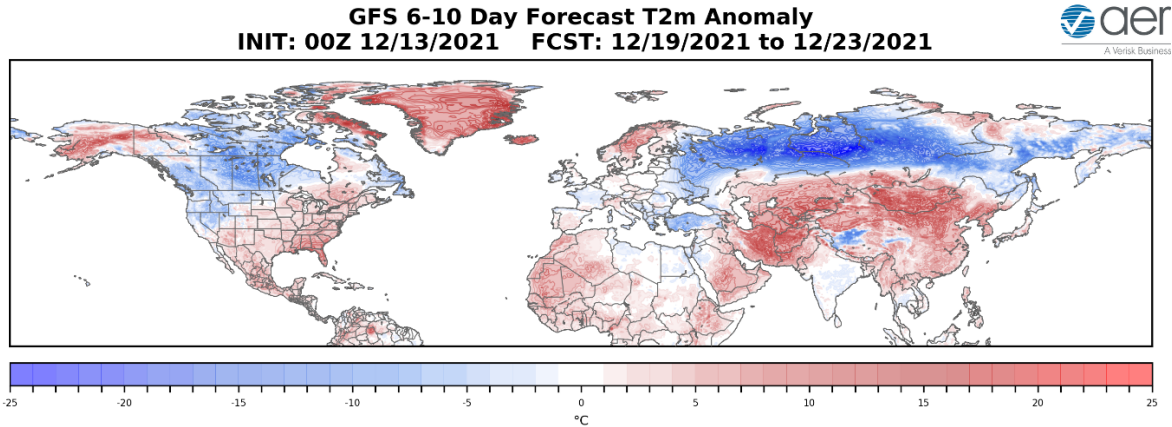


Figure 6. Forecasted surface temperature anomalies (°C; shading) from 19 – 23 December 2021. The forecasts are from the 00Z 13 December 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies between the Dateline and the Aleutians will anchor troughing/negative geopotential height anomalies across much of Canada and the US West Coast with ridging/positive geopotential height anomalies across the Southeastern US this period (**Figure 5**). This will favor normal to below normal temperatures across eastern Alaska much of Western and Northern Canada and the Northwestern US with normal to above normal temperatures in the Southern and Eastern US (**Figure 6**).

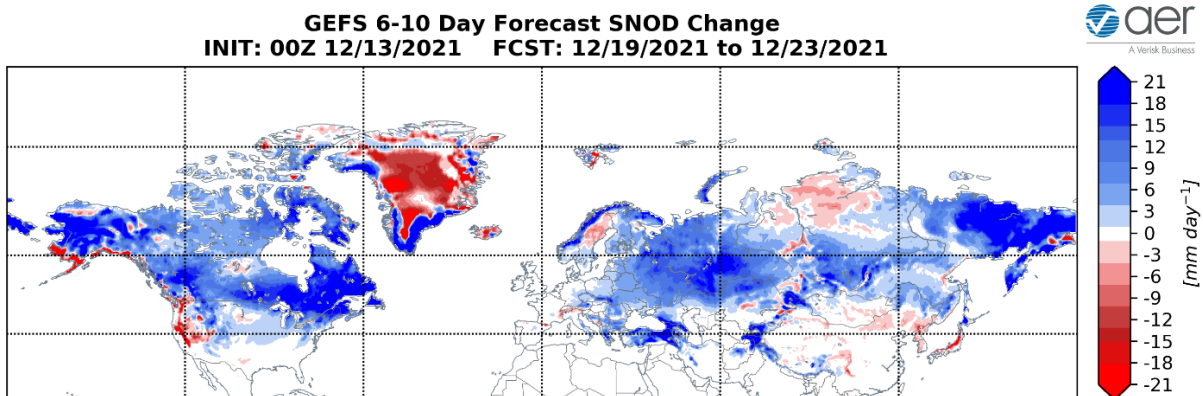


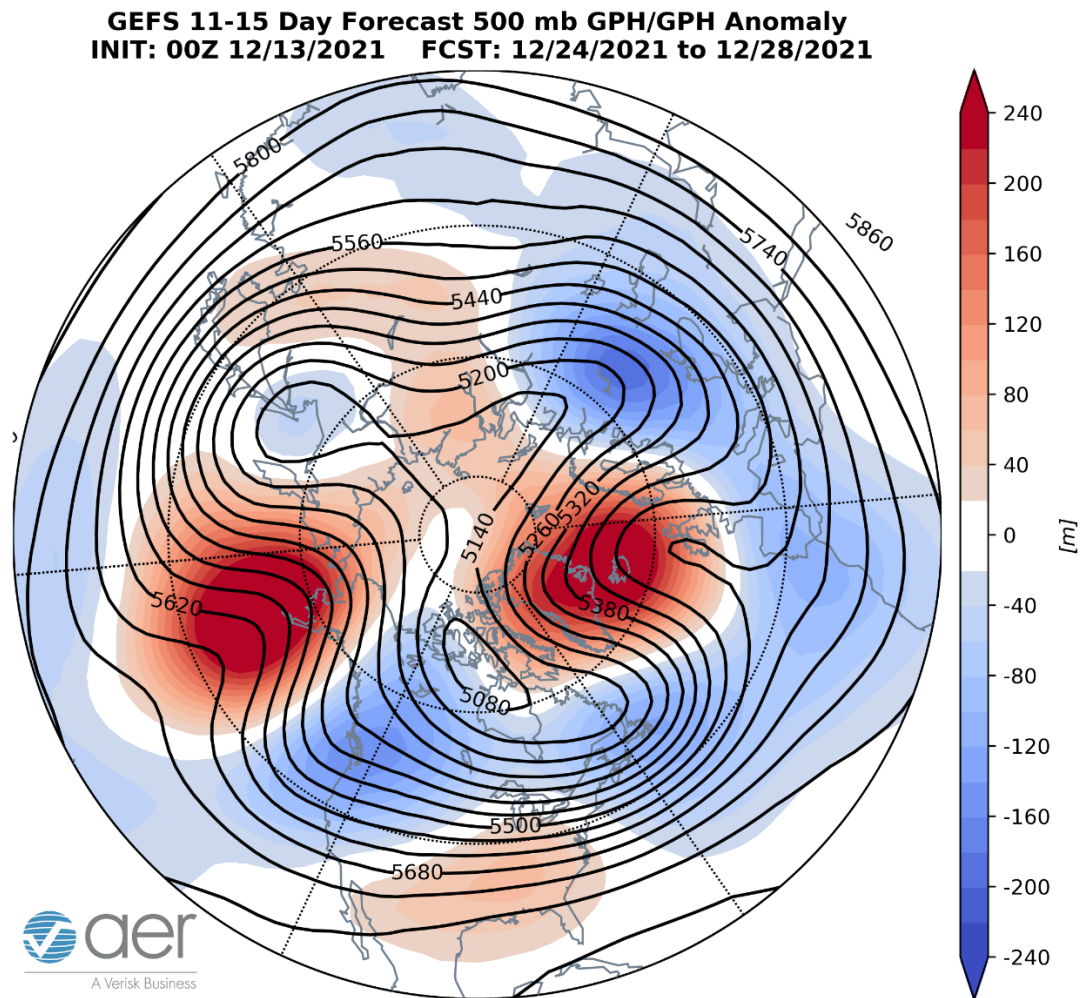
Figure 7. Forecasted snow depth changes (mm/day; shading) from 19 – 23 December 2021. The forecast is from the 00Z 13 December 2021 GFS ensemble.

Troughing and/or cold temperatures are predicted to support new snowfall across Norway, Eastern Europe, Turkey, Northern Asia and the Tibetan Plateau while milder temperatures promote snowmelt across Sweden, Finland and the Alps (**Figure 7**). Troughing and/or cold temperatures are predicted to support new snowfall across

Alaska, much of Canada the Great Lakes and the Northeastern US while milder temperatures promote snowmelt across the Western US (**Figure 7**).

11-15 day

With mixed negative geopotential height anomalies predicted to persist across the Arctic and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO should remain near neutral to negative this period (**Figure 1**). With predicted positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is forecasted to remain negative this period.



European ridging/positive geopotential height anomalies are predicted to drift between Iceland and the UK favoring troughing/negative geopotential height anomalies across Eastern Europe this period (**Figure 8**). This pattern favors more normal to above normal temperatures across much of Western Europe including the UK with normal to below normal temperatures across Central and Eastern Europe this period (**Figures 9**). As European ridging continues to drift westward, troughing/negative geopotential height anomalies in Western Asia are predicted to deepen with more ridging/positive geopotential height anomalies across Southeast Asia this period (**Figure 8**). This pattern favors normal to below normal temperatures across Western and Northern Asia with normal to above normal temperatures across Southern and Eastern Asia this period (**Figure 9**).

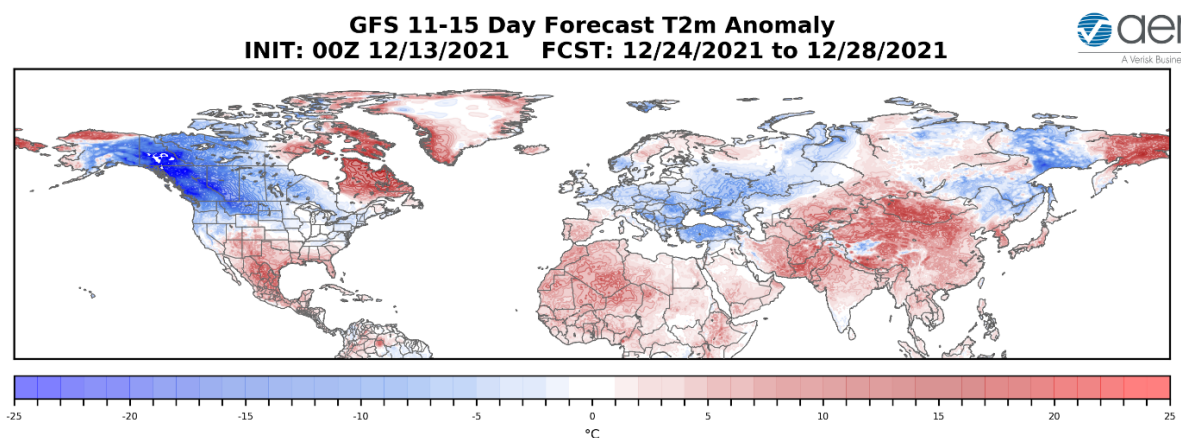


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 24 – 28 December 2021. The forecasts are from the 00z 13 December 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies between the Dateline and the Aleutians will anchor troughing/negative geopotential height anomalies in western North America with persistent ridging/positive geopotential height anomalies across the US east of the Rockies and centered in the Ohio Valley this period (**Figure 8**). This pattern favors normal to below normal temperatures across Eastern Alaska, Western and Central Canada and the Northwestern US with normal to above normal temperatures in Northeastern Canada and the Southern and Eastern US (**Figure 9**).

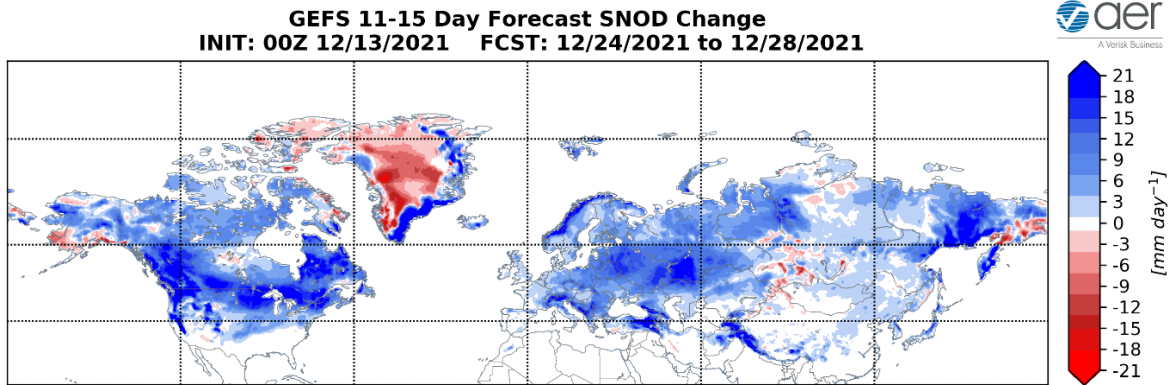


Figure 10. Forecasted snow depth changes (mm/day; shading) from 24 – 28 December 2021. The forecast is from the 00Z 13 December 2021 GFS ensemble.

Trouching and/or cold temperatures are predicted to support possible new snowfall across Central and Eastern Europe including Turkey and much of Northern and Western Asia while milder temperatures promote snowmelt across east Asia (**Figure 10**). Trouching and/or cold temperatures are predicted to support possible new snowfall across Alaska, much of Canada and the US Pacific Northwest, the Northern and Central Rockies, the Upper Midwest and the Northeast (**Figure 10**).

Longer Term

30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to cold/negative PCHs throughout the stratosphere and near normal PCHs in the troposphere (**Figure 11**). The largest negative departures are currently in the upper stratosphere (**Figure 11**), which could propagate down to the troposphere in early January. Currently the stratosphere and troposphere are decoupled and waiting for coupling to resume, though exactly how is an open question to me.

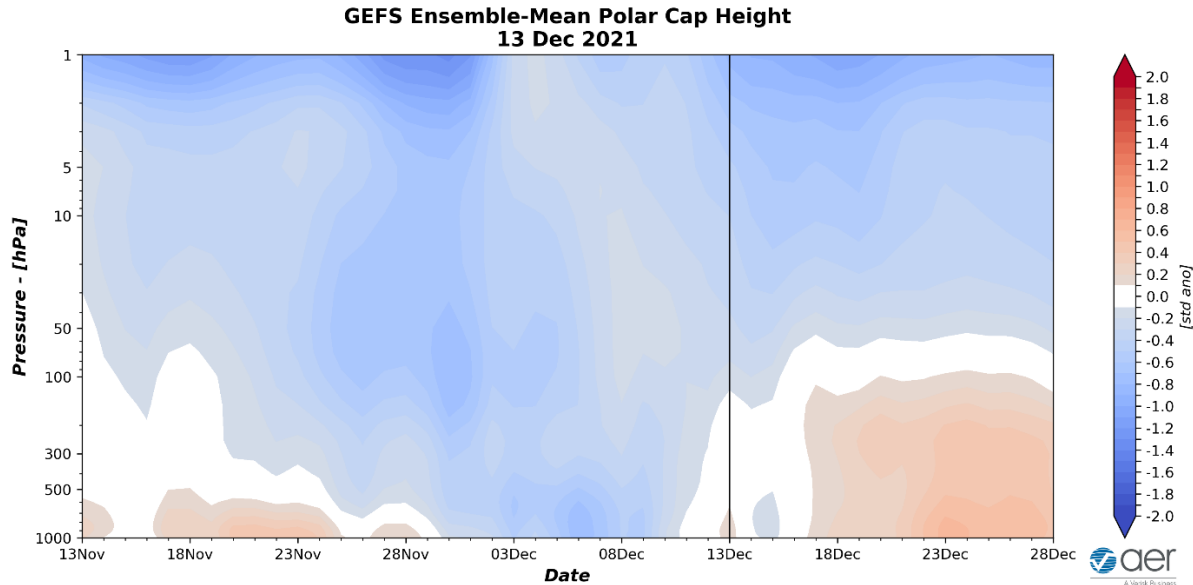


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 13 December 2021 GFS ensemble.

The normal to below normal PCHs predicted this week in the lower tropospheric are consistent with the predicted positive surface AO this week (**Figure 1**). However, as PCHs warm in the lower troposphere next week the AO is predicted to trend negative (**Figure 1**).

The vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere or poleward heat transport in the stratosphere is predicted to remain somewhat more active for much of December (**Figure 12**). The uptick in WAFz is consistent with Ural ridging this week (**Figure 12**). However, the positive WAFz anomalies are relatively weak, and the strong polar vortex should remain strong for much of the month. Though the GFS looks suggestive of a stretched polar vortex, so something to watch.

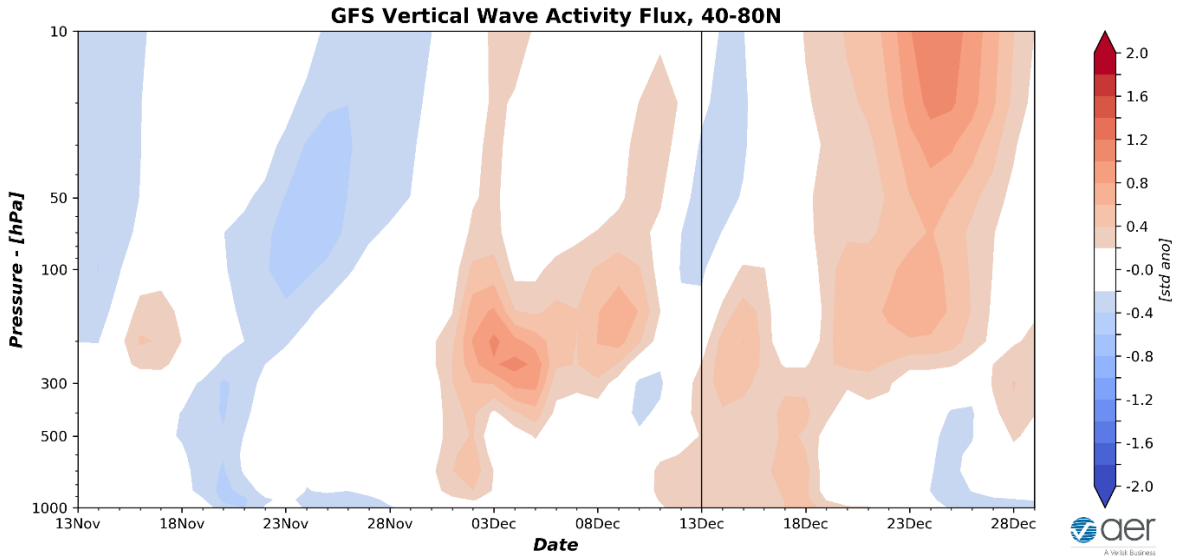


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 13 December 2021 GFS ensemble.

The recent uptick in WAFz has perturbed the stratospheric PV the PV displaced towards Eurasia and centered in the East Siberian Sea with ridging and polar stratospheric warming east of the Dateline and warming across Northwestern Canada (**Figure 13**). However, the perturbation is relatively minor and the PV is relatively strong resulting in a current positive stratospheric AO (**Figure 11**).

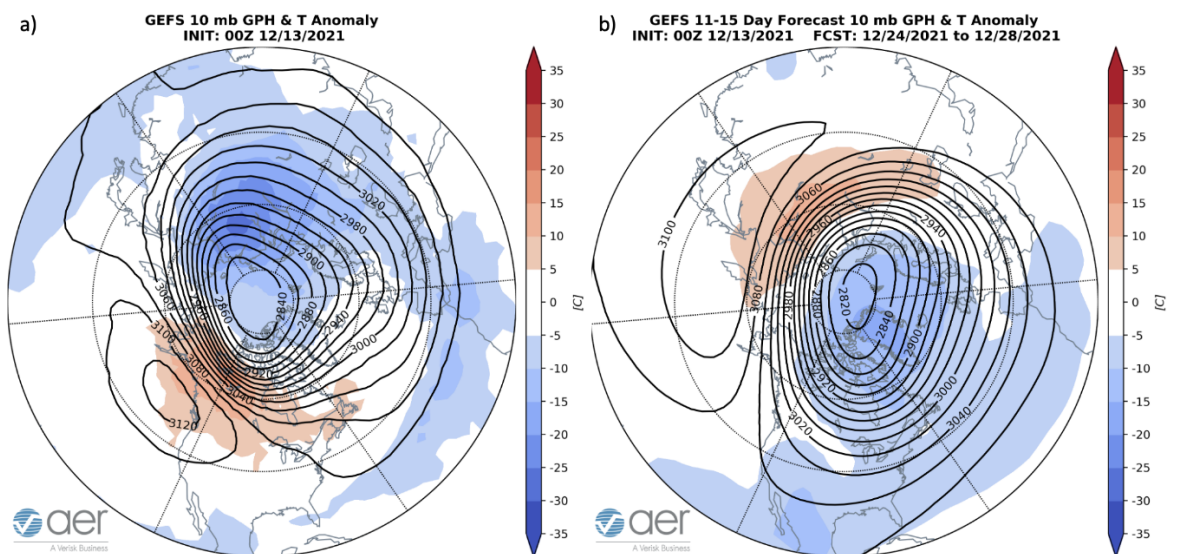


Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 13 December 2021. (b)

Same as (a) except forecasted averaged from 24 – 28 December 2021. The forecasts are from the 00Z 13 December 2021 GFS model ensemble.

In the near term the active WAFz is predicted to be minor allowing for the PV to remain relatively strong PV and centered near the North Pole once again by mid-December (**Figure 13**) with a persistent positive stratospheric AO the next two weeks (**Figure 11**). However, the polar stratospheric warming coming out of Asia could be suggestive of a stretched PV.

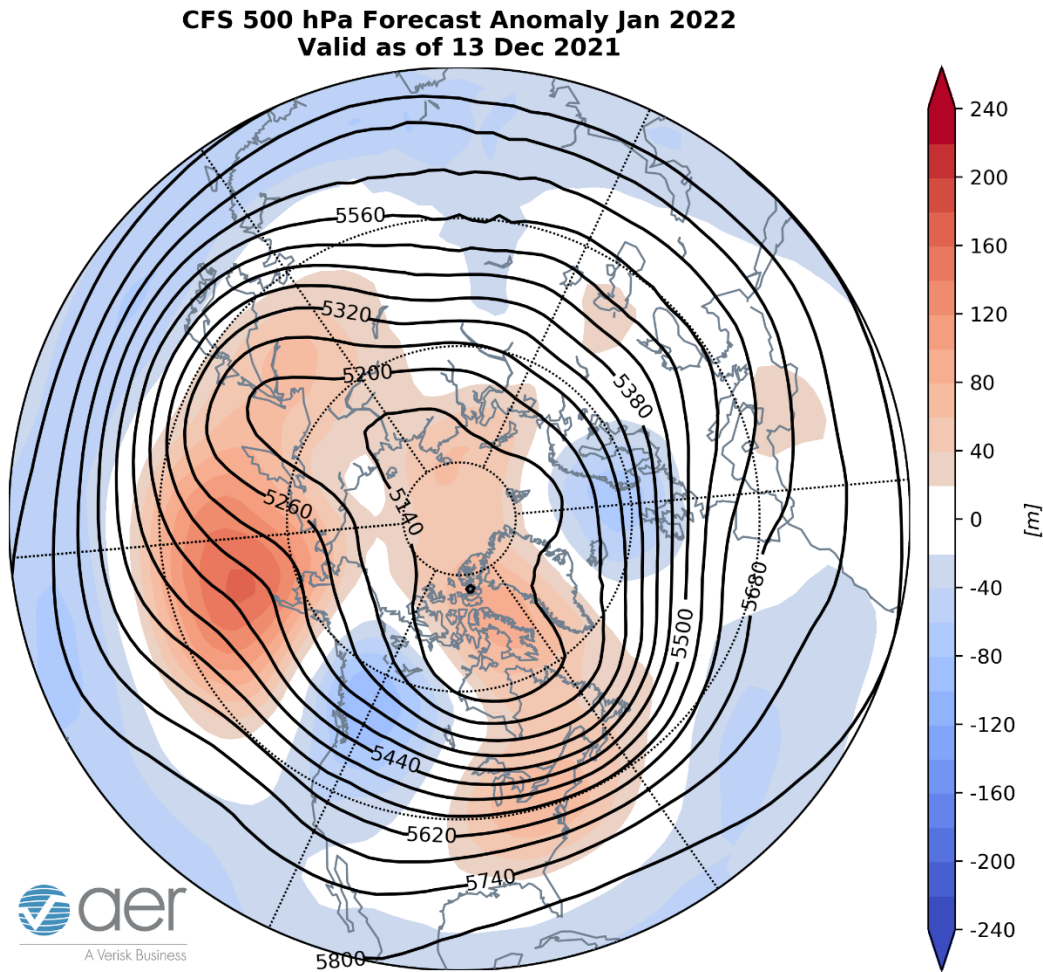


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for January 2022. The forecasts are from the 00Z 13 December 2021 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and surface temperatures for January (**Figure 15**) from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging centered in the Central Arctic, centered between the Dateline and

the Aleutians and in the Southeastern US with troughing across Northwestern Europe, Central and East Asia and western North America (**Figure 14**). This pattern favors seasonable to relatively warm temperatures widespread across far Northern Europe, Southern Asia and the Eastern US with seasonable to relatively cold temperatures across much of Europe, Northern Asia, Alaska, much of Canada and the Western US (**Figure 15**).

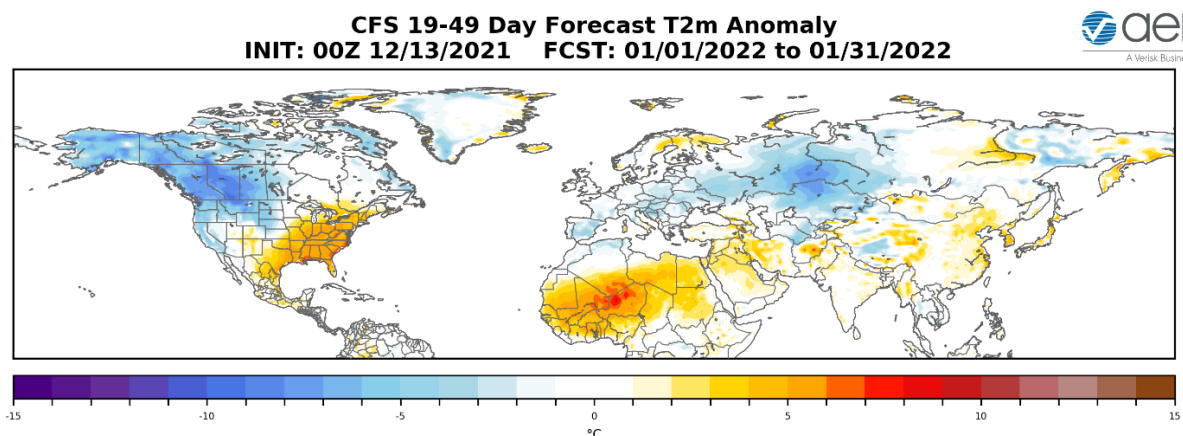


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for January 2022. The forecasts are from the 00Z 13 December 2021 CFS.

Surface Boundary Conditions

Arctic Sea ice

Arctic sea ice is growing but remains below normal east of Greenland but especially in Baffin Bay and Hudson Bay. In the Barents-Kara Seas extent is getting closer to normal. Sea ice is above normal in the Bering Sea. Below normal sea ice in the Barents-Kara seas favors cold temperatures in Central and East Asia, while below normal sea ice in Baffin Bay favors cold temperatures in the Eastern Europe and Northern Europe 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, Beaufort and Bering seas may favor colder temperatures across North America but has not been shown to weaken the PV.

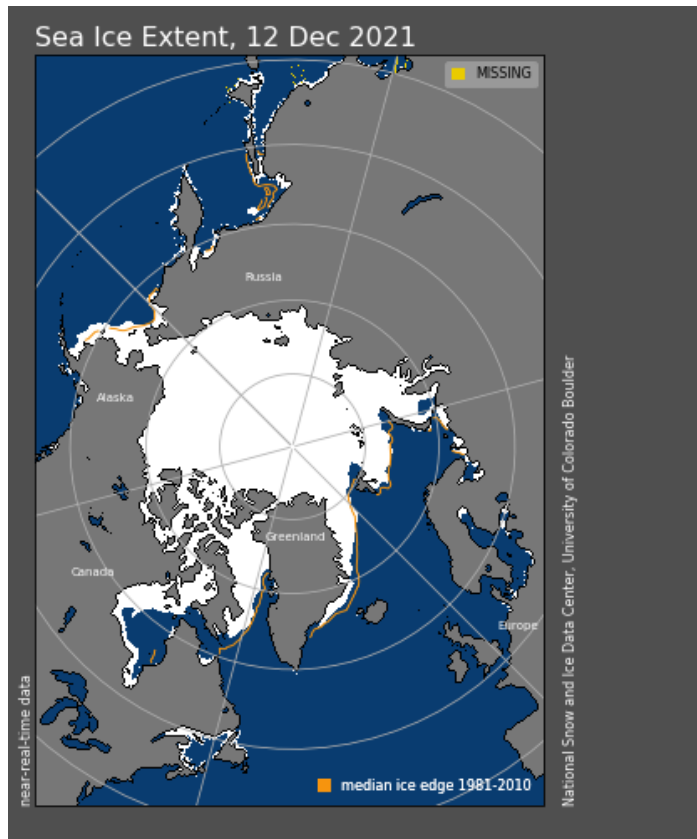


Figure 16. Observed Arctic sea ice extent on 12 December 2021 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are below normal and we continue to observe weak La Niña conditions (**Figure 17**) and La Niña conditions are expected through the winter. Observed SSTs across the NH remain well above normal especially in the central North Pacific (west of recent years), the western North Pacific and offshore of eastern North America though below normal SSTs exist regionally especially in the North Pacific. Not my expertise but the SST pattern in the North Pacific are strongly resembling a negative Pacific Decadal Oscillation (PDO) pattern that favors colder temperatures across northwestern North America and milder temperatures across southeastern North America.

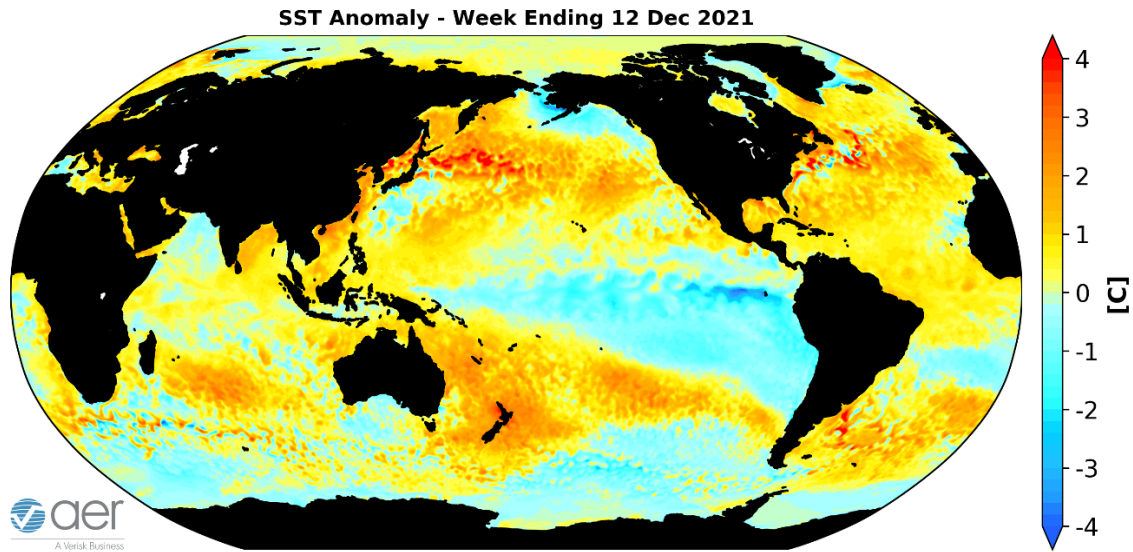


Figure 17. The latest weekly-mean global SST anomalies (ending 12 December 2021).
Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase seven (**Figure 18**). The forecasts are for the MJO to bounce around between phase six and seven in late December. MJO phases six and seven favor high latitude blocking including Alaska with transitioning ridges and troughs in the US. However phase six favors initially ridging and warm temperatures in the Eastern US and phase seven favors troughing and cold temperatures in the Eastern US. the warm forecasts are consistent with MJO forcing the next two weeks but admittedly this is outside of my expertise.

