

Arctic Oscillation and Polar Vortex Analysis and Forecasts

December 27, 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 negative and is predicted to remain negative to neutral the next two weeks as positive pressure/geopotential height anomalies over Alaska are predicted to push into the Central Arctic with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently negative and is predicted to remain neutral to negative as positive pressure/geopotential height anomalies are predicted to persist across Greenland the next two weeks.
- The next two weeks, ridging/positive geopotential height anomalies across Greenland will favor troughing/negative geopotential height anomalies coupled with normal to below temperatures across Northern and Eastern Europe with ridging/positive geopotential height anomalies coupled with normal to above normal temperatures across Western and Central Europe including the United Kingdom (UK).
- The predicted general pattern across Asia the next two weeks is troughing/negative geopotential height anomalies across Northern Asia with ridging/positive geopotential height anomalies across Southern Asia. This will favor normal to below normal temperatures across Northern Asia with normal to above normal temperatures across Southern Asia.
- Persistent and nearly stationary ridging/positive geopotential height anomalies south of the Aleutians will favor troughing/negative geopotential height anomalies in Western Canada and the Western US with ridging/positive geopotential height anomalies in Eastern Canada and the Eastern US. However, over the next two weeks the ridging near the Aleutians will push north and merge with ridging centered in the Laptev Sea supporting the North American troughing expanding into eastern North America. This pattern favors normal to below normal temperatures across Alaska, Western and Central Canada and the Western US with normal to above temperatures for much of the Southern and Eastern US and Eastern Canada. However, over the next two weeks, the cold air in western North America will slowly filter eastward.
- In the *Impacts* section I discuss the how I feel that the atmosphere how I remain flummoxed by the behavior of the polar vortex (PV) and how it may impact the remainder of the winter for the Northern Hemisphere (NH).
- *Impacts* section I discuss the how I feel that the atmosphere has made a turn but not decisive, towards a weaker polar vortex (PV) in January and how it may impact the remainder of the winter for the Northern Hemisphere (NH).

Plain Language Summary

As I have been discussing, I feel that the atmosphere has approached a fork in the road for the winter. The first path is an overall colder solution while the second path means an overall milder remainder to the winter. I remain conflicted how the winter will evolve over the coming weeks. However, I am confident that a stretched polar vortex will occur in early January and therefore I expect cold temperatures in western North America to expand eastward during the first two weeks of January. Though the models are providing little or shaky support for my expectations.

Impacts

I continue to be baffled from the extended period where the stratosphere and the troposphere remain uncoupled. In the past three blogs now, I have discussed, at least for me, how the winter evolves from here has reached a fork in the road and I can see two distinct paths with very different outcomes. The first path is a troposphere-stratosphere-troposphere (T-S-T) coupling event that in the short term is characterized by a relatively cold period across the Northern Hemisphere (NH) continents but transitions to an extended period of a strong polar vortex (PV), a positive AO/NAO and widespread relatively mild temperatures across the NH continents starting most likely in mid-January. This first path is supported by the polar cap geopotential height anomalies (PCHs) which shows cold/negative PCHs in the stratosphere and we are currently in the mid-point of this T-S-T coupling event where the mild tropospheric response to the strong PV is delayed but it is coming.

The second path is where the relatively cold period across the NH continents for the end of December and into early January disrupts the overall mild T-S-T coupling event. In its place, we are at the very beginning of a T-S-T coupling event that favors a more disrupted PV and the remainder of the winter is overall colder than the first path. In this second path or scenario the upcoming cold period would not be continuous but would also transition to a milder period in mid- to late-January, but a significant weakened PV would couple to the surface leading to potentially an extended cold period in late winter. And it is frustrating for me at least that I still am not confident of one scenario over another.

Looking at the latest polar cap geopotential height anomalies (PCHs) plot (see **Figure 11**), the PCHs in the stratosphere have been trending warmer and they may even turn slightly warm the first week of January, suggestive of a disruption of an overall mild T-S-T coupling event. This would at least allow for a colder second half of winter for the US east of the Rockies, parts of Europe and maybe even East Asia (East Asia may remain cold regardless).

What I am more confident this week than the past two weeks is that a stretched polar vortex (PV) event will occur in early January. The GFS forecasts are starting to evolve into a more recognizable configuration/pattern associated with a stretched PV. See [Cohen et al. 2021](#) for composites of the stratospheric and tropospheric

circulation during stretched PV events. In the stratosphere, the dynamical model forecasts are consistently showing ridging/high pressure between Eastern Siberia and Alaska, a clearly stretched PV and strong cross polar flow from Siberia to Canada (see **Figure 13**). In the troposphere some impressively amplified ridging/high pressure across Alaska and into the Beaufort Sea coupled with downstream troughing/low pressure in Eastern Canada (see **Figure 8**). But even with this favorable circulation for cold temperatures east of the Rockies, the models continue to hang back the cold in the Western US and flip flopping on whether the cold ever moves into the Central and Eastern US. I think that I have been fairly consistent in expressing my expectations that the cold does move east. Not sure why the models remain so hesitant to move the cold east, but it could be related to the La Niña/negative Pacific Decadal Oscillation/Madden Julian Oscillation stalled in phase seven overwhelming other signals.

As I mentioned last week often after a stretched PV event, the PV can quickly strengthen. I think a relevant example for this winter would be winter 2019/20. A stretched PV event in December transitioned to a record strong PV in January and February. Right now, I don't see a repeat. On this date in 2019, the GFS was already predicting low geopotential heights in the Central Arctic and a dramatic warmup across all of Northern Eurasia except for Eastern Siberia. Though the hemispheric pattern is less than optimal to disrupting the PV, I think that the relatively cold temperatures across Northern Asia will likely persist and will exert some sort of torque on the PV. Will it be enough to meaningfully disrupt the PV, to be honest I don't know.

In summary, still lots of uncertainty how the weather pattern evolves across the Northern Hemisphere beyond a week. I am most confident about a stretched PV that should pull the cold air western North America east of the Rockies at least into the Great Lakes region but the dynamical models are not supportive of this idea. I don't think a stretched PV is supportive of cold temperatures in Europe, but it does seem cold air in Western Asia may be available for advection into Eastern Europe. The tropospheric response to a stretched PV is typically two weeks or less and temperatures would turn milder later in January regardless. Later in January or in February there could be another stretched PV, a more significant PV disruption related to a sudden stratospheric warming (SSW) or a stronger than normal PV. Either of the two PV disruptions would favor an overall colder pattern with the cold focused in North America for a stretched PV but across northern Eurasia for an SSW. The strong PV would favor an overall milder pattern.

Live by the PV, die by the PV. I wish I had something more profound to say but this just remains such a challenging winter to understand and predict. I have been surprised how the EPS has consistently predicted a strong to very strong PV for many weeks now. I admit this scenario is plausible with a stretched PV directing deflecting any upwelling energy away from the PV allowing it to strengthen. As I mentioned earlier, I am expecting relatively cold temperatures in Asia to lessen the likelihood of this scenario. I will just end that not only is it a challenging forecast for me but for the

dynamical models as well and hopefully if nothing else it will be a great learning experience.

1-5 day

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

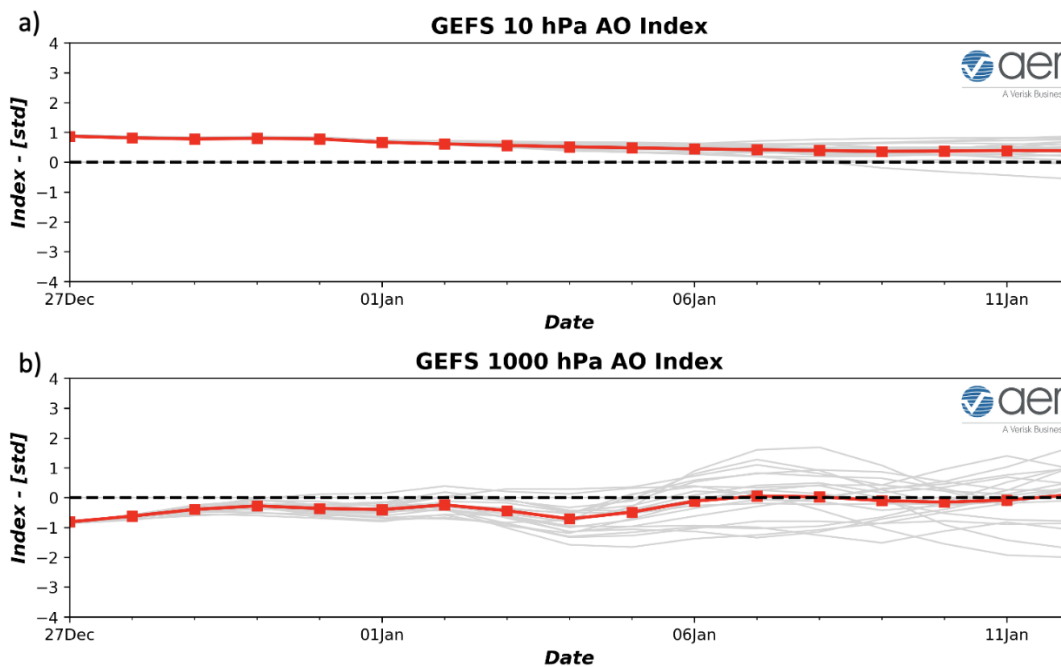


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 27 December 2021 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 27 December 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week, ridging/positive geopotential height anomalies centered across Greenland will favor troughing/negative geopotential height anomalies across Northern and Eastern Europe except for ridging/positive geopotential height anomalies across the Western and Central Europe including the UK this period (**Figures 2**). This will result in normal to below normal temperatures across much of Northern and Eastern Europe with normal to above normal temperatures across Western and Central Europe including the UK (**Figure 3**). This week, ridging/positive geopotential height anomalies centered in Laptev Sea will extend to Western Siberia sandwiched by troughing/negative geopotential height anomalies across Northwestern Asia and Northeastern Asia with

more ridging/positive geopotential height anomalies across Southern Asia (Figure 2). This pattern favors normal to below normal temperatures across much of Northwestern and Northeastern Asia with normal to above normal temperatures across Western Siberia and Southern Asia (Figure 3).

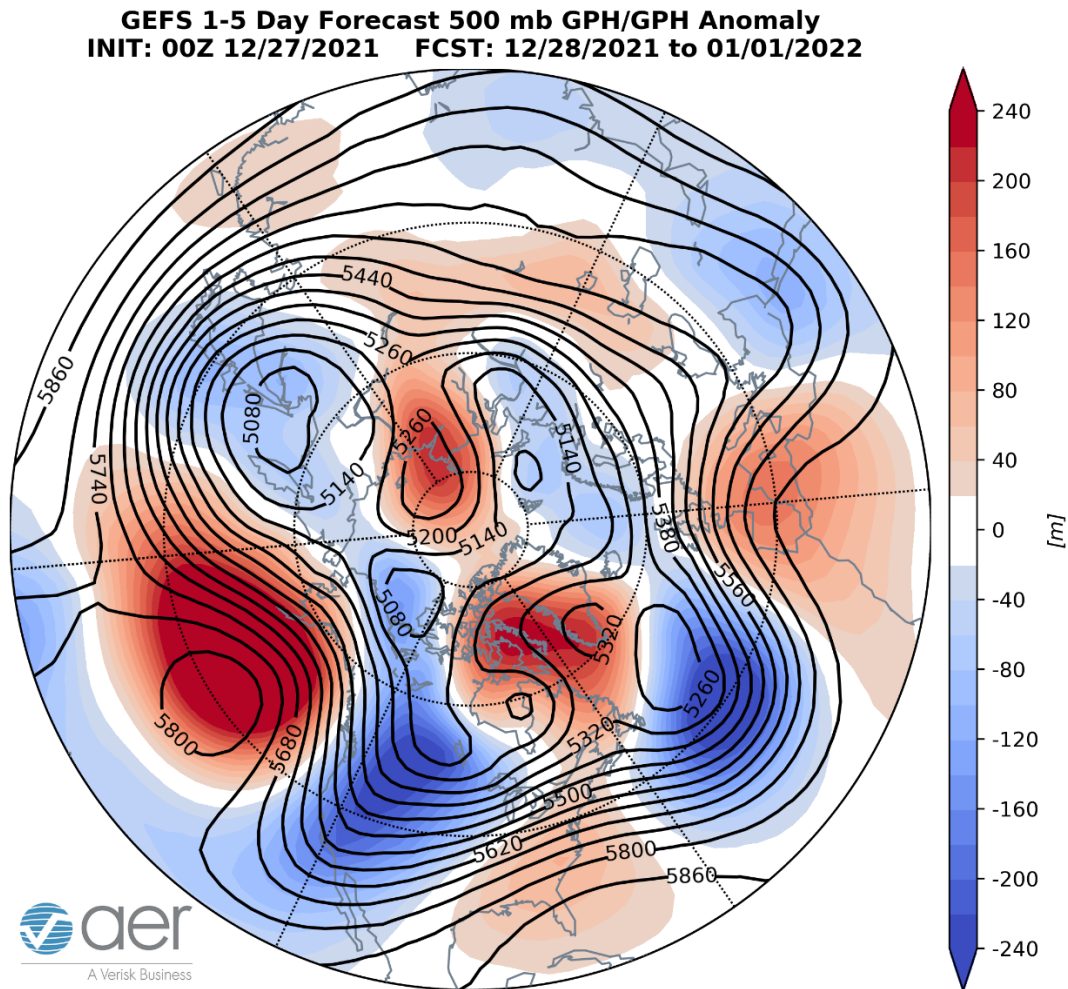


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 28 December 2021 – 1 January 2022. The forecasts are from the 00z 27 December 2021 GFS ensemble.

Amplified ridging/positive geopotential height anomalies south of the Aleutians will contribute to deep troughing/negative geopotential height anomalies in western North America with ridging/positive geopotential height anomalies across Northeastern Canada and the Southeastern US this period (Figure 2). This will favor normal to below normal temperatures across northern Alaska, Western and Central Canada and the Western US and the Northern Plains with normal to above normal temperatures in Eastern Canada and much of the Southern and Eastern US (Figure 3).

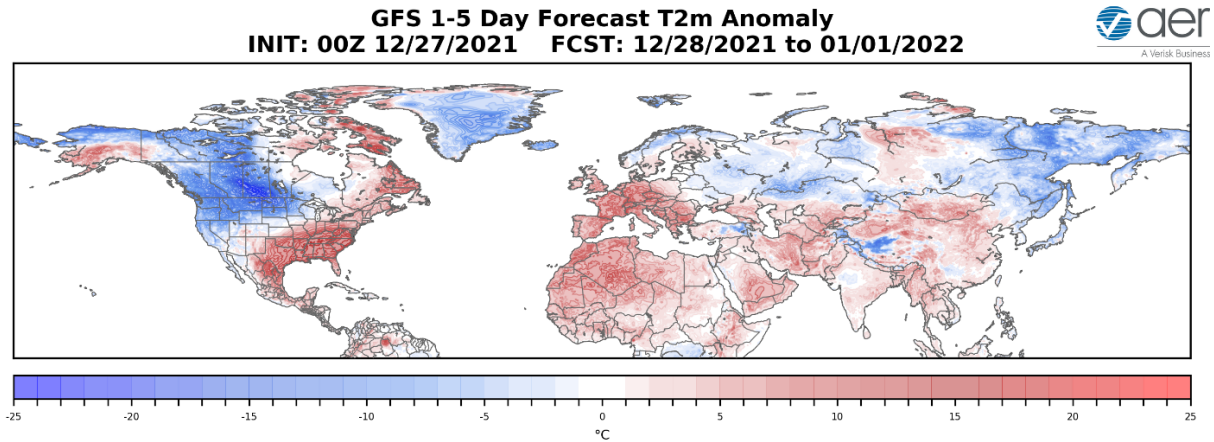


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 28 December 2021 – 1 January 2022. The forecast is from the 00Z 27 December 2021 GFS ensemble.

Trouging and/or cold temperatures are predicted to support new snowfall across Northern Europe, Western, Central and Eastern Asia while mild temperatures promote snowmelt in Central and Eastern Europe and the high elevations of Southern Asia (**Figure 4**). Trouging and/or cold temperatures are predicted to support new snowfall across Alaska, much of Western and Eastern Canada and the Western and Northern US while mild temperatures promote snowmelt in New England (**Figure 4**).

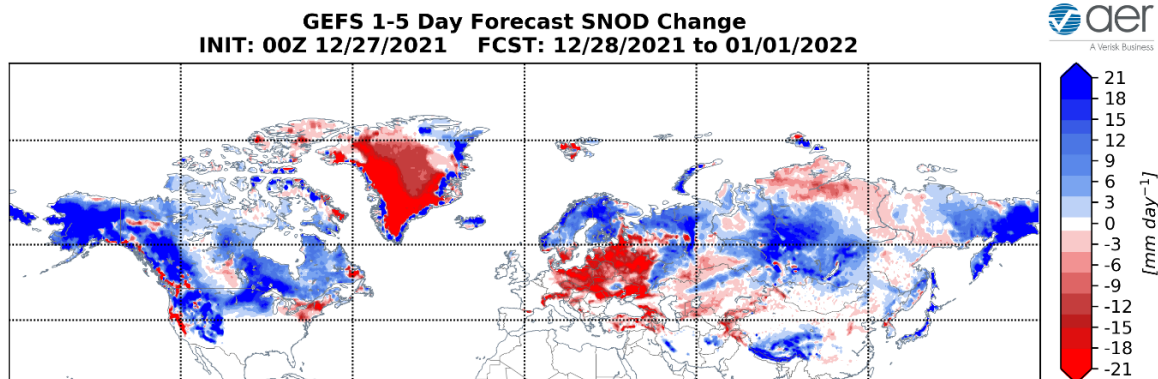


Figure 4. Forecasted snow depth changes (mm/day ; shading) from 28 December 2021 – 1 January 2022. The forecast is from the 00Z 27 December 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain negative this period (**Figure 1**) as positive geopotential height anomalies dominate the Arctic with mixed geopotential height anomalies across

the mid-latitudes of the NH (**Figure 5**). And with persistent positive geopotential height anomalies across Greenland (**Figure 5**), the NAO is predicted to remain neutral to negative this period.

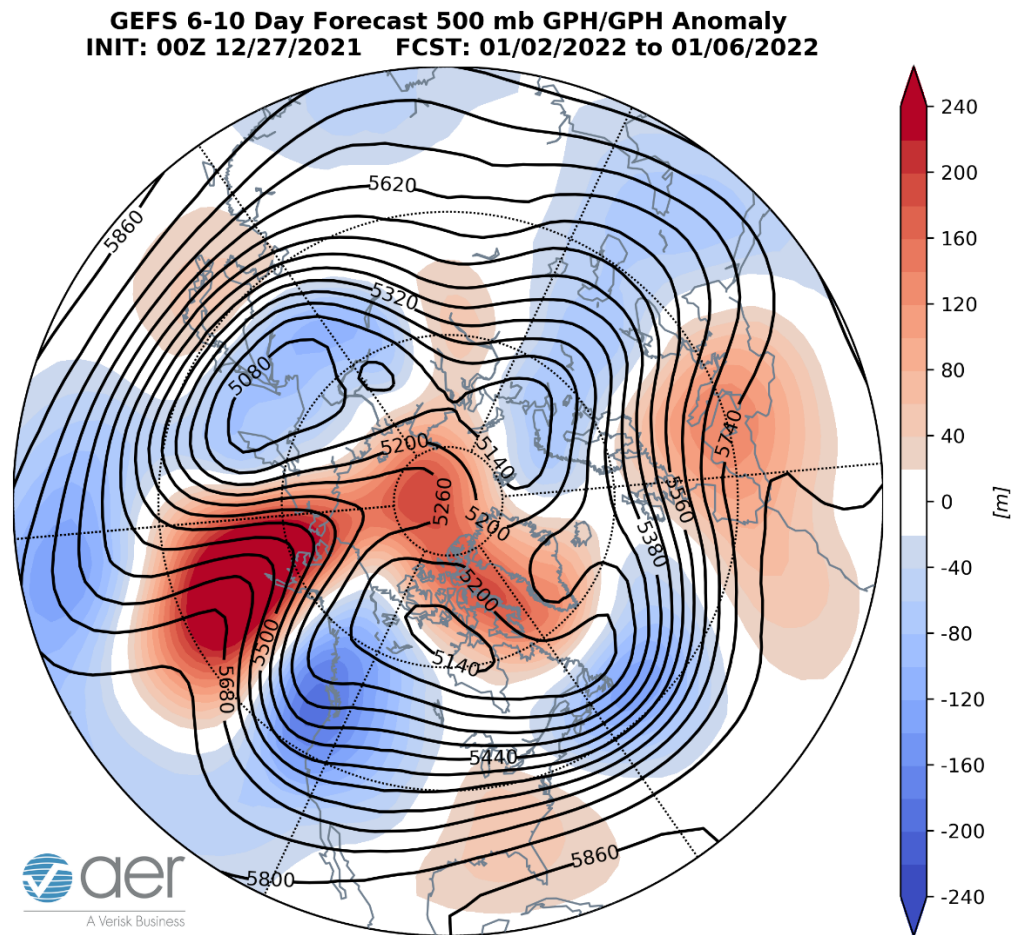


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 2 – 6 January 2022. The forecasts are from the 00z 27 December 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies previously across Greenland will continue to support troughing/negative geopotential height anomalies widespread across Northern and Eastern Europe with ridging/positive geopotential height anomalies across Western Europe including the UK (**Figures 5**). This will result in normal to below normal temperatures across Northern and Eastern Europe with normal to above normal temperatures across Western and Central Europe including the UK (**Figure 6**). Troughing/negative geopotential height anomalies are predicted to stretch across all of Northern Asia with ridging/positive geopotential height anomalies across Southern Asia this period (**Figure 5**). This pattern favors normal to below normal

temperatures across much of Northern and Eastern Asia with normal to above normal temperatures across Western and Southern Asia (**Figure 6**).

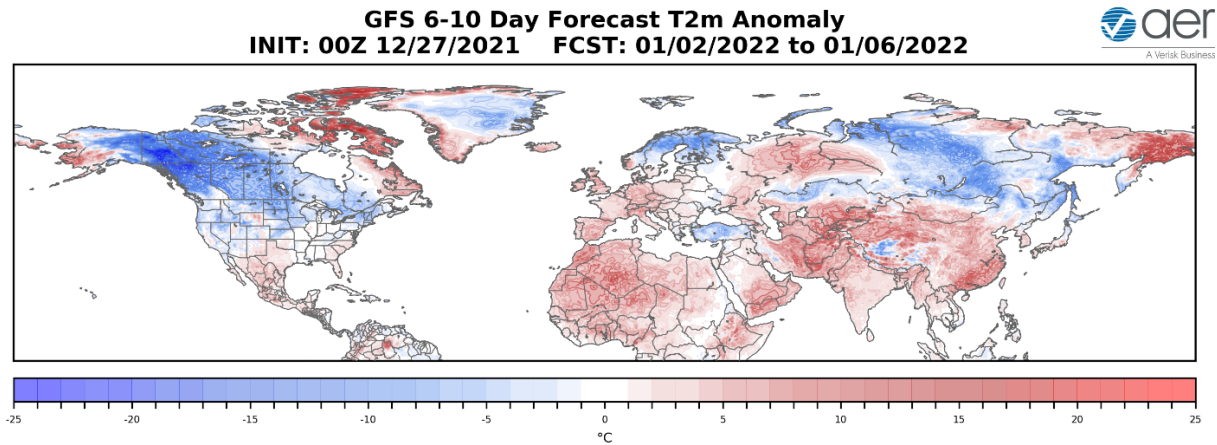


Figure 6. Forecasted surface temperature anomalies (°C; shading) from 2 – 6 January 2022. The forecasts are from the 00Z 27 December 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies south of the Aleutians will anchor troughing/negative geopotential height anomalies across Western Canada and the Western US with ridging/positive geopotential height anomalies across Northeastern Canada and in the US along the Gulf of Mexico this period (**Figure 5**). However more widespread ridging in the Central Arctic and Baffin Bay will support more troughing in Southeastern Canada and the Northeastern US (**Figure 5**). This will favor normal to below normal temperatures across Alaska, Western and Southern Canada and the Northern and Western US with normal to above normal temperatures in Northeastern Canada and the Southeastern US (**Figure 6**).

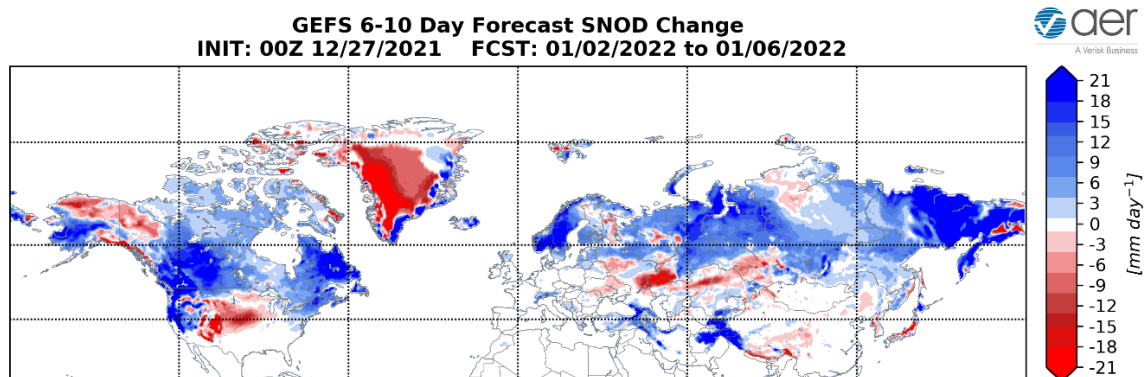


Figure 7. Forecasted snow depth changes (mm/day; shading) from 2 – 6 January 2022. The forecast is from the 00Z 27 December 2021 GFS ensemble.

Trouging and/or cold temperatures are predicted to support new snowfall across Northern and Eastern Europe, the Alps, Eastern Turkey, Northern Asia and the Tibetan Plateau while milder temperatures promote snowmelt across the higher elevations of Southeastern Europe and Southern Asia (**Figure 7**). Trouging and/or cold temperatures are predicted to support new snowfall across southwestern Alaska, much of Canada and the Western and Northeastern US while milder temperatures promote snowmelt across the US Plains (**Figure 7**).

11-15 day

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

GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 12/27/2021 FCST: 01/07/2022 to 01/11/2022

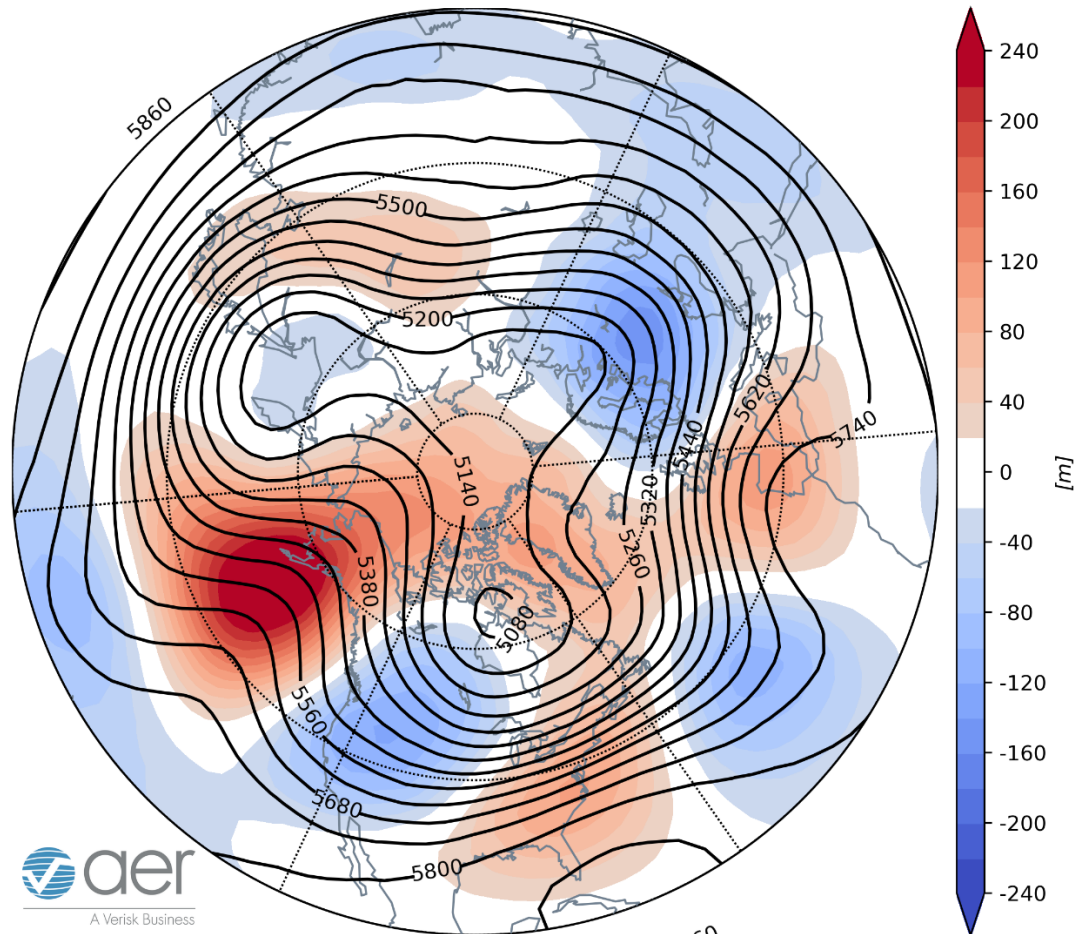


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 7 – 11 January 2022. The forecasts are from the 00z 27 December 2021 GFS ensemble.

Persistent Greenland ridging/positive geopotential height anomalies are predicted to continue to support troughing/negative geopotential height anomalies across Northern and Eastern Europe with ridging/positive geopotential height anomalies across Western Europe this period (**Figure 8**). This pattern favors more normal to below normal temperatures across Northern and Eastern Europe with normal to above normal temperatures across Western Europe including the UK this period (**Figures 9**). Troughing/negative geopotential height anomalies are predicted across Northern and especially in Western Asia with ridging/positive geopotential height anomalies across Western Siberia and Southern Asia this period (**Figure 8**). This pattern favors more widespread normal to above normal temperatures across Southern Asia and Western Siberia with normal to below normal temperatures across much of Northern Asia this period (**Figure 9**).

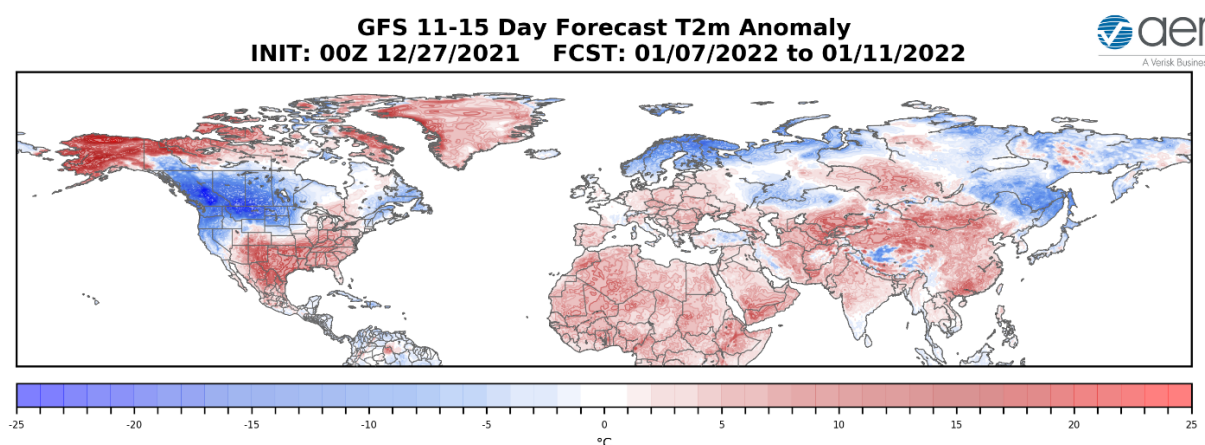


Figure 9. Forecasted surface temperature anomalies (°C; shading) from 7 – 11 January 2022. The forecasts are from the 00z 27 December 2021 GFS ensemble.

Persistent ridging/positive geopotential height anomalies centered south of the Aleutians are predicted to anchor troughing/negative geopotential height anomalies in western North America with ridging/positive geopotential height anomalies across Northeastern Canada and the Southeastern US this period (**Figure 8**). This pattern favors normal to below normal temperatures across Western and Southern Canada, the Northwestern US and New England with normal to above normal temperatures in Northern and Eastern Canada and the Southern and Eastern US (**Figure 9**).

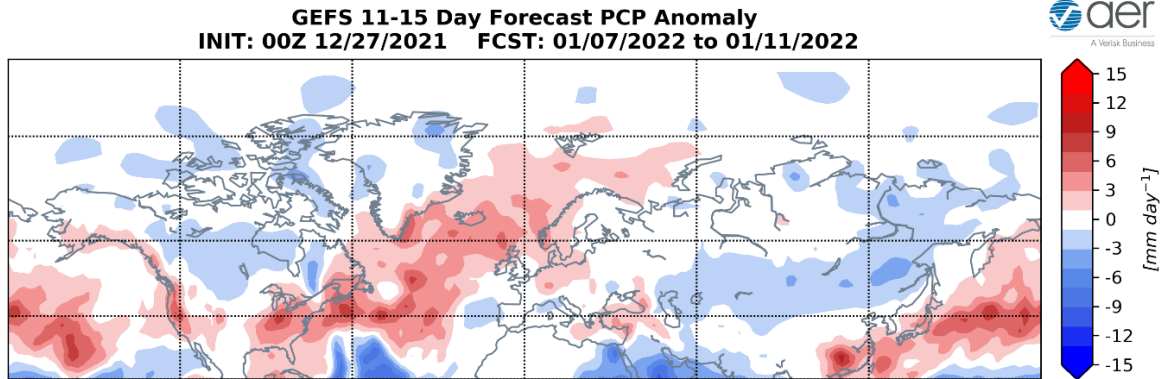


Figure 10. Forecasted snow depth changes (mm/day; shading) from 7 – 11 January 2022. The forecast is from the 00Z 27 December 2021 GFS ensemble.

Trouging and/or cold temperatures are predicted to support possible new snowfall across Central and Eastern Europe including Turkey and much of Western and Northern Asia while milder temperatures promote snowmelt across the higher elevations of Southern Asia (**Figure 10**). Trouging and/or cold temperatures are predicted to support possible new snowfall across Southern Alaska, Southern and Eastern Canada and the Northern US while milder temperatures promote snowmelt across parts of Alaska, Western Canada and the Western US (**Figure 10**).

Longer Term

30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows cold/negative PCHs throughout the stratosphere and warm/positive PCHs in the troposphere (**Figure 11**). The largest negative departures are currently and are predicted to weaken to neutral in the upper stratosphere (**Figure 11**). Currently the stratosphere and troposphere are decoupled and waiting for coupling to resume, though exactly how remains an open question to me.

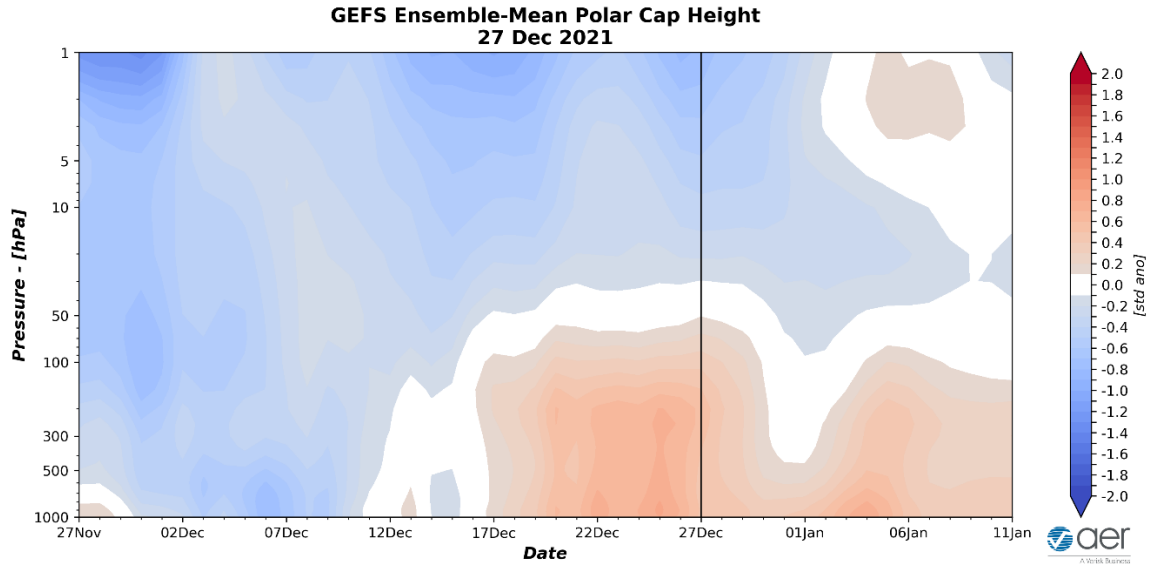


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 27 December 2021 GFS ensemble.

The normal to above normal PCHs predicted this week in the lower troposphere are consistent with the predicted negative surface AO this week and negative to neutral AO next week (**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 through mid-January (**Figure 12**). The uptick in WAFz is consistent with recent and predicted Urals and to the east of the Urals ridging this week and next week (**Figure 12**). However, the positive WAFz anomalies are relatively weak, and the strong polar vortex should remain normal to strong through mid-January as suggested by the near normal to relatively cold stratospheric PCHs. Though I continue to believe a stretched polar vortex will take place in early January, so something to watch.

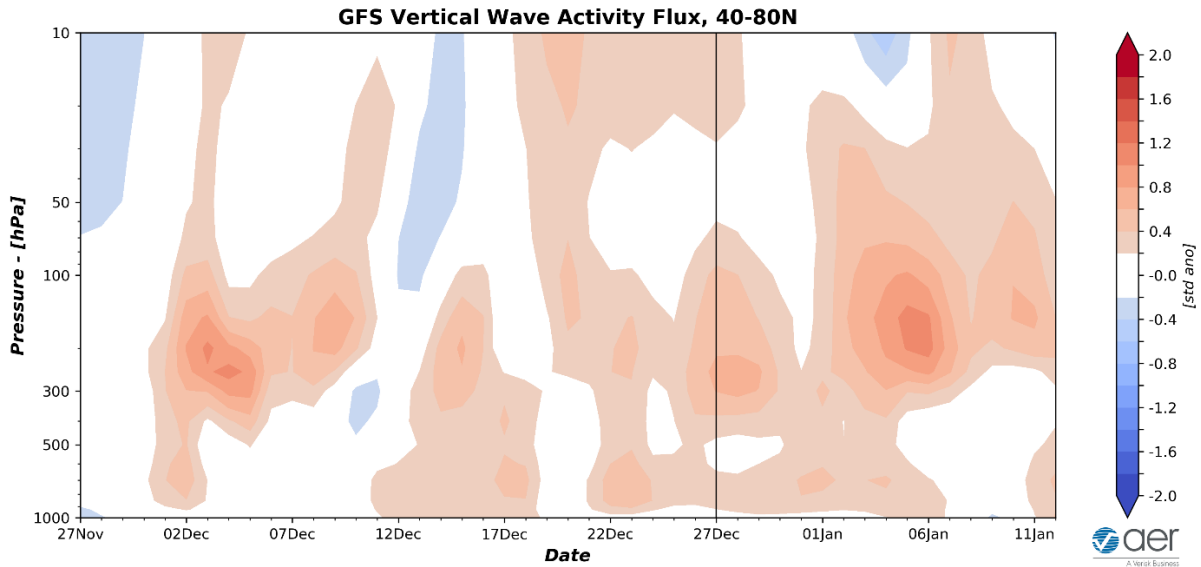


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 27 December 2021 GFS ensemble.

The recent uptick in WAFz has perturbed the stratospheric PV with the PV center displaced towards the North Atlantic and centered over Svalbard with ridging between Eastern Siberia and the Dateline and polar stratospheric warming across Eurasia (**Figure 13**). However, the perturbation is relatively minor, and the PV is relatively strong resulting in a current positive stratospheric AO (**Figure 11**).

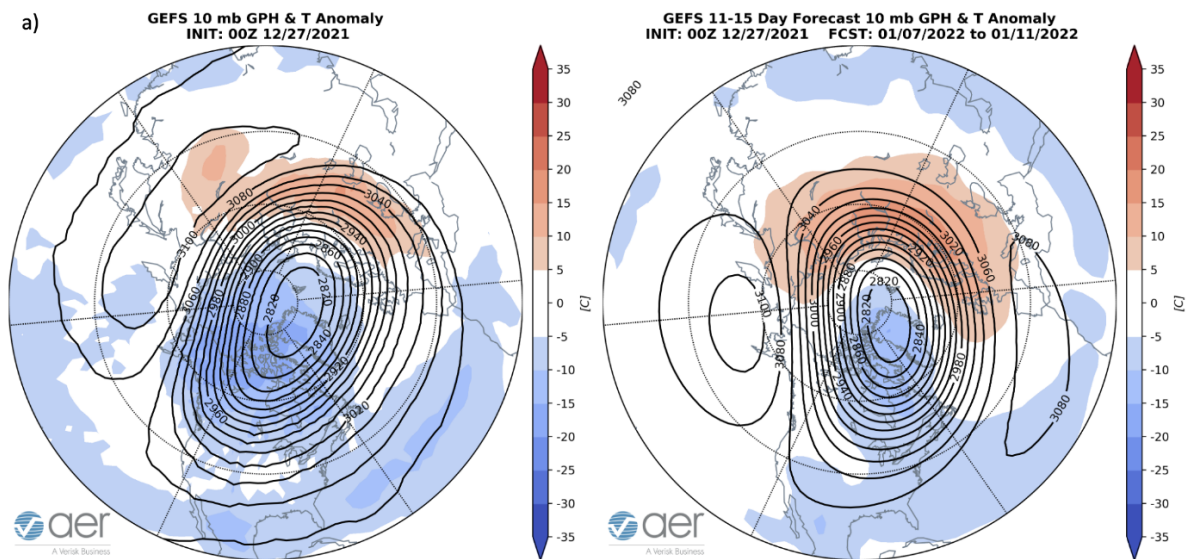


Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 27 December 2021. (b)

Same as (a) except forecasted averaged from 7 – 11 January 2022. The forecasts are from the 00Z 20 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 with the PV centered near Greenland the second week of January (**Figure 13**) with a persistent positive stratospheric AO the next two weeks (**Figure 11**). However, strengthening polar stratospheric ridging near the Dateline with additional warming swinging to the east out of Eurasia is suggestive of a stretched PV (**Figure 13**). In fact, the strong cross polar flow from Siberia to Canada is looking more canonical stretched PV.

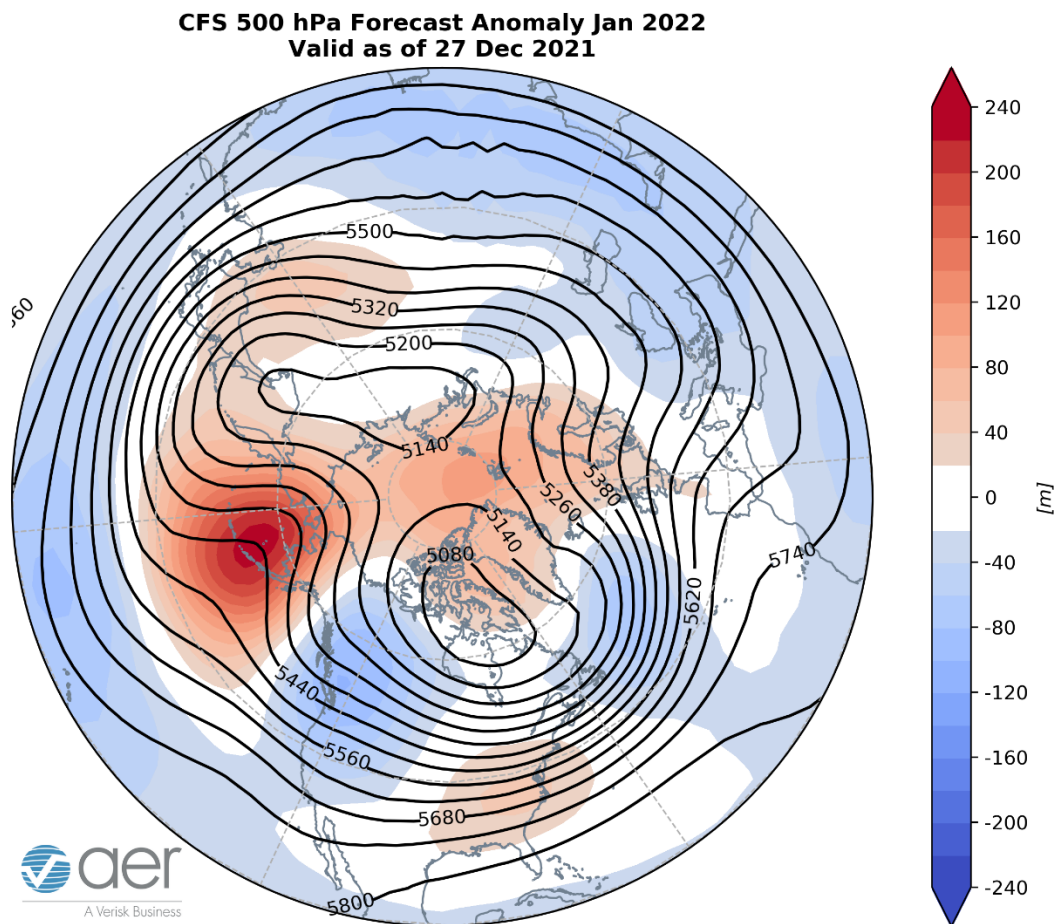


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for January 2022. The forecasts are from the 00Z 27 December 2021 CFS.

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 over Western Europe, Central Asia and especially centered near the Aleutians and in the Southeastern US with troughing across Western Asia, Northeastern Asia and western North America (**Figure 14**). This pattern favors seasonable to relatively warm temperatures widespread across Western and Central Europe, the Southern two thirds of Asia, Eastern Canada and the Eastern US with seasonable to relatively cold temperatures across Northern Europe, Northern Asia, Alaska, much of Western and Central Canada and the Western US (**Figure 15**). The cold in Western Canada could be extreme based on the CFS forecast.

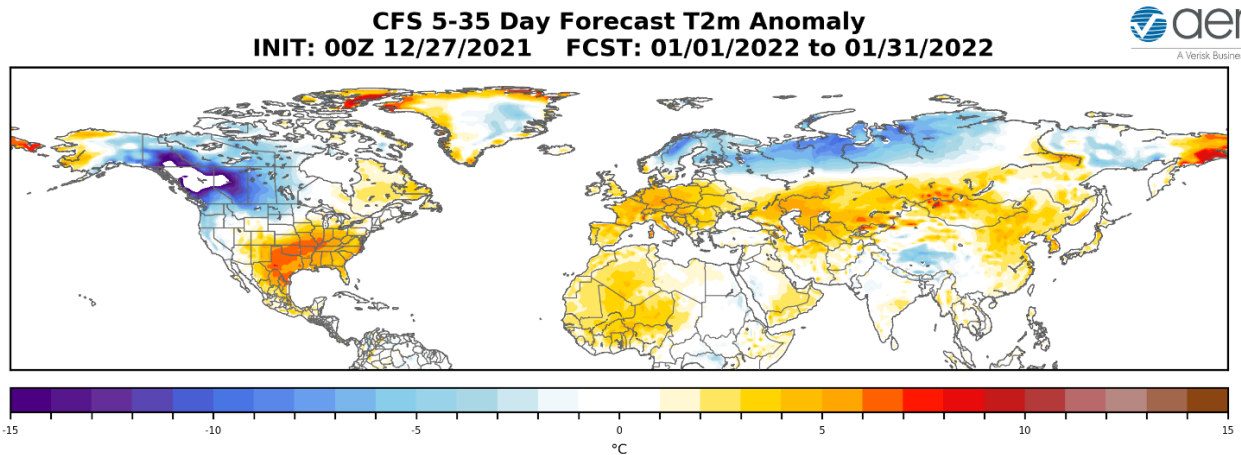


Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for January 2022. The forecasts are from the 00Z 27 December 2021 CFS.

Surface Boundary Conditions

Arctic Sea ice

Arctic sea ice is growing but remains below normal mostly in Baffin Bay. In the Barents-Kara Seas extent is close 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.

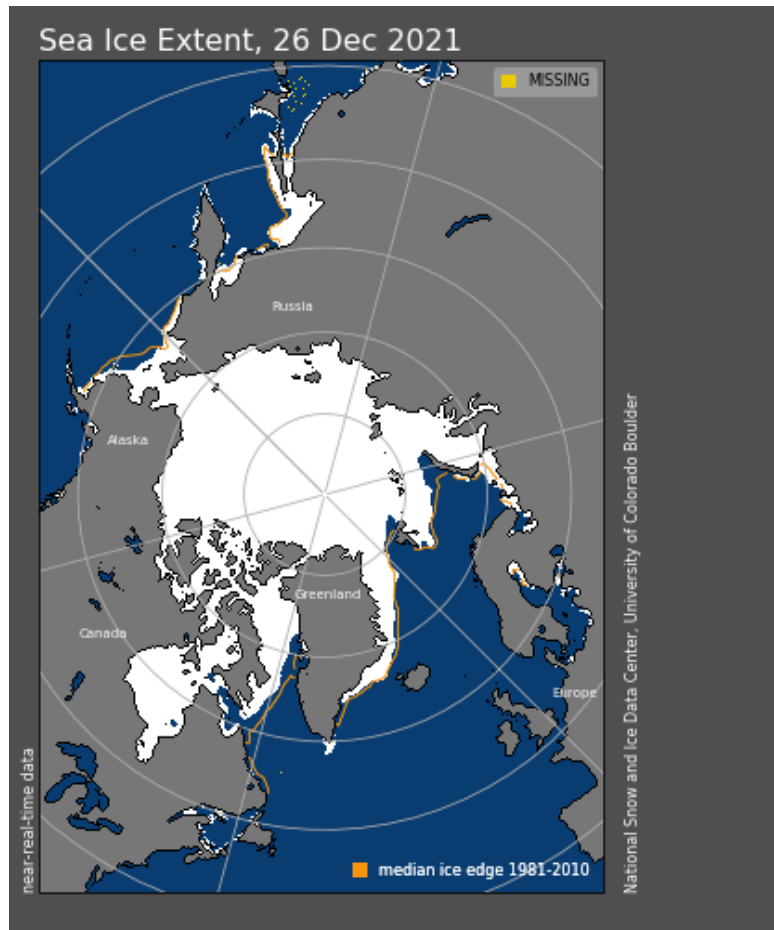


Figure 16. Observed Arctic sea ice extent on 19 December 2021 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies are below normal and we continue to observe weak to possibly moderate 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.

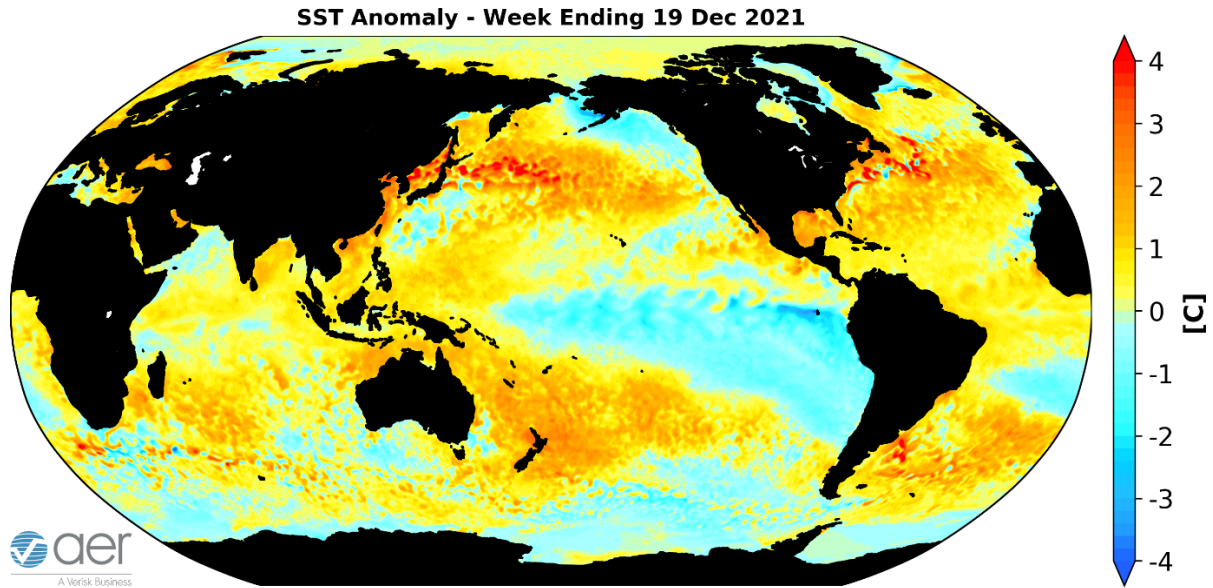


Figure 17. The latest weekly-mean global SST anomalies (ending 19 December 2021). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase seven (**Figure 18**). The forecasts are for the MJO to linger in phase seven through early January. MJO phase seven favors high latitude blocking including Alaska. Initially phase seven favors troughing and cold temperatures in the Western US and ridging and mild temperatures in the Eastern US but then reverses. The warm forecasts in the East are consistent with MJO forcing this week but admittedly this is outside of my expertise.

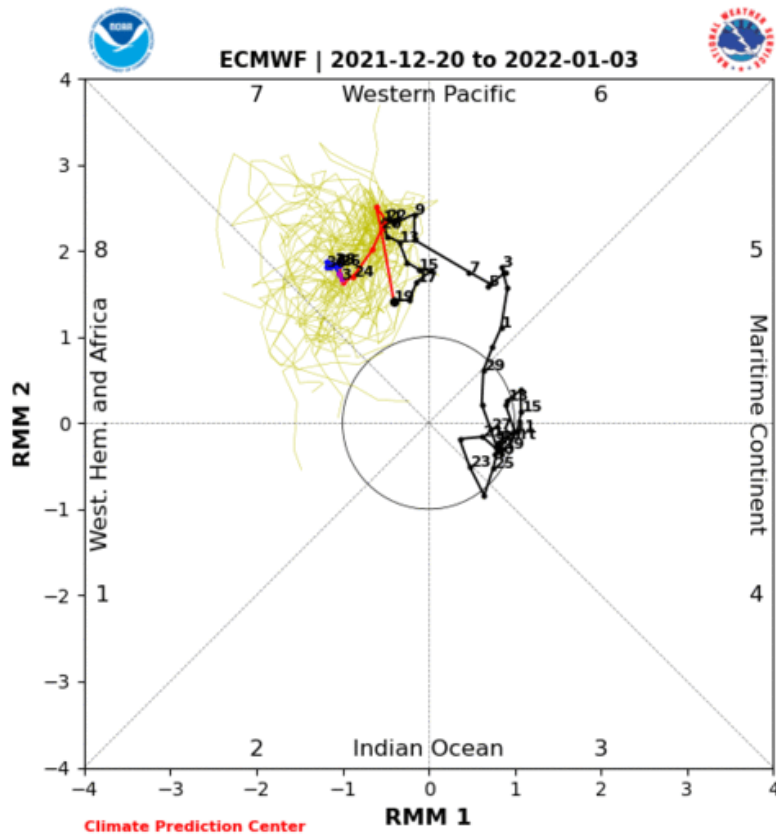


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 20 December 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>

Get Detailed Seasonal Weather Intelligence with sCast

We appreciate your taking the time to read the public Arctic Oscillation blog from Dr. Judah Cohen and the AER Seasonal Forecasting team.

Dr. Cohen’s detailed monthly seasonal forecast, sCast, is also available for purchase. sCast provides a monthly 30-60-90-180-day outlook into temperature and precipitation, solar flux and wind anomalies across the globe, and regional population weighted cooling and heating degree forecasts for the US.

Our sCast principal engineer, [Karl Pfeiffer](#), can help you use sCast and other AER seasonal forecast products to deliver important, long-lead time weather intelligence to your business. Please reach out to Karl today!