

Arctic Oscillation and Polar Vortex Analysis and Forecasts

November 20, 2023

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. In late 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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Summary

- The Arctic Oscillation (AO) is currently neutral and is predicted to slowly trend negative the next two weeks as pressure/geopotential height anomalies across the Arctic are currently mixed and are predicted to become mostly positive over the next two weeks. The North Atlantic Oscillation (NAO) is currently neutral with weak and mixed pressure/geopotential height anomalies across Greenland and the NAO is predicted to trend negative the next two weeks as pressure/geopotential height anomalies become increasingly positive across Greenland.
- Over the next two weeks, ridging/positive geopotential height anomalies in the North Atlantic including Greenland will force troughing/negative geopotential

height anomalies across Northern and Eastern Europe with more ridging/positive geopotential height anomalies across Southwestern Europe. This pattern will support normal to below normal temperatures across Northern and Eastern Europe including the United Kingdom (UK) with normal to above normal temperatures across Southwestern Europe the next two weeks.

- The next two weeks an omega pattern is predicted across Asia with ridging/positive geopotential height anomalies across Central Asia bookended by troughing/negative geopotential height anomalies across Western and Eastern Asia. This pattern favors widespread normal to above normal temperatures across much of Asia especially Central Asia including much of Siberia with normal to below normal temperatures limited to Northwest Russia and Northeastern Asia. One exception is this week with normal to below normal temperatures across Western and Central Siberia.
- The general predicted pattern across North America the next two weeks is ridging/positive geopotential height anomalies across western North America forcing troughing/negative geopotential height anomalies across eastern North America. However next week troughing will spread west across the United States (US). This pattern generally favors normal to above normal temperatures across Alaska, Western Canada and the Western US with normal to below normal temperatures across Eastern Canada and the Eastern US this week. However next week below normal temperatures will spread across the Western US as well.
- in the Impacts section I discuss my expected evolution of polar vortex (PV) behavior over the coming weeks and the impact on Northern Hemisphere (NH) weather.

Plain Language Summary

All models predict a stretching of the polar vortex (PV) like a rubber band being pulled on both ends to bring colder and snowier weather to East Asia and eastern North America in the last week of November (see **Figure 6**). Separately some high pressure in the North Atlantic and possibly even Greenland will bring colder weather to Northern Europe to end the month of November.

Longer term the outlook for December is exceptionally challenging in my opinion. The default is mild and is the forecast by the weather models (see **Figure iii**). But disruptions of the polar vortex (PV) could bring locally colder weather.

Impacts

The stretched PV for the end of November is on track and much of the US is predicted to be cold for the last third of November (see **Figure 6**). What seems independently to me, high pressure ridging is predicted to bring colder temperatures to Europe as well, especially across Northern Europe. Right now, the cold air is mostly confined to Northern Europe but is predicted to become more widespread with time. The GFS more so than the ECWMF model and the Canadian models, is predicting some

Greenland blocking as well, which if correct could result in even colder temperatures for Europe. But as far as I can tell the Greenland blocking is not connected to variability in the polar vortex (PV) and therefore should be of limited duration.

Not sure what is going on with Scandinavia, but it is the standout region across the Northern Hemisphere (NH) to the cold side. Looking at the fall so far it is the one region that has been below normal for the fall of 2023 (see **Figure i**). That does not look to change in the near term and to be honest, I am not sure why Scandinavia has defied the record-breaking warmth observed globally this fall. But other than Scandinavia, it has been hard to find below normal temperatures across the NH!

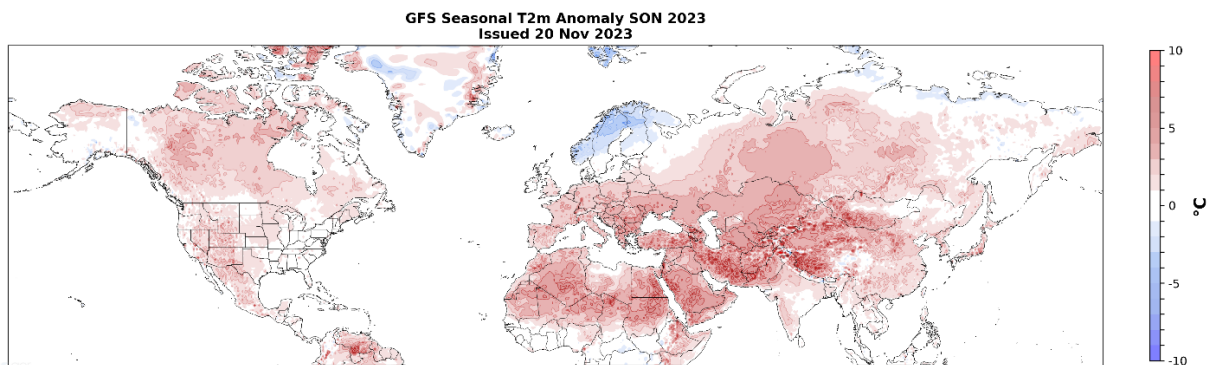


Figure i. Observed surface temperature anomalies ($^{\circ}\text{C}$; shading) from 1 September – 20 November 2023. The observations are from the GFS initializations.

However, once we roll over into December, I think the outlook becomes much more clouded. It looks to me a good possibility is a second stretched PV or a reinforcement of the late November stretched PV for early December. So, we have some seasonably cold temperatures to end the month of November, a relaxation of the pattern of sorts so back to seasonably mild and then a reinforcement of the cold air and a return to seasonably cold. So far neither stretched PV event looks impassive so for now I think a stretch (or period) of unseasonably cold weather is less likely.

But beyond the first week or so of December the forecast becomes highly uncertain. As I mentioned in last week's blog, our PV strength forecast model is showing a gradual weakening of the PV starting at the end of the week into the second week of December. But for now, I don't see a major disruption of the PV known as a sudden stratospheric warming (SSW). But whether the PV weakens consistent with our PV model forecast or not, will depend on the wave structure of the Jet Stream. And in my opinion the atmosphere is literally sitting on a fence and can go in one of two ways. It can move in a direction that weakens the PV farther or strengthens the PV.

I show in **Figure iia** the 500 hPa geopotential height forecast for the remainder of November from the CFS. We have an omega block pattern predicted across Eurasia with a trough in Europe, a ridge in Central Asia and another trough in East

Asia. In **Figure iib**, I show from the Encyclopedia of Atmospheric Sciences the climatological wave (as the anomaly from the zonal mean or latitudinal average) across Eurasia which consists of a ridge across Europe and a trough in East Asia. Amplification or constructive interference of the climatological wave across Eurasia weakens the PV and de-amplification or destructive interference of the climatological wave across Eurasia strengthens the PV. The predicted East Asian trough constructively interferes with the climatological standing wave pattern across Eurasia while the European trough destructively interferes with the climatological standing wave pattern across Eurasia. Meanwhile the Central Asia ridge is sitting in this no man's land or in the node of the Eurasian climatological standing wave, where I believe it is mostly impotent to affect the Eurasian wave and therefore the stratospheric PV.

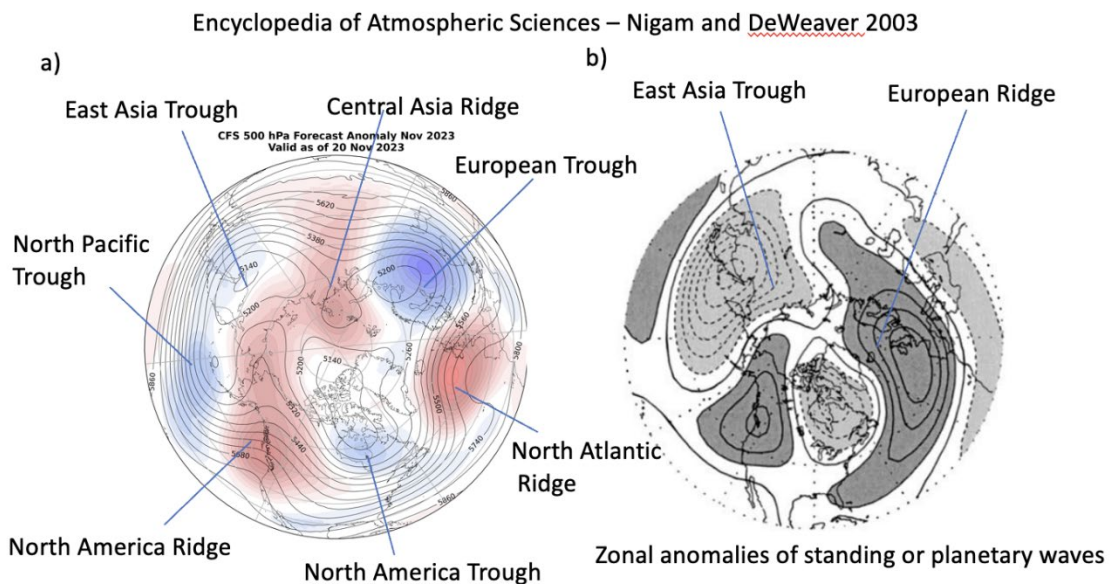


Figure ii. (a) Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for November 2023. The forecasts are from the 00Z 20 November 2023 CFS. (b) Idealized climatological anomalies from the zonal mean or latitudinal average in the geopotential heights.

Another important point is that waves one and two (you can count one or two full waves across the Northern Hemisphere) are the waves that mostly influence the stratospheric PV. We can see in **Figure iib** in the climatological average the atmosphere is strongly wave-two. However, the predicted pattern is clearly strong wave-three, not optimal for weakening the PV. In my opinion the predicted wave pattern is sufficient for the minor PV disruption of stretching but nothing larger. However, the ECMWF weeklies and the CFS are predicting that the North Atlantic ridge will slide east and maybe merge with the Central Asia ridge with the North American ridge and trough persisting (see **Figure**

14 for the CFS December forecast). If accurate then the wave three pattern of November would consolidate into a wave two pattern in December and constructively interfere with the climatological standing wave of **Figure iib** and lead to more significant weakening of the stratospheric PV. With the ridge over Europe, Europe would likely turn milder relative to normal.

I don't foresee an SSW in December, but the models seem to be suggesting a pattern that is referred to as a *Canadian warming* with high pressure ridging in the polar stratosphere over Canada and not near the Dateline and/or Alaska as in PV stretching. The orientation of the flow becomes more westerly and not northerly over North America and temperatures can turn fairly mild over the US and especially Canada during Canadian warmings. Below normal temperatures tend to be confined to Northern and Eastern Siberia closer to the PV center. I am basing this on ongoing analysis that I am involved with.

Canadian warmings can be precursors to SSWs if the forcing persists, which seems to be implied for the CFS forecast for what that is worth. Setting up the potential for an SSW in January. But I think that overall, the forecast is highly uncertain and can go in many different directions and can change significantly from week to week. The scenario where high latitude blocking almost completely disappears also needs to be respected and would lead to an extended mild period across the NH. This seems to be consistent with the dynamical model forecasts archived at Copernicus (see **Figure iii**). All the models are predicting universal warmth across the NH continents. A forecast I only see likely to verify if the PV says quite strong in the month of December.

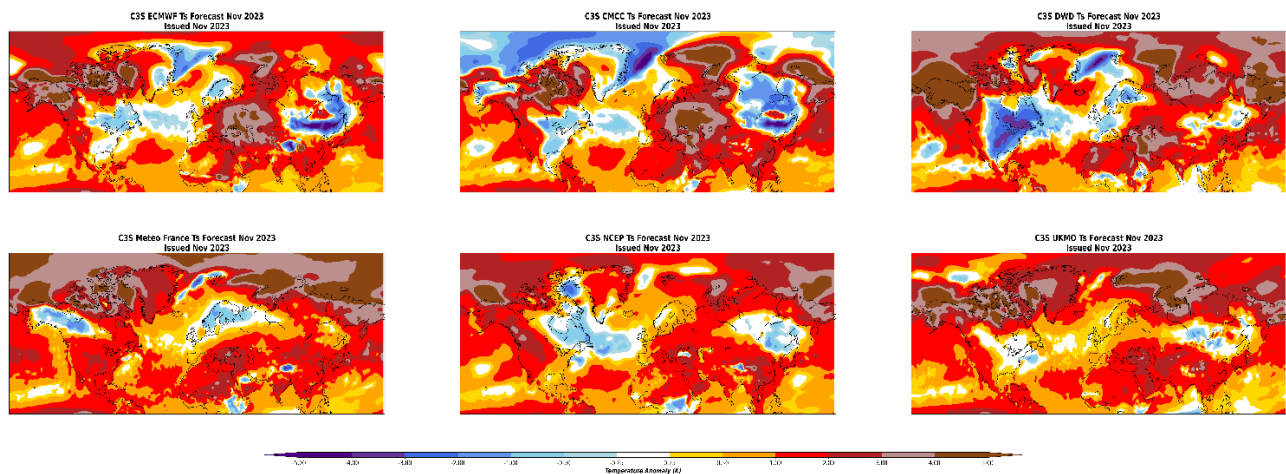


Figure iii. Forecasts for December surface temperature anomalies (°C; shading) from various dynamical models archived on the Copernicus website: https://climate.copernicus.eu/charts/packages/c3s_seasonal/

Near-Term

This week

The AO is predicted to be neutral this week (**Figure 1**) with mixed geopotential height anomalies across the Arctic and with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). With weak and mixed geopotential height anomalies across Greenland (**Figure 2**), the NAO is predicted to be near neutral this period as well.

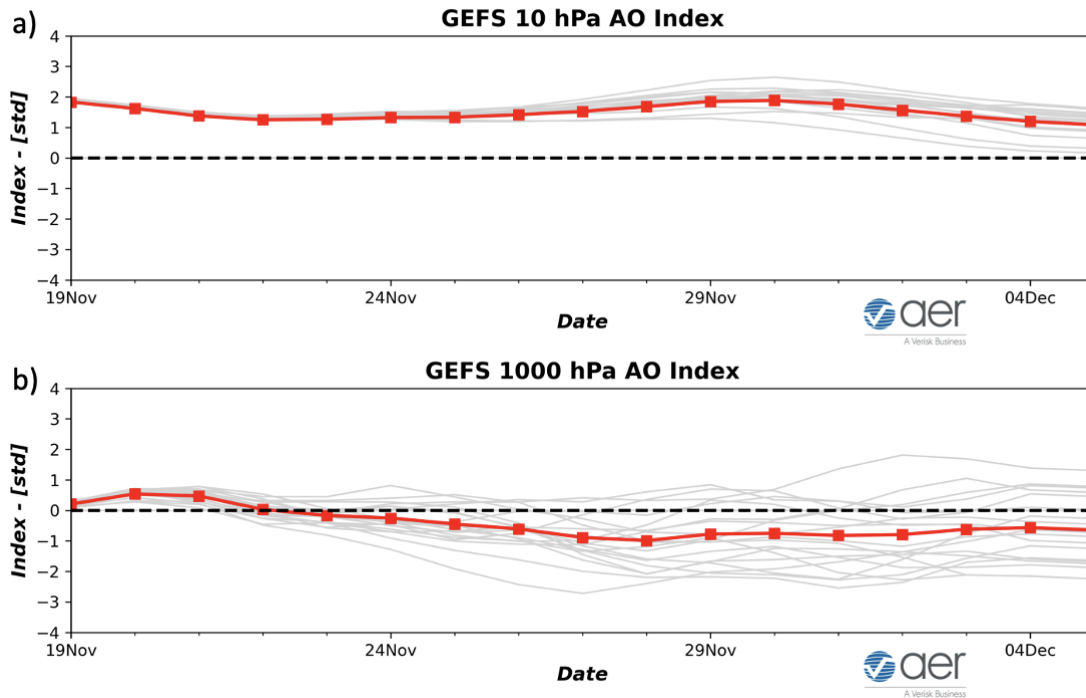


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 20 November 2023 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 20 November 2023 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Ridging/positive geopotential height anomalies centered south of Iceland will support troughing/negative geopotential height anomalies across Northern and Eastern Europe with more ridging/positive geopotential height anomalies across Western Europe this week (**Figures 2**). The pattern favors normal to below normal temperatures across Northern and Eastern Europe with normal to above normal temperatures across Western and Southern Europe including the UK (**Figure 3**). This week Central Asia is predicted to be dominated by ridging/positive geopotential height anomalies centered in east of the Urals with troughing/negative geopotential height anomalies in Western and Eastern Asia (**Figure 2**). This pattern favors widespread normal to above normal temperatures across Southern and much of Central Asia with normal to below normal temperatures across Northwest Russia, Central and Western Siberia and parts of Northeast Asia (**Figure 3**).

GEFS 1-5 Day Forecast 500 hPa Anomaly
INIT: 00Z 11/20/2023 FCST: 11/21/2023 to 11/25/2023

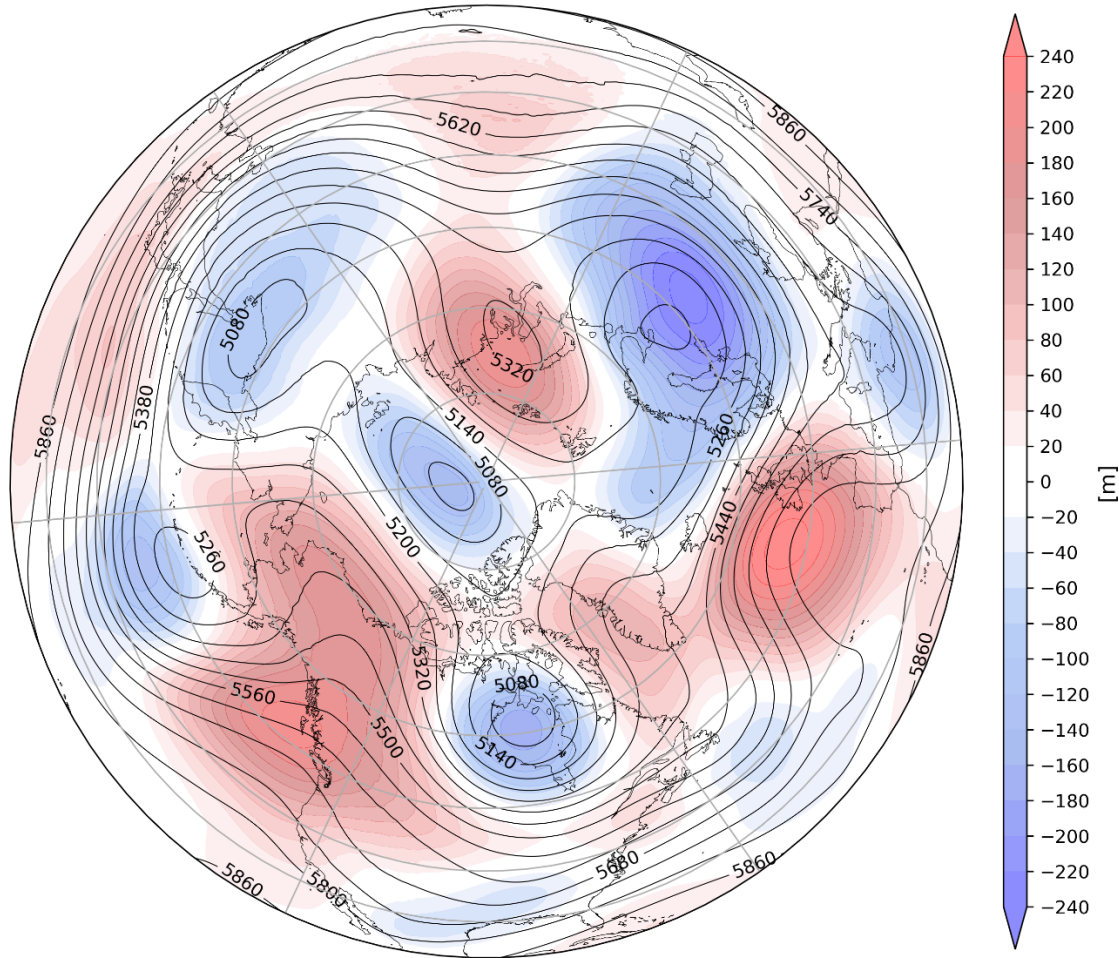


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 21 – 25 November 2023. The forecasts are from the 00z 20 November 2023 GFS ensemble.

The pattern this week across North America is ridging/positive geopotential height anomalies across western North America forcing troughing/negative geopotential height anomalies eastern North America (**Figure 2**). This pattern will favor widespread normal to above normal temperatures across Alaska, Western Canada and the Western US with normal to below normal temperatures across parts of Eastern Canada and the Eastern US (**Figure 3**).

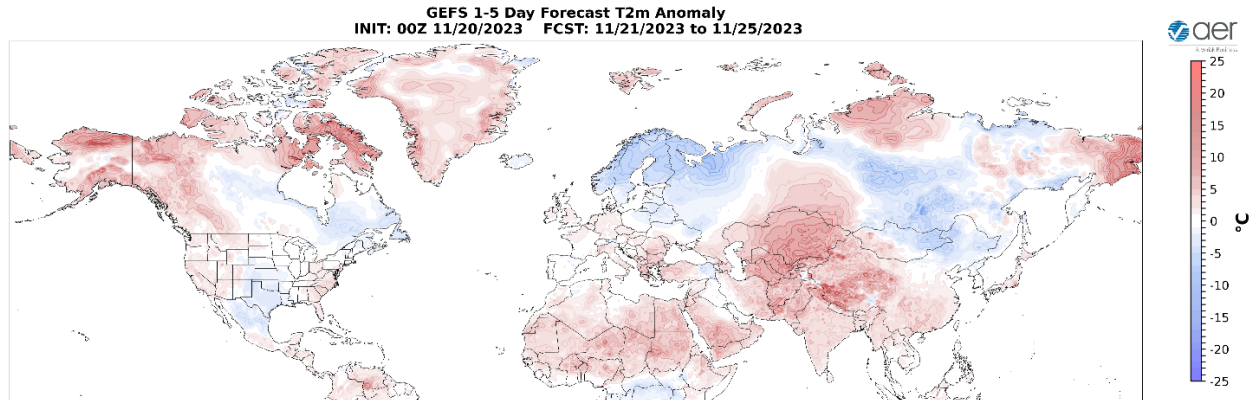


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 21 – 25 November 2023. The forecast is from the 00Z 20 November 2023 GFS ensemble.

Trouging and/or cold temperatures will support new snowfall across Scandinavia, the Alps and much of Northern Asia while mild temperatures will support snowmelt across Southern Scandinavia and parts of Central Asia this week (**Figure 4**). Trouging and/or cold temperatures will support new snowfall across Southeastern Alaska, Eastern Canada, the US Rockies and New England while mild temperatures will support snowmelt across parts of Alaska and Western Canada this week (**Figure 4**).

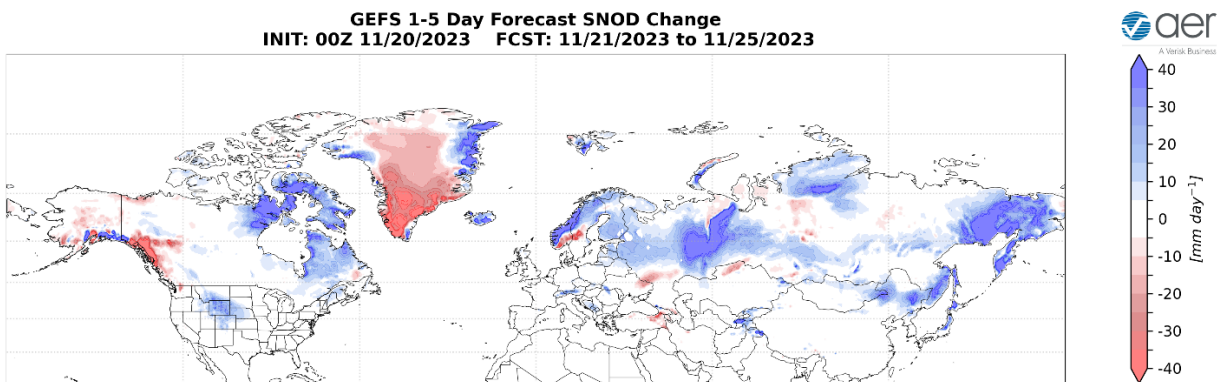


Figure 4. Forecasted snow depth changes (mm/day; shading) from 21 – 25 November 2023. The forecast is from the 00Z 20 November 2023 GFS ensemble.

Near-Mid Term

Next week

With mostly positive geopotential height anomalies across the Arctic and with mixed geopotential height anomalies across the mid-latitudes this period (**Figure 5**), the AO should turn negative this period (**Figure 1**). With predicted mostly positive

pressure/geopotential height anomalies across Greenland (**Figure 5**), the NAO will likely turn negative this period as well.

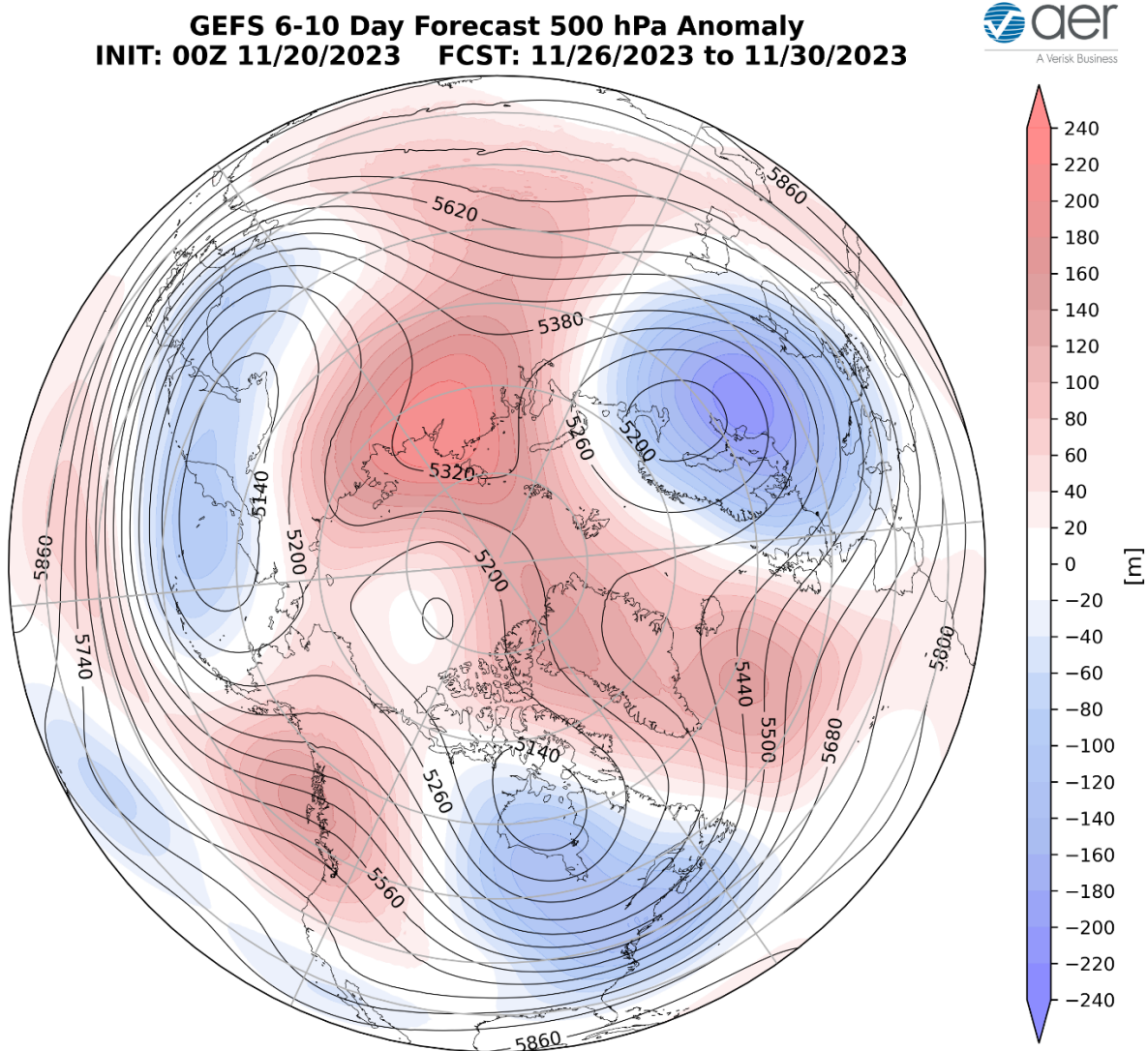


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 26 – 30 November 2023. The forecasts are from the 00z 20 November 2023 GFS ensemble.

Persistent ridging/positive geopotential height anomalies across the North Atlantic and Greenland will support troughing/negative geopotential height anomalies across Northern and Eastern Europe with more ridging/positive geopotential height anomalies across Southwestern Europe are predicted this period (**Figure 5**). The pattern will favor normal to below normal temperatures across Northern Europe including the UK with normal to above normal temperatures across far Southern Europe (**Figures 6**). Persistent troughing/negative geopotential height anomalies in Northwest and Northeast Asia are predicted to bookend ridging/positive geopotential height

anomalies stretched across Central Asia this period (**Figure 5**). This pattern favors widespread normal to above normal temperatures across much of Southern and Central Asia with normal to below normal temperatures limited to Northwest and Northeast Asia this period (**Figure 6**).

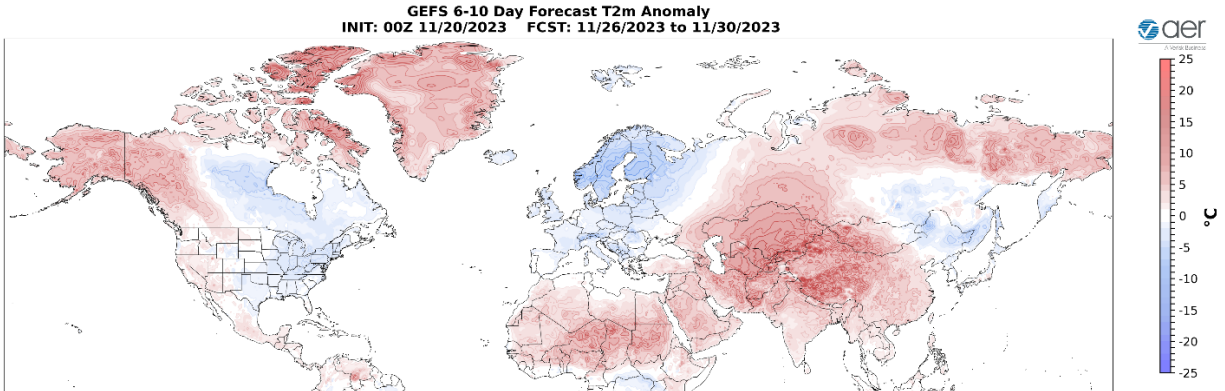


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 26 – 30 November 2023. The forecasts are from the 00z 20 November GFS ensemble.

The predicted general pattern across North America this period is persistent ridging/positive geopotential height anomalies across Alaska and Western Canada forcing downstream troughing/negative geopotential height anomalies across eastern North America (**Figure 5**). This pattern favors normal to above normal temperatures across northern Alaska, Western Canada and the Southwestern US with normal to below normal temperatures across Eastern Canada and the Northern and Eastern US (**Figure 6**).

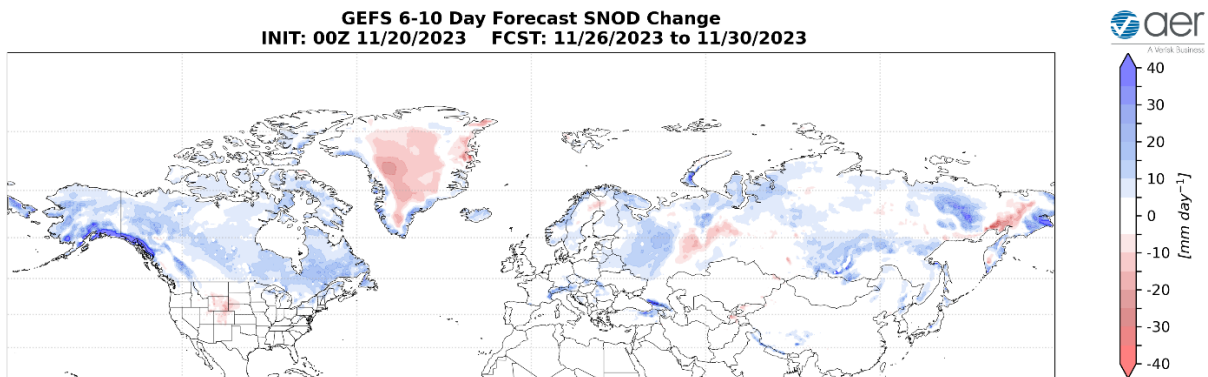


Figure 7. Forecasted snow depth changes (mm/day ; shading) from 26 – 30 November 2023. The forecast is from the 00Z 20 November 2023 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Norway, the Alps, Western Russia and much of Siberia while mild temperatures will support snowmelt in the southern Urals this period (**Figure 7**). Troughing and/or cold temperatures will

support new snowfall across much of Alaska, Northern and Eastern Canada and New England while mild temperatures will support snowmelt in the US Rockies and Plains this period (**Figure 7**).

Mid Term

Week Two

With predicted mostly positive geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes this period (**Figure 8**), the AO should remain neutral to negative this period (**Figure 1**). With predicted weak but positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO will also likely be neutral to negative this period as well.

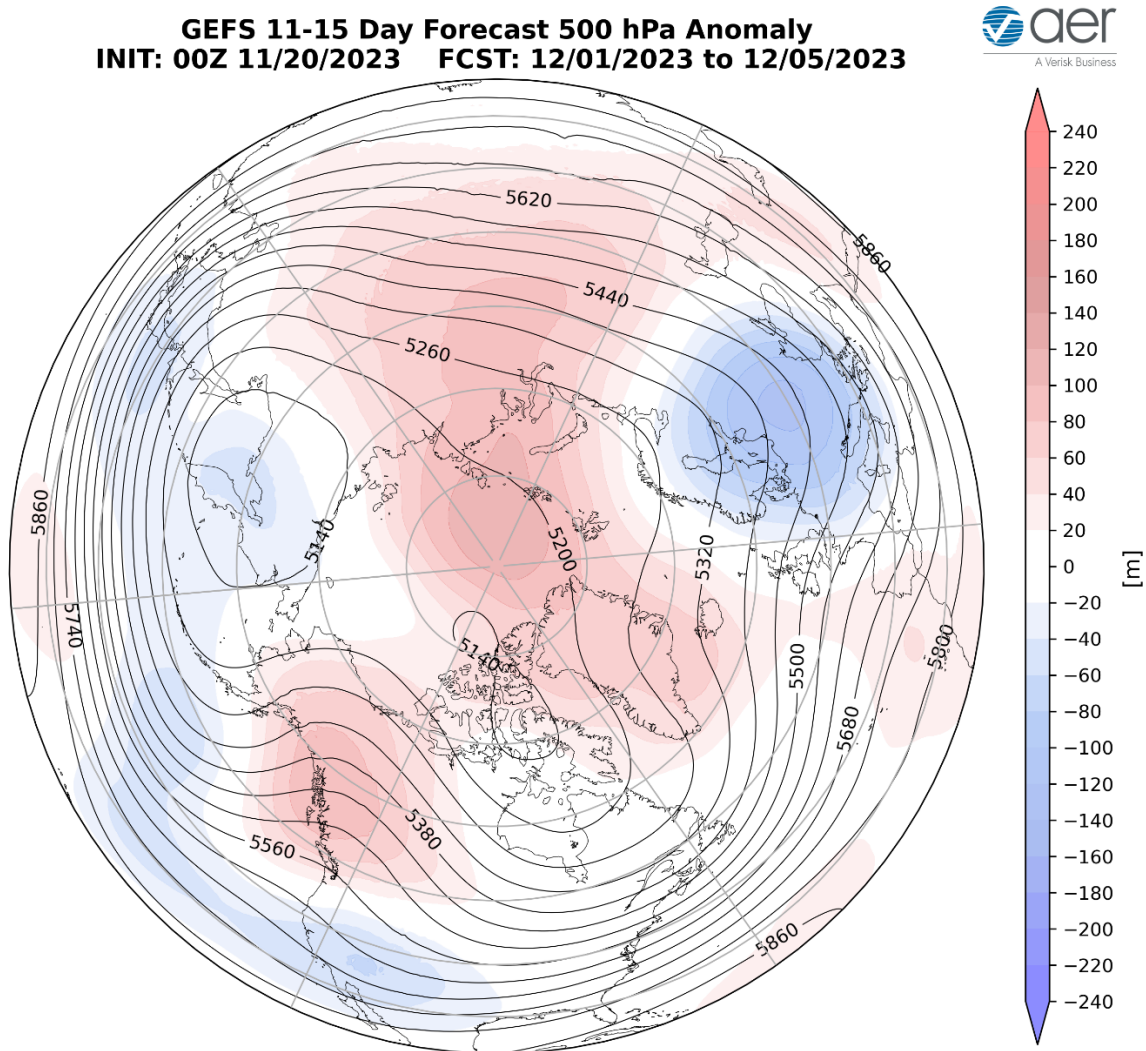


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 1 – 5 December 2023. The forecasts are from the 00z 20 November 2023 GFS ensemble.

Predicted ridging/positive geopotential height anomalies across Greenland should continue to anchor troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height anomalies across Southern Europe should persist this period (**Figure 8**). This pattern should favor normal to below normal temperatures across Northern Europe including the UK with normal to above normal temperatures limited to the Mediterranean region this period (**Figures 9**). Ridging/positive geopotential height anomalies are predicted to continue to dominate Southern and Central Asia bookended by troughing/negative geopotential height anomalies across Western and Eastern Asia this period (**Figure 8**). The predicted pattern favors widespread normal to above normal temperatures across Southern and Central Asia with normal to below normal temperatures mostly limited to Northwest Russia and parts of Northeast Asia this period (**Figure 9**).

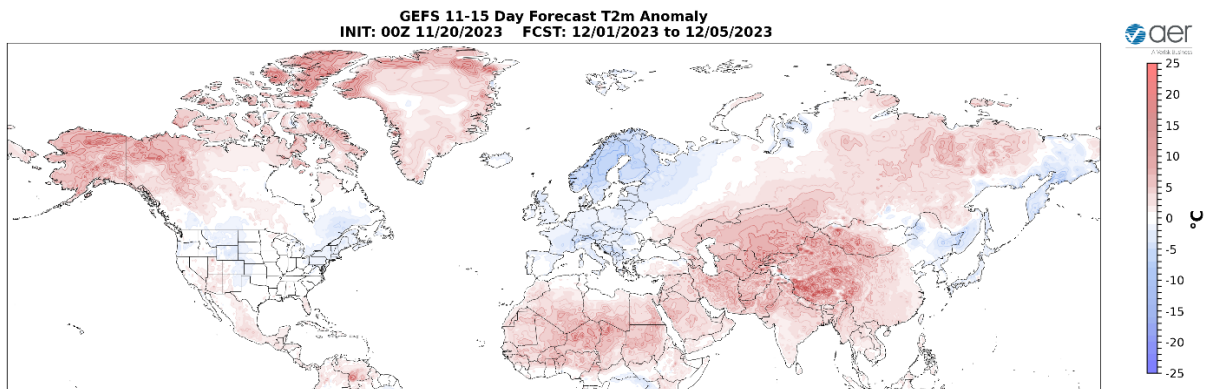


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 1 – 5 December 2023. The forecasts are from the 00z 20 November 2023 GFS ensemble.

Persistent ridging/positive geopotential height anomalies centered across Alaska and Western Canada will force downstream troughing/negative geopotential height anomalies across Eastern Canada and much of the US this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across Alaska, Northern and Western Canada and the Southwestern US with normal to below normal temperatures widespread across Southern and Eastern Canada and the Northern and Eastern US (**Figure 9**).

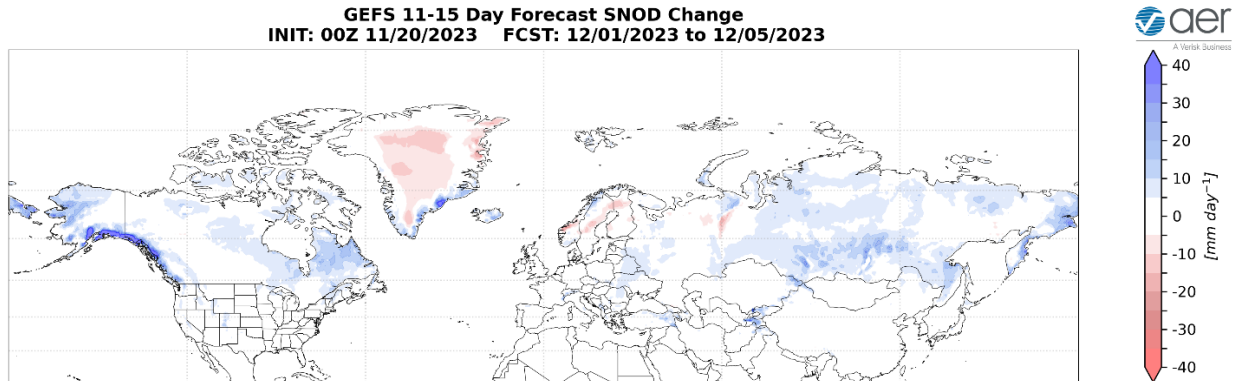


Figure 10. Forecasted snow depth changes (mm/day; shading) from 1 – 5 December 2023. The forecast is from the 00Z 20 November 2023 GFS ensemble.

Trouging and/or cold temperatures will support new snowfall across Norway, the Alps, parts of Turkey and Eastern Europe and Siberia while mild temperatures will support snowmelt in Sweden and the Urals this period (**Figure 10**). Trouging and/or cold temperatures will support new snowfall across parts of Alaska, Western and Eastern Canada and the US Rockies while mild temperatures will support snowmelt in parts of Western Canada this period (**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 in the troposphere (**Figure 11**). However, at the end of this week and into next week warm/positive PCHs are predicted to develop in the troposphere (**Figure 11**).

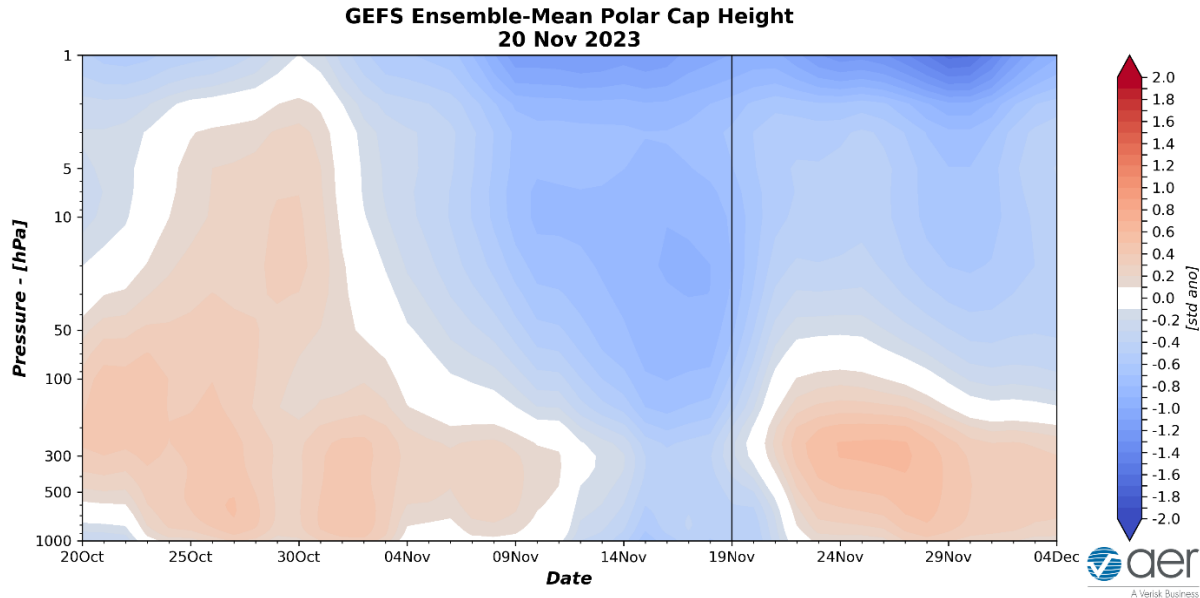


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 20 November 2023 GFS ensemble.

The predicted warm/positive PCHs in the lower troposphere much of the next two weeks (**Figure 11**) are consistent with the predicted neutral to negative surface AO the next two weeks (**Figure 1**).

Also shown in **Figure 1** is the stratospheric AO. The stratospheric AO is currently positive and is predicted to remain positive to strongly positive for much of the next two weeks. This is consistent with cold/negative stratospheric PCHs and a strong PV that is often associated with widespread mild temperatures across the NH.

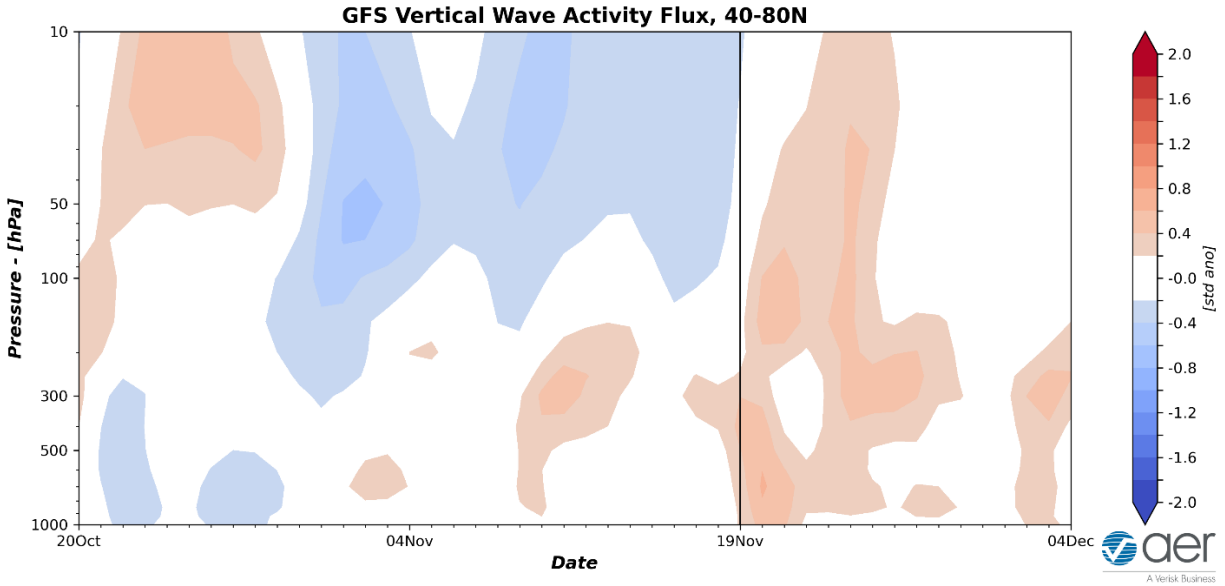


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 20 November 2023 GFS ensemble.

Vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere or poleward heat transport in the stratosphere has been overall less active than normal since the end of October (**Figure 12**). This favors cooling of the polar stratosphere (**Figure 11**) and a strengthening of the positive stratospheric AO (**Figure 1**). However, over the next two weeks the WAFz is predicted to become somewhat more active (**Figure 12**) and could lead to minor disruptions of the PV starting this week and into December.

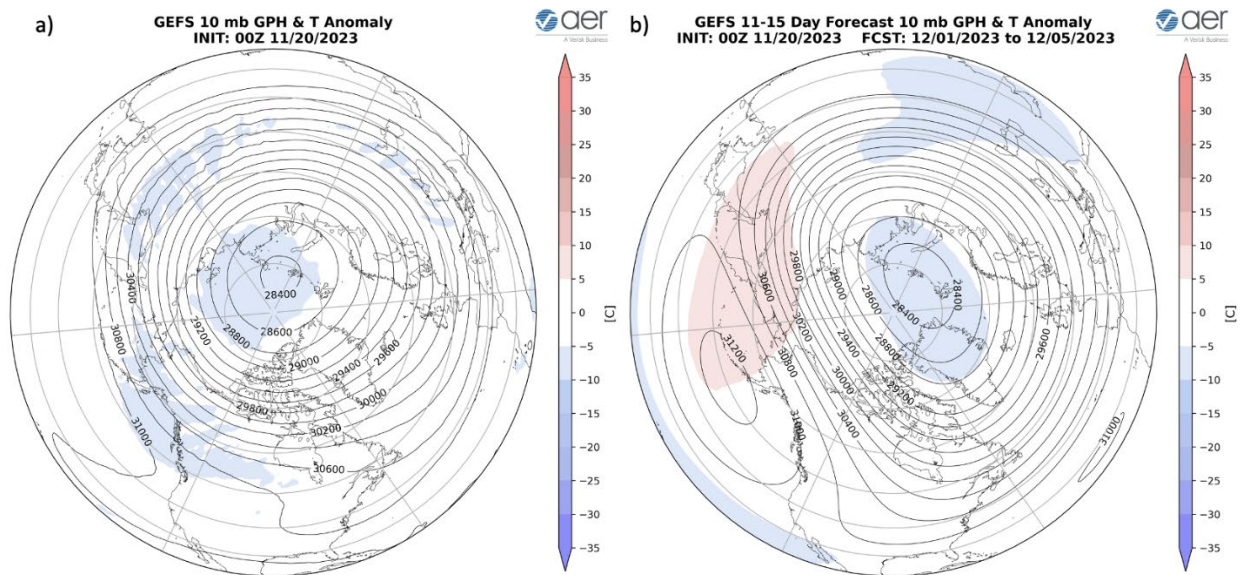


Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for 20 November 2023. (b) Same as (a) except forecasted averaged from 1 – 5 December 2023. The forecasts are from the 00Z 20 November 2023 GFS model ensemble.

Currently the polar vortex (PV) is circular in shape with the PV center shifted slightly south of the North Pole in the direction of the Barents-Kara Seas (**Figure 13a**). The nearly circular PV shape is characteristic of a strong PV. However, starting next week and continuing into early December, the PV shape is predicted to become more elongated along an axis from Western and Central Siberia to Central Canada (**Figure 13b**). This elongated PV configuration is characteristic of a stretched PV that often favors colder temperatures across East Asia and eastern North America.

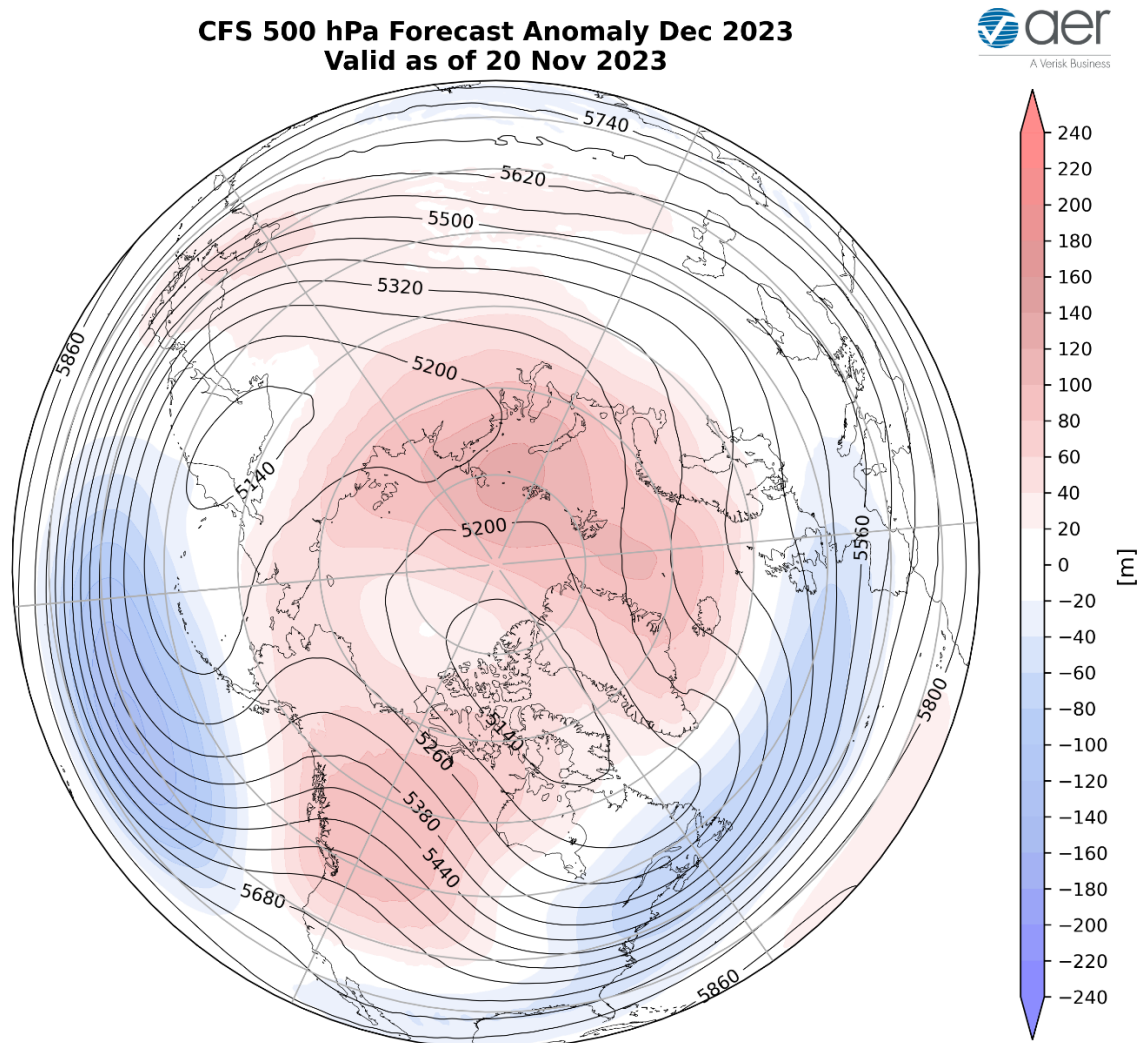


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for December 2023. The forecasts are from the 00Z 20 November 2023 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and surface temperatures for December (**Figure 15**) from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging extending across Greenland to Scandinavia and then the Barents-Kara Seas, the Central Arctic, Alaska, Western Canada and the Western US with troughing in Western Europe, Western Asia, Siberia, Northeast Asia and across the North Pacific, eastern North America and extending into the North Atlantic (**Figure 14**). This pattern favors seasonable to relatively warm temperatures across Southern Europe, Southern Asia, Alaska, Western Canada and the Western US with seasonable to relatively cold temperatures across Northern Europe, Northern Asia including Siberia, Northeast Asia, Southeastern Canada and the Eastern US (**Figure 15**).

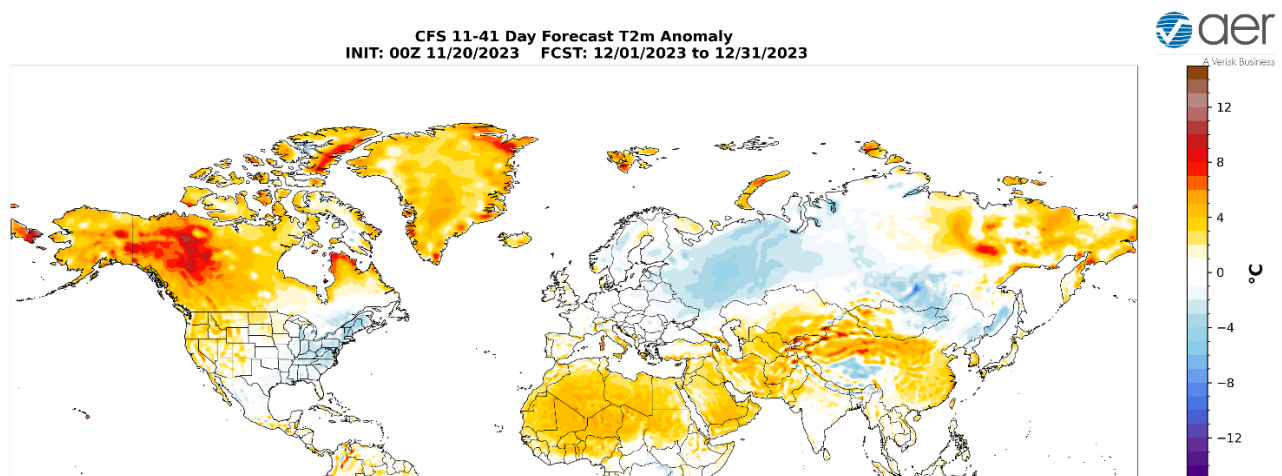


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for December 2023. The forecasts are from the 00Z 20 November 2023 CFS.

Boundary Forcings

Arctic sea ice extent

Arctic sea ice extent continues to grow at a good clip. I continue to expect that the negative sea ice anomalies will become more focused in the North Atlantic sector, though so far this has not happened. Blocking in the Barents-Kara sea region is critical from keeping a runaway PV that will squash any widespread and meaningful cold in Northern Eurasia and eastern North America for weeks and possibly even months to come.

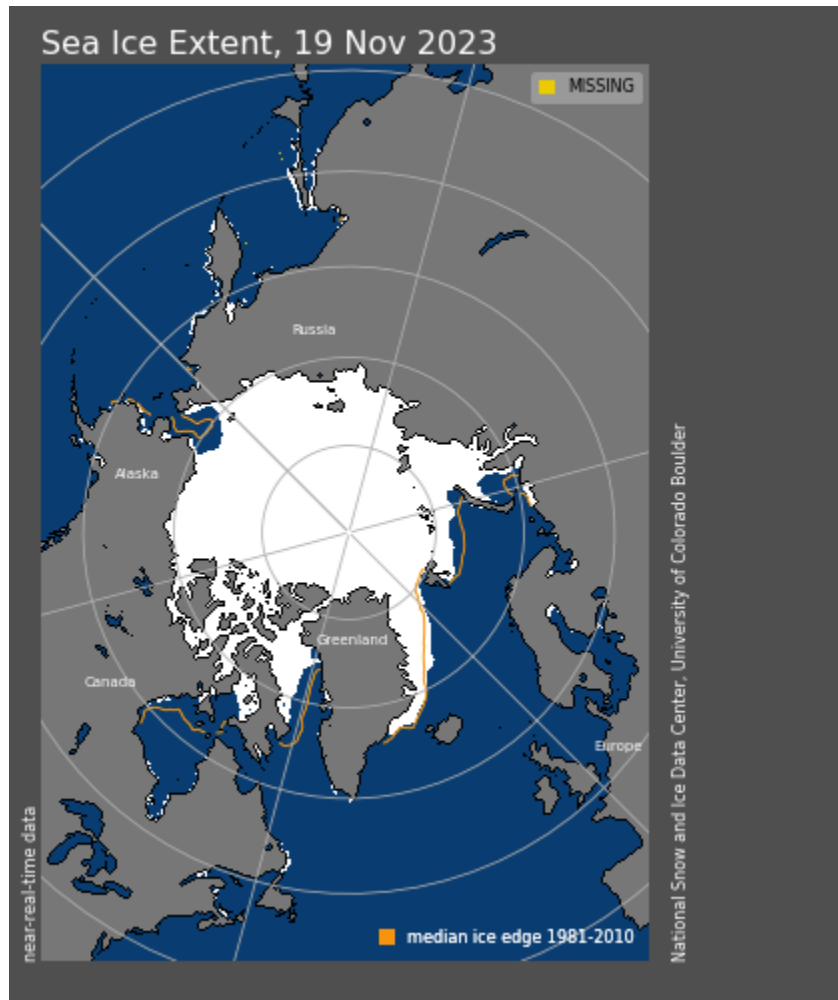


Figure 16. Observed Arctic Sea ice extent on 19 November 2023 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific Sea surface temperatures (SSTs) anomalies are well above normal, especially along the South America coast, indicating that an El Niño is pretty much a sure thing (**Figure 17**) and El Niño 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, the eastern North Atlantic and offshore of eastern North America though below normal SSTs exist regionally especially in the South and North Pacific and the North Atlantic.

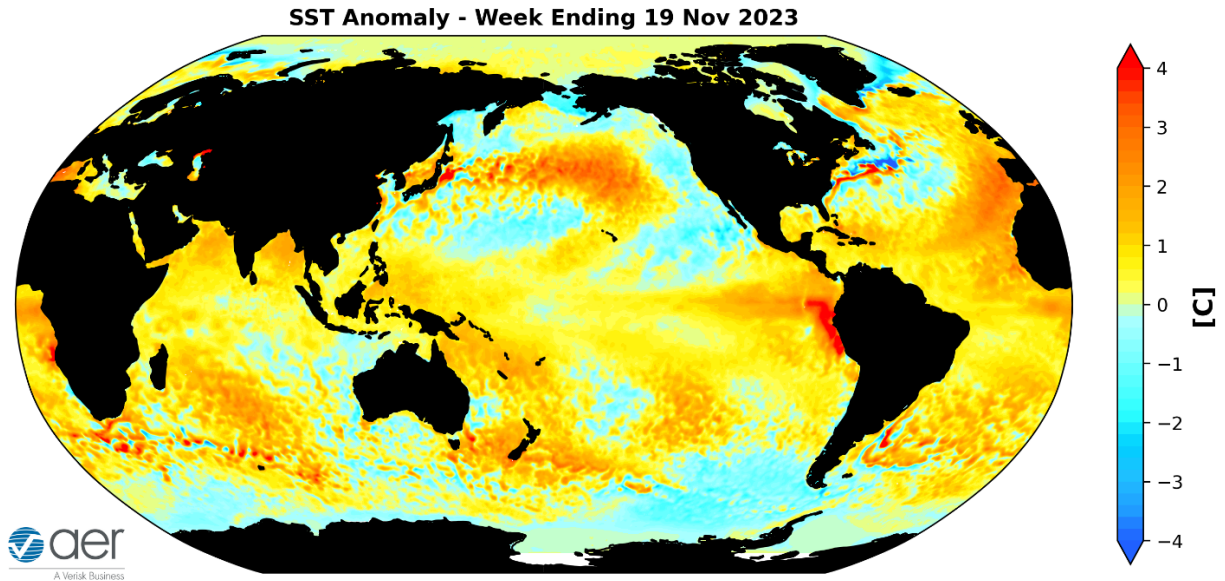


Figure 17. The latest weekly-mean global SST anomalies (ending 19 November 2023). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently the Madden Julian Oscillation (MJO) is in phase one favored (**Figure 1**). The forecasts are for the MJO to move into phase two and then weaken where no phase is favored. Phases one and two favor troughing along the west coast of North America and ridging in eastern North America. Therefore, it seems that the MJO is not having much influence on North American weather next week. But admittedly this is outside of my expertise.

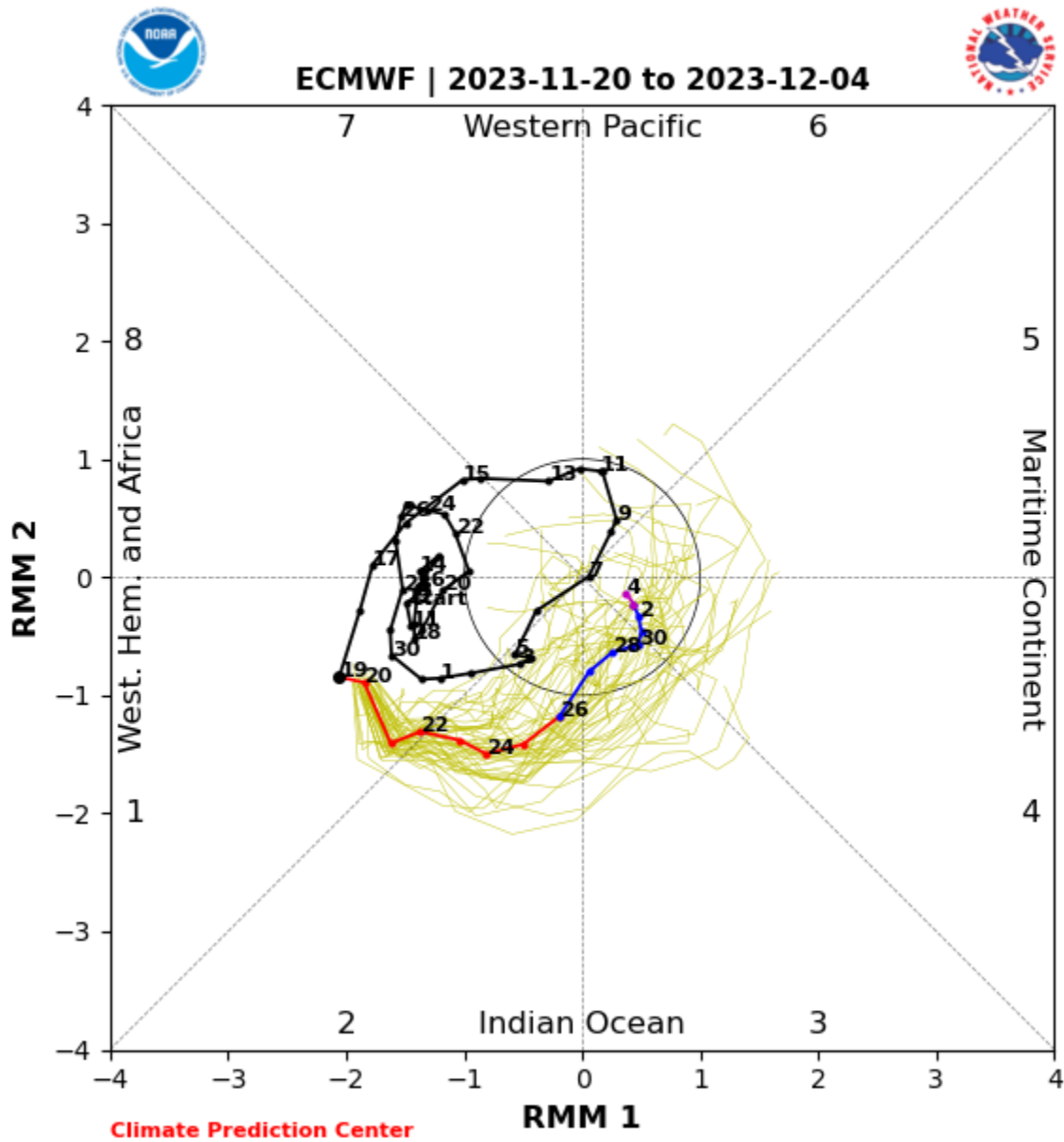


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 20 November 2023 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate the phase of the MJO, with geographical labels indicating where anomalous convection occurs during that phase. Image source:

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar_wh.shtml

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!