Arctic Oscillation and Polar Vortex Analysis and Forecasts

November 14, 2022

Dr. Judah Cohen from Atmospheric and Environmental Research (AER) embarked on an experimental process of regular research, review, and analysis of the Arctic Oscillation (AO) and Polar Vortex (PV). This analysis is intended to provide researchers and practitioners real-time insights on one of North America's and Europe's leading drivers for extreme and persistent temperature patterns.

During the winter schedule the blog is updated once every week. Snow accumulation forecasts replace precipitation forecasts. Also, there is renewed emphasis on ice and snow boundary conditions and their influence on hemispheric weather. With the start of spring, we transition to a spring/summer schedule, which is once every two weeks. Snow accumulation forecasts will be replaced by precipitation forecasts. Also, there will be less emphasis on ice and snow boundary conditions and their influence on hemispheric weather.

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Summary

- The Arctic Oscillation (AO) is currently neutral and is predicted to straddle neutral for the next tendays before possibly dipping negative as pressure/geopotential height anomalies across the Arctic are currently and are predicted to remain mixed with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently near neutral and is predicted to vacillate around neutral the next two weeks as pressure/geopotential height anomalies are currently and are predicted to remain mixed and weak across Greenland.

- Over the next two weeks troughing/negative geopotential height anomalies in the eastern North Atlantic will favor ridging/positive geopotential height anomalies across Europe but centered over Scandinavia. This pattern will favor normal to above normal temperatures across much of Europe including the United Kingdom (UK). However, the North Atlantic troughing could extend far enough east to bring normal to below normal temperatures across Western Europe including the UK. Also, some cold air could start to bleed from the east into Eastern Europe from Western Asia.

- Over the next two weeks, predicted European coupled with Eastern Siberia ridging/positive geopotential height anomalies will force troughing/negative geopotential height anomalies across Northern Asia especially Western and Central Siberia. This pattern favors expanding normal to below normal temperatures across Northern Asia with normal to above normal temperatures across Central and Southeastern Asia the next two weeks.

- The general pattern the next ten days across North America is amplified ridging/positive geopotential height anomalies centered in the Gulf of Alaska and Alaska and extending into Western Canada forcing downstream troughing/negative geopotential height anomalies in eastern North America and the Central and Eastern United States (US). However, by the end of the month troughing/negative geopotential height anomalies will slide into the Gulf of Alaska with ridging/positive geopotential height anomalies in the Central US. This pattern favors this week widespread normal to above normal temperatures across Alaska, Western Canada and the Western US with normal to below normal temperatures across Central and Eastern Canada and the Central and Eastern US. However, starting next week milder temperatures will spread east of the Rockies in Canada and the US.

- In the near term I think of the cold temperatures in Siberia and how it might influence the behavior of the polar vortex (PV) and Northern Hemisphere (NH) temperatures in the coming weeks.

- *Impacts* section I continue to discuss October Eurasian snow cover extent and current Arctic sea ice and how they might portend the behavior of the polar vortex (PV) and the Northern Hemisphere (NH) winter.

Plain Language Summary

Not only am I experiencing whiplash as far as the weather (a hurricane and snow separated by a day) but whiplash as what to predict this winter. October suggested to me a mild winter while November a colder winter. I think the feature that needs the closest monitoring are the developing cold temperatures across Siberia in early December. The winter could very well be tethered to how long that feature can persist.

Impacts

First let me start out by saying that I think that I have died and gone to heaven. Here in Houghton, Michigan it seems like it just snows all the time. Though if you like to see the sun in the winter months, Houghton can be pretty depressing.

Other than maybe the first week of October the snow cover advance across Eurasia was lackluster and other than one snowstorm not terribly notable across North America either. Also observed ridging in Siberia for much of October is favorable for an undisturbed stratospheric polar vortex (PV). Ridging in the Eastern US left record warmth and a rare US landfalling hurricane in November.

But November has been more interesting in regards to winter weather. Snow cover extent has been robust across East Asia but has stalled across Western Asia. Though as I have discussed in previous blogs based on recent research this dipole of positive anomalies in East Asia and negative anomalies in West Asia could be favorable for disrupting the PV (for example Park et al. 2020 and Wegmann et al. 2020). Meanwhile North American snow cover has expanded rapidly and is currently at decadal highs (see **Figure i**). For this and/or next week across the US a rare coast-to-coast below normal temperatures was predicted.

But the weather anomaly that has most got my attention is the potential for extreme cold in Siberia. The models have been playing now you see it, now you don't with a Scandinavia-Dateline ridge-bridge across the Eurasian Arctic that would force low heights deep into Northern Asia (see **Figure 8**). It is my belief that a cold winter in East Asia, the Eastern US and Europe begins with an expansive cold pool in Siberia in the late fall and early winter. The longer that feature persists the more likely it is to disrupt the polar vortex and lead to an extended or repetitive cold period(s) for different regions across the mid-latitudes. The cold will persist as long as high latitude blocking persists in the North Atlantic sector but especially in the Scandinavian/Urals/Barents-Kara seas region. For what it is worth, the CFS predicts that it will be a prominent feature in December (see **Figure 14**) resulting in cold temperatures from the Urals to East Asia (see **Figure 15**).
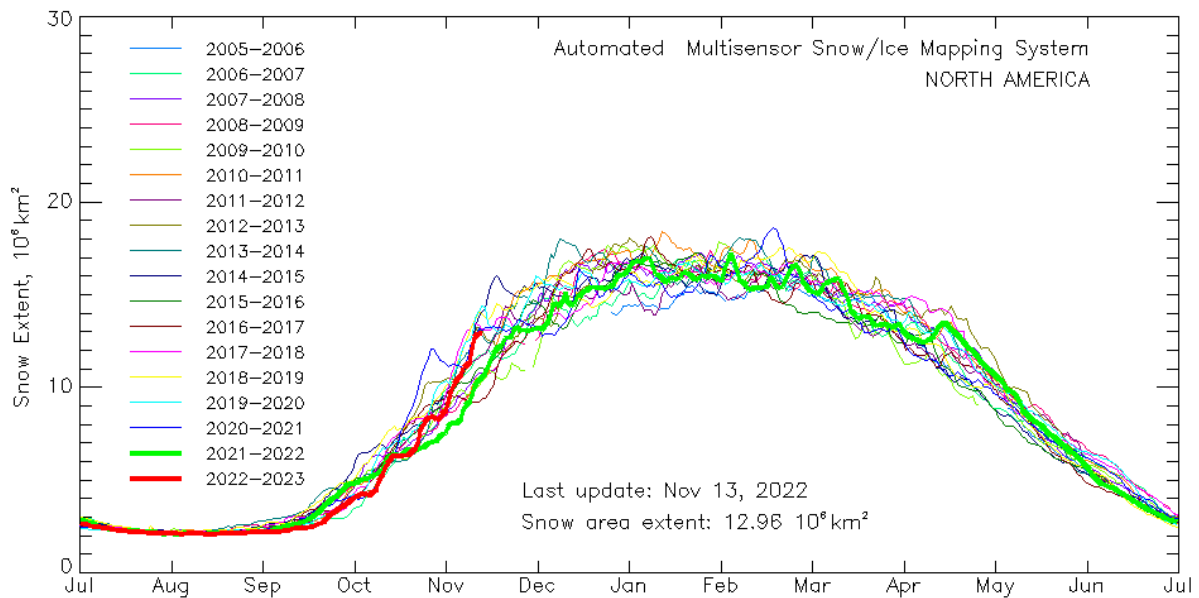
Figure i. Observed North American snow cover extent through 13 November 2022. Plot from
https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_monitor.html

Still for now there are few signs of a large PV disruption with PV stretching favored probably over the next month rather than a sudden stratospheric warming (SSW). Our experimental and speculative PV forecast model shows no signs of a larger PV disruption. I guess the high pressure ridging near the Aleutians and typical of La Niña winters is interfering with the optimal wave pattern to initiate a large transfer of vertical wave energy of sufficient magnitude to significantly disrupt the PV (see **Figure 12**). It does look like another PV stretched event will take place next week (see **Figure 13**). But following a stretched PV there is always the possibility of the PV strengthening and at least the GFS seems to be suggesting a stronger, more circular PV for late November and into early December (see **Figure ii**). So, if the GFS forecast is correct, it will become a battle between Urals/Barents-Kara Seas blocking in the troposphere which favors a disruption of the PV, which favors a relatively cold pattern and a strong circular PV that favors the dissipation of high latitude blocking in the troposphere and an overall mild pattern. And our winter could literally come down to who is the last man standing.

GEFS 11-15 Day Forecast 10 mb GPH & T Anomaly
INIT: 00Z 11/14/2022   FCST: 11/25/2022 to 11/29/2022
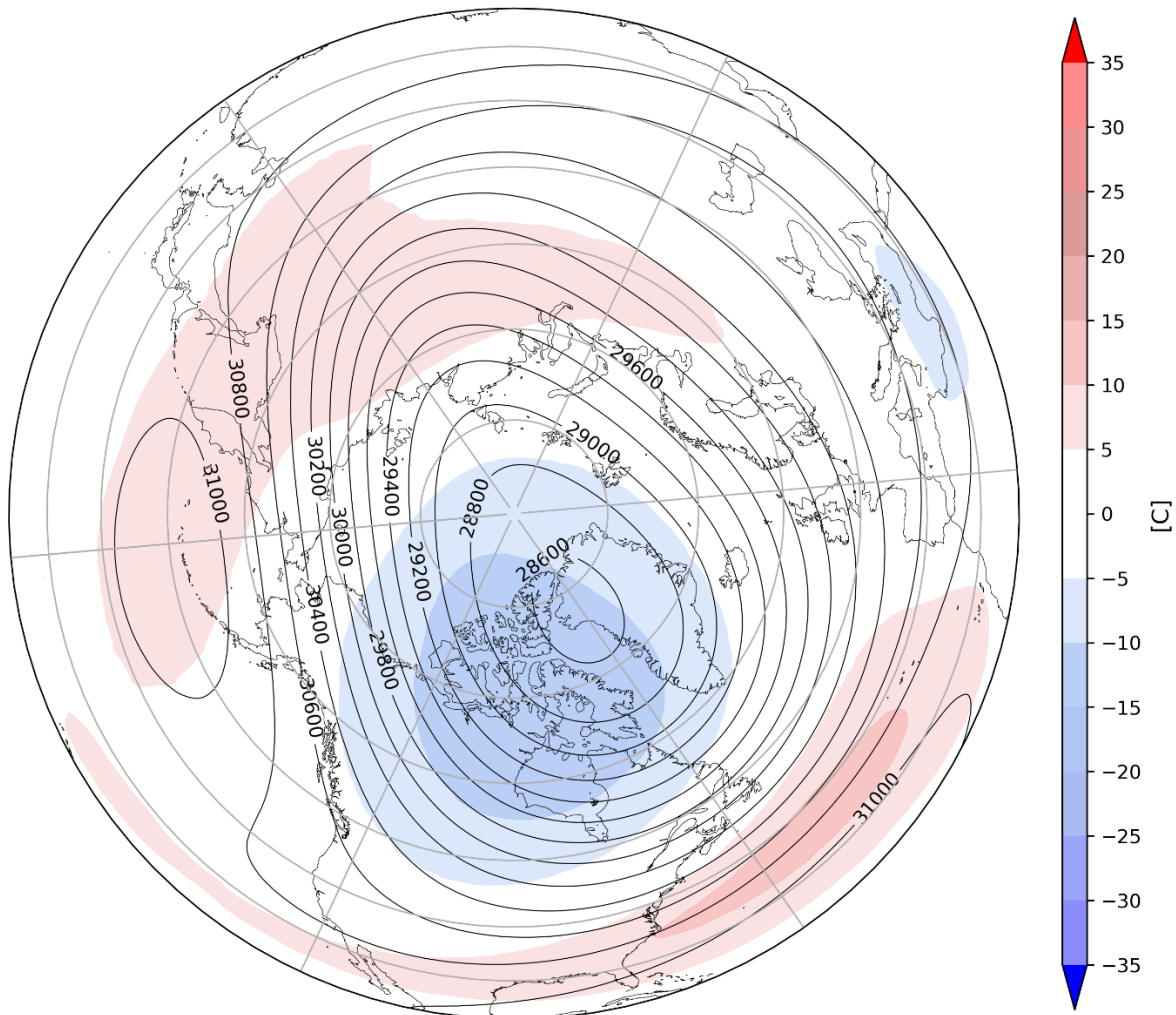
Figure ii. Forecasted 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere averaged from 25 – 29 November 2022. The forecasts are from the 00Z 14 November 2020 GFS model ensemble.

Looking at Arctic sea ice, it still seems surprisingly extensive to me (see **Figure iii**). Obviously, it is below normal but I don't see any large regional anomalies that are of sufficient amplitude for influencing the behavior of the PV. Large ice deficits in the Barents-Kara Seas could help lock in high latitude blocking predicted for the region, but I am not sure the current anomalies are sufficient to help persist blocking in the region. In my opinion lots of mixed and conflicting signals about the upcoming winter. Seems that the winter forecast is never easy, and this winter is certainly no exception and if anything seems to be even more challenging.
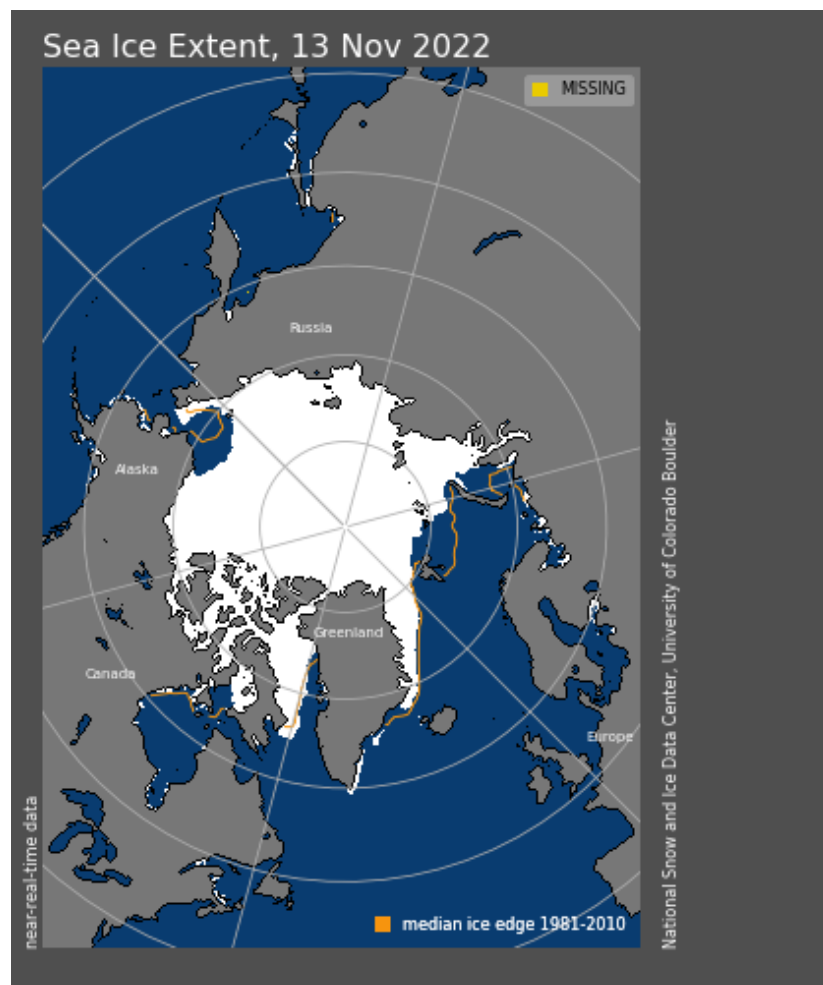
Figure iii. Observed Arctic sea ice extent on 13 November 2022 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC).

Recent and Very Near Term Conditions

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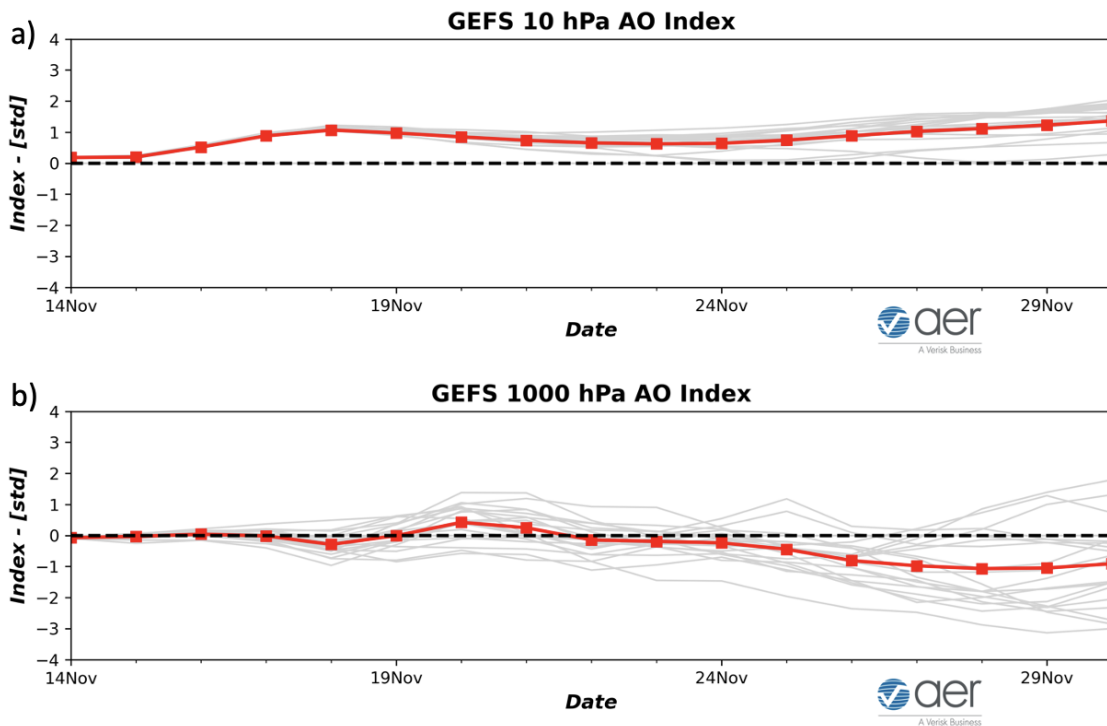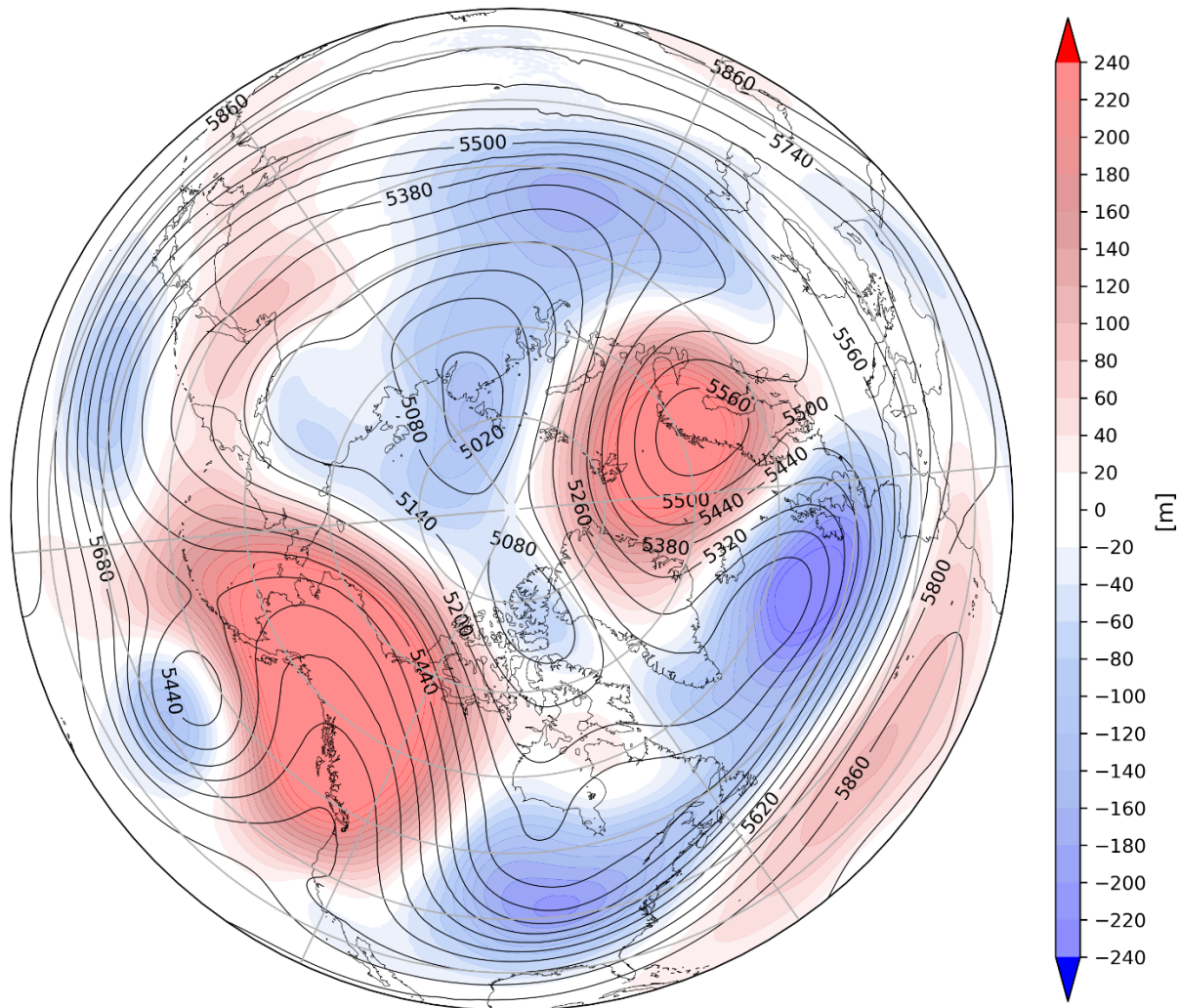

Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 14 November 2022 GFS ensemble. (b)The predicted daily-mean near-surface AO from the 00Z 14 November 2022 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Predicted troughing/negative geopotential height anomalies in the eastern North Atlantic will force ridging/positive geopotential height anomalies across Europe (**Figure 2**). This will favor normal to above normal temperatures across much of Europe including the UK (**Figure 3**). However the ridging will be far enough north this period to allow some colder air to filter into Eastern Europe from the east (**Figure 3**) from Western Asia. Ridging/positive geopotential height anomalies in Europe are predicted to force downstream troughing/negative geopotential height anomalies across Siberia that extend southwestward into Western Asia with ridging/positive geopotential height anomalies in East Asia (**Figure 2**). This pattern favors normal to below normal

temperatures across Siberia and Western Asia with normal to above normal temperatures across Eastern Asia (**Figure 3**).
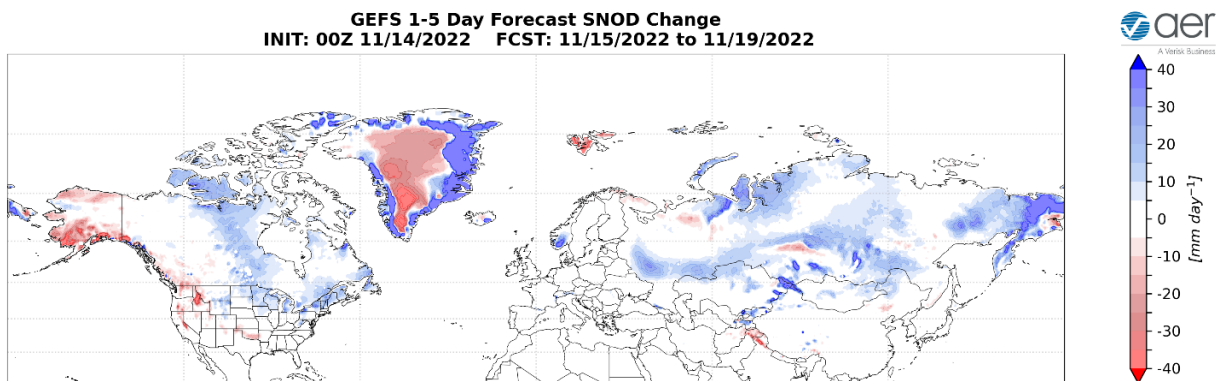

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 15 – 19 November 2022. The forecasts are from the 00z 14 November 2022 GFS ensemble.

Amplified ridging/positive geopotential height anomalies are predicted for Alaska, Western and the Western US with troughing/negative geopotential height anomalies in Eastern Canada and the Eastern US(**Figure 2**). The pattern will favor 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 (**Figure 3**).
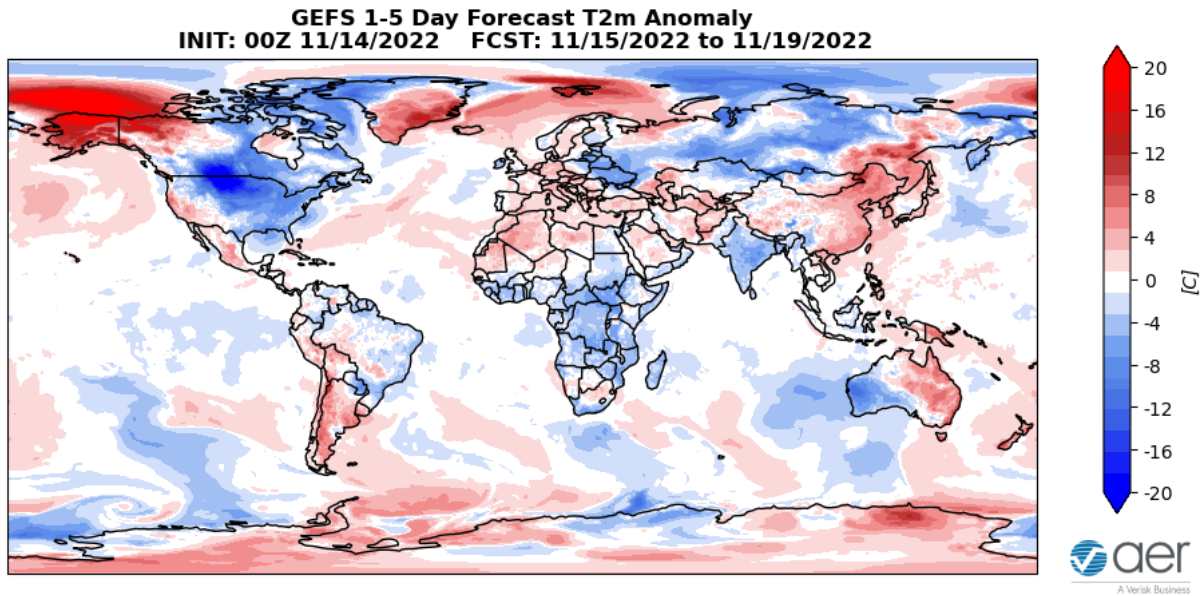
Figure 3. Forecasted surface temperature anomalies (°C; shading) from 15 – 19 November 2022. The forecast is from the 00Z 14 November 2022 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Scotland, Norway, Northern and Central Asia and the Tibetan Plateau (**Figure 4**). Troughing and/or cold temperatures will support new snowfall across Eastern Canada and the Northeastern US while mild temperatures will support snowmelt in Alaska and along the west coast of North America (**Figure 4**).

Figure 4. Forecasted snow depth changes (mm/day; shading) from 15 – 19 November 2021. The forecast is from the 00Z 14 November 2021 GFS ensemble.

Near-Term

1-2 week

The AO is predicted to remain neutral this period (**Figure 1**) as geopotential height anomalies remain mostly mixed across the Arctic and mixed across the mid-latitudes (**Figure 5**). With mixed geopotential height anomalies across Greenland (**Figure 5**), the NAO is predicted to remain near neutral this period as well.


GEFS 6-10 Day Forecast 500 hPa Anomaly
INIT: 00Z 11/14/2022   FCST: 11/20/2022 to 11/24/2022
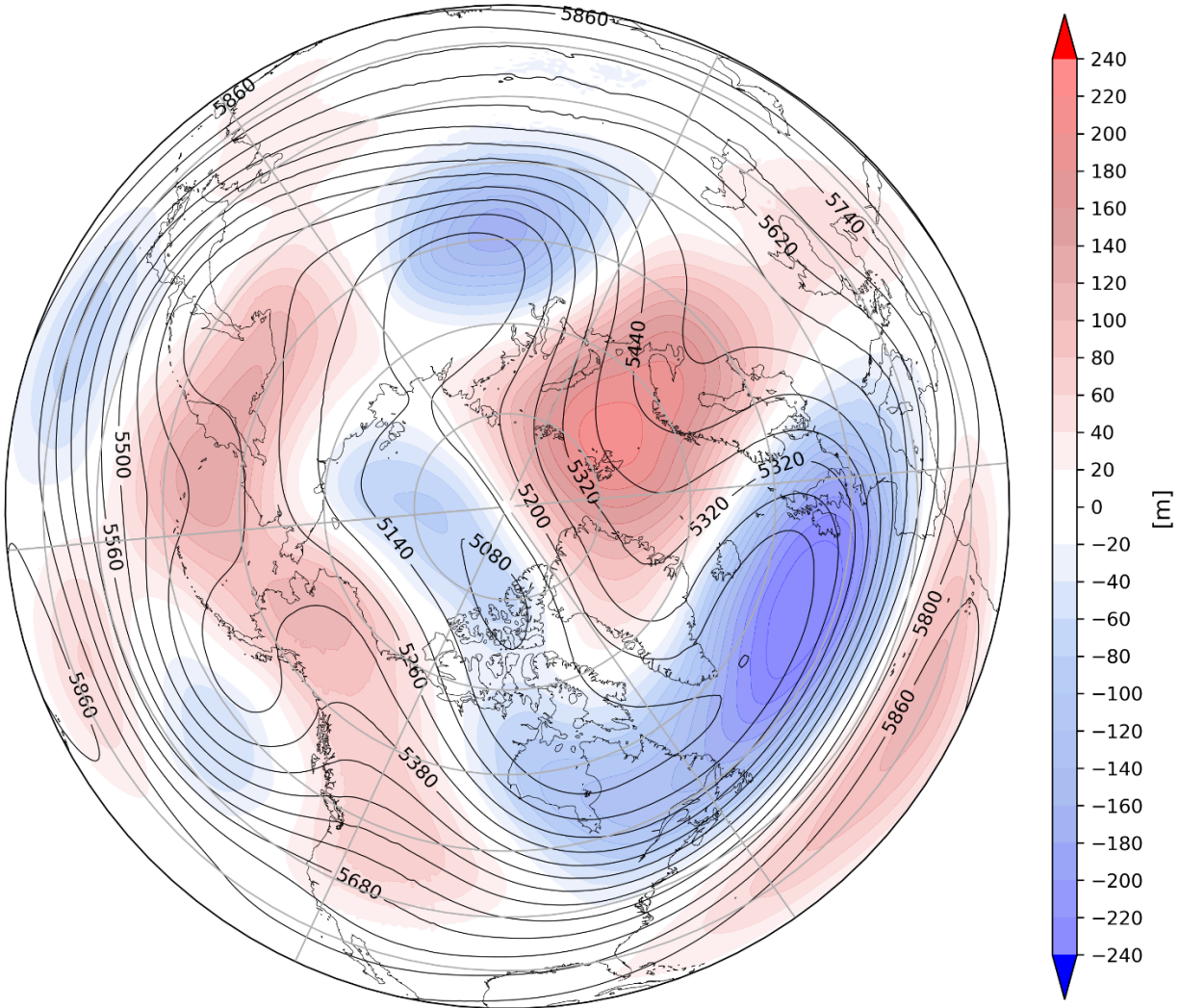
Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 20 – 24 November 2022. The forecasts are from the 00z 14 November 2022 GFS ensemble.

Predicted persistent troughing/negative geopotential height anomalies in the eastern North Atlantic will continue to support ridging/positive geopotential height anomalies persisting across Central and Eastern Europe and near Scandinavia with the exception of troughing/negative geopotential height anomalies in Western Europe (**Figures**

5). The pattern is predicted to result in widespread normal to above normal temperatures across Europe with normal to below normal temperatures limited to Ireland, Scotland and far Eastern Europe (**Figure 6**) where colder air will continue to filter in from the east. Persistent European ridging/positive geopotential height anomalies are predicted to anchor downstream troughing/negative geopotential height anomalies across Siberia that extends southwestward towards the Caspian Sea with ridging/positive geopotential height anomalies in Far Eastern Asia this period (**Figure 5**). This pattern favors widespread normal to below normal temperatures across Northern and Western Asia with normal to above normal temperatures across East Asia (**Figure 6**).
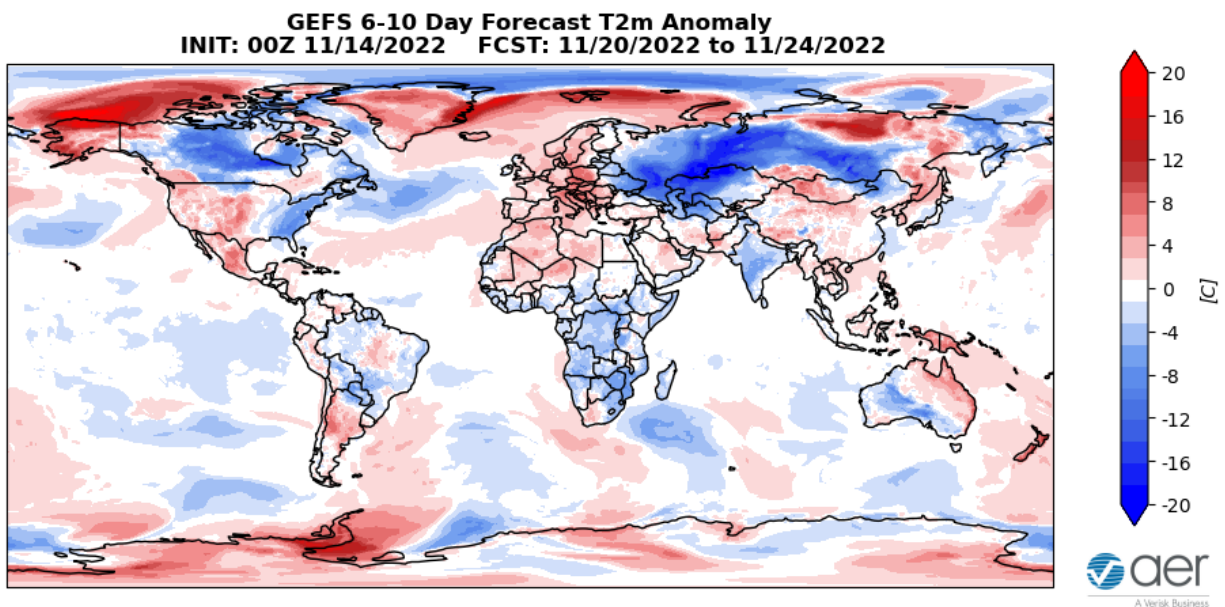
Figure 6. Forecasted surface temperature anomalies (°C; shading) from 20 – 24 November 2022. The forecast is from the 00Z 14 November 2022 GFS ensemble.

Predicted persistent ridging/positive geopotential height anomalies across Alaska and Western Canada will force troughing/negative geopotential height anomalies across eastern North America centered over Quebec this period **(Figure 5).** This pattern will favor 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 **(Figure 6).**
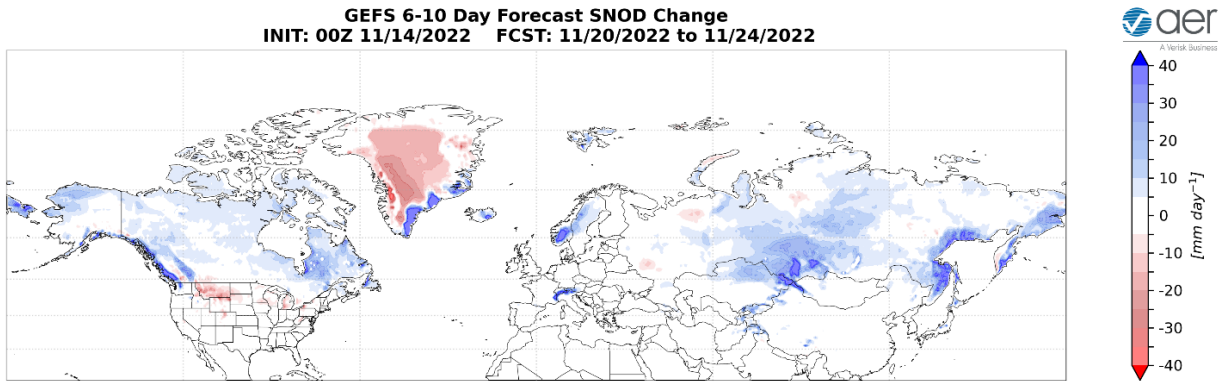
Figure 7. Forecasted snow depth changes (mm/day; shading) from 20 – 24 November 2021. The forecast is from the 00Z 14 November 2022 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Norway, the Alps Northern and Central Asia while mild temperatures will support snowmelt in Northwest Russia (**Figure 7**). Troughing and/or cold temperatures will support new snowfall across northern Alaska, Western and Eastern Canada while mild temperatures will support snowmelt in the US Northern Plains and Great Lakes (**Figure 7**).

3-4 week

Positive geopotential height anomalies are predicted to expand across the Eurasian sector of the Arctic with mixed across the mid-latitudes this period (**Figure 8**), therefore the AO could turn more negative this period (**Figure 1**). With weak but mostly positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO could also dip negative this period.
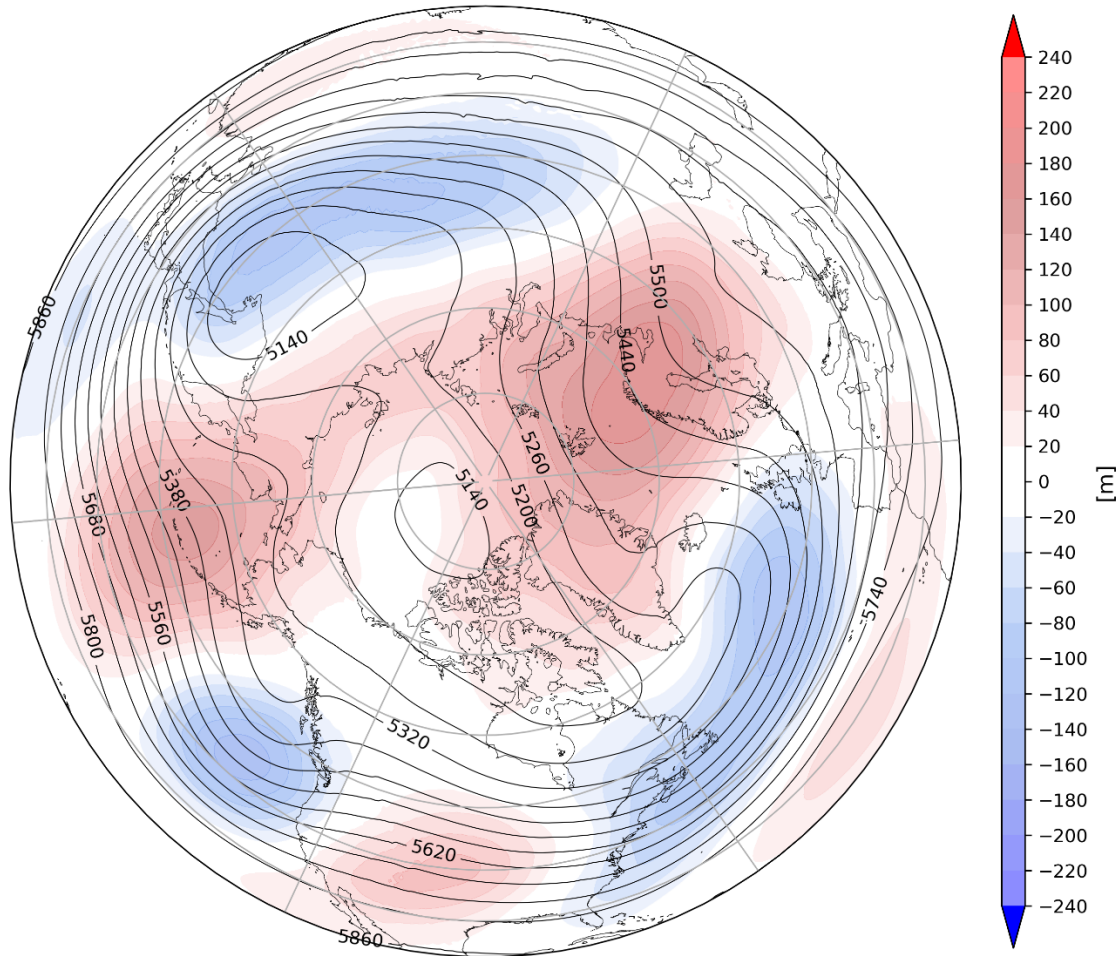
Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 25 – 27 November 2022. The forecasts are from the 00z 14 November 2022 GFS ensemble.

Persistent eastern North Atlantic troughing/negative geopotential height anomalies are predicted to continue to force ridging/positive geopotential height anomalies across Central and Eastern Europe but centered near Scandinavia this period (**Figure 8**). This pattern favors normal to above normal temperatures across much of Central and Eastern Europe with the exception of normal to below normal temperatures in Western Europe including the UK (**Figures 9**). Persistent European ridging/positive geopotential height anomalies will start to slide east into Western Asia will continue to contribute to troughing/negative geopotential height anomalies across Siberia and now East Asia with ridging/positive geopotential height anomalies persisting in Eastern Siberia (**Figure 8**). This pattern favors widespread normal to below normal temperatures across much of Northern and Eastern Asia with normal to above normal temperatures spreading across Western Asia and Eastern Siberia (**Figure 9**).
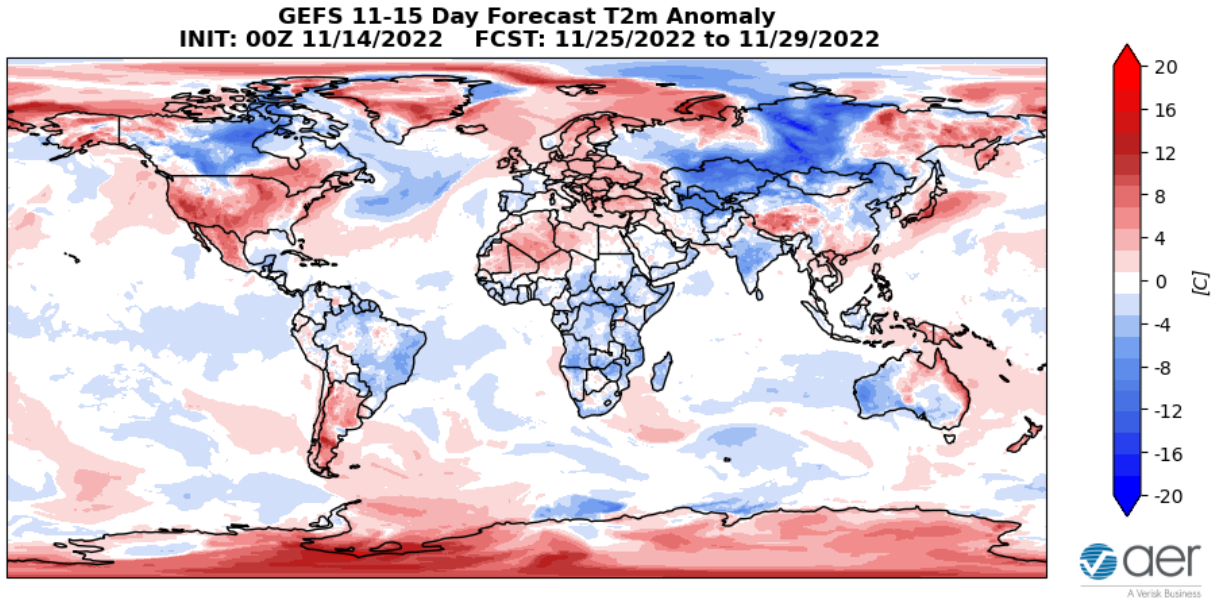
Figure 9. Forecasted surface temperature anomalies (°C; shading) from 25 – 27 November 2022. The forecast is from the 00Z 14 November 2022 GFS ensemble.

Ridging/positive geopotential height anomalies previously centered on Alaska are predicted to drift westward towards the Dateline allowing downstream troughing/negative geopotential height anomalies to develop in the Gulf of Alaska with more troughing along the east coast of North America with ridging/positive geopotential height anomalies developing in the Central US this period (**Figure 8**).   This pattern favors widespread normal to above normal temperatures across Alaska, Southwestern Canada, the Western and Central US with normal to below normal temperatures across much of Canada and the US East Coast (**Figure 9**).
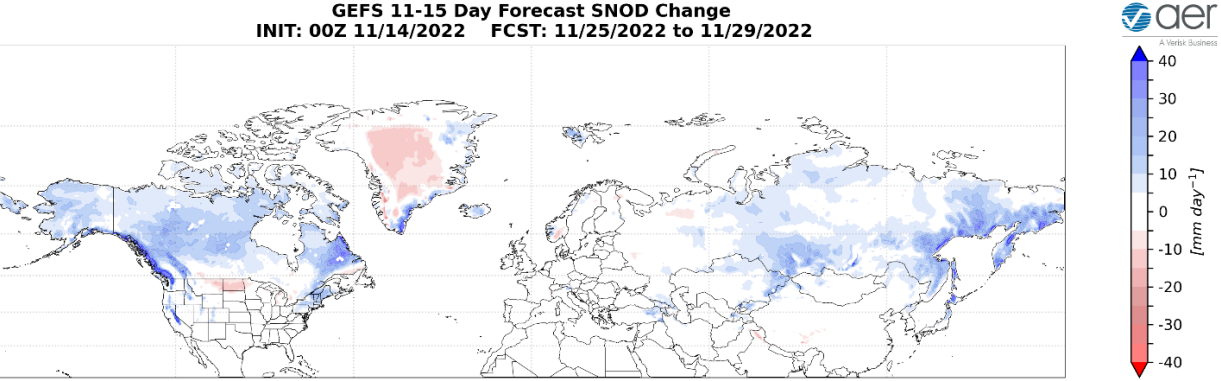

Figure 10. Forecasted snow depth changes (mm/day; shading) from 25 – 27 November 2022. The forecast is from the 00Z 14 November 2021 GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across Scotland, Norway, Northern and Eastern Asia while mild temperatures will support snowmelt in Northwest Russia (**Figure 10**). Troughing and/or cold temperatures will support new snowfall across Alaska, Canada, the higher elevations of the Western US and Northeastern US while mild temperatures will support snowmelt in the US Northern Plains (**Figure 10**).

Longer Term

30−day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows cold/negative PCHs in the upper to mid stratosphere with warm/positive PCHs in the lower stratosphere and the troposphere (**Figure 11**). However, the cold/negative PCHs currently observed in the upper and mid stratosphere are predicted to descend into the lower stratosphere while PCHs remain warm/positive in the troposphere (**Figure 11**).
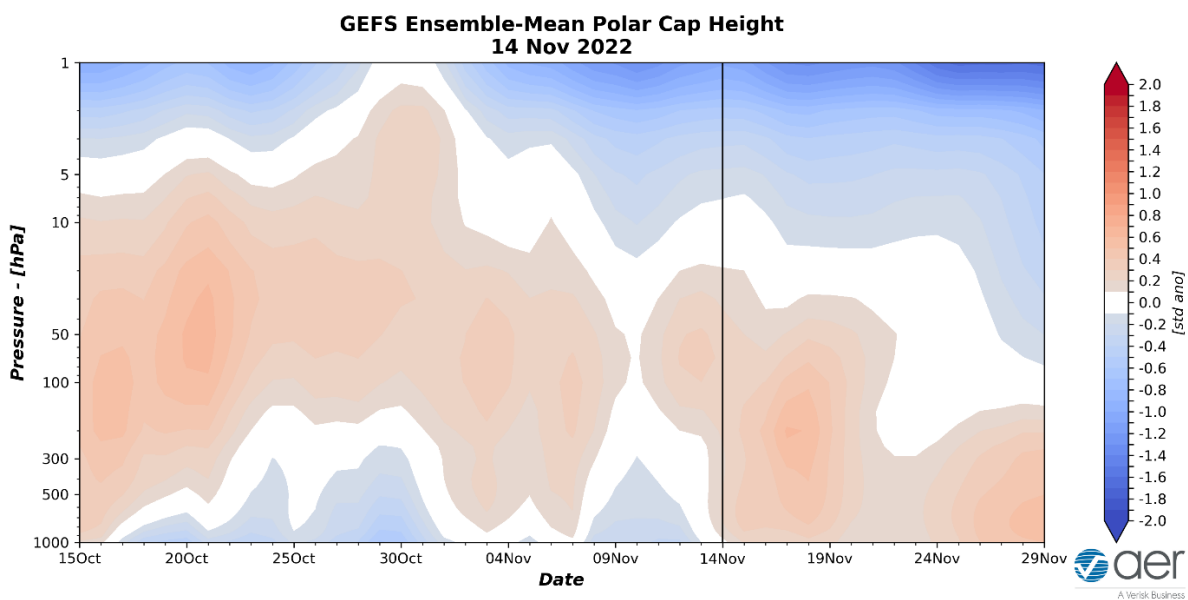

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 14 November 2022 GFS ensemble.

The warm/positive PCHs in the lower troposphere (**Figure 11**) are consistent with the predicted neutral to negative surface AO predicted for the next two weeks (**Figure 1**). However next week when the warm/positive PCHs in the lower troposphere are predicted to strengthen (**Figure 11**), the surface AO is predicted to be more likely to turn negative (**Figure 1**).
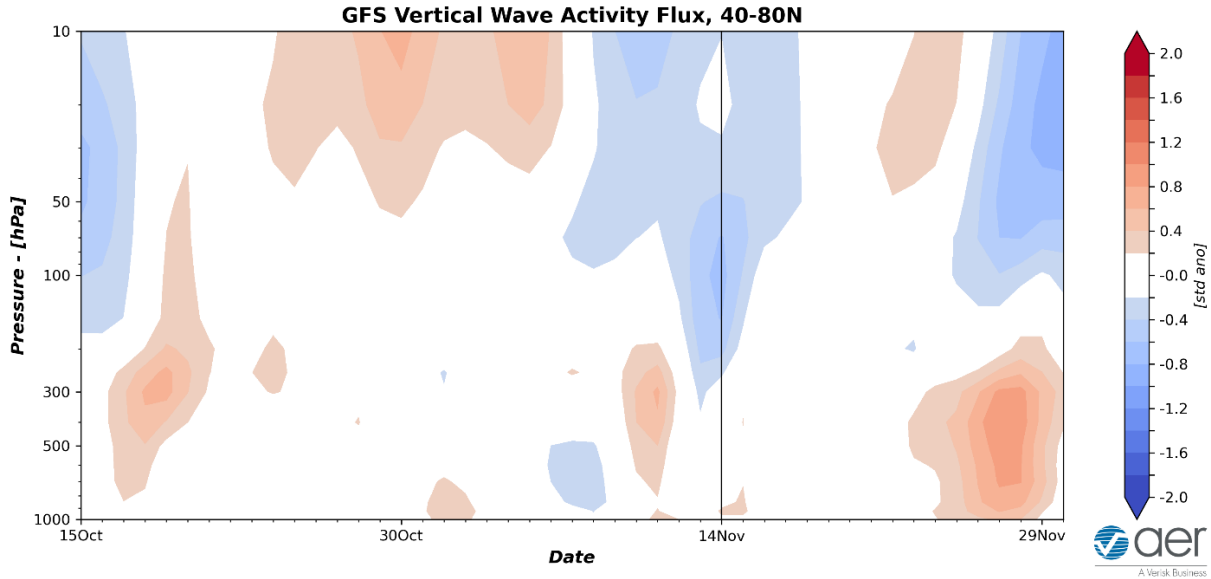
Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 14 November 2022 GFS ensemble.

The near normal vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere or poleward heat transport in the stratosphere the past two weeks has allowed the mid to upper stratospheric PCHs to cool (**Figure 12**). The GFS is not predicting a more period of WAFZ, resulting in stratospheric PCHs to further cool (**Figure 12**).
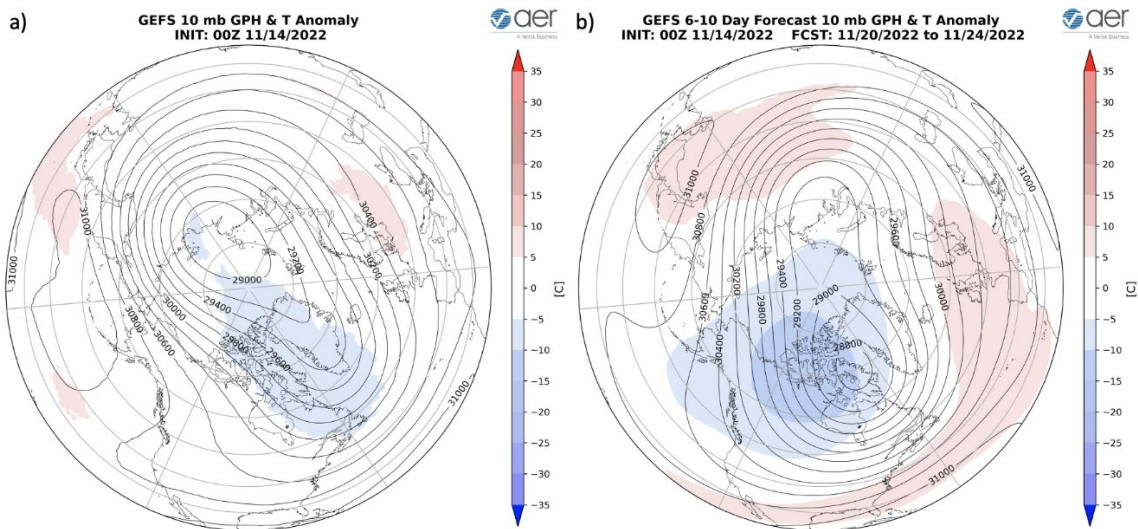
Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 14 November 2022. (b)

Same as (a) except forecasted averaged from 20 – 24 November 2022. The forecasts are from the 00Z 14 November 2020 GFS model ensemble.

Still the near normal WAFz has caused a minor perturbation of the stratospheric PV and it is currently displaced from the North Pole towards the Laptev Sea and stretched or elongated **(Figure 13)**. And enough WAFz is predicted this week to maintain an elongated configuration of the PV (**Figure 13**) extending from Siberia to Hudson Bay and is related to the developing troughing in eastern North America this week. The models are suggestive of two lobes of the PV to develop resembling a PV split but I think that it is best to think of the PV experiencing a more extreme stretching rather than a splitting. However, the PV is predicted to be normal to stronger than normal over the next two weeks despite remaining in a mostly elongated configuration the next two weeks (**Figure 13**). Therefore, the stratospheric AO is predicted to remain neutral to positive over the next two weeks **(Figure 1)**.

**CFS 500 hPa Forecast Anomaly Dec 2022
Valid as of 14 Nov 2022**
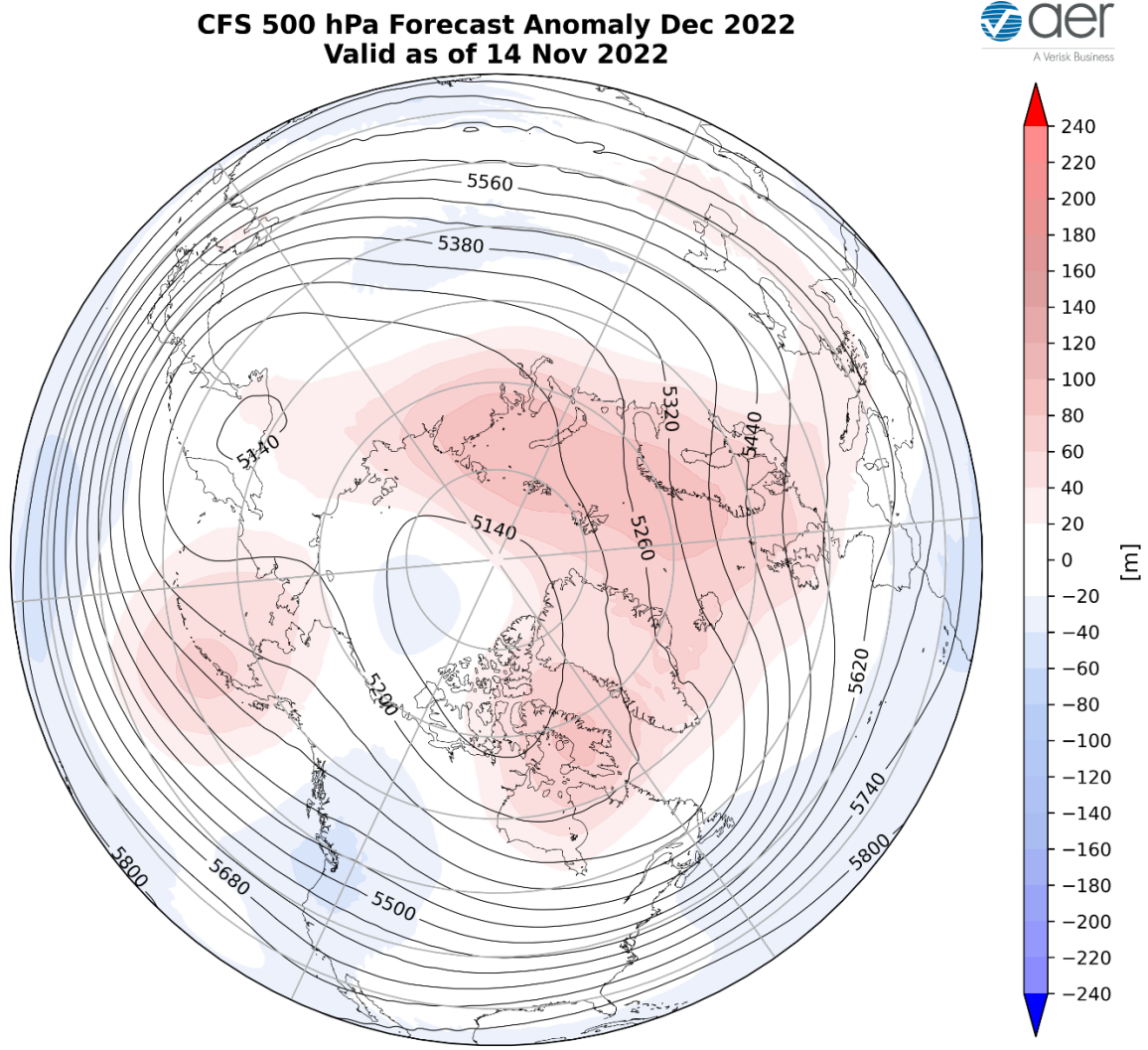
Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for December 2022. The forecasts are from the 00Z 14 November 2022 CFS.

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 centered across Scandinavia, the Barents-Kara Seas, the Aleutians, and Baffin Bay with troughing across the western Mediterranean, Siberia, East Asia, Western Canada and the Western US (**Figure 14**).   The most important feature in my opinion is the ridging centered in the Barents-Kara Seas. This pattern favors seasonable to relatively warm temperatures across Europe, Eastern Siberia, Southern Asia, Alaska, Northern and Eastern Canada and the Eastern US with seasonable to relatively cold temperatures across the Western, Northern and Eastern Asia, Western Canada and the Western US (**Figure 15**).
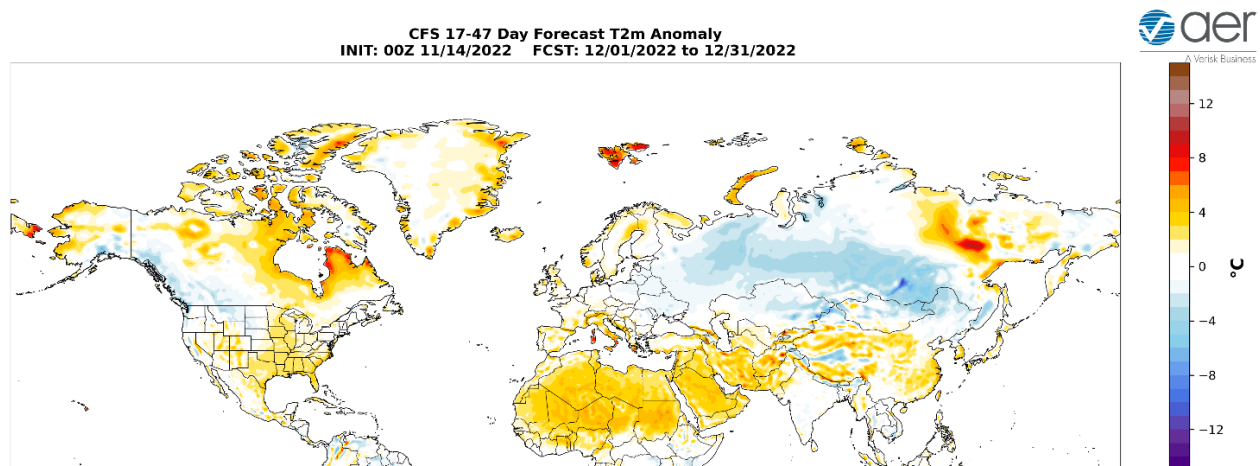

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for December 2022. The forecasts are from the 00Z 14 November 2022 CFS.

## *Boundary Forcings*

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 16)** and La Niña conditions are expected through the fall. 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 South Pacific.
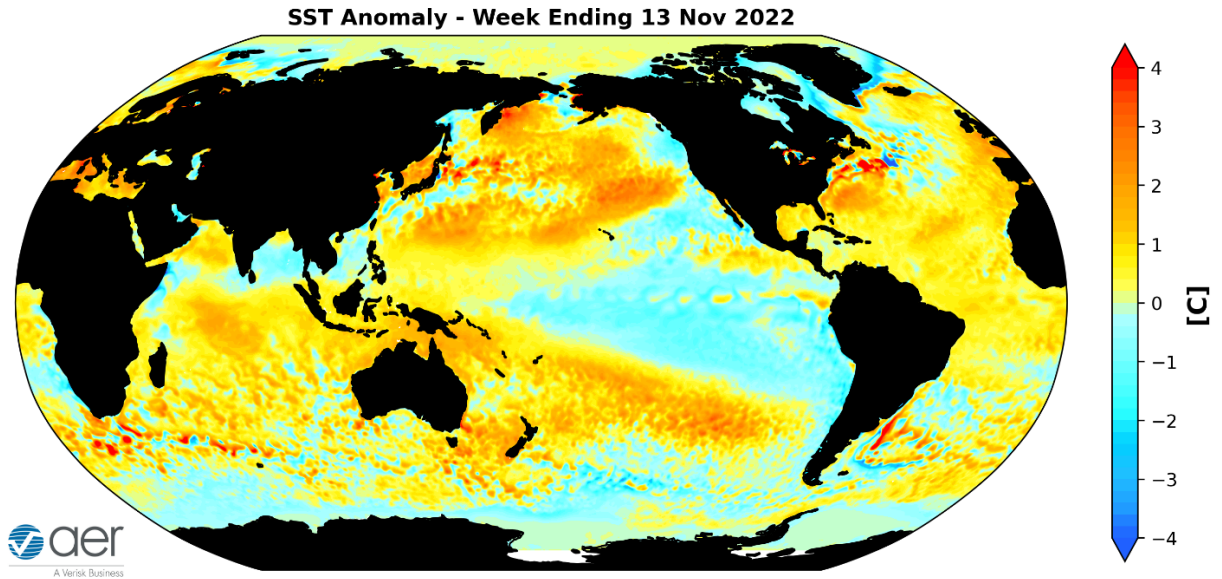
Figure 16. The latest weekly-mean global SST anomalies (ending 13 November 2022). Data from NOAA OI High-Resolution dataset.

Madden Julian Oscillation

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 17**). The forecasts are for the MJO to emerge in phase six and then move into phase seven. MJO phase six favors ridging in the Western US with troughing in the Eastern US while MJO phase seven favors a deep Aleutian low with ridging across Canada and troughing across the US. I don't see much evidence of the influence of the MJO on the weather across North America. But admittedly this is outside of my expertise.
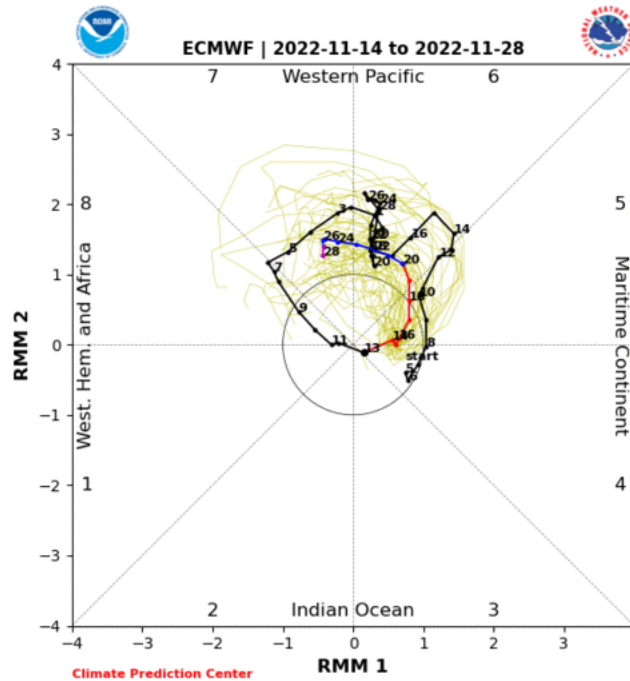
Figure 17. Past and forecast values of the MJO index. Forecast values from the 00Z 14 November 2022 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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

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!