

Arctic Oscillation and Polar Vortex Analysis and Forecasts

March 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 positive and is predicted to remain neutral to positive through late-March with mixed to mostly negative pressure/geopotential height anomalies across the Arctic especially the North Atlantic side of the Arctic and mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is also positive and is predicted to remain positive as pressure/geopotential height anomalies are predicted to remain negative across Greenland the next two weeks.
- The next two weeks, troughing/negative geopotential height anomalies across Greenland will favor ridging/positive geopotential height anomalies over Northern Europe centered over Scandinavia/the Baltic Sea forcing downstream troughing/negative geopotential height anomalies over Southern Europe. This pattern favors normal to above normal temperatures across much of Northern Europe including the United Kingdom (UK) with normal to below normal temperatures across Southern Europe but especially Southeastern Europe and Turkey.
- The dominant pattern across Asia the next two weeks is likely related to the predicted polar vortex (PV) disruption with the major PV center over Western Siberia. In the troposphere this will result in troughing/negative geopotential height anomalies centered in Western Siberia and extending southwards across Central Asia with ridging/positive geopotential height anomalies across Eastern Siberia and Southern Asia. This favors normal to below normal temperatures first in Western and Central Siberia and then

spreading west across Western Asia and east into Eastern Asia with normal to below normal temperatures across Eastern Siberia and Southern Asia.

- The pattern this week across North America is ridging/positive geopotential height anomalies across the United States (US) with troughing/negative geopotential height anomalies across Canada, However beginning next week the flow will become more aligned with the minor daughter PV center over Eastern Canada with strengthening ridging/positive geopotential height anomalies centered near Alaska with downstream troughing/negative geopotential height anomalies across Eastern Canada inducing northerly flow in Central Canada. The pattern this week favors normal to below normal temperatures in Alaska and Northern Canada with normal to above normal temperatures across Southern Canada and most of the US. Beginning next week normal to below normal temperatures will spread from Alaska and Northern Canada southward across Southern Canada and the Northern US with normal to above normal temperatures in the Southern US.
- In the *Impacts* section I continue to discuss my expectations of the largest and possibly last polar vortex (PV) disruption of the year. The upcoming PV disruption is a more classical sudden stratospheric warming (SSW) and will likely impact the weather of the Northern Hemisphere (NH) into April.
- I am transitioning to a spring and summer schedule which is every other week beginning next week and there will likely not be a new blog next week.

Plain Language Summary

The next polar vortex disruption looks to be of a different nature of previous disruptions and is known as a sudden stratospheric warming. Lots of uncertainty to the weather impacts as weather models struggle at this forecast time horizon. But I believe that eventually this a good likelihood of Greenland blocking/high pressure that favors colder and/or stormier weather across Europe and possibly the Eastern US.

Impacts

The big upcoming event that I am focused on is the predicted significant disruption of the PV in the coming weeks. Unlike all previous disruptions to the PV this winter, which were relatively minor and involved stretching, this upcoming PV disruption is much larger and will result in a PV split (to be honest I wouldn't consider myself an expert in differentiating between PV splits and displacements, but this looks to me as a PV split). Most model forecasts are predicting that this PV disruption will meet the criteria of a major warming (where the zonal winds at 60°N and 10hPa reverse from westerly to easterly or from positive to negative).

We included our new energy diagnostics mostly to identify wave energy reflection but this week's initialization, I think shows nicely the reason for the PV split. In **Figure i** you can observe two distinct regions of vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere or poleward heat transport in the stratosphere upward WAF - one over Asia (from 60-180°E) and another stronger region of upward energy propagation over Canada and the North Atlantic (270-360°E or 90-0°W). This is helping to develop two ridge centers one in each ocean basin (see **Figures 13a**) that will eventually pinch the PV center creating two daughter vortices.

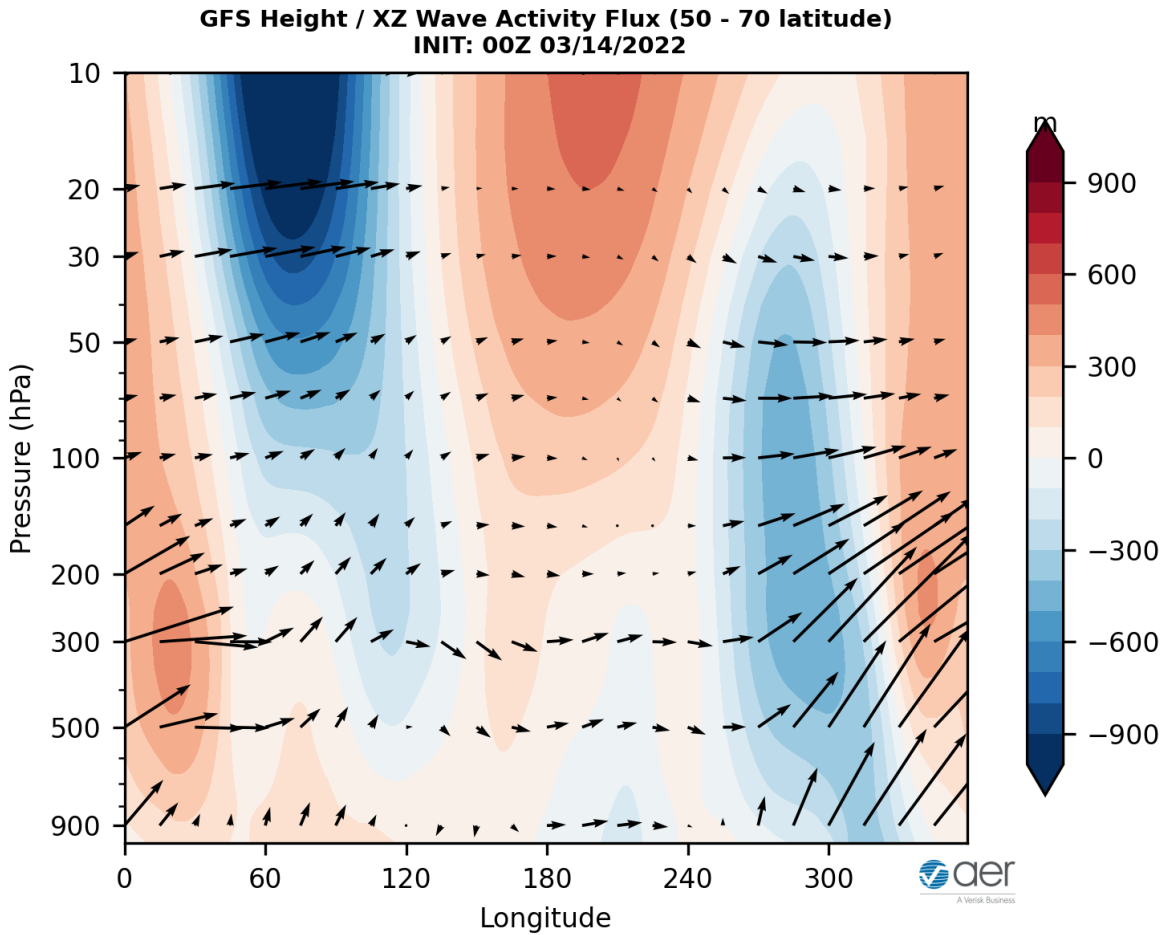


Figure i. Longitude-height cross section of geopotential eddy height anomalies and wave activity flux vectors and wave activity flux vectors in the longitudinal and height directions from the surface through 10-hPa initialized for 14 March 2022. The forecast is from the 00Z 14 March 2022 operational GFS.

If this were December or January instead of March, I would consider this a more significant event in regard to the upcoming weather and would be emphasizing an increased risk for severe winter weather across the NH. But it takes time for the full impact of a sudden stratospheric warming (SSW) to reach the surface, which could be as early as the end of March but more likely April. By April it is difficult to get cold and snow in many populated regions except far to the north or high in elevation but still possible across the Northern US and Northern Europe. But if high latitude blocking develops, extreme weather can still occur of the non-wintery variety, such as flooding. The most recent March SSW was in 2016 and that was followed by a spring of widespread extreme weather events as seen in Figure 7 of [Cohen et al. 2017](#). I copied it here in **Figure ii.** Longitude-height cross section of geopotential eddy height anomalies and wave activity flux vectors and wave activity flux vectors in the longitudinal and height directions from the surface through 10-hPa for 18 – 22 March 2022. The forecast is from the 00Z 7 March 2022 operational GFS.

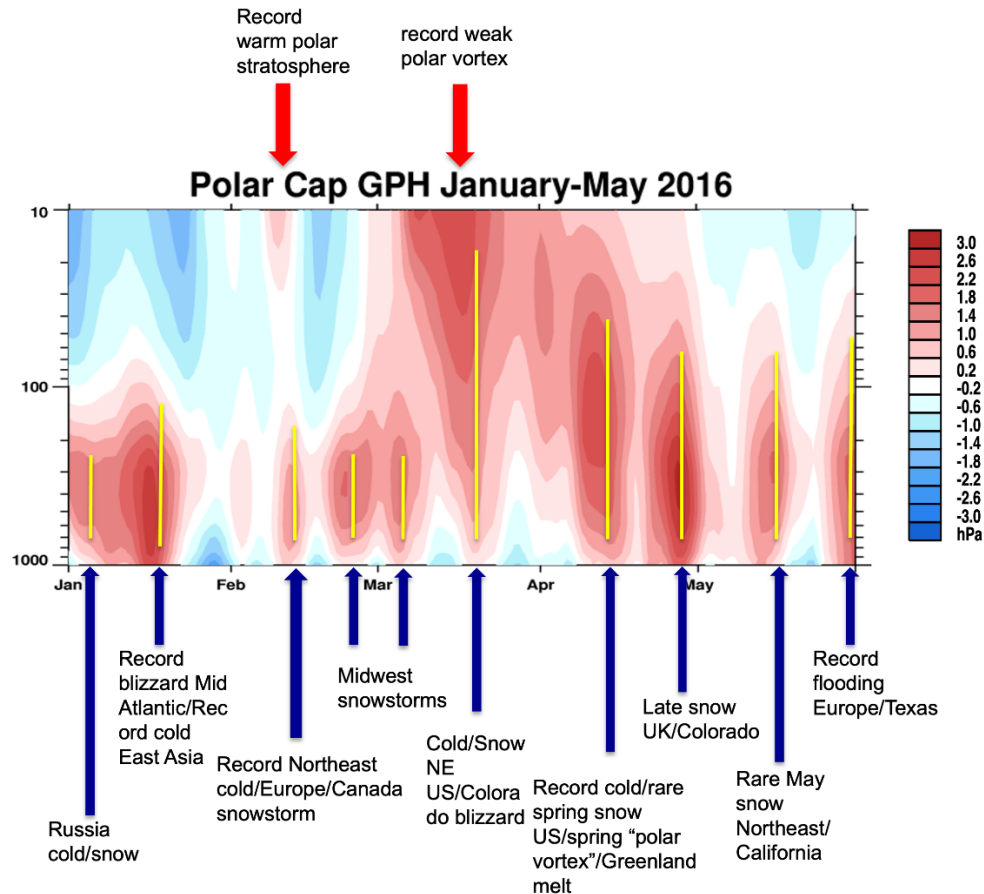


Figure ii. Anomalies of daily standardized polar cap (60-90°N) geopotential height from 1 January 2016 through 31 May 2016. Anomalously high heights (corresponding with warm temperatures) shaded in red. Blue arrows denote extreme weather events across the Northern Hemisphere, while the red arrow shows the date of the two sudden stratospheric warmings. Yellow bars are simply meant to align for the reader the pulsating of the PCH with an extreme event.

But for some analogous impacts of an SSW such as March 2016, I believe that we would need to observe a robust descent of warm/positive polar cap geopotential height anomalies (PCHs) from the upper stratosphere to the surface as was observed in spring 2016. This can happen in 2022 but from **Figure 11** it is not predicted by the GFS just yet. Anomalies to the stratospheric PV tend to persist the longest in the lower stratosphere and the strong PV of this winter is persisting the longest in the lower stratosphere. I do think that there is a very good chance that the warm/positive PCHs will eventually make it to the lower stratosphere and then from there through the troposphere but so far, the GFS is not predicting this scenario within its time horizon. But I think it is worth watching for either the coupling of the stratosphere and troposphere to happen quicker than the GFS is predicting or just beyond its forecast period of two weeks.

If the stratosphere and troposphere do couple with warm/positive PCHs observed in both, then high latitude blocking should increase. I also think that there is a good chance that high latitude blocking could be centered near Greenland, which is the classical response to an SSW. If Greenland blocking does occur, then colder weather could be favored for Northern Europe and Asia and possibly the Eastern US. The colder weather could be accompanied by stormier weather as well.

1-5 day

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

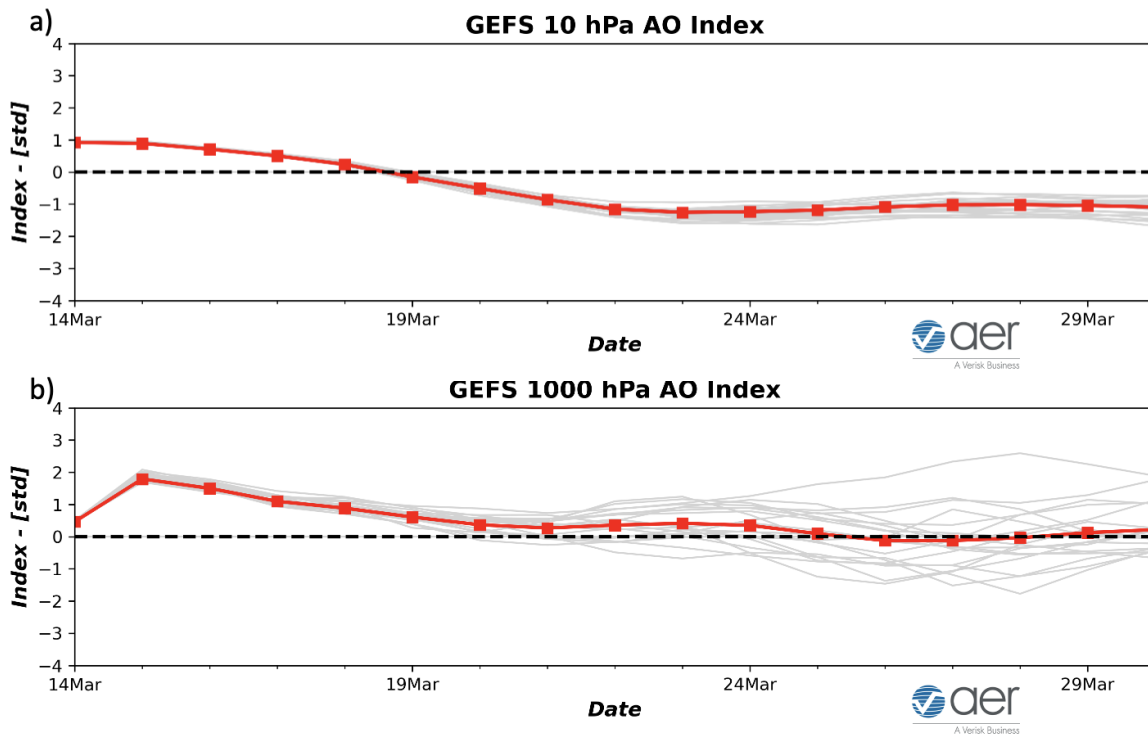


Figure 1. (a) The predicted daily-mean AO at 1000 hPa from the 00Z 14 March 2022 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 14 March 2022 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red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

Persistent troughing/negative geopotential height anomalies across Greenland will support ridging/positive geopotential height anomalies across Scandinavia forcing downstream troughing/negative geopotential height anomalies across much of Eastern Europe and Spain (**Figures 2**). This will result in normal to above normal temperatures across Western and

Northern Europe including the UK with normal to below normal temperatures across Southern and Eastern Europe including Turkey and possibly Portugal and Western Spain due to low heights and/or northerly flow (**Figure 3**). The current displacement of the major center of the stratospheric PV over Western Siberia will help to anchor troughing/negative geopotential height anomalies over Western Siberia that trails southwestward across Southwestern Asia with ridging/positive geopotential height anomalies widespread across Southern Asia and Eastern Siberia this period (**Figure 2**). This pattern favors normal to below normal temperatures across Western, Central and Eastern Asia with normal to above normal temperatures across the North Slope and Southern Asia (**Figure 3**).

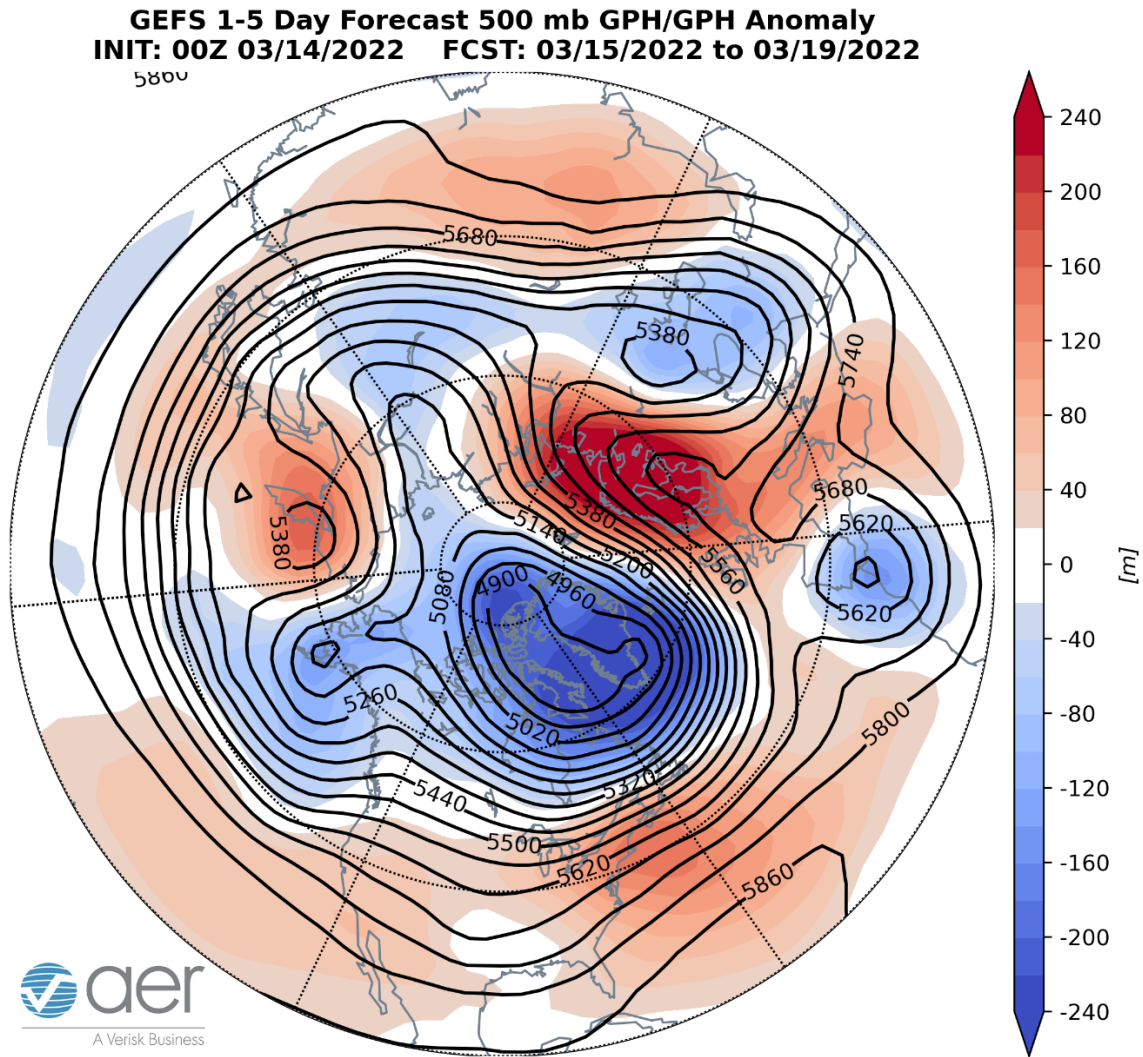


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 15 – 19 March 2022. The forecasts are from the 00z 14 March 2022 GFS ensemble.

Across North America the tropospheric circulation pattern is related to an evolving stratospheric PV split with coupled troughing/negative geopotential height anomalies in the stratosphere and

troposphere across Alaska and much of Canada with ridging/positive geopotential height anomalies across the US (**Figure 2**). The resultant zonal flow will favor normal to below normal temperatures across Alaska and Northern Canada with normal to above normal temperatures in Southern Canada and much of the US (**Figure 3**).

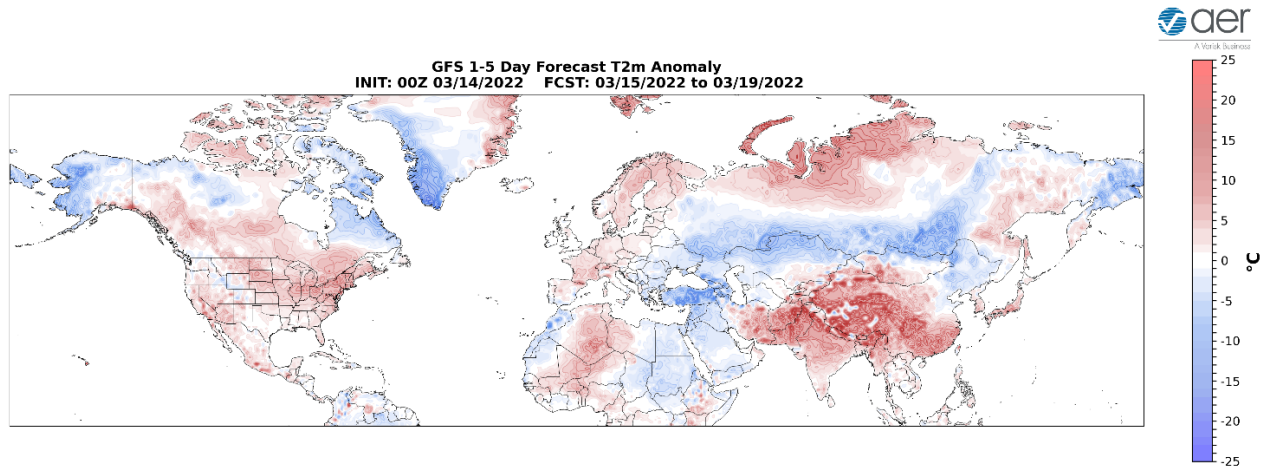


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 15 – 19 March 2022. The forecast is from the 00Z 14 March 2022 GFS ensemble.

As the sun continues to rise in the NH sky, snowmelt is predicted to be widespread across Eurasia and North America with new snowfall limited to parts of Central and Eastern Asia, Southern Alaska and Northern Canada (**Figure 4**).

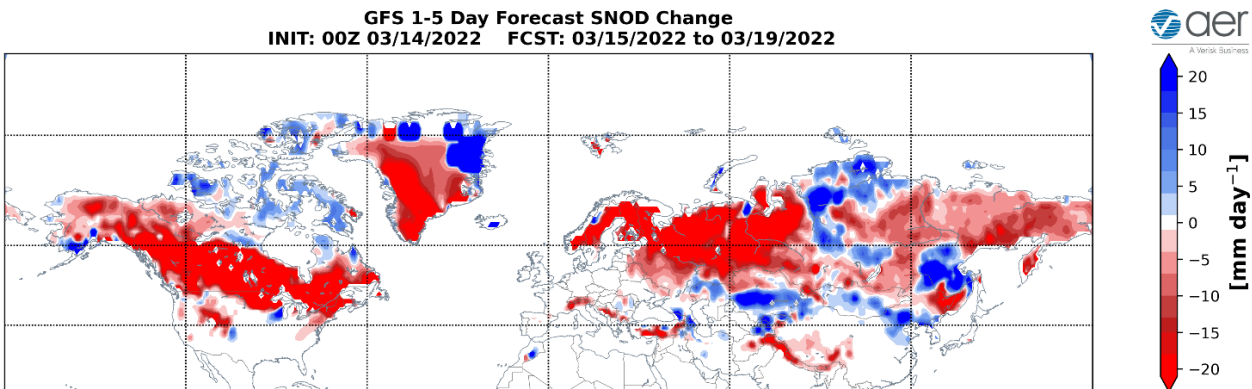


Figure 4. Forecasted snow depth changes (mm/day; shading) from 15 – 19 March 2022. The forecast is from the 00Z 14 March 2022 Operational GFS.

Mid-Term

6-10 day

The AO is predicted to remain neutral to positive this period (**Figure 1**) with mostly negative geopotential height anomalies spread across the Arctic especially the North Atlantic side of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with negative geopotential height anomalies across Greenland (**Figure 5**), the NAO is predicted to remain positive this period.

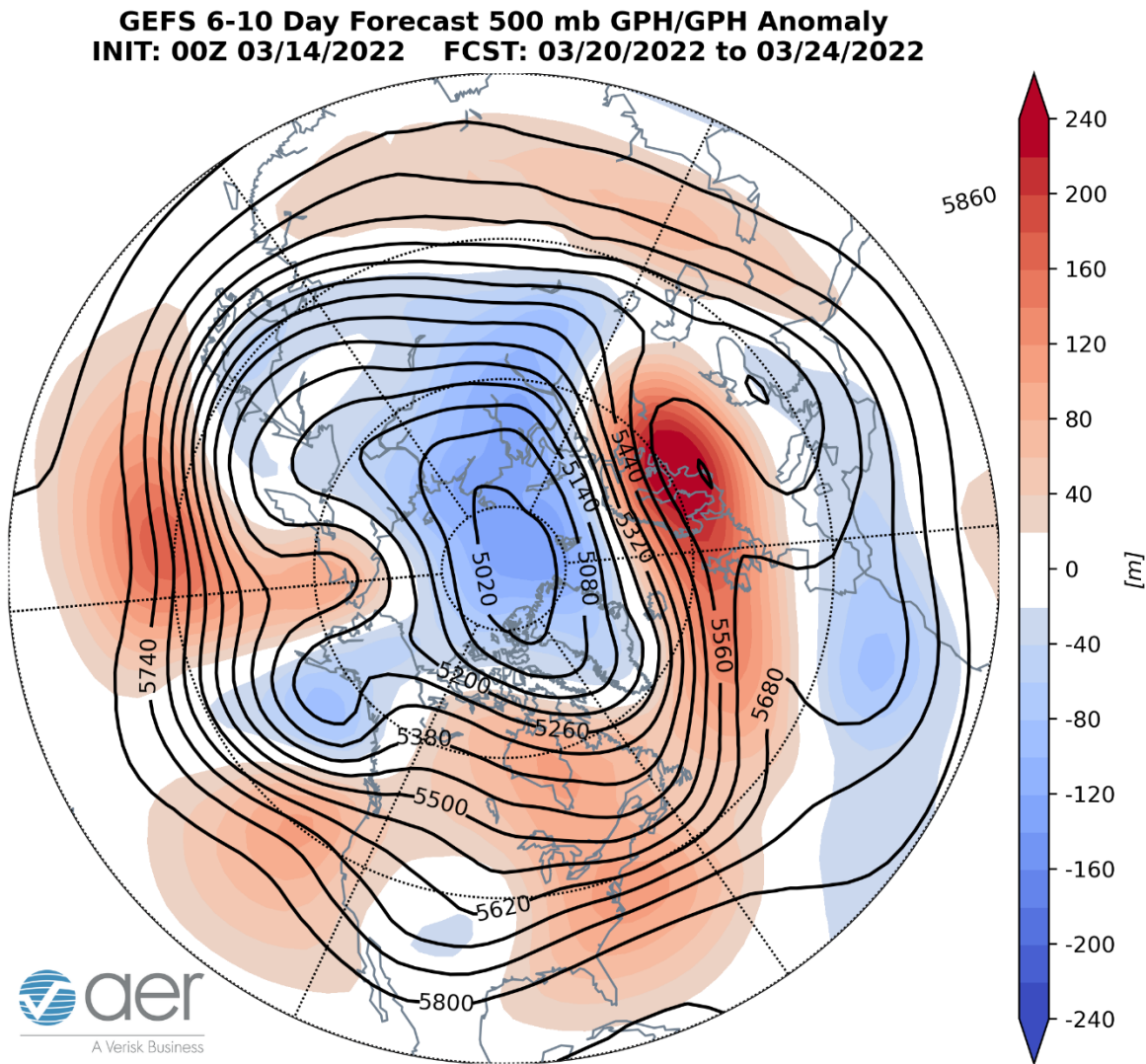


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 20 – 24 March 2022. The forecasts are from the 00z 14 March 2022 GFS ensemble.

Persistent troughing/negative geopotential height anomalies across Greenland will support ridging/positive geopotential height anomalies across Northern Europe centered over the Baltic Sea forcing downstream troughing/negative geopotential height anomalies across Southern Europe (**Figures 5**). This will result in normal to above normal temperatures across much of Northern Europe including the UK with normal to below normal temperatures across Southern Europe due to low heights and/or northerly flow (**Figure 6**). The continued displacement of the

main center of the stratospheric PV over Central Asia will help to persist troughing/negative geopotential height anomalies across Northern and Central Asia with ridging/positive geopotential height anomalies widespread across Southern Asia this period (**Figure 5**). This pattern favors widespread normal to above normal temperatures across much of far Northern and Southern Asia with normal to below normal temperatures sandwiched in between across Central Asia (**Figure 6**).

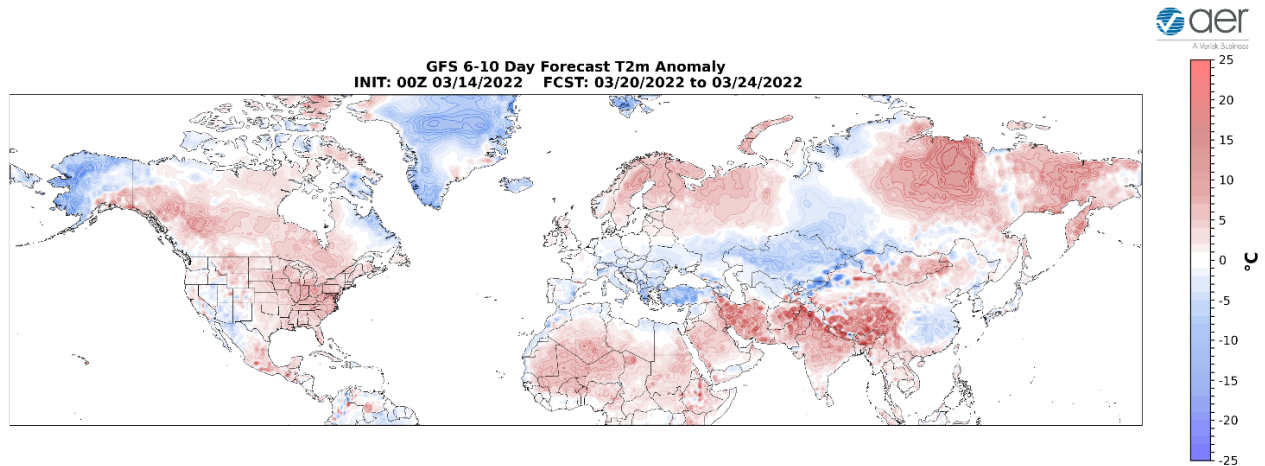


Figure 6. Forecasted surface temperature anomalies (°C; shading) from 20 – 24 March 2022. The forecasts are from the 00Z 14 March 2022 GFS ensemble.

Across North America a continuation of troughing/negative geopotential height anomalies limited to Alaska and Northern Canada with ridging/positive geopotential height anomalies across Southern Canada and the US is predicted with additional troughing in the Western US (**Figure 5**). This will favor normal to below normal temperatures across Alaska, Northern Canada and the Western US with normal to above normal temperatures in Central and Eastern Canada and the US east of the Rockies (**Figure 6**).

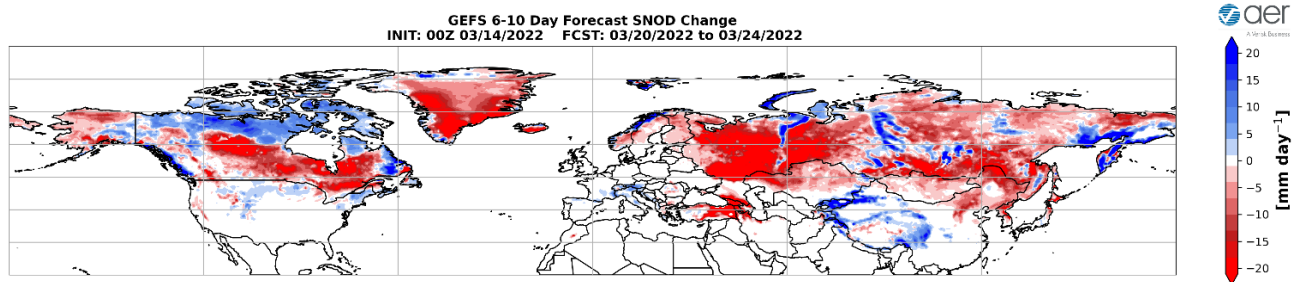


Figure 7. Forecasted snow depth changes (mm/day; shading) from 20 – 24 March 2022. The forecast is from the 00Z 14 March 2022 GFS ensemble.

Widespread snowmelt is predicted across Eurasia and North America with new snowfall limited to Southeastern Europe, Siberia, the Tibetan Plateau, Northern Canada, the US Rockies and possibly New England (**Figure 7**).

11-15 day

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

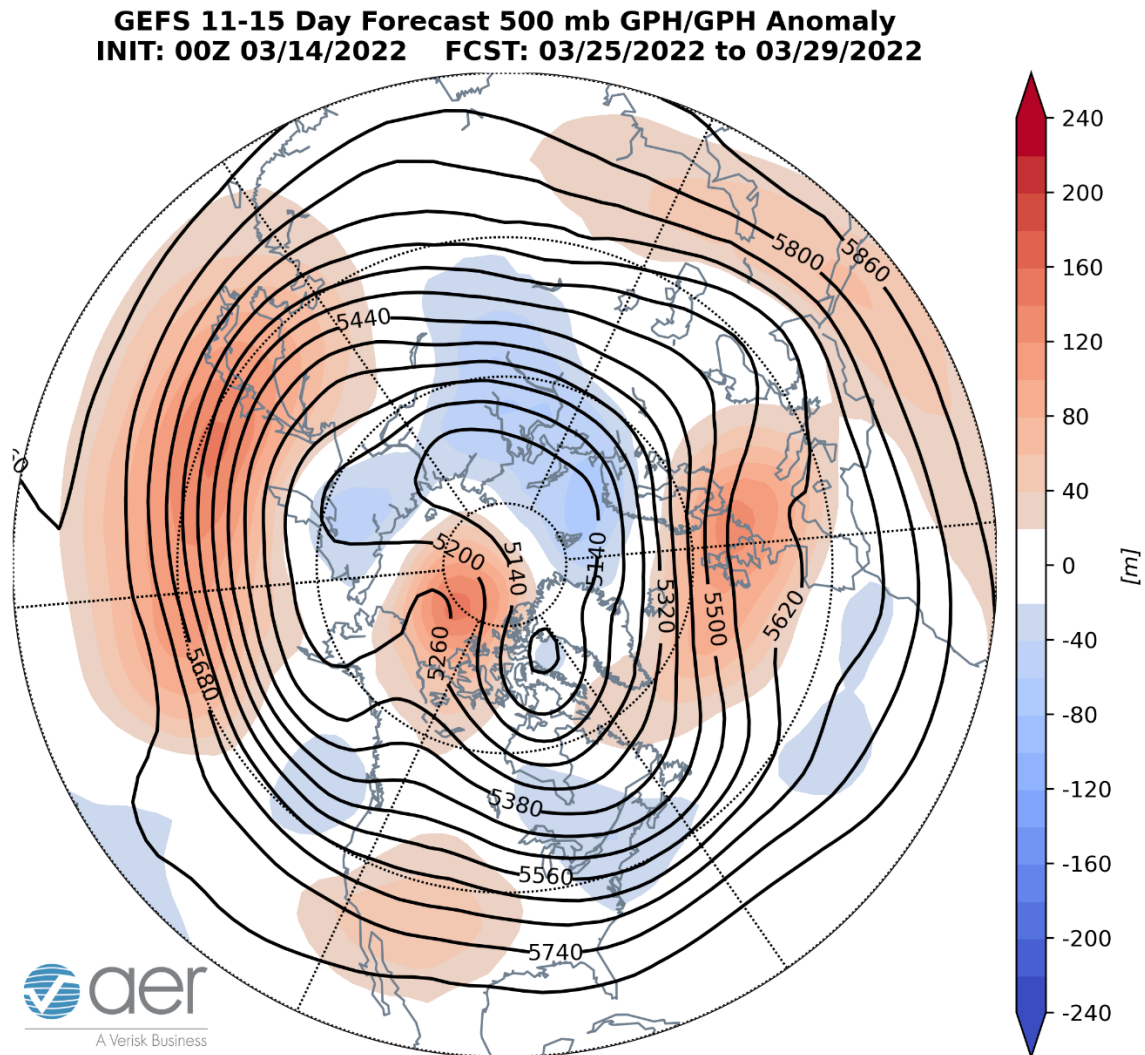


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 25 – 29 March 2022. The forecasts are from the 00z 14 March 2022 GFS ensemble.

Persistent but weakening troughing/negative geopotential height anomalies across Greenland will continue to support ridging/positive geopotential height anomalies across Northern Europe forcing weak troughing/negative geopotential height anomalies across Southern Europe this period (**Figure 8**). This pattern favors more normal to above normal temperatures widespread

across much of Europe including the UK with normal to below normal temperatures limited across the Mediterranean due to low geopotential heights and/or northerly flow (**Figures 9**). The pattern of troughing/negative geopotential height anomalies across Siberia and Central Asia with ridging/positive geopotential height anomalies across Southern and Northeastern Asia is predicted to persist this period (**Figure 8**). This pattern favors widespread normal to above normal temperatures across much of Northern and Southern Asia with normal to below normal temperatures across Central and Southeast Asia due to low geopotential heights and/or northerly flow this period (**Figure 9**).

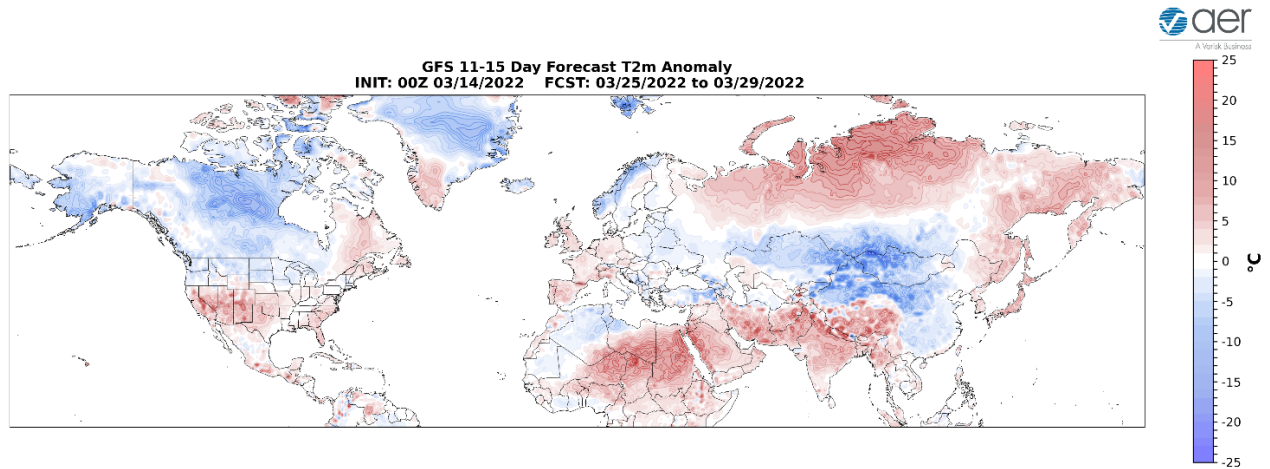


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 25 – 29 March 2022. The forecasts are from the 00z 14 March 2022 GFS ensemble.

The pattern across North America is predicted to transition to ridging/positive geopotential height anomalies across Alaska and Western Canada and the Western US forcing deepening troughing/negative geopotential height anomalies across Central and Eastern Canada that extends southwards into the Northeastern US this period (**Figure 8**). This pattern favors normal to below normal temperatures across Alaska, much of Canada and the Northern US with normal to above normal temperatures in far Eastern Canada and the Southern US (**Figure 9**).

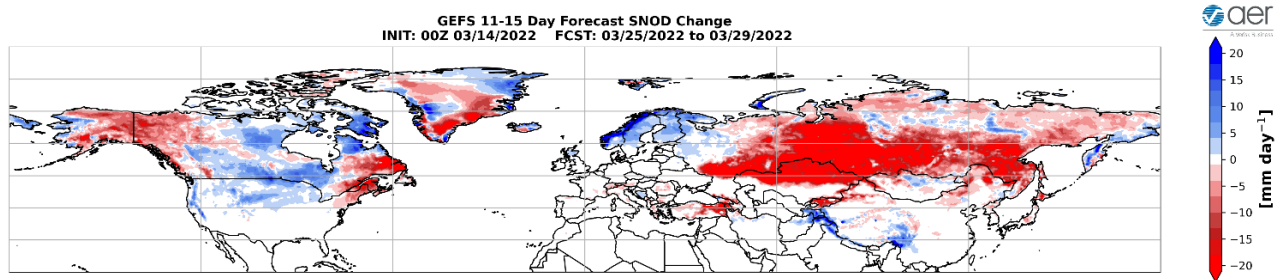


Figure 10. Forecasted snow depth changes (mm/day; shading) from 25 – 29 March 2022. The forecast is from the 00Z 14 March 2022 GFS ensemble.

Snowmelt is predicted to remain widespread across Eurasia and North America with new snowfall limited to parts of Scandinavia, the Tibetan Plateau, Central Canada and the Central US (**Figure 10**).

Longer Term

30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows cold/negative PCHs throughout stratosphere and troposphere. However warm/positive PCHs are predicted to form this week in the upper stratosphere and then mid stratosphere (**Figure 11**). The positive departures in the upper stratosphere are predicted to be quite large next week and are related to a significant disruption to the PV (**Figure 11**). Meanwhile the cold/negative PCHs in the lower stratosphere are predicted to persist through next week with warm/positive PCHs developing in the low to mid troposphere (**Figure 11**).

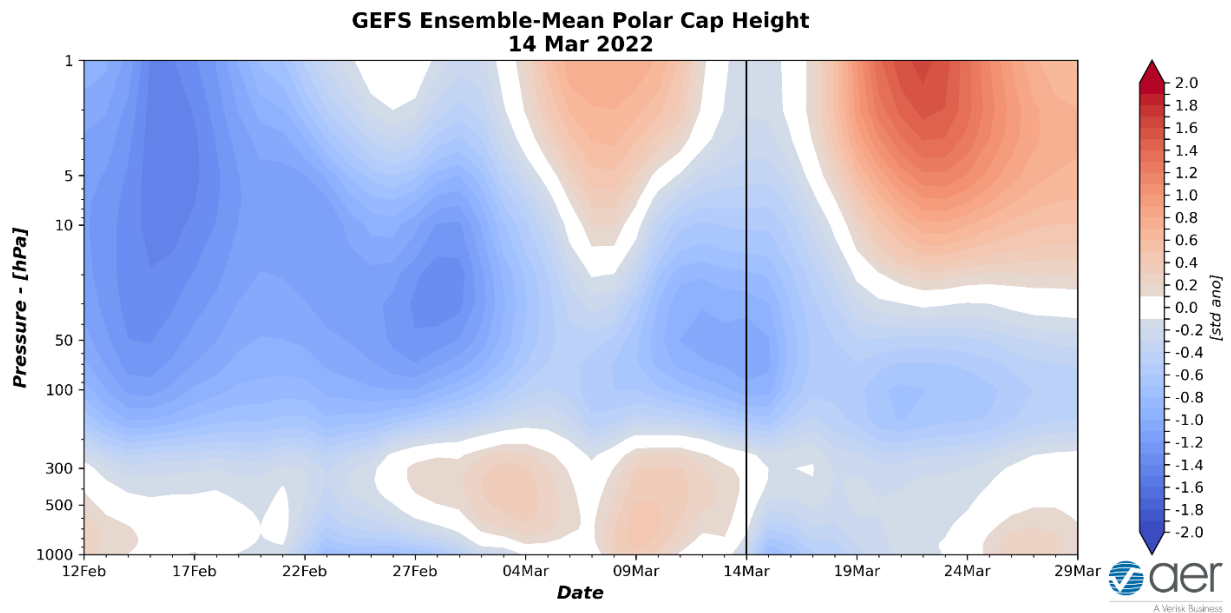


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 14 March 2022 GFS ensemble.

The normal to below normal PCHs predicted in the lower troposphere are consistent with the predicted positive surface AO during the same time period (**Figure 1**). The positive to neutral AO are predicted to persist despite the normal to above normal PCHs in the lower troposphere, but future AO forecasts could become increasingly negative.

The largest pulse of the year in vertical Wave Activity Flux (WAFz) from the troposphere to the stratosphere or poleward heat transport in the stratosphere is predicted for this week (**Figure 12**). More positive WAFz anomalies are also possible next week and will continue to support a

relatively weak PV as suggested by the relatively warm PCHs in the upper-stratosphere that extends to the mid-stratosphere next week.

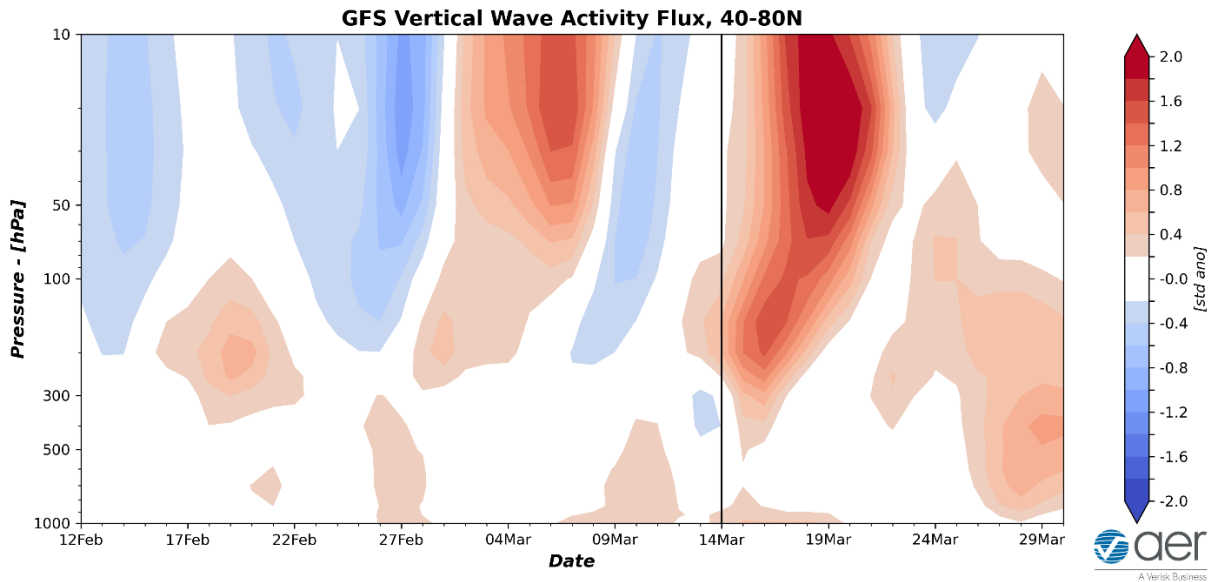


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 7 March 2022 GFS ensemble.

The strong pulse of WAFz this week is likely to force a major sudden stratospheric warming (where the zonal winds at 60°N and 10hPa reverse from westerly to easterly). This is predicted to also result in the first negative stratospheric AO of the year next week (**Figure 11**).

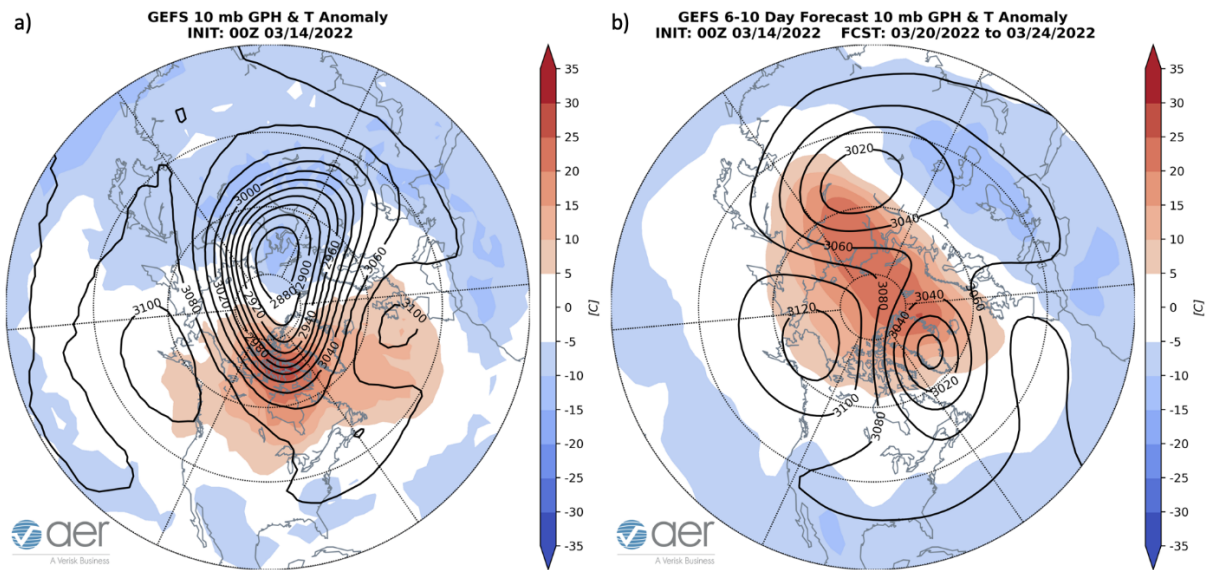


Figure 13. (a) Initialized 10 mb geopotential heights (dam; contours) and temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere averaged for 7 March 2022. (b) Same as (a) except forecasted averaged from 20 – 24 March 2022. The forecasts are from the 00Z 14 March 2022 GFS model ensemble.

The PV is already somewhat disrupted because of the strong pulse of WAFz last week (**Figure 12**). The PV is displaced towards Western Siberia with polar stratospheric warming spread across the North American Arctic with ridging centered near Alaska and the UK (**Figure 13a**). The polar stratospheric ridging in both ocean basins is predicted to eventually pinch the PV center into two daughter vortices with one center over Central Asia and the other center over Greenland (see **Figure 13b**) resulting in a PV split.

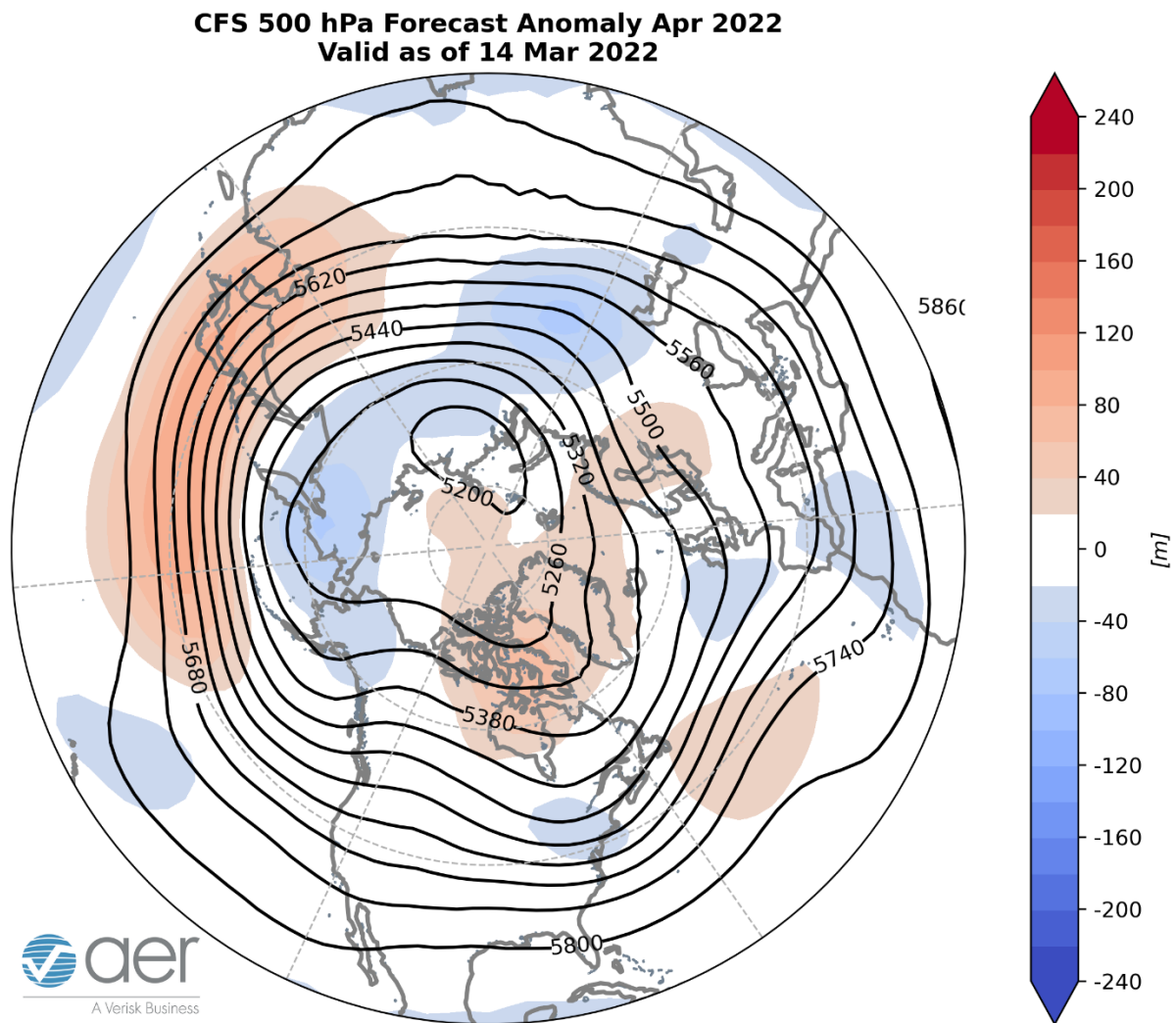


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for April 2022. The forecasts are from the 00Z 14 March 2022 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and surface temperatures for March (**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 Northeastern Canada into the Central Arctic, near Scandinavia, from East Asia to the Aleutians and the western North Atlantic with troughing across Western and Southern Europe, Western Asia, Siberia, Alaska, the Gulf of Alaska into the West Coast of North America, Eastern Canada and the Northeastern US (**Figure 14**). This pattern favors seasonable to relatively warm temperatures across Central Europe, Northern and Southern Asia, Central Canada and the Western US with seasonable to relatively cool temperatures across Eastern Europe, Turkey, Southwest Asia, East Asia, Alaska, Western Canada and the Eastern US (**Figure 15**).

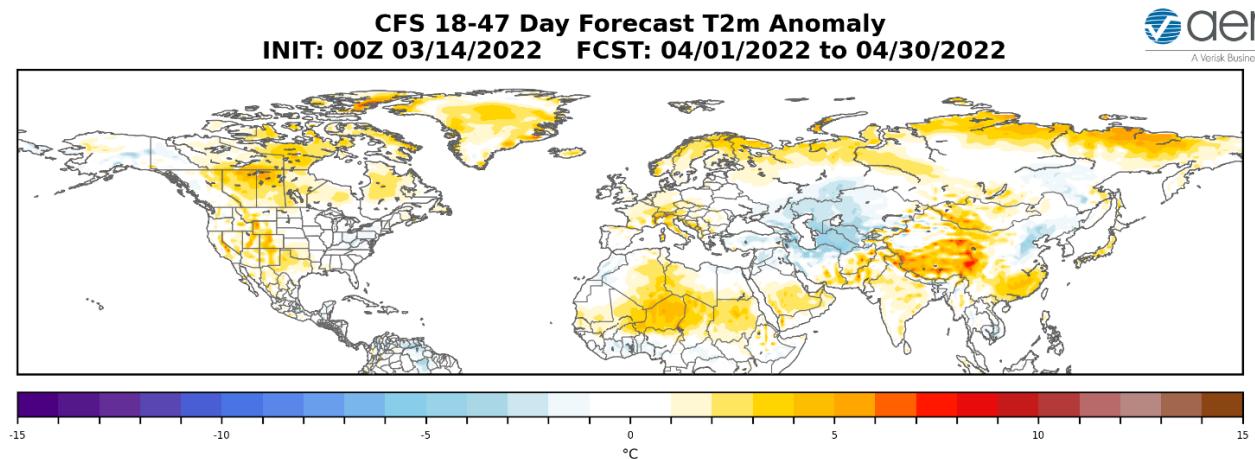


Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for March 2022. The forecasts are from the 00Z 14 March 2022 CFS.

Surface Boundary Conditions

Arctic Sea ice

Arctic sea ice growth has stalled and remains below normal mostly in Sea of Okhotsk and recently in the Barents and even Bering Seas. Overall sea ice is relatively extensive compared to recent winters, though it remains relatively thin. Below normal sea ice in the Barents-Kara seas favors cold temperatures in Central and East Asia, however this topic remains controversial. Recent research has shown that the regional anomalies that are most highly correlated with the strength of the stratospheric PV are across the Barents-Kara seas region where low Arctic sea ice favors a weaker winter PV. Low sea ice in the Chukchi, Beaufort and Bering seas may favor colder temperatures across North America but has not been shown to weaken the PV.

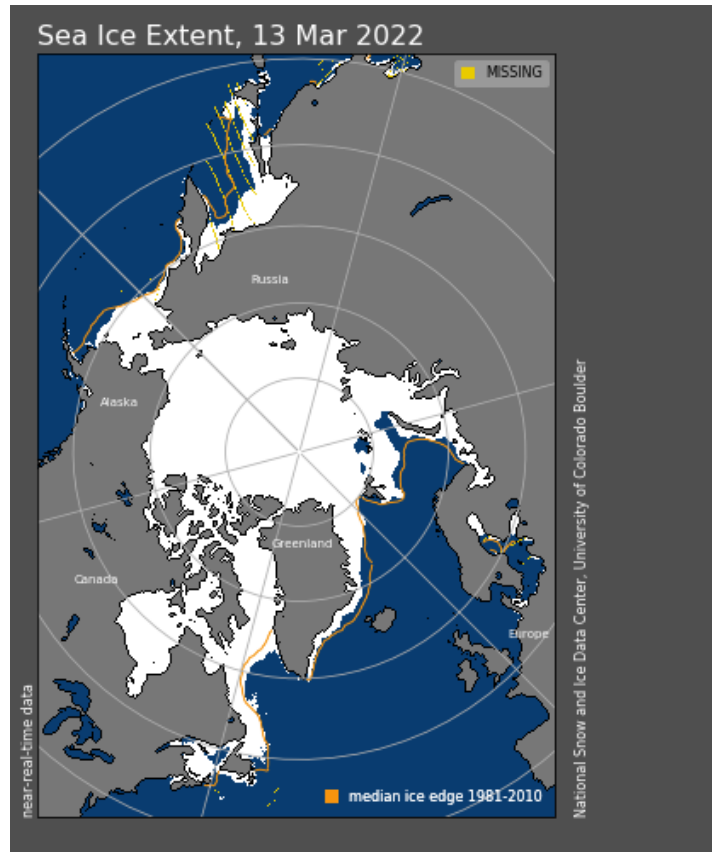


Figure 16. Observed Arctic sea ice extent on 13 March 2022 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image from the National Snow and Ice Data Center (NSIDC).

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 into the spring. 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.

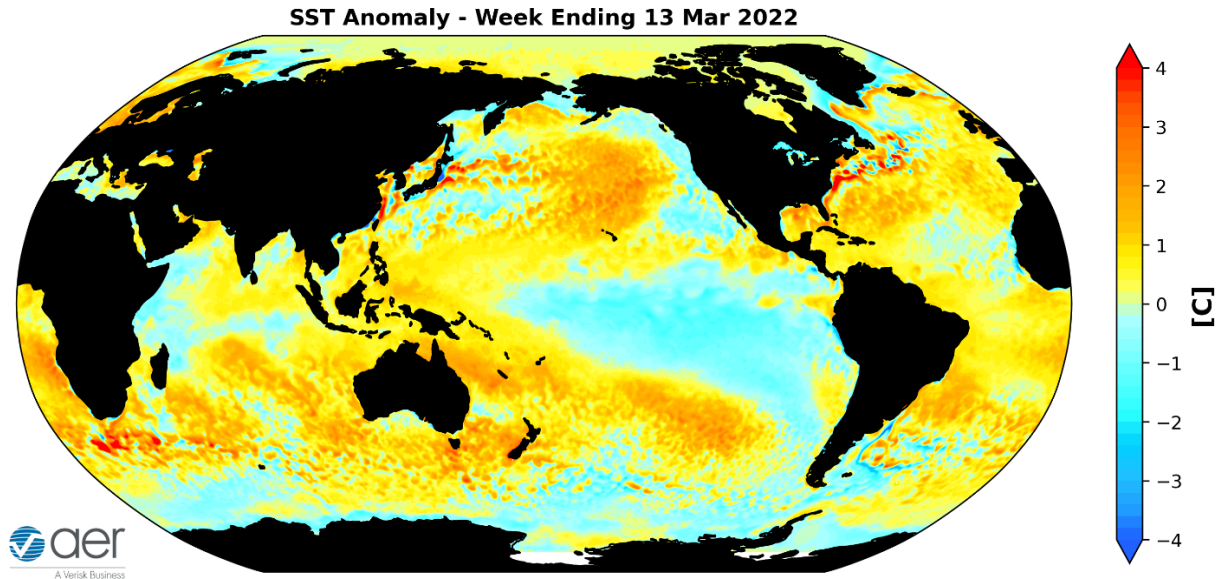


Figure 17. The latest weekly-mean global SST anomalies (ending 13 March 2022). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase two (**Figure 18**). The forecasts are for the MJO to quickly transition to phases three, four and five before weakening to where no phase is favored. Phase two and three favor ridging in the Gulf of Alaska that drifts west with time and troughing in the Eastern US so hard to for me to see that the MJO is likely influencing the weather across North America. But admittedly this is outside of my expertise.

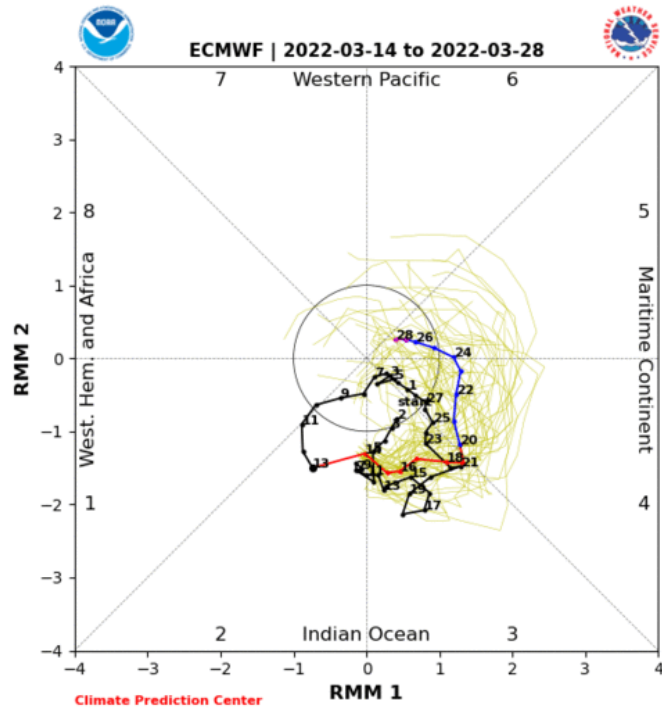


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 14 March ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate the 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>

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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.

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