Arctic Oscillation and Polar Vortex Analysis and Forecasts

December 9, 2019

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) recently 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.

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The AO/PV blog is partially supported by NSF grant AGS: 1657748.

Summary

- The Arctic Oscillation (AO) is currently positive and is predicted to first turn more strongly positive and then slowly trend negative over the next two weeks towards neutral.
- The current positive AO is reflective of mostly negative pressure/geopotential height anomalies across the Arctic and mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is positive with negative pressure/geopotential height anomalies spread across Greenland; and the NAO is predicted to also first trend even more positive and

then trend back to neutral as heights turn weakly positive across Greenland next week.

- The general pattern for the next two weeks is of troughing/negative pressure/geopotential height anomalies over Northern Europe with ridging/positive geopotential height anomalies over Southern Europe. This will result in a mild westerly flow of air across the continent with widespread normal to above normal temperatures across Europe including the United Kingdom (UK) with the possible exception of localized normal to below normal temperatures in Northern Europe under the lowest heights.
- Currently ridging/positive geopotential height anomalies and normal to above normal temperatures dominate much of Asia. However, the ridging will become more focused across the Urals helping to deepen some troughing/negative pressure/geopotential height anomalies and normal to below normal temperatures across East Asia next week. Also, troughing/negative pressure/geopotential height anomalies with ridging/positive geopotential height anomalies are predicted to develop next week over the Tibetan Plateau bringing normal to below normal temperatures across northern Indian subcontinent.
- This GFS is predicting for this week ridging/positive geopotential height anomalies and normal to above normal temperatures across Alaska and western North America with troughing/negative geopotential height anomalies and normal to below normal temperatures across Eastern Canada with close to seasonable temperatures in the Eastern United States (US). Eventually the western ridging is predicted to break down allowing lowering heights across Alaska and western North America with colder temperatures.
- In the Impacts section I the inevitable and now annual winter forecast freak-out but why ultimately, I am staying the course.

Impacts

Seems like it is that time of the winter where this forecaster experiences an existential crisis and panic sets in whether the winter forecast will work out. Just about every predictor that I can list favors at least some cold temperatures across the Northern Hemisphere (NH). The predictor that I have studied the longest, October Eurasian snow cover extent was well above normal and the seventh greatest extent over the past 50+ years. Though the snow advance index (SAI) was only slightly positive. Arctic sea ice extent is well below normal. For the September sea ice minimum, it was the third lowest on record and has continued to be close to record low ever since. I also use an October sea level pressure index for anticipating high latitude blocking and that was not as strong this October as other recent years. Still all three of these predictors – above normal snow cover extent, below normal sea ice extent and an increased likelihood for high latitude blocking – favor a disrupted stratospheric polar vortex (PV) accompanied by cold temperatures across large regions of Eurasia and/or North America.

Those are the predictors that are used in the AER model but there are additional predictors that have been shown to favor cold winter temperatures across the Northern Hemisphere. These include low solar activity, an easterly quasi-biennial oscillation (QBO, or at elast a descending easterly QBO) and a positive Indian Ocean dipole. There are two other factors more pertinent for North America than Eurasia. Besides Eurasia, snow cover advance across North America was relatively rapid this fall. That should favor colder temperatures across North America. Finally, sea surface temperatures (SSTs) in the eastern North Pacific are well above normal. I believe the warm SSSTs could favor ridging/high pressure in the region favoring troughing downstream across North America accompanied by cold temperatures. I am considering El Niño/Southern Oscillation a non-factor since it is neutral but there are others who argue that it favors relatively cold temperatures. The one factor, and it is a big one that favors a warm winter, is that the globe in general but the oceans in particular are much warmer than even a few decades ago and the oceans are a constant reservoir of excess heat in the system.

As I wrote in earlier blogs, the NH November atmospheric circulation projected strongly onto composites of the atmospheric response to the Eurasian snow cover advance in October, with cold temperatures in East Asia and high pressure/blocking centered near the Urals (see **Figure i**). Also, the wave activity became more active in response to the Ural blocking and this has perturbed the PV. Our statistical model and the dynamical models were all predicting a significant disruption of the PV in early to mid-December. However. all the dynamical models have backed off of the magnitude of the PV disruption and it only looks to a relatively minor disruption.

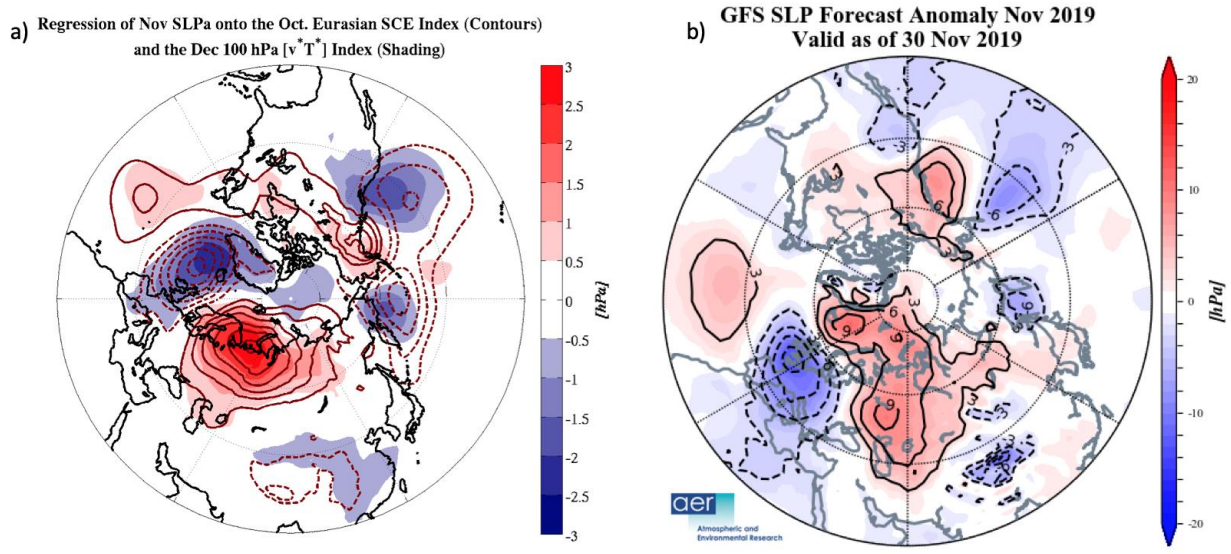

Figure i.

) Regression of November SLP anomalies (hPa) onto October monthly-mean Eurasian snow cover extent (contouring) and onto December meridional heat flux anomalies at 100 hPa, averaged between 40°N and 80°N (shading). This figure is the same as Figure 4 from **Cohen et al. (2014).** b) Observed mean sea level pressure (contours) and sea level pressure anomalies (shading) for November 2019.

As an aside the disruption this week of the PV is looking more and more like a "reflective" disruption and not an "absorptive" disruption. The anomalies in vertical wave activity flux are currently negative (see **Figure 12**) quickly followed by strong mid-tropospheric ridging centered near Alaska farcing downstream troughing (e.g. **Figure 2**) and relatively cold temperatures across eastern North America but focused in Canada (e.g. **Figure 3**).

However, the sea ice forcing of a disruptive PV in my opinion was not as strong this fall as in the past two falls with the largest sea ice extent anomalies not focused in the Barents-Kara seas but rather on the North Pacific side in the Chukchi and Bering Seas. In fact some modeling studies have shown that lwo sea ice in the Chukchi-Bering seas strengthens not weakens the stratospheric Pv (e.g., McKenna et al. 2017). Though open water still exists in the Chukchi Sea that looks to ice over as well in the very near future, which could swing the largest negative anomalies back to the North Atlantic side of the Arctic in the Barents Kara and West Greenland Seas. Still warmth in the Chukchi sea region (presumably aided by below normal sea ice extent) favors cold temperatures in eastern North America. This was shown by Kug et al. (2015) and Blackport et al. (2019), though Blackport et al. argue that the relationship between warm Chukchi Sea region and cold North American temperatures is not related to low sea ice in the region and is a statistical relationship but not a physical one. I include a similar analysis in **Figure i**i.

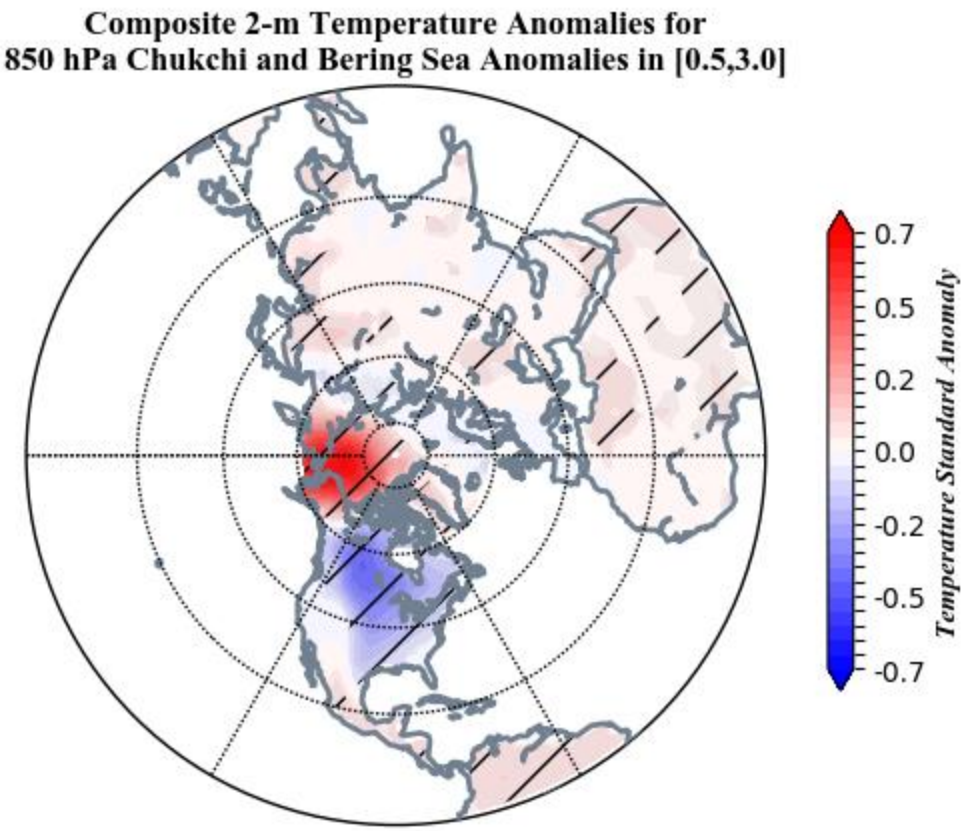

Figure ii. Observed Northern Hemisphere near-surface air temperature anomalies for all days when 850 hPa temperature anomalies were between 0.5 and 3.0 standard deviations above the climatological average for all winters (December, January, February) 1950–2019 in the Chukchi-Beaufort Seas,

Now that the dynamical models have backed off a significant PV disruption for pretty much the remainder of December and with no strong Ural blocking predicted (see **Figure iii** with our estimate of the December sea level pressure anomalies), I have a hard time predicting a significant PV disruption in the foreseeable future. And I strongly believe that without a disrupted PV or if the PV strengthens and becomes circular in shape, then it is nearly impossible for cold air to gain a foothold across the NH with some regionalized exceptions. This scenario is becoming a greater risk in my opinion.

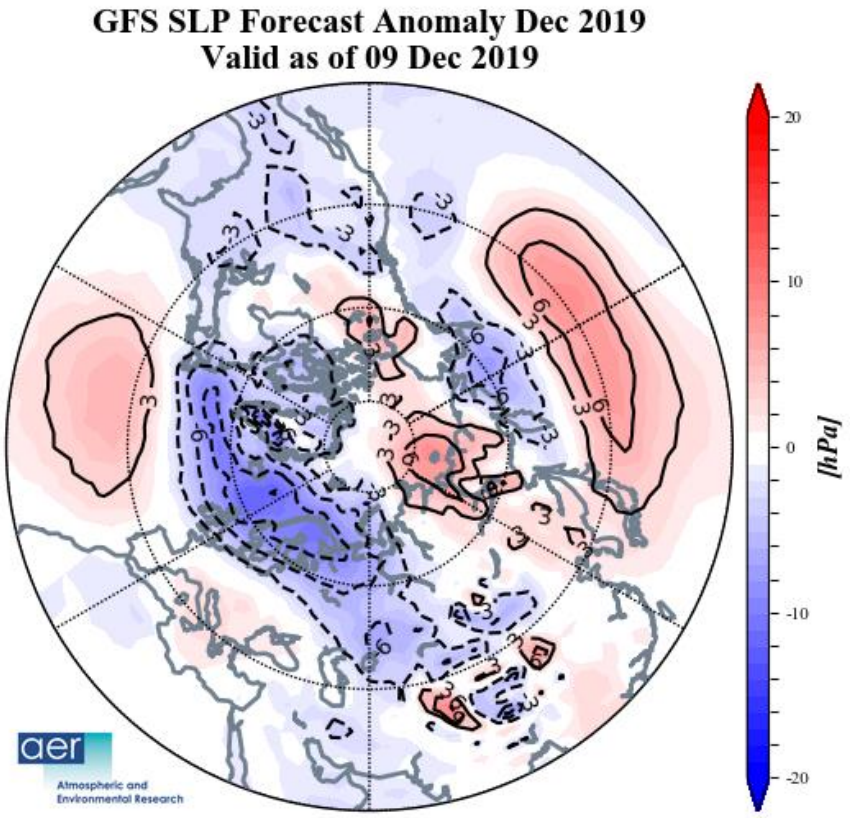

Figure iii. Estimate of Northern Hemisphere sea level pressure anomalies for December 2019 based on GFS analyzed data through December 9 and the GFS forecast through December 24, 2019.

Still I believe strongly that the Arctic is having a significant influence on mid-latitude weather. The warm Arctic, the rapid advance of snow cover this past fall, the below normal sea ice extent and the warm SSTs in the eastern North Pacific continue to favor cold temperatures in both Siberia (with some of that cold spilling into East Asia) and North America. I do believe these factors favor cold more so in North America and Asia than Europe this winter, at least so far. And though the emotional part of me wants to cut and run and I am having a harder time seeing exactly how the winter forecast verifies, I am sticking with the forecast. I strongly believe in the Arctic influence on our winter weather borne out in my own observational analysis and the vast majority observational analysis performed by my colleagues. And I think during these emotional rollercoasters, you need to stick with the more rational analysis performed under less stressful moments. As they say, “the captain always goes down with the ship” and at least for this winter, if the Arctic ship goes down I am going down with it.

Near Term Conditions

1-5 day

The AO is currently positive **(Figure 1**) with negative geopotential height anomalies across the North Atlantic side of the Arctic (which dominates the AO signal) and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with negative geopotential height anomalies across Greenland (**Figure 2**), the NAO is positive as well.

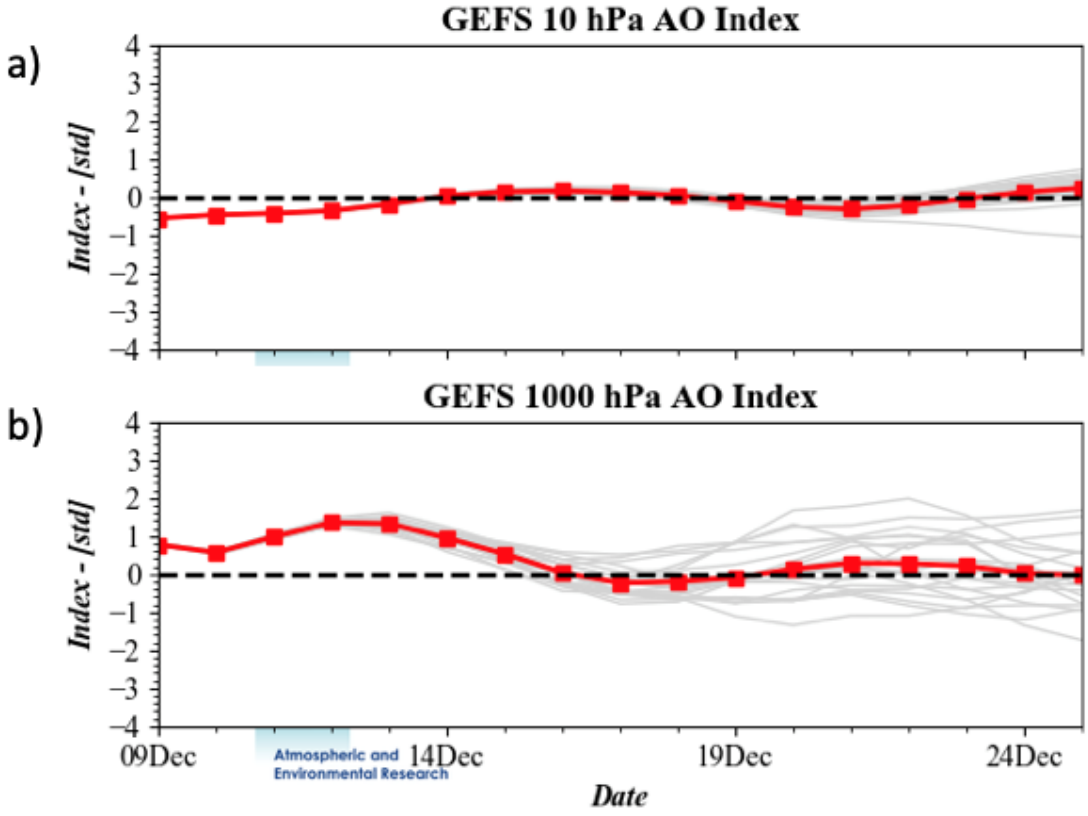

Figure 1. (**a**) The predicted daily-mean AO at 10 hPa from the 00Z 9 December 2019 GFS ensemble. (**b**)The predicted daily-mean near-surface AO from the 00Z 9 December 2019 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO indexgiven by the red line with squares.

This week predicted troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height anomalies across Southwestern Europe (**Figure 2**) will result in a mostly westerly flow of air and normal to above normal temperatures across much of Europe including the UK with the possible exception of normal to below normal temperatures across Scotland and Norway, which are under the lowest heights (**Figure 3**). This week ridging/positive geopotential height anomalies are predicted to dominate much of Asia (**Figure 2**) favoring widespread normal to above normal temperatures **across much of Asia (Figure 3**). One exception is Eastern Siberia where weak troughing/negative geopotential height anomalies (**Figure 2**), likely a

reflection of the cold temperatures in the polar stratosphere, are predicted to result in normal to below normal temperatures **(Figure 3**).

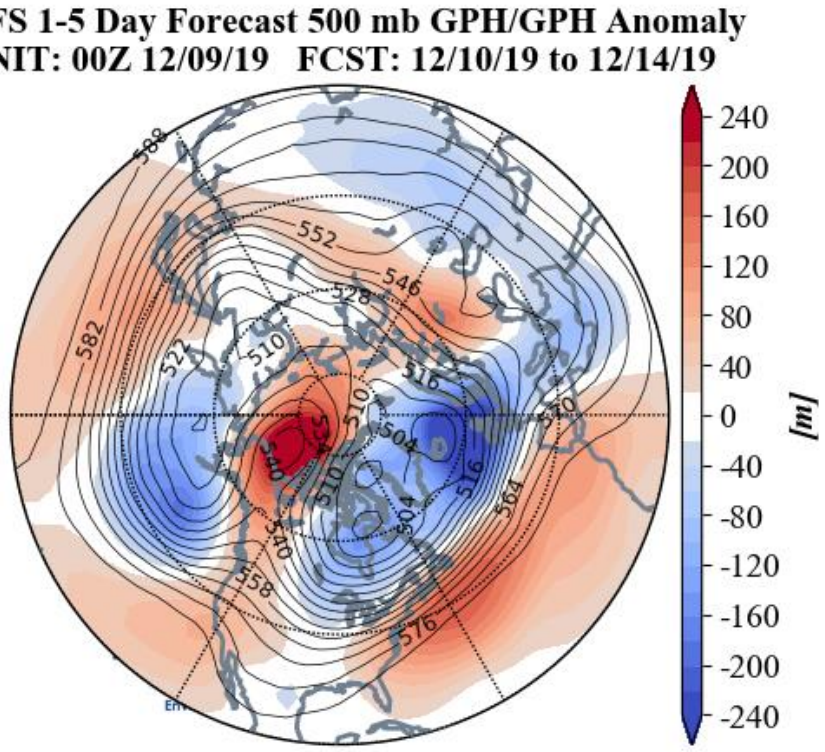

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 10 – 14 December 2019. The forecasts are from the 9 December 00z GFS ensemble.

This week, ridging/positive geopotential height anomalies are predicted across Alaska and western North America forcing troughing/negative geopotential height anomalies downstream mostly over Eastern Canada **(Figures 2).** This is predicted to result in normal to above normal temperatures in Alaska, Western Canada and the Western US with normal to below normal temperatures across Central and Eastern Canada with close to seasonable temperatures for the Eastern US **(Figures 3).**

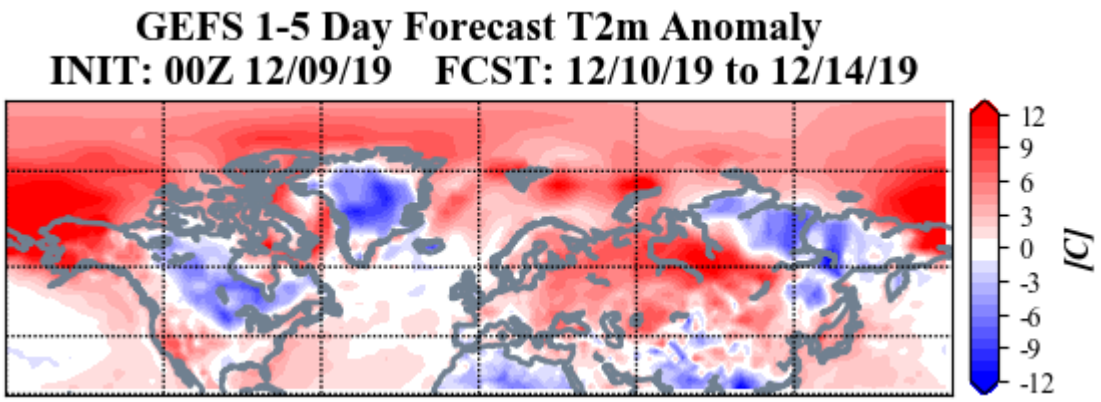

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 10 – 14 December 2019. The forecast is from the 00Z 9 December2019 GFS ensemble.

Troughing and/or cold temperatures are predicted to bring new snowfall across Siberia, the Tibetan Plateau, Scandinavia and the Alps (**Figure 4**). However, intrusion of warm air will melt snow in Northwestern Russia (**Figure 4**). Troughing and cold temperatures are predicted to bring new snowfall to much of Canada, the Northern US, and possibly the Mid-Atlantic (**Figure 4**). Warmer temperatures are predicted to result in snowmelt for Alaska and the Northeastern US (**Figure 4**).

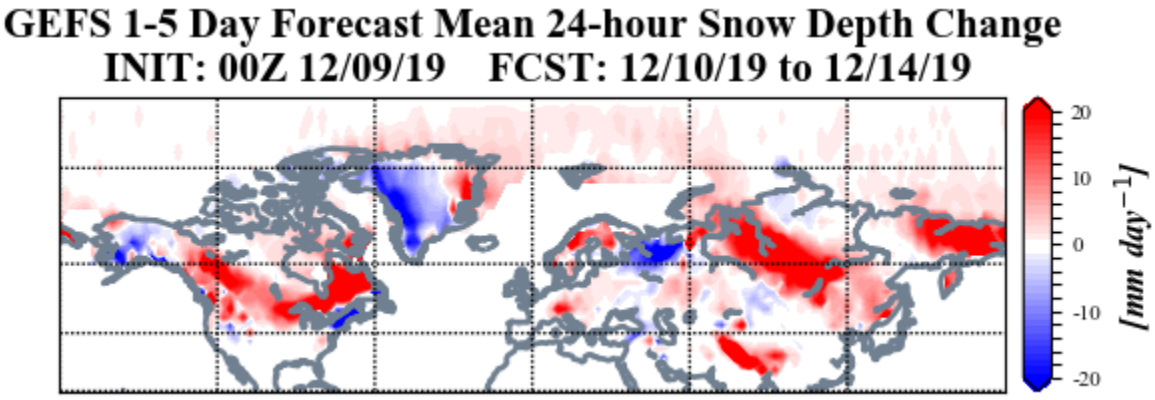

Figure 4. Forecasted snowdepth anomalies (mm/day; shading) from 10 – 14 December 2019. The forecast is from the 00Z 9 December2019 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to trend negative towards neutral this period **(Figure 1**) as geopotential height anomalies turn more positive across the Central Arctic and the

North Atlantic side of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with weak positive geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to also trend towards neutral.

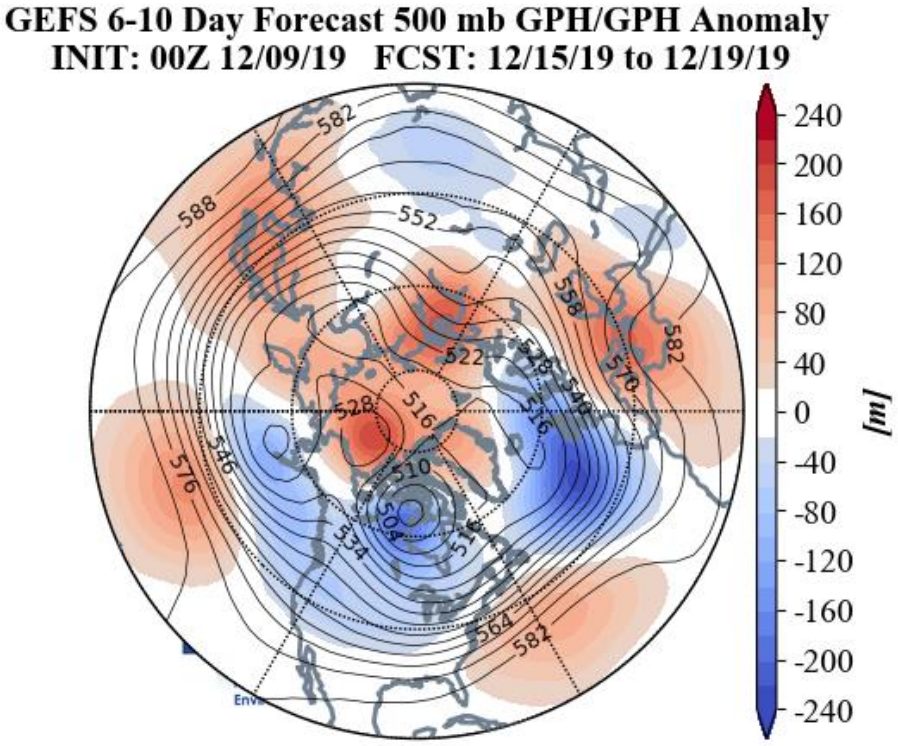

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 15 – 19 December 2019. The forecasts are from the 9 December 00z GFS ensemble.

Predicted troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height anomalies across Southern Europe will strengthen the westerly, mild flow of air across the continent with normal to above normal temperatures for much of Europe Including the southern UK with the exception of Norway and the northern British Isles where below normal heights will support cold temperatures (**Figures 5 and 6**). Ridging/positive geopotential height anomalies will dominate much of Asia, however the ridging will become focused near the Urals helping to deepen troughing/negative geopotential height anomalies across Central Siberia (**Figure 5**). This is predicted to yield normal to above normal temperatures for most of Asia with normal to below temperatures across much of Siberia while persistent troughing/negative geopotential height anomalies across the Tibetan Plateau (**Figure 5**) will result in normal to below normal temperatures for the northern Indian subcontinent **(Figure 6**).

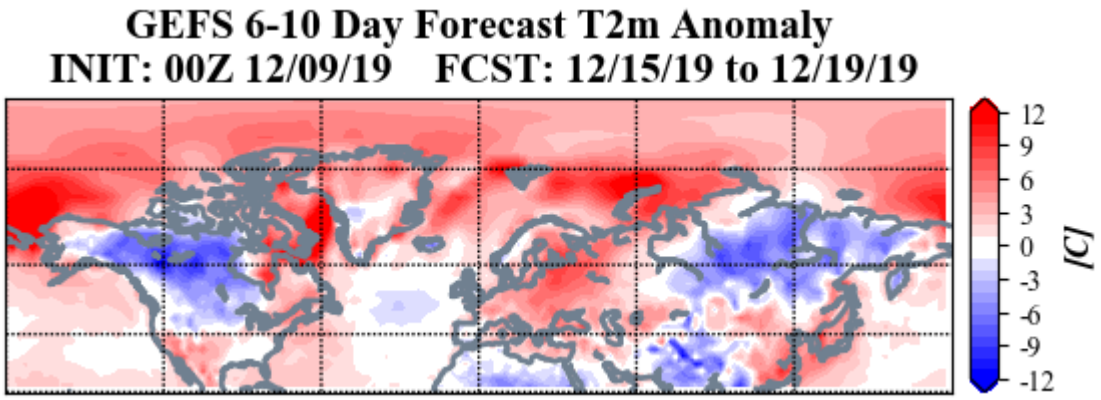

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 15 – 19 December 2019. The forecasts are from the 00Z 9 December 2019 GFS ensemble.

Troughing/negative geopotential height anomalies previously near the Dateline are predicted to undercut the ridge center north of Alaska lowering heights across Alaska and western North America with ridging/positive geopotential height anomalies mostly confined to northern Alaska and the US Eastern Seaboard **(Figure 5).** This pattern is predicted to bring normal to above normal temperatures across northern Alaska, the Canadian Maritimes, US Southwest and the US East Coast with normal to below normal temperatures in much of Canada and the Northwestern US **(Figure 6).**

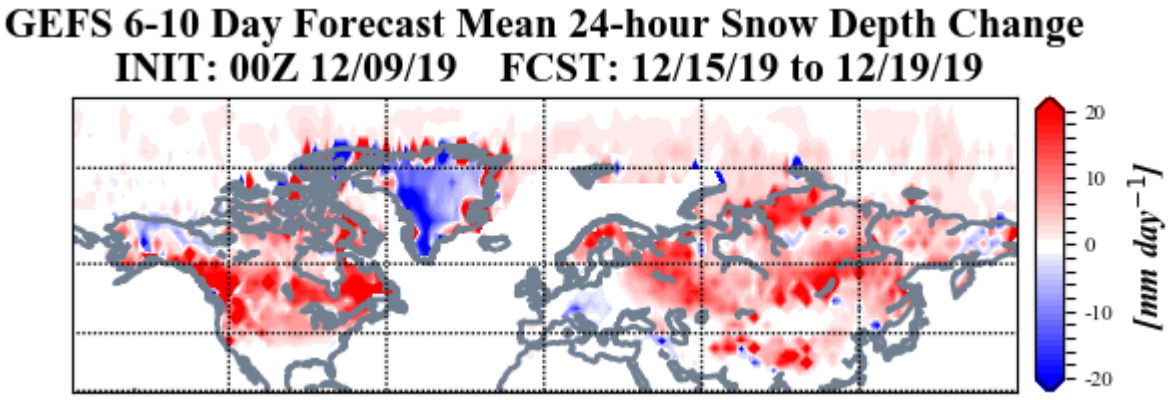

Figure 7. Forecasted snowdepth changes (mm/day; shading) from 15 – 19 December 2019. The forecasts are from the 00Z 9 December 2019 GFS ensemble.

Troughing and/or cold temperatures will support the potential for new snowfall across much of Northern Asia, Western Russia, Central Asia, the Tibetan Plateau, Northeast Asia, much of Canada and the Northern US (**Figure 7**). Some snowmelt is predicted in Eastern Europe and parts of Alaska (**Figure 7**).

11-15 day

With only weak geopotential height anomalies predicted for the Arctic (**Figure 8**), the AO is predicted to remain near neutral this period (**Figure 1**). With predicted weak positive pressure/geopotential height anomalies across Greenland (**Figure 8**), the NAO is likely to remain near neutral this period as well.

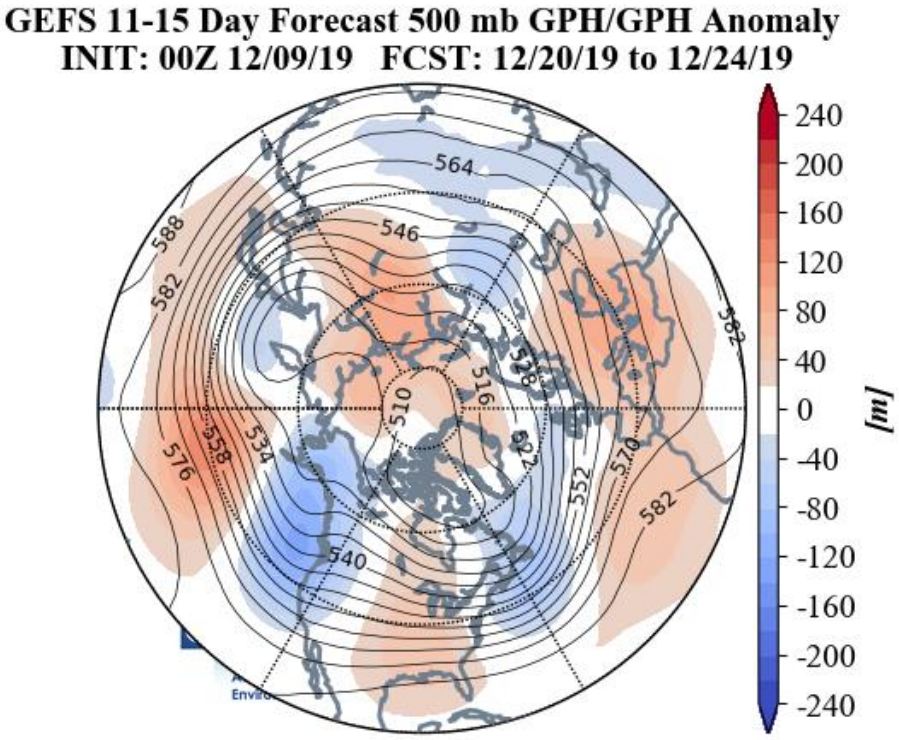

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 20 – 24 December 2019. The forecasts are from the 9 December 00z GFS ensemble.

Predicted persistent troughing/negative geopotential height anomalies across Northern Europe and ridging/positive geopotential height anomalies across Southern Europe (**Figures 8**) will maintain a westerly, mild flow this period with widespread normal to above normal temperatures across much of Europe including the UK this period with the possible exception of northern Scandinavia under the lowest heights (**Figures 9**). Ridging/positive geopotential height anomalies previously over the Urals will slide a bit more east, forcing troughing/negative geopotential height anomalies previously over Central Siberia into Eastern Siberia and Northeast Asia (**Figure 8**). This pattern favors normal to above normal temperatures across much of Asia including the Middle East and Southeast Asia with normal to below normal temperatures in Eastern Siberia and Northeast Asia (**Figure 9**). Persistent troughing/negative geopotential height anomalies

across the Tibetan Plateau (**Figure 8**) will continue to support normal to below normal temperatures for the northern Indian subcontinent (**Figure 9**).

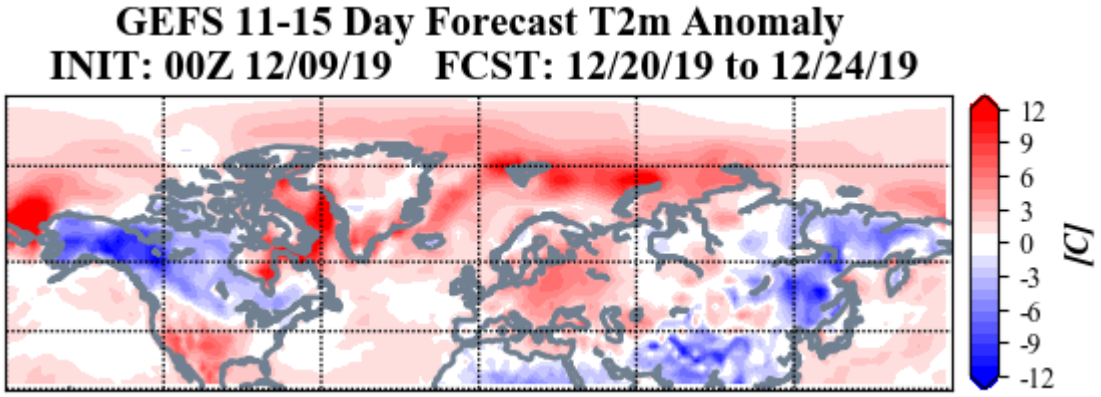

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 20 – 24 December 2019. The forecasts are from the 9 December 00z GFS ensemble.

The GFS is predicting a continuation of the troughing/negative geopotential height anomalies in western North America and Eastern Canada that now extends southward along the US East Coast with ridging/positive geopotential height anomalies centered over the Mississippi Valley (**Figure 8**). This is predicted to favor normal to below normal temperatures across Alaska, most of Canada and the US East Coast with normal to above normal temperatures in the Western and Central US (**Figure 9**). It is worth noting that the ECMWF is predicting a milder pattern with US ridging more amplified and pushing further north.

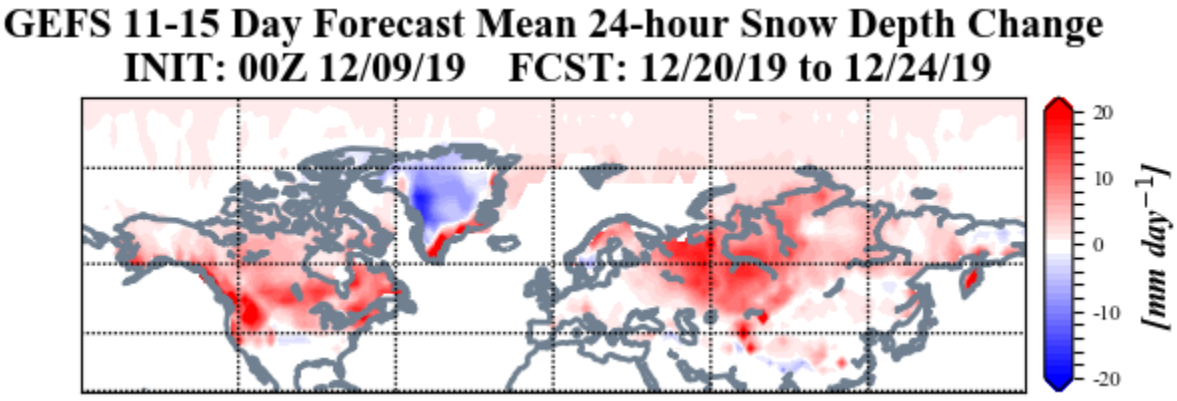

Figure 10. Forecasted snow depth changes (mm/day; shading) from 20 – 24 December 2019. The forecasts are from the 00z 9 December GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across much of northern Asia but with the best chances across Northwestern Russia, Central Asia, Scandinavia and possibly the Alps, Alaska, much of Canada and the Northwestern and Northeastern US (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows above normal PCHs in both the lower stratosphere and the upper troposphere with below normal PCHs in the lower troposphere (**Figure 11**). The cold PCHs in the lower troposphere are consistent with a predicted positive AO this week (**Figure 1**), however, the warm PCHs in the upper troposphere are predicted to descend into the lower troposphere next week (**Figure 11**), contributing to a predicted negative trend in the AO (**Figure 1**). The models have completely backed off a sudden stratospheric warming (SSW) for mid-December and the latest GFS ensembles predict close to normal conditions in the polar stratosphere.

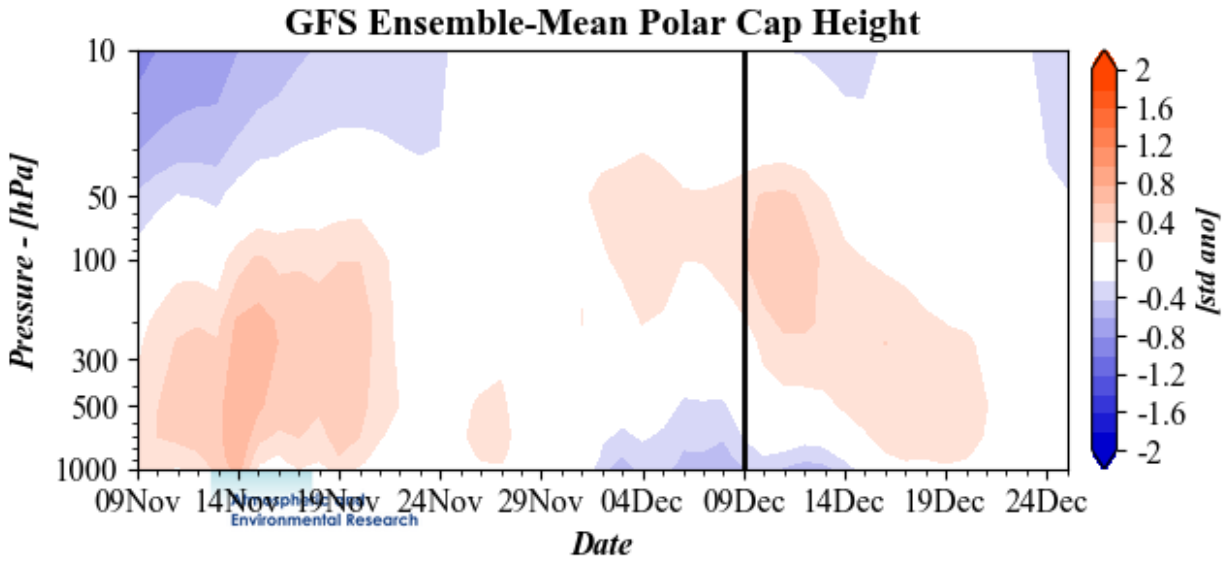

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 9 December 2019 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows strong negative anomalies just ending followed by strong positive anomalies for the upcoming week (**Figure 12**). The predicted positive WAFz for the upcoming week are not predicted to result in significant weakening of the stratospheric PV.

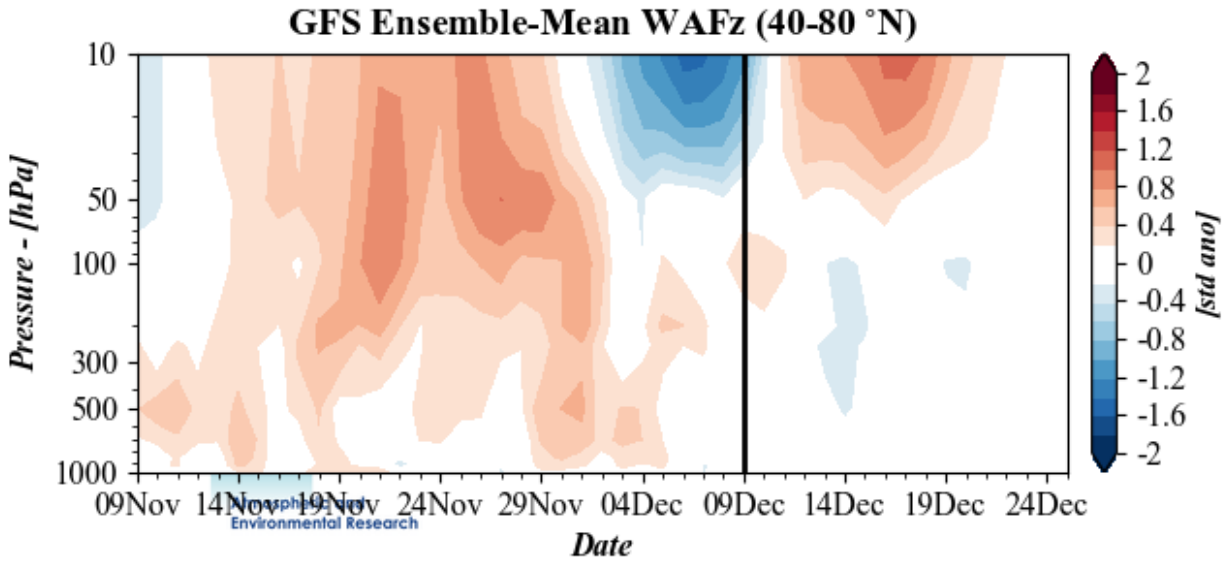

Figure 12. Observed and predicted daily vertical component of the wave activity Wux (WAFz)
standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 9 December 2019
GFS ensemble.

The stratospheric AO is currently slightly negative (**Figure 1**) reflective of a slightly perturbed PV. However, despite the positive WAFz predicted this week, the stratospheric AO is predicted to remain near neutral (**Figure 1**). The strong negative WAFz anomalies followed by strong ridging near Alaska in the mid-troposphere are consistent with a reflective disruption of the stratospheric PV that result in short-lived cold air outbreaks in central and eastern North America.

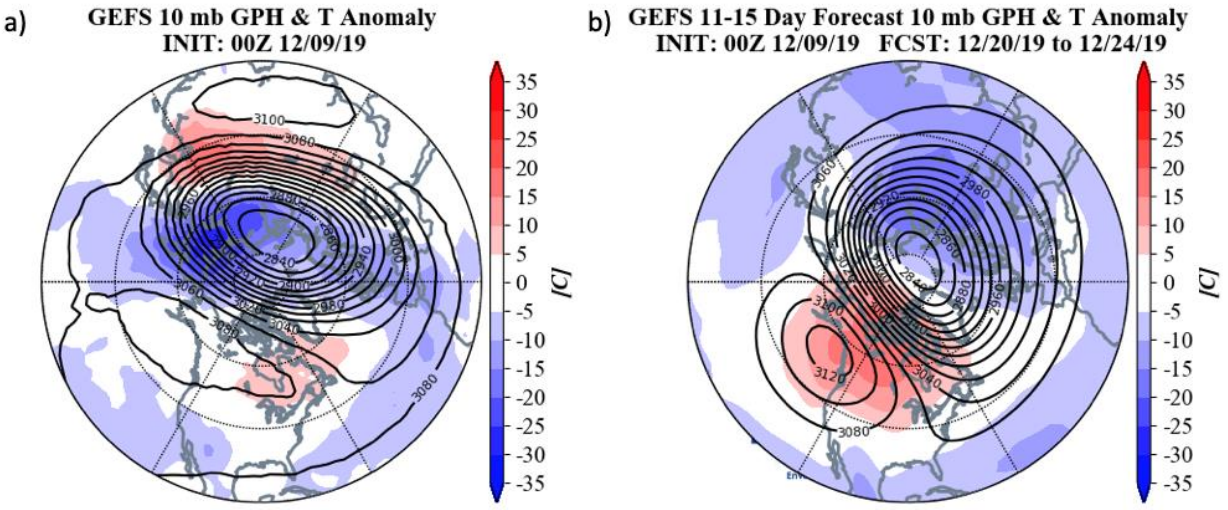

Figure 13. (**a**) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C;
shading) across the Northern Hemisphere for 9 December 2019. (**b**) Same as (a) except forecasted
averaged from 20 – 24 December 2019. The forecasts are from the 00Z 9 December 2019 GFS operational
model.

Despite the strong circulation around the PV center and relatively low heights, the PV is not circular in shape but rather elongated centered near the Urals, with the flow around the PV heavily skewed towards the Eurasian sector, signs of some disruption (**Figure 13**). The largest negative temperature departures in the polar stratosphere are over Eastern Siberia, likely supporting the cold temperatures in that region.

Currently there is warming and ridging centered over Canada in the stratosphere with more robust warming over East Asia (**Figure 13).** Over time the new WAFz pulse is predicted to amplify the warming over East Asia as it advects poleward and eventually reinforces the ridging centered over Alaska and Canada (**Figure 13)**. Also, the PV center is predicted to remain displaced towards northwest Eurasia over the next two weeks. The displacement of the PV center towards Scandinavia is likely contributing to a tropospheric reflection helping to deepen the troughing across Siberia next week (e.g., **Figure 5**). Despite the displacement of the stratospheric PV towards Eurasia and more WAFz there are no real signs of a more significant PV disruption.

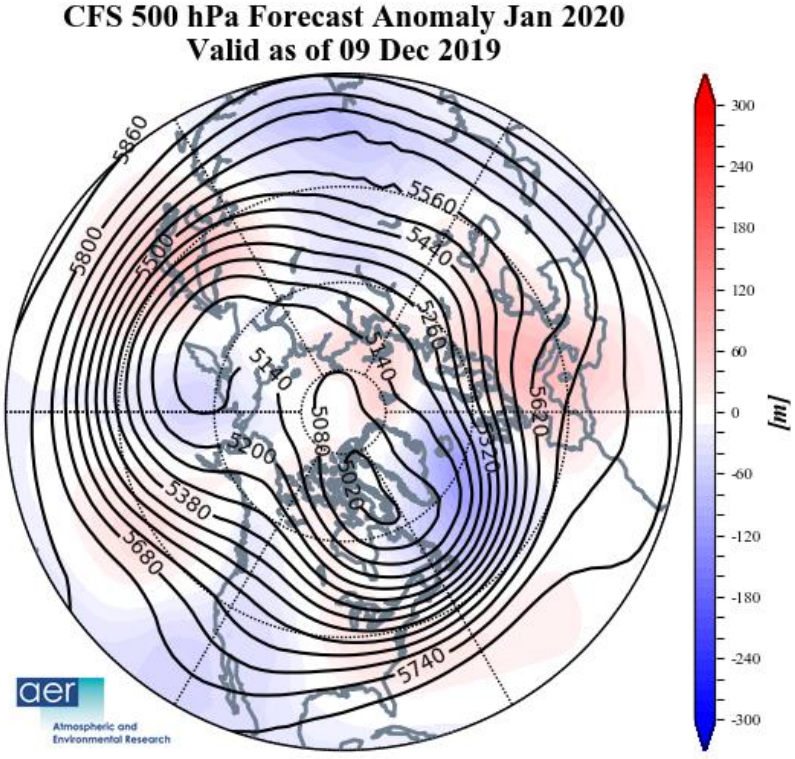

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for January 2020. The forecasts are from the 9 December 2019 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) forecast for January from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging across Europe, the Barents-Kara Seas, East Asia, the Gulf of Alaska and Western Canada with troughs over Greenland and Iceland, Southeastern Europe, Central Asia, Eastern Siberia, the Dateline, and eastern North America (**Figure 14).** This pattern favors relatively mild temperatures for much of Europe, Western Asia and Western North America with seasonable to relatively cold temperatures for Siberia, Northeast Asia, Eastern Canada and the Northeastern US (**Figure 15**). The CFS forecast for January has backed off somewhat its circulation pattern prediction that projects on to the pattern of variability associated with a negative AO.

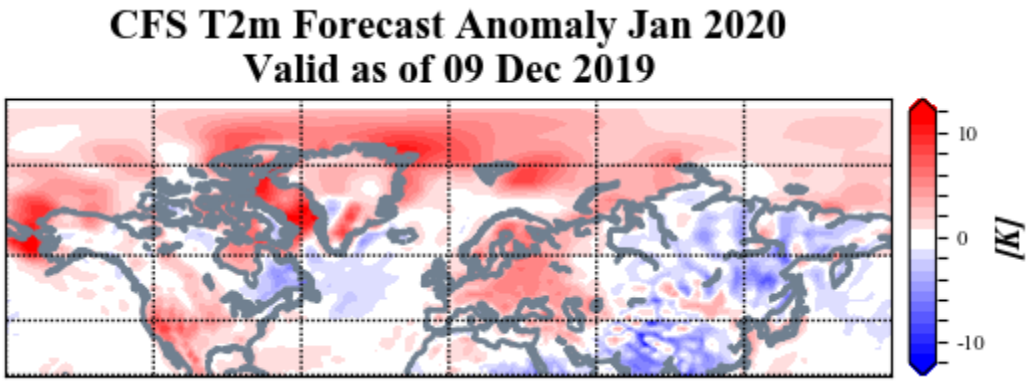

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for January 2020. The forecasts are from the 9 December 2019 CFS.

Surface Boundary Conditions

Arctic sea ice extent

Arctic sea ice growth rate continues to grow slowly and remains well below normal. Large negative sea ice anomalies exist in three regions: the Chukchi-Bering, around Greenland-Canadian Archipelagos and Barents-Kara Seas. The anomalies in the North Pacific sector have emerged as the most well below normal (**Figure 16**), however, based on model forecasts sea ice in the Chukchi-Bering Seas may grow more quickly in the next two weeks. Below normal sea ice in and around Greenland and the Canadian Archipelagos may favor a negative winter NAO. Based on recent research low sea ice anomalies in the Chukchi and Bering seas favors cold temperatures in central and

eastern North America while low sea ice in the Barents-Kara seas favor cold temperatures in Central and East Asia, however this topic remains controversial. Recent research has shown that 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.

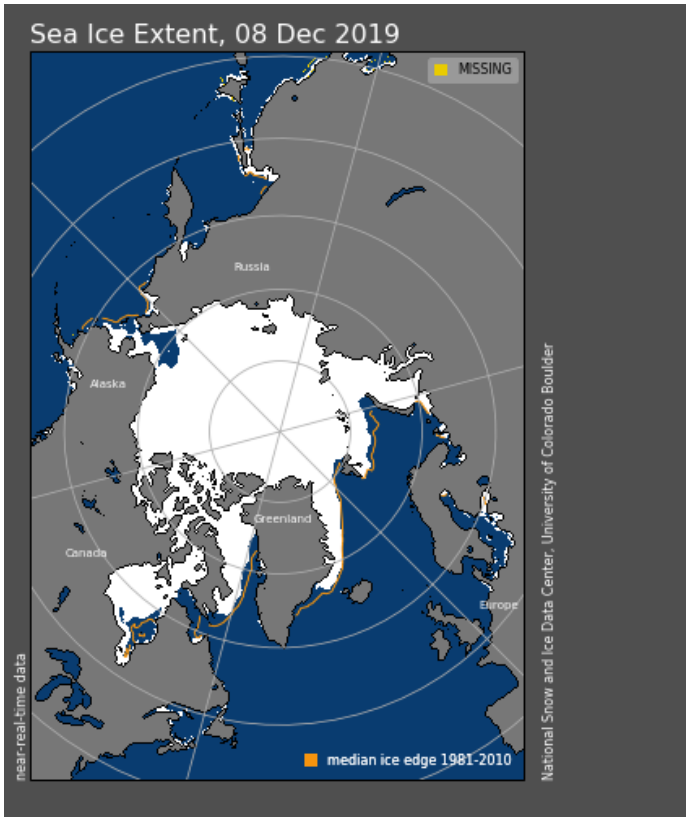

Figure 16. a) Observed Arctic sea ice extent on 8 December 2019 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010.

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies have cooled and Neutral El Niño/Southern Oscillation (ENSO) conditions seem most likely (**Figure 17**). Observed SSTs across the NH remain well above normal especially near Alaska and along the north slope of Asia though below normal SSTs exist regionally especially west of South America. Warm SSTs int eh Gulf of Alaska may favor mid-tropospheric ridging in the region this upcoming winter.

This is really outside of my expertise but the relatively warm SSts east of Africa and relative cold SSTs west of Indonesia in the Indian Ocean are known as the positive phase of the Indian Ocean Dipole (+IOD). This has been shown to suppress convection over the Maritime continent. These correspond to some of the Madden Julian

Oscillation (MJO) phases associated with warmer weather patterns in the Eastern US during the winter months (Benedict et al. 2015).

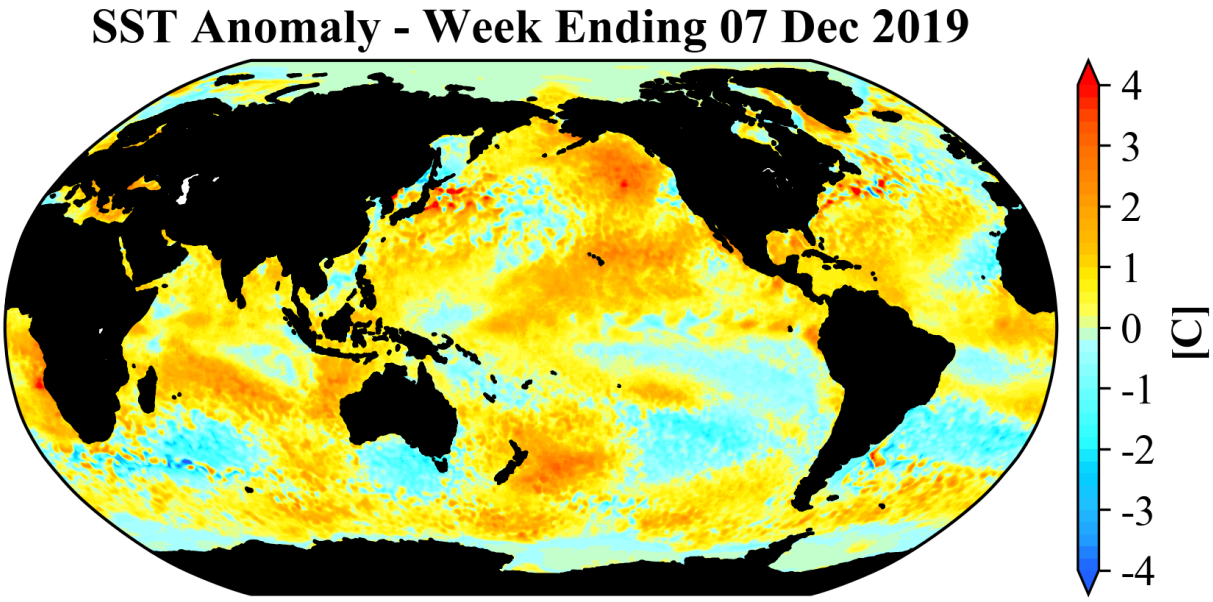

Figure 17. The latest weekly-mean global SST anomalies (ending 7 December 2019). Data from NOAA OI High-Resolution dataset.

Currently weak phase 2 phase of the Madden Julian Oscillation (MJO) is favored (**Figure 18**). The forecasts are for the MJO to hang around phase 2 and then weaken again to where no phase is favored over the next two weeks. Some MJO influence is possible across North American weather in the forecast period as phase two favors ridging in the Eastern US and troughing in the Western US, which is to some degree predicted by the models.

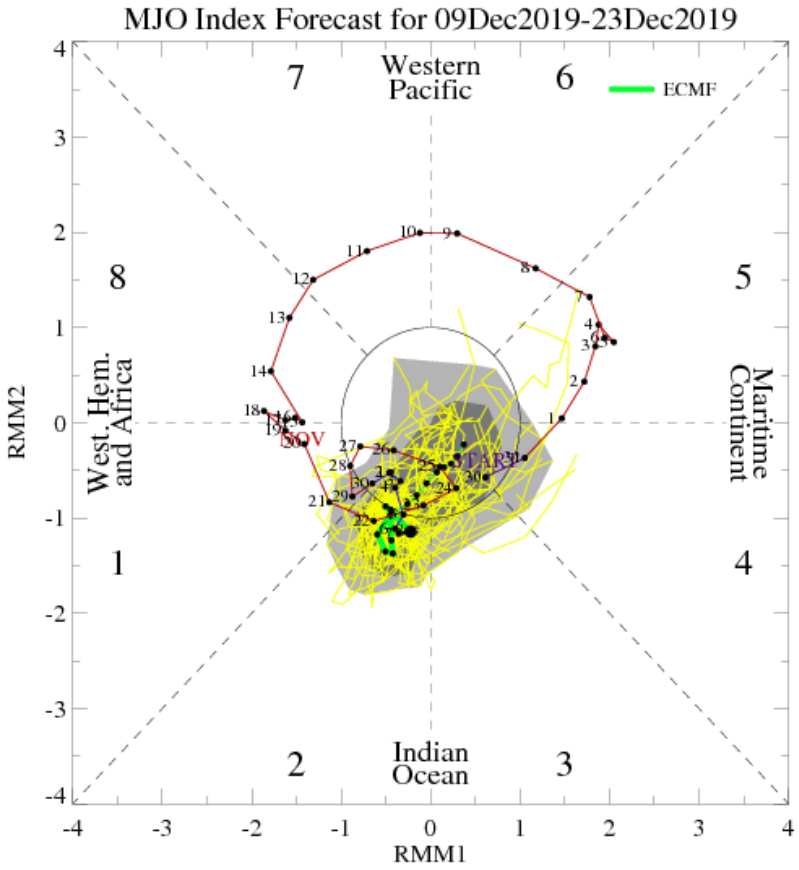

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 9 December 2019 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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

Northern Hemisphere Snow Cover

Snow cover advance continues its climb across Eurasia and is currently near decadal averages. Snow cover will likely continue to advance especially across Western Asia next week as troughing and cold temperatures spread across the region. Above normal snow cover extent in October, favors a strengthened Siberian high, cold temperatures across northern Eurasia and a weakened polar vortex/negative AO this upcoming winter followed by cold temperatures across the continents of the NH.

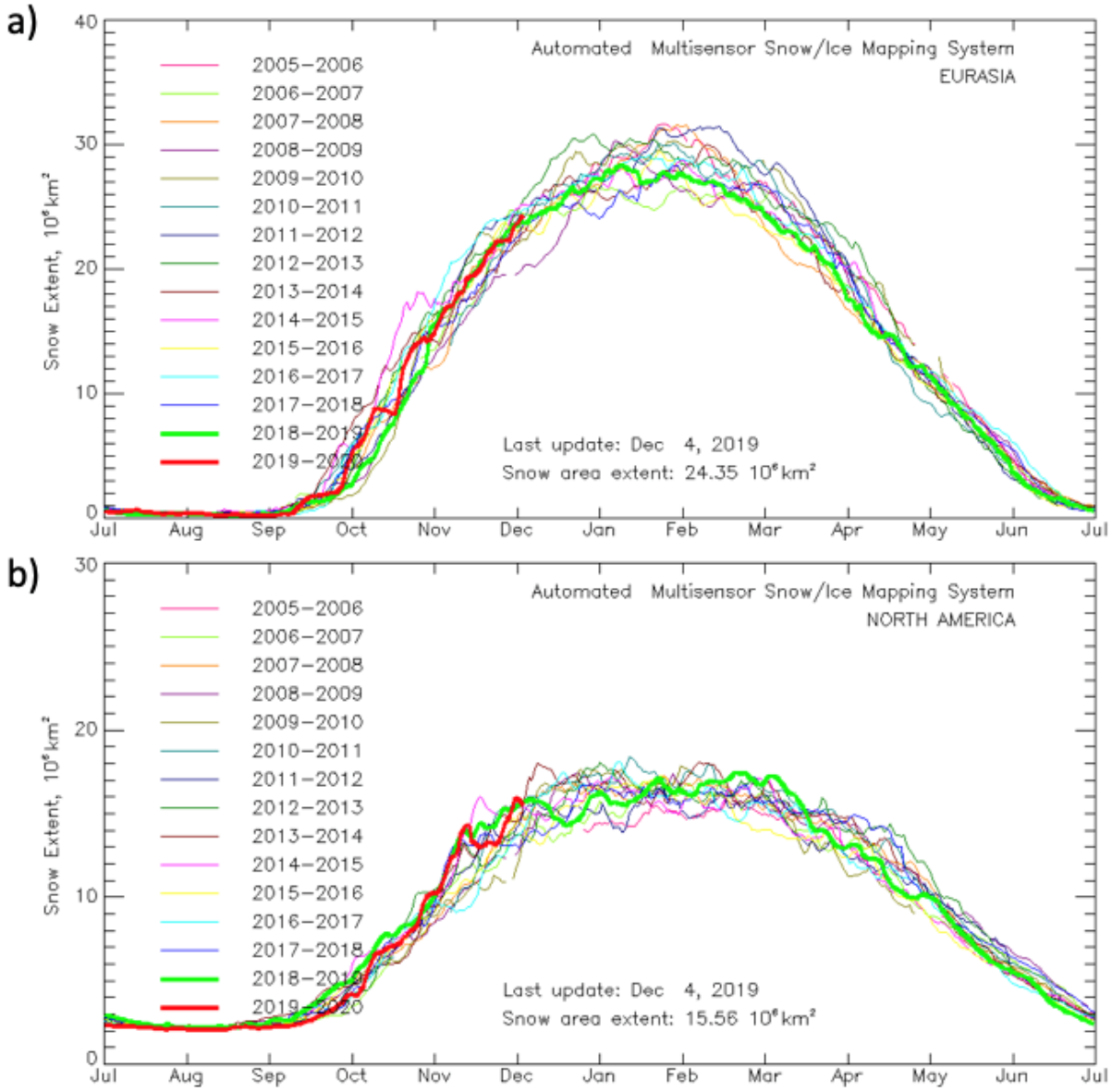

Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 1
December 2019. Image source:
https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover has melted back this past week, with warmer temperatures but extent remains near decadal highs. The early advance of snow cover across Canada this fall, has likely contributed to an early start of cold temperatures across the Western US and now the Eastern US.