Arctic Oscillation and Polar Vortex Analysis and Forecasts

December 16, 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 neutral and is predicted to remain neutral to negative over the next two weeks.
- The current neutral AO is reflective of mixed pressure/geopotential height anomalies across the Arctic and mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is also near neutral with mixed pressure/geopotential height anomalies spread across Greenland and Iceland; and the NAO is predicted to remain near neutral as height anomalies remain weak across Greenland the next two weeks.

- Currently troughing/negative pressure/geopotential height anomalies over the eastern North Atlantic/Western Europe with ridging/positive geopotential height anomalies over Eastern Europe is promoting a mild southwesterly flow of air. This will result in widespread normal to above normal temperatures across Europe including the United Kingdom (UK) especially in Eastern Europe. Right at the end of December some colder air might start to filter in from east.
- Currently ridging/positive geopotential height anomalies and normal to above normal temperatures dominate much of Western and Eastern Asia with troughing/negative pressure/geopotential height anomalies and normal to below normal temperatures confined to Central and Eastern Siberia and parts of Central Asia. However, the troughing/negative pressure/geopotential height anomalies and normal to below normal temperatures are predicted to become more widespread over the next two weeks across Northern Asia.
- Currently troughing/negative pressure/geopotential height anomalies with widespread normal to below normal temperatures dominate Canada and the Western United States (US) with ridging/positive geopotential height anomalies and normal to above normal temperatures confined to the Southeastern US. However, the forecast is for ridging/positive geopotential height anomalies and normal to above normal temperatures to become more widespread across the continent before troughing and colder temperatures return to western North America while ridging and relatively mild temperatures persist across eastern North America.
- In the Impacts section I discuss why we should all care why Siberia is predicted to be cold and what I learned from the fall meeting of the American Geophysical Union (AGU) 2019.

Impacts

I spent last week in San Francisco attending the Fall AGU and one thing that I was trying to understand was the quasi-biennial oscillation (QBO). I was under the impression that the QBO was in its easterly phase this winter that favors disruptions of the stratospheric polar vortex (PV) in early winter. The winds along the equator are indeed easterly in the mid to upper stratosphere but are still westerly in the lower stratosphere (see **Figure i**). Therefore, the QBO influence on the PV is more consistent with a westerly QBO that does not favor a PV disruption in the early part of the winter. I raise this because our statistical model (which I have acknowledged suffers from too many false positives) and the dynamical weather prediction models all predicted a significant if not major disruption of the PV that failed to verify for early to mid-December. I think categorizing the QBO this winter as westerly and not easterly helps to place those poor forecasts in context. It reminds me of early winter 2016/17 when a weakening PV was predicted by the dynamical models to achieve major warming status (reversal of the zonal mean zonal wind from westerly or positive to easterly or negative at 60°N and 10 hPa) but never did and instead the PV quickly spun up contributing to a mild pattern across the Northern Hemisphere (NH) for an extended period. Westerly QBO favors a strong PV as atmospheric vertical energy transfer is directed towards the

tropics and away from the North Pole that favors a strong PV. Still if a major warming is to occur during a westerly QBO winter, it is preferred mid to late winter.

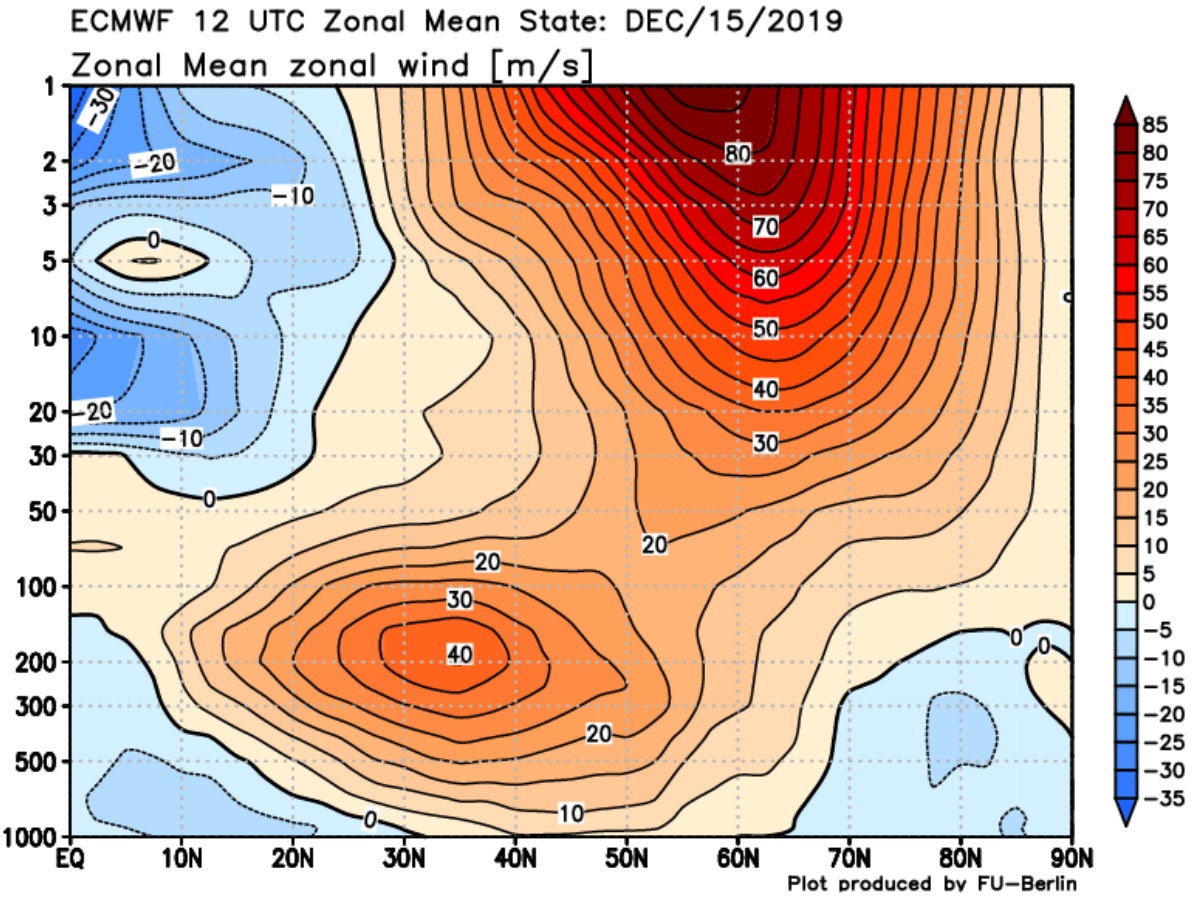


Figure i. ECMWF analyzed zonal mean zonal winds from the equator to the North Pole and from 100 to 1 hPa (plot taken from https://www.geo.fu-berlin.de/en/met/ag/strat/produkte/winterdiagnostics/index.html).

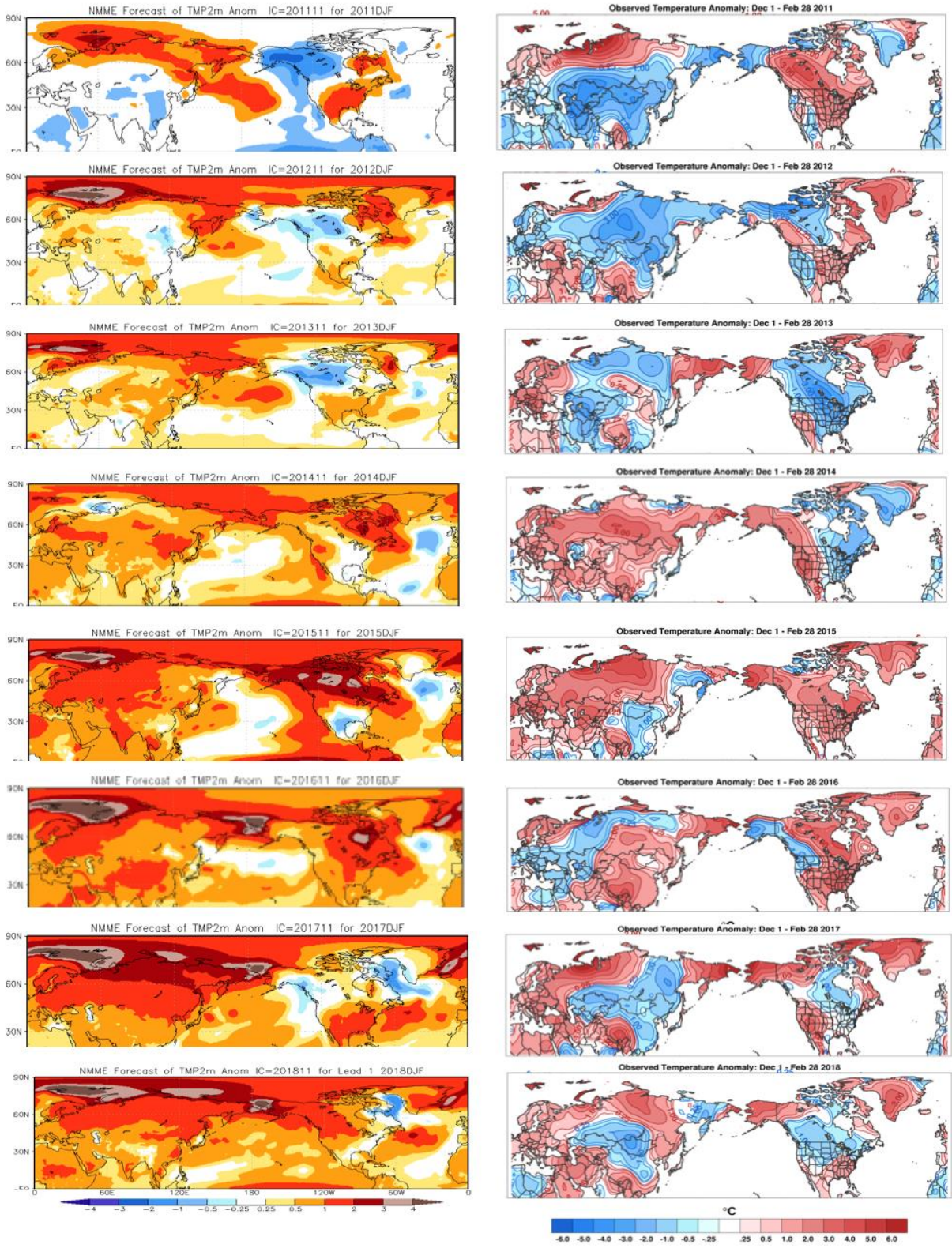
The QBO phase this winter seems similar to me as in 2017/18 when a major warming occurred in February. Whether the QBO is easterly or westerly does not change our temperature forecast as it is not currently used as a predictor, though there are studies that argue easterly QBO favors colder winters relative to westerly QBOs. Still in our analysis on reflective PV disruptions (Kretschmer et al. 2018), it did seem that they are more common in westerly QBO winters, which does favor colder winters in central and eastern North America and has been the pattern so far this winter. The GFS is predicting a return of blocking in the Barents-Kara Seas so I expect perturbations to the PV to continue into the New Year.

I tweeted out yesterday that the models are predicting colder temperatures to become more widespread across Siberia and wherever you live in the NH mid-latitudes this is

something that you should pay attention to, if you are interested in knowing the weather. On the simplest level cold air that builds in Siberia often discharges to the southeast towards East Asia or west towards Europe. But even for North America, relatively cold temperatures in Siberia are favorable for more active atmospheric vertical energy transfer that disrupt the stratospheric PV. The largest PV disruptions can unleash severe winter weather in favored locations for an extended period but especially the more minor PV disruptions that I refer to as "reflective" events that are of shorter duration - favor cold temperatures focused in central and eastern North America. It does look like such an event is possible the end of December with the surface impacts felt in early January. So, as I have been saying for years, "Siberia is the refrigerator for the NH" and if Siberia turns cold that increases the risk of cold air outbreaks in East Asia, Europe and even eastern North America.

But that is not the main point that I want to make. In my mind the best support that the Arctic influences mid-latitude weather is if Siberia experiences a cold winter. And if high Eurasian snow cover/low Arctic sea ice can contribute to a cold winter in Siberia, then high Eurasian snow cover/low Arctic sea ice can contribute to cold winters elsewhere including East Asia, Europe and the US. This idea was the main focus of my two talks at Fall AGU. Most of the critics of the idea that Arctic change (warmer temperatures, less sea ice and I include heavier snowfall) can contribute to colder temperatures in the mid-latitudes argue that any observed cold winters over the past two decades are due to chance (or maybe due to tropical variability) and therefore cannot be attributed to the Arctic. The main tool to support this argument are the dynamical models that when forced with low Arctic sea ice they do not simulate cold temperatures across the continents. Therefore, if we observe cold temperatures it is not forced but rather is attributable to randomness in the atmosphere or natural variability.

However, I believe that the warm models and colder observations are not symptomatic of randomness but rather due to systemic errors in the models. To me the most compelling support of this position is juxtaposing the model forecasts with the observations. In **Figure ii,** I show the winter (Dec-Jan-Feb) surface temperature anomaly forecasts from the North American Multi-Model Ensemble (see NMME website) from 2011/12 through 2018/19 on the left and the observed winter surface temperature anomalies on the right. The forecast temperatures are always warmer than the observed temperatures for the NH. But sometimes the models do predict cold temperatures across North America but never for Northern Eurasia. I am assuming this is because in the models, tropical variability (mostly ENSO) can force cold temperatures in North America but not Eurasia. In the models the only truly important forcing for Eurasia is increasing greenhouse gases (which may include the warming influence of Arctic sea ice loss). Yet despite the model forecasts Eurasia is always observed to be colder than the forecasts, with the one possible exception of winter 2014/15, where any observed cold was regional.


NMME Forecast of TMP2m Anom IC=201111 for 2011DJF
Observed Temperature Anomaly: Dec 1 - Feb 28 2011
NMME Forecast of TMP2m Anom IC=201211 for 2012DJF
Observed Temperature Anomaly: Dec 1 - Feb 28 2012
NMME Forecast of TMP2m Anom IC=201311 for 2013DJF
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Observed Temperature Anomaly: Dec 1 - Feb 28 2018
90N
60N
30N
0
60E
120E
180
120W
60W
−4 −3 −2 −1 −0.5 −0.25 0.25 0.5 1 2 3 4
°C
-6.0 -5.0 -4.0 -3.0 -2.0 -1.0 -0.5 -.25 .25 0.5 1.0 2.0 3.0 4.0 5.0 6.0

Figure ii. Predicted from the NMME suite of models (left) and observed (right) Northern Hemisphere surface air temperature anomalies for all for all winters (December, January, February) 2011/12–2018/2019.

If we can predict that the model forecast will be universally warm for Siberia and that the observations will be colder, then this is less consistent with randomness and more with systemic model errors i.e., the models incorrectly simulate the influence of Arctic forcing on mid-latitude temperatures, or at least Arctic influence is incorrectly overwhelmed by tropical influence and/or global warming.

What about this winter? In **Figure iii**, I present from the C3S (the ensemble of European models – ECMWF, UK MetOffice and Meteo-France made available at **Copernicus**) forecast for both sea level pressure and temperature anomalies for Nov-Dec-Jan 2020. I show these three months because we already have a fairly good idea how the forecasts are verifying. All the models predicted a strong signal for relatively low pressure across the entire Arctic basin and the predictable universal relative warmth across the NH. I thought the forecasts were especially notable since as I argue all the time in the blog, low sea ice and warm temperatures in the Arctic favor high pressure and not low pressure. For example, the daily trend of geopotential heights shows increasing pressures in the Arctic troposphere throughout the winter (see **Figure iv**).

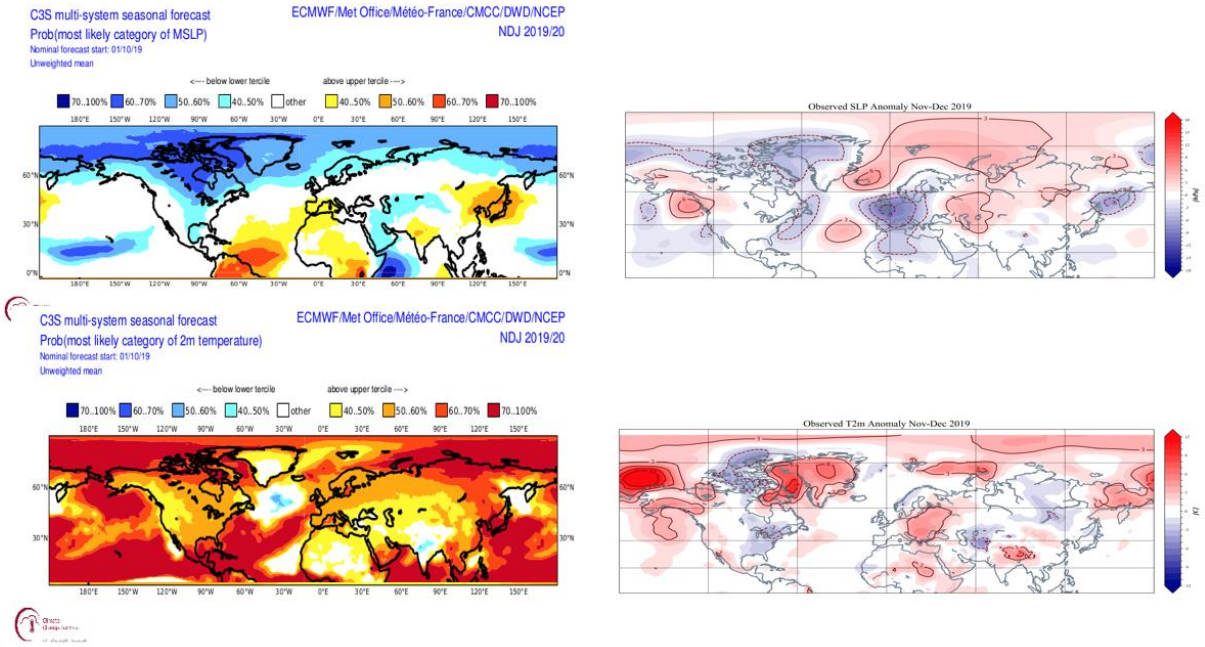

Figure iii. Predicted from the C3S suite of models (left) and observed (right) Northern Hemisphere sea level pressure (top) and surface air temperature (bottom) anomalies for November, December and January 2019/2020. Observations only go through December 16, 2019.

I include in **Figure iii** the observations for Nov-Dec-Jan 2020 through today and so far, the Arctic is not completely dominated by low pressure and the NH continents are not universally warm. In fact the regions of cold are downstream of the two regions that are warmest in the Arctic - in eastern North America downstream of the warm bullseye in the Chukchi Sea region (presumably aided by below normal sea ice extent) and in Siberia downstream of the warm bullseye in the Barents-Kara Seas region. This warm Arctic cold-continent relationship was shown by Kug et al. (2015) and others. I would argue that if the temperature variability across the NH resembles previous analysis related to Arctic warming that is not a random but supportive for a previously constructed argument. That is why I was excited to see the cold forecasts for Siberia because in my opinion it is consistent with Arctic influence favoring colder temperatures.

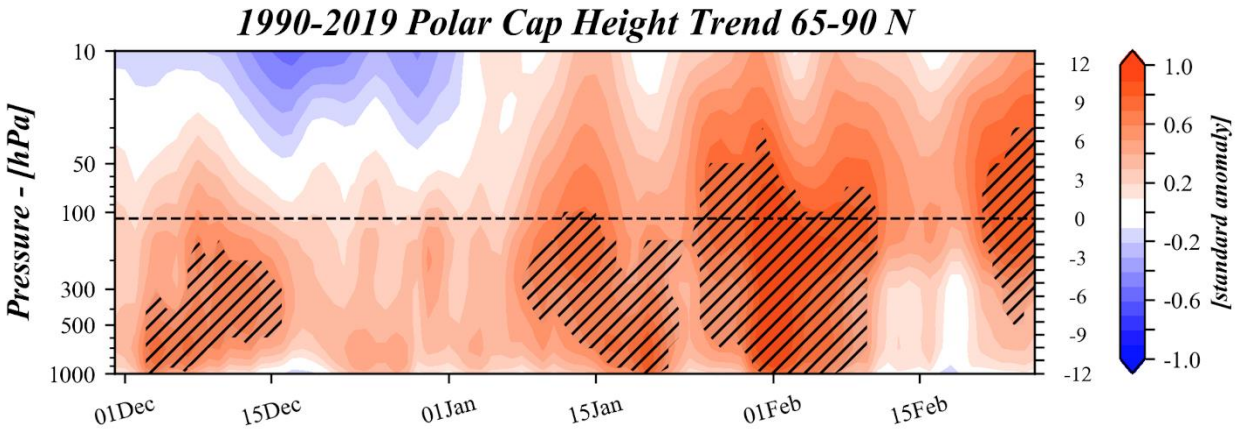

Figure iv. The annual daily trend in the polar cap geopotential height (PCH) from the surface to the mid-stratosphere (10 hPa). Statistical significance above 90% for PCH trends are hatched in dark gray.

Finally, there is also relatively high pressure in the Gulf of Alaska above the very warm sea surface temperatures (SSTs). I have argued in previous blogs that the warm SSTs could favor cold temperatures downstream across North America. If nothing else I have learned over the years not to assume anything. Of course, the winter is not over, and January is likely to be a pivotal month and the model forecasts can still verify. And if they do verify, I would consider that compelling evidence against all my arguments here in today's blog.

Near Term Conditions

1-5 day

The AO is currently neutral **(Figure 1**) with mixed geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with mixed geopotential height anomalies across Greenland and Iceland (**Figure 2**), the NAO is neutral as well.

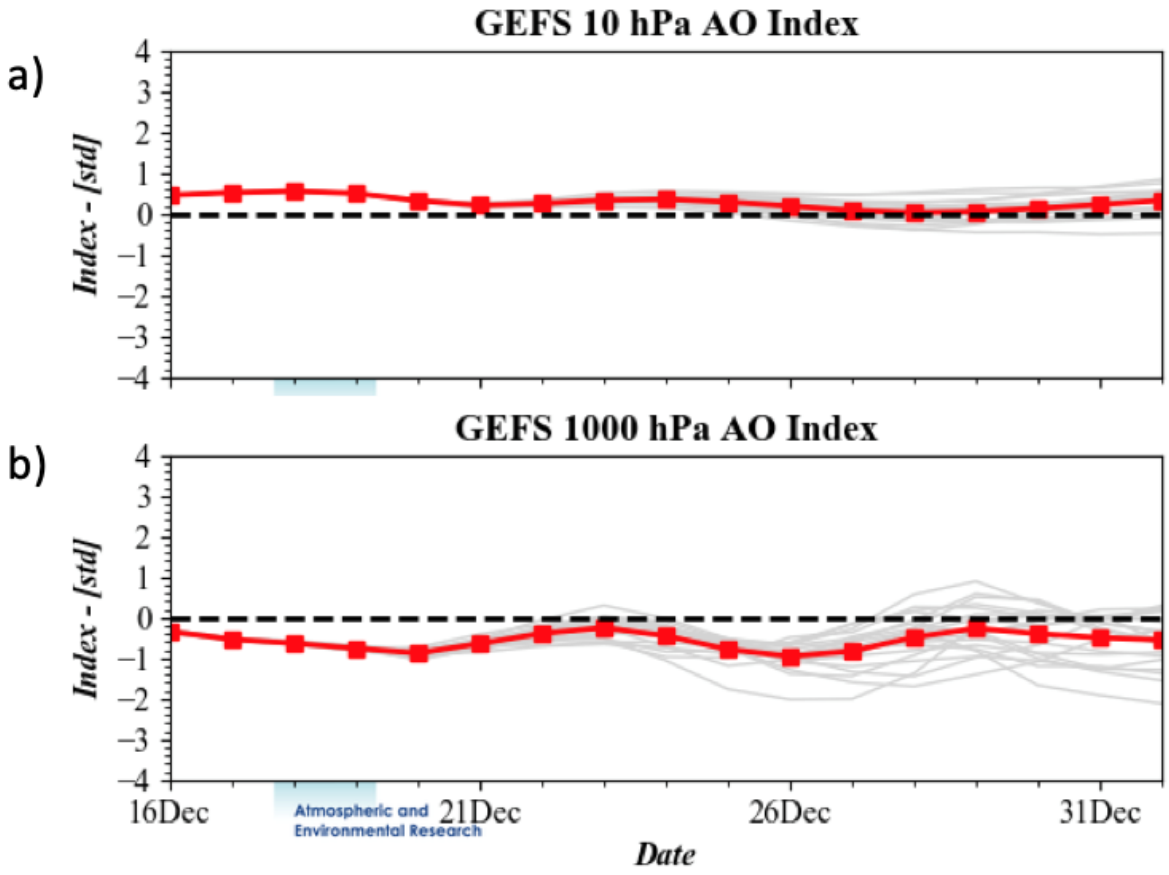

Figure 1. (**a**) The predicted daily-mean AO at 10 hPa from the 00Z 16 December 2019 GFS ensemble. (**b**) The predicted daily-mean near-surface AO from the 00Z 16 December 2019 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

This week predicted troughing/negative geopotential height anomalies in the eastern North Atlantic and Western Europe combined with ridging/positive geopotential height anomalies in Eastern Europe (**Figure 2**) will result in a mostly southwesterly 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 West and East Asia (**Figure 2**) favoring widespread normal to above normal temperatures across much of Asia **(Figure 3**). Exceptions are Central and Eastern Siberia and parts of Central Asia where troughing/negative geopotential height anomalies (**Figure 2**) are predicted to result in normal to below normal temperatures **(Figure 3).**

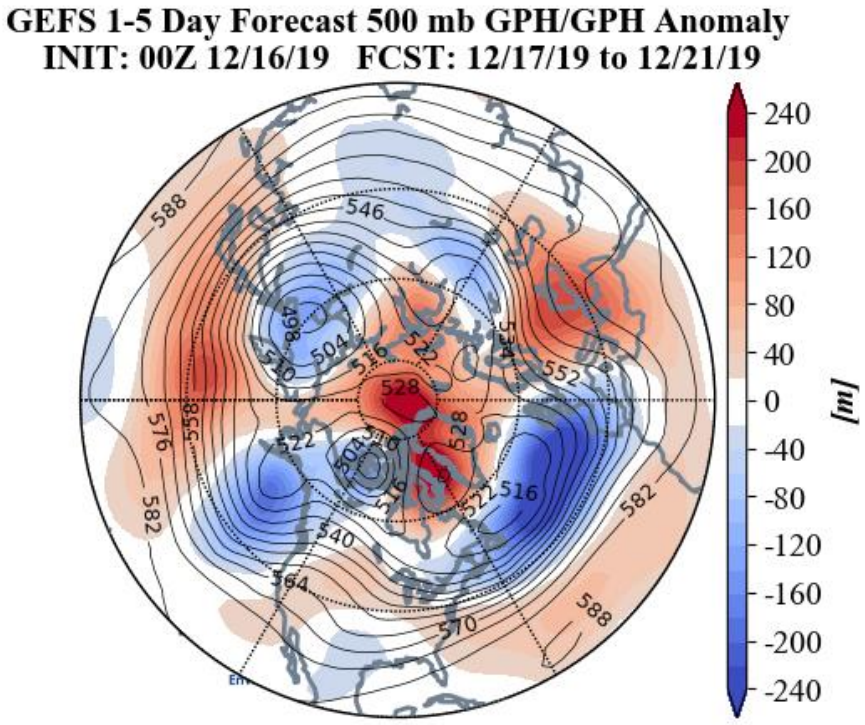

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 17 – 21 December 2019. The forecasts are from the 16 December 00z GFS ensemble.

This week, troughing/negative geopotential height anomalies in Alaska and the Gulf of Alaska will force downstream ridging/positive geopotential height anomalies across Alaska western North America while ridging near Greenland will force troughing/negative geopotential height anomalies to the south over Southeastern Canada and the Northeastern US (**Figure 2**). This is predicted to result in normal to above normal temperatures in Southwestern Canada and the Western US with normal to below normal temperatures across Alaska, Northwestern and Southeastern Canada and the Northeastern US **(Figure 3).**

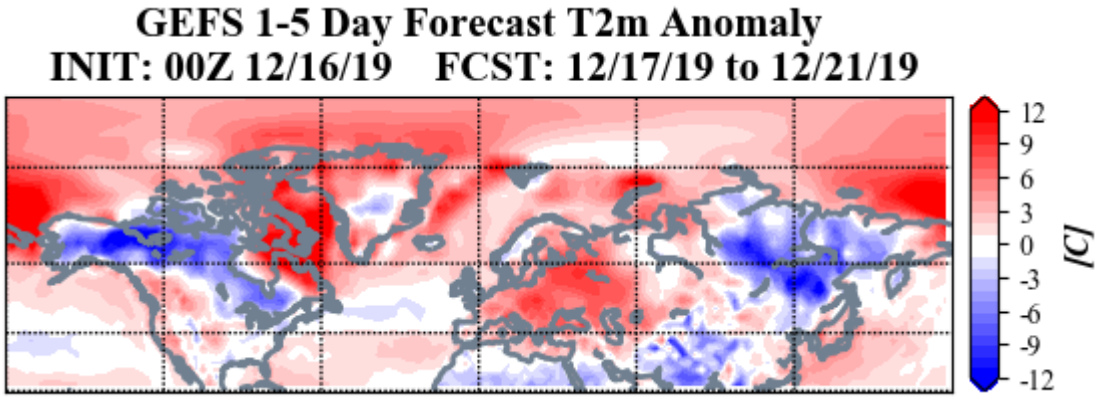

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 17 – 21 December 2019. The forecast is from the 00Z 16 December2019 GFS ensemble.

Troughing and/or cold temperatures are predicted to bring new snowfall across Siberia, the Tibetan Plateau, East Asia and Northwestern Russia (**Figure 4**). Troughing and cold temperatures are predicted to bring new snowfall to much of Canada and the Northeastern US (**Figure 4**). Warmer temperatures are predicted to result in snowmelt for Alaska and the Northwestern US (**Figure 4**).

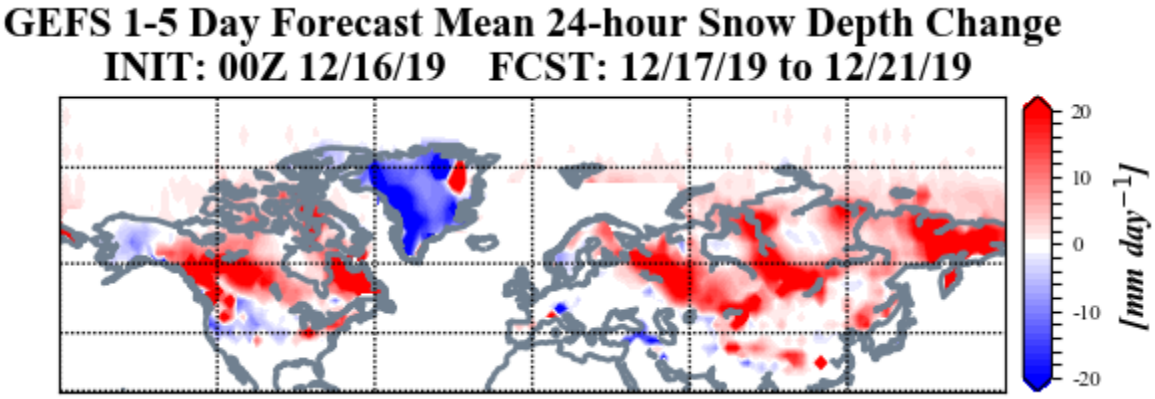

Figure 4. Forecasted snowdepth anomalies (mm/day; shading) from 17 – 21 December 2019. The forecast is from the 00Z 16 December2019 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain neutral to negative this period **(Figure 1**) as geopotential height anomalies turn more positive across 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 remain neutral to slightly negative.

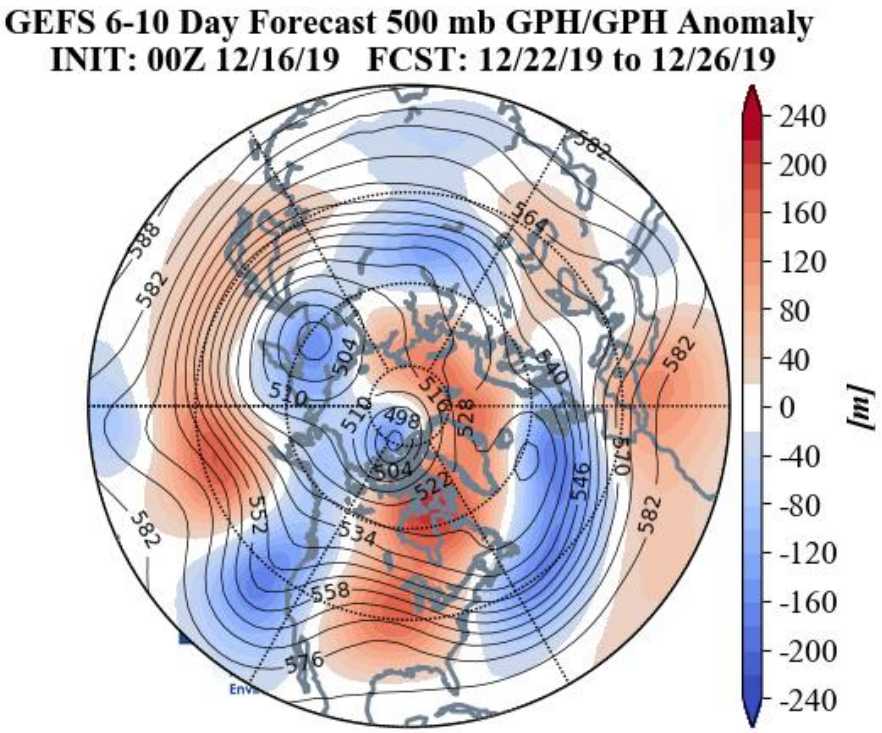

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 22 – 26 December 2019. The forecasts are from the 16 December 00z GFS ensemble.

Predicted troughing/negative geopotential height anomalies across Northern Europe with ridging/positive geopotential height anomalies across Southern Europe will persist the westerly, mild flow of air across the continent with normal to above normal temperatures for much of Europe Including the UK with the exception of Northern Scandinavia where below normal heights will support cold temperatures (**Figures 5 and 6**). Ridging/positive geopotential height anomalies will dominate Southeastern and far Western Asia with troughing/negative geopotential height anomalies across much of Siberia and Central Asia (**Figure 5**). This is predicted to yield normal to above normal temperatures for much of Western and East Asia with normal to below temperatures across much of Siberia and parts of Central Asia **(Figure 6**).

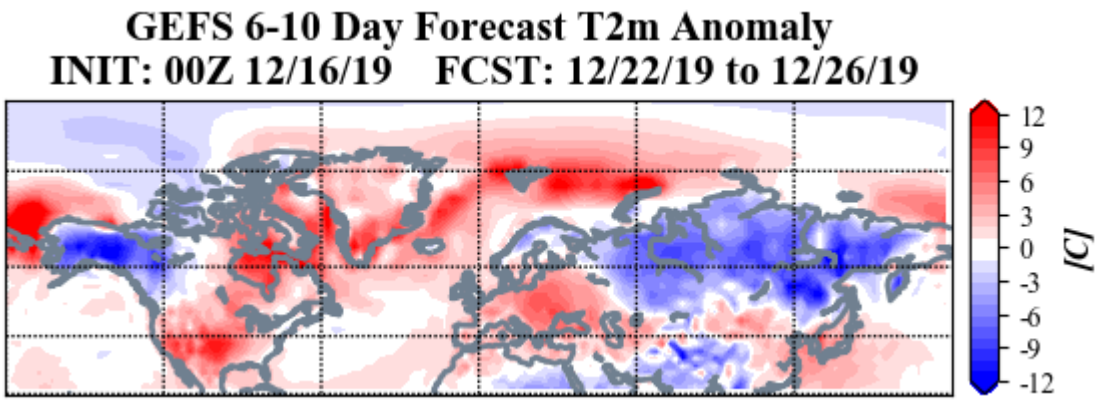

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 22 – 26 December 2019. The forecasts are from the 00Z 16 December 2019 GFS ensemble.

Troughing/negative geopotential height anomalies in Alaska and just off the west coast of North America are predicted to force ridging/positive geopotential height anomalies across much of North America **(Figure 5).** This pattern is predicted to bring normal to below normal temperatures across Alaska and Northwest Canada with normal to above normal temperatures to the remainder of Canada and much of the US (**Figure 6**). One exception could be the Northeastern US where cold air and snow cover from the previous period persist **(Figure 6).**

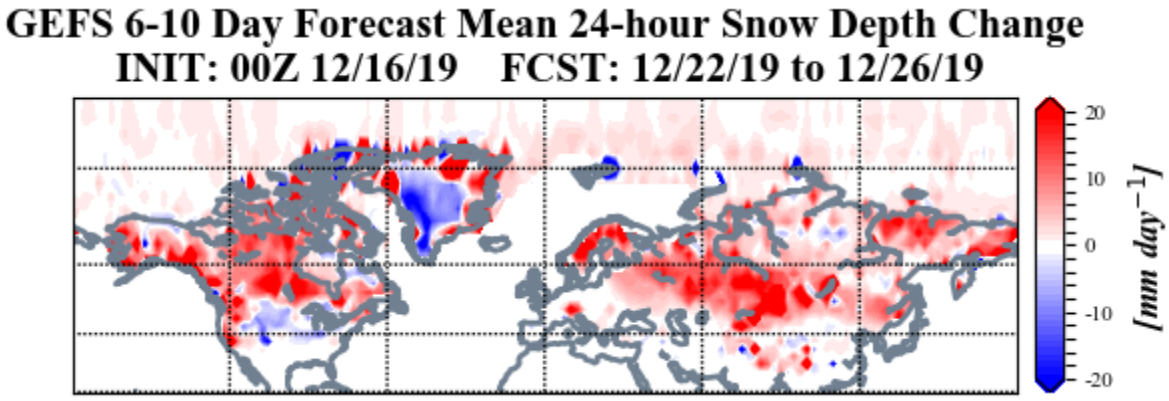

Figure 7. Forecasted snowdepth changes (mm/day; shading) from 22 – 26 December 2019. The forecasts are from the 00Z 16 December 2019 GFS ensemble.

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, Alaska and the Western US and possibly even Eastern Europe (**Figure 7**). Some snowmelt is predicted in the Rockies and the US Plains (**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.

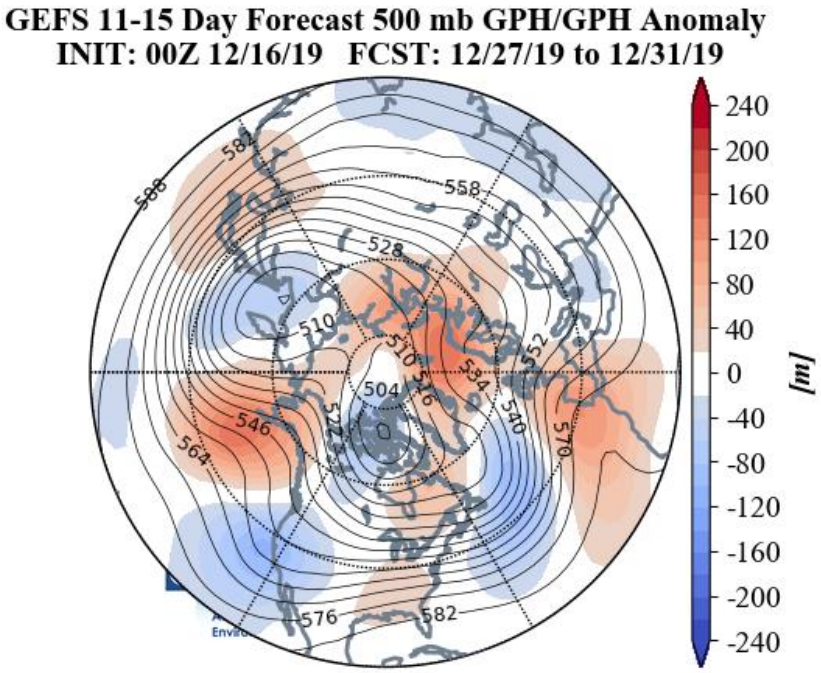

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 27 – 31 December 2019. The forecasts are from the 16 December 00z GFS ensemble.

Ridging/positive geopotential height anomalies previously over Southwestern Europe are predicted to push north across Western Europe forcing some weak troughing/negative geopotential height anomalies across Eastern Europe (**Figures 8**). Above normal heights dominating the region will continue to favor widespread normal to above normal temperatures across much of Europe including the UK this period, however troughing in Eastern Europe could start to allow colder temperatures to start filtering in from the east, especially over Scandinavia (**Figures 9**). Ridging/positive geopotential height anomalies previously over Western Russia will slide north towards the Barents-Kara Seas, helping to persist troughing/negative geopotential height anomalies over Siberia and Central Asia (**Figure 8**). This pattern favors normal to above normal temperatures across much of Southern Asia including the Middle East and Southeast Asia with normal to below normal temperatures in Siberia and Northwest Russia (**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**).

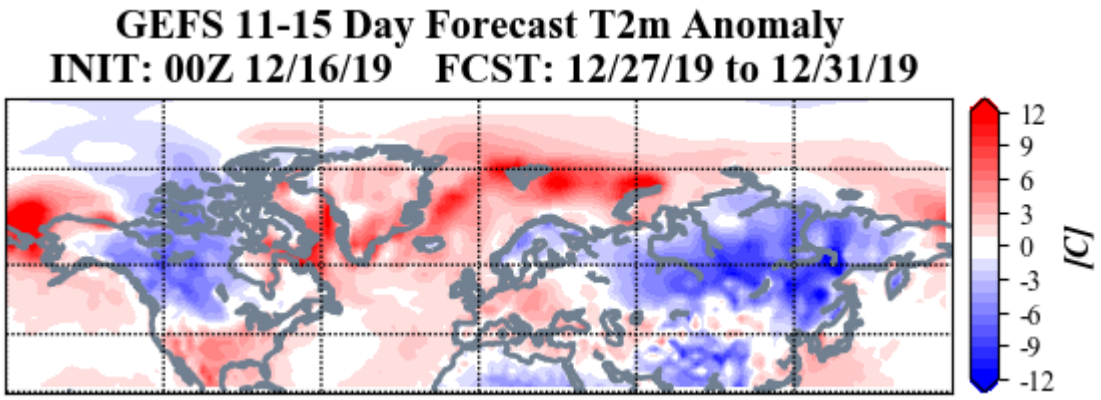

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 27 – 31 December 2019. The forecasts are from the 16 December 00z GFS ensemble.

The GFS is predicting that the troughing/negative geopotential height anomalies previously off the North American west coast will come on shore this period into western North America shunting the ridging/positive geopotential height anomalies into the Eastern US (**Figure 8**). Meanwhile building ridging/positive geopotential height anomalies across Alaska will help to amplify downstream troughing/negative geopotential height anomalies across Western Canada (**Figure 8**). This pattern is predicted to favor normal to below normal temperatures across interior Alaska, most of Canada and the Western US with normal to above normal temperatures in the Central and Eastern US (**Figure 9**). This week the ECMWF forecast is not as mild as the GFS for the Eastern US.

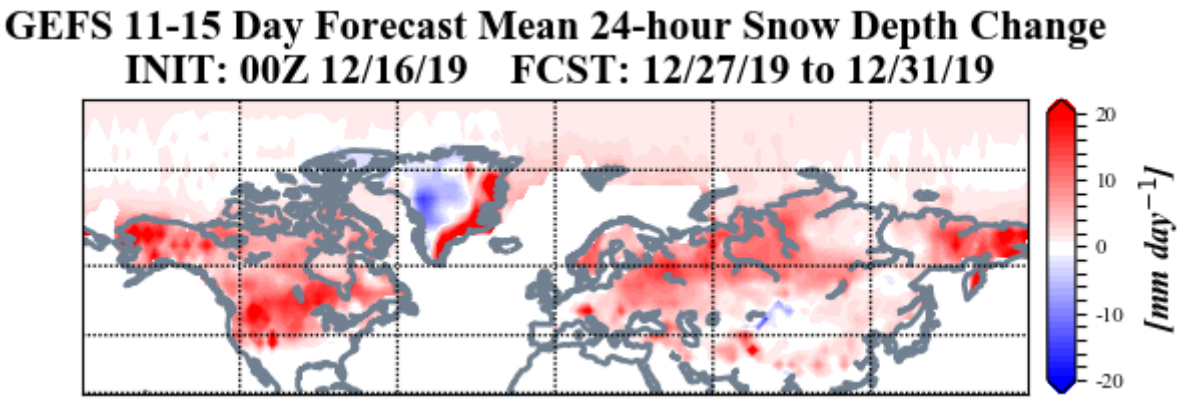

Figure 10. Forecasted snow depth changes (mm/day; shading) from 27 – 31 December 2019. The forecasts are from the 00z 16 December GFS ensemble.

Troughing and/or cold temperatures will support new snowfall across much of northern Asia but with the best chances across Northwestern Russia, Eastern Siberia and Scandinavia (**Figure 10**). Snow has been slow to advance towards Europe this winter,

but the probability of snow is looking better this period for Eastern Europe. New snowfall is possible across Alaska, much of Canada, the Northern US and the Rockies (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows only weak anomalies with above normal PCHs in the mid- to lower- troposphere with below normal PCHs in the middle stratosphere (**Figure 11**). The weak warm PCHs in the lower troposphere are consistent with a predicted neutral to negative AO this week (**Figure 1**). The models have completely backed off a sudden stratospheric warming (SSW) for December and the latest GFS ensembles predict cooling in the polar stratosphere and some strengthening of the stratospheric PV.

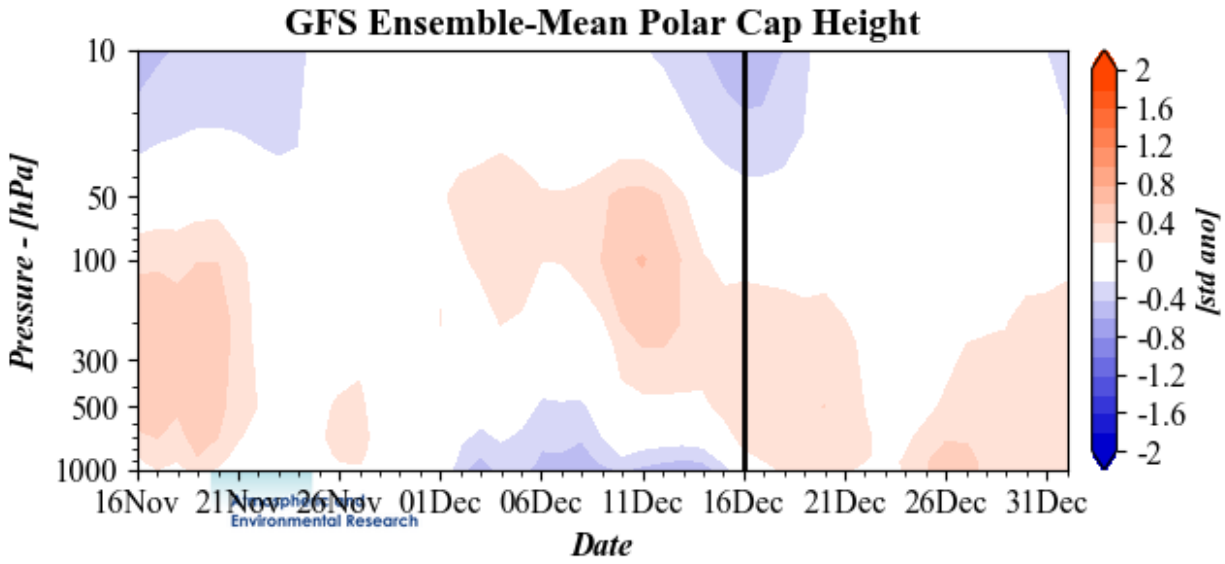

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 16 December 2019 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows relatively active two weeks especially next week with strong positive anomalies predicted (**Figure 12**). The predicted positive WAFz for the upcoming week are not predicted to result in significant weakening of the stratospheric PV but only in a minor disruption.

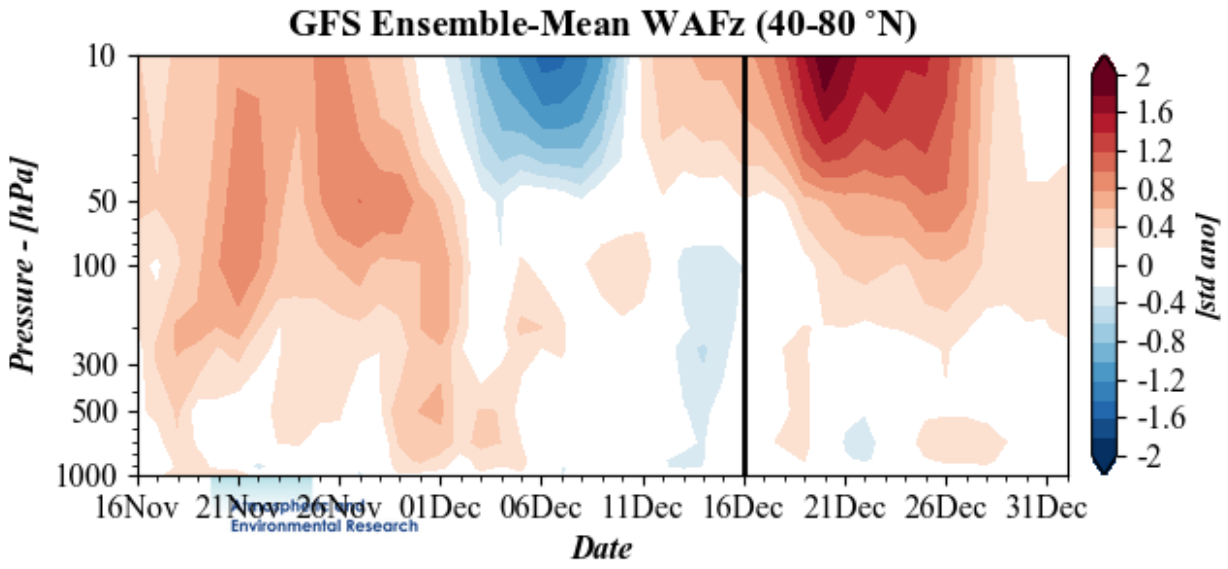

Figure 12. Observed and predicted daily vertical component of the wave activity Wux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 16 December 2019 GFS ensemble.

The stratospheric AO is currently slightly positive (**Figure 1**) reflective of a relatively normal 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. This is probably related to the tropospheric PV predicted to cross New England mid-week.

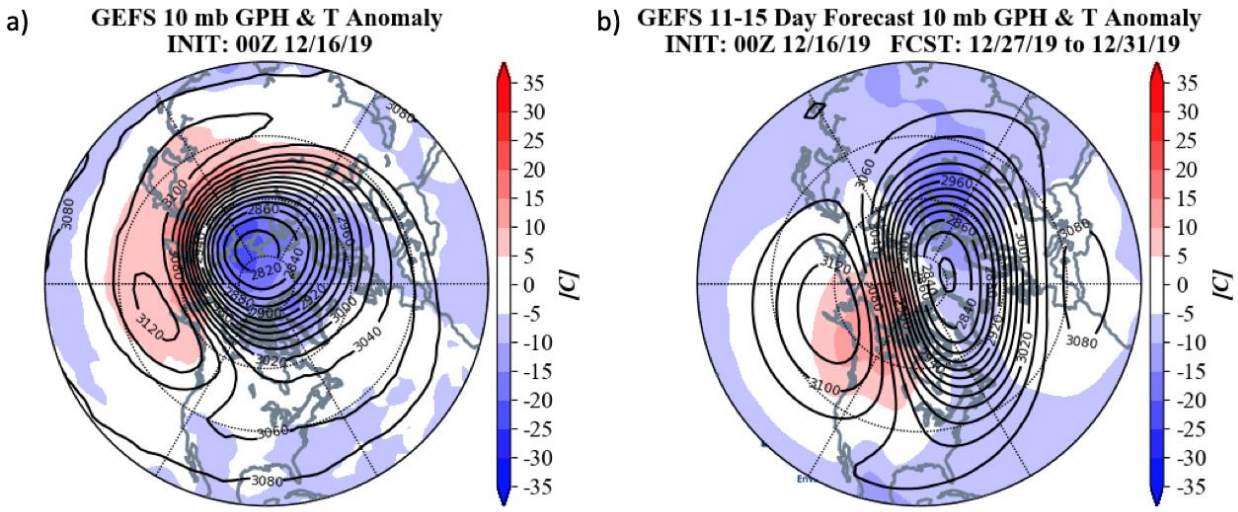

Figure 13. (**a**) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 16 December 2019. (**b**) Same as (a) except forecasted averaged from 27 – 31 December 2019. The forecasts are from the 00Z 9 December 2019 GFS operational model.

Despite the stratospheric PV being displaced, strong and circular circulation exists around the PV center with relatively low heights (**Figure 13**). The largest negative temperature departures in the polar stratosphere are over Central and Eastern Siberia, likely supporting the cold temperatures in that region. Had the strong PV returned to the North Pole in this current configuration, it would likely contribute to a relatively mild pattern across the NH. For now this is not the forecast but a scenario worth considering.

Currently there is warming and ridging centered near the Aleutians in the stratosphere with more warming over East Asia (**Figure 13).** Over time the new WAFz pulse is predicted to amplify the warming over East Asia as it advects into the North Pacific sector of the Arctic and eventually reinforces the ridging centered over Alaska while the PV center is predicted to remain displaced towards the North Atlantic side of the Arctic (**Figure 13)**. Ridging near Alaska with PV center towards displaced towards Greenland and elongated resembles a “reflection” PV disruption that favors cold temperatures in central and eastern North America. This event is likely separate from the event that is predicted to briefly bring cold temperatures to New England this week.

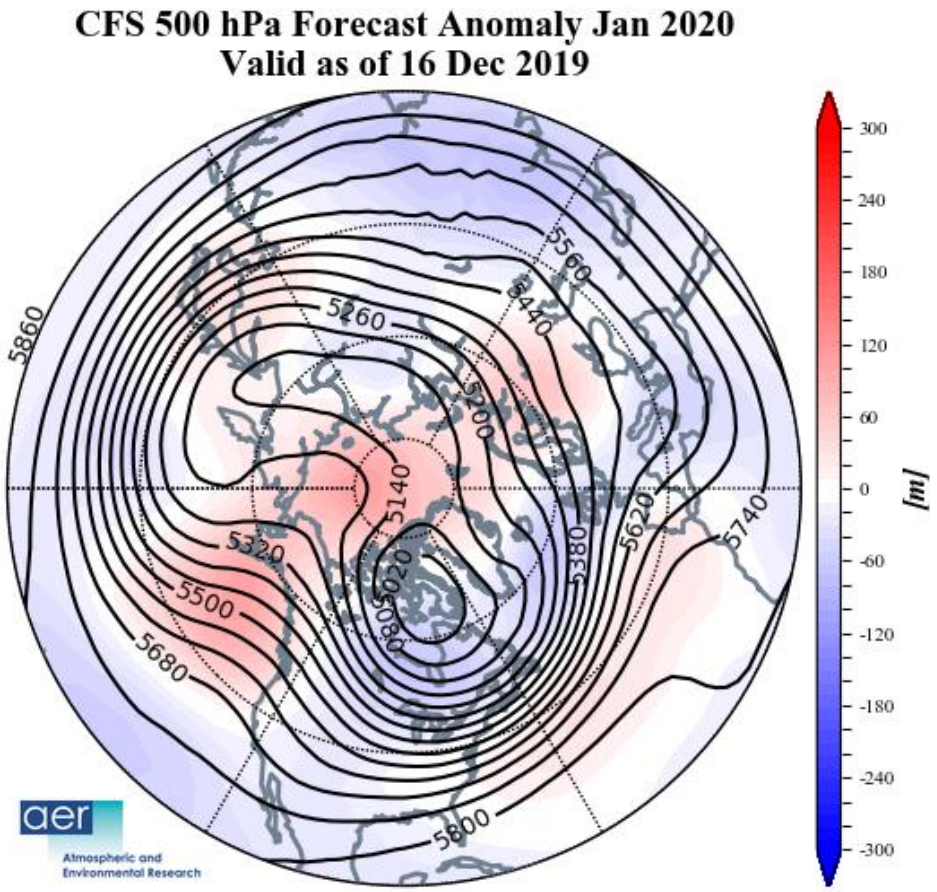

Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for January 2020. The forecasts are from the 9 December 2019 CFS.

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 Southwestern Europe, much of the Arctic, East Asia, Alaska and the Gulf of Alaska with troughs over the eastern Mediterranean, Central Asia, Eastern Siberia, the Dateline, and central North America (**Figure 14).** This pattern favors relatively mild temperatures for Eastern Europe, Western Asia and western North America with seasonable to relatively cold temperatures for Western Europe. Siberia, Northeast Asia, Eastern Canada and the Northeastern US (**Figure 15**). The CFS forecast for January has returned to predicting a circulation pattern prediction that projects on to the pattern of variability associated with a negative AO.

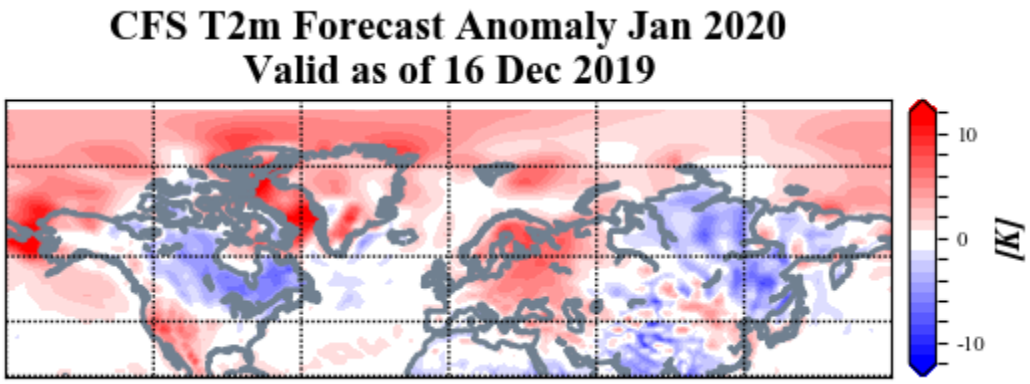

Figure 15. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for January 2020. The forecasts are from the 16 December 2019 CFS.

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 Seas, 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.

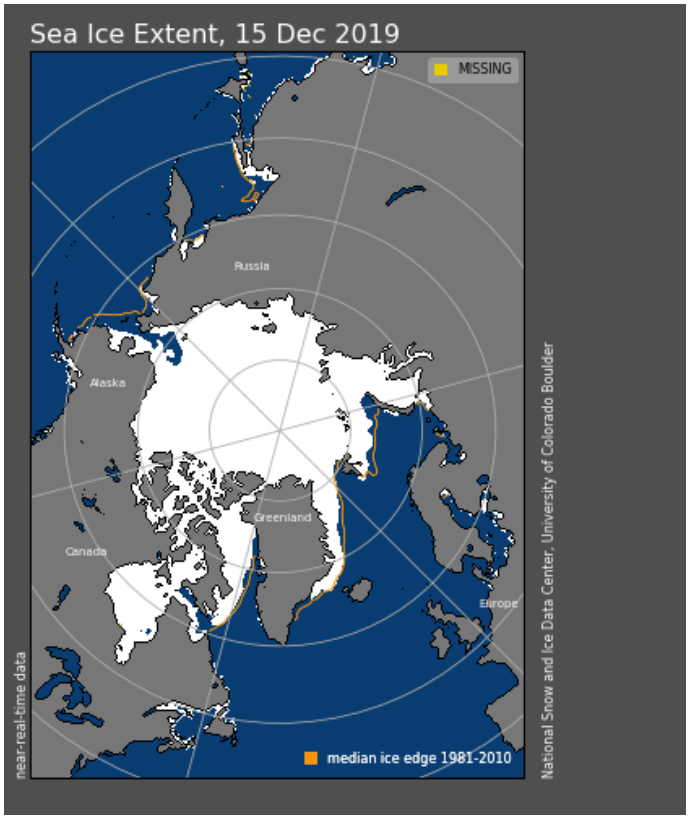

Figure 16. a) Observed Arctic sea ice extent on 15 December 2019 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010.

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 in the 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).

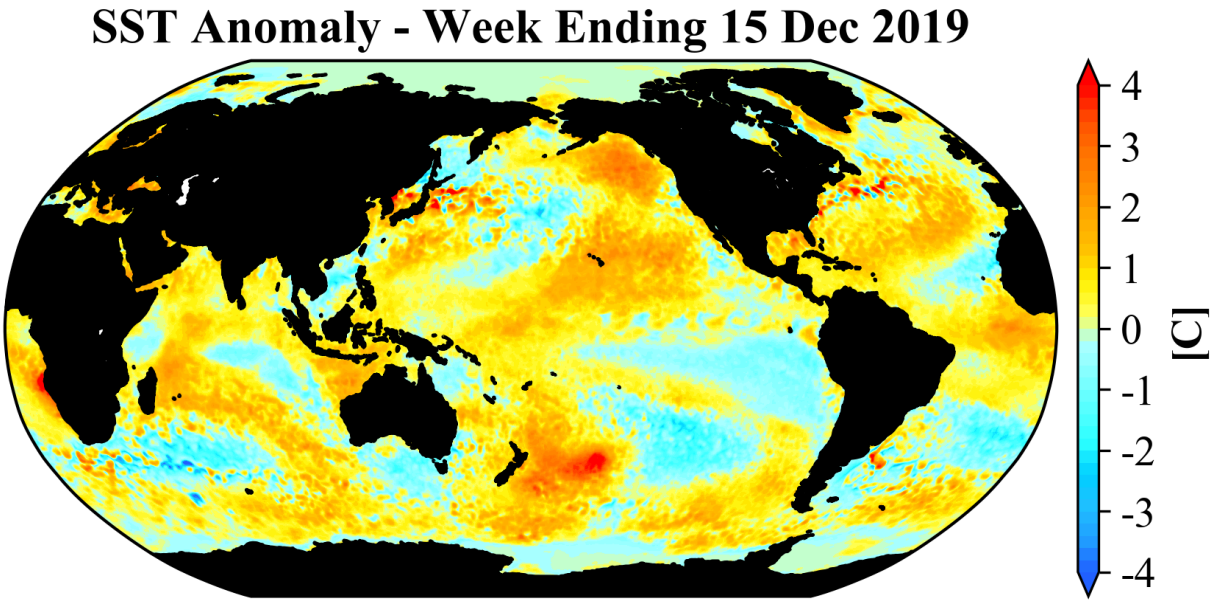

Figure 17. The latest weekly-mean global SST anomalies (ending 15 December 2019). Data from NOAA OI High-Resolution dataset.

Currently weak phase 3 phase of the Madden Julian Oscillation (MJO) is favored (**Figure 18**). The forecasts are for the MJO to immediately weaken so thatno no phase is favored over the next two weeks. Little MJO influence is expected for the weather across North American in the forecast period.

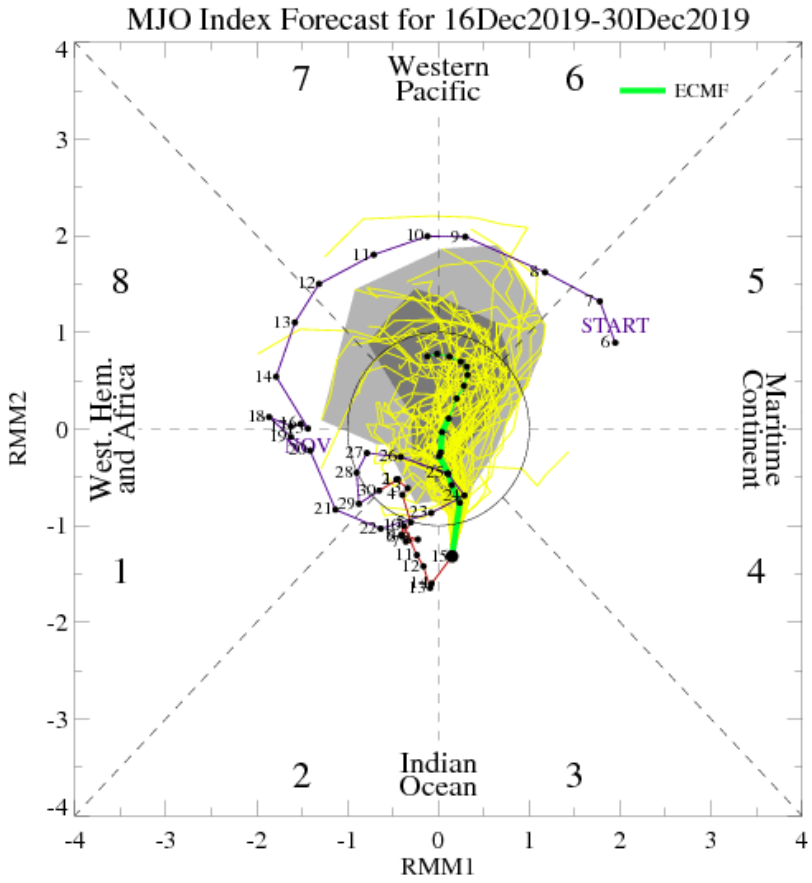

Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 16 December 2019 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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 has melted back across Eurasia and is currently near decadal lows. 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.

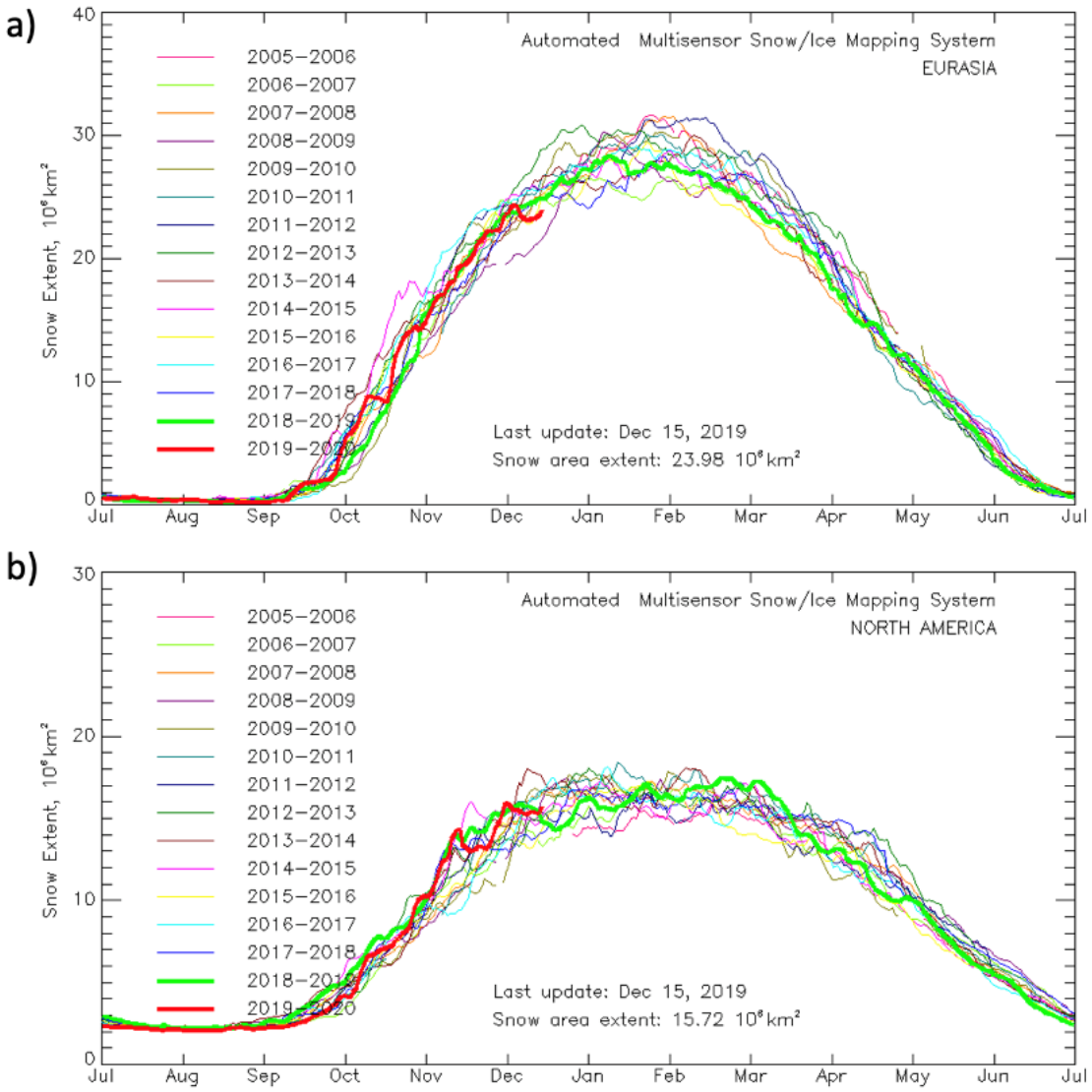

Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 15 December 2019. Image source: https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover has also melted back this past week with warmer temperatures and is now near decadal means. 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.