**January 14, 2019**

***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). 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.

With transition to a fall/winter schedule, postings are once every week.  Precipitation forecasts will be replaced by snow accumulation forecasts along with more 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 for almost ten days before trending negative through the end of January.
- 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 currently slightly positive with mixed pressure/geopotential height anomalies across Greenland and positive pressure/geopotential height anomalies across the mid-latitudes of the North Atlantic and is predicted to trend negative as height anomalies turn mostly positive across Greenland over the next two weeks.
- Ridging/positive geopotential height anomalies centered south of Iceland and extending into Western Europe are predicted to bring seasonable to above normal temperatures to much of Europe including the United Kingdom (UK) but force troughing/negative geopotential height anomalies and cold temperatures for Eastern but especially Northern Europe. However next week the ridging is predicted to become focused across Greenland, allowing troughing and cold temperatures across most of Europe including the UK except for Southeastern Europe.

- Much of Asia is currently dominated by ridging/positive geopotential height anomalies and relatively mild temperatures with troughing/negative geopotential height anomalies and relatively cold temperatures mostly focused across northeastern Asia. However, over the next two weeks troughing/negative geopotential height anomalies and cold temperatures will become widespread across Northern Asia including much of Siberia with ridging/positive geopotential height anomalies and relatively mild temperatures across Southern Asia including the Middle East, the northern Indian subcontinent and East Asia.
- Currently ridging/positive geopotential height anomalies and normal to above normal temperatures are widespread across North America with just pockets of below normal temperatures. However, over the next two weeks ridging/positive geopotential height anomalies are predicted to become focused across Alaska, Northwest Canada and the Gulf of Alaska forcing troughing/negative geopotential height anomalies across eastern North America. This pattern will increasingly favor relatively mild temperatures across western North America with relatively cold temperatures first across Central and Eastern Canada and then across the Eastern United States (US).
- In the Impacts section, I discuss my expectations of the remainder of the winter based on the stratospheric polar vortex (PV) split.

***Impacts***

Today's *Impact* section might read like an acceptance speech for a lifetime achievement award but seems appropriate in this juncture of the lifecycle of the ongoing troposphere-stratosphere-troposphere (T-S-T) coupling event. It is my observation that in the field of climatology a simplification or generalization created that allows for an important advance in our understanding of atmospheric dynamics can overtime become a crutch or even an impediment for further advances. One example is the Arctic Oscillation (AO) or Northern Annular Mode (NAM) framework.

The AO/NAM framework is an index or barometer that measures the exchange of pressure or mass between the high and lower latitudes. In the normal state of the stratosphere where the PV is stable or strong i.e., positive AO/NAM - pressure/mass is lower over the Arctic and higher over the mid-latitudes. In the disrupted or weakened PV i.e., negative AO/NAM then mass converges at the North Pole and pressure/mass is anomalously high over the Arctic and anomalously low over the mid-latitudes. It was then shown that this seesaw in pressure or exchange of mass that occurs in the stratosphere can lead a similar seesaw in pressure or exchange of mass in the troposphere about two weeks later. As I have said previously this was shown in an influential paper on my own research - [Baldwin and Dunkerton 1999](#).

In the late 1990's I was arguing that anomalies in Siberian snow cover extent can also partially force or at least predict the same seesaw in pressure or exchange of mass in the troposphere only but on a time scale of months and not weeks. But then with the publication of the research of Baldwin and Dunkerton and even earlier studies that decade, I was forced to rethink my own explanation of how Siberian snow cover can influence winter weather. Instead of a cycle that involved the troposphere only, our group argued for a T-S-T coupling where the signal starts with Siberian snow cover bounces off the stratospheric PV and boomerangs back into the troposphere. I showed the earliest iteration of the schematic illustrating that T-S-T coupling event last week

This discovery that atmospheric circulation changes in the stratosphere can lead to like changes in the troposphere by two weeks supported the idea that variability in the stratospheric PV can be exploited for longer range weather prediction. However, the framework that made this discovery possible was binary it only considered a positive and negative AO/NAM, and for the negative AO/NAM events in the stratosphere only the most extreme, which are referred to as major mid-winter warmings (MMW; where the zonal mean zonal wind reverses from westerly to easterly at 60°N and 10 hPa). And coupling between the stratosphere and troposphere is only considered when similar phase changes in the AO/NAM are observed throughout the depth of the atmospheric column. These same signed NAM anomalies are seen as fingers or tentacles extending down from the stratosphere to the troposphere and is referred to as the "dripping paint" plot. In fact I always found it ironic that in a follow up paper (Baldwin and Dunkerton 2001) the authors showed the winter of 1998/99 to argue the NAM coupling between the stratosphere and the troposphere where there are five distinctive NAM events but only one couples to the troposphere; a success rate of 20% is not very compelling for use in weather forecasting.

But the AO/NAM framework is one that I adopted, and it worked very well in my first winter forecast success of 2002/03 (documented in this Science article from 2003). The following winters, I had mixed success but with the possible exception of winter 2005/06 (which I discussed last week) for the most part it worked well enough so that I was a believer in the AO/NAM framework to understand and observe stratosphere-troposphere coupling. This was only further ingrained by the exceptional AO/NAM winters of 2009/10, 2010/11 and 2012/13. But the next two winters really gave me pause.

I was watching the stratospheric PV in winter 2013/14 in real time and in amazement as the PV pulled and stretched all winter long like a rubber band but never broke. And as far as I can tell the behavior of the tropospheric PV was mimicking the behavior of the stratospheric PV. In **Figure i**, I present the geopotential heights in both the mid stratosphere and mid-troposphere and to me at least the coupling or similarity in the pattern is obvious, though my plot doesn't really do it justice. This resulted in a surprisingly harsh winter for much of North America (but not Europe) but using the AO/NAM framework you could not provide support for any stratosphere-troposphere coupling. And maybe the biggest irony of all - the winter of 2013/14 when there was this most unusual behavior of the PV - turned out to be the PV's coming out party in the media.

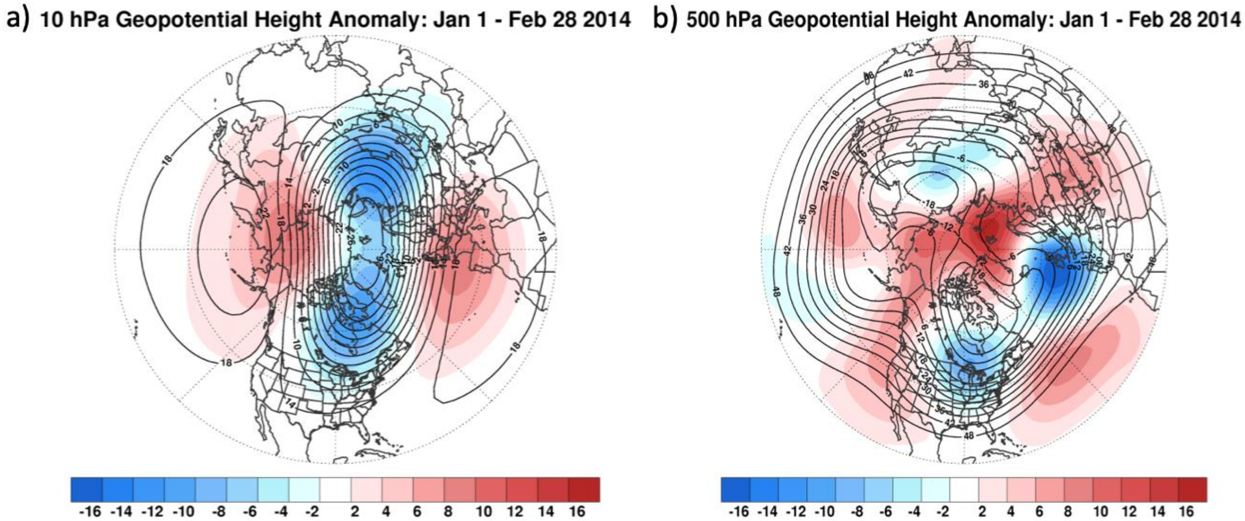


**Figure i**. a) Observed 10 mb geopotential heights (contours) and geopotential height anomalies (m; shading) for 1 Janaury - 28 February 2014 and b) Observed 500 mb geopotential heights (contours) and geopotential height anomalies (shading) for 1 Janaury - 28 February 2014.

This was followed up by winter 2014/15. That winter, there was what I would consider a more classic and significant PV disruption and split in early January and exactly two weeks later the most intense period of winter weather of my lifetime that I have ever experienced commenced. Again, I would argue from **Figure ii** that the atmospheric circulation in the troposphere followed the lead of the atmospheric circulation in the stratosphere. The problem again though, there is little evidence of stratosphere-troposphere coupling within the AO/NAM framework. In both winter of 2013/14 and 2014/15 the stratospheric PV was disrupted, which projected onto the tropospheric PV or circulation, severe winter weather was observed in the Central and Eastern US all consistent with a negative AO/NAM but the problem is that the AO/NAM was neutral to positive.

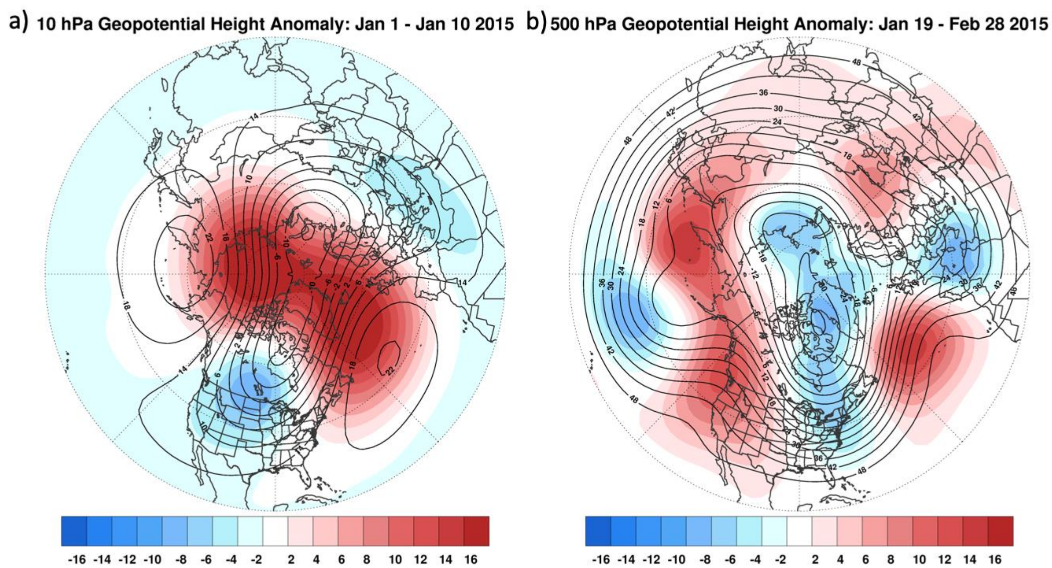


**Figure ii**. a) Observed 10 mb geopotential heights (contours) and geopotential height anomalies (m; shading) for 1 -10 Janaury 2015 and b) Observed 500 mb geopotential heights (contours) and geopotential height anomalies (shading) for 19 Janaury - 28 February 2015.

After those two winters I thought that the AO/NAM were too limiting in understanding stratosphere-troposphere coupling and applying it to long range weather forecasting. Since then I have been migrating away from the NAM framework and more focused on an independent PV framework that resulted in a prolific (for me anyway) of research papers last year - two papers with Marlene Kretschmer et al. 2018a and Kretschmer et al. 2018b and even a third paper Cohen et al. 2018a. Ironically for me as much as I was trying to escape the AO/NAM framework the reviewers wouldn't let me. And all (and many, many reviewers) complained that everything that we were arguing could be explained by the AO/NAM framework, which led to many auxiliary figures demonstrating that this was not accurate. I do consider not limiting myself to explaining troposphere-stratosphere coupling only through an AO/NAM framework liberating in trying to understand climate variability. But one man's liberation can be another man's carelessness.

So now to this winter. Even I was surprised how much uncertainty there existed in the models whether the current stratospheric PV disruption would achieve MMW status and if the PV would split. But once confidence was growing that both would be achieved the next question became would the circulation anomalies in the stratosphere couple with the troposphere. And if you measure stratosphere-troposphere coupling in an AO/NAM framework that remains an outstanding question even today. I might be unique but based on a figure that I tweeted out last week and I show in **Figure iii**, the stratosphere and troposphere are already clearly coupled. I don't believe that it is a coincidence that the most impressive cold and snow of last week in Central and Southeastern Europe, New England and Eastern Canada were respectively directly beneath the two daughter vortices in the stratosphere.  That cold air in New England did something highly anomalous (at least to me) it bled westward and fed the Central Plains to Mid-Atlantic snowstorm. The US is not Europe and normally the cold air does not feed in from the east. But this is an unusual weather event in the stratosphere, and I think expect more surprises.

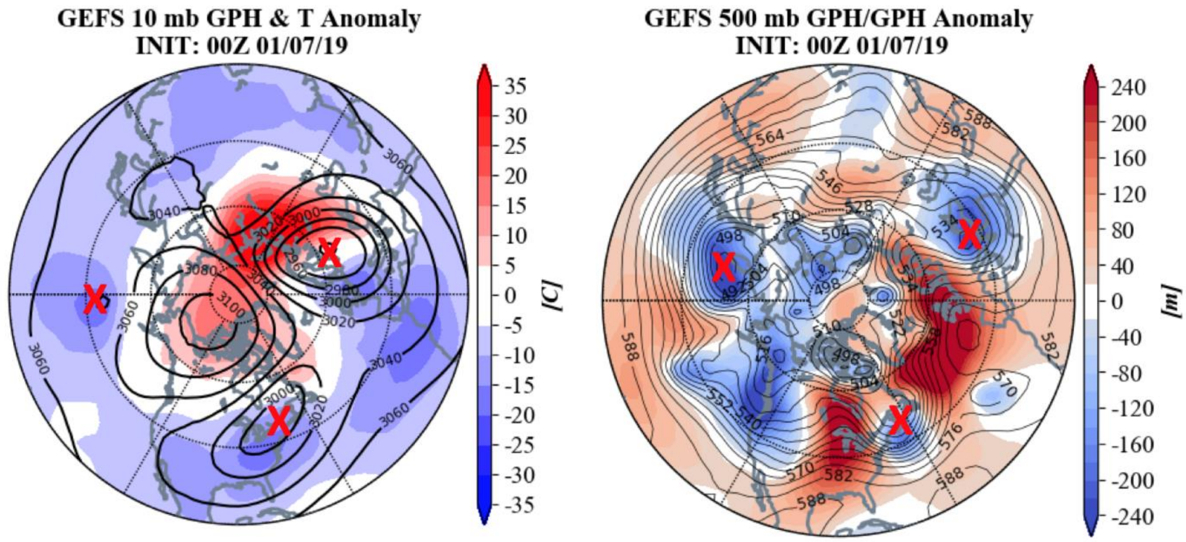


**Figure iii**. a) Observed 10 mb geopotential heights (contours) and geopotential height anomalies (m; shading) for  7 January 2019 and b) Observed 500 mb geopotential heights (contours) and geopotential height anomalies (shading) for 7 January 2019. Red "X" indentifies centers of polar vortices in both stratosphere and troposphere.

I have been saying for many weeks now stratosphere-troposphere coupling is a challenge for the weather models and expect that to be the case until the warm PCHs descend into the lower stratosphere and then the models will likely converge on a solution.  This was based on my analysis in my latest paper Cohen et al. 2018b and it is amazing (to me anyway) how much that is discussed in that paper from last winter  is relevant to this winter.  That the models struggled with the pattern post the PV split did not surprise me (as I just mentioned, I was surprised though by how much the models struggled with the PV split right up to the event itself).  I have shared on Twitter that I have limited access to the ECMWF forecasts.  One reason that I resist getting greater access because I don't want to simply regurgitate the models and I do consider the ECMWF to be the best long-range model in the business.  But it too suffers the shortcomings common to the other models and I believe better for me to be disagree with the models and be wrong then agree with the models and be wrong.  And I am certainly glad that I did resist ECMWF data.  The ECMWF forecast that came out right before New Year's predicting beginning to end mild January seemed to convince many forecasters that winter was just about done and if I religiously followed the ECMWF, I too may have panicked and raised the white flag on my expectations and forecast.  Now that the models all seem to be converging on a colder solution including the ECMWF, I am glad that I never wavered on the winter forecast but please don't misunderstand me, the blog from last week is still valid, there is still plenty of winter left and the outcome remains uncertain, just not the forecast.

What to expect the rest of winter.  This has been an extreme winter in the stratosphere, but no one will remember this winter other than a handful stratospheric dynamicists if that is the whole story.  But the extreme circulation anomalies need to successfully propagate down to at least the mid-troposphere to have a meaningful impact on the weather.  As I said earlier, I would argue the coupling has already begun and it will continue even sporadically or episodically projecting onto the negative AO/NAM giving the "dripping paint" impression seen in the polar cap geopotential height anomalies (PCHs) plot.  When the PCHs pulsate red or warm expect periods of elevated risk of severe winter weather across the US, Europe and even Asia.   (But to be clear I would expect severe winter weather risk to be more elevated even if the "dripping paint" is not observed in the classical sense.) For now, I think a good analog could be the last MMW/PV split in early January winter 2012/13.  In **Figure iv** I show the PCHs plot from that winter with some severe winter weather events highlighted when the PCHs pulsate red or warm across the Northern Hemisphere (NH).  That winter it took until March for the most positive PCHs to reach the mid to lower troposphere and it could take a while for something similar to occur.  I for one am not expecting winter's last hurrah to be this weekend.

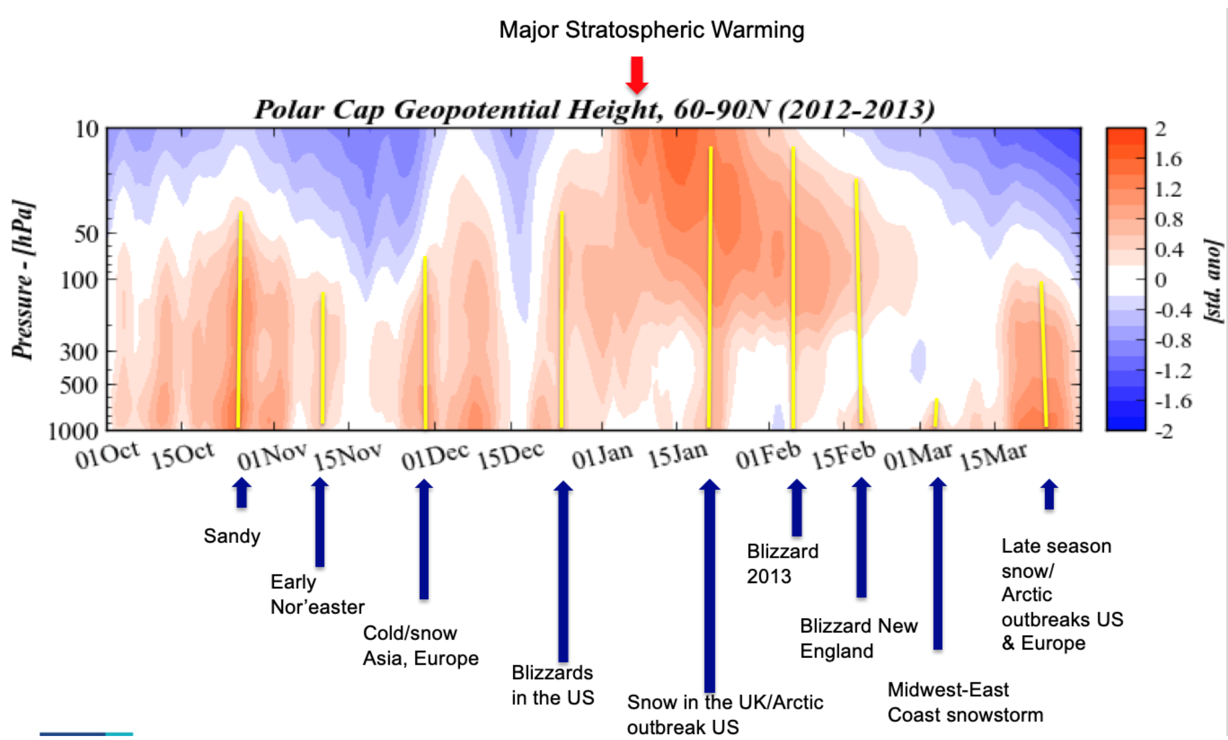

**Figure iv**.Extreme weather events coincided with enhanced Arctic warming as indicated by anomalies of daily standardized polar cap (60°N–90ºN) geopotential height (GPH) from 1 October 2012, through 31March 31, 2013. Anomalously high heights (corresponding with warm temperatures) are shaded in red. Blue arrows denote extreme weather events across the Northern Hemisphere, while the red arrows show the dates of a sudden stratospheric warming. Yellow bars highlight the alignment of pulses in the polar cap GPH with an extreme event.

***Near Term Conditions***

*1-5 day*

The AO is currently neutral **(Figure 1**), with mixed geopotential height anomalies across the Arctic **(Figure 2)**.  Geopotential height anomalies are mixed across Iceland and Greenland with positive geopotential height anomalies across the mid-latitudes of the North Atlantic **(Figure 2)** and therefore the NAO is slightly positive.

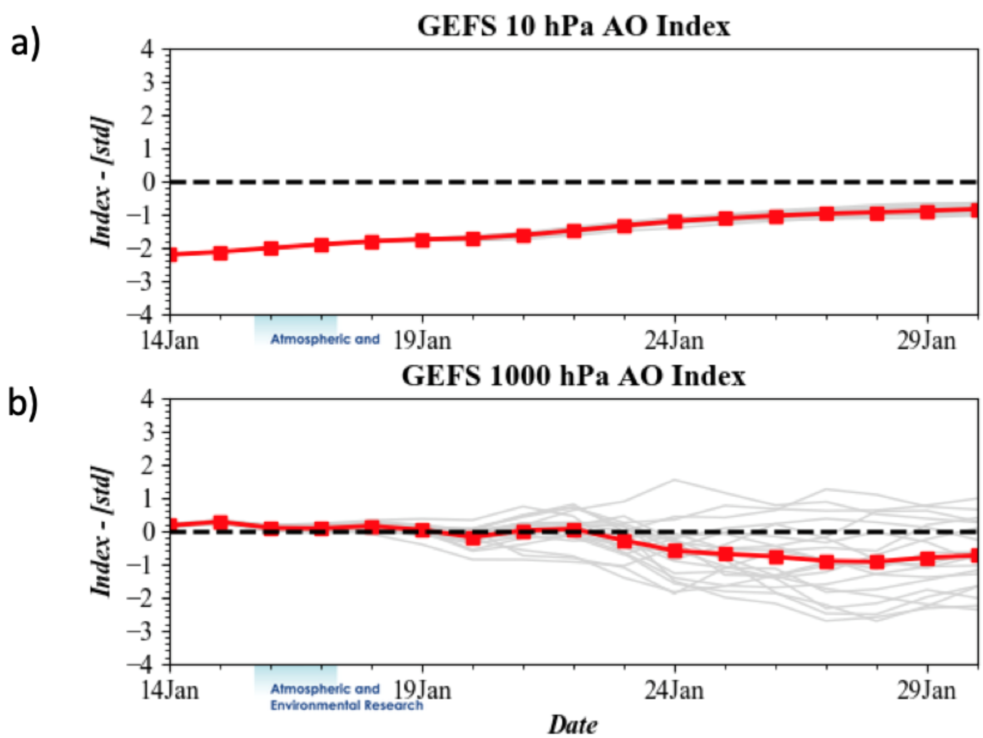


**Figure 1**. (**a**) The predicted daily-mean AO at 10 hPa from the 00Z 14 January 2019 GFS ensemble. (**b**) The predicted daily-mean near-surface AO from the 00Z 14 January 2019 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Currently ridging/positive geopotential height anomalies centered South of Iceland and extending across Western Europe (**Figure 2**) are forcing troughing/negative geopotential height anomalies downstream across Northern Europe that extend southward across Eastern Europe (**Figure 3**).  With high heights and mostly a westerly flow of air dominating, normal to above normal temperatures are widespread across much of Europe including the UK while low heights and northerly winds are bringing normal to below normal temperatures for Northern Europe and parts of Southeastern Europe and even into the Middle East (**Figure 3).**  Troughing/negative geopotential height anomalies extend across Central and Eastern Siberia with ridging/positive geopotential height anomalies widespread across the remainder of Asia (**Figure 2**) yielding widespread normal to above normal temperatures across much of Asia including Western and East Asia with the exception of normal to below normal temperatures for Central and Eastern Siberia (**Figure 3).**   However, regional troughing/negative geopotential height anomalies across the northern India subcontinent (**Figure 2**), are predicted to result in normal to below normal temperatures across Northern India and Pakistan **(Figure 3).**

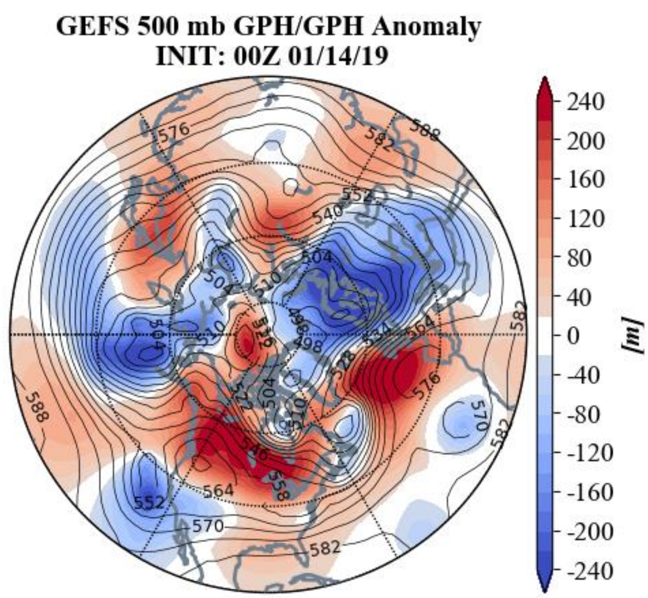


**Figure 2.** Observed 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) for 00Z 14 January 2019.

Troughing/negative geopotential height anomalies centered near the Dateline are forcing downstream ridging/positive geopotential height anomalies across much of North America with the exception of troughing/negative geopotential height anomalies in Newfoundland and the US Southwest (**Figure 2**).  However, during the week troughing/negative geopotential height anomalies are predicted to deepen and expand across Eastern Canada resulting in normal to below normal temperatures widespread across Canada with normal to above normal temperatures for Alaska and much of the US Lower 48**(Figure 3).**

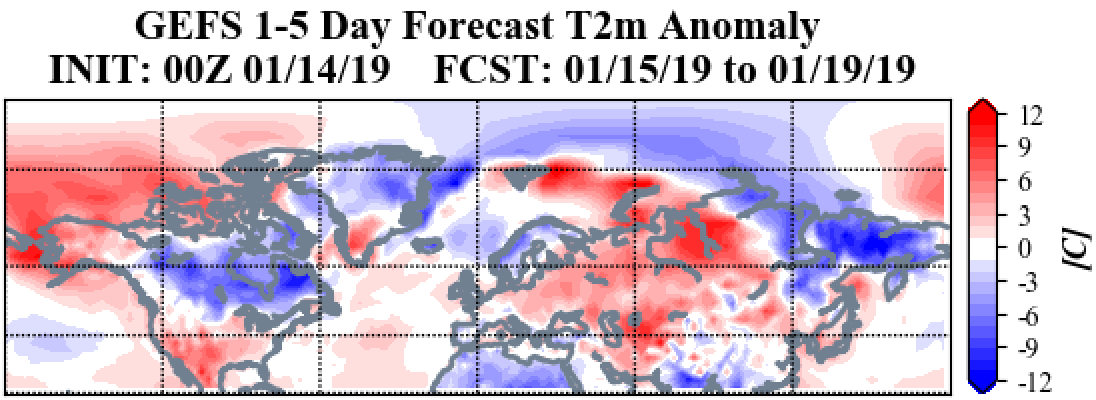


**Figure 3**. Forecasted surface temperature anomalies (°C; shading) from 15 – 19 January 2019. The forecast is from the 00Z 14 January 2019 GFS ensemble.

Troughing and/or cold temperatures will bring widespread new snowfall to Northern Europe, Turkey, parts of the Middle East, Northern and Eastern Asia (**Figure 4**). Across North America, troughing and cold temperatures will bring widespread new snowfall across Canada, the Northwestern US and even New England while milder temperatures will result in snowmelt across parts of Alaska and the Mid-Atlantic (**Figure 4**).

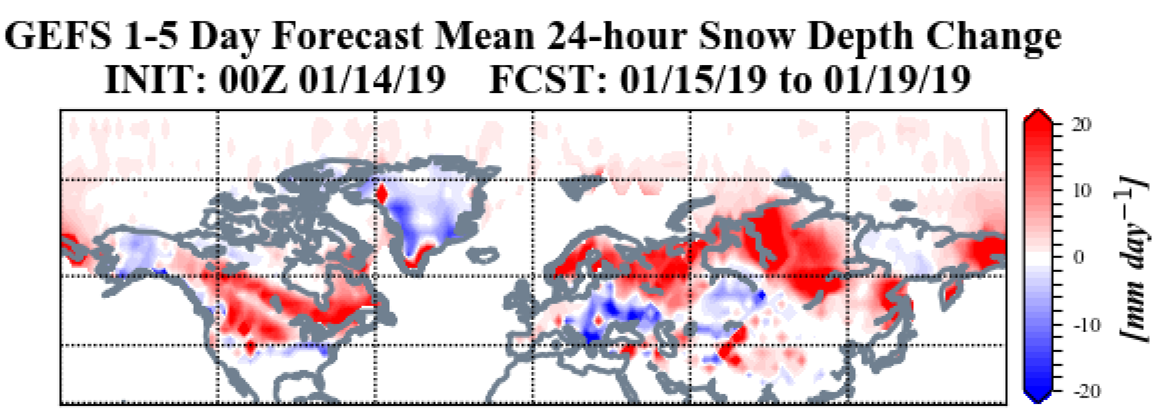


**Figure 4**. Forecasted snowfall anomalies (mm/day; shading) from 15 – 19 January 2019. The forecast is from the 00Z 14 January 2019 GFS ensemble.

*Mid-Term*

*6-10 day*

The AO is predicted to remain near neutral next week **(Figure 1**) with mixed geopotential height anomalies across the Arctic and mixed geopotential height anomalies across the mid-latitudes (**Figure 5a**). And with weak geopotential height anomalies across Greenland, the NAO will likely be near neutral as well next week.

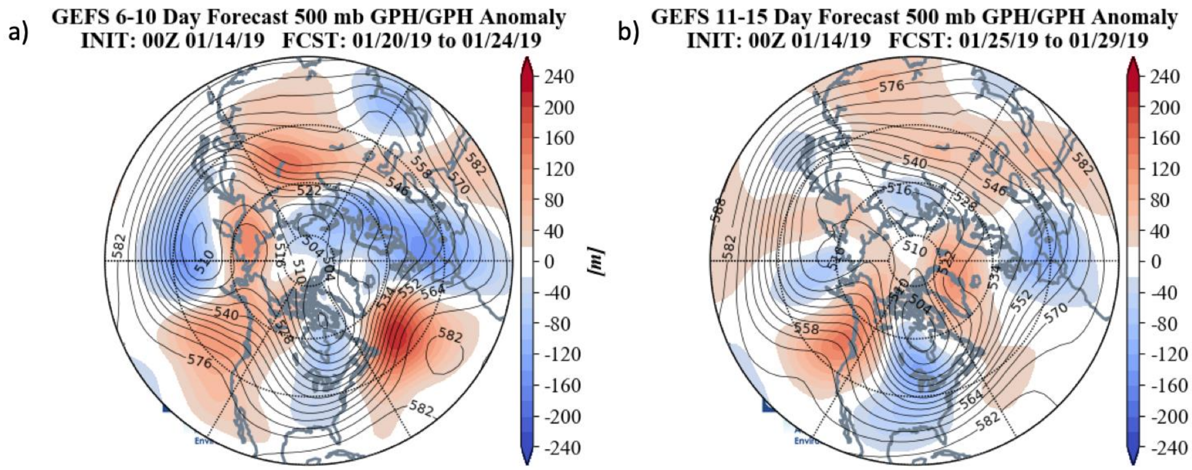


**Figure 5.** (a) Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 20 – 24 January 2019. (b) Same as (a) except averaged from 25 –29 January 2019. The forecasts are from the 14 January 2019 00z GFS ensemble.

Ridging/positive geopotential height anomalies centered previously south of Iceland are predicted to drift south of Greenland allowing troughing/negative geopotential height anomalies across much of Europe this period (**Figure 5a**). This is likely to result in a normal to below normal temperatures for much of Europe including the UK with normal to above normal temperatures for Southeastern Europe due to a southwesterly flow of milder air (**Figure 6**). Troughing/negative geopotential height anomalies previously in Scandinavia will push into Western Siberia while ridging/positive geopotential height anomalies centered in southcentral Siberia dominate much of the remainder of Asia (**Figure 5a**). This is predicted to yield normal to below normal temperatures for Northwestern Asia and Northern Siberia with normal to above normal temperatures for the rest of Asia including the Middle East, East Asia and likely most of the northern Indian subcontinent (**Figure 6**). Troughing/negative geopotential height anomalies across Iran, Pakistan and Afghanistan (**Figure 5a**) re predicted to yield normal to below normal temperatures for those three countries **(Figure 6**).

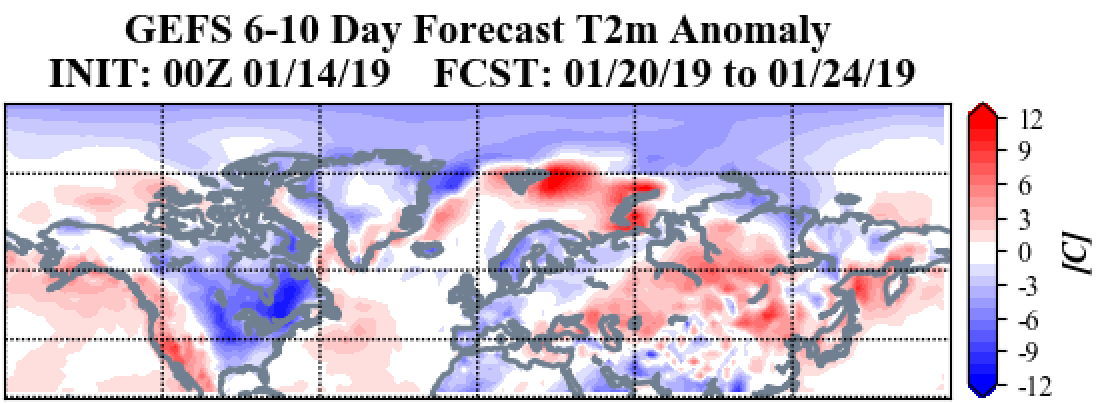


**Figure 6**. Forecasted surface temperature anomalies (°C; shading) from 20– 24 January 2019. The forecasts are from the 00Z 14 January 2019GFS ensemble.

Predicted troughing/negative geopotential height anomalies anchored near the Dateline are predicted to focus ridging/positive geopotential height anomalies across Alaska and the Gulf of Alaska with deepening troughing/negative geopotential height anomalies in Eastern Canada and the Eastern US (**Figure 5a**). The resultant temperature anomalies across North America are predicted to be normal to above normal temperatures across much of Alaska, the West Coast of Canada and the West Coast of the US with normal to below normal temperatures for Eastern Canada and the Eastern US(**Figure 6).**

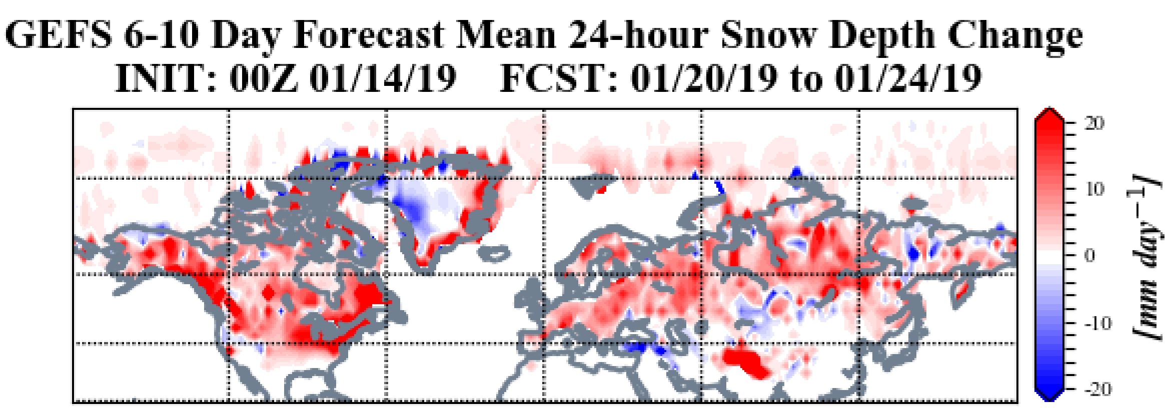


**Figure 7**. Forecasted snowfall anomalies (mm/day; shading) from 20 – 24 January 2019. The forecasts are from the 00Z 14 January 2019 GFS ensemble.

Troughing and cold air will bring the potential for new snowfall across almost all of Europe Northern and Central Asia (**Figure 7**). Across North America, new snowfall is possible in Alaska, much of Canada and the Northeastern US (**Figure 7**). Increasingly milder temperatures could result in snowmelt in parts of Turkey and even possibly parts of the Western US (**Figure 7**).

*11-15 day*

With mostly positive but weak geopotential height anomalies predicted for the Arctic (**Figure 5b**), the AO is likely to trend negative this period (**Figure 1**). With positive pressure/geopotential height anomalies across Greenland, the NAO is predicted to turn negative this period as well (**Figure 1**). The predicted negative AO is related to “dripping” of warm/positive polar cap geopotential height anomalies from the stratosphere to the troposphere.

Ridging/positive geopotential height anomalies across Greenald to Svalbard are predicted to persist troughing/negative geopotential height anomalies for much of Europe (**Figure 5b**). Low heights and northerly flow are likely to result in normal to below normal temperatures for much of Europe including the UK (**Figure 8**). However, a more westerly flow of air across Southeastern Europe and high heights across northern Scandinavia could bring relatively mild temperatures to those regions (**Figure 8**). Troughing/negative geopotential height anomalies will become more widespread across Siberia and extend into Northeast Asia with ridging/positive geopotential height anomalies predicted for Southern Asia (**Figure 5b**). This pattern favors normal to below normal temperatures for Northern Asia, including all of Siberia and Northeast Asia with normal to above normal temperatures for Southern and Central Asia including the Middle East, Northern India, Pakistan and Southeast Asia (**Figure 8**).  Some residual troughing could bring normal to below normal temperatures for the northern Indian subcontinent including Pakistan (**Figure 8**).

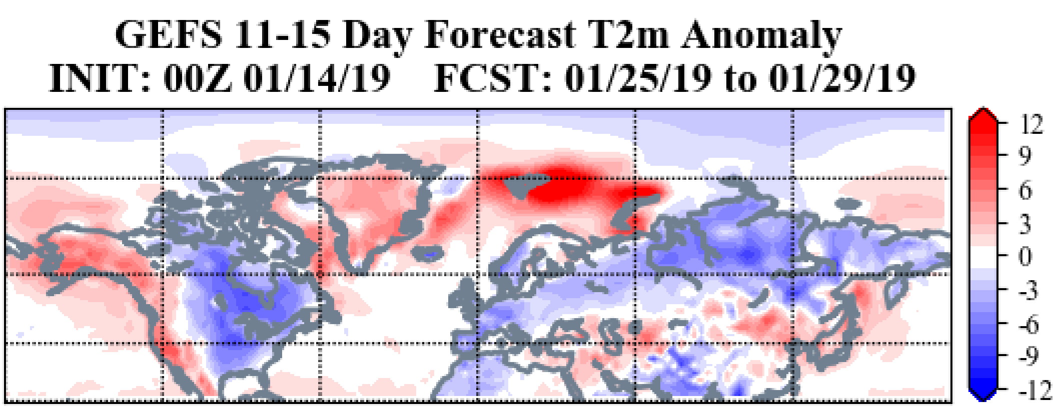


**Figure 8**. Forecasted surface temperature anomalies (°C; shading) from 25 – 29 January 2019. The forecasts are from the 00Z 14 January 2019 GFS ensemble.

Troughing/negative geopotential height anomalies still centered near the Dateline will continue to support ridging/positive geopotential height anomalies downstream over western North America centered over in the Gulf of Alaska with more troughing/negative geopotential height anomalies across eastern North America (**Figure 5b**). This will favor normal to above normal temperatures across Alaska, Western Canada and the Western US with normal to below normal temperatures for the Eastern Canada and the Eastern US (**Figure 8**).

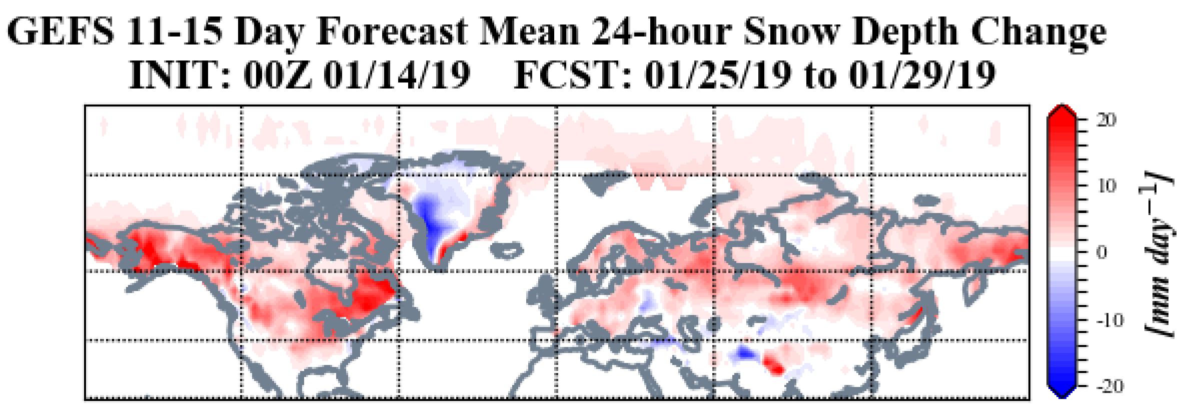


**Figure 9**. Forecasted snowfall anomalies (mm/day; shading) from 25 – 29 January 2019. The forecasts are from the 00Z 14 January 2019 GFS ensemble.

Once again additional snowfall is possible across much of northern Eurasia including Siberia, Western Asia, Scandinavia, Eastern, Central and even possibly Western Europe (**Figure 9**). Seasonable to cold temperatures across Alaska, Canada and even the Northern US will also support potentially new snowfall (**Figure 9**). Mild temperatures could result in snowmelt across Southeastern Europe, Turkey, Central Asia and Greenland (**Figure 9**).

*Longer Term*

*30–day*

The latest plot of the polar cap geopotential heights (PCHs) shows in general predicted normal to above normal PCHs in the stratosphere with normal PCHs in the troposphere (**Figure 10**). The near normal PCHs in the lower troposphere are consistent with a predicted neutral AO this week (**Figure 1**). The above normal PCHs in the stratosphere are also consistent with the negative stratospheric AO for the next two weeks (**Figure 1**). The strongly positive PCHs and negative stratospheric AO are related to a sudden stratospheric warming (SSW) and a major mid-winter warming (MMW; where the zonal mean zonal wind reverses from westerly to easterly at 60°N and 10 hPa). The strongest positive stratospheric PCHs are currently in the mid-stratosphere but are predicted to propagate down to the lower stratosphere next week, consistent with downward propagation expected with these events. So far and in the near term only weak "dripping" of the positive PCHs through the troposphere to the surface are seen in the plot. The first drip took place this weekend and another is predicted for the end of the week. However, as the peak positive PCHs reach the lower stratosphere I would expect that the dripping into the troposphere to intensify.

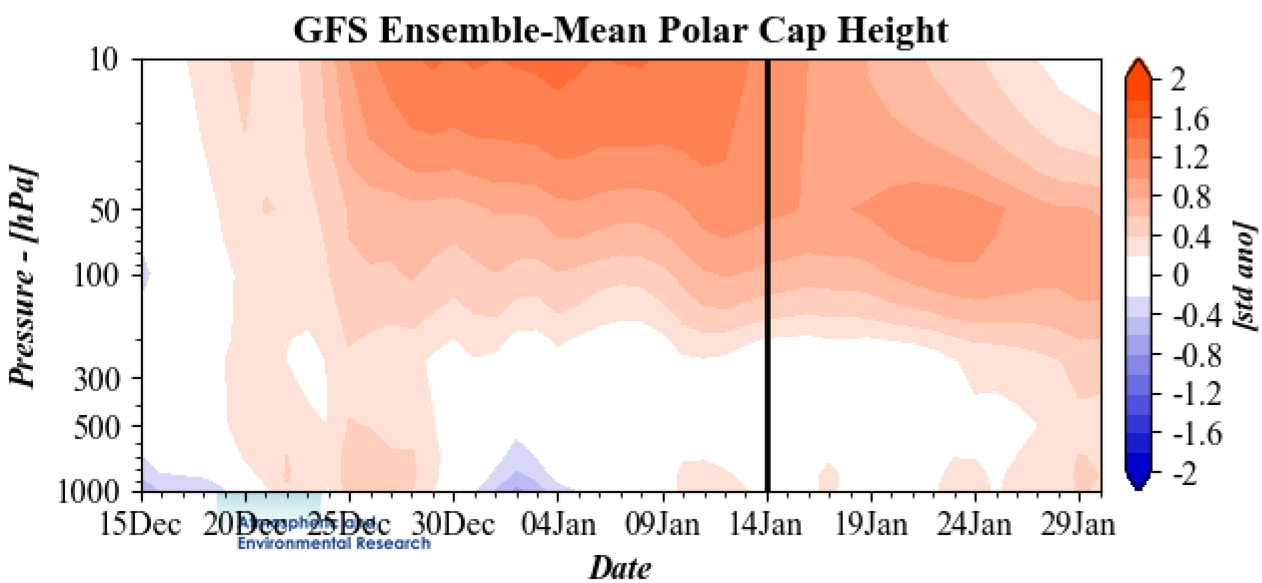


**Figure 10**. Observed and predicted daily polar cap height (i.e, area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 14 January 2019 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport indicates mostly negative WAFz **(Figure 11**). Below normal WAFz is consistent with a reversal in the winds in the stratosphere. The below normal WAFz is also likely related to the downward propagation of warm PCHs through the stratosphere and troposphere.

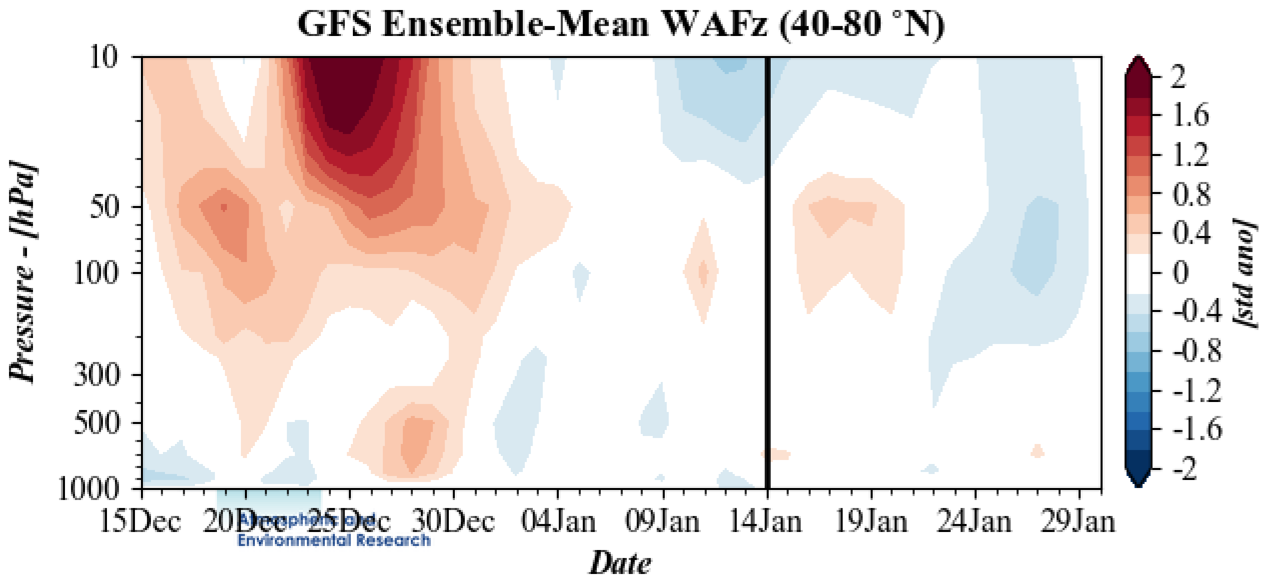


**Figure 11.** Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 14 January 2019 GFS ensemble.

Currently the stratospheric PV remains split into two pieces or daughter vortices. The major daughter vortex is centered near the Urals and a minor daughter vortex is centered over Hudson Bay with ridging centered on Alaska and into the Beaufort Sea and accompanying warming over the North Pole and extending towards Scandinavia (**Figure 12**). The daughter vortex over the Urals is predicted to drift west across Siberia and fill with time while the other daughter vortex over Hudson Bay remains nearly stationary and deepens so that it becomes the major daughter vortex.

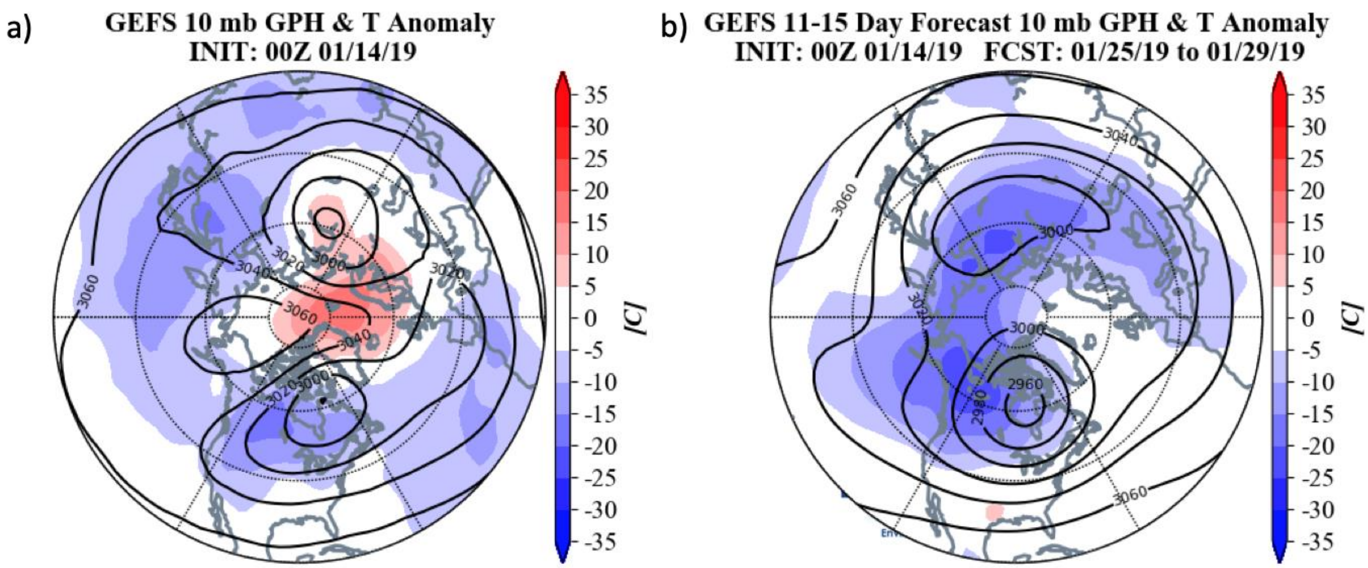


**Figure 12. (a)** Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 14 January 2019. (**b**) Same as (**a**) except forecasted averaged from 25 – 29 January 2019. The forecasts are from the 00Z 14 January 2019 GFS operational model.

This seems to me to be an unusually long duration MMW as well as a PV split. With the prediction of the peak positive PCHs from the mid to lower stratosphere confidence is increasing that the PV disruption will have a significant impact on the NH weather. It also appears that the models are coming into better agreement with their forecasts with all models predicting colder temperatures for eastern North America and Europe. I expect the warm/positive PCHS to “drip” down into the troposphere and intensify heading into late January and February. A sudden stratospheric warming not only leads to a warm Arctic in the stratosphere but also at the surface as well. And a warmer Arctic favors more severe winter weather in the NH midlatitudes including the Eastern US. I do think there still remains uncertainty how much the Arctic warms in the lower troposphere and surface and could play a major role in the duration and magnitude of the weather impacts of the PV split. However, the models are predicting more blocking and warming near Greenland which is consistent with previous significant stratospheric disruptions.

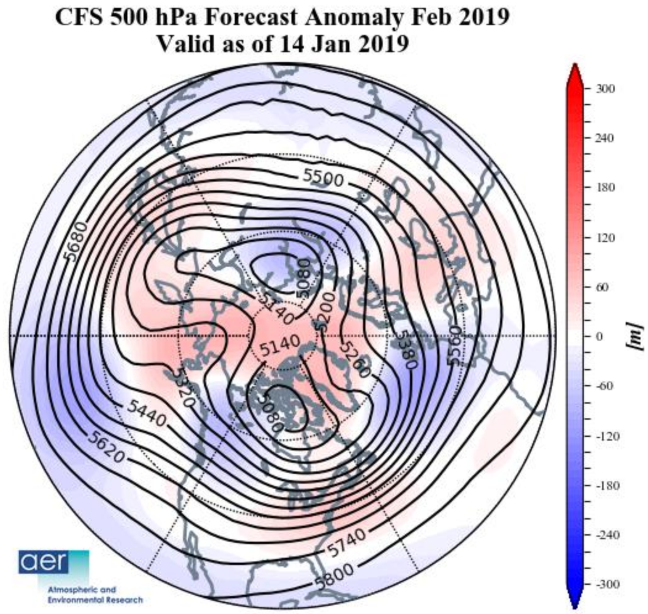


**Figure 13**. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for February 2019. The forecasts are from the 14 January 2019 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 13**) and the surface temperatures (**Figure 14**) forecast for February from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging centered over the Eastern US, Greenland, the Central Arctic, Eastern Europe, the Middle East and the Bering Sea with troughs across Western Canada, Western Europe, Siberia, and near Hawaii (**Figure 13).** This pattern favors cold temperatures for Northern Europe, Northern Asia and Canada with relatively mild temperatures for most of the remainder of Europe, the Middle East, Southeast Asia and much of the US. I am highly skeptical of the latest CFS forecast for February.

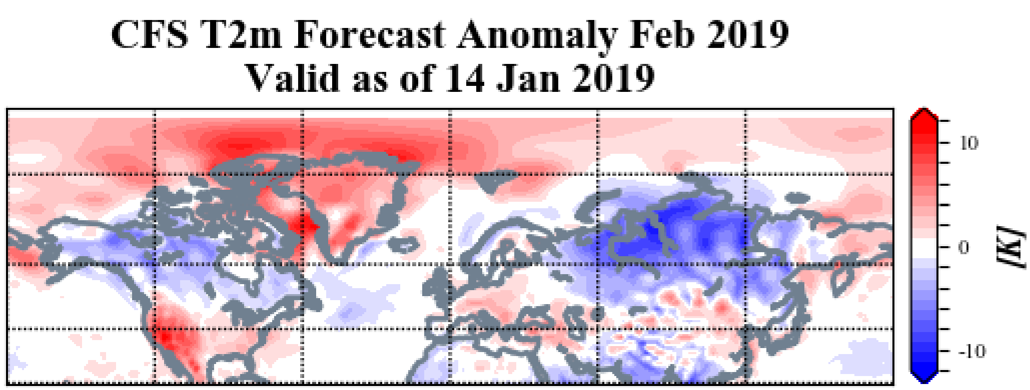

**Figure 14**. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for February 2019. The forecasts are from the 14 January 2019 CFS.

*Surface Boundary Conditions*

*Arctic Sea Ice*

Arctic sea ice growth rate continues at a slow rate and remains well below normal but higher than recent years. However the negative sea ice anomalies are now mostly confined to one region - the Barents-Kara Seas (**Figure 13**). Normal to above normal sea ice in and around Greenland and the Candian Archipelagos may favor a positve 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. However it is looking more and more like the the greatest negative anomalies are going to persist in the Barents-Kara Seas this winter and this may be the region most favored for ridging/blocking during the winter months. I expect that the forecasts of lower heights and colder temperatures near Alaska will continue to help sea ice grow in the Chukchi and Bering seas in the near term.

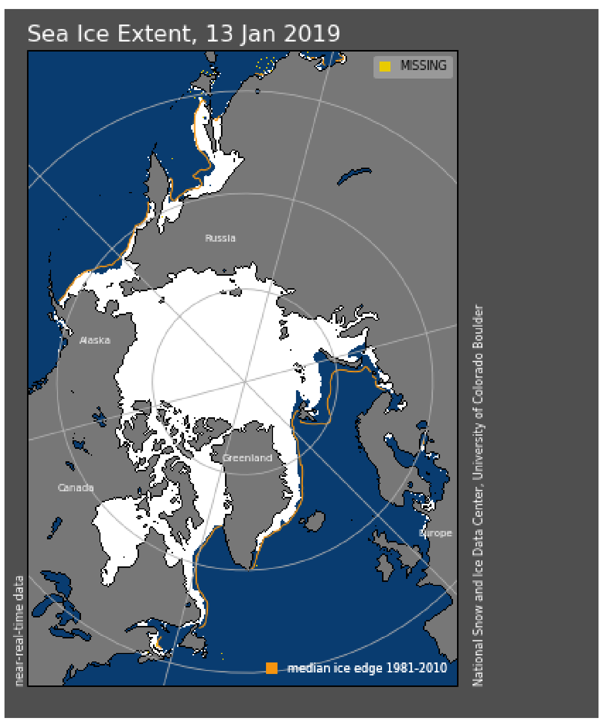

**Figure 15.** Observed Arctic sea ice extent on 13 January 2019 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

*SSTs/El Niño/Southern Oscillation (no update for SST mapdue to government shutdown)*

Equatorial Pacific sea surface temperatures (SSTs) anomalies remain warm and support El Niño conditions (**Figure 13**), and the forecast is for likely weak to possibly moderate El Niño conditions for this winter. The expectations have been for a Central Pacific El Niño however, the warmest SST anomalies are now near the South American coast more similar to a canonical El Niño, though uncertainty continues. Observed SSTs across the NH remain well above normal especially in the North Pacific though below normal SSTs exist regionally. Well above normal SSTs in the northern North Pacific near Alaska are reminiscent of the "blob" winters of 2013/14 and 2014/15 and could support mid-tropospheric ridging in the coming months. However warm SSTs near Alaska are not as positive as they were in the fall. However SSTs have cooled in the North Pacific and could support a stronger North Pacific jet. Cold SSTs south of Iceland and in the subtropcs of the North Atlantic with above normal SSTs in the mid-latitudes are thought to favor a positive winter NAO.

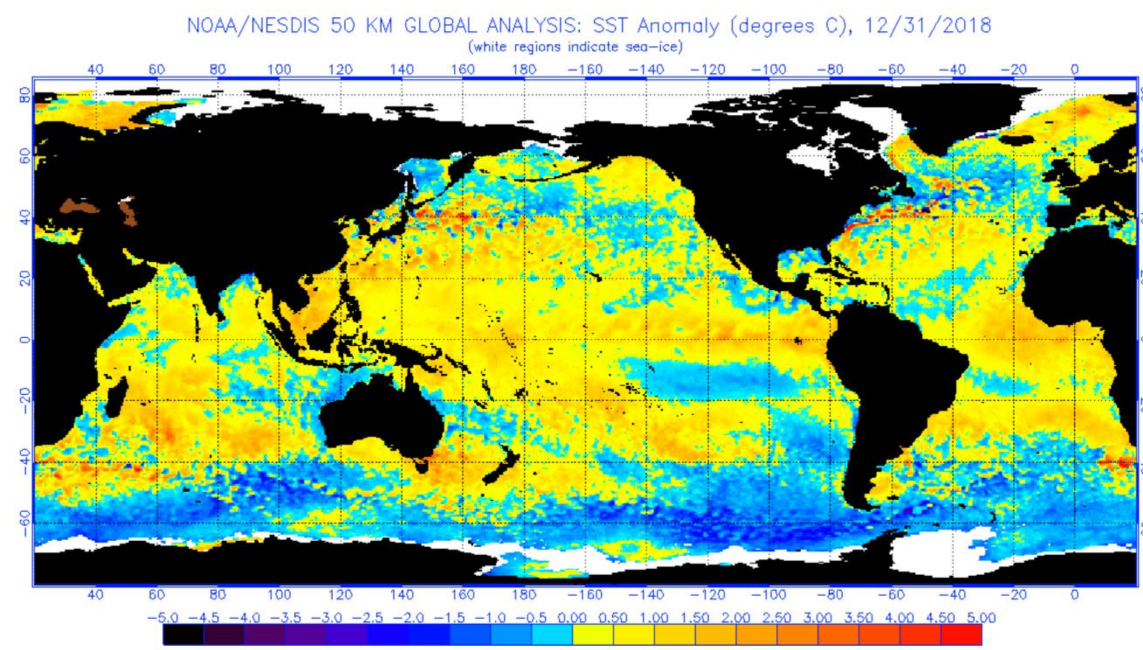


**Figure 16**. The latest weekly-mean global SST anomalies (ending 31 December 2018 ). Data from NOAA OI High-Resolution dataset. *(Updated from https://www.ospo.noaa.gov/Products/ocean/sst/anomaly/anim_full.html due to US Govenrment shutdown)*.

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 14**). However the MJO is expected to phases four, five and six over the next two weeks. MJO phases 4-6 favors ridging over eastern North America with mild temperatures and troughing over western North America with cold temperatures. It is not obvious to me that the MJO is influencing North American weather.

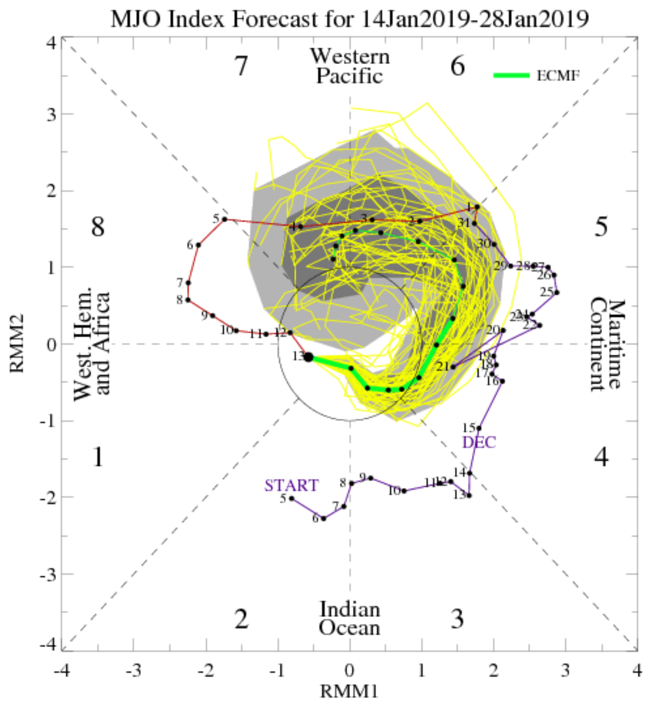


**Figure 17**. Past and forecast values of the MJO index. Forecast values from the 00Z 7 January 2019 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers 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 has stalled across Eurasia and remains near decadal means. Snow cover advance could advance further as cold temperatures start spreading west into Northern and Eastern Europe next week. Above normal snow cover extent this past October, favors a strenghtened 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.

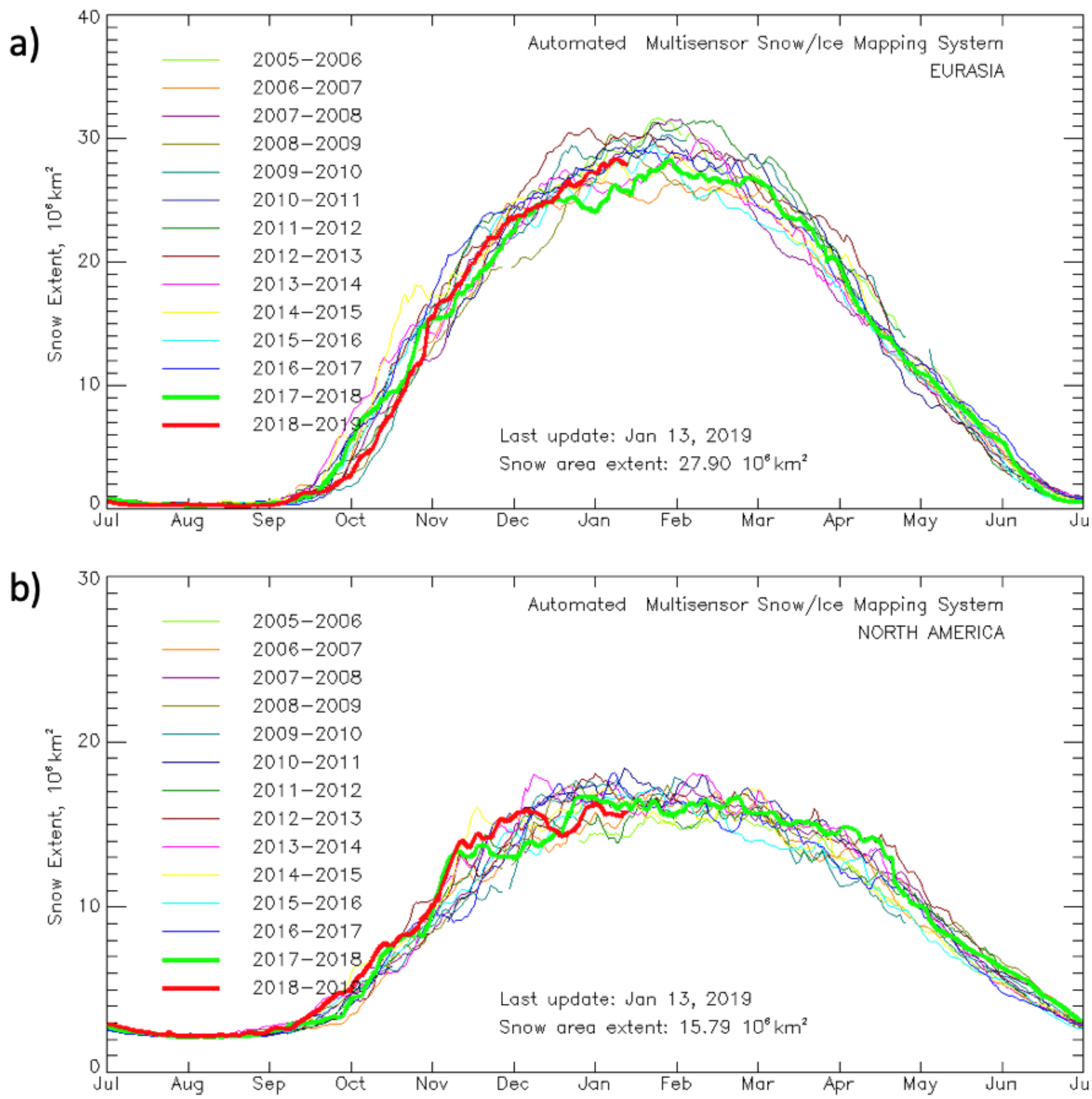


**Figure 18.** Observed Eurasian (top) and North American (bottom) snow cover extent through 6 January 2019. Image source:

https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover has declined once again back to near decadal lows. The early advance of snow cover across Canada this fall, has likely contributed to an early start to winter across the Northern US.