September 23, 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.

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

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

Summary

- The Arctic Oscillation (AO) is currently slightly positive and is predicted to remain positive this week before returning to neutral.
- The current slightly positive AO is reflective of mixed pressure/geopotential height anomalies across the Arctic and mostly positive pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is neutral with mixed pressure/geopotential height anomalies spread across Greenland and Iceland; and the NAO is predicted to turn negative over the next two weeks as geopotential height anomalies are predicted to decidedly turn positive across Greenland over the next two weeks.
- Troughing/negative geopotential height anomalies with seasonable to below normal temperatures currently dominate Eastern Europe with ridging/positive

geopotential height anomalies and above normal temperatures dominating much of Western Europe including the United Kingdom (UK). However, the forecast is for troughing/negative geopotential height anomalies with normal to below normal temperatures to eventually dominate much of Europe in early October.

- This week, ridging/positive geopotential height anomalies with above normal temperatures are predicted to dominate Southern Asia with troughing/negative geopotential height anomalies and below normal temperatures across Northern Asia especially Western Russia. However, the pattern is predicted to transition with ridging/positive geopotential height anomalies and above normal temperatures across much of Asia with troughing/negative geopotential height anomalies with below normal temperatures mostly confined to East Asia.
- The general pattern predicted across North America for the next two weeks is for ridging/positive geopotential height anomalies in the Gulf of Alaska with downstream troughing/negative geopotential height anomalies with normal to below normal temperatures for western North America and ridging/positive geopotential height anomalies with normal to above normal temperatures for eastern North America but especially for the Eastern United States (US).
- In the Impacts section below I go through a lengthy discussion in the defense of Arctic-midlatitude linkages motivated by a recent publication.

Impacts

Trying to anticipate what the upcoming winter has in store across the Northern Hemisphere (NH) the first clue is coming into focus in my opinion – sea ice extent. Most seasonal forecasters rely heavily on the El Niño/Southern Oscillation (ENSO) in producing a winter forecast. However, most models now predict a neutral ENSO for this winter and therefore I believe provides little information on the upcoming winter. There are those that argue that a neutral ENSO favors below normal temperatures in the Eastern US, but I am hesitant to read a signal from a non-signal.

Today is the fall equinox and this is climatologically the time of year when the Arctic sea ice minimum is observed. Hard to tell if the sea ice has reached a minimum for the year yet from the satellite data with sea ice extent both increasing and decreasing over the past month. Right now, there is some discrepancy among sea ice data sets, but the extent is slightly above or below 4 million km^2. This would place it in second place for lowest ever observed Arctic sea ice extent or tied for second with 2007 and 2016.

Regardless Arctic sea extent is well below normal and will likely remain well below normal for the remainder of the fall and winter. If you read the blog regularly then you know that I use sea ice extent anomalies in the AER winter temperature (and precipitation) forecast. In the model, below normal sea ice favors well above normal temperatures in the Arctic obviously but below normal temperatures regionally in Eurasia and North America and above normal sea ice favors below normal temperatures in the Arctic and above normal temperatures in parts of Eurasia and North America. This relationship is not universal and below normal sea ice extent may also favor above normal temperatures in certain regions. For example, recent analysis suggests that below normal sea ice in the Barents-Kara seas favors above normal temperatures along the US East Coast.

Below normal sea ice extent favors colder temperatures regionally in Eurasian and North America. I also believe that below normal sea ice extent favors a disruption of the stratospheric polar vortex (PV). However, this is regionally dependent and negative sea ice anomalies in the Barents-Kara Seas are most favorable for disrupting the PV. As seen in **Figure i**, the sea ice anomalies are greater on the North Pacific side of the Arctic relative to the North Atlantic side of the Arctic. Therefore, the expectation that low sea ice will contribute to a highly disrupted PV followed by an extended period of widespread cold temperatures across the Northern Hemisphere for now is overly simplistic.

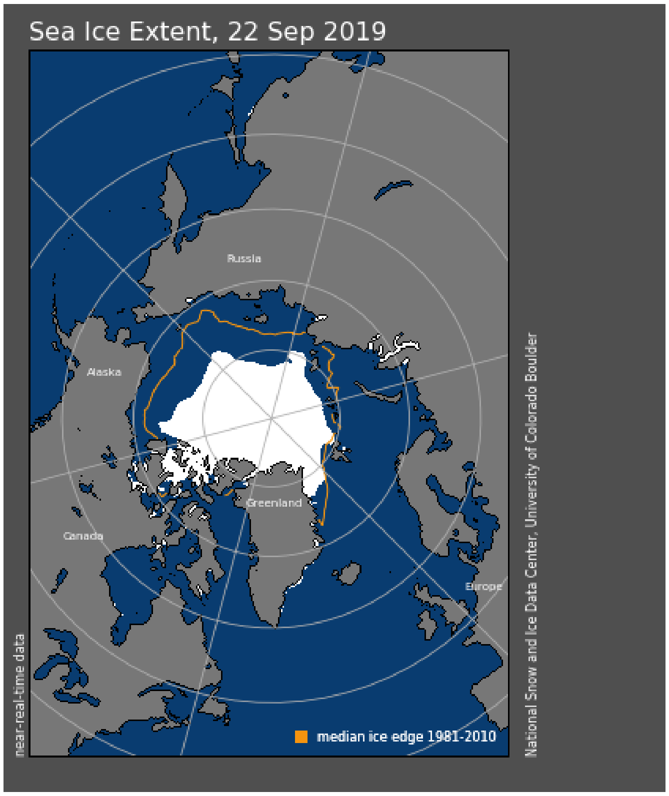

Figure i. Observed Arctic sea ice extent on 22 September 2019 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

By the way, in my opinion there is no better sign that the sea ice melt season is over than the change in the temperature anomalies over the Arctic Ocean. During the summer the anomalies over the central Arctic were near zero or even negative and now they are strongly positive basin wide (see **Figure ii**). This is a sign that excess heat that has entered the Arctic Ocean during the late spring and summer is now returning to the atmosphere. The transfer of heat from the ocean to the atmosphere means that the ocean temperatures are cooling, conducive to sea ice growth. Once the atmosphere cools below freezing, the dramatic increase of temperature anomalies across the entire Arctic basin represents a tremendous transfer of heat from the ocean to the atmosphere. This didn't begin in the era of low sea ice but today the contracted and thinner ice and the greater heat content of the ocean all but guarantee strong positive air temperature anomalies in the fall. This is a good segue to the rest of my unusual and long discussion below.

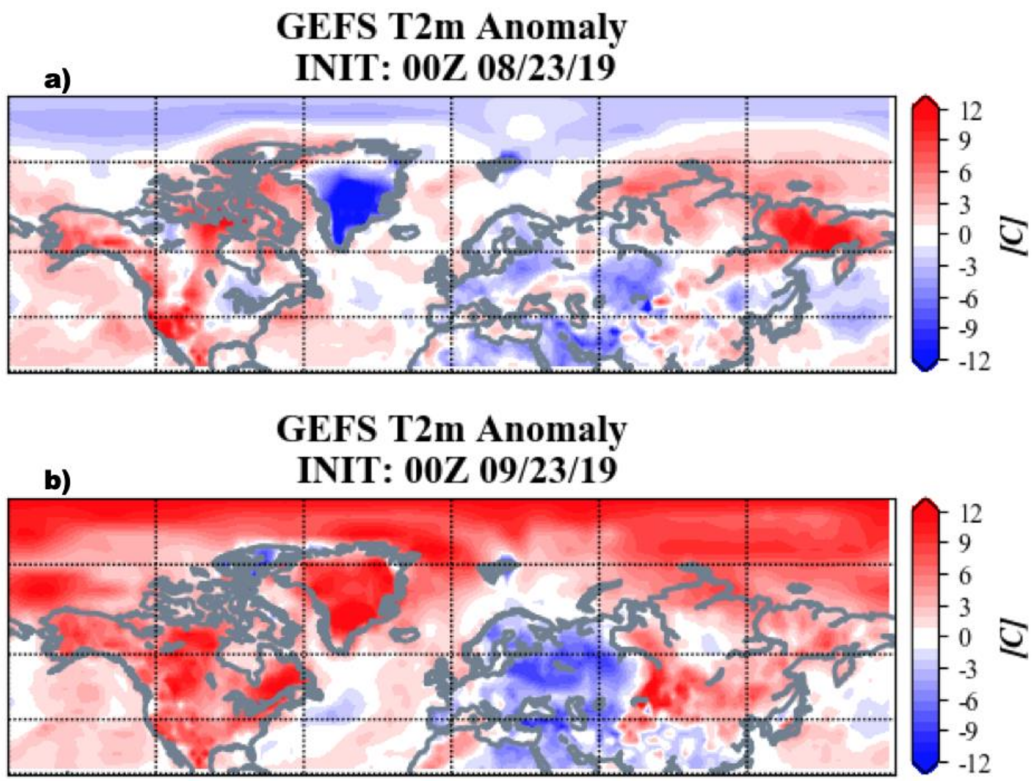

Figure ii. Analyzed surface temperature anomalies (°C; shading) for **a**) August 23, 2019 and **b**) September 23, 2019.

While I was on vacation a paper was published that concluded "that reduced sea ice has a minimal, if any, influence on cold mid-latitude winters (Blackport et al. 2019)." Now I don't believe that it is the best use of my time to refute every science publication that disagrees with my published research or that disagrees with opinion and what I present in the blog and it probably isn't even appropriate and until now something that I have avoided. But I am going to make an exception for this paper for the following reasons. This article was published in a high-profile journal and received some fairly widespread news coverage, especially when you consider that it is a negative result. This paper may very well be the "last word" on the subject in the public discourse as we head into the fall and winter season and will likely be considered and raised when myself and others try to make the argument that severe winter weather is related to sea ice loss/accelerated Arctic warming. But probably most importantly, an opinion piece that accompanied the article concluded that "the evidence presented by Blackport and colleagues brings the case to a close. Midlatitude cooling in winter is not caused by Arctic sea ice loss (Fyfe 2019)." This is admittedly a controversial topic, still being debated and far from settled but that language is uncharacteristically absolute with no wiggle room for uncertainty.

The focus of my career has been making the argument that snow cover and sea ice anomalies can influence the behavior of the PV which then feeds back on the surface weather for an extended period. Obviously, I approach the topic subjectively and one could argue that I have a substantial stake promoting the veracity of this idea. So, the paper and the accompanying opinion piece made me wonder, if I were presented with irrefutable evidence that my ideas are wrong, would I recognize that? Or would my innate bias prevent me from seeing the obvious.

After a long consideration, I concluded that the paper at most has only made an incremental advance on the topic and certainly I would not consider the matter settled and here are some of my reasons. My first rebuttal I believe is the most important. The main argument of the paper is the lack of correlation between sea ice extent and NH continental surface temperatures. I don't think that I can impress upon my audience enough how many reviews of my papers and proposals open with "correlation is not causation." This is not lost on me and something that I think about very deeply throughout my career. That is one of the main reasons for the blog – correlation cannot prove causation but predicting the future successfully should be considered much more compelling. But if correlation cannot prove causation then the inverse is true as well. The lack of causality does not prove the lack or absence of causation. This might seem strange but as an example or proof I present ENSO. Correlation of ENSO with NH surface temperatures shows no significant correlations in the Northeastern US and pretty much all of Eurasia (see **Figure iii** and Figure 5 in Cohen et al. 2018a). Yet there are many scientific papers on the influence of ENSO on Canada US, European, Asia weather and even the NAO. If lack of correlation was definitive in demonstrating no causation these papers shouldn't exist and yet they do. In fact, the most agreed upon boundary forcing is the impact of ENSO on universal weather patterns across the globe.

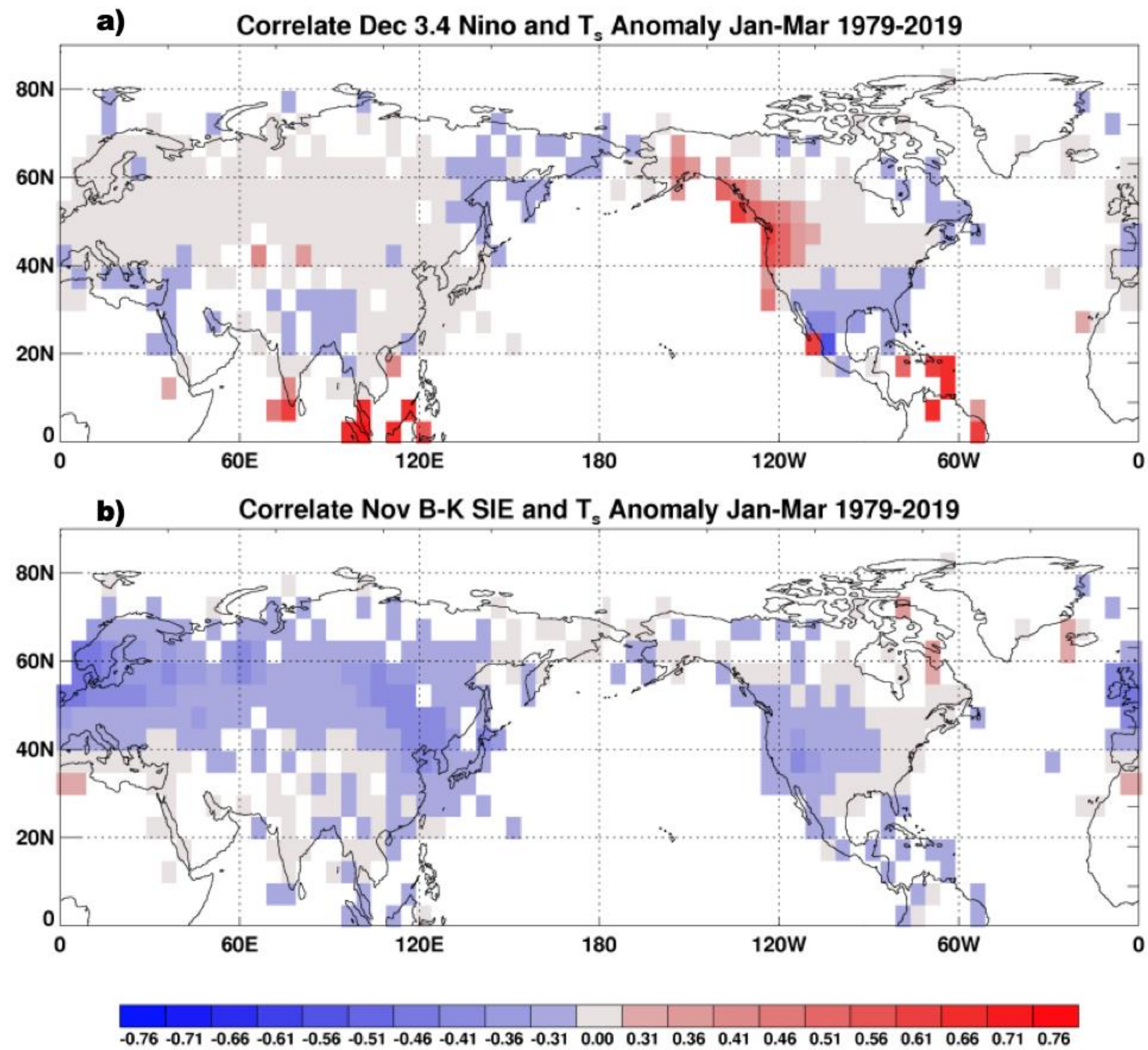

Figure iii. Correlation of **a**) December Niño 3.4 index and **b**) November Barents Kara Sea ice concentration anomaly from 1979-2019. All times series are detrended. Only values that are found to exceed the 95% confidence level of statistical significance are color shaded. Temperature data from the Climate Research Unit http://www.cru.uea.ac.uk/data.

The authors begin the paper by showing that Arctic sea ice is statistically significantly correlated with NH continental surface temperatures but when two adjustments are made the correlations are no longer significant. The first adjustment is to divide sea ice influence by the direction of the turbulent heat flux (THF) anomalies. THF involves the exchange of heat and moisture between the surface of the ocean and the atmosphere above. If the THF anomalies are upward for the entire winter season that is considered the sea ice forcing the atmosphere and if the THF anomalies are downward for the entire winter season that is considered the atmosphere forcing the sea ice (see **Table i**). And when you correlate only for those winter seasons that are deemed to be sea ice forcing the atmosphere then there are no longer large-scale significant correlations indicating cold temperatures across the continents when sea ice is low. The second adjustment is to do lead lag correlations. When the authors perform correlations when sea ice leads the atmosphere, the large-scale significant correlations indicating cold temperatures across the continents when sea ice is low disappear.

		Direction of Anomalous Heat Transfer	
		Down	Up
Sea Ice	High	Sea ice forcing (-5.4)	Atmosphere forcing (+5.2)
	Low	Atmosphere forcing (-5.5)	Sea ice forcing (+3.1)

Tabel i. High and low sea ice combined with vertical direction of turbulent heat transfer or flux that determines whether a winter season is categorized as "sea ice" forcing and "atmosphere" forcing. Included is the magnitude and sign of the turbulent heat flux for the average winter. Based on Figure 1 of Blackport et al. 2019.

I will address the second argument first since that is more straightforward. I with colleagues as well as others have performed lead lag correlations between sea ice and NH continental surface temperatures that showed significant continental cooling for low sea ice when sea ice leads (e.g., Furtado et al. 2015). In **Figure iiib,** I show an unpublished result of November Barents-Kara Sea ice extent anomaly with January through March over the reanalysis period. All timeseries are detrended and only correlations that are statistically significant at 95% confidence or higher are color shaded. Here is a plot where sea ice leads the atmosphere and low sea ice is related to an impressive extent of cold continental temperatures so much so that I am almost embarrassed to show the plot. I have no good answer how to explain the discrepancy, my plot is a seasonal mean and the Blackport et al plots are monthly and daily means. Given the high autocorrelation of sea ice anomalies I wouldn't expect much variability certainly on daily but even monthly timescales within a season, especially in the era of well below normal sea ice of the past decade and a half. I never analyzed daily sea ice but I did correlate Arctic temperatures, which does vary on much shorter time scales, with continental temperatures and the correlations peak when Arctic temperatures lead continental temperatures by five days (see Figure 5 from Cohen et al. 2018b).

The first argument of the paper is more complicated to rebut. First, I think it is important to say that the uncertainty with the surface energy balance in the Arctic is large and that arguments made with the surface energy balance need to be tempered with the acknowledgment of the likelihood of large errors. My very first per reviewed publication was on the difference of the surface energy balance of the land surface when it is snow covered and snow free (Cohen and Rind 1991). We found that the THF increased in the absence of snow cover relative to the presence of snow cover. There were two possible factors that could cause this difference, the vertical temperature gradient and the speed of the horizontal wind. We found no significant differences in the horizontal wind speed, so we attributed the difference to a stronger temperature difference between the surface and the atmospheric layers in the up direction, where the temperature decreases more quickly with height in the absence of snow cover during the day.

If this is true with snow cover, the finding should be even stronger with sea ice, where the removal of sea ice uncovers a continuous heat source from below not comparable with the removal of snow cover. With all things being equal, to first order the disappearance of sea ice will destabilize the boundary layer, increase the vertical temperature gradient and increase the THF, full stop. In the US we see a very dramatic example of this every winter. When a cold air mass flows over the unfrozen Great Lake(s) this can result in violent snowfalls with feet of snow accumulating in a matter of hours. If that same air mass flows over a completely frozen Great Lake(s) then nothing, it's a sunny day and no snow falls. What about when a warm, moist air mass flows over a frozen/unfrozen surface? This difference I think is more common among all of our experiences. If the ground is not snow/ice covered a good chance nothing happens. If there is snow/ice present, then often fog forms. Fog is an indication that the air mass has been cooled to the condensation point. Greater cooling of the air mass means more heat is being drawn from the overlying air and being transferred to the surface or an increase in the downward THF (in other words the absence of ice increases the upward THF). Therefore, under both warm and cold temperature advection the ice forcing is the same. During cold (warm) advection the absence of ice results in greater upward (less downward) THF and the presence of ice results in less upward (greater downward) THF or in other words the absence (presence) of ice always results in greater (less) upward THF.

In my opinion sea ice forcing is binary – less ice increases the upward THF and more ice decreases the upward THF, these hairs cannot be split any finer or more layers of this onion cannot be peeled. Sea ice forcing can only be divided into less and more sea ice and the temperature advection over the present or absent sea ice needs to be considered independent of the sea ice forcing. No matter what the atmosphere is doing the sea ice is doing the same thing.

And in a community wide white paper on the subject, we reported that the THF over the Arctic is in an increasing trend as well as the overall energy balance in fall and/or winter especially over the Barents-Kara Seas and Chukchi regions (see Figure 3 from Cohen et al 2018c). However, in the white paper we did not find that the THF was the biggest contributor to Arctic warming but instead it was downwelling infrared radiation. Based on that 1) that the most direct impact of sea ice disappearance is to increase the THF and 2) THF is not the only and likely not even the dominant contributor to warming the Arctic atmosphere. Therefore in my opinion, to differentiate the forcing of sea ice on the atmosphere from the atmosphere forcing the sea ice solely based on the seasonal THF anomaly seems arbitrary and questionable at best.

The main analysis in the paper is based on seasonal means of the anomalous THF and the authors also included analysis with monthly means but there is large variability in these values and they change not only month to month but week to week, day to day hour but hour and even minute by minute. So how representative of the impact of the presence or absence of sea ice is the seasonal mean? Others and I have argued that the pathway of sea ice from the Arctic to continents is through the PV. Following a PV disruption, the temperature response to the PV disruption can last weeks, even months and therefore can leave a signature on seasonal means. A just published paper, Lee et al. 2019, argues that a synoptic event can result in a significant PV disruption and a PV split that is characterized by low pressure near Greenland and high pressure near Scandinavia. If the absence of sea ice in the Barents-Kara Sea regions amplifies the Scandinavian high pressure, half of the low-high couplet, enough to push a PV disruption from a minor to a major event, then the influence of sea ice on the time scale of days can be of sufficient duration to modulate seasonal temperature means. In this scenario, the true impact of sea ice anomalies is likely lost in a seasonal mean.

Now there can be second order impacts of the removal of sea ice that can change the horizontal wind speed and vertical temperature gradient, which would then can impact the THF. The proposed atmospheric response to sea retreat is high pressure and a warm atmospheric column. Inside of high pressure is sinking air and weak horizontal winds. These atmospheric conditions are conducive to suppressing upward heat transfer and possibly even cause downward heat transfer. The proposed atmospheric response to sea expansion is low pressure and a cold atmospheric column. Inside of low pressure, air is rising and horizontal winds are relatively strong. These atmospheric conditions are conducive to increasing upward heat transfer. If low (high) fall sea ice extent forces high (low) pressure that suppresses (increases) heat transfer, then the atmosphere which that then triggers a major PV disruption that only reinforces high pressure over the Arctic for up to two months during the winter this matches the anomalous heat transfer that is attributed to atmospheric forcing only. In contrast the outliers are attributed to sea ice forcing (low sea and anomalous upward heat transfer, high sea ice and anomalous downward heat transfer). It is therefore not surprising that in the paper the atmospheric forcing winters are consistent with previous analysis to sea ice forcing and the sea ice forcing winters looks different because it is only the deviations that are included in the composites. Now the authors acknowledge this possibility, but their only response is the lead-lag correlations, which as discussed above does not match my analysis and other previously published analysis.

Just as an aside in my **Table i** included the anomalous turbulent heat transfer/flux from the paper and I found the sum for both atmosphere and sea ice forcing a curious thing.

The total of the atmospheric forcing the downward flux is relatively small and close to zero the total sea ice forcing is greater by an order of magnitude yet the surface warming for when the atmosphere is forcing is much greater than when sea ice is forcing. It seems to me the temperature response is not consistent with the energy balance. Of course, one easy answer is that the THF is not the only energy term but that gets to my earlier point that defining sea ice forcing by THF only, is a non-trivial assumption.

With all that said, I am glad that this paper was published it made me reflective about Arctic-mid latitude linkages more so than any other recent paper where I was not an author. In addition, the title and the accompanying opinion piece made bold conclusions, which I do admire even if I respectfully disagree. Hopefully the post contributes to a beneficial discussion of the topic.

Near Term Conditions

1-5 day

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

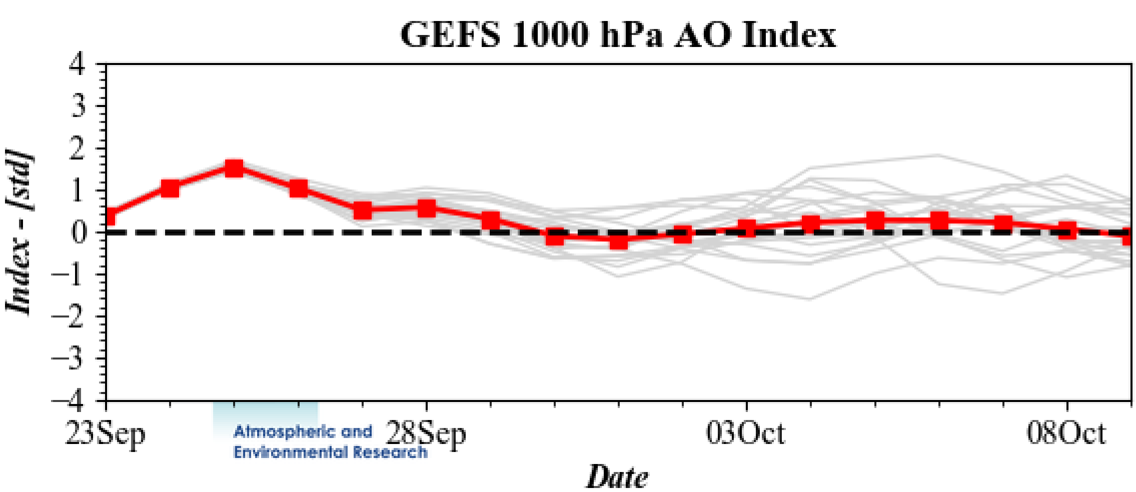

Figure 1. The predicted daily-mean AO at 10 hPa from the 00Z 23 September 2019 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Currently troughing/negative geopotential height anomalies over Eastern Europe will slide east this week allowing ridging/positive geopotential height anomalies in Western

Europe to dominate much of the continent (**Figure 2**) resulting in normal to above temperatures across much of Europe including the UK with the exception of normal to below normal temperatures across Scandinavia and far Eastern Europe under northerly flow (**Figure 3**). This week troughing/negative geopotential height anomalies are predicted to dominate Northern Asia with ridging/positive geopotential height anomalies across Southern Asia (**Figure 2**). This is predicted to yield normal to above normal temperatures for much of Southern Asia including the Middle East with normal to below normal temperatures for Northern Asia but especially Western Russia **(Figure 3**).

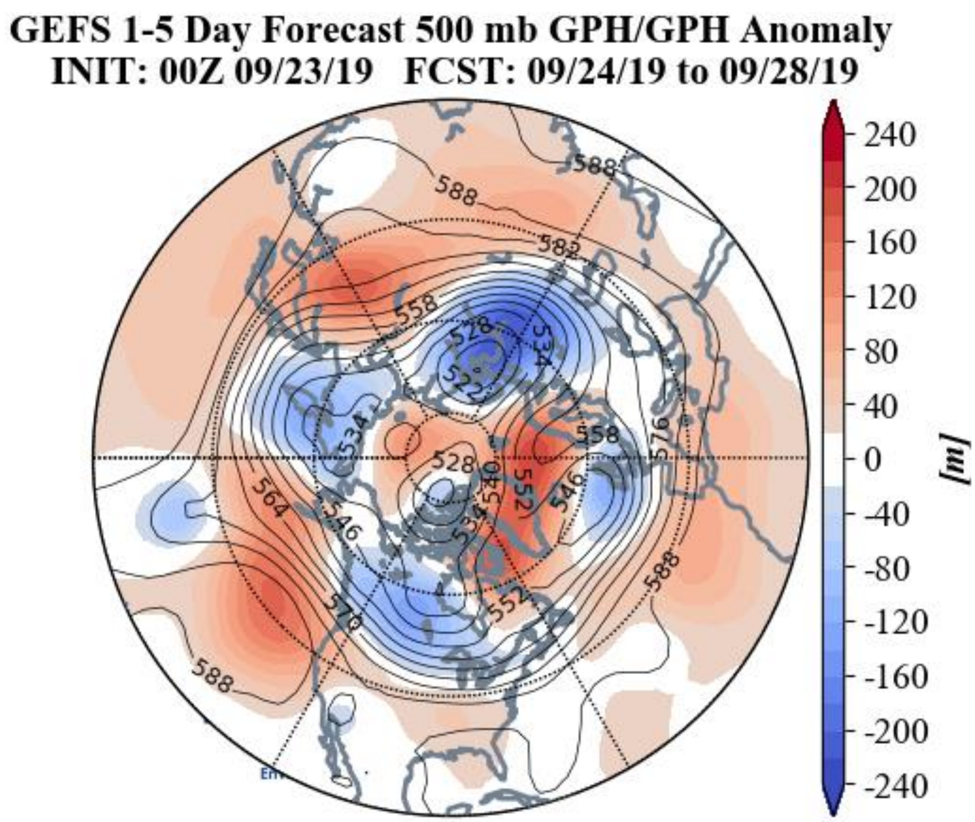

Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 24 – 28 September 2019. The forecasts are from the 23 September 00z GFS ensemble.

This week ridging/positive geopotential height anomalies stretching from Alaska south into the Gulf of Alaska are predicted to force downstream troughing/negative geopotential height anomalies with more ridging/positive geopotential height anomalies for the Eastern US (**Figure 2**). This pattern is predicted to deliver normal to above normal temperatures in Alaska, Eastern Canada and the Eastern US with normal to below normal temperatures mostly confined to Western Canada that will bleed into the US Pacific Northwest **(Figure 3).**

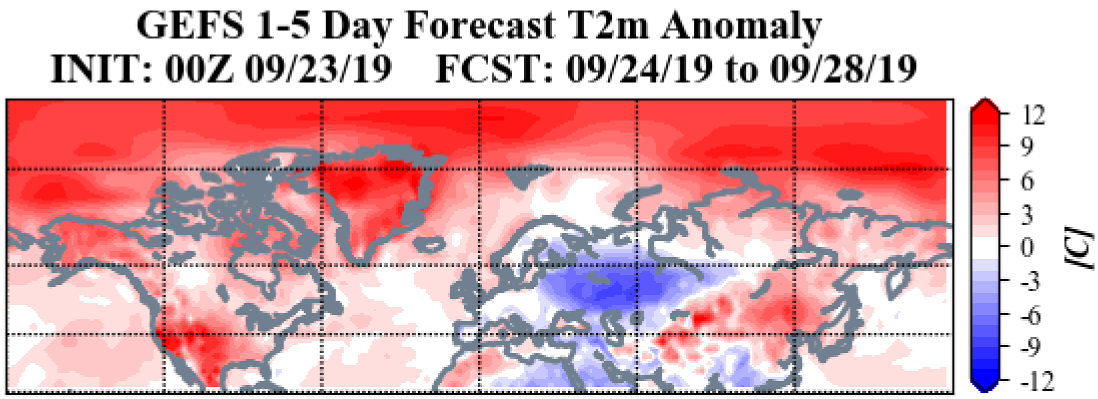

Figure 3. Forecasted surface temperature anomalies (°C; shading) from 24 – 28 September 2019. The forecast is from the 00Z 23 September 2019 GFS ensemble.

Much of Europe, Asia and North America are predicted to receive near normal precipitation (**Figure 4**). Ridging is predicted to bring below normal precipitation to Northern Europe and East Asia (**Figure 4**).

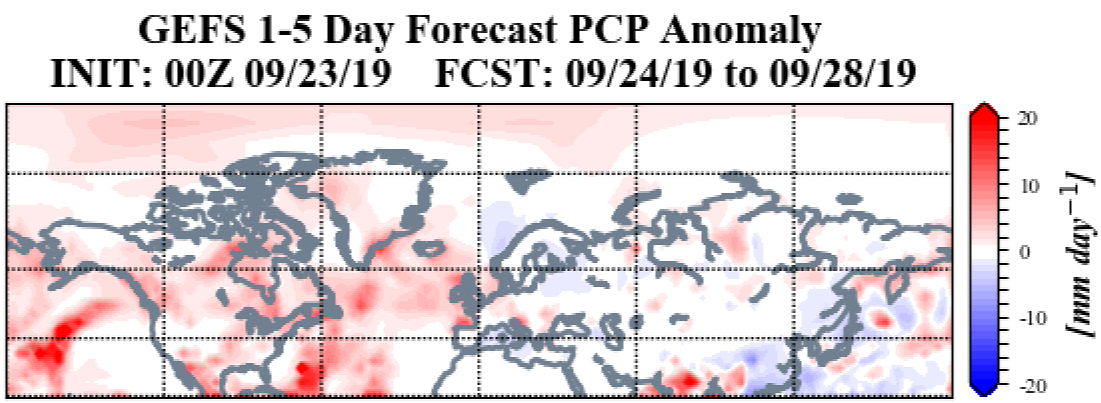

Figure 4. Forecasted precipitation anomalies (mm/day; shading) from 24 – 28 September 2019. The forecast is from the 00Z 23 September 2019 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain near neutral this period **(Figure 1**) with weak positive geopotential height anomalies across the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with positive geopotential height anomalies across Greenland (**Figure 5**), the NAO will likely turn negative.

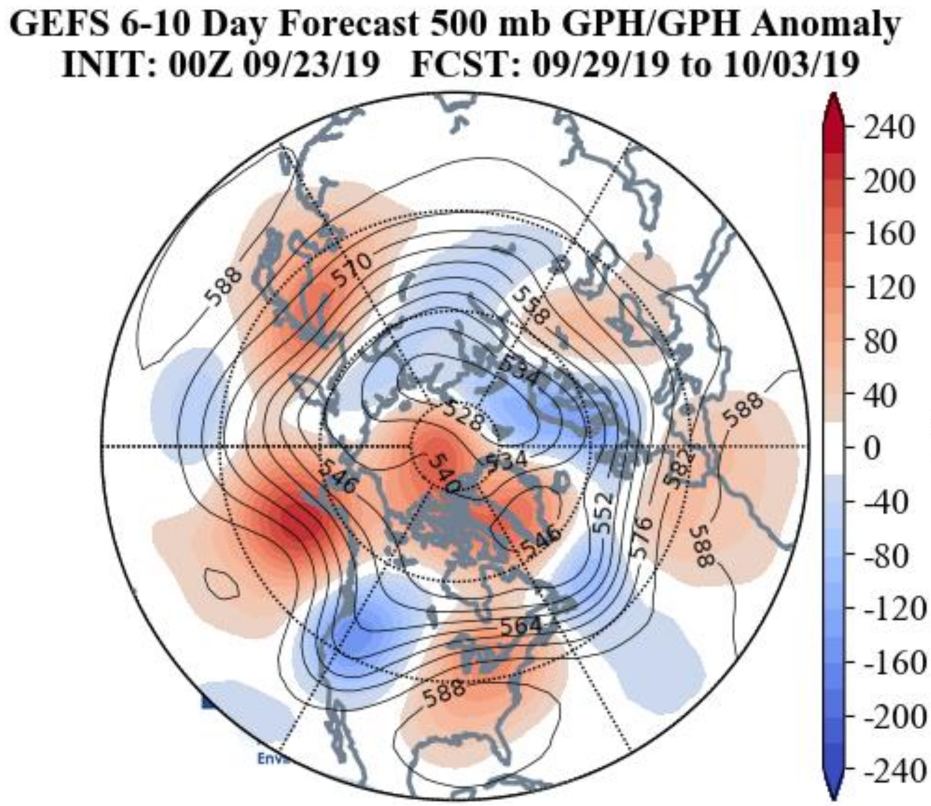

Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 29 September – 3 October 2019. The forecasts are from the 23 September 00z GFS ensemble.

Troughing/negative geopotential height anomalies from the previous period centered west of the UK are predicted to sweep across Northern Europe with mostly ridging/positive geopotential height anomalies across Southern Europe (**Figure 5**). This pattern favors normal to above normal temperatures across much of Europe including the UK with normal to below normal temperatures confined to Scandinavia (**Figure 6**). The pattern from the previous period is predicted to persist this period across Asia with troughing/negative geopotential height anomalies across Northern Asia that now extends south into Central Asia with ridging/positive geopotential height anomalies in Southern Asia (**Figure 5**). This is predicted to yield widespread normal to above normal temperatures for much of East Asia and Southwestern Asia including the Middle East with normal to below normal temperatures for much of Siberia and Central Asia including Northern India **(Figure 6**).

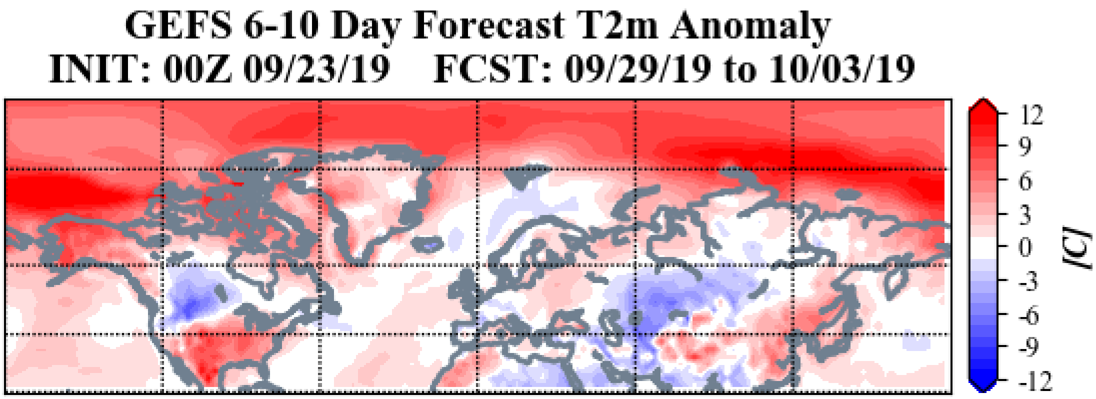

Figure 6. Forecasted surface temperature anomalies (°C; shading) from 29 September – 3 October 2019. The forecasts are from the 00Z 23 September 2019 GFS ensemble.

Troughing/negative geopotential height anomalies are predicted to persist in western North America with downstream ridging/positive geopotential height anomalies in Eastern Canada and in the Eastern US (**Figure 5**). This pattern is predicted to bring normal to above normal temperatures across Alaska and the Eastern US with normal to below normal temperatures in the Western US and Western Canada that begins to bleed into Eastern Canada **(Figure 6).**

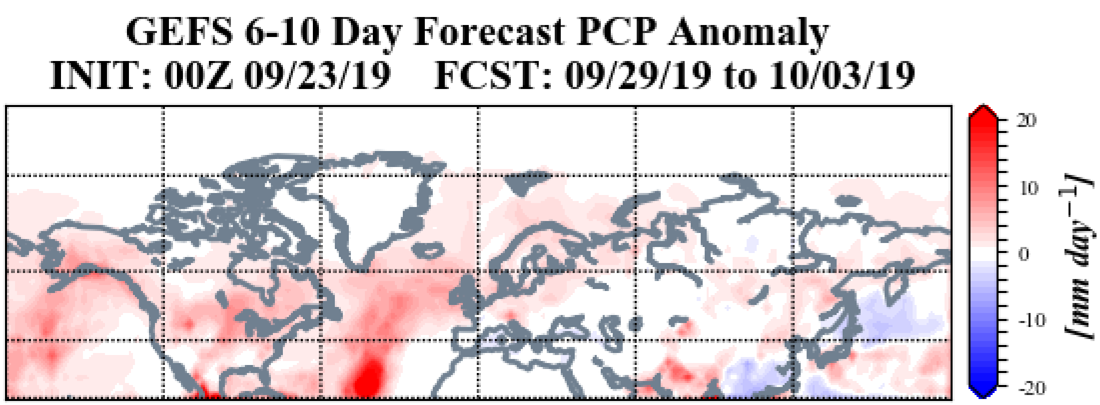

Figure 7. Forecasted precipitation anomalies (mm/day; shading) from 29 September – 3 October 2019. The forecasts are from the 00Z 23 September 2019 GFS ensemble.

Much of Eurasia is predicted to receive near normal precipitation with above normal precipitation across Northern Europe and India (**Figure 7**). Troughing is predicted to bring above normal rainfall to the monsoon region of Mexico and along the US-Canadian border (**Figure 7**).

11-15 day

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

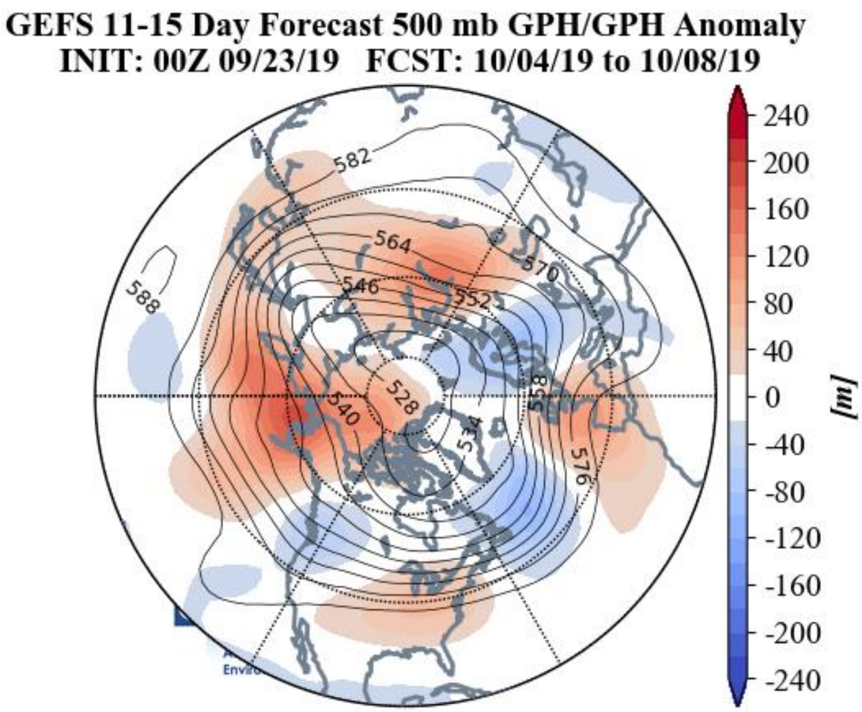

Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 4 – 8 October 2019. The forecasts are from the 23 September 00z GFS ensemble.

Ridging/positive are predicted to persist this period across Western Europe with more troughing/negative geopotential height anomalies across Eastern Europe (**Figure 8**). This pattern is predicted to result in seasonable to above normal temperatures for Western Europe including the UK but especially Spain with normal to below normal temperatures for Central and Eastern Europe (**Figure 9**). The predicted pattern across Asia this period is predicted to flip with ridging/positive geopotential height anomalies punching into Western and Eastern Siberia with troughing/negative geopotential height anomalies in Southwestern Asia and Northeast Asia (**Figure 8**). This pattern favors normal to below normal temperatures for Central Siberia, Northeast Asia and parts of Southern Asia with normal to above normal temperatures for the remainder of Asia including the Middle East and Southeast Asia (**Figure 9**).

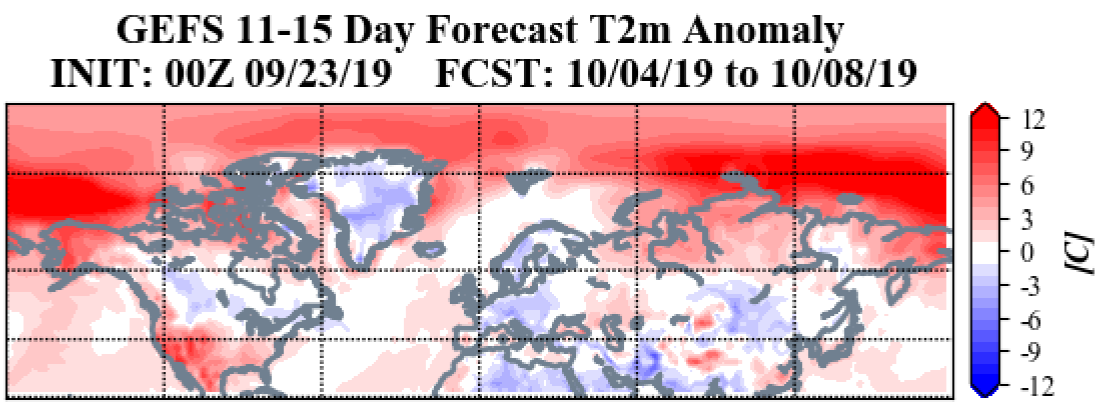

Figure 9. Forecasted surface temperature anomalies (°C; shading) from 4 – 8 October 2019. The forecasts are from the 00Z 23 September 2019 GFS ensemble.

The overall pattern across North America is predicted to persist with ridging/positive geopotential height anomalies stretching from Alaska into the Gulf of Alaska, troughing/negative geopotential height anomalies in western North America and downstream ridging/positive geopotential height anomalies in the Eastern US (**Figure 8**). This will favor normal to above normal temperatures across Alaska and the Southern and Eastern US with normal to below normal temperatures widespread across Canada and the Northwestern US (**Figure 9**).

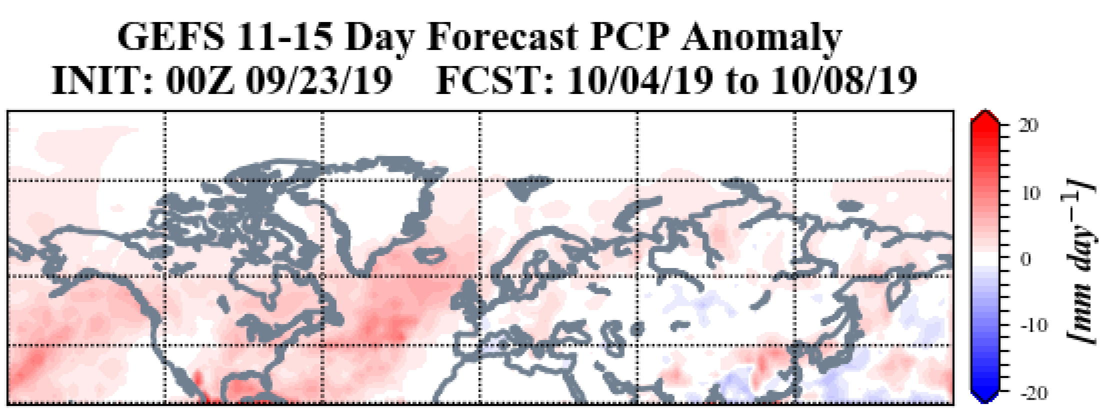

Figure 10. Forecasted precipitation anomalies (mm/day; shading) from 4 – 8 October 2019. The forecasts are from the 00Z 23 September 2019 GFS ensemble.

Much of Eurasia and North America are predicted to receive near normal precipitation with the potential of above normal precipitation across northern Eurasia and eastern North America (**Figure 10**).

Longer Term

30–day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to below normal PCHs in the stratosphere and normal to above normal PCHs in the upper troposphere (**Figure 11**). In the low to mid troposphere PCHs are below normal, consistent with the positive AO (**Figure 1**).

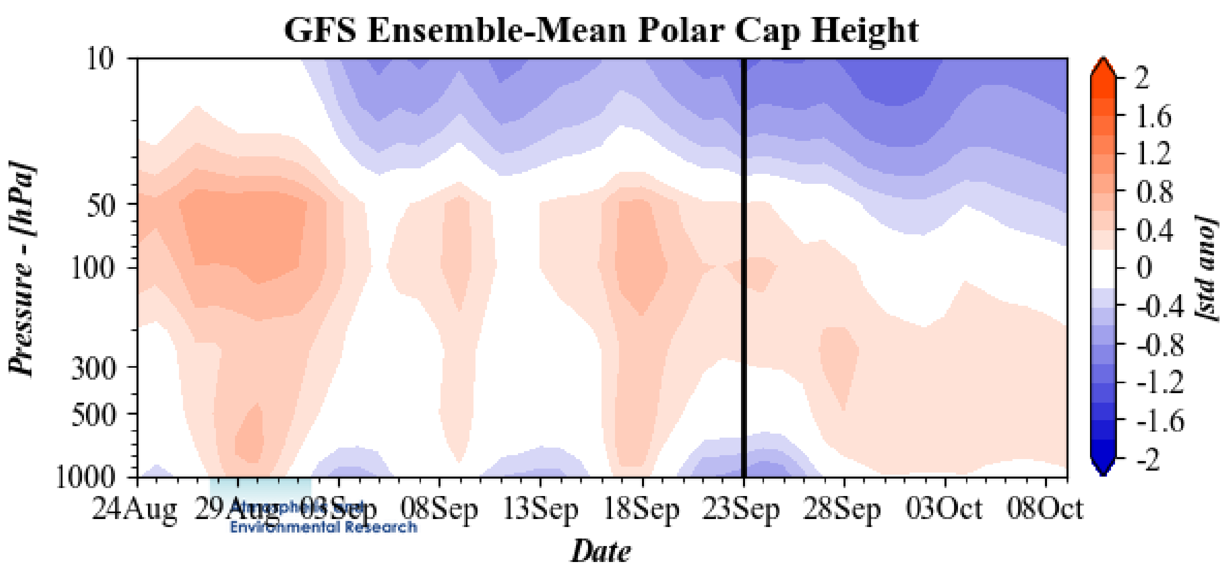

Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 23 September 2019 GFS ensemble.

Positive PCHs in the upper troposphere are predicted to descend into the lower troposphere end of this week (**Figure 11**). This should cause the AO to trend negative to near neutral through the second week of October. However, if the warm PCHs that descend into the lower troposphere are stronger than predicted the AO could turn negative.

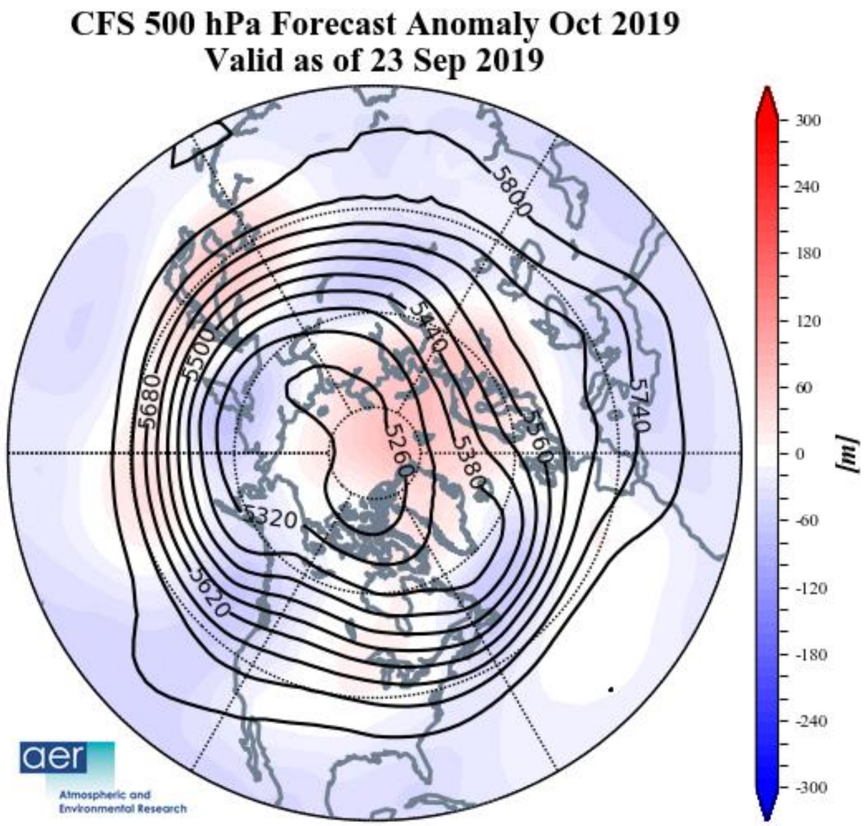

Figure 12. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for October 2019. The forecasts are from the 23 September 2019 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 12**) and the surface temperatures (**Figure 13**) forecast for October from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging centered across Northern Europe and the Barents-Kara Seas, East Asia and central North America with troughs in Southern Europe, Central Asia, Eastern Siberia, the Gulf of Alaska and the Canadian Maritimes (**Figure 12).** This pattern favors relatively warm temperatures for Northern Europe, East Asia, Western Canada and the Western US with seasonable to relatively cool temperatures for Southern Europe, Central Asia, Southeast Canada and the Northeastern US (**Figure 13**).

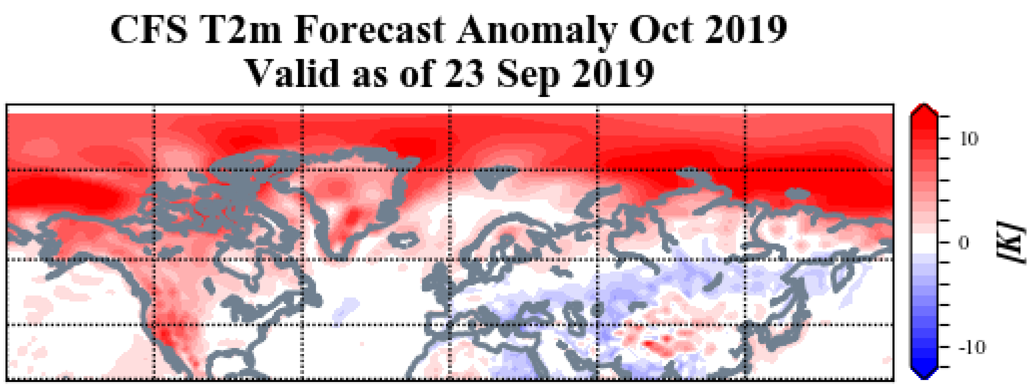

Figure 13. Forecasted average surface temperature anomalies (°C; shading) across the Northern Hemisphere for October 2019. The forecasts are from the 23 September 2019 CFS.

Surface Boundary Conditions

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies have cooled and whether El Niño conditions will continue has become questionable especially now that that SSTs in the eastern equatorial Pacific are cool to normal (**Figure 14**). 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.

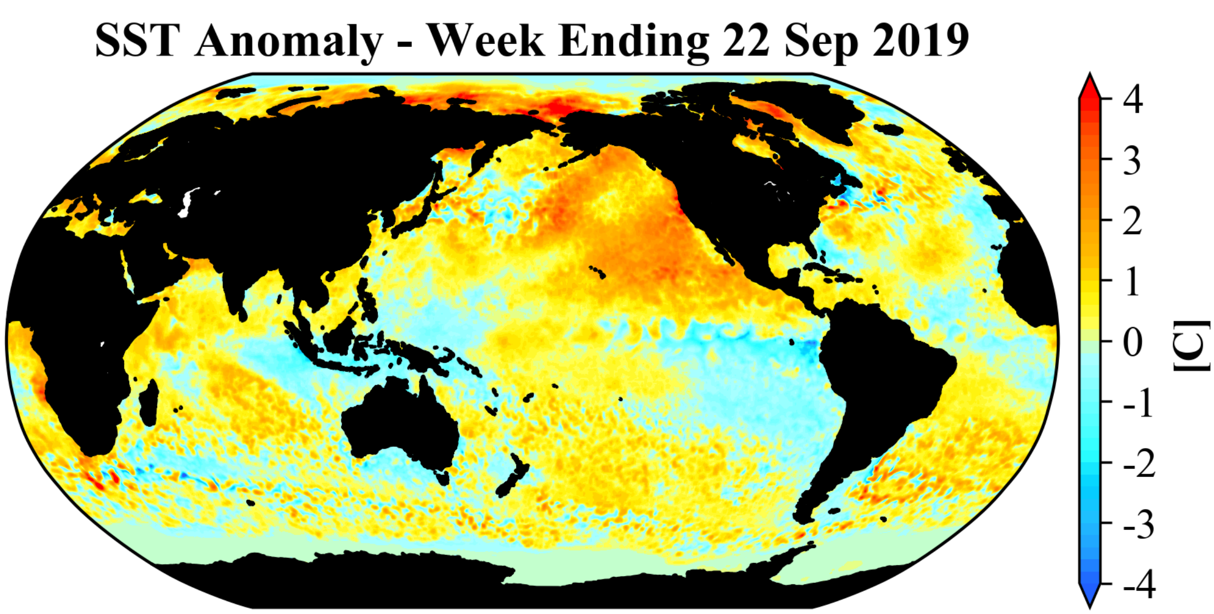

Figure 14. The latest weekly-mean global SST anomalies (ending 22 September 2019). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase one (**Figure 13**). The forecasts are for the MJO to remain in phase one for the next two weeks. Phase one favors ridging in the Eastern US and toughing in western North America, consistent with the forecast and supportive of a strong MJO influence on the weather across North America.

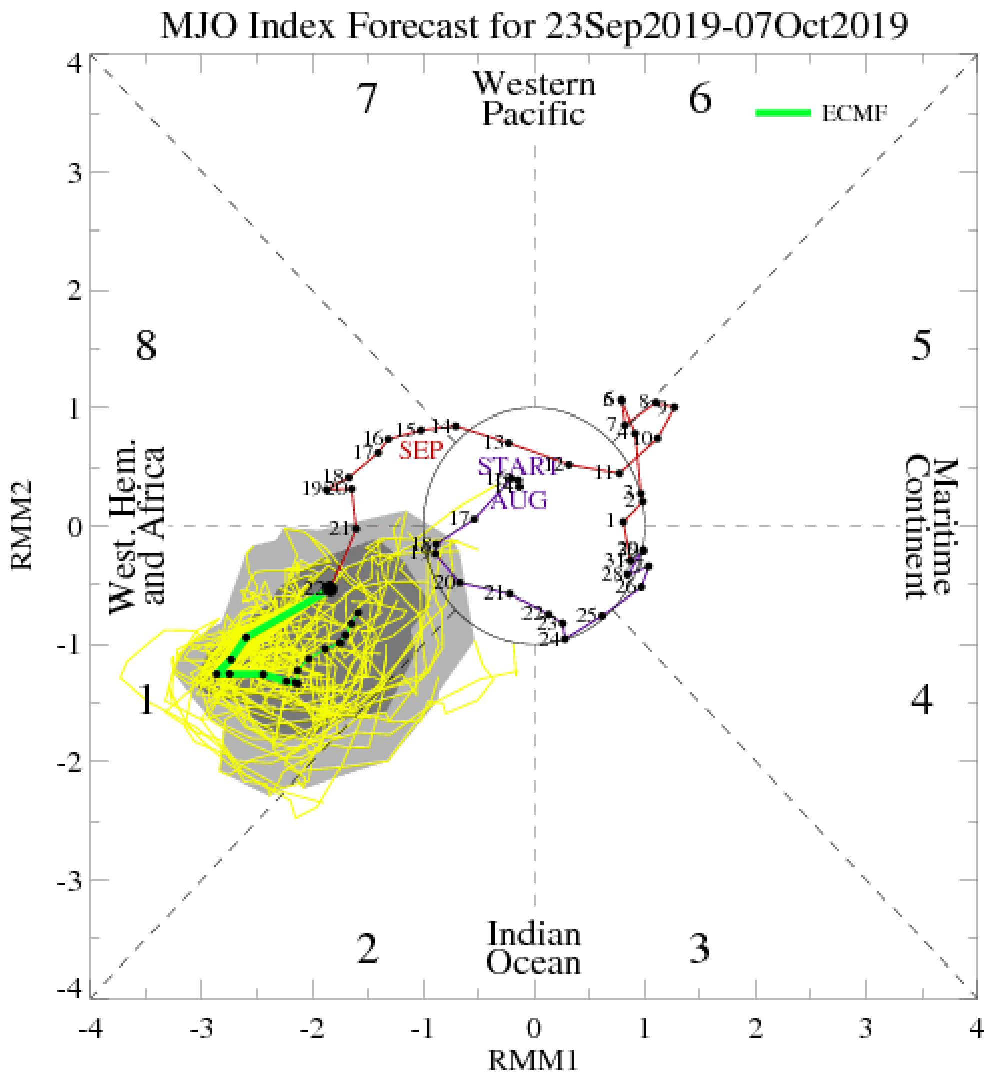

Figure 13. Past and forecast values of the MJO index. Forecast values from the 00Z 9 September 2019 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model "spread" is denoted by the gray shading. Sector numbers indicate 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