

February 11, 2019

*Special blog on winter 2016/2017 retrospective can be found here*  
- <http://www.aer.com/winter2017>

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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 positive and is predicted to first remain positive and then trend negative back to neutral over the next two weeks.
- The current positive AO is reflective of mostly negative pressure/geopotential height anomalies across the Arctic and mostly positive pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is currently neutral with weak pressure/geopotential height anomalies across Greenland and mixed pressure/geopotential height anomalies across the mid-latitudes of the North Atlantic and is predicted to slowly trend negative as height anomalies turn mostly positive across Greenland over the next two weeks.
- Ridging/positive geopotential height anomalies with normal to above normal temperatures are predicted to dominate much of Europe including the United Kingdom (UK) over the next two weeks.
- Currently ridging/positive geopotential height anomalies with normal to above normal temperatures dominate much of Asia except for troughing/negative geopotential height anomalies and relatively cold temperatures in Eastern Siberia and into Northeast Asia. However, predicted ridging/positive geopotential height anomalies in Europe and building across Greenland starting next week in tandem

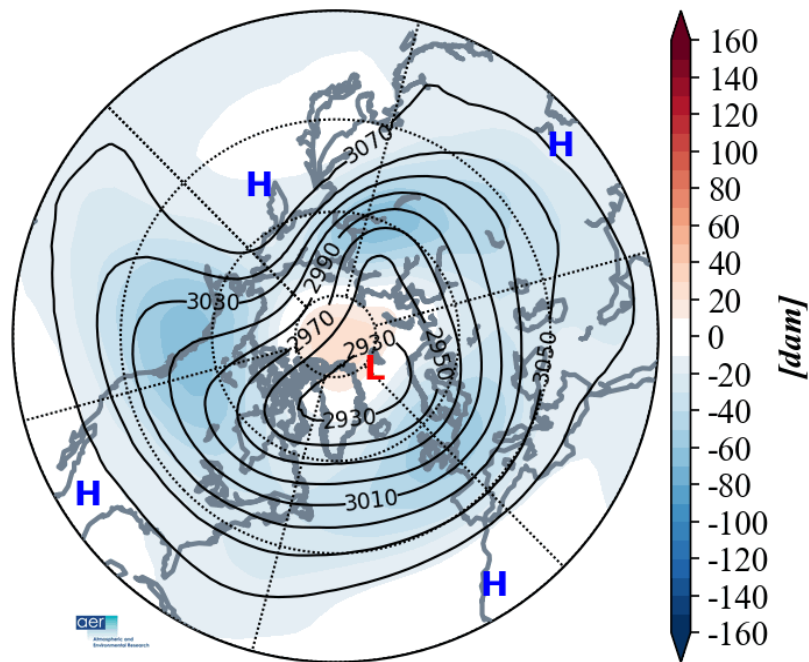
will force troughing/negative geopotential height anomalies across Western Siberia bringing colder temperatures to much of Siberia and Western Asia.

- This week, ridging/positive geopotential height anomalies centered south of the Aleutians are predicted to force downstream troughing/negative geopotential height anomalies and relatively cold temperatures across much of Canada and the Western United States (US) with ridging and relatively mild temperatures for the Eastern US. However, ridging/positive geopotential height anomalies are predicted build across Greenland starting next week forcing troughing/negative geopotential height anomalies across eastern North America allowing cold temperatures to sweep across the Eastern US except for the Deep South.
- In the *Impacts* section, I discuss my thoughts for March.
- A link to our video explaining the link among Arctic amplification, polar vortex (PV) disruptions and severe winter weather across the mid-latitudes including the US Europe and East Asia is now included on our web page.

### ***Impacts***

In my opinion following the temperature anomalies in the stratosphere has worked well in anticipating surface temperature anomalies so far this winter but probably more so in North America than Europe. Stratospheric anomalies correctly indicated cold for November and early December in eastern North America, milder temperatures mid-December until early January and then colder again in late January and into February. And as I have consistently discussed in the blog since January 21<sup>st</sup>, polar stratospheric temperatures suggest the cold across North America will be focused in western North America during February. Based on the latest stratospheric forecasts I see no reason to deviate from that expectation. In **Figure i**, I include an animation of the 10 hPa geopotential heights two-week forecast that still shows the largest negative departures extending from Central Siberia across the Arctic into Western North America. In addition, though the Arctic is currently warm, the forecast is for the Arctic to turn colder once again. As I have discussed previously, I do believe that a cold Arctic favors western North America for the core of the severe winter weather.

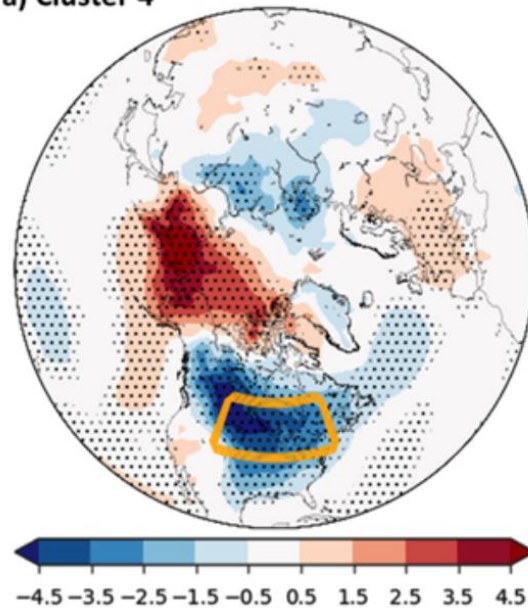
### Initialized 00Z 10 hPa HGT/HGTa 11-Feb-2019



**Figure i.** Animation of forecasted average 10 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for February 11 - 27, 2019.

Still is my empirical observation that a cold pattern that begins in Western North America with time shifts eastward, we certainly saw an example of that last winter from February to March 2018. That would be my thinking for the current pool of cold air across North America, for the core of the cold to slowly shift east with time. Also, a new predicted minor stratospheric PV disruption might assist in pulling the cold eastward across the US. This upcoming PV disruption differ from the PV split that has dominated much of the winter. This is a reflective disturbance (the signature is the positive anomalous upward WAFz in the stratosphere followed by negative anomalous upward WAFz in the troposphere seen in **Figure 11**) described in our recent paper [Kretschmer et al. 2018](#) and as in contrast to the absorbing disturbance that resulted in the PV split. Here tropospheric energy boomerangs off of the stratospheric PV back down into the troposphere over the course of several days and forces mid-tropospheric ridging or high pressure near Alaska with downstream troughing across North America. Based on composites, cold temperatures extend across much of Canada the Central and Eastern US and resembles the 6-10- and 11-15-day temperature forecast across North America (compare **Figure ii** with **Figures 6&8**).

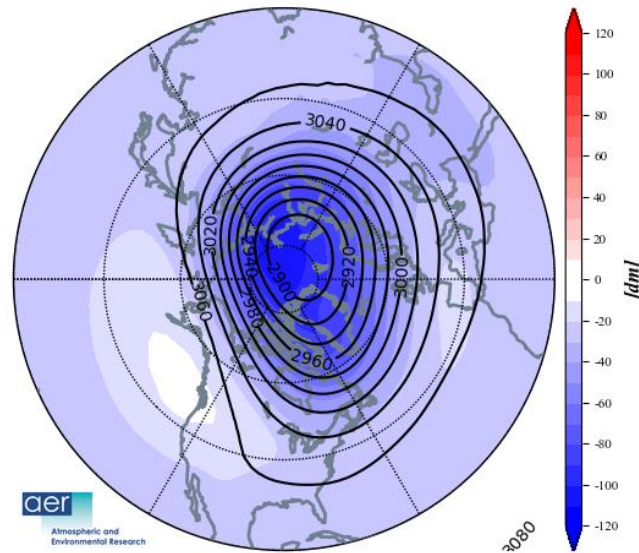
a) Cluster 4



**Figure ii.** Composite of surface temperature anomalies for all reflective PV disruptions (Figure copied from Keretscmer et al. 2018).

As I said in a tweet, waiting for more persistent cold in the Eastern US and maybe even Europe has felt like waiting for Godot and maybe it will never come this winter. I do attribute the fleeting cold and low snowfall to the Arctic being surprisingly cold this winter with the exception of warmth focused in the Barents Kara Seas. That temperature pattern across the Arctic is not related to cold winter temperatures in either the Eastern US or Northern Europe (see **Figure I** from last week's blog). But I do remain more optimistic for the Eastern US turning colder based on the predicted reflective minor stratospheric PV disruption. Not sure how much skill the CFS has in predicting the PV in March but the predicted configuration would suggest driving cold air into eastern North America and no longer western North America (**Figure iii**). This could setup a relatively cold March in the Eastern US consistent with recent Marches. And if Greenland blocking can become well established this may force a colder pattern across Northern Europe as well.

**CFS 10 hPa Forecast Anomaly Mar 2019**  
**Valid as of 11 Feb 2019**

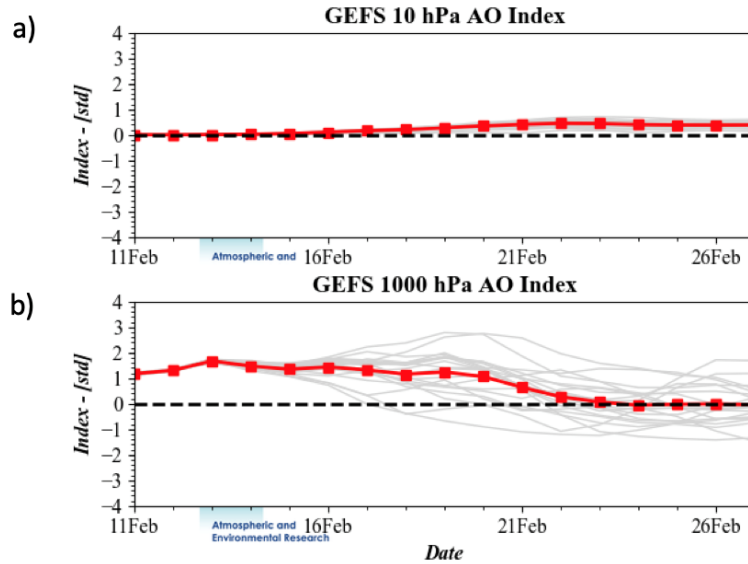


**Figure iii.** Forecasted average 10 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for March 2019. The forecasts are from the 11 February 2019 CFS.

### ***Near Term Conditions***

#### *1-5 day*

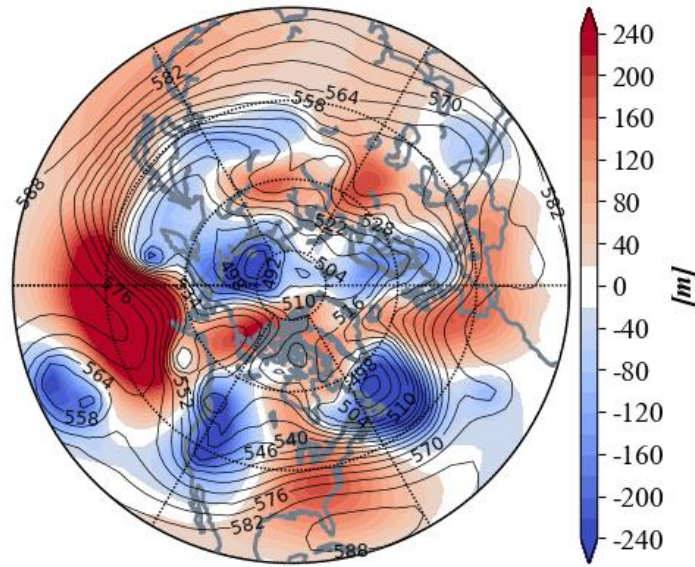
The AO is positive (**Figure 1**), with mostly negative pressure/geopotential height anomalies across the Arctic and mostly positive pressure/geopotential height anomalies across the mid-latitudes (**Figure 2**). Geopotential height anomalies are weak across Greenland and mixed across the mid-latitudes (**Figure 2**) and therefore the NAO is neutral.



**Figure 1.** (a) The predicted daily-mean AO at 10 hPa from the 00Z 11 February 2019 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 11 February 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 just west of the UK and Spain are predicted to quickly slide east and dominate much of Europe this week (**Figure 2**) yielding mostly normal to above normal temperatures for Europe including the UK (**Figure 3**). Ridging/positive geopotential height anomalies dominate much of Asia except for troughing/negative geopotential height anomalies in Eastern Siberia and into Northeast Asia that extends southwestward into Central Asia (**Figure 2**). This pattern is predicted to yield widespread normal to above normal temperature for Asia including the Middle East and Southeast Asia with normal to below normal temperatures in Eastern Siberia, Northeast Asia and into Central Asia (**Figure 3**).

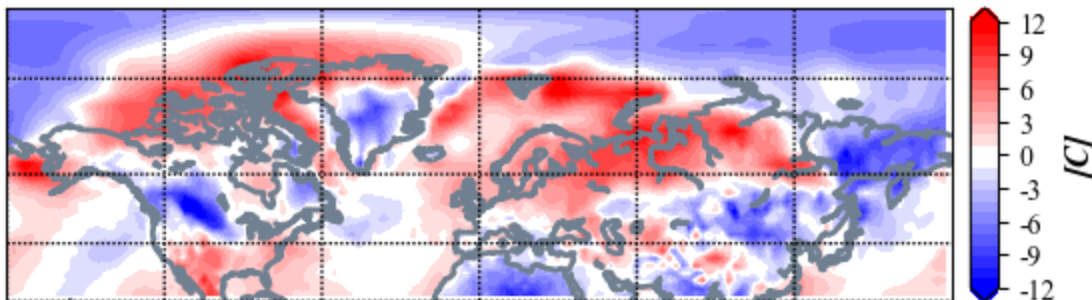
**GEFS 500 mb GPH/GPH Anomaly**  
**INIT: 00Z 02/11/19**



**Figure 2.** Observed 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) for 00Z 11 February 2019.

Ridging/positive geopotential height anomalies across Alaska and south of the Aleutians are anchoring downstream troughing/negative geopotential height anomalies across the West Coast of North America with more ridging/positive geopotential height anomalies across eastern North America (**Figure 2**). This pattern is predicted to result in normal to below normal temperatures for Western, Central and Northeastern Canada and the Western US with normal to above normal temperatures for Alaska and the Eastern US (**Figure 3**).

**GEFS 1-5 Day Forecast T2m Anomaly**  
**INIT: 00Z 02/11/19 FCST: 02/12/19 to 02/16/19**

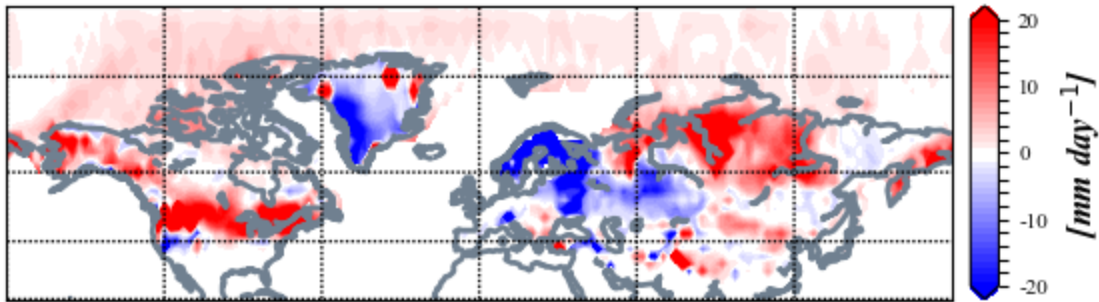


**Figure 3.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 12– 16 February 2019. The forecast is from the 00Z 11 February 2019 GFS ensemble.



Trouching and/or cold temperatures will bring new snowfall to Siberia, Central Asia and parts of Southeast Europe (**Figure 4**). Across North America, troughing and cold temperatures will bring widespread new snowfall across Southern Canada and the Northern US (**Figure 4**). Milder temperatures will result in snowmelt across Northern and Eastern Europe and the Southwestern US (**Figure 4**).

**GEFS 1-5 Day Forecast Mean 24-hour Snow Depth Change**  
**INIT: 00Z 02/11/19 FCST: 02/12/19 to 02/16/19**

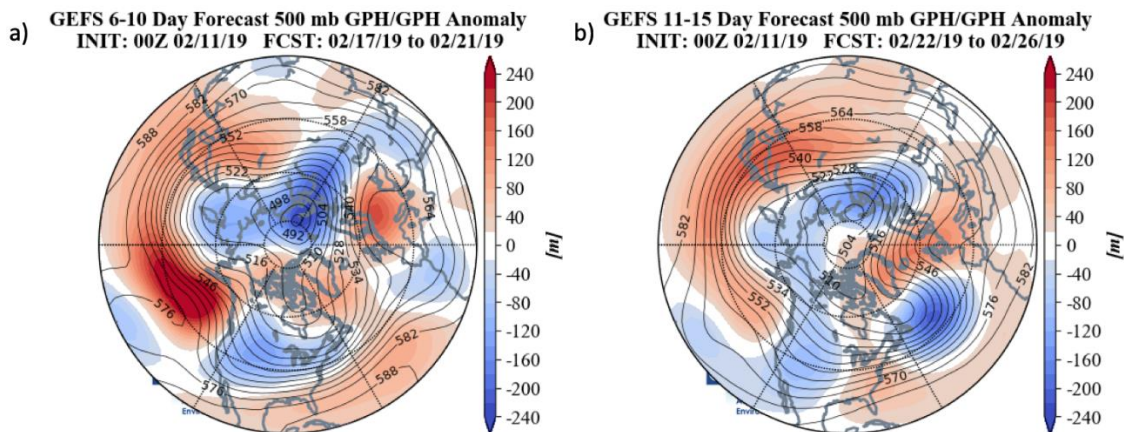


**Figure 4.** Forecasted snowfall anomalies (mm/day; shading) from 12 – 16 February 2019. The forecast is from the 00Z 11 February 2019 GFS ensemble.

*Mid-Term*

*6-10 day*

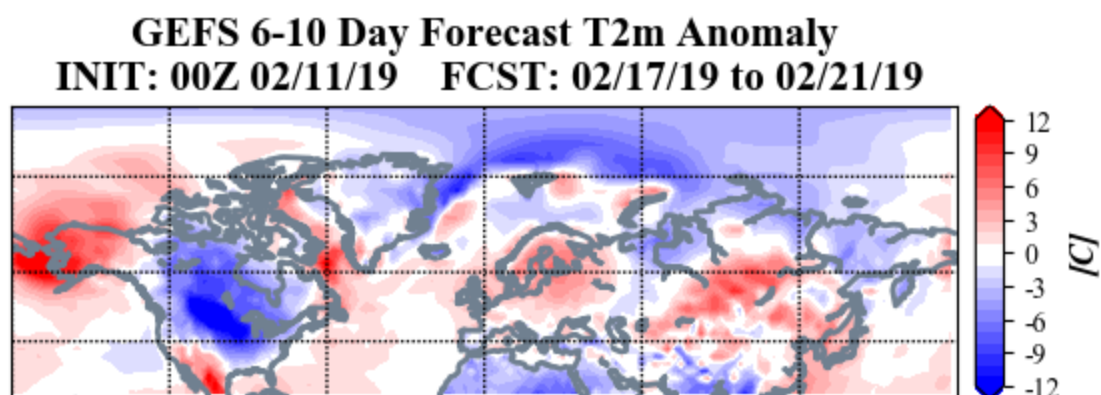
The AO is predicted to remain positive next week (**Figure 1**) with mostly negative geopotential height anomalies across the Arctic and positive geopotential height anomalies across the mid-latitudes of the NH (**Figure 5a**). And with weak geopotential height anomalies across Greenland, the NAO will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





**Figure 5.** (a) Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 17 – 21 February 2019. (b) Same as (a) except averaged from 22 – 26 February 2019. The forecasts are from the 11 February 2019 00z GFS ensemble.

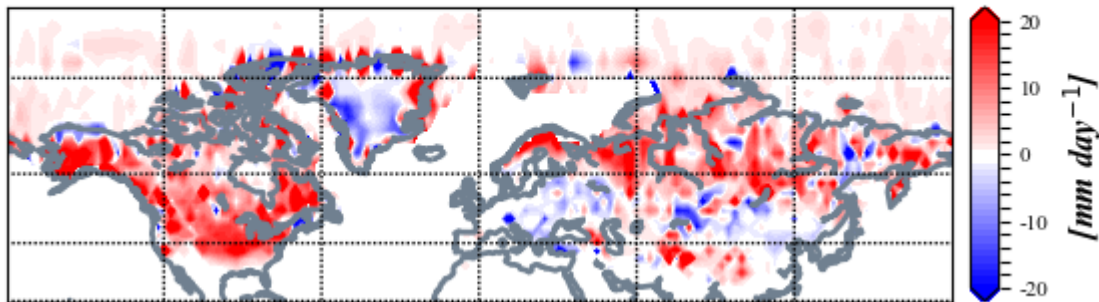
Ridging/positive geopotential height anomalies are predicted to dominate much of Europe with the exception of troughing/negative geopotential height anomalies across Southern Spain and Southeast Europe this period (**Figure 5a**). Widespread high heights are predicted to result in normal to above normal temperatures widespread across Europe including the UK while low heights will favor normal to below normal temperatures for parts of Southern Europe (**Figure 6**). Ridging/positive geopotential height anomalies in Europe and across Greenland favor troughing/negative geopotential height anomalies downstream across Western Asia and most of Siberia with ridging/positive geopotential height anomalies across East Asia (**Figure 5a**). This is predicted to yield normal to below normal temperatures for most of Northern Siberia and Western Asia including the Middle East with normal to above normal temperatures for Central and East Asia (**Figure 6**). Some residual troughing/negative geopotential height anomalies across Northern India (**Figure 5a**) are predicted to yield normal to below normal temperatures for Northern India and possibly into Pakistan (**Figure 6**).



**Figure 6.** Forecasted surface temperature anomalies (°C; shading) from 17 – 21 February 2019. The forecasts are from the 00Z 11 February 2019 GFS ensemble.

Ridging/positive geopotential height anomalies south of the Aleutians are predicted to anchor troughing/negative geopotential height anomalies in Western Canada and the Western US with more ridging/positive geopotential height anomalies in the Southeastern US (**Figure 5a**). However, building heights across Greenland are predicted to suppress heights across the Northeastern US as well this period (**Figure 5a**). The resultant temperature anomalies across North America are predicted to be normal to below normal temperatures across much of Canada and the US with normal to above normal temperatures for Alaska, Florida and far eastern Quebec (**Figure 6**).

**GEFS 6-10 Day Forecast Mean 24-hour Snow Depth Change**  
**INIT: 00Z 02/11/19 FCST: 02/17/19 to 02/21/19**



**Figure 7.** Forecasted snowfall anomalies (mm/day; shading) from 17 – 21 February 2019. The forecasts are from the 00Z 11 February 2019 GFS ensemble.

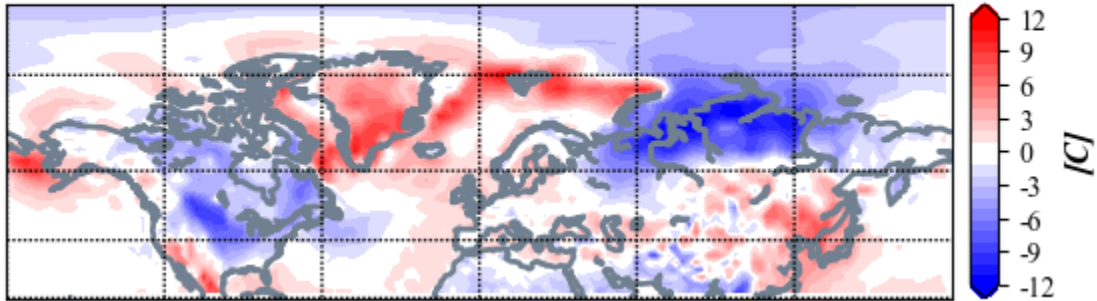
Trouching and cold air will bring the potential for new snowfall across Scandinavia, Northern and Central Asia (**Figure 7**). Across North America, new snowfall is possible in Alaska, much of Canada and the Northern US (**Figure 7**). Mild temperatures could result in snowmelt in parts of Europe and Central Asia (**Figure 7**).

*11-15 day*

With mostly positive geopotential height anomalies predicted for the North Atlantic side of the Arctic and negative geopotential height anomalies predicted for the North Pacific side of the Arctic (**Figure 5b**), the AO is likely to be close to neutral this period (**Figure 1**). With weak positive pressure/geopotential height anomalies across Greenland, the NAO is predicted to remain neutral to slightly negative this period as well (**Figure 1**).

Persistent ridging/positive geopotential height anomalies across much of Europe (**Figure 5b**) are predicted to result in normal to above normal temperatures for much of Europe including the UK once again (**Figure 8**). European ridging is predicted to force downstream troughing/negative geopotential height anomalies across Western Asia that extends across Siberia with ridging/positive geopotential height anomalies predicted for East Asia (**Figure 5b**). This pattern favors normal to below normal temperatures for much of Northern and Western Asia, but especially Siberia with normal to above normal temperatures for Southern Asia including the Middle East and Southeast Asia (**Figure 8**). Some residual troughing/negative geopotential height anomalies across Northern India (**Figure 5a**) are predicted to yield normal to below normal temperatures for Northern India and Pakistan (**Figure 6**).

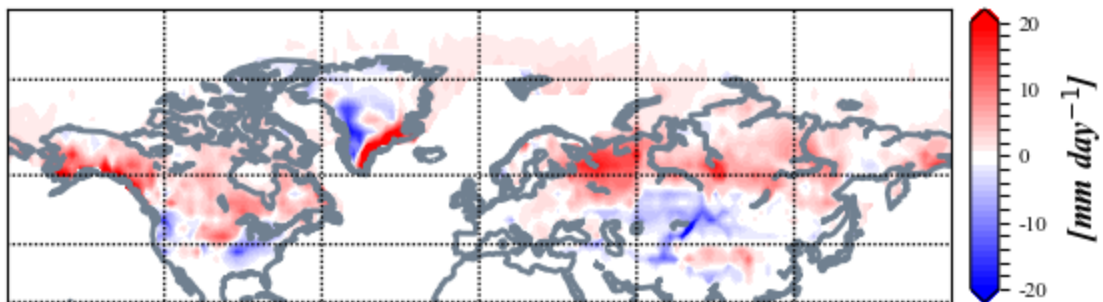
**GEFS 11-15 Day Forecast T2m Anomaly**  
**INIT: 00Z 02/11/19 FCST: 02/22/19 to 02/26/19**



**Figure 8.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 22 – 26 February 2019. The forecasts are from the 00Z 11 February 2019 GFS ensemble.

Persistent ridging/negative geopotential height anomalies centered south of the Aleutians will continue to support troughing/negative geopotential height anomalies across western North America with ongoing ridging/negative geopotential height anomalies across the Southeastern US (**Figure 5b**). This will favor normal to below normal temperatures across much of Canada and the US with normal to above normal temperatures confined to Alaska and parts of the Southern (**Figure 8**).

**GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change**  
**INIT: 00Z 02/11/19 FCST: 02/22/19 to 02/26/19**



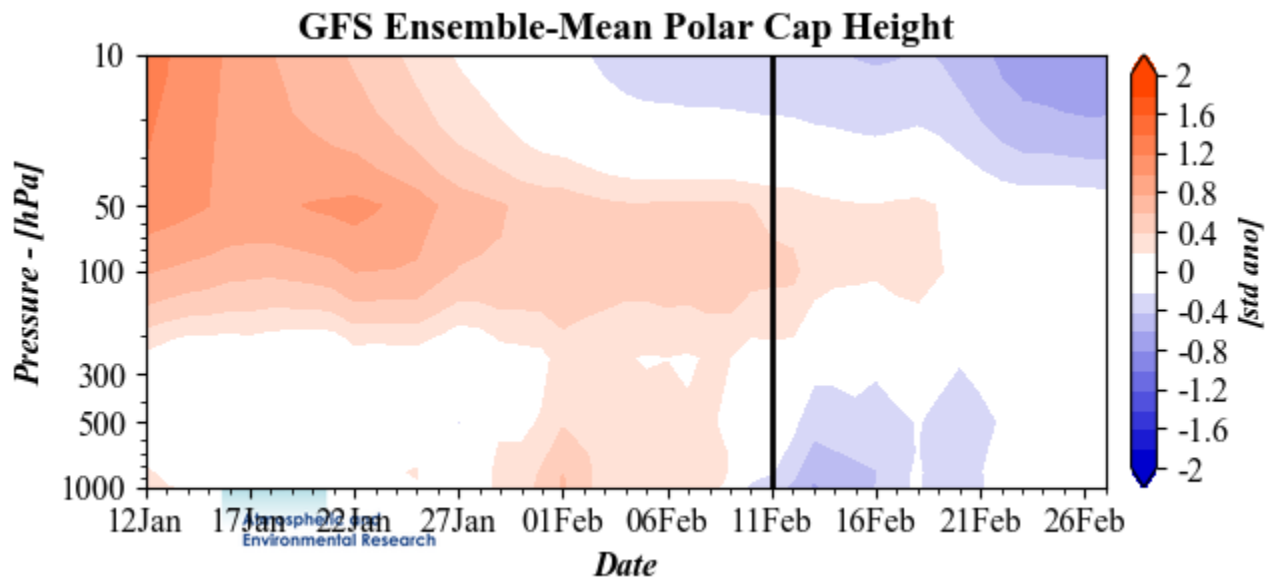
**Figure 9.** Forecasted snowfall anomalies ( $\text{mm}/\text{day}$ ; shading) from 22 – 26 February 2019. The forecasts are from the 00Z 11 February 2019 GFS ensemble.

Once again additional snowfall is possible across much of northern Eurasia including Scandinavia, Eastern Europe, Siberia and Western Asia (**Figure 9**). 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 Central Asia and the lower Mississippi Valley (**Figure 9**).

Longer Term

30-day

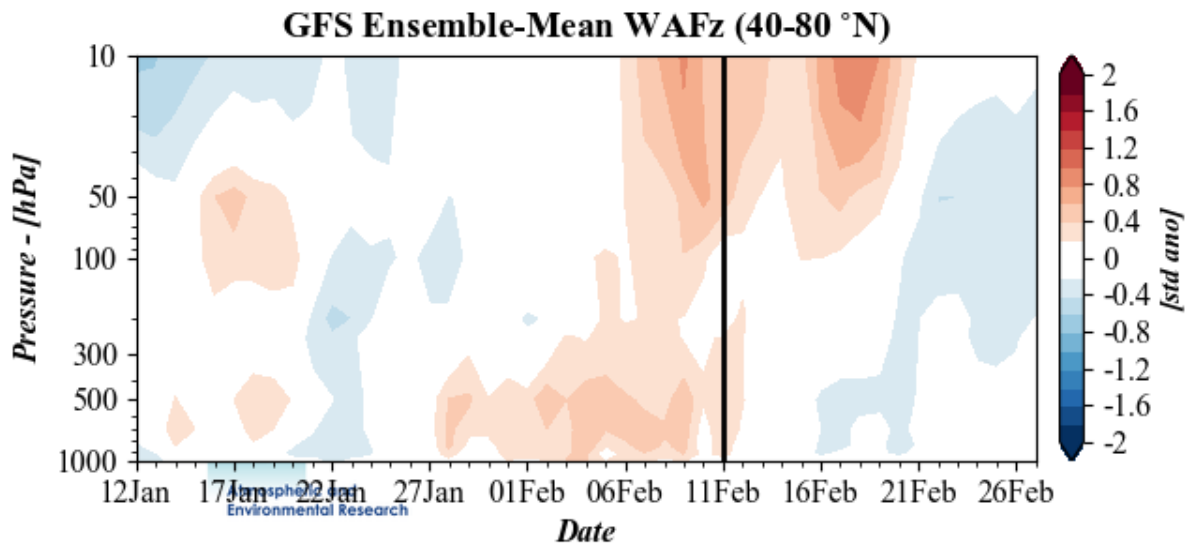
The latest plot of the polar cap geopotential heights (PCHs) shows in general predicted normal to above normal PCHs in lower stratosphere with normal to below normal PCHs in both the mid stratosphere and the troposphere (**Figure 10**). The below normal PCHs in the troposphere are consistent with a positive AO predicted for this week and into next week (**Figure 1**). The below normal PCHs in the mid stratosphere are consistent with a return to near neutral stratospheric AO for the next two weeks (**Figure 1**). The positive PCHs in the lower stratosphere are related to downward propagation of circulation anomalies related to the 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) back in January.



**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 11 February 2019 GFS ensemble.

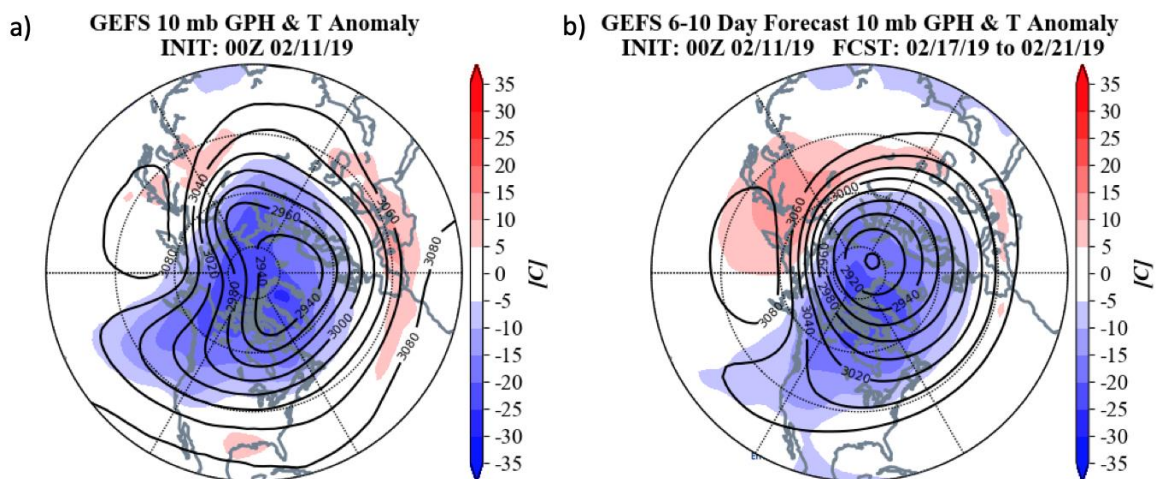
The GFS forecast of PCHs gives an ambiguous impression of when the coupling between the PV disruption and the troposphere will end. The argument could be made that the impact of the SSW on the weather ended last week or that it may continue into late February or even early March. It has been shown previously that the impact of the SSW on the weather can be from four to eight weeks. Both scenarios are within that general range. Either way I would argue that the influence of the SSW on our weather will likely continue into March. The PV split created favorable conditions for the buildup

of cold air in western North America that is predicted to persist for at least two more weeks.



**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 11 February 2019 GFS ensemble.

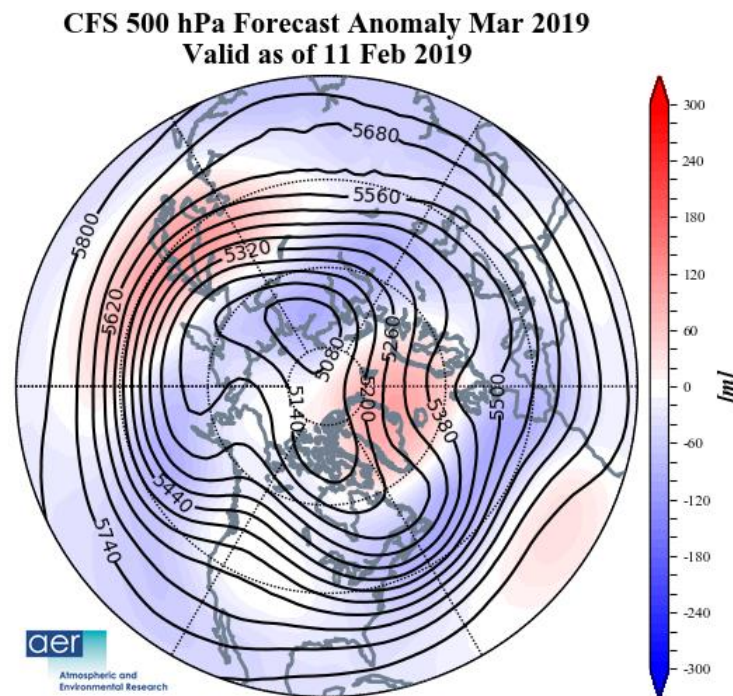
Now that the westerly winds have returned to the mid stratosphere, the plot of Wave Activity Flux (WAFz) or poleward heat transport shows more active WAFz since early February (**Figure 11**). Warming is predicted to swing around from the Mediterranean towards East Asia and Alaska and could have important implications for the weather in the US. Such relatively minor polar stratospheric warmings tend to favor cold in Central and Eastern North America, however, the core of the cold temperatures over western North America in the stratosphere suggest a westward shift of the cold anomalies.





**Figure 12. (a)** Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies ( $^{\circ}\text{C}$ ; shading) across the Northern Hemisphere for 11 February 2019. **(b)** Same as **(a)** except forecasted averaged from 17 – 21 February 2019. The forecasts are from the 00Z 11 February 2019 GFS operational model.

The stratospheric PV is currently centered over Svalbard and Greenland (**Figure 12**). As I discussed in the last three weeks of the blog the cold temperatures in the stratosphere are focused in Siberia and western North America and could be a sign where the coldest temperatures at the surface may be focused as well during the remainder of the month of February.

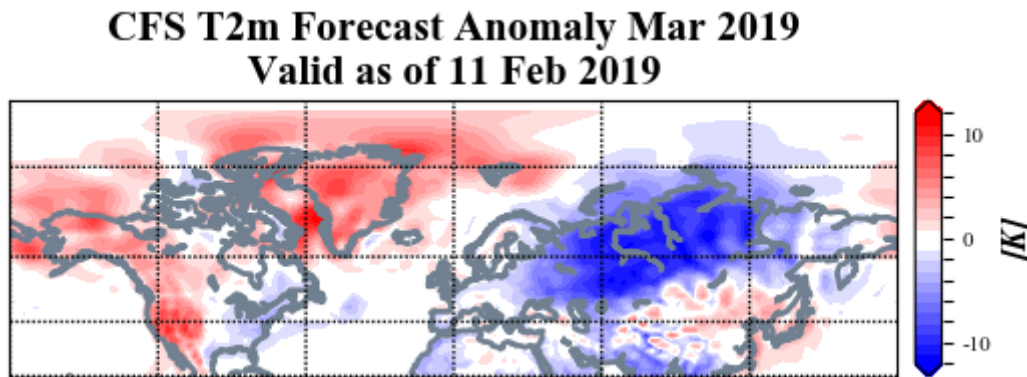


**Figure 13.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for March 2019. The forecasts are from the 11 February 2019 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 13**) and the surface temperatures (**Figure 14**) forecast for March from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging centered in Western Canada, from Greenland over to Scandinavia and in East Asia with troughs across south of the Aleutians, eastern North America, Europe and Siberia (**Figure 13**). This pattern favors cold temperatures for much of Europe, Northern Asia especially Siberia, Eastern Canada and the Eastern US with relatively mild temperatures for Southeast Asia and much of western North



America (**Figure 14**). This forecast may be too cold for Eurasia but otherwise seems plausible to me.

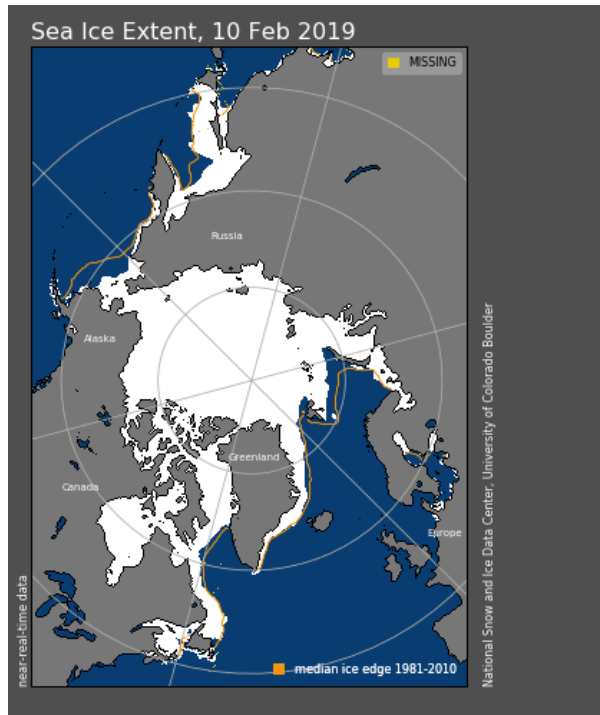


**Figure 14.** Forecasted average surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) across the Northern Hemisphere for March 2019. The forecasts are from the 11 February 2019 CFS.

#### *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. The regions with the largest negative departures are the Barents-Kara and Bering Seas (**Figure 13**). I would argue that the greatest negative anomalies so far this winter in the Barents-Kara Seas has favored this region for ridging/blocking during the winter months. Some research shows low sea ice in the Sea of Okhotsk favors a positive AO/NAO. Normal to above normal sea ice in and around Greenland and the Canadian Archipelagos may favor a positive 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.

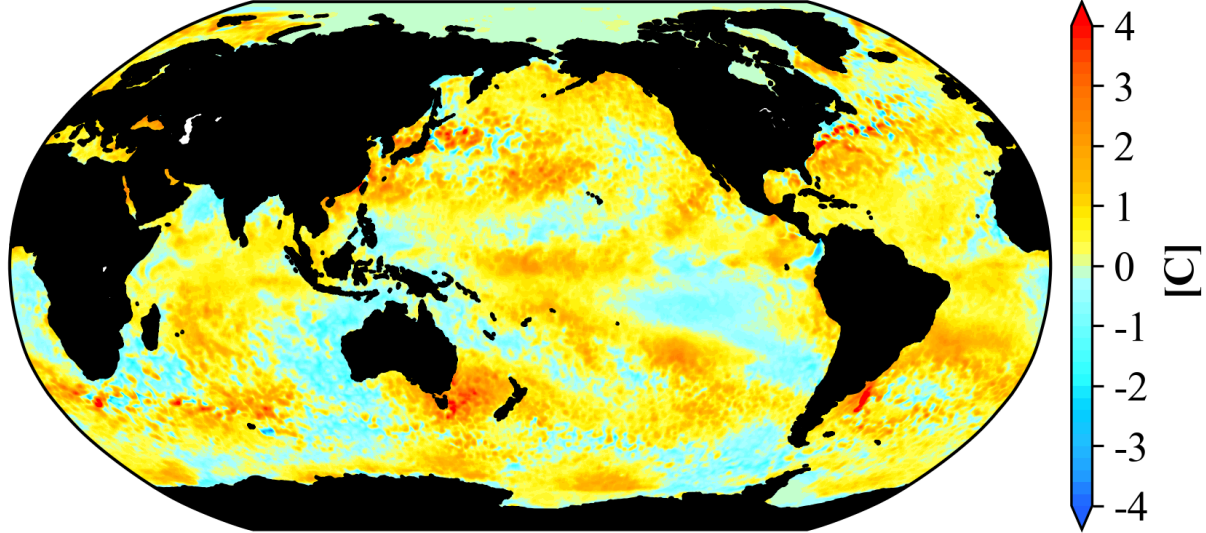


**Figure 15.** Observed Arctic sea ice extent on 10 February 2019 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

### *SSTs/El Niño/Southern Oscillation*

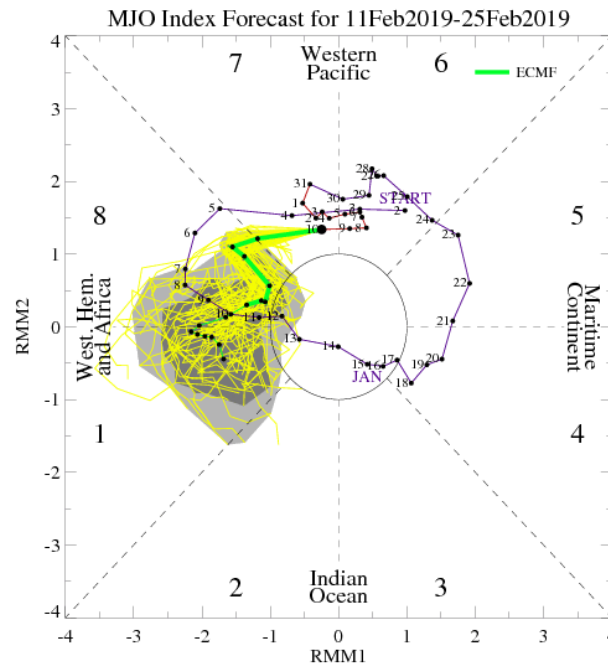
Equatorial Pacific sea surface temperatures (SSTs) anomalies remain warm but no longer support El Niño conditions (**Figure 13**). Observed SSTs across the NH remain well above normal though below normal SSTs exist regionally. Cold SSTs south of Iceland and in the subtropics of the North Atlantic with above normal SSTs in the mid-latitudes are thought to favor a positive winter NAO.

## SST Anomaly - Week Ending 10 Feb 2019



**Figure 16.** The latest weekly-mean global SST anomalies (ending 10 February 2019). Data from NOAA OI High-Resolution dataset. (Updated from [https://www.ospo.noaa.gov/Products/ocean/sst/anomaly/anim\\_full.html](https://www.ospo.noaa.gov/Products/ocean/sst/anomaly/anim_full.html) due to US Government shutdown).

Currently phase seven of the Madden Julian Oscillation (MJO) is favored (**Figure 14**). However the MJO is expected to transition to phase eight and then one. Phases 7, 8 and 1 eventually favor troughing over eastern North America with cold temperatures and ridging over western North America with mild temperatures.

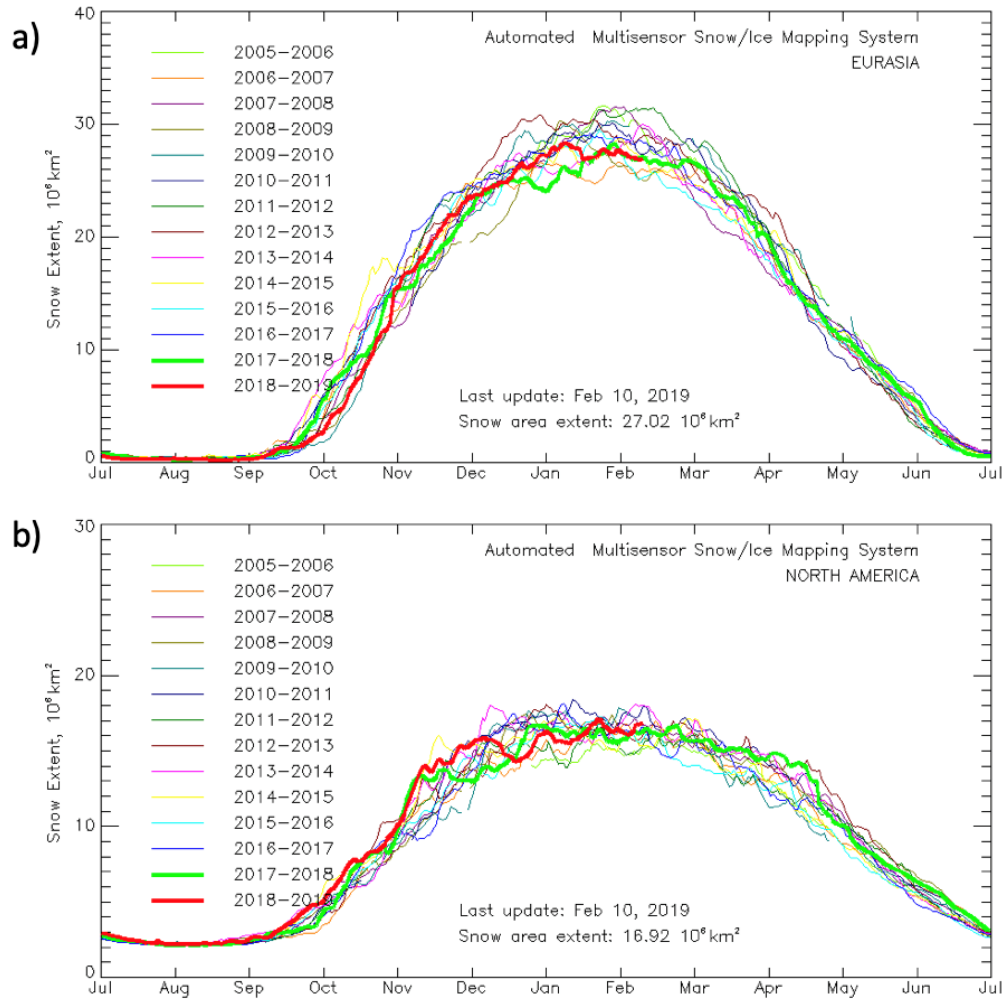


**Figure 17.** Past and forecast values of the MJO index. Forecast values from the 00Z 11 February 2019 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate the phase of the MJO, with geographical labels indicating where anomalous convection occurs during that phase. Image

source: <http://www.atmos.albany.edu/facstaff/roundy/waves/phasediags.html>

### *Northern Hemisphere Snow Cover*

Snow cover advance continues its recent stall across Eurasia but remains near decadal means. Snow cover advance could advance is unlikely in the next couple of weeks as Europe turns milder. Above normal snow cover extent this past 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 18.** Observed Eurasian (top) and North American (bottom) snow cover extent through 10 February 2019. Image source:

[https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow\\_extent\\_plots.html](https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html)

North American snow cover has remained steady near decadal means. Snow cover could advance further as cold air becomes more widespread across the continent.