

March 4, 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.*

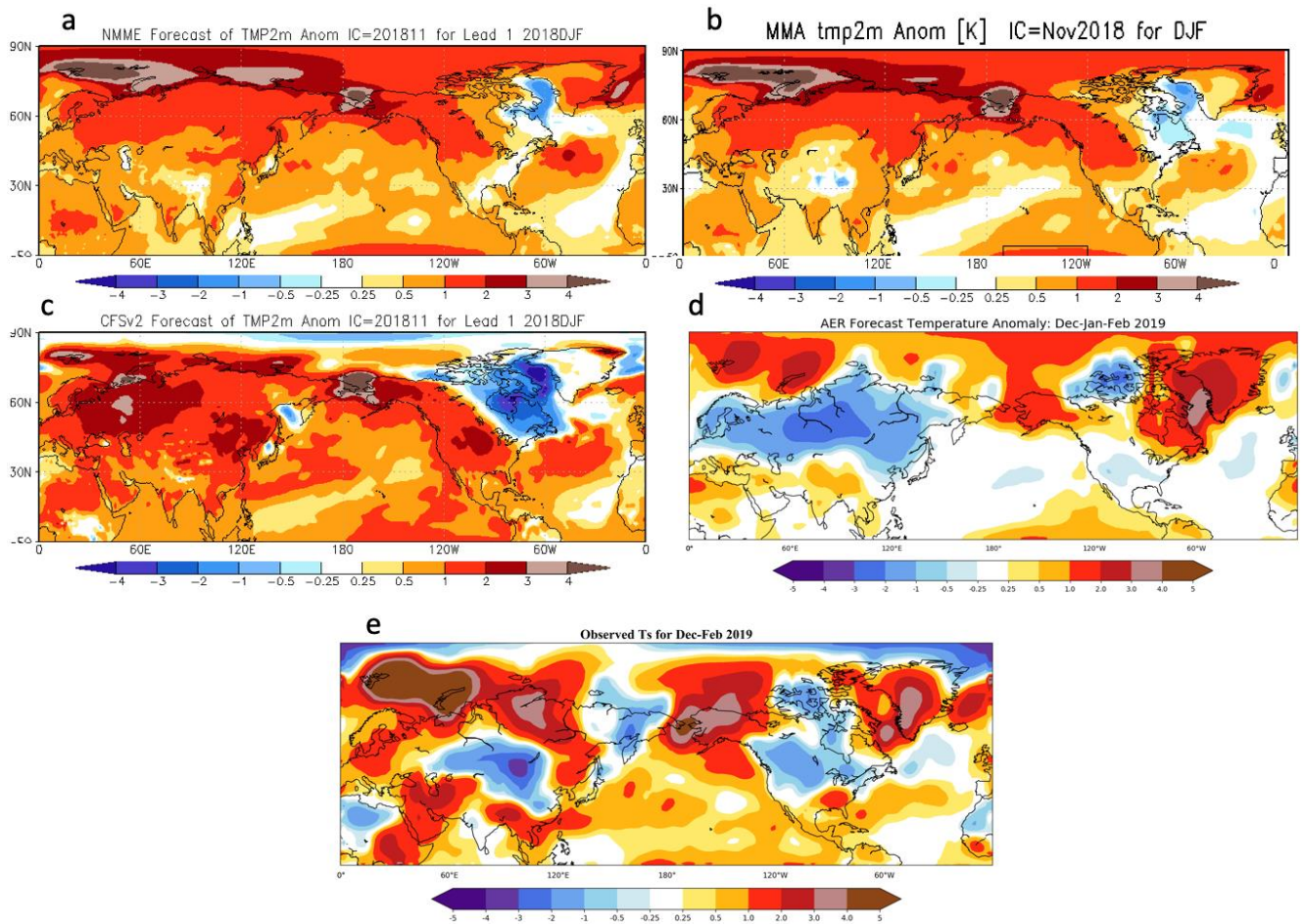
### ***Summary***

- The Arctic Oscillation (AO) is currently positive and is predicted to remain positive over the next two weeks but trend towards neutral mid-month.
- The current positive AO is reflective of mostly negative pressure/geopotential height anomalies across the Eurasian and Central Arctic and mixed 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 remain neutral to positive over the next two weeks.
- Ridging/positive geopotential height anomalies are predicted to dominate Southern Europe with troughing/negative geopotential height anomalies across Northern Europe for much of the next two weeks. This will yield a pattern of normal to above normal temperatures for Southern and Central Europe with normal to below normal temperatures across Northern Europe including the United Kingdom (UK) this week. However, starting next week, troughing/negative geopotential height anomalies will extend south allowing cold temperatures to spread across much of Europe.

- In general, ridging/positive geopotential height anomalies with normal to above normal temperatures dominates much of Central and East Asia with troughing/negative geopotential height anomalies across northwestern and Southern Asia with normal to below normal temperatures across Western Siberia and Southern Asia including the Middle East, Northern India and Pakistan. Over the next two weeks the troughing will abate with milder temperatures across Southern Asia while troughing deepens across Northern Asia with cooling temperatures.
- This week ridging/positive geopotential height anomalies with relatively mild temperatures are predicted to be centered across Alaska and Northwest Canada forcing downstream troughing/negative geopotential height anomalies and relatively cold temperatures across much of the remainder of Canada and the United States (US) with the exception of ridging and relatively mild temperatures for the Southwestern US. However, the ridging/positive geopotential height anomalies is predicted to become widespread next week focusing the troughing/negative geopotential height anomalies and relatively cold temperatures in the interior of North America with milder temperatures elsewhere.
- In the *Impacts* section, I show the forecast of winter surface temperature anomalies including from the AER model and observed winter surface temperature anomalies.
- I will be transitioning to the spring and summer schedule of posting a new blog every two weeks possibly as early as next week.

### ***Impacts***

Due to the snow day here in Boston and unexpectedly heavy snowfall, I am running late with the blog and will keep this section short. With the conclusion of meteorological winter last week, I have included the four-panel winter surface temperature anomaly forecast that I showed in November along with the observed winter surface temperature anomaly. For both the forecast and the observations I use the NCEP/NCAR reanalysis. The dynamical model forecasts include the North American Multi-Model Ensemble (NMME), the International Multi-Model Ensemble (IMME) and the Climate Forecast System (CFS). All dynamical model forecasts are taken from <https://www.cpc.ncep.noaa.gov/products/NMME/>.



**Figure i.** Predicted surface temperature anomalies (shading) for December 1, 2018 – February 28, 2019 from the a) NMME b) IMME c) CFS d) AER and e) observed surface temperature anomalies (shading) for December 1, 2018 – February 28, 2019.

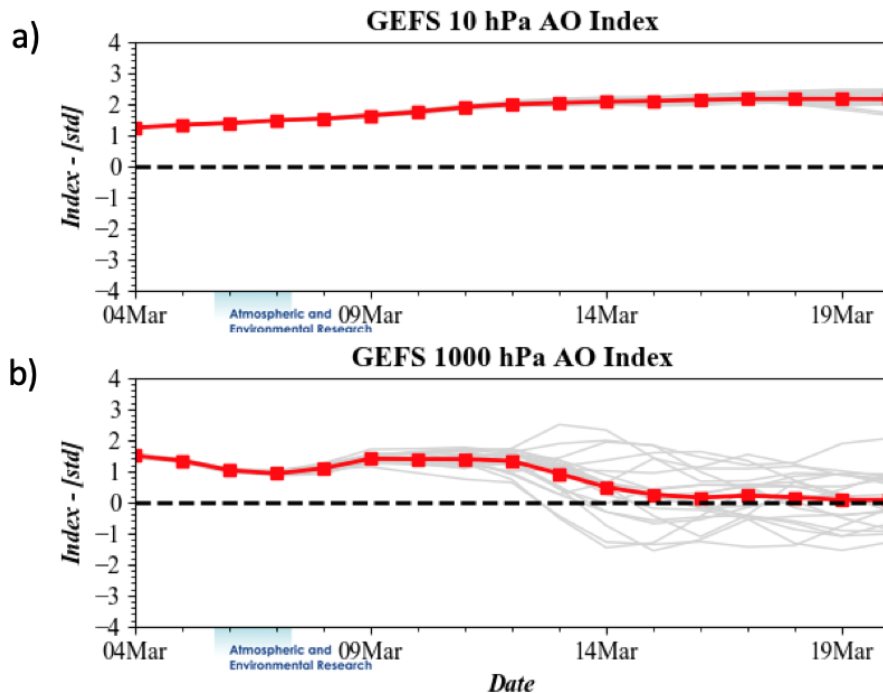
Maybe the most obvious response to seeing the forecasts and the observations is that it was a challenging forecast. No obvious teleconnection patterns emerge including El Niño/Southern Oscillation (ENSO) and the AO. Despite the impressive and long duration polar vortex split and even extended influence on the troposphere, the surface temperature anomalies don't match a composite of such previous events. The dynamical model forecasts can be characterized as predicting nearly universal warmth across the Northern Hemisphere with the exception of Northeastern Canada, possibly due to extensive sea ice in the region during the fall. The AER forecast in contrast did predict regional cold temperatures on both continents with more extensive cold across the Eurasian continent. Cold temperatures across both continents was more extensive than predicted by the dynamical models. The AER model overpredicted the extent of the cold for Eurasia and underpredicted the extent of the cold in North America. I wish I knew but I don't have a good reason or even a good guess as to why the warmth typically (at least in recent years) found in the Central Arctic was displaced towards the Eurasian continent instead this winter.

All forecasts underpredicted the warmth in the Barents-Kara Seas, which I do think was an important influence on the weather that coupled with the cold central Arctic that was only correctly predicted by the CFS model. I don't think that it is a coincidence that the recent reversal of this temperature pattern in the Arctic has coincided with more snowfall in the population centers of the Northeastern US.

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

1-5 day

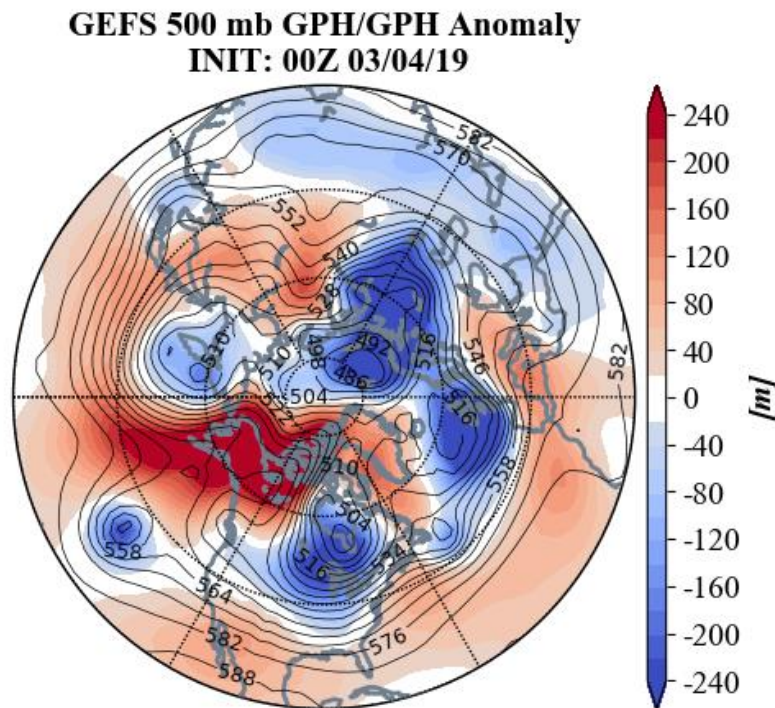
The AO is positive (**Figure 1**), with mostly negative pressure/geopotential height anomalies across the Eurasian side of the Arctic and Central Arctic with mixed pressure/geopotential height anomalies across the mid-latitudes (**Figure 2**). Geopotential height anomalies are weak across Greenland and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



**Figure 1.** (a) The predicted daily-mean AO at 10 hPa from the 00Z 4 March 2019 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 4 March 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.

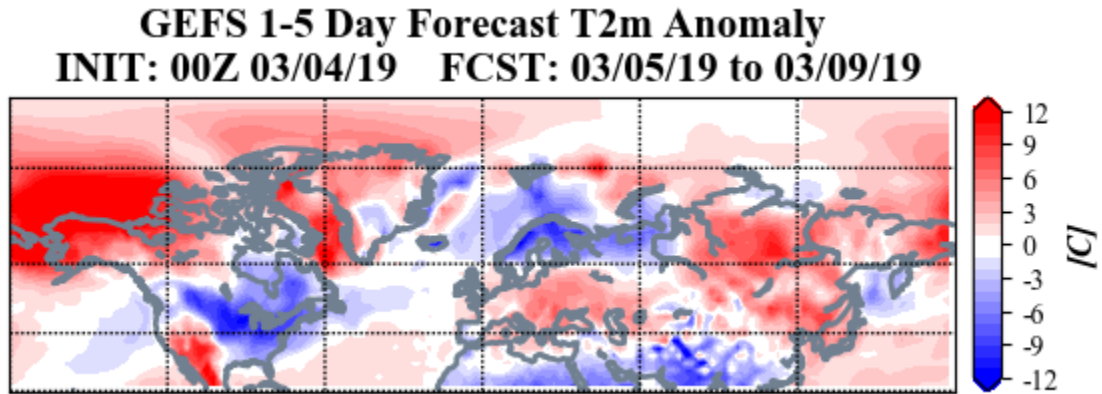
Ridging/positive geopotential height anomalies centered over Southern Europe with troughing/negative geopotential height anomalies across Northern Europe is predicted for this week (**Figure 2**) yielding mostly normal to above normal temperatures for

Europe except for normal to below normal temperatures across Northern Europe including the UK (**Figure 3**). Ridging/positive geopotential height anomalies dominate Central and East Asia with troughing/negative geopotential height anomalies in northwestern and Southern Asia (**Figure 2**). This pattern is predicted to yield widespread normal to above normal temperature for Central and East Asia with normal to below normal temperatures in Western Siberia, Northwest Asia, the Middle East, Northern India and into Pakistan (**Figure 3**).



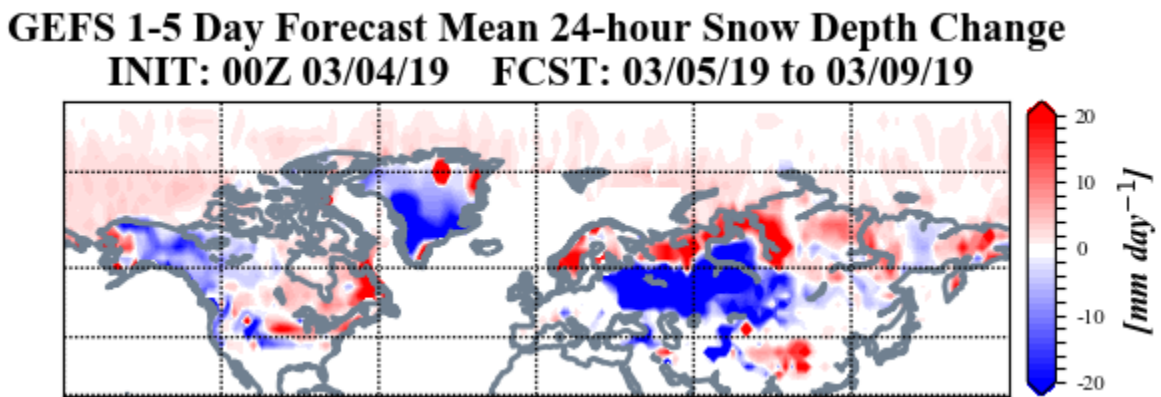
**Figure 2.** Observed 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) for 00Z 4 March 2019.

Ridging/positive geopotential height anomalies across Alaska and Northwestern Canada are forcing downstream troughing/negative geopotential height anomalies across central and eastern North America with more ridging/positive geopotential height anomalies across the Southwestern US (**Figure 2**). This pattern is predicted to result in normal to below normal temperatures for much of Canada and the US with normal to above normal temperatures for Alaska, Northwest Canada and the US Desert Southwest (**Figure 3**).



**Figure 3.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 5 – 9 March 2019. The forecast is from the 00Z 4 March 2019 GFS ensemble.

Trouthing and/or cold temperatures will bring new snowfall to Scandinavia, Northern Siberia and the Tibetan Plateau (**Figure 4**). Across North America, trouthing and cold temperatures will bring widespread new snowfall Central, Eastern Canada and the Northeastern US (**Figure 4**). Milder temperatures will result in snowmelt across Eastern Europe, Western and Central Asia, Alaska and Western Canada (**Figure 4**).



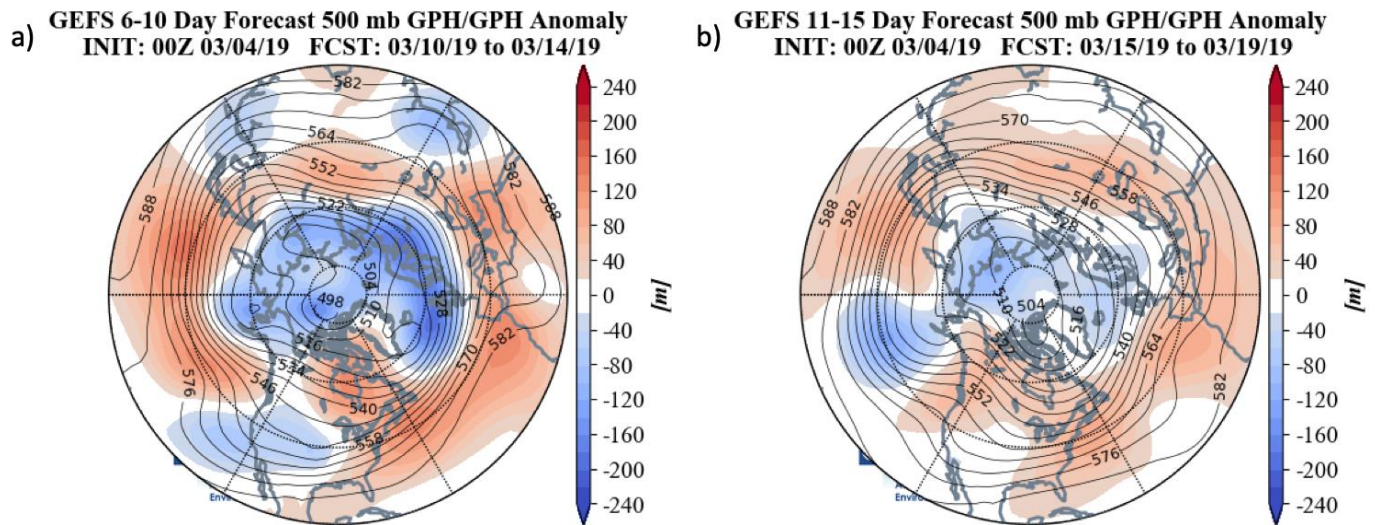
**Figure 4.** Forecasted snowfall anomalies ( $\text{mm}/\text{day}$ ; shading) from 5 – 9 March 2019. The forecast is from the 00Z 4 March 2019 GFS ensemble.

*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

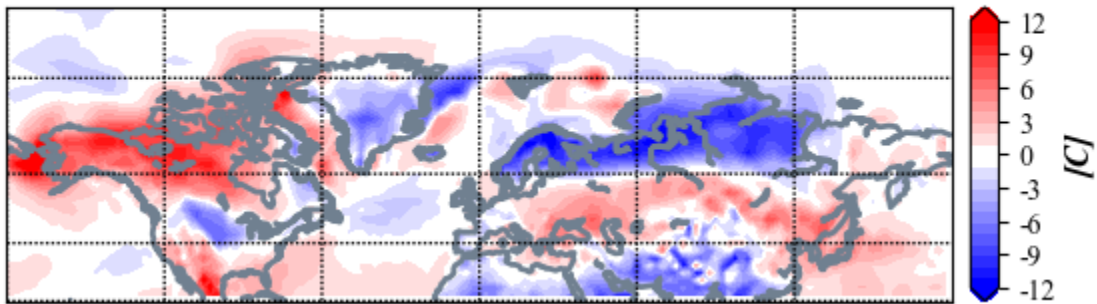
anomalies across the mid-latitudes of the NH (**Figure 5a**). And with weak geopotential height anomalies across Greenland, the NAO will likely be near neutral next week.



**Figure 5.** (a) Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 10 – 14 March 2019. (b) Same as (a) except averaged from 15 – 19 March 2019. The forecasts are from the 25 February 2019 00z GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to continue to dominate much of Southern Europe with troughing/negative geopotential height anomalies across Northern Europe this period (**Figure 5a**). This pattern is predicted to result in normal to above normal temperatures widespread across Southern and Central Europe with normal to below normal temperatures for far Northern Europe including the UK (**Figure 6**). The overall pattern across Asia is predicted to persist with ridging/positive geopotential height anomalies in Central and East Asia with troughing/negative geopotential height anomalies across Northern Asia including most of Siberia and Southern Asia (**Figure 5a**). This is predicted to yield normal to below normal temperatures for most of Northern Siberia and Western Asia with normal to above normal temperatures for Central and East Asia (**Figure 6**). Persistent troughing/negative geopotential height anomalies from the Middle East and across to Northern India (**Figure 5a**) are predicted to yield normal to below normal temperatures for the Middle East, Northern India and Pakistan (**Figure 6**).

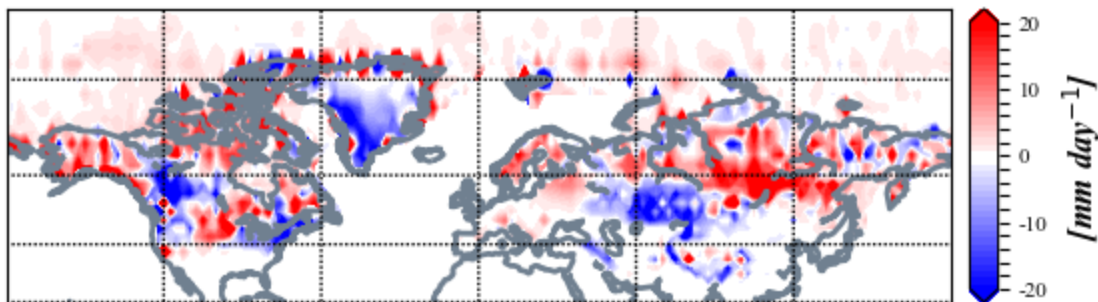
**GEFS 6-10 Day Forecast T2m Anomaly**  
**INIT: 00Z 03/04/19 FCST: 03/10/19 to 03/14/19**



**Figure 6.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 10 – 14 March 2019. The forecasts are from the 00Z 4 March 2019 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to return to eastern North America with troughing/negative geopotential height anomalies in Alaska, Western Canada and the Western US (**Figure 5a**). Still the resultant temperature anomalies across North America are predicted to be normal to above normal temperatures across much of Alaska, Canada and the US except for normal to below normal temperatures for Plains of Southern Canada and the Northern US (**Figure 6**).

**GEFS 6-10 Day Forecast Mean 24-hour Snow Depth Change**  
**INIT: 00Z 03/04/19 FCST: 03/10/19 to 03/14/19**



**Figure 7.** Forecasted snowfall anomalies ( $\text{mm}/\text{day}$ ; shading) from 10 – 14 March 2019. The forecasts are from the 00Z 4 March 2019 GFS ensemble.

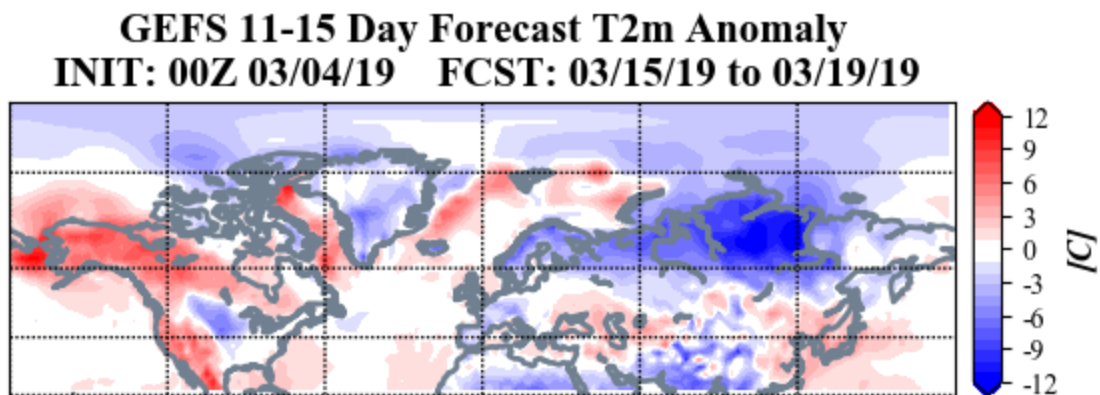
Troughing and cold air will bring the potential for new snowfall across Scandinavia, possibly parts of Eastern and Central Europe and Northern Asia (**Figure 7**). Across North America, new snowfall is possible across Alaska and parts of Canada (**Figure 7**). Mild temperatures could result in snowmelt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



11-15 day

With only weak geopotential height anomalies predicted for the Arctic (**Figure 5b**), the AO is likely to remain close to neutral this period (**Figure 1**). With weak negative pressure/geopotential height anomalies across Greenland, the NAO is also likely to be slightly positive to neutral this period (**Figure 1**).

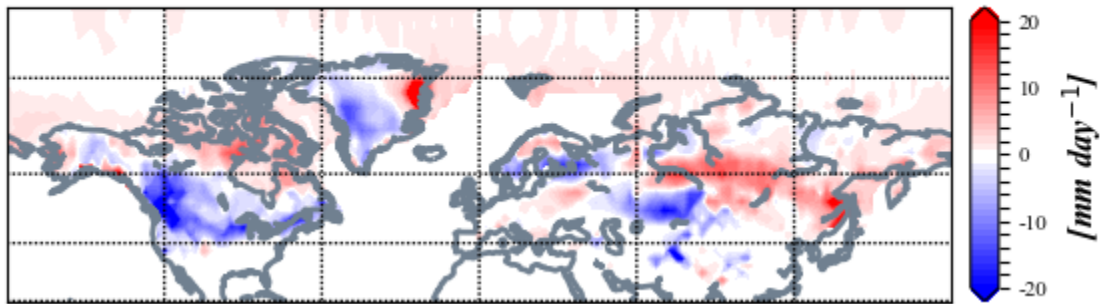
Cold temperatures are predicted to become more extensive across northern Eurasia this period as AO returns to neutral. Troughing/negative geopotential height anomalies across Northern Europe will become more expansive this period with ridging/positive geopotential height anomalies confined across far Southern Europe (**Figure 5b**). Therefore, normal to below normal temperatures are predicted for much of Europe including the UK with in normal to above normal temperatures confined to Southeastern Europe (**Figure 8**). Little change is predicted in the circulation pattern across Asia with troughing/negative geopotential height anomalies across Northern Asia that extends east across Siberia with ridging/positive geopotential height anomalies predicted for Central and East Asia (**Figure 5b**). This pattern favors normal to below normal temperatures for much of Northern Asia, including much of Siberia with normal to above normal temperatures for Central and East Asia (**Figure 8**). Residual troughing/negative geopotential height anomalies that extends from the Middle East and across Northern India (**Figure 5a**) are predicted to yield normal to below normal temperatures for the Middle East, Northern India and Pakistan (**Figure 6**).



**Figure 8.** Forecasted surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) from 15 – 19 March 2019. The forecasts are from the 00Z 4 March 2019 GFS ensemble.

Ridging/negative geopotential height anomalies are predicted to dominate much of North America with the exception of troughing/negative geopotential height anomalies across central North America (**Figure 5b**). This will favor normal to above normal temperatures across much of Alaska, Canada and the Eastern US with normal to below normal temperatures confined to the Southern Plains of Canada and the Northern Plains of the US (**Figure 8**).

**GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change**  
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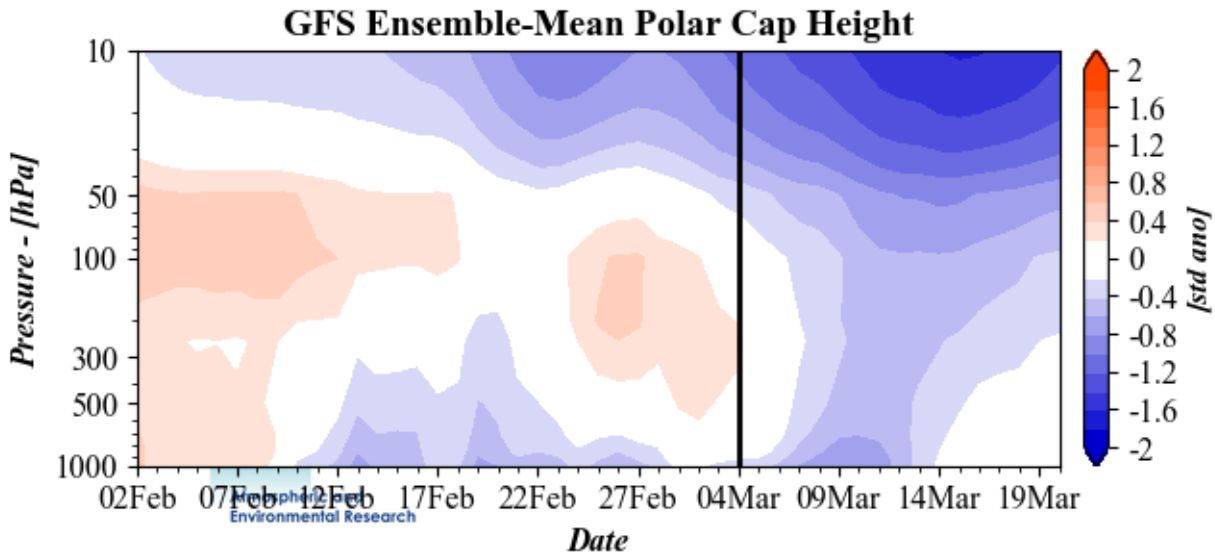
**Figure 9.** Forecasted snowfall anomalies (mm/day; shading) from 15 – 19 March 2019. The forecasts are from the 00Z 4 March 2019 GFS ensemble.

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

*Longer Term*

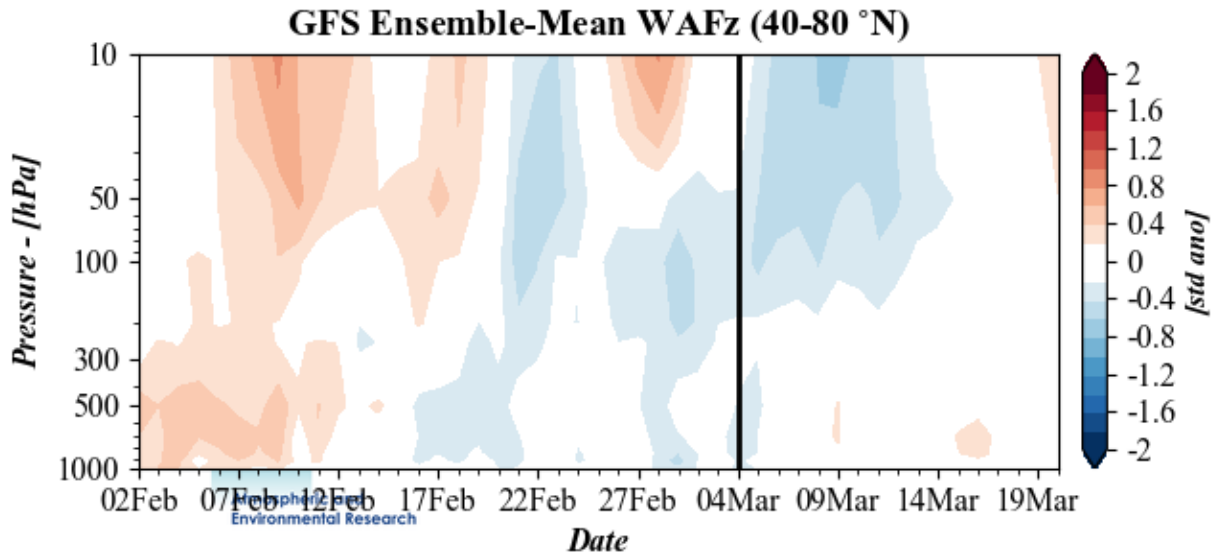
*30-day*

The latest plot of the polar cap geopotential heights (PCHs) currently shows in general normal to above normal PCHs in the lower stratosphere and upper troposphere with normal to below normal PCHs in both the mid stratosphere and the lower troposphere (**Figure 10**). However, for later this week the forecast is for normal to below PCHs extending from the stratosphere to the troposphere. The predicted below normal PCHs in the lower 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 positive stratospheric AO for the next two weeks (**Figure 1**).



**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 4 March 2019 GFS ensemble.

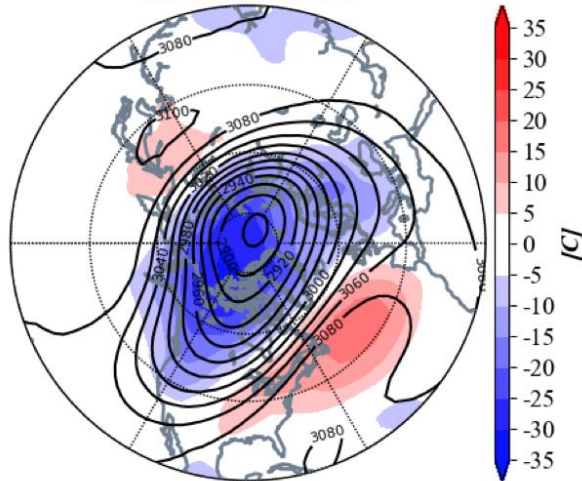
The positive PCHs in the lower stratosphere appear to be related to downward propagation of circulation anomalies related to the sudden stratospheric warming (SSW) and a major mid-winter warming (MMW; where the zonal mean zonal wind reverses from westerly to easterly at 60°N and 10 hPa) back in early January. Based on the latest PCH plot it does look as if any influence from the SSW in early January on the atmospheric circulation will finally come to an end this first week of March. It has been shown previously that the impact of the SSW on the weather can be from four to eight weeks. I would argue that the influence of the SSW on our weather likely went the full eight weeks, at least across North America.



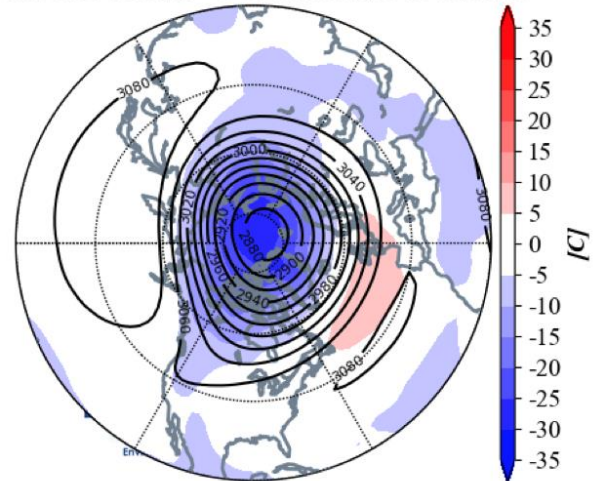
**Figure 11.** Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 4 March 2019 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows mostly below normal WAFz for the next two weeks (**Figure 11**). This is predicted to favor further cooling of the stratospheric PCHs that couples to the troposphere this week. Negative PCHs in the troposphere and the positive AO favor mild temperatures in the Eastern US and Europe. Though the forecast is milder for the Eastern US than Northern Europe starting next week.

**a) GEFS 10 mb GPH & T Anomaly  
INIT: 00Z 03/04/19**

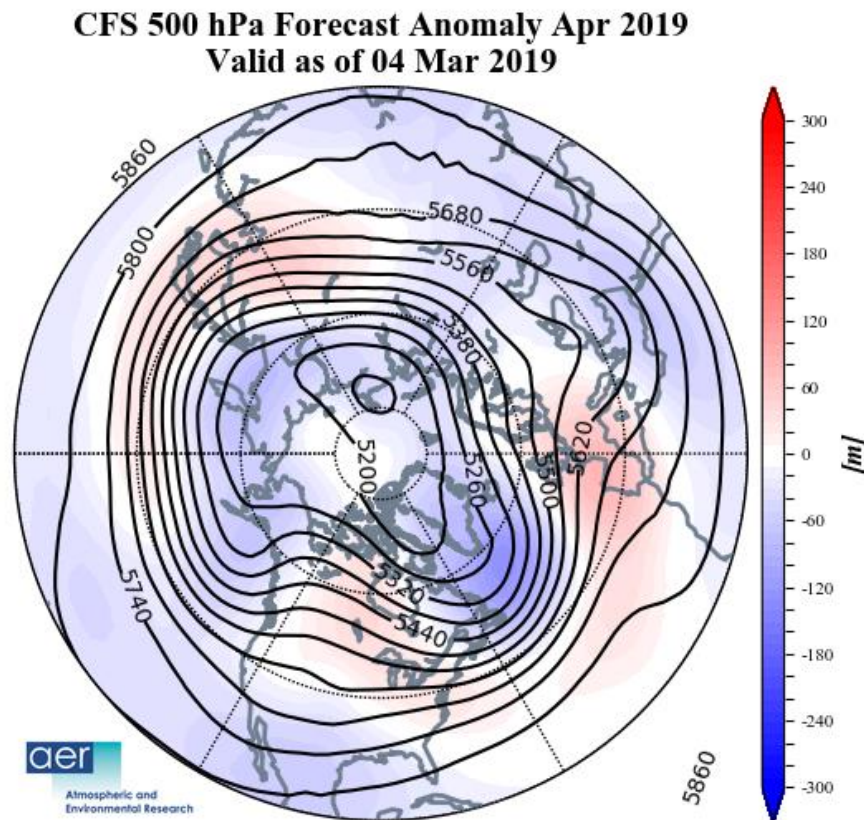


**b) GEFS 11-15 Day Forecast 10 mb GPH & T Anomaly  
INIT: 00Z 03/04/19 FCST: 03/15/19 to 03/19/19**



**Figure 12. (a)** Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies ( $^{\circ}\text{C}$ ; shading) across the Northern Hemisphere for 4 March 2019. **(b)** Same as **(a)** except forecasted averaged from 15 – 19 March 2019. The forecasts are from the 00Z 4 March 2019 GFS operational model.

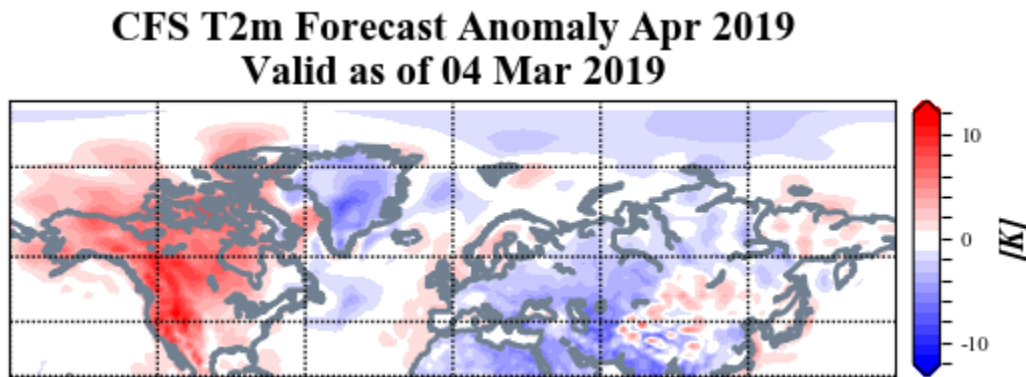
The stratospheric PV is currently centered close to the North Pole and is predicted to remain there over the next two weeks (**Figure 12**). The coldest temperatures in the stratosphere are focused in the Arctic and is consistent with a strong stratospheric PV. This pattern typically favors relatively mild temperatures across the mid-latitudes.



**Figure 13.** Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for April 2019. The forecasts are from the 4 March 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 April from the Climate Forecast System (CFS; the plots represent yesterday’s four ensemble members). The forecast for the troposphere is ridging centered in Northern Canada, the Eastern US, Europe and East Asia with troughs in western North America, Greenland, Siberia and Western Asia (**Figure 13**). This pattern favors cold temperatures for Northern and Western Asia, the Middle East, Northern India and Eastern Canada with relatively mild temperatures for

much of North America and East Asia (**Figure 14**). The widespread cold temperatures across Eurasia are likely overdone.

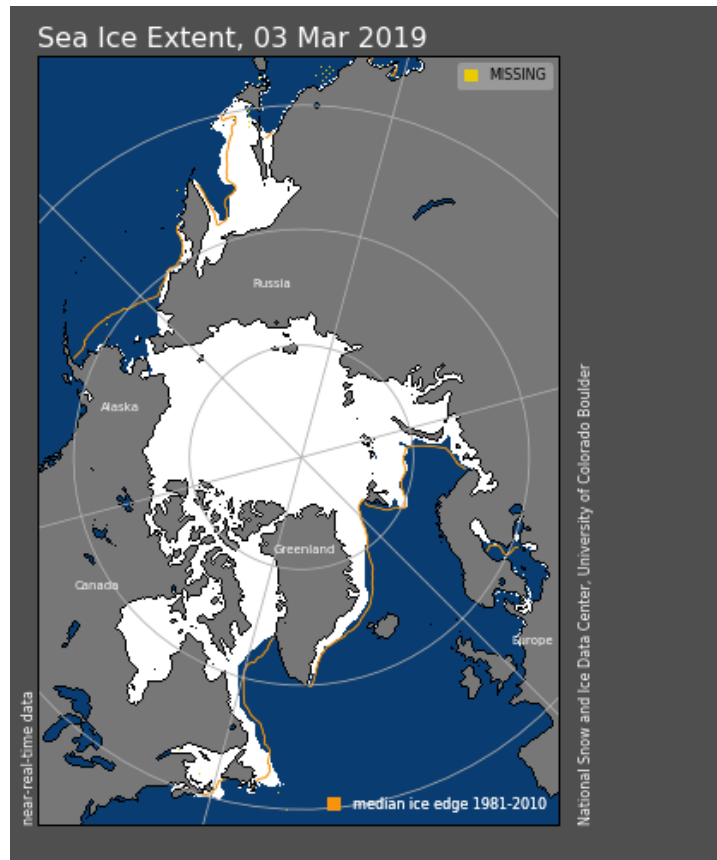


**Figure 14.** Forecasted average surface temperature anomalies ( $^{\circ}\text{C}$ ; shading) across the Northern Hemisphere for April 2019. The forecasts are from the 4 March 2019 CFS.

#### *Surface Boundary Conditions*

##### *Arctic Sea Ice*

Arctic sea ice growth rate abruptly ended this week and remains well below normal. The region with the largest negative departures is the Bering Sea (**Figure 13**). The large negative anomalies in the Bering may help shift the greatest Arctic warming closer to Alaska. 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.

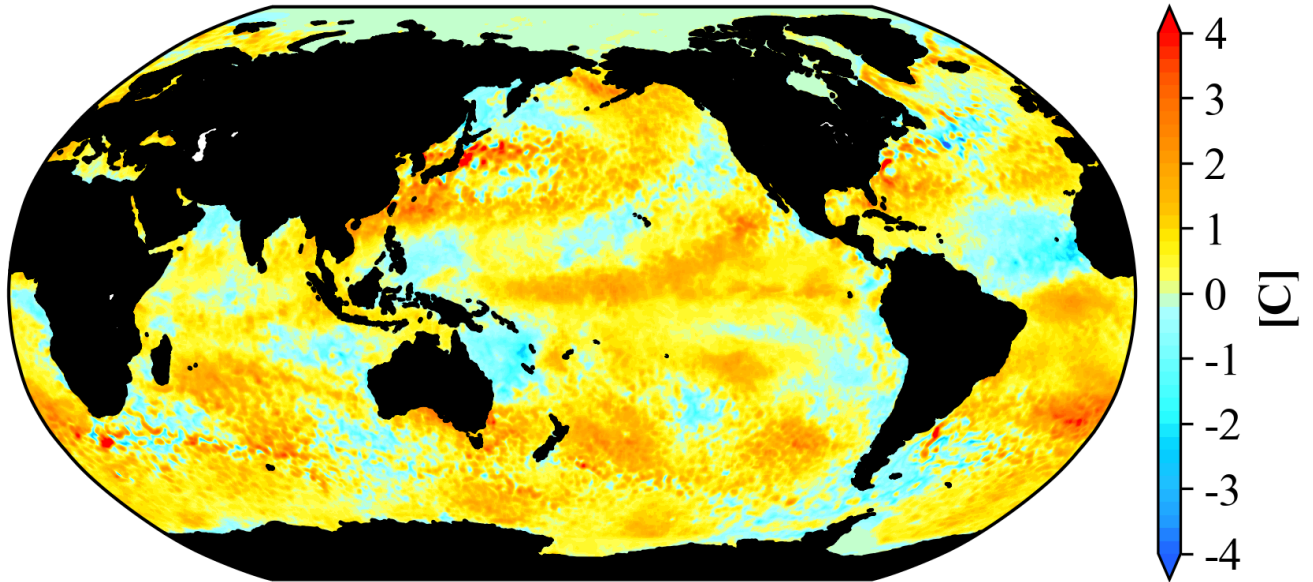


**Figure 15.** Observed Arctic sea ice extent on 17 February 2019 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

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

Equatorial Pacific sea surface temperatures (SSTs) anomalies remain warm and NOAA has declared the return of 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 NAO.

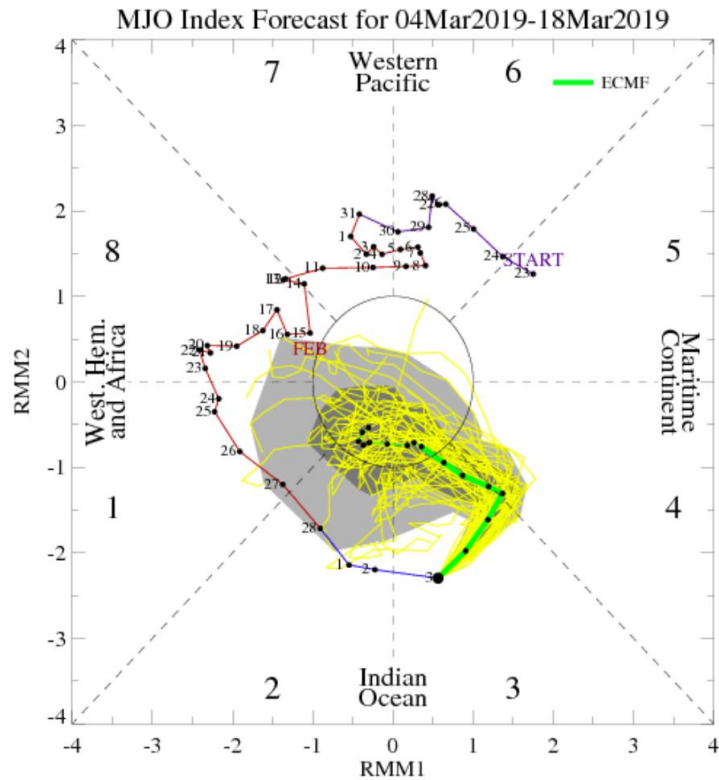
## SST Anomaly - Week Ending 03 Mar 2019



**Figure 16.** The latest weekly-mean global SST anomalies (ending 3 March 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 three of the Madden Julian Oscillation (MJO) is favored (**Figure 14**). However the MJO is expected to transition to where no phase is favored. Phase three favors troughing over eastern North America with cold temperatures and ridging over northwestern North America with mild temperatures. This is consistent with short term model forecasts.



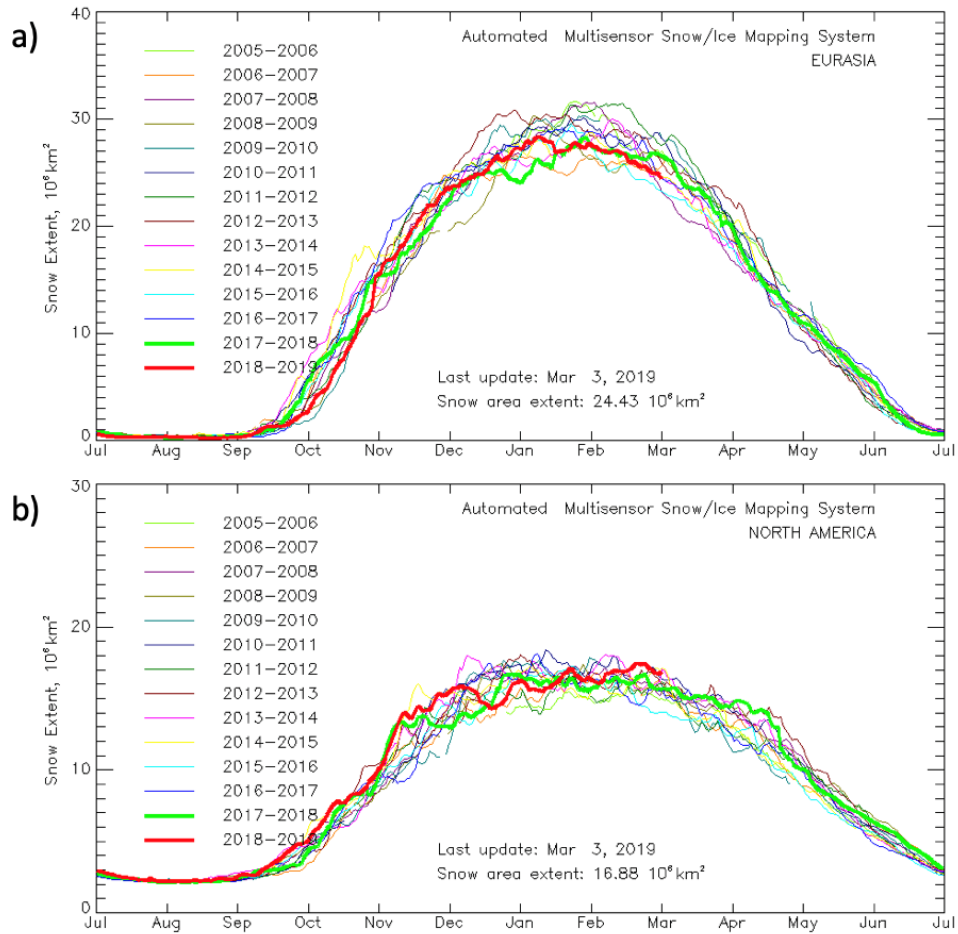


**Figure 17.** Past and forecast values of the MJO index. Forecast values from the 00Z 4 March 2019 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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 may have ended across Eurasia for this winter season and has begun to decline and is near decadal means.



**Figure 18.** Observed Eurasian (top) and North American (bottom) snow cover extent through 17 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 stayed near a decadal high mostly helped by above normal snow cover in the Western US. Snow cover will likely begin its seasonal decline by the end of the week.