

February 25, 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.
- The current positive AO is reflective of mostly negative pressure/geopotential height anomalies across the 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 with normal to above normal temperatures across much of Europe including the United Kingdom (UK) this week but then retreat across Southern Europe by next week. However, with troughing/negative geopotential height anomalies across the north and ridging to the south will create a mild, maritime westerly flow of air across much of Europe for next week and possibly beyond.
- In general, ridging/positive geopotential height anomalies with normal to above normal temperatures across East Asia with troughing/negative geopotential height anomalies with seasonable to below normal temperatures across Siberia

and Southern Asia including the Middle East, Northern Indiana and Pakistan are predicted for the next two weeks.

- This week and into next week, ridging/positive geopotential height anomalies centered across Alaska are predicted to force downstream troughing/negative geopotential height anomalies and relatively cold temperatures across much of Canada and the United States (US) with ridging and relatively mild temperatures for the deep Southern US. Some of the cold air in Eastern Canada will seep into the Northeastern US this week. However, the second week of March the ridging/positive geopotential height anomalies over Alaska are predicted to sink south of the Aleutians once again focusing the troughing/negative geopotential height anomalies and relatively cold temperatures across western North America with ridging/positive geopotential height anomalies and milder temperatures building in the Eastern US.
- In the *Impacts* section, I discuss my thoughts for March given that the influence of the polar vortex (PV) split from early January seems to be finally winding down.

Impacts

As I have written many times in the blog this fall and winter season the influence of a significant stratospheric PV disruption typically lasts on the order of four to eight weeks. It certainly looks like the PV split from early January has gone the distance and has persisted for a full eight weeks or possibly even a little longer. Based on the latest polar cap geopotential heights (PCHs) forecast the whole event is winding down over the next week or so. Therefore, I think that we can start to draft the obituary for this event.

The stratosphere-troposphere coupling differed from last year's PV split and other previous similar events but certainly not all. Though the "dripping" of warm PCHs occurred periodically, there were long gaps between "drips" where the tropospheric PCHs even turned cold for an appreciable period. Also, the AO and NAO never turned strongly negative nor was there any persistent period where both indices remained in negative territory. This is in strong contrast to last winter. As I wrote in last week's blog, I think at least part of the reason might be the relatively cold central Arctic this winter compared with the last several winters where the Arctic was near or at record warm.

Though despite what could be considered atypical or less traditional stratosphere-troposphere coupling following the stratospheric PV split, I would argue there were still some impressive impacts on the weather. Maybe those impacts were more discernable and more impressive across North America than Eurasia, but both continents had record cold and snow. In **Figure i**, I show the Northern Hemisphere (NH) surface temperatures before and after the impact of the PV split. There was a large swing in temperatures centered in the interior of the North American continent from strongly

positive to strongly negative accompanied by well above normal to record snowfall in regions.

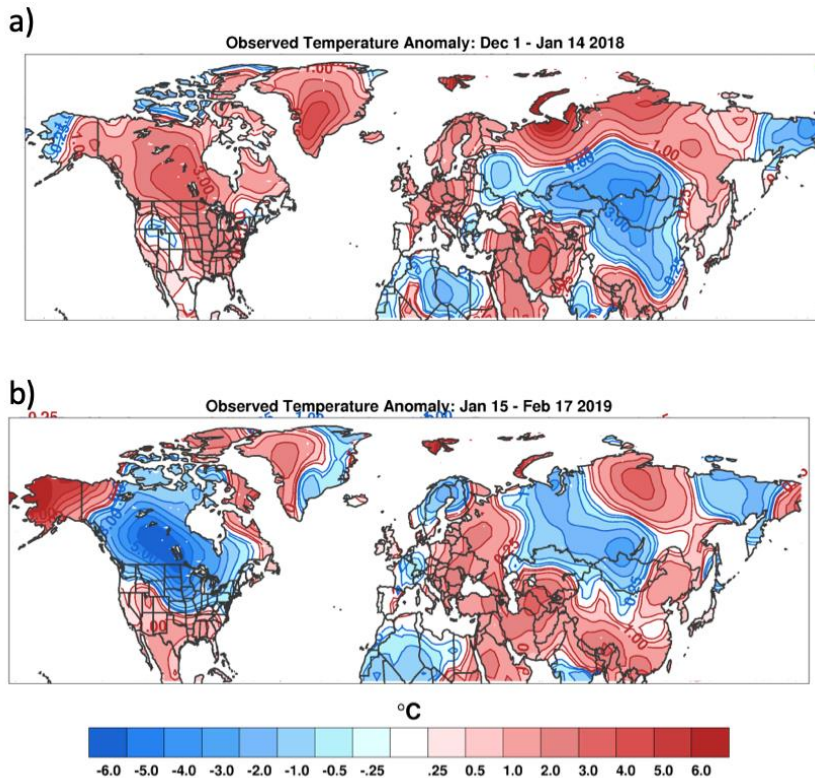


Figure i. a) Observed surface temperature anomalies (shading) for December 1, 2018 - January 14, 2019. b) Observed surface temperature anomalies (shading) for January 15 - February 17, 2019.

So, what to expect as the who stratosphere-troposphere coupling event wraps up. For Europe, temperatures are already mild and with the AO predicted to remain positive and could potentially turn even more strongly positive if the cold PCHs couple all the way to the surface, it is hard for me to see a return to any kind of prolonged cold this month. Across North America it is more complicated. Cold temperatures are predicted to be expansive across the continent and even record cold is possible over the next week or so. In addition, snow cover is relatively extensive and, in many locations, unusually deep especially on either side of the US-Canadian border. I don't expect the cold air across in North America to simply disappear anytime soon, but if the if the cold PCHs couple all the way to the surface, this would favor the cold temperatures being mostly confined to western North America. I also feel that circulation and temperature anomalies in the stratosphere suggest a relatively cold western North America and relatively mild eastern North America especially Eastern US. And despite the cold start to March in the Eastern US the models are predicting a return to mild conditions by the middle of March.

But one important caveat - I believe that when the models suggest a pattern change, they are often correct however they are also premature in predicting the change. So, I could see the cold in the Eastern US lingering longer than predicted by the models. Maybe an early hint of this, the GFS is less bullish today of the cold tropospheric PCHs and Eastern US the second week of March today compared to yesterday.

Near Term Conditions

1-5 day

The AO is positive (**Figure 1**), with mostly negative pressure/geopotential height anomalies across the Arctic and 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.

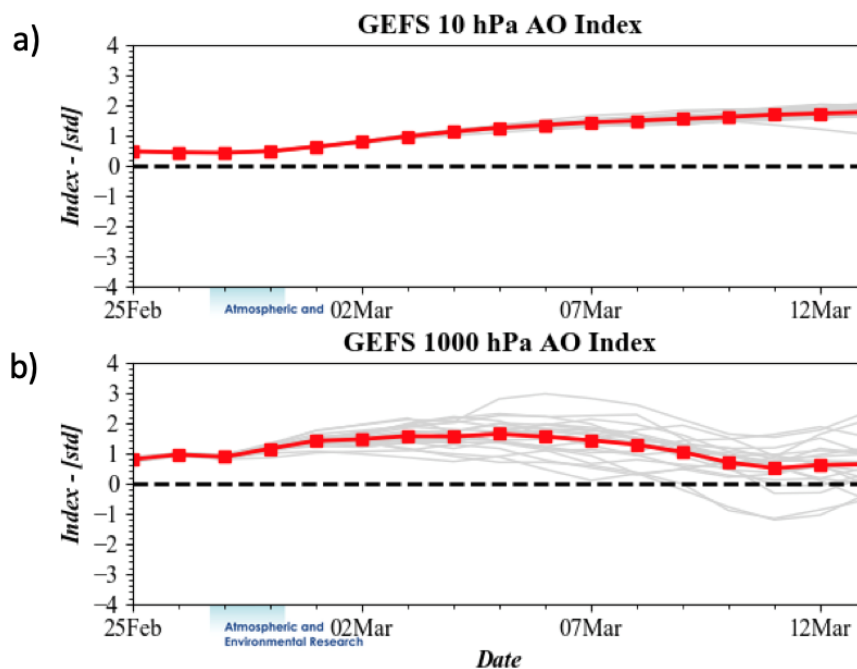


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 25 February 2019 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 25 February 2019 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Currently ridging/positive geopotential height anomalies centered over Western Europe 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 East Asia with troughing/negative geopotential height anomalies in Western and Southern Asia and Northern Siberia (**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 Northern Siberia, Northwest Asia, the Middle East, Northern India and into Pakistan (**Figure 3**).

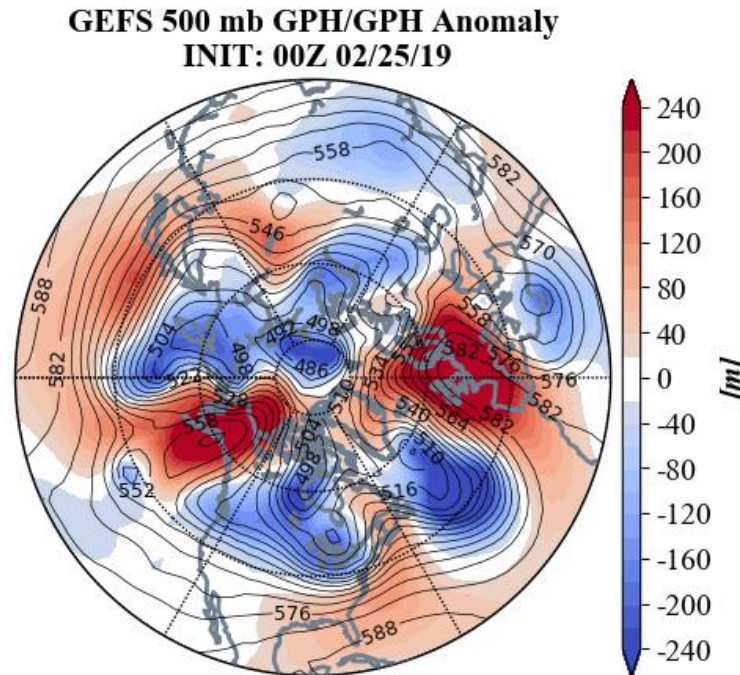


Figure 2. Observed 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) for 00Z 25 February 2019.

Ridging/positive geopotential height anomalies across Alaska are forcing downstream troughing/negative geopotential height anomalies across western North America and along the US/Canadian border with more ridging/positive geopotential height anomalies across the Southeastern US (**Figure 2**). This pattern is predicted to result in normal to below normal temperatures for much of Canada and the Western and Northern US with normal to above normal temperatures for Alaska and the Southeastern US (**Figure 3**).

GEFS 1-5 Day Forecast T2m Anomaly
INIT: 00Z 02/25/19 FCST: 02/26/19 to 03/02/19

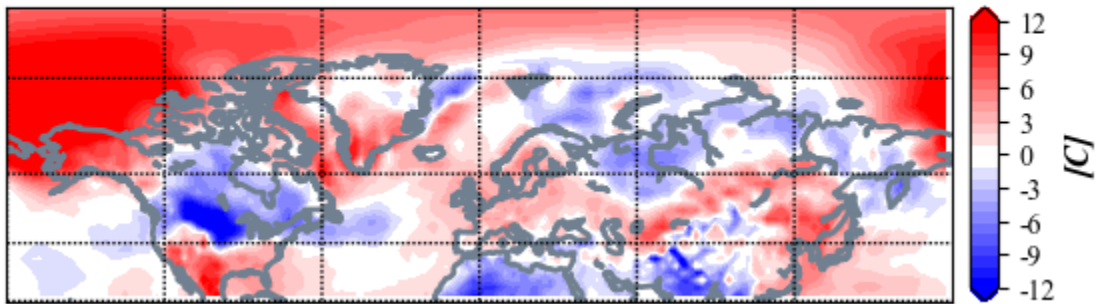


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 26 February – 2 March 2019. The forecast is from the 00Z 25 February 2019 GFS ensemble.

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

GEFS 1-5 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 02/25/19 FCST: 02/26/19 to 03/02/19

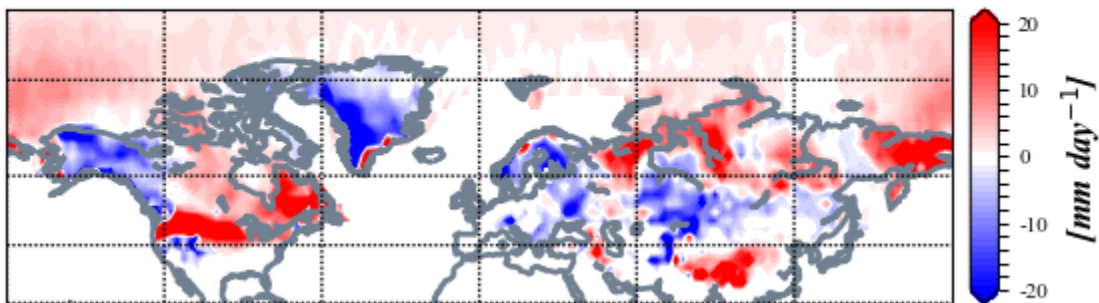


Figure 4. Forecasted snowfall anomalies (mm/day ; shading) from 26 February – 2 March 2019. The forecast is from the 00Z 25 February 2019 GFS ensemble.

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 mixed 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.

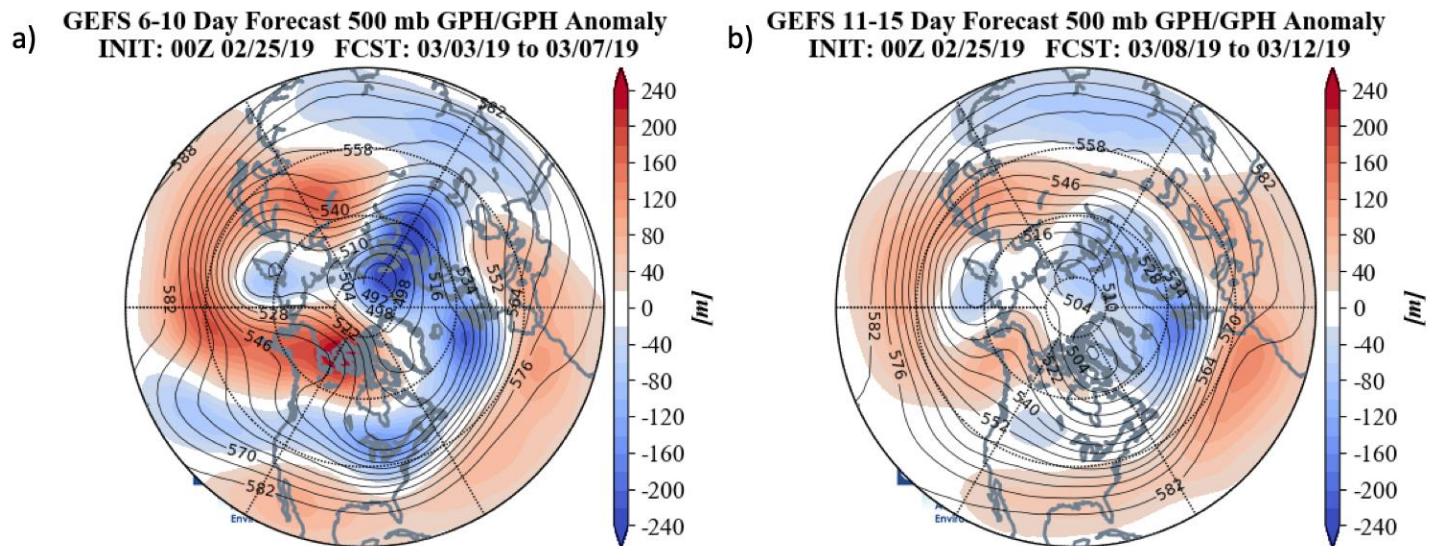


Figure 5. (a) Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 3 – 7 March 2019. (b) Same as (a) except averaged from 8 – 12 March 2019. The forecasts are from the 25 February 2019 00z GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to continue to dominate much of Southern Europe with the return of troughing/negative geopotential height anomalies across Northern Europe this period (**Figure 5a**). Induced westerly between low heights to the north with high heights to the south are predicted to result in normal to above normal temperatures widespread across Europe including the UK while the low heights could yield normal to below normal temperatures for far northern Scandinavia (**Figure 6**). The overall pattern across Asia is predicted to persist with ridging/positive geopotential height anomalies in East Asia with troughing/negative geopotential height anomalies across Western Asia, 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 02/25/19 FCST: 03/03/19 to 03/07/19

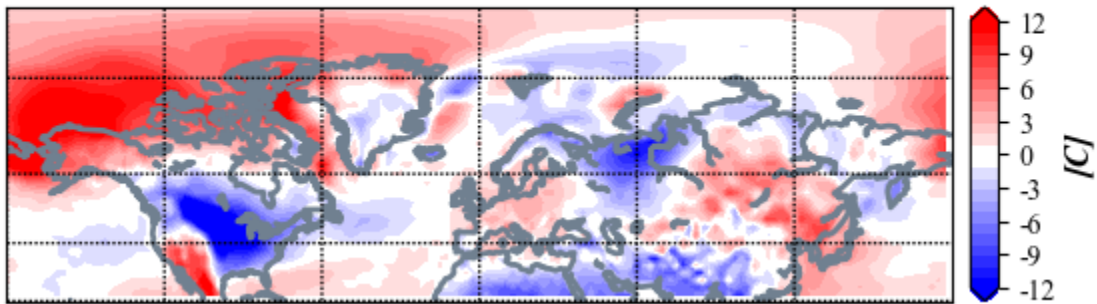


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 3 – 7 March 2019. The forecasts are from the 00Z 25 February 2019 GFS ensemble.

Ridging/positive geopotential height anomalies across Alaska will continue to anchor troughing/negative geopotential height anomalies in Western Canada and the Northern US with more ridging/positive geopotential height anomalies across the Southern US (**Figure 5a**). The resultant temperature anomalies across North America are predicted to be normal to below normal temperatures across much of Canada and the Northern and Eastern US with normal to above normal temperatures for Alaska, the Southwestern US and Florida (**Figure 6**).

GEFS 6-10 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 02/25/19 FCST: 03/03/19 to 03/07/19

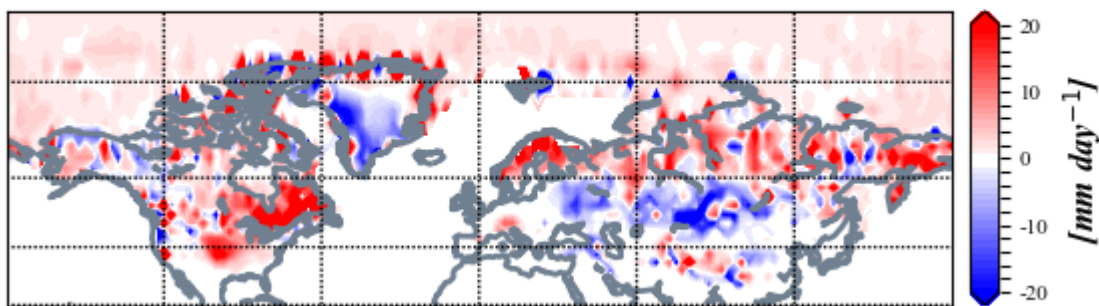


Figure 7. Forecasted snowfall anomalies (mm/day ; shading) from 3 – 7 March 2019. The forecasts are from the 00Z 25 February 2019 GFS ensemble.

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

11-15 day

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

Continued ridging/positive geopotential height anomalies across Southern Europe with troughing/negative geopotential height anomalies across Northern Europe (**Figure 5b**) will persist a westerly flow of relatively mild air across the continent and result in normal to above normal temperatures for much of Europe including the UK once again with the exception of Scandinavia where persistent low height anomalies will result in normal to below normal temperatures (**Figure 8**). Little change is predicted in the circulation pattern across Asia with troughing/negative geopotential height anomalies across Western Asia that extends east 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, including much of Siberia with normal to above normal temperatures for East Asia (**Figure 8**). Persistent troughing/negative geopotential height anomalies that extends from the Middle East and across Northern India and even into Southeast Asia (**Figure 5a**) are predicted to yield normal to below normal temperatures for the Middle East, Northern India, Pakistan and Southeast Asia (**Figure 6**).

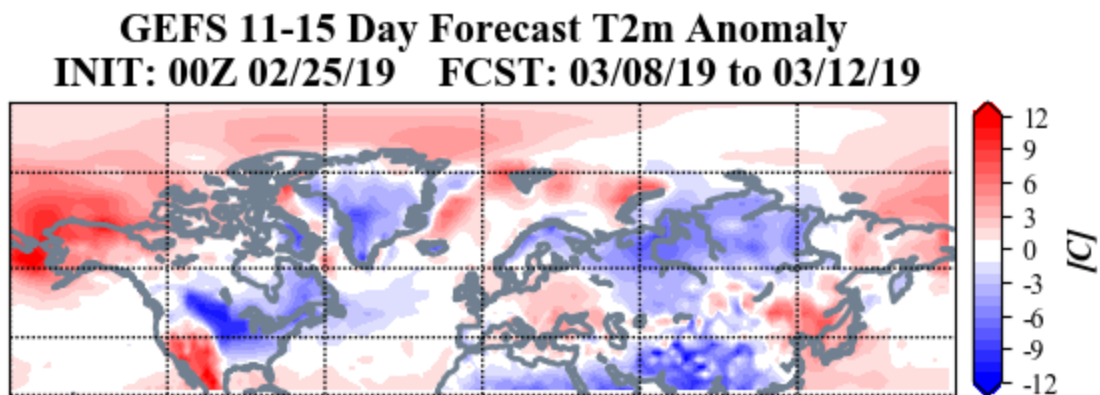


Figure 8. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 8 – 12 March 2019. The forecasts are from the 00Z 25 February 2019 GFS ensemble.

Ridging/negative geopotential height anomalies centered across Alaska will continue to support troughing/negative geopotential height anomalies across western North America and Eastern Canada with ridging/negative geopotential height anomalies building 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, Northwestern Canada, the Southwestern US and Florida (**Figure 8**).

GEFS 11-15 Day Forecast Mean 24-hour Snow Depth Change
INIT: 00Z 02/25/19 FCST: 03/08/19 to 03/12/19

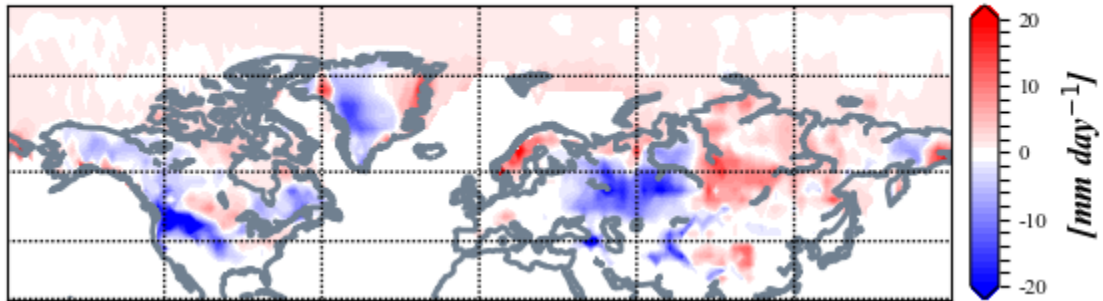


Figure 9. Forecasted snowfall anomalies (mm/day; shading) from 8 – 12 March 2019. The forecasts are from the 00Z 25 February 2019 GFS ensemble.

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

Longer Term

30-day

The latest plot of the polar cap geopotential heights (PCHs) shows in general predicted normal to above normal PCHs in the lower stratosphere and upper troposphere with normal to below normal PCHs in both the mid stratosphere and the lower troposphere over the next week (**Figure 10**). For the second week of March the forecast is for normal to below PCHs in both the stratosphere and troposphere. The 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**).

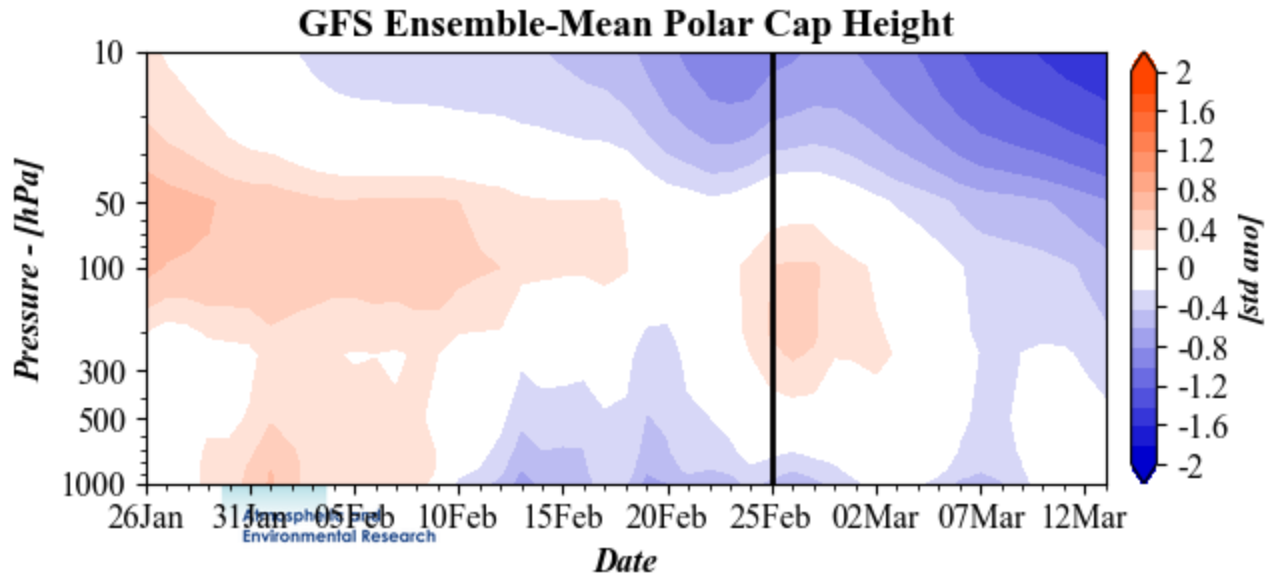


Figure 10. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 25 February 2019 GFS ensemble.

As I argued in the *Impacts* section, 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. The argument could be made that the impact of the SSW on the weather will finally end in early 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 will likely continue into March and is the full eight weeks, at least across North America. The PV split created favorable conditions for the buildup of cold air in western North America that is predicted to persist and expand east in early March.

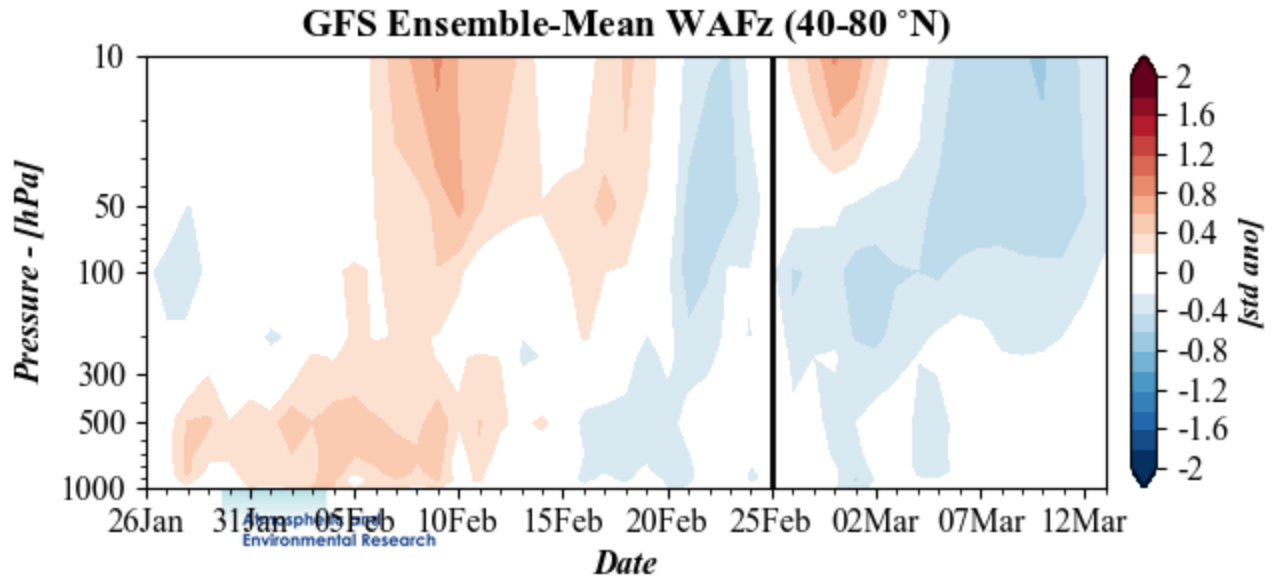
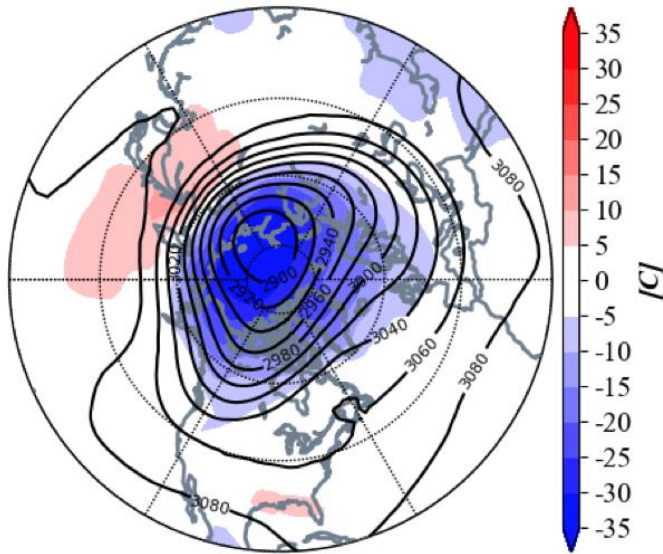


Figure 11. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 25 February 2019 GFS ensemble.

The plot of Wave Activity Flux (WAFz) or poleward heat transport shows a short positive pulse this week but otherwise below normal WAFz for the next two weeks (**Figure 11**). This could be interpreted as a reflective wave with upward WAFz last week bouncing off the stratospheric PV and reflecting back down into the troposphere. Such relatively minor polar stratospheric warmings tend to favor cold in Central and Eastern North America, which is now predicted by the models. However, the core of the cold temperatures over western North America in the stratosphere could suggest a westward shift of the cold anomalies. As I wrote last week, I do admit that I am ambivalent whether to attribute the predicted return of cold to the Eastern US as one last hurrah of the PV split back in January or due to a new reflective perturbation of the stratospheric PV, or maybe both.

a) GEFS 10 mb GPH & T Anomaly
INIT: 00Z 02/25/19



b) GEFS 6-10 Day Forecast 10 mb GPH & T Anomaly
INIT: 00Z 02/25/19 FCST: 03/03/19 to 03/07/19

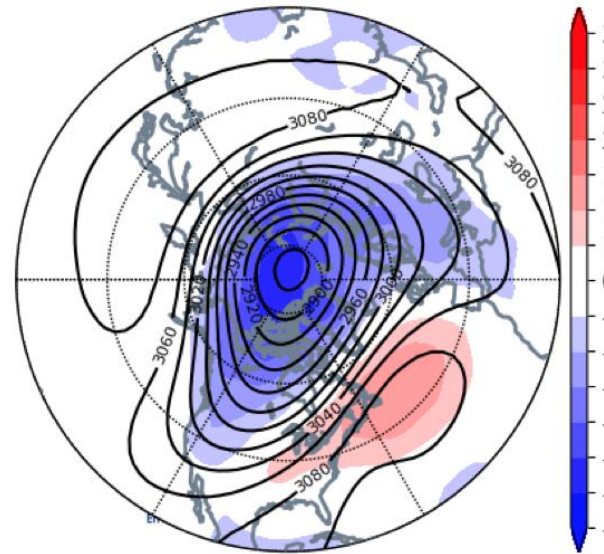


Figure 12. (a) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for 25 February 2019. (b) Same as (a) except forecasted averaged from 3 – 7 March 2019. The forecasts are from the 00Z 25 February 2019 GFS operational model.

The stratospheric PV is currently centered over the Laptev Sea (**Figure 12**). The coldest temperatures in the stratosphere are focused in Northern Siberia and Western Canada and seems to be co-located with the coldest temperatures at the surface. Based on the stratospheric anomalies the cold may continue to be focused in these same regions as well during the remainder of the month of February and into early March.

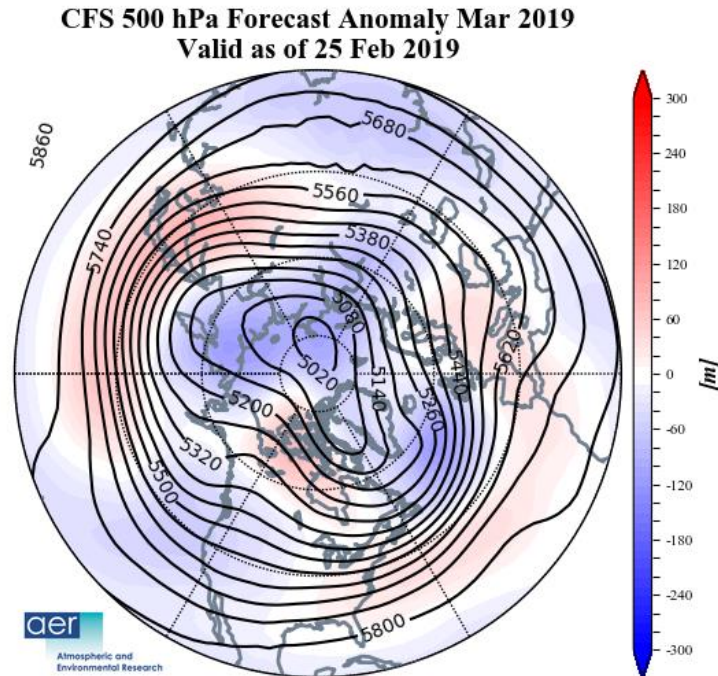


Figure 13. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for March 2019. The forecasts are from the 25 February 2019 CFS.

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 Northern Canada, the Eastern US, Europe and East Asia with troughs in the Western US, Greenland, Siberia, Western Asia (**Figure 13**). This pattern favors cold temperatures for Northern and Western Asia but especially Siberia, the Middle East, Northern India, the Central US and Eastern Canada with relatively mild temperatures for much of western North America, the Southeastern US, Europe and East Asia (**Figure 14**). I think there is much uncertainty with the forecast.

CFS T2m Forecast Anomaly Mar 2019 Valid as of 25 Feb 2019

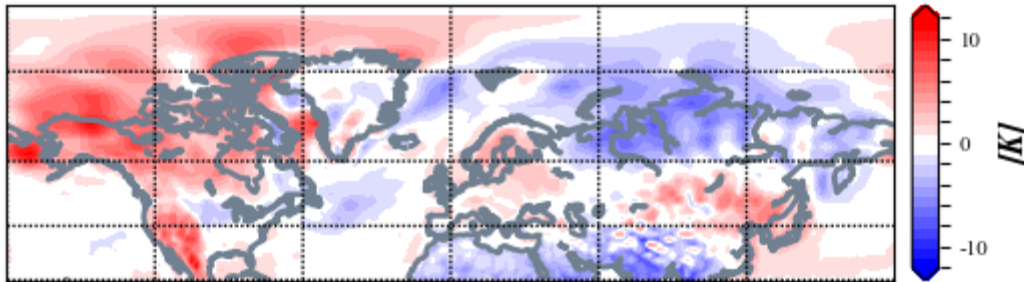


Figure 14. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for March 2019. The forecasts are from the 25 February 2019 CFS.

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. However due to colder temperatures in the Barents-Kara Seas and warmer temperatures in the Bering Sea, the anomalies in the Bering sea are now the greatest negative departures and may help shift the greatest Arctic warming closer to Alaska. 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 also 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.

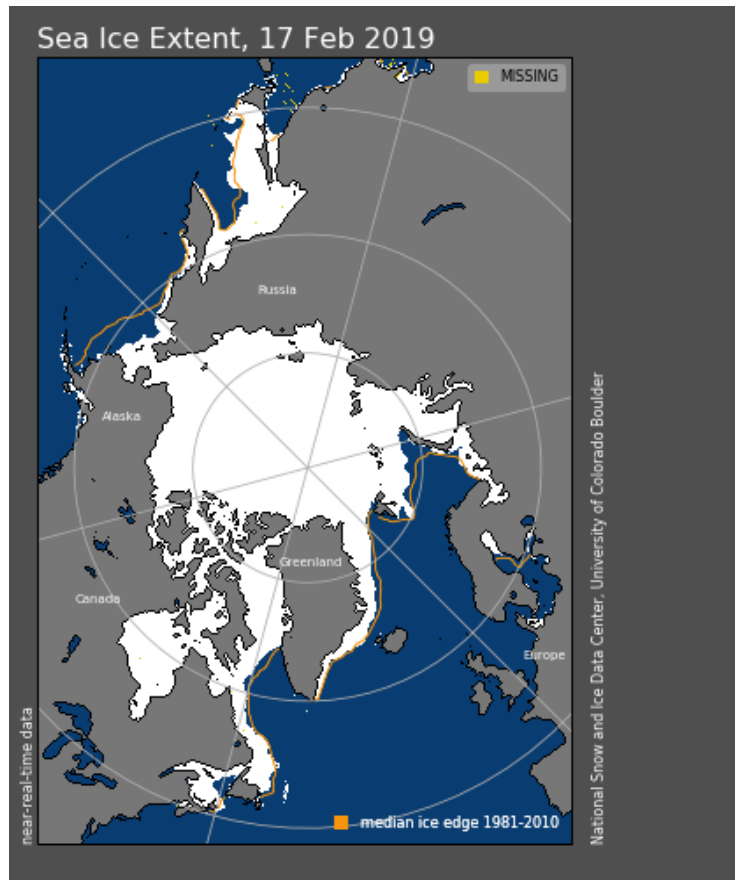


Figure 15. Observed Arctic sea ice extent on 17 February 2019 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC). Snow and Ice Data Center (NSIDC).

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 winter NAO.

SST Anomaly - Week Ending 24 Feb 2019

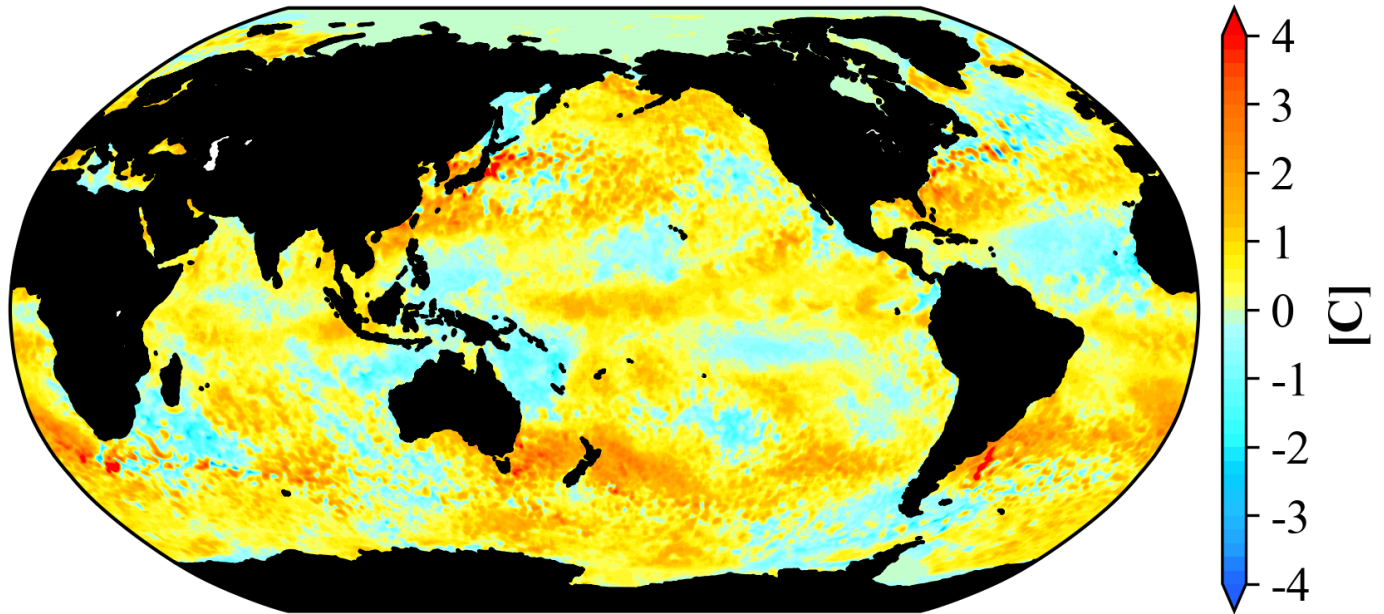


Figure 16. The latest weekly-mean global SST anomalies (ending 24 February 2019). Data from NOAA OI High-Resolution dataset. (Updated from https://www.ospo.noaa.gov/Products/ocean/sst/anomaly/anim_full.html due to US Government shutdown).

Currently phase one of the Madden Julian Oscillation (MJO) is favored (**Figure 14**). However the MJO is expected to transition to phase two and then three. Phase one favors troughing over eastern North America with cold temperatures and ridging over western North America with mild temperatures. However phases two and three favor the opposite ridging over eastern North America with mild temperatures and troughing over western North America with cold temperatures. This is consistent with model forecasts.

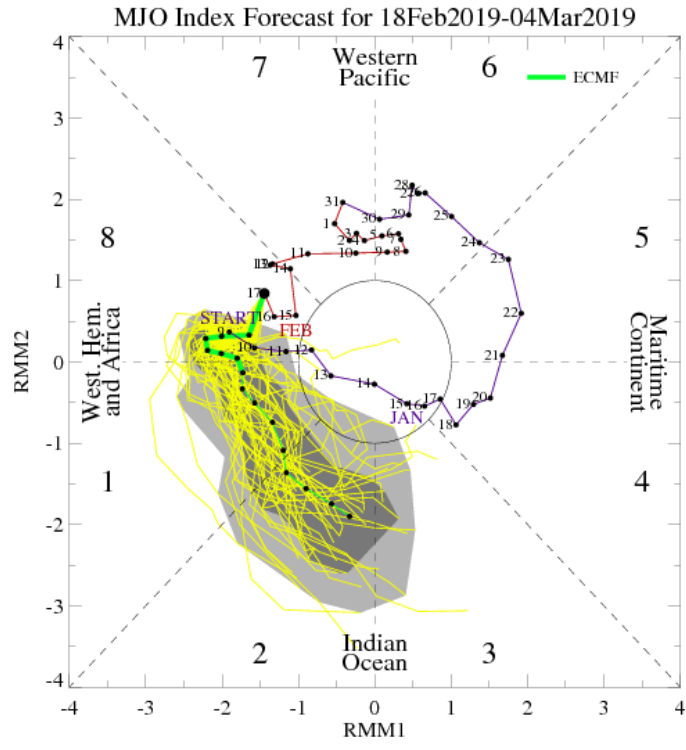


Figure 17. Past and forecast values of the MJO index. Forecast values from the 00Z 11 February 2019 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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 may have ended across Eurasia for this winter season and has begun to decline and is near decadal lows. Snow cover advance could advance is unlikely in the next couple of weeks as Europe remains mild. 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.

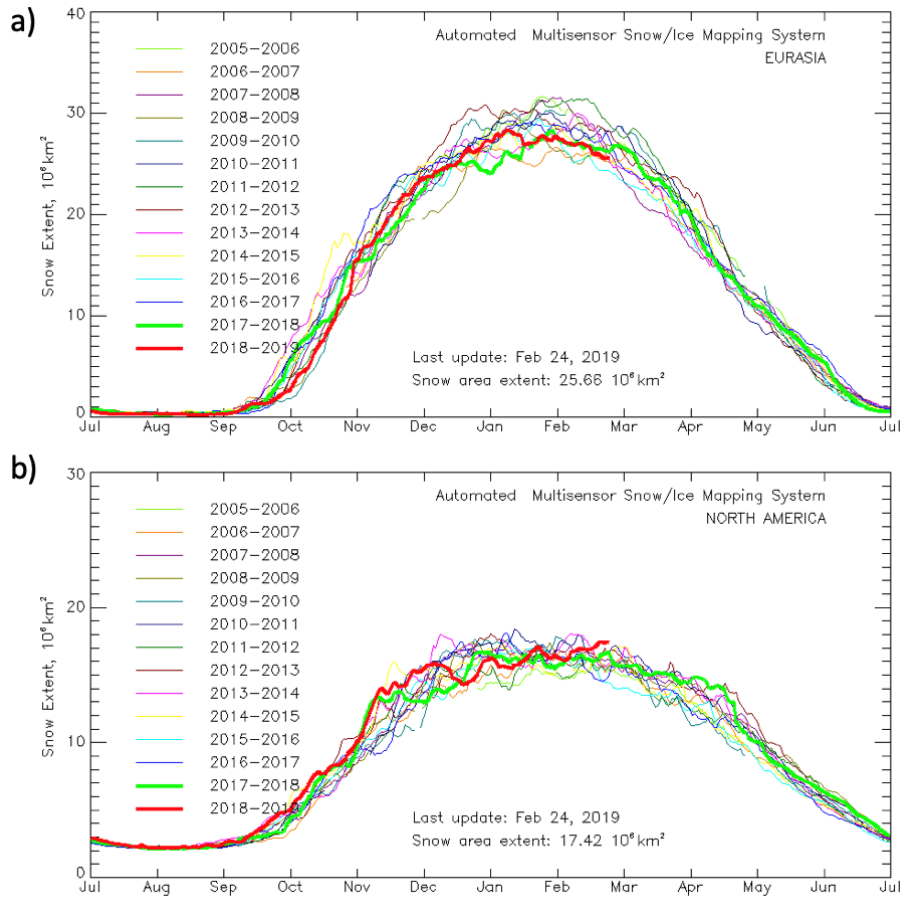


Figure 18. Observed Eurasian (top) and North American (bottom) snow cover extent through 17 February 2019. Image source:

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

North American snow cover has increased and is at a decadal high mostly helped by above normal snow cover in the Western US. Snow cover could advance further as cold air becomes more widespread across the continent.