

April 29, 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.

Subscribe to our email list or follow me on Twitter (@judah47) for notification of updates.

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

Summary

- The Arctic Oscillation (AO) is currently slightly negative and is predicted to remain neutral to negative over the next two weeks.
- The current slightly negative AO is reflective of mostly positive pressure/geopotential height anomalies across the Arctic especially on the North Atlantic side of the Arctic and mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is more strongly negative as currently positive pressure/geopotential height anomalies are spread across Greenland and Iceland and is predicted to remain mostly negative over the next two weeks.
- Ridging/positive geopotential height anomalies across Greenland are predicted to force troughing/negative geopotential height anomalies downstream across

Europe. This pattern favors relatively cool temperatures across the continent including the United Kingdom (UK).

- Currently ridging/positive geopotential height anomalies across the Arctic is forcing troughing/negative geopotential height anomalies with normal to below normal temperatures across Northern Asia especially Siberia. However, over the next week or so that cold air will split into two pieces with one piece spreading into Europe and the other piece spreading into Eastern Asia while moderating. By week two ridging/positive geopotential height anomalies and normal to above normal temperatures are predicted to dominate Western and Northern Asia.
- Over the next two weeks ridging/positive geopotential height anomalies with relatively mild temperatures across Greenland and much of the North American Arctic are predicted to force troughing/negative geopotential height anomalies and relatively cool temperatures to the south across Canada and the Northern United States (US). Ridging/positive geopotential height anomalies are predicted over the next two weeks across the Southern and Eastern US with relatively warm temperatures.
- In the *Impacts* section I discuss the surprising troposphere-stratosphere-troposphere coupling of late April and early May.

Impacts

I hadn't intended to post a new blog today, but I felt compelled to do so with the unusual behavior of the stratosphere and coupling with the troposphere. Two different phenomena I expected with spring, which I expressed in earlier blog posts. The first is cold polar cap geopotential height anomalies (PCHs) in the stratosphere due to radiative cooling from increased greenhouse gases in the stratosphere and the second was aggressive warming across the continents at least in part due to rapidly disappearing snow and ice in the high latitudes. So far neither has happened.

Instead of cold stratospheric PCHs, warm PCHs are predicted associated with the Final Warming in the stratosphere (defined as when the stratospheric PV disappears for the summer and winds are persistently easterly at 60°N and 10 hPa). Though the Final Warming occurs due to increasing solar radiation in the polar stratosphere, this year's Final Warming appears to be in large part due to dynamic warming of the polar stratosphere. The sea level pressure anomaly for the month of April (**Figure i**) is similar to November and December 2018 exhibiting strong Scandinavian blocking/high pressure sandwiched by low pressure in the North Atlantic and North Pacific ocean basins forming a tripole pressure anomaly pattern (compare with Figure 3 from the winter 2018/19 winter retrospective <https://www.aer.com/siteassets/ao-archives/winter-2019-recap.pdf> that is so favorable for increased Wave Activity Flux (WAFz) or poleward heat transport. And April WAFz has been unusually active during the month of April (see below **Figure 11**). The active WAFz is predicted to warm the

PCHs in the stratosphere (see below **Figure 10**) resulting in a negative stratospheric AO (see below **Figure 1**). The warm/positive stratospheric PCHs are predicted to descend with time into the troposphere resulting in a negative tropospheric AO (see below **Figure 1**). The warm tropospheric PCHs are characterized by strong Greenland blocking (see below **Figures 2&5**) something absent from the stratospheric PV disruption back in January.

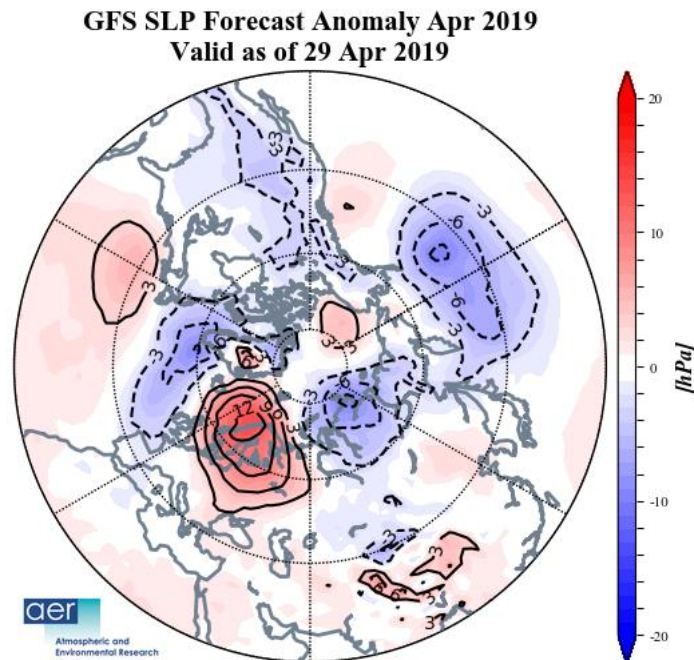


Figure i. Observed sea level pressure (SLP) anomalies from 1 April - 29 April 2019. To complete the month of April the GFS predicted SLP anomaly for 30 April 2019 is included.

Final Warmings are not my expertise, but I am surprised to observe what appears to be very robust troposphere-stratosphere-troposphere coupling so late in the season and for it to apparently have the classic tropospheric signature of Greenland blocking and cold temperatures both in Europe and North America. Though it does seem that such an event is not unprecedented. I thank @nitzancohen for pointing out to me that something similar occurred in May 1997. I include the PCHs for all of 1997 (**Figure ii**) and I was surprised to see that the most impressive warming of the stratospheric PCHs for that entire year took place in May. The warm/positive PCHs in the lower troposphere lasted for about a month from early May until early June. Observed temperature anomalies from May 5 through June 5, 1997 shows below normal temperatures in eastern North America and Northern Europe for that period (**Figure iii**).

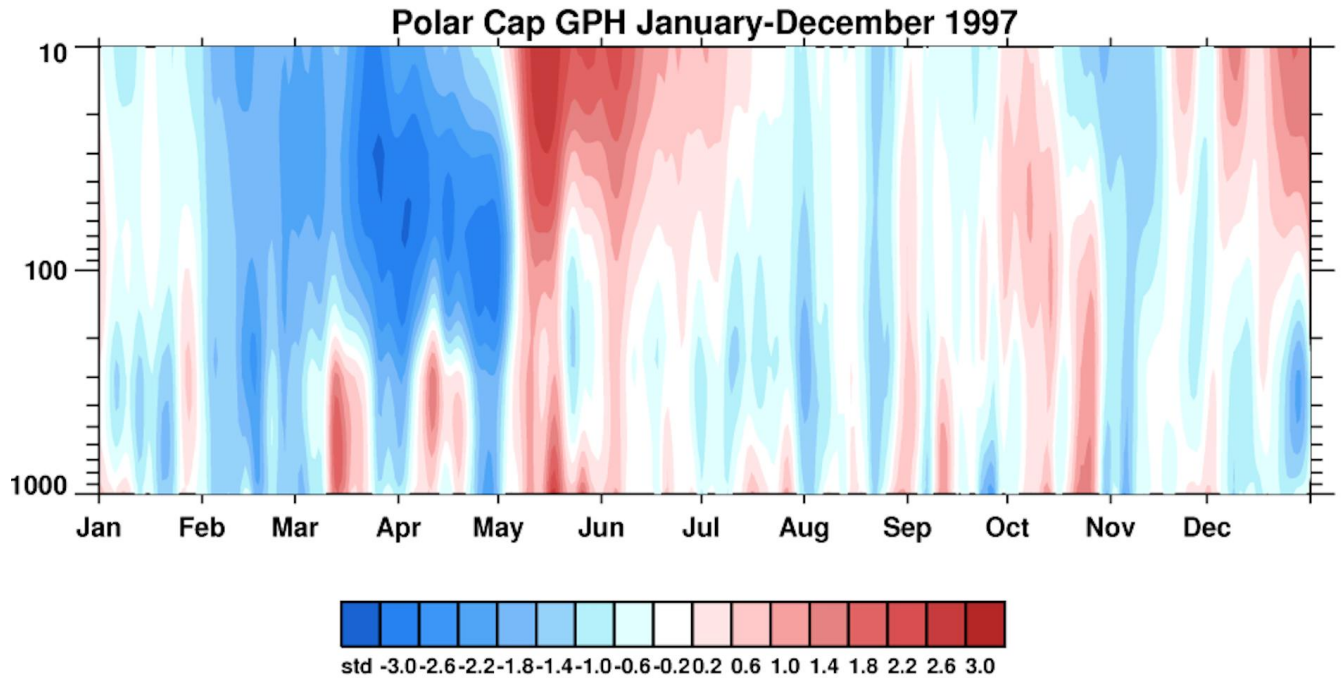


Figure ii. Observed daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies from 1 January - 31 December 1997.

There are no signs from the models of something similar for May 2019, but I think May 1997 provides an example of what is possible. The tropospheric response could linger up to a month including warm tropospheric PCHs, negative AO, Greenland blocking with below normal temperatures in eastern North America and/or Europe. It is hard to express too much confidence in any particular outcome given the unusualness of such apparent late season troposphere-stratosphere-troposphere coupling. And it will be interesting to observe what transpires.

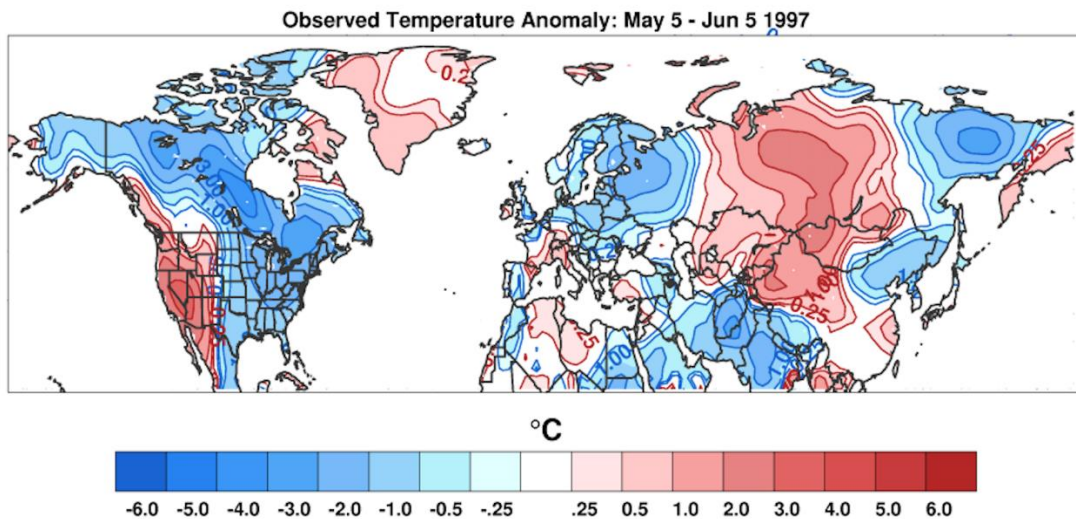


Figure iii. Observed surface temperature anomalies ($^{\circ}\text{C}$; shading) from 5 May – 5 June 1997.

Finally, to end on an even more speculative note, I do think the dynamic nature of the Final Warming does favor a weak stratospheric PV to the beginning of the 2019/20 season next fall. My first prediction for winter 2019/2020.

Near Term Conditions

1-5 day

The AO is currently slightly negative and is predicted to remain neutral to negative over the next week (**Figure 1**) as positive geopotential height anomalies dominate the North Atlantic side of the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with strong positive geopotential height anomalies across Greenland (**Figure 2**), the NAO will likely remain strongly negative this week.

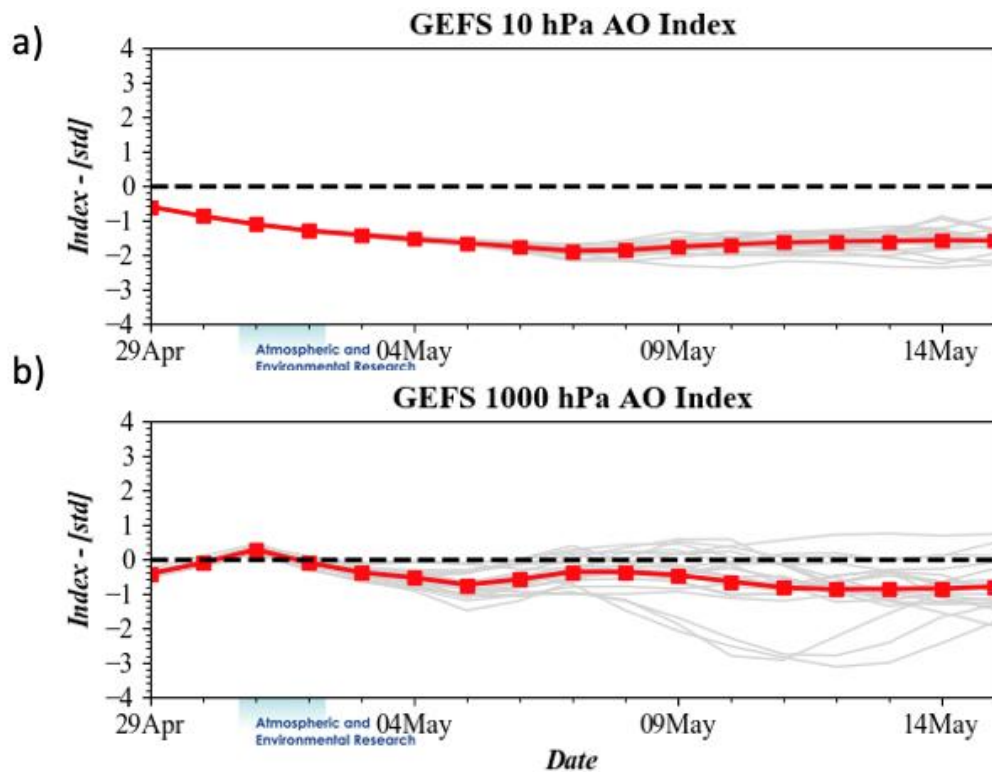


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 29 April 2019 GFS ensemble. (b) The predicted daily-mean near-surface AO from the 00Z 29 April 2019 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Ridging/positive geopotential height anomalies across Greenland are predicted to force troughing/negative geopotential height anomalies across much of Europe this week (**Figure 2**). This pattern is predicted to result in widespread normal to below normal temperatures across Europe including the UK except for normal to above temperatures across Spain underneath mid-tropospheric ridging (**Figure 3**). The combination of ridging/positive geopotential height anomalies across Greenland and strengthening north of Alaska will force deep troughing/negative geopotential height anomalies across Northern Asia with more ridging across East Asia and the Middle East (**Figure 2**). This is predicted to yield widespread normal to below normal temperatures for most of Northern and Western Asia but especially Siberia with normal to above normal temperatures across the Middle East and East Asia (**Figure 3**).

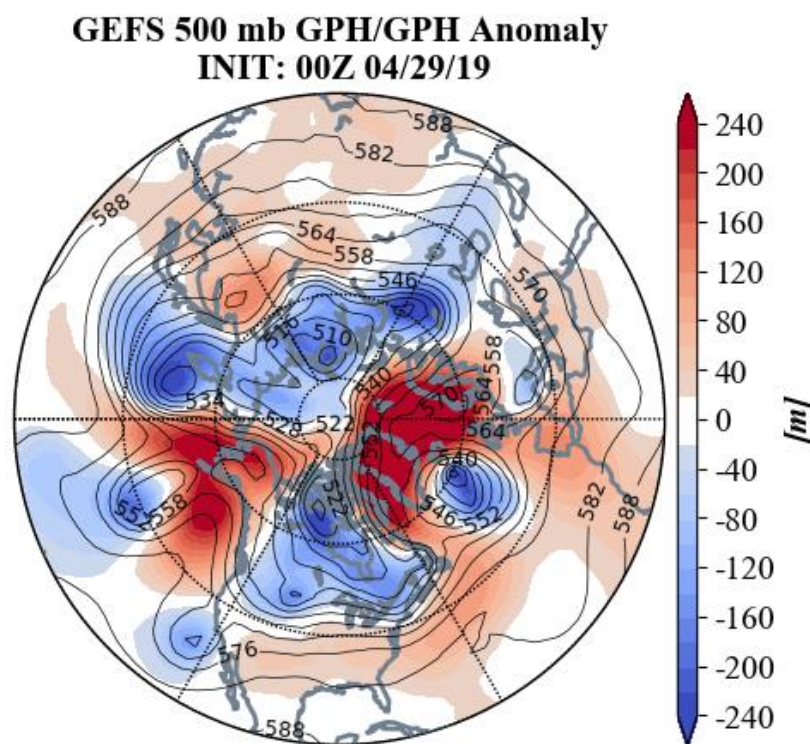


Figure 2. Observed 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) for 00Z 29 April 2019.

Ridging/positive geopotential height anomalies across Greenland and Alaska are predicted to force troughing/negative geopotential height anomalies in Western Canada and the Western US with more ridging/positive geopotential height anomalies along the East Coast of the US (**Figure 2**). This pattern is predicted to bring normal to below normal temperatures across much of Canada and the Western US with normal to above normal temperatures for Alaska and the Eastern US with the exception of New England (**Figure 3**).

GEFS 1-5 Day Forecast T2m Anomaly
INIT: 00Z 04/29/19 FCST: 04/30/19 to 05/04/19

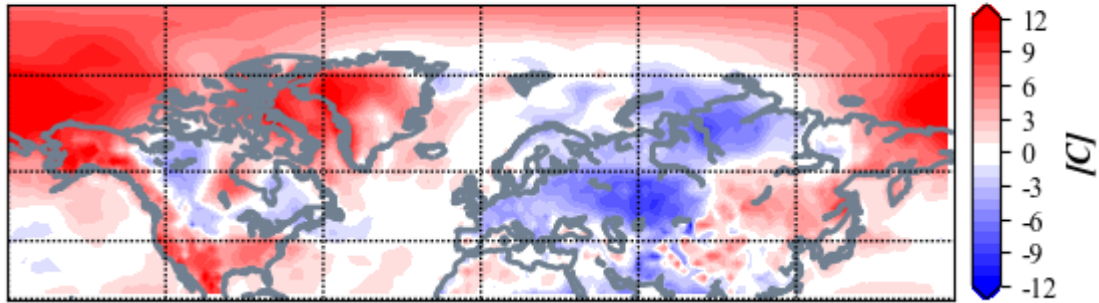


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 30 April – 4 May 2019. The forecast is from the 00Z 29 April 2019 GFS ensemble.

Trouthing is predicted to bring above normal rainfall to Southeastern Europe, Scandinavia, the Central and Northern US and Canada (**Figure 4**).

GEFS 1-5 Day Forecast PCP Anomaly
INIT: 00Z 04/29/19 FCST: 04/30/19 to 05/04/19

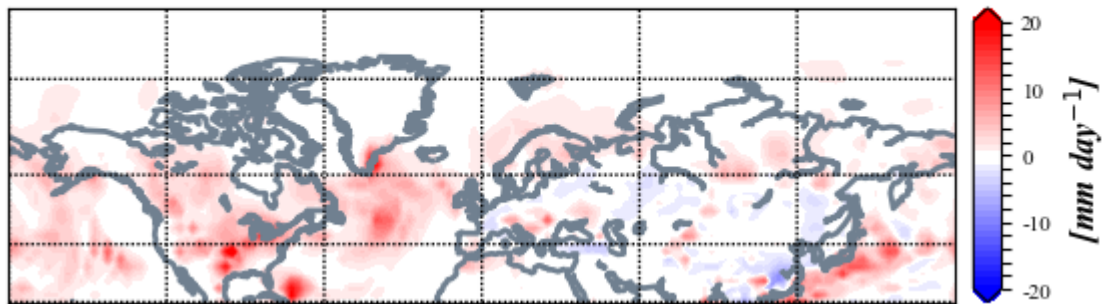


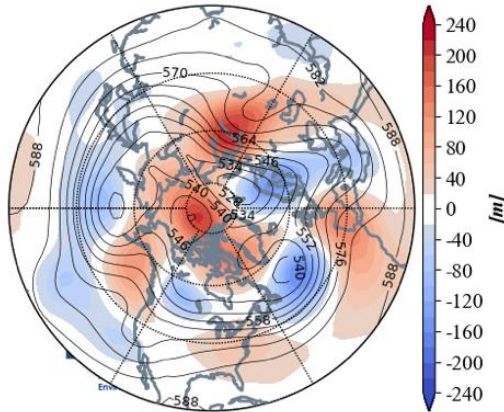
Figure 4. Forecasted rainfall anomalies (mm/day ; shading) from 30 April – 4 May 2019. The forecast is from the 00Z 29 April 2019 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain negative next week (**Figure 1**) as positive geopotential height anomalies are predicted to dominate the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5a**). And with persistent positive geopotential height anomalies across Greenland (**Figure 5a**), the NAO will likely remain strongly negative next week.

a) GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 04/29/19 FCST: 05/05/19 to 05/09/19



b) GEFS 11-15 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 04/29/19 FCST: 05/10/19 to 05/14/19

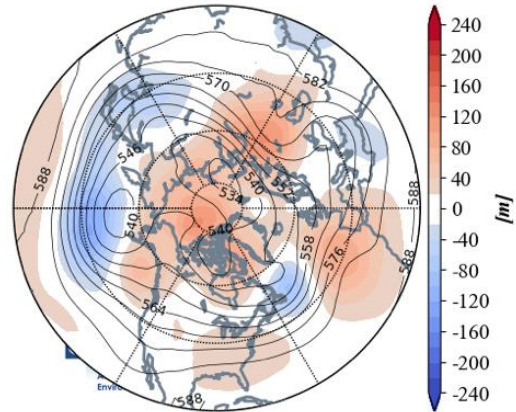


Figure 5. (a) Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 5 – 9 May 2019. (b) Same as (a) except averaged from 10 – 14 May 2019. The forecasts are from the 29 April 2019 00z GFS ensemble.

Continued ridging/positive geopotential height anomalies across Greenland are predicted to anchor troughing/negative geopotential height anomalies across much of Europe next week (**Figure 5a**). This pattern is predicted to result in widespread normal to below normal temperatures across Europe including the UK except for normal to above temperatures across Spain underneath persistent mid-tropospheric ridging (**Figure 6**). The negative temperature departures are predicted to peak across Europe this period as the air mass originates from Siberia. The deep trough/negative geopotential height anomalies previously across Siberia will split into two with one piece sliding southwestward into Europe and a second piece propagating to the east into East Asia. In its stead, ridging/positive geopotential height anomalies will strengthen across Western and Northern Asia (**Figure 5a**). This is predicted to yield widespread normal to above normal temperatures for most of Northern and Western Asia including the Middle East with normal to below normal temperatures across Mongolia and much of China (**Figure 6**).

GEFS 6-10 Day Forecast T2m Anomaly
INIT: 00Z 04/29/19 FCST: 05/05/19 to 05/09/19

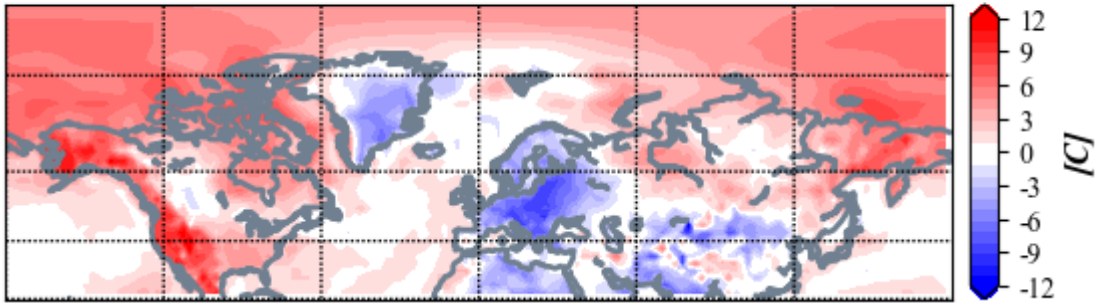


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 5 – 9 May 2019. The forecasts are from the 00Z 29 April 2019 GFS ensemble.

Ridging/positive geopotential height anomalies stretching from the Gulf of Alaska to the Beaufort Sea are predicted to maintain troughing/negative geopotential height anomalies in Western Canada with more ridging/positive geopotential height anomalies along the East Coast of the US (**Figure 5a**). This pattern is predicted to bring normal to below normal temperatures across much of Western Canada and the Northern US with normal to above normal temperatures for Alaska and the Southern US (**Figure 6**).

GEFS 6-10 Day Forecast PCP Anomaly
INIT: 00Z 04/29/19 FCST: 05/05/19 to 05/09/19

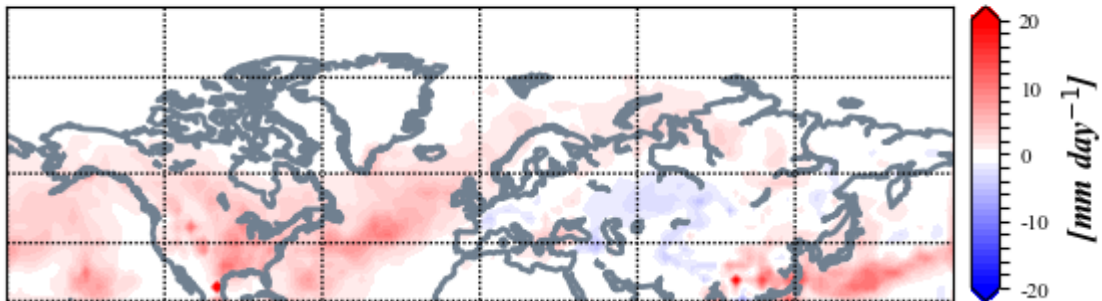


Figure 7. Forecasted rainfall anomalies (mm/day ; shading) from 5 – 9 May 2019. The forecasts are from the 00Z 29 April 2019 GFS ensemble.

Troughing is predicted to bring above normal rainfall to Scandinavia, Southern China, the Central and Eastern US and Canada (**Figure 7**).

11-15 day

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

With ridging/positive geopotential height anomalies persisting across Greenland and in the eastern North Atlantic will force weak troughing/negative geopotential height anomalies downstream across Europe (**Figure 5b**). This pattern is predicted to result in normal to below normal temperatures for most of Europe including the UK except for normal to above normal temperatures for Spain and Scandinavia underneath mid-tropospheric ridging (**Figure 8**). Little change is predicted for the circulation across Asia with ridging/positive geopotential height anomalies anchored across Northern and Western Asia with troughing/negative geopotential height anomalies across East Asia and the Middle East (**Figure 5b**). This pattern favors normal to above normal temperatures for Northern and Western Asia with normal to below normal temperatures for East Asia and the Middle East (**Figure 8**).

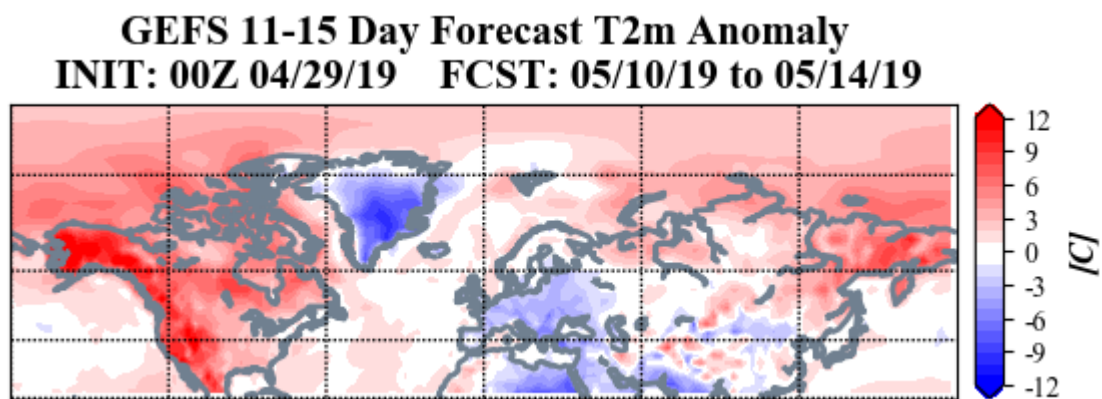


Figure 8. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 10 – 14 May 2019. The forecasts are from the 00Z 29 April 2019 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to dominate much of North America with residual troughing/negative geopotential height anomalies in Southwestern Canada and the Central US (**Figure 5b**). This will favor normal to above normal temperatures across Alaska, Northern Canada, the Southeastern US and the West Coast of the US with normal to below normal temperatures for Southwestern Canada and the Central US (**Figure 8**).

GEFS 11-15 Day Forecast PCP Anomaly
INIT: 00Z 04/29/19 FCST: 05/10/19 to 05/14/19

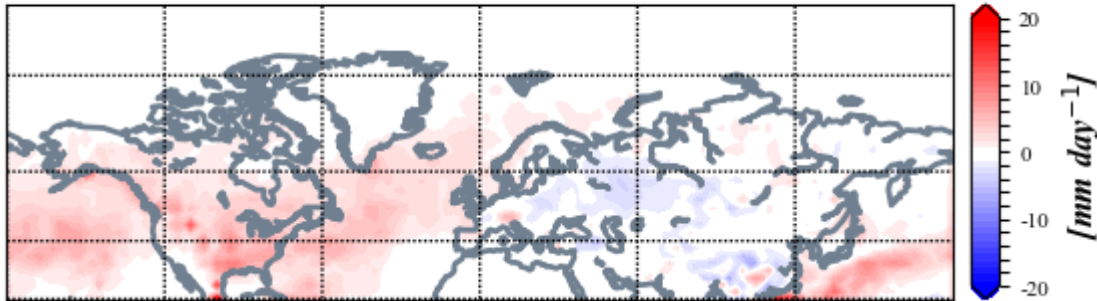


Figure 9. Forecasted rainfall anomalies (mm/day; shading) from 10 – 14 May 2019. The forecasts are from the 00Z 29 April 2019 GFS ensemble.

Trouching is predicted to bring above normal rainfall to parts of Europe, the Central and Eastern US and Canada (**Figure 9**). Ridging will bring dry conditions to Eastern Europe and Western Asia (**Figure 9**).

Longer Term

30-day

The latest plot of the polar cap geopotential heights (PCHs) shows predicted normal to above normal PCHs throughout the stratosphere and the troposphere (**Figure 10**). The above normal PCHs in the stratosphere are consistent with a predicted negative stratospheric AO for the next two weeks (**Figure 1**) while the predicted above normal PCHs in the lower troposphere are consistent with a neutral to negative surface AO predicted for the next two weeks (**Figure 1**). The positive PCHs in the stratosphere appear to descend into the troposphere over time (**Figure 10**).

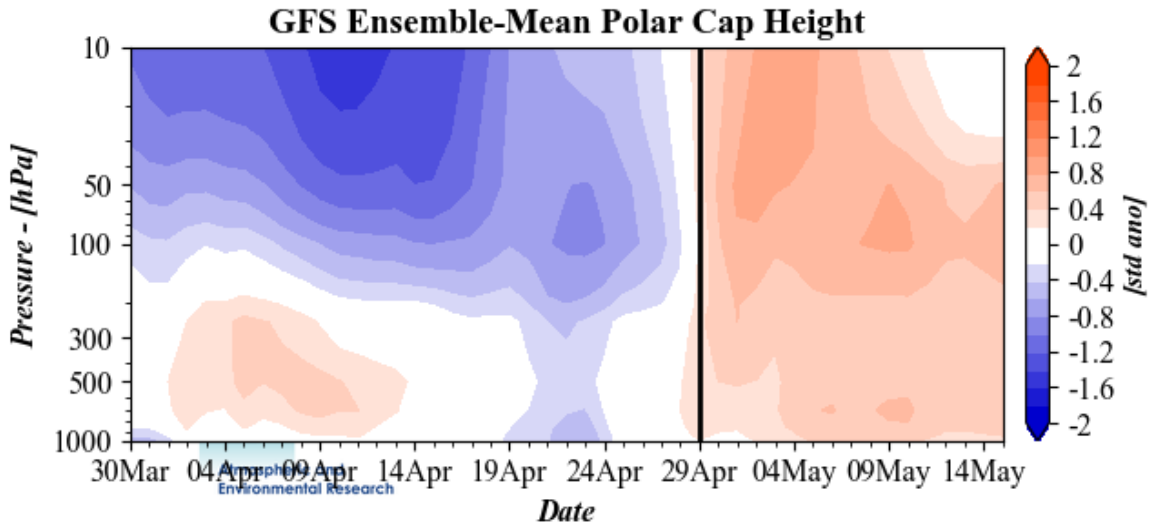


Figure 10. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecasts are from the 00Z 29 April 2019 GFS ensemble.

The positive PCHs throughout the stratosphere are a cumulative result of the active Wave Activity Flux (WAFz) or poleward heat transport the second half of April (**Figure 11**). I had predicted negative PCHs in the stratosphere to persist from the spring until at least the beginning of next fall. This prediction has turned out to be wrong due to the unusually active WAFz for this time of year.

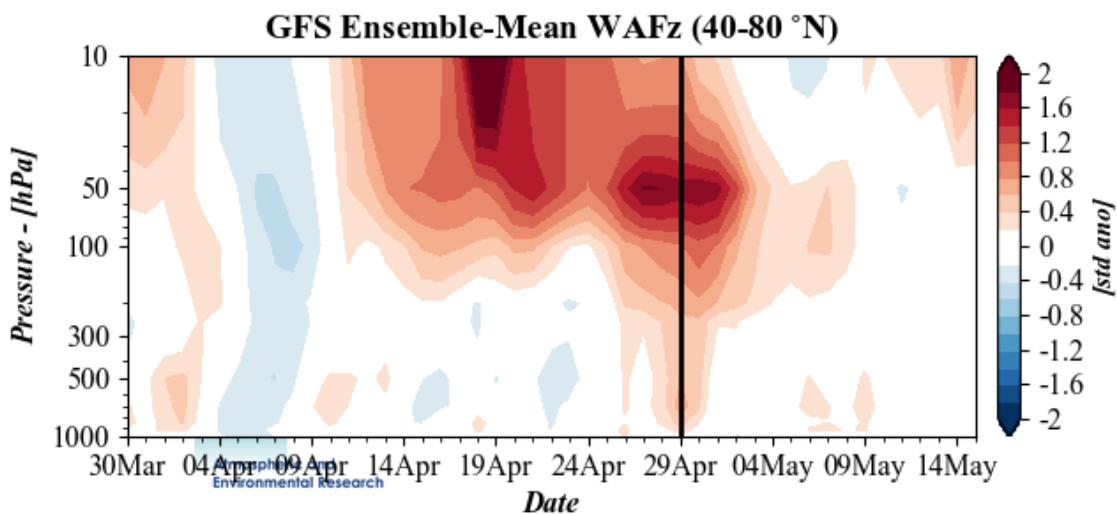


Figure 11. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 29 April 2019 GFS ensemble.

The plot of WAFz or poleward heat transport shows the WAFz returning to normal after this week (**Figure 11**). So, I do expect stratosphere-troposphere to finally come to an end until next fall and for PCHs to turn colder in the stratosphere.

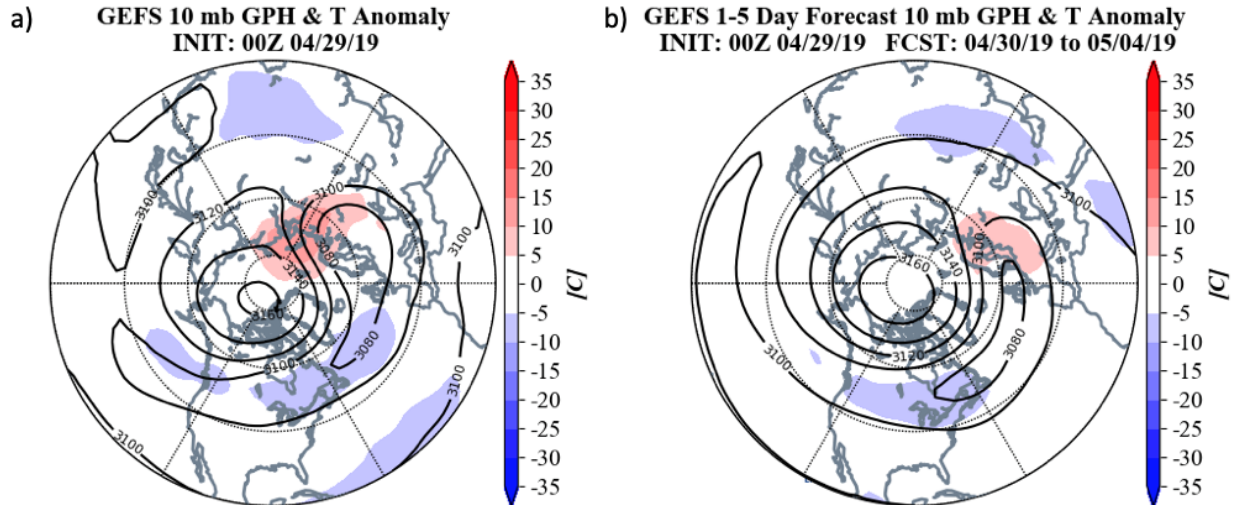


Figure 12. (a) Analyzed 10 mb geopotential heights (dam; contours) and temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for 29 April 2019. (b) Same as (a) except forecasted averaged from 30 April – 4 May 2019. The forecasts are from the 00Z 29 April 2019 GFS operational model.

The Final Warming (where the stratospheric PV disappears for the summer and winds are persistently easterly at 60°N and 10 hPa) has already occurred (**Figure 12**). However, a remnant of the stratospheric PV can be seen over Europe that extends into Canada. Tropospheric troughs with their associated below normal temperatures are located underneath the remnants of the stratospheric PV in Europe and Canada.

**CFS 500 hPa Forecast Anomaly May 2019
Valid as of 29 Apr 2019**

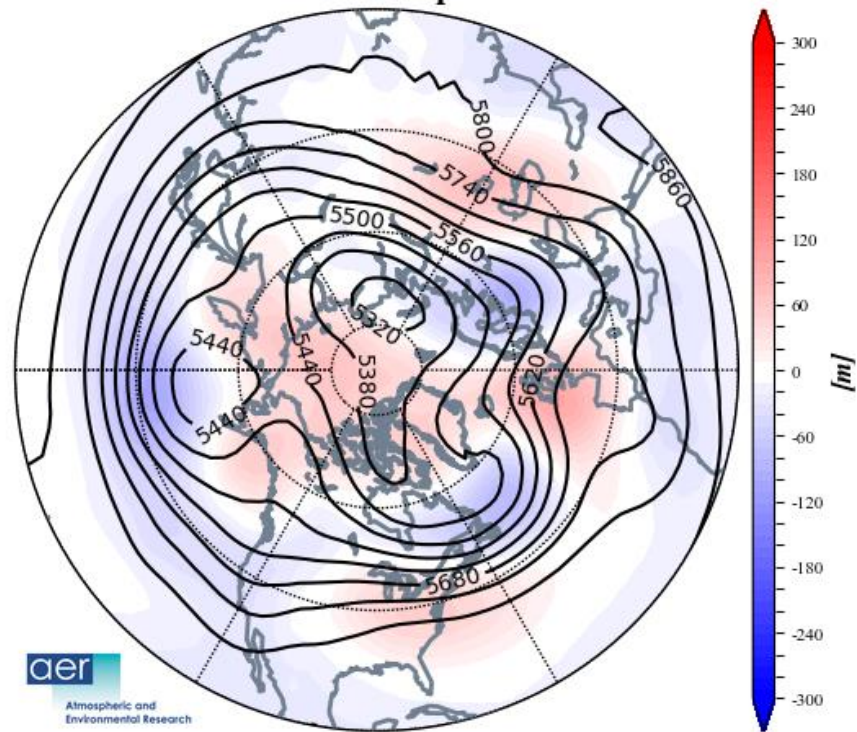


Figure 13. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for May 2019. The forecasts are from the 29 April 2019 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 13**) and the surface temperatures (**Figure 14**) forecast for May from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast for the troposphere is ridging centered across Western Europe, Central Asia, Eastern Siberia, the Gulf of Alaska and the Eastern US with troughs in the Eastern Europe, Siberia, East Asia, the Western US and Eastern Canada (**Figure 13**). This pattern favors cool temperatures for Eastern Europe, the Middle East, East Asia and Eastern Canada with relatively mild temperatures for Northern Europe, Central Asia and much of North America (**Figure 14**).

CFS T2m Forecast Anomaly May 2019 Valid as of 29 Apr 2019

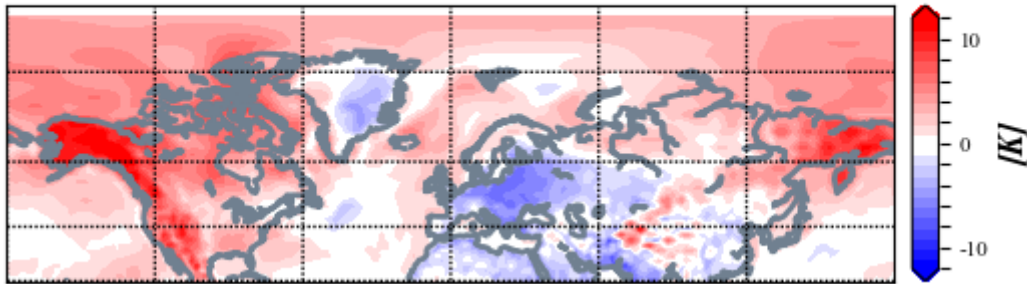


Figure 14. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for May 2019. The forecasts are from the 29 April 2019 CFS.

Surface Boundary Conditions

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 28 Apr 2019

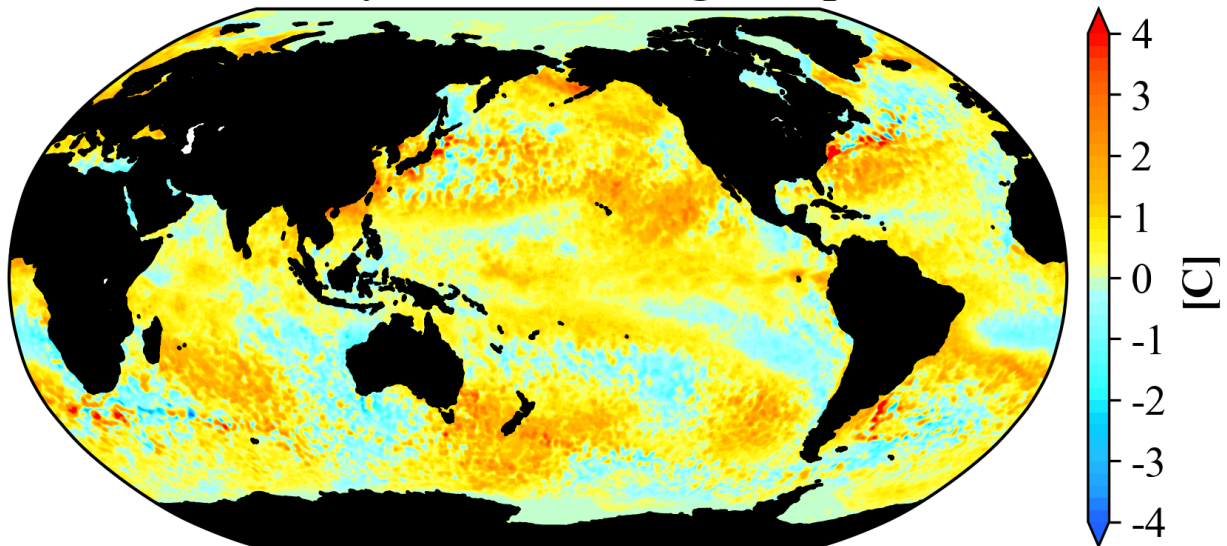


Figure 16. The latest weekly-mean global SST anomalies (ending 28 April 2019). Data from NOAA OI High-Resolution dataset.

Currently the Madden Julian Oscillation (MJO) is in phase 4 (**Figure 14**). And the forecasts are for no phase of the MJO to be favored by the end of the week and then for the MJO to emerge in phases 7 and 8. MJO phase 4 does favor ridging in the Eastern US and could be contributing to the predicted ridging in the Eastern US. Phases 7 and 8 favor troughing in the Eastern US instead.

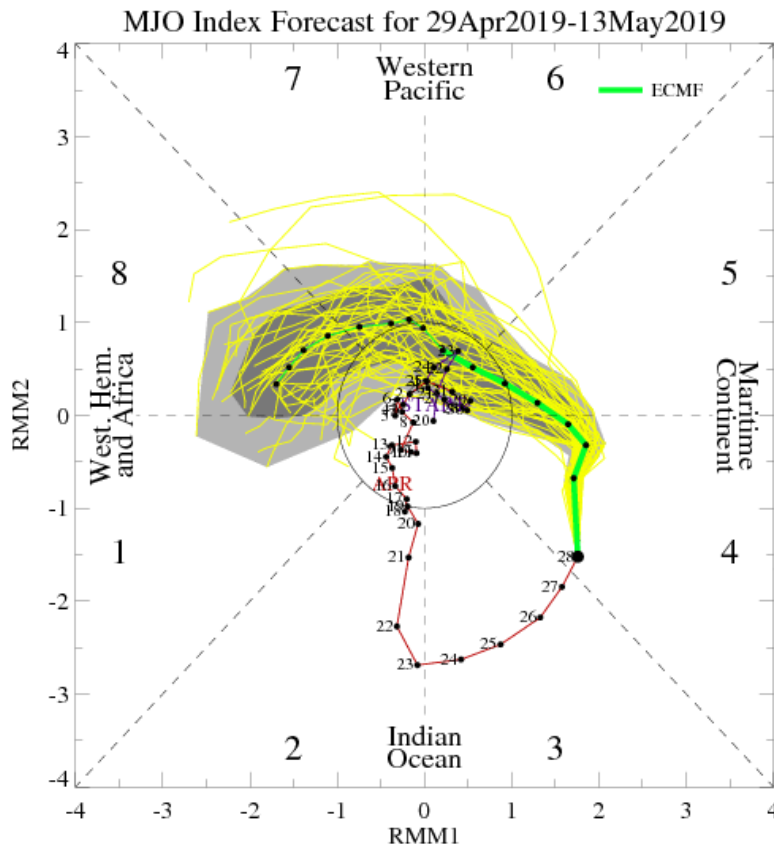


Figure 17. Past and forecast values of the MJO index. Forecast values from the 00Z 29 April 2019 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate 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>