Long-Range Forecast for the North Atlantic Oscillation and UK Weather in January-February 2020

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Forecast Summary

We anticipate the North Atlantic Oscillation will be negative and that United Kingdom temperatures will be colder than normal during January-February 2020.

We present an extended-range forecast for the North Atlantic Oscillation (NAO) and winter Central England Temperature (CET) for January-February 2020. Our forecast employs solar and stratosphere cyclic signals from summer 2019 as predictors. These predictors point to a higher than normal likelihood that the NAO will be negative and that the CET will be colder than normal for January-February 2020. There is an 87% chance the NAO will be less than the 1981-2010 mean and a 65% chance the CET will be the colder than the 1981-2010 mean. Examination of data between 1953 and 2019 shows that nine of the ten years where these predictor fields had the same sign and similar magnitude to that in summer 2019 were followed in January-February by a negative NAO and by a CET colder than the climatology.

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1. Background

The winter climate experienced by the UK, by large parts of Europe and by the eastern seaboard of North America exhibits large year-to-year variability. For example, recent UK winters have seen January-February (hereafter JF) CETs range between 2.1°C in 2010 (cold and snowy winter) and 6.0°C in 2014 (mild, wet and stormy winter). This interannual variability in winter climate is linked to the NAO. The NAO is defined in terms of the difference in sea level pressure between the Azores subtropical high pressure system and the Icelandic subpolar low pressure system. These large-scale variations in sea-level pressure over the North Atlantic are linked to changes in the track and strength of the jet stream that, in turn, are associated with changes in winter temperature, precipitation and windspeed (Figure 1).

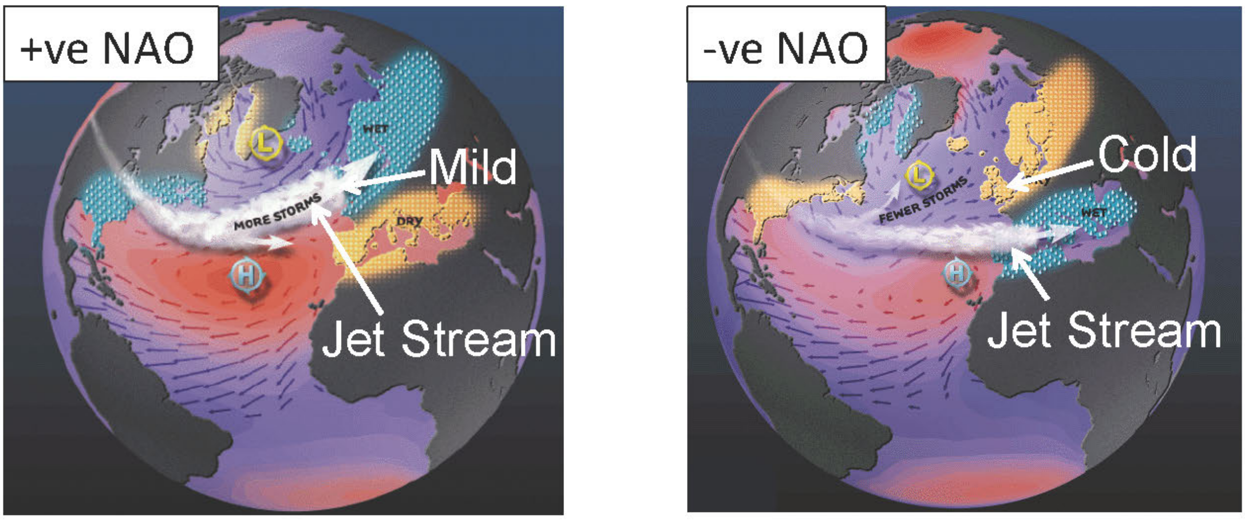

Figure 1: Schematic showing the nature and impacts of the positive and negative phases of the winter North Atlantic Oscillation (NAO). Adapted from images created by Martin Visbeck (Columbia, USA).

2. Data and Methods

2.1 Data used: Our analysis employs four data sets. These are the monthly solar 10.7 cm flux data published by Natural Resources Canada (2019), the monthly Quasi-Biennial-Oscillation (QBO) zonal wind data published by the Free University of Berlin (2019), the monthly NAO data published by the Climatic Research Unit, University of East Anglia (updated from Jones et al., 1997), and the monthly CET data published by the Met Office (updated from Parker, Legg and Folland, 1992). We employ data between January 1953 and June 2019 for all data sets. Our analysis starts with 1953 data as this is when the QBO zonal wind data are first recorded.

2.2 Selection of winter NAO and winter CET predictors: We select our winter predictors and winter predictand period following a robust assessment of the strength (r^2) of the lagged and contemporaneous links 1953-2019 between monthly, two-monthly and seasonal values of solar 10.7 cm radio flux, QBO 30 hPa zonal winds, and QBO 50 hPa zonal winds, and the NAO data for December-January-February and for January-February. The solar 10.7 cm radio flux is a widely used index of solar activity. The QBO zonal winds at 30 hPa and 50 hPa (corresponding to altitudes of ~22 km and ~19 km) in the lower stratosphere are known to influence atmosphere circulation at altitudes and latitudes beyond their primary tropical location. Many studies have documented links between solar activity and Northern Hemisphere winter climate (the paper by Chiodo et al. (2019) provides a recent review), and several studies have documented links between the QBO and winter climate (the paper by Anstey and Shepherd (2014) provides a recent review). However, a robust probabilistic long-range forecast of winter climate has, to our knowledge, not been attempted before using solar activity and the QBO as predictors.

2.3 Use of normalised data: Our regressions, including the computation of r^2, are all performed using normalized data. This ensures that the requirements of linear regression modeling are met; namely that observations are drawn from normal distributions and that regression errors are normally distributed with a mean of zero. The distributions for solar flux, QBO zonal winds and the NAO are all non-normal. We normalized these data sets for the 1953-2019 period as follows. The solar flux and NAO data are transformed to normalized distributions by using Wakeby and Dagum statistical distributions respectively. The QBO data are normalized by using the cumulative probability method illustrated in Figure 1 of Lloyd-Hughes and Saunders (2002).

2.4 Method for computing probability of exceedance: Probability of exceedance provides the likelihood of each predictand outcome occurring based on prior model performance and is underpinned by a thorough quantification of forecast uncertainty. We compute probability of exceedance values for the January-February NAO (hereafter JF NAO) predictand as follows. The same six-step methodology applies also to January-February CET (hereafter JF CET):

(i) Create a multi-predictor linear regression model using prior normalized data for the predictors and JF NAO.
(ii) Compute normalized input values for each predictor for the 2020 JF NAO.
(iii) Make a prediction for 2020 JF NAO by using the normalized values obtained in (ii) applied to the regression model in (i).
(iv) Compute the hindcast error for 2020 JF NAO by taking the difference between the JF NAO values obtained in (iii) and (ii).
(v) Standardize the hindcast error in (iv) by dividing by the standard deviation of the regression model residuals obtained in (i).
(vi) Compute the probability of exceeding the standardized hindcast error in (v) by recognizing that this value is part of a standard normal cumulative probability distribution.

2.5 Forecast predictors: Our long-range NAO and CET forecast model employs two predictors. These are the projected solar 10.7 cm radio flux for August-September 2019 and the Quasi-Biennial-Oscillation (QBO) 50 hPa zonal average wind for April-May-June 2019. We find that these predictor lagged periods give the strongest and most significant solar and QBO links to JF NAO. Our projected August-September 2019 value for the solar 10.7 cm flux is 68 solar flux units (sfu), where 1 sfu = 10^{-22} W m^{-2}. Hz^{-1}. This value is typical of the minimum in the 11-year solar cycle and has a standardised value of -1.33. The April-May-June 2019 value for QBO zonal wind at 50 hPa is 9.4 ms^{-1}. This value corresponds to a moderately strong QBO 50 hPa westerly-phase wind and has a standardised value of 0.59.

2.6 Forecast model: Our multi-predictor linear regression model for predicting JF NAO is built using the 22 years 1954-2019 (with year here being the predictand year) where the August-September solar 10.7 cm radio flux is in the lower tercile. This model is appropriate with August-September 2019 solar flux having a standardised value of -1.33. Our forecast model for predicting JF CET is the average of two model outputs. These models employ the same predictors that we use to predict the JF NAO but differ in that one model uses the observed JF CET data as the predictand and the other model uses linearly detrended JF CET data as the predictand.

3. Forecasts for January-February 2020

3.1 North Atlantic Oscillation (NAO):

Our deterministic (single most likely) forecast for the 2020 JF NAO is a value of -0.86 or -0.85 in standardised units. This would rank the 2020 JF NAO as the most negative JF NAO since JF 2010 and the thirteenth most negative JF NAO since 1953.

Our 2020 JF NAO forecast is displayed in terms of probability of exceedance in Figure 2. This plot gives the forecast likelihood of each JF NAO value being exceeded in 2020 based on prior model performance since 1953. Figure 2 shows that there is an 87% chance the 2020 JF NAO will be less than the JF NAO 1981-2010 mean value of 0.75. Furthermore the chance the 2020 JF NAO will be negative is double the long-term average chance (71% probability versus 33% probability).

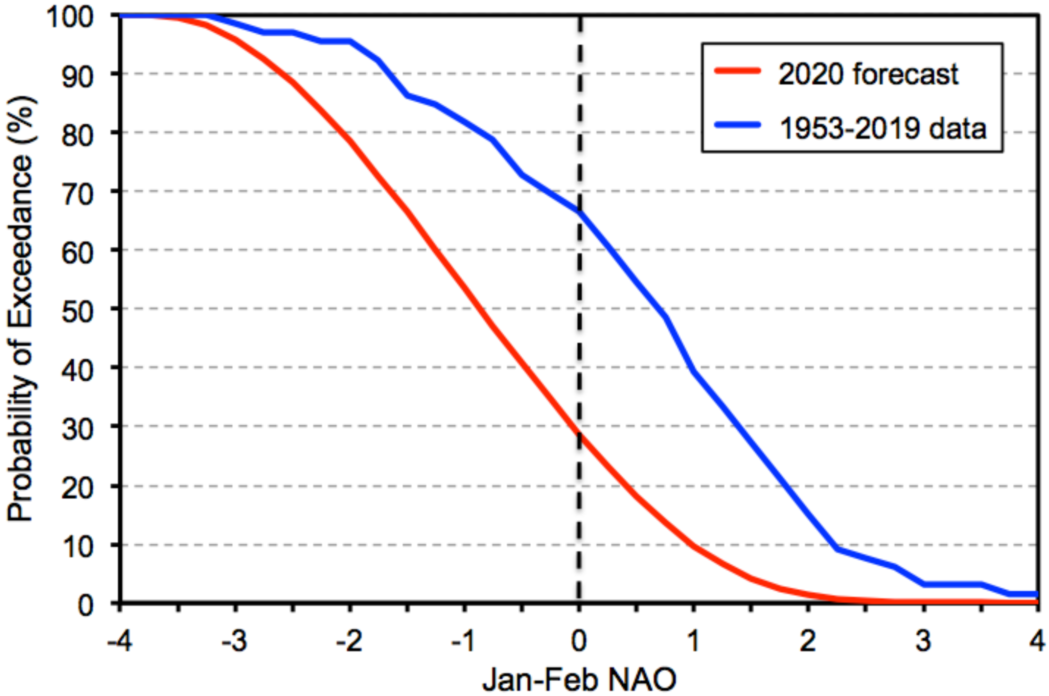

Figure 2: Probability of exceedance (PoE) curves for our forecast 2020 JF NAO and for the observed JF NAO 1953-2019. The abscissa displays actual (not standardised) NAO values.

3.2 Central England Temperature (CET):

Our deterministic forecast for the 2020 JF CET is a value of 3.9°C or -0.34 in standardised units relative to the 1981-2010 data period. The 3.9°C average temperature is 0.5°C below the 1981-2010 JF CET average. This would rank the 2020 JF CET as the coldest winter since JF 2013 when the CET value was 3.35°C. It would also rank JF 2020 as the seventh coldest winter in the last 30 years, and the 23rd coldest winter since 1953.

Our 2020 JF CET forecast is displayed in terms of probability of exceedance in Figure 3. This plot gives the forecast likelihood for each 2020 JF CET value being exceeded based on the prior performance of our model since 1953. Figure 3 shows that there is a 57% chance the CET will be colder than the 4.1°C JF CET value in 2018 thus making it the coldest JF CET since 2013. Furthermore there is a 65% probability that the 2020 JF CET value will be below the 1981-2010 average JF CET value of 4.41°C. In addition there is only a 20% chance that the 2020 JF CET value will exceed 5.0°C.

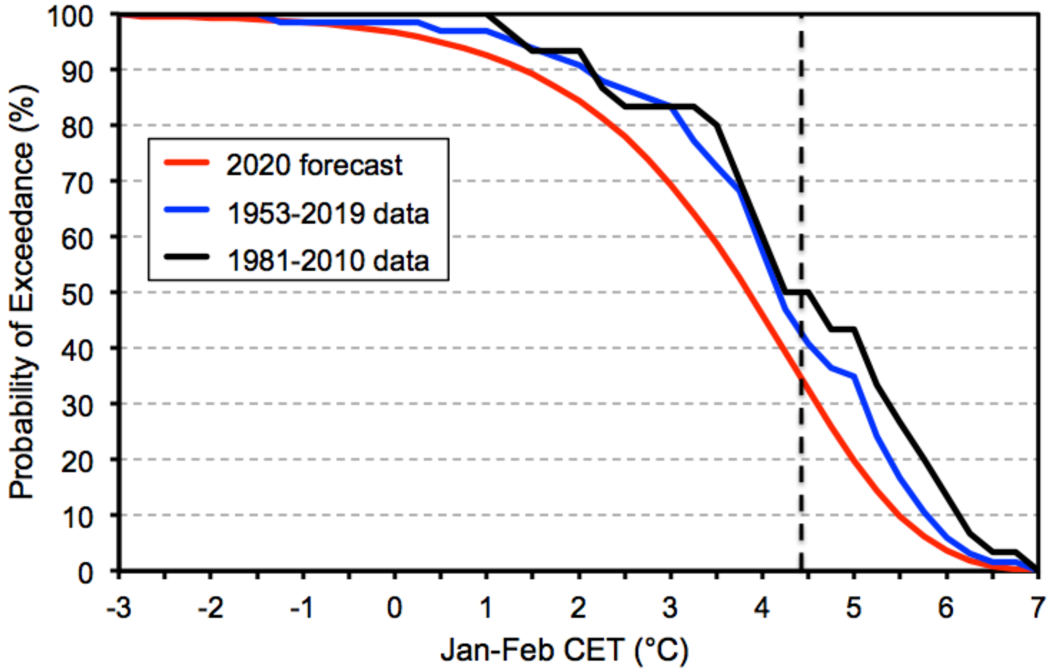

Figure 3: Probability of exceedance (PoE) curves for our forecast 2020 JF CET and for the observed JF CET for 1953-2019 and 1981-2010. The abscissa displays actual (not standardised) CET values. The dashed black vertical line denotes the JF CET 1981-2010 mean value of 4.41°C

4. Outcomes in Similar Prior Years

How does our NAO and CET forecast model verify in winters following years such as 2019 when the AS solar flux is low and when the AMJ 50 hPa QBO winds are westward? We find that nine of the ten years since 1953 that had a low AS solar flux (defined as an AS solar flux in the lower tercile) and westward AMJ 50 hPa QBO winds were followed in January-February by a negative NAO (Table 1).

Table 1. JF NAO and JF CET Outcomes in Prior Years 1954-2019 Where the Two Predictor Fields have the Same Sign and Similar Magnitude to that in Summer 2019

	Predictor Values (Standardised)		Outcomes (Actual)	
Year	AS Solar Flux	AMJ 50 hPa QBO	JF NAO	JF CET (°C)
1954	-1.00	1.18	-0.17	2.8
1963	-0.61	1.88	-2.34	-1.4
1965	-1.21	0.86	-1.22	3.2
1966	-0.90	0.71	-0.76	4.3
1975	-0.55	0.21	0.57	5.6
1977	-0.98	0.92	-0.95	4.0
1986	-1.16	0.40	-1.09	1.2
1987	-1.29	1.04	-1.03	2.2
1996	-1.03	0.57	-1.33	3.4
2010	-1.27	1.34	-2.52	2.1
2020	-1.33	0.59	?	?

Note. 'Years' corresponds to the JF (January-February) year and are ordered chronologically. They correspond to the ten most positive AMJ 50 hPa QBO years 1953-2018 when AS solar flux is in its lowest tercile. 'AMJ' means April-May-June and 'AS' means August-September. The predictor field values for 2019 are included for reference.

The years in Table 1 include the notably cold UK winters of 1962/3, 1986/7 and 2009/10. The mean JF NAO value for the ten years in Table 1 is -1.08 (which is 1.89 below the 1981-2010 JF NAO average). The mean JF CET value for the ten years in Table 1 is 2.74 °C (which is 1.67°C below the 1981-2010 JF CET average). We note that the year '1975' in Table 1 that did not have a negative JF NAO was preceeded by predictors that had the least extreme values of any year in Table 1.

5. Forecast Relevance

We suggest that our forecast and its underpinning findings matter for the following reasons:

- Our forecast will benefit decision making through improved anticipation of upcoming risk. The performance of much of UK industry is 'weather sensitive' and especially to cold winters. For example, the 'Beast from the East' freezing weather in late winter 2018 shut down construction sites, kept shoppers at home and caused transport chaos. This led the Bank of England to cut its growth forecast for the UK economy by 0.4% in May 2018 (BBC, 2018).
- Our extended forecast offers the potential for longer-range predictability of the winter NAO and cold winters. This forecast could have been issued in early July 2019 which is 6-months before the January-February winter season. Furthermore as our predictors are cyclical with periods of ~11 years and ~28 months their values may be predicted well in advance thereby enabling skill at leads out to a year or longer.
- Our findings will help to improve understanding of the drivers of UK and European winter climate variability. In particular our finding that the solar flux link to upcoming Northern Hemispheres winter climate is strongest for prior summer solar flux conditions is new.

6. References

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