

# European Circulation Indices: Winter Atlantic Pressure Gradient (North Atlantic Oscillation – NAO)

## Introduction to UKCP European Circulation Indices

This is one of a series of factsheets that describe a set of indices representing large-scale drivers of UK weather and climate in UKCP Global (60km) - a product from the latest UK Climate Projections published in 2018 consisting of 28 global climate model simulations. The factsheets and indices data are aimed at users wishing to carry out in-depth analysis of climate model behaviour.

The day-to-day or year-to-year variations in large-scale atmospheric circulation conditions over the Atlantic and wider European region drive significant fluctuations in the rainfall, temperature or wind strength and direction that might be experienced in a particular part of the UK. There are a number of different ways of characterising these large-scale drivers of UK and European climate. The index covered in this factsheet describes the North Atlantic Oscillation (NAO), other factsheets describe the Atlantic jet stream (strength and latitude) and European weather patterns (sets of 8 and 30). The factsheets are available on the [UKCP web pages](#) and the metrics are available through the [CEDA Archive](#).

The European circulation indices provide users with the opportunity to explore the impact of changes in the drivers of variability and future changes on climate variables that may have more direct impacts, such as rainfall, windiness or local temperatures. How the large-scale drivers might respond to a warming atmosphere as a result of increasing greenhouse gases remains uncertain, contributing significantly to uncertainty in future changes in local weather and climate. Exploring projections in this way can improve our understanding of the changes that we see to UK climate in the UK Climate Projections and potentially help us to build confidence in UK climate impacts assessments.

This factsheet provides an introduction to the Atlantic pressure gradient as an indicator of the North Atlantic Oscillation (NAO). We include some key results from analysis which show how realistically the models used in UKCP Global (60km) represent the winter NAO compared to observations, and how the NAO changes in the projections of future climate out to 2100 under RCP 8.5.

These indices are available for UKCP Global (60km) under a single high emission scenario (RCP 8.5). This 28-member dataset include 15 variants of the Met Office Hadley Centre's model (referred to here as 'PPE-15') and 13 models from other modelling centres around the world from the Coupled Model Inter-comparison Project 5 (referred to here as 'CMIP5-13'). These two ensembles are combined to form the 28-member UKCP Global (60km) in order to capture uncertainty associated with the choice of model used. We recommend that users read the UKCP18 Science Overview (Lowe et al., 2018) to understand the different components of the projections and a comprehensive description of the underpinning science, evaluation and results; see the UKCP18 Land Science Report (Murphy et al, 2018).

## What is the NAO?

The term 'North Atlantic Oscillation' (NAO) is used to refer to variations in the large-scale surface air pressure gradient in the North Atlantic region, which are responsible for much of the variability in the weather experienced in the UK and Europe. The strength of the pressure gradient between the region of low near Iceland (the 'Icelandic low') and the region of high pressure near the Azores (the 'Azores high') influences both the strength and position of the Atlantic storm track. When the pressure difference is large, the NAO is described as positive and the westerly winds are strong and storms tend to be stronger, more frequent and travel across north-western Europe. When the pressure difference is small, storms tend to travel across southern Europe. Although the NAO occurs throughout the year, it is particularly dominant during the winter.

The NAO is known to be strongly associated with some historical winter flooding and wind events. By using its relationship to UK and European precipitation, UKCP Global could potentially be used to understand the NAO's influence on projected increases in winter precipitation, alongside other drivers such as increases in atmospheric moisture content. However, please note the results presented below showing the small climate change impact compared to the year-to-year variability.

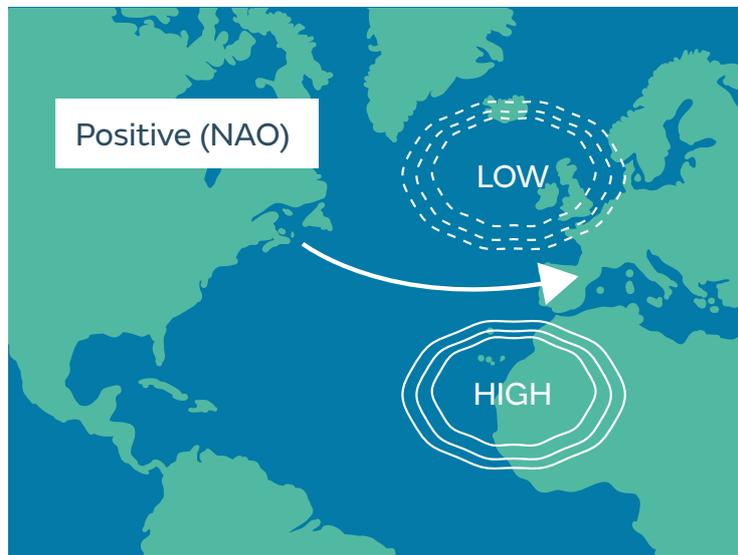


Figure 1 Schematic representation of the North Atlantic Oscillation.

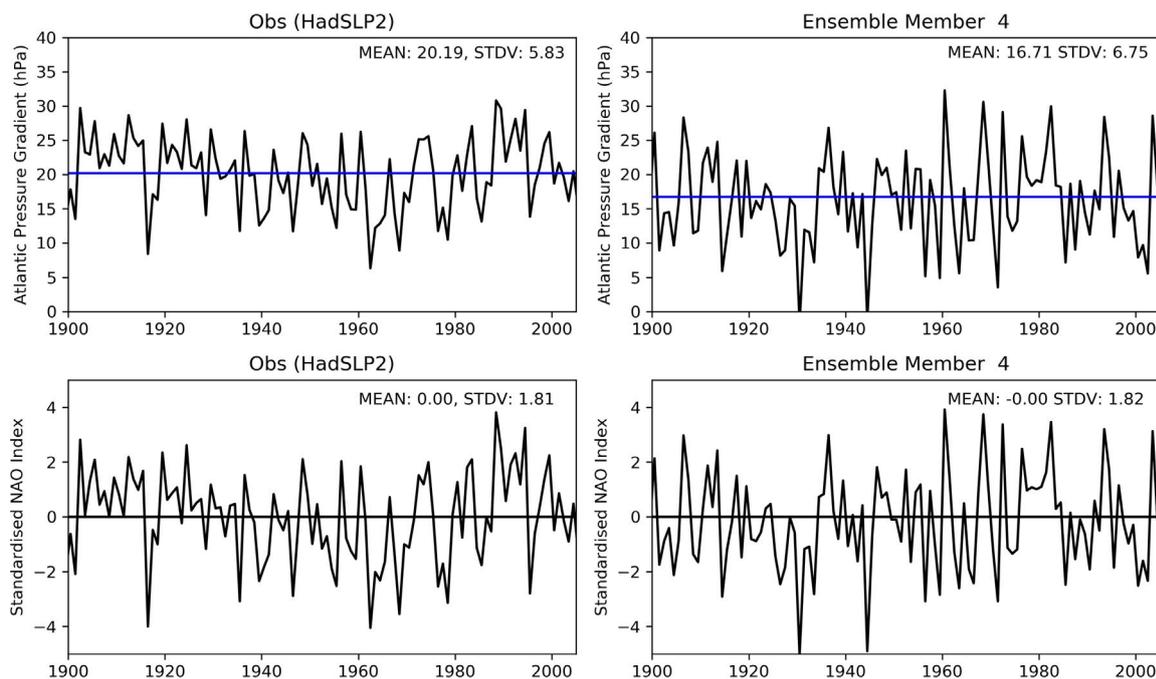
The fluctuations in the NAO occur on a wide range of timescales. There are day-to-day changes associated with weather systems, and slower changes associated with seasonal and longer term variability. A NAO description is available on the [Met Office website](#).

## What is the Atlantic Pressure Gradient index and how does it relate to the NAO?

The winter Atlantic Pressure Gradient index made available in UKCP is calculated as the seasonal mean (December-January-February) of the difference in sea-level pressure between Iceland and Gibraltar. Higher values indicate a strong pressure gradient and are associated with unsettled conditions over the UK, while lower values are associated with more stable UK conditions.

The Atlantic Pressure Gradient index is different to more commonly used indices: the NAO is often represented by an index which can be calculated either as a normalised<sup>1</sup> difference between the sea-level pressure between weather stations near the Icelandic low and the Azores high (e.g. Reykjavik, Iceland and Gibraltar in Jones et al. (1997), or Reykjavik, Iceland and Lisbon, Portugal as in Hurrell et al. (1995)), or as an index calculated using a statistical (principal components) analysis of seasonal sea-level pressure anomalies over the Atlantic sector (Hurrell, 1995). Both of these other approaches result in an index with values around 0 to 3 for positive NAO (large pressure gradient over the North Atlantic), and -3 to 0 for negative NAO (a small pressure gradient over the Atlantic). While these methods are a useful way to look at the variability in the observed data, they can be less useful for comparing climate model projections because they eliminate useful information about the mean and standard deviation of the pressure gradient between Iceland and Gibraltar, which varies considerably between different models. For the UKCP Global models, we therefore offer the absolute (non-normalised) pressure gradient between Iceland and Gibraltar.

The benefits of using the Atlantic Pressure Gradient rather than the standardised NAO index is illustrated in Figure 2. The plot shows one example ensemble member and an observed sea level pressure dataset (HadSLP2). You can see in Figure 2 that the mean (horizontal blue line and stated in the top right corner) is different between the Obs and Ensemble Member 4 in the top panels, and also its standard deviation is higher than for the Obs (STDEV value in top right corner), indicating that this particular member has a weaker Atlantic Pressure Gradient than the observations and that its interannual variability is higher. We cannot not see this difference between the Obs and Ensemble member in the standardised NAO index in the bottom panels, because, by definition, the standardisation sets them to the same value.

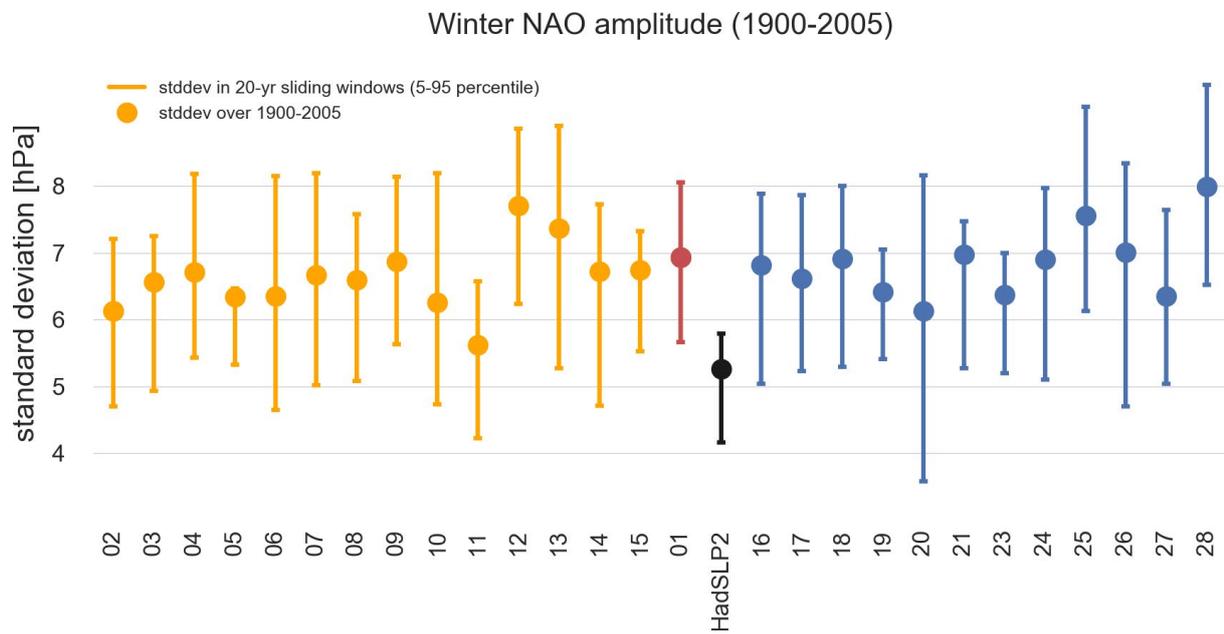


**Figure 2** A comparison between NAO indices calculated for in Observations (HadSLP2) and an example member from the UKCP Global (60km) ensemble (Member 04) for the period 1900-2005. The top panels show the absolute pressure gradient between Iceland and Gibraltar (top), while the bottom panels show a standardised NAO index (calculated using as the difference between normalised pressure timeseries for Iceland and Gibraltar). The MEAN refers to the average NAO value for each data-series (also shown as a horizontal line), and the STDV refers to the standard deviation or variation around the mean value within each data series.

<sup>1</sup> Normalising data means to subtract the mean of the data and divide by its standard deviation.

# How well do the models represent the NAO and its variability?

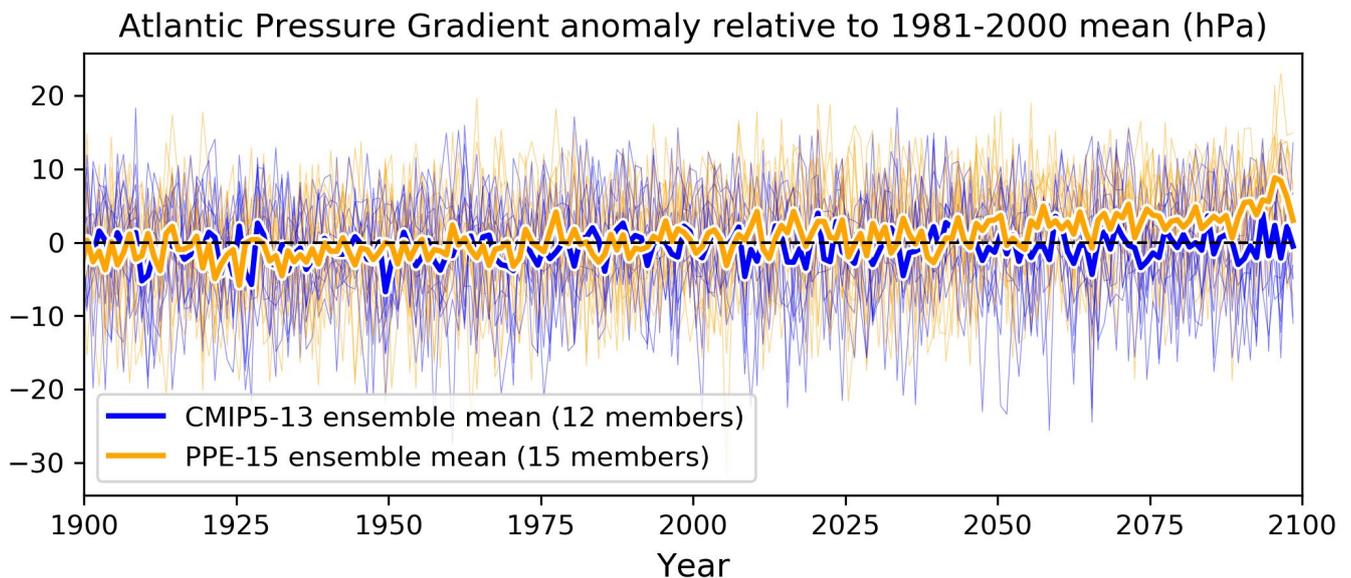
The UKCP Global models (both the PPE-15 and CMIP5-13) typically have a high amount of variability in their Atlantic Pressure Gradient compared with observations (HadSLP2 - Figure 3).



**Figure 3** Standard deviation (stddev) of the annual winter NAO index in the historical period (1900-2005) for each member of UKCP Global (60km). Equivalent values for observations (HadSLP2) are in black. The stddev refers to the standard deviation or variation around the mean value within each value. Taken from Murphy et al, 2018.

## How does the winter NAO change in projections of future climate?

The PPE-15 members in the UKCP Global models indicate an overall increase in the Atlantic Pressure Gradient, or a tendency towards more NAO positive conditions (Figure 4). This long-term increase is small relative to the year-to-year variability of this index. However, this increase is not seen in the CMIP5-13 members. These different responses of the different models in UKCP Global illustrate the uncertainty in this aspect of future European climate, and offer the opportunity to explore this uncertainty and its implications for changes in other variables.



**Figure 4** Evolution of the Atlantic Pressure Gradient anomaly in UKCP Global 1900-2100 under RCP 8.5. The bold lines represent the ensemble averages for each of PPE-15 and CMIP5-13, and the thinner lines, each individual member.

## What Atlantic Pressure Gradient data are available?

Atlantic Pressure Gradient data are available as a single value per year representing the average pressure gradient for winter (DJF) that year. Data is available for UKCP Global under the RCP 8.5 emissions scenario for the period December 1899 to November 2099. This index is not available for ensemble member 27. The data can be downloaded from the [CEDA Archive](#).

## This document can be cited as:

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## References

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