Atmospheric Circulations and Drought Conditions in British Catchments: Highlighting the Role of the East Atlantic Pattern

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1. INTRODUCTION

The spatiality of drought events is complex in Britain, as is the propagation of rainfall to flows within catchments (Barker et al. 2016; Tanguy et al. 2021). Distinctive differences in both rainfall and flow regimes have been found between the north-western and south-eastern regions which are related to a range of climatological and hydrological variables. Spatial patterns in the propagation of drought is further complicated as it is influenced by both climate and catchment characteristics (Van Loon & Laaha 2015). Droughts are inherently driven by climatic processes, and for Britain and most of NW Europe, the North Atlantic Oscillation (NAO) atmospheric-oceanic circulation has long been identified as the leading mode of climate variability (Hurrell et al. 2003) affecting rainfall across Britain (West et al. 2019). The NAO is defined by two meridional diploes—the Icelandic Low and Azores High/Anticyclone. When the sea level pressure difference between these two locations is greater than average the NAO is said to be in a positive phase (NAO+), whilst a weaker than average SLP difference represents a negative phase (NAO-).

The East Atlantic Pattern (EA) has also been acknowledged to have an impact on climate (West et al. 2021; 2022b) and has been referred to as a southward shifted NAO-like pattern. Studies have noted that the phase and magnitude of the EA also influences rainfall spatial distribution and volume across Europe, and consequently by using a combination of the NAO and EA we may be able to describe climate variability more accurately (Moore et al. 2013; Comas-Bru & McDermott, 2014).

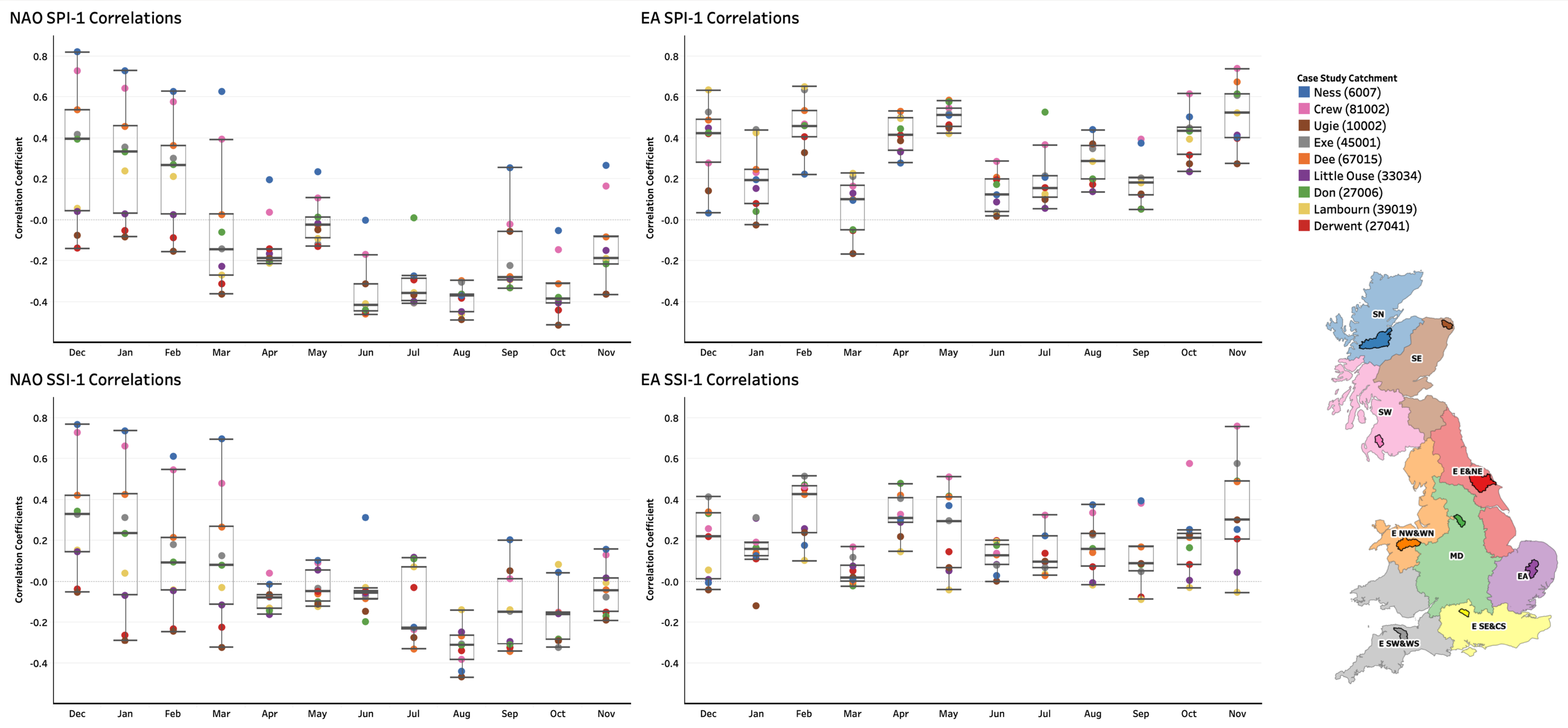
The above highlights the complex interplay between climate and hydrological systems, which manifests in spatiotemporal variability in rainfall, flow responses, and subsequent drought characteristics and propagation, generally along a N/S or NW/SE gradient in Britain. **This study aims to bring together understandings of the influence of the NAO and EA on rainfall distribution and magnitude, and the variable nature of meteorological to hydrological drought (rainfall-streamflow) propagation.**

2a. CORRELATION ANALYSIS

To assess the general relationship between the NAO/EA and rainfall and streamflow, correlation analysis was undertaken for 291 catchments across GB. Rainfall is represented by the Standardised Precipitation Index (SPI) and flow by the Standardised Streamflow Index (SSI) - both with a one month accumulation period (Tanguy et al. 2017; Barker et al. 2018).

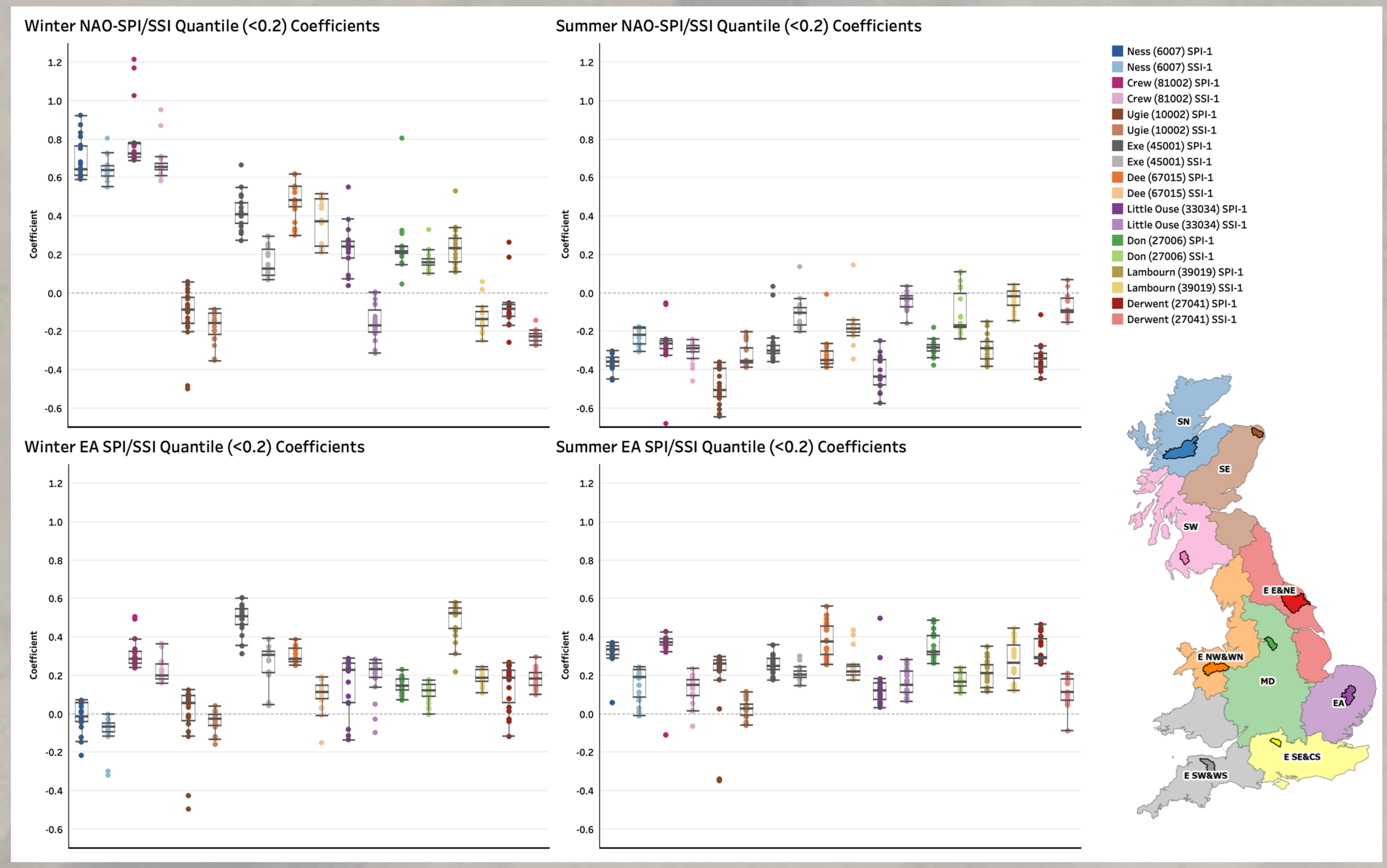
To develop a more detailed understanding of the combined effect of the NAO and EA on meteorological drought, and how rainfall deficits propagate through to hydrological drought, nine case study catchments were selected for further analysis. One catchment from each of the Met Office Climate Districts was chosen to ensure a spatially representative sample across Great Britain. The catchments were chosen as they vary not only geographically, but also represent a range of characteristics such as size, terrain and geology.

Correlations for the full 291 catchments can be found in West et al. (2022a). The graph below shows the correlation coefficients for the nine case study catchments for each month. Quantile regression analysis and a drought severity/frequency analysis was then undertaken to explore the relationship between the two circulations and low/negative SPI-1/SSI-1 values.



2b. QUANTILE REGRESSION

A standard generalised linear regression model would assume that the NAO or EA have an equal influence on both wet and dry conditions (high/low rainfall and flows). The use of a quantile regression model allows for an assessment of the relationship between each teleconnection index and low SPI-1/SSI1 values at different quantile levels. We performed quantile regression using 99 quantiles between the NAO and EA indices and the catchment SPI-1 and SSI -1 values. We extracted the quantile regression coefficients for SPI-1/SSI-1 quantiles below 0.2 (Amini et al., 2020), which equated to standardised index values <-1.



The correlation and QR analysis shows:

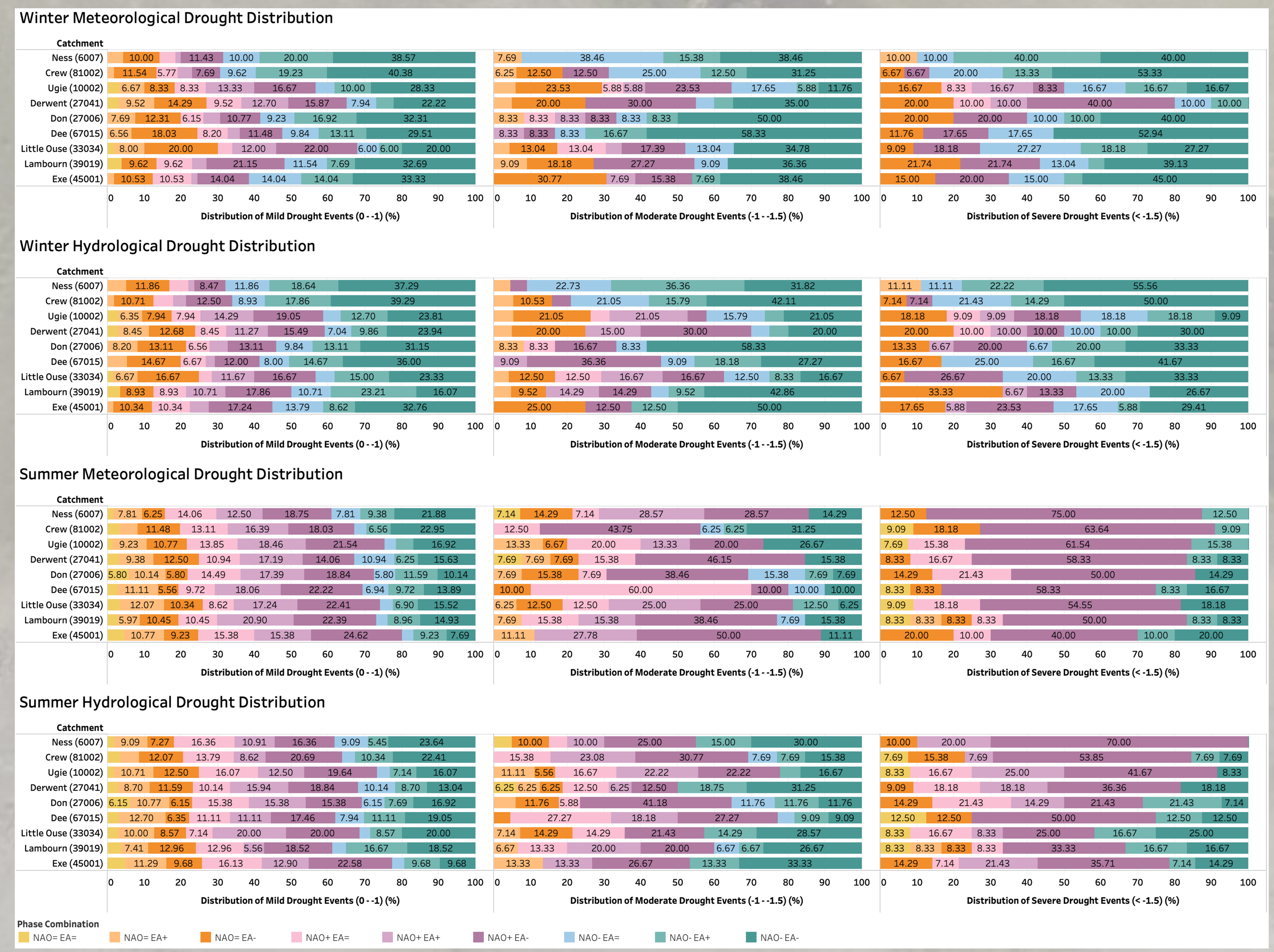
- Catchments in the NW have strong winter low rainfall/flow with the NAO. Whilst EA associations are stronger in the southern catchments.
- In summer more spatially consistent (and somewhat weaker) associations are present.
- Catchments variably show circulation-rainfall-flow propagation due to certain characteristics (e.g. high bedrock permeability in some case study catchments) (West et al 2022c).

2c. DROUGHT FREQUENCY ANALYSIS

A frequency analysis quantifying the relationship between the phase of the two teleconnections and low SPI-1 and SSI-1 values was undertaken. We also calculated the frequency of mild (0 > index < -1), moderate (-1 > index < -1.5) and severe (index < -1.5) drought under different combinations of NAO and EA phases. , the monthly teleconnection index values were classified. Months with teleconnection index values > 0.25 were classified as positive phases, whilst months with index values.

This analysis shows:

- In the NW during winter meteorological and hydrological droughts are associated with NAO- conditions. Southern catchments more variably have drought associated with EA- conditions.
- In the summer NAO+ conditions result in drought conditions, however the severity of the drought is potentially moderated/enhanced by the phase of the EA.



3. SUMMARY

Through a convergence of evidence from these analyses we make three key observations:

1. Firstly, in the winter months both the NAO and EA exert an influence on drought conditions, however there is spatial variability in the relative influence of the NAO and EA; the NAO has a stronger influence in the north-west, whilst the EA has a stronger influence in the southern and central regions.
2. Secondly, in the summer months, less distinctive spatial differences were found, with higher probability of drought conditions under NAO+ phases, which however can be enhanced or moderated by the EA.
3. Finally, as a result of catchment characteristics there is spatio-temporal variability in the propagation of meteorological to hydrological drought.

Our findings suggest that by considering the NAO and EA in combination, we can better describe climate and drought variability in both the winter and summer months.

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