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A Space-Time Geostatistical Approach to Exploring the Stationarity of North Atlantic Oscillation Driven Wet/Dry Conditions in Great Britain

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The North Atlantic Oscillation Index (NAOI) characterises the variability of the North Atlantic jet stream, and as the primary teleconnection affecting British climate, has been well studied. However, the spatio-temporal influence of the NAO on the wet-dry continuum is less well understood. Recent publication of spatially and temporally consistent Standardised Precipitation Index (SPI) time-series, offers an opportunity to examine rainfall patterns under different NAOI phases, and examine their stationarity. In this study, we classify SPI (1-month accumulation period) into a state of NAOI positive, negative or neutral condition, monthly, for 116 water years (1899/1900-2014/2015).

We use two novel geostatistical methods to identify spatio-temporal patterns in SPI under NAOI phase on a 5km consistent grid. Firstly, we use an 'emerging hot-spot' analysis based on the Getis-Ord Gi* statistic, which is calculated on each bin in the data array (an array was created for each calendar month and NAO phase) to identify spatially significant clusters of high/low SPI-1. Over the full array, the Mann-Kendall trend test calculates, for each grid square, the percentage of time a location is in a significant cluster of high (wet)/low (dry) values. Secondly, we apply a 'time-series clustering' analysis which identified locations that are most similar in terms of SPI-1 and partitions them into clusters, where each cluster member has similar space-time characteristics. Related to this analysis is an assessment of deviation within each spatial cluster over time.

Our analysis reveals significant differences occur in the spatial signature of rainfall under NAO positive and negative phases. Whilst these patterns have been examined previously, our analysis moves the field forward by showing the consistency in NAO driven rainfall patterns over a long study period. In winters under NAOI positive, large clusters of significantly wet conditions emerge (which occur for >80% of the time-series) in the north-west; while during NAOI negative winters, large clusters of significantly dry conditions emerge in these regions (>80% of the time-series). Our geostatistical analysis reveals a clear and stationary winter NAO-driven spatial divide in rainfall across the UK. The south/east of the UK during winter typically responds in a directly opposing way to the north/west (in the magnitude of 60% of the time series either in high or low clusters of SPI-1 values). During the summer months the significance of this pattern decreases, and the spatio-temporal signature is far more homogenous. However, the direction of rainfall deviation is inverted to the NAOI-driven pattern in winter; positive NAOI produces drier conditions (in >60% of the time-series), and NAOI negative produces wetter conditions (in >60% of the time-series) across much of Britain.

This is the only study, as far as we are aware, which applies novel geostatistical techniques to allow for the spatio-temporal influence of the NAO on rainfall patterns, which show various degrees of stationarity, to be distinguished. Understanding these patterns and their consistency allows for better water resources management as our ability to predict the NAO continues to develop.