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 (NAO)

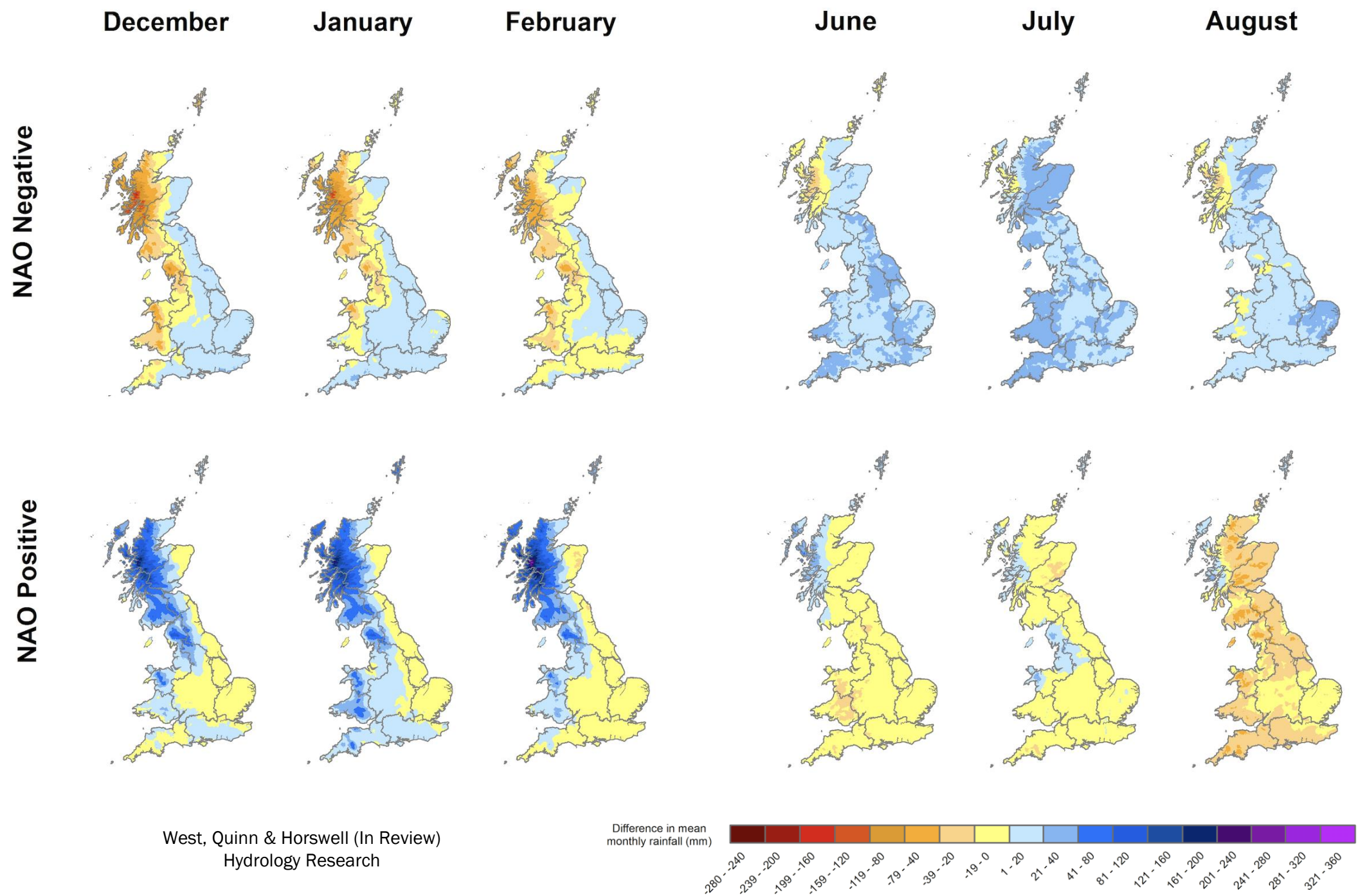
- Oceanic-atmospheric circulation interactions (teleconnections) are a key influence on regional climate (Wilby et al., 1997).
- Weather in GB is highly variable, often fluctuating between wet and dry conditions.

- The North Atlantic Oscillation (NAO) characterises some of the variability in the North Atlantic jet stream.
- The NAO is the single most important teleconnection influencing climate variability in Northern Europe (Rodwell *et al.,*1993; Sweeney & O'Hare, 1992).

The NAO Rainfall Spatial Signature

- The NAO fluctuates between a positive and negative state; each state produces characteristics climatic patterns over GB (Simpson & Jones, 2014).
  - A positive NAO represents stronger than usual sea level pressure between Iceland and the Azores.
  - A negative NAO represents the reverse with a weaker than usual SLP between Iceland and the Azores.
- Each phase leads to differential rainfall patterns, which vary over space and time.
- Some evidence of local influences which an amply or dampen the NAO's effect on rainfall – e.g Burt & Howden (2013).

The NAO Rainfall Spatial Signature



West, Quinn & Horswell (In Review)
Hydrology Research

Limitations of Previous Work

- Analysis has previously been undertaken with spatially and temporally limited datasets.
- Some studies rely on descriptive statistics such as mean/median rainfall which is averaged over large regions.
- Generally studies use non-spatial statistical methods to look at the relationship between the NAO and rainfall, e.g. correlation analysis.
- No studies that we are aware of have looked at the variability/consistency in the NAO rainfall spatio-temporal signatures.

Research Aim

- To use geostatistical techniques to explore the spatio-temporal characteristics of NAO driven precipitation patterns over Great Britain.
- In doing so, we aim to explore the consistency of these precipitation patterns.
- All using the latest available datasets to represent the NAO and precipitation.

Datasets – The NAOI

- The North Atlantic Oscillation Index (NAOI) is a quantitative measure of the pressure gradient between Iceland & the Azores.

- Various NAOI calculation methods (e.g. Station-Based vs Principal Components EOF).
- The choice of method can impact on analysis results (Pokorná & Huth, 2015).

- We used the PC method (Hurrell, 2003) and defined NAO phase as half the standard deviation plus/minus the long-term mean (Berton *et al.*, 2017).

Datasets – The SPI

- The Standardised Precipitation Index (SPI) (McKee *et al.*, 1993) was sourced at monthly intervals (1899-2015) from the UK Centre for Ecology & Hydrology (Tanguy *et al.*, 2017).

- One-month accumulation period was used in this study.

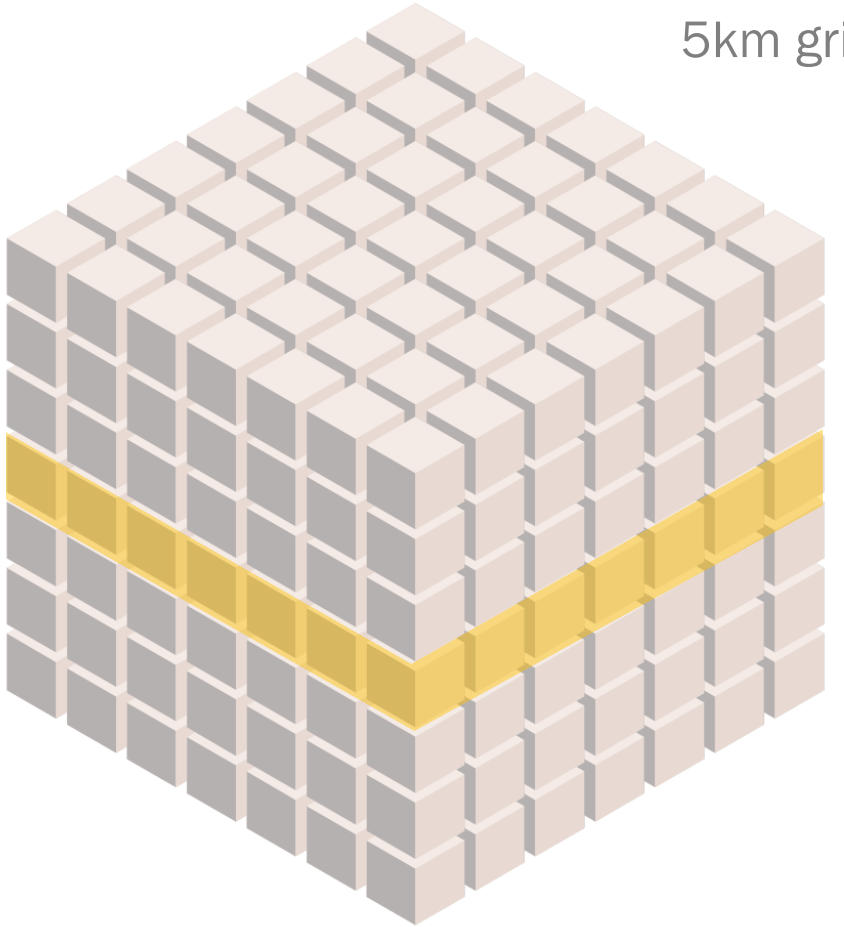
- Fitted with a gamma distribution (Stagge *et al.*, 2015) with a standard period of 1961-2010.

- Normally distributed data which is standardised in space and time.

Data Arrays

Monthly SPI-1

Array per month per phase

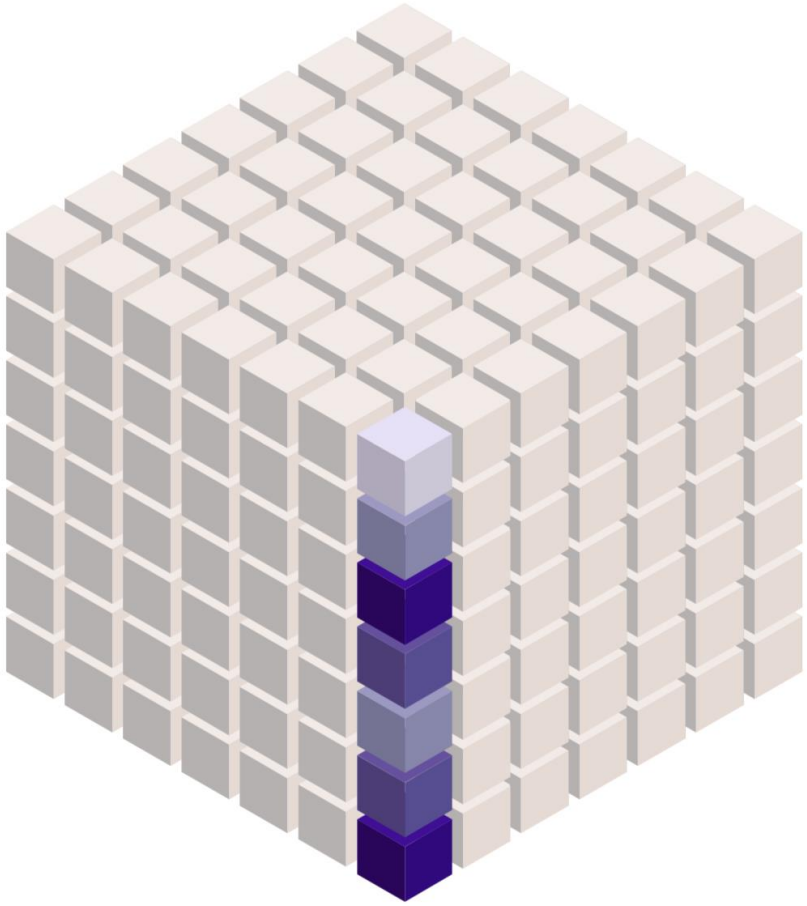


5km grid covering the UK

Slide graphics adapted from Bennett *et al.* (2018)

Geostatistical Analysis I

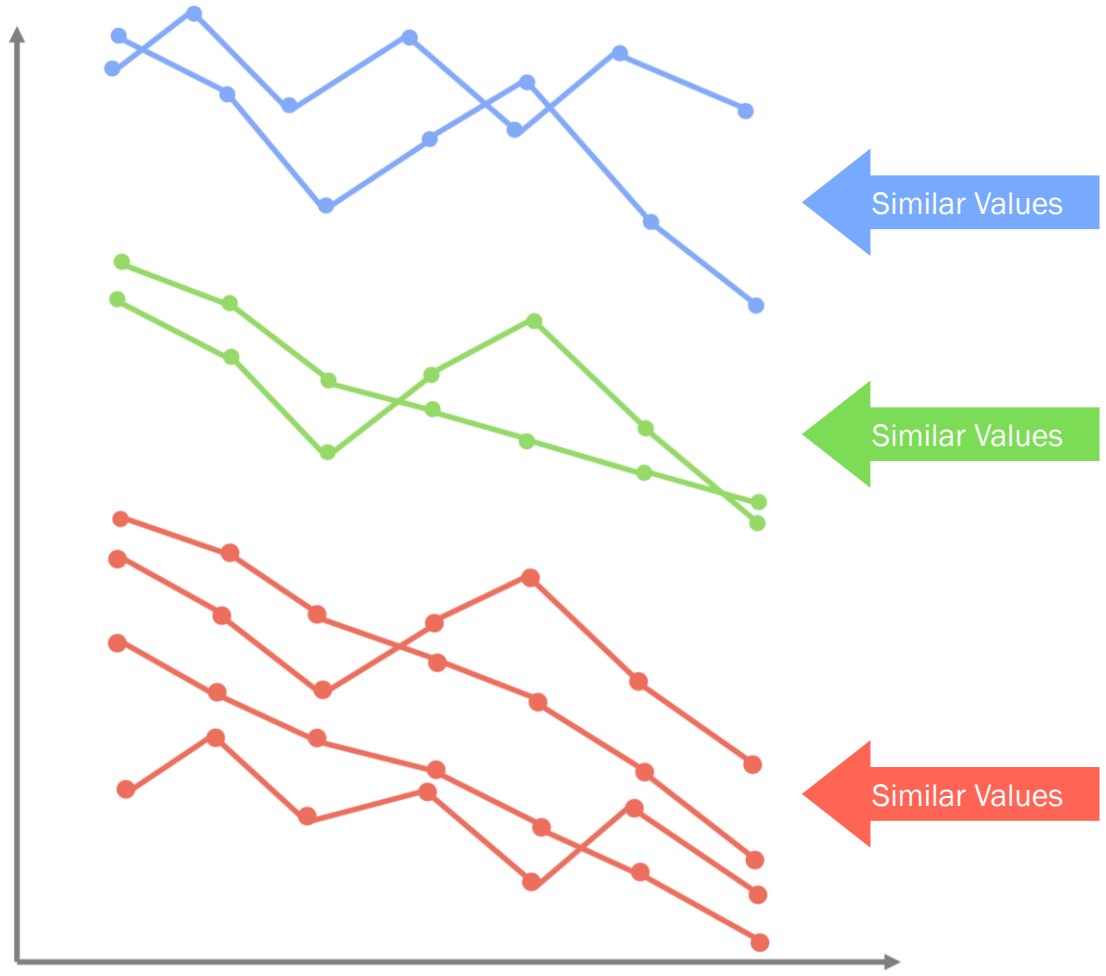
- Firstly, we applied a 'Time Series Cluster' analysis.
  - Partitions the time series in the cube on the similarity of either **value** or profile (Bennett *et al.*, 2018).
  - Undertaken monthly for each NAO phase, e.g. Dec NAO+ and Dec NAO-.



Slide graphics adapted from Bennett *et al.* (2018)

Geostatistical Analysis I

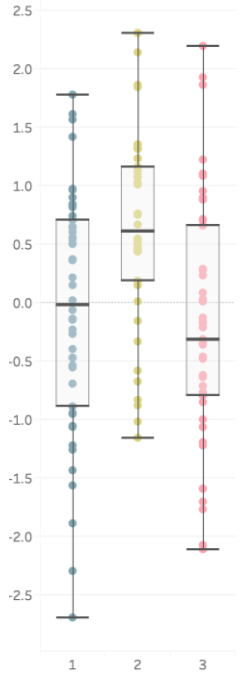
- Optimal number of clusters evaluated using the spectral gap heuristic.
- Based on the magnitude of difference between values in a dissimilarity matrix.
- Optimal number of clusters was consistently 3.

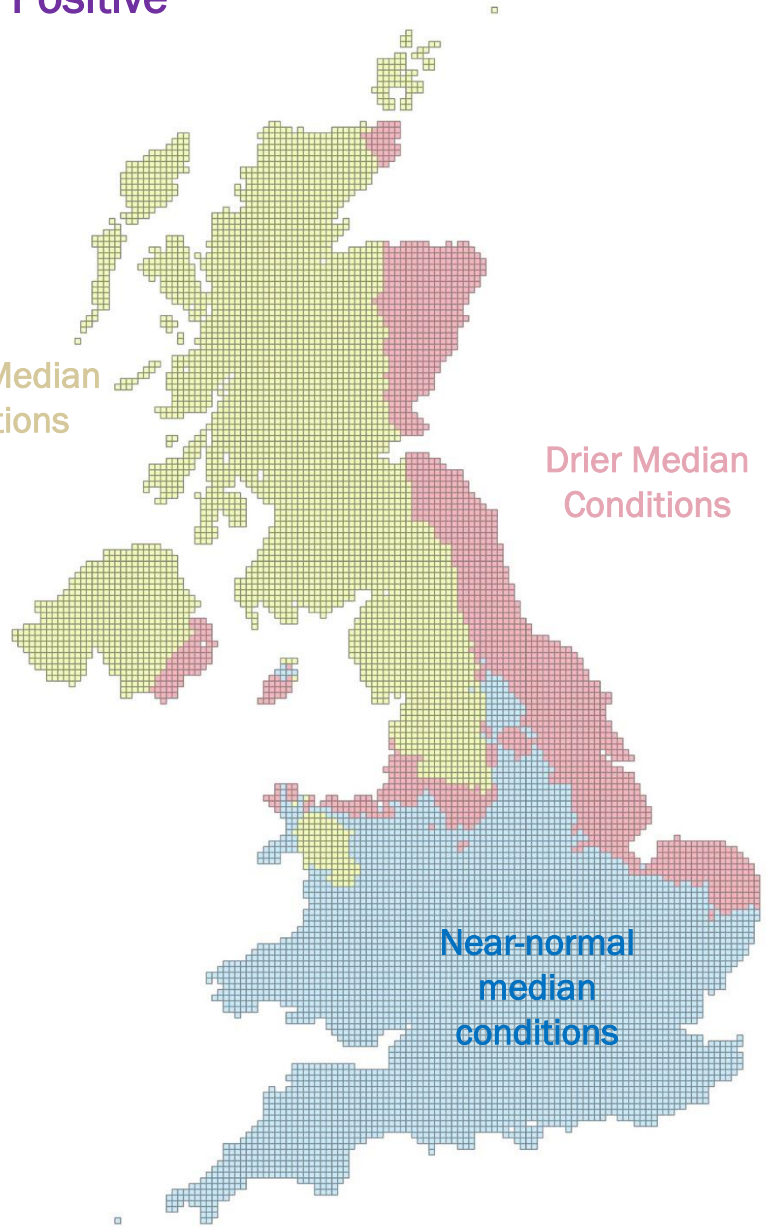


Slide graphics adapted from Bennett *et al.* (2018)

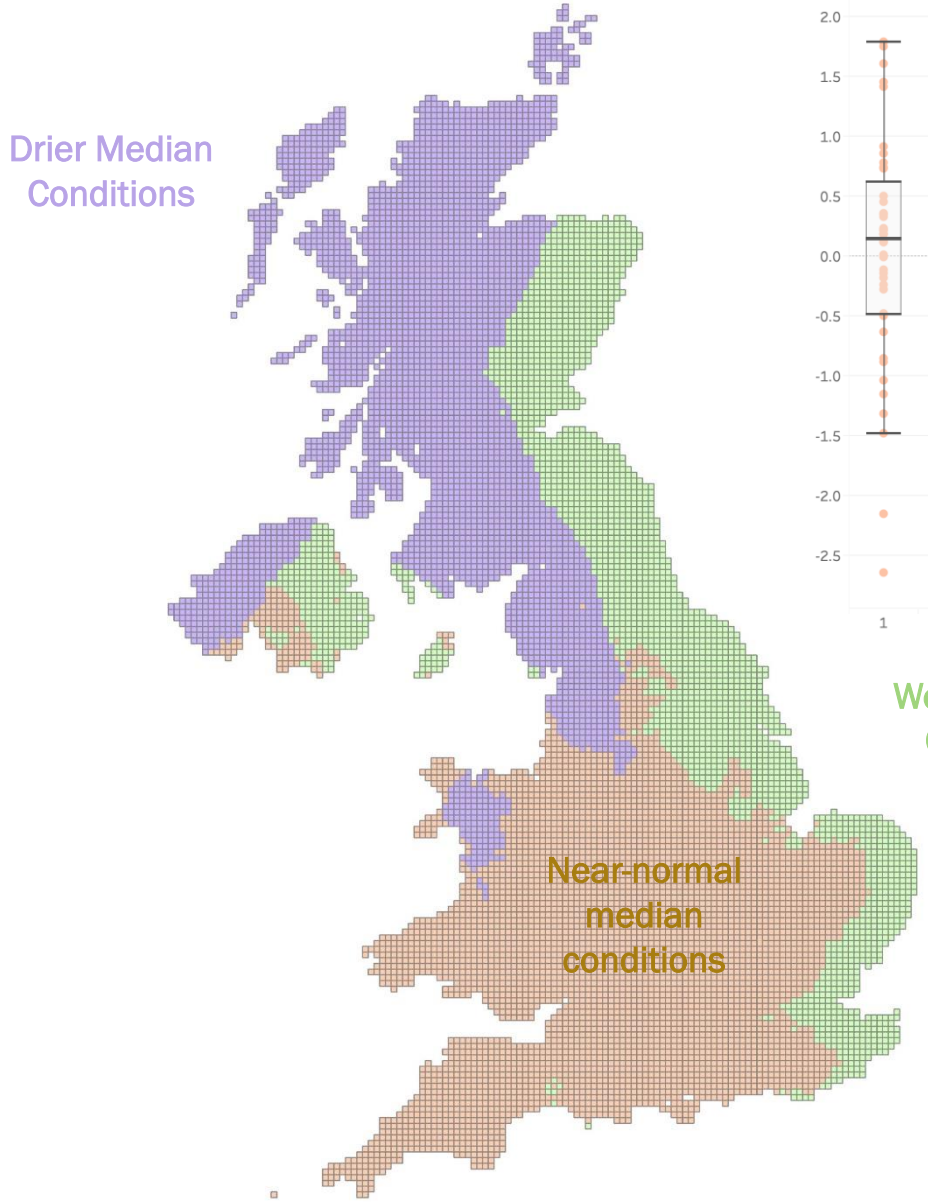
Winter Clustering

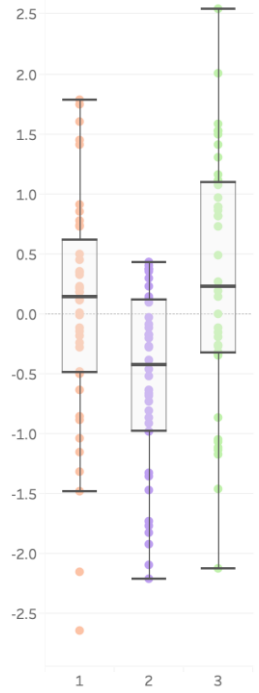
NAO Positive





NAO Negative





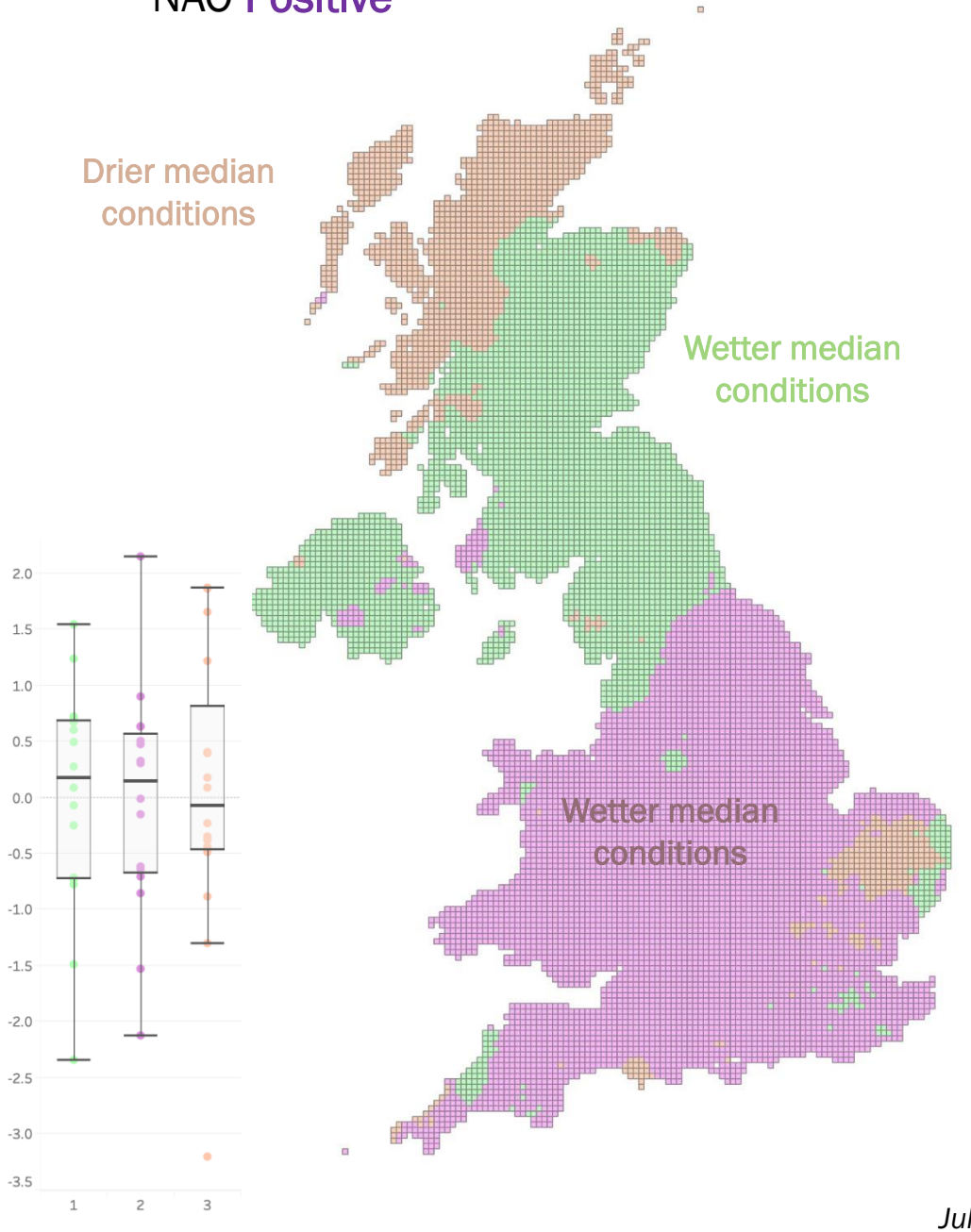
Wetter Median Conditions

Dec Shown Above

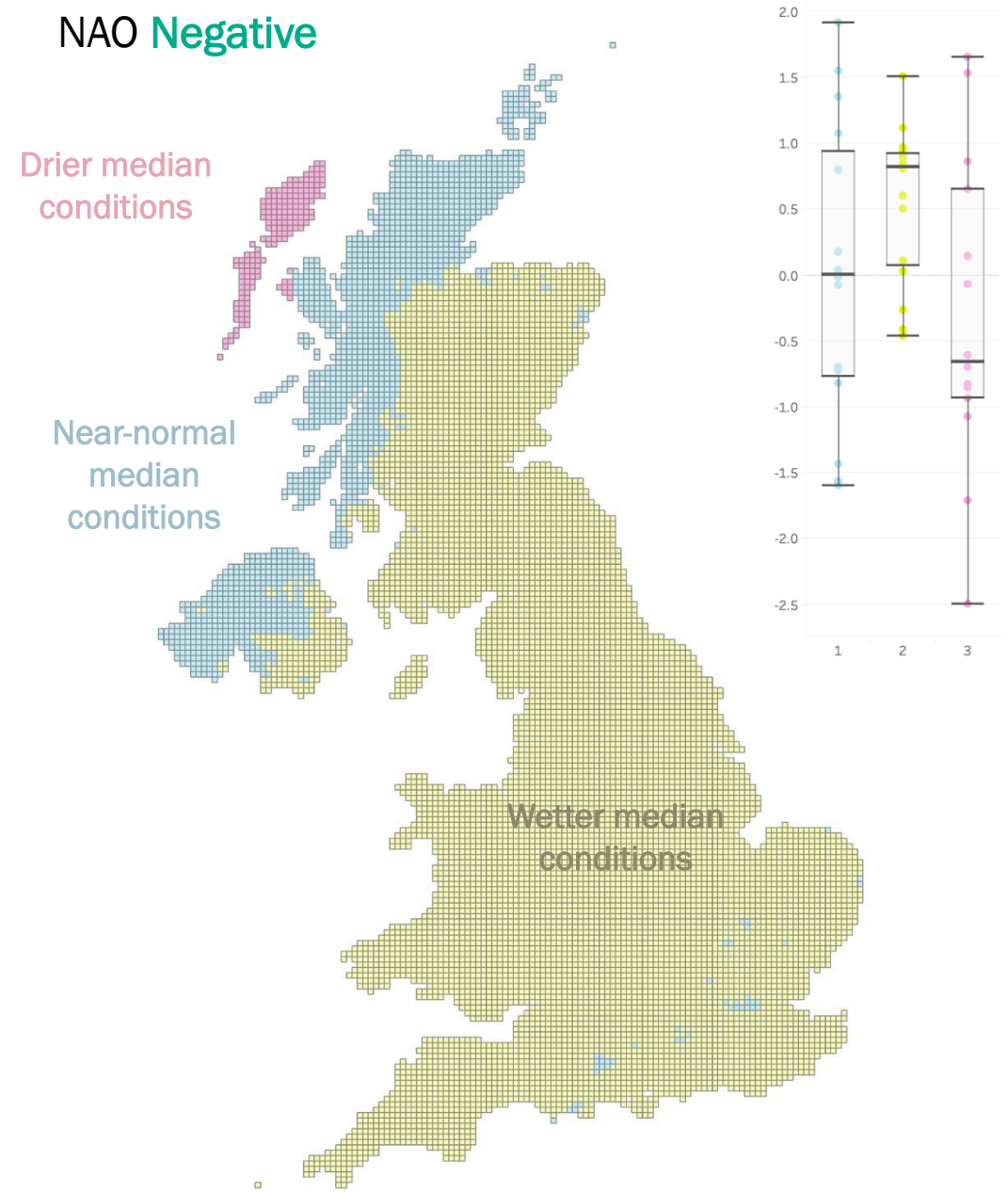
Colours are for discriminatory purposes only

Summer Clustering

NAO Positive



NAO Negative



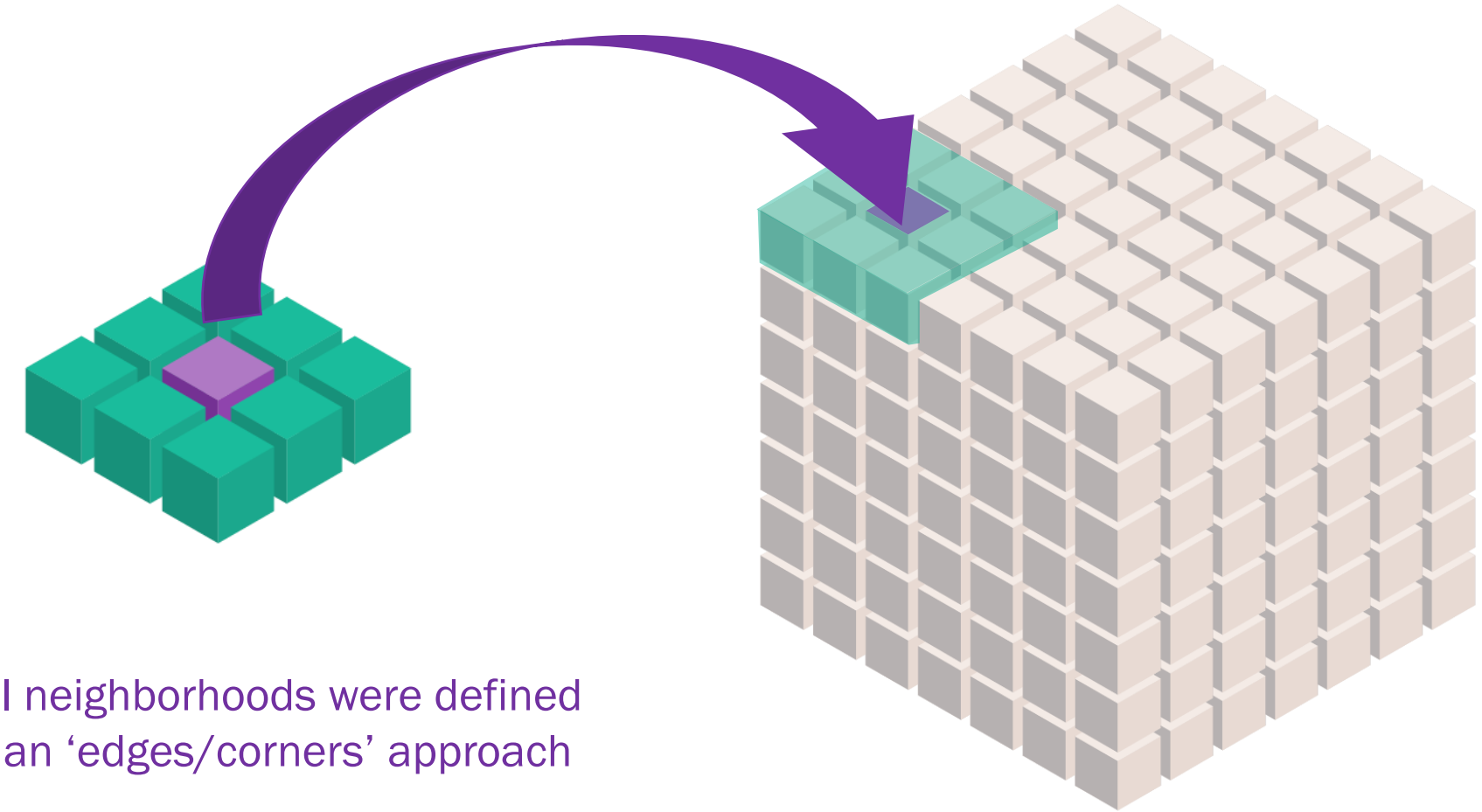
Jul Shown Above

Colours are for discriminatory purposes only

Geostatistical Analysis II

- "Emerging Hot Spot Analysis" is a temporal 'version' of the standard spatial Getis-Ord Gi* statistic
  - The Getis-Ord Gi* statistic is calculated for each bin in the array.
  - Hot/Cold Spot trends for each bin are evaluated using the Mann-Kendell trend test (Esri, 2019).

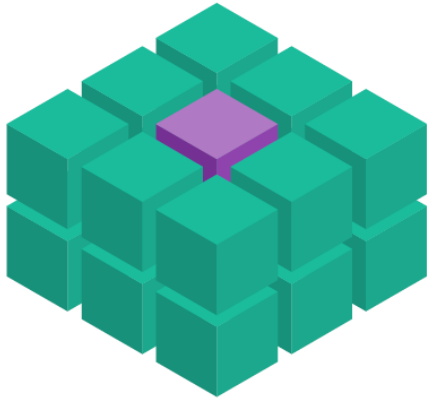
Emerging Hot Spot Analysis

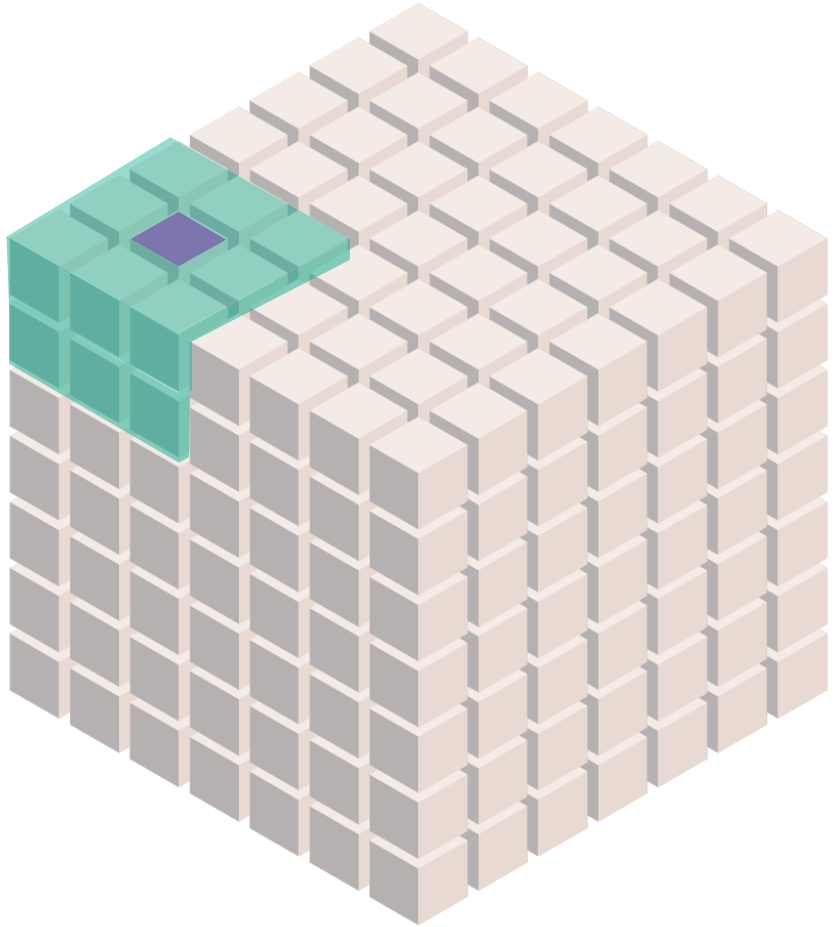


Spatial neighborhoods were defined using an ‘edges/corners’ approach

Slide graphics adapted from Bennett *et al.* (2018)

Emerging Hot Spot Analysis





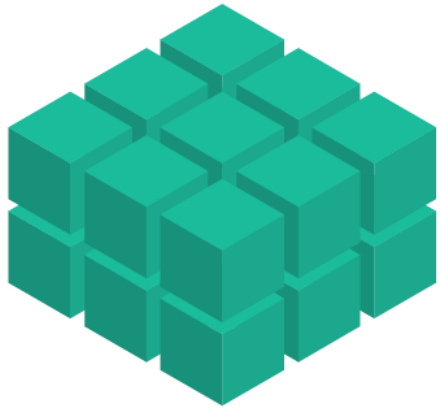
Neighborhoods are also defined in time (previous month in a given phase)

No temporal bias in the aggregation

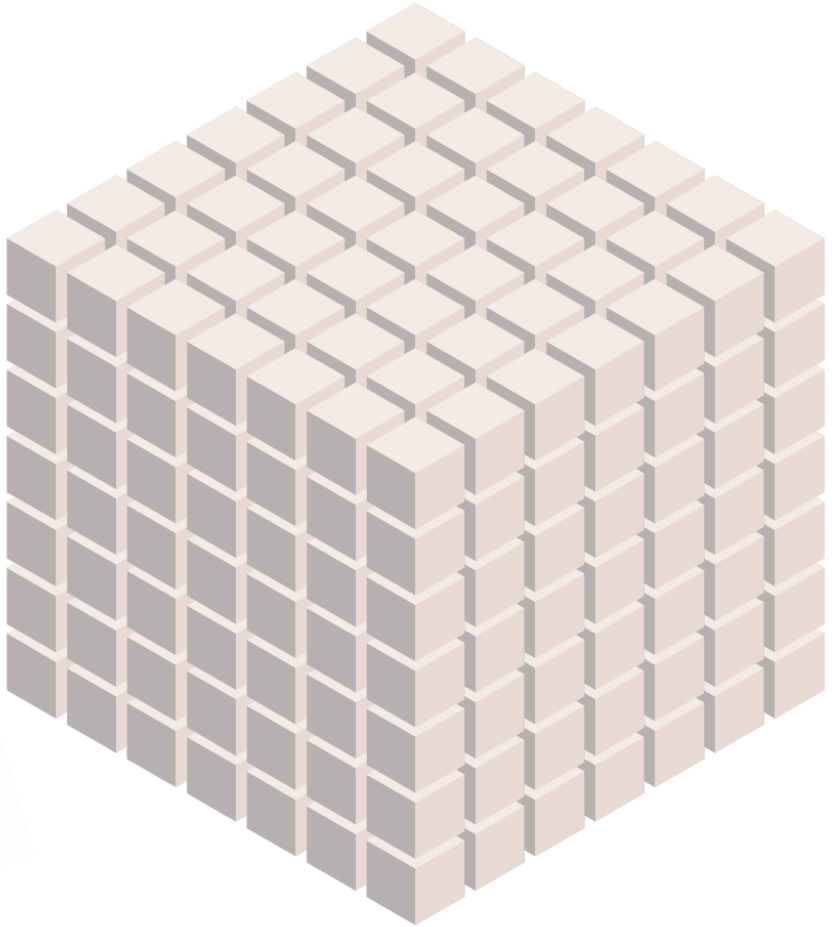
Slide graphics adapted from Bennett *et al.* (2018)

Emerging Hot Spot Analysis

Is this neighborhood?



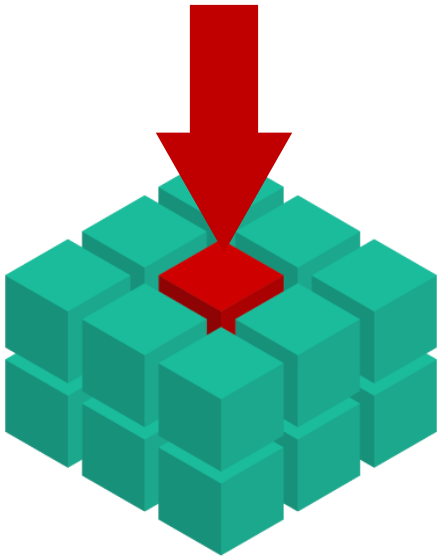
Significantly different from the rest of the data?



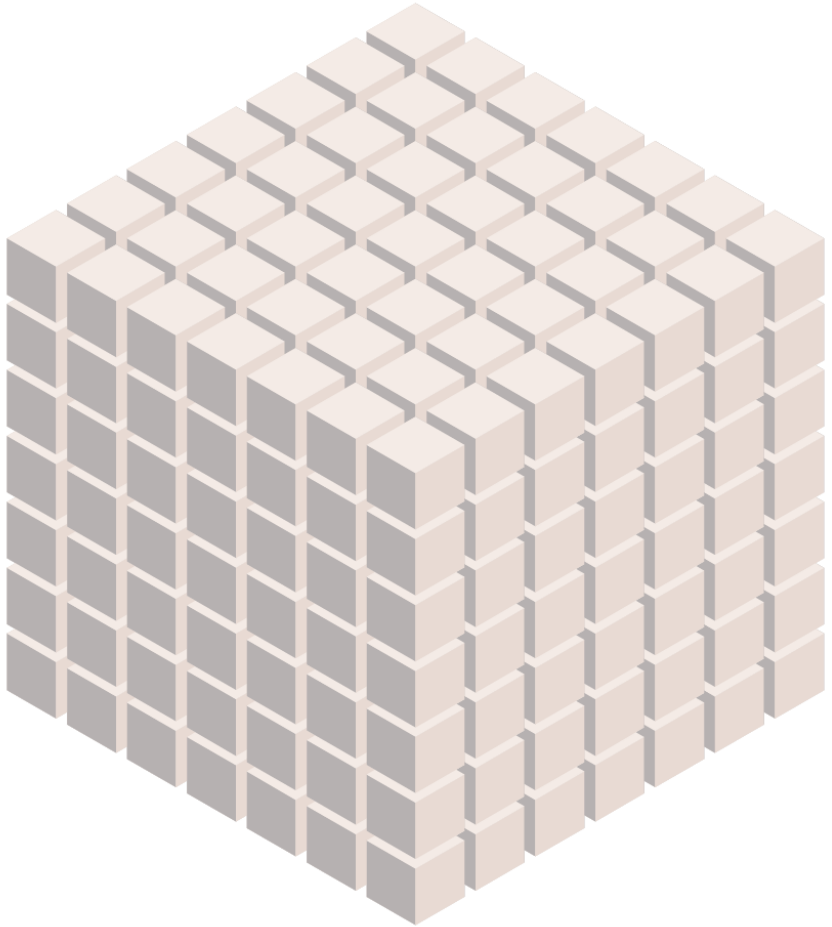
Slide graphics adapted from Bennett *et al.* (2018)

Emerging Hot Spot Analysis

"Hotspot"



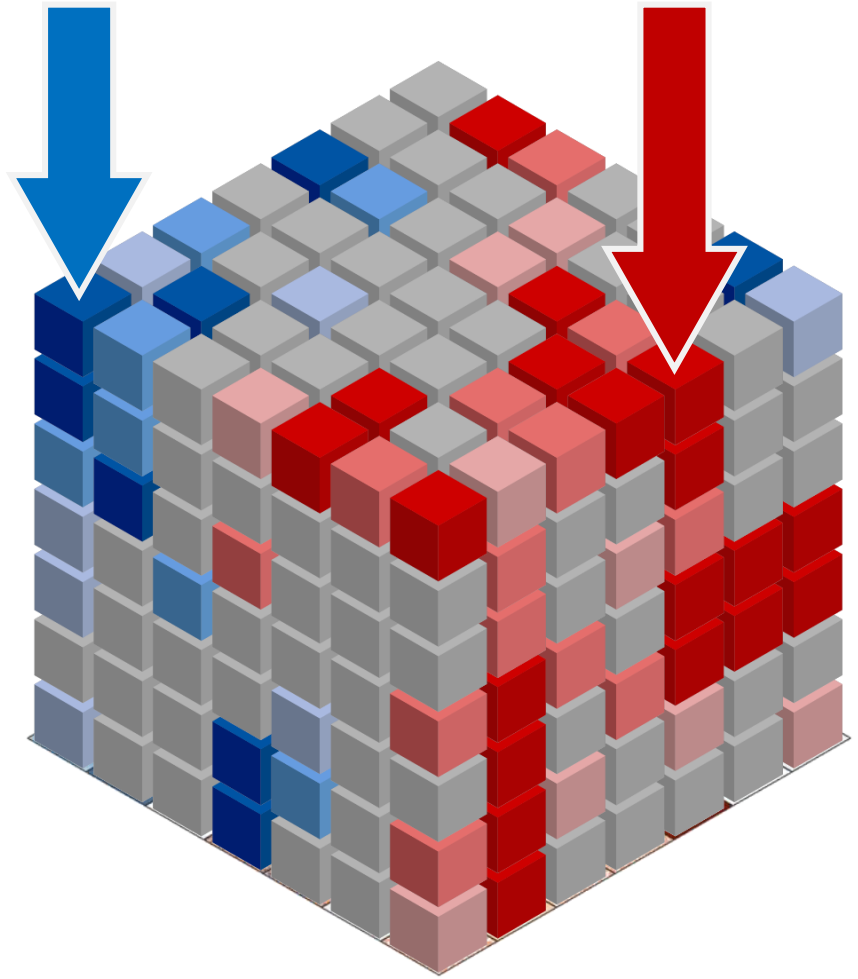
If it is significantly higher we identify that bin as a hot spot



Slide graphics adapted from Bennett *et al.* (2018)

Emerging Hot Spot Analysis

For what percentage of the period (i.e. the number of times a given month is in a given NAO phase) is each bin in a **hot** or **cold** spot?



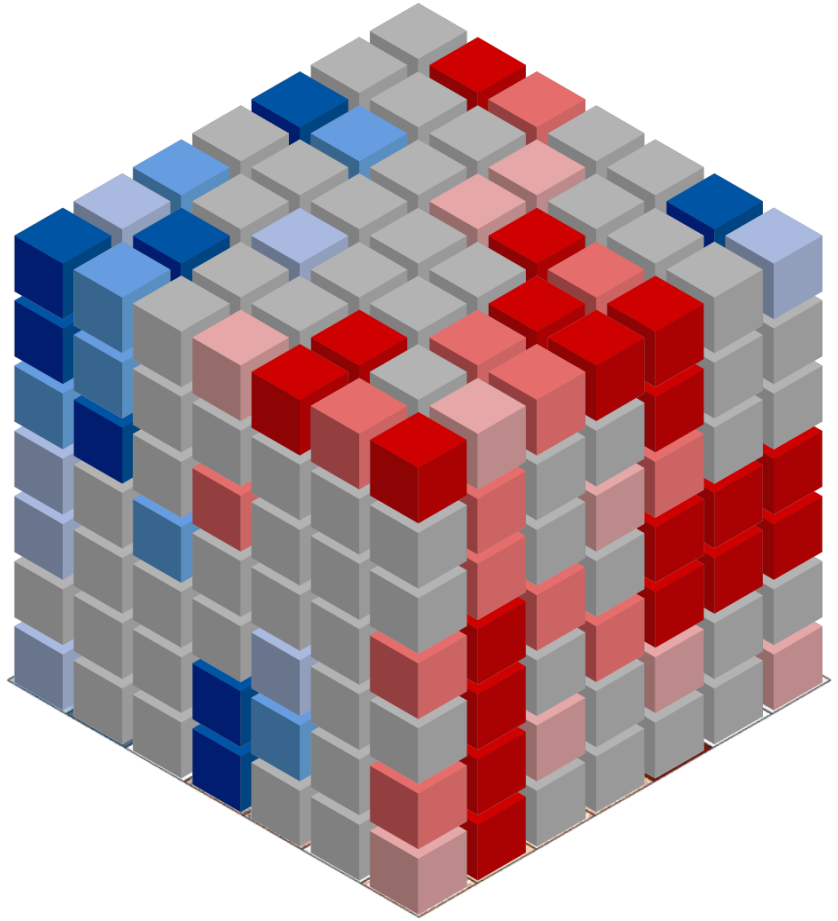
Slide graphics adapted from Bennett *et al.* (2018)

Emerging Hot Spot Analysis

Colour Warning!!

Low SPI = COLD Spot = DRY

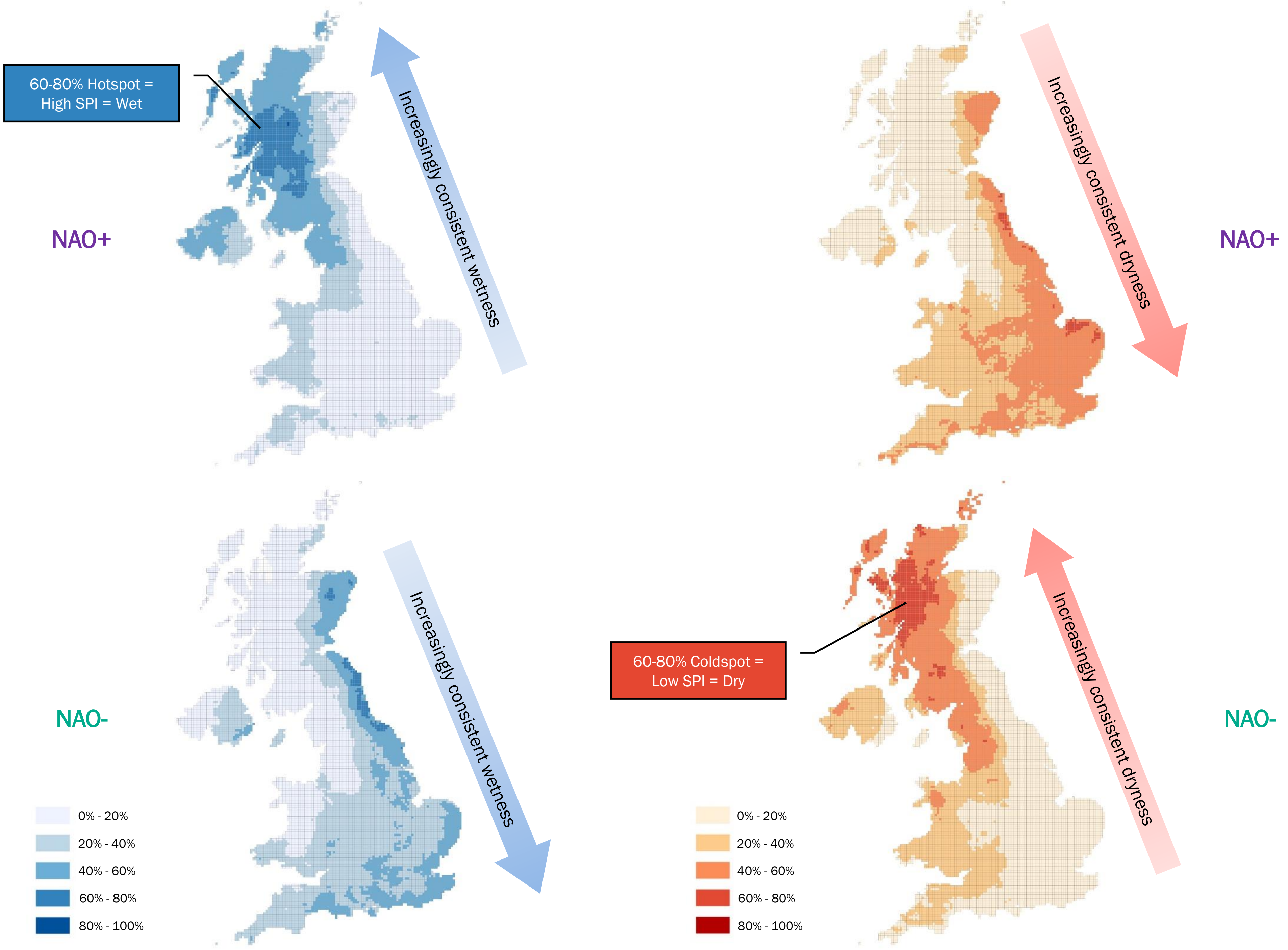
High SPI = HOT Spot = WET



Slide graphics adapted from Bennett *et al.* (2018)

Winter Precipitation Variability

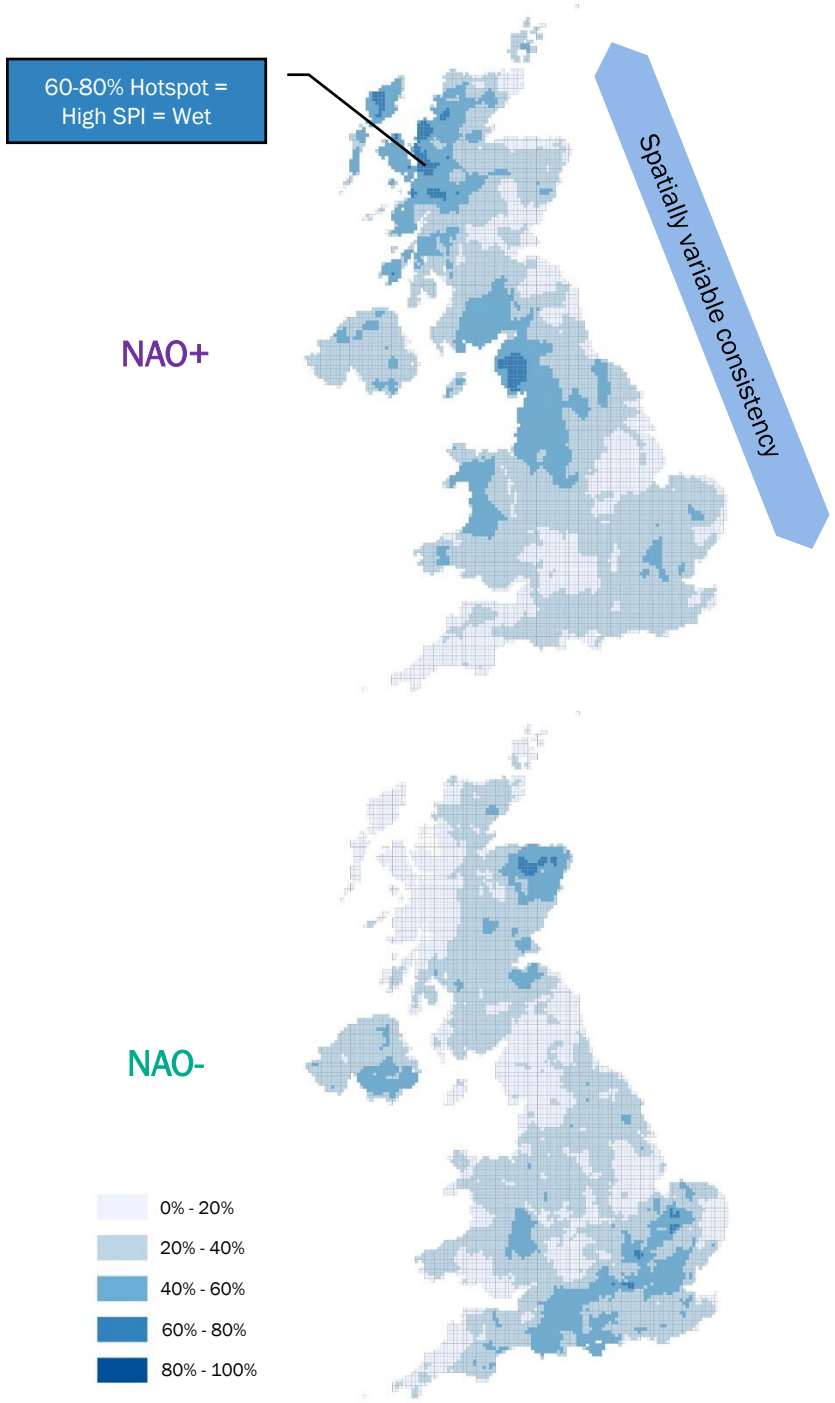
% Time Hot/Cold Spot

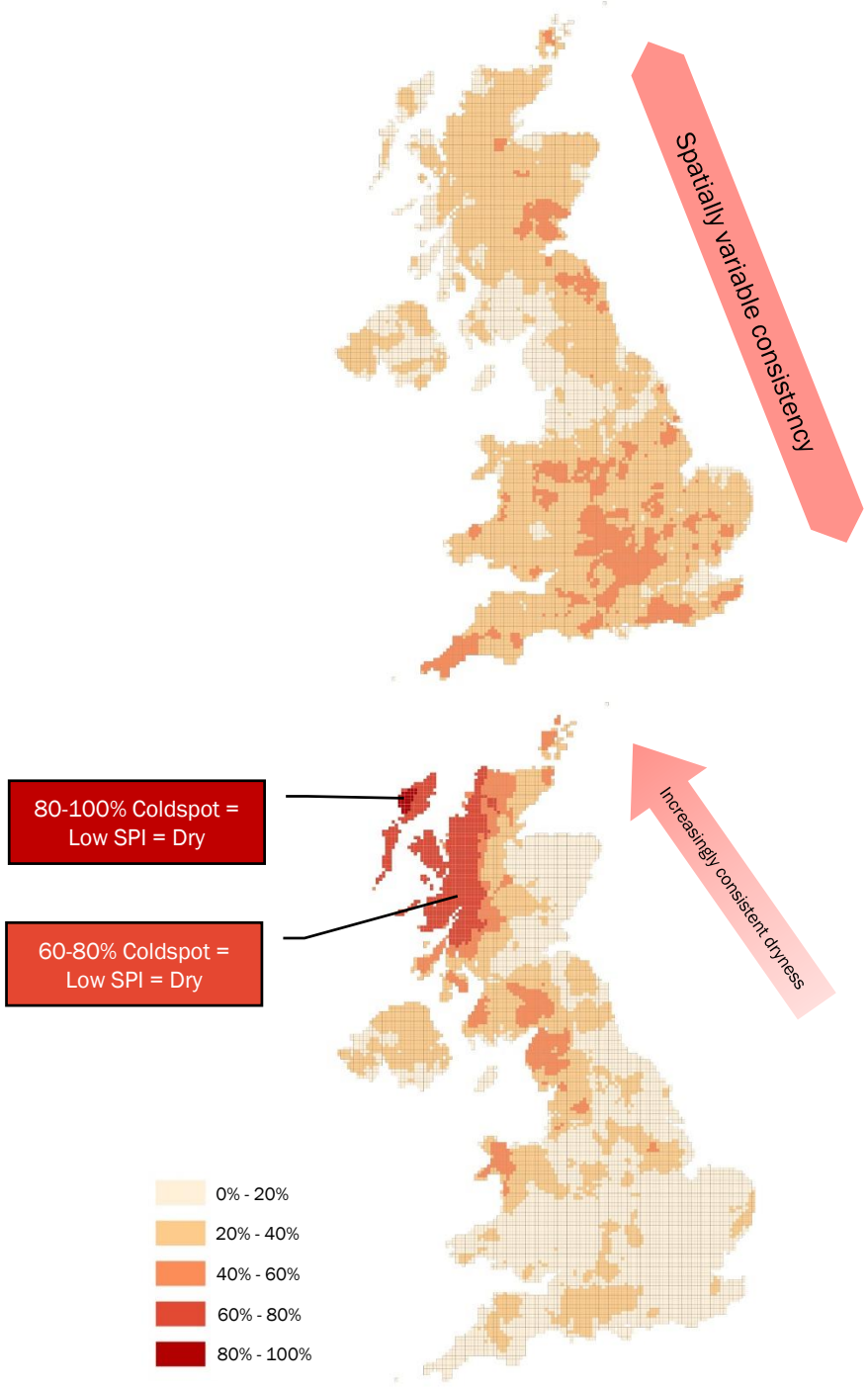


Dec Shown

Summer Precipitation Variability

% Time Hot/Cold Spot

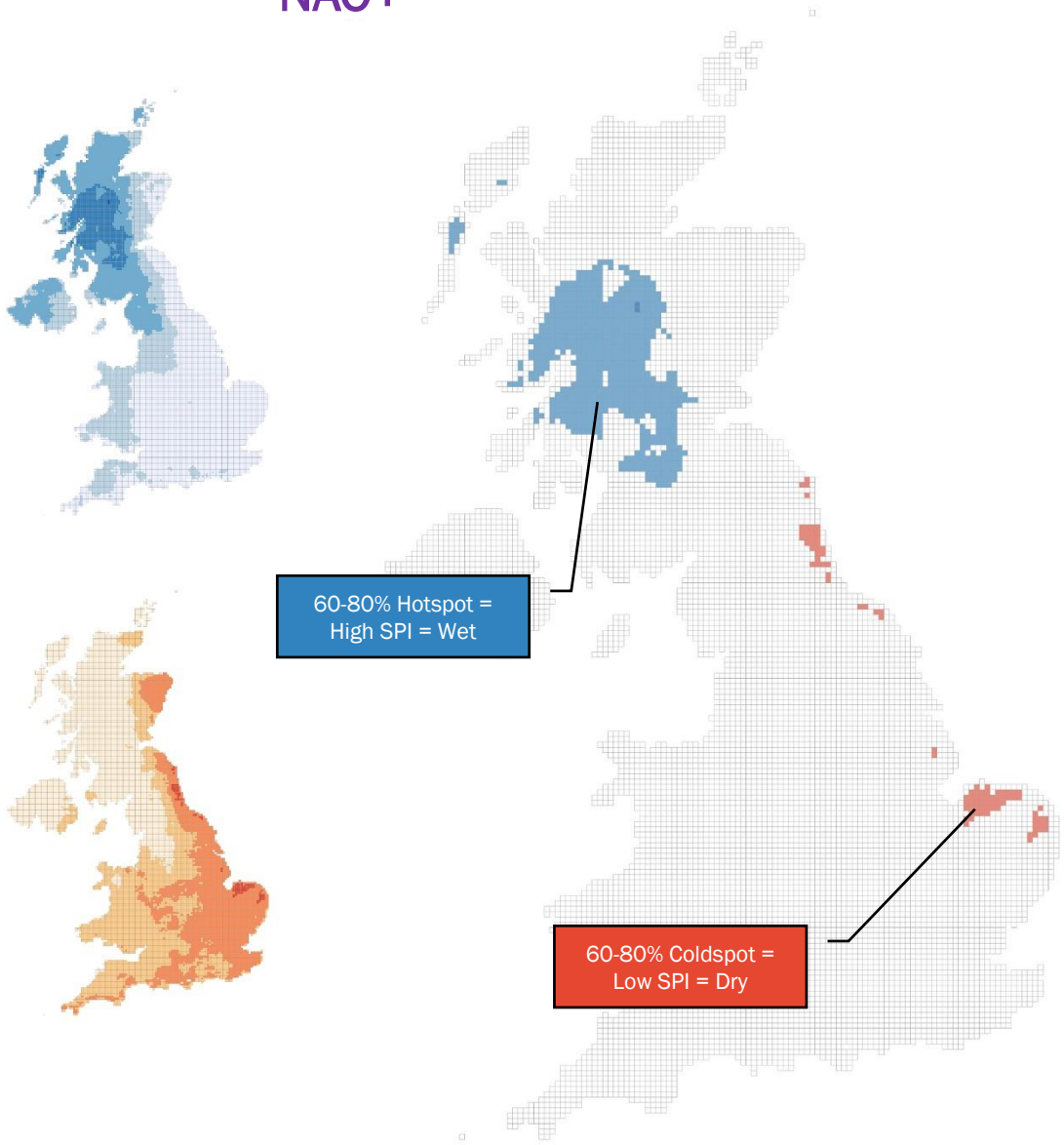




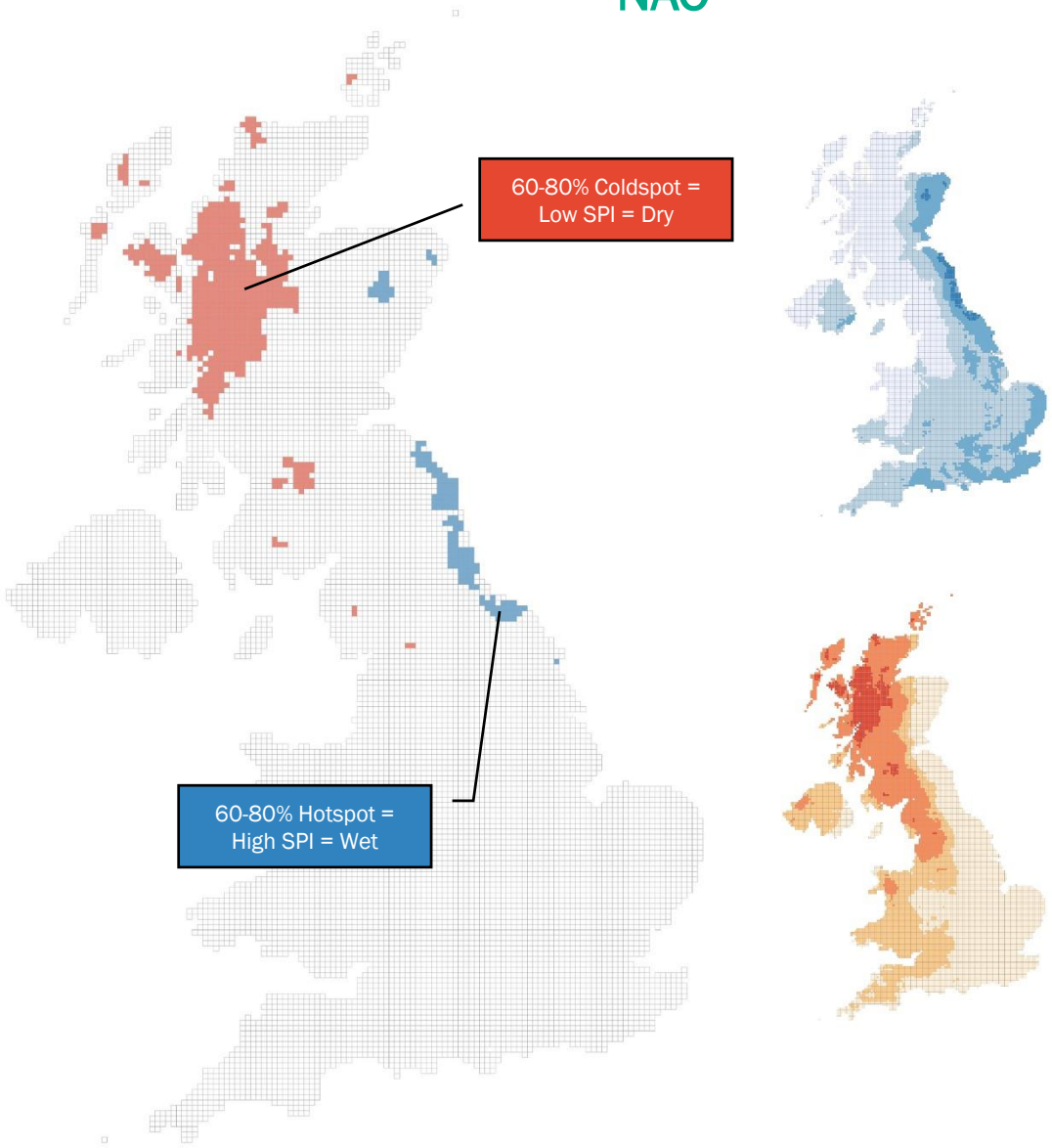
Jul Shown

Winter Pattern Consistency

NAO+



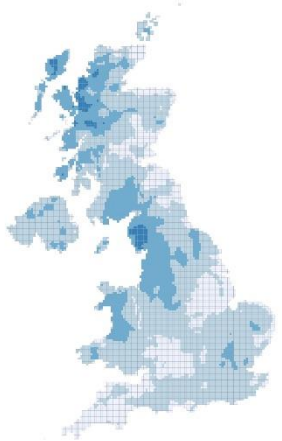
NAO-

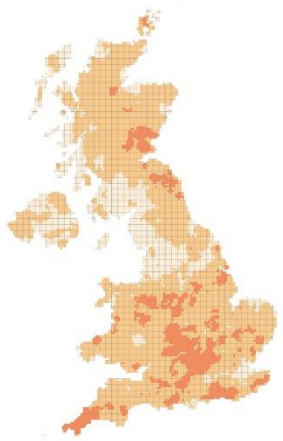


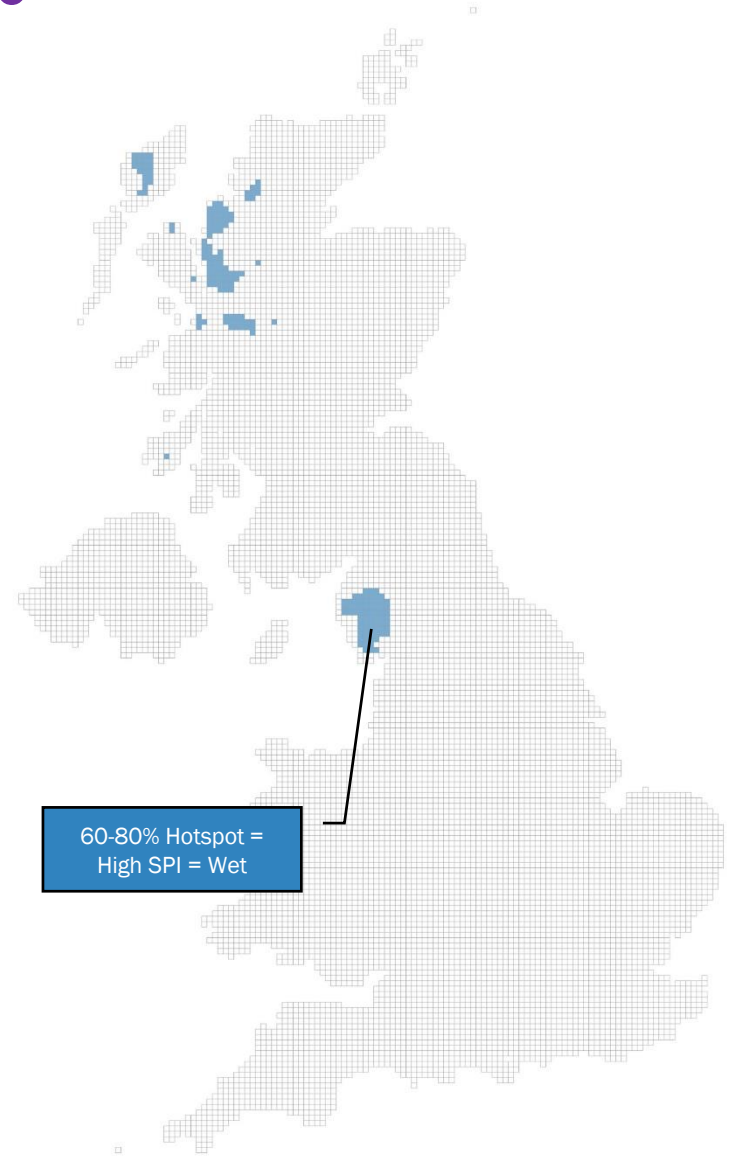
Dec Shown

Summer Pattern Consistency

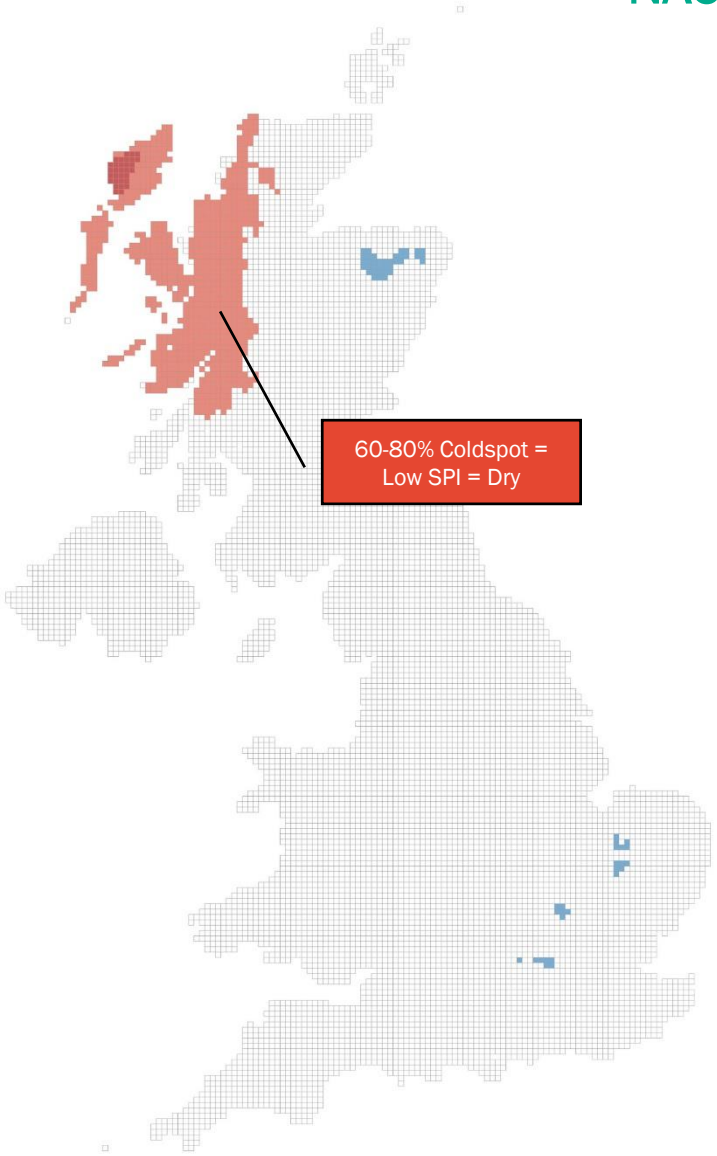
NAO+

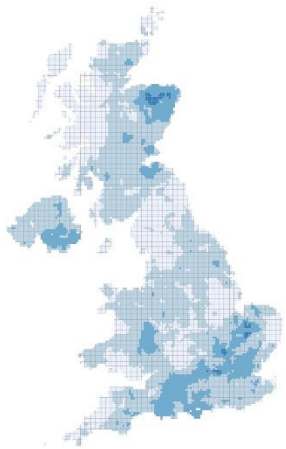


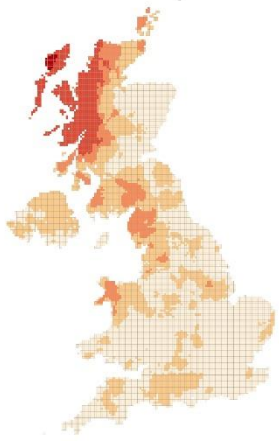




NAO-







Jul Shown

Next Steps…

- Explore local scale factors which might affect the patterns shown in both of our analyses (e.g. elevation, distance inland).

- Explore the drivers of NAO pattern variability (e.g. NAO interaction with other teleconnections).

- Explore the relationship between consistency/variability and magnitude of the deviation in precipitation.

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Thank you

Any Questions?