# Mapping Wet-Dry Signatures of the North Atlantic Oscillation (NAO) in British Catchments

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# Overview

# The North Atlantic Oscillation (NAO)

- The hydro-meteorology of Great Britain is influenced by a number of large (sub-)planetary scale processes.
- Oceanic–atmospheric circulation interactions (also referred to as teleconnections) have a key influence on regional climate.
- Climate change is expected to significantly alter these processes and therefore hydro-meteorological patterns in Great Britain.
- Key for Great Britain and Northern Europe is the North Atlantic Oscillation (NAO) which characterizes some of the variability of the North Atlantic Jet Stream (Wilby *et al.*, 1997; Folland *et al.*, 2009).

# NAO Precipitation Patterns

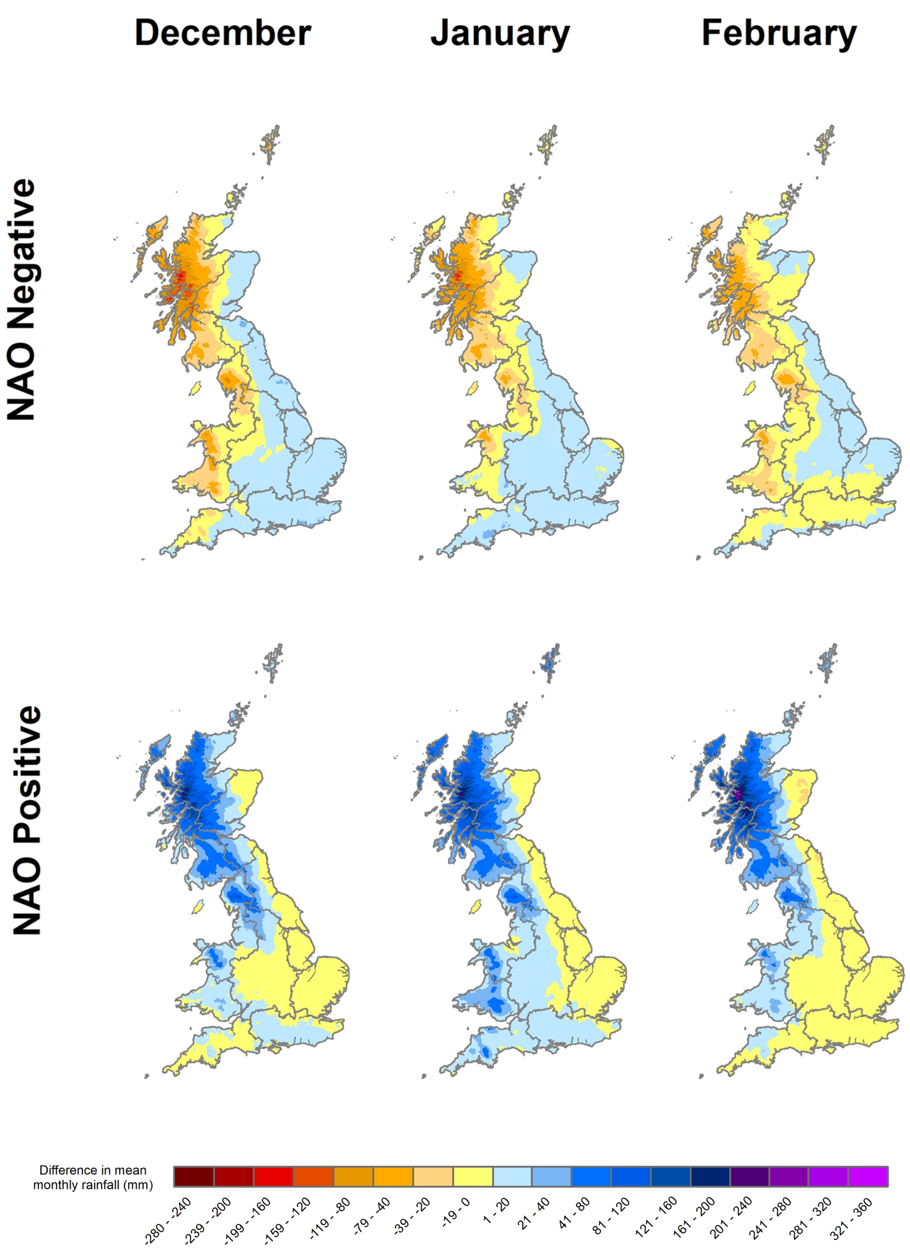
- The NAO switches between two phases (Positive and Negative). Each known to produce characteristic precipitation patterns in Britain (Hurrell *et al.*, 2003; Rust *et al.*, 2018).

- West, Quinn and Horswell (2019) mapped the regional rainfall response to the NAO using a 1km gridded rainfall dataset (Gridded Estimates of Areal Rainfall (GEAR) (Tanguy *et al.*, 2016)).
- As part of this analysis average monthly rainfall under NAO Positive, Negative and Neutral conditions was calculated. Following which the change in rainfall under Positive and Negative conditions was compared to when the NAO is Neutral.
- Extracts from this analysis are shown on the following two slides.

# Winter NAO Precipitation

Figure from West *et al.*, 2019 (*Hydro Research*)

(based on GEAR data - Tanguy *et al.*, 2016)




Winter NAO precipitation spatial signatures are characterized by a north-west/south-east pattern across GB.

Correlations between the NAO Index (NAOI) and rainfall are typically strong positive in the NW, and weak negative in the SE.

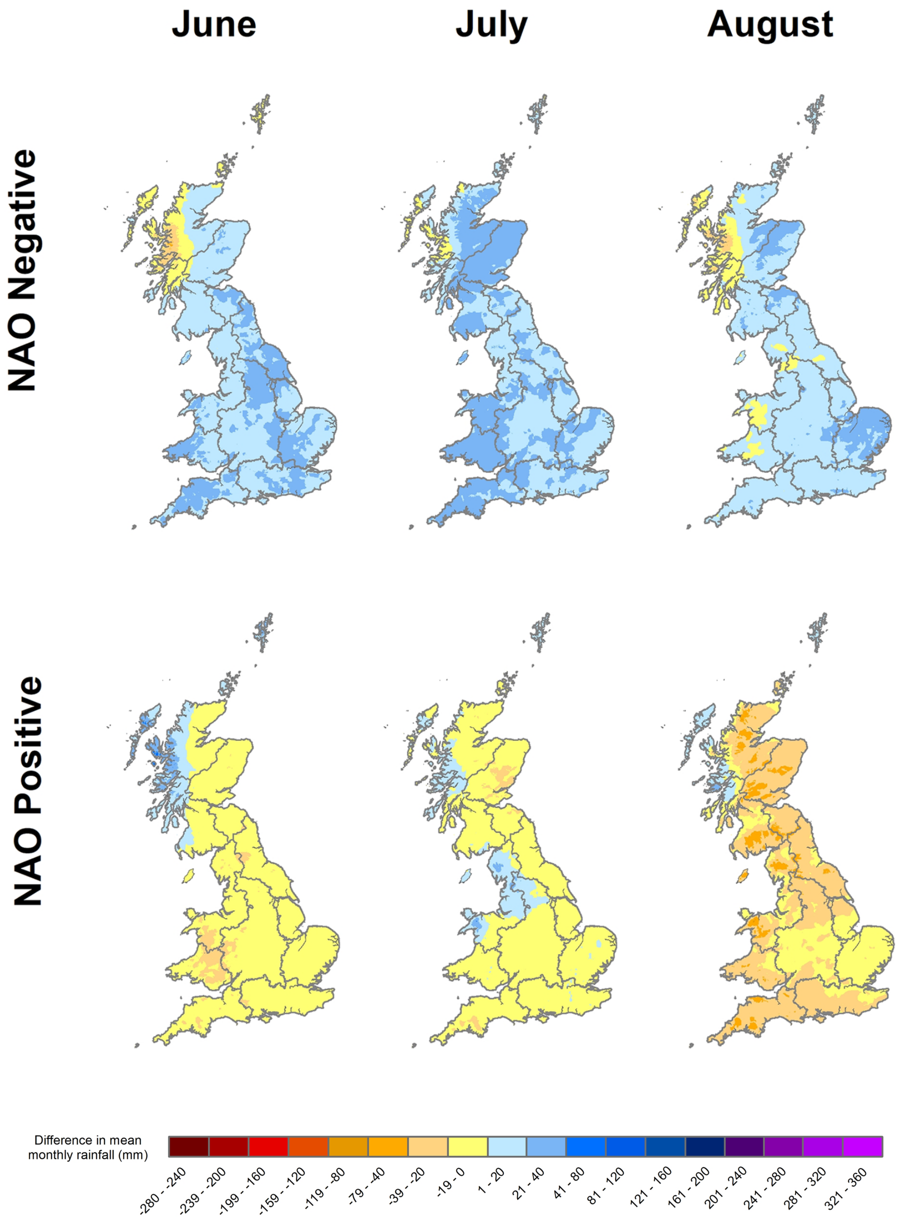
Under NAO Negative conditions the same areas receive significantly less rainfall.

Under NAO Positive conditions regions in the NW receive significantly higher rainfall than under NAO Neutral conditions.

# Summer NAO Precipitation

Figure from West *et al.*, 2019 (*Hydro Research*)

(based on GEAR data - Tanguy *et al.*, 2016)




Summer NAO precipitation signatures are typically more spatially homogeneous.

Correlations between the NAO Index (NAOI) and rainfall are typically weak negative across GB.

The directionality of the NAO's wet/dry influence is inverse to that in winter.

NAO Negative results in moderately wetter conditions, while NAO Positive results in moderately drier conditions (especially in August).

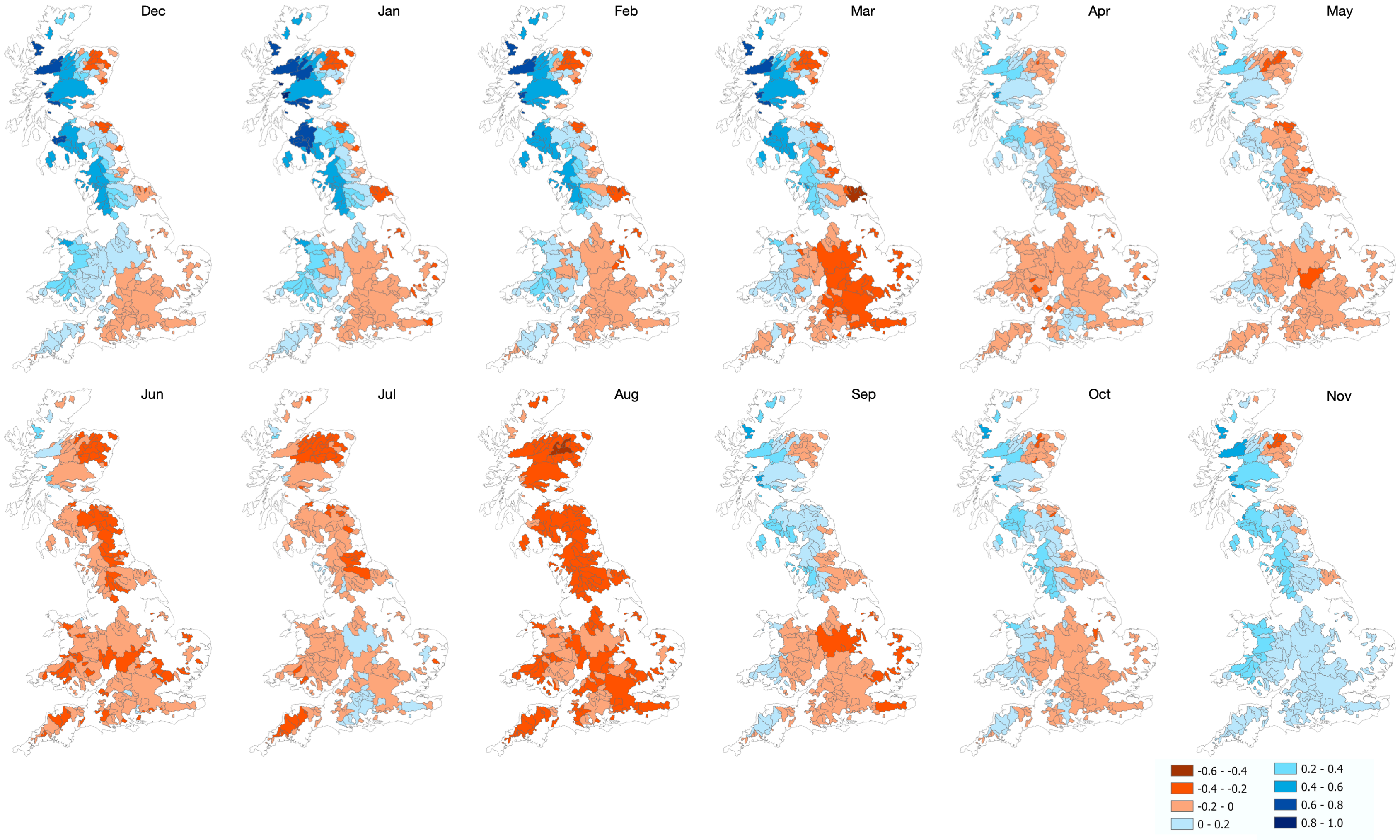
# Research Questions

**This study aims to explore the influence the NAO has on high and low flows in 291 British catchments.**

We:

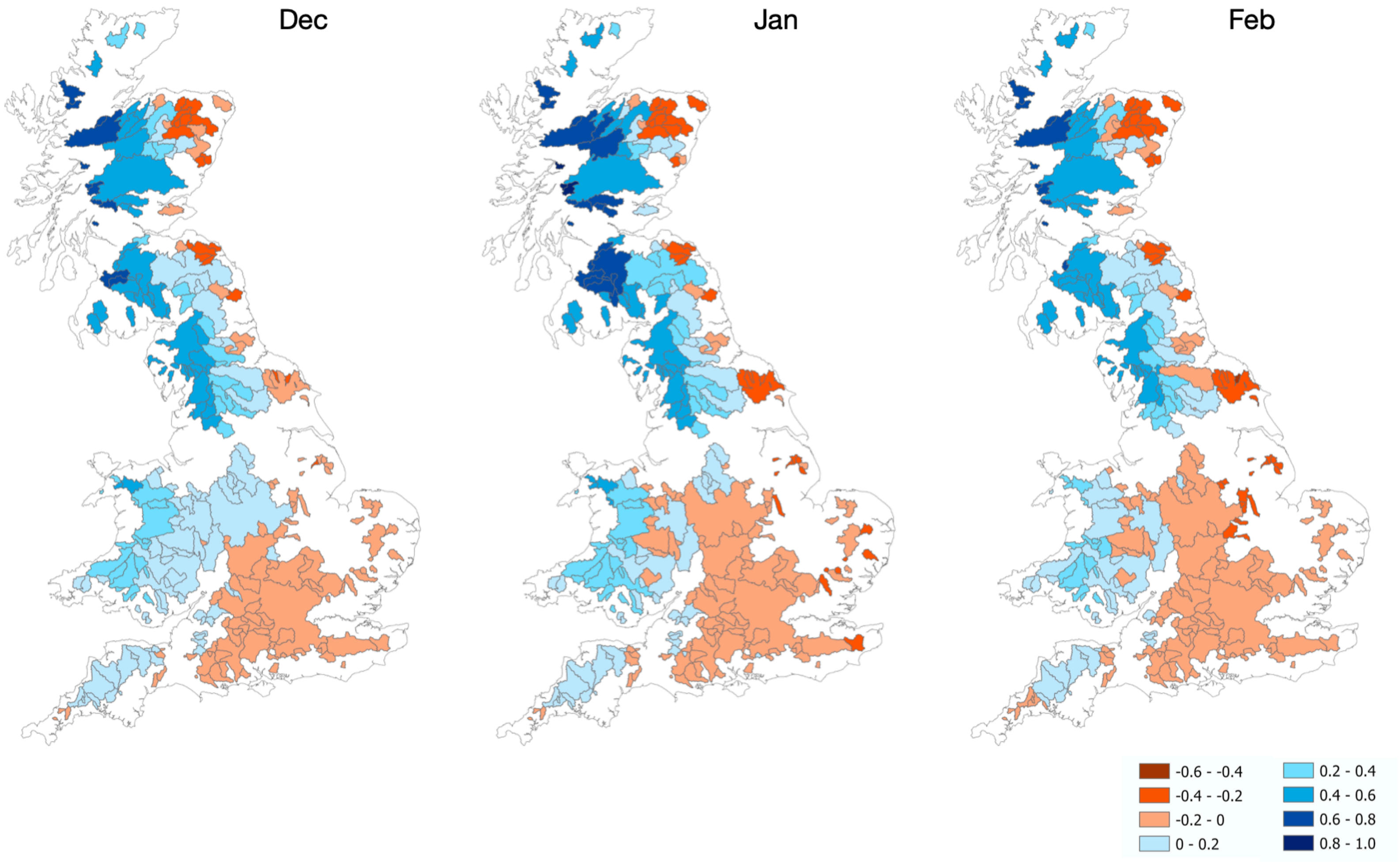
1. Explore correlations between the NAOI and Standardised Streamflow Index (SSI).
2. Quantify changes in streamflow using historic reconstructed flow data.
3. Compare NAO catchment streamflow signatures with the rainfall signatures previously discussed.

# Correlations between the NAOI and SSI



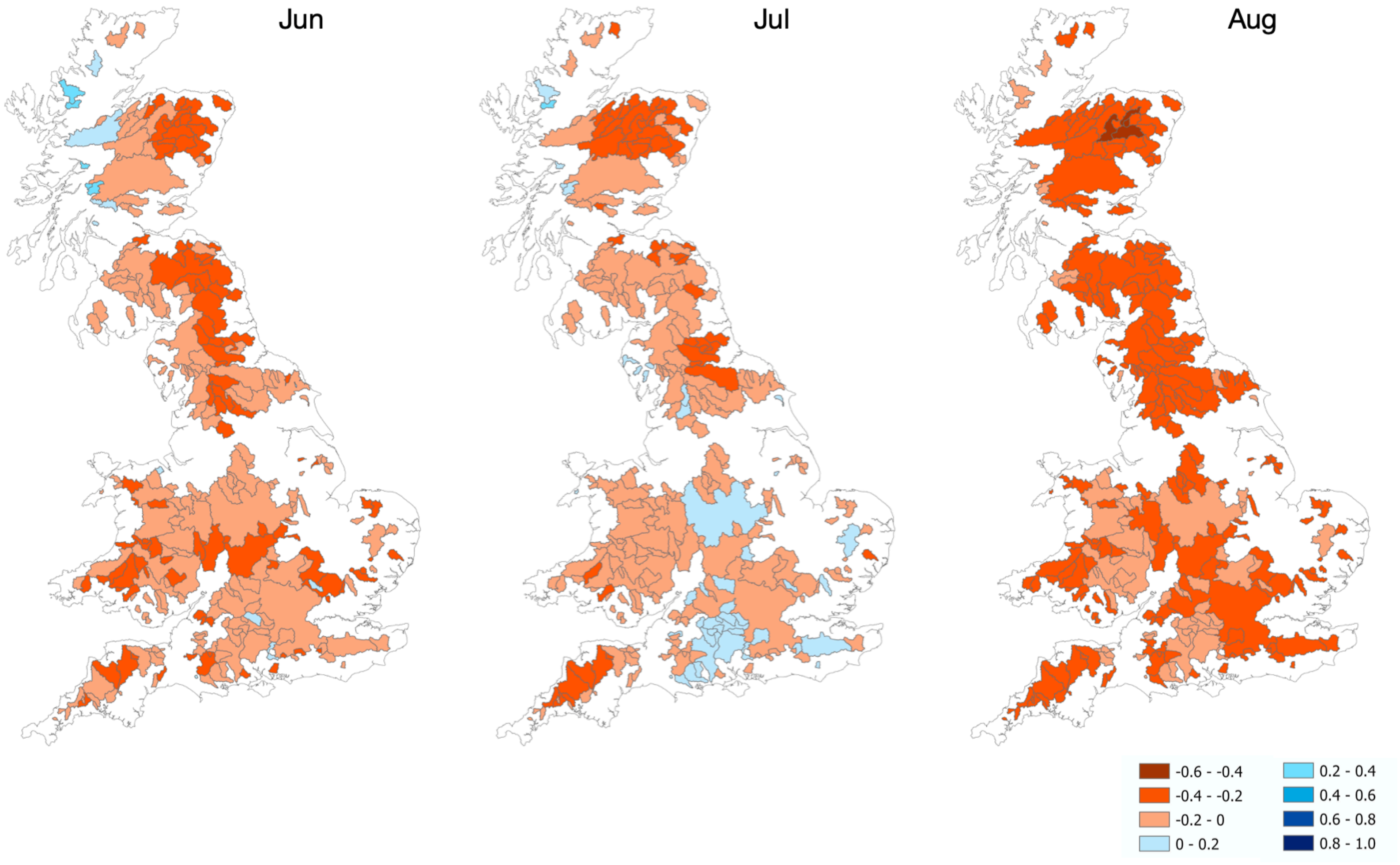

The figure above maps Pearson correlations between monthly NAOI data (from NCAR) and SSI with a 1-month accumulation period (from Barker *et al.*, 2018). This was undertaken for the period Jan 1900-Nov 2015.

# Correlations between the NAOI and SSI (Winter)




Similar to the patterns in rainfall previously discussed, the winter NAO is associated with a NW/SE spatial signature in the SSI dataset. There are strong positive correlations in the NW and weak negative correlations in the SE.

# Correlations between the NAOI and SSI (Summer)

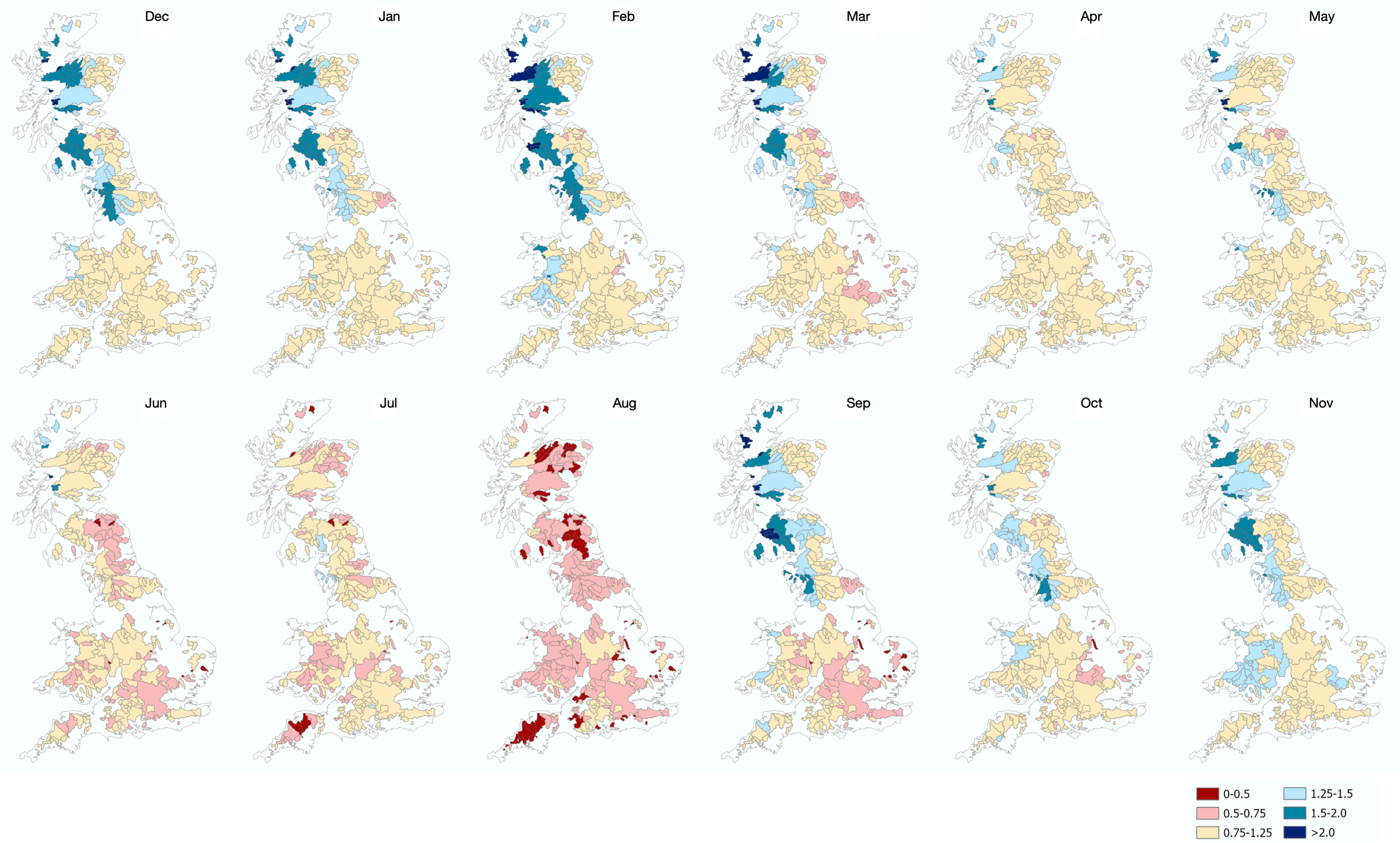



Summer is marked by a more homogeneous response, with almost all 291 catchments producing weak negative correlations (typically these are strongest at the height of summer in August).

# Flow Deviations under NAO

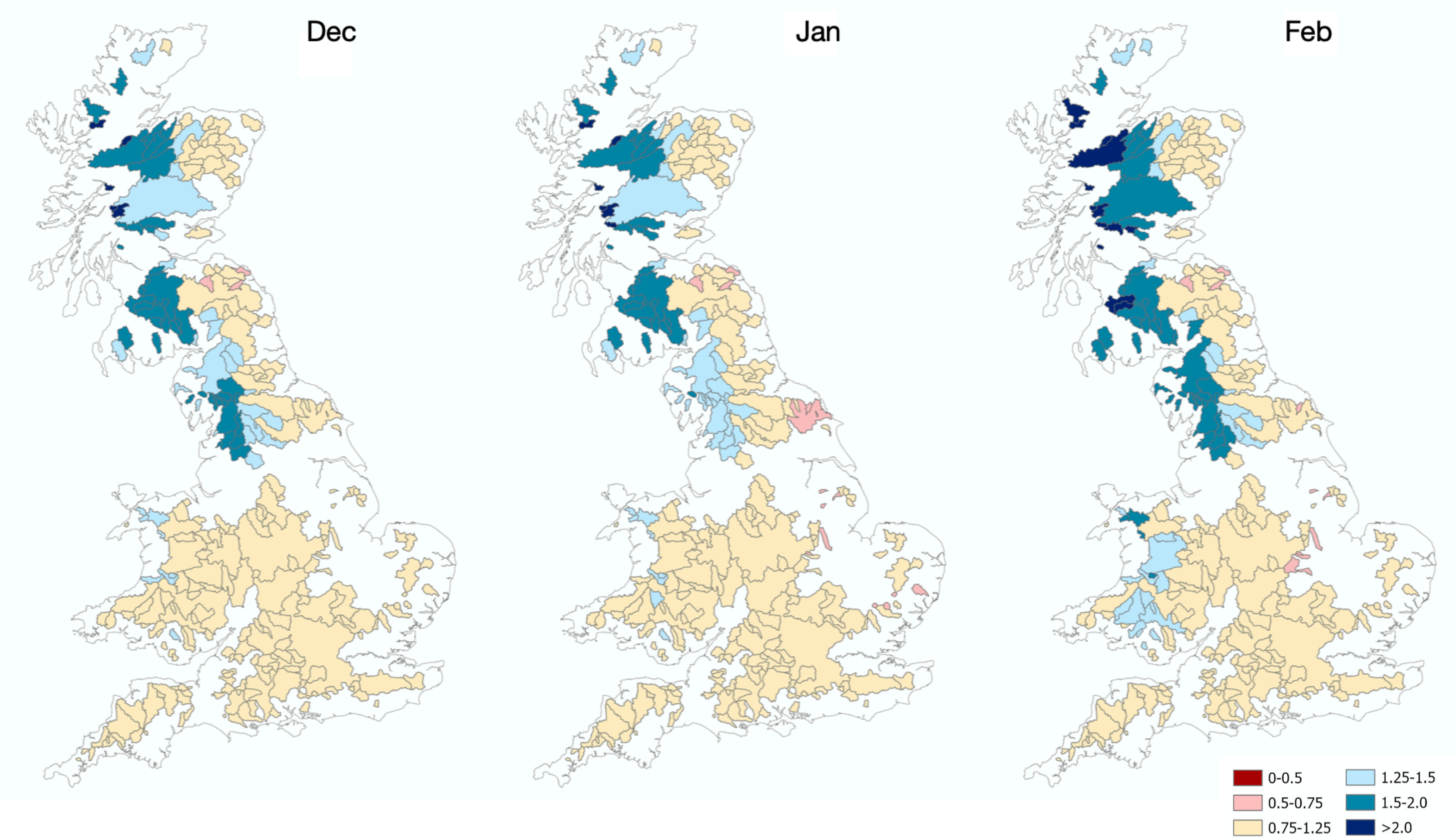
- To explore the implication of these correlations we use daily reconstructed historic flow data for the 291 catchments (Smith *et al.*, 2018) for the same study period (Jan 1900-Nov 2015).
- Mean monthly flow volumes were calculated and normalized by catchment area under NAO Positive and Negative phases.
  - NAO phases were identified using the NAOI (half the standard deviation plus/minus the long-term mean – after Berton *et al*. 2017).
- Flow ratios between the two phases were then mapped - normalised mean monthly flow volumes in NAO Positive phase were divided by normalised mean monthly flow volumes in the NAO Negative phase.
  - This provides an indication as to the change in runoff/unit area under NAO Positive as opposed to NAO Negative conditions.
  - The results of this analysis are shown on the next slide.

# Flow Deviations under NAO (Winter)



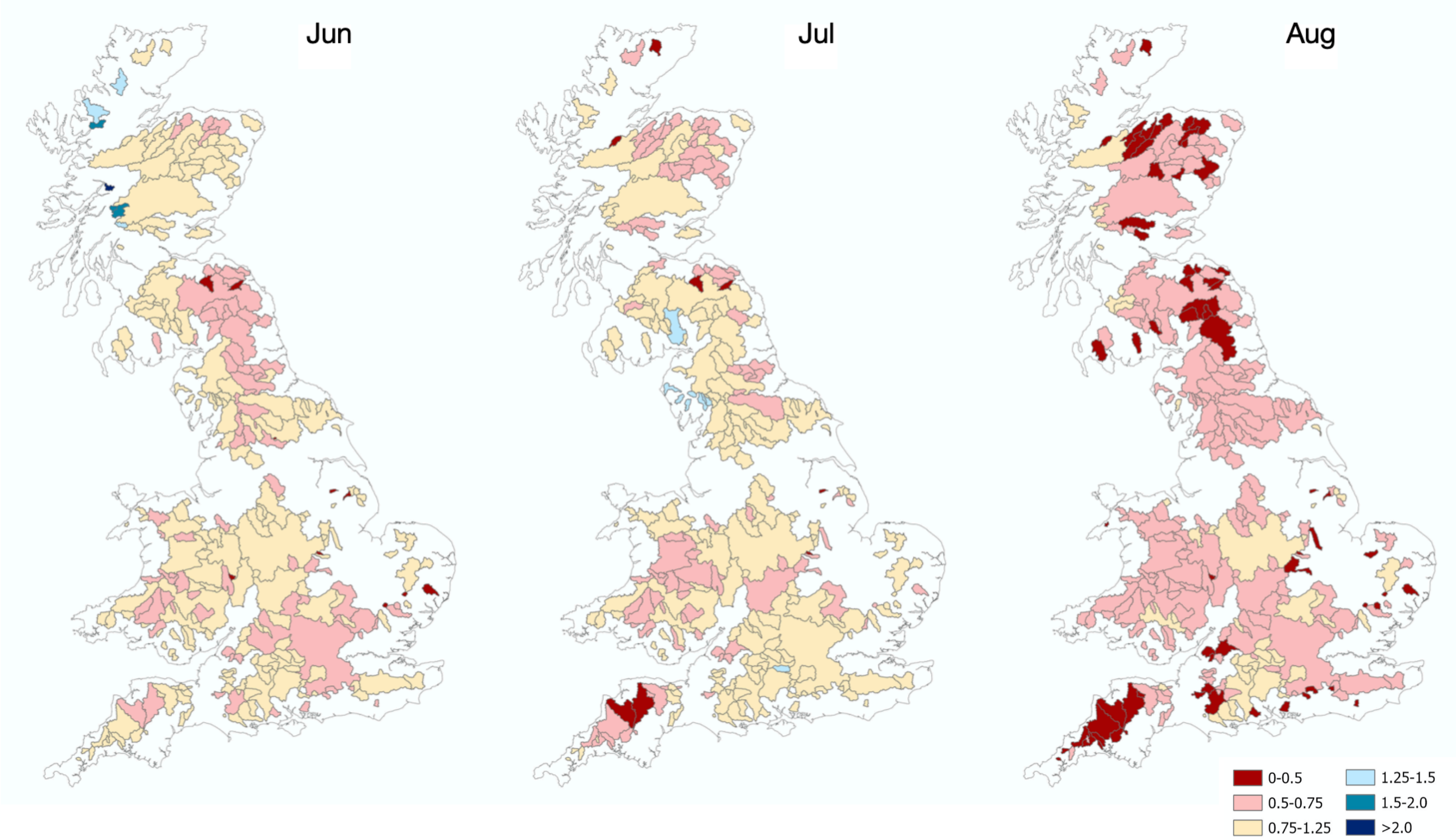

In the above figure values greater than 1 indicate that average flows are higher under NAO Positive than Negative. While values less than one indicate flows are lower under NAO Positive. Catchments where Pos/Neg change is within 25% (0.75-1.25) are shaded yellow.

# Flow Deviations under NAO (Winter)




During winter some NW catchments see flows 1.5-2.0 times higher during positive phases. These strong wet signatures may be associated with the characteristics of these catchments. Catchments in NW Britain are quick to respond to rainfall (Chiverton *et al.*, 2015) and may be experiencing the 'double orographic enhancement' effect associated with NAO Positive conditions (Burt & Howden, 2013).

# Flow Deviations under NAO (Summer)




As noted in the rainfall patterns, NAO Positive phases typically results in drier than normal summers. This rainfall signature cascades down to streamflow. Flows in some catchments can be as much as halved under NAO Positive phases compared to NAO Negative.

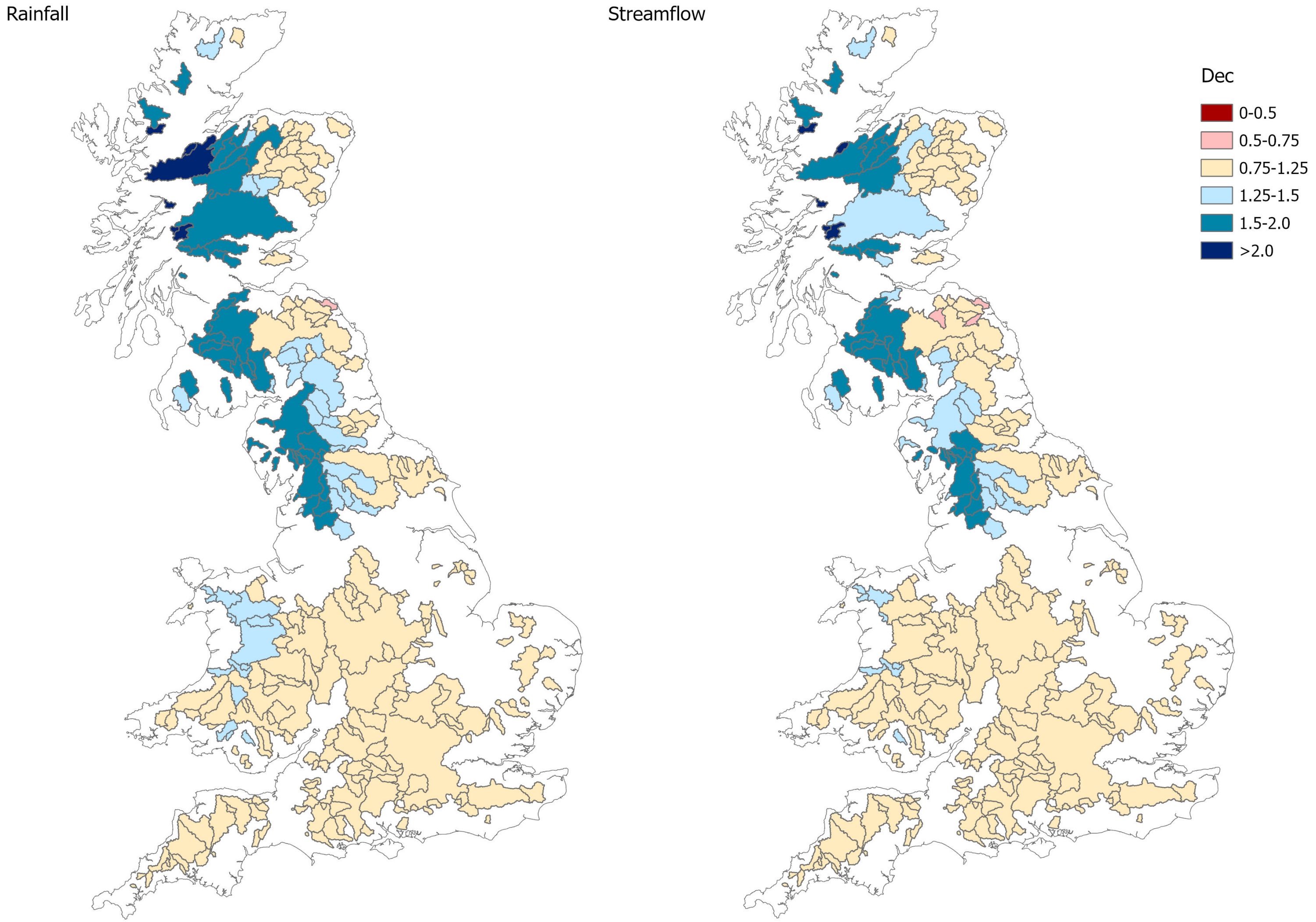
# Comparisons with Rainfall Signatures

- For comparison we spatially average the monthly GEAR rainfall data (presented on 1km grids on slides 5/6) per NAO phase for each catchment.

- We then divide the NAO Positive average monthly rainfall by NAO Negative to produce the same ratio as mapped for the flows in slides 12-14.

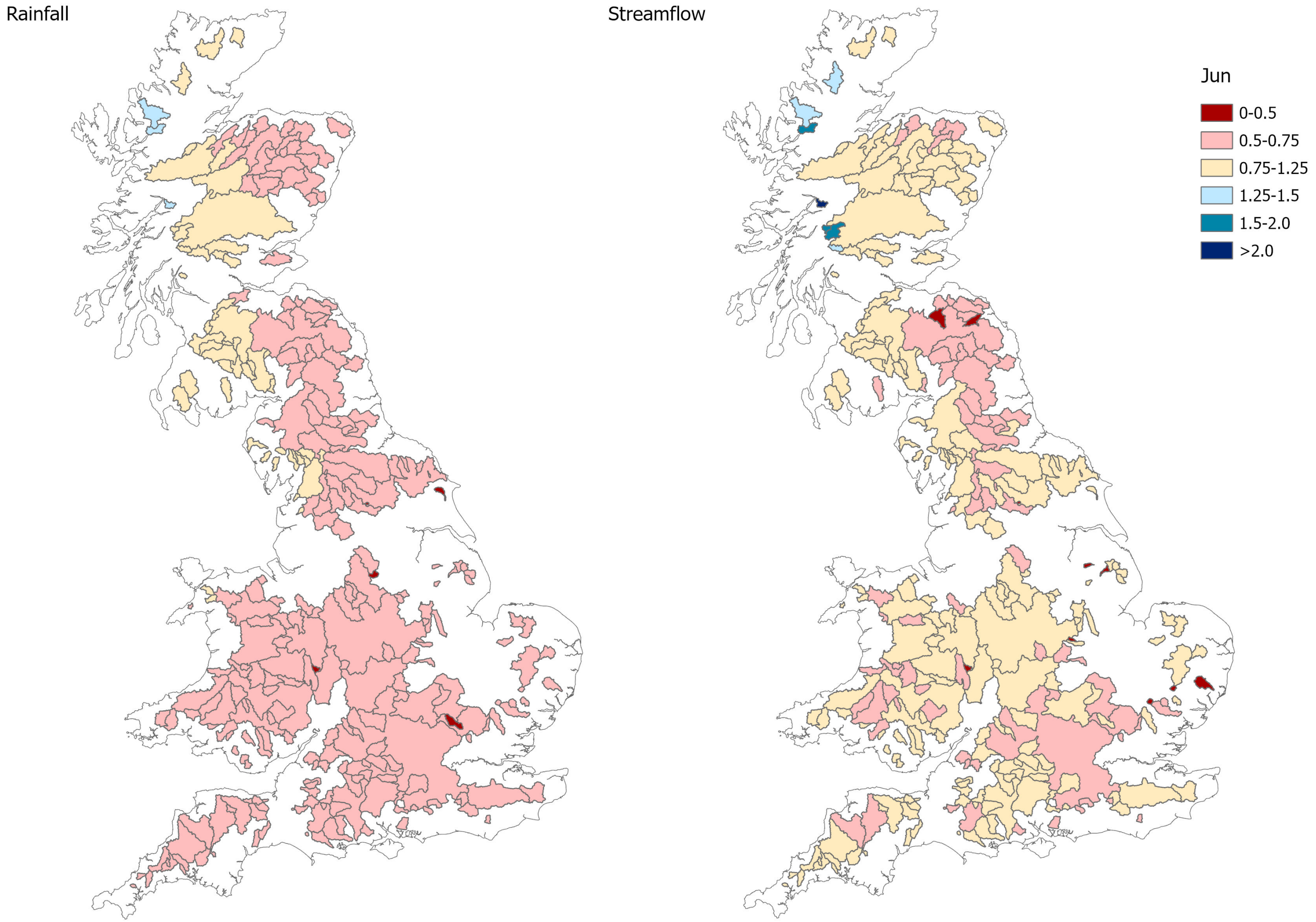
- This allows for a comparison between the NAO's influence on rainfall and streamflow.

# Comparisons with Rainfall Signatures
(Winter)



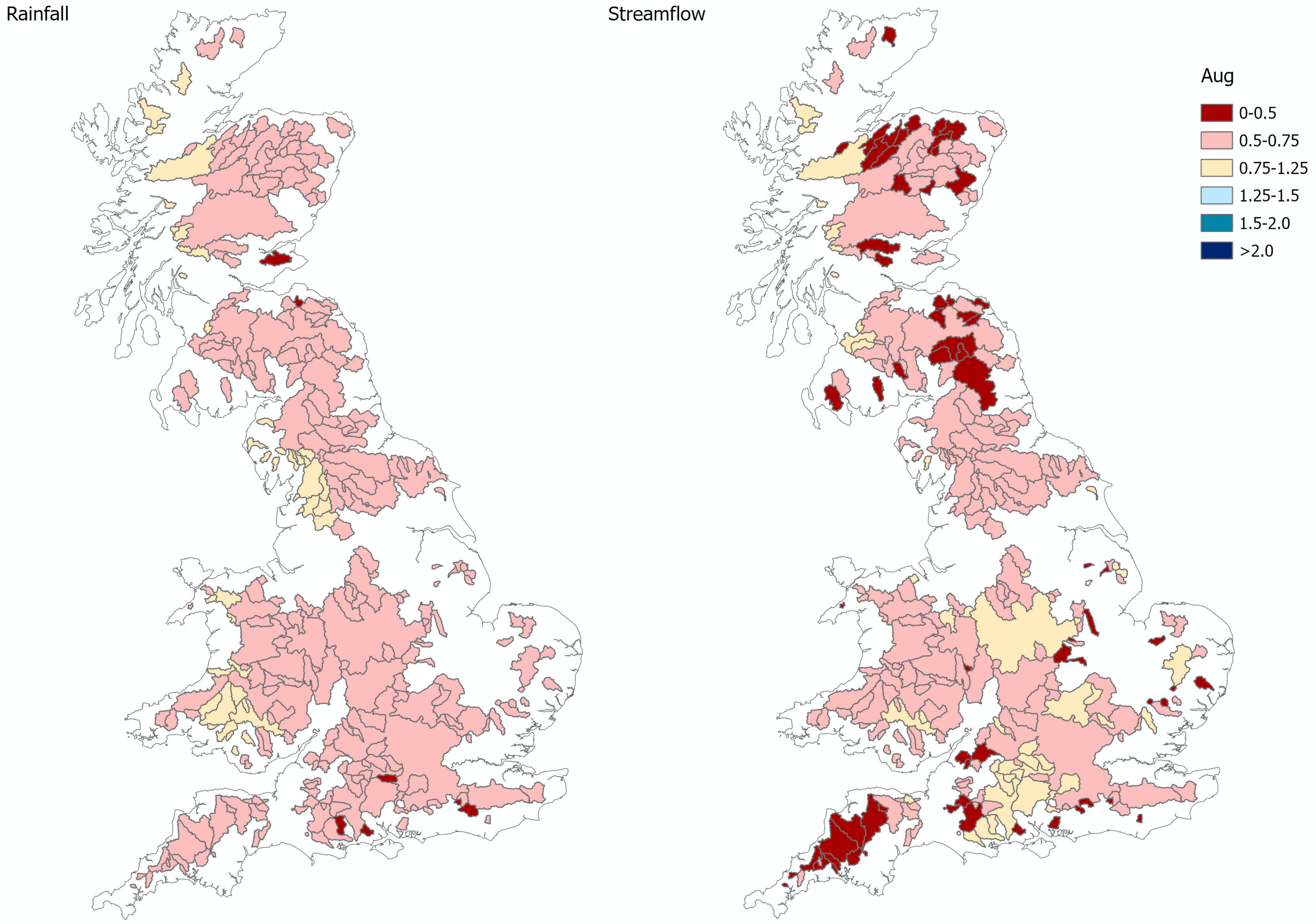

In winter similar spatial signatures in the relative influence of NAO Positive phases and NAO Negative phases are observed (Dec shown as an exemplar above). Catchments in the NW see a significant uplift in rainfall during NAO Positive phases which cascades down to streamflow.

# Comparisons with Rainfall Signatures (Summer)




In spring and early summer (June shown above) the rainfall and flow signatures differ. NAO Positive results in 25-50% less rainfall than NAO Negative for large parts of the country. While this is reflected in some catchments, many are within 25% deviation. This indicates that potentially catchment characteristics moderate the NAO rainfall signature.

# Comparisons with Rainfall Signatures
(Summer)




Throughout summer NAO Positive phases consistently result in drier average conditions compared to NAO Negative. In later summer (August shown above) these dry signatures are also notably evident in flows (as previously discussed on slide 14). For many of these catchments this follows a 25-50% reduction in rainfall.

# Conclusions

- Our analysis of historic flows indicate that wet/dry signatures can be associated with the NAO.
- Catchments in the NW of the country can experience significantly higher streamflow under NAO Positive conditions (likely the result of increased precipitation due to the southerly position of the North Atlantic Jet Stream).
- During the summer months NAO Positive conditions can result in notably lower flows, with some catchments' flow being on average halved, when compared to NAO Negative summer flows.
- These flow signatures are fairly similar to NAO rainfall signatures in winter, however some differences can be observed in summer.
- There is some evidence suggesting that catchment characteristics could either enhance and moderate the effect of the NAO, for example, flashy catchments in the NW (slide 13) and slower responding catchments in the SE and central regions (slide 17).

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