Examining Spatial Variations in the Utility of SPI as a 1 to 3 Month-Ahead Streamflow Indicator

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1 Introduction

Understanding the relationships between different hydrological cycle components is key for effective water management in light of future climate change. However, reliable information regarding extreme event characteristics remains a barrier. Hydrological event propagation is not a linear process - the intensity and frequency of events is driven by both climate and catchment controls (1,2).

The UK Drought Portal (https://eip.ceh.ac.uk/apps/droughts/) provides the Standardised Precipitation Index (SPI) at a number of accumulation periods (1, 3, 6, 12, 18, 24) months) on a 5km grid (3). The Historic Droughts project (https://historicdroughts.ceh.ac.uk/) has also produced time-series of the Standardised Streamflow Index (SSI) (4) for 303 catchments in the UK (293 in Great Britain) (5,6). Unlike the SPI which is nationally contiguous, the SSI is based on streamflow, so can only be calculated where discharge is measured or modelled.

Whereas the SPI is an indicator of meteorological (rainfall) drought, the SSI is an indicator of hydrological (streamflow) drought. As drought generally propagates from meteorological to hydrological, this raises the question of whether the SPI can be used as a proxy for the likelihood of streamflow conditions in months to come. If so, this would be useful, because SPI at various accumulation periods is easily accessed via the drought portal, whereas SSI may only become so in the future, and this would only be for gauged catchments. Studies have found strong correlations between SPI of various accumulation periods and SSI-1, and at lags of up to 6 months, suggesting that there is potential for using of SPI as an early warning for hydrological drought (7).

What is the Standardised Precipitation Index (SPI)?

The SPI expresses rainfall at a particular location in relation to the rainfall over a reference period, normally chosen to be sufficiently long to represent 'average' conditions. In the UK, this reference period is the 50-year period 1961-2010. The resulting score ranges from a negative to a positive number, with negative numbers representing drier than normal and positive numbers wetter than normal. The magnitude of the number also expresses the deviation from normal conditions and a verbal descriptor is attached to each category, for example an SPI of <-2 is regarded as 'extremely dry'. If a 1-month accumulation period was chosen and this showed an SPI of -2 for July, this would mean that relative to all the Julys in 1961-2010, this particular July was extremely dry. Because this is based on rainfall only, this would potentially be an indicator of meteorological drought. In contrast, values >2 would mean extremely wet conditions, and could suggest a potential for flooding.

What is an accumulation period?

The accumulation period represents the number of months over which the total amount of rainfall is being calculated. For example, a three-month accumulation period would mean you would be comparing rainfalls totalled over May, June and July against all the other totals for this three-month period in the fifty-year period (1961-2010). Similarly, a 12-month accumulation period means you are comparing annual rainfall over the last 12 months with all the other similarly defined years in the fifty-year period.

What is the SSI?

The Standardised Streamflow Index (SSI) uses the same principle as the SSI, except that instead of rainfall, streamflow (monthly total discharge volume) is being compared. The same 50-yr standard period applies (1961-2010), and the same verbal descriptors are used. Whereas the SPI can be used as an indicator of meteorological drought, the SSI can be used as an indicator of hydrological drought.

2 Aim

To examine the utility of SPI of various accumulation periods as an indicator of streamflow conditions (defined using SSI), one, two and three months ahead.

3 Method

SPI data (1,3,6,9 accumulation periods) were spatially averaged for each of the 293 SSI catchments in Great Britain.

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SPI (1,3,6,9) and SSI (1,3) for the period 1900-2015 were cross-correlated at lags of zero, one, two and three months.

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R^2 values between SPI and SSI were mapped (with thresholds of 0.5 and 0.7) and the SPI accumulation period with the highest R^2 value with SSI1/3 was identified.

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Spatial variation in the utility of SPI as a 1 to 3 month ahead streamflow indicator was evaluated against the BFI.

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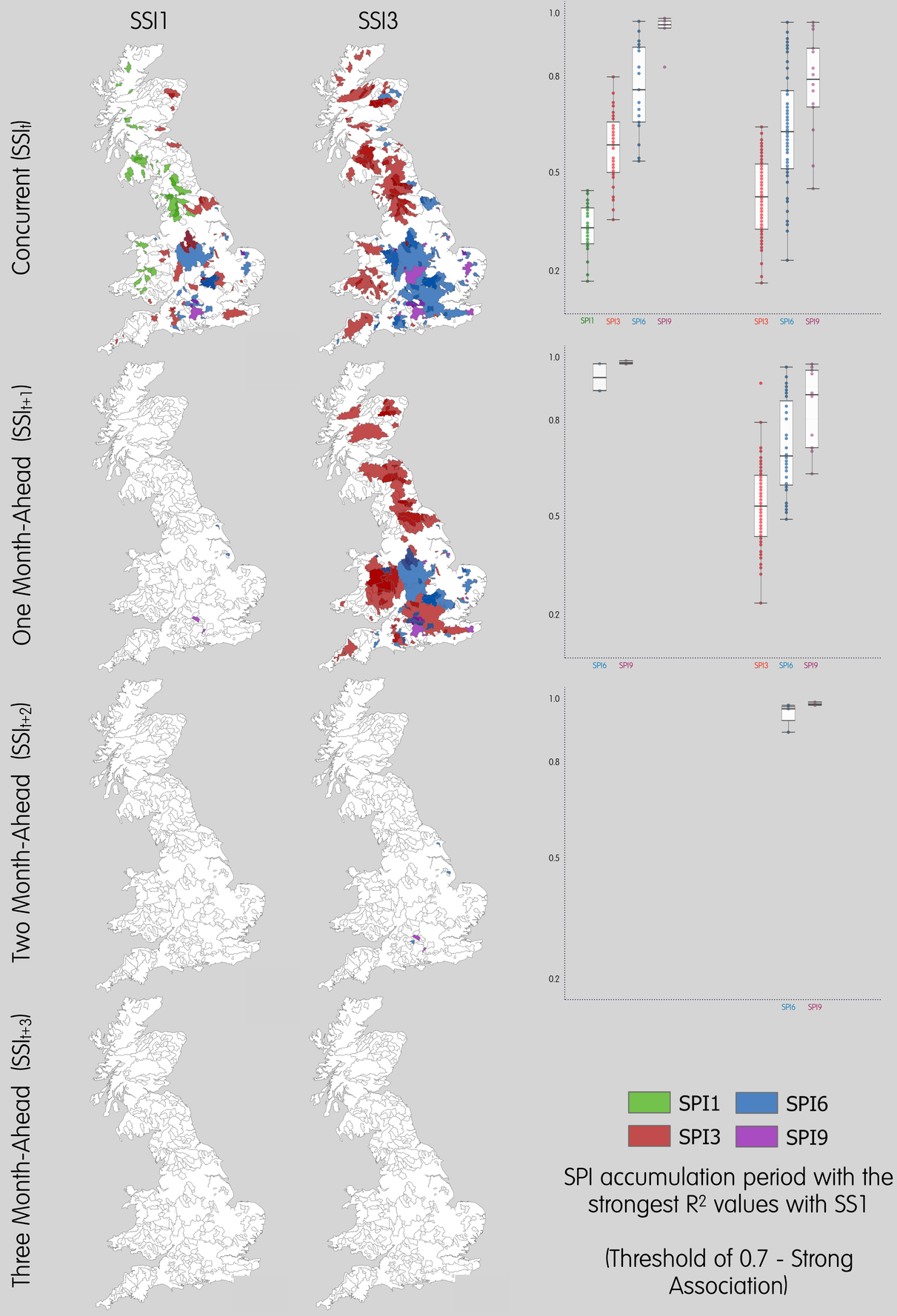
4 Results



Concurrent SPI / SSI	• Clear spatial relationships between SPI/SSI R^2 values and BFI. • Strongest SPI/SSI association is found across all accumulation periods when SPI is not lagged (7).
1 Month Ahead (SSI_{t+1})	• With an R^2 value threshold of 0.7 only five catchments have an SPI/SSI association. • There is an extensive association between SSI3 and various accumulation periods of SPI. The length of the most strongly associated SPI accumulation period is related to BFI.
2 Month Ahead (SSI_{t+2})	• With an R^2 value threshold of 0.7, only five catchments have an SSI3 association with SPI6/9. • These catchments have very high BFI values.
3 Month Ahead (SSI_{t+3})	• With an R^2 value threshold of 0.7 there is no SSI association with any SPI accumulation period. • With a lower threshold of 0.5 (moderate association) there are some catchments with an SSI3 and SPI6/9 association.

5 Conclusions

- SPI with longer accumulation periods has some value as an up to 2-month-ahead streamflow condition indicator (if defined using SSI3).
- Catchments with a BFI of approximately 0.4-0.6, have a strong SSI3 to SPI3 association, 0.6-0.8 have a strong SPI6 association, and above 0.8 an SPI9 association, when looking one-month ahead.
- Based on the R^2 values SPI has no utility as a three-month ahead indicator of SSI.
- We show the potential of using SPI as an indicator of streamflow condition up to two-months ahead. However this assumes that SSI with a 3-month accumulation period is a useful conception of hydrological drought for the user.

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