



An assessment of runoff trends in undisturbed catchments in Celtic regions of NW Europe

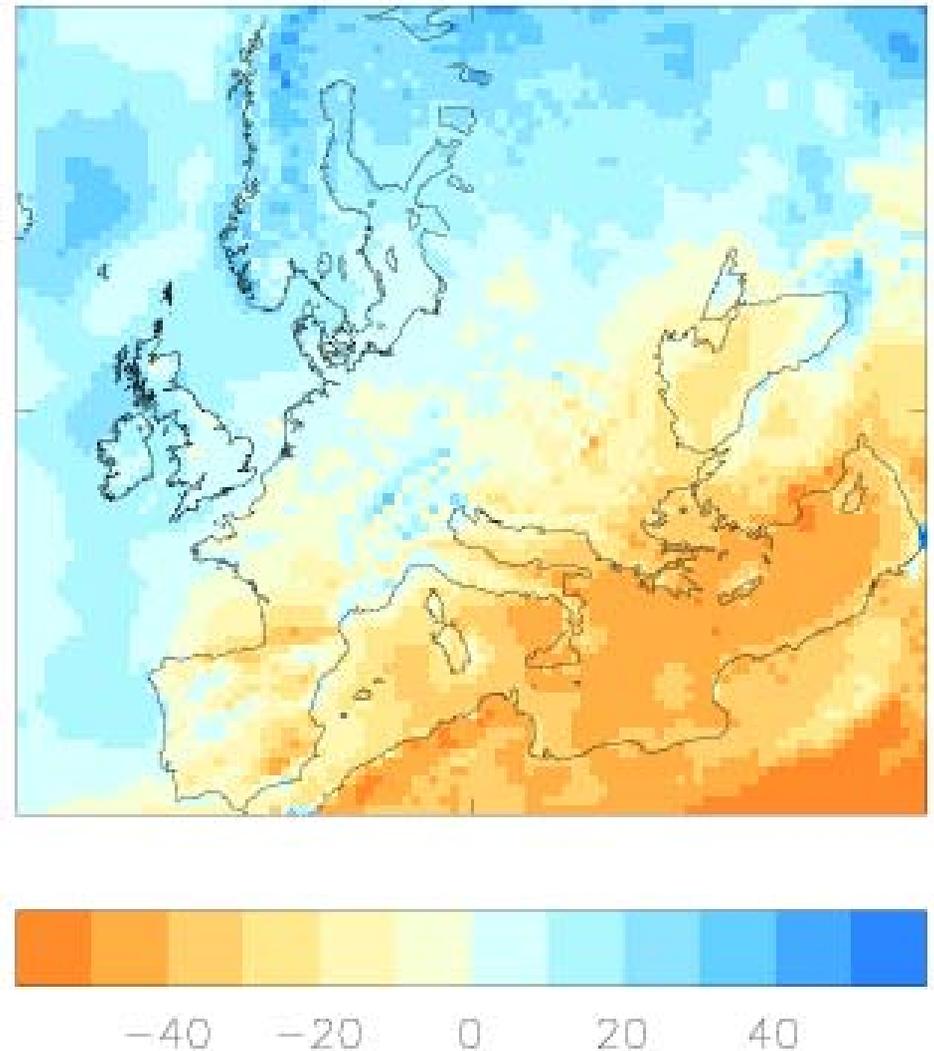
**Fourth InterCeltic Hydrology Colloquium,
Guimaraes, Portugal 11th July 2005**

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UK National River Flow Archive**

- Background:
 - Climate change in the Celtic region
 - Observational records and the recent past
 - Artificial influences and the benchmark network
- Study Objectives
- Data and Methods
- Results:
 - regional trends
 - comparisons with lowland UK
- Sensitivity to study periods and importance of long hydrometric records
- Relationships with North Atlantic Oscillation Index
- Conclusions

Projected changes for UK (UKCIP02)

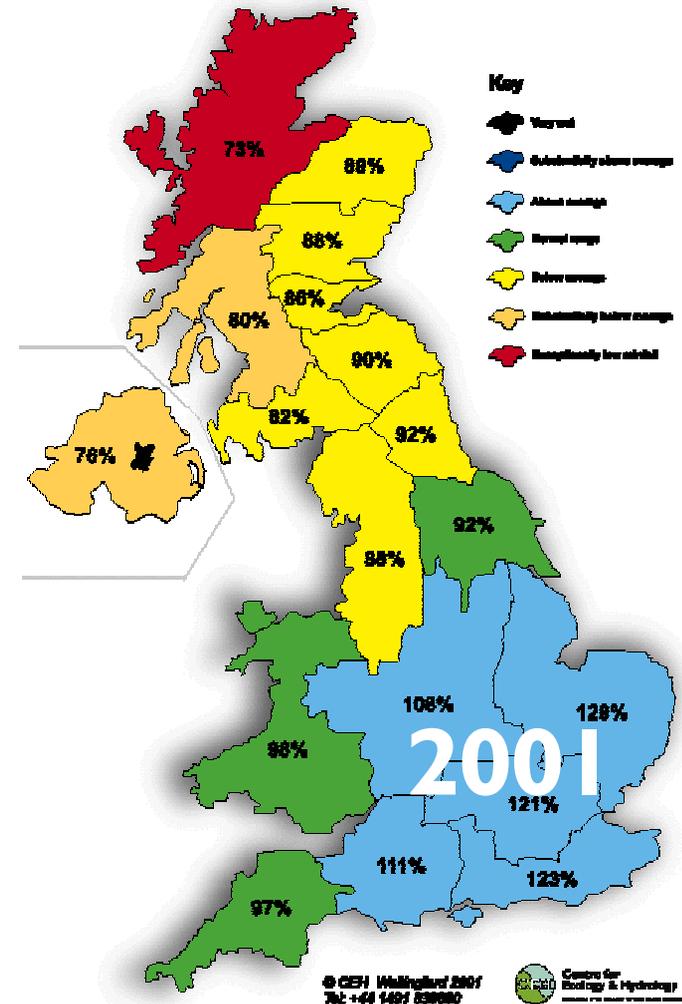
- Increases in annual precipitation
 - Enhanced seasonality (wetter winters, drier summers)
 - Enhanced NW/SE gradient in rainfall
 - More extreme rainfall events
 - Impacts on water utilisation and flood management
- **Need for monitoring networks to provide 'groundtruth' for modelling and to discern emerging trends**



HadRM3 annual precipitation changes over Europe to 2080 (Buonomo *et al.* 2005)

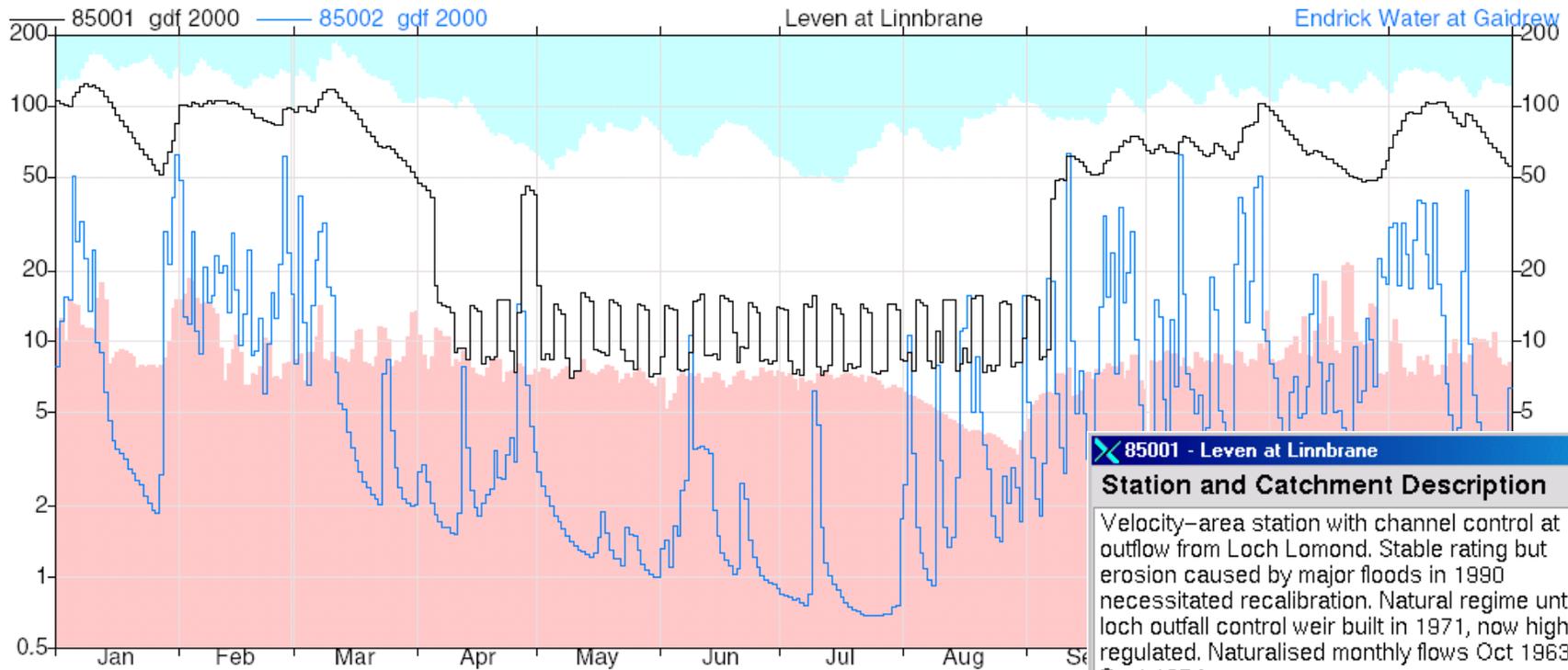


Rainfall accumulation for January 2001 - July 2001



Previous studies in the NW Celtic region

- Increasing flooding and annual runoff in Scotland (Black, 1996)
- Notable volatility in the Celtic region (Green *et al.*, 1996 – First Celtic Colloquium)
- Increase in rainfall and four rivers in Ireland (Kiely, 1999)



85001 - Leven at Linnbrane

Station and Catchment Description

Velocity-area station with channel control at outflow from Loch Lomond. Stable rating but erosion caused by major floods in 1990 necessitated recalibration. Natural regime until loch outfall control weir built in 1971, now highly regulated. Naturalised monthly flows Oct 1963 – Sept 1974.

Large, wet, upland catchment. Geology dominated by ancient metamorphic formations – overlain by Drift in the west.

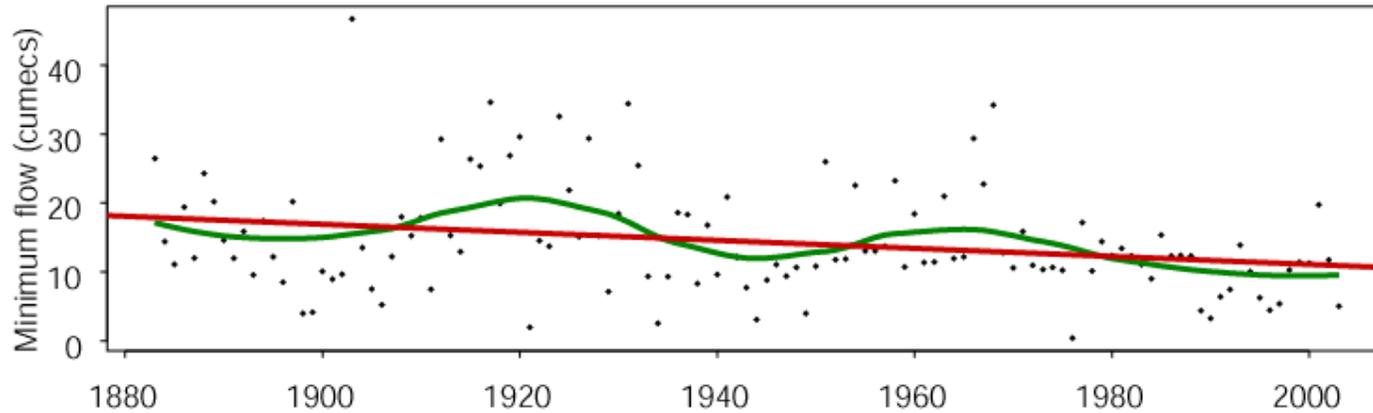
Factors Affecting Runoff

Reservoir(s) in catchment affect runoff.

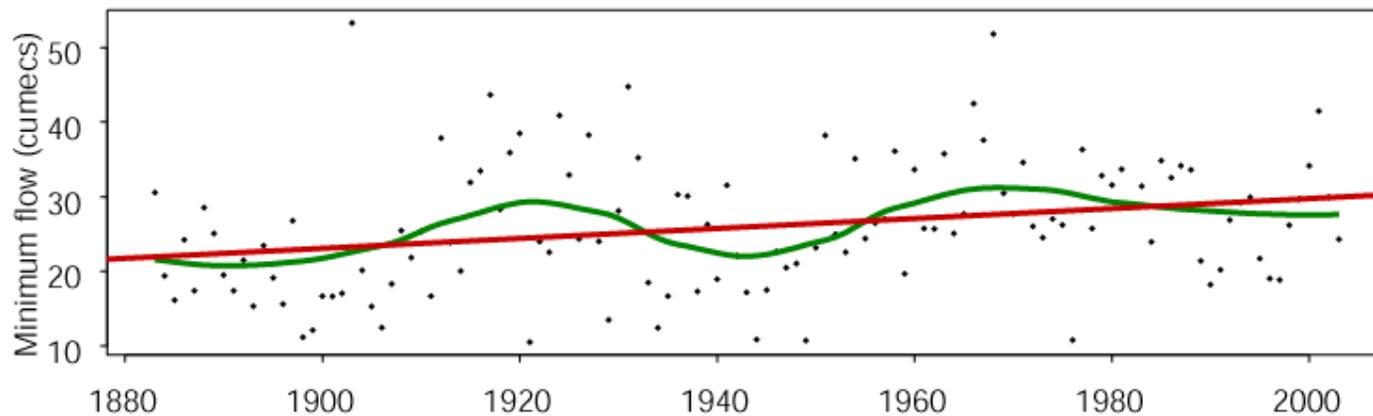
Close

- Impoundments
- Heavy abstraction
- Hydropower
- Land Use change

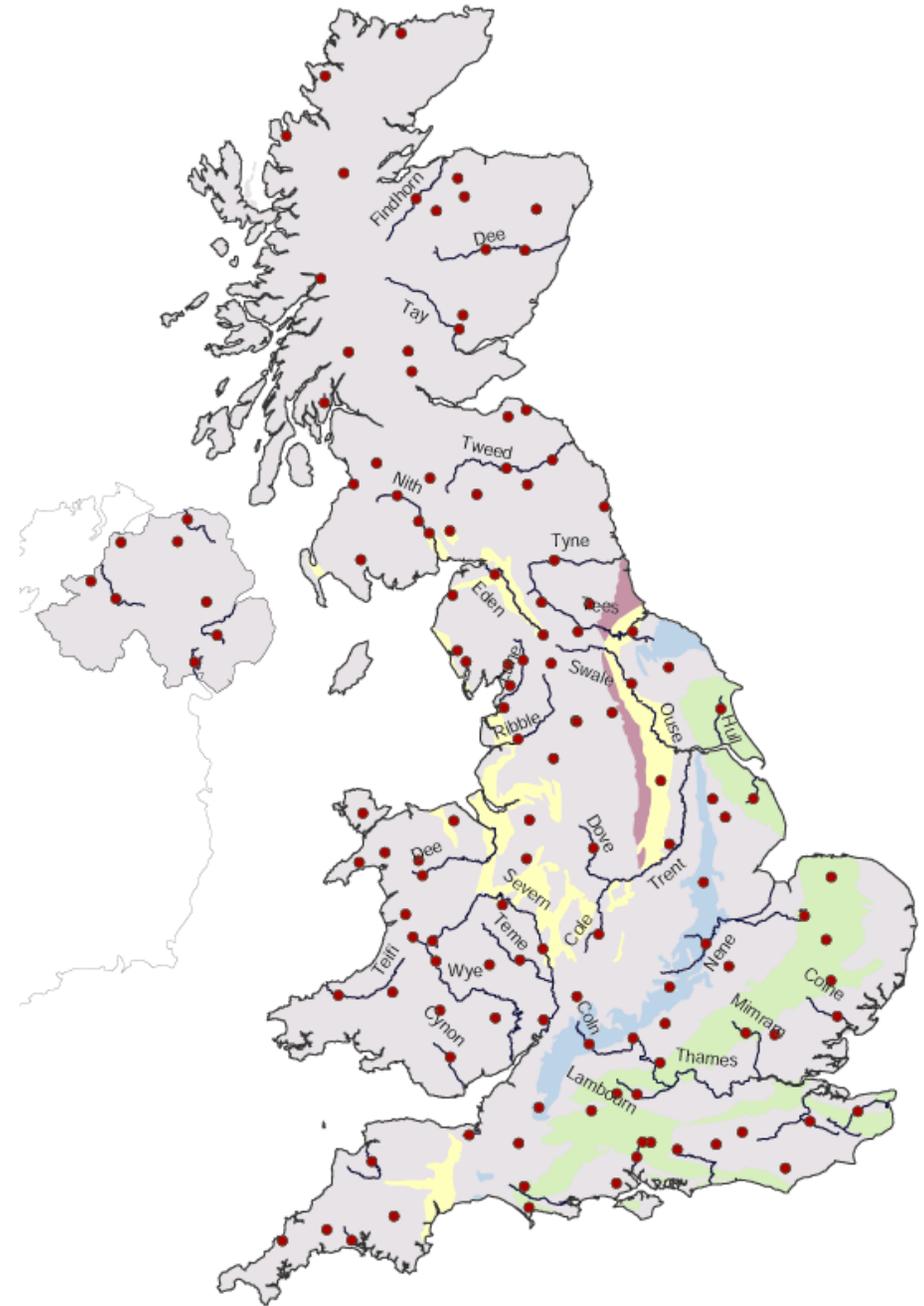
a) River Thames - Gauged



b) River Thames - Naturalised



- Designated to strengthen our ability to identify and interpret trends
- Criteria for selection:
 - Sensibly natural regime
 - Good hydrometric performance
 - Sensibly long records
 - Representative



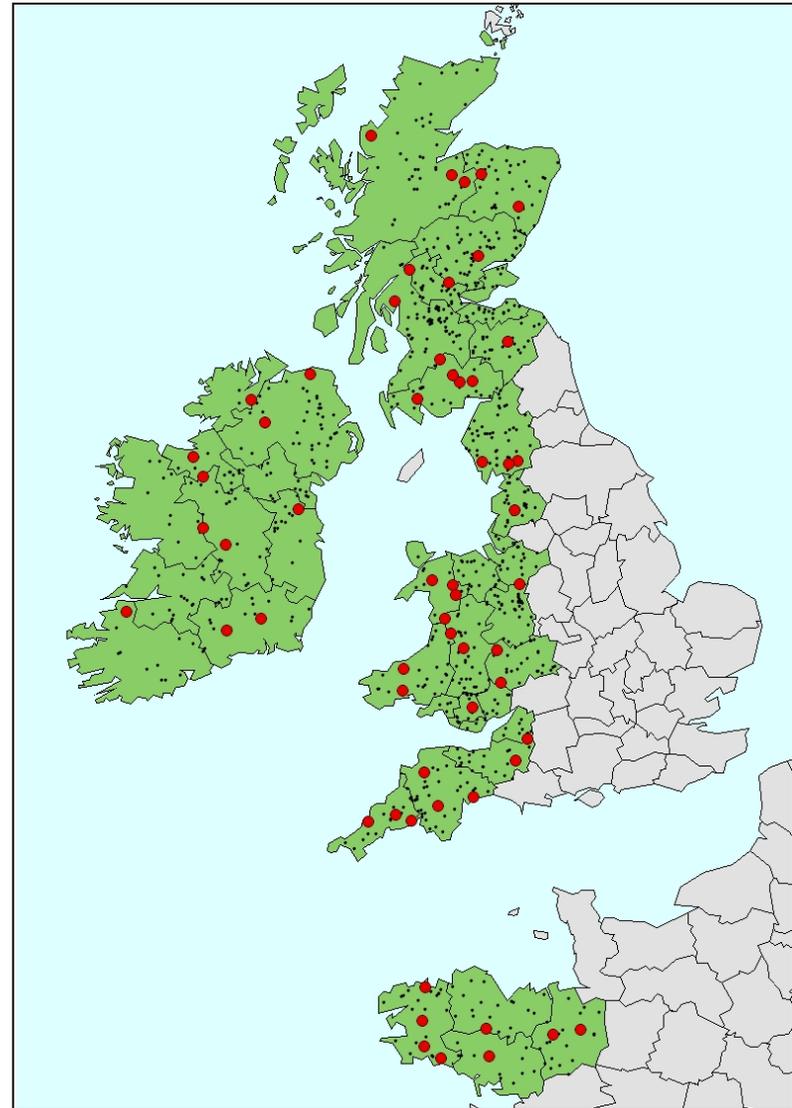
UK Celtic regions share many climatic, geological and physiographic traits with the Republic of Ireland and Brittany.

- Pan-Celtic overview of runoff trends using the benchmark network in the UK and undisturbed catchments in Ireland and Brittany

Questions:

- Is there any evidence for trends in annual and seasonal runoff in Celtic regions of NW Europe, over the last 30 – 40 years, using natural indicator catchments?
- Are there any convincing regional signals in observed trends?
- To what extent do observed trends in the UK Celtic region compare with adjacent, lowland areas of the UK?
- To what extent are observed trends sensitive to the period of study?

- Data – annual runoff and seasonal runoff
- 60 sites – UK benchmark network and relatively undisturbed sites in Ireland and Brittany.
- Ireland and Brittany - selected by consultation with hydrometric data providers and web-based metadata
- Methods – regression trend test. Permutation methods to assess significance (resampling requires no distributional assumptions)



NW Celtic Region as used in this study!

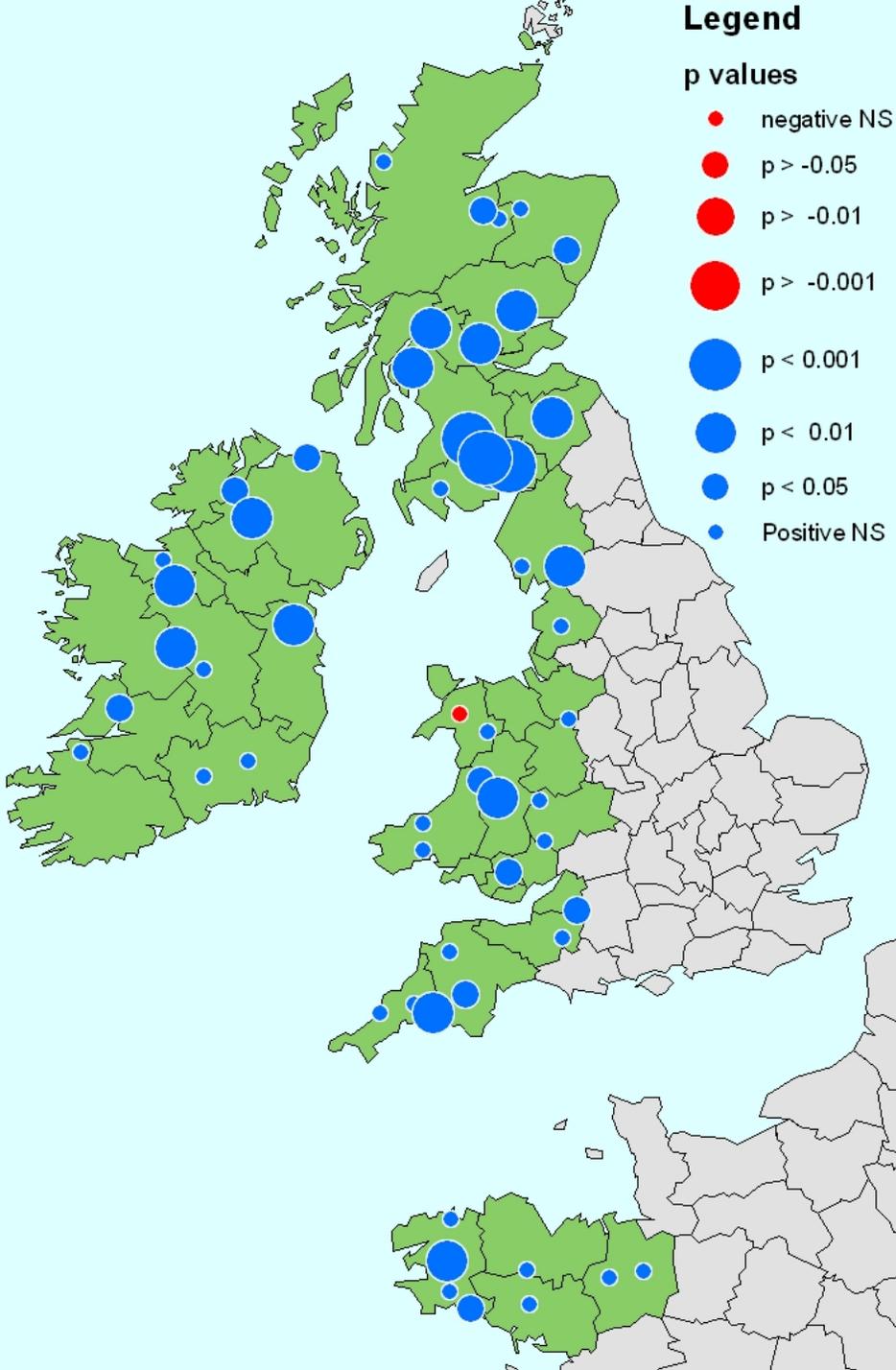
Table showing % of Significant trends across Celtic region from:

- 60 sites (1968 – 2003)
- 31 Sites (1963 – 2003)

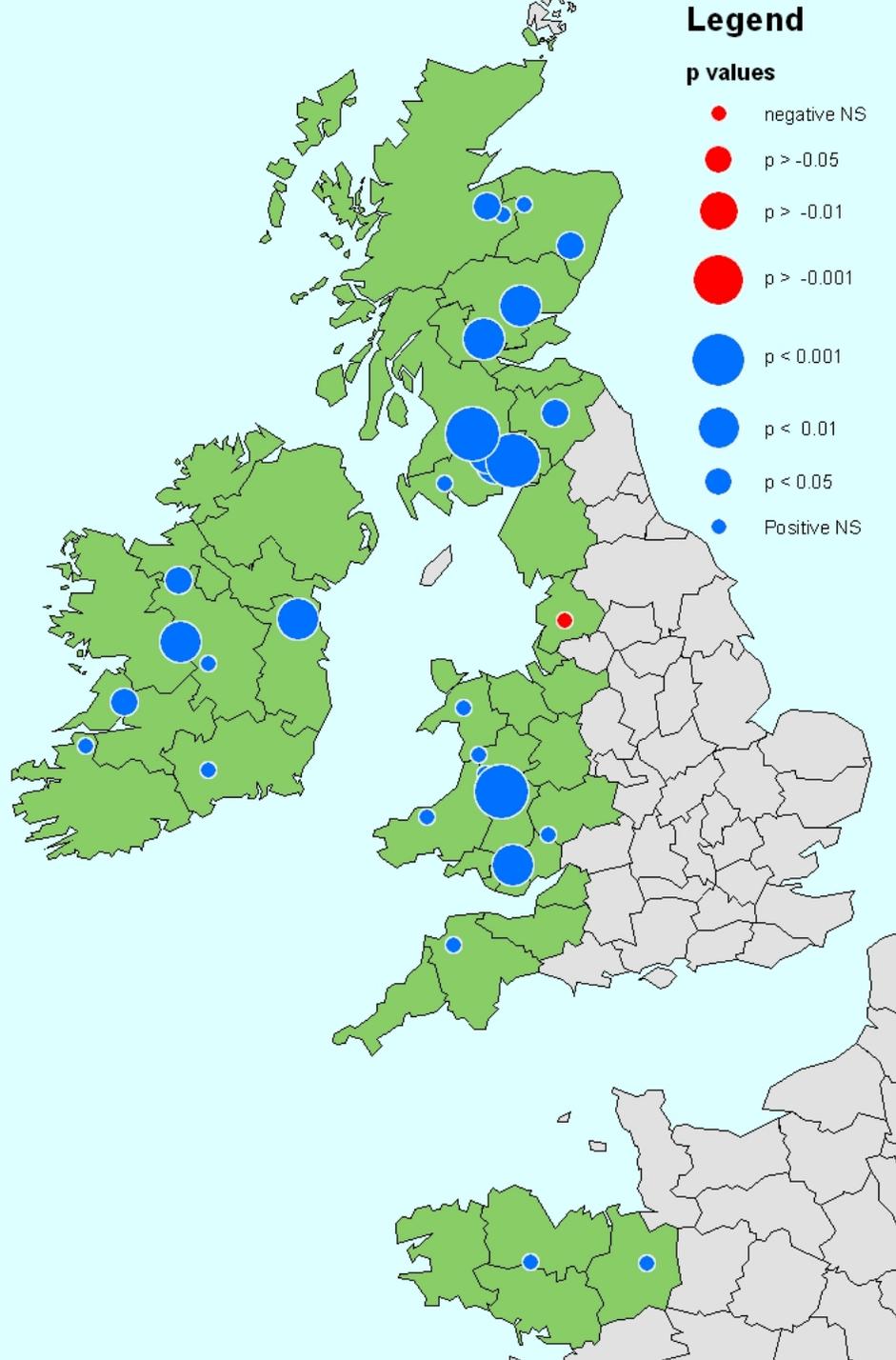
	Negative Trends (<i>p</i>)				Positive Trends (<i>p</i>)			NS
	NS	>-0.05	>-0.01	->0.001	<0.001	<0.01	<0.05	
Annual Runoff								
1968 – 2003 (60 sites)	1.7	0	0	0	13.3	15.0	18.3	51.7
1963 – 2003 (31 sites)	3.2	0	0	0	19.4	12.9	16.1	48.4
Seasonal Runoff (1968-2003)								
Winter (Oct-Mar)	2.2	0	0	0	20.0	15.6	13.3	48.9
Summer (Apr - Sep)	26.0	0	0	0	0	0	2.0	72.0

Legend**p values**

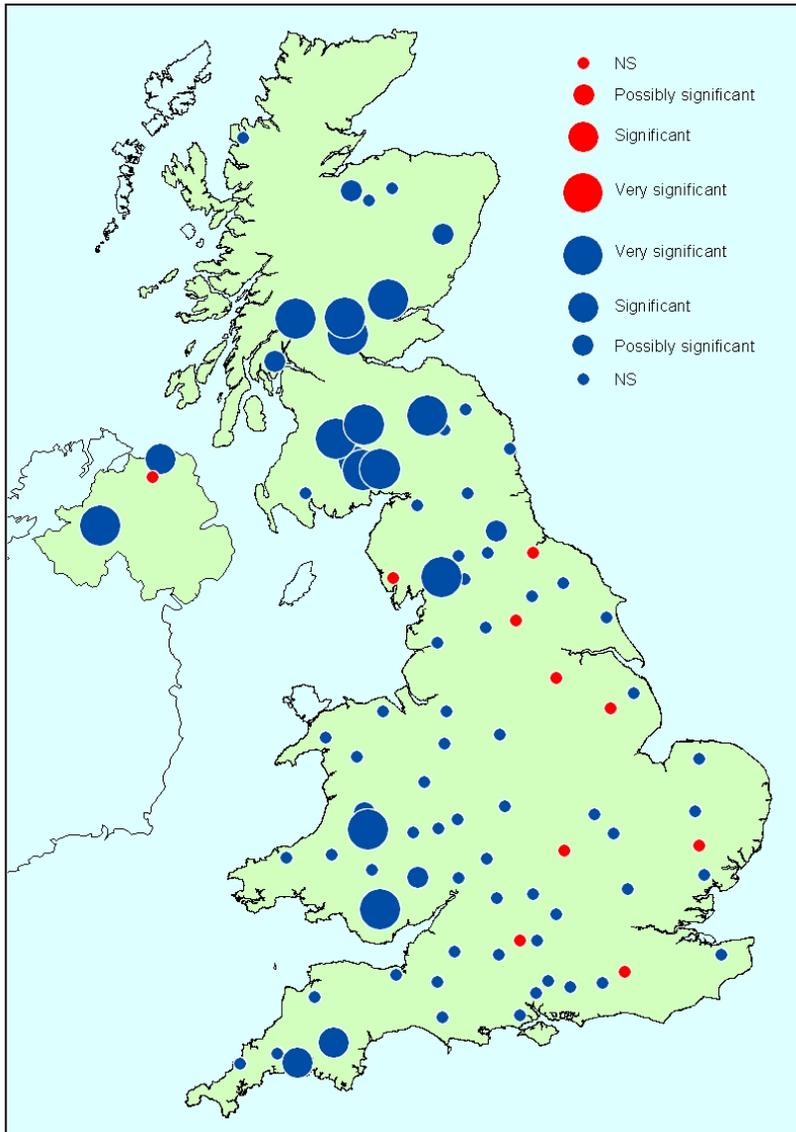
- negative NS
- $p > -0.05$
- $p > -0.01$
- $p > -0.001$
- $p < 0.001$
- $p < 0.01$
- $p < 0.05$
- Positive NS



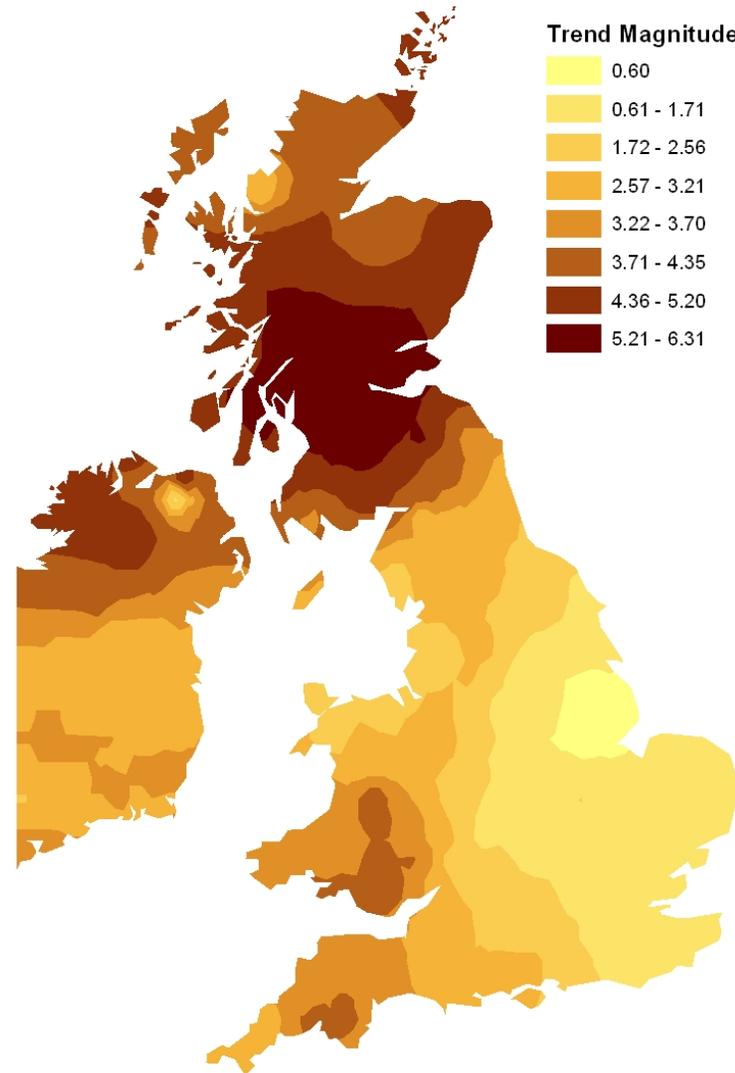
Regional trends 1968 – 2003



Regional trends 1963 – 2003



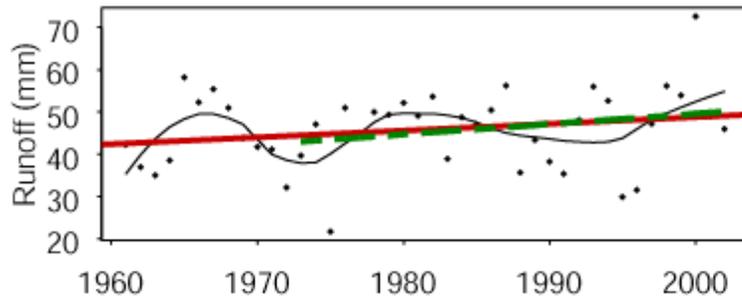
Significance levels 1973 - 2002



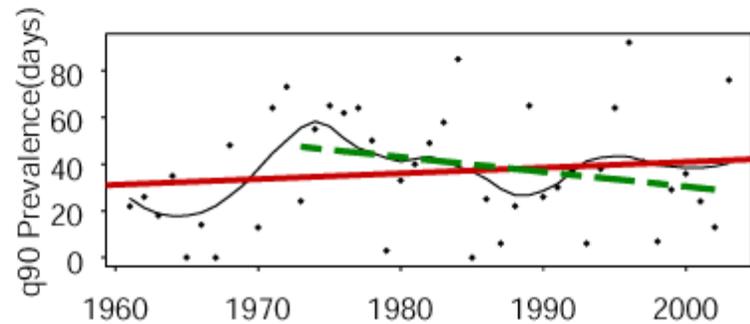
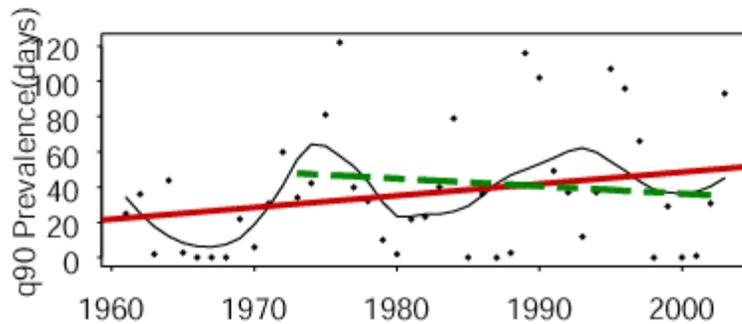
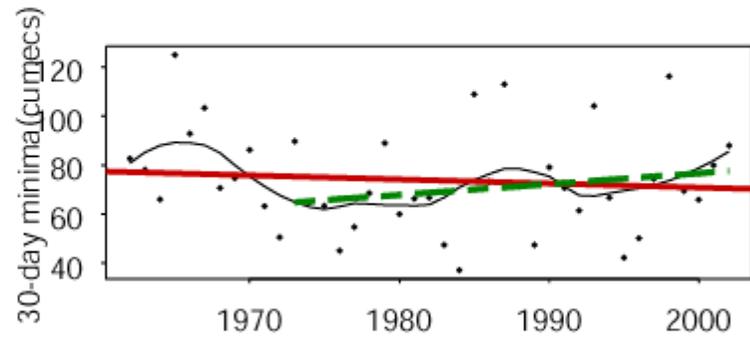
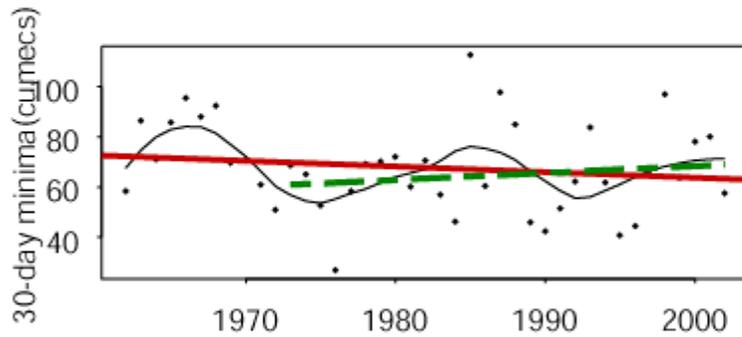
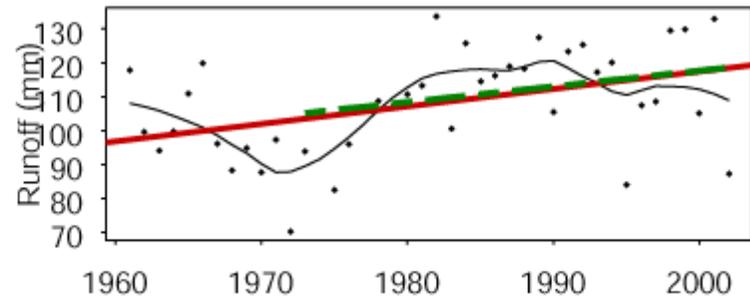
Normalised trends 1973 - 2002

Sensitivity to study period

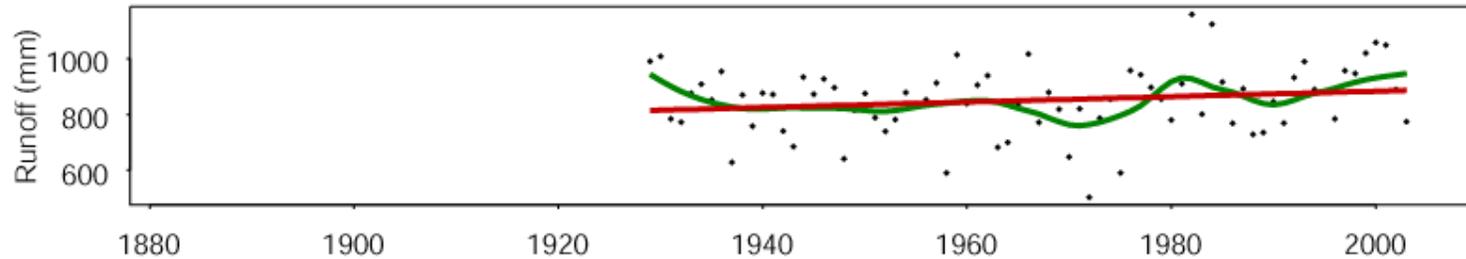
England and Wales



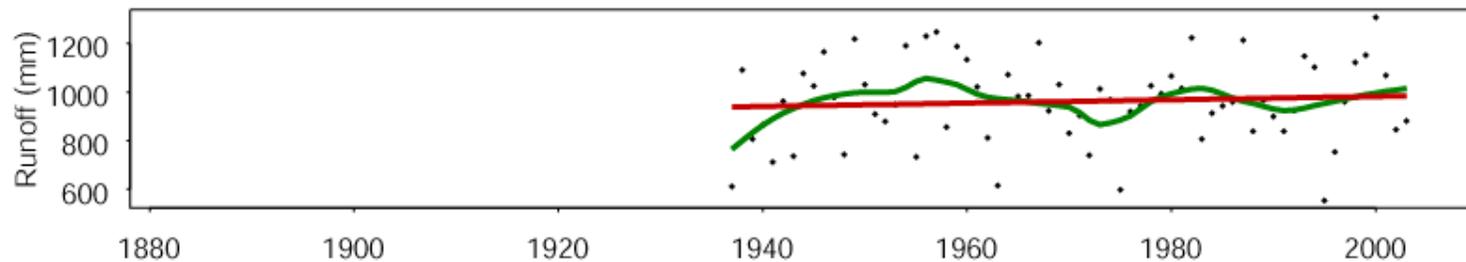
Scotland



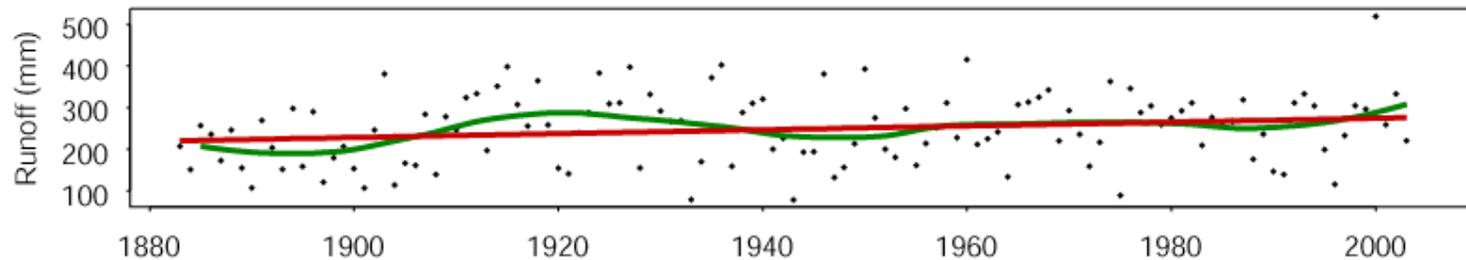
Dee at Woodend (Scotland)

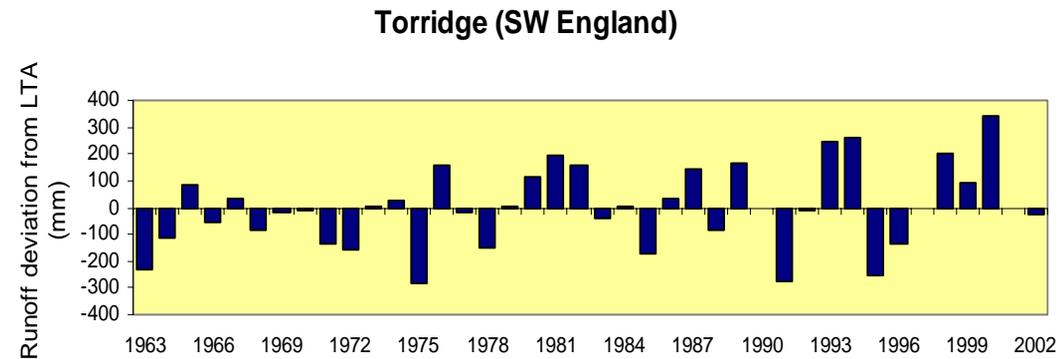
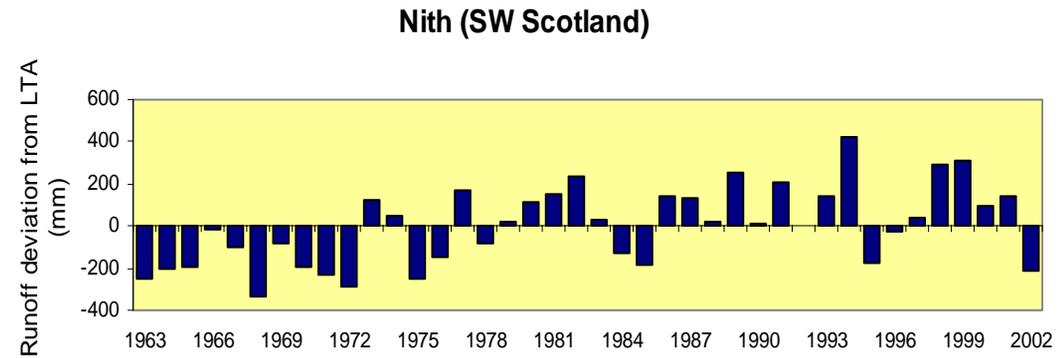
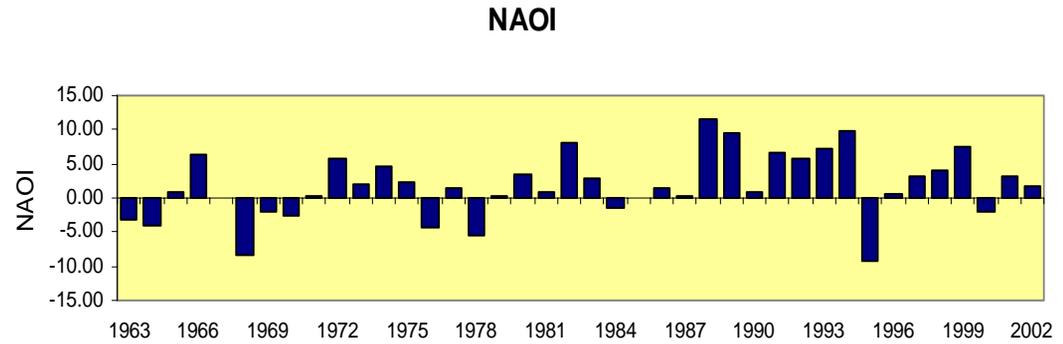
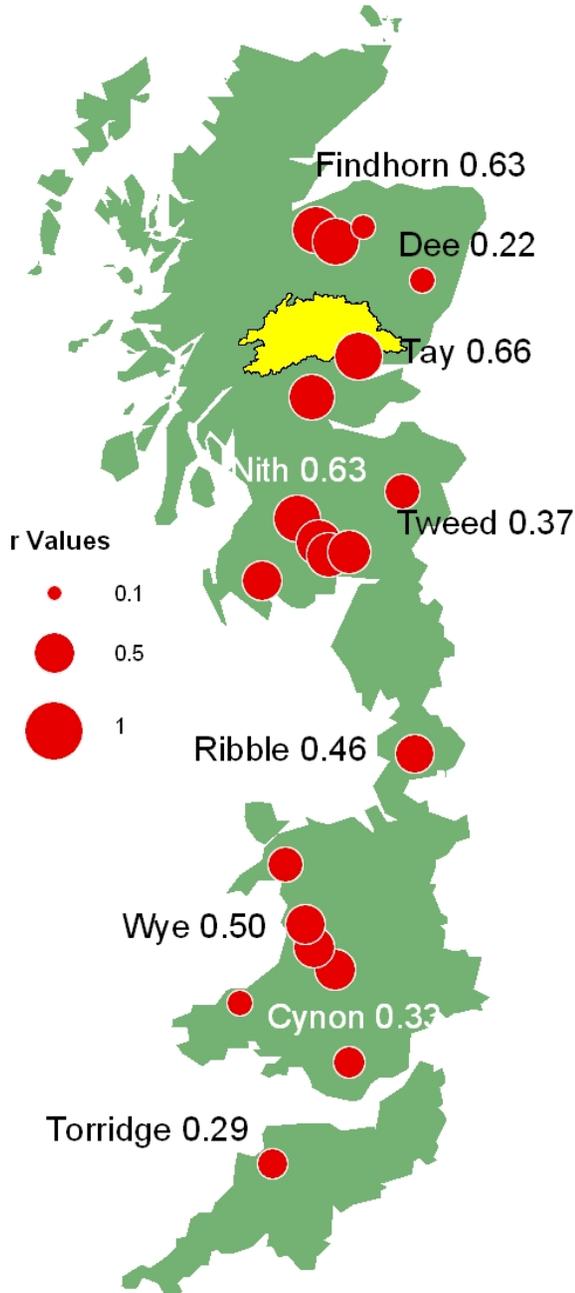


Dee at Manley Hall (Wales)



Thames at Kingston (England)





- Tendency for increasing runoff over the last c.40 years from across the NW Celtic region, on the basis of natural indicator catchments
- Evidence of strong positive runoff trends in Scotland and Ireland. Some significant trends in Wales, SW, Brittany – less compelling regional signal
- Increasing annual runoff driven by an increase in winter runoff; no significant trends in summer runoff
- In the UK, positive runoff trends in Celtic region in maritime north and west contrast with no significant changes in the English lowlands
- These trends reflect atmospheric circulation patterns associated with increasing trend in the NAO. Indications of N/S and E/W contrasts in the strength of the relationship – More work needed on relationships with NAOI
- Trends may reflect climate variability rather than change – though models predict an increase in the NAO associated with global warming (Gilet *et al.* 2003)
- Records are short so recent positive trends need to be placed in a broader historical context. Long records indicate relative stability with fluctuations about a relatively stable mean

- Black, A.R. (1996). Major flooding and increased flood frequency in Scotland since 1988. *Phys. Chem. Earth*, **20**, 463-468.
- Buonomo, E., Jones, R., Huntingford, C. and Hannaford, J. (2005). The robustness of high resolution predictions of changes in extreme rainfall for Europe. Submitted to *Q. Jour. R. Met. Soc*
- Green, S., Sanderson, F.J. and Marsh, T.J. (1996). Evidence for recent instability in runoff and rainfall patterns in the Celtic regions of western Europe. In Merot, P, Jigorel, A. (Eds). *Hydrologies dans les pays Celtiques*, Proceedings of the first InterCeltic Colloquium, Rennes. INRA, Paris.
- Hannaford, J. and Marsh, T.J. (2005) An assessment of trends in runoff and low flows in undisturbed catchments in the UK. Submitted to *Int. J. Climatol*.
- Kiely, G. (1999). Climate change in Ireland from precipitation and streamflow observations. *Adv. Wat. Resour.* **23**(2): 141-151.