Geography and Environmental Science

University of Reading

ATMOSPHERIC RIVERS:
A HYDROLOGICAL PERSPECTIVE

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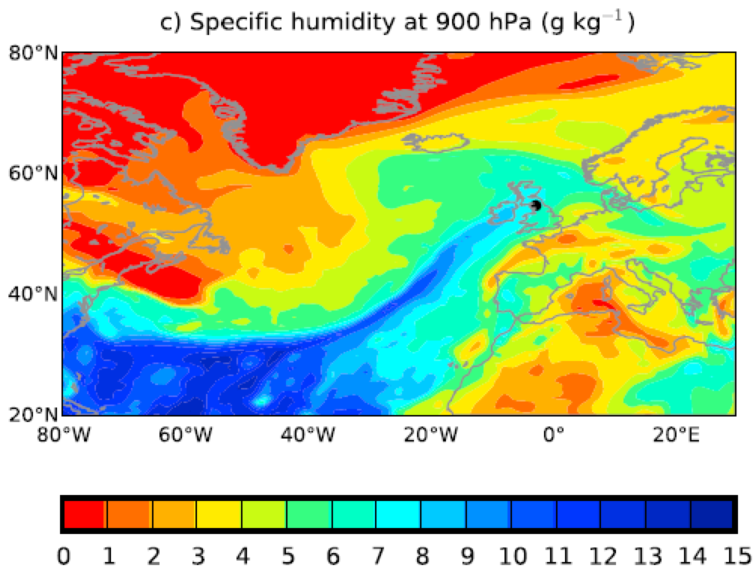
JBA consulting

ECMWF

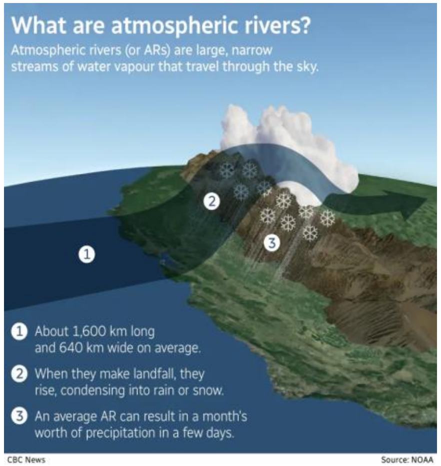
UKRI Natural Environment Research Council

SHORT-TERM HYDROLOGICAL IMPACTS



Lavers et al. 2011. GRL

Cockermouth 2009.
Credit: Environment Agency / Flickr.



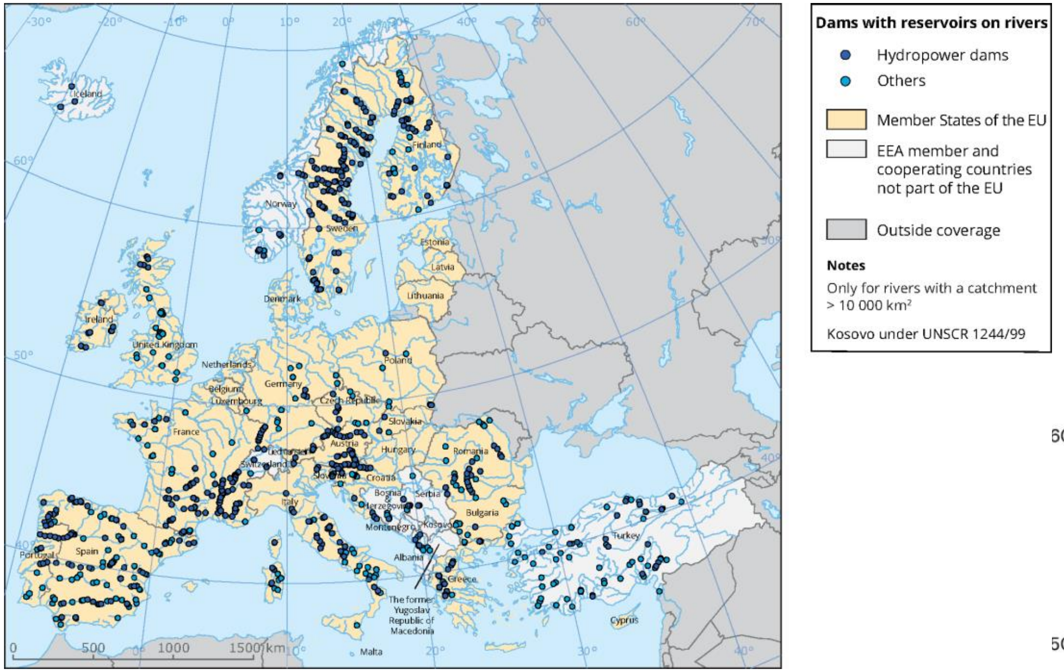
Snow?

EFAS
European Flood Awareness System

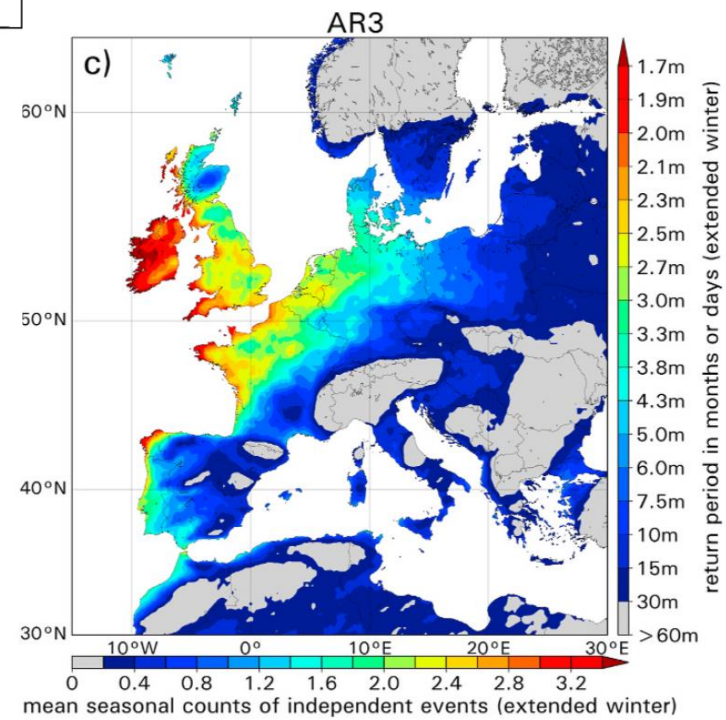
FLOOD FORECASTING CENTRE

Drought, heatwave breaker - and supply chains?

SHORT-TERM HYDROLOGICAL IMPACTS

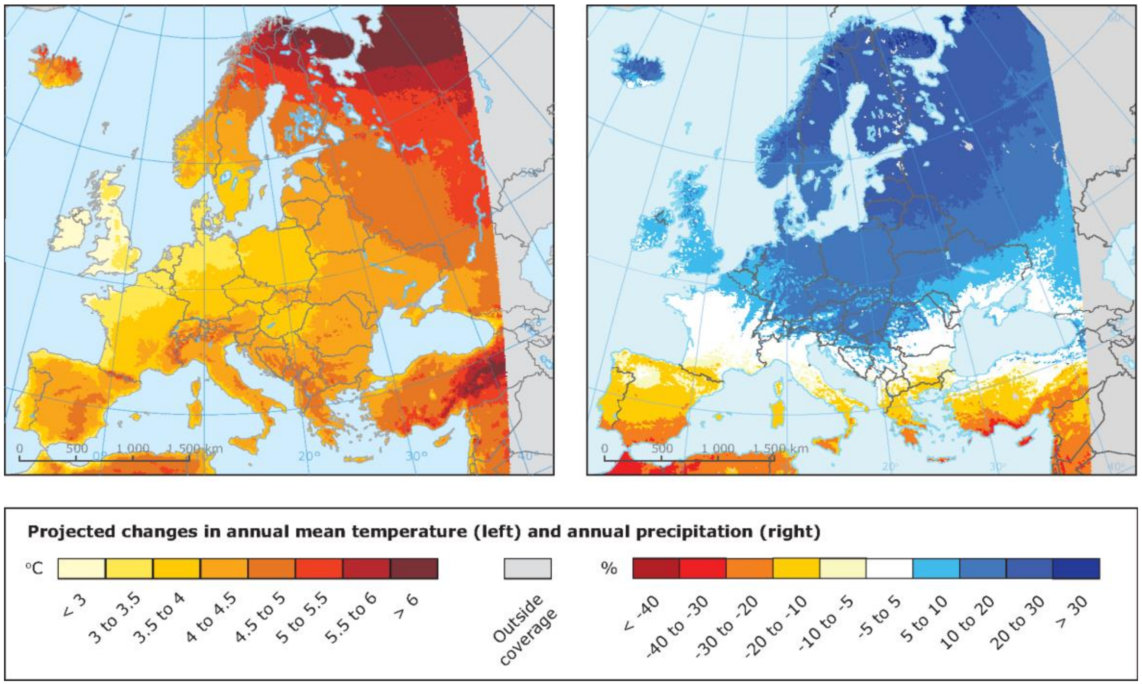


EU major reservoirs.
Credit: European Environment Agency, 2016.



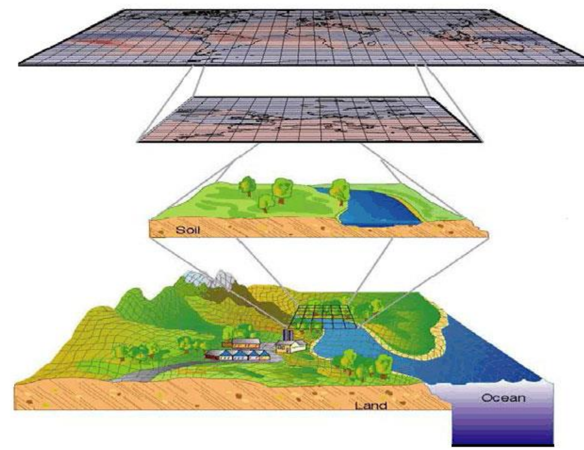
Eiras-Barca et al., 2021. Weather and Climate Extremes.

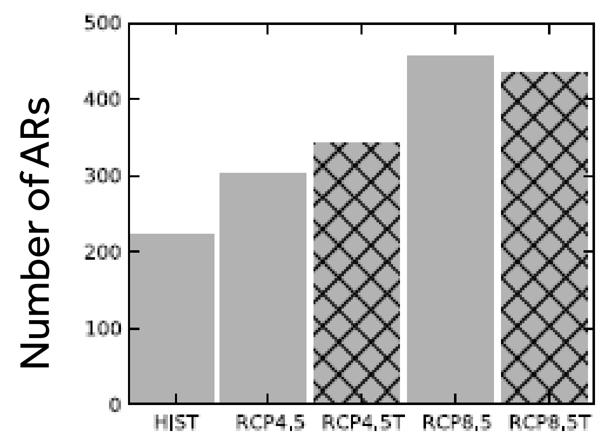
LONGER-TERM (CLIMATE CHANGE) IMPACTS



EURO-CORDEX ensemble. Projected changes for 2071-2100, compared to 1971-2000, based on the average of a multi-model ensemble forced with the RCP8.5 scenario.

Down-scaling?





Lavers et al., 2013. GRL

PROJECTED INCREASE IN AR FREQUENCY

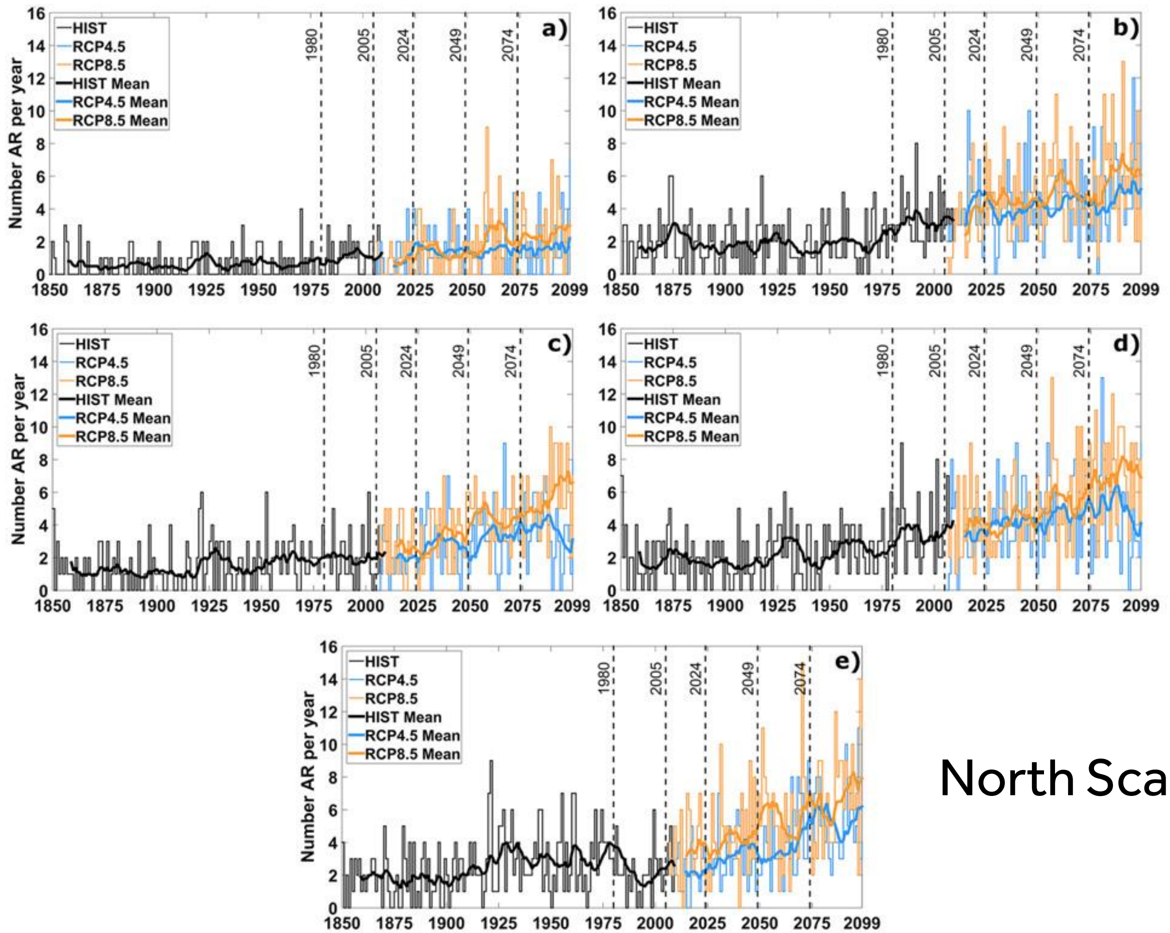
Iberia

France

UK

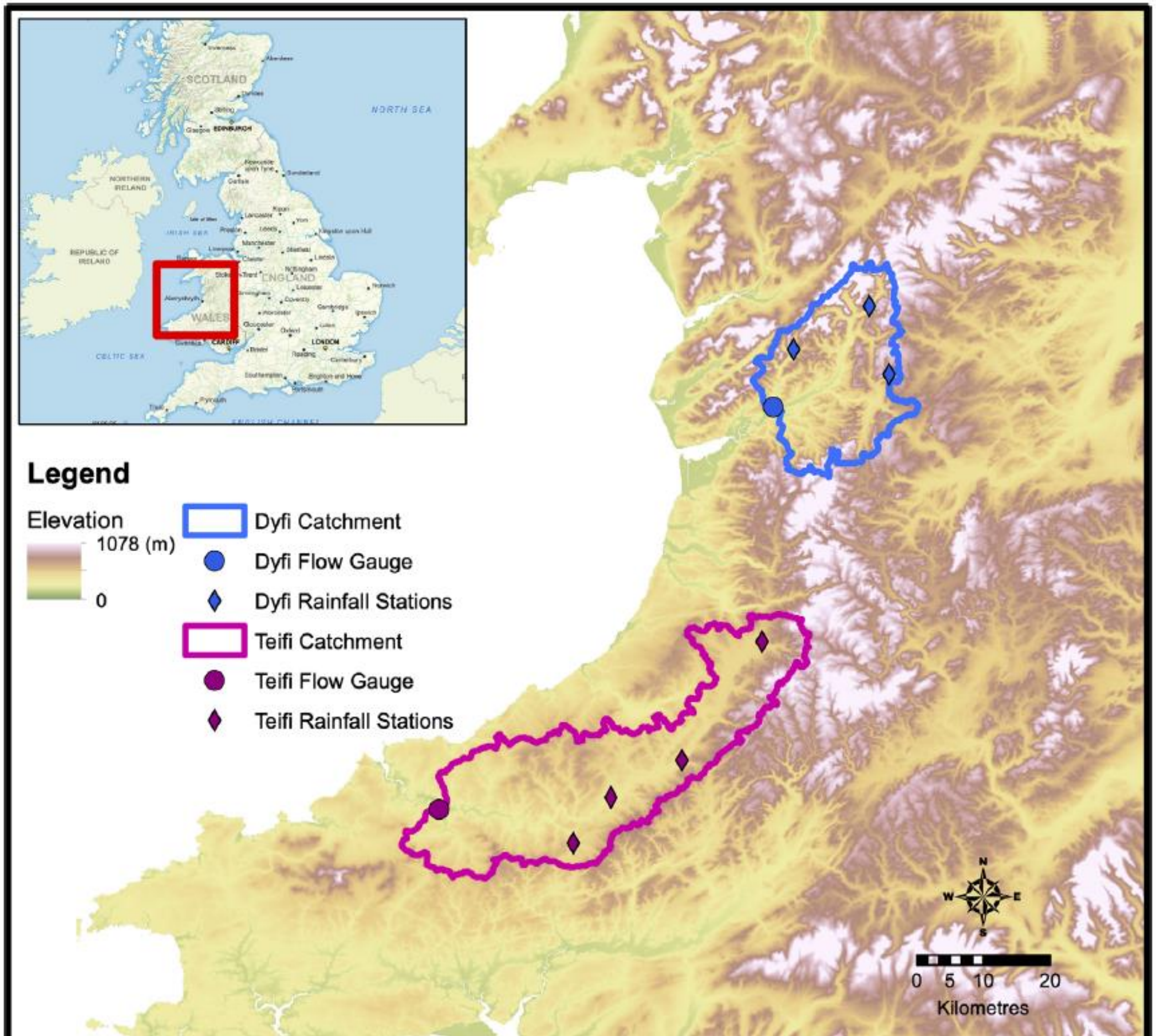
Central Europe

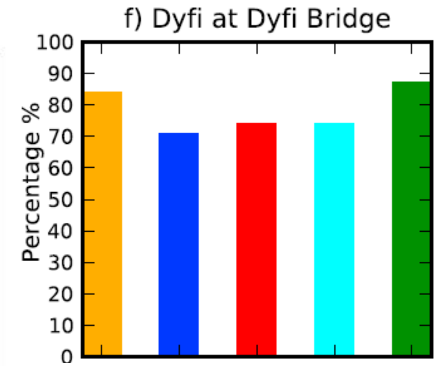
North Scandinavia

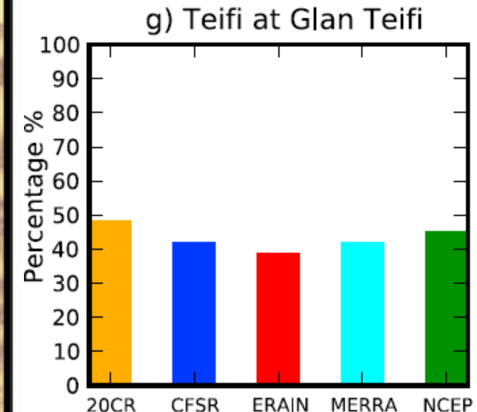


Projected changes in atmospheric rivers affecting Europe in CMIP5 models
Alexandre M. Ramos, Ricardo Tomé, Ricardo M. Trigo, Margarida L. R. Liberato, Joaquim G. Pinto
22 August 2016, **https://doi.org/10.1002/2016GL070634**

INTERACTIONS WITH THE LAND SURFACE







Percentage of POT-1 floods related to persistent ARs in five re-analysis products.

Lavers et al., 2012. JGR-A

RECOMMENDATIONS

- Same hydrological reasons to study ARs as US west coast
- Climate change as well as short-term forecasting
- SST cold bias in GCMs
- Different hydrological responses in different catchments
  - Complexity of AR front
  - Further validation of how different catchments respond to ARs

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ATMOSPHERIC RIVERS AND THE LAND SURFACE: DRIVERS OF EXTREME WINTER UK FLOODS?

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JBA consulting

Environment Agency

ECMWF

UKRI Natural Environment Research Council

The detection of atmospheric rivers in atmospheric reanalyses and their links to British winter floods and the large-scale climatic circulation

David A. Lavers,[1,2] Gabriele Villarini,[3,4,5] Richard P. Allan,[1,6] Eric F. Wood,[3] and Andrew J. Wade[2,7]

Received 29 April 2012; revised 12 September 2012; accepted 15 September 2012; published 19 October 2012.

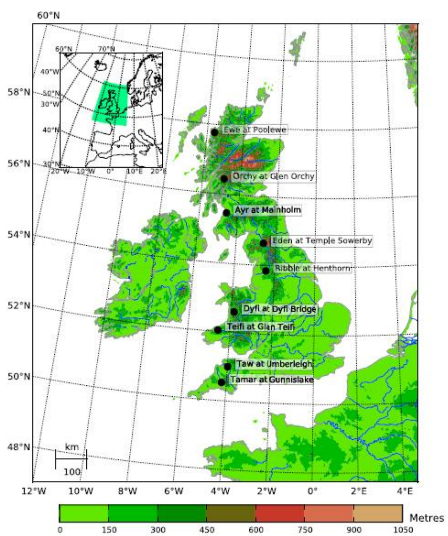


Figure 2. A map of the British Isles showing the location of the nine river basins.

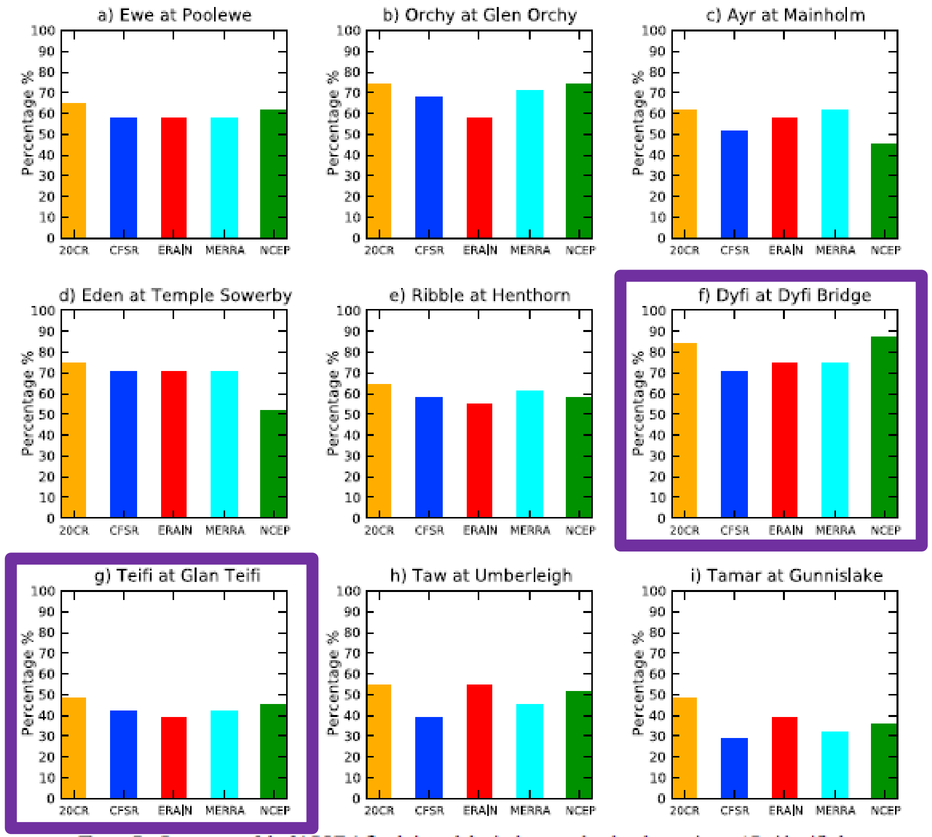
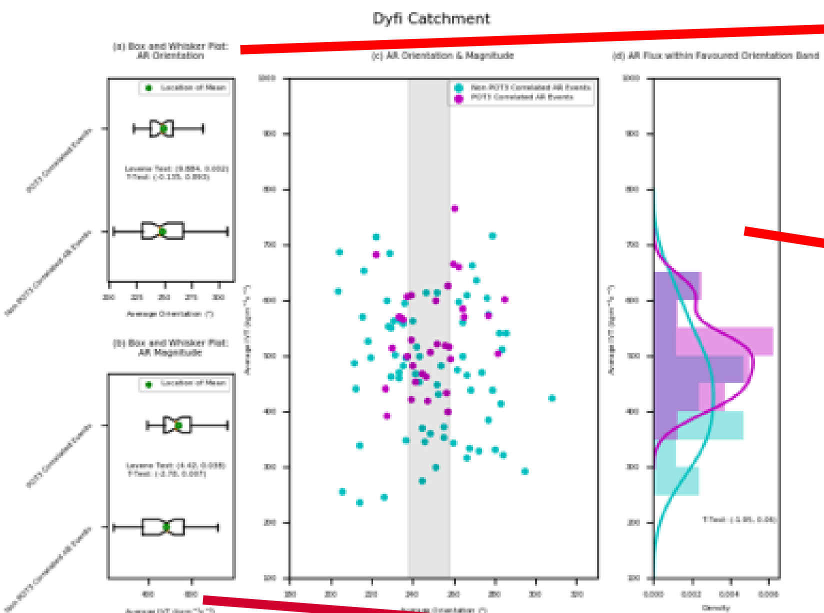


Figure 7. Percentage of the 31 POT-1 floods in each basin that are related to the persistent ARs identified in the five reanalyses.

Inspect the properties of the ARs that result in floods as compared to those that don't…



Significant difference in orientation variance (Levene Test) = evidence of orientation control?

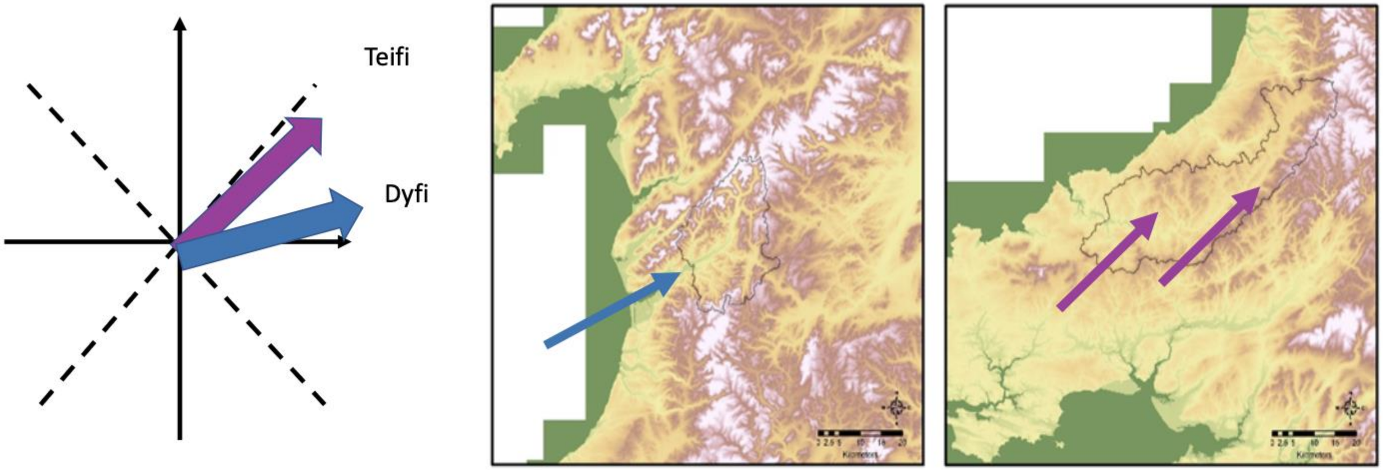
Looking at the results within the favoured orientation band, can we see evidence for a flux threshold too?
Orientation Dominated

Significant difference in means (T-Test) = evidence of IVT control?
Flux dominated

Is there a threshold above which flood flood causing ARs must reside?

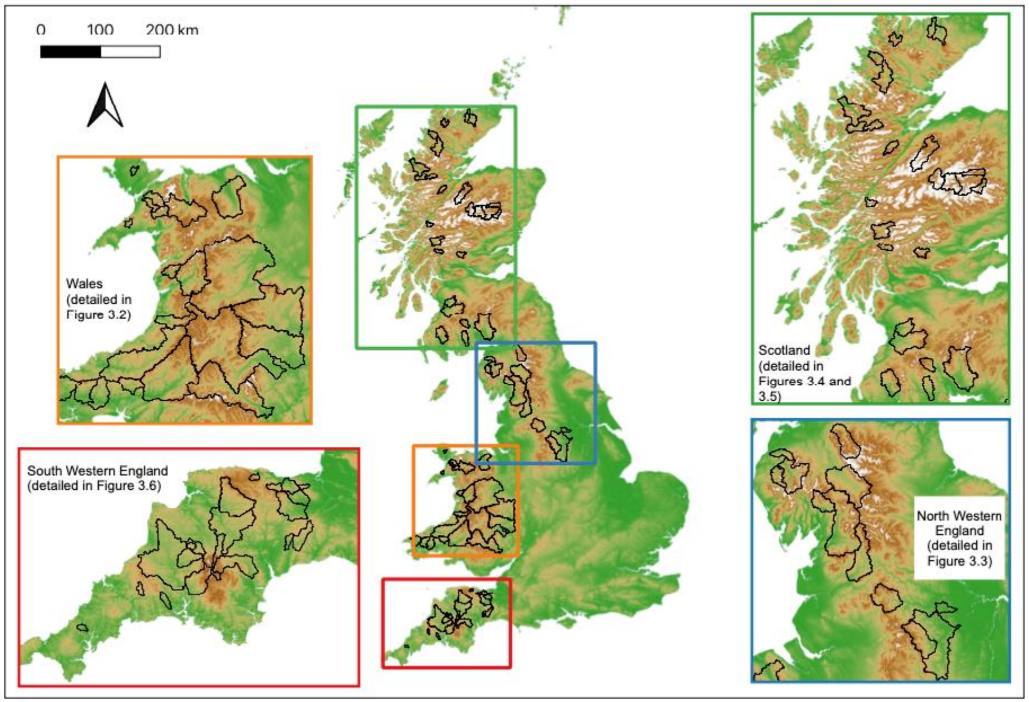
Griffith et al. 2020

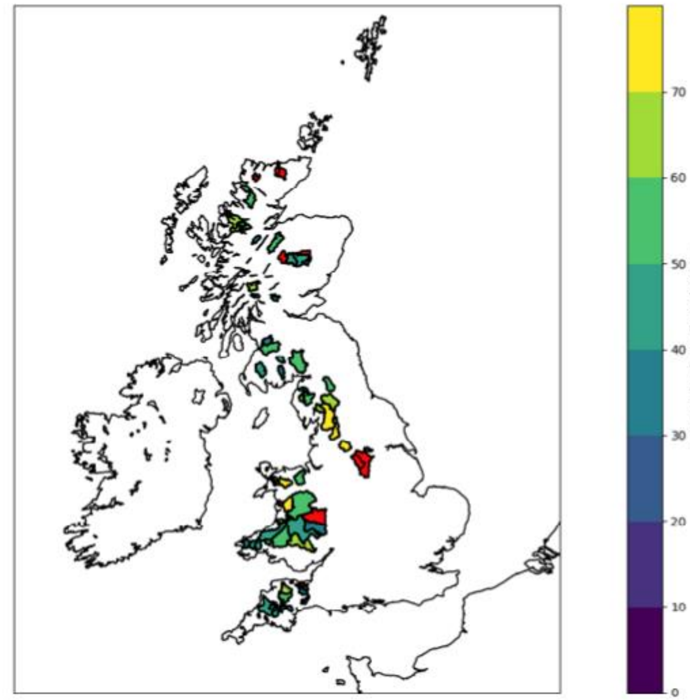
Orientation (followed by IVT) is key to understanding the most impactful ARs at the Dyfi and Teifi catchments!



Griffith et al. 2020

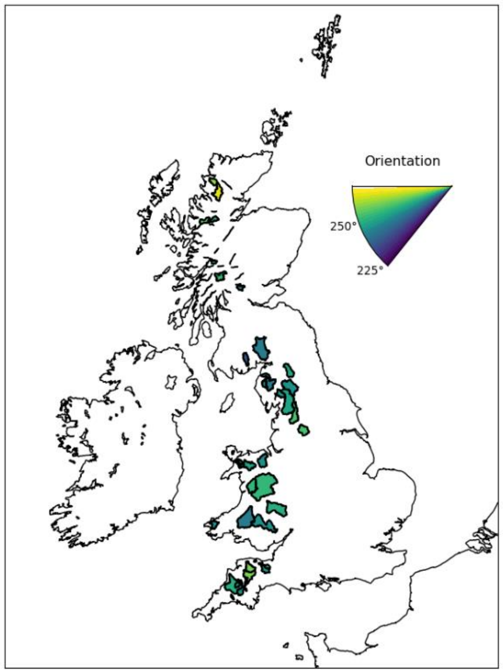
How about the rest of the UK?

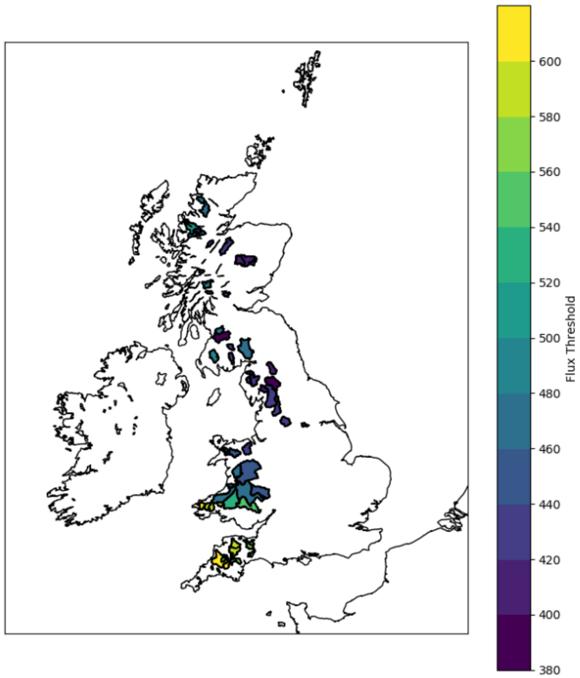


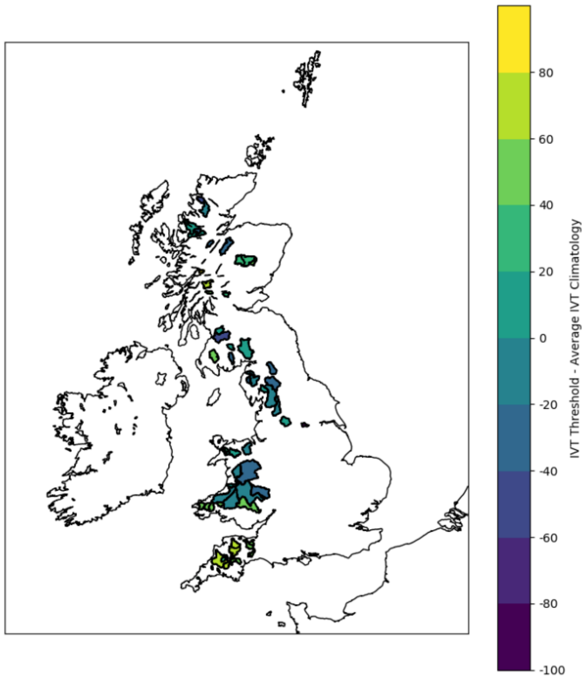


The percentage of POT3 floods associated with ARs across the UK varies. That is, catchments respond differently to incident ARs!

…and the orientations/strengths that are observed within impactful ARs also vary from catchment to catchment!

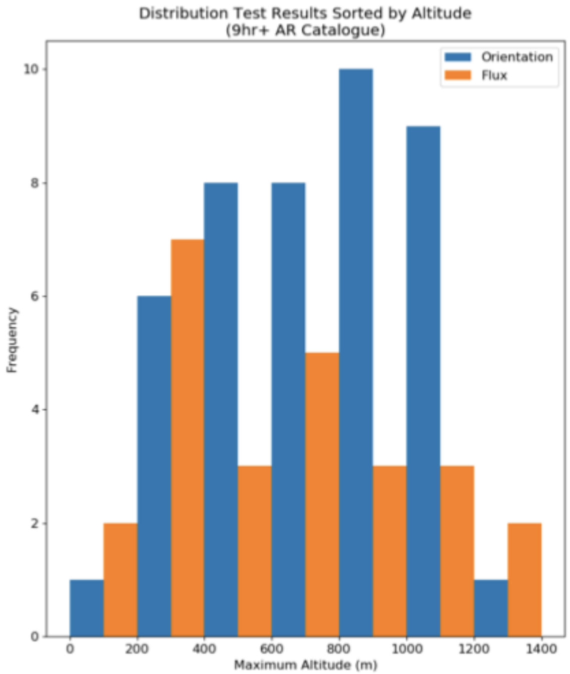


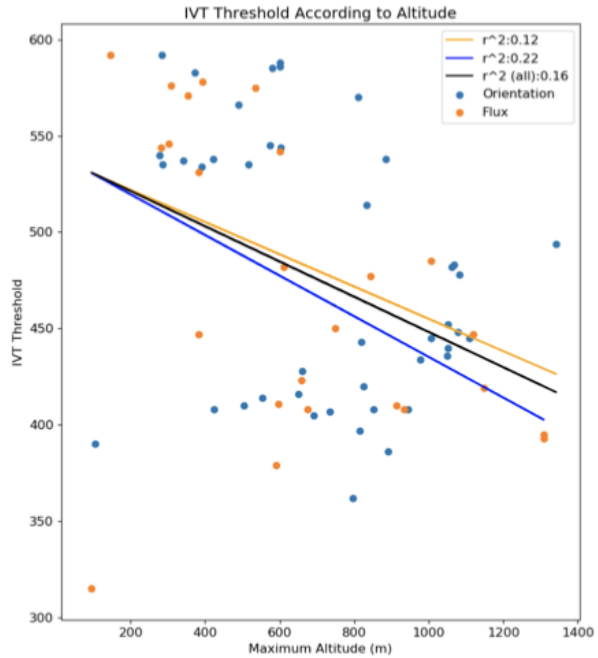




Why?

We can broadly understand what determines whether a catchment requires an particular AR orientation…

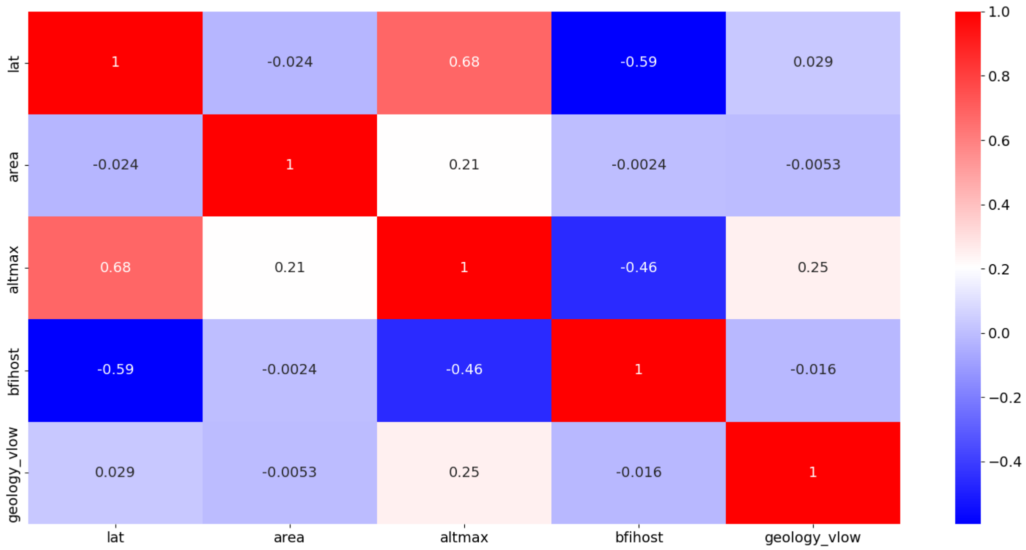




Catchments with a maximum elevations of 400m or more, are most likely to demonstrate an preferential orientation of impactful ARs.

The threshold of IVT intuitively falls as maximum catchment elevation rises…with scatter (!)

…however, the IVT threshold at each catchment is more complicated. Perhaps the inclusion of the land-surface and dominant hydrological processes can help us here…



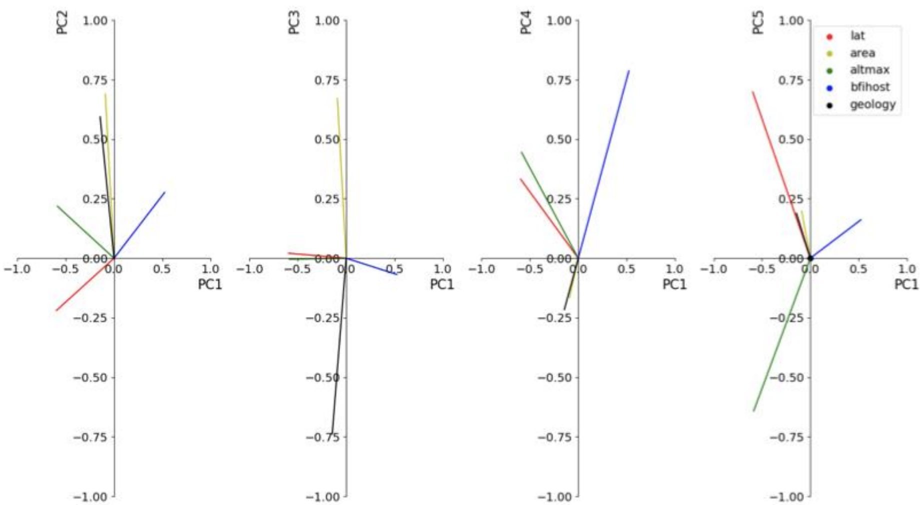
Characterise our test catchments according to several hydrologically based descriptors (source: FEH)

Latitude
BFIHost
Catchment Area
Impermeable geology
Maximum Elevation

However, as these descriptors remain correlated to some extent, we need to apply Principal Component Analysis to ensure independent axes...

Which catchment characteristics are the most important in controlling IVT threshold?

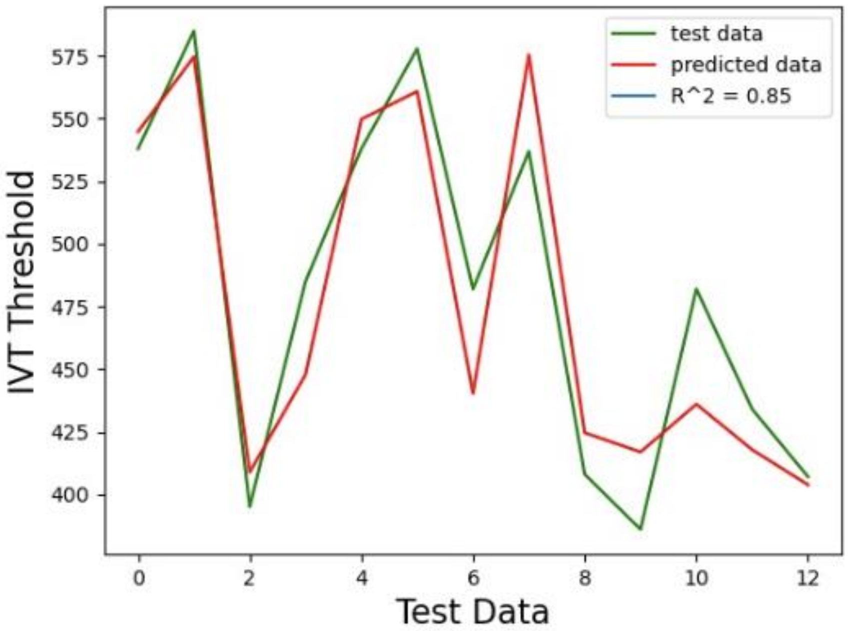
PC	Proportion Variance	Cumulative Variance	LAT	AREA	ALTMAX	BFIHOST	Geology (% of Very Low Permeability Bedrock)
1	0.44	**0.44**	-0.596	-0.147	-0.589	0.525	-0.016
2	0.21	**0.65**	0.059	-0.146	-0.215	-0.244	-0.932
3	0.20	**0.85**	-0.171	0.949	0.070	0.142	-0.213
4	0.10	**0.95**	-0.373	0.137	-0.376	-0.799	0.251
5	0.05	**1.00**	-0.688	-0.195	0.679	-0.079	-0.149



By projecting onto the PCA axes, we investigate the extent to which the variability in IVT threshold can be explained by the above descriptors.

- The first principal component (PC1) accounts for **44% of the variance** in the catchment descriptor dataset (upper panel). The loading plots (lower panel) allow identification of the drivers of PC1: **catchment latitude** and **maximum elevation**.
- Following a similar process, PCs 2 and 3 are driven by the **impermeable geology** and **catchment area** respectively accounting for around **20% of the variance** each. Using the first three PCs alone therefore, it is possible to account for **85% of the variance** in the independent dataset.

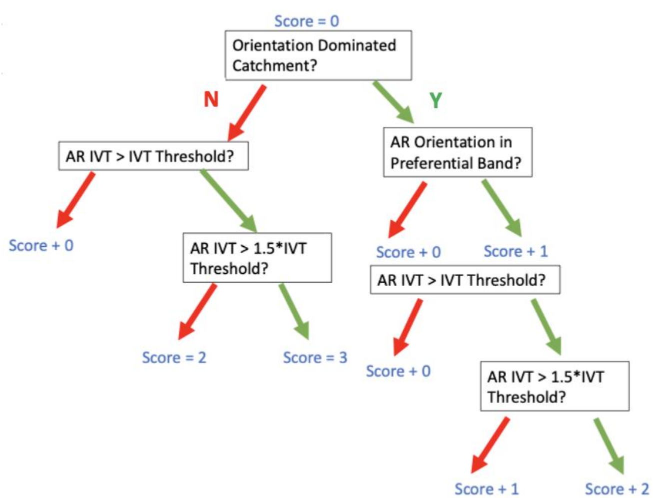
Potential to predict IVT threshold based on catchment properties?

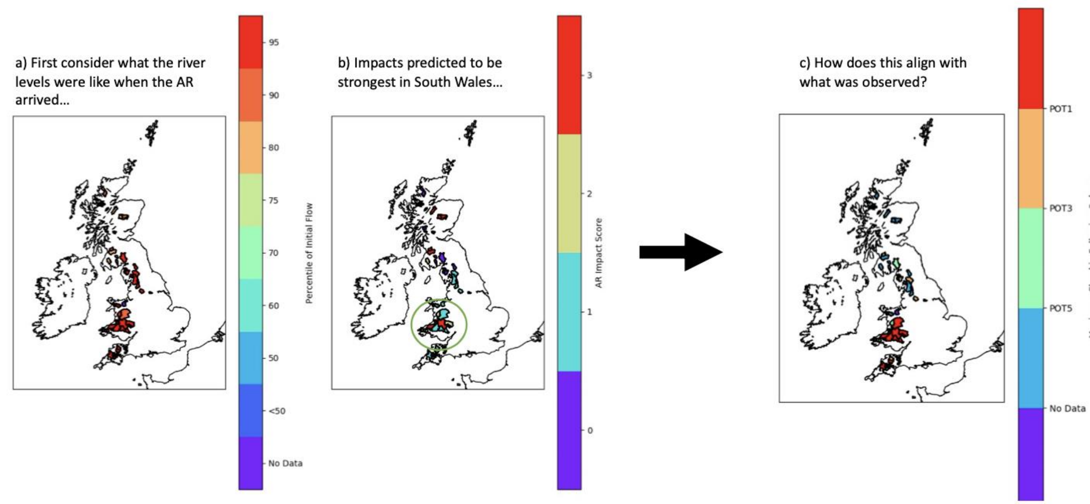


Variable	Importance
PC1	0.899
PC5	0.018
PC3	0.013
PC4	0.017
PC2	0.052

R^2
0.848

How about adding to (existing) impact prediction frameworks?





CONCLUSIONS

1. Understanding the strength and duration of an overhead AR is not enough if we want to predict the most impactful events across the UK.
2. The catchment is able to amplify or dampen the effects of an overhead AR dependent on the dominant hydrological processes within the basin.
3. How does this relate to AR Recon? Our ability to forecast key AR properties offers to potential to directly infer ground level impacts (thus avoiding complicated downscaling…)