Which catchment characteristics control the temporal dependence structure of daily river flow?

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Introduction

Hydrology has yet to achieve a widely agreed-upon classification system (Wagener et al., 2007).

A broad classification process should be possible, based on the general assumption that some level of organisation and therefore predictability in catchment 'function' (i.e. the translation of catchment input into river flow) exists (Bloschl et al., 2013).

Temporal dependence represents the similarity between the river flow on a given day and river flow on the preceding days (an integration of water input, storage and flow pathways within the catchment) and can be characterised with a (semi-)variogram (Figure 1).

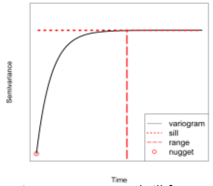

Figure 1. Range and sill for a theoretical semi-variogram.

Clustering based on the temporal dependence structure has some key advantages:

1) Raw data is used, rather than having to calculate indicators from discharge data (e.g. annual or seasonal averages, minimum or maximum flows).
2) It can handle missing data.
3) The resulting clusters are based on catchment function, not a specific part of the flow regime

Quadratic discriminant analysis was used to:

1) Identify which catchment characteristics influence the temporal dependence structure.

2) Analysis whether un-gauged catchments could be clustered accurately, using their catchment characteristics.

The selected catchments (Figure 2) have less than 5% missing data between 1970 and 2010 and limited artificial impacts.

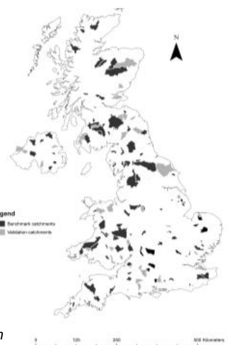

Figure 2. Location of the 116 benchmark and 49 validation catchments

Clustering results

The benchmark catchments were clustered on the basis of their semi-variograms.

Ward's hierarchical clustering method was used, resulting in four clusters (Figures 2 and 3).

Cluster 1 is comprised of catchments with small lag times and low storage (i.e. steep topography, peat soils and rock with essentially no groundwater (Figure 4)).

The opposite is seen in cluster 4 where the majority of catchments overlay highly productive fractured aquifers (Figure 4).

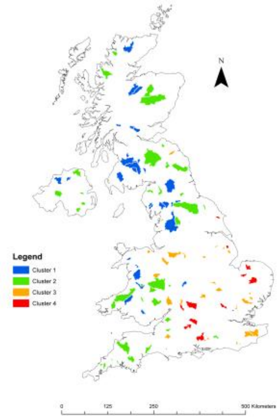

Figure 3. Location of the catchments in the four clusters.

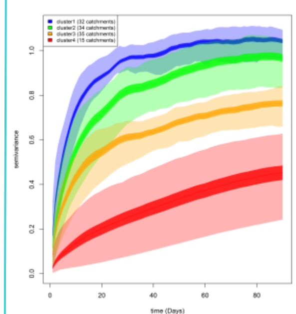

Figure 3. Semi-variograms for the four identified clusters with the 95 % confidence intervals (dark shaded area) and the upper and lower bounds of each cluster (light shaded area).

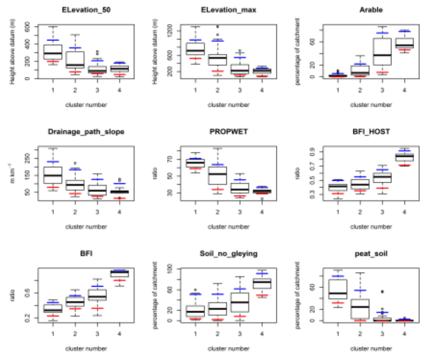

Figure 4. Box plots of characteristics which differ between all four clusters.

Quadratic discriminant analysis results

Quadratic discriminant analysis was used to independently investigate how accurately catchment characteristics can be used to predict the membership of the clusters (Table 1).

This demonstrates that using a combination of catchment characteristics enables the shape of the variogram to be estimated for an un-gauged catchment. Model 5 was deemed the best model.

Table 1. Different discriminant models and the percentage of catchments which were correctly classified by using the catchment characteristics.

Model number (number of variables)	% classified correctly (benchmark)	% validated correctly	% woodland	Average drainage path length	Area	% grassland	Elevation 10	Longest drainage path	Floodplain extent	Drainage path slope	Gleyed less than 40cm	Gleyed between 40 and 100cm	No gleyed soil	% Arable land
12	89.7	32.7												
11	89.7	30.6												
10	87.9	57.1												
9	86.2	63.3												
8	81.9	53.1												
7	80.1	57.1												
6	75.9	63.2												
5	72.4	71.4												
4	70.7	71.4												
3	68.1	73.4												
2	67.2	75.5												
1	54.3	55.1												

Conclusion

Clustering the catchments based on the temporal dependence is an effective way to obtain separate groups of catchments based on their catchment function.

The catchment characteristics able to best discriminate between catchments were found to be: percentage of arable land, depth to the gleyed layer in soils, slope and elevation.

It is likely that arable land is not a driver behind the different clusters, but a surrogate for a combination of other characteristics which drive infiltration and hence the precipitation-to-flow relationship.

Further work

This methodology will be developed to examine non-stationarity in precipitation-to-flow relationships; it could also be expanded on to transfer information about the precipitation to flow relationship from gauged to un-gauged catchments.

References:

BLOSCHL, G., SIVAPALAN, M., WAGENER, T., VIGLIONE, A. & SAVENIJE, H. 2013. *Runoff Prediction in Ungauged Basins, Synthesis accorss Processes, Places and Scales* Cambridge University press.

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