A PHYSICAL SIMILARITY APPROACH TO REGIONALISATION USING A GLOBAL DATABASE OF CATCHMENTS.

JBA risk management

EGU European Geosciences Union

Background

There is a growing demand for global-scale flood risk management which in turn requires reliable Prediction in Ungauged Basins (PUB). One approach to PUB is to form a model for an ungauged site from the parameter values of a set of donor catchment models. The donor catchments must be gauged and the models correctly calibrated. The choice of donor models is then made according to an appropriate nearest-neighbour metric.

Simple access to gridded catchment features and meteorological data, and the power of modern model optimisation tools make this approach feasible for global scale applications. However, at these large scales, it is important to assess the skill of PUB for two donor catchment selection methods: (1) purely according to catchment feature similarity; and, (2) feature similarity but with an additional weighting for the Kling Gupta Efficiency[1] (KGE) of the original donor model. The results show that it is better to sacrifice some catchment similarity in favour of well-calibrated models when selecting donor catchments.

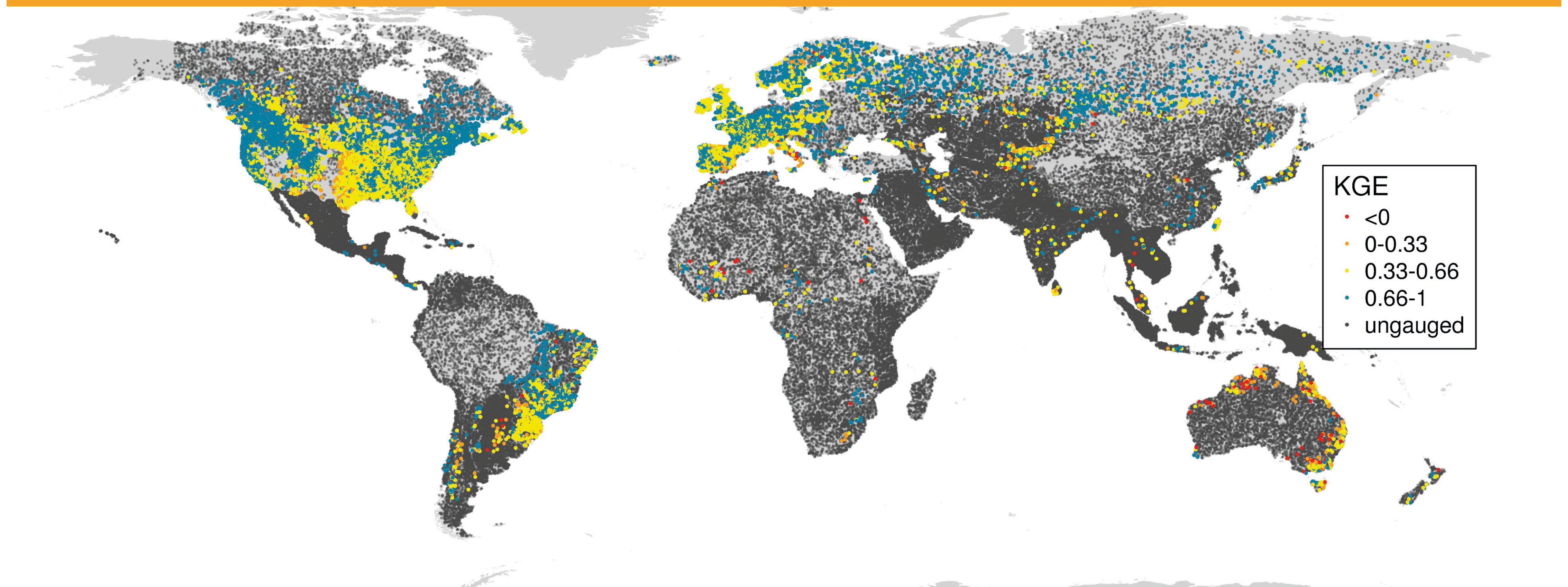
Global Catchment Database

The Global Catchment Database (GCD) developed at JBA Risk Management maintains streamflow observations and physiographic-climatic properties for more than 18,000 gauged and over 130,000 ungauged catchments. The database also maintains an IHACRES[2] model scheme for gauged sites calibrated using KGE, where a score of 1 indicates best possible performance.

The GCD uses the following data sources:

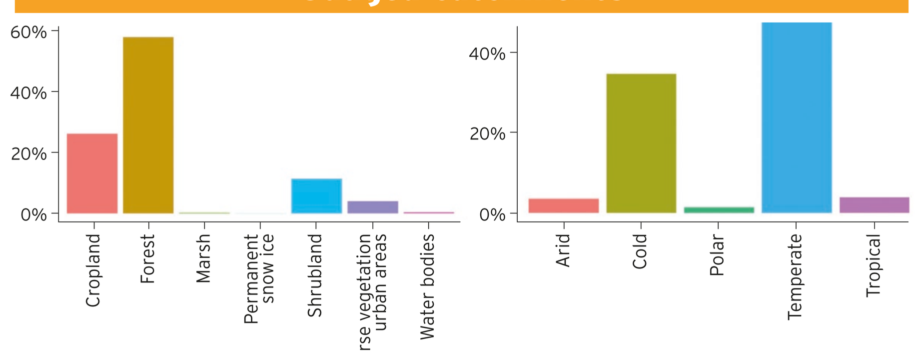
- Streamflow data for calibrating the IHACRES models, obtained from multiple sources at daily or monthly time resolution;
- Gridded meteorological data (precipitation and temperature) aggregated by catchment to form daily timeseries;
- A digital terrain model used to delineate catchment boundaries; and,
- Catchment attributes: global gridded datasets for soil, climate, land cover and elevation

Performance of the IHACRES models, evaluated using KGE

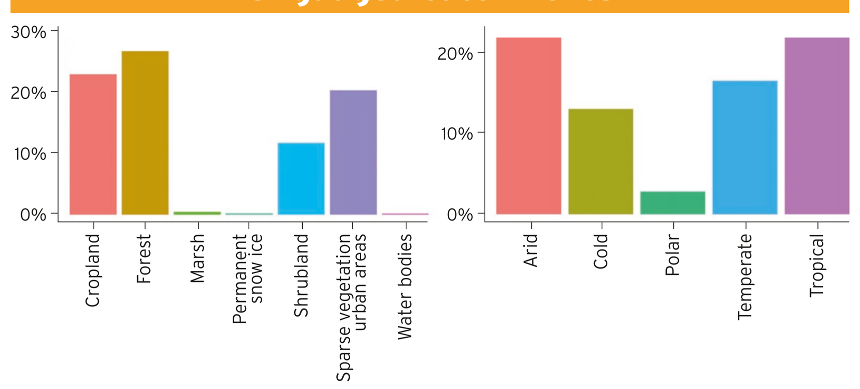


Catchment Attributes

Gauged catchments



Ungauged catchments



The median catchment size is 630 km². There are a higher frequency of catchments located in forest land cover and with temperate to cold climates, as defined by the Köppen climate index. In contrast, most ungauged catchments are in arid regions within agricultural and urban areas.

The performance of the IHACRES models varies with the attributes of the catchments, especially with climate. The worst performance is observed in arid catchments although this finding is based on fewer locations due to the shortage of gauged sites. The variation in the model performance as well as the large differences between the catchment properties of the gauged and ungauged catchments makes the regionalisation extremely difficult.

Performance of the calibrated hydrological models, grouped by climate type. Numbers in parentheses indicate percentage of total.

KGE	Arid	Cold	Polar	Temperate	Tropical
<0	39 (6.0)	8 (0.1)	2 (0.8)	55 (0.5)	25 (3.6)
0-0.33	117 (18.0)	180 (2.9)	10 (3.9)	538 (5.2)	56 (8.0)
0.33-0.66	258 (39.9)	1871 (29.9)	56 (22.0)	5468 (53.2)	283 (40.7)
0.66-1	233 (36.0)	4209 (67.2)	186 (73.2)	4213 (41.0)	332 (47.7)
Total	647	6268	254	10274	696

IHACRES model optimisation

The IHACRES model is a lumped conceptual-metric hydrological model. The structure of the IHACRES model as implemented in GCD can be summarised as:

Module	Description	Number of Parameters
Snowmelt	degree day model	8 (4 fixed)
Soil moisture	non-linear model (CMD)	5 (1 fixed)
Flow routing	two linear transfer functions	5 (0 fixed)

The PSO (Particle Swarm optimization) routine was used to maximise the KGE score using pre-defined ranges for the model parameters. In addition, the IHACRES models were visually reviewed and catchments with very poor model fits were classified as ungauged.

Streamflow estimation at ungauged catchments

A regionalisation method has been developed at JBA, which uses the following steps:

- Cluster analysis, based on catchment attributes is used to identify a set of the closest catchments (donors) in physiographic-climatic space
- The IHACRES model parameters for each one of the these donor catchments are used to simulate the streamflow at the ungauged catchment
- A weighted average of these dataseries is used to derive the flow at the ungauged catchment

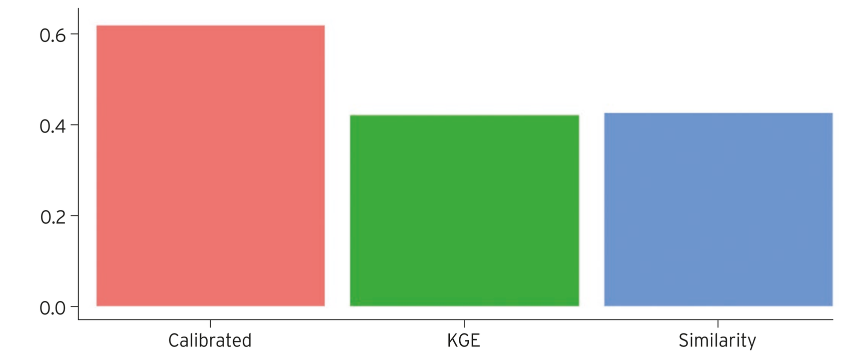
As there is uncertainty in the model calibration and in the clustering process, the selection of a weighting scheme can have significant effect on the performance of the regional models. Two different methods are being evaluated to assign weights:

- Similarity of attributes - models that are most similar to the target catchment receive higher weights
- KGE score - models that have higher KGE score receive higher weights

Performance of the regionalisation

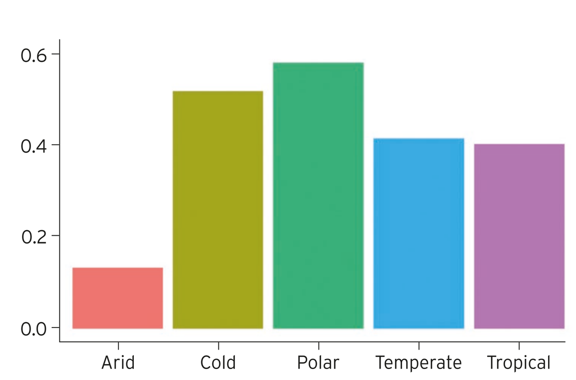
In order to assess the applicability of the two weighting methods, a sample of around 3,000 gauged catchments, treated as ungauged, was randomly selected. The overall performance of the two weighting schemes was similar: the median KGE for the calibrated catchments was 0.6 but dropped to 0.4 for both weighting methods when they were treated as ungauged.

Comparison between the KGE values for the two weighting methods and the KGE values of the calibrated models

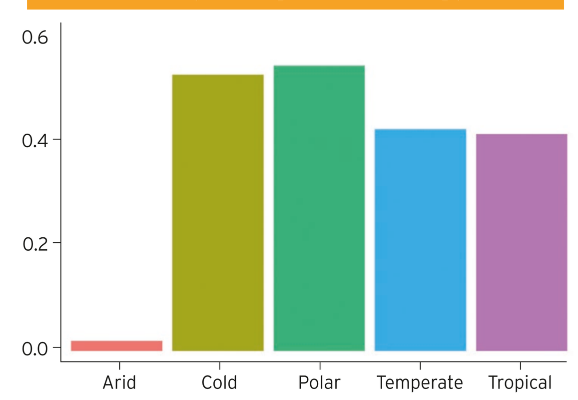


However, when the fit results were grouped by climate types, the better performing regionalisation method was the one where more weight was given to the models with higher KGE values:

Model averaging using similarity score, split by climate types



Model averaging using KGE score, split by climate types



Conclusions

By taking advantage of a very large repository of calibrated rainfall-runoff models, catchment geometries, and catchment descriptors, it has been possible to cross-validate the performance of alternate donor catchment selection methods. The key findings are:

- When using the donor catchment method outside of the ideal criteria of very similar catchments AND well-calibrated donor catchments, the shortcomings in one metric can, to a certain extent, be offset by strengths in the other; and,
- Given the option of many donor catchments with good similarity to the ungauged site, it is better to sacrifice some similarity in favour of donor catchments with a good calibration score.

References

1. Gupta, H. V., Kling, H., Yilmaz, K. K., & Martinez, G. F. (2009). Decomposition of the mean squared error and NSE performance criteria: Implications for improving hydrological modelling. *Journal of Hydrology*, 377(1), 80-91.
2. Jakeman, A.J., Littlewood, I.G., Whitehead, P.G., (1990). Computation of the instantaneous unit hydrograph and identifiable component flow with application to two small upland catchments. Journal of Hydrology 117, 275-300.

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