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► **To cite this version:**

Julien Plasse, Claire Lang Delus, Gilles Drogue. Evaluation of three regionalization approaches for continuous streamflow simulation. IAHS 90th ANNIVERSARY -Prediction in Ungaged Basins, Oct 2012, Delft, Netherlands. hal-04822244

HAL Id: hal-04822244

<https://hal.science/hal-04822244v1>

Submitted on 6 Dec 2024

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Evaluation of three regionalization approaches for continuous streamflow simulation

Application to water quality measurements reanalysis

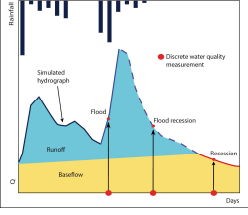
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1 A challenge for making water quality data more meaningful

The opposite table exhibits signs of correlation generally observed between nitrate concentrations in river flows (daily values and time variability) and some hydrological variables (antecedent daily river flow, river flow, Base Flow Index).

	Q _{n-i}	Q _n	BFI
[NO3]	(+)	(-)	
CV [NO3]			(-)

Reconstructing the hydrological context of WQM in ungauged catchment

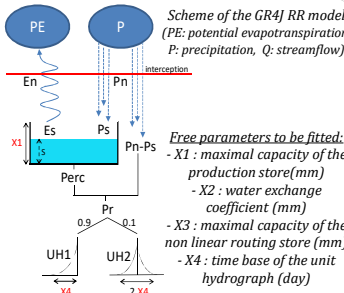


In the French part of the Rhine-Meuse basin, monitoring networks include 468 pollution-control sites. Most of them are ungauged or only few streamflow measurements exist. Therefore, when reanalysing the water quality measurements (WQM) through data mining methods, it is difficult to interpret field data and trends on pollutants indicators without any information on the hydrological context (key elements are flood, flood recession and recession) of discrete WQM.

2 Model and data

Rainfall-runoff model

We use GR4J, an empirical lumped daily rainfall-runoff (RR) model depending on four free parameters (Perrin et al., 2003).

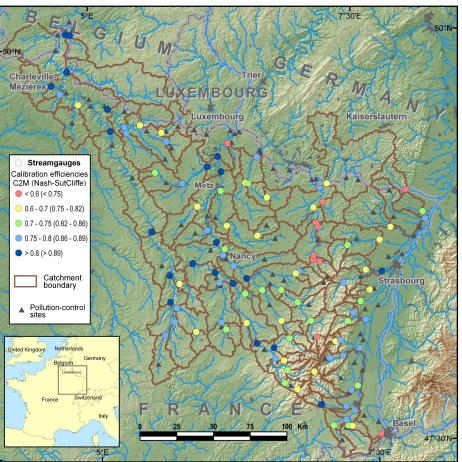


Model assessment

The RR model has been applied on 104 unregulated river basins located in French part of the Rhine-Meuse basin. Climate data have been extracted from the SAFRAN gridded climatology. Calibration of the model was performed for each basin using the BFGS method (hill-climbing optimization technique). We used the Nash-Sutcliffe efficiency criterion computed on root square transformed flow values (NS_{sqrtQ}) as objective function. Twenty years (1990-2009) were available for calibration. Each catchment was modeled on this period for getting optimal parameter sets used for regionalization purposes. Model efficiency is expressed as the C2M_{sqrtQ} criterion, a bounded version of the NS criterion (Mathevet et al., 2006).

$$C2M = \frac{NS}{2 - NS}$$

The performance of the model on the 104-catchment set is variable. The mean (median) C2M_{sqrtQ} value is very close to 0.73 (0.75).



Computing a regional parameter sets library

Optimal parameter sets θ_i were collected into a parameter library used for running the RR model on pseudo-ungauged catchments. Three well-known methods for transferring model parameters in space were considered:

- ✓ The spatial proximity approach;
- ✓ The Top-kriging approach;
- ✓ The regression-based approach.

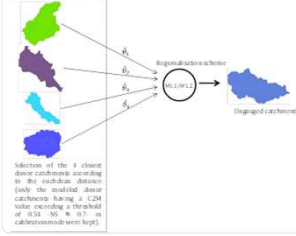
Physical catchment descriptors

76 physical descriptors were considered for georegression purposes.

References: Mathevet T., Michel C., Andréassian V., Perrin C. 2006. A bounded version of the Nash-Sutcliffe criterion for better model assessment on large sets of basins. IAHS Red Books Series n°307, pp. 211-219. Perrin C., Michel C., Andréassian V., 2003. Improvement of a parsimonious model for streamflow simulation, Journal of Hydrology, 279(1-4), 275-289. Skøten J.O., 2009. Rtop - an R package for interpolation along the stream network. Geophysical Research Abstracts, Vol. 11, EGU2009-10533. Acknowledgements: We would like to acknowledge Météo-France for providing the SAFRAN reanalysis data, the DREAL Lorraine for providing access to the HYDRO streamflow archive and the Rhine-Meuse Water Agency for its financial support.

3 Transfer of model parameters

M1 : Spatial proximity

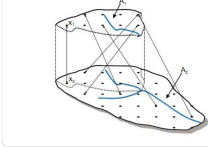


❖ An optimal scheme was found with 4 donor catchments leading to an estimation of the daily flow values at the target basin through equations written as :

$$\text{Method M1.1: } \hat{Q}_{j,k} = \frac{1}{4} \sum_{i=1}^4 \hat{Q}_{j,i}(\hat{\theta}_i)$$

$$\text{Method M1.2: } \hat{Q}_{j,k} = f(\hat{\theta}_i)$$

M2 : Top-kriging



❖ Topological kriging is a method for estimating variables. It takes both the area and the nested nature of catchments into account (Skøien, 2009).

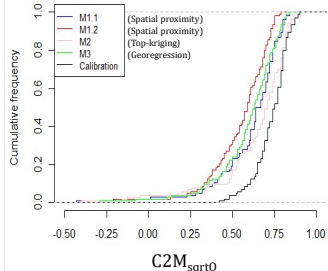
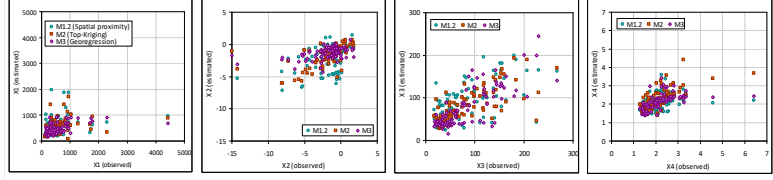
M3 : Georegression

	X1	X2	X3	X4
R ² (mean value)	0.25	0.22	0.65	0.29
Number of descriptors	5	4	3	3

- ❖ Regression catchment descriptors:
- Topographical index (X1, X3, X4);
 - Smoothed altitude (X2, X4);
 - Permeability (X1, X2);
 - Evapotranspiration (X1);
 - HOST class n°8 (X1, X2);
 - Fraction of artificialized area (X2, X3, X4);
 - Fraction of forest cover (X3).

4 Success and failure...

We use the leave-one-out cross validation procedure in order to test the efficiency of the regionalization methods, each of the 104 catchments successively being considered as ungauged.



Based on C2M_{sqrtQ} values, results for the 3 regionalization schemes show that:

- ✓ Top-Kriging is the best method and provide efficiencies slightly below their values in calibration mode (0.64 against 0.73 for the mean efficiency);
- ✓ Top kriging and spatial proximity (M1.1) provide very close efficiencies.

Whatever the regionalization method, we found that:

- ✓ Observed parameter values are poorly estimated: relatively good efficiencies come up from parameter compensation;
- ✓ Some optimal parameter sets were found for (natural or poorly gauged) outlier catchments. Those catchments were already identified in calibration mode;
- ✓ For some catchments (the so-called hydrological monsters) a tailor-made modelling might be developed (e.g. chalk catchments).

5 Main outcomes

This study rises the challenging question of searching or applying a « multi-regionalization » strategy for continuous flow simulation in ungauged basins. Despite the fact that for some catchments, model extrapolation could lead to poor flow estimations, in a context of rather dense monitoring streamgauge network, a simple regionalization method like the one based on spatial proximity allows to reconstruct the hydrological context of past WQM. A way to improve flow simulations might be to look for the best neighbors for almost ungauged catchments.