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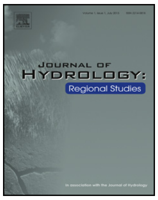

# Catchment model regionalization approach based on spatial proximity: Does a neighbor catchment-based rainfall input strengthen the method?

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ABSTRACT

*Study region:* The Upper Rhine-Meuse catchment (French part).
*Study focus:* A rainfall input-related sensitivity analysis was conducted to assess if, with a neighbor catchment-based knowledge of optimal rainfall input, rainfall-runoff modeling becomes more competitive for estimating streamflow at ungauged catchments.
*New hydrological insights for the region:* Results show that when streamflow is known at the outlet of a catchment, optimal rainfall input for a lumped catchment model is mostly computed with a subset of raingages. When streamflow is unkown at the outlet of a catchment, a regionalisation approach of model parameter values based on spatial proximity is not able to take advantage of a neighbor-catchment based knowledge of optimal rainfall input. This report encourages to search for a catchment model regionalization approach based on spatial proximity which makes no explicit use of measured rainfall to estimate streamflow at an ungauged location.

## 1. Introduction

Precipitation is the main atmospheric forcing of the hydrological catchment response. As stated by Larson and Peck (1974), "*without accurate measurements or estimates of precipitation, water balance studies and modelling become meaningless*". Hence, quantifying accurately precipitation still remains a challenge for many hydrological applications especially in regions with complex topography due to orographic effects and small-scale slope effect (Sevruk, 2004). A 10% error on precipitation estimates may lead to a higher error on streamflow estimates according to the non-linearity of the precipitation-streamflow transformation.

While space correction and integration of the point meteorological precipitation records have clear benefits providing the model with consistent rainfall data (see, for example, Stisen et al., 2012), producing consistent catchment-scale estimates for rainfall-runoff modelling operational purposes implies to go one step further. In order to assess "*how areal rainfall, calculated from a consistently estimated field, is transformed into runoff*" (Andreassian et al., 2001), the catchment precipitation estimate issue should not be considered independently to the catchment system which acts as a filter attenuating the rainfall

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variability. A rainfall-runoff model being a simplification of the real catchment behaviour, the characteristics of the raingage network, the quality and the quantity of rainfall data should be adjusted to the specific needs of catchment modelling.

Scientific works conducted on this topic demonstrated the usefulness of the rainfall information provided by optimal raingages (Anctil et al., 2006; Bardossy and Das, 2008; Dong et al., 2005; Tsintikidis et al., 2002; Xu et al., 2013). A common feature of these publications is that specific subsets of raingages may lead to a better hydrograph estimation than when all available raingages are used to calculate the catchment precipitation input.

While contributing to a significant breaktrough in the diagnosis of model behaviour when streamflow is known at the outlet of a catchment, all these sensitivity studies do not focus on how the regionalization problem in rainfall-runoff modelling is impacted by rainfall knowledge at the catchment-scale. Hence, we believe that additionnal researches should be carried out to improve our expertise on the sensitivity of hydrograph estimation to raingage network distribution at river points where streamflow is unknown. In order to identify potential optimal raingage networks, our research firstly focused on how sensitive a lumped catchment model is to a change in the selected raingages and related rainfall input at gauged catchments. Secondly, we tested the impact of using the optimal raingage networks for rainfall estimation as input in a catchment model, regionalised through the transfer of parameter sets from a combination of a few neighbor catchments to the target catchment.

## 2. Case study and data

### 2.1. General characteristics of the study area

Bordered to the west by the Meuse river and to the east by the Rhine river, the investigated territory mainly corresponds to the French part of the Rhine-Meuse district (Fig. 1). It comprises a large panel of relief units like the Lorraine cuestas, the low Vosges Mountains, the Ardennes and part of the Rhine graben. The Vosges Mountains, because of their north to south axis, induce climatic gradients among the highest in France. Therefore the semi-oceanic climate of the Lorraine plateau is relayed east of the Vosges by a climate where the continentality is expressed with more strength. The nivometric coefficient (ratio of solid precipitation to liquid precipitation) is estimated at 4% in the Rhine graben, 20% around 700 m a s l, 30% around 1000 m a s l and 60% around 1350 m a s l close to the top of the Vosges. However, the areas affected by an important snowing up are reduced. Considering the weak influence of snow on the hydrological regime of the upstream mountain rivers, the snow component was not taken into account in this paper.

### 2.2. Period of investigation

To conduct a robust dynamic sensitivity analysis of a catchment model to rainfall data, it is preferable to have several years of measurements. The period appointed for our analysis extends from 1990 to 2002 because it makes it possible to carry out the sensitivity analysis with the same set of raingages over a relatively long period. The average, minimum and maximum annual catchment rainfall values are respectively 1180 mm/year, 760 mm/year and 2430 mm/year.

### 2.3. Meteorological dataset

Based on the data collected by the various national weather services of the study area, the climate data set mobilized for our study consists of 90 daily rainfall series and 69 monthly air temperature series (Fig. 1). For a specific catchment, the set of meteorological stations consists of stations whose perimeter of influence intersects the catchment contours (Fig. 1). The measurement network density is quite high, with an average area of about 400 $\mathrm{km}^2$ per raingage and 550 $\mathrm{km}^2$ per air temperature monitoring station. However, beyond a certain altitude (approximately 600 m a s l), like in many other mountainous areas in France, the area becomes data-scarce. For example, in the meteorological database that we set up for this study, only 1 raingage providing a continuous series of daily precipitation depths over the period 1990–2002 is located at an altitude higher than 800 m a s l. This corresponds to a density of approximately 1 raingage per 2400 $\mathrm{km}^2$, which is much coarser than a density of 1 raingage per 250 $\mathrm{km}^2$ as recommanded by the WMO for the mountainous areas (WMO, 2008). The same is valid for the air temperature monitoring network. This low density of monitoring stations may have an impact on the sensitivity of the catchment model to rainfall data.

### 2.4. Hydrological dataset

The sensitivity analysis reported in this paper relies on a dense hydrometric network (approximately 1 station per 260 $\mathrm{km}^2$) made up by 148 reliable hydrometric stations offering daily streamflow values validated on the target period 1990–2002 (Fig. 1). The streamflow regime of the rivers selected for the study is considered to be “natural”, *i.e.* being not significantly influenced by anthropogenic activities (regulation, water pumping, etc). The sample of catchments includes 106 stations located along the hydrographic borders of the French part of the Rhine-Meuse catchment whereas 42 stations are located on their circumference, in a corridor of 20 km, in France (29), Germany (9) and Belgium (4) (Fig. 1). These peripheral stations are included in our analysis to increase the number of potential donor catchments (see Section 3.3). The drainage areas are distributed as follows: 68 lie between 5 and 250 $\mathrm{km}^2$, 41 between 250 and 800 $\mathrm{km}^2$ and 39