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Technical Note

On evaluating the robustness of spatial-proximity-based regionalization methods

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SUMMARY

In absence of streamflow data to calibrate a hydrological model, its parameters are to be inferred by a regionalization method. In this technical note, we discuss a specific class of regionalization methods, those based on spatial proximity, which transfers hydrological information (typically calibrated parameter sets) from neighbor gauged stations to the target ungauged station. The efficiency of any spatial-proximity-based regionalization method will depend on the density of the available streamgauging network, and the purpose of this note is to discuss how to assess the robustness of the regionalization method (i.e., its resilience to an increasingly sparse hydrometric network). We compare two options: (i) the random hydrometrical reduction (HRand) method, which consists in sub-sampling the existing gauging network around the target ungauged station, and (ii) the hydrometrical desert method (HDes), which consists in ignoring the closest gauged stations. Our tests suggest that the HDes method should be preferred, because it provides a more realistic view on regionalization performance.

1. Introduction: Why is it relevant to assess the sensitivity of regionalization methods to the density of the hydrometric network?

Hydrological models with parameters that cannot be directly derived from physical catchment characteristics require calibration for parameter identification. Calibration is mostly based on observed flow series. Therefore, ungauged catchments, where no observed runoff data are available, require specific treatment. Much work has been done since the 1970s to handle the lack of runoff data (see e.g. James (1972) and Magette et al. (1976)), and the corresponding approaches are usually referred to as regionalization approaches (Gottschalk et al., 1979). Recent advances on regionalization within the framework of the IAHS Prediction on Ungauged Basin (PUB) decade have been recently reviewed by Hrachowitz et al. (2013), to which we refer our reader for more details on the variety of possible approaches to transfer information from gauged to ungauged catchments.

Among the commonly used regionalization approaches, some use the principle of physical similarity, based on the hypothesis that basins with similar physical characteristics have hydrologically similar responses (see e.g. Burn and Boorman (1993), McIntyre et al. (2005) and Oudin et al. (2010)). Other approaches use information from the catchment's spatial neighborhood, based on the hypothesis that surrounding physical conditions are similar (see e.g. Egbuniwe and Todd (1976) and Vandewiele et al. (1991)). In this paper, we will specifically focus on this second type of approach, the efficiency of which strongly depends on the density of the hydrometric network.

One of the important expected properties for a regionalization method is robustness, i.e. its capacity to limit the degradation of its performance when the hydrometric network becomes sparser. Two regionalization methods could perform very similarly in a data-rich environment and perform much differently under conditions of more limited data availability: assessing the sensitivity of any regionalization method to the level of information availability (typically the density of the surrounding hydrometric network in case of proximity-based approaches) is a good way to avoid disappointments when comparing academic methods to real-world data (Andréassian et al., 2010). Operational networks are rarely as dense as we hydrologists wish they were.

From what we have been able to read in the hydrological literature, the impact of hydrometric data density on regionalization efficiency does not seem to be a matter of concern. We addressed this issue in a previous study on the regionalization of the Turc-Mezentsev regionalization formula (Lebecherel et al., 2013). Here we would like to defend the point of view that this sensitivity test

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is not a mere matter of "hydrological comfort" but rather a scientific necessity, a kind of essential "crash test" to ensure credibility before practical use (Andréassian et al., 2009).

This note explores spatial-proximity-based regionalization methods. It proposes and compares two methods to evaluate the impact of hydrometric network density on regionalization performance. We start with a description of the material in Section 2: a data set of 609 French catchments, a rainfall-runoff model and a spatial proximity-based regionalization method. Section 3 presents the two alternative methods to evaluate the robustness of a regionalization method: the hydrometrical random reduction (HRand) method and the hydrometrical desert method (HDes). Finally, the two methods are compared.

2. Material

2.1. Catchment set

The two evaluation methods of regionalization robustness were tested on a data set consisting of 609 small to medium-size French catchments (Fig. 1), where daily streamflow, rainfall and potential evaporation time series were available over the 1997–2006 period. These catchments are spread over France and encompass a variety of hydrometeorological conditions, as shown in Table 1.

Areal catchment rainfall was calculated using the SAFRAN gridded values provided by Météo-France (Vidal et al., 2010). Areal catchment potential evapotranspiration was computed using the formula provided by Oudin et al. (2005) based on air temperature and extra-terrestrial radiation. Streamflow time series were extracted from the HYDRO national archive (http://hydro.eaufrance.fr). These data are generally considered to be of good quality.

Table 1 gives the main characteristics of the data set in terms of catchment area, mean elevation catchment, mean annual streamflow, precipitation and potential evaporation.

Table 1
Main characteristics of the 609 catchments used.

Quantiles	0.05	0.25	0.5	0.75	0.95
Mean elevation catchment (km)	87	180	375	781	1350
Mean annual precipitation, P (mm/yr)	714	863	1003	1209	1688
Mean annual runoff, Q (mm/yr)	159	272	411	643	1308
Mean annual potential evaporation, PE (mm/yr)	533	616	655	687	782

2.2. Rainfall-runoff model and calibration procedure

The GR4J hydrological model (Perrin et al., 2003), a daily lumped continuous model with four free parameters, was used. The GR4J model parameters need to be calibrated (on gauged catchments) or transferred from neighbors (on ungauged catchments). A sketch of the model structure is shown in Fig. 2 and the meaning of the parameters is given in Table 2. The model has two stores: a production store, which computes effective rainfall,

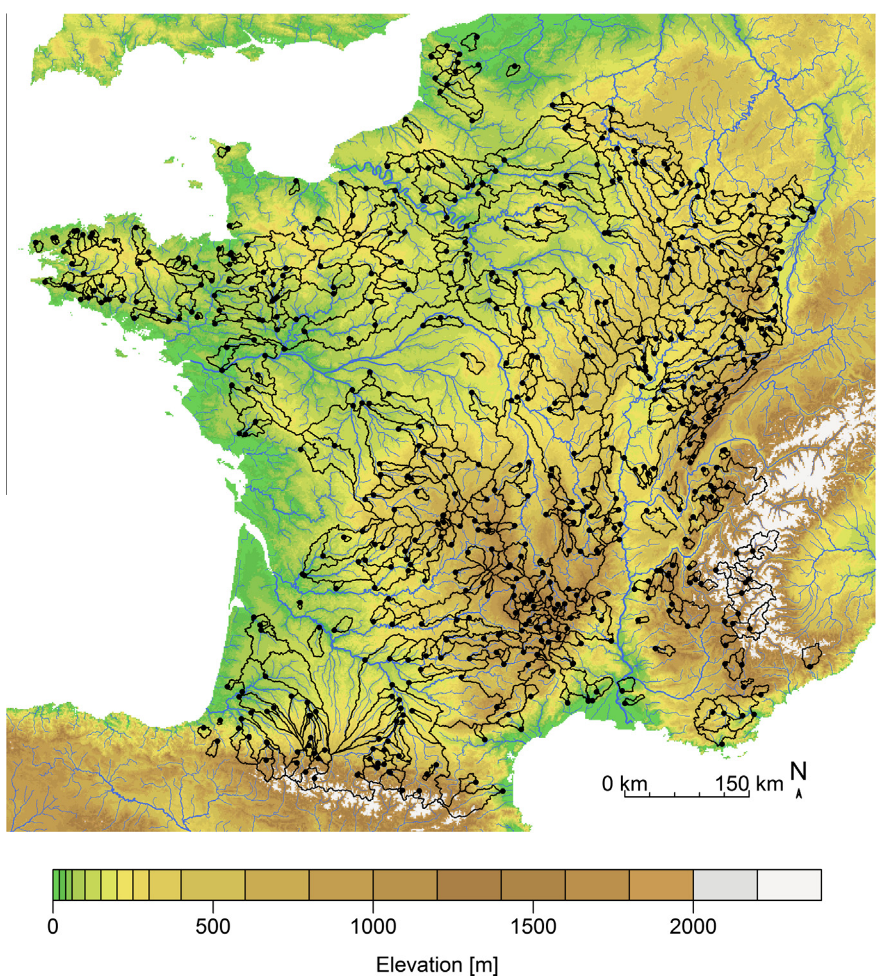

Fig. 1. Location of the 609 French catchments used in this study (dots indicate the gauging stations and solid lines the catchment boundaries).