Producing small timestep rainfall data under future climate for use in urban hydrology

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Highlights

- A method to elaborate time series of future precipitation at the rainfall event scale.
- A method that meets a demand for urban drainage modelling in order to evaluate urban drainage system sensitivity regarding impacts of climate change.
- A combination of downscaling and temporal disaggregation.

Introduction

Climate change is a growing concern in general and particularly for urban water systems. In the Mediterranean basin, the impacts of rising temperatures in the future will produce variations in frequency and intensity of heat waves, and probably more intense rainfall events (Tramblay and Somot, 2018). These variations will depend on local conditions on the investigated site.

Variations in precipitation patterns strongly impact the operation of sanitation systems. However, the climate projection data are only available on a daily time step, whereas the response of urban drainage systems occurs on smaller time steps. The type of hydrological response strongly depends on the shape of the hyetograph, very intense events producing usually the highest flow peaks. Modelling small time step future rainfall is a challenge for hydrologists and different approaches are developed including statistical methods, geographical analogue search and past/future analogue search.

This communication presents a method to generate continuous series of future rainfall data at fine time steps for use in urban hydrology, by combining spatial downscaling and temporal disaggregation of daily time step rainfall data. The method was applied to the city of Valence in the south of France under a Mediterranean climate.

Methodology

Available data

Two sources of rainfall data are used to elaborate the future timeseries of precipitation. The first source is the DRIAS 2020 dataset that offers results of climate simulations at France scale until the end of year 2100. The simulations are taken from various European models including coupling between GCM (Global Climate Model) and RCM (Regional Climate Model). In order to take uncertainty into account, results are provided for 12 couples of models. For each one, the results are available on a daily time step, on an 8x8 km grid and for different RCP (Representative Concentration Pathway) scenarios according to the simulations.

The second source of data is the historical rainfall data handled by Valence-Romans conurbation at a daily time step since 1997 and at a 6-minute time step since 2005.

First step: downscaling

The spatial definition of RCMs does not allow to consider the orography in a very fine way. This causes difficulties to accurately simulate the climate parameters at a precise location on the grid. To use the results at a local scale, for example at city scale, a downscaling step is necessary. It consists in correcting the simulated data based on observations on the studied site. In our case, we used the CDF-t method

(Cumulative Distribution Function-transform method) for this purpose (Vrac, 2016). This method, derived from the quantile-quantile method, consists in determining the mathematical function allowing to adjust simulated data according to observed data over a shared period. This obtained function, the transform, is then applied to future data.

Second step: temporal disaggregation

The second step of the process consists in temporal disaggregation that converts daily time step data into 6-minute time step data. To do this, for each future day, we look for the best analogous day in the dataset for which the data are available at a 6-minute time step. This method is inspired from the ADAMONT method developed initially to deal with data from the French Alps (Verfaillie, 2017). The criteria retained for searching the best analogue between past / future days are: the season, the daily total rainfall depth, the average daily temperature and the maximum daily temperature. Indeed, temperature and its daily variation are closely linked to the type of precipitation (Westra et al., 2013; Herath et al., 2017). The determination for each future day of the best past analogue day was done by minimizing the Euclidean distance on all the past / future parameters considered. We suppose then that the 6-minute hyetograph for each future day will be the one observed during the analogous day in the past. Values of rainfall intensity are only corrected to fit the total daily rainfall depth predicted for each day in the future.

Results and discussion

The method described above makes it possible to obtain, via a code established under R, a continuous file with a 6-minute time step between January 1st, 2021 and December 31, 2100.
This file was elaborated for the GCM CNRM-CM5 / RCM ALADIN pair of models designed by the French meteorological service and according to the RCP8.5 scenario.
After CDF-t adjustment, we notice that the highest daily accumulations tend to be greater, especially for distant horizons. The trend is marked for all seasons but to a lesser extent for fall (Figure 1).

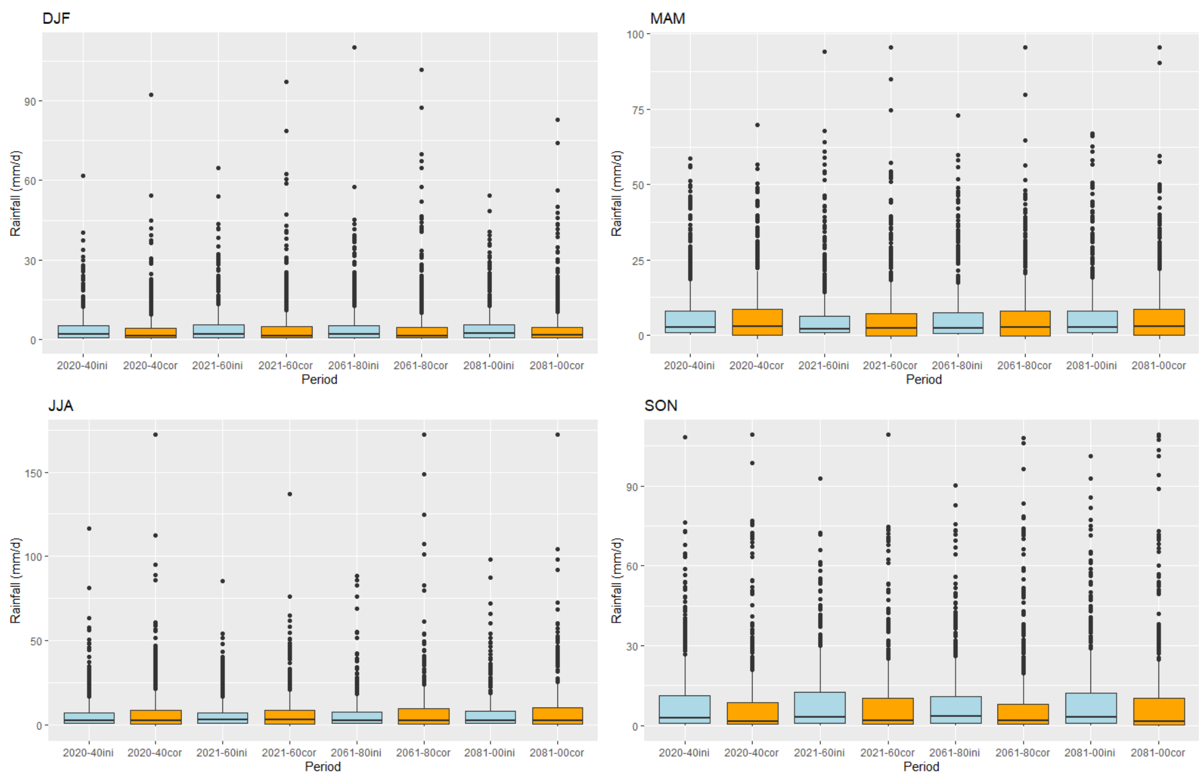

Figure 1. Comparison of precipitation distribution quantiles by future 20-year periods (x-axis) and for each season (vignette: winter, spring, summer, autumn from left to right and top to bottom) for the CNRM-CM5/Aladin simulation data (blue) and for the CDF-t corrected data (orange).

The search for analogous days has then been conducted on CDF-t downscaled data. For each best match, we get the value of the Euclidean distance. In order to make it more concrete, two examples of comparison between historical rainfall event and future rainfall event are provided in Figure 2. We notice that for the median value of the Euclidean distance (left part of Figure 2), the future and past days show a very strong correspondence for all the comparison parameters. For the maximum Euclidean distance value (right part of Figure 2), the correspondence is weak mainly due to intense rainfall episodes simulated in the future and for which there is no (very) similar observation.

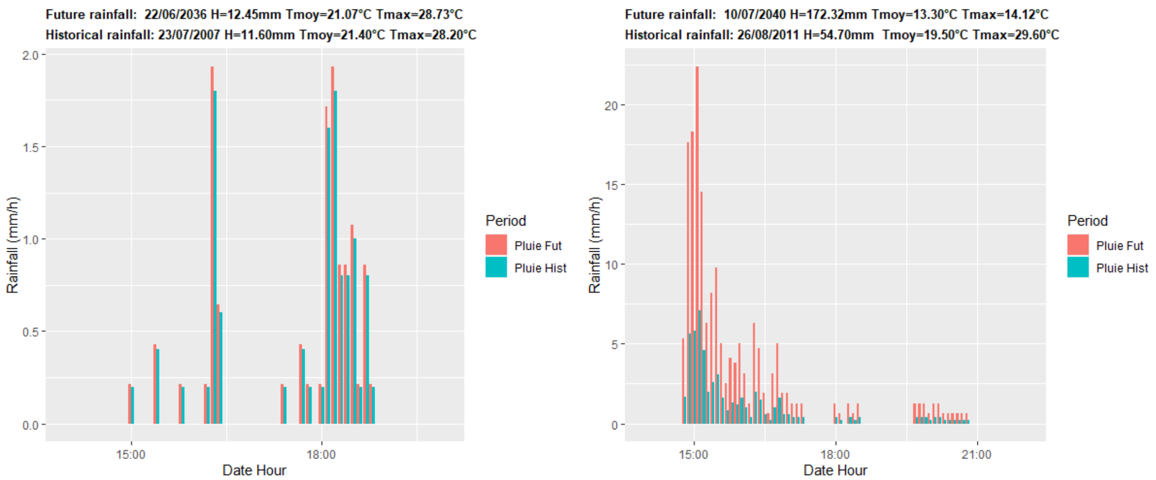

Figure 2. Comparison of hyetographs for similar periods in the case where the Euclidean distance is median (left graph) and in the case where the Euclidean distance is maximum (right graph). The comparison criteria for past and future days are listed at the top of each graph.

The strong assumption of this method is that the shapes of the hyetographs in the future will be the same as those observed in the past. This hypothesis, which is difficult to verify, nevertheless seems to make good sense, and there is yet no research stating otherwise, to our knowledge.
The main limitation of this method is the quantity and quality of historical data available. The search for analogues was carried out on fifteen years of data available at a 6-minute time step. A set of data available over 30 years would make it possible to better overcome internal climate variability and then reduce the values of highest Euclidean distances.

Conclusions and future work

The method presented here is reproducible and relatively simple to implement. It requires public simulation results and measurements, which are very often available from local authorities.
It responds to a need for future rainfall information at a fine time step to feed urban hydrological models allowing to evaluate the sensibility of water urban management in a climate change context. This method will be implemented to determine the evolution of network CSOs on the main spillway in Valence city. This future work will focus on a comparison between a rain / discharge model based on an artificial neural network (ANN), and a traditional distributed model. One of the goals will be to determine if a quite easy to build model such as ANN models can be a satisfying alternative to predict evolution of CSOs for an urban sewer system under climate change.
The authors wish to thank the Valence-Romans conurbation as well as the French meteorological service for providing the data used in the context of this work.

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