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From regional climate simulations to the hydrological information needed for basin scale impact studies

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Remarkable research efforts have been thus far addressed to understand the predictability of the climate system by improving the climate model physics, resolution, parameterizations for unresolved processes, which result in the development of high-resolution GCMs and RCMs. Nevertheless, the simulated climate behaviour is still limited and far from being consistent across the range of space and time scales which is basically needed to undertake impact studies. As required by most hydrological investigations, in fact, the reliability of the simulated climate forcing should be verified beyond the observed mean climatology. In the case of predicted daily precipitation over a study area, comparison with observational dataset should focus on the statistical features of alternating dry and wet periods, and on extreme weather conditions these being crucial aspects for the hydrological processes characterizing Mediterranean environments. This kind of consistency analysis is seldom reported in the validation of global and regional climate models.

In this study, we present a methodology to evaluate local rainfall scenarios based on the statistical comparison of basin-scale observations and model control simulations. The evaluation of the local scale scenarios is therefore based on the estimation of projected statistical parameters for the 21^{st} century. Our objectives are, first, to describe the predictive performance of a state-of-art regional climate model with respect to the daily rainfall fields, and then to propose a simple framework to integrate a statistical downscaling technique with a stochastic rainfall generator.

A high-horizontal-resolution model has been adopted which was specifically developed for Southern Europe, Mediterranean and the Balkan areas within the SINTA Project, a scientific cooperation by the Italian INGV, the Serbian Republic Hydro Meteorological Service (RHMSS) and the University of Belgrade (UB). A control run spanning over a 30-year period (1961-1990), and one covering the first part of 21^{st} century (2002-2030) under SRES scenario A1b were considered. The study area refers to 9 model cells covering about 2.000 km^2 of the Candelaro river basin, a semi-arid catchment facing the Adriatic coast of Southern Italy. The dataset of rainfall observations refers to 13 rainfall stations and is extended for the same period of the model's control run. This study is part of a research activity aiming at the assessment of potential impacts of climate change on the hydrological processes, in the framework of the CIRCE Project (IP for Climate Change and Impact Research in the Mediterranean Environment).

The adopted method is based on the analysis of the temporal structure of daily rainfall process. Thanks to the demonstrated exponential frequency distributions of daily storm occurrence, intensity and duration, the intermittent behaviour of dry and wet spells was represented by a small set of independent parameters, such as the mean wet and dry duration and the mean storm intensity. These parameters were adopted as synthetic descriptors of the rainfall climatology and were extracted on a seasonal basis from both the observational and simulated datasets. Similarly, the inter-storm periods and the storm durations were analyzed for different rainfall thresholds to characterize the frequency of more intense events.

The predictive performance of the SINTA-RCM was then investigated for the reference period by comparing the corresponding parameters from the observations. A generalized and significant over-estimation in the length of the dry periods was found in the model run except for the autumn season in which a good model performance was observed regardless of the adopted rainfall threshold. Conversely the mean storm duration and intensity were remarkably under-estimated by the model thus yielding much less rainfall to the study catchment than reported in the observations.

Under the reasonable hypothesis that the model mismatch is due above all to an imperfect parameterization of the precipitation physics, we could assume the expected alteration of the rainfall regime (under the A1b scenario) from the scale factor of the aforesaid statistics between the 21^{st} century run and the control run. Among the major findings, mean inter-storm period increased by 50% in summer and 10% in autumn; mean storm duration decreased by 11%, 7% and 18% respectively in autumn, winter and summer; and mean storm intensity showed a slight decrease in winter and spring, while a tremendous increase in summer (98%) and autumn (57%) is predicted. As a post-processed rainfall scenario for the study area, we applied the reported percentage alteration to the parameters extracted from the observation records.

A non secondary result of this study is in the immediate applicability of the analysed rainfall parameters as input to stochastic weather generators which are recognized as a useful operational tool for the development of post-processing methods to achieve the best possible prediction at the local scale.