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Novel stacking models for improved extreme rainfall predictions under climate change scenarios.

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Future projections under global warming scenarios of local extreme precipitations by downscaling models is still open challenge. A number of downscaling statistical models have been proposed to link large scale atmospheric circulation features, as simulated by Global Circulation Models (GCMs) and/or Regional Circulation Models (RCMs), to the temporal and spatial distribution of local rainfalls.

Despite the efforts, comparisons between simulations and observations show that statistical downscaling methods, although able to realistically reproduce most of the mean rainfall attributes as seasonal or monthly rainfall amount, fail to simulate extreme precipitation with acceptable accuracy. This is due to the difficulties to: (i) select the optimal set of atmospheric variables used as predictors; (ii) solve the non-linear dependencies that link the rains to the atmospheric variables; (iii) assess the temporal dependencies between wet and dry states.
To overcome such criticalities, in order to improve extreme precipitation forecasting, in this study we introduce in rainfall downscaling a paradigm already known in other disciplines of data science: the "stacking models". Stacking models combine different simulations from multiple predictive models. According to this approach we used Random Forest, extreme gradient boosting and Non-homogeneous Hidden Markov Model (NHMM).
The validation was performed first on the individual models, calibrating the parameters individually and evaluating them globally with a cross validation approach. The performance of the proposed stacking model is assessed by comparing the daily rainfall amount simulations with those obtained by a state-of-the-art NHMM model, in which the probability of the rainfall occurrence is just modeled using a logistic regression with parameters depending upon climatology variables. We show that the stacking model outperforms the latter model, especially in simulating the extreme precipitations. Furthermore, such performance improvement is obtained by using a minor number of atmospheric predictors.

Once the downscaling model has been calibrated and validated, we evaluated changes of precipitation extremes under climate change scenarios. The simulations were performed using the variables obtained from a GCM, Community Climate System Model v4 - NCAR, whose scenario is defined by CMIP5 - RCP 8.5. To evaluate the confidence bands of the simulated rainfall it was used an ensemble of simulations obtained by running the latter GCM with different initial conditions.

The Lazio region was chosen as a study case. The Lazio Region is located in Central Italy, whose hydrogeological features make it particularly vulnerable to eventual future changes of hydrological cycle such as those induced by climate change. The Mediterranean is made up of many of these vulnerable areas, which makes the application of the method to this case study of general interest.