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Using genetic algorithms to achieve an automatic and global optimization of analogue methods for statistical downscaling of precipitation

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Analogue methods (AMs) rely on the hypothesis that similar situations, in terms of atmospheric circulation, are likely to result in similar local or regional weather conditions. These methods consist of sampling a certain number of past situations, based on different synoptic-scale meteorological variables (predictors), in order to construct a probabilistic prediction for a local weather variable of interest (predictand). They are often used for daily precipitation prediction, either in the context of real-time forecasting, reconstruction of past weather conditions, or future climate impact studies.

The relationship between predictors and predictands is defined by several parameters (predictor variable, spatial and temporal windows used for the comparison, analogy criteria, and number of analogues), which are often calibrated by means of a semi-automatic sequential procedure that has strong limitations. AMs may include several subsampling levels (e.g. first sorting a set of analogs in terms of circulation, then restricting to those with similar moisture status). The parameter space of the AMs can be very complex, with substantial co-dependencies between the parameters. Thus, global optimization techniques are likely to be necessary for calibrating most AM variants, as they can optimize all parameters of all analogy levels simultaneously.

Genetic algorithms (GAs) were found to be successful in finding optimal values of AM parameters. They allow taking into account parameters inter-dependencies, and selecting objectively some parameters that were manually selected beforehand (such as the pressure levels and the temporal windows of the predictor variables), and thus obviate the need of assessing a high number of combinations. The performance scores of the optimized methods increased compared to reference methods, and this even to a greater extent for days with high precipitation totals. The resulting parameters were found to be relevant and spatially coherent. Moreover, they were obtained automatically and objectively, which reduces efforts invested in exploration attempts when adapting the method to a new region or for a new predictand. In addition, the approach allowed for new degrees of freedom, such as a weighting between the pressure levels, and non overlapping spatial windows.

Genetic algorithms were then used further in order to automatically select predictor variables and analogy criteria. This resulted in interesting outputs, providing new predictor-criterion combinations. However, some limitations of the approach were encountered, and the need of the expert input is likely to remain necessary. Nevertheless, letting GAs exploring a dataset for the best predictor for a predictand of interest is certainly a useful tool, particularly when applied for a new predictand or a new region under different climatic characteristics.