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Spatial downscaling of reanalysis data for climate analysis with the analog ensemble method

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With respect to climate analysis on regional and local scales, the availability of suitable information is a necessity for the development of climate change adaption or mitigation strategies. In this respect, precipitation is an essential parameter with its major importance for the assessment of high-impact weather and its importance for downstream hydrological analyses. On one hand, point-based observations are often available for multiple decades, high-quality spatial precipitation data may be difficult to acquire. On the other hand, reanalyses provide high-quality spatial information on the atmospheric state for several decades. Yet, especially with regard to precipitation, the quality of the estimates at regional and local scales are often not sufficient for aforementioned applications.

Therefore, in order to increase the value of reanalyses, a statistical downscaling approach can be applied by combining the long-term coarser reanalysis information with high-quality, finer resolution data sets which are often only available for a short period of time (e.g., radar-based products). Such a downscaling approach acts as a correction of systematic errors in the reanalysis while transferring its long-term information to the finer scale. In our downscaling approach, we use the analog ensemble technique to generate a synthetic precipitation data set for Central Europe. The approach reconstructs the past data by finding analogs in the existing high-resolution data of the training period (7 years) for each time step in the downscaling period (12 years). Thus, at each time step, a metric based on the coarser resolution data determines the most similar cases in the training data set and the analog ensemble members are then drawn from the high-resolution data as the most similar cases. The two main advantages of the method are that (1) no transformation is performed, i.e. the approach does not try to estimate the distribution of the fine-scale data through a statistical approximation but samples it from the true distribution in the training period and (2) multiple ensemble members are provided, thus allowing for an immediate uncertainty estimation of the downscaled data or the possibility to force a subsequent ensemble of a downstream simulations.

The method is first evaluated by comparing it to other downscaling approaches against a one-year hold-out sample of the fine resolution training data. Then, the estimates for the long-term downscaling period are validated against independent (point-based) observations to demonstrate its performance for the retrospective reconstruction.