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Atmospheric circulation in regional climate models over Central Europe: links to surface air temperature and the influence of driving data

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We examine simulation of atmospheric circulation and links between circulation and daily surface air temperatures in current climate models over Central Europe. Large-scale atmospheric circulation is represented by circulation indices (flow direction, strength and vorticity) derived from mean sea level pressure. We explore control simulations of five 25-km resolution RCMs from the ENSEMBLES project, driven by the ERA-40 re-analysis and the ECHAM5 GCM, and runs of one RCM (RCA) driven by different GCMs. The driving GCMs are investigated as well. The models' performance is compared against the dataset gridded from a high-density stations network (temperature) and the ERA-40 re-analysis (pressure). The aims of the study are (i) to identify errors in simulated distributions of circulation indices in individual seasons, (ii) to identify errors in simulated temperatures under particular circulation indices in winter and summer, and (iii) to compare performance of individual RCMs with respect to the driving data.
We find that most of the RCMs qualitatively reflect observed distributions of the airflow indices; however, each produces distributions significantly different from the observations. General biases include overestimation of the frequency of strong cyclonic vorticity and of strong flow days. HIRHAM driven by ECHAM5 and RCA driven by BCM are the RCMs with the most distorted atmospheric circulation. Our results show that some circulation biases obviously propagate from the driving data. For example, ECHAM5 and all simulations driven by ECHAM5 underestimate frequency of easterly flow. However, except for HIRHAM, all RCMs driven by ECHAM5 improve on the driving GCM in simulating atmospheric circulation. A set of RCA simulations with different driving data demonstrates that the influence on circulation characteristics in the nested RCM differs between GCMs. We find relatively strong relationships between circulation indices and surface air temperatures in the observed data for Central Europe. The RCMs qualitatively reproduce these relationships, which differ by season and are usually stronger for daily maxima than minima. Our results suggest that the RCM formulation appears to be more important than the driving data in representing the links to surface temperature. Differences of the circulation-to-temperature links among the RCA simulations are smaller and the links tend to be more realistic compared to the driving GCMs.

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