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Regional climate model simulations of atmospheric circulation and relationships with central England temperature extremes

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The regional atmospheric circulation is a major driver of climate for western Europe and so the ability of climate models to accurately simulate its characteristics forms an important part of the rigorous testing of their performance. Here, the skill of 7 regional climate models (RCMs) from the PRUDENCE set of experiments is examined for the model control period of 1961-1990 in reproducing minimum, mean and maximum daily temperatures for the central England region by comparison with observed data. Their ability to reproduce observed characteristics of the circulation is also tested using three air flow indices; flow direction, flow strength and vorticity. These indices are calculated from gridded mean sea level pressure data, firstly from observations which are then compared with corresponding indices derived from the RCMs. The models are compared in terms of their ability to reproduce the observed frequency distributions of each index, the relationships between the daily air flow indices and temperature, including daily extremes and also the ability of models to reproduce the observed persistence of specific flow regimes and the temperature response to this persistence.

It is demonstrated that RCM selection introduces uncertainty into temperature simulations and that there is no single model which performs more skilfully than others. Although the models qualitatively reproduce the observed distributions of the air flow indices reasonably well, most models produce distributions that are statistically significantly different to those for observations. Importantly, most models also exhibit biases in the relationships between circulation and temperature for extreme values of the air flow indices. The persistence of flow regimes is shown to have a significant effect on the observed temperature. However, whilst the models reproduce the form of these relationships for some flow types they have difficulty in reproducing the magnitude of the response to this persistence, for example, all models underestimate the warming effect of spells of westerly flow during winter.

The results presented here not only form a useful model validation exercise but also further highlight the need for the use of multi-model ensembles in the generation of future climate scenarios to represent uncertainties inherent in climate model structures. Assessing climate models in terms of their ability to reproduce physical circulation regimes might also offer a robust method for the weighting of climate models in the generation of probabilistic climate change scenarios. Furthermore, they suggest that the use of atmospheric circulation in statistical downscaling methods might be enhanced by the inclusion of persistence as a predictor variable, particularly when producing scenarios of temperature extremes and associated impacts.