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The Intermediate Complexity Atmospheric Research Model

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The high-resolution, non-hydrostatic atmospheric models often used for dynamical downscaling are extremely computationally expensive, and, for a certain class of problems, their complexity hinders our ability to ask key scientific questions, particularly those related to hydrology and climate change. For changes in precipitation in particular, an atmospheric model grid spacing capable of resolving the structure of mountain ranges is of critical importance, yet such simulations can not currently be performed with an advanced regional climate model for long time periods, over large areas, and forced by many climate models. Here we present the newly developed Intermediate Complexity Atmospheric Research model (ICAR) capable of simulating critical atmospheric processes two to three orders of magnitude faster than a state of the art regional climate model. ICAR uses a simplified dynamical formulation based off of linear theory, combined with the circulation field from a low-resolution climate model. The resulting three-dimensional wind field is used to advect heat and moisture within the domain, while sub-grid physics (e.g. microphysics) are processed by standard and simplified physics schemes from the Weather Research and Forecasting (WRF) model. ICAR is tested in comparison to WRF by downscaling a climate change scenario over the Colorado Rockies. Both atmospheric models predict increases in precipitation across the domain with a greater increase on the western half. In contrast, statistically downscaled precipitation using multiple common statistical methods predict decreases in precipitation over the western half of the domain. Finally, we apply ICAR to multiple CMIP5 climate models and scenarios with multiple parameterization options to investigate the importance of uncertainty in sub-grid physics as compared to the uncertainty in the large scale climate scenario. ICAR is a useful tool for climate change and weather forecast downscaling, particularly for orographic precipitation or for uncertainty analysis in which large ensembles are required. In addition, ICAR may be useful to fields that have not traditionally been able to use an atmospheric model, but require transient simulations of precipitation with respect to, e.g., glacial or landscape evolution.