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Three recommendations to improve simulations with the Intermediate Complexity Atmospheric Research (ICAR) model

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The output of general circulation models is too coarse to adequately capture the features influencing local climate and weather, particularly in complex topography. To asses the long-term impact of a changing global climate in mountainous regions, regional climate models need to be run on a fine spatial and temporal grid. Here the Intermediate Complexity Atmospheric Research (ICAR) model is a computationally frugal and physics based alternative to full physics regional climate models such as the Weather Research and Forecasting (WRF) model. A sizable portion of the computational efficiency of ICAR stems from its application of linear mountain wave theory to determine the wind field in the domain, thereby avoiding a numerical solution of the Navier-Stokes equations of motion. Heat, moisture and other atmospheric quantities are then advected in this wind field. Microphysical conversion processes between water vapor and various hydrometeor species are handled by a complex microphysics scheme. Altogether ICAR does not require measurements and enables computationally cheap downscaling, particularly in mountainous regions with complex topography, yielding a physically consistent set of atmospheric variables. However, in a real-world application and evaluation of ICAR we observed a strong sensitivity of the model performance to the elevation of the model top (Horak et al., 2019).

We present three recommendations, derived from idealized simulations, that improve different aspects of ICAR simulations. The simulations constitute an idealized ridge experiment with a non-dimensional mountain height of 0.5. The ridge is specified by a witch of Agnesi function and the sounding characterized by a saturated, horizontally and vertically homogeneous atmosphere with constant and stable stratification. The wind field calculated by ICAR is compared to the exact analytical solution. Furthermore, the water vapor, suspended hydrometeor and precipitating hydrometeor fields are used as proxies to identify inconsistencies in the model output, such as the dependence of the results on the elevation of the model top. To highlight the deviations of ICAR results from a full physics model, resulting from non-linearities in the wind field, the ICAR output was additionally compared to that of a WRF simulation. The results of our investigation strongly suggest that ICAR simulations can be significantly improved by (i) calculating the Brunt-Väisälä frequency from the forcing data set instead of the perturbed state of the atmosphere, (ii) setting the model top to an elevation of at least 11.4 km and, (iii) by applying a zero value boundary condition to the water vapor and hydrometeor species at the model top. To our knowledge none of the preceding studies employing ICAR satisfied these three conditions. Overall our investigation deepens the understanding of the ICAR model sensitivity to crucial model components, thereby increasing the potential of the model as a tool for long-term impact studies in data-sparse regions with complex topography.

References

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