The High-resolution Intermediate Complexity Atmospheric Research (HICAR v1.0) Model Enables Fast Dynamic Downscaling to the Hectometer Scale

Referee Comments

This work introduces a new high-resolution version of the Intermediate Complexity Atmospheric Research (ICAR) model. At grid spacings on the hectometric range, terrain effects on the wind field are inevitable, therefore new terrain descriptors are implemented in the model to modify the near-surface wind speed. As input data, either COSMO-1 or COSMO-2 runs are used, allowing the authors to avoid downscaling based on linear wave theory and the divergence problem mentioned by Horak et al. (2021). HICAR exhibits a good performance compared to WRF simulations, which are used as a “reference”: HICAR is able to show lee-side eddies, realistic precipitation patterns and realistic cold-air pool development. Some of these capabilities of HICAR were surprising for the authors; the major advantage of HICAR is, however, the light use of computational resources. The manuscript is well-written and gives a comprehensive overview over the changes made to suit ICAR for high resolutions. However, improvements in the presentation of the results are necessary, namely replacing the current colormaps in the Figures. Furthermore, some discussion points should be made, especially the dependency on high-resolution input data. When these changes are implemented in the manuscript, it can be accepted for Geoscientific Model Development.

General comments

1. Introduction.The authors point out the great advantage of HICAR in terms of saving computational resources. However, the authors might also mention that ICAR does not require topography smoothing as opposed to standard NWP models. The more realistic topography has a positive impact on simulated wind speeds.

2. Figure quality (color schemes). Please avoid using the “rainbow”, “jet”, “brg” or other miscellaneous color maps in Figs 4-8 (exception: topography plots). These colormaps are outdated outdated, because they are not perceptually uniform

and do not give useful information about variable quantities (Stauffer et al. 2014). For example, in Fig 7, the colormap is completely contradictory to the results shown. Please change to a sequential colormap and completely avoid the aforementioned colormaps. If you use matplotlib in Python, you can easily choose a sequential colormap from here: `https://matplotlib.org/stable/tutorials/colors/colormaps.html`

3. The authors are surprised by the good performance of HICAR, which is perhaps every model developer's dream. However, as the authors mention in the manuscript as well, HICAR seems to profit stronlgy from the high-resoultion input data from either COSMO-1 or COSMO-2. I wonder whether these positive effects on lee-side eddies and cold-air pools would be also present in ICAR with a 'coarser' input dataset, for example from IFS, ERA-5, or a coarser-resolution WRF run. Did the authors perform test runs with coarser input data? This might be of interest for mountainous regions where high-resolution NWP model output is sparse (i.e., the Himalayas or the Andes). After reading the manuscript, HICAR only seems to work with an already high-resolution input data set ($\Delta x < 3\,\mathrm{km}$), because linear wave theory can be avoided. Please discuss this necessity of a high-resolution input data set in the manuscript in more detail.

4. The manuscript would profit from an overview table on the different model setups of ICAR, with which one has smoothed topography or not, and which setup useses physics coupling, etc. The table would make it easier to remember the contents of Section 3.5 while reading about the results.

Specific comments

- line 249: Put the references in a bracket
- line 284: these reasonS
- line 348: The overestimation of wind speeds by WRF has been also reported by Umek et al. (2021) and Goger et al. (2022).
- line 356,367: I think this is one of the major advantages of HICAR. You can highlight this in both the introduction and the conclusions.
- line 363: Up-slope flow. In mountain meteorology, the term "up-slope flow" is usually attributed to thermally-induced flows due to differential heating. I would re-word it to "reverse flow", since the lee-side eddy seems to be dynamically-induced.
- line 391: What do you mean exactly by effective resolution?
- line 447, "surface layer": Do you mean stable boundary layer?

- line 453: COSMO is actually successfull in simulating thermally-induced flows associated with cold air pools (Goger et al. 2018, their Fig. 3). Another method to "check" whether a NWP model is able to simulate the revelant ABL processes in a valley is to check whether at least ten grid points are present along a cross-section between the ridges (Wagner et al. 2014).
- line 474: You can mention Piz Daint and its specifications within this paragraph if you wish.
- line 505: I think you can remove the text in capslock

References

Goger, B., M. W. Rotach, A. Gohm, O. Fuhrer, I. Stiperski, and A. A. M. Holtslag, 2018: The impact of three-dimensional effects on the simulation of turbulence kinetic energy in a major alpine valley. *Boundary-Layer Meteorol*, **168 (1)**, 1–27, doi:10.1007/s10546-018-0341-y.

Goger, B., I. Stiperski, L. Nicholson, and T. Sauter, 2022: Large-eddy simulations of the atmospheric boundary layer over an alpine glacier: Impact of synoptic flow direction and governing processes. *Q. J. R. Meteorol. Soc*, **148 (744)**, 1319–1343, doi:https://doi.org/10.1002/qj.4263.

Horak, J., M. Hofer, E. Gutmann, A. Gohm, and M. W. Rotach, 2021: A process-based evaluation of the intermediate complexity atmospheric research model (icar) 1.0.1. **14 (3)**, 1657–1680, doi:10.5194/gmd-14-1657-2021.

Stauffer, R., G. J. Mayr, M. Dabernig, and A. Zeileis, 2014: Somewhere Over the Rainbow: How to Make Effective Use of Colors in Meteorological Visualizations. *Bull. Amer. Meteor. Soc.*, **96 (2)**, 203–216, doi:10.1175/BAMS-D-13-00155.1.

Umek, L., A. Gohm, M. Haid, H. C. Ward, and M. W. Rotach, 2021: Large eddy simulation of foehn-cold pool interactions in the Inn Valley during PIANO IOP2. *Q. J. R. Meteor. Soc.*, **147 (735)**, 944–982, doi:10.1002/qj.3954.

Wagner, J. S., A. Gohm, and M. W. Rotach, 2014: The Impact of Horizontal Model Grid Resolution on the Boundary Layer Structure over an Idealized Valley. *Mon. Wea. Rev.*, **142 (9)**, 3446–3465, doi:10.1175/MWR-D-14-00002.1.