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Dynamically downscaling wind storms over complex terrain with WRF: establishing the model performance and associated uncertainties

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This study aims at identifying a setup of the Weather Research and Forecasting (WRF) model that minimises systematic errors in hindcast simulations focused on the simulation of surface wind over complex topography. The existence of many options to configure this kind of simulation, e.g. the choice of PBL scheme, the nesting techniques or the number of vertical levels, leads to an important level of uncertainty that needs to be addressed prior the use of the downscaled product. The sensitivity of the model performance to these factors is assessed in this study. To accomplish this evaluation, a number of sensitivity simulations reaching a spatial resolution of 2 km are carried out and compared to an observational dataset. Given the importance of wind storms, the analysis is based on case studies selected from 24 historical wind storms that caused great economic damage in Switzerland. These situations are downscaled using a total of 9 different model setups, but sharing the same driving data set: Era Interim. The PBL schemes evaluated are selected with the aim of spanning a great part of the uncertainty space. The results show that the unresolved topography leads to a general overestimation of wind speed in WRF. However, this error can be substantially ameliorated by a suitable choice of the PBL scheme, which also yields an improvement of the spatial structure of wind speed. Wind direction, although generally well reproduced by the simulation, is not very sensitive to this choice and presents systematic errors that can not be reduced with a suitable model configuration. Further sensitivity tests are carried out aiming at identifying the role of three types of nesting: not nudging at all, re-forecast runs, analysis nudging and spectral nudging. Results indicate that restricting the freedom of the model to develop large-scale disturbances generally increases the temporal agreement with respect to the observations, although none of such techniques outperforms the others. Thus we conclude that nudging techniques are generally advisable when the simulation aims at reproducing real situations, where the temporal agreement is important. Finally, the necessary number of vertical levels is addressed. The analysis demonstrates that 40 vertical levels is a sensible choice, since experiments doubling the number of levels do not yield more reliable results, whereas it increases the computational cost.