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Convection-resolving climate modeling: Prospects and challenges

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Currently, major efforts are underway towards refining the horizontal grid spacing of climate models to about 1 km, either by increasing the resolution of current GCMs or by extending the computational domain of high-resolution RCMs. There is well-founded hope that this increase in resolution represents a quantum jump, as it enables replacing the parameterizations of moist convection and gravity-wave drag by explicit treatments. It is expected that this will improve the simulation of the water cycle and extreme events and reduce uncertainties in climate projections. However, the development of such modeling strategies requires a concerted effort.
Here we report about the Swiss crCLIM initiative to investigate some of the key scientific and technical challenges associated with such an undertaking. The presentation is largely based on a paper that is currently in preparation (see reference below).
In exploring high-resolution climate modeling, we utilize an RCM that is able to conduct decade-long continental-scale simulations at 2 km resolution. We argue that the key challenges are similar as those with a GCM. The model employed is a version of the COSMO model that runs entirely on graphics processing units (GPUs). Examples will highlight the prospects and key challenges. It is demonstrated that horizontal resolutions around 1 km enable the credible simulation of many mesoscale phenomena. Although cloud structures are not yet fully resolved, studies suggest that in a bulk sense there is convergence at grid resolutions around 2 km, i.e. the respective feedbacks with the larger-scale flow are approximately captured.
It is argued that the output avalanche of high-resolution simulations will make it impractical or impossible to store and analyze the data. Rather, repeating the simulation and conducting online analysis may become more efficient. A prototype system of this type will be presented. The ultimate goal is to develop a binary-reproducible simulation system that ensures reproducibility across hardware architectures, in conjunction with a data virtualization layer as a common interface for output analyses. An assessment will be provided of the potential of these novel approaches. These considerations suggest that workflows for maintaining models and conducting high-resolution simulations may fundamentally change in the next decade.

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