Submission for PRACEdays 2022 presentation

Title: Kilometer-resolution climate modelling on Graphics Processing Units

Abstract:

It is now unequivocal that global warming is caused by man-made greenhouse gases, according to the latest Intergovernmental Panel on Climate Change report. While observations and climate models qualitatively agree for the past, large uncertainties remain for the future. One of the key challenges in climate modelling is the representation of convective clouds and precipitation (i.e. rain showers, thunderstorms). Due to the lack of adequate computational resolution, conventional climate models are unable to explicitly represent convective motions and use semi-empirical parameterization schemes.

During the last decade, a tremendous effort has become evident to overcome this challenge by refining the horizontal grid spacing of global and regional climate models to less than 4 km. This development enables the explicit representation of deep convective clouds, without semi-empirical parameterization, and allows a more adequate representation of clouds, precipitation systems and extreme events. Our group exploits a regional-scale climate modeling capability at 2-3 km horizontal grid spacing over large domains spanning up to 2750 x 2065 x 60 grid points. The simulations are conducted with a version of the COSMO (Consortium for Small-scale Modelling) model that runs on Graphics Processing Units (GPUs) exploiting a Domain Specific Language (DSL). This development of this version has been driven and lead by at MeteoSwiss. The implementation allows climate simulations over large domains at a reasonable cost. It has led to exciting scientific breakthroughs in the climate community, enabled by three PRACE projects awarded since 2017.

We will show results for two large computational domains: Europe and the tropical Atlantic. Our convection-resolving modelling approach has enabled the first European-scale decade-long climate simulations at km-scale resolution. The model is notably able to reproduce hourly and sub-hourly precipitation statistics, short-term precipitation extremes, cloud cover, and wind realistically. Moreover, it now includes hail and lightning diagnostics, which permits to better understand the mechanisms associated with severe weather events, such as those that led to damages, flash floods and casualties in the summer 2021. The model is used to make projections of future precipitation statistics in response to global warming. Over the Tropical Atlantic, our simulations enabled the intercomparison of tropical clouds between km-scale regional and global climate models. The motivation is to better represent the tropical cloud cover, which is considered to be the key reason for the uncertainty in global warming. Results show a dramatic improvement in the reprersentation of tropical cloud cover, both for deep and shallow convective clouds. The high resolution also enable the representation of spatial organization, such as cloud clusters and hurricanes. Such simulations enable a better understanding of cloud formation and their role in climate projections.

Our research is embedded within European and Swiss projects that engage with stakeholders to support the generation of strategies towards climate change adaptation. In addition, the COSMO model has stimulated efforts to port global climate models to GPUs, among these the ETH-based EXLAIM project.

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