Simulating the composition of the atmosphere

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Climate models are an essential tool when estimating how climate will change in the future. The atmospheric core of these models simulates the circulation of the atmosphere by solving fundamental physical equations of conservation of motion, mass, and energy as well as the equation of state. However, climate is affected also by several other processes than the atmospheric circulation and to get an accurate projection of future climate, it is necessary to incorporate all these processes in the model. Such processes are e.g. cloud formation (warm clouds, ice clouds), cryosphere (ice/snow), land surface (soil, reflectance), biosphere (ecosystems, agriculture), ocean (heat transport). These processes are calculated with individual submodels which are coupled to the core atmospheric model and they are also coupled to each other so that they interact. The number of grid cells can be from thousands to millions in modern climate models. When most of these processes are calculated for all grid cells for every simulated 10 minutes simulating the climate for centuries is a computationally challenging task even for modern supercomputers.

One of the largest uncertainties in predicting future climate is the effect of aerosol particles, i.e. particles ranging from nanometer sizes to hundreds of micrometers in diameter. Aerosol particles affect the climate directly by reflecting and absorbing solar radiation back to space and by acting as cloud condensation nuclei (CCN) which serve as sites for the formation of cloud droplets. Unlike well-mixed greenhouse gases, the concentration of atmospheric particles varies greatly both spatially and temporally due to their highly inhomogeneous sources and short lifetimes (of the order of days). While it is well known that the number of CCN in the atmosphere has increased due to anthropogenic influence, the Intergovernmental Panel on Climate Change concludes that the effect of these additional CCN on cloud properties is the largest single source of uncertainty in current estimates of the anthropogenic radiative forcing.

On top of the computational challenges regarding the model spatial and temporal resolution, the variability of chemical and physical properties of aerosol particles poses a significant computational challenge. The size of the particles spans over several orders of magnitude. The chemical compounds that are involved in the aerosol processes are counted in hundreds. Thus, it is impossible to accurately solve these processes with current supercomputers so global aerosol models require heavy simplifications which in turn cause uncertainty and decreases their accuracy. However, machine learning methods and emulator techniques are emerging in the climate science. We have investigated the potential of these methods to decrease the error coming from simplifications of aerosol processes in global aerosol models. Our results show that machine learning methods can significantly increase the accuracy of coarse aerosol models without significantly increasing their computational burden.

Brief Bio

Harri Kokkola is the group leader of Atmospheric Modeling group at the Research Centre of Eastern Finland, Finnish Meteorological Institute. He is working on atmospheric modeling and aerosol-cloud interactions. The main focus in his research is global scale aerosol-climate modeling and has been one of the main developers of the aerosol-chemistry-climate model ECHAM-HAMMOZ. His research group has developed an aerosol microphysics module SALSA which has been implemented in a cloud scale model, an air quality model as well as regional and global climate models. They are also actively involved in AeroCom project which is an open international initiative of scientists interested in the advancement of the understanding of the global aerosol and its impact on climate.