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Machine learning based automated parameter tuning of ICON-A using satellite data

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Global climate models use parameterizations to represent the effect of subgrid scale processes on the resolved state. Parameterizations in the atmosphere component usually include radiation, convection, cloud microphysics, cloud cover, gravity wave drag, vertical turbulence in the boundary layer and other processes. Parameterizations are semi-empirical functions that include a number of tunable parameters. Because these parameters are loosely constraint with experimental data, a range of values are typically explored by evaluating model runs against observations and/or high resolution runs. Fine tuning a climate model is a complex inverse problem due to the number of tunable parameters and observed climate properties to fit. Moreover, parameterizations are sources of uncertainties for climate projections, thus fine tuning is a crucial step in model development.

Traditionally, tuning is a time-consuming task done manually, by iteratively updating the values of the parameters in order to investigate the parameter space with user-experience driven choices. To overcome such limitation and search efficiently through the parameter space one can implement automatic techniques. Typical steps in automatic tuning are: (i) constraining the scope of the study (model, simulation setup, parameters, metrics to fit and corresponding reference values); (ii) conducting a sensitivity analysis to reduce the parameter space and/or building an emulator for the climate model; and (iii) conducting a sophisticated grid search to define the optimum parameter set or its distribution (e.g., rejection sampling and history matching). The ICOsahedral Non-hydrostatic (ICON) model is a modelling framework for numerical weather prediction and climate projections. We implement a ML-based automatic tuning technic to tune a recent version of ICON-A with a spatial resolution typically used for climate projections. We evaluate the tuned ICON-A model against satellite observations using the Earth System Model Evaluation Tool (ESMValTool). Although automatic tuning technics allow to reach the optimum parameter values in less steps than with the manual tuning, they still require some experience-driven choices throughout the tuning process. Moreover, the performances of the tuned model is limited by the structural errors of the model, inherent to the mathematical description of the parameterizations included in the model.