EGU2020-4636
https://doi.org/10.5194/egusphere-egu2020-4636
EGU General Assembly 2020

Machine Learning Rain Formation and the Impacts on Clouds, Precipitation and Radiation

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Cloud, aerosols and precipitation processes are perhaps the most critical uncertainties for weather and climate prediction. The complex nature of sub grid scale clouds makes traceable simulation of clouds and precipitation across scales difficult (or impossible). However, many observations and detailed simulations of clouds are available as input to larger scale models. Machine learning provides another potential tool to improve our empirical parameterizations of clouds. Here we present a comprehensive investigation of replacing the warm rain formation process in an earth system model with emulators that use detailed treatments from small scale and idealized models: specifically a stochastic collection kernel and a superdroplet approach. The emulators consist of multiple neural networks that predict whether specific tendencies will be nonzero and the magnitude of the nonzero tendencies. We describe the opportunity (massive speed up of cloud process calculations) and the risks of overfitting, extrapolation and linearization of a non-linear problem by using perfect model experiments with and without the emulators. The impacts on short term time tendencies of clouds and precipitation, as well as long term climatological means and important emergent properties of the climate system (like radiative forcing through aerosol-cloud interactions and cloud feedbacks to climate change) are assessed.