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Machine learning to quantify cloud responses to aerosols from satellite data

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The Earth's radiation budget may be altered by changes in atmospheric composition or land use. This is called radiative forcing. Among the human-generated influences in radiative forcing, aerosol-cloud interactions are the least understood. A way to quantify a key uncertainty in this regard, the adjustment of cloud liquid water path (LWP), is by the ratio (sensitivity) of LWP to changes in cloud droplet number concentration (Nd). A key problem in quantifying this sensitivity from large-scale observations is that these two quantities are not retrieved by operational satellite products and are subject to large uncertainties.

In this work, we use machine learning techniques to show that inferring LWP and Nd directly from satellite observation data may yield a better understanding of this relationship without using retrievals, which may lead to large and systematic uncertainties. In particular, we use supervised learning on the basis of available high-resolution ICON-LEM (ICOsahedral Non-hydrostatic Large Eddy Model) simulations from the $HD(CP)^2$ project (High Definition Clouds and Precipitation for advancing Climate Prediction) and forward-simulated radiances obtained from the radiative transfer modeling (RTTOV, Radiative Transfer for TOVS) which uses MODIS (Moderate Resolution Imaging Spectroradiometer) data as a reference. Usually, only two channels from the reflectance of MODIS can be used to estimate the LWP and Nd. However, having access to 36 bands allows us to exploit data and find other patterns to get these parameters directly from the observation space rather than from the retrievals. A machine learning model is used to create an emulator which approximates the Radiative Transfer Model, and another machine learning model to directly predict the sensitivity of LWP - Nd from the satellite observation data.