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Cloud type machine learning shows better present-day cloud representation in climate models is associated with higher climate sensitivity

Peter Kuma[1], Frida Bender[1], Alex Schuddeboom[2], and Adrian McDonald[2]
[1]Stockholm University, Department of Meteorology (MISU), Stockholm, Sweden (peter.kuma@misu.su.se)
[2]School of Physical and Chemical Sciences, University of Canterbury, Christchurch, Aotearoa New Zealand

Uncertainty in cloud feedback in climate models is a major limitation in projections of future climate. We analyse cloud biases and trends in climate models relative to satellite observations, and relate them to equilibrium climate sensitivity, transient climate response and cloud feedback. For this purpose, we develop a deep convolutional artificial neural network for determination of cloud types from low-resolution daily mean top of atmosphere shortwave and longwave radiation images, corresponding to the World Meteorological Organization (WMO) cloud genera recorded by human observers in the Global Telecommunication System. We train this network on a satellite top of atmosphere radiation dataset, and apply it on the Climate Model Intercomparison Project phase 5 and 6 (CMIP5 and CMIP6) historical and abrupt-4xCO2 experiment model output and the ERA5 and Modern-Era Retrospective Analysis for Research and Applications Version 2 (MERRA-2) reanalyses. We compare these with satellite observations, link cloud type occurrence biases and trends to climate sensitivity, and compare our cloud types with an existing cloud regime classification based on the Moderate Resolution Imaging Spectroradiometer (MODIS) and International Satellite Cloud Climatology Project (ISCCP) satellite data. We show that there is a strong linear relationship between the root mean square error of cloud type occurrence and model equilibrium climate sensitivity, transient climate response and cloud feedback (Bayes factor 7×10^2, 4×10^2 and 13, respectively). This indicates that models with a better representation of the cloud types have a more positive cloud feedback and higher climate sensitivity. Along with other studies, our results point to a choice between two explanations: either high sensitivity models are plausible, contrary to combined assessments of climate sensitivity and cloud feedback in previous review studies, or the accuracy of representation of present-day clouds in models is negatively correlated with the accuracy of representation of future projected clouds.