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Defining regime specific cloud sensitivities using the learnings from machine learning

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Clouds remain a core uncertainty in quantifying Earth's climate sensitivity due to their complex dynamical and microphysical interactions with multiple components of the Earth system. Therefore it is pivotal to observationally constrain possible cloud changes in a changing climate in order to evaluate our current generation of Earth system models by a set of physically realistic sensitivities. We developed a novel observational regime framework from over 15 years of MODIS satellite observations, from which we have derived a set of regimes of cloud controlling factors. These regimes were established using the relationship strength, as measured by using the weights of a trained, simple machine learning model. We apply these as observational constraints on the r1i1p1f1 and r1i1p1f3 historical runs from various CMIP6 models to test if CMIP6 climate models can accurately represent key cloud controlling factors.. Within our regime framework, we can compare the observed environmental drivers and sensitivities of each regime against the parameterization-driven, modeled outcomes. We find that, for almost every regime, CMIP6 models do not properly represent the global distribution of occurrence, raising into question how much we can trust our range of climate sensitivities when specific cloud controlling factors are so badly represented by these models. This is especially pertinent in southern ocean and marine stratocumulus regimes, as the changes in these clouds' optical depths and cloud amount have increased the ECS from CMIP5 to CMIP6. Our results suggest that these uncertainties in CMIP6 cloud parameterizations propagate into derived cloud feedbacks and ultimately climate sensitivity, which is evident from a regimed based analysis of cloud controlling factors.