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A quantitative performance assessment of cloud regimes in climate models

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Differences in the radiative feedback from clouds account for much of the variation in climate sensitivity amongst General Circulation Models (GCMs). Therefore metrics of model performance which are demonstrated to be relevant to the cloud response to climate change form an important contribution to the overall evaluation of GCMs. In this paper we demonstrate a method for assigning model data to observed cloud regimes. We apply the method to ten GCMs submitted to the Cloud Feedback Model Intercomparison Project (CFMIP), evaluate the simulated cloud regimes and analyse the climate change response in the context of these regimes. We also propose a cloud regime metric which is specifically targeted at assessing GCMs for the purpose of obtaining the global cloud radiative response to climate change and could be included in a basket of measures of model performance.

Most of the global variance in the cloud radiative response between GCMs is due to low clouds, with 47% arising from the stratocumulus regime and 18% due to the regime characterised by clouds undergoing transition from stratocumulus to cumulus. This result is found to be dominated by two structurally similar GCMs. The shallow cumulus regime, though widespread, has a smaller contribution and reduces the variance. For the stratocumulus and transition regimes, part of the variance results from a large model spread in the radiative properties of the regime in the control simulation. Comparison with observations reveals a systematic bias for both the stratocumulus and transition regimes to be overly reflective. If this bias was corrected with all other aspects of the response unchanged, the variance in the low cloud response would reduce. The response of some regimes with high cloud tops differ between the GCMs. These regimes are simulated too infrequently in a few of the models. If the frequency in the control simulation were more realistic and changes within the regimes were unaltered, the variance in the cloud radiative response from high-top clouds would increase. As a result, use of observations of the mean present-day cloud regimes suggests that whilst improvements in the simulation of the cloud regimes would impact the climate sensitivity, the inter-model variance may not reduce. When the cloud regime metric is calculated for the GCMs analysed here, only one model is on average consistent with observations within their uncertainty (and even this model is not consistent with the observations for all regimes), indicating scope for improvement in the simulation of cloud regimes.