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GCM intercomparison of global cloud regimes: Present-day evaluation and climate change response

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The radiative feedback from clouds remains the largest source of variation in climate sensitivity amongst general circulation models (GCMs). A cloud clustering methodology is applied to six contemporary GCMs in order to provide a detailed intercomparison and evaluation of the simulated cloud regimes. By analysing GCMs in the context of cloud regimes, processes related to particular cloud types are more likely to be evaluated. In this study, the mean properties of the global cloud regimes are evaluated, and the cloud response to climate change is analysed in the cloud-regime framework. Most of the GCMs are able to simulate the principal cloud regimes, however none of the models analysed have a good representation of trade cumulus in the tropics. The models also share a difficulty in simulating those regimes with cloud tops at mid-levels, with only ECHAM5 producing a regime of tropical cumulus congestus. Optically thick, high top cloud in the extra-tropics, typically associated with the passage of frontal systems, is simulated considerably too frequently in the ECHAM5 model. This appears to be a result of the cloud type persisting in the model after the meteorological conditions associated with frontal systems have ceased. The simulation of stratocumulus in the MIROC GCMs is too extensive, resulting in the tropics being too reflective.

Most of the global-mean cloud response in the GCMs is found to be a result of changes in the cloud radiative properties of the regimes, rather than changes in the relative frequency of occurrence (RFO) of the regimes. It is shown here that evaluation and subsequent improvement in the simulation of the present-day regime properties has the potential to reduce the variance of the global cloud response, and hence climate sensitivity, amongst GCMs. For the ensemble of models considered in this study, the use of observations of the mean present-day cloud regimes suggests a potential reduction in the range of climate sensitivity of almost a third.