Geophysical Research Abstracts
Vol. 15, EGU2013-12172-1, 2013
EGU General Assembly 2013

Investigation of the MBL cloud feedback mechanism with a hierarchy of models

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Marine boundary layer (MBL) clouds strongly influence the Earth's radiation budget, and their response to climate changes is one of the central uncertainties in climate models. To study this response, we use a hierarchical modeling framework spanning an idealized GCM, a single-column model (SCM), and a large-eddy simulation (LES) model. The idealized GCM has an eddy diffusion/mass flux (EDMF) closure and a PDF-based cloud scheme to represent the turbulent and cloud processes in a unified and physically well-founded way. The subtropical MBL clouds are simulated in a wide range of model climates. Their coverage strongly decreases as the climate warms, suggesting a positive climate feedback. The SCM with the same parameterizations is run with idealized yet climatically plausible forcing terms representing the large-scale processes. The statistical equilibrium states from the SCM are comparable to the GCM results. Controlled experiments are performed in the SCM to separate dynamic and thermodynamic effects. The processes primarily responsible for the cloud response to warming are discussed in the context of a further simplified SCM, on the basis of which scaling results are derived. The SCM results are also validated with the LES model.