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Inhomogeneities of clouds – A statistical scheme for large-scale models

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Clouds play a key role in our climate system, since they influence both the radiation budget as well as the hydrological cycle. Global climate models used for simulating the future climate are limited to a coarse resolution on the order of 100 km horizontal grid space due to computational costs. Hence, most clouds are not resolved in these models and must be parameterized. One key issue is the inhomogeneity of clouds: General circulation models (GCM) use grid mean quantities of cloud properties to calculate cloud microphysical processes i.e. representing homogeneous layers of clouds. In nature, however, clouds are inhomogeneous in terms of microphysical and radiative properties, which must be represented by using subgrid-scale parameterizations. Errors in simulations occur due to the nonlinearity of all processes inside a cloud.

For a better representation of clouds we propose a new statistical scheme. We are implementing a sub-column algorithm into the ECHAM5 GCM to account for a distribution of cloud condensate and number concentration instead of one mean value of each. Cloud cover is then distributed over the sub-columns depending on the diagnosed cloud amount and the number of chosen sub-columns. The sub-boxes in each layer are either clear or completely cloudy. Therefore the vertical cloud overlap is explicitly defined using a maximum-random overlap assumption. Mass and number concentration of cloud droplets and ice crystals are distributed randomly over the sub-columns according to frequency distributions, obtained from aircraft observations conserving the mean. All microphysical processes are then calculated independently for all sub-columns. At the end of each time step the average grid-mean cloud properties are calculated and passed on to the rest of the model. This procedure introduces subgrid-scale variability in the microphysical properties of the clouds, which then affect the cloud processes (e.g. rain formation). Due to the better representation of cloud inhomogeneities using this statistical scheme, a more physical treatment of microphysical interactions inside clouds and sub-cloud layers as well as of their radiative properties can be achieved.

Simulations with the Single Column Model version of ECHAM5 for the EPIC campaign (East Pacific Investigation of climate) and the MPACE campaign (Mixed-Phase Arctic Cloud Experiment) were performed. Both cases show that the inhomogeneities lead to an earlier precipitation formation and therefore consequently a decrease in cloud lifetime for the initial clouds. For the MPACE campaign precipitation was enhanced by accretion in a multi-layer cloud. Changes in the distribution width of the mass and number concentrations show a lower sensitivity than changes between the original model version and the sub-column scheme.