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Improvement and implementation of a parameterization for shallow cumulus in the global climate model ECHAM5-HAM

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Convection is a crucial component of weather and climate. Its parameterization in General Circulation Models (GCMs) is one of the largest sources of uncertainty. Convection redistributes moisture and heat, affects the radiation budget and transports tracers from the PBL to higher levels. Shallow convection is very common over the globe, in particular over the oceans in the trade wind regions.

A recently developed shallow convection scheme by von Salzen and McFarlane (2002) is implemented in the ECHAM5-HAM GCM instead of the standard convection scheme by Tiedtke (1989). The scheme of von Salzen and McFarlane (2002) is a bulk parameterization for an ensemble of transient shallow cumuli. A life cycle is considered, as well as inhomogeneities in the horizontal distribution of in-cloud properties due to mixing.

The shallow convection scheme is further developed to take the ice phase and precipitation in form of rain and snow into account. The double moment microphysics scheme for cloud droplets and ice crystals implemented is consistent with the stratiform scheme and with the other types of convective clouds. The ice phase permits to alter the criterion to distinguish between shallow convection and the other two types of convection, namely deep and mid-level, which are still calculated by the Tiedtke (1989) scheme. The lunching layer of the test parcel in the shallow convection scheme is chosen as the one with maximum moist static energy in the three lowest levels. The latter is modified to the "frozen moist static energy" to account for the ice phase. Moreover, tracers (e.g. aerosols) are transported in the updraft and scavenged in and below clouds.

As a first test of the performance of the new scheme and the interaction with the rest of the model, the Barbados Oceanographic and Meteorological EXperiment (BOMEX) and the Rain In Cumulus over the Ocean experiment (RICO) case are simulated with the single column model (SCM) and the results are compared with large eddy simulations (LES). The profiles of the SCM correspond well to LES simulations in both cases. The overall results however show a good performance of the modified von Salzen and McFarlane (2002) scheme.

The implementation of the von Salzen and McFarlane (2002) shallow convective scheme replacing the Tiedtke (1989) scheme affects the ECHAM5-HAM model climate considerably. The modifications described above have a strong impact, in particular permitting the formation of shallow convection at higher latitudes, but also in some cases in the subtropics and tropics, where the Level of Neutral Buoyancy (LNB) is located at temperatures below freezing. The frequencies of occurrence of the different convective types in the GCM are in much better agreement with observations. The amount of shallow convection is generally decreased. This results in increasing stratus and stratocumulus. In general, the results show an improvement in the performance.

References

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