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The Role of three-dimensional radiative Transfer on convective Cloud Formation

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The impact of heteorogeneous surface heating on the life cycle of fair weather cumulus clouds due to their own shadows is investigated. Under favorable background conditions, the formation of cumulus clouds is mainly driven by the surface heating which is determined by the incident solar radiation. The spatial and temporal distribution of the surface irradiance, i.e. the amount of heat flux reduction in cloud shadows and its enhancement in cloud gaps depend on the radiation transfer through the three-dimensional cloud field. Results of radiation transfer calculations depend on the cloud geometry, the cloud liquid water content and the cloud droplet size distribution.

Cloud resolving models (CRMs) are an important tool to improve our understanding of cloud radiation interactions. A method for the accurate yet fast three-dimensional calculation of surface short-wave irradiance within a cloud resolving model has been developed. The algorithm has been optimized for parallelization which enhances its applicability in cloud resolving models. In our implementation, the computational time of the cloud resolving model increased only by 3% compared to the reference run without radiation. Comparisons between our fast approximation and detailed three-dimensional radiative transfer calculations showed very good agreement for different cloud conditions and several solar zenith and azimuth angles with a root mean square difference of 6%.

Numerical simulations of the life cycles of fair weather cumulus clouds were performed to study the influence of the three-dimensional radiation transfer. The new fast

yet accurate radiative transfer algorithm has been applied. By comparing simulations with and without differential surface heating the influence on cloud formation has been investigated. It has been shown that the consideration of three-dimensional radiative effects can have a significant impact on the formation and development of convective clouds.