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Land-surface atmosphere coupling in an earth system model

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The interaction between the atmosphere and the strongly heterogeneous land surface is one of the central scientific topics within Earth system sciences and especially climate research. Many processes, such as vegetation dynamics and the development of spatial patterns in the Subtropics and permafrost regions, take place on scales much below the scale of model resolution. Thus, it is an important scientific challenge to consider the influence of sub-scale heterogeneity on the vertical near-surface fluxes of energy and water.

Most climate models do not take into account the actual scale of surface heterogeneities. When coupling a heterogeneous surface to the atmosphere often coupling methods are employed, which include the underlying assumption that the horizontal extent of the individual heterogeneity is so small that the turbulent vertical fluxes stemming from the different surface heterogeneities within one grid-box have mixed horizontally below the lowest model level of the atmosphere. This assumption allows a comparatively simple land-surface-atmosphere coupling with a horizontally homogeneous state of the atmosphere, but it may also be the source of significant errors.

In order to access the extent of error introduced we designed an experiment in which the results of three different coupling schemes were compared. The first one is a parameter-aggregation scheme, the second a flux-aggregation scheme based on the assumption of a horizontally homogeneous atmosphere on the lowest atmospheric model level and the third one is a coupling scheme which allows, up to a given height, for the atmosphere to be horizontally heterogeneous within a grid-box. These coupling methods were implemented in the land-surface model JSBACH which was then coupled to the general circulation model ECHAM6, both part of the Max Planck Institute for Meteorology's earth system model MPI-ESM.

In a first step sensitivity studies are being carried out to gain process understanding and to disentangle the direct effects of the land-surface-atmosphere coupling and the atmospheric response.

To evaluate the overall impact, of a given coupling scheme, 20-year-AMIP-type simulations were performed. First analysis indicates that the results obtained with the three coupling schemes do significantly differ. These differences are not only visible on a sub-grid scale e.g. the sub-grid fluxes, but also on the grid-scale the choice of the coupling scheme significantly affects the simulated global climate and large-scale patterns. Furthermore the difference in the simulated climate between using the improved and the standard flux-aggregation scheme are in the same order of magnitude as those between the parameter aggregation scheme and the standard flux-aggregation scheme.