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The role of three dimensional radiation in transitions from shallow to deep convection

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While radiative transfer through cloud fields is a 3D process, we generally solve this only in 1D due to the high computational costs involved. As a consequence, large-eddy simulations with 1D radiation have highly simplified shortwave heating and longwave cooling in clouds. Also, surface fields of direct radiation have cloud shadows at the wrong location and surface diffuse radiation is too concentrated below the clouds.

We have investigated whether the above mentioned shortcomings have an impact on the transition from shallow to deep convection over land using large-eddy simulations with 3D radiation solvers of different complexity. First, we show with large-eddy simulations using the TenStream solver that simulations with 3D radiative transfer develop larger and thicker clouds, which we attribute to modified land-atmosphere interactions. Also, we find that with 3D radiative transfer, the spatial variability of the surface fluxes is considerably larger than with 1D radiative transfer. The liquid water path is also dominated by larger length scales, hinting that 3D modifies cloud organization. Second, with GPU-accelerated large-eddy simulations with a coupled ray tracer, we quantify the necessity of having very accurate surface solar irradiance fields in producing correct clouds and cloud organization.

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