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Accelerating simulations of convective clouds by reducing the spectral resolution of radiative transfer

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The energy transfer by electromagnetic radiation drives atmospheric processes on a wide range of scales: Solar irradiance drives heat and moisture fluxes from the surface and the net radiative cooling of the upper troposphere enables deep convection. However, computing accurate radiative fluxes in atmospheric models is expensive because of the integration over the non-linear absorption spectra of the atmosphere. This integration is typically approximated using so-called correlated k-distribution or similar methods and requires a large number (~10^2) of spectral quadrature points. In this study, we aim to find the lowest spectral resolution that still allows for accurate cloud field properties in large-eddy simulations of convective clouds. First, we reduce the spectral resolution of the radiation parametrization RRTMGP with an optimization algorithm that repeatedly combines adjacent quadrature points while maintaining the highest possible accuracy on a set of radiative metrics. Reduced sets of quadrature points are then tested further using three distinct sets of large-eddy simulations of convective clouds: deep convection in radiative-convective equilibrium (RCEMIP), shallow convection with precipitation shallow cumulus over the ocean (RICO), and shallow convection over land with a tight connection to the surface energy balance. We find that the spectral resolution of the radiation model, and thereby its computational costs, can be reduced by a factor three to four while retaining statistically similar cloud field properties. While this could reduce the total computational costs of an atmospheric simulation, or allow for a smaller radiation time step, it may also be a crucial step in increasing the feasibility of using 3D radiative transfer in large-eddy simulations.