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Computational Challenges of 3D Radiative Transfer in Atmospheric Models

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The computation of radiative heating and cooling rates is one of the most expensive components in todays atmospheric models.
The high computational cost stems not only from the laborious integration over a wide range of the electromagnetic spectrum but also from the fact
that solving the integro-differential radiative transfer equation for monochromatic light is already rather involved.
This lead to the advent of numerous approximations and parameterizations to reduce the cost of the solver.
One of the most prominent one is the so called independent pixel approximations\,(IPA) where horizontal energy transfer is neglected whatsoever and radiation may only propagate in the vertical direction\,(1D).
Recent studies implicate that the IPA introduces significant errors in high resolution simulations and affects the evolution and development of convective systems.
However, using fully 3D solvers such as for example MonteCarlo methods is not even on state of the art supercomputers feasible.
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The parallelization of atmospheric models is often realized by a horizontal domain decomposition, and hence, horizontal transfer of energy necessitates communication.
E.g. a cloud's shadow at a low zenith angle will cast a long shadow and potentially needs to communication through a multitude of processors.
Especially light in the solar spectral range may travel long distances through the atmosphere.
Concerning highly parallel simulations, it is vital that 3D radiative transfer solvers put a special emphasis on parallel scalability.

We will present an introduction to intricacies computing 3D radiative heating and cooling rates as well as report on the parallel performance of the TenStream solver.
The TenStream is a 3D radiative transfer solver using the PETSc framework to iteratively solve a set of partial differential equation.
We investigate two matrix preconditioners, (a) geometric algebraic multigrid preconditioning(MG+GAMG) and (b) block Jacobi incomplete LU (ILU) factorization.
The TenStream solver is tested for up to 4096 cores and shows a parallel scaling efficiency of 80–90\% on various supercomputers.