Contribution ID: **19** Type: **Contributed Talk**

Adaptive mesh refinement in Earth-system modeling: first steps

Tuesday 8 October 2024 11:30 (20 minutes)

The currently available computing power limits the resolution in chemistry climate models, even on upcoming exascale machines. This is, for example, due to the much larger number of prognostic variables, including chemical tracers. However, to further enhance the reliability and accuracy of climate projections, smaller scales have to be taken into account.
Adaptive methods offer a solution here, as they allow to dynamically focus computational power on specific areas in time and space.This allows to drastically increase the level of details while keeping the time to solution and resource consumption low. However, adaptivity also requires a sophisticated selection of adaptation criteria, algorithms, memory layouts, and communication patterns to fully utilize modern HPC infrastructures.
Within the project ADAPTEX we develop a new framework for Earth-system modeling simulations on climate scales based on adaptive meshes. The overall aim is to make a variety of applications exascale-ready. The centerpiece is the Modular Earth Submodel System (MESSy), which is a flexible chemistry climate model. It is used e.g. for global chemistry climate applications and air quality studies but can also be applied in idealized setups. To enable adaptive mesh refinement within MESSy, we employ the parallel mesh management library t8code and the flow solver Trixi.jl, both of which have already demonstrated excellent scaling properties. Trixi.jl implements a high order discontinuous Galerkin scheme, which allows for consistent accuracy on coarser meshes and for efficient algorithms due to mainly local computations. Robustness is ensured by utilizing state-of-the-art entropy stable flux functions.
Furthermore Trixi.jl is written in Julia, a modern high-level programming language, which delivers performance comparable to classical languages but is also convenient to use. In our framework it allows domain scientist to quickly explore alternative dynamical cores while leveraging the underlying computing power and vendor agnostic GPU support.
In this conference contribution we want to provide an introduction to using adaptive mesh refinement for Earth-system modeling applications at the example of the chemistry climate model MESSy and present the current status and the envisioned final setup.

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Session Classification: Applied & Numerical Mathematics