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Towards integrated regional earth system modeling: A coupled biosphere-hydrosphere-atmosphere model with dynamic vegetation and chemistry

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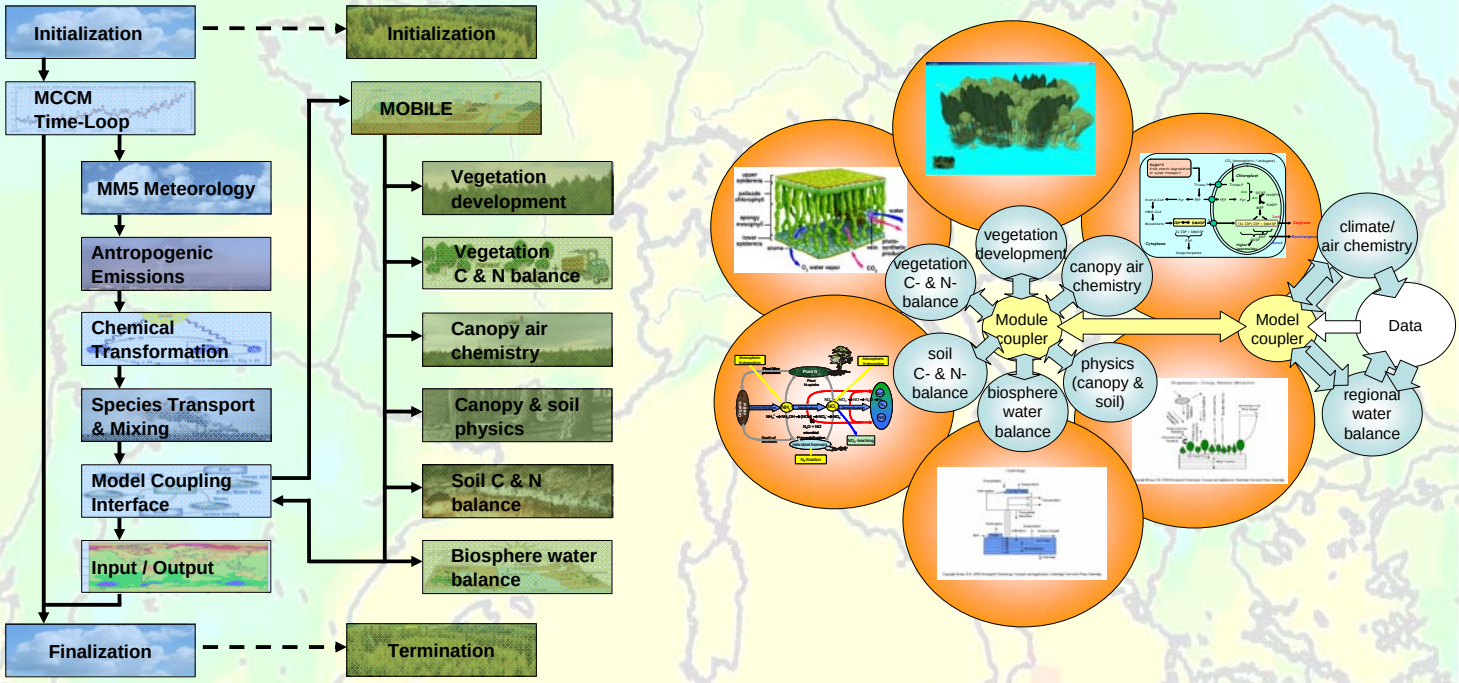
Abstract Climate change impacts the entire coupled Biosphere-Hydrosphere-Atmosphere (BHA) system. Quantification of the feedbacks between the BHA-System and regional climate requires the compartment-cross-cutting description of all climate relevant physical, chemical, and biological processes. Integrated regional climate change impact analysis still lacks an adequate BHA-modeling system.

In order to investigate these complex feedback mechanisms between climate and regional ecosystems, a new BHA-modeling system is developed, based on 1) the biosphere-hydrosphere model-framework MOBILE (MOdular BIosphere simuLation Environment) which is coupled 2) to the regional meteorology-chemistry-climate-model MCCM.

MCCM is based on a climate version of MM5, which is extended by a chemistry transport model, including gas phase air chemistry mechanisms and primary/secondary aerosols processes. MOBILE consists of modules accounting for dynamic vegetation development, soil water and energy balance, biogenic VOC emissions, bio-geochemical C/N cycles in vegetation and soil. It has a modular design, based on individual well established and extensively evaluated stand alone models of different levels of complexity. It accounts for variable vegetation- and land use types within different ecosystems and allows variable numbers of layers for canopy, foliage and soil.

In our regional BHA-modeling system, the more detailed hydro- and biosphere modules of MOBILE replace the original, simpler MCCM land surface model. The bidirectional data exchange between MCCM and MOBILE accounts for the different time scales of the underlying processes resulting in information update frequencies between seconds and 24 hours.

MCCM-MOBILE Model-Coupling



Implementation

The model coupling approach is using Fortran90 and C++ mixed language programming, as the models were developed in different programming languages. The biosphere-hydrosphere-land-surface model was implemented as a module into the MCCM integration scheme, such that both models affect each other on concurrent time levels.

The resulting modelling system is parallelized using OpenMP and MPI parallelization techniques for the efficient use on Linux-Cluster HPC-environments.

Current Developments

- Replacement of the currently used empirical emission model with a bio-chemically based process model.
- Replacement of the MCCM soil model with the more detailed model that additionally accounts for C & N bio-geochemical processes.
- Incorporating canopy air chemistry processes to account for VOC degradation and transformation within the biosphere.

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