



## A modular framework for matter flux simulation at the catchment scale

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Modeling nutrient fluxes in a catchment is a complex and interdisciplinary task. Building and improving simulation tools for such complex systems is often constraint by the expertise of the engaged scientists: Since different fields of science are involved like vadose zone and ground water hydrology, plant growth, atmospheric exchange, soil chemistry, soil microbiology, stream physics and stream chemistry, a single work group cannot excel in all parts. As a result, either parts of the system, where no scientist involved is an expert, include rough simplifications, or a "complete" group is too big for maintaining the system over a longer period. However, many approaches exist to create complex models that integrate processes for all sub domains. But a tight integration bears the problem of freezing a specific state of science in the complex system.

A model infrastructure, which takes the complex feedback loops across domain boundaries (e.g. soil moisture and plant growth) into consideration and is still flexible enough for adoption to new findings in any of the scientific fields is therefore needed. This type of infrastructure can be obtained by a set of independent, but connectible models.

The new Catchment Model Framework (cmf), a module for subsurface water and solute transport, is an example of an independent yet open and easily extendible framework for the simulation of water and solute transport processes. Openness is gained by implementing the model as an extension to the Python programming language. Coupling of cmf with models also providing an interface to the Python language dealing with other system compartments, as plant growth, biogeochemical or atmospheric dispersion models etc. can easily be done. The models used in the coupling process can either be spatial explicit models, plot scale models with one instance per mesh node of the landscape model or pure reaction functions using the integration methods of cmf.

The concept of extending an existing and well adopted programming language, to become an ecological modeling language facilitates the integrating of independent models for matter cycling studies, but simplifies also the experimenting with and testing of single models as well as the adoption to specific data availability. This approach may lead to a fast knowledge exchange across disciplinary boundaries.

The cmf model itself is setup by a Python script, where the user connects different water storages like rivers, soil layers and canopies with different models of water flow. For subsurface transport, the user can choose between Darcy's law, Richard's equation or conceptual potential functions. The subsurface water storages can be discretized horizontally as connected elements, like triangles, squares and thiessen polygons, fields and wetness index classes, but can also create water storages covering whole sub basins for lumped models or create a semi distributed model, if no explicit subsurface transport between soil water storages is defined. Vertically can the soil columns discretized as a single layer, as a unsaturated and a saturated zone or as a higher number of layers.

We present the general layout of cmf and its modeling environment. Hydrological process simulations for hillslope and catchment systems are shown, both for the Maimai study site in New Zealand, as well as a prototype of coupling cmf with an N-budget model proxy.