Modelling framework for water transport and soil-plant-atmosphere interactions using observations of stable isotopes in soil and xylem water

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WSL

1. We develop a modelling framework for dynamical systems describing water transport within soil-plant-atmosphere systems using stable isotope observations.
2. Preferential, non-equilibrium flow and transport is to be implemented based on the SWIS model (Sprenger et al. 2018).
3. Flexibility of model components should allow to test model hypotheses and/or render modelling conclusions robust.

Background

Isotope measurements allow to track water fluxes across multiple pools. They are applied from global to local scales (e.g. Good et al. 2015, Mueller et al. 2014). Providing additional information on fluxes, they complement observations of storage such as volumetric water content resulting in a more complete picture of system dynamics.

Mathematical models, as *dynamic or static* functional descriptions of systems, can be used to exploit and generalize information contained in such combined data sets. Thereby data sets constrain the description of the studied systems.

Isotopic observations can contain information that shed light on processes such as homogenous mixing of water in the vadose zone versus non-equilibrium or preferential flow (Volkmann et al. 2016a), or fractionation during root water uptake and vascular transport in plants (Treydte et al. 2014).

Recent measurement advances allow high-resolution sub-daily observations of stable isotopes within the soil-plant-atmosphere continuum (Stumpp et al. 2018, Volkmann et al. 2016a, 2016b).

Objective

We develop a modelling framework for dynamical systems describing water transport and interactions within the soil-plant-atmosphere continuum specifically tailored for stable isotope observations.

Approach

Design criteria of intended modelling framework:

- multiple target variables including stable isotope observations
- flexibility in model components, enabling model simplification and modelling of dynamic or static relationships between variables
- provide library of alternative 0- or 1D models for soil storage compartment including validation test cases
- easy use of observed or synthetic data

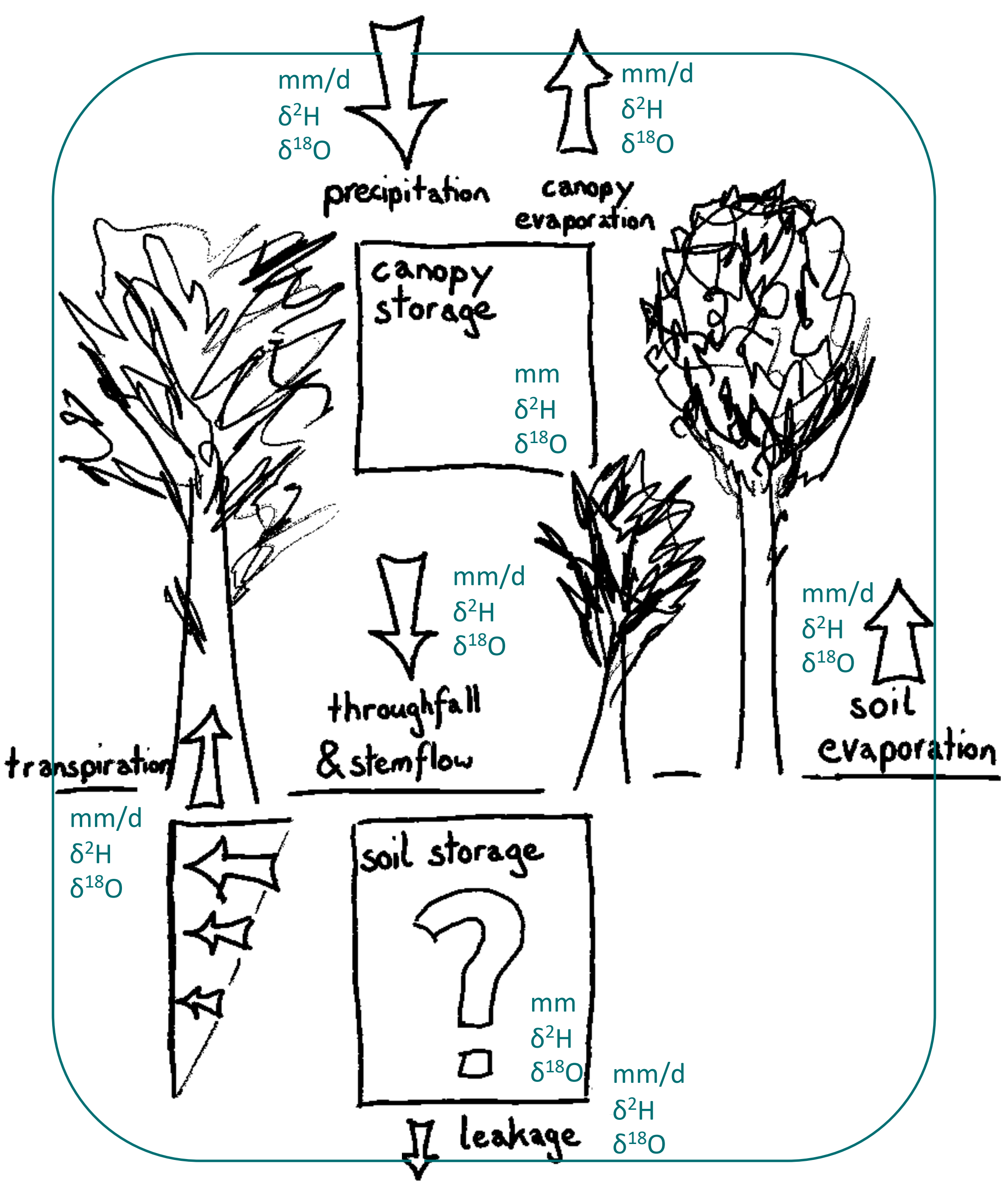
Analysis

Flexibility in structural description of included processes is a central aspect of the envisioned modelling framework. This allows to assess sensitivity of model outcome to underlying hypotheses.

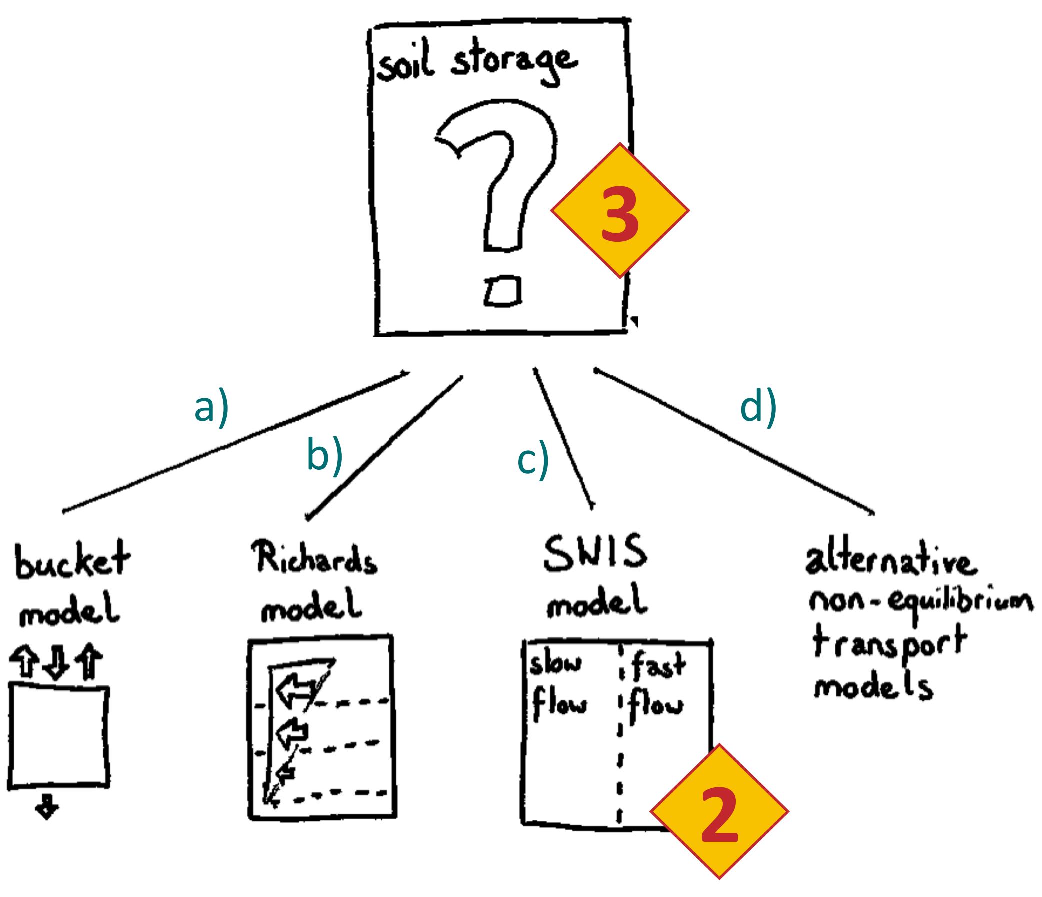
Comparing of model performance and parameter identifiability of different model structures, allows to:

1. draw conclusions regarding the relevance and suitability of the modelled processes for reproduction of the observations.
2. assert conclusions are independent of underlying modelling approach.

Typical system definition



Model flexibility: e.g. alternative soil storage models



a) bucket model: *lumped*
b) Richards model: *vertically distributed, equilibrium*
c) Soil Water Isotope Simulator (SWIS) model: *vertically distributed, non-equilibrium, dual-permeability model*
d) other non-equilibrium transport models

What degree of model complexity is warranted by water-limited ecosystems? Guswa et al. (2002) characterized ecosystems with non-dimensional parameters to distinguish between models a) and b).

The SWIS model (c, Sprenger et al. 2018) simulates dynamic vapour exchange between the two flow domains towards an equilibrium.

Alternative, non-equilibrium transport models (d) might include multi-porosity or multi-permeability models such as MURT or TRANSMIT (see Šimůnek et al. 2003) or be parametrized using the finite water content discretization approach of Talbot and Ogden (2008).

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