Vegetation competition model for water, oxygen and light limitation: I, vegetation model description and diurnal - yearly dynamics

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Introduction

In lowland areas in the temperate climate zone groundwater can have a significant influence on vegetation growth and vice versa. However in vegetation models groundwater is almost never taken into account, while in groundwater models vegetation dynamics are not included. We created a simulation model to investigate this coupled system. We focus on the competition for water and light, where water can limit growth both as a result of shortage and surplus, causing either water or oxygen stress.

Although we are interested in dynamics at a long time scale (up to a 1000 years) we chose to use a detailed bio-physical, soil-plant-atmosphere continuum (SPAC) model, because our goal is to study this system under changing climate conditions.

The resulting model is used as a basis for a spatio-temporal vegetation model coupled to a 3-d hydrological model.

Model Description (Fig 1)

The vegetation model follows a 'big-leaf' approach and is based on a bio-physical SPAC model. Transpiration and carbon assimilation of the vegetation are based on the work of Daly et al. (2004). The model follows two principles:

- Transpiration and stomatal conductance both depend on atmospheric forcing and soil moisture content. Assuming that vegetation reacts instantaneously, steady state can be assumed and equilibrium exists between ‘atmospheric demand’ and the amount of water a plant can transport form soil to leaves.
- Carbon assimilation depends on environmental conditions, stomatal conductance and biochemical processes. In this case equilibrium is assumed between biochemical capacity for carbon assimilation and the CO_2 that can enter through stomata, where both depend on intercellular CO_2 content.

In order to use this model for vegetation growth and competition in temperate climates we expanded the model with:

- Light competition between vegetation types
- Oxygen limitation due to high soil moisture contents
- Growth and respiration of vegetation
- Climatic forcing by a stochastic weather generator.

Results: Daily - Yearly Dynamics (Fig 2 and 3)

We tested the model for short time scales to semi-hourly flux data that have been measured in a temperate beech forest in Hainich, Germany. Measured radiation (Fig 2a), soil moisture content (Fig 2b), air temperature (Fig 2c), atmospheric vapour pressure deficit (Fig 2d) and precipitation (Fig 2e) content have been used as input for the model.

Modeled evapotranspiration (Fig 2g) and carbon flux (Fig 2H) show the same trend as the measured data. The sum of semi-hourly fluxes of evapotranspiration (Fig 3a) and carbon assimilation (Fig 3b) over a year show similar results.

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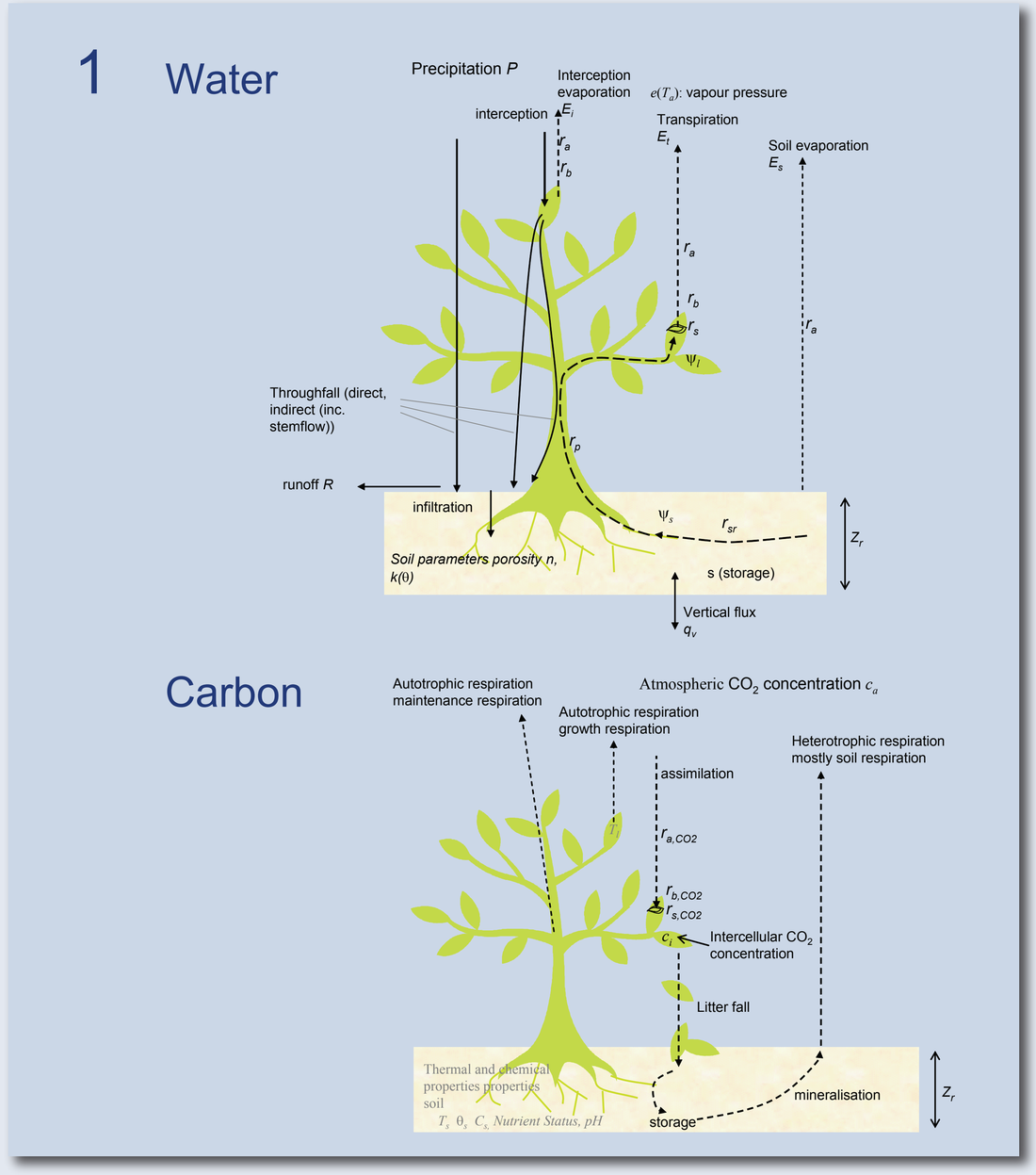

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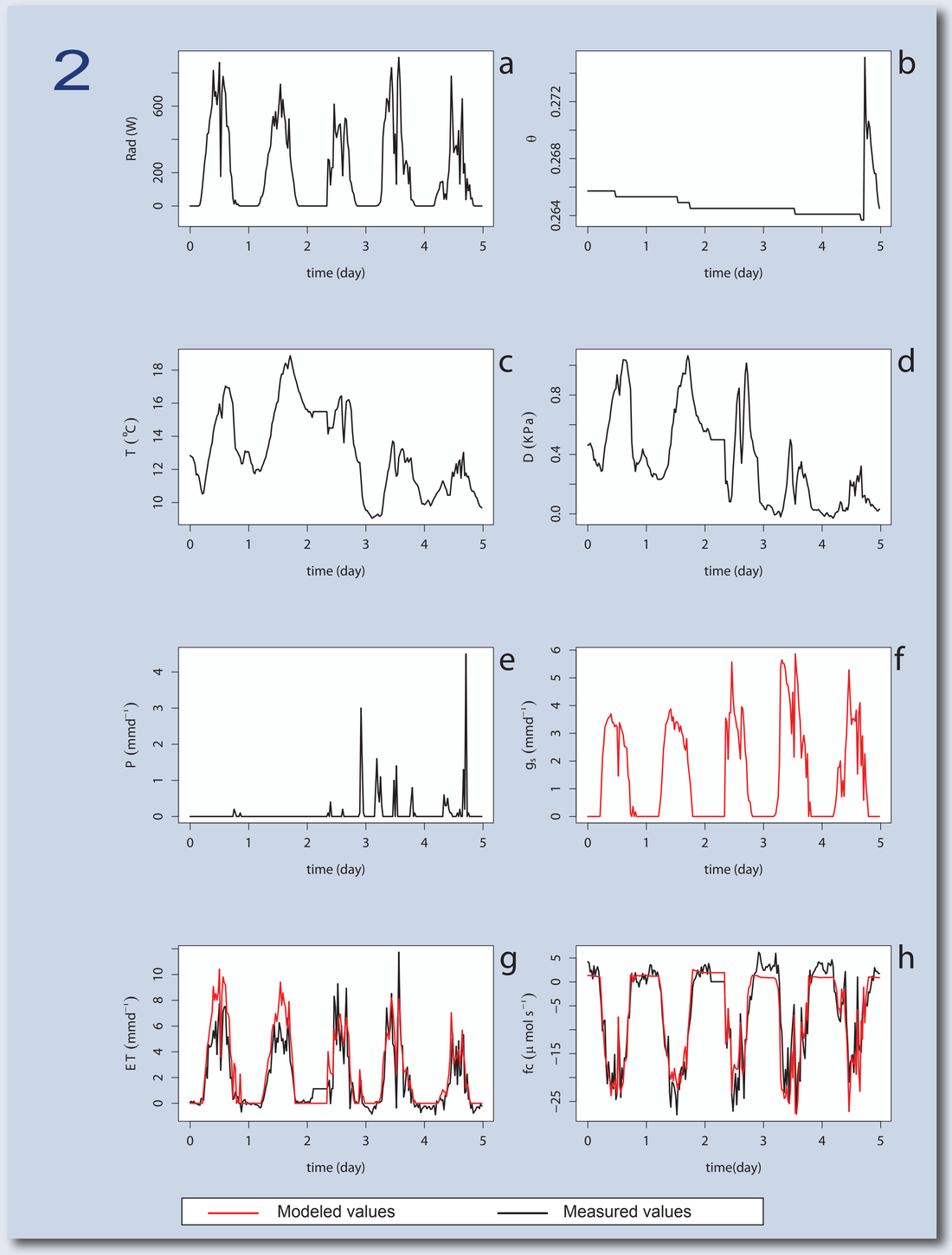

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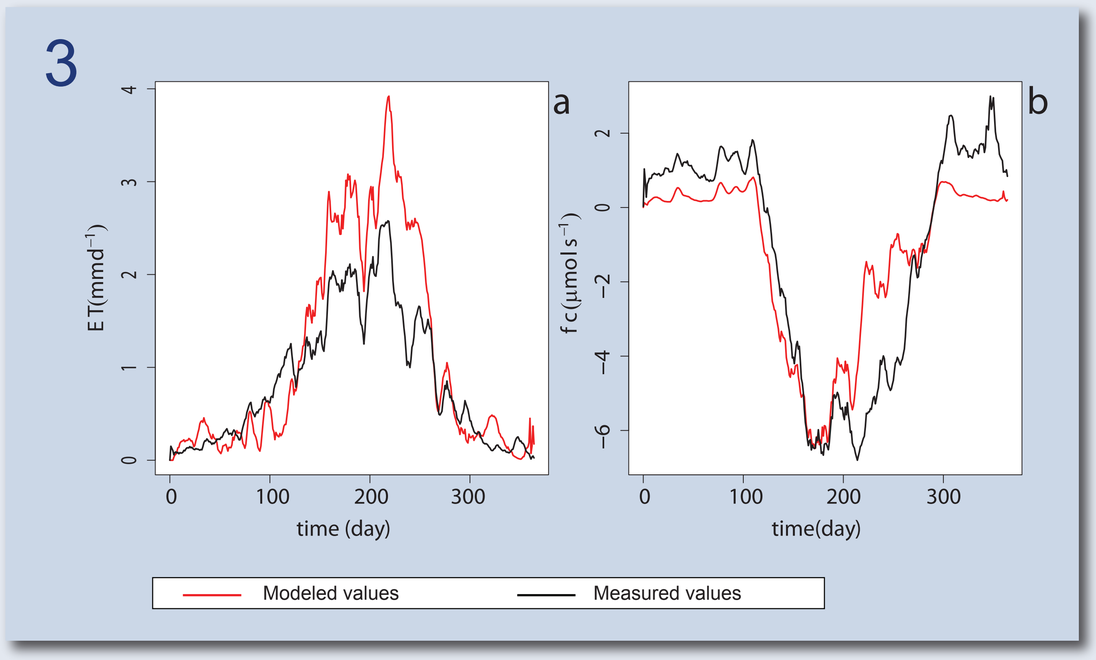

Daly, E., Porporato, A. Rodriguez-Iturbe, I. (2004), Coupled dynamics of photosynthesis, transpiration, and soil water balance. Part I: Upscaling from hourly to daily level, Journal of Hydrometeorology, 5, 546-558.