Joint modeling and behavior of the water- and energy fluxes between the atmosphere and the land surface in the TERENO prealpine region

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1. Motivation and objectives

In the mountainous regions e.g. The *TERrestrial ENvironmental Observatories* (TERENO) pre-alpine region (Fig. 2), echohydrological processes exhibit rapid changes within short distances due to the complex orography and heterogeneity in topography, soiltype, landuse, climate and land-atmosphere interactions (Fig. 3). Energy exchange between the land surface and the atmosphere is one of the most important processes in ecosystems. **Therefore, the aims of this research are:**

- **to quantify the elevation-gradient variability of the water– and energy budgets using the hydrometeorological data analysis (including eddy covariance (EC) measurements) and a high-resolution hydrological modeling GEOtop,**
- **to estimate the dependence structures of the water– and energy variables using the empirical Copulas based on bivariate distribution.**

2. Methodology

2.1. The GEOtop model

The simulation of water and energy fluxes was done by GEOtop 2.0 model developed by Endrizzi et al. (2014) for a period of May to July 2013 (calibration) and 2015 (validation). GEOtop covers all aspects of hydrological modeling, from the energy-water balance to snow cover and snowmelt as well as the effect of vegetation in the complex terrain, which makes it feasible to model the interactions between the land-atmosphere and hydrological processes in the heterogeneous regions (Fig. 1).

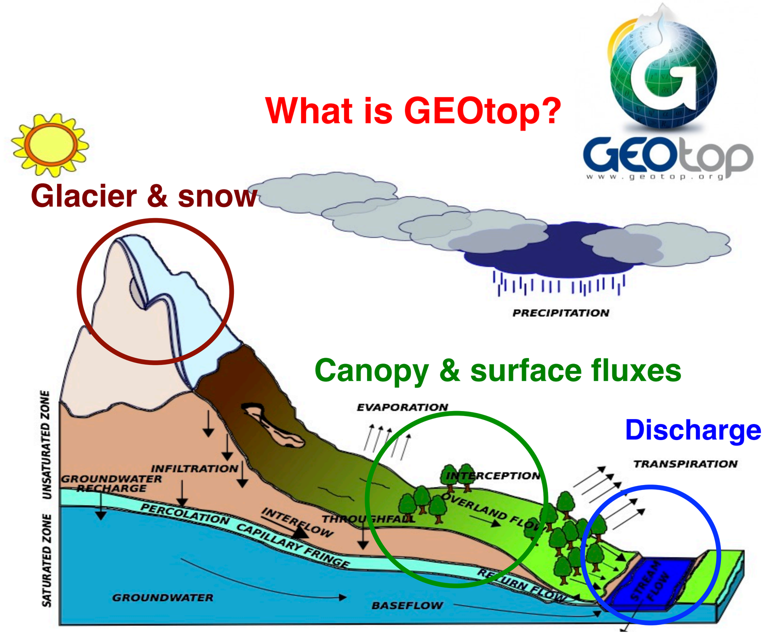

Fig. 1 GEOtop model overview

2.1.1. Input data

1) **Static data:**
   - DEM
   - River network
   - Aspect and slope
   - Landuse and soil type maps.
2) **Meteo forcing (hourly):**
   - Precipitation
   - Wind speed and direction
   - Relative humidity
   - Air temperature
   - Radiation components.

2.1.2. Calibration and validation

A manual procedure was carried out to calibrate the model's outputs. The sensitive model parameters to the water- and energy flux outputs were iteratively estimated, and the following were identified as the most significant parameters:

- soil parameters of K_h and K_v hydraulic conductivities and water content (a) as well as thermal conductivity
- surface water flow parameters of C_m and γ and the channel width ratio (W_{dx})
- surface parameter of canopy fraction (*cop*) and emissivity.

Furthermore, a multiple performance statistics were applied for validation.

2.2. The empirical Copulas

To estimate the dependence structure (joint probability distribution) of the water– and energy variables the empirical Copulas, which is based on a bivariate distribution, was applied. The empirical Copula was defined e.g. in Laux et al. (2011):

$$C_n(u,v) = 1/n \sum_{t=1}^{n} 1\left(\frac{r_1(t)}{n} \le u, \frac{r_2(t)}{n} \le v\right)$$

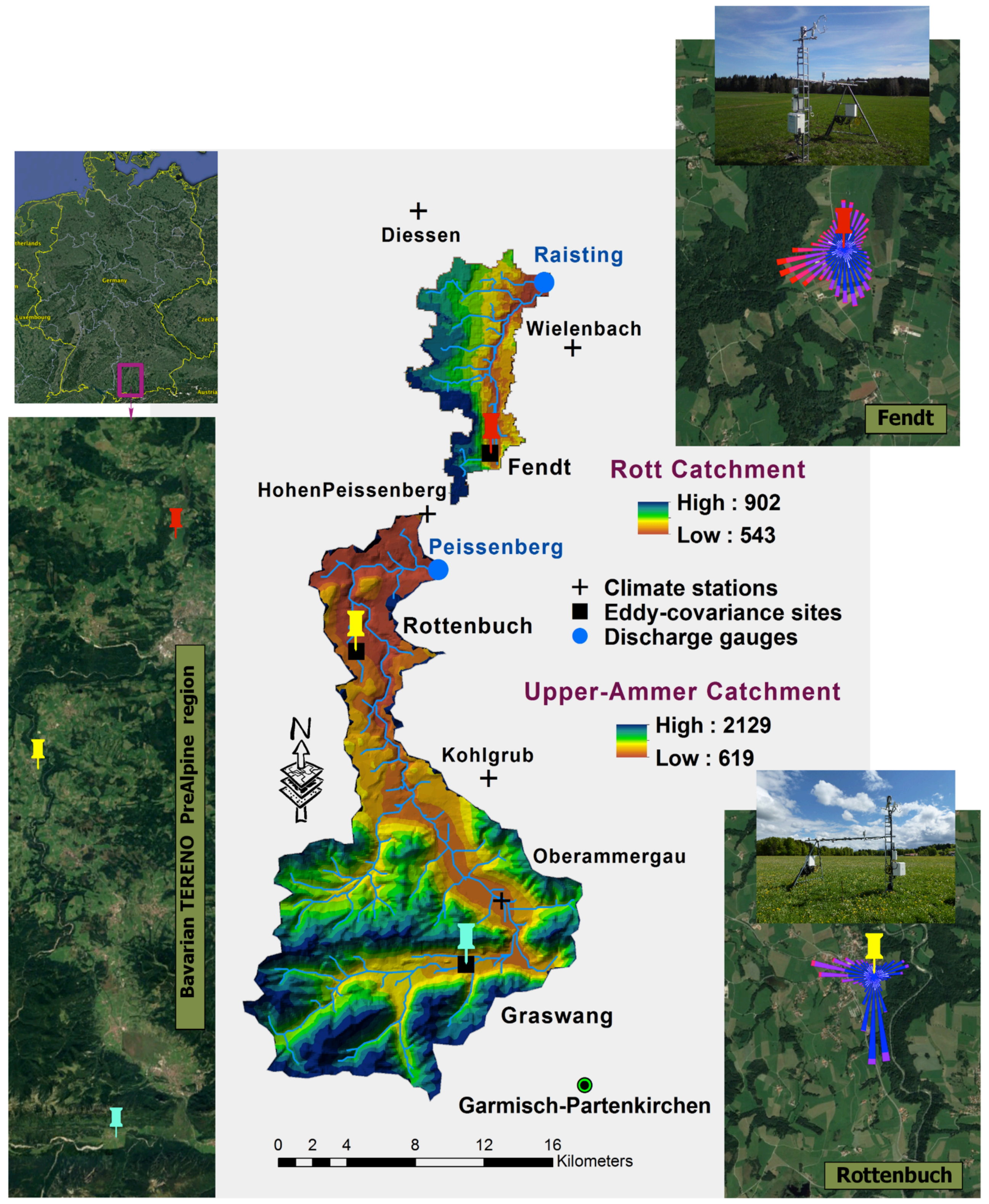

Fig. 2 TERENO prealpine region

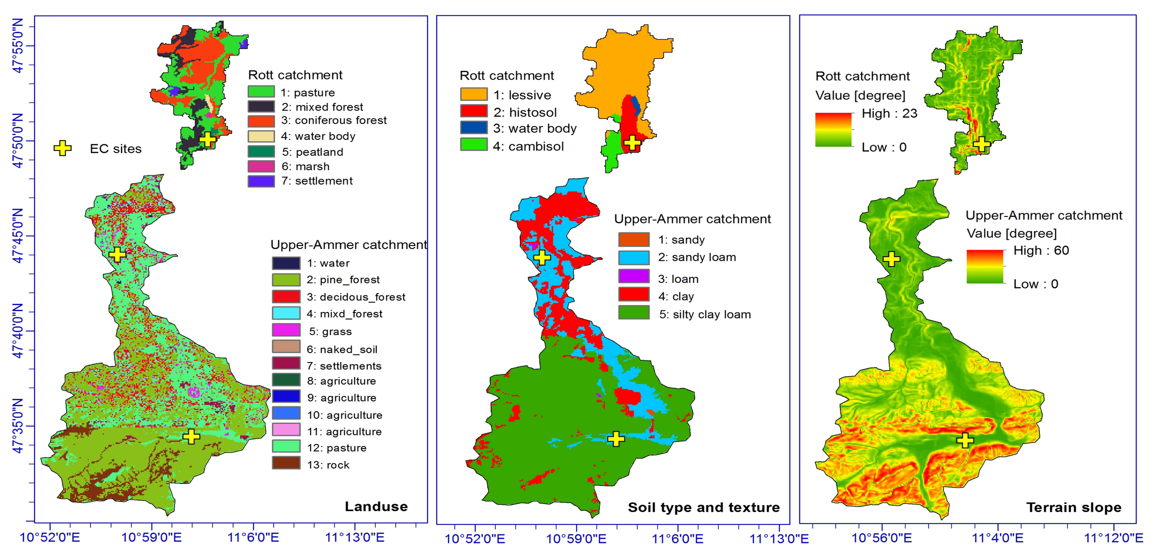

Fig. 3 Soil and landuse types as well as terrain slope in the TERENO prealpine catchments

3. Results

The manually-calibrated GEOtop outputs for the water- and energy fluxes as well as the empirical Copulas-based dependence structures of the hydrometeorological variables are presented.

3.1 Joint simulation by GEOtop

Here, the GEOtop model is being applied for the simulations in Rott and Upper-Ammer catchments. The observed and simulated: discharges (Fig. 4) and energy balance components (Fig. 5), as well as the simulated soil moisture for the whole basin in Rott catchment (Fig. 6) are plotted.

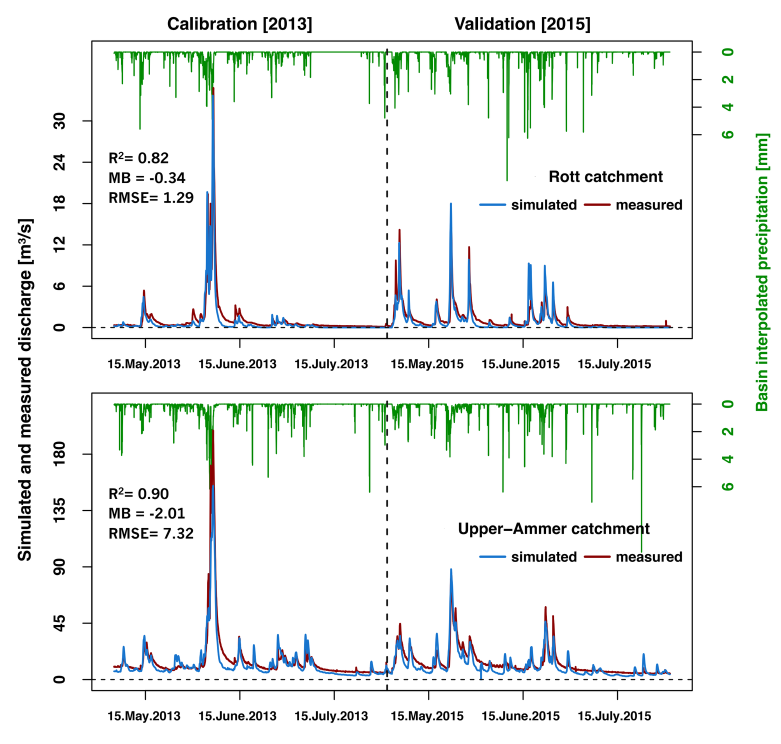

Fig. 4 Discharge (calibration 2013 and validation 2015)

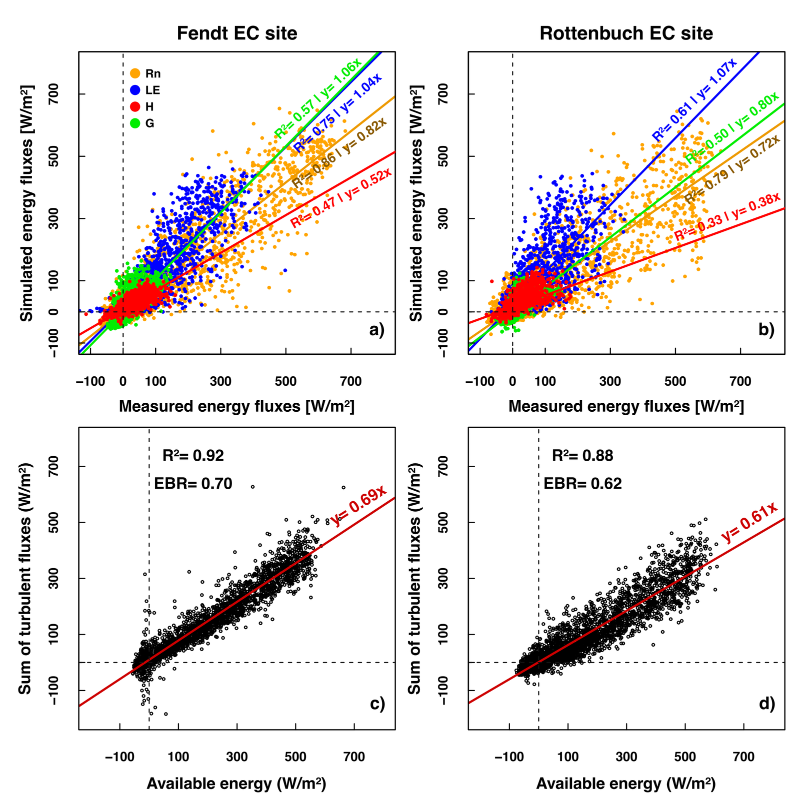

Fig. 5 Energy balance components (calibration 2013)

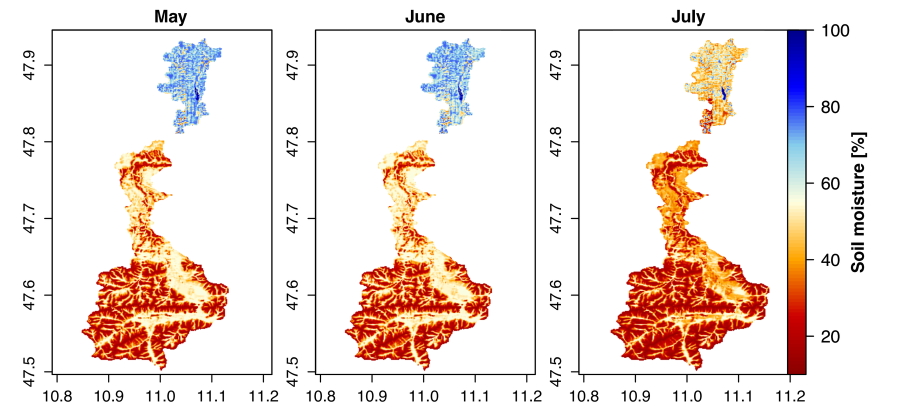

Fig. 6 Distributed soil moisture (calibration 2013)

3.2 Joint behavior by Copulas

The joint behavior of the hydrometeorological variables using empirical Copulas for the Upper-Ammer catchment are plotted in Fig. 7.

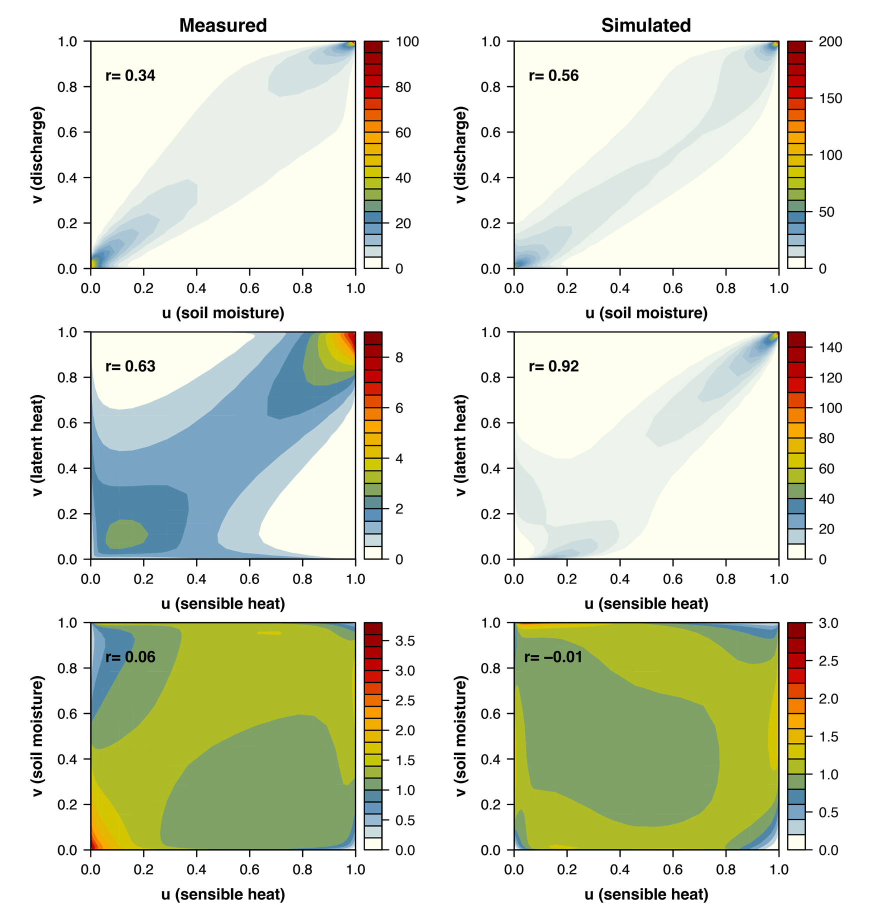

Fig. 7 Copula density of variables At Upper-Ammer (calibration 2013)

4. Outlook

i. Automatic calibration using a Parameter ESTimation PEST
ii. Sensitivity analysis using SENSAN utility of PEST
iii. Uncertainty and confidence intervals analyses

References:

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[3] Mauder M., and Foken T. (2015) Documentation and instruction manual of the eddy covariance software package TK3, Arbeitsergebnisse, Univ Bayreuth, Abt Mikrometeorol, Nr. 62, Bayreuth, Juli 2015.

Acknowledgement: This research was financially supported by the Helmholtz Research School on Mechanisms and Interactions of Climate Change in Mountain Regions (MICMoR).

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