High Resolution Joint Water and Energy Balance Observation and Modeling in a Prealpine Environment

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Motivation & Objectives

Water and energy fluxes at and between the land surface/subsurface and the atmosphere are inextricably inter- twined over a large range of space- and time-scales. Changes in either the energy balance or the water balance propagate through the connected cycles and change the respective other component. Improved understanding and prediction of the hydrological cycle and its potential changes therefore requires the joint consideration of both the water and the energy fluxes. In this work the distributed Water and Energy budget simulation modell GEOtop was applied to the catchment of the Rott, a river in the prealpine region in southern Germany. For the validation of the model we intercompare the simulation results with observed streamflow measurements, soil moisture and soil temperature measurements in different depths, and energy flux observations obtained by a Eddy-Covariance tower at the TERENO test site "Fendt" for the year 2010.

The GEOtop model

- high resolution, gridded, distributed water and energy budget model
- full surface energy balance calculation (snow covered and snow free terrain)
- inclusion of the influence of vegetation cover on simulating turbulent fluxes and snow accumulation and melt
- coupled blowing snow model for snow fall and redistribution
- coupled numerical solution of the heat and water flow equations for the saturated and unsaturated soil zones
- 3-dimensional modelling of water movement with the Richards equation after Paniconi and Putti (1994)
- distributon of atmospheric conditions (temperature, wind, radiation) over study area [www.geotop.org]

The Rott catchment

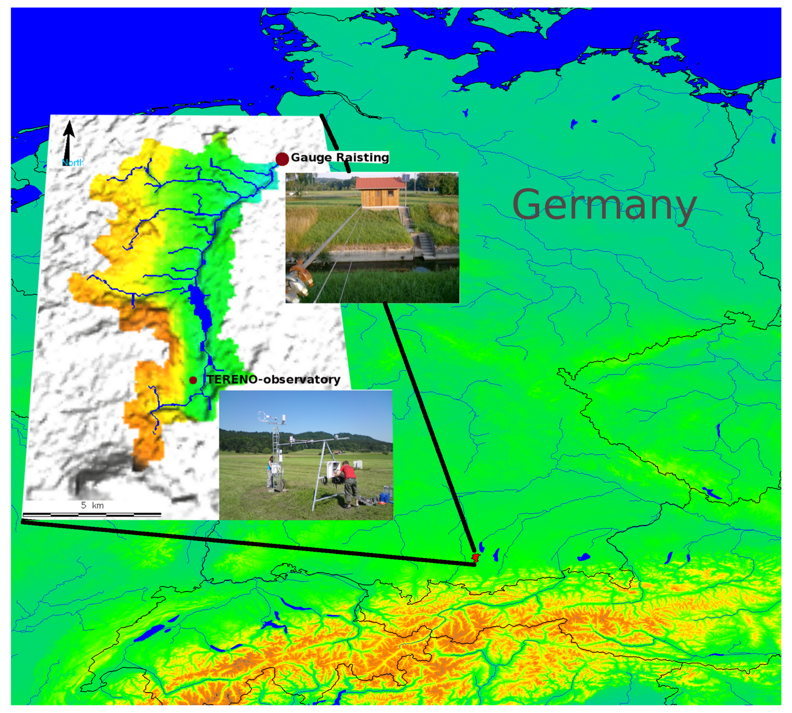


Figure 1: *The catchment of the Rott with the position of the discharge gauge in Raisting and the TERENO test site "Fendt"*

- Part of the Danube cacthment
- Catchment area: $55.40\,km^2$
- Gauge elevation: $534.86\,m$
- Maximum elevation: $902\,m$
- River length: $4\,km$

Table 1: *Mean discharge values for the gauge in Raisting, Source: HND-Bayern*

Discharge	Winter	Summer	Year	unit
lowest daily means	0,03	0,03	0,03	$\frac{m^3}{s}$
means of all lowest daily means	0,23	0,19	0,17	$\frac{m^3}{s}$
means of all observed years	0,91	0,81	0,86	$\frac{m^3}{s}$
means of all highest observations	14,5	20,7	22,9	$\frac{m^3}{s}$
highest observations	41,5	56,5	56,5	$\frac{m^3}{s}$

The "Fendt" site of the TERENO Bavarian Alps /pre-Alps observatory

TERENO is an interdisciplinary and long-term research programme involving six Helmholtz Association Centers. The Earth observation network of the TERENO programme extends across whole Germany from the Bavarian Alps to the North German lowlands Its objectives are to catalogue the longterm ecological, social and economic impact of global change at regional level [teodoor.icg.kfa-juelich.de].

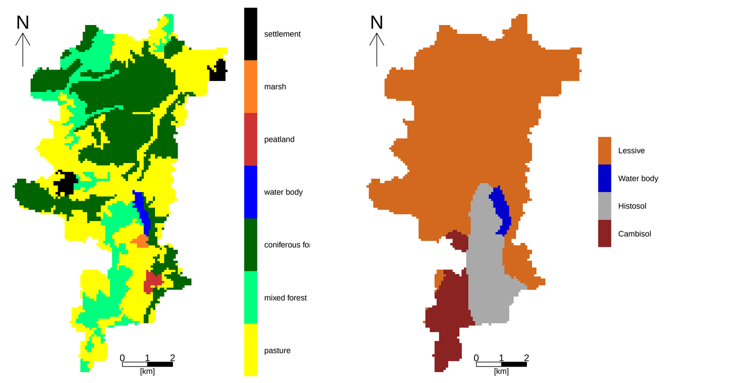
Observation Equipment at the "Fendt" test site:

- Lysimeter network (36 lysimeters)
- Climate stations
- Eddy-covariance systems
- Isotope laser systems for determination of water vapour and CO2 fluxes
- TDL-systems for N2O and CH4 flux measurements
- Closed chamber measuring systems for determination of CO2, N2O and CH4 fluxes at the soil atmosphere interface
- Rain radar

Model Input

Geographical Input Data:

- Soil data, scale 1:200.000
- Land use data, scale 1:100.000
- Digital Elevation Model: SRTM 90m



(a) (b)

Figure 2: *The land use (a) and the soils (b) of the Rott catchment*

Derived Spatial Parameters:

- River network
- Drainage direction
- Slope
- Aspect
- Sky view factor

Meteorological Input Data:

Hourly point measurements of:

- Air temperature $[°C]$
- Relative air moisture $[\%]$
- Precipitation $[mm]$
- Wind speed $[m/s]$
- Global radiation $[W/m^2]$

Results

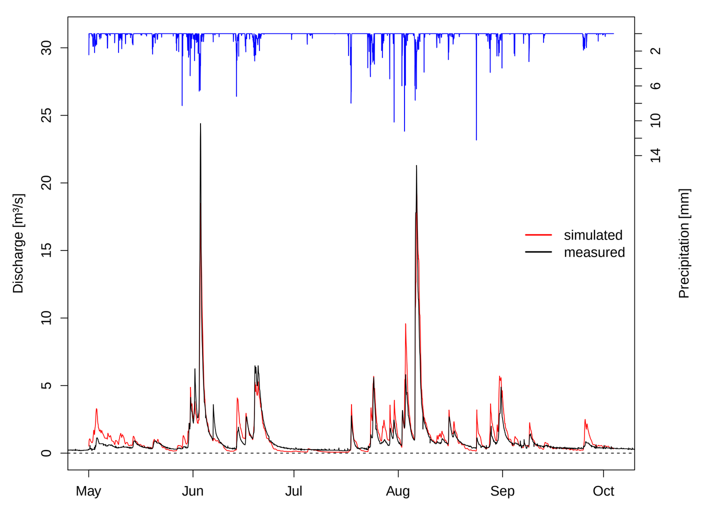
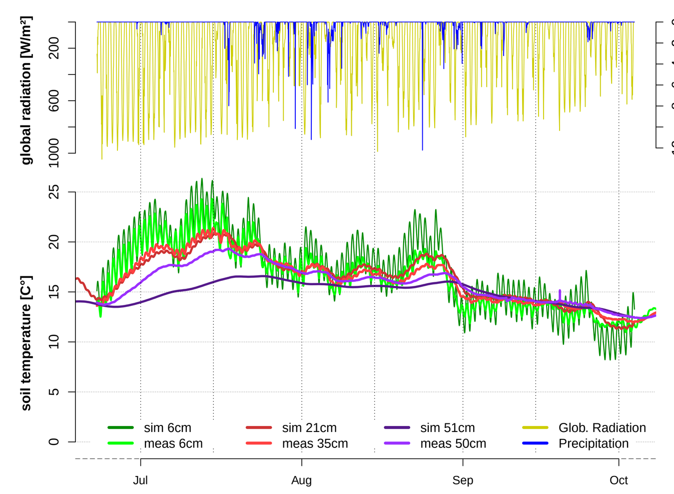


Figure 3: *Simulated and measured discharge at the Gauge in Raisting. A Nash-Sutcliffe coefficient of 0.87 and a R^2-value of 0.88 indicate good congruency of simulation and measurement. One way to improve the simulations would be to minimize interpolation faults of the meteorological forcing as a result of a coarse observational network.*

Figure 4: *Simulated and measured soil temperature for different depths in one pixel at the TERENO-observatory and the whole observational period. The simulated soil temperatures show a good reproduction of the measured dynamics. Good congruency of the simulated temperature in 21 cm with the measured in 35 cm as well as the offset in 50 cm depth indicate a too steep simulated temperature gradient with increasing depth.*



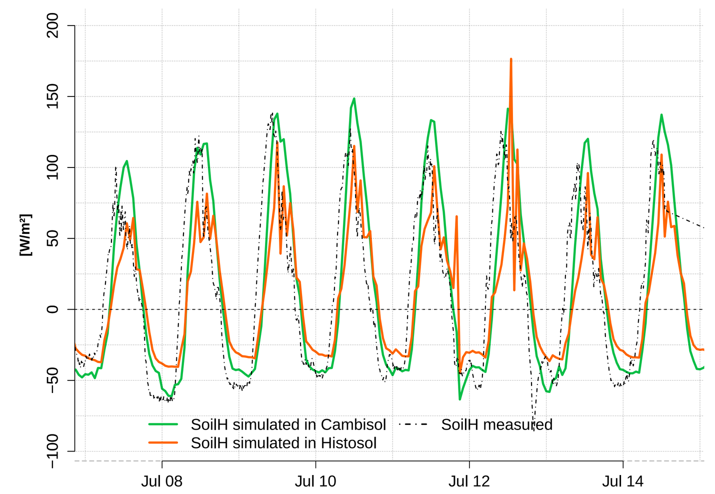
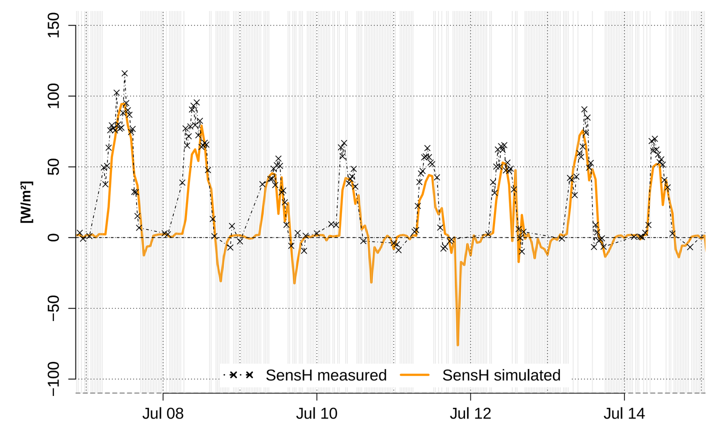


Figure 5: *Simulated and measured soil heat flux for one pixel at the TERENO-observatory for a small section of the three monthly observational period. According to the used soil map, the soil type of the correspondent pixel is Histosol. More current observations demonstrate that only the upper 50 cm of the soil consist of Histosol. Below the Histosol follows the same Cambisol as defined for neighboring cells on the basis of the soil map. Hence the simulated soil heat flux in Cambisol shows much better congruency to the measurements than in Histosol.*

Figure 6: *Simulated and measured sensible heat flux for the same pixel and time section as displayed in figure 5. The gray bars show time steps, where measurements of the sensible heat don't meet a statistical quality criterion wherefore they are omitted in the graphic. This criterion is dependent on turbulences in the atmosphere, that's why it is met quite seldom at night. Thus negative sensible heat fluxes as they occur at night in the simulations are difficult to verify. At time steps with reliable measurements good accordances of the measurements to the simulations are apparent.*



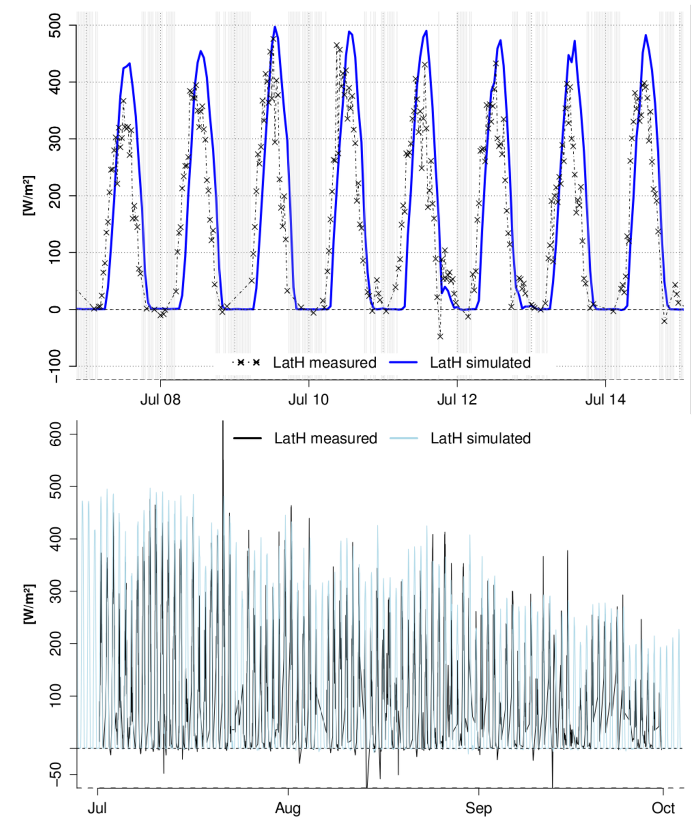
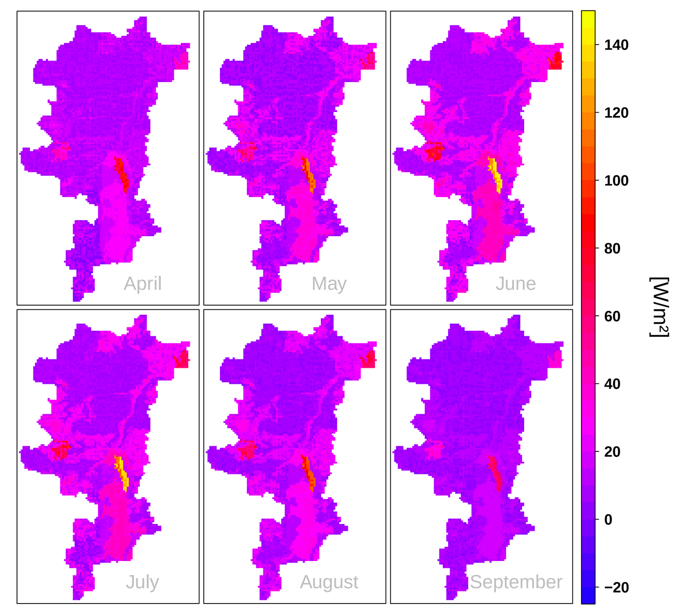


Figure 7: *Simulated and measured latent heat flux for the same pixel as displayed in figure 5. The gray bars at upper figure show time steps with no reliable measurements as explained in figure 6. In the lower figure the latent heat flux for the whole observational period is displayed. The simulations show the same dynamics as the measurements, but tend to overestimate the latent heat flux. This impression gets reinforced due to time steps with missing observed data because of the omitted measurements of less quality. Small time steps as displayed in the upper part of the image show high analogy between the measured and simulated Latent Heat Flux at time steps with available observations.*

Figure 8: *Distributed monthly means of the simulated latent heat flux for the whole simulation period. The appearing patterns of more or less homogeneous areas of similar mean latent heat flux values show up clearly, especially in the summer months. They shape the areas of different land use types and secondarily of different soil types defined in the land use (Figure 2(a)) and soil map (Figure 2(b)) respectively. With respect to time maximum values of the latent heat flux conform with the highest position of the sun therewith the radiation maximum.*



Conclusion

The performed modeling of the energy and water balance with the distributed model GEOtop in the Rott catchment achieved good congruency between simulations and measurements. A very high degree of accuracy was obtained in modeling the discharge. Similarities between modeled and observed energy balance components can be seen in mesoscale temporal dynamics as well as in their daily variability. Differences between simulated and measured fluxes can originate besides from the model SetUp also from inaccuracy of the applied measurement techniques and used observations:

- The high variability of meteorological phenomenons in the prealpine study area leads to measuring faults which are propagated through interpolation over the whole catchment.
- Reliable *soil heat flux* and *soil temperature* measurements require a constant composition of the soil, which can be changed very easy through activities of the soil fauna.
- The applied eddy-covariance method to detect turbulent fluxes produces data of differing quality depending on the respective atmospheric condition which leads to gaps in the time series.
- The resolution of the used soil and land use data emerged to be not sufficient.

Despite the mentioned problems the advantages of combined water and energy budget simulation got apparent, especially for the prediction of low an mid water events.

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