Combined field- and model-based intercomparison of hillslope hydrological response under different vegetations covers

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HYDROLOGY

Introduction

Hydrological dynamics can be described in terms of **water sources**, **flowpaths**, **solute transport** and **water ages**. Reliable predictions of water quantity and quality at ungauged sites or under changing environmental conditions need a profound understanding of the underlying process controls.

Vegetation is known to be a principal, but in both space and time highly variable driver of these dynamics. Not only the hydrograph response, but also the time-variant water ages are expected to differ among contrasting vegetation covers. In order to identify effects of vegetation on hydrological dynamics, other controlling variables must be eliminated.

We thus built this study on a **hillslope hydrometric observation network**, that was intended for the **intercomparison approach**. Our aim is to measure hillslope dynamics of shallow water tables, subsurface flow and solute transport in the field and replicate the experimental observations with the hillslope model **HillVi**.

Study site and instrumentation

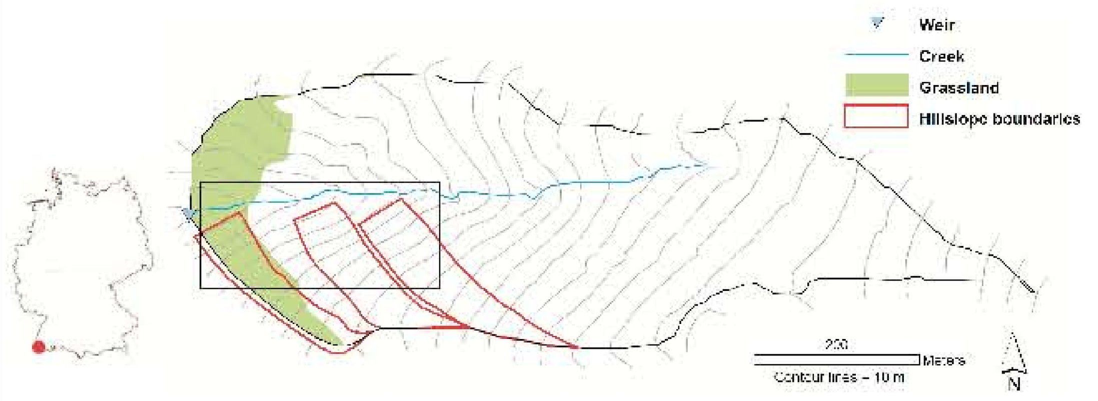
Large-scale monitoring and intercomparison network

Objective: Assessing the influence of vegetation cover on shallow water table and subsurface flow dynamics and associated spatio-temporal variability.

Three adjacent hillslopes:

similar:	different vegetation cover:
- **geology** (gneiss overlain by periglacial drift cover) - **soil** texture (loam) and type (Cambisol) - **topography**, slope (mean 27°), aspect (NW)	- grassland with sporadic sheep grazing - coniferous forest (spruce, fir, douglas fir) - mixed forest (European beech, fir)

Previous studies at the site revealed...
- high variability of water table and subsurface flow response within the seemingly homogenous hillslopes,
- patterns of water table development/persistence differ between adjacent wells, transects and seasons,
- based on hillslope characteristics, this behavior can only be explained to a low degree,
- other not measured features (bedrock topography, preferential flow) may be of major importance.



Catchment (0.21 km²)
located in SW Germany

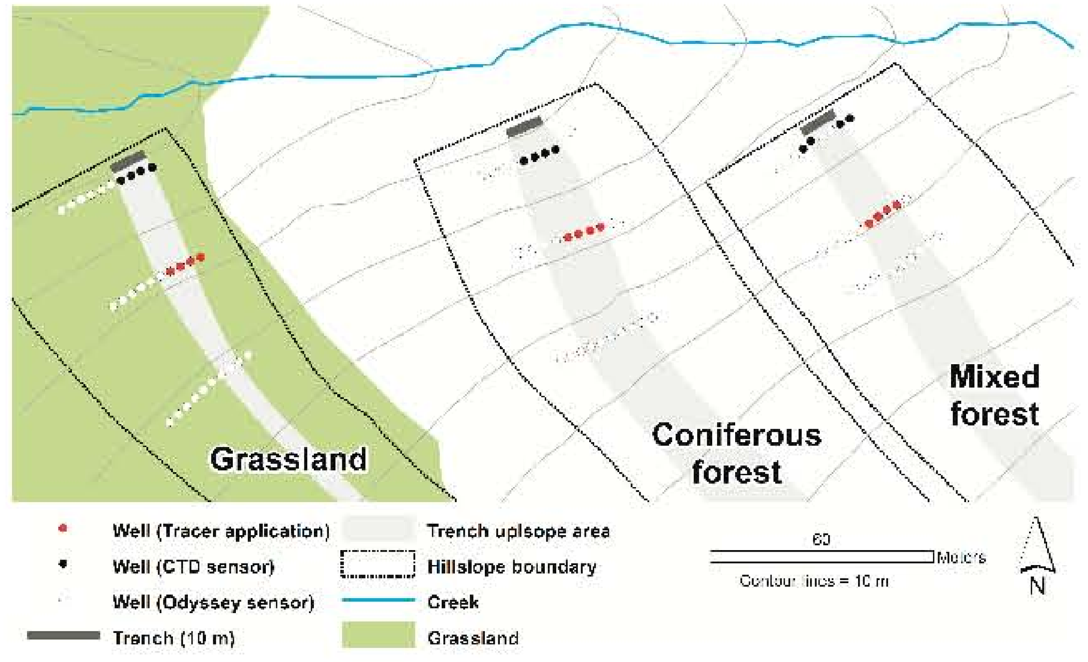
V-notch weir:
discharge, temperature, electrical conductivity

Weather station:
300 m WNW from weir

Hillslope instrumentation

90 shallow groundwater wells:
- depth max. 2 m
- capacitance probes (Odyssey)
- 12 of them with CTD sensors (Decagon)

3 refilled trenches:
- 10 m long, ~2 m deep
- subsurface flow rates
- electrical conductivity

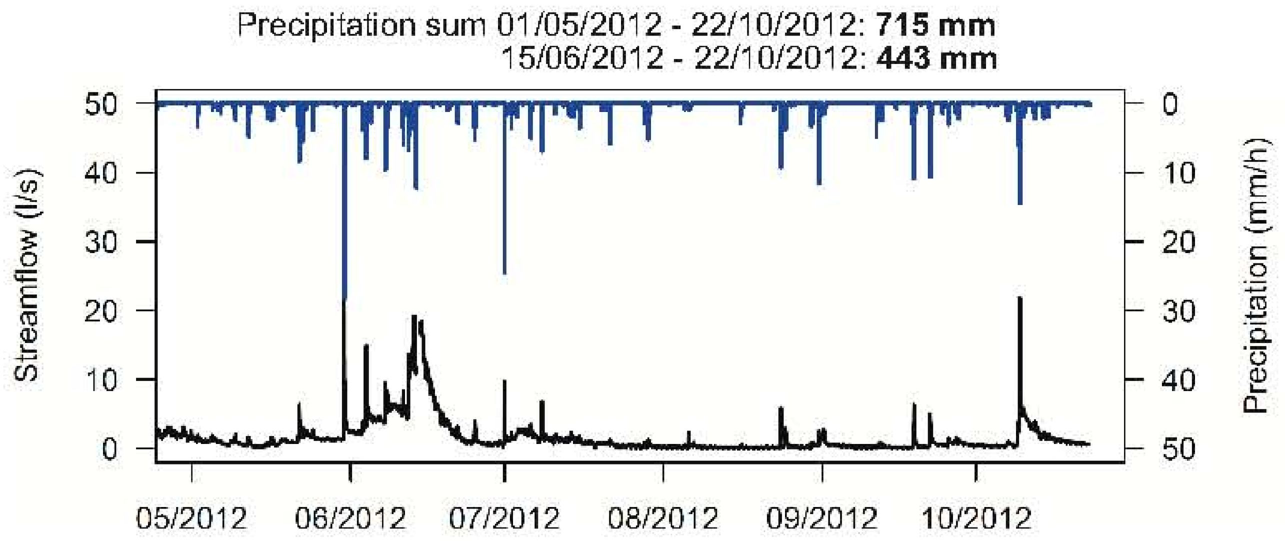


Field experiment

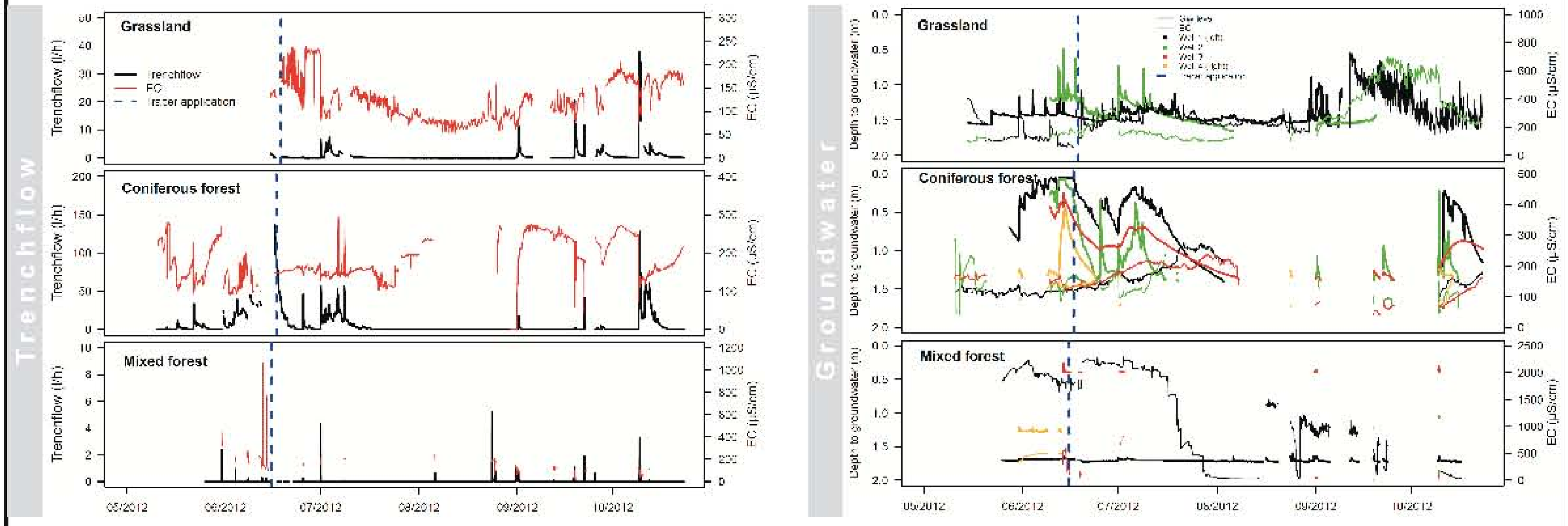
Tracer application

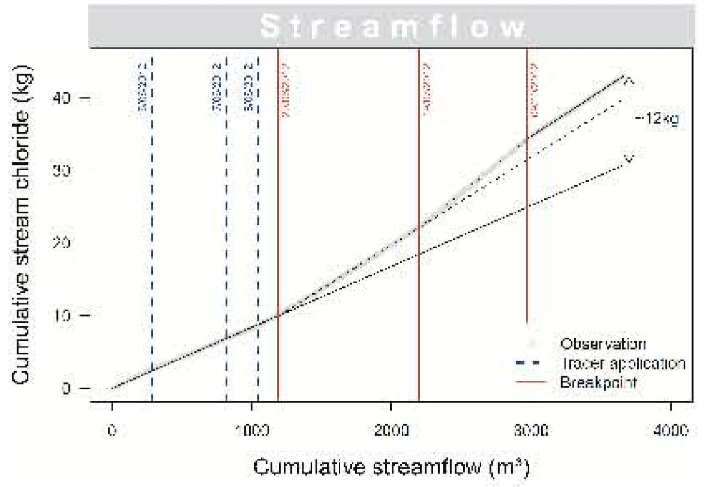
June 2012:
Injection of **60 kg of sodium chloride** (NaCl) into the 12 middle transect wells (5 kg each), located approximately 30 m upslope of the trenches.

Electrical conductivity (EC) of stream water, trenchflow and groundwater in the lower transect wells was monitored to record tracer breakthrough. Additionally, trench- and streamflow was sampled and analyzed for anions.



Results





Measured trenchflow volumes and flow rates vary over orders of magnitude between the hillslopes mainly because of surface and subsurface microtopography (coniferous forest: concave slope; mixed forest: bedrock ridge).

EC data of both trenchflow and near trench groundwater show marked responses to rainfall events (dilution). However, **no clear increase** of EC or chloride concentration is obvious from the data. Chloride recovery can not be calculated because of unstable background concentrations and shifting hydrochemical compositions of subsurface flow.

The double mass curve suggests an **increased chloride export via the stream** starting only 2 to 5 days after the tracer applications, despite no corresponding increases of trenchflow EC.

Conclusions

- **Chloride recovery** in trenchflow was practically not noticeable.
- **Hillslope-stream connectivity** possible via deep (>2 m) and fast (~10 m/d) subsurface flowpaths.
- **Shallow subsurface flow** is probably not restricted solely to the basal layer and shallower soil horizons may significantly contribute to the observed trenchflow dynamics.
- **Model results** show moderate to good agreement for trenchflow data. However, groundwater level dynamics are not sufficiently reproduced.
- Simulated **water ages** of storages and fluxes are highly variable in time.

Current process knowledge about the study site is not yet sufficient to isolate and assess the influence of contrasting vegetation covers. For more reliable results several hillslopes of each vegetation type must be monitored.

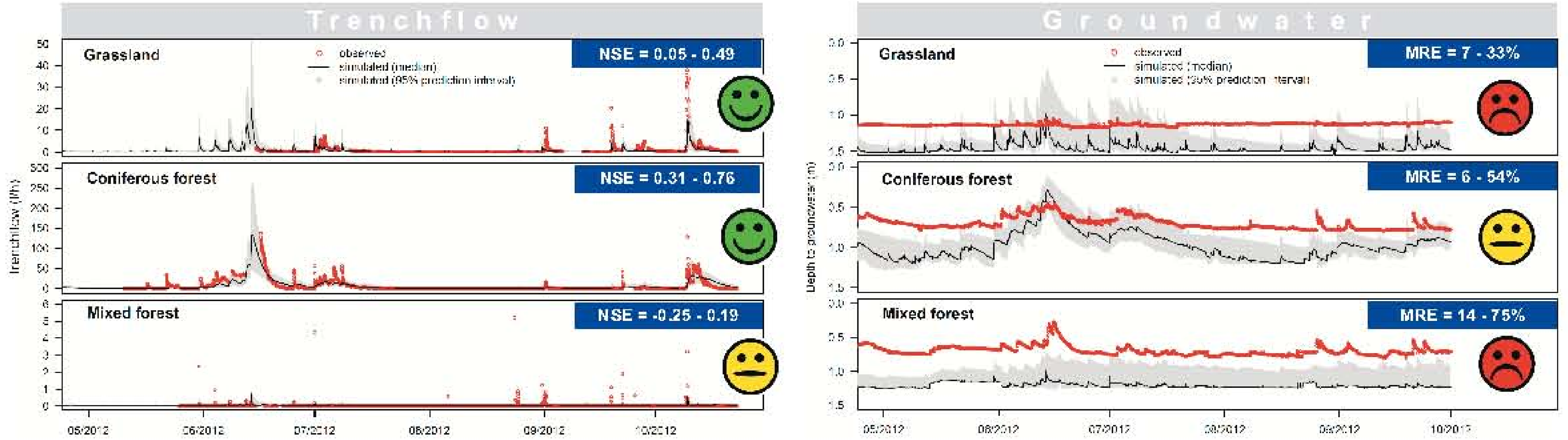
Model experiment

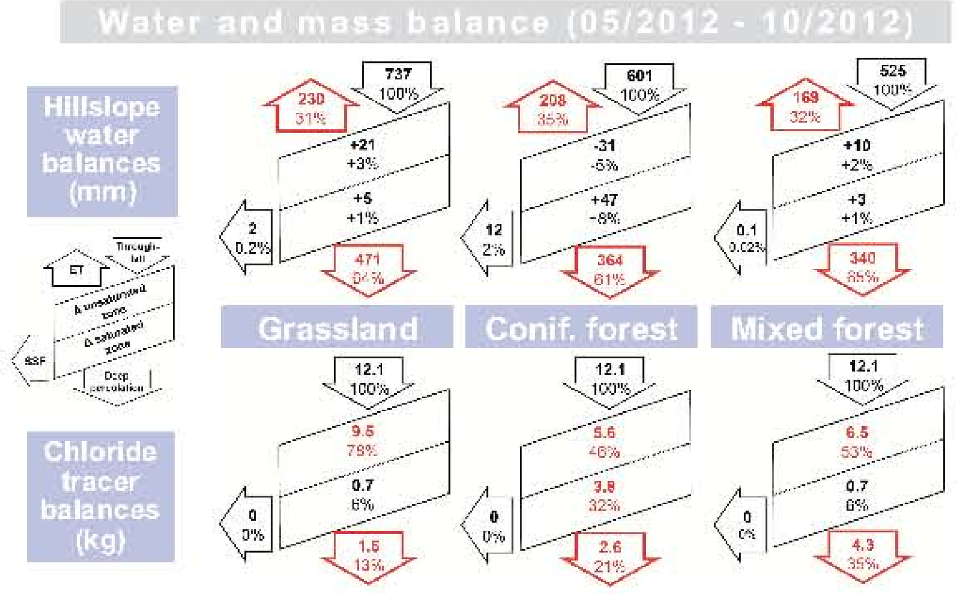
HillVi model

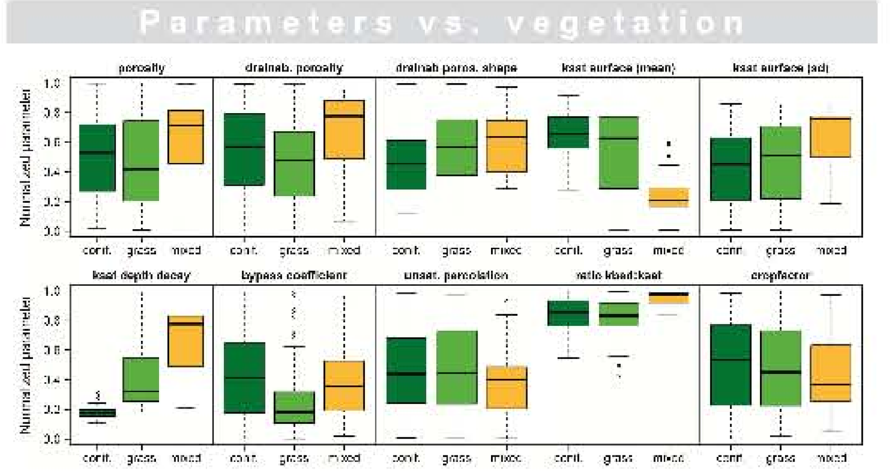
- ☑ spatially distributed
- ☑ mainly physically based
- ☑ unsaturated and saturated zones interact
- ☑ solute transport routine
- ☑ permeable hillslope base (deep percolation)
- ☑ exponential ksat decay with soil depth
- ☑ random fields of ksat
- ☑ random fields of depth to basal layer ("soildepth")

- ☑ simulation period 05/2012 - 10/2012 (+1 month warm-up)
- ☑ latin hypercube sampling
- ☑ trenchflow objective function: Nash-Sutcliffe Efficiency (NSE)
- ☑ groundwater objective function: Mean Relative Error (MRE)
- ☑ accounting for observational uncertainty

Results (100 best parameter sets)

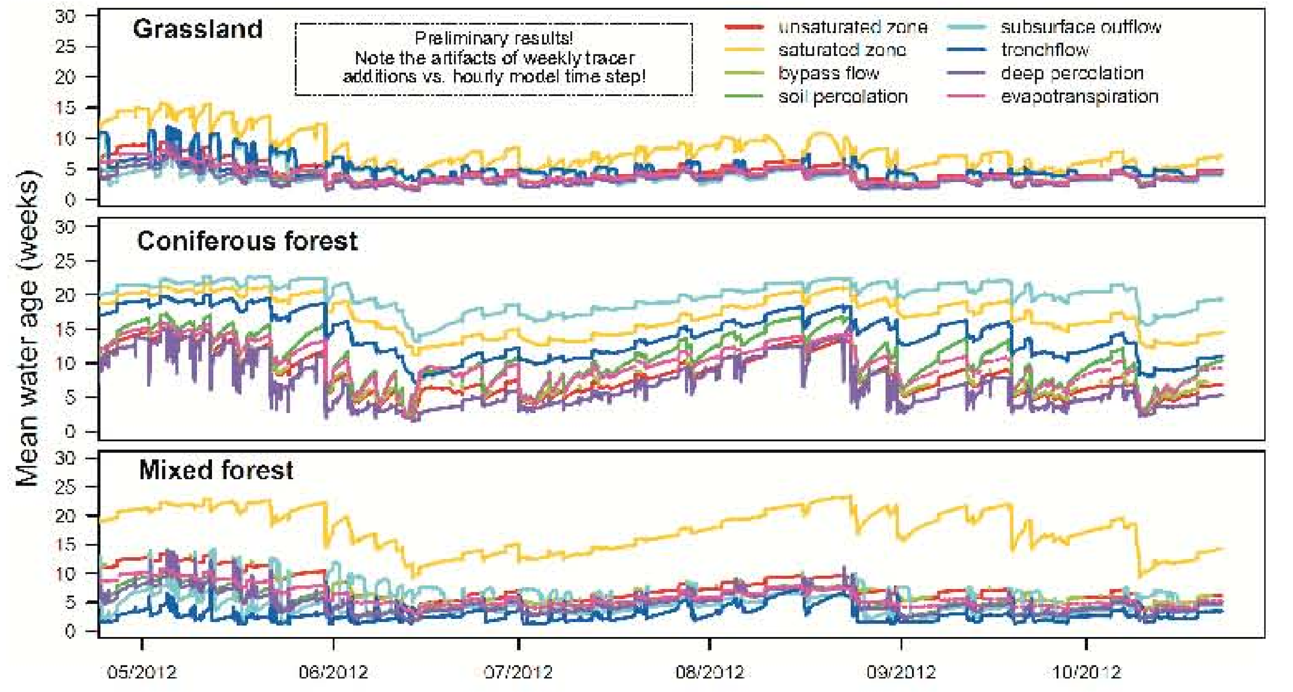






Some optimized model parameters deviate between the hillslopes, however, mainly reflect the observed differences of trenchflow and therefore not real vegetation cover effects.

Outlook: Time-variant residence and transit time estimations



The solute transport routine of HillVi was modified to allow regular **virtual time tracer** injections into the system via rainfall. Each tracer can be tracked through all storages and fluxes which allows the estimation of time-variant water age distributions and the calculation of mean/median water ages.

As anticipated, preliminary results show **temporal variations** of residence and transit times depending on wetness state and flowpath connectivity.

Although the different calibrated hillslope models may not only represent vegetation effects, the resulting time-variant water age timeseries will be evaluated in a sensitivity analysis. By this **virtual experiment** we expect further insight into the key controls of water age dynamics at the hillslope scale.

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