Distributed water balance modeling in the Berchtesgaden National Park

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Introduction

The **regional water balance** of mountainous catchments in the northern limestone Alps is affected by the temporal and spatial variability of meteorological parameters, steep gradients and a complex hydrogeological situation. We investigate an Alpine catchment where the water balance is influenced by a karst aquifer and complex snow cover. We apply the **hydrological model WaSiM** (Schulla, 2012) to analyze surface and subsurface water processes in a high Alpine catchment (Fig.1) and to adapt snow and groundwater modeling to the Alpine environment.

Study Area

The test site for our study is situated in the **Berchtesgaden Alps** (Fig. 1) in the northern limestone alps and covers an area of 430 km^2.

A massive karstified aquifer in the region with a wide range of subsurface flow channels and spring has so far unknown effects on the spatial and temporal dynamic of the water balance due to unknown storage capacities and water flux conditions.

The water balance in the region is controlled by the dynamics of the **snow cover** and the respective water fluxes. High altitudinal gradients and small scale **orographic effects** cause a large temporal and spatial **variability of snow accumulation, storage, redistribution, and ablation.**

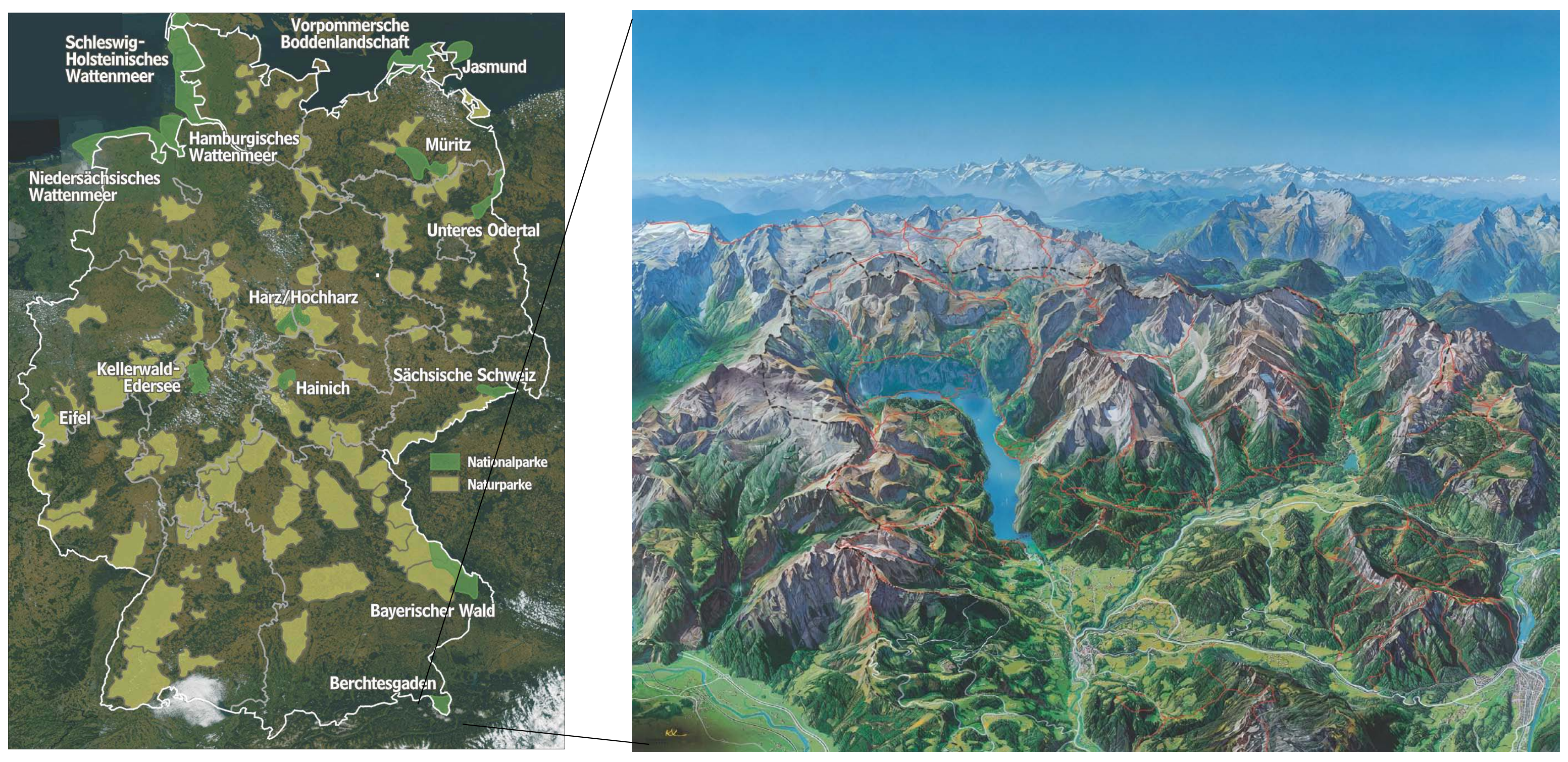

Fig.1: Study area (Images: NPV-BGD)

Distributed Modeling

The water balance is modeled with the physically based, distributed model WaSiM (Schulla & Jasper, 2007). It is a physically based model that was applied in 50x50m^2 horizontal resolution. Based on 9 available gauges and the DEM the study area is divided in 9 subbasins. Three head subbasins are situated in high alpine karst terrain (Fig.2). Meteorological input data was provided by 33 weather stations. Spatial input data are the DEM, landuse and soil classification and parameters for the horizontal groundwater model. Fig. 3 presents the modular structure of the hydrological model.

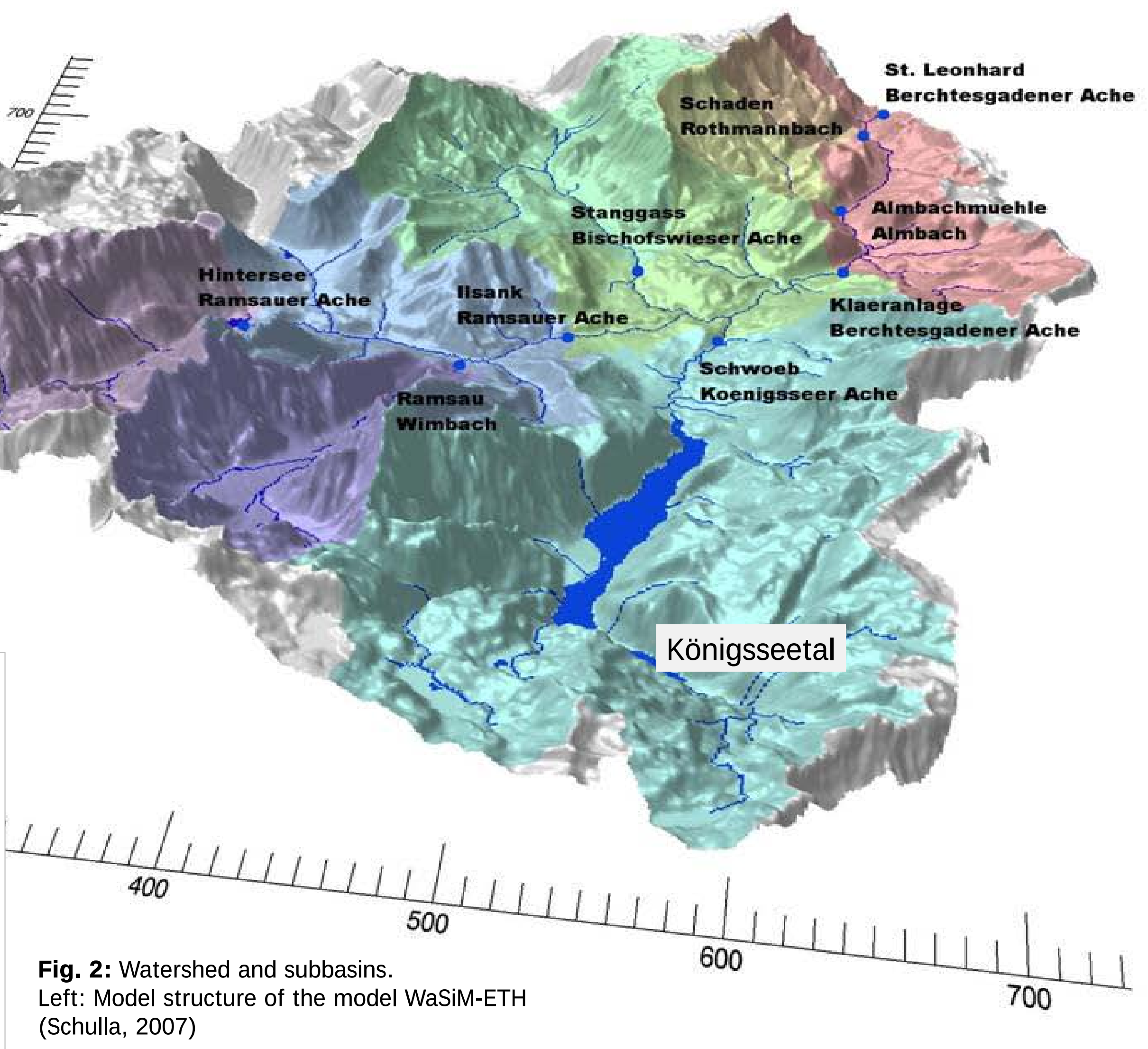

Fig. 2: Watershed and subbasins.
Left: Model structure of the model WaSiM-ETH (Schulla, 2007)

Snow cover dynamics

To improve the **modeling of snow processes**, we have complemented WaSiM-ETH with principles derived from the **high-alpine specific snow model AMUNDSEN** (Strasser, 2008). Subsequent changes in modeled snow cover dynamics and discharge generation are compared and validated via runoff gauge data, measurements of snow water equivalent, and remote sensing data. Model efficiency is increased by the simulation of **lateral snow transport** and the calculation of snow ablation using an **energy balance** approach (Warscher et al., 2013) (Fig 4., Fig. 5).

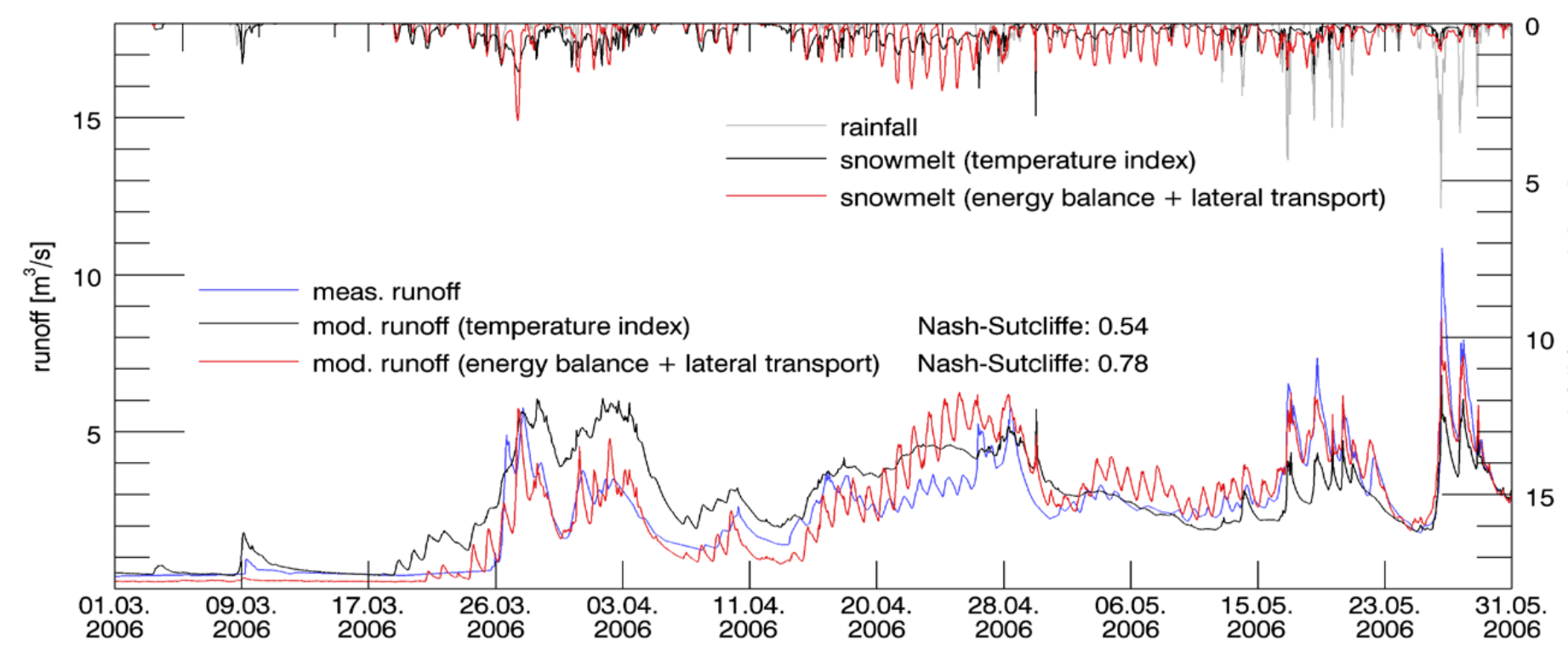

Fig. 4: Runoff, snowmelt and rainfall at gauge Hintersee (melting period spring 2006)

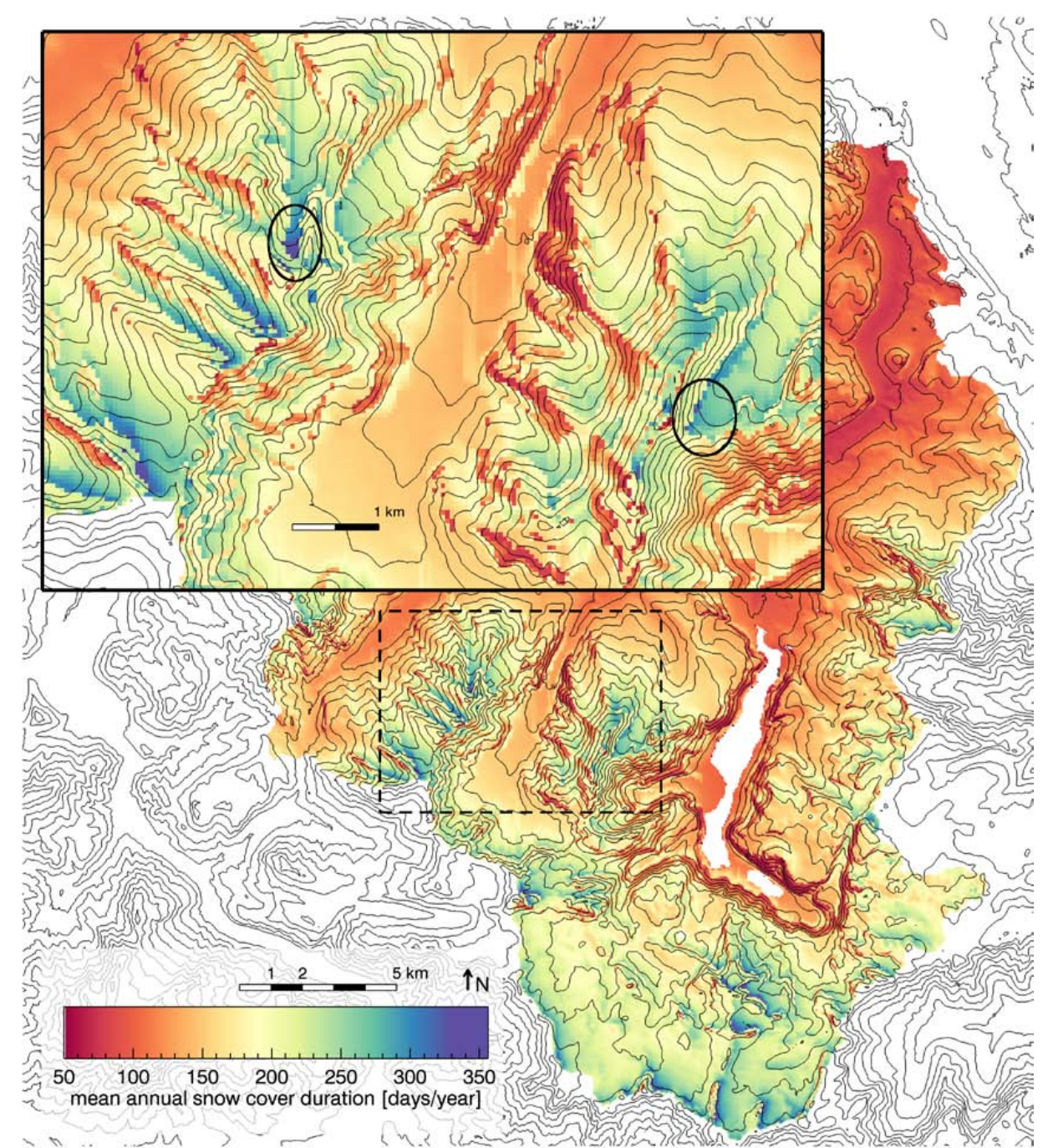

Fig. 5: Modeled mean annual snow cover duration

Subsurface water storage

The model assumes porous conditions and does not account for karst environments within the groundwater module. Results showed that **runoff is systematically under- and overestimated** in three high Alpine neighboring karstified subbasins. This corresponds with the outcomes of the comprehensive summary of karst research in the area (Kraller et al., 2011) and indicates hydrological model limitations in karst terrain. We developed an artificial network, a statistical-empirical method to account for the missing water fluxes in the hydrological model.

The **Artificial Neural Network** (Fig.6) reproduces heterogeneous karst water storage and serves as **dynamic influx in the groundwater module** of the hydrological model (Fig.7). We applied this method in the subbasin Königssetal (Kraller et al., 2012).

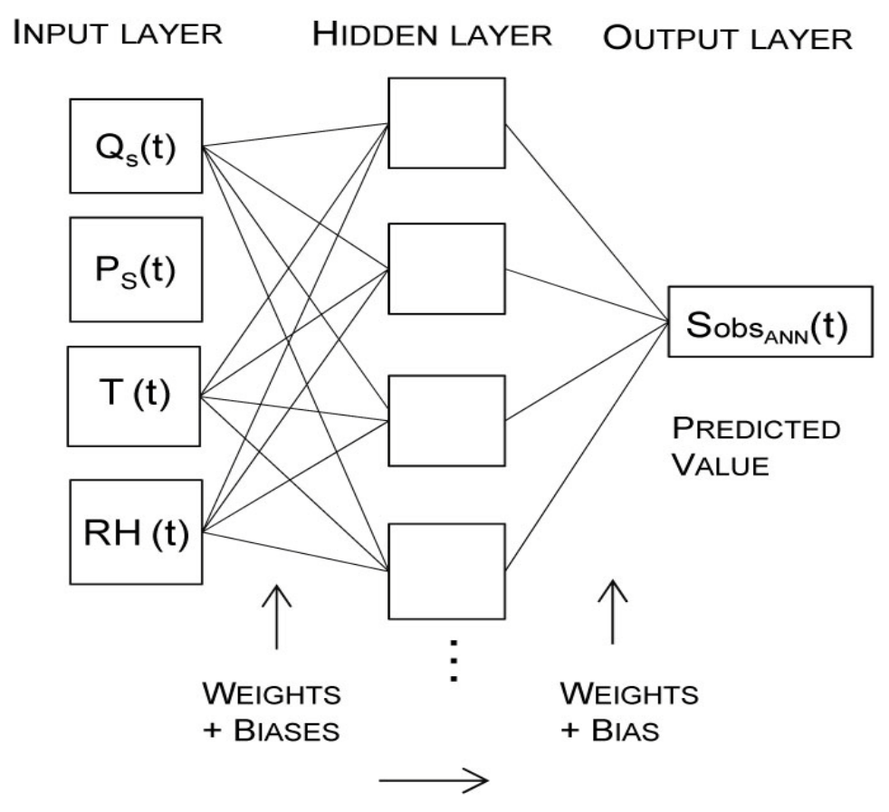

Fig. 6: Artificial Neural Network

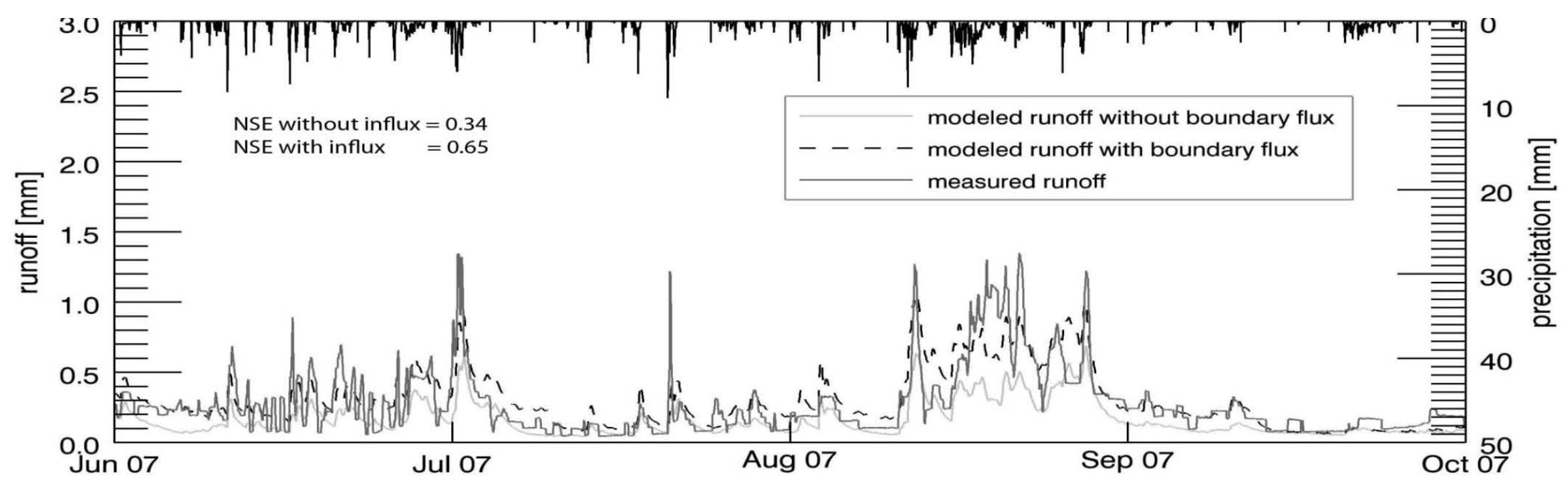

Fig. 7: Hydrological model results before and after model correction in subbasin Königsseetal.
NSE = Nash Sutcliffe Efficiency

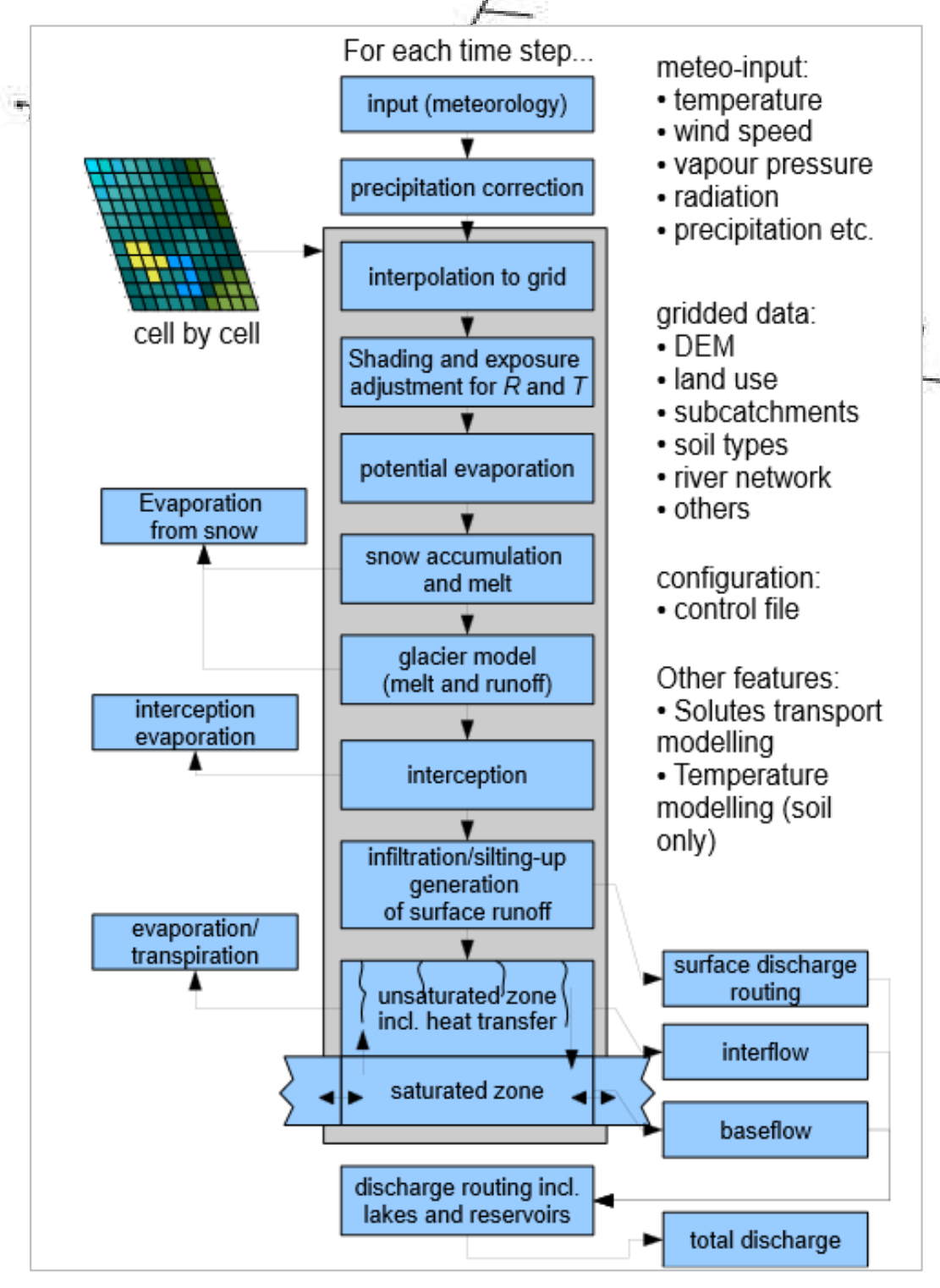

Fig. 3: Model structure of the model WaSiM-ETH (Schulla, 2012)

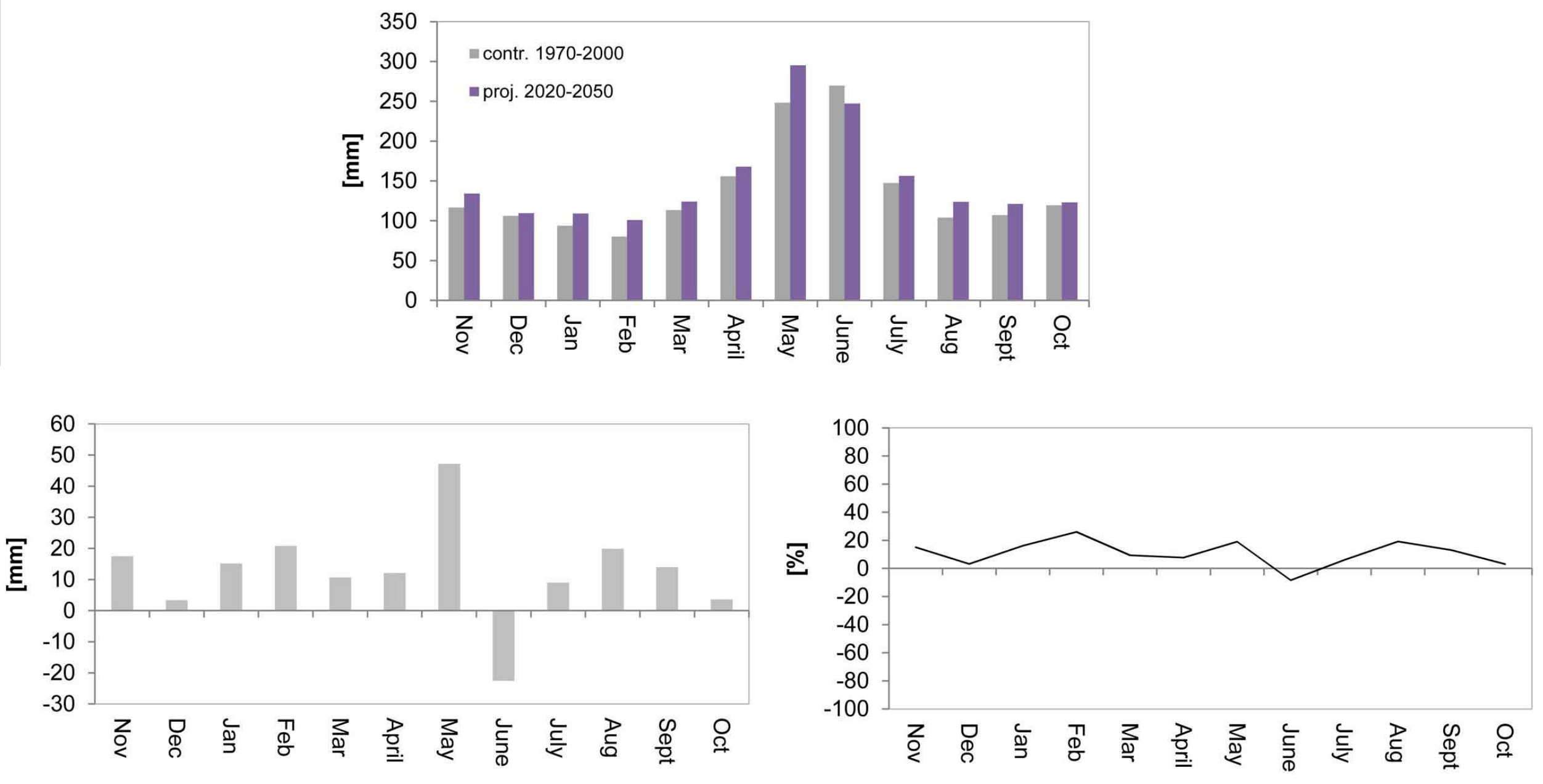

Fig. 8: Modeled runoff at river gauge St. Leonhardt for the control and future time period.

Climate Impact Analysis

The improved model system (snow cover dynamics, subsurface water storage) is finally forced with scenario data of a regional climate model (RCM: **WRF** 7 km, GCM: **ECHAM5**, MPI/OM T63/L32, **Scenario A1B**) to assess potential impacts of a **changing climate** on the regional water balance. Model results are compared between the control period 1970 – 2000 and the future period 2020 – 2050. Results show shifts in precipitation amounts throughout a year and an elevation-dependent decreasing trend in snow cover duration. The absolute changes in evapotranspiration, seasonal snowmelt and runoff amounts are projected to remain relatively small (Fig.8).

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