Hydrological processes and dynamics in the changing climate and environment:

Lessons learned from multiple temporal and spatial scales

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ABSTRACT

Climate change, along with the changes in land use and land cover (LULC), is the key factor driving the changes in hydrological processes and dynamics in a basin. This thesis emphasized on understanding the impact of both long-term climate change and abrupt anthropogenic driven agricultural intensification or natural driven insect-induced forest disturbance on hydrological processes and dynamics at varying spatial and temporal scales in two diverting terrestrial environment.

Two pattern-based investigations, one case study in a forest region in Central Europe and another in a semi-arid region in Central Asia, were aimed to answer the main research question "*what are the responses of hydrological dynamics and the related hydro-geochemical conditions to climate change and certain changes in LULC at a basin-scale?*". The long-term hydro-climatic dataset was used for conducting statistical analyses and establishing hydro-climatic modelling at the basin scale. We further conducted process-based studies, attempting to understand how and why the specific hydrological dynamics were altered at smaller spatial and temporal scales: (i) a catchment-scale tracer-based experiment was conducted to examine multi-timescales changes in subsurface chemical composition and in runoff generation processes after bark beetle infestation; (ii) a soil column-scale theoretical analysis was studied to address the importance of velocity-celerity difference in studying tracer transport; (iii) two plot-scale model-based evapotranspiration estimations in a Soil-Vegetation-Atmosphere-Transfer (SVAT) model scheme were conducted to offer an alternative to better understand evaporation from soil, transpiration, and evaporation from canopy; and (iv) a plot-scale sap flow experiment was designed to estimate the canopy conductance during the vegetation period of beech forest.

Two pattern-based case studies pointed out the significant hydrological responses to the warmer climate under different environment, in the studied mid-latitude Central Europe Mountain the runoff seasonality shifted in terms of total runoff share, occurrence of peak flows and low flows, while Central Asia experienced a decrease in river flow and significant changes in riverine nitrogen concentrations. The processes-based studies highlighted that complex hydrological processes including streamflow, subsurface flow, geochemical conditions, and evapotranspiration are actively interacting with the changes in climate and LULC. In the experimental catchments of Central Europe undergone climate-induced bark beetle infestation, the geochemical changes, showing as an increased annual mean in-stream electrical conductivity (EC), are profound in the disturbed catchments were rapid after extensive infestation and last long over decades. The old water with substances of nitrogen and carbon released by dead trees was mixing with the rainwater in the rainfall-runoff events, and the shifts in EC-discharge hysteresis loops at each event implied changes in the subsurface chemical composition and runoff generation process. Such tracer-related studies require deep understanding in subsurface flow, we, therefore, proposed a celerity function that has been theoretically proved the usefulness when assists in studying the runoff behaviours and tracer transport.

Furthermore, evapotranspiration in the forested region is a key domain in the hydrological cycle. The newly developed SVAT model was applied in two different environments (i.e., forest and maize) where had full sets of dataset for validating the model, and the performance was better due to the more detailed description of energy transfer and the formation of advective soil vapour transport. One step forward, the results from sap flow experiment tracked the transpiration process in the beech forest, based on which the reversely-calculated canopy conductance was given to address the importance of knowing the site/species-specific canopy conductance for an area, which assists better understanding the transpiration process in newly formed beech stands after bark beetle outbreak in Central Europe.

Key words: hydrological processes, runoff, climate change, agricultural intensification, forest disturbance, geochemical transformation, celerity, evapotranspiration, SVAT model, sap flow, stomatal conductance