Elevated atmospheric CO_2 - a neglected source of uncertainty in future hydrological projections in different climate zones

Prediction how much water will be available under future climatic conditions is currently the core of hydrological research. Hydrologists are using various tools of different complexity, called hydrological models, to mimic hydrological processes occurring at different scales: from small river basins to entire globe. Unfortunately, the simulated future response of the hydrological system to analysed drivers depends on numerous factors, of which many are unknown. Some of these factors are well-studied, while others are not. Factors such as the choice of greenhouse gas emission scenario, the choice of climate model or the choice of hydrological model have been studied well. However, elevated atmospheric CO_2 concentration (eCO_2) and its effect on plant growth is a factor that has not attracted sufficient attention yet. This project will try to bridge this gap by studying the role of eCO_2 on hydrological projections for the future.

eCO_2 is the direct driver for all climate models resulting in future projections of temperature, precipitation, etc. At the same time, with increased CO_2, plants are able to use water more efficiently because of reduced degree of plant stomata opening (measured by stomatal conductance), which leads to an increased photosynthesis. eCO_2 also leads to an increased leaf material in canopy (measured by Leaf Area Index). These processes are either neglected in current hydrological models or they are accounted for, but in a very simplified way. This is a clear shortcoming, because plants cover the vast majority of landscape, they transpire large amounts of water from the soil, and thus indirectly affect how much water is available in aquifers, streams and rivers and how this availability changes in space and over time. In this project, we will focus on one specific process-based hydrological model called SWAT+, which is one of the few models of this type that include a plant growth component and eCO_2 effect. However, it suffers from a few limitations in its description of the effect of eCO2 on other processes: lack of dynamic changes in CO_2, lack of plant-specific response to eCO2, incorrect process description for very high CO_2 levels (levels that will likely be experienced in 30-40 years). The ambition of this project is to address all these limitations and develop a modified model version that will ultimately help to derive more reliable projections for the future.

The general objective of this project is to increase the understanding about the role that eCO_2 has on future hydrological projections across different climate zones. CO_2 levels are usually considered as globally uniform, but the potential responses to its future changes are not. Therefore, it is planned to carry out the research in study areas (small river basins) located in different climate zones, from tropical to arid, temperate and cold. In order to make it possible to compare the results between climate zones, the input data and modelling approaches will be as harmonized as possible. Running hundreds of model simulations for different scenarios of future climate will allow to answer the question about the added value of improving description of eCO_2 effect in the model. It is expected that the role of eCO2 will be significant, in other words, the response of a hydrological system to climate change will be different with eCO2 effect than without eCO2 effect. It is also expected that the response will be dependent on climate zone and on composition of land cover in the river basin. Finally, it is expected that still, climate models will remain the dominant source of uncertainty in future projections.