Geophysical Research Abstracts
Vol. 21, EGU2019-5691, 2019
EGU General Assembly 2019

Atmospheric feedbacks induced by human water use and their impact on local to remote water resource availability

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Assessing the availability of freshwater resources under current and future climatic conditions requires an improved understanding of the terrestrial–atmospheric system and anthropogenic impacts. Especially during heatwaves and droughts, additional groundwater is abstracted to meet increased water demands for e.g. agriculture, thereby putting water resources under additional stress. While recent studies highlight the direct impacts of human water use on terrestrial water fluxes and states, the impact may be much larger, more far-reaching, and potentially exacerbated through atmospheric feedbacks induced by human water use. Moreover, these atmospheric feedbacks can exceed watershed boundaries and affect local to remote water use sustainability.

In this study, we use the coupled groundwater-to-atmosphere modeling platform TerrSysMP to assess the impact of human water use on land and atmospheric processes, such as evaporation, water vapor transport and precipitation. Furthermore, we apply the Lagrangian particle dispersion model FLEXPART to the output from TerrSysMP, which allows us to trace atmospheric water vapor and identify feedback pathways. Simulations cover continental Europe and consist of a four-member human water use ensemble to account for uncertainties in water use estimates and the associated feedbacks during the heatwave year 2003. We determine atmospheric feedback pathways of human water use and evaluate their reach across watersheds, which enables us to disentangle contributions to water availability change. Our results indicate that human water use affects atmospheric processes beyond the watershed-scale, and that these atmospheric feedbacks crucially contribute to terrestrial water storage change. In particular, arid watersheds in Southern Europe suffer additional drying through atmospheric feedbacks induced by human water use. Moreover, we find that the incorporation of human water use in the modeling system improves the simulation of local evaporation and precipitation by 3 and 13% on average, respectively. Our findings constitute a novel process-based view of the anthropogenic impact on the full terrestrial hydrologic cycle across watersheds, and highlight concerns of sustainability.