SPECIAL PROJECT FINAL REPORT

Project Title:	Integrated Simulations of the Terrestrial System over the European CORDEX Domain
Computer Project Account:	spdekoll
Start Year - End Year :	2018 - 2018
Principal Investigator(s)	Stefan Kollet
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Other Researchers (Name/Affiliation):	Jessica Keune Samuel C. Zipper

The following should cover the entire project duration.

Summary of project objectives

The objective of this study was to identify and quantify feedback pathways of human water use on the atmospheric moisture transport using a Lagrangian particle dispersion model and high-resolution fully coupled aquifer-to-atmosphere simulations over the European CORDEX domain. The Lagrangian particle dispersion model FLEXPART was planned to be used to trace atmospheric water vapour, and facilitates the identification of moisture sources leading to precipitation. Simulations from our previous special project were used as input data to address the impact of human water use, here considered as irrigation and groundwater abstraction, on precipitation recycling.

Summary of problems encountered

We encountered some issues with the particle dispersion model FLEXPART and its coupling to the weather prediction model COSMO from the German Meteorological Service, as part of the aquifer-to-atmosphere modelling system TerrSysMP. To date, FLEXPART-COSMO has only been used for small-scale applications, such as the tracing of pollutants from a point source in the air. The setup of this model to trace atmospheric water vapour over large-scale domains, such as the European CORDEX domain, constituted a novel approach that required the continuous tracing of millions of particles. This setup comprised several run time and parallelization issues that needed to be addressed in collaboration with the model developers. Due to these issues and the limited special project duration (6 months), we were not able to perform the planned simulations with FLEXPART-COSMO on the CCA.

Experience with the Special Project framework

Our experience has been positive with all administrative aspects.

Summary of results

Due to the issues with FLEXPART-COSMO, as described above, no additional simulations were performed. However, continuous access to the CCA and the archive enabled us to perform follow-up-studies of our previous special project (SPDEKOLL 2016-2017) on the CCA and resulted in two peer-reviewed publications, which address 1) the added value of incorporating human water use in aquifer-to-atmosphere simulations, and 2) the impact of land use/ land cover change on heat and drought in Europe. The outcomes of these studies were published in peer-reviewed journals (as listed below).

1) **Potential added value of incorporating human water use on the simulation of evapotranspiration and precipitation in a continental-scale bedrock-to-atmosphere modeling system: A validation study considering observational uncertainty**

   Keune, J., Sulis, M., & Kollet, S. J. (2019). Potential added value of incorporating human water use on the simulation of evapotranspiration and precipitation in a continental-scale bedrock-to-atmosphere modeling system – A validation study considering observational uncertainty. Journal of Advances in Modeling Earth Systems, 11.

   Abstract. *Human activities, such as human water use, have been shown to directly influence terrestrial water fluxes and states. Simulations of soil moisture, river discharge, evapotranspiration and groundwater storage are significantly improved, if human interactions, such as irrigation and groundwater abstraction are incorporated. Yet, improvements through the incorporation of human water use on the simulation of local and remote precipitation are rarely studied, but may contribute to the skill of land surface fluxes. In this study, we evaluate the impact of human water use on the skill of evapotranspiration*

and precipitation in a fully-coupled bedrock-to-atmosphere modeling platform. The results show that human water use can potentially increase the skill of the simulations across scales. However, observational uncertainty at the watershed scale limits the identification of model deficiencies and added value related to human water use. Locally, daily precipitation statistics potentially benefit from the incorporation of human water use. Although the incorporation of human water use does not remove the wet bias, it can increase the model skill.

2) **Land use change impacts on European heat and drought: remote land-atmosphere feedbacks mitigated locally by shallow groundwater**

Zipper, S. C., Keune, J., & Kollet, S. J. (2019). Land use change impacts on European heat and drought: Remote land-atmosphere feedbacks mitigated locally by shallow groundwater. Environmental Research Letters, 14(044012).

Abstract. *Heat and drought are projected to increase globally but maybe mitigated or exacerbated by land use/land cover (LULC) change. Here, we show that remote land-atmosphere feedbacks caused by historical European LULC change led to widespread changes in the energy and water balances, drought, and heat. Using a continental-scale bedrock-to-atmosphere model, we find that LULC change following the Soviet Union collapse and European Union formation may have substantially increased cloud cover and decreased incoming shortwave radiation in western Europe, even in locations where LULC did not change. These changes to the water and energy balances had spatially heterogeneous impacts on drought and heat, including drying in the Mediterranean and Eastern Europe regions. The response of the water and energy balances to remote feedbacks was lessened in areas with shallow groundwater, indicating that local- and continental-scale responses to LULC change are influenced by the coupling between the subsurface, land surface, and atmosphere.*

List of publications/reports from the project with complete references

Keune, J., Sulis, M., & Kollet, S. J. (2019). Potential added value of incorporating human water use on the simulation of evapotranspiration and precipitation in a continental-scale bedrock-to-atmosphere modeling system – A validation study considering observational uncertainty. Journal of Advances in Modeling Earth Systems, 11. https://doi.org/10.1029/2019MS001657

Zipper, S. C., Keune, J., & Kollet, S. J. (2019). Land use change impacts on European heat and drought: Remote land-atmosphere feedbacks mitigated locally by shallow groundwater. Environmental Research Letters, 14(044012). https://doi.org/10.1088/1748-9326/ab0db3

Future plans

Due to the end of the PhD project from Jessica Keune, there exist no future plans yet.