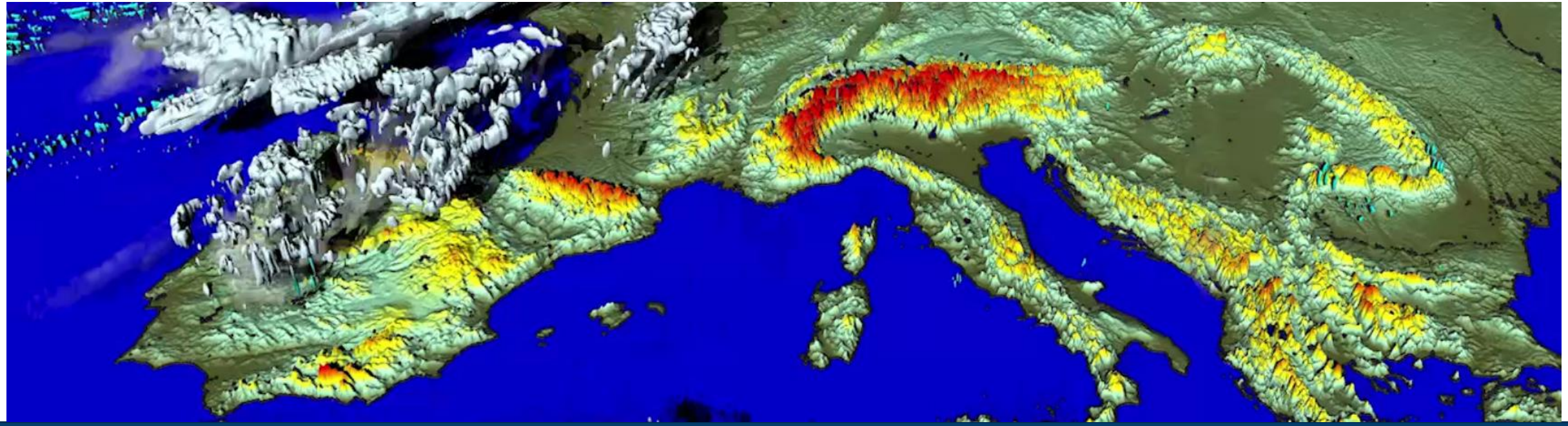

Exploring the mechanism behind successive droughts

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A B C/J geoverbund aachen bonn köln jülich

HPSC TerrSys

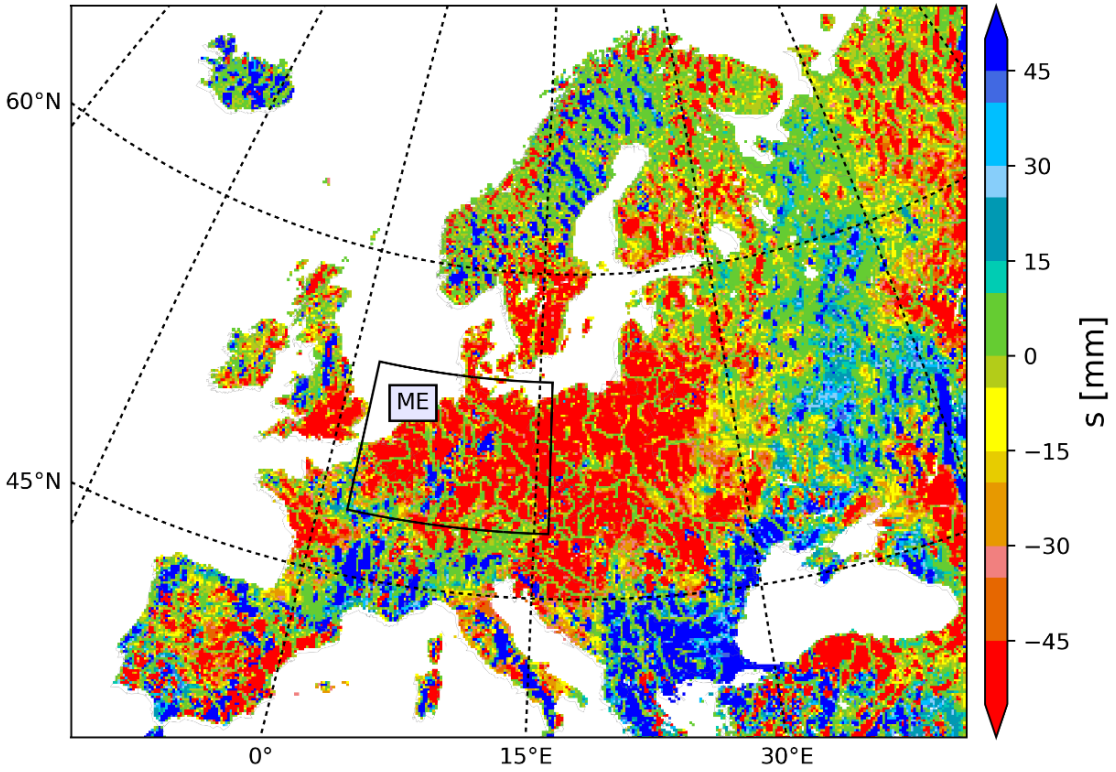
ESM Advanced Earth System Modelling Capacity

JÜLICH Forschungszentrum

Motivation

Terrestrial system simulation to investigate possible intensification with successive droughts

- Repeated drought events in the recent past over Europe (2011, 2018, 2019)
- Significant influence on the energy budget of the land surface
- Indirect influence on the boundary layer and the atmosphere
- Fully coupled terrestrial modelling includes all these feedbacks.
- Feedbacks could lead to intensification of drought events in the next year.

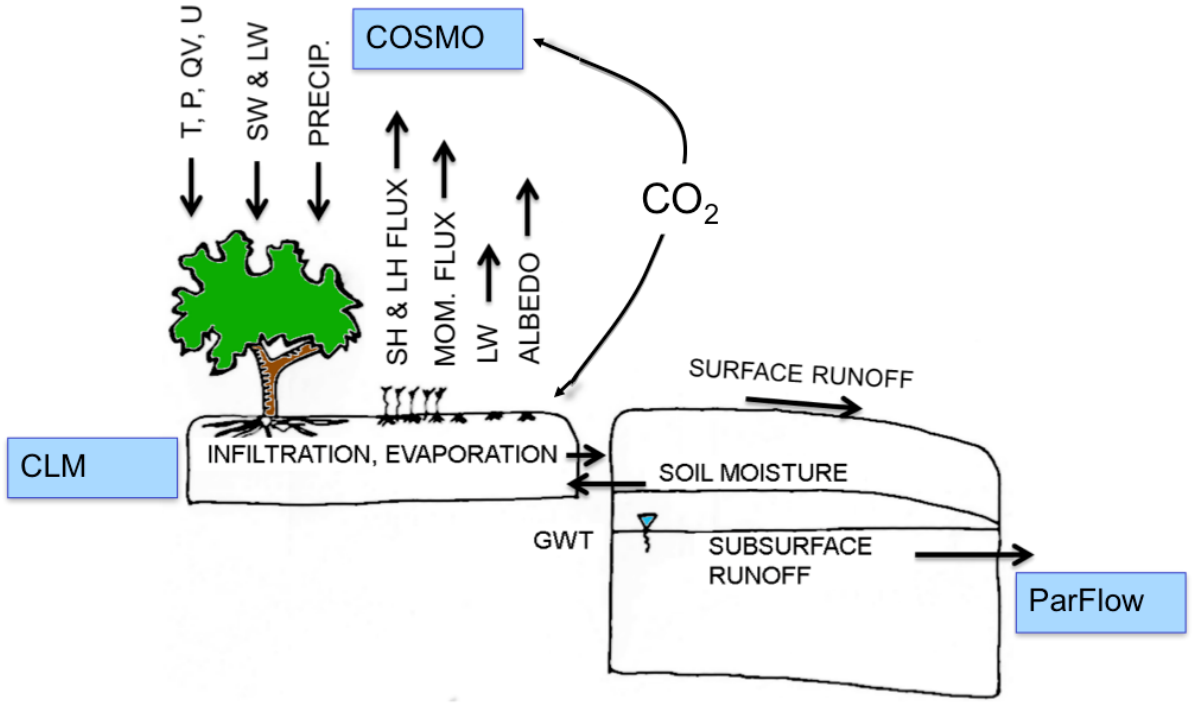


Subsurface water anomalies August 2018 (Hartick et al., 2021)

Terrestrial Systems Modeling Platform, TSMP

https://www.terrsysmp.org

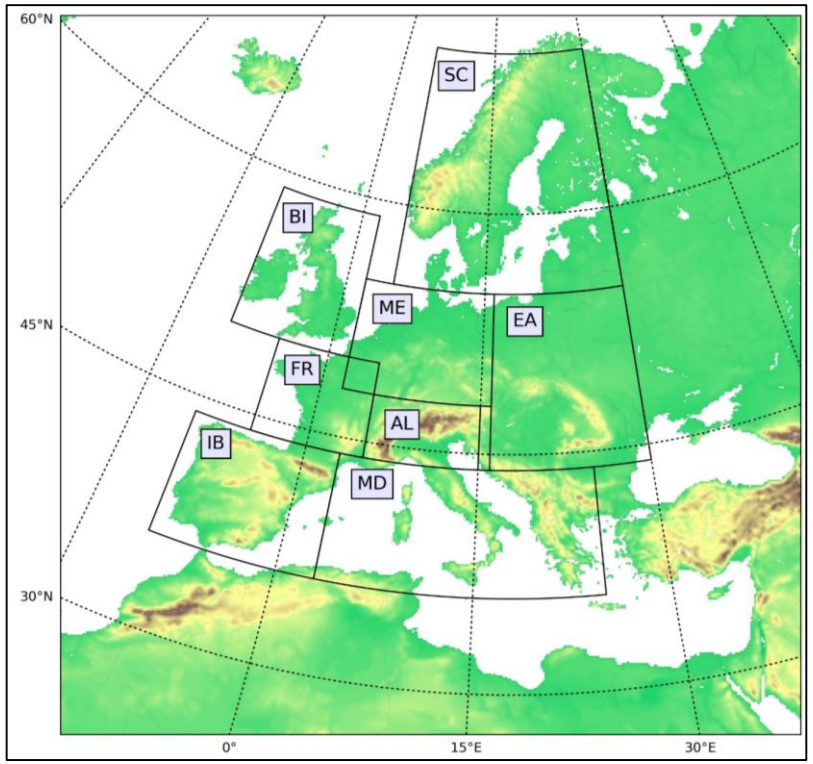
- Scale consistent modelling platform consisting of: COSMO (atmosphere), CLM (land surface) and ParFlow (subsurface)
- Aim: modelling the coupled water cycle from the top of the atmosphere to the water table
- Transport processes and feedbacks between the different systems are included.
- Ongoing developments of including newer model components and implementing GPU-capability with ParFlow



F. Gasper et al. (2014)

Model setup

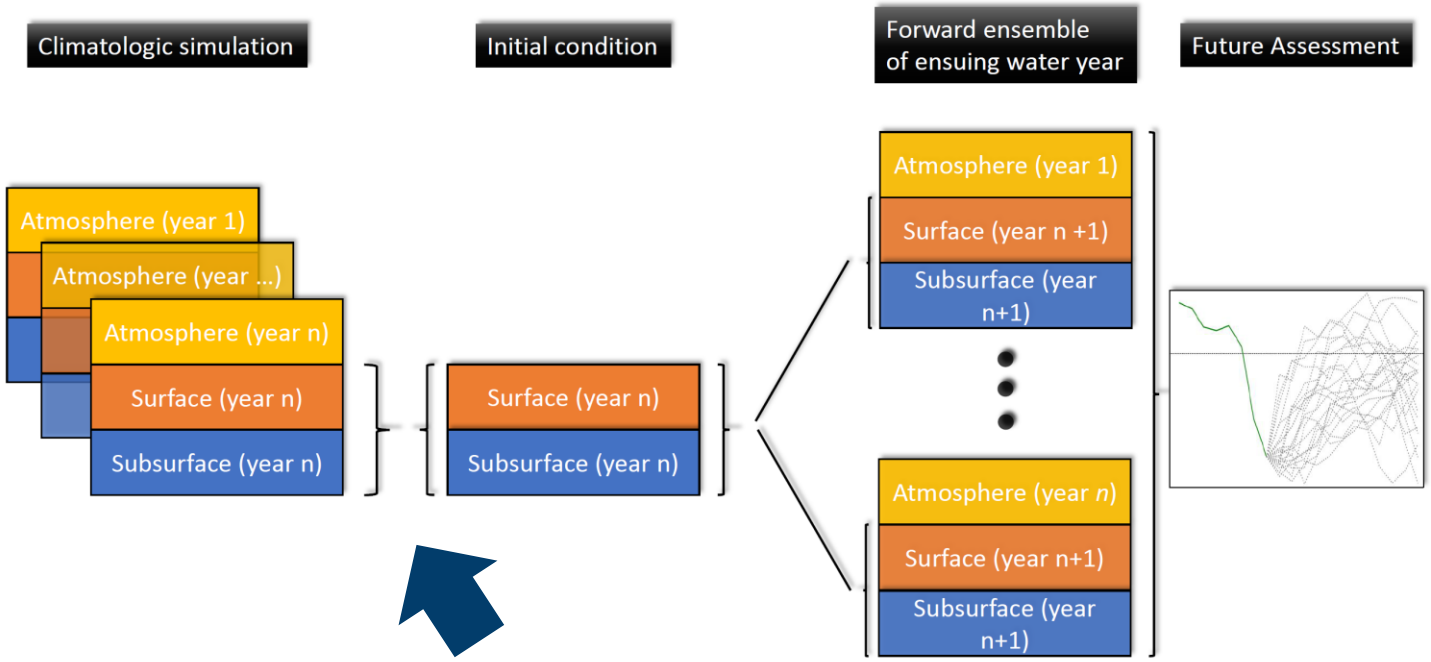
- 0.11° resolution with 412 x 424 grid points (EURO-CORDEX EUR-11 model domain)
- Time period: 1996 - 2019
- Focus on Middle-Europe (ME)



Model	Vertical levels	Time step	Input data
COSMO	50	60 s	ERA-INTERIM
CLM	10	900 s	MODIS
ParFlow	15	900 s	FAO, BGR

Experiment design

- State of land- and subsurface are extracted from long-term TSMP model run (climatology) and paired with multiple atmospheric boundary conditions.
- Can be used to create a probabilistic ensemble of the drought year.
- Furthermore, the ensemble can be compared to the original realization in the climatology to identify significant increments.
- To calculate the increments years with the same boundary condition are compared.



Extracting drought years (2011, 2018, 2019)

Hartick et al. (2021)

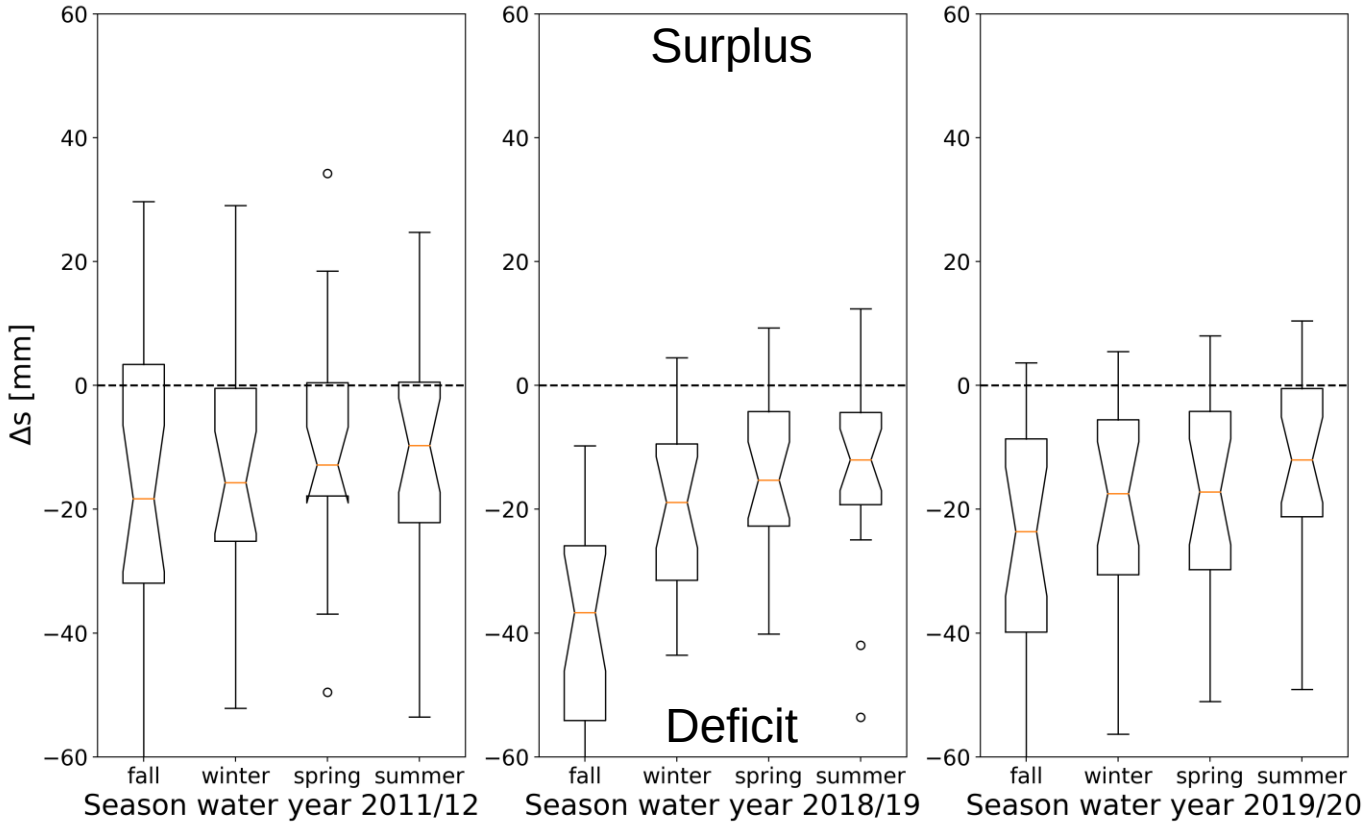
Calculation of increments to original climatology

Subsurface water storage in ME

- Subsurface water storage is calculated by the sum of storage in all layers. For each individual layer the storage is calculated with the multiplication of saturation, porosity and the extent of the individual layer.

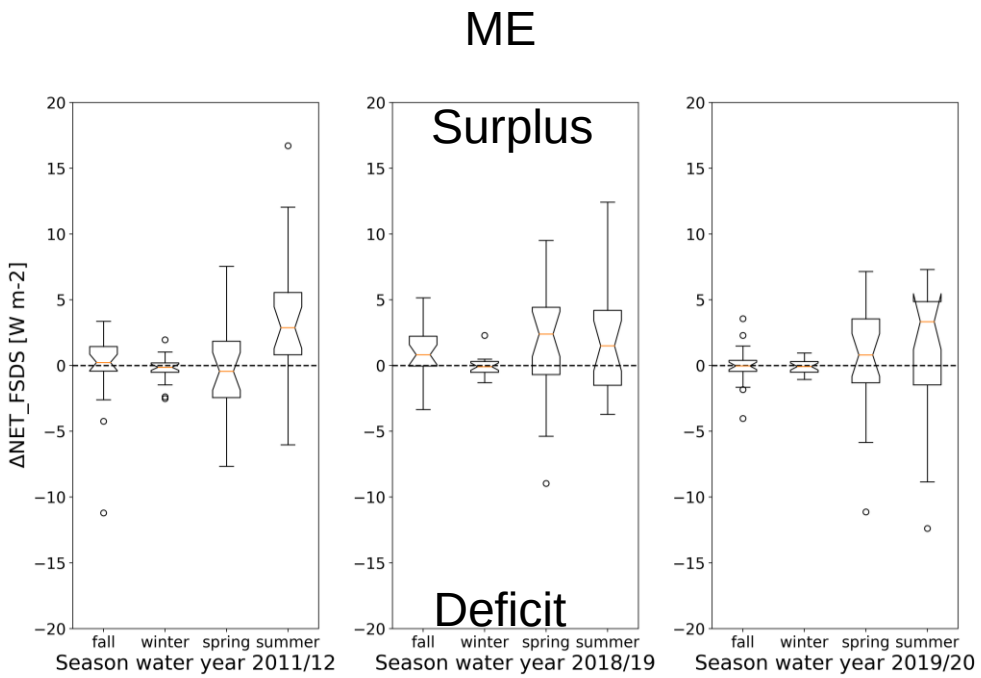
- In all experiments a consistent deficit of subsurface water storage still exists in the next summer after the initialization in the previous fall.

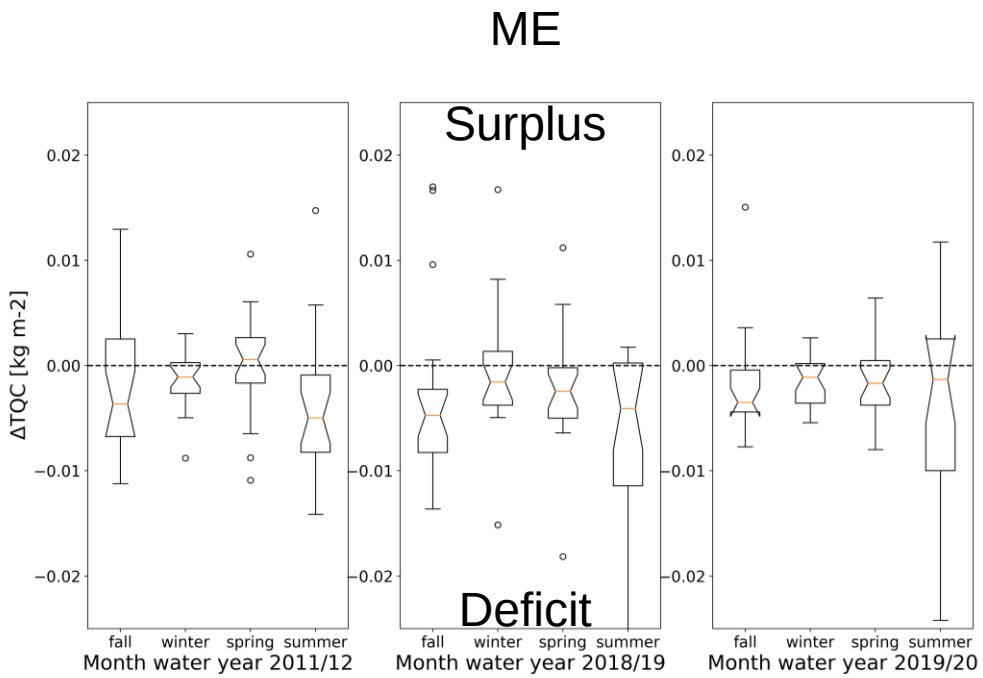
- Does this lead to a feedback on cloud cover and the energy fluxes?



Feedbacks: Net solar radiation and cloud water

Experiments with initial drought conditions compared to the original climatology





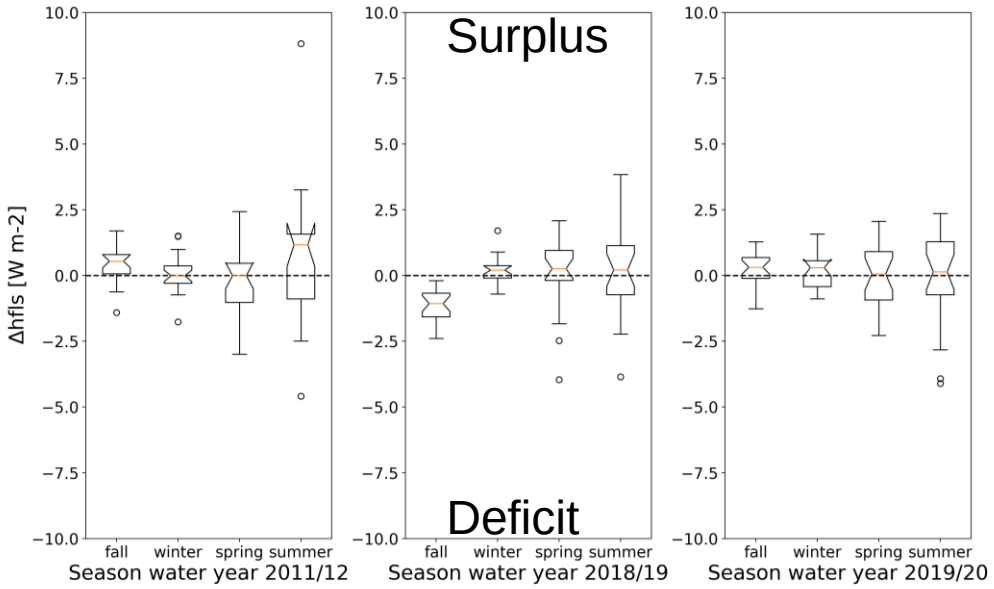
Consistent surplus of net solar radiation and deficit of total cloud water in the next summer

What about the energy fluxes?

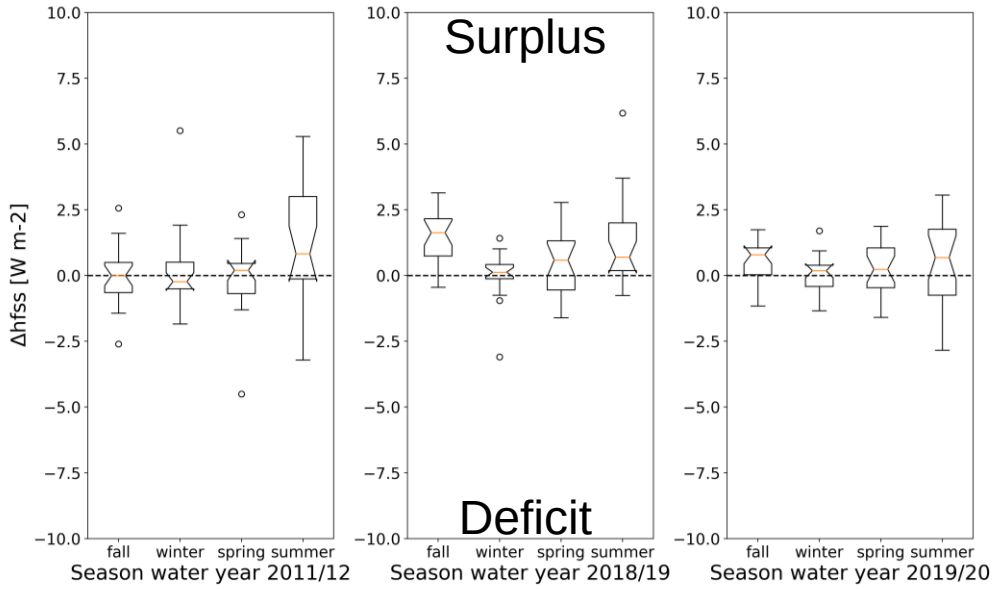
Feedbacks: Latent heat and sensible heat flux

Experiments with initial drought conditions compared to the original climatology

ME



ME



Change in sensible heat flux is consistent and likely more influential to solar radiation/cloud cover than the latent heat flux.

Summary and conclusions

- We applied ensemble simulations of the three anomalously dry water years (September to August) 2011, 2018 and 2019 over Europe with the Terrestrial Systems Modeling Platform (TSMP).

- Each of the three ensembles is simulated with ERA-Interim boundary data from 1996 to 2019, enabling possible feedbacks between the drought conditions and various evolutions of large-scale weather.

- All three ensembles show a significant increase in solar radiation in the summer after the initialization which could mean an intensification of drought conditions on the interannual timescale.

References

- Gasper, F., Goergen, K., Shrestha, P., Sulis, M., Rihani, J., Geimer, M., and Kollet, S.: Implementation and scaling of the fully coupled Terrestrial Systems Modeling Platform (TerrSysMP v1.0) in a massively parallel supercomputing environment – a case study on JUQUEEN (IBM Blue Gene/Q), Geosci. Model Dev., 7, 2531–2543, https://doi.org/10.5194/gmd-7-2531-2014, 2014.
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- Hartick, C., Furusho-Percot, C., Goergen, K., & Kollet, S. (2021). An interannual probabilistic assessment of subsurface water storage over Europe using a fully coupled terrestrial model. Water Resources Research, 57, e2020WR027828. https://doi. org/10.1029/2020WR027828

Appendix: Idealized experiments

Additional experiment to show potential feedback

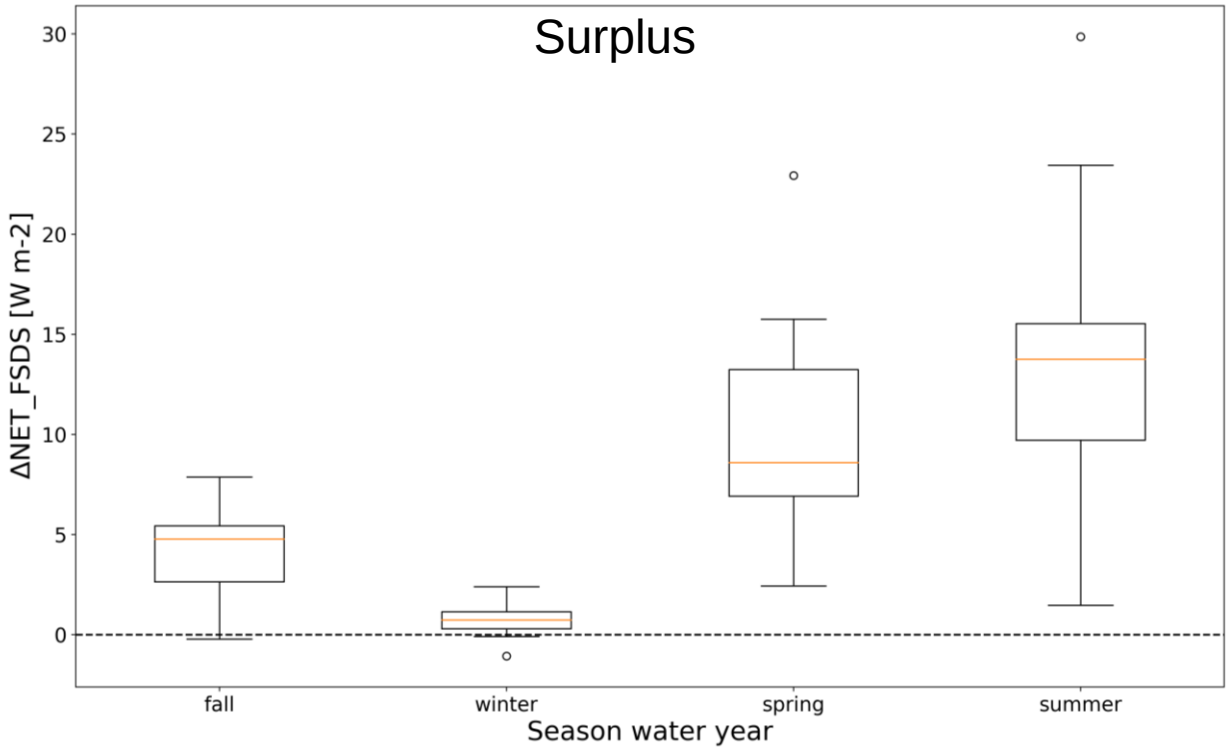
- Ensemble with ERA-Interim boundary data from 1996 to 2019 with constant subsurface conditions
- Dry: subsurface is kept at the wilting point
- Wet: subsurface is kept completely saturated
- What is the maximum feedback in terms of net solar radiation in the model?

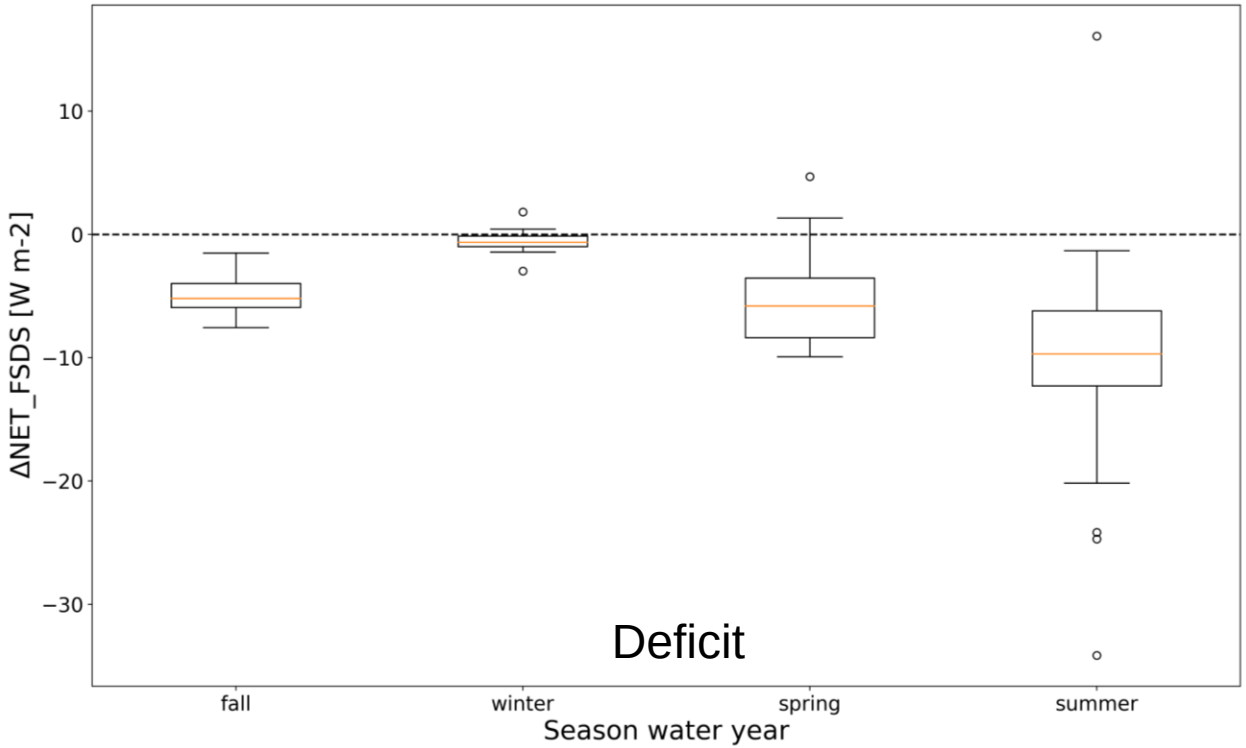
Increments for the idealized experiments

Net solar radiation

Dry

Wet





Idealized experiments lead to clear positive/negative increments.