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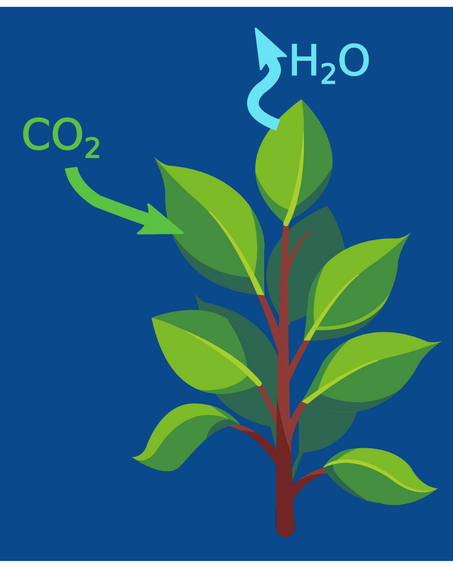
Variability of terrestrial ecosystem water-use efficiency in Europe

Introduction

In the course of more likely and severe hydrological extreme conditions in Europe with ongoing climate change, we take on to quantify the effects of droughts on ecosystem process such as the assimilation of carbon through photosynthesis and the evapotranspiration of water. By making analyses of multiple data sources and measurement and modelling scales, we assess the change of the water-use efficiency (WUE, photosynthesis, GPP, divided by evapotranspiration, ET) during droughts. Additionally, we conduct an exploratory causal network analysis to discover spatio-temporal as well as land-cover related patterns of environmental drivers of WUE.

We made use of the compute time resources of the jibg31 project and JURECA-DC. The pan-European 3 km study domain consisted of 1544 x 1592 grid cells and was modelled using 1152 cpus in parallel, that calculated 8 simulation years per day. After finishing the 1500 simulation year spin-up procedure, we conducted 24-year production runs from 1995-2018.



Methods

Data

- **Remote sensing**
  - GLASS (Photosynthesis, Evapotranspiration)
- **Reanalyses**
  - COSMO REA6 (Meteorology)
- **In-Situ**
  - eLTER (Carbon and water flux)

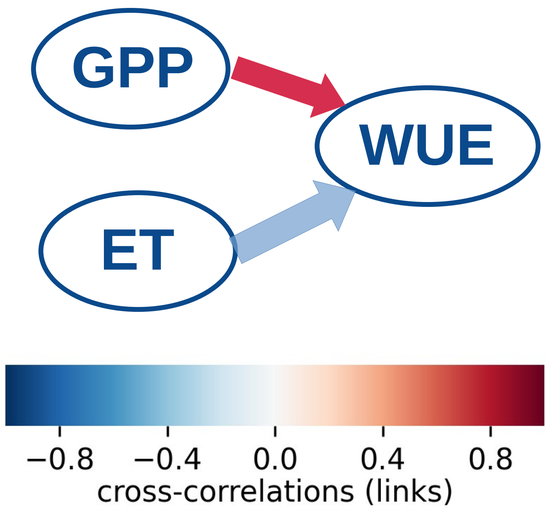
CLM5-BGC Model

- **Pan-European domain**
  - 3 x 3 km
- **Dynamic Carbon and Nitrogen**
  - Vegetation modelled dynamically
- **Output vegetation states**
  - Continuous timeseries
  - Carbon and water fluxes
  - Hydrological conditions considered

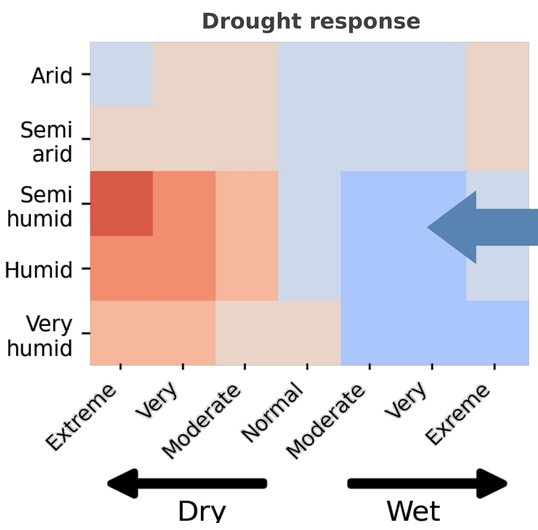
Analyses

- **Long term trends**
  - 1995 to 2018
  - From observations and models
- **Drought response**
  - WUE anomalies when there is a soil moisture deficit
- **Environmental driver analysis**
  - Causal networks around WUE

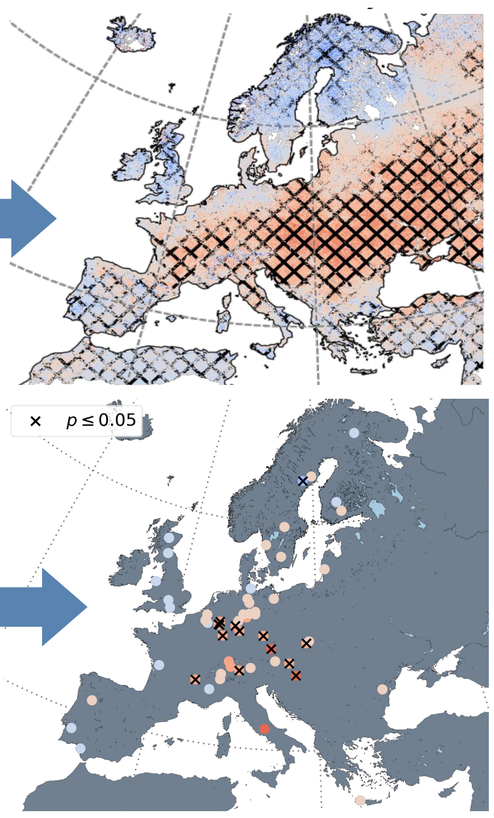
Example subset of causal network

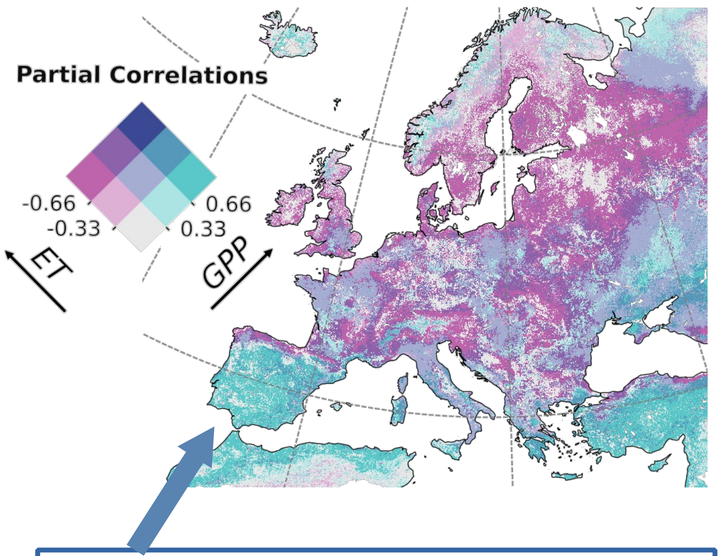


Results



- **Decreasing Trends in Central and Eastern Europe**
- **Increasing Trends in Northern and Southern Europe**
- **Largest negative drought response in semi humid hydro-climates**
- **Unavailability of eddy-covariance sites in Eastern Europe hinder discovery of WUE trends with in-situ that are visible in remote-sensing data**





- **WUE change is mostly explained by Evapotranspiration (ET) in Central and Eastern and by Photosynthesis (GPP) in Southern Europe in observation and CLM5.**

Conclusion

We find concurrent extents of WUE trends between observations (satellite and in-situ) and the CLM5 model. In particular, we find decreasing WUE in Central Europe, where evapotranspiration governs WUE variability. Increasing atmospheric water demand lead to more drought-stress in the vegetation, decreasing the water use efficiency irrespective of the hydro-climate an d land-cover class. We emphasize the role of atmospheric dryness on ecosystem functioning and that this threat could downgrade the performance of ecosystems as an impact of climate change. Further studies are needed to scrutinize land-cover specific responses by considering transpiration only as ecosystem water-use and normalizing plant physiological responses to different VPD regimes through stomatal adaptations. The environmental drivers that cause ET and GPP, in turn, still need to be analysed and discussed as well, to have the complete causal ecosystem network around WUE covered and track the drivers of ecosystem functions that WUE is composed of. Lastly, we underline the missing opportunities of verification and evaluation in Southern and Eastern Europe because of the lack of in-situ sites.