POTSDAM INSTITUTE FOR
CLIMATE IMPACT RESEARCH

Forest Type and Groundwater Recharge under Climate Change: A Study using the Eco-Hydrological Model SWIM in mesoscale Sub-Basins of the Havel River, Germany

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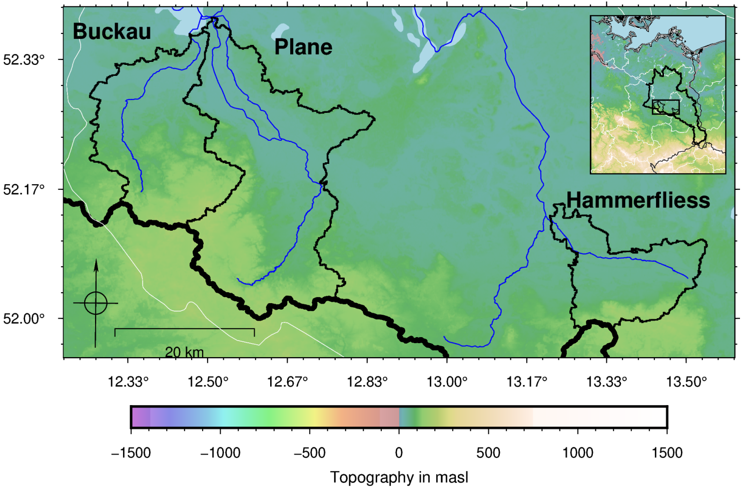
Presented by Henry Engelhardt

SWAT-Conference, Aarhus, June 28, 2023

Introduction

Sources: https://www.youtube.com/watch?v=ye8zcgxWMDc,
https://www.sueddeutsche.de/politik/wasser-trockenheit-berlin-brandenburg-1.5559236?reduced=true,
https://www.thuenen.de/de/themenfelder/waelder/forstliches-umweltmonitoring-mehr-als-nur-daten/waldschaeden-durch-trockenheit-und-hitze,
https://www.maz-online.de/lokales/potsdam-mittelmark/seddiner-see/nun-doch-nieplitz-wasser-soll-seddiner-see-retten-NERPRHND7JVCM2BI7U76CR76BM.html

Introduction - Subcatchments

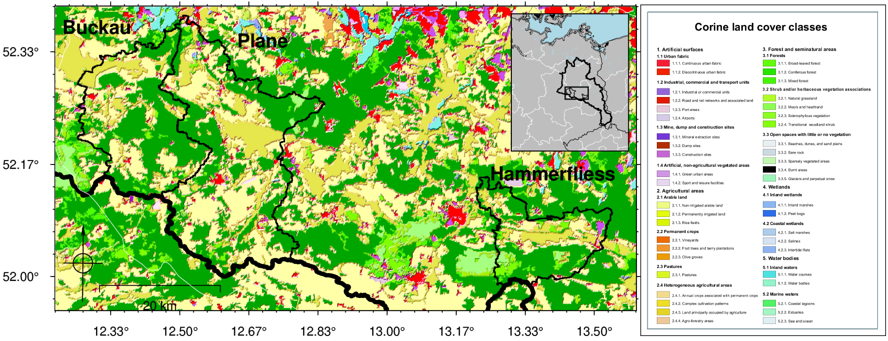


Buckau: 360 km²; Plane: 600 km²; Hammerfließ: 210 km²

Source: Topo Map - NASA SRTM (Farr et al. 2007)

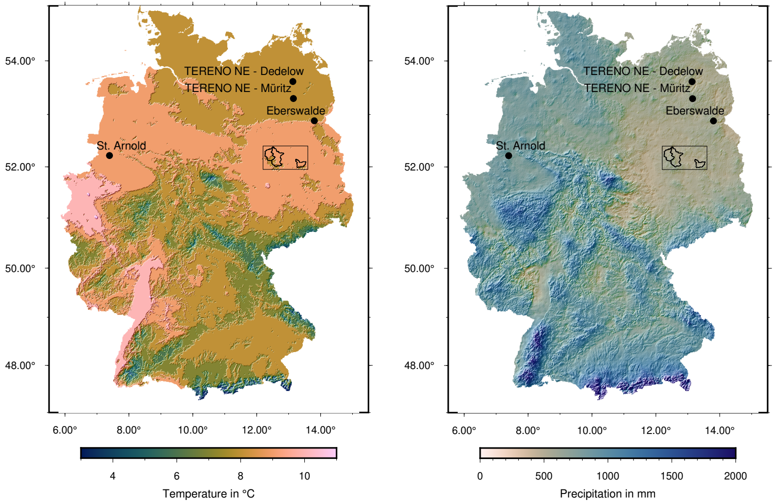
Introduction - Land Use

- Land use is dominated by conifer forest and agricultural land
- Only small plots of decidious or mixed forest
- Surrounding is densely populated (Berlin, Potsdam) but low population density in the catchments



Source: Copernicus 2020

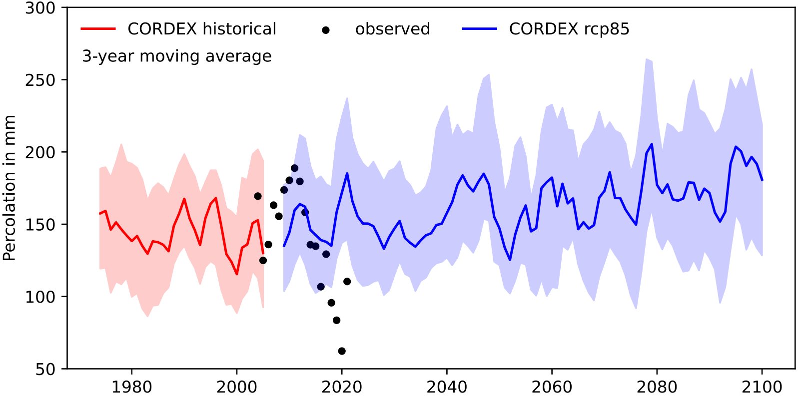
Introduction - Climate Situation



Source: DWD CDC n.d.(c); DWD CDC n.d.(b)

Introduction - CMIP5 Projections

- CMIP5 models project an increase in percolation in the RCP85 scenario
- Observations show a decrease in percolation in recent years

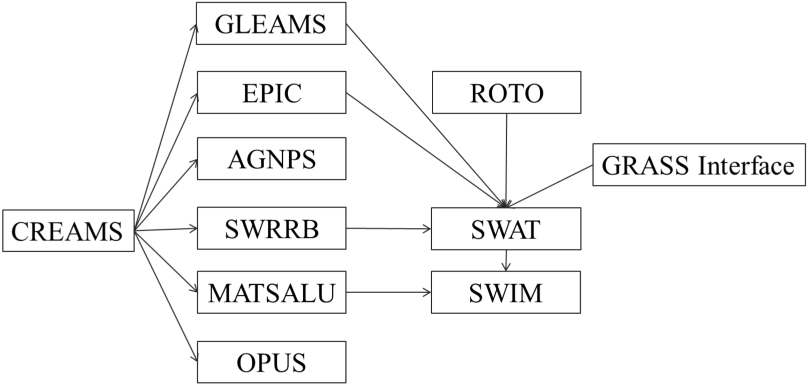


Introduction - Research Question

- How does forest restructuring affect groundwater recharge in the Havel River Basin?
- How does climate change affect groundwater recharge in the Havel River Basin?
- Are there differences between the CMIP5 and CMIP6 ensembles?
- Do CMIP6 models capture the observed trends in recent years?

Methods - SWIM Soil and Water Integrated Model

- SWIM is the eco-hydrological model used in this study
- Similar to SWAT because it is based on SWAT and MATSALU
- MATSALU integrated a three layer spatial disaggregation (soil, landuse and watersheds)



Source: Krysanova et al. 2000

Methods - Data used for the model setup

- Subcatchments are run seperately in Havel River Basin model
- Model operates on 10m resolution and daily timestep

- Climate station data (DWD) interpolated using kriging
- RADKLIM (1km radar based precipitation data) from DWD (Winterrath et al. 2018)
  - available from 2001-2021

- Discharge from 12 gauges in the Havel River Basin (4 used for calibration) from LfU Brandenburg

Methods - Discharge Calibration

- Calibration was conducted for three subcatchments (Buckau, Plane, Hammerfliess)
- Plane catchment was calibrated to two outflows of a subcatchment (Temnitz and Plane)

- Years were divided for the purpose of calibration (11 years) and validation (9 years)
- Selection was randomized and repeated until mean precipitation and variance were below 1 mm and 10 mm

- Nash Sutcliffe Efficiency (NSE) and Kling Gupta Efficiency (KGE) were used as objective functions
- Percent Bias (PBIAS) was used as additional objective function

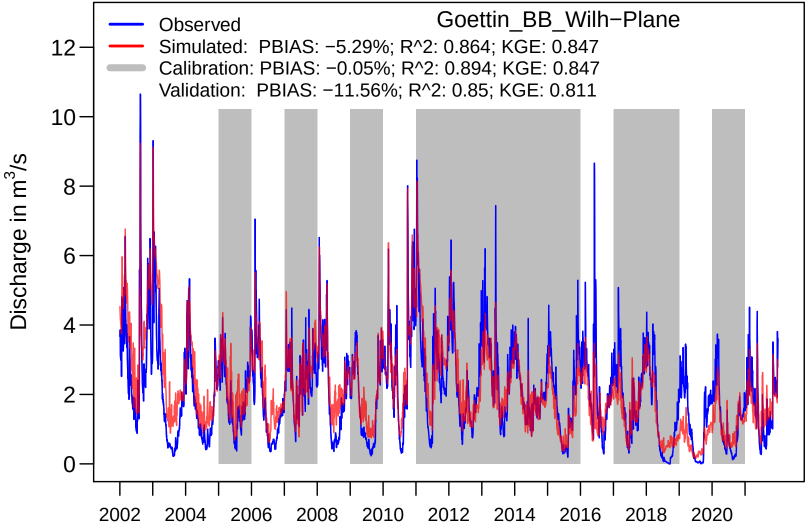
Methods - other Calibrations

- Calibration of forest canopy storage
  - Throughfall data from (Blume et al. 2021)
    - Stemflow was neglected due to unavailable data and minor influence
- Forest specific water balances from lysimeter data (Harsch et al. 2009; Müller 2013)
  - Large variation due to specific characteristics (e.g. age of stands)
  - Overall: Percolation is higher for decidious forests
- Potential evapotranspiration (PET) with DWD data (monthly grids, AMBAV) and data from a close climate station (Groh et al. 2020; DWD CDC n.d.[a])
  - both datasets suggest more PET in winter
  - therefore use of Turc-Ivanov with monthly correction factor

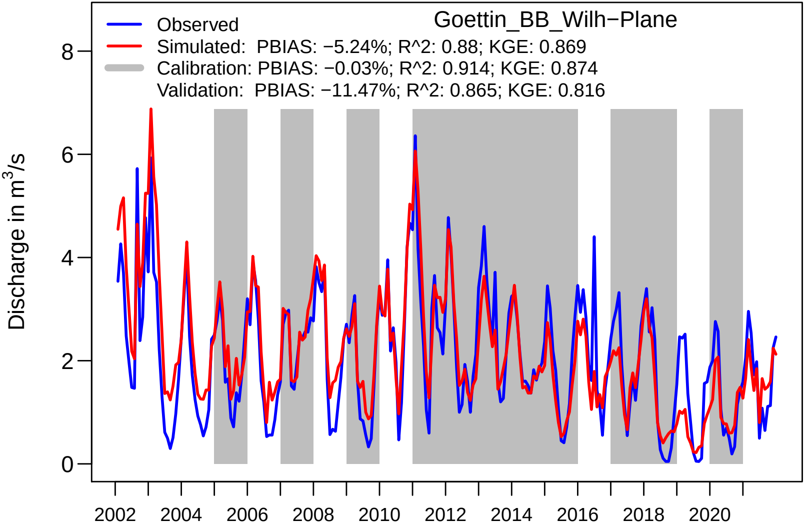
Methods - Study setup

- Sensitivity analysis
  - runs with only decidious forest, only coniferous forest and exclusion of interception process
  - runs with increased temperature, decreased precipitation, increased PET and increased radiation
- Climate change projections (hist and SSP-585/RCP85)
  - CMIP6 data from the ISIMIP project (0.5°) (Lange 2021)
  - CMIP6 data from the NEX-GDDP project (0.25°) (Thrasher et al. 2022)
  - CMIP5 data from the CORDEX project (EUR11; 0.11°) (Jacob et al. 2014)
- Forest restructuring scenarios (over climate projection period)
  - 100% coniferous forest, 100% decidious forest
  - ordered versus random restructuring based on differences in percolation in the sensitivity runs

Results - Discharge Calibration - Monthly



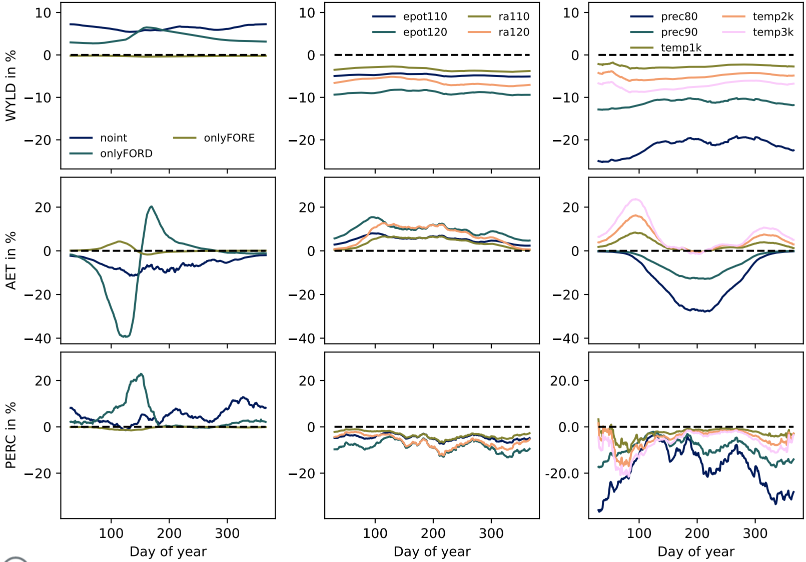
Results - Discharge Calibration - Daily



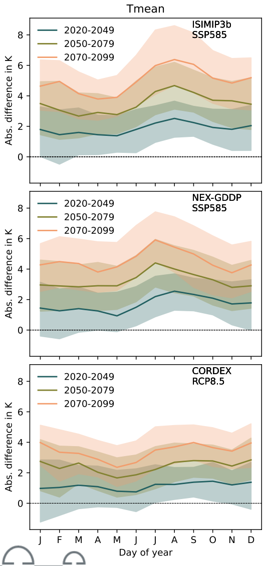
Results - Discharge Calibration

- Monthly simulations show a good fit for all subcatchments ($0.86 > \text{KGE} < 0.90$)
- Some years with high differences (e.g. 2003, 2004, 2014, 2015 and 2019)
  - because of drought conditions?
- First half of the simulation (wetter years) more problems with summer discharge
- Second half (drier years) more problems with winter discharge
- Sufficient discharge calibration for the aim of the study

Results - Sensitivity runs

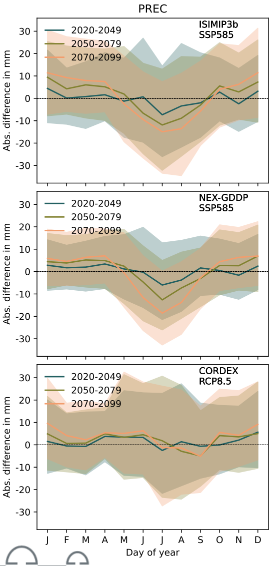


Results - Climate projection runs - Temperature



- All ensembles show a strong temperature increase
- The increase is more pronounced in the CMIP6 SSP585 pathway than in CMIP5 RCP8.5
- CMIP6 ensembles have peak increase in summer months

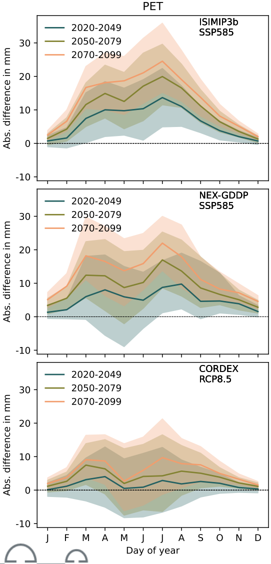
Results - Climate projection runs - Precipitation



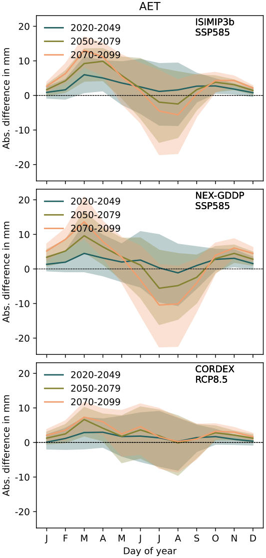
- CMIP6 ensembles show a decrease in summer precipitation
- increase in winter precipiation

- CORDEX ensemble suggests increase in all months but in JAS

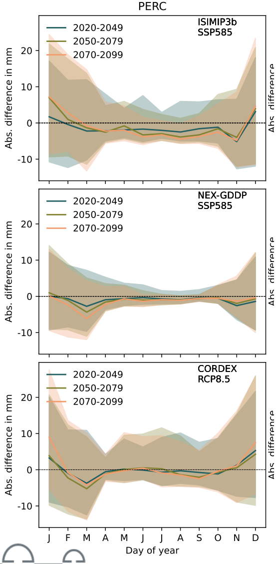
Results - Climate projection runs - PET and AET



- Increase in PET is not met by AET
- AET shows a decreasing trend in summer for CMIP6 ensembles
- Strong increase in winter and spring months



Results - Climate projection runs - Percolation

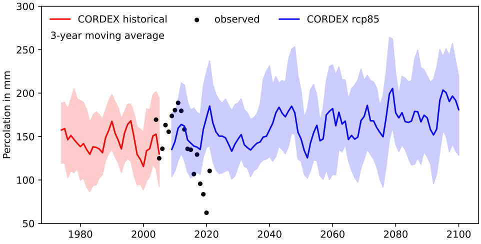


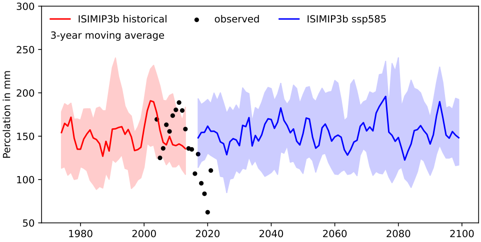
- A decrease is observed in all seasons except winte

- Slight decrease in all seasons including winter

- Increase in winter, decrease in March and late summer

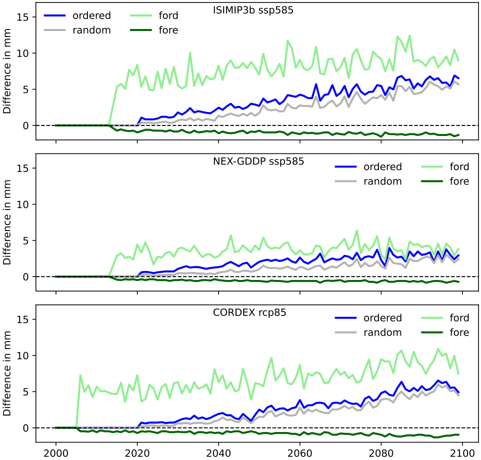
Results - Climate projection runs - Percolation





- ISIMIP3b ensemble projects relatively consistent percolation rates
- Increase in winter percolation and decrease in summer percolation balance each other out

Results - Forest conversion scenario



- Ordered forest conversion has a larger impact on percolation than random forest conversion

Conclusions

- Forest conversion has the potential to increase percolation by up to 10mm at the end of the century
- Assessing the capacity of different areas to promote groundwater recharge might increase the impact especially in the recent future
- Changing climate conditions might increase the difference between FORE and FORD in groundwater recharge

- CMIP6 ensembles capture the recent observed trend slightly better
- Especially the decrease in summer precipitation is included

Source: https://www.washingtonpost.com/opinions/2022/11/07/elon-musk-mars-twitter-verification/

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