Calibration Complexity and Climate Impacts: The Role of Plants and ET

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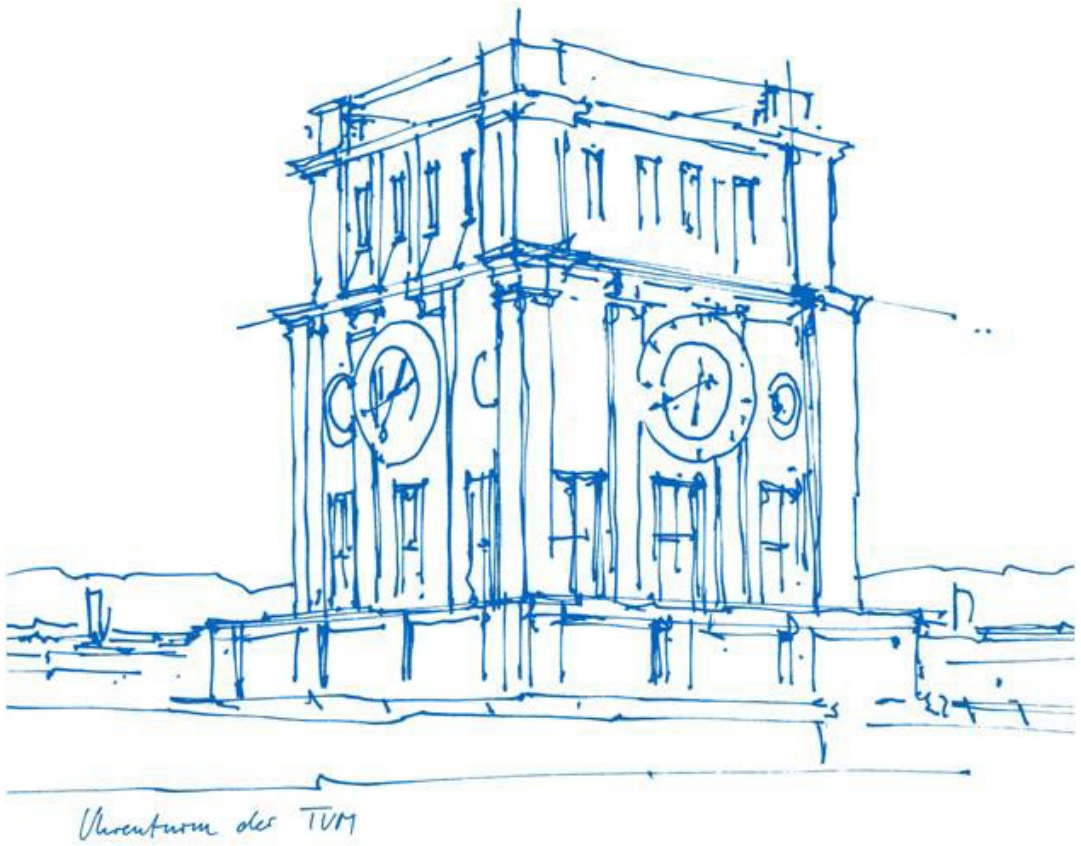
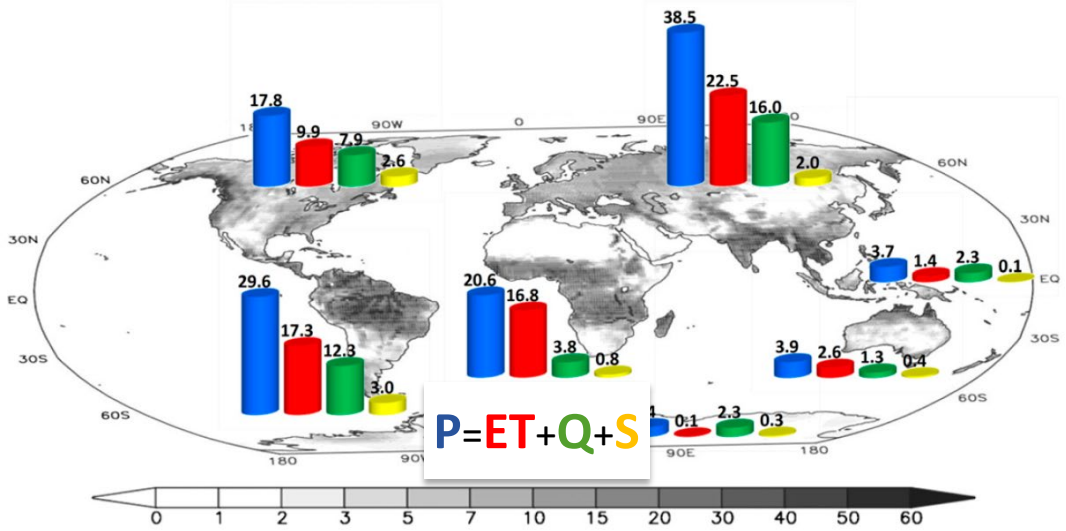
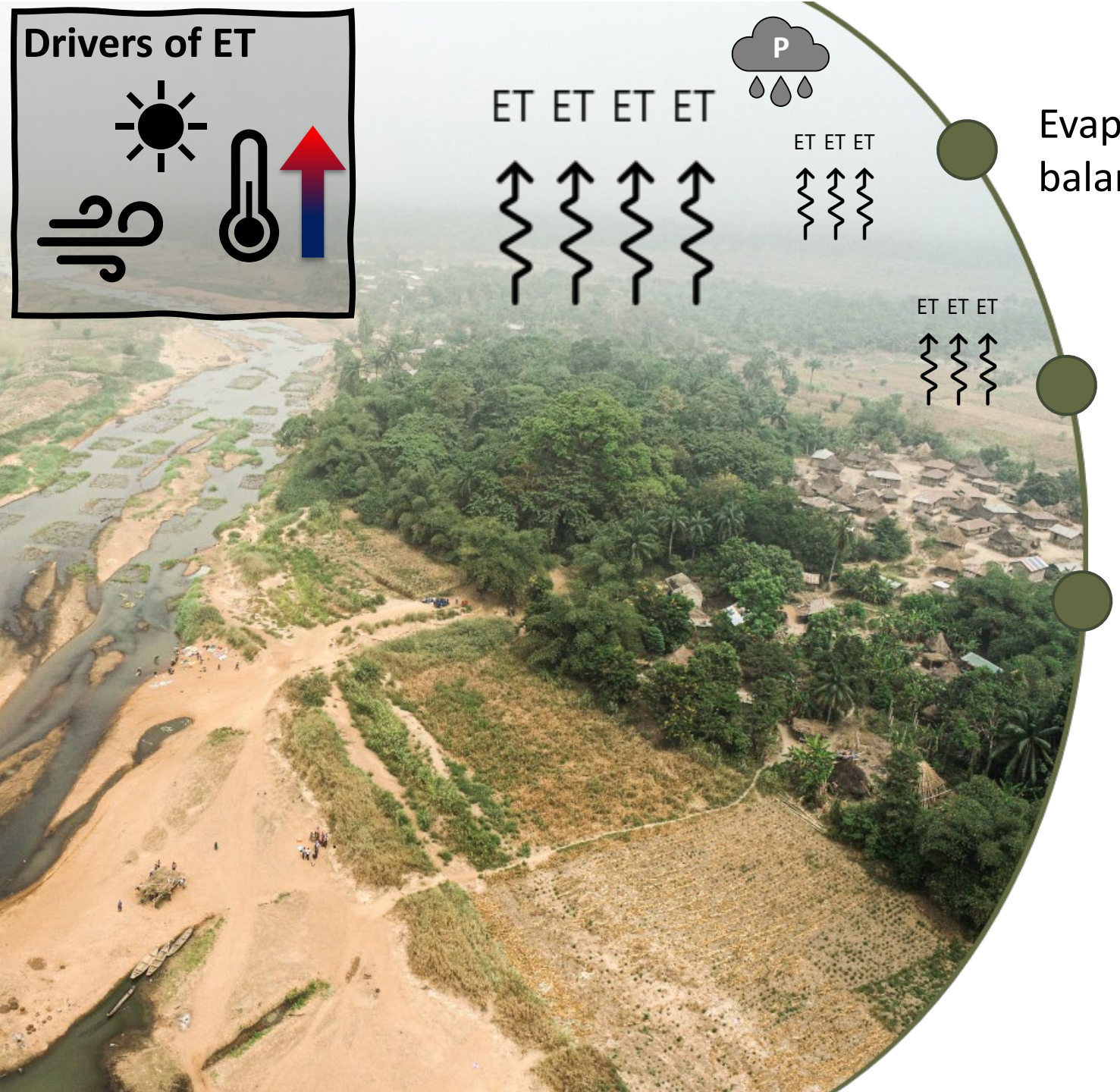


Motivation and Background

Evapotranspiration (ET) is essential water balance process in the tropics: **ET/P ≈ 70 - 80%**



Global annual-mean fluxes (10^3 km^3/yr) Rodell et al. (2015)



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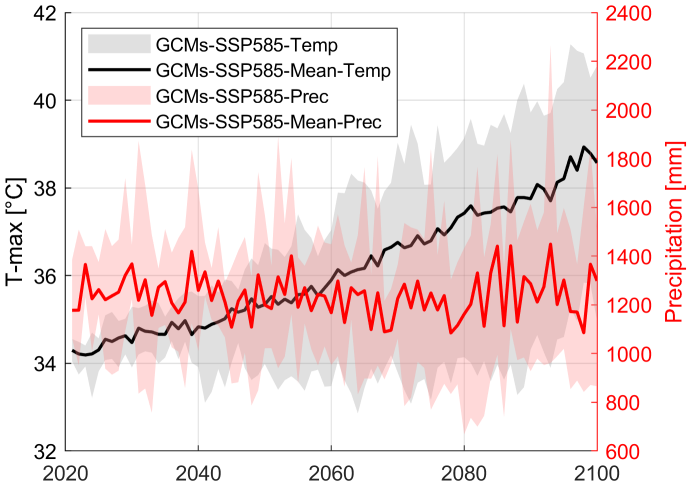
Depends on energy (T, rad, wind, rh)

Estimated with LAI in SWAT

The drivers for ET are changing

Higher future radiation & temperature



Drivers of ET

River	CC Data	ΔP	ΔQ	ΔAET	Study
Niger basin					
Koulikoro	AMMA-ENSEMBLES (A1B; near, mid, far future)	+[1]	+	*none*	Angelina et al. (2015)
Niger	CMIP5 (RCP2.5, 8.5; end of 21st century)	o[2]	+	*none*	Krysanova et al. (2017) & Eisner et al. (2017)
Kaduna	CORDEX-Africa (RCP8.5; complete 21st century)	o	+	-*	Animashaun et al. (2023)
Niger	CMIP5 (RCP2.6, 6.0, 8.5; far future)	o	-	-	Chawanda et al. (2024)
Togo					
Mono	CORDEX (RCP4.5, 8.5; 2021–2070)	+[1]	+	*none*	Houngue et al. (2023)
Ouémé basin					
Djougou	REMO (A1B, B1; near future)	-	-	-*	Bossa et al. (2012)
Ouémé	REMO (A1B, B1; near future)	-	-	-*	Bossa et al. (2014)
Upper Ouémé	REMO (A1B, B1; mid future)	-	-	+*	Danvi et al. (2018)
Ghana					
Volta	ECHAM4 (A1B; mid/far future)	-	-	-*	Sood et al. (2013)
White Volta	Ensemble from ECHAM4 & CSIRO (A1FI; near/mid future)	-	-	*none*	Kankam-Yeboah et al. (2013)
Pra	Ensemble from ECHAM4 & CSIRO (A1FI; near/mid future)	-	-	*none*	Kankam-Yeboah et al. (2013)
Owabi	CCCMA (RCP2.6, 4.5, 8.5; near future)	-	-	*none*	Osei et al. (2019)
Pra	CORDEX-Africa (RCP8.5; near, mid, far future)	o	o	*none*	Awotwi et al. (2021)
Vea	CORDEX-Africa (RCP4.5; near to mid future)	+	-	+*	Larbi et al. (2021)
Burkina Faso					
Tougou	CMIP6 (SSP2-4.5, 8.5; near to mid future)	+	+	*none*	Yonaba et al. (2023)

Merk et al., in preparation

P

ET ET ET

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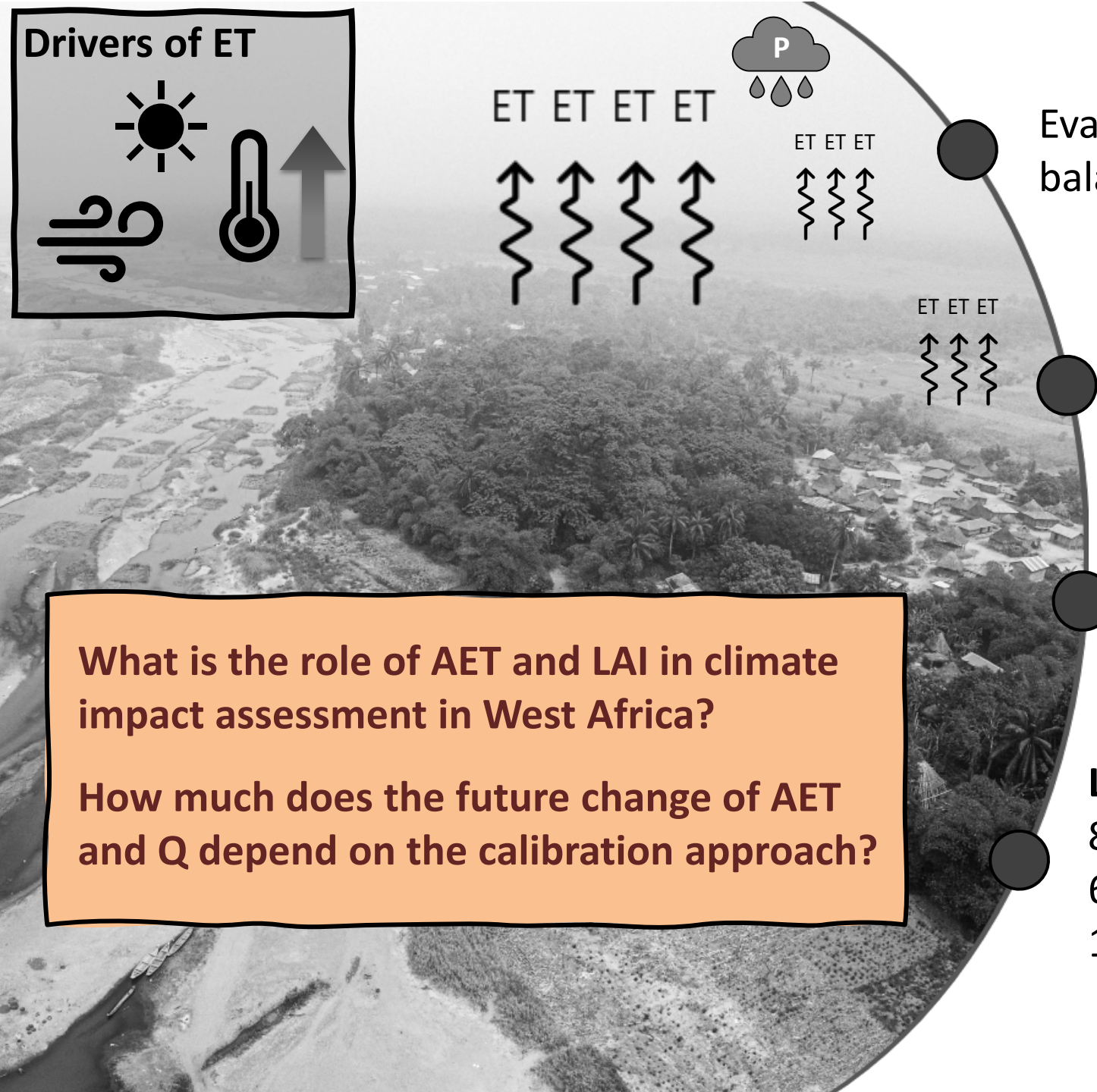
Lack of ET for climate change in West Africa
8 of 15 SWAT studies: no ET at all
6 of 15 studies: ET without calibration
1 of 15 studies: ET changes with calibration



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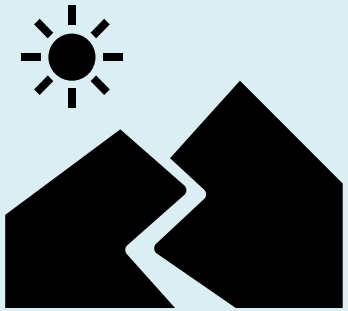
What is the role of AET and LAI in climate impact assessment in West Africa?

How much does the future change of AET and Q depend on the calibration approach?

Methodology

Methodology – 4 key steps

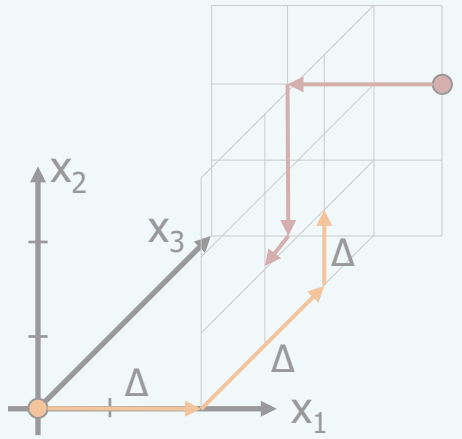
1



SWAT-T
catchment scale

SWAT-T by Alemayehu et al., 2017

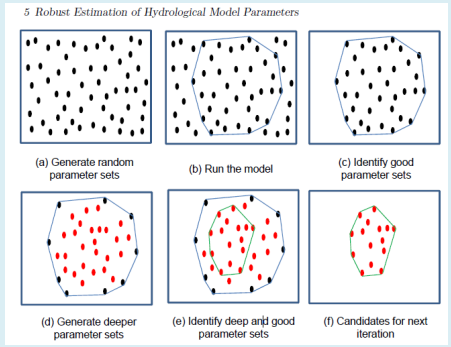
2



Global SA
with the Morris method (LAI)

27 parameters of SWAT-T

3

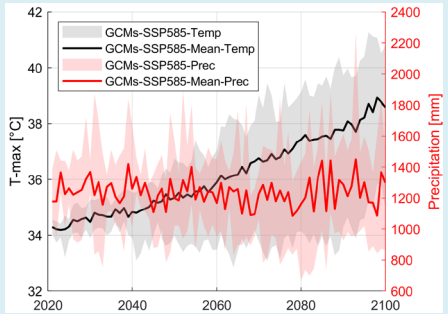


Singh (2014)

Optimization
with 3 strategies, ROPE algorithm

Bardossy & Singh, 2008

4



Climate impacts
from 3 calibration approaches

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Methodology – 4 key steps

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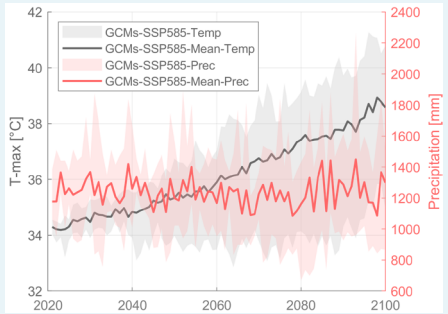

Climate impacts
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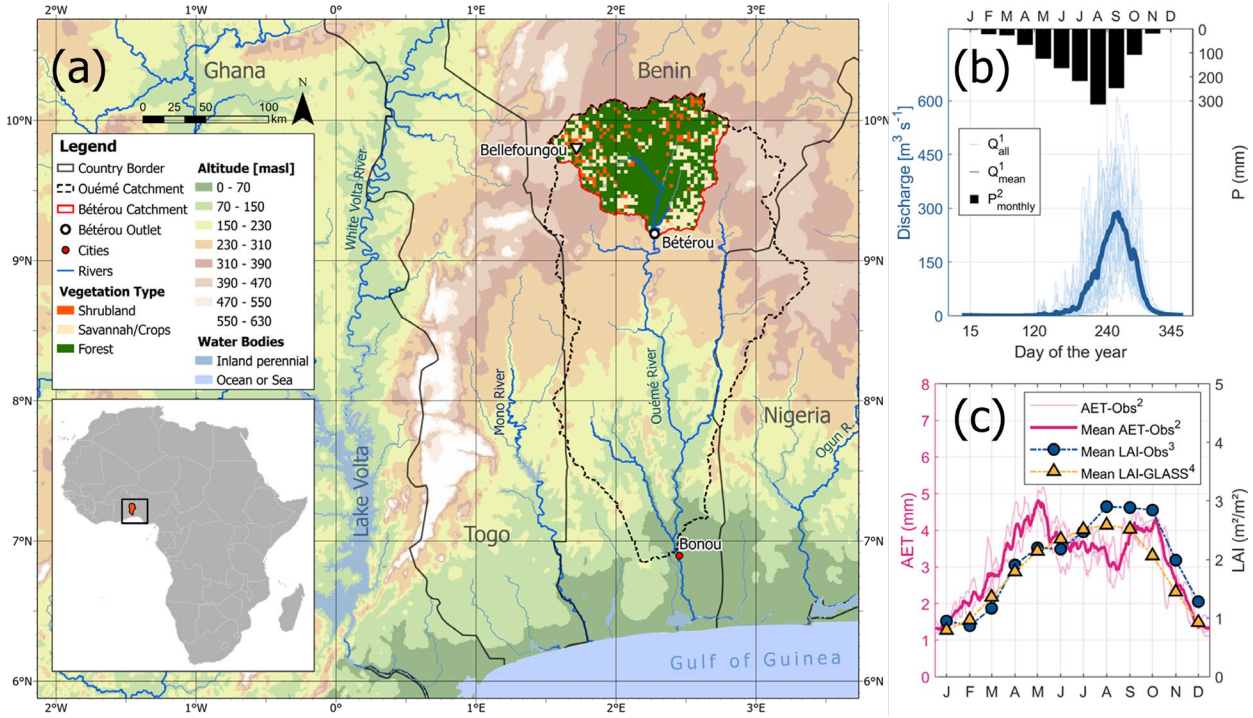
Bétérou Catchment



Distinct wet/dry seasonality

Sub-humid climate

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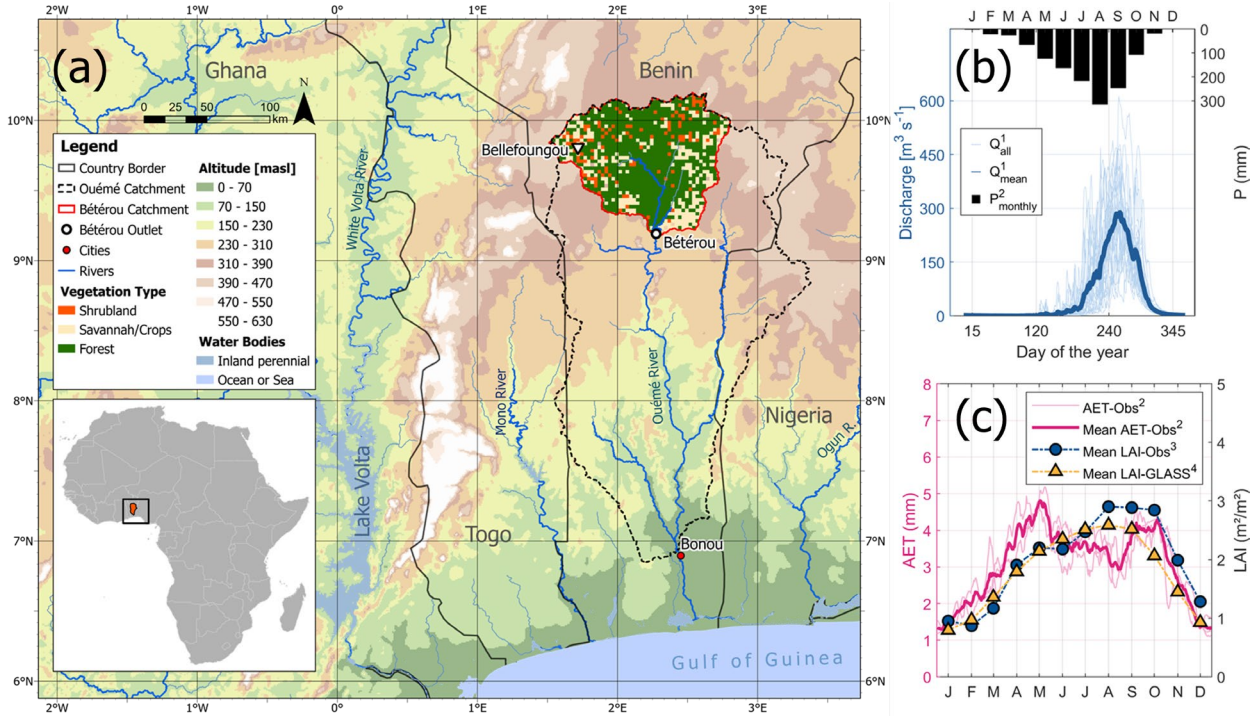
Methodology – 4 key steps

Bétérou Catchment

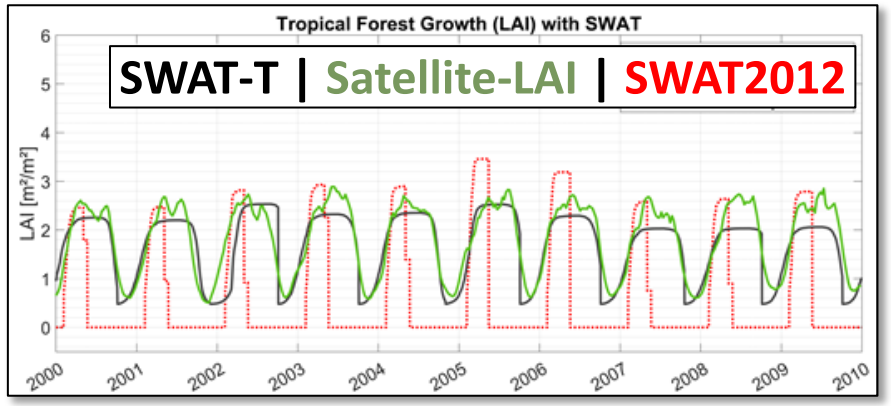


Distinct wet/dry seasonality

Sub-humid climate

We use the SWAT-T by Alemayehu et al., 2017:

→ Improved modelling of LAI in the tropics



Variables used for model evaluation:

Variable	Time	Source	Catchment
Q	Daily	Monitoring network	Outlet
LAI	8-daily	LAI-GLASS (Liang et al., 2014)	Global cover
AET	8-daily	FLUXCOM (Jung et al., 2019)	Global cover

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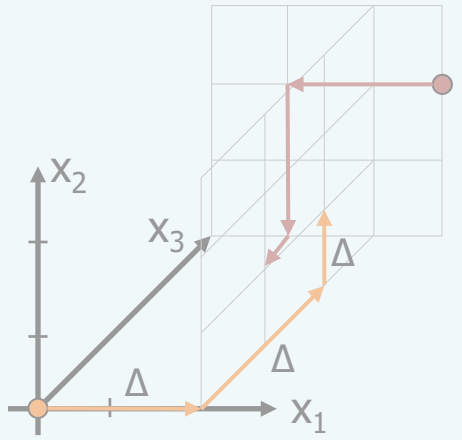
Methodology – 4 key steps

We use **3 calibration approaches** with different levels of complexity to evaluate the role of LAI and AET:

Label	Target	Objective function
Q	Q	$KGE_{eff} = KGE_Q$
QL	Q, LAI	$KGE_{eff} = ½\ KGE_Q + ½\ KGE_{LAI}$
QLA	Q, LAI, AET	$KGE_{eff} = 1/3\ KGE_Q + 1/3\ KGE_{LAI} + 1/3\ KGE_{AET}$

2 forcing data sets:

- W5E5 → baseline of ISIMIP future data
- Observed data → cross validation and ROPE potential



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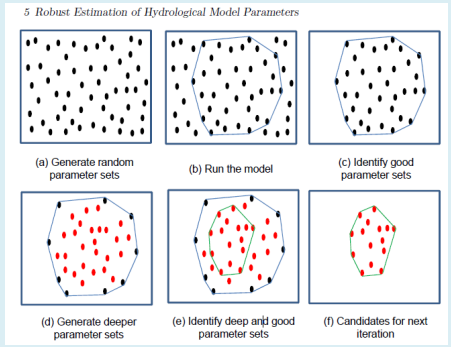
Global SA with the Morris method (LAI)

27 parameters of SWAT-T



Singh (2014)

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Optimization with 3 strategies, ROPE algorithm

Bardossy & Singh, 2008

Methodology – 4 key steps

ROPE = robust parameter estimation

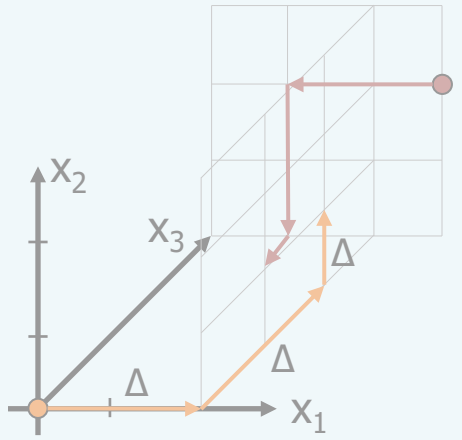
Key features of ROPE algorithm:

- Iterative optimization based on objective function, here: KGE
- Robustness: it uses a depth function to select good parameters for the next loop

Advantage: multiple **sets of parameters** that are near-optimal *(equifinality)*

Limit: multiple sets of parameters that are near-optimal → **no the global optimum**

Outcome: 20 sets of equally good parameters



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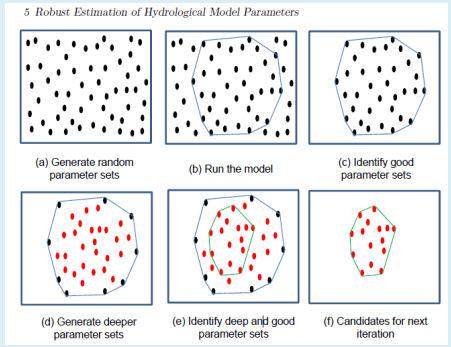

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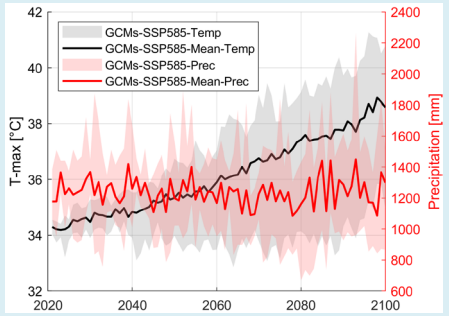
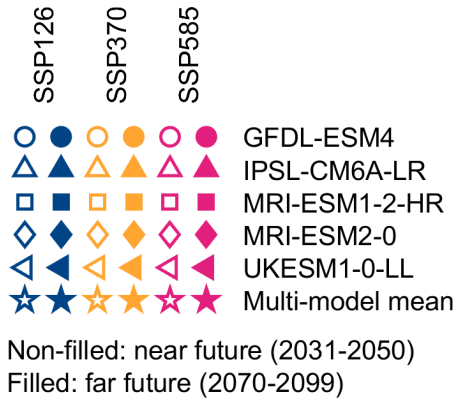


Climate impacts
from 3 calibration approaches

Future climate forcing data from ISIMIP3:

- 5 GCMs
- 3 SSP scenarios
- Evaluation: near and far future



Non-filled: near future (2031-2050)
Filled: far future (2070-2099)

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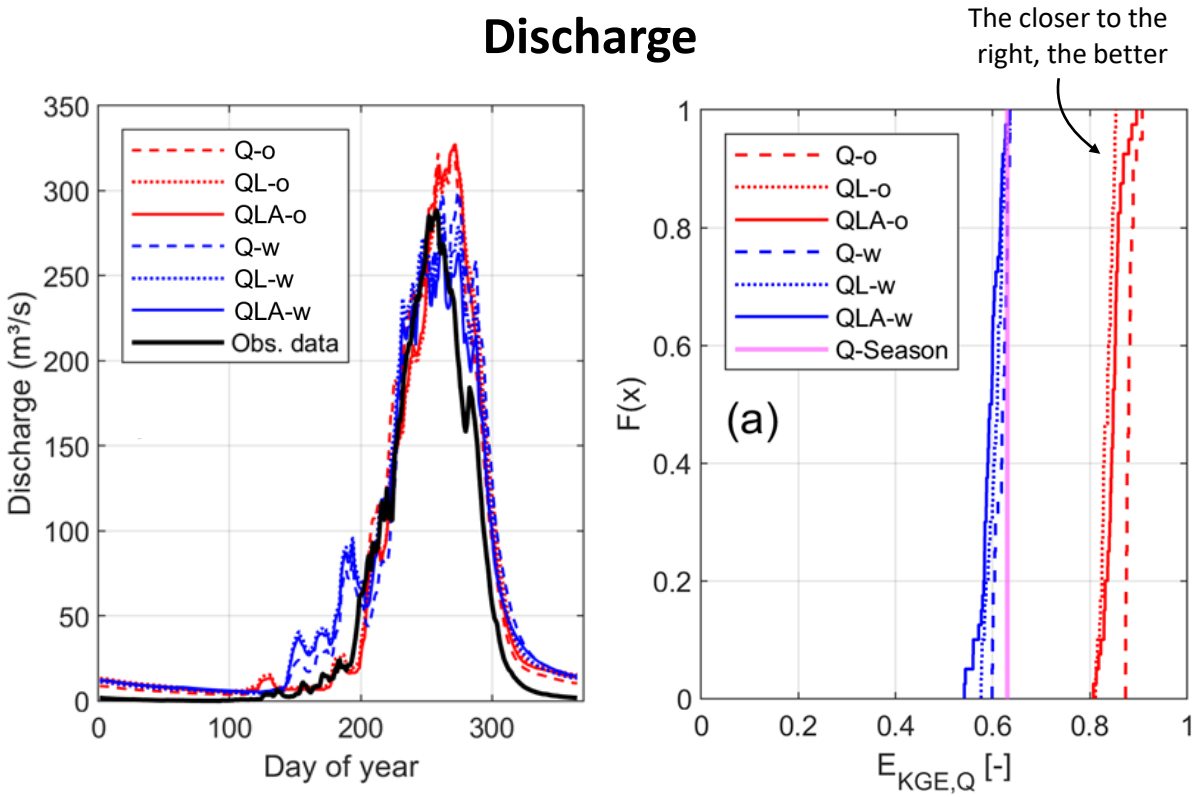
Results

Optimization with 3 approaches

Approaches:	Forcing data:	ROPE:
Q only	W5E5	20 sets
Q + LAI	Observed	
Q + LAI + AET		

Discharge



- **Discharge: W5E5 as good as seasonality**

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Optimization with 3 approaches

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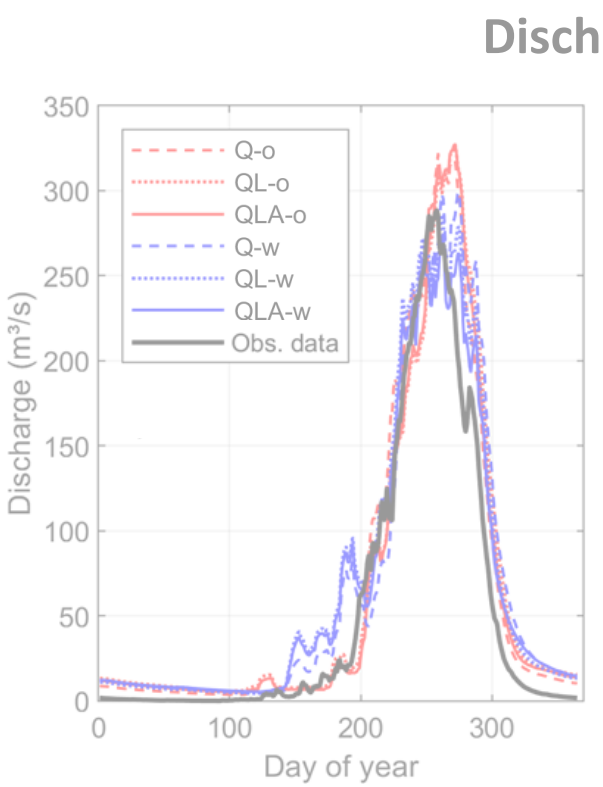

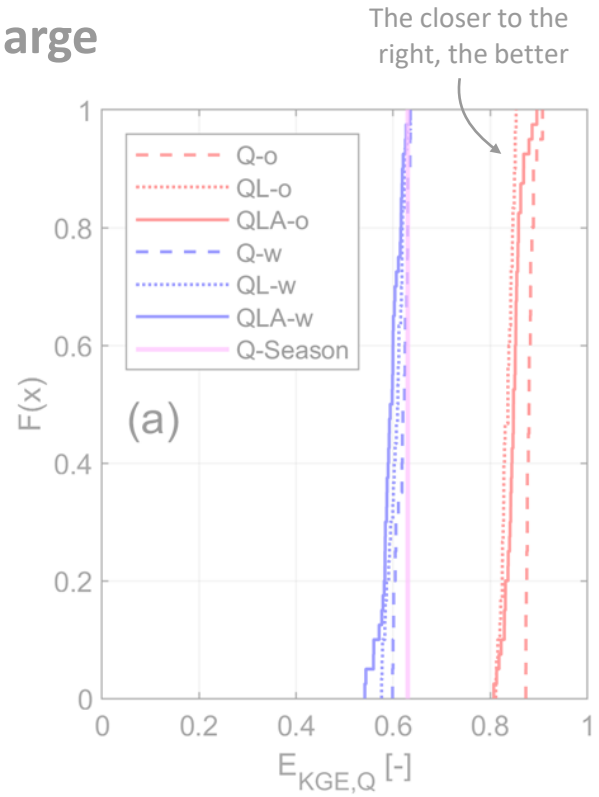

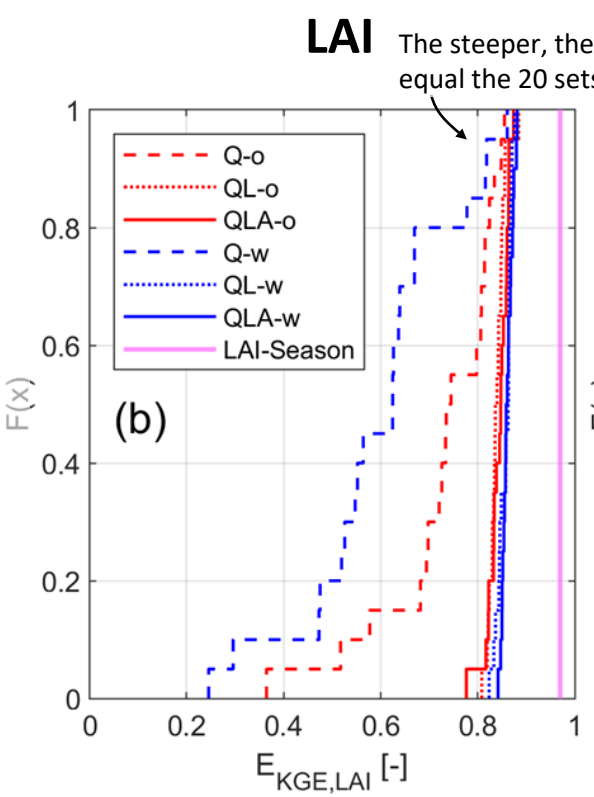

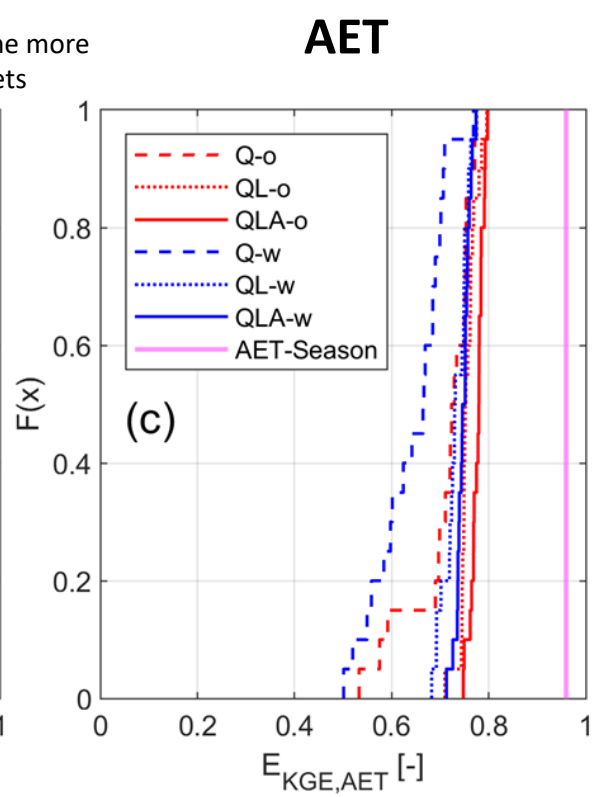

- Discharge: W5E5 as good as seasonality
- LAI: good fits if LAI is calibrated
- **AET: "Q + LAI" can also predict AET!**

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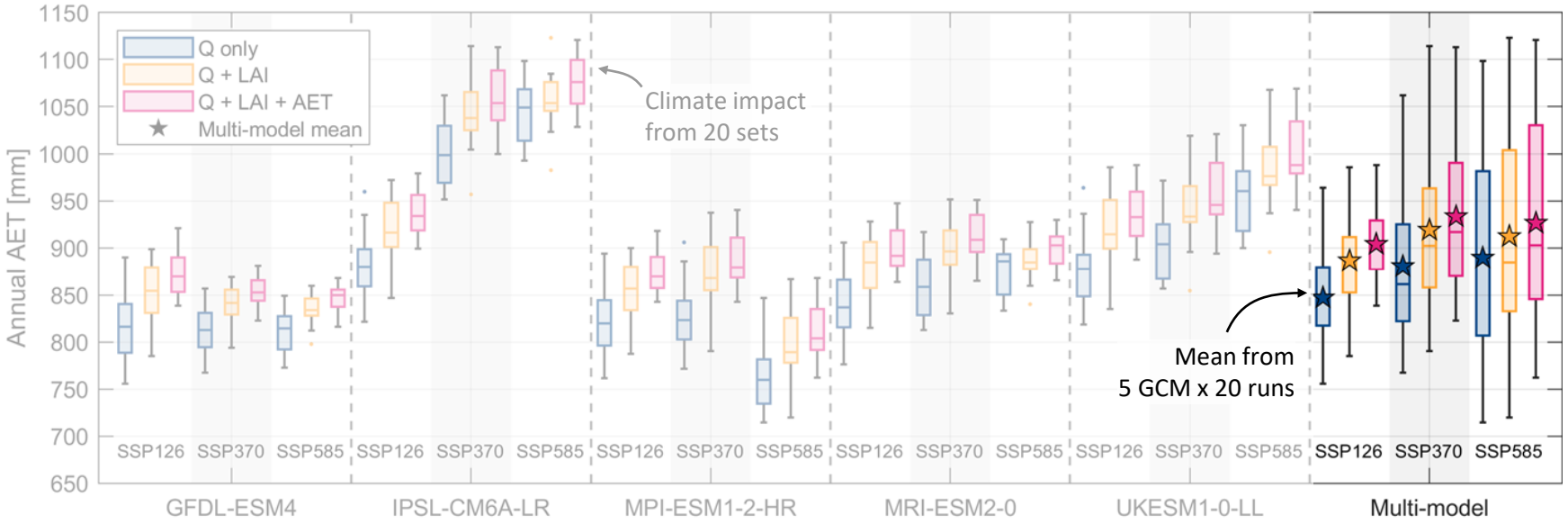
Climate impact assessment

Approaches:	Forcing data:	ROPE:
Q only	W5E5	20 sets
Q + LAI	~~Observed~~	
Q + LAI + AET	**ISIMIP3**	

What are the impacts of calibration approaches on the AET prediction?



Annual AET from 20 sets, far future (2070-2100)

- N = 20 in each boxchart
- "Q only" underestimates annual AET
- "Q+LAI" predicts annual AET like "Q+LAI +AET"
- **AET change prediction:**
  Q only = 4.03 %
  Q+L+A = 11.7 %

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Climate impact assessment

Approaches:	Forcing data:	ROPE:
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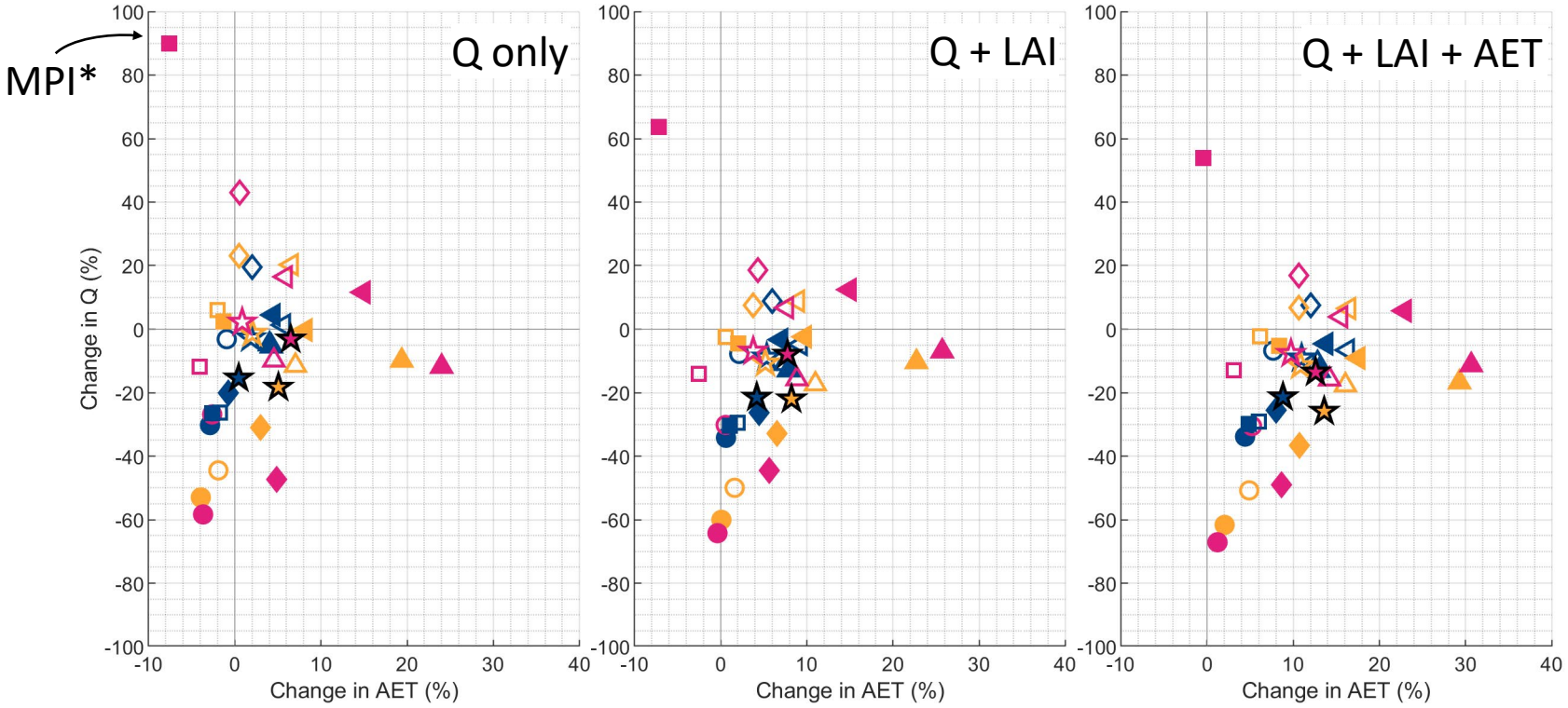
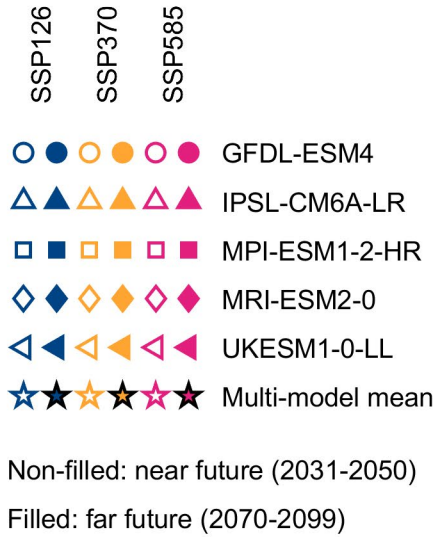
Future changes of discharge and AET



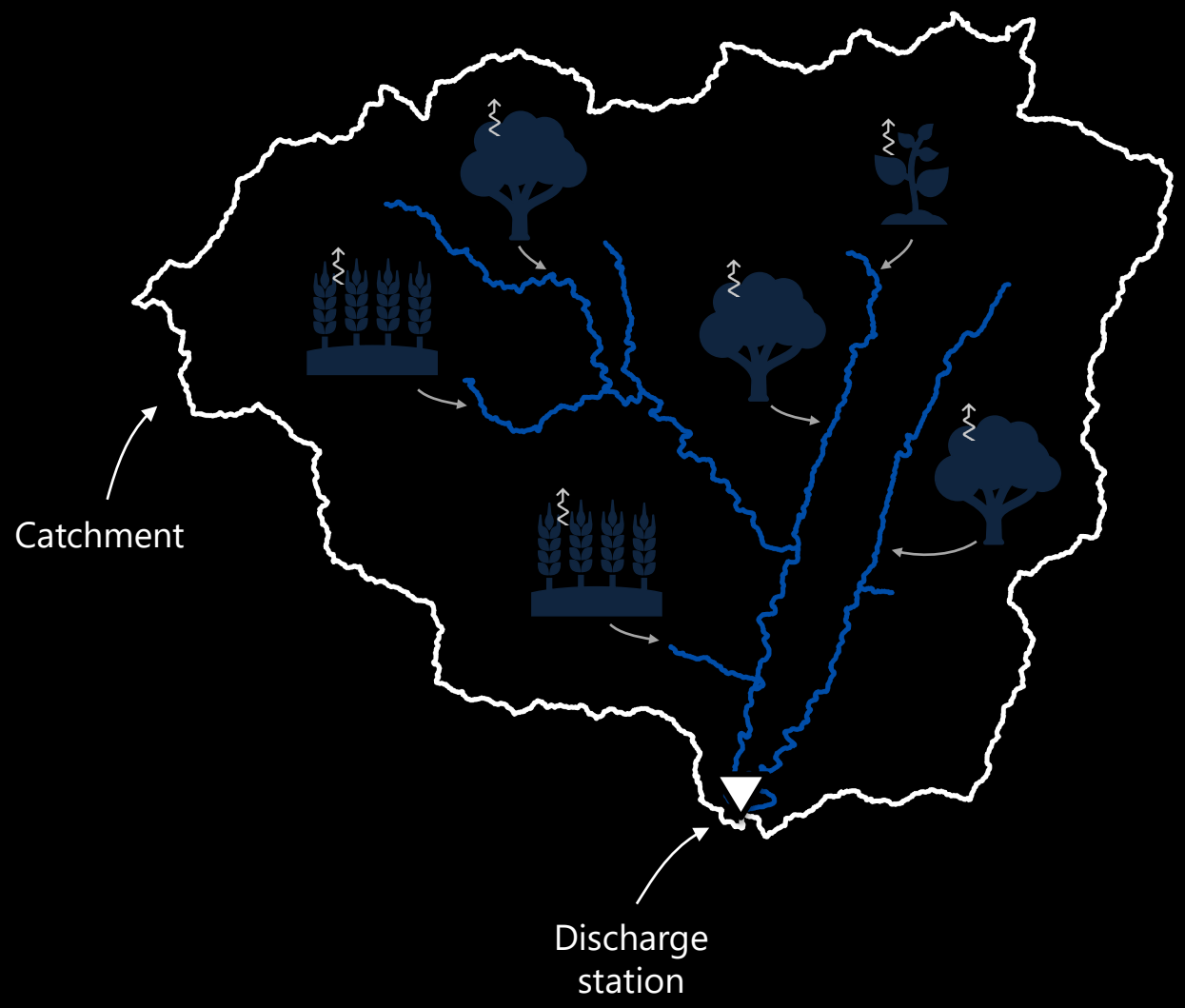


Non-filled: near future (2031-2050)

Filled: far future (2070-2099)

- High variability for GCM application e.g., *MPI predicts increase in P, minor increase in T
- Discharge less sensitive to calibration approach
- Multi-model mean: **decrease in discharge, increase in AET**

Conclusion



Catchments are complex systems of fluxes dependent on land cover, soil, and topography.

In West Africa, AET is a key process, but still often neglected in climate impact assessment.

ISIMIP/W5E5 applicable for West Africa, but limitations for current state

Calibration approach matters:
Predictions with AET vs. no AET:
Differences of 7 % (far) to 9 % (near)

Less sensitive for discharge prediction

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Thank you for your attention!

Funding and support:

Federal Ministry of Education and Research

FONA
Research for Sustainability

Contact:
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