EGU General Assembly 2020
HS5.1.2 Water resources policy and management - systems solutions in an uncertain world

How to inform decision making under uncertainty?

Quantifying and evaluating different sources of uncertainty in environmental modelling

Conrad Jackisch, Anett Schibalski and Boris Schröder
c.jackisch@tu-braunschweig.de

RUINS
Risk, Uncertainty and Insurance under Climate Change. Coastal Land Management on the German North Sea.
Bundesministerium für Bildung und Forschung
FONA Forschung für Nachhaltige Entwicklung BMBF

TU Braunschweig, Institute of Geoecology
Landscape Ecology and Environmental Systems Analysis
Technische Universität Braunschweig

Key messages

and topics of the display

To qualify uncertainty as additional information, it has to be specific to the respective issue.

Identifying the system properties relevant to the issue fundamentally reduces or avoids cascading uncertainty.

Since decision support has to work out the expected consequences of possible alleys of action, the task of environmental modelling is not only to quantify involved uncertainty, but to work out those relevant for the respective decision context based on system understanding.

general example setting

a **general model** is **not a blueprint to address uncertainty**

a **simple**, specific **system approach reduces uncertainty**

conclusions and points for discussion

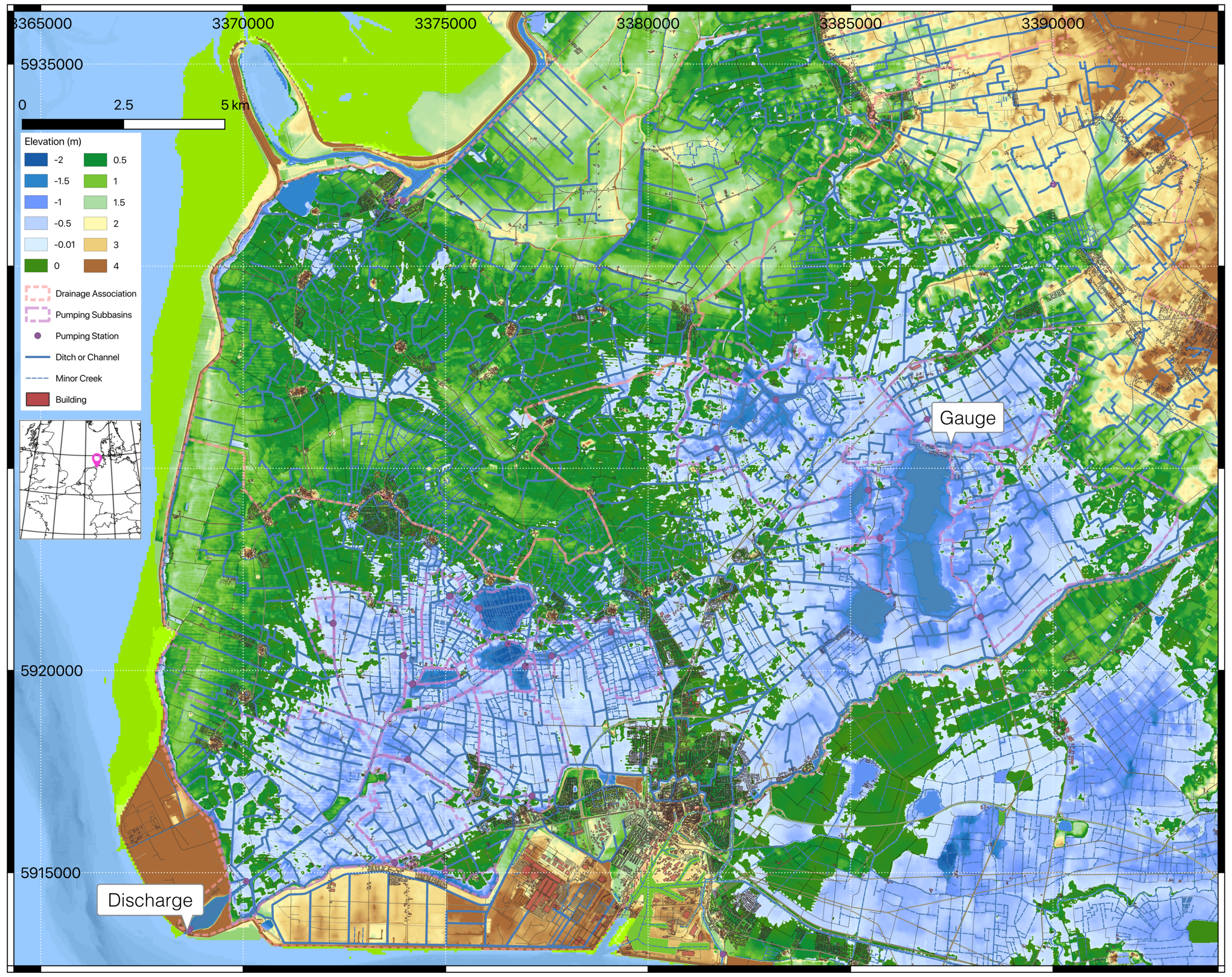
project back-ground

select topic

Example setting: flood mitigation

The Krummhörn region

- 1/3 below m.s.l.
- established drainage system



Climate change projections:

- increase of extreme events
- shift to wetter winters and drier summers *[Spekat 2007, GERICS 2018]*
- rise of mean sea level *[Grinsted 2015]*

Possible alley of action:

"Increase drainage capacity…"

- until when?
- how much?
- where? …

"The scientist shall do their work properly — and must not come up with a different value each time."

national news channel "heute journal" 2019-12-10

‹‹ overview ›› next: general model approach

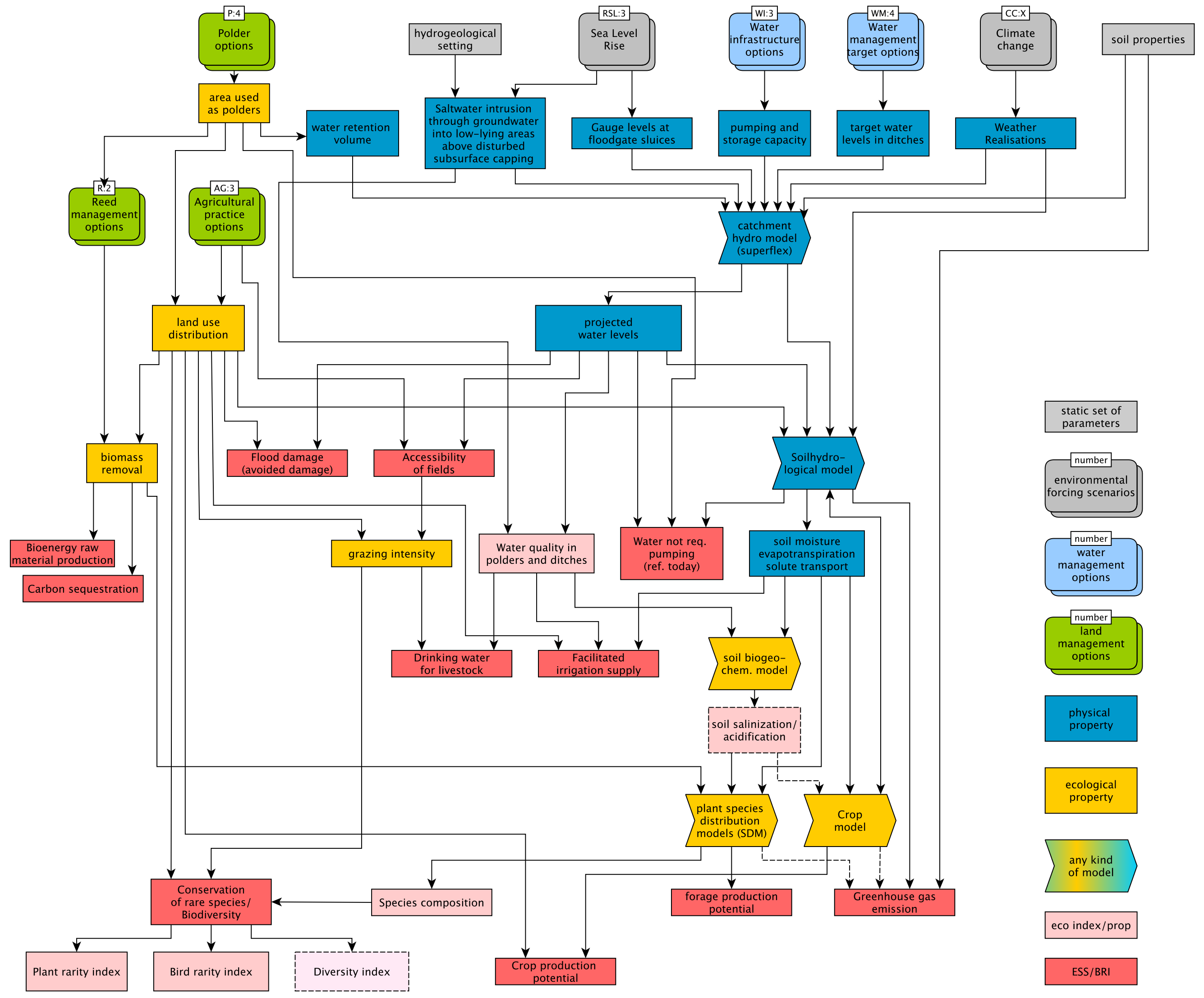
Classic approach: One model to rule them all

Complex model framework around hydrological model

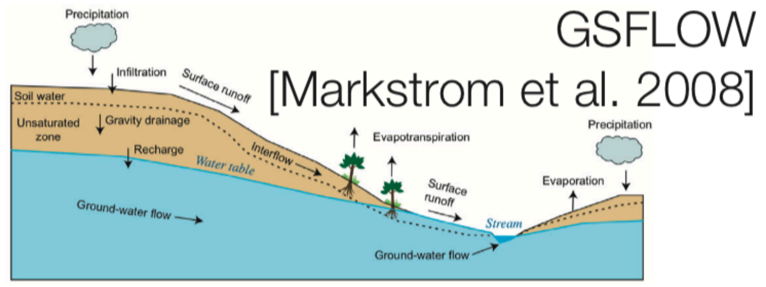
Complex model framework
- full "system" representation
- many levels of interaction
- central hydrological model

Include model structural uncertainty
- consult different models
- explore sensitivity

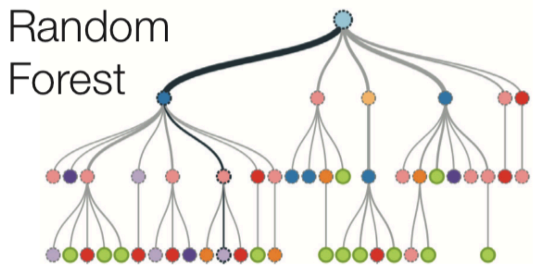
Include uncertainty about driving variables
- climate model projections
- site parameters ...



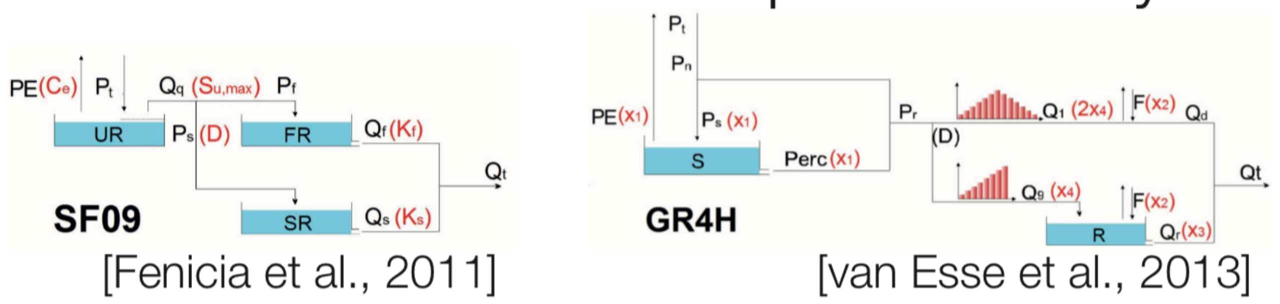
Distributed model:



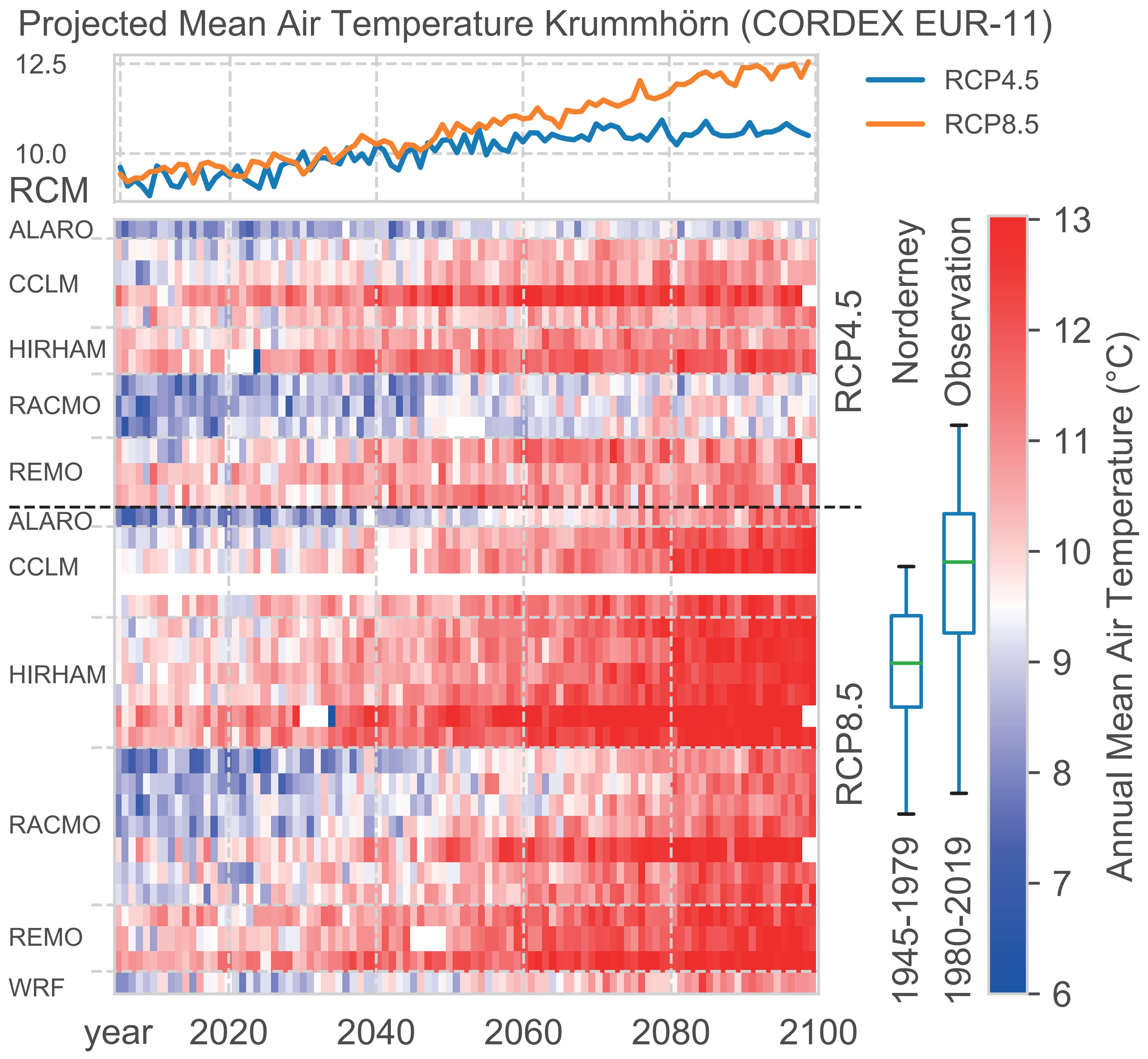
Statistical model:



Bucket models of the Superflex family:

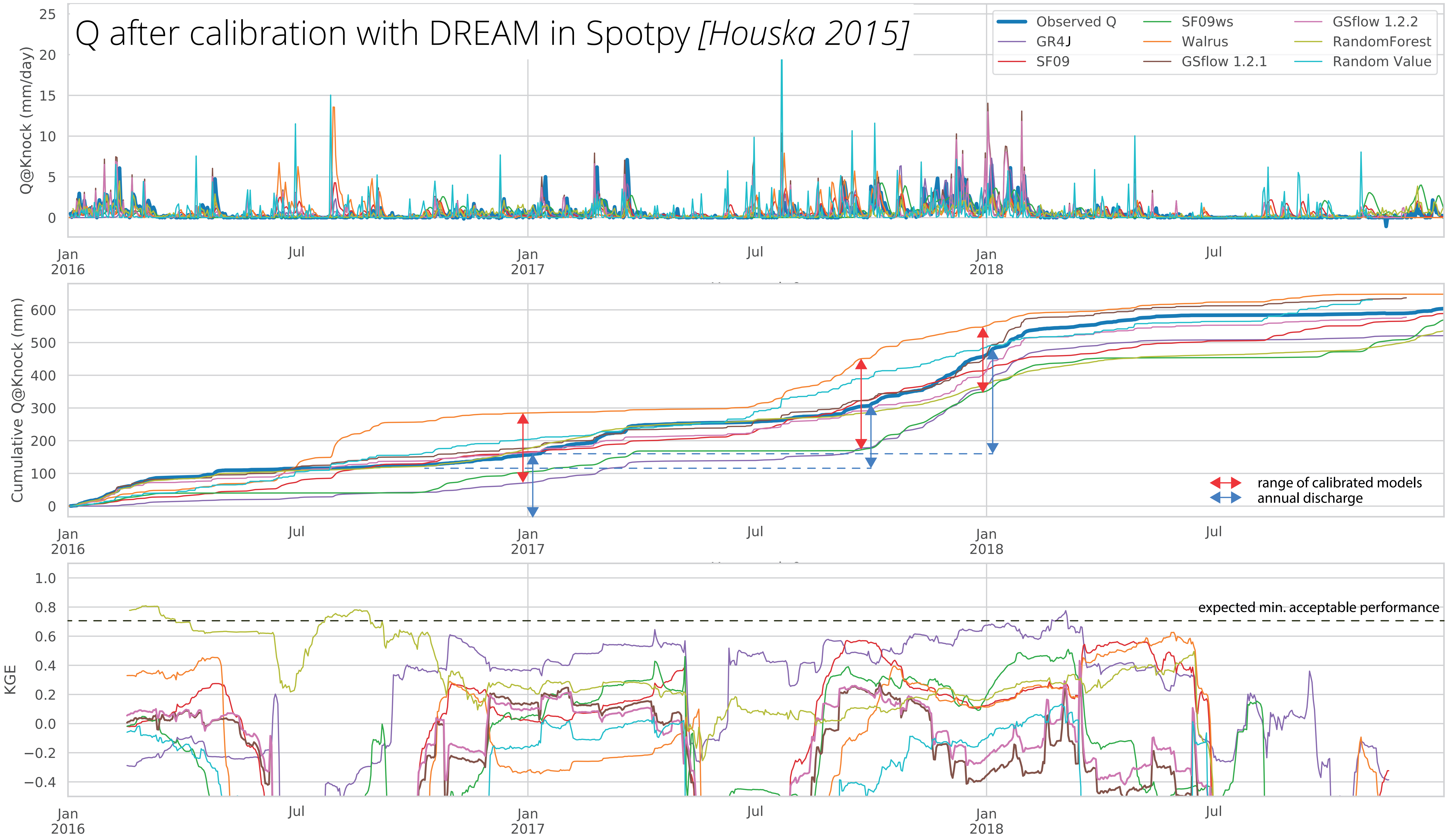


Specific lowland models:

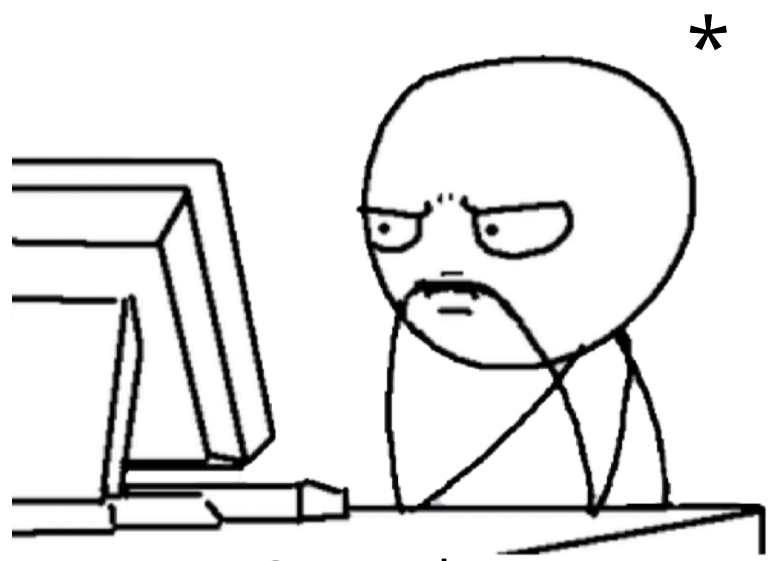


Krummhörn not reproduced as catchment

Classic approach :: intermediate results from the hydrological models

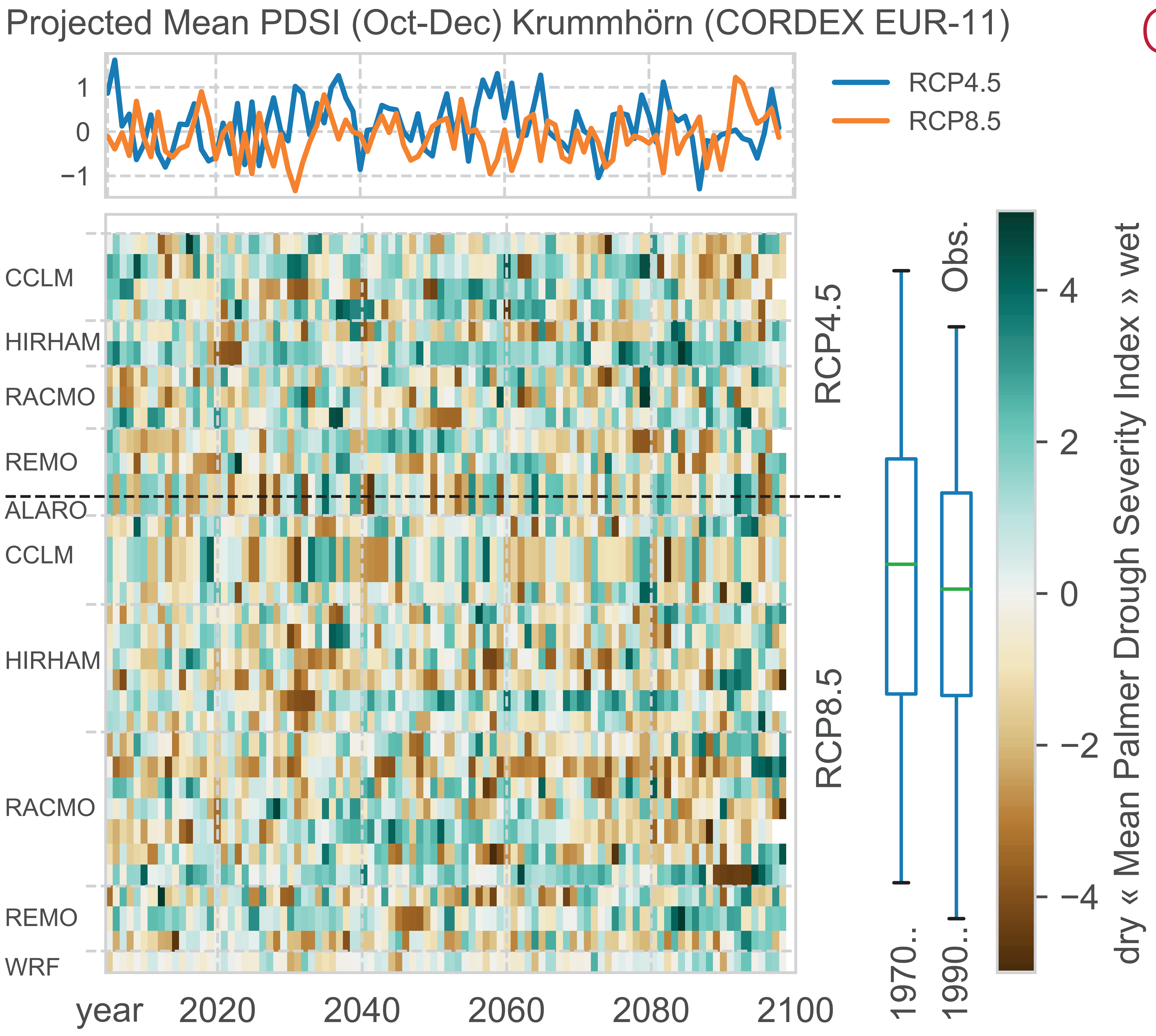


- best calibration runs of different models to reproduce drainage at main floodgate sluice
- dynamics do not match - especially in summer
- structural uncertainty ranges at annual runoff



Conrad

Weak driving signal

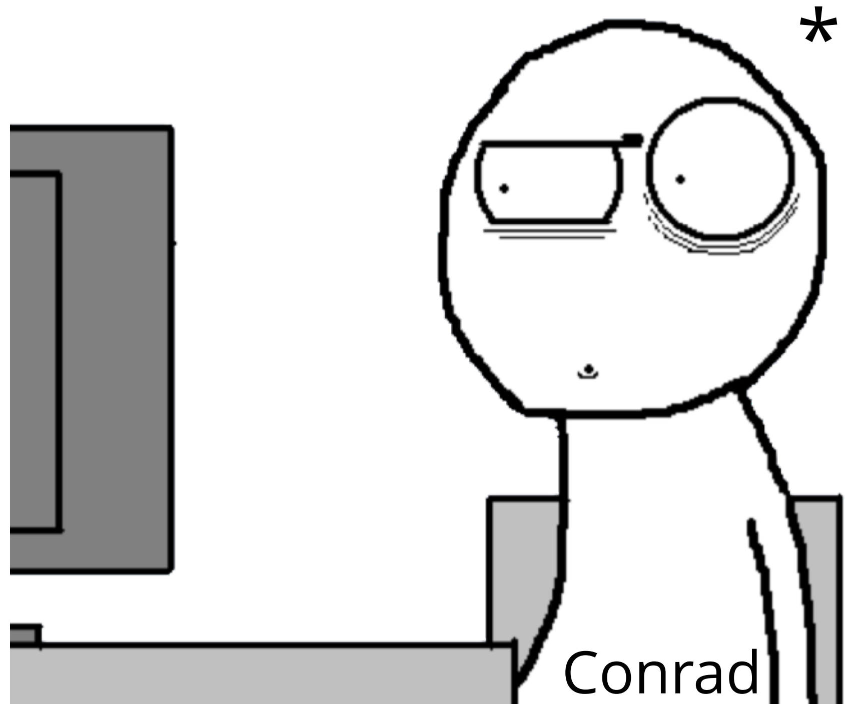


Classic approach :: Get the driving signal

CORDEX EUR-11 data

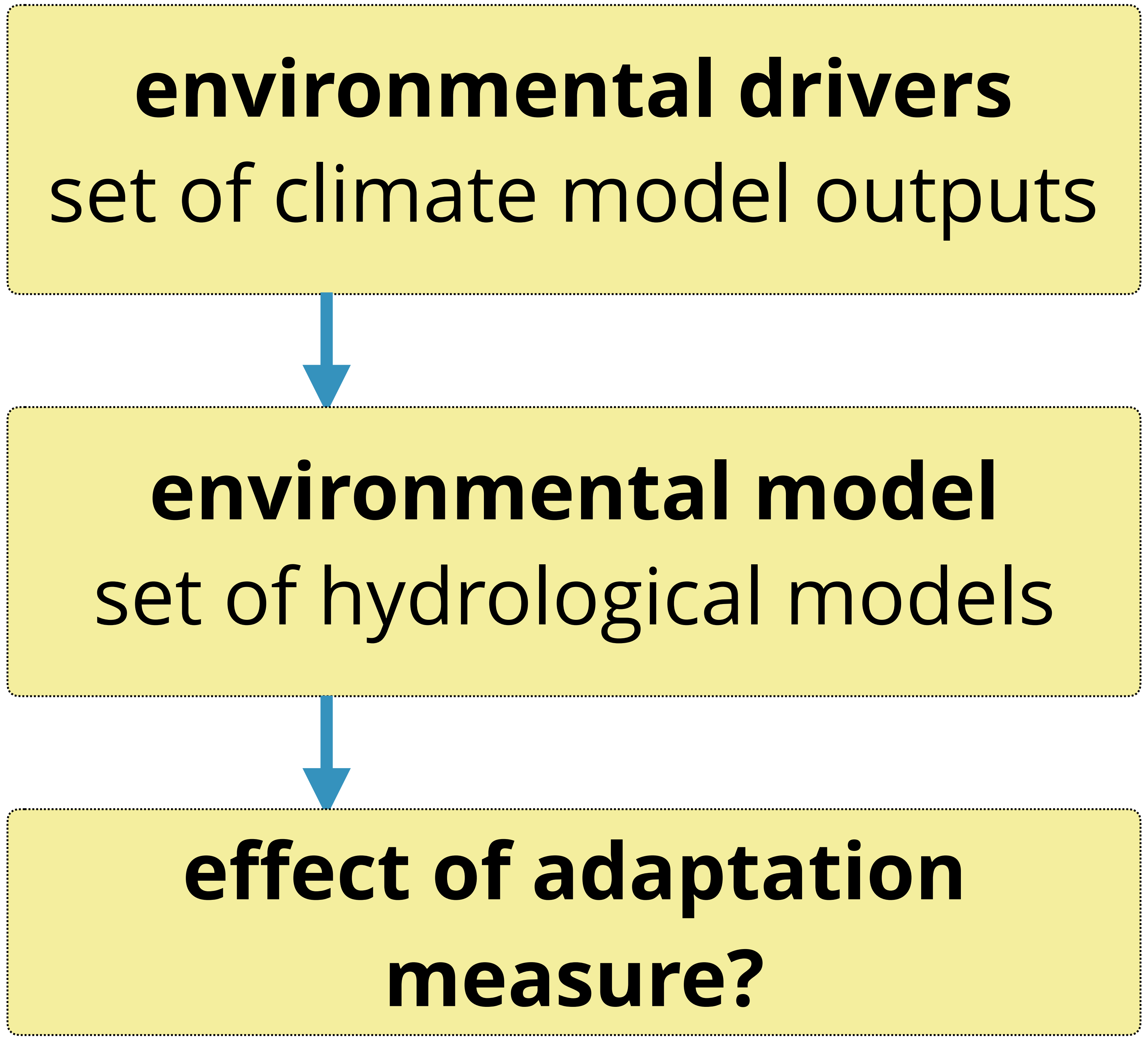
- self-calibrating Palmer Drought Severity Index *[Wells et al. 2004]*
- mean over autumn months
- No strong patterns
- No strong correlation among RCMs

- **Where are the anticipated wet winters?** *[GERICS 2018]*



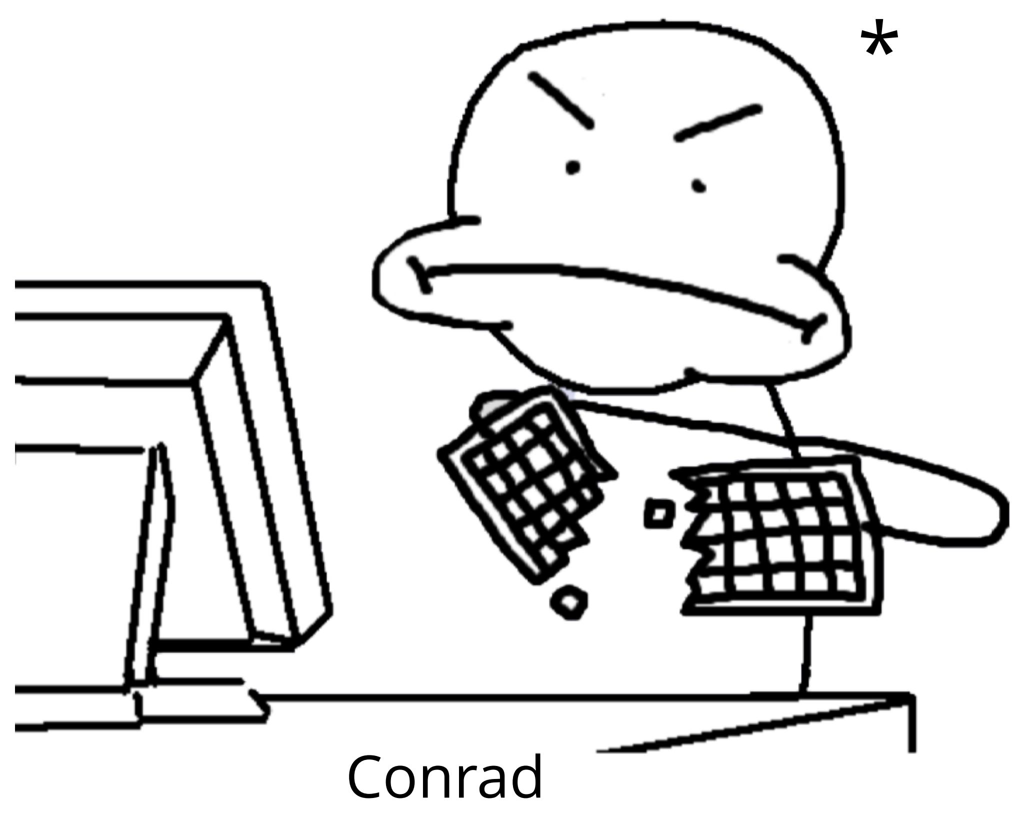
The general approach fails

Quantification of uncertainty in model chain simply cascades



A weak and uncertain change in the environmental drivers

meets models with uncertainty exceeding effects of climate change and possible mitigation strategies.



› **not feasible for decision support, especially with respect to uncertainties**

But the fault is not with the models. It is an insufficient representation of the system!

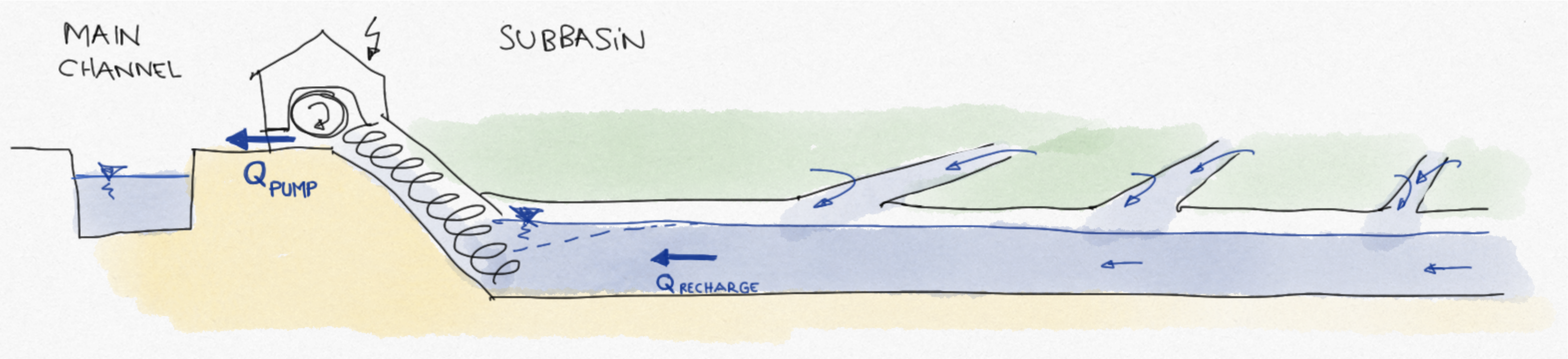
‹‹ overview
›› next: simple system approach

Simple model with focus on the system

A simple Darcy take on runoff generation in the subbasins

Available data

- meteorological data
- water levels at subbasin pumps
- subbasin pumping electric power



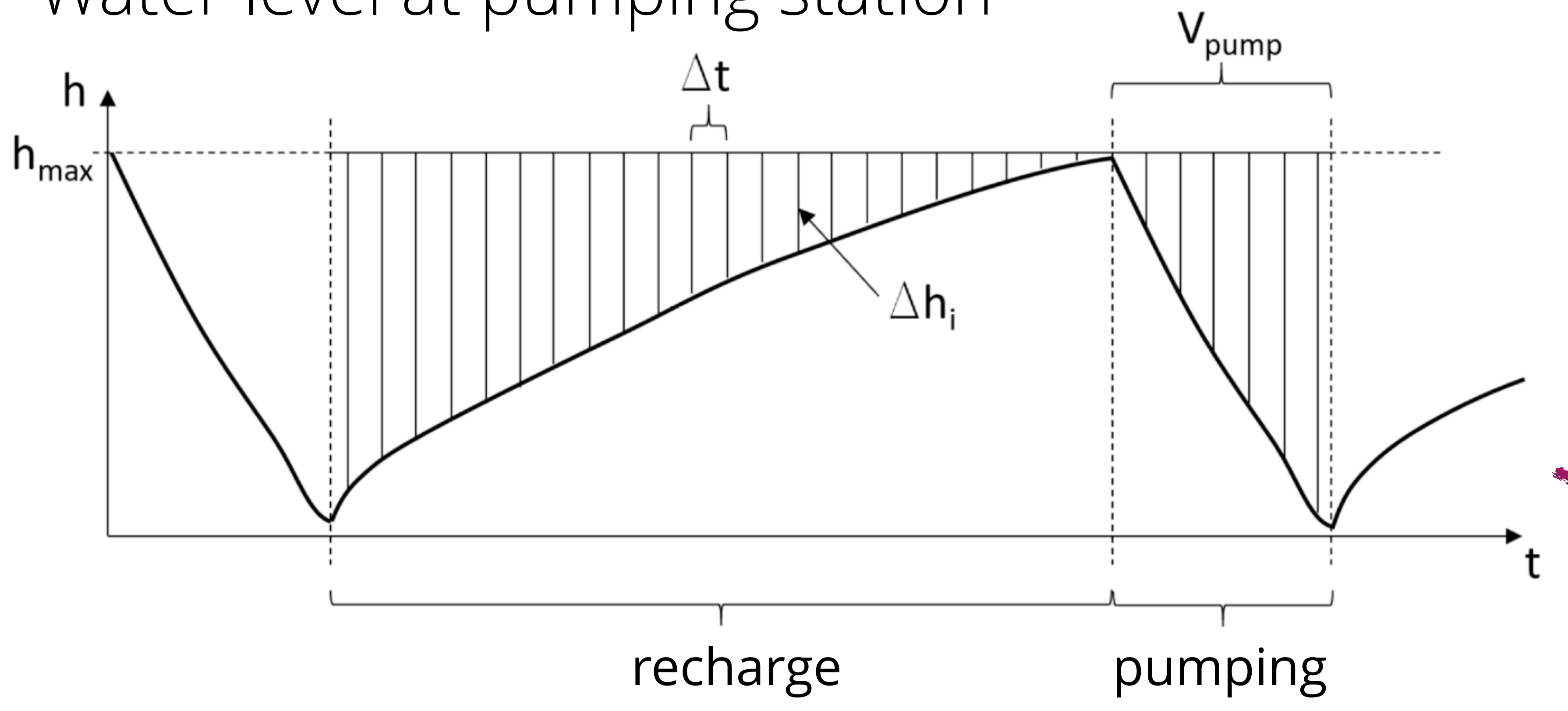
Specific questions

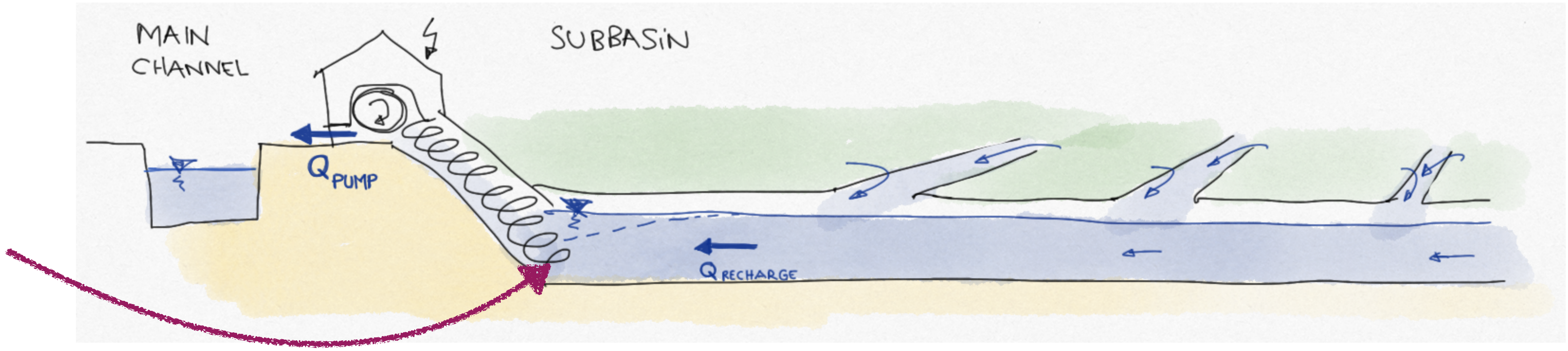
- Q1: What are the bottle necks of drainage?
- Q2: What is the natural runoff generation in the subbasins?

Q1: What are the bottle necks of drainage?

Mere data analysis allows to identify fields of mitigation.

Water level at pumping station





Even without any model:

- $t_{recharge} \approx 3 \cdot t_{pump}$ in main subbasins
- capacity of pumps not exceeded

Hence:

- flood protection has to address local drainage over bigger subbasin pumps
- increase capacity of channels and control of hydraulic head towards pumping station

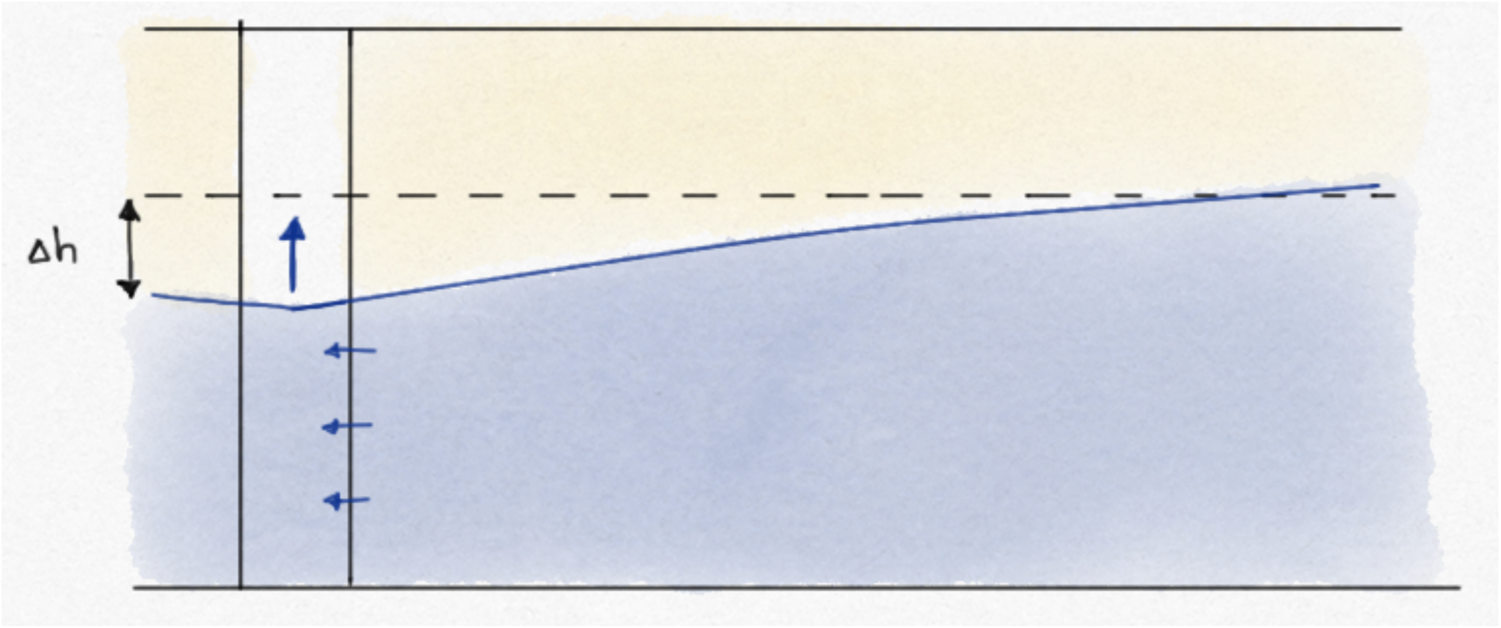
Q2: What is the natural runoff generation?

A Darcy -interpretation of recharge dynamics reveals natural runoff

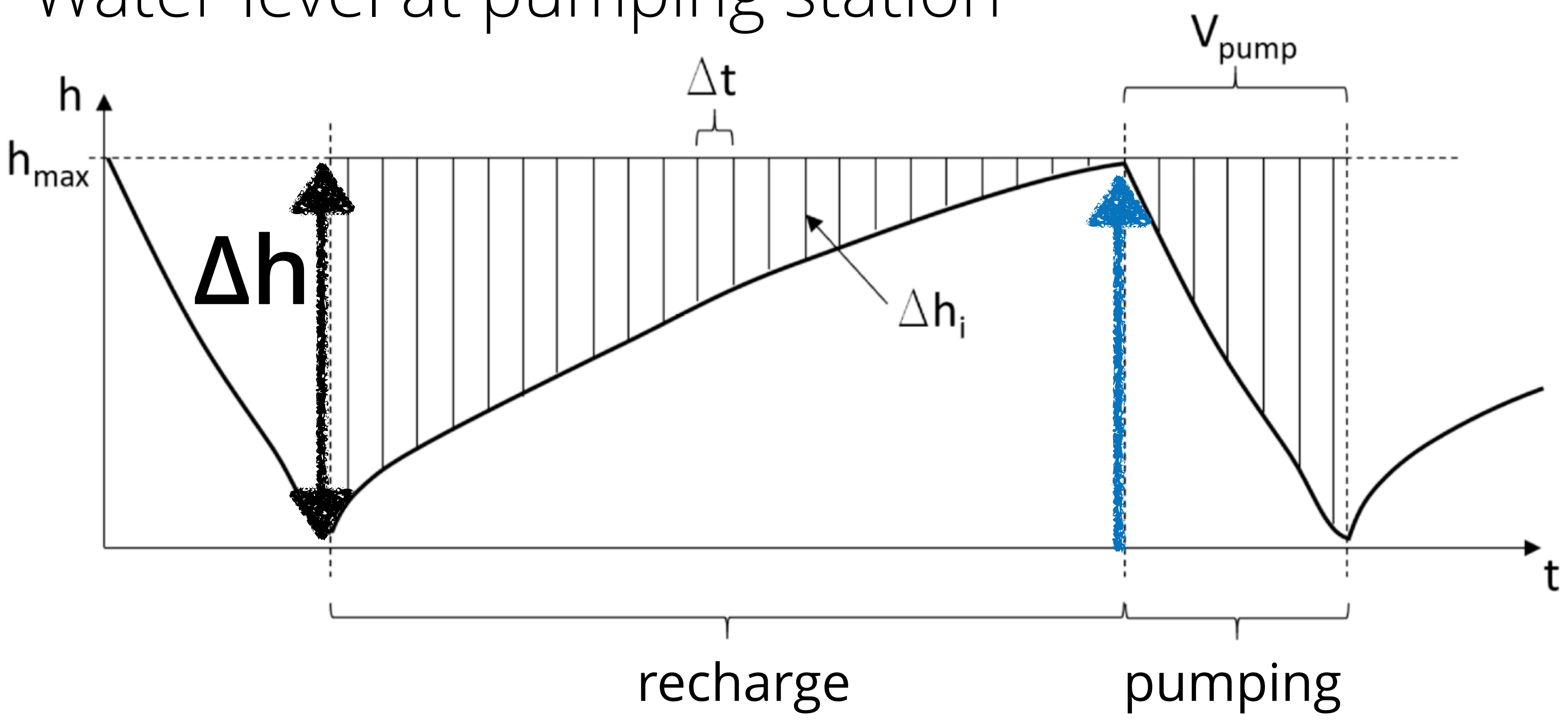
Subbasin recharge as bail-test (hydrogeology):

- estimate conductivity k_S of porous medium by resilience dynamics after water removal

Darcy-Approach

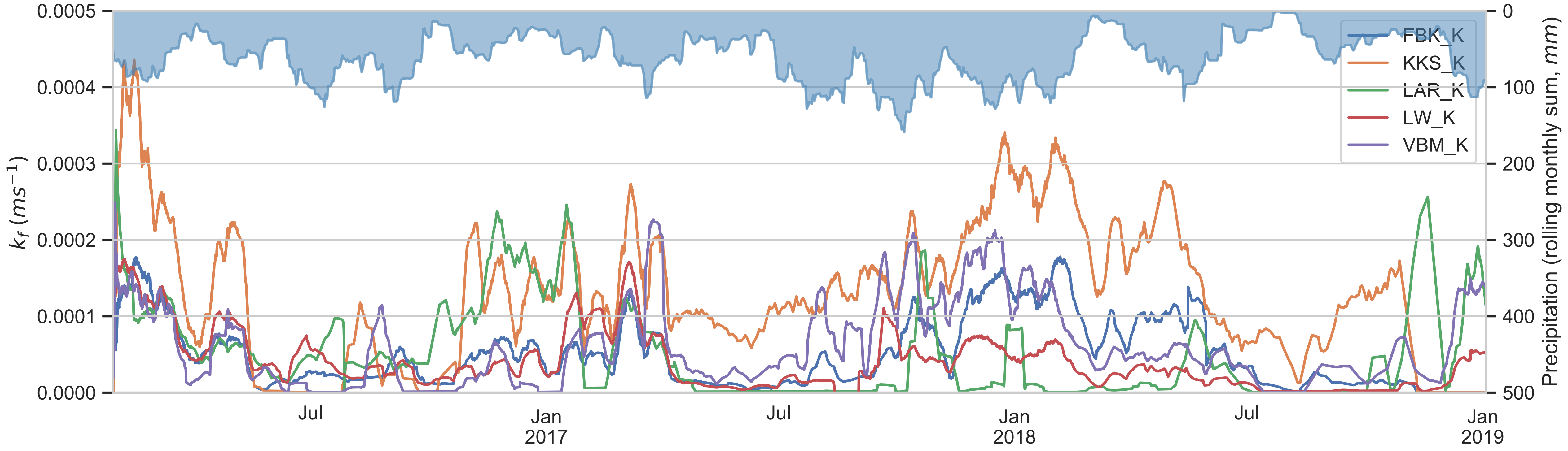


Water level at pumping station

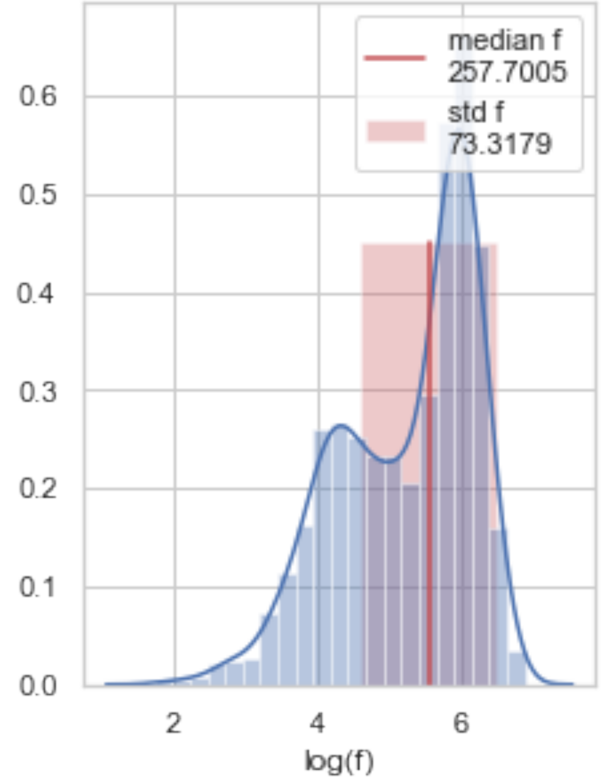


- we get a k_S for every recharge event and can re-calculate the natural runoff

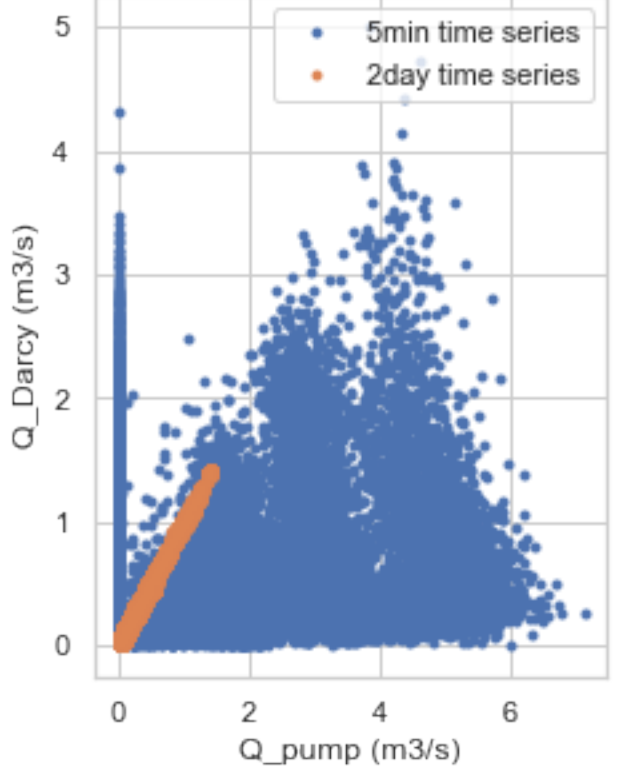
k_S as time series



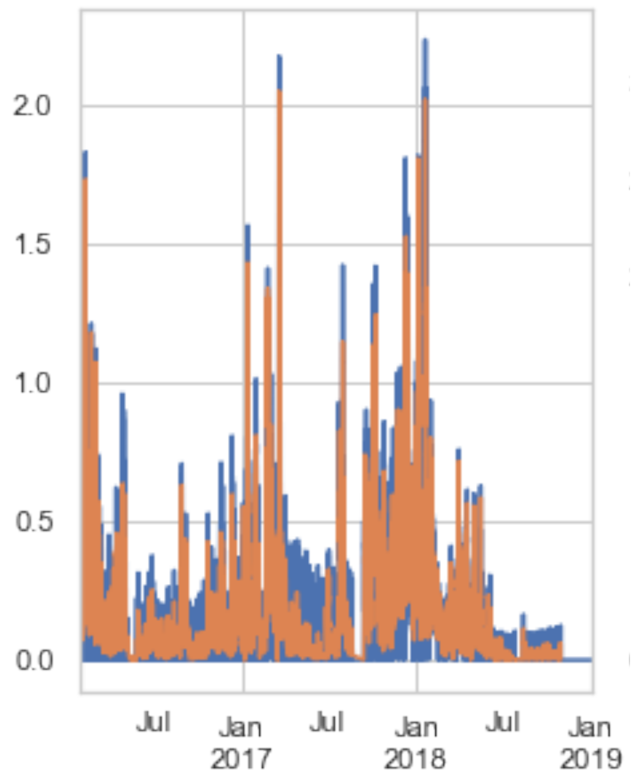
geometry factor



Q_{pump} vs. $Q_{recharge}$



$Q_{recharge}$ as runoff

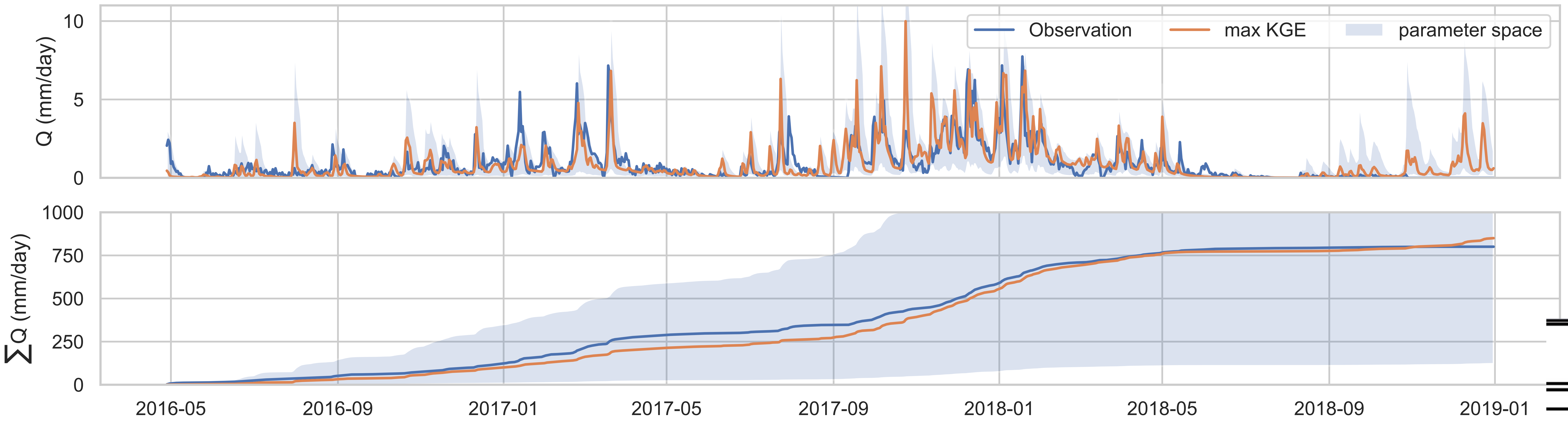


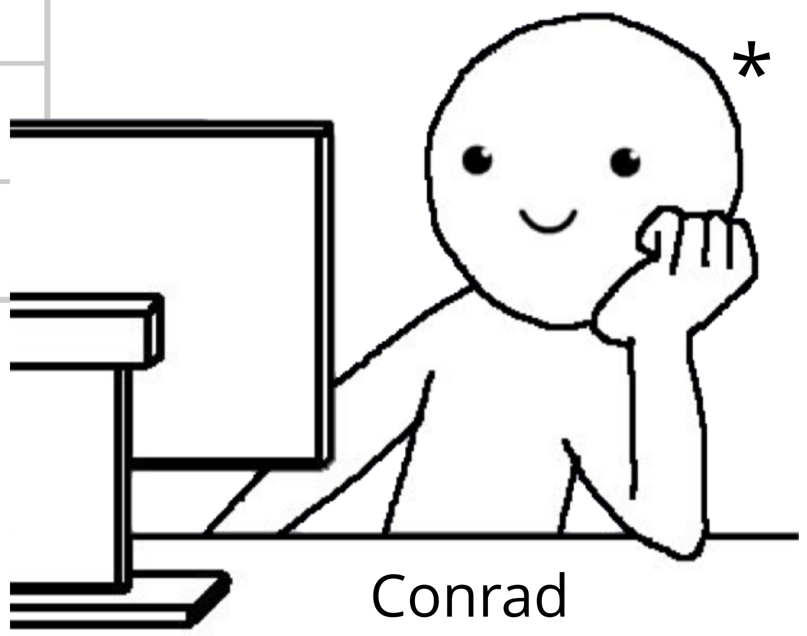
Apply a hydrological model to inferred runoff

The simple, focussed model can reproduce the system dynamics

- The recharge flux can be reproduced with a hydrological model (Δt=1d, GR4J, KGE=0.71)
- relevant system detail captured
- now, further details can be explored

Q with GR4J after calibration with DREAM in Spotpy *[Houska 2015]*





‹‹ overview
›› next: conclusions

System-based filter of relevant uncertainty

Conclusions and points for discussion

a general model is not a blueprint to address uncertainty

In a decision support context, the analysis of uncertainty can become rather demanding and even obscured by limited specificity of the system representation.

a simple, specific system approach reduces uncertainty

The specific analysis of the system turned out prerequisite to represent the observed dynamics and to remove uncertainty, which would be unrelated to the decision question.

However, the remaining uncertainty might still be difficult to be seen as essential information for the decision maker.

Further, specificity must not be confused with subjectivity.

Bundesministerium für Bildung und Forschung

FONA Forschung für Nachhaltige Entwicklung BMBF

RUINS

Risk, uncertainty and insurance under climate change. Coastal Land Management on the German North Sea

Adapt to Climate Change

- Effect on level of ecosystem service provision
- Effect on uncertainty

Methodological Focus

- How can we analyse and convey such projections?
- How can we expose uncertainty as crucial information?

Inter- & Transdisciplinary

- Environmental economy
- Ecosystem modelling
- Stakeholder workshops

Bibliography

Brauer, C C et al. (2014). “The Wageningen Lowland Runoff Simulator (WALRUS): a lumped rainfall–runoff model for catchments with shallow groundwater”. *Geoscientific Model Development* 7.5, pp. 2313–2332. https://doi.org/10.5194/gmd-7-2313-2014.

Esse, W R van et al. (2013). “The influence of conceptual model structure on model performance: a comparative study for 237 French catchments”. *Hydrology and Earth System Sciences* 17.10, pp. 4227–4239. https://doi.org/10.5194/hess-17-4227-2013.

Fenicia, Fabrizio, Dmitri Kavetski, and Hubert H G Savenije (2011). “Elements of a flexible approach for conceptual hydrological modeling: 1. Motivation and theoretical development”. *Water Resources Research* 47.11, W11510. https://doi.org/10.1029/ 2010WR010174.

GERICS (2018) Climate Service Center Germany, “Änderung des Klimas in Bremen und Niedersachsen”. https://www.climate-service-center.de/imperia/md/content/csc/cordex/bundesland_bremen-niedersachsen_version1.2.pdf

Grinsted, A et al. (2015), “Sea level rise projections for northern Europe under RCP8.5”, *CLIMATE RESEARCH*, 64(1), 15–23, https://doi.org/10.3354/cr01309.

Houska, Tobias et al. (2015). “SPOTting Model Parameters Using a Ready-Made Python Package.” *PLoS ONE* 10.12, e0145180. https://doi.org/10.1371/journal.pone.0145180.

Kroes, J G et al. (2017). “SWAP version 4”. Tech. rep. Wageningen. http://edepot.wur.nl/416321.

Markstrom, S L et al. (2008). “GSFLOW—Coupled Ground-Water and Surface-Water Flow Model Based on the Integration of the Precipitation-Runoff Modeling System (PRMS) and the Modular Ground-Water Flow Model (MODFLOW-2005)”. Tech. rep. https: //pubs.usgs.gov/tm/tm6d1/pdf/tm6d1.pdf.

Spekat, A et al. (2007). “Neuentwicklung von regional hoch aufgelösten Wetterlagen für Deutschland und Bereitstellung regionaler Klimaszenarios auf der Basis von globalen Klimasimulationen mit dem Regionalisierungsmodell WETTREG auf der Basis von globalen Klimasimulationen mit ECHAM5/MPI-OM T63L31 2010 bis 2100 für die SRES-Szenarios B1, A1B und A2.” Tech. rep. https://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/3133.pdf

Wells, N et al. (2004). “A Self-Calibrating Palmer Drought Severity Index”, J. Climate, 17(12), 2335–2351, https://doi.org/10.1175/1520-0442(2004)017<2335:ASPDSI>2.0.CO;2.

*comics thanks to David Kriesel http://www.dkriesel.com/start

‹‹ overview