WORK OUTLINE 1/3

Exploring elevation zone similarity in large case studies for the semi-distributed regionalisation of the HBV model parameters

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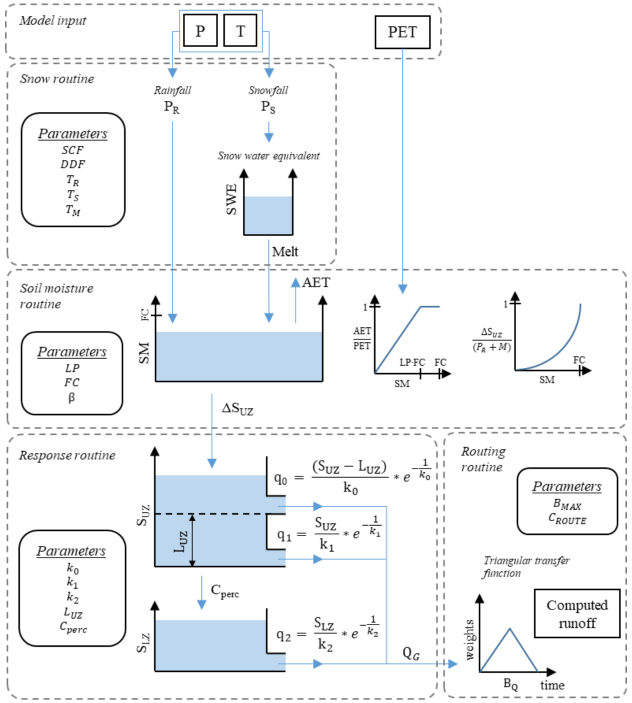
Key points:

- Runoff generation processes can be dominated by multiple factors which change across different study areas, across different catchments but also with **elevation**
- Understanding how **runoff dynamics vary with elevation** allows improvements in hydrological modelling and simulations
- Can we gain useful information understanding **how catchment similarity change with elevation**?
- Study sets: Austria and US-CAMELS

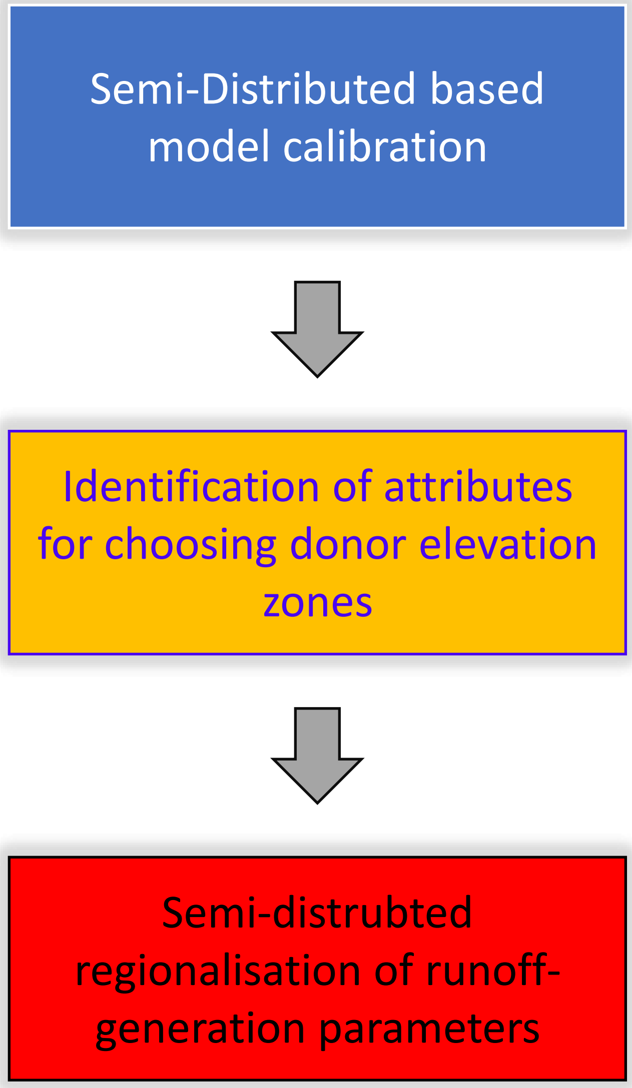


Outline of the work

WORK OUTLINE 2/3

Taking advantage of the semi-distributed structure (where meteorological forcing is spatially distributed based on elevation zones) of the HBV-based **TUW model** (https://cran.r project.org/), applied over a large set of Austrian and United States catchments, we have:

- Tested an innovative semi-distributed calibration of the model based on elevation zones ("at site"semi-distributed calibration) – and then compared the results with the standard calibration, where the model parameters are instead uniform over all elevation zones in the same catchment
- Identified the optimal similarity attributes to be used in the regionalisation approach, applied at sub-basin scale
- Assuming that, in turn, each catchment is ungauged, applied a semi-distributed regionalisation of the model parameters that govern the runoff generation module over each elevation zone, searching the most similar donor elevation zones rather than based on the similarity of the entire catchment



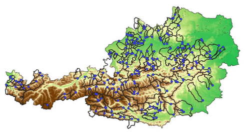
Outline of the work

WORK OUTLINE 3/3

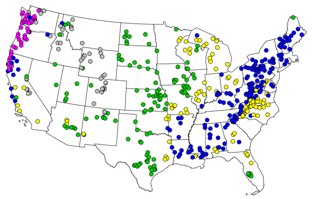
- Is such semi-distributed approach giving benefits to rainfall-runoff model performances at gauged sites (i.e. calibrated "at site")?
- Can we improve simulation in ungauged basins?
- How is similarity changing across elevation zones (and data sets)?

Two large case studies:

Austria



US



Click here for first conclusions

Click here for more details..

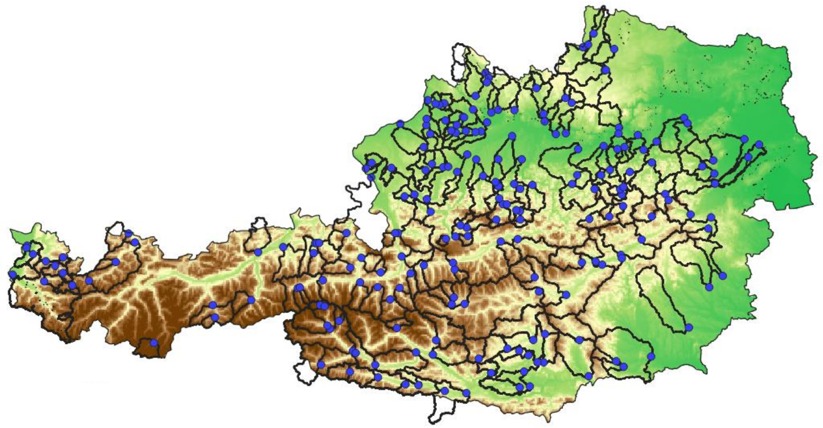
Semi-Distributed based model calibration

Identification of attributes for choosing donor elevation zones

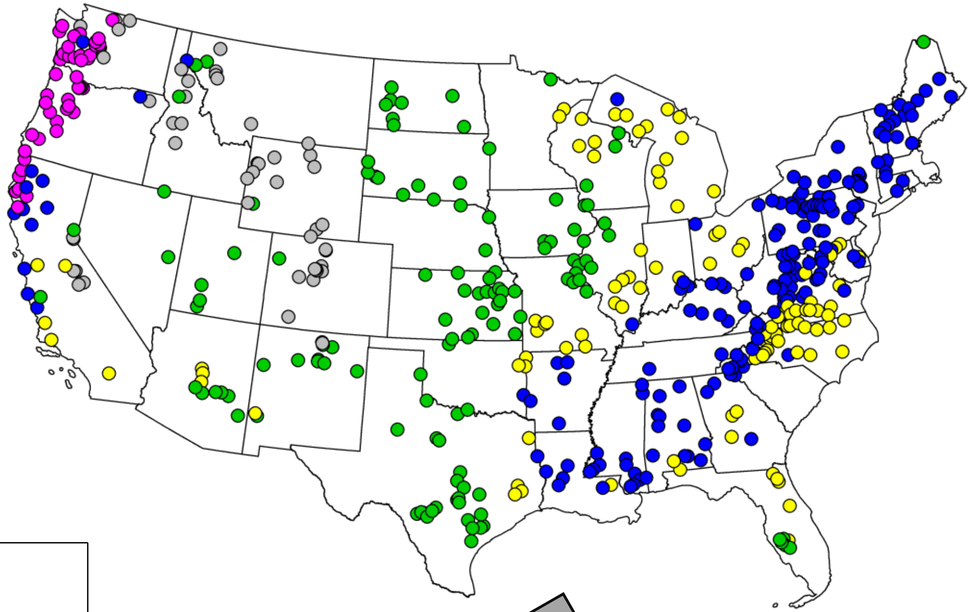
Semi-distrubted regionalisation of runoff-generation parameters

Two case studies

1) Very densely gauged set of 209 catchments across Austria



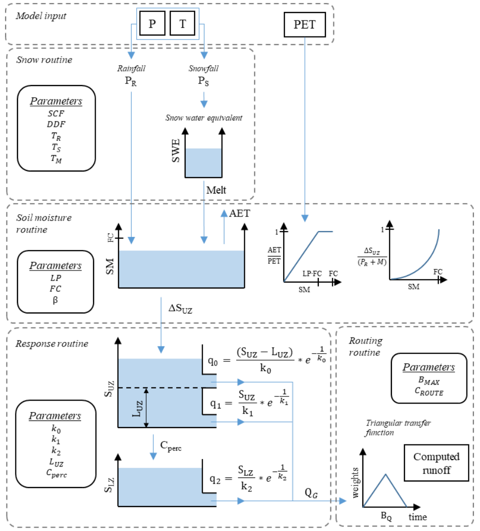
2) 515 US watersheds (part of the CAMELS dataset) including wider variety of hydrological conditions and catchment characteristics



The dataset is divided into the 5 “regime clusters” identified by *Brunner et al. (2020, HESSD)*

TUW model

- A semi distributed version of HBV
- **Rainfall runoff model input:** over separate 200 m (100m for US) elevation zones



* Package TUWmodel on CRAN repository
Authors: Alberto Viglione, Juraj Parajka

Semi-distributed calibration strategy "at site"

N.B.: The model processes the sub-basins (or zones) as autonomous entities that contribute separately to the total outlet flow

Five (six for US) **macro zones** are defined:

I. 0 – 800 m → for US split in:
- Ia. 0 – 400m
- Ib. 400 – 800m

II. 800 – 1400 m

III. 1400 – 2000 m

IV. 2000 – 2400 m

V. 2400 – 3800 m

Semi-distributed parameter set

Macrozone I	Macrozone II		Macrozone n
SCF_1	SCF_2		SCF_n
DDF_1	DDF_2		DDF_n
Tr_1	Tr_2	…	Tr_n
$Ts_1=Tm_1$	$Ts_2=Tm_2$		$Ts_n=Tm_n$
$LPrat_1$	$LPrat_2$		$LPrat_n$
FC_1	FC_2		FC_n
$Beta_1$	$Beta_2$		$Beta_n$

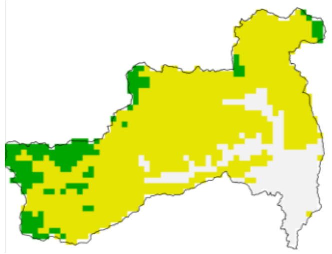
Runoff generation parameters ***zone-differentiated***

k0
k1
k2
Luz
cperc
Croute

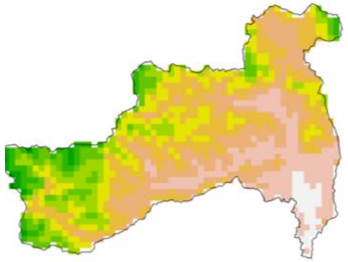
Runoff propagation parameters ***uniform over the zones***

Runoff **generation parameters are allowed to vary** over the different macro elevation zones

Parameters calibration strategy: aggregated macro zones



Meteorological inputs: 200m (100m in US) elevation zones



Calibration technique

Opt. Algorithm → Dynamically Dimensioned Search (Tolson et al., 2007)

Objective function → Kling-Gupta Efficiency (Gupta et al., 2009)

Benchmark calibration strategy "at site"

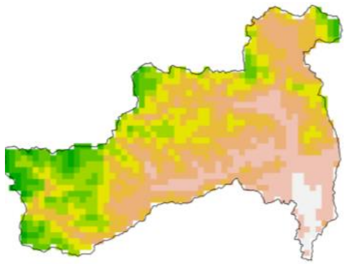
Uniform parameter set

SCF
DDF
*Tr
*Ts=Tm
LPrat
FC
Beta

k0
k1
k2
Luz
cperc
Croute

- The parameter set is unique for all the macrozones
- Same calibration technique
- Meteorological inputs still defined over 200/100m elevation zones

Meteorological inputs: 200m (100m in US) elevation zones



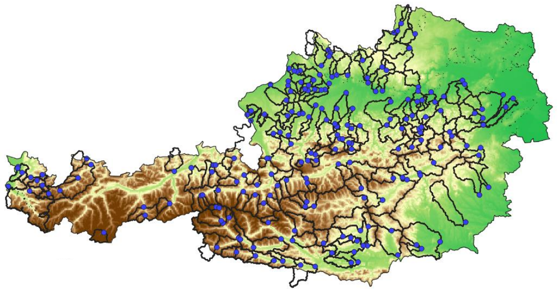
Calibration technique

Opt. Algorithm → Dynamically Dimensioned Search (Tolson et al., 2007)
Objective function → Kling-Gupta Efficiency (Gupta et al., 2009)

“At site” calibration results – Austria

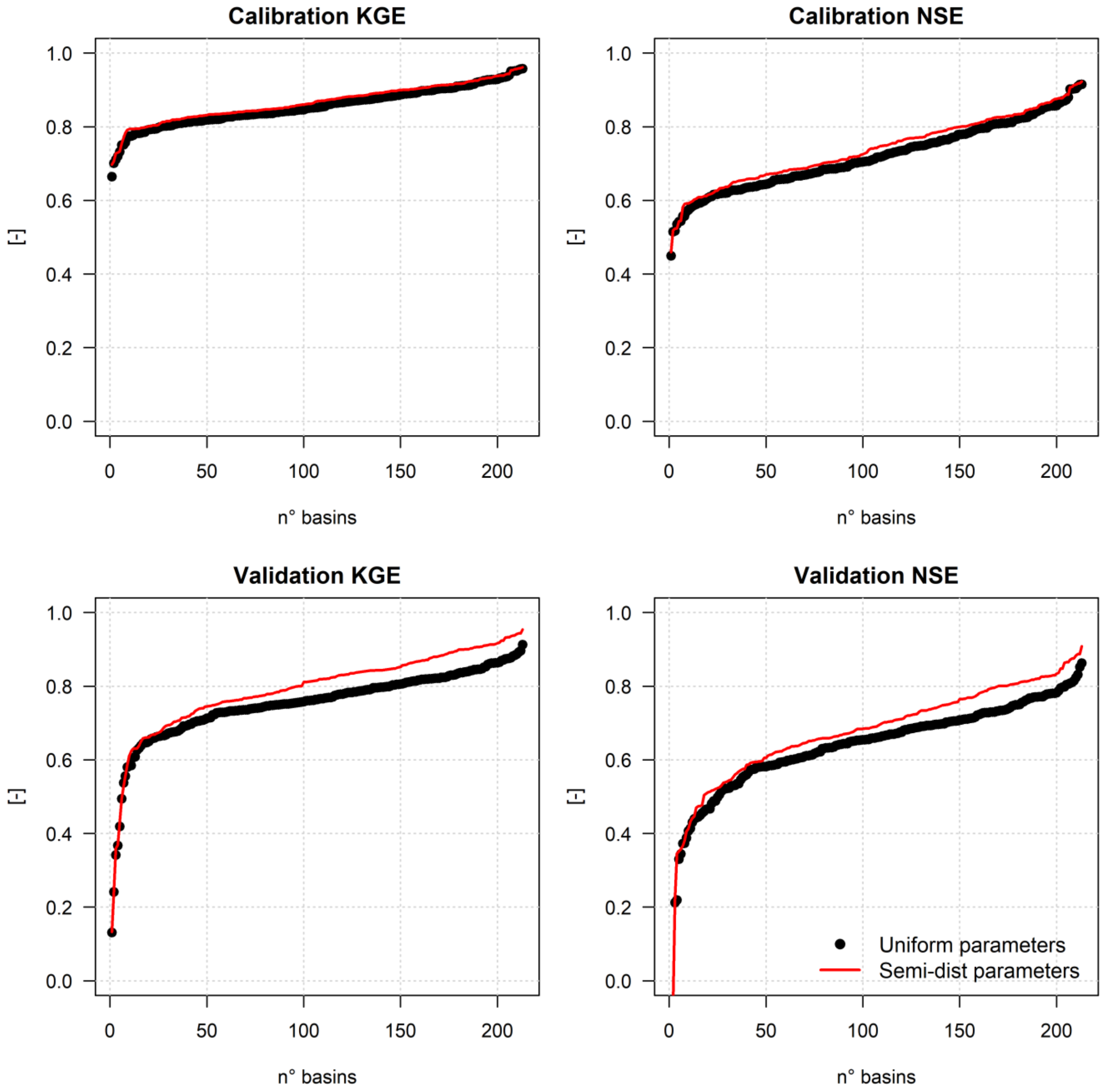
Comparison between the proposed calibration strategies:

- Similar performances for calibration period
- **Slight improvement** in (already quite good) performances for validation period



Calibration period: 1978 – 1992
Validation period: 1991 – 2008
Warm-up: 1 year

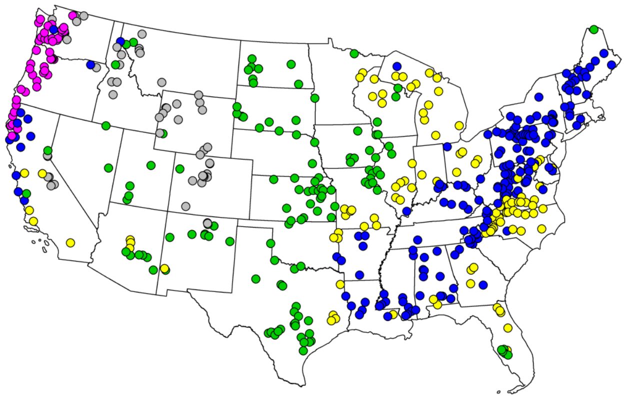
Cumulative distribution curve of model efficiency



“At site” calibration results – US

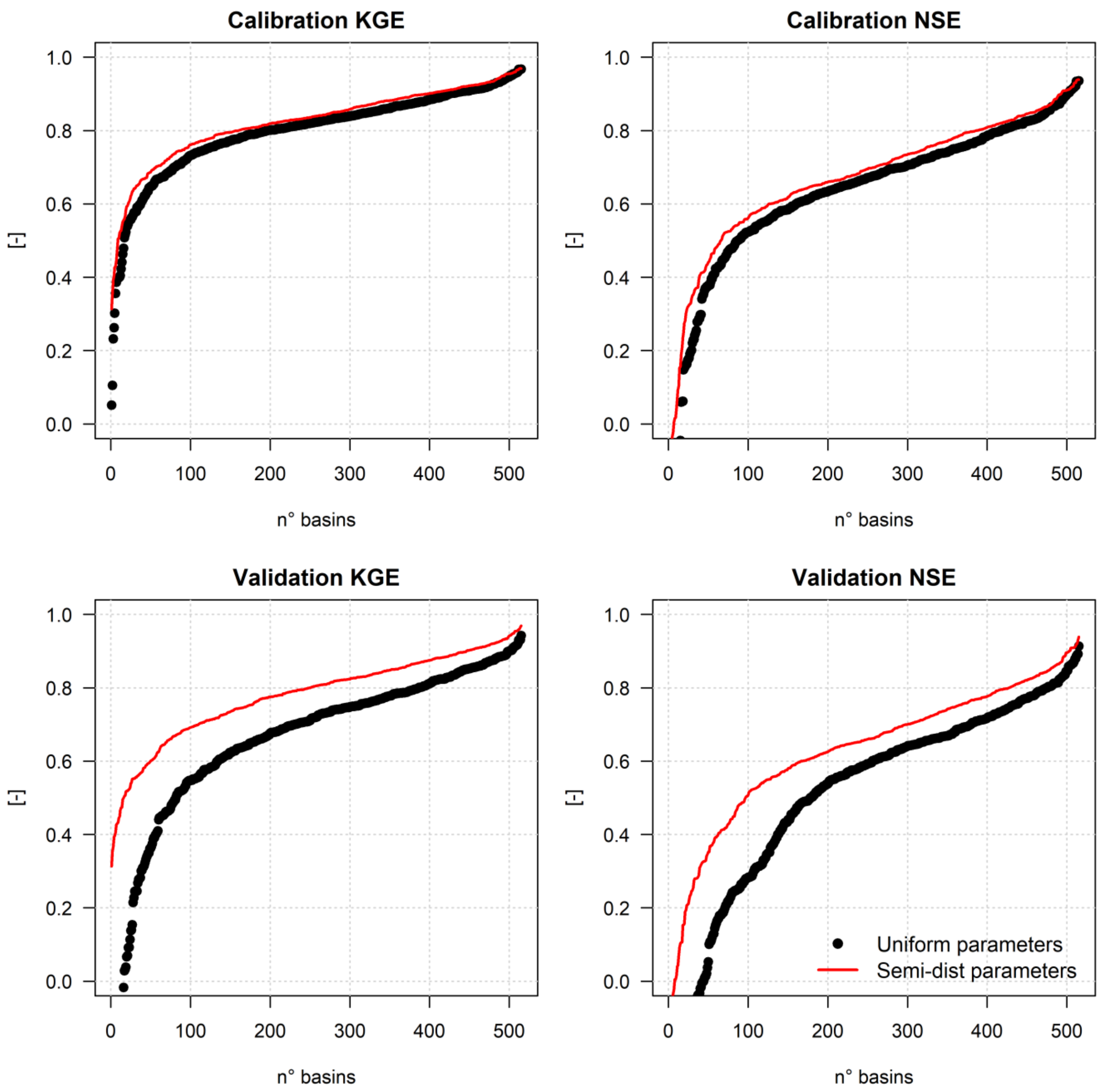
Comparison between the proposed calibration strategies:

- Similar performances for calibration period
- **Substantial performance improvement** for validation period



Calibration period: 1980 – 1998
Validation period: 1993 – 2011
Warm-up: 5 years

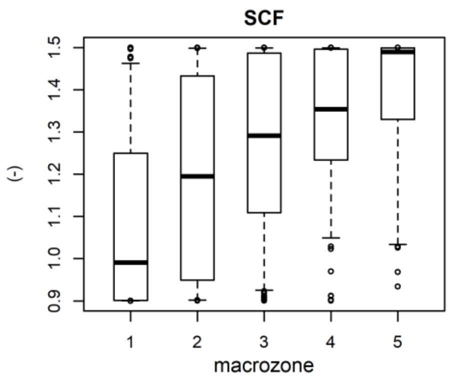
Cumulative distribution curve of model efficiency



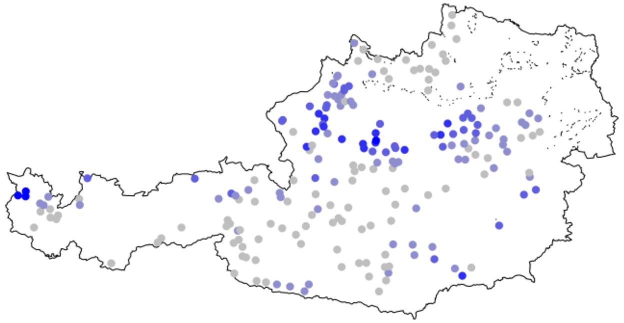
Parameter distribution across macrozones

Future studies will include the analysis of the **distribution of the calibrated parameters** values across both:

1. **Macro – elevation zones**



2. **Different regions**



Different sensitivity of the parameters?

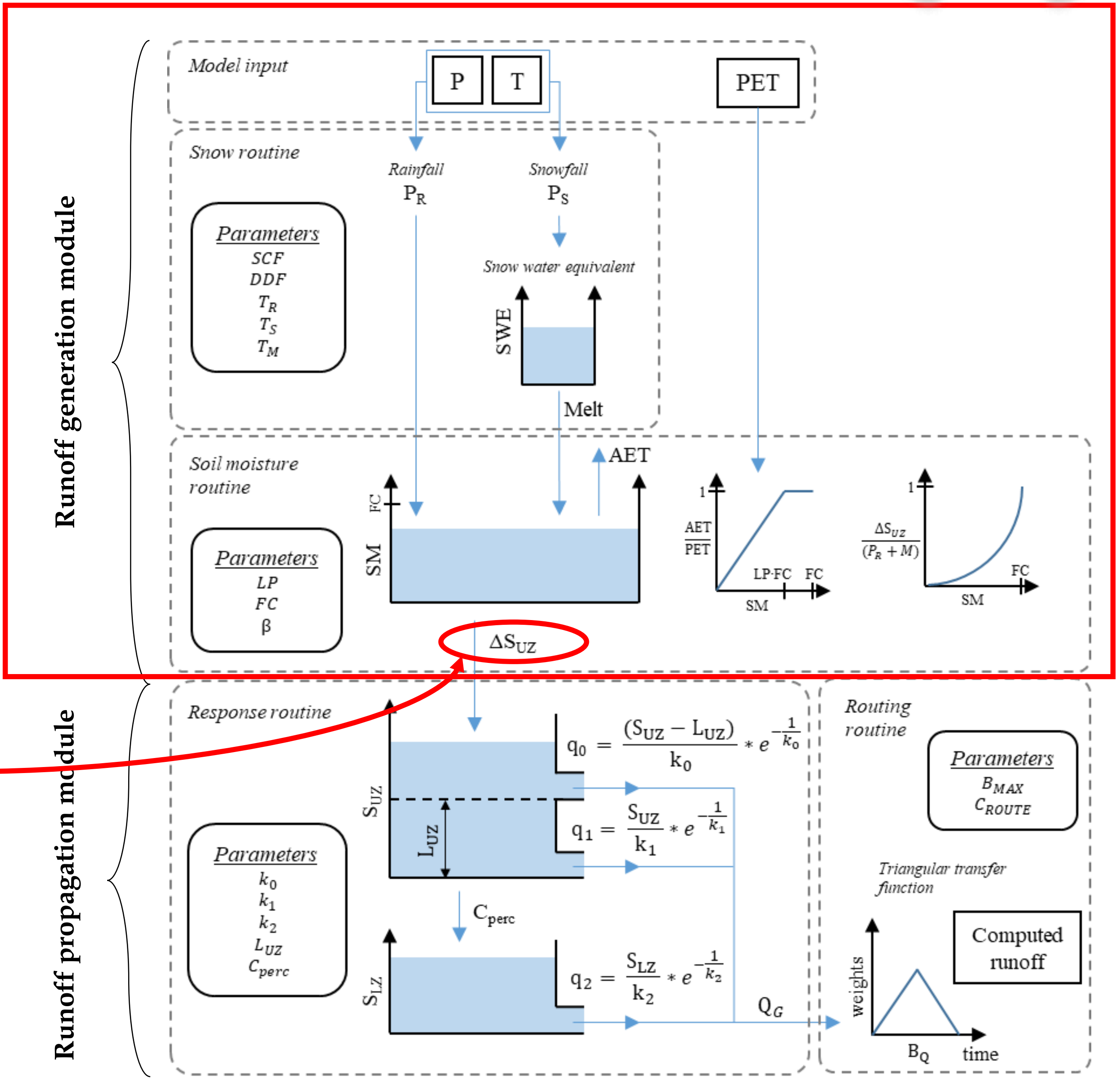
Focusing on the runoff generation…

TUW model

The analysis intents to focus on the **dynamics leading to the production of the runoff**, rather than its propagation through the catchment

- The unique runoff generation module is considered for regionalization and similarity studies.
- The resulting "runoff production" obtained with the model parameters **calibrated "At Site" with the semi-distributed strategy** (best performances) is considered to be the "truth" for assessing regionalisation accuracy

Each macrozone is considered as an **autonomous entity**



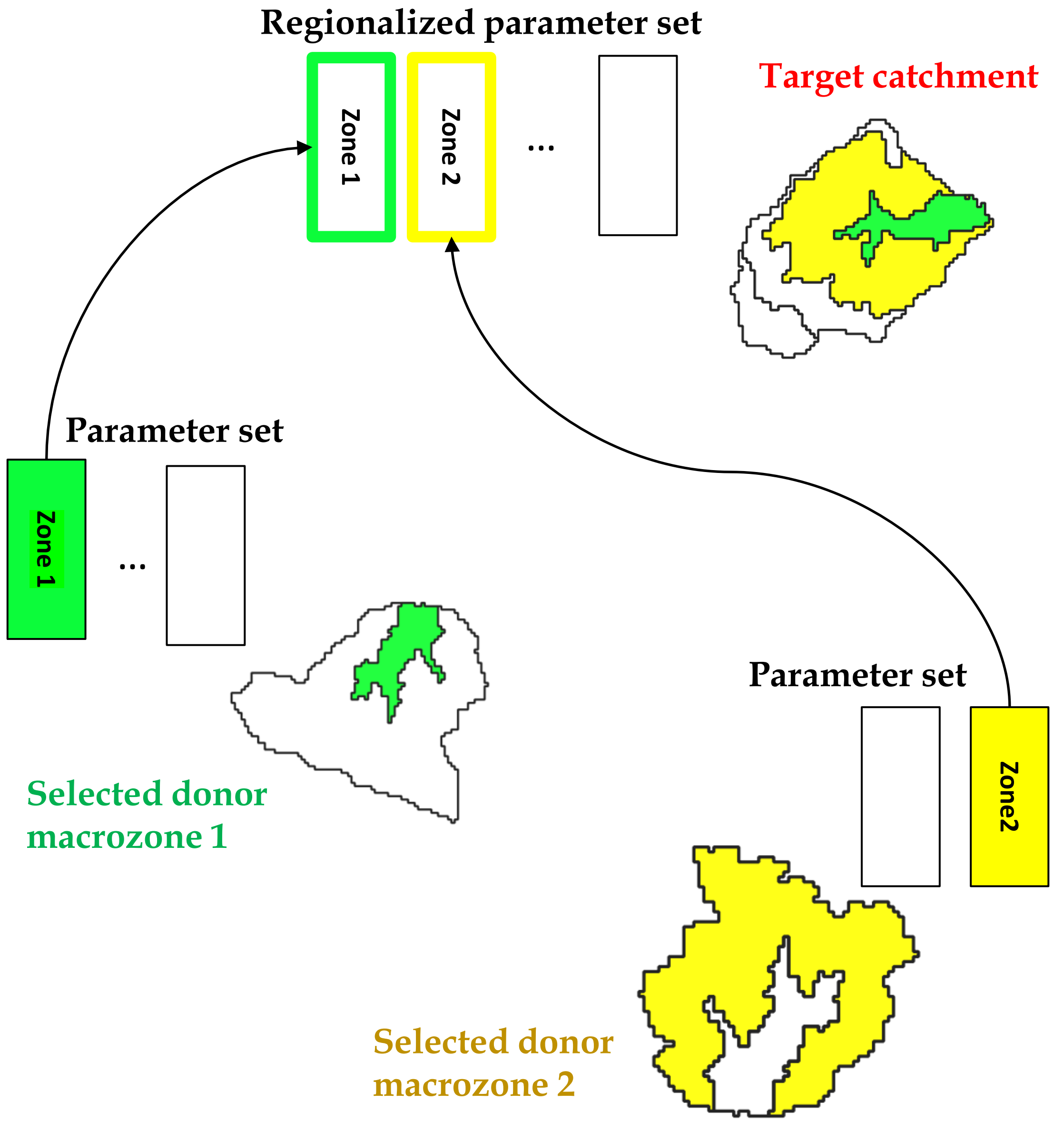
Regionalisation approaches for the runoff generation parameters (1)

Innovative Semi-Distributed parameters approach

- For each macrozone, the **entire set of generation parameters** is taken from the **most similar macrozone** at the same altitude

- Similarity is defined through the "distance" in the normalized attributes space : for each macrozone, the **combination of two attributes** giving best performances in terms of KGE of the zone runoff production (tested in LOOCV*) is selected

Similarity is "optimised" (choice of the attributes) at **sub-basin level**



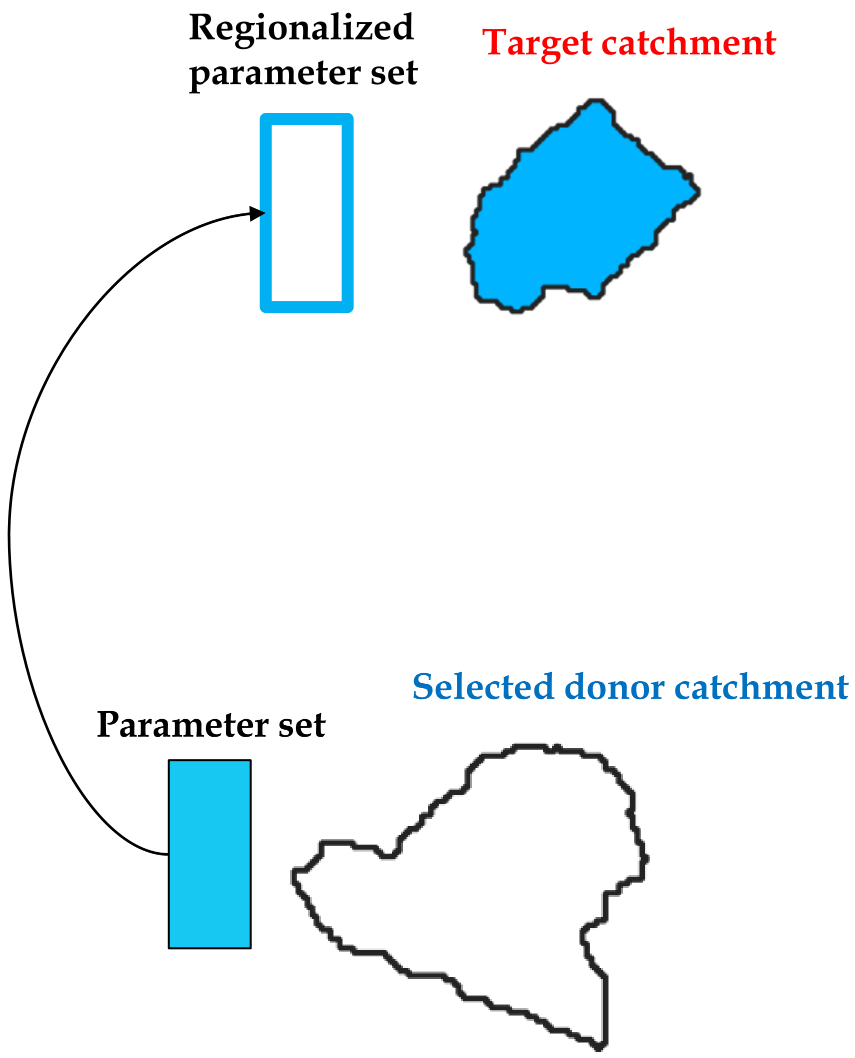
*leave-one-out cross-validation

Regionalisation approaches for the runoff generation parameters

Benchmark: standard "uniform parameters" approach

- For each catchment, the **entire set of generation parameters** is taken from the **most similar donor basin**
- Similarity is defined through the "distance" in the normalized attributes space: the **combination of two attributes** giving best performances in terms of KGE of the total runoff production (tested in LOOCV*) is selected.

Similarity is "optimised" (choice of the attributes) at **catchment level**



*leave-one-out cross-validation

First conclusions

- **Semi-distributed calibration** can improve model performances “at site”
- Calibrated **parameters** may show certain **patterns across macrozones:** this deserves more investigation and could help to further calibration constraint and to facilitate parameter regionalisation.
- The optimization of the best catchment/macrozone descriptors to apply in the regionalisation approaches can underline most important attributes to characterise similarity
- Preliminary results on **semi-distributed based regionalization** of runoff production did not lead to substantial improvement in model performances in its actual form for Austria (but standard regionalisation performances are already very good). Analysis on US set are on-going…

Thank you!

For any comment/question/suggestion please feel free to contact us!

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Otherwise see you at the chat room!

Main references

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