Satellite inspired hydrology in an uncertain future: an H SAF and HEPEX workshop
ECMWF, Reading, November 2019

Snow processes in bucket-type hydrological models – does increased realism lead to better simulations?

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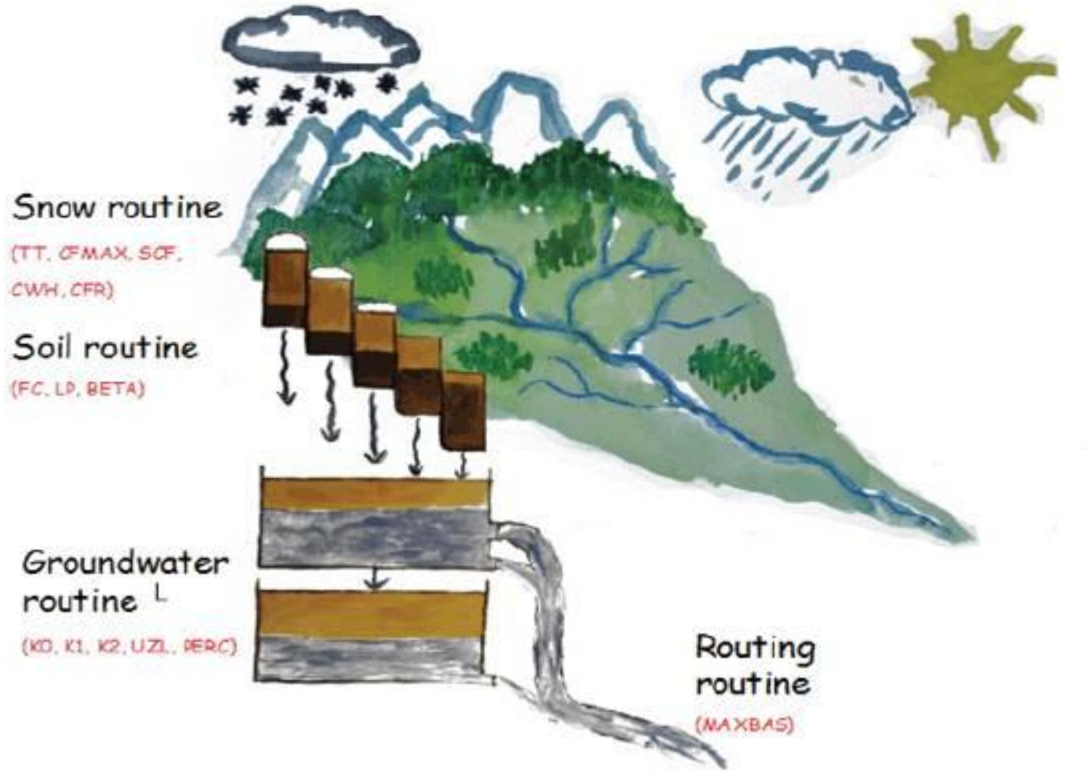
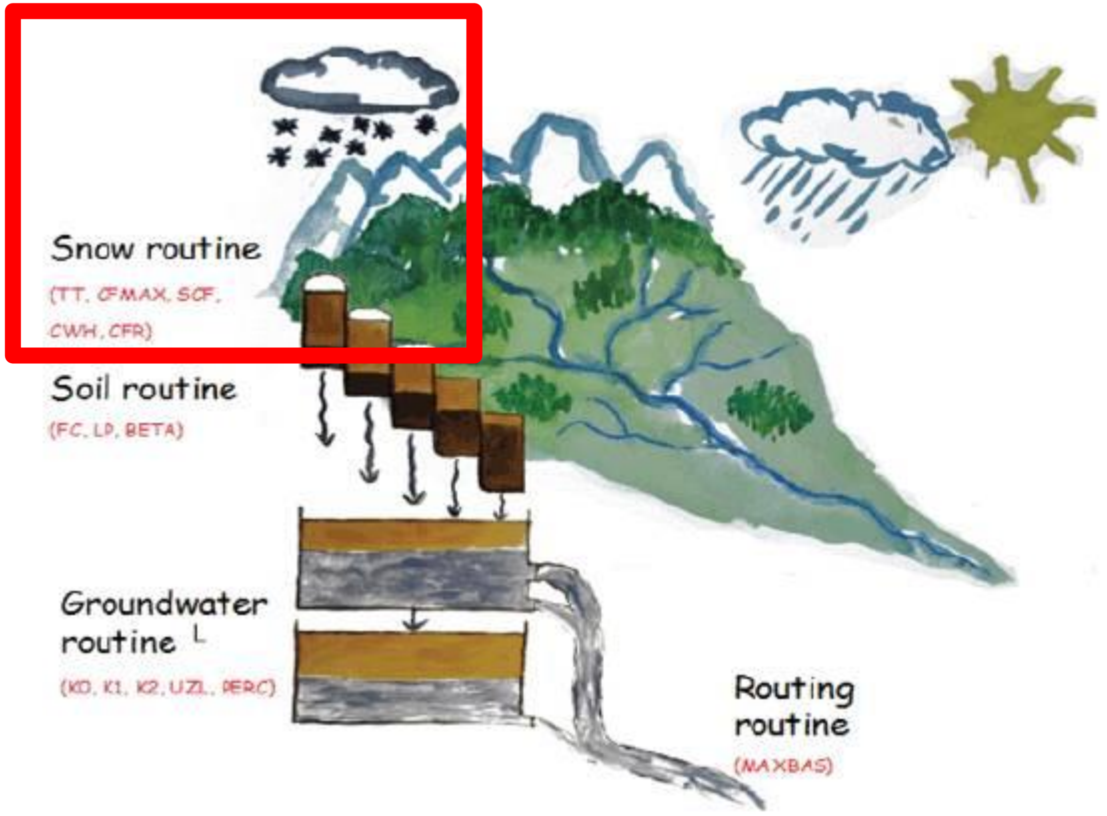
HBV model - a typical bucket-type model



- Semi-distributed rainfall-runoff model
- Developed at SMHI, Sweden (Bergström, 1976; Lindström et al., 1996)
- Simple model structure
- Few model parameters (~10-15)
- Low data requirements
- Our version: 'HBV light'

Seibert and Vis, 2012, HESS

Snow routine of the HBV model



- Threshold temperature T_T

- Degree-day method for snowmelt

$$M = C_{FMAX}\,(T - T_T) \qquad [\mathrm{mm\ d^{-1}}]$$

- Snow pack retains some melt water (C_{WH}, usually 0.1)

- This water can refreeze

$$M = C_{FR}\,C_{FMAX}\,(T_T - T) \qquad [\mathrm{mm\ h^{-1}}]$$

$$C_{FR} = \sim 0.05 \quad [-]$$

Seibert and Vis, 2012, HESS

Can we improve the snow routine?

…while maintaining HBV's characteristic simplicity and low data requirements.

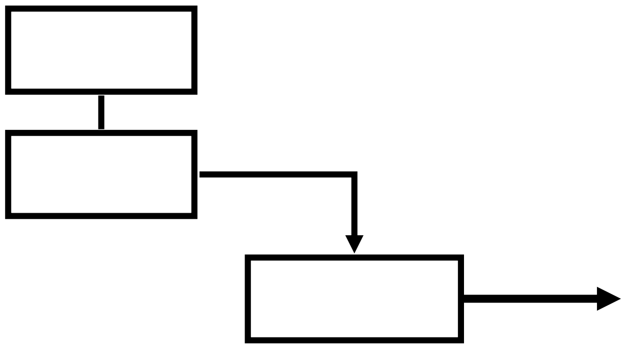
Philosophy: which model will fly?

Should we improve the snow routine?

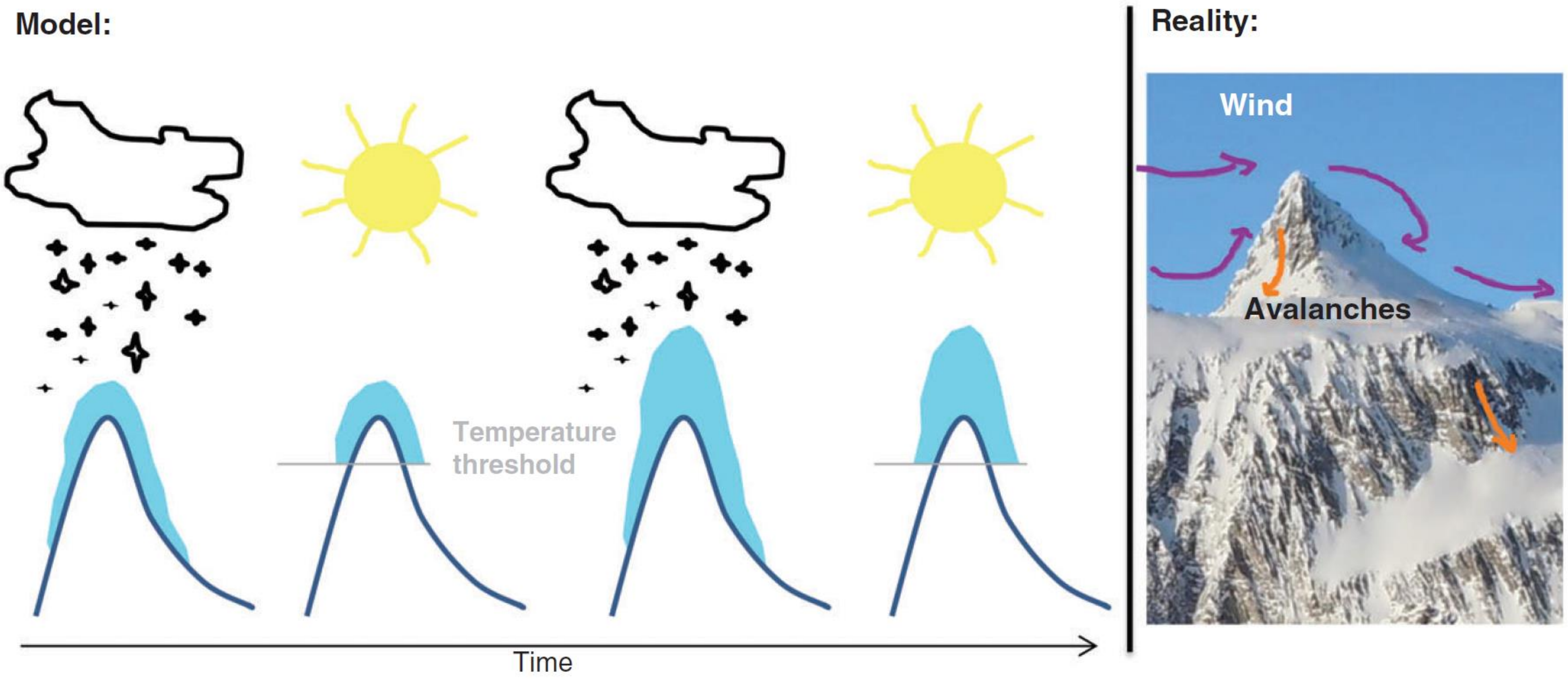
All models are wrong, but some are useful

(George Box)

Models that are less wrong, might be more useful

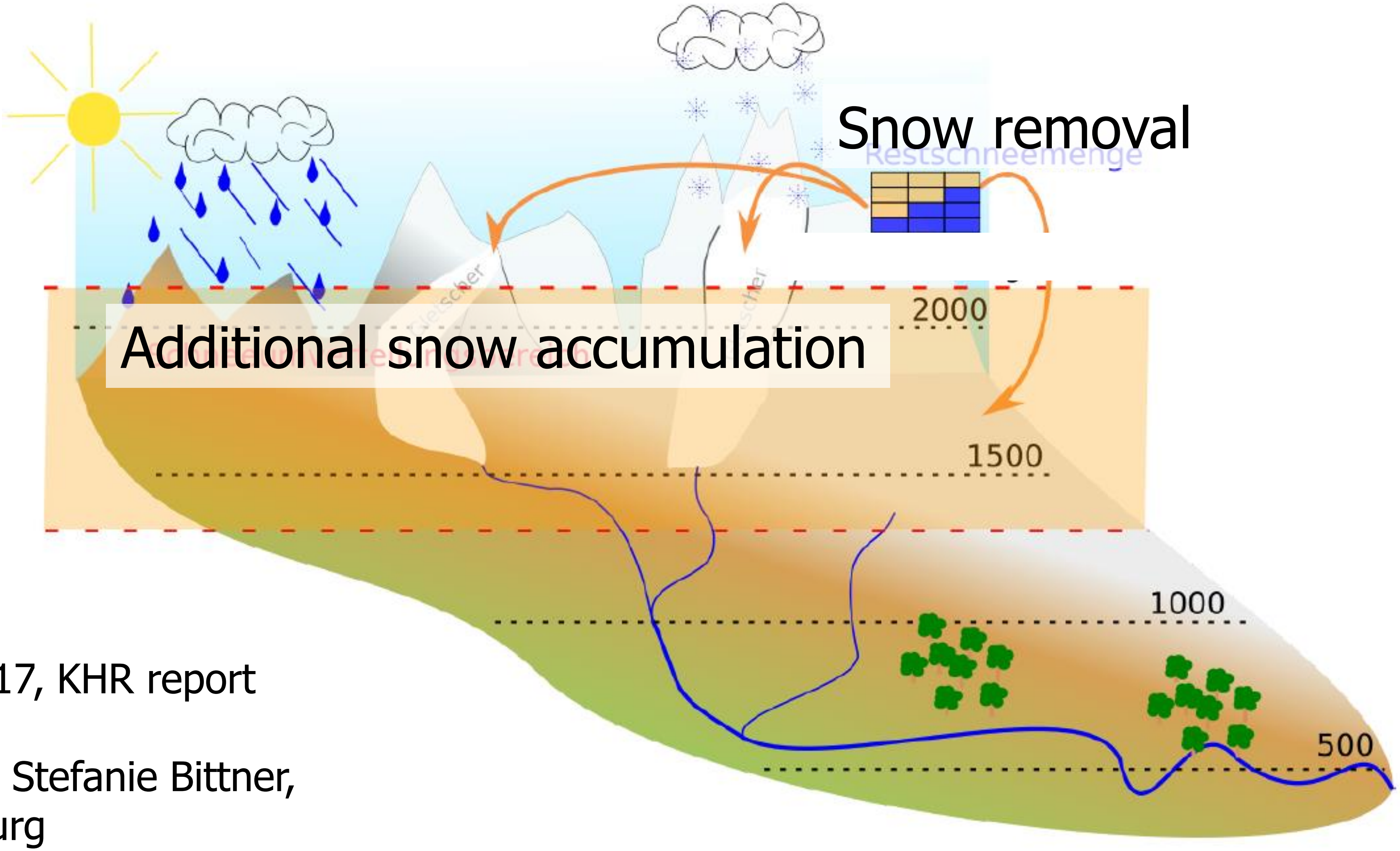


’Snow towers’



Freudiger et al., 2017, WIRES Water

Simple snow redistribution approach



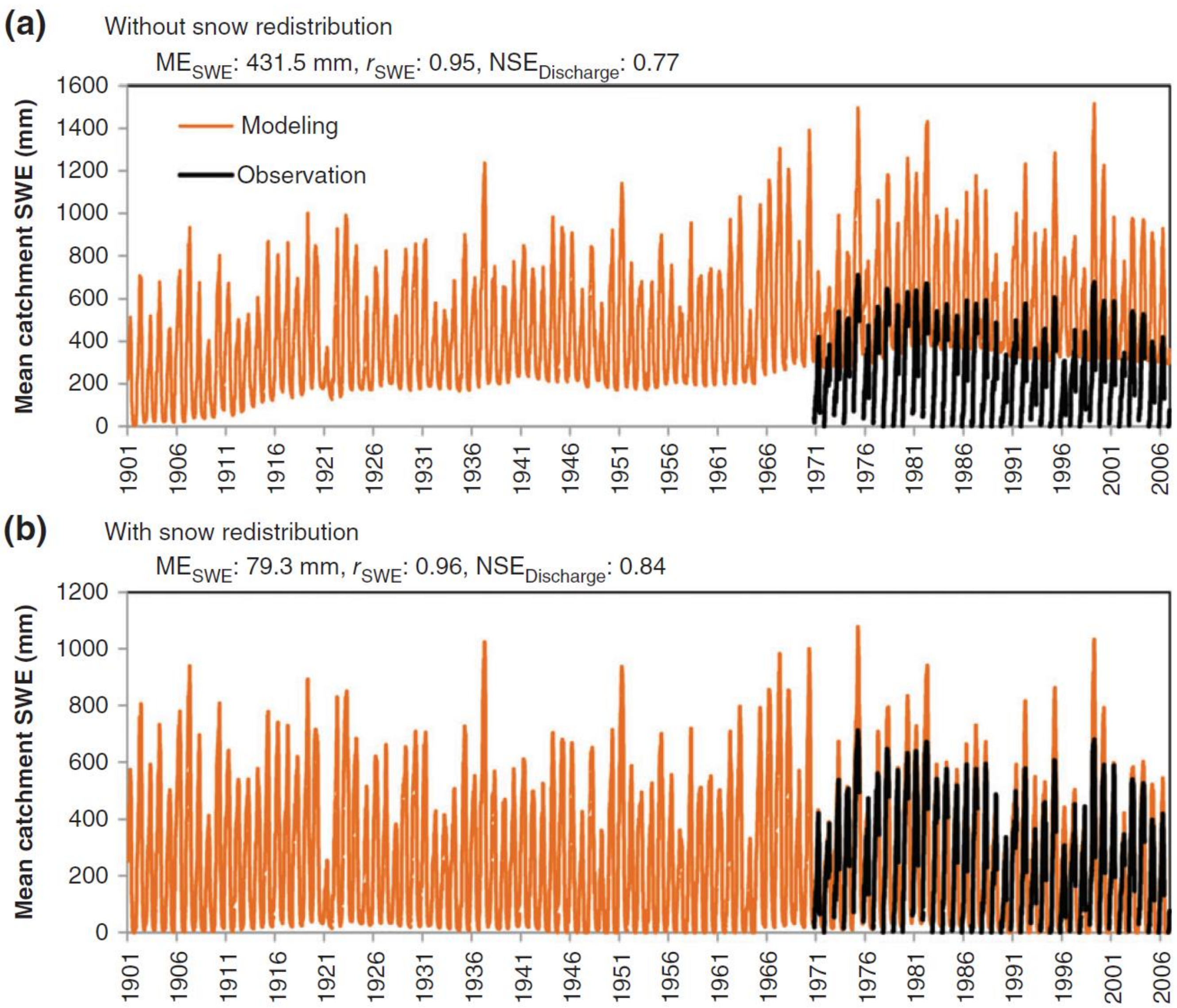
Stahl et al. 2016&2017, KHR report

Figure modified from Stefanie Bittner, MSc thesis Uni Freiburg

Model improvement

No snow redistribution

With snow redistribution

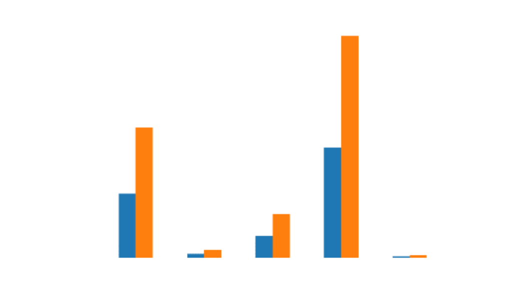


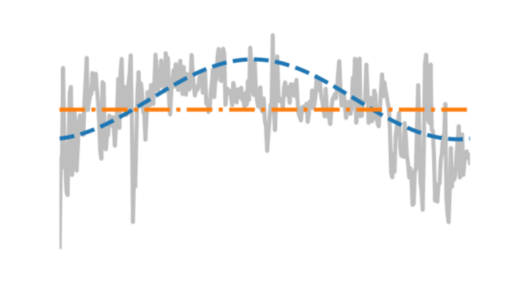
Observations

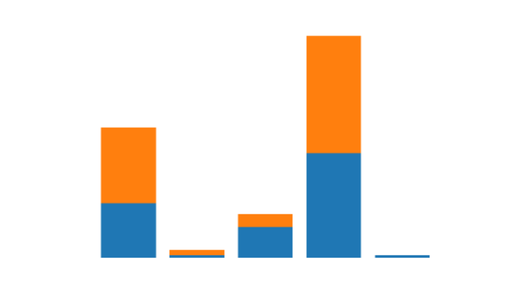
Simulations

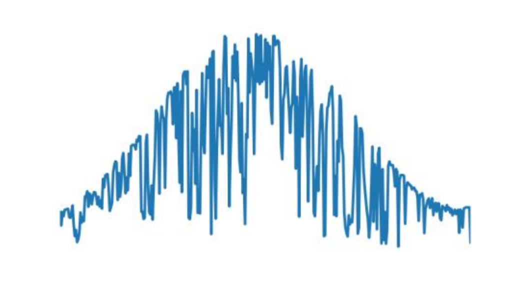
Freudiger et al., 2017, WIRES Water

Possible snow routine modifications

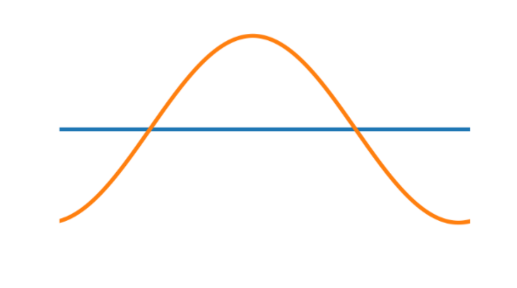
Precipitation


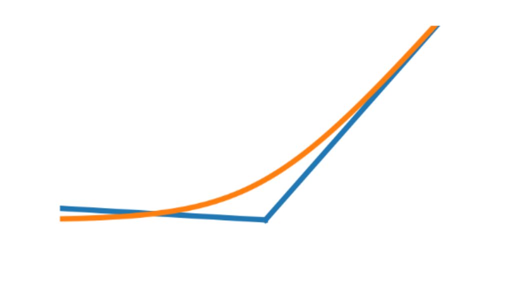
Temperature


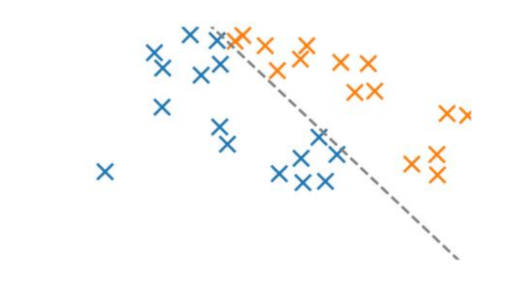
Rain/snow partition


Global radiation


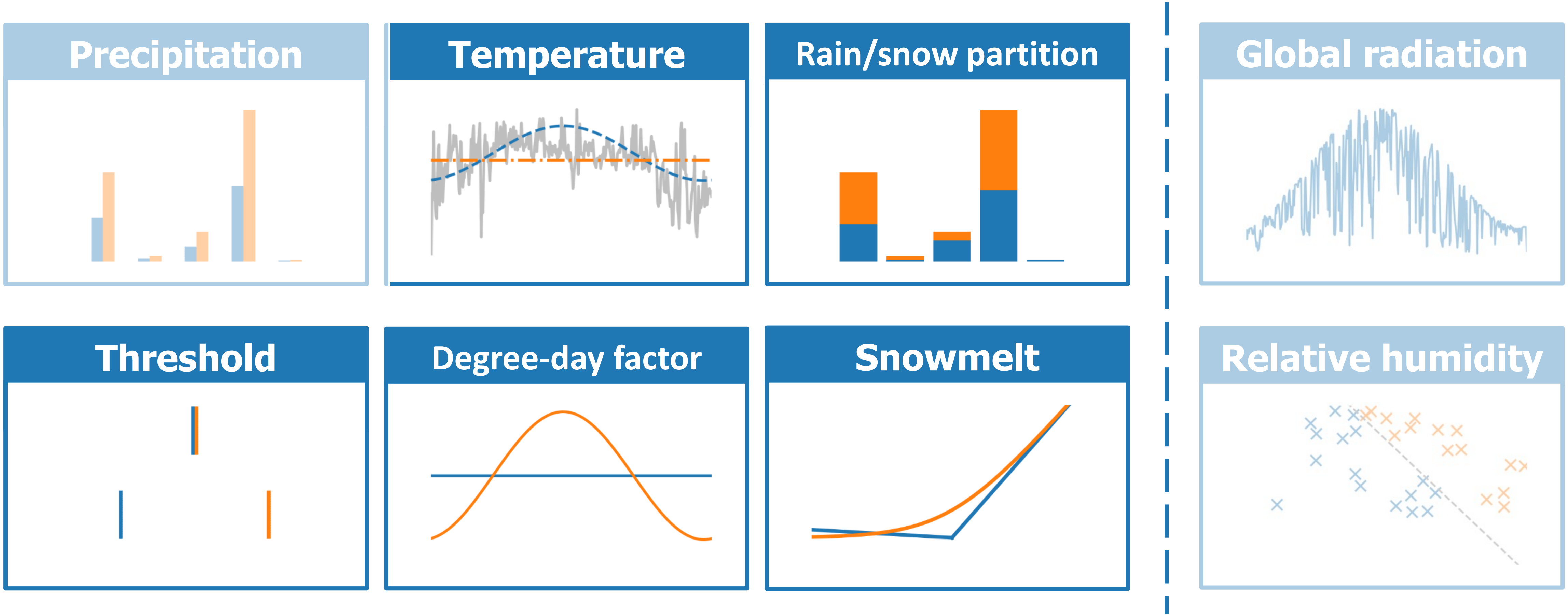
Threshold


Degree-day factor


Snowmelt


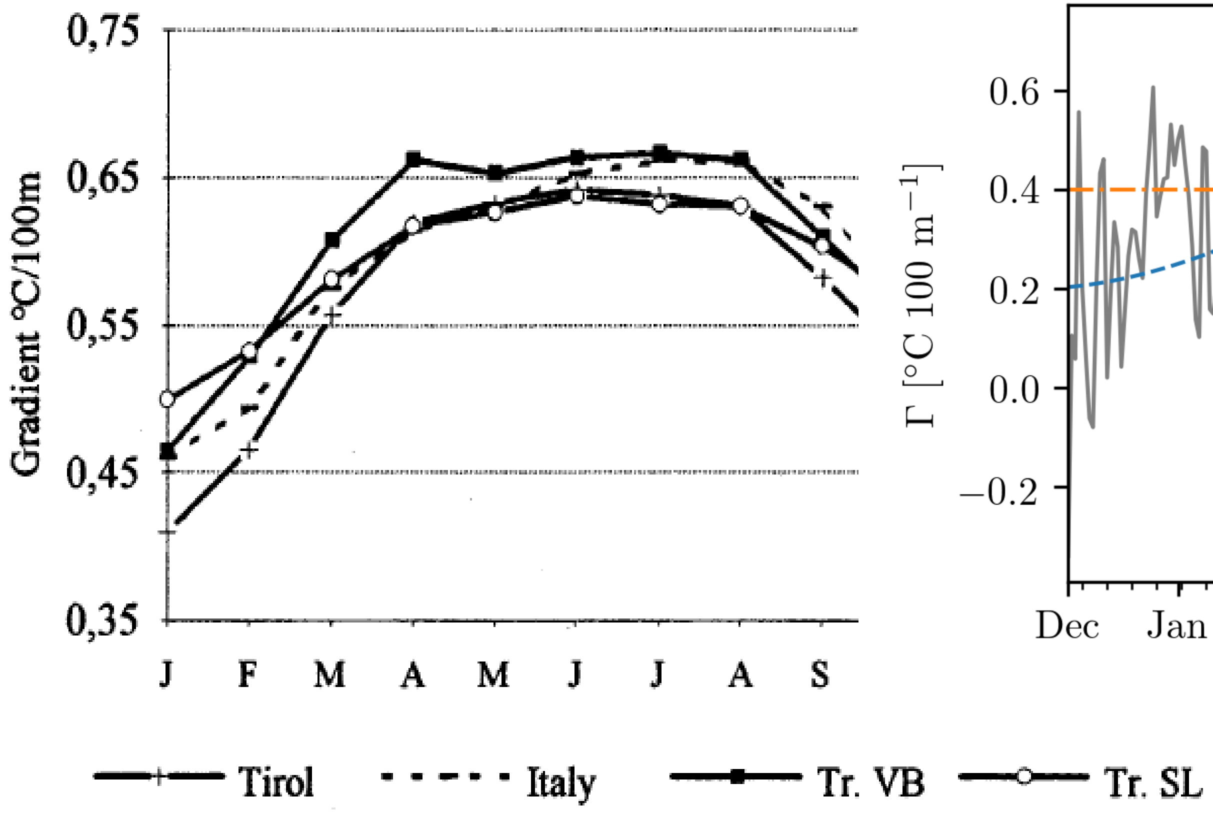
Relative humidity


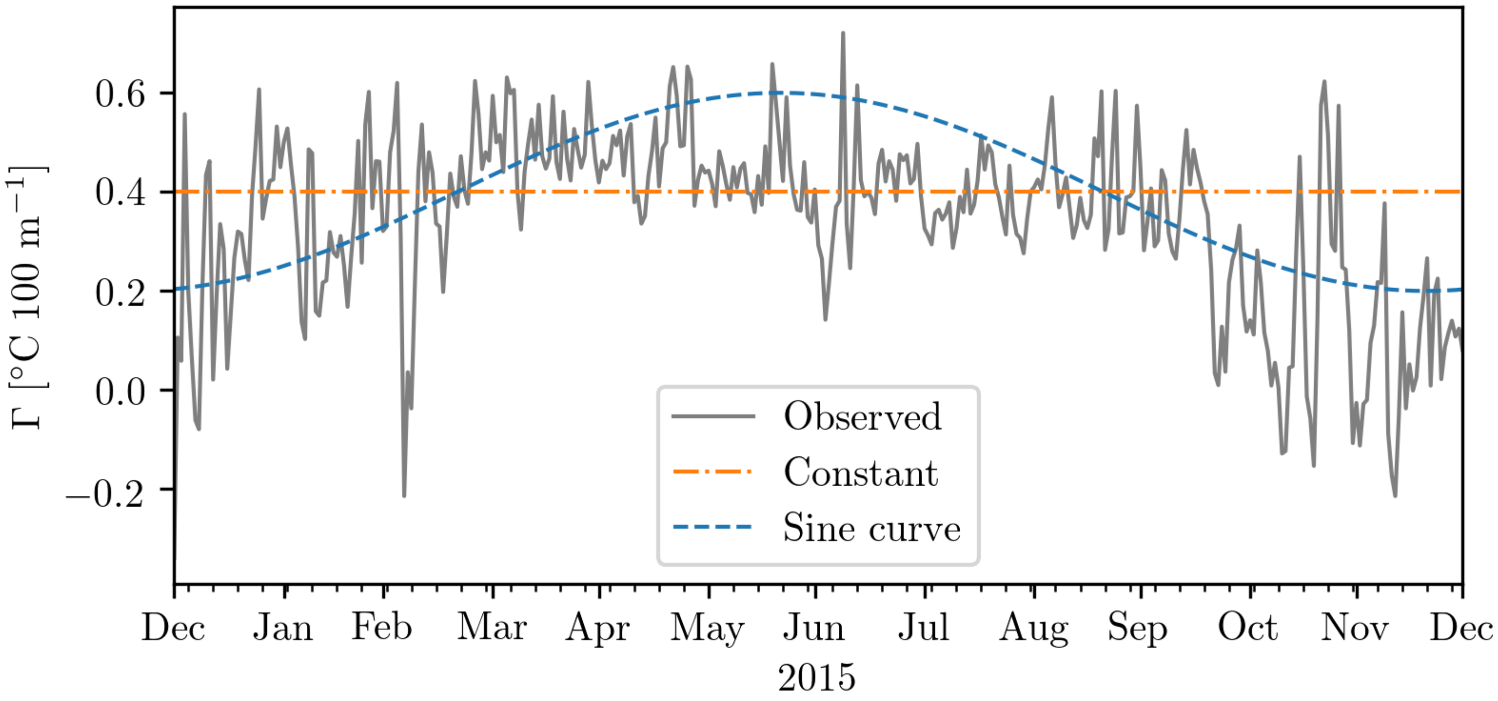
Possible snow routine modifications



Temperature lapse rate

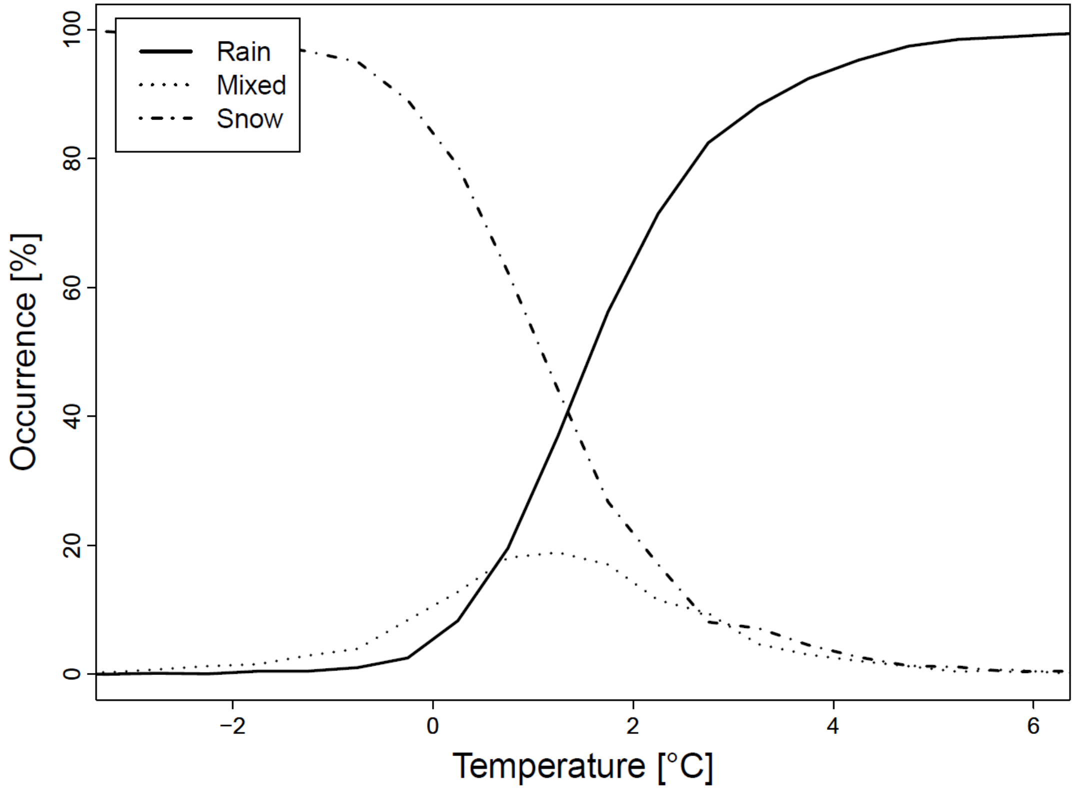
Temperature lapse rate



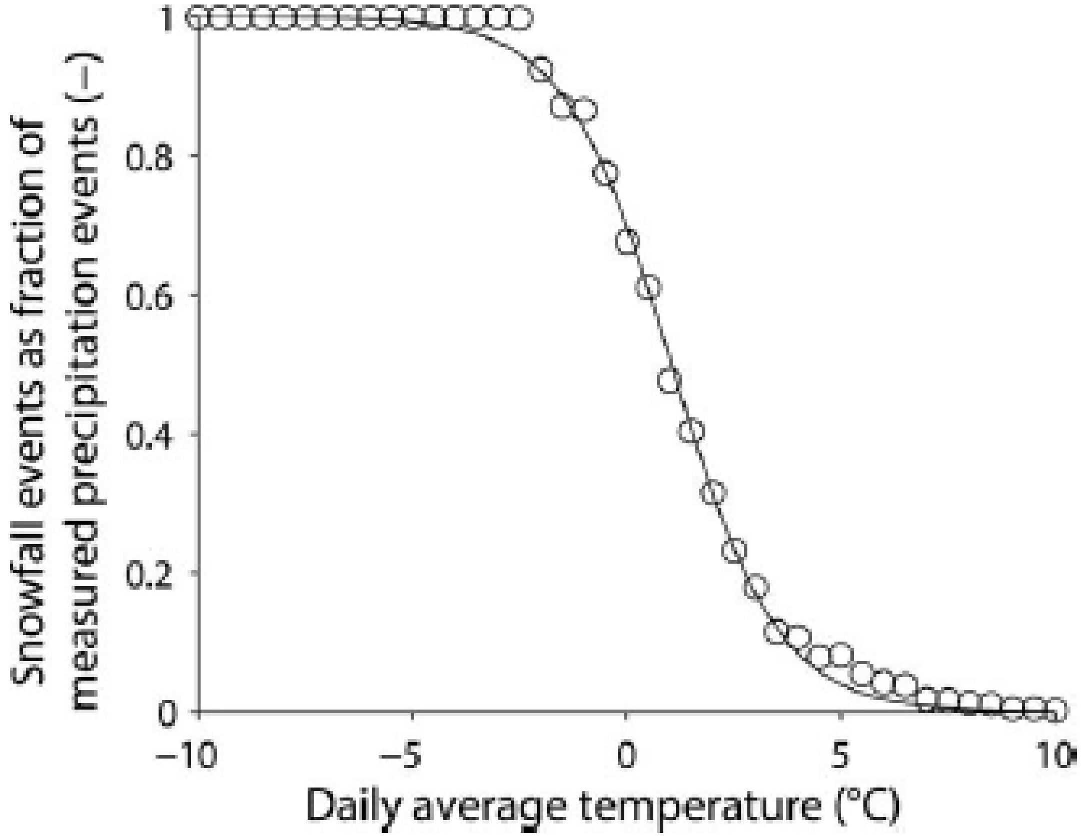


Rolland (2002)

Rain-snow partition

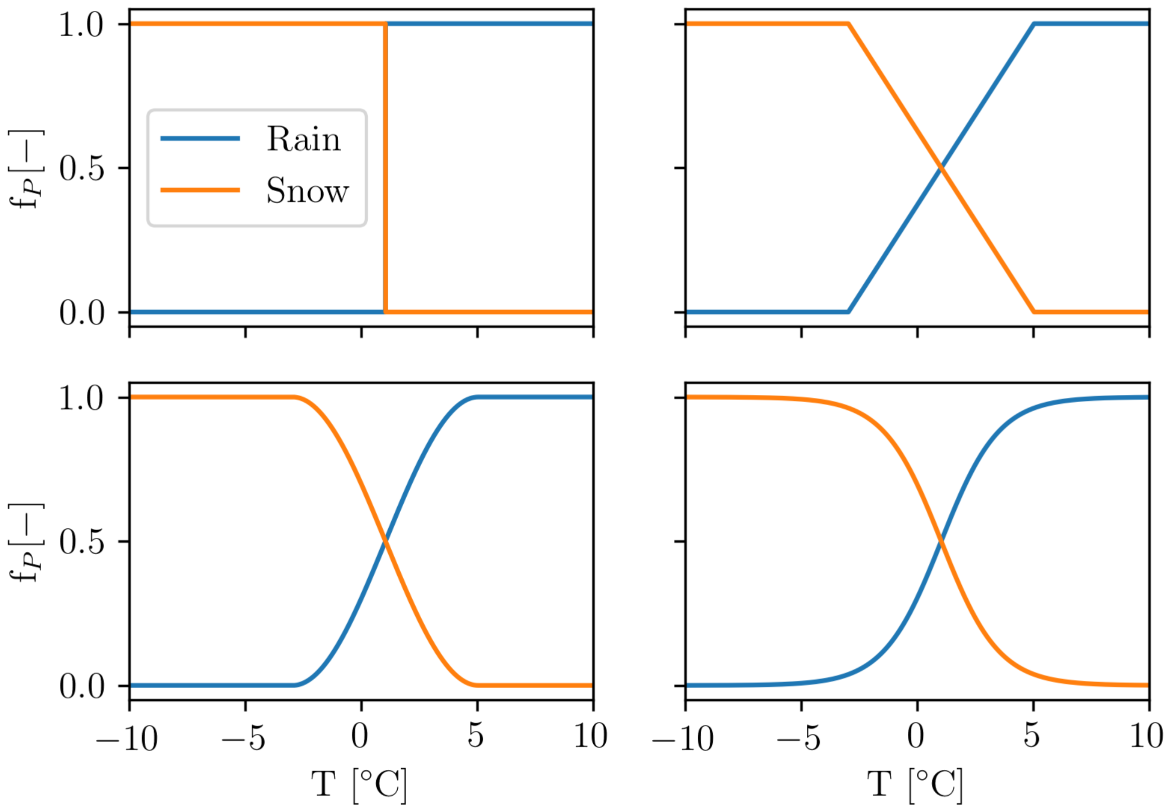


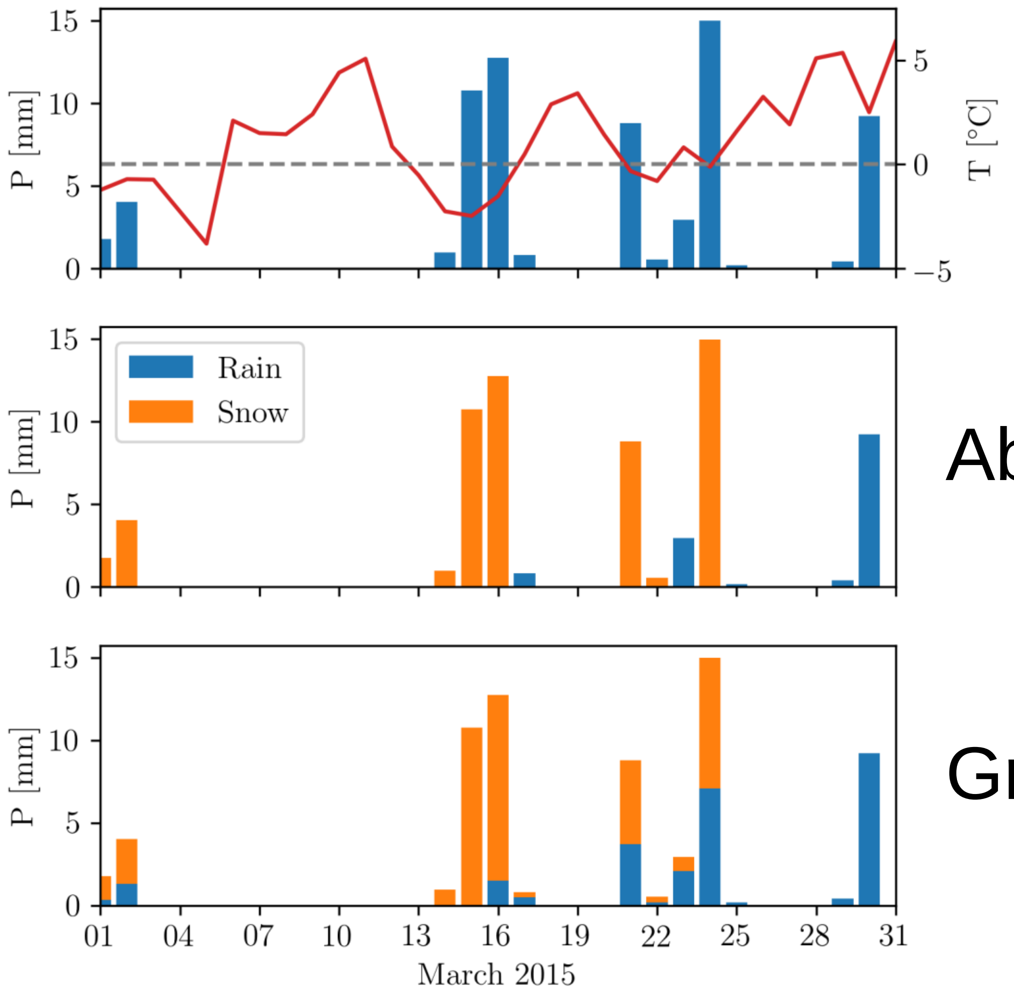
Froidurot et al., 2014



Magnusson (2014)

Rain-snow partition

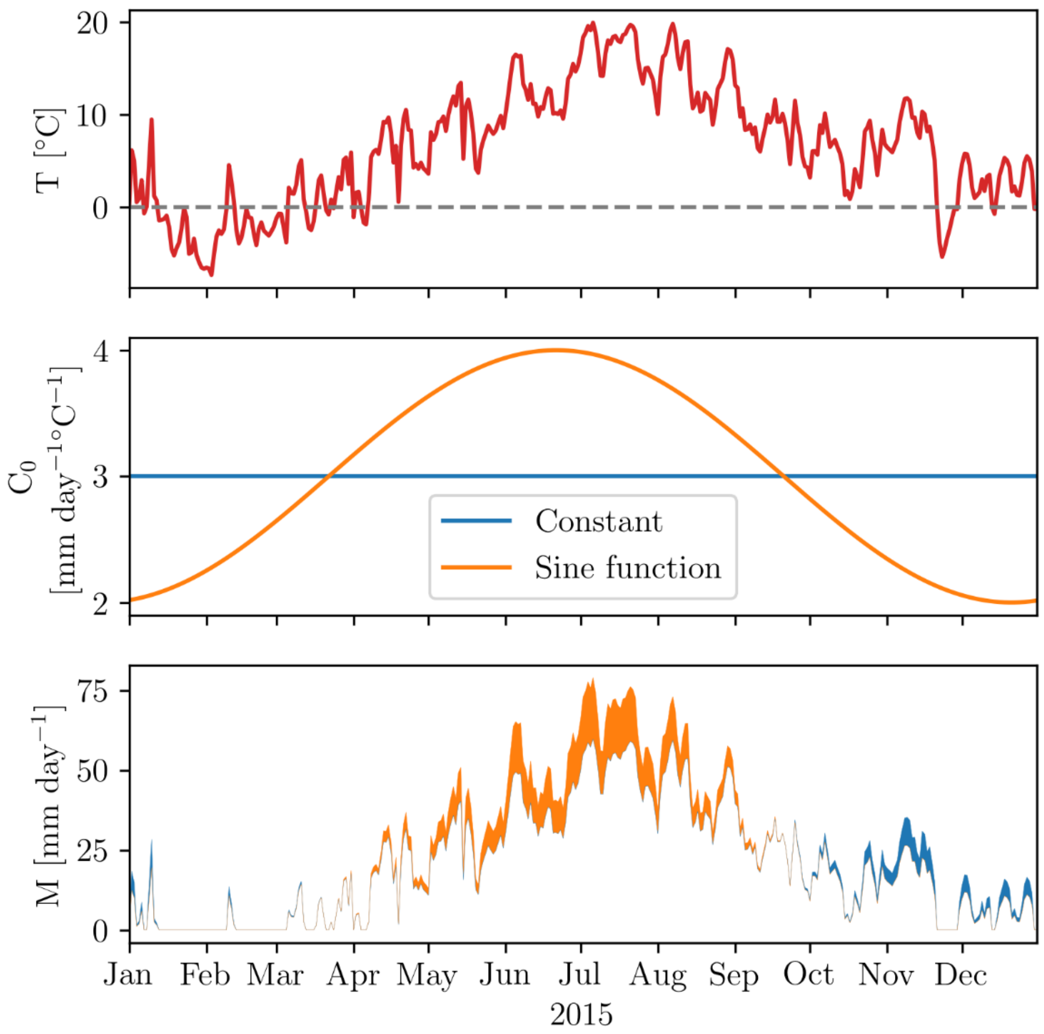




Abrupt

Gradual

Degree-day factor

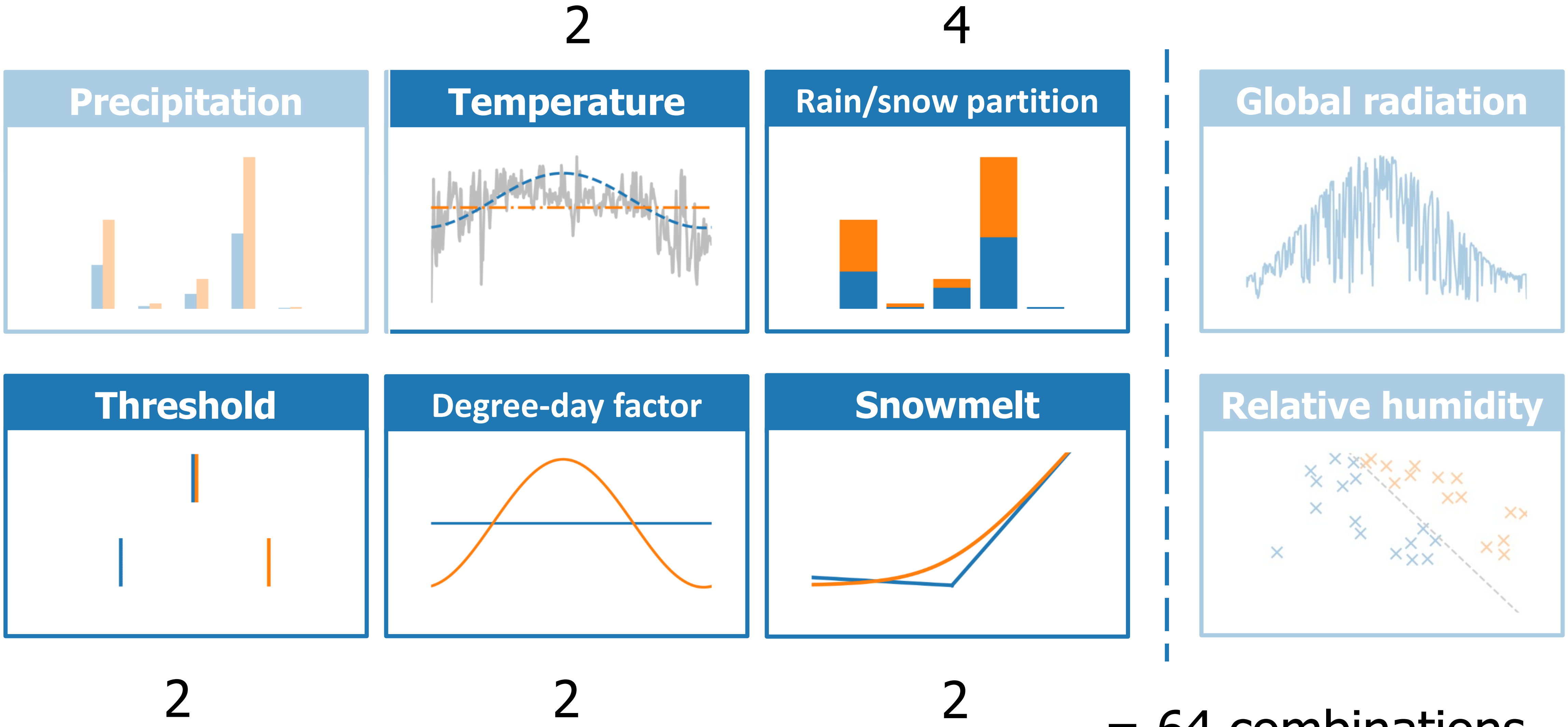


$$M = C_0\,(T - T_T)$$

$$C_0(\mathrm{n}) = C_0$$

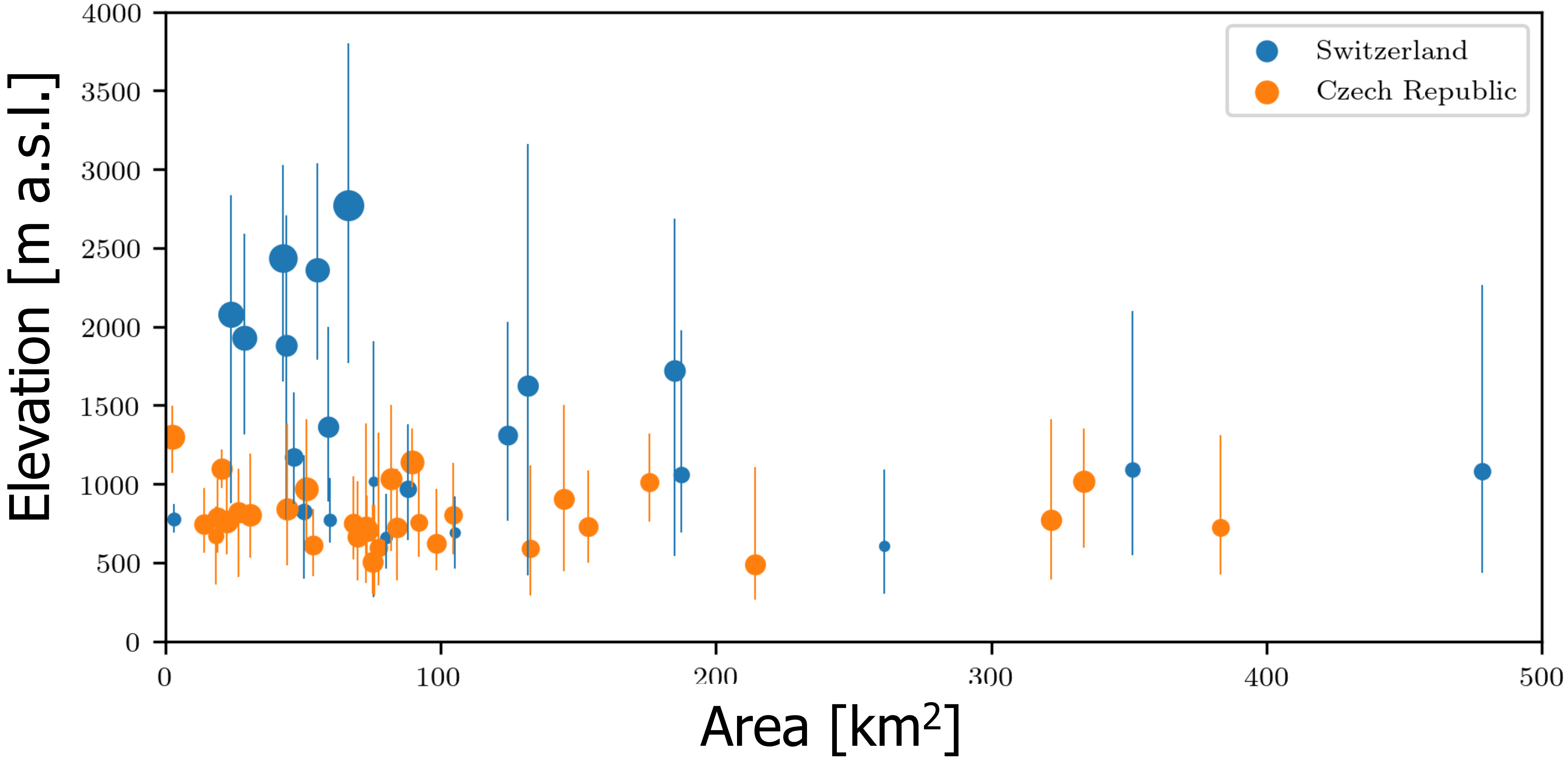
$$C_0(\mathrm{n}) = C_0 + \frac{1}{2} C_{0,i} \sin \frac{2\pi(n-81)}{365}$$

Possible snow routine modifications



= 64 combinations

54 test catchments in Switzerland and the Czech Republic



Circle size ~ snow melt contribution (5 – 38 %)

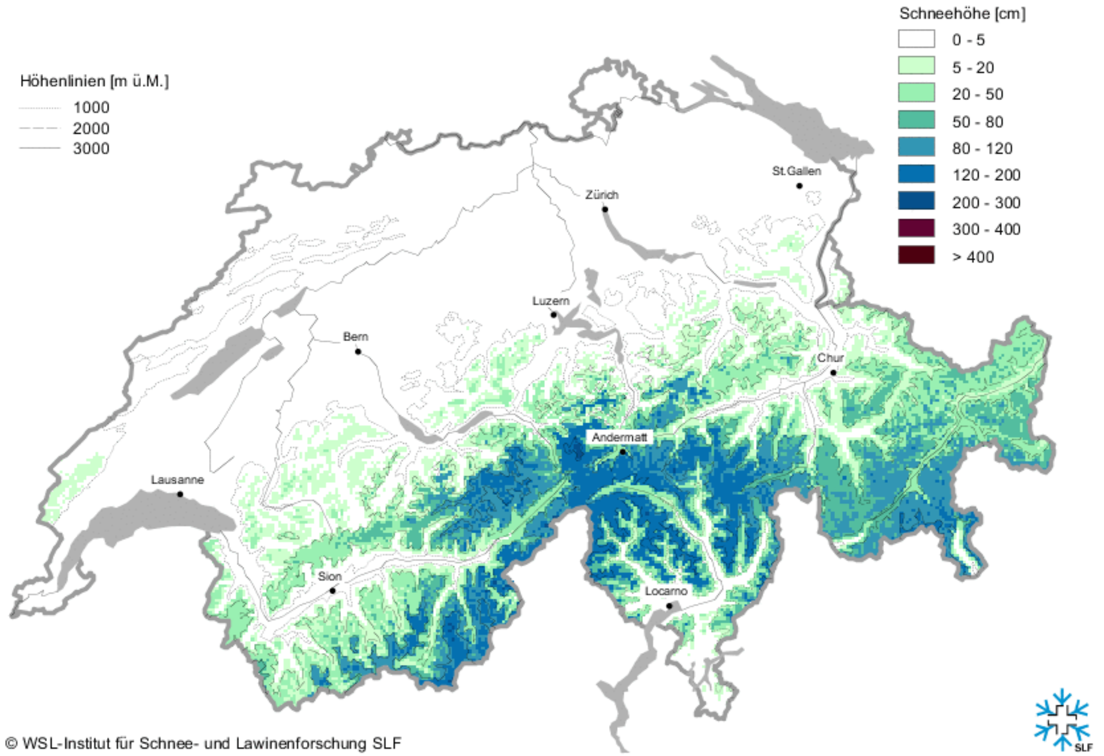
Model setup

18 years of data
(2 y warming up, 8 y calibration, 8 y validation)

P, T and Q (daily data)

SWE: station data (for CH: interpolation by SLF, Tobias Jonas)

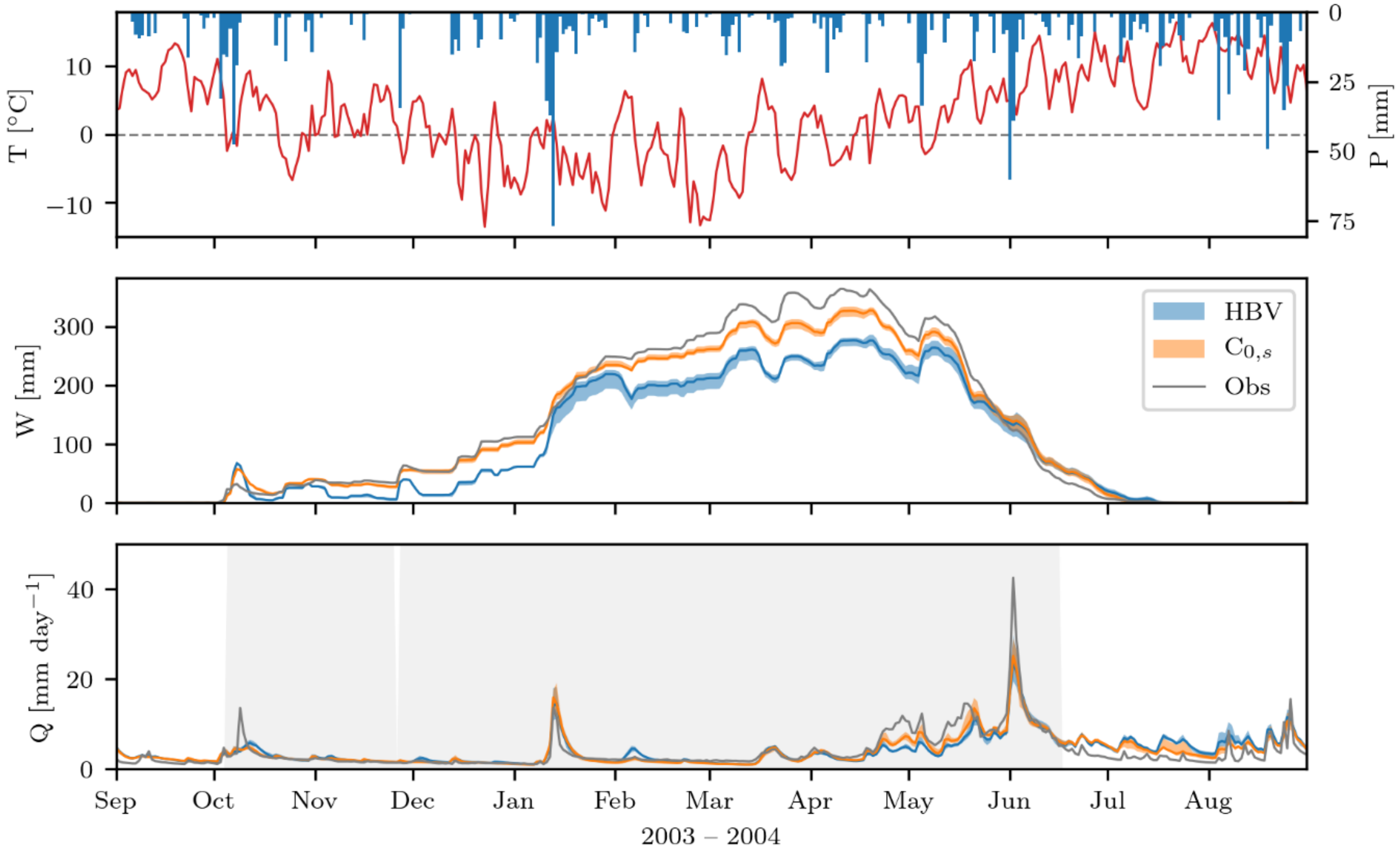
Evaluation:
NSE of **log(Q)** and **SWE**



A lot of model runs …

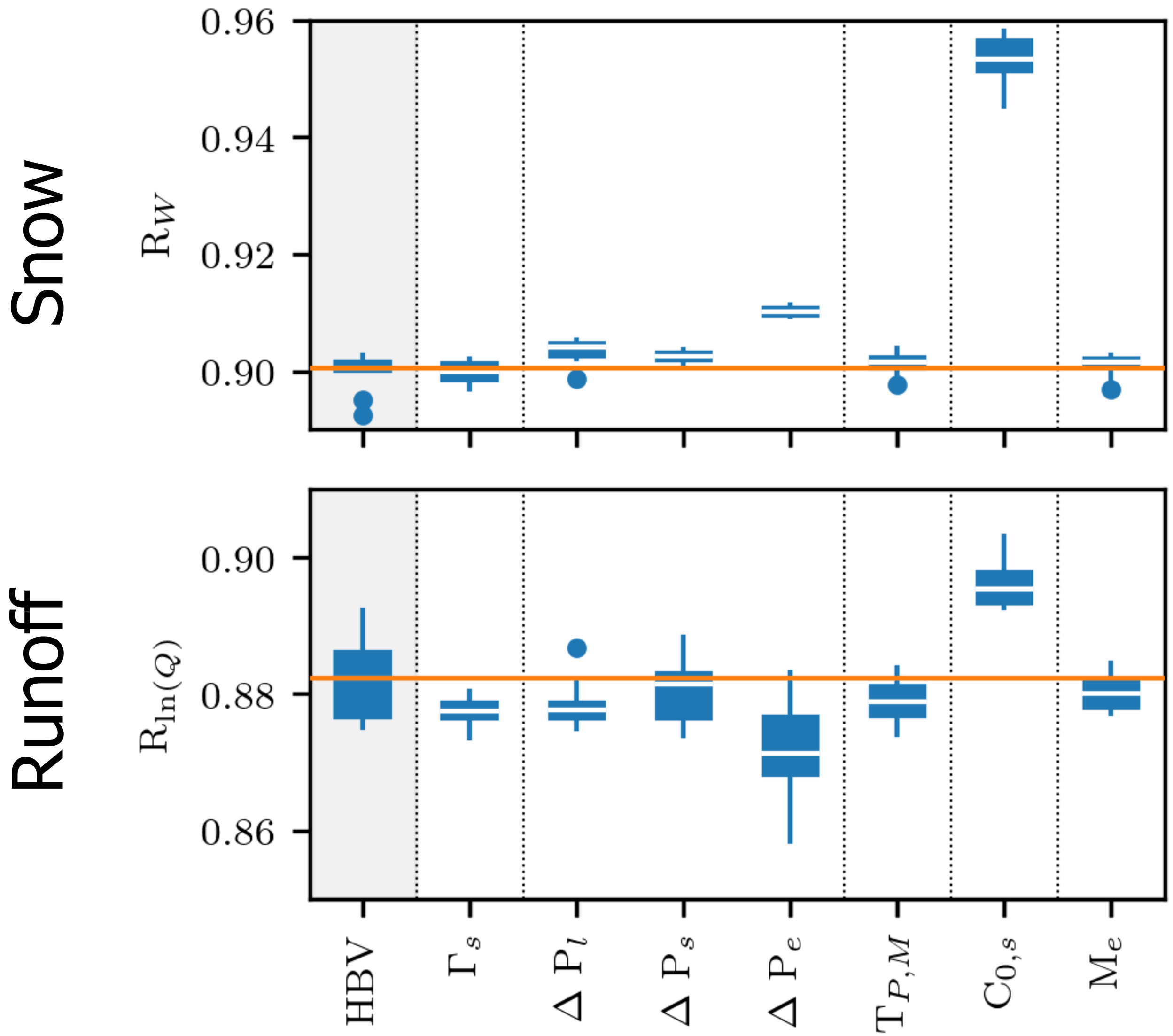
64	Model modification combinations
54	Catchments
2	Objective functions
2	Time periods
10	Calibration trials, each with 3500 model runs

= **almost 500 million model runs**



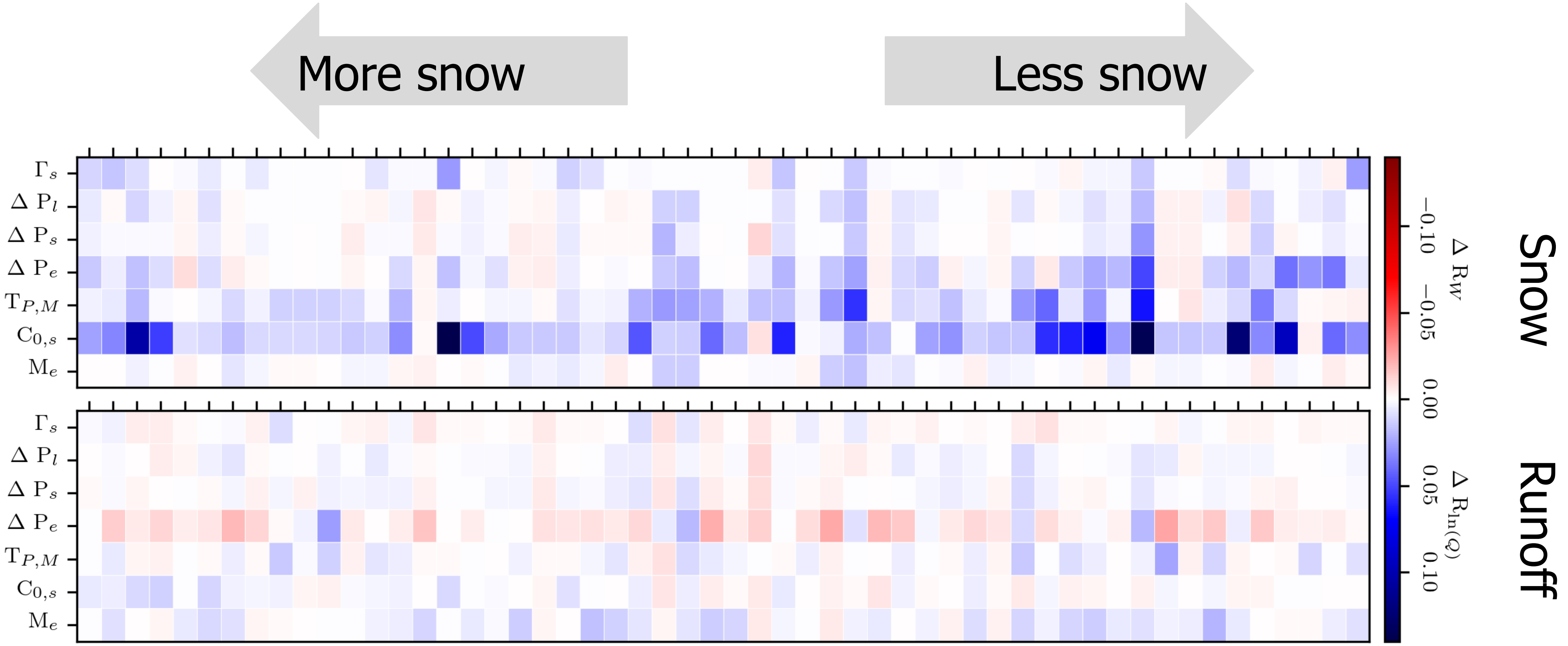
T [°C]
P [mm]
W [mm]
Q [mm day^{-1}]
HBV
$C_{0,s}$
Obs
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
2003 – 2004

Effect of single modifications



Example for one catchment (Allenbach)

Effect of a single modification for the different catchments

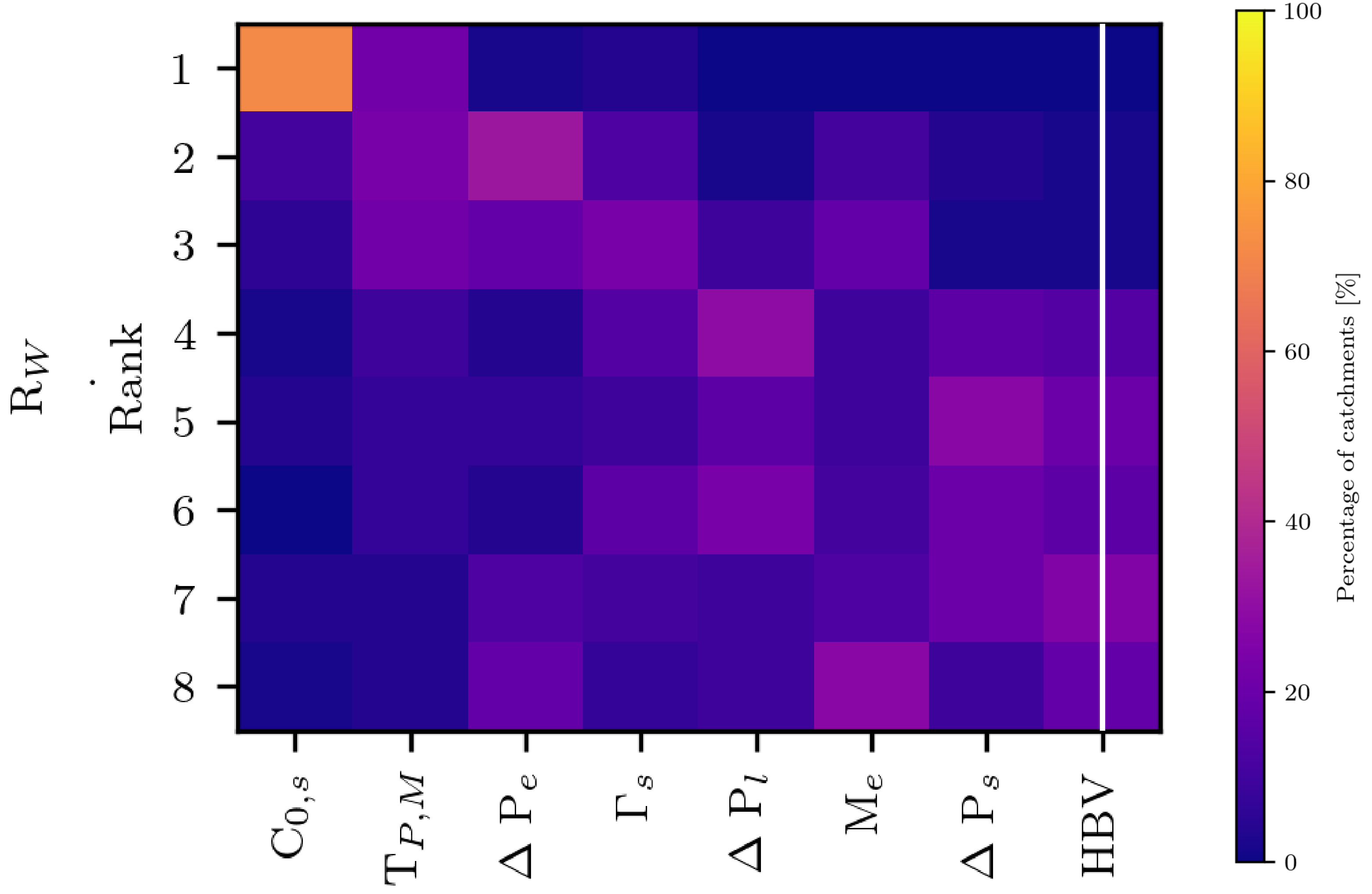


Variable DDF = improvement

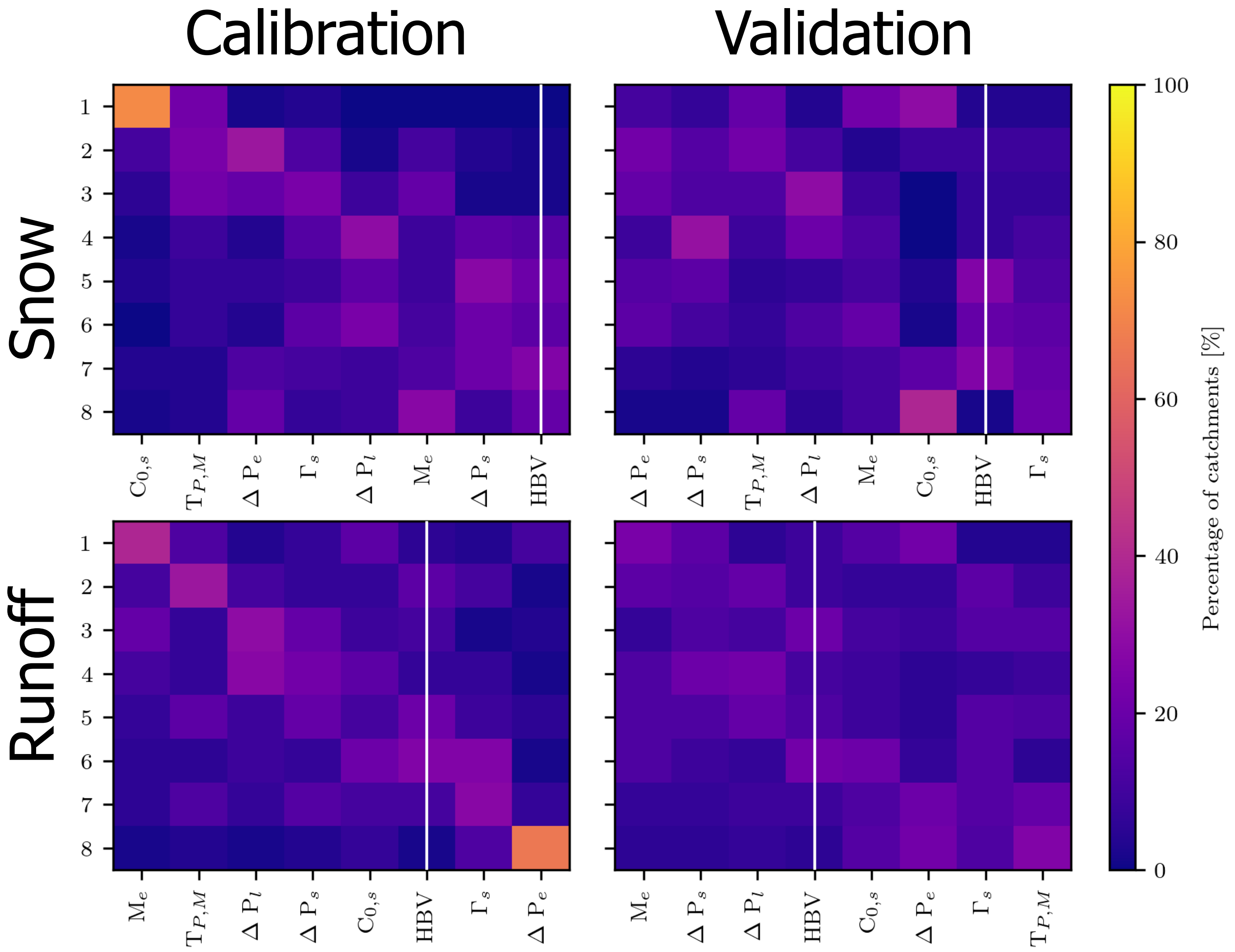
Large variability between catchments

Ranks of the modifications in the different catchments

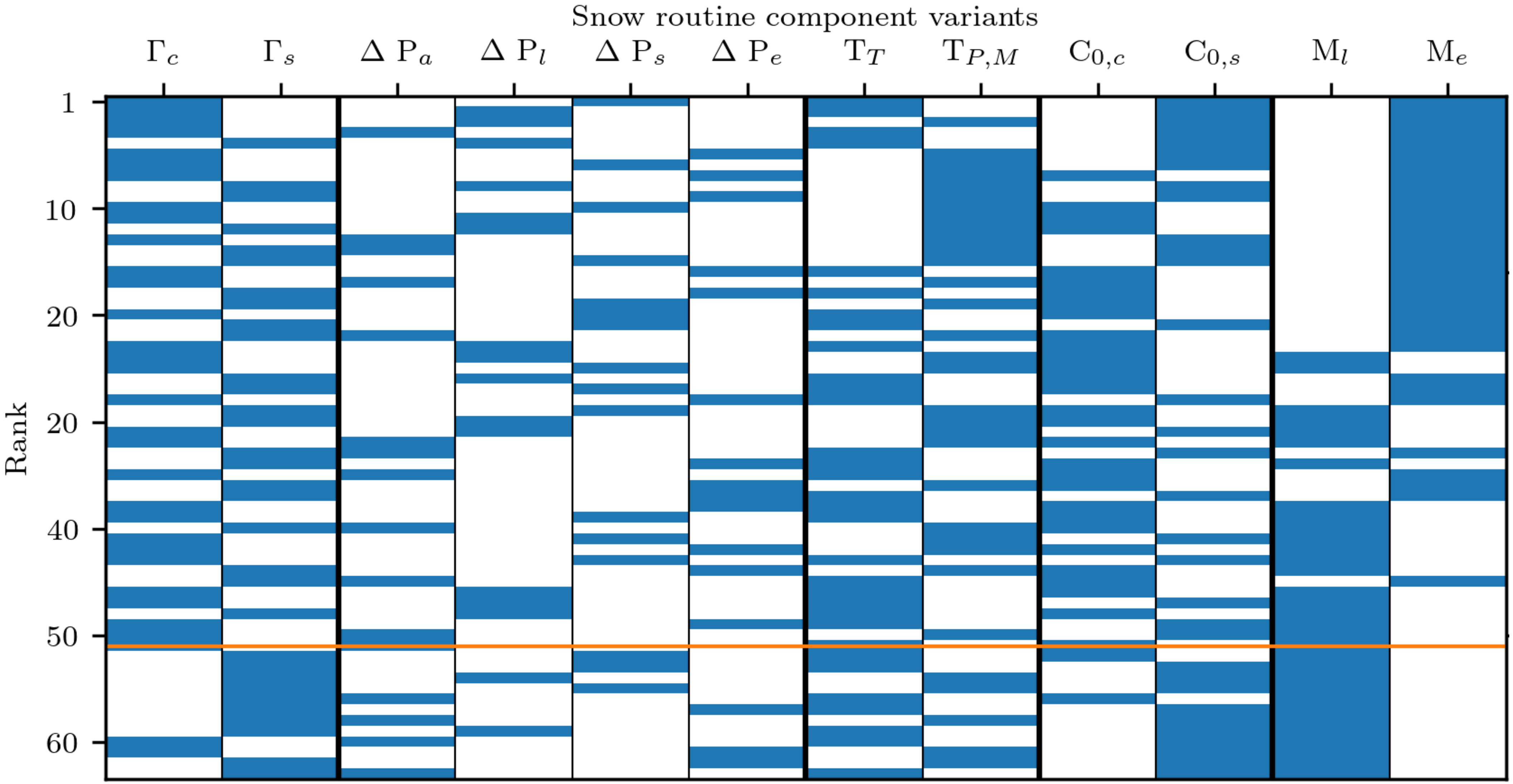
Snow Calibration



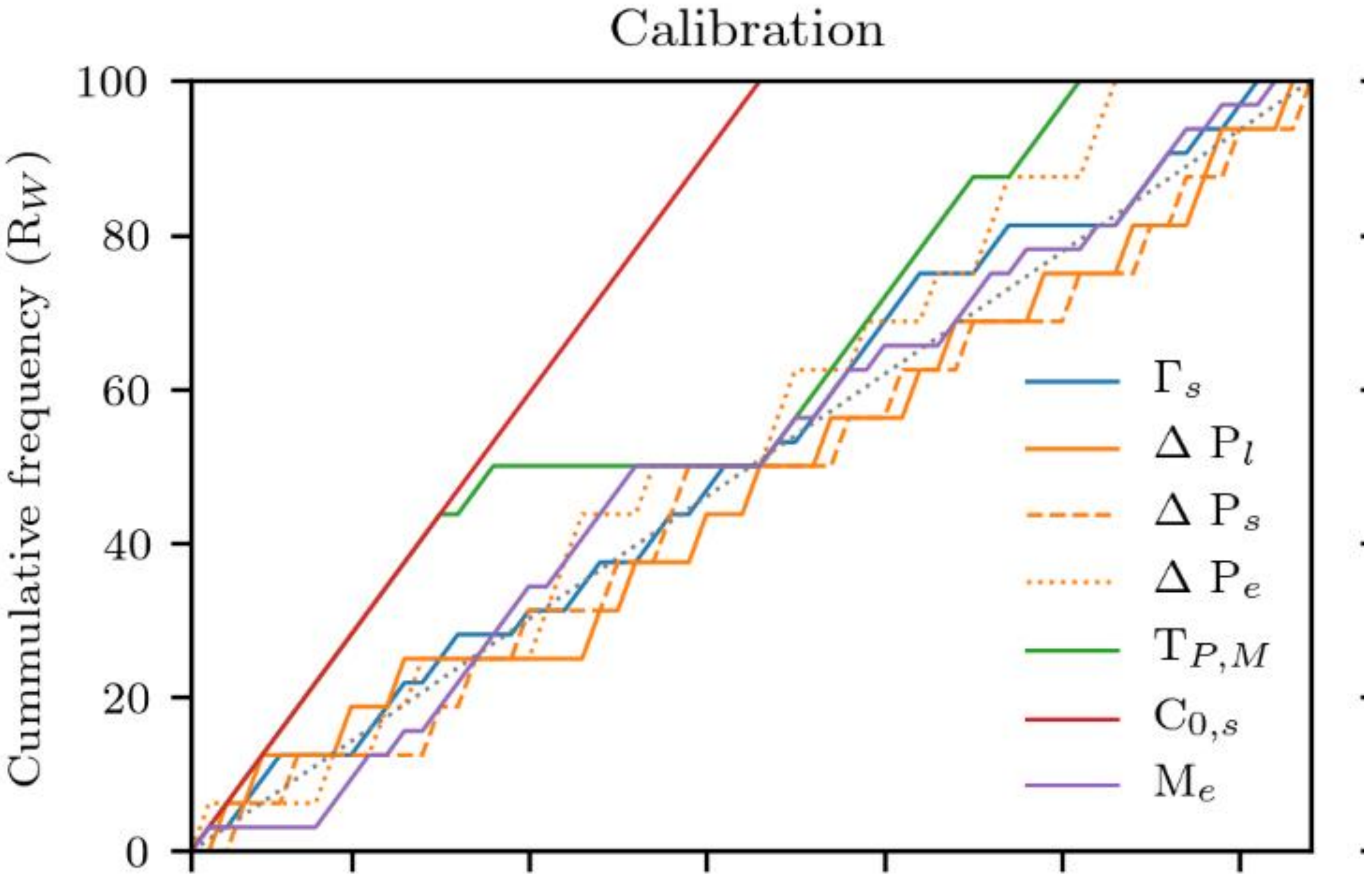
Ranks of the modifications in the different catchments



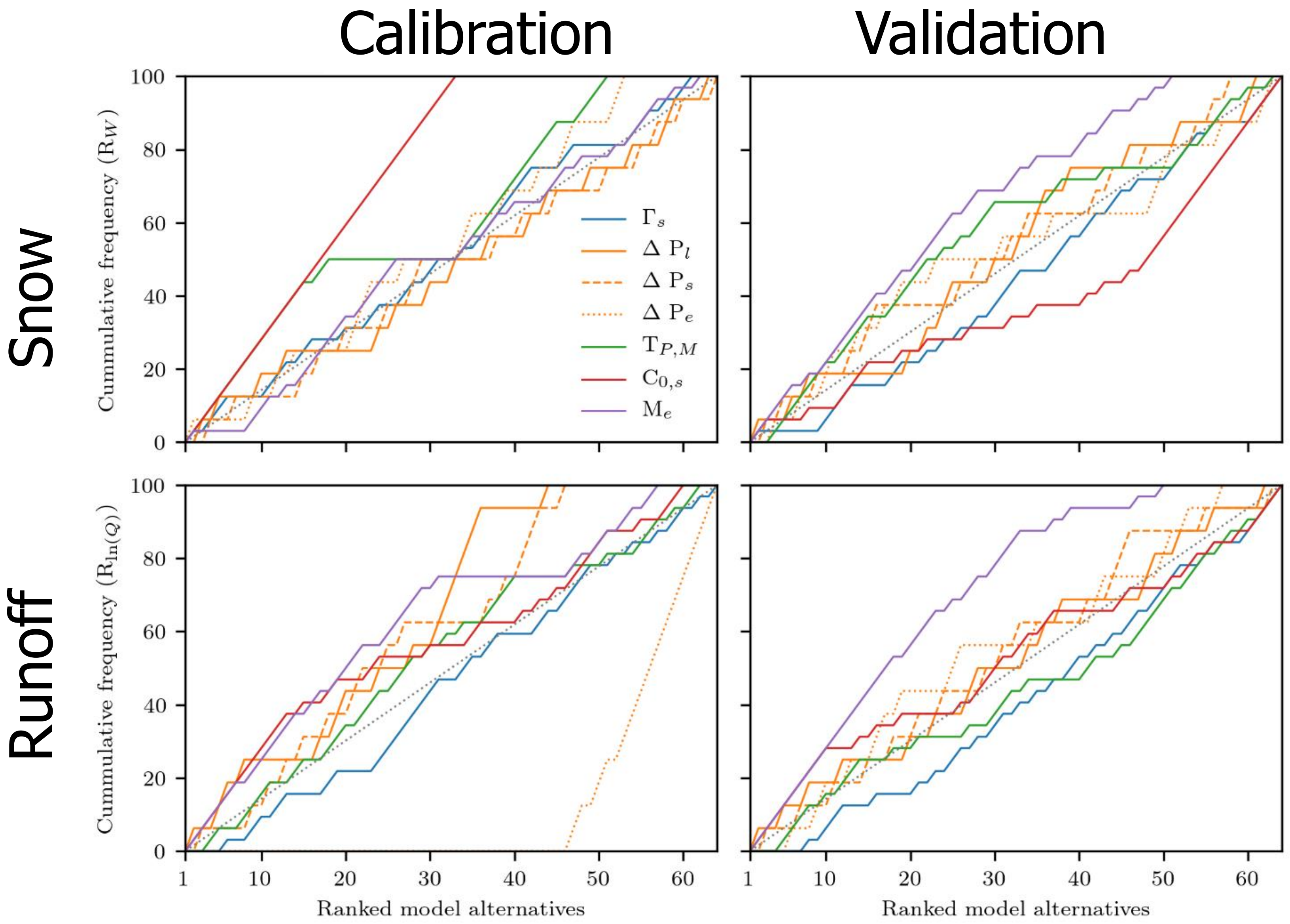
Combination of modifications



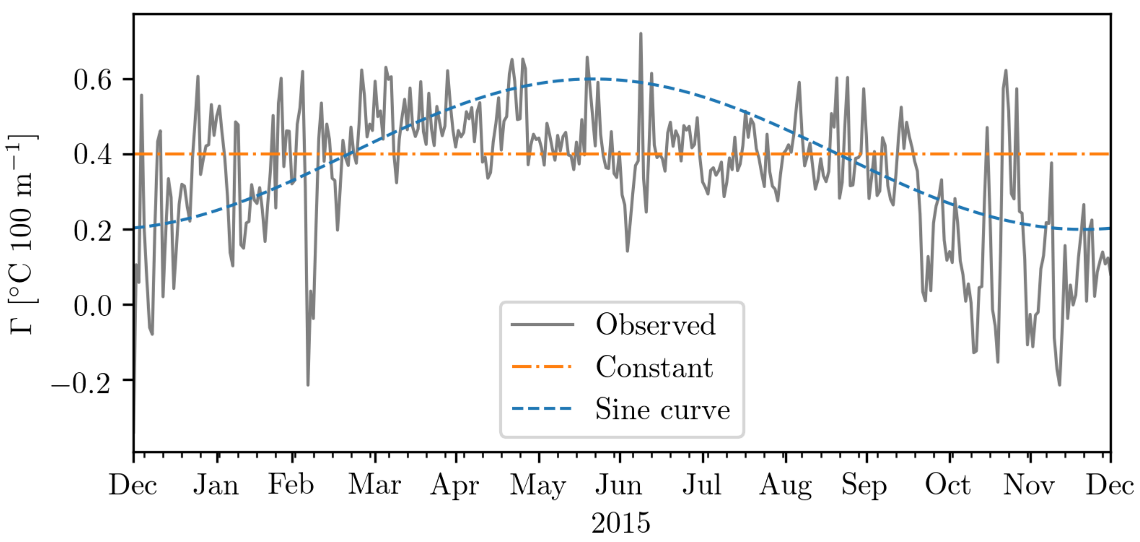
Snow Calibration

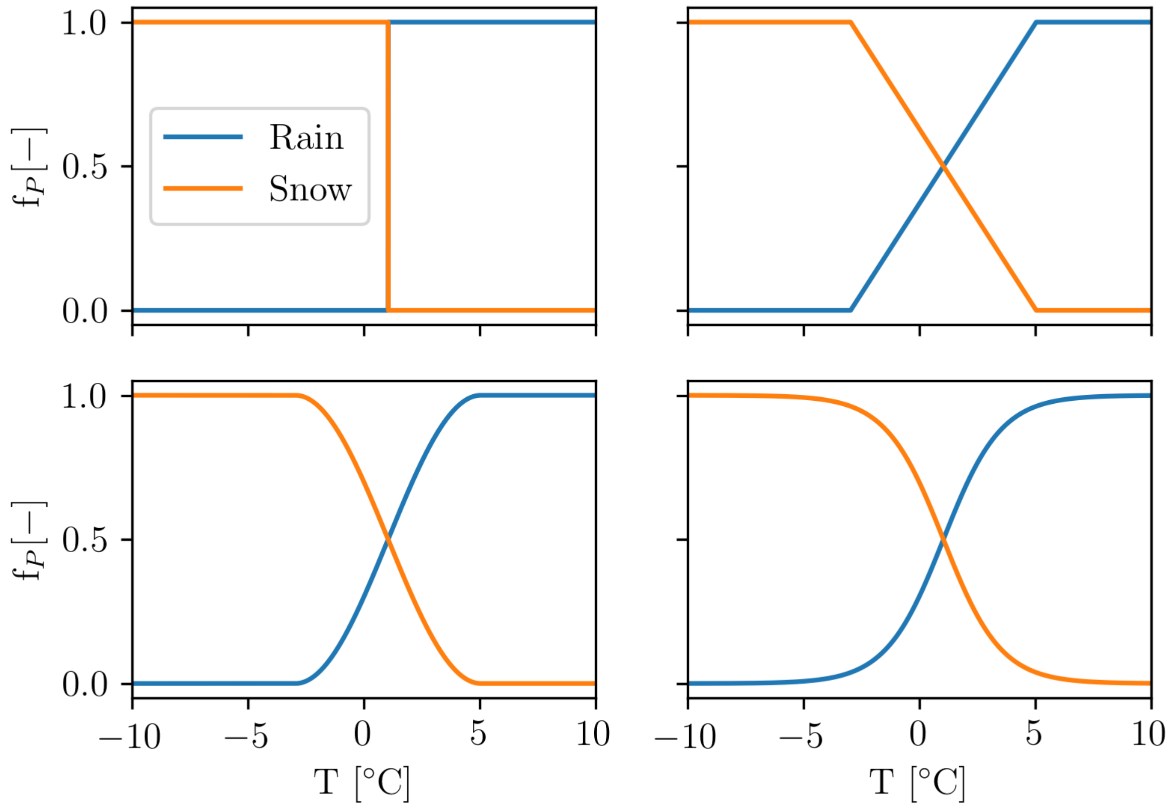


Ranked model alternative

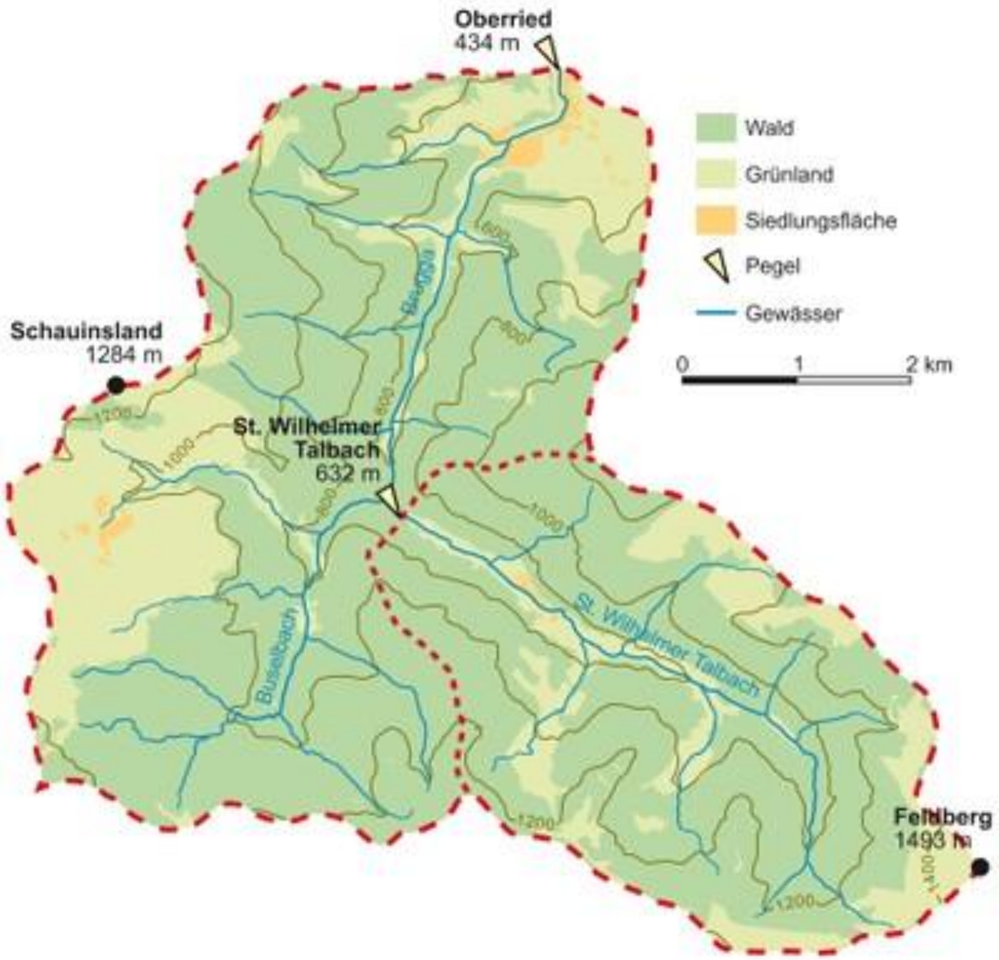

Calibration
Validation
Snow
Runoff
Cummulative frequency (R_W)
Cummulative frequency ($R_{\ln(Q)}$)
Γ_s
Δ P_l
Δ P_s
Δ P_e
$T_{P,M}$
$C_{0,s}$
M_e
Ranked model alternatives
Ranked model alternatives

No clear improvements - Why?



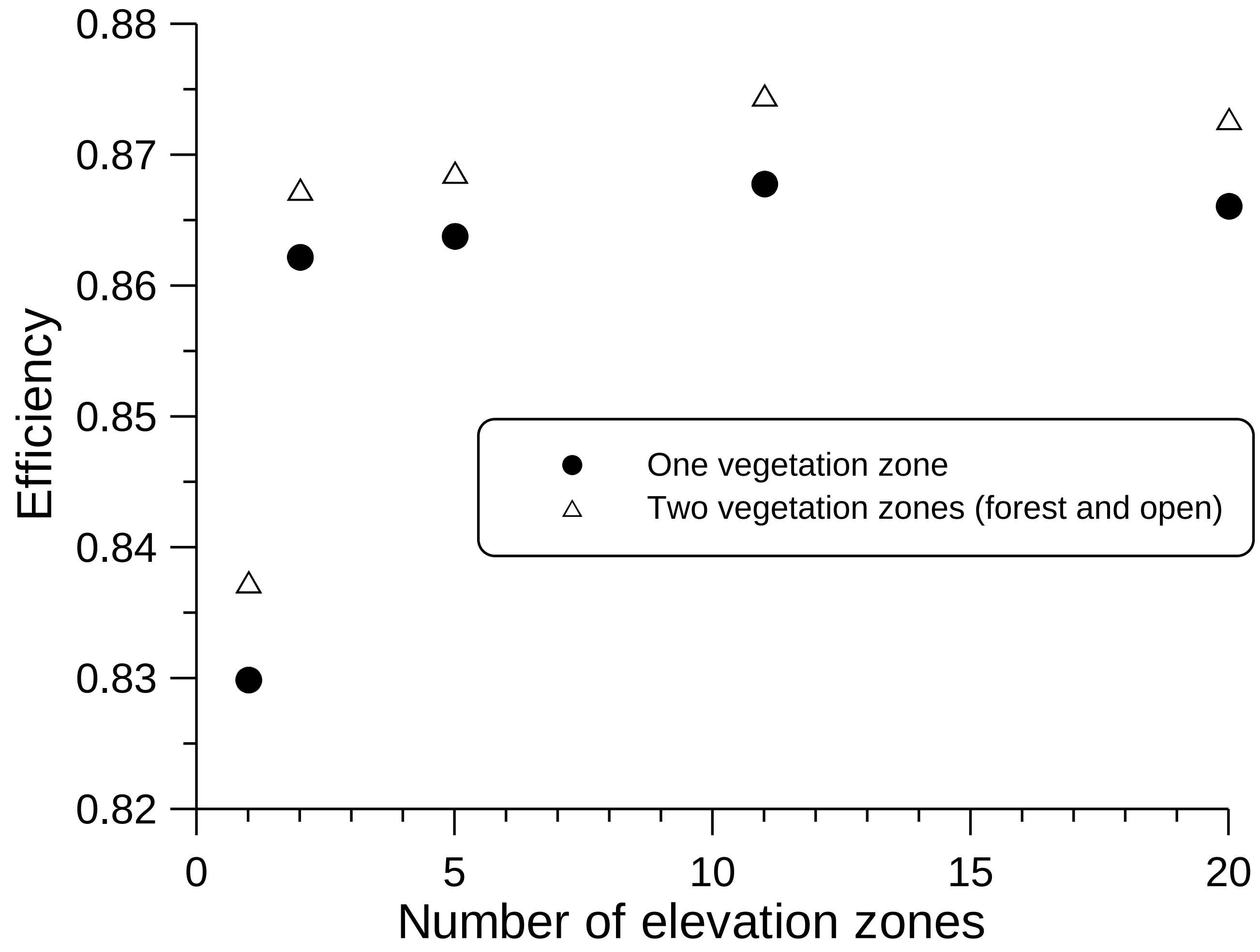


Unce upon a time …



Uhlenbrook et al., 1999, HSJ

Effect of number of elevation zones



Uhlenbrook et al., 1999, HSJ

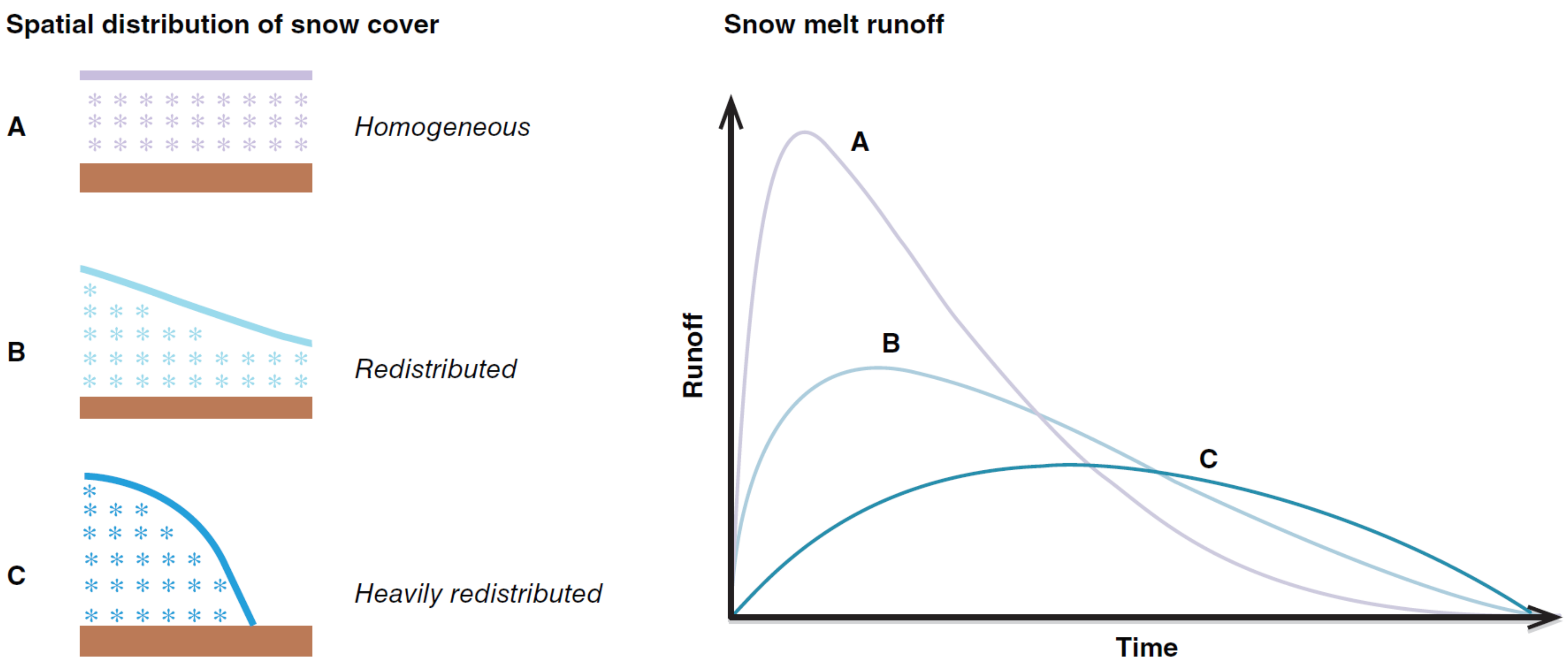
Future plans

More catchments?

Other evaluation criteria?

Additional data for evaluation?

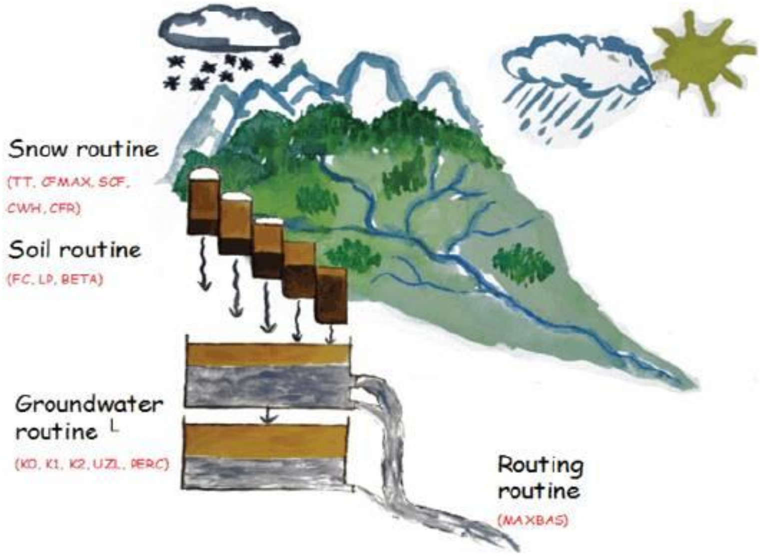
Other modifications?



Freudiger et al., 2017, WIRES Water

Thank you! – Questions?

Snow processes in bucket-type hydrological models
– does increased realism lead to better simulations?



Seibert and Vis, 2012, HESS

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