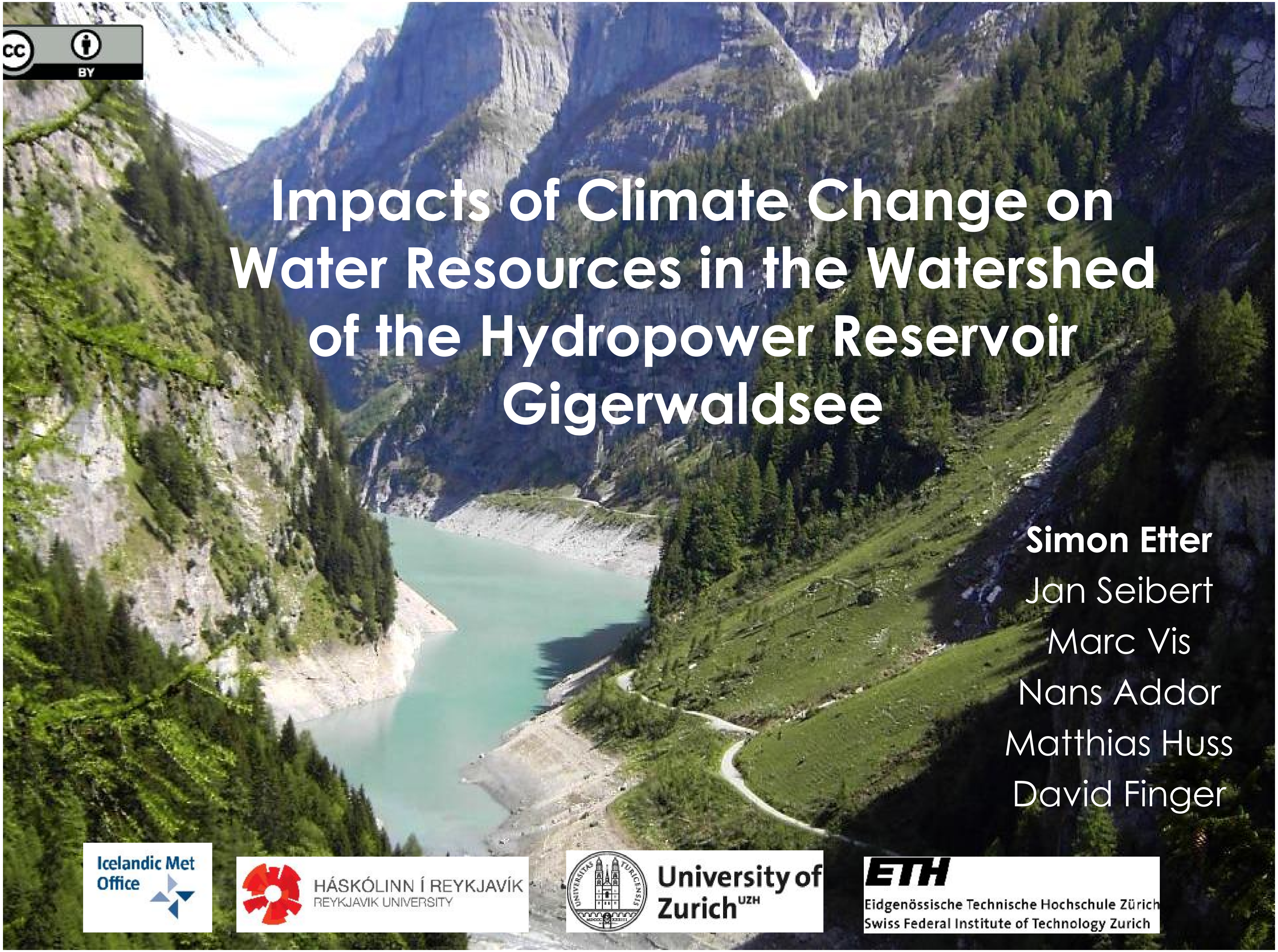

cc BY

Impacts of Climate Change on Water Resources in the Watershed of the Hydropower Reservoir Gigerwaldsee

Simon Etter
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Marc Vis
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REYKJAVIK UNIVERSITY
University of Zurich UZH
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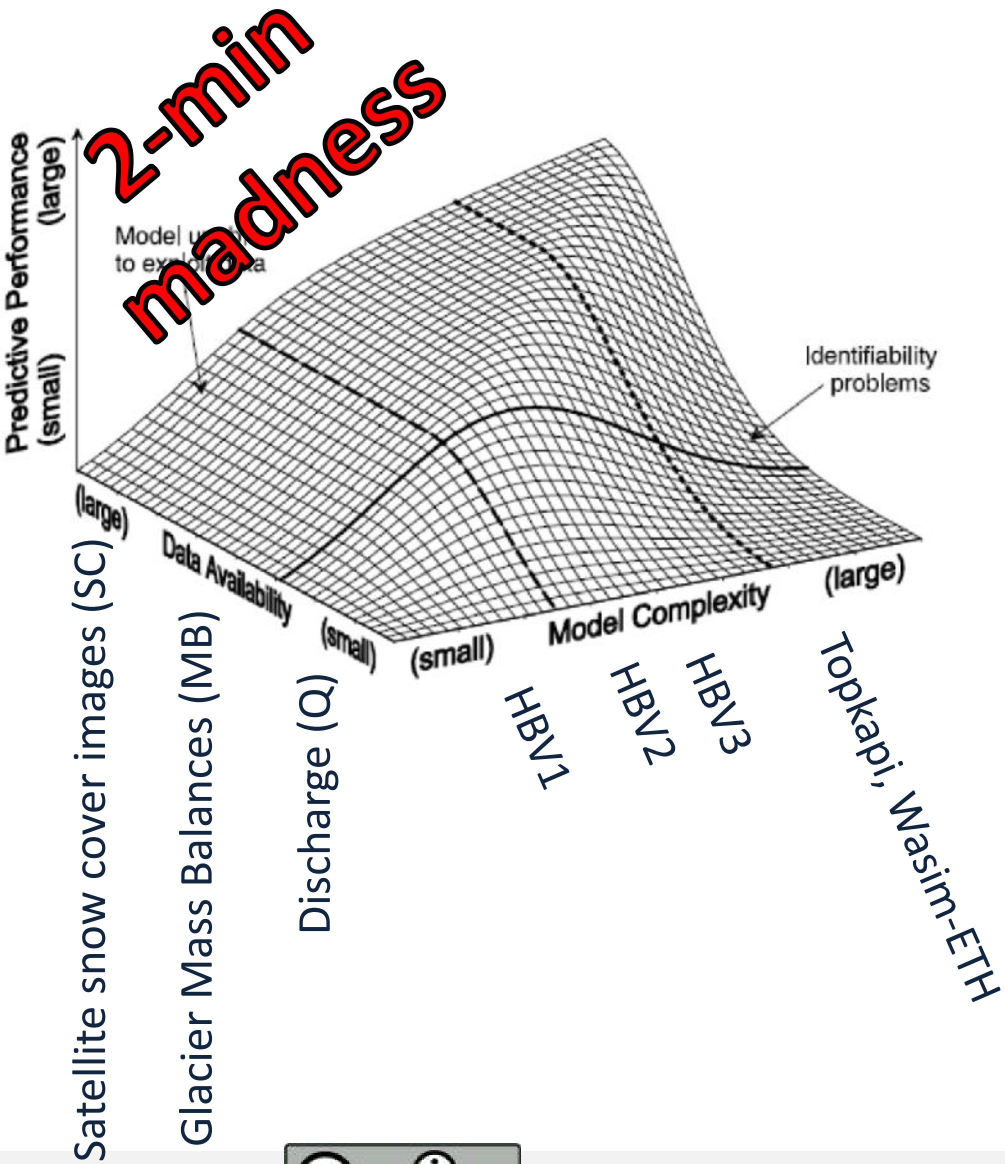
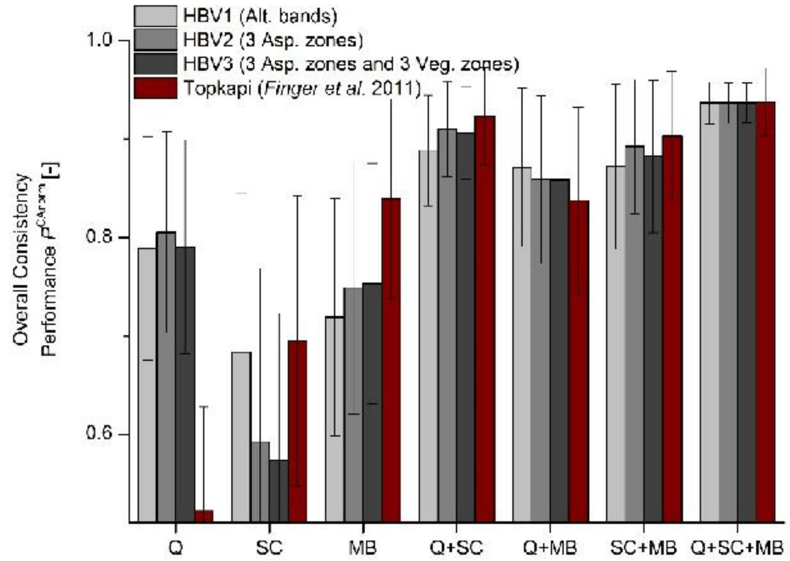
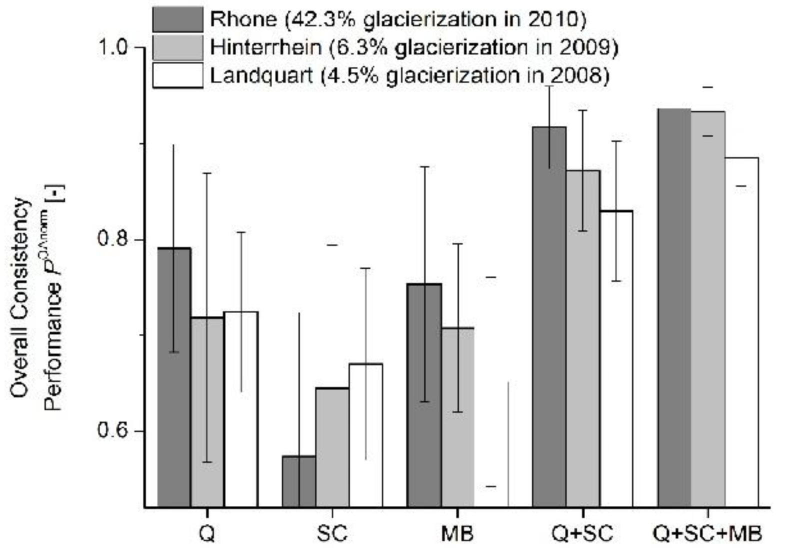
Swiss Federal Institute of Technology Zurich

Motivation: demonstrate applicability of multi dataset calibration in conceptual models to assess climate impact on hydropower





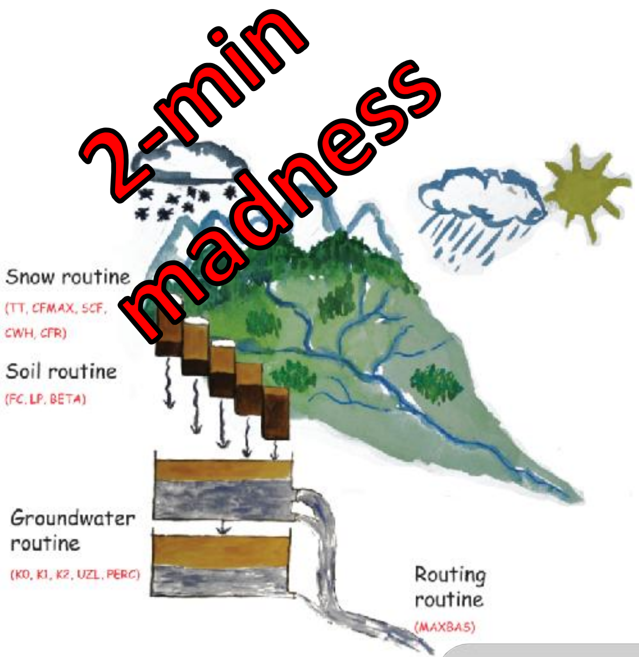


Finger et al. 2015

Study site


Sardonagletscher
2-min madness
Glasergletscher
Plattenseeli
Gigerwaldsee
Mels
Gigerwaldsee, Pfäfers (SG)
Calfeisental: 52km^2
Weisstannental: 45km^2
Glacierised Area: 0.5km^2
Pfäfers
Bad Ragaz
CC BY

HBV-LIGHT



- Catchment Characterisation
- Data from Past Weather

Model Setup

Selection of 10 Parameter Sets

- Observed Discharge
- Observed Snowcover
- Observed Mass Balances

7 Climate Scenarios

- Climate Model Data
- Glacier Model Data

3 Glacier Scenarios

210 plausible Scenarios

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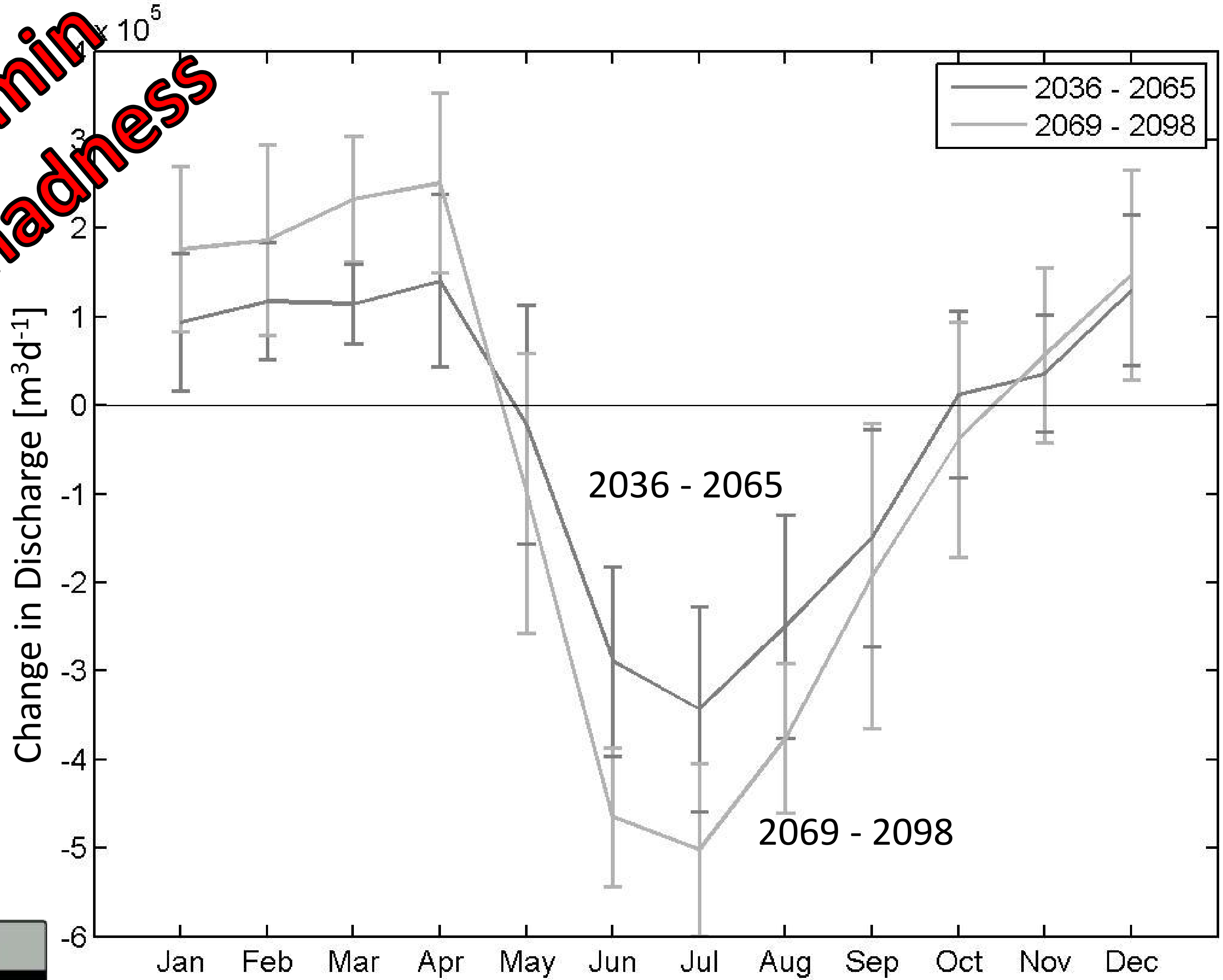
2-min madness



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2-min
madness
Thank you for
your attention

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VAW

Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie

BACKGROUND

- snow cover and glaciers acting as natural water reservoirs are projected to decline further in the 21st century (Zierl & Bugmann, 2005).
- Less runoff expected in glacierised catchments (Huss 2008)
- Hydropower is heavily dependent on the water availability throughout the year.
- 58% of the Swiss electricity created with hydropower (World Commission on Dams 2000).

RESEARCH QUESTIONS

Research Question I

- What is the improvement of using multiple datasets to calibrate the HBV model?

Research Question II

- How will changing temperatures and precipitation patterns affect the amount and distribution of water flowing into the Gigerwaldsee?

Research Question III

- How big are the contributions of snow melt, glacial melt and rain water now and how will their relative and absolute shares change throughout the 21st century?

Research Question IV

- What is the contribution of the model parameters and climate scenarios (and glacier scenarios) on the variance of the resulting future discharge scenarios?

HYPOTHESIS

- The results are similar to the findnigs of Finger et al. (2012) in the Vispertal:
  - They expect the melt water to form earlier in the season due to higher temperatures and therefore more runoff in spring and less in the second half of the year.

STUDY AREA

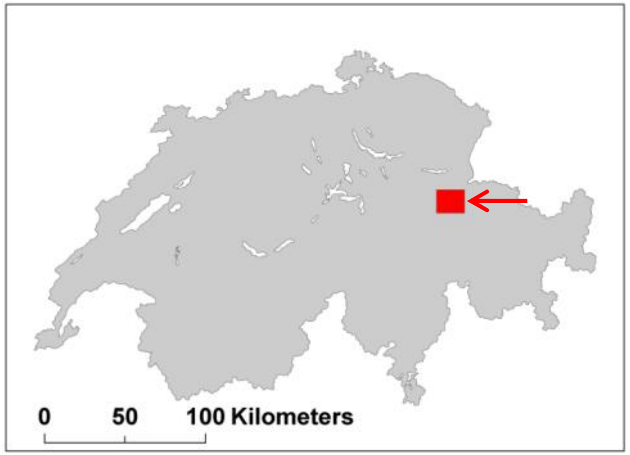
CATCHMENT

Gigerwaldsee, Pfäfers (SG)

Calfeisental: 52km²

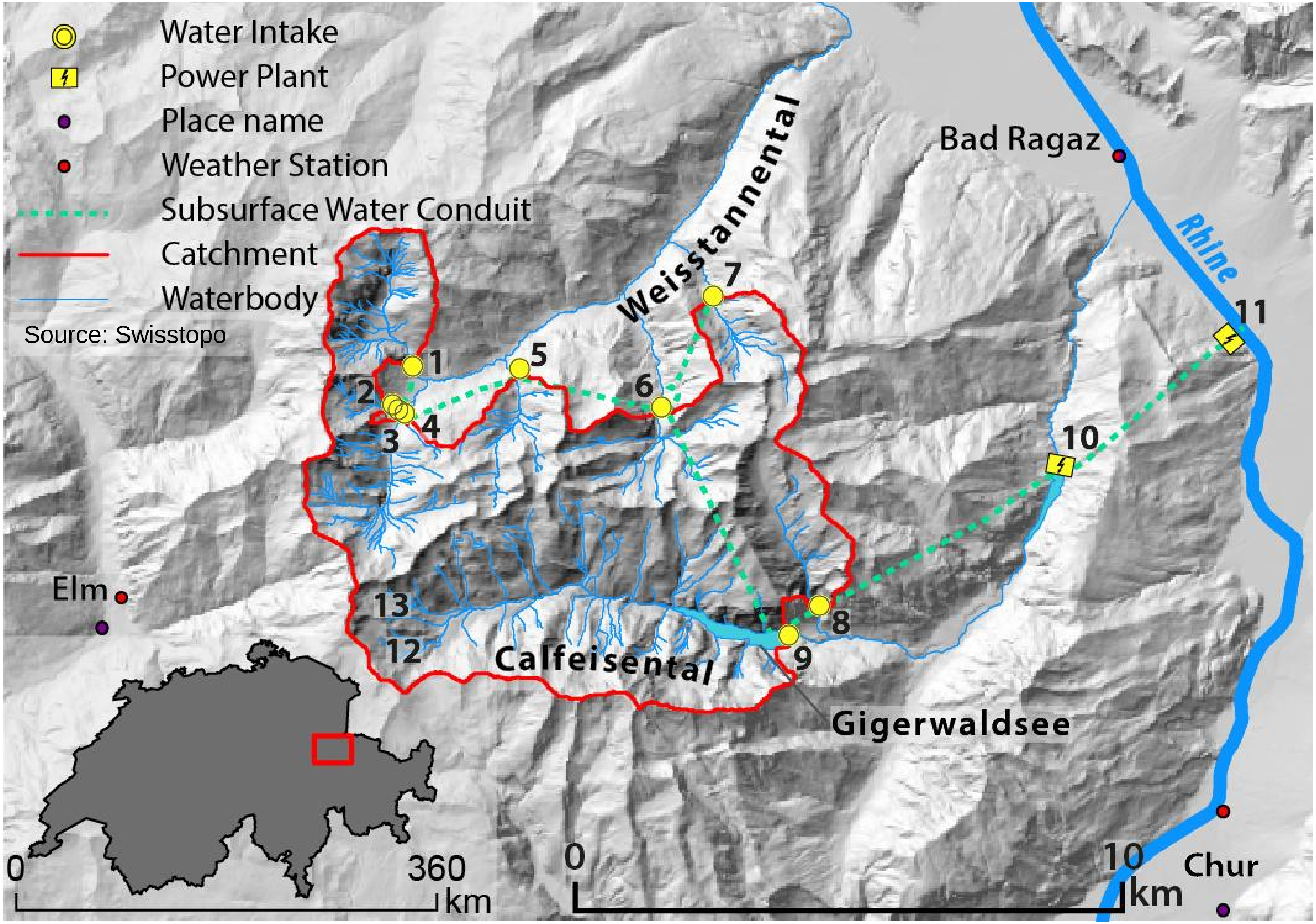
Weisstannental: 45km²

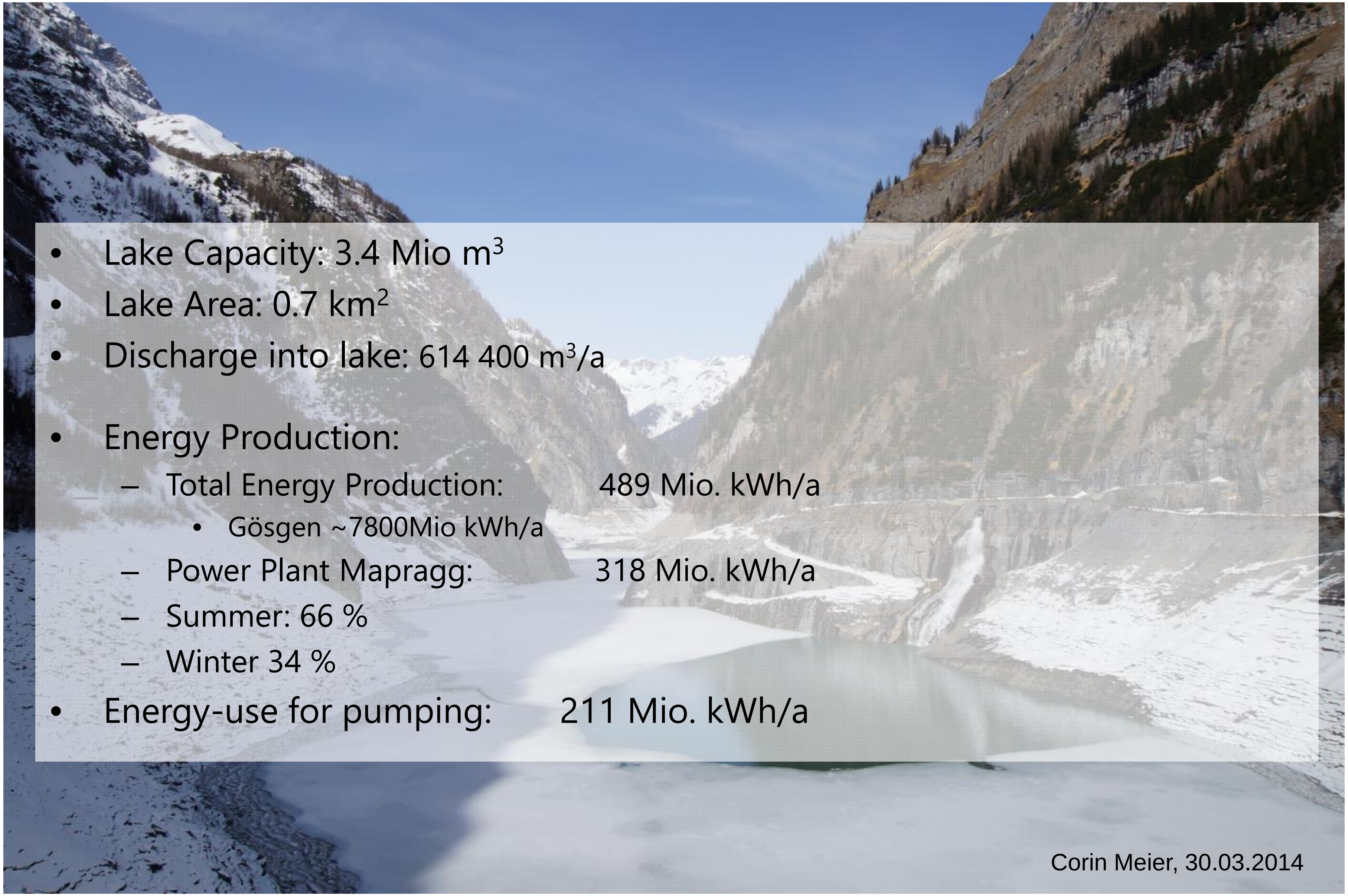
Glacierised Area: 0.5km²



Source: Swisstopo, Vector 200

Source: Digital Atlas of Switzerland


Water Intake
Power Plant
Place name
Weather Station
Subsurface Water Conduit
Catchment
Waterbody
Source: Swisstopo
Weisstannental
Bad Ragaz
Rhine
Elm
Calfeisental
Gigerwaldsee
Chur
1
2
3
4
5
6
7
8
9
10
11
12
13
0
360
km
0
10
km



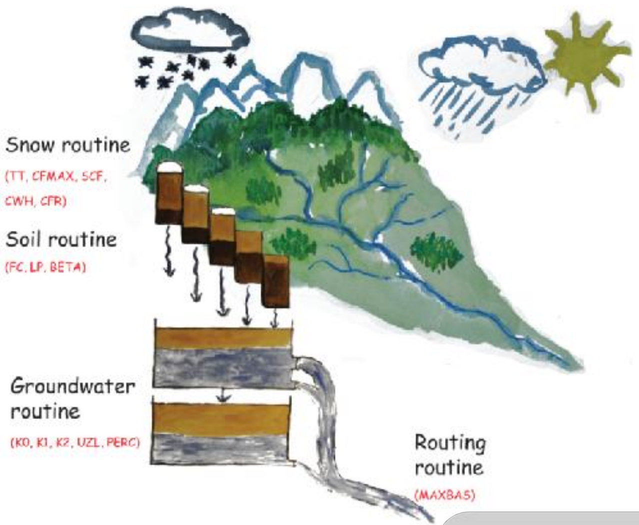
- Lake Capacity: 3.4 Mio m^3
- Lake Area: 0.7 km^2
- Discharge into lake: 614 400 m^3/a

- Energy Production:
  - Total Energy Production: 489 Mio. kWh/a
    - Gösgen ~7800Mio kWh/a
  - Power Plant Mapragg: 318 Mio. kWh/a
  - Summer: 66 %
  - Winter 34 %
- Energy-use for pumping: 211 Mio. kWh/a

Corin Meier, 30.03.2014

METHODS & DATA

HBV-LIGHT



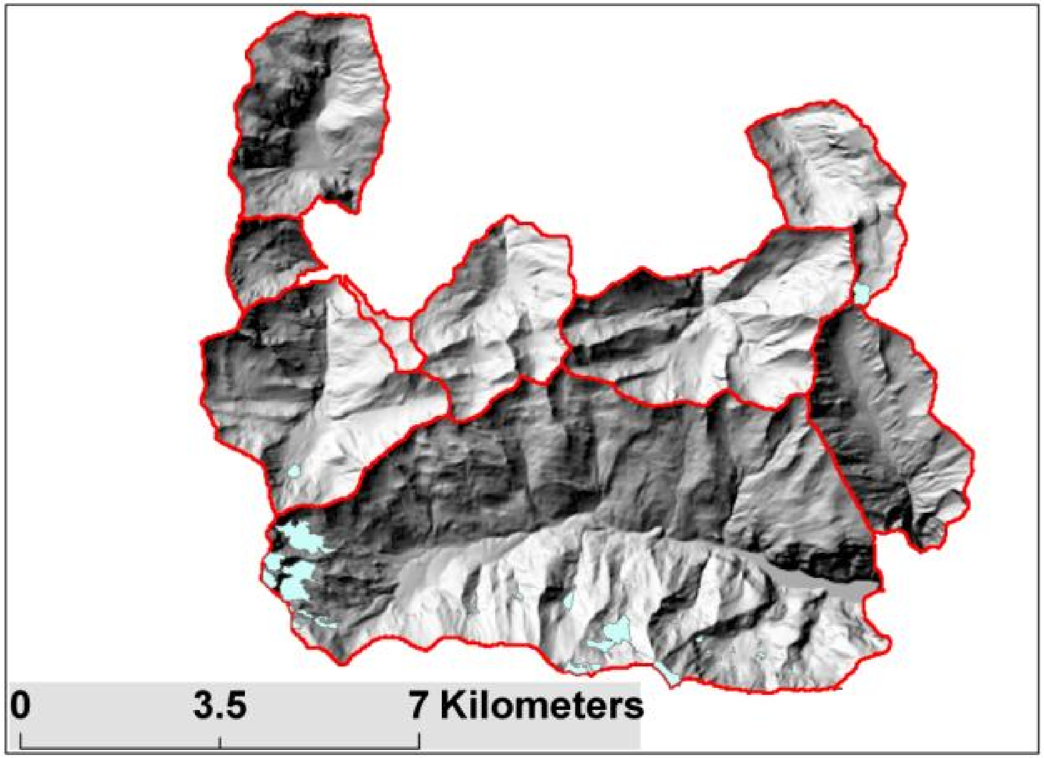
Model Setup
- Catchment Characterisation
- Data from Past Weather

Parameter Selection
- Observed Discharge
- Observed Snowcover
- Observed Mass Balances

Discharge Scenarios
- Climate Model Data
- Glacier Model Data

HBV INPUT DATA

Glacierised and non-glacierised Area



Source: Swisstopo swissTLM3D

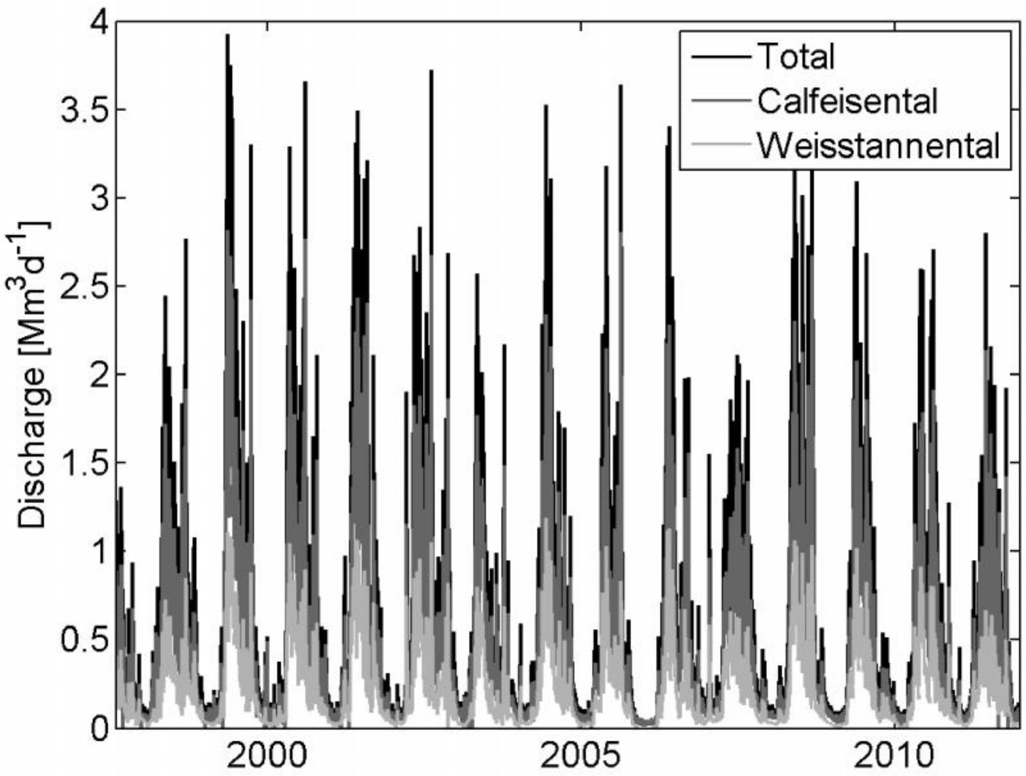
HBV INPUT DATA

Gridded Meteoswiss Dataset

- Daily Precipitation
- Temperature
  - and thereof the Evapotranspiration

MULTI-VARIABLE CALIBRATION

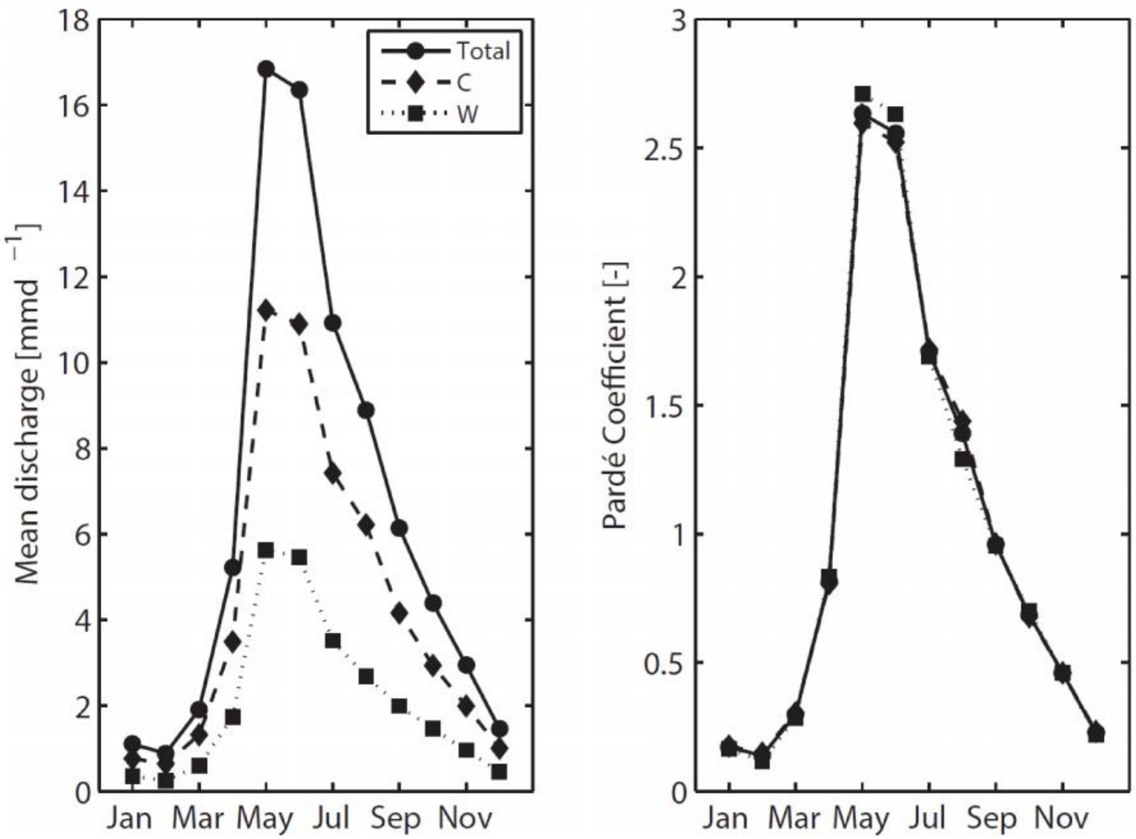
Daily sums of lake-level-derived discharge data



Kraftwerke Sarganserland AG

MULTI-VARIABLE CALIBRATION

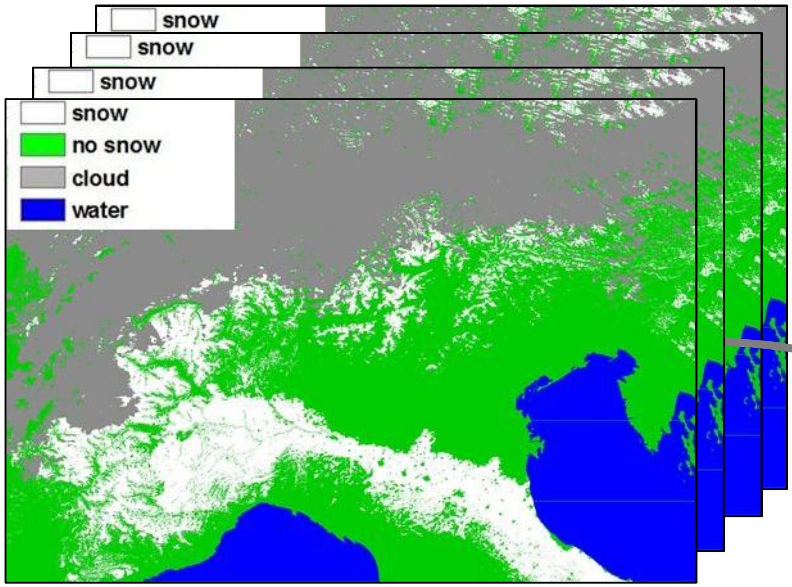
Daily sums of lake-level-derived discharge data



Kraftwerke Sarganserland AG

MULTI-VARIABLE CALIBRATION

Daily interpolation of MODIS snowcover maps



Hall et al, 2002

01100
10010
10111
01011

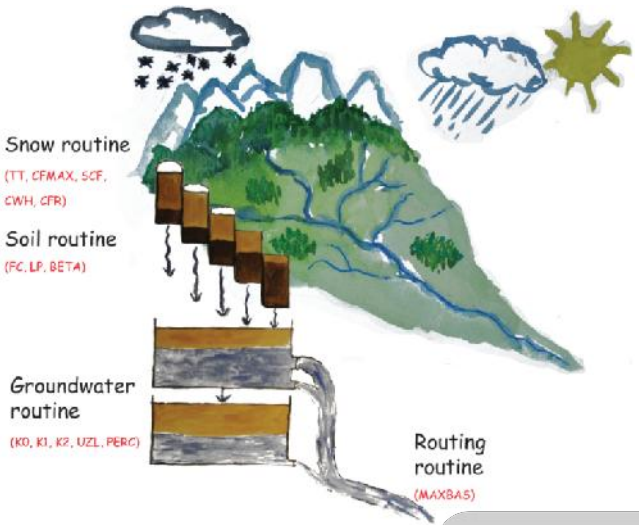
2003339.000000	0.634208
2004015.000000	0.943849
2004056.000000	0.952052
2004097.000000	0.947401
2004138.000000	0.608409
2004179.000000	0.049542
2004220.000000	0.011564
2004261.000000	0.031270

MULTI-VARIABLE CALIBRATION

- Annual Glacier Mass Balances (Huss et al. 2010)

Date	MB
19971001	0
19981001	-31.0261169
19991001	-36.0121321
20001001	-46.7666395
20011001	-42.0899756
20021001	-60.5782657
20031001	-106.271274
20041001	-111.603035
20051001	-134.549624
20061001	-167.140694
20071001	-185.101267
20081001	-199.258639
20091001	-216.327553
20101001	-230.885262
20111001	-267.279534
20121001	-289.116097

HBV-LIGHT



Model Setup
- Catchment Characterisation
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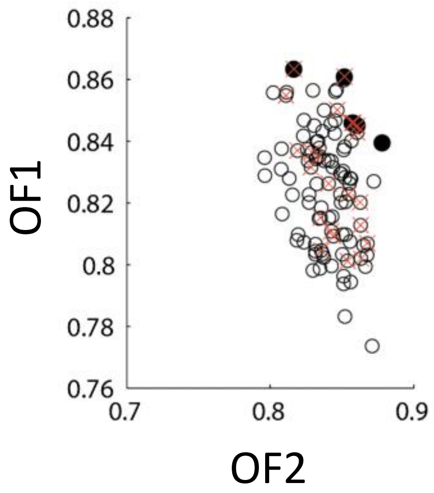
- Observed Discharge
- Observed Snowcover
- Observed Mass Balances

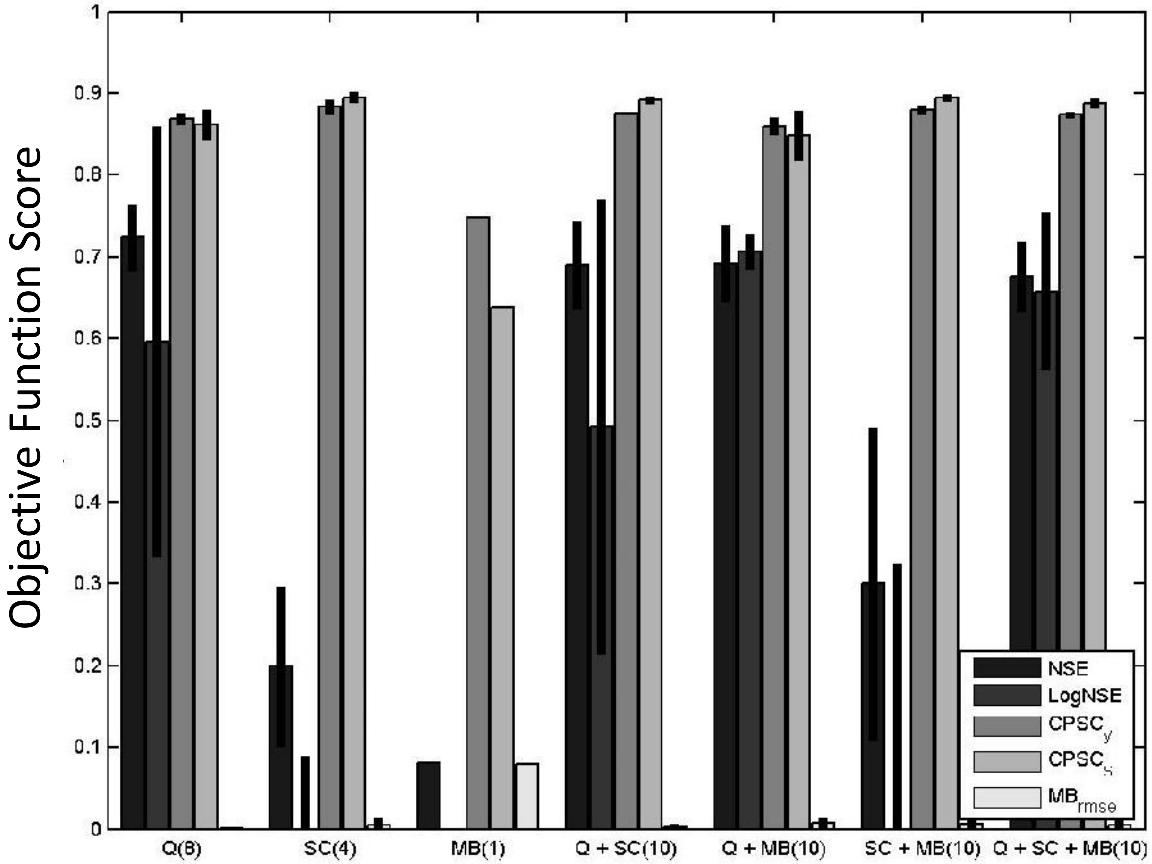
Discharge Scenarios
- Climate Model Data
- Glacier Model Data

MULTI-VARIABLE CALIBRATION

The Pareto solutions represent tradeoffs among the different [...] objectives, having the property that moving from one solution to another results in the improvement of one objective while causing deterioration in one or more others (Vrugt et al. 2003).

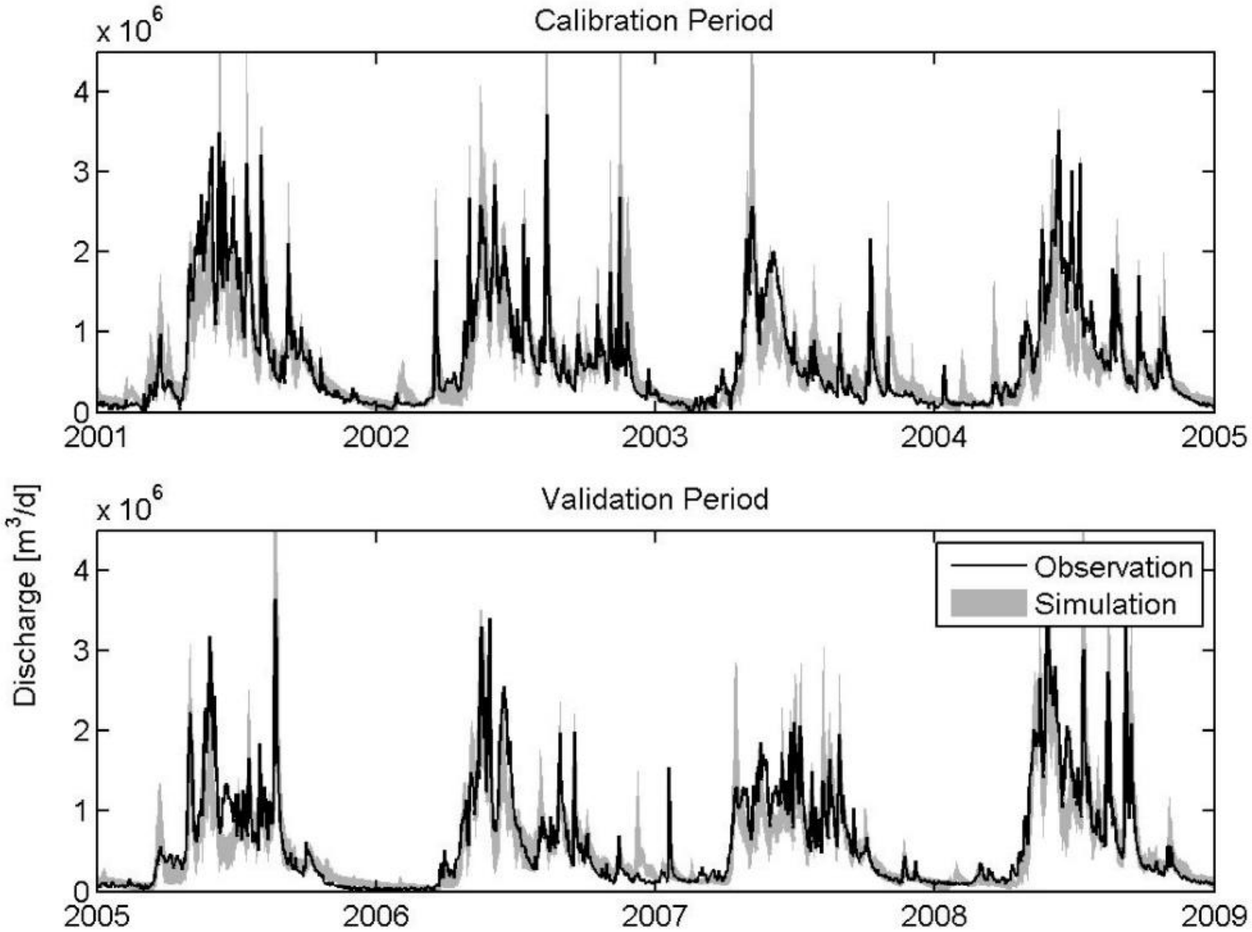


MULTI-VARIABLE CALIBRATION

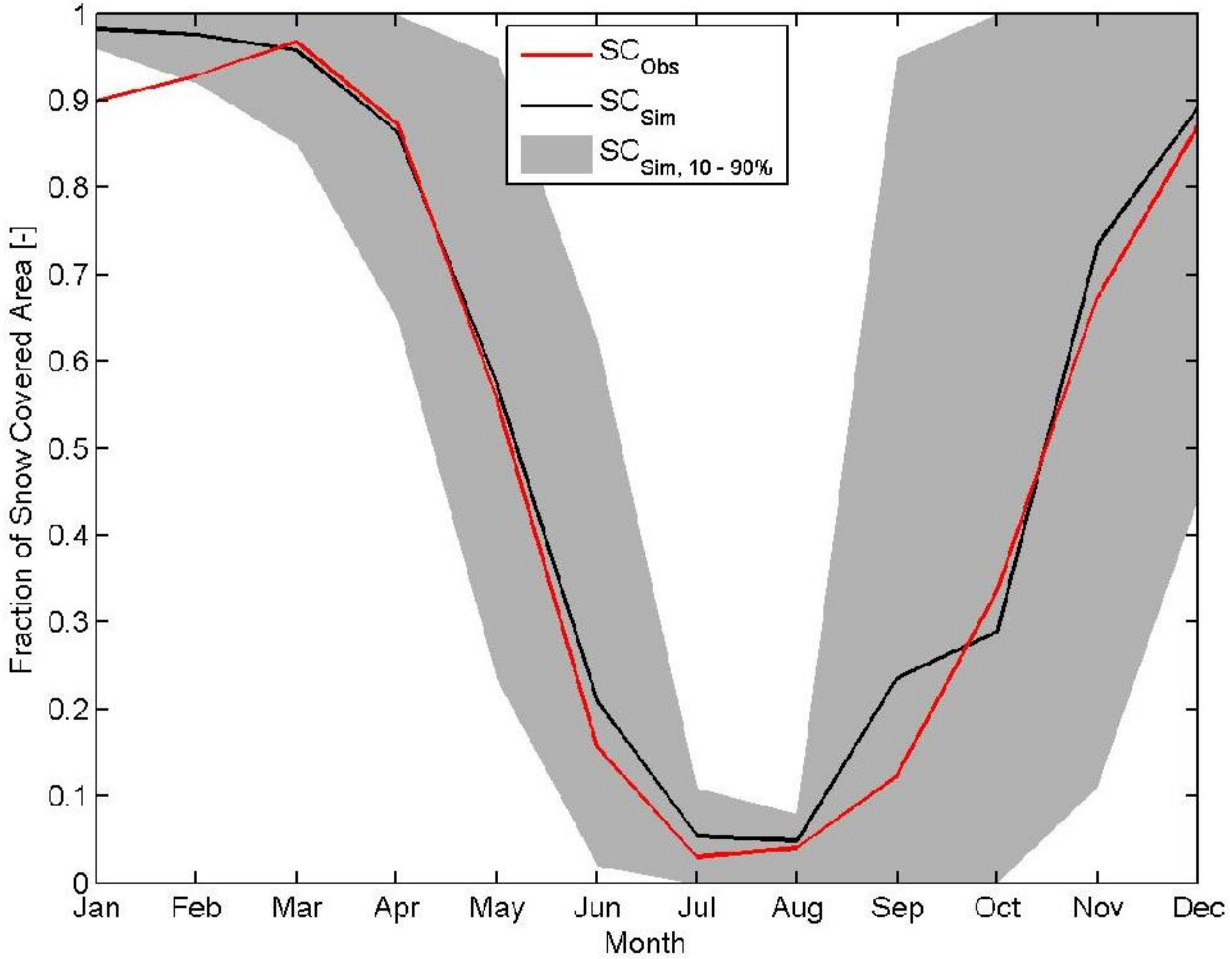


10 best Parameters sets

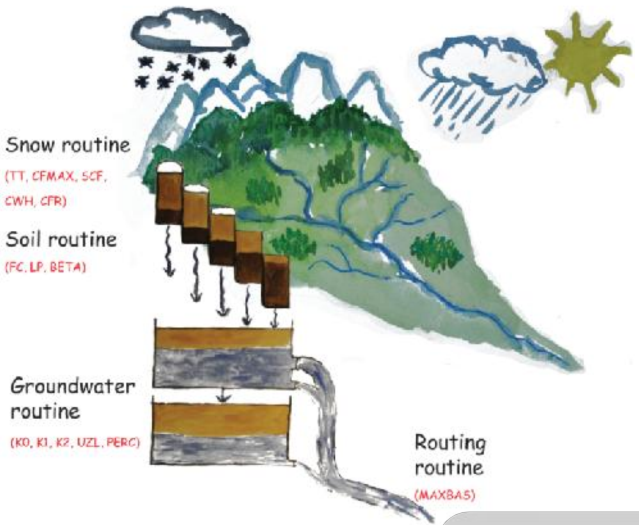
MODEL PERFORMANCE



MODEL PERFORMANCE



HBV-LIGHT



Model Setup

- Catchment Characterisation
- Data from Past Weather

Parameter Selection

- Observed Discharge
- Observed Snowcover
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Discharge Scenarios

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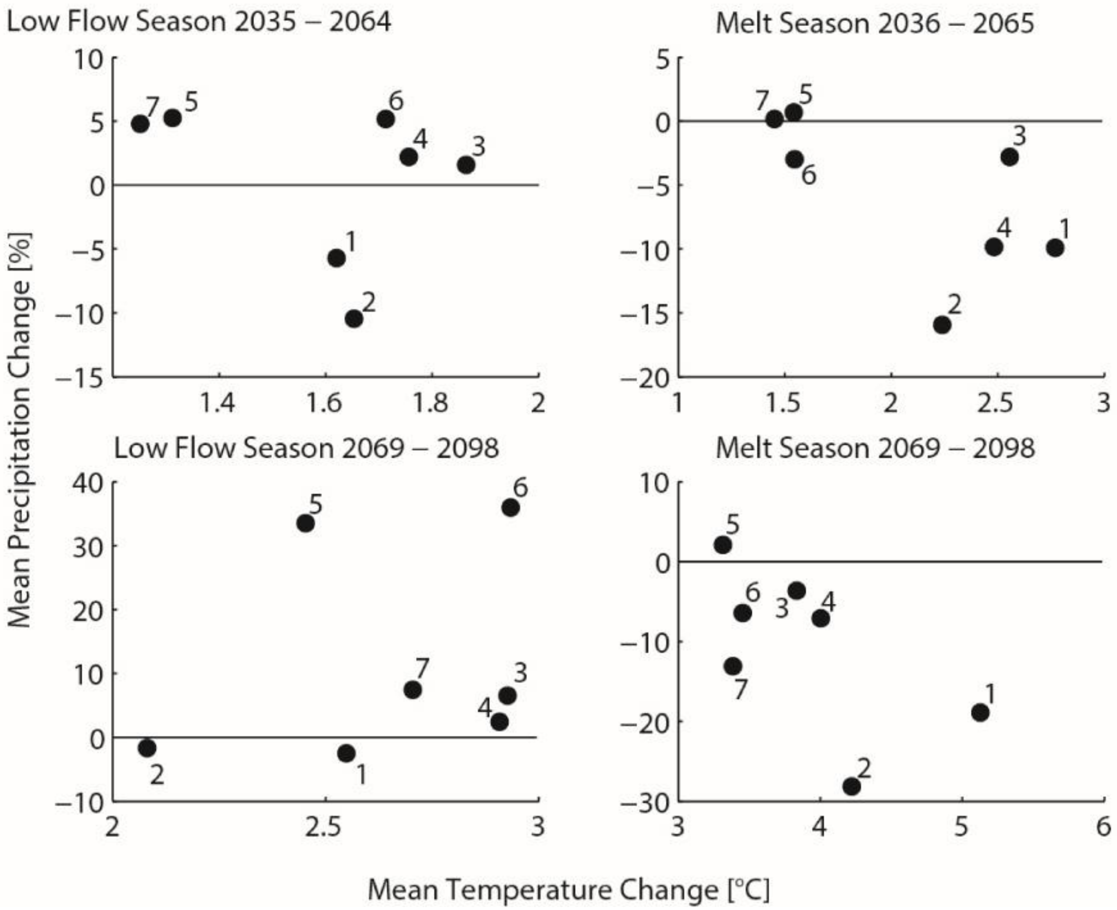
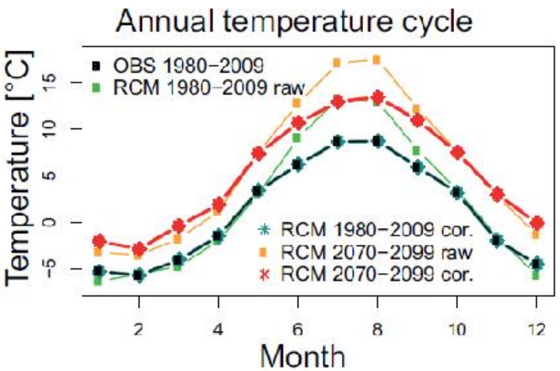
- Glacier Model Data

7 CLIMATE SCENARIOS

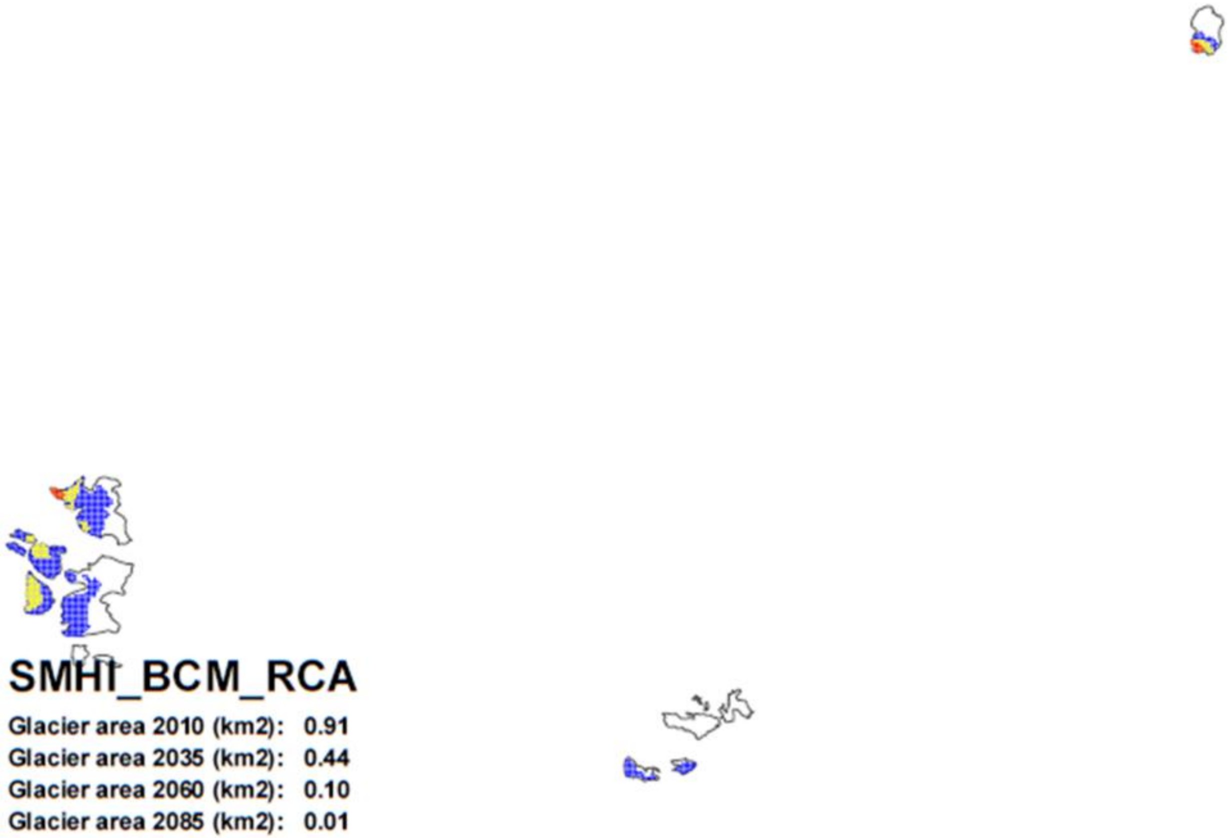


Nr	GCM	Institute	RCM
1	ARPEGE	CNRM	ALADIN5.1
2	ARPEGE	DMI	HIRHAM5
3	HadCM3Q0	ETHZ	CLM
4	HadCM3Q0	HC	HadRM3Q0
5	ECHAM5-r3	KNMI	RACMO2
6	ECHAM5-r3	MPI	REMO
7	BCM	SMHI	RCA

Downscaled using Quantile Mapping

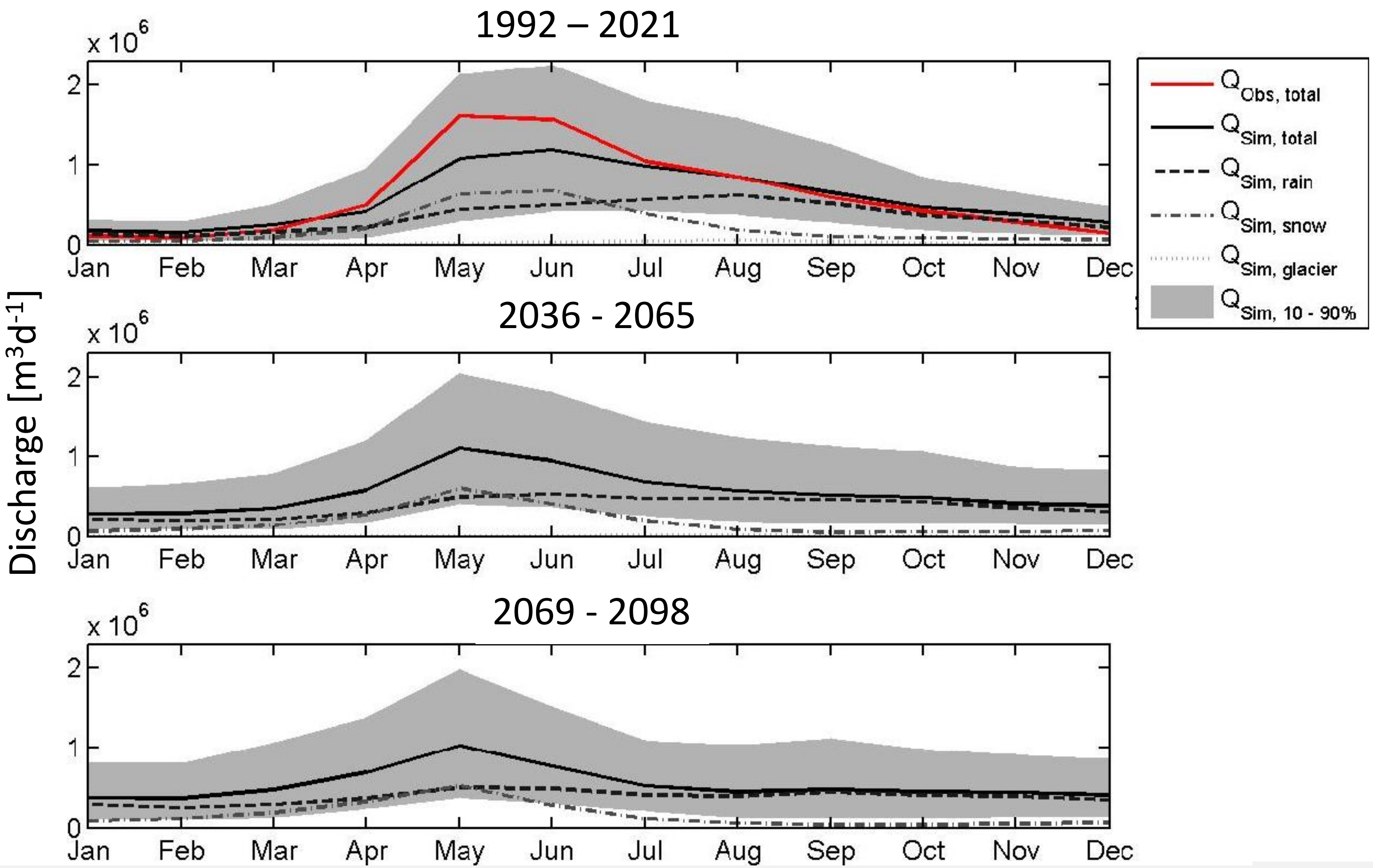


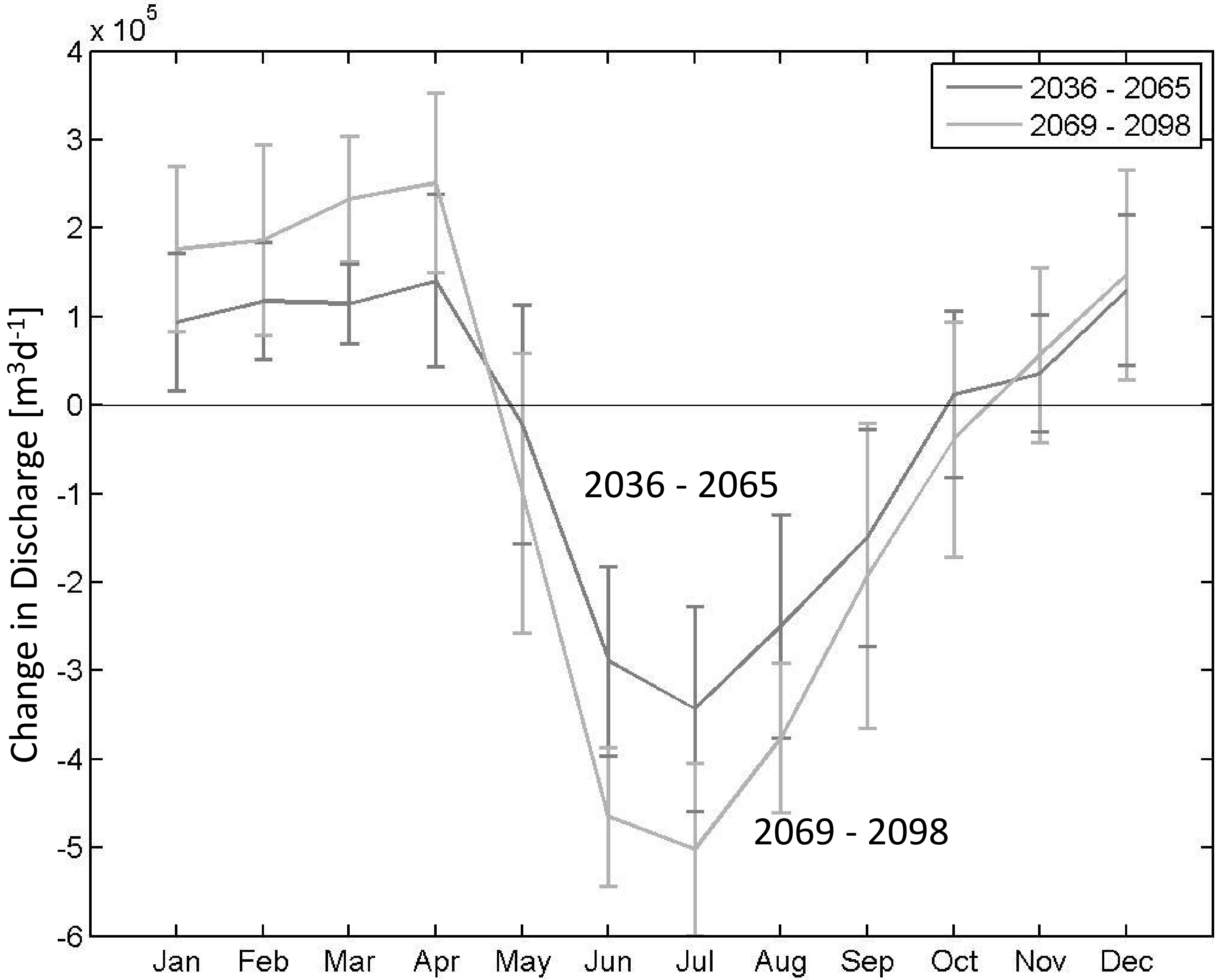
3 GLACIER SCENARIOS



RESULTS

DISCHARGE SCENARIOS




x 10^5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
Change in Discharge [m³d⁻¹]
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2036 - 2065
2069 - 2098
2036 - 2065
2069 - 2098

Discussion & Conclusion

Research Question I:

What is the improvement of using multiple datasets to calibrate the HBV model?

- internal model consistency improved
- «Right – or wrong – for the right reasons»

Research Question II:

How will changing temperatures and precipitation patterns affect the amount and distribution of water flowing into the Gigerwaldsee?

- discharge increase in spring due to warmer temperatures → increased snow melt → amplified by more precipitation falling as rain and a general increase of precipitation during low flow season
- Decrease in summer discharge from snow melt and less precipitation → reduced total runoff in summer
- Towards winter months precipitation starts to increase again, causing more discharge from rain water
- The role of the glaciers can be neglected due to their small size

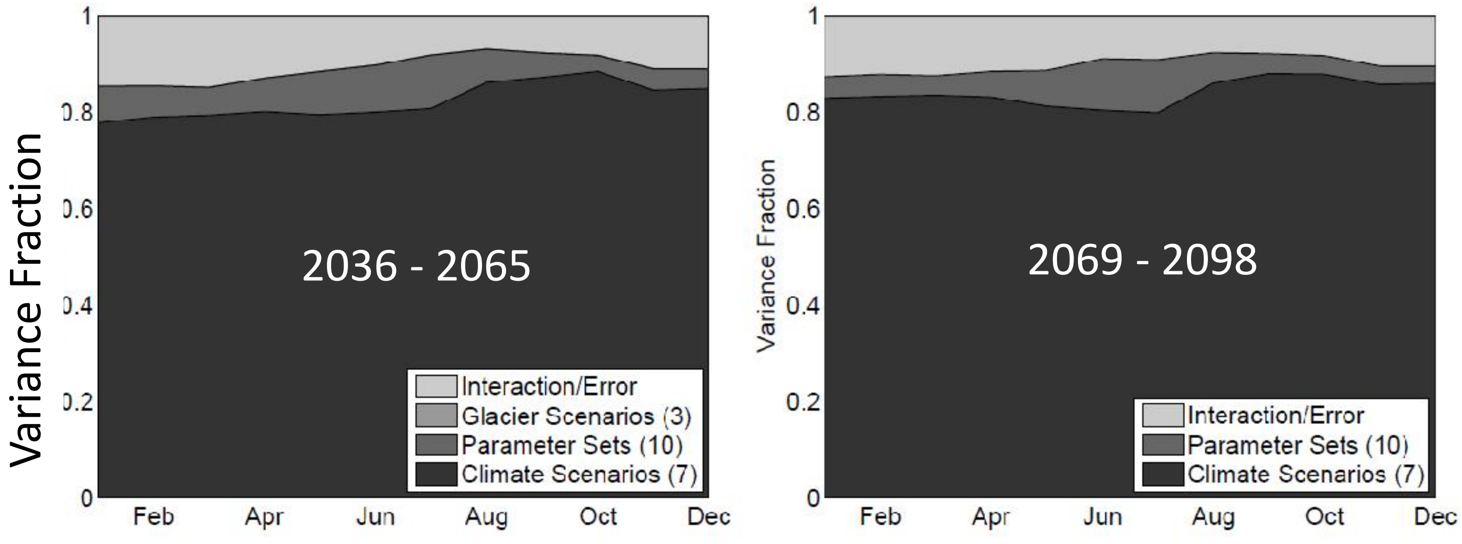
Research Question III:

How big are the contributions of snow melt, glacial melt and rain water now and how will their relative and absolute shares change throughout the 21st century?

Q Shares	Reference Period		Mid-Term		Long-Term	
	[M m^3]	[%]	[M m^3]	[%]	[M m^3]	[%]
Qtot	216	100	204	94(±7.8)	197	91(±11.5)
Qrain	128	100	138	108(±21.6)	140	109(±23.4)
Qsnow	82	100	65	78.6(±18.3)	57	70.0(±19.6)
Qglacier	6	100	1	15.3(±26.8)	0	0

Research Question IV:

What is the contribution of the model parameters and climate scenarios (and glacier scenarios) on the variance of the resulting future discharge scenarios?



(a) 2036 - 2065 (b) 2069 - 2098

- biggest fraction of the variance is made up by the climate scenarios ~82/84% throughout the year.
- Parameter sets make up less than **7/10%** on average throughout the year and the glacier scenarios only about **0.00004%**. The rest of about **11/10%** is made up by interactions of the three.

THANK YOU FOR YOUR ATTENTION

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