

# What is the contribution of snow and glacier to discharge in Swiss alpine headwater catchments under climate change?



Good morning!

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Schweizerische Eidgenossenschaft  
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Bundesamt für Umwelt BAFU  
Office fédéral de l'environnement OFEV  
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# Context

This project is part of three sister projects with the aim to model daily contribution to discharge from rainfall, snow and glacier melt for the past & future 100 years for the entire Rhine River catchment (ASG1 & ASG2) and for all glacierized headwater catchments in Switzerland (HYDRO-CH2018).



## ASG1:

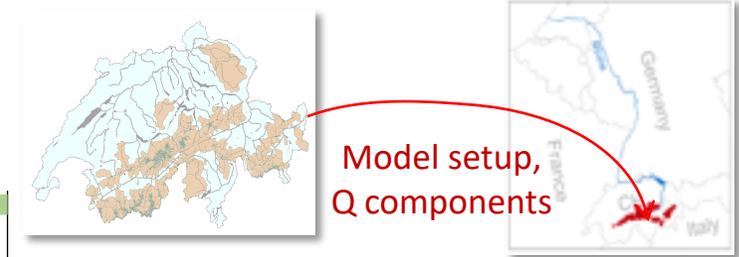
- Hydrological model chain HBV+LARSIM
- Model development with focus snow & ice
- Tracking of discharge components

## HYDRO-CH2018:

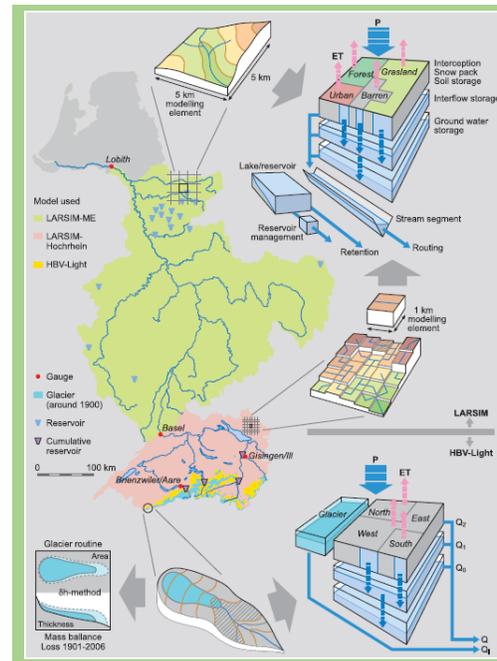
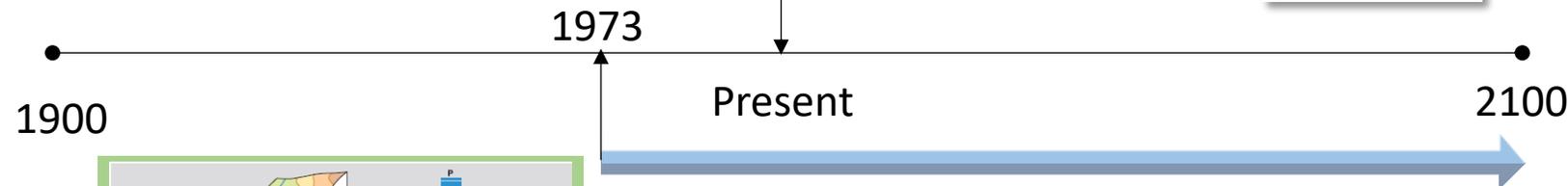
- HBV-light

## ASG2:

- Model chain



Model setup, Q components



## Further informations:

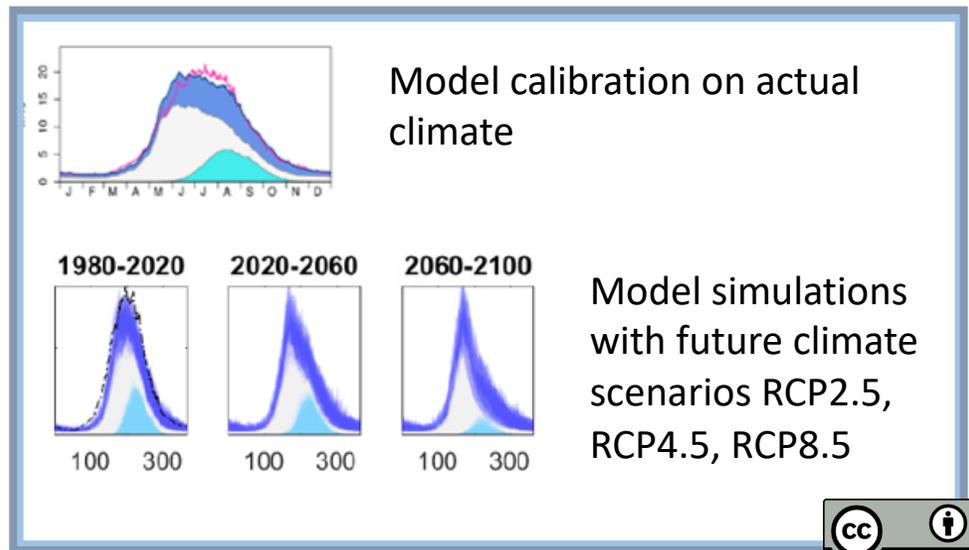
Stahl et al (2017), CHR/KHR report.

[http://www.chr-khr.org/sites/default/files/chrpublications/asg-rhein\\_synthesis\\_en.pdf](http://www.chr-khr.org/sites/default/files/chrpublications/asg-rhein_synthesis_en.pdf)

<https://www.nccs.admin.ch/nccs/de/home/das-nccs/themenschwerpunkte/hydroch2018/hydro-ch2018-forschungsprojekte.html>

HYDROCH-2018 Synthesis report (in prep.)

<https://www.nccs.admin.ch/nccs/de/home/das-nccs/themenschwerpunkte/hydroch2018/hydro-ch2018-forschungsprojekte.html>



How will discharge components change over time? What to expect during dry summers? What if all glaciers are gone? Etc.



# Research questions?

## ASG1:

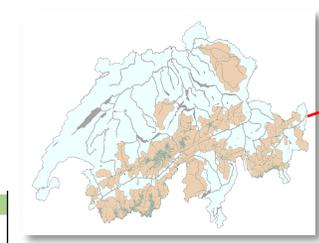
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## HYDRO-CH2018:

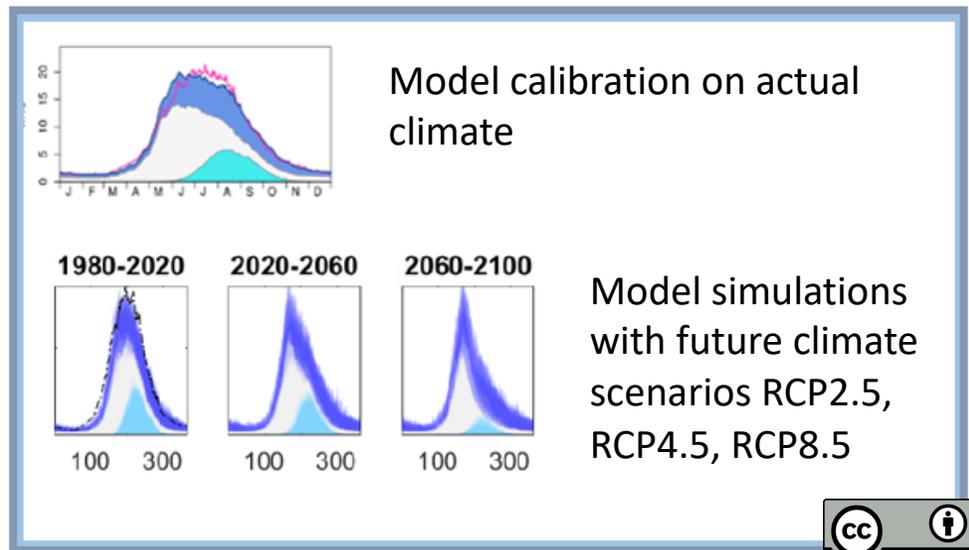
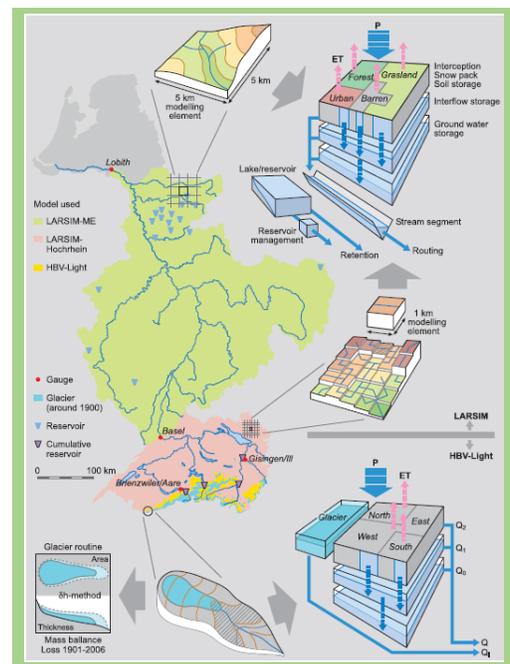
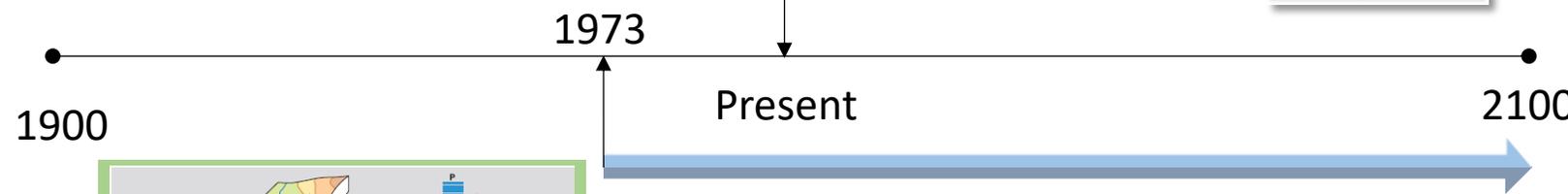
- HBV-light

## ASG2:

- Model chain



Model setup, Q components

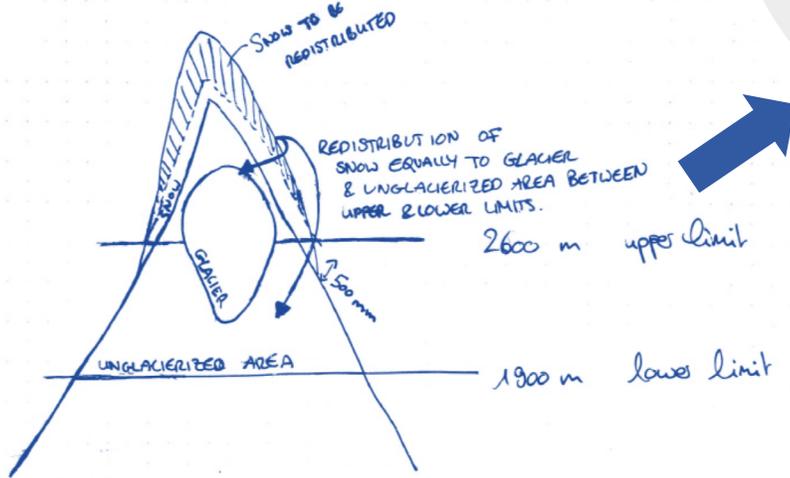


# Model for headwater catchments

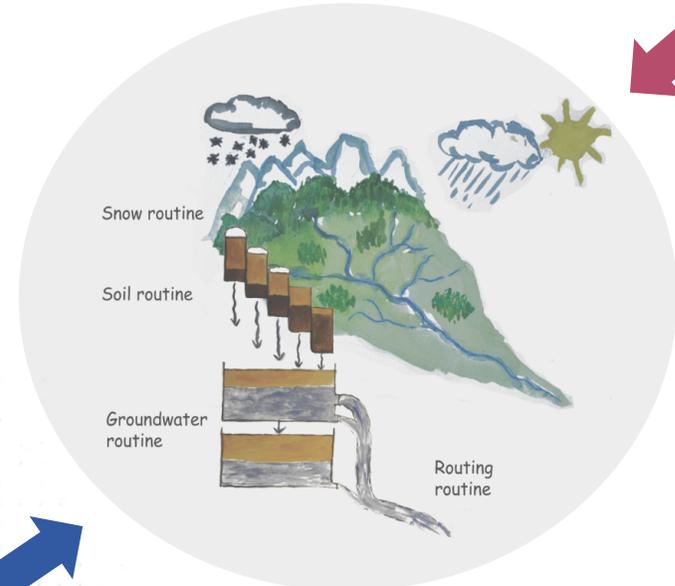
For the simulation of the glacierized headwater catchments, we use the bucket-type model HBV-light. We developed a snow redistribution algorithm and implemented the  $\Delta h$ -parameterization for the glacier simulations.



## Snow Redistribution

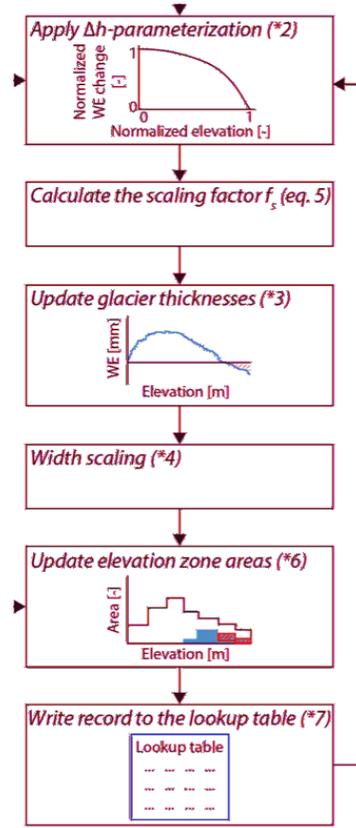


REDISTRIBUTION AREA = GLACIER + UNGL. AREA



HBV-light  
Seibert and Vis, HESS, 2012

## Glacier Geometry Changes

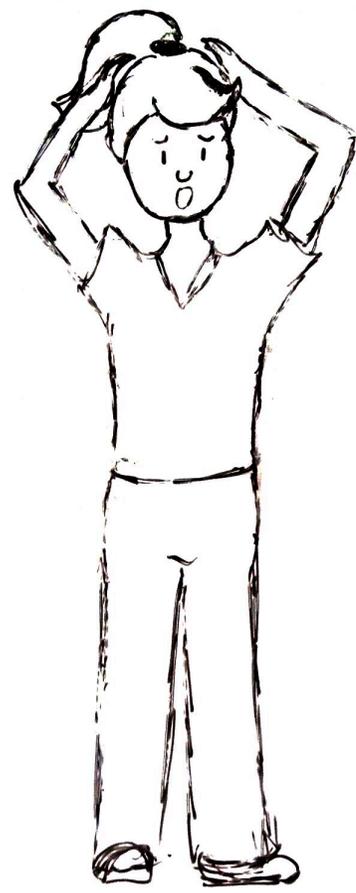


Seibert et al., HESS, 2018

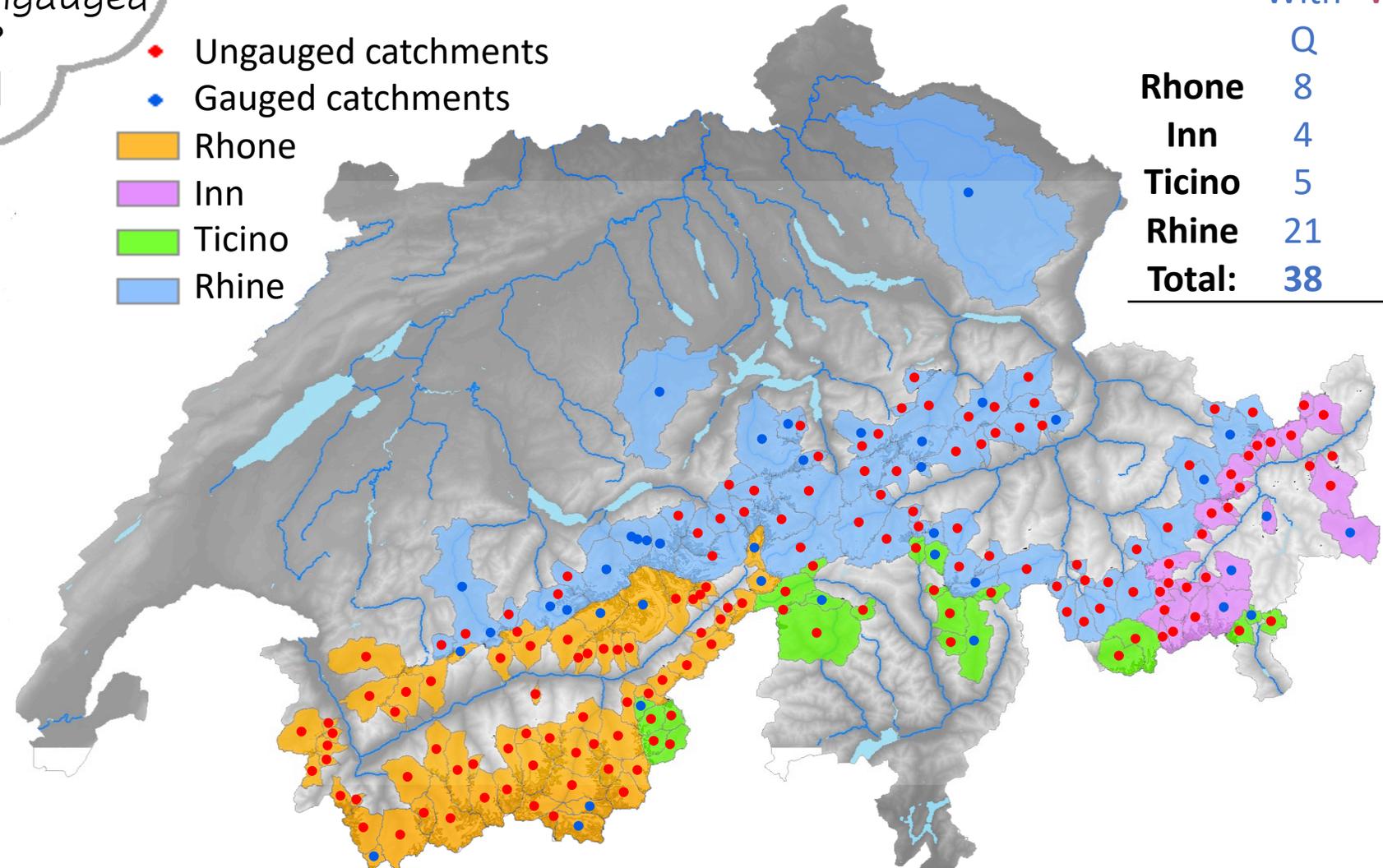
# Glacierized headwater catchments

In Switzerland, undisturbed catchments are rare. Therefore, from 195 headwater catchments, only 38 have discharge measurements.

How to deal with ungauged catchments?



- ◆ Ungauged catchments
- ◆ Gauged catchments
- Rhone
- Inn
- Ticino
- Rhine



	Number of catchments		Total
	With Q	Without Q	
<b>Rhone</b>	8	59	67
<b>Inn</b>	4	23	27
<b>Ticino</b>	5	19	24
<b>Rhine</b>	21	56	79
<b>Total:</b>	<b>38</b>	<b>157</b>	<b>195</b>

Q: Discharge

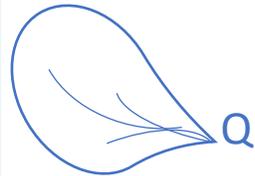
# Calibration of gauged catchments

The gauged catchments were calibrated using weighted objective functions for discharge, snow and glacier properties with a different weighting depending on the quality of the data.



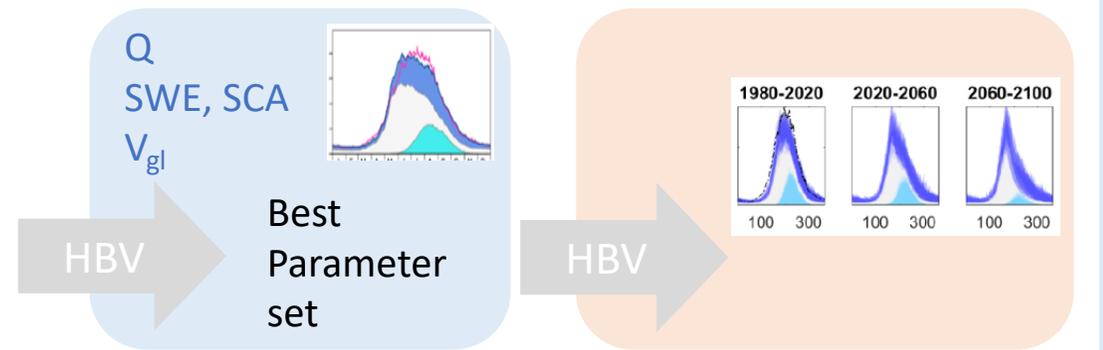
Q: discharge  
 P: precipitation  
 SWE: Snow water Equivalent  
 SCA: Snow covered area  
 Vgl: Glacier volume

Gauged Catchments



Calibration on Present climate (1973-2017)

Simulation of Q components Climate models



## Objective functions if precipitation (P) and Q are OK:

Q (50%):

- Lindstrom Measure (20%)
- Nash Sutcliff efficiency (log, 15%)
- Seasonal Nash Sutcliff efficiency (jun-sept, 15%)

Snow & glacier (50%):

- SCA: Root Mean Square Error (15%)
- SWE: Mean Absolute Normalized Error (15%)
- Glacier: Absolute Mean Relative Error (20%)

## if P << Q:

Q (30%):

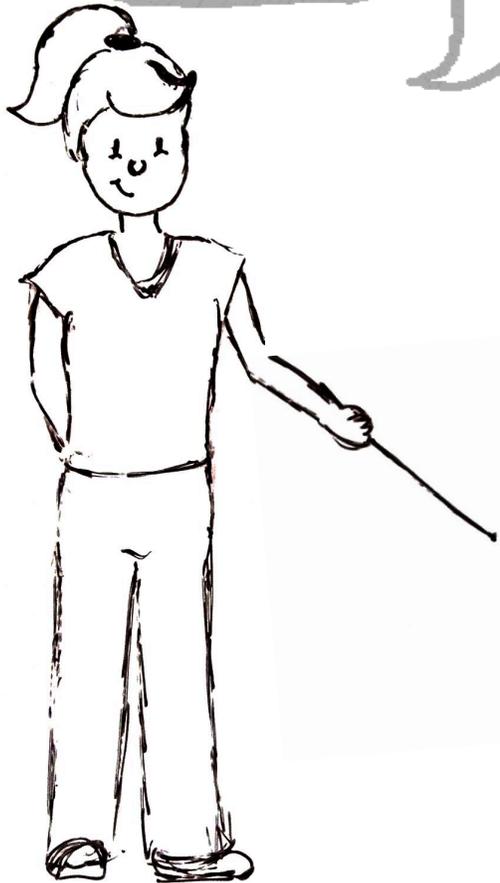
- Spearman Rank (30%)

Snow & glacier (70%):

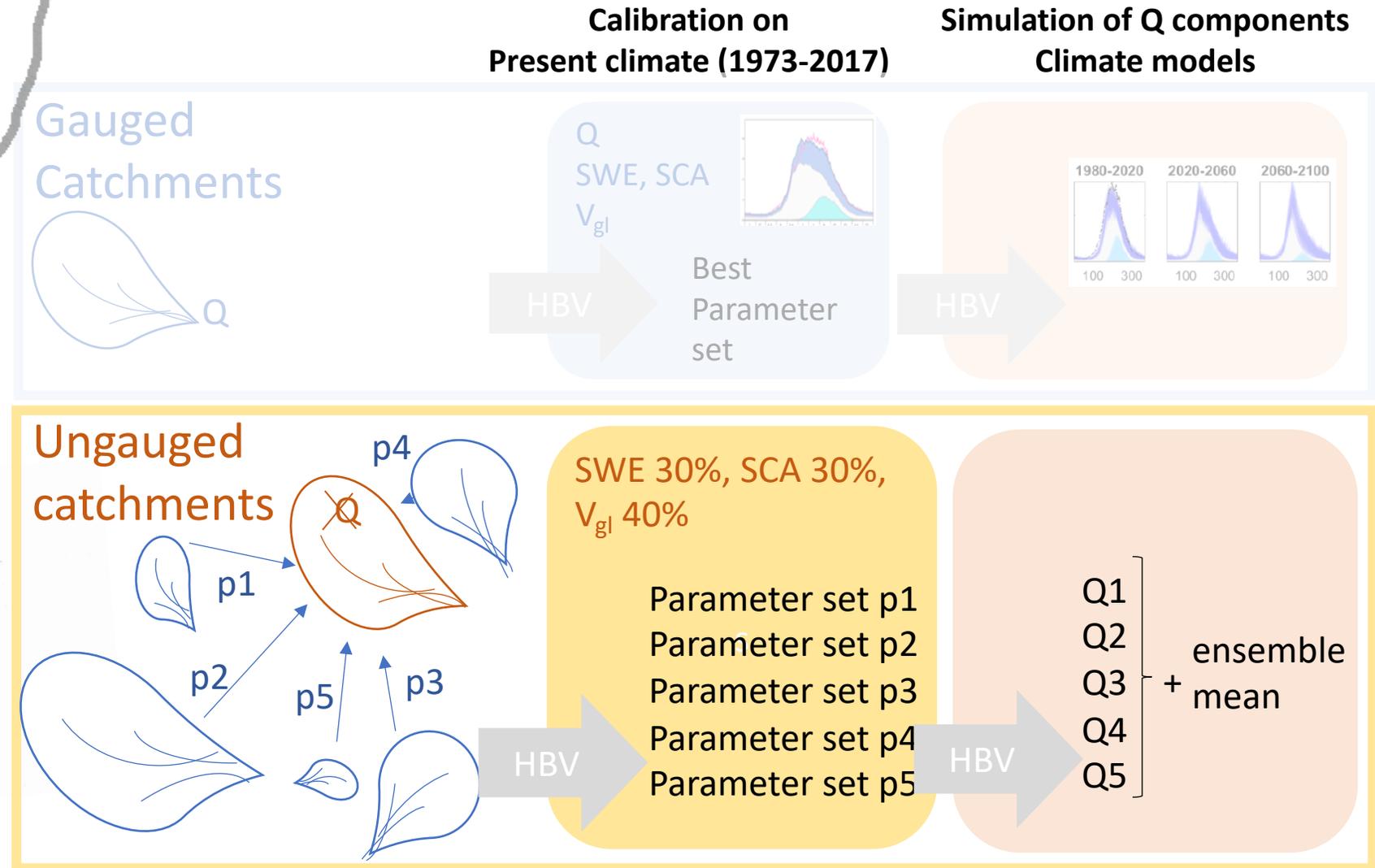
- SCA: Root Mean Square Error (21%)
- SWE: Mean Absolute Normalized Error (21%)
- Glacier: Absolute Mean Relative Error (28%)

10 GAP-calibration, 50 parameter sets, >3500 runs

For the ungauged catchments, the discharge parameters were regionalized from the five most similar gauged catchments. The rest of the parameters were calibrated with weighted objective functions on snow and ice.

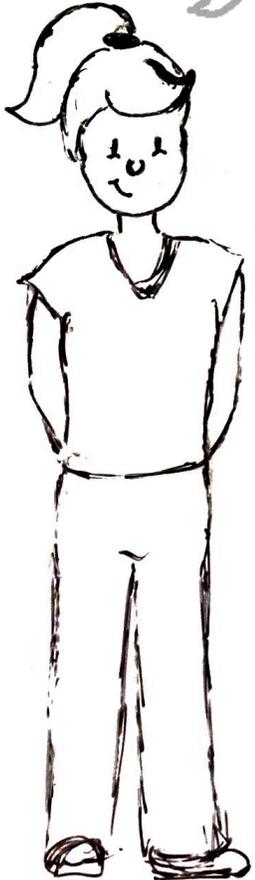


# Regionalization of ungauged catch.



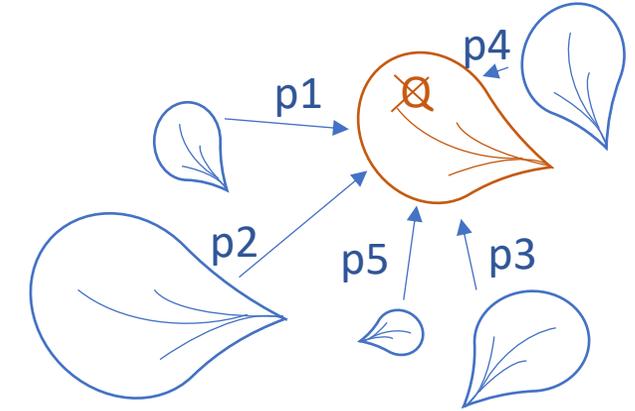
# Criteria for regionalization

For the regionalization, the donor catchments were ranked based on nine categories.

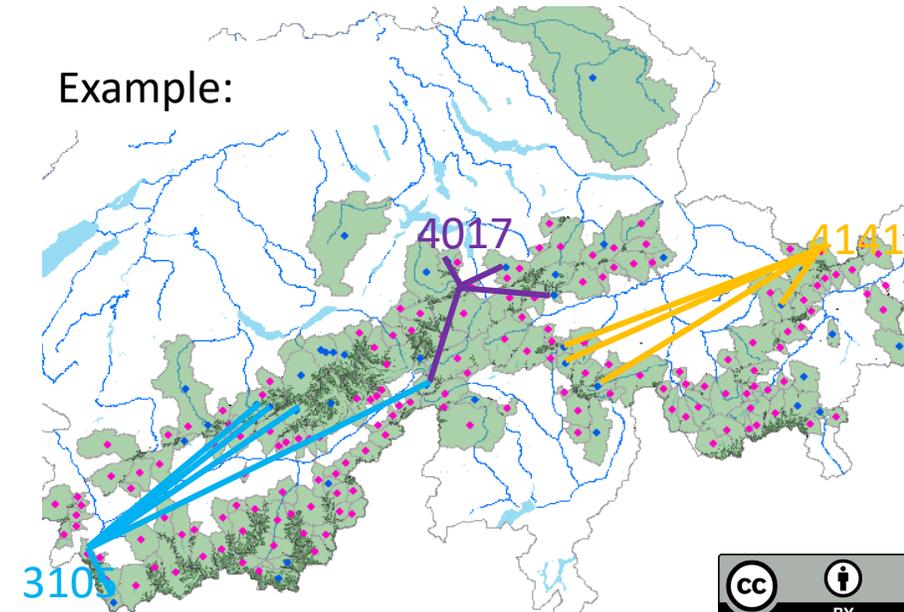


Categories (all same weight):

- 1-4) Geographic & topographic catchment properties
  - Distance, Area, Slope, Exposition
- 5) Elevation:
  - Mean, min, max, Range
- 6) Glacier:
  - Area 1973, Area change (2010/1973), Elevation, Exposition, Slope, Thickness 1973
- 7) Meteorologie:
  - Precipitation, Temperature, Rain/Snow, SWE, P/T Gradients, PET, 1°C-Elevation, Water balance
- 8) Regions:
  - SLF, Alpine Regions (HADES)
- 9) Groundwater type



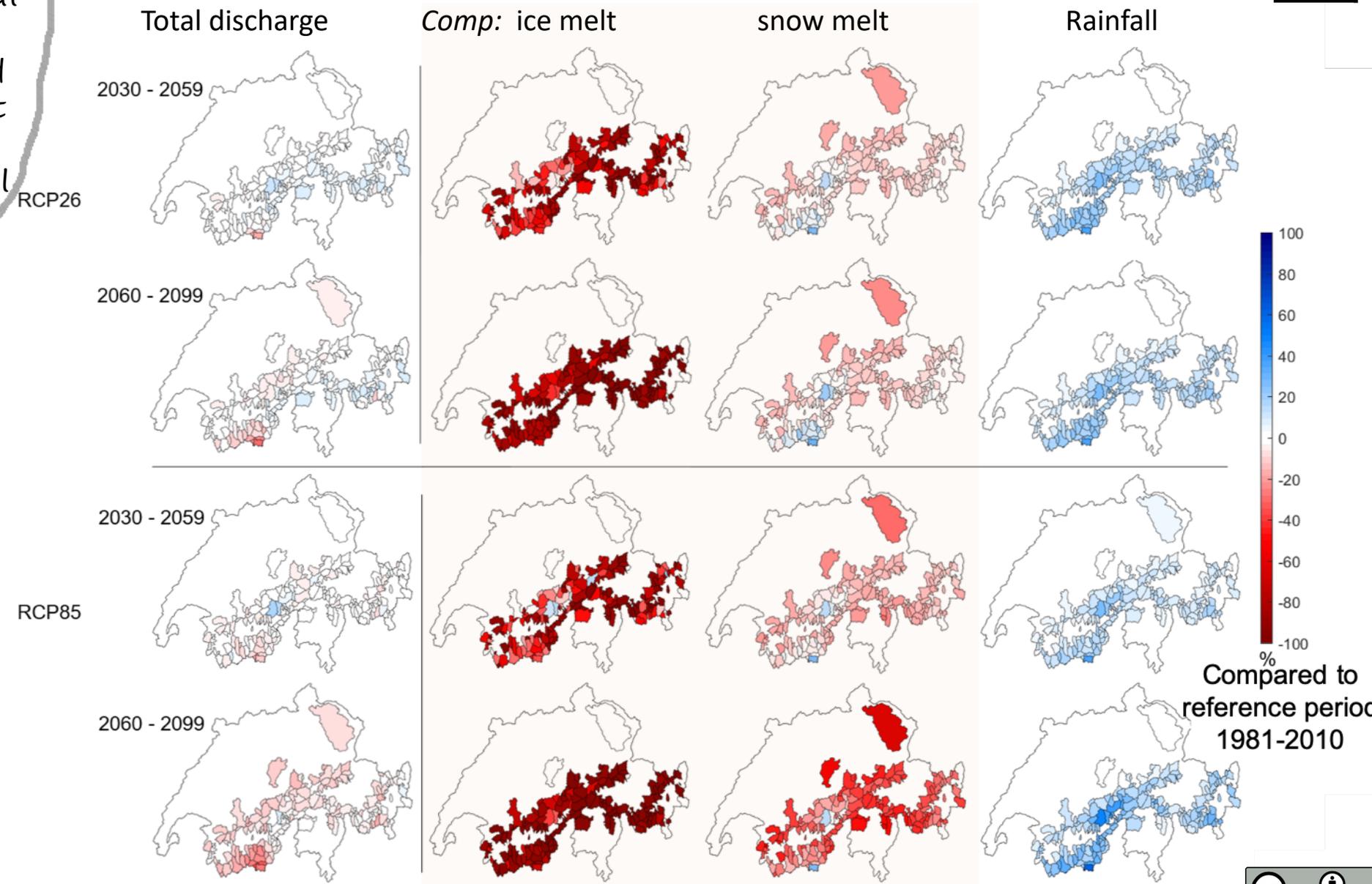
Example:



This is one example of the results we get from our simulations. Large regional differences between the components are expected for the future, snow melt and ice melt having different impacts on total discharge.



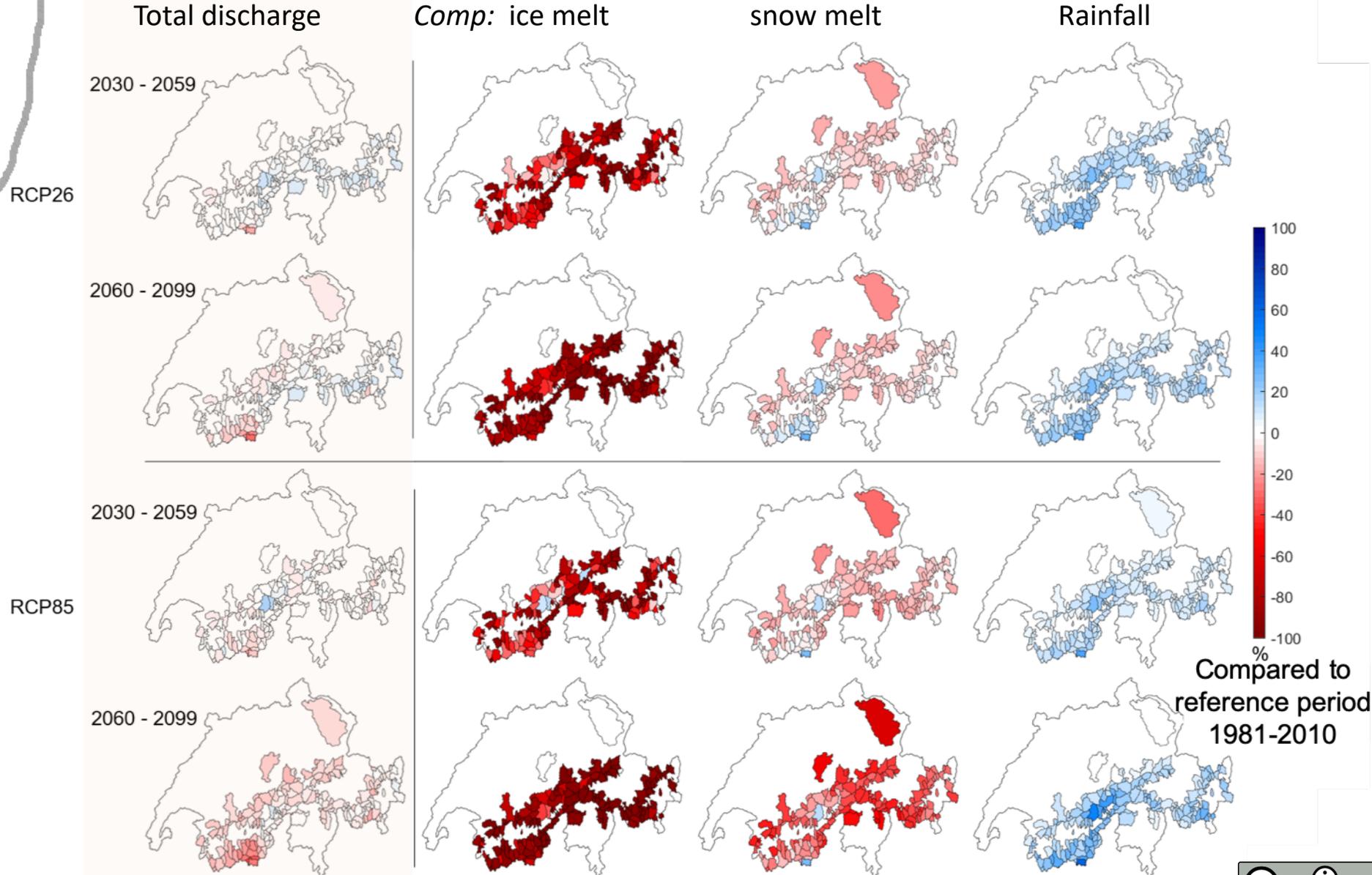
# Changes in discharge components

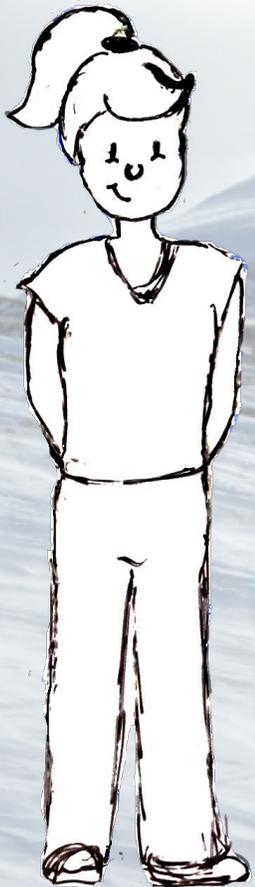


The patterns are slightly different depending on the emission scenario and time period. Overall, total discharge is expected to decrease at the end of the century, especially under RCP85.



# Changes in discharge components





THANK YOU VERY  
MUCH FOR YOUR  
ATTENTION

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