Institute for Environmental Sciences
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Modeling Streamflow Sensitivity in a Complex Watershed

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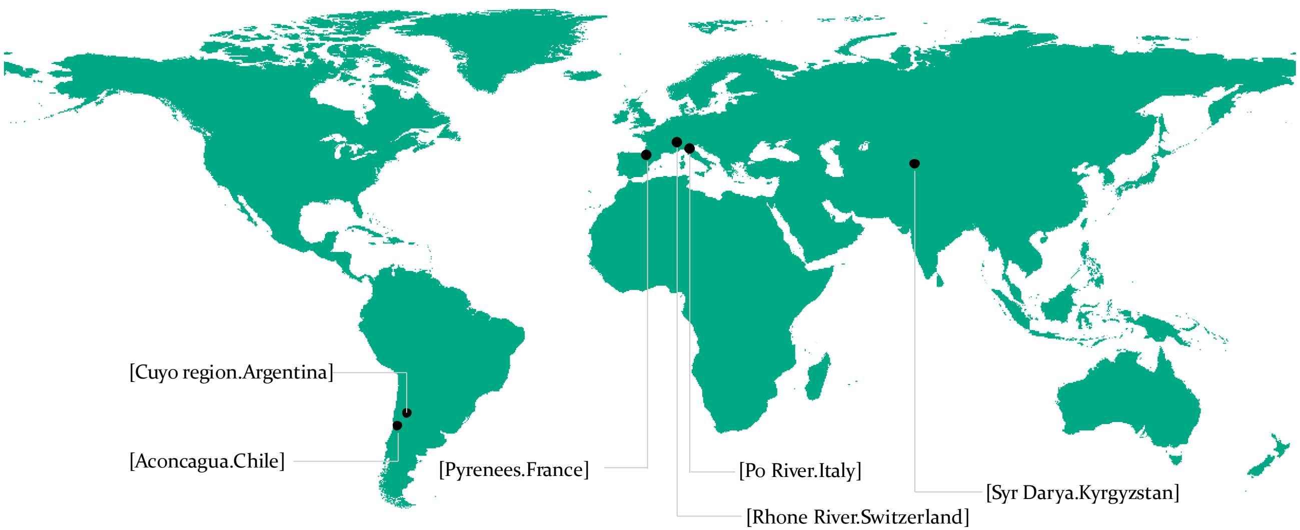
Background

- 40% of stream runoff comes from snow and glacier melt in the Rhone valley (Huss el al., 2009).
- In Switzerland, 84 out of 85 glaciers under observation became shorter (WGMS, 2008).
- Alarming negative mass balance trend observed in the Rhone Glacier (Funk et al., 2008).
- 55% of Swiss energy from hydropower (Schleiss et al., 2007).

Background

Assessing Climate Change Impact on Quantity and Quality of Water



For more info please visit: www.acqwa.ch

Objectives

Can we simulate such a highly complex watershed ?

Considering:

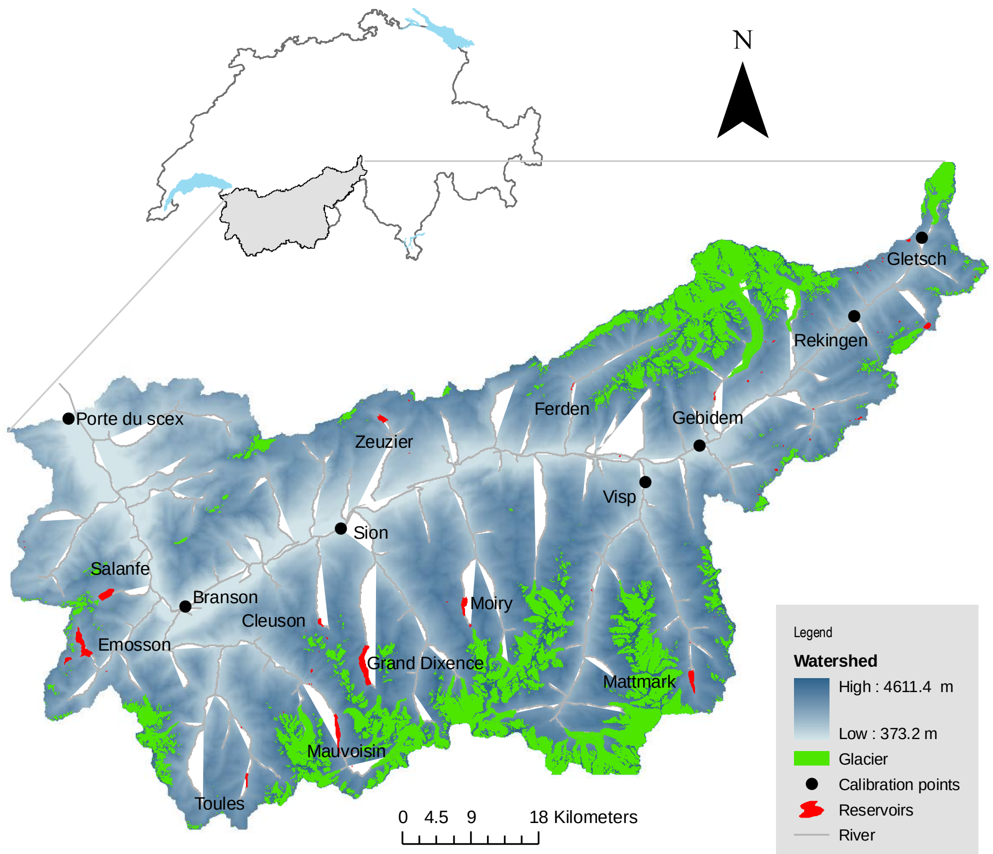
Water transfer
Orographic precipitation
Snow and glacier melt

Can we simulate such a highly complex watershed ?

Why is this important ?

- Energy Production
- Drinking Water and Agriculture
- Biodiversity and Ecosystems

Study Area



Watershed Area:
5500 km^2

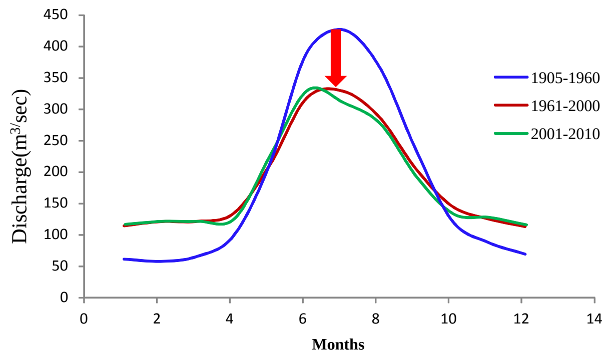
Elevation:
Min. 378 m
Max. 4237 m

Land-Use :
Glacier (14%)
Solid Rocks (24%)
Forest (41%)

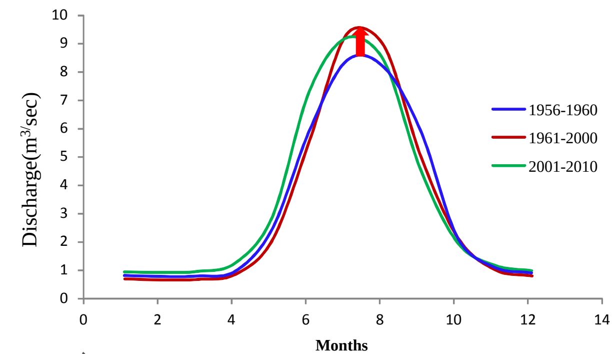



Source: FOEN

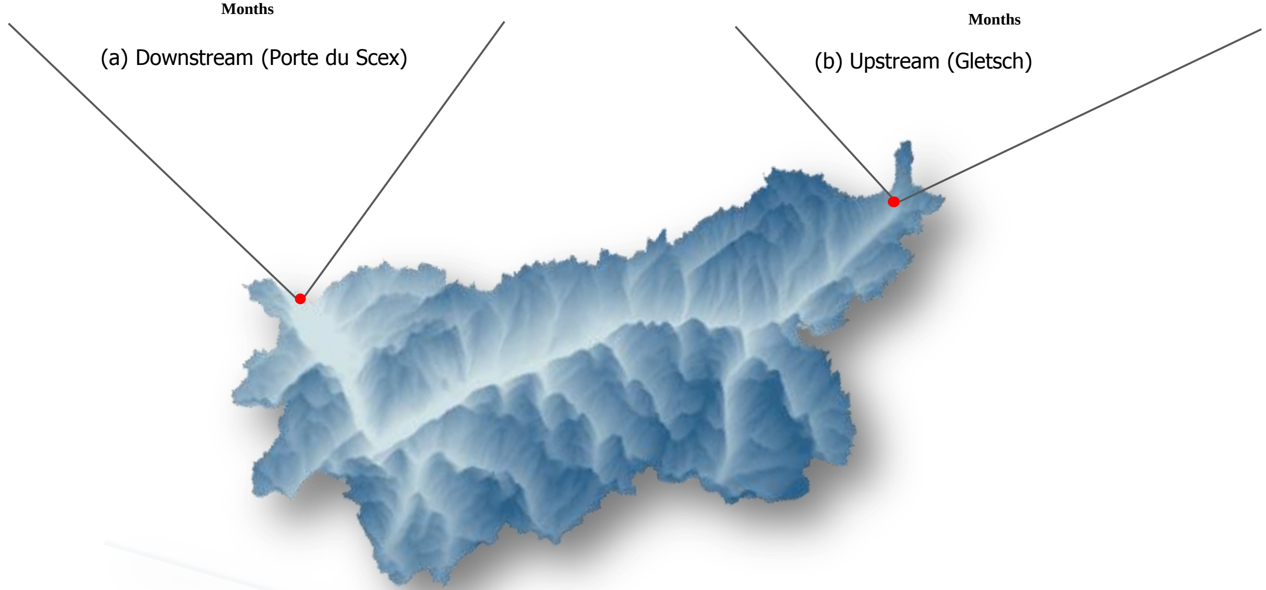
Long Term Hydrograph Analysis



(a) Downstream (Porte du Scex)

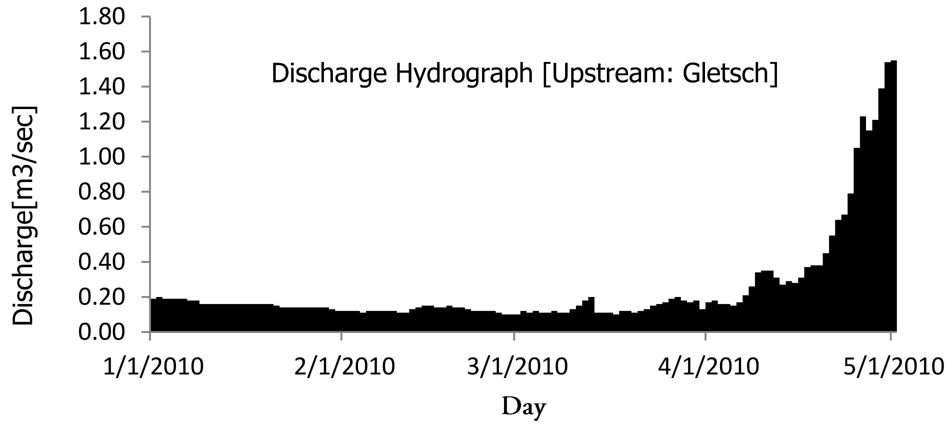


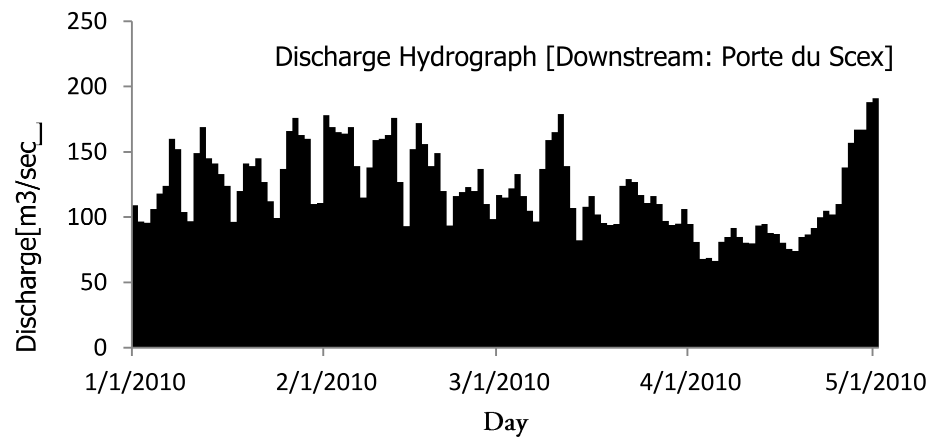
(b) Upstream (Gletsch)



Method

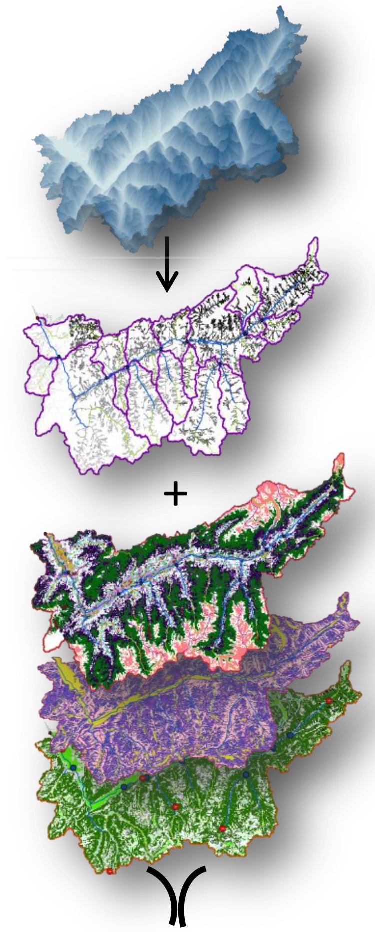
Upstream-Downstream Variation (Hydropower Effect)





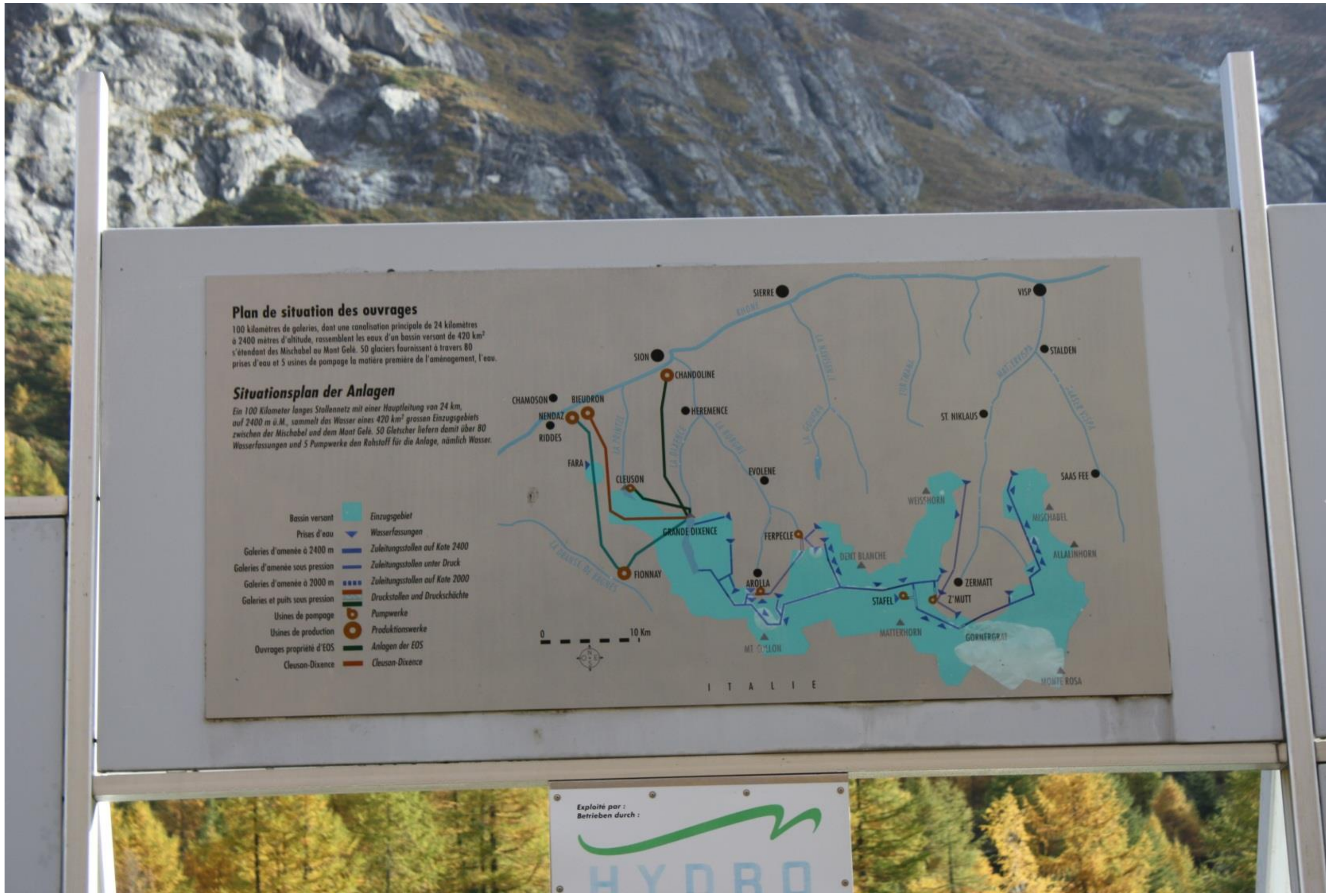
Method

Data Used and Sources



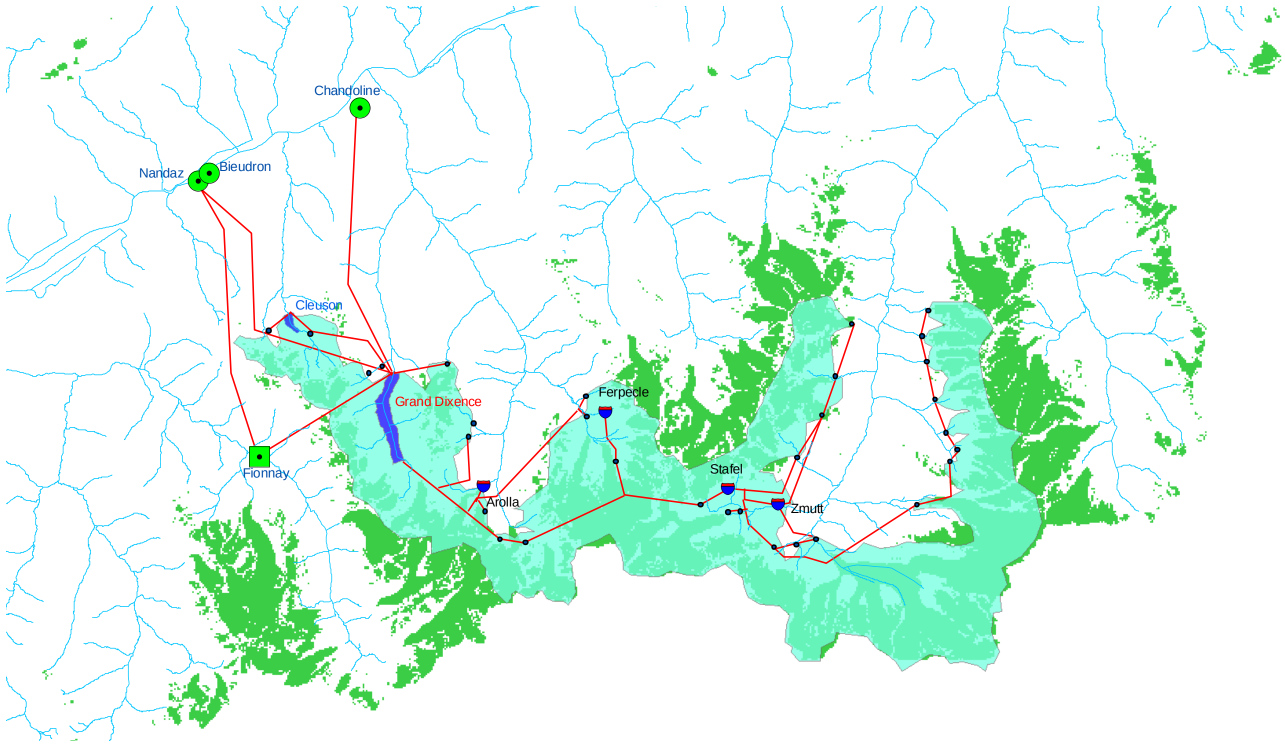
Data Type	Data Source
Digital Elevation Model (DEM)	Swiss-topo (grid cell: 25 m · 25 m) www.swisstopo.ch
Land-Use	Swiss Federal Statistical Office (grid cell: 100 m · 100 m) http://www.bfs.admin.ch
Soil Type	Swiss Federal Statistical Office (grid cell: 100 m · 100 m) http://www.bfs.admin.ch
River & Channel Network	FOEN (grid cell: 100 m · 100 m) http://www.bfs.admin.ch
Hydrometeorological Data	MeteoSwiss http://www.meteosuisse.admin.ch
River Flow	FOEN, Switzerland http://www.hydrodaten.admin.ch
Hydropower Data	Alpiq [www.alpiq.ch] E-dric[www.edric.ch]

Method



Plan de situation des ouvrages
100 kilomètres de galeries, dont une canalisation principale de 24 kilomètres à 2400 mètres d'altitude, rassemblent les eaux d'un bassin versant de 420 km² s'étendant des Mischabel au Mont Gelé. 50 glaciers fournissent à travers 80 prises d'eau et 5 usines de pompage la matière première de l'aménagement, l'eau.
Situationsplan der Anlagen
Ein 100 Kilometer langes Stollennetz mit einer Hauptleitung von 24 km, auf 2400 m ü.M., sammelt das Wasser eines 420 km² grossen Einzugsgebiets zwischen der Mischabel und dem Mont Gelé. 50 Gletscher liefern damit über 80 Wasserfassungen und 5 Pumpwerke den Rohstoff für die Anlage, nämlich Wasser.
Bassin versant — Einzugsgebiet
Prises d'eau — Wasserfassungen
Galeries d'amenée à 2400 m — Zuleitungsstollen auf Kote 2400
Galeries d'amenée sous pression — Zuleitungsstollen unter Druck
Galeries d'amenée à 2000 m — Zuleitungsstollen auf Kote 2000
Galeries et puits sous pression — Druckstollen und Druckschächte
Usines de pompage — Pumpwerke
Usines de production — Produktionswerke
Ouvrages propriété d'EOS — Anlagen der EOS
Cleuson-Dixence — Cleuson-Dixence
SIERRE
VISP
SION
CHANDOLINE
STALDEN
CHAMOSON
BIEUDRON
NENDAZ
HEREMENCE
RIDDES
ST. NIKLAUS
FARA
CLEUSON
EVOLENE
SAAS FEE
WEISSHORN
MISCHABEL
GRANDE DIXENCE
FERPECLE
DENT BLANCHE
ALLALINHORN
FIONNAY
AROLLA
ZERMATT
STAFEL
Z'MUTT
MATTERHORN
GORNERGRAT
MONTE ROSA
0
10 Km
I T A L I E
Exploité par :
Betrieben durch :
HYDRO

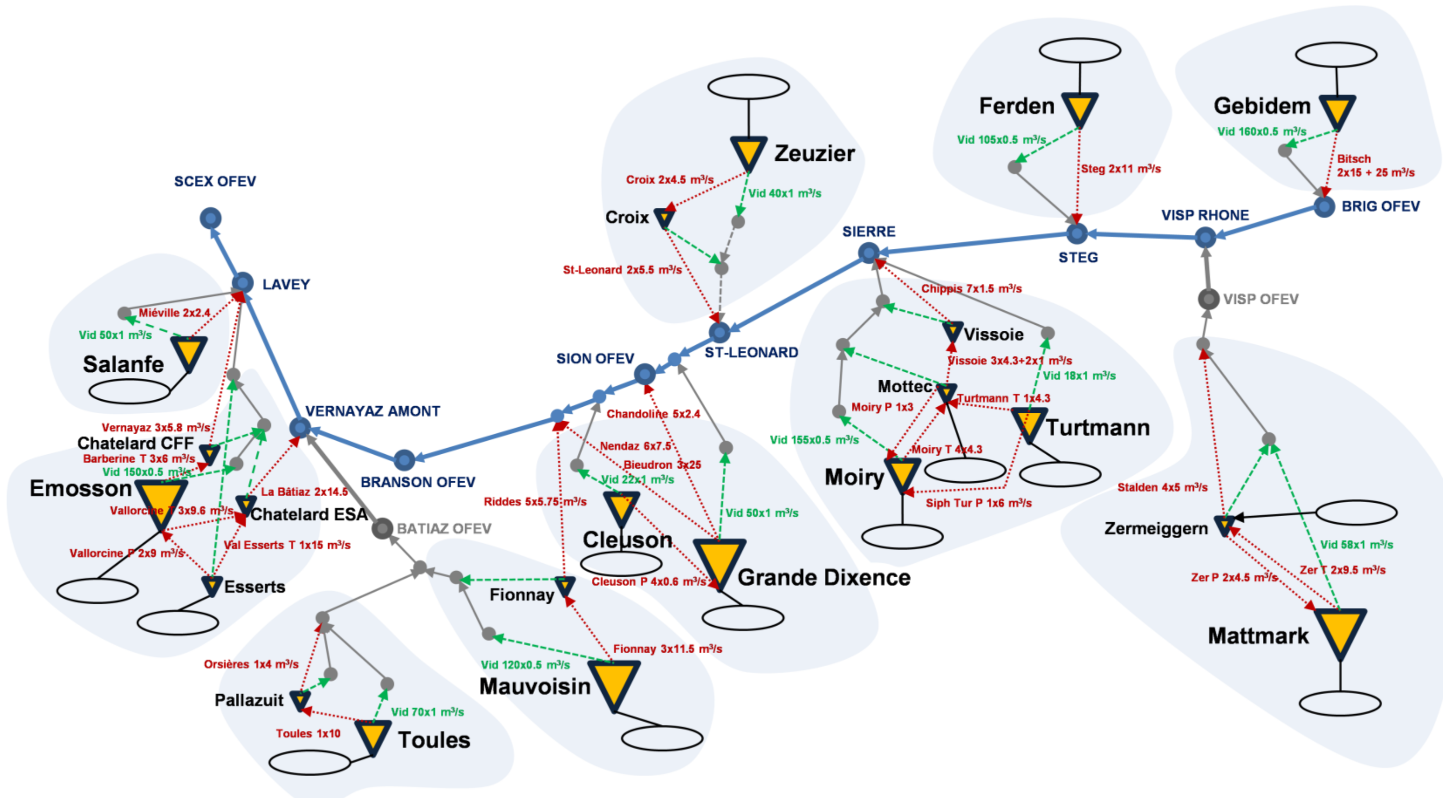
Method



[Source: Jordan, 2007]

Method

Network of the Entire Basin



[Source: Hernández, 2011]

Model Interface: ArcSWAT 2009

Total Years Studied: 1981-2010 (30 years)

- Warm-Up Period: 1997-2000
- Calibration Period: 2001-2006
- Validation Period: 2007-2010

- Time Step: Monthly Average
  Daily Average

- Model Evaluation: Visually (graph fitting)
  Statistically (NSE R^2 PBIAS)

Method

Moriasi, D.N. et al., 2007.

(NSE > 0.5, RSR ≤ 0.70, PBIAS = ± 25%)

Criteria	Equation	Daily	Monthly
NSE	$NSE = 1 - \left[\frac{\sum_{i=1}^{n}(X_i^{obs} - X_i^{sim})^2}{\sum_{i=1}^{n}(X_i^{obs} - X_i^{mean})^2}\right]$	0.64	0.72
PBIAS	$PBIAS = \left[\frac{\sum_{i=1}^{n}(X_i^{obs} - X_i^{sim}) \times 100}{\sum_{i=0}^{n}(X_i^{obs})}\right]$	-13.18	-12.13
RSR	$SR = \frac{RMSE}{STDEV_{obs}} = \left[\frac{\sqrt{\sum_{i=1}^{n}(X_i^{obs} - X_i^{sim})^2}}{\sqrt{\sum_{i=1}^{n}(X_i^{obs} - X_i^{mean})^2}}\right]$	14.87	12.40

Where X_i^{obs} = observed variable (flow in m^3s^{-1})
X_i^{sim} is the simulated variable (flow in m^3s^{-1})
X_i^{mean} is the mean of n values and n is the number of observations

Results

Before Calibration

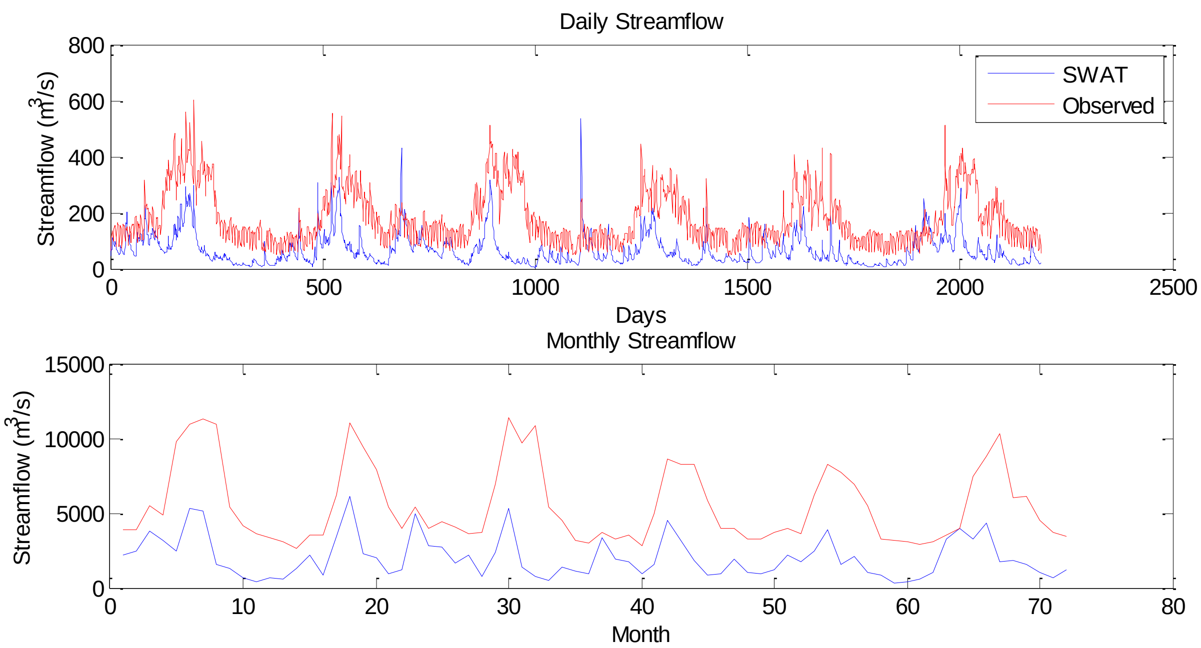
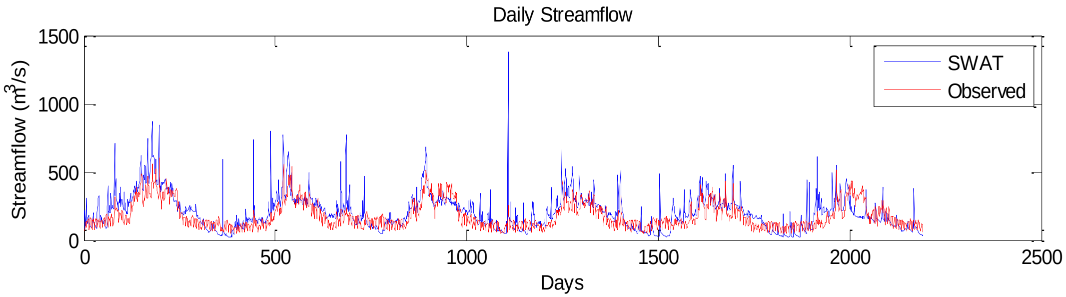


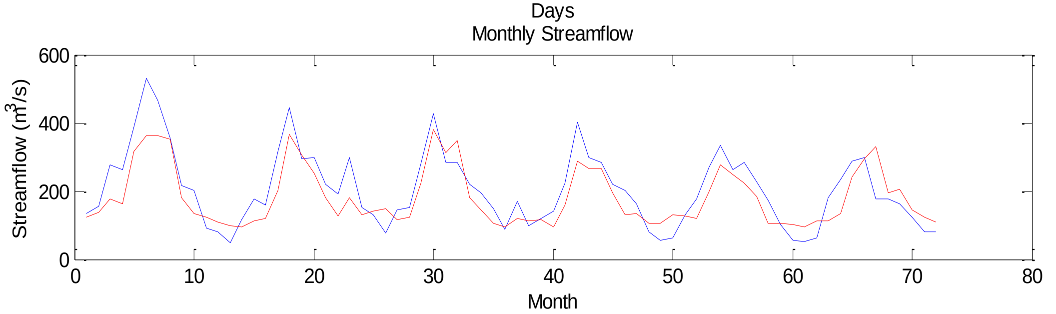
Figure: Daily and Monthly Discharge at Porte Du Scex

Results

Implementing Hydropower Network

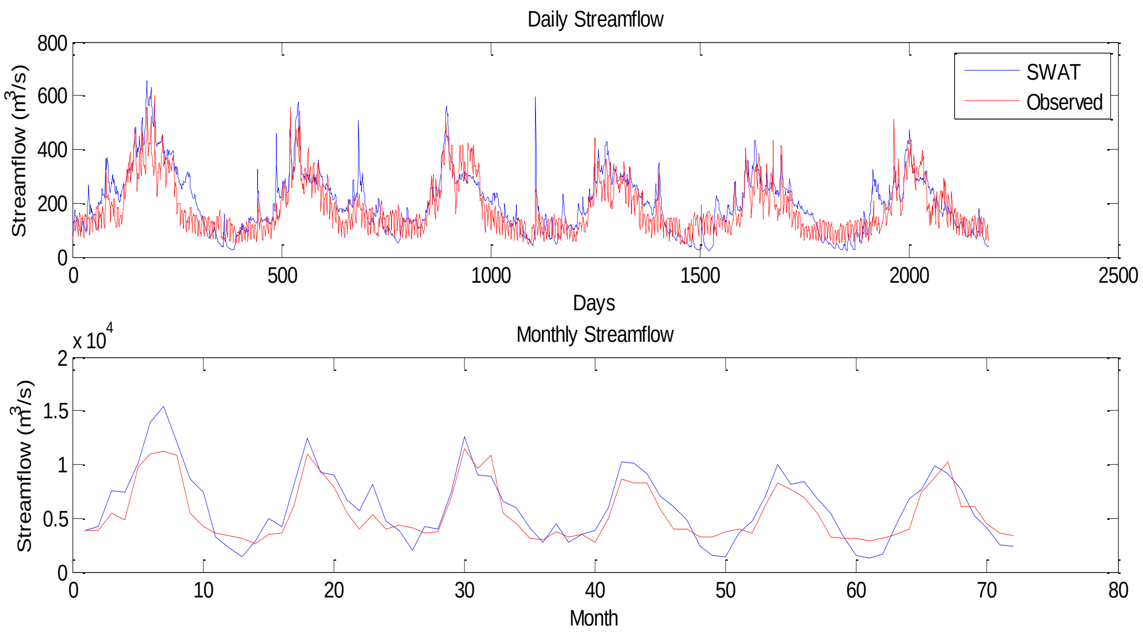


Criteria	Daily
R^2	0.5
NSE	0.38
VR	1.1303
PBIAS	-13.03



Criteria	Monthly
R^2	0.74
NSE	0.48
VR	1.12
PBIAS	-12.96

Manual Calibration



Criteria	Daily
R^2	0.72
NSE	0.64
VR	1.1303
PBIAS	-13.03

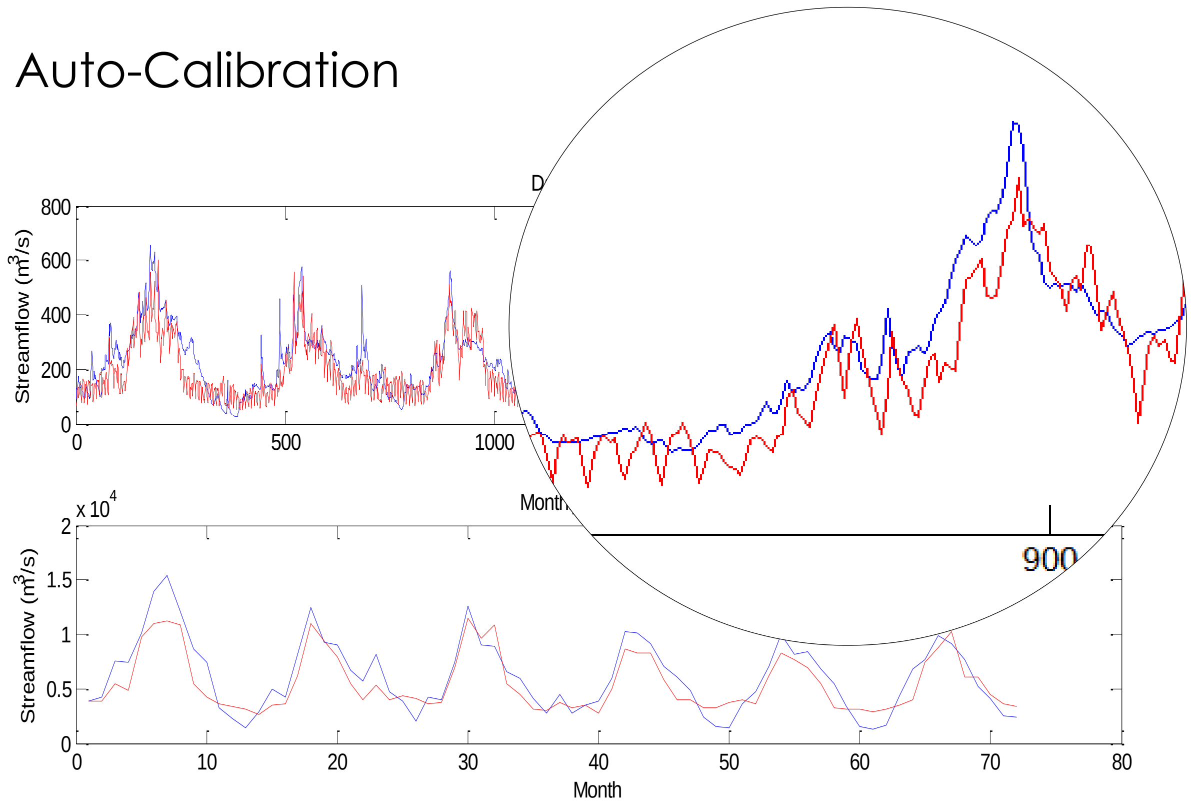
Criteria	Monthly
R^2	0.78
NSE	0.72
VR	1.12
PBIAS	-12.96

[SFTMP: SMTMX: SMFMN: TIMP: SURLAG: CN]

Results

[Vrugt et al.,2007]

Auto-Calibration



AMALGAM

Conclusions

Key Findings…

- Model generated streamflow has close match with measured runoff.
- Snow and glacier melt related parameters are most sensitive.
- Precipitation and temperature lapse rates play a significant role in model performance.
- Hydropower operation rules have a very significant impact on streamflow (discharge can vary by 50% within a single day).

Conclusions

Water Resour Manage
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Streamflow Modeling in a Highly Managed Mountainous Glacier Watershed Using SWAT: The Upper Rhone River Watershed Case in Switzerland

Kazi Rahman · Chetan Maringanti · Martin Beniston · Florian Widmer · Karim Abbaspour · Anthony Lehmann

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Abstract Streamflow simulation is often challenging in mountainous watersheds because of irregular topography and complex hydrological processes. Rates of change in precipitation and temperature with respect to elevation often limit the ability to reproduce stream runoff by hydrological models. Anthropogenic influence, such as water transfers in high altitude hydropower reservoirs increases the difficulty in modeling since the natural flow regime is altered by long term storage of water in the reservoirs. The Soil and Water Assessment Tool (SWAT) was used for simulating streamflow in the upper Rhone watershed located in the south western part of Switzerland. The catchment area covers 5220 km^2, where most of the land cover is dominated by forest and 14 % is glacier. Streamflow calibration was done at daily time steps for the period of 2001–2005, and validated for 2006–2010. Two different approaches were used for simulating snow and glacier melt process, namely the temperature index approach with and without elevation bands. The hydropower network was implemented based on the intake points that form part of the inter-reservoir network. Subbasins were grouped into two major categories

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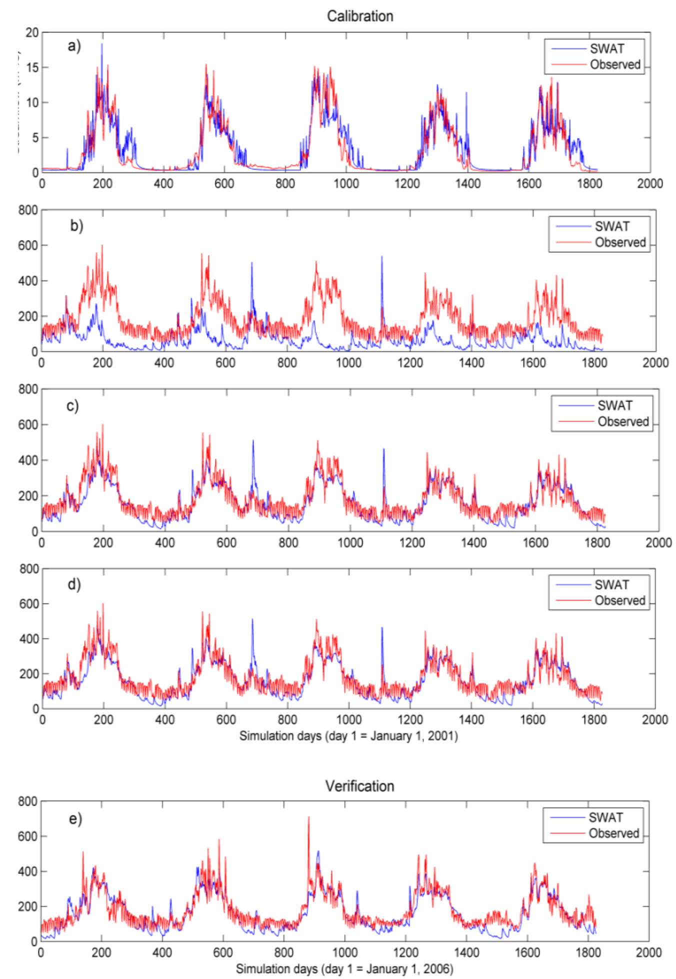

Thank you