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Research and innovation in the hydropower domain

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WP2: Key contributions 2017-2020

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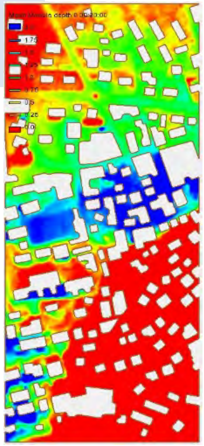
Task 2.1	*Task 2.2*	*Task 2.3*	*Task 2.4*
Morpho-climatic controls on future HP production	HP infrastructure adaptation to future requirements	Environmental impacts of future HP operating conditions	Integrated simulation of HP systems operation

Research directions

- **Increase of flexibility** in hydropower operation – structural and operation requirements
- Update of **climate change impacts** on HP production
- Extreme **natural hazards** and risk of HP operation
- Design of **new projects under uncertainties**
- **Reservoir sedimentation** and sustainable operation of storage hydropower plants

+ 3 Demonstrators



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Task 2.1
«Morpho-climatic controls on future HP production»

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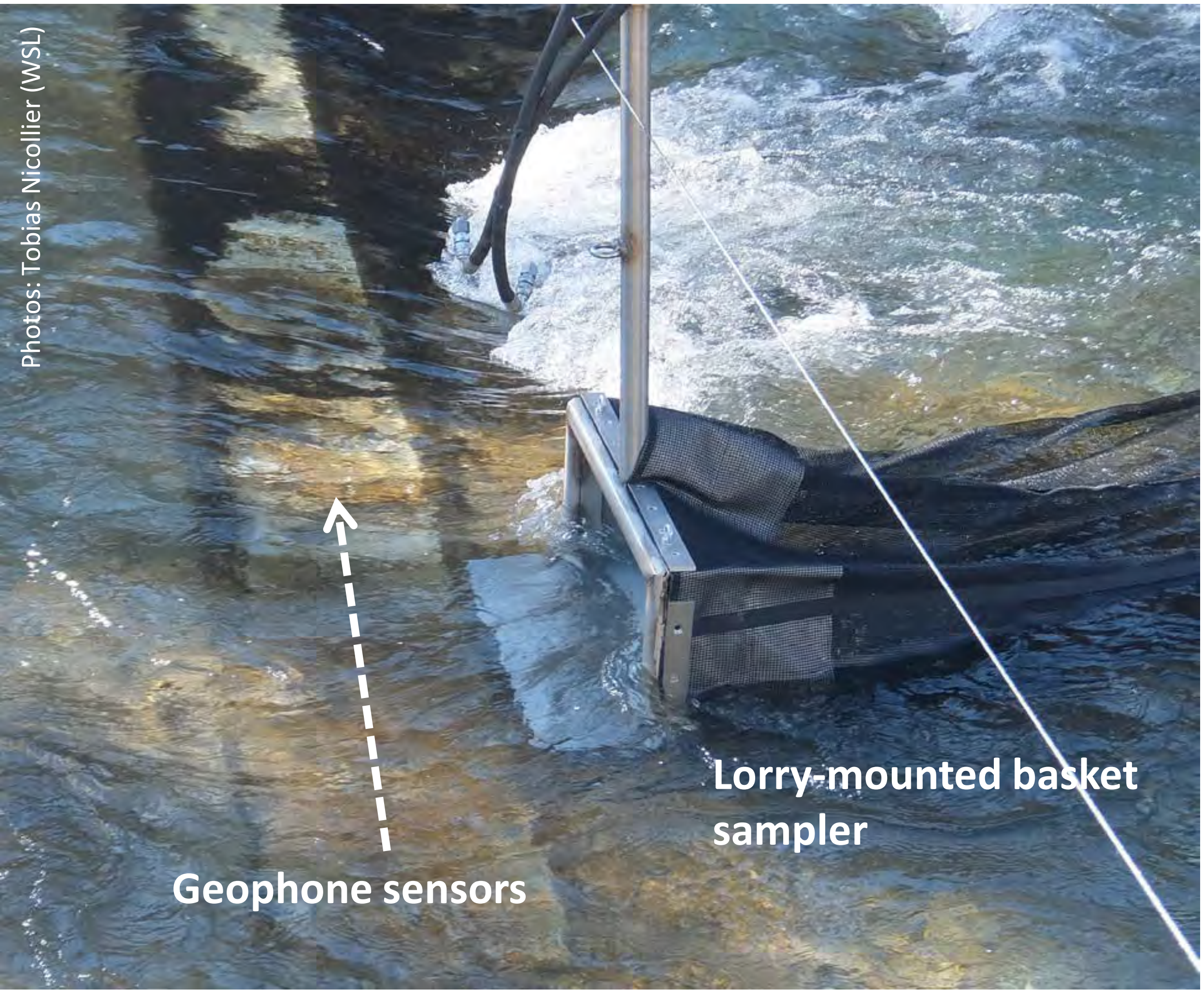
Sediment transport measurements Albula (upstream of Solis HP reservoir)

- Comprehensive calibration measurements (spring 2018)



HEPS4Power
Extended-range Hydrometeorological Ensemble Predictions for Improved Hydropower Operations and Revenues

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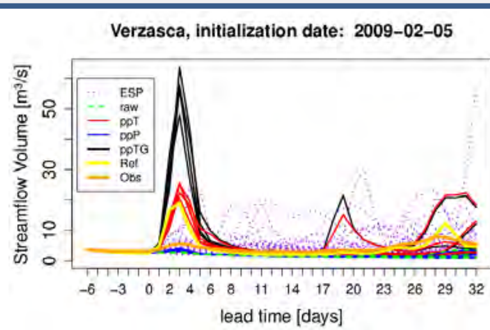
Final outcome: Statistically corrected sub-seasonal meteorological forecasts improve runoff predictions and revenues of hydropower production in alpine catchments.

Partners: MeteoSchweiz, WSL Swiss Federal Institute for Forest, Snow and Landscape Research WSL, ETH zürich, hydrique.

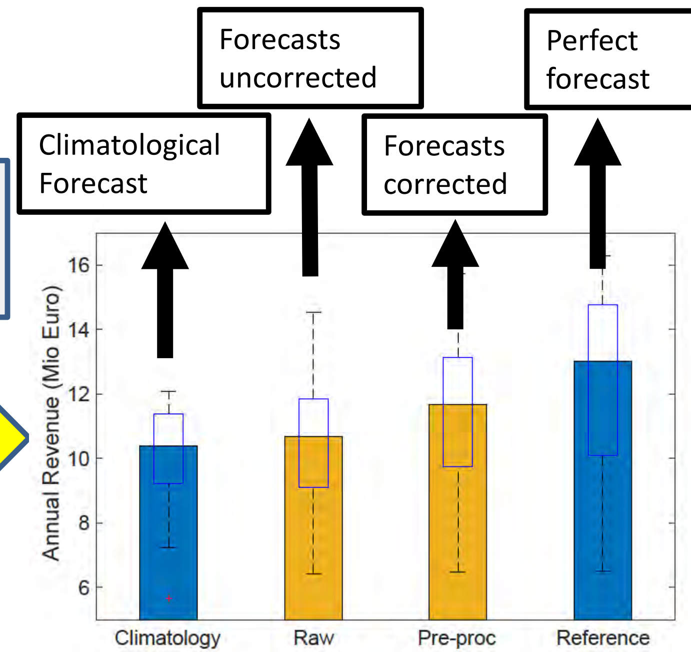
Global meteorological forecasts

Statistical corrections



Hydrological runoff predictions up to 32 days

Hydropower optimization

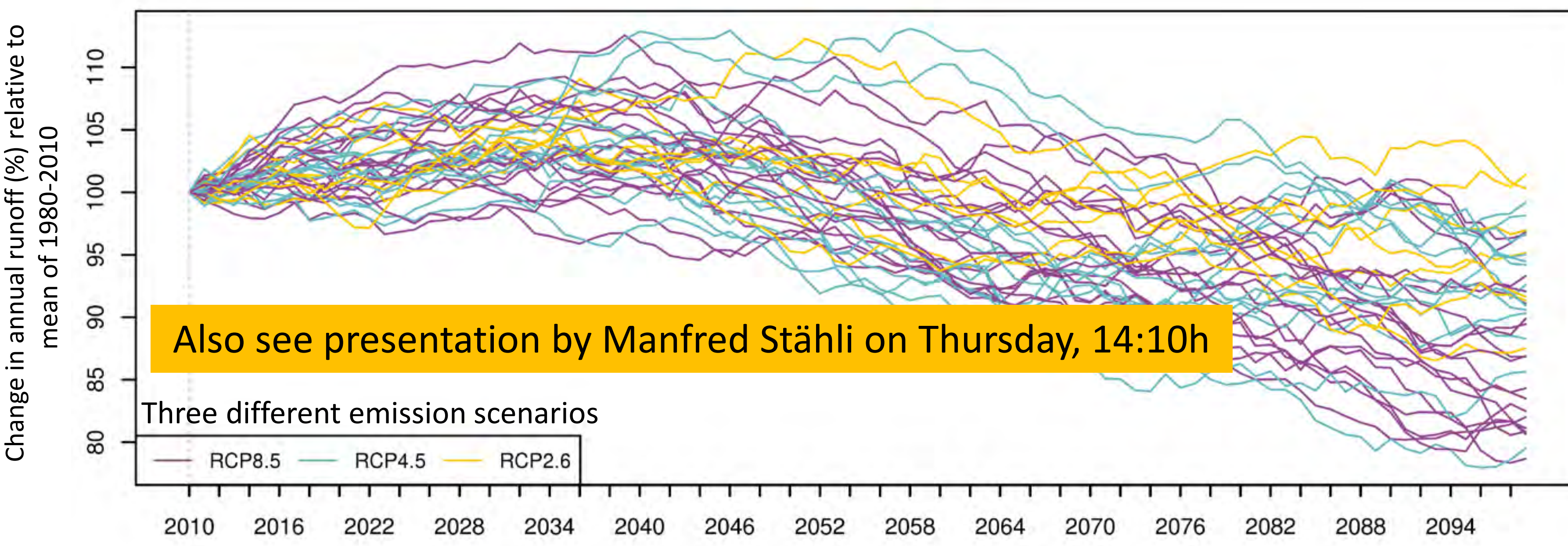


Potential to increase existing hydropower revenues

New climate change scenarios CH2018 used for SCCER SoE synthesis

- Official release of CH2018: 13 Nov 2018 at ETH Zürich

Example of preliminary results: Change in runoff for a region in the Valais in the course of the 21st century



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Task 2.2
«Infrastructure adaption to future requirements»

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Design Optimization of Alpine Desanding Facilities

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- Development of enhanced design recommendations considering integral system including approach flow conditions

Measurement campaign
- Functional check
- Prototype data
- Flow/settling proc.

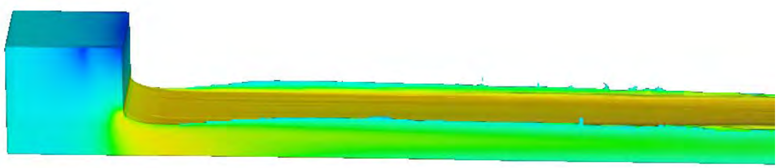
Numerical model
- Concept and setup
- Calibration and validation

Parameter study
- Geometry
- Hydraulics
- Structures

Air demand of high head bottom outlets

Hydraulic model tests

Numerical modelling



Prototype measurements

New design equation for air demand:

$$\beta = 0.007\ \mathsf{F}_c^{1.20}\zeta^{-0.25}(L/h_t)^{0.26}(1+S)^{-0.92}$$

See presentation by Benjamin Hohermuth on Friday, 9:45h

Hydropower potential of Swiss periglacial environment

- Analysis and rating of 62 potential future sites for HPP production (Society, Economy, Environment)

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Top 7:

new reservoir	MW	GWh/a
① Aletsch Glacier	73	218
② Gorner Glacier	78	235
③ Grindelwald Glacier	28	85
④ Hüfi Glacier	35	105
⑤ Rhône Glacier	29	88
⑥ Roseg Glacier	77	231
⑦ Trift Glacier	80	145
Total	**401**	**1108**

See presentation by Robert Boes on Thursday, 15:20h

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Task 2.3
«Environmental impacts of future HP operating conditions »

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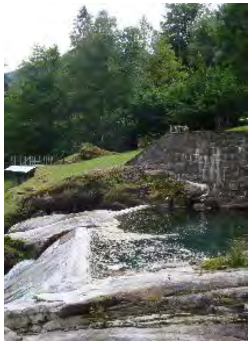
Topics

Managing environmental flows



Impacts of small-scale hydropower plants

Impacts of new hydropeaking regimes

Hydroecology and Floodplain Sustainability in Application – HyApp

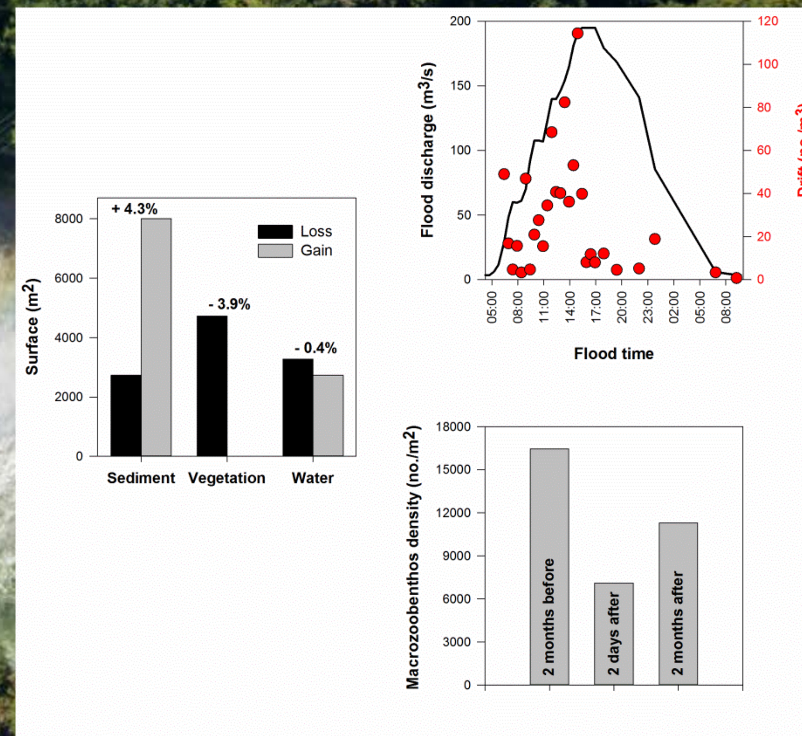
Preliminary results of the artificial flood in the Sarine (peak discharge 195 m^3/s)

Structural effects

- Decrease of ruderal vegetation (-3.9%)
- Increase of bare sediment area (+4.3%) mainly because of erosion of vegetation
- In general no major erosion and deposition of sediment (-10 – -20 cm)
- Short travel distance of gravel particles (40-80 m; max. 300 m)
- Sediment replenishments behaved as predicted in laboratory experiments

Functional effects

- Major drift of macroinvertebrates, organic matter (seston) and microbes occurred when streambed sediment started to move
- Short-term reduction in macroir abundance, but fast recovery of



Also see presentations by Severin Stähly on Friday, 10:15h and by Annunziato Siviglia on Friday, 11:00 h

zhaw Life Sciences and Facility Management, Institute of Natural Resource Sciences
EPFL École Polytechnique Fédérale de Lausanne
University of Zurich UZH
eawag aquatic research
70 NRP Energy Turnaround National Research Programme

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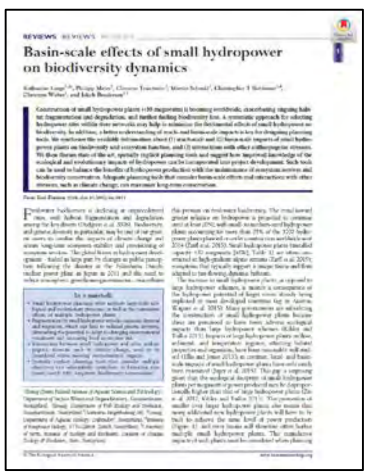
Small-scale hydropower plants in Alpine streams – studying ecological effects across different scales

Objective: Quantification of the ecological effects of small-hydropower plants and the propagation across the longitudinal and lateral dimension of alpine streams.

Work at Eawag: Combination of two approaches

1. Literature review

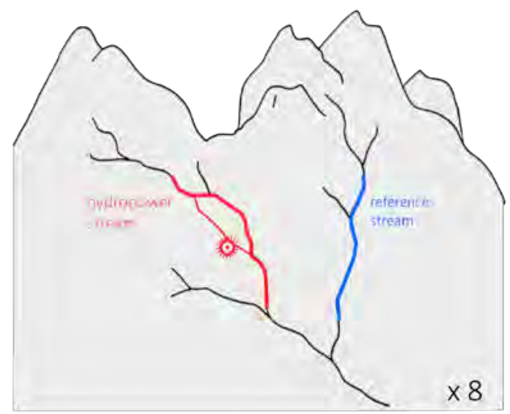
(Lange et al. 2018)


REVIEWS

Basin-scale effects of small hydropower on biodiversity dynamics

2. Field study

(in 8 stream pairs)



See presentation by Christine Weber on Friday, 11:15h

Effects of hydropower on stream temperature heterogeneity

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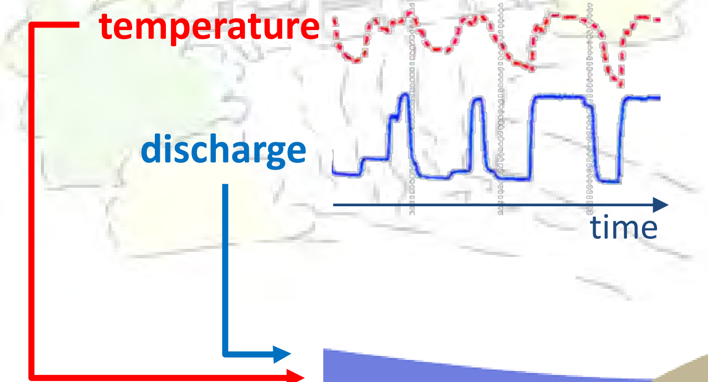
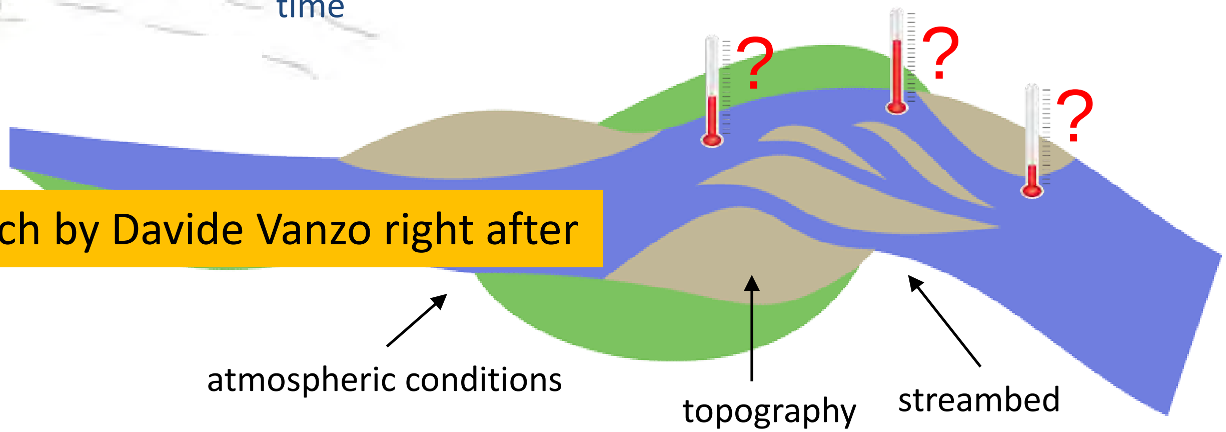


Hydropower production causes **discharge** and **temperature** alterations that might influence **local river thermal patterns**



See poster pitch by Davide Vanzo right after

→ How is **river thermal heterogeneity** affected by hydropower production?

→ How can we **model** and **quantify** such thermal alterations?

Hydropower and water temperature:
modelling the effects of management scenarios on river thermal heterogeneity

Davide Vanzo, Martin Schmid, Christine Weber and Michael Döring

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Task 2.4
«Integrated simulation of HP systems operation»

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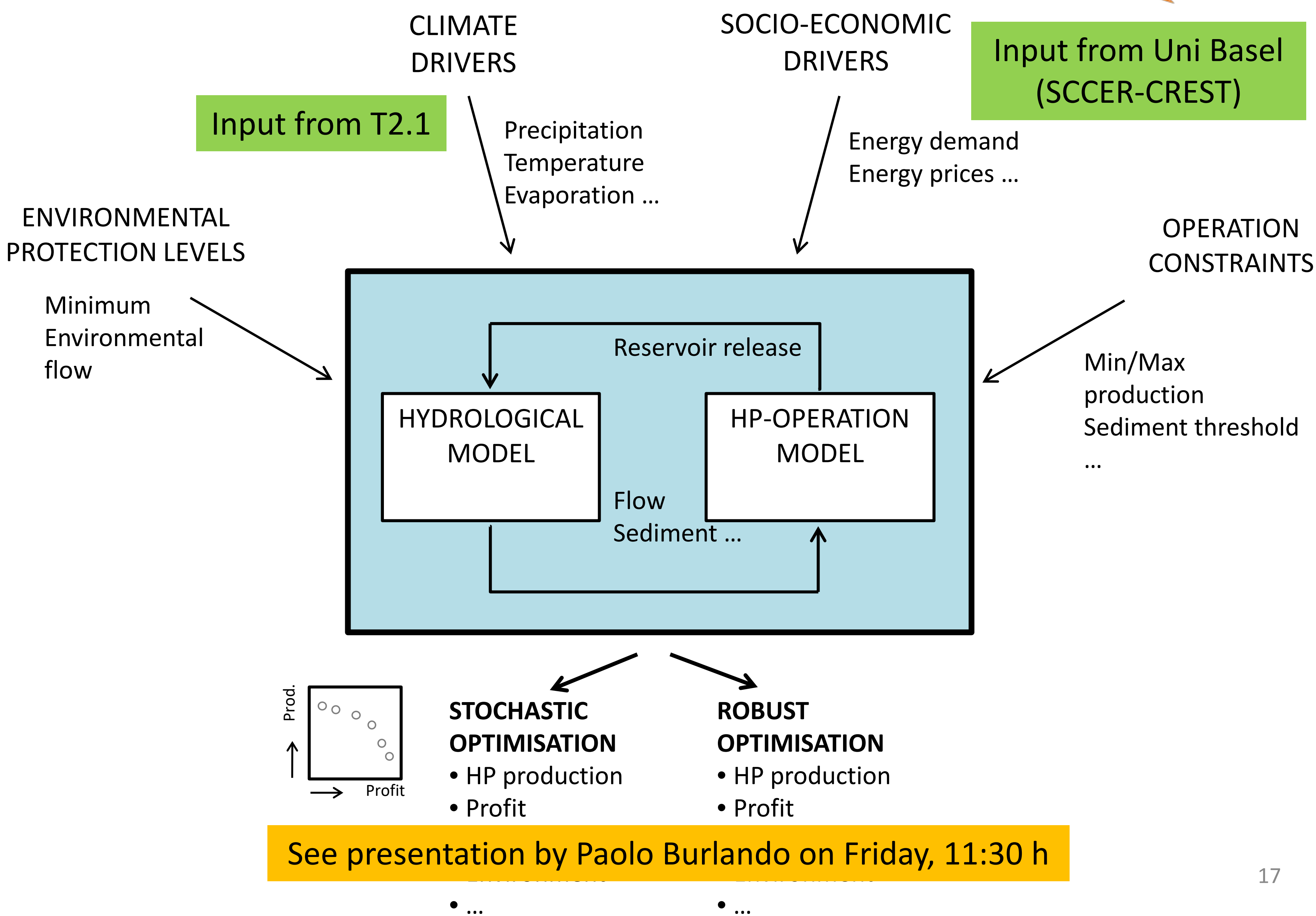
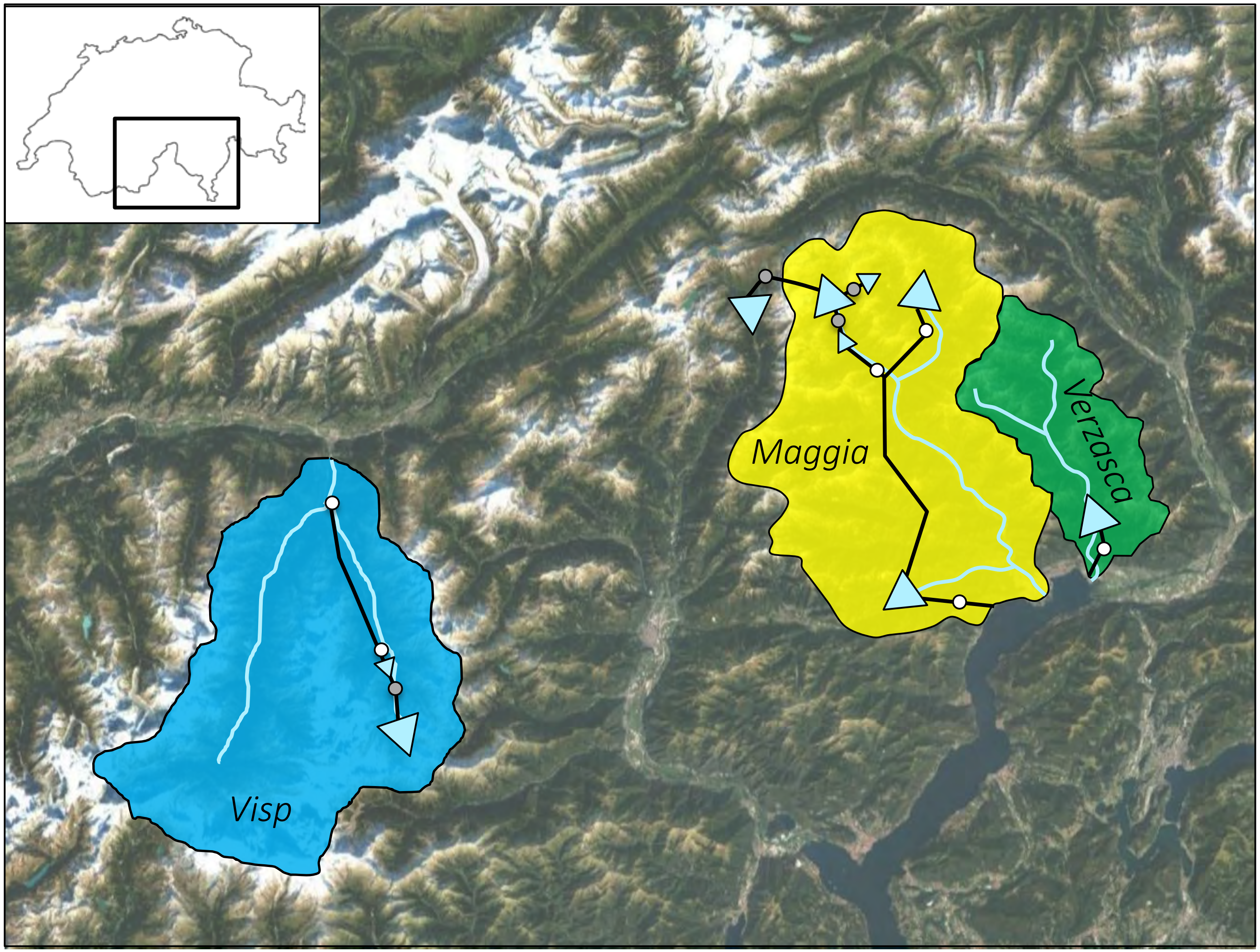
Integrated modelling framework



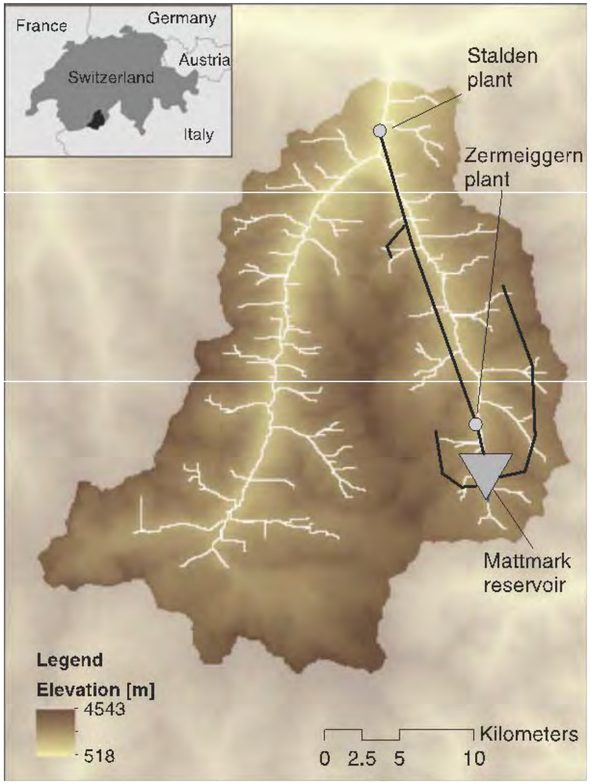
See presentation by Paolo Burlando on Friday, 11:30 h

Three case studies

with different features



The Visp valley



Objectives:

- Reoptimize the operation looking at tradeoff between production and revenue
- Assess the system vulnerability under changing climate and energy prices
- Assess, via reoptimization the adaptation capacity to projected water and energy changes

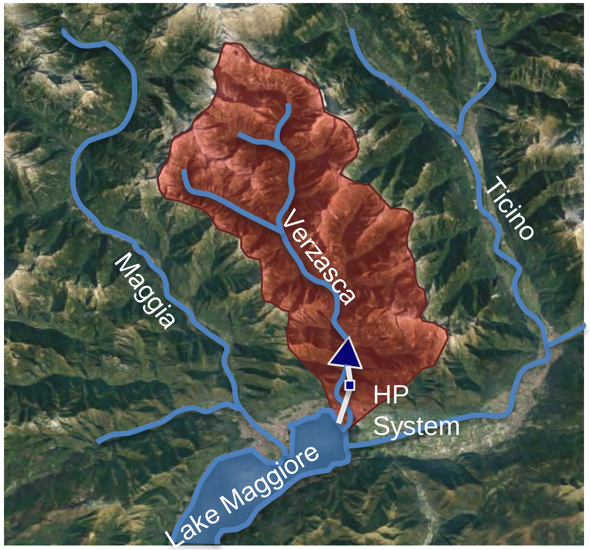
Features:

- Single reservoir hydropower system
- Production and pumping plants
- Glacier in the watershed

Outcomes:

- **All objectives reached**
- Anghileri et al. Alpine Hydropower in the Decline of the Nuclear Era: Trade-Off between Revenue and Production in the Swiss Alps, *JWRPM*, 144(8), 2018
- Anghileri et al. , A comparative assessment of the impact of climate change and energy policies on Alpine hydropower, *WRR* (in press)
- + 2 MSc theses and several presentation at International Conferences

The Verzasca dam



Objectives:

- Assess the room for improving the operation using hydrometeorological forecasts
- Contrasting forecast value (HP revenue improvement) and accuracy (forecast performance)
- Assessing the impact of bias correction on forecast value and accuracy

Features:

- Single-reservoir hydropower system
- Production plants
- Snow and rain fed

Products:

- 2 MSc Theses
- Presentations at international conferences

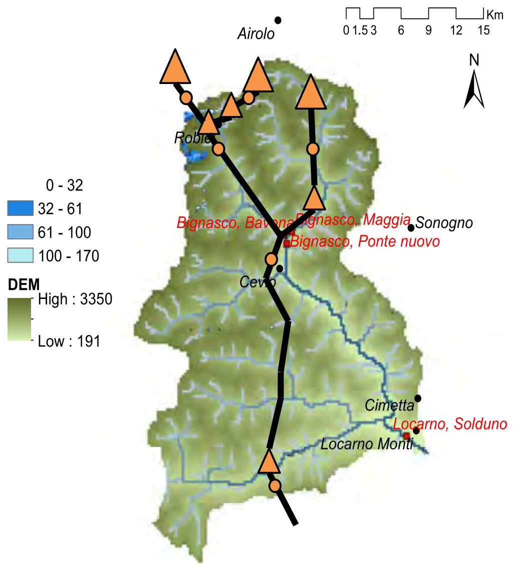
Outcomes:

- Extended hydrological forecasts generated by using ECMWF-CY40r1 and the hydrological model PREVAH
- Model Predictive Control based design of the dam operation
- Bias-correction improves the forecast quality but not much its value

see poster WP2.4-01

The Maggia system

see poster WP2.4-02



Features:

- Multi-reservoir hydropower system
- Production and pumping plants
- Extensive diversion network
- One of the few remaining natural alluvial braided floodplains in Switzerland

Objectives:

- Assess flexibility of complex HP plants (including pumping) to climate and price variability
- Multiobjective optimization of HP operation including the environment
- Trade off analysis between HP production, revenue and a set of ecosystem indicators

Outcomes:

- Model of the whole system calibrated and validated…
- … and coupled with a Multiobjective Evolutionary Direct Policy Search optimization framework
- First optimization results with HP production vs revenue

Next step:

- Inclusion of environment as additional (robust) optimization objective

WP2: Key contributions 2017-2020

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Task 2.1

Morpho-climatic controls on future HP production

- Climate change impact (M. Stähli)
- Ice thickness determination (M. Grab)
- Subglacial sediment transport (I. Delaney)
- HP potential (world / CH) (V. Round, D. Farinotti / R. Boes)

Task 2.2

HP infrastructure adaptation to future requirements

- Periglacial HPP infrastructure (P. Manso)
- Reservoir sedimentation (D. Ehrbar)
- Surge tank adaptations (N. Adam)
- Turbidity current venting (S. Chamoun)
- Bottom outlet hydraulics (B. Hohermuth)

Task 2.3

Environmental impacts of future HP operating conditions

- Mitigation of impacts by HP operation (S. Stähli)
- Downstream impacts of SBT operation (A. Siviglia)
- Ecological effects of SHPP (C. Weber)

Task 2.4

Integrated simulation of HP systems operation

- Multiobjective optimal operation of Alpine HP systems (P. Burlando)
- Simulation of climate variables for present & future climates (N. Peleg)

Thank you for your attention!

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High spatio-temporal resolution climate scenarios for snowmelt modelling in small alpine catchments

Michael Schirmer, Nadav Peleg

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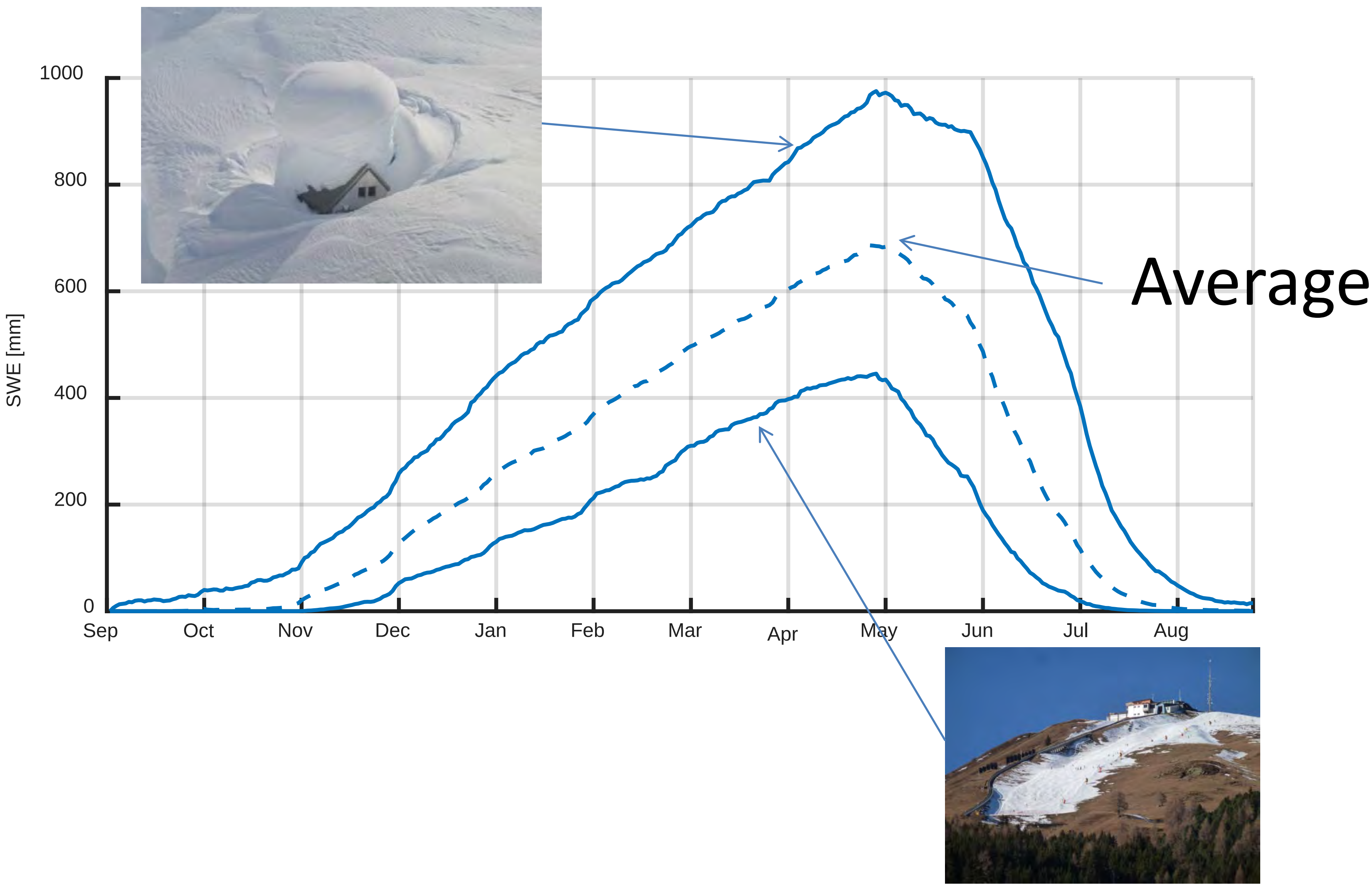
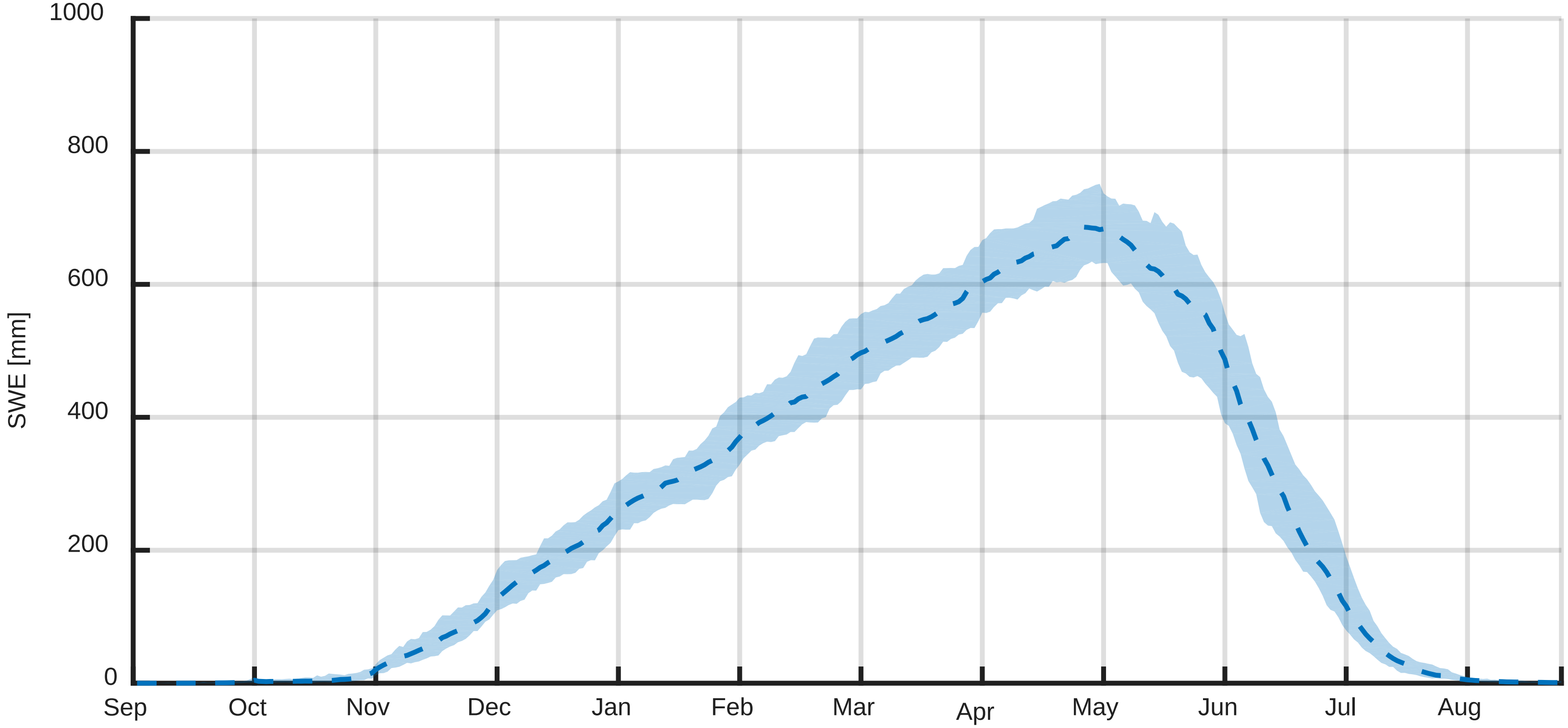
Snow or no snow?

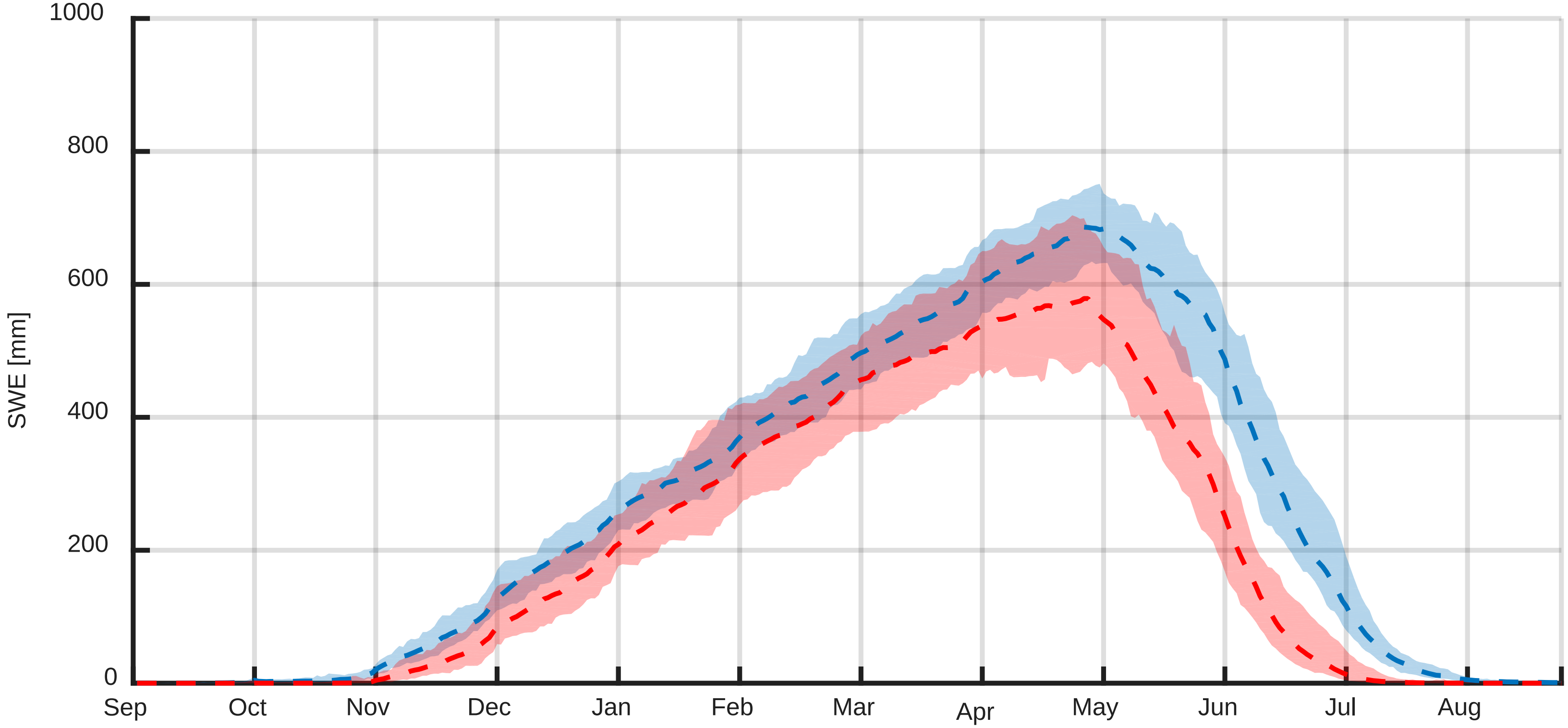
Natural variability



How coincidental is the 30-year average?



How certain is a future climate different from the current climate?



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High spatio-temporal resolution climate scenarios for snowmelt modelling in small alpine catchments

Michael Schirmer, Nadav Peleg

Motivation

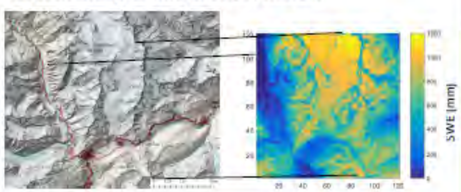
The aim of this project is to support economic risk assessments of long-term investments by small hydropower plant (SHP) operations due to a changing climate. We estimate the impact of climate change on snow water equivalent (SWE) and snowmelt using an innovative combination of novel components: a stochastic 2-dimensional weather generator, and a high-resolution energy balance snow cover model. This allows to include relevant uncertainty sources at a local scale (e.g. natural climate variability).

Methods

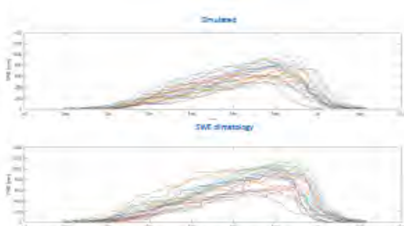
Future climate scenarios are generated based on newest global and regional climate models for the extreme RP8.5 scenario for the mid and the end of this century. Multiple realisations of future climate periods (30 years) are considered to assess the irreducible impact of natural climate variability. The likelihood of a single winter in a future climate (or of a climate period of 30 years) to be significantly different to our current climate can be assessed.

The model chain in high resolution (100 m x100 m) ensures that relevant processes are considered as for example terrain shading of shortwave radiation, realistic space-time structure of precipitation fields influenced by orographic enhancement, as well as redistribution of snow by wind based on terrain roughness.

Location and spatial model output example

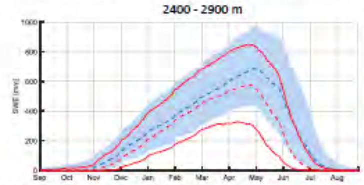


Model results against 'observations'



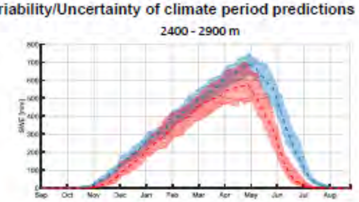
- Average SWE of 30 years in an elevation band of 2900 to 3400 m
- Dynamics well preserved
- Conservative spread between the years
- Approx. 10% less precipitation (under further investigation)

Natural variability of single years – mid of century



- Simulated SWE (5, 50,95 percentiles)
- Current climate (blue), 900 years
- Future climate (red), 5 climate models (RCP8.5) x 300 years
- The spread between dry and wet years is substantially larger than the effect of climate change.
- This spread evolves mainly from natural variability.
- A relevant change between current and future climate can be observed during melt season, while the amount of SWE is not changing relevantly.
- Changes are more evident in lower elevation bands, however, in the shown band most of SWE is stored.

Variability/Uncertainty of climate period predictions



- Same as above, however, the spread of median values of 30-year blocks are analyzed (5 and 95 percentiles) , i.e.
- "How uncertain are our predictions of a future climate including natural variability and climate model uncertainty?"
- Overlapping areas can be interpreted as a likelihood of no change in SWE between the current und future climate period.
- Mid of this century there is a substantial likelihood of having as much snow as today during peak winter, although considering the extreme climate scenario RCP8.5. A substantial change in average melt out is very likely.
- Both natural climate variability and climate model uncertainty contribute to this range.

Conclusion and Outlook

- Natural climate variability in a constant climate is responsible for both single years and climate periods of 30 years to be different from each other (e.g. dryer or wetter).
- Because of natural climate variability it is quite uncertain to state that a substantially warmer climate (RCP8.5, mid if this century) will lead to less SWE in this elevation range (2400 - 2900 m).
- **For the end of this century RCP8.5 scenarios show a significant change in the amount of SWE for all elevation bands.**
- We want to answer, for which climate scenario and for which elevation ranges the impact of climate change is clearly visible, and how this uncertainty in SWE can be translated to runoff.

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Multiple-purpose use of reservoirs in high alpine areas under climate change: a national view

Manuela Brunner, Astrid Björnsen Gurung, Massimiliano Zappa, Manfred Stähli
(Swiss Federal Research Institute WSL)

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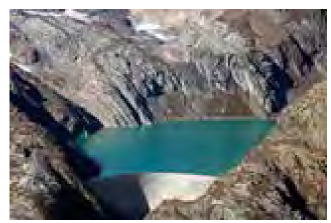
Comparison of water availability, water reservoirs and water demand

Water reservoirs

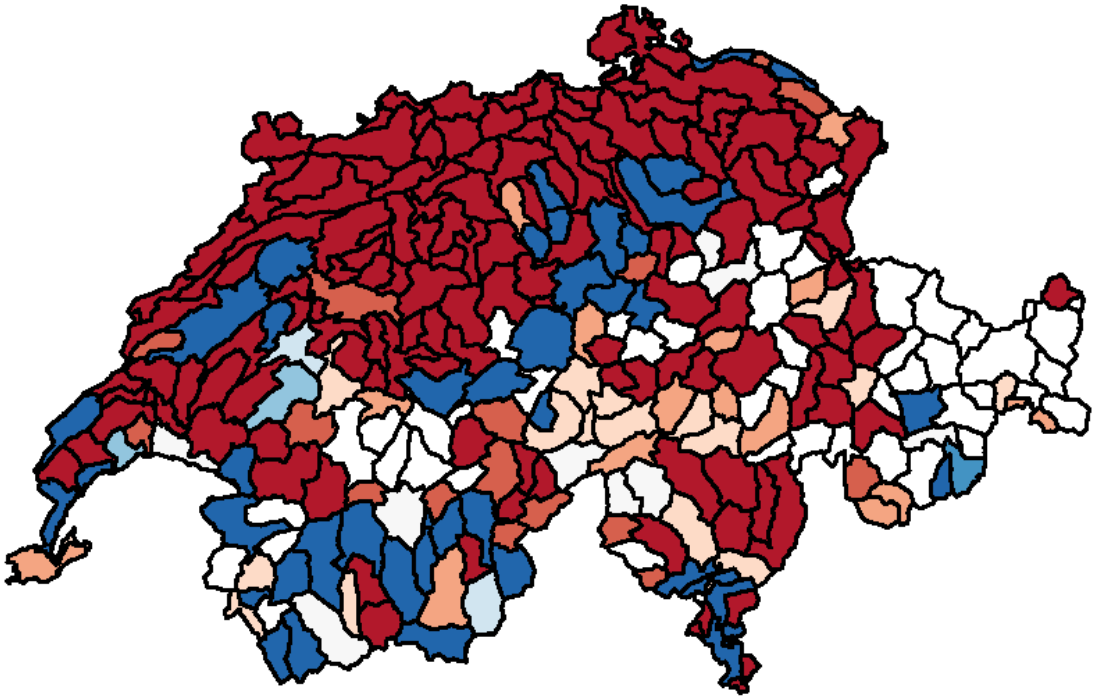



Water demand






Potential of reservoirs for alleviating water shortages



Year 2003 (heat wave and drought in Switzerland)

storage < seasonal shortage

storage > seasonal shortage

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Sediment management in swiss reservoirs : experiences and challenges

Samuel Vorlet
(LCH, EPFL)

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Schweizerisches Talsperrenkomitee
Comité suisse des barrages
Comitato svizzero delle dighe
Swiss Committee on Dams

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Sediment management in swiss reservoirs: experiences and challenges

Samuel Vorlet, Pedro Manso*

Platform of Hydraulic Construction (PL-LCH), École Polytechnique Fédérale de Lausanne (EPFL), Switzerland
**Corresponding author: samuel.vorlet@epfl.ch*

Figure 1: *Sediment deposition; Giétroz du Fond, 2018*

Figure 2: *Reservoir sedimentation, Raeterichsboden, KWO*

Figure 3*: Reservoirs of the survey*

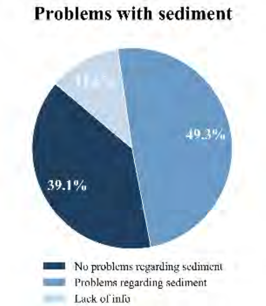

Figure 4*: Preliminary results*

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Storage hydropower potential from dam heightening

David Felix, Andrin Leimgruber, Robert Boes

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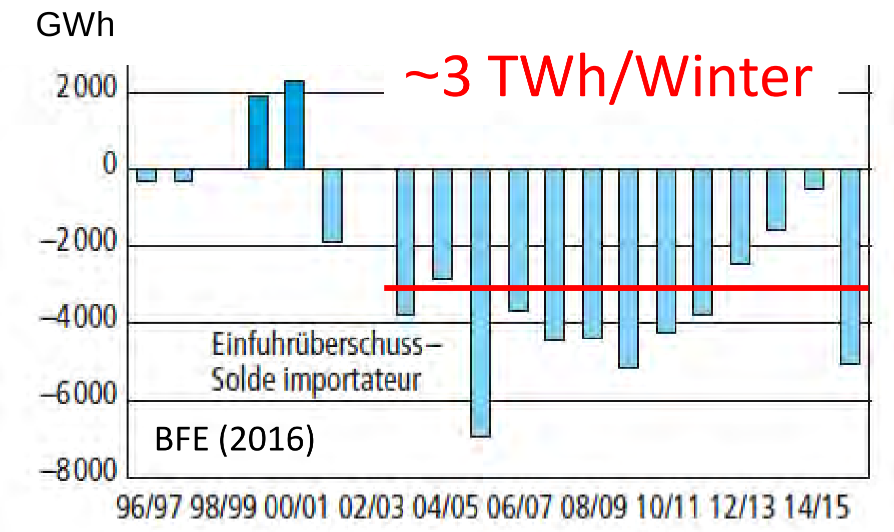
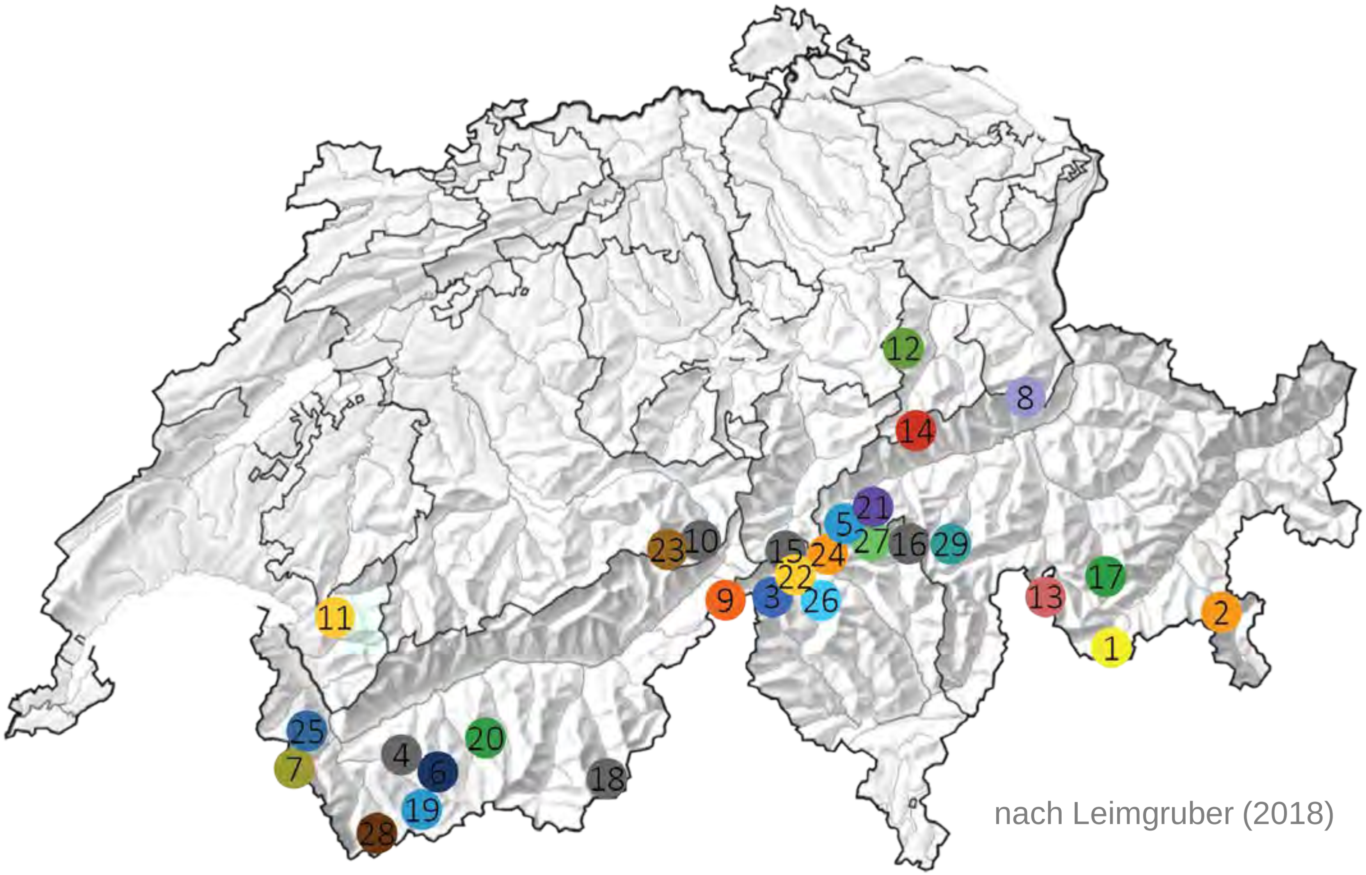
Potential von Talsperrenerhöhungen



Potentialstudie an 38 grösseren Stauseen in der Schweiz

→ mit Erhöhungen von 16 bis 29 Talsperren
um 5% bis 20% der bestehenden Sperrenhöhen
Umlagerung von **1.7** bis **2.8 TWh** vom Sommer in den Winter

Potential von Talsperrenerhöhungen



1 Lago d'Albigna
2 Lago Bianco
3 Lago di Cavagnoli
4 Lac de Cleuson
5 Lai da Curnera
6 Lac des Dix (Gde. D.)
7 Lac d'Emosson
8 Gigerwaldsee
9 Griessee
10 Grimselsee
11 Lac d'Hongrin
12 Klöntalersee
13 Lago di Lei
14 Limmernsee
15 Lago di Lucendro
16 Lago di Luzzone
17 Lai da Marmorera
18 Mattmarksee
19 Lac de Mauvoisin
20 Lac de Moiry
21 Lai da Nalps
22 Lago del Naret
23 Oberaarsee
24 Lago Ritom
25 Lac de Salanfe
26 Lago del Sambuco
27 Lai da Santa Maria
28 Lac des Toules
29 Zervreilasee

SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

Hydropower and water temperature: modelling the effects of management scenarios on river thermal heterogeneity

Davide Vanzo, Martin Schmid, Christine Weber and Michael Döring

In cooperation with the CTI

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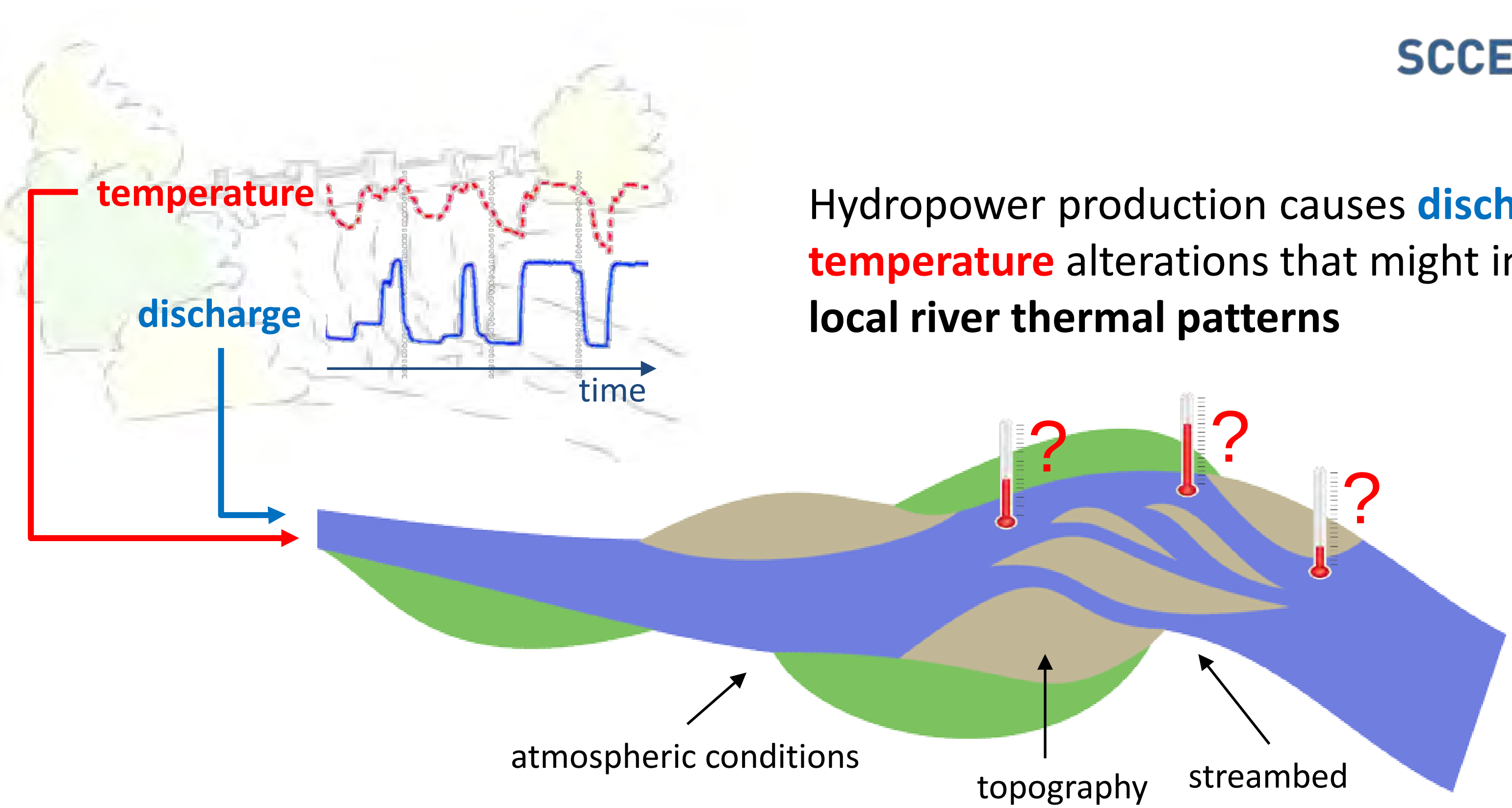

Hydropower production causes **discharge** and **temperature** alterations that might influence **local river thermal patterns**

→ How is **river thermal heterogeneity** affected by hydropower production?

→ How can we **model** and **quantify** such thermal alterations?

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