

Operation of a complex Alpine hydropower scheme across four decades:

Inferring behavior patterns through data science

FLEXSTOR

Solutions for flexible operation of storage hydropower plants in changing environment and market conditions

José Pedro Matos

Stucky SA (formerly EPFL, LCH)



In cooperation with the CTI



Energy

Swiss Competence Centers for Energy Research



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

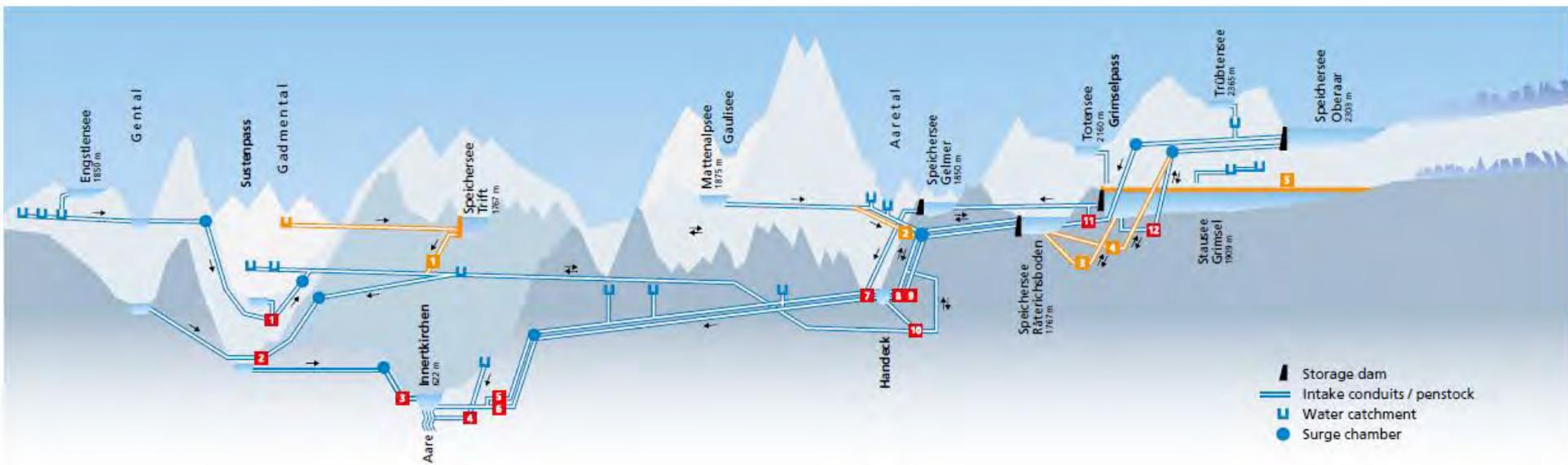
Commission for Technology and Innovation CTI



The hydropower scheme



Further information at <http://www.grimselestrom.ch>





Data and goals

Core of the available data

- Average daily discharges and water levels within the system from 1980 to 2015.
- Average hourly discharges and water levels in the system for 2005.

- 35 measurement locations.

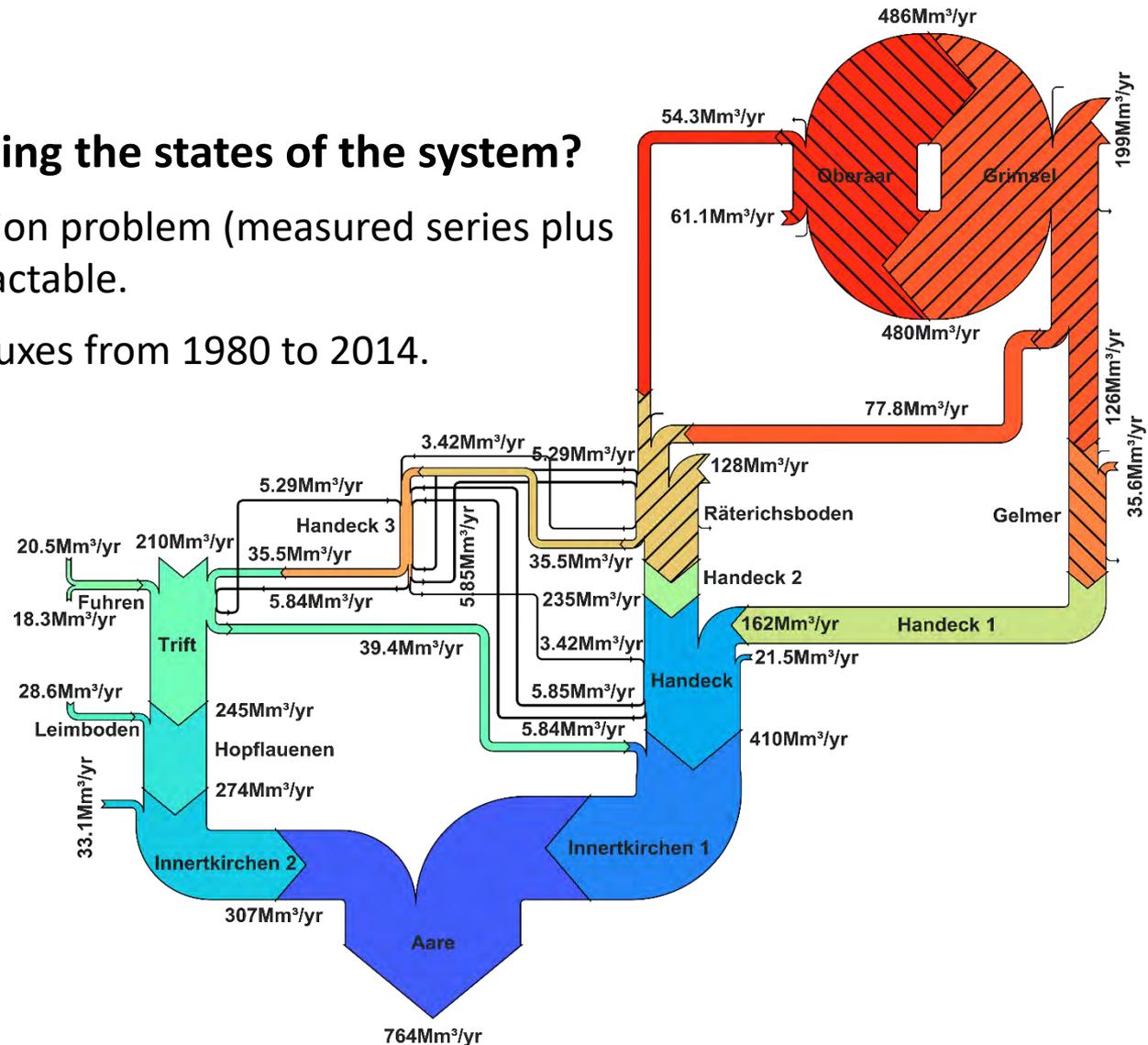
Understanding what are the forces driving the system from the data

- Hydrology (volume and timeliness)
- Energy markets (evolution of energy demand and selling prices)
- Physical limitations of the hydropower scheme

Visualization

How to start characterizing the states of the system?

- Translating a 36 dimension problem (measured series plus time) into something tractable.
- Sankey plot – average fluxes from 1980 to 2014.

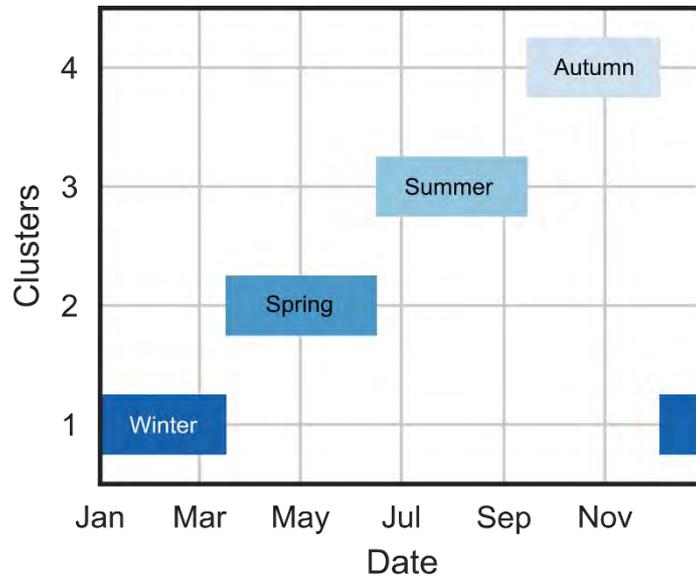




Characterization

Unraveling systems states through clustering algorithms

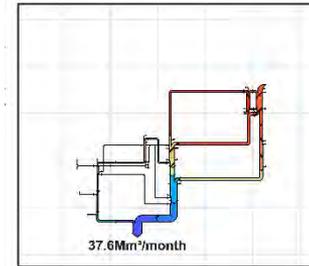
- Yearly modes of operation.



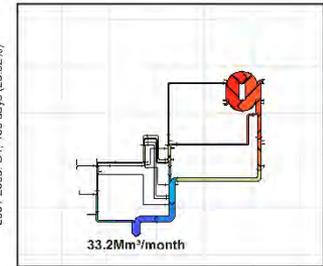
1980-1984

2001-2005

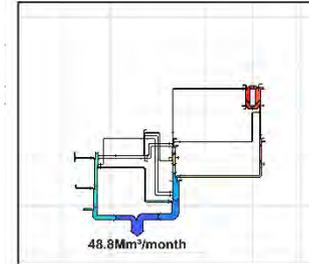
Winter



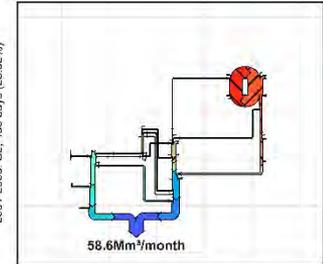
2001-2005. C1, 466 days (25.52%)



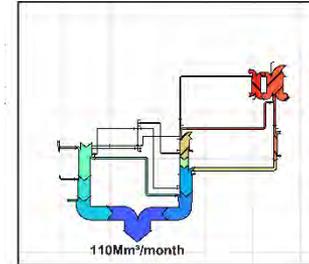
Spring



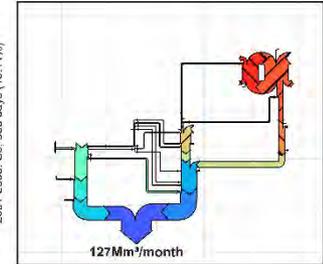
2001-2005. C2, 435 days (23.82%)



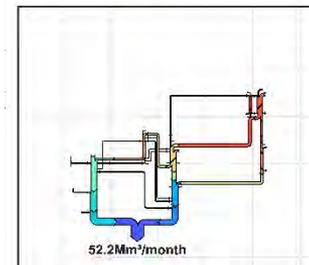
Summer



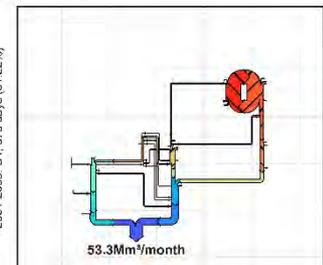
2001-2005. C3, 356 days (19.44%)



Autumn



2001-2005. C4, 570 days (31.22%)





Characterization

Daily vs sub-daily operations

Hourly data from 2005

1980-1984

2001-2005

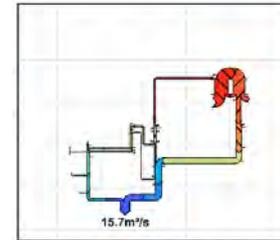
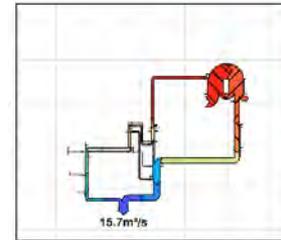
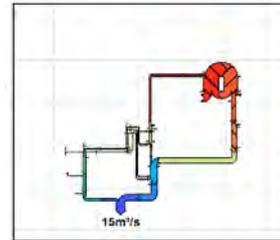
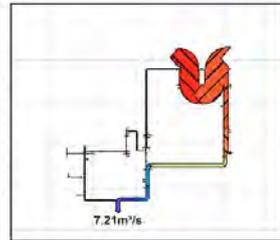
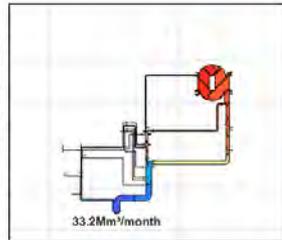
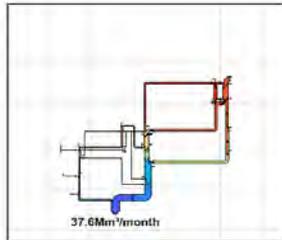
0-6 h

6-12 h

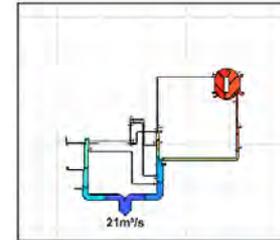
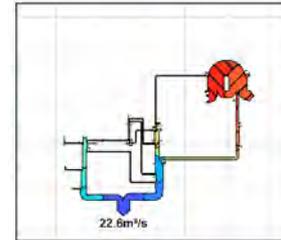
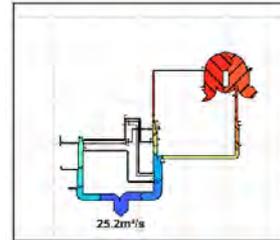
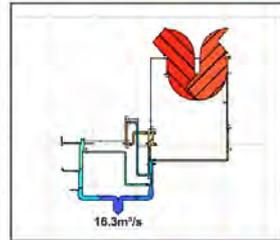
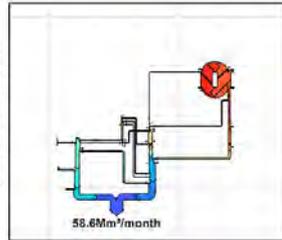
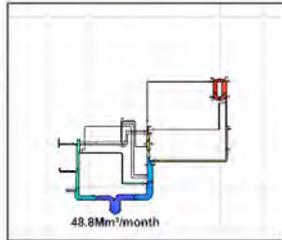
12-18 h

18-24 h

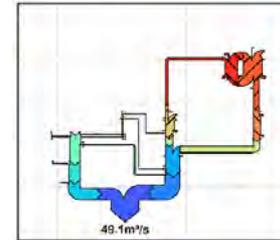
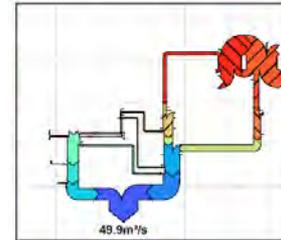
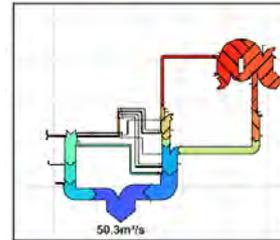
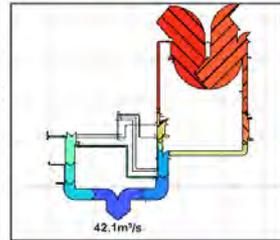
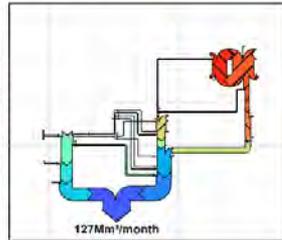
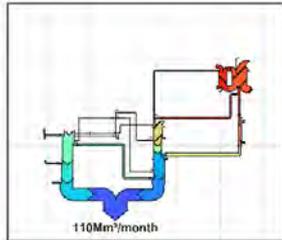
Winter



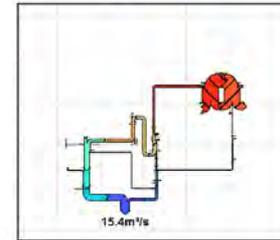
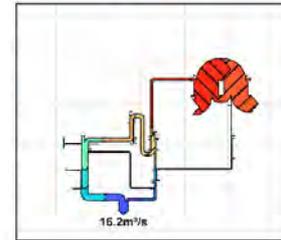
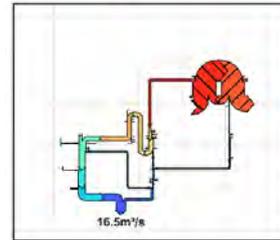
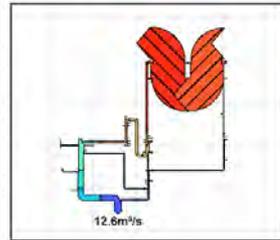
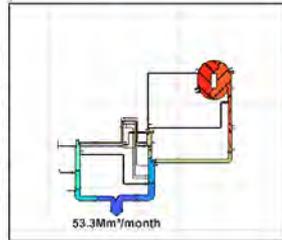
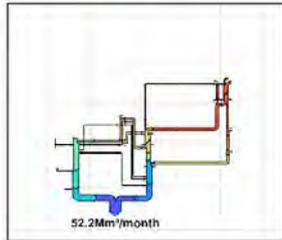
Spring



Summer



Autumn

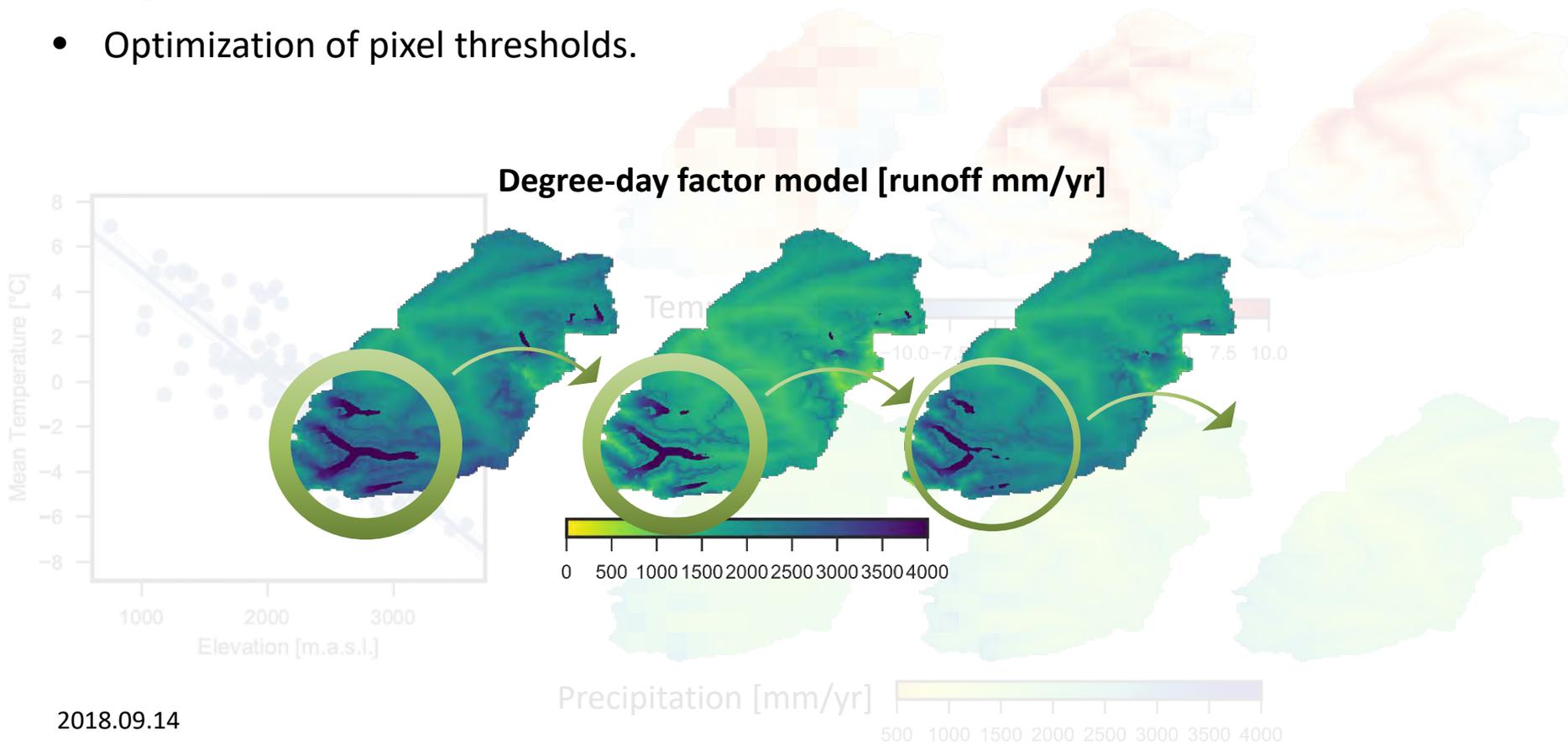




Hydrology

Representing how hydrology may have affected the system since 1980

- Downscaling model based on gridded data from MeteoSwiss.
- High resolution DEM.
- Optimization of pixel thresholds.

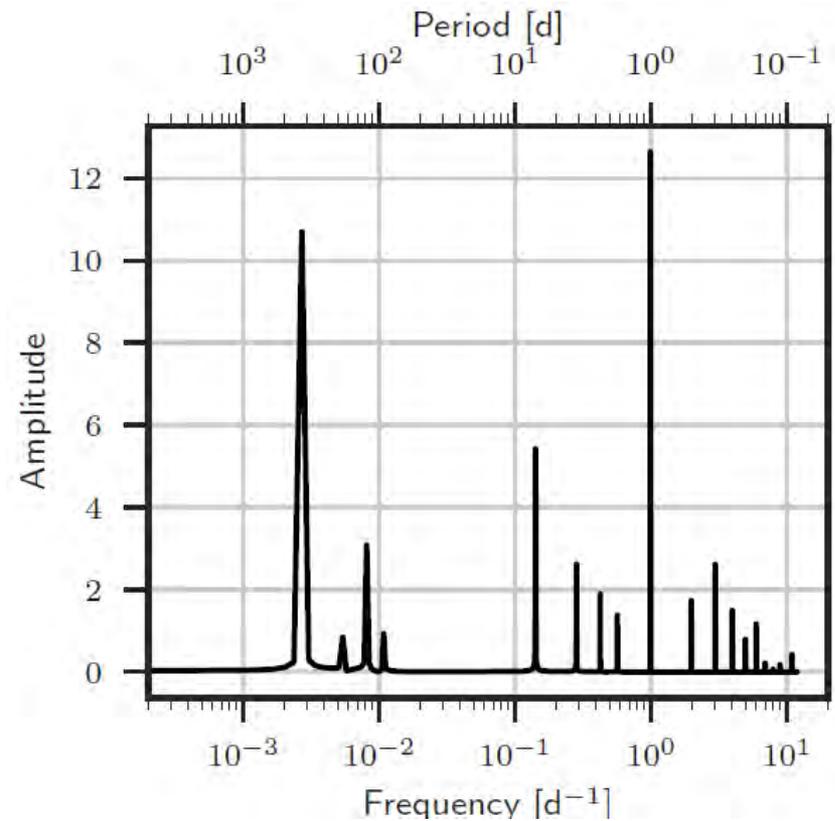
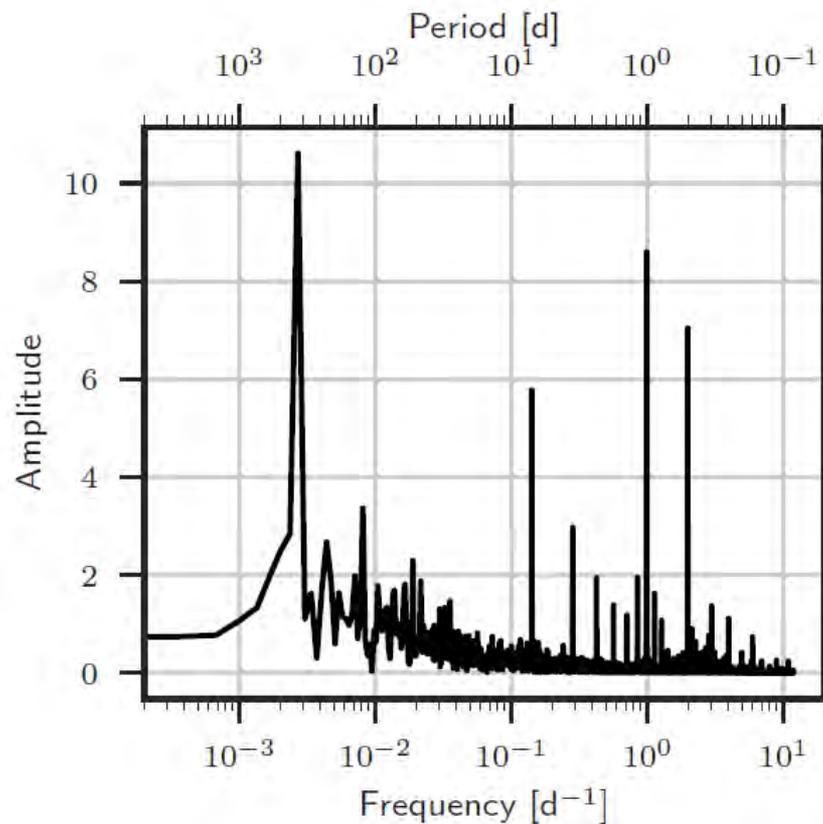




Energy market

Data available from 2007 onwards

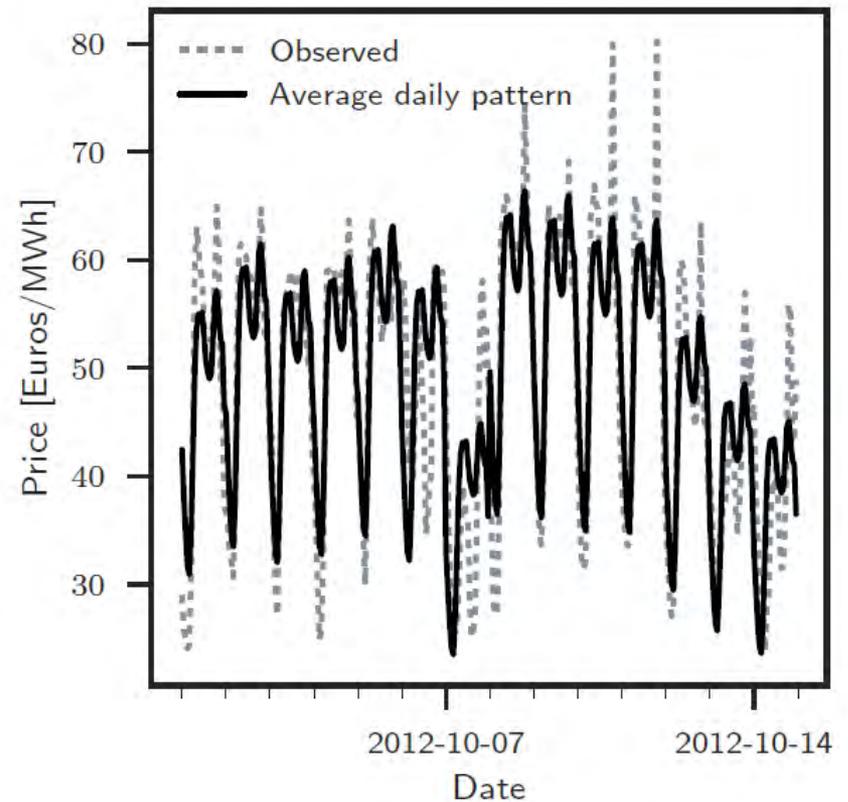
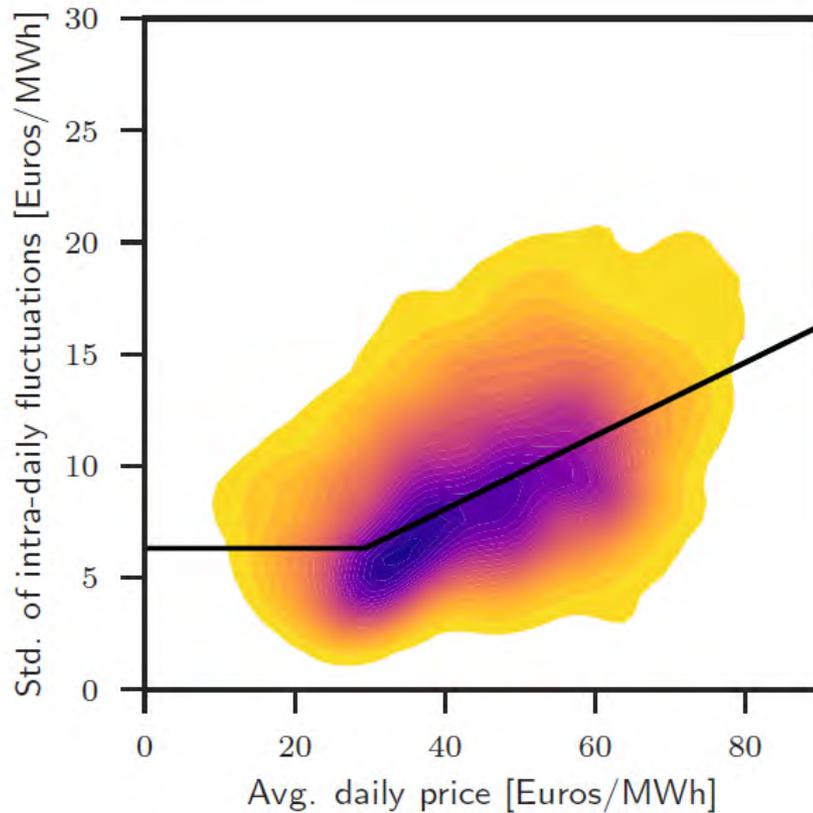
- How to characterize past operations?



Energy market

Data available from 2007 onwards

- How to characterize intra-daily operations?



Prediction

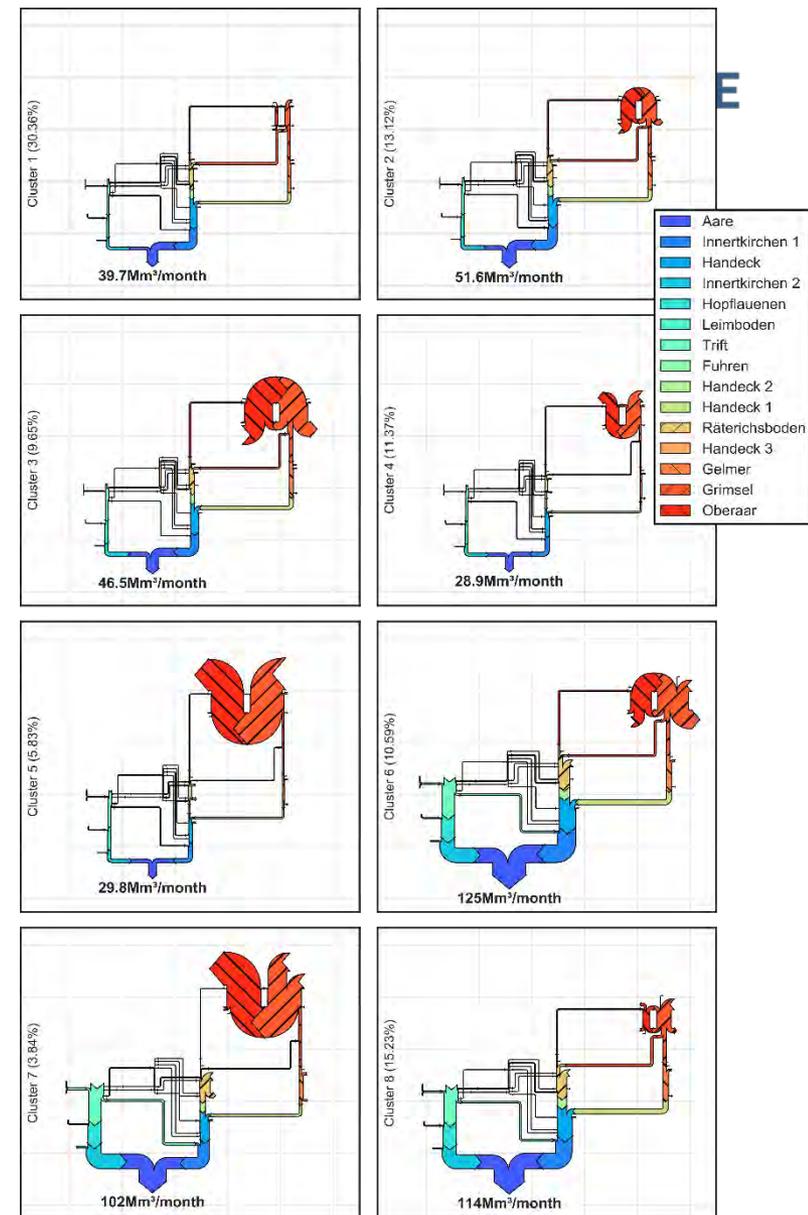
Identify which are the fluxes in the system from relevant variables:

- Long-term trend (date).
- Annual cycle.
- Weekly cycle.
- Water levels in the main reservoirs.
- Hydrology.

Classification of the operations into clusters.

Prediction made with machine learning techniques:

- Logistic regression.
- Support-vector machines.
- Random forests.

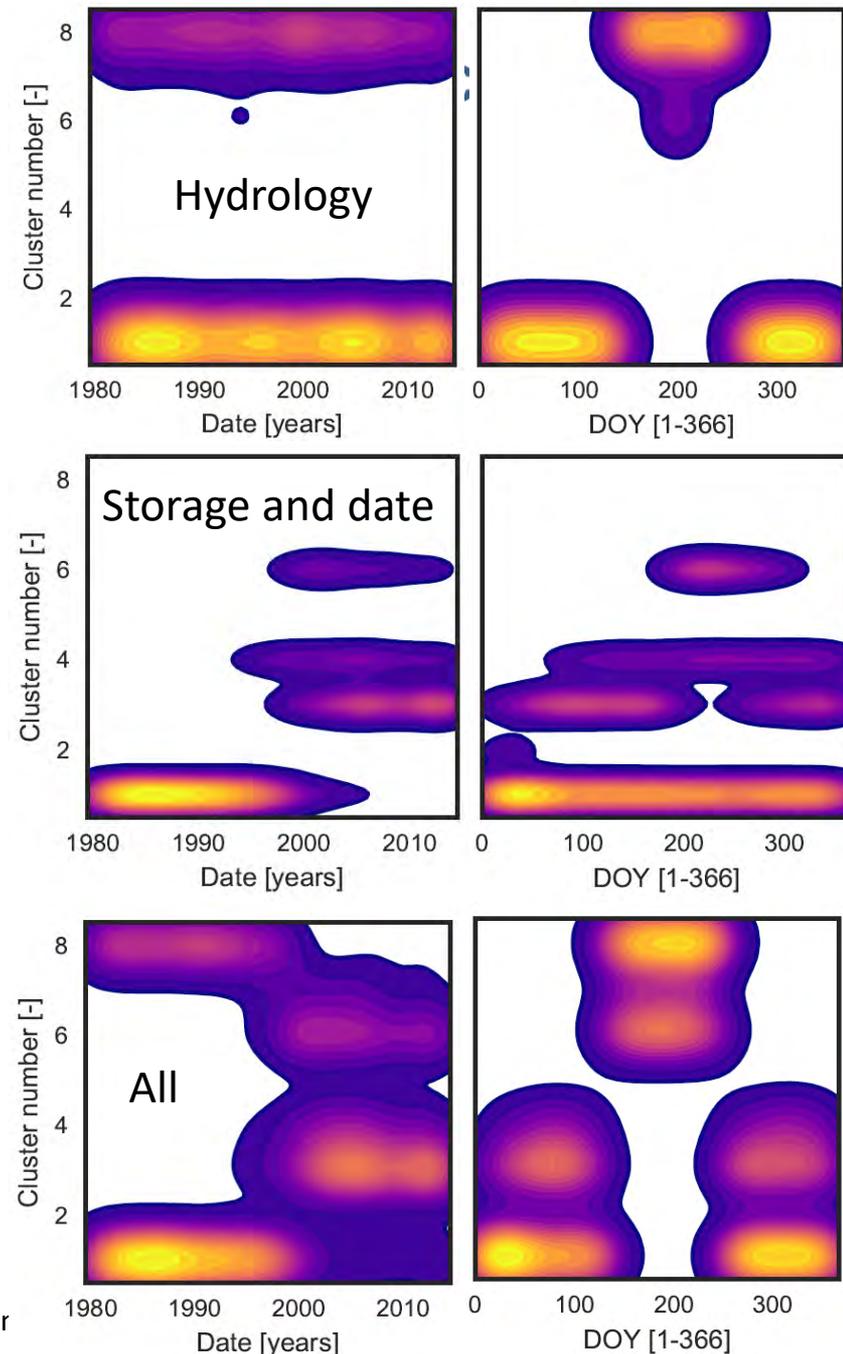
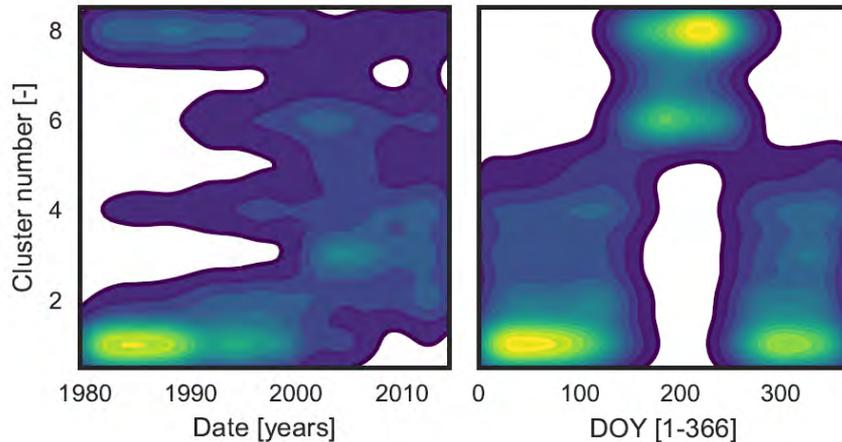


Prediction

Identify which are the fluxes in the system from relevant variables:

- The correct cluster can be identified 55% of the times.
- Hydrology has the same predictive power as storage and date.

Observed clusters

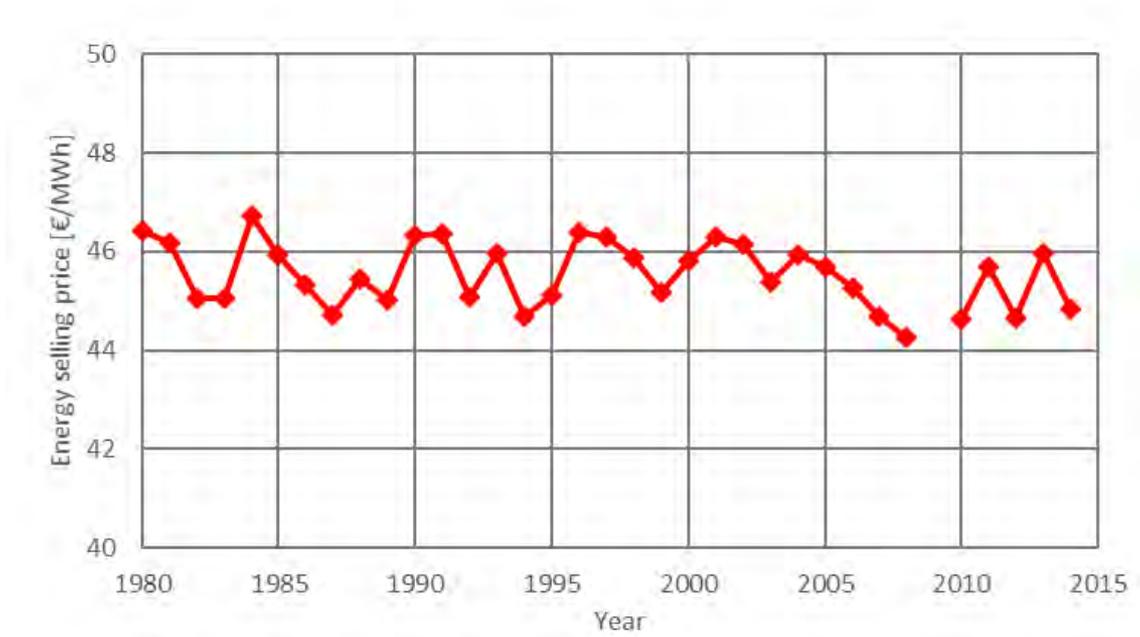




Influence of the market

A synthetic price series was applied to all the daily data (1980-2014).

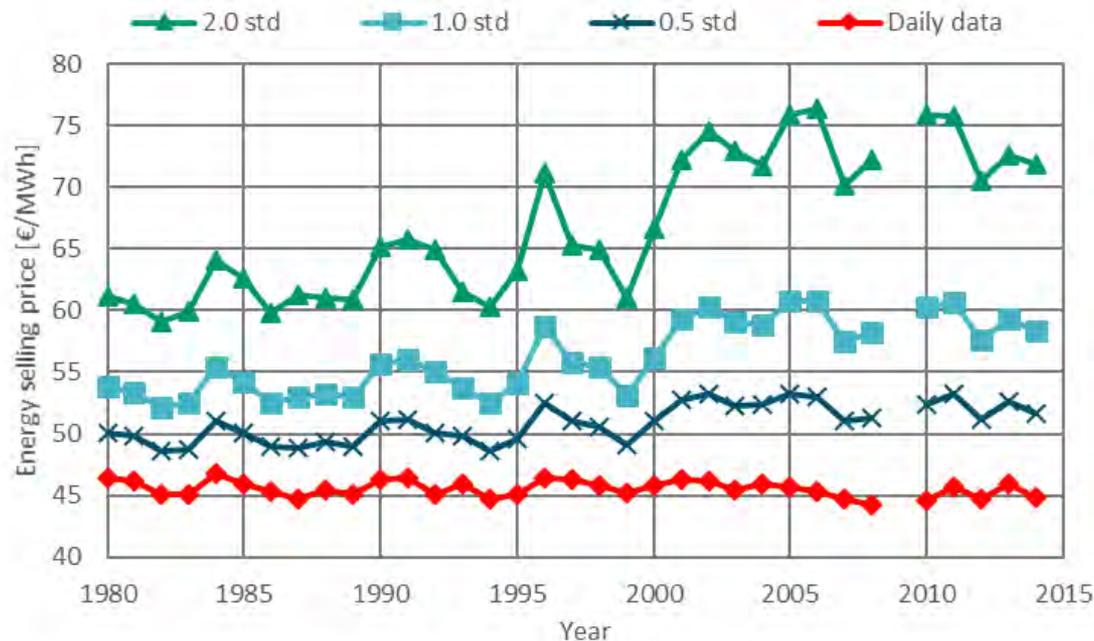
- Two metrics analyzed the changes in the system.
 - Effectiveness: how much of the system potential is being used.
 - Efficiency: how “well” are the water resources being used.



Influence of the market

Why did the system operation not improve over time?

- The operation is not daily!
- Sub-daily prices were modelled, and daily fluctuations used as an explanatory variable.



Thank you

**Operation of a complex Alpine hydropower scheme across four decades:
Inferring behavior patterns through data science**

In cooperation with the CTI



Energy

Swiss Competence Centers for Energy Research



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Commission for Technology and Innovation CTI