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Runoff seasonal forecast in alpine catchments: application on the SECLI-FIRM case study

M. Callegari[1], V. Cavedon[2], A. Crespi[1], F. Greifeneder[1], M. Petitta[1,3], M. Zebisch[1], and C. Notarnicola[1]

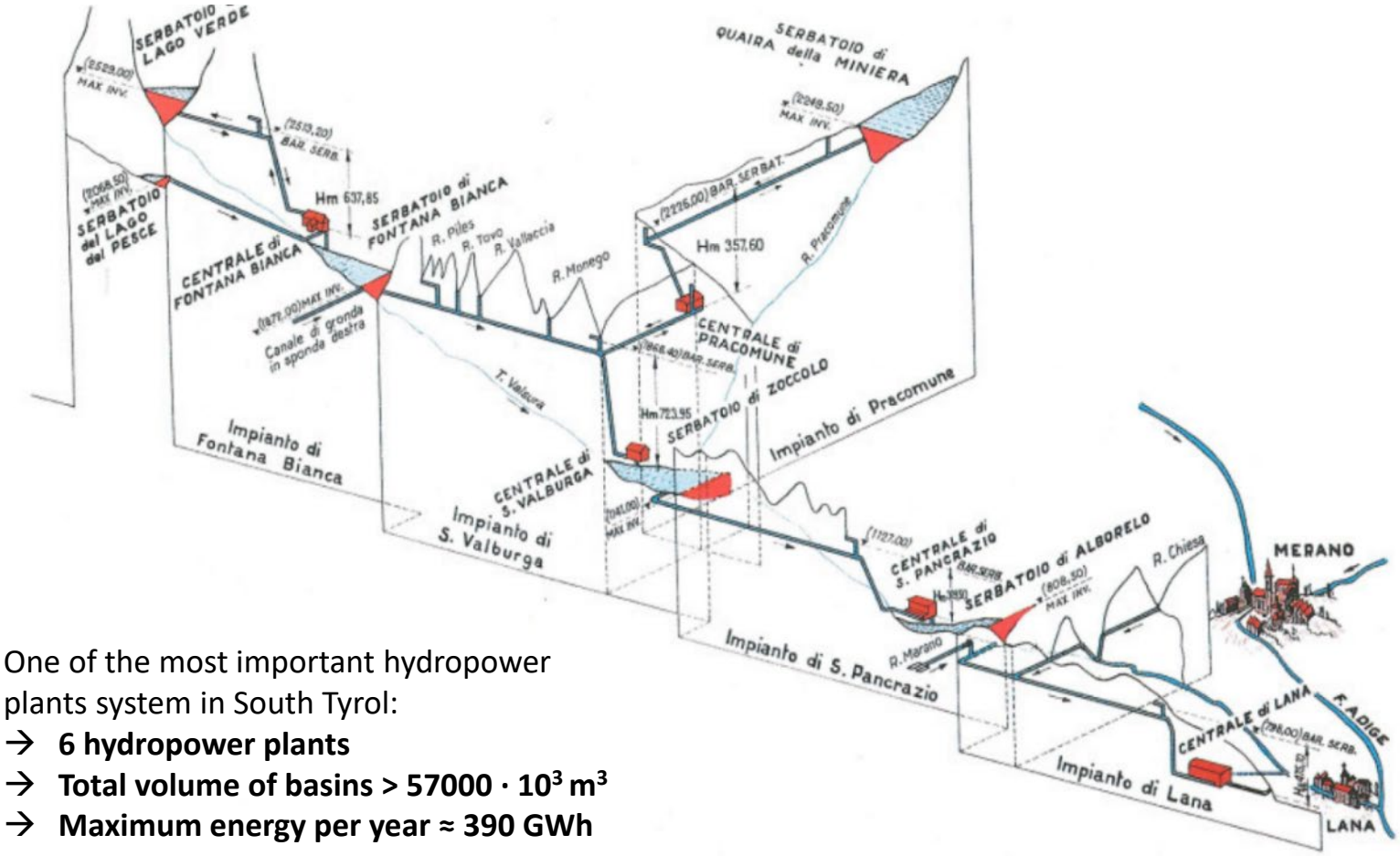
[1] Eurac research - Institute for Earth Observation, [2] Alperia, [3] ENEA

Motivations

Runoff seasonal forecast, from one to several months ahead, is a relevant application for **hydropower plant management**. A reliable estimation of the seasonal runoff can be used to:

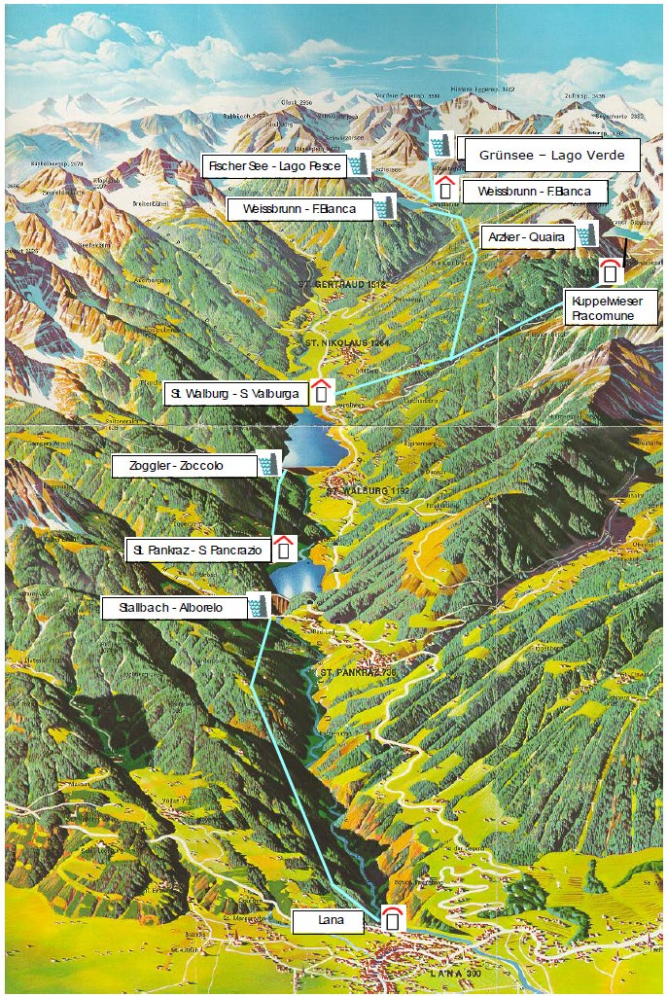
- Improve the management of the level of the basins to **optimize** the current and future **energy production**
- Predict the energy that will be produced by a specific hydropower plant system, enabling an **enhanced management on the energy market**
- Improve the management of the hydropower basins to **prevent the risk of floods** and to **reduce the impact of drought**

Hydropower plants in Ulten Valley

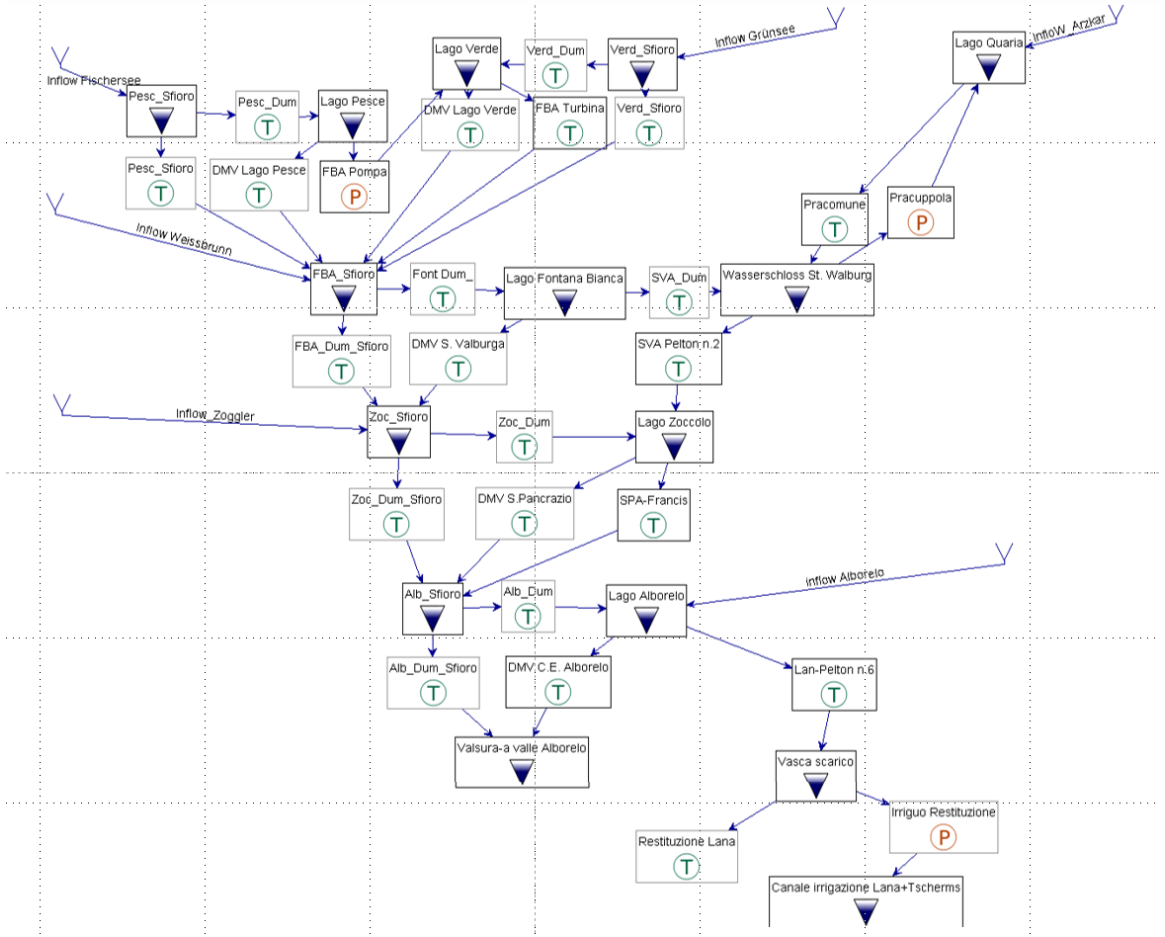


One of the most important hydropower plants system in South Tyrol:

- → **6 hydropower plants**
- → **Total volume of basins > 57000 · 10^3 m^3**
- → **Maximum energy per year ≈ 390 GWh**



The “Hydro-tool” model



INPUTS

- Predicted natural runoff in the basin
- Initial reservoir level
- Predicted energy price
- Obligations in plant management, e.g. min/max reservoir level, max water emptying speed, min environmental flow, etc.

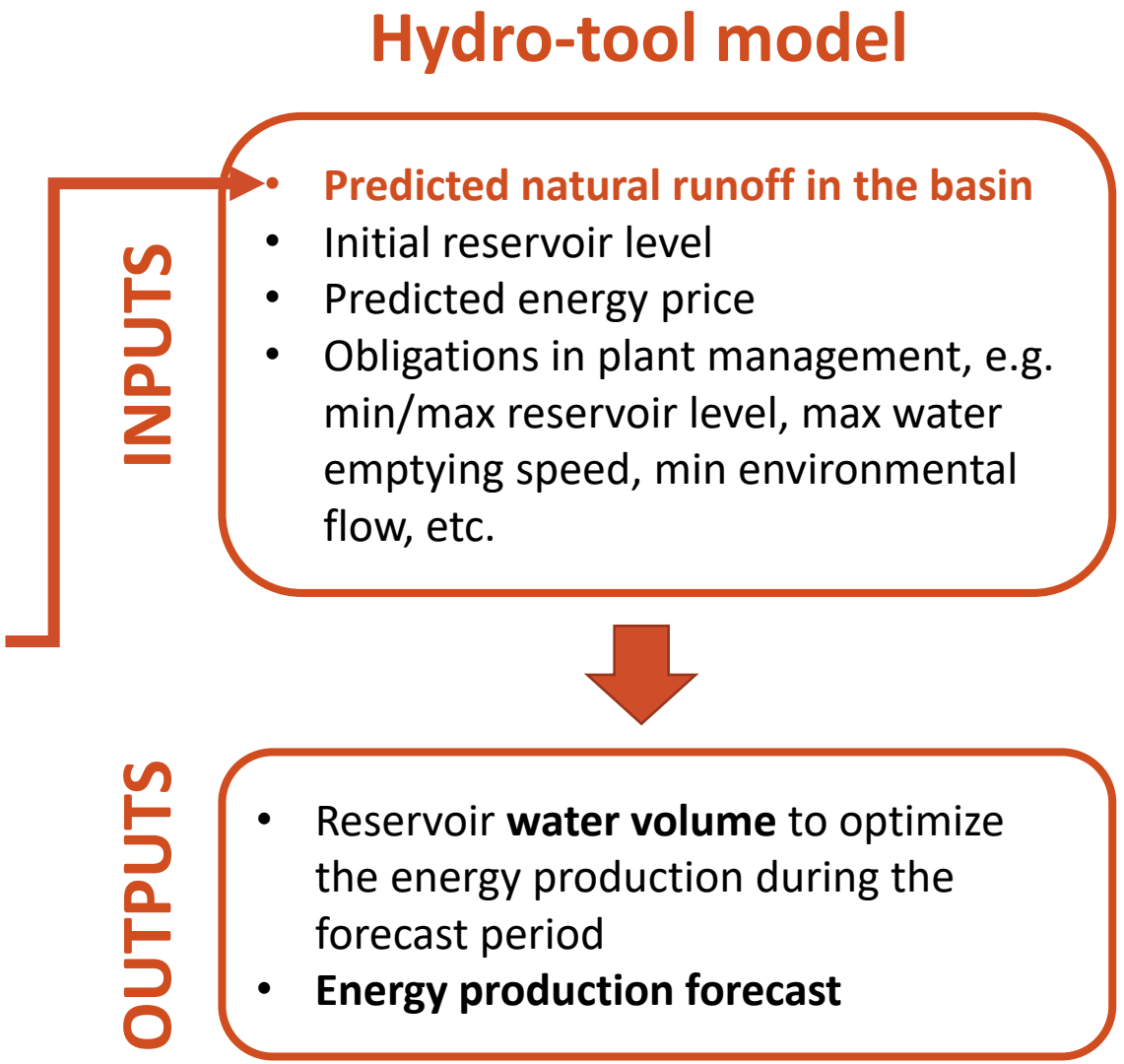
OUTPUTS

- Reservoir **water volume** to optimize the energy production during the forecast period
- **Energy production forecast**

Objective

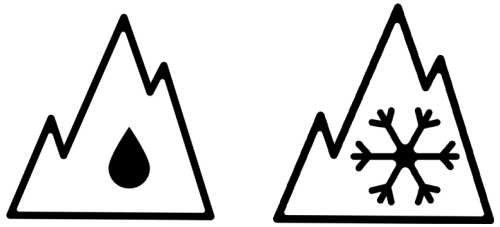
To develop a method for **runoff seasonal forecast**, **from one to several months ahead** that:

- Can produce reliable **inputs** for the **Hydro tool model**, to optimize the hydropower plant management in the Ulten Valley
- Makes use of **seasonal forecast** data
- Can be **easily applied in other areas**, i.e. minimum in-situ data availability is required



Monthly mean runoff forecast

Catchment state variables:
- Soil moisture
- Snow water equivalent



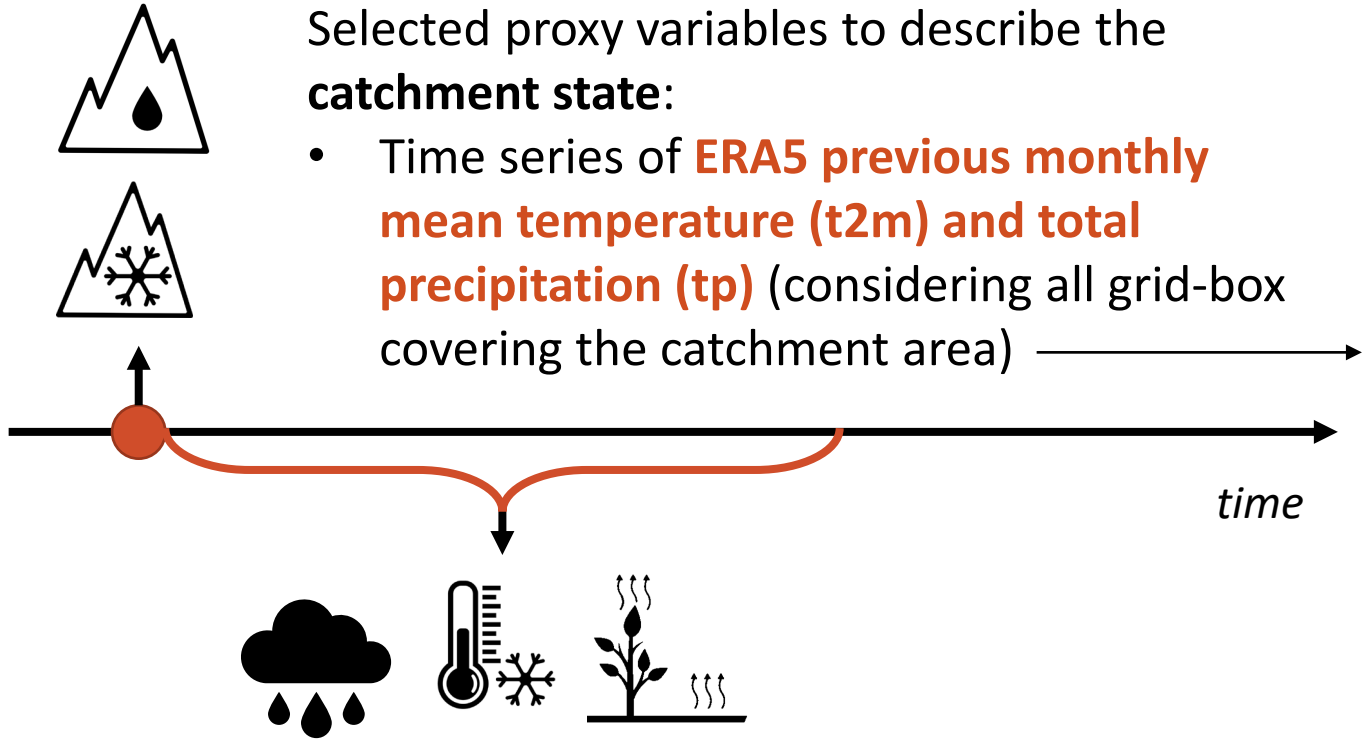
Contribution in the forecast period:
- Rainfall
- Snowmelt
- Evapotranspiration

Machine learning for runoff forecast

Machine learning models may represent a valuable solution with respect to hydrological model:

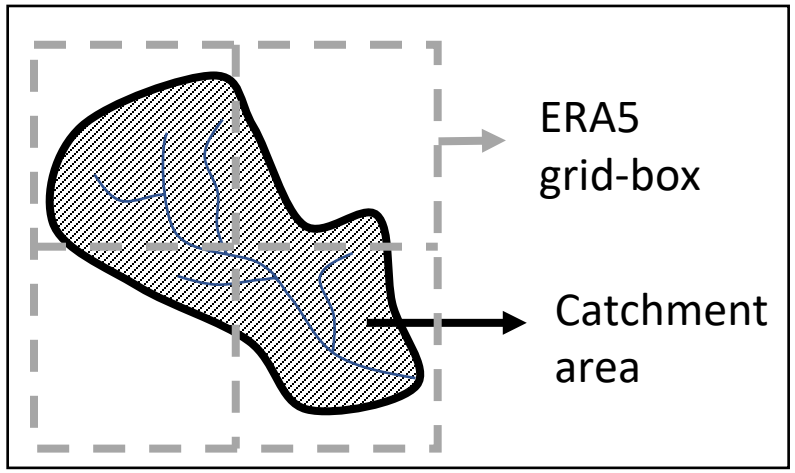
Some proxy variables which are representative of all the variables can be selected. No need to estimate exactly each variable (i.e. catchment state, contribution in the forecast period variables)

Selected proxy input variables



Selected proxy variables to describe the **catchment state**:

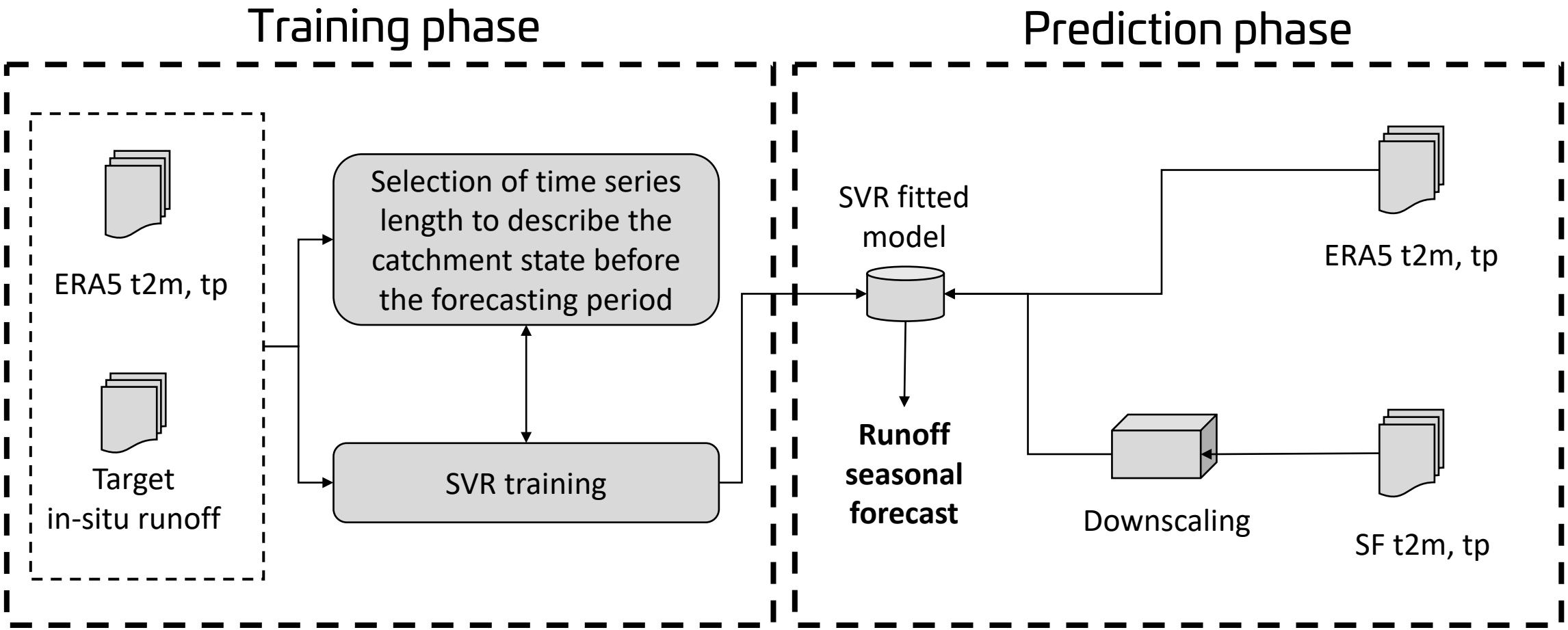
- Time series of **ERA5 previous monthly mean temperature (t2m) and total precipitation (tp)** (considering all grid-box covering the catchment area)



Selected proxy variables to describe the **contribution during the forecast period**:

- **Seasonal forecast (SF) of monthly mean temperature (t2m) and total precipitation (tp)** downscaled at the ERA5 resolution (considering all grid-box covering the catchment area)

Method workflow



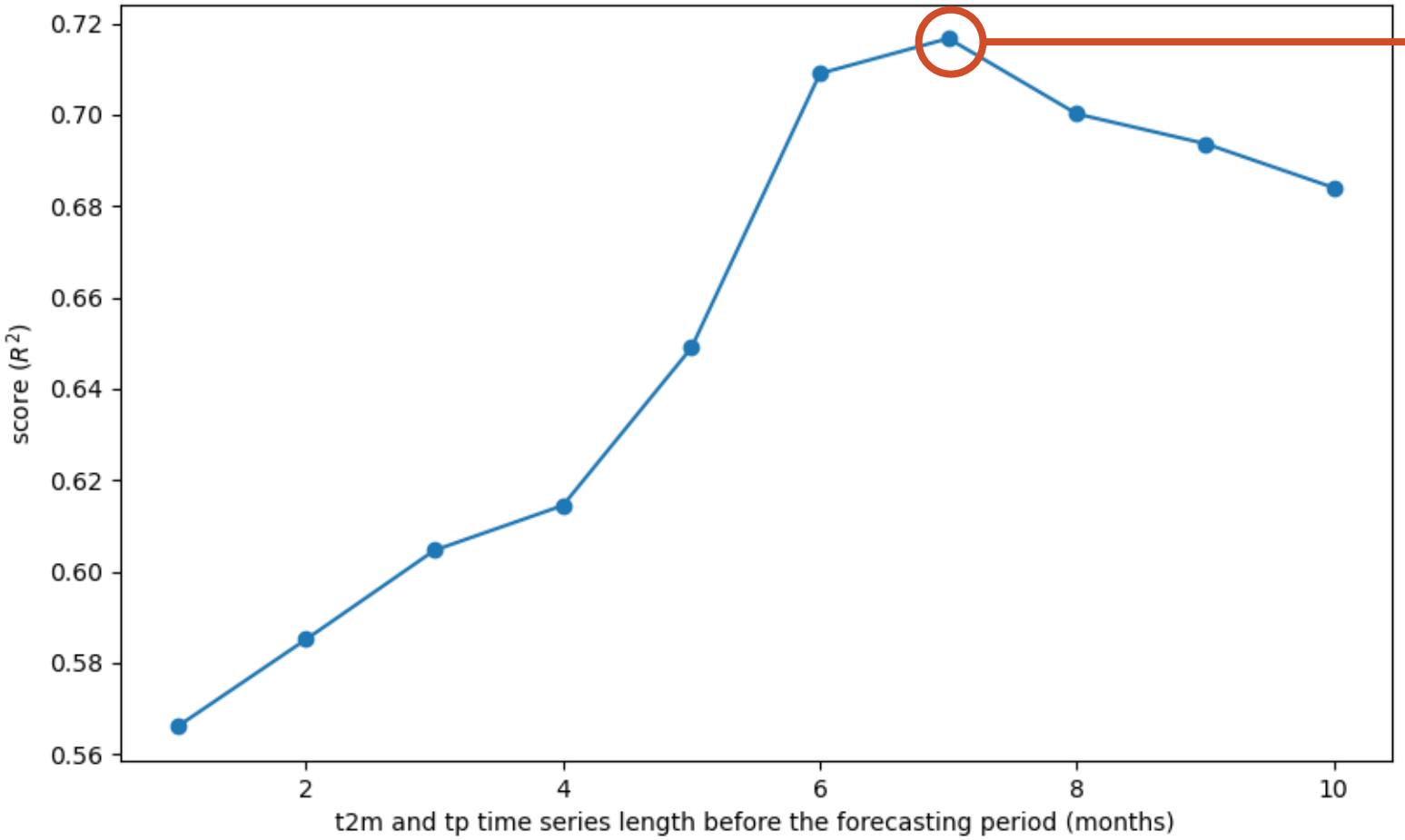
Method performances

Experiment goals:

- To evaluate the **forecast performance** of the proposed method with respect to a **benchmark method**, i.e. **runoff climatology**.
  → Iteratively train and run the forecast excluding one year to test the performance – **Leave one out cross validation (LOO-CV) strategy**

- To investigate whether there is a **limit of applicability** with respect to the **length of the runoff time series**
  → The forecast is repeated using **simulation of runoff time series of different length**

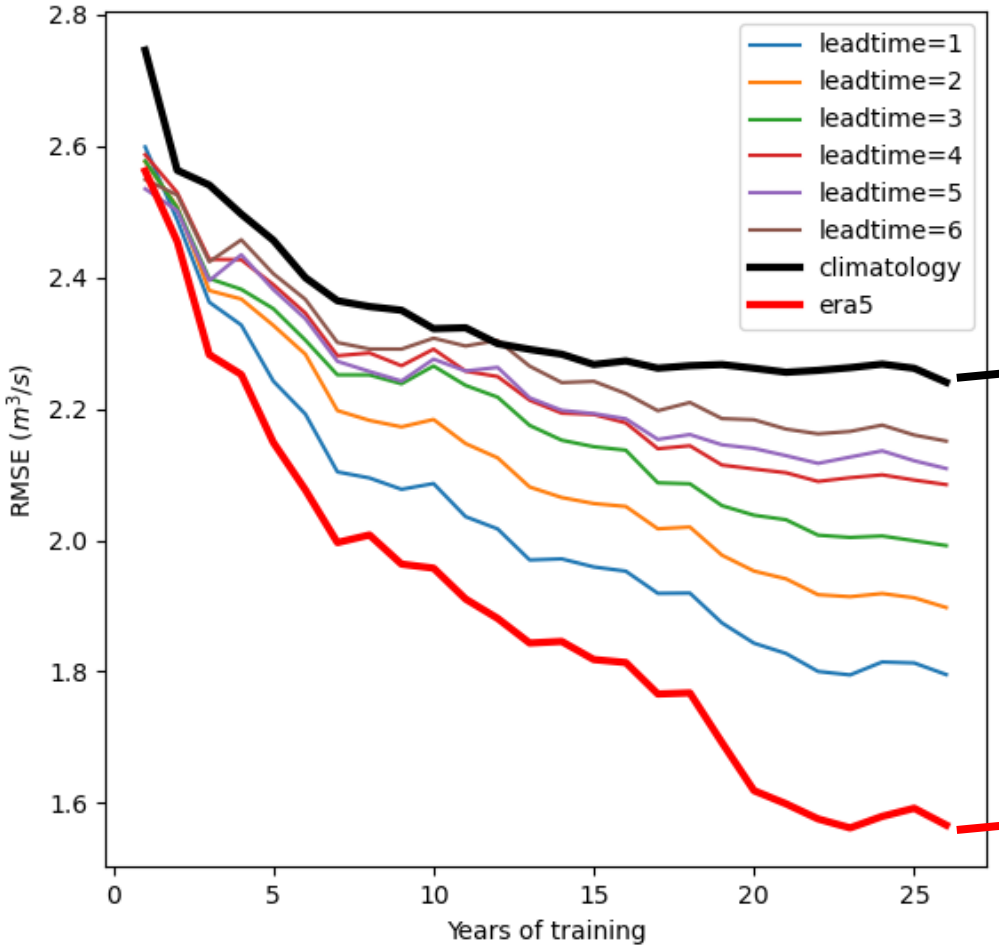
Time series length selection



Optimal time series lenght for temperature and precipitation to describe the catchment state before the forecasting period

= **7 months**

Results



Benchmark: Runoff climatology computed using the same years available for training the machine learning model

Perfect forecast: In this simulation the seasonal forecast of temperature and precipitation is substituted by the actual values of era5

Conclusions

- **Seasonal forecast downscaled on ERA5** allow to train the runoff prediction model on ERA5 inputs

- For the selected case study **the proposed method outperforms the climatology for monthly mean runoff forecast** for all the lead times (from 1 to 6 months)

- The **seasonal forecast of the runoff** obtained with the proposed method can be employed to **improve the management of the basins**. This may lead to an **optimization of energy production** and an **increase of the overall profit**.