Research Center energetic

Institute of Electricity Economics and Energy Innovation

Institute of Hydraulic Engineering and Water Resources Management

TU Graz

Hydropower Time Series Modelling for Climate-Resilient Energy System Optimization

19. Symposium Energieinnovation 2026

Lukas Kloiber

04.07.2025

Agenda

I **Motivation** and **Objective**

II High-Level **Overview**: Process

III **Preprocess Weather** Data

IV **Creating** Hydropower Plant **Database**

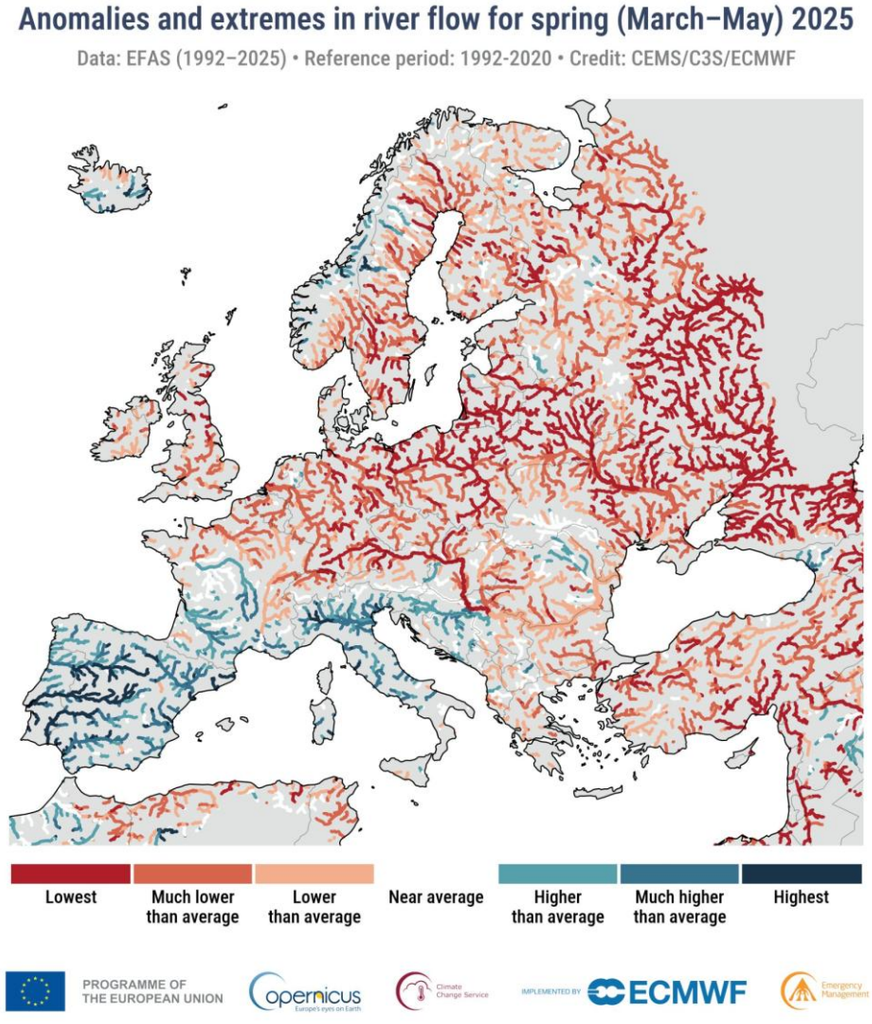
V **Hydrologic Modelling – GR4J**

VI HPP **Energy Generation** and Simulation **Results**

VII **Summary** and Possible Future **Perspectives**

Motivation and Objective - Climate Change and Hydropower

Increase of extreme weather phenomena



ENERGIE

Könnten Dürren zunehmend zur Gefahr für die Wasserkraft werden?

Klimawandel lässt Flüsse und Speicherseen teils immer mehr austrocknen. Dadurch sinkt auch die Stromproduktion der Wasserkraft. Welche Folgen das hat –

rreich

STROM | WASSERKRAFT

1 Minuten Lesezeit

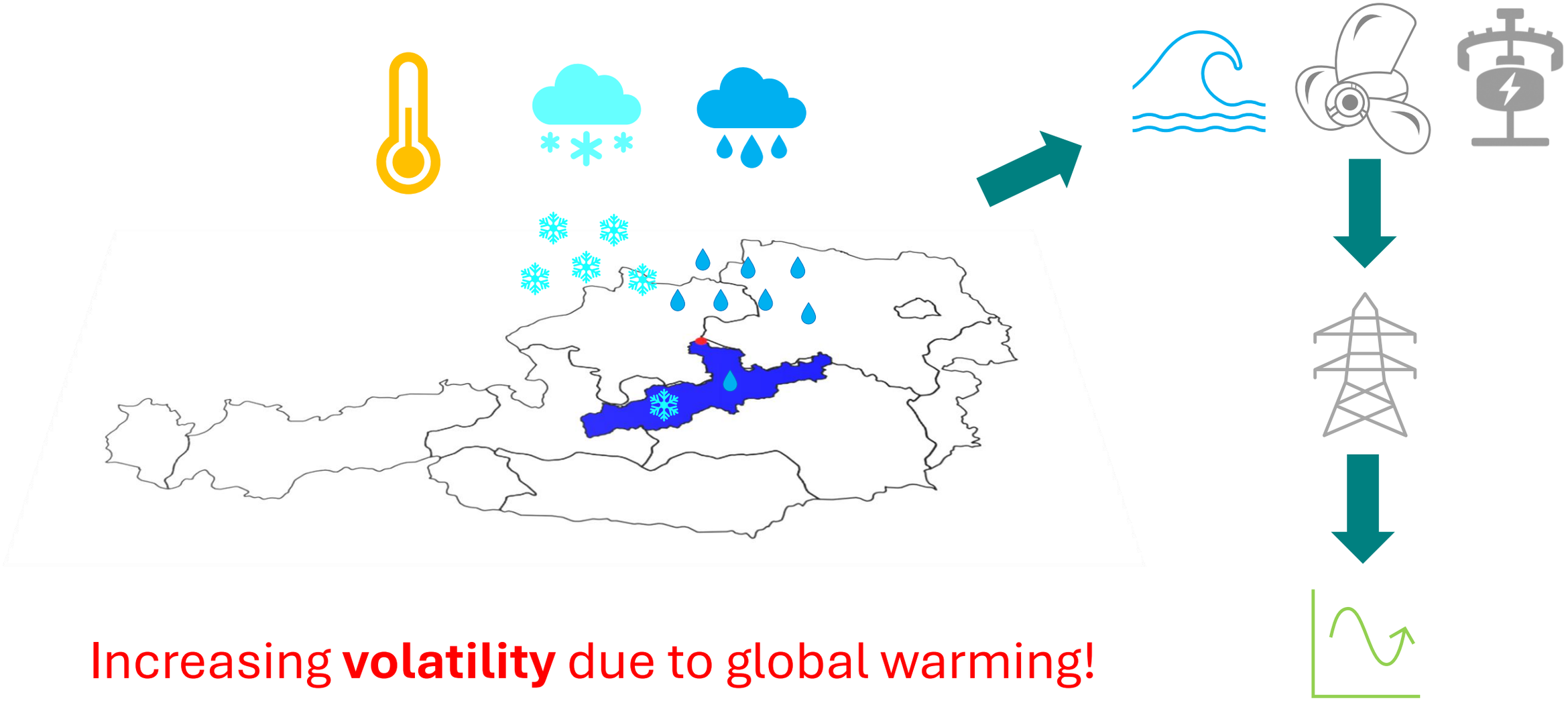
Hochwasser schränkt österreichische Wasserkraft ein

(Montel) Die Hochwasserlage in Österreich hat zu Einschränkungen bei der Wasserkraft geführt. Der Verbund hat die Produktion in drei Donaukraftwerken mit zusammen 600 MW komplett eingestellt, teilte der Versorger am Montag auf Nachfrage mit.

Sources: https://www.energate-messenger.de/news/252589/extrem-trockenes-fruehjahr-belastet-wasserkraft, https://www.salzburg24.at/news/salzburg/salzach-fuehrt-so-wenig-wasser-wie-seit-1990-nicht-art-287752, https://montelnews.com/de/news/f9965b6c-cf5e-4d96-bb51-0e2db1d2d8a5/hochwasser-schraenkt-oesterreichische-wasserkraft-ein, https://www.profil.at/wissenschaft/warum-das-wasser-in-oesterreich-knapp-wird/402349899, https://www.derstandard.de/story/3000000252888/koennten-duerren-zunehmend-zur-gefahr-fuer-die-wasserkraft-werden, https://climate.copernicus.eu/copernicus-exceptionally-dry-spring-parts-north-western-europe-second-warmest-may-globally

Motivation and Objective - Summary

Calculating hydropower time series for energy production from weather data



Increasing **volatility** due to global warming!

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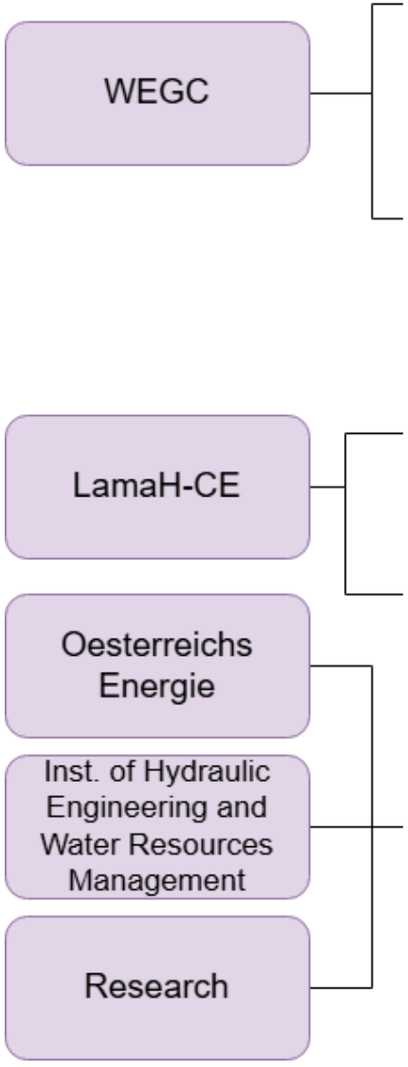
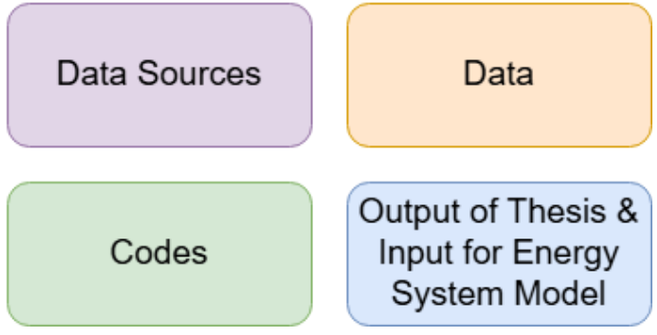
High-Level Overview: Process

From data aggregation to Hydropower Time Series for Climate-Resilient Energy System Optimization





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Integration of Snow Module

Degree-Day Model

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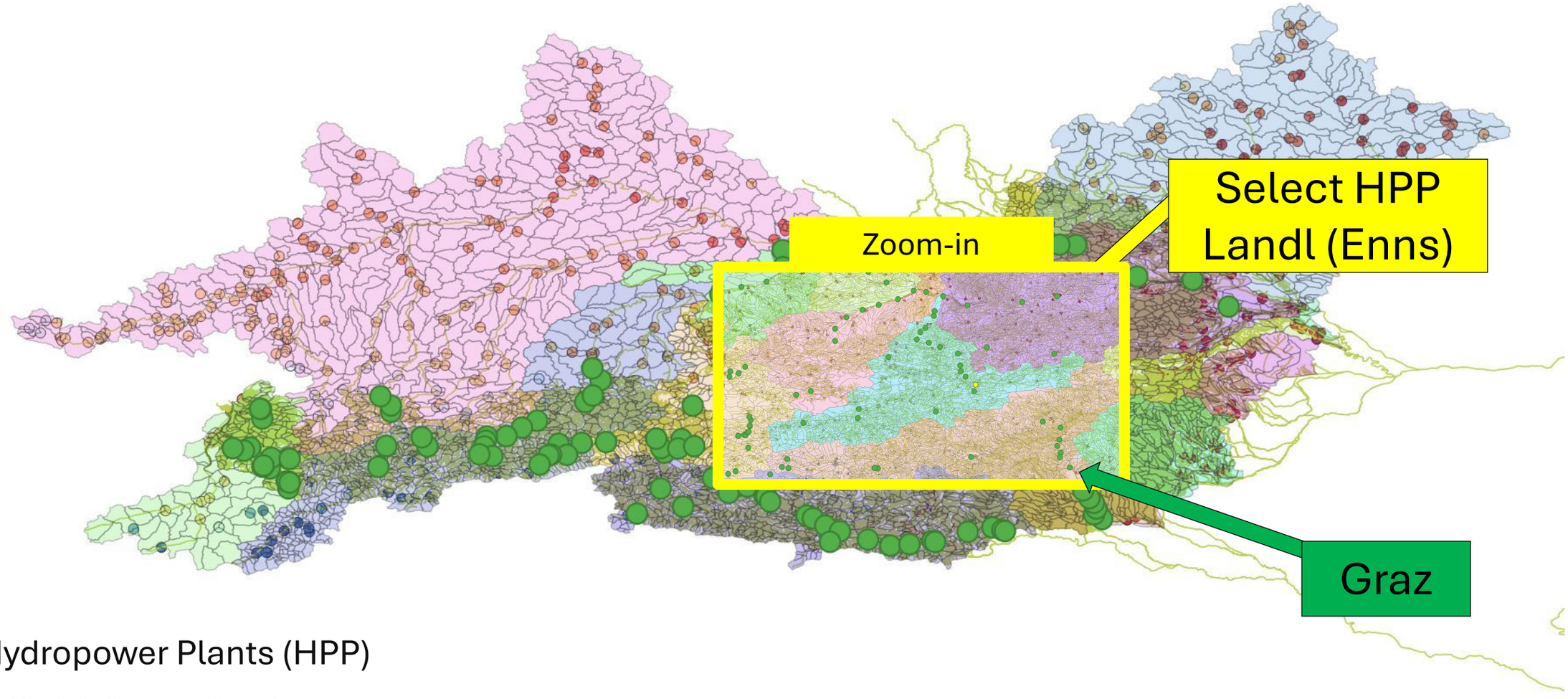
Automated Catchment Area Determination

Example for hydropower plant Landl (Enns)



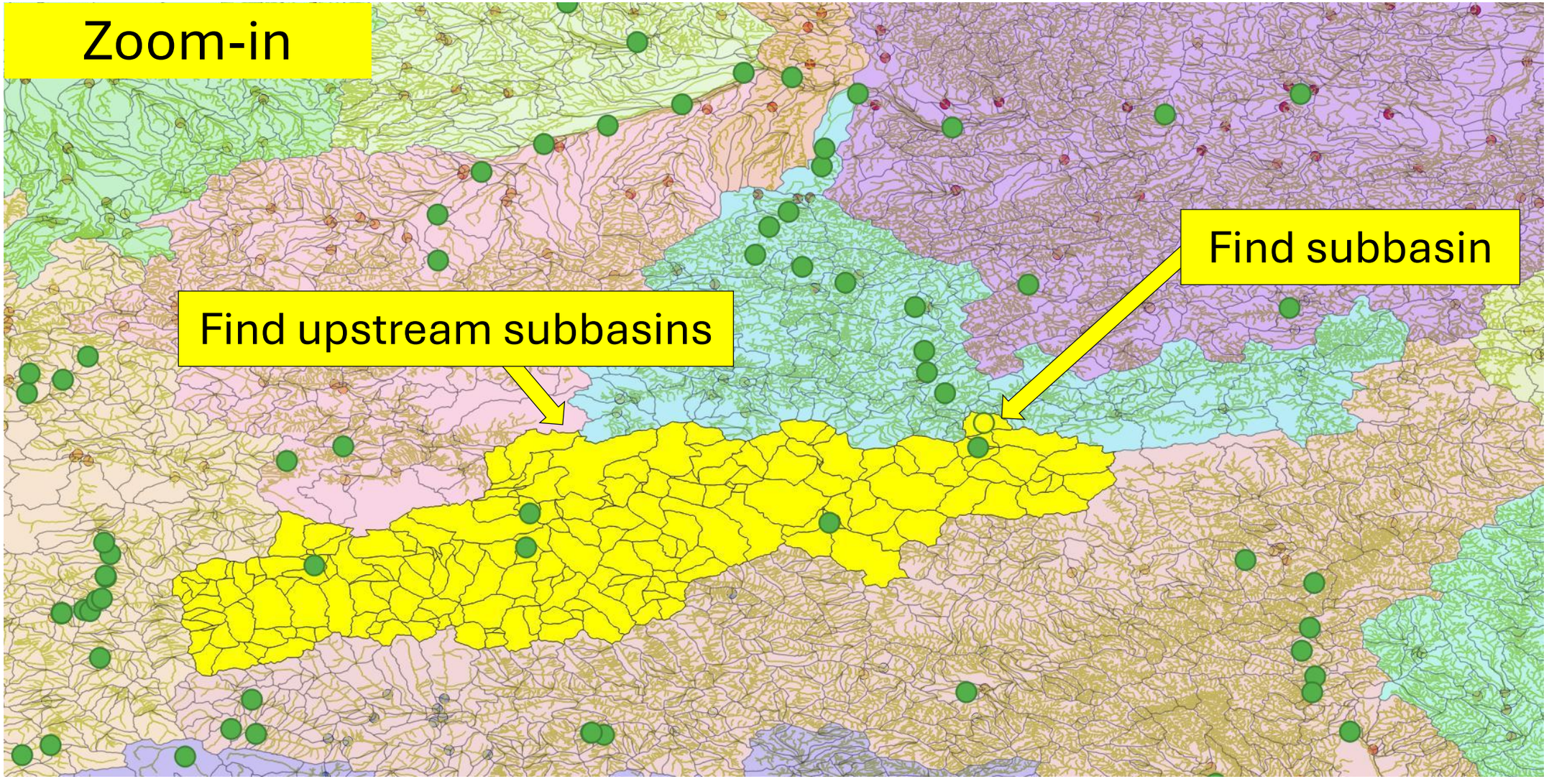
Hydropower Plants (HPP)

Official Gauge Stations

Source of Subbasins: LamaH-CE Dataset

Automated Catchment Area Determination

Example for hydropower plant Landl (Enns)



CA...Catchment area
HPP...Hydropower plant

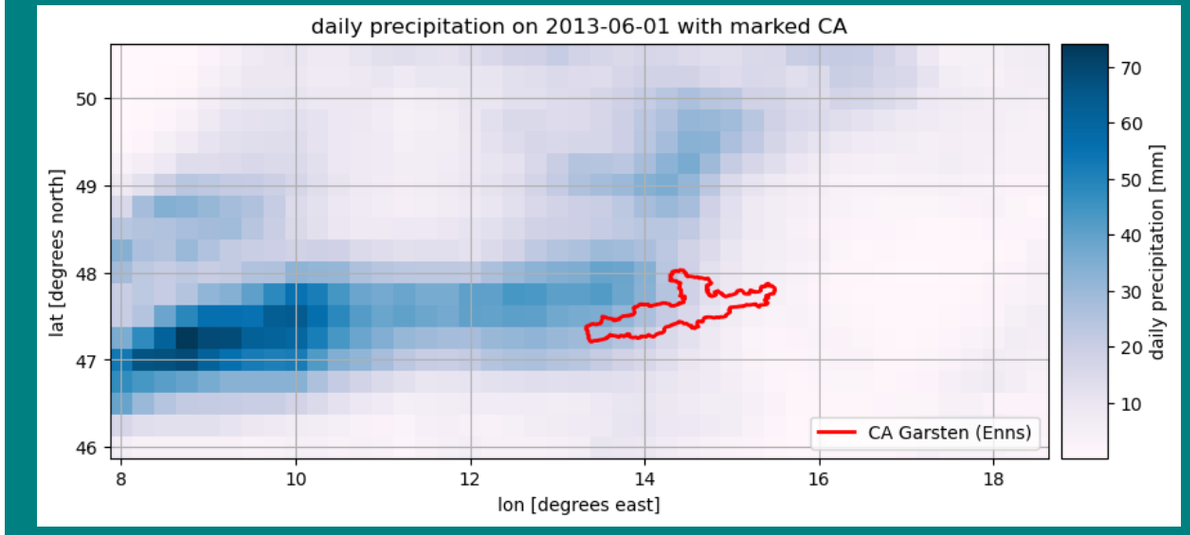
Source of Subbasins: LamaH-CE Dataset

Prepare Weather Data for GR4J

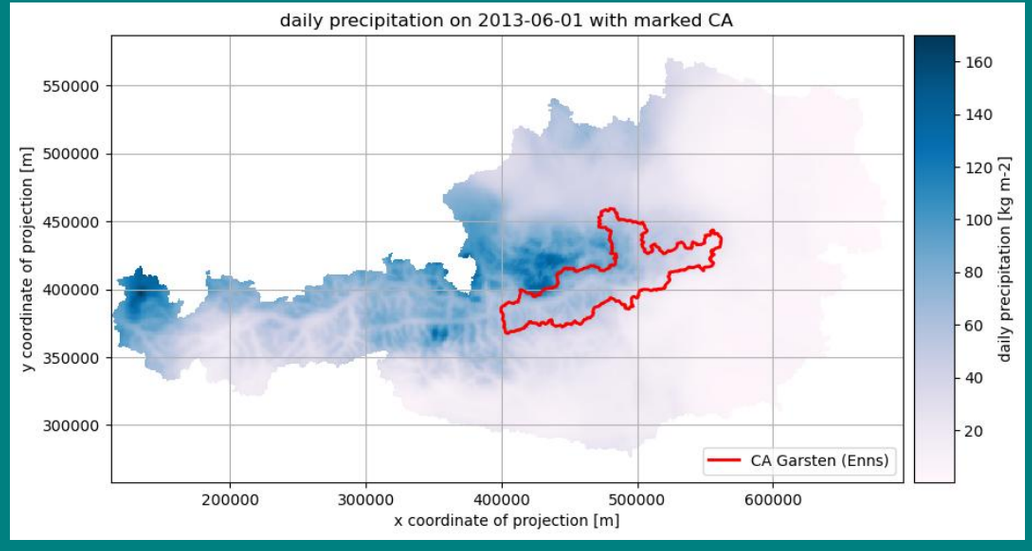
Compare resolution of ERA5 and Spartacus/Winfore/INCA datasets

- Coarse resolution of ERA5 data compared to Sparatacus, Winfore or INCA (~525 km^2 ↔ 1 km^2)

ERA5



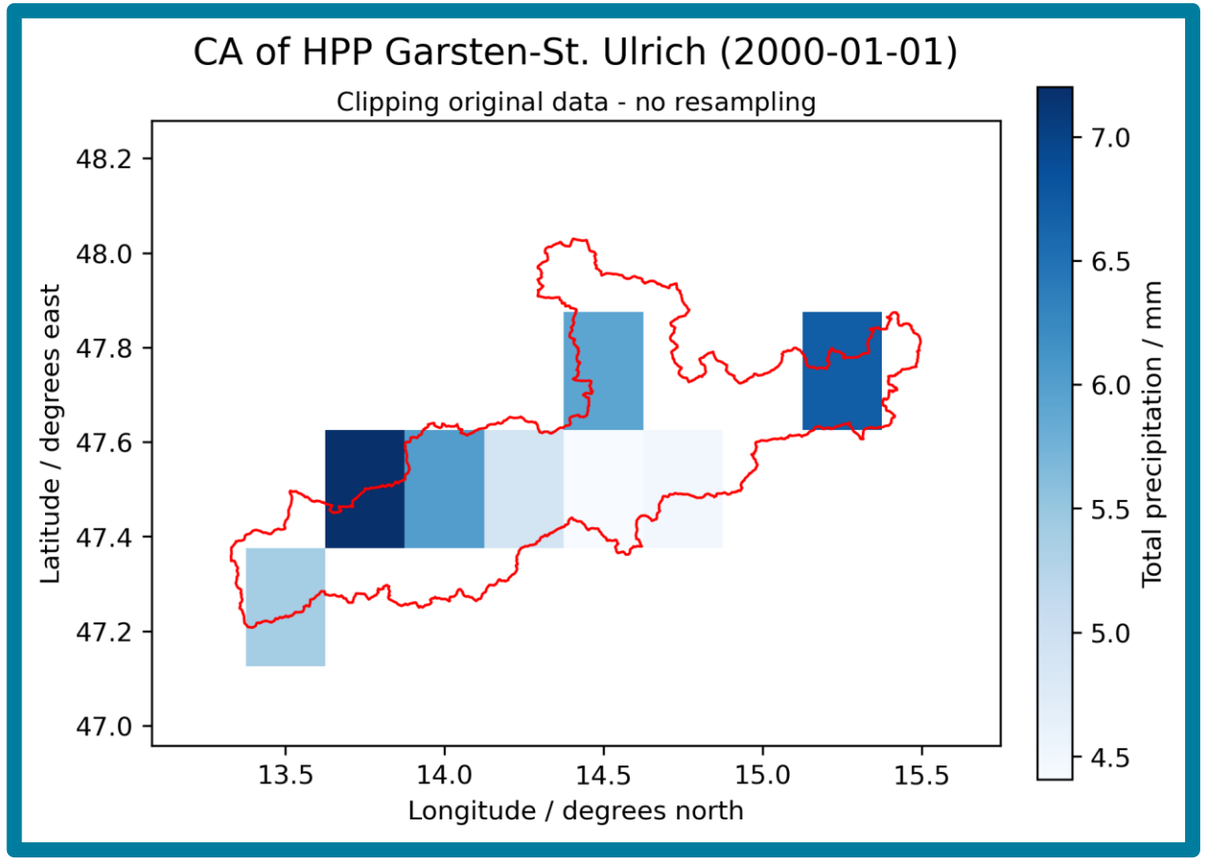
SPARTACUS

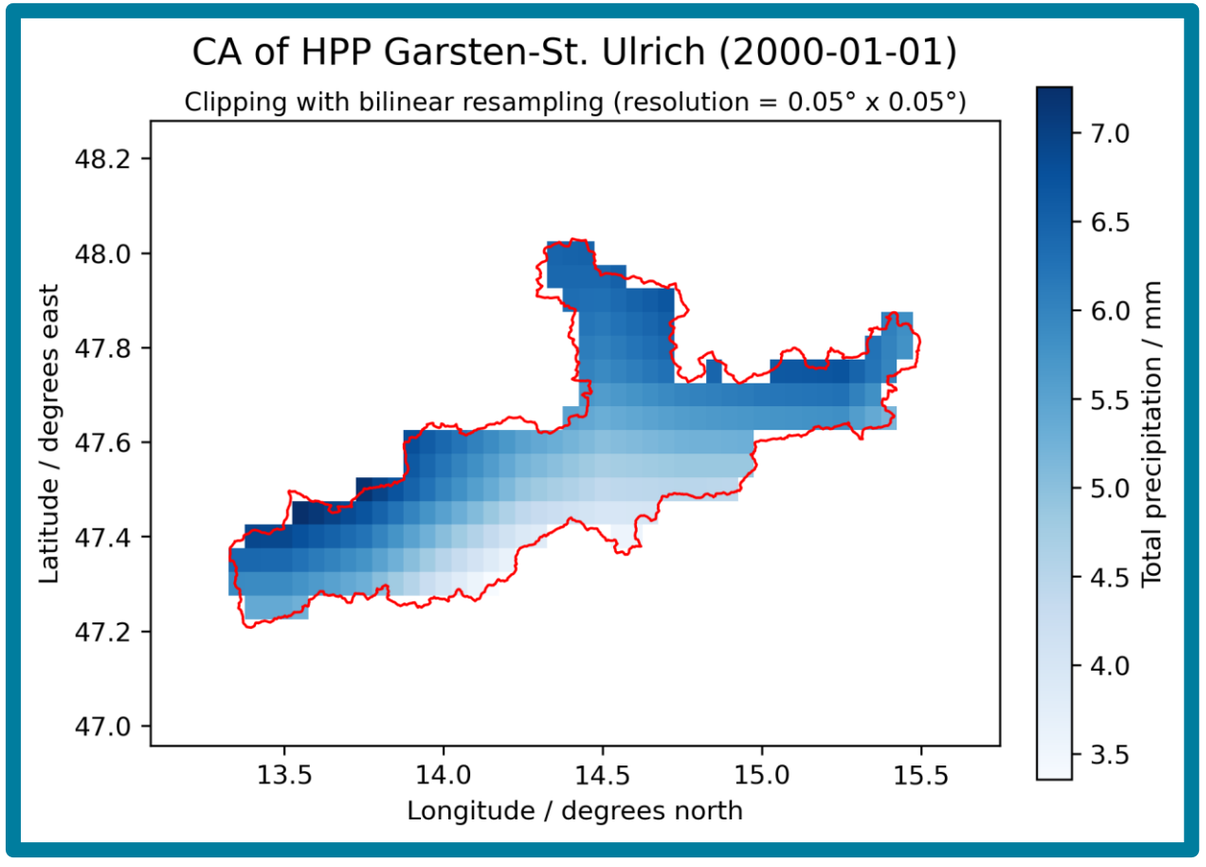


Prepare weather data for GR4J

Resampling data and clipping to CA

- Biliniar resampling of the ERA5-data to clip the data to the CA





CA...Catchment area
HPP...Hydropower plant

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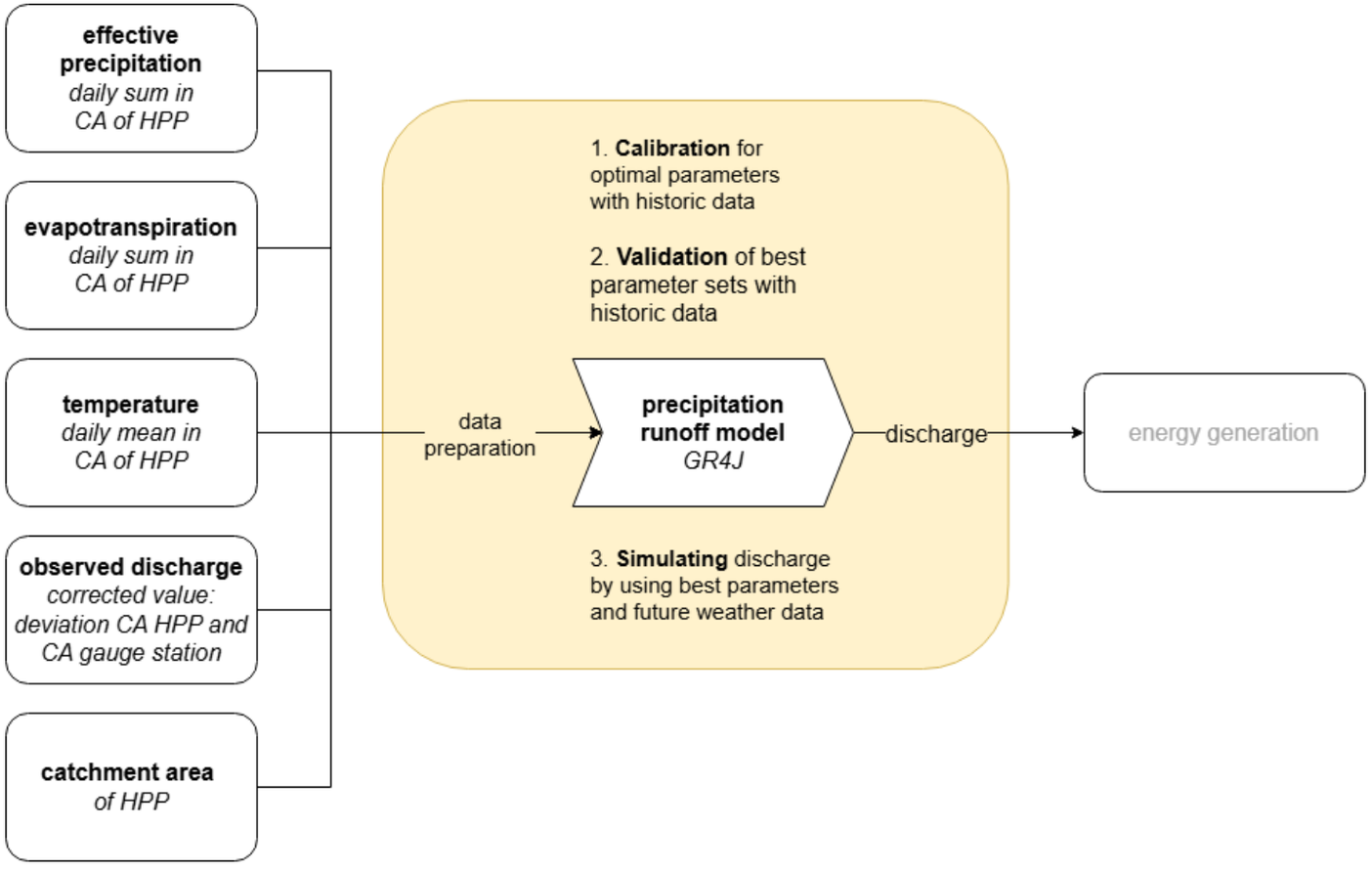
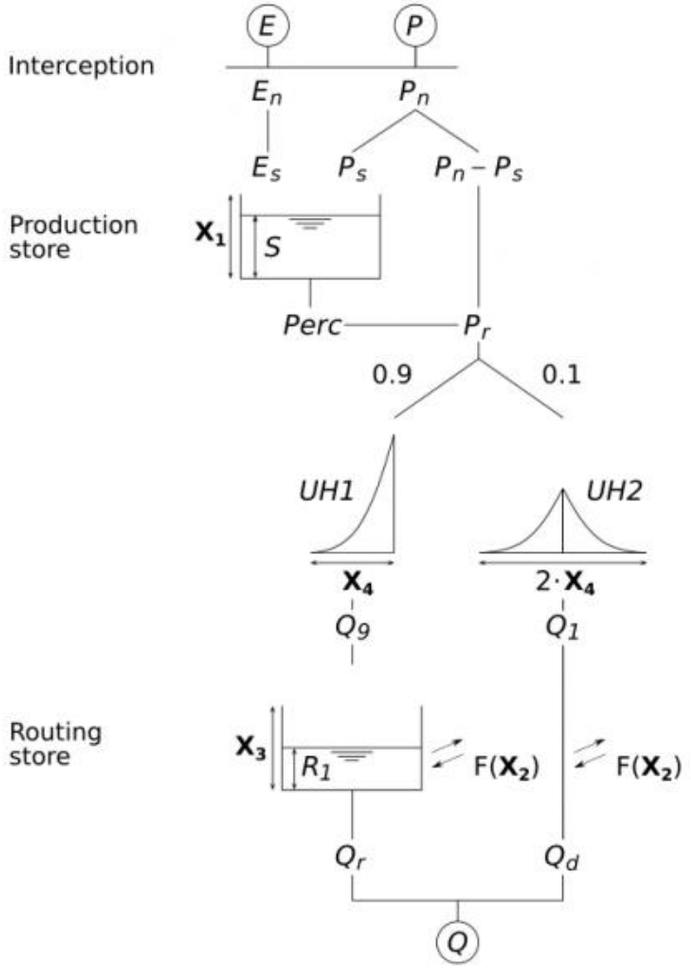
Hydrological Model - GR4J

Used for daily time steps

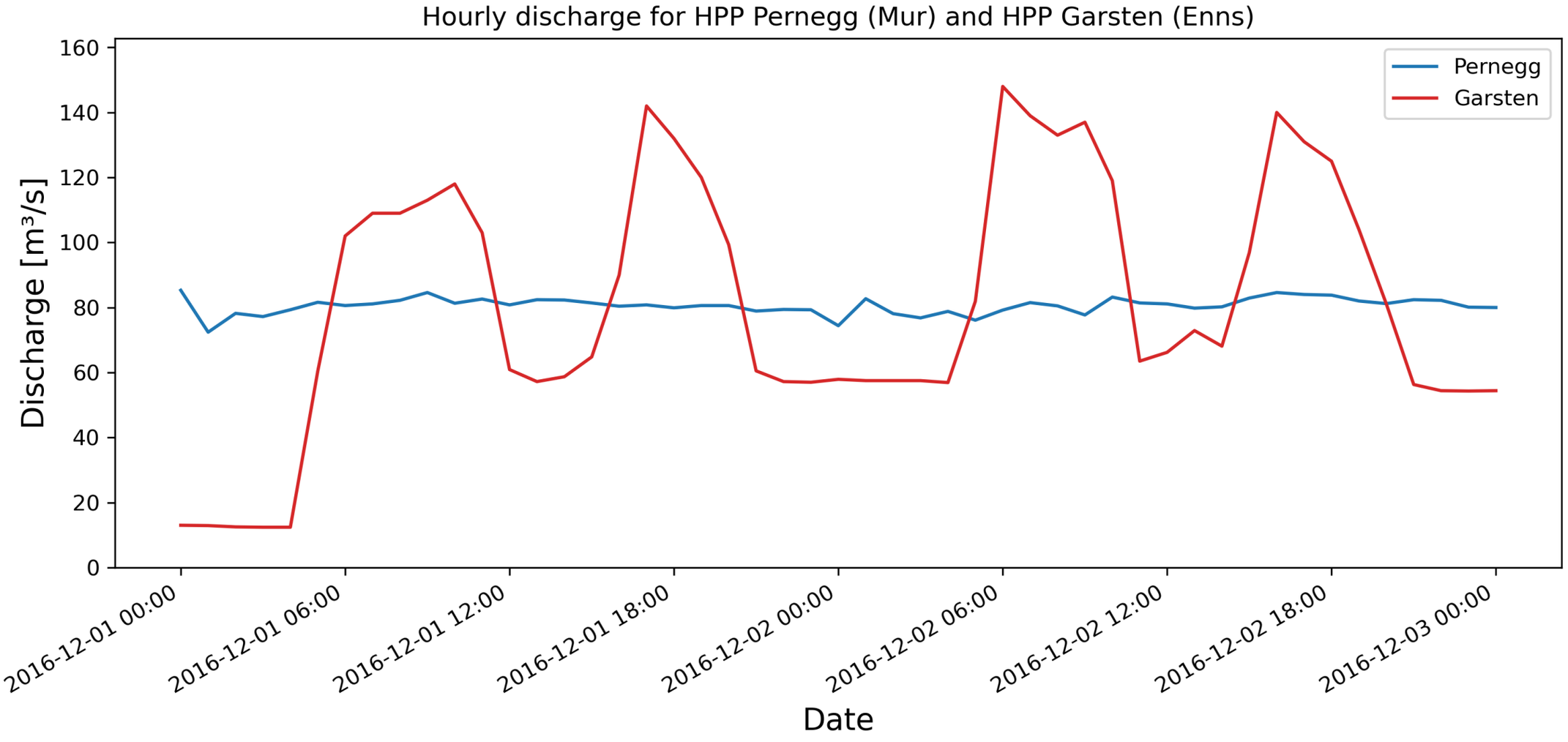




Sources:
https://webgr.inrae.fr/eng/tools/hydrological-models/daily-hydrological-model-gr4j

Hydrological Model - GR4J

Used for daily time steps



Source: Plotted with LamaH-CE dataset

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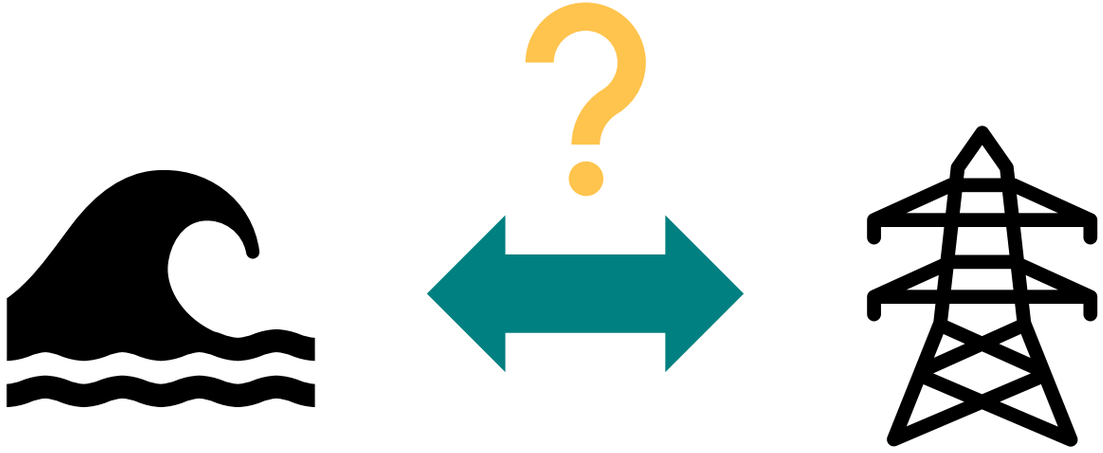
HPP Energy Generation

Converting discharge into energy amounts



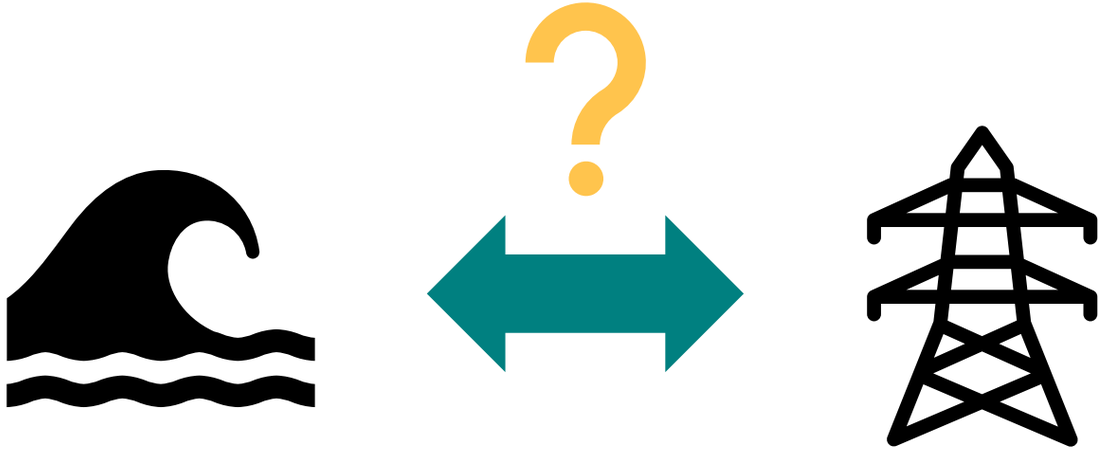
$$\text{generation}(h) = \frac{discharge\ (h,\ simulation)}{design\ flow\ (HPP_i)} \times installed\ capacity(HPP_i)$$

If discharge exceeds the design flow: generation(h) = installed capacity

CA…Catchment area
HPP…Hydropower plant

HPP Energy Generation

Need for calibration of energy production

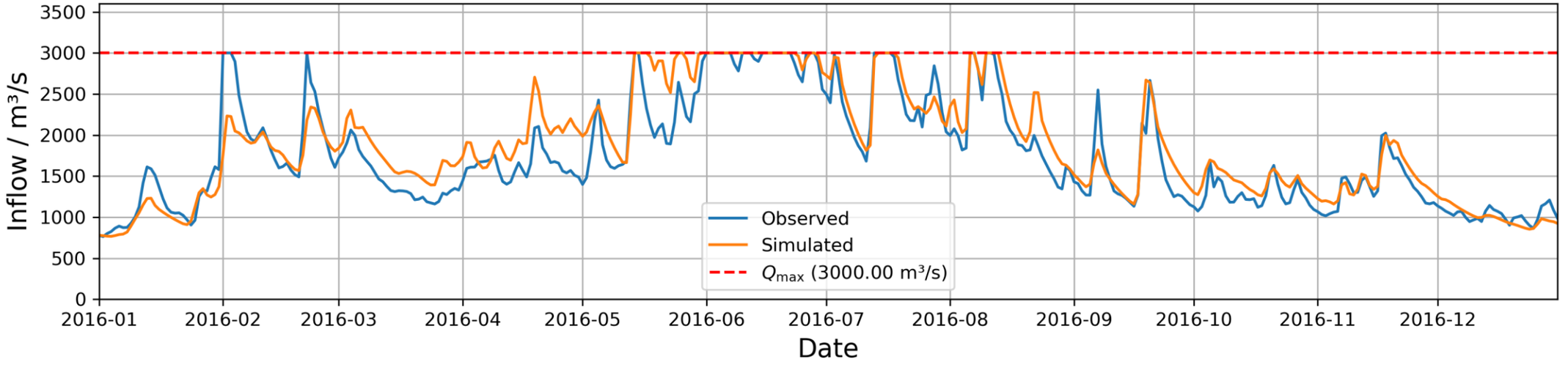


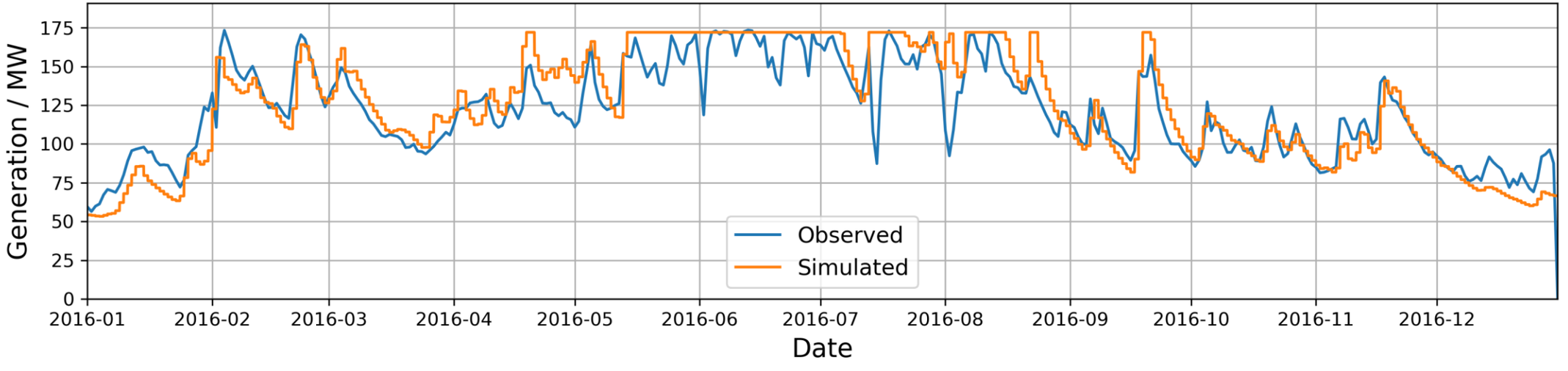
Compare **mean annual production** and **simulated production** without any correction over some years

Deviation → **correction** (calibration) **factor**

Simulation Results

Electricity generation for a sample HPP at the Danube in 2016





Simulation Results

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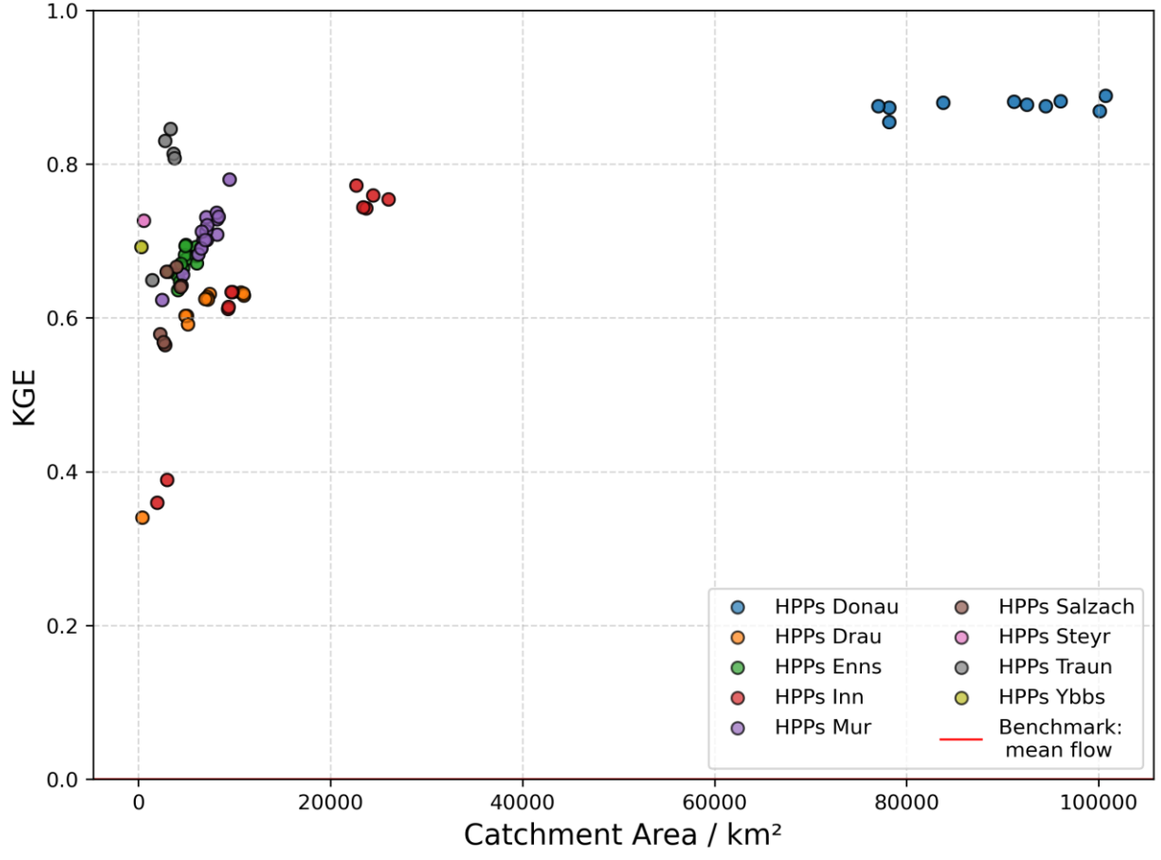

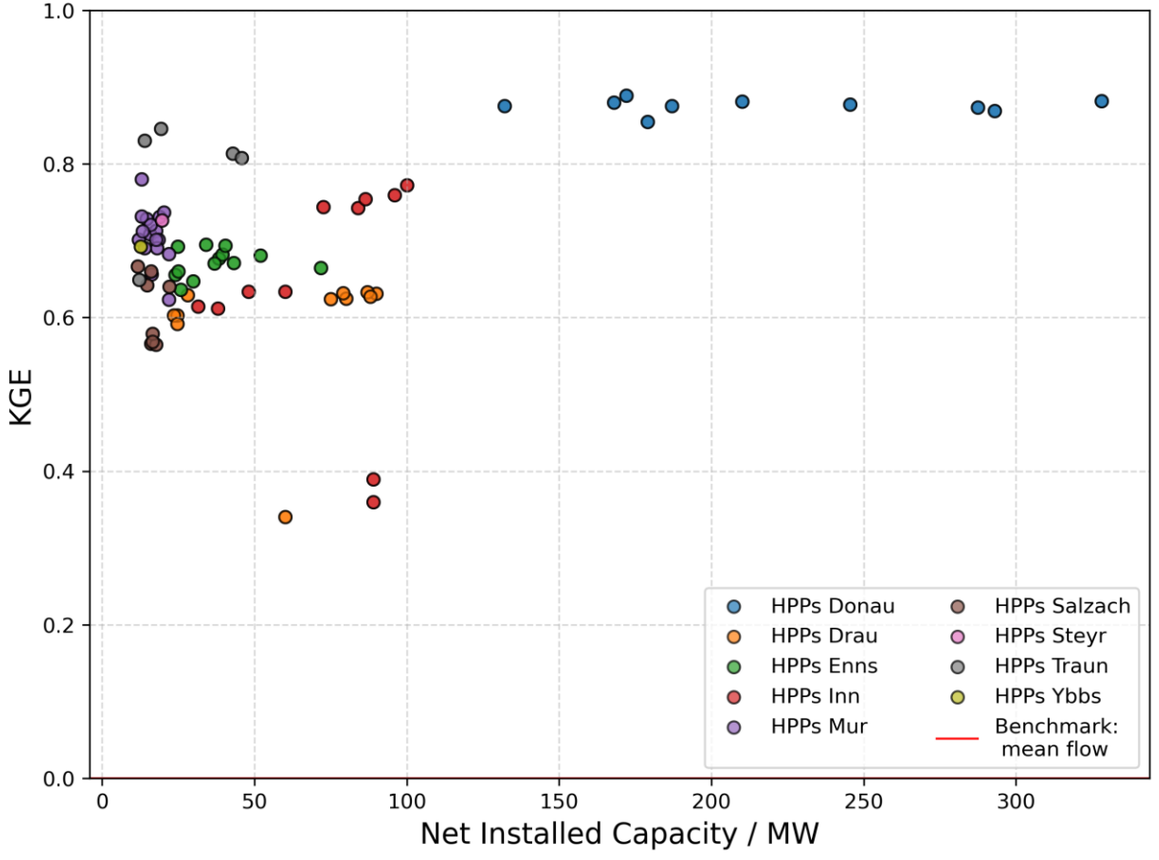

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Summary

Achieved goals and potential application fields

Achieved Goals

- Robust **forecasting tool** for electricity generation by **run-of-river hydropower**
  - Input: weather, HPP, and discharge data
  - Output: forecasted energy amounts per day (hour)
- Covers about **40 %** of the total **Austrian** public electricity **generation**
- **Extentible** to whole **Europe** with discharge and HPP data

Potential Application Fields

- Climate-resilient **energy system optimization** models
- **Long-term** energy production **forecasts**
- **Planning** support for **new hydropower** projects

CA…Catchment area
HPP…Hydropower plant

Further Possible Model Improvements

Examples which could lead to better performance of the tool

Improved PET Estimation
Calibration, more complex methode

Optimized Hydrological Calibration
Individual parameter ranges

Elevation Weather Correction
Altitude-adjusted temperature

Extended Data
Longer historical datasets

Flood Shutdowns
No generation while flood events

Eco Flow Constraints
Consider ecological water needs

Dynamic Degree-Day Factor
Variable snowmelt factors

Enhanced Hydrological Model
More complex model

Advanced Energy Calibration
More complex correction

Adaptive Resampling Resolution
Based on size of catchment area

Time Series Smoothing
Prevent jumps between days

Thank you!

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