Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

SCCER SoE
SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

Balancing Hydropower Production and Environment Through Flexible Operation

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ETHZ – HWRM

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In cooperation with the CTI

Energy funding programme
Swiss Competence Centers for Energy Research

Schweizerische Eidgenossenschaft
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Swiss Confederation

Commission for Technology and Innovation CTI

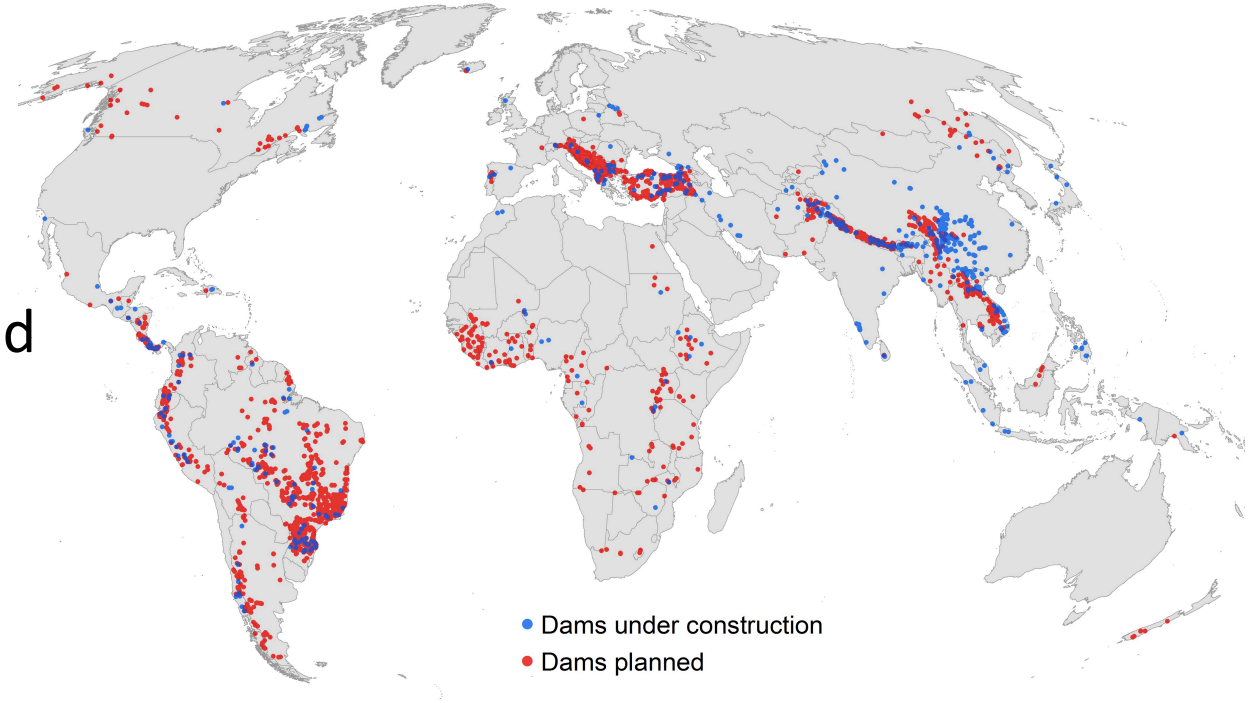
Hydropower has a number of benefits …

Clean: contributing to decarbonisation

Versatile: can generate power to the grid immediately

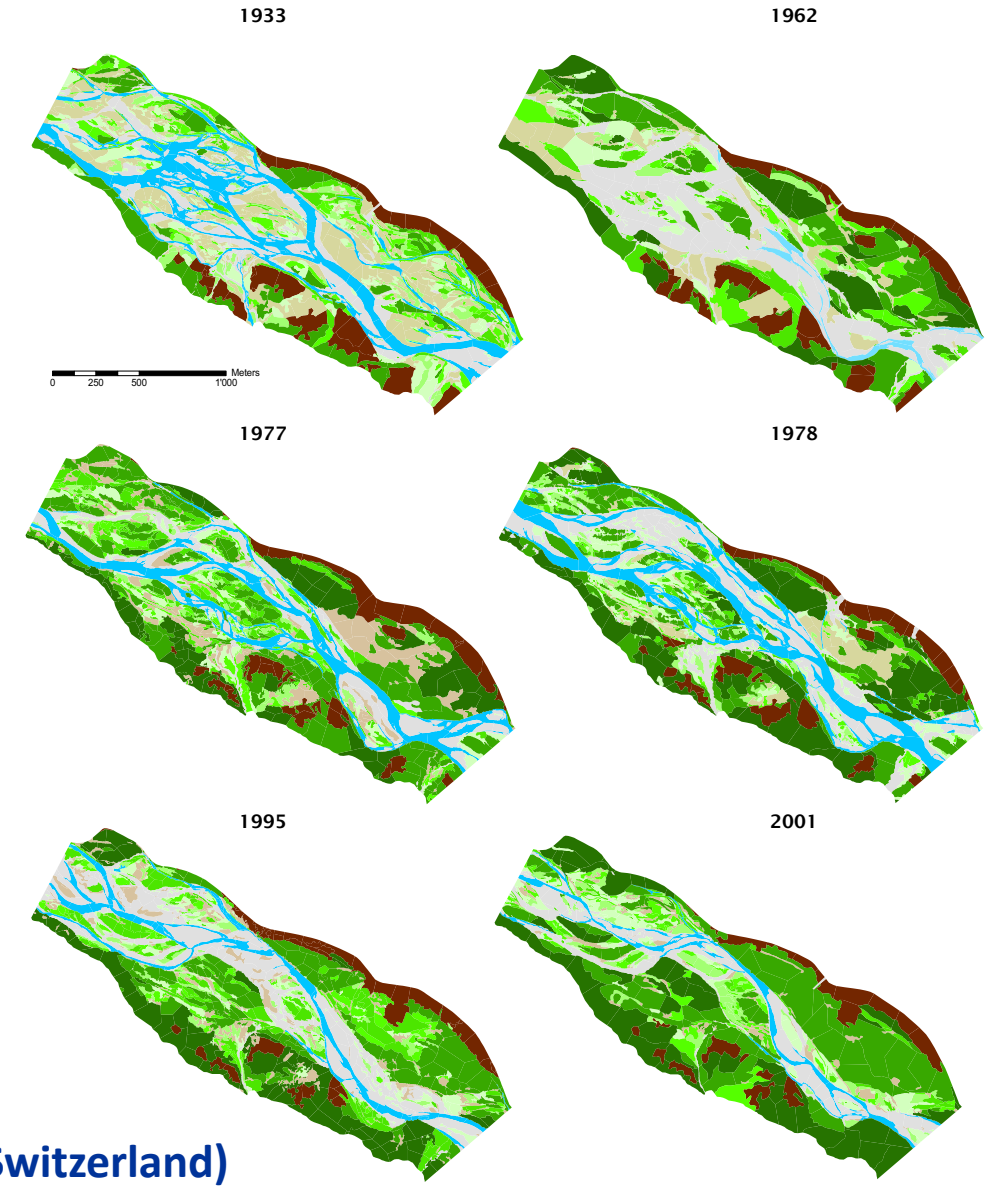
Flexible: can be used for balancing increased variability induced by RES

… and many others



3500 new dams being planned or built around the world

… yet can generate substantial externalities



(Maggia River, Switzerland)

> ***long-term narrowing*** of the active braided channel system, a ***decrease in pioneer vegetation*** stages, and a gradual ***maturing of the*** floodplain ***forest***

> evidence of ***short-term*** response following large floods, ***reworking*** of the ***channel bed***, increase in morphological heterogeneity, ***vegetation uprooting*** due to scour

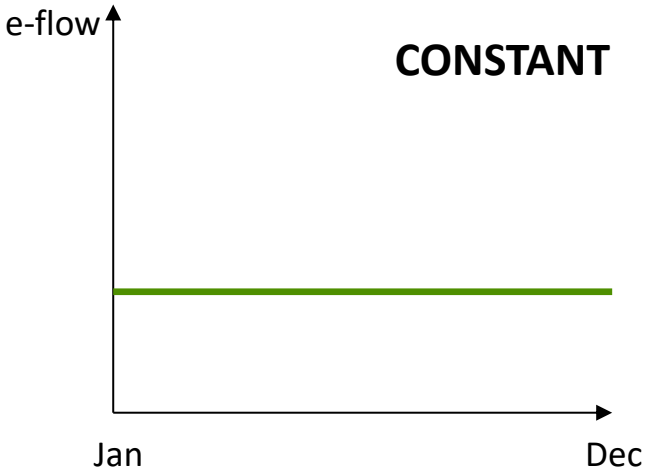
> evidence of changes in tributary dynamics due to streamflow regulation

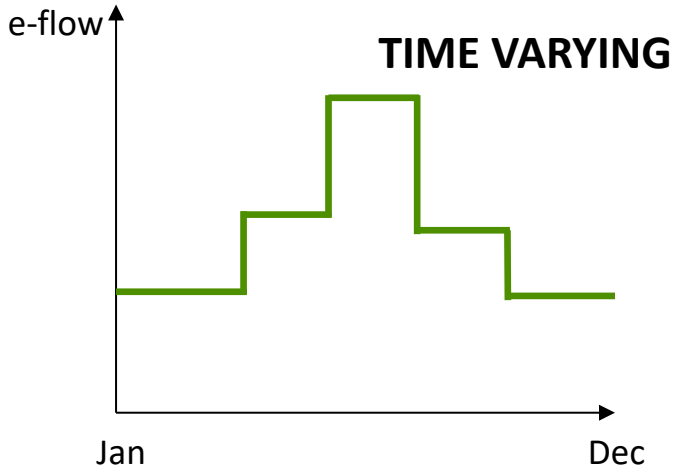
- A (Water)
- B (Sediment)
- C (Herb. Vegetation)
- D1 (Shrubs 25%)
- D2 (Shrubs 50%)
- D3 (Shrubs 75%)
- D4 (Shrubs 100%)
- E1 (Young Forest)
- E2 (Mature Forest)
- F (Non-alluvial Area)

[Sturzenegger, 2005]

Can we internalize these externalities?

Traditional approach: e-flow constraint





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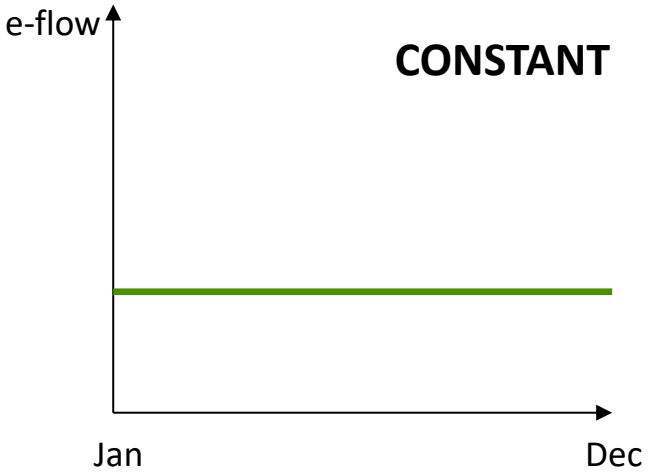
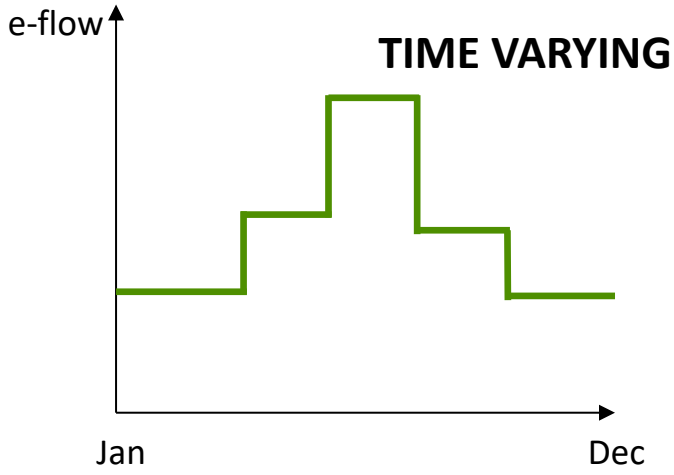


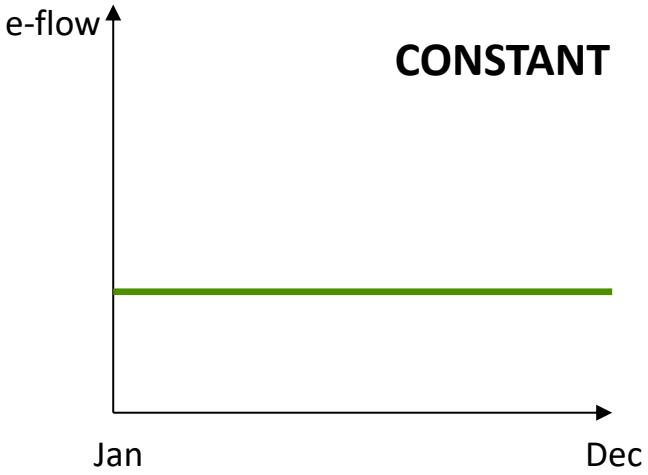


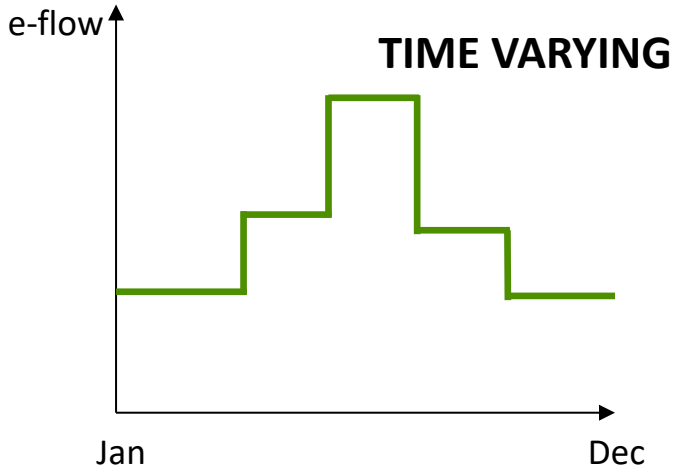
Tages-Anzeiger – Dienstag, 3. September 2019

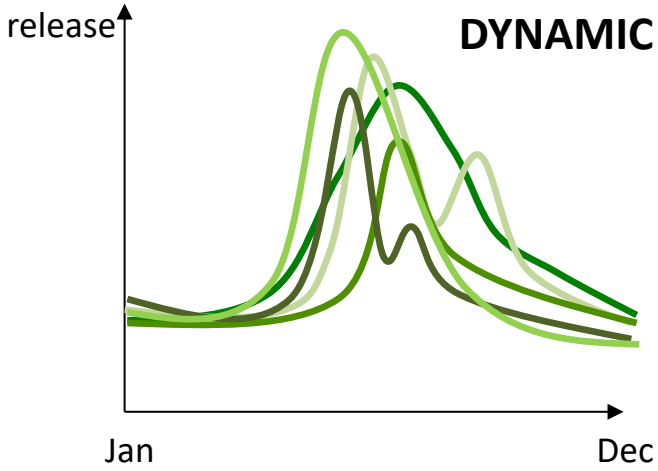
Der Bund korrigiert das Ausbaupotenzial der Wasserkraft nach unten.

Höher als 2012 angenommen sind zudem die künftigen Produktionsverluste, die aus Umweltschutzgründen entstehen. So müssen Werke, die ihre Konzession erneuern, strengere Restwasserbestimmungen einhalten, sie müssen also mehr Wasser ungenutzt durch den natürlichen Wasserlauf lassen als bisher.

IDEA: dynamic e-flow

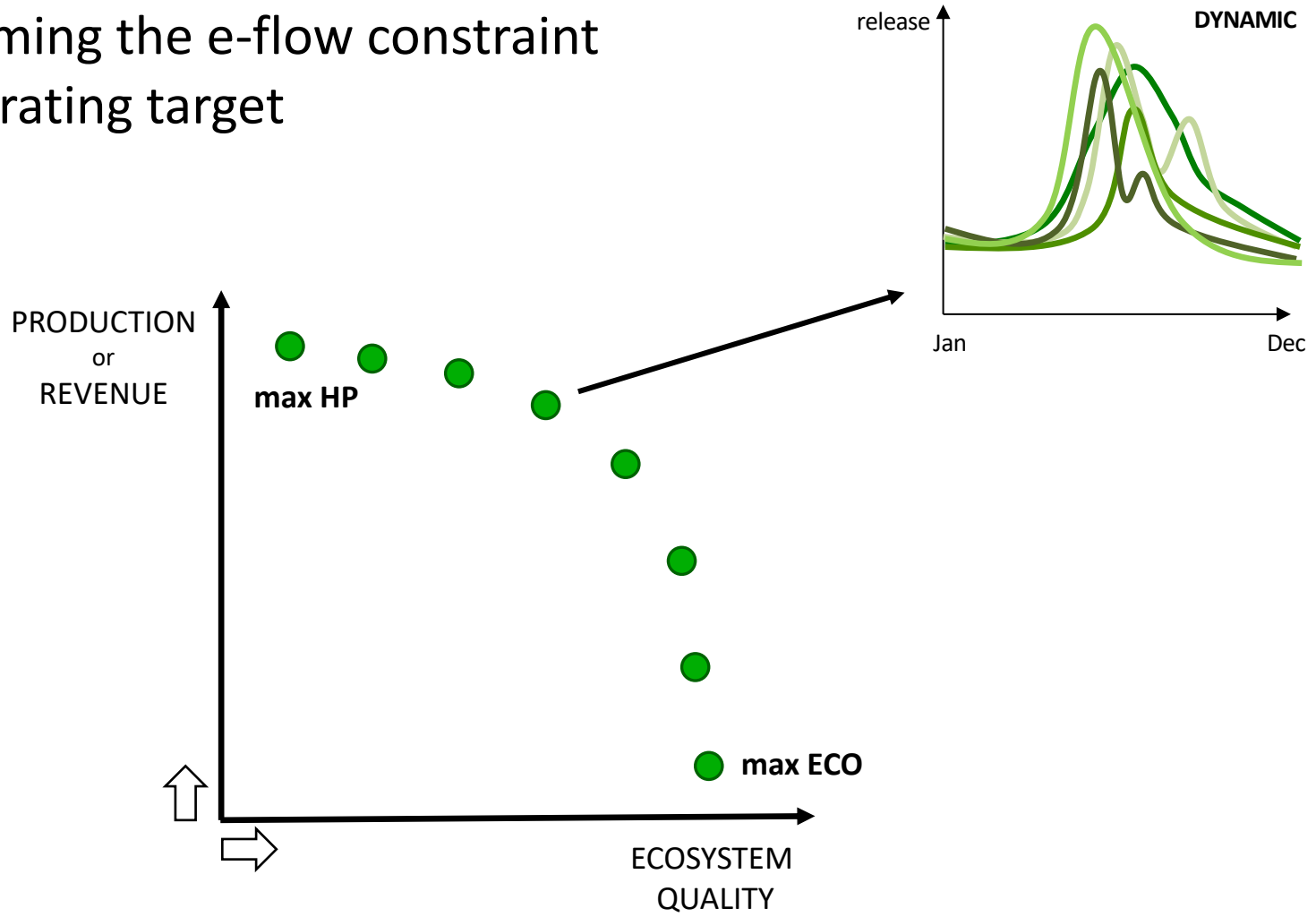






How to design a dynamic e-flows

by transforming the e-flow constraint into an operating target



Numerical experiments on the Maggia valley hydropower system

The Maggia valley – battery of the Tessin

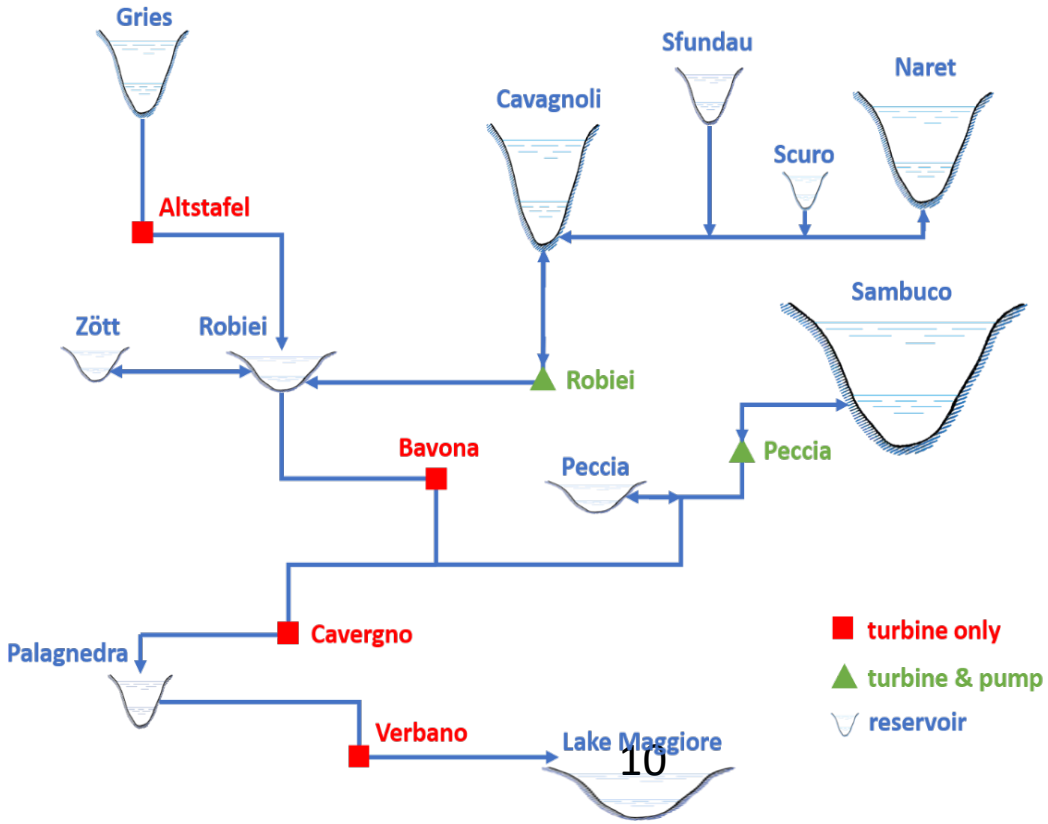
MAIN FEATURES

Storage capacity: 134.22 Mm^3

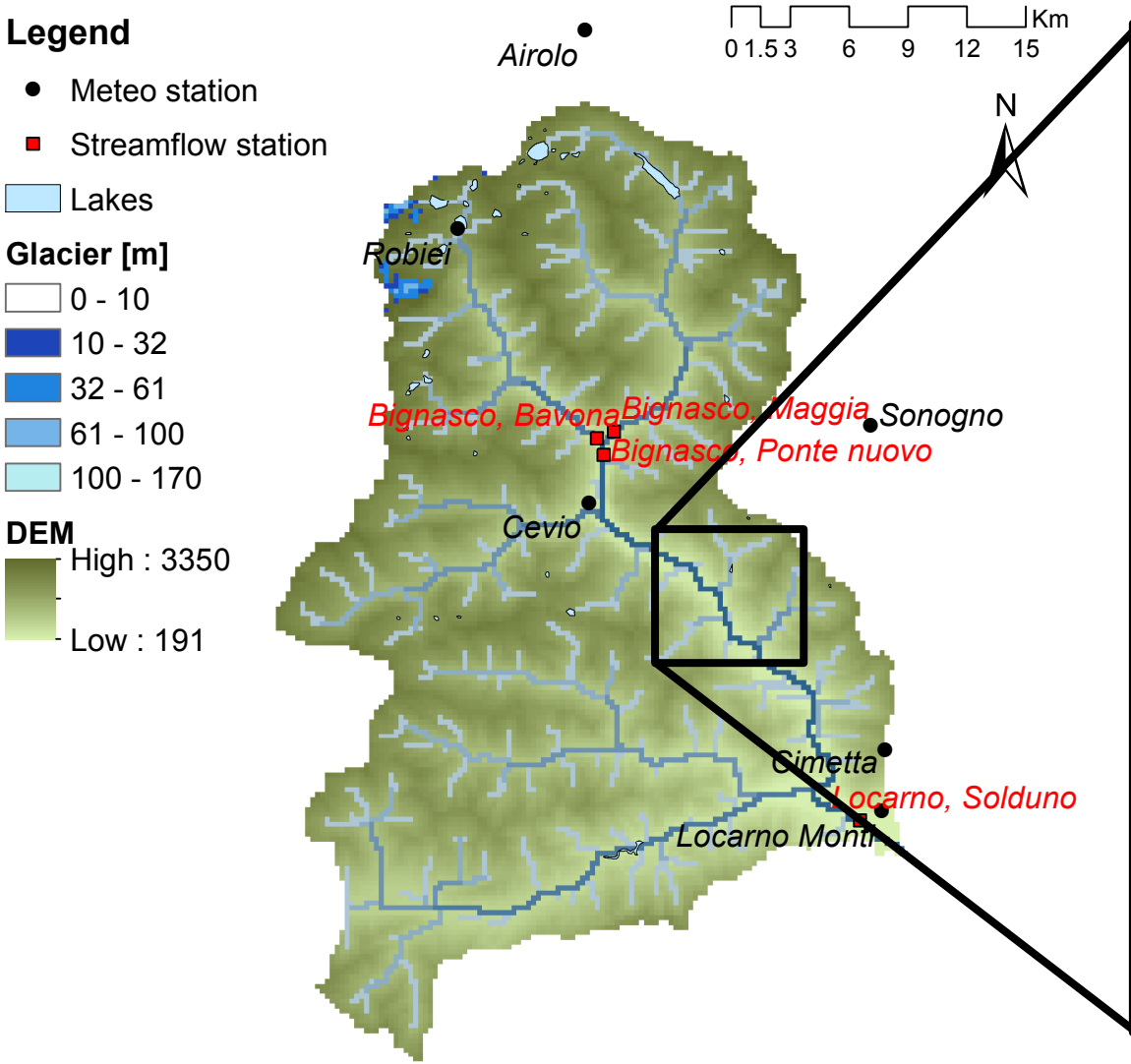
Annual inflow: 749 Mm^3

Installed power: 600 MW

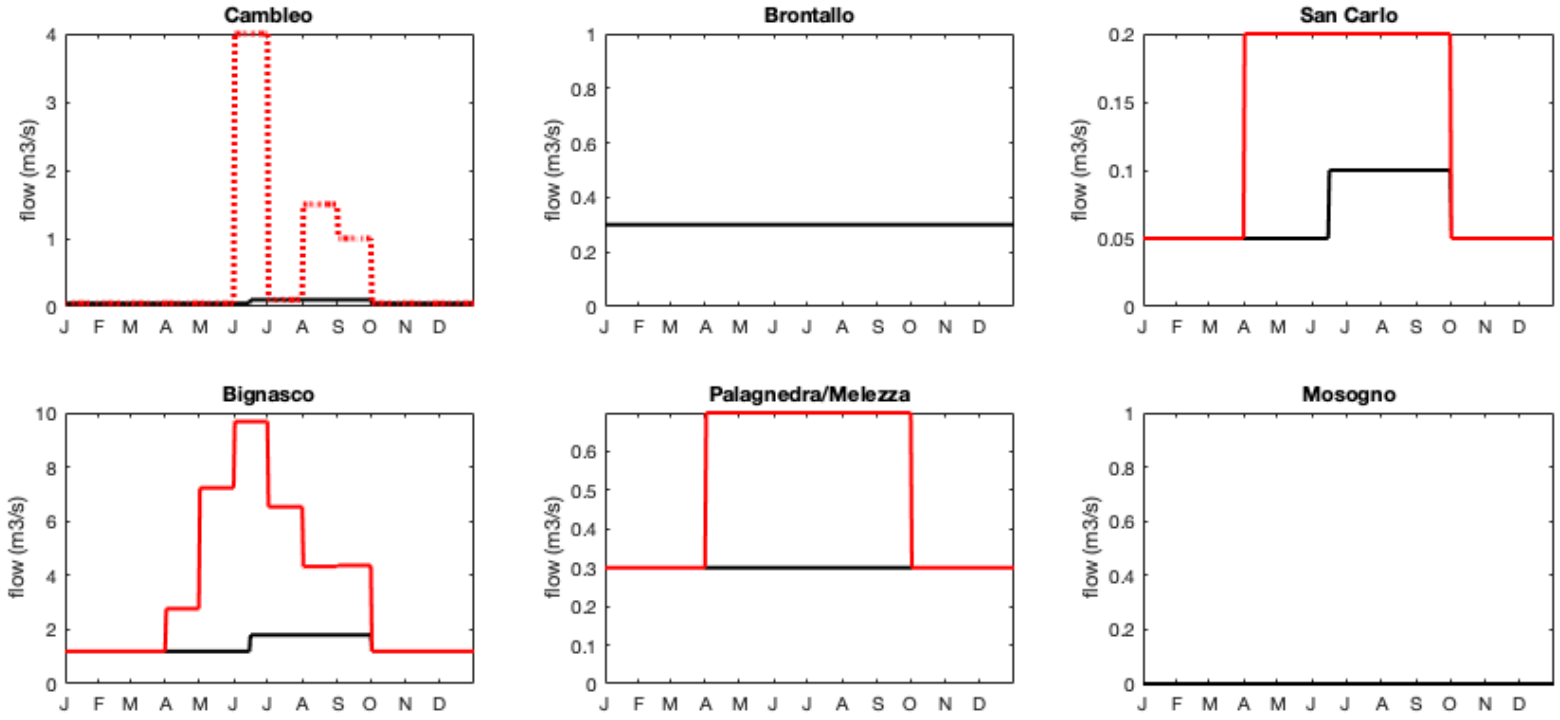
Annual production: 1265 GWh



The Maggia valley – a unique riparian ecosystem



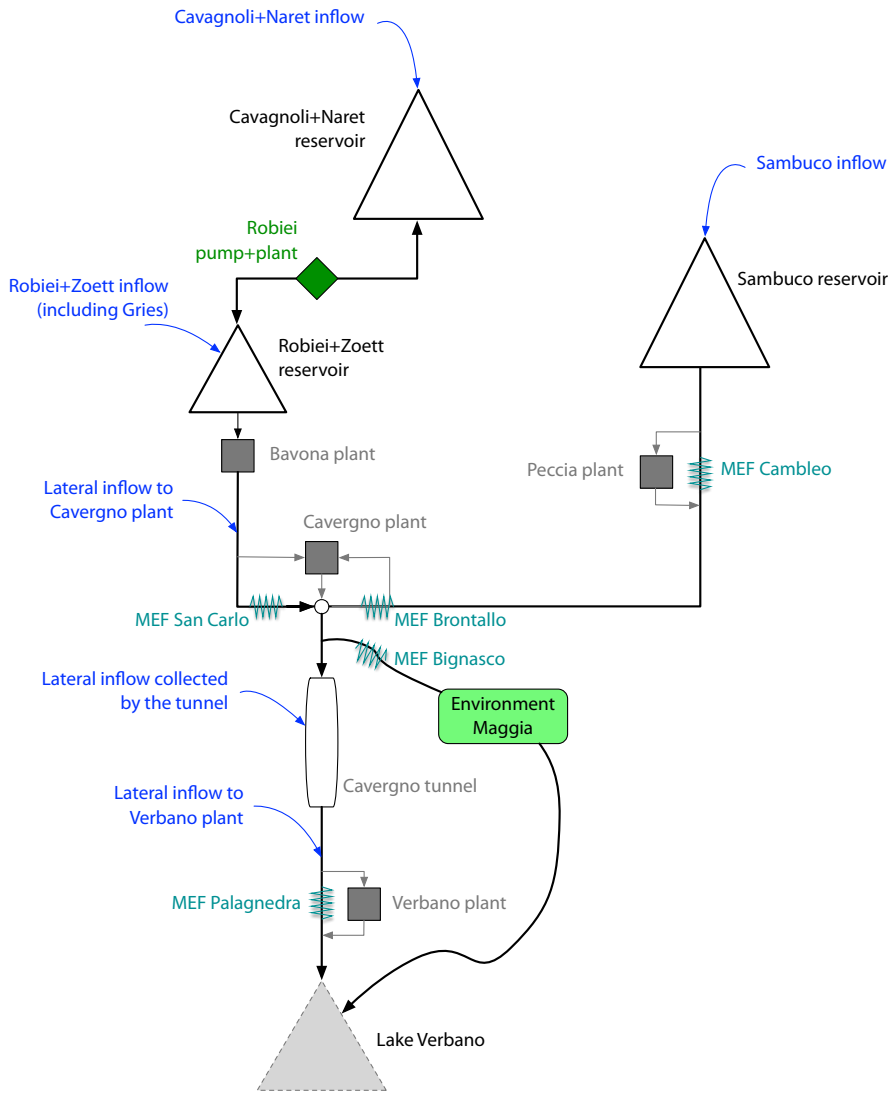
New 2018 e-flow regulation



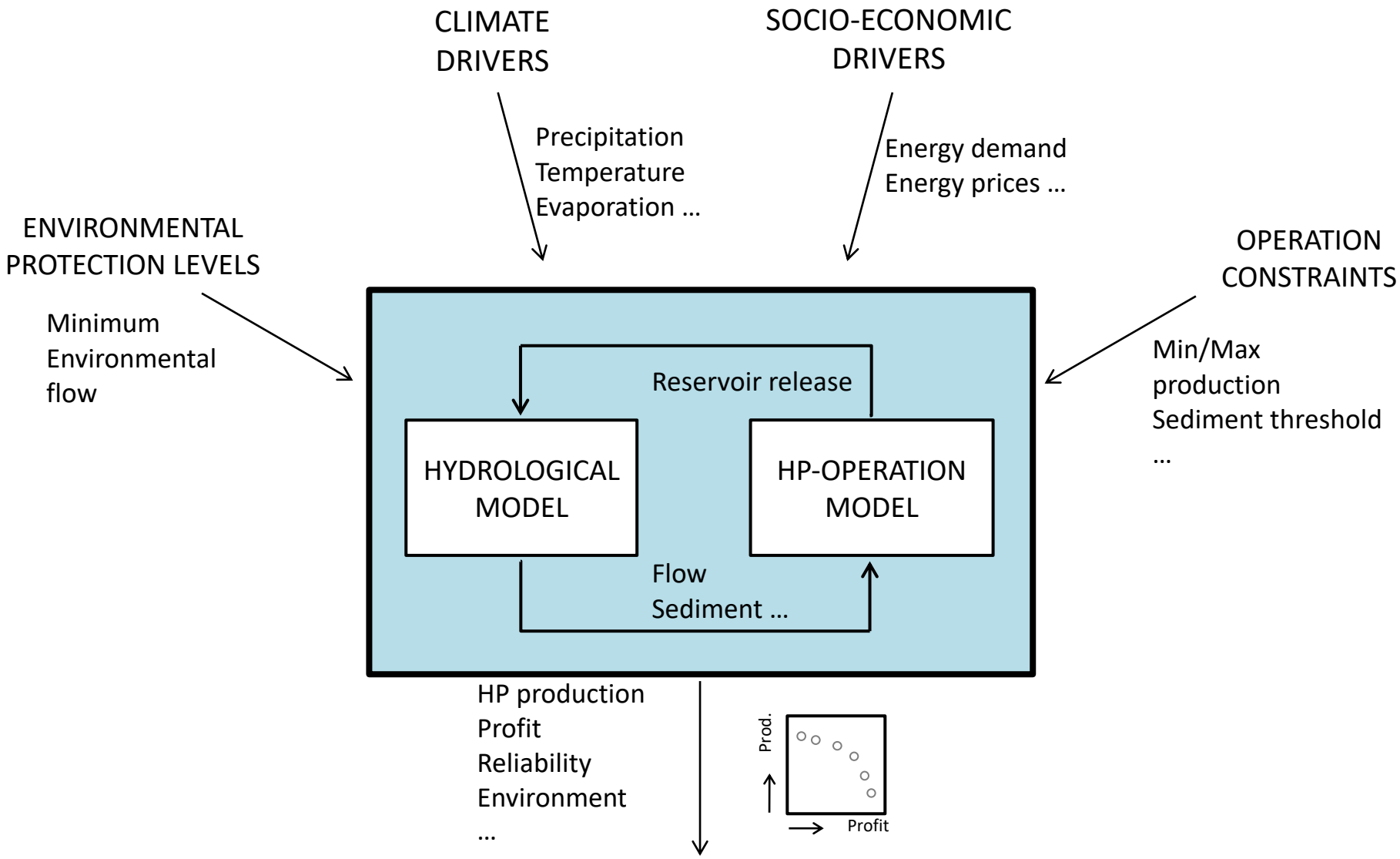
new e-flow

past e-flow

vs DYNAMIC e-flow



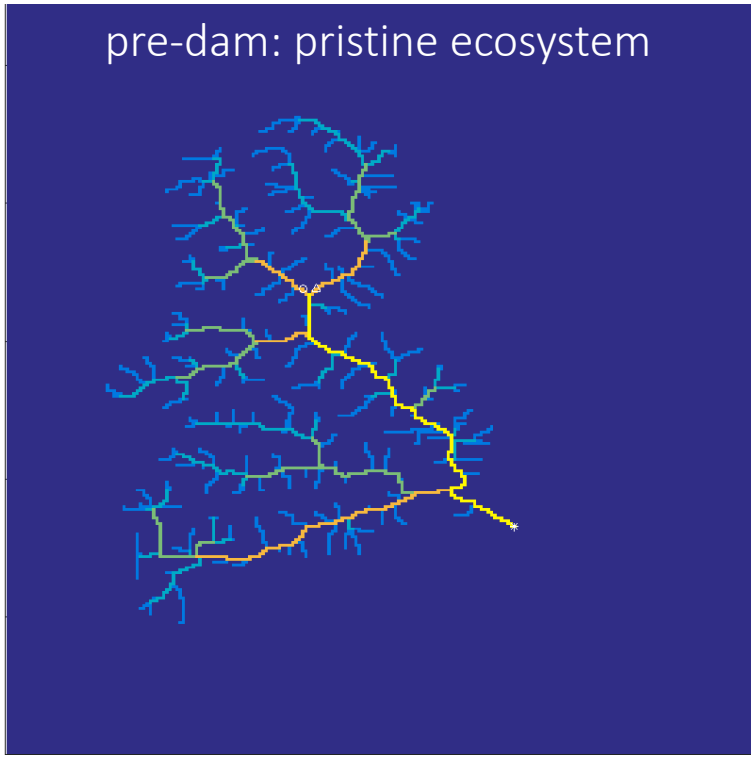
Multi-objective modelling framework

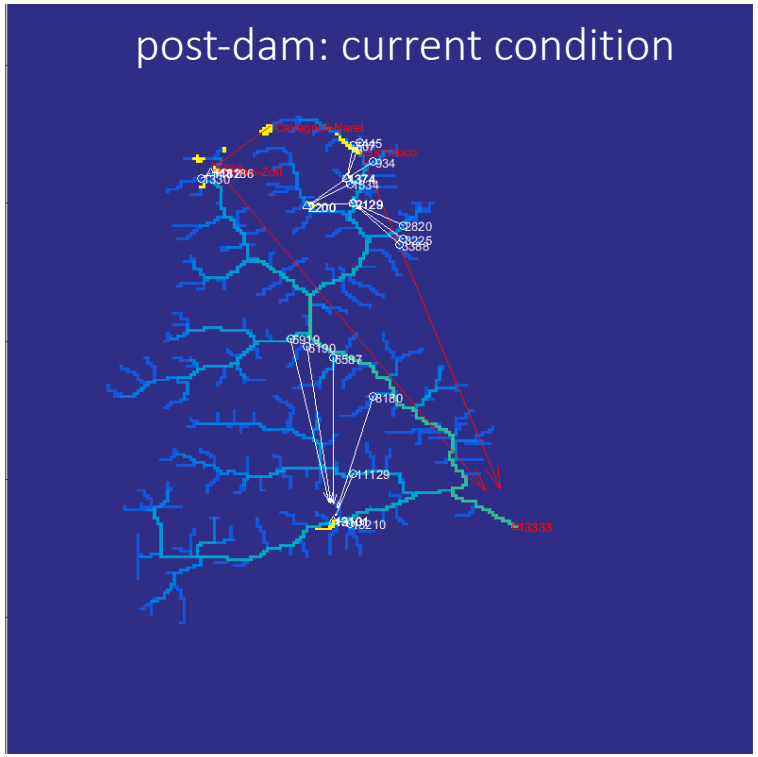


Hydrological modelling: TPK-ETH

Setup (preliminary, historical data):

- Temporal resolution = 1 day
- Spatial resolution = 250 m

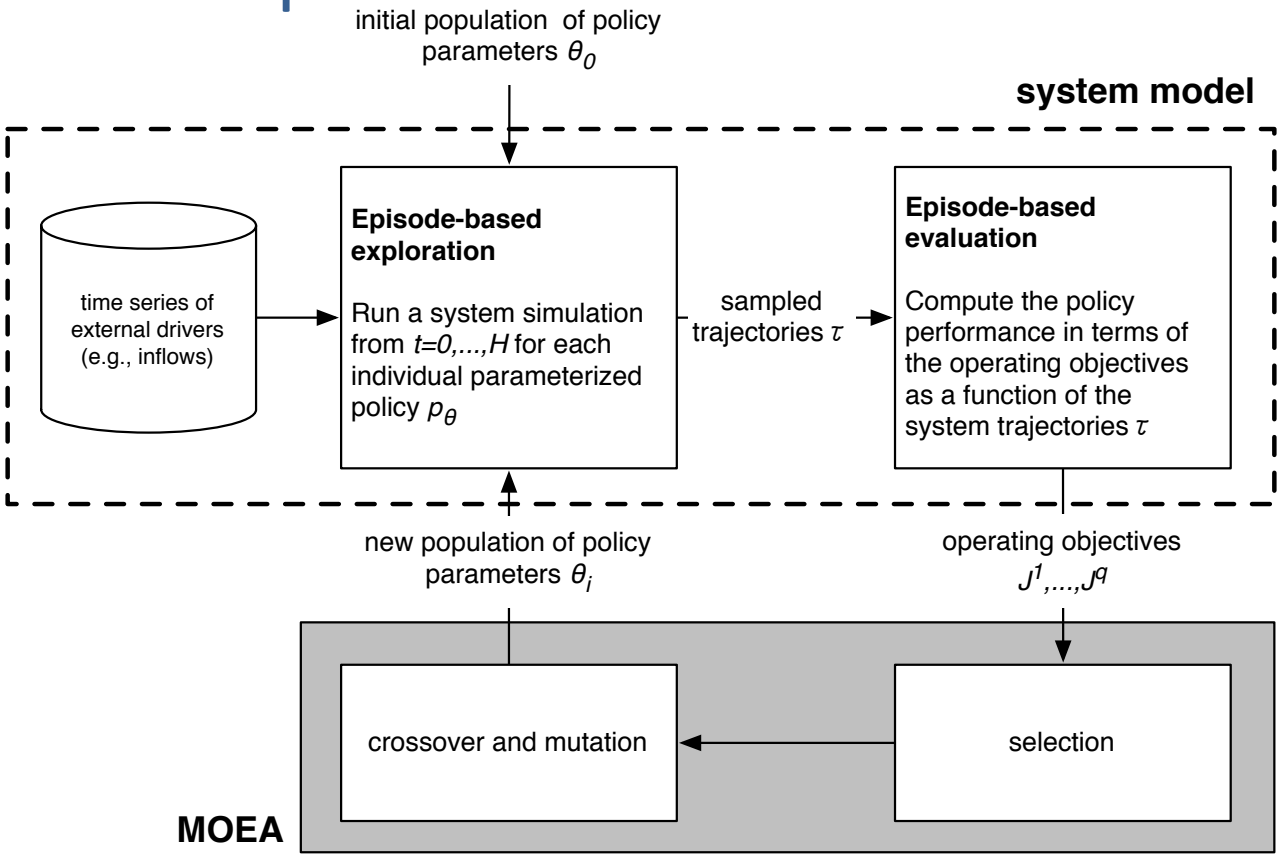




1949

time

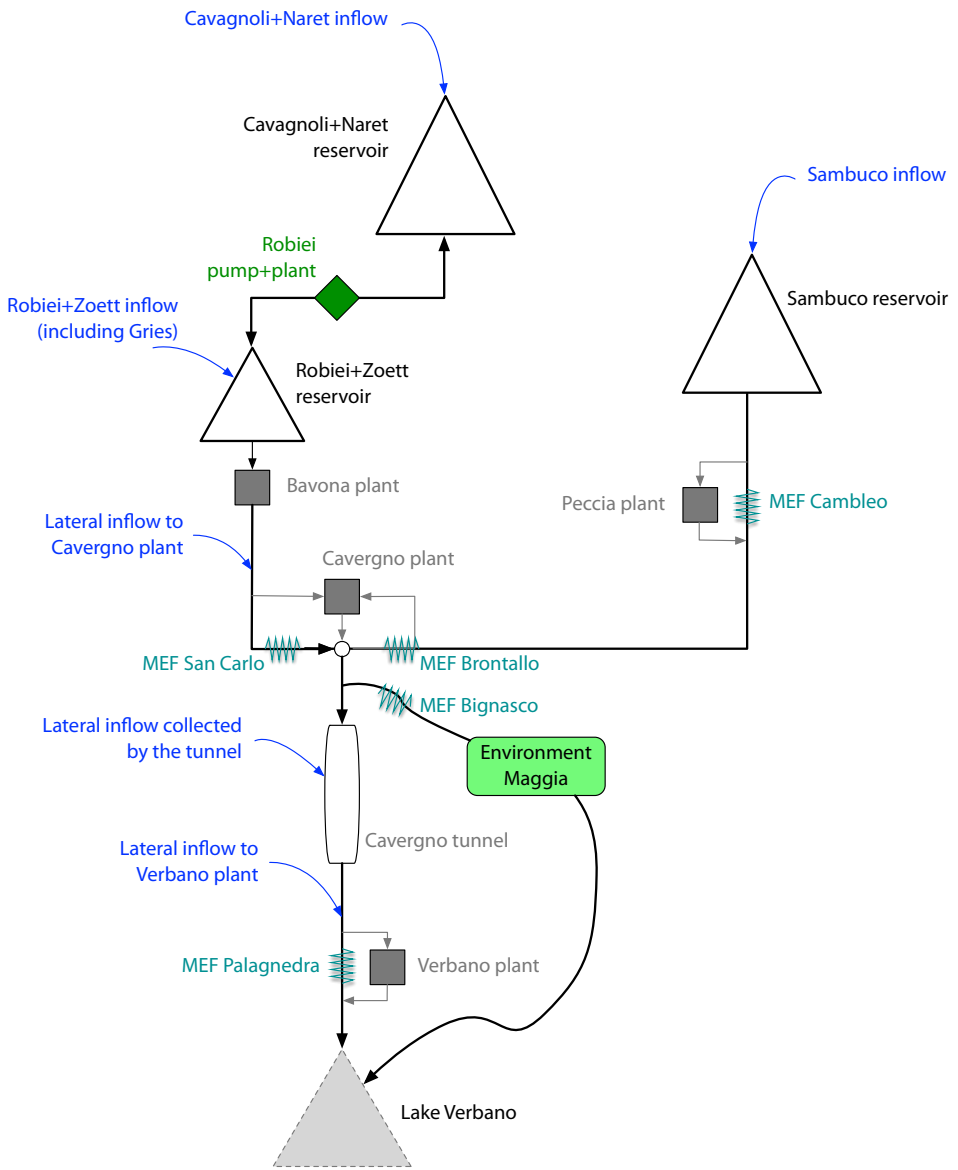
HP-operation model: EMODPS



[Giuliani et al. 2016]

Reservoir operating policies:

- Radial basis functions (170 parameters)
- 1 million function evaluations x 20 random trials
- computational time: **5600 hours** on the ETH cluster

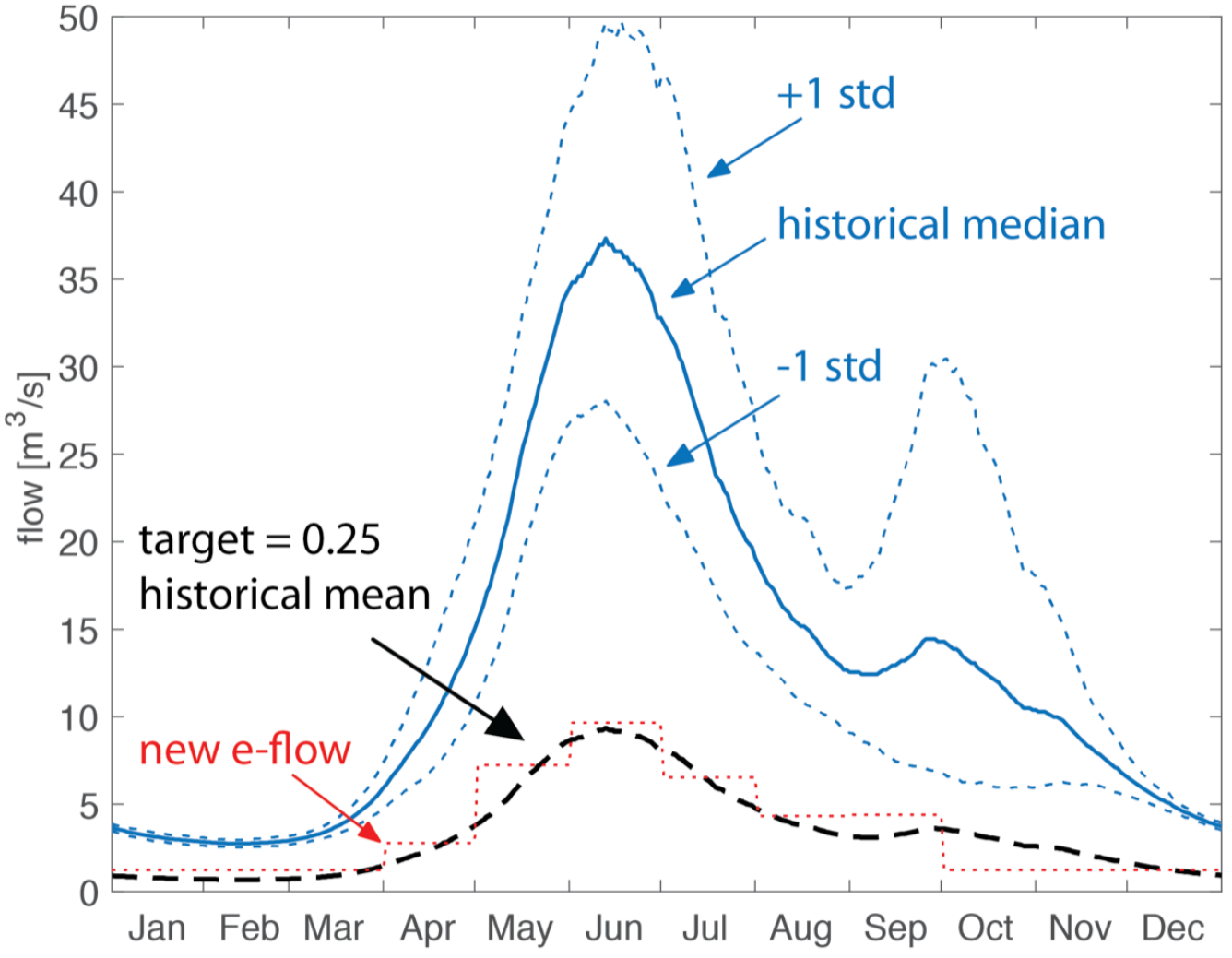


Operational targets

Multi-objective optimization:

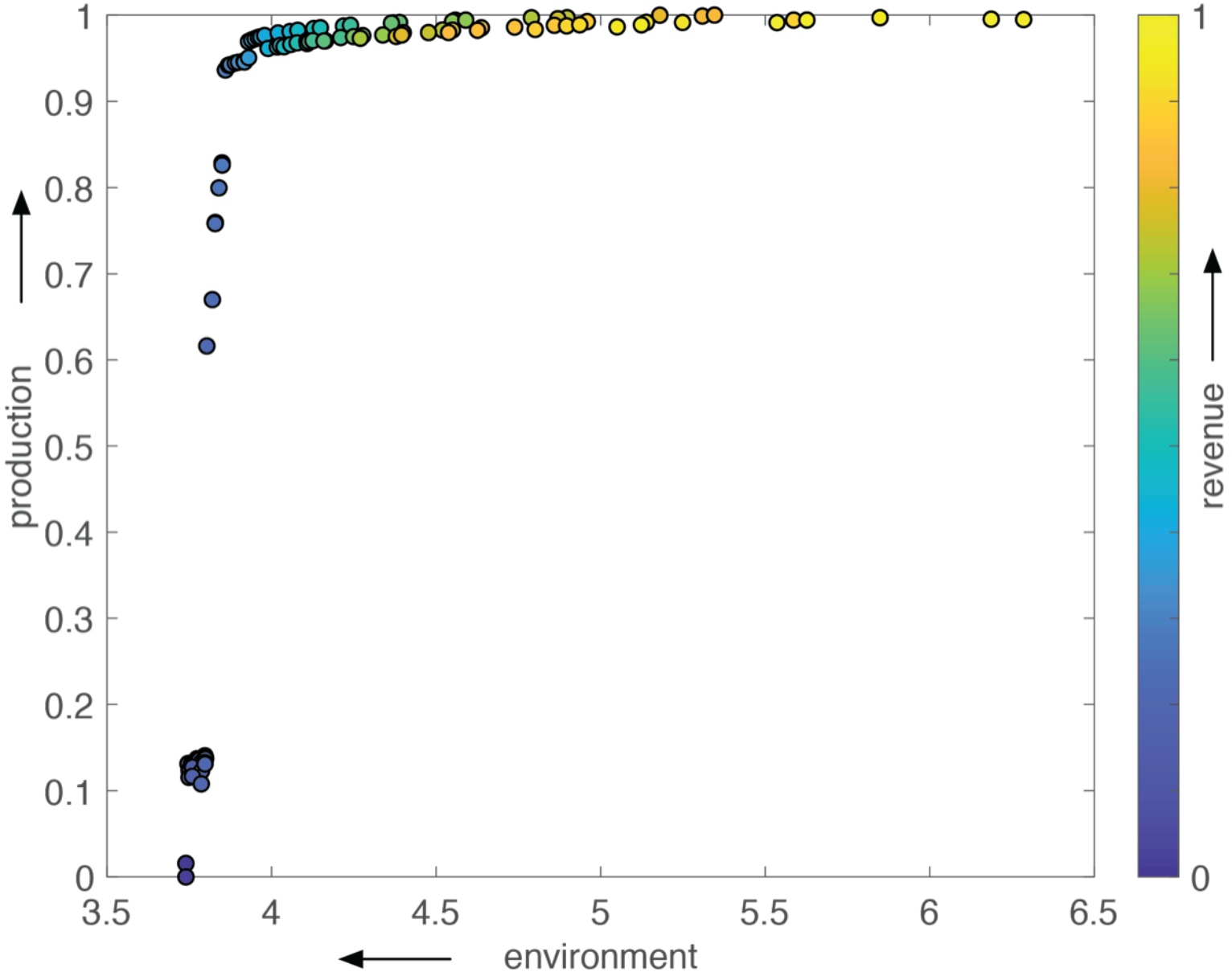
- maximize electricity production
- maximize revenue
- maximize ecosystem quality

How do we measure ecosystem quality?

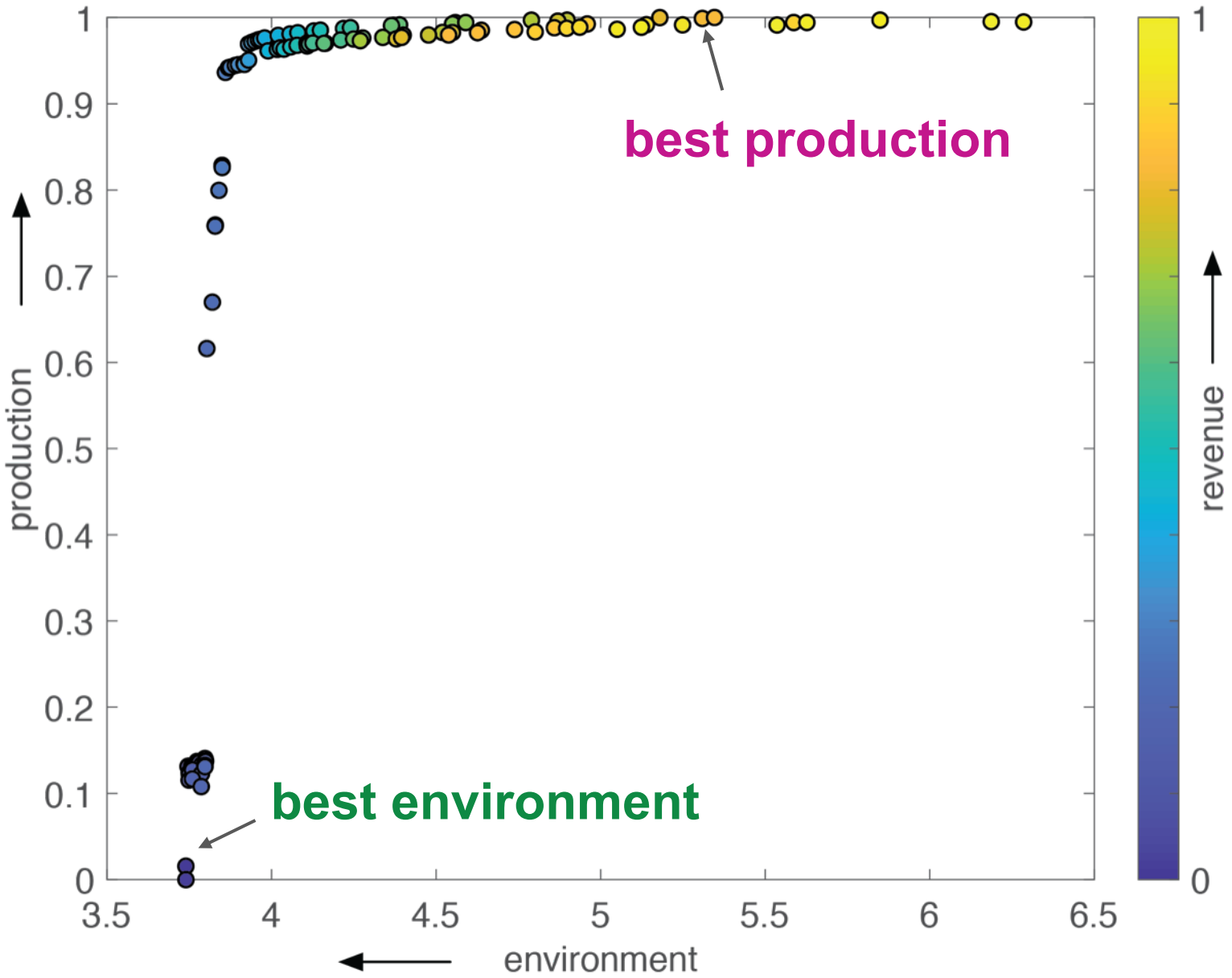


Numerical Results

Trade-off analysis (past e-flow)



Trade-off analysis (past e-flow)



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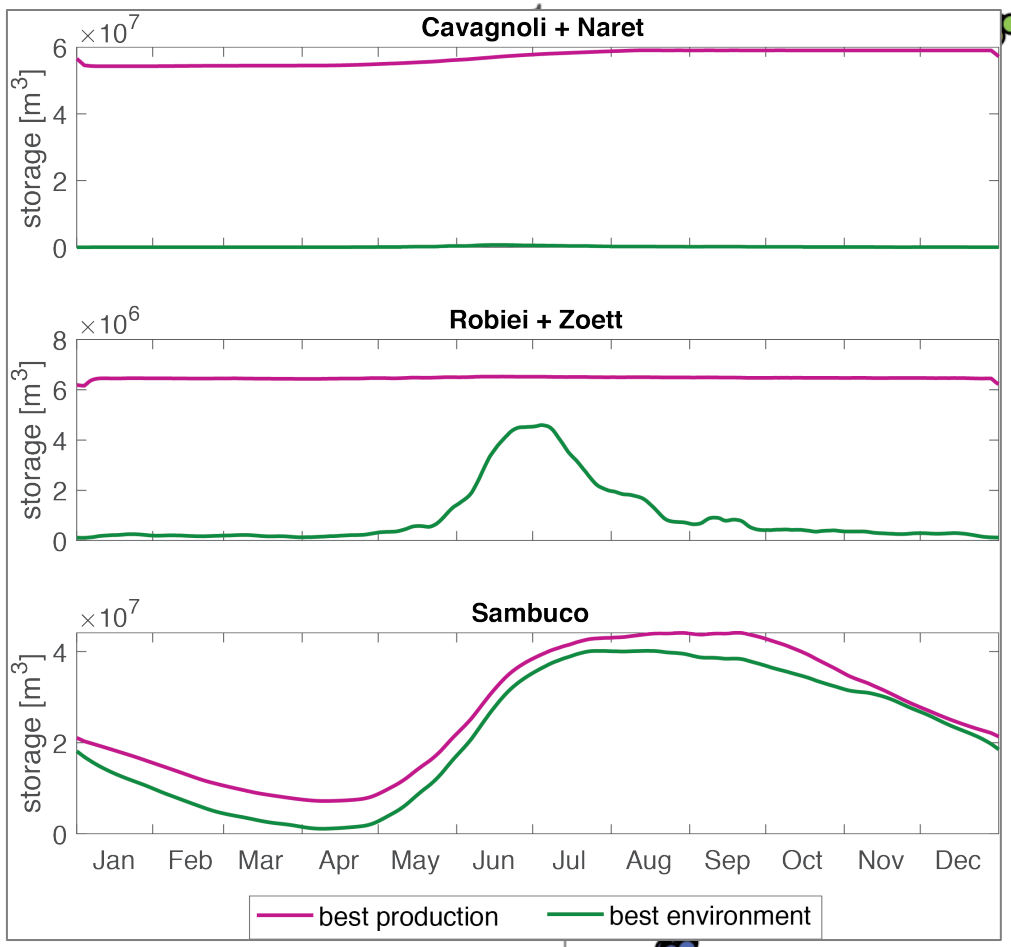
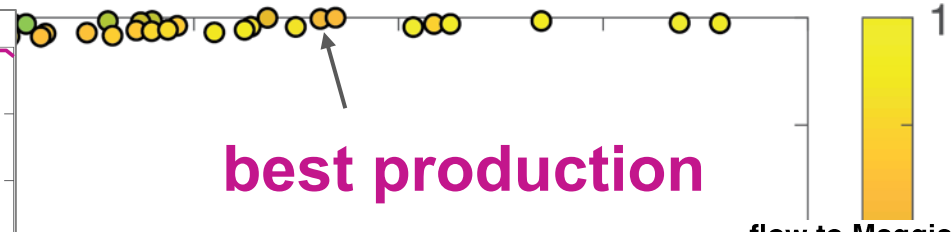
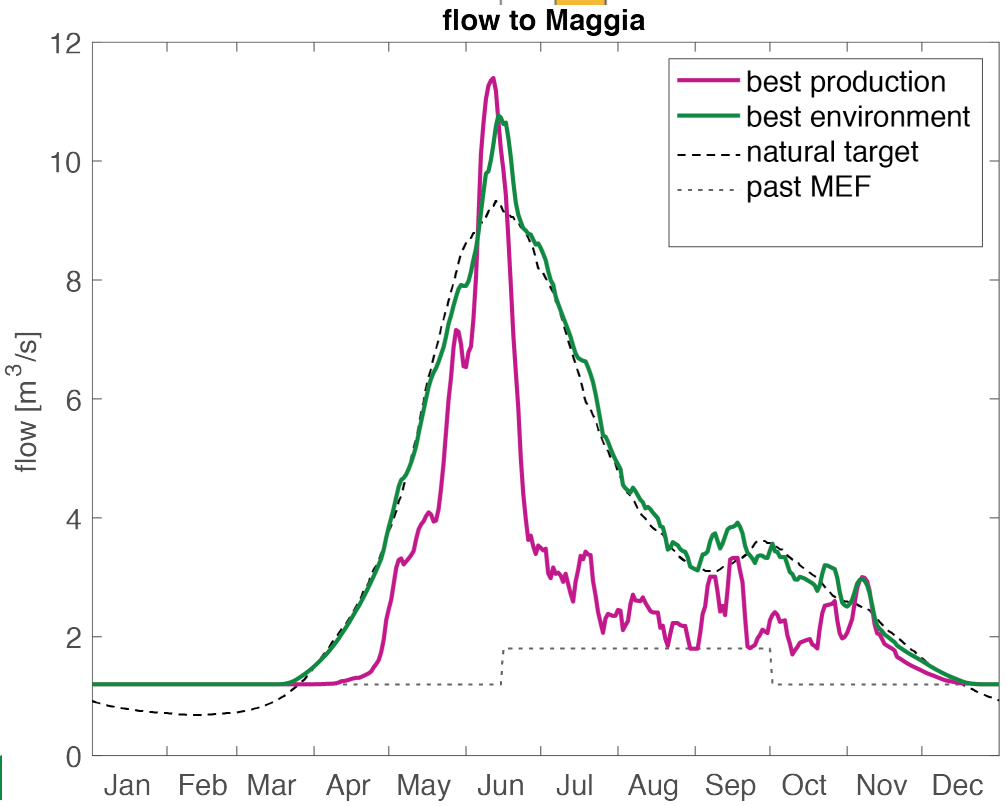
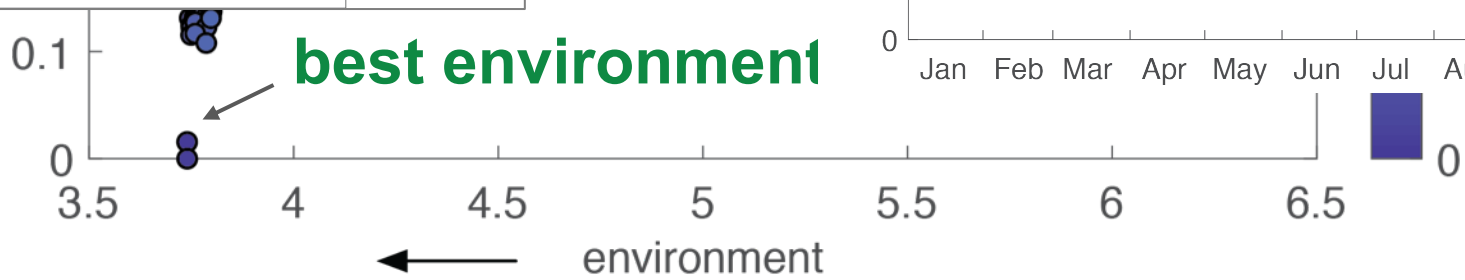
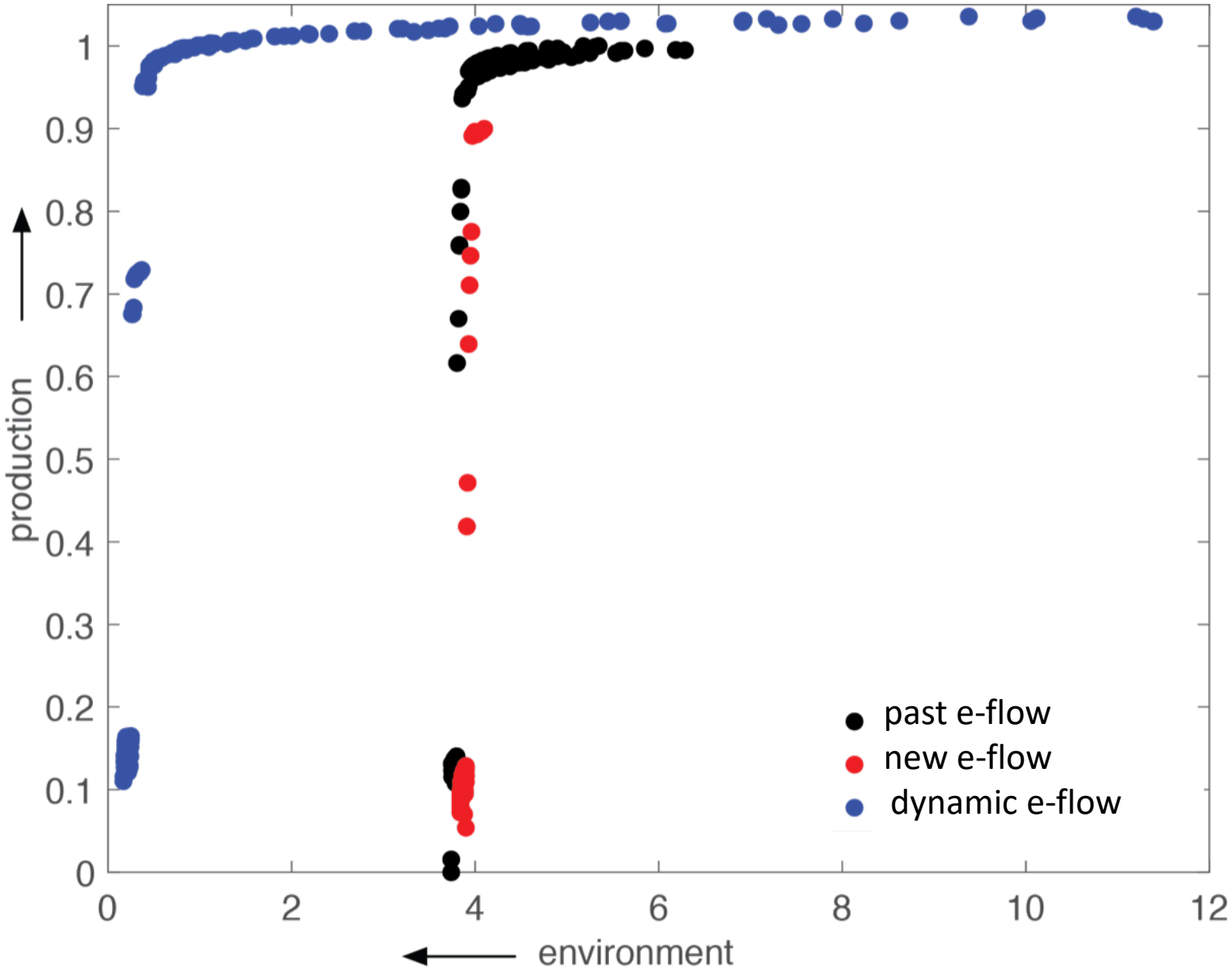








Contrasting past, new, and dynamic e-flow



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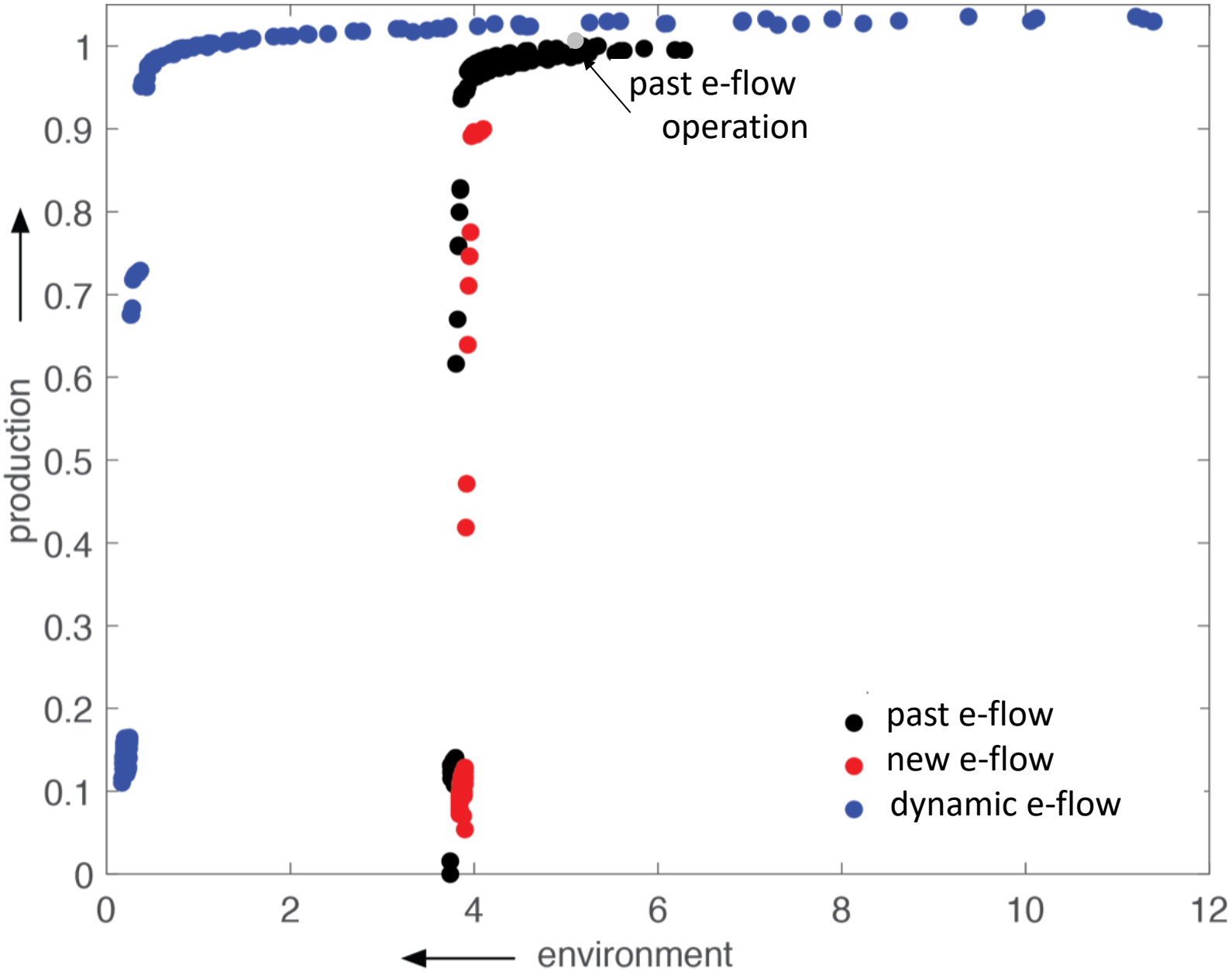

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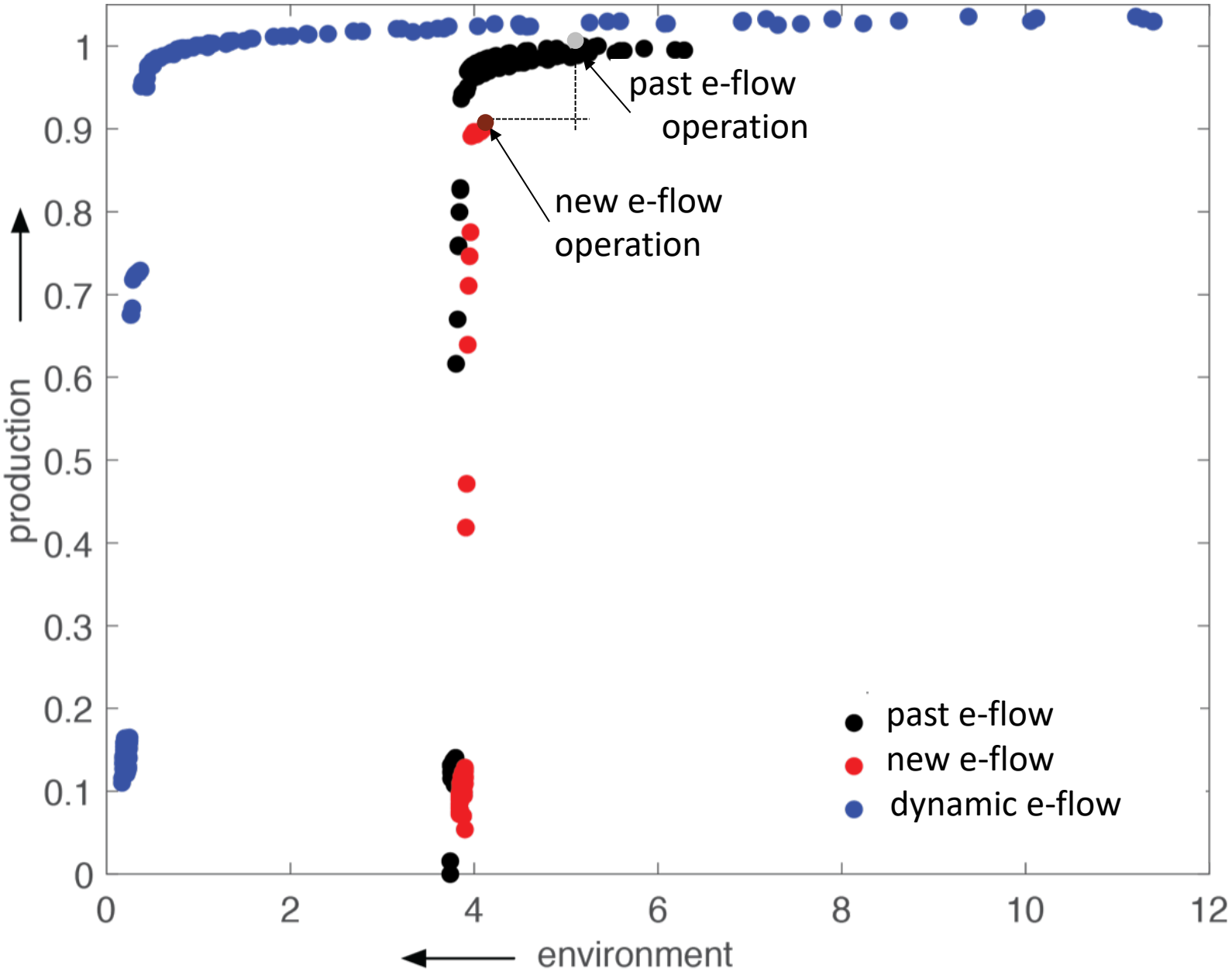
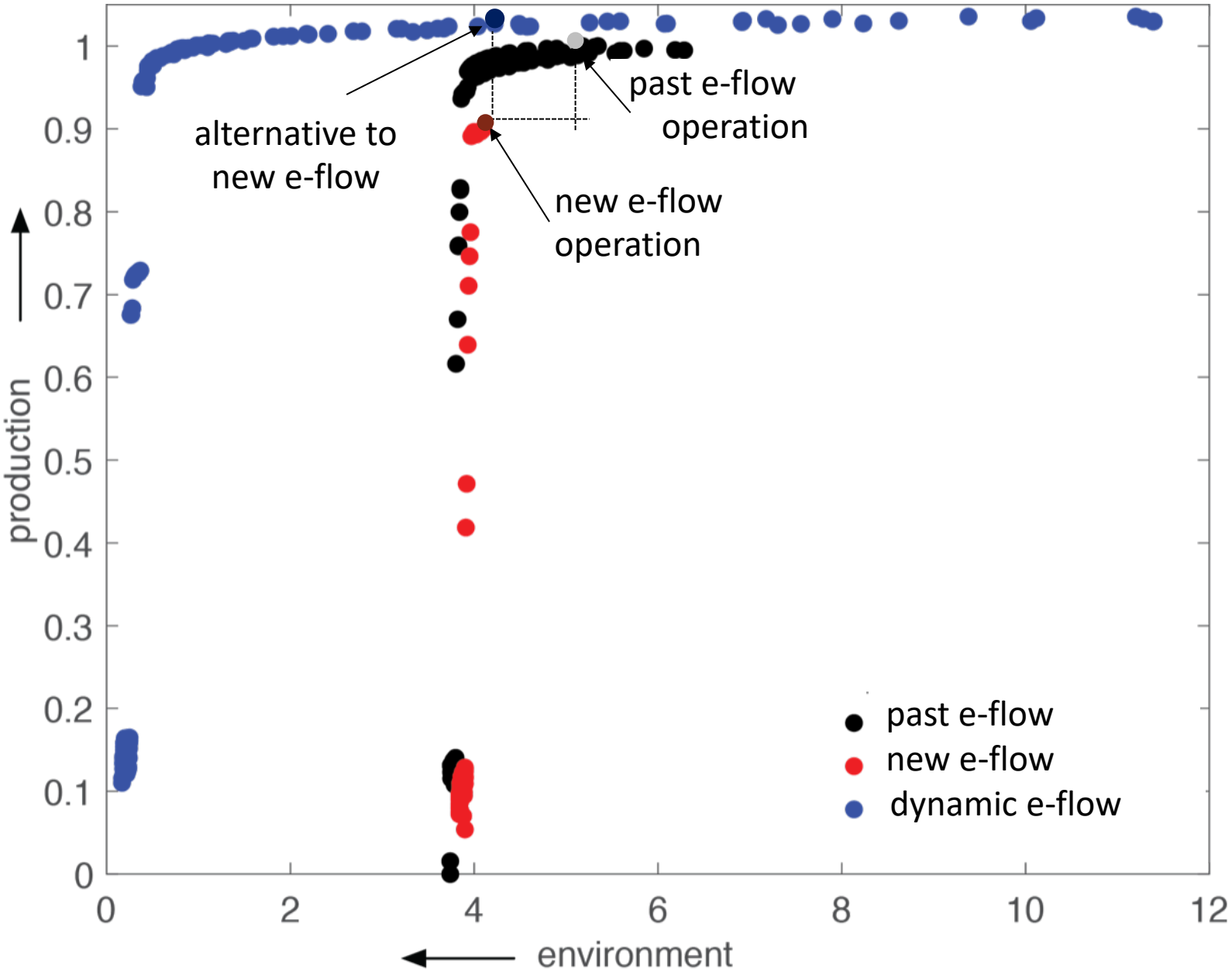


Alternative strategies



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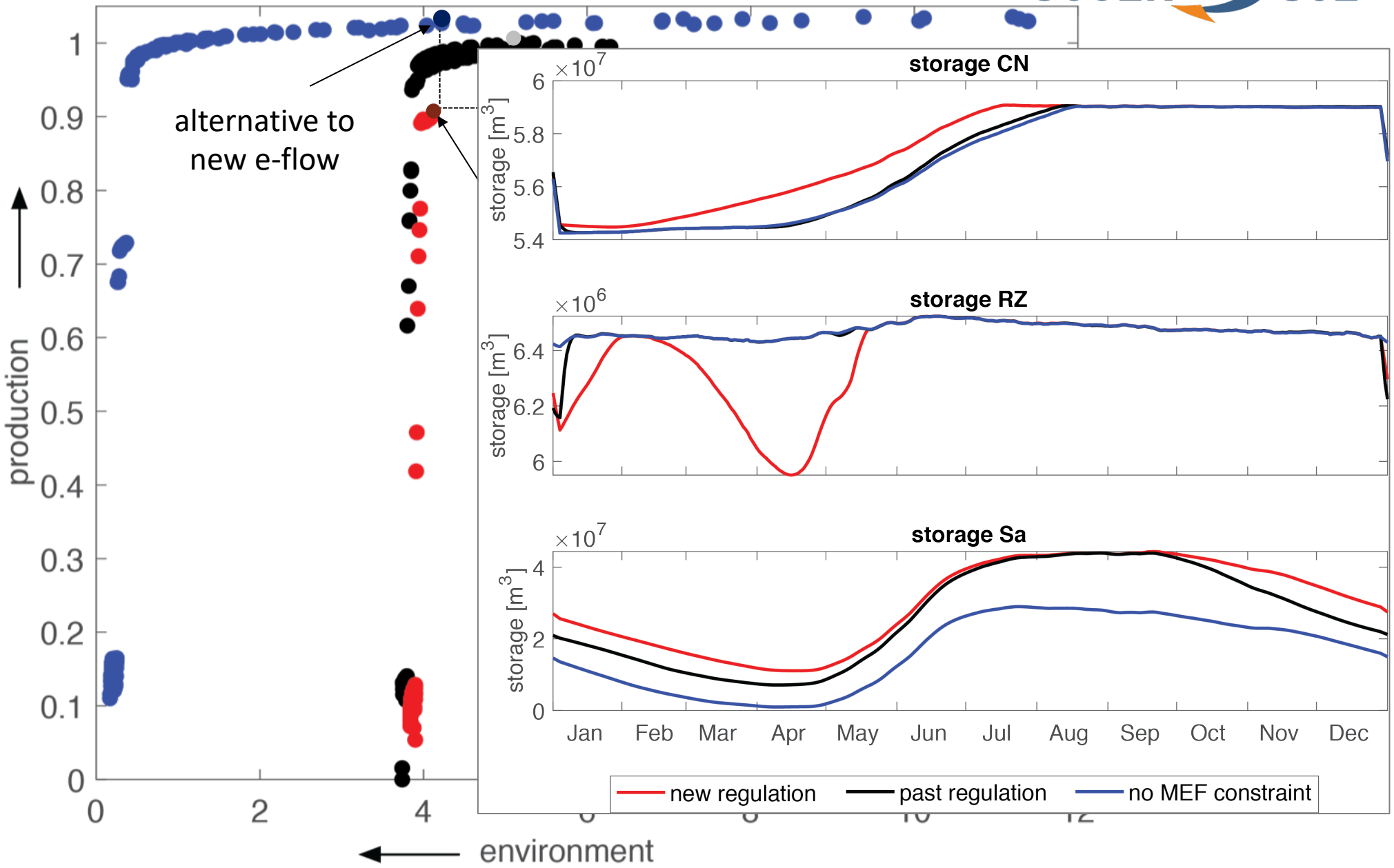
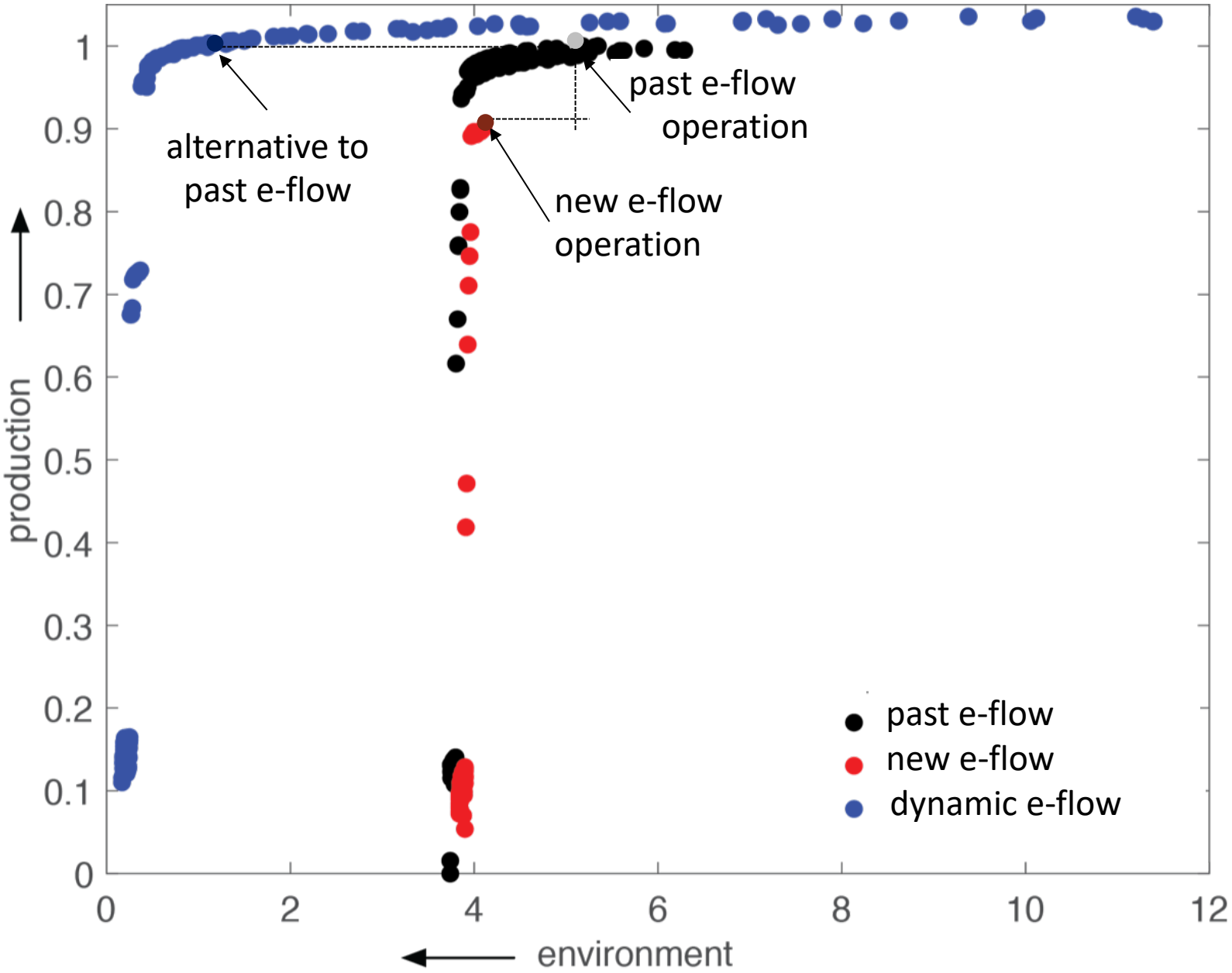


Alternative strategies 2

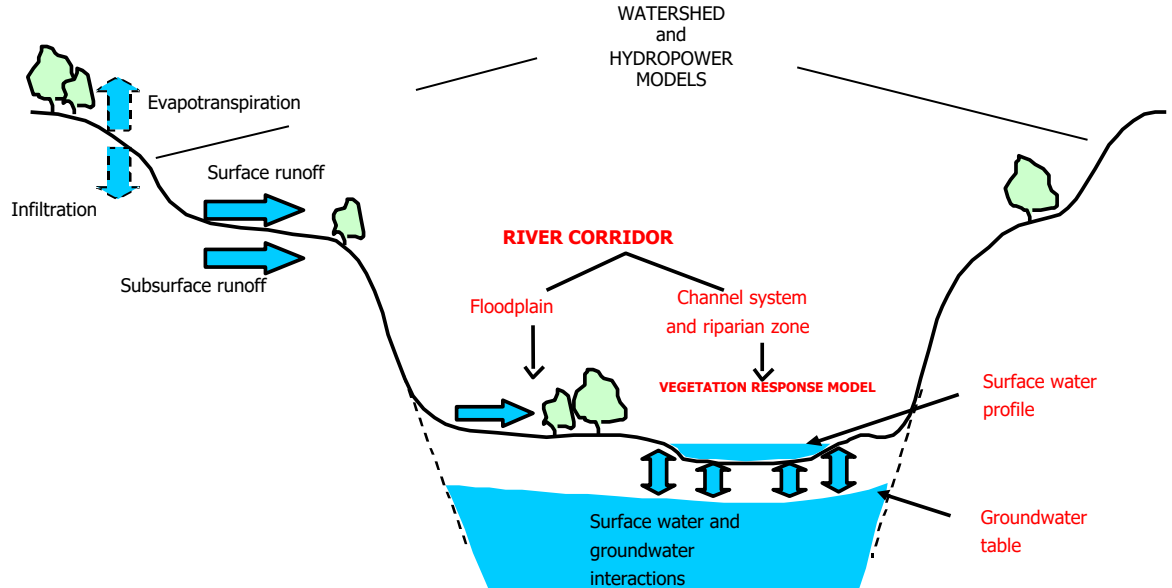


TAKEAWAYS

1. Dynamic e-flow allows for win-win solutions

2. Key aspect is the definition of the environmental operating target

3. Coupling with high resolution ecohydrological model to assess impact on a finer scale



Thank you