

Anticipate faecal contamination in rivers



Yoann Cartier^{1,2}, Arthur Guillot-Le Goff^{1,2}, Rémi Carmigniani², Brigitte Vinçon-Leite¹

¹LEESU, ENPC, Institut Polytechnique de Paris, Univ Paris Est Créteil, Marne-la-Vallée, France

²LHSV, ENPC, Institut Polytechnique de Paris, EDF R&D, Chatou, France

1. Introduction

1.1. Context and stakes

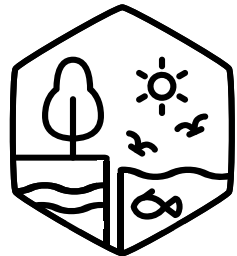
Microbiological contamination in the rivers: fecal indicator bacteria (FIB).



Bathing (quality of life, nature in city)

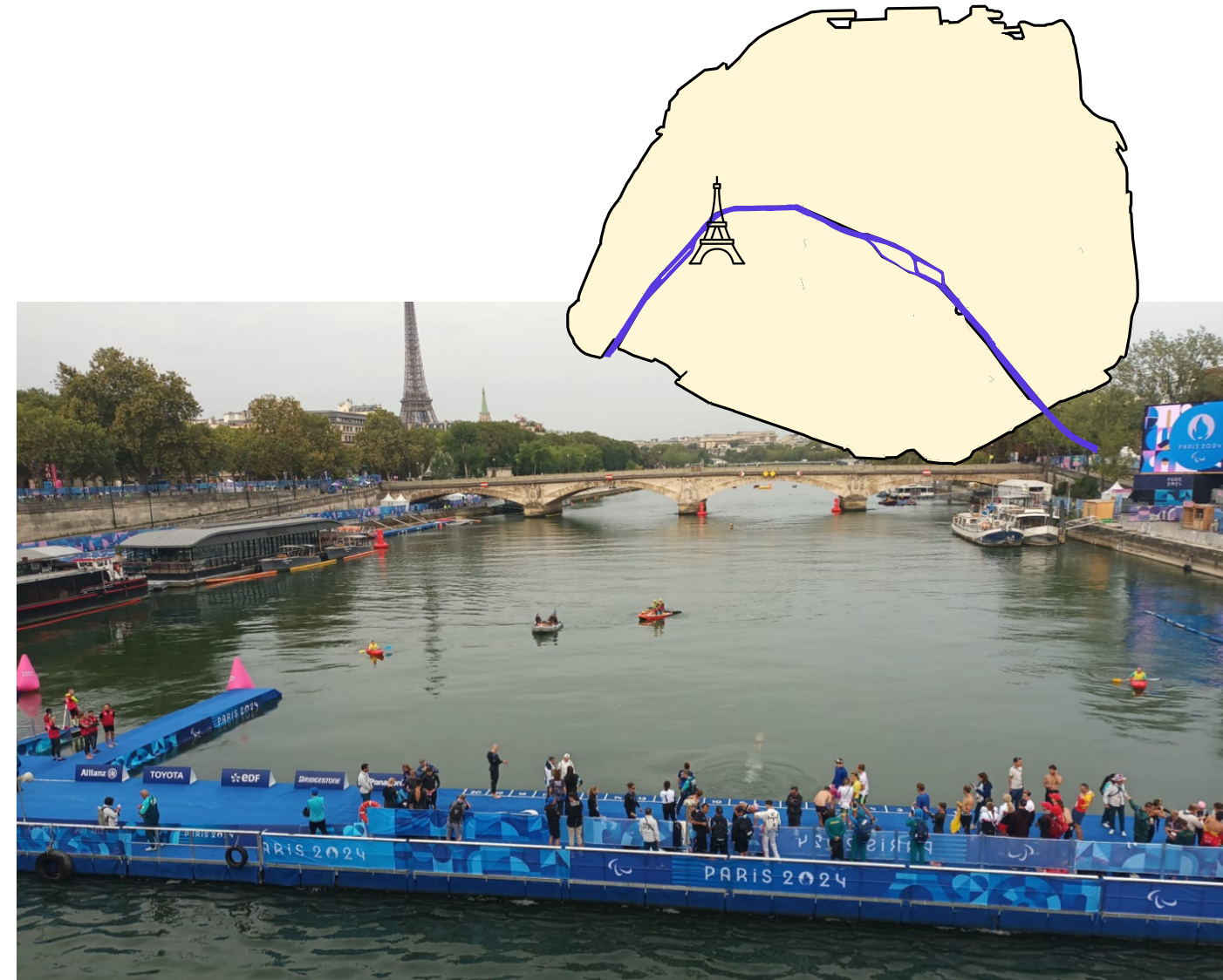


Drinking water pumping



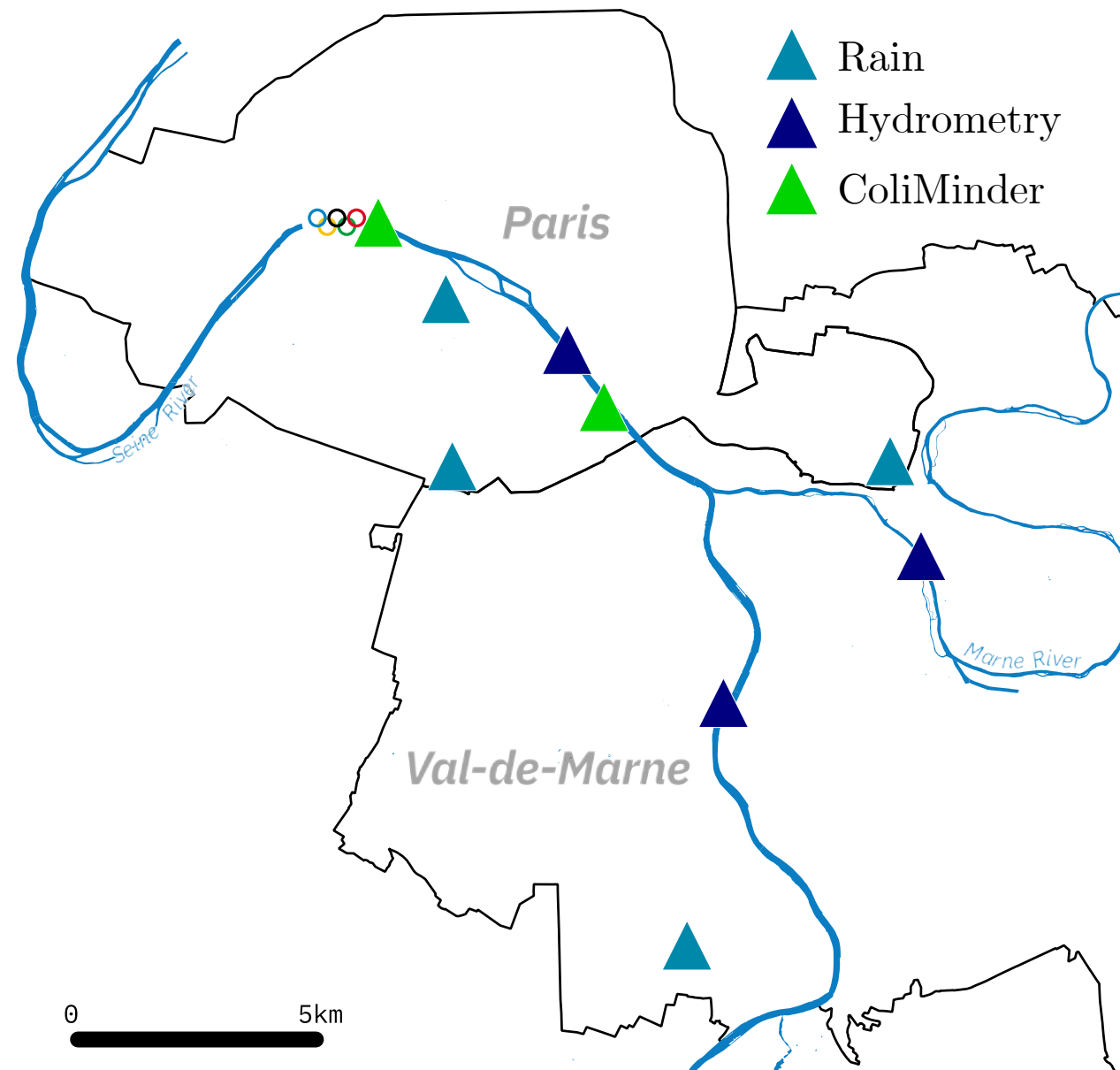
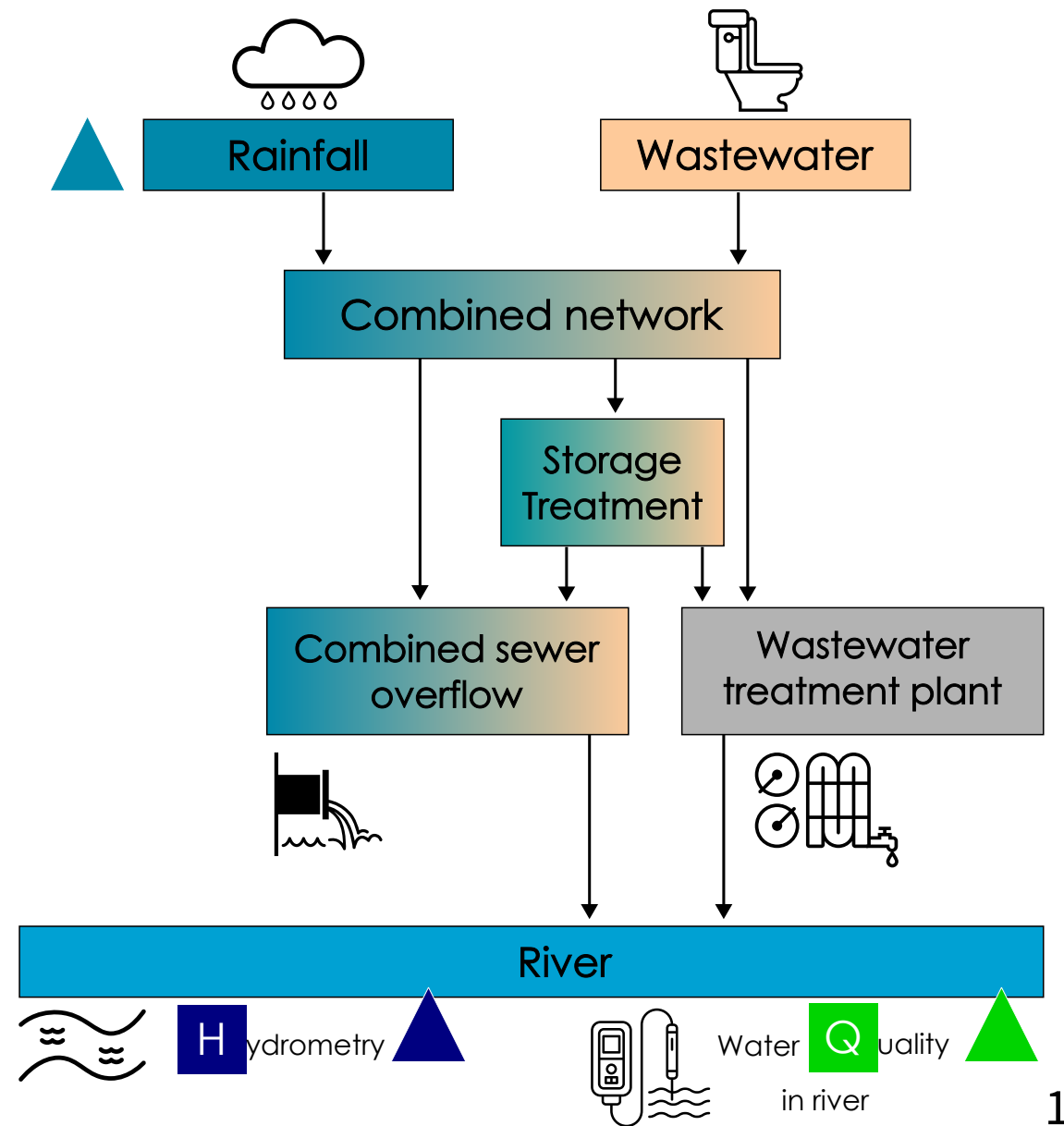
Reduce human pressure on ecosystems

River



Credit : Nicolas Becker, FFTri, 30/08/2024

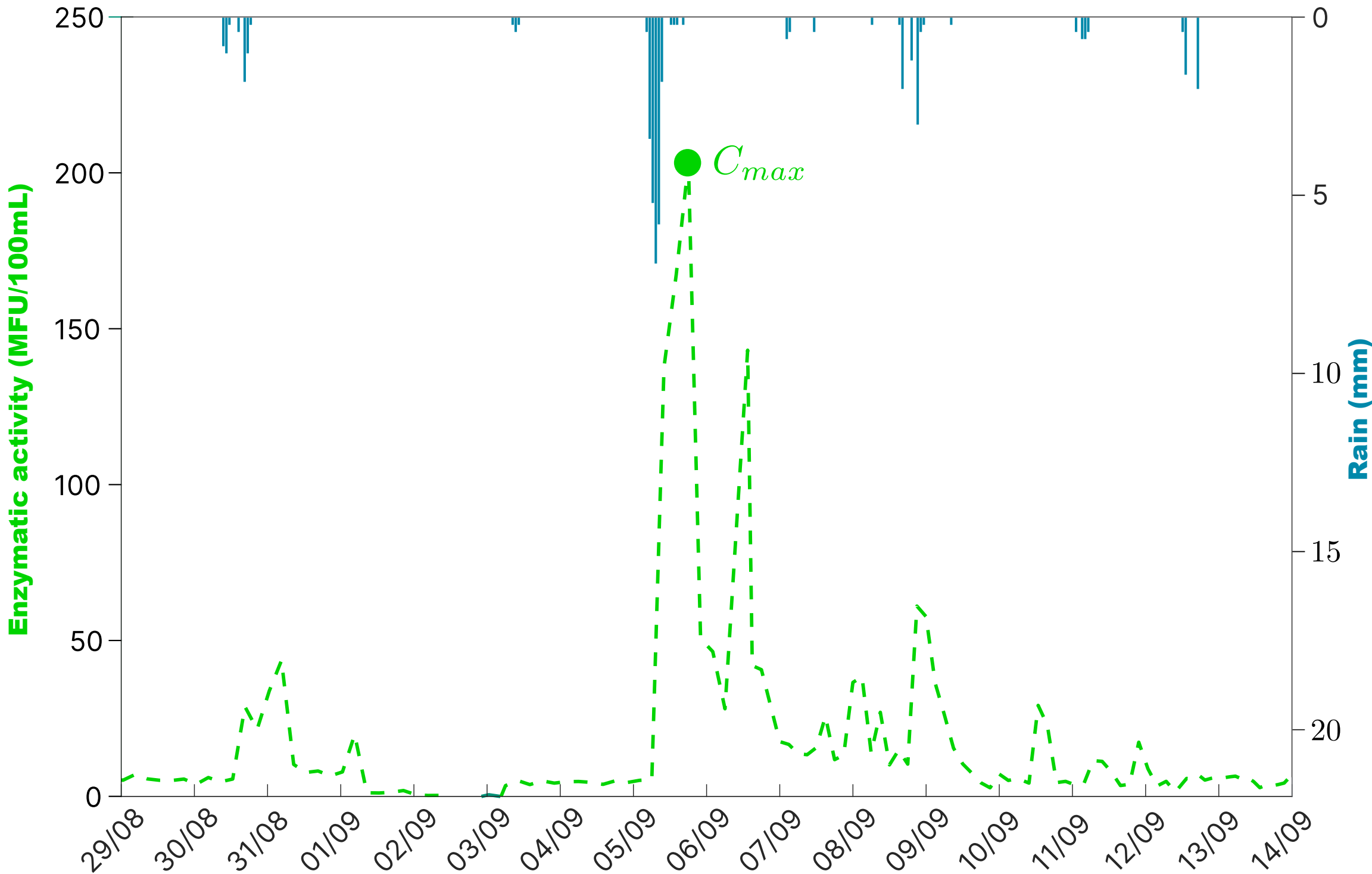
1.2. Objective: anticipate contamination



Objective: Anticipate contamination from rainfall

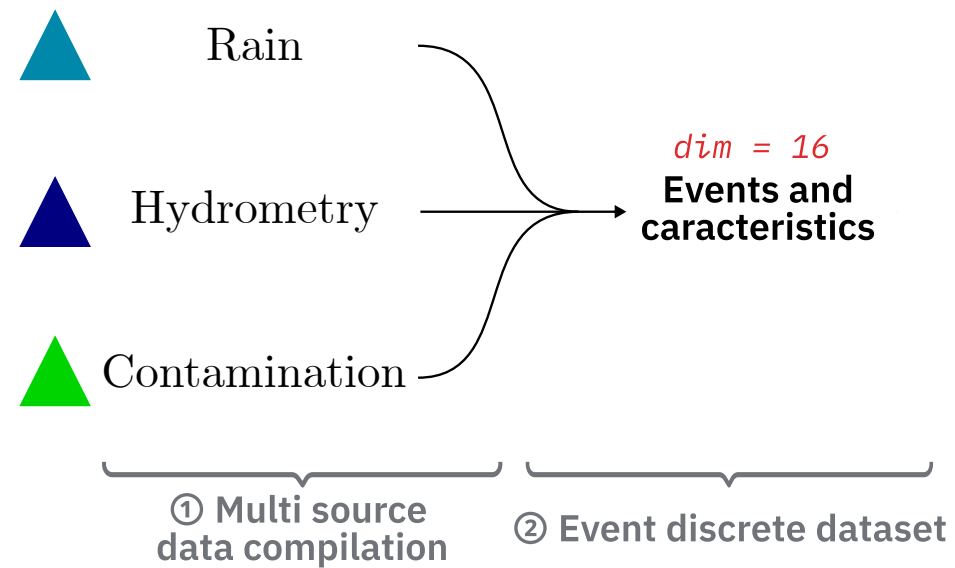
1. reworked from Chocat, Bertrand-Krajewski, and Barraud (2021).

2. Anticipate contamination from rainfall



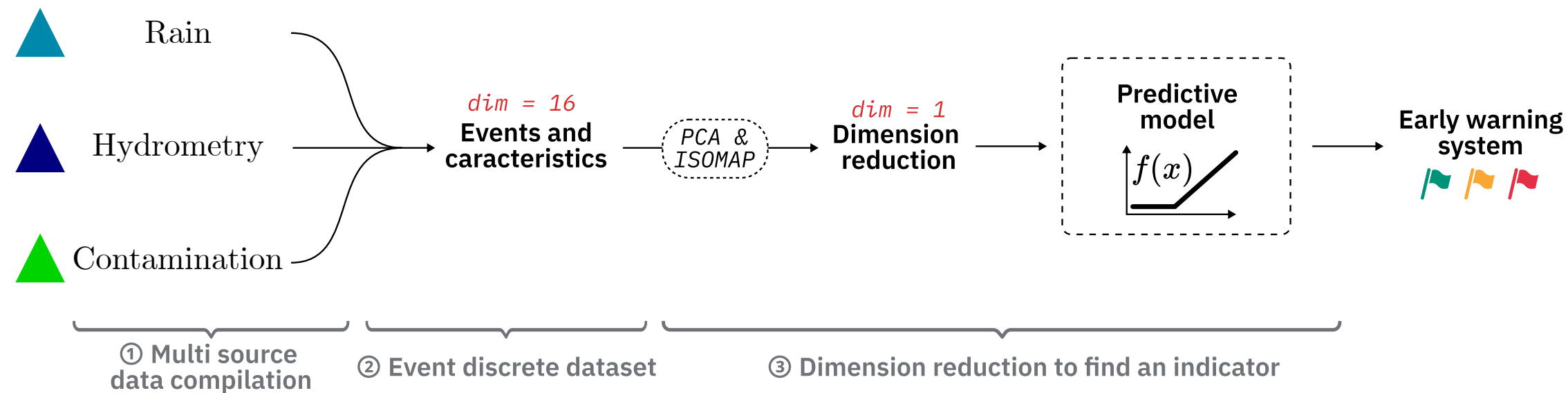
Anticipate C_{max}
from rainfall

2.1. Anticipate contamination: methodology

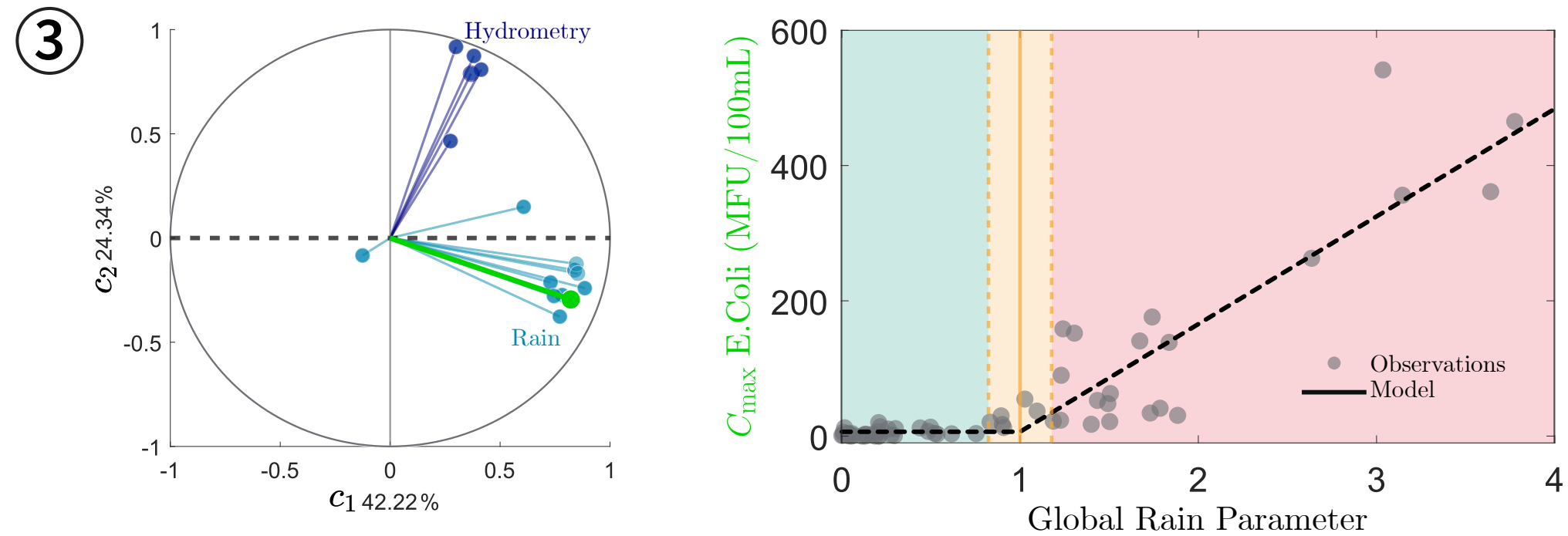


- ② • Rain
 - Depth (mm)
 - Max. intensity (mm/h)
 - Duration (h)
- Hydrometry
 - Flow rate (m^3/s)
 - Water level (m)

2.2. Anticipate contamination: methodology

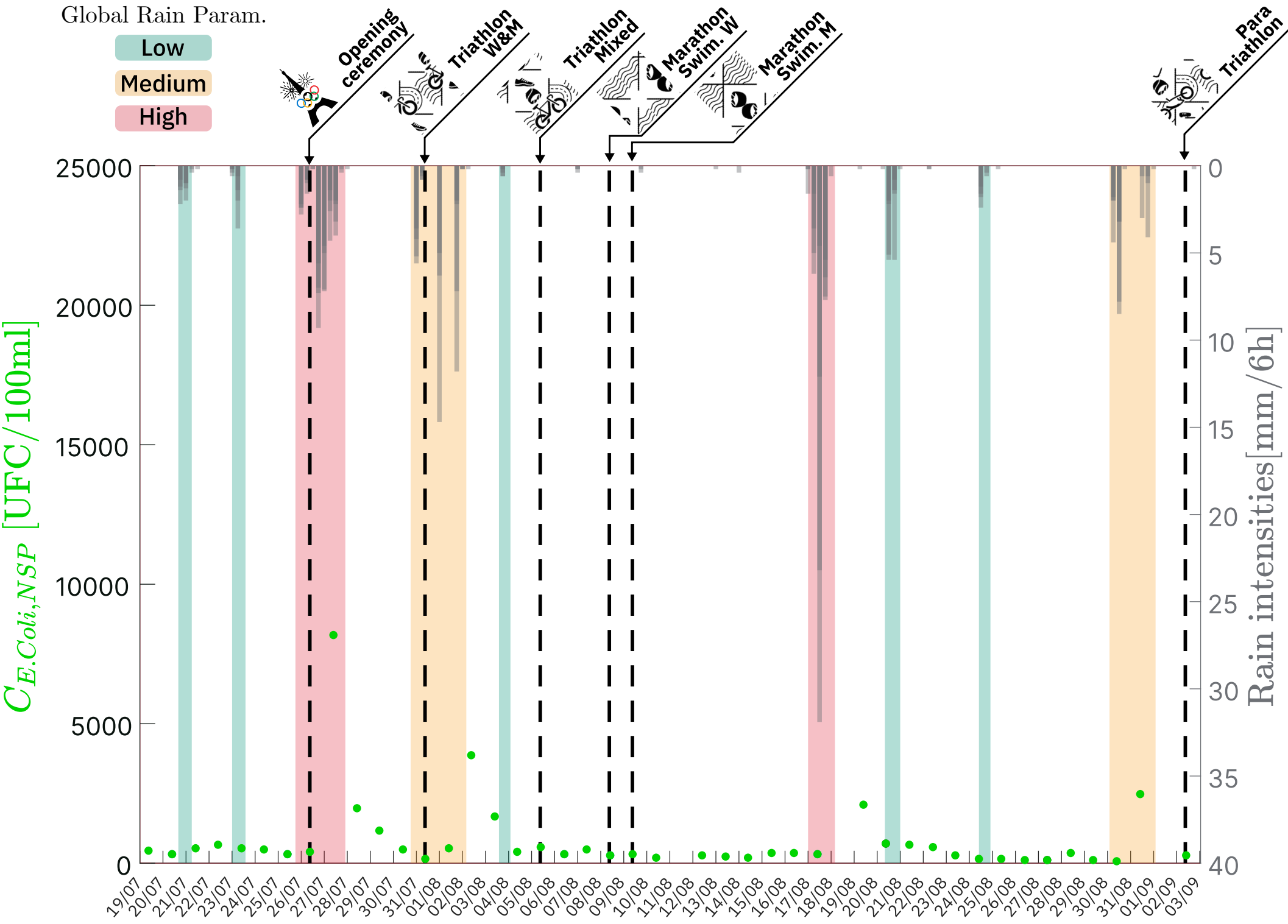


- ② • Rain
- Depth (mm)
 - Max. intensity (mm/h)
 - Duration (h)
- Hydrometry
- Flow rate (m^3/s)
 - Water level (m)



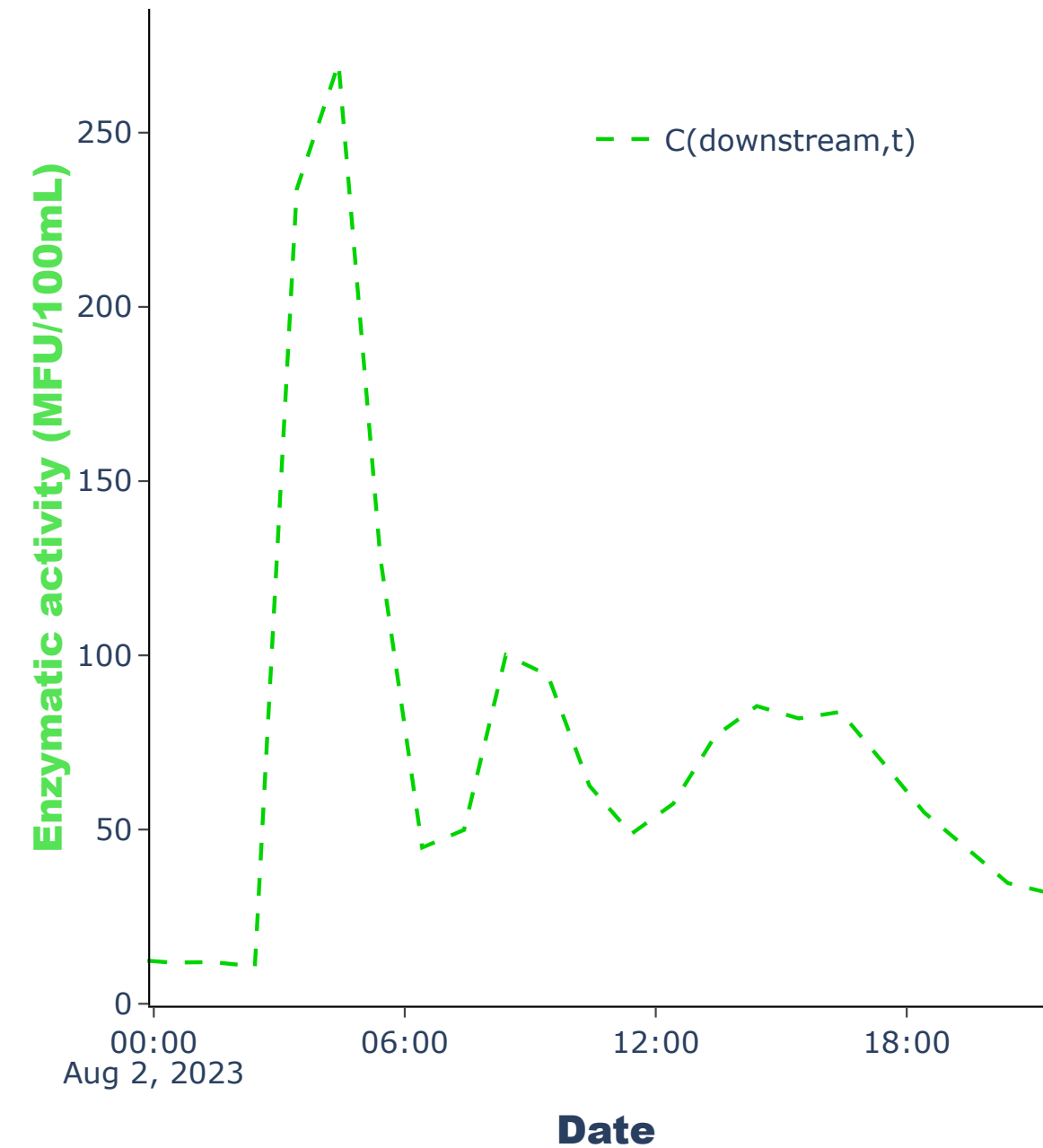
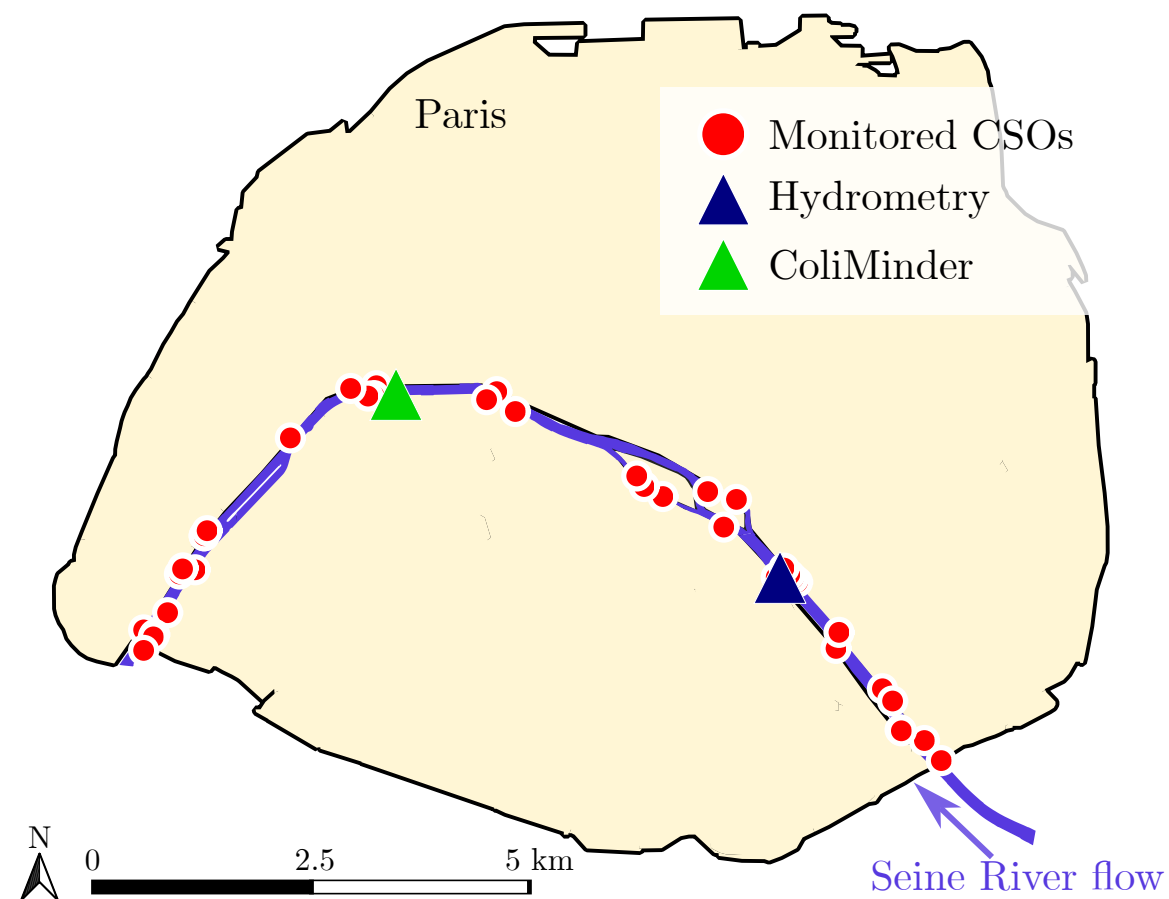
Best=ISOMAP+variables selection

2.3. Anticipate contamination: Paris Olympics

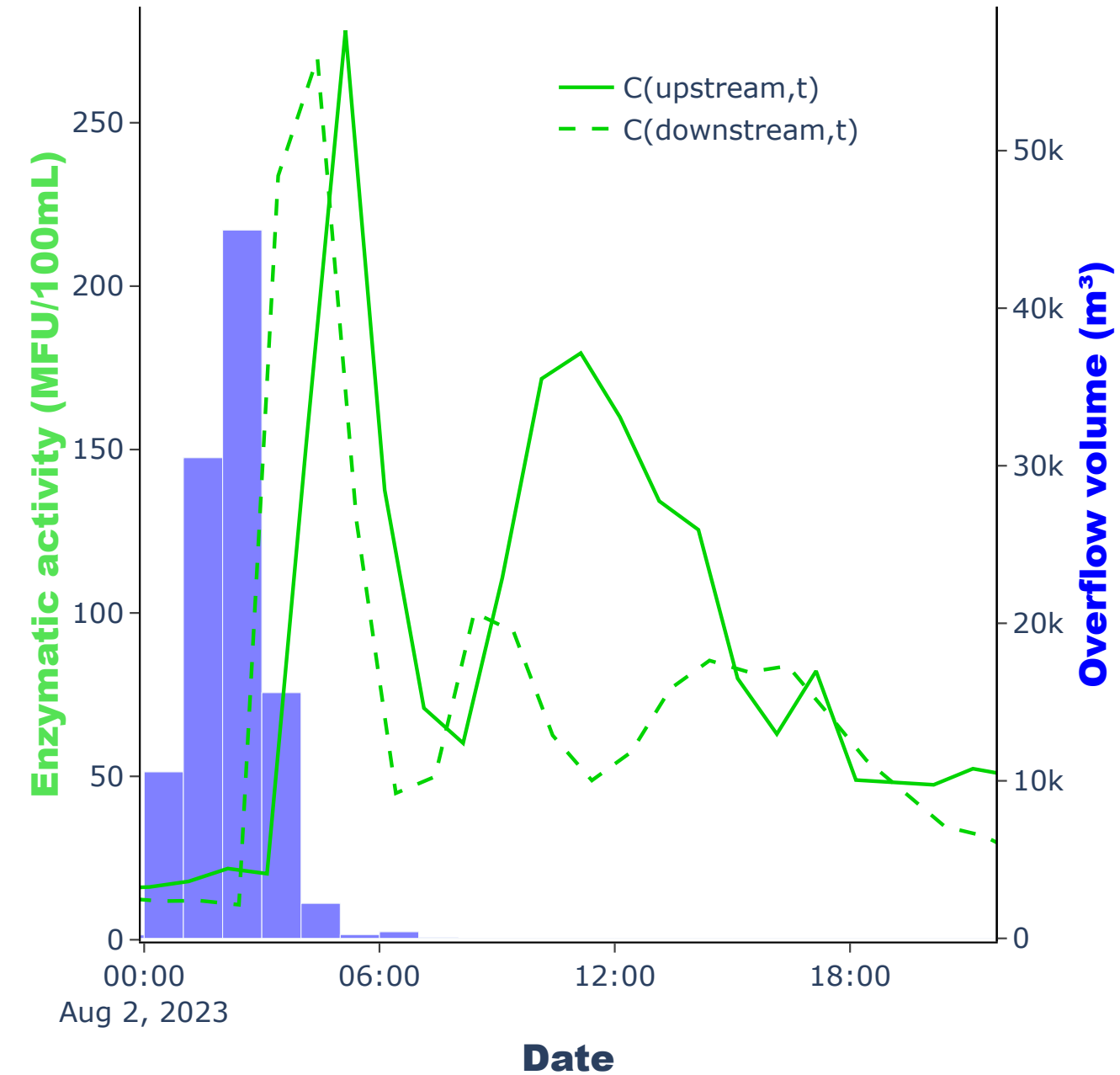
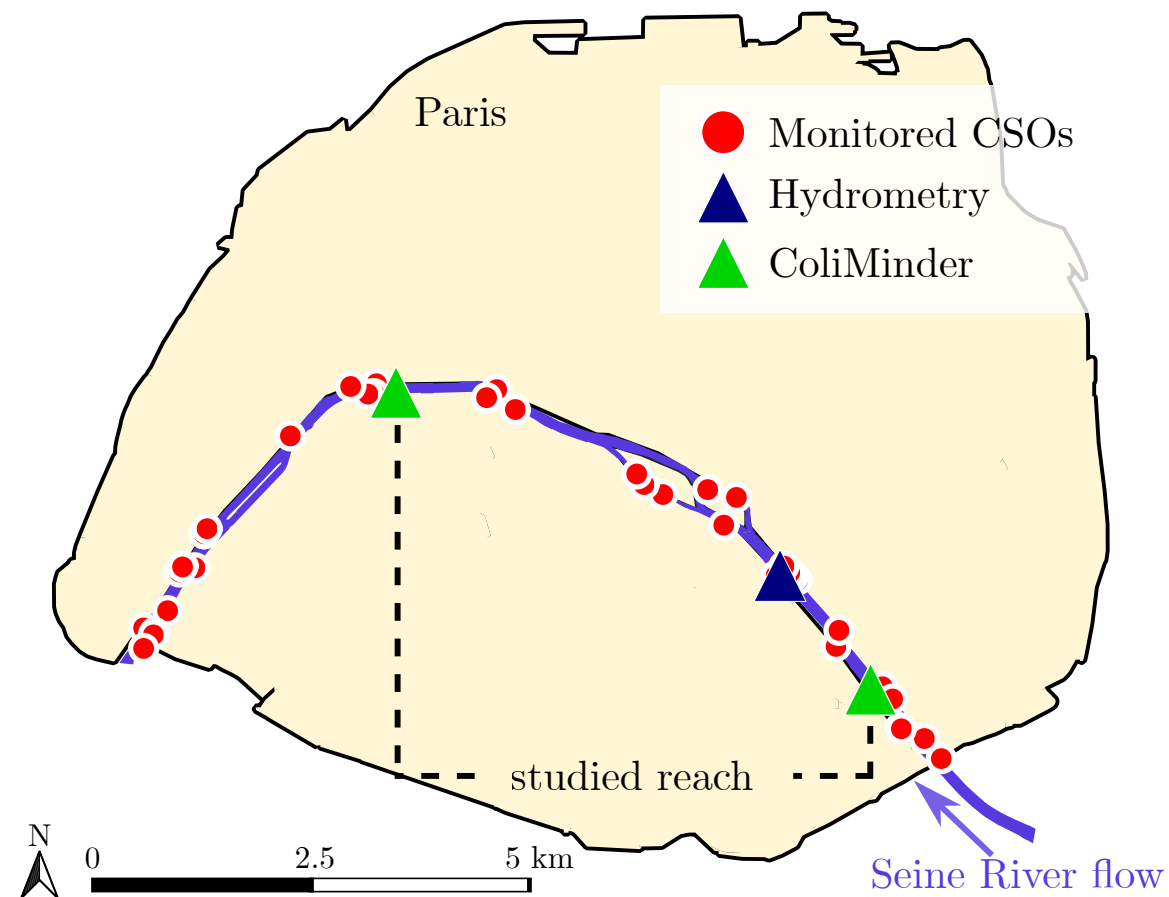


Estimate maximum level
of contamination from
global rain indicator
=
early warning system

3. Where does contamination originate?

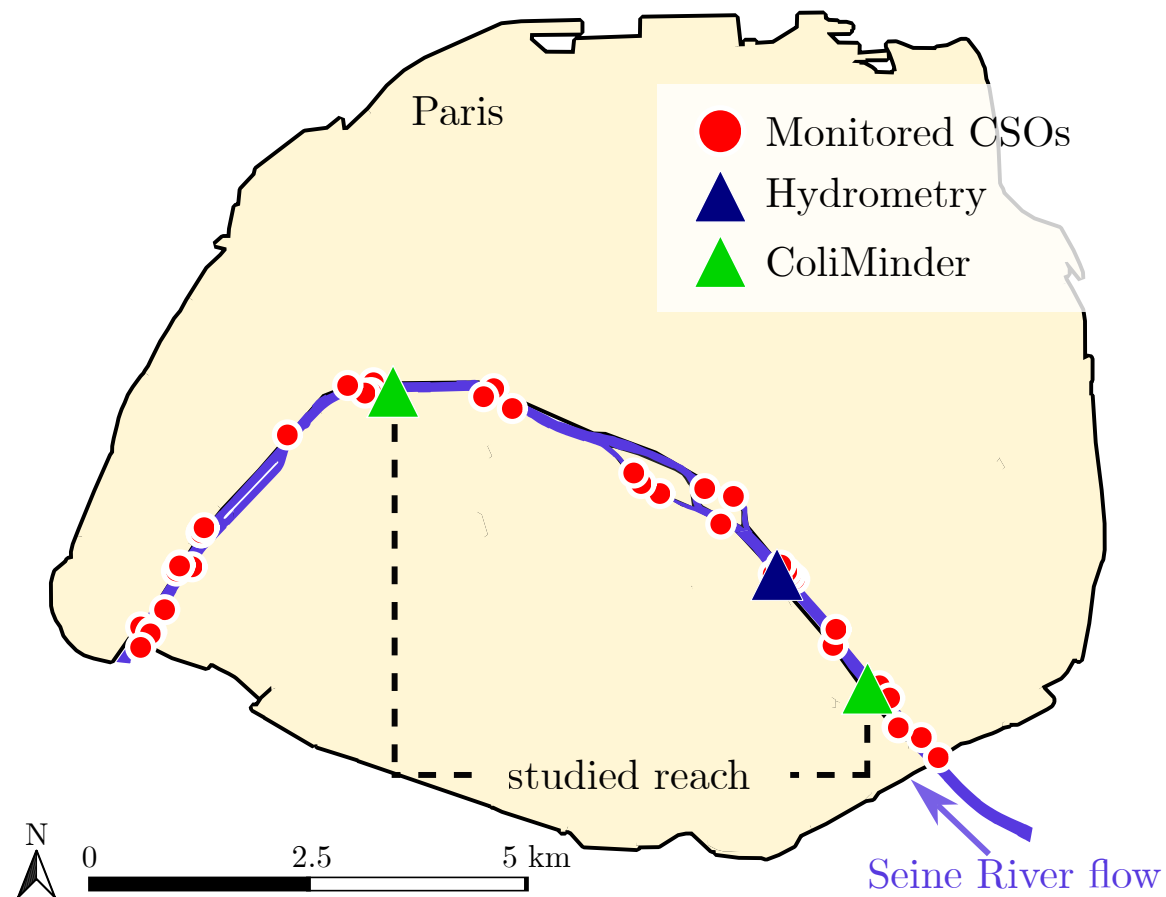


3. Where does contamination originate?



Contamination comes from CSOs

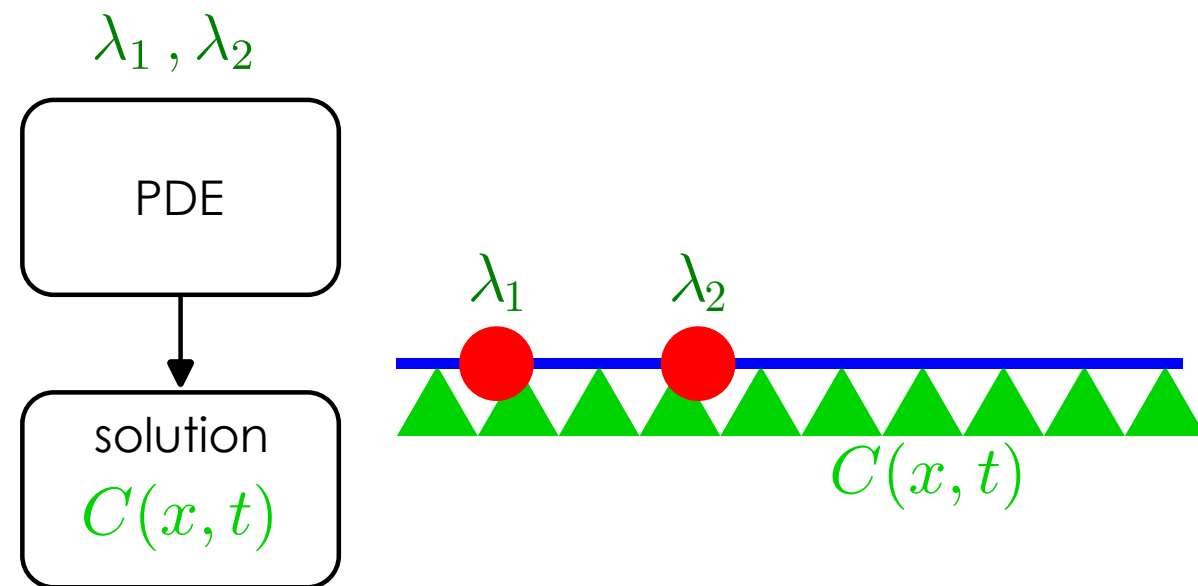
3.1. Bacterial transport model (1D)



$$\frac{\partial C}{\partial t} + \underbrace{u \frac{\partial C}{\partial x}}_{\text{advection}} - \underbrace{D \frac{\partial^2 C}{\partial x^2}}_{\text{diffusion}} + \underbrace{k_T C}_{\text{decay}} = \underbrace{\sum_{i=1}^N \frac{\lambda_i s_i(t)}{A} \delta(x - x_i)}_{\text{CSOs}}$$

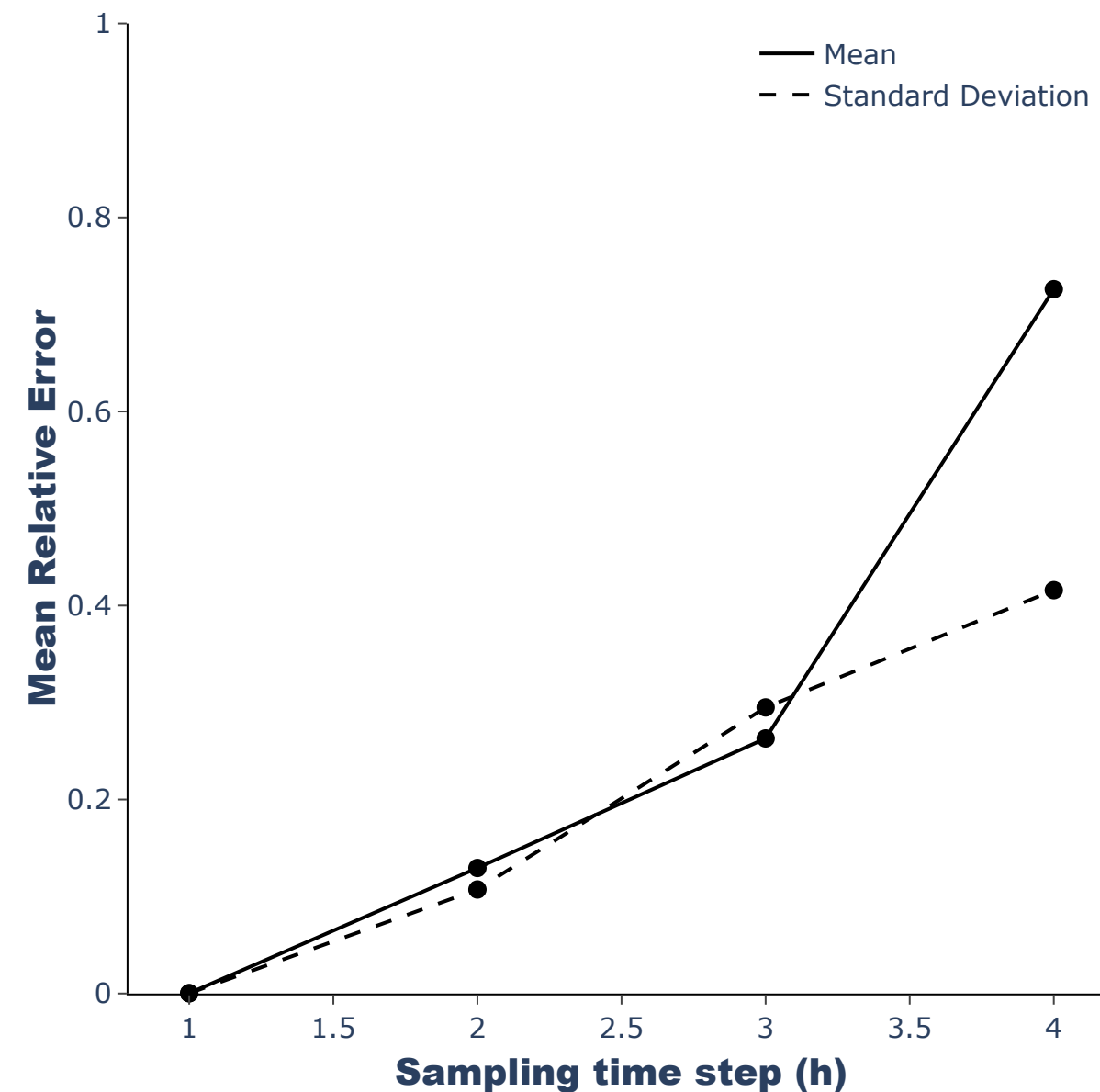
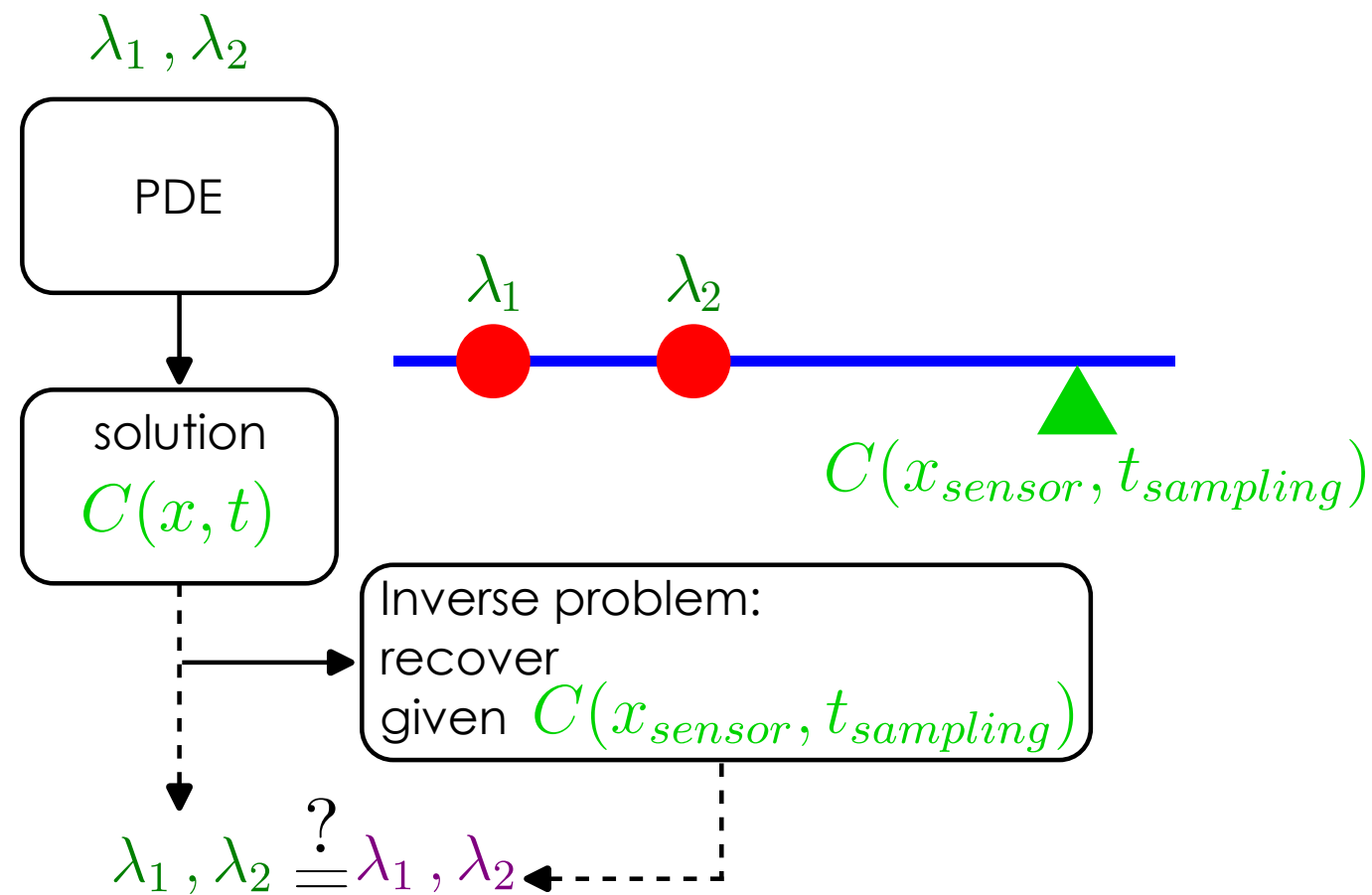
At what time step to measure C to identify CSO concentration λ_i ?

3.2. Synthetic data with known concentration



framework using Rackauckas and Nie ([2017](#))

3.3. Source indentifiability regarding time step



Inverse method: Deconvolution.

Different identifiability regimes → can be used to advice operators

$$\text{Relative error} = \frac{1}{N} \sum_{i=1}^N \frac{|\lambda_{inv_i} - \lambda_{ref_i}|}{\lambda_{ref_i}}$$

4. Conclusion and prospects

Our work provides baselines

- Early warning system of contamination events from rainfall.
- Inverse method to retrieve CSO concentration from river concentration measurements.

How AI could be integrated into our work ?

- Supervised dimensionality reduction, e.g.: Partial Least Squares (PLS) and kernel PLS.
- Physics Informed Neural Networks (PINNs): transport and source identification at the same time.
- Main limitation: data availability.

Thanks for your attention

Arthur Guillot-Le Goff (arthur.guillot-legoff@enpc.fr), Yoann Cartier (yoann.cartier@enpc.fr)

Explanatory variables



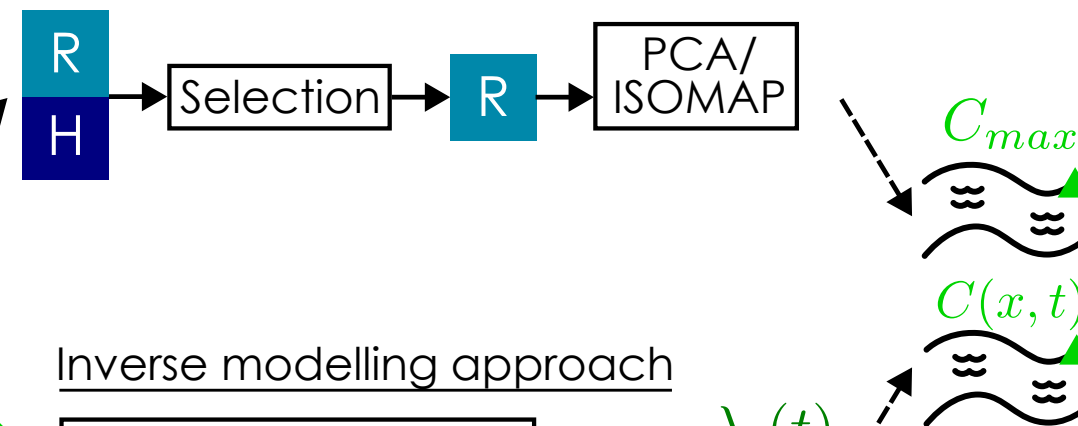
Variables of interest



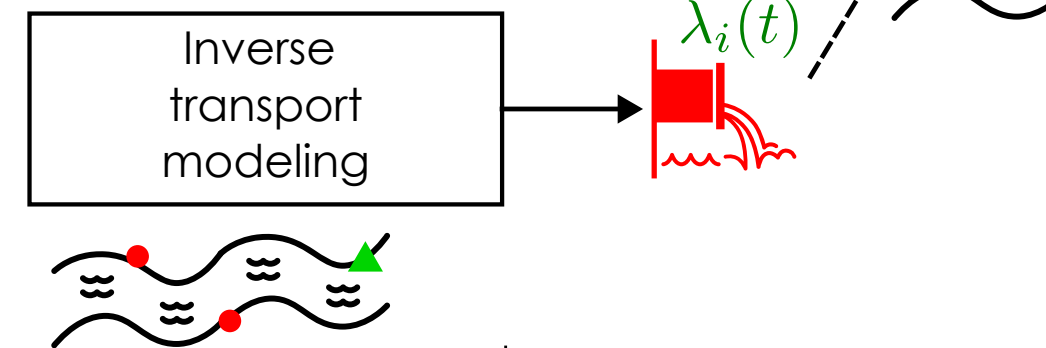
Event definition



Dimension reduction approach



Inverse modelling approach



$$CSO_i = \lambda_i(t) s_i(t) \delta(x - x_i) \quad \left| \begin{array}{l} \lambda_i(t): \text{fecal concentration in CSO} \\ s_i(t): \text{CSO flow towards river} \end{array} \right.$$

Acknowledgment: City of Paris for the overflow and the water quality data

5. References

- Chocat, Bernard, Jean-Luc Bertrand-Krajewski, and Sylvie Barraud. 2021. “Pollution Des Rejets Urbains de Temps de Pluie.” In *Techniques de l’Ingénieur*, article W 6800 v2, 38 p.
- Rackauckas, Christopher, and Qing Nie. 2017. “DifferentialEquations.jl – A Performant and Feature-Rich Ecosystem for Solving Differential Equations in Julia.” *Journal of Open Research Software* 5 (1). <https://doi.org/10.5334/jors.151>.