Monitoring and modelling of aquatic environments how is artificial intelligence used ?

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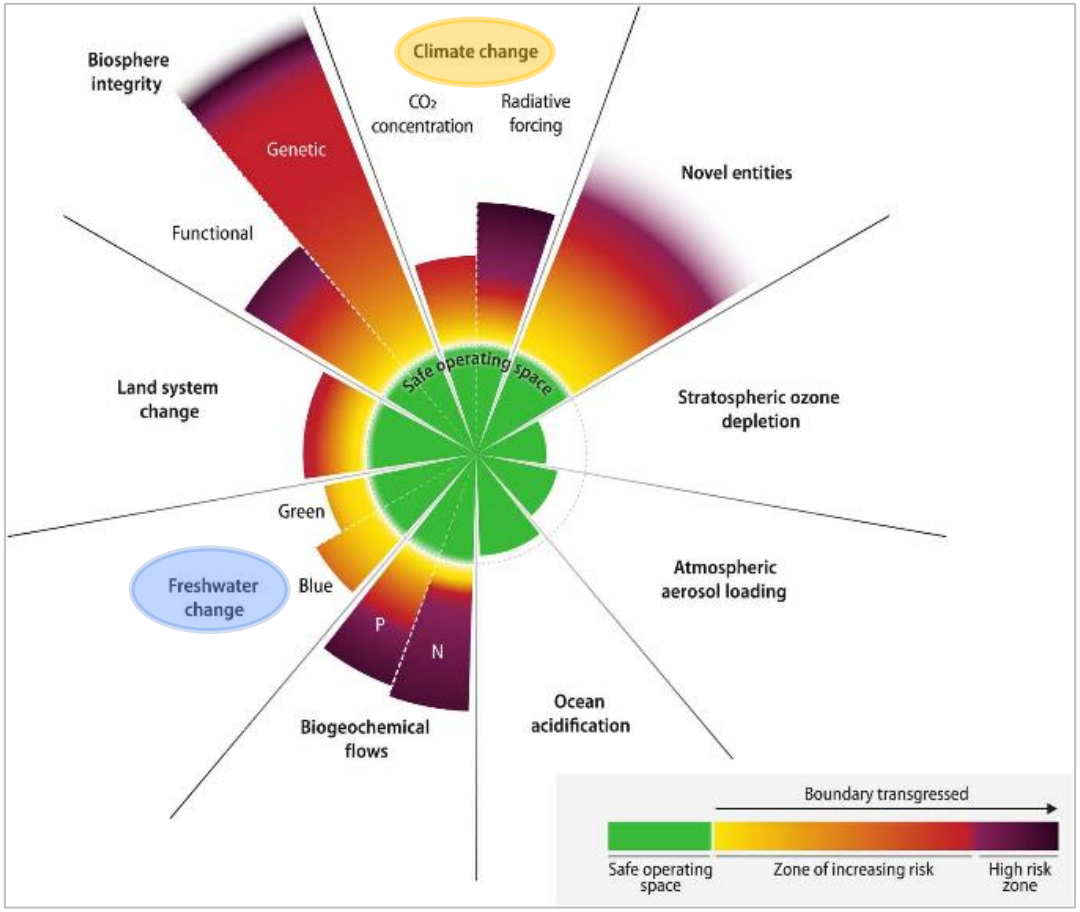
LEESU
Ecole nationale des ponts et chaussées

- Water, Environment & Urban systems
- Urban hydrology
- Research fields
  - *Monitoring and modelling of inland waters*
  - Alternative solutions for urban water management
  - Nature-based solutions

Inland waters

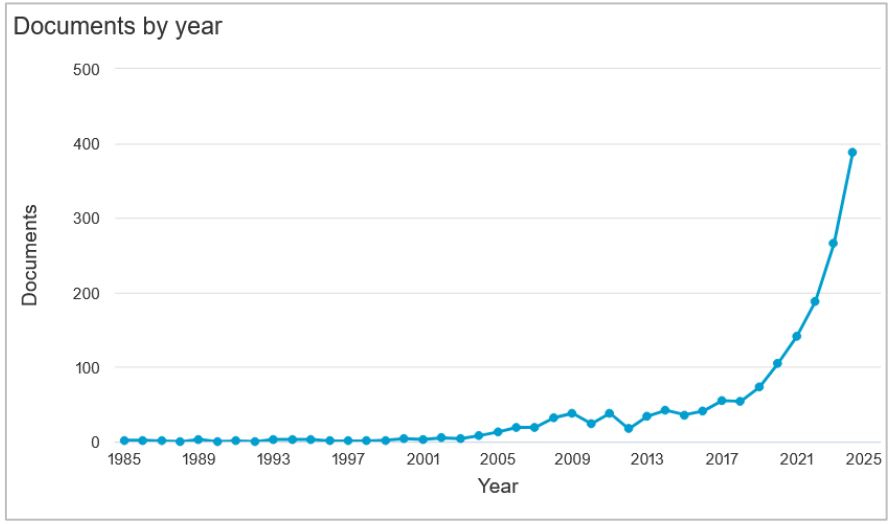
- Planetary limits
- Freshwaters & Climate change

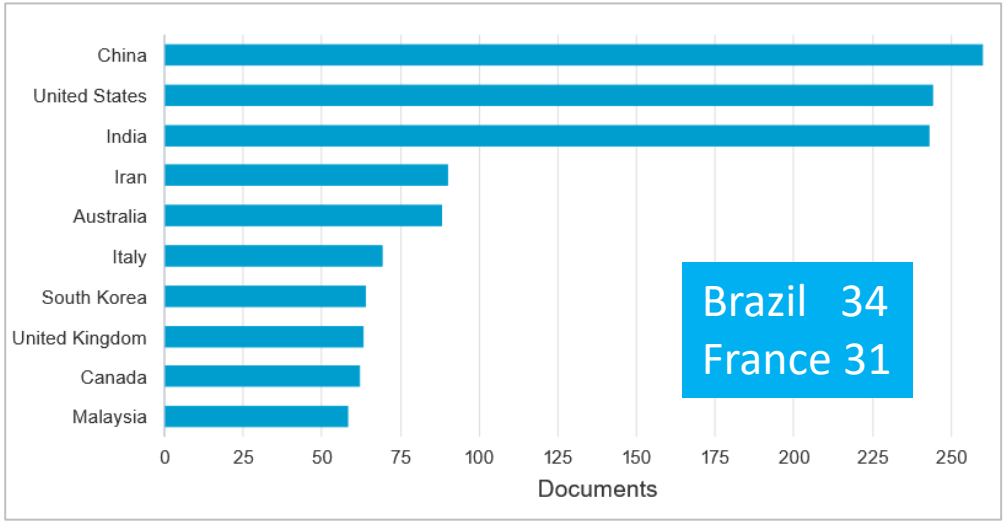


Rockström et al., (2009). A safe operating space for humanity. *Nature*, https://doi.org/10.1038/461472a

Bibliographic analysis

- Scopus
- ‘Artificial Intelligence’
  AND hydrology OR limnology OR 'water AND quality AND monitoring' OR 'modelling’
- 1989 – 2024 : 1670 documents





Artificial Intelligence and monitoring and modelling aquatic environments

- Big data
- Rare long-term timeseries on aquatic environments
- Increasing use of online sensors and measuring devices

2 examples
- Microbiological contamination of urban rivers : the Seine river in Paris

- Blooms of toxic species in urban lakes : Lake Créteil

Microbiological contamination of rivers

- Heavy rainfall episodes
- Fecal contamination of the river
- *Overpass of the regulatory threshold?*

- Triathlon in the River Seine
- *Will the competition take place?*

Forecast of microbiological contamination

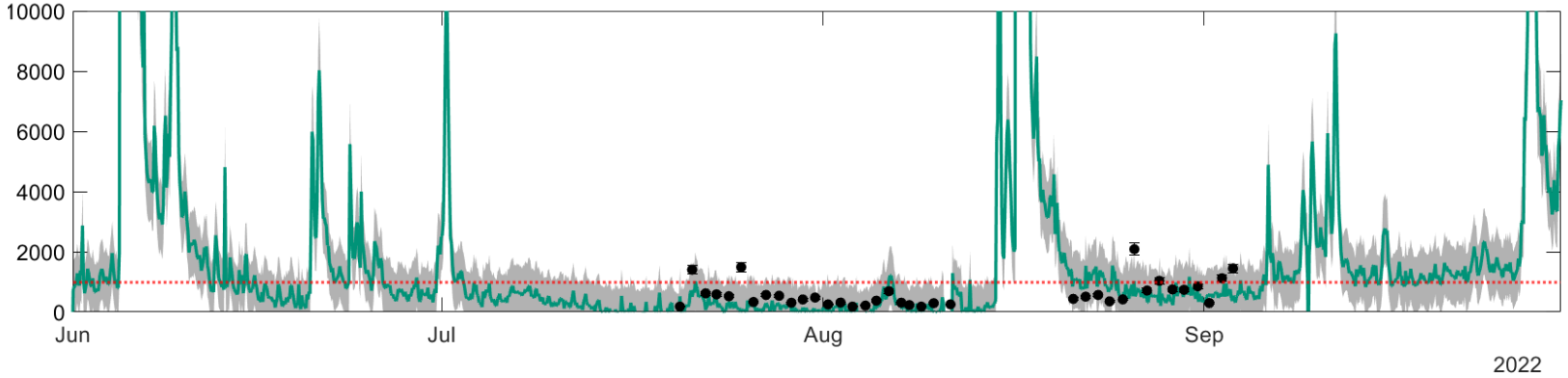
- *E.coli* ϵ fecal indicator bacteria
- Lab analysis ≥ 12h - 24h

- New monitoring devices
- High-frequency monitoring
- Forecast based on hydrological and weather conditions

High-frequency monitoring of *E.coli* in the Seine

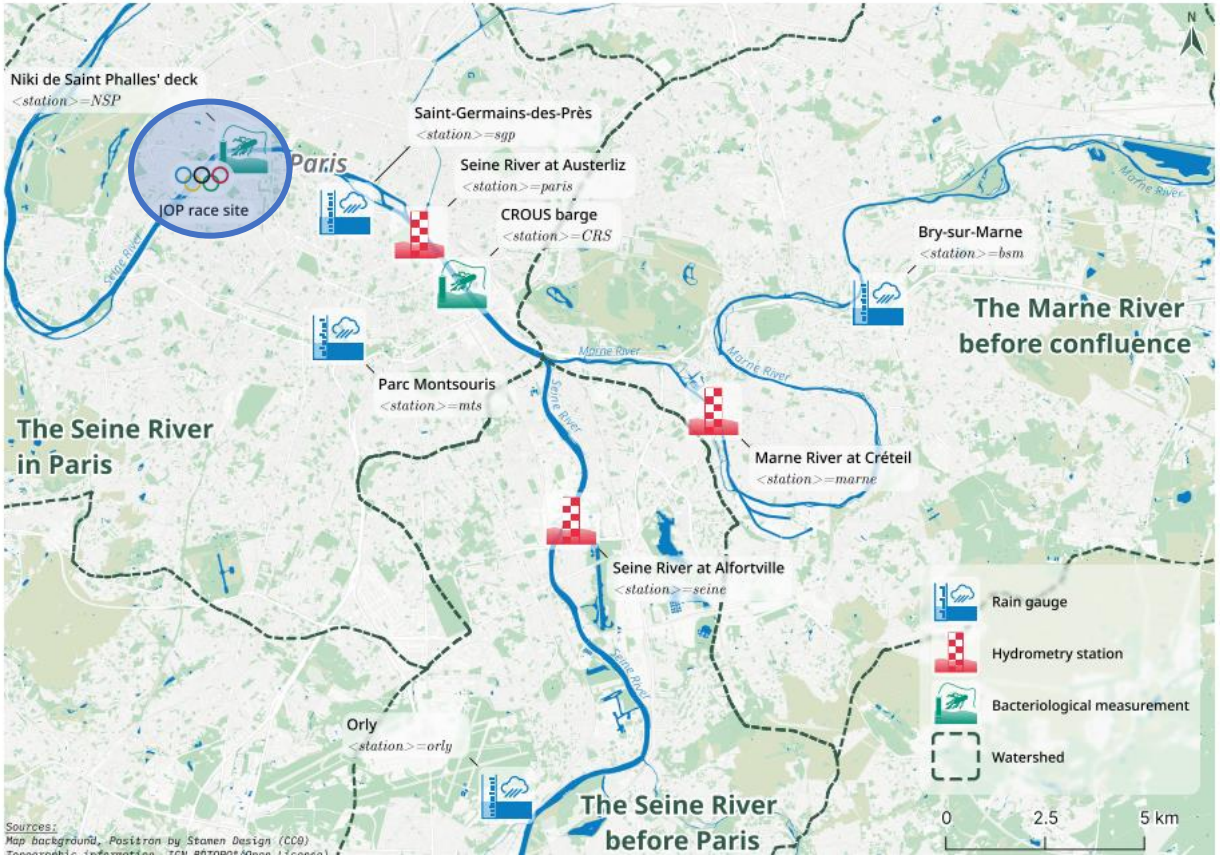
Arthur Guillot-Le Goff
Rémi Carmigniani
ENPC, LEESU & LHSV

PARIS



$\Delta t = 2h$

Rain and hydrological data



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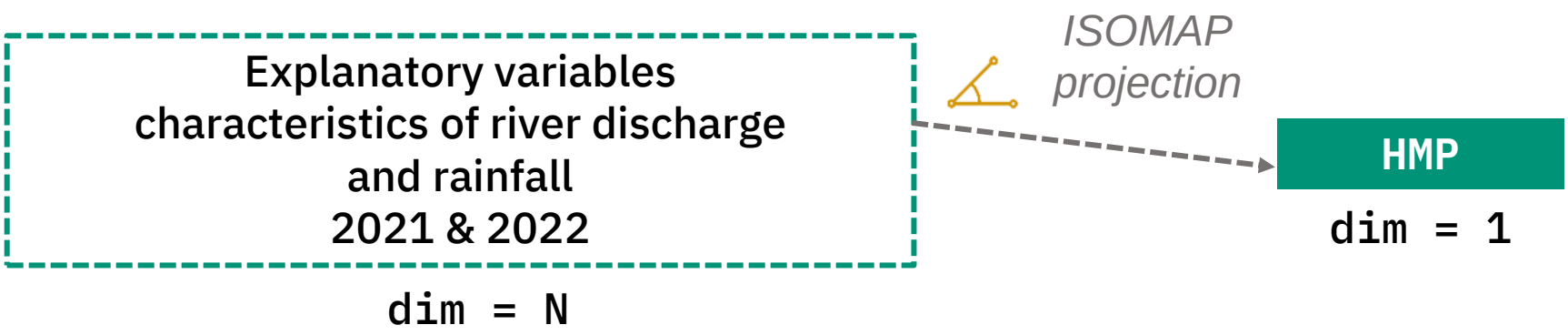
Explanatory variables of FIB → Meteo & Hydro

- **SEINE in PARIS**
  - **Rain** : *Saint-Germains-des-Près; Montsouris*
  - **Hydro** : *Pont d'Austerlitz*
- **SEINE Upstream**
  - **Rain** : *Orly*
  - **Hydro** : *Alfortville*
- **MARNE**
  - **Rain** : *Bry-sur-Marne*
  - **Hydro** : *Créteil*

Single hydro-meteorological indicator of the rainfall events

- Reduction of the dataset dimension
- Non-linear method: ISOMAP
- Global indicator

→ Global hydro-meteo parameter (HMP)

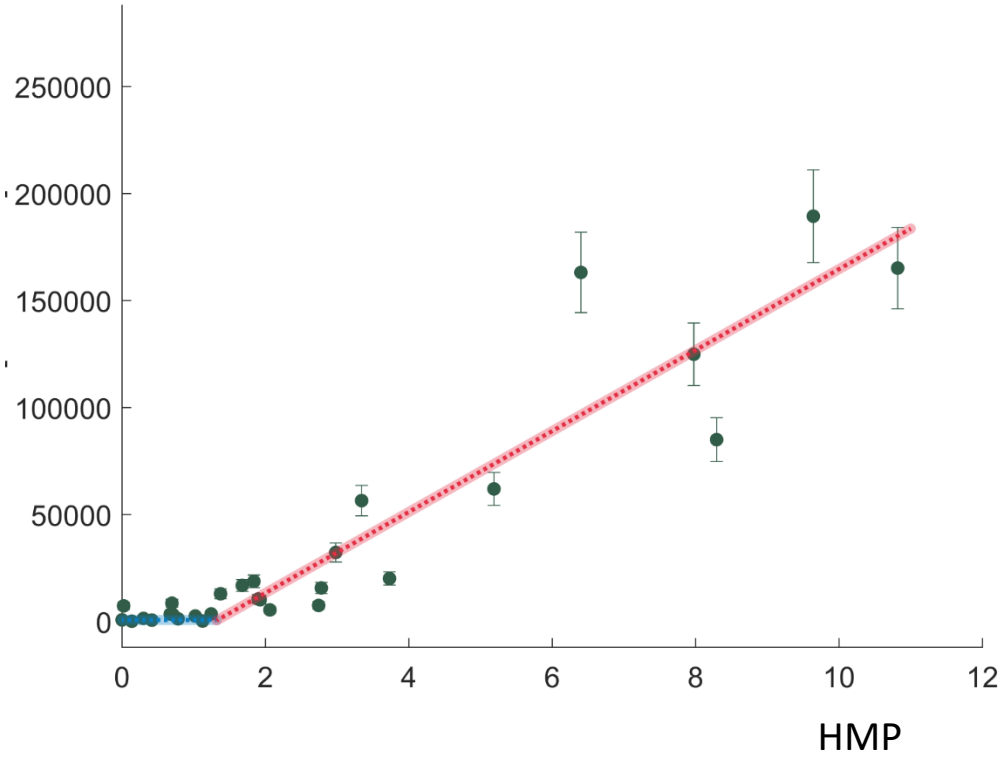


Relationship between HMP and the contamination level

Threshold effect

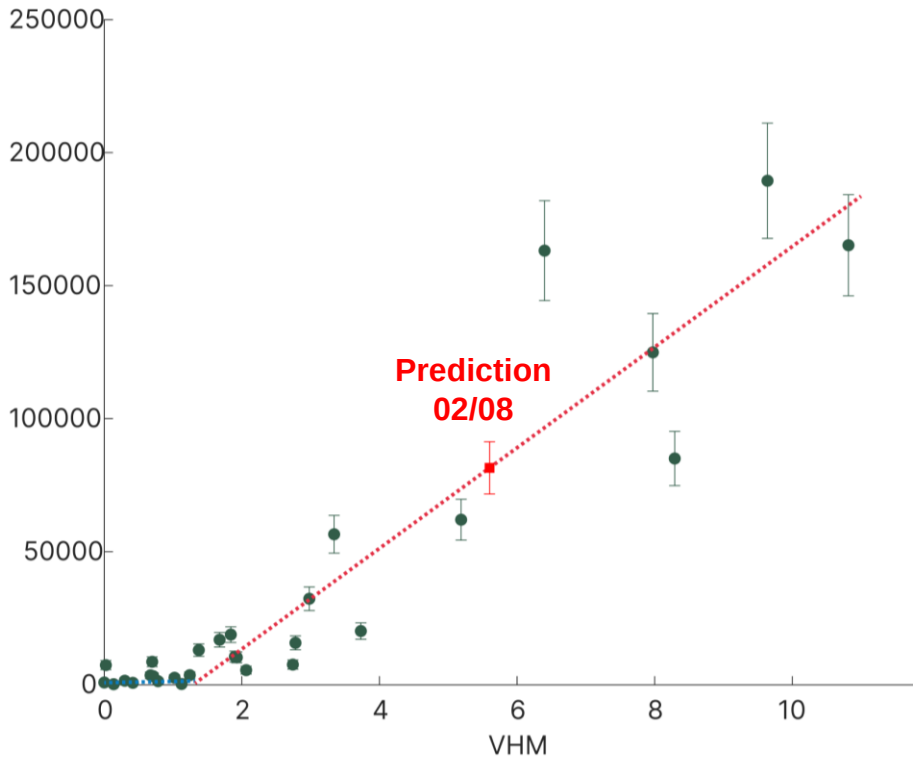
HMP ⩽ threshold → no contamination

HMP > threshold → increasing contamination



Triathlon test event - August 2nd 2023

- ISOMAP using the 2021 and 2022 dataset
- HMP value on 02/08/2023



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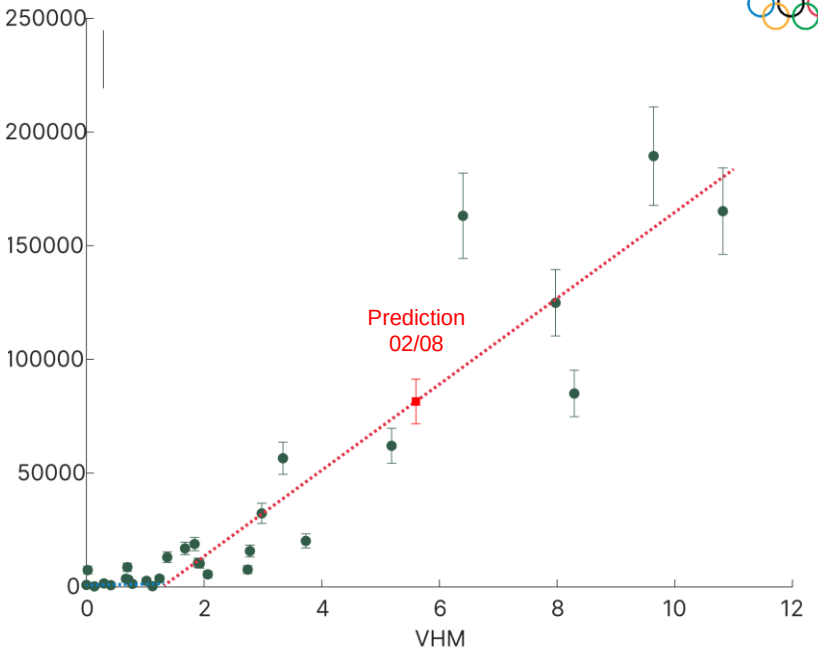
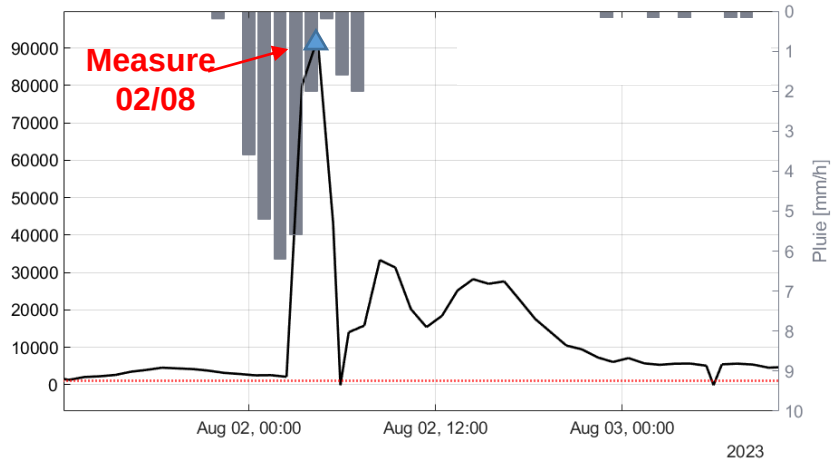
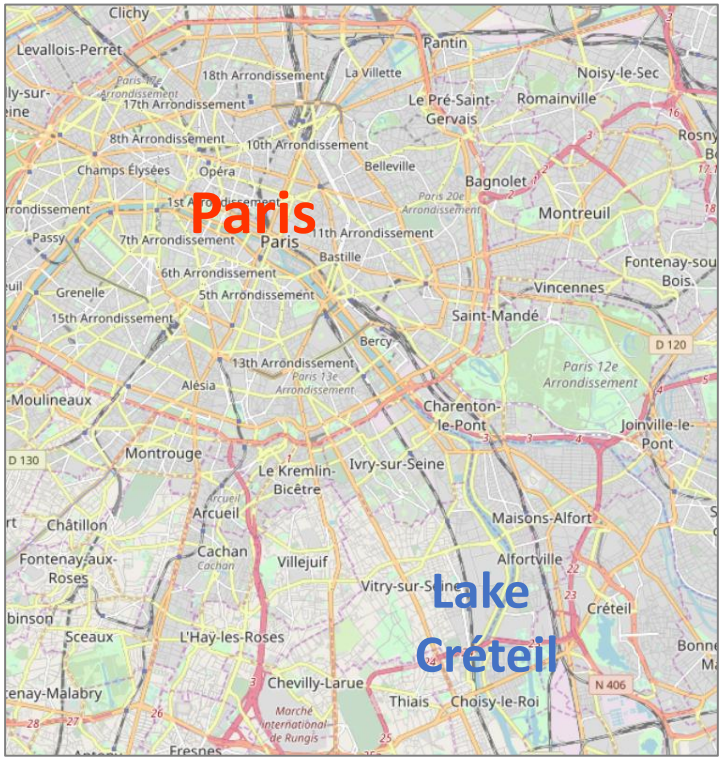


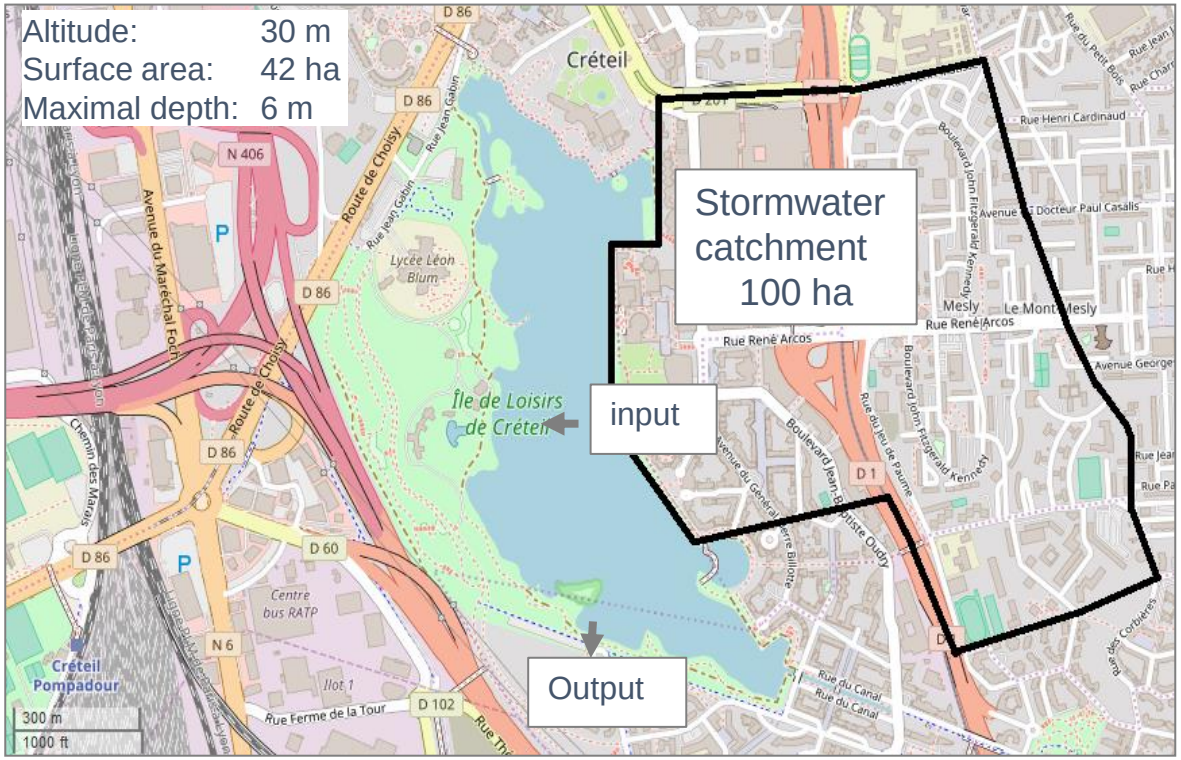


2-year timeseries
Correct prediction of *E.coli* maximum concentration


Urban lakes
Bloom of potentially toxic cyanobacteria

Lake Créteil



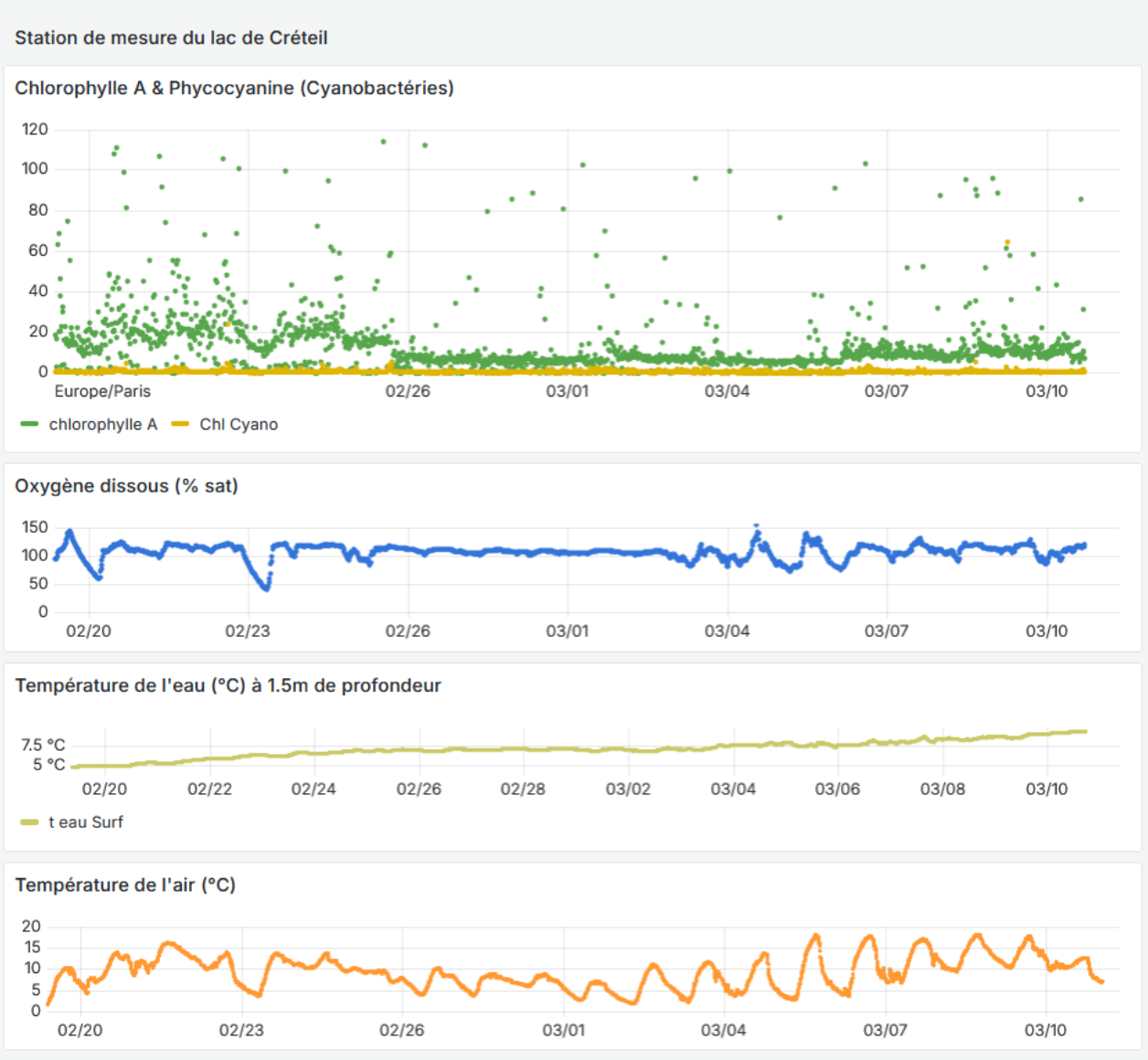


- South-East of Paris
- Typical sandpit urban lake
- Recreational activities
- Cyanobacteria blooms

Lake Créteil monitoring station

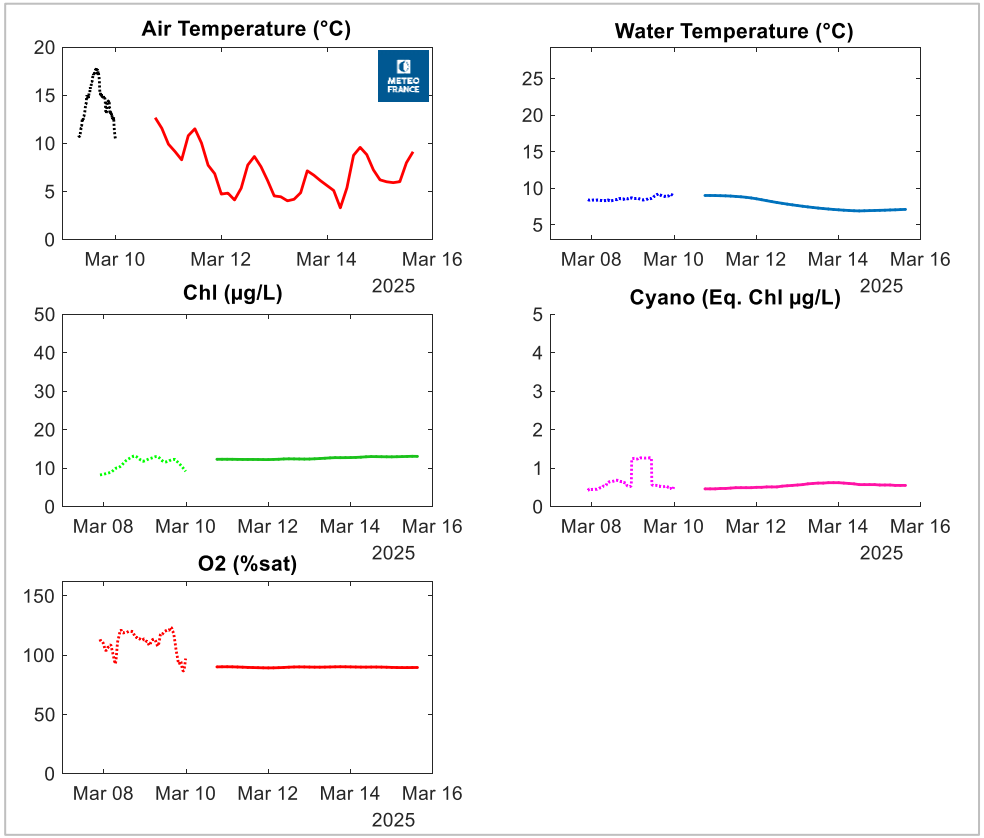
- Meteorological station
- Underwater sensors
  - Water temperature
  - Conductivity
  - O_2
  - Chlorophyll
  - Phycocyanin

Field timeseries

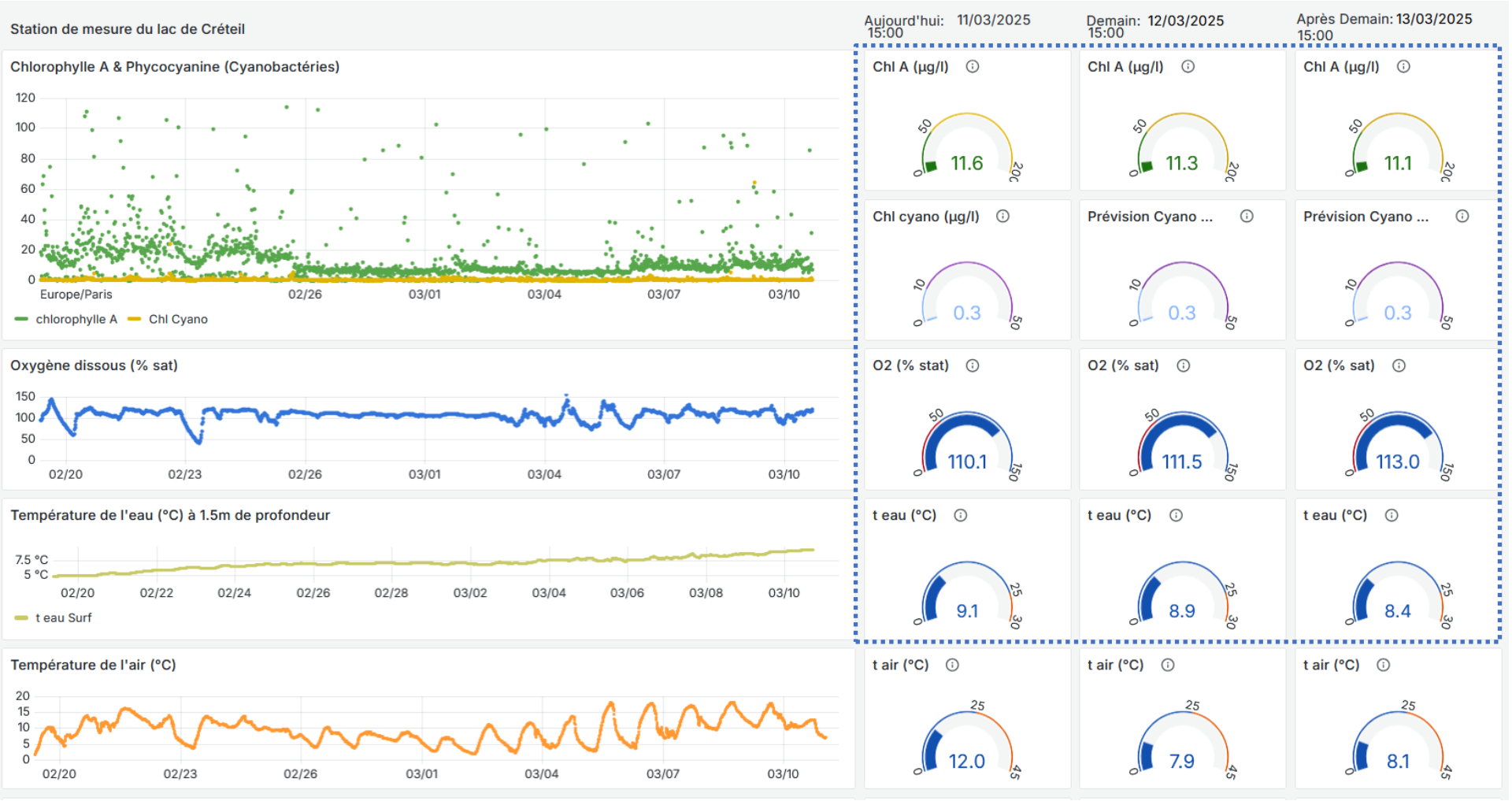


Short-term forecast of Chlorophyll and Cyanobacteria

- Non-linear autoregressive neural network
- Field data
  - Chlorophyll
  - Phycocyanin
  - Water temperature
  - Oxygen
- Meteorological forecast
  - Air temperature



Field timeseries and prediction



Physic-informed neural ODE

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For a variable of interest $u(t)$ and an external forcing $g(t)$ we can write the following ODE system,

$$\frac{\mathrm{d}u}{\mathrm{d}t}(t) = f_{\phi}^{(\mathrm{PHY})}(u(t), g(t)) + f_{\theta}^{(\mathrm{NN})}(u(t), g(t)),$$

where $f_{\phi}^{(\mathrm{PHY})}$ is the known physics model with parameters ϕ and $f_{\theta}^{(\mathrm{NN})}$ is a Neural Network with parameters θ.

- Physics constraints
- Require less data

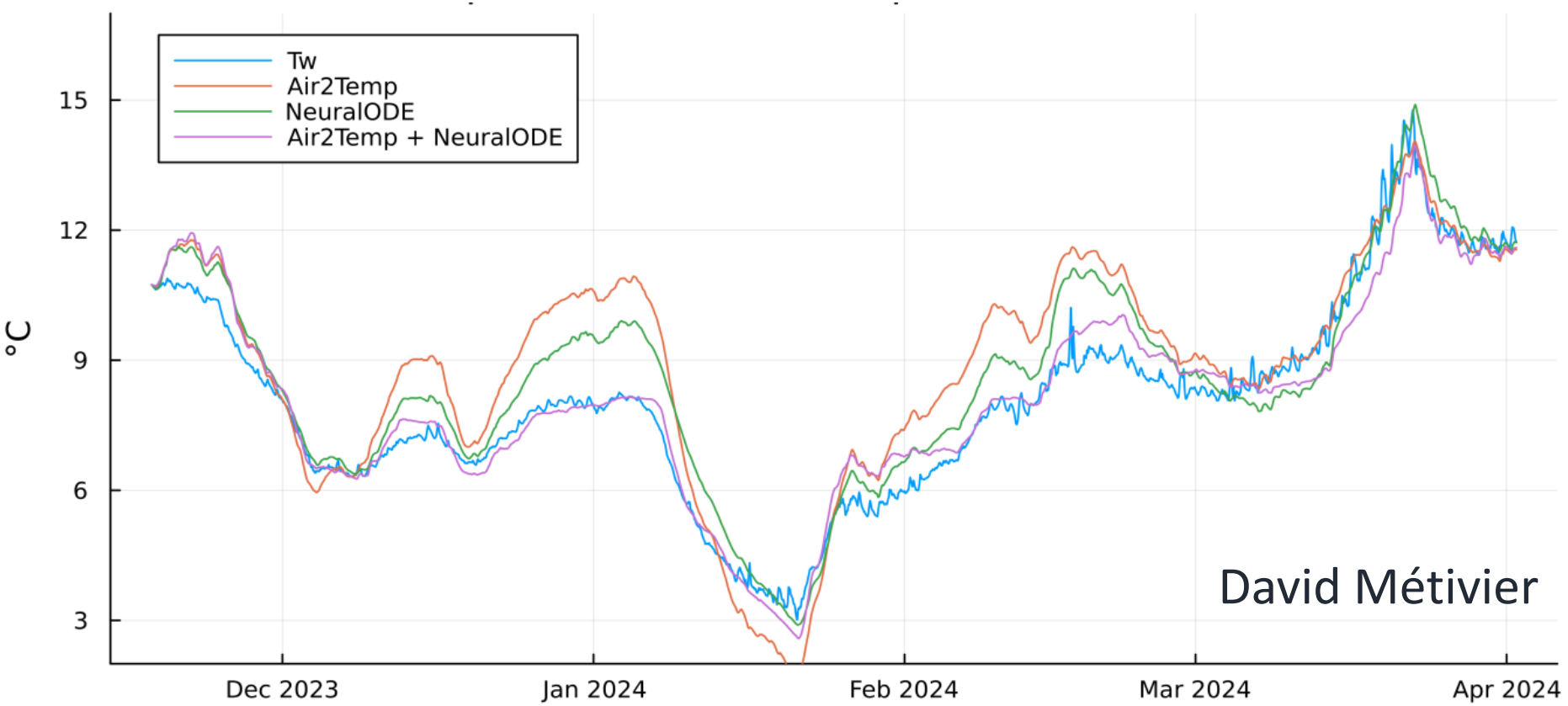
Application to lake water temperature

$u(t) = T_{\text{water}}(t)$ and the external forcing $g(t) = T_{\text{air}}(t)$.

We use the **`Air2Temp`** 4-parameters model (Piccolroaz et al. 2013)

$$f_\phi^{(\text{PHY})}(t) = \left(\phi_1 + \phi_2 T_{\text{air}}(t) - T_{\text{water}}(t) + \phi_3 T_{\text{water}}(t)\right) e^{(T_{\text{water}}(t) - T_{\text{ref}})/\phi_4}$$

$$f_\theta^{(\text{NN})}(T_{\text{water}}, T_{\text{air}}) = \text{Simple Dense NN}$$ typically one or two layers of 16 neurons.



Thank you for your attention!
Obrigada!