NAIADES

Webinar Series

Organised by MANDAT INTERNATIONAL

EVENT DETECTION IN THE WATER SECTOR

FEB. 15 , 2022
10-13.00 CET

ONLINE

Join Us!

NAIADES Speakers

CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

konnektable TECHNOLOGIES

IBA IBATECH

guardtime

External Speakers

FIWARE 4 WATER

aqua3S

Digital Water .City

Some info

This session will be entirely recorded and published on the NAIADES channels.

Feel free to post your questions in the chat.

Please feel free to share your thoughts about the workshop on Twitter, via:

@naiadesproject, using #NAIADESwebinars

Speakers

Moderation by:

Tuuli Lõhmus
Guardtime, NAIADES

Agenda

Webinar Series

SESSION 1 – NAIADES PERSPECTIVE

- **Data-driven weather forecasting:** Thanasis Anagnostis, *CERTH*
- **An event detection interface in the water sector:** Nikolaos Angelopoulos, *Konnektable*
- **NAIADES' smart solutions for chlorates prediction in water:** Filippo Cristian Salemi, *Ibatech*

SESSION 2 – INVITED GUESTS FROM DW2020

- **Leak Detection & Localisation:** Brett Snyder, *University of Exeter, Aqua3S*
- **The Fiware4Water project as a vehicle to de-risk a UK-based smart metering pilot:** Gareth Lewis, *University of Exeter, Fiware4Water*
- **Fiware4Water - Water supply system real time operational management:** Stelios Samios, Vasiliki Polychniatou, *EYDAP, Fiware4Water*
- **Digital solutions to early warn and support decisions for safe water reuse:** Serena Radini, *Università Politecnica delle Marche, digital-water.city*

PANEL DISCUSSION & WRAP-UP

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Session 1:
NAIADES PERSPECTIVE

Thanasis Anagnostis
CERTH

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Data-driven weather forecasting

Thanasis Anagnostis, CERTH

Weather forecasting

- Weather forecasting is the application of science and technology to predict the conditions of the atmosphere for a given location and time.
- People have attempted to predict the weather informally for millennia and formally since the 19th century.
- The basic idea of numerical weather prediction is to sample the state of the fluid at a given time and use the ***equations of fluid dynamics and thermodynamics*** to estimate the state of the fluid at some time in the future. - Wikipedia

- This is computationally expensive and directly related to the desired spatial granularity.
- Meaning that the higher the detail, the more expensive (computationally and financially) it gets.
- Not all forecasting needs are the same though…

Numerical weather forecasting

Pros

- Very accurate
- Physics-based
- Considers atmospheric phenomena
- Big-picture insights
- Results can include a wide range of variables

Cons

- Conditionally accurate
- Parameterises micro-scale phenomena
- Time-consuming (long time to run)
- Resource-intensive (needs computing clusters)
- Costly €€€

How do we tackle the cons?

Alternative: Data driven weather forecasting

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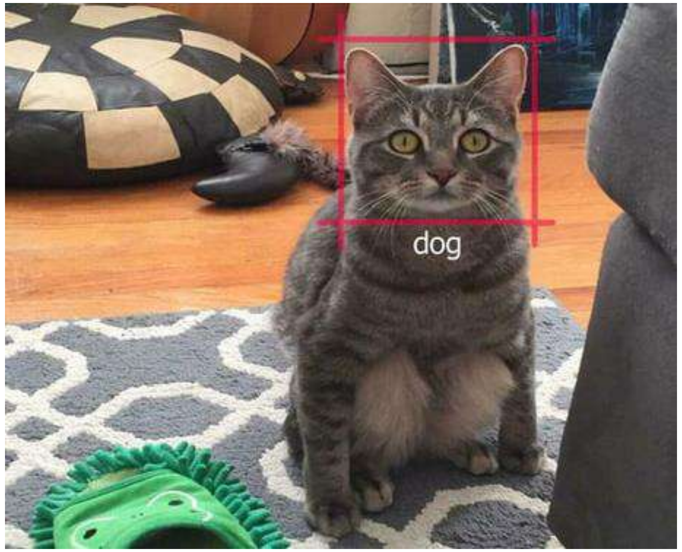
- Data-driven weather forecasting employs historical data and AI algorithms to produce predictions.
- AI approaches solve specific problems, based on the collected data.

Age of Data

Hardware costs

Mathematics / AI



Why data-driven weather forecasting?

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Operational

- City planning
- Facility management
- Agriculture
- Aviation
- Construction
- Mining
- Event management
- Insurance
- Transportation

Technical

- Deal with microclimate effects.
- Increase spatial granularity.
- Reduce computational cost.
- Continuously improve through time.
- Add/Remove parameters with ease.
- Utilize heterogenous streams of data.

Hyperlocal weather!

The F1 example

Temp 33°C
Humidity 90%
Wind speed 7m/s

Road temp 43°C

Road temp 75°C

Temp 28°C
Humidity 100%
Wind speed 3m/s

Temp 35°C
Humidity 70%
Wind speed 5m/s

Types of data and analysis

Collection

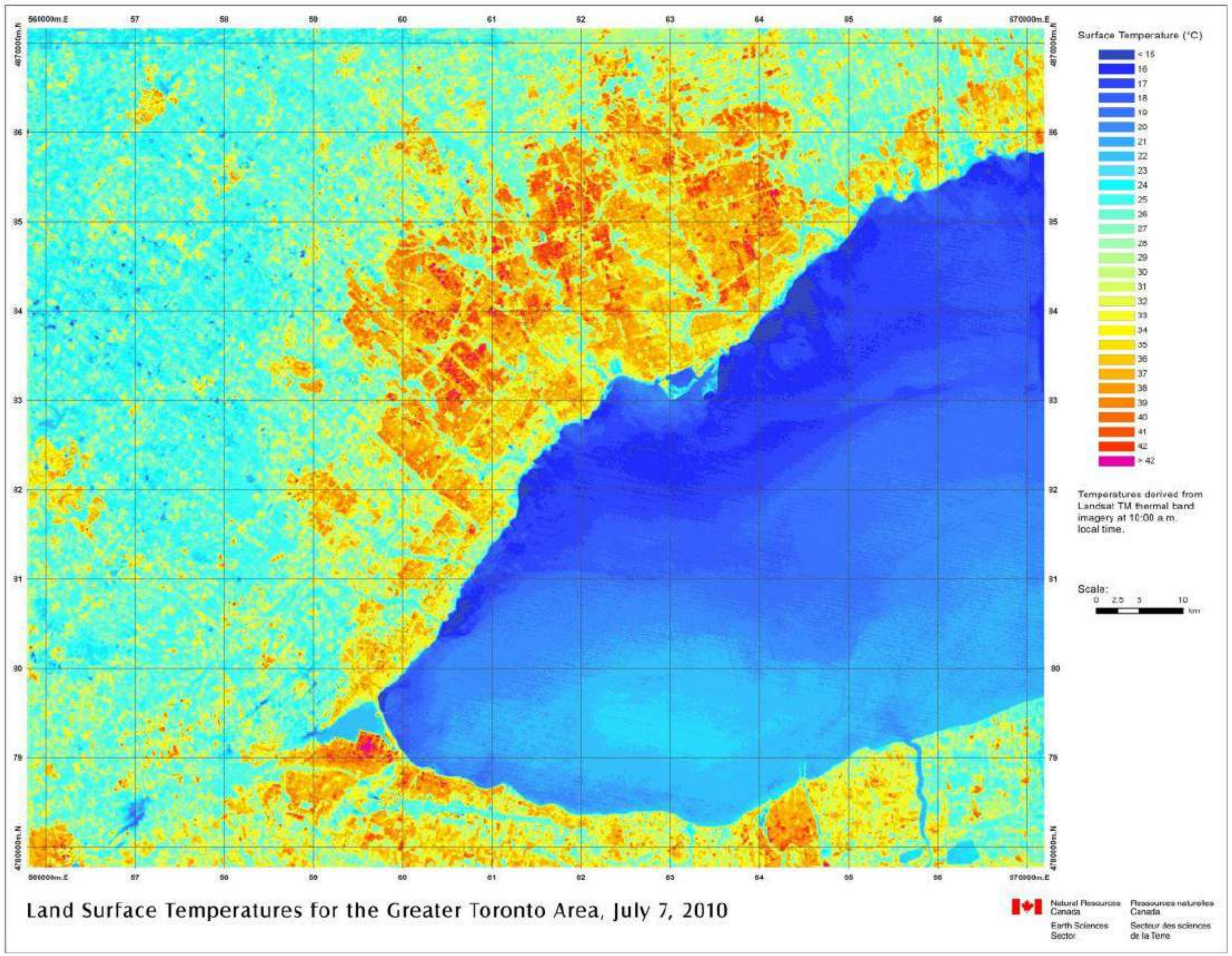
- Timeseries
- Spatial
- Short-term
- Long-term
- Climate (very long-term)

Sources

- Weather stations
- Airplanes and drones
- IoT cars
- Cell towers
- Street cameras

Huge potential!

Relevance to the water sector

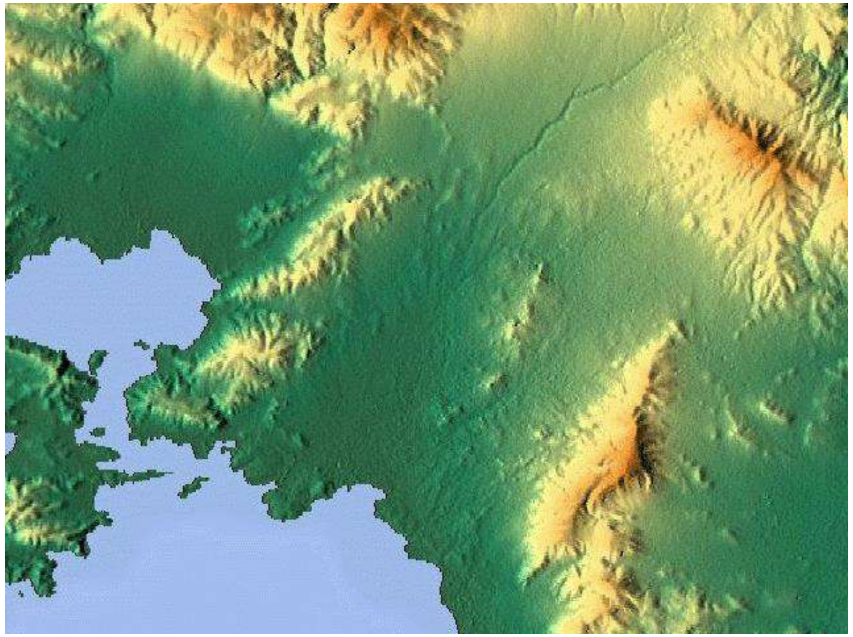


- Temperature variability in urban environments.
- Water demand/consumption is directly related to weather conditions
- Water utilities / municipalities can plan resources management
- Localized operations, maintenance and infrastructure repairs
- Prepare for extreme weather events (storms, heatwaves, blizzards, floods)
- Implement precision irrigation

Image courtesy of © *Toronto Star*

Microclimate effects

- Example: Athens
- 4 mountains
- 17 hills
- ~5M population



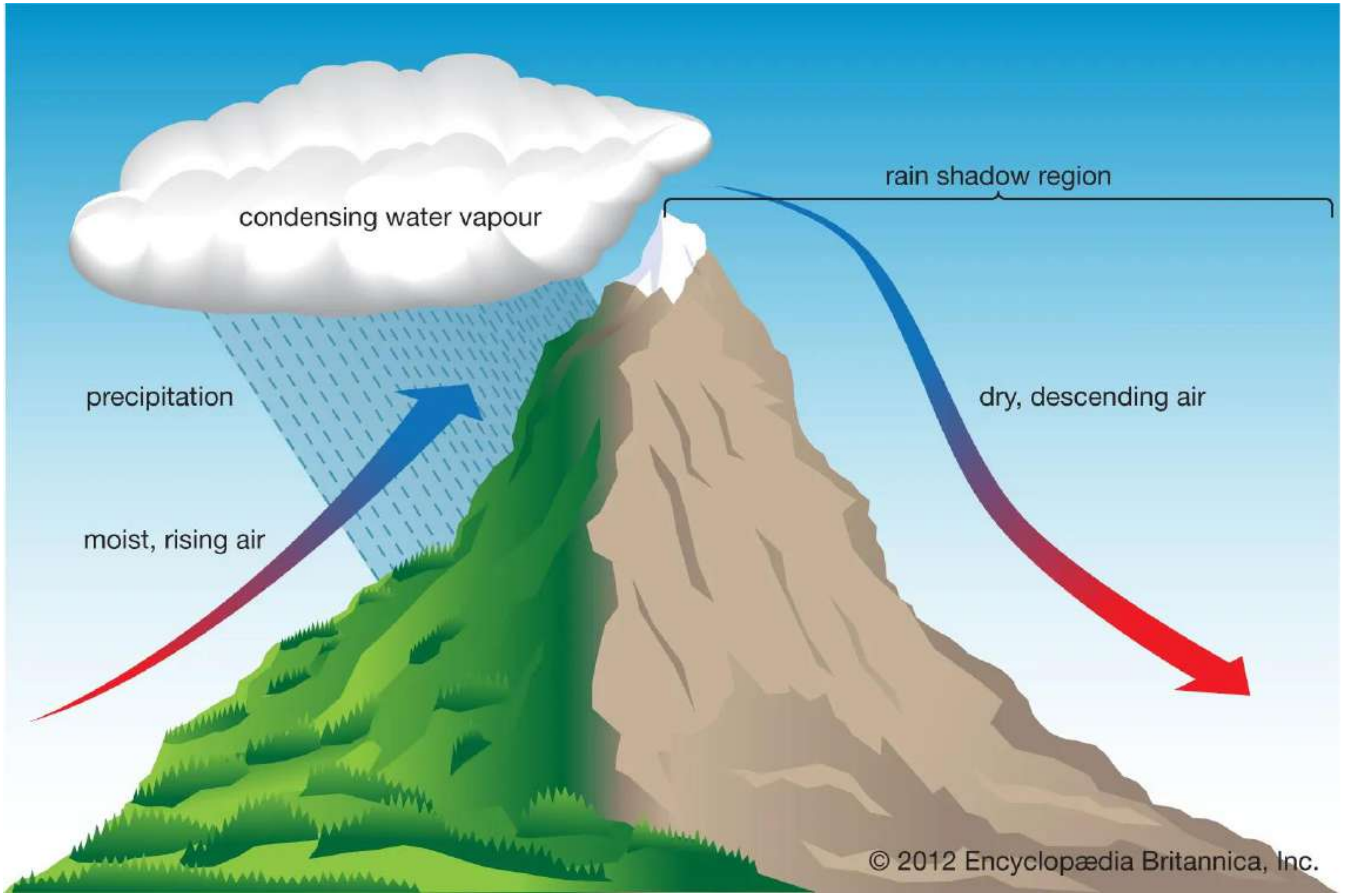
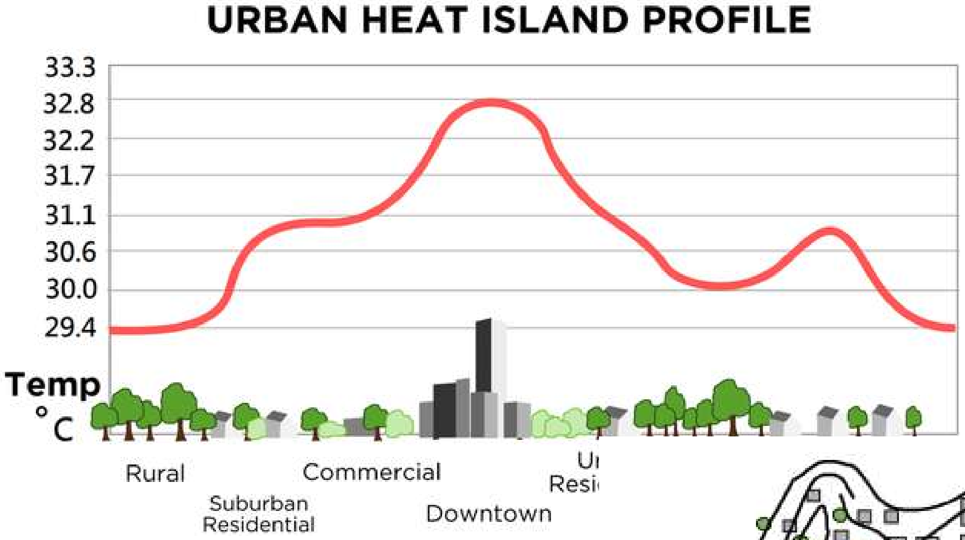
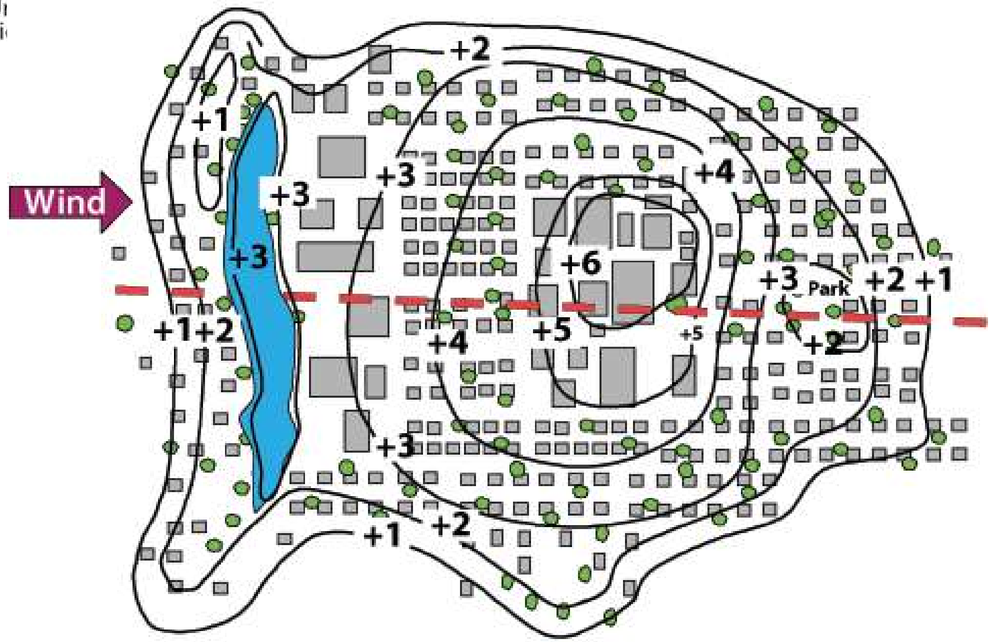


Image courtesy of *© Encyclopaedia Britannica*

Urban heat island





Images courtesy of *© Geography Launchpad*

NAIADES weather forecasting approach

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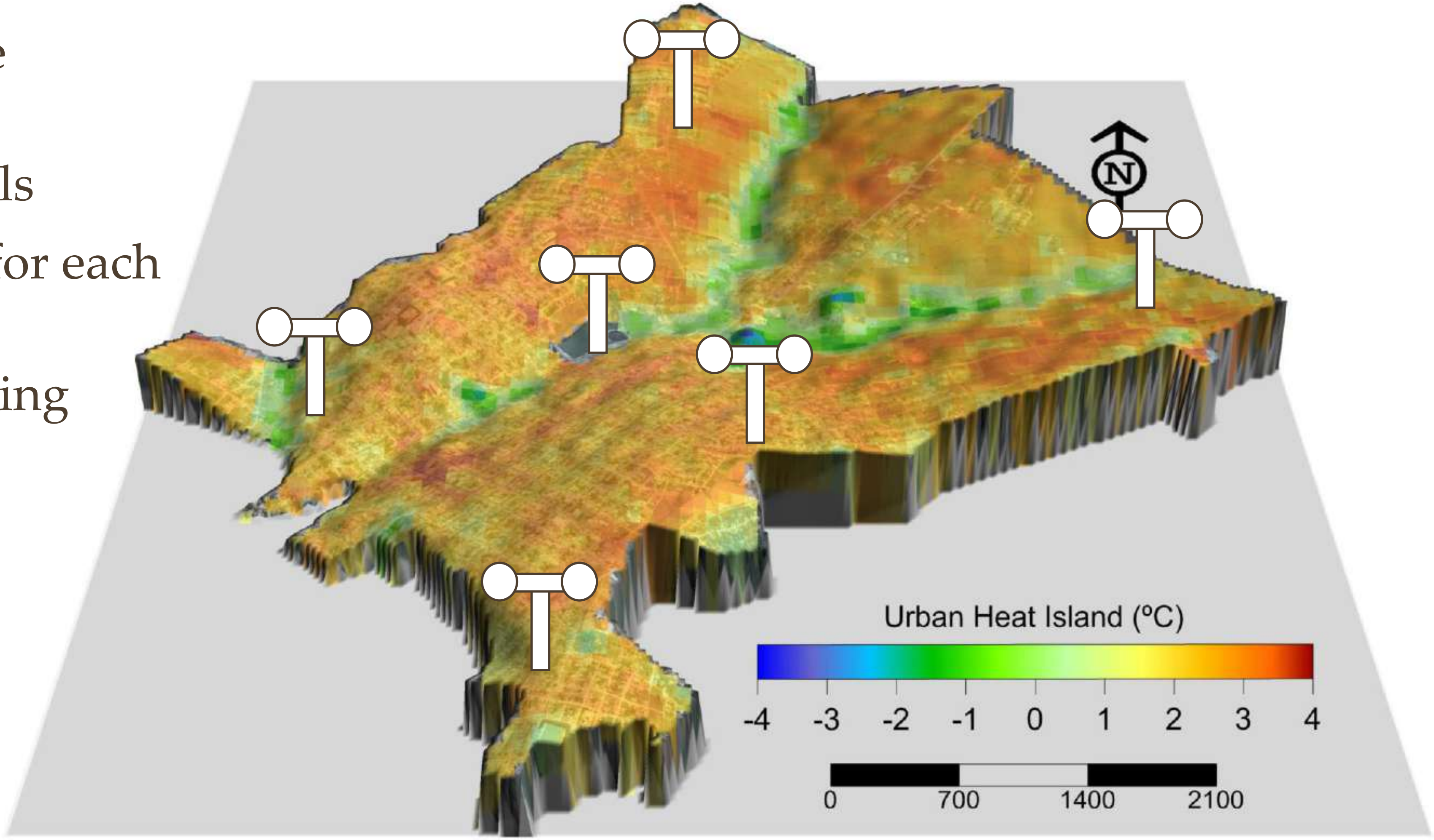
- Collect data from multiple locations
- Train AI forecasting models
- Predict future conditions for each location
- Create a localized forecasting service



Lima Alves, E.D.; Lopes, A. The Urban Heat Island Effect and the Role of Vegetation to Address the Negative Impacts of Local Climate Changes in a Small Brazilian City. *Atmosphere* **2017**, *8*, 18. https://doi.org/10.3390/atmos8020018

NAIADES desired outcome

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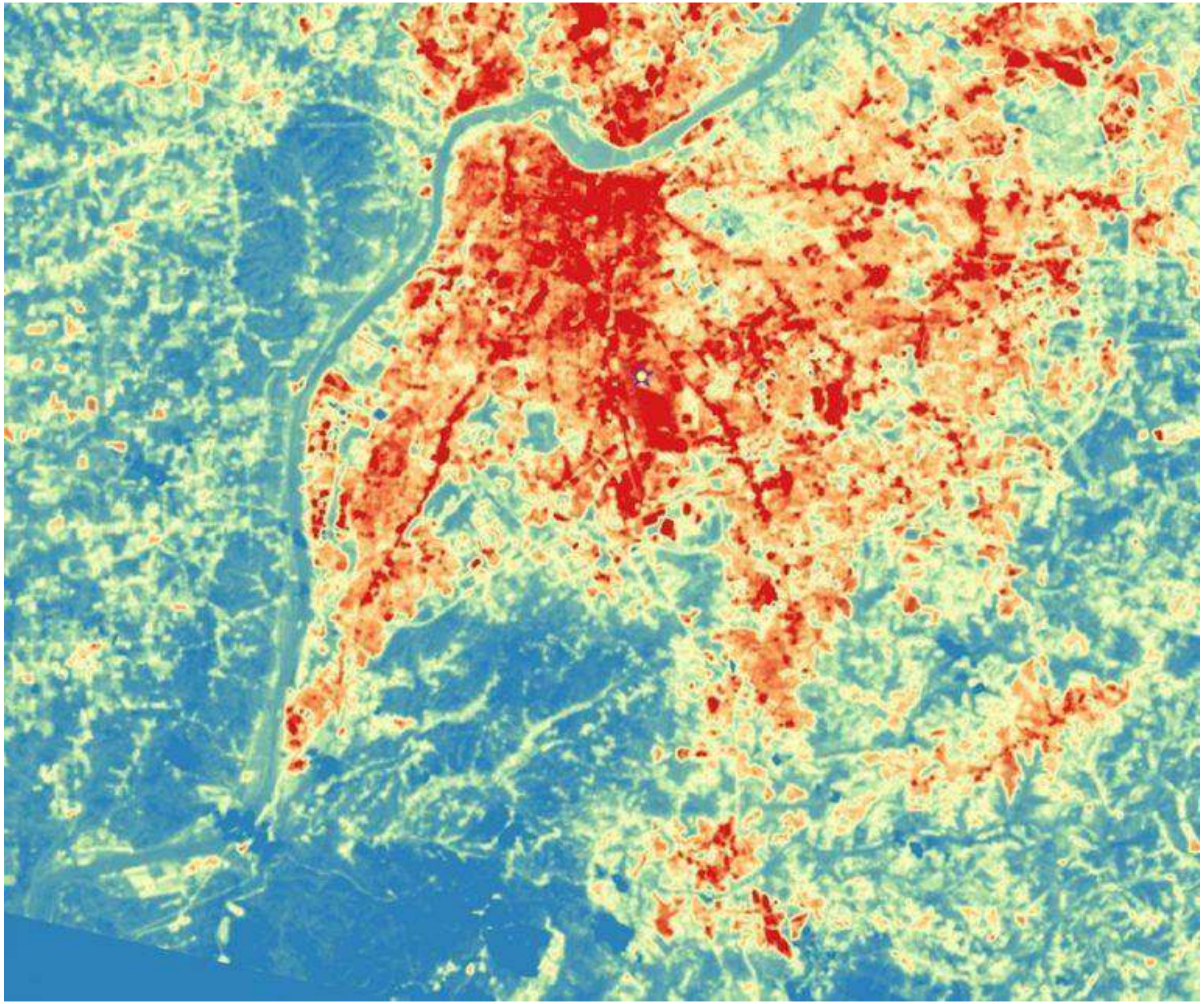
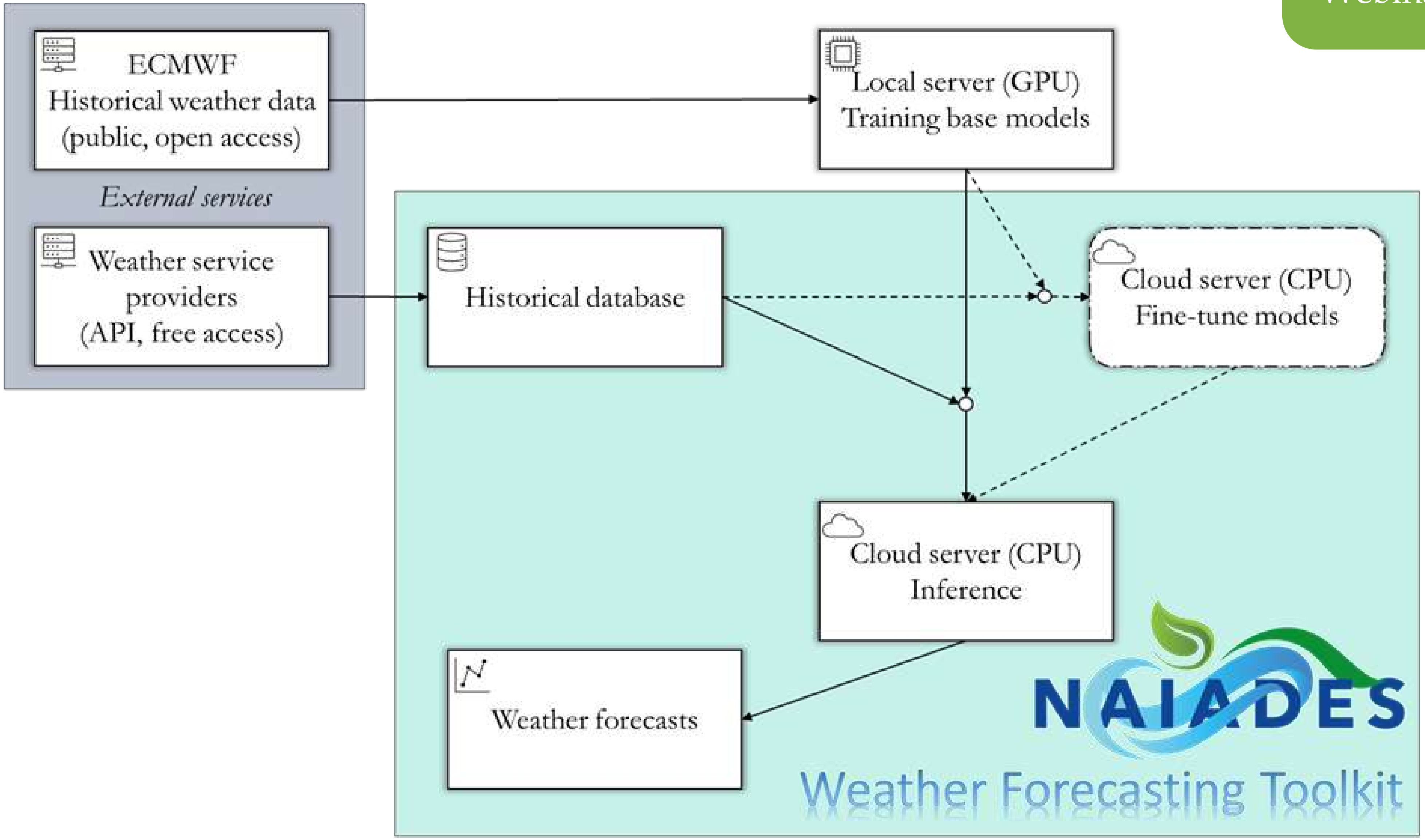


Image courtesy of © Earth.org

NAIADES technical implementation



Pilot cities

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Pilot 1 – Alicante

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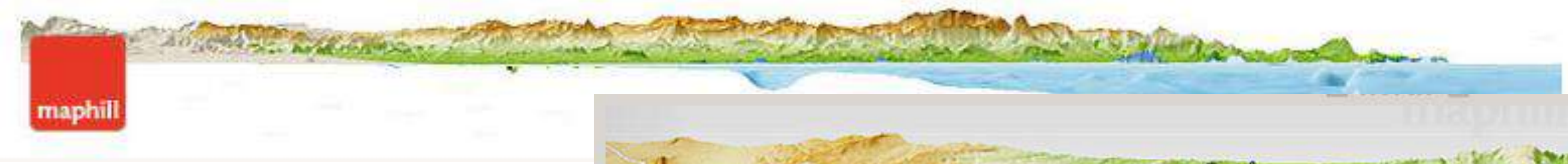

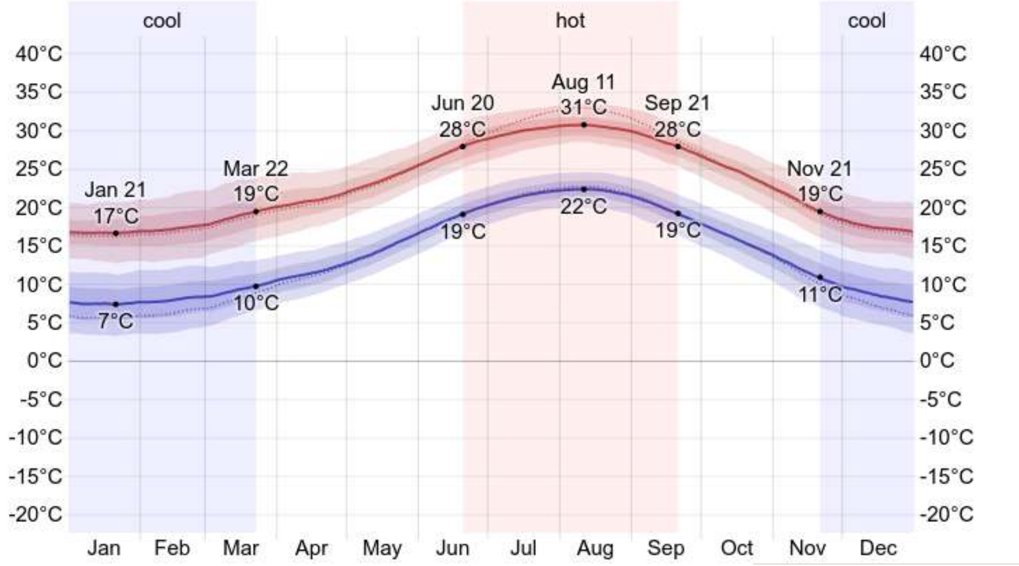

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Pilot 2 - Brăila

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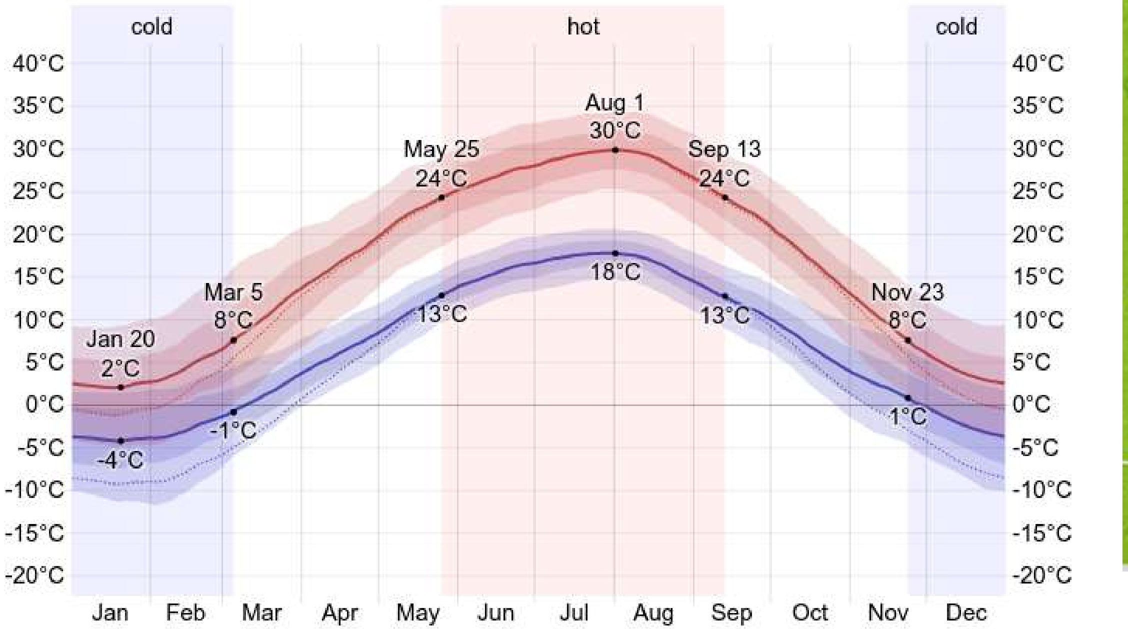

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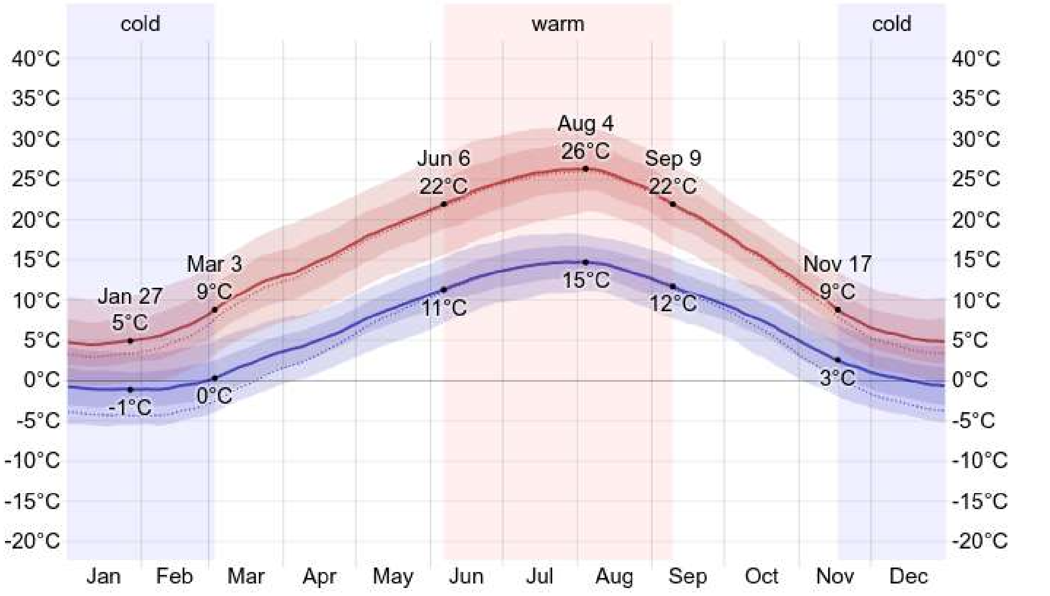
Pilot 3 - Carouge



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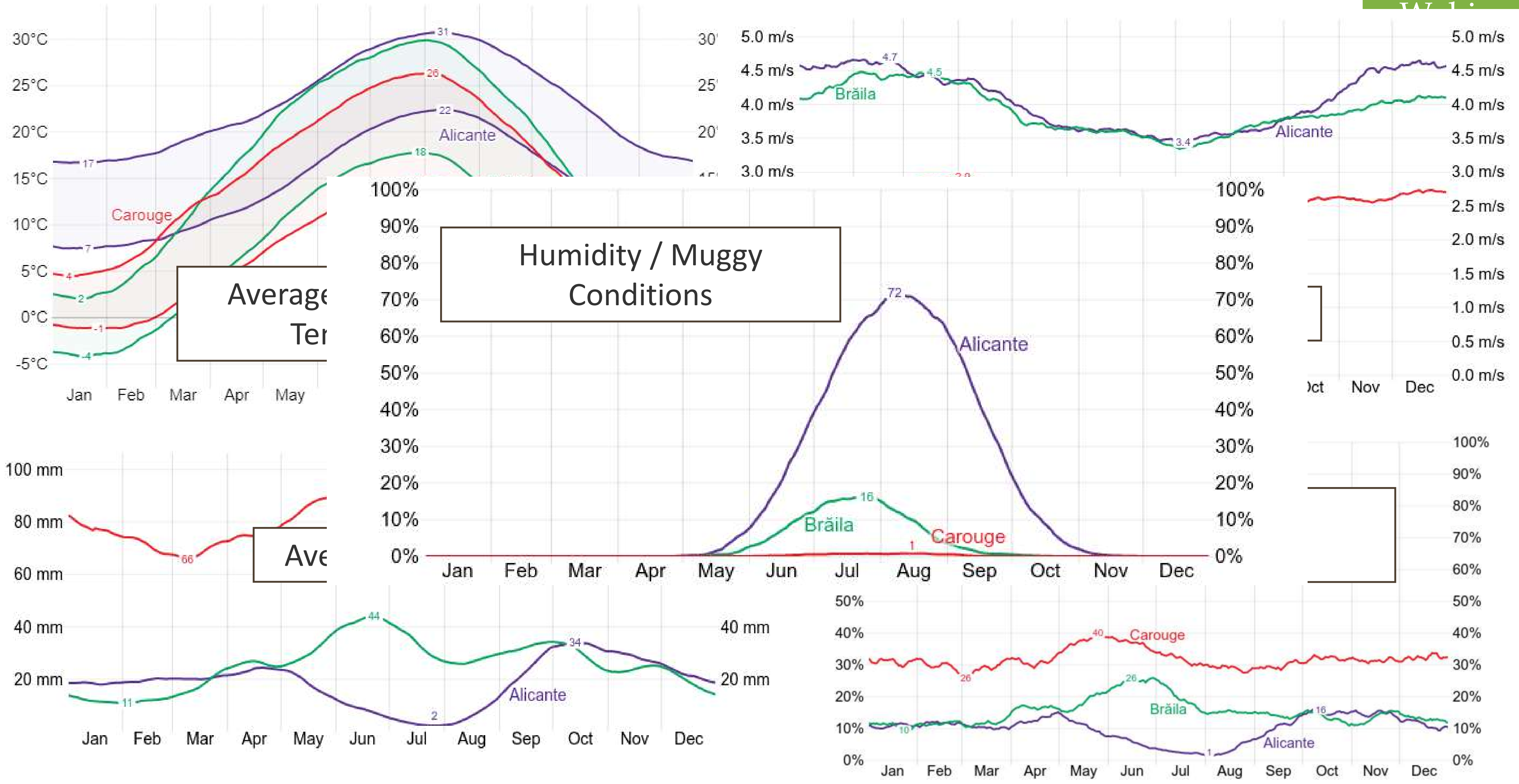
Same approach right?



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Alicante Temperature

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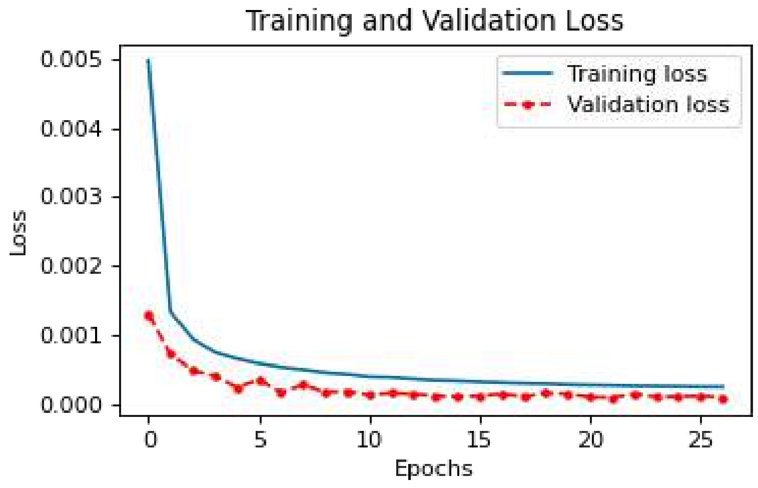
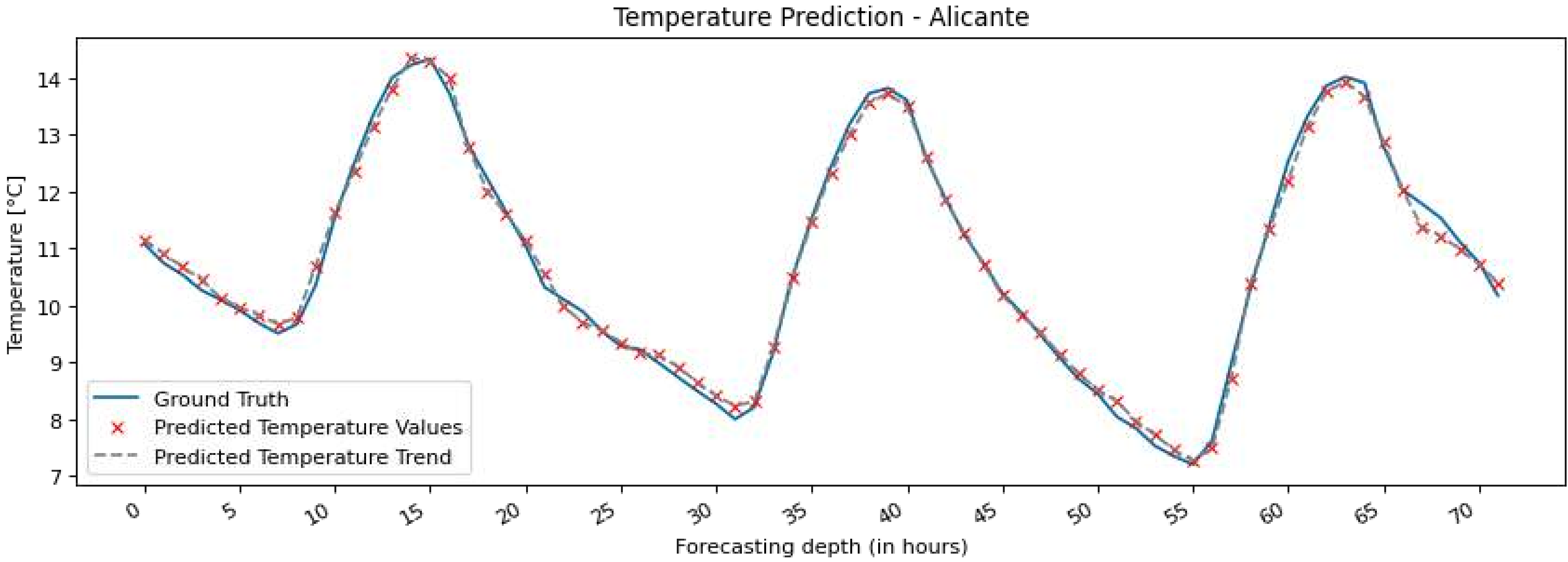
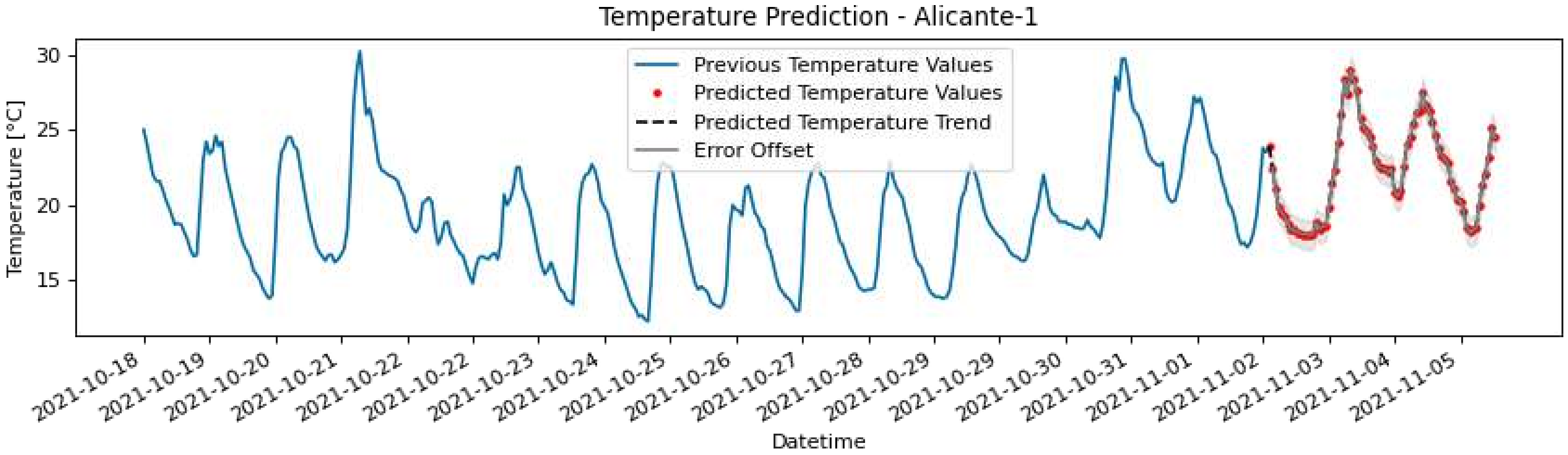
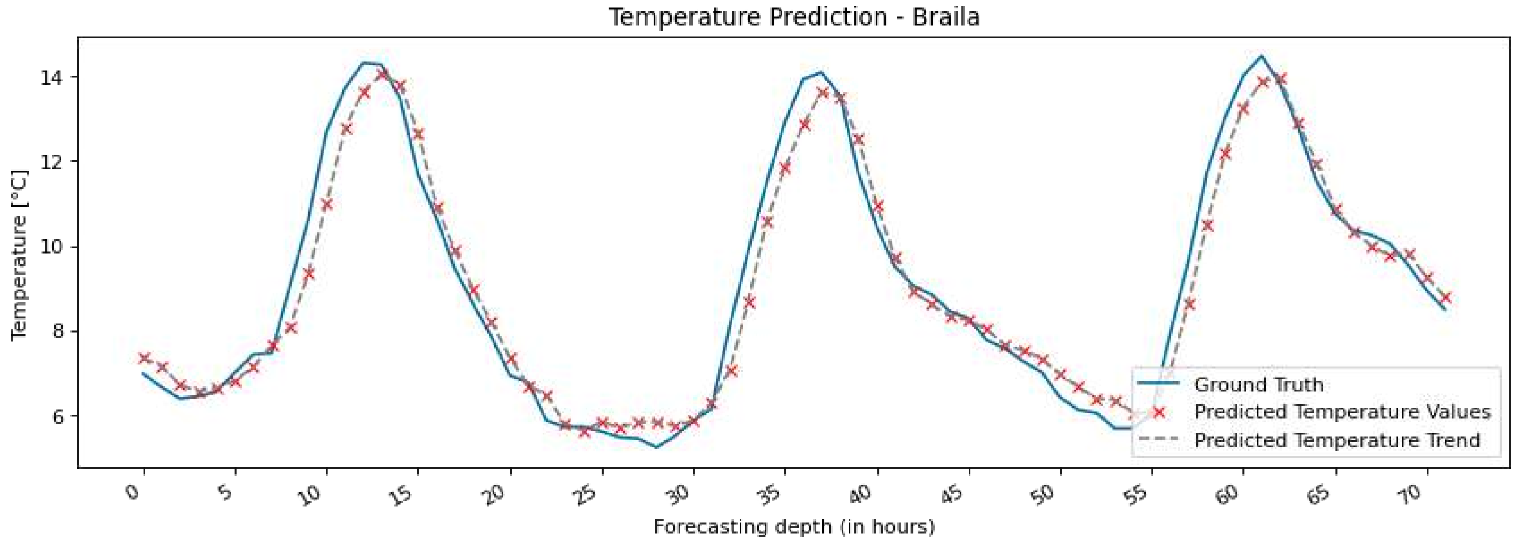


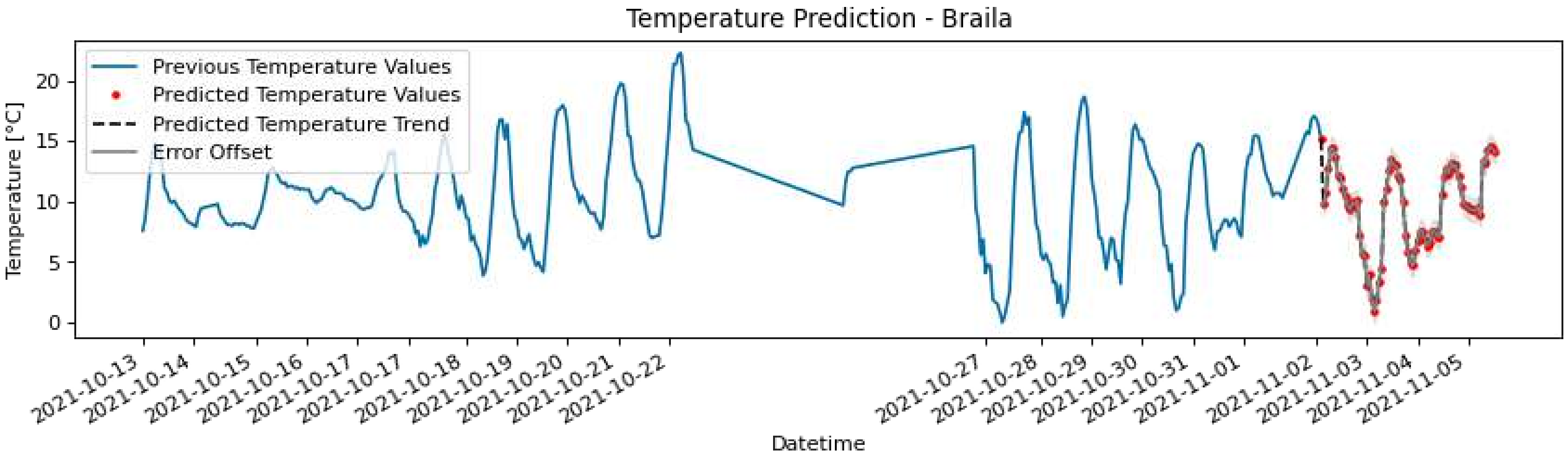




Brăila - Temperature

- Training & Validation
- Forecasting

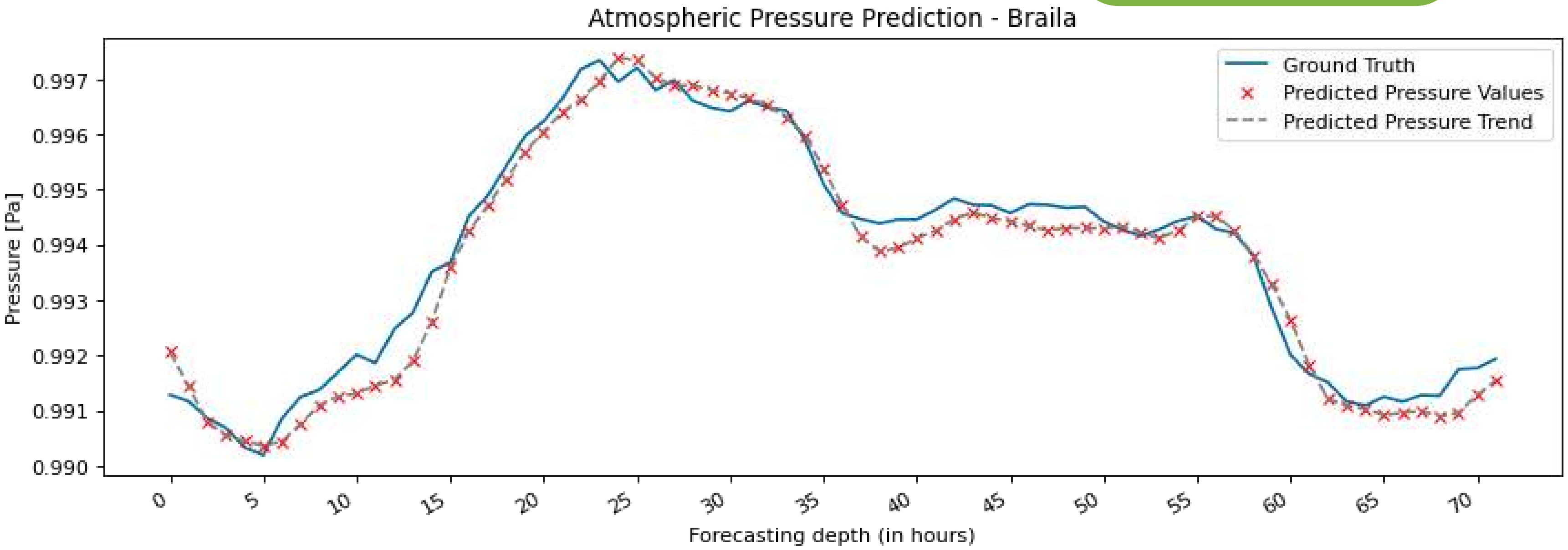


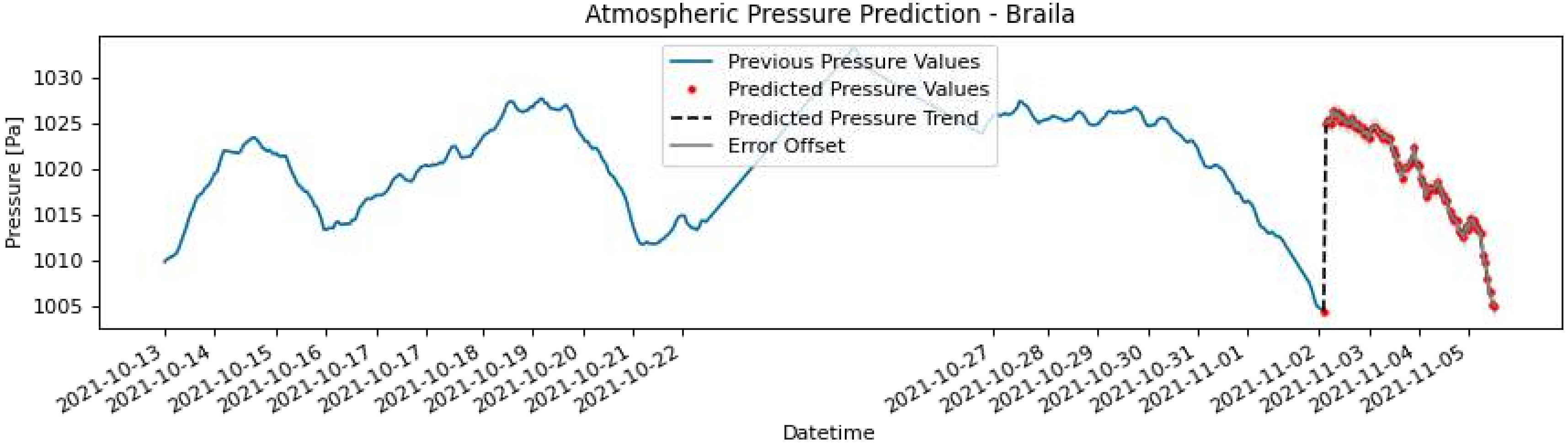


Brăila - Atm Pressure

Webinar Series

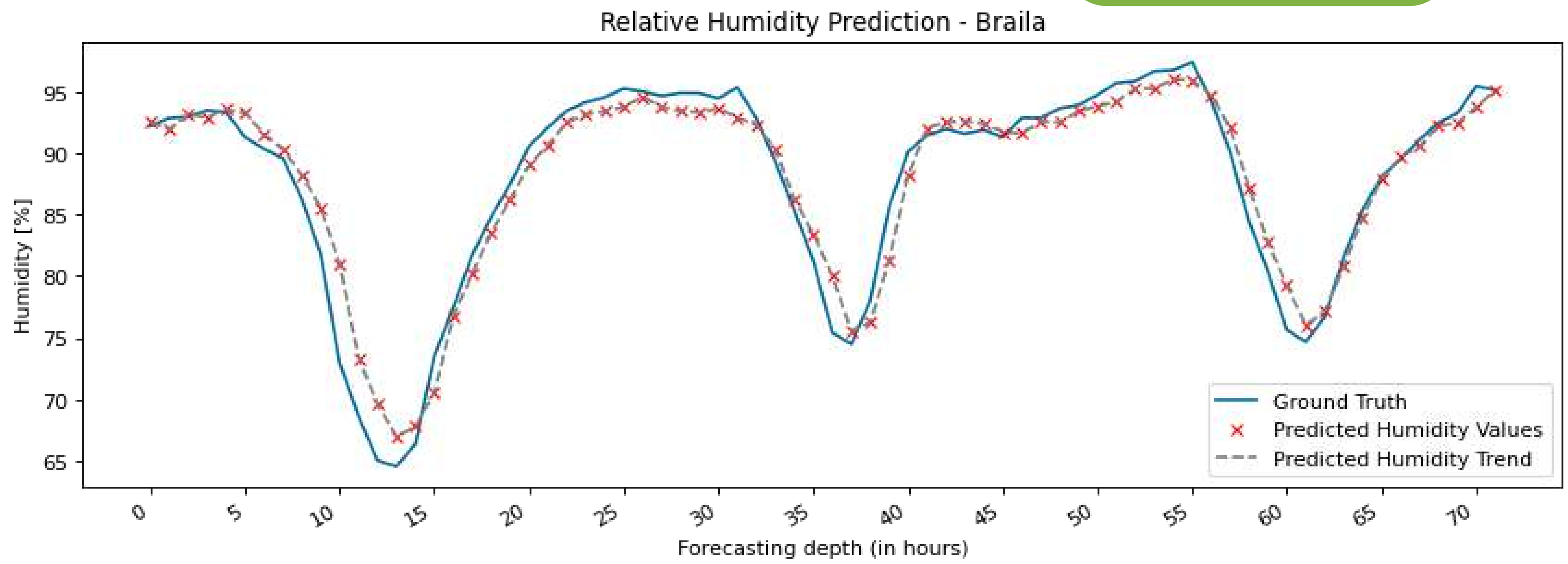
- Training & Validation
- Forecasting

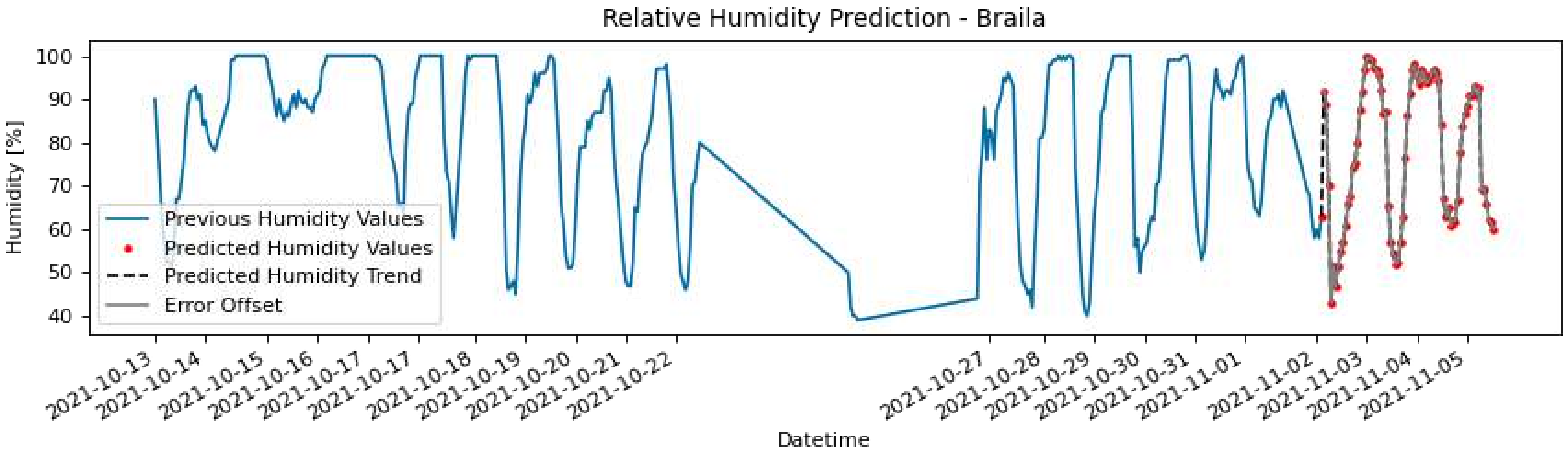




Brăila - Relative Humidity

- Training & Validation
- Forecasting





Carouge – Relative Humidity

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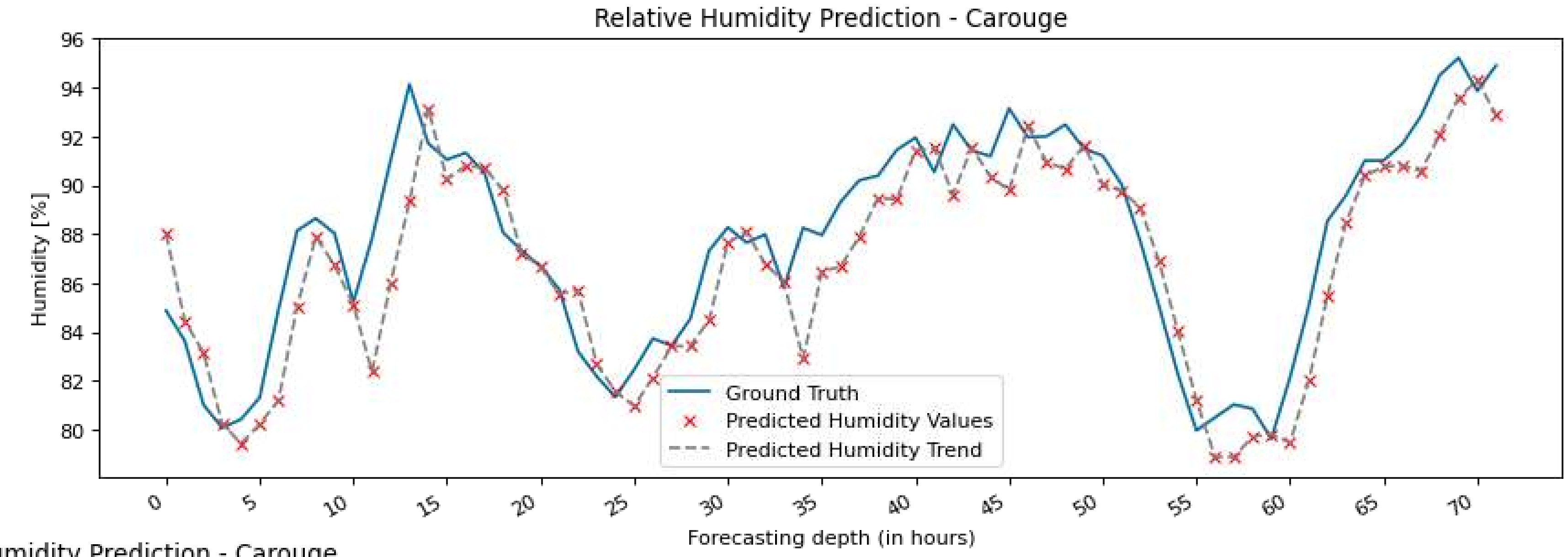
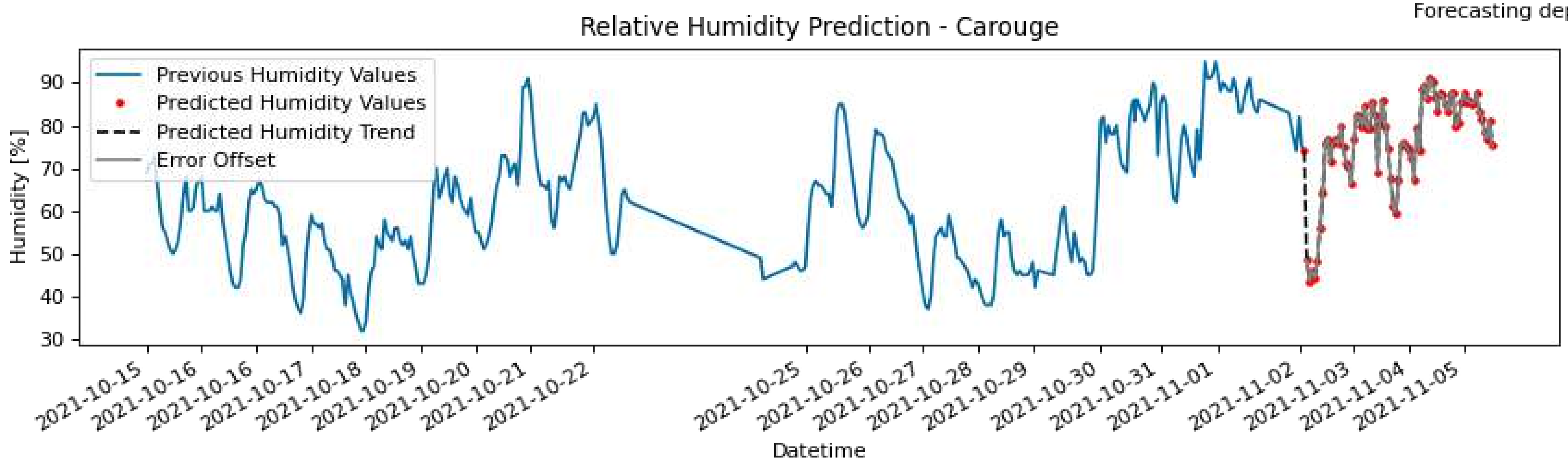
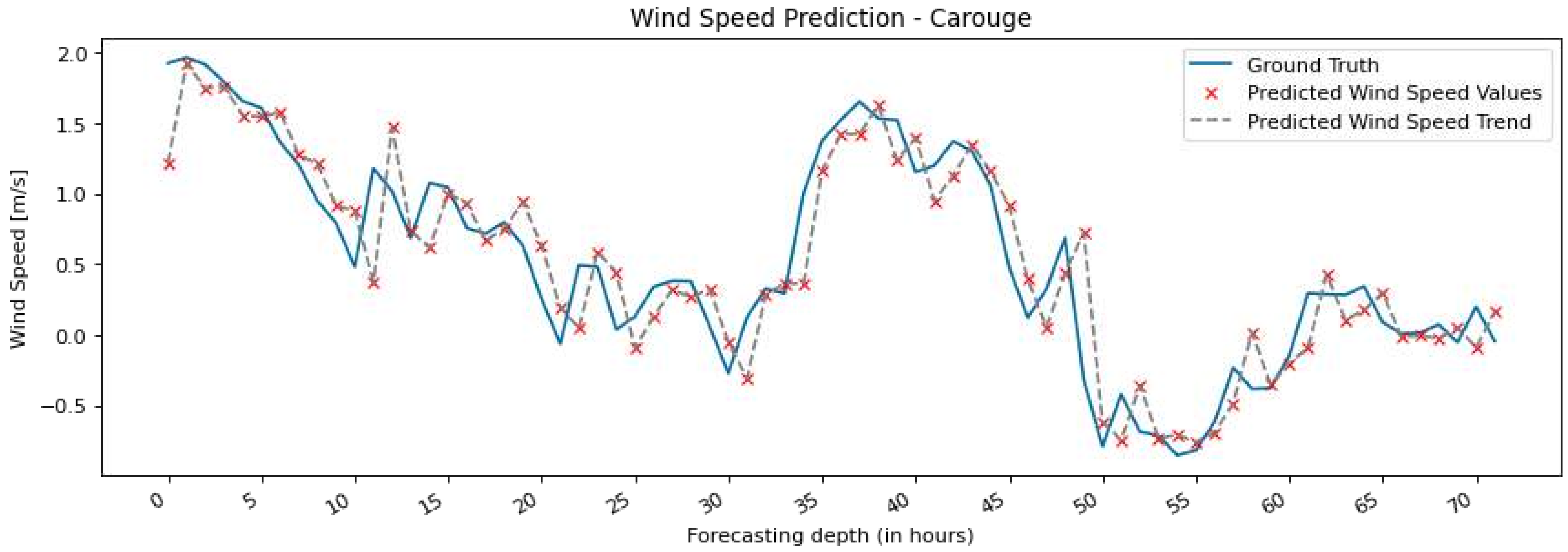
- Training & Validation
- Forecasting

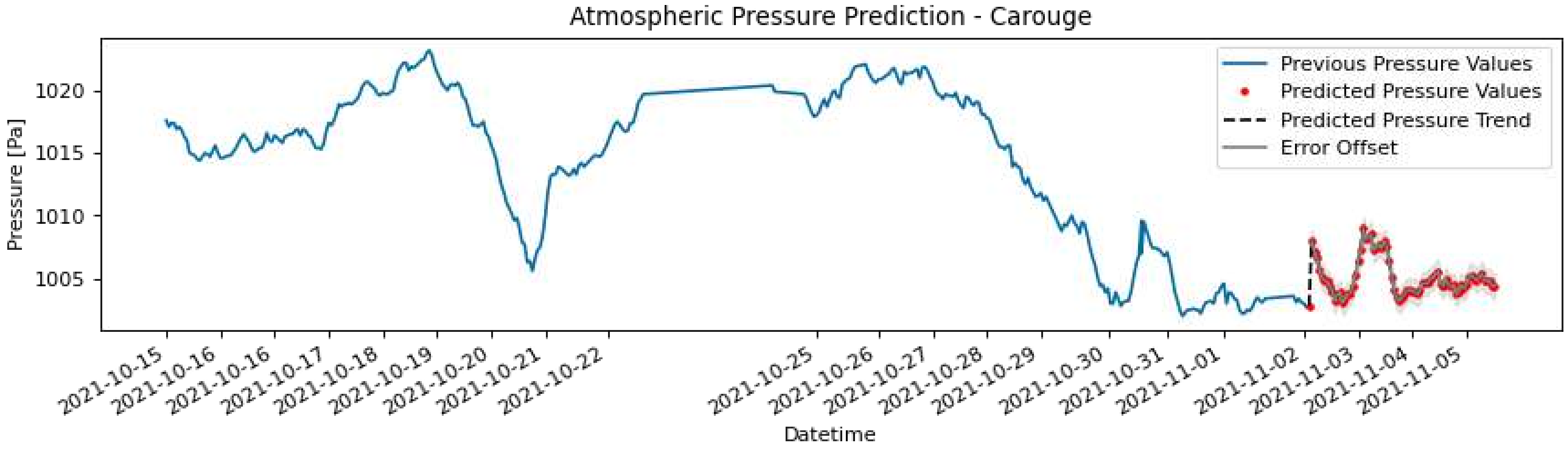




Carouge – Wind Speed

- Training & Validation
- Forecasting





Data-driven weather forecasting

Cons

- Useful data for particular problems
- Black box phenomena
  - Explainability
  - Physical phenomena
- Training is computationally intensive
- Narrow view of the problem (in most cases)

Pros

- Data availability
- High accuracy
- Inference is fast and computationally light (in most cases)
- Parametrization and flexibility
- Deployment versatility

Hybrid-models are the solution?

So, what next?

- •Timeseries
  - Phenomena that don't fall under certain trends (precipitation)
  - Rare events (storms, blizzards, heatwaves)

- •Spatial information
  - Cloud type and movement (precipitation)
  - Rare events (typhoons)

- •Deployment
  - Energy efficient deployment (edge devices vs cloud)
  - Increase parametrization for heterogenous inputs

- *Listen to the end-users' needs…*

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THANK YOU

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Nikolaos Angelopoulos

Konnektable

Webinar Series

An Event Detection Interface in the water sector

Nikolaos Angelopoulos, Konnektable

Human Machine Interface | Home Page

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Human Machine Interface | UC Braila

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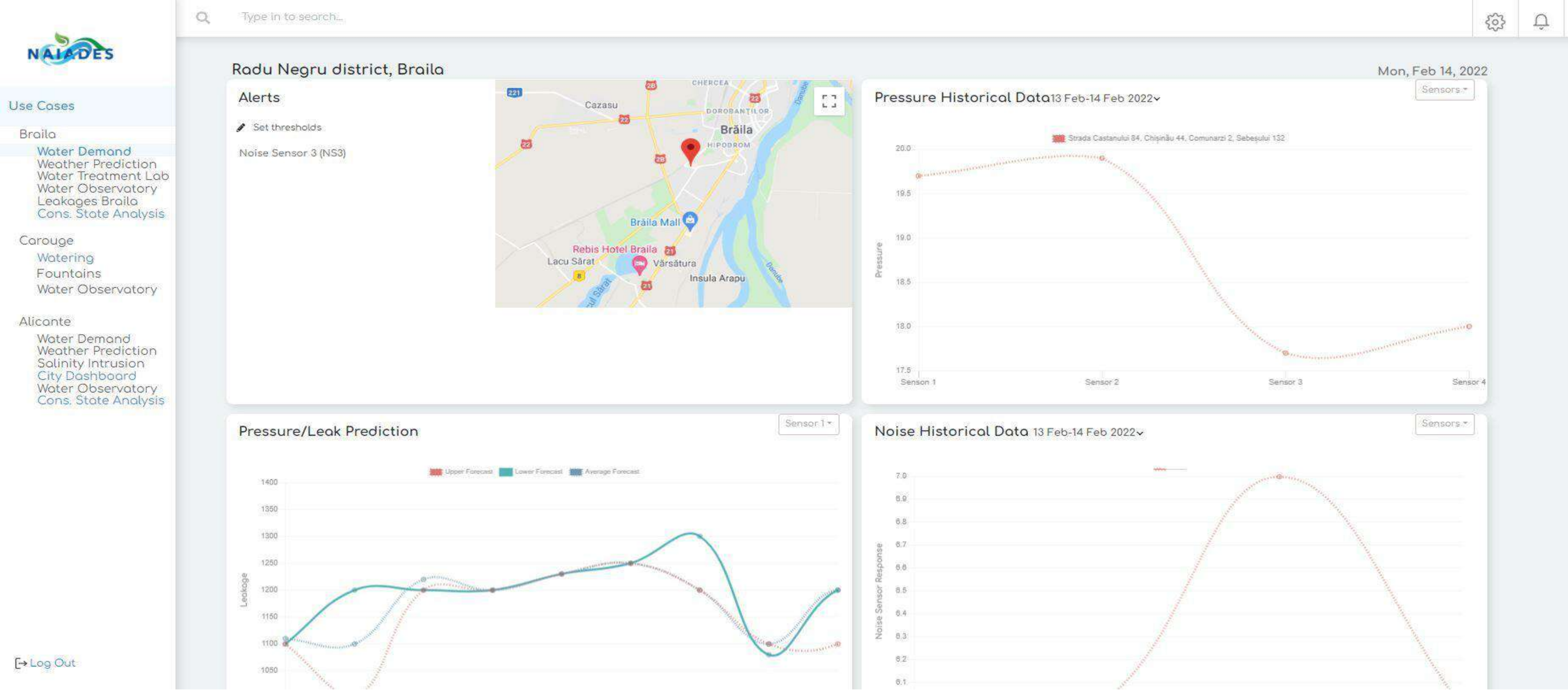
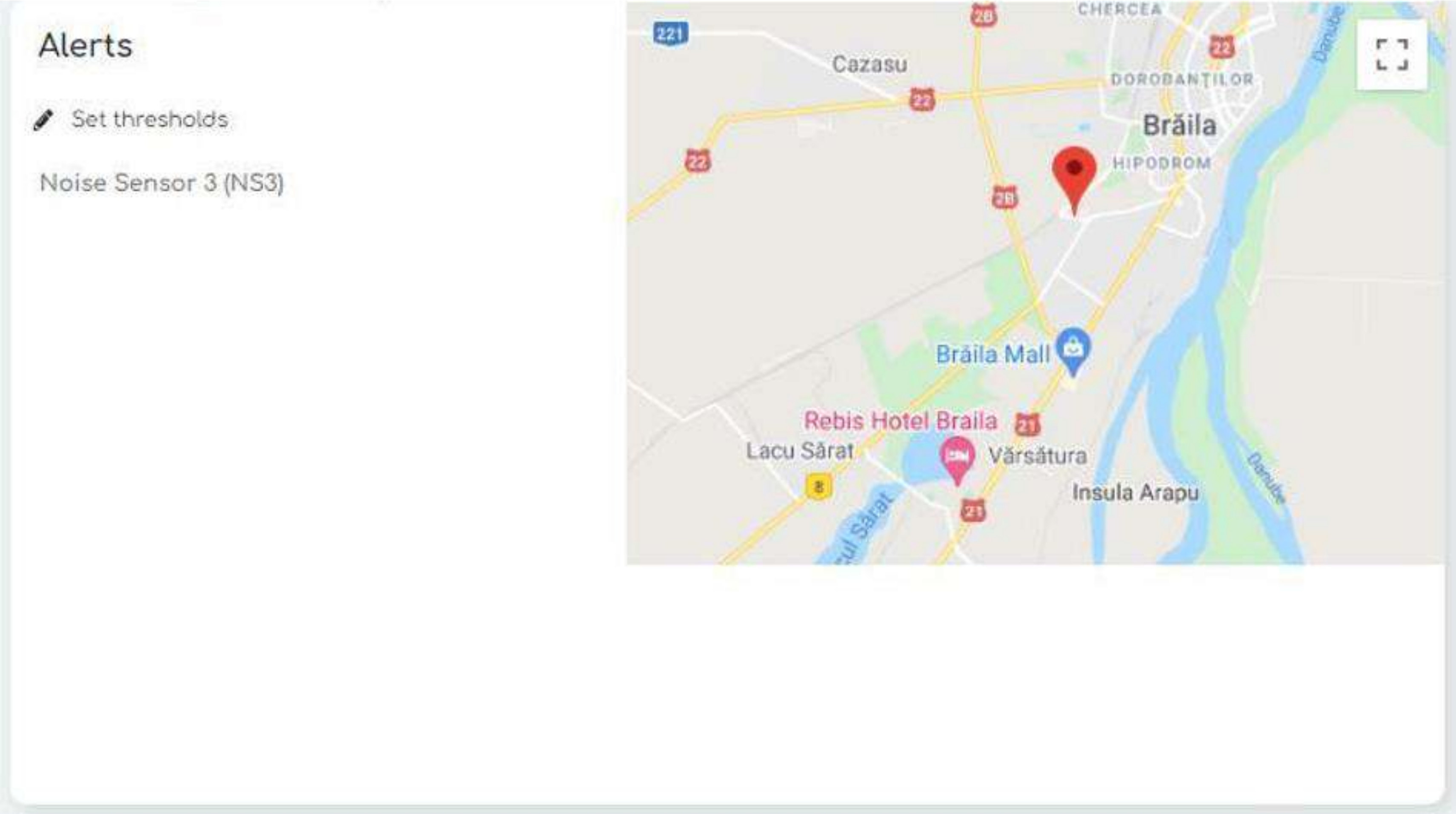


Human Machine Interface | UC Braila
Water Demand - Alerts

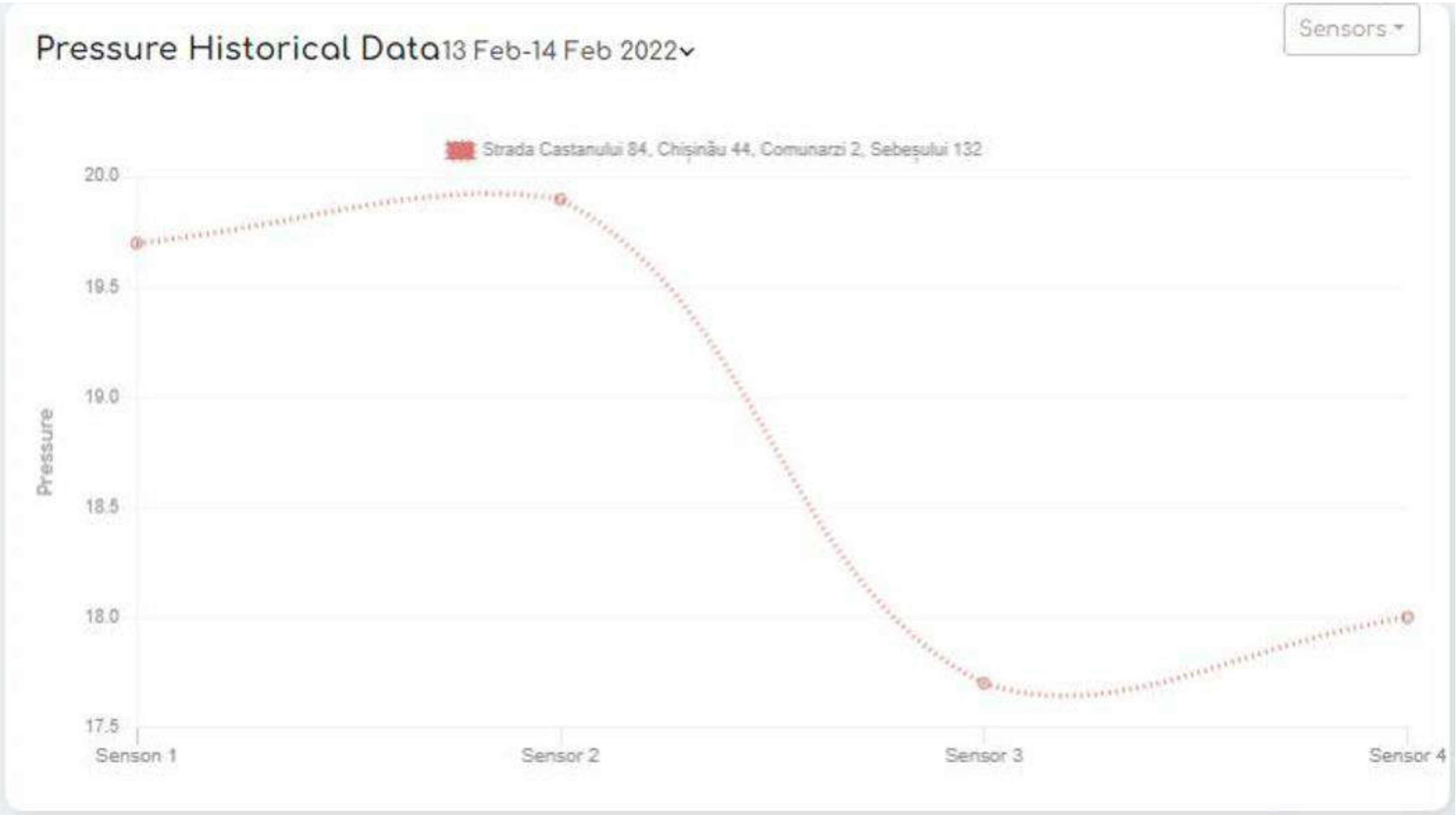
- Alerting by monitoring specific thresholds of values coming from the noise sensors

- Deep learning algorithms applied for short-term and long-term water demand predictions



Human Machine Interface | UC Braila
Pressure measurements Historical Data

- Pressure measurement values for a user-defined time period



Human Machine Interface | UC Braila Pressure/Leak Prediction

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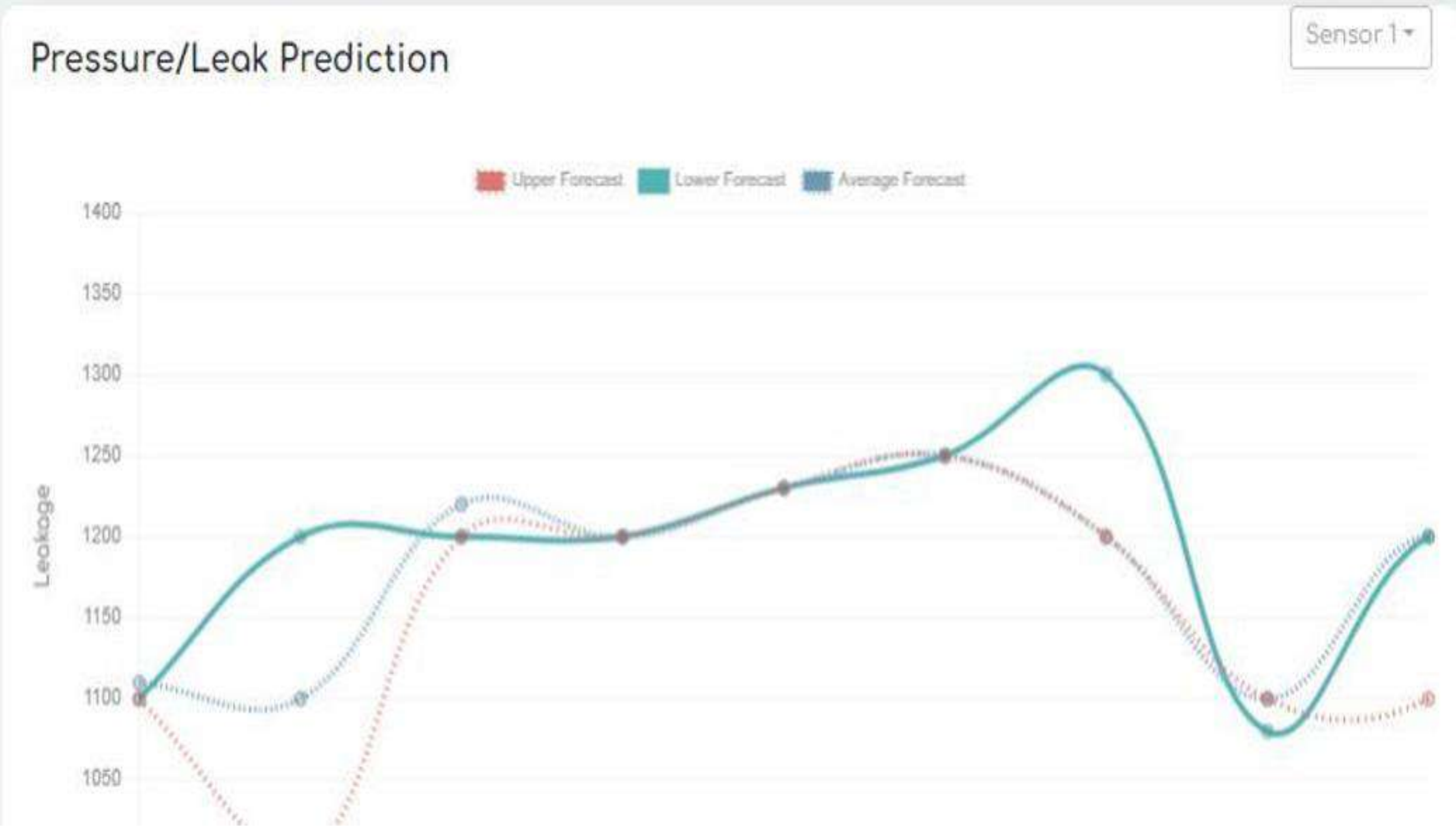
- This diagram receives prediction data depending on the user-defined leakage and pressure parameters.

- The prediction is divided into 3 levels:
  - o Lower Forecast
  - o Average Forecast
  - o Upper Forecast



Human Machine Interface | UC Braila Weather Forecast

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Weather Forecast

Day/Hour (Local)	02/14/2022 (10:00)	+6h (16:00)	+12h (22:00)	02/15/2022 (04:00)	+24h (10:00)	+30h (16:00)	+36h (22:00)	02/16/2022 (04:00)	+48h (10:00)	+54h (16:00)	+60h (22:00)	02/17/2022 (04:00)
Temperature Min	13.7 °C	5.5 °C	1.0 °C	7.4 °C	7.6 °C	3.2 °C	-2.2 °C	1.9 °C	6.8 °C	-1.8 °C	-3.5 °C	3.1 °C
Temperature Max	13.7 °C	5.5 °C	1.0 °C	7.4 °C	7.6 °C	3.2 °C	-2.2 °C	1.9 °C	6.8 °C	-1.8 °C	-3.5 °C	3.1 °C
Relative Humidity Min	42.0 %	70.4 %	90.6 %	66.6 %	44.6 %	57.8 %	83.7 %	78.8 %	43.0 %	77.2 %	96.7 %	78.3 %
Relative Humidity Max	42.0 %	70.4 %	90.6 %	66.6 %	44.6 %	57.8 %	83.7 %	78.8 %	43.0 %	77.2 %	96.7 %	78.3 %
Wind Speed	1.2km/h	1.5km/h	1.0km/h	4.6km/h	4.8km/h	4.0km/h	1.9km/h	2.9km/h	2.8km/h	2.7km/h	1.1km/h	1.5km/h

- This module produces weather predictions every 6 hours for the next 3 days.

Human Machine Interface | UC Braila Water Observatory

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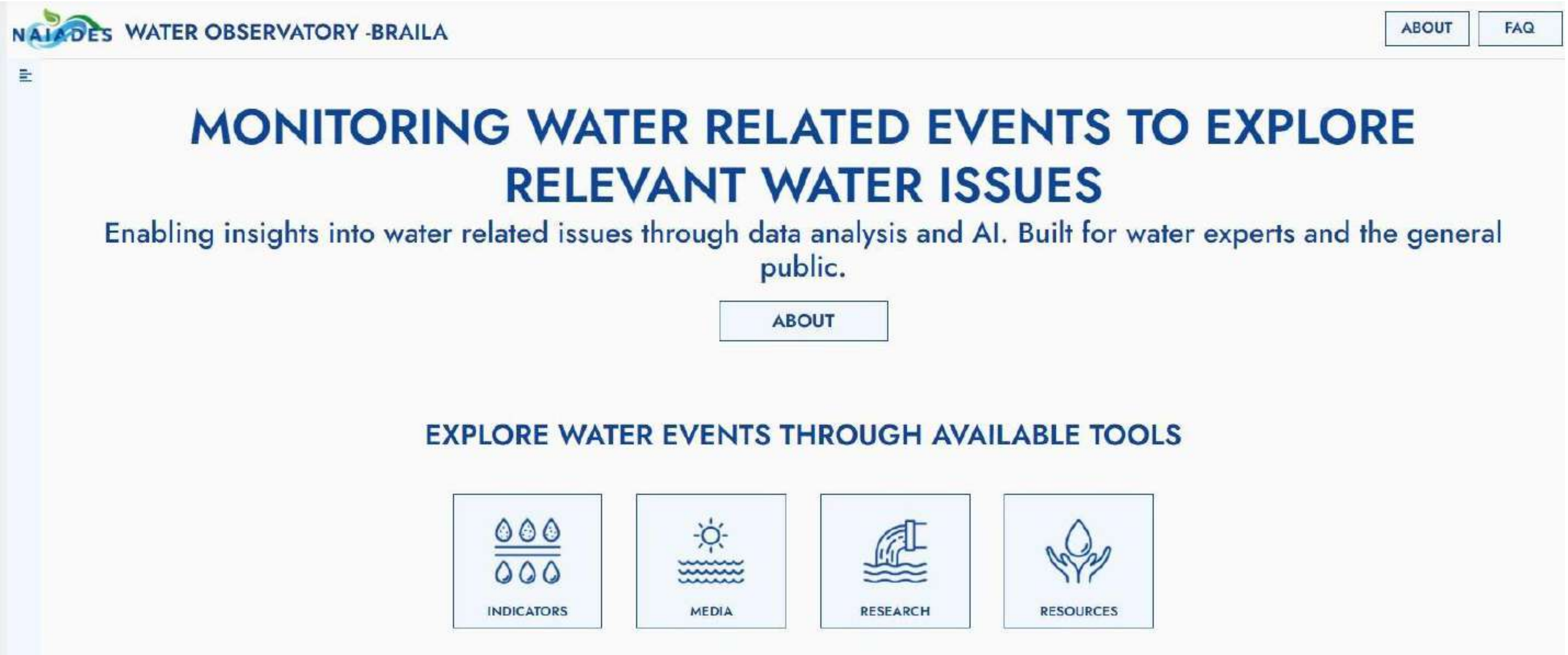
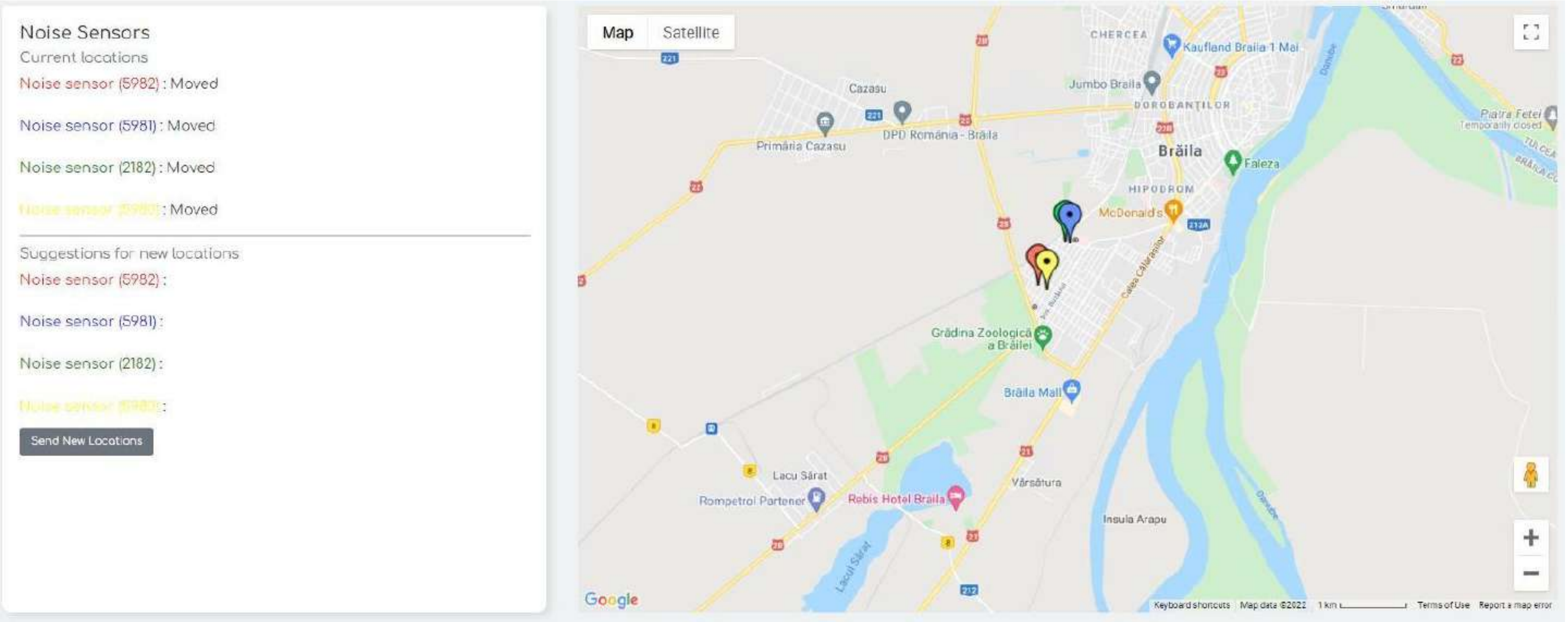
- The end-user can observe past events with similarly raised alarms from the Water Supply Sector. This module empowers through knowledge and awareness on the actions to be applied, in order to face the current issue, providing access to relevant *indicators*, *media*, *research* and *resources*.



Human Machine Interface | UC Braila Leakage Detection

This module provides:

- The original location of the sensors
- The status of the sensors
- Alerts regarding the status of the sensors and sensor measurements
- Suggestion for new location in case of leakage/failure detection



Human Machine Interface | UC Carouge

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Type in to search...

Use Cases

Braila
- Water Demand
- Weather Prediction
- Water Treatment Lab
- Water Observatory
- Leakages Braila
- Cons. State Analysis

Carouge
- Watering
- Fountains
- Water Observatory

Alicante
- Water Demand
- Weather Prediction
- Salinity Intrusion
- City Dashboard
- Water Observatory
- Cons. State Analysis

Log Out

Fountain des Tours + Add new fountain

Mon, February 14, 2022

Water Quality

Historical

Date observed: Friday, November 5th 2021, 12:27:04 pm

PH Level	6.8
Avg per hour	6.8
Avg per day	6.8
Free Chlorine	0.25
Avg per Hour	0.25
Avg per Day	0.25
Total chlorine	0.07
Chlorate Estimation	0
Avg per hour	0
Avg per day	0
Temperature	12.9
Avg per hour	12.9
Avg per day	12.9
Turbidity	9.8
Avg per day	9.8
Redox	0.348

Daily Report

Mon Tue Wed Thu Fri Sat Sun

Fill Report Weekly Report

Water Quality Forecast

Day/Hour (Local)	01/21/2022 (10:00)	+6h (16:00)	+12h (22:00)	01/21/2022 (04:00)	+24h (10:00)	+30h (16:00)	+36h (22:00)	01/21/2022 (04:00)	+48h (10:00)	+54h (16:00)	+60h (22:00)	01/01/1970 (04:00)
Chlorate	1.864579558	1.767506957	1.242912173	1.514566422	1.354356289	1.732353687	0	2.363450527	0	0	0	0
Conductivity	0	0	0	0	0	0	0	0	0	0	0	0
Free Chlorine	0.022885129	0.281559765	0.61404109	0.514137685	-0.085228816	0.209492013	0	0.811241806	0	0	0	0
pH	6.993663788	7.266806126	7.178091049	7.75484705	7.254029751	7.216527939	0	7.463978291	0	0	0	0
Total Chlorine	0.825314522	0.999299347	1.82943368	0.668306172	1.224642277	1.673656106	0	1.438574314	0	0	0	0
Turbidity	0	0	0	0	0	0	0	0	0	0	0	0

Weather Forecast

Day/Hour (Local)	02/14/2022 (10:00)	+6h (16:00)	+12h (22:00)	02/15/2022 (04:00)	+24h (10:00)	+30h (16:00)	+36h (22:00)	02/16/2022 (04:00)	+48h (10:00)	+54h (16:00)	+60h (22:00)	02/17/2022 (04:00)
Temperature	5.4 °C	-0.3 °C	-1.5 °C	0.3 °C	5.5 °C	3.5 °C	1.0 °C	0.9 °C	8.5 °C	2.8 °C	3.8 °C	4.3 °C
Relative Humidity	69.6 %	78.5 %	73.6 %	59.7 %	71.7 %	83.9 %	83.4 %	77.5 %	70.9 %	85.1 %	82.8 %	94.7 %
Wind Speed	19.8 km/h	12.5 km/h	12.3 km/h	7.9 km/h	6.1 km/h	12.1 km/h	15.2 km/h	13.5 km/h	7.7 km/h	16.4 km/h	16.9 km/h	13.3 km/h
Precipitation Probability	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %

Reported Issues Feed

- pH is normal.

Human Machine Interface | UC Carouge Watering

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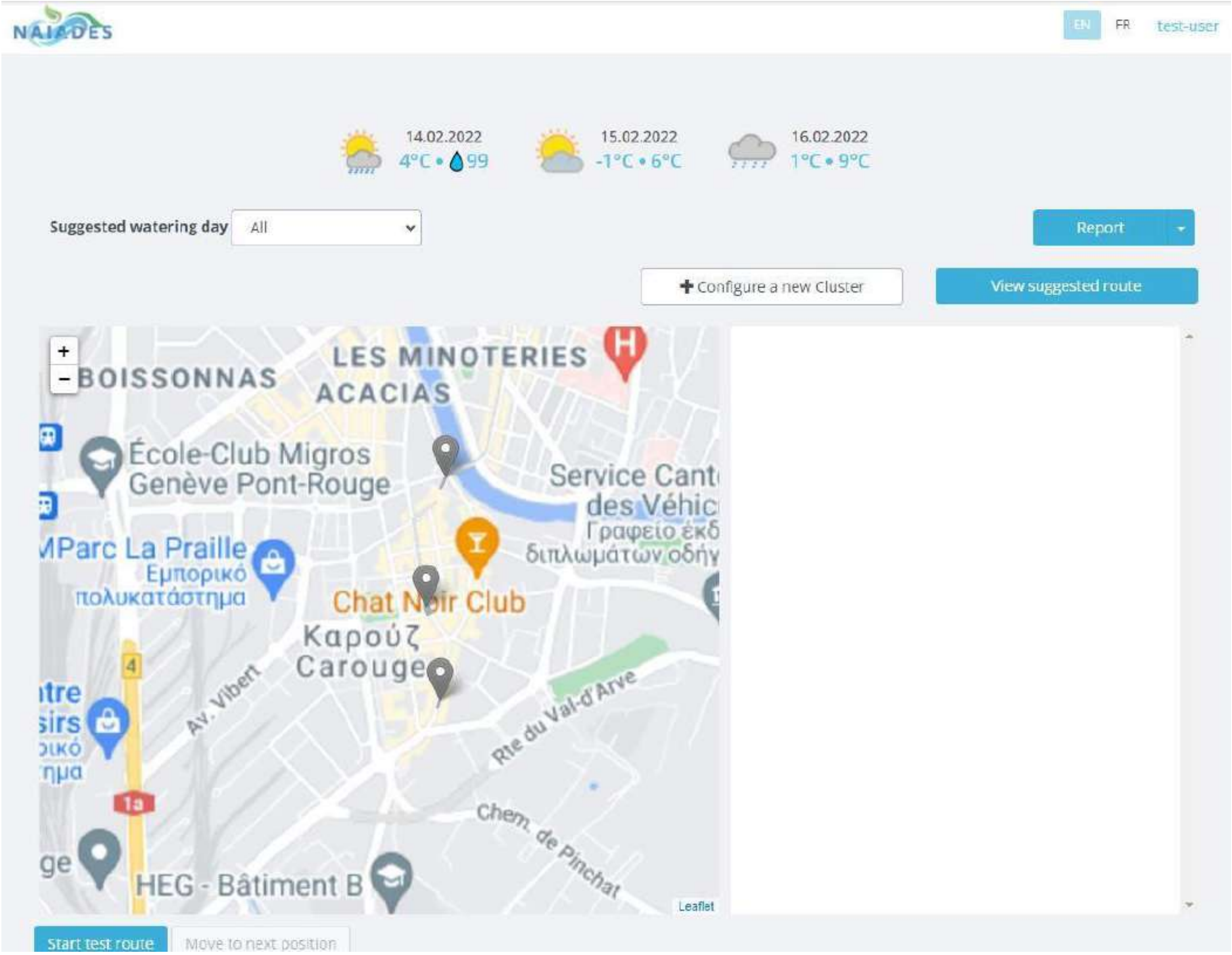
This pop-up module provides:

- A garden watering dashboard inside the city.
- Suggesting watering day
- Reports with the final actions



Human Machine Interface | UC Carouge Fountain

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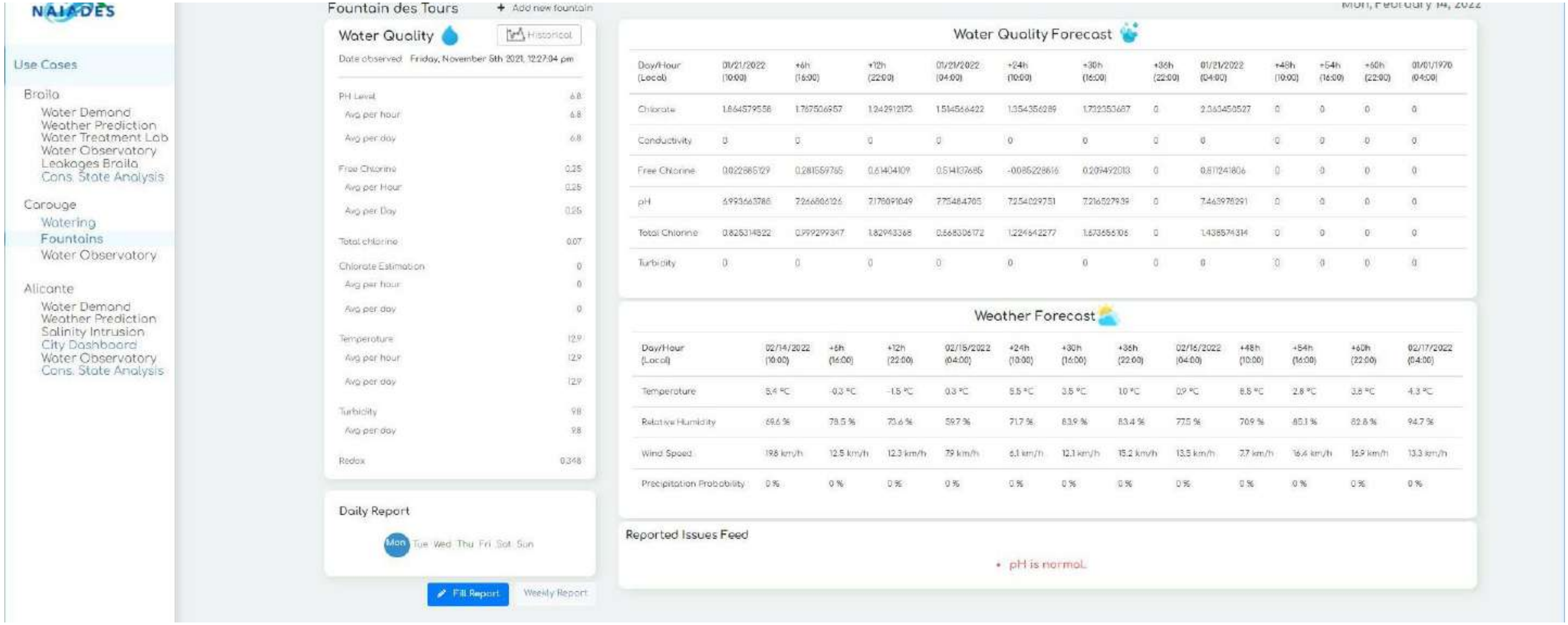
This module provides:

- Water Quality measurements
- Water Quality forecast
- Weather forecast
- Daily reports
- Reported Issues feed



Human Machine Interface | UC Carouge Fountain – Historical Data

Diagrams with historical values of *PH, Chlorine, Turbidity, Temperature* and other Water Quality measurements

Human Machine Interface | UC Carouge Fountain – Add new Fountain

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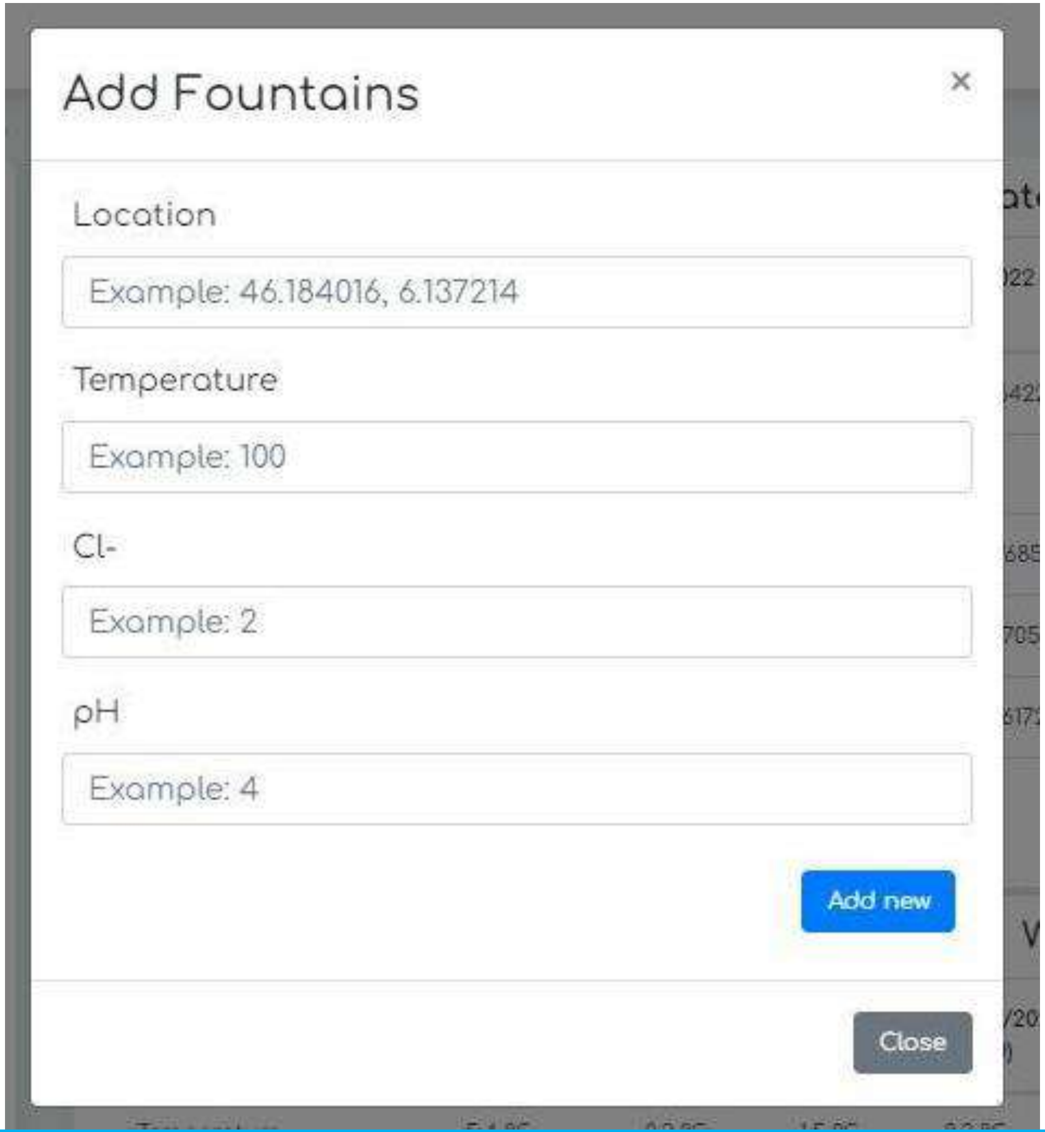
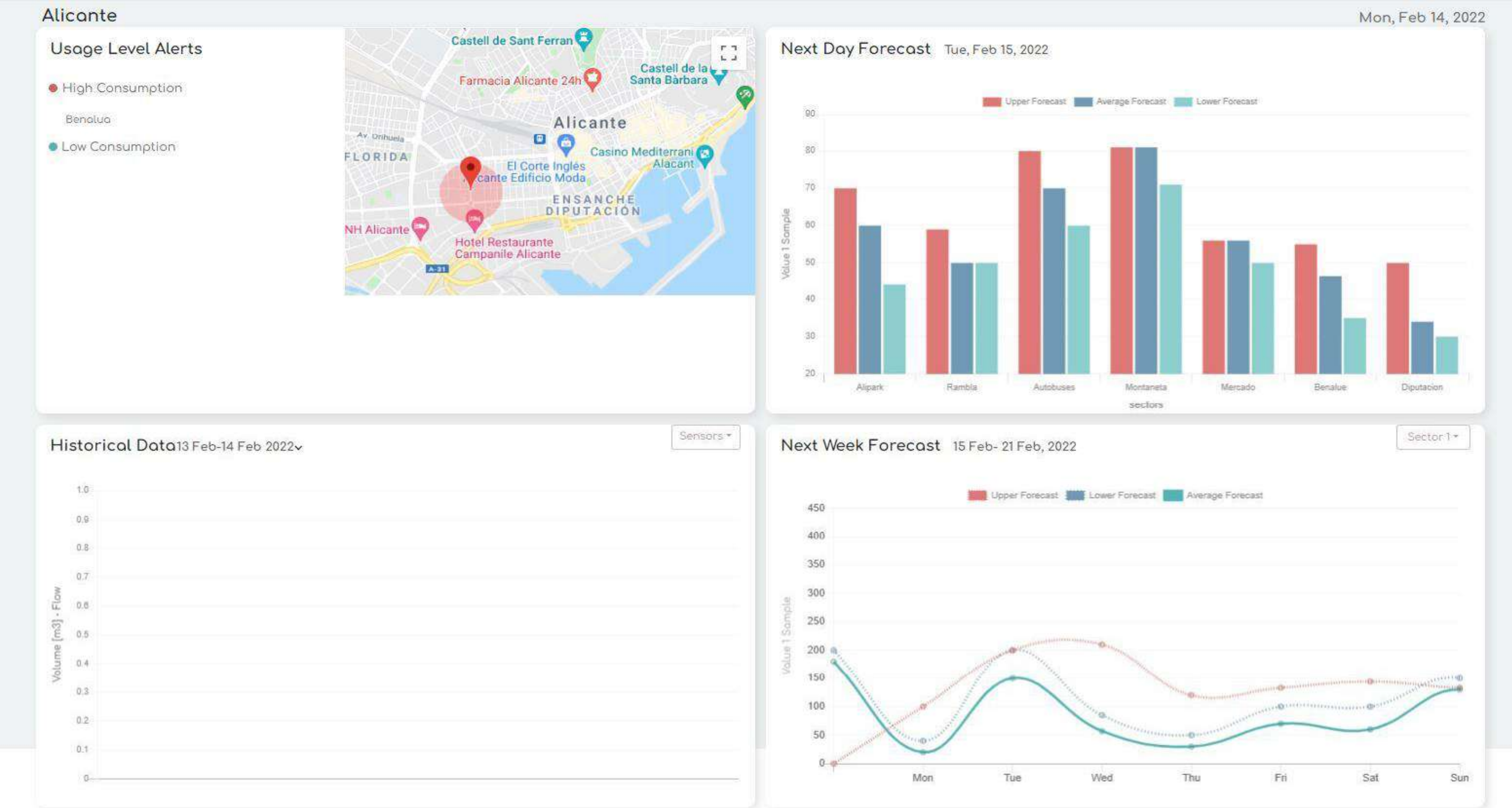
The end-user can add a new fountain to be used and monitored along with the others through this pop-up function.



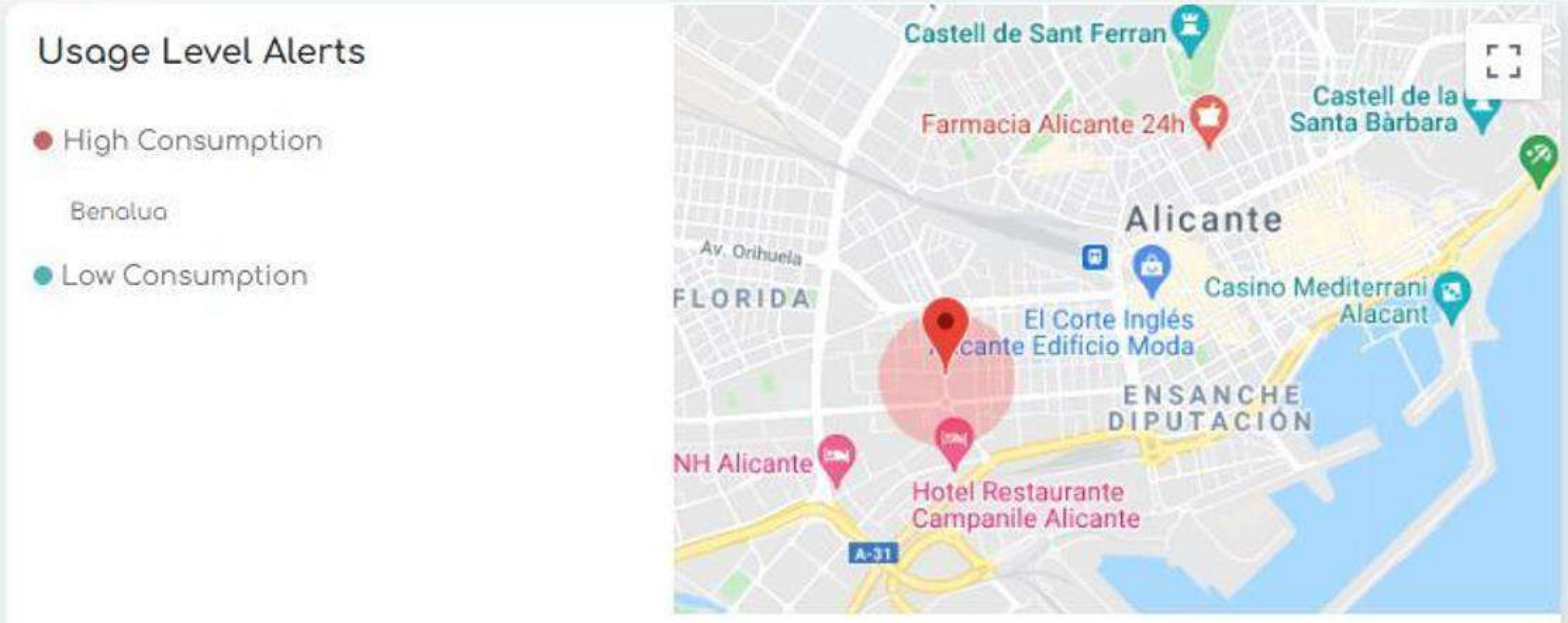
Human Machine Interface | UC Alicante



Human Machine Interface | UC Alicante Usage level Alerts

This module provides:

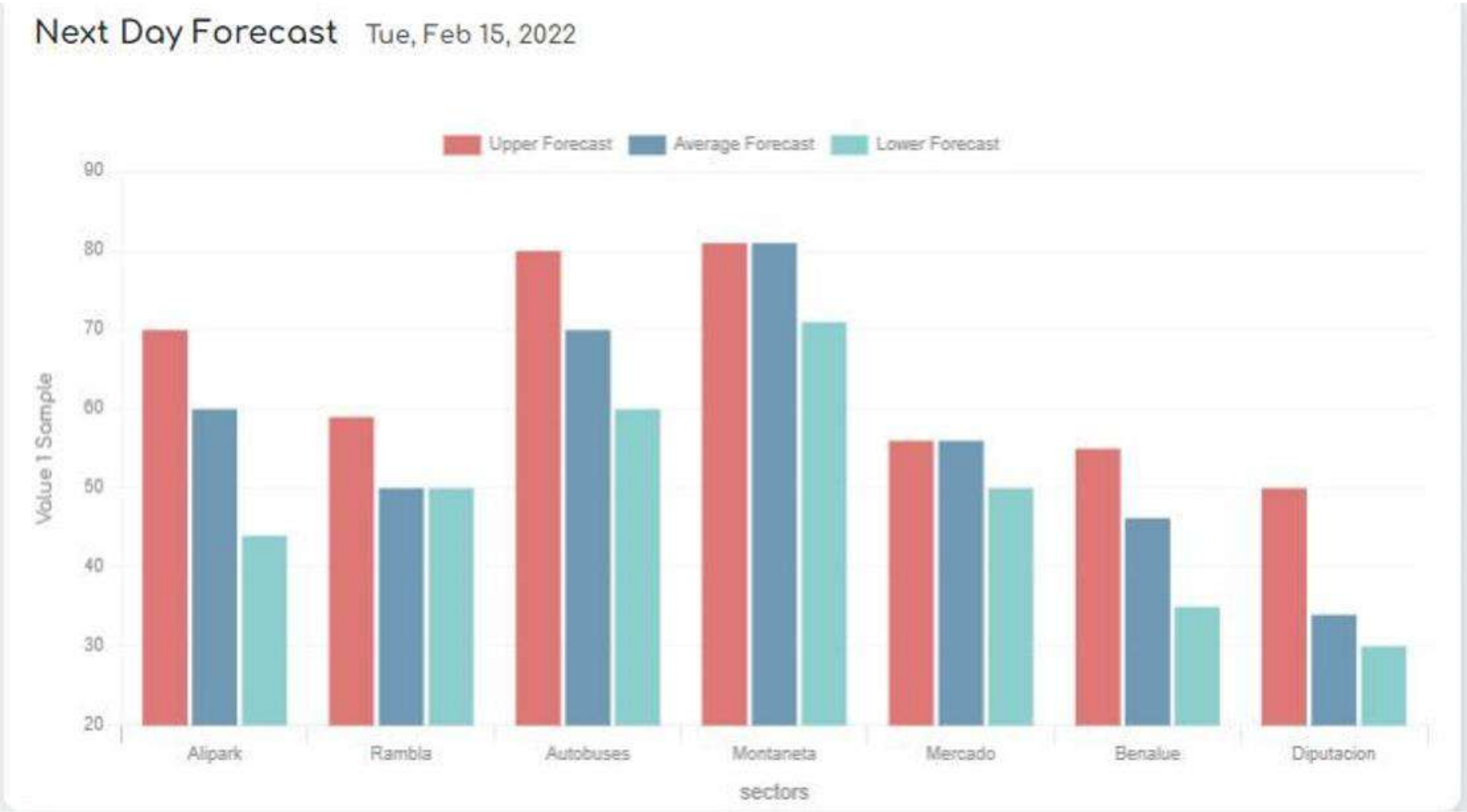
- Usage Alerts by area
- Short-term and long-term Forecast
- Consumption Predictions



Human Machine Interface | UC Alicante
Water Demand - Next day Forecast

Webinar Series

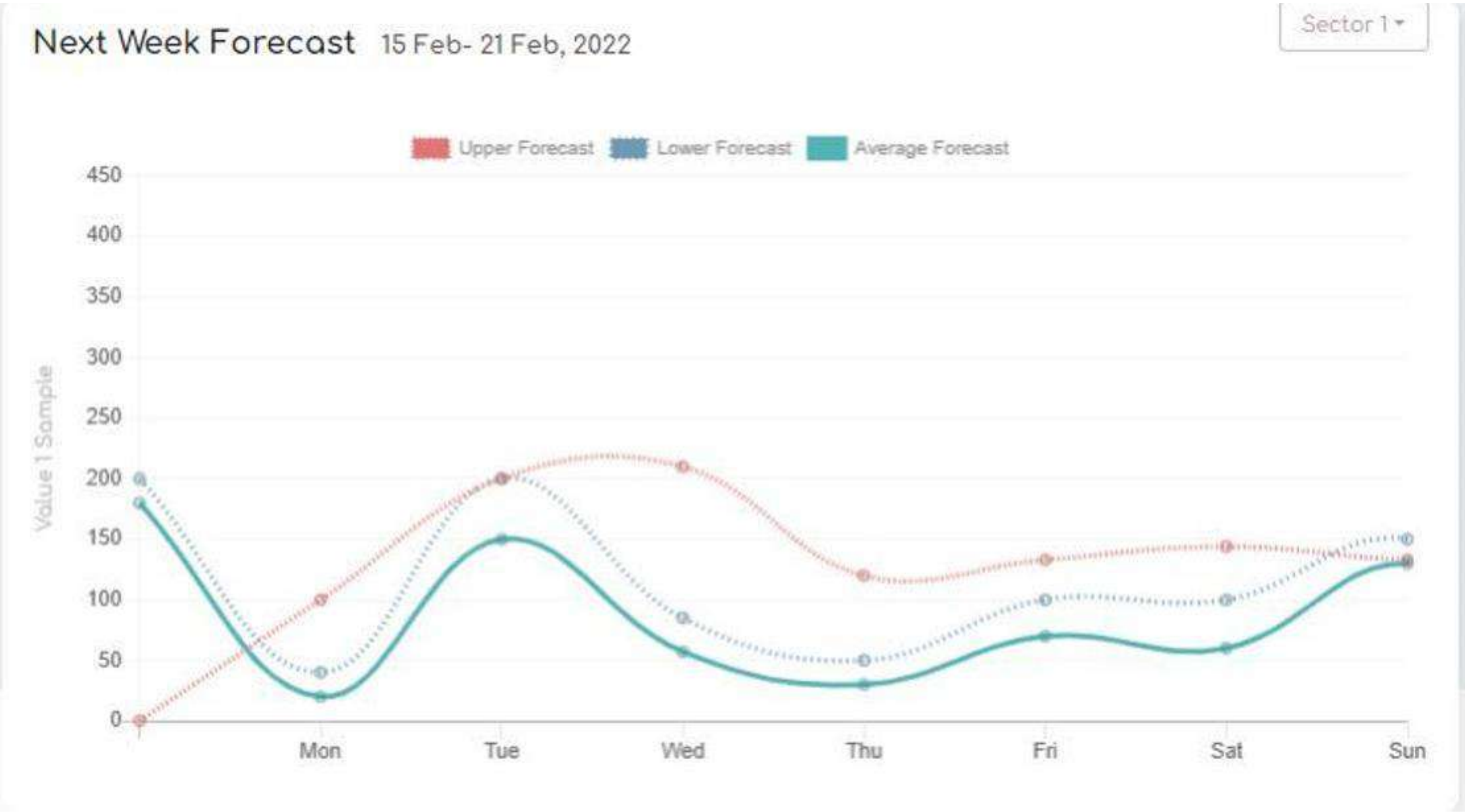
This module provides Upper, Avg and Lower (Short-term) Forecast on specific areas of the city.



Human Machine Interface | UC Alicante
Water Demand - Next week Forecast

NAIADES
Webinar Series

This module provides Upper, Avg and Lower (Long-term) Forecast on specific areas of the city.



Human Machine Interface | UC Alicante Water Demand - Next week Forecast

NAIADES Webinar Series

This module provides historical data regarding Water Consuption over a specific, user-defined, time period.

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Webinar Series

Filippo Cristian SALEMI
IBATECH

Sergio MONTERO
IBATECH

NAIADES

Webinar Series

NAIADES' smart solutions for Chlorates prediction in water

F. Cristian Salemi & Sergio Montero, IBATECH

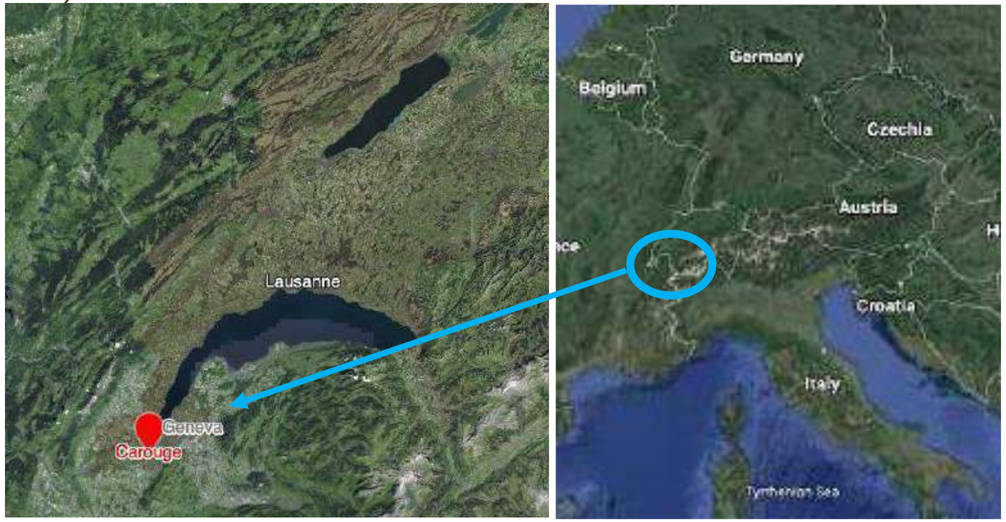
NAIADES @Carouge

2 Use Cases

- Carefully identified by the city's relevant department (SVEM)
  - Watering of flowerbeds
  - **Water management in public fountains**

General Goals:

- Decrease water usage by further optimizing it
- Reduce the workload by improving its efficiency



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Use Case: Detection of saline intrusion

- Pilot area selected for
  - High density of sewer mains
  - Older pipes
  - Higher risk of saline intrusion

General Goals: Detect and monitor saline intrusion by:

- Flow, conductivity and water-level sensors
- Smart Data analysis (Anomaly Detection)

Fountain Use Case

- Iconic fountain located in the very centre of the City
- Beloved from inhabitants, especially families
- A source of refreshment during the hot summer days

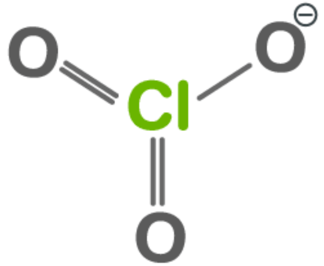
The problem(s)

- Lack of continuous measurements and limited set of parameters measured
- No sensors exist for some key parameters such as **chlorates or bacteria**
- High fluctuation of the measured parameters and situation can escalate quickly → **Early detection of issues is key**

NAIADES solution for the fountains

- **Integrated sensor platform with wider range of sensors, LoRa**
- **Novel approach to determine presence of chlorates**
- AI-based water quality forecast based on measurements history
- Decision support system (DSS) based on multidimensional criteria
- HMI application for city staff and management

Chlorate´s problems



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- Chlorates (ClO_3-) are present in the Carouge water.
- Chlorates concentration may increase as disinfection by-products from Chlorine dioxide (ClO_2) or Sodium hypochlorite (NaClO).
- It is a chemical compound that may **have negative effects on human health and the environment.**
- Chlorates measurement is made by taking water sample and analysed in laboratory, with results within few days → **no early detection.**
- There is **not specific sensor or method in the market** for real time Chlorates measurement or estimation.

Technical Solution = Prototype

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- **Fountain prototype has been developed** to measure key water quality parameters and to find out a potential Chlorates concentration prediction → **early detection (no water samples, no labs)**
- The Fountain prototype main features:
  - Integrated sensors: Temperature, pH, Free Cl (Cl2), Combined Cl (indirect), Total Cl, Turbidity (NTU) and Redox (ORP)
  - IoT communication with existing LoRa WAN network
  - Data logging and local monitoring

  - **Oxidation Reduction Potential (ORP) sensor measures** the ability of a solution to act as an oxidizing agent or reducer, in which **Cations or Anions** are formed. Such ability is measured in potential values (mV). Hence as **Chlorate (ClO_3^-) is an Anion (-), the ORP sensor is useful in the Chlorate detection.** *ORP sensor is one of the greater contributors in the ClO_3^- estimation in water.*

Research Objectives

- **Chlorates estimation Research is based on an correlation formula**, using the measured parameters, **to create an real time indicator to predict chlorates concentration**

- Evaluation of Chlorates production in water as **disinfection by-products** from for example Chlorine dioxide (ClO_2) or Sodium hypochlorite ($NaClO$).

Chlorates Experimentation Approach

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The chlorates experimentation was divided into five (5x) main steps as follows:

- *Method 0: Analysis of sensors response to ClO_3^- concentrations on distilled water*
- *Method A: Analysis of natural ClO_3^- production due to NaClO degradation within 7 days period*
- *Method B: Analysis of natural ClO_3^- production due to NaClO degradation in presence of initial ClO_3^- within 5 days period*
- *Method C: Simulation of realistic concentration conditions:*
  - *Method Ca: Analysis of natural ClO_3^- production due to NaClO degradation within 7 days period*
  - *Method Cb: Analysis of natural ClO_3^- production due to NaClO degradation in presence of initial ClO_3^- within 7 days period*
- *Method D: Analysis of Real Water Samples from Carouge Fountain*

Chlorates Experimentation Results

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- ***Method 0: Analysis of sensors respond to ClO_3^- concentrations on distilled water.***

This method is carried out to assess the sensors response at ClO3-concentrations without any interferent in water. Thus, Chlorates have been added in different concentrations with distilled water as follows:

- ✓ *1 L Distilled Water (as sensor respond background)*
- ✓ *1 L Distilled Water + 10 ml of ClO3- (Chlorates) concentrated at 1000 mg/L*
- ✓ *1 L Distilled Water + 20 ml of ClO3- (Chlorates) concentrated at 1000 mg/L*
- ✓ *1 L Distilled Water + 30 ml of ClO3- (Chlorates) concentrated at 1000 mg/L*
- ✓ *1 L Distilled Water + 40 ml of ClO3- (Chlorates) concentrated at 1000 mg/L*
- ✓ *1 L Distilled Water + 50 ml of ClO3- (Chlorates) concentrated at 1000 mg/L*

Equation of the Model :

ClO3-(mg/L)=712,251243429412-44,82636718345*pH-66,3367276422549*Cl2(mg/L)+372,454561380321*TCl(mg/L)-0,87579365990067 5*ORP(mV)-4,51465618459959*T(ºC)+1,17321348815874*Turbidty (NTU)

Chlorates Experimentation Results

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- ***Method A: Analysis of natural $ClO3^-$ production due to NaClO degradation within 7 days period.***

This method aims to assess the degradation NaClO into $ClO3^-$ as result of one of the natural Chlorate productions in a period of 7 days disinfection. It is expected to clearly evaluate the $ClO3^-$ production due to the "concept": the more the Sodium Hypochlorite (NaClO) in water (H2O), the more the hypochlorite (OCl^-) ions", and consequently more probabilities that OCl^- degrades into $ClO3^-$ according to the equation: 1) $3OCl^- \rightarrow ClO3^- + 2Cl^-$.

*In keeping with such "concept", **the added value in this method is clearly quantify Chlorates generation at high levels of NaClO** despite being out of measuring range of Fountain prototype sensors (Free & Total). This was solved due to the availability of HPLC lab instrument which enable much wider measuring ranges.*

Equation of the Model :

ClO3-(mg/L)= 0,34366645775127-1,76809924578623E-02*pH+9,20095883286937E-07*Cl2(mg/L)-4,5523704902956 3E-04*ORP (mV)+7,24871337095194E-03*Tº (ºC)

Chlorates Experimentation Results

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- ***Method B: Analysis of natural $ClO3^-$ production due to NaClO degradation in presence of initial $ClO3^-$ within 5 days period.***

The approach of method B is to assess the degradation NaClO into $ClO3^-$ as result of one of the natural ways of Chlorate production in water (like in Method A) but adding an initial presence of Chlorates in the water but keeping the same "concept" of: the more the Sodium Hypochlorite (NaClO) in water (H2O), the more the hypochlorite (OCl^-) ions".

Furthermore, this method give important information about the potential $ClO3^-$ capability of being a catalyser in the production of new Chlorates.

Equation of the Model :

Clo3-=2,74061401393949-8,59502363512417E-02*pH+4,9123067309378E-04*Cl2 (mg/L)-3,05149635319072E-04*TCl (mg/L)-2,57884887014161E-03*ORP (mV)+4,69791111502907E-03*Tº (ºC)

Chlorates Experimentation Results

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- ***Method C: Simulation of realistic concentration conditions.***

The approaching of this method is to keep the same philosophy from Method A and B: Analysis of natural NaClO degradation with and without initial $ClO3^-$ presence but in this case, simulating real concentration conditions, namely, NaClO and $ClO3^-$ concentrations within ranges which can be found in any public Fountain. It is important to note that the advantage of the Method C is that enables to get values from both sources, Fountain prototype and HPLC which means that fountain sensor values were also validated with lab instrument.

- **Method Ca: Analysis of natural ClO_3^- production by NaClO degradation (7 days period)**

Parameter	Value
Sodium hypochlorite [mg/l]	1.00±0.010
Sodium hypochlorite [mg/l]	2.00±0.010

- **Method Cb: Analysis of natural ClO3- production by NaClO degradation in presence of initial ClO3- (7 days period)**

Parameter	Value
Sodium hypochlorite [mg/l]	1.00±0.010
Sodium hypochlorite [mg/l]	2.00±0.010

+

Parameter	Value
Chlorate [mg/l]	1.00±0.05
Chlorate [mg/l]	5.00±0.05

Equation(s) of the Model(s) :

Method Ca → Clo3-=2,41840247818555-4,38725641757871E-02*pH+0,670467600246094*Cl2(mg/L)-0,669365973598627*TCl (mg/L)-3,02592842093426E-03*ORP (mV)

Method Cb → Clo3-=150,051966853095-23,9500319179889*pH-18,9447685981935*Cl2(mg/L)+18,9046734480759*TCl (mg/L)+6,61759395215635E-02*ORP (mV)

Lesson Learned 1/2

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- Method 0:
  - Fountain Prototype in distilled water (with no interferent compounds) is sensitive to $ClO3^-$ concentration changes (Total Cl2 Free Cl2, Total Cl2 and ORP >0,5). Anyhow, the application of this formula in the Naiades platform produced inconsistent results.
- Method A & B & C:
  - In laboratory, with stable conditions, without solar radiation and with minimum diurnal temperature variation, the aging of NaClO over a period of five (5) or seven (7) days and its conversion to $ClO3^-$ is negligible, even with high initial concentration of Chlorates.
  - The readings of sensors (Free Cl2, Total Cl2) are directly related to the overall concentration of NaClO. The concentration of Chlorates ($ClO3^-$) are not significantly detected by Fountain Sensors.
  - Despite the wide measurement range of the ORP sensor (-1500 to +1500 mV), all measurements are in a very small range. The observed variation is generally in the range of a few units for Method A, to maximum a couple of tens for Method B, and maximum 3-4 tens for Methods Ca and Cb.
  - The ORP measurement decreases slightly with the increase of Chlorates; and decreases with the increase of NaClO (Free Cl2, Total Cl2).
  - The initial value and the variation of ORP sensor is more related to the NaClO concentration than to the concentration of Chlorates ($ClO3^-$).

Lesson Learned 2/2

- Method A & B & C:
  - Chlorate concentration generally increased inversely proportional with the concentration of Free Chlorine (FCl) and Total Chlorine (TCl). It is apparently due to a mass balance.
  - The mass loses of the initial NaClO concentration is equivalent, almost at 100%, to the $ClO3^-$ concentration production in a period of 5 or 7 days. Although the change is neglectable.
  - ORP behaviour is quite steady estate like the tendencies of values in pH & Temp.
  - It was found out that ORP, Free Chlorine and Total Chlorine sensors were also quite sensitive to the water composition of anions or cations (Ca^{++}, Mg^{++}, Na^+, K, HCO_3^-, NO_3^-, $SO4^{--}$, etc.).
  - Real conditions (solar radiation, temperature variations and organic compounds in water) have a clear influence in the outcomes obtained, and in conjunction with the water composition, may play a "**catalytic role**" in the production of $ClO3^-$ and consequently affecting the estimation formula outcomes.

  - **NOTE: !!! Methods A & B & C were performed using "Laboratory-Simulated" water !!!**

Chlorates Experimentation Results

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- ***Method D: Analysis of Real Water Samples from Carouge Fountain.***

*The approach of this method is to measure the values of chlorates concentrations of **real water** samples and then correlate statistically with to the values measured by the Fountain prototype (pH, ORP, Free and Total Chlorine, Turbidity, etc).*

Sample	dateObserved	ClO_3^- (mg/l)	turbidity	temp	pH	redox (mV)	freeChlorine	totalChlorine
1	2021-09-18 12:00h	0,489	**2,66**	20,30	7,28	714,00	0,14	0,63
2	2021-09-19 08:17h	0,502	**3,00**	19,23	7,25	714,00	0,14	0,61
3	2021-09-20 11:00h	0,513	**2,90**	17,78	7,20	741,00	0,14	0,65
4	2021-09-21 11:00h	0,535	**3,60**	15,00	7,28	745,00	0,14	0,81
5	2021-09-22 14:00h	0,532	**412,50**	15,70	7,39	720,00	0,23	1,11
6	2021-09-23 08:00h	0,518	**412,50**	14,30	7,09	739,00	0,23	1,07
7	2021-09-24 15:00h	0,512	**412,50**	18,10	7,38	660,00	0,24	0,64

Lab

Fountain Prototype

Equation of the Model:

ClO3-=0,399230565973119+1,2129678955946E-03*turbidity (NTU)-1,26667095373139E-02*temp (ºC)+0,138852185653503*pH+1,92072362038609E-04*redox (mV)-5,03934612461565*freeChlorine (mg/l)-0,156822186626706*totalChlorine(mg/l)

Validation & Conclusions

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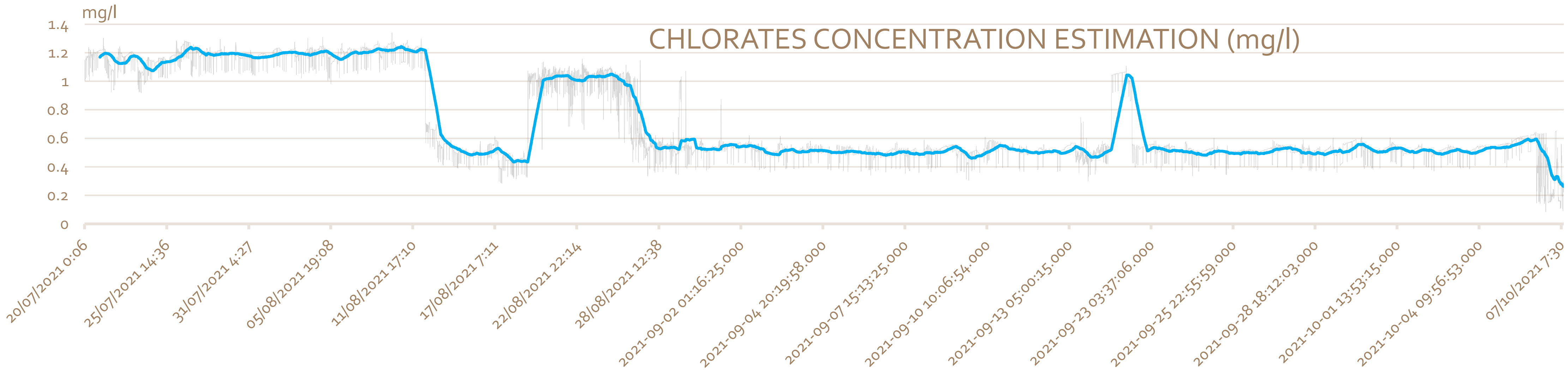
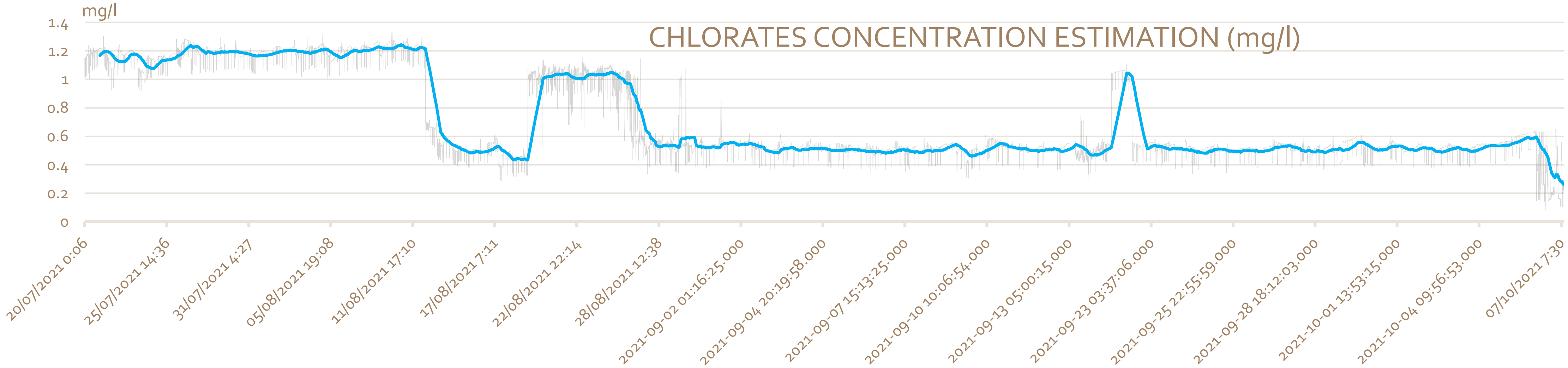
- Method D:
  - In order to evaluate the equation viability, $ClO3^-$ equations have been applied on the entire registered sensor data (raw data) collected by the NAIADES platform from 20/07/2021 to 7/10/2021. Results have been plotted graphically.



The retroactive application of the formula to the historical data collected by the NAIADES platform makes assume that the prediction is coherent and ready for final validation.

Future Applications

- There is not a Commercially off the Shelf product that can predict Chlorate concentration in water.
- This novel application, developed under NAIADES project, can be extrapolated to similar use cases taking in consideration the specific surrounding variables of the matrix water and interpolating the data with chemical-physical sensors (FCl, TCl, ORP, pH, T, NTP, etc).



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Session 2: INVITED GUESTS

Dr. Brett Snider
University of Exeter, Aqua3S

NAIADES

Webinar Series

Developing a Comprehensive Leak Detection System

Dr. Brett Snider, University of Exeter, aqua3S

Leak Detection in Water Distribution Systems

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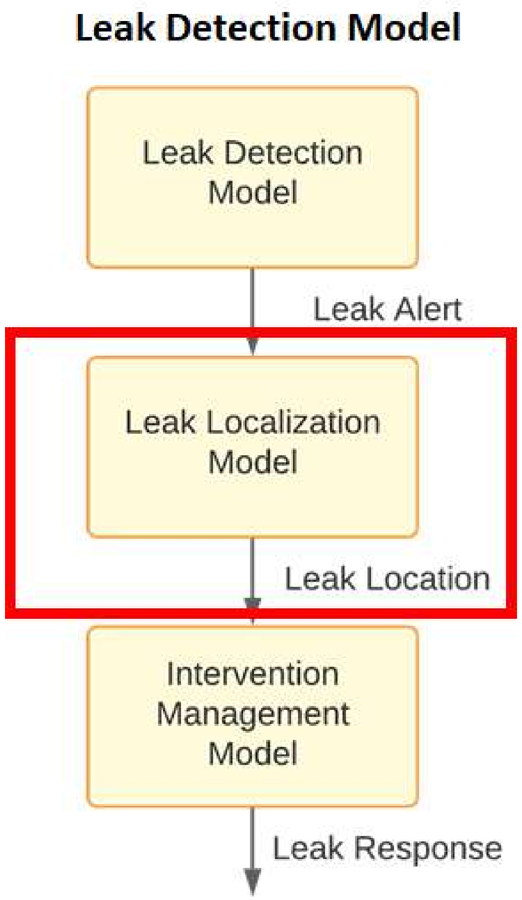
- Pipe Bursts in WDS increasing throughout the world
- Technical tools developed to assist with pipe bursts:
  - Preventative:
    - Asset management tools
    - Critical infrastructure live monitoring
  - Reactive:
    - Leak detection tools
    - Water Audits
    - Remote sensor detection systems
    - Etc.

Comprehensive Leak Detection System

1. **Detect**
2. **Locate**
3. **Respond**



Leakage Localisation

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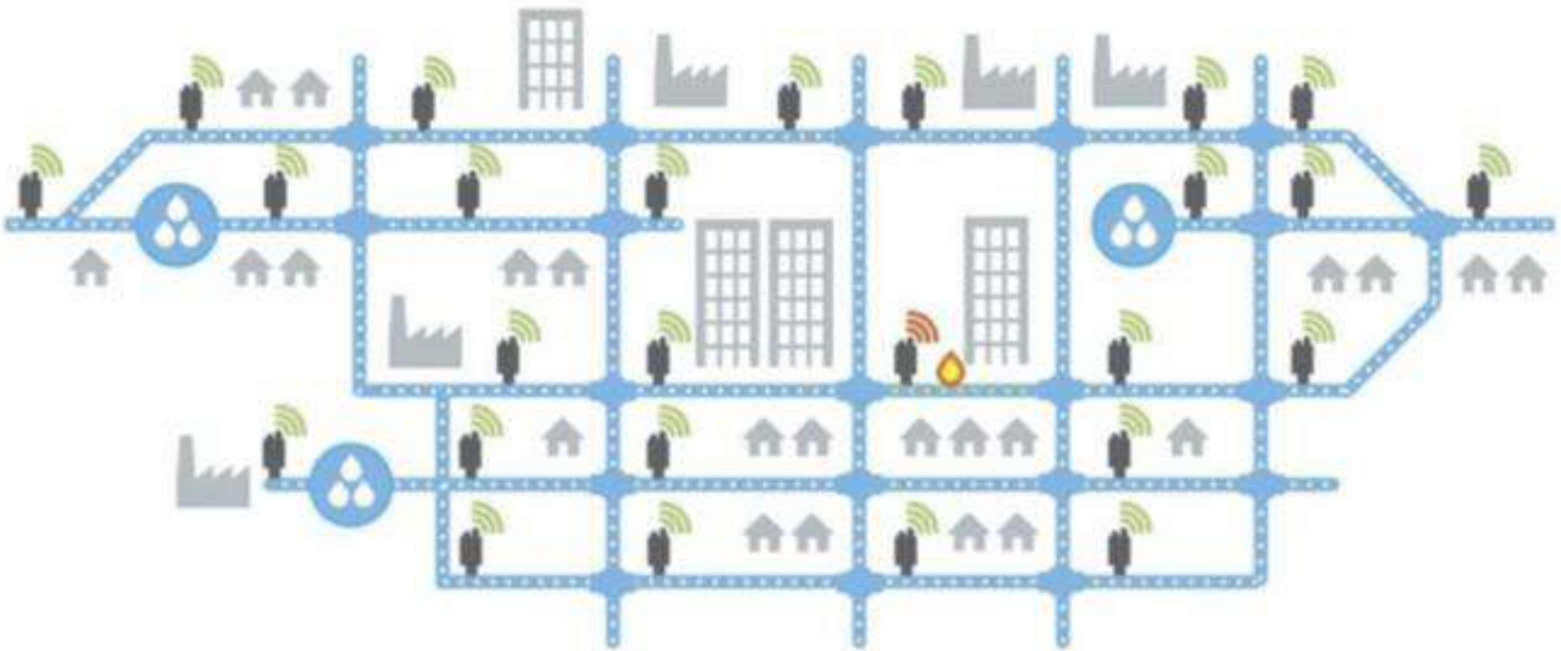
- # of Sensors are limited & WDS are large
- Localisation models identifying where the event is occurring
- reduce search time
- contain the event quicker
- reduce impact on end users.

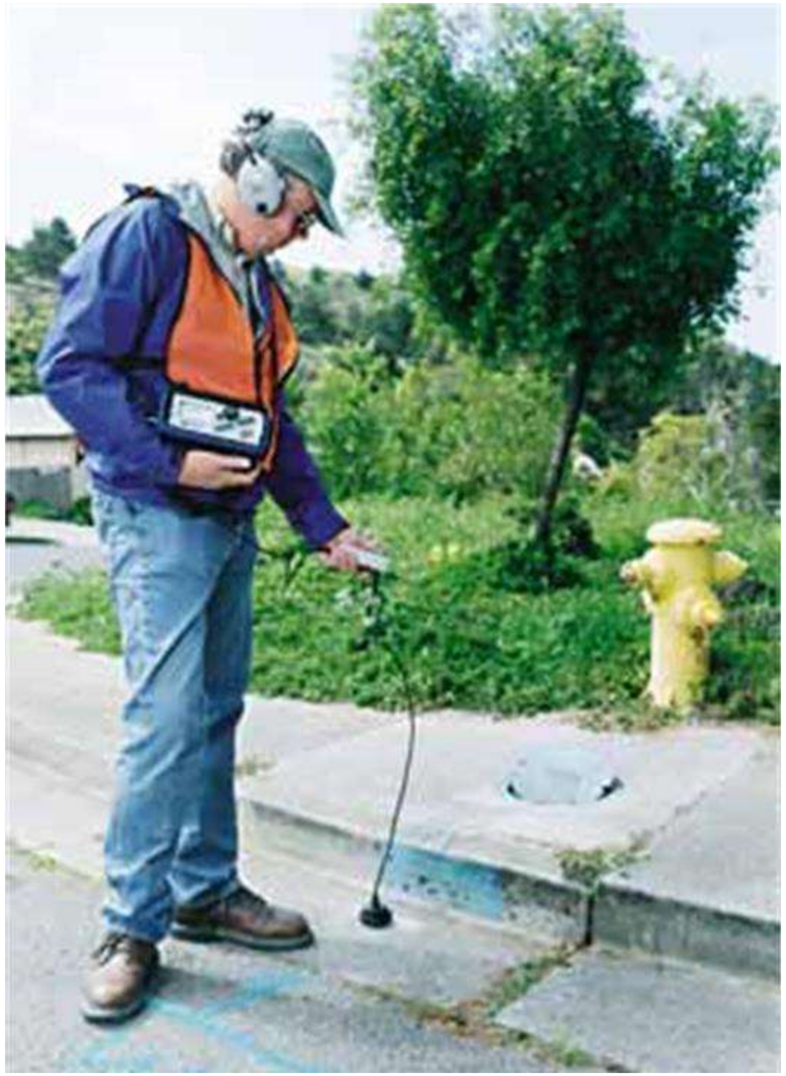


Leak Localisation - What To Predict?

Webinar Series

How should we predict leak location?

- Identify leak node?
  - Classification ML Models
- Identify leak location, (X-Y coordinates)
  - Regression ML Models
- **Identify leak Search Area for detection crew**
  - ?



Maximum Coverage Location Problem

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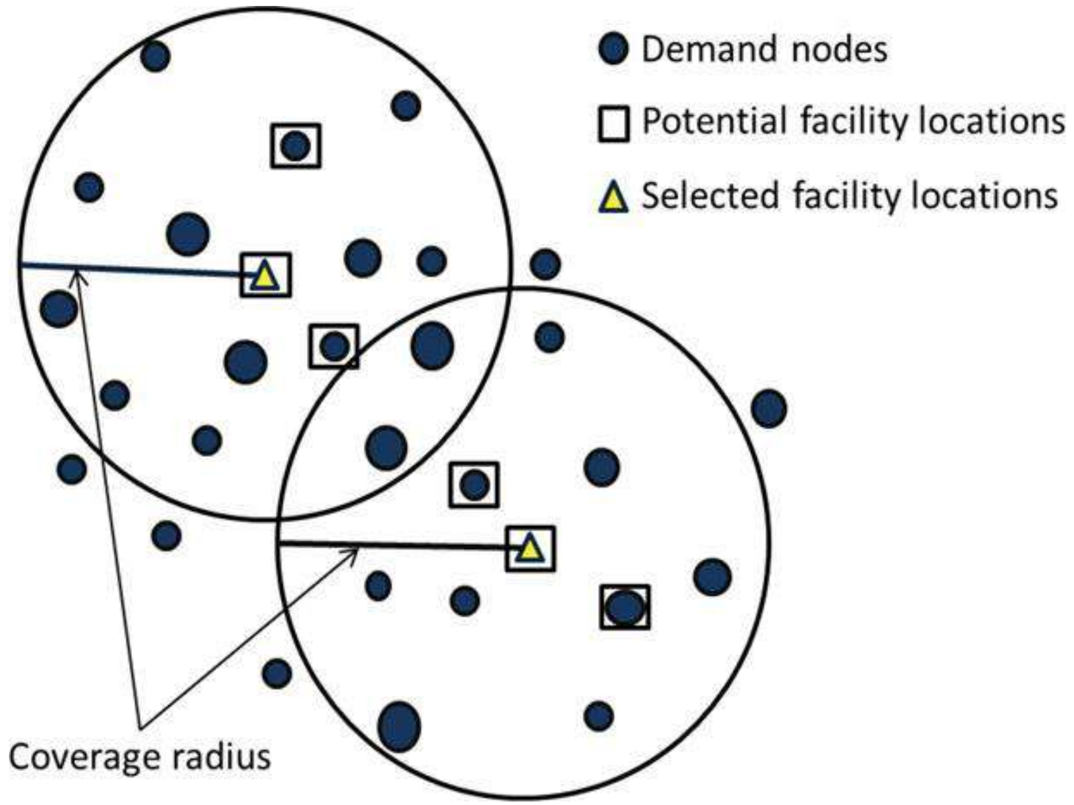
How do we determine ideal search areas that cover the largest probability of leak location?

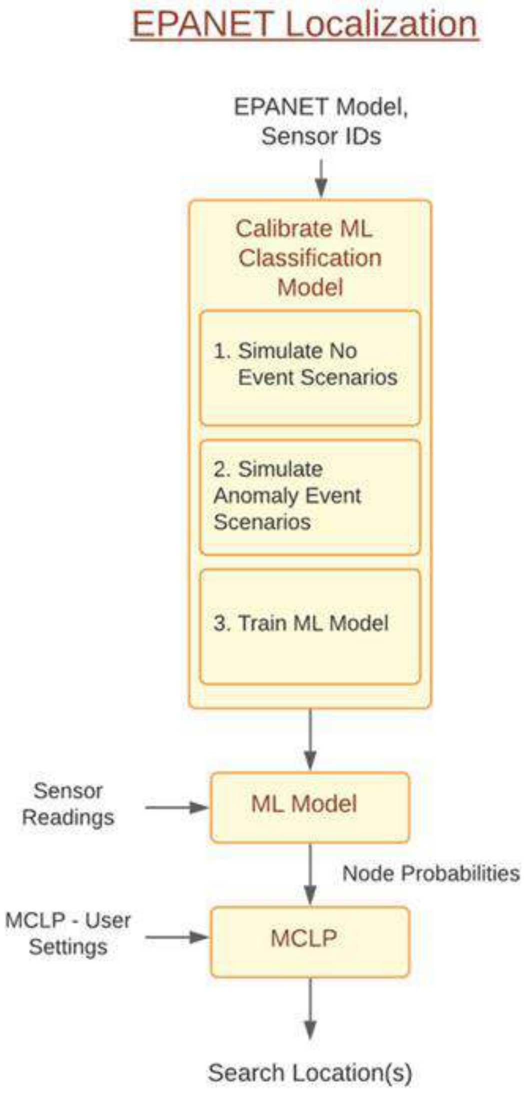
- The Maximal Covering Location Problem by Church & ReVelle (1974)
  - Objective: Maximize the anomaly event probability covered
  - Constraints:
    - event node is covered if search area centroid is within a certain distance from demand node
    - A maximum number search areas



Leak Localisation Methodology

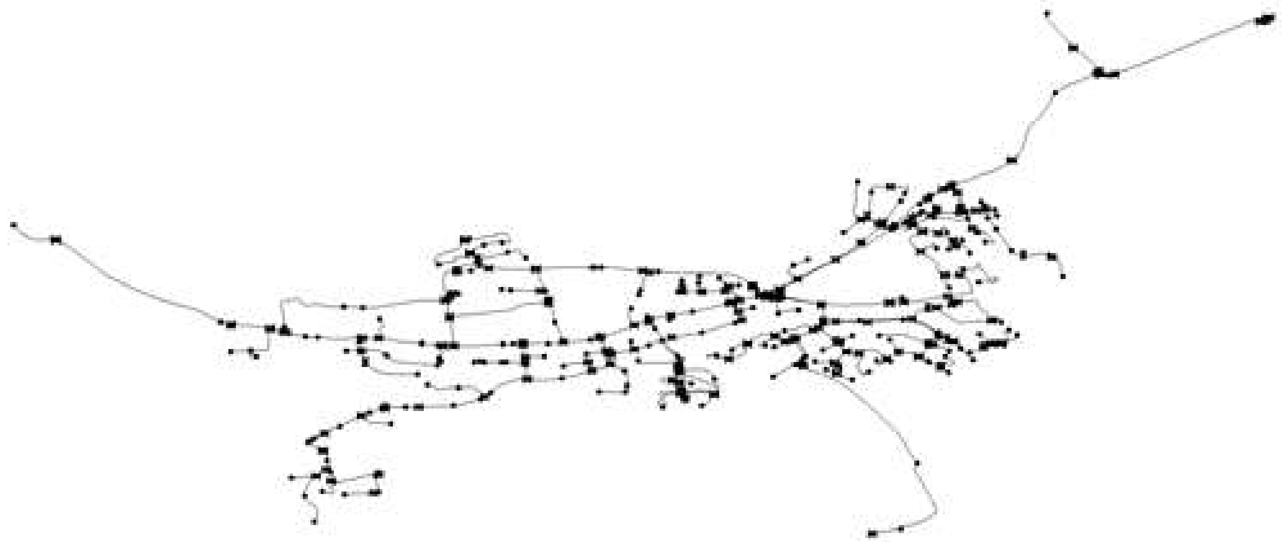
Model Driven Calibration Approach:

1. Simulate No Leak Event Dataset
2. Simulate Leak Event Dataset:
3. Train Machine Learning Model



Case Study

- # of Junctions: 1004
- Length of Pipes: 25 km
- Simulated 13 Sensors (7 flow, 6 pressure)
- Geographical Area = $12km^2$
- Test Set: 200 leaks scenarios



Sensitivity Analysis

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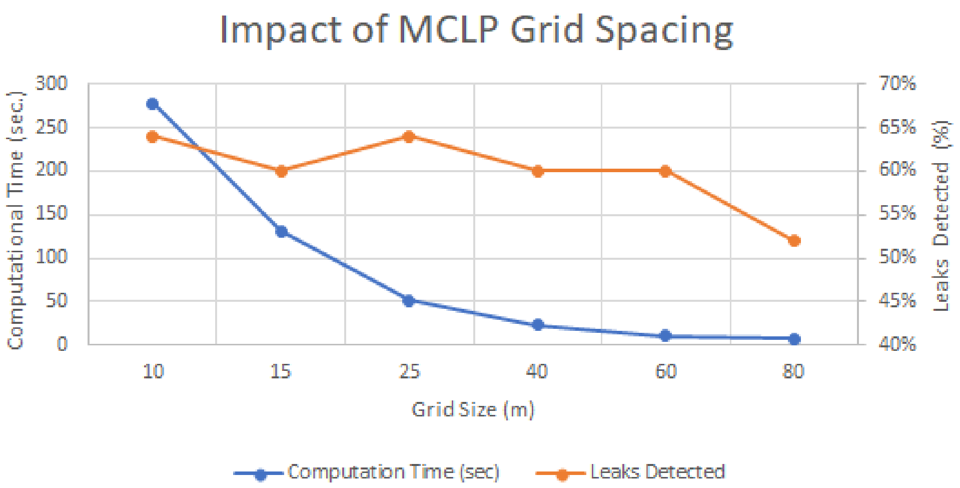

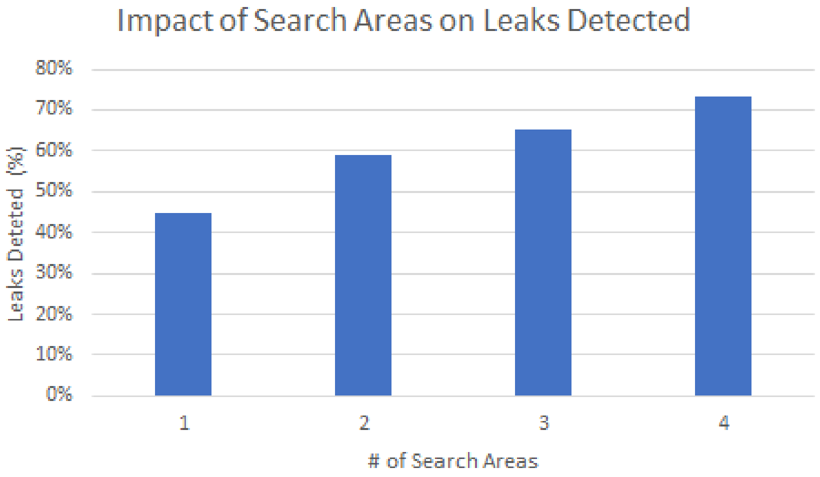

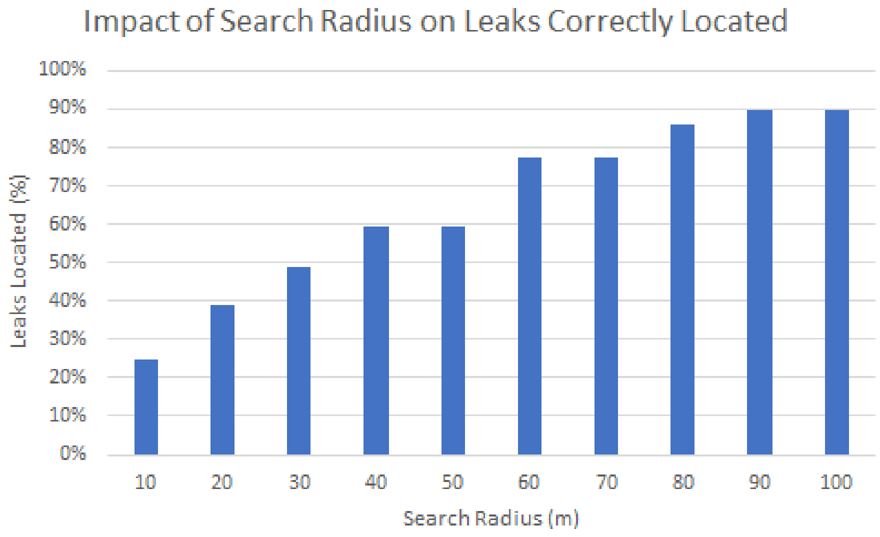

Comparing MCLP Approach

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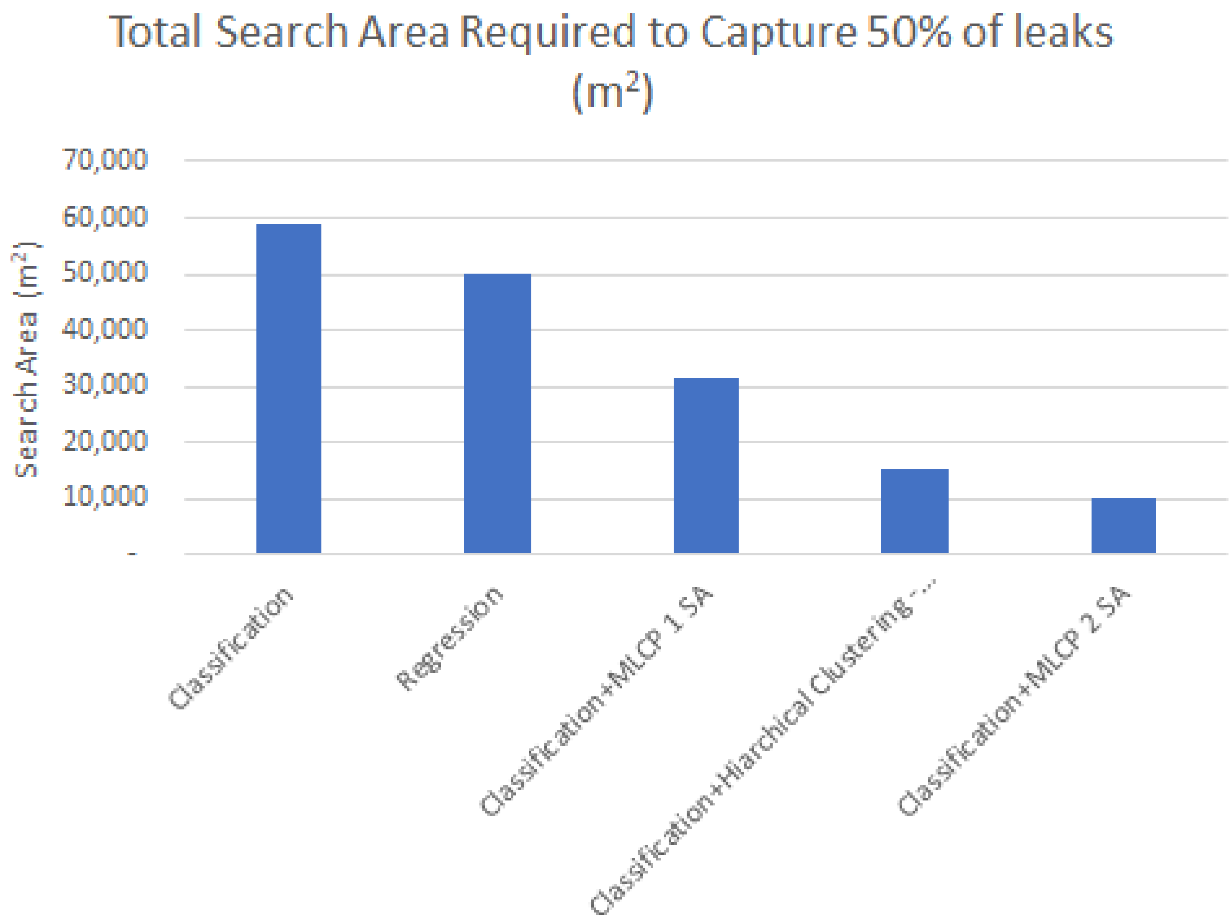
- MCLP with 1 search area reduces search space by 35% compared to regression
- MCLP with 2 search areas reduces search space by 80% compared to regression
- MCLP outperforms clustering model (34%)



Conclusion:

- The utility's end-use must be considered when developing leak detection models
- Leak Location model substantially reduces the leak search area
- Leak Location model can be customised to meet specific needs of the utility

Next Steps

- Integrate models into Visual Dashboard
- Assess with real sensor data
- Receive feedback regarding PIs for IMM

Webinar Series

Gareth Lewis

University of Exeter, Fiware4Water

Webinar Series

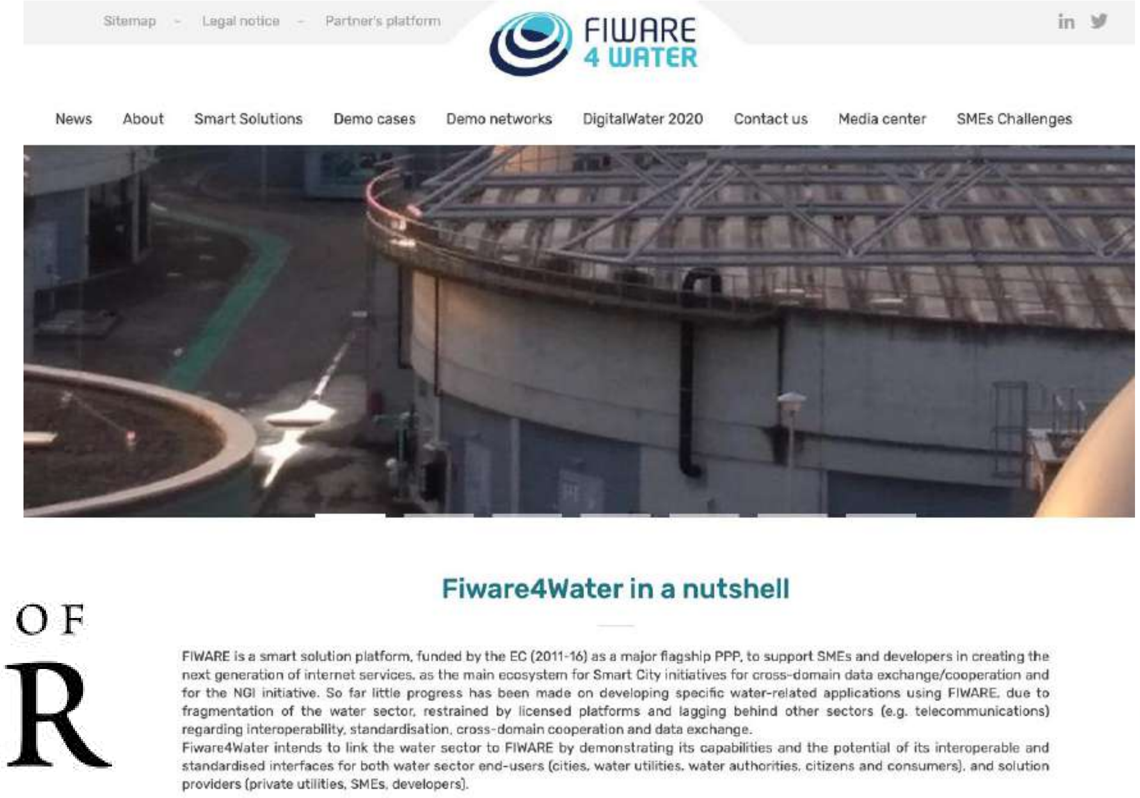
The Fiware4Water project as a vehicle to de-risk a UK-based smart metering pilot

Gareth Lewis, University of Exeter, Fiware4Water

Situation

Webinar Series

South West Water



egm

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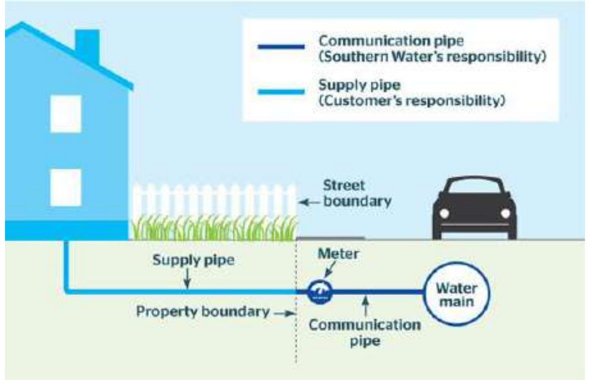
Powered by FIWARE

https://www.fiware4water.eu/

SouthWest Water

Brent Cross, 6/7/2020



Customer-side leaks: Leaky Loos

WaterSafe®
LOCAL APPROVED PLUMBERS

What to Do About Leaky Loos

What better time to talk about leaky loos than World Toilet Day (19 November)? WaterSafe asked **Andrew Tucker, Water Efficiency Manager at Thames Water** to highlight how even a tiny trickle could be wasting around 400 litres a day – equal to five daily baths!

Sadly, that water trickling into your toilet bowl isn't a cool design feature to help keep it clean! If your loo is constantly dribbling, it's probably leaky.

What's a leaky loo?

A 'leaky loo' usually refers to clean water leaking from your cistern down into your toilet bowl. If you have one, you may notice a steady trickle of water at the back of the bowl or hear a constant dripping sound inside the tank. Leaky loos are easy to miss, so it's no wonder around 5% of all households and a third of businesses have one.

Why fix a leaky loo?

A little dribble may seem like nothing, but don't be fooled. If you're on a metered bill, a leaky loo can be really expensive. Water sector research shows that the average leaky loo loses around 400 litres a day, equivalent to five full bathtubs, or an average family's total daily water use – doubling their bill if they're metered. Every day we find leaky loos that are wasting over 8,000 litres a day!

So, what's the cause?

SouthWest Water Smart Pilot

Fiware Conceptual Model

NAIADES Webinar Series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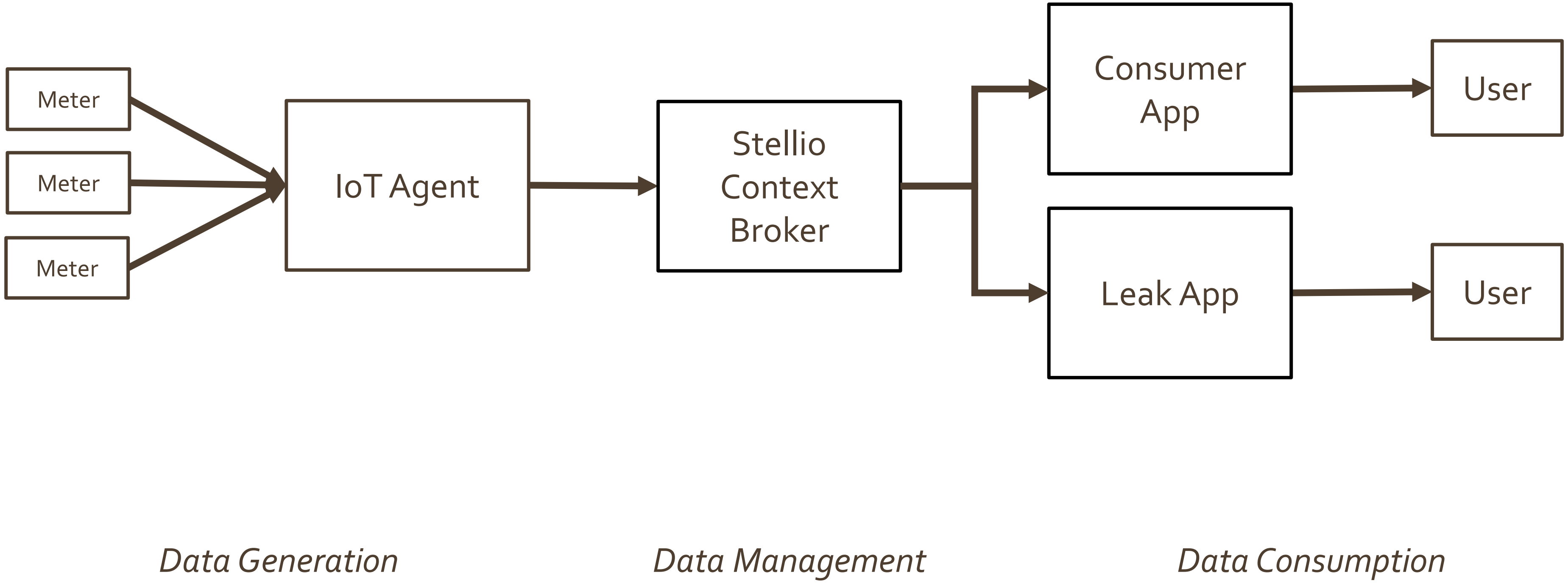

Fiware Data processing

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```
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        1234567890123456789012345678901 1234567890123456789012345678
: 38    XXXeXXXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXX_____________________
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: 38    XXXeXXXXXXXXXeXXXXXXXXXXXXXXXXX XXXXXXX_____________________
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```

Estimated readings (e), vs. actual readings (X)

```
        2022:1                          2022:2
                 1111111111222222222233          1111111111222222222
        1234567890123456789012345678901 1234567890123456789012345678
: 38    XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXX_____________________
: 31    __X__XX_XXXXXXX_XXXXXXXXXXXX_XX XXXXXXX_____________________
: 19    _XX_XXXXXXXXX_XX_____________XX ___XXXX_____________________
: 16    XX_________X___X_XXX__XXXX___X_ _XX_XX______________________
: 3     XXX____________________________ ____________________________
: 0     _______________________________ ____________________________
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```

Flow persistence (possible leak) detected (X)

Results to date

- Prior to installing the smart metering network
  - Identification and rectification of 4 large customer leaks, c1,000 litres per day
  - Identification of 1 large commercial leak c2,500 litres per day
  - 344 customer water efficiency visits, saving around 60 litres per day per customer
  - 70% of smart meter customers saving money (av.£327, largest £860 per annum)

Webinar Series

Stelios Samios
EYDAP

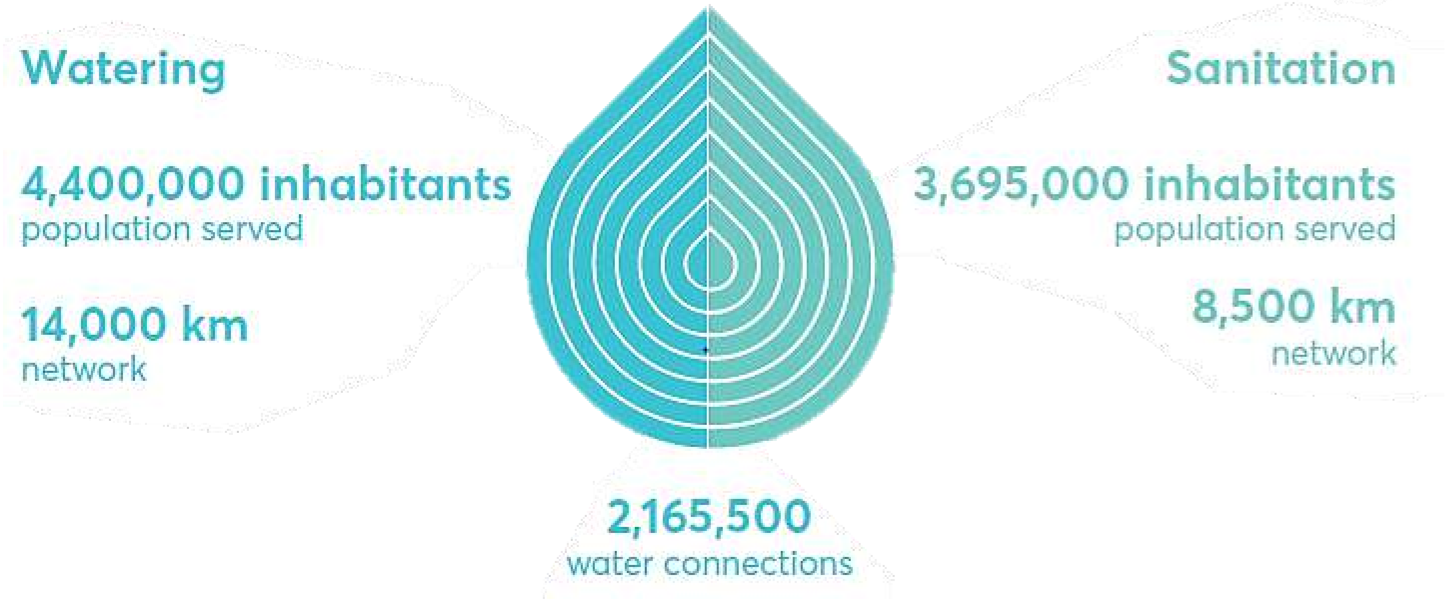
Vasiliki Polychniatou
EYDAP

Fiware4Water - Water supply system real time operational management

Stelios Samios, Vasiliki Polychniatou, EYDAP

EYDAP - Short presentation

- EYDAP, Athens Water Supply and Sewerage Company is Greece's largest company in the water market
- It serves >40% of the country's total population
- Supplies Attica with some of the highest quality water in Europe



Water supply sources

- **Main water sources (Lakes)**: Mornos, Evinos
- **Auxiliary water sources (Lakes)**: *Marathonas* and *Yliki*
- **Backup water source**: underground water resources – boreholes

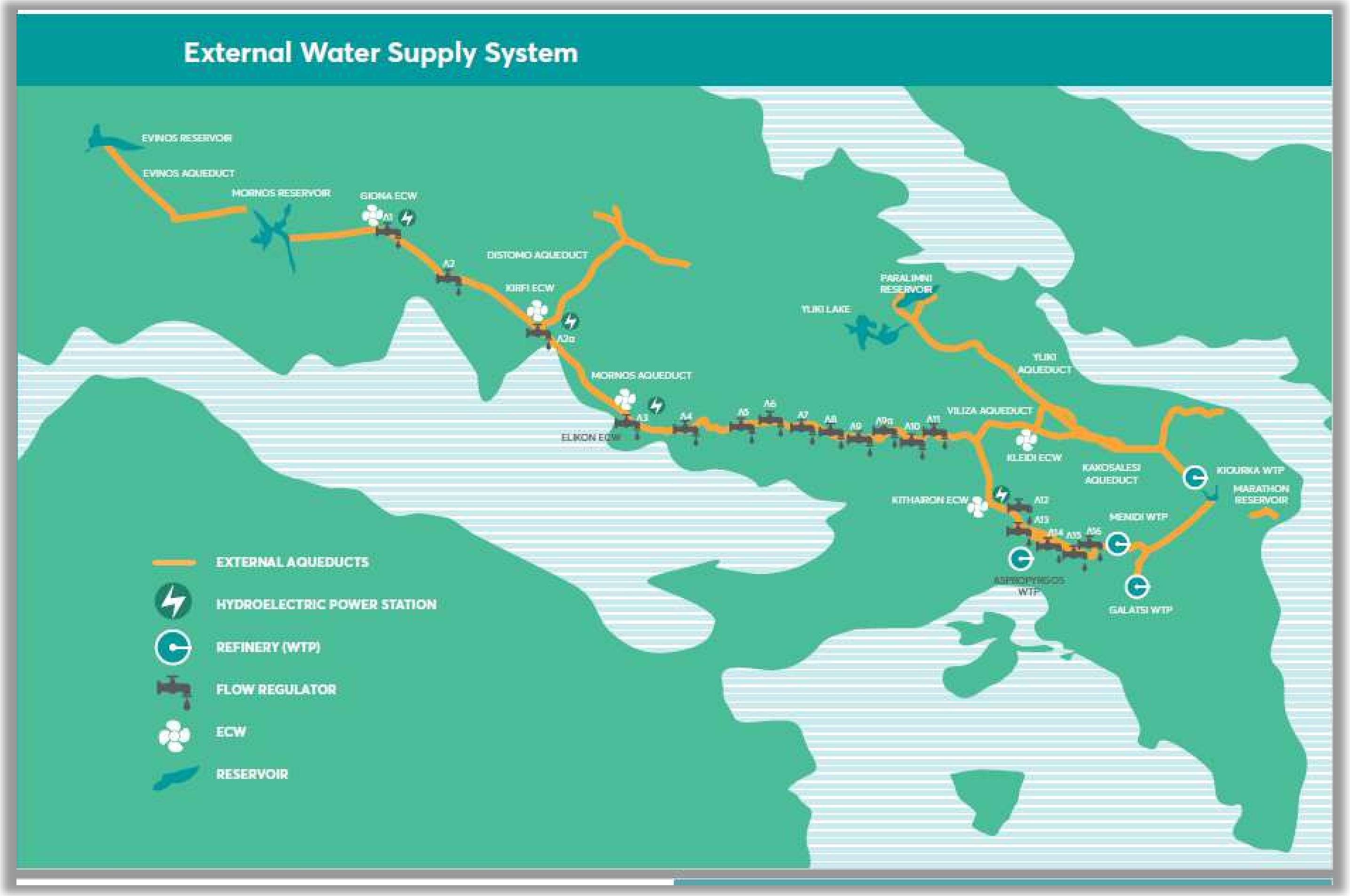
Quality of the water resources is monitored conventionally according to the Directive 75/440/EEC for surface water quality standards and national healthcare provision A5/2280/1983 by random checks of the water quality in the reservoirs.

External Water supply network

The total length of EYDAP supply system is 495 km.

Constant **monitoring** of the aqueduct enables EYDAP to monitor and control water losses and be immediately alerted in case of an accident

Monitoring is performed via multiple installed sensors, controlled by SCADA: 13 water quality stations, 73 water level meters, 20 flowmeters, 38 water sluice gates & 34 pumping stations.



Athens demo case – Fiware4Water

EYDAP is responsible for the demonstration of the FIWARE integration with operational sensors and other (novel) surveillance methods into a **common operational picture** (in real time)

Goal:

- Upgrade the supervisory system and digital water strategy of the Company

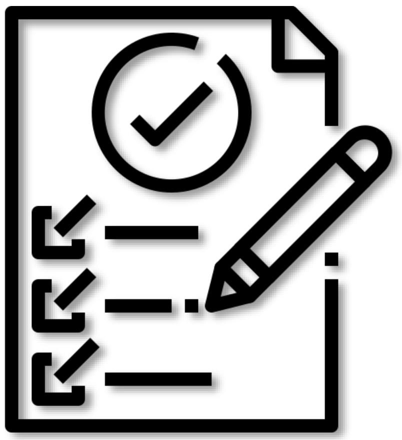
Challenges:

- Integrate different sensors from different vendors into a common system
- Develop different applications (models, analytics) using available data more efficiently
- Interface seamlessly with and provide added value to legacy systems (sensors and online control systems)

FIWARE 4 WATER

EYDAP FIWARE 4 WATER

Identification of use cases & requirements
Design of the FIWARE-compliant web platforms



Water flow application

- **Monitor flow conditions**
    - Access and analyze real-time and historical data
- **Understand flow conditions**
    - Warnings about unusual flow conditions
    - Estimation of water balance and future water demand
- **Advice on change flow conditions**
    - Optimal sluice gate settings and scheduling

Water quality application

- **Monitor raw-water quality**
    - Access and analyze real-time and historical quality data
- **Understand raw-water quality**
    - Warnings about unusual quality events and metering faults
    - Short-term forecast of water quality (turbidity)

Identification of current state of the legacy system

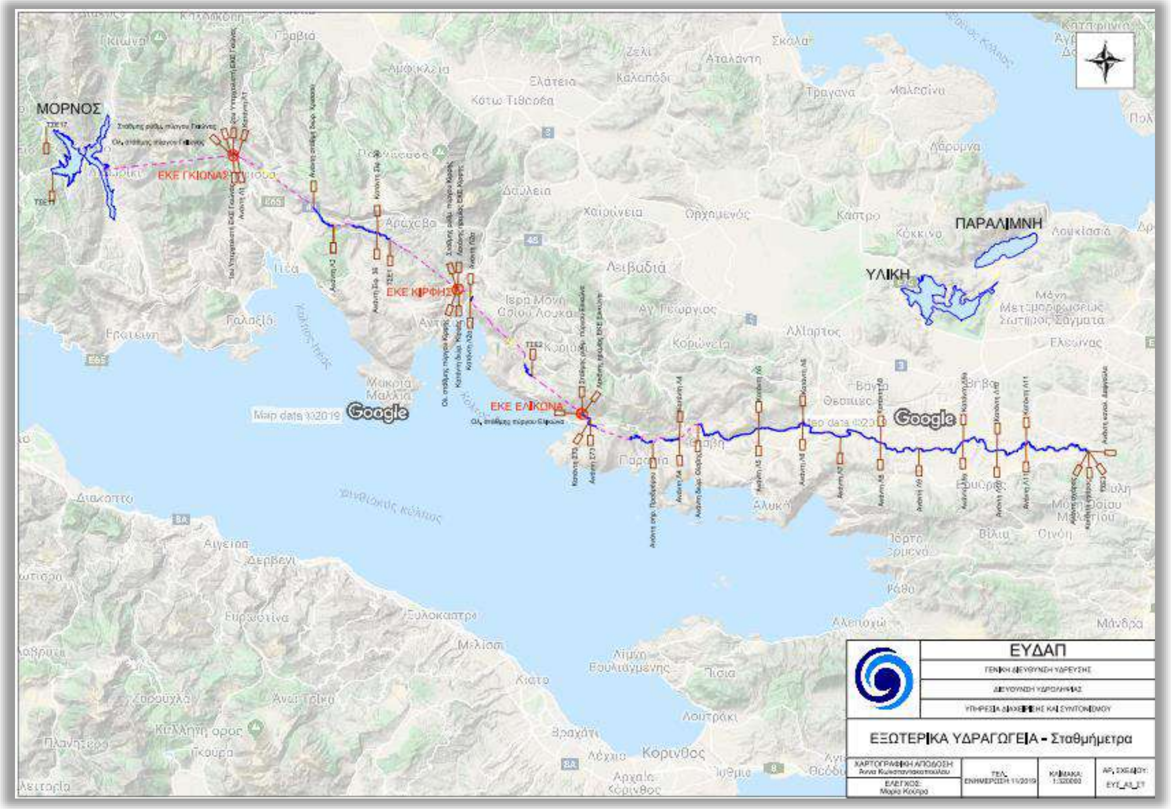
- Selection of the demo part of the aqueduct- **Gkiona-Dafnoula (131 km)**

- **Identification of the legacy sensors already installed:**
  - 5 open channel flow meters
  - 46 water level meters
  - 8 sluice gate opening valves
  - 6 water quality meters (turbidity, conductivity, temperature)

- **Documentation of the characteristics of all metering stations** and physical elements of the conveyance system

- **Identification and analysis of legacy information systems of EYDAP**

- **Collection of historical data from already existing sensors**



- **New sensors**

EYDAP FIWARE 4 WATER

Installation of new sensors in the channel

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- **Deployment of 1 portable open channel Doppler flow meter**
- **Installation of 5 water level meters** at "ungauged" critical points in the channel to improve the accuracy of hydraulic simulation

EYDAP
FIWARE 4 WATER

Smart platforms for water flow and quality management

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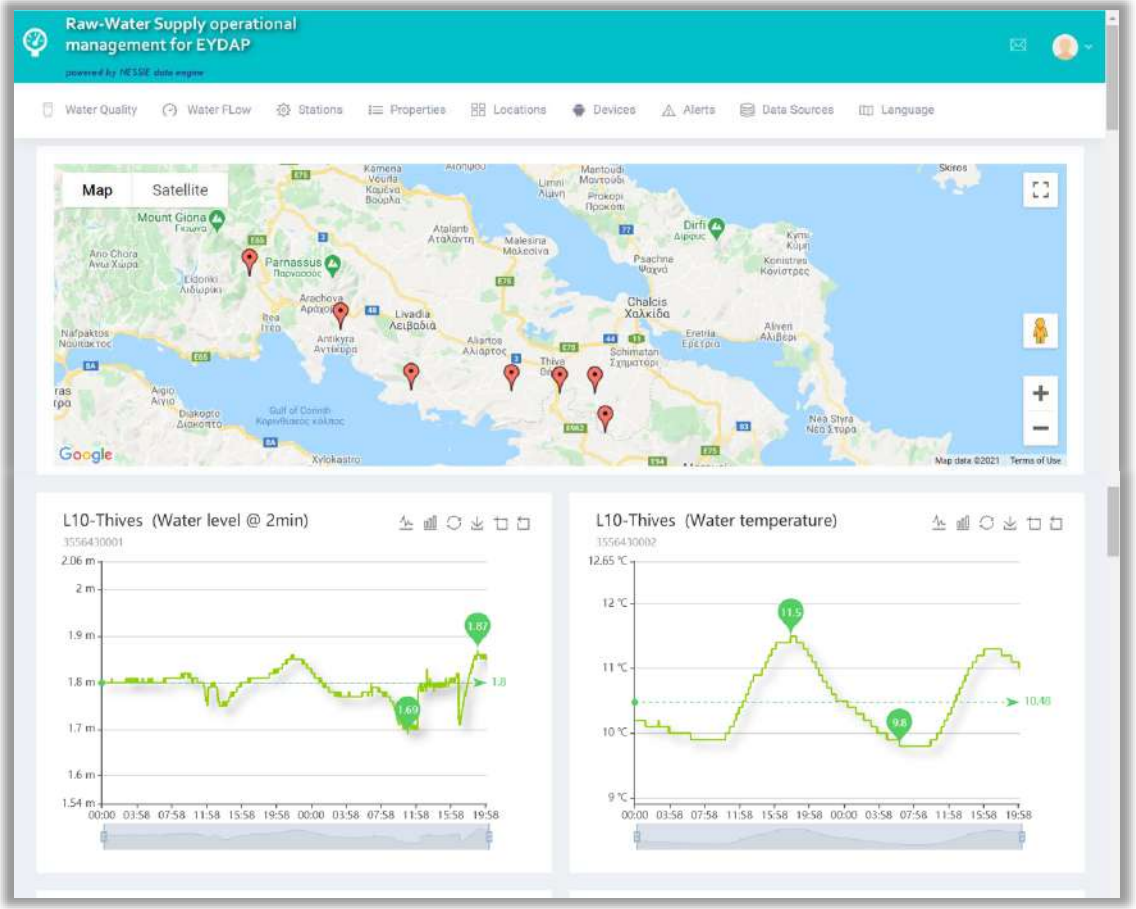
- **A web platform for the processing, analysis and visualization of real-time data from all existing sensors in the conveyance system is being developed.**
- **Prototypes for both water flow and quality applications are currently in a “live” environment, receiving real-time data.**
- Nessie system (information system developed by NTUA) was configured to integrate **into a common operational system** real-time data from:
  - Flow meters
  - Water level meters
  - Sluice-gate opening meters
  - Water Quality sensors
- Two distinct dashboards have been implemented to provide feedback to the relevant operation staff in EYDAP.



EYDAP

FIWARE 4 WATER

Setting-up Athens Water Forum

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EYDAP took the initiative to create the **first Athens Water Forum**.

A group of organizations and individuals interested in water issues in the city opens the discussion on the most important natural asset of the planet, the protection of which is one of the greatest invitations of the 21st century.

ATHENS WATER FORUM

Partners involved:

NTUA, GWP, Municipality of Athens, HCMR, UOA, NCSR, MIO-ECSDE, UrbanDig project, SNFCC

Under the umbrella of WWQA World Water Quality Alliance

EYDAP FIWARE 4 WATER

Athens Water Forum

Work done so far

Decided on specific water issues and then opened a dialogue with the public through a targeted audience survey.

Circulated a digital questionnaire from January 10 to 21, 2022 on the members of the Athens Water Forum networks to investigate and classify the interests of citizens around water in Athens.

Next steps

Two open-air activities by May 2022, which will foster dialogue on water, the environment, climate change and other issues identified in the city, while enhancing active citizen participation and cooperation.

EYDAP FIWARE 4 WATER

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Thank you

Serena Radini

Polytechnic University of Marche

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Webinar Series

Digital solutions to early warn and support decisions for safe water reuse

Serena Radini, Francesco Fatone - Università Politecnica delle Marche, digital-water.city

Digital Water City

Main goal is to link the digital and physical worlds along the water value chain by **developing 15 advanced digital solutions** to address water-related challenges

TREATMENT PLANT LEVEL:
Early Warning System for water reuse
Case study: Peschiera Borromeo WWTP – Milan peri-urban area

Improve, control, monitor and share with stakeholders and users health risks with the reuse of treated by maximizing the benefits of effective water reuse in productive agriculture

https://www.digital-water.city/solution/early-warning-system-for-safe-reuse-of-treated-wastewater-for-agricultural-irrigation/

Early warning system for safe reuse of treated wastewater for agricultural irrigation

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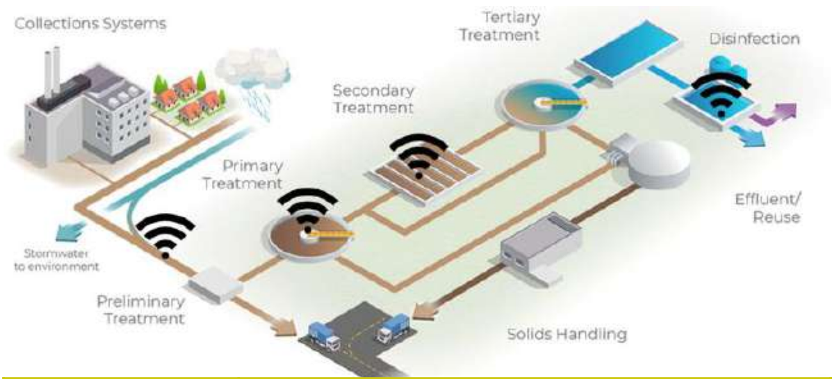
It's a risk-based decision support tool that integrates real data and modelled data, to assess water reuse related risks and forecasting analysis, using:

- Data sources in-situ real-time data from multi-parameter sensor network
- Offline data
- Simulated data
- Generated data from machine learning / statistical correlation

Tool for process monitoring and control



Monitoring and supervision	Data elaborator and integrator to predict water quality
Green light for water reuse	Provide warnings if quality requirements for water reuse are at risk of non-achievement

Tool to support decision making

Decision Support	Integration in digital twin providing data/scenarios supporting decisions to optimize cost-benefit of plants and processes in terms of (waste)water-health nexus

Tool to support risk management

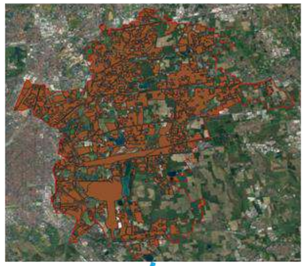
Risk minimization	Integration of EWS in risk management, together with online sensor control from remote, data elaborations and periodic analysis (QMRA) as control measures to reduce risk.

Case study: water reuse in Milan peri-urban area

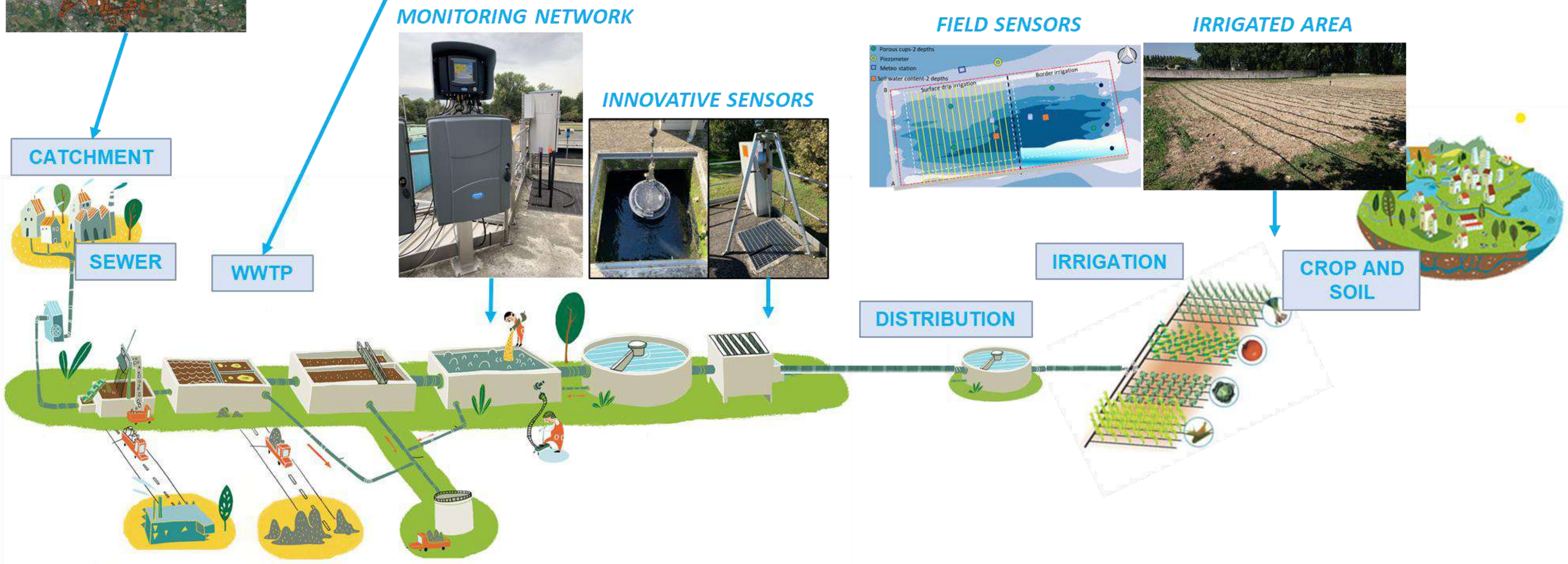
Existing monitoring sensors + innovative sensors for TOC, UV, Ecoli

- **RELIABILITY OF SENSORS DATA**
- **BACTERIAL CONTAMINATION AFFECTED BY TSS**

PERI-URBAN AREA PESCHIERA BORROMEO



PESCHIERA BORROMEO WWTP



Issues with sensors reliability

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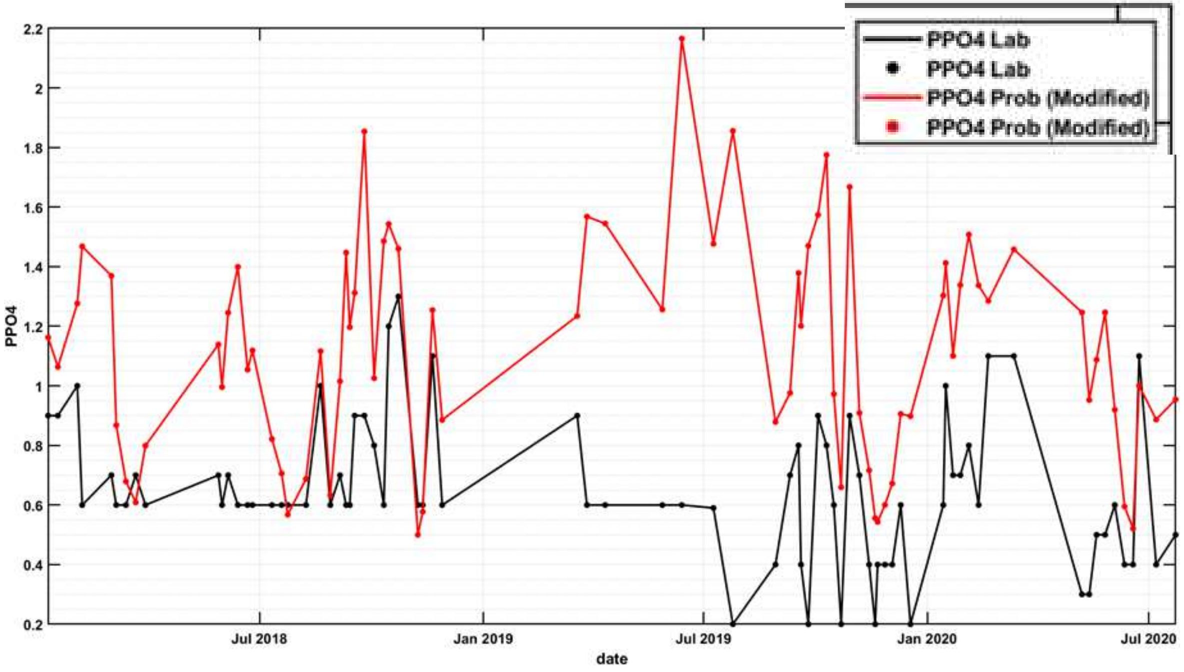
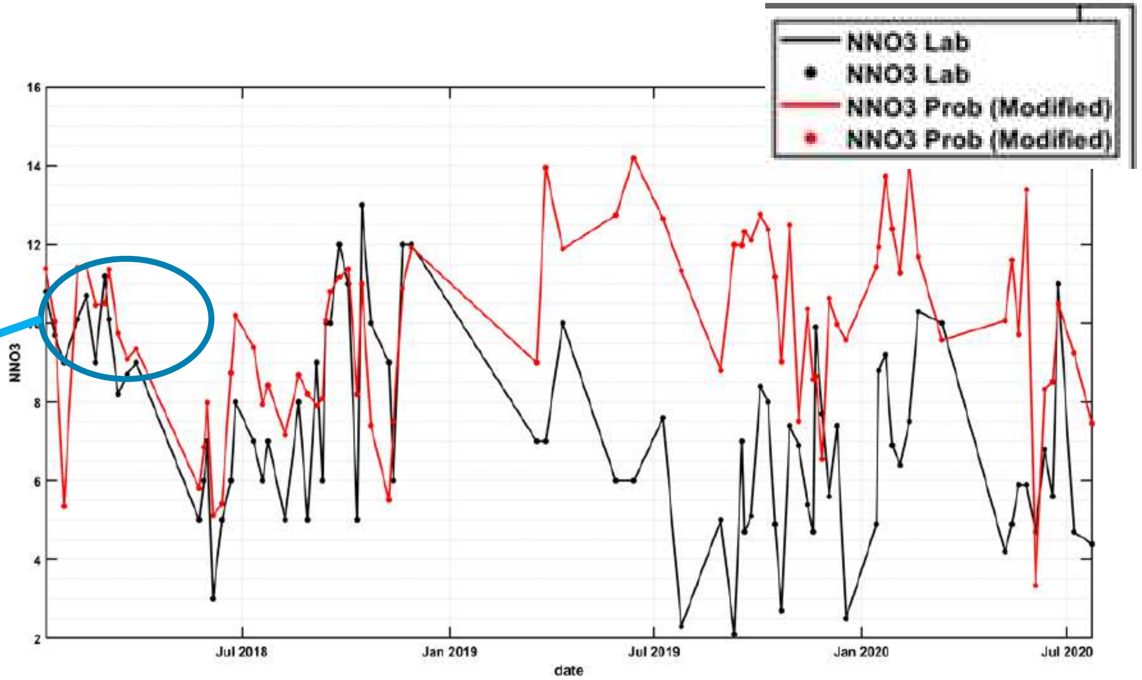
Most of sensors data were not reliable, and measured values differed from laboratory data



	Average BIAS
NH_4	36%
NOx	56%
PO_4	104%
TSS	7043%



Only limited time-series are comparable

Architecture of EWS

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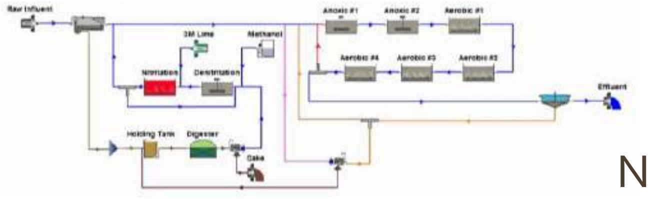
Data from Model Sim

A



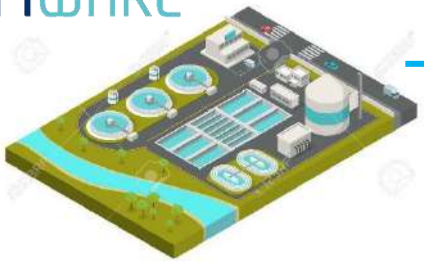
Needed for ANN generation (Lambda function)

AWS
Lambda

1. Real-time evaluation of TSS, BOD, COD (parameters that are not measured by sensors)
2. Predictive WWTP performance (time series ANN to predict water quality parameters in the effluent)

Data from WWTP

FIWARE



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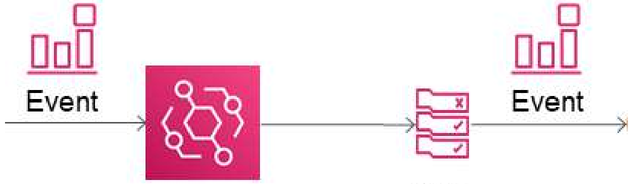

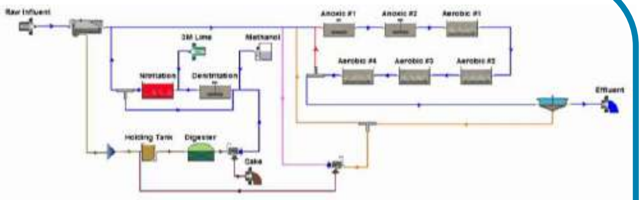

Simulations: identification of malfunction and selection of the best preventive action

Early warning for water reuse

Support from modeling

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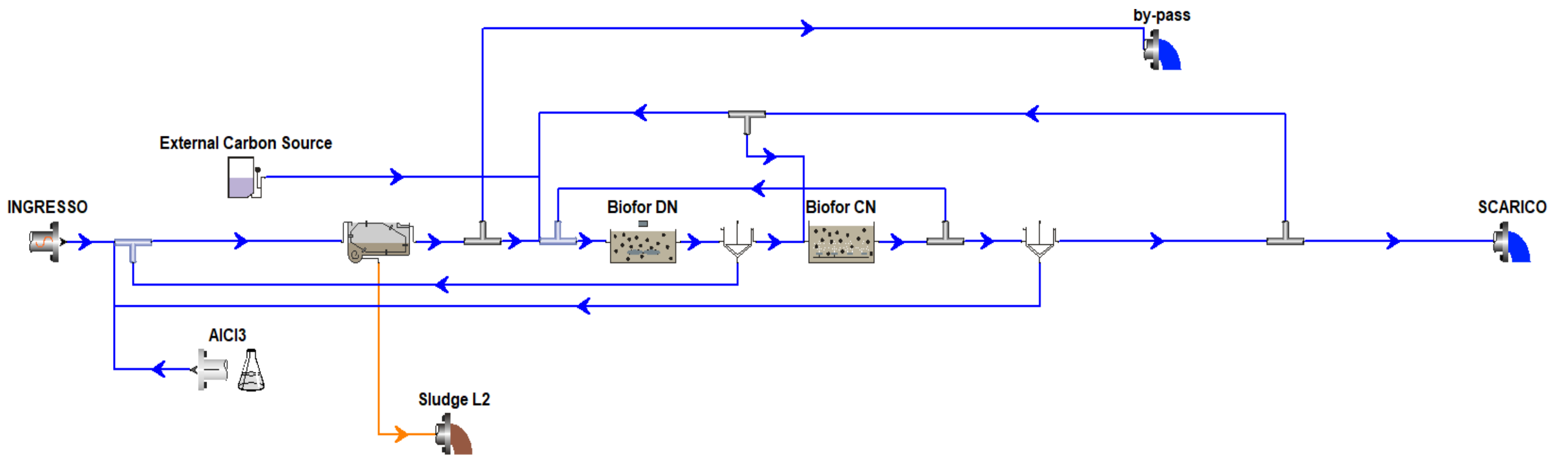
Model of Peschiera Wastewater Treatment Plant



Simulation validated using laboratory data from Peschierra-Borromeo WWTP obtained during different seasons of the year

+

GENERATION OF DATA RELATED TO EXTREME EVENTS

Simulated data

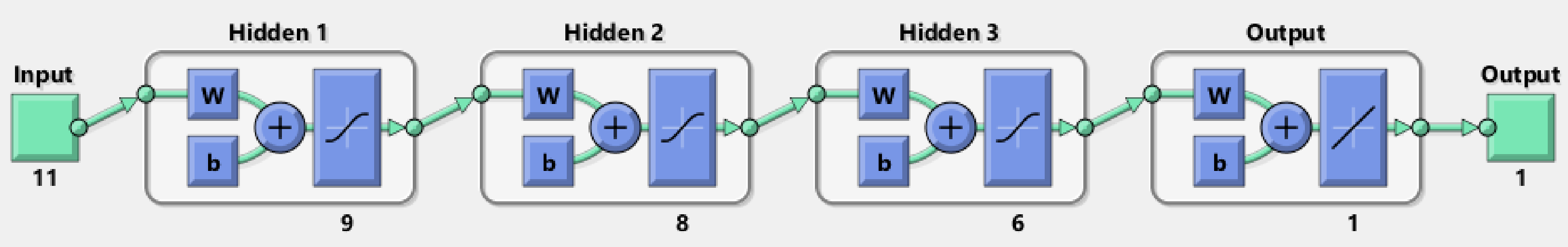
Influent:
- Q
- N-NH4
- P-PO4
- pH

Biological process:
- DO
- T

Effluent:
- Q
- N-NH4
- N-NOx
- P-PO4
- pH
- **BOD_5**
- **COD**
- **TSS**

Simulated Malfunction	Note
Aeration interruption/reduction	Different durations of air interruption/reduction were simulated
Error in the recirculation of the mixed liquor	Simulation performed with different Qr
Simulation of Q backwash reduction or interruption	
Industrial discharge	Wastewater influent with pH 5 or pH 11 High COD load
Rain event	High Q entering the WWTP for different durations/intensity of simulated meteoric events
Error in external carbon dosage for denitrification	
Error in sludge spillage from sedipac unit	

ANN for TSS prediction



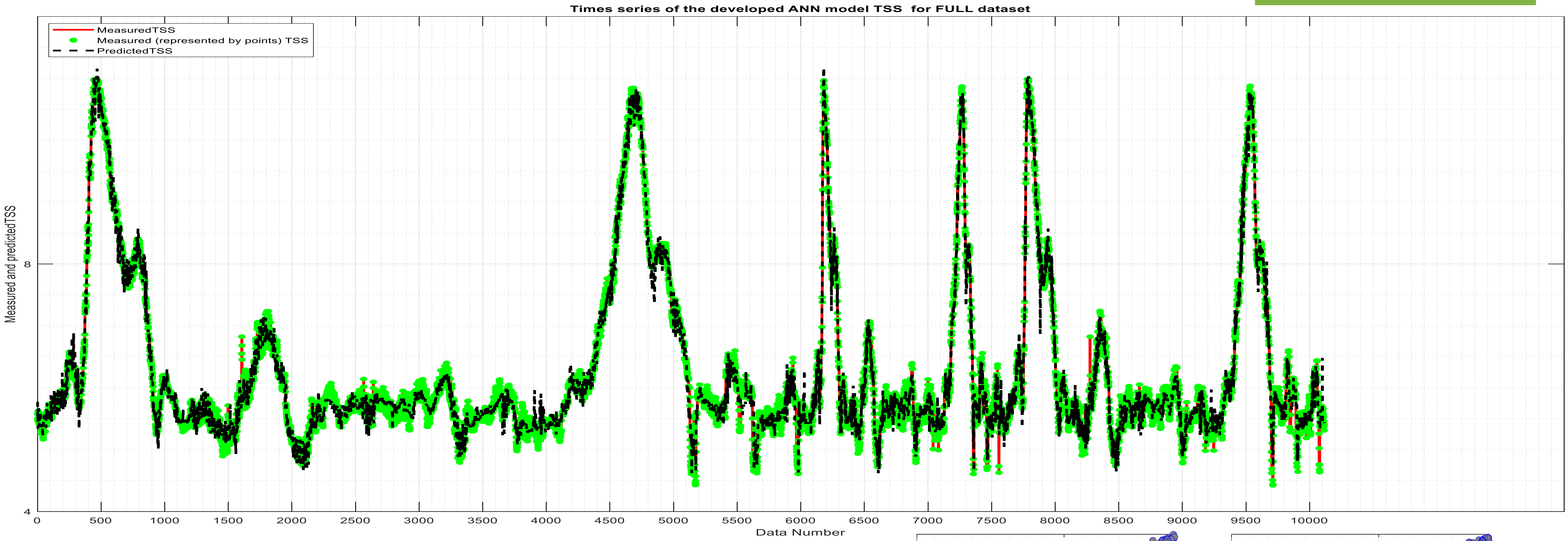
Parameters and their range – ANN network

Network type	Train function	Divisions	Number of inputs and outputs
Feedforwardnet (Feed forward neural network)	'trainlm'	Train ratio = 60/100 Validation ratio = 15/100 Test ratio = 25/100	Inputs = 11 Output = 1 (Effluent TSS)

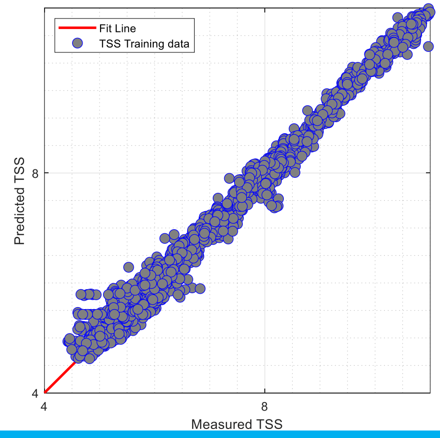
Input parameters at time t	min	std	mean	max
Influent Flow	17881	26717	76721	252000
Influent pH	7.100	0.181	7.674	8.000
Influent NNH4	4.225	5.537	16.101	37.315
Influent PPO4	0.288	0.420	1.237	3.610
Biofor DN Temperature	3.714	3.690	18.880	25.982
Biofor CN - Dissolved oxygen	0.000	1.474	5.238	7.750
Effluent Flow	16386	26717	75226	250504
Effluent pH	6.792	0.084	6.992	7.488
Effluent NNH4	0.073	2.217	1.042	19.956
Effluent NNOx	0.000	2.628	6.538	15.289
Effluent PPO4	0.001	0.401	0.627	2.134

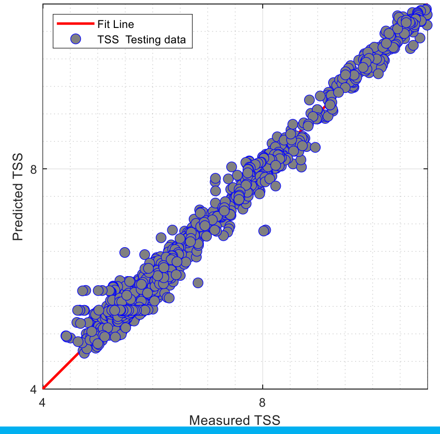
Output parameters at time t+HRT	min	std	mean	max
Effluent TSS	4.421	1.338	6.284	10.997

ANN for TSS prediction – simulated data



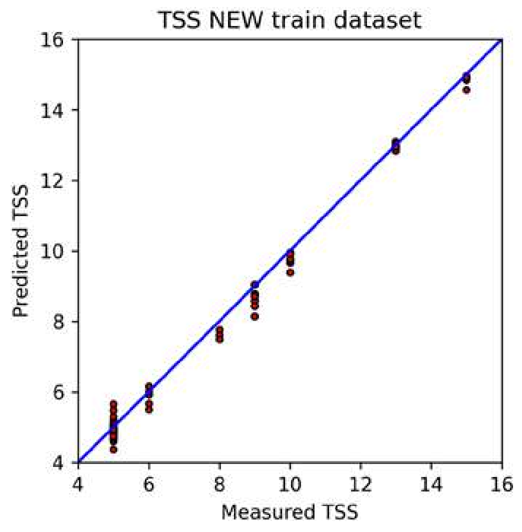
Data type	CC	RMSE	SI	BIAS
Train	0.993	0.159	0.025	-0.562
Test	0.992	0.175	0.028	-3.951
Full	0.992	0.165	0.026	-15.488



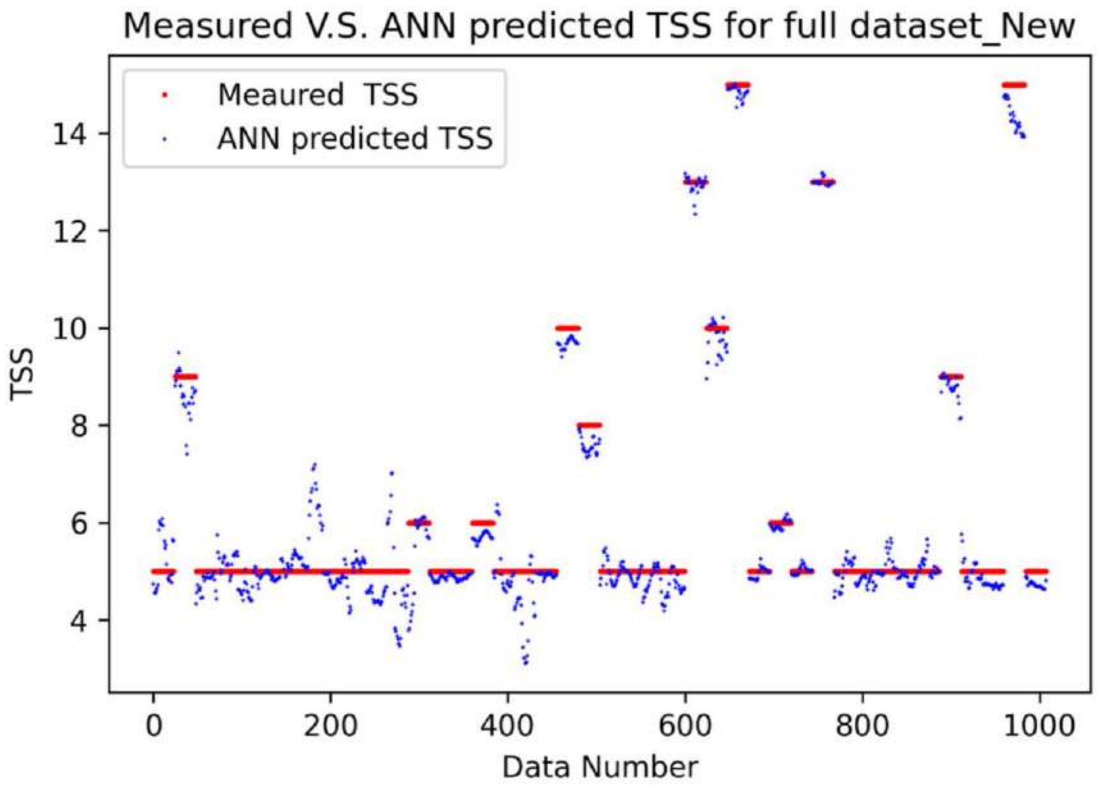


ANN for TSS prediction – validation with real data

Domain adaptation: re-training of the developed ANN model by using real sensor data



Real-time prediction of TSS by soft-sensor



Webinar Series

Panel discussion
&
wrap-up

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