REPORT

TASK 3.1 – CONCEPTS DESIGN WORKSHOP – 12 JANUARY 2022

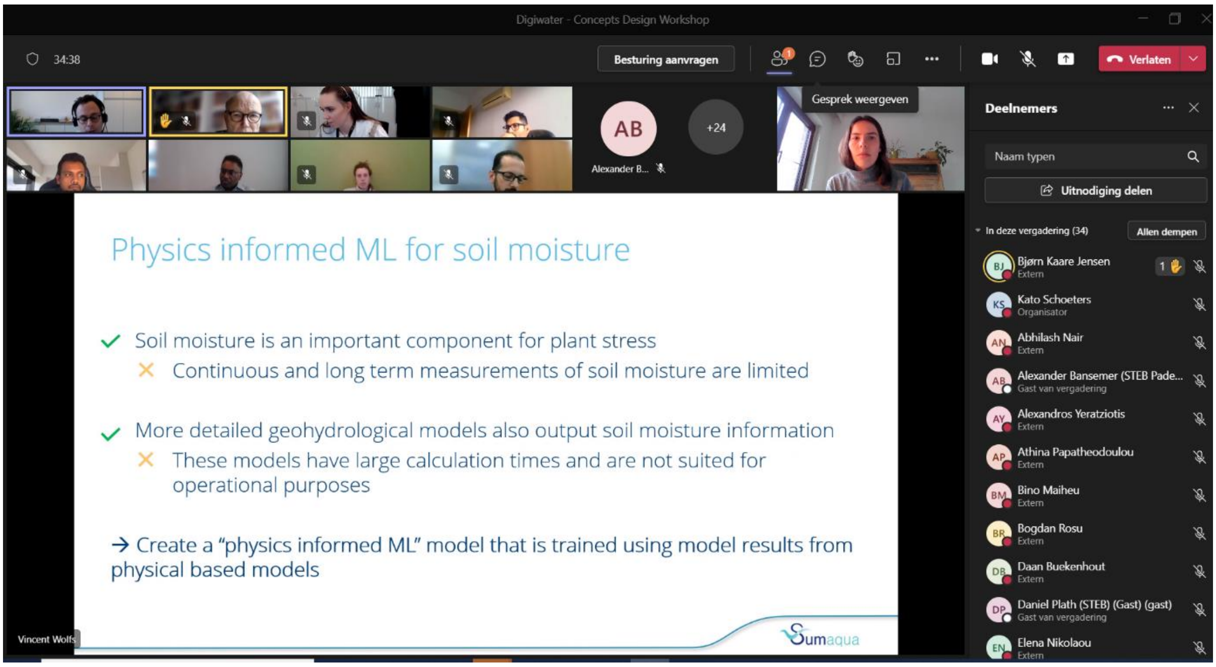
SUMMARY

This workshop identified more than **40 ideas** on how ICT can help us to tackle today's and tomorrow's water challenges.

The workshop included 2 key-note presentations:

- Operational application on IoT and Big Data
- General overview on Cybersecurity

The Digiwater project organised this workshop. The workshop brought together **33 participants** from European countries and various stakeholder groups. The workshop was facilitated by 3 moderators (2 of Sumaqua (BE) and 1 of NMBU (NO)).



KEY FINDINGS

Table 1 shows a list of all collected ideas during the workshop. In **bold** the ideas which were considered as most interesting to elaborate further (e.g. during the upcoming innovation camps).

Table 1: List of all collected ideas during the workshop

Theme	(New) applications
Drought	• Predicting low water levels on unnavigable waterways • Forecasting groundwater level • Forecasting soil moisture • Forecasting for management of irrigation systems • Surface temperature monitoring for crop growth • Tool showing areas which will turn into a dessert (e.g. Cyprus)

Flooding	• Smart control of flooding areas
	• Intelligent control of buffer capacity
	• Intelligent control of rainwater systems
	• Flood maps for specific return periods
	• Flood mapping with remote sensing
	• **(Early) warning systems** (e.g. WarnWetter)
	  ○ Urban flood nowcasting
	  ○ Flood forecasting
	• **Translation of water data to communicate the flood impacts through platforms**
	• Registration of maintenance
	• New forecasting conceptual models – decision support
	• Tackle mismatch between predictions and measurements

Water-quality	• Wastewater online monitoring • Riverquality monitoring (e.g. pathogens) • Development of a virtual laboratory in which experiments are carried out • **Wastewater treatment plant optimisation (e.g. digital twin)** • Integrated modelling (sewer/wwtp/river) • Software sensors (interactive data-visualisation) • Assessment of impacts on groundwater and surface water quality during droughts • AI for prediction and prioritization of water quality parameters in supply sources e.g. dependent on land use • **Consumer confidence reporting not only on quantity, but also on quality** • Relationship between waterquality and catchment areas

Theme	(New) applications
Cyber-security	• Algorithm to detect cyber-attack • Anomalies detection (e.g. in distribution system) • Systemredundancy • Improve the trustiness around cybersecurity softwares • Secure the data cloud • Secure the data transmission in IIOT • Security aspect of the service • Transmit the process data from RTU/PLC to Cloud (e.g. MQTT)

Others	• Transfer of knowledge
	  ○ Relationship to other sectors
	• **Strategy for visualisation**
	• **Virtual or augmented reality**
	  ○ for support of operations and maintenance
	  ○ for training and education (e.g. tour of WWTP, 360°-technologies)
	• More interactive area
	• To deal with data, prepare data and make dashboards
	  ○ Deals with real data + plugin model that already exists
	  ○ Model deployment
	• Real-time monitoring of domestic water use via app
	• Training of staff using digital twins

Table 2 shows the elaboration of the 4 most popular ideas. Following questions were solved during the discussions: what is the benefit of the application, which data/technology is needed to develop the application, …?

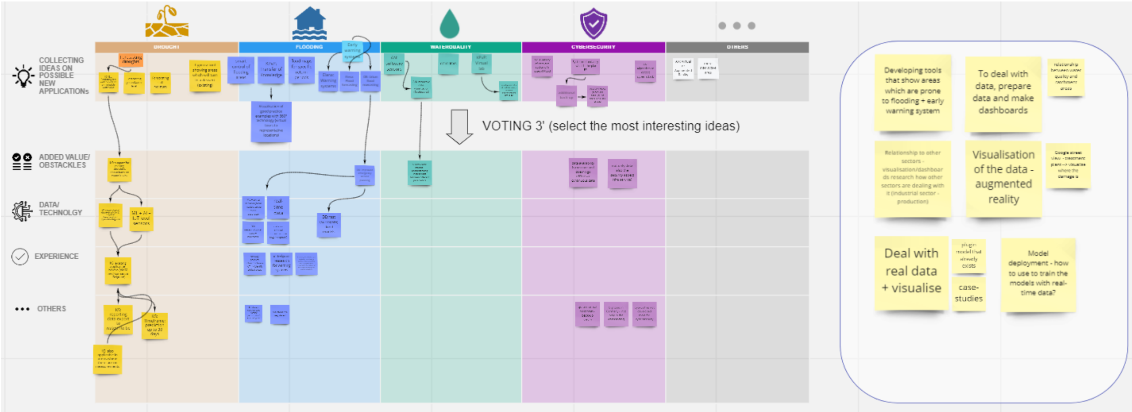
Table 2: Elaboration of the 4 most popular ideas

Early warning systems	
	Benefit: improved emergency service planning
	Data: data on critical infrastructure, meteorological data + nowcasts (real-time data) Technology: ML + extra sensors, train models to be more accurate, fast flood models
	Experience: Warnwetter (GE), BE-Alert (BE), …
Translation of water data to communicate the flood impacts through platforms (e.g. strategy for visualisation)	
	Benefit: Shorter response times – better preparedness, easily interpretable indicators Obstacle: Financing

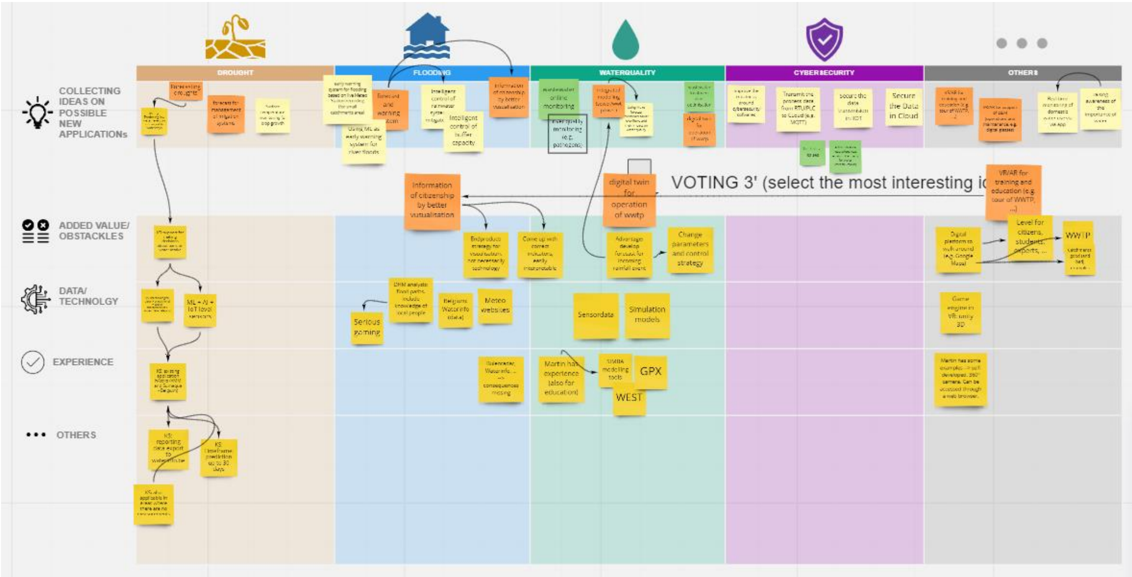
	Data: Sensors and meteorological radars, include knowledge of local people Technology: GIS, flood forecasting models, serious gaming,
Consumer confidence reporting not only quantity but also on quality	
	Benefit: better protection and preservance of water resources through awareness
	Data: smart water meters, IoT sensors for multiple quality parameters Technology: smart water meters, digital twin, authentication tool, GIS (spatial resolution), dashboard HMI's for different user categories, SIMBA-modelling,
Virtual or augmented reality for training and education (e.g. tour of WWTP)	
	Benefit: visualise where the damage is, digital platform to walk around (e.g. Google maps), level for citizens, students, experts, …
	Data & Technology: Martin Oldenburg (TH OWL) has some self-developed examples

1. **Ideas map and suggested actions:**

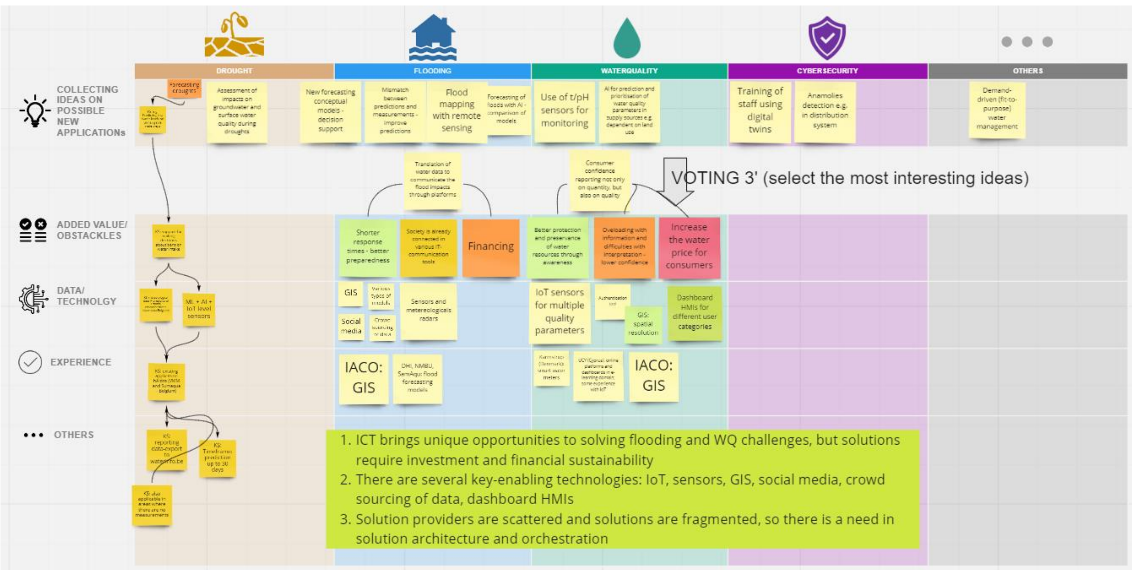
GROUP 1



GROUP 2



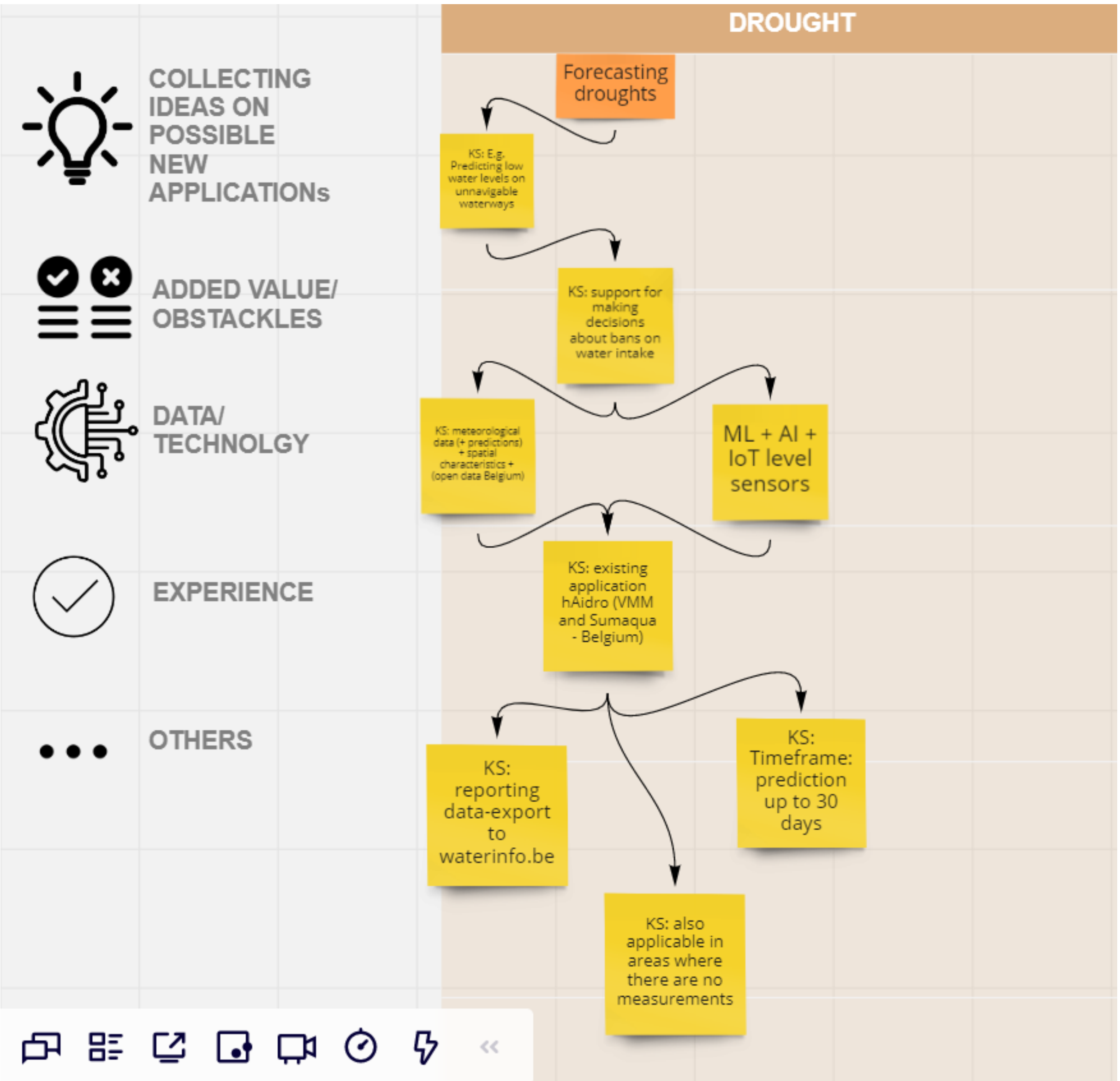
GROUP 3



Miro was used as a tool to improve the speed and quality of online group brainstorming, facilitating discussion and building consensus. Miro has been used around the world both virtual and face to face to capture what people think in real time.

Working questions

Workshop participants were offered to brainstorm for innovative applications for water digitalisation, the following example was given as inspiration:



Role of the moderators

The brainstorming break-out rooms were facilitated by three facilitators. The facilitators used Miro to collect the ideas:

- How can digitalization and ICT help to tackle today's and tomorrow's water challenges? Collect ideas on possible new applications regarding drought, flooding, waterquality and cybersecurity.
- What is the added value of this application? Are there any obstacles?
- Which technology/data is needed to develop this application?
- Do you have any experience within this application field?
- ...

Workshop structure

The brainstorming phase was structured into 4 steps:

STEP 1: Brainstorm on new applications 15'

STEP 2: Voting (most interesting suggestions of new applications) 3'

STEP 3: Elaborate the most interesting ideas 30'

STEP 4: Summarize 5-10'

LIST OF PARTICIPANTS

	Name	Email	Role
1	Kato Schoeters	kato.schoeters@sumaqua.be	main facilitator
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3	Vincent Wolfs	Vincent.wolfs@sumaqua.be	facilitator
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Annex – Workshop materials

I – Workshop slides

Concepts Design workshop

12/01/2022

Kato Schoeters
Vincent Wolfs
Mehmet Emin Pasaoglu

Agenda (13h – 15h)

13h00 – 13h45: Introduction

Digiwater project (context|objectives |timing)

Partners and today's participants

Aim of the Concepts Design Workshop

- Operational application on IoT and Big Data (Vincent Wolfs | Sumaqua)
- Presentation on Cybersecurity (Mehmet Emin Pasaoglu | ITU)

13h45 – 14h45: Brainstorm sessions in 3 break-out rooms

14h45 – 15h00: Feedback + next steps

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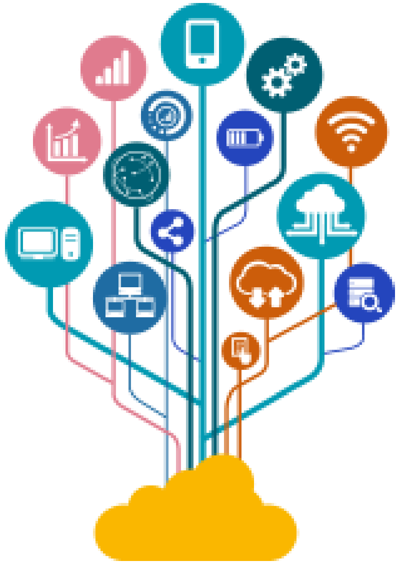
Digiwater project

Context Digiwater



Objectives Digiwater

- Strenghten the **innovation capacity** of the water industry
- **Tackle the digital skills mismatch** in the water industry
- **Improve social engagement** of universities educating water specialists

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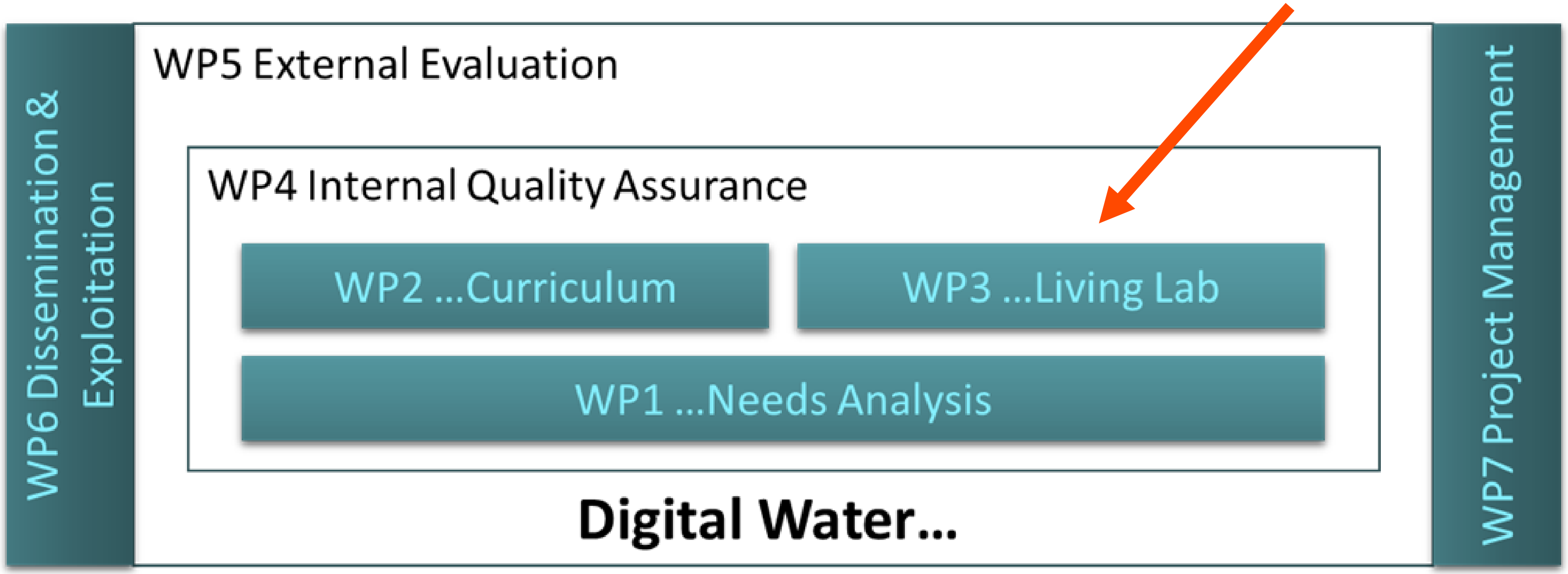
Timing Digiwater

- Timing (2021 – 2023)



- **Deliverables** (some examples)
  - Digital Water Roadmap
  - Curriculum
  - Innovation camps + prototyping reports
  - Quality assurance plan
  - External evaluation report
  - Project website, promo-material, publications, ...
  - ...

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Partners of the Digiwater project

Universities (6)	Companies
NMBU (Norway)	Doscon (Norway) Research and development company providing innovative technologies and solutions for digitalisation of water and wastewater treatment markets
THOWL (Germany)	STEB Paderborn (Germany) Municipal operator of the wastewater system
ITU (Turkey)	MEMSIS (Turkey) Company that provides technical support, design and consultancy activities of membrane systems in water and wastewater treatment.
KU Leuven (Belgium)	Sumaqua (Belgium) SME focusing on digital water management
UCY (Cyprus)	I.A.CO (Cyprus) SME: Environmental & Water Consultants
UGAL (Romania)	SmarTech (Romania) Information Technology (i.a. SCADA systems, water and sewerage systems, wastewater treatments plants, …)
	EWA European Water Association

Today's participants

Group 1 (Kato Schoeters) (BE)	Group 2 (Vincent Wolfs) (BE)	Group 3 (Zakhar Maletskyi) (NO)
Harsha Ratnaweera (NO)	Martin Oldenburg (GE)	Susann Andersen (NO)
Bino Maiheu (BE)	Laurens Breugelmans (BE)	Patrick Willems (BE)
Elena Nikolaou (CY)	Photiadisth	Pieter Cabus (BE)
Katharina Pilar van Pilchau (GE)	B Westermann (GE)	A Bansemer (GE)
Noama Shareef (GE)	Nataly Sivchenko (NO)	Bjorn Kaare Jensen (DK)
D Plath (GE)	Marius Mouskoundis (CY)	Ayis Iacovides (CY)
Stefan Wolf (GE)	Goitom Kahsay Weldehawaryat (NO)	Mitrita Zanet (RO)
Abhilash (NO)	Jascuna Veronica	Athina Papathedodoulou (CY)
Daan Buekenhout (BE)	Laurentiu Luca	Recep Kaya
Sevde Korkut	Ayis Iacovides	

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Aim Concepts Design Workshop

TODAY

Collecting ideas

- Big Data and IoT
- Cybersecurity

Innovation camps + prototyping

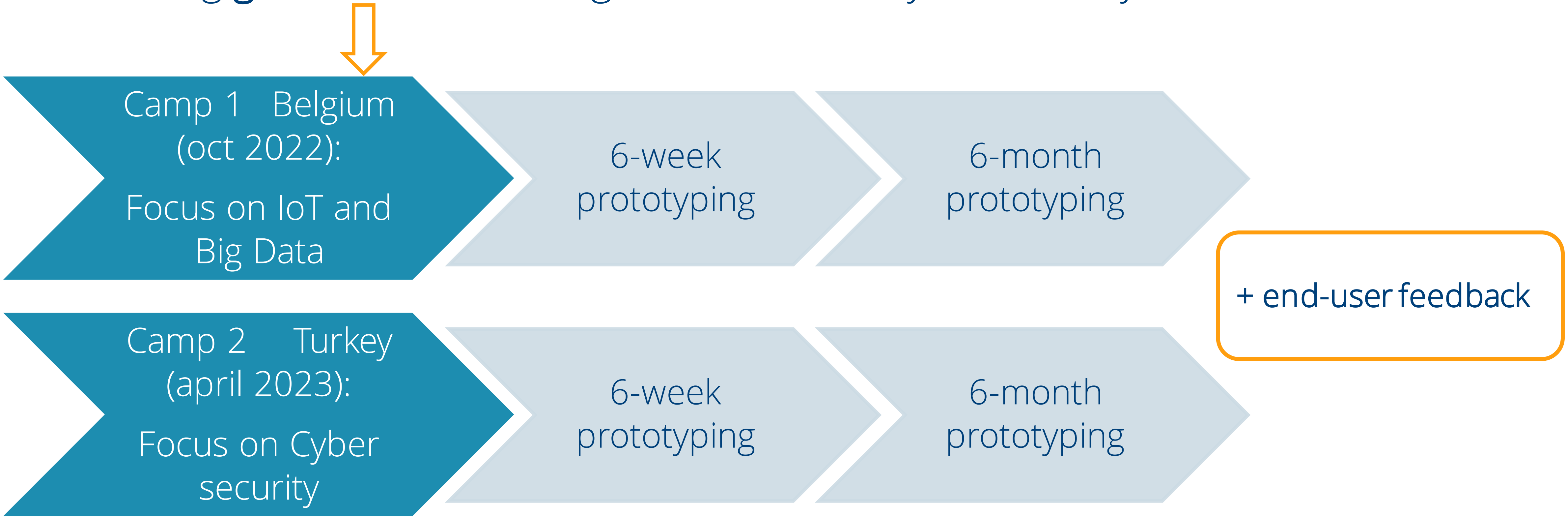
- Further elaboration of the selected ideas

End-user involvement

- Feedback on best prototypes by end-users

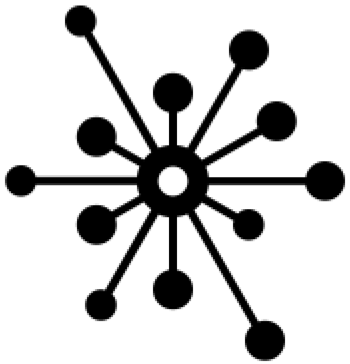
Aim Concepts Design Workshop

Establishing **general ideas** on digitalisation and cybersecurity in the water sector



→ We aim to demonstrate at least **6 innovative ideas** brought up during this workshop

Today: collecting ideas



Big Data & IoT

- Low flow forecasting
- Flood forecasting
- Measuring water quality
- ...

Cybersecurity

- Blockchain
- SCADA
- ...

Machine Learning for drought mitigation: some practical examples

Dr. ir. Vincent Wolfs
ir. Tim Franken

With support of

VLAAMSE
MILIEUMAATSCHAPPIJ

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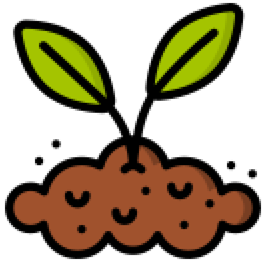
Introduction

why machine learning models for drought simulations?

Practical ML examples

Simulating and forecasting
low flows
in smaller rivers

Simulating and forecasting
groundwater levels



A physics informed
soil moisture model

Conclusions

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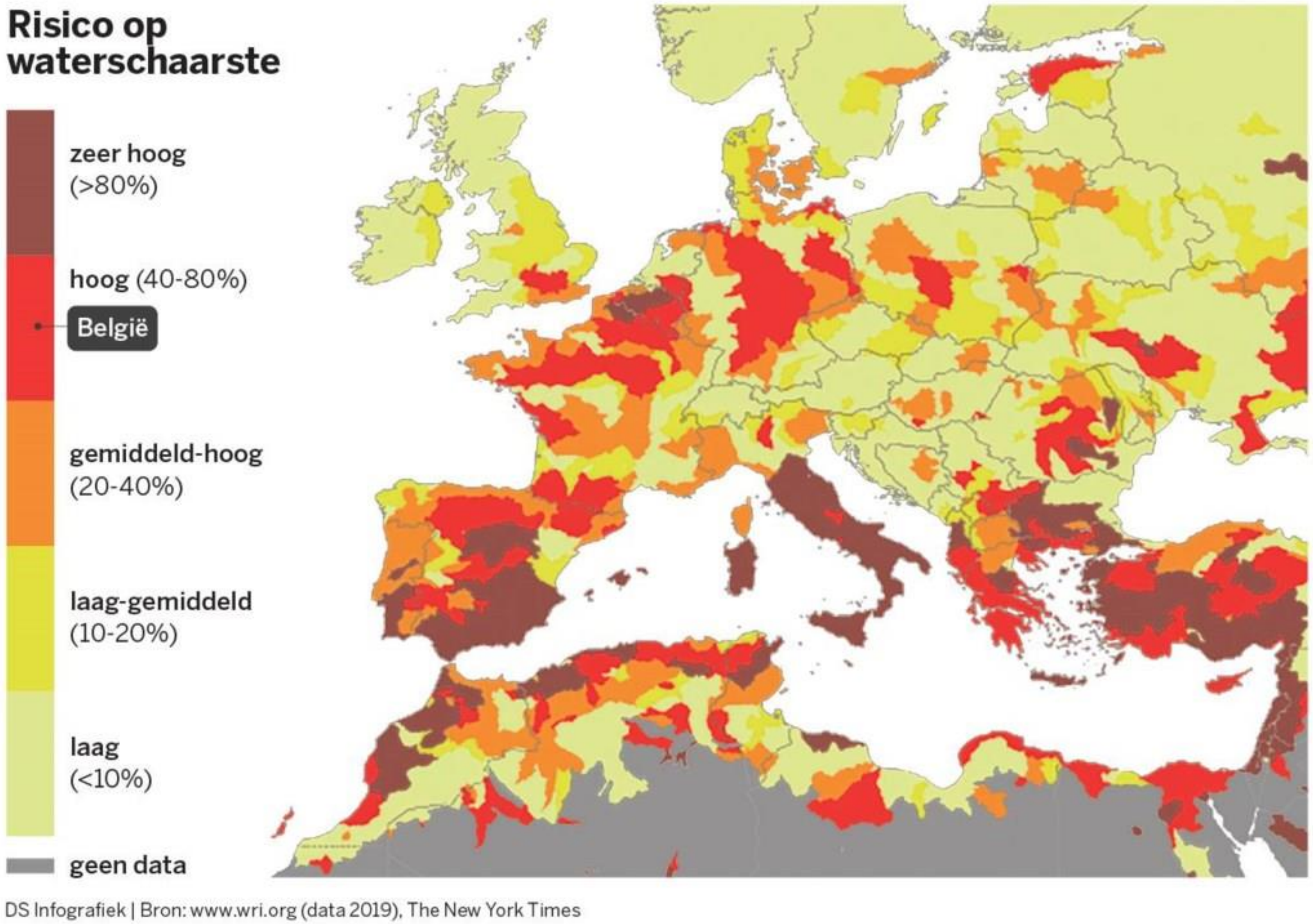
Introduction

- Flanders has a high water shortage risk
- Recent dry summers have highlighted the problem

➢ VRAG: Flemish assessment framework to mitigate drought risks

➢ Need for information about ground water levels, low flows and soil moisture on higher spatial and temporal resolutions



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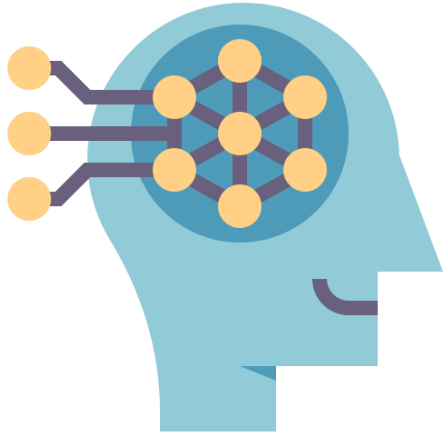
Introduction

Why Machine Learning?

- **Difficult to model with "traditional" hydrological models** (e.g. PDM)
  - Flanders has a high population density
  - High impact of artificial discharges and extractions in measured data
- Models are used in operational context → **ML models are fast!**



Integrated ML approach with products for:

- Soil moisture
- River discharge
- Groundwater levels

Presentation of 3 projects, with support of Vlaamse Milieumaatschappij (Belgium)

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MILIEUMAATSCHAPPIJ

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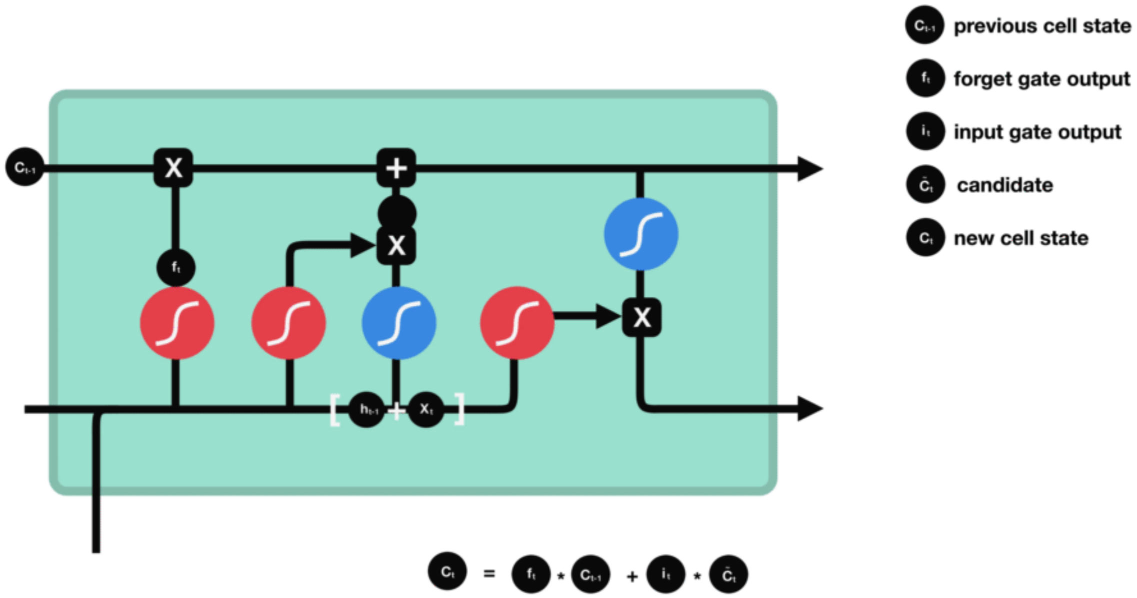
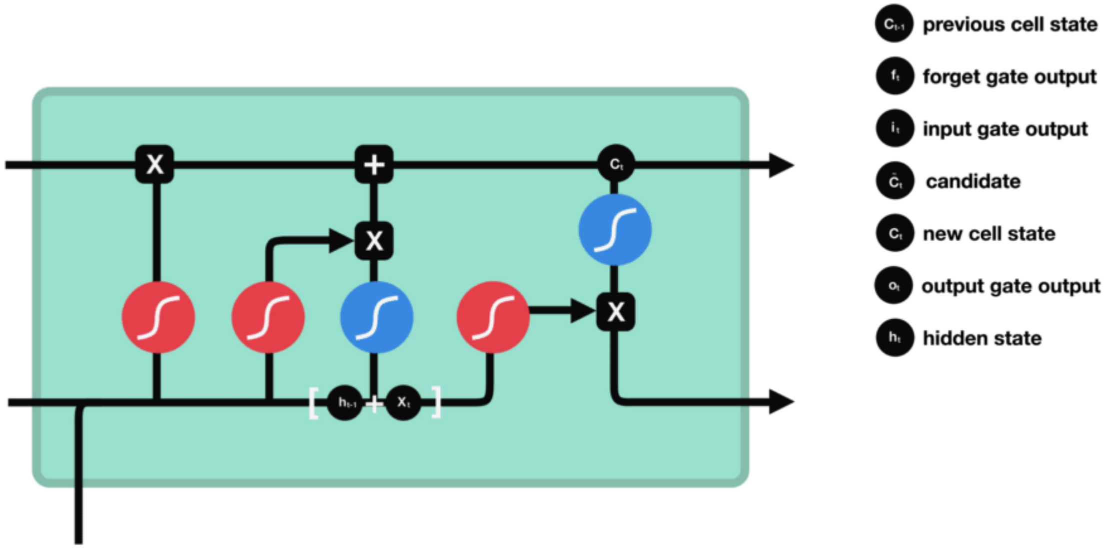
Aim

Goal: build a fast and accurate machine learning model to simulate low flows in (small) rivers for drought management

Use of an LSTM model structure:



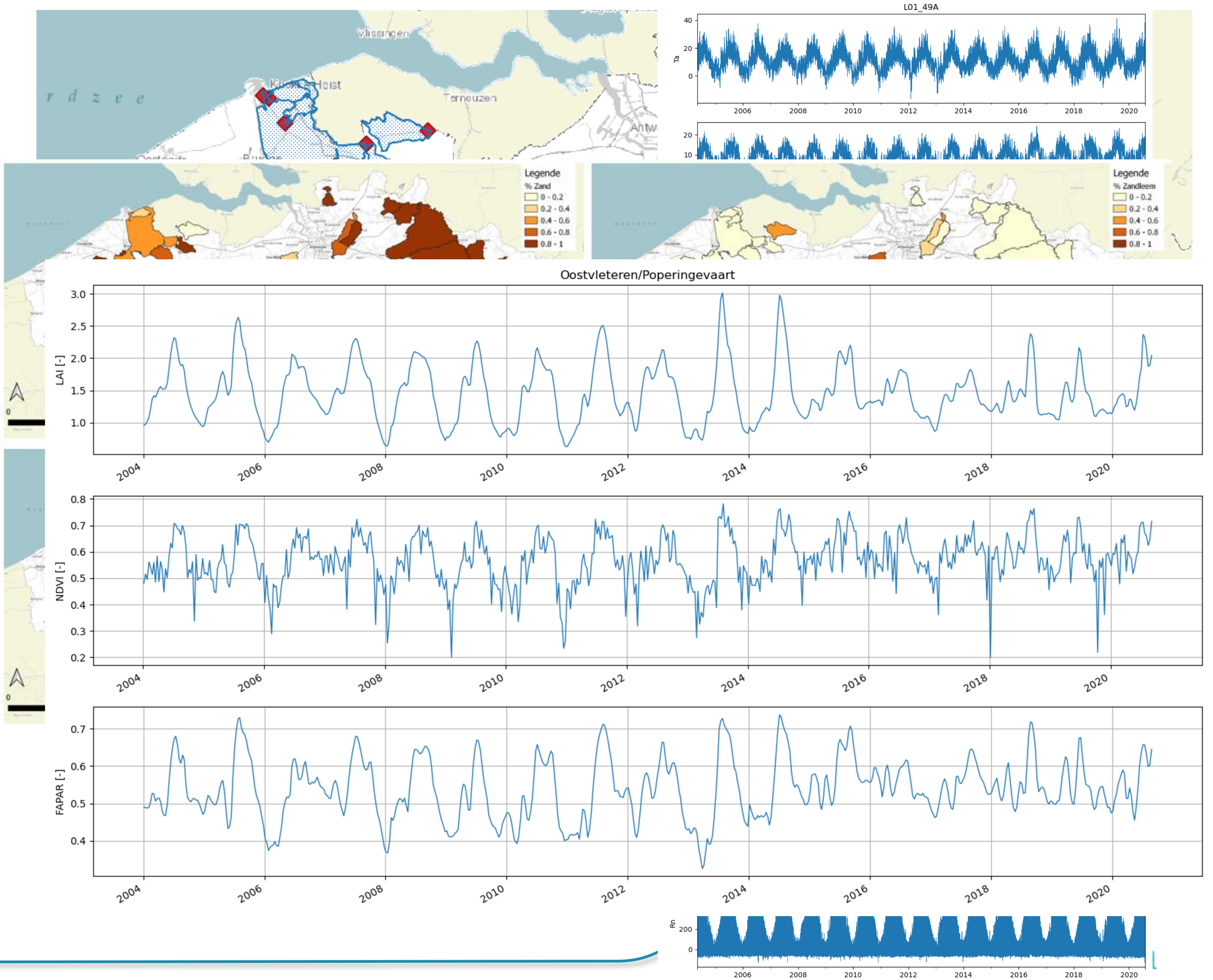


Data

Target variable:
Discharge measurements of 100 locations distributed across Flanders

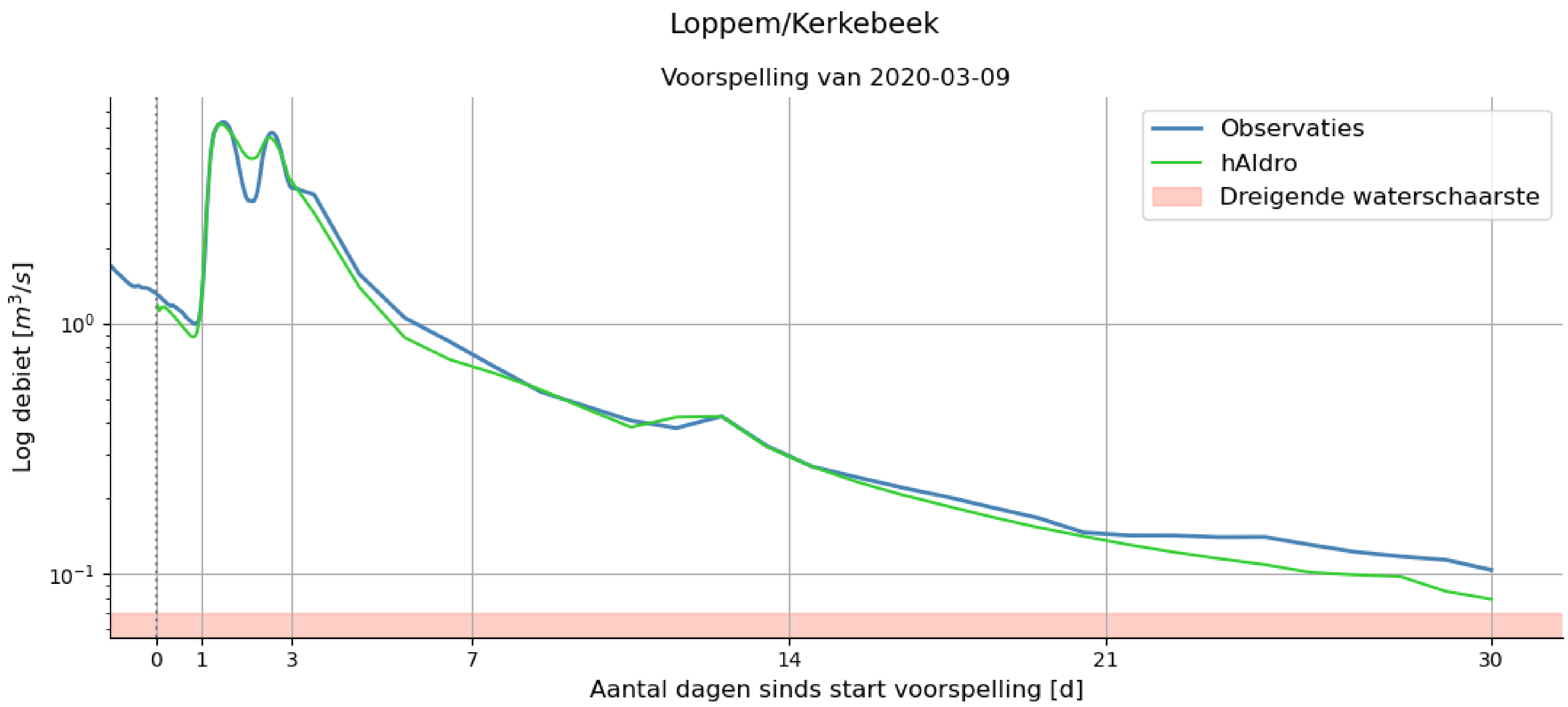
Predictors:
- Meteorological measurements
- Static properties of each catchment
- Effluent from water treatment plants
- Remote sensing data (LAI, NDVI, FAPAR)

1 "regional" model for all basins
→ +- 8×10^6 datapoints for training



hAIdro with discharge as input

Simulation with known rainfall



Discharge (log) [m^3/s]

Forecast horizon [days]

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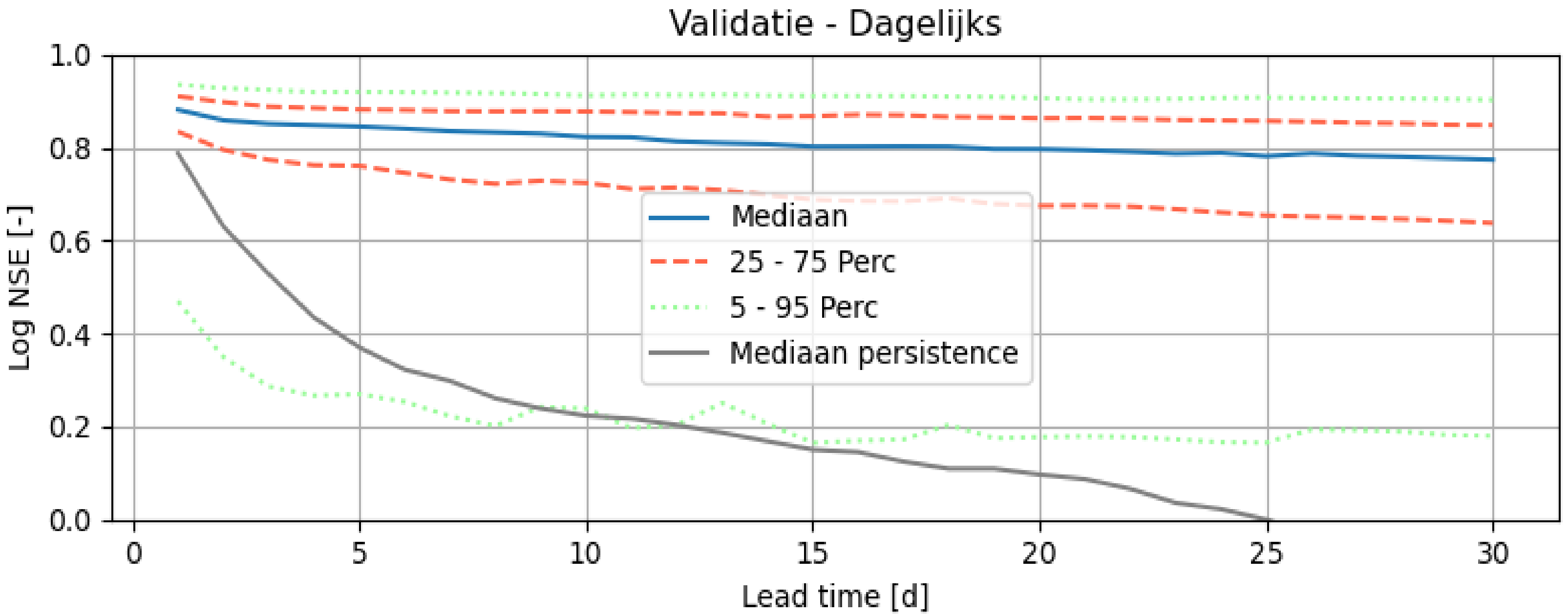
hAIdro with discharge as input



Accurate

(median log NSE value ≈ 0,8 for longer lead times)

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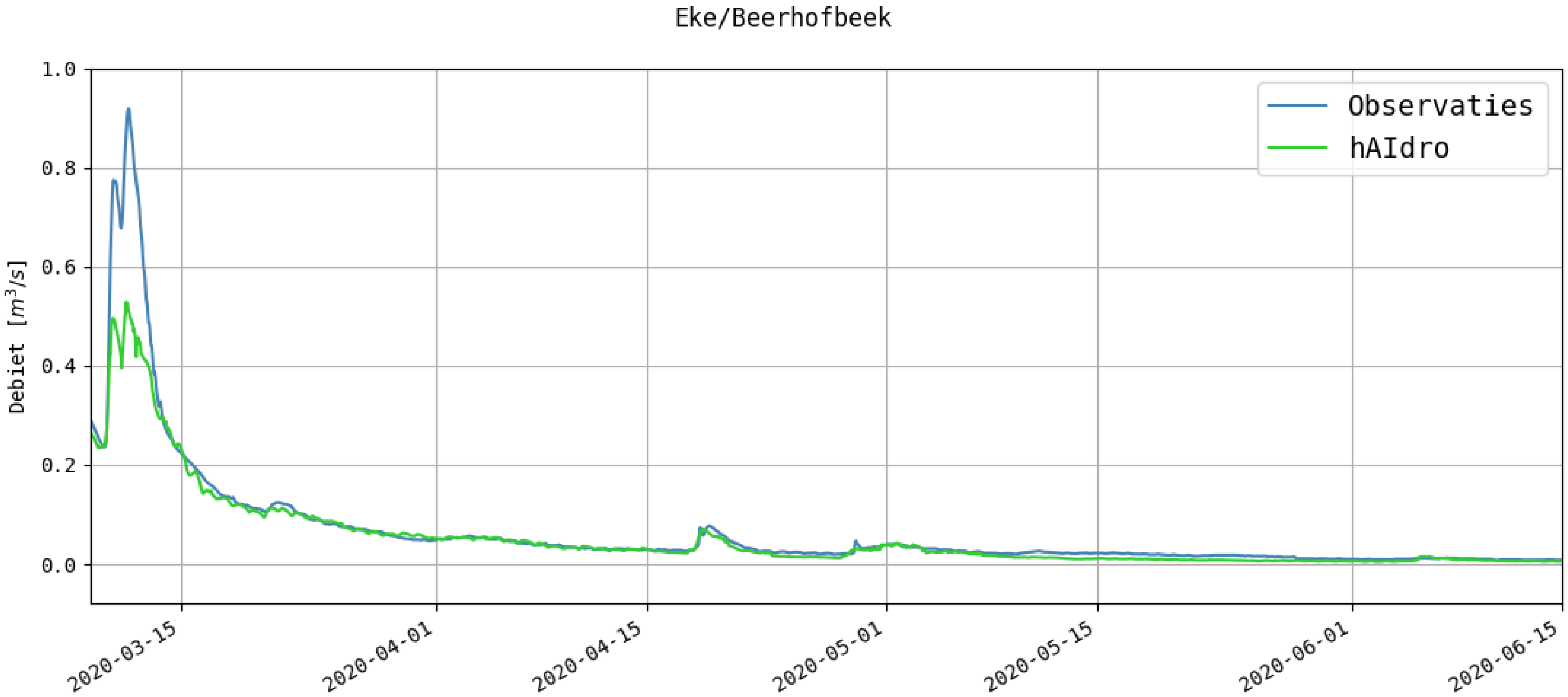
hAIdro without discharge



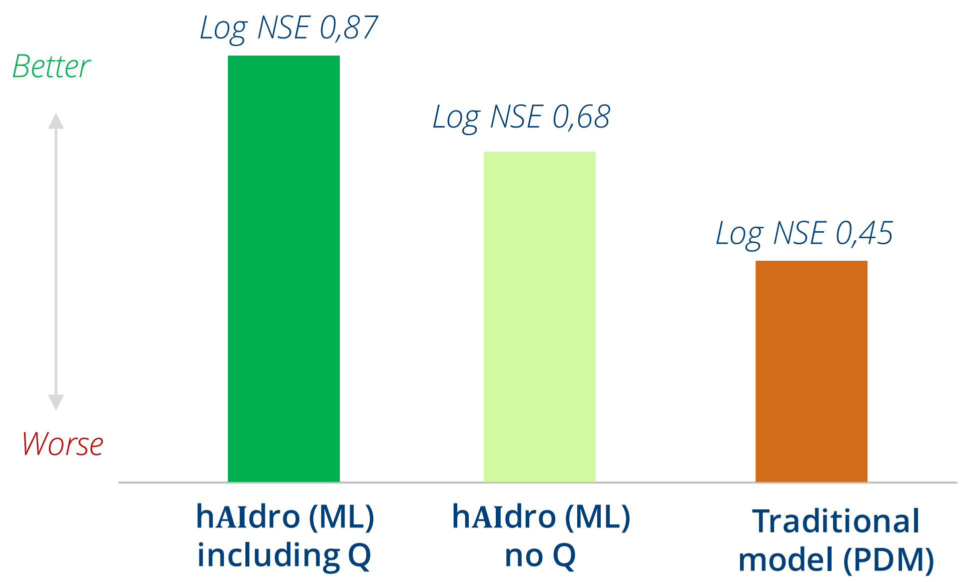
If recent past discharge measurements are not used as input:

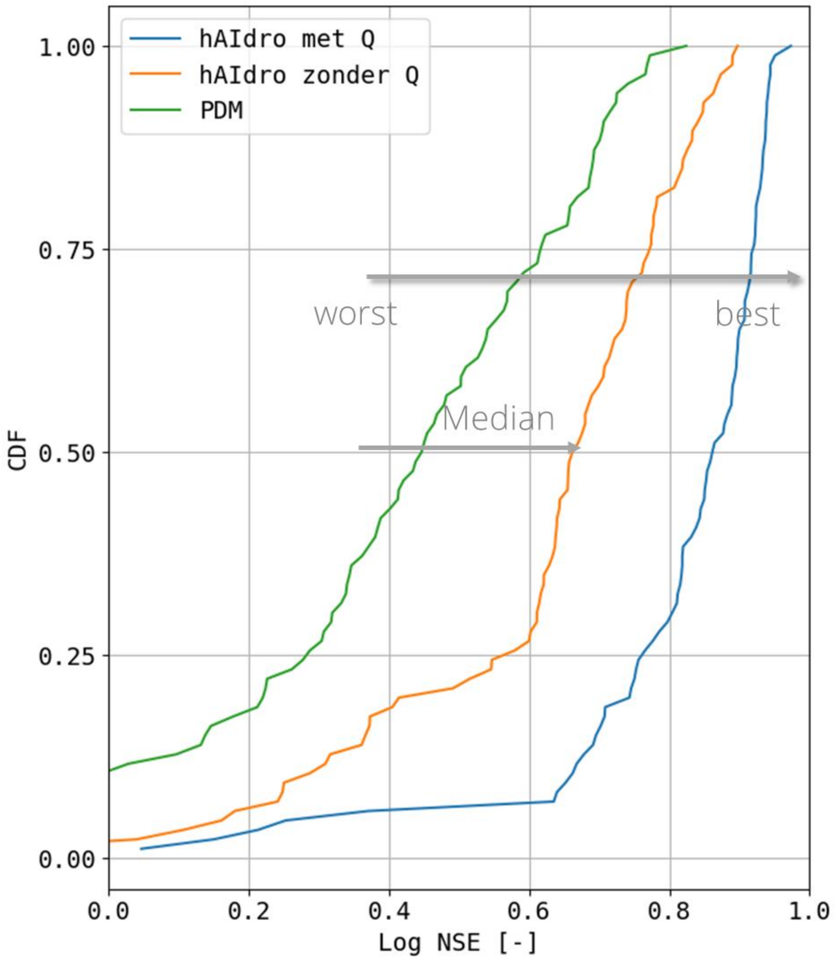
- Short term peaks are not well simulated
- Drought simulation remains accurate

➔ The ML model "HAIDRO" can also be used in absence of continuous discharge measurements

Machine learning versus traditional models

Performance:





Thus:

- ✓ Machine learning can lead to accurate and reliable models
- ✓ Additional local information further improves the machine learning models → benefit of installing (IoT) sensors!

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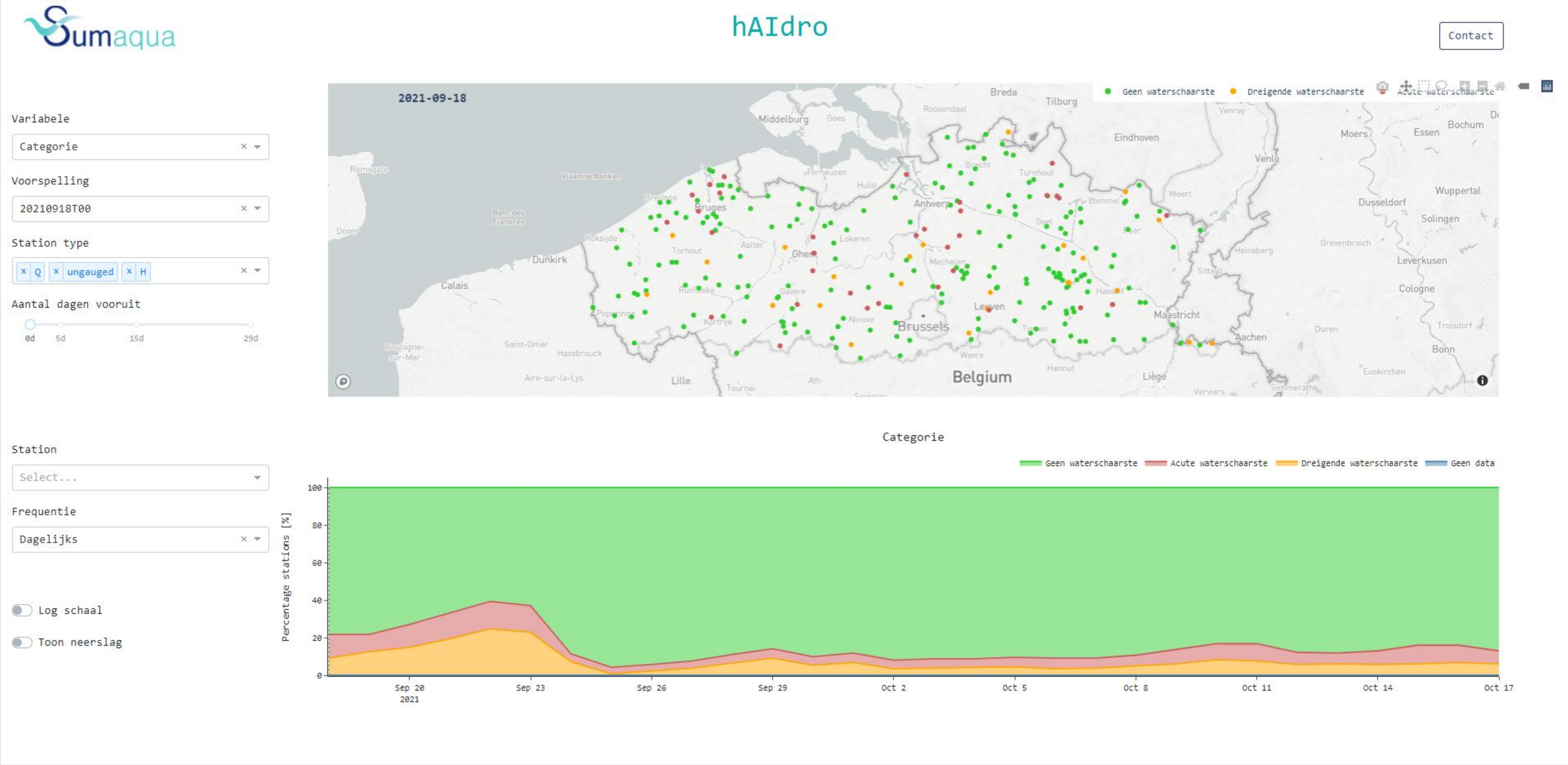
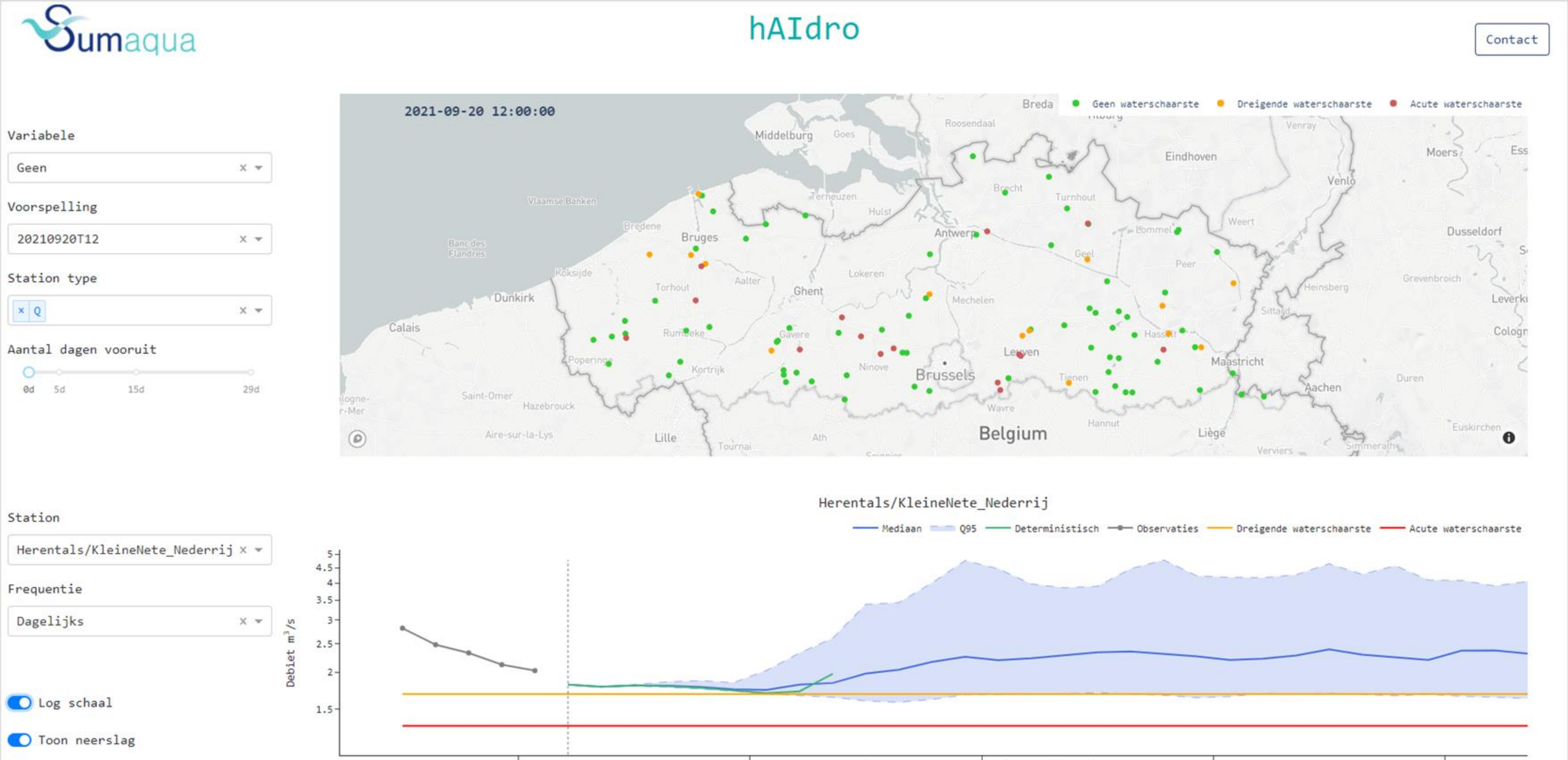
From ML models to an operational framework



From ML models to an operational framework



Lead time (up to 30 days ahead)

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groundwater levels

A physics informed
soil moisture model

Conclusions

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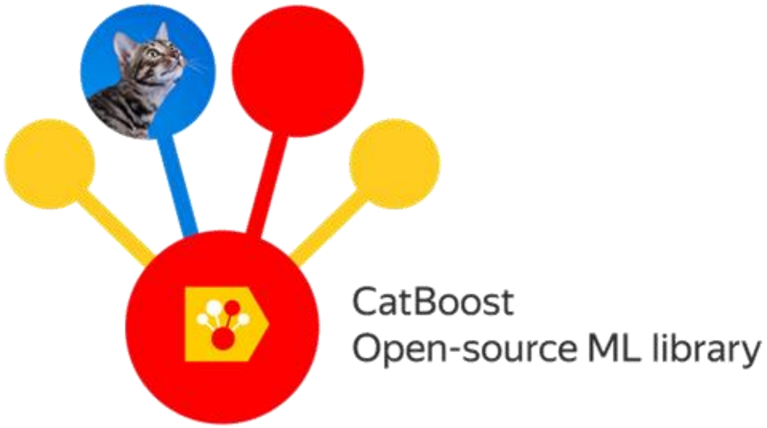
ML for groundwater levels

- Similar approach and models as for river discharge

- But… ground water levels are less transferrable and LSTM model alone introduces a bias

- Final model combines to ML models in a single structure:
  - ✓ CatBoost model (=Tree based algorithm) to estimate the average ground water level
  - ✓ LSTM to simulate the temporal evolution



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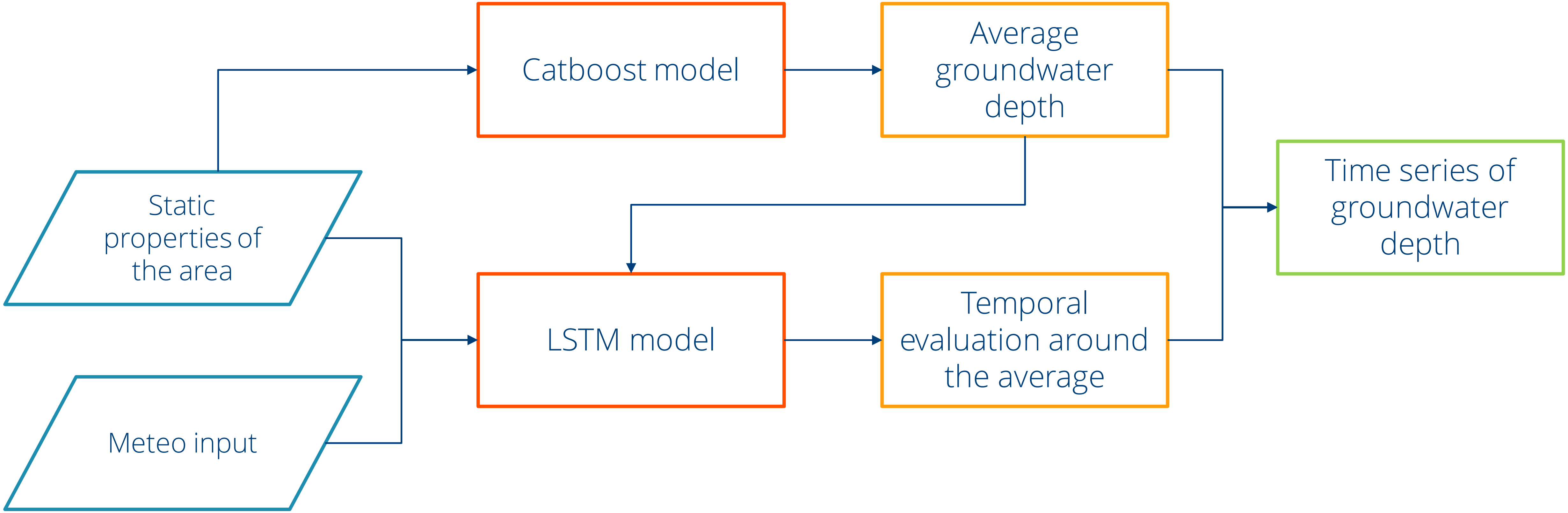
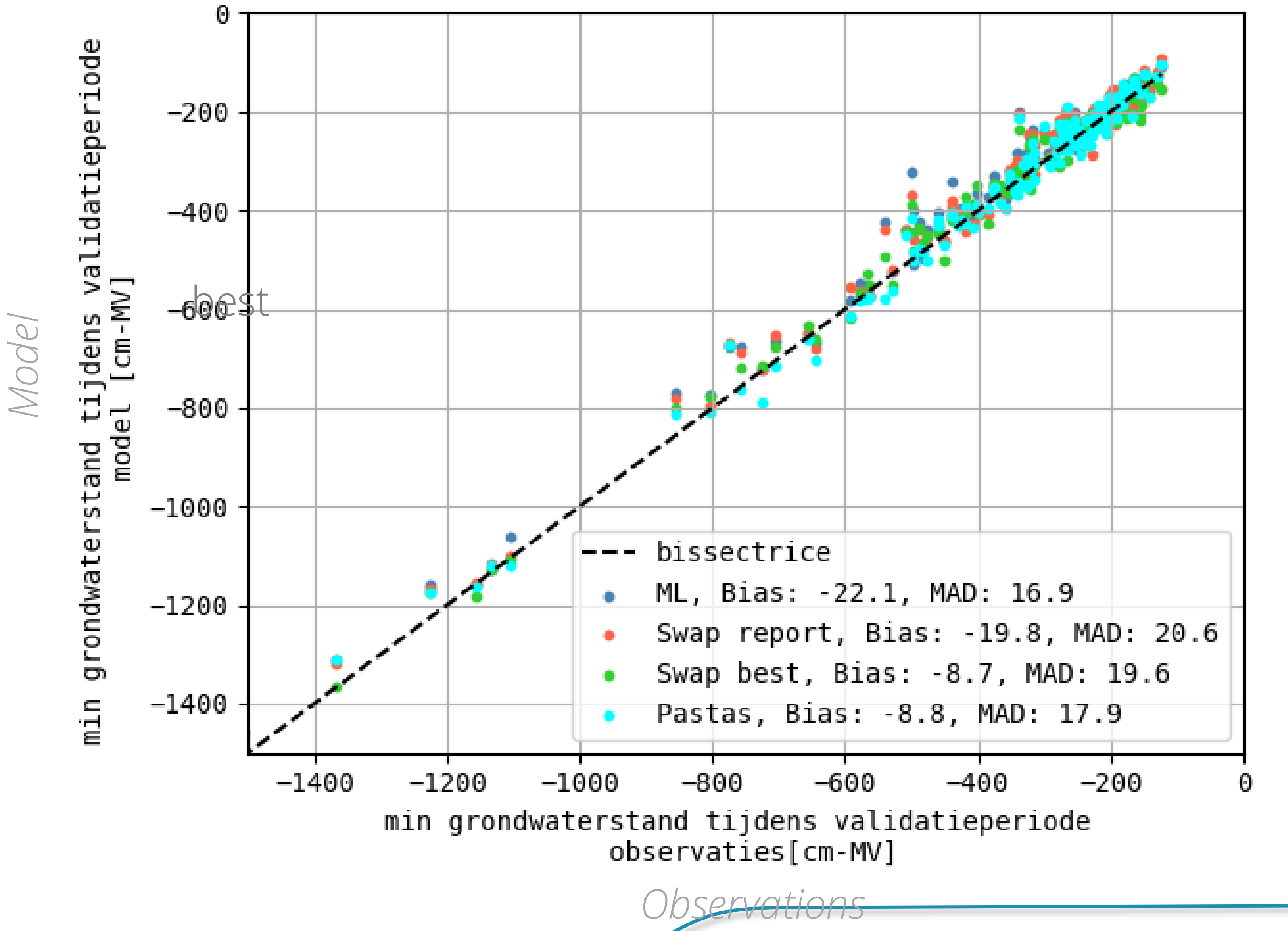
ML model


Catboost model
Average groundwater depth
Static properties of the area
Meteo input
LSTM model
Temporal evaluation around the average
Time series of groundwater depth

Results

- **Machine learning models have the best overall performance** in both calibration and validation dataset (lowest Mean Absolute Deviation; MAD)

- But the model (currently) is **not the best at simulating the (very) low groundwater levels**



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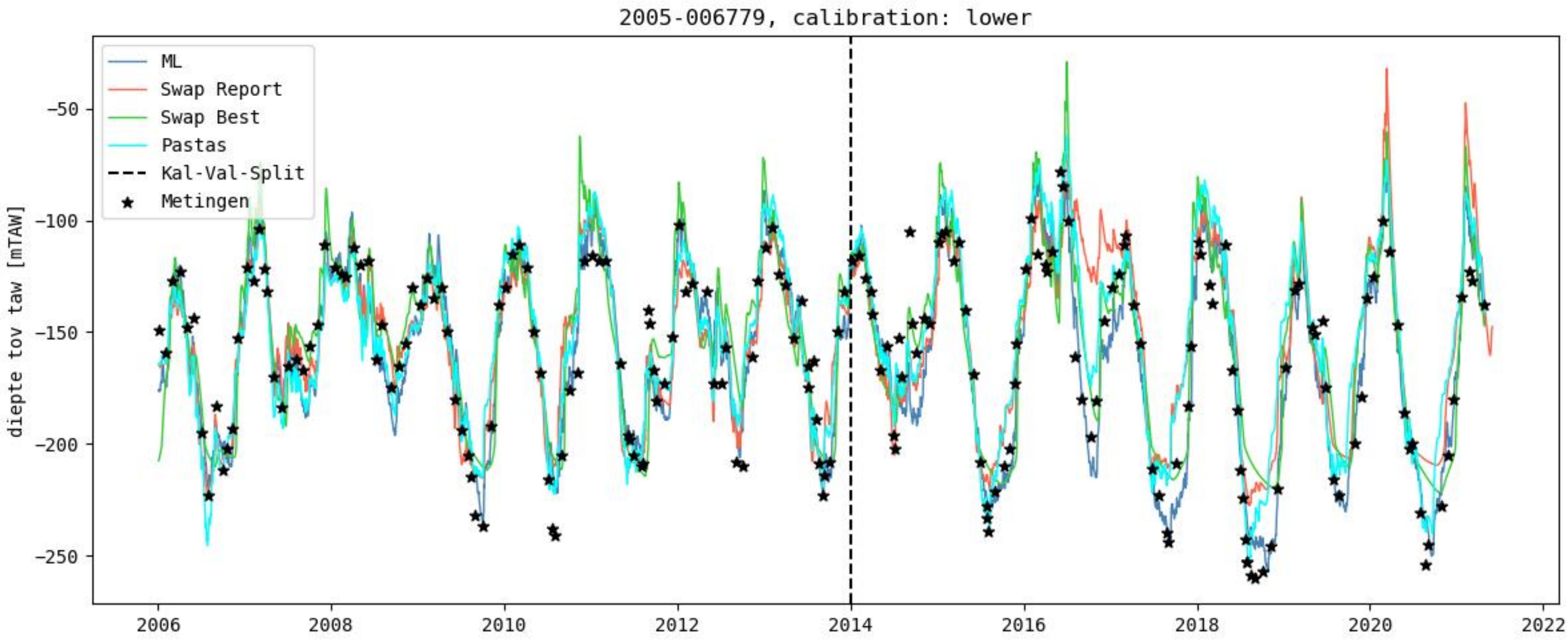
Results



2005-006779, calibration: lower
ML
Swap Report
Swap Best
Pastas
Kal-Val-Split
Metingen
diepte tov taw [mTAW]
-50
-100
-150
-200
-250
2006
2008
2010
2012
2014
2016
2018
2020
2022

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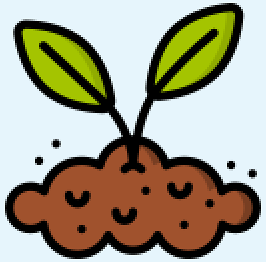

A physics informed
soil moisture model

Conclusions

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Physics informed ML for soil moisture

- ✓ Soil moisture is an important component for plant stress
  - ✗ Continuous and long term measurements of soil moisture are limited

- ✓ Physical based groundwater also output soil moisture information
  - ✗ These models have large calculation times and are not suited for operational purposes

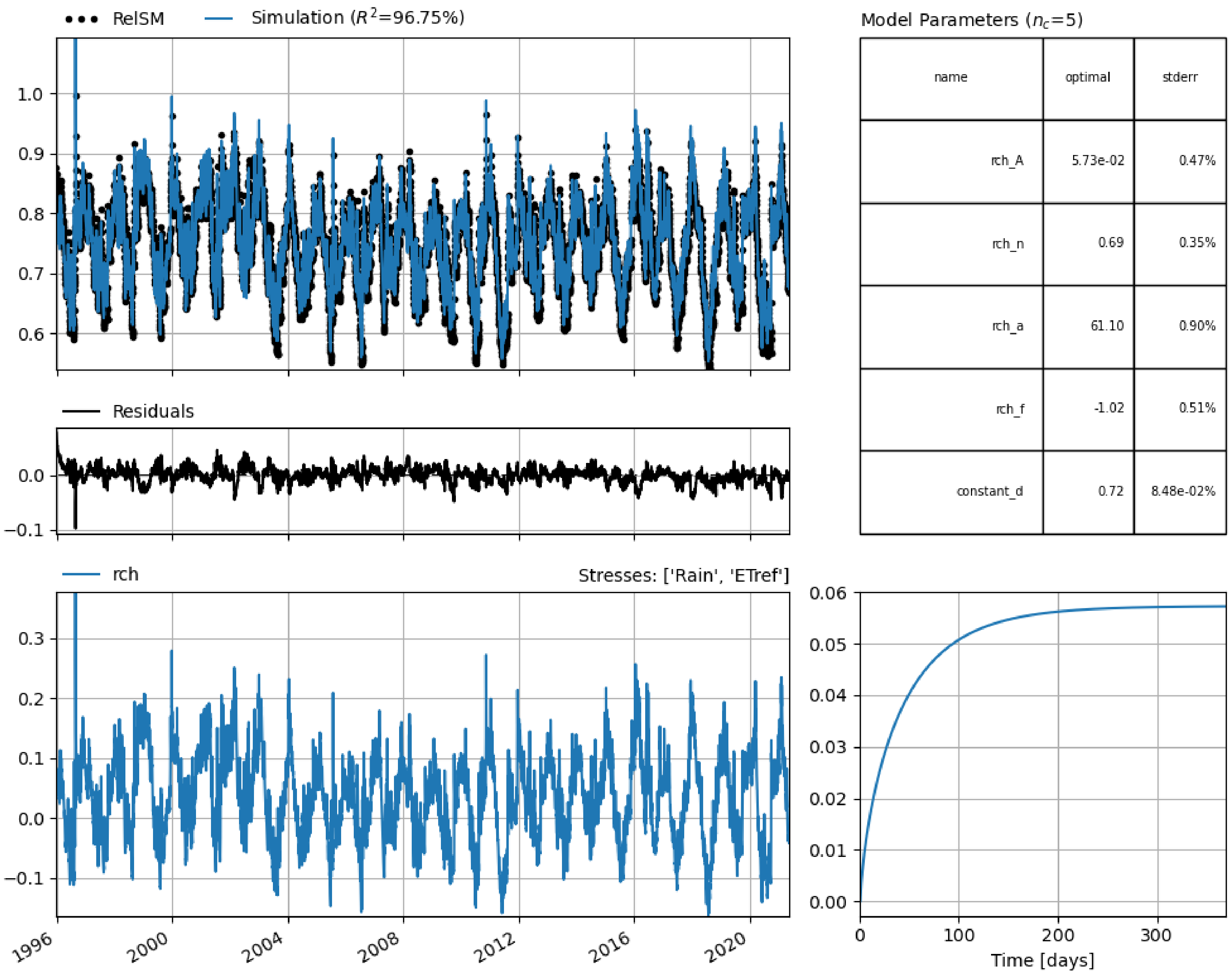
→ Create a "physics informed ML" model that is trained using model results from physical based models

Soil moisture

- Transfer functions translate rainfall and evapotranspiration to soil moisture

- Transfer functions are calibrated on offline simulations with physical based model

✓ **Resulting models are very fast, sufficiently accurate**(R^2 = 0,9675) **and can easily be incorporated in operational environment!**



name	optimal	stderr
rch_A	5.73e-02	0.47%
rch_n	0.69	0.35%
rch_a	61.10	0.90%
rch_f	-1.02	0.51%
constant_d	0.72	8.48e-02%

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Conclusions

- ML models are very well suited for operational purposes as they can provide accurate, timely and relatively cheap forecasts on different crucial components of the water cycle
- Improving your input data has a much higher effect than hyperparameter tuning → ML models directly profit from more (IoT) sensors on the field
- Don’t stick to a single model but use the strengths and weaknesses of each model to reinforce the final solution
- Even black box models can provide valuable insights in your data and physical processes: what are the most important drivers of the water system

Contact

Questions?

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Erasmus+ DIGIWATER Project
Concept Design Workshop

CYBERSECURITY

Dr. Mehmet Emin Pasaoglu & Dr. Recep Kaya

Istanbul Technical University (ITU) &
National Research Center on Membrane Technologies (MEM-TEK)

Jan 11, 2022

- *What is Cybersecurity?*

Cybersecurity is the practice of protecting systems, networks, and programs from digital attacks. These cyberattacks are usually aimed at accessing, changing, or destroying sensitive information; extorting money from users; or interrupting normal business processes.

Types of cybersecurity threats

	Types of cybersecurity threats
Phishing	Phishing is the practice of sending fraudulent emails that resemble emails from reputable sources. The aim is to steal sensitive data like credit card numbers and login information.
Ransomware	Ransomware is a type of malicious software. It is designed to extort money by blocking access to files or the computer system until the ransom is paid. Paying the ransom does not guarantee that the files will be recovered or the system restored.
Malware	Malware is a type of software designed to gain unauthorized access or to cause damage to a computer.
Social engineering	Social engineering is a tactic that adversaries use to trick you into revealing sensitive information. They can solicit a monetary payment or gain access to your confidential data. Social engineering can be combined with any of the threats listed above.

Why is cybersecurity important for water?

- In addition to the general cybersecurity threats, critical infrastructure (CI) related to energy production, manufacturing, water supply and other systems can come under attack.

- For example, drinking water utilities are increasingly incorporating computer technology into their routine operations and are therefore increasingly vulnerable to cyber-threats. Systems control and data acquisition (SCADA) systems used to manage automated physical processes essential to water treatment and distribution systems have become standard in medium to large drinking water utilities and in any small water systems.

- However, even with the application of standard information technology cybersecurity best practices these types of systems have proven to be vulnerable to cyber-attacks. In 2015, the US Department of Homeland Security (DHS) responded to 25 cybersecurity incidents in the Water Sector and to 46 incidents in the Energy Sector.

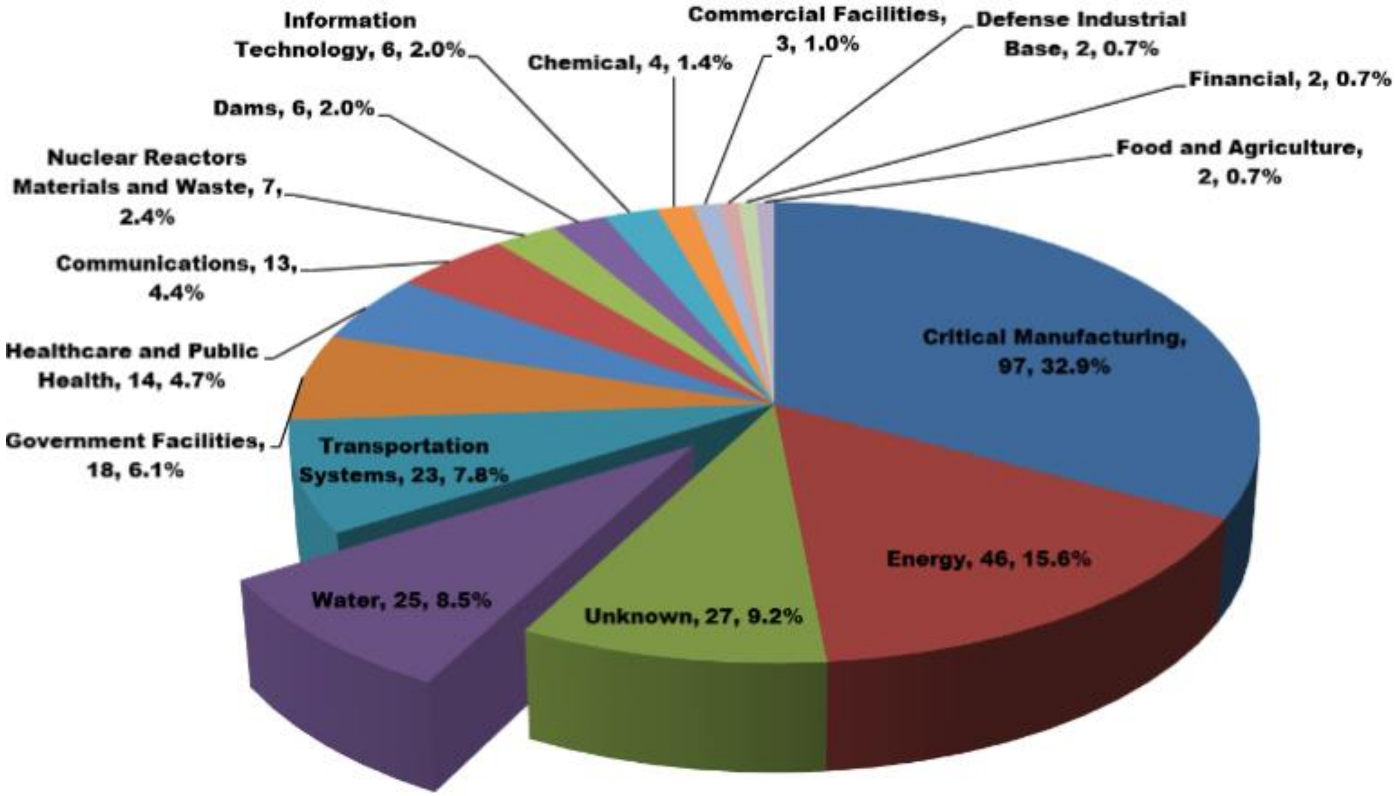
Why is cybersecurity important for water?

- Cyber-security is an increasing focus in the water industry because water utilities are increasingly using industrial control system (ICS) networks to control the physical processes essential to water treatment and distribution systems (Ginter, 2016). Drinking water utilities have become dependent on SCADA systems which are a class of ICSs that are becoming standard for all medium to large drinking water utilities. SCADA systems are frequently integrated into large-scale processes that can include multiple sites and large distances.

Ginter, A.P. (2016). "Cyber Perimeters for Critical Infrastructures" in Cyber-Physical Security at the State, Provincial, and Local Level: Protecting Critical Infrastructure edited by Robert M. Clark and Simon Hakim. Springer International Publishers, Switzerland

Why is cybersecurity important for water?

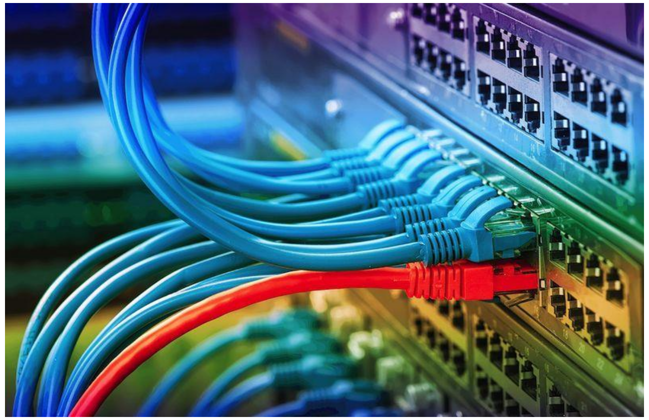
In 2015, the DHS responded to 245 incidents reported by asset owners and industry partners as summarized in the Figure. According to the data in Figure the **Water sector** reported the **fourth largest number of incidents** resulting in DHS incident response support behind Critical Manufacturing, Energy, and Unknown (DHS 2016). As can be seen in the figure the second largest number or reported incidents was in the **Energy sector which could have a direct impact on water supply systems**.

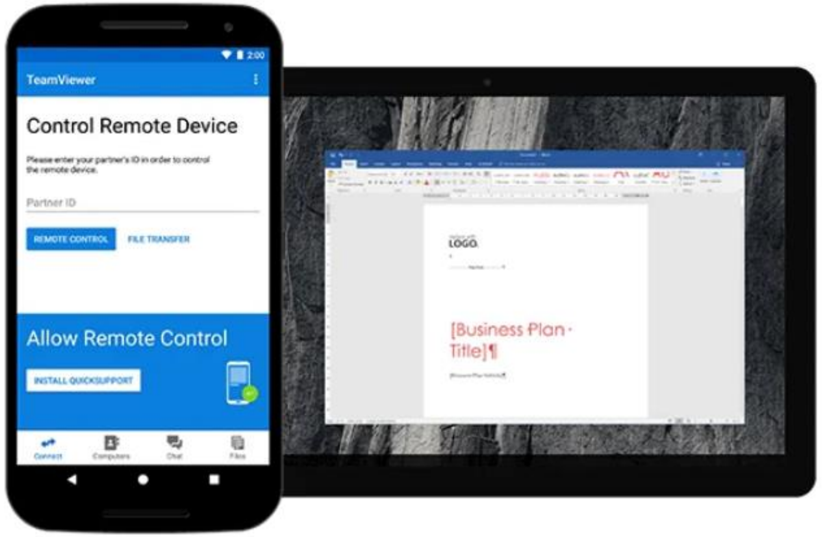


Robert M. Clark, Srinivas Panguluri, Trent D. Nelson, Richard P. Wyman. PROTECTING DRINKING WATER UTILITIES FROM CYBER THREATS Prepared for the U.S. Department of Energy, Office of Nuclear Energy, Under DOE Idaho Operations Office, Contract DE-AC07-05ID14517

The top five areas of common security gaps in water supply are:

- 1 - Network configuration
- 2 - Media protection
- 3 - Remote Access
- 4 - Documented policies and manuals
- 5 - Trained staff





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Creating a cybersecurity culture is important

There are several publications that can provide useful guidance on this area (Panguluri, et al., 2016)). Fisher (2014) lists an eight-stage process for creating major change:

- Establishing a sense of urgency – Identify and discuss the crises or potential crises.
- Creating the guiding coalition – Putting together a group with the power to lead change.
- Developing a vision and strategy including policies and procedures to define and enforce security.
- Communicating the change vision
- Empowering broad-based action
- Generating short-term wins
- Consolidating gains and producing more change
- Anchoring new approaches in the emergent culture

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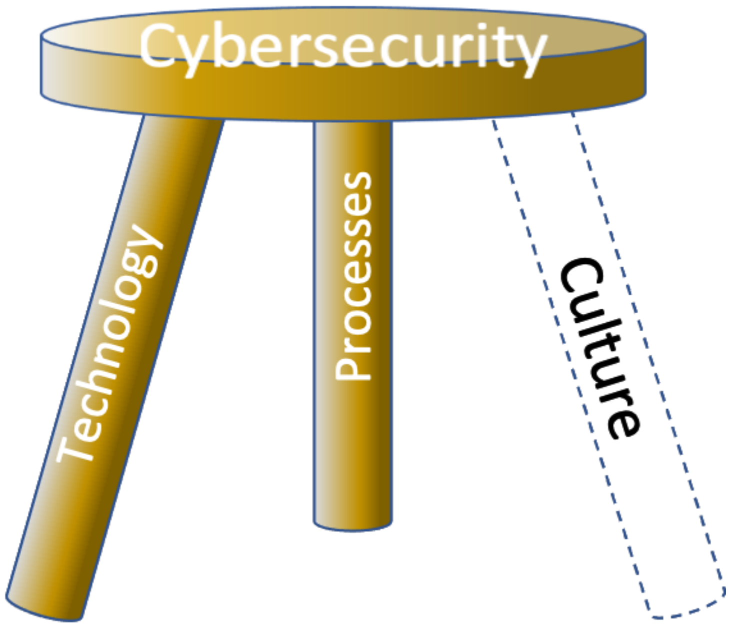
Creating a cybersecurity culture is important

Establishing a cyber-security culture is the framework for implementing a strong defense in depth program.

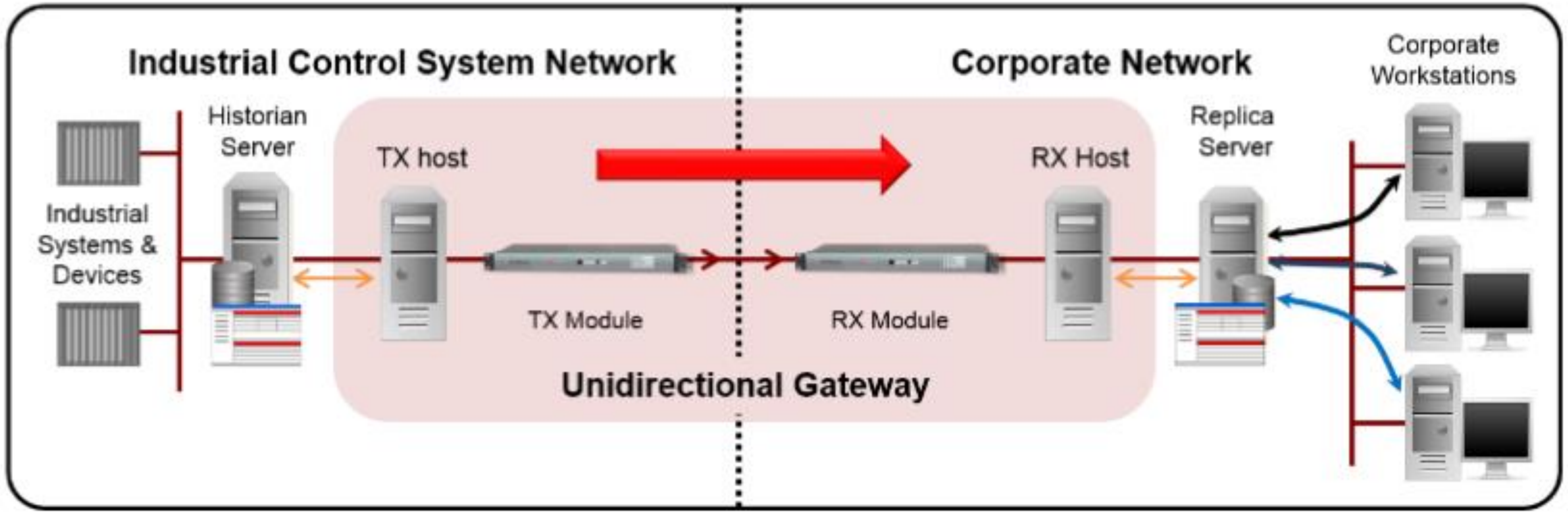
It puts the three legs (technology, people, and physical protection) of cyber- security on a firm foundation.

Physical protection process implies locating IT equipment in a safe location.



Secured Network Design is also important

Experts are recommending technological innovations such as **unidirectional gateways** be used as the modern alternative to firewall perimeter protections for ICSs. An example of a unidirectional gateway deployment is illustrated in Figure.



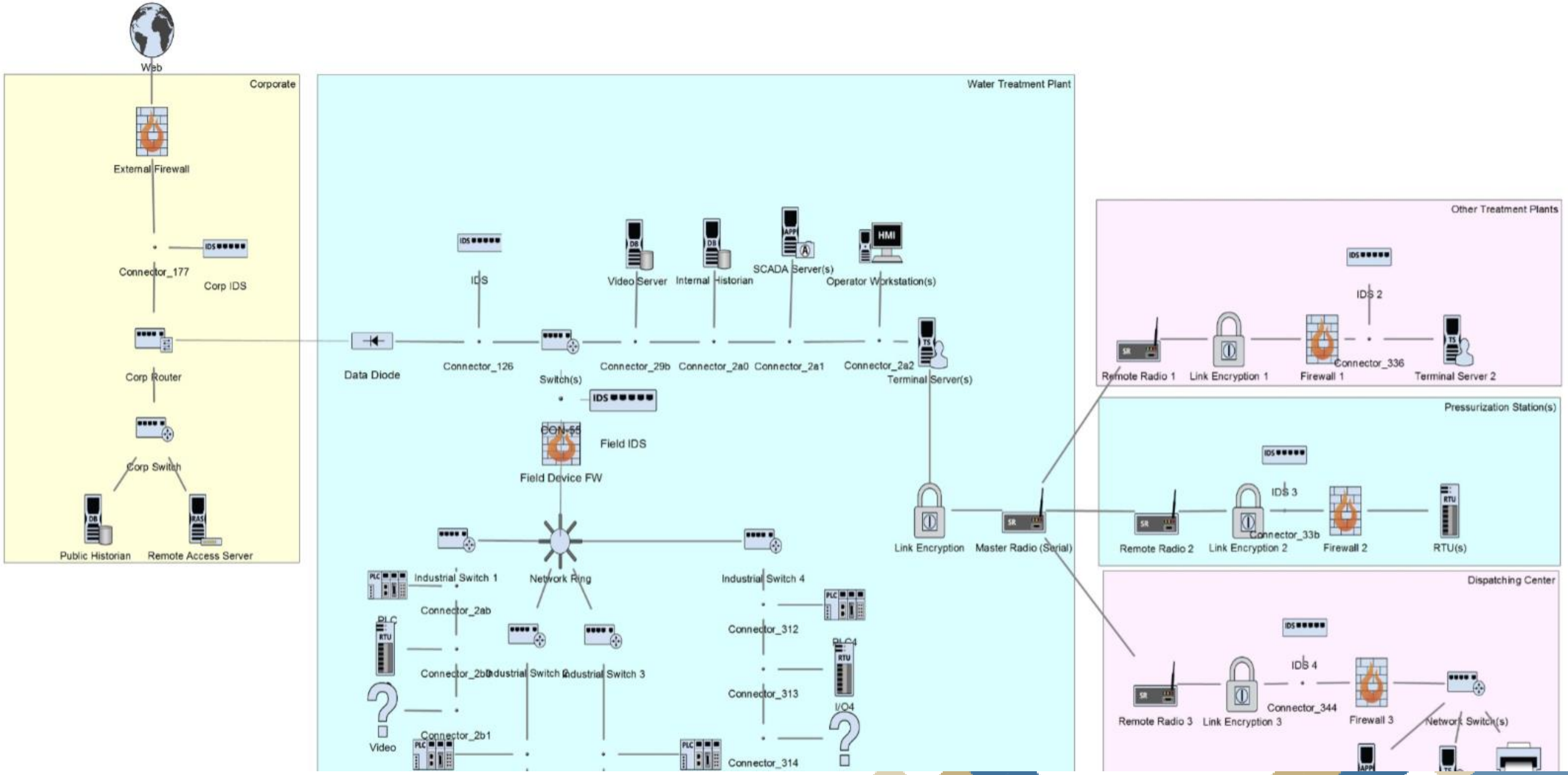
Example of a Unidirectional Network (Ginter, 2016)

Secured Network Design is also important

Good cybersecurity designs strive to limit access or incorporate isolation capabilities of ICS/SCADA systems. The isolation of a ICS system can be achieved by establishing security enclaves (or zones) with virtual local area networks (VLANs) or subnets that are segregated from lower security zones like corporate networks or any Internet accessible zones. Information passing from one security zone to another should be monitored.

Next figure illustrates an example of a secure PWS architecture.

Protecting water systems from cyber attacks



Examples of cyber attacks to water plants in 2021

Ransomware Attack on SCADA Systems at three Water Facilities in U.S.

The October 14, 2021, alert from the U.S. government agencies describes recent ransomware attacks that impacted industrial control systems (ICS) at water facilities[4]:

- In the first incident, cybercriminals used unknown ransomware to target a water facility in Nevada in March 2021. The malware affected SCADA and backup systems.
- In the second incident, hackers deployed the ZuCaNo ransomware, which made its way onto a wastewater SCADA computer in Maine in July 2021. The treatment system was run manually until the SCADA computer was restored using local control and more frequent operator rounds.
- In the third incident, threat actors deployed a piece of ransomware named Ghost on the systems of a water plant in California in August 2021. The ransomware was discovered roughly a month after the initial breach, after the organization noticed three SCADA servers displaying a ransomware message.[5]

Conclusions

- Cyberattacks are usually aimed at accessing, changing, or destroying sensitive information that can effect SCADA systems at Water facilities
- Cyber-security is very important in the water industry because water facilities are increasingly using industrial control system (ICS) networks to control the physical processes essential to water treatment and distribution systems
- The top five areas of common security gaps in cyber world should be addressed in Water facilities
- Creating a cybersecurity culture for staff using digital Water applications like IoT and SCADA is important
- Secured Network Design at the Water facilities is also very important

Thanks for your time !

Agenda (13h – 15h)

13h00 – 13h45: Introduction

Digiwater project (context | objectives | timing)

Partners and today's participants

Aim of the Concepts Design Workshop

- Operational application on IoT and Big Data (Vincent Wolfs | Sumaqua)
- Presentation on Cybersecurity (Mehmet Emin Pasaoglu | ITU)

13h45 – 14h45: Brainstorm sessions in 3 break-out rooms

14h45 – 15h00: Feedback + next steps

Brainstorm sessions using Miro

How can digitization and ICT help to tackle today's and tomorrow's water challenges?

What is the added value of this application?

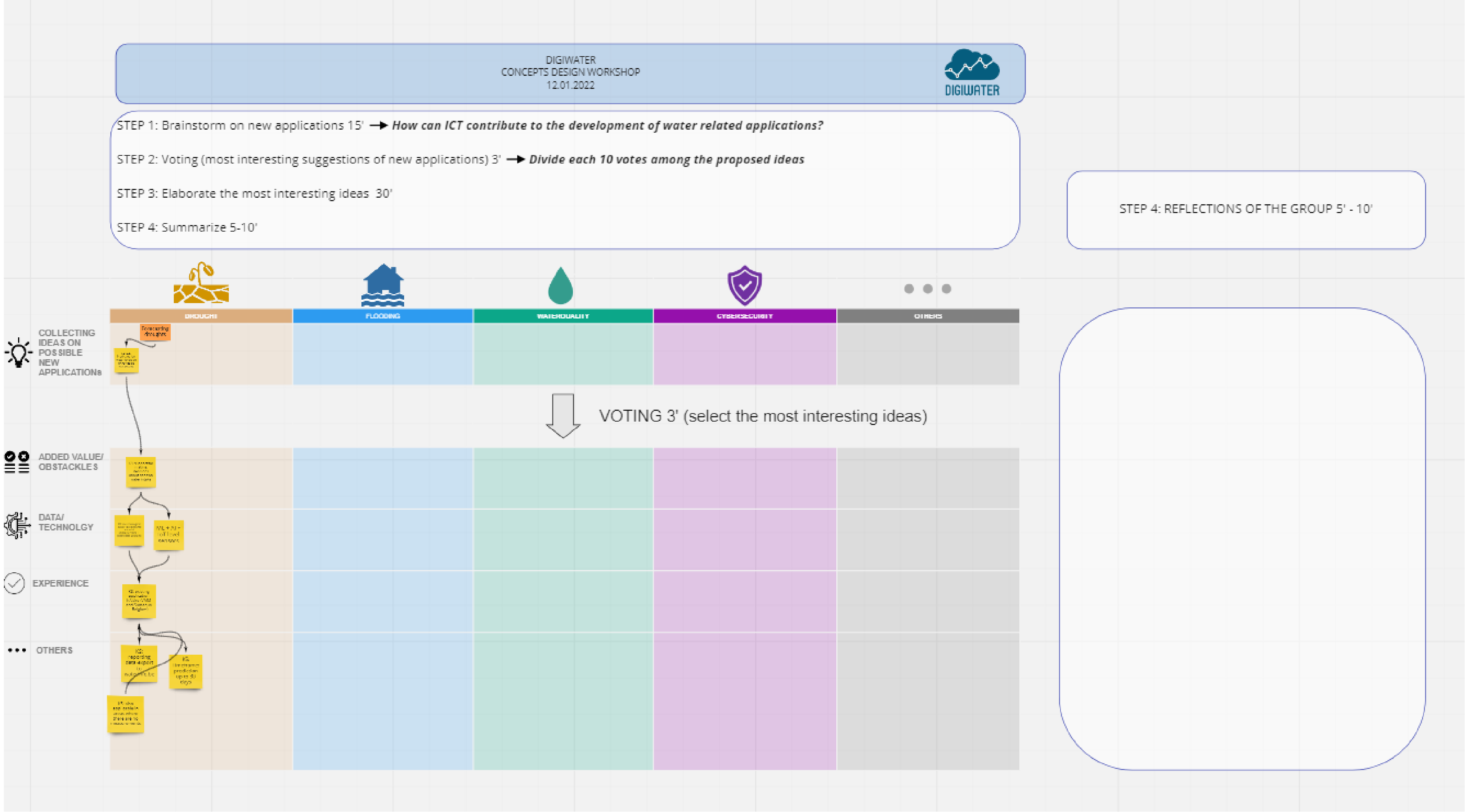
Which technology/data is needed for this application?

Do you have any experience within this application field?

...

Sumaqua

Example in Miro



Break outs!

Summary break outs

Next steps

→ Report

Camp 1 Belgium (oct 2022):

Focus on IoT and Big Data

6-week prototyping

6-month prototyping

Camp 2 Turkey (april 2023):

Focus on Cyber security

6-week prototyping

6-month prototyping

+ end-user feedback

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