WaterJPI project

# SMARTControl

Smart framework for real-time monitoring and control of subsurface processes in managed aquifer recharge (MAR) applications

## Deliverable D4.2

**Web-based real-time monitoring and control capabilities**
Implementation of web-based real-time monitoring tool on INOWAS platform

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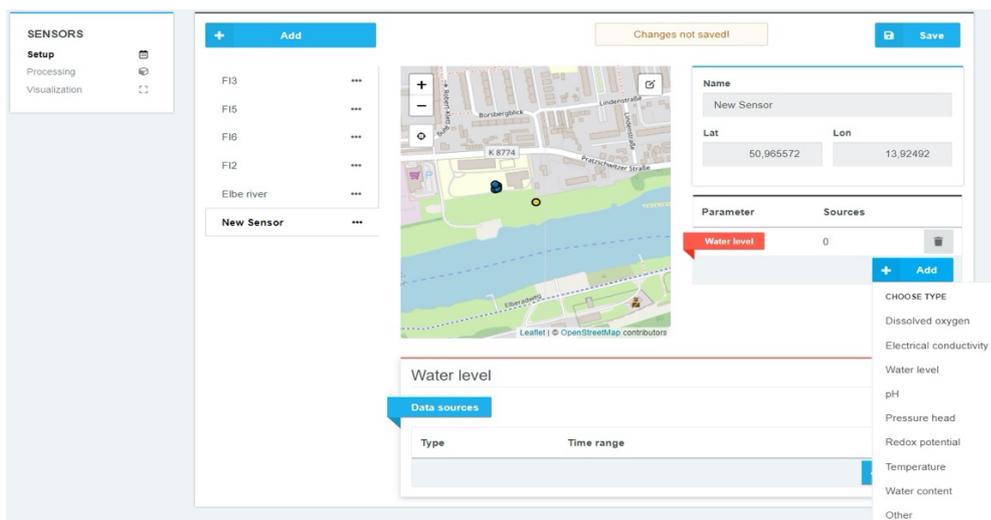
https://www.smart-control.inowas.com

April 2020

# Deliverable D4.2

## Web-based real-time monitoring and control capabilities

Implementation of web-based real-time monitoring tool on INOWAS platform

## Short summary

This report describes the main functionality of the web-based tool T2. Real time monitoring and control. The tool facilitates the operational management of MAR sites by collecting real-time data from the in-situ site-specific observation systems. Besides data collection, pre-processing and visualisation, the real-time monitoring tool is also equipped with basic decision rules and control features to help identify the occurrence of risks at a MAR facility.

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|---|---|
| **Work package** | WP4: Development of web-based monitoring and modelling platform for real-time control and risk assessment. |
| **Deliverable number** | D4.2 |
| **Partner responsible** | Technische Universität Dresden (TUD) |
| **Deliverable author(s)** | Jana Glass (TUD), Ralf Junghanns (TUD), Robert Schlick (TUD), Catalin Stefan (TUD) |
| **Quality assurance** | Alexander Schlosser (UIT) |
| **Planned delivery date** | November 2019 |
| **Actual delivery date** | April 2020 |
| **Dissemination level** | PU (Public) |

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# ABSTRACT

The web-based real-time monitoring and control tool (T2) facilitates the operational management of MAR sites by collecting real-time data from the in-situ site-specific observation system. Besides data collection, pre-processing and visualisation, the real-time monitoring tool is also equipped with basic decision rules and control features to help identify the occurrence of risks at a MAR facility (e.g. critical thresholds). The tool is divided into three main components: sensor setup, data processing and visualisation. Various data sources can be connected covering historical data (as CSV files) and real-time data (via FTP connection to SENSOweb, Prometheus). Real-time data is automatically updated as soon as new data is transmitted. The processing of the time series data covers value processing (e.g. filtering, mathematical operations) and time processing (resampling, filling of missing values). The visualisation allows the comparison of time series data of various sensors.

The developed real-time monitoring tool allows an easy observation of real-time data at MAR facilities under consideration of various data sources and processing algorithms.

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# 1. INTRODUCTION

## 1.1 BACKGROUND

Managed aquifer recharge (MAR) is used worldwide for sustainable management of water resources. MAR implies the storage of surface water in the underground and its utilisation for different purposes such as domestic and agricultural use, or for ecological benefits. What differentiates MAR from other groundwater recharge practices (i.e. leakage from sewerage networks) is the intentional recharge of the aquifers by injecting water under controlled conditions. In order to safeguard and protect the good status of the aquifers, a monitoring system provides qualitative and quantitative data necessary for the safe operation of the MAR scheme. Depending on site-specific requirements, the monitoring system contributes to the optimisation of the operational scheme in order to reduce the MAR-associated risks. The role of monitoring systems consists in assessing the water quality parameters of the influent water, native groundwater and recovered water in respect to existing regulations. This can be done by manually sampling the water at regular time intervals and analyzing the water samples in the laboratory.

Considering the relatively high costs of the analyses and the rather long time interval between two sampling campaigns, automatic monitoring systems consisting in multi-parameter probes can deliver continuous measurements of most relevant parameters and deliver the values in near-real time conditions. The systems can be equipped with additional control functionalities that have the capability to intervene in the operational management and, for example, to stop the water inflow when the water quality does not meet the desired quality thresholds.

## 1.2 ABOUT THE SMART-CONTROL PROJECT

"SMART-Control" is an international research project funded through the Water Joint Programming Initiative (WaterJPI) and implemented by nine institutions from Germany, France, Cyprus and Brazil. The main objective of the project is to reduce the risks associated to MAR by the development of an innovative web-based real-time monitoring and control system (RCMS) in combination with risk assessment and management tools. The SMART-Control approach relies on coupling a real-time in-situ observation system consisting of state-of-the-art online sensors and a web-based groundwater monitoring and modelling platform. The resulting system shall provide operators and managers of MAR schemes with automatic decision support tools for monitoring, controlling and prediction of processes occurring during MAR. The approach will be tested and validated at six MAR sites under different environmental and operating conditions. More information about SMART-Control is available on the project website: https://www.smart-control.inowas.com.

## 1.3 SIMULATION TOOLS

The SMART-Control platform is based on the free groundwater modelling platform developed by the Research Group INOWAS at Technische Universität Dresden, Germany The platform contains a collection of empirical, analytical and numerical tools for assessing groundwater flow processes with focus on managed aquifer recharge applications (https://www.inowas.com). The INOWAS platform will be amended in the SMART-Control project by four additional simulation tools (more info and the complete documentation of the tools is available at: https://www.smart-control.inowas.com/tools):

- **T1. Initial risk assessment.** The tool represents an easy-to-use instrument to evaluate the viability of a MAR project and the preliminary assessment of human health and environmental risks. The tool will include a quantitative microbial risk assessment (QMRA) component consisting of hazard identification, exposure assessment, dose analysis and risks characterisation to predict the risk of an infection or disease related outcome. The risk will be assessed for selected reference pathogens such as bacterial, protozoan and viral pathogens for different hydraulic residence times during MAR.

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- **T2. Real-time monitoring and control.** This tool aims at facilitating the operational management of MAR sites. The tools includes a web-based monitoring system developed for real-time integration of time series data into the INOWAS modelling platform. Sensors installed at MAR facilities worldwide can be connected to the INOWAS platform to transfer collected data in real time. The data can be visualized, processed, downloaded and prepared for further usage, e.g. as a boundary or observation point in a real-time groundwater flow model.
- **T3. Automatic groundwater model update and simulations.** Real-time observations collected from MAR sites will be integrated into the web-based modelling workflow. The system relies on existing groundwater modelling capabilities of the INOWAS platform, which will be expanded by adding additional features. The integration of real-time monitoring data into the simulation workflow will enable fast response time and optimized management, which helps to minimize and control the associated risks.
- **T4. Predictions for advanced system management.** The tool will allow building climate change and development scenarios in the groundwater flow models to predict future boundary conditions and compare them to the present situation using the INOWAS Scenario Analyser. This will provide a novel way of using real-time, web-based groundwater models to assess the effects of climate change urbanisation, land use change (irrigation demand) and population growth on spatial and temporal water availability.

This report describes the main functionalities of tool **"T2. Real-time monitoring and control"**. For the description of the other tools see the project website: https://www.smart-control.inowas.com.

## 1.4 TECHNICAL INFRASTRUCTURE

The tool T2 consists of a web-based monitoring system developed with the aim of integrating time series data into the INOWAS modelling platform. The raw data can be visualized, analyzed with a set of simple statistical tools, downloaded and processed for further usage, e.g. as a boundary or observation point in a real-time groundwater flow model running also on the INOWAS platform (tool T3). The main functionality of the tool consists thus in unifying data collected in real-time by sensors installed at the project case studies and post-processing the data for the use in web-based applications on the INOWAS platform (Figure 1). The online documentation of the tool is available at: https://inowas.com/tools/t10-real-time-monitoring/.
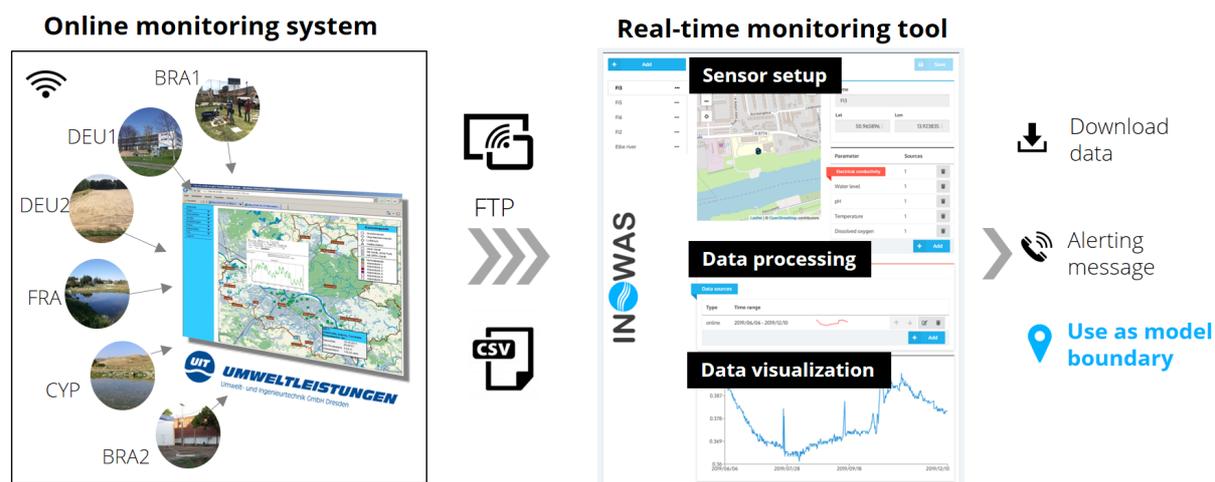


**Figure 1.**     Concept of the real-time monitoring tool.

For development purpose, it was preferred that all sites use the same types of sensors manufactured by the project partner Umwelt- und Ingenieurtechnik GmbH Dresden (UIT). As first step, the sensors equipped with GSM-based telemetry functions transmit the measurements to the SENSOweb server. SENSOweb is a web-based platform developed by UIT for collecting and visualization of online sensor data (https://www.uit-gmbh.de/de/softwareloesungen_723/getProdInfos-2388/). Within the SMART-Control project, a FTP

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connection was established between SENSOweb and INOWAS servers to enable the transfer of data between the two systems. Since in most cases, manual measurements are also available prior to the installation of the sensors, data can also be uploaded manually, as complementary feature to the automatic sensor-based acquisition. Further upload options include the possibility of connecting external web sources via Prometheus, an open-source monitoring system and time series database (https://www.prometheus.io). Further on, customized communication protocols are established with third-party sensor producers for case studies using sensors from other manufacturers. More details about the technical implementation of the data transfer solutions are available in the report D.3.1 on the main project website: https://www.smart-control.inowas.com.

The technical infrastructure of the tool includes a client component (user web browser), a webserver and a set of worker microservices (Figure 2). The client application is programmed in JavaScript and TypeScript and includes feature-rich frameworks such as React, Redux and Leaflet to create a modern, user-friendly interface. The webserver is used for user authentication and for storing the state of the web-application. The microservices aim at solving highly specialized tasks like geoprocessing, time-series processing or running numerical models. The system can integrate additional microservices written in different programming languages with the aid of dedicated APIs.
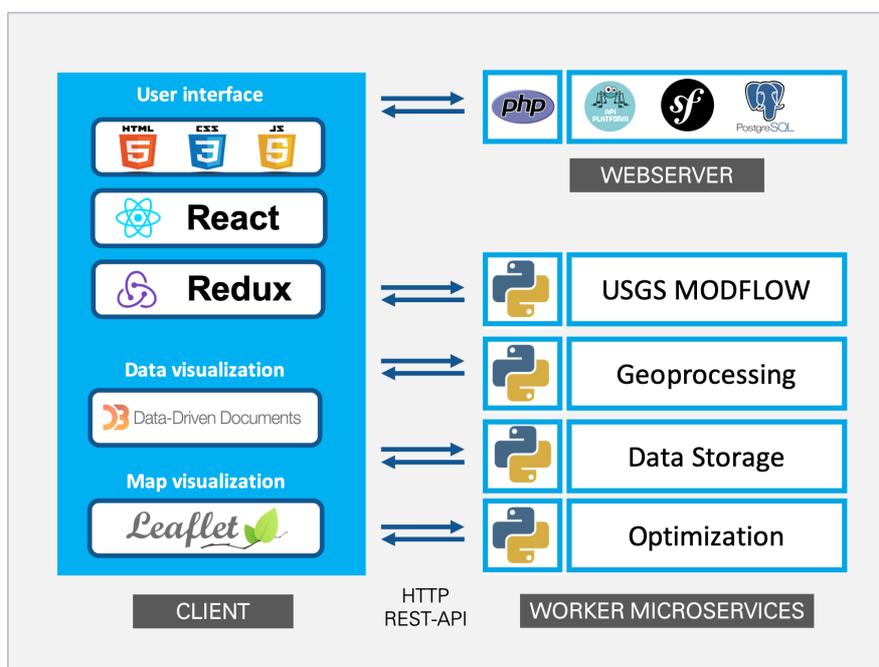


**Figure 2.    Technical infrastructure of the real-time monitoring tool.**

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# 2. SENSOR SETUP

The first step when creating a new real-time monitoring project is to setup a new sensor, followed by the definition of parameters and selection of data sources. For each project, multiple sensors can be added, for example those that belong to the same monitoring network.

## 2.1 ADD SENSOR

A new sensor can be added by using the "+Add" button. The sensor location needs to be included by clicking on the specific location on the map (Figure 3). The exact location can be later edited and specified using the sensor coordinates.
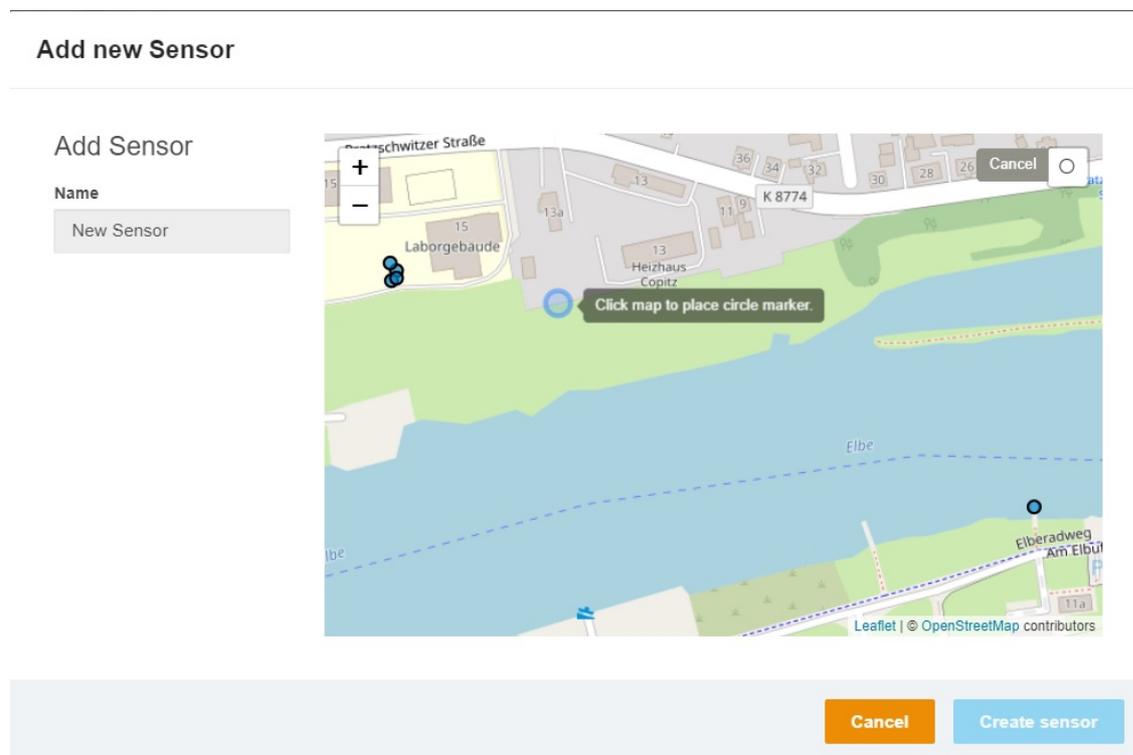


**Figure 3.**      **Setup of a new sensor.**

## 2.2 CHANGE METADATA AND ADD PARAMETER

After creating the sensor, the metadata including the name and location (coordinate system WGS84) can be edited and the following parameters can be added (Figure 4):

- Electrical conductivity
- Water level
- Pressure head
- Dissolved oxygen
- Temperature
- pH
- Water content
- Redox potential
- Others

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In case of multi-probe sensors, more than one parameters can be added for each sensor. When "Others" is selected, new parameters can be defined including the type of parameter, description and units.
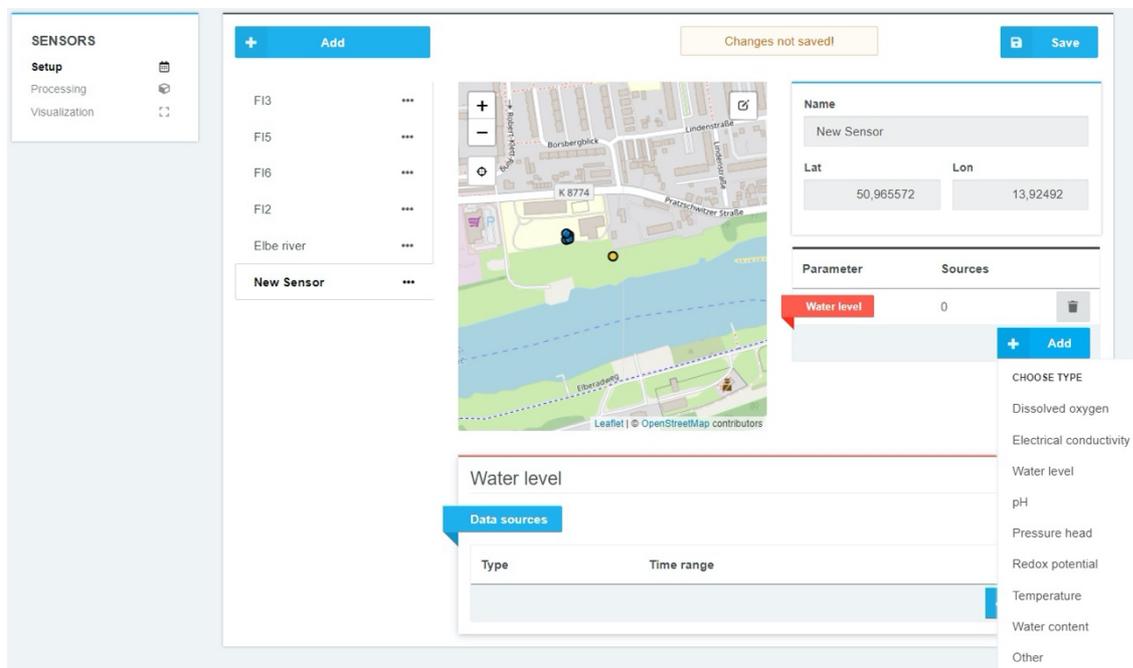


**Figure 4.**     **Changing of metadata and adding of parameters.**

## 2.3 ADD DATA SOURCES

A source of data can be assigned to each parameter created at previous step. To assign a data source, click on parameter's name and a new field "Data sources" will be created under the list of parameters. Time series data can be added by clicking the "+Add" button in "Data sources" file. Three different types of sources can be selected: "file" (in CSV format), "online" (from a FTP server connected to the INOWAS platform) or "prometheus" (external source using a Prometheus server connection).

### 2.3.1 Import data as CSV file

To upload a time series via CSV, click on Data Source "+Add" and choose the type "file". A new browser window will appear where you can specify the CSV file, the date-time format and the column of the CSV file which corresponds to the date-time as well as the parameter (Figure 5). In addition, the desired time range which should be uploaded (default is the whole time series saved in the CSV) as well as the value range can be specified. After clicking "Apply", the data is added to the platform.

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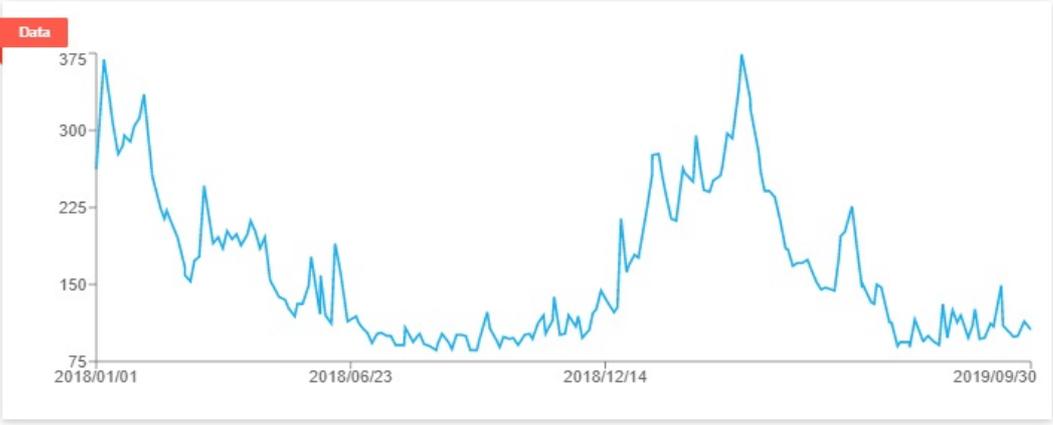


**Figure 5.** Upload CSV data.

### 2.3.2 Import real-time data from sensors

To add real-time sensor data, the sensor needs to be previously connected to the INOWAS server (through Prometheus or by http-API). In the SMART-Control project, a limited number of servers are available but additional sources can be added upon request. Please contact the INOWAS team at Technische Universität Dresden if you would like to add your own online sensor (contact details are available at https://www.inowas.com).

To add real-time data from external sources via Prometheus, a specific query can be made (Figure 6). As an example, at the time when this report is published, the water level of the river Elbe provided by Pegelonline WSV (https://www.pegelonline.wsv.de) is connected to the INOWAS platform via Prometheus.

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In addition to the Prometheus web service, groundwater monitoring sensors manufactured by the company UIT (https://www.uit-gmbh.de/de/uit__5/?) can also be connected via FTP and SENSOweb to the INOWAS platform. A detailed description how the connection is established can be found in Deliverable Report D3.1 (https://smart-control.inowas.com/deliverables/).
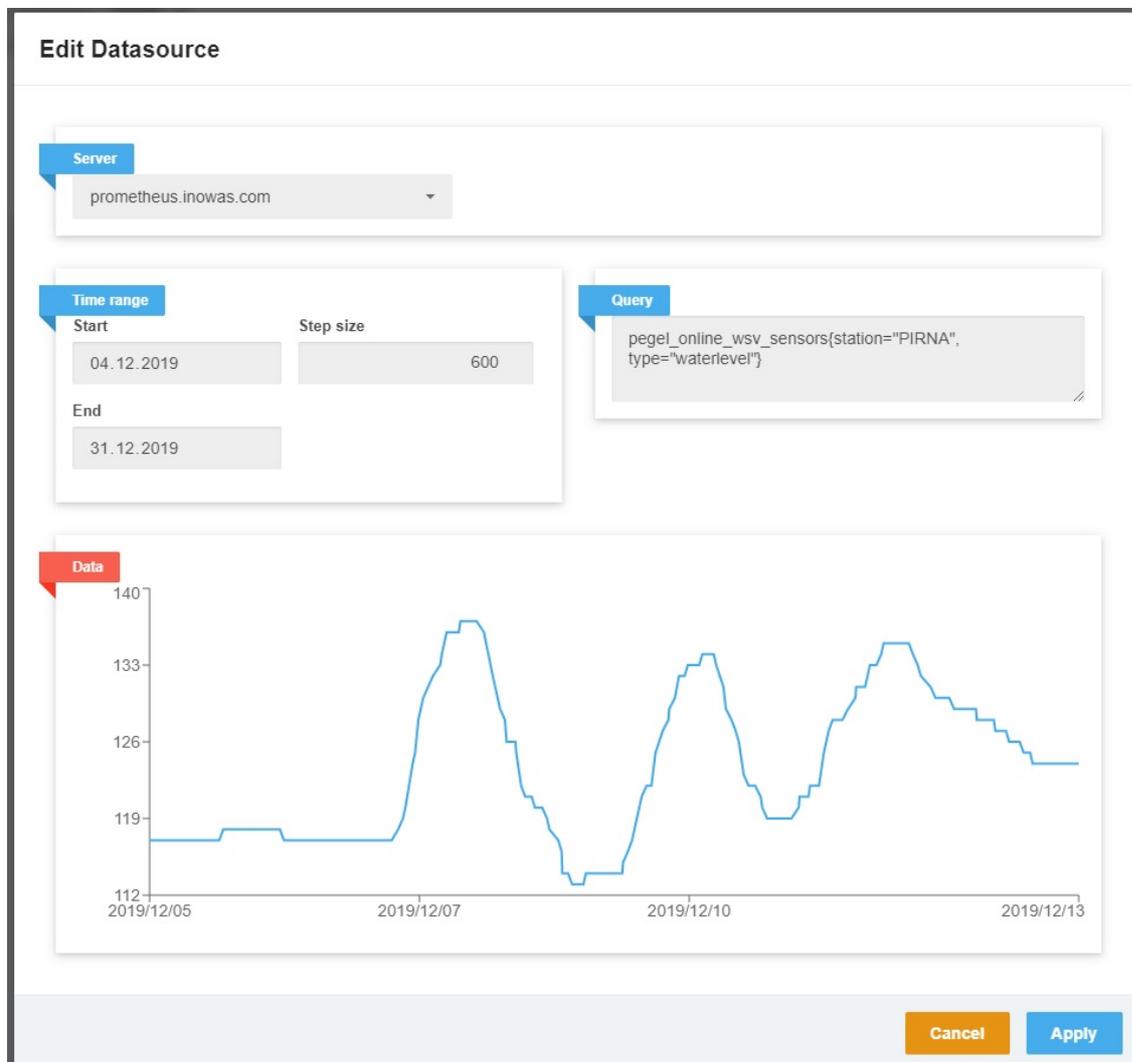


**Figure 6.**      **Setup of Prometheus server connection.**

To import data from an existing UIT sensor, select the data source type "online" when assigning a new source to the parameters. Under the metadata section, select the specific project, sensor and desired parameter (Figure 7). In addition, the time and value ranges can be used to pre-filter the imported data. At this stage, the list of projects is limited to the case studies included in the SMART-Control project (see https://smart-control.inowas.com/case-studies/) but further projects can be added later upon request.

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**Figure 7.      Setup of SENSOweb connection.**

### 2.3.3 Import data from various sources

Various data sources of mixed data types for one parameter can be included as shown in Figure 8. Here, a historical time series of water level is combined with an online sensor which is added through the INOWAS Prometheus service.

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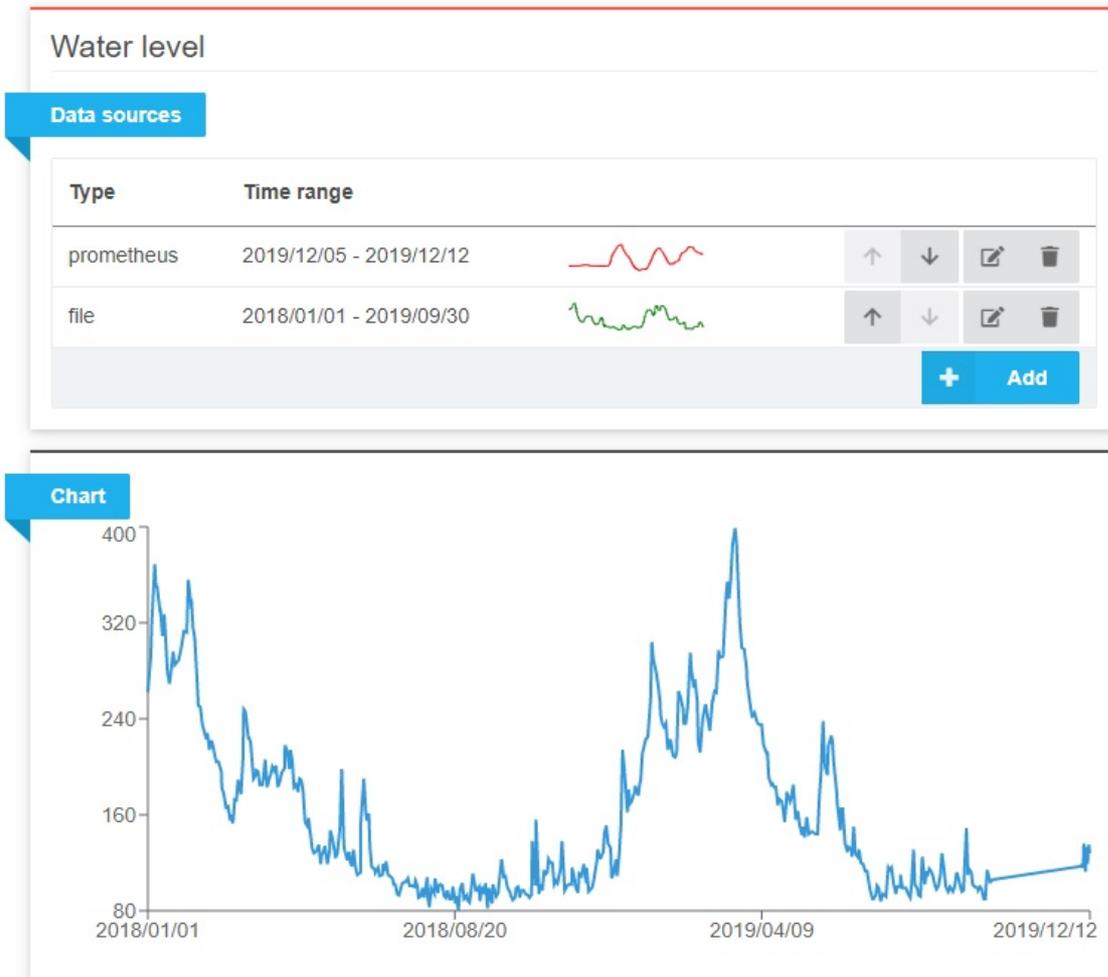


**Figure 8.**    **Connecting sensor data with various data sources.**

The data of the various data sources need to have the same unit (e.g. water level in cm). Please be aware that if time periods of various data sources overlap, the second data source (bottom) overwrites the values of the first data source (top). The order of the data sources can be changed using the "up" and "down" arrows (Figure 8). If no time period overlaps, the data of the various data sources are simply merged into one single time series.

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# 3. SENSOR DATA PROCESSING

The uploaded data can be processed for further usage. Processing is divided into time processing and value processing.

## 3.1 VALUE PROCESSING

Value processing comprises all processing algorithms which directly influence the values of a time series and includes mathematical operations as well as filtering rules. The following processing operations are implemented:

> \+ : add a constant value
> \- : substract a constant value
> \* : multiply by a constant value
> / : divide by a constant value
> < : filter all data points that are smaller than the value
> <= : filter all data points that are smaller or equal to the value
> \> : filter all data points that are bigger than the value
> \>= : filter all data points that are bigger or equal to the value
> = : assign a constant value

The operation can be either applied to the whole time series length or only to an interval defined by the start and end date (Figure 9). In the example below, all the values measured between 24.08.2019 and 24.09.2019 have been replaced with the value 0.4.
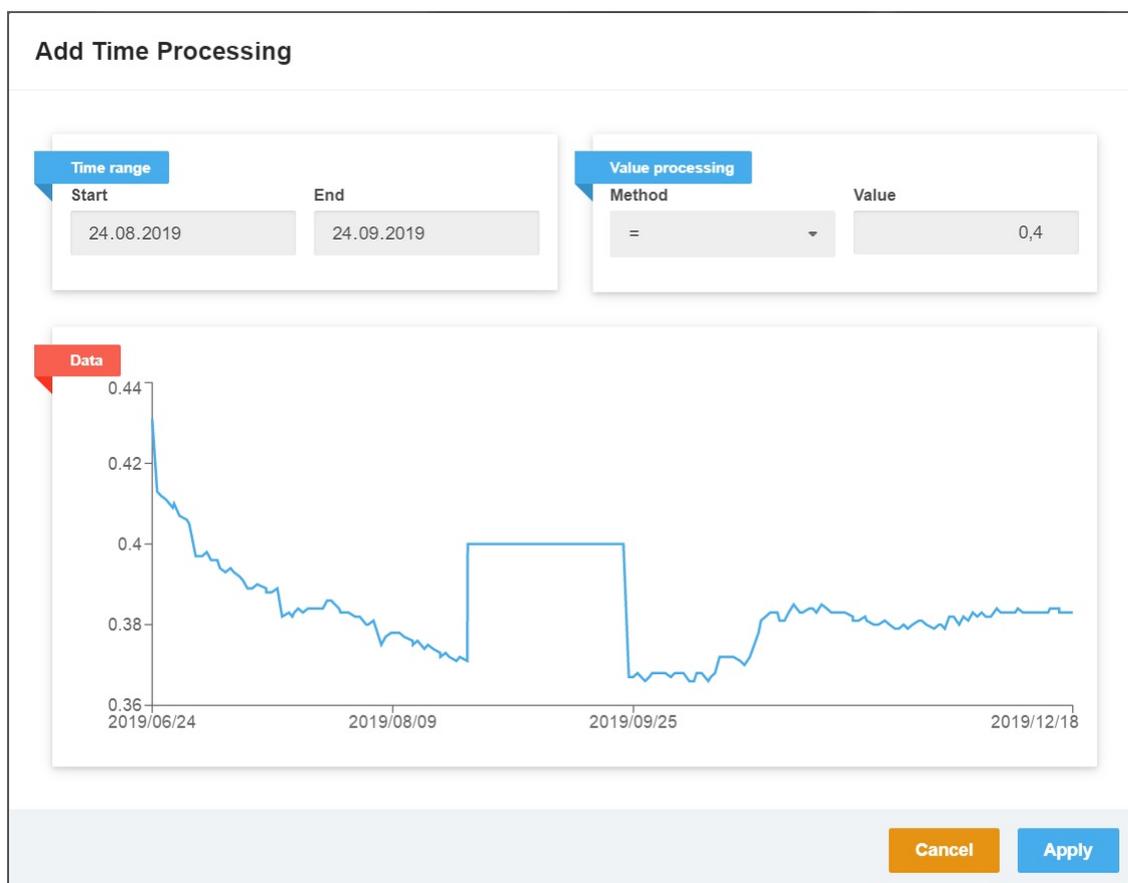


**Figure 9.**      **Value processing of time series data.**

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## 3.2 TIME PROCESSING

In the time processing section, gaps in the time series can be filled (interpolated) and the data set can be resampled to a different time resolution. For this, the interpolation method and the time resolution (Rule) needs to be defined.

The interpolation methods currently implemented comprise:

- *cubic*
- *linear*
- *nearest*
- *quadratic*
- *slinear*
- *time*
- *zero*

The documentation for the various interpolation methods can be found in the Python Pandas documentation (https://pandas.pydata.org/). The time resolution of the new, processed time series needs to be given as an integer followed by the corresponding time discretization (i.e. "1d" = 1 day; "6m" = 6 months etc.):

- *t : second*
- *min : minutes*
- *d : days*
- *w : weeks*
- *m : months*
- *y : years*

In Figure 10, an example is given where the time series data is resampled by the method "time" with a time resolution of one day ("1d") between the 24.08.2019 and the 18.10.2019.

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**Figure 10.      Time processing of time series data.**

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# 4. SENSOR DATA VISUALISATION

In the visualisation section, data from various sensors and parameters can be compared. One option is to compare the values of the same parameter measured by different sensors (example from Figure 11). The system displays automatically all sensors that provide measurements for this parameter. Another option is to display a second parameter (by clicking on the "Add parameter" button). In this case, the values of the second parameter are displayed on a second y-axis together with the values of the first parameter.

In all steps, data displayed in charts can be downloaded either as JPG image or as CSV file.
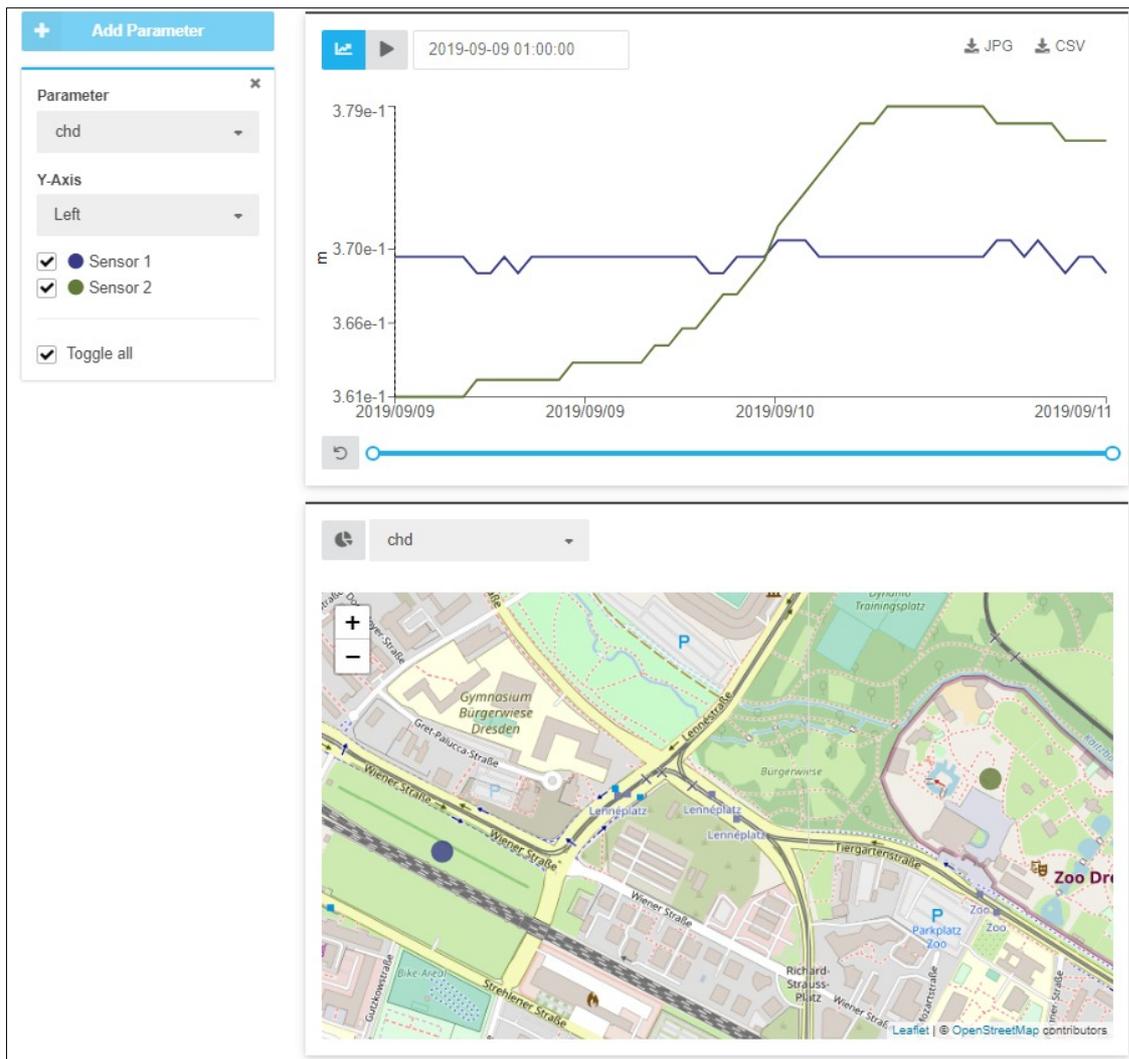


**Figure 11.** **Visualization of multiple sensors.**

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# 5. CONCLUSIONS

The developed tool can be used for the integration of real-time monitoring data into the web-based INOWAS modelling platform. In this way, various data sources ranging from historical data sets to real-time data (UIT sensors, external sensors via Prometheus) can be jointly connected, processed and visualized on one platform. When the connection to a real-time sensor is established, data is automatically updated and integrated as soon as new data is transmitted.

The time series data can also be processed for further usage, e.g. by filtering, resampling or unit conversion. Once the processing routine is established for a sensor, new data is automatically processed and can be further used as a boundary condition or observation point in a real-time model on the INOWAS platform.