WETSCAPES2.0 Sensor Data Retrieval App – Documentation

This document provides user documentation for the WETSCAPES2.0 Sensor Data Retrieval App. This is a web-based application that, through a User Interface (UI), combines time-series raw data, measured with WETSCAPES2.0 sensors registered in The Things Network (TTN, https://thethingsnetwork.org/) and stored in our InfluxDB instance at the University of Rostock (UR, https://sensors.wetscapes.uni-rostock.de:58086/), with static metadata for such sensors, stored in the GFZ Sensor Management System (SMS, https://sensors.gfz.de/). The application is designed for WETSCAPES2.0 members to easily access the sensor data across various (screening or core) sites and visualize temporal variations of different sensor measurements. The UI supports both online and local execution, with plots exportable to PNG or JPEG formats for easing explaining the data, and time series downloadable in CSV format for enabling further automated analysis.

1. Architecture components

The architecture of the application consists of back-end, middle, and front-end layers:

- **Back-end layer (Data layer):** The back-end layer is composed of the SMS and InfluxDB (see Figure 1). SMS stores the metadata for sensors, their measured quantities, and their configurations on sites. InfluxDB stores the sensor time-series raw data.

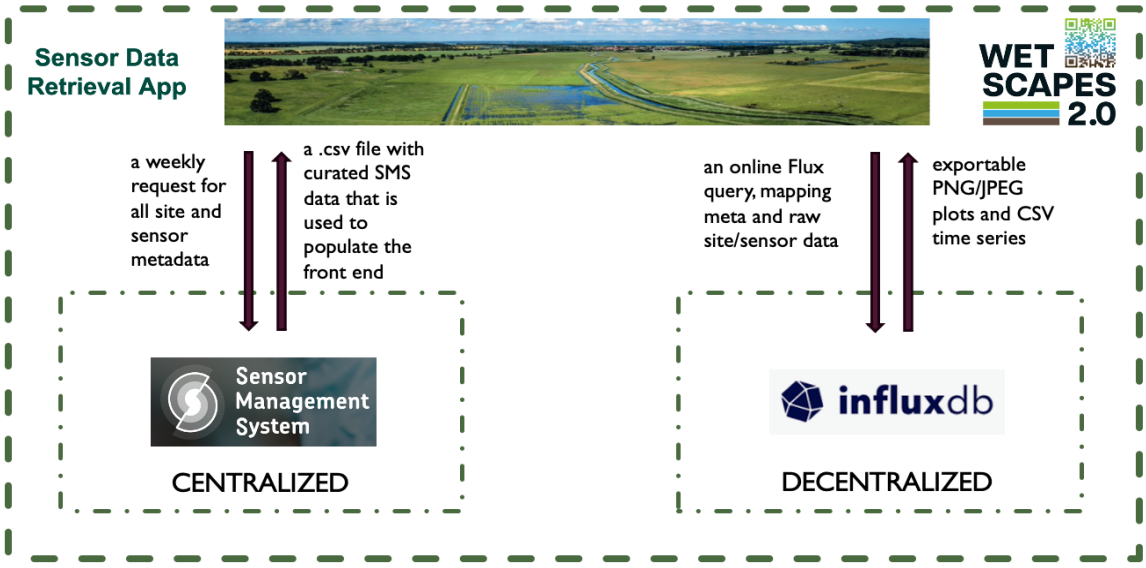


Figure 1: The back-end and middle layers.

- **Middle layer (Functional layer):** A lightweight JavaScript(JS) is adopted to (1) retrieve site names, measurements, and sensor names from the SMS, (2) formulate Flux queries for the InfluxDB via HTTPS requests, and (3) generate downloadable and friendly plots and datasets.
- **Front-end Query Builder (UI layer: query builder section):** HTML and CSS are used for the UI design of the interactive query builder. Users can build an InfluxDB query by selecting site name(s), measurement(s), sensor name(s), and a date range, and executing this query by pressing the "Run Query" button (see Figure 2).

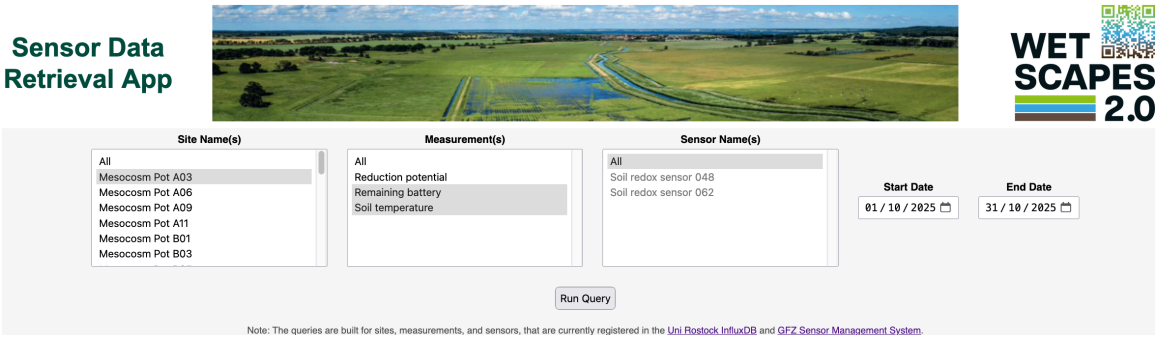


Figure 2: The UI query builder section and possible user selections in it.

- **Front-end Results (UI layer: results section):** HTML and CSS are used for the visualization (Chart.js), and file-export buttons (see Figure 3). By pressing the "Run Query" button, users can generate plots, visible below this button. One plot is generated per selected measurement. Users can save these plots in files with PNG or JPEG formats (via the "Save Plot Image" buttons), or the time-series data underlying the plots in CSV files (via the "Save Plot CSV" and "Save All Results" buttons).

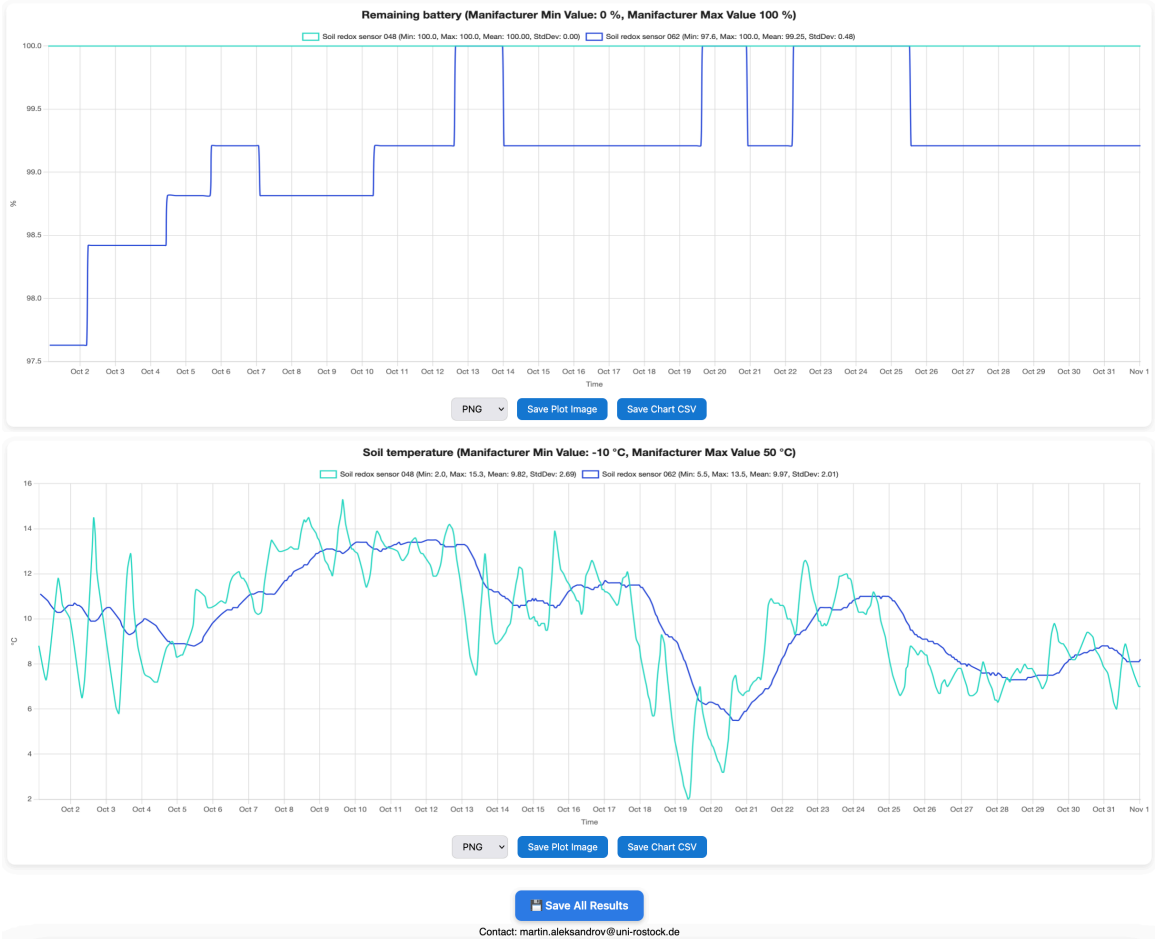


Figure 3: The UI results section and the generated plots in it for the user selections from Figure 2.

2. Runtime analysis

The application runs entirely on the client-side. Queries are sent directly from the browser to the InfluxDB API via HTTP requests. Depending on the numbers of selected sites, measurements, and sensors, as well as the length of the selected date range, query execution time may vary from a few seconds to several minutes. We next give a few examples, thus aiming to draw estimates of the best- and worst-case query execution time and, therefore, of the run-time complexity of the application.

2.1. Best-case runtime boundaries: a single selected site, a single selected measurement, and a single selected sensor

For a single selected site, measurement, and sensor, the query execution time is a few seconds even when the selected date range is the longest possible currently, i.e. from the beginning of the WETSCAPES2.0 project until the present day (see Figure 5). This is acceptable, and it means that the best-case runtime is even lower, because we may be interested in a shorter date range.

Figure 5: The application's runtime is around **5 seconds** for generating a "Soil temperature" plot with data measured with the "Soil redox sensor 048", which is located in the "Mesocosm Pot A03".

2.2. Worst-case runtime boundaries: all selected sites, all selected measurements, and all selected sensors

The application runtime in this case depends severely on the length of the selected date range. For a data range of up to a month, the runtime of the application can be around 2 minutes (see Figure 6) and, for the date range from the beginning of WETSCAPES2.0 to a recent day, the runtime may increase two to three times (see Figure 7).

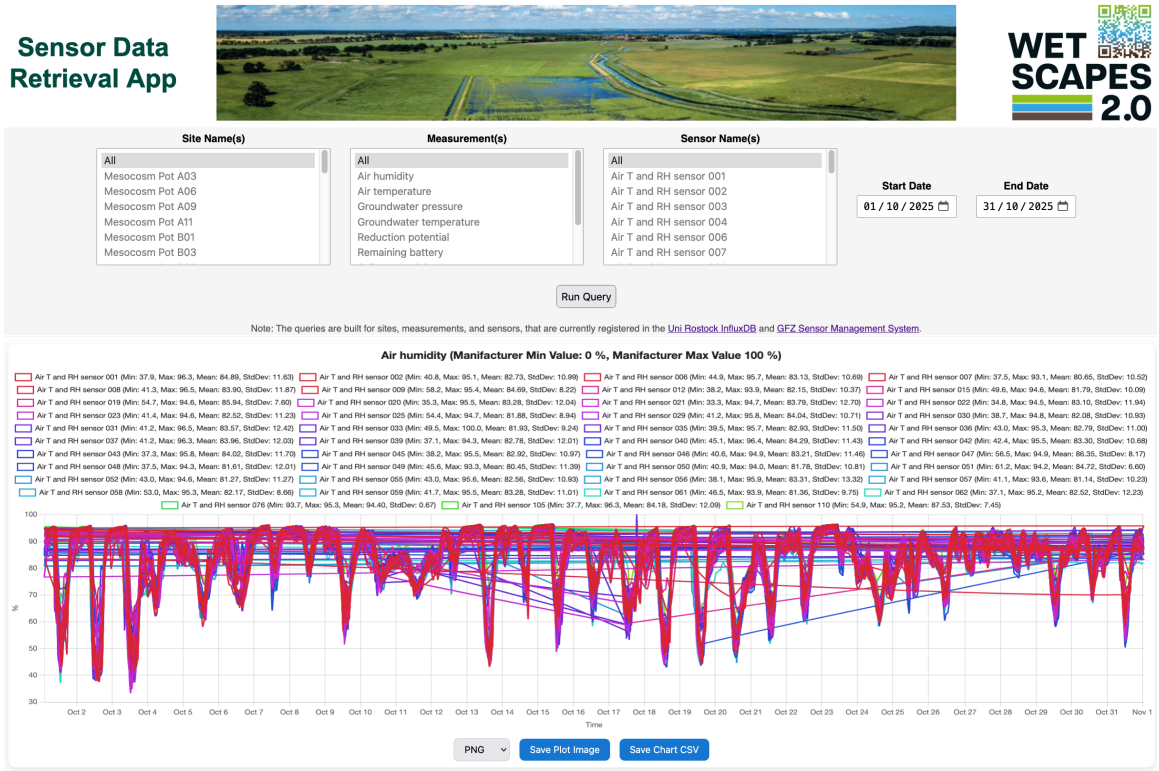
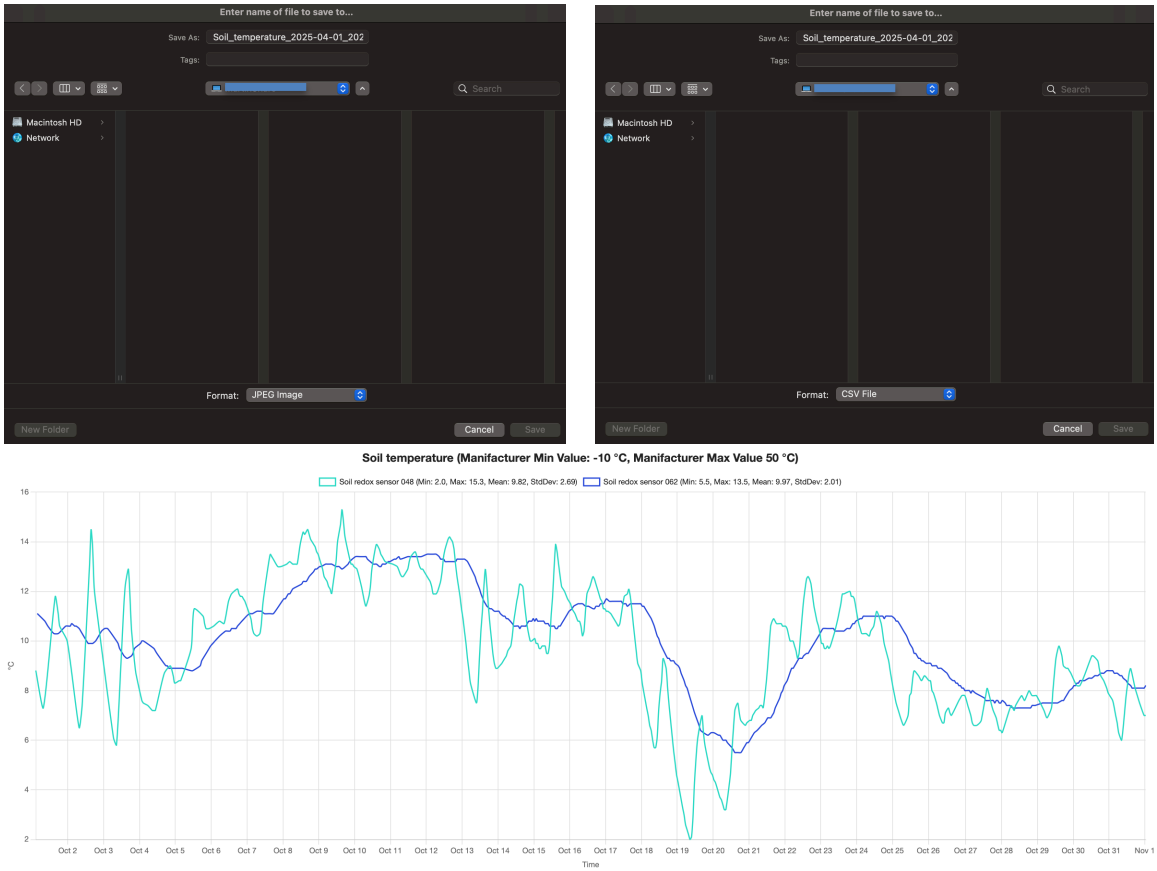


Figure 6: The application runtime is around **2 minutes** for generating all measurement plots for all sensors on all sites, given that the date range includes all days in October 2025. To reduce the length of the documentation, only the “Air humidity” plot is presented.

Figure 7: The application runtime is around **5 minutes** for generating all measurement plots for all sensors on all sites, given that the date range includes all days from April 1, 2025, to today. To reduce the documentation length, only the “Groundwater humidity” plot is presented.

3. Exporting results

Users can export the generated plots and datasets by pressing the “Save Plot Image” and “Save Plot CSV” buttons, respectively. Doing this enables them to save plots and datasets locally (see Figure 8).



Timestamp	Sensor Name	Remaining battery (%)	Soil temperature (°C)
2025-10-01T00:37:03.794168242Z	Soil redox sensor 048	100	8.8
2025-10-01T01:38:39.391985705Z	Soil redox sensor 062	97.628456	11.1
2025-10-01T05:37:00.382725716Z	Soil redox sensor 048	100	7.3
2025-10-01T06:38:36.237779046Z	Soil redox sensor 062	97.628456	10.8
2025-10-01T08:38:34.934344182Z	Soil redox sensor 062	97.628456	10.6
2025-10-01T12:38:32.29080059Z	Soil redox sensor 062	97.628456	10.3
2025-10-01T13:36:54.707537357Z	Soil redox sensor 048	100	11.8
2025-10-01T15:36:53.284398929Z	Soil redox sensor 048	100	11.1
2025-10-01T15:38:30.296684796Z	Soil redox sensor 062	97.628456	10.3
2025-10-01T16:36:52.593248178Z	Soil redox sensor 048	100	10.6
2025-10-01T20:38:27.049756737Z	Soil redox sensor 062	97.628456	10.6
2025-10-01T21:36:49.096972888Z	Soil redox sensor 048	100	10

Figure 8: The application enables local export and storage of plots and their underlying datasets. The presented plot and datasets are generated and saved for the selection in Figure 2.

4. Current limitations

The application enables us to identify problems in our existing pipeline. For example, there are sensors which are deployed on the field and registered in the various systems, i.e. TTN, InfluxDB, and SMS, but their data does not arrive and, therefore, is not stored in InfluxDB. One such sensor has SMS name “Soil redox sensor 064” and TTN name “ws2-sdi12-0105”. Other examples include “Soil redox sensor 034” (“ws2-sdi12-0118”), “Water level sensor 019” (“ws2-sdi12-0089”), and “Water level sensor 021” (“ws2-sdi12-0007”). For such sensors, the application returns no plots and issues the following warning:

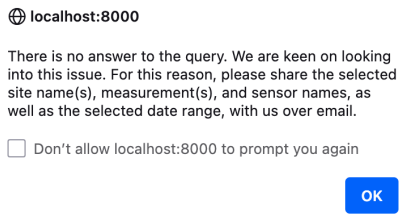


Figure 9: The warning issued by the application whenever data for the given user selection is not stored in the InfluxDB.

5. Future Improvements

In the next versions of the application, we will add features for plot scaling and detecting outliers. We will also add more measurements, e.g. water level. Finally, we expect that new sensors will be deployed, configured, and maintained, as well as currently deployed sensors will replaced or re-configured. As a result, we will be extending the lists of sites, measurements, and sensors, over the course of the project, thus enabling the real-time retrieval of richer data.

WETSCAPES2.0 Sensor Data Retrieval App Documentation v1.1

The new version 1.1 of the web app offers the following features: an interactive map with clickable legend and popup configuration summaries; new query building features – filtering by WS2.0 application and presetting time ranges; new data-quality features – detecting out-of-range values and removing them; improved CSV outputs in long format.

1. Interactive Map

The **interactive map** visualized the 'active' and 'inactive' sensor configurations. *Active* configurations are mounted on the field, whereas *inactive* configurations correspond to configurations that have been previously active but subsequently unmounted.

For each given site S, the new app version enables users to retrieve measurements, regardless of how many sensor configurations had been mounted at S, and/or subsequently unmounted from S, over time.

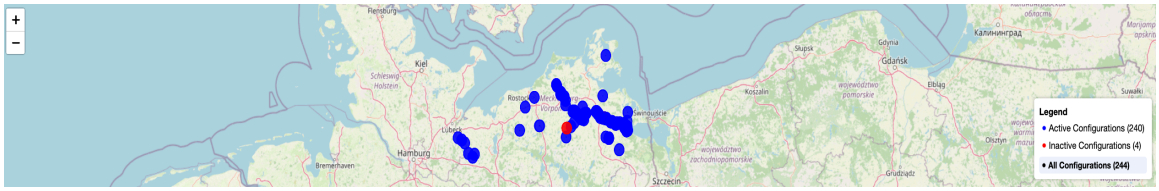


Fig. 1: Screening-site configurations.

It features:

- ***Clickable legend*** to toggle visibility of active and inactive configurations.

- ***Jittered locations*** for configurations sharing the similar sensor coordinates, with ***spider lines*** connecting jittered markers to true locations.

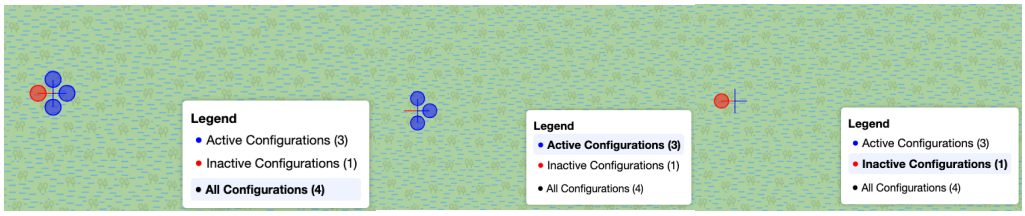


Fig. 2: Interactive legend for the jittered configuration locations and their spider lines at site 'S055_Peenewiesen'.

- ***Popup windows*** showing detailed information about each configuration.

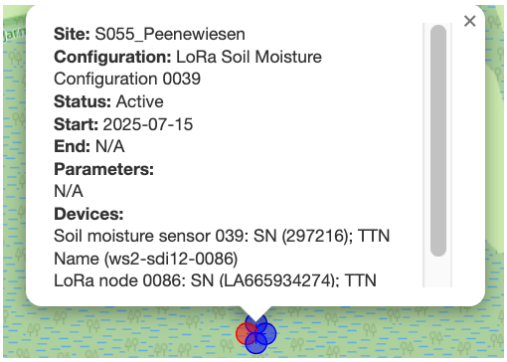


Fig. 3: The popup window for one of the active sensor configurations at site 'S055_Peenewiesen'.

2. Query-builder Features

Enhancements in the query-builder include:

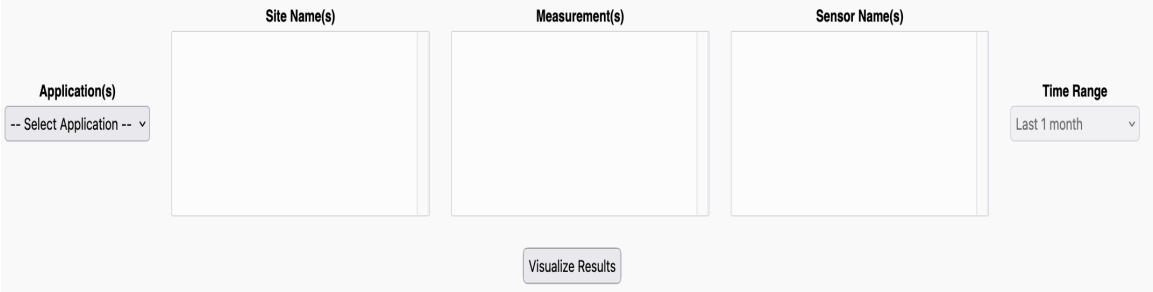


Fig. 4: The new query builder.

- a new "***Groundwater level***" measurement option for our KELLER and DRAGINO sensors.

- new "***Soil moisture temperature***" and "***Soil redox temperature***" measurement options for our STEVENS and SWAP sensors.

- a new "***Application(s)***" ***dropdown*** menu to select data sources.

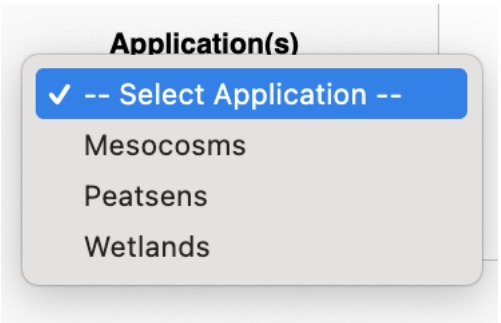


Fig. 5: 'Mesocosms' contains the mesocosm configurations, 'Peatsens' contains the peatsens configurations, and 'Wetlands' contains the ws2.0 screening-site configurations.

- a new "***Time Range***" ***dropdown*** with presets options '*Last 1 day*', '*Last 1 week*', '*Last 1 month*', and '*Custom*'.

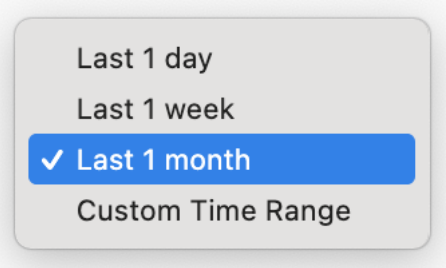


Fig. 6: The dropdown menu with preset time ranges.

- Whenever the '*Custom*' option is selected, users can specify '*Start Date*' and '*End Date*', as in the previous version of the app.

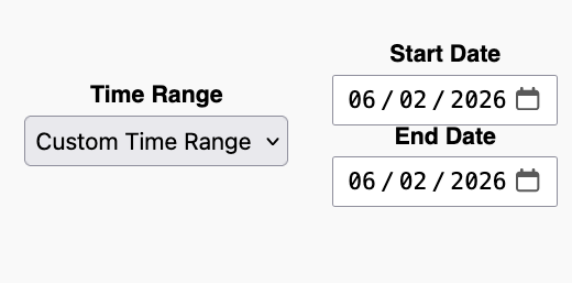


Fig. 7: The menu for specifying custom start and end dates.

3. Result Section

The result section now includes two new buttons:

- "***Detect Out-of-Range Values***": When pressed, highlights data points in the plot that fall outside manufacturer-specified measurement ranges, visually darkening those points.

- "***Remove Out-of-Range Values***": Removes highlighted points from the plot and updates the chart trends and legend accordingly.

- Button states change dynamically: initially, "Remove Out-of-Range Values" is disabled; after detection, it becomes enabled; after removal, both buttons are disabled.

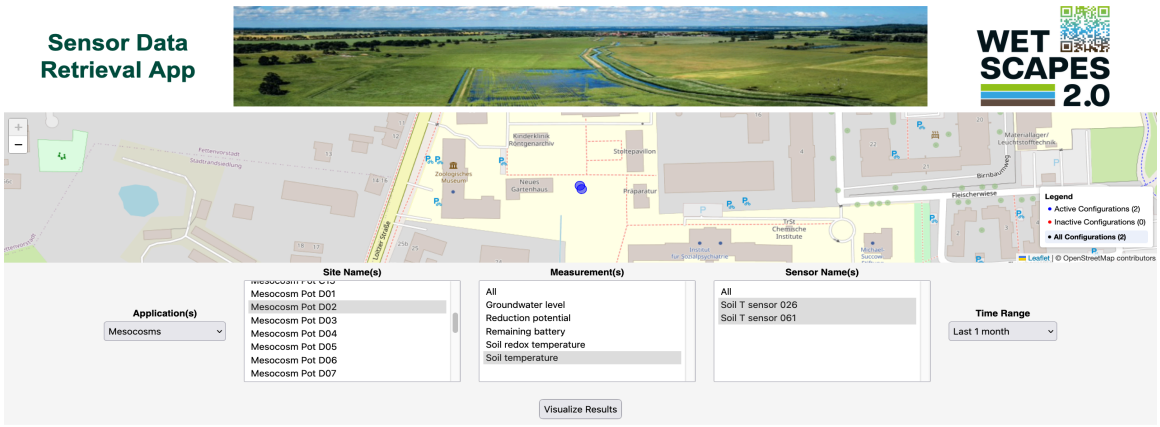


Fig. 8: A query that retrieves the soil temperature measurements made during the last 1 month at mesocosm pots C05 and D02.

Fig. 9: The soil temperature measurements made during the last 1 month at mesocosm pots C05 and D02.

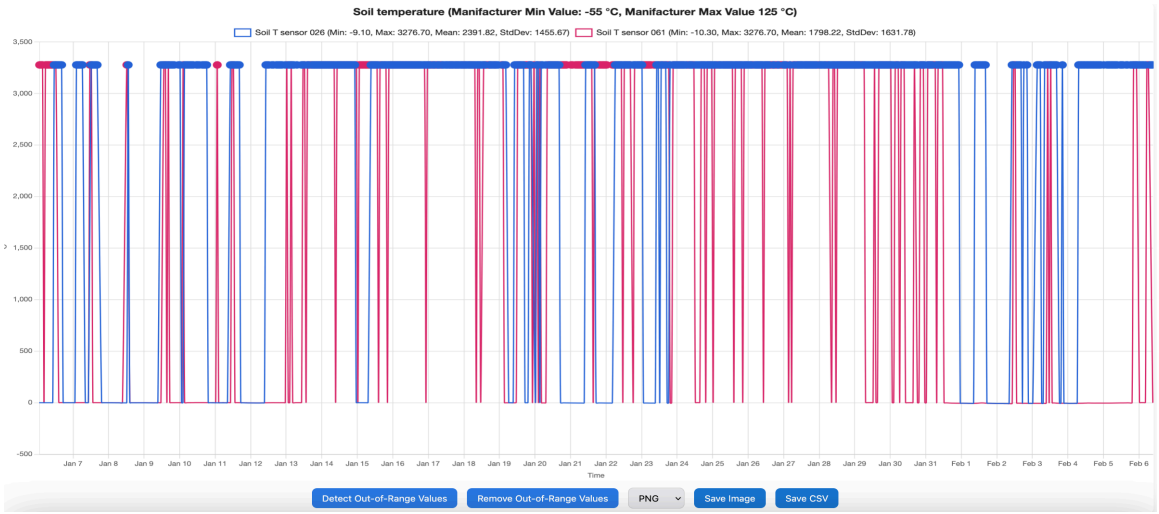


Fig. 10: Detection of out-of-range measurements made during the last 1 month at mesocosm pots C05 and D02.

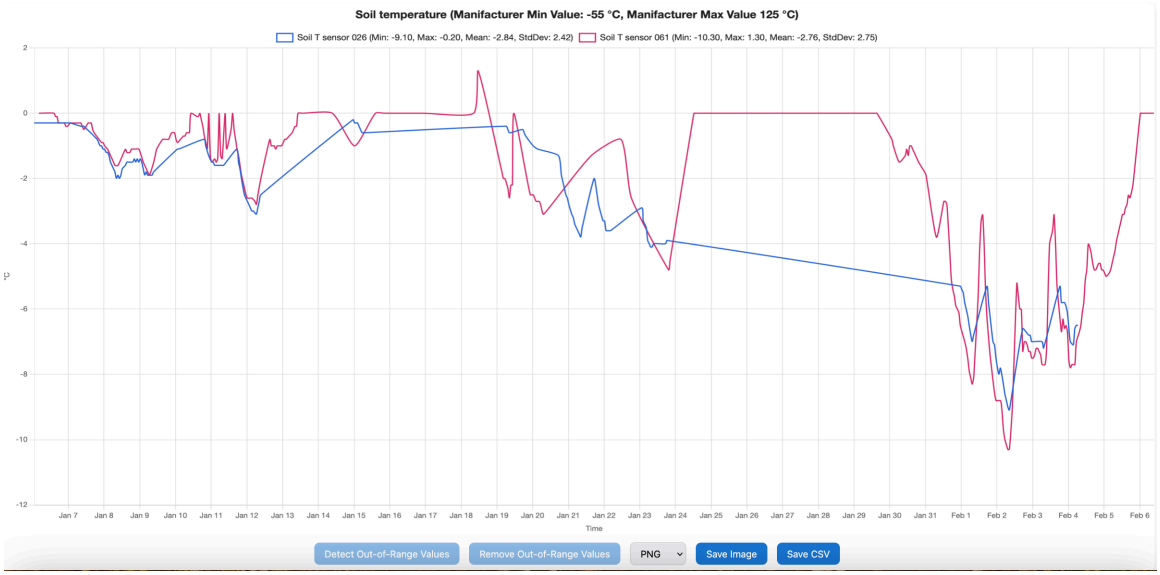


Fig. 11. Removal of out-of-range measurements made during the last 1 month at mesocosm pots C05 and D02.

4. CSV Export Features

The 'Save CSV' and 'Save All Results' buttons now export data in ***long format***, which has these benefits:

- Suitable for datasets with ***multiple measurements per sensor*** and ***multiple sensors per measurement***.
- Avoids issues of ***missing data*** and wide horizontal scrolling common in wide-format CSVs when sensors have ***asynchronous timestamps***, ***different deployment sites***, and ***different sampling rates***.

- Facilitates easier *data manipulation* and *compatibility* with many tools: ***databases***, ***pandas***, ***R***, ***Flux***, and ***scientific workflows all prefer long format***.

- The long format contains the following columns: *Timestamp*, *Site Name*, *Sensor Name*, *Pole Latitude*, *Pole Longitude*, *Measurement*, *Measurement Value*, *Measurement Min Value* (according to the manufacturer), *Measurement Max Value* (according to the sensor manufacturer), *Measurement Unit*, *Out-of-Range Flag* (yes/no).

Timestamp	Site Name	Sensor Name	Pole Longitude	Pole Latitude	Measurement	Measurement Value	Measurement Min Value	Measurement Max Value	Measurement Unit	Out-of-Range F
2026-02-06T00:34:05.3622021432	Mesocosm Pot A03	Soil T sensor 010	13.36465362	54.09185558	Soil temperature	-2	-55	125	°C	No
2026-02-06T01:34:05.5030362972	Mesocosm Pot A03	Soil T sensor 010	13.36465362	54.09185558	Soil temperature	-2	-55	125	°C	No
2026-02-06T02:34:05.6465108032	Mesocosm Pot A03	Soil T sensor 010	13.36465362	54.09185558	Soil temperature	-2	-55	125	°C	No
2026-02-06T03:34:05.7880471382	Mesocosm Pot A03	Soil T sensor 010	13.36465362	54.09185558	Soil temperature	-2	-55	125	°C	No
2026-02-06T04:34:05.9463701872	Mesocosm Pot A03	Soil T sensor 010	13.36465362	54.09185558	Soil temperature	-2	-55	125	°C	No
2026-02-06T05:34:06.0928374912	Mesocosm Pot A03	Soil T sensor 010	13.36465362	54.09185558	Soil temperature	-2	-55	125	°C	No

Fig. 12. A sample of long-format output data generated with the app.

5. Troubleshooting

Site Name(s), ***Measurement(s)***, and ***Sensor Name(s)*** boxes in the query builder are populated with the latest sensor metadata from SMS (https://sensors.gfz.de/) for configurations with static locations. The ***Visualize Results*** button assumes that such sensors are registered in TTN (https://eu1.cloud.thethings.network/) and, during their connectivity time span, have sent data to our UR InfluxDB instance (https://sensors.wetscapes.uni-rostock.de:58086) at least once. Unfortunately, this is not the case for all sensors registered in SMS. Here is an example:

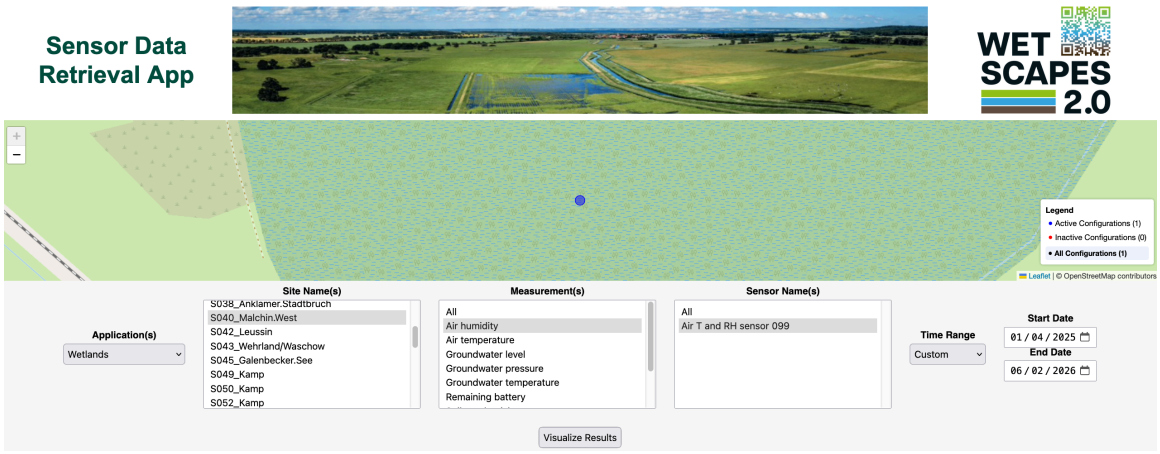


Fig. 13. An example query for the air humidity sensor at site 'S040_Malchin.West'.

The selected sensor in Fig. 12 is registered in TTN. However, it has never sent data to our UR InfluxDB instance, confirmed in Fig. 13, so the app issues a warning message, see Fig. 14.

Fig. 14. The air humidity sensor at site 'S040_Malchin.West' is not sending data.

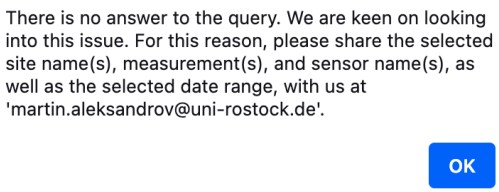


Fig. 15. The warning message issued by the app for non-responsive sensors.

6. Future work

In the future versions of the app, I plan to implement various other data-quality checks. Another possible avenue is to explore connecting the app to TTN for retrieving sensor and gateway statuses, and using these to generate justifications for why, in some cases, results cannot be retrieved: e.g. see Section 5. Wide format support is also planned for future work, but this would require synchronization of sensors over time, which requires research on estimating measurement values for time intervals when sensors do not transmit data.

WETSCAPES2.0 Sensor Data Retrieval App Documentation v1.2

Version 1.2 of the WETSCAPES 2.0 Sensor Data Retrieval web application introduces several functional improvements and extends the range of available sensor data. The update focuses on improving usability of the query interface and integrating additional LI-COR sensor measurements. The main improvements in this version include: A) redesign of the Application selection interface, enabling users to select multiple sensor groups simultaneously; B) introduction of two additional sensor-group options: "All" and "Licors"; C) integration of two additional monitoring sites and seven new measured quantities from LI-COR sensors; and D) support for visualization and export of these newly integrated datasets. These improvements allow users to explore a broader range of environmental sensor measurements and to retrieve data more efficiently for further analysis.

1. Application Options

In version **1.1** of the web application, the **Application** selection element in the query-builder was implemented as a standard drop-down menu. This menu allowed users to choose between three sensor groups: **Mesocosms**, **Peatsens**, and **Wetlands** (Figure 1).

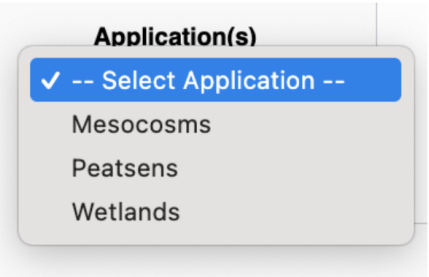


Figure 1: The application-select element in v1.1 of the web app.

While functional, this drop-down interface had an important limitation: it allowed the selection of **only one sensor group at a time**. As a result, users could not easily explore or compare data across multiple groups within a single query.

To address this limitation, version **1.2** replaces the drop-down menu with a **scrollable multi-selection list** that enables users to select multiple sensor groups simultaneously. In addition, two new sensor-group options have been introduced:

- **All** – selects sensors from all available groups
- **Licors** – selects LI-COR sensor systems

The updated interface is illustrated in **Figure 2**.

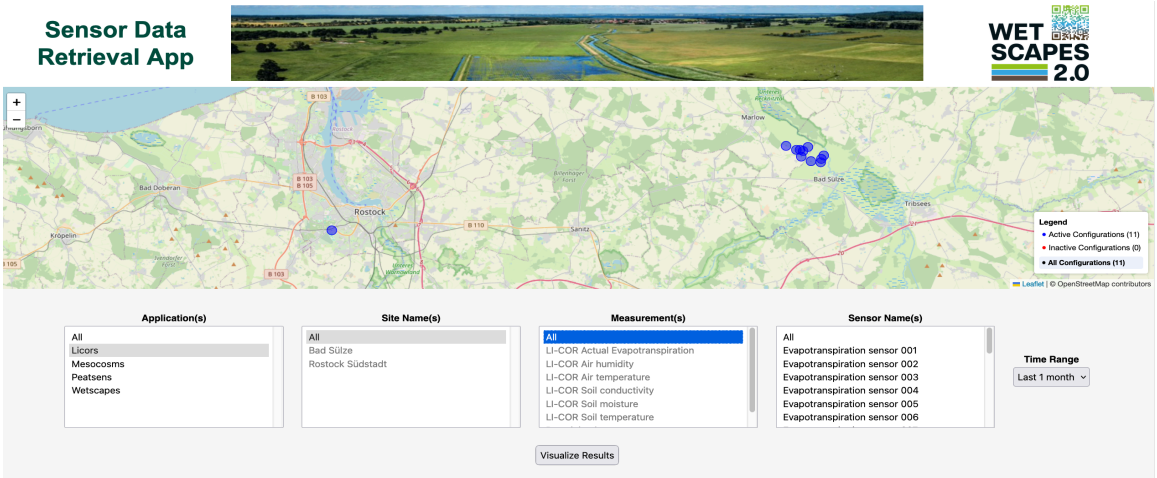


Figure 2: The application-select element in v1.2 of the web app.

2. The "Licors" Sensor Group

The newly introduced **Licors** sensor group currently includes:

- **11 evapotranspiration sensors**
- **11 soil moisture probes**

Support for this sensor group required several enhancements to the query builder. The following options have been added:

New site options

- **Bad Sülze**
- **Rostock Südstadt**

New measurement options

- Actual evapotranspiration
- Air humidity

- Air temperature
- Soil conductivity
- Soil moisture
- Soil temperature
- Remaining battery

These additions enable users to **inspect temporal trends from LI-COR sensors directly within the application**. Users can inspect sensor measurements over time, identify and remove out-of-range values, and export the cleaned datasets as **plots or tabular data**.

Figure 3 shows the trend of **actual evapotranspiration (AET)** measured during the previous month before any out-of-range values were removed.

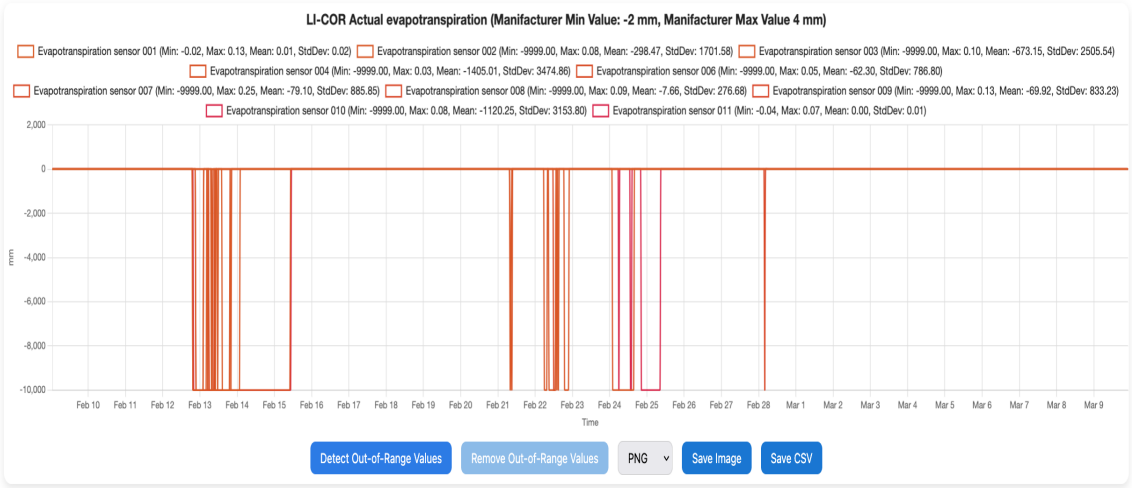


Figure 3: AET trend for the last month before removing out-of-range values.

Figure 4 shows the same dataset after applying out-of-range filtering.

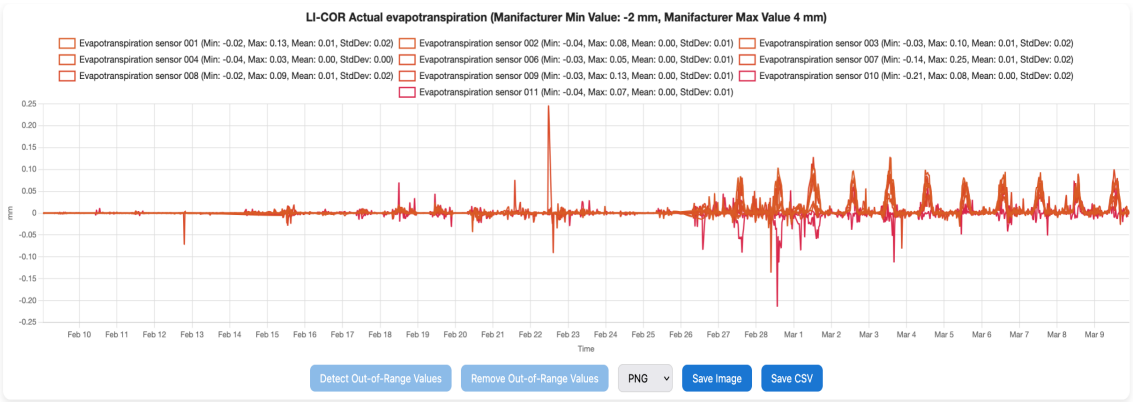


Figure 4: AET trend for the last month after removing out-of-range values.

Figure 5 presents the **soil moisture trend**, which does not contain out-of-range values during the selected time period.

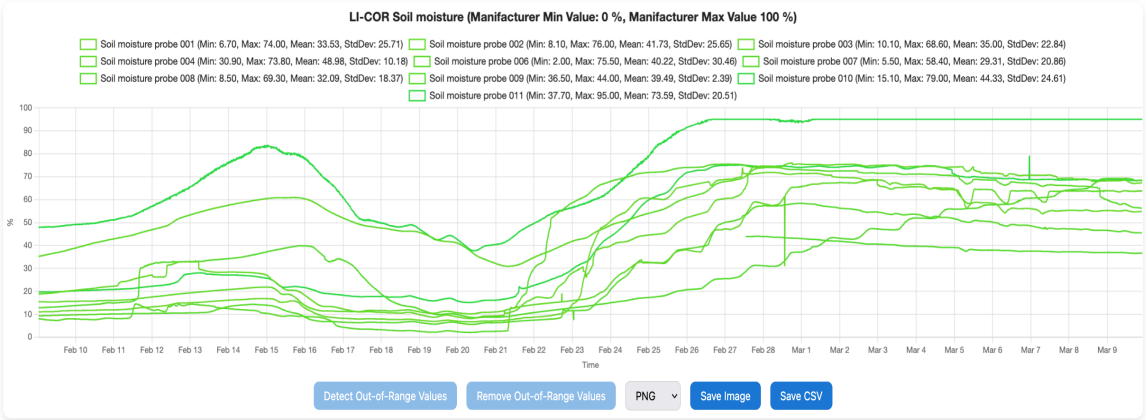


Figure 5: Soil moisture trend for the last month.

3. Planned Developments

Future versions of the application will include additional data quality assessment mechanisms to further improve the reliability of retrieved datasets.

Planned enhancements also include the integration of additional sensor systems, such as Extensometer sensors, thereby expanding the range of environmental observations available within the platform.

Another feature currently under consideration is support for wide-format data export. Implementing this functionality requires temporal synchronization of measurements across multiple sensors. Because sensor transmissions often occur at irregular intervals, further methodological work will be required to develop suitable approaches for estimating or interpolating measurement values during periods where data is not available.