Co-UDlabs

Data Storage Report

Sediment depth measurements for surrogate modeling of sediment build-up in gully pots using temperature data

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1. INTRODUCTION

1.1. SCIENTIFIC BACKGROUND

Sediments in urban drainage systems stem from various sources, such as traffic, construction activities, and vegetation (Rietveld et al., 2020). During rainfall these particles get carried away by the surface runoff into the gully pots. Once the gullies are filled up this is a major concern for several reasons. First, these sediments can be remobilized during rain events, greatly increasing the suspended solid loads (Bertrand-Krajewski, 2021). Second, pollutants can be adsorbed on the surfaces of these sediments and transported into the environment (Chen et al., 2022). For example, during rainfall when the capacity of sewers is exceeded, causing combined sewer overflows (CSO). Third, sediments lead to a decrease of hydraulic capacity in sewers, by blocking sewer pipes, resulting in an increased risk of flooding (Ashley et al., 2004). Another difficulty lies in the detection of these sediment deposits. They are often only found during a visual inspection of the sewer. These inspections cost time and resources. Sensors could be installed in sewers and provide continuous data on sedimentation depths, but such sensors to detect sediments are not yet commercially available. Promising results were obtained by using temperature sensors to measure sediment depths in urban drainage systems (Regueiro-Picallo et al., 2023a). Temperature measurements were commonly used as a tracer of groundwater and surface water interactions in fluvial environments (Anderson, 2005). In addition, temperature sensors were used for monitoring riverbed sediment transport (Sebok et al, 2017).

1.2. OBJECTIVES

This report presents data collected from a field campaign performed in Zurich (Switzerland). The data collected was part of the MSc Thesis "Automated surrogate model to estimate sediment accumulation from temperatures in urban drainage systems", developed by Lenard Fuchs at the ETH Zurich in 2023.

The experiments were designed to further develop an innovative methodology for monitoring sediment bed deposits in UDS based on temperature data analysis (Anta et al., 2022; Regueiro-Picallo et al., 2023a; Regueiro-Picallo et al., 2023b). Particularly, the aim of this campaign was to develop and test a surrogate model to estimate sediment depths in gully pots based on heat transfer processes. For this purpose, temperature time series were measured at different heights inside two gully pots to relate the heat transfer processes to the volume of sediments.

The report is structured as follows. The description of the field campaigns is shown in Section 2. This section includes a description of the field measurement systems. The subsequent sections describe the measurements performed in the experimental campaign: temperatures (Section 3), sediment level (Section 4), and sediment thermal properties (Section 5). Each section describes the instruments and sensors used, the parameters measured, and how the data were recorded and processed. Section 6 describes the organization of the data in folders and files. Finally, Section 7 and Section 8 include the bibliographical references and appendices, respectively.

2. FIELD EXPERIMENTAL CAMPAIGN

2.1. FIELD SYSTEM EQUIPMENT

The measurement in this thesis were collected using the MONitoring Temperatures in SEdiments (MONTSE) system that was developed at the SensorLab at Eawag (Sensor Lab, 2023). The system was designed to collect data from up to seven temperature sensors and measure the thermal properties with a Dual-Probe-Heat-Pulse (DPHP) system.

The DPHP system consists of one temperature sensor and one heating probe. The exact distance between the sensor and the heating probe, and the input energy of the heater should be determined in advance. The heat pulse lasts for 120 s and the temperature sensor is measuring for an additional 450 s. The attenuation of the heat pulse was then used to estimate the thermal properties.

A PROBAG-PT100 (Switzerland) was used as a heater probe. The distance between the two probes was fixed with a 3D-printed adapter with specified dimensions for each setup. The temperature measurements were collected by DS18B20 (DFROBOT, China) sensors. All sensors were connected to an Arduino micro controller (MKR WAN 1310) that controlled the measurement frequency and stored the data locally on a MicroSD card. A 12 V battery supplies the system with energy in the field. The micro controller and battery were placed inside a watertight black box. All components are shown in Figure 1.

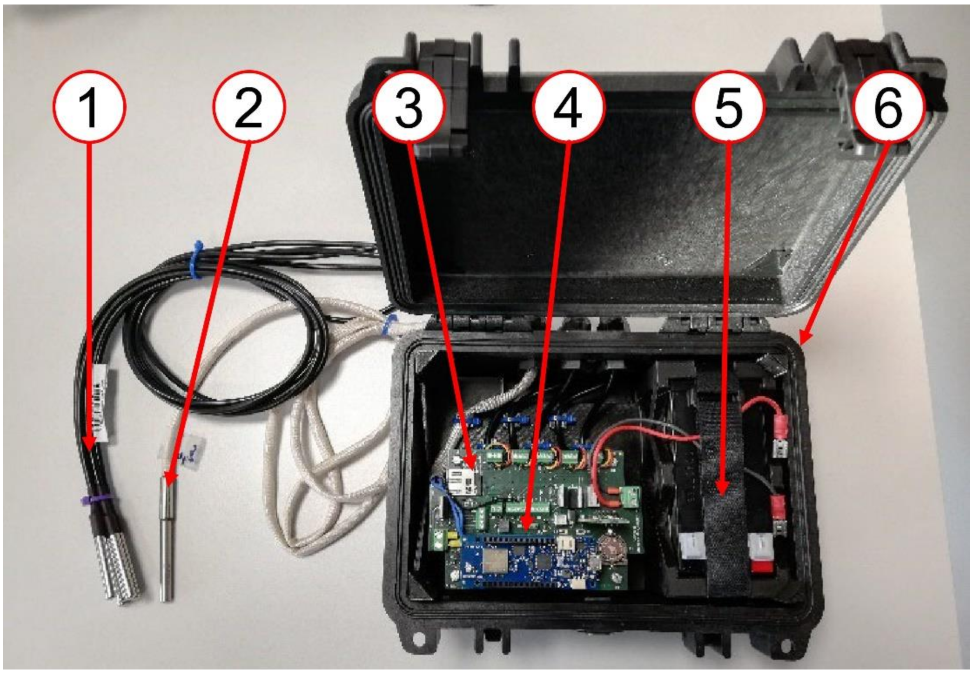

Figure 1: MONTSE system components: 1) DS18B20 temperature sensors, 2) PROBAG heater probe, 3) Micro-SD-card, 4) Arduino MKR WAN 1310, 5) Battery (12 Volt), 6) Watertight box. Figure from Regueiro-Picallo et al. (2023b).

2.2. FIELD SYSTEM SETUP

The electronics were then assembled into two MONTSE-setups, which were installed in gully pots from the urban drainage system of Zürich (Switzerland). The first setup was installed at Eawag Campus (Dübendorf) and the second in Rüschlikon. The setups consisted of seven passive temperature sensors (DS18B20) as well as one heater probe. The passive sensors were distributed vertically along a PVC-pipe with a constant distance between the sensors. The average distance between the sensors was 10 cm at Eawag, and 5.5 cm at Rüschlikon, except for one DS18B20 sensor that was placed at the top of the gully pot to measure the air temperature (Figures 2). In addition, the DPHP-system was installed at the bottom of the pvc-pipe, consisting of the PROBAG heater probe and one passive DS18B20 sensor (blue box in Figure 2). The DPHP-system was angled at 90° and pointed towards the gully pot centre, while the remaining DS18B20 sensors were installed parallel to the gully pot wall.

During the installation, the pvc-pipe with the sensors was positioned at the bottom of the gully pot and attached to the wall by using a metal clamp. The box with the electronics was then attached to the metal clamp with a carabiner for easy access. The distances from the pvc-pipe to the wall was 17 cm at Eawag and 29 cm at Rüschlikon.

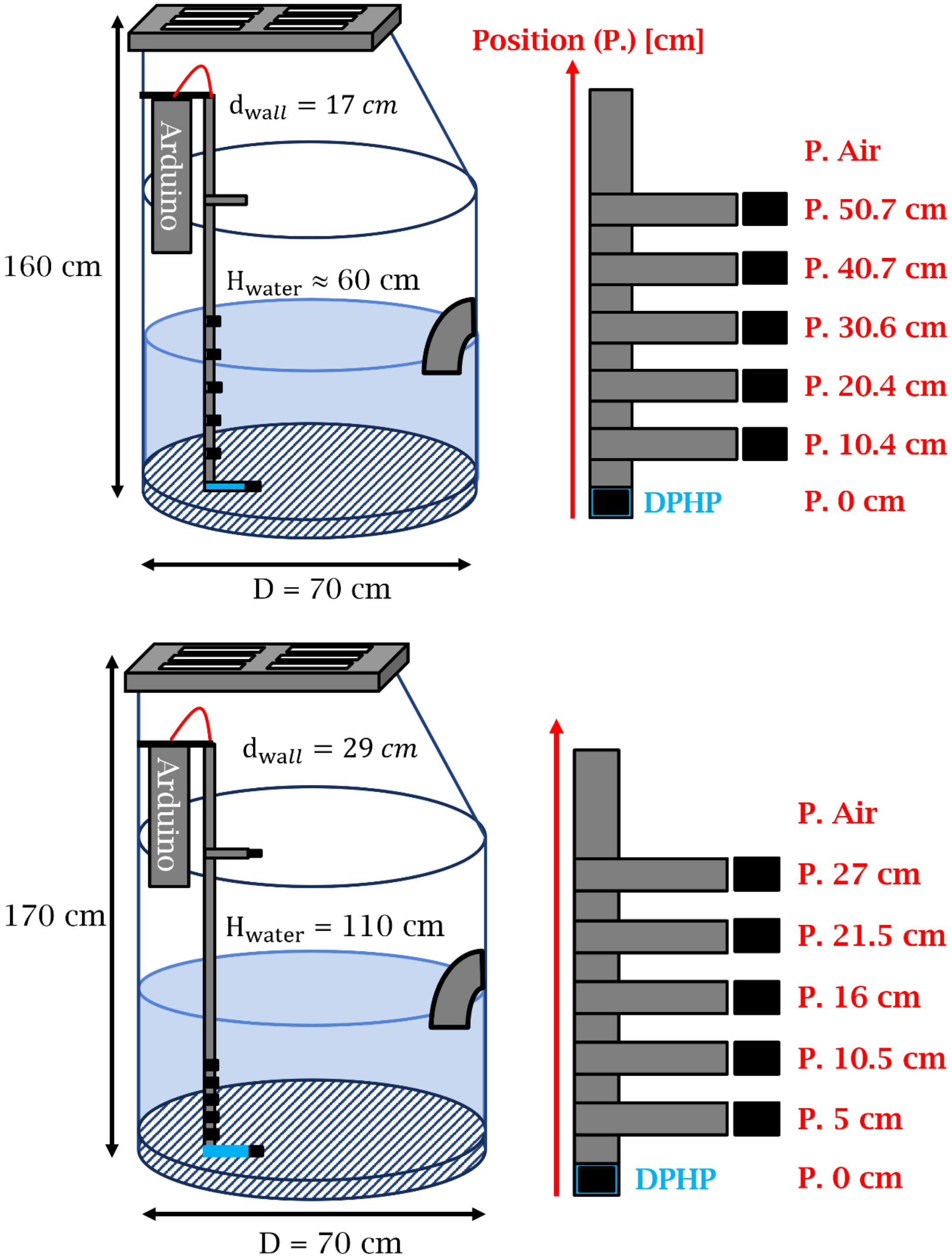

Figure 2: Overview of the sensor setup installed at Eawag (Top) and Rüschlikon (Bottom). d_{wall} corresponds to the distance of the setup from the wall, H_{water} is the permanent water height in the gully pot, D is the diameter of the gully pot. The position (P.) refers to the installation height above the gully pot bottom. The DPHP system is marked in blue.

2.3. SPATIAL AND TEMPORAL REFERENCE SYSTEMS

The bottom of each gully pot was taken as the origin of coordinates.

Location ID:	Eawag campus, Dübendorf
Location coordinates:	47.24164 N, 8.36416 E
General features:	Industrial area, impervious surface

Pictures:

Figure 3: Eawag setup installation and surroundings

Location ID:	Rüschlikon ZH, Seestrasse 78
Location coordinates:	47.307227 N, 8.558398 E
General features:	Residential area, impervious surface, normal asphalt, road ca. 30 years old

Pictures:

Figure 4. Rüschlikon surroundings and setup installation

Timestamps were referenced to UTC+1 for the field campaign measurements. Considering the location of MONTSE, the duration of the field measurements was as follows:

- Eawag, Dübendorf: 23/05/2023 till 22/08/2023
- Rüschlikon: 29/06/2023 till 31/08/2023

Passive temperatures were collected every 60 s by the MONTSE system. In addition, the thermal properties of the sediment were measured with the DPHP-system in a fixed interval. The DPHP measurement period was increased from 24 hours to 2 weeks during the field campaign to improve the battery lifespan. To perform active and passive measurements the MONTSE goes through the following 4 states:

- State 1: Pre-heater activation phase.
  - Time interval: 30 s.
  - Time resolution: 1 s.
- State 2: active heat phase.
  - Time interval: 120 s.
  - Time resolution: 1 s.
- State 3: Initial phase of heat recovery in the sediment.
  - Time interval: 450 s
  - Time resolution: 1 s.
- State 4: Passive measures phase, starting from 24 hours, then extended to 1 and 2 weeks, respectively.
  - Time interval: 86’400 s (24 hours) / 604’200 s (1 week) / 1’208’400 s (2 weeks)
  - Time resolution: 60 s.

2.4. FIXED PARAMETERS

The following parameters have been assumed to be fixed:

- Thermal properties of the sediments were assumed to be constant in each location.
- The same calibration parameters of the temperature sensors were applied during the entire campaign.

2.5. ADDITIONAL REMARKS

2.5.1. FORCING RUNOFF EVENTS

Due to the limited duration of the field campaign, only few natural rain events were observed. Consequently, several rain events were artificially created by pouring tap water from a hose into the gully pot. The list of these events can be seen in Table 1, including the dates (DD/MM/YYYY hh:mm), duration (min), hose water temperature (ºC), and volume (L) that was poured into the gully pot.

Table 1. Synthetic rain events: starting date time (format, DD/MM/YYYY hh:mm), duration (min), tap water volume (L) and temperature (ºC) poured into the gully pot at Eawag.

Start Time	Duration (min)	Volume (L)	Temperature (°C)
11/07/2023 09:25	20	100	17
02/08/2023 15:13	30	140	18
03/08/2023 10:36	18	140	18

03/08/2023 15:28	15	90	18
07/08/2023 15:43	15	120	17
09/08/2023 15:53	15	120	17
10/08/2023 10:30	15	120	18
11/08/2023 09:00	12	120	17
16/08/2023 13:15	15	130	17
18/08/2023 08:38	15	120	18

2.5.2. FORCING SEDIMENT ACCUMULATION

Due to technical and time constraints, neither the gully pot at Eawag nor in Rüschlikon were cleaned out before the field campaigns started. Consequently, sediment depths of 9 and 7 cm were measured at the beginning of the experiment in Eawag and Rüschlikon, respectively. For the gully pot at Eawag, the sediment build-up process was accelerated by pouring soil samples. These samples showed similar thermal properties (see Section 5.3) and were poured periodically into the Eawag gully pot. The sediments added were soil samples, stemming from a study of green roofs in Zurich. Unfortunately, the initial soil samples were not enough to complete the field campaign, which required adding a second type of samples. These samples are hereinafter referred to as soil types 1 and 2.

Table 2: Reference sediment depths: Time of measurement (UTC+1, DD/MM/YYYY hh:mm:ss), sediment depth Hsed (mm), and soil type added. The increases of sediment depth were caused by pouring soil samples to the gully pot at Eawag.

Time UTC+1 (DD/MM/YYYY hh:mm:ss)	Reference Hsed (mm)	Soil type added
23/05/2023 12:00:00	9	0
31/05/2023 12:00:00	9	0
09/06/2023 12:00:00	9	0
09/06/2023 12:30:00	20	1
15/06/2023 12:00:00	20	1
15/06/2023 12:30:00	23	1
21/06/2023 12:00:00	23	1
23/06/2023 12:00:00	23	1
13/07/2023 12:00:00	23	1
13/07/2023 12:30:00	25	2
25/07/2023 12:00:00	25	2
26/07/2023 12:00:00	25	2
26/07/2023 12:30:00	28.5	2
02/08/2023 09:30:00	28.5	2
02/08/2023 10:30:00	39	2
09/08/2023 10:30:00	39	2
16/08/2023 11:00:00	38	2
16/08/2023 11:15:00	45	2
16/08/2023 11:30:00	45	2
22/08/2023 10:00:00	45	2

0: gully pot sediments, 1: soil type 1, 2: soil type 2.

3. TEMPERATURE MEASUREMENTS

3.1. INSTRUMENTS

Temperature measurements were recorded with DS18B20 sensors (DFROBOT, China), which showed a reference accuracy of ±0.50 ºC. Temperature sensors were connected to Arduino MKRZero boards, which included a MicroSD card and a RTC DS3231 board (Accuracy of time clock: ±2 ppm). In total, 14 DS18B20 sensors and 2 Arduino MKRZero boards were used:

- **Field setups:**
  - **Eawag** board operated using 7 x DS18B20 sensors, one heater probe.
  - **Rüschlikon** board operated using 7 x DS18B20 sensors, one heater probe.

Table 3 shows the distribution of temperature sensors for each field setup.

Table 3. Temperature sensor information for the field campaign.

Sensor ID	Measure	Sensor	Location	System	Position / Orientation	Zcoord. (cm)	Acquisition units
28611694970E0389	Temp.	DS18B20	Eawag (Dübendorf, CH)	Eawag	Water / horizontal	0.0	deg.C
28ED2796F0013C68	Temp.	DS18B20	Eawag (Dübendorf, CH)	Eawag	Water / horizontal	10.4	deg.C
28645796F0013C79	Temp.	DS18B20	Eawag (Dübendorf, CH)	Eawag	Water / horizontal	20.4	deg.C
28298396F0013C07	Temp.	DS18B20	Eawag (Dübendorf, CH)	Eawag	Water / horizontal	30.6	deg.C
286E4C96F0013CBA	Temp.	DS18B20	Eawag (Dübendorf, CH)	Eawag	Water / horizontal	40.7	deg.C
28B0F596F0013CD1	Temp.	DS18B20	Eawag (Dübendorf, CH)	Eawag	Water / horizontal	50.7	deg.C
28337096F0013C7B	Temp.	DS18B20	Eawag (Dübendorf, CH)	Eawag	Air / -	150	deg.C
28A44B94970A03BF	Temp.	DS18B20	Rüschlikon (CH)	Rüschlikon	Water / horizontal	0	deg.C
28DE3194970A0338	Temp.	DS18B20	Rüschlikon (CH)	Rüschlikon	Water / horizontal	5	deg.C
28E1069497010307	Temp.	DS18B20	Rüschlikon (CH)	Rüschlikon	Water / horizontal	10.5	deg.C
28D5B45704E13D53	Temp.	DS18B20	Rüschlikon (CH)	Rüschlikon	Water / horizontal	27	deg.C

28DBCA5704E13D8F	Temp.	DS18B20	Rüschlikon (CH)	Rüschlikon	Water / horizontal	16	deg.C
28975294970103A7	Temp.	DS18B20	Rüschlikon (CH)	Rüschlikon	Water / horizontal	21.5	deg.C
28E0085704E13D3B	Temp.	DS18B20	Rüschlikon (CH)	Rüschlikon	Air / -	160	deg.C

3.2. MEASURED PARAMETERS

DS18B20 digital sensors were programmed to provide 12-bit Celsius temperature measurements (0.0625 ºC resolution). Each DS18B20 communicates over a 1-Wire bus that requires only one data line (and ground) for communication with the Arduino MKR-WAN-1310 board. In this project, we directly record the temperature values from DS18B20 sensors by using the Arduino library *ds18b20_utils.h*.

3.3. DATA COLLECTION

Raw temperature measurements were saved as text files by the Arduino microcontrollers in microSD cards. Subsequently, raw measurements were corrected by introducing calibration coefficients, which were previously obtained from reference temperature measurements. For this purpose, calibration of DS18B20 sensors was performed by comparing the temperature measurements with those of set in the water bath (±0.01 ºC stability). Data were saved in calibration-corrected formats.

3.4. POST-PROCESSING

DS18B20 sensors were calibrated before the experimental and field campaigns by setting constant temperatures in the water bath, within the temperature range expected to be found in the field campaigns (10-35ºC). For this purpose, temperatures were measured after the water temperature was stabilized in the water bath. Temperature measurements were compared and adjusted with the reference temperature of the water bath. Therefore, a linear regression was applied to perform the transformation from raw to corrected temperature measurements (*\Sensors_calibration*). See Appendix 10.1. for further details regarding the calibration coefficients.

3.5. ADDITIONAL REMARKS

NA

4. SEDIMENT DEPTHS

4.1. INSTRUMENTS

Another important part of the field campaign was the reference measurements of the sediment depth. These were done with a measurement stick that takes inspiration from a similar measurement system developed by Mall Umweltsysteme (Mall Umweltsystme, 2018) and Rietveld et al. (2020). First, the tool included a disk at the bottom of the stick to foresee the top of the sediment layer. Then, the distance from the top of the tool to a reference mark, e.g., the gully pot lid, was measured (z1). Second, the stick was introduced up to the bottom of the gully pot. Again, the distance to the same reference mark was measured, (z0). Finally, the sediment depth resulted from subtracting the two measurements (z1- z0).

The measurement setup worked efficiently for low sediment depths. However, when the sediment depth exceeded 20 cm, it was difficult to push the stick through the sediment layer towards the bottom of the gully pot. Therefore, the measurement approach was adjusted to only measure the distance to the sediment layer and compare it with the previously measured gully pot geometry. As an additional reference measurement, an endoscope with a camera was used to visually measure the sediment depth, see Figure 5.

Figure 4: Sediment depth measurement tool (left) and endoscope photo (right).

4.2. MEASURED PARAMETERS

The sediment depth was obtained by measuring the top of the sediment layer (z1) and then the bottom of the gully pot (z0) using a grading stick. Subtracting both values results in the sediment depth.

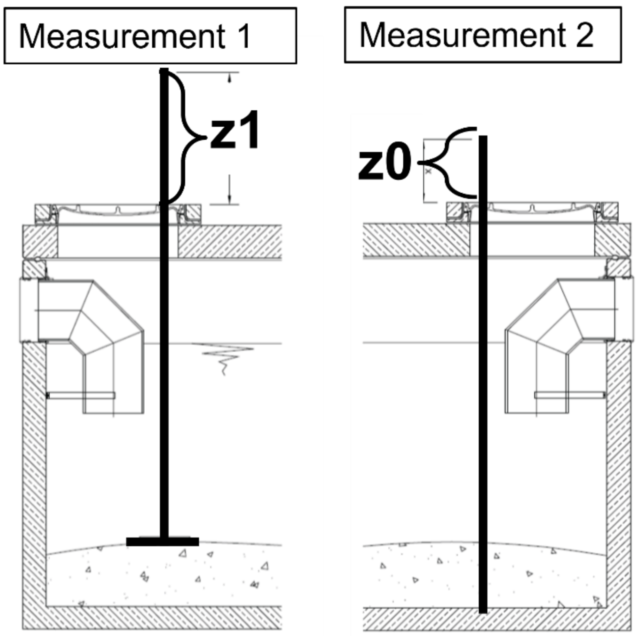

Figure 5: Sediment depth measurement process.

4.3. DATA COLLECTION

Reference sediment depths were measured before and after installing the MONTSE setup, as well as each time data were collected and when new sediments were added to the gully pot at Eawag. The sediment depth close to the sensor setup was taken as the reference value.

4.4. ADDITIONAL REMARKS

NA

5. THERMAL PROPERTIES ANALYSIS

5.1. INSTRUMENTS

Thermal properties were measured with the DPHP system in the field campaign. The DPHP system combined a heat-pulse form the heater cartridge and temperature measurements with a DS18B20 sensor. The heat-pulse features, i.e., the power supply and the distance between the DS18B20 sensor and the heater, were adjusted by using reference measurements from a TP01 sensor (Hukseflux, The Netherlands). The TP01 sensor contains a wire that heats the surrounding sediment and a thermopile sensor that generates a voltage output, as a reaction to the radial temperature difference around the heating wire. The sensitivity of the voltage output was provided by the manufacturer (Sensitivity, S = 139.7 × 10^{-6} V/ºC, and uncertainty = ± 14.0 × 10^{-6} V/ºC). Furthermore, the TP01 sensor was used to measure the thermal properties of the soil samples added to the Eawag gully pot in the laboratory under saturated conditions before pouring into the gully pot.

5.2. MEASURED PARAMETERS

This study was focused on characterizing thermal properties of gully pot sediments. The properties analyzed are listed below (see also *THERMAL_PROPERTIES*):

- Thermal conductivity (W/m/ºC).
- Volumetric heat capacity (J/m^3/ºC).
- Therm. diffusivity (m^2/s) = Thermal conductivity / Volumetric heat capacity.

5.3. DATA COLLECTION

The data was collected in regular measurement intervals by the DPHP system installed inside each gully pot. The system measures the thermal properties at the bottom of the gully pot, see Figure 2. The thermal properties of the sediments added to the gully pot at Eawag were measured with the TP01 sensor in the laboratory under saturated conditions prior to being deposited inside the gully.

Table 4. Thermal properties of sediments in Eawag and Rüschlikon gully pots, and soil samples added in Eawag gully pot [min - max]. The thermal properties of soils type 1 and 2 were measured in the laboratory with the TP01 sensor, whereas gully pot sediments from Eawag and Rüschlikon were measured in the field with the DPHP system.

Parameter	Soil Type 1	Soil Type 2	Eawag	Rüschlikon
Therm. conductivity [W/m/K]	1.14 – 1.17	0.87 - 0.88	0.83 – 0.90	0.70 - 0.71
Therm. diffusivity [$m^2/s * 10^{-7}$]	3.54 – 3.75	2.75 - 2.82	2.75 – 2.99	1.89 - 1.91

Vol. heat capacity [M J/m³/K]	3.12 – 3.22	3.07 - 3.15	3.01 – 3.08	3.73 - 3.73

5.4. ADDITIONAL REMARKS

NA

6. CODE

The database includes the scripts used to develop and apply the automated tool for estimating sediment depths in gully pots from temperature signals. The scripts were coded in Python ad could be adapted to each location (Eawag and Rüschlikon) based on the geometry of the gully pots, the sensor installation, and the boundary conditions (e.g., thermal properties). This code is described in Fuchs (2023).

7. DATA AND CODE FILES ORGANIZATION

Main folders correspond to data and code files. The data were organised in three folders:

- **Field campaign.**

  This folder contains the temperature measurements, the reference sediment depths and the location information where the MONTSE systems were installed. The names of the .csv files containing the temperature data and the reference sediment depths include the Location (Eawag or Rüschlikon).

  Temperature CSV-files (*eawag_Temp_processed(degC).csv* and *Rueschlikon_Temp_processed(degC).csv*) include the timestamp in the first column with the time format dd/mm/yyyy hh:mm:ss (UTC+1). The second column corresponds to the MONTSE measuring state (see Section 2.3), and the following columns correspond to the temperature measurements of the DS18B20 sensors, including the Sensor ID in the header (see Table 3).

  Reference sediment depth CSV-files (*_FLD_eawag_measure_info.csv* and *_FLD_Rueschlikon_measure_info.csv*) include the timestamp in the first column with the time format dd/mm/yyyy hh:mm:ss (UTC+1), and the sediment depth (in cm) measured with the stick (see Section 4.1). For Rüschlikon, a second stick, which was made of metal, was used to measure the sediment depth. However, this second instrument had the disadvantage of causing compaction of the sediment layer.

  Location CSV-file (*_FLD_sensor_info.csv*) include the sensor ID, the type of measurement and sensor, the location (including the place and coordinates), the setup ID, the version, the position and orientation of the sensors, the Z-coordinates relative to the bottom of the gully pot (in cm), and the acquisition units.

- **Thermal properties.**

  The thermal properties were measured in the field by the Dual-Probe-Heat-Pulse system. The setup takes a DPHP measurement once in a set time period. The week of each measurement and the day that the measurement took place at are indicated in the file name, both refer to the date of installation.

- **Sensor calibration.**

  This folder contains the description of the calibration process of the temperature sensors. The two subfolders contain the data of the DPHP calibration and the ds18b20 temperature sensor calibration. The DPHP folder is further split into two subfolders containing information to both sensor setups. Both measured the thermal properties in two different media, sand and agar. The setup, sensor, medium and temperature of the medium is indicated in the file name, the number stands for the repetition of the measurement. The ds18b20 calibration results are shown Calibration_DS18B20_info.csv file with the raw data for different calibration runs in the other files.

Table 5 summarises the organisation of the data collected in this report.

Table 5. Folders and file organization.

	FIELD_CAMPAIGN	Folder
	eawag_Temp_processed(degC).csv	.csv file
	Rueschlikon_Temp_processed(degC).csv	.csv file
	_FLD_sensor_info.csv	.csv files
	_FLD_Rueschlikon_measure_info.csv	.csv file
	_FLD_eawag_measure_info.csv	.csv file
	THERMAL_PROPERTIES	Folder
	EAWAG	Subfolder
	SOIL_ADDED_TYPE1	Subfolder
	TP_Soil_type1_raw_1.csv	.csv file
	TP_Soil_type1_raw_2.csv	.csv file
	TP_Soil_type1_raw_3.csv	.csv file
	SOIL_ADDED_TYPE2	Subfolder
	TP_Soil_type2_raw_1.csv	.csv file
	TP_Soil_type2_raw_2.csv	.csv file
	TP_Soil_type2_raw_3.csv	.csv file
	TP_Week1_day1_eawag.csv	.csv file
	TP_Week1_day2_eawag.csv	.csv file
	TP_Week1_day3_eawag.csv	.csv file
	TP_Week1_day4_eawag.csv	.csv file
	TP_Week1_day5_eawag.csv	.csv file
	TP_Week1_day6_eawag.csv	.csv file
	RUESCHLIKON	Subfolder
	TP_Week1_day1_Rueschlikon.csv	.csv file
	TP_Week1_day2_Rueschlikon.csv	.csv files

	TP_Week1_day3_Rueschlikon.csv	.csv file
	SENSORS_CALIBRATION	Folder
	DS18B20	Subfolder
	Calibration_DS18B20_info.csv	.csv file
	Temp_RawSignal(degC)_Calib_1.csv	.csv file
	Temp_RawSignal(degC)_Calib_2.csv	.csv file
	Temp_RawSignal(degC)_Calib_3.csv	.csv file
	Temp_RawSignal(degC)_Calib_4.csv	.csv file
	Dual-Pulse-Heat-Probe	Subfolder
	Calibration_info.csv	.csv file
	TP01_info_voltage.csv	.csv file
	EAWAG	Subfolder
	EAWAG_TP01_Sand_raw_at_22C_deg(C).csv	.csv file
	EAWAG_TP01_Agar_raw_at_36C_deg(C).csv	.csv file
	EAWAG_DPHP_Agar_raw_at_26C_deg(C).TXT	.txt file
	EAWAG_DPHP_Agar_raw_at_36C_deg(C).TXT	.txt file
	EAWAG_DPHP_Sand_raw_at_22C_deg(C).TXT	.txt file
	RUESCHLIKON	Subfolder
	RUESCHLIKON_TP01_Agar1_raw_deg(C).csv	.csv file
	RUESCHLIKON_TP01_Agar2_raw_deg(C).csv	.csv file
	RUESCHLIKON_TP01_Agar3_raw_deg(C).csv	.csv file
	RUESCHLIKON_TP01_Sand1_raw_deg(C).csv	.csv file
	RUESCHLIKON_TP01_Sand2_raw_deg(C).csv	.csv file
	RUESCHLIKON_PT100_Agar1_at_22C_deg(C).TXT	.txt file
	RUESCHLIKON_PT100_Agar2_at_22C_deg(C).TXT	.txt file
	RUESCHLIKON_PT100_Agar3_at_22C_deg(C).TXT	.txt file
	RUESCHLIKON_PT100_Sand_at_20C_deg(C).TXT	.txt file

Figures 20 and 21 plot processed temperatures for several field campaign measurements.

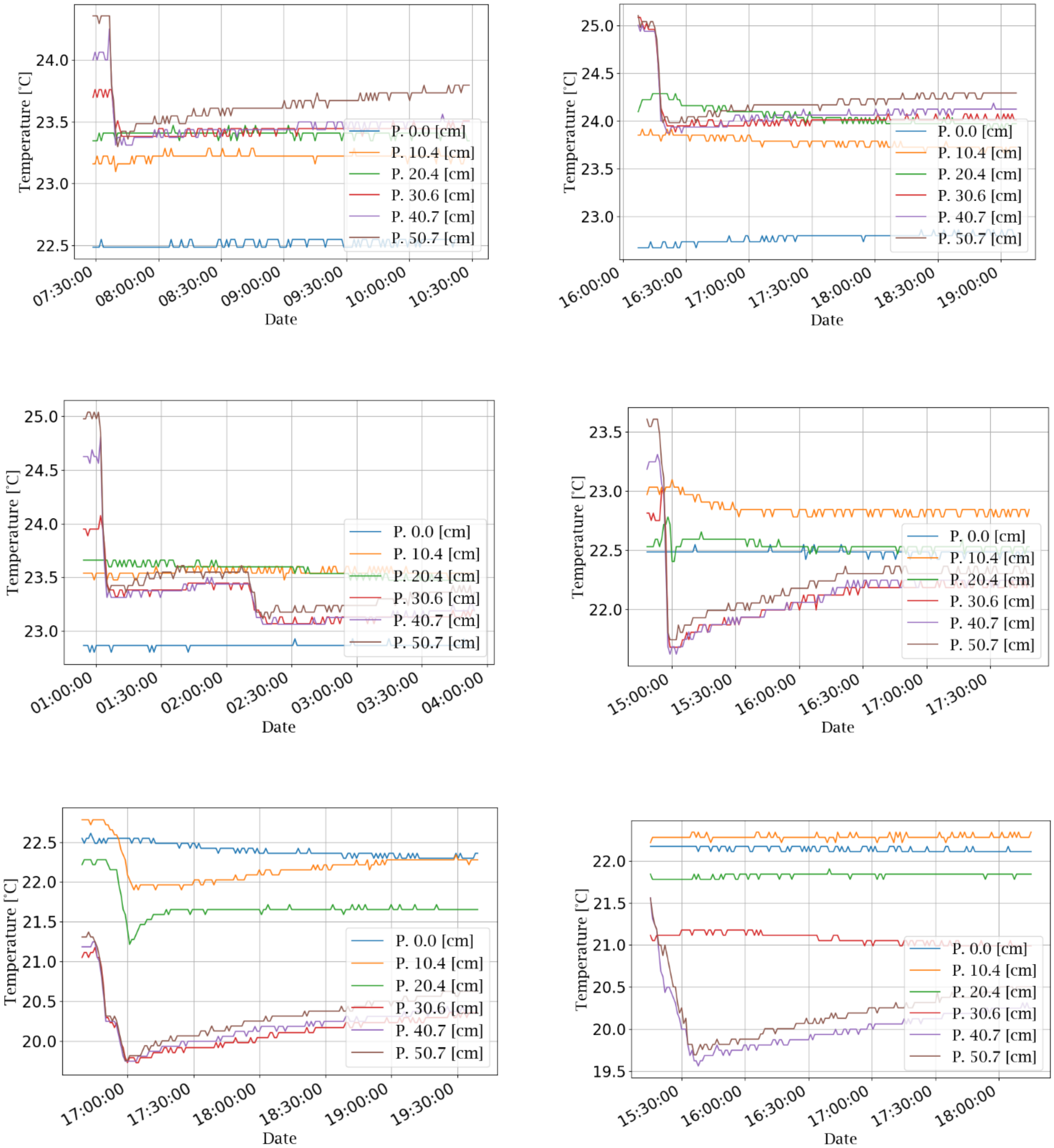

Figure 20. Temperature time series observed in the eawag gully pot at different heights. The lower sensors reacted slowly to the temperature change are inside the sediment, while sensors inside the water react more quickly. All events displayed originate from natural rainfall events.

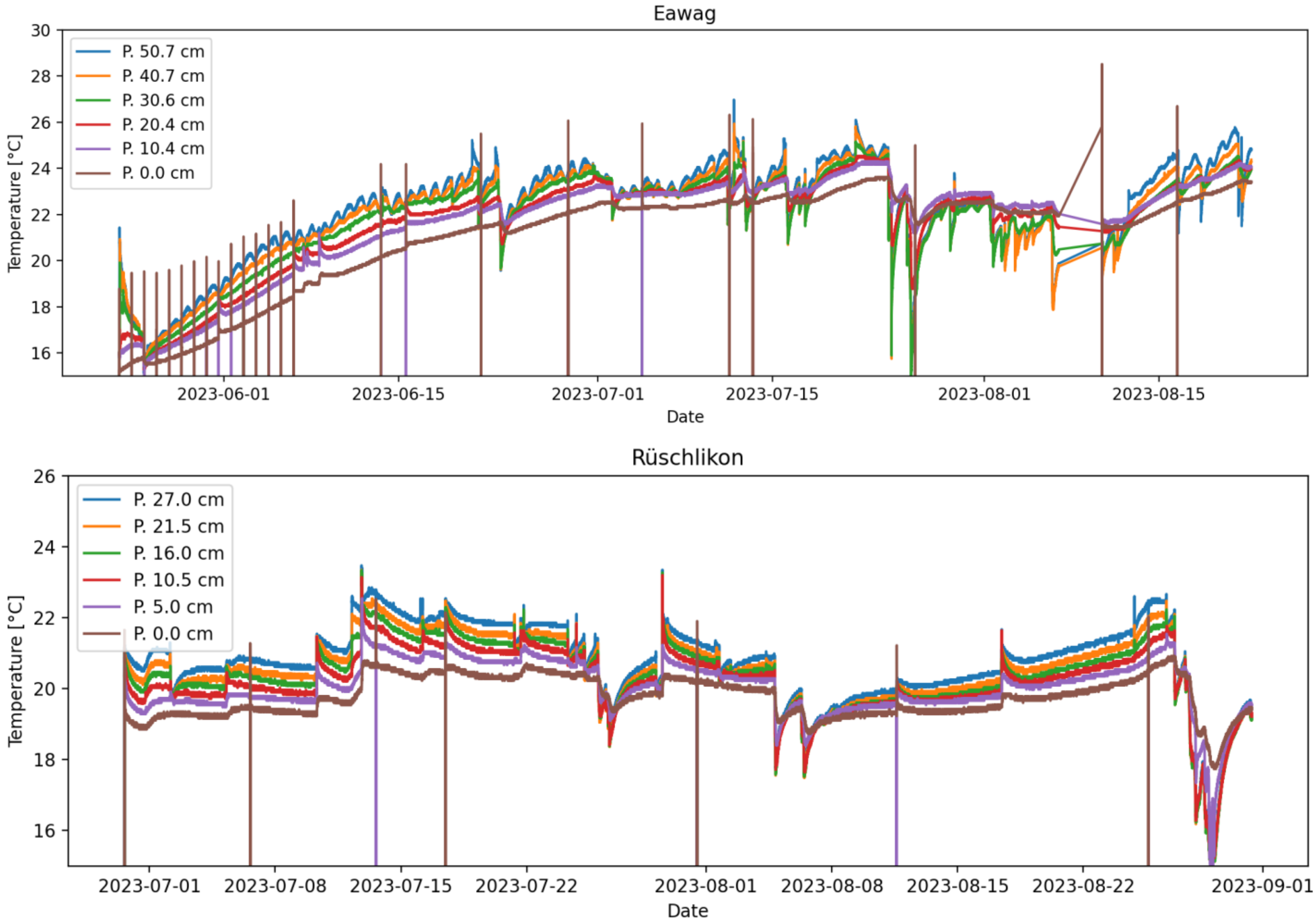

Figure 21. Temperature time series in the gully pot at different heights and locations: Eawag (top) and Rüschlikon (bottom). Sudden drops and straight drops in temperature stem from the active measurement temperature sensors measure a default of -127°C during the duration of the active measurement.

Regarding the code files, two scripts are provided to develop and apply the automated tool, respectively. The automated tool is based on a surrogate model that uses features from the temperature time series during storm events to obtain the sediment depth. The folder that contains the scripts also includes the list of libraries required to run the scripts (*requirements.txt*), and a readme file that describes the inputs and outputs from each script (*codes_readme.txt*).

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9. APPENDICES

9.1. DS18B20 TEMPERATURE SENSOR CALIBRATION

DS18B20 sensors were calibrated by setting 5-step temperatures in the rage of 10-30ºC. For this purpose, the sensors were introduced in a water control system and temperatures were measured for 5 minutes with a time resolution of 1 second. The water temperature was controlled by a Julabo FN25-ME (Julabo, Germany) that set and kept a stable water temperature (stability: ±0.01 °C). Thus, linear regression equations could be obtained by setting the following equation:

$$T_{\text{reference}} = a \cdot T_{\text{raw}} + b$$

where T_{raw} represents raw temperature measurement (ºC), and a and b are the linear regression coefficients of the DS18B20 calibration. a-coefficients showed values close to 1, as expected, while b-coefficients showed slight oscillations in the offset setting. Table 6 represents the regression coefficients of the DS18B20 sensors.

Table 6. Regression coefficients of the DS18B20 sensors.

File name	Sensor ID	a	b
Temp_RawSignal(degC)_Calib_1.csv	28B0F596F0013CD1	1.0052	0.1557
	28645796F0013C79	0.9973	-0.0327
	286E4C96F0013CBA	0.9994	-0.1096

	285E0777910111D8	0.9846	2.6776
	28EF4296F0013CC5	0.9940	0.3074
Temp_RawSignal(degC)_Calib_2.csv	28298396F0013C07	0.9921	-0.3845
	28C5D876E0013CB5	0.9939	0.2101
	28ED2796F0013C68	0.9930	0.4398
	28337096F0013C7B	1.0034	-0.6034
	281B2196F0013C34	0.9910	0.2372
Temp_RawSignal(degC)_Calib_3.csv	28E0085704E13D3B	0.9567	1.1387
	28A44B94970A03BF	0.9963	-0.9657
	28C21A94970103B5	1.0045	-1.4504
	28611694970E0389	0.9943	-1.2957
	28E1395704E13D45	0.9907	0.3994
	2895C15704E13D99	0.9947	0.2897
	28DBCA5704E13D8F	1.0181	-0.6594
Temp_RawSignal(degC)_Calib_4.csv	28DE3194970A0338	1.0043	1.3700
	28E1069497010307	1.0022	-1.3802
	28D5B45704E13D53	1.0049	-0.1535
	28DBCA5704E13D8F	1.0210	-0.7003
	28975294970103A7	1.0025	-1.1589