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► **To cite this version:**

Qingchuan Zhu, Frederic Cherqui, Jean-Luc Bertrand-Krajewski. A low-cost, autonomous, and connected rainfall monitoring station. Novatech 2023, GRAIE, Jul 2023, Lyon, France. hal-04162433

**HAL Id: hal-04162433**

**<https://hal.science/hal-04162433>**

Submitted on 14 Jul 2023

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## A low-cost, autonomous, and connected rainfall monitoring station

### Une station pluviométrique à bas coût, autonome et connectée

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## RÉSUMÉ

Un suivi des précipitations à une échelle spatiale fine dans les zones urbaines permettra d'améliorer la gestion des eaux pluviales et la prévision des inondations urbaines. Cependant, le déploiement à grande échelle de pluviomètres conventionnels est coûteux. Nous proposons dans cette communication de rendre compte de la mise en œuvre de trois stations de mesure des précipitations à bas coût. L'objectif est d'évaluer la performance et la fiabilité de ces instruments en les comparant avec des instruments conventionnels installés sur le même site. Les premiers tests ont montré la capacité des systèmes à fonctionner de manière autonome sur le terrain (avec un mesurage toutes les minutes) et à transmettre les grandeurs mesurées (horodatage, précipitations, tensions de sortie) toutes les cinq minutes.

## ABSTRACT

It is necessary to increase rainfall monitoring spatial distribution in urban areas to improve stormwater management and urban flooding forecast. However, the large-scale deployment of conventional rainfall monitoring instruments is costly. This abstract presents the implementation of three low-cost rainfall monitoring stations. The objective is to evaluate the performance and reliability of these low-cost instruments in comparison with conventional instruments installed on the same site. First tests have shown that the designed systems can operate autonomously in the field (with one measurement every minute) and report measured quantities (time stamp, precipitation, output voltages) every five minutes.

## KEYWORDS

Low-cost instrument, on-site calibration, rain gauge, sensing network, stormwater.

# 1 INTRODUCTION

In recent years, urban flooding is becoming a growing concern. Floods in Zhengzhou City, China on July 20, 2021, caused great loss of life and property (Wang *et al.*, 2021). High spatial and temporal resolution rainfall monitoring is a prerequisite for stormwater management and urban flooding forecast. However, the large size and high price of conventional rainfall monitoring instruments hinders the implementation of ubiquitous rainfall monitoring. Thanks to developments in the fields of open-source hardware, wireless communication technology and low-cost sensors, a promising paradigm for large scale soil, air and water monitoring appeared (Valente *et al.*, 2020). Using this paradigm to rainfall monitoring field (Verbeiren *et al.*, 2020), we designed an autonomous miniaturized low-cost rainfall monitoring station and test three of them in the field.

# 2 MATERIAL AND METHODS

## 2.1 Hardware

After initial tests, we choose the following modules to build our low-cost rainfall monitoring station. Their names, functions and approximate prices are given in Table 1. The designed rainfall monitoring station is able to work on the long term with solar energy. The whole station costs less than 200 € including two different rain gauge systems, SD card, solar panel and LiPo battery. It has a surface smaller than 2 square decimetres.

Table 1. Modules used in the low-cost rainfall monitoring station.

Module name	Function	Approximate price
Arduino MKR WAN 1310	Main control board and communication	~ 30 €
Arduino MKR Mem Shield	Save data in SD card	~ 20 €
DS3231	Real time clock	~ 5 €
LiPo Rider Pro	Operate solar panel and LiPo battery, power the system	~ 15 €
RG-15	Low-cost optical rain gauge	~ 80 €
WH-SP-RG	Low-cost tipping bucket rain gauge	~ 20 €

## 2.2 Software

Operating codes are written in Arduino IDE language (close to C++). The software flow chart is shown in Figure 1.

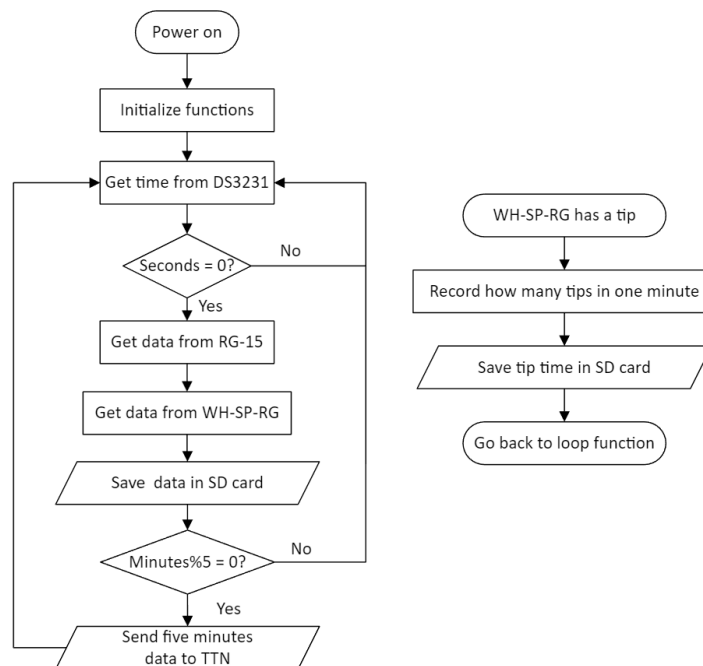


Figure 1. Software flow chart: main loop (left), interrupt function (right).

### 2.3 Site

The experimental site is the GROOF (Green ROOF experimental Facility) platform at INSA Lyon. Figure 2 shows the three same stations and the reference tipping bucket rain gauge installed on the GROOF platform.



Figure 2. Low-cost rainfall monitoring stations installed on the GROOF platform.

### 3 RESULTS AND DISCUSSION

During the first one month in field test, the designed system was able to operate autonomously and to report measured quantities (time stamp, precipitation, output voltages of battery and solar panel) every five minutes. Cumulative rainfall depth reported by i) the reference tipping bucket rain gauge, ii) three low-cost tipping bucket rain gauges, and iii) three low-cost optical rain gauges are shown in figure 3 and figure 4, for the first month of operating.

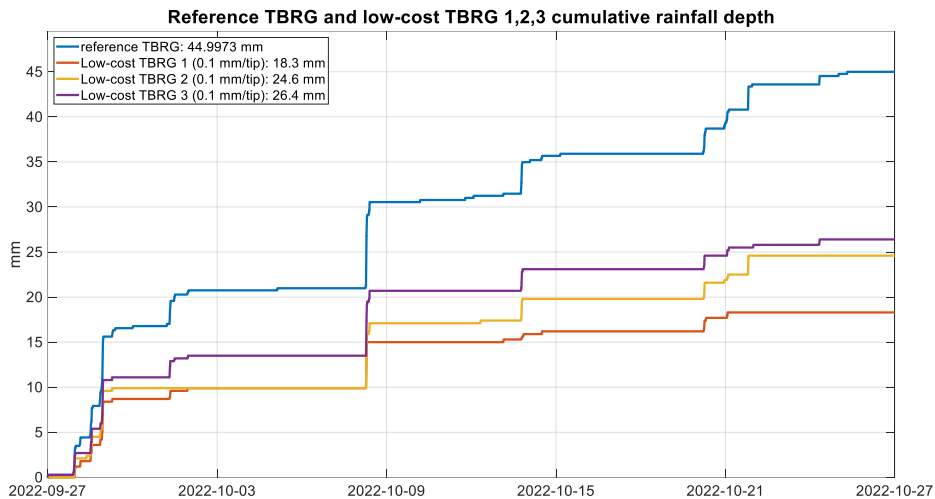


Figure 3. Cumulative rainfall depth reported by the reference Tipping Bucket Rain Gauge (TBRG) and low-cost tipping bucket rain gauges No. 1, 2, 3 from 27 September to 27 October 2022.

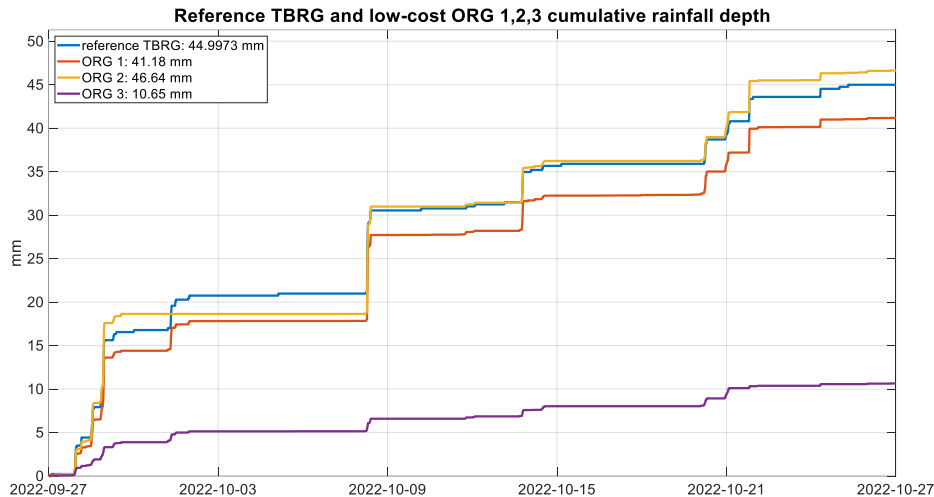


Figure 4. Cumulative rainfall depth reported by the reference Tipping Bucket Rain Gauge (TBRG) and low-cost Optical Rain Gauges (ORG) No. 1, 2, 3 from 27 September to 27 October 2022.

The three low-cost tipping bucket rain gauges WH-SP-RG have systematically underestimated rainfall intensities; dynamic calibration will be conducted to correct this bias. The three low-cost optical rain gauges RG-15 exhibit poor reproducibility. It should be noted that ORG No. 3 was purchased later than ORG No. 1 and No. 2, and we are suspecting a different firmware or a different internal setup (we have contacted the manufacturer but have not received any answer yet). We are presenting very preliminary results corresponding to a limited number of rain events. Additional months of monitoring will allow a deeper assessment and more robust conclusions for the Novatech conference.

## 4 CONCLUSION

We developed an autonomous miniaturized low-cost rainfall monitoring station and began to test three of them in field. These stations can run autonomously, are small, affordable, and are “self-monitored” as the user can check online data in near real-time (including battery voltage). The installation of a solar panel is expected to significantly increase the battery life; however, the test hasn’t been yet performed during winter in Lyon. All these features make it suitable to deploy in ubiquitous rainfall sensing networks. The evaluation and qualification of the low-cost rainfall monitoring station is planned over a minimum duration of one full year, with comparison with the data of other traditional rain gauges of the GROOF platform. Such an evaluation will help to better characterise the performance of the sensors and possibly improve the existing setup.

## ACKNOWLEDGMENT

This research received financial support from Melbourne Water, through the Melbourne Waterway Research-Practice Partnership (<http://mwrpp.org>), from the European Union's Horizon 2020 research and innovation programme under Grant Agreement no. 786566 (<https://mind4stormwater.org>), and from the Rhône Méditerranée Corse Water Management Agency under the Cheap'Eau project. This research was performed within the framework of the OTHU (Field Observatory for Urban Water Management) and the EUR H2O'Lyon (ANR-17-EURE-0018). The PhD thesis of Qingchuan Zhu is funded by the China Scholarship Council (contract 201806560056).

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