Interactive comment on "Performance of post-processing algorithms for rainfall intensity measurements of tipping-bucket rain gauges" by M. Stagnaro et al. (Reply to Referee #1).

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Let us first thank Reviewer #1 for his/her constructive comments and the careful scrutiny of our paper that certainly improved the quality of our manuscript. Below we provide a point-by-point reply to the issues raised in the review (here reported in bold), while in a separate comment, a revised version of the manuscript is presented.

The title could be "Performance of post-processing algorithms for rainfall intensity using measurements of tipping-bucket rain gauges? or "Performance of post-processing algorithms for rainfall intensity using measurements of observation system with tipping-bucket rain gauges" because TBRGs measure the amount of rain (precipitation liquid) and determination of RI is calculated using a system (software).

We accepted the reviewer suggestion and changed the title as follow:

"Performance of post-processing algorithms for rainfall intensity using measurements from tipping-bucket rain gauges."

In the "1 Introduction" section: - a) it is interesting to describe the term "measurement uncertainty" according to the VIM (International Vocabulary of Metrology - Basic and General Concepts and Associated Terms).

In accordance to the reviewer, we describe the term "measurement uncertainty", following the VIM (JCGM, 2012) definition, in the introduction of the revised version of the manuscript.

In the "2 Field site and instrumentation" section: - a) page 2, line 25 include a better description of the OSK, such as operating principle (optical), technical characteristics (catchment area, accuracy of measurement, nominal uncertainty, etc.) and the calibration date (corrections, expanded uncertainty, coverage factor, confidence level, etc.);

As the referee pointed out, the operating principle of OSK is optical, this has been clarify in the text.

Concerning the technical characteristics, the catching area is already reported in Table 1 (expressed by the funnel diameter). In this table, we added the values of measurement accuracy for the OSK and the two TBRGs.

Regarding the calibration of the OSK, we now indicate the uncertainty of the drop volume, which is declared as 63.93 ± 1.9 mm^3 (in the range from 10 to 120 mmh^{-1}), which translates into a rainfall depth sensitivity of 5.21 $\pm 0.15 \cdot 10^{-3}$ mm.

b) page 2, line 32, in Table 1, include more information on the manufacturers' specifications (catchment area, accuracy of measurement, nominal uncertainty - if provided, etc.);

The information about the collector's area was already present in Table 1 (expressed as the diameter of the instrument funnel) and we added in Table 1 the measurement accuracy of the TBRGs as provided by the manufacturers. No further information is available from the manufacturers.

c) page 3, describe the installation of rain gauges (height, distance between them, obstacles, etc.). These factors may be relevant sources of uncertainty of measurements. If possible include figure of site

We included in this section a description of the field test site and a drawing where the position of the three instruments is highlighted, as follows:

" *The three instruments have been placed in the west corner of the field test site of the Hong Kong Observatory (depicted in Fig. 1). Both the TBRGs and the OSK drop counter have been installed on the ground. The minimum distance from the main obstacle close to the instruments is about 18 m. From Fig. 1 it is possible to observe the position of the SL3 (blue box), LGO (red box) and the OSK (green box); the distance between the SL3 and the OSK is about 5.8* m*, while the LGO is located at about 2.1* m *south of the OSK.*"

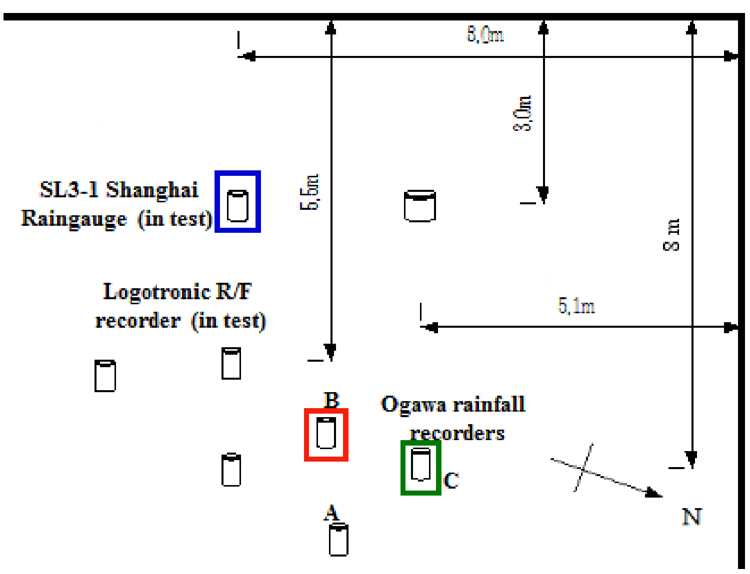

Figure 1. The West corner of the Hong Kong Observatory field test site where the SL3 (blue box), the LGO (red box) and the OSK (green box) are located. The distance of each instrument from the field site borders is indicated.

d) page 3, describe the complete system from the rain gauge (measurement) until the final data. The TBRGs measures the amount of rain, it means that there is a data acquisition system for storing the tips and timestamp (hh:mm:ss) and a system for calculating the RI. How the RI was obtained (datalogger, software)?;

For the TBRGs, each instrument is simply connected with a data-logger and the timestamp is recorded whenever a tip occurs. Regarding the OSK drop counter the data-logger records the number of detected drops every 10 seconds. The timestamps are stored in the form “yyyy-mm-dd HH:MM:SS.000". For this study, the RI is calculated via software starting from the timestamps recorded by the data-logger.

e) page 3, was calibration performed for the complete system (sensors and data acquisition system or only sensors)? The datalogger’s contribution may be insignificant, but what is the uncertainty of the datalogger in the time record (timestamp)? Describe uncertainty or accuracy of datalogger. It may be important to one of the algorithms;

The calibration was performed only for the sensors and not for the data-logger. The sensitivity pf the data-logger is 1/1000 s, while the associated uncertainty is unknown. The uncertainty of the data-logger is not expected to influence the results significantly.

f) page 3, report data from the "Calibration Certificate" / calibration (correction, uncertainty, etc.) of all sensors and range. Instruments with different measuring principles produce different results, but compatible in most cases (statistically equal), depending on their measurement uncertainties;

Calibration was performed for all the instruments. For the OSK drop counter the drop volume has been provided to indicate the precision level of the instrument. For TBRGs a power law correction curve has been applied to the dataset of each instruments. Since the aim of this work consists in comparing the use of two RI algorithms, we have not indicated the parameters of those curves and we have not shown the beneficial effects derived from adopting the correction curves.

g) abbreviations or acronyms used in figures should be explained in the legend (see figure 2 and review all figures).

Indeed, there were inconsistencies in the use of some acronyms and abbreviations in the submitted manuscript. We checked the text to fix it, and the legend of each figure has been also checked in order to avoid any unexplained terminology.

In the "3 Method" section: - a) review all acronyms, for example RI_{ref} and not RI_ref, RI_{raw} and not RI_raw, etc, including the graphics and legends of graphics and figures (see the "Manuscript composition" of Manuscript preparation guidelines for authors of AMT);

Acronyms have been checked throughout the manuscript, including captions and legends of each figure, according to the "Manuscript composition" guidelines of AMT.

b) use the same acronym for reference (DC or OSK or REF?) in the text, graphics and the chart legends, as well as other sensors;

We checked the manuscript and changed the dual acronyms for all the sensors in the revised version of the manuscript.

c) Figure legends should clarify all the symbols used and should appear in the figure (see the "Manuscript composition" of Manuscript preparation guidelines for authors of AMT);

Following the referee comment, the legends of the figures have been verified and modified in order to explain all the symbols used.

d) Use the term uncertainty, as described in VIM;

We rephrased using the term *inaccuracies* rather than *uncertainty* since it seems more appropriate in the context of this sentence.

e) Describe all terms used in the formulas, for example RI$_n$ (and which values for n?, review all formulas);

We clarified in the revised version of the manuscript the terms used in the mentioned equation.

Regarding the terms RI_n, the subscript “n” indicates a “standardized” value of the one-minute rainfall intensity variable, regardless of the instrument and the algorithm used.

f) page 4, equations should be referred to in the text according to the Manuscript preparation guidelines for authors of AMT;

All equation references have been corrected following the Manuscript preparation guidelines.

g) What were the computational tools (language, software, operating system) used to run programs (algorithms under study) and how RI is calculated using the TBRG LGO, SL3 and OSK/REF?

The software used to manage data was developed by the authors using Matlab codes in the MS Windows operating system. The one-minute values for RI are calculated starting from the timestamp of the tips of the TBRGs and the drop frequency for the OSK. The calculation for the OSK consists in a simple count of droplets falling in each minute. Regarding the TBRGs, for the tip-counting algorithm the calculation of RI consists in a simple count of tips for each minutes, while for the inter-tip algorithm the one-minute RI values have been calculated performing a weighted average of the inter-tip RIs falling in the same minute.

In the "4 Results" section: - a) page 5, the TBRG measures the amount (tips) of rain. The limit is the limit of the system that calculates the RI;

We adjusted the text accordingly in order to separate the effect of the RI calculation method from the gauge characteristics.

b) and how the propagation of uncertainty for calibration of the sensors was treated in the results? It is interesting to express "the measure $\pm$ uncertainty" for each rain gauge;

The propagation of the calibration uncertainty was not considered in the results. The objective of this paper is not to investigate the sources of uncertainty and their contribution, but rather to compare two different RI calculation methods by using field measurements. We added a simple comment to section 4, when commenting Figure 5, to clarify this point.

c) due to the graphic resolution; it is interesting to show used clearer in the chart when the exception occurs;

We highlight in the graphs the limit of 6 mmh^{-1} where the behaviors of the algorithms change.

d) the abbreviation "Fig." should be when it appears in running text and should be followed by a number unless it comes at the beginning of a sentence, e.g.: "The results are depicted in Fig. 5. Figure 9 reveals that..." (see the "Manuscript composition" of Manuscript preparation guidelines for authors of AMT);

We modified the abbreviation of the figure in the text of the revised version of the manuscript according to the AMT guidelines.

e) The TBRi(Ttip) acronym is not commented in the text and in the figure legend;

The terms SL3, LGO and TBR_i indicate the three tipping bucket instruments here considered (the Shanghai SL3-1, the Logotronic and the synthetic/ideal TBRG respectively). The subscript indicates the algorithm used to obtain the RI values from the TBRG’s data. The subscript “Ttip” denotes the use of the inter-tip algorithm, while the “raw” subscript is employed to denote the use of the tip counting algorithm. This point is now clarified in the legend of the figures and in the text of the revised manuscript.

f) page 5, line 21, list the figure of this paragraph;

This paragraph still refers to Fig. 4 (Fig. 5 in the revised version of the manuscript) like the previous one. Explicit reference is now added in the revised text.

g) improve the Y axis scale of graphic of figure 5 (review all scales of all graphics).

The scale of the Y axis (for both Figure 4 and 5) has been limited to [-100%, 100%] to allow appreciating both the large variability of the results below 6 $\mathrm{mm h^{-1}}$ and the changes above that value, even with some boxplots actually exceeding this range. A larger scale would compromise the readability of the second part of the graph.

In the "5 Conclusions" section: - a) page 6, line 31, cite examples of sources of uncertainties in field operation;

In field operation, instruments are subject to environmental factors like wind-induced effects or the presence of particles in the atmosphere and in the rainwater. Wind-induced effects can lead to an underestimation of the rain amount, which is composed by a systematic bias and an unknown uncertainty. A few examples are now cited in the concluding section.

b) rewrite the paragraph to make the text clearer, once the rain intensity is calculated from the measured rain (tips) made by TBRGs and time resolution used is theusually 1 minute, but other time resolutions may be chosen. Make it clear when compare results obtained by different forms of RI calculations.

In this study, we considered only the time resolution of one minute (as recommended by the WMO) for the calculation of the RI, for both the inter-tip and the tip-counting algorithms. A sensitivity analysis on the time resolution of the RI output would be of interest as well, although it is beyond the scope of the present paper.

References

JCGM: International vocabulary of metrology - Basic and general concept and associated terms (VIM), Joint Committee for Guidelines in Metrology, 3rd edn., 2012.