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Short Contribution

On the correction of processed historical rainfall data of siphoned rainfall recorders

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Abstract— Historical rainfall data registered by siphoned rainfall recorder (SRW) devices have been widely used for a long time in rainfall intensity investigations. A relatively known counting error of the SRW devices is the siphoning error, when the registration of rainfall is blocked temporarily, during the drainage of measure tank. This issue causes a systematic underestimation in the rainfall and rainfall intensity measurement results. To reduce its consequences, a data correction is crucial when SRW data are used, for example as a reference for climate comparison studies, or for proceeding of intensity-duration-frequency curves, etc. In this paper, a formula is presented to fix the siphonage error of SRW devices for historical rainfall data. The early measures were processed in a significant percentage of cases, and sometimes the original measurement results (registration ribbon) have been lost. An essential advantage of the presented formula is that it can be applied for these processed data, which show only the intensity of a known length time interval. For this correction, the average rainfall intensity and the length of the time window are needed, over the physical parameters of the SRW device. The data correction can provide a fixed value of the rainfall intensity, which is undoubtedly closer to the real average rainfall intensity. The importance of this formula is in the reprocessing and validation of the historical rainfall intensity data, measured by siphoned rainfall recorders.

Key-words: historical rainfall data, siphoned rainfall recorder, rainfall intensity, data correction, siphoning issue

1. Introduction

The rainfall intensity measurement has particular importance in several fields of sciences. The measurement of the rainfall intensity has a 300-year-long history

(*Kurytka*, 1953). There are several arrangements and devices which were used to measure and register this parameter for scientific, and mainly for engineering applications. One of the most widely used instruments for this aim is the siphoned rainfall recorder (SRW), which has been used mostly in the first two-thirds of the 20th century, and there are several devices in use even nowadays. Some old shops produce these instruments, and there are new producers, as well (e.g., Dr. Alfred Müller MI KG, Theodor Friedrichs Atelier). Some of these kinds of devices were electrified, using sensors and data loggers to ensure the further use of these instruments in the future in a simpler way. There was a widely spread opinion about the excellent accuracy and reliability of these instruments; however, the accuracy issues during the most intensive part of showers, induced by a break during the siphonage were well known. Kallós investigated these errors in the Hungarian practice in the 1950s (*Kallós,* 1955), who had a proposal to fix this kind of error on the base of the registration ribbon. A similar proposal was given by Luyckx and Berlamont, on the base of a theoretical approach and laboratory measurements (*Luyckx* and *Berlamont*, 2002). The suggestion of Luyckx and Berlamont, similarly to the result of Kallós, is related to the correction of the registration ribbons of the SRWs. They have presented the relative error of the SRW devices, which has the same magnitude as the tipping bucket rainfall recorders. However, the method of Luyckx and Berlamont is a simple and handful tool for the data correction of continuously registered data, and its use is limited to the repair of the complete registration ribbon.

However, rather often the registration ribbons cannot be available anymore; there are only the processed data of characteristic rainfall intensity values of unique showers. This kind of processing has resulted in the highest intensities of some time window, for example, the maximum intensities of the 5-10-20-30-60 minutes long time intervals. In these cases, the previously mentioned correction methods cannot be used, since the instantaneous rainfall intensity is unknown, but it still would be necessary to correct the effect of siphonage error, at least approximately. The correction of this issue is important, since the relation of the rainfall intensities in the past in a given geographical site can be determined only on the base of these historical data. In this paper, a method is presented to approach this issue and to fix the early, processed rainfall intensity data for the use of the hydrologists of our age.

2. Methods

The method of *Luyckx* and *Berlamont* (2002) is based on the determination of the time of siphoning during the rainfall, and the realistic volume of rainwater can be calculated using the added siphoning time. As the real volume is available, the real rainfall intensity can be recalculated and determined. As the error is a systematic undercatch, the fixed intensity is always higher than those, which were determined on the base of the registration ribbon. For this method, the instantaneous intensity is needed at the siphoning period, over the technical parameters of the SRW, as the siphonage rate and the catching surface of the funnel.

This method can be extended to longer time windows only with the average rainfall intensity, without knowing the internal raw data of the time interval. In this paper, a correction method for time windows of any lengths is presented. The proposed method is an approach, which helps to get the data closer to the realistic rainfall intensity values. The correctness of the proposed formula will be shown.

3. Results and discussion

3.1. The correction method for rainfall intensities of a t time interval

A rainfall event can be divided into various time intervals, and these intervals can be characterized by rainfall intensity. In a *t* time interval, the value of the rainfall intensity is i_t. The V_t volume of the fallen rain measured by the instrument during this period is

$$V_t = t \times i_t. \quad (1)$$

During these time windows, one or more siphonage can occur if the fallen rainfall depth reaches the width of the registration ribbon at least once. The number of siphonage during the *t* time window is the integer part of the quotient of the volume of the fallen rainfall expressed in depth over a unique surface. The recording limit of the device is expressed in rainfall depth, as well. The recording limit is practically the maximum depth of the rainfall which can be drawn on the ribbon, after which the siphonage must happen, and the drawing of the rainfall depths can be continued from the base edge of the paper. The recording limit value in practice is 10–15 mm rain depth, depending on the type of device. So, *n* can be calculated with the following formula:

$$n = int\left(\frac{V_t}{h_s}\right) = int\left(\frac{t \times i_t}{h_s}\right), \quad (2)$$

where *n* is the average repetition number of the siphonage during the *t* interval, h_s is the recording limit of the SRW device.

The duration of siphoning is an essential parameter of the instruments since, during its drainage, the measurement is suspended. The length of the siphonage period depends on the technical parameters of the device and the actual rainfall supply. The duration of the siphonage is a constant technical parameter of the device, in the magnitude of 10-30 seconds. Another key parameter is the siphonage rate of the device; it is in relation to the siphonage time and the volume of the receiving tank of the SRW instrument. The drainage rate is a known technical parameter, as well. If there is no rainfall supply, a base value of the siphonage rate can be gained. If there is a rain replenishment, the siphonage period must be longer. If the rainfall intensity would be equal to the base value of the siphonage rate, the rainwater could flow through the gauge without being measured. Still, of course, the siphonage rate chosen by the producers is high enough to avoid this situation. During the rainfall supply, the time of siphonage can be calculated by the following formula, according to *Luyckx* and *Berlamont* (2002):

$$t_s = \frac{t_{s,0}}{1-\frac{q}{q_s}}\,, \tag{3}$$

where t_s – the length of a unique siphonage period, $t_{s,0}$ is the length of the emptying of the device, if there is no water collected during the siphoning, q is the rate of the rainfall, and q_s is the rate of the siphonage.

In a time window, more siphoning periods can occur. For the time window, only the i_t average rainfall intensity is known. The $t_{s,tot}$ total siphonage time during the *t* time window, supposing that the rainfall intensity, so the rate of the rainfall is constant and equal to its average value is

$$t_{s,tot} = n \times t_s\,. \tag{4}$$

The V_s rainfall volume, which falls during the siphonage and has not been measured can be calculated as

$$V_s = t_{s,tot} \times i_t\,. \tag{5}$$

The V_{corr} corrected volume of the rainfall is the sum of V_t measured volume and V_s calculated unmeasured volume, which seems to be collected during a more extended period than *t*; but this means only that over the incompletely collected rainfall, there is an amount of rainwater to be added to the registered volume. So, the corrected volume is

$$V_{corr} = V_t + V_s = \left(t + t_{s,tot}\right) i_t\,. \tag{6}$$

In reality, the volume V_{corr} of rainfall falls in *t* time, so the $i_{t,corr}$ corrected rainfall intensity in the *t* interval is

$$i_{t,corr} = \frac{V_{corr}}{t}\,. \tag{7}$$

The rainfall rate is the discharge of rainwater which flows down from the funnel of the gauge during the measurement. The rainfall rate can be written as

$$q = A_f \times i_t, \tag{8}$$

where A_f is the area of the catching surface of the gauge.

The unified formula of the correction can be the following:

$$i_{corr} = \frac{\left(t + int\left(\frac{t \times i_t}{h_s}\right)\left(\frac{t_{s,0}}{1-\frac{A_f \times i_t}{q_s}}\right)\right)}{t} \times i_t\ . \tag{9}$$

3.2. Verification of accuracy

The confirmation of the proposed method is presented with a comparison to the result of the series of unique corrections of the siphoning issue. This process is practically the core of the data fixing procedure of Luyckx and Berlamont, using it for a series of siphoning in a given *t* time interval. In the followings, this comparison is going to be presented.

The core of the correction part is the time of siphonage, t_{corr}, when the measurement is suspended. In Eq. (9) is the second part of the expression between the brackets:

$$t_{corr} = int\left(\frac{t \times i_t}{h_s}\right)\left(\frac{t_{s,0}}{1-\frac{A_f \times i_t}{q_s}}\right). \tag{11}$$

For the verification, the series of unique corrections must be inspected. The correction part of the siphonage error of a unique siphonage can be expressed as

$$t_{u,corr} = \left(\frac{t_{s,0}}{1-\frac{A_f \times i_u}{q_s}}\right), \tag{12}$$

where i_u is the instantaneous rainfall intensity at the period of a unique siphonage.

The total siphonage error in a particular *t* time interval when *n* siphonages occur is

$$t_{\sum u,corr} = \sum_{j=1}^{n}\left(\frac{t_{s,0}}{1-\frac{A_f \times i_{u,j}}{q_s}}\right) . \qquad (13)$$

The question is whether or not Eq. (11) converges to Eq. (13). The simplification of the Eq. (11) for the proposed method results in the following:

$$t_{corr} = t_{s,0} \times q_s \times int\left(\frac{t \times i_t}{h_s}\right)\left(\frac{1}{q_s - A_f \times i_t}\right) \sim int\left(\frac{t \times i_t}{h_s}\right)\left(\frac{1}{q_s - A_f \times i_t}\right). \qquad (14)$$

After making a similar transformation on Eq. (13), the result is

$$t_{\sum u,corr} = t_{s,0} \times q_s \sum_{j=1}^{n}\left(\frac{1}{q_s - A_f \times i_{u,j}}\right) \sim \sum_{j=1}^{n}\left(\frac{1}{q_s - A_f \times i_{u,j}}\right). \qquad (15)$$

The value of rainfall intensity i_t is the time average of the increment of caught rainfall volume in t time, meanwhile $i_{u,j}$ are instantly measured intensities at the siphoning processes in the same t time window. However, the $i_{u,j}$ intensities are unique intensities of the same rainfall; their averages are not similar to the i_t , these averages can differ a lot theoretically. The occurrence of $i_{u,j}$ values has a sampling character; after the first siphoning in the interval, the emptying – and so the sampling – happens regularly, catching a certain volume of rainwater. This sampling character ensures that for a long period and/or shorter siphoning periods, the average of unique intensities must approach the calculated average intensities. Of course, a unique intensity value during the siphoning process always differs from the average intensity of the correction, notwithstanding, the correction provides a good approximation for its value. In a hypothetical case, if there would be infinite numbers of siphoning during the time window, the average of the unique intensities must be equal to the calculated average intensity.

In reality, as the time windows showing the highest intensities always occur at the supremum or local suprema of the rainfall, the peak of the intensity is somewhere in the middle of the interval. A significant difference between the two averages could occur, if there would be an incredibly high and narrow peak of rainfall depth in the time window between two siphoning, but, despite the high variability of the temporal rainfall intensities, this situation is not likely at all. On the basis of this consideration, the i_t and the average of $i_{u,j}$ intensities might be close enough to each other, and this means that the proposed approach is a reasonable estimation of the reality.

4. Conclusion

The presented method is a simple tool for the correction of the earlier measured rainfall intensity data of siphoning rainfall recorders, where the original data are not available, and only some intensities can be found for known time intervals. The method can fix the main systematic error of these devices. For the procedure of the correction, the hydraulic characteristics of the device are needed, as the catching surface of the funnel and the siphoning rate of the instrument's discharging system. The accuracy of the correction was presented over some extreme theoretical cases, and the corrected intensity data approach the results efficiently based on a correction executed uniquely by the siphoning occurrences. This method helps to clear the historical databases to make them a better reference for the investigation of the climate change, relating to the rainfall intensities.

The proposed correction does not solve the other significant source of error of rainfall measurements the windfield deformation, which demands a solution to ensure a real accuracy of the collected data. This kind of error would have particular importance in the future.

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