Storm Properties: Literature Review

Khalid BARKOUKI, Ilias KACIMI, Najat SERHIR

Abstract: To decide on the necessary elements in the analysis of storms properties, a review of literatures was detailed for the parameters used worldwide. Several studies in North and South America, Asia, Europe and Africa were consulted. The analysis of the bibliographic references shows different definitions of a storm. Moreover, before analyzing the instantaneous rainfall, it is relevant to define the elements allowing the separation and the analysis of storms. The analysis of storms concerns generally the minimum inter-event time (MIET), storms duration and storms depth. Storms can be also classified according to their quartiles. The definition and choice of storms to be analyzed must take into account the predefined objectives, the data available and the time allocated to the data processing.

Index Terms: Instant rainfall, minimum inter-event time (MIET), quartiles, storm definition, storm depth, storm duration, synthetics storm.

1 INTRODUCTION

The analysis of instant rainfall characteristics is very important in hydrological and climatic studies. Indeed, instant rainfall hyetographs are crucial in water storm management (Pan et al. 2017). It constitutes a very important input of hydrological models (Awadallah and Elsayed 2017). Strom analysis can also be used in soil erosion studies ((Haile et al. 2011), (Chen et al. 2015)). To analyze the characteristics of instant rainfall, storm analysis is a practical method commonly used (G.Brown, W.Katz, and H.Murphy 1985). The analysis of the bibliographic references shows different definitions of a storm. These definitions generally depend on the available data used, the objectives of the studies carried out and the time allocated to data processing. Moreover, rainfall is represented by a hyetograph, which is the temporal distribution of precipitation recorded in a point or area for a duration of a precipitation. The analysis of the statistical characteristics of the observed hyetographs allows an understanding of the temporal distributions of rain (William Harold Asquith 2003). Thus, before analyzing the instantaneous rainfall, it is relevant to define the elements allowing the separation of storms. It is a question of determining the parameters used worldwide by referring to the publications in relation with the subject of research. Nevertheless, the choice of parameters is not always dictated by previously fixed criteria but depends also on the best management practices (William H. Asquith et al. 2006). Indeed, for example, the analysis of hydraulics structures operations is not based only on the characteristics of storms but also on the characteristics of the structure as well. For example, for a detention pond, there are the detention capacity, the drawdown time, etc. Thus, the choice of the MIET also depends on the available detention capacity and the drawdown time adopted by the manager of the detention pond.

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2 STORM DEFINITION

The definition of a storm is a prerequisite before trying out the analysis of instant rainfall (Yen and Chow 1983). The main definitions adopted by the researchers are as follows:
A storm is a continuous rain that may contain dry periods of less than a specified duration ((A.Huff 1990),(G.Brown, W.Katz, and H.Murphy 1985)).

1. This definition is very practical and it is the most adopted in the research analyzing the storms, especially for the development of synthetic rainfall distribution like Huff curves.
2. A storm is a rain defined from a minimum duration separing two successive rains with a non-significant correlation (Güntner et al. 2001). The minimum duration can be established through an autocorrelation analysis of rainfall data (Ceressetti 2011). Nevertheless, it is difficult to identify independent storms for precipitation from several successive events (Joo et al. 2014). This independence may be related to the response of the studied watershed. Two storms are therefore independent if the effects of the first stop before the beginning of the second (Jean-Luc Bertrand- Krajewski 2007). The application of this definition requires a thorough comparison of rainfall and hydrometric data in the study area.
3. A storm is a rainfall exceeding a given threshold within a specified period of time (J.Keifer and Chu 1958). It may involve part of a continuous rain event. This is the principle adopted in the treatment of storms according to the Chicago method. The use of this definition leads to the adoption of some truncated storms.
4. A storm is a rain that comes from the same cloud group moving as a single unit even if there are dry periods. Physically, this definition is the most desirable (Yen and Chow 1983). However, we thought that this definition is as difficult as impossible to implement, in the event of missing any spatialized data.
5. A storm is a continuous rain whose definition depends on the time step (Δt) of precipitation recording. Thus, if there is a cessation of precipitation for less than Δt, the two episodes of successive precipitation are considered as a single storm (Yen and Chow 1983). This method was used for rains recorded with an hour time step or more (Yen and Chow 1983). We suppose that this definition becomes less used because of the small-time step recordings of the modern automatic rain gauges.

These definitions have been classified from the most used to the least used in studies and researches related to the treatment of instantaneous rainfall. The storms defined does not necessarily correspond to a meteorological reality and contain a part of arbitrariness ((Jean-Luc Bertrand- Krajewski 2007). The definition of rainy events must take into account the needs for the use of the processed data (Y. Guo and Adams 1998).

In the following paragraphs, we adopt the first definition which is very practical by detailing the parameters allowing its good application. This choice is also justified by:

1. The final objective of our research work which concerns the development of synthetics storm patterns, specifics to the Moroccan context, like Huff curves, SCS curves, etc. It will be the subject of future publications.
2. The basic data available, in Moroccan context, which are instantaneous rain recorded, with a time step of 5 minutes, at the automatic rain gauges.

3 CRITERIA FOR SELECTION AND CLASSIFICATION OF STORMS

Before starting the analysis of the properties of storms, it is essential to define the criteria of storms selection.

The extraction and classification of storms is based generally on the ((Haile et al. 2011),(Terranova and Iaquinta 2011),(William H. Asquith et al. 2006) (S. Wu, Yang, and Tung 2006)):

1. Minimum inter-event time (MIET) or the dry period (no rain)
2. Storm depth or minimum depth of rain;
3. Storm duration;
4. Storm quartiles.

The following paragraphs define these elements.

3.1 Minimum Inter-Event Time (MIET)

Rainfall records describe rainy sequences and dry sequences. Increasing the duration of the dry period makes it possible to differentiate between distinct storms according to a specific minimum duration (William H. Asquith et al. 2006). It is the minimum duration between storms or the minimum inter-event time (Fig. 1). The definition of the minimum inter-event time is a very important step for the identification of storms. Incorrect identification will impact the statistical results obtained and the analysis performed (Joo et al. 2014). Some researchers have chosen a fixed minimum duration between storms. Values of 2 hours ((Powell et al. 2007), (S. J. Wu, Yang, and Tung 2006)), 6 hours ((Terranova and Gariano 2014),(Y. Guo and Adams 1998) ,(A.Huff 1990)), 24 hours (Vandenberghe et al. 2010) have been adopted by some researchers. Other values can be found in the literature (Dolšak, Bezak, and Šraj 2016). However, values between 1h and 6h are recommended for urban areas (Joo et al. 2014).

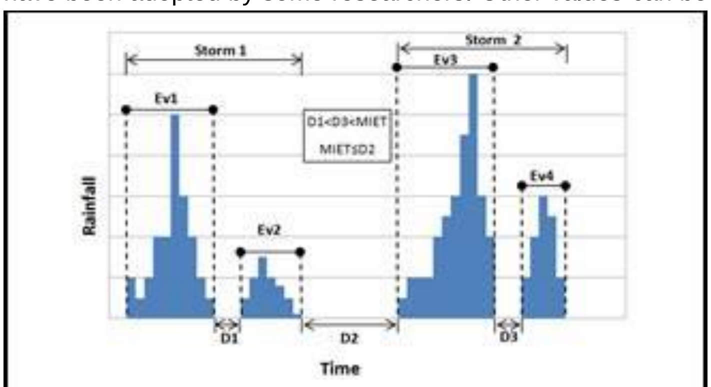

Fig. 1. *Separation of storms according to the MIET (Ev: storm event, D: duration between successive events)*

The minimum duration between storms may depend on the design criteria. A duration greater than or equal to the concentration time of the watersheds studied can be adopted ((Vandenberghe et al. 2010), (William H. Asquith et al. 2006)). The choice of a long duration is interesting to identify independent storms. Nevertheless, it will cause the long dry episodes to be taken into account by skewing the average duration and intensity of storms (Gaál, Molnar, and Szolgay 2014).

To determine the most appropriate minimum value between storms, three methods have been mentioned in the literature. The proposed methods are:

1. The analysis of the autocorrelation of storms (Gaál, Molnar, and Szolgay 2014);
2. The use of the variation in the average annual number of rainy events according to the minimum duration chosen between storms (Molina-sanchis et al. 2016);
3. The use of the coefficient of variation of the minimum durations chosen between storms (Restrepo 1982).

The three methods were used in Seoul (Korea) and give a wide variation in the minimum inter-event time, ranging from 5h to 20h (Joo et al. 2014). The choice of the minimum inter-event time is also governed by the objectives of application of the results obtained (Y. Guo and Adams 1998). Thus, several minimum inter-event time can be examined to provide more flexibility in applying the results obtained (William H. Asquith et al. 2006).

3.2 Storm depth

For a specified minimum storm depth (threshold), the number of storms with a given duration depends on the minimum inter-event time (Xie and Nearing 2016).

A large number of studies related to the synthetic rainfall distribution like Huff curves, adopts a minimum threshold of 12.7 mm (0.5 inch) ((Dolšak, Bezak, and Šraj 2016), (Bonta 2004)), (Xie and Nearing 2016), (Terranova and Gariano 2014), (A.Huff 1990)) and even 25 mm ((Natale et al. 2014),(Azli and Rao 2010),(William Harold Asquith 2003)). This choice allows, if necessary, a comparison of the different curves developed all over the world (Dolšak, Bezak, and Šraj 2016). Some researchers have used smaller thresholds up to 1mm (Y. Guo and Adams 1998). The threshold of 12.7 mm is also adopted in researches concerning the erosion index. This choice is justified sometimes by saving time during data processing (Xie, Liu, and Nearing 2002). Storms are also selected if they manage to produce runoff at the watershed (El- Sayed 2016). Thus, the selection threshold may depend on the runoff conditions of the studied watersheds. The 10 mm threshold was also proposed to avoid measurement errors corresponding to low rainfall (Li, Shao, and Renzullo 2010).

3.3 Storm duration

In its analysis of instantaneous rainfall in the southwestern areas of the United States, NOAA (National Oceanic and Atmospheric Administration in USA) treated 6, 12, 24 and 96 hour storms (J. C. Y. Guo 2008). Similar duration groups have been adopted by other authors (Sharafati and Zahabiyoun 2013). In the urban area, hydrologists are generally interested in storms of less than 6 hours duration ((Sighomnou and Desbordes 1988),(Marsalek and Watt 1984)). Smaller durations of 2h (Awadallah and Elsayed 2017), 3h (Nojumuddin 2015), 4h (Powell et al. 2007) and 5 h were also adopted in some researches for rainwater drainage needs (Yen and Chow 1983). Durations of 1h (Pan et al. 2017), 18h (El- Sayed 2016), 48 h ((Xie and Nearing 2016),(Rostami and Rostami 2014)) and 72 h (Williams-Sether et al. 2004) has been used in some researches especially for the development of synthetic rainfall distribution. For hydrological modeling purposes, rainfall analysis also depends on the concentration time (tc) of the watersheds. The durations retained vary between tc and 2xtc ((Hassini and Guo 2017), (Al-rawas et al. 2012),(Marsalek and Watt 1984)). The duration of treated storms is sometimes arbitrary or based on choices made in similar conducted studies ((Haile et al. 2011), (T.Tyrrell and R.Hasfurther 1983)).

3.4 Quartiles

Storms are usually characterized by their total duration and depth. Neverthless, these two parameters are not sufficient to compare different storms (Pan et al. 2017). The use of dimensionless curve makes it possible to eliminate the two parameters (total duration and total storm depth) and to keep the temporal distribution of the rain event (Nojumuddin 2015). Thus, it becomes possible to compare different events (A.Huff 1990). The dimensionless curve is calculated from the cumulative precipitation of a rain event and allowing its classification according to quartiles (first (Q1), second (Q2), third (Q3), fourth (Q4)) (Williams-Sether et al. 2004). Some authors have chosen the classification of storms in 8 groups instead of 4 (Powell et al. 2007). Indeed, it is a question of classifying the storms generally in four groups according to the quarter which receives the maximum of precipitations ((Vandenberghe et al. 2010), (A.Huff 1990)). Thus, a storms belongs to the first quartile group (Q1) if its greatest precipitation is recorded during its first quarter (Sharafati and Zahabiyoun 2013). The choice between the design curves of the different quartiles can be done by the designer ((Powell et al. 2007), (Back 2011)).
The dimensionless curve (Fig. 2) of each storm is calculated through the following equations (Xie and Nearing 2016):

$$d_t = P_t/P \quad (1)$$

And $$D_t = T_t/T \quad (2)$$

With:
T and P are respectively the total duration and the total depth of the storm; Tt and Pt are respectively the cumulatives

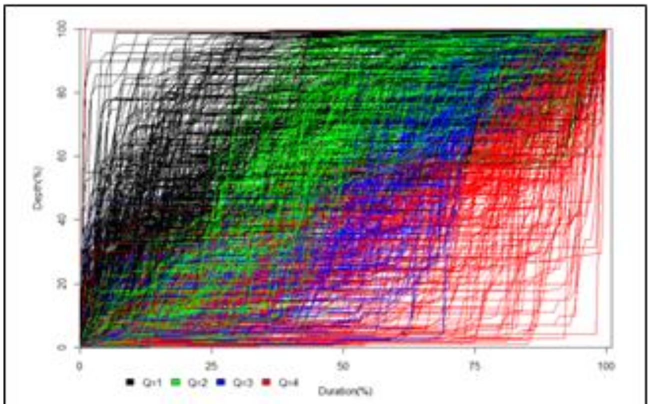

Fig. 2. *Classification of storms according to their quartiles (MIET=24h) (Barkouki et al. 2018)*

duration and depth of storm at a moment « t »; dt and Dt are respectively the adimensional rain and adimensional duration of storm at a moment « t » , they vary between 0 and 1.

4 CONCLUSION

The analysis of storms is used in hydrological studies, soil erosion studies and climatological studies. The definition of storms to use and the criteria for their selection is a crucial step.
The criteria adopted for the selection and classification of storms are generally:

1. The minimum inter-event time: It is an important criterion in the selection of storms. Its choice can be made based on the intrinsic characteristics of the precipitations or according to the objectives of the studies. The choice of different values of MIET offers a flexibility of application of the results obtained.
2. The minimum storm depth (threshold): An understanding of the characteristics of the watersheds studied will allow a good choice of the threshold to be adopted. The choice may also depend on the instantaneous rainfall data available (length of series, quality of recordings, etc.).
3. The storm duration: The values selected vary between the urban context and the rural context and can also be related to the time of concentration of the watersheds studied. The duration of the selected storms also depends on the hydraulics structures operations. The choice of different durations offers a flexibility of use of the obtained results.
4. The storm quartiles: They allow the comparison of storms of different depths and durations. The classification of adimensional storms can be used for the development of synthetic rainfall distribution.

The definition and choice of storms to be analyzed must be made taking into account the predefined objectives, the data available and the time allocated to the data processing.

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