Comment No. 1:

The authors fully agree with the comments made. The text has been amended and supplemented as suggested. Precipitation episodes in the manuscript mean independent precipitation events, which have been separated from long-term rainfall series. As a result, the first sentence in Chapter 4.1 (P9L4) was modified as follows:

One of the basic conditions allowing for the completion of a synthetic precipitation generator is the separation of single independent rain events (episodes) in the ranks of rainfalls.

Comment No. 2:

Thank you very much for your comments. Chapter 4 has been modified. The order of its subchapters has been changed and in the new layout it is as follows:

4. Methodology
4.1. Simulation of the annual number of storm overflow events using a hydrodynamic model
4.2. Logistic regression
4.3. Separation of rain events and synthetic rainfall simulator
4.4. Annual rainfall series simulator

A new Subchapter 4.1 has been introduced in Chapter 4 entitled 'Simulation of the annual number of storm overflow events using a hydrodynamic model' (P9L3). The content of it is as follows:

One of the possible solutions allowing for the verification of empirical dependencies describing the operation of stormwater systems is the simulation of this operation with the use of a calibrated hydrodynamic model. It is an approach applied in engineering practice, which is confirmed by a number of works in this field (Bacchi et al. 2008; Doménech et al. 2010). Simulations performed with a hydrodynamic model on the basis of rainfall data allow to verify the prediction capabilities of probabilistic models designed to simulate the quantity and quality of stormwater and the operation of separate objects located on the stormwater system (tanks, overflows).
Within the framework of the conducted analyses, a calibrated model of the catchment basin made in the SWMM (Storm Water Management Model) program was used to verify the number of storm overflow events. The total area of the examined catchment is 62 ha, while the area of partial catchments is from 0.12 ha to 2.10 ha. The number of stormwater junction in the catchment area is 200 and the number of stormwater pipes located in this area is 72. The retention height of the imperviousness surfaces of the catchment area is 2.5 mm and the retention height of the pervious surfaces is 6.0 mm. The roughness coefficient of imperviousness areas is equal to 0.025 [$m^{-1/3}$ s] and of pervious areas 0.250 [$m^{-1/3}$ s]. The roughness coefficient of the stormwater channels is equal to 0.018 [$m^{-1/3}$ s].
The results of simulation with hydrodynamic model were compared with the results of calculations made with the use of logit models for the data from the examined catchment from the period 2008-2016, which allowed to verify the determined relation $p = f(x_1, x_2, x_3, ..., x_i)$. Simultaneously, using the measurement data from the period 1961-2000, a simulation of the annual number of storm overflow events was performed, taking into account the precipitation genesis, which allowed for verification of the developed probabilistic model.

Subchapter 5.1 has also been modified (P12L12). Its title is now 'Logit model and its verification'. The following text is included in this subchapter below the logit models description therein (P12L13-P13L11):

The values of the SENS (sensitivity) and SPEC (specificity) coefficients are usually calculated to assess the predictive capability of the models. However, SENS = f(SPEC) may also be used for this purpose. In this case, the higher the area value (the maximum value is AUC = 1) between the SENS = SPEC and SENS = f(SPEC) curves, the more accurate the model will be (Fig. A1).

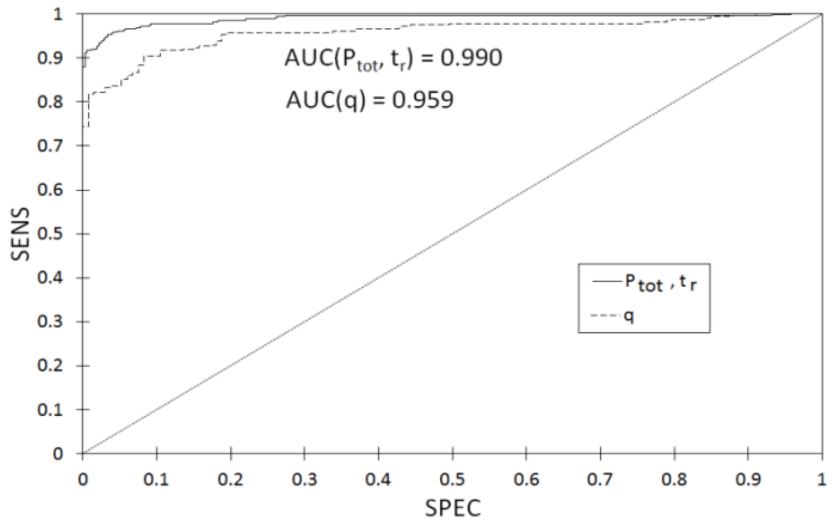

Fig. A1. Relation SENS = f(SPEC) for the logit curves p = f(q) and p = f(P_{tot}, t_r).

To verify the predictive capabilities of the logit models and their dependencies, a calibrated hydrodynamic model was used. The results of the simulation obtained with the hydrodynamic model for data from the period 2008-2016 were compared with the results of calculations made with the use of logit models p = f(q) and p = f((P_{tot}, t_r) (see Table A1).

Table A1: Comparison of measurements of the annual number of overflow events with the calculations results obtained with hydrodynamic and logit models

Year	Z	Z_{SWMM}	$Z_{logit(P,t)}$	$Z_{logit(q)}$
2008	13	15	14	12
2009	15	16	16	14
2010	17	18	19	16
2011	19	20	19	17
2012	13*	21	20/14*	19/11*
2013	13*	22	20/13*	20/11*
2014	16*	29	28/16*	27/14*
2015	25	26	26	23
2016	26	22	21	24
2017	16	17	17	14

The markings in Tab. A1 mean: Z – the measured annual number of storm overflow events in the analyzed urban catchment area, SWMM – the modeled number of storm overflow events by means of a calibrated hydrodynamic model of the catchment area, $Z_{logit(P,t)}$ – the modeled number of storm overflow events by means of the relation p = f(P_{tot}, t_r), $Z_{logit(q)}$ – modeled number of storm overflow events using the relation p = f(q), * – storm overflow events in the period (2012-2014) determined on the basis of the maximum filling of the distribution chamber (DC).

Referring to comment No. 2, the text in Subchapter 5.1 (from P13L12 to P13L23) has also been modified:

The above relations (3), (4) are of a local character and can be applied in principle only in relation to the analysed catchment area. With this in mind, an attempt was made to build a universal model by modifying these relations. Based on the theoretical considerations of Thorndahl and Willems (2008), who investigated the relationships between the characteristics of catchment areas, including the limit retention that determines the volume of overflow, the following equations were determined:

$$0.566\,P_{tot} - 0.004\,t_r - 2.152 = 0\ /\cdot \frac{1}{0.566}\ = P_{tot} - 0.007\,t_r - 3.802 = 0 \quad \text{(a1)}$$

$$P_{tot} - 0.007t_r - 3.802 = P_{tot} - 0.007t_r - d_{av} = 0 \quad \text{(a2)}$$

$$0.312\,q - 1.257 = 0\ /\cdot \frac{1}{0.312}\ = q - 4.03 = 0 \quad \text{(a3)}$$

$$q - 4.03 = q - d_{av} = 0 \quad \text{(a4)}$$

Analysing the values of coefficients in equations (a2) and (a4), one can see that the values of the free word in these equations are close to the value of the weighted mean of the retention height of the catchment area (d_{av}). The difference between the weighted mean of the catchment retention and the values of the free words in the equations does not exceed 5 %. Simulation calculations of the annual number of overflow events in the tested catchment area confirm the above statement (Table A1). At the same time, this fact is supported by the results obtained in Fig. A2, which indicate that the results of the simulation of the annual number of overflow events using the hydrodynamic model are within the scope of a probabilistic solution. However, due to the fact that the presented analyses were performed only for a single catchment, it is necessary to verify the obtained results using examples of other catchments with different physical and geographical characteristics.

Comment No. 3:

Thank you very much for your comments. The contents of Chapters 3, 4 and 5 have been modified. We consider Chapter 3 to be an important part of our work in terms of the goals we have set. The article discusses the problem of storm overflows in the urban catchment area, caused by rainfall of different origins. One of the elements of the proposed probabilistic model for modeling the number of storm overflow events is a generator of synthetic rainfall. In order to simulate this model, rainfall events with different genesis had to be taken into account. The conducted analyses allowed to determine the influence of the distribution of the average annual number of precipitation episodes with different genesis of precipitation on the variability of the number of storm overflow events. Therefore, in our opinion, it is important to familiarize the reader with the main processes and mechanisms occurring in the troposphere over central Europe, which are reflected in high precipitation. The presentation of this problem is presented in the introduction to Chapter 3 of the manuscript. The main characteristics of convective precipitation, frontal precipitation and convergence zones presented in this chapter are the result of the exceptional variability of meteorological conditions in this part of the European continent and are therefore presented in a broader context. However, we agree with the Reviewer's

comment that the considerations on this subject presented in Chapter 3 may be shortened and partly moved to the introductory chapter of the article.
Therefore, the following changes have been made to the manuscript:

– the title of Chapter 3 (P4L7) has been changed as follows: ‘Rainfall data and analysis’
– the previous content presented in the text from P4L8 to P5L17 was modified in the following way and moved to Chapter 1 (after P3L7):

Rainfall is universally classified into three types (Sumner, 1988): convective, cyclonic and orographic. The main distinguishing feature between convective precipitation in air mass and frontal precipitation in mid-latitudes is its spatial extent and duration. The range of convective precipitation associated with local air circulation is much smaller than in the case of travelling extratropical cyclones with weather fronts. Convective precipitation induced by single thunderstorm cells, their complexes or squall lines is short-lived, but is characterized by high average intensity (Kane et al., 1987) and causes flash floods in many areas (Gaume et al., 2009; Marchi et al., 2010; Bryndal, 2015). On the other hand, the lifespan of the mechanisms of creating cyclonic precipitation is much longer than that of convective precipitation – in the order of days rather than hours. Hence, the effect of this is long-term rainfall with a high depth (Frame et al., 2017), often causing regional floods (Barredo, 2007). The presented classification of precipitation types distinguished by Sumner (1988) due to the origin of the phenomenon, developed for the British Isles and Western Europe, cannot be directly applied in practical hydrology in other regions of the continent, especially in its eastern and central parts. This is the result of exceptional variability of meteorological conditions occurring in the temperate zone of warm transition climate – on the borderline of air masses coming from the Atlantic and continental masses from the east (Twardosz and Niedźwiedź, 2001; Niedźwiedź et al., 2009; Twardosz et al., 2011; Łupikasza, 2016). Analysis of maximum rainfall of different duration in Poland carried out at the end of the 1990s (Kupczyk and Suligowski, 1997, 2011), supplemented by the analysis of synoptic situation (on the base of surface synoptic charts of Europe, published in Daily Meteorological Bulletin of the Institute of Meteorology and Water Management – IMGW in Warsaw) and a calendar describing the types of atmospheric circulation together with air masses and air fronts (Niedźwiedź, 2019), led to the separation of three types of genetic precipitation: convective in air mass, frontal and convergence zones.

– also Figure 2 (P6L1) has been removed from Chapter 3.

The main changes in Chapter 4 have been discussed earlier. In addition, the following introduction text from the existing Chapter 4.3 ('Synthetic precipitation generator'), i.e. contained from P10L17 to P10L23, has been moved to the introductory chapter (P2L22):
Multidimensional scaling and fractal geometry methods are used to simulate rainfall series (Rupp et al., 2009; Licznar et al., 2015; Müller-Thomy and Haberlandt 2015). Alternative approaches are solutions based on multidimensional distributions created on the basis of theoretical distributions and copula functions (Vandenberghe et al., 2010; Vernieuwe et al., 2015). However, these solutions are relatively complex and require expert knowledge. To predict the annual number of storm overflow events, hydrodynamic models are usually used, whereas less frequent are empirical models (Szeląg et al. 2018). However, this approach is very local and in many cases requires the construction of a catchment model.

In view of the above changes, the text after P9L19 has also been modified as follows:

Taking into account the calculation algorithm described in Chapter 4 (Methodology) and developed on the basis of theoretical distributions of rainfall characteristics describing the operation of a storm overflow, a model for simulating synthetic rainfall series was used for further analyses. The model was determined using the Monte Carlo method modified by Iman-Conover (1982). This model gives the possibility of simulation of independent variables taken into account in the research on the basis of theoretical distributions determined for them. In the Monte Carlo method used the variability of the considered variables is described by boundary (theoretical) distributions, and the basis for evaluation of their correlation is the Spearman correlation coefficient. The conditions, which must be met in order for the results obtained to be considered correct, are as follows:

– in the data obtained from simulation and measurements, the mean values $(\mu_1, \mu_2,...,\mu_i)_s$ and the standard deviations $(\sigma_1, \sigma_2,...,\sigma_i)_s$ of the variables (x_i) considered in j samples do not differ by more than 5%,
– theoretical distributions of x_i variables obtained from simulation are consistent with those obtained from measurements; in order to meet this condition it is recommended to use the Kolmogorov-Smirnov test,
– the value of the correlation coefficient (R) between individual dependent variables (x_i) obtained for data from MC simulation does not differ by more than 5% from the value of R obtained for empirical data.

If the above mentioned conditions are met, the results of the simulation performed with the IC method can be considered correct. If this is not the case, the sample size of the MC needs to be increased (Wu and Tsang, 2004). In order to limit the sample size and improve the efficiency of the Iman-Conover algorithm, a modification has been developed by using the Latin-Hybercube algorithm, which is part of the layered sampling methods aimed at improving the "uniformity" of the numbers generated from the boundary distributions.

On the basis of the determined boundary distributions of rainfall characteristics, simulations of synthetic rainfall series were performed with the use of the Monte Carlo method with Iman-Conover modifications and taking into account the Latin-Hypercube algorithm.

With reference to Subchapter 5.2, the text of it was divided into the following three Subchapters:

5.2. Identification of empirical distributions and theoretical rainfall characteristics

Subchapter 5.2 includes analyses related to the determination of statistical distributions of the following variables: rainfall depth (P_{tot}), rainfall duration (t_r), average rainfall intensity (q), and number of rain events in a year of varied genesis.

Chapter 5.2 in the manuscript contains the text from P13L24 to P17L5.

5.3. Impact of rainfall genesis on the probability of storm overflow occurring

Subchapter 5.3 presents the determined relationship between the genesis of rainfall and the probability of overflow event, as well as the ranges of variation of average rainfall, taking into account the rainfall genesis, which determines the occurrence of storm overflow event.

Subchapter 5.3 in the manuscript contains the text from P17L6 to P18L27.

5.4. Impact of precipitation genesis on the annual number of overflow events

Subchapter 5.4 presents the annual number of overflow events caused by rainfall (convective, frontal, convergence zones). At the same time, a comparative analysis of the annual number of overflow events obtained with a simplified logit model (based on the average rainfall intensity) and the number of overflow events obtained with an accurate model (based on the total amount of rainfall and its duration) is carried out in this chapter.
Subchapter 5.4 in the manuscript contains the text from P18L28 to P20L16 in the manuscript.

The text in P18L30 has been modified as follows:

Simulation calculations performed with the calibrated hydrodynamic model of the catchment area show that the results of the simulation of the annual number of storm overflow events (Fig. A2) caused by precipitation of different genesis are within the scope of the solution obtained with the probabilistic model. This confirms that the probabilistic model developed in the paper is an alternative solution to the hydrodynamic model. The above fact is also confirmed by the annual number of overflow events caused by rainfall of different genesis obtained on the basis of measurements. (rys. A2). The conformity of simulation results obtained with the probabilistic and hydrodynamic model may indicate that the values of free words determined in the relevant equations may correspond to the weighted average retention of the catchment area.

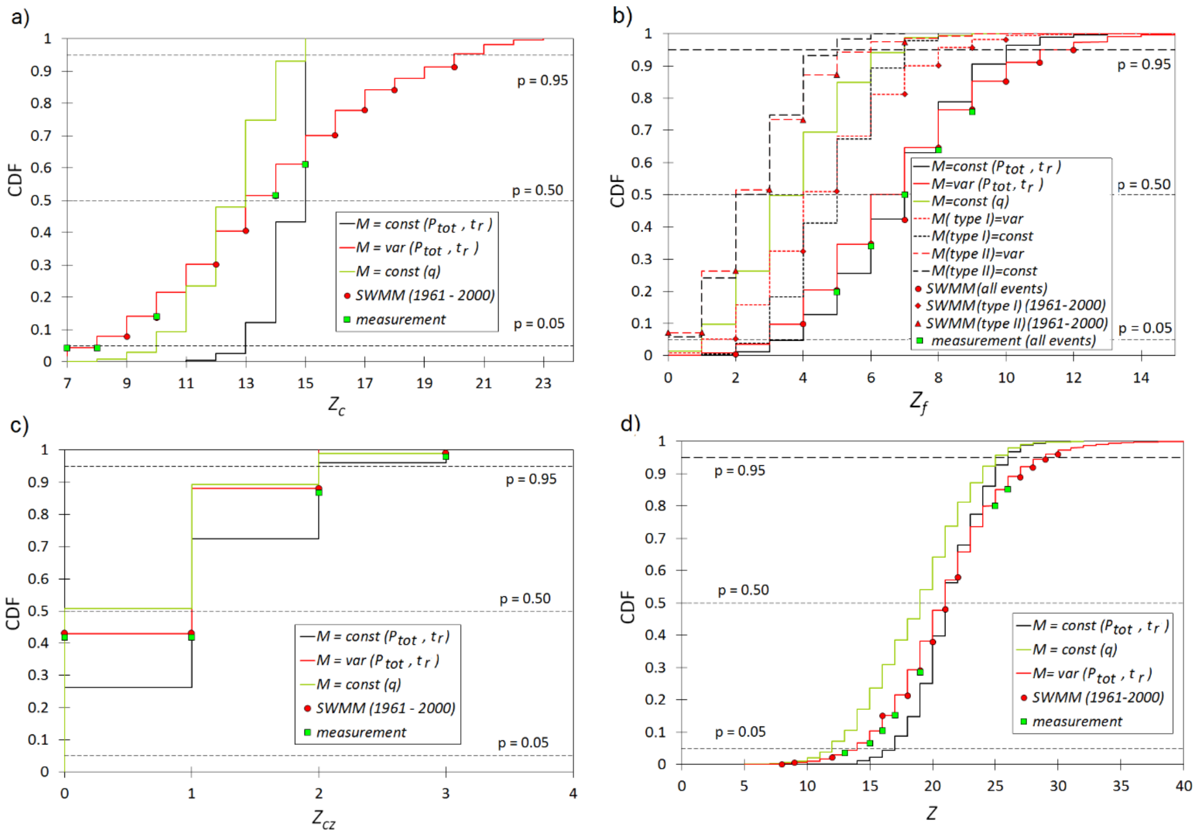

Fig. A2. (a) Distribution function (CDF) showing the annual number of storm overflow events caused by convective rainfall (Z_c); (b) Distribution function showing the annual number of overflow events caused by frontal rainfall (Z_f); (c) Distribution function showing the annual number of overflow events caused by rainfall in convergence zones (Z_{cz}); (d) Curve showing the probability of exceeding the annual number of overflow events (Z); M – number of rain events in a year: M = const(x_i) – in the probabilistic model the average number of rain events from the period 1961-2000 was adopted in the calculations; M = var(x_i) – in the probabilistic model theoretical distributions describing the number of rain events in a year were adopted (Table A1).

Specific comments:
P2L5:

Indeed, the quoted guidelines are foreign. The paper also takes into account national Polish guidelines in the form of the Regulation of the Minister of the Environment of 18 November 2014 on the conditions to be met when discharging sewage into water or soil and on the substances particularly harmful to the aquatic environment.

P3L18:

The characteristics of the catchment area have been extended. In item P3L24 of the manuscript the following additional information has been added:

Analysis of the measurement data (2008-2016) concerning the analysed catchment area showed that the antecedent period there lasted 0.16–60 days and storms occurred 27–47 times a year. The average annual air temperature during the period under consideration varied from 8.1 to 9.6^{o}C. At the same time, the analysis of measurement data of flows recorded with the MES1 flow meter showed that in the antecedent periods the temporary stream of stormwater was from 0.001 to 0.009 m^3s^{-1}, which indicates the occurrence of infiltration in the stormwater system under study.

Figure 4:
Taking as a starting point the diagram of the algorithm in Fig. 4 (P8L8), two approaches to the simulation of the annual number of overflow events were analysed. In the first one the genesis of rainfall M = const(P_{tot}, t_r) or M = const(q) (Fig. A2d) was omitted. In the second approach the developed rainfall generator (Fig. 5), described in Subchapter 4.4 ('Simulator of synthetic annual rainfall series'), was used and the results obtained are shown in Fig. A2d in the form of M = var(P_{tot}, t_r) curve. The additional dependencies showed in Fig. A2a, A2b, A2c are a detailed description of the results of the simulation analyses and illustrate the annual number of overflow events caused by rainfall of various origins (convective, frontal, convergence zones). Indeed, in the original version of the manuscript, this may lead to confusion. The corrected manuscript therefore contains the following table of symbols at the end of the article (Table A2):

<table>
<tr><th>L.p.</th><th>Symbol</th><th colspan="2">Meaning</th></tr>
<tr><td>1</td><td>N</td><td colspan="2">number of samples in the Monte Carlo simulation</td></tr>
<tr><td>2</td><td>p</td><td colspan="2">probability of a storm overflow event</td></tr>
<tr><td>3</td><td>P_{tot}</td><td colspan="2">rainfall depth</td></tr>
<tr><td>4</td><td>t_r</td><td colspan="2">rainfall duration</td></tr>
<tr><td>5</td><td>q</td><td colspan="2">average rainfall rate (q =166.7 P/t)</td></tr>
<tr><td>6</td><td>f(x)</td><td colspan="2">probability density function of the variable x</td></tr>
<tr><td>7</td><td>CDF</td><td colspan="2">cumulative distribution function of probability density</td></tr>
<tr><td>8</td><td>M =const(q)</td><td rowspan="2">calculation variant (annual number of overflow events), in which for simulation constant average annual number of rainfall events is used and to</td><td>logit model p =f(q)</td></tr>
<tr><td>9</td><td>M =const(P_{tot},t_r)</td><td>logit model p =f(P_{tot}, t_r)</td></tr>
</table>

		identify the overflow in a rainfall episode the following logit models were applied:	
10	M =var(q)	calculation variant (annual number of overflow events), in which the annual number of rainfall events caused by precipitation (convective, frontal, convergence zones) is modelled, and for identification of overflow in a rainfall episode the following logit models were applied:	logit model p =f(q)
11	M =var(P_{tot},t_r)		logit model p =f(P_{tot}, t_r)
12	Z	annual number of storm overflow events	
13	Z_c	annual number of storm overflow events due to rainfall:	convective
14	Z_f		frontal
15	Z_{cz}		convergence zones
16	M_c	annual rainfall events number caused by rainfall:	convective
17	M_f		frontal
18	M_{cz}		convergence zones
19	$F(\zeta)_c$	theoretical distribution to simulate the annual number of rainfall events:	convective
20	$F(\zeta)_f$		frontal
21	$F(\zeta)_{cz}$		convergence zones
22	$F(x)_c$	theoretical distribution to simulate rainfall characteristics due to rainfall:	convective
23	$F(x)_f$		frontal
24	$F(x)_{cz}$		convergence zones

P5L9:

Thank you for the valuable comment and signalling that one of the reasons given for the variability in the frequency, intensity and duration of rainfall associated with atmospheric fronts in Central Europe was unclear and awkward. The discussion on this issue was omitted, as mentioned above (in response to Comment No. 3). The existing content presented from P4L8 to P5L17 was modified and moved to Chapter 1 (after P3L7).

P17L4:

The text of the manuscript in P17L3 has been modified as follows:

The aim of the simulation calculations was to compare the results of calculations of the annual number of overflow events by means of a model taking into account the genesis of rainfall and a simplified model, in which only a differentiated number of rainfall events was included with the omission of the rainfall genesis. Reference data constituting the basis for the comparison was the number of storm overflow events obtained taking into account the rainfall genesis – M = var(P_{tot},t_r) (Fig. A2d). Due to the fact that the determined statistical distribution describing the annual number of rainfall events (Fig. 6a) indicated overestimation of the minimum values and underestimation of the maximum values, the obtained results of the simulation of the annual number of overflow events on the basis of such distribution would differ from the values obtained on the basis of the empirical distribution. Thus, the comparison of the simulation results between the simplified model and the model taking into account the rainfall genesis would be burdened with an error, which would have a negative impact on the evaluation and interpretation of the calculation results. Obtained results of the simulation with a simplified model and one taking into account rainfall genesis can of course be compared, but it would be difficult to draw conclusions from this comparison to determine how the simplification introduced in the simulation of the annual number of overflow events (omitting rainfall genesis) affects the results of the simulation.

In the corrected manuscript, items P17L4 and P17L5 were removed.

P18L31:

Thank you for your comments. The term 'exact model' has been replaced by the term 'model that takes into account the genesis of rainfall'.

P2L19:

The order of names has been changed: 'Willems and Thorndahl (2008) is now replaced by "Thorndahl and Willems (2008)'.

P11L3:

Indeed, IC is the abbreviation for the Iman-Conover method.

P3L2:

The word ‘knowledge’ has been removed from the text.