Dear editor and referees,

Thank you very much for the reassessment of our manuscript and for the interesting complementary comments. Concerning the relevant suggestion made by referee #1 to show the effect of offset on the breakdown coefficients of disaggregated data, we have done some supplementary analysis, which revealed interesting results. Therefore, we have added two figures in the Supplementary Material and two relative comments in section 5.2 about these results.

Best regards,

Kaltrina Maloku

Response to anonymous referee #1

We thank referee #1 for carefully reassessing the revised manuscript and for the constructive comments. The comments are noted with RC and our responses with AC.

RC1.1 The authors demonstrate that resampling the disaggregated time series with a constant offset clearly affects time series statistics (Figure S11). While overall the effect of offsetting appears smaller for asymmetric models, the effects are not negligible for asymmetric models, particularly when considering autocorrelation. Curiously, offsetting appears to increase error in some cases and decrease it in others. Have the authors considered why this is?

> **AC1.1** *In Figure S11 we first wanted to point out the stability of the statistics when they are estimated with different offsets. All in all, stability is better when the asymmetry dependency is accounted for in the cascade generator. We acknowledge that this is not clear for model A+ when considering the autocorrelation. At this point, we cannot give a precise explanation to this result. It may be partly due to the boxplot representation (the number of points shown as outliers or included otherwise in the boxplot) or to the fact that the disaggregation to 10min uses a cascade generator estimated on larger temporal scales (for the 10 and 20min scales, we use the scaling laws obtained for scales > 40min). This will need further investigation.*
> *However, note that better stability is obtained whatever the statistics for model B+. Except for autocorrelation, a significant improvement in the stability is also obtained with model A+ when compared to models A and B. This is especially the case for the ECDFs of the breakdown coefficients. See our response to comment RC1.2 below.*

RC1.2 Instead of comparing statistical error, the matter could be addressed by more directly examining the distribution of the BDCs recreated from the disaggregated data, before and after offsetting (as in Rupp et al. 2009). I request that the authors show effect of offsetting on the BDCs of the disaggregated data, either through histograms such as those on page 13 of the authors' response (egusphere-2023-544-author_response-version1.pdf), or through the effect on the distribution of the asymmetry index Z.

AC1.2 *Thank you for this very relevant suggestion. We have done this analysis and it is indeed very conclusive. Therefore, we have added two figures in the Supplementary Material and two relative comments in section 5.2 about the results. These results have also been recalled in the conclusion.*
*The two figures added to the SM (New Figures S12 and S13) are given below. Basically, the suggested analysis even better highlights the interest in including precipitation asymmetry in the cascade generator. It allows us to show the two following additional results:*

- *As shown in Figure 3 of the manuscript, the statistical distribution of BDCs is expected to strongly depend on the external pattern of precipitation and more precisely on the value of the asymmetry index Z. When the asymmetry index Z is larger, the probability p01 (resp. p10) is expected to be smaller (resp. larger) and the mean of the distribution is expected to be larger (cf. ECDF of BDCs for Zurich data in Figure 3). As illustrated in Figure S12 and S13 of SM, the dependency of ECDF of BDCs on Z is actually almost perfectly reproduced with models A+ and B+, when precipitation asymmetry is accounted for in the cascade generator. Conversely, it is fully missed in models A and B: with models A and B, the dependence of the ECDF of BDCs on Z seems to fully disappear and the ECDFs turn to be always symmetric. It is not a surprise, owing to the symmetric formulation of the cascade generator in both models.*

- *On the other hand, the statistics of a precipitation time series are not expected to change when the time series is offset in time by a small time duration. This should be the case for standard statistics, and as suggested by Reviewer1 this should be also the case for the ECDFs of the BDCs.*

  1. *This is indeed the case, when the offset experiment is applied on observed data: the statistics, estimated on the four offset time series respectively, are similar. This was illustrated in the previous manuscript version in Figure S10 for standard precipitation statistics of 12 stations. As expected, this is also the case for the ECDFs of the observed BDCs as illustrated for Zurich data in figures S12 and S13.*

  2. *As mentioned in our manuscript, the offset-independence property is conversely not necessarily satisfied when the offset experiment is applied to the times series generated with the disaggregation models. When calculated on disaggregated data, the estimates calculated for different offsets are no longer necessarily similar. In general, the models A and B (without asymmetry) are much more sensitive to temporal offset than models A+ and B+: This was illustrated for standard statistics as highlighted in Figure S11 of the SM. This is even worse for the ECDFs of BDCs as illustrated in Figures S12 and S13 of the SM. Including the asymmetry in the*

generator allows to almost fully correct this limitation, making the ECDFs rather insensitive to the offset.
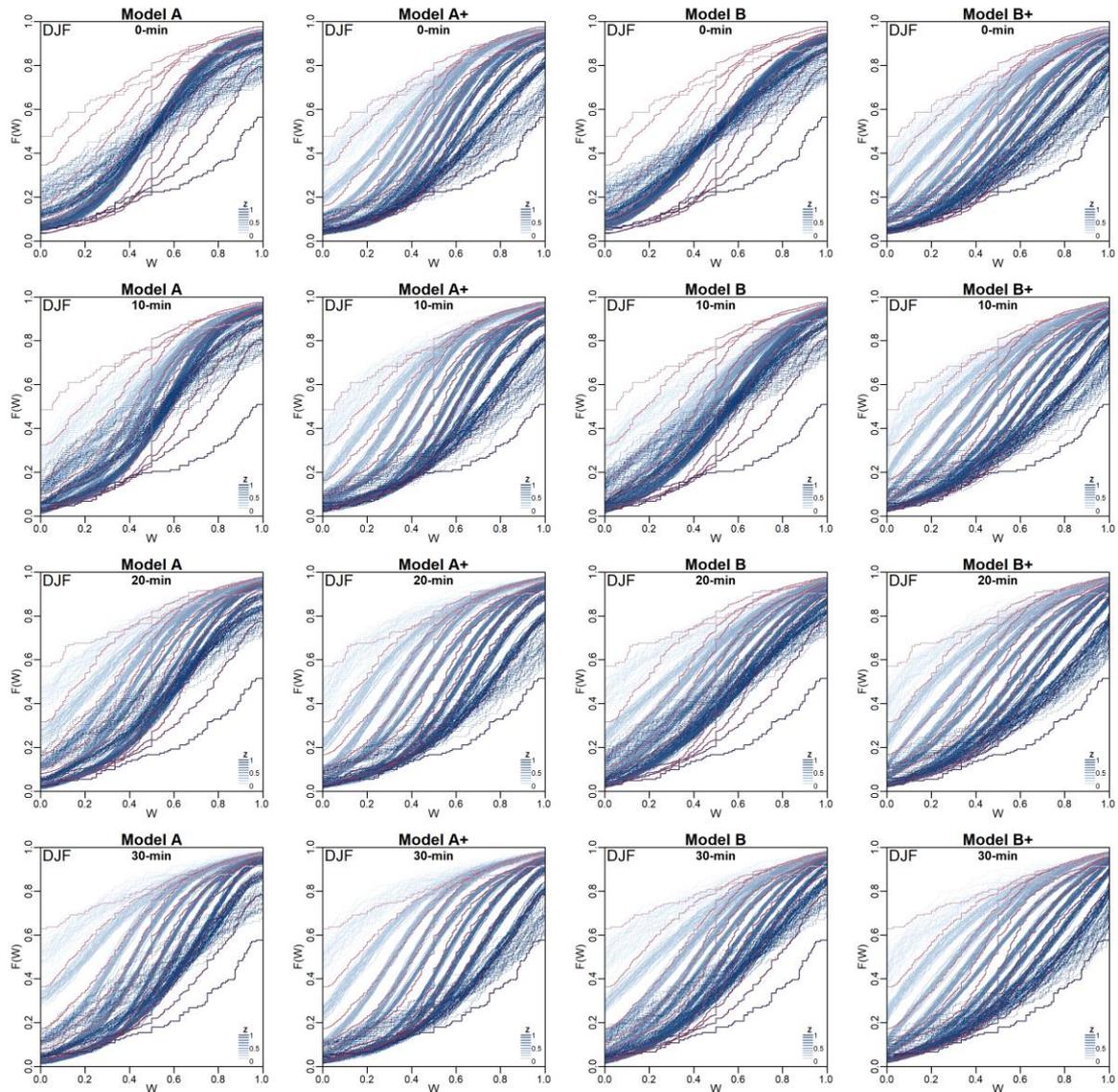
New Figure S12. Empirical cumulative distribution function of observed and simulated BDCs by each model and with different offsets (first line : no offset, 2nd, 3rd, 4th lines : 10min, 20, min, 30min offsets). The ECDFs are plotted for different classes of the asymmetry index, as in Figure 3 of the manuscript. The first lines show the ability of the model to reproduce (Model A+ and B+) and the inability to reproduce (Model A and B) the dependency of the ECDF to the Z class. The ECDFs obtained with model A and B are all symmetric, contrary to what is observed. Winter season.
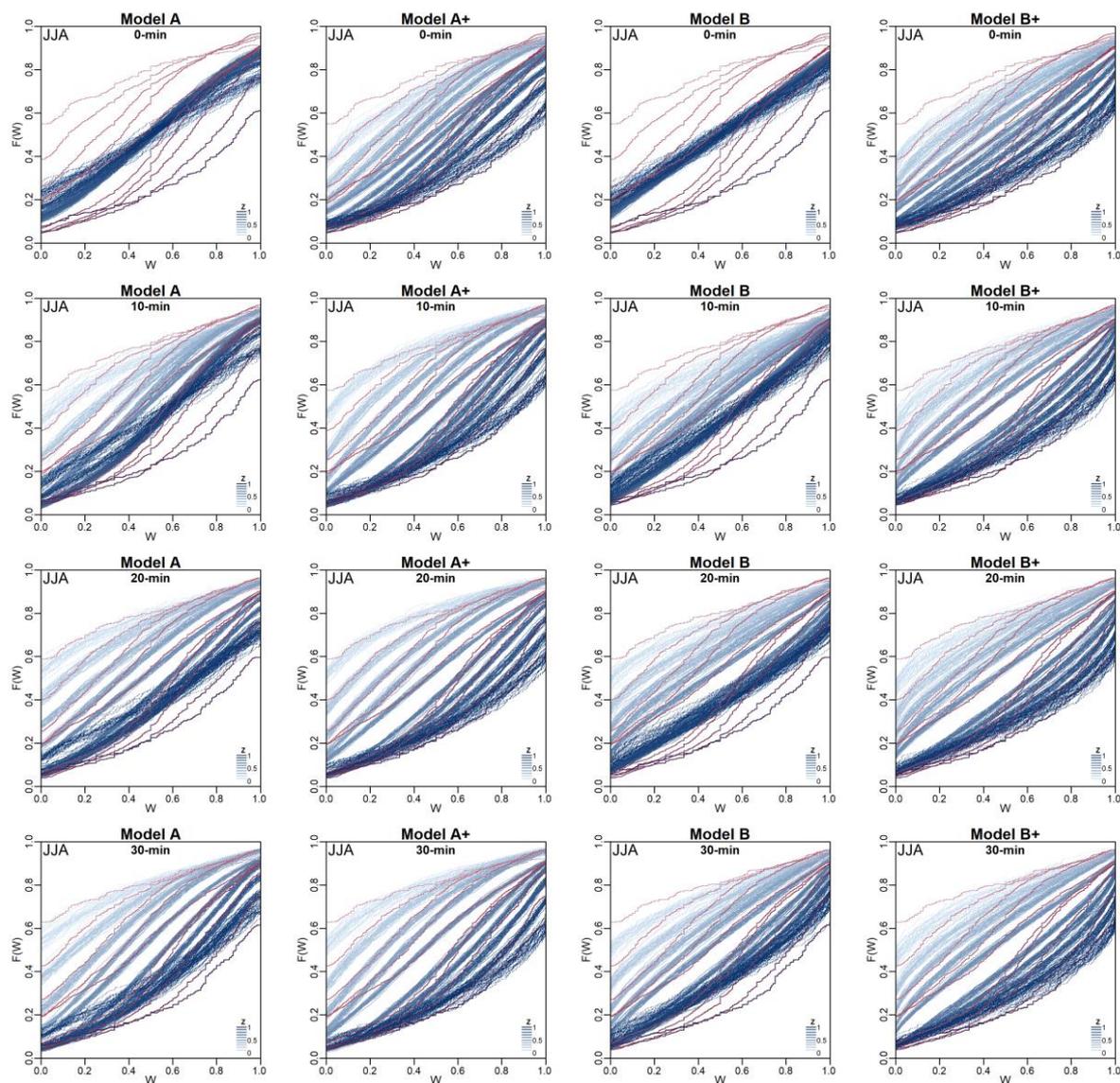
New Figure S13. Same description but for summer season.

RC1.3 While the authors have done an admirable amount of additional analysis, I do not think they have yet shown strong evidence that refutes the "suspicion" given by Rupp et al. (2009), although they claim in their response that this suspicion was likely wrong.

It may well not be (and need not be) that the authors' paper is the one the provides a definitive answer to the question. Still, I think the authors downplay the issue in their Discussion given apparent asymmetry is so central to their approach. It would be more appropriate to acknowledge that this remains an unresolved issue.

> **AC1.3** *We believe that the Rupp et al. suspicion was likely wrong or at least not as critical as they suggest. However, we acknowledge that additional analyses are required to confirm our results. We have adapted our text accordingly.*
>
> > • *In the text (ln 415): "We argue that a large part of the dependency on the temporal scale is also a result of this precision artefact. This is clearly*

shown here concerning the probability $p_x(I)$." > we changed "clearly shown" by "strongly suggested"

- *We have also added line 420 "Further investigations will be worth to assess if this would still hold in other contexts worldwide."*

RC1.4 L77: Replace "worth to be mentioned" with "worth mentioning."

AC1.4 *Thank you for the suggestion. It has been accounted for.*

RC1.5 L122: The authors don't need a reference for the Beta distribution itself. If they to cite McIntyre et al. (2016) as a case where the 2-parameter Beta distribution was used to characterize the distribution of W, is McIntyre the earliest example of this? If not, they could instead cite a first or early use of it in this context (if known) or, at minimum, put "e.g." before McIntyre et al.

AC1.5 *As far as we are aware this study is one the earliest examples of the use of two-parameter Beta distribution to model the distribution of W. Nevertheless, we added e.g. before McIntyre et al. as suggested.*

RC1.6 L189: Replace "is the asymmetry of the sequence" with "the asymmetry of the sequence is".

AC1.6 *It has been done.*

RC1.7 L203-204: Why is "increasing" called "right valley" if the low point is to the left? Similarly, with "left valley". Am I misunderstanding something?

AC1.7 *The sentence formulation is a priori right. 6 external patterns are sometimes defined, as follows (fig 1 of Hingray et Ben Haha (2005), following Ormsbee (1989)):*
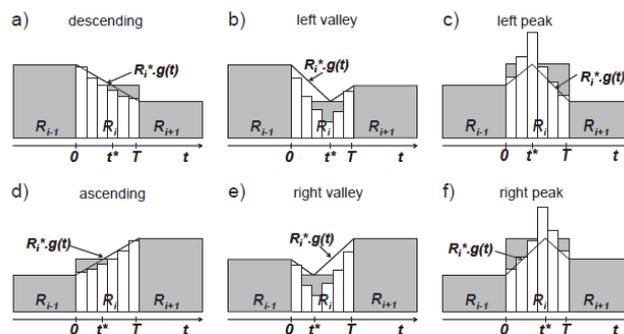

Fig. 1. Geometric similarity between external and internal temporal rainfall patterns for the six pattern classes according to Ormsbee (1989). The internal temporal pattern determined by the time evolution $g(t)$ of rainfall intensity is proportional to the piece wise linear function $R_i^* \cdot g(t)$ plotted on the schemes. The rainfall volume of each 10-min bar is derived from $g(t)$ via Eq. (7).

In the classes "descending", "left valley" and "left peak", $R_{t-1} > R_{t+1}$
In the classes "ascending", "right valley" and "right peak", $R_{t-1} < R_{t+1}$
This is coherent with what is written in lines L203-204 :

"$Z_t<0.5$ indicates an "increasing" or "right valley" sequence, i.e. a sequence where $R_{t-1} < R_{t+1}$, while $Z_t>0.5$ indicates a "decreasing" or "left valley" sequence ($R_{t-1} > R_{t+1}$).

RC1.8 L325: Replace "20 years return period" with "20-year return period".

L325: Replace the "The 5-year, respectively 20-year, return level" with "The 5 and 20-year return level, respectively".

L327: Replace "5-year, respectively 20-year", with "5 and 20 years, respectively."

AC1.8 *Thank you very much for the welcomed suggestions. This has been modified.*

RC1.9 L395-396: Replace "thanks to" with "by".

AC1.9 *This has been modified.*

RC1.10 L422: I believe the actual Licznar et al. (2011) paper that applied the random perturbations was: "Licznar, P., Schmitt, T. G., & Rupp, D. E. (2011). Distributions of microcanonical cascade weights of rainfall at small timescales. Acta Geophysica, 59, 1013-1043" although this paper is not listed in the References.

AC1.10 *Thank you for noticing this error. We now cite the correct reference in the revised manuscript.*

RC1.11 L428-429: I don't understand what "further leading on removal of parts" means. Please rephrase.

AC1.11 *The dependency of W distribution to the temporal aggregation level for small intensities is partly due to the precision artefact as discussed above in the same section. In Figure 4 of the authors' response to Reviewer 1, we show how the dependency to the temporal scale reduces after employing the jittering process since over-represented values of BDC W = 1/2, 1/3,…, are partly removed. We will rephrase as follows: "This leads in turn part of the "scaling dependencies" mentioned above to disappear".*

RC1.12 L454 and elsewhere: Sometimes "Supplementary Material" is written and sometimes simply "SM". Please be consistent.

AC1.12 *Thank you for noting this inconsistency. We now write "Supplementary Material" when referred to it for the first time in Section 4.1, and "SM" otherwise.*

RC1.13 How were the disaggregated 40-minute time series further disaggregated to 10 minutes? Using the MRC models? Or was each 10-minute interval allotted 25% of 40-minute rainfall total?

AC1.13 *The 40-minute disaggregated time series were further disaggregated to 10-minute time series using the same MRC models used to disaggregate to 40-minute time series. To get the parameters of the generator for the high resolutions, we use the scaling relationships identified from the lower resolutions. We now precise this information in the revised manuscript.*

RC1.14 L461: Why "thirty" 10-minute time series?

    AC1.14 *The disaggregation to 40-minute resolution is performed thirty times as mentioned in Section 2.6, thus thirty 40-minute time series are obtained by each MRC model and station. Each of these scenarios is further disaggregated into a 10-minute time series, resulting in thirty 10-minute time series by model and station.*

RC1.15 L463: I think "no more similar" should be "no longer similar".

    AC1.15 *The paragraph has been rewritten to include new discussions (see RC1.2 above).*

RC1.16 L468: Replace "accounted for for a long time" with "considered for a long time".

    AC1.16 *Thank you for your suggestion. It is modified.*

Response to anonymous referee #2

We thank referee #2 for carefully reassessing the revised manuscript and for the very encouraging comments. The comments are noted with RC and our responses with AC.

RC2.1 RC2.7 Section 2.2 When introducing Zt the authors could state the intended application briefly and refer to Sec. 2.4 with the detailed description: It only affects p01 and p10, px remains unaffected.

AC2.7 Thank you for the suggestion. We will do so.

-> I could not find any modification in the manuscript to this point.

AC2.1 *Thank you for this comment. Yes, px remains unaffected. It affects p01 and p10, and in addition, it also affects the mean of the distribution of the positive cascade weights (0<W<1). In this section, we refer to these details to the following sections. In line 197 we have added:* <u>*Details about the use of this index in the cascade generator are given in the following sections.*</u>

RC2.2 RC2.13 Fig. 5a) 'Standard deviation' – of what?

AC2.13 Thank you for noting that the description needs to be detailed. We will add "Standard deviation of precipitation".

-> 'Standard deviation of precipitation' is not concise and can represent various characteristics, I suggest 'Standard deviation of precipitation intensity'.

AC2.2 *As the time series represent precipitation amounts, we have added "Standard deviation of precipitation amounts".*