

AUTHOR COMMENT AC7

Response to the comments of referee report RC2

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1 Introduction

This author comment responds to report RC2, which raises a block of general comments on the framing, the structure and the methodological clarity of the manuscript, together with four detailed comments, and concludes that the manuscript is not suitable for publication in its present form. We thank the referee for a report that identifies precisely where the manuscript forces the reader to reconstruct what the text ought to set out. The observations on the literature review, on the order of the exposition and on the separation between model and results are accepted without reservation.

Each comment is addressed in three parts. What we accept gathers the referee's observations that we consider correct and concedes them without reservation. What we maintain sets out the points on which we disagree or add precision, with the verification that supports them. Committed changes to the revised manuscript lists what is incorporated.

The numbering continues that of author comment AC6, which responds to report RC1: the arguments run from 27 to 56 and the committed changes from C20 to C43, so that no identifier is repeated within the discussion. Where this document cites earlier author comments it does so by their identifier, AC1, AC3 and AC6. The text of the report is reproduced at the beginning of each section.

We state the balance in advance to assist the reading. We accept that the literature review is insufficient, and we extend the introduction with the developments published since 1987 in stochastic rainfall modelling and in the regionalisation of IDF curves, placing MIT-Q and the IDFP curves against them. We delimit the novelty with respect to Beltrán (2023), which already presented a spatial application of MIT-Q: it does not lie in the principle, which AC6 acknowledged to be the Gibbs construction, but in the formalisation of the arrangement of bursts as a random variable of the event, in the exact link between the exponents of the official IDF curves and the parameters of the extreme storm, and in the regional extension derived from it. We restructure the manuscript, separating methods from results, and we add the explicit chain that runs from the functional to what the simulation executes. We separate the two operations that the manuscript performs with IDF curves: the generator does not use them; the regional construction does. We document the provenance of the relationships of the spatial module in Beltrán (2003), we describe the directional rule as it is executed, and we declare the critical motion condition as a hypothesis of the model. And we exhibit, in the two cases where the referee asks for it, the mechanism that the text stated as a result: the one that produces the windward-leeward asymmetry, and the one that underpins the comparison by quartiles, which is made here against the storms recorded at Quito-Observatory and not only against Huff (1990), and whose differences are measured, declared and explained.

2 General comments

2.1 Comment: the literature review is limited

While this is an important topic well-represented in the hydrological literature, the current literature review is overly limited. The introduction relies almost exclusively on the foundational work by Rodriguez-Iturbe et al. (1987) and Beltrán (2023). Given the extensive advancements since 1987, a broader review of recent literature is needed.

2.1.1 Response

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2.1.1.1 *What we accept*

27. We accept the observation. The introduction cites Rodríguez-Iturbe et al. (1987) as the only reference for the stochastic modelling of rainfall events and does not take up thirty-five years of subsequent development of that same line. The consequence is not merely bibliographic: without that context the reader has no terms in which to judge what MIT-Q does that existing models do not, which is exactly what the referee points out in the comment that follows.

28. We also accept that the extended review must position the work rather than enumerate titles. A list of titles does not answer the objection. The revised manuscript organises the review into families, states what each of them represents, and states how the formulation proposed here separates from them.

2.1.1.2 *What we maintain*

29. The families that structure the review, and the position of MIT-Q with respect to each of them, are the following.

Poisson-cluster point processes. The line opened by Rodríguez-Iturbe et al. (1987), in which storms arrive according to a Poisson process and the total intensity is the sum of the contributions active at each instant, continues in the Neyman-Scott and Bartlett-Lewis models. Cowpertwait and O'Connell (1997) distinguish convective and stratiform cells and regionalise the parameters by elevation and location; Cowpertwait et al. (2002) take the family into the space-time domain and examine its behaviour in the extremes; and Onof and Wang (2020) review the recent developments of the Bartlett-Lewis variant and their effect on short-duration and sub-hourly extremes. In this family the cell is the unit and the event results from its clustering. MIT-Q starts from the other end: the event is the unit, with its own duration and depth, and its internal structure is the arrangement of m bursts.

Stochastic space-time generators. AWE-GEN-2d (Peleg et al., 2017) simulates gridded climate variables at 2 km and 5 min; Pidoto and Haberlandt (2023) couple an hourly rainfall model with resampling of the remaining variables; and NEOPRENE (Diez-Sierra et al., 2023) generates multi-site series with a Neyman-Scott process, reproducing the observed statistics at different scales, with the code released as open-source software. MIT-Q shares the aim of a coherent spatial field and separates from them in the mechanism: the position of the event is set by the feedback with the annual isohyet field, so that the simulated annual accumulation approaches the observed field by construction (items 50 to 53).

Intra-event structure and scaling. The storm hyetograph has been described by scaling models: Koutsoyiannis and Fofoula-Georgiou (1993) show that the statistical properties of rainfall within the storm depend on the duration of the event, that a simple scaling model reproduces that internal structure, and that this model provides a theoretical basis for the concept of the mass curve, the normalised cumulative depth against normalised time. The hyetograph has also been described by multifractal formulations (Veneziano et al., 2006), by few-parameter design storms, such as the two-parameter gamma function fitted to 73 storms in Valencia (García-Bartual and Andrés-Domènech, 2017), and by the quartile-based time distributions of Huff (1967, 1990), applied outside Illinois by, for example, Back (2011). The distinction by storm type also reaches the extremes: Ulrich et al. (2021) model the seasonal variation of extreme rainfall at 132 German stations and find that short, convective events peak in summer, whereas long, stratiform ones vary regionally. This is the family closest to Eq. (15): the normalised mass profile is a two-parameter mass curve. The difference lies in how it is specified: here the profile belongs

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to a family characterised by an explicit potential, $C = E + C_r$, whose members share the same variational identity, and the quadratic member was chosen empirically within that family (AC6, items 17 to 20). The family provides the framework for comparing profiles; it does not provide the choice, nor the ordering law of the bursts.

IDF curves and their framework. Koutsoyiannis et al. (1998), already cited, sets the framework for construction and fitting; Cheng and AghaKouchak (2014) extend IDF curves to the non-stationary case. The IDFP curves of this work are a different extension: not of frequency in time, but of spatial coverage under a sparse network.

Regionalisation of IDF curves under a sparse network. The estimation of design intensities where there is no recording rain gauge is addressed by regional frequency analysis based on L-moments (Hosking and Wallis, 1997), by national formulations that interpolate parameters between stations, such as the INAMHI formulation that this work takes as its basis, and by IDF curves derived from remote sensing estimates for sparse networks (Marra et al., 2017; Shehu et al., 2023). These approaches estimate the frequency at the point; the IDFP curves address something else: which part of the intra-event structure is not recorded by a network that samples far from the storm centre, and they are presented as model-conditioned scenarios (AC6, item 26), whose transformation does not by itself establish a different observed exceedance frequency.

Entropy in hydrology. Entropic inference has its own tradition within the discipline: Koutsoyiannis (2005a, b) derives from the maximum entropy principle the distributional and time-dependence properties of hydrological processes, and Koutsoyiannis (2014) unites the thermodynamic notion with the stochastic one. To these are added the reference to Jaynes (1957) that the manuscript already cites and the inference over trajectories (Pressé et al., 2013) incorporated in AC6. This is the literature that places the variational formulation within hydrology and not only within statistical physics.

Rainfall over Andean terrain. In addition to Garreaud (2009) and Escobar-González et al. (2022), already cited, the spatial variability of rainfall in the Ecuadorian Andes is documented by high temporal resolution monitoring in páramo (Padrón et al., 2015), by rainfall regimes differentiated according to topographic position (Campozano et al., 2016) and by a regional hydroclimatic synthesis (Espinoza et al., 2020). This is the context that justifies why the annual isohyet field can be used as structural information in the model.

2.1.1.3 Committed changes to the revised manuscript

C20. Extension of Section 1 with the review organised into the seven families of item 29, stating for each of them what it represents and how MIT-Q separates from it, with the references given there.

C21. Closing paragraph of the review stating the problem on which it converges: the generation of intense short-duration events over terrain with a strong orographic gradient and a sparse observation network, and the advances towards obtaining IDF curves at sites without a recording rain gauge.

2.2 Comment: the novelty with respect to Beltrán (2023) is not clear

Additionally, because Beltrán (2023) presents similar theory applied to the same dataset, the distinct novelty of this manuscript—which appears to lie in developing a storm model from IDF curves—should be articulated more clearly.

2.2.1 Response

2.2.1.1 *What we accept*

30. We accept that the separation between the two works is not declared. The manuscript cites Beltrán (2023) as the origin of the principle, but it does not say what it takes from it and what it adds, and the reader is left with no basis on which to judge the contribution. We also accept two further points. First, that after the concessions of AC6 the novelty cannot reside in the principle: the constancy of Maximum Certainty is the Gibbs identity (AC6, item 1) and no distinct principle of inference is claimed (AC6, C8). Second, that Beltrán (2023) is not only the origin of the principle: its Section 4.4 already presents a spatial and temporal application of MIT-Q over 1600 km², with random PRE and DT, a 200-year simulation and comparison with IDF curves at five stations. The manuscript should have said so and does not.

2.2.1.2 *What we maintain*

31. The separation is as follows, on three levels. Components inherited from Beltrán (2023): the functional and its maximisation, the quadratic truncated exponential as the temporal pattern, the duration DT and the depth PRE as random variables of the event, and the architecture of the spatial generator over the DMQ, compared at that time for 10 min to 6 h with a 200-year simulation. Extensions of the evaluation in the present work: 2500 km², 500 years, durations from 5 min to 12 h, and the explicit exposition of the temporal and spatial construction, including the provenance of its relationships in Beltrán (2003) (item 54). Developments proper to the present work: the arrangement of the m bursts formalised as the effective random variable of the event, with its ordering rule declared (AC6, C9); the exact link, with no fitted parameter, between the exponents (b_1 , b_2) of the official IDF curves and the parameters of the tangent extreme storm (Section 2.4; AC6, item 24); and the construction, on that link, of the scaling factor ϕ and of the IDFP scenarios for the 66 stations of the national network. In the revised manuscript the three levels are declared separately.

32. With respect to the wording of the comment itself, we add a precision: there are two distinct operations with IDF curves that the manuscript does not separate clearly. In Section 2.3 the IDF curves are not an input to the generator: the storms are generated with distributions and rules parametrised beforehand; the Quito-Observatory curve intervenes in the calibration of α_0 and the other four only in the subsequent comparison (item 39). In Section 2.4, by contrast, the referee's reading is correct: for each point of an official IDF curve the extreme storm (PRETr, DT) is constructed whose mean intensity is tangent to the curve, which translates the exponent b into a shape parameter of the storm with no fitted parameter. That second operation is the bridge between the event model and the regional extension, and the revised manuscript presents it as such.

2.2.1.3 *Committed changes to the revised manuscript*

C22. Express paragraph in Section 1, with a cross-reference from Section 2.1, delimiting what is taken from Beltrán (2023), the extensions of the evaluation and the developments proper to this work, in the terms of item 31, and stating the contribution in three points: the arrangement of bursts as a random variable of the event with an explicit rule; the exact relationship between the exponents of the official curves (b_1 , b_2) and the parameters of the tangent extreme storm, from which the scaling factor is derived; and the IDFP scenarios over the national network.

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2.3 Comment: the framing of the introduction comes late

The introductory narrative would also benefit from earlier framing; general statements on complex systems occupy the first few paragraphs, and the specific focus on intense rainfall events only appears at line 45.

2.3.1 Response

2.3.1.1 What we accept

33. We accept the observation, and it is a matter of direct correction. The first three paragraphs deal with invariants and conservation laws, with entropy and statistical inference, and with the formulation of the PCM; intense rainfall appears at line 46. Part of the material objected to has already been withdrawn by earlier commitments: AC3 §4.2.1 and AC6, C2, withdraw the reference to Noether and the passage on proper and improper divergence relations. With that withdrawal, the reordered introduction begins with the hydrological problem.

2.3.1.2 Committed changes to the revised manuscript

C23. Reordering of Section 1: the first paragraph poses intense rainfall over complex topography, its intra-event structure and the problem of a sparse network; the literature review of C20 follows; the probabilistic framework and the variational formulation are presented afterwards, with the problem already posed, and within the space left by the withdrawal of AC6, C2.

2.4 Comment: the technical description lacks clarity and structure

Throughout the manuscript, the technical description lacks sufficient clarity and structure, often interjecting general theoretical background into specific technical sections. For instance, at line 280 (Section 2.3.1), the discussion on exponential random variables covering seismic events, radioactive decay, and mechanical failures feels disconnected from the description of the MIT-Q model. Similarly, Sections 2.1 and 2.2 present general considerations regarding the Maximum Certainty Principle, but these concepts remain loosely connected to the rainfall model presented in Section 2.3 and the application that follows. The manuscript would be significantly improved by establishing a clear, explicit link between the Maximum Certainty Principle and the proposed storm model.

2.4.1 Response

2.4.1.1 What we accept

34. We accept the diagnosis in its two parts. The first concerns placement: the paragraph at lines 282 to 284, with the times between earthquakes, radioactive decay and the lifetime of electronic components, is general justification material that interrupts the description of the model. What is pertinent in that passage is the truncated exponential applied to extreme magnitudes, supported by Thingbaijam and Mai (2016) and Cosentino et al. (1977); Traxl et al. (2016) documents exponential cut-offs in the sizes of extreme rainfall clusters, and is cited as such and not as support for the distribution of Eq. (13)

35. The second is substantive and coincides with the second major comment of report RC1, which AC6 already accepted: the manuscript defines the random object in Section 2.1.2 and makes it concrete in Section 2.3.1, but it does not set out in a single place the chain that links

both with what the simulation executes (AC6, items 13 and 15).

2.4.1.2 What we maintain

36. The chain exists, it is explicit, and in the revised manuscript it is presented in five steps that distinguish what is derived from the functional from what is an assumption of the model. With $u = t/DT$ and $\alpha_0 = \lambda_0 \cdot DT$: (1) choice of the potential $C = -\alpha u + \ln(1 - e^{-\alpha u})$, which specifies the family and the member (AC6, items 17 to 20); (2) derivation conditional on that choice: Eq. (13) defines the auxiliary distribution F , and Eq. (15) sets the depth of each burst as an increment of $G = F^2$; (3) additional rule: Eq. (18) gives the selection weights w_j and the successive selection proportional to the remaining weights (AC6, item 10); (4) realisation: the arrangement π of the m bursts is the effective random variable of the event and the realised cumulative depth is $H\pi(kDT/m) = \sum_{\ell \leq k} h\pi(\ell)$; (5) spatial coupling, which uses the temporal realisation and is not deduced from the functional (item 53). With $\alpha_0 = 10$ and $m = 8$, the depths by rank are 50.91, 33.35, 11.10, 3.31, 0.96, 0.28, 0.08 and 0.02 % of PRE, and the weights of Eq. (18) place the burst of highest rank in the eight positions with probabilities 41.9, 27.0, 16.1, 8.7, 4.1, 1.6, 0.5 and 0.1 %. Both sets of figures are analytical; they were verified against the 1 024 225 storms of the 500-year simulation that accompanies the manuscript as supplementary material.

37. That same ordering of the bursts (AC6, items 7 and 10) links the temporal model with the spatial module: the position occupied by the burst of highest rank sets the upwind offset of the starting centre, so that the largest burst occurs when the centre is over the target cell (item 53). This is the link the referee asks for, and it is in the code without being in the paper.

2.4.1.3 Committed changes to the revised manuscript

C24. Withdrawal of the paragraph at lines 282 to 284 and its replacement by a sentence stating the use of the truncated exponential in the representation of extreme magnitudes, with the citations of Thingbaijam and Mai (2016) and Cosentino et al. (1977), and with Traxl et al. (2016) cited for what it documents. The attribution «Kiran et al., 2016» is corrected at line 286 and in the reference list: the paper is by Thingbaijam, K. K. S. and Mai, P. M., and it documents the truncated exponential distribution of coseismic slip, not of landslides during earthquakes.

C25. New subsection at the beginning of Section 2.3, entitled From the functional to the storm model, setting out the chain of item 36 in its five steps, accompanied by a diagram, and declaring which steps are derived from the functional and which are additional assumptions of the model. It complements the change already committed in AC6, C9.

C26. Transfer to an appendix of the general-scope material of Sections 2.1 and 2.2 that does not take part in the construction of the model, keeping in the body the part used by the chain of C25.

2.5 Comment: methodological workflow, calibration and spatial variability

The methodological workflow and calibration details also require clarification. It is currently unclear whether the synthetic storms are derived from a single IDF curve or integrated across all station IDF curves, and how spatial variability is represented.

2.5.1 Response

2.5.1.1 What we accept

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38. We accept that the methodological workflow is not set out. The manuscript does not say in a single place what enters the generator, which parameters are fixed, with which data they are fixed, what the simulation produces and against what it is contrasted. The referee's question as to whether the storms are derived from one IDF curve or from the set of them is a direct consequence of that absence.

2.5.1.2 *What we maintain*

39. The synthetic storms are not derived from any IDF curve, neither from one nor from the set. The generator produces each event from its own variables: the duration DT with a shifted quadratic truncated exponential distribution, with lower bound 0.47 h, upper bound 24.5 h and dimensionless parameter 8.9, that is, the same member of the family as the temporal pattern of Eq. (15); the depth PRE with a shifted Weibull distribution, with shape 1.3, scale 19.4 mm and location 20.9 mm; the arrangement of the m bursts with the weights of Eq. (18); and the position and the displacement with the spatial module. These laws, together with $\alpha_0 = 10$, $m = 8$ and the spatial rules, define the parametrised generator, and they are declared in the table of C27. The IDF curves intervene after the simulation, in two distinct roles: the official curve of the Metropolitan Public Water and Sanitation Company of Quito (EPMAPS) at the Quito-Observatory station served to fix α_0 by sensitivity analysis, and the curves of the other four stations intervened only in the subsequent comparison (Figs. 5b to 5e). That distinction is already committed in AC6, C11, together with the change of terminology from validation to comparison.

40. Spatial variability is not represented by the IDF curves but by the spatial module, through two mechanisms that operate on the annual isohyet field of the EPMAPS and that are described in items 50 to 53: the frequency with which event centres are located in each zone, and the advection of the centre during the life of the event. Both cause the simulated annual accumulation to approach the isohyet field by construction; the second also adds the distortion of the temporal pattern recorded at a fixed point. Neither mechanism takes information from the IDF curves; the only curve that intervenes in the model, that of Quito-Observatory, does so in the calibration of α_0 .

41. The simulated set that accompanies the manuscript allows the above to be verified: 1 024 225 storms in 500 years, that is 2048 events per year over the 2500 km², with DT between 0.47 and 24.49 h, median 3.79 h, and PRE between 20.9 and 164.2 mm, median 35.5 mm.

2.5.1.3 *Committed changes to the revised manuscript*

C27. Incorporation in Section 2.3 of a methodological flow diagram with four blocks, inputs, generation, outputs and contrast, accompanied by a specification table for the generator: distributions of PRE and DT with their parameters; α_0 and m; the relationships n, k and translation speed; the annual isohyet field; the directional rule of item 53 with its reference point; and, for each element, its value, its source and its role in the calibration. Where the provenance is not documented, the table says so.

C28. Express statement, in Section 2.3.3, that the IDF curves are not an input to the generator and that spatial variability comes from the annual isohyet field through the two mechanisms of the spatial module.

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2.6 Comment: the model and the results are presented together

Furthermore, the manuscript blends the presentation of the model with the discussion of results, making the overall structure difficult to navigate and making it challenging to evaluate the model's validity.

2.6.1 Response

2.6.1.1 What we accept

42. We accept the observation. Section 2.3.2 presents the treatment of wind and at the same time sets out results from one simulated storm and from a sample of 475 events; Section 2.3.3 states the calibration procedure and at the same time discusses the fits of Figs. 5a to 5e. The reader cannot separate what the model assumes from what the model produces, which is the condition for evaluating its validity.

2.6.1.2 Committed changes to the revised manuscript

C29. Restructuring of the manuscript: Section 2 keeps only the formulation, the model and the procedure; a Section 3 of results receives Fig. 2, Fig. 4, Figs. 5a to 5e and the α_v values, with their discussion; and the comparison with the IDF curves of the four additional stations moves to results with the terminology already committed in AC6, C11.

3 Detailed comments

3.1 Comment: lines 262 to 263, calibration and validation

Lines 262–263: The sentence regarding calibration and validation is unclear. The text implies that 500 years of synthetic precipitation generated by the MIT-Q model are used to calibrate and validate a secondary model, but this secondary model has not yet been defined.

3.1.1 Response

3.1.1.1 What we accept

43. We accept that the sentence invites that reading. There is no secondary model. What is calibrated and contrasted is MIT-Q itself: from the 500-year synthetic sample the extreme intensities for different durations, between 5 min and 12 h, are obtained, and those intensities are contrasted with the official curves. The sentence at lines 262 and 263 omits that intermediate step, which is what leaves the contrasted object without an antecedent.

3.1.1.2 Committed changes to the revised manuscript

C30. Rewriting of lines 262 and 263 in these terms: the study area is 2500 km²; from the synthetic sample delivered by a 500-year stochastic simulation the extreme intensities per duration are obtained, and those intensities are the object compared with the observed IDF curves. It is further stated that α_0 was fixed with the curve of the Quito-Observatory station and that the remaining stations intervened only in the subsequent comparison, consistently with AC6, C11.

3.2 Comment: lines 273 to 275, Figure 2 and Huff (1990)

Lines 273–275: Please clarify how Figure 2 supports the statement attributed to Huff (1990) regarding early-peaked storm behavior.

3.2.1 Response

3.2.1.1 What we accept

44. We accept the observation. The statement that intense storms frequently exhibit an early peak is a result of Huff (1990), obtained from his own sample, and Fig. 2 neither demonstrates it nor can demonstrate it: the sample of 475 simulated storms in Fig. 2 is selected for being first-quartile storms, so the figure contrasts the shape of the cumulative curve within that group, not the frequency with which the group occurs. The reference to the figure at the end of the sentence attributes to the figure what the figure does not prove. The same precision was already stated in AC6, item 16, point (d).

3.2.1.2 What we maintain

45. What Fig. 2 does support is a contrast of shape, and on that plane the result is compatible: the curve of Eq. (15) that best fits Huff's 10 % curve is obtained with $\alpha v = 12.7$; the value $\alpha v = 5.8$ fits the 50 % curve and $\alpha v = 2.8$ the 90 % curve, and the αv values of the simulated sample lie between 5.1 and 15.2 with mean 8.6, within the interval of the profiles compared. This is a descriptive compatibility of shape; it does not demonstrate that Huff's exceedance probabilities are reproduced.

46. The comparison of frequencies, which is what the referee asks for, can be made and we provide it here. Classifying each of the 1 024 225 events of the 500-year simulation according to the quarter of the event that concentrates the largest fraction of the depth, which is Huff's criterion, the simulated set gives 68.90 % first-quartile events, 24.84 % second, 5.70 % third and 0.56 % fourth. Huff (1990) reports, for point rainfall, 37, 27, 21 and 15 %, and for mean rainfall over areas of 50 to 400 mi², 33, 33, 23 and 11 %. The local reference exists and is the pertinent one. Beltrán (1995) classified by quartiles the 283 storms recorded at the Quito-Observatory station, taken as the four annual storms of greatest 24 h precipitation over the whole period of record, making each hyetograph dimensionless and assigning to it, by least squares, the closest Huff curve. Over the complete range of durations, from 34 to 1920 min, he obtains 60.8 % first-quartile events, 15.9 % second, 11.7 % third and 11.7 % fourth; over the 138 storms of shorter duration, from 34 to 499 min, he obtains 65.9 / 17.4 / 9.4 / 7.2 %.

47. The preceding distribution is not an emergent result of the simulation but a consequence of the weights of Eq. (18): with $m = 8$, the first quartile comprises positions 1 and 2 of the sequence, and the probability that the burst of highest rank, which contains 50.9 % of the depth, occupies one of them is $41.9 + 27.0 = 68.9$ % for $\alpha_0 = 10$ (AC6, item 10); the analytical calculation gives 68.97 / 24.76 / 5.71 / 0.56 %. The simulated set reproduces it because the classification is made on the generated event, before advection. The parameter α_0 , fixed by sensitivity against the IDF curve of Quito-Observatory, thus governs both the short-duration intensity and the quartile frequency of the generated event; this is a limitation of the model and it is declared in the revised version.

Against the Illinois sample, the model concentrates more generated events in the first quartile; against the local sample, the difference is three percentage points. The Quito-Observatory subset comparable by duration, the 138 storms from 34 to 499 min, has 65.9 % of its events in

the first quartile and the simulated set has 68.90 %. The larger differences lie in the following quartiles: the model places more events in the second, 24.8 against 17.4 %, and almost none in the fourth, 0.6 against 7.2 %. The comparison should be bounded by four precisions that do not fully explain it. First, the classification criterion is not the same: Beltrán (1995) assigns to each dimensionless hyetograph the closest Huff curve by least squares, whereas the simulated set is classified by the quarter that concentrates the largest fraction of the depth; in the model both criteria coincide, because the burst of highest rank carries 50.9 % of the depth and always draws its quartile with it. Second, the populations are not comparable in duration when the complete range is taken: the local sample reaches 32 h, whereas 97.2 % of the simulated events last 12 h or less and 75.9 % last 6 h or less, which is why the contrast is made on the subset of shorter durations. Third, the classification of the simulated set is made on the generated event; the record at a fixed point receives the event already advected, with α_v falling to 2.4 over part of the area the event covers (Fig. 4b), and a more uniform pattern transfers mass to the later quartiles. The direct comparison with a point record is therefore the one from the record at the virtual stations, which Module 6 builds and which the revised manuscript reports. Fourth, Huff's sample comes from networks in Illinois and he himself warns that time-distribution relations vary between regions with different climatic regimes, which makes the Quito-Observatory sample the pertinent reference for contrast.

3.2.1.3 Committed changes to the revised manuscript

C31. Separation, at lines 273 to 275, of the statement attributed to Huff (1990), which is kept as his result and with his citation, from the contrast that Fig. 2 provides. The caption of Fig. 2 states that the simulated sample is conditioned on the first quartile and that the contrast is one of shape of the cumulative curve, not of frequency of occurrence.

C32. Incorporation, in the results section, of the quartile distribution of the generated event against the analytical distribution of Eq. (18), against that of the storms recorded at Quito-Observatory (Beltrán, 1995) and against that of Huff (1990), with the declaration of the limitation of item 47; and of the quartile distribution of the record at the virtual stations, computed on chronological hyetographs with Huff's definition of an event (a minimum separation of 6 h without rainfall), which is the one directly comparable with point rainfall.

3.3 Comment: line 290, residence time

Line 290: Clarify the usage of "residence time" here, as its application differs from standard hydrological terminology.

3.3.1 Response

3.3.1.1 What we accept

48. We accept the observation. In hydrology, residence time denotes the time a mass of water remains in a store, and it is defined over a control volume with inflows and outflows. The variable T at line 290 is not that: it is the time during which the event remains in growth conditions. Using the hydrological term for that other object is misleading. In the revised manuscript T is called growth-stage time, distinct from the duration DT and from the development time td , and it is declared as an auxiliary variable interpreted within the model.

49. The second part of the matter has already been accepted before report RC1 and it is worth

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stating here because the referee touches the same sentence: the identification of T with the time spent in the development state is an interpretative hypothesis, not a result. T was not measured as such, it has no observational definition that distinguishes it from DT and from td, and its distribution was not tested (AC6, item 13).

3.3.1.2 Committed changes to the revised manuscript

C33. Replacement, at line 290 and throughout the manuscript, of residence time by growth-stage time, T, with a note stating that the term does not denote residence time in the hydrological sense, that T is distinct from DT and from td, and with a cross-reference to the statement of hypothesis already committed in AC6, C9.

3.4 Comment: Section 2.3.2, the effect of wind

Section 2.3.2: The effect of wind is modeled by adjusting λ_0 to λ_v . Please elaborate on how this scalar parameter shift physically captures the distinct spatial mechanisms described (i.e., increased intensity on the windward side versus reduction on the leeward side).

3.4.1 Response

3.4.1.1 What we accept

50. We accept the observation. A scalar shift from λ_0 to λ_v cannot capture two spatial mechanisms, and that is not what the model does. Section 2.3.2 states the result without exhibiting the mechanism that produces it, and read in that way the criticism is correct. The revised manuscript sets out the mechanism before naming λ_v .

3.4.1.2 What we maintain

51. λ_v is not the cause of the asymmetry: it is its measure at a point. MIT-Q represents kinematically the interaction between the temporal structure of the event, its expansion and its translation; the asymmetry is produced by the spatial module of Module 1 (Appendix A, Fig. A1) through two distinct mechanisms that the manuscript does not separate, and λ_v is the effective parameter that a fixed recording rain gauge infers from the record reaching it once those two mechanisms have acted, not a measured wind speed. Orographic enhancement is not represented with explicit dynamics: it enters solely through the annual field that the module must reproduce.

52. First mechanism, the frequency of events. The centre of each storm is chosen over the annual field; the depth of the event is subtracted from that field; the next centre goes to the cell with the largest relative deficit with respect to its own isohyet, and the year ends when the mean remaining value falls below 2 % of the initial maximum. The simulated annual accumulation thus approaches the target isohyet field by construction. Since the windward zone has a larger annual target and each event delivers a bounded depth, more events must be centred there. Measured over the 1 024 225 storms of the 500-year simulation, against the EPMAPS isohyet raster that the model uses as input, the centres per cell by isohyet quintile are 37.2, 58.1, 77.7, 110.8 and 227.3: the wettest quintile receives 6.1 times more storm centres per cell than the driest, with monotonic growth; an independent 100-year simulation gives 6.11. A precision follows from this: in the model, the larger annual accumulation on the windward side is produced by a greater frequency of events, not by a greater depth per event, since PRE is drawn independently of

position. This is a property of this parametrisation, not a statement about the physical mechanism of orographic enhancement.

53. Second mechanism, the advection of the centre. The magnitude of the translation speed is $7.8 \cdot DT - 0.744$ km/h, the same expression as the mean radial growth celerity $k = R/DT$; from that equality it follows that the storm travels one radius during its life. The direction is set by a rule that we describe as it is executed: around a reference point, displaced by 20 % from the cell of the annual maximum towards the cell of the Quito-Observatory station, the minimum of the annual field is sought within a window of ± 2 cells; the signs of the displacement to that minimum set the quadrant of travel, and the partition of the speed between its two components is drawn at random keeping the prescribed magnitude. The winds that translate the storms thus go from zones of high annual precipitation towards zones of low annual precipitation. The coefficient 0.2 and the reference cell are part of the rule; they are declared in the specification of the model (C27) and their sensitivity is reported in the revised version (C41). Contrasted with the descent of the gradient of the same raster over 933 808 events, the quadrant agrees in 65.3 % of cases, the east-west sign in 86.3 % and the north-south sign in 74.0 %; this is a diagnostic of the internal consistency of the rule, not a validation of the wind. The starting centre is offset upwind by a fraction pico/m of the path, where pico is the position occupied by the burst of highest rank in the sequence, so that this burst occurs when the centre is over the target cell selected by the remaining field. A fixed point therefore samples a different part of the event depending on where it lies with respect to the trajectory, and that is what shifts the observed temporal pattern from λ_0 to λ_v . Fig. 4b of the manuscript already shows the result within a single storm: αv between 2.4 and 14.6 with mean 8.6 depending on the zone.

54. The three relationships that govern the spatial module have as their antecedent the fits of Beltrán (2003) for 15 storms selected with simultaneous records at three or more stations of a network of six, which is the basis available in that study. His Figs. 4.17, 4.18 and 4.19 give $n/DTc = 4.4159 \cdot DTc - 1.2992$ with $R^2 = 0.9821$, $K/DTc = 9.1561 \cdot DTc - 1.7686$ with $R^2 = 0.9631$ and $V/DTc = 5.9258 \cdot DTc - 1.787$ with $R^2 = 0.9279$, that is $n = 4.4159 \cdot DTc - 0.2992$, $K = 9.1561 \cdot DTc - 0.7686$ and $V = 5.9258 \cdot DTc - 0.787$, with DTc the duration at the storm centre. The values in force, $n = 4.05 \cdot DT - 0.282$ and $k = 7.8 \cdot DT - 0.744$, result from the general calibration fit with the Quito-Observatory station: with respect to 2003, the coefficient of n varies by 8 % and its exponent by 6 %; the common coefficient 7.8 lies between the two antecedents, 15 % below that of K and 32 % above that of V , with an exponent differing by 3 % from that of K . The constants of the spatial module therefore have a documented origin, and the table of C36 shows each of them alongside its antecedent.

55. The equality between the translation speed and the mean radial celerity is a hypothesis of the model and not a result of those fits, and it is declared as such. What Beltrán (2003) supports is that both quantities scale with duration with exponents differing by 2.4 %, obtained from two independent fits; the coefficients, by contrast, give a ratio V/K between 0.66 and 0.62 over the range of durations analysed. The model adopts a single law for the two quantities. We call that hypothesis the critical motion condition: the storm advances, on average during the event, at the same speed with which it expands, so that it travels one radius during its life; the instantaneous radius grows as $r(t) = R \cdot (1 - e^{(as(t/DT))}) / (1 - e^{as})$, with $as = 3.126$, and K is its mean value.

56. The ordering of the bursts (AC6, items 7 and 10) is what sets that offset. It is an explicit link between the temporal model and the spatial module, and it is at present in the code without being in the paper. It is also the concrete answer to the request for a link in item 35.

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3.4.1.3 Committed changes to the revised manuscript

C34. Rewriting of Section 2.3.2: the two mechanisms, frequency of events and advection of the centre, are set out before λv is introduced, and it is stated that λv is a diagnostic of the point record and not a wind parameter.

C35. Express statement that the translation speed coincides with the mean radial celerity, $7.8 \cdot DT - 0.744$, with its consequence: the storm travels one radius during its life; and of the law of instantaneous growth of the radius with $a_s = 3.126$.

C36. Citation of Beltrán (2003) in Section 2.3.2 and in Appendix A as the provenance of the three relationships of the spatial module, with a three-row table setting the relationship obtained in 2003, with its coefficient of determination and its basis of 15 storms with records at three or more stations of a network of six, against the value in force after calibration.

C37. Statement of the critical motion condition as a hypothesis of the model, with the empirical support behind it, exponents of the radial celerity and of the translation speed differing by 2.4 %, and with the express declaration that the 2003 coefficients are not equal and that the equality is set by the calibration.

C38. Statement of the directional rule as it is executed: reference point displaced by 20 % from the annual maximum towards the Quito-Observatory cell, window of ± 2 cells, quadrant set by the signs and random partition of the speed; with the figure of consistency with the gradient, 65.3 % of the quadrant over 933 808 events, presented as an internal diagnostic.

C39. Statement of the link between the ordering of the bursts and the initial position of the centre, in the new subsection of C25, with the precision that the implementation takes as its reference the end of the interval of the largest burst and the cell selected by the remaining field.

C40. Renaming of the Burst column of the supplementary storm file, which contains α_0 and not a number of bursts, consistently with AC6, C11.

C41. Sensitivity analysis of the directional rule to the coefficient 0.2 (including the value 0) on the distribution of centres by quintile and on the intensities at Quito-Observatory, reported in Appendix A.

C42. Version note for the generator in Appendix A, identifying the version with which the 500-year run was produced and correcting the case in which the burst of highest rank occupies the last position of the sequence, where the offset variable is not updated (0.08 % of the events for $\alpha_0 = 10$ and $m = 8$).

C43. Table of the origin of the figures reported by this response and by the manuscript, distinguishing analytical identities (Eqs. 15 and 18), bibliographic antecedents (Beltrán, 1995; Beltrán, 2003; Huff, 1990) and empirical diagnostics from the simulation, the latter with the version of the generator, the catalogue, the isohyet field and the computation procedure.

4 Conclusions

Report RC2 and report RC1 coincide on one point: the manuscript states results without exhibiting the mechanism that produces them, and it forces the reader to reconstruct it. The four observations of exposition in the report, the literature review, the order of the introduction, the interpolation of general material into technical sections and the blending of model with results, are accepted without reservation and are corrected in changes C20 to C29.

The two observations that touch the substance receive the mechanism that was missing. The effect of wind is not a scalar shift of a parameter: it is two spatial mechanisms, the frequency with which centres are located over the remaining annual field and the advection of the centre during the life of the event, and λv is what a fixed recording rain gauge measures after both have acted. The three relationships that govern that spatial module come from Beltrán (2003); the directional rule is described as it is executed, with its reference point declared; and the equality between translation speed and mean radial celerity is declared as a hypothesis of the model. The contrast with Huff (1990) is one of shape and is conditioned on the first quartile; the comparison of frequencies, which the manuscript did not make, is provided here against the local reference, the 283 storms recorded at Quito-Observatory (Beltrán, 1995), with which the generated event agrees in the first quartile to within three percentage points and departs in the tail, is explained as a consequence of the parameter α_0 through Eq. (18), and is declared as a limitation in the revised manuscript together with the comparison at virtual stations, which is the directly pertinent one.

The figures in this response have three origins, identified in each case: the depth fractions and the ordering probabilities are analytical, obtained from Eqs. (15) and (18) with $\alpha_0 = 10$ and $m = 8$; the relationships of the spatial module and their coefficients of determination come from Beltrán (2003), and the reference quartile frequencies from Beltrán (1995) for Quito-Observatory and from Huff (1990) for Illinois; the empirical diagnostics (items 41, 46, 52 and 53) were measured over the set of 1 024 225 storms of the 500-year simulation that accompanies the manuscript as supplementary material, and the revised manuscript documents the version of the generator and the procedure with which they were computed (C43), so that the referee can reproduce them.

On novelty, the position is the one left by AC6. The principle is not claimed as a contribution: the constancy of Maximum Certainty is the Gibbs identity. Beltrán (2023) already presented a spatial application of MIT-Q, and the present work extends it in area, in length of simulation and in range of durations. What this work contributes is the arrangement of bursts formalised as a random variable of the event with its rule declared, the exact link between the exponents of the official IDF curves and the parameters of the tangent extreme storm, and the regional extension derived from that link, whose closed form is established in AC6.

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Sincerely,
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