A two parameter design storm for Mediterranean convective rainfall

Authors: R. García-Bartual and I. Andrés-Doménech

MS No.: hess-2016-644

Status: Open Discussion on HESSD

Response to Referee Comment 2016-644-RC3 – Prof. A. Montanari

The authors are very grateful to Prof. Montanari for the work he has done on the draft and the observations and suggestions he has made. Thanks to his remarks we have been able to improve the content of the manuscript. We would particularly like to underline the new results and the discussion incorporated in the revised text, as a result of question number 4.

The rest of the questions have been also answered and all the minor remarks made by Prof. Montanari have been duly considered and incorporated into the new version of the manuscript.

1. On the principal component analysis

The principal component X_1 gives more weight to rainfall intensity than to cumulative rainfall depth, although both are considered in a weighted way. Any of the two variables (I_{10} or P) separately, explains less variance of the process than X_1, which is then introduced in the analysis exclusively with the goal of assigning a return period T to the storm.

Given the assignment of T, procedure essentially involves a single variable. X_1 was chosen for that purpose as it explains 92% of the variance. Thus, variable X_1 is an adequate quantification of the magnitude of the event, affected both by intensity and total rainfall depth.

In order to know the effect of ignoring 8% of the variance, it would be necessary to consider both variables simultaneously, either X_1 and X_2 or I_{10} and P , which is not compatible in practice with the usual univariate analyisis and a single-variable statistics linked to a given T.

2. On the uncertainty in determining equation 25

Equation 25 introduces the ratio between the total cumulative depth of the storm and its maximum intensity I_{10}, for a time level of aggregation $\Delta t = 10\ \text{min}$. This ratio has been assessed for the totality of the selected events, resulting in the cloud of points displayed in figure 2. In view of the former graph, and after splitting the sample in families of different duration, it was verified that the ratio α experienced small variations within each of them, with significant regression coefficients values for each of the families (longer, medium and short storm durations).

This fact enables the characterization of each family according to their ratio $\alpha = \frac{P}{I_{10}}$. If regressions had not been acceptable, such an empirical characterization would have not been acceptable either, and the proposal of three design storms i(t) with different values of the parameter α would have no empirical basis.

On this empirical basis, it is suggested to postulate the characteristic value of ratio α as a starting condition for building each design storm, one per family.

3. On the goodness of fit of the gamma function to explain the temporal pattern

The goodness of fit of a gamma-type pattern to represent rainfall intensity in time after convective rainfall events was studied in (Andres-Domenech et al, 2016). The index employed there was an objective function combining in a weighted way the squared differences between the empirical and the theoretical values of the following variables: rainfall intensities of each time interval, total cumulative depth, duration, maximum intensity and relative position of the peak intensity. Details can be found in (Andrés-Domenech et al, 2016), including illustrative examples for different rainfall events. After processing all the sample, the typical deviation of the error for the total cumulative rainfall depth was 6.4%, while the one corresponding to maximum peak intensity was 5%.

4. On the underestimation of the impact of extreme rainfall

Given that original storms of the sample have not an a priori assigned return period T, it becomes difficult to contrast accurately the potential overestimation derived from this method. Nonetheless, if we assume as valid the criteria for T assignment described in sections 3.3 and 3.4, it is feasible to assign an empirical value of T to the storms of the sample. In that case, it is possible to make a comparison with the theoretical storms resulting from the application of the procedure described in section 4, obtained for that same T value.

As an example, this task was performed for the most intense storm of the sample. It took place in Valencia, on June the 14th, 2004. This storm is a typical convective-type storm during warm season with high rainfall intensities. It presents a value of X_1=177.18, corresponding to a return period of T=26 years according to extreme value analysis of section 3.4. Its duration is equal to 40 min, thus, belongs to the intermediate duration family ($\alpha=\alpha_2$). The theoretical gamma-design storm for $\alpha=\alpha_2$ and T=26 years can be built following procedure in section 4. On the other hand, and using the traditional method for the construction of the alternating block design storm, a storm is built for T=26 years, using the ID curve for T=26 years.

The following table shows the resulting values of I_{10} and P.

Parameter	**Historical storm**	**Aggregated Gamma Storm**	**IDF Alternating Block Storm**
I_{10} (mm/h)	172.80	170.85	165.81
P (mm)	45.00	45.40	60.94

As shown in the table, the gamma shaped design storm reproduces very well the observed peak and volume, while the IDF Alternating Block storm reproduces also well the peak intensity (-4%), but overestimates the total depth (+35%). These results are obviously not conclusive, but indicate consistency of the method and are in accordance to previously found results in reference to IDF Alternating Block storm behaviour.

5. On the different outcome for the longest rainfall duration in Figure 4

The question raised by Prof. Montanari in regard to the comparison shown in figure 4, opens an interesting discussion.

In fact, as pointed out by the reviewer, the outcome for the longer duration is graphically similar, although the aggregated Gamma model storm gives a larger cumulative rainfall. On the contrary, for shorter durations the IDF alternating block design storm seems to be more pessimistic. From this point of view, the outcome for the longest duration is different, as the reviewer indicates.

It is important to notice that, conceptually speaking, there should be a duration limitation of any gamma-shaped design storm, imposed by the actual life cycle of the convective rainfall cell. In the sample studied (section 3.1), the average duration found is 38 minutes, with durations over 1 hour only in 15% of the rainstorms. In accordance to this fact, it should not be adequate to build representative design storms with the Gamma model exceeding the natural duration of the process, resulting in systematic overestimation of the total depth. The longer duration of the Gamma model storm in figure 4 lies in the limit of 1 hour.

This limitation is not really affecting to the IDF alternating block design storm procedure, as duration can be arbitrary chosen and the method can be applied anyway. In fact, it is perfectly possible to build IDF alternating block design storms with durations well over the actual historical durations of independent storm events for a given geographical point. This is not very realistic.

But going back to figure 4, it is interesting to point out that conclusions are inverted when variable I_{10} is taken as reference. That is, the aggregated Gamma model is more pessimistic for shorter durations, exhibiting higher peaks than the IDF alternating block design storm.

Finally, if variable X_1 is taken as reference for the analysis, both methods produce similar results for all durations. To improve clarity of results, and after the question raised by Prof. Montanari, table 5 has been modified, including a new column (variable X_1), and simplifying it for a clearer comparison. The following is the modified version of table 5 in the revised manuscript.

Table 5. Comparison of volume, peak intensity and magnitude of the Gamma aggregated and IDF alternating block design storms.

		Duration (min)	Maximum intensity (mm/h)	Volume (mm)	Magnitude (X_1)
Storm α_1	Gamma aggregated	20	175.0	34.8	175.45
	IDF alternating block	20	164.4	43.2	168.71
Storm α_2	Gamma aggregated	40	169.2	45.0	173.84
	IDF alternating block	40	164.4	60.3	175.05
Storm α_3	Gamma aggregated	60	156.0	80.9	174.87
	IDF alternating block	60	164.4	69.3	178.38

Regarding to this update in table 5, the following sentences will be added in Page 15, line 15 in the revised manuscript: "With regards to variable X1, results are very similar for both methods, as shown in table 2".

Minor remarks

a) Please define the symbol i10. I understand it is the maximum rainfall intensity of a given storm, but I do not understand why the subscript 10 is used.

I_{10} is the maximum intensity for an interval aggregation of 10 minutes. Its general definition is given in equation (21).

b) Please make clear when introducing Figure 2 that the different patterns are identified basing on storm duration. When reading at the bottom of page 10 I had the feeling that patterns were identified by looking at the exponent of the regression lines. My doubt was resolved when reading the text at lines 22 and 23 at page 13. I think the authors should make clear at page 10 already that the regressions refer to different storm durations.

The first sentence of this section (page 10 – lines 4-5) will be rewritten as follows:

"Three different sets of events were identified, according to their duration. As shown in figure 2, each of them can be characterized in terms of a representative value of the ratio:"

c) I think the authors should define at page 11 what is meant by "magnitude" of the storm event.

In the revised manuscript, the following sentence will be added just after equation 26:

"According to the relationships between the cumulative rainfall depth and the storm maximum intensity, both variables are used together to define a new combined variable able to represent the storm magnitude in terms of volume and maximum intensity".

d) In eq. 28 the symbol "i" looks like an exponent. I suggest changing the notation.

We agree. In the revised manuscript we will change the notation to $I_{i,10}$.

e) Please use the symbols IDF and ID coherently. I think both of them indicate the depth-duration-frequency curve.

In the revised manuscript all "IDF" and "ID" symbols will be reviewed and duly replaced.

f) Please clarify how the numbers of blocks at line 26 of page 13 were identified.

In the revised manuscript, the sentence "A continuous… blocks respectively" will be ended adding the following:

"… as once the truncation criterion is selected, the storm duration is established (equation 9), so that, for a given time level of aggregation (ΔT), the number of blocks can be derived".

New references

Resulting from reviewer #3 comments, suggestions, and critics, the following reference will be added to the revised version of the manuscript:

Di Baldassarre, G., A. Brath, and A. Montanari (2006), Reliability of different depth-duration-frequency equations for estimating short-duration design storms, Water Resour. Res., 42, W12501, doi: 10.1029/2006WR004911.