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Interactive Comment

Interactive comment on "On the role of the runoff coefficient in the mapping of rainfall to flood return periods" *by* A. Viglione et al.

A. Viglione et al.

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We thank Gaume (2009) for his review of our paper which allows us to clarify some points that were apparently not clear in the original manuscript. From our reading of his comments there are two main criticisms: (1) on the way we represent the design storm procedure; (2) on the way we define the design storm return period.

(1) DESIGN STORM PROCEDURE:

Apparently, Gaume (2009) is unfamiliar with the 'design storm method' and suggests that it is equivalent to the 'rational formula'. In particular, he states: "the design storm procedure, initially developed in urban hydrology to my knowledge, is a non-satisfactory last-resort solution used sometimes in rural hydrology by consultants, when limited streamflow data is available or extrapolation is needed" (p. S273). He also disputes

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the fact that the design storm method is widely used in practice: ".. the authors argue that the approach presented corresponds to common practice. I totally disagree with this" (p. S274).

The 'design storm method' may not be widely used in France but it is indeed the standard method for estimating design floods from rainfall in many countries around the world (see below). Let us first recall what the cornerstones are of the method (as summarised on p. 631-632 of our paper):

- selecting many storms of different durations reading off their mean intensities from the IDF curve corresponding to the return period Tp of interest and applying a rainfall time pattern to these storms to represent intense bursts within the storm. Rigorously, the design temporal patterns need to be appropriate for the intense bursts within storms, and not for complete storms, to have a return period Tp,

- transforming the design storms to design flood hydrographs by an event based rainfall runoff model with chosen initial soil moisture conditions, and

- selecting the maximum flood peak of the flood hydrographs produced by the storms of different durations, and assuming that the return period of the flood peak, Tq, is equal to Tp.

This procedure is part of the official guidelines of estimating design floods in numerous countries. For example, the German guidelines (that are also applicable in Austria) have "Among the design storms of a given frequency and different durations one has to select the storm that produces the largest flood peak at the cross section of interest" (DVWK, 1999, p. 49). An example is given in Ihringer and Höfer (2006) and an example from Switzerland is given in Job et al. (2002). The design flood method is also part of the Australian guidelines (Institution of Engineers, Australia, 1987) and part of the guidelines of the United Kingdom, i.e., the Flood Estimation Handbook (FEH, 1999). Clearly, varying the storm duration is a key part of the procedure. Occasionally, formulas for the storm duration are given in the guidelines to short cut the procedure but this

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is not essential, as the aim is the same, i.e., to obtain the largest peak when varying storm duration. Gaume (2009) strongly suggests to only use one storm duration equal to time of concentration as if varying storm duration were wrong (p. S274, line 7), but this short cut is neither needed nor general. The UK Flood Estimation Handbook explicitly states that the formula given for the duration "APPROXIMATES the duration giving the largest flood magnitude" (FEH, 1999, p. 4-41, our emphasis) and further expands that the more general procedure is to "consider a range of design storm durations". (FEH, 1999, p. 4-43). Other examples are Akan (1993) who states on p. 6: "generally, several different storm durations need to be tried to identify the most critical design storm duration" and the Hydrology Handbook of the American Society of Civil Engineers (1996, p. 557): "generally, the critical storm duration can be determined only after trying several different storm durations and investigating the sensitivity of the peak discharge and the runoff volume to variable storm duration". The Handbook of Hydrology (Maidment, 1993) is the standard reference of applied hydrology and has an extended section on the design storm method which is exactly what we used in our paper. For example, p. 9.14 has: "where the design procedure does not specify the duration, floods should be calculated from design rainfalls of several durations" and the largest flood peak should be selected (their Figure 9.3.1). Similarly, in the context of the Unit Hydrograph Method, the Handbook of Hydrology states: "In determining a design hydrograph, a range of rainfall durations must be used in this procedure to determine the critical duration and maximum peak discharge" (p. 9.29). The list of guidelines and examples could be extended almost infinitely. We are hence not sure what makes Gaume (2009) think that the method is a last resort SOMETIMES used (our emphasis) and that it does not correspond to common practice in hydrology.

Gaume (2009) seems to confuse the design storm method with the rational formula where storm duration is not varied. Instead, in the rational formula the flood peak (not the entire hydrograph) is estimated from a runoff coefficient, catchment area and rainfall read off the IDF curve for the time of concentration of the catchment. There is only one storm duration in the rational formula which is set to the time of concentration.

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There are two variants of the rational formula and Gaume (2009) does not specify which one he is referring to. The first variant is the deterministic one where storage is neglected, so is only applicable to small (usually urban) catchments. The second variant is the probabilistic rational method that accounts for storage, so is applicable to a wider range of catchments (Pilgrim, 2003, pp. 9.15 and 9.18). In the second variant, the runoff coefficient becomes a calibration factor that is adjusted in a way that makes Tq and Tp match. It is not the runoff coefficient of an individual event. The probabilistic rational method is similar to the method of Gaume (2006) and differs from the design storm method in an essential way: in the design storm approach (and our paper) the focus is on individual events. In contrast, in the probabilistic rational method and in Gaume (2006) the focus is on the frequency distributions and not on individual storms. In our paper we are not interested in the probabilistic rational method as this is an alternative approach. In the revised paper we will add a clarification on this to assist the reader in understanding the differences between the rational method and the design storm procedure. We believe this will be a useful addition to the manuscript.

There is, of course, a relationship between the design storm method and the rational method. The relationship has to do with the basic motivation of the rational method that setting the storm duration to a value on the order of the time of concentration (in case it can be specified) tends to maximise the flood peak. This is also where the results of Gaume (2006) are consistent with the results of our paper. Gaume (2009) suggests that, for a linear reservoir, the time of concentration is 1.8 - 2 times the response time of the catchment. This is exactly what we obtain as a critical duration in Viglione and Blöschl (2009) and also in this paper (see, e.g., line 11 on p. 635). However, this is trivial and not the main focus of the paper.

(2) DESIGN STORM RETURN PERIOD

Gaume's (2009) major criticism is terminology: ".. and this is my major criticism, the problem as defined in the manuscript is ill-posed! Return periods (i.e. probability of exceedance or distribution function values) can not strictly speaking be attributed to

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rainfall events and floods but to some of their characteristics: peak discharges, average intensity over a given duration (IDF curves)" (p. S273). This is trivial and, of course, accounted for in our paper. We have used the shorter wording ’storm return period’ and ’flood return period’ for brevity but the exact meaning is clearly defined on p. 631-632, on p.633 lines 9-12 as well as in equation B12. Also, there is a detailed definition of Tp in Viglione and Blöschl (2009) this paper builds upon. Given that it was not clear to the reviewer, there is a need to restate the definitions more clearly in the revised manuscript.

More importantly, Gaume (2009) has concerns about the validity of the definition of Tp and repeatedly suggests that it is inconsistent with the IDF curves (e.g. p. 273. lines 22 ff and p. S275, line 13). We disagree. In the general case, when storm intensity may vary within storms, the design storm return period is the ’return period read off the IDF curves for the intensity averaged over an aggregation level corresponding to the main burst of the storm’ (as stated on p. 631, line 25 and p. 632, line 4 of our paper). This general case will be dealt with in future papers as we have chosen to focus in this paper on a simplified world of block rainfall. Assuming block rainfall helps us obtain analytical solutions for the relationship between Tq and Tp. For the case of block rainfall, the design storm return period is still the ’return period read off the IDF curves for the intensity averaged over an aggregation level corresponding to the main burst of the storm’. However, since the main burst corresponds to the whole rectangular storm, for this particular case, the design storm return period corresponds to the ’return period of the storm intensity averaged over an aggregation level equal to its duration’. This is stated on p. 632, line 18-21 of our paper.

This definition of Tp is consistent with design practice where the average intensities are read off the IDF curve for different durations and for one return period. This is what IDF curves are constructed for. Tp is simply the return period on the IDF curve. Gaume’s (2009) concerns about the validity of the definition of Tp are hence unfounded.

On p. S273, Gaume (2009) states: "Tp is something like a statistical UFO ’Uniden-

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tified Flawed Object’ with complex links to the IDF curves even in the simplistic case considered in the manuscript (rainfall events rectangular pulses, see appendix of the paper)". UFO is a strong wording given that Gaume (2009) is apparently confused about storm duration (denoted as t_r in our paper) and the aggregation level used in the IDF curve (denoted as t_IDF in our paper). In fact, we have chosen the wording ’aggregation level’ for t_IDF to help distinguish it from storm duration. The links of Tp to the IDF curve are not complex, Tp can simply be read off the diagram of the IDF curve as stated above. Gaume (2009) (p. S275) seems to imply that we are using t_r and t_IDF interchangeable: " the storm duration has no relation with the aggregation level!!! This corresponds to a wrong application of the design storm method based on IDF curves! Errors, if they exist, should not be propagated." and that we construct the IDF curves from intensity of the rain event over its duration (p. S273, line 22). t_r and t_IDF are clearly separated in our paper, the IDF curves are constructed using t_IDF (Eq. B11) and the application of the design storm method is correct.

On p. S273, Gaume (2009) further states: "the considered duration changes from one event to the other: the various Tps are computed using different IDF curves which is also not consistent." This comment would be valid if we had defined a frequency curve of storm intensities in this way, i.e., putting intensities into one curve for different aggregation levels. We never do that. The various Tps are not compared with each other, they are compared with Tq for individual events. As mentioned above, in our paper we are interested in INDIVIDUAL events as consistent with the design storm approach. In our paper the question is what is the return period of the flood peak produced by a given storm event (in this case with a given duration and return period) under given conditions (in this case a given runoff coefficient). In contrast, the paper of Gaume (2006) examines the similarity (in the tails) between storm and flood frequency distributions, i.e., his interest is on the frequency curves (and their moments) and not on individual events.

Finally, a comment is in place about the purpose of the paper. Gaume (2009) states:

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"As illustrated in the paper, this approach .. is inappropriate as its basic assumption (i.e. equality of flood and rainfall return period) does not hold. This is never really acknowledged by the authors" (p. S273). The design storm method, indeed, usually assumes that Tq is equal to Tp but the very purpose of our paper (as stated in the abstract) is to better understand the relationship between Tq and Tp and we never assume that Tq is equal to Tp. Our main motivation is that, once the relationship is better understood, the design storm method can be applied with better confidence than is currently possible. Obviously, within the framework adopted in the paper, if the runoff coefficient is appropriately chosen, the correspondence holds, and we are giving guidance on how to select the runoff coefficient (Figs. 7 and 11 of our paper). In a similar vein, Gaume (2009) notes that "the fact that the described design storm approach is inappropriate, especially for 'dry' catchments, should be underlined. In this case, the return period of the flood peak discharge is strongly determined by the return period of the runoff coefficient which is chosen arbitrarily" (p. S272). The design storm approach is appropriate, provided a suitable runoff coefficient (or, generally, catchment initial condition) is chosen. This choice is not straightforward, particularly in dry catchments, but it is not an arbitrary choice, it is clearly defined. We also examine in the paper how sensitive the flood peak return periods are to this choice to contribute to a more informed hydrological design practice. Again, as the purpose of the paper was apparently not clear to the reviewer, we will provide a more focused statement of the purpose of the paper in the revision.

Even if we disagree with the thrust of Gaume (2009), his comments will certainly help us to provide more detailed explanations of these issues in the revised paper.

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