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Hydrology and Earth System Sciences Discussions

Interactive comment on "A look at the links between drainage density and flood statistics" *by* B. Pallard et al.

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1. GENERAL COMMENTS

We thankfully acknowledge P. Allamano, G. Blöschl and a third anonymous Referee for providing constructive reviews and very useful comments on the original version of the manuscript. The three reviews cast an overall positive view of the study, and indicate that all Referees found the general scope of the study interesting. The referees raise a series of good points that helped us identifying a few technical elements that need to be adjusted and parts of the presentation that need to be clarified.

We would like to take advantage of the interactive discussion for illustrating how the revision process is addressing the Referees' major points to improve the technical soundness of the study and the quality of the presentation. Our comment is divided into three different sections that address separately comments made by P. Allamano, G. Blöschl and Referee #3.

2. COMMENTS ON THE REVIEW OF P. ALLAMANO (Referee #1)

Here below we provide an itemized description of how the Referee's remarks were addressed.

- The first major point raised by Referee #1 refers to the analytical derivation of the links between drainage density and flood statistics. In particular, Referee #1 supports Horton's schematisation of the instantaneous infiltration rate, but suggests to estimate the effective rainfall by (1) integrating the infiltration rate over the rainstorm duration d and (2) taking the mean rather than referring to the instantaneous infiltration rate. We found this suggestion to be very sensitive and therefore we are modifying the analytical derivation accordingly. However, the results we obtained seem to confirm the general patterns in the link between flood statistics drainage density that we found with the previous schematisation of the infiltration process.

- We agree with the Referee. The units of the parameters will be changed when revising the paper. Also, we will modify the concepts in lines 16-21 of page 2908.

- We agree with the Referee (and with a similar remark by Referee #3) and therefore analyse the significance of the regression (Figure 4) in the revised version of the paper. In fact, we now write in the revised paper: "Although the linear regression models reported in panels a and b of Figure 4 are not statistically significant, we decided to include them in the figure to better illustrate the general increasing tendency of reduced μ and σ with D_d. Also it seems useful to remark here that the progression of μ and σ in Figures 1 and 2 can be effectively represented through a power law (i.e., linear model of the log-transformed variables) and that a linear

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regression of the log-transformed empirical data is significant at the 10% level for both reduced μ and σ". Moreover, we revised Figure 4. In the new version of the paper, it reports reduced mean and standard deviation (i.e., mean and standard deviation divided by catchment area raised to a regional scaling exponent, see Castellarin et al., 2005; Castellarin, 2007; Gaume et al., 2009) instead of the empirical mean and standard deviation (Referee #3).

Referee #1 also provided minor comments that were all addressed when revising the paper.

3. COMMENTS ON THE REVIEW OF G. BLÖSCHL (Referee #2)

We fully agree with the Referee #2 when he underlines that processes should be the red line throughout our paper. Also, we particularly appreciated his classification of impacts of drainage density on flood frequency regime into direct and indirect controls. We support his suggestion to introduce the simulation study and the analytical derivation by characterizing the physical processes that are represented by either approach. In fact, we think this is a very useful hint and therefore we restructured the introduction of the study, which now explicitly cite Blöschl (2008), and the description of the analytical derivation and the simulation study in order to reflect these comments.

Here below we provide an itemized description of how the other Referee's remarks were addressed.

- In order to provide an analytical interpretation of the results, a simple conceptual and linear rainfall-runoff model has been used. Linearity is requested in order to analytically derive the distribution of the flood statistics and linearity implies that the return period of rainfall is equal to the return period of runoff. Therefore linearity is more a mathematical constrain than a priori assumption. In fact, the proposed simple analytical model is not aimed to provide a reliable representation of reality, but only a possible explanation for the critical value of the drainage

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density. In this case the possible explanation is the interplay between the Horton infiltration curve and the depth-duration-frequency curve for rainfall. If the analytical model was reliable, the possible explanation would be the correct one. Actually, we already stated in the previous version of the paper that we believe a combination of causes interacts to determine the results we obtained. In conclusion, the analytical model is not necessarily providing a complete representation of reality but it enables us to analitically derive a symplified representation of the relationship between D_d and CV of annual maximi floods. For instance, the conceptual model assumes that the return period of the annual maximum flood coincides with the return period of the rainfall event generating the flood. This assumption is rarely satisfied in real world cases, and it is an approximation also in the case of block rainfall, rectangular unit hydrograph and constant runoff coefficient (Viglione and Blöschl, 2009). Nevertheless, it was deemed appropriate for the scope of this study as it simplifies the casual relationship between the rainfall forcing and the induced flood.

We discussed the limitations of the linear model assumption in the revised paper, at the end of Section 3.1.5, and we cite the work of Viglione and Blöschl (2009) at the end of the Section itself.

- As Referee #2 suggested, the revised manuscript contains a discussion of the outcomes of our study in the light of classical studies that investigate on the dependency of flood moments (particularly CV) on drainage area (see e.g., Blöschl and Sivapalan, 1997). In detail, the following text has been added to the conclusions: "Previous studies (Blöschl and Sivapalan, 1997) found that the coefficient of variation of annual peak flows seems to reach a maximum at a certain threshold area of the upstream river basin, while we found here a minimum at a certain threshold drainage density. These findings are apparently in disagreement if one assumed that the concentration time is the main control in both cases. However, it is important to note that Blöschl and Sivapalan (1997) found the maximum of

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the CV for a catchment area of about 100 km^2 while we found here the minimum for a value ranging between 15 and 25 km^2. Therefore the above results are not in disagreement and postulate that the progress of the CV with the basin area is actually fluctuating. We postulate that such progress is governed by the interplay between the depth-duration-frequency relation for rainfall and the infiltration curve we and are currently investigating this issue with more detail".

- We provided an extended explanation at the end of Section 3.2 for the behaviour of the coefficient of skewness in the AFFDEF simulations. In details, the following text was added: "For what concerns the AFFDEF simulation the increase of k for increasing drainage density is dominated by a corresponding increase of the rainfall skewness, while the causes for the increase of k for very low drainage densities are less clear. We believe the complexity of the spatially distributed infiltration pattern dominates in this case as a consequence of the increased residence time of water in the hillslopes".
- We added the reference to the work by Merz and Blöschl (2009).

4. COMMENTS OF THE REVIEW OF REFEREE #3

Referee #3's review is the most critical of the three, recommending major revisions before publication. In particular, accordingly to the Referee's opinion (i) the methods used are inadequate, (ii) the modelling and assumptions are questionable and (iii) the case study does not support the findings. Nevertheless, we are persuaded that a good part of the criticism derives from possible weaknesses in the presentation of the analysis and its main objective. We believe that the revised manuscript delivers a better overview of the study and therefore better addresses the concerns of the referee. Here below we provide our replies to the Referee's remarks in the form of an itemized list.

- We do not fully understand the comment of the Referee. The AFFDEF model computes runoff generation at local scale, depending on soil type, land cover, lo-

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cal slope and input meteorological variables. Therefore the link between drainage density and runoff generation is established through soil type and slope, given that these latter and D_d are linked each other through the mechanism of soil erosion. That is, a permeable soil is typically prone to soil erosion and therefore characterised by higher values of D_d, while soil erosion affects the local slope. At the basin scale, the link between drainage density and hydrological response is also established through the mechanism of runoff concentration in the river network. All these processes are properly dealt with by AFFDEF, although in a simplified manner. This point is made clearer in the revised version of the paper, in Section 2. Therefore we believe the argument of the Referee is not justified. We also would like to comment about the final suggestion of the Referee to this regard, that is: "From my point of view, it would be more valuable to investigate whether the authors could identify a relationship between their model parameters determining runoff generation and the actual drainage density in their test catchments".

This would be a very interesting object for future researches, but the calibration of AFFDEF to 44 catchments is clearly out of the scope of the present study. Moreover, the advantage of the modelling part of our study is to focus on one selected catchment for which we would like to investigate the flood response for different values of the drainage density. We do not see, in the context of the present study, the reason to investigate the links between the AFFDEF parameters and drainage density.

- The reason why the Horton infiltration approach was used is that it provides a reasonable schematisation of the infiltration process for the study catchment. This point is made clear in the revised paper, Section 3. Actually, the interplay of the Horton equation with the depth-duration-frequency curve for rainfall is a possible explanation for the critical value of the drainage density. If we computed infiltration by simply adopting a constant runoff coefficient, the CV would be constant with

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respect to drainage density, as equation 7 of our paper clearly shows. Therefore the application would be completely useless.

We believe that the analytical part of the paper is very significant. However, the analytical computation requires the use of a simplified model. Therefore we believe it is necessary to adopt a simple scheme which should be nevertheless capable of reproducing the relevant processes. The runoff coefficient approach would be too simple and therefore not appropriated.

- We agree with Referee #3 and therefore the revised manuscript will illustrate the results of the regional case study (catchment of the River Po) by depicting discharge data standardized by catchment area and providing indications on the significance of the detected links between annual flood moments and drainage density (as suggested by Referee #1 also). Concerning the last remark of Referee #3 we would like to mention that our paper is a preliminary study that investigates the relationship between flood frequency regime and drainage density (i.e., an objective catchment descriptor that can be easily retrieved for ungauged catchments), which is an issue that received a limited attention in the literature. Therefore we intentionally decided to focus on drainage density and flood statistics alone. We are fully aware that drainage density is also related to soil properties, climatic behaviours and other forcings (this issue was also mentioned in the paper, page 2910 lines 23-27). But we believe a multivariate analysis that involves drainage density together with other physiographic and climatic catchment descriptors is not the subject of the present work. This will be clearly stated in the conclusions of the revised manuscript.

Once again, we would like to express our gratitude to the three referees. We have been served with very helpful comments and a very efficient review process.

REFERENCES

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Blöschl, G. and Sivapalan, M.: Process controls on regional flood frequency: Coefficient of variation and basin scale, Water Resour. Res., 33, 2967–2980, 1997.

Castellarin, A.: Probabilistic envelope curves for design-flood estimation at ungaged sites, Water Resour. Res., 43, W04406, doi:10.1029/2005WR004384, 2007.

Castellarin, A., Vogel, R. M. and Matalas, N. C.: Probabilistic behavior of a regional envelope curve: Water Resour. Res., 41, W06018, doi:10.1029/2004WR003042, 2005.

Gaume, E., Bain, V., Bernardara, P., Newinger, O., Barbuc, M., Bateman, A., Blaskovicova, L., Blöschl, G., Borga, M., Dumitrescu, A., Daliakopoulos, I., Garcia, J., Irimescu, A., Kohnova, S., Koutroulis, A., Marchi, L., Matreata, S., Medina, V., Preciso, E., Sempere-Torres, D., Stancalie, G., Szolgay, J., Tsanis, I., Velasco, D., Viglione, A., A compilation of data on European flash floods, Journal of Hydrology, In Press, 2009.

Merz, R., and Blöschl, G.: Process controls on the statistical flood moments - a data based analysis, Hydrol. Proc., 23, 675–696, 2009.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 5, 2899, 2008.