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Hydrology and
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Discussions

Interactive comment on “A modelling approach to assess the hydrological response of small Mediterranean catchments to the variability of soil characteristics in a context of extreme events” *by* C. Manus et al.

C. Manus et al.

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Important preliminaries :

This document contains few equation that are difficult to upload properly through the HESSD website procedure. Please refer to the pdf document available at the following address : http://ltheln21.hmg.inpg.fr/PagePerso/anquetin/Access.html

Referee : General comments The paper presents an interesting and positive appeal. In particular I appreciated the approach which is more devoted to increase the under-

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standing of main hydrological processes than to (only) reproduce the observed catchment behaviour. Also I observe that good points within the modeling assumptions are those regarding the soil behaviour description which is also corroborated by good quality datasets.

Authors : We thank the reviewer for this encouraging comment.

Referee : On the other hand a number of suggestions could be given in order to improve the quality of the paper. A number of strong hypotheses are made practically without any verification, in particular: Lateral flow is missing; Hillslope routing is neglected; Bedrock is impervious; Flow velocity in the stream is equal to 1 m/s.

Authors : The model presented in the paper is a first step of a more complete modelling approach we plan to develop. The modelling platform used in the study is modular. It allows building models step by step by increasing the level of complexity. By proceeding step by step, we believe it will be easier to quantify the relative importance of the various processes as well as the impact of each process on the streamflow dynamics and shape of the hydrographs.

The approach presented in the paper is based on simple hypotheses. With such hypotheses, we wanted to test if the modelling was able, on one hand, to provide a relevant description of the peak discharge/area relationship established for the September 2002 event, and, on the other hand, be used for mapping the potential risk, including ungauged catchments. To complement the study, a sensitivity study of model to the type of implemented processes is undertaken for larger catchments like Saumane (99km2) and Uzès (86km2). Some results are given in the General Comments but not presented in this paper.

1/ The hypothesis about a constant flow velocity is discussed in the general comments and in the response to Reviewer #1. Some information about flow velocity is retrieved from past flood surveys and commented.

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2/ The bedrock is assumed impervious. For most of the catchments, the bedrock is formed of fractured schist or granite, which are thus not totally impervious. However, there is up to now no regional observation of the flow which can infiltrate in this substratum. Thus the simplest hypothesis was to assume it was impervious. As mentioned in the first version of the paper (p. 2698 lines 23-28), simulations were performed assuming a gravitational flow at the bottom of the hydro-landscapes. The results are quite sensitive to this choice, with a large impact on the runoff volume and a significant impact on peak discharge. However, this simulation is probably the lowest limit for the simulated peak discharge, as it does not account for the blocking effect of the quasi-impervious bedrock on the bottom flow.

3/ Hillslope routing is neglected. This impact is minimized as we have chosen to discretize the catchments into small size sub-catchments (see Figure 5). We are aware that this hypothesis is likely to modify the timing of the flow. The average size of the sub-catchments is around 1 km2. A typical length towards the river ranges from 100 to 500m. If we assume a hillslope velocity of about 0.1 m s-1, the travel time would range from about 15min to 1.5 h. A velocity of 1 m s-1 would lead to 1 to 8 min delay. In this first phase of the modelling we focused on maximum peak discharge. For some catchments, the timing of the flow is also available and if differences are too large, this simplified hypothesis will be relaxed.

4/ Lateral flow is missing. As for flow routing, the travel time of flow within the soil can be estimated. If we consider a quite high value of hydraulic conductivity (100 mm hr-1 = 0.1 m hr-1), an average slope length of about 100m, the time to reach the river would be much larger than the event duration (a few hours). We are aware that this process should be important in the studied region where topography is steep in some places. But the impact would be more in the recession phase and on soil moisture redistribution between events. As it was mentioned in the conclusion of the first version (p. 2704, line 19-20) it is a perspective for future studies (see also answer to the following comment).

Referee : The first of these also has particular impact on the overall paper. In fact

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the authors state that their model is able to reproduce both hortonian and dunne type of runoff generation. Actually they assume that a Dunne type of runoff generation is obtained whenever the soil cell is saturated. I do not believe that this hypothesis is correct because a dunne type of runoff occurs whenever the water table beneath the river network intercept the soil surface. The water table level mostly depends on fluxes recharging the groundwater through lateral flow which absent in the modelling assumption.

Authors : In addition to the comments to the previous question, we would like to add the following comments. In the literature, the nature of saturation excess runoff is questioned. Dunne and Black (1970) suggest that saturated areas can equally result from saturation down to the bedrock or from a relatively impermeable layer in the soil profile. Due to the high heterogeneity and space variability of the watershed characteristics (land use, soil type and depth, sub-soil, local slope, upstream contributing area) and to antecedent moisture conditioning, these processes are likely to be active at the same time in various combinations (Smith and Goodrich, 2005). Latron and Gallart (2007, 2008) showed the existence of both mechanisms on a small Mediterranean catchment using field survey and piezometer and tensiometer data analysis. Thus we consider that, contrarily to what is suggested by the reviewer, the definition of saturation excess mechanism must not be restricted (as often relevant in humid climates) to groundwater table rising. This point is quite extensively discussed in Latron and Gallart (2007). Cosandey and de Oliveira (1996) also showed, from the study of one small catchment in the Cévennes-Vivarais region, France, that two mechanisms were acting simultaneously to generate runoff. The first one is the rising of perched water table close to the streams and the talwegs with a saturation going upstreams as long as the water table rises. But this process does not explain the largest floods. They also evidenced the saturation of upward parts of the catchments, due to shallower soils, not directly connected to the river. The extension of these saturated areas progress downstreams and when both saturated areas connect to each other, the streamflow rises quickly.

Furthermore, we want to underline that, in the studied catchment, there is no permanent groundwater and it is assumed that perched water tables can locally be formed, due to the vertical heterogeneity of the soils. Saturation can also occur due to full saturation of the soil. In addition, we would like to underline that the implementation of the Richards equation we use, is able to deal with saturated and unsaturated soils. Thus in case of an existing initial groundwater table or of a quick infiltration towards the bottom of the soil column, the model is able to simulate the rising of the groundwater level from a vertical recharge from the topsoil. In the version of the model used in this study, lateral transfer is not included but this possibility is already implemented into the model and is being tested in other contexts (Branger, 2007).

The following sentences were added to section 4.4.

Given the initial conditions (without pre-existing water table) and the absence of lateral transfer in the present version of the model, we are only able to evidence saturation excess linked to saturation of the topsoil or complete saturation of the soil reservoir (referred to as type-B saturation excess by Latron and Gallart, 2007). Saturation excess due to groundwater rising (type-A saturation excess of Latron and Gallart, 2007) could be simulated in case of a soil with very high hydraulic conductivity for which the infiltration front would reach quickly the column bottom and subsequent infiltration would produce a rising of the water table.

Referee : Another lack in the paper was already raised by the editor and by the first reviewer: the model lacks of validation. The authors should fill this gap by using a gauged basin for validation, as the first reviewer suggested, or by adding more information about the observed events.

Authors : As all the reviewers raised this point, it has been answered in the General comments section. We also add a validation section in the manuscript.

Referee : For example by reproducing the hydraulic propagation of the flood wave along different sections of the critical channel reach and comparing these simulation results with traces of flooding left by water.

Authors : Given the routing method used in the present model, the direct comparison with flood marks is not possible. Furthermore, the latter have been used to estimate the peak discharge used as validation data in our study.

Referee : On the other hand also one of the most promising topic of the paper is not completely developed. It is the comparison between the use of different ptfs. While the authors show what is the difference in the hydraulic properties of soil, a discussion of the impact of such uncertainty in terms of peak discharge is missing.

Authors : A sentence has been added in the revised version. For the September 2002 event, the impact of the various ptfs on peak discharge is very small (there are some difference at the beginning of the event), but once the soils are fully saturated the impact is negligible. Thus, it would be more appropriate to perform this comparison for less intense events.

Referee : Minor comments The paper would deserve some stylistic rearrangements. More than in one case there are concepts hat are repeated in different parts of the paper (page 2691, paragraph 5). The authors should check and rearrange the paper in order to be sure that all repetitions are eliminated.

Authors : The manuscript is being revised in this direction.

Referee : The heterogeneity of soil features is delineated for the entire study area, less details is devoted to the studied basins.

Authors : The position of the studied sub-catchments on the soil map is shown in Figure 5 and some information are provided in a new Table.

Referee : The use of fractions of ks and tetas (page 2697 par 15) used for replacing bedrock permeability appears too empirical and not supported.

Authors : Rock fragments affect infiltration by their presence in the soil matrix and on

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the soil surface (Brakensiek et al., 1994). They modify the infiltration rate, the flow paths and water storage. Thus, rock fragment leads an overestimation of the water content (Morvan et al., 2004). In that sense, stone content was accounted for soil porosity n and hydraulic conductivity K. The comment addresses the way these two variables were modified. Note that stones are considered impervious and non porous (or having a closed porosity non accessible to water).

- Soil porosity n: Soil porosity is defined as the volume of pores Vp divided by the total volume Vt of a soil elementary cell. If stones are present in the cell occupying a volume Vs (e.g. Vs=Vt/2), Vp is reduced in proportion (Vp reduces by 2 in the example) and Vt is unchanged. Thus, soil porosity is reduced exactly in proportion (n divided by 2 in the example) of the stone content.

- Hydraulic conductivity K: This is more complicated and has no exact solution for general case, but we claim that a reduction of the hydraulic conductivity proportionally to the stone content is the simplest way to account for it without further information on the stone distribution in space, volumes and shapes. K is used within Darcy's law to calculate a water flux Q in the direction of the hydraulic head gradient :

Q = K S Delta H/Delta z (1)

where S is cross section area, H is hydraulic head and z is vertical axis (the same development can be made however if flow occurs in another direction). Stone content affects both K and S. However, the same S value will be used in the model whatever the stone content is. Thus, the modified conductivity value K* has to account for both K and S effects :

Q = K* S Delta H/Delta z (2)

For clarity purpose, consider two particular cases :

a) Stone distribution in space consists in a continuous layer perpendicular to the flux direction. Then, no flow can occur. This case is unrealistic in our study because it would be described as another layer within the soil database.

b) Stone distribution in space consists in a continuous layer parallel to the flux direction. Then, flow can occur only in the porous part of the cross section (e.g. cross section area is reduced by 2 if Vs=Vt/2). This case is realistic in our study because stones and porous matrix lies within the same layer.

If K* is reduced proportionally to the stone content (K*=K/2 in the example) this accounts exactly for the reduction of the cross section area while the flow lines within the soil matrix are unchanged (along the z axis). In reality, the soil matrix conductivity is unchanged and K* accounts only for cross section area effect.

The general case consists in randomly distributed stones within the soil layer. No general simple solution exists for this case. The solution we proposed in the paper is to consider that the closest simple situation is the b) case. K* accounts for cross section [L2] reduction which is approximately equal to the soil matrix volume [L3] reduction while flow lines within the soil matrix are considered parallel to the hydraulic head gradient although there are certainly not. Obviously, there is a difference between cross section and soil matrix volume reduction factors but we are not aware of an existing relation between the two for randomly distributed stones (certainly of different volumes and shapes!) within the soil layer.

The two effects not accounted for are: 1. The cross section area reduction is not exactly equal to the soil matrix volume reduction, but we assume that they are only slightly different, 2. The deformation of flow lines around the stones within the soil matrix, impossible to account for without information about the stone volumes, shapes and distribution in space. But this effect is certainly minor compared to the previous one.

Finally, note that a reduction of K by a 2-fold does not imply a reduction of fluxes by a 2-fold. Indeed, because of the soil porosity reduction, water will move faster vertically for a given infiltrated volume and thus, the hydraulic head gradient will tend faster to

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unity.

In conclusion, the solution we proposed in the paper is simple and unbiased. The effects not accounted for (1. and 2. above) are impossible to estimate.

The use of the Richards equation in a semi-distributed model is relevant. The authors should more comment on this and in particular on the adoption of soil cells of 1 cm thickness and area equal to the soil unit area (not specified in the paper). We chose to use the Richards equation as it was able to account for the vertical description of soils which was available in the data base, that was supposed to be influential (as shown in section 4 of the paper) on the water flow and soil saturation dynamics. The vertical resolution of 1cm was chosen to have a sufficient resolution for shallow soils (the average soil depth was 55cm over the region) and to account for the vertical structure of the soil. It was also a compromise between model accuracy and computing resources.

References

Brakensiek et al., 1994, Variation within Texture Classes of Soil Water Parameters. TRANSACTIONS OF THE ASAE 24 (2): 335-339 1981

Branger, F., 2007. Utilisation d'une plate-forme de modélisation environnementale pour représenter le rôle d'aménagements hydro-agricoles sur les flux d'eau et de pesticides. Application au bassin versant de la Fontaine du Theil., Université Joseph Fourier, Grenoble I, Grenoble, France,. Available on line at http://www.lyon.cemagref.fr/doc/these/branger/index.shtml

Cosandey, C. and de Oliveira, M., 1996. Surfaces saturées, surfaces contributives:localisation et extension dans l'espace du bassin versant. Hydrological Sciences Journal - Journal des Sciences Hydrologiques, 41(5): 751-761.

Dunne T. and R.D. Black, 1970, Partial area contributions to storm runoff in a small New England watershed, Water Resources Research, 6(5), 1296-1311.

Latron, J. and Gallart, F., 2007. Seasonal dynamics of runoff-contributing areas in a small mediterranean research catchment (Vallcebre, Eastern Pyrenees). Journal of Hydrology, 335(1-2): 194-206.

Latron, J. and Gallart, F., 2008. Runoff generation processes in a small Mediterranean research catchment (Vallcebre, Eastern Pyrenees). Journal of Hydrology, 358(3-4): 206-220.

Morvan et al., 2004, Prédiction des propriétés de rétention en eau des sols d'un bassin versant à l'aide de fonctions de pédotransfert : influence de la densité apparente et de la teneur en éléments grossiers. Etude et Gestion des Sols, 11, 117-135

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