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Interactive Comment

Interactive comment on "Which spatial discretization for which distributed hydrological model?" *by* J. Dehotin and I. Braud

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p. S220, first paragraph First of all, we would like to thank Referee #1 for his constructive comments, which will help us improving the quality of the manuscript and better explain our objectives. We recognised that the title of the paper may have been misleading. Our aim was not to provide a conclusive answer to the very complex question raised in the title, but to use the interactivity of the discussion offered by HESS to share our views, expressed in section 2.6 and 3. These views are based on a review of existing knowledge provided in the first part of the paper. It was probably not clear enough in the first version of the paper that the methodology proposed in section 3 was directed towards large scale catchments. For these catchments, explicit consideration of all the details of the landscape cannot be considered. Furthermore the section 3 is only one part of a more general line retained to get the final discretization that will

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be used in the hydrological modelling. The methodology proposed in this section must be viewed as a first pragmatic answer addressing the delineation of a catchment for distributed modelling. We are aware of some limitations of the technique, which are discussed more precisely in the section 4.2.4. Finally, in section 4, we do not propose an application to the Saône catchment (in the sense of an hydrological modelling) but rather an illustration of the classification technique proposed in section 3. To better focus the aim of the paper, we modified the title as follows: "Which spatial discretization for which distributed hydrological model? Proposition of a methodology for medium to large scale catchments".

p. S220-221, second paragraph Referee #1 did not understand the methodology we proposed in section 3, probably because we omitted to remind, as explained in section 2.6, that it corresponds to the second step of the discretization process. The first discretization level is the sub-catchment (or REW) scale, organised along the river network. The method proposed in section 3 provides a second level of discretization to take into account landscape variability within theses sub-catchments if the latter is consistent with the modelling objectives. But the REW can be used as modelling units if further discretization is not found consistent with the representation of the processes or the landscape variability. Furthermore, we can add that the methodology proposed into the paper forms part of a more general effort aiming at developing a modelling framework, using an improved description of the landscape heterogeneity representation for distributed hydrological models. Within the framework, process modules are built as independently as possible so that they can be run with their characteristic temporal and spatial discretizations. Referee #1 asked how hydrological connectivity and could be taken into account in our approach. A first way to take it into account is through the river network at the sub-catchment scale. When using a refined discretization as proposed in the paper, two options can be considered. The first one is to use distribution function (the tile or grouped response-unit approaches, mentioned by Referee #2) if the connectivity between the units is not thought important. The second option is to consider the connectivity between irregular units, for instance to estimate lateral transfer. This might require a third discretization step to get for instance convex modelling units, so that traditional numerical methods are applicable (see also answer to Referee #2). The proposed methodology may be used with existing grid square models. The classification method to map landscape heterogeneity may be viewed as a simplification of traditional GIS layer superposition. In this case, the connectivity between model units would remain as defined inside these models.

p. S221, lines 3-4: As mentioned above, our goal was not to answer the question raised in the title, but to contribute to scientific exchanges around this difficult question. Our aim in this paper is more modest. We propose a first and pragmatic methodology, trying to rationalize the derivation of hydro-landscape units taking into account the available data scale, the modelling goal and the relevant scale for water cycle components modelling. In this first phase of the research, as outlined by Referee #1, we do not use models based on this discretization. This will be reported in forthcoming publications. The only "evaluation" we are providing in the paper is a "visual" and statistical comparison with more traditional methods proposed in GIS such as smoothing or suppression of smaller units. We agree that the only way to answer which discretization is better suited would be through comparison with data when the discretization will be used in a comprehensive model of the water cycle. However, as previous studies have shown, it is not obvious to be able to "prove" that one discretization is better than another, because the quantity and nature of the available data will probably be insufficient to verify all the simulated variables. And we might end up with endless quarrels about the "best model". A more constructive way to use the discretization could be through sensitivity analysis of model responses and a test of functioning hypotheses about the representation of landscape heterogeneity through the comparison between model answers (in terms of statistical properties such as the hydrological regime, flow duration curves or spatial and temporal aggregation properties along the river network at various spatial and temporal scales). This could help in deciding which type of hypotheses is able to reproduce the observed behaviour (see for instance Vivoni et al., 2007).

p. S221, lines 5-12: (1) We agree with Referee #1 that the use of raster-based format is one limitation of the method, although it can be applied with any resolution, including new high resolution images which could be relevant for the riparian zones mentioned by Referee 1. The technique we propose can be used with data at any resolution. The question is not if riparian zones can be identified with a 200m resolution and it probably cannot. The 200m resolution retained in the example presented in the paper is illustrative and consistent with the type of question we wanted to address (daily water balance studies). The question should be formulated differently. If according to the study objectives (for instance pollution limitations), riparian zones are thought or known to be important, they should be represented. The representation can be explicit and in this case, the size of the objects the modeller wants to represent will condition the size of the modelling units and the resolution of the required data. Riparian zones can also be represented in a simplified manner. If the required information is not available, the conclusion should be that the objective of the study couldn't be reached. The proposed methodology allows to think about the objects (and their size) which must be represented in the modelling before building or choosing the appropriate model. (2) We agree that for numerical reasons, models should require a higher resolution and it is not incompatible with our approach. The hydro-landscape units obtained using the method of section 3 can be further subdivided into smaller units, which will use their limits as support for the discretization. If lateral flow is considered in the modelling, a convexity property of the modelling units is also required to solve partial differential equations and libraries are available for this task. If lateral flux is represented more simply, some index can be defined to quantify the non convexity of the modelling units. Such simplified representation of lateral transfer can for instance be inferred from detailed numerical models at small scale or through dedicated experiments.

p. S221, 13-15: At this state of the investigation, the data used are related to the land-scape factors or parameters that are relevant, according to the chosen hydrological processes. The goal of the data description of section 4.1 is to present the catchment. As all the mentioned data were not used in the example, it may have introduced con-

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fusion about their role in the presented technique. We will modify the paper to give an overview of the modelling we are thinking about and how the other layers will be used.

p. S221, 16-17: See first comment paragraph; we present an illustration. The relevance of the data scale, and the derived hydro-landscape units depend on the processes to be taking into account in the modelling step.

p. S221, 18-20: ‘Predefined digital network’ is related to the river network provided by the National Geographic Institute. It was not derived from the Digital Elevation Model but from scan of 1/250000 map. This river network order is the one used by the official basin agency managers. The basin area is about 11700 km2.

p. S221, 23-26: The presentation of the illustration on the Saône catchment (p.800, 4.2.2) was certainly not clear enough. We indeed used the distributions to provide the maps shown in Figure 7. The classification technique was applied to the map obtained by standard overlay of the retained landscape factors shown in Figure 5 (d). Table 1 summarises the landscape factors we retained for the classification and which led to Figure 5 (d) after a simple overlay. The choice of the factors depends on the hydrological processes to be modelled. In Table 2 are presented the combined factors relevant to the modelling goal and which were used to define the reference zones. We are not sure to have understood correctly the question about “non-homogeneous reference zones”. If Referee #1 means that within this zone all the pixels do not belong to the same combination factor class, this is true. For the reference zones, histograms of composition were also calculated. They were used to perform the classification later on.

p. S222, 3-5: A REW is a sub-catchment as traditionally used in hydrology. The word was popularised by the theoretical work of Reggiani et al. (1998, 1999, 2000) who provided a unifying framework for hydrological processes description at this scale.

p. S222, 6-8: In the P.804, we present a comparison of the proposed method with more traditional approaches. The base of the comparison is not here a model result. We just compare the capacity of this approach to keep in the landscape suitable factor avoiding homogenous removing based on the unit's surface. The histograms show here that we can keep more easily relevant landscapes units according to the modelling purposes (because of the reference zones definition). At this stage, our goal is to show that we can obtain a better representation of the landscape heterogeneity, not better results in terms of the simulation of the hydrological behaviour. In a next publication, we will present some result of this landscape discretization within an integrated distributed modelling under development.

p. S222, 9-10: The computation of the confidence map is presented p.796. It is simply the map of the distance between each pixel and the reference zone to which it is assigned. An example of distance is given in Eq. (1). In this case, the distance is the difference between the histogram of one point (within his neighbourhood windows) in the landscape and the histogram of the defined references zones.

Figures and Tables were improved as suggested by Referee #1.

Minor comments:

p. 792 lines 5-7. We will reformulate in the revised version: For instance, in the example of section 4, we retained p=3 factor maps: the land use divided into n1=9 classes, the lithology divided into n2=7 classes, the slope map divided into n3=5 classes. The combination of these factors lead to a map of the combined factors with a maximum of n1 x n2 x n3= 9 x 7 x 5 = 315 classes.

p. 792 lines 21-22 and p. 796 lines 4-5. Accuracy can be inferred from the distance map, which quantifies the quality of the classification. Acceptable value is the lowest ones, ensuring proximity with the nearest reference zone value. So we do not use a threshold, but each point is affected to the closest reference zone. p. 796, the 'second image' is the map of the distance between the histogram of each point and the affected reference zone. We modified the text to avoid ambiguity.

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p. 800 line 5. We use the D8 algorithm.

p. 801, line 1. As I said above, the goal of the example is to show an illustration. It's the modeller's responsibility to use factor maps he finds relevant according to the component of the water cycle he wants to represent.

p. 802, lines 21. The two variables don't have the same meaning. In Figure7, the 1.4 km size refers to the neighbourhood windows size needed for the classification purposes. This size will condition the final size of the units. In Figure 8, the 1.6 km size refers to the minimum size of the map features.

p. 802-803. OK with this comment.

References: Reggiani, P., Sivapalan, M. and Hassanizadeh, S.M., 1998. A unifying framework for watershed thermodynamics : balance equations for mass, momentum, energy and entropy, and the second law of thermodynamics. Advances in Water Resources, 22(4): 367-598. Reggiani, P., Sivapalan, M., Hassanizadehb, S.M. and Gray, W.G., 1999. A unifying framework for watershed thermodynamics: constitutive relationships. Advances in Water Resources, 23(1): 15-39. Reggiani, P., Sivapalan, M. and Hassanizadeh, S.M., 2000. Conservation equation governing hillslope response : exploring the physical basis of water balance. Water Resources Research, 36(7): 1845-1863. Vivoni, E. R., D. Entekhabi, R. L. Bras, and V. Y. Ivanov. 2007. Controls on runoff generation and scale-dependence in a distributed hydrological model. Hydrology and Earth System Sciences Discussion 4:983-1029.

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