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Hydrology and Earth System Sciences Discussions



# *Interactive comment on* "Robust extraction of thalwegs network from DTM: application on badlands" *by* N. Thommeret et al.

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First of all, the authors would like to thank the anonymous reviewer #2 for his constructive comments and recommendations that, I hope, will improve this paper. Most of the recommendations have been directly used to modify the text. We rewrote the unclear paragraphs as you recommended. Below, we try to supply some answers to the main issues that have been raised.

Major comments:

Since we used the term "robust" with a non-common sense, we preferred to remove it from the title. However the suggestion of the Referee #2 is quite valuable and relevant to this paper. Therefore, we intend to include in the reviewed manuscript results of both higher and lower resolution to deal with the method robustness regarding at least, data spatial resolution. We propose to complete the study by testing the CI based method on a 50 cm-resolution and a 2m-resolution DTM. Quantitative assessment of the resulting networks shows robustness of the results, since it does not occur major changes in the results. Since the elevation data stems from the same LiDAR mission (same flight, some common specifications), the landform information of the DTMs can be easily compared. The difference of pattern between the three networks extracted using the CI based method is really due to the changes of resolution: the main part (the highest order streams) are similar and the lower orders grows as the resolution is higher, getting closer to the field reference. It shows that the networks extracted using the CI based method really express the DTM landform information and it helps proving the method robustness.

We propose a new title: "On the extraction of thalweg network from DTM: application to badlands".

Minor comments:

3) (Chapter 3.3): The thinning of the raster area is achieved using the mathematical morphology operation known as skeletonisation. It results in a one-pixel wide network with a course leaded by the shape of the area. This raster network is then vectorised. As we want a continuous and tree-structure vector network, the vectorisation process integrate both the main information – the raster network – and flow direction grid. The incorporation of the flow direction in the calculation permits to obtain a continuous network, with upstream / downstream consistency, and without closed loops. The vector network joins the centre of network pixels.

6) We mention the multiple-direction flow algorithms in the reviewed manuscript. However, we assume that, in badlands landscapes, the hypothesis of tree-structure scheme is the more valid. For that reason, we focus only on unidirectional flow algorithms.

7) The figure 6 has been removed because, as the Referee#2 mentioned it, we weren't

able to give quantitative results about the entire network. Indeed, the ground-truth does not cover the whole catchment but only a test sub-catchment (considered as representative of bare-soil areas). We totally agree with the fact that "less thalweg segment" doesn't mean that the extraction is worse.

Besides, we agree that over-detection and under-detection should be more discussed. The over-detection in the western part of the catchment comes from the fact that it is a forested area. The over-detection in this part illustrates the main limit to the method performance. Since the noise distribution model has been built only on bare-soils areas, we encounter this kind of problems in forested areas since noise distribution of DTM may differ.

4) and 8) The questions about the geometric comparison point a wider problem we are currently dealing with. The answers are not obvious and choices have been made for this work. For the assessment based on buffer, the process is automatic and simple: FP and FN are length measure of network portions (it gives indications about the over-detection and under-detection)

The stream-by-stream assessment is based on a stream matching. The stream-by-stream assessment answers directly to the question: which thalweg segments match with the ground truth and which don't? We make a one-way matching, from the extracted network to the field network: the extracted thalweg segments are associated to field thalweg segments. The matching is first based on the construction of streams and then on the research of couples (between the two networks). A stream is not necessarily an edge between 2 junctions, it is a Strahler stream: all the contiguous edges of the same order form a single stream. For highest orders, Strahler streams are cut into sections to highlight the fact that a main stream may be correct on one portion and not correct on another portion. The cutting process considers the main junctions (both upstream edge of high order) of the stream. Concerning the research of couples, the aim is to match streams of the two networks. The matching process is done by hand: it is an interpretation mostly based on a proximity criterion. As a limit of this matching,



HESSD

7, C406–C411, 2010

it works for networks that have similar patterns. The stream matching raises a question about the length of the streams: can we match a 10-meters length stream with a 2-meters length one? The solution we choose is to consider that a matching is done if there is a stream on both networks no matter the length. This choice can be justify by the possible difference of scale between the networks: the ground-truth network is multi-scale because it has been drawn on the field so it can be more detailed than the network computed with a fixed resolution. Consequently, a computed stream is consistent if the operator can identify a matched field-drawn stream. Then matched and non-matched segments are counted and normalised by the total number of extracted segments. Nevertheless, the stream-by-stream assessment isn't necessary for this study. For that reason, we propose to remove it from the reviewed manuscript in order to focus on more important points.

9) Fig 5: in grey, we see the virtual valley delimitation that we can compared to a gully network. This virtual valley is build up around a virtual thalweg network. So the computed network should fit the valley.

10) Bretar et al. (2009) and us worked on data stemming from the same LiDAR mission and same reference altimetrical points. But Bretar et al. (2009) worked on the full-wave form signal they processed themselves, whereas we used the point cloud resulting from the last echo. The point cloud has been filtered and interpolated using the usual Axelsson (1999) method, by a French company Sintegra to create a grid DTM.

Technical remarks and recommendations: Most of the technical remarks are taken into account in the reviewed manuscript. We supply here answers to the major ones.

We follow your recommendation and use the singular "thalweg network" along the text.

(882:6) The main key elevation scaling law is the constant drop property. "Broscoe (1959) noted that the average drop Hw along Strahler streams of order w was approximately constant i.e. independent from the order" (Tarboton et al., 1991, p.83).



HESSD

7, C406–C411, 2010

Interactive Comment

(883:25) The grid DTM results from linear interpolation from the set of filtred points cloud built from last-return point cloud. Bretar et al. (2009) didn't use the last pulse point cloud but built its own point cloud coming from a specific process on the full-wave form data.

(884: 2) The 1 m-DTM RMSE id arounf 0.17 m. The DTM spatial distribution of the altimetrical error was modelized. However, we think that details about this model should not be extended (excluding the parameters and the type of covariance function) in this paper since it is another topic.

(884:22) The two studies propose to integrate curvature parameter so the channelization criteria is based on a landform parameter. We will try to provide a synthesis of the previous study conclusions. Indeed, these studies show that the incorporation of a terrain parameter is a good solution to answer to the channel head localisation issue.

(885:1,2) We used the plan curvature more than tangential curvature because this index provides a direct information on the contour curvature which indicates the thalwegs. We were interested by the contour curvature results as it is the information used for a manual detection of thalwegs from topographic maps.

(884:24,25) Indeed, we tried to use the CI because of the successful results by Bretar et al. (2009). In this work, the authors show the potential of CI for the extraction of thalwegs and ridges.

(888:1,2) We had to fill the DTM before the flow direction calculation. We tried to make it clearer on the reviewed manuscript.

(888:11-14) The network is settled from raster gully floors area with this assumption: we consider that the area central line represents the thalweg network. As a consequence, thalweg sinuosity will be erased unless the area also describes a meander. In Draix badlands landscape, this assumption seems reasonable because the thalweg path fit well to the gully morphology.

(888:16) The thinning is done using the mathematical morphology operator called skeletonisation. The skeletonisation of a raster area results in a one-pixel wide network with a course leaded by the area shape. The operation is done only on the binary grid of gully floor without incorporating the flow direction grid. However, the flow direction is used for the vectorisation step.

(888:18) Toward the filter: it is a removing process.

(888:18) By "loop development" we mean a kind of braided network. As we want a directed tree-structure network, we have to avoid the development of loops.

(889:23) Normalisation: it is normalised by the total length of the mapped network (the one taken as reference).

(892:7) The reference network was mapped in the field.

(893:15, 16) By "highly disrupted in geometry and topology", we mean a mismatch of geometry and topology compared to the mapped reference-network.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 7, 879, 2010.