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Hydrology and Earth System Sciences Discussions

Interactive comment on "Which type of slope gradient should be used to determine flow-partition proportion in multiple-flow-direction algorithms – tangent or sine?" *by* L.-J. Zhan et al.

Anonymous Referee #1

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General Comments

The authors point out that overland flow partitioning along downslope directions in multiple flow direction algorithms should be computed by using the sine of the terrain inclination angle (sin β), and not the tangent of the terrain inclination angle (tan β) as originally suggested by the developers of these algorithms. The paper is well written and it touches relevant issues. As presently presented, however, the problem is stated with insufficient scientific rigor and the analysis done is inadequate. The paper title and content seem to indicate that multiple flow direction algorithms can be suitably used to describe overland flows. Under this perspective, a theoretical improvement of these methods is suggested. However, multiple flow direction algorithms have been shown to produce improvements in the quantification of terrain attributes such as the specific drainage area over single flow direction algorithms, but they have never been shown to provide a reliable description of overland flows. As presently written, this paper contributes to generate confusion by failing to distinguish methods for the determination of terrain attributes and methods for the description of overland flows. The paper presented by the authors clearly focuses on overland flow modeling, and more specifically on the problem of determining how overland flow partitions along downslope directions. Under this perspective, however, the analysis done is inadequate and potentially misleading. In my opinion, this paper should not published in Hydrology and Earth System Sciences in the present form. Following there are specific comments that I hope will help the authors to prepare a technically sound paper.

Specific Comments

Page 6409, title. The specific question given in the title is not very relevant. In fundamental open channel hydraulics, "sin β" is used in preference to "tan β." However, the issue addressed in the paper is how overland flow partitions along downslope directions in multiple flow direction algorithms (page 6410, line 23). This is a complex issue that is not just determined by the use of "tan β" or "sin β."

Page 6410, line 17. The D8 algorithm is not the best single flow direction algorithm available. It has been substantially improved by the D8-LTD method introduced in Orlandini et al. (2003). Another significant contribution to the determination of flow directions has been provided in Tarboton (1997). A more accurate analysis of the literature would probably help the authors to identify relevant problems and suitable solution methodologies.

Page 6410, lines 19–22. It is reported here that: "Generally, MFD performs better than SFD, especially when the flow-direction algorithm is used to derive the spatial pattern

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of hydrological parameters (such as specific catchment area and topographic wetness index) at a fine scale (Wolock and McCabe, 1995; Qin et al., 2011; Wilson, 2012)." This sentence is potentially very misleading. The MD8 multiple flow direction algorithm was introduced by Freeman (1991) and Quinn et al. (1991) to provide improved estimations of local terrain attributes such as specific catchment area with respect to those provided by the D8 single flow direction algorithm by O'Callaghan and Mark (1984). Gallant and Hutchinson (2011) have however shown that Tarboton's (1997) method outperform Freeman's (1991) and Quinn et al.'s (1991) method in the computation of specific drainage area. More importantly, the authors' sentence seems to imply that multiple flow direction algorithms outperform single flow direction algorithms in the prediction of surface flows while this may not be the case. The authors' paper clearly focuses on overland flow modeling and not on the determination of terrain attributes such as specific catchment area, and implicitly assumes that multiple flow direction algorithms can be suitably used for this task. However, there is at present no scientifically valid evidence that multiple flow direction algorithms consistently outperform single flow direction algorithms in the description of overland flows. The sentence reported on lines 19–22 of the submitted manuscript is not adequately supported by results reported in the literature, and contributes therefore to generate confusion by failing to distinguish methods for the determination of terrain attributes and methods for the description of overland flows.

Page 6410, line 23. It is reported here that: "The key issue in MFD is how to partition the flow into multiple downslope cells." I agree, but this problem needs to be addressed in a sounder manner than reported in the paper. See the other comments reported in the present review.

Page 6411, lines 18–20. It is reported here that: "In this paper, the general flow-partition function is deduced based on hydrological theory, and approximation of the hydraulic gradient using tan β to determine the flow-partition proportions in existing MFD algorithms is found to be questionable." Yes, the use of "tan β" is questionable,

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but the use of "sin β" does not suffice to determine a sound partitioning of flow based on hydrological theory. Perhaps, the use of "sin β" in preference to "tan β" provides some improvement, but this should be tested in some way. Stating that a technically sound flow partitioning is obtained by simply using "sin β" in preference to "tan β" in equation (1) is technically misleading.

Page 6412, lines 15–21. The authors find here that the sine of the terrain inclination angle at the power 1/2 has to be used to provide a technically sound solution to the problem of overland flow partitioning. However, the theoretical analysis reported here is not technically sound for several reasons. The Manning equation is commonly accepted to describe surface flows in regular, low-gradient channels. I sympathize with the authors in their attempt to use the Manning equation to describe high-gradient channel flows and overland flows. However, there is field evidence that the Manning resistance coefficient (n) significantly depends on terrain slope under these circumstances (e.g., Jarrett, 1984; Jarrett, 1990). In addition, the assumption that the hydraulic radius is constant over all the downslope directions is not very realistic. For large surface flows the hydraulic radius is essentially equal to the flow depth. How can be assumed that the mean overland flow depth along different downslope directions is the same? One may think that the consistency between the structures of equations (1) and (5) is supportive. However, the ability of equation (1) to describe overland flows has never been tested and this needs to be considered. I feel that field data are needed to support models of flow partitioning along downslope cells.

Page 6415, lines 11–17. The conclusions reported here are not supported by a sound theoretical analysis or by field data. On the basis of fundamental open channel hydraulics, one can think that "sin β" is potentially more suitable than "tan β." On the basis of experimental terrain analysis, one can think that "tan β" is potentially better than "sin β." The fact is that the flow partitioning provided by equation (5) — as well as that provided by equation (1) — has not been adequately tested and thus it should not be reported in a scientific paper as a technically sound means for describing overland

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flows.

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