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Interactive comment on "Computing water flow through complex landscapes, part 1: Incorporating depressions in flow routing using FlowFill" *by* Kerry L. Callaghan and Andrew D. Wickert

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In this paper, Kerry Callaghan and Andy Wickert describe a method that computes water flow through complex landscapes represented by digital elevation models (DEMs). The manuscript mainly deals with the description of the algorithm and its testing with two moderately sized DEMs. As the title indicates, the manuscript is part of a two- or more-part manuscript which suggests that there will be an application or further testing of the FlowFill algorithm in another manuscript. At the time of writing this review, the second part was not yet available.

Major comments

1. The authors set their work in the context of DEM preprocessing. They review a number of preprocessing techniques such as filling and carving and the hybrid methods that exist and conclude that these methods fail to resolve the problem of hydrological connectivity. Filling (or carving) all depressions would not reflect the actual water flows and the existance of internal drainages whose occurrence is highly dependent on the magnitude of runoff events. I totally agree. Blindly applying existing DEM preprocessing algorithms can result in flow paths that do not reflect actual flow patterns. However, is FlowFill a viable solution to the problem of deciding which topographic depressions should be filled (or carved) or not? I think that FlowFill is quite an elegant solution to the problem. Routing water downstream and filling topographic depressions until they spill over (thus sequentially filling nested pits which some algorithms struggle with) reflects the actual water movements and puts each sink in relationship with its upstream area. The drawback of this approach, however, is that the filling of a particular sink is highly dependent on what happens upstream. An insignificant sink along a river may not be filled, because there are sinks upstream that hold water back. Sink removal is thus highly dependent on the topology of the network of topographic sinks. Of course, this may be an issue if sinks are rather a data artefact than true sinks. But DEM preprocessing techniques actually deal with and correct for these artefacts. If FlowFill is not designed for this, and line 1 on page 18 actually suggests this, than FlowFill is not really a DEM preprocessing technique. Rather, it is a highly simplified simulation tool that models water flow across landscapes without loss through infiltration or evaporation.

2. The flow routing model is a highly simplified representation of flow across complex terrain. Still, it is computationally intense because it takes time to converge. The DEMs that the authors test are very small compared to globally available DEMs and commonly available LiDAR DEMs (Sangamon has 550x550 cells (provided that the DEM is square), Rio Toro has 800x800 cells). I wonder whether the objective of determining the amount of water in each topographic sink given a runoff volume can be obtained

more easily. My idea draws from what I have stated above: modelling water flow using a network of sinks. Specifically, this could be done by following steps of a bucket model:

- Filling the DEM
- Calculating the volume of each sink
- Deriving flow directions
- Deriving drainage basins of each sink. The drainage basin of each sink thereby should exclude the basins of upstream sinks.
- Compare sink volume to total runoff in the upstream drainage basin.
- Topologically order sinks from top to bottom.
- Route excess water to downstream sinks if runoff volume exceeds sink volume.

This procedure would not explicitly model water flow across each sink. But it would help decide which sinks spill over and which not. Clearly, the proposed algorithm becomes increasingly complex if nested pits exist. But that is something one could deal with in a network of sinks.

Overall, I like the paper. However, I think that the paper would benefit from placing more emphasis of FlowFill being a modelling tool to study hydrological connectivity of complex landscapes, rather than a preprocessing technique. I encourage the authors to reconsider their algorithmic approach to this problem because working with network of sinks might be much faster.

Minor comments:

3-9f This should not come as a self-promotion of my own work, but quantile carving (Schwanghart and Scherler 2017) may also be a technique worth mentioning in the context of hybrid DEM preprocessing techniques.

4-15 Figure 2 was not mentioned before. Be consistent with the order of figures and the order of how their references appear in the text.

8-13 These numbers are not consistent with Table 2 which shows that Rio Toro was also tested with 1 mm runoff.

13-2 "more realistic"? More realistic than what? Where do you demonstrate this statement? Validation is lacking. Will this be handled in the second part of the manuscript?

Figure 11 The y-axis is difficult to read because there is only one tick label.

20-6 You might want to mention the project ID of the TanDEM-X DEM project.

References:

Schwanghart, W. and Scherler, D.: Bumps in river profiles: uncertainty assessment and smoothing using quantile regression techniques, Earth Surface Dynamics, 5(4), 821–839, doi:10.5194/esurf-5-821-2017, 2017.

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