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Geoscientific Model Development Discussions

Interactive comment on "The Landlab OverlandFlow component: a Python library for computing shallow-water flow across watersheds" *by* Jordan M. Adams et al.

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This paper presents a new component of the Landlab model that simulates runoff generation and surface-water flows in watersheds. The novelty of this component in the context of landscape evolution models is that: (i) it represents non-steady state runoff (in contrast to other models that typically assume steady state, i.e. Q = PA) and (ii) it implements a two-dimensional hydrodynamic algorithm, the formulation of which allows for computational efficiency and stability on steep and shallow terrains. After presenting details of the algorithms and methods, the paper outlines some example simulations of the performance of the overland flow component on synthetic and real watersheds and compares against the steady-state runoff assumptions of other land-

scape evolution models (LEMs). Finally, the paper presents fluvial erosion simulations by coupling the flow and incision components in Landlab.

I'm excited to see this new component developed and implemented in Landlab and I can see many potential applications and future developments based on it. Technically, I think it is sound and the algorithm developments are quite clearly explained. Overall, this paper will make a nice contribution to GMD and I look forward to seeing it published soon. However, in my opinion the paper requires some restructuring and editing to make it clearer, more focused and to improve the flow. There are few aspects of the paper that need to be more clearly explained up front. For me these are:

1) What are the intended timescales of application of OverlandFlow (event, year, decade, 10^3y, 10^4y, 10^5y etc.)? If is intended to be flexible, then some discussion is needed as to how the various modes can be implemented (especially the long timescales which are not addressed in the paper). Given the myriad of watershed hydrological models out there that can do what OverlandFlow does and much more for event to decadal scales, I feel that the novelty of this component within Landlab would be better pitched as an improved flow component within an LEM. 2) As a hillslope person, I get easily confused with phrases "throughout the watershed" as I tend to think that includes the hillslopes as well as the channel. It would be very helpful if the paper explained more clearly what processes occur in which parts of a basin. I assume that OverlandFlow could be coupled to a surface wash geomorphic transport law (GTL) on the hillslopes? This could be discussed in section 8. 3) There is no mention of infiltration until section 8 at the end of the paper. I think it would be very helpful to the reader if the assumptions are mentioned up front and if there was a clear explanation behind the rationale of effective rainfall and how this is calculated for the examples. I think there is an existing Green and Ampt infiltration component for Landlab, so I assume this can be easily coupled to OverlandFlow? Again, this would be worth discussing. 4) Hydrological theory needs beefing up in the background section as many of the model results discussed are common knowledge in hydrology. Please provide

theoretical background on runoff generation, steady vs nonsteady runoff, spatial and temporal variations in discharge and the role of basin characteristics, and the impact of this runoff on erosion and incision.

Specific points: 1) Manuscript structure: My personal preference would be for the two 'Background' sections (6.1 and 7.1 on p. 9 and 11) to be incorporated into the Introduction of the paper. Much of the information in those sections is key to appreciating the new component developments (i.e. steady state vs non-steady state runoff) and the impacts on fluvial incision. The novelty of the new component (relative to typical approaches in LEMs) needs to be stated much more clearly upfront. 2) Abstract: The first couple of sentence do not link well to the rest of the abstract and they lack flow to the rest of the section. I'm not convinced that a couple of token general sentences about hydrological or rainfall-runoff models add anything or help direct the reader. I think what would work better would be to discuss the hydrological capabilities of LEMs and go from there. There is a plethora of very sophisticated hydrological models for event to decadal timescales, which is probably not relevant in the context of Landlab – so I'm not convinced that those are the ideal starting point for the paper. Finally, I think that the abstract should more clearly state what the novelty of the new component is, what the assumptions in the paper are (i.e. no infiltration), and what the timescales of the application in this paper are (i.e. individual storm to 10 years of simulation). On [5] what do you mean by "longer term landscape evolution"? 3) Introduction (p.2): The opening paragraph [2-6] is in my opinion, a slightly odd (atypical) selection of applications for overland flow models. Maybe it's just me, but I wouldn't put urban flooding and post-wildfire runoff as the top two examples of overland flow models! Again, I'm not so sure that this section is even needed. I would focus the discussion on the hydrology within LEMs which are still relatively unsophisticated in terms of hydrological processes compared to hydrological models. Because even in your improved representation, there is a lack of hydrological processes (subsurface or infiltration components), and is predominantly therefore, a flow routing algorithm (using uniform effective rainfall as a proxy for runoff generation). In other words, if you were developing a watershed hydrological

model for use over short timescales (event to decades) then this would not really be considered that novel. 4) p2 [12-13] merge these two sentences as they repeat the same thing. 5) p2 [18] What is a "hydrological timestep" and a "geomorphic timestep"? Do you mean timescale? 6) P2 [22] I would say most (not "many") hydrological models route storm hydrographs through basins and represent non-steady discharge. This is a pretty standard feature in watershed hydrological models. 7) P2 [30 - 34] and P3 [1-9] It would be helpful if the introduction included some outline of hydrological theory regarding runoff generation, steady vs nonsteady runoff, spatial and temporal variations in discharge and the role of basin characteristics, and the impact of this runoff on erosion and incision. I just feel like we're missing a step or two in fundamental theory which would provide a useful backdrop to the reasonableness or not of the various assumptions in LEMs. 8) P3 [17] What is "short-term landscape evolution"? Please define "short-term" in this context. 9) P3 [23] "scientific problems" is too vague. 10) P5 [21-22] "too-large timesteps" and "too-small timesteps" is awkward expression. Please reword and also define "too small" and "too large" in this context. 11) Section 3.1: Please explain how rainfall is treated. I am assuming there is no infiltration component (as there is no mention of infiltration) – so how do you derive this effective rainfall rate over the basin? 12) P6 [21] Does "flat" mean zero slope or less than some threshold? 13) P6 [23] "Similar criterion were implemented" – reword as either 'a similar criterion was implemented' or 'similar criteria were implemented'. 14) P7 [1] What is the meaning of "water discharges driven by overland flow"? 15) P9, section 6.1 first 6 lines of Background feel too cursory. 16) P10 [5-10] "Changing discharge values" unclear 17) P 10 [18] Are hydrologists the target audience here? Not geomorphologists? If so, there needs to be some discussion of the assumptions (no infiltration, no subsurface flows etc.) that hydrologists would care about. 18) P10 [23] Please provide a sentence or two as to why Spring Creek was chosen as a test case. 19) P10 [32-33] Please explain why 5 mm/h for 2 hours was chosen as the effective rainfall. Is this based on real data or chosen as a typical value for that place? Is this supposed to represent a large storm? 10 mm of uniform surface overland flow (effective rainfall) over a whole

basin is pretty high. 20) P11 [1-2] Please explain the rationale for doing this. The peak Q at the outlet is unlikely to correspond to the peak shear stress on the hillslopes or other parts of the channel. 21) P11 [5-15] These are not really results – it's as you would expect (basically, the model is behaving) 22) P11 [22] What is the meaning of "the flow of hydrographs"? 23) P13 [1] "Discharge was recorded at all points throughout the watershed". Does this mean on hillslopes and in channels? Please be specific. 24) P13 [13-15] What is the rationale for looking at 10 year simulations? 25) P13 [22] "all points in the hydrograph are much less than the predicted steady-state". Unclear sentence. Do you mean the non-steady discharge is always lower than the steady state discharge or that the total volume of water exiting the basin is lower? 26) P13 [25-30] As expected. 27) P14 [3-5] What is the meaning of comparing erosion results from one single storm to geomorphic steady state? 28) P14 [13-16] This is missing some context. It is the first mention of 10 years and number of storms (intensity, duration etc.). 29) P15 Section 8. First mention of infiltration here. Needs to come further up. Beyond the examples of applications of this component, here I would really like to see more discussion of how the representation of hydrological processes may evolve within Landlab in the future and how the authors envision this rainfall-runoff component will be used to simulate long-term landscape evolution driven by surface wash (on hillslopes) and fluvial incision. It would be good to see some reflection on the representation of spatial variability too (e.g. in surface properties). I think you're missing a great opportunity to sell this model and its future potential by pitching to the landscape evolution / geomorphic community. 30) Fig 6: Only channel hydrology 31) Fig 7: Please redefine within caption h, S, n and all other symbols used in figure.

I hope this helps. I look forward to seeing it published soon, and I will attempt to use it myself at some point!

Best wishes, Katerina Michaelides

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