Reviewer #3: Eric A. Barefoot

Synopsis

In this manuscript, Martin and Edmonds present a numerical approach to studying how abandoned channels affect flow routing and channel stacking patterns in alluvial fans. The authors formulate a randomwalk model that finds a route for water and sediment on a fan surface, thereafter evolves the channel bed in one dimension along this path until an avulsion criterion is met, and then re-routes the flow according to a random walk until a new path is forged. This relatively simple algorithm is decorated with a few extra rules, which turn out to make a great deal of difference in the outcomes. The first, and most important rule, is that previous channels in the landscape can either be a preferred path for the random walk, or an unpreferred path for the random walk when the algorithm is in the routefinding phase. This attractive or repulsive quality of the abandoned channels is a continuous variable for each that modifies the probability of a given random walk cell. The second rule is that channels do not persist on the landscape forever, and are "healed" according to one of three procedures: (1) eroding high elevations until only swales remain, (2) filling depressions until only ridges remain, or (3) the topography both raises and lowers until no topographic features remain. Their model design is motivated by observations from large alluvial fans, where the authors see a large density of relict alluvial ridges, as well as a lower density of channels beyond some critical distance from the mountain front. The authors find that with these two continuous variables, and three mechanisms for abandoned channel modification, they can produce a rich diversity of outcomes in the model. In particular, they find that only the third (3) mode of channel healing is capable for achieving a steady-state fan, and that the degree that channels either repulse or attract reoccupation fundamentally shifts where avulsions occur in a strike-average sense. Moreover, their model results broadly mimic the general topographic features of the fans they drew inspiration from, lending some credence to the approach.

- We appreciate Dr. Barefoot's thoughtful review of our manuscript and kind words regarding its novelty. The reviewer provided useful and comprehensive feedback on improving the understandability of figures and tables, and we were able to make all changes except for the colorbar on Figure 2 (for reasons provided below). We thank the reviewer for their efforts and feedback.
- Note: line numbers referenced by the reviewer refer to the original manuscript, while (unless otherwise explicitly stated) line numbers in our responses refer to the revised manuscript with tracked changes accepted.

Overall Comments

I found this manuscript to be clear, well-structured, and very detailed. The model design makes a lot of sense, and I think the authors have shown a few very intuitive outcomes while also demonstrating a few less intuitive ones that spark interest. In particular, I thought the outcome where avulsion locations shift basinward when abandoned channels are barriers to flow was very intuitive, and makes for a satisfying result. In contrast, I found it surprising that imposing a rule that only negative or positive relief can be erased can drive the model to never achieve steady-state. These outcomes are presented and framed well, the conclusions are well-supported and impactful. My constructive comments are limited to a few minor comments on the visual presentation of the figures, and a few clarification questions on a few modeling choices. Other than these, I recommend the article be published. I look forward to citing this paper when my future work involves the stratigraphic architecture of fans.

Minor Comments

1. I have a question about this modeling choice. I am not sure if I understand why the simulation has to abort if a timestep results in a failed routing. If this were a real fan, the avulsion does not get a do-over, it has to fill the pond until it overflows, and then carries on its way. I wonder if by imposing this rule, you've introduced an artificial artifact of channel choice, where avulsions from the far-distant past can prohibit the present channel from traversing an entire sector of the fan. What if you adopted a really simple flooding algorithm instead? If while doing the random walk, the river encounters a dead end, it floods the area until it finds the nearest low point, and then starts routing from there. line 325

> - The reviewer raises an excellent point. It's certainly true that there is likely a wide variety of possible ways that a failed avulsion can progress. The reviewer's scenario makes sense as one possible outcome, and we had previously considered ourselves that a "spill-and-fill" model of failed avulsion pathfinding would result in abandoned channel levees no longer being complete repulsors to pathfinding flow. However, it is incorrect to say that on real fans avulsions do not get "do-overs". Failed avulsions are commonplace as crevasses have insufficient immediate slope to "succeed" (Slingerland and Smith 2004). In fact, we view every healed crevasse as a failed avulsion, and these are routinely observed on fans. We ourselves have observed frequent, repeated, and sometimes failed avulsions in the Landsat remote sensing record in a related study, cited in lines 98-99 of this manuscript (Edmonds et al. 2022, at https://doi.org/10.1130/G49318.1). One example would be the attempted avulsion c. 2015-2020 on the Rapulo river, which is excellently viewable via Google Earth Engine's Timelapse tool (link to the exact view at: https://earthengine.google.com/timelapse#v=-14.64137,-66.50818,10.136,latLng&t=2.93&ps=50&bt=19840101&et=20201231&startDwell=0&endDwell=0). This avulsion initiates into a lake adjacent to the channel (flowing towards the mountain for a short span!) then pathfinds through river-right forests before rejoining a downstream abandoned channel. The flow never collapses into a single coherent channel, however, and instead eventually returns to the original pathway and avulses to reoccupy an abandoned channel on river-left. This entire scenario plays out over a shorter timescale than the decadal timestep used in our model. This scenario more closely resembles our "do-over" implementation, though there are undoubtedly some geomorphic effects of such a failed avulsion that we do not include. In sum, the reviewer correctly puts their finger on an important mechanism that is under-understood and that deserves further exploration. We have added lines to our methods (374-379) to explain to the

reader that while our implementation matches the limited remote sensing record, it is undoubtedly simplified compared to the breadth of possible real world outcomes.

2. I think you mean Equation 12 instead of 17? line 341

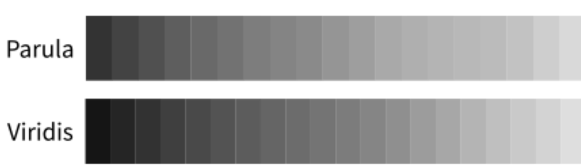
- Yes we did! Thank you.

Figures

– Throughout, I found myself struggling with the choices of colorbar used here. The authors are using parula, I think, which is a marked improvement in Matlab to the previous default colorbar, jet. However, parula is still not perceptually uniform. If a sequence of numbers that was strictly linear was plotted in parula, a viewer would perceive nonlinear jumps in intensity along the gradient. Put another way, there are features in the colormap that show up in plots that are not features of the dataset. To plot elevations, maybe try a single-hue colormap, or winter which I think is perceptually uniform.

- The reviewer is correct that we used parula to plot model output elevations. We chose parula because it is friendly to color vision deficiencies (which we tested using the Coblis – Color Blindness Simulator), and (we thought) perceptually uniform. Others have noted this about parula (ex. Nuñez et al. 2018, at https://doi.org/10.1371/journal.pone.0199239) and Hughes 2019, at https://brushingupscience.com/2019/10/01/default-colormaps-are-parula-and-viridis-really-an-improvement-over-jet/). Moreover, Matlab described parula as uniform in their original justification posts for switching from Jet to Parula (https://blogs.mathworks.com/steve/2014/10/20/a-new-colormap-for-matlab-part-2-troubles-with-rainbows/). In particular, the middle link to Hughes' blog post has this small section worth reproducing:

  The primary criterion in developing Parula and Viridis was to ensure the default colourmaps are perceptually uniform. One way to interpret this is that it means that if the colourmap is converted to grayscale, it should be linear. Parula and Viridis certainly achieve that, albeit with a limited range between light and dark for Parula.

  With that said, it appears on further review of an early matplotlib colorbar blog post, that while parula may be nearly perceptually uniform, it is not perfectly so! (https://bids.github.io/colormap/). As such, we imported a Viridis colorbar to Matlab and re-ran models to update the colorbar for all planform figures. These outputs have been replaced.

– In general, I have one piece of feedback that applies to all your figures. As a point of style, you seem to have opted to putting a heavy black frame around every plot. While in the design phase, I can imagine it is helpful to have such a frame to see spacing between elements. For a finished product though, it intrudes on the visual space and commands attention, subconciously distracting the reader from the contents of the figure. Rules, used judiciously, can establish visual hierarchy (Figure 1 is a good example), but in a lot of cases here it is just too much. For all of your figures, I recommend getting rid of the bounding boxes.

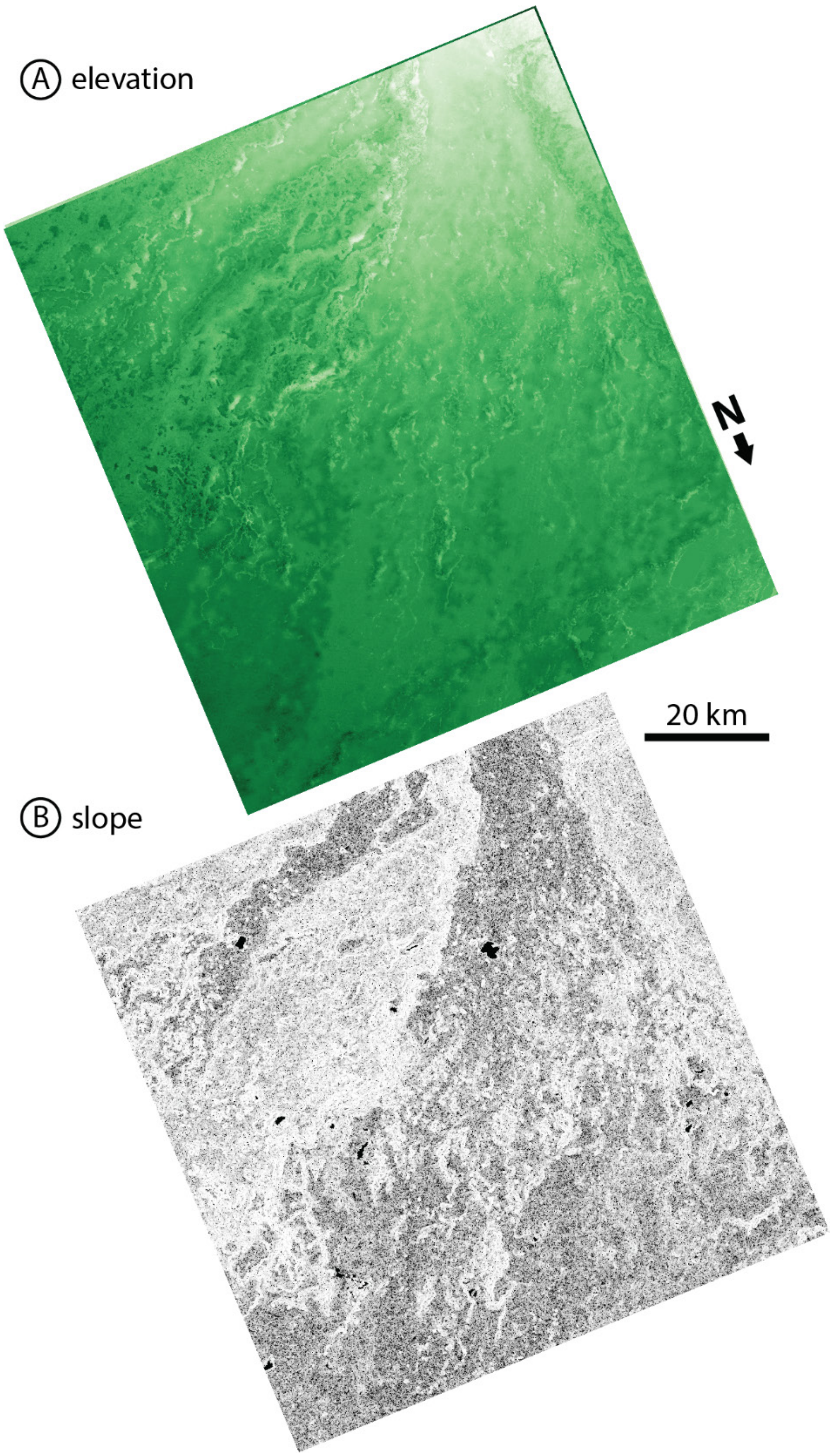
- Thank you for the suggestion. You're right that the black bounding boxes helped with layout and framing, and were present so that the figures could be reproduced at the specific size and shape desired on paper without any rescaling. As such, at this stage in production, they are no longer necessary. We have removed them (where present) from Figures 2, 4, and 6-12. I kept them in Figures 1, 3, and 5 in order to preserve necessary visual hierarchy.

– For example, here in Figure 2, the boxes around the annotations are essential, because otherwise the reader will never see them. However, I would remove the box around the figure, and take away the boxes around each of your colorbars. For these elements, proximity is all you need to establish a connection.

- Fixed.

- On the subject of color, I would recommend a different colormap [for Figure 2]. The one here is distorting the visual presentation of the data. This colormap is really good at highlighting contrast in certain parts of its spectrum (e.g. yellow-to-red), and so the nice contrast showing the ridges that you want to see is limited to an arcuate band halfway through each map. I might instead recommend making four maps. In one pair, show just elevation in a single-hue colormap from light to dark so that the reader can see the conical shape. In the other pair, compute the slope map and plot that in a different single-hue colorbar. That way we can see both the ridges and the overall shape, but separated into two panels.

- We agree that the colorbars in Figure 2 are non-perceptually linear. We tried to implement the reviewer's suggestions by plotting both elevation maps and slope maps with linear monochromatic colorbars for both megafans; see results below for the Rapulo (Figure 2A), where lighter colors represent higher elevations and slopes.



We believe that our original colorbar, while not perfect, does a better job of communicating the abandoned channel topographic features while also communicating the overall slope of the megafans. Unfortunately, this is a particularly challenging geomorphic feature to show using the data provided, because of at least two reasons. First, while megafans are generally low relief features, there still remains a much greater drop in elevation between the highest and lowest values shown in the figure (~70 m change) relative to the elevation of abandoned channels (~meters scale); as the reviewer foreshadowed, the signal of downslope change makes it hard to observe abandoned channels. Normally this would be a good opportunity to use a slope map to show local features, as the reviewer suggested, but unfortunately, results in this case are poor. This is because the features are small relative to the noise present in the radar-derived and corrected SRTM (BEST) used in our analysis. This setting is just too low-relief to get quantitatively meaningful results from our imagery. For the same reason, hillshades, semi-transparent slope maps, and other analyses were tried but did not yield a product that was more effective at communicating the degree of floodplain channelization than the original colormap.

- With that said, we do agree with the importance of making readers aware of some of the pitfalls of non-perceptually uniform colormaps, and have therefore updated the figure caption (161-162) to bring this matter to the reader's attention.

– Figure 3 is very nice, and seems intuitive and helpful, but it appears to have lost its caption.

- You are correct, thanks for pointing this out.,

– I like Figure 4 a lot. It's very helpful.

- Thank you!

– In Figure 7, why do you think there is this odd, smoothly-sinusoidal lobe-switching? I didn't see it discussed in detail, but this is shockingly regular, and only seems to occur in the deposition-only or erosion-only healing modes

- We agree that this was a result in need of more exploration in our manuscript, and as such, have added content to sections 5.5 (614-637) and 6.3 (690-696).

Tables

Usually for a manuscript, table design is not super important, but for ESurfD, it seems that they simply publish tables as-is, instead of reformatting them. Since this is the case, I have a few constructive comments that will make your tables much more legible.

– Vertical rules are not a great way of guiding a reader's eye. Alignment is a much better tool in the vertical direction […] Horizontal rules are great for breaking up your tables visually into topical or related sections and for connecting items across rows, which is much harder for human eyes on the written page.

- While we don't disagree, our reading of the ESurf author guidelines (at https://www.earth-surface-dynamics.net/submission.html#figurestables) suggests that "Horizontal lines should normally only appear above and below the table, and as a separator between the head and the main body of the table." We took a quick glance at some recent papers, however, and found examples of tables both with (ex. https://doi.org/10.5194/esurf-10-97-2022) and without (ex. https://doi.org/10.5194/esurf-

10-43-2022) horizontal rules throughout tables, so I'm not sure how firm this particular guideline is.

– So for Table 1, remove the box around the outside, and leave just the horizontal rule separating the heading from the table elements. See if you can make the individual cells single-spaced, while leaving some breathing room between cells. All the same for Table 2.

- Done as suggested. We don't feel too strongly about this, so we are happy to hear from the editor/production if they prefer the old or new formatting for the table.

– For Table 3, do the same things like tightening the spacing within cells while leaving space between cells, also consider making the headings for each column bold. I would put the first column for figure references at the end. Also, the bit about having a parameter marked as "variable, see figure X" is very confusing, and forces your reader to flip back and forth. Instead, I would have groups of rows (set apart with horizontal rules) where you show every model run with every parameter combination. I know its a lot, but this table is already almost a page, so why not just make it a well-designed full-page table and go for it?

- As requested, we put the figure title column at the end, added the range of parameter values to the table (instead of referring to the tables), removed all vertical rules, and used horizontal rules to separate runs. We also bolded the headers and did the same to Tables 1 and 2.