IMPORTANT NOTE: all line numbers refer to the manuscript WITH tracked changes

Dear Authors, dear Editor

Thank you for giving me the chance to review the second version of this manuscript. I find that the additional sections on the scope of the model and on model limitations work well. Moreover, the supporting information are very helpful in further clarifying the model approach and in understanding the limits. Most of my comments have been clearly addressed, but, especially in the light of the comments by R1 and R2, I still see some problems that could be targeted. I hope these comments help to further improve the manuscript and look forward to seeing the next version.

With best wishes,

Aaron Bufe

Model predictions, conclusions and limits

Questions were raised on what can be predicted by the model and how sensitive the model is to its limitations. Now, in the supporting information, the authors have included sensitivity tests of the model to some of the most important of these limits. However, I found that these tests were not clearly referenced in the main manuscript (in particular in the section on model limits). Therefore, I would suggest to expand the limit section to include references to the supporting information and address (1) the grid size issue and the variability of results with different grid size, (2) the fact that the channel width is not explicit in the model (which is linked to the grid size issue), (3) the potential effects of the height scaling that is independent on slope, (4) the extent to which the model is scalable in space and time (see below).

Then, it might help to explicitly sum up the conclusions that can be safely made with the model and contrast these with observations and predictions of the model that should be treated with care because they are highly variable and could be dependent on the specific model limits (such as the grid size, treatment of sediment etc.). As far as I understand, (1) the model is able to show that a curvature-based erosion law in a landscape evolution model can produce wide valleys that vary as expected with bedrock erodibility; (2) the model can predict some relative differences in patterns and timing of lateral erosion that depend on the UC versus TB model – these could be summarized. Importantly, unless more sensitivity tests

are made, the effect of some of the limits remain unknown and, therefore, the model does not seem to be able to predict the absolute timing, lengths, and magnitude of the lateral erosion. This becomes important when discussing field tests of the model (see below).

Grid size and implicit channel width

R2 raised an issue with the grid size of the model, and the exploration in the supporting information in response to that comment is useful. However, it does not get around the complication that he stream is assumed to occupy the entire cell in all cases. This part was separately addressed by another point in the supporting information which is great. However, these two limits (varying grid size and no explicit width of the stream) are linked. As far as I understand, vertical erosion is always assumed to be uniform across the entire cell (because the stream is assumed to occupy the entire cell). Therefore, by increasing the pixel without changing anything else, it seems to me that there should be "more" vertical incision at a point with the same discharge and slope. In contrast, the lateral erosion should not be affected in the same way. Could that explain the part of the model response at higher grid sizes? In any case, the sensitivity test performed, the link between grid size and "water occupying one cell", and the corresponding uncertainties on how to interpret the sensitivity test could be addressed more clearly in the model limit section.

Absolute time in the model

As R2 noted, the chosen runoff values are very large and the authors explain that these are representative of peak values. In the supporting information the term "flood" was used so it seems like that there is a mechanism somewhere in the model that alternates these floods with times when the runoff is lower. However, I either missed that in the manuscript, or the mechanism by which to go from peak flow to kiloyears of model run time is not explained. How is the absolute time in the model obtained?

Comparison with field examples

I tend to agree with R2 that, given the variability of absolute lateral erosion rates with grid size (demonstrated in the supporting info), and the potential dependence of these parameters on other model limits, it seems like using absolute numbers of the timing, rate, and scale of lateral erosion events as an indicator for the correctness or incorrectness of the model is not possible. Therefore, it is not clear to me how it would help to have a field experiment in which the rates of lateral erosion and the exact channel geometries are known (P26 L24-27). Are there any qualitative observations or ratios of parameters that hold for any of the model

parameterizations and grid sizes? For example, are there responses of the TB or UC to changes in water flux that are consistent for all different grid sizes, or are there patterns of upstream versus downstream width that always evolve in a certain way etc.? In short, it isn't clear to me which part of the model is a key predictive part that could be compared with a field example. Could this be clarified?

Contrast with meandering models and channel movement in the model

R1 notes that it is not clear how streams switch directions. I believe that the key here is that the neighboring node is made to have the elevation of the downstream node. I might have missed that in the text but I couldn't find that information in the manuscript (apart from the figure). I would suggest to mention this point. Then, once the lateral node is eroded, there are, in some cases, two possible paths. I would guess the path is chosen at random but I am not sure whether that is mentioned anywhere. Mentioning these two points in the manuscript might help clarify how channels move in the model.

R1 further notes that the Howard and Knutson meandering model could not explain meandering with only a curvature-based law. Within the LEM, lateral erosion is obtained with just this simple law. Maybe this difference could be emphasized in the results.

Deducing valley widening due to lateral erosion

Figure 12 and P19L15-17: The argument here is that the valley widening in TB1 is only due to sediment infilling. Therefore, the difference between the other models and TB1 is the component of the widening due to lateral erosion. I think, this is not strictly true. For example, everything else being equal, the same amount of sediment deposited in a narrow valley and in a wider valley should lead to a larger "widening" in the narrow valley. Therefore, as valleys are widened by lateral erosion, the sediment aggradation component becomes "less important". Moreover, the observed widening will depend on the slopes of the valley walls. The difference between all models and TB1 can still serve as a proxy but, perhaps, this limit should be addressed.

Treatment of deposition in the model

In the supporting material (page 1, point 3, subpoint 5), it seems unclear whether eroded material is added to Qs or immediately deposited as bedrock downstream. The former makes the most sense to me. Can this be made clearer in the supporting info and in the main text?

This raises another point. It seems like the eroded material is added to Qs even in the UC models – only the "collapsed" material is removed as washload. Isn't that inconsistent with the premise of the UC models that all eroded material can be easily transported away?

Detachment versus transport and the definition of "weak" and "strong" bedrock

P22L1210-14: I wonder if it is worth to specify what is meant by "weak bedrock"? One could have loose sediment (for example loose sand or gravel) that is easy to detach but when you detach it, it has to be transported away as part of the bedload. On the contrary, one could have consolidated clays that need to be detached, but once they are, they will wash down as washload. I think, somewhere at the beginning of the manuscript (perhaps under "scope") there should be a definition of the term "weak bedrock" and "strong bedrock" as used in this paper and perhaps a brief clarification of the simplification of the detachment and the transport components.

Structure of the introduction and scope sections

Large parts of the Scope section seem to introduce previous literature and partly repeat points that have been made in the introduction. Perhaps sections 1-2 could be restructured into three different sections: Section 1: a short, focused introduction, Section 2: A detailed background of existing model approaches and limits (including the differences between LEMs and channel-scale physics models), and Section 3: The modeling approach and scope of the model.

Minor line comments

P1L23: "wide bedrock valleys *in* incising rivers" – seems odd

P2L1: can the term "virtual velocity of sediment" be used without explanation? It is not a word that I intuitively associate with but maybe that is my problem.

P3L1: Mention that Howard and Knutson's model was developed for an alluvial river

P3L3: "scales inversely with **the** radius of curvature"

P3L7: Suggest change to "at reach and small catchment scales and **at** time scales **of** up to […]".

P3L23: "Lateral migration […]" this sentence seems a bit out of place in the middle of the discussion of different strath terrace formation models. Maybe move this? Also, I think, this needs references.

P7:L18: Typo in equation

P7L20: K_l is mentioned here but it wasn't defined yet.

P8L8: "We hypothesize […]" – you can mention the meandering models here again. Something like "Consistent with previous meandering models (references), we hypothesize xxx.

P10L10: I think "greater" should be "greatest"

P10L35: for two occurrences, need: "of streams that **are**"

P11L28: "bedrock channels **is** less clear"

P12L3-5: This sentence is odd. Suggesting: "Water flux was introduced **at** the top of the model by designating a node as an inlet with an area of 20,000 m^2**, and at this node,** sediment flux was introduced at carrying capacity**. This setup allowed each run to have** a primary channel […]".

P13L24: Comma missing "Most often**,** the"

P14L19: I would rephrase. "A wide valley implies that significant lateral erosion has occurred **relative to vertical incision**".

P14L28: Please specify the direction in which this slope is calculated. Down channel or perpendicular to the channel?

P16L20: "In order for this **model** to be"

P16L28: "to an event such as **a** stream capture"

P17L12: The reference to Figure 10 is out of sequence.

P17L21: I suggest to specify the timescale over which the valleys persist. When I read it, I thought that valleys are thought to persists for the remainder of the model but it is only a few 10s of ky.

P18L2-9: I believe that I mentioned that in my comments from last time. I think, in order to see the described sequence of event in the figures, there are some time periods missing from the figure. Moreover, I am unsure, why the UC and TB models compared here are with two different ratios of Kv/Kl. Now, we have two variables that change, the erosion model and the ratio of vertical-to-lateral. This makes it harder to compare the effect of the two erosion models.

P19 Line 2 (when using the line number 5 as reference), Line 4 when counting from the top of the page: In addition to the model only responding by changes in width, I would also remind the reader that the sediment deposition is producing bedrock.

P19L30: I would suggest to say "**differential** bedrock valley width" because the figure doesn't show the absolute valley width

P19L34: Same as above, "variability in **differential** valley width"

P20L11: Just after discussing the differential valley widths shown in Fig 12, I wasn't sure whether the term "mean valley width" now referred to absolute values or the differential values. A reference to Figure 11 could resolve this issue.
P20L16: to better qualify "flat" give the range of slope values. Moreover, is the downstream slope meant or is the slope of the valley perpendicular to the stream referred to?
P21L13: The way the sentence is phrased, it seems to assume an equivalence between landscapes of weak bedrock and landscapes of low relief. This equivalence has not been established before. Could this be expanded?
P21L23 valley**s**
P22L1 (counted from top of page): I am not sure about the term "blocky material" in this context. What does that mean? What about blocky but very easily eroded material? Maybe consider removing this term or expanding on it?
P22L6-7 (counted from top of page): the switch to "terraces" here seems fairly specific – especially in this mode that does not distinguish between bedrock and sediment. I am unsure I understand what the sentence is meant to convey
P22L8 (counted from line number 5): "lateral erosion **of** a bank that has been laterally undercut and **where** the remaining material"
P22L10: It wasn't clear to me until I read the supplement that all sediment produced by lateral erosion is not just added to Qs but immediately deposited downstream. Therefore, I wasn't sure about the statement "not redeposited in the model" – maybe that deposition of material can be clarified earlier in the manuscript.
P22L26: The comparison between bedrock valleys that are either "several times" (in the model) or "many times" (in some natural examples) the width of the channel seems vague. Can you specify how many times? Perhaps 3-5-times (in the model) or up to 100 times (in the real world)?
P22L28-29: The sentence "The model also did not show […]" directly contradicts the conclusion statement on P 27L21: "Increased channel mobility […]". In general, I think it can be confusing to speak of bedrock shielded by sediment in this model that does not treat sediment and bedrock separately.
P23L7 (counted from line number 5): "**an** important next step"
P23L19: I suggest changing to "**One** main impact". It is not clear that the changes in vertical incision are the main impact. In a study that should be accepted shortly, we demonstrate that some combination of autogenic dynamics and changes in water and sediment fluxes can cause order of magnitude changes in the rate of lateral erosion with only small changes in vertical incision.

P23L24: Suggest “needs to be **constructed**”.
P23L25: For a proposed mechanism for how sediment cover can change lateral erosion rates See Turowski’s paper in Earth Surface Dynamics Discussion “Alluvial cover controlling the width, slope and sinuosity of bedrock channels”
P23L29: I believe this should be “erosion **minus** deposition”
P23L32: I do not understand how a fixed kw is appropriate for landscapes in “quasi-equilibrium”. First, I am not sure what is meant by a “quasi-equilibrium”, second, I am not sure if the model that is proposed here looks at landscapes in equilibrium (or quasi-equilibrium), especially when water and sediment fluxes are changed.
P24L28: I suggest to weaken the statement by saying “it **appears to be** an important one” because there is no clear proof put forward here (or did I misunderstand something?)
P25L14: “aggradation **in** the high alpha”
P25L18-19: The sentence “does not lead to increased sediment cover on the bed […] but […] results in […] channel aggradation” is a bit odd when the process that is commonly referred to as “channel aggradation” will lead to “increased sediment cover on the bed”. Maybe rephrase.
P25L21: It would be good to specify whether a “relative” (as in relative to vertical incision) or an “absolute” increase in lateral erosion rates is referred to.
P26L11: Shouldn’t this be the “channel-scale” rather than the landscape scale?
P26L24: “A challenge remains **in** how”
P26L24: I believe, the sentence starting with “The robust data set […] are” has to be rephrased.
P26L31: valley**s**
P27L1-2 (counted from top of the page): The sentence “nor have we identified an appropriate natural experiment” seems to contradict the following paragraph where a natural experiment that is apparently deemed appropriate is described.
P27L17: “channel equilibrium” is not unambiguous in my mind. Maybe say something like “until the slopeof the channel is adjusted to the new sediment and water input conditions”
P27L21-23: Again, I find it odd to talk about implications of sediment cover of the bed in a model that does not treat sediment differently from bedrock. The observation that can be made in the model is that “when the bed is aggraded, we do not incise”

Figure comments

Figure 1: I suggest to:

- Enlarge the labels (especially the axes labels on the cross section)

- Indicate north-south, or northeast southwest etc. on the cross section
- Change the color of the title in panel b – the black Is hard to see
- Make the cross section on panel b thicker and the labels larger (could be done on all panels but on panel b it is especially hard to see
- Make the north arrow larger and underlain with a white box
- Indicate the wetted area on the cross sections (for example, make the topography black and then the wetted area in blue – with thick lines)
- Change the color of the outlined strath terraces in panel c (for example to white) – these are extremely hard to see
- Possibly change the cross section labels according to the panel letter (A-A', B-B' etc.)

Figure 1 Caption

- Suggest to change first sentence to: "Field examples of wide bedrock valleys cut by lateral erosion"
- It is not clear where the cross sections and images are from. I presume from Google Earth – in that case, I suggest indicating that the images are from that source and that the cross sections are based on the 90m-srtm DEM from Google Earth.
- I suggest to make labels on the cross section with arrows to the parts of the cross section that are referred to in the figure caption (e.g. the table mountain and the 10-m terrace in panel c).

Figure 2 I suggest to

- Annotate the black arrow on the figure "height that has to be eroded"
- Note in panel d that the slumped material is transported as washload

Figure 2 caption

- Line 3: "H, is shown **by** the dashed".
- Line 5: Could say "black double arrow" to make clear which arrow is meant

Figure 3:

- Panel letters are missing in the figure
- Y axis is missing in the upper panels
- Legend could be made bigger (UC model, TB model)

Figure 4

- I would suggest to reorganize the panels so that a and b are next to each other as in all other figures in the paper. That will also make the y and x axes the same in each line and column

- One could consider to spell out the parameter λ to help readers that are quickly glancing over the figures and don't carefully read the entire manuscript.

Figure 5

- The z axis could be labeled
- I know this is nitpicky, but I still think the figure titles could be made so that they do not overlap with the grid. That would make the figure look cleaner.

Figure 7

- There is enough space to label the zone of increased waterflux on the figure panel
- This zone could also be shaded in light grey or light green to make clear that it is a zone
- The same could be done in Figures 11 and 12 in which the shading would go until the end of the experiment.

Figure 8

- On panel b, the legend could be moved down to not overlap with data

Supporting information comments

Page 1 point 5 – subpoint 1: I think it should read "The volume of sediment […] so that it's elevation is equal to the **downstream**, node".

Page 7 Paragraph 4 (last paragraph), L6: "valley width **is** generally increased".

Page 7 paragraph 4 L13: delete "carved"

Page 9 L4: "actual valley width **that** emerges"

Figure 2

- In panel a, I would suggest to shade the two possible lateral nodes red and add a label on the figure that indicates that these two nodes are chosen at random

Figure 5

- I got confused why the model with the spinup (panel a) shows lateral erosion right at t=0 whereas the other model (panel b) shows lateral erosion only after c.a. t=200. Maybe expand upon that
- The time is missing units (I presume y or ky?)

Figure 7

- I note that the direction of the y axis (decreasing values downstream) is inconsistent with the direction of equivalent figures in the main manuscript. That led to a short confusion

Figure 8

- Same comment with the shading and labeling the zone of increased water flux as in the main manuscript

Figure 9

- The axes of panel c and f could probably be changed so that all data is included on the figure.
- Same comment with the shading and labeling the zone of increased water flux as in the main manuscript

Figure 10

- Why is t = 0 and t = 25ky here whereas all other models (Figs 11-12) the time steps shown are t=50 and t=75?