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Earth Surface Dynamics Discussions

Interactive comment on "Measuring bank retreat in fluvial environments with Terrestrial Laser Scanning (TLS)" *by* M. Foerst and N. Rüther

Anonymous Referee #1

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General Comments: This paper focuses on using repeat TLS (terrestrial laser scanning) data to measure bank erosion at three sites in a northern lowland river. Although TLS is a fairly new technology, it has been used for this kind of analysis by others. Thus, this paper needs to add something new in terms of how the data are used or interpreted. The analysis of the gradient of the bank data approaches this, and that was a nice addition to the paper. However, I would have liked to see more discussion of processes and broader uses of the dataset beyond the generation, creation and processing of the data. Most of the paper focused on methodology, but it is not strong enough to be a methodology paper on its own. Overall, I do not feel that this is a strong enough paper to merit publication in many of the journals I am familiar with.

Specific Comments: I will frame my comments based on the three main categories

listed above: Scientific Significance, Scientific Quality, and Presentation Quality, followed by an assessment of questions posed to reviewers on the ESurf website.

Scientific Significance: Does the manuscript represent a substantial contribution to scientific progress within the scope of Earth Surface Dynamics (substantial new concepts, theories, methods, or data)?

No, does not represent a substantial contribution to scientific progress. It is an analysis of streambank erosion using TLS. This is a relatively new technique, but has been used before by others. The paper is not strong enough as a methods paper alone, but at the moment, there is not enough science to bolster it as a paper using TLS data to investigate bank erosion processes or meander migration.

I think this paper would be stronger if the authors were able to use the data collected to say something more significant about streambank erosion processes. I think the authors should rewrite their paper with a greater focus on results with an eye towards understanding erosion and depositonal processes. As it is written now, it is primarily a methods paper. The results are presented very dryly as changes in numbers of changes in bank form, without really putting these changes back into context. There are useful ideas sprinkled throughout – these should be highlighted more and made the focus of the paper. In particular: A) Streambank erosion is highly variable around a bend. B) The link (or lack thereof) between peak flow events and erosion rates should be discussed more. We have actually seen similar results in a study I am working on using TLS to measure bank erosion – there are high rates of erosion in the winter, even with low spring melt floods. What is the role of saturation on erosion? Perhaps the authors can add something to this. C) The gradient analysis seems to show that there is erosion from above that is depositing on the portion of the bank that is being analyzed. Thus leads to slope relaxation ("flattening") and "sedimentation". This process should be discussed more and highlighted.

Scientific Quality: Are the scientific approach and applied methods valid? Are the

results discussed in an appropriate and balanced way (consideration of related work, including appropriate references)?

The scientific approach is valid, although I do have concerns about how they consider uncertainty in their data. The authors are aware of the uncertainty associated with several aspects of their research methodology, and these are stated as ranges of error associated with the instrumentation, the GPS, and the registration of scans, but they do not integrate these uncertainties, nor do they propogate them through to the data analysis. Change detection is conducted for individual points – presumably a large fraction of those points lie within the range of uncertainty, and thus change is undetectable in that range. The authors need to do a better job with this. I would direct them to papers by Day et al. (2012) and Wheaton et al. (2010) among others. Overall, the consideration of related work is not adequate, and there are many relevant references missing. I have included a list of references at the end that the authors may want to investigate further.

Presentation Quality: Are the scientific results and conclusions presented in a clear, concise, and well-structured way (number and quality of figures/tables, appropriate use of English language)?

The results could be more clearly written. I would also suggest that many items brought up in the conclusions section should be moved to the discussion section. The discussion section focuses too much on errors and uncertainty in the data and not enough of interpreting the results in terms of fluvial processes, and erosional and depositional processes. Overall, I would cast the paper more as a study of river bank erosion, and less as a methods paper on using TLS. I think it is still important to pay close attention to the shortcomings and uncertainties associated with the TLS methodology, but that should be covered in its own section and should not be the primary focus of the discussion.

The paper is fairly concise as written. I would suggest inclusion of more figures, not

less. Specifically, a figure showing vertical profiles for a couple transects over time would help to better illustrate the changes in slope as deposits occur on the toe slope. In addition, it might be helpful to compare rates of erosion, not just retreat distances (per Figure 3), since there are many different time periods between scans.

Overall, in terms of grammar, the paper could use some improvement. Many phrases are not understandable or use an uncommon word ordering. I would suggest the authors find a native English speaker to assist with some of these issues.

Additional questions posed by ESurf for reviewers:

1. Does the paper address relevant scientific questions within the scope of ESurf? Yes

2. Does the paper present novel concepts, ideas, tools, or data? See above

3. Are substantial conclusions reached? Not clearly. There are conclusions reached, but they are not highlighted, nor is the importance of the conclusions discussed in the larger context of stream bank erosion, river processes, and meander migration.

4. Are the scientific methods and assumptions valid and clearly outlined? Yes, with the exception of uncertainty and error propagation.

5. Are the results sufficient to support the interpretations and conclusions? Yes

6. Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)? I think the description of the methods could be a little more informative. The authors should mention the RTK-GPS system up front in the methods and how that system was used in scan alignment. Were there targets used for scan alignment? Was the GPS data used to georeferenced tie points to link scans together from different time periods? How about within a single time period? How far from the top of the bluff were data collection (the authors mention they cut off the bank at 2.8 m a.s.l., but how much farther up did the bank go?)? This is important in assessing the “sedimentation” data seen in some scan periods.

7. Do the authors give proper credit to related work and clearly indicate their own new/original contribution? Their work is clearly their own, but they do not do a thorough job of citing the TLS literature (or bank erosion literature).

8. Does the title clearly reflect the contents of the paper? Yes

9. Does the abstract provide a concise and complete summary? Yes, although it focuses on methodology and methodologic results rather than the relevance and importance of the results to fluvial processes (as does the paper).

10. Is the overall presentation well structured and clear? Mostly. Many items in the conclusions section should first be brought up in the discussion. The error and uncertainty analyses could be their own subsection, rather than dominating the discussion section. There are a few places that are a little hard to follow (noted below).

11. Is the language fluent and precise? In places, it is poorly written. I think some of the grammatical errors may stem from a non-native English background. I would suggest the authors have a native speaker read through the paper and correct a few odd phrases and problem sentences.

12. Are mathematical formulae, symbols, abbreviations, and units correctly defined and used? Yes

13. Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated? See above notes on discussion and conclusions sections. The data for the MHSG should be presented in some fashion.

14. Are the number and quality of references appropriate? No, they need more references.

15. Is the amount and quality of supplementary material appropriate? N/A

Technical Comments:

These comments focus on specific items within the text.

P. 952, Line 6: Give actual years, not “the last three”

11: simultaneously

11-13: “Further is the slope gradient. . .” sentence is confusing and should be rewritten Abstract overall – make sure you cover the implications of your results on processes: sporadic erosion, high erosion rates in winter and spring, evidence of slopes laying back between periods of toe erosion, etc.

21: “estimate the sediment balance”. . . Add in: “over short timescales”. [People have been measuring bank erosion for a long time, but only recently have they been able to really reduce the timescale of observation and still get accurate results.]

23: more erosion pin references: Couper et al., 2002; Haigh, 1977; Lawler 1978; Thorne, 1981

p. 953, line 3: Terrestrial Laser Scanning is also referred to as “ground-based lidar”. It is a lidar-based technology. The way this text is written it seems to distinguish between TLS and LiDAR, but they are really the same thing.

8: Other TLS streambank references: O’Neal and Pizzuto, 2011, Day et al. 2012, 2013 (bluffs – essentially high banks)

10: Other photogrammetry references: Matthews, 2008

25: You state the riverbanks have heights 1-20 meters above the water. These are bluffs, not banks (not hydraulically connected with the channel anymore). In addition, if you cut your data at 2.8 m up, then you are really missing a lot of the bank, aren’t you? How high are the banks that you actually scanned? Perhaps they are not so high.

26: post-glacial sediments of what type? Glacio-fluvial? Glaciolacustrine? Tills or diamictons?

p. 954, line 3: fell and slid

3: What kind of vegetation patches are you referring to? Brush? Grasses? Young trees?

6+ : Where is the gage located where you are getting the stage information from?

8-9: rainfall "with a flood character" – this is a little confusing. Do you mean an overbank flood? A bankfull flood? A flood > 1 yr recurrence interval?

11: decreases

6 and elsewhere: Your elevations are all referenced to m a.s.l. which I interpret as meters above sea level (you should define it, please). Are your sites really only a few meters above sea level? If so, aren't tidal effects important here?

p. 955, line 1-3: You list error associated with registration. What about errors with the instrument itself, errors associated with the GPS, errors associated with surface roughness and holes, etc.?

8-9: Why did you only pick banks to compare based on similar heights? What about location with respect to the bend?

11: You state that you focus on the toe of the slope to isolate the effects of the river rather than mass movements in the upper part of the bank. But any erosion occurring above your study zone will affect the results in the study zone itself. This is most likely why you see net deposition (sedimentation) in many of the time periods. It is sediment coming from above. So you can't really isolate the effects of the river by only focusing on the toe.

17-25: This description of the filtering method was very confusing. You need to rewrite for clarity.

25-29: You mention that wood was manually removed in ArcGIS. Are you looking down on the bank from above in Arc? Or did you reorient your axes to look from the side? In addition, Arc displays raster data in 2D only, and banks contain 3D data (especially in

places with overhangs or vegetation where you have been able to view the bank behind the vegetation in your side-looking scans). Is it possible to remove the vegetation in your point cloud software package, thus preserving more of the dataset?

p. 956, line 3: degree, has been

4: You refer to figure 4. I may have missed it, but did you already refer to figure 3? You need to refer to figures in numeric order.

9: rotated, so that the

p. 957, line 2: grid cells at the same height – is this the same elevation? Or the same height above the water surface?

5: exist, (add comma)

5: maximum distance has been defined as 0.5 m. I am not clear in what direction this distance is being measured – horizontally? Vertically? Into the bank?

12: rounded up in Table 2 – why did you round up?

13: colours

17: scans for and after (do you mean "before")

19-20: Patch 1 and patch 2. . . this is an important point. You are seeing erosion from above during winter months and then toe erosion following that.

24: flattening? Do you mean the slope is getting lower? Is there another way to say this more clearly? (since the bank is not becoming flat)

25: men? I am confused what this line is supposed to say.

26: How does accumulation towards the river happen physically? I think the sediment comes from above. Please be clear about this. At first I thought you were referring to deposition from the channel, but I think it looks like sedimentation from the upper bank falling on the lower bank. Which is it?

p. 958, line 1-2: The winter 2012/2013 triggers an erosion ?? and a distinct replacement of the edge – I'm not sure what you are saying here. Please reword.

3: when are the water level peaks?

11: What does the "wider slope" refer to?

19: If the changes have little effect on average slope, do they affect how the gradients are distributed on the bank?

26: use a word other than "flattening"

29: What are the average slopes in Patch 2? Please list them in the text, like you did for Patch 1.

p. 959, line 3: Figure 5 has only mean in vertical direction, right? The text states that it has both vertical and horizontal.

26: fix "flatting"

p. 960, line 12: You need to define MHSG and present data, not just P-values.

21: Never-the-less

18+: Here, the filtering parameters are discussed, but no information was really given on what filter parameters you used. Could you go into more detail on the filtering method and important parameters? It was described (rather confusingly) on p. 955, but the final parameters are not given.

p. 961, line: 6: reword: "The Kruskal-Wallis test showed that the difference in most of the slope gradients are highly significant between successive scans." (I'm not sure if this is what you are trying to say, but it needs to be reworded.

12-13: You give the total mass moved – these are very small amounts. What is your true error? Can you incorporate that into your volume measurements and see what is and is not signal vs. noise?

18: time has to be done carefully

19-20: However. . . - this line does not make sense. Please rewrite.

23-24: "This gives insight in peak processes and long term alternating water levels." What is "this"? And what insight does it give? I don't see the connection made between your data and alternating water levels, etc. You need to provide justification for this statement.

29: The last line of this page (and first on next page) needs to be revised. It is not clear.

p. 962, line 2: This is the first time you mentioned the GPS data. You need to mention the RTK-GPS and how you used it in your methods section.

18-19: I think you can better quantify your uncertainty and improve what you can and cannot say quantitatively. See work by Wheaton et al. 2010; Day et al.2012; Milan et al. 2010

25: insignificant, even though the water level

27: influence on erosion

Discussion comment in general: What about saturation of the banks? Or other antecedent conditions? How does that affect erosion/

p. 963, line 1: You state "the calculated erosion is within this tolerance". Please indicate on your change detection maps and in your data which data are outside the bounds of the tolerance and which are not. i.e. which change is real and which is within uncertainty. You should be able to quantify this for individual points, volumes, and volume/areas.

6: On the basis of these filtered data, the

13-18: This paragraph is confusing and should be rewritten.

21: I think it is misleading to say that Patch 3 had overall sedimentation, when the

sediment is coming from the sane bank, just higher up and outside your window of reference. It is actually a signal of erosion (from above), not deposition (from the river, for example).

22-23: gradient in patch 2 show that a . . .

25-26: "This leads to the hypothesis. . . before it will be transported further." This is a good point, and it should be in the discussion.

26-27" This means, that all material. . .below its source." This statement is confusing. Please rephrase.

p. 964, line 2: started, all

Table 1: This is a question about the # of points, not the table itself. How did you deal with differing #s of points from year to year? Is this the # of points that then went into DEM creation? (as opposed to the # of points that ended up in the DEM). Why are there such large variations from year to year? Is it a variation in the extent of the area measured? Or something else?

Table 2: You need to include units for volume change: total (is that m3?) and is the one labeled m2 actually m3/m2? You need to define MHSG and MVSG on the table.

Figure 1: Can you label the contour interval?

Figure 2: Where are the loggers? Can you put their location on the map on the previous page?

Figure 3: Can you label the time interval covered by the scans and not just the # of the scan? So instead of saying "Scan 01-02", you would label it "Scan 01-02, May '11 – July '11" Is there some way to standardize over the different time periods? Perhaps include another figure with rates (bank retreat/time between scans) so that we can compare rates of erosion and not just amount of erosion?

Figure 4: Label them with time of scan, not just scan #. Include in the caption informa-

tion on time of scan, and explain the red and orange triangles in the caption.

Additional figure? Given your assessment of slope changes, perhaps you could include a figure with vertical profiles of a few specific sites over time to better illustrate your point about changes in the slope profile through time. Instead of plotting slope, plot the actual elevations, so we can visually see the slope replacement going on as erosion from above is deposited on the toe of the slopes.

Here are some references to consider:

Buckley SA, Howell JA, Enge HD, Kurz TH. 2008. Terrestrial laser scanning in geology: data acquisition, processing, and accuracy considerations. Journal of the Geological Society of London165:625-638.

Couper P, Scott T, Maddock I. 2002. Insights into river bank erosion processes derived from analysis of negative erosion pin recordings: observations from three recent UK studies. Earth Surface Processes and Landforms27:59-79.

Day, S. S., Gran, K. B., Belmont, P., & Wawrzyniec, T. (2012). Measuring bluff erosion part 1: terrestrial laser scanning methods for change detection.Earth Surface Processes and Landforms.

Day, S. S., Gran, K. B., Belmont, P., & Wawrzyniec, T. (2013). Measuring bluff erosion part 2: pairing aerial photographs and terrestrial laser scanning to create a watershed scale sediment budget. Earth Surface Processes and Landforms.

Gulyaev SA, Buckeridge JS.2004, Terrestrial methods for monitoring cliff erosion in an urban environment. Journal of Costal Research20, 871-878.

Haigh MJ. 1977. The use of erosion pins in the study of slope evolution. Shorter Technical Methods (II), Finlayson BL (ed). British Geomorphological Research Group Technical Bulletin Group 18: 31–49.

Lawler DM. 1978. The use of erosion pins in river banks. Swansea Geographer16:9–

18. Lim M, Rosser NJ, Allison RJ, Petley DN.2010. Erosional processes in the hard rock coastal cliffs at Staithes, North Yorkshire. Geomorphology114:12-21.

Matthews N. 2008, Aerial and Close-Range Photogrammetric Technology: Providing Resource Documentation, Interpretation, and Preservation. by Neffra A. Matthews Technical Note 428 Bureau of Land Management.

Milan DJ, Heritage GL, Hetherington D. 2007.Application of 3D laser scanner in the assessment of erosion and deposition volumes and channel change in a proglacial river. Earth Surface Processes and Landforms32:1657-1674.

Milan DJ, Heritage GL, Large ARG and Fuller IC. 2010. Filtering spatial error from DEMs: Implications for morphological change estimation. Geomorphology. 125(1): 160-171. DOI:10.1016/j.geomorph.2010.09.012.

O'Neal, Michael A., and James E. Pizzuto. "The rates and spatial patterns of annual riverbank erosion revealed through terrestrial laserâĂŘscanner surveys of the South River, Virginia." Earth Surface Processes and Landforms 36.5 (2011): 695-701.

Rosser NJ, Petley DN, Lim M, Dunning SA, Allison RJ. 2005. Terrestrial laser scanning for monitoring the process of hard rock costal cliff erosion. Quarterly Journal of Engineering Geology and Hydrogeology38: 363-375.

Thorne CR. 1981. Field measurements of rates of bank erosion and bank material strength.Erosion and Sediment Transport Measurement (Proceedings of the Florence Symposium, June 1981). IAHS Publication 133, International Association of HydrologicalSciences: Wallingford. 503–512.

Wawrzyniec TF, McFadden LD, Ellwein A, Meyer G, Scuderi L, McAuliffe J, Fawcett P. 2007. Chronotopographic analysis directly from point-cloud data: A method for detecting small seasonal hillslope change in Black Mesa Escarpment, NE Arizona. Geosphere3:550-567.

Wheaton JM, Brasington J, Darby SE and Sear D. 2010. Accounting for Uncertainty in

DEMs from Repeat Topographic Surveys: Improved Sediment Budgets. Earth Surface Processes and Landforms. 35 (2): 136-156. DOI: 10.1002/esp.1886.

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