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Interactive comment on "River patterns reveal landscape evolution at the edge of subduction, Marlborough Fault System, New Zealand" *by* Alison R. Duvall et al.

Anonymous Referee #2

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This paper presents topographic and geomorphic data to evaluate the tectonics and associated drainage systems evolution in a complex tectonic setting. The data and analyses presented are valuable and well worth publishing in ESurf. However, I think that for this paper to reach its full potential, and the widest audience possible, significant changes are needed. Most of my detailed comments, below, address the three following main issues: (1) the paper needs a Methods sections, clarifying the techniques and criteria followed for their analysis; and also a much greater separation of the methods, results and discussion, as well as greater differentiation of which are the interpretations derived from their analysis and from published data. References to published data and interpretations are spread across all sections of the paper, making it

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Discussion paper

hard sometimes to let this paper's findings come through. (2) The paper often relies too heavily on readers being very familiar with other papers, either on the methods, or on the background geological setting and previous studies in the area. By down so, the authors are narrowing down their readership, making it more regional- and expert-focused. Providing a wider background on the previous geologic constraints, and more explicit information about the methods would attract a broader readership interested in drainage evolution linked to tectonics, but not familiar with the area, or interested in the study area but not familiar with drainage analysis. (3) Is it really necessary to separate the study area in two "domains"? Given that the divide is arbitrary and that many geomorphic and tectonic characteristics are transitional, this does not seem necessary, and in some cases, doing so unnecessarily complicates the analyses (see comments below). I suggest just referring to the ENE and WSW sides of the study area, or using some features (town names, peaks, etc.) as references.

Introduction

Line 50: based on your later results, I suggest writing "the position and orientation of rivers" rather than only orientation.

Lines 66-67: in this sentence you are listing all your analysis, so I do not think that saying "including" is appropriate here, as it gives the impression that there are more analysis than those on the list. I would rephrase to simply say "In this study, we present analysis on the topography, fluvial morphologies in planform and profile forms, and orientations of rivers compared to active and inactive faults"

Geologic Setting

At present, the last 3 paragraphs of the Geologic Setting read a bit convoluted because they go from making a general statement on the overall evolution, to talking about the present-day configuration and slip rates, to the early deformation phase, and the evolution from Late Miocene to today. I would suggest following a chronological order, so switching lines 88-94 to the end of the section. Alternatively, if the authors prefer pre-

senting the names of the faults before talking about the geological evolution, I suggest these lines should go in the 1st paragraph of the section, so that once the geological evolution starts to be discussed, a clear chronological order is followed. Lines 88-92 could go after the "The MFS. . . collision" sentence, and lines 92-94 could go at the end of the paragraph, so that discussion about the 2016 earthquake is not spread across the ends of two different paragraphs.

Line 90: how have these slip rate estimates been derived? GPS? Offset dated surfaces? A large number of studies are referred, but readers should not need to be familiar with those in order to have a general idea – a general statement saying "derived from. . ." would be helpful.

Line 97: please be more specific with the geologic time you are referring to when saying "Early in the plate boundary history" (is it Late Oligocene, Early Miocene, Early to Mid Miocene. . .?). You could add a parenthesis specifying this before the coma.

Line 98: what type of structures? Just saying "a few important structures" is vague. Figure 4 suggests that these were primarily thrusts and folds associated with them, but this information should be clearly presented in the geological setting, particularly given that it is going to be heavily included in the discussion.

Line 104: again, I think the readers would benefit from greater clarity on the time you are referring to (25 Ma?). Also, to follow a clear chronological order, I would suggest that this sentence goes when the geological history is starting to be discussed, at the beginning of the 2nd paragraph.

Line 108: here or when discussing current slip rates – could you provide with some estimates on the partitioning of vertical vs. lateral motion? "Lesser" is quite vague.

Line 110: readers would benefit from a brief statement describing how have the "estimates of timing, cumulative decrease in total offset, and increase in slip rates" have been derived, or at least what type of data set they come from. Also, could you please

explain what is meant by “cumulative decrease in total offset”? I understand how an increase in offsets could inform about the time since fault activity started, but I am not sure how could a decrease in offsets inform of that, or how it could even be identified or resolved.

Topography and planform river patterns

Given that the dividing line is arbitrary, and that many of the landscape features are transitional – is dividing the área in “domains” actually necessary? I suggest that the authors simply refer to the ENE and WSW parts of the study area, or include some other features (peaks, towns) as a point of reference, rather than making an arbitrary division that I also think complicates their interpretations in the following figures, given that this divide position does not actually correspond with any clear geomorphic boundaries.

The first two paragraphs of this section read a lot like information that should be on the Geological Setting section, given that, except the swath profiles, there is no “result” of analysis presented. I suggest moving these paragraphs that simply describe the landscape features from the DEM and the positions of the faults based on published data, to a sub-section of the Geological Setting. Also, I see that the DEM used and the source of the faults map are listed in the caption of the figure, but this is important information that should be included on the main text, in a Methods section. Drainage anomalies

Lines 138-139 belong in the introduction, along more background information about the use of these anomalies to infer tectonic perturbations. Why are these particular features chosen for analysis, and what are they indicative of? Rather than simply saying here “Following McCalpin (1996) and Craw and Waters (2007)”, I suggest briefly summarizing these previous works in the introduction, and why river elbows, barbed tributaries, etc. are can be indicative of drainage perturbations related to tectonics. Before presenting the results, a description of the criteria followed to identify an “anomaly”

should be presented in a Methods section, which should include information on how have river elbows, barbed tributaries, water gaps and underfit channels have been defined and identified. Why have river elbows only been marked in the main channels? How do the authors assess if a channel is "fit" or "underfit", have they used any published (or compiled themselves) graph of valley width vs. discharge? Do the channels mapped as "underfit" deviate sufficiently from the overall trend to be distinctly identified? A graph showing the overall trend of valley width vs. discharge, and how "underfit" channels deviate should be included in the main text or in the supplementary information.

Information on the maps used and their resolution also belongs in a Methods section, not in the results.

Lines 154: can you use these slip rate estimates to infer minimum time since the Clarence started flowing to the SE in its lower reaches? Or using the offset to estimate the beginning of slip in the Kekerengu fault? This would better highlight the potential of drainage patterns on informing about tectonic evolution.

Line 166: the previous line mentions both the Awatere and the Clarence river, so it is not clear what river and what segment is referred to when saying "this segment", please be more specific.

Lines 167-168: this short sentence says twice "in the headwaters of the Awatere river" – I suggest rephrasing to "In the headwaters of the Awatere river, a small water gap and an underfit stream (number X and X on figure X) could indicate the previous pathway of the river, if indeed it once had larger headwaters to the west".

Figure 2a and 2b: these are two important figures for the paper's results, but it is often hard to follow the results because the figures are too small and cluttered, and two important features for the analysis, the relief and the faults, are displayed in other figures, making it harder to relate them to the drainage network. I suggest moving the faults and river orientation analysis (panels c and d) to another figure, and make this

figure a bigger panel figure with 4 or 2 panels, each showing the drainage network, the faults, and hillshade relief in black and white (or the DEM in a paler color scale), but in each highlighting in color only one or two of the mapped features (watergaps, elbows, underfit channels, barbed tributaries). This would also allow more space to add Id or labels to the key features discussed in the text, so that rather than saying "a small water gap in the headwaters (e.g. line 167)", the authors can write "a small water gap (n°14) in the headwaters". This would considerably help following the information presented in this section. Also, the orange and red colors chosen for underfit rivers and barbed tributaries are very hard to differentiate in printed versions of the paper, I suggest displaying these in different panels or using a more different color for one of them.

Orientations of Rivers and Faults

Lines 175-177: These sentences belong in the Geological Setting, they are not the results of this paper. The "every-direction variogram" analysis is not routinely used in geomorphology, so the authors' analysis is going to build up on this, they should include a methods section in which they summarize the method.

Lines 180-183: These information is important, but belongs in a methods section. Also, please explicitly state whether you follow the same criteria as GNS to consider if a fault is active or inactive, and what do you mean by "mature" faults (ie. An inactive fault could be mature? For example if it was active for long enough to significantly weaken the bedrock).

Clearly A5 and A8 span both domains, so it is problematic to overlap the previous Inland Malborough vs. Kaikoura domains to this grid pattern. I understand the practicalities of diving the area in grids, but as they are right now, these grids are not truly representative of the different areas, and if anything, they could be masking some trends. The choice of number and size of grids should also be discussed in the methods, as right now it seems highly arbitrary, and that it can have a strong impact in the

results presented in Fig.2c and 2d. Is it not possible to rotate the grid or map to align the grid boundaries with the dominant ENE-WSW pattern of the faults and the relief? That way the different grids would be more representative of the true gradients in relief and tectonics (rivers and faults should still show in the radial plots their true orientation, I just suggest changing the reference grids used to divide the area up in zones).

Line 186: why have these channel orders been selected? This needs a brief justification in the methods.

Line 187: some description of what these "network segment and plotting routines" are and do is needed in the methods. Readers should not have to be familiar with Philip Steer's contribution to TopoToolbox in order to at least have a 1st order idea on how you have treated your data in your paper. Of course you can always redirect readers to published studies for more detailed information, but the core of the analysis and methods should be briefly discussed. If no paper exists for these contributions, please provide a link as reference.

Line 186: again, this belongs in the methods, it is not a result. How have you done this normalization? Can this normalization mask results, if the orientation of the largest, dominant faults means that their influence in the graphs is heavily weighted down by their length?

I strongly suggest using a more quantitative, statistics-based way to assess the overlap of the inactive and active faults and river orientations (Also, perhaps adding a box plot near the radial plots could help visualize the overlapping better?). Looking at panels A2 or A3 for example, I would never say that the orientations "overlap strongly" as it's said in Line 191. Even visually, it is hard to fully assess the overlapping when the active faults are depicted in opaque black (also, maybe two different translucent colors could be used for active and inactive faults, so that overlapping areas can be more easily visualized as a color combination?).

Line 192: what about the fact that in A1, A2 and A3 active faults have a much narrower

distribution than inactive ones?

Line 193: it is hard to assess the true degree of overlapping for A7 (translucent colors may help, see above), but A4 appears to have a significant number of overlapping rather than two “clustered” different populations as it is mentioned here.

Line 195: it is a bit bold to say that all the difference between active and inactive faults orientation comes from the influence of the Malborough domain, looking at the data this does not seem to be the case. I would suggest for example using a different color scheme for this “all faults plot” (and perhaps making it bigger, showing it as another entire panel), with different colors for each area, but different degrees of opacity for active/inactive? Also, maybe you could you use the “degrees of rotation” from the inactive to active faults population to reconcile it with the overall rotation estimated for the deformation field from previous studies?

Line 200: do rivers in the Malborough align N-S? it seems to me that a NE orientation prevails, which is pretty similar to many rivers in the Kaikoura domain.

Lines 202-203: A4 and A7 in the Malborough domain have almost as many NW-SE orientated rivers as A8 has.

Overall I find the results and discussion of this section unclear, because it relies on qualitative and subjective visual assessments and on the overlapping of two arbitrary sets of divisions on the study area, which mask the important key findings: a) active faults are more E-trending than inactive faults, (b) overall, river and fault orientations overlap, (c) to the NE and S of the study area, there are also NW-SE-oriented rivers that do not overlap with the existing faults. Please see my comment at the beginning of this review about the Inland Malborough vs. Kaikoura domain separation, I suggest eliminating this arbitrary separation, even more on light of the results presented in Fig.2c and 2d. This would also make the presentation of results more straightforward and focused on the overall, significant trends.

River Profiles and Channel Steepness

Lines 208-218: none of this are results from this study, this paragraph belongs in the introduction.

Line 220: I suggest adding a lithological map of the study area, it would be very helpful for readers not familiar with this area of NZ but interested in your drainage evolution results.

Lines 225-234: all this belongs in a Methods section. What “default values”? From what paper/software? Rather than simply saying “we use other default values”, please include all parameters used in a table on the supplementary information. Why is this particular drainage area threshold used?

Line 233: the chi-plots used to identify breaks in slope should be included in the supplementary information.

Line 236: ksn should have units of m0.9 if a reference concavity of 0.45 ($\sim$0.5) is used.

Lines 245-251 and 254-256: contextualizing this paper’s findings with previous published studies belongs in the discussion, not in the results. Also, if discussion is going to refer often to several published thermochronology studies, I would suggest adding a summary figure with the available thermochronological data and the exhumation patterns derived from this (could be another panel in Fig. 1 for example).

Line 58: the ksn value presented in Fig. 3b is actually lower for the lower Awatere reach than for the intermediate one. . .

Landscape evolution at the edge of the Hikurangi subduction

I would strongly suggest discussing the key findings and interpretation of your data analyses first – i.e. what do they indicate in terms of drainage evolution, and what type of tectonic perturbations would they suggest? – before contextualizing your data in the wider geological setting. Essentially switching the order of your current sections

5 and 6. You say in line 269 that you link the large-scale drainage evolution with the known tectonic history, but for that, a summary of the large-scale drainage evolution that includes the key findings and interpretations of your data should be provided first.

In the text, you write “stage 1, stage 2. . .” but in the figures you write “Early Miocene, Mid Miocene. . .”. Please be consistent so that it is easier to follow. For example, you could write I both: “Stage 1: Early to Mid Miocene”, “Stage 2: Mid to Late Miocene”, etc.

Line 292: and as they responded to the increase in uplift. . .

Line 332-333: this should have been mentioned in the results.

Discussion

Line 364: I suggest adding “enough displacement to [. . .] or to produce significant relief”

Conclusions

Line 400: please do state explicitly what factors were investigated – many people read the conclusions of a paper before deciding whether to read it entirely or not, so this would be relevant information.

TYPOS, ETC.

Line 38: space missing between “e.g.” and “Wobus” Line 17: for clarity, please insert “drainage” here, so that it reads “history of drainage capture and rearrangement” Line 64: space missing between “e.g.” and “King” Line 69: I suggest changing “complicated” for “complex”, otherwise the word “complicated” is repeated 3 times in 6 lines. Line 75: typo, “Puysegur” not “Puyseguer” Line 139: space missing between “e.g.” and “Bishop” Line 409: it is “Philippe Steer” not “Phillipe Steere”

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