

Reviewer comments are provided in bold-faced type. All line and page numbers refer to manuscript version with changes accepted.

Author responses are italicized

REVIEWER 3 (Anonymous)

Specific comments:

Major:

My first and largest concern is with the presentation of the constructive vs. destructive argument. The current manuscript implies that this is a new idea and a new way of thinking about delta formation, when in fact this idea has been widely discussed in the deltaic literature (both sedimentology- and geomorphology-related) since at least the 1960s. Yes, it is slightly in contrast to the Galloway diagram, but it is not in contrast to an abundance of delta literature. It needs to be made clear through (1) an enhanced discussion section (and possibly some more background as well) and (2) increased referencing throughout the paper that this idea is not new. What IS new and exciting is that you can start to quantify this with the data presented in the current manuscript, showing that you have indeed significantly advanced the science while still giving sufficient credit to the vast quantity of existing literature that presents or at least references this framework. I have listed some references for you below, compiled from only a very quick search.

We are grateful to the reviewer for taking the time to collect these references and present them to us. We never intended to miss this literature, but it unfortunately happened. We have now revised the discussion to reflect our contribution more clearly. Please see P14L10-25.

Second, you chose not to include basin depth as an environmental variable in your analysis, and you state that that is because the basin depth at the time of delta formation cannot be known from modern bathymetry. You have a similar statement regarding the last 26 years of sea level data. Unfortunately, this is also true for all of the variables you include. Many of these deltas are thousands of years old, at least. How can you take modern river discharge and relate it to delta formation without knowing if the modern river discharge is responsible for modern delta existence? I have two suggestions to remedy this because I still believe your analysis to be a useful one, despite the obvious problem of time. (1) Be abundantly clear in your language throughout the paper that you can map delta existence (not formation) in the modern state and you have some modern environmental variables, but provide the caveat that deltas were formed by past environmental conditions that are largely impossible to know. This is an easy partial fix, although somewhat unsatisfying, but absolutely needs to be stated up front. It is absent from the current manuscript in regard to all other variables.

This is a good suggestion and we thank the reviewer for pointing this out because it helps us clarify our effort to readers. There is a point here that deserves more clarification. What our analysis effectively assumes is not that the modern discharge is the same as at the time of delta formation, but rather that the present deltaic configuration along the shoreline has adapted to modern conditions. Indeed, we now refer in the text to others papers that show delta response time scales are fairly short (order 100-1000 yrs) such that our assumption that river mouths are roughly in equilibrium with current conditions is

reasonable. After all, work by one of our co-authors shows that waves can easily rework deltas in 100s of yrs (Nienhuis, et al., 2013). We now state this important caveat on P5L18-25: “We use modern data collected for each of these environmental variables, even though some deltas may have initially formed under different conditions 6000 to 8500 years ago as sea-level rise slowed after deglaciation (Stanley and Warne, 1994). We assume that the current river delta (or lack thereof) is adapted to the modern environmental variables because scaling analyses suggest the diffusive response time of river delta deposition and wave reworking is on the order of 100-1000 years (Jerolmack, 2009, Nienhuis et al., 2013). Of course, the diffusive response time depends nonlinearly on delta size, so larger deltas may still be adapting to changing environmental variables.” We also added a line in the introduction at P3L12 that says “We use modern values of these environmental variables under the assumption that present day delta formation is adapted to current conditions.”

It is also worth mentioning that this issue is why we use predam values of sediment and water flux from Milliman and Farnsworth, because it insures that we are using the environmental variable that is most likely responsible for the current delta configuration. Regrettably we did not specify our use of predam values before, but we have now corrected that omission.

In regard to the suggestion of using ‘existence’ in place of ‘formation’ we opt to stick with our original language. The word existence obviously implies formation of a delta and because we do not know when the current deltas achieved their present configuration, we don’t think changing the wording affects our messaging. In this sense, it is possible that many of the deltas in our study have undergone cycles of formation and destruction as water and sediment fluxes and wave fields have changed over time. There are also quite a few documented examples of this presented in Anthony (2015). This makes it difficult to pinpoint when the current deltas experienced their most recent formation. In this way, we view ‘delta formation’ as a nearly continuous process that is always occurring (or not occurring), rather than as a discrete process that happened once 7000 years ago. To help clarify this we refer to ‘modern delta formation’ now.

(2) For a subset of river systems, compile any and all regional historic climate data (may also include paleo reconstructions) to evaluate how the regional conditions were different in the past or perhaps even at the time of delta formation. This will at least give you a distribution of how conditions may have changed over longer timescales and will allow you to determine if some systems might be moving more towards constructive or destructive phases.

This is an intriguing idea. We followed through on this and found that longer term sea-level rates do not actually increase success of predicting delta formation. We used model results from the well-known ICE_6G_C model. Please see P9L2-7 for this new discussion.

With regards to the points made above, part of the difficulty is that it is not straightforward to know when any given delta ‘formed’, which makes it difficult to estimate sea level change over the lifetime of the delta. Even when these longer term RSL rates are used, it still did not have a statistical affect on delta likelihood and was thrown out of the final logistic regression. There are likely many different reasons for this, but we come back to the point mentioned above: when did the current array of deltas defined in this paper start forming? Perhaps the 26kyr to present time frame is too long to average over, but it at least represents a longer time scale average than the 25 yr duration from AVISO. It is tempting to assume that a duration from 7 kyr to present is more appropriate following Stanley and Warne (1994). But it is worth noting that they record the progradation of deltas following decelerating post glacial sea level. This does

not mean the delta did not exist prior to deceleration. In fact, it is possible a smaller delta existed in a more landward portion during the transgression. So even for those deltas the timing of delta formation is not entirely clear.

We think that it is plausible, given the relatively rapid adaptation timescales of deltas we quote above, that deltas may have gone through multiple cycle of construction and destruction. In this sense, it is difficult to cleanly link a 'time' of delta formation to historical conditions, which would make it difficult to perform an analysis like this. While this kind of analysis of historic climate data could yield interesting results it does not bear on the outcome of the present study. As we state above, we effectively assume the deltas have adapted to modern conditions, which is reasonable given their relative rapid adaptation timescales. Even if we did find that some deltas have undergone changing conditions, we would still need to show that the morphodynamic adjustment is incomplete. This would necessarily require a modeling study. While we do agree with the reviewer that this may provide some interesting results, we do not think such an analysis will bear strongly on our results or conclusions. Given that our paper is tightly focused we prefer to leave this analysis for a different contribution.

Argus, D.F., Peltier, W.R., Drummond, R. and Moore, A.W.(2014) The Antarctica component of postglacial rebound model ICE-6G_C (VM5a) based upon GPS positioning, exposure age dating of ice thicknesses, and relative sea level histories. *Geophys. J. Int.*, 198(1), 537-563, doi:10.1093/gji/ggu140.

Third, I know that data on upstream and downstream variables is difficult to assemble, especially if you want all apples instead of a mix of apples and oranges. However, I find it surprising that you chose to use only one dataset of river discharge from 2011. Is there not any additional discharge data that can help you use more of your river/delta dataset in your statistical analyses? Have you checked the Global Runoff Data Centre or maybe even the Global Forest Information Service? Increasing your data usage can only make your own dataset(s) more valuable to the community.

Thank you for pointing out these additional datasets. We agree that having more data is strongly preferable, but we wanted to use the best possible data and as the reviewer points out we wanted to avoid comparing different types of data. That is why we used the Milliman and Farnsworth data because they represent measured observations, not models. Moreover, the MF dataset uses available data from the GRDC.

Finally, the paper needs a bit more information on the datasets involved in this study. How did you map the rivers and deltas? Entirely by hand? Over what timeframes are your discharge data? I can go pull the MF2011 dataset myself, but this should be included in your manuscript, as it is for the marine data. Your supplemental table is helpful, but please also include in it your mapped river widths and the values of Q_w , Q_s , and Ab .

We now clarify that the rivers and deltas are mapped by hand and that the annual fluxes of water and sediment are calculated from many years of data, though the number of years varies for each record.

The Milliman and Farnsworth data are from a book that is available for purchase and we felt it was not appropriate to publish their data here to avoid copyright infringement. We included in our dataset only the data we created, i.e. the marine data. We have now clarified that all of our data are modern in timescale and how we mapped the deltas (we did it by hand). While we did measure the width to make sure the river was > 50 m, it was not recorded and not included in any analyses in this paper and

therefore not relevant to reproducing our results. We now state in the methods that the environmental variables were collected over many years.

Minor:

The introduction would benefit from elaborating on what we DO know about the conditions that lead to delta formation. You state that they are not completely known, but you fail to really provide much information about what we do already know, either from a fluid dynamics perspective, sediment supply, or even things like effects of basin depth on delta formation.

We have now added some references and brief discussions in our introduction. Please see P2L9-16

Page 3 line 21: How do you determine (quantitatively) if the protrusion has a 'relatively smooth depositional shoreline?

We don't make this determination quantitatively because it would require that the shoreline is defined from high resolution images as current shoreline datasets are spatially too coarse to distinguish between depositional and rocky shorelines.

Why did you choose the 75th percentile of bathymetric slopes?

We choose the 75th percentile because it best characterized the offshore bathymetric slope when we checked our method against select field results.

Page 10 Line 15-16: There is no apparent linear decrease.

We agree that the linear decrease is not strong, and the language we use to describe this reflects that. But, we still maintain that when the tail of the distribution is eliminated there is a linear decrease. We reworded this sentence to more clearly reflect that.

Page 10 Line 21-22: Reserve this observation for the discussion, as it is elaborated on sufficiently there.

Fixed.

Figure 7: Is there a reason this can't be shown with all the data rather than binned data? At least include as supplemental, if not in the paper itself.

The data must be binned because the data on the y-axis (before binning and averaging) are binary. That is, they represent the observation of a delta or not. So to create a continuous L_d that can be compared to predictions from equation 1 we have to bin the data. We added a sentence in the caption to reflect this.

Page 15 Lines 3-5: But there is a concern with preservation in the rock record as well that makes this difficult.

This concern is now addressed starting at P15L14.

Technical corrections:

Figure 1: Please provide the locations of the coastal environments shown in the caption.

Fixed.

Page 4 Line 15: 'representative of the river, devoid of significant downstream widening.'

Fixed

Figure 2: Add to caption what the bounding boxes are or where they're discussed in the manuscript.

Fixed.

Page 7 Line 19 (and elsewhere basin bathy/depth is mentioned): Add appropriate references. Eg. Carlson et al., 2018, Wang et al., 2019

Added.

Page 10 Line 11: 'between the mean or median Qs/Qw values'

fixed

Page 11 Line 6: Your independent variables were not 'collected on all rivers,' as you state in the next sentence. Please reword.

fixed

Page 13 Line 4: If downstream variables are secondary, reword/reorder to reflect that.

We thank the reviewer for this suggestion but prefer to keep the paragraph organized as it is.