Response to referee #1:

Line-by-line comments and responses:

Referee: "The authors clarified many issues raised in the reviews in their revised manuscript. However, one central point remains unresolved: how the particular spatiotemporal settings of the Piedmont deposits are crucial for creating low branching angles. Regarding the question of structural control: Piedmonts are geologic structures. The caption of Fig. 11, for example, reads: "Junction angles tend to be lower in areas with late-Cenozoic deposits." Thus, if the authors argue that specific properties of Piedmont deposits cause narrow branching angles, this is a clear structural argument. If not, it is simply a slope/roughness effect and should also be presented as such. For reporting the pure observation that piedmonts are gently sloped surfaces with small surface roughness and thus more elongated drainage basins with smaller branching angles, a one-page technical note would be sufficient, rather than an extensive article."

Response: Thank you for this comment. We disagree with the statement "Piedmonts are geologic structures." The definition of piedmont is "a gentle slope leading from the base of mountains to a region of flat land" (Oxford Dictionaries). Piedmonts are, therefore, exclusively defined by slope, not lithology or any other aspect of geologic structure. We have modified the caption of Fig. 11 to read: "Junction angles tend to be lower in areas with late-Cenozoic alluvial piedmont deposits." In terms of our analysis of data from real landscapes, we have established a correlation between the presence/absence of late-Cenozoic alluvial piedmont deposits and junction angles. Our proposed interpretation is that late Cenozoic alluvial piedmont deposits have a low ratio of small-scale roughness to large-scale regional slope/tilt. We have provided extensive theory and numerical modeling to bolster this interpretation, but we cannot rule out other explanations. As such, we cannot state that the sole reason for the correlation is the slope/roughness effect. Please also note that the previous version of our paper stated that we are using the presence/absence of late-Cenozoic alluvial piedmont deposits as a proxy for the roughness and slope factors that we propose are the primary control on junction angles (lines 373-379): "It is important to emphasize that the presence/absence of late-Cenozoic alluvial piedmont deposits is a proxy for what we hypothesize is the primary control on junction angles: initial S_l/S_r. Lower initial S_l/S_r values are likely associated with late-Cenozoic alluvial piedmont deposits compared to bedrock/older deposits because such landforms tend to have a relatively low microtopographic amplitude prior to incision as a result of the avulsions and topographic diffusion associated with aggradation, e.g., local variations in elevation of ~1 m over spatial scales of ~100 m, as discussed conceptually in Section 1 and documented in the example data of Section 3.1.1."

Referee: Although Casteltort did not explicitly refer to branching angles, his convergence argument for drainage basins equivalently applies to the networks therein. Moreover, Seybold et al. explicitly discussed the slope dependence, although they neglected the influence of surface roughness.

Response: Thank you for this comment. Had we simply established a correlation between mean tributary fluvial network junction angles and the ratio of small-scale roughness to the regional slope/tilt, we would agree with the referee that our paper could be shortened. But the central argument of our paper is based on the geometric model of Howard (1971), which Castelltort and Yamato (2017) did not mention nor does the referee mention in their review of our revision. In this and in many other ways that we detailed in our response to the prior round of review, we have demonstrated that our work is not a trivial extension of Castelltort and Yamato (2017). We agree with the referee that Seybold et al. discussed the slope dependence of junction angles in their first paper (Seybold et al., 2017), and we have noted in our revision that Seybold et al. (2017) established a slope control on junction angles and concluded that the slope control was smaller than the aridity control (as their abstract states: "The correlation of mean junction angle with aridity is stronger than with topographic gradient…"). Seybold et al.'s (2017) conclusion that slope is a minor control is consistent with their Figure 4b, which shows that the correlation between junction angles and slope is extremely low (R^2 = 0.035). This is precisely why the roughness effect on junction angles was so important to document. No paper before ours has done that.

Referee: "We all agree, that piedmonts are gently sloped surfaces with small tolographic roughess. However, as the authors show by using Landscape Evolution Modeling and analyzing channel networks of aeolian deposits on the Loess Plateau, the specific ground into which the channels are carved is irrelevant for the narrower branching angle argument. In fact, the LEM used for the analysis does not seem to depend on any surface properties and simply applies a classical stream power incision law. Consequently, ANY landscape (Fig.12) that fulfills the slope and roughness conditions displays narrower branching angles. This point must be made very clear in a revised manuscript and not simply brushed away by "Sl/Sr values of which we did not study and don't feel qualified to comment on.

Response: Thank you for this comment. There is no evidence that "ANY" landscape that fulfills the slope and roughness conditions displays narrower branching angles. Figure 12 is a model. As such, it cannot definitively state what is true in real landscapes. In the previous round of review, the referee asked us to comment on whether some volcanic landscapes exhibit the same effect that we established between landscapes with and without late-Cenozoic alluvial piedmont deposits. Volcanic landscapes are often highly porous and, as such, erosion may be dominated by subsurface flows that do not follow the surface topography (e.g., Jefferson et al. (2010), doi:10.1002/esp.1976). We agree with the referee that any landscape that is the result of a model in which erosion is dominated by surface water flows and that exhibits no structural control or other heterogeneity and that fulfills the low roughness and/or high slope conditions likely displays narrower branching angles. But as far as real landscapes are concerned, our manuscript makes clear (lines 664-671) that many other factors besides roughness/regional slope control junction angles: "…we have left out many potential mechanisms, particularly those in bedrock landforms, that may influence junction angles, including preferential erosion along vertically oriented joints (Pelletier et al., 2009), lateral tectonic advection (Hallet and Molnar, 2001), etc. We emphasize the role of initial Sl/Sr in this study because we believe that it is the most relevant factor for understanding the spatial variations in mean junction angles in CONUS, especially the difference between incised late-Cenozoic alluvial deposits and bedrock/older deposits. However, it is far from the only control on fluvial network junction angles." What we can say confidently is what we have said, i.e., that there is a strong correlation between the presence/absence of late-Cenozoic alluvial piedmont deposits and mean tributary fluvial network junction angles averaged at the 2.5-km scale in the conterminous United States. We posited that this was primarily the result of a low ratio of roughness to regional slope/tilt in late-Cenozoic alluvial piedmont deposits compared to other landscapes. The referee appears to want us to go further and state unequivocally that initial topography is the only reason why junction angles differ between landscapes carved into late-Cenozoic alluvial piedmont deposits versus those incised into bedrock, i.e., that lithology or other factors that may differ between bedrock and alluvial piedmont deposits play no role. We don't feel confident in making that statement. More broadly, we disagree with the referee that, by comparing landscapes formed into late-Cenozoic alluvial piedmont deposits versus those incised into bedrock, we are making a purely structural argument. Bedrock landscapes and late-Cenozoic alluvial piedmont deposits differ in many ways, one of which is slope (see the OED definition of piedmont above).

Several other technical points also need to be explained more clearly so that a reader can understand the author's procedures and arguments.

Below, the authors can find more specific comments referring to particular sections of the text:

L 13: "when orientations and slopes are computed using drainage basins rather than …" This sentence is still confusing. What is a basin's orientation? How is the basin's slope defined? Is it a basin regional slope, a mean roughness slope …, etc.? The authors should be more precise in their description.

Response: Thank you for this comment. Added: "BA properties are computed by averaging the local orientation and slope computed between each pixel and its nearest neighbors using the D8 or steepest-descent algorithm using all of the pixels in the drainage basin."

L 16/17 Contrast between Piedmont deposits and bedrock: The model argument following this sentence is purely based on the roughness/regional slope arguments and thus does not include any specific properties of bedrock vs deposits. Consequently, the argumentation should be reversed. The authors identified that regional vs. roughness slope controls branching angles, and depositional piedmonts are more likely to have gentle slopes with low surface roughness than mountainous bedrock regions.

Response: Thank you for this comment. We think it is important to separate the results of the data analysis using real landscapes from our theoretical interpretation and prioritize the data analysis because it relates to real landscapes. We have not identified in any data analysis that roughness/

slope controls branching angles. We have established that there is a strong correlation (much stronger than aridity) between junction angles and the presence/absence of late-Cenozoic alluvial piedmont deposits. We disagree with the referee's statement that the ratio of the roughness to the regional slope/tilt is not one of the "specific properties of bedrock vs (piedmont) deposits". We believe that bedrock and late-Cenozoic alluvial piedmont deposits differ in many ways, including in their ratio of initial roughness to regional slope/tilt. Given all of the possible differences between late-Cenozoic alluvial piedmont deposits and other kinds of environments/substrates, we have posited, following Castelltort and Yamato (2017), that the ratio of initial roughness to the regional slope is a likely reason (but perhaps not the sole reason) for the difference in mean junction angles. We believe this is a reasonable approach.

L.86: Climate does not form channels. As far as I remember, Seybold et al.'s argument is based on the relative dominance of diffusive channel-forming processes, which, in turn, vary systematically with climate.

Response: Thank you for this comment. We did not state that climate forms channels. We stated "Seybold et al. (2017; 2018) attributed the variation between 45° and 72° primarily to climate (with lower mean junction angles in more arid regions)." This is a correct statement.

L155: How do the authors define drainage basin averaged direction and slope? The authors should clearly describe their procedure.

Response: Thank you for this comment. Clarified: "BA properties are computed by averaging the local orientation and slope computed between each pixel and its nearest neighbors using the D8 or steepest-descent algorithm using all of the pixels in the drainage basin."

L 189: The authors say that the AVB model uses a search distance upstream/downstream until an elevation change of 10m is reached. In some cases, this can be multiple Kilometers. How do the authors consider cases when there is another junction Ustream?

Response: Thank you for this comment. The algorithm does not stop arbitrarily when it encounters another junction up or downstream. It continues past any junction. Noted in the revised manuscript.

L 191: Please clarify the orientation and slope of a single pixel is? Orientation of the steepest descent in a D-8 flow Routing scheme?

Response: Thank you for this comment. Yes. D8. Noted in the revised manuscript. Please also note that the code is publicly available, so some technical questions (such as whether D8 or some other procedure is used to define orientation) can be resolved by examination of the code.