Reviewer Comments and Author Responses

May 26, 2025

1 RC1

"These series of papers by Wild and coauthors introduce GravelScape, a novel model for simulating sediment grain size dynamics in sedimentary basins. The model couples a landscape evolution model with a self-similar grain size fining model, allowing for the investigation of how both external factors, such as tectonics and climate, and internal processes, such as channel avulsions, influence sediment deposition. One study focuses on the model's validation and general behavior. Another explores the relative importance of autogenic processes versus external forcing and the final study examines the evolution and the stratigraphic record of flexural foreland basins using the model. The GravelScape model offers advancements over previous models, particularly in its ability to simulate grain size fining in multiple dimensions and account for autogenic processes. Overall, the manuscripts are well written, results are nicely demonstrated and discussed. I recommend it to be published after addressing a few minor comments. "

- Thank you for taking the time to read through, summarize, and review the articles.

"Regarding model validation, it is based on a comparison with Duller et al. (2010)'s single-channel model. However, GravelScape is a multi-dimensional model designed for complex sedimentary systems. The manuscript should provide more justification on that."

- Within the validation of Paper 1, we have separated Figure 4 into more sub-plots to more clearly show the two grain size validations that were made comparing the Duller et al. (2010) solutions with our GravelScape model. First we compared the Duller et al. (2010) results to our computation limiting the model to a single channel (2 cell wide) solution to validate our integration of the Fedele and Paola (2007) equation (subplots c and d in Figure 4). Then we include multiple-channel dynamics to the model and compare this to the single channel solution (subplots e and f in Figure 4).
- In the discussion of Paper 1, we added text (see the following bullets) to the discussion explicitly noting where the application of a single channel vs multi-channel grain size models can be justified:
- "...The results from our validation (Figure 4) indicate that single-channel solutions are most applicable under more uniform flow and early basin filling states (low F) where our GravelScape multi-channel solution showed little deviation. Such is likely the case in the Pobla Basin, Montsor Formation where Duller et al. (2010) applied the Fedele and Paola (2007) grain size fining model assuming subsidence is equal to deposition rate. The Montsor formation is described as a progradation of extensive alluvial fans filling a wedge top basin during a period of intense thrust activity and subsidence in the southern Pyrenees Axial zone (Duller et al., 2010). However, a more complex, multi-channel, lateral model that decouples deposition from subsidence rate is justified, if not necessary, to simulate grain size in systems in high bypass (high F), with steeper topography, or with more diverse geomorphology and stratigraphy (e.g. variations in channel dynamics, fan, and floodplain)..."
- "Additional factors (e.g. slope) that influence grain size fining in alluvial fans aside from subsidence and mean deposition rate, have long been debated in the literature (Stock et al., 2008)...D'Arcy et al. (2017)'s correction factor is one example that justifies the need for the multi-channel grain size model that can predict lateral depositional variations in real time, especially in systems where grain size fining cannot easily be explained through subsidence alone."

"The model assumes downstream deposition is the primary control on grain size fining, how would the pre-existing topography affect the grain size distribution? "

- We added a line to the discussion of Manuscript 1 to address the impact of pre-existing topography: "...This topographic influence on grain size implies that factors that can increase topography, such as initial topography or certain basin geometries, could impact the grain size fining when multi-channel solutions are considered. This warrants further study that we present in Wild et al. (2024) along with further applications of the multi-channel model....".

- We then expand on this in the appendix of Paper 2, where we discuss the impact of slope on grain size in greater detail in an alternative framework, stating: "Within the main text, we prioritized β configurations as one approach to inducing higher slopes and more autogenically dominated conditions, due to β' s measurability at the landscape scale. However, our results also showed how transient conditions (lower K) and higher G can increase slope and autogenic dynamics. With limited subsidence, any initial topography present within the basin could perpetuate increased slope, rugosity, and autogenic fining conditions. However, under high subsidence conditions, impacts of initial topography in a basin would likely be rapidly buried, leading to flatter slopes, low across basin topographic variability, and subsidence dominated fining conditions. There are many more scenarios that could impact slope and subsequent autogenic fining conditions that warrant further study."

- Within Paper 3, we also added a sentence addressing initial topography within the introduction: "Initial topography can impact the timing of basin infilling and, when initial conditions raise elevation, promote more continental opposed to marine dominated infilling conditions (Gérard et al., 2023)."; and methods: "We imposed a slight initial topography in the model to promote continental conditions in the foreland basin where we can compute grain size (see Gérard et al. (2023) for a description of how initial topography impacts foreland basin evolution)." of the paper clarifying the impact of initial topography within the context of foreland basin evolution modeling.

"Minor technique correction Line 4: change Fedele and Paola (2007) to (Fedele and Paola, 2007) "

- We have corrected the citation error from Fedele and Paola (2007) to (Fedele and Paola, 2007) and corrected other minor typos and errors within the text.

2 RC2

"In this contribution, the authors present a significant advancement in landscape and stratigraphy modeling by developing a new framework that integrates a planform grain size model with a landscape evolution model. The ability to simulate downstream grain size fining across multiple channels in a landscape offers valuable insights into the mechanisms (autogenic versus allogenic) driving the development of grain size trends in the stratigraphic record. The authors have taken great care in restructuring the original submission into three standalone yet closely related manuscripts. I found the revision to be well-organized, with the significance of the work clearly articulated."

- We thank the reviewer for their positive comments and for taking the time to read through the articles.

" I believe the manuscript meets the standards for publication, and I offer two major comments for the authors' consideration to further improve clarity: 1. The second manuscript specifically addresses disentangling the effects of autogenic processes and external controls on model outcomes. Although the introduction mentions autogenic processes, the only one explicitly modeled appears to be avulsion (line 51), if I have interpreted the manuscript correctly. Given that autogenic processes are central to this component of the study, I suggest adding a brief paragraph elaborating on the specific autogenic processes included in the model. For instance, what mechanisms of avulsion are being represented in the simulations? "

- We added a short section titled 'Modeled Autogenic Dynamics' where we specify the scale and specific autogenic dynamics included within the numerical model. In this section, we not only provide a clearer description of what is included in the model, but also refer to the work of Hajek and Straub (2017) where they described autogenic dynamics and the different scales at which they operate. In this way, we can describe our model within the context of work on real-world autogenic dynamics without needing to re-define already well-described processes/phenomena within the literature.

"2. In the third manuscript, the authors examine the Alberta Basin and interpret the stratigraphic and grain size trends in terms of their development conditions. If I understand the methods correctly, these interpretations are based on qualitative interpretation of key modeling parameters, such as F and β, derived from model outcomes and the basin's stratigraphic architecture and paleogeography. While this is not an inversion study, providing some back-of-the-envelope, quantitative constraints on these parameters would strengthen the interpretations and add credibility to the conclusions. "

- Within Manuscript 3, we added three paragraphs at the end of the "General Evolution" section addressing further quantitative constraints on model parameters within the context of the Alberta Basin.
- While addressing the reviewer's comment, we noticed a minor mistake between some of the K and precipitation values (impacting our computations of β) in the input table of Paper 3 and those used in some of the model simulations. Also, since multiple modeling approaches (e.g. with and without flexure) were applied in paper 3 that used different input fields, we realized that the original table of inputs was a bit confusing or misleading. To address this, we separated the table of inputs into two columns adding more clarity regarding the two different (with and without flexure) modeling approaches used in Paper 3 and corrected the β values in the table, text, and figures. These changes did not alter the interpretations or F evolution (e.g., autogenic vs. subsidence-dominated) within the framework or text.
- Finally, without changing the interpretation or simulations used, we replotted the high β foreland evolution (Figure 4 in Manuscript 3) in the exact same manner (e.g., using the same color scheme and same panel setup) as the low β simulation in order to improve the comparison between the two basin simulations for the reader.

"Minor comments: 1. Manuscript 1, line 8-11 "we also show…": This sentence is too long and very hard to read. "

"We show that, when multi-channel dynamics (i.e. avulsions) are prevented, by reducing the planform model to a single downstream dimension, our new model can reproduce results obtained by other methods that assume that fining is controlled by subsidence only. We demonstrate that including across-basin (two-dimensional) effects can lead to deviations from previous subsidence predictions for grain size fining. The magnitude of these deviations correlates with the extent of sediment bypass and the configuration of surface topography, both of which influence the amplitude of across-basin variability within the sedimentary system."

"2. line 182 "by the flux of..": Do you mean "to the flux of…" "

- Yes, we changed line 182 to state: "to the flux of...".

"3. Figure 4 is hard to read, especially subplot c and d. Consider having more subplots or break this up into two figures. For example, subplot c and d showing multiple comparisons in one figure that are hard to follow "

- We added additional subplots to Figure 4 in Manuscript 1. More specifically, we split the original Figure 4 subplots c and d into subplots c,d,e, and f. We also removed the F=1000 scenario from all subplots in order to reduce the number of lines within the plots to improve clarity.

"4. Manuscript 2, line 120: could you provide some end member examples of this shape parameter. For example, something like "high catchment precipitation and low basin length will result in high beta value" or "high beta value typically will indicate small/large basins". The point is that, having some end member examples of low and high beta value, and how it is directly linked to the topography/size of the basin/catchment, will help reader to visualize the parameter, which will make reading the following discussions much easier. "

- We added three lines to Manuscript 2 summarizing the parameter end member scenarios: "In short,β is a measure of the difference in area (extent) and precipitation rate between the orogen catchment and the sedimentary basin. Combinations of high precipitation and drainage area in the orogen with low basin length and basin aridity result in high, orogen dominant, β values. Inversely, large basin areas, especially with higher precipitation relative to the orogen, result in low, basin dominant, β values."

"5. line 125: shouldn't this be "alpha/LB"?"

- We corrected the sentence: "β is in fact the ratio of the length/size of the fan, $\nu_M L_M/\nu_B$ to the size of the subsidence function, αL_B." to read: "β is in fact the ratio of the length/size of the fan, $\nu_M L_M/\nu_B$ to the size of the subsidence function, α/L_B."
- We also tried to provide more clarification and consistency in the handling of β throughout the text in all manuscripts.

"6. line 216-217 "To quantify this difference...": this sentence is hard to read and understand, consider break it up."

- We have rewritten the sentence: "To quantify this difference, we define a parameter that is sensitive to the amplitude of local deposition rate events independent of the deposition rate caused by the imposed basement subsidence." as: "To quantify this difference, we define a parameter sensitive to local deposition rate fluctuations. We explicitly remove the background mean deposition rate, induced by basement subsidence, to isolate the amplitude of depositional variability."

"7. Manuscript #3, line 24 "accommodation space": the word "accommodation" means "available space", so technically you can just say accommodation without "space". This term has been used multiple times, please consider changing it. "

- Although both the terms "accommodation" and "accommodation space" are used in the literature, we removed the "space" from line 24 and other areas of the text to reduce repetition and redundancy.