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Earth Surface Dynamics Discussions

Interactive comment on "Quantifying Thresholds of Barrier Geomorphic Change in a Cross-Shore Sediment Partitioning Model" *by* Daniel J. Ciarletta et al.

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[[This work by Ciarletta & colleagues is an engaging and well-written exploration of cross-shore barrier dynamics in a deliberately simplified numerical model. The authors are clear about what the model does and does not explicitly address, and that it serves a tool for first-order quantitative insight into transitions between barrier states and behaviors otherwise framed in conceptual terms. The differentiated regime space indicates the rich dynamics that the model is capable of simulating, and the authors are careful to keep one foot in the real world by constraining the fundamental parameters of the model with empirical rates.]]

+ Thank you. We hope to deliver additional first-order insights through field-model comparison in the near future.

[[My comments are minor, but I hope offer some helpful suggestions:

Abstract, Introduction – To me, snippets of the Abstract (and related snippets of the Introduction) are written in a way that suggests a decade is approximately the upper end of the model-world time scale here. (Other parts of the manuscript are clearer in this regard.) Just to reflect: the model runs on an annual increment and can comfortably tick over for a couple of centuries, which means the interesting changes occur on decadal time scales. If the authors describe it as a model of multi-decadal barrier dynamics – on the order of 101–102 years – I think that might help readers have a better sense from the outset of what the model does and doesn't do. (And it creates useful space for the interesting discussion, late in the manuscript, regarding what explicitly including event-driven changes and fast-acting processes might add.)]]

+ We agree that the way we currently describe this is a bit confusing, and stating as "multi-decadal" instead of "decadal" seems like a straightforward way to make this clearer.

[[P3L66 and elsewhere – Recommend cutting "we believe," since it's implicit in the conditional statement that follows. Would also change instances of "believe" on P14L440/442 – prefer "thought to be. . ." or similar.]]

+ Recommendations implemented.

[[P3L76 – "Whole-barrier dynamics at the mesoscale (10s to 100s yrs) are poorly represented by models, partly because the complexity of geomorphic processes at this scale cannot be easily represented by simple linear relationships. . ." – I think Werner (2003) on complex hierarchy offers a helpful explanation here (because what manifests at the mesoscale is a mix of linear and nonlinear), and I'd offer that McNamara & Werner (2008a, 2008b) are one example of a barrier model that does quite well in

this regard (and ultimately manages to account for both natural and human-dominated conditions). The operational blocks of this model (i.e., triangles, partitioned distribution) in many ways appear related, at least conceptually, to that earlier work. And even if the similarity ends there, it's a sound foundation. Furthermore, the spatially extended version of the LTA14 model exhibits some interesting mesoscale behaviour – which the authors cite (Ashton & Lorenzo-Trueba, 2018). All that is to say – I suggest the authors cut back the "poorly understood" spin throughout the Introduction and take a lighter, more open tone like the one at P3L80 – a framing of the problem that makes plenty of room for previous work. Another reason for that subtle adjustment is that this work, too, is, as the authors rightly state, a "first-order" model, steered but hardly constrained by empirical parameters.

Sticking with this same introductory sentence – I'm not sure that geomorphic processes operate at the whole-barrier scale (and I think the authors would concur). Returning to Werner (2003) – whole-barrier dynamics are an emergent property of geomorphic processes of sediment transport at smaller-than-whole-barrier scales. So perhaps the authors could revisit their warrant here. My sense is that models struggle to represent whole-barrier dynamics because they aren't built to capture emergent properties – which I think is more or less what this sentence is trying to convey.

P3 (Section 2) – I think the first half of the Background could be folded into the Introduction, with some adjustments for repetition. There's a shift at P4L95 to the "motivation" for the model – the conceptual model by Psuty (2008) – that could set up the Methods as the start of Section 3. Then there is another shift at p4L115 that reaches toward implications, which as a reader I wasn't ready for until I'd seen the model do its work. I think those last two paragraphs of Section 2 would sit well in the Discussion, and establish a far more interesting beachhead than the current paragraphs about the Bruun rule (see related comment below).]]

+ We will address the aforementioned points together, since they are interrelated. After consideration for the response from another reviewer, we agree that the first paragraph

of the Background is largely redundant with the Introduction and work this into the third paragraph of Section 1 (see modifications below). We also agree with the suggestions to cut back on the "poorly represented" language and add citations for Werner (2003) and McNamara and Werner (2008ab). We integrate these references into the Introduction to clarify the philosophy behind the model (chiefly, the characteristic timescale of barrier landscape formation), as well as provide some context for what such a model is built to explore.

We retain the remaining Background section with some light modifications (particularly the last two paragraphs) since this is information that helps explain the need for the model, as well as define how some of the model parameters (e.g. vertical accommodation) are understood from the field. The latter point is relevant since another reviewer specifically requested that we clarify early in the paper what vertical accommodation is and how it varies from one location to another.

To be clear, we feel it is important to make the distinction early on that this framework is not simply a rehash of the earlier model (Ciarletta et al., 2019), but a greatly expanded system specifically designed to answer questions that go beyond Psuty's conceptual model and exceed the capabilities of the old framework. These questions require some background to understand, especially for researchers who may be working in seemingly disparate environments, and we attempt not to blindside in the Discussion.

Modifications to Introduction, Paragraph 3 (P2): "[. . .] However, such a model need not be event-based to approximate the net result of flux-driven changes in time, allowing for reduced-complexity simulation (French et al., 2016). This is consistent with the hierarchal view of natural systems by Werner et al. (2003), which considers characteristic timescales of landscape self-organization from processes occurring over shorter time intervals. The concept is particularly suited to mesoscale modeling of barrier evolution, where emergent morphology is at least partly understood from observational and historical records (Psuty, 2008; Psuty and Silveira, 2013) but cannot be easily driven by linear relationships alone (Cooper et al., 2018). Furthermore, by idealizing the ge-

ometry of barrier systems, it is possible to partition sediment volume within a simple deterministic framework, relying on geometric and algebraic relationships to shape the morphology of the system as a function of not just sediment fluxes, but changes in other external forcing (e.g. changing accommodation due to SLR). A similar type of modeling has been accomplished by McNamara and Werner (2008a/b) who constructed a geometrically simplified barrier model with partitioned sediment distribution driven by beach replenishment tied to human development."

[[P8–9 – I like the narrative of Section 3.3 – but I think it belongs in the Results as 4.1, where it would nicely set up the subsequent sections that discuss trade-offs between variables.]]

+ We've renumbered this section and made some minor adjustments to wording to integrate as the first section of the results.

[[P14, P15 – Glad to see the nod to alongshore sediment transport and vegetation feedbacks. Plenty of scope for further work – and the right acknowledgement here of what's important but just out of scope.]]

+ Thanks! We definitely tried to make sure the scope of our work is well understood. There is a lot of parallel research going on that could make for interesting collaborations and model integration down the road.

[[P12L370 – Does there need to be so much text chasing the Vousdoukas et al. (2020) result? (I understand the rhetorical move to make the underlying point about nonlinear versus linear response to exogenous forcing.) Perhaps the second paragraph of that point – P13L387 – is what pushes it slightly out of balance. The idea of asking what it take for this model to return those rates of retreat is interesting, but it reads as a kind of excursion – all the more because it begins the Discussion. Rather than cut it completely, it could just be condensed.]]

+ We agree that some of paragraph 13 is a bit excessive. To streamline it, we remove

most of the first part of this paragraph relating directly to Vousdoukas:

"Additional factors that may buffer the potential loss of natural beaches include preexisting dune volume and island width. Wide barriers, in particular, can provide space for subaerial accumulation and a glut of sediment to directly counter erosion caused by sand deficits and increasing SLR. This is exemplified by formerly and presently wide barrier islands such as Cedar and Parramore islands in Virginia–both of which were historically around four times wider than the 400 m wide barrier initialized in our model investigation. Despite experiencing an acceleration in relative SLR of 3 to 4 mm yr-1 over the last century (Boon and Mitchell, 2015), these islands have recently or historically sustained kilometer-scale landward shoreline migration over decadal to centennial timescales (McBride et al., 2015; Deaton et al., 2017; Shawler et al., 2019). Similar longer-term and sustained narrowing of previously wide barriers has also been inferred at the Bogue Banks, North Carolina, a system of formerly progradational islands that began to undergo net shoreline erosion approximately 1 kya (Timmons et al., 2010). The combination of our modeling results and observations from natural systems therefore suggest that net sand surpluses over geological to historical timescales that serve to enhance system volume storage may render barriers more resistant to periods of sediment deficit or accelerated SLR, particularly over the mesoscale."

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