REVIEWING: 2 – Michal Tal

This paper puts forward the use of a hydrodynamic model as a robust tool for reproducing flow depths and velocities from physical experiments conducted in the laboratory in complement to the range of other measurement methods typically used (laser scans, photogrammetry, dye, point gauge, PIV). The authors compare and analyze results of a hydrodynamic model (Nays2D) with measurements conducted in two physical experiments (evolution of meandering and tidal influence on estuaries).

As a researcher with experience conducting physical experiments and more recently using hydrodynamic and morphodynamic models in field-based studies, I am familiar with the challenges, advantages, and limitations of these different approaches, and I proceeded to read this article with a keen interest in learning about the advantages offered by combining these approaches.
Thank you!

I have several general suggestions for how I think this paper can be improved to be more in line with the main goal of this paper which is to demonstrate the advantages of using numerical models as a complementary tool in experimental/physical studies.

2.1) To begin, I think the novelty of this work is a bit overstated and should be better framed within the context of other existing studies. Furthermore, the claim that there is a lack of studies combining experiments and models needs to be nuanced in order to provide more context about the novelty of this study. Classic hydraulic engineering studies based on physical models of fixed beds in combination with hydraulic numerical models have been used for decades and are not discussed. Meanwhile numerical morphodynamic models have been increasingly used in combination with physical models. Below is a very small sample of existing studies combining numerical models and physical experiments. I think that these or similar studies should be presented in the introduction and how this study clearly differs from / complements / builds on these studies discussed.
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We agree with the reviewer that the manuscript would benefit from a clearer description of the kinds of studies that combine experiments and numerical models. We will rewrite part of the introduction to make clear how our study differs / complements / builds on other studies. Please find below a brief explanation how our approach differs from the studies presented by the reviewer. This is followed by the proposed text changes in the introduction section.

Firstly, our approach differs from experiments with flow depth of >10 cm, where topographic constraints make calculations of shallow water equations simpler, and the larger water depth allows the use of advanced measurement equipment.

Secondly, our general approach differs. In the engineering approach, comparison of the modelled and measured morphodynamics tells us mainly about the reproducibility of the experiment morphology by the model, rather than the model complementing the measured DEM with water depth and flow velocity data.

Proposed text (changes underlined): … *The focus of this study is on landscape scale experiments that simulate morphodynamics with shallow water depths of at maximum a few centimetres, i.e. in or just above the viscous sublayer. This kind of scale experiments differs from classical hydraulic flume studies* *(e.g. Struiksma et al., 1985; Neary et al., 1999) and larger scaled experiments (e.g. Zanichelli et al., 2004; Siviglia et al., 2013) with water depths >10 cm in which flow data can be more easily measured with lasers and submerged flow meters (e.g. ADCP). In contrast, data collection in landscape experiments is often difficult, infrequent and hindered by various problems (Fig. 1).*

Typical data collection in landscape scale experiments targets the following three elements: (1) the morphological development from overhead imagery and digital elevation models (DEMs) from laser scanning or stereo photography on a dry bed (e.g. Ashworth et al., 2004; Hoyal & Sheets, 2009; Leduc et al., 2019); (2) water depth estimated from dye and light attenuation, possibly combined with absolute water level point measurements (e.g. Peakall et al., 2007; Tal & Paola, 2007; 2010), and; (3) flow velocity from particle imaging velocimetry on the water surface from floating particles or dye injections (e.g. Tambroni et al., 2005, Braudrick et al., 2009). Due to the shallow water depths in landscape experiments, it is technically difficult to conduct flow measurements by submerged instruments without disturbance of the sediment transport and with the same spatial resolution as of the bathymetry. To overcome the drawbacks of data collection and post-processing, there has so far been one research team (Tesser et al., 2007, Stefanon et al., 2010; 2012) that modelled water depth and flow velocity over DEMs of tidal basin scale experiments. However, the modelled data acquired by this novel method was not extensively validated against measured data and the model only applies for uniform flow conditions (Marani, 2003).

Here we explore the possibility of extending the numerical flow model application by Tesser et al. (2007) and Stefanon et al. (2010; 2012) for unsteady, nonuniform flows in landscape scale experiments. We aim to complement the measured morphological data with continuous, spatiotemporally dense numerical data of water depth, flow velocity and bed shear stress. On the one hand, this is a similar practice to modelling flow over the measured morphology of real rivers and estuaries (e.g. Berends et al., 2019), whilst here the shallow water equations need to be solved. On the other hand, this practice differs from remodelling the morphological development of a scale experiment (e.g. Struiksma et al., 1985), which are subject to all the combined errors of sediment transport predictors (Baar et al., 2019). The extended integration of experimental data and a numerical flow would not only expand the possibilities for data analyses of a series of experiment bed scans, but would also open up fast methods of testing alternative experimental settings for either an experimental or idealised morphology.

Struiksma, N., Olesen, K. W., Flokstra, C., & De Vriend, H. J. (1985). Bed deformation in curved alluvial channels. Journal of Hydraulic Research, 23(1), 57-79.
Neary, V. S., Sotiropoulos, F., & Odgaard, A. J. (1999). Three-dimensional numerical model of lateral-intake inflows. Journal of Hydraulic Engineering, 125(2), 126-140.
Zanichelli, G., Caroni, E., & Fiorotto, V. (2004). River bifurcation analysis by physical and numerical modeling. Journal of Hydraulic Engineering, 130(3), 237-242.
Siviglia, A., Stecca, G., Vanzo, D., Zolezzi, G., Toro, E. F., & Tubino, M. (2013). Numerical modelling of two-dimensional morphodynamics with applications to river bars and bifurcations. Advances in Water Resources, 52, 243-260.
Baar, A. W., Albernaz, M. B., van Dijk, W. M., & Kleinhans, M. G. (2019). Critical dependence of morphodynamic models of fluvial and tidal systems on empirical downslope sediment transport. Nature communications, 10(1), 1-12.

2.2) The work presented in this paper combines numerical models with physical models consisting of mobile beds that can evolve morphodynamically. I think this point should be presented and discussed much more explicitly, as it raises the question of the relevance and what insights are gained by using a hydraulic model with a fixed bed to compare with experiments in which the bed is continuously evolving. How often do scans of the experiment need to be conducted and the model updated in order to be able to compare the evolution? Why not compare the experiments to morphodynamic models?
We thank the reviewer for bringing this up. Morphological changes are slow relative to hydrodynamic changes so the flow model on the static DEM represents conditions over many tidal cycles. This is also

seen in numerical morphodynamic modelling where the flow time step is usually at least an order of magnitude smaller than the morphological change time step. The idea of our model is to apply it in the future to a series of bed scans, but not to try and predict the morphological change, which would be subject to all the combined errors of sediment transport predictors. Using a fixed bed is therefore no issue here.

-> We will clarify this in the introduction (see proposed text under comment 2.1) and in the discussion section of our manuscript.

2.3) Beyond the direct comparison of the numerical and experimental data, which are interesting, I do not think the paper goes far enough in analyzing and “selling” the added benefits of using a hydrodynamic model and evaluating the cost-benefits in terms of the time investment and insights gained. In other words, I came away from the paper without a clear conviction that combining these approaches is worth the investment and that the gains from taking a combined approach surpass the results of using only one approach (numerical modelling or physical experiments). I think the authors can go further in their analyses and discussion to make a stronger case for what this paper argues for: that experimental data-model integration allows for experiments to be conducted in a manner requiring fewer measurements and less post-processing in a simple, affordable and labour-inexpensive manner. I think that part of the problem stems from the fact that the paper relies heavily on the details of physical experiments conducted and published previously. While I have no problem with the author’s applying a numerical model to previously vetted and published experiments, the details of the experiments and the measurements presented here are insufficient to evaluate the steps and investment in acquiring them. The insights gained by applying a numerical study to experimental data that already exists from a previous study is not necessarily equivalent to the cost/benefits of designing new (future) experiments that integrate both methods at once. While the authors make a good argument for how these approaches and data sets complement / complete each other, they do not go far enough in demonstrating that the combined approach yields results that are greater than the sum of its parts (i.e., results of two separate studies/approaches). Given that all studies are limited in time and resources this point seems very relevant when designing a study. I encourage the authors to be more creative in analyzing and presenting their results in order to make this argument more compelling by, for example, specifying the new insights that were gained into how the system behaves/evolves by using a combined approach versus just one or another, and/or how using the numerical model cut down the need for measurements.

We thank the reviewer for the feedback and we will clarify and emphasise in the discussion section (1) how the numerical model complements the experiment, and; (2) how the model may be used for experimental setup design. Please see below our comments on (1) and (2).

(1) Since the numerical model requires a static bathymetry of an experiment DEM, the numerical study is integrated with the experiment study and therefore cannot be seen as a completely separate study but more as a complementation to the experiment. The model allows for the calculation of hydrodynamics of full spatial coverage that adhere to mass continuity, unlike in-situ measurements of water depth and flow velocity. So, parameters such as tidal prism and tidal excursion length may be computed much more accurately with modelled data (see Fig. 10 in first version manuscript that shows how wrong this goes if based on in-situ measurements). Additionally, the model produces maps of bed shear stress that give insight in sediment transport fields.

    Instead of estimations, these parameters and others that may be derived from the modelled hydrodynamics can now be quickly calculated. And if the model is applied to a series of DEMs, one may come to a more quantitative and more complete interpretation the development of the hydrodynamics.

    -> We will emphasise how new parameters, such as tidal prism, can be calculated from the modelled data.

-> We will clarify to the reader that the experimental data-model integration may be used to a series of DEMs to track the development of its hydrodynamics over time (see also our comment to comment 2.1 by Reviewer 2).

(2) The design of a flume experiment normally requires a number of tests that need to be done in series before the 'actual' experiment is run. Parameters such as input discharge, downstream water level and downstream flume slope may need testing to get the desired setup.

The benefit of testing these parameters in the numerical model is twofold. Firstly, the initial and boundary conditions can be tested *in parallel*. Based on the resulting flow fields and bed shear stress maps at the start of the modelled setups (sediment transport is not included), preferred flume settings may be readily derived and applied to the physical flume. Therefore, most probably fewer tests are required in the physical flume, which greatly reduces the total lab time. This is especially the case for experiments with different sediment mixtures and with vegetation, for which the flume needs to be emptied and cleaned after every run. This requires the parameterisation of vegetation in the input roughness maps.

Secondly, water depth and flow velocity measurements that are commonly done near the time stamps the DEMs, are no longer required, apart from a few measurements for model validation. This is, because the hydrodynamic data are generated by the model. Therefore, less time is needed for acquiring and post-processing measured data, which cuts down time spent in the lab and/or speeds up the lab work.

-> We will clarify in the manuscript how flume design settings can be tested by the numerical model and how this reduces the iteration to the desired experiment setup and settings.

2.4) Finally, I recommend that the order of sections 2.2. and 2.1 either be reversed or that section 2.1. be moved to the methods so that the flow of the paper moves from the introduction and overview of techniques to the methods and specific setup of the experiments used in this study.

We will change the order of sections 2.1 and 2.2 and will make small text changes to maintain the flow of text.