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A satellite-image-based method to overcome data scarcity for river morphodynamic modelling

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Introduction

Data scarcity poses a big challenge to morphodynamic modelling of large fast-changing rivers. Modellers need to rely on field measurements to construct their models, but dynamic changes may limit the validity of survey data to a few months only. Moreover, even field surveys using echosounders or acoustic Doppler velocity profilers add uncertainties to the system (Czuba et. al., 2011). That leads to our main question: What if field measurements are missing or incomplete? Then, modellers need to develop some engineering analysis to overcome data limitations and create alternative paths. In this study, we present a method to generate river bed levels, and sediment erosion-and-deposition maps from satellite images of a large braided-anabranched river. The method provides a solid data production way to compensate for frequent surveys. The resulting data can be used as a sole source of bed topography input, but also as an intelligent interpolator in case of scarce measurement data, or as a basis for validation of field survey data. We applied the method to the morphological modelling of the Jamuna River in Bangladesh.

Case Study

The Jamuna River in Bangladesh is one of the most dynamic and braided rivers in the world. Bank erosion causes portions of the bank-line to retreat hundreds of metres annually; affecting millions of people (Mosselman, 2006). We carried out morphological modelling of the Jamuna River to develop suitable interventions to increase flood safety, preserve the stability of the banks, and to improve flow conditions into the Old Brahmaputra offtake (Fig. 1). We developed the model in Delft3D by using a 2D depth-averaged model with a structured mesh.

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Despite the availability of hydrological and sediment grain size data in the project region, the lack of bathymetric survey data was found to be a critical hurdle for the model setup and validation. Therefore, additional engineering approaches were sought to overcome this situation.

Figure 1: Map of the project region

Method

We use two satellite images; in this case from the years 2017 and 2018 (Fig. 2). First, we mark the positions of the bars in each image (Fig. 3a). The comparison with the previous year's image reveals the movement of bars in one year. It also indicates the locations where sediment eroded or deposited within that year; if the bars were captured dry when the image was taken (Fig. 3b). A combination of ArcGIS, Open Earth Tools, and the QuickIn tool of Delft3D software were used to process the data, and project it on the model grid.

Results

The result of the applied method for the 2017-2018 period is given in Fig. 4. The erosion and deposition locations can be observed from the resulting map. The observed pattern can be used to calibrate and validate the model in the absence of survey data. In this study, we used these maps in the model calibration step, viz. in identifying the suitable sediment transport formula and morphological model parameter settings. Once the model retrodicted the erosion and deposition patterns observed on the 2017-2018 map, we could validate the model by using another year, for instance, the 2018-2020 erosion-and-deposition map.

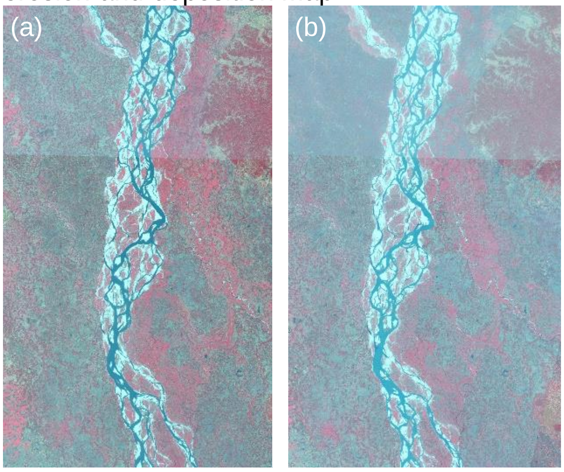

Figure 2: Satellite images of the Jamuna river (a) at 2017 and (b) at 2018

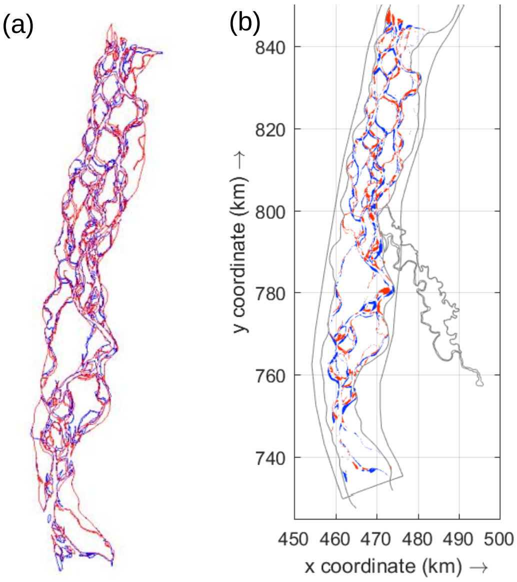

Figure 3: (a) Bar locations in 2017 (blue) and in 2018 (red) (b) interpolated sediment erosion-and-deposition map (erosion locations: blue, deposition locations: red)

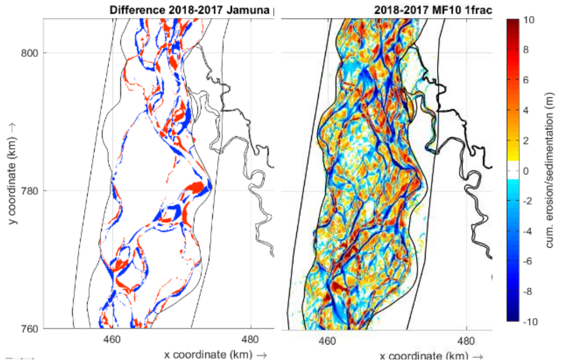

Figure 4: Comparison of model results with the validation data

Conclusion and Discussion

A modeller needs to cope with several uncertainties in a project. Maybe the most important tackle comes when the region lacks reliable data. Especially in river morphology modelling projects, where one generally cannot see the practical results in a near future, validation methods need to be reliable. The method presented here can be used to overcome data scarcity in terms of bathymetric surveys. It can be used safely to generate sediment erosion and deposition maps for the major bars, using only the satellite images. Although these maps do not provide an idea about the magnitude of erosion or deposition in full, they indicate the locations of the deposition and erosion, which can be used for calibration and validation of the model. Moreover, from the satellite images of preceding years several maps can be obtained to have more insight into the system dynamics. Nonetheless, the application of the method is limited to the parts of the river, which are dry during low flows, such that they are visible on the images. Perennially submerged locations cannot be distinguished using the satellite images.

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