Modeling Morphodynamics in the Vietnamese Mekong Delta Using Telemac Mascaret System

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INTRODUCTION

Morphodynamics is the base for river delta formation and supports ecosystems in the coastal wetland and estuaries. However, the morphology in the Vietnamese Mekong Delta (VMD) has been significantly degraded. Morphological degradation is caused by sediment reductions in the Mekong River which have been significantly reduced by dams, climate change, land use change, and sand mining. Therefore, understanding morphodynamics and causes and consequences plays an important role to have appropriate measures.

The objective of this study is to examine variations of morphodynamics in fluvial-dominated, tide-affected rivers in the VMD. This objective is achieved using data observed from two field survey campaigns and a 2D coupled hydrodynamics, sediment transport, and riverbed evolution model.

MATERIALS AND METHODS

We conducted two boat-based field surveys from August to September 2017 (flood season) and from March to April 2018 (dry season) along approximately 250 km of the Tien and Hau rivers and the Vam Nao channel (Fig. 1). The first field survey was to measure the river bathymetry, flow velocity, discharge, and suspended sediment concentration using a ADCP and an Infinity-ATU75W2-USB turbidity meter. These devices were mounted 0.3 m below the water surface. The interval of the turbidity meter measurements was two minutes. In total, 82 cross-sections were measured. The ADCP raw data were checked for noise filters due to boat movement and then were processed using the WinRiver II software. In the second field survey, we measured two-dimensional velocity and turbidity longitudinally and vertically using the Infinity velocity and turbidity meters. We measured 3–6 vertical profiles at each cross-section depending on the river width. The positions of the measured profiles were recorded by a handheld Garmin GPS.

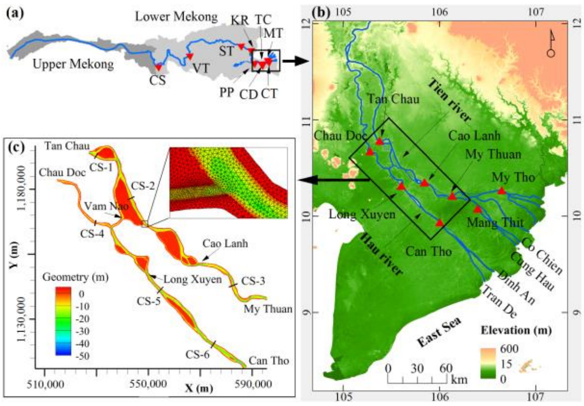

Fig. 1 (a) The Mekong River basin with the main hydrological stations. (b) the VMD with the main rivers and hydrological stations. (c) the mesh with geometric data of the coupled Telemac-2D and Sisyphe model, including boundaries and locations for model calibration and validation. CS: Chiang Saen; VT: Vientiane; ST: Stung Treng; KR: Kratie; PP: Phnom Penh; TC: Tan Chau; CD: Chau Doc; MT: My Thuan; CT: Can Tho.

We simulate the morphodynamics in the upper Tien and Hau rivers, including the Vam Nao diversion channel, from Tan Chau/Chau Doc to My Thuan/Can Tho (Fig. 1c). The simulated domain includes a

200–300 m wide floodplain extending from both banks of the rivers and all islands. The unstructured triangle mesh is generated by the finite element method. The mesh has a grid spacing of 80 m in the main rivers, islands, and floodplains, and 30–40 m in the narrow channels. In total, the domain consists of 106,413 nodes and 206,455 elements.

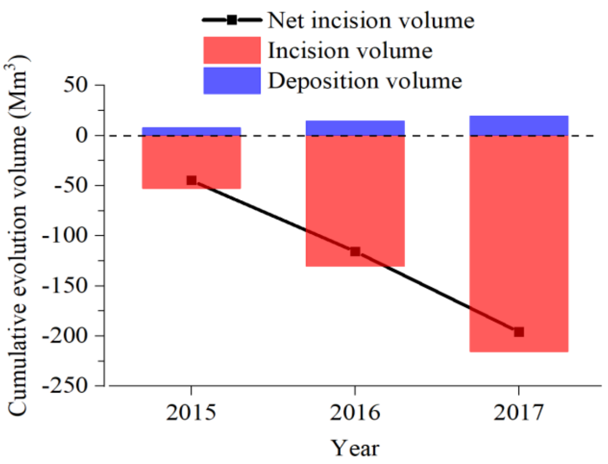

Fig. 2 Cumulatively simulated riverbed erosion and deposition volume of the entire study domain. Riverbed experiences an annual net erosion.

RESULTS AND DISCUSSIONS

The results show that the riverbed of the Vam Nao channel is highly incised compared to the Tien and Hau rivers. The simulated mean net riverbed incision depth of the Vam Nao, Tien, and Hau rivers are -2.38, -1.12, and -0.68 m, respectively, from 2014 to 2017. These values are corresponding to the incision rate of 0.79, 0.37, and 0.23 m/yr, respectively. Riverbed incision mainly occurs in the outer bank of the meandering and in the middle of the channel, where the flow velocity is high. On the other hand, the deposition mostly appears in the inner bank of the meandering, at the tail of the islands, and in secondary channels, where the velocity is low. The maximum incision depth reaches -5.5 m, while the maximum deposition depth is less than 1 m. In the Tien River, the most riverbed incision sections are from Tan Chau to Vam Nao and from Cao Lanh to My Thuan. In the Hau River, the riverbed is more incised from Chau Doc to Long Xuyen and the area around Can Tho. Especially, the model detects several scour holes. At these scour holes, the incision rate is largest in 2017 when high flood flow combines with low SSC.

Simulated results show that the mean cumulatively incision volume of the entire study domain from 2014 to 2017 is -65.3 Mm^3/yr (Fig. 2), which is 22.4% underestimated compared to the measured volume of -84.1 Mm^3/yr in the same period. The model underestimates the incision volume and depth because we did not include sand mining effect in our model. The simulated riverbed incision in 2015 is the least among the simulated timescales because of its low flood flow. Otherwise, riverbed incision in 2017 is the most significant (85.2 Mm^3 incision compared to only 5.1 Mm^3 deposition) because of its high flood flow and relatively low SSC. Additionally, the total net simulated incision volume of the entire study domain is -196 Mm^3 from 2014-2017.