The role of geological mouth islands on the morphodynamics of back-barrier tidal basins

Yizhang Wei[1], Yining Chen[2], Jufei Qiu[3], Zeng Zhou[1,4], Peng Yao[1], Qin Jiang[4], Zheng Gong[1], Giovanni Coco[5,1], Ian Townend[1,6] and Changkuan Zhang[1]

5   [1]State Key Laboratory of Hydrology-Water Resources and Hydraulic Engineering, Hohai University, Nanjing 210098, China

[2]Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou 310012, China

[3]East Sea Marine Environmental Investigating and Surveying Centre, State Oceanic Administration of China, Shanghai 310115, China

10   [4]Jiangsu Key Laboratory of Coast Ocean Resources Development and Environment Security, Hohai University, Nanjing 210098, China

[5] Faculty of Science, University of Auckland, Private Bag 92019, Auckland, New Zealand

[6] Ocean and Earth Sciences, University of Southampton, Southampton SO17 1BJ, UK

Correspondence to: Dr Zeng Zhou (zeng.zhou@hhu.edu.cn)

15   **Abstract.** Researchers have extensively investigated the back-barrier islands morphodynamics using numerical methods. ~~The morphodyamics of back-barrier tidal basins have been extensively investigated by numerical modelling, but~~ However, the influence of rocky mouth islands, ~~(~~which may be submerged ~~under future~~by sea--level rise~~)~~ has been rarely explored. Using the Dongshan Bay in southern China as a reference ~~site~~, this study~~we~~ numerically explore~~s the effects of geological constraints (i.e., islands) on the long-term morphodynamics of back-barrier basins~~ the long-term morphodynamic effect of

20   geological constraints (e.g., rocky islands) for back-barrier basins. Model results indicate that the spatial configuration of mouth islands can considerably affect the morphological development of tidal basins. ~~The presence of mouth islands can increase both the current velocity and the residual current by narrowing the inlet cross-sectional area~~ The presence of mouth islands narrows the inlet cross-section area, increasing flow velocity and residual current, resulting in more sediment suspension and transport. Meanwhile, ~~erosion tends to occur in the tidal basin and sedimentation occurs in the ebb delta

25   area, and the erosion (or sedimentation) volume is larger with the presence of more mouth islands~~ mouth islands tend to increase erosion in the tidal basin and sedimentation in the ebb-delta area. ~~Further~~ Furthermore, the spatial distribution of mouth islands can also ~~considerably~~ affect tidal basin evolution: the basin-side mouth islands tend to cause more basin erosion with higher tidal currents and more sediment transport. ~~, while~~In contrast, the delta-side ones may ~~play a hindering role resulting in sediment deposition~~increase relative sediment deposition in the basin. Finally, larger tidal prisms are

30   observed ~~in basins~~ with more mouth islands and ~~those~~ with basin-side mouth islands, suggesting that the number and location of ~~mouth~~ islands can ~~also~~ affect the relationship between the tidal prism and inlet cross-sectional area. This modelling study furthers the understanding of barrier basin morphodynamics affected by rocky mouth islands and informs management strategies under a changing environment.

1 Introduction

35   During the post--glacial sea-level rise, ~~a large number of~~many low-lying basins and valleys were submerged, forming various embayed coasts and mouth islands, ~~back-barrier systems~~ accounting for 10-15% of the world'~~'~~s coastline (De Swart and Zimmerman, 2009; Fitzgerald and Miner, 2013). Back-barrier systems are easily found around the world, such as the

Wadden Sea (Wang et al., 2012), the Venice Lagoon (Feola et al., 2005), and the Massachusetts Bay (Rosen and Leach, 1987). Knowledge ~~of~~on the morphodynamic processes and the evolution of barrier systems is of great significance for better

40   protection and management of this type of coastal zone~~s~~.

Morphodynamics of back-barrier systems ~~are~~ is affected by the interaction of various factors, including hydrodynamic processes (e.g., tides and waves), biological activities (e.g., presence of mangroves and/or salt marshes), climate change (e.g., global warming and sea-~~-~~level rise) and anthropogenic activities (e.g., land reclamation and artificial construction)~~, such as land reclamation and artificial construction~~ (Murray et al., 2008). These processes result in an ever-changing

45   morphology of tidal channels, tidal flats and flood/ebb deltas (Wang et al., 2012). Coastal morphodynamics ~~are~~ is ~~typically~~ characterized by the two-way feedback between hydrodynamics and topography. Hydrodynamics can shape the geomorphic characteristics of coastal landforms through sediment transport, while the ~~changed~~ landforms can also feedback to hydrodynamics, forming a morphodynamic loop ~~which~~ that eventually drives the system to some sort of dynamic equilibrium state (Coco et al., 2013; Zhou et al., 2017).

50   In the last decades, many studies have been carried out on the morphodynamics of tidal barrier systems. ~~Otvos (1981) analysed the rock drilling data of the Mississippi barrier island chain, and reported that sand bar drifting down from the core area of the island may be necessary for the early stage of barrier island survival.~~ Using laboratory experiments, Stefanon et al. (2010) showed that the experimental tidal channels and tidal flats generated were comparable ~~to that in~~with natural back-barrier systems, and sea-~~-~~level variations can leave morphological signatures ~~in these systems~~ in terms of

55   channel network incision and retreat. Numerical modelling is another effective ~~and virtual~~ tool compared with laboratory experiments, (Zhou et al., 2014b). ~~compared the laboratory experiment and numerical simulation of the morphological evolution in barrier basins, and t~~Their results suggested that the initial bathymetry and geometric characteristics of barrier basins ~~have a great influence on~~greatly influence the development of tidal channels. Marciano (2005) numerically simulated the branching channel patterns observed in the Wadden Sea basins, ~~and model~~results indicated that tidal channel

60   patterns were governed by the morphological characteristics (e.g., the bottom slope and the water depth) and the Shields parameters (e.g., flow strength and sediment properties). Using a similar ~~type of~~ model type, Dastgheib et al. (2008) explored channel network formation in a multi-inlet tidal system, and ~~model~~the results qualitatively followed the empirical equilibrium equations, indicating that initial bathymetry and the ~~effect of~~ adjacent basins can ~~significantly~~ affect the evolution of barrier basins. Van Maanen et al. (2013a) developed a ~~new~~ 2D morphodynamic model and explored the effects

65   of both tidal range and initial bathymetry on producing different ~~morphological~~ patterns. Several studies ~~also~~ highlighted the importance of wave action on the morphodynamics of back-barrier systems. For instance, Herrling and Winter (2014) simulated the sediment dynamics in the mixed energy tidal inlet systems and demonstrated that the pathway and sediment distribution are ~~much~~ different under fair weather and storm conditions, indicating that waves significantly influence~~have a great influence on~~ sediment transport pattern and morphological evolution of the back-barrier systems (see also Nahon et

70   al. (2012)). ~~With respect to~~Concerning the effect of sea-~~-~~level rise on back-barrier basins, Dissanayake et al. (2012) and Van Maanen et al. (2013b) designed schematized models to explore ~~their~~ long-term evolution, and ~~model~~results suggested that sea-~~-~~level rise can ~~lead to the~~ change ~~of~~the sediment transport from seaward to landward and the intertidal area can reduce considerably. For river-influenced barrier systems, Zhou et al. (2014a) applied a~~n idealized~~ barrier basin model to simulate the effects of different landscape conditions (e.g., basin shape and river inflow location) ~~on barrier basins~~,

75   suggesting that Tthe ~~presence of a~~river presence ~~was fundamental for the~~influences sediment budget and the morphological evolution.

The above modelling studies have significantly advanced our understanding of the influence~~d of various~~d factors on back-barrier tidal basins, but few studies ~~directly~~ consider the role of ~~isolated~~ rocky islands which are very common landforms at the inlet mouth. It remains unclear how back-barrier basins evolve with and without mouth islands. For example, Figure 1 shows two ~~example~~ sets of neighbouring barrier basins ~~around the world~~: the Massachusetts Bay and the Plymouth Bay along the eastern coast of the USA, and the Zhaoan Bay and the Jiuzhen Bay along the southern coast of China. All of them are embayed and drowned basins, probably formed by topographic drowning due to sea-level rise in the post-glacial period (Fitzgerald, 1993; Jagoutz and Behn, 2013). Furthermore, the tidal basins in these examples have relatively close distances (about 30-40km) with similar geomorphic shapes and tidal currents (Jiang and Meng, 2008).~~The tidal basins in these two sets of examples have relatively close spatial distance (about 30-40km) with similar geomorphic shapes~~ but with ~~they have developed quite~~ different morphological patterns due to the ~~different~~ various geological constraints (e.g., rocky islands) at the inlet mouth. As ~~showed~~ shown in Figure 1, shallow areas with dendritic channel networks are present~~have been developed~~ in ~~the~~ Plymouth Bay and ~~the~~ Jiuzhen Bay. In contrast, ~~few~~ several islands are observed in ~~the basins of~~ Massachusetts Bay and ~~the~~ Zhaoan Bay~~,~~ where tidal flats and tidal channels ~~only~~ developed very limitedly. Although all of these four barrier systems are semi-closed tidal basins, the existence of ~~mouth~~ rocky islands may be one of the main contributors to their different morphologies. ~~In the past few decades, a large number of studies have been carried out on the formation and classification of islands in geological research, which generally believed that islands can be classified into three types: continental islands, oceanic islands (including volcanic islands and coral islands) and alluvial islands (Liu and Liu, 2008; Huang and Zhang, 2006). The mouth islands in Figure 1 are continental islands, which are probably formed by the migration of continental plates and sea level rise in post-glacial period (Fitzgerald, 1993; Jagoutz and Behn, 2013).~~

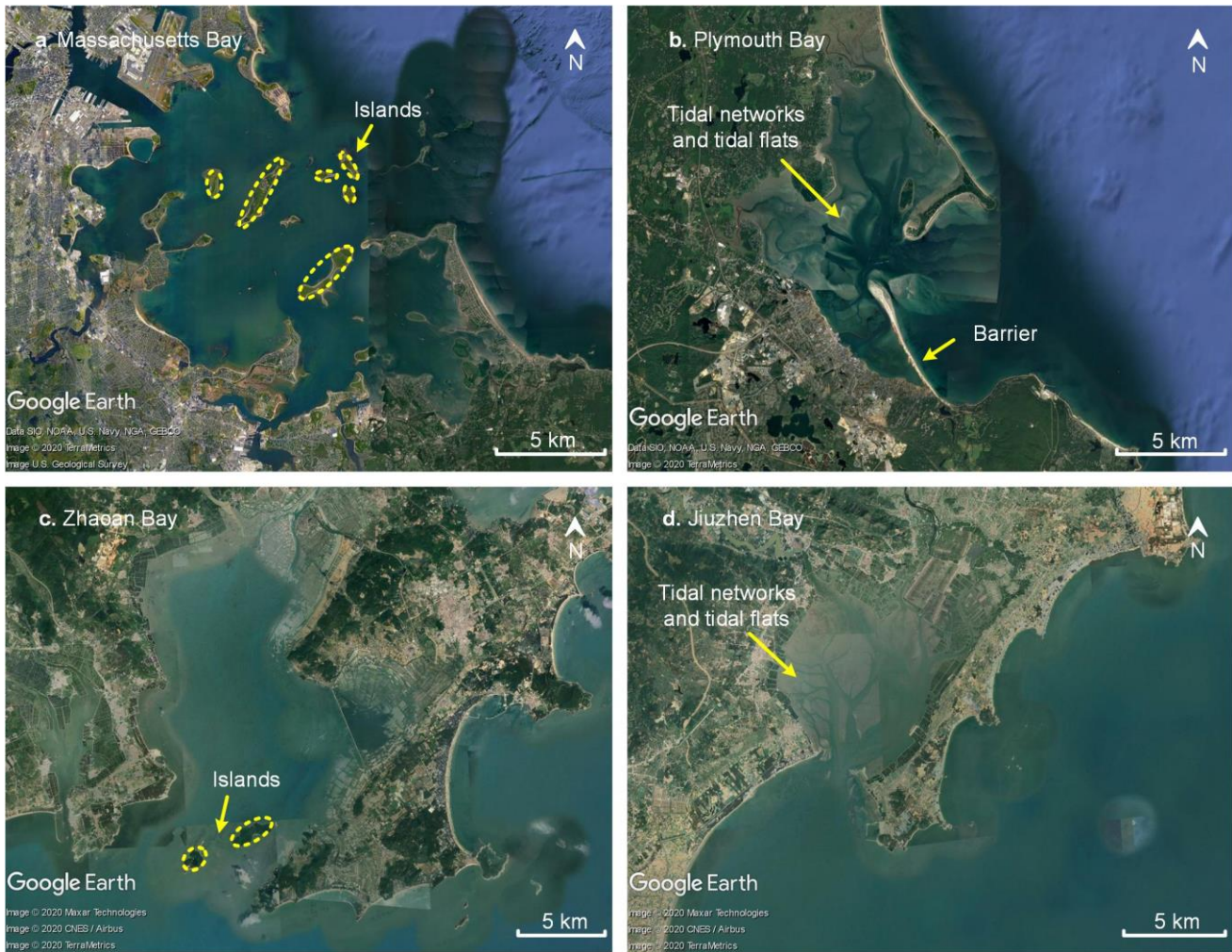



Figure 1: Aerial view of two sets of tidal barrier basins (about 30-40 km from each other) along the eastern coast of the USA and the southern coast of China. (a) Massachusetts Bay (42° 18' 36" N, 70° 58' 12" W); (b) Plymouth Bay (42° 00' 18" N, 70° 39' 18" W); (c) Zhaoan Bay (23° 40' 12" N, 117° 18' 36" E); (d) Jiuzhen Bay (23° 59' 6" N, 117° 42' 36" E). Image © Google Earth 2020, TerraMetrics.

This study aims to gain insight into the presence of ~~geological~~ rocky mouth islands that lead to the observed different morphologies ~~in back barrier tidal basins~~from the comparison. Specific research questions ~~include~~are: (1) What is the morphodynamic behaviour of tidal basins with a varying number of mouth islands? (2) ~~What is the role of different island locations on basin morphological evolution~~ How does island location impact the basin's morphological evolution? To answer these questions, an idealized morphodynamic model is established, with the Dongshan Bay, China as a reference basin size~~, to investigate the impacts of mouth islands on the evolution of a semi-enclosed basin~~. The outcome of this study can assist coastal managers and policymakers to ~~make more sustainable~~improve management strategies for ~~the~~ reclamation and artificial -island construction.

2 Methodology

2.1 Model description

Based on the Delft3D open-source software, a 2D morphodynamic model is set up, which solves the coupled equations governing tidal flow, sediment transport, and bed level updating (Lesser et al., 2004; Marciano, 2005; Van Der Wegen and

Roelvink, 2008). The alternative direction implicit ~~(ADI)~~ method is used to solve the shallow water equations. ~~for a detailed description of flow field, which~~ The result describes a detailed flow field that is used in the calculation of sediment transport. Then the morphological change caused by the sediment transport is also fed back to the hydrodynamics at each time step. In this study, ~~a~~ the widely adopted Engelund and Hansen formulation for sediment transport ~~formula~~ is considered ~~to calculate sediment transport. The formula of~~ (Engelund and Hansen, 1967) ~~as follows~~:

$$S = \frac{0.05U^5}{g^{1/2}C^3\Delta^2 D_{50}} \tag{1}$$

where~~,~~ S is the total sediment transport (m^2/s), U is the depth-averaged flow velocity (m/s), g is the gravity constant (m/s^2), C is the Chézy friction coefficient (m$^{1/2}$ s^{-1}), Δ is the relative density, $\Delta = (\rho_s - \rho_w)/\rho_w$, and D_{50} is the median grain size ~~of sediment~~ (m).

In order to speed up morphodynamic calculations, a "morphological factor" (MF) is applied ~~to~~ following Roelvink (2006). In this approach, the sediment erosion and deposition fluxes ~~are~~ scale~~d~~ up by a constant factor (MF) at each hydrodynamic time step to mimic morphological changes over a longer duration. This approach has been extensively used ~~in previous studies~~, including schematic cases (Roelvink, 2006; Van Der Wegen and Roelvink, 2008) and real-world situations (Dastgheib et al., 2008; Van Der Wegen and Roelvink, 2012). ~~It has been suggested that The~~the value of MF should be determined via sensitivity experiments (Zhou et al., 2014a; Van Der Wegen and Roelvink, 2012). ~~S~~ome sensitivity tests with varying MF values are performed ~~in order~~ to select the MF value. Specifically, it is necessary to ensure that the increased bed elevation in each time~~-~~ step is small enough relative to the water depth~~,~~ so that the hydrodynamic ~~process results~~ in the next time step ~~is~~ are not significantly different from ~~the morphological factor of application 1~~MF=1 (Ranasinghe et al., 2011). In this way, ~~on the basis of ensuring~~to ensure the calculation accuracy, ~~the MF value~~MF=50 is selected ~~as 50 to reduce the computational cost~~.

2.2 Model configurations

In this numerical experiment, an idealized model is set up with a comparable dimension as the Dongshan Bay, China, a typical barrier basin with ~~a number of~~ mouth islands near the inlet (Figure 2). The schematic model consists of a "~~"~~stomach"~~"~~ shaped basin and a semi-circular open sea area with a radius of approximately 30 km (Figure 2a). For the initial basin bathymetry, an idealized central channel is ~~set up and~~ defined as -5 m at the landward head and linearly varying to -10 m near the inlet. The bottom of the outer sea is linearly sloped with an elevation of -10 m near the inlet to -40 m at the sea boundary, mimicking a shallow continental shelf. The idealized bathymetry ~~adopted~~ in this study ~~is intended to~~intends to investigate the effect of mouth islands on the long-term morphodynamic processes and the formation of tidal channels from a flat topography. Since this study mainly focuses on the morphology inside the basin, ~~the spatial grid has smaller grid sizes~~the grid size is smaller in the basin (cell size of 100 m) and larger in the open sea area ~~in the basin and larger grid sizes~~ (cell size of 400 m) ~~in the open sea area~~.

(a) Dongshan Bay, China

(b) Schematic plot of the 2D model

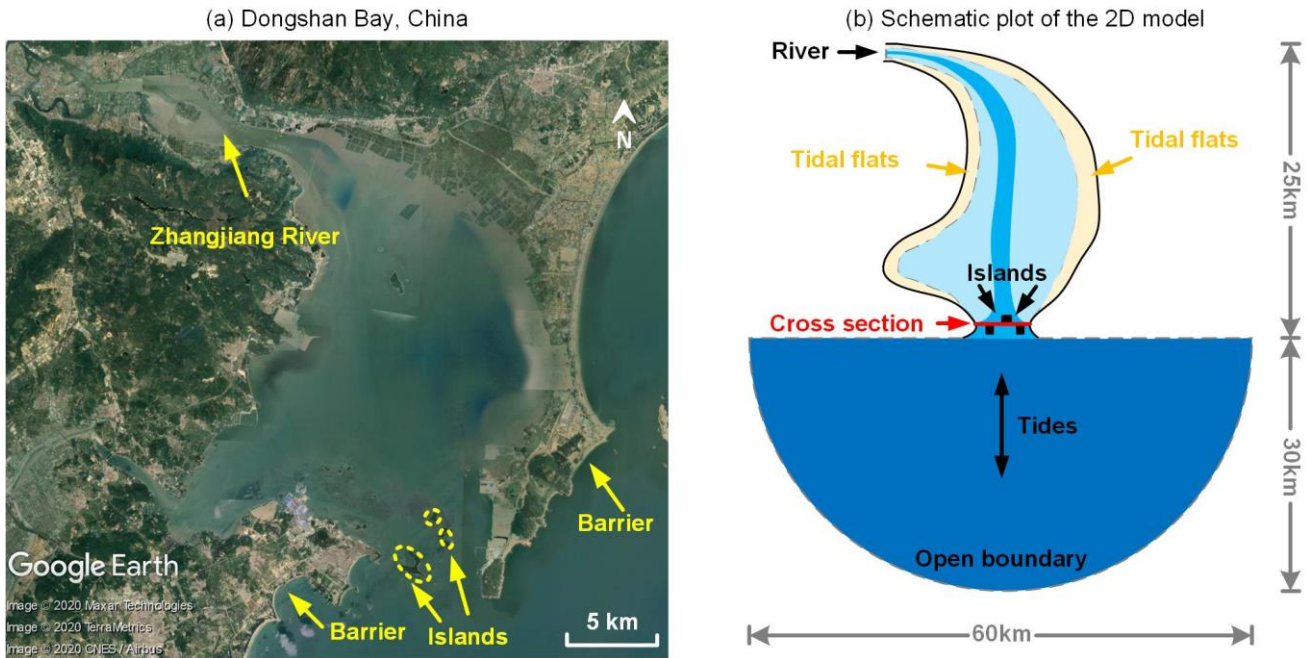



Figure 2: (a) The reference barrier basin with three mouth islands near the inlet, Dongshan Bay (23° 49' 48" N, 117° 31' 18" E; Image © Google Earth 2020, Maxar Technologies); (b) The schematized model domain used in this study.

The hydrodynamic processes considered in this model include tides and riverine inflow because the emphasis is on the inner basin morphology~~, while waves inside the basin are limited due to the sheltering of islands and hence neglected for simplicity~~. The mouth islands limit the waves inside the basin, hence are neglected. ~~The river inflow is added at the landward end of tidal basin~~ The landward end has a rived inflow with a constant discharge of 50 m³/s. A semidiurnal harmonic tide with a tidal range of 2.4 m is specified at the southern semi-circular sea boundary following Chen et al. (1993). The sediment fraction considered in this study is non-cohesive sand only, which is the most abundant component in the Dongshan Bay ~~and defined by~~with a mean grain size of 135 μm (Chen et al., 1993). ~~A sediment transport boundary condition of equilibrium sediment concentration is adopted at both the sea boundary and the river boundary~~ Sediment transport conditions at the river and sea boundaries are in equilibrium. This means the sediment input through the inflow boundaries can be immediately adapted to the local flow condition, ensuring the bed level near the model boundaries is almost unchanged. Sensitivity tests have been carried out to determine some other model parameters, such as the Cheźy friction coefficient (65 m$^{1/2}$/s^{-1}), horizontal eddy viscosity (1 m²/s), and hydrodynamic time step (60 s).

2.3 Sensitivity scenarios

Islands can potentially be submerged or even disappear~~ed~~ due to projected sea-level rise and human activities (Webb and Kench, 2010)~~.,~~ ~~T~~thus, the number and location of mouth islands can be changed accordingly. However, ~~there is still a lack of systematic understanding of~~ the effect of varying numbers and locations of mouth islands on basin morphodynamics is yet to be well understood. Two ~~scenarios~~ sets of simulations are set up to explore the~~ir~~ effects on basin morphologies. ~~and~~ The model configurations are shown in Figure 3. ~~Four cases are designed to investigate the effects of island numbers (0-3) which are hereafter indicated as ''0i'', ''1i'', ''2i'' and ''3i'' for simplicity (Figure 3a-d)~~ Cases in Figure 3a-d investigate the effect of island numbers, 0 to 3 islands, and for simplicity, they are indicated as ''0i'', ''1i'', ''2i'' and ''3i'' respectively. The ~~other three~~ cases in Figure 3e-g ~~are designed to~~ explore the role of island locations which are ~~hereafter~~ indicated as ''IL'', ''BS'' and ''DS'' ~~for simplicity (Figure 3e-g)~~respectively. ~~In all cases,~~All cases adopt the same initial bathymetry

is adopted so that model results can be compared. ~~Besides, the shape and size of the island may also be two of the important~~ ~~factors affecting the morphological evolution, which are going to be investigated in future studies. For this study, a non-~~ ~~erodible island with the shape of rectangle (1 km long and 1 km wide) is designed, which is assumed to mimic a rocky~~ ~~island near the inlet.~~Additionally, the islands in this initial study are non-erodible (rocky) and square (1 km×1 km). In the future, different sizes and shapes of islands will be investigated to determine how these parameters impact morphological outcomes.

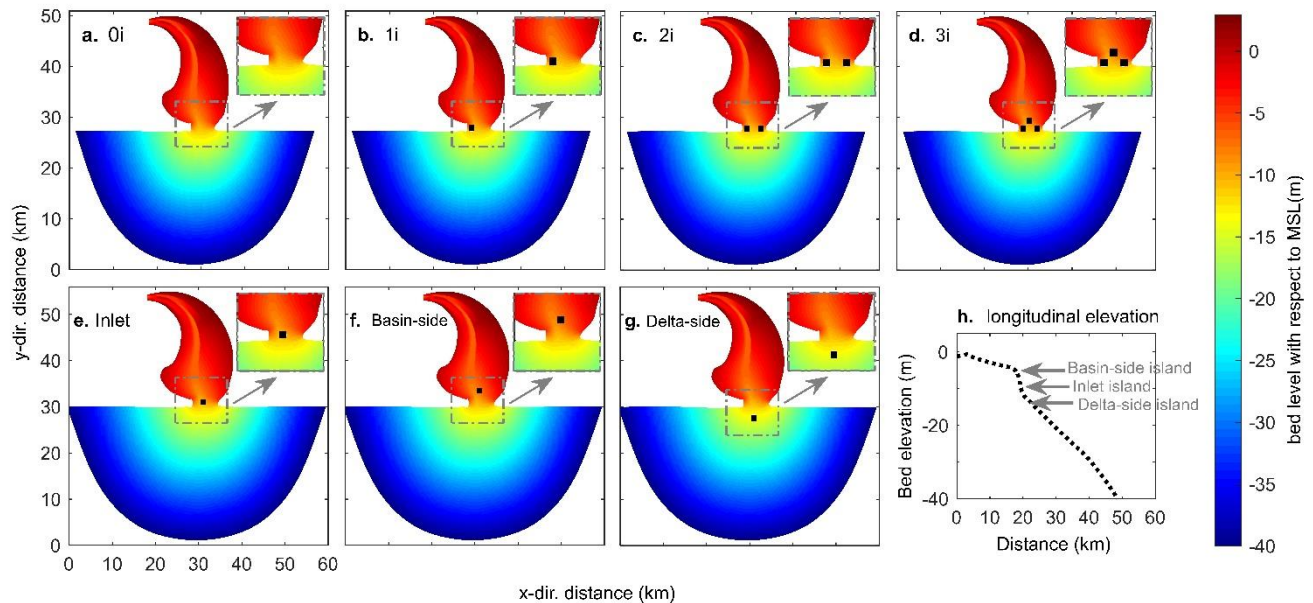



Figure 3: Initial mode domain shape and bathymetry: (a) basin without island ("0i"); (b) basin with one island ("1i"); (c) basin with two islands ("2i"); (d) basin with three islands ("3i"); (e) the mouth island is at the inlet ("IL"); (f) the mouth island is at the basin-side near the inlet ("BS"); (g) the mouth island is at the delta-side near the inlet ("DS"); (~~d~~h) longitudinal profile of the initial bed elevation and the location of mouth islands. In Figures 3a-3g, the black solid area in each plot represent the mouth islands and we zoom in part of the model domain where there are different island settings. The arrows indicate locations of the mouth islands~~Locations of the mouth islands are indicated by the arrows~~ in the longitudinal profile.

3 Model results

3.1 Influence of the number of mouth islands

Morphological evolution firstly occurs in the mouth zone where tidal currents are strongest~~, and~~ as well as the river input zone ~~where there are river inflows~~due to fluvial input. The initial morphodynamic development is characterized by large bathymetric changes and rapid development of tidal channels (Figure 5). In the subsequent morphological evolution, the tidal channels ~~keep on dissecting~~dissect the shallow basin through headward growth (D'alpaos, 2005). This process of channel branching and ~~elongating of the channels~~elongation ultimately leads to the formation of a dendritic channel network and ~~a great~~ many scattered sand bars. Finally, the tidal basin gradually becomes stable in shape~~,~~ and only minor bathymetric changes occur (Figure 4).

The presence of different numbers of mouth islands causes local differences in morphodynamic patterns near the inlet. For the 0i ~~case of zero island~~ case~~(0i)~~, extensive erosion rapidly occurs near the inlet mouth because of strong tidal currents therein~~,~~ ~~and~~ a small-scale channel network is formed in the first 100 years (Figure 4d). After 300 years of development, the tidal network has ~~been~~ further developed~~, and a~~A large amount of sediment has been transported to the open sea, forming a complex channel network in the tidal basin (Figure 4h). ~~With the continuous morphodynamic evolution, few differences~~

~~are observed in the horizontal distribution of the tidal channels, which are only gradually deepened in the vertical direction, indicating that the tidal basin has reached a stable state (Figure 4l).~~ After 500 years, the horizontal channel's distribution has few morphological differences, and they become deeper, indicating that the basin has reached a stable state (Figure 4l).

When a mouth island is added at the left side of the inlet, a large area of back-barrier deposition is observed behind the island, and the water depth at the sides of~~beside~~ the island is relatively larger. In addition, the tidal network on the left side is developed into a higher intertidal area compared with the ~~scenario of zero island~~ 0i scenario (Figures 4e, 4i, 4m). ~~If another mouth island is added at the right side of the inlet, similarly, another back-barrier deposition is observed behind the island.~~ The same happens if an island is added to the right side of the inlet. ~~The sediment in the basin is transported to near the tidal inlet owing to the larger tidal currents produced by the narrower tidal inlet~~The addition of islands narrows the inlet, and the tidal current increases; as result, a larger spatial scale tidal network is observed in the first 100 years –(Figures 4f, 4j, 4n). ~~Further~~ By increasing the number of mouth islands, ~~larger spatial scale tidal network is observed in the first 100 years. And~~ more erosion occurs in the tidal inlet mouth, indicating that the hydrodynamic conditions are even stronger (Figures 4g, 4k, 4o). ~~While~~ Meanwhile, in the upstream zone, ~~small~~ minor differences are observed ~~in~~ between the cases 0-3i~~four cases~~, indicating that ~~the effect of~~ hydrodynamic effects on this area ~~is~~ are relatively limited (Figures 4p-4s).

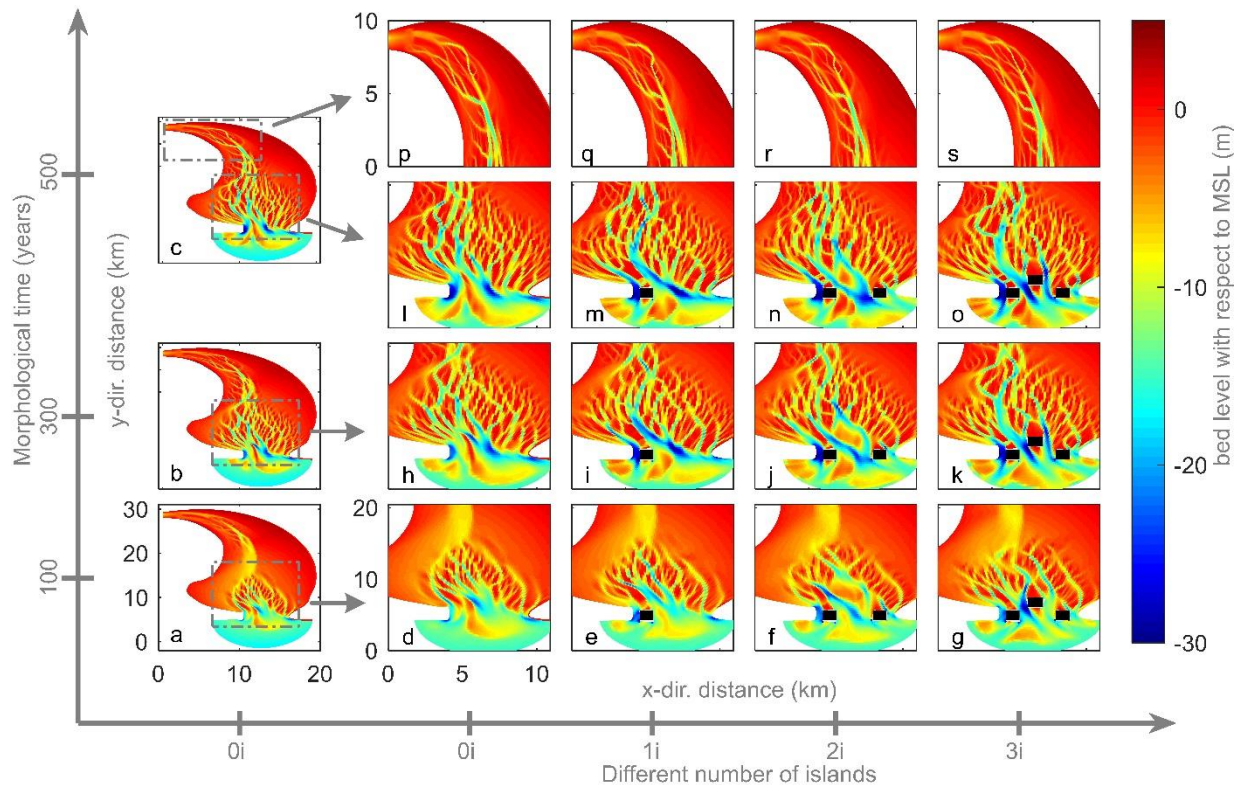



Figure 4: Morphological evolution after 100 years (a, d-g), 300 years (b, h-k) and 500 years (c, l-s) of basin without island ("0i"), basin with one island ("1i"), basin with two islands ("2i") and basin with three islands ("3i") ~~after the same morphological time~~ **respectively. Here we only plot part of the model domain, where the bed level changes. The black solid rectangles in subplots m, n, o, i, j, k, e, f and g represent mouth islands.**

The presence of mouth islands leads to stronger tidal currents at the inlet mouth. The initial flow field near the inlet at flood tide and ebb tide is shown in Figure 5. ~~The existence of a mouth island divides the tidal inlet into~~ With one island, the inlet is divided into two ~~parts and creates another~~ narrow tidal inlets, forming a dual-channel system. The narrower cross-section of the inlet also causes the increases of current velocity both at flood tide and ebb tide (Figure 5), leading to more ~~sediment suspended and transported, forming a deeper channel in the inlet~~suspended sediment transport and forming deeper inlet

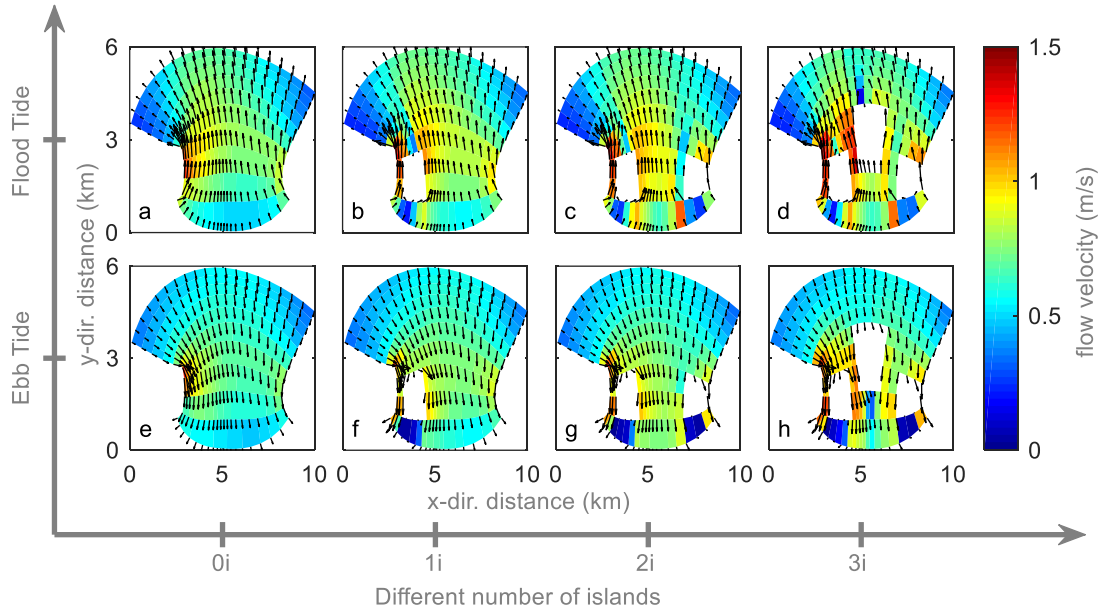
220 channels. On the other hand, due to the sheltering of the non-erodible island, a large back-barrier deposition is observed behind the island, where the tidal current velocity is relatively small (Figure 5). When another island is added at the right side of the inlet, the cross-sectional area of the inlet is further narrowed, making~~which makes~~ the current velocity further increase~~s~~ at the inlet (Figures 5c, 5g). For the ~~case of~~ three islands case ("3i"), an even larger flow velocity is observed both at flood tide and ebb tide (Figures 5d, 5h).

225

Figure 5: Flow field near the inlet: (a-d) represent at the time of flood tide of basin without island ("0i"), basin with one island ("1i"), basin with two islands ("2i") and basin with three islands ("3i") and (e-h) represent at the time of ebb tide respectively. Arrows for flow direction and colour for depth-averaged flow velocity (m/s).

3.2 Influence of the location of mouth islands

230 The morphological evolution of cases with different mouth island locations~~locations of mouth islands~~ is shown in Figure 6. Tidal channel networks quickly develop in the first 100 years and gradually become stable after 300 years. However, tidal basins with different mouth island locations~~mouth islands of different locations~~ show quite different morphological patterns near the inlet but a similar pattern in the upstream estuary zone. Initially, an idealized bed elevation is defined as shown by the black dotted line in Figures 6d-6l. Three cross-sections are selected along the estuary to show the detailed

235 morphological differences between different cases. ~~The c~~Cross-section 1 (CS1) is far away from the tidal inlet and the river discharge is relatively small, thus the effect of hydrodynamics on morphologies at this cross-section is limited. Hence, all cases show small bed level changes and develop a similar cross-sectional bed elevation after 500 years (Figures 6d-6f, 6m). While near the tidal inlet (CS2), the tidal channels develop quickly in the first 100 years showed by large bed level changes. As the morphological evolution continues, the channel~~s~~ gradually develop~~s~~ into the upper intertidal area and form~~ing~~ a

240 complex channel network. For the ~~scenarios of~~ inlet island scenarios ("IL"), it develops a larger number of tidal channels compared with the other two cases (Figures 6g, 6n), indicating that this type of mouth island can lead to tidal currents dispersing~~e~~ into the basin. For the ~~case of~~ basin-side island case ("BS"), a better- developed channel network is found ~~in~~ on the left side of the tidal basin and the tidal channels are gradually merged~~ together~~, showing a wider but ~~a~~ smaller number of channel~~s network~~ (Figure 6h, 6n). The tidal channels in the ~~scenarios of~~ delta-side island scenarios ("DS") are relatively

245 shallow but there is a main channel developed ~~at~~ in the middle of the basin (Figure 6i). That is~~'s~~ because the presence of this type of mouth island leads to ~~larger~~ stronger currents beside the island but ~~smaller~~ weaker currents behind the island,

thus ~~resulting in~~ the convergence of tidal currents entering the basin ~~and~~ creating larger erosion in the middle of the tidal basin. In terms of ebb-delta area (CS3), ~~model results also show a different morphological development in different cases~~ the morphology is also significantly influenced by the longitudinal placement of the island. ~~On both sides of ebb delta, it suffers large erosion and develops tidal channels. While in the middle of ebb-delta, it shows large deposition and develops ebb-delta.~~ The inlet island scenario ("IL") develops several tidal channels in the ebb-delta area due to the diversion created by the inlet island (Figure 6a). In the BS and DS cases, the ebb-delta area has a similar morphology, with extensive deposition developing in the middle of the ebb delta. However, larger sedimentation occurs in the BS case, suggesting that it produces more significant sediment transport (Figure 6k, 6l).

255

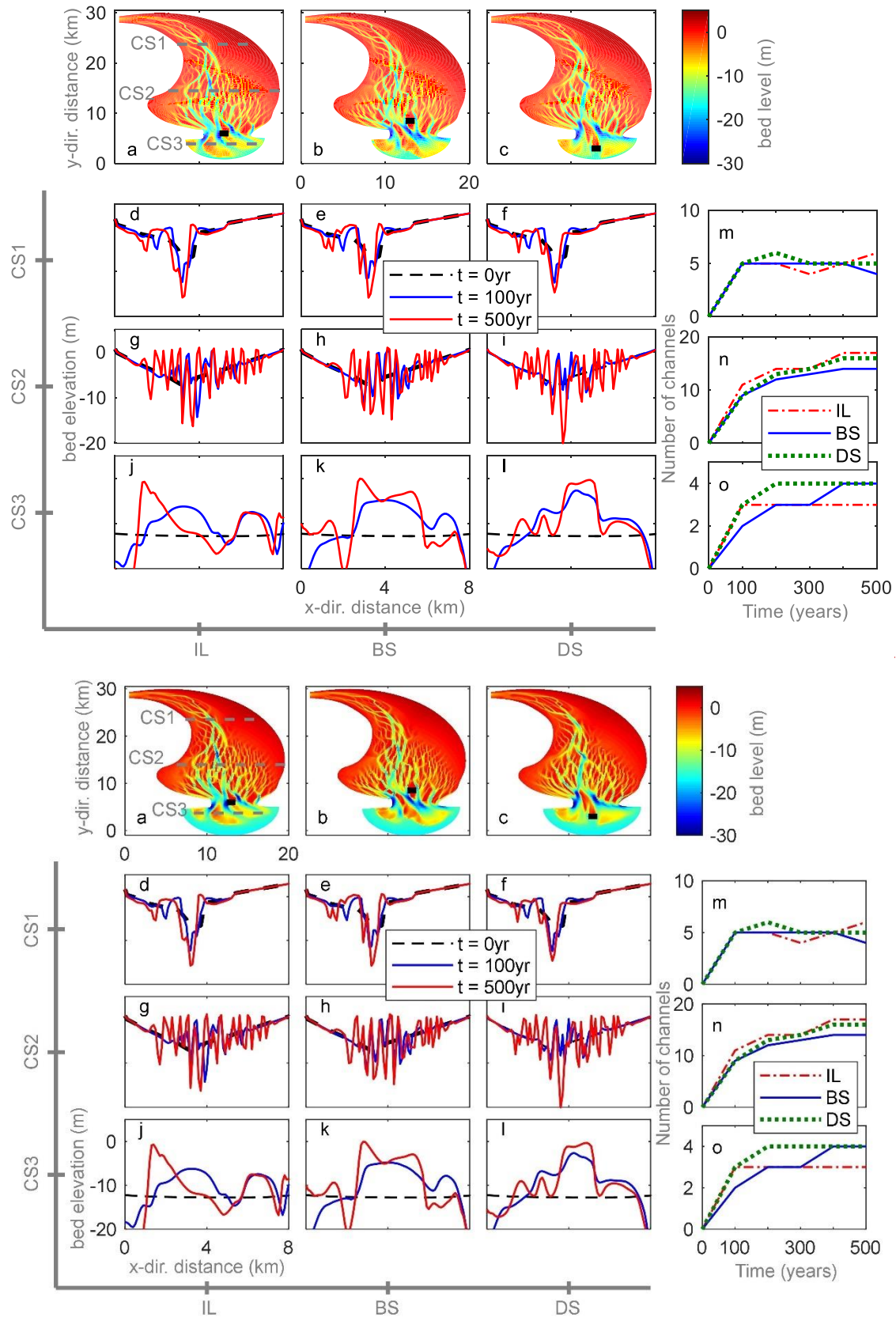



Figure 6: Morphological evolution after 500 years (a-c) of basin with mouth island at the inlet ("IL"), at the basin-side ("BS") and ~~at~~ the delta-side ("DS") respectively. Figures d-l represent the temporal cross-sectional bed elevation of different cases: (d-f) cross-section 1; (g-i) cross-section 2 and (j-l) cross-section 3. Figures m-o represent the number of channels of different cross-

 section~~s~~ respectively. In some subplots, T~~t~~he black rectangle area ~~in some figures~~ represents the mouth island and the grey dotted lines represent the ~~position of cross-section~~cross-section position.

3.3 Patterns of residual currents and residual sediment transport

The above morphological evolution characterised by ~~the formation of~~ shoals and channels is highly linked to the variation in residual tidal current and sediment transport patterns. This section compares~~In this section, we compare tidal~~ residual currents in the beginning and after 300 years to illustrate the mechanisms of this type of ~~evolution a~~ basin evolution (Figure 7). The residual currents are calculated by averaging the flow field over a tidal cycle, which produce residual sediment transport, leading to the morphological evolution of the basin (Leonardi et al., 2013).

The presence of mouth islands leads to a higher residual current. Initially, the residual currents near the inlet are mostly landward ~~(flood-directed)~~ and circulating residual currents are found outside the basin (Figures 7a). When a mouth island is added, some of the tidal residual currents are directly reflected ~~back~~ into the sea, while others enter the inner basin through the narrowed inlets with a stronger current velocity (Figures 7b). If another island is added at the right side of the inlet, the spatial distribution of residual currents is approximately symmetric and two circulating residual currents are formed behind the island (Figures 7c). As the inlet becomes much narrower, the landward residual currents become much stronger. For the ~~case of~~ three islands case ("3i"), the residual currents are larger than ~~that of~~ the other cases, leading to ~~a~~ stronger residual sediment transport in the basin. In the beginning, the residual currents are relatively large with the tidal basin being morphodynamically active, so tidal flats and channels develop rapidly in the first decades. After 300 years, the residual currents decrease and the basin morphology tends to be stable (Figure 4). The formation of tidal channels and sand bars significantly impacts~~has a significant impact on~~ the spatial distribution of residual currents (Figures 7e–7h). The residual currents decrease to the magnitude of approximately 0.3 m/s after 300 years, indicating that hydrodynamics gradually adapt to basin morphology ~~towards~~ and a relative equilibrium state.

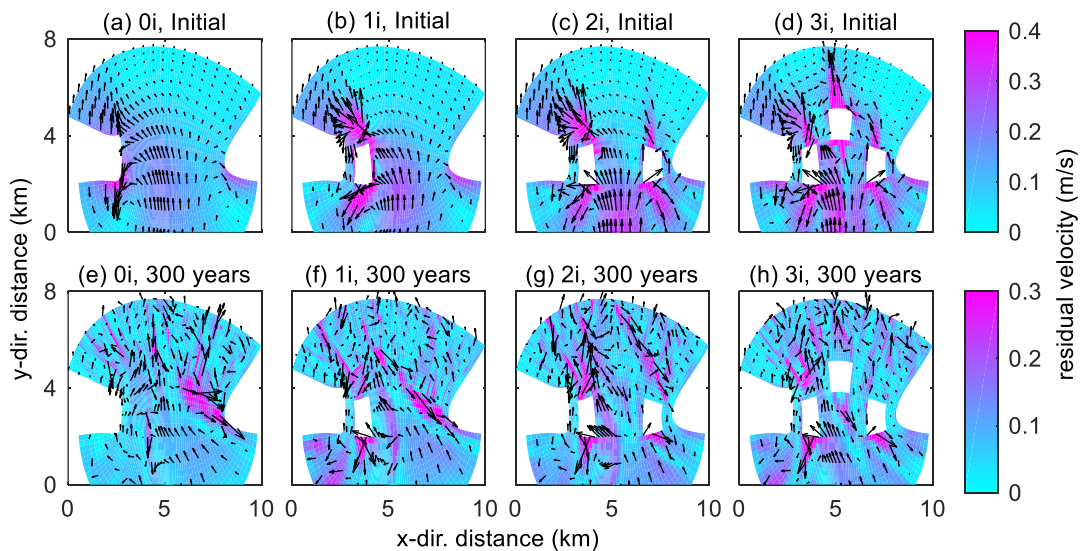



Figure 7: Spatial distribution of the residual current (arrow vectors indicate the direction) near the tidal inlet of four different scenarios: (a-d) represent without island ("0i"), one island ("1i"), two islands ("2i") and three islands ("3i") at the beginning respectively~~;~~. (e-h) after 300 years. The white area in the plot represents the mouth islands and the background ~~color~~colour represents the magnitude of residual velocity.

The presence of mouth islands enhances seaward residual sediment transport. The temporal evolution of the residual sediment pattern near the tidal inlet is shown in Figure 8. The cross-~~-~~section is ~~located~~ placed in the delta-side near the tidal

inlet and ensures that the initial cross--section area is the same for all cases (Figure 8h). AtIn the beginning of morphological evolution, residual currents are landward (Figures 78a-78d) but there is a seaward net sediment transport is observed in the middle of the tidal inlet, forming a two-way transport pattern in the tidal inlet (Figures 8a). When a mouth island is added, a seaward residual sediment transport can beis observed behind the mouth island (Figures 8b). Further increase in the number of mouth islands result in the increases of the magnitude of seaward residual sediment transport (Figures 8b-d), and the maximum magnitude in the 3i case"3i" case can reachreaches about 0.8 m³/s (Figure 8o). Since the residual sediment transport patterns control the morphological evolution of tidal basins and estuaries, and the magnitude of residual sediment transport determines the rate of morphological changes (Guo et al., 2015). As shown in Figure 8o, the 3i case"3i" case has a relatively higher residual sediment transport, thus the tidal system may develop and evolve more rapidly than the scenarios with fewer mouth islands. In the cases of with different island locations, when the mouth island is moved further into the basin, the seaward residual sediment transport is larger a larger area of seaward residual sediment transport is observed when the mouth island moved further into the basin (Figure 8e-g). Model results indicate that the basin-side island tends to resultes in a more extensivelarger residual sediment transport than the delta-side island (Figure 8q-r). After 300 years of morphodynamic development, the residual sediment transport pattern is highly affected by the developing channels and shoals and the magnitude of sediment transport has decreased significantly, only 0.1-0.2 m³/s (Figure 8p, r). As the morphological evolution continues, the magnitude of residual sediment transport continues to decreasefurther decreases, and the final stage for sediment transport is similar for all cases.and it seems that the final state of the sediment transport turns to a similar pattern among all cases (Figure 8h-k), indicating that the evolving basin morphologies adapt to the tidal hydrodynamics towards a morphodynamic equilibrium state. However, it is worth noting that although the residual sediment transport gradually decreases over time, it is never close to zero over the whole tidal cycle and a dynamic equilibrium state is formed reached (Zhou et al., 2017).

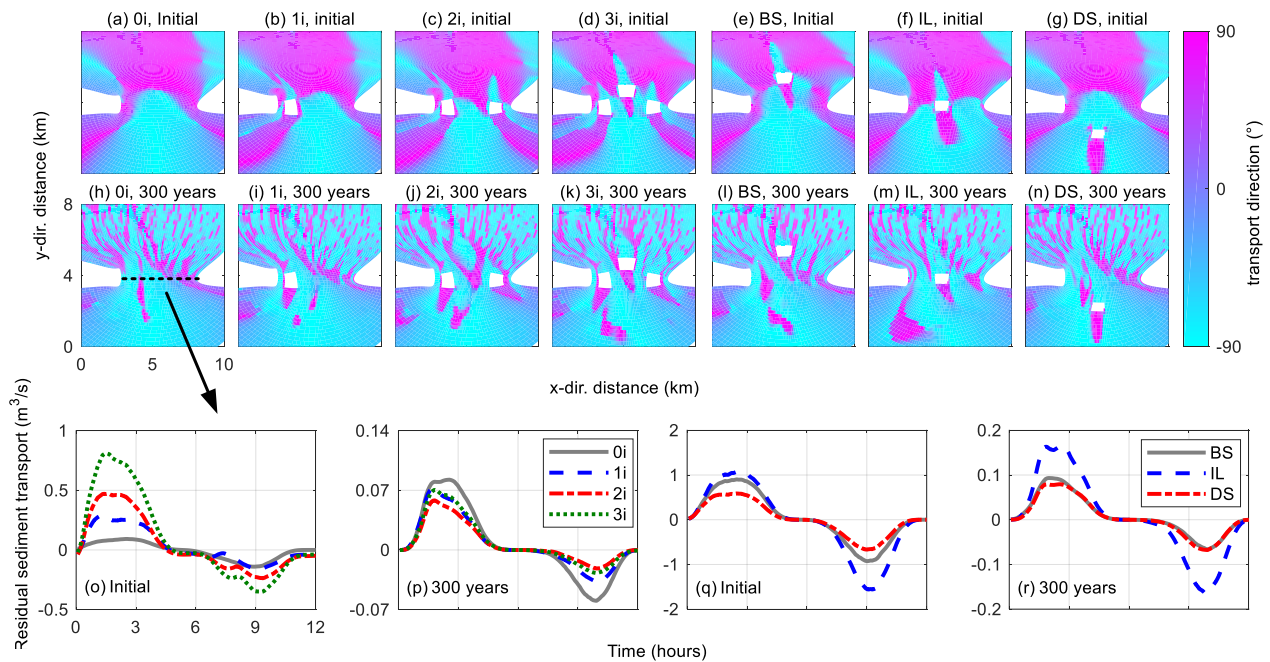



Figure 8: Residual sediment transport pattern near the tidal inlet in the scenarios offor different number of mouth islands (a-d, h-k) and different number of mouth islands locations (e-g, l-n) at the beginning and after 300 years respectively. The white area in the plot represents the mouth islands and the background colour represents the direction of residual sediment transport (90 degrees indicate landward transport while -90 degrees indicate seaward transport). Tidal residual sediment transport via a cross-

section of different scenarios at ~~time of~~ 0 ~~year~~ (o, q) and 300 years (p, r) respectively. In ~~each plot~~subplots 8o-r, a positive value
indicates seaward transport while a negative value indicates landward transport.

3.4 Hypsometry curves and "P-A" relation

One useful metric that links the morphology to the hydrodynamics of tidal basins is hypsometry, which can provide information on the percentage of shoal area and channel area (Townend, 2008; Vivoni et al., 2008). Figure 9 shows t~~T~~he hypsometry of the inner basin for different scenarios after 100 and 500 years ~~is shown in Figure 9~~, and ~~we divide~~ the intertidal zone and subtidal zone is divided according to the tidal amplitude (1.2 m). The initial profile decreases linearly towards the sea;~~Initially, a schematic profile is defined and an elevation inclined linearly toward the sea,~~ thus the hypsometry appears to be linear (~~see the~~ grey dotted line in Figure 9a). In the first 100 years, all cases show a rapid development of channels and tidal flats, indicating vertical redistribution of sediments. Case 3i shows a more pronounced development after increasing the number of mouth islands~~As the increase of mouth islands, a more pronounced development is found in the 3i case~~ (~~see the~~ green solid ~~dash-dot~~ line in Figure 9a). ~~Compared to the hypsometric curves at 100 years, the ones gradually move to the left side and become convex after 500 years~~After 500 years, hypsometric curves become noticeably convex, which indicates that shallower tidal flats and accreted shoals are developed in the basins (~~see~~ dotted lines in Figure 9a). For the cases of different island locations, the area of tidal flats grows slightly slower under the delta-side scenario and slightly faster under the basin-side scenario (solid line in Figure 9b). After 500 years, the magnitude of shoals and flats developed under all cases are similar (dotted lines in Figure 9b).
~~Tidal basin with different location mouth island shows somewhat differences in hypsometric curves. Since all models use the same initial bathymetry, the initial hypsometry curve is the same as the cases of different number of mouth islands (see the grey dotted line in Figure 9b). After 100 years of development, there are less accreted flats in the basin with a delta-side mouth island. While the basin with a basin-side mouth island develops largest volume of tidal flats among the three cases (see the dash dot line in Figure 9b). After 500 years of evolution, almost the same magnitude of shoals and tidal flats are developed in all cases (see dotted lines in Figure 9b).~~

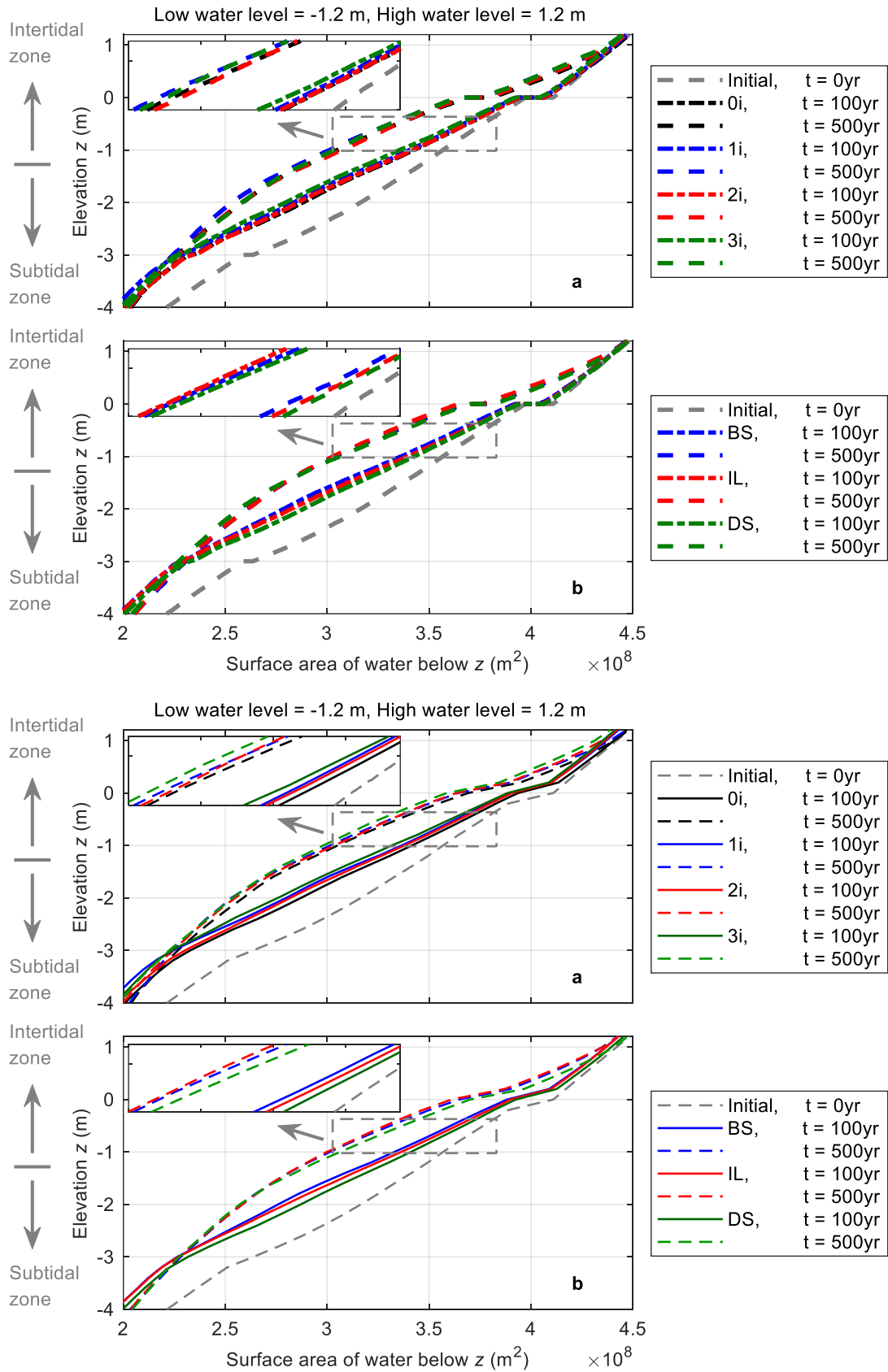



Figure 9: Hypsometry of the tidal basin for the simulations of different scenarios: (a) the scenarios of ~~the~~ different ~~number of~~ mouth island~~s~~ numbers; (b) the scenarios of different ~~location of~~ mouth island~~s~~ locations after 100 and 500 years respectively. The tidal amplitude in all cases is 1.2 m.

Another useful analysis connecting the geomorphic characteristics and hydrodynamic forces is the relationship between the cross-sectional area and the tidal prism (P-A relation) (O'brien, 1931; Jarrett, 1976; Friedrichs, 1995; Townend, 2005). The P-A relation is as follows:

345
$$A = KP^n \tag{23}$$

where A is the cross-sectional area (m^2), P is tidal prism (m^3), K and n are fitted coefficients. The evolution of the P-A relation is ~~closely~~ related to ~~a number of~~several factors, such as the hydrodynamic forces, sediment transport, and geological landform. In recent decades, many numerical studies ~~have been conducted to~~ explored the P-A relation of estuaries (Lanzoni and Seminara, 2002; Van Der Wegen et al., 2010) and tidal inlets (Powell et al., 2006; D'alpaos et al., 2010). However, few

350   studies consider the effect of mouth islands on the morphology of basins, and our knowledge ~~of~~on the P-A relation of mouth basins is limited. Since islands are common landforms in the mouth of tidal basins, it is ~~therefore~~ of great significance to explore their influence on the P-A relation. In this study, ~~we adopt~~ a widely used method is adopted to calculate the tidal prism, following the ~~studies~~work of Savenije (2012) and Zhou et al. (2014a). Specifically, the tidal prism is calculated by the flow flux volume through a defined cross-section during the flood and ebb. This study uses the minimum width cross-

355   section~~In this study, the minimum width cross section is used~~, as shown by the black dotted line in Figure 8h.

$$P = \sum_1^n v * h * \Delta y * \Delta t \tag{34}$$

~~w~~Where n is the number of grids in the cross--section, v is the velocity component along the inlet, h is the water depth, Δy is the grid size of the cross-section, and Δt is the hydrodynamic time step. Figure 10 shows ~~T~~the variation of the tidal prisms and the inlet cross-sectional area for different mouth island scenarios ~~is shown in Figure 10~~. For the scenarios of

360   different ~~number of~~mouth island numbers, the existence of islands reduces the cross-sectional area of the inlet~~,~~ ~~but~~and increases the tidal current velocity, so ~~that~~ the initial tidal prism ~~of the "1i" case, the "2i" case and the "3i" case~~in cases 1i, 2i and 3i is larger than the ~~"0i"~~case 0i (Figure 10a). In the first 100 years, the tidal prism and cross-sectional area increase rapidly~~a rapid increase is observed in the tidal prism and cross-sectional area~~ because the tidal basin is ~~far away from~~not in the equilibrium state.~~,~~ This stage is characterized by the development of tidal flats and channels. Regarding the scenarios

365   with the~~As for~~ different ~~number of~~mouth island numbers~~scenarios~~, the 3i case ~~the tidal prism of the "3i" case increases fastest in the first 100 years, and it also~~develops the ~~more~~most tidal prism~~flats and channels~~ (Figure 10a). However, after 100 years, the tidal prism ~~begins to~~ decreases gradually, while the cross-sectional area tends to stabilise~~be stable~~ (Figure 10b). This is because the developed shoals directly ~~decrease~~ reduce the ~~accommodation space for water~~water accommodation space, ~~and thus also~~leading to a decrease in the tidal prism~~the tidal prism decrease~~.

370   For the scenarios of different mouth island locations~~location of mouth island~~, model results also show ~~that~~a sharp increase ~~is observed both~~ in the tidal prism and the cross-sectional area in the first 100 years (Figures 10c-d). The ~~basin~~cases with a basin-side mouth island ~~has~~have a relatively larger tidal prism and cross-sectional area than~~the relatively larger tidal prism and cross-sectional area compared with~~ the ~~other two~~ cases IL and DS. ~~This is because a~~Although they have the same inlet cross-sectional area, the basin-side island can further increase the current velocity entering the tidal basin. Similarly, there

375   is a decrease in tidal prism in all cases after 100 years, but the cross-sectional area is still evolving~~of tidal prism in all cases after 100 years, but the cross-sectional area is still evolving~~, which is characterized by the deepening of water depth. After 300 years, the tidal basin tends to be stable, as shown~~ed~~ by an increasingly~~a gradually~~ stable tidal prism (Figure 10c).

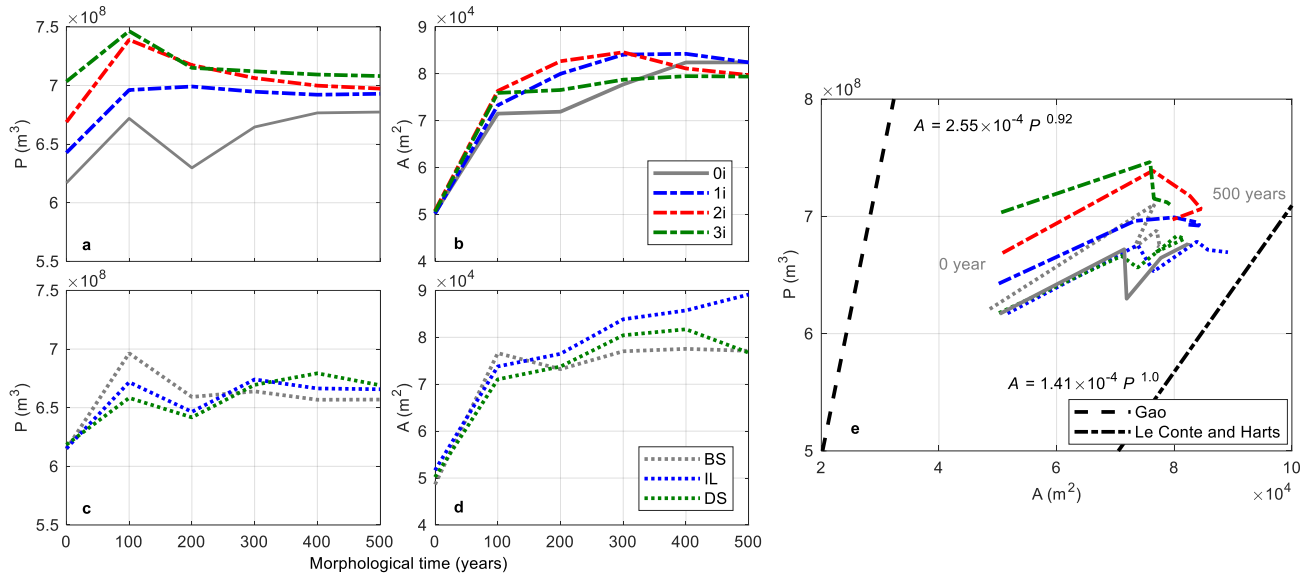



Figure 10: The evolution of tidal prism, inlet cross-sectional area and "P-A relation" for the different mouth island scenarios over 500 years. (a) and (b) for the scenarios of different ~~number of~~ mouth island~~s~~ numbers, (c), and (d) for the scenarios of different ~~location of~~ mouth island~~s~~ locations.

The ~~tidal basins~~cases with different mouth island scenarios gradually evolved to stable morphologies (Figure 4), ~~which is~~ characterized by the decrease of residual current and sediment transport flux (Figure 8). Similarly, in the scenarios in Figure 10a-10d, the tidal prism and inlet cross-sectional area tend to equilibrium~~Similarly, the tidal prism and inlet cross-sectional area in different scenarios tend to develop to a stable value (Figure 10a-10d)~~. Model results show that the number and location of mouth islands affect~~s~~ the P-A relationship. For example, ~~the basins with different number and location of mouth islands develop different tidal prism and cross-sectional area evolution trends.~~ if the number of mouth islands increases, the tidal prism increments gradually, but the cross-sectional area evolves quite differently~~Similarly, with the increase of the number of mouth islands, the tidal prisms of these tidal basins increase gradually and tend to have a similar development trend, but their cross-sectional area evolution is quite different~~. Figure 10e shows the simulated trajectories of P-A points at different times and is compared with ~~some of~~ existing empirical P-A relationships (e.g., Le Conte and Harts (1905) and Gao (1988)). These scattered P-A points of different mouth island basins tend to evolve towards an equilibrium state and the tidal basins with mouth islands may take a shorter time to reach ~~an~~ equilibrium. Model results suggest that the tidal basins with mouth islands appear to ~~be able to~~ develop a larger tidal prism and cross-sectional area. As indicated by previous studies, the P-A relationship is highly affected by many factors, including site-specific and scale-dependent factors~~,~~ (D'alpaos et al., 2010), hydrodynamic and sediment properties (Townend, 2005), river discharge and initial basin bathymetry (Van Maanen et al., 2013a; Zhou et al., 2014a). This study suggests that the number and location of mouth islands as geological constraints near the tidal inlet can also play an important role ~~on~~ in the evolutionary trends of basin morphology, ~~thus~~ affecting the P-A relationship.

3.5 Distances affected by mouth islands

In this section, the 0i case is used as a reference to quantify the impact of mouth islands at different locations and explore how large is the area affected by the islands. Figure 11 shows the cross-sectionally averaged flow velocity and sediment transport variations compared to the 0i case in the longitudinal direction.

The mouth island greatly influences the hydrodynamic and sediment transport in local areas (e.g., tidal inlet), but the variations in the whole tidal basin are relatively small. In terms of flow velocity, the variations are calculated between other cases and the 0i case.

$$r_v = \frac{(v - v_{0i})}{v_{0i}} \tag{4}$$

where v is the velocity in other cases (m/s), v_{0i} is the velocity of the reference case. As shown in Figure 11a, the variations mainly concentrate near the tidal inlet, and gradually decrease in the landward and seaward directions. When the mouth island location is at the delta-side, velocity in front and back of the island decreases while it increases on the sides. The velocity in other areas is almost the same as the reference case (green dotted line in Figure 11a), indicating that this type of island has little impact on the flow velocity inside the basin. If the mouth island is located at the tidal inlet, a greater increase of 70% is observed near the tidal inlet, but the velocity decreases drastically inside the basin. At 5 km from the tidal inlet (landwards), it is reduced by 30% (red dotted line in Figure 11a). When the mouth island is located at the basin-side of the inlet, a greater increase of 60% is observed near the island, and then gradually decreases in the landward direction (blue dotted line in Figure 11a). Similarly, variations are highly concentrated near the tidal inlet in terms of cross-sectionally sediment transport. A coefficient (r_s) is also used to quantify the differences between cases.

$$r_s = \frac{(s - s_{0i})}{s_{0i}} \tag{5}$$

where s is the sediment transport in other cases (m/s), s_{0i} is the sediment transport of the reference case. Comparing the different curves, we can see that where the islands exist can lead to more significant sediment transport. Moreover, a sediment transport more than three times that of the reference case is found in the IL case. However, other areas show minimal variations in the inner and outer basins (Figure 11b). It is worth noting that due to the non-linear relationship between sediment transport and velocity, island-induced relative differences in sediment transport are much greater than flow velocity (Figure11).

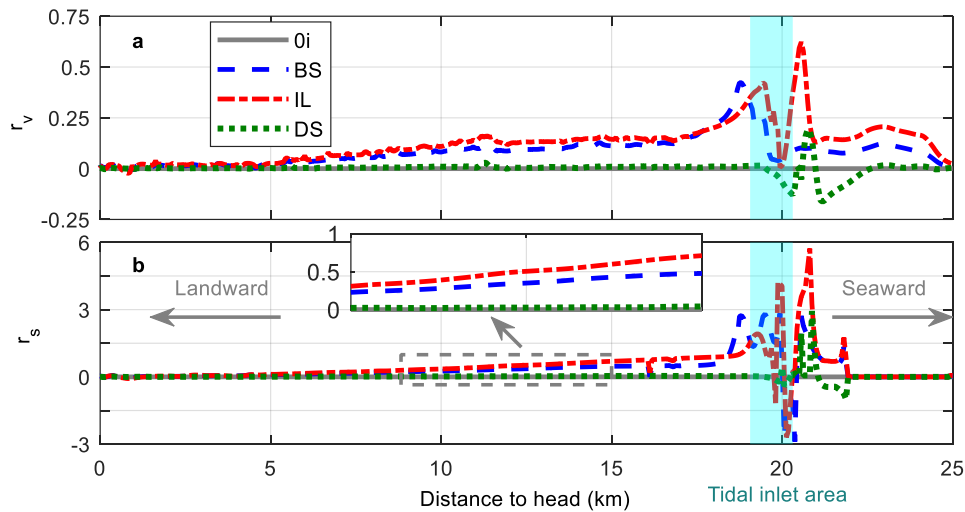



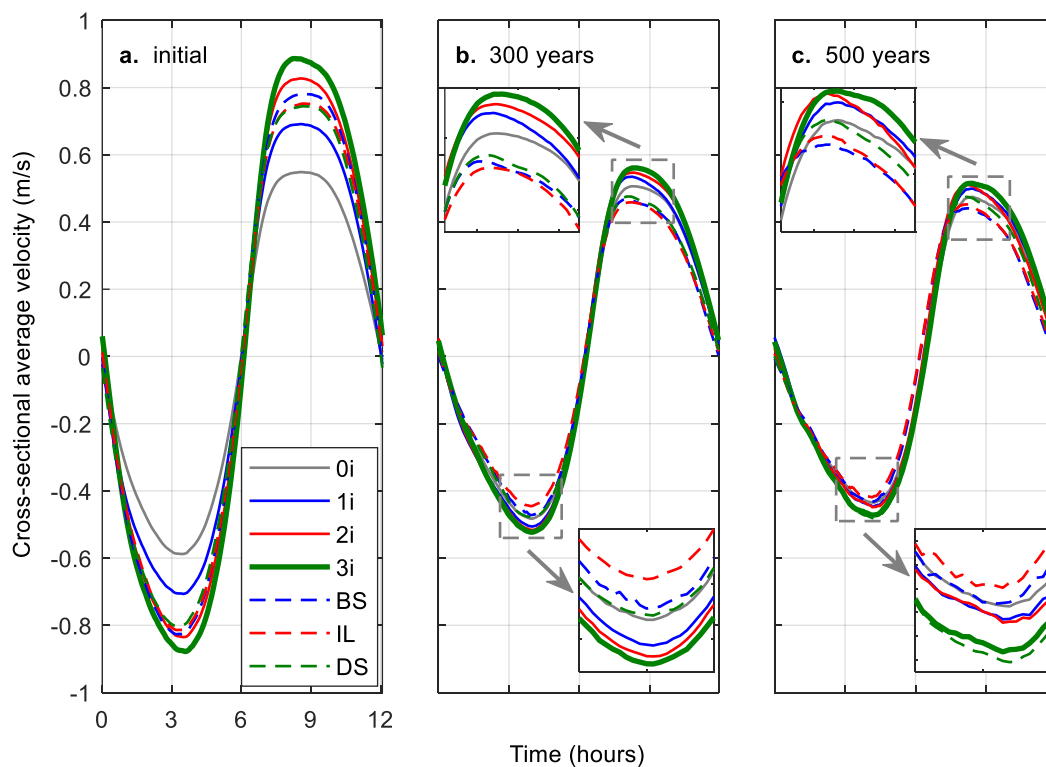
Figure 11: Longitudinal variations of cross-sectionally averaged flow velocity (a) and sediment transport (b) compared to the 0i case at the high tide of the first year.

4 Discussion

4.1 How does the mouth island affect basin morphology?

430   The ~~existence of~~ mouth islands ~~affects~~affect the local hydrodynamics near the inlet and the sediment transport patterns, ~~and~~ hence the long-term morphological evolution of tidal basins. Figure ~~11~~12 shows the cross-sectional average velocity at the tidal inlet over one tidal cycle. Initially, the maximum flood and ebb ~~tidal~~ velocity in the ~~case of~~ "0i" case ~~are~~is nearly the same (about 0.58 m/s). When a mouth island is added, the tidal current velocity increases ~~both~~ during the flood and the ebb. Tidal velocity increases with the increase in the number of islands (Figure ~~11a~~12a). Concerning the~~With respect to~~ different

435   island locations, a larger flood and ebb ~~tidal~~ velocity is observed in the ~~case of~~ "BS" case (Figure ~~11a~~12a). After 300 years, tidal velocity in the ~~case of~~ "0i" case decreases ~~slightly~~ to about 0.5 m/s, while ~~in~~ other cases show a more significant decrease~~it decreases significantly~~. The tidal basin with larger numbers of islands also has a higher velocity (Figure ~~11b~~12b). ~~When the basin evolves to~~After 500 years, the tidal velocity shows a slight decrease in all cases~~in all cases decrease only slightly~~, indicating that the systems ~~were~~are approaching morphodynamic equilibrium. The islands' role is similar to bridge

440   piles, they constrict the inlet and generate flow convergence, nevertheless this effect is dominant at the inlet.

~~Figure 11:~~Figure 12: The cross-sectional average velocity over a tidal cycle of different scenarios after: (a) 0 years, (b) 300 years, and (c) 500 years. The flood tidal velocity is positive.

The flow velocity at the inlet is affected by the various locations of mouth islands, thus affecting the sediment dynamics,

445   and plays an essential role in morphological evolution~~The presence of mouth islands at different locations alters the flow velocity near the tidal inlet, resulting in different sediment suspension and transport, and plays an important role in morphological evolution~~. Figure 13 shows the development of different geological conditions in the tidal flat are: intertidal storage volume (V_s), channel volume (V_c), the ratio of V_s/V_c and a/h~~Figure 12 shows the development of the tidal flat area, intertidal storage volume (V_s), channel volume (V_c) and ratio of V_s/V_c and a/h of different geological conditions respectively~~.

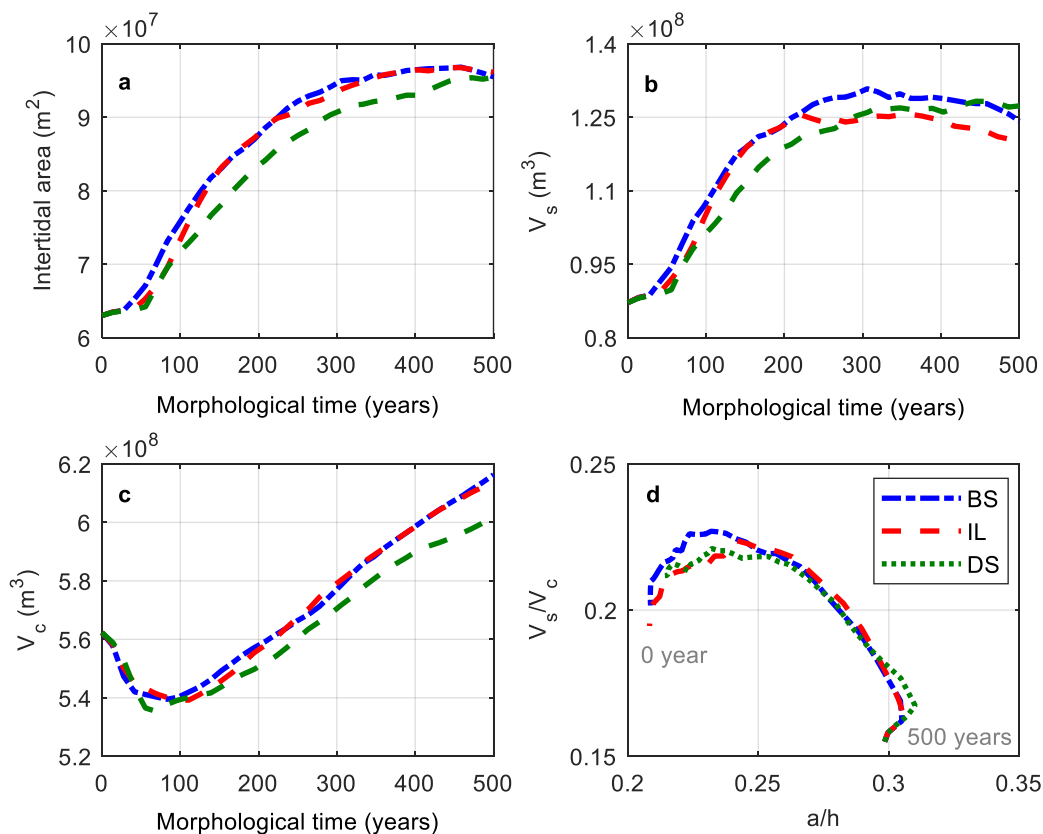
450   In this study, the tidal flat area is defined as the area between mean high water (MHW) and mean low water (MLW), V_s is

defined as the ~~volume of~~ water volume~~over~~ in the intertidal area, and V_c is defined as the ~~total~~ water ~~volume~~ below MLW (Friedrichs and Aubrey, 1988). Regarding the tidal flat area~~In terms of tidal flat area~~, it is found that the tidal flat develops rapidly in the first 300 years (Figure ~~12a~~13a). For case BS, ~~T~~the ~~existence of~~ basin-side island contributes to the development of more tidal flats ~~in tidal basins~~, which has the fastest development rate. After 300 years ~~of evolution~~, the

455 development of tidal flat slows down, and the tidal basin tends to become stable gradually~~to be stable gradually~~ (see also Figure 4). But this does not mean that morphodynamic equilibrium is reached at the end of 300 years, because the intertidal storage volume and the channel volume are still developing and evolving (Figures ~~12b~~13b-c). In terms of intertidal storage volume, a gradual~~there is a gradually~~ decrease after 300 years, indicating the tidal flat is still developing (Figure ~~12b~~13b). In contrast~~Different from the tidal flat area and the intertidal storage volume (V_s)~~, the channel volume (V_c) shows a drastic

460 decrease~~sharply decreasing~~ in the first 100 years and then continuously increas~~es~~ing. ~~It is likely that~~Likely, the horizontal redistribution of sediment was mainly driven by the morphological evolution in the first 100 years~~morphological development in the first 100 years was mainly caused by the horizontal redistribution of sediment~~, while the deepening of channels led to the continuous development ~~and evolution~~ of tidal flats and channel networks. The ratio of V_s/V_c and a/h ~~is an indicator~~indicates ~~to determine~~ the tidal asymmetry condition of a tide-dominated system (Friedrichs and Aubrey, 1988).

465 Overall, the a/h ratio is small (<0.3) for the three cases (Figure ~~12d~~13d) and the ratio between V_s/V_c and a/h increases in the first 100 years and then gra~~u~~dually decreases. Following Friedrichs and Aubrey (1988), ~~a numer of~~several modelling efforts suggest that the tidal systems were flood-dominant (a/h->0.3) or ebb-dominant (a/h<0.2), while the other key parameter V_s/V_c became crucial (0.2<a/h<0.3). T~~Due to t~~he a/h value of the three cases is about 0.2-0.3 and the parameter V_s/V_c is about 0.15-0.23, which suggests that the tidal basins are an ebb-dominated system. Model results also indicate that

470 the effect of mouth islands is limited on the tidal asymmetry.

~~Figure 12:~~Figure 13: Temporal variation of intertidal flat area (a), intertidal storage volume (b), channel volume (c) and the ratio of V_s/V_c in the inner basin of different island locations.

The mouth islands also affect the sediment transport process and distribution. Figure 14 shows the results for~~The temporal~~
475 ~~changes of~~ cumulative erosion ~~or~~ and sedimentation ~~in tidal system are shown in Figure 13~~. ~~We find that, a~~All cases experience~~show~~ sedimentation in the ebb-delta and erosion in the tidal basin (Figure ~~13~~14). If mouth islands are added, the inner basins face more significant~~undergo more~~ erosion ~~with the morphological evolution~~, because ~~of~~ the ~~presence of~~ islands ~~that~~ produce larger flow velocities, resulting in more sediment transport. Consequently~~Accordingly~~, the delta shows sediment deposition and the sedimentation volume increases continuously with the increase of mouth islands (Figure
480 ~~13a~~14a).

Regarding the cases that~~As for the scenario runs~~ investigat~~e~~ing the role of mouth island location~~s~~, ~~model~~ results ~~also~~ show that erosion occurs in the inner basin and sedimentation occurs in the delta (Figure ~~13b~~14b). The ~~basin~~ case with a basin-side mouth island has a larger magnitude of erosion or sedimentation, indicating ~~that more~~greater sediment suspension and transport in the basin. That is probably ~~because~~ due to the fact that the mouth island at this location can facilitate~~boost~~ and
485 increase tidal ~~currents entering~~flow into the basin, which play~~s~~ a determin~~ing~~ed role in sediment transport and morphological evolution. For the ~~case of~~ delta-side island case, the sediment volume change is relatively small~~, which indicates that this type of mouth island can directly alter the tidal current into the basin and play a key role in local sediment transport process~~ (Figure ~~13b~~14b).

This study shows that although the residual currents have a landward direction in the initial bathymetry, the net sediment
490 transport is seaward~~In this study, it is worth noting that the residual currents are landward in the initial bathymetry, while the net sediment transport is seaward~~ (Figur~~e.~~ ~~13~~14). The river discharge is relatively small (50 m^3/s), ~~its~~and the impact on residual current and residual sediment transport is therefore limited. A possible explanation can be provided in terms of the Stokes return flow that interacts with the tidal current generating larger residual sediment transport than residual current (Guo et al., 2014). A phase lag between the water levels and velocities induces a landward Stokes drift that causes a
495 landward accumulation of water and momentum, resulting in a water level gradient (negative seaward) (Van Der Wegen and Roelvink, 2008; Van Der Wegen et al., 2008). This water level gradient induces a seaward return flow (Stokes return flow), enhancing the basin's ebb dominant and exporting character~~ebb dominant and exporting character of the basin~~.

4.2 How far is the area affected by the mouth island?

In this section, we use a reference case ("0i") to quantify the impact of mouth islands at different locations and discuss how large the area is affected by the islands. Figure 14 shows variations of cross-sectionally averaged flow velocity and sediment transport compared to the case of zero island in the longitudinal direction.

The mouth island has a great influence on the hydrodynamic and sediment transport in local areas (e.g., tidal inlet), but the variations in the scale of the whole tidal system are relatively small. In terms of flow velocity, we use the case of zero island ("0i") as a reference case and calculate the variations between other cases and reference case.

$$r_v = \frac{(v - v_{0i})}{v_{0i}} \tag{5}$$

where, v is the velocity in other cases (m/s), v_{0i} is the velocity of reference case ("0i"). As shown in Figure 14b, the variations mainly concentrate near the tidal inlet, and gradually decrease both in the landward and seaward directions. If the mouth island is located at the delta side of basin, there is a decrease in the front and back of the island and an increase on both sides of the island. The velocity in other areas is almost the same as the reference case (see the green dotted line in Figure 14b), indicating that this type of island has little impact on the flow velocity in the basin. If the mouth island is located at the tidal inlet, a greater increase of 70% is observed near the tidal inlet, but the velocity decreases sharply in the tidal inlet. In the tidal basin, it decreases by 30% at 5 km away from the tidal inlet (see the red dotted line in Figure 14b). When the mouth island is located at the basin-side of inlet, a greater increase of 60% is observed near the island, and then gradually decreases in the landward direction (see the blue dotted line in Figure 14b). Similarly, variations are highly concentrated near the tidal inlet in terms of cross-sectionally sediment transport. We also use a coefficient (r_s) to quantify the differences between different cases.

$$r_s = \frac{(s - s_{0i})}{s_{0i}} \tag{6}$$

525

4.~~3~~2 Implications for realistic tidal basins

530   ~~Even though t~~This study is inspired by the observations of two ~~at a pair of~~ adjacent tidal basins (Massachusetts Bay and Plymouth Bay), ~~but this study~~but it has been highly simplified ~~in order~~ to gain direct knowledge of the mouth islands role~~role of mouth islands~~. Numerical experiments demonstrate that the presence of mouth islands can significantly affect the local hydrodynamics and residual sediment transport, and thus influence ~~local~~ channel-shoal morphology. However, in this ~~study~~work, all simulations result in the development of a dendritic channel network that does not seem to be able to

535   capture~~cannot explain~~ the dichotomy shown in the comparison~~.,~~ It is suggested~~which implies~~ that mouth islands are only one of the determinative factors contributing to the ~~overall shape of the~~ basin morphology. It is therefore worth not~~h~~ing other potential effects that possibly lead to the different morphology.

From a morphodynamic standpoint, initial bathymetry and tidal range play a significant role in channel network and intertidal area development~~the development of channel network and intertidal area~~ (Dastgheib et al., 2008; Zhou et al.,

540   2014a). Initial bathymetry influences the overall sediment availability, while tidal range affects the bed level change by determining the amount of sediment that can be redistributed (Van Maanen et al., 2013a). ~~By comparing two tidal inlets that they are close and sharing similar tidal ranges, but we observe quite different bathymetries (Figure 1).~~ The average bathymetry~~water depth~~ in Massachusetts Bay is about 6 m (Signell and Butman, 1992), which is larger than 2 m in Plymouth Bay (Gontz et al., 2013). This shows that different amounts of sediment can be redistributed in the basins, which is one of

545   the possible reasons accounting for the differences in morphology. Besides, the sedimentary environment is also different. Massachusetts Bay is a muddy environment, while Plymouth Bay is sandy (Ford, 2010). The sediment properties ~~are found to~~ influence the final profile shape and vertical ~~distribution of~~ sediment distribution (Zhou et al., 2016), thus affecting the overall morphology. Also, Massachusetts Bay is an ebb-dominated system with a~~stronger~~ ~~velocity~~ tidal currents ~~is~~

~~developed at the inlet of Massachusetts Bay~~ (Knebel et al., 1991; Tubman, 2007), which may also result in the suspension and export of fine sediment. Finally, human activities have a major impact on basin morphology,~~. and since~~ for instance, waterway dredging~~the Boston harbour is~~ in Massachusetts Bay~~, waterway dredging~~ can be one of the main factors attributed to the deeper watershed and over-deepened channel.

Regarding~~With the focus on~~ the role of mouth islands, some assumptions and simplifications ~~have been~~were inevitably made in our numerical modelling, so the results are easier to interpret~~in order to make it easier to interpret model results~~ and ~~clarify potential~~gain insights. However, further research effort is needed~~should be made~~ to clarify~~shed light on~~ some of the neglected mechanisms: (1) In this model, mouth islands are considered non-erodible and rectangular, while natural systems are erodible with irregular shapes~~The mouth islands are considered in the model as non-erodible and of rectangular shape, while natural islands are often slowly eroded with time and have irregular shapes~~. The erosion rate varies between different types of islands. Sandy islands can be completely destroyed and reformed over decadal timescales (Vousdoukas et al., 2020). Rocky islands can be eroded in a range of 0.01-0.1 myr^{-1}, which largely depends on mechanical wave action and rock strength (Andriani and Walsh, 2007). (2) While the model neglects the wave action, it may significantly influence the morphodynamic evolution of tidal basins, especially in the ebb-delta~~The effect of wave action is excluded in the model while it may have a great influence on the morphodynamic evolution of tidal basins especially on the ebb-delta area~~. Nearshore waves can enhance alongshore sediment resuspension and drift, increasing seaward sediment transport~~resulting in more sediment being transported to the open sea and~~, forming larger ebb deltas (Hayes, 1980; Fagherazzi and Wiberg, 2009). (3) Sea level change is not considered~~in this model~~, while it may play a remarkable role in the morphological evolution at the centennial and millennial timescales. Notably~~Particularly~~, some of the low islands may be submerged with sea--level rise. ~~Besides, e~~Existing studies ~~have~~suggest~~ed~~ that the sediment transport pattern may shift from exporting to importing forced by sea--level rise (Dronkers et al., 1990; Van Der Wegen, 2013; Van Maanen et al., 2013b). (4) Salt-tolerant vegetation (e.g., salt marshes and mangroves) ~~is found to~~ play an important role ~~on~~in basin morphological evolution, which is not considered in this model. Several~~A number of~~ studies have indicated that vegetation can trap and stabilize sediment by decreasing the flow velocity (Townend et al., 2016; Chen et al., 2018). On the other hand, the sedimentary environment can also help vegetation ~~to~~ grow, forming positive feedback between morphology and vegetation.

5 Conclusion

This experiment numerically investigates ~~In this experiment, we numerically investigate~~ the long-term effects of the distribution and amount of mouth islands in a back-barrier tidal system~~the effects of the number and the spatial distribution of geological mouth islands on long-term evolution of a back-barrier tidal inlet system~~. Model r~~R~~esults indicate that~~both~~ the flow velocity and residual currents increase with the number of islands,~~ thus~~ enhancing the sediment transport and bed level change near the inlet. The basin tends to erode while the ebb-delta shows sedimentation, and the erosion/sedimentation volume increases with the number of mouth islands~~Erosion tends to occur in the tidal basin and sedimentation in the ebb-delta area, and the erosion (sedimentation) volume increases with the increase in the number of mouth islands~~. The spatial distribution of mouth islands is also ~~found to be~~ essential~~important~~ in~~to~~ determin~~e~~ing the local channel-shoal morphology of the basin and the ebb delta. If a mouth island is located towards the inlet side, it enhances the ebb dominance of tidal currents and promotes erosion at the basin and deposition at the ebb delta~~If a mouth island is located at the basin side near the inlet, it tends to enhance the ebb dominance of tidal currents and hence favours the erosion of the basin while the~~

deposition of the ebb delta. If a mouth island is located at the delta side near the inlet, it can directly hinder and divert the landward tidal current entering the basin and decreases theplay an inhibiting role for basin morphological development. Besides, model rResults also suggest that the number and location of mouth islands can affect the empirical relation between the tidal prism and inlet cross-sectional area (the so-called P-A relation): the basin tidal prism increases with the number of

590   islandsmore mouth islands result in larger tidal prisms in the basin; a basin-side island near the inlet also leads to larger tidal prisms than that of thea delta-side island. The influence of mouth islands on local areas (e.g., tidal inlet) is solid but weak on the upstream estuary where river influence is dominantThe influence of mouth island on local areas (e.g., tidal inlet) is evident but very limited on the upstream estuary zone (where river starts to dominate). Aspects that are not well reproduced appear to relate to processes that have been omitted (e.g., initial bathymetry and sediment composition) and

595   would merit further investigation. Overall, this study shed lights on the long-term morphodynamic effect of the influence of mouth islands (which may be submerged under future sea level rise) on the long-term morphodynamic evolution of tidal basins, hence providing new insights into the evolution of these this systems.

Code and data availability

The results are simulated using the open-source Delft3D software package (Delft3D-flow version 4.03.01) and the code is

600   accessible through the https://oss.deltares.nl/web/delft3d. The input files of the default model are available at Zenodo: https://doi.org/10.5281/zenodo.5508801 (Wei, 2021).

Author contributions

Yizhang Wei, Zeng Zhou and Yining Chen proposed the idea for this study. Zeng Zhou, Qin Jiang, Zheng Gong and Changkuan Zhang acquired the funding. Yizhang Wei built the numerical model, processed and analysed the data, and

605   wrote the manuscript. Zeng Zhou, Yining Chen, Peng Yao, Jufei Qiu,, Ian Towend and Giovanni Coco provided logistical support and revised the manuscript. All authors were involved in reviewing and editing the manuscript, and gave final approval of the version to be published. The authors also thank the reviewers for providing detailed and constructive feedback.

Competing interests

610   The authors declare that they have no conflict of interest.

Acknowledgements

This study is supported by the National Key Research and Development Program of China (Grant No.2018YFC0407501), the National Natural Science Foundation of China (NSFC, Grant Nos. 41976156, 51620105005), and the Natural Science Foundation of Jiangsu Province (Grant No. BK20200077), and the Fundamental Research Funds for the Central

615   Universities (Grant No. B210204022).

References

Andriani, G. F. and Walsh, N.: Rocky coast geomorphology and erosional processes: a case study along the Murgia coastline South of Bari, Apulia—SE Italy, Geomorphology, 87, 224-238, https://doi.org/10.5281/10.1016/j.geomorph.2006.03.033, 2007.

620   Chen, F., Liu, W., Chen, R., Lin, R., Xu, Q., Chen, Y., Qiu, H., and Zhou, D.: Gulf records of China (Volume 8), Ocean Press, 310-343 pp.1993.

Chen, Y., Li, Y., Thompson, C., Wang, X., Cai, T., and Chang, Y.: Differential sediment trapping abilities of mangrove and saltmarsh vegetation in a subtropical estuary, Geomorphology, 318, 270-282, https://doi.org/10.1016/j.geomorph.2018.06.018, 2018.

625   Coco, G., Zhou, Z., van Maanen, B., Olabarrieta, M., Tinoco, R., and Townend, I.: Morphodynamics of tidal networks: Advances and challenges, Mar. Geol., 346, 1-16, https://doi.org/10.1016/j.margeo.2013.08.005, 2013.

D'Alpaos, A.: Tidal network ontogeny: Channel initiation and early development, J. Geophys. Res., 110, F02001-F02001, https://doi.org/10.1029/2004jf000182, 2005.

D'Alpaos, A., Lanzoni, S., Marani, M., and Rinaldo, A.: On the tidal prism–channel area relations, J. Geophys. Res., 115,

630   F01003-F01003, https://doi.org/10.1029/2008jf001243, 2010.

Dastgheib, A., Roelvink, J. A., and Wang, Z. B.: Long-term process-based morphological modeling of the Marsdiep Tidal Basin, Mar. Geol., 256, 90-100, https://doi.org/10.1016/j.margeo.2008.10.003, 2008.

De Swart, H. E. and Zimmerman, J. T. F.: Morphodynamics of Tidal Inlet Systems, Annu. Rev. Fluid. Mech., 41, 203-229, https://doi.org/10.1146/annurev.fluid.010908.165159, 2009.

635   Dissanayake, D. M. P. K., Ranasinghe, R., and Roelvink, J. A.: The morphological response of large tidal inlet/basin systems to relative sea level rise, Climatic Change, 113, 253-276, https://doi.org/10.1007/s10584-012-0402-z, 2012.

Dronkers, J. J., Misdorp, R., and Spradley, J.: Strategies for adaptation to sea level rise, Ministry of Transport and Public Works, Rijkswaterstaat, Tidal Waters Division.1990.

Engelund, F. and Hansen, E.: A monograph on sediment transport in alluvial streams, Teknisk Forlag, 62-62 pp.1967.

640   Fagherazzi, S. and Wiberg, P. L.: Importance of wind conditions, fetch, and water levels on wave-generated shear stresses in shallow intertidal basins, J. Geophys. Res., 114, F03022-F03022, https://doi.org/10.1029/2008jf001139, 2009.

Feola, A., Belluco, E., D'Alpaos, A., Lanzoni, S., Marani, M., and Rinaldo, A.: A geomorphic study of lagoonal landforms, Water. Resour. Res., 41, W06019, https://doi.org/10.1029/2004wr003811, 2005.

FitzGerald, D. M.: Origin and Stability of Tidal Inlets in Massachusetts, in, edited by: Aubrey, D. G., and Giese, G. S.,

645   American Geophysical Union, 1-61, https://doi.org/10.1029/CE044p0001, 1993.

FitzGerald, D. M. and Miner, M. D.: Tidal Inlets and Lagoons along Siliciclastic Barrier Coasts, in, Academic Press, 149-165, https://doi.org/10.1016/B978-0-12-374739-6.00278-5, 2013.

Ford, K. H.: Seafloor Sediment Composition in Massachusetts Determined Using Point Data, https://doi.org/10.13140/RG.2.2.23565.33766, 2010.

650   Friedrichs, C. T.: Stability shear stress and equilibrium cross-sectional geometry of sheltered tidal channels, J. Coastal. Res., 11, 1062-1074, 1995.

Friedrichs, C. T. and Aubrey, D. G.: Non-linear tidal distortion in shallow well-mixed estuaries: a synthesis, Estuar. Coast. Shelf. S., 27, 521-545, https://doi.org/10.1016/0272-7714(88)90082-0, 1988.

Gao, S.: P-A relationships of tidal inlets along the east china sea coast, Marine Sciences, 15-19, 1988.

655   Gontz, A. M., Maio, C. V., and Rueda, L.: The Duxbury Sunken Forest-Constraints for Local, Late Holocene Environmental Changes Resulting from Marine Transgression, Duxbury Bay, Eastern Massachusetts, USA, Journal of Coastal Research, 29, 168-176, https://doi.org/10.2112/JCOASTRES-D-12-00183.1, 2013.

Guo, L., van der Wegen, M., Roelvink, J. A., and He, Q.: The role of river flow and tidal asymmetry on 1-D estuarine morphodynamics, Journal of Geophysical Research: Earth Surface, 119, 2315-2334,

660   https://doi.org/10.1002/2014jf003110, 2014.

Guo, L., van der Wegen, M., Roelvink, D. J. A., Wang, Z. B., and He, Q.: Long-term, process-based morphodynamic modeling of a fluvio-deltaic system, part I: The role of river discharge, Cont. Shelf. Res., 109, 95-111, https://doi.org/10.1016/j.csr.2015.09.002, 2015.

Hayes, M. O.: General morphology and sediment patterns in tidal inlets, Sediment. Geol., 26, 139-156,

665   https://doi.org/10.1016/0037-0738(80)90009-3, 1980.

Herrling, G. and Winter, C.: Morphological and sedimentological response of a mixed-energy barrier island tidal inlet to storm and fair-weather conditions, Earth. Surf. Dynam., 2, 363-382, https://doi.org/10.5194/esurf-2-363-2014, 2014.

Huang, Z. and Zhang, L.: Dictionary of Earth Sciences: Volume of Basic Sciences, 11, Geological Publishing House, China, 1201 pp.2006.

670   Jagoutz, O. and Behn, M. D.: Foundering of lower island-arc crust as an explanation for the origin of the continental Moho, NATURE, 504, 131-134, https://doi.org/10.1038/nature12758, 2013.

Jarrett, J. T.: Tidal Prism - Inlet Area Relationships, US Department of Defense, Department of the Army, Corps of Engineers1976.

Jiang, M. and Meng, Z.: The Massachusetts Bay Hydrodynamic Model: 2005 Simulation, 2008.

675 Knebel, H. J., Rendigs, R. R., and Bothner, M. H.: Modern sedimentary environments in Boston Harbor, Massachusetts, Journal of Sedimentary Petrology, 61, 791-804, https://doi.org/10.1306/D42677D5-2B26-11D7-8648000102C1865D, 1991.

Lanzoni, S. and Seminara, G.: Long-term evolution and morphodynamic equilibrium of tidal channels, J. Geophys. Res., 107, 3001-3001, https://doi.org/10.1029/2000jc000468, 2002.

680 Le Conte, L. J. and Harts, W. W.: Discussion of ``Notes On the Improvement of River and Harbor Outlets In The United States'', T. Am. Soc. Civ. Eng., 55, 306-317, 1905.

Leonardi, N., Canestrelli, A., Sun, T., and Fagherazzi, S.: Effect of tides on mouth bar morphology and hydrodynamics, J. Geophys. Res-Oceans., 118, 4169-4183, https://doi.org/10.1002/jgrc.20302, 2013.

Lesser, G. R., Roelvink, J. A., van Kester, J. A. T. M., and Stelling, G. S.: Development and validation of a three-
685 dimensional morphological model, Coast. Eng., 51, 883-915, https://doi.org/10.1016/j.coastaleng.2004.07.014, 2004.

Liu, X. and Liu, H.: A study on the origin and classification of ocean islands, Geographical Research, 119-127, 2008.

Marciano, R.: Modeling of channel patterns in short tidal basins, J. Geophys. Res., 110, F01001-F01001, https://doi.org/10.1029/2003jf000092, 2005.

Murray, A. B., Knaapen, M. A. F., Tal, M., and Kirwan, M. L.: Biomorphodynamics: Physical-biological feedbacks that
690 shape landscapes, Water. Resour. Res., 44, W11301, https://doi.org/10.1029/2007wr006410, 2008.

Nahon, A., Bertin, X., Fortunato, A. B., and Oliveira, A.: Process-based 2DH morphodynamic modeling of tidal inlets: A comparison with empirical classifications and theories, Mar. Geol., 291-294, 1-11, https://doi.org/10.1016/j.margeo.2011.10.001, 2012.

O'Brien, M. P.: Estuary tidal prisms related to entrance areas, Civil. Eng., 1, 738-739, 1931.

695 Otvos, E. G.: Development and Migration of Barrier Islands, Northern Gulf of Mexico, Geol. Soc. Am. Bull., 81, 241-246, https://doi.org/10.1130/0016-7606(1970)81[241:DAMOBI]2.0.CO;2, 1981.

Powell, M. A., Thieke, R. J., and Mehta, A. J.: Morphodynamic relationships for ebb and flood delta volumes at Florida's tidal entrances, Ocean Dynamics, 56, 295-307, https://doi.org/10.1007/s10236-006-0064-3, 2006.

Ranasinghe, R., Swinkels, C., Luijendijk, A., Roelvink, D., Bosboom, J., Stive, M., and Walstra, D. J. C. E.:
700 Morphodynamic upscaling with the MORFAC approach: Dependencies and sensitivities, Coastal Engineering, 58, 806-811, https://doi.org/10.1016/j.coastaleng.2011.03.010, 2011.

Roelvink, J. A.: Coastal morphodynamic evolution techniques, Coast. Eng., 53, 277-287, https://doi.org/10.1016/j.coastaleng.2005.10.015, 2006.

Rosen, P. S. and Leach, K.: Sediment Accumulation Forms, Thompson Island, Boston Harbor, Massachusetts, Glaciated
705 Coasts, 233-250, 1987.

Savenije, H. H. G.: Salinity and Tides in Alluvial Estuaries, Elsevier, 163-163 pp., https://doi.org/10.1016/B978-0-444-52107-1.X5000-X, 2012.

Signell, R. P. and Butman, B.: Modeling tidal exchange and dispersion in Boston Harbor, Journal of Geophysical Research: Oceans, 97, 15591-15606, https://doi.org/10.1029/92JC01429, 1992.

710 Stefanon, L., Carniello, L., D Alpaos, A., and Lanzoni, S.: Experimental analysis of tidal network growth and development, Cont. Shelf. Res., 30, 950-962, https://doi.org/10.1016/j.csr.2009.08.018, 2010.

Townend, I.: An Examination of Empirical Stability Relationships for UK Estuaries, J. Coastal. Res., 215, 1042-1053, https://doi.org/10.2112/03-0066r.1, 2005.

Townend, I., Wang, Z. B., Stive, M., and Zhou, Z.: Development and Extension of An Aggregated Scale Model: Part 2-
715 Extensions to ASMITA, China Ocean Engineering, 030, 651-670, https://doi.org/10.1007/s13344-016-0042-6 2016.

Townend, I. H.: Hypsometry of estuaries, creeks and breached sea wall sites, P. I. Civil. Eng-Mar En., 161, 23-32, https://doi.org/10.1680/maen.2008.161.1.23, 2008.

Tubman, M. W.: Boston Harbor navigation channel improvement project, field data collection program final report, 2007.

van der Wegen, M.: Numerical modeling of the impact of sea level rise on tidal basin morphodynamics, J. Geophys. Res-
720 Earth., 118, 447-460, https://doi.org/10.1002/jgrf.20034, 2013.

van der Wegen, M. and Roelvink, J. A.: Long-term morphodynamic evolution of a tidal embayment using a two-dimensional, process-based model, J. Geophys. Res., 113, 16-16, https://doi.org/10.1029/2006jc003983, 2008.

van der Wegen, M. and Roelvink, J. A.: Reproduction of estuarine bathymetry by means of a process-based model: Western Scheldt case study, the Netherlands Geomorphology, 179, 152-167,
725 https://doi.org/10.1016/j.geomorph.2012.08.007, 2012.

van der Wegen, M., Dastgheib, A., and Roelvink, J. A.: Morphodynamic modeling of tidal channel evolution in comparison to empirical PA relationship, Coast. Eng., 57, 827-837, https://doi.org/10.1016/j.coastaleng.2010.04.003, 2010.

730 van der Wegen, M., Wang, Z. B., Savenije, H. H. G., and Roelvink, J. A.: Long-term morphodynamic evolution and energy dissipation in a coastal plain, tidal embayment, Journal of Geophysical Research, 113, F03001-F03001, https://doi.org/10.1029/2007jf000898, 2008.

van Maanen, B., Coco, G., and Bryan, K. R.: Modelling the effects of tidal range and initial bathymetry on the morphological evolution of tidal embayments, Geomorphology, 191, 23-34, https://doi.org/10.1016/j.geomorph.2013.02.023, 2013a.

735 van Maanen, B., Coco, G., Bryan, K. R., and Friedrichs, C. T.: Modeling the morphodynamic response of tidal embayments to sea-level rise, Ocean. Dynam., 63, 1249-1262, https://doi.org/10.1007/s10236-013-0649-6, 2013b.

Vivoni, E. R., Di Benedetto, F., Grimaldi, S., and Eltahir, E. A. B.: Hypsometric control on surface and subsurface runoff, Water. Resour. Res., 44, 181-198, https://doi.org/10.1029/2008wr006931, 2008.

Vousdoukas, M. I., Ranasinghe, R., Mentaschi, L., Plomaritis, T. A., Athanasiou, P., Luijendijk, A., and Feyen, L.: Sandy
740 coastlines under threat of erosion, Nature Climate Change, 10, 260-263, https://doi.org/10.1038/s41558-020-0697-0, 2020.

Wang, Z. B., Hoekstra, P., Burchard, H., Ridderinkhof, H., De Swart, H. E., and Stive, M. J. F.: Morphodynamics of the Wadden Sea and its barrier island system, Ocean. Coast. Manage., 68, 39-57, https://doi.org/10.1016/j.ocecoaman.2011.12.022, 2012.

745 Webb, A. P. and Kench, P. S.: The dynamic response of reef islands to sea-level rise: Evidence from multi-decadal analysis of island change in the Central Pacific, Global. Planet. Change., 72, 234-246, https://doi.org/10.1016/j.gloplacha.2010.05.003, 2010.

Wei, Y.: The role of geological mouth islands on the morphodynamics of back-barrier tidal basins [Data set], https://doi.org/10.5281/zenodo.550880, 2021.

750 Zhou, Z., van der Wegen, M., Jagers, B., and Coco, G.: Modelling the role of self-weight consolidation on the morphodynamics of accretional mudflats, Environmental Modelling & Software, 76, 167-181, https://doi.org/10.1016/j.envsoft.2015.11.002, 2016.

Zhou, Z., Coco, G., Jiménez, M., Olabarrieta, M., van der Wegen, M., and Townend, I.: Morphodynamics of river-influenced back-barrier tidal basins: The role of landscape and hydrodynamic settings, Water. Resour. Res., 50, 9514-
755 9535, https://doi.org/10.1002/2014wr015891, 2014a.

Zhou, Z., Olabarrieta, M., Stefanon, L., D'Alpaos, A., Carniello, L., and Coco, G.: A comparative study of physical and numerical modeling of tidal network ontogeny, J. Geophys. Res-Earth., 119, 892-912, https://doi.org/10.1002/2014jf003092, 2014b.

Zhou, Z., Coco, G., Townend, I., Olabarrieta, M., van der Wegen, M., Gong, Z., D Alpaos, A., Gao, S., Jaffe, B. E.,
760 Gelfenbaum, G., He, Q., Wang, Y., Lanzoni, S., Wang, Z., Winterwerp, H., and Zhang, C.: Is "Morphodynamic Equilibrium" an oxymoron?, Earth-Science Reviews, 165, 257-267, https://doi.org/10.1016/j.earscirev.2016.12.002, 2017.