EVREST Evolution and Resilience of Barrier Island Systems

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Report Title	Modelling morphological impact of sea-level rise in the Ria Formosa lagoon
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1. Introduction

This report covers the activities performed in the framework of the following tasks: 'Task 4: Modelling barrier island and lagoon system', subtask 4.1. Model Setup; and subtask 4.2. Definition of RSLR and storm impact modelling scenarios.

The objective of this task was to assess the morphological evolution of the barrier islands and lagoon system according to different SLR and storm impact scenarios.

This task was programmed for a duration of 14 months, to which this report refers, was coordinated by A. Rita Carrasco, with the collaboration of Óscar Ferreira and Theocharis Plomaritis.

The modelling approach was developed by A. Rita Carrasco, and the obtained results were acquired by Kim van den Hoven, during a six-month internship (see Hoven, 2019).

Methods and results are described in detail in sections 2 to 3, including references to publications and websites.

2. Modelling Approach

2.1 Study area

The impacts of sea-level rise (SLR) over the Ria Formosa lagoon in 2100, from the 2011 baseline year, were accessed for the tidal channels and inlets identified in Figure 1. The study area includes the Faro-Olhão and Armona inlets and the main tidal channels running from them, Culatra, Olhão, and Armona channel (Figure 1). Olhão channel starts at the Faro-Olhão inlet and runs up to the port of Olhão. Culatra channel flows north of Culatra island, in between the bifurcation from Olhão channel and Armona inlet. Armona channel runs between Armona inlet and Olhão port.

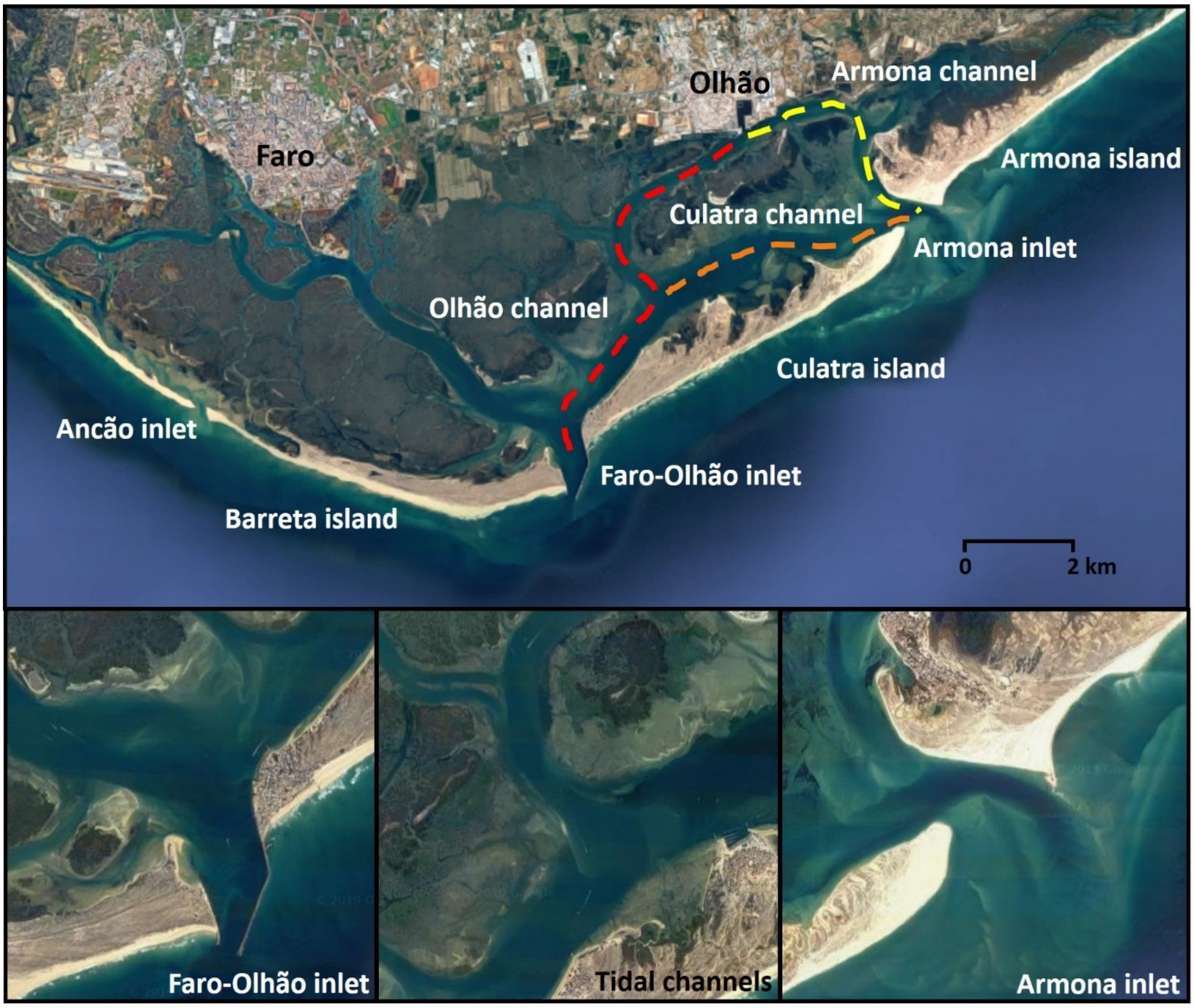

Figure 1. Study area in the Ria Formosa lagoon including Olhão (red), Culatra (orange), Armona (yellow) channels and Faro-Olhão and Armona inlets. Photographs taken from Google Earth (images obtained on 19/11/2017) (Hoven, 2019).

2.2 Model setup

A modelling approach previously used by Gonzalez-Gorbeña et al. (2018) and Carrasco et al. (2018), using Delft3D-FLOW was applied. The hydrodynamics module was coupled to morphodynamics for a 2D depth averaged simulation (Lesser et al., 2004). Building on a calibrated and validated baseline model from Gonzalez-Gorbeña et al. (2018), a few adjustments were made to optimize settings for the present research focus. Several observation points and cross-sections were distributed in the study area to monitor morphological impacts of sea-level rise (Figure 2).

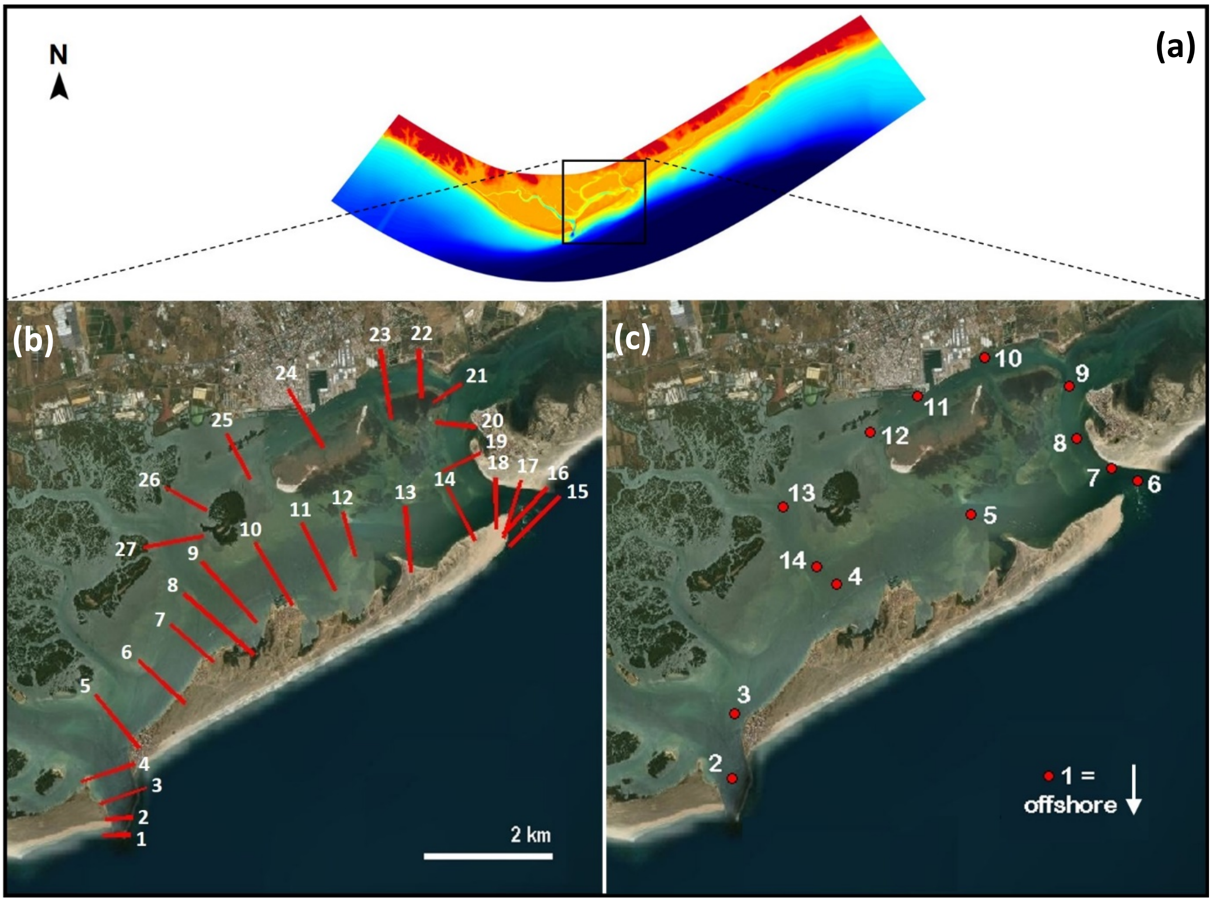

Figure 2. (a) Model domain, (b) zoom to study area showing the cross sections used to monitor the bathymetric changes, and (c) zoom to the study area showing the observation points used to monitor the hydrodynamic changes induced by sea-level rise (adapted from Hoven, 2019).

The model bathymetry was based on LIDAR data obtained in 2011 and bathymetric surveys from 2016 (González-Gorbeña et al., 2018). A curvilinear orthogonal grid followed the cuspate shape of the Ria Formosa lagoon. The 492 N x 1100 M grid had a varying resolution to capture the complex morphology. Resolution differed from 750 x 175 m offshore to 20 x 15 m in the inlets and was continuously refined. Waves were neglected in the model set-up. The model was forced with an

offshore water level boundary and with water level gradients at the cross-shore Neumann boundaries. Astronomical forcing consisted of a combination of the M2 component, an M2 amplitude correction factor, and a morphological tide correction (see Gonzalez-Gorbeña et al., 2018 for more details). The main local tidal constituents were derived from the TPXO global tidal model (Egbert and Erofeeva, 2002). The amplitude of the main tidal constituent, the M2, was corrected to the Ria Formosa area. The morphological tide was applied to represent a full year astronomical tide in combination with the use of a morphological acceleration factor (morfac, see Lesser et al., 2004), by producing similar residual transport and morphological evolution (Lesser, 2009).

A spin-up time of 1 day and a time-step of 30 seconds were adopted. Manning coefficient values were assigned for bottom friction. Besides the original morfac value of 48, an additional morfac value of 100 was tested to evaluate the effect of a stronger morphological acceleration on the morphological evolution of the tidal channels. The conducted simulations enclosed a simulation time frame of 92.25 days (for more details see Hoven, 2019).

2.2 Definition of SLR and modelling scenarios

Sea-level rise estimates used in the modelling scenarios accounted for the latest global IPCC projections (in agreement with Carrasco et al., 2018). The worst-case scenario RCP8.5, predicting an increase of 0.98 m SLR by 2100 (highest value of the likely range), was tested in this study (IPCC, 2014; 2019). Sea-level rise was incorporated in the model as a linear increase of water level over time (e.g., Best et al., 2018)

The morphological evolution of the lagoon was predicted for 2011 to 2100 period. Two modelling conditions were simulated: (1) without SLR; and (2) with SLR. The following time steps were used for analysis: year 2011 (model baseline), 2036, 2061, 2086, and 2100 (end of simulation after 89 years).

3. Morphological evolution in the lagoon: global trends

Small accretion and erosion patterns were observed in the study area between 2011 and 2100, for both modelling conditions, without and with SLR. Being most apparent in the tidal inlet regions, in the channels near the inlets, and in the region west of Faro-Olhão inlet (in between Faro-Olhão inlet and Ancão inlet, Figure 3); within these regions, bathymetric differences of about 1 m between the two modelling conditions were observed (Figure 4). Saltmarsh areas and the secondary tidal channels revealed low magnitude bathymetric changes (Figure 4).

The bathymetry of Culatra channel and the upstream part of Olhão channel seemed unchangeable during the 89 years of simulation, regardless of the application of SLR. The Olhão and Armona channels

showed channel axis displacement towards the mainland in 2100. However, moving further away from the inlets, bathymetry of secondary tidal channels remained almost unchanged between 2011 and 2100 (Figure 4).

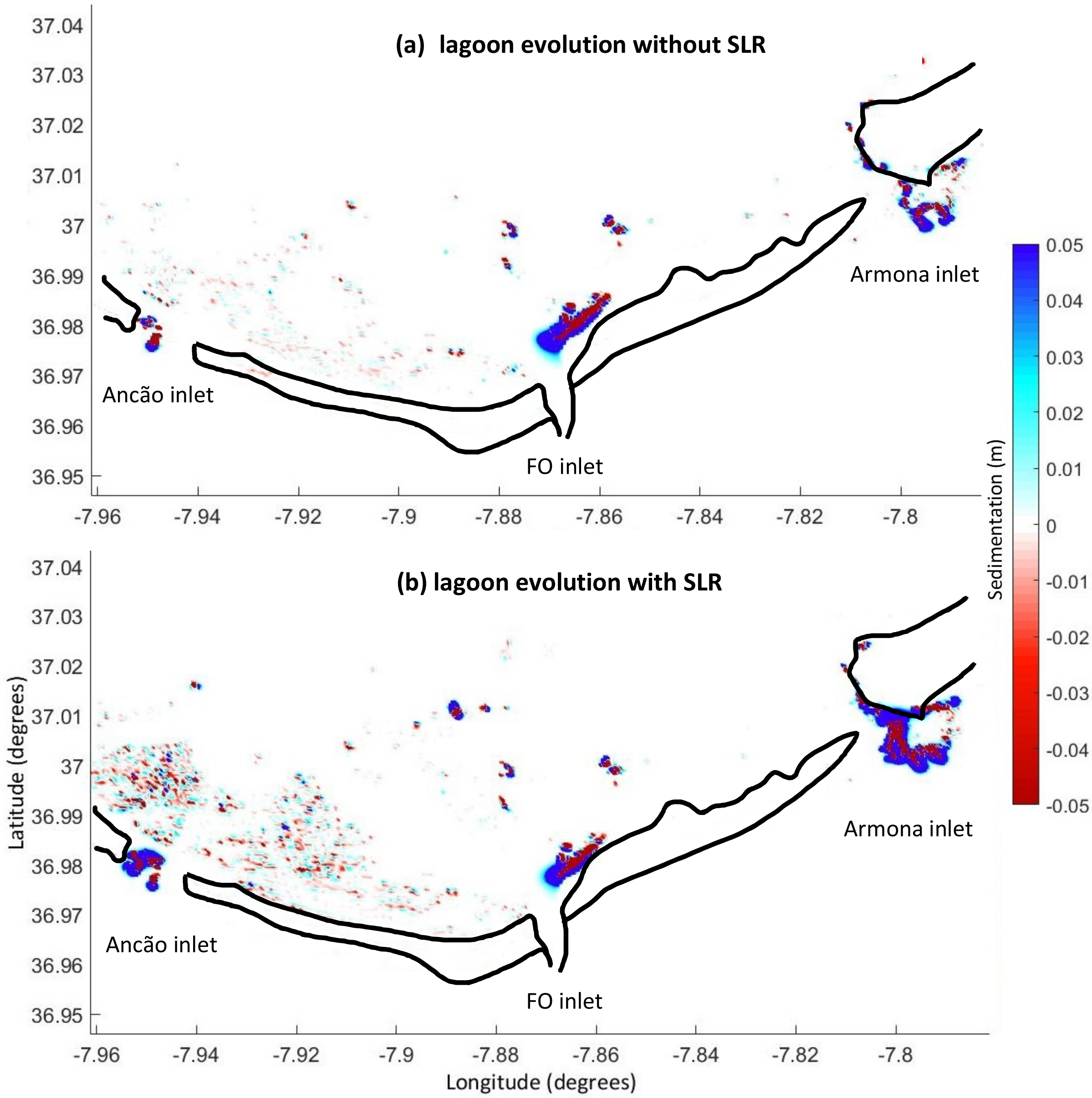

Figure 3. Bathymetric differences between the baseline bathymetry from 2011 and the bathymetry at the end of the simulations, year 2100, for the two modelling conditions: (a) without sea-level rise (SLR), and (b) with SLR (FO inlet refers to Faro-Olhão inlet; red colour refers to bottom erosion, blue colour refers to bottom accretion) (adapted from Hoven, 2019).

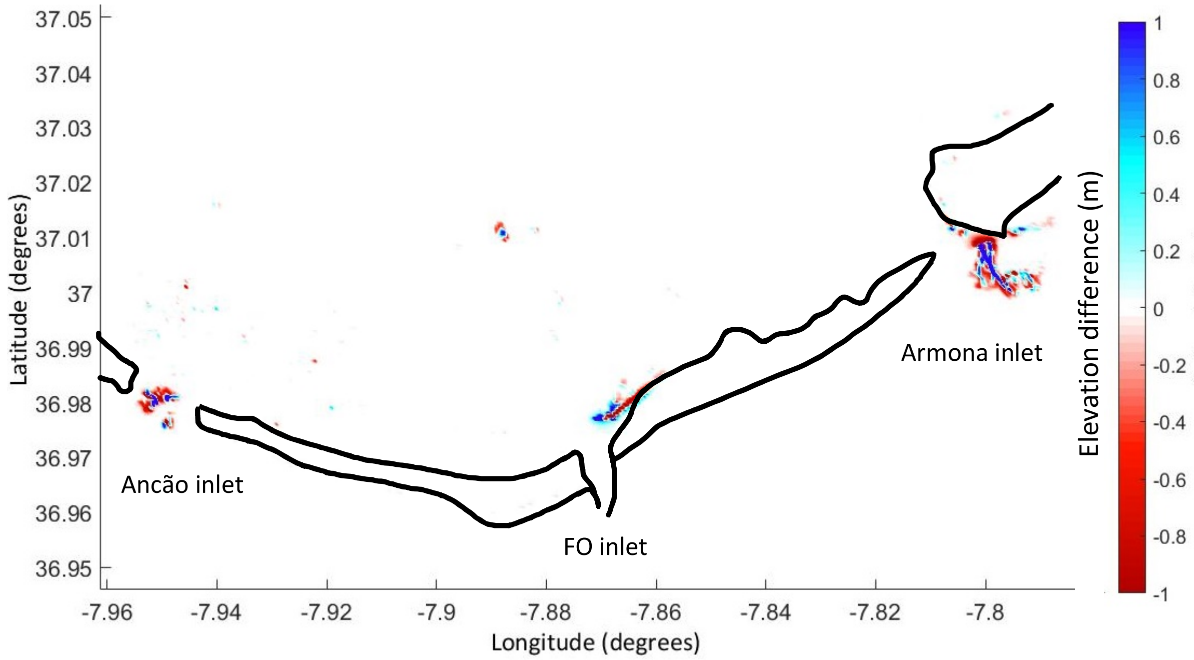

Figure 4. Bathymetric differences between the two modelling conditions, without sea-level rise (SLR) and with SLR, in 2100 (FO inlet refers to Faro-Olhão inlet; red colour refers to bottom erosion, blue colour refers to bottom accretion) (adapted from Hoven, 2019).

The low magnitude changes observed between 2011 and 2100 might be related to the low sediment transport concentrations verified during simulations, which could in turn be caused by the absence of additional sediment input sources in the model setup. Also, cohesive sediment was not modelled, and no mud transfer or transport within the system was considered. With limited sedimentary input, the only sediment exchange occurred by local erosion and accretion of the initial bathymetry. This can explain why bathymetric changes were focussed in the tidal inlet's vicinity, where velocity currents are usually high enough to enable sediment mobilization. Nevertheless, additional tests, are needed to be run.

4. Final Remarks

The conducted research is the first approach to study long-term sediment transport and adjacent morphological evolution in the Ria Formosa lagoon, as response to SLR. The adopted modelling approach elaborates on a scenario in which human intervention completely limits sediment input into the Ria Formosa lagoon, which can be considered as an extreme scenario. Moreover, no storm conditions were superimposed.

Obtained results point out modelling limitations that can and should be improved in the future. The three main limitations were: (1) an oversimplification of sediment input (grain-size and available sources), (2) exclusion of waves, and (3) a linear application of SLR, amongst other minor factors.

To be able to improve our understanding of the Ria Formosa system, some suggestions for future additions to the present modelling approach are:

- Include additional sediment sources to the model setup;
- Consider the influence of cohesive sediment;
- Represent vegetation throughout the lagoon;
- Include the effect of waves;
- Include the effect of wind;
- Improve the initial bathymetry around Armona inlet;
- Improve the grid resolution.

Furthermore, studying the influence of SLR on a coastal lagoon can be improved by the following:

- Apply accelerating SLR curves;
- Test additional SLR scenarios (e.g., based in national SLR data sources);
- Include human interventions, such as dredging activities.

5. References

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