Estuarine, Coastal and Shelf Science 167 (2015) 14–24

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Tidal dynamics in a changing lagoon: Flooding or not flooding the marginal regions

Carina L. Lopes, João M. Dias*

NMEC – Estuarine and Coastal Modelling Division, CESAM – Centre for Environmental and Marine Studies, Physics Department, University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal

ARTICLE INFO

Article history:
Accepted 23 May 2015
Available online 30 May 2015

Keywords:
Ria de Aveiro
tidal propagation
estuarine dynamics
tidal analysis
coastal morphology
future scenarios

ABSTRACT

Coastal lagoons are low-lying systems under permanent changes motivated by natural and anthropogenic factors. Ria de Aveiro is such an example with its margins currently threatened by the advance of the lagoonal waters recorded during the last decades. This work aims to study the tidal modifications found between 1987 and 2012 in this lagoon, motivated by the main channels deepening which induce higher inland tidal levels. Additionally it aims to study the impact that protective walls designed to protect the margins against flooding may have in those modifications under sea level rise predictions. The hydrodynamic model ELCIRC previously calibrated for Ria de Aveiro was used and tidal asymmetry, tidal ellipses and residual currents were analyzed for different scenarios, considering the mean sea level rise predicted for 2100 and the implementation of probable flood protection walls. Results evidenced that lagoon dominance remained unchanged between 1987 and 2012, but distortion decreased/increased in the deeper/shallower channels. The same trend was found under mean sea level rise conditions. Tidal currents increased over this period inducing an amplification of the water properties exchange within the lagoon, which will be stronger under mean sea level rise conditions. The deviations between scenarios with or without flood protection walls can achieve 60% for the tidal distortion and residual currents and 20% for the tidal currents, highlighting that tidal properties are extremely sensitive to the lagoon geometry. In summary, the development of numerical modelling applications dedicated to study the influence of mean sea level rise on coastal low-lying systems subjected to human influence should include structural measures designed for flood defence in order to accurately predict changes in the local tidal properties.

1. Introduction

Coastal lagoons are shallow water bodies that connect at least intermittently to the ocean by one or more restricted inlets (Kjerfve, 1994). The flow within a coastal lagoon is determined by the exchanges between the lagoon and the ocean, by the interaction with the atmosphere and by the discharge of its tributaries that promotes the resuspension of materials, nutrients and small organisms, contributing to their biological productivity (Alongi, 1998; Perez-Ruzafa et al., 2013; Umgiesser et al., 2014). However, their dynamics is constantly modified by changes on its drivers and on its geomorphological features induced by both natural and anthropogenic factors (Zhang et al., 2010; Song et al., 2013; Lopes et al., 2013a,b; Gao et al., 2014; Li et al., 2014).

Duck and da Silva (2012) described that the artificialization and regulation of inlets, the construction of port areas and terminals, the dredging operations and the construction of tanks for aquaculture are some common examples of man induced geomorphological changes occurring in several coastal lagoons worldwide, such as Ria de Aveiro, Venice, Vistula, Ria Formosa and Tuzla Lake lagoons.

Besides the increase of anthropogenic pressures in these systems the natural drivers are also being modified as result of climate changes. The global mean sea level rise (MSLR) motivated by the sea water thermal expansion and glacier melting is a very likely consequence of temperature increase expected for the end of 21st century (Church et al., 2013). As a consequence, the MSLR will impact sediment redistribution, the partitioning of habitats,

* Corresponding author.
E-mail addresses: carinalopes@ua.pt (C.L. Lopes), joao.dias@ua.pt (J.M. Dias).

http://dx.doi.org/10.1016/j.ecss.2015.05.043
0272-7714/

salinity, tidal range and submergence periods (Nicholls, 2011; Nicholls et al., 2011; IPCC, 2014). According to Ferrarin et al. (2014) the climate changes expected for the end of this century will strongly affect the dynamics of Mediterranean coastal lagoons. Numerically studying ten Mediterranean coastal lagoons, those authors found a homogenization of the lagoons physical features under climate change conditions. Moreover, in response to the anticipated increase of natural hazards it is expected a growing number of coastal protection measures to be build by man. Thus, the landward migration may be restricted due to human occupation and intervention (IPCC, 2014). Indeed, flood protection structures already exist in several coastal areas. The River Thames barrier gates in UK, various dikes around the Netherlands coastal region and mobile gates in the Venice lagoon inlets are just some examples of coastal protection works.

However, the sensitivity of tidal propagation to flooding confinement under MSLR scenarios in coastal areas, and especially in lagoons, was not studied deeply until the present. Pelling et al. (2013a) found that the tidal dynamics in the European Shelf under MSLR conditions is strictly dependent on the coastal geometry emphasizing the importance to define as precise as possible the position of protection walls in order to obtain accurate results.

Often, the consequences of MSLR in low-lying coastal systems are studied admitting vertical walls of unlimited height surrounding the entire domain and consequently no changes in the coastal geometry resulting from higher sea surface levels are allowed (Hong and Shen, 2012; Mendes et al., 2013; Picado et al., 2013; Valentim et al., 2013; Ahmadian et al., 2014; Chua and Xu, 2014). Moreover, other works consider the inundation of marginal areas but discard the construction of flood protection measures (Fortunato et al., 2013; Lopes et al., 2013a; Yang et al., 2015). In low-lying coastal lagoons subjected to high human influence such as Ria de Aveiro lagoon (Fig. 1) and where flood protection works are expected, these approaches may not be realistic. It is very likely that in future the inundation problems in Ria de Aveiro will be exacerbated by the MSLR, as the lagoon margins present reduced altitude. Nevertheless, as the lagoon adjacent region is a densely populated area, that presents also important biodiversity resources and various economic activities, flood protection works are expected in order to minimize the negative consequences of expected marginal inundation.

This study aims to investigate the tidal propagation changes within Ria de Aveiro motivated by geomorphological changes and by the MSLR through hydrodynamic modelling. Particularly, this study is focused initially on tidal modifications that occurred between 1987 and 2012 motivated by the main channels deepening and secondly on tidal modifications expected for the future as consequence of MSLR and consequent construction of flood protection walls in threatened regions. To achieve this goal the hydrodynamic model ELCIRC, previously calibrated for Ria de Aveiro

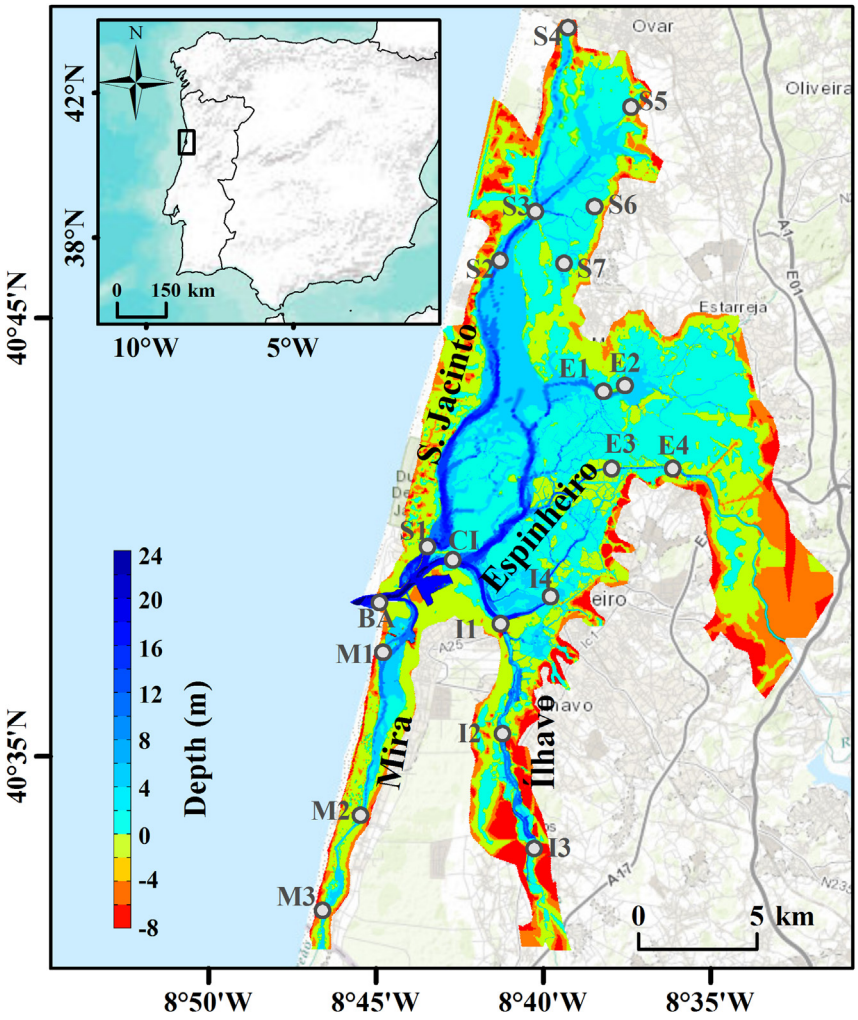

Fig. 1. Digital elevation model of Ria de Aveiro lagoon indicating the stations used to validated the hydrodynamic model.