Mapping inundation of estuarine margins driven by ocean and fluvial forcings

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ABSTRACT

Inundation maps are required for spatial planning. This paper describes the generation of inundation maps for the margins of the upstream region of the Tagus estuary (Portugal). Maps are constructed separately for a major river flood and an extreme storm surge, and then combined. The impact of sea level rise is also assessed.

1. Introduction

Spatial planning for territories located on the margins of water bodies requires inundation maps for both present and future conditions. Estuarine margins are a peculiar case, as they can be inundated by either oceanic phenomena, namely spring tides combined with storm surges, or extreme river flows. The dominant cause of inundation varies spatially: river floods dominate in the upper estuary, while floods of oceanic origin are preponderant downstream. To generate inundation maps for a municipality at the upstream limit of the Tagus estuary, flood events of oceanic and river origin are simulated separately. The final flood maps are generated by combining information for floods of oceanic and river origins.

2. Methods

Inundation maps were generated with a 2DH implementation of the shallow water model SCHISM (Zhang et al., 2016), including its wind-wave module WWM. The model domain (Fig. 1a) extends from the ocean to 90 km upstream, including all the areas that can potentially be flooded in the Vila Franca de Xira municipality located in the upper estuary. The grid resolution varies between 10 m in some floodable areas to 2000 m at the ocean boundary. Because this resolution is insufficient to represent narrow dikes, a row of nodes is placed over the crest of the dykes. The model is forced by tides, surges, waves, atmospheric pressure, wind and river flow (Fortunato et al., 2017). Elevation root-mean square errors are of the order of 5-20 cm for a one-year period (Fig. 1b). The model was also validated for extreme events, including a river flood with a return period of 100 years and a major storm with large waves. Past inundation occurrences were used for the spatial validation of the model results.

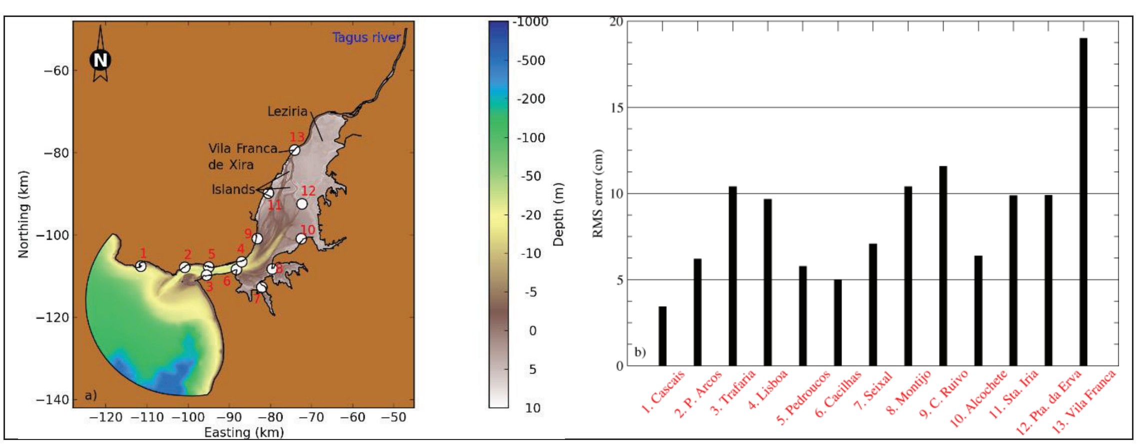

Fig. 1. Estuarine model: a) domain and bathymetry – the orange points indicate nodes located on the crest of the dykes; b) model validation

Inundation maps were generated for two events with return periods of the order of 100 years: the February 1941 cyclone, and the February 1979 river flood. Atmospheric conditions for the 1941 were provided by an application of the model WRF-ARW forced by the 20^{th} Century Reanalysis (20CRv2). These conditions were also used to force the wave model WW3 in the North Atlantic to provide the wave boundary conditions for the estuarine model (Fortunato et al., 2017). Atmospheric pressure, offshore significant wave height (Hs) and river flow reached 952 hPa, 14 m and 4500 m^3/s, respectively. For the 1979 flood, the hydrograph at the river boundary was obtained by routing the hydrograph gauged at the Almourol staff, 40 km upstream. Observations from another staff gauge were available closer to that boundary, but the rating curve was only defined inside the main channel. For river flows above 2200 - 4000 m^3/s (depending on the sediments accumulated in the riverbed), that rating curve is inadequate because the river spills onto the flood plain. Atmospheric pressure, Hs and river flow reached 998 hPa, 6 m and 15100 m^3/s, respectively.

3. Results and discussion

Inundation maps for the two extreme events described above were produced for the present mean sea level and assuming a 1.5 m sea level rise (Fig. 2). For each mean sea levels, the maps for the two events were combined by assuming the worst of the two scenarios at each location.

For the present mean sea level, the inundation of ocean origin includes the three islands, 15.5 km^2 in the left margin of the Tagus, and 4.1 km^2 in the right margin. For the river flood case, the Lezíria is partially flooded from upstream, and the three islands are also partially or totally flooded. In the right margin, the inundation is significantly smaller than for the storm surge case.

Considering an additional 1.5 m rise in mean sea level, the extent of the inundation increases drastically. The Lezíria and the three islands are totally inundated in the storm surge scenario. The extreme water levels increase from 2-3 m to about 4 m. This growth is due not only to the direct effect of the higher sea level, but also to an increase in the amplification of tidal amplitudes by resonance (Guerreiro et al., 2015). Flooding of ocean origin becomes more severe than the one of fluvial origin.

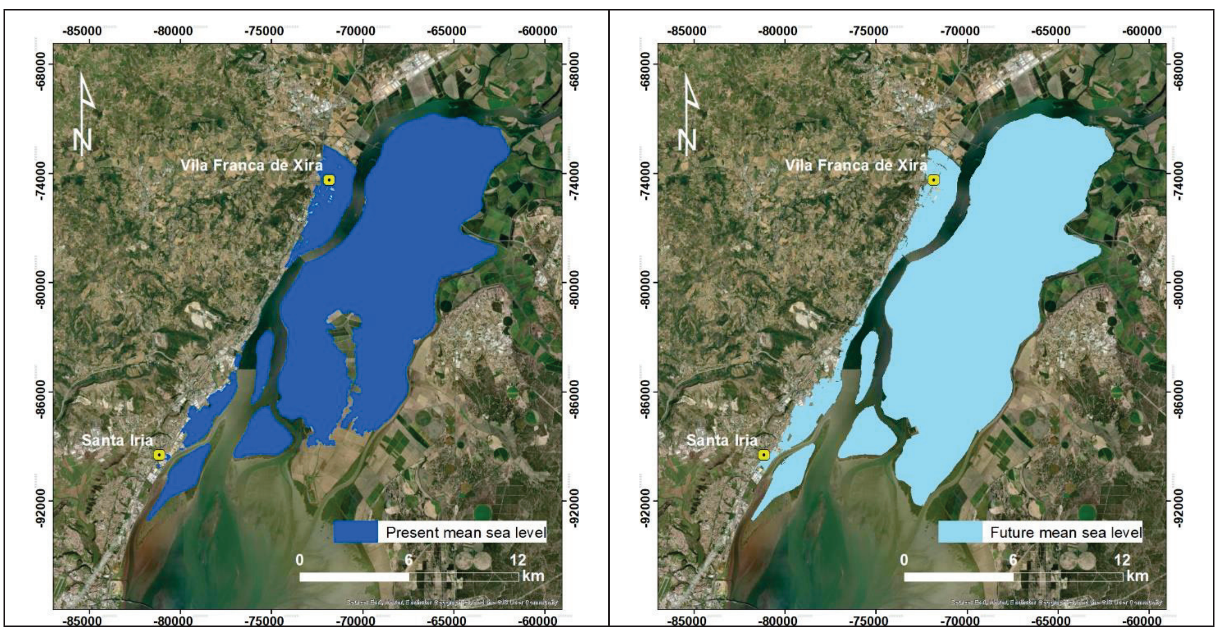

Fig. 2. Combined inundation of ocean and river origins in the upper Tagus estuary for the present and future mean sea levels

Acknowledgements

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