SHIP-INDUCED DEPRESSION WAKES AND SHORELINE EROSION

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Abstract
Shoreline retreat as an effect of ship wakes was studied in a navigation channel of the industrial port of Venice, Italy: the Malamocco-Marghera Channel. The investigation revealed unprecedented erosion rates, up to 4 m y^{-1}, that determined a total loss of about 1.2 million of m^3 of soil in the period 1970-2015. This interaction between navigation and the channel margins must be considered in order to understand the past evolution of the central Venice Lagoon and for a sustainable management of the port traffic in the future sea-level rise scenario.

Keywords: Gis, Erosion, Waves, Adriatic Sea

Ship traffic is one of the most important human activities in the world oceans and large navigable rivers. Besides underwater noise, pollution, and diffusion of invasive species, ship traffic introduces in the aquatic environment a considerable amount of energy in form of wake waves as vessels move along their routes. This has major morphological consequences in coastal and shallow water areas, as well as rivers and estuaries.
In confined or semi confined navigation channels depression wakes (figure 1) may cause extensive drawdown in the water level [1], propagate far from the channel [2] and play the largest role in sediment resuspension [3] and on the morphology of shoreline. This process is common in many areas worldwide and there are visual evidences of such wakes, for example, in the Elbe River in Germany, near Hamburg, where shoreline erosion is also an issue, the port of Fort Lauerdale in Florida, USA, and the Galveston-Houston Channel in Texas, USA.

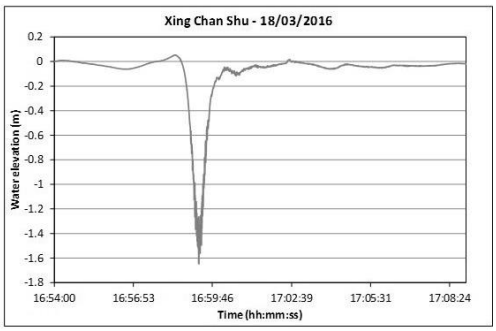

Fig. 1. Depression wake generated by the transit of a cargo ship (Xin Chang Shu, length 280 m, width 40 m, draught 10.3 m), in the Malamocco-Marghera channel, Venice Lagoon, Italy.

A study based on the analysis of historical aerial and satellite imagery combined with in situ measurements revealed a fast shoreline regression on the side of a major waterway in the Venice Lagoon, Italy (figure 2).
The research considered long and short-term recession rates caused by ship-induced depression wakes in an area which was reclaimed at the end of the '60s for the expansion of the nearby Porto Marghera Industrial Zone and was left unused since then. The GIS analysis performed with the available imagery shows an average retreat of about 4 m yr^{-1} in the period between 1965 and 2015. Field measurements carried out between April 2014 and January 2015 also revealed that the shoreline retreat still proceeds with a speed comparable to the long-term average regardless of the distance from the navigation channel, however is not constant through time. Periods of high water levels determined by astronomical tide or storm surges, more common in the winter season, are characterized by faster regressions. During these periods it is likely that wakes from ships can penetrate further inshore.

The retreat is proceeded by the collapse of slabs of the reclaimed muddy soil after erosion and removal of the underlying original salt marsh sandy sediments and is a discontinuous process in time and space depending on the morphology, properties and vegetation cover of the artificial deposits.

The digitalization of historical maps and new bathymetric surveys made in April 2015 enabled the construction of two digital terrain models for both past and present situations. The two models have been used to calculate the total volume of sediment lost during the period between 1970 and 2015: about 1.2 million of m^3. The results of this study shows that ship-channel interactions can dominate the morphodynamics of the waterway and its margins to a considerable distance and enable a better understanding as to how this part of the lagoon reacted to the pressure of human activities in the post-industrial period. Evaluation of the temporal and spatial variation of the shoreline position is also crucial for the development of future sea-level scenarios and for the management of the lagoon and its shallow water ecosystem.

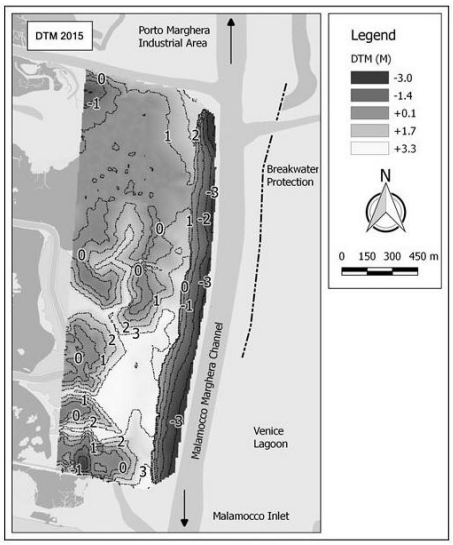

Fig. 2. Digital terrain model (DTM) of the studied area. In dark gray (negative values) the volumes removed from 1970 and 2015.

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