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Changes in the wind-wave field within the Venice Lagoon in the last four centuries and related salt-marsh lateral erosion

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Salt-marsh erosion by wind-wave attack is one of the main mechanisms leading to marsh loss in estuaries and lagoons worldwide and includes both the removal of small size particles and the sudden detachment of marsh-edge portions. The existence of a linear relationship between wave power density and salt-marsh lateral retreat has recently been demonstrated on theoretical and empirical grounds, although less attention has been devoted to the temporal evolution of wave power density. The aim of the present work is to evaluate, through the use of a two-dimensional Wind Wave Tidal Model (WWTM) that has been widely tested by comparing model results to hydrodynamic and wind-wave data collected in the Venice lagoon, the changes in the wave field through time and the effects of wave action on marsh boundaries. To this end, we first analysed the spatial distribution of wave power density during the last four centuries in the Venice Lagoon and then we investigated the relationship between the incident wave power density and salt-marsh erosion rate.
We applied the fully coupled WWTM to six different configurations of the Venice Lagoon (namely 1611, 1810, 1901, 1932, 1970 and 2012). The model was forced with a one-year-long record of water levels, wind speeds and directions collected in the Venice Lagoon in 2005, a representative year in terms of wind forcings. The determination of the wave height and wave group celerity within the Lagoon permits the computation of the wave power density, in the entire basin.
In order to obtain a map of the eroding margins we used two sets of aerial photographs, acquired in 1978 and 2010, whose georeferencing and superimposition allowed us to compute the erosion rate in the central and southern portions of the Venice Lagoon.
For each configuration we computed the mean wave power density (MWPD) over the one year-long simulations. We show that while the MWPD did not significantly change from 1611 to 1901, in the last century a rapid increase was observed due to the larger depths and fetches that characterize the most recent Lagoon configurations (1932, 1970 and 2012). In particular, in the central-southern part of the Lagoon the wind forcing can easily generate fetch unlimited conditions and the resulting wave field produces higher power densities.
The erosion rate (computed between 1978 and 2010) was associated to the MWPD of 1970 (R2= 0.93), 2012 (R2= 0.84) and 1994 (R2= 0.94), obtained through a linear interpolation of the 1970 and 2012 wave fields, in order to evaluate which MWPD field displayed the best correlation. The relationship between the erosion rate and the MWPD was observed to be linear for all the three cases. However, we obtained the best result when considering the intermediate MWPD of 1994 that accounts for the changes in the bathymetry that occurred between 1970 and 2012.