Wind wave-induced erosion in the Venice Lagoon in the last four centuries: a statistical characterization

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1. Introduction

The morphodynamic equilibrium of shallow tidal basins is strongly influenced by wind-wave induced erosion events (Fagherazzi et al., 2006; Green and Coco, 2014). The Venice Lagoon provides a clear example in this framework, as it has experienced strong erosion processes in the last centuries, which progressively deepened tidal flats, promoted the loss of fine cohesive sediments after storms, and led to extensive salt-marsh loss. We employed a fully-coupled finite element model to six historical configuration of the Venice Lagoon, namely 1611, 1810, 1901, 1932, 1970, and 2012, in order to analyse spatial and temporal characteristics of wind-wave induced erosion events, with the aim to develop a synthetic theoretical framework to study the long-term biomorphodynamic evolution of tidal environments.

2. Methods

We applied the fully-coupled wind-wave tidal model, developed by Carniello et al. (2011), to the six different configurations of the Venice Lagoon to analyse the temporal evolution and spatial distribution of the local bottom shear stress (BSS) on the basis of a "Peak Over Threshold" method, once a critical shear stress for the erosion of cohesive sediments, τ_c, was assumed. This allowed us to identify single erosion events, their interarrival time (the time between two consecutive cross-up occurrences), intensity, and duration for each historical configuration of the Lagoon. We performed a Kolmogorov-Smirnov goodness-of-fit test, to test the hypothesis that the interarrival time of events is a random variable described by an exponential distribution, and, consequently, the wind-wave induced over-threshold exceedances can be modeled as a Poisson process (D'Alpaos et al., 2013; Carniello et al., 2016). Where this hypothesis is verified, the erosion work (i.e., the annual erosion *sensu* Mariotti and Fagherazzi (2013)) is computed as a function of the mean interarrival, mean duration and mean intensity of the over-threshold event.

3. Results and Conclusions

For all the analysed historical configurations of the Venice Lagoon, our results suggest that the interarrival time between two events, their durations and intensities are exponentially distributed random variables over most of the tidal and subtidal flats within the lagoon and, thus, resuspension events can be modeled as a marked Poisson process. In general, we show that, along the last four centuries, the interarrival times of erosion events have increased, as well as their durations and intensities, thus leading to less frequent but stronger events. Interestingly, the erosion work, which is a combination of frequency, duration and intensity of resuspension events, remained almost constant until the beginning of the 20th century, when it rapidly increased showing a maximum in 1970 and finally decreaseg in the present configuration. We therefore highlight that because of the generalized deepening of the basin, the wind-wave induced erosive trend is slightly decreasing over time after having reached a peak in the recent past.

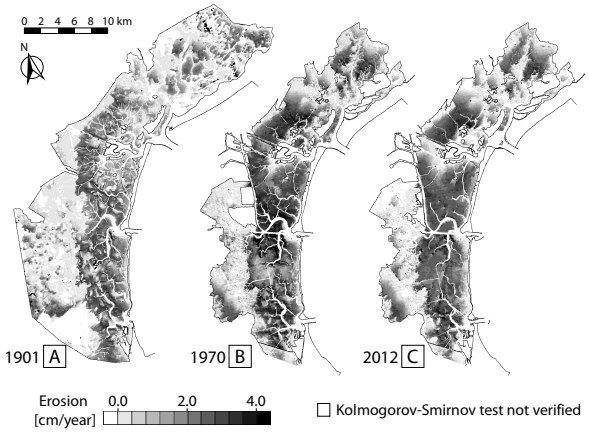

Figure 1. Spatial distribution of the erosion work, at sites where bed shear stress can be modelled as a marked Poisson process, for three different configurations of the Venice Lagoon: 1901 (a), 1970 (b), and 2012 (b).

References

Carniello, L., D'Alpaos, A., Botter, G., and Rinaldo, A. (2016). Statistical characterization of spatiotemporal sediment dynamics in the Venice lagoon. *Journal of Geophysical Research: Earth Surface*.

Carniello, L., D'Alpaos, A., and Defina, A. (2011). Modeling wind waves and tidal flows in shallow micro-tidal basins. *Estuarine, Coastal and Shelf Science*.

D'Alpaos, A., Carniello, L., and Rinaldo, A. (2013). Statistical mechanics of wind wave-induced erosion in shallow tidal basins: Inferences from the Venice Lagoon. *Geophysical Research Letters*.

Fagherazzi, S., Carniello, L., D'Alpaos, L., and Defina, A. (2006). Critical bifurcation of shallow microtidal landforms in tidal flats and salt marshes. *Proceedings of the National Academy of Sciences*.

Green, M. O. and Coco, G. (2014). Review of wave-driven sediment resuspension and transport in estuaries. *Reviews of Geophysics*.

Mariotti, G. and Fagherazzi, S. (2013). Wind waves on a mudflat: The influence of fetch and depth on bed shear stresses. *Continental Shelf Research*.