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Rethinking the resilience of salt marshes to land subsidence and sea-level rise: The RESTORE project approach

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INTRODUCTION

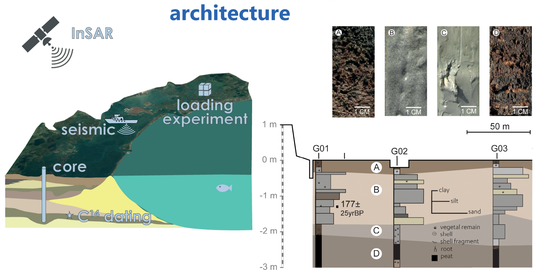
Salt marshes are among the most productive ecosystems in the world, supporting various natural functions and providing important ecosystem services to human society. Because of their low elevation, salt marshes are expected to be severely threatened by the accelerated sea-level rise (SLR) and their resilience will depend on the capability to keep pace with SLR. Recent field studies and modelling analyses suggest that Holocene events in terms of sedimentation rates and lithology distribution could significantly influence the evolution and resilience of salt marshes under expected climate changes.

AIM

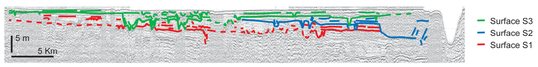
Using the Venice Lagoon (Italy) as a case study, the project RESTORE: Reconstruct subsurface heterogeneities and quantify sediment needs TO improve the REsilience of Venice saltmarshes proposes a new multidisciplinary approach that combines geological conceptualizations, numerical modelling, and vulnerability assessment to quantify the amount of sediment needed by the salt marshes to keep pace with the relative SLR. Specific attention is paid to the architecture of the shallow subsurface and the type of deposits, which play a key role in the process of land subsidence and autocompaction, i.e., natural compaction by the sediments' own weight.

GEO-CHARACTERISATION

3D reconstruction of Holocene stratigraphic architecture



RESTORE presents a state-of-the-art model of the Holocene stratigraphic architecture and evolution of the Venice Lagoon, and develops a simplified 3D geological model based on the relationship between the main depositional units and the potential compressibility of the sediments and according to their lithology, age, and depth, as input for the numerical simulation.

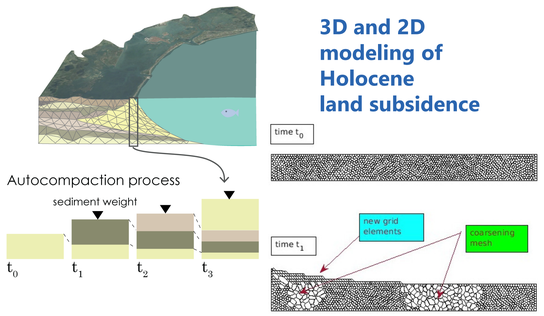


A multidisciplinary approach is adopted integrating

- Very High Resolution Seismic surveys data that allow tracing the main reflectors that subdivide the different seismo-stratigraphic units
- Sedimentological-stratigraphic and paleontological analyses on sedimentary cores to identify depositional environments
- C14 dating datasets available for the lagoon and neighbouring areas to set up a geochronological model

MODELING

3D and 2D modeling of Holocene land subsidence

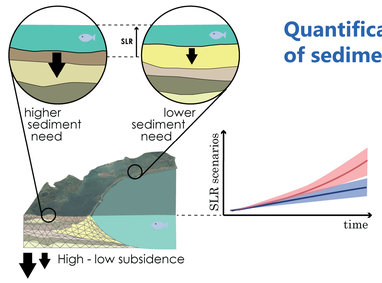


RESTORE presents a sedimentation-compaction model (NATSUB3D) for the Venice Lagoon, which properly accounts for sediment autocompaction during the evolution of depositional landforms.

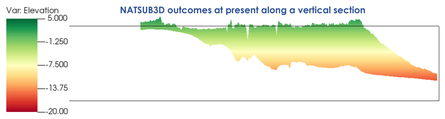
- NATSUB3D is based on the coupled solution of Darcy's groundwater flow equation and the consolidation equation based on Terzaghi's effective stress.
- The partial differential equations are numerically solved through the Finite Element (FE) method with a tetrahedral discretization in a 3D time-evolving domain following landform aggradation and compaction.
- Results are compared with a 2D model where a Virtual Element Method (VEM) is applied in combination with a mesh coarsening strategy. The VEM extends the FE method on general polytopal meshes through special polynomial projections of the basis functions and their derivatives. The mesh coarsening strategy allows deformed elements to be joined, thus reducing the overall mesh size.

QUANTIFICATION

Quantification of sediment needs



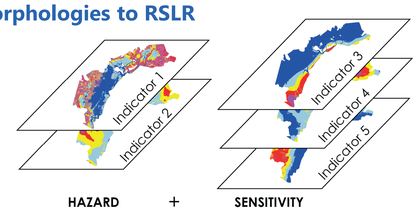
RESTORE quantifies the sediment need in the lagoon basin in a medium- and long-term scale of interventions highlighting areas that cannot keep pace with RSLR due to reduced sediment availability.



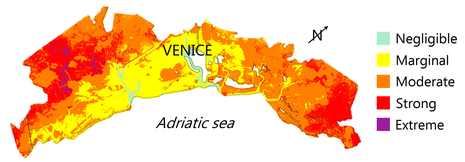
- Autocompaction of morphological landforms with NATSUB3D combined with the regional land subsidence and SLR component is compared to accretion rates by sediment deposition available from literature data. Sediment deficit is assigned to areas where sediment accumulation cannot sustain RSLR.
- The quantification of future sediment needs is also carried out under future SLR scenarios, and considering the possible variations of sediment availability due to activation of the storm-surge barriers at the three inlets.

VULNERABILITY

Vulnerability of tidal morphologies to RSLR



RESTORE conceptualises and applies a novel approach of vulnerability to RSLR that considers the mutual dependence of the tidal-flats and saltmarsh system as a continuum and the spatial variability of land subsidence and subsurface architecture. The results of NATSUB3D are also taken into account.



- The analysis of tidal morphology vulnerability to RSLR is based on the hazard and sensitivity status appropriately combined. Hazard consists in the RSLR while Sensitivity is defined through physical-environmental parameters that describe the intrinsic characteristics of the morphologies.
- Using an index-based method, the relevant indicators are appropriately classified, weighted, and aggregated.

National Recovery and Resilience Plan (NRRP)
Component C2, Investment 1.1: Fund for the National Research Programme (NRP) and Research Projects of Significant National Relevance (PRIN)
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PRIN 2022 PNRR Project, Funded by the European Union – NextGenerationEU

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