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Embedding compaction processes in long-term evolution modeling of tidal marshes

Riccardo Xotta, Claudia Zoccarato, Philip S. J. Minderhoud, and Pietro Teatini
Department of Civil, Environmental and Architectural Engineering, University of Padova, Padova, Italy

Tidal marshes are vulnerable and dynamic ecosystems with essential roles from protection against marine storms to biodiversity preservation. However, the survival of these environments is threatened by external stressors such as increasing mean sea level, reduction in sediment supply, and erosion. Tidal marshes are formed by deposition over the last centuries to millennia of sediments transported by surface water and biodegradation of organic matter derived from halophytic vegetation. Therefore, the sediment at the surface is characterized by high porosity and their large consolidation potential plays an important role in the future elevation dynamics, which is often not fully recognized.

Here we propose a novel three-dimensional numerical model to simulate the long-term dynamics of tidal marshes. A 3D groundwater flow equation in saturated conditions is implemented to compute the over-pressure dissipation with the aid of the finite element (FE) method, whereas the sediment consolidation is computed according to Terzaghi's theory.

A Lagrangian approach is implemented in the FE numerical model to properly consider the large soil deformation arising from the deposition of highly compressible material. The hydro-geomechanical properties, that depend on the intergranular effective stress, are highly non-linear.

The model takes advantage of a dynamic mesh that simulates the evolution of the landform elevation by means of an accretion/compaction mechanism: the elements deform in time as the soil consolidates and increase in number as the new sediments deposit over the marsh surface. The deposition is treated as input to the consolidation model and can vary in space and time.

The model is applied to simulate the long-term evolution of realistic tidal marshes in terms of accretion and consolidation due to the coupled dynamics of surficial and subsurface processes.