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Simulating the impact of creep in natural consolidation and subsidence in depositional environments

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Depositional landforms, such as tidal marshes and deltas, formed by sediment deposition over the last centuries to millennia. They are complex, vulnerable, and dynamic systems with important roles from environmental and human points of view. The survival of these lowlying landforms is threatened by multiple stressors, e.g. sea level rise and reduction in sediment supply. In addition to these external factors, natural compaction of the sedimentary bodies may have an important role on the elevation dynamics because of the large porosity and compressibility that characterize the shallow deposits. A three-dimensional (3D) finite element simulator (NATSUB3D) has been recently developed to model the long-term dynamics of transitional landforms. The model couples a 3D groundwater flow module to compute over-pressure dissipation with a 1D compaction module based on the elasto-plastic Terzaghi theory. NATSUB3D properly accounts large deformations thanks to an accreting/compacting mesh that follows the grain movements (Lagrangian approach). The NATSUB3D formulation is updated to account for viscous deformations using the NEN-Bjerrum constitutive relationship. Indeed, creep may represent an important process in fine unconsolidated deposits forming Holocene coastal landforms. With the new constitutive model, soil deformation is effective stress and time dependent. The new simulator has been applied on 1D synthetic cases mimicking long-term accretion of sedimentary columns. Hydro-geomechanical properties typical of sediment classes composing depositional landforms are used. A sensitivity analysis has been performed on sedimentation rates and secondary compression coefficients, which are the main parameters affecting the viscous deformation, leading to significantly different elevation dynamics. In the simulation of these processes (i.e., the formation of a sedimentary landform), the overconsolidation ratio (OCR), which is the geomechanical parameter most difficult to quantify and highly impacting soil compaction, can be simply set equal to 1 for the newly formed soil layer. Indeed, OCR is then properly updated by the model itself because the simulation follows the soil deformation since time of sediment deposition, with soil experiencing compaction because new sedimentation occurs on the landform top.