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Numerical Constraints of Current Rates of Surface Elevation Change Due to Compaction of Holocene Sediments in the Louisiana Delta Plain

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Abstract

Planning for and implementing cost-effective coastal and wetland restoration in Louisiana requires accurate measurements or estimates of current rates of ground-surface displacement (subsidence) on scales of 10s to 1000s of km^2. Given the geologic complexities of the stratigraphy and dynamic processes contributing to subsidence of the delta plain, it is difficult to extrapolate observations or estimates any appreciable distance. However, previous research suggests that current subsidence rates are directly proportional to the thickness and stratigraphy of Holocene deposits, and gravitational reduction in porosity of these deposits is considered by many to contribute substantially (but not solely) to modern subsidence rates. Yet we lack detailed analysis of the compaction history of Holocene sediments, and so can not accurately quantify present subsidence due to compaction. We numerically model compaction processes with a Monte Carlo approach to capture the anticipated range of present compaction rates, and provide modeled rate distributions that allow the probability of occurrence of a given rate at a location to be determined despite limited geologic knowledge of the site.

We estimate the compaction history of Holocene sediments by solving one-dimensional, multi-lithology compaction models based on Darcy (vertical) flow and Terzaghi effective stress principles using a finite difference technique. This technique allows calculations of cumulative sedimentation and surface displacement, as well as historic and present rates of vertical surface displacement. Synthetic stratigraphies are generated randomly by selecting layer properties (thickness, depositional rate, and geotechnical parameters) from predefined distributions with observed (or otherwise conservative) ranges. Modeling multiple synthetic stratigraphies allows a full range of sediment types, stratigraphic successions, geotechnical parameters, depositional rates, and accumulation times to be considered. Detailed modeling of compaction rates using radiometrically-dated stratigraphy of United States Geological Survey/Louisiana Geological Survey deep borings in Terrebonne Parish can then be put into context given a range of anticipated values for that site. We provide graphic solutions for assessing maximum probable surface-displacement rates due to compaction over time at any site of interest, provided characteristics of some of the above variables are moderately well known.