Modeling the Sediment Loading Effect on Land Subsidence in the Mississippi Delta

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Sea-level rise due to the melting of polar ice has become one of the main global environmental problems, and it will pose adverse challenges for the subsistence of socio-ecosystems in low-lying coastal plains. The densely populated Mississippi Delta is an exceptional example in this regard. The long-term land subsidence makes it particularly vulnerable to accelerated sea-level rise and this issue has evolved into a major concern. Land subsidence along the central US Gulf Coast is a well-known geological fact. Several deformational processes, such as salt tectonics, lithospheric flexural downwarping, glacial isostatic adjustment, and sediment compaction, have been proposed. However, the dominant driving force continues to be debated, and rates derived from different methods are sometimes in conflict. Therefore, a thorough understanding of subsidence is of both scientific and practical importance.

Lithospheric flexural downwarping due to sediment loading associated with postglacial aggradation of fluvial sediments and the subsequent growth of the Mississippi Delta has been proposed as a major player. Previous modeling has inferred subsidence rates of about 5 mm/yr in a large portion of the deltaic plain due to this process. These rates are at least an order of magnitude higher than those inferred using long-term relative sea-level records. Here we model land subsidence using a multi-layered, radially symmetrical, gravitationally consistent, Maxwell earth model and a state-of-the-art sediment model constructed using stratigraphic data from about 600 boreholes and seismic track lines onshore and offshore of the Mississippi Delta. Sensitivity analyses reveal that the thickness of the lithosphere and the viscosity of the upper mantle are the key parameters governing the magnitude and the relaxation time of the deformation, respectively. Using a set of earth model parameters optimally constrained by Holocene relative sea-level records and a linear growth pattern of the delta with a shifting depocenter, we predict relatively low subsidence rates in most parts of the deltaic plain. Also the predicted deformational signal diminishes immediately away from the birdfoot delta. Our results show that the role of Holocene sediment loading as a contributor to subsidence is not as important as recently suggested.