

## Long and Short-Term Variability of Subsidence Patterns Across the Mississippi River Delta Plain

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### Abstract

Subsidence of the Mississippi River delta has piqued the curiosity of geoscientists for more than a century. During this time it has been identified as a fundamental phenomenon of the delta plain, contributing toward the expansion of deltaic headlands, the character of stratigraphic relationships that develop during progradational events, and the patterns of relative sea level rise that lead to wetland loss and shoreline erosion. Scientific and public attention has increasingly focused on the patterns and causes of the regional subsidence because of the high wetland loss and coastal erosion rates that threaten the extant Louisiana coastal zone and the intended benefits of regional coastal ecosystem restoration plans. Despite wide recognition for its role in coastal landform evolution, quantifying the patterns of subsidence and identifying the underlying causative mechanisms has proven to be challenging. This is problematic because knowledge of the patterns of subsidence is integral to understanding the mechanisms driving subsidence and developing reasonable approaches to living within a coastal zone impacted by high rates of subsidence.

Early researchers of the delta region qualitatively recognized the process of north-central Gulf subsidence because of gradual submergence below sea level of formerly subaerial deltaic land, and “anomalously” thick stratigraphic successions that required the downward adjustment of underlying intervals to accommodate overlying expanded sedimentary sections. Within the last several decades, quantitative assessments of subsidence have been attempted through an analysis of tide-gauge records, benchmark re-leveling surveys, geographic positioning system data, and burial depths of radiocarbon-dated peat horizons adjusted for paleo sea levels. However, each of these methods of analysis is uniquely different with regard to: 1) the datums to which they are referenced and the vertical shifts that they actually record, 2) the temporal range of subsidence trends that they potentially document, 3) the spatial extent for which the motion of an individual point record can be extrapolated beyond its location, and 4) the magnitude of error they inherently possess and consequently, the resolution on subsidence rates they provide.

Within this suite of instrumentation and analysis methods a convenient classification scheme of the data they provide recognizes their independently variable temporal ranges, namely: 1) millennial-scale time frames, herein referred to as long-term records trends, 2) centennial-scale time frames providing short-term trends and, 3) decadal-scale time frames that can be regarded as very short term trends. Recognizing this range of temporal variability in patterns is paramount to a successful interpretation of the underlying causes of vertical motion.

A number of distinct processes contribute to delta plain subsidence, such as compaction of subsurface strata, fault movement, and regional isostatic crustal adjustments. Empirically derived and modeled rates for these types of mechanisms indicate that the respective rates of surface elevation change imparted by each of these should vary within the proposed time scales. For example, laboratory testing has shown that a large percentage of total sediment compaction expected for a high-porosity stratum occurs soon after burial as a result of initially rapid dewatering. Age-depth relationships for Holocene peats of the delta that have been depth corrected for paleo sealevels indicate that rapid subsidence takes place within the first approximately 2,000 years after burial. Peats older than 2,000 years yield significantly lower rates of motion and are interpreted to reflect a boundary for the time frame within which primary compaction takes place and when other mechanisms of subsidence become more dominant in the record of vertical motion. Consequently, short-term measurements methods, such as GPS, are expected to most

likely record mechanisms that cause rapid subsidence such as compaction, whereas long-term methods of measurement may record initially rapid rates of compaction but through time more accurately reflect mechanisms that operate on longer-term scales, such as crustal isostasy. Sorting the individual contributions of known subsidence processes from any measurement, whether long or short-term, is challenging. Comparison of long- and short-term rates does however offer an opportunity to gauge the relative influence of individual subsidence mechanisms through a careful comparison and knowledge of the most likely degree of influence by these mechanisms within the various time frames of measurements.