

Adapting to Rising Sea Level: A Florida Perspective

Randall W. Parkinson

RW Parkinson Consulting, Inc., 2018 Melbourne Ct., Suite 205, Melbourne, Florida 32901, USA

Abstract. Global climate change and concomitant rising sea level will have a profound impact on Florida's coastal and marine systems. Sea-level rise will increase erosion of beaches, cause saltwater intrusion into water supplies, inundate coastal marshes and other important habitats, and make coastal property more vulnerable to erosion and flooding. Yet most coastal areas are currently managed under the premise that sea-level rise is not significant and the shorelines are static or can be fixed in place by engineering structures. The new reality of sea-level rise and extreme weather due to climate change requires a new style of planning and management to protect resources and reduce risk to humans. Scientists must: (1) assess existing coastal vulnerability to address short term management issues and (2) model future landscape change and develop sustainable plans to address long term planning and management issues. Furthermore, this information must be effectively transferred to planners, managers, and elected officials to ensure their decisions are based upon the best available information. While there is still some uncertainty regarding the details of rising sea level and climate change, development decisions are being made today which commit public and private investment in real estate and associated infrastructure. With a design life of 30 yrs to 75 yrs or more, many of these investments are on a collision course with rising sea level and the resulting impacts will be significant. In the near term, the utilization of engineering structures may be required, but these are not sustainable and must ultimately yield to "managed withdrawal" programs if higher sea-level elevations or rates of rise are forthcoming. As an initial step towards successful adaptation, coastal management and planning documents (i.e., comprehensive plans) must be revised to include reference to climate change and rising sea-level.

Keywords: Global Climate Change, Sea-Level Rise

PACS: 89.60.-k, 92.70.Mn

INTRODUCTION

Global climate change and concomitant rising sea level will have a profound impact on Florida's coastal and marine systems. Rising sea level will increase erosion of beaches, cause saltwater intrusion into water supplies, inundate coastal marshes and other important habitats, and make coastal property more vulnerable to erosion and flooding. More extreme weather events predicted to accompany rising seas, including intense rainfall, floods, droughts, and tropical storms, will alter freshwater flow into estuaries and lagoons, exacerbate polluted runoff and water supply problems, and damage coastal habitats and property [1].

Most coastal areas are currently managed under the premise that sea-level rise is not significant and that the shorelines are static or can be fixed in place by engineering structures [2]. The new reality of sea-level rise and extreme weather due to climate

change requires a new style of planning and management to protect resources and reduce risk to humans.

BACKGROUND

Past Sea-Level Change

Geologists have documented broadly fluctuating sea level elevations of as much as 300 meters over the past 250 million years. Using isotopic data from ice cores dating back more than 400,000 years, changes in sea level have been shown to co-vary with proxies for average earth temperature and atmospheric carbon dioxide levels. This association is well demonstrated even over the broad range of values documented during the four glacial-interglacial cycles which occurred during the Late Pleistocene (Fig. 1 and 2).

These cycles and the associated covariance of temperature, CO₂, and sea level persisted until the Industrial Revolution (~1760 to 1830). Thereafter temperature and carbon dioxide levels have risen well beyond historical values, triggering polar and alpine glacial melting and rising sea level at rates much higher than historical records (Fig. 3). Historical tide data clearly document this acceleration and shoreline stability studies indicate the response of most North American coastlines has been moderate to severe coastal erosion (Fig. 4).

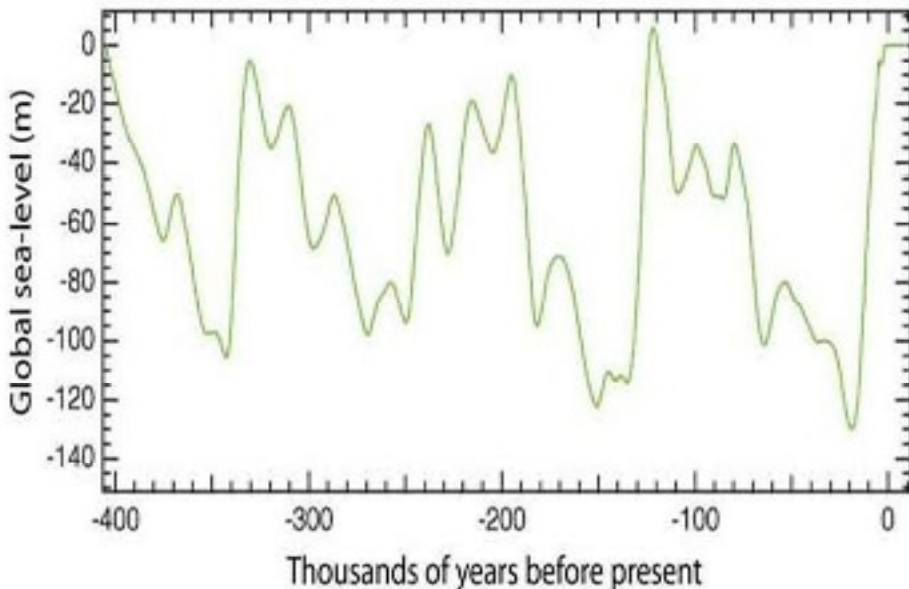


FIGURE 1. Large variations in global sea-level elevation over past 400,000 years. Reprinted from [2].

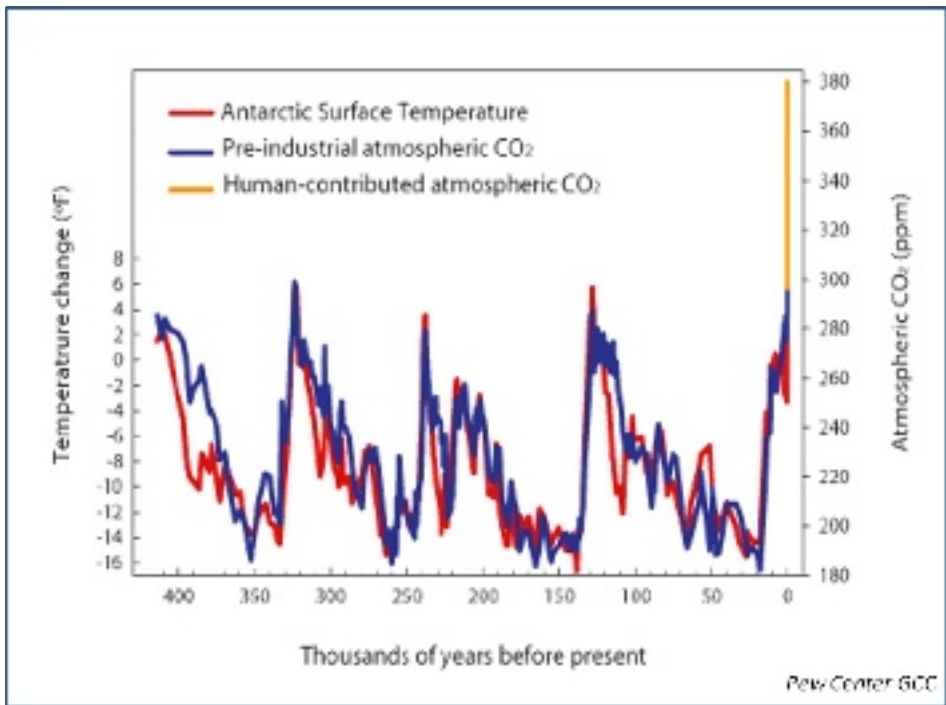


FIGURE 2. Co-variance of average earth temperature and atmospheric carbon dioxide levels over past 400,000 years. Reprinted from [3].

Forecasting Coastal Response to Future Sea-Level Rise

The rate of sea-level rise began to increase at the end of the Industrial Revolution and recent studies now suggest an additional two meter rise is possible by the year 2100. How will our coastlines respond and what can we do?

Successfully adapting to rising sea level requires technical information be clearly communicated to decision makers. Scientists must (1) continue to assess *existing* coastal vulnerability to address *short term* management issues and (2) model *future* landscape change and develop sustainable plans to address *long term* planning and management issues. Planners, managers, and elected officials must have access to both science and scientists to ensure their decisions are based upon the best available information.

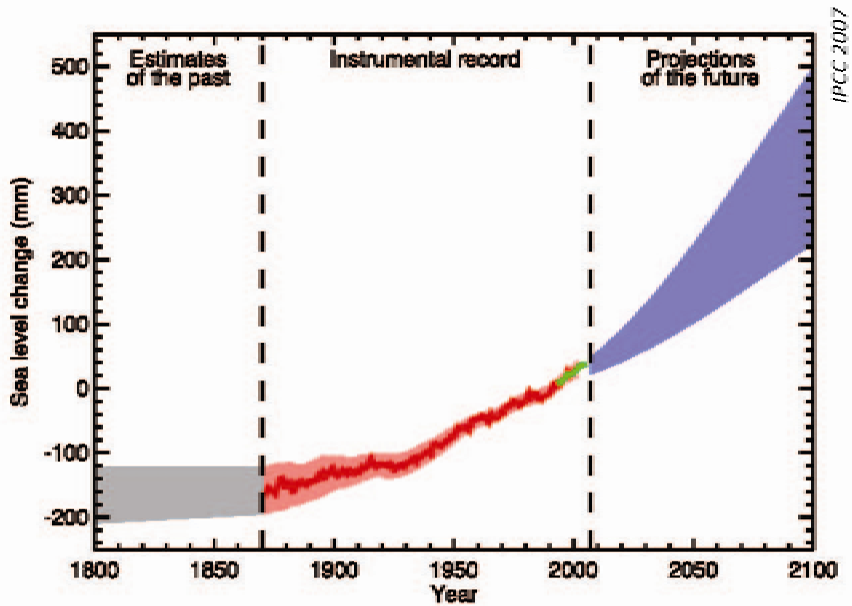


FIGURE 3. Past, present, and future sea level elevation. Reprinted from [4].

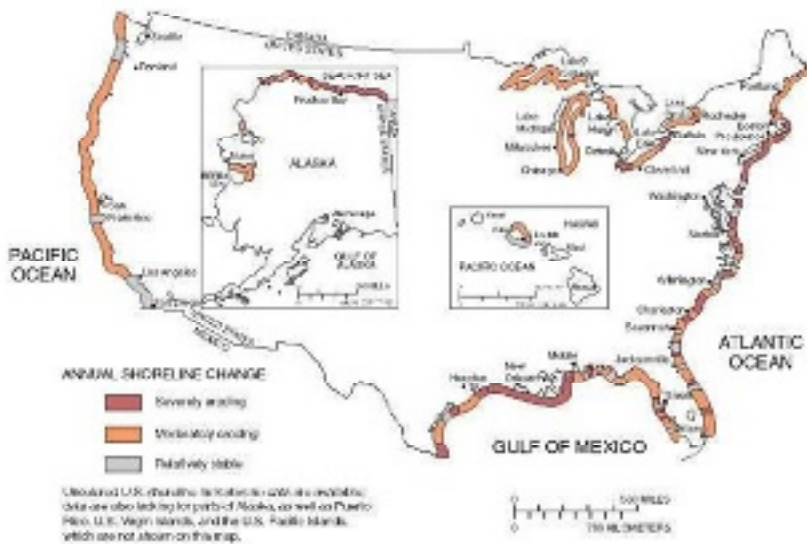


FIGURE 4. Historical trends in North American shoreline stability. Reprinted from [2].

Forecasting how our coastlines will respond to future sea level rise can be accomplished in part using geological models. For example, based upon sedimentologic data obtained from the continental shelves of North America, geologists have been able to reconstruct the details of sea-level rise since the Last Glacial Maximum, as well as the coastal response. This information provides a conceptual framework from which to model the potential effects of sea-level rise forecasted to accompany global climate change (Table 1).

Real-time investigations of the coastal zone can also be used to model the effects of sea-level rise. Detailed topographic surveys of coastal elevations can be mapped to detect changes of less than one foot using LIDAR technology. When coupled with GPS, aerial photography, and existing GIS files of land use and infrastructure, vulnerability assessments can be conducted to determine how flooding will impact a coastal municipality. For example, in a recent (2008) vulnerability assessment of Miami Beach, Peter Harlem (Florida International University) determined a 1, 2, and 3 foot rise in sea level would submerge 1%, 10%, and more than 30% of the landscape by the year 2084, respectively.

Vulnerability assessments using LIDAR can be further improved upon by introducing a dynamic element so that selected areas of the landscape can evolve in the presence of ocean waves and currents; i.e., by incorporating geomorphic change associated with coastal retreat and wetland sedimentation.

ADAPTING TO RISING SEA LEVEL

Given the projected rates and elevations of sea level, it is highly probable Florida coastlines will migrate landward via erosion or submergence. Adapting to these changes can be grouped into two options.

TABLE 1. Data used to predict shoreline response to variable rates of sea level rise (compiled by the author using available peer reviewed publications).

| Period | Time Interval | Rate (mm/yr) | Coastal response |
|------------------------------------|-----------------------|-----------------|---|
| Late Pleistocene to early Holocene | 20,000 - 7,000 ybp | 10 to 20 | Submergence, overstep, widespread shoreline retreat |
| mid-Holocene | 7,000 to 3,000 ybp | 2 | Formation of coastal environments, barrier islands, shoreline retreat |
| late-Holocene | 3,000 to present | 0.1 to 0.2 | Aggradation, shoreline stabilization and progradation |
| 20th Century | 1900 to 2000 | 2 | Shoreline retreat |
| Recent | 1994 to 2008 | 3.4 | Shoreline retreat |
| Predicted | 1990 to 2100 | 3 to 14 | Shoreline retreat, submergence and overstep |

The first option is *shore protection* that utilizes coastal engineering structures designed to protect land from inundation, erosion, flooding. I consider this to be short-term solution viable only when sea level is at lower elevations or rates of rise. This option is implemented in an attempt to (1) keep the shoreline at a fixed position using a variety of structures including seawalls, bulkheads, and revetments or (2) protect against flooding or permanent inundation using topographic obstacles like dikes or dunes.

The second option towards adapting to rising sea level is *managed withdrawal*. This response is designed to minimize hazard potential and environmental impacts by removing or diverting development from the most vulnerable coastal areas. In contrast to the previous option, it is a more dynamic response that can be updated by real-time observations. This option is, in my opinion, a long-term solution and especially applicable to higher sea-level elevations or rates of rise. Along *developed* coasts it would consist of the relocation of structures, buyout programs, and rolling easements. Along *undeveloped* coasts the managed withdrawal option is achieved using conservation easements or environmental land acquisition programs.

Where and when should these options be implemented? Most experts agree decisions regarding how best to adapt to rising sea level must be made within the next decade [5]. Thereafter, the extent and momentum of urban development will have eliminated many of the obvious retreat pathways and thereby committed us to a policy of shore protection that is both expensive and unsustainable.

The best adaptation strategy should be based upon science; the continued collection of relevant data and improvement of predictive models. In addition, the construction of thematic maps (i.e., coastal vulnerability [6]) must continue. These maps identify high risk zones (i.e., shorelines prone to high rates of coastal erosion or overwash) which can form the basis for delineating a preferred response; i.e., shore protection vs. managed withdrawal.

More importantly, this information must be effectively conveyed to ensure decision makers are well informed. A recent survey of management and planning documents undertaken by the author indicated reference to climate change or sea-level rise is rare (see also [1]) and that most shore protection structures or setback policies are based upon the current rate of sea-level rise [2]. At best Florida's existing policies suggest only that these phenomena should be studied (c.f. Volusia County Comprehensive Plan website [7]).

SUMMARY AND RECOMMENDATIONS

The cost of inaction could not be greater. A present, nearly one half of Florida's sandy shorelines are critically eroding. The state has attempted to manage less than half of these, yet has spent more than 600 million dollars over the past four decades [8]. In a recent economic assessment by Tufts University [9], ignoring climate change and rising seas (aka the *Business as Usual Strategy*) would cost the State of Florida hundreds of billions of dollars over the next 50 years. The cost of inaction to our environment is perhaps even more problematic, as a modest rise of only 15 cm will trigger widespread habitat loss and the collapse of numerous commercial and recreational fisheries along the Florida coast and continental shelf [10].

While there is still uncertainty regarding the details of rising sea level, comprehensive plans and associated development decisions are being made today which commit public and private investment in real estate and associated infrastructure. With a design life of 30 yrs to 100 yrs, many of these investments are on a collision course with rising sea level and the resulting impacts will be significant. We have about another decade in which to debate the evidence of global climate change and rising sea level. Thereafter the opportunity to mitigate and adapt will be lost and the cost of indecision placed squarely on the shoulders of our children and the generations which follow.

ACKNOWLEDGEMENTS

The author would like to acknowledge Peter Harlem, Florida International University, for permission to use his Miami Beach vulnerability data.

REFERENCES

1. Florida Coastal and Ocean Coalition, *Preparing for a Sea Change in Florida – A strategy to Cope with the Impacts of Global Warming on the State’s Coastal and Marine Systems*, 40 pgs (2008).
2. United States Climate Change Science Program, *Coastal Sensitivity to Sea Level Rise: A focus on the Mid-Atlantic Region*, Synthesis and Assessment Product 4.1, 790 pgs (2009).
3. Pew Center on Global Climate Change, “Global Warming Basics - Facts and Figures”, <http://www.pewclimate.org>, accessed April 20, 2009.
4. International Panel on Climate Change, “Chapter 5 – Observations: Oceanic Climate Change and Sea Level”, 2007, pp. 385-432.
5. Zwick, P., and Carr, M., *Florida 2060 - A population distribution scenario for the State of Florida*, prepared for the 1000 Friends of Florida by the Geoplan Center at the University of Florida. 29 pgs (2006).
6. Thieler, E.R., and Hammar-Klose, E.S., “National Assessment of Coastal Vulnerability to Sea-Level Rise: Preliminary Results for the U.S. Gulf of Mexico Coast”, Open-File Report 00-179. 1 sheet, (2000).
7. Volusia County Comprehensive Plan. “Chapter 11 - Coastal Management Element”, <http://www.volusia.org/growth/planinfo.htm>, accessed April 20, 2009.
8. Florida Department of Environmental Protection, Bureau of Beaches and Coastal Systems, “Strategic Beach Management Plan”, <http://www.dep.state.fl.us/beaches/>, accessed April 20, 2009.
9. Stanton, E., and Ackerman, F., *Florida and Climate Change – The Costs of Inaction*, Tufts University, 104 pgs, (2007).
10. National Wildlife Federation, *Unfavorable Tide – Global Warming, Coastal Habitats and Sportfishing in Florida*, 60 pgs, (2006).