Last month a manuscript by Dean and Walton (FSBPA's Chair Emeritus and the current academic appointment to the Board, respectively) was published in SHORELINE. We are now presenting another quite distinct perspective on sea-level rise. Intent is solely to provide an alternative reassessment of sea-level rise at the respectful request of the authors. The opinions and conclusions set forth in both of these articles are solely those of the authors and do not represent the position of the Florida Shore & Beach Preservation Association.
(D. Flack, President)

Bursting the Bubble of Doom and Adapting to Sea Level Rise

Randall W. Parkinson, Ph.D., P.G.
RWParkinson Consulting, Inc.
Melbourne, Florida

and

Joseph F. Donoghue, Ph.D.
Department of Geological Sciences
Florida State University
Tallahassee, Florida

Introduction

Late Holocene sea level rise is now well documented to have accelerated subsequent to the Industrial Revolution (c.f. Church and White 2006) and current models suggest a rise of one meter or more by the year 2100 (c.f. Vermeer and Rahmstorf 2010). In addition, recent modeling projects a near doubling of Category 4 and 5 storm frequency by the end of the 21st century, with the largest increases to occur in the Western Atlantic (Bender and others 2010). This combination of factors substantially elevates the levels of risk or hazard potential assigned to Florida's built and natural coastal environments.

Unfortunately, the mainstream media has not properly noted the trend towards scientific consensus on these issues (c.f. Doran and Kendall 2009), but rather continues to emphasize uncertainty. Scientists are also to blame as they have not successfully countered media shortcomings. As a consequence, most Floridians have yet to seriously consider how best to adapt to sea level rise or for that matter any of the other elements of climate change.

In light of these threats or perhaps to make light of them, Walton and Dean (2010) posed the rhetorical question "*Should Floridians be moving to the mountains?*" Of course the answer is no, but statements like these are counterproductive and encourage the business-as-usual approach of continued development in Florida's high hazard coastal zone.

Next Page

What we have learned from past transgressions of the sea

Over the past 20,000 years sea level has been rising at a decelerating rate towards its present elevation due primarily to the melting of ice sheets as our climate transitioned into a warmer, inter-glacial interval. This long-term trend was punctuated by intervals (years to decades) of extremely rapid rise (i.e., >30 mm/yr) triggered by abrupt shifts in climate.

Florida's geologic record (i.e., sedimentology, stratigraphy, radiocarbon dating, paleontology) indicates this post-glacial marine transgression can be subdivided into three intervals, each characterized by a distinct rate of rise and unique shoreline response (**Table 1**). These data clearly indicate Florida shorelines were subject to landward retreat by erosion and submergence when sea level rose at a rate of 2 mm/yr or more. The only interval of coastal stability occurred during the late Holocene (3,000 ybp to present), when sea level was rising a few tenths of a millimeter per year.

Marine transgression interval	Period	Time Interval	Rate (mm/yr)	Coastal response
1	Late Pleistocene to early Holocene	20,000 - 8,000 ybp	10 to 20	Submergence, overstep, widespread shoreline retreat
2	mid-Holocene	8,000 to 3,000 ybp	2	Formation of coastal environments, barrier islands, shoreline retreat
3	late-Holocene	3,000 to present	0.1 to 0.2	Aggredation, shoreline stabilization, and progradation
NA	Historical	1870 to 2000	2	Shoreline retreat
	Recent	1993 to 2006	3.3	Shoreline retreat
	Predicted	2010 to 2100	7 to 16	Shoreline retreat, submergence, and overstep (with increasing rate)

Table 1 - Observed and predicted coastal response to sea-level rise. Late Pleistocene to late Holocene data from Parkinson (unpublished). Historical, Recent, and Predicted rates of sea-level rise described in text.

Next Page

During the 20th century, long-term tide-gauge data indicate the rate of sea level rise averaged 1.7 mm/yr, with an increase in the rate of rise over this period (**Figure 1**). This rate is faster than the preceding 3,000 year interval and is attributed principally to rising atmospheric temperatures and concomitant thermal expansion of the ocean's surface layer. All 30 coastal states have experienced moderate to severe erosion during this interval of accelerated sea level rise (Williams and others 2009).

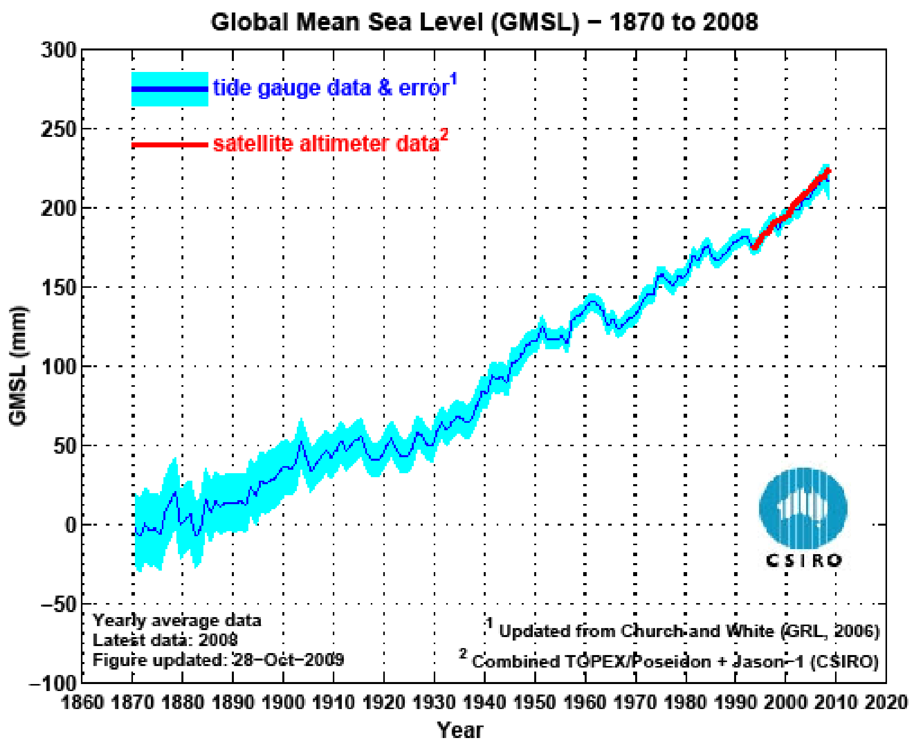

Figure 1 - Changes in global sea level 1870 to 2009. From CSIRO at http://www.cmar.csiro.au/sealevel/index.html.

More recently (1993 to 2006), high precision satellite altimeters indicate sea level has been rising at 3.3 ± 0.4 mm per year (Rahmstorf and others 2007). This most recent interval of acceleration is a direct consequence of the ever increasing influx of glacial meltwater from Antarctica and Greenland. Given the strong relationship between the rate of sea level rise and Florida coastal response (**Table 1**), this recent acceleration has likely exacerbated historical trends in coastal erosion, flooding, and related deleterious effects (i.e., salt water intrusion into local aquifers).

Next Page

Future sea level rise

During the past two decades the most widely reported sea level forecasts were published by the Intergovernmental Panel on Climate Change (IPCC). The most recent or Fourth Assessment Report (AR4) was published in 2007 and included a forecast by Bindoff and others (2007) of between 18 cm (7 in) and 59 cm (23 in) by 2100. This estimate of sea level rise was immediately regarded as too low by many scientists because the models used by IPCC scientists ignored the rapid disintegration of Antarctic and Greenland ice-sheets documented by studies released at the time of publication. The IPCC's estimate also failed to account for two other phenomena likely to affect sea level rise: climate cycle "feedback loops" (such as release of the potent greenhouse gas methane from thawing permafrost) and greenhouse gas emissions from China and India that have grown far faster than anticipated in the models used by the IPCC. The need for a revised forecast was also supported by satellite altimeter data that tracked rising sea level along the upper boundary of IPCC model predictions (**Figure 2**). Subsequent studies predict much higher sea level elevations by the end of this century (c.f. Vermeer and Rahmstorf 2010, Mitrovica and others 2009; **Figure 3**).

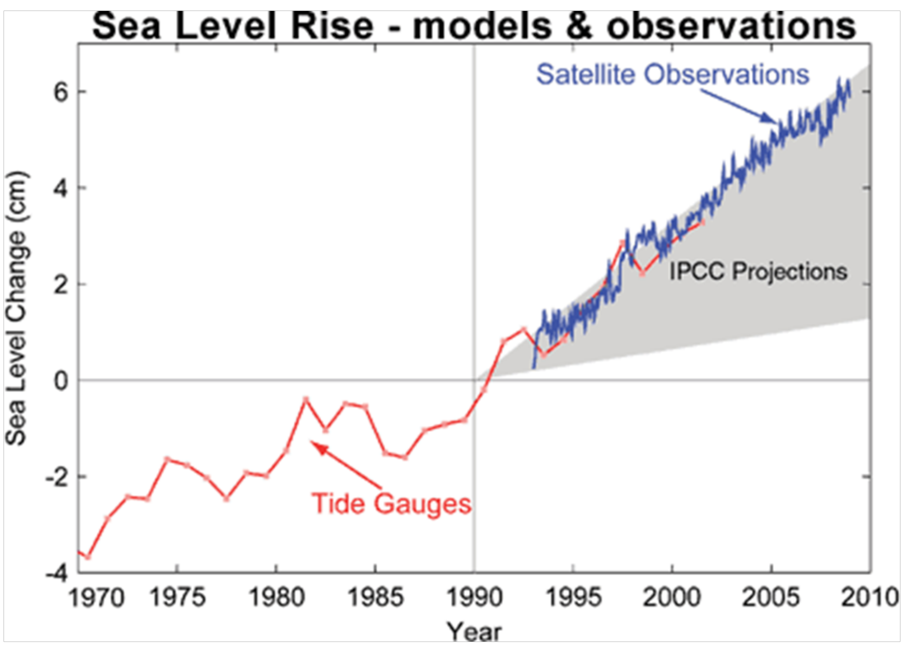

Figure 2 - Sea level change during 1970-2010. The tide gauge data are from Church and White 2006 and satellite data from Cazenave and others 2008. The grey band shows IPCC projections. From Allison and others 2009.

Next Page

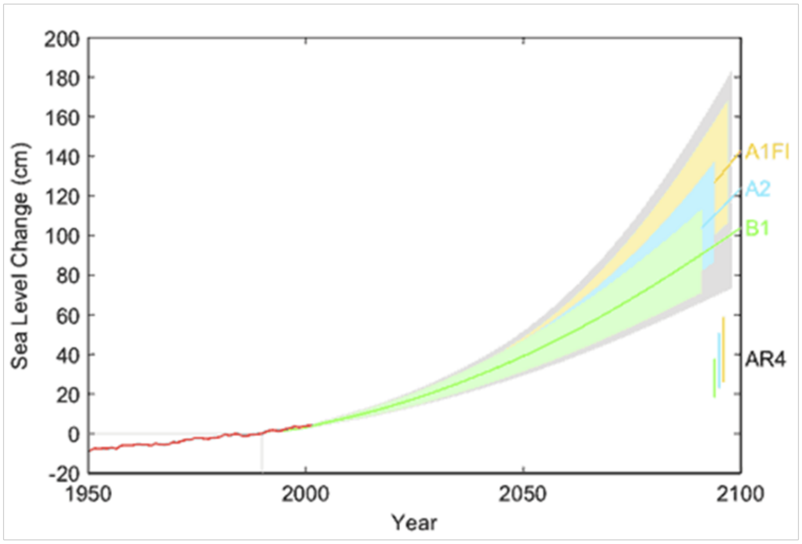

Figure 3 – New projection of sea-level rise 1990 to 2100. The IPCC 2007 forecast is shown as the three vertical bars on the bottom right and labeled AR4. From Vermeer and Rahmstorf 2010.

It is equally relevant to note that although nearly every sea level rise forecast only makes predictions out to year 2100, sea level will certainly continue to rise thereafter as a consequence of system momentum, the continued addition of greenhouse gases into the earth's atmosphere, and the relatively long residence time of atmospheric carbon dioxide and other greenhouse gasses. Continued warming can be expected and with the loss of the West Antarctic Ice Sheet alone, sea level would rise by about 5 to 6 meters (Tol and others 2006; Dasgupta and others 2007).

Regardless of these uncertainties, the forecasts of sea level rise generated using complex computer-based Global Climate Models (GCMs) are much more reliable than estimates based upon simple extrapolations from long-term tide gauge data. Simply stated, the magnitude and rate of environmental change observed during the 21st century are already very different from the conditions under which the long-term tide gauge data were acquired. The desire to plan for the future based upon historic observations is unfortunately so prolific it has been cited by regional planners as one of the greatest obstacles towards implementing plans to appropriately address sea level rise (c.f. Hallegatte 2008). And although there are some differences between local sea level as recorded along the Florida coastline and the global eustatic signal (c.f. Maul 2008), these are minor in comparison to the other elements of uncertainty accepted when modeling future sea level rise. For the purpose of this paper it is therefore assumed there is no significant difference between global eustatic and local sea level rise.

Next Page

The rate of rise predicted during the 21st century and beyond is significantly higher than that of the past 8,000 years and closer to those which occurred during the interval of rapid glacial retreat between 20,000 and 8,000 years ago (**Table 1**). During that time, Florida shorelines were subject to widespread submergence and broad landward shifts across the coastal plain (i.e. overstep).

Is doom or adaptation in Florida's future?

Five response strategies are available to address sea level rise: (1) attack, (2) defend, (3) accommodate, (4) withdraw, and (5) do nothing. What should Floridians do?

Selecting a response to rising seas is most effectively undertaken using a two-step process. The first step is to *assess vulnerability*; how will sea level rise and related elements of climate change (i.e. storminess) affect a community's built and natural environments? Next, an *adaptive management plan* is implemented. Adaptive management is an on-going and iterative process that specifies one or more essential actions necessary to reduce the vulnerability of built and natural environments to rising seas. The overall plan and each specific action are monitored and adjusted as outcomes from management action(s) and other events (i.e. ice sheet melting) become better understood. Initial actions may be limited to: (1) the development of a timeline describing future actions and (2) no-regret policies. Reactive measures may be formulated and subsequently triggered by specific tipping points built into the plan. As uncertainty diminishes and consensus emerges, more robust plans, programs, and actions are implemented. The City of Satellite Beach, Florida, has just completed a vulnerability assessment and is currently working on an adaptive management plan. The project was funded by the EPA Climate Ready Estuaries Program, although other agencies (i.e. Florida Coastal Management Program) offer financial support to coastal municipalities seeking to address climate change, sea level rise, and disaster preparedness.

Coastal municipalities should immediately begin planning for sea level rise; a "do nothing" approach is unacceptable as over time this response will lead only to additional unwise decisions, increased risk, and rising costs. Inspection of a municipality's hypsographic curve, which illustrates the relationship between sea level elevation and cumulative percent land area submerged, can be used to develop an appropriate timeline for implementing specific actions as described in the plan.

Next Page

Final thoughts

Sea level rise has accelerated subsequent to the Industrial Revolution to its current rate of 3.3 mm/yr and is predicted to rise even faster over the balance of this century. By 2100, sea level will very likely have risen a meter or more.

Unfortunately, a majority of Florida coastal municipalities have not yet begun to think about how sea level rise, increasing storminess, and related elements of climate change will affect their built and natural environments. Perhaps distracted by State and Federal cost sharing, they continue to focus on "critically" eroding shoreline segments and the defense of upland structures using engineered solutions. This focus on engineered solutions is in part *responsible* for high density development in the coastal zone and the elevated loss of property and life following landfall of catastrophic events (i.e. Hurricane Katrina). Coastal engineering projects were initially advocated as a solution to erosional shorelines at a time when the relationship between sea level rise and shoreline retreat was not widely understood. Yet Walton and Dean (2010) argue these strategies are also a logical means by which to address sea level rise. Coastal municipalities should instead be encouraged to consider all five response strategies when formulating an adaptive management plan.

Shore protection projects as have been frequently employed to address historic shoreline erosion and coastal submergence will likely have a role during the *early* stages of adaptive management. These *attack* and *defend* strategies could provide short term solutions and otherwise address existing needs. That said, these efforts should eventually be undertaken in association with a robust long term adaptive management plan. In fact, shore protection projects as historically configured are not sustainable over the long term given escalating costs, dwindling offshore sand reserves, cumulative impact on natural resources, and the porous nature of Florida's coastal geology. Alternate response strategies must be devised if we are to successfully adapt to sea level rise. The question is then "*What proactive contributions can the coastal engineering community make towards ensuring both the built and natural environments remain resilient during what will surely become a challenge of historic proportion?"*

Next Page

Acknowledgments

This paper would not have been written had we not attended a scientific symposium on sea level rise and Florida sponsored by the Florida Institute for Conservation Science and held at Archbold Biological Station, January 18-20, 2010. A post-event summary of symposium content and including attendee presentations is available at: http://www.flconservationscience.org/programs/symposium.shtml. The following colleagues provided input to significantly enhance the quality of this paper, although the authors are solely responsible for its content: Timothy H. Dixon, Reed Noss, Anthony Oliver-Smith, Francis Putz, Thomas Ruppert, Kenneth Edward Sassaman, and Michael Volk.

References Cited

Allison, I., N. L. Bindoff, R.A. Bindoff, R.A. Bindschadler, P.M. Cox, N. de Noblet, M.H. England, J.E. Francis, N. Gruber, A.M. Haywood, D.J. Karoly, G. Kaser, C. Le Quéré, T.M. Lenton, M.E. Mann, B.I. McNeil, A.J. Pitman, S. Rahmstorf, E. Rignot, H.J. Schellnhuber, S.H. Schneider, S.C. Sherwood, R.C.J. Somerville, K.Steffen, E.J. Steig, M. Visbeck, A.J. Weaver. 2009. The Copenhagen Diagnosis, 2009. Updating the world on the Latest Climate Science: The University of New South Wales Climate Change Research Centre (CCRC), Sydney, Australia, 60pp.

Bender, M.A., Thomas R. Knutson, Robert E. Tuleya, Joseph J. Sirutis, Gabriel A. Vecchi, Stephen T. Garner, and Isaac M. Hel, 2010. Modeled Impact of Anthropogenic Warming on the Frequency of Intense Atlantic Hurricanes: Science v. 327, no. 5964, pp 454-458.

Bindoff, N.L., J. Willebrand, V. Artale, A, Cazenave, J. Gregory, S. Gulev, K. Hanawa, C. Le Quéré, S. Levitus, Y. Nojiri, C.K. Shum, L.D., Talley and A. Unnikrishnan, 2007. Observations: Oceanic Climate Change and Sea Level. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S.,D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Cazenave, A., Dominh, K., Guinehut, S., Berthier, E., Llovel, W., Ramillien, G., Ablain, M., and G. Larnicol, G., 2009. Sea level budget over 2003-2008: A reevaluation from GRACE space gravimetry, satellite altimetry and ARGO. *Global and Planetary Change v.* 65, pg. 83-88.

Church, J. A. & N. J. White, 2006. A 20th century acceleration in global sea level rise. *Geophysical Research Letters* 33, L01602.

Dasgupta, S., B. Laplante, C. Meisner, D. Wheeler and J. Yan, 2007. The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis. World Bank Policy Research Working Paper 4136, Washington DC: The World Bank.

Doran, P. T. and M. Kendall Zimmerman, 2009. Examining the Scientific Consensus on Climate Change, *Eos Trans. AGU, 90(3),* doi: 10.1029/2009EO030002, available at http://tigger.uic.edu/~pdoran/012009_Doran_final.pdf

Next Page

Hallegatte, S., 2008. Strategies to adapt to an uncertain climate change. Global Environmental Change, v. 19, pg. 240-247.

Maul, G., 2008. Florida's changing sea level. Shoreline, May 2008.

Mitrovica, J.X., M. Gomez, P.U. Clark, 2009. The sea level fingerprint of west Antarctica collapse. Science 323: 753.

Rahmstorf, S., Cazenave, A., Church, J., Hansen, J., Keeling, R., Parker, D., and Somerville, R., 2007. Recent climate observations compared to projections. Science, v 316 (4 May), pg. 709.

Tol, R.S.J., M.Bohn, T.E. Downing, M.L. Guillerminet, E. Hizsnyik, R. Kasperson, K. Lonsdale, C. Mays, and Co-authors 2006 Adaptation to five metres of sea level rise, Journal of Risk Research 9: 467-482.

Vermeer, M. and Rahmstorf, S., 2010. Global sea level linked to global temperature. Proceedings of the National Academy of Sciences, available at www.pnas.org_cgi_doi_10.1073_pnas.0907765106

Walton, T., and Dean, R., 2010. Thoughts outside the bubble on sea level rise. Shoreline, February 2010.

Williams, S.J., B.T. Gutierrez, J.G. Titus, S.K. Gill, D.R. Cahoon, E.R. Thieler, K.E. Anderson, D. FitzGerald, V. Burkett, and J. Samenow, 2009. Sea level rise and its effects on the coast. In: *Coastal Sensitivity to Sea level Rise: A Focus on the Mid-Atlantic Region*. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [J.G. Titus (coordinating lead author), K.E. Anderson, D.R. Cahoon, D.B. Gesch, S.K. Gill, B.T. Gutierrez, E.R. Thieler, and S.J. Williams (lead authors)], U.S. Environmental Protection Agency, Washington DC.

Back to Main Page