Florida and the Environment: From "La Florida" to Global Warming

Duane E. DeFreese

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2008 Jillian Prescott Memorial Lecture

by Duane E. De Freese

Stephen Hawking's book, *A Brief History in Time* begins with a short passage about a well-known scientist giving a public lecture on astronomy and the meaning of the universe...

> *"He described how the earth orbits around the sun and how the sun, in turn, orbits around the center of a vast collection of stars called our galaxy. At the end of the lecture, a little old lady in the back of the room got up and said: "What you have told us is rubbish. The world is really a flat plate supported on the back of a giant tortoise." The scientist gave a superior smile before replying, "What is the tortoise standing on?" You're very clever, young man, very clever" said the old lady. "But it's turtles all the way down!"* [1]

Hawking goes on to say *"Most people would find the picture of our universe as an infinite tower of tortoises rather ridiculous, but why do we think we know better?"* [2] Hawking presented this story to provide a per-

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1. Stephen Hawking, *A Brief History in Time: From the Big Bang to Black Holes* (New York: Bantam Books, 1988), 1.
2. Ibid.

spective about scientific ideas, empirical data, history, and the search to understand the origin and ultimate fate of our universe. How does this story relate to the theme of the 2008 Florida Historical Society Annual Meeting and the Jillian Prescott Memorial Lecture (*Florida and the Environment: From "La Florida" to Global Warming*)? Knowledge about the history of our planet is essential to understand the complex geological, chemical, physical and biological systems that sustain life on Earth. An understanding of both history and science, with an appreciation for the complexity of spatial and temporal scale, is a fundamental first step to prepare society for the scientific and human implications of global climate change.

Global climate change is one of the great scientific and social challenges of the 21st century. It is an issue that connects the ecological and human dimensions of science across all levels of a global society (i.e. from small-scale local concerns of rural coastal communities to global-scale poverty, hunger and disease). Climate change has generated concern and controversy among people and nations around the world. For the first time in the history of Earth, over 6.6 billion people inhabit the planet, with millions of people and trillions of dollars of infrastructure at risk from climate change.[3] Over 53 percent of the nation's population lives within the narrow ribbon of coastal land that represents 17 percent of the contiguous land area of the United States.[4] While global population projections for coastal areas vary from study to study, with much discussion regarding methodologies and accuracy, estimates suggest that half the global population (about 3.2 billion people) lives in a coastal margin just 200 kilometers wide.[5] A 2003 study estimated the global "near-coastal population" within 100 km of a shoreline and 100 m of sea level at 1.2 billion people.[6] Regardless of the actual population size,

3. R.J. Nichols, et al., "Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates," OECD Environment Working Papers, No. 1 (OECD Publishing).
4. C. Crossett, T.J. Culliton, P.C. Wiley, and T.R. Goodspeed, "Population Trends Along the Coastal United States: 1980-2008," Coastal Trends Series, National Oceanic and Atmosperic Admistration, National Ocean Service Special Project.
5. Don Hinrichsen, *Coastal Waters of the World: Trends*, Threats and Strategies (Washington DC: Island Press, 1999); Hinrichsen, *Ocean Planet in Decline* (Online Publication posted 19 February 2008. http://www.peopleandplanet.net/doc.php?id=429&section=6.
6. C. Small and R.J. Nicholls, "A Global Analysis of Human Settlement in Coastal Zones," Volume 19, No. 3 (2003), *Journal of Coastal Research*: 584-599.

it is clear that climate change and sea level rise will present overwhelming challenges to a coastal world already impacted by a variety of non-climate related issues (i.e. population growth, infrastructure challenges, loss of natural coastal resources, declining fisheries, vulnerability to storm and flooding events, *et al.*). Recent projections suggest that impacts will be experienced in 84 coastal developing countries representing 5 regional departments of the World Bank.[7] The list includes: Latin America and the Caribbean (25 countries); Mid-East and North Africa (13 countries); Sub-Saharan Africa (29 countries); East Asia (13 countries) and South Asia (4 countries). In 2007, Dasgupta *et al.* provided a sobering view of the scope of the threat: *"A sea level rise of 39 inches (1 meter) would turn about 56 million people in 84 developing countries into refugees."*[8] Most developing coastal nations, islands and communities lack the capacity to manage coastal population growth or to develop and implement comprehensive coastal management plans that can provide resiliency to the synergistic impacts of climate change and sea level rise. These impacts will be complex and will occur at multiple scales. The United States, a wealthy, post-industrial country with a strong institutional capacity to respond to emergencies, now understands the scope of the potential challenges after Hurricane Katrina in 2005. Katrina made landfall as a Category 3 hurricane on the morning of August 29, 2005, in southeast Louisiana. The surprising scale of the storm surge, property damage, human population displacement and economic loss was a hard lesson learned about the value of comprehensive, proactive planning for natural and human-caused catastrophes. As we think about the implications of global climate change and sea level rise, it is important to remember Hurricane Katrina was a single, regional-scale, short-duration weather event.

While scientists continue to fine-tune methodologies for coastal population and climate change projections, there are several undeniable truths: 1. A significant portion of the world's population lives near the coast; 2. The coastal economy is important to the global economy; and 3. Coastal communities face a complex

7. S. Dasgupta, B. Laplante, C. Meisner, D. Wheeler, and J. Yan, "The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis," World Bank Policy Research Working Paper 4136.
8. Ibid As quoted by Deborah Zabarenko, Environmental Correspondent, Thomson Reuters news agency in "Sea level rise could hit poor countries hard: study" (13 February 2007). http://www.reuters.com/article/scienceNews/id USN 1340440520070213.

mosaic of risks from the immediate impacts of beach erosion on infrastructure to the long-term implications of climate change and sea level rise. For Florida, and coastal states and nations throughout the world, climate change and the effects of sea level rise will be felt most harshly. Global climate change and sea level rise present environmental, social, economic and technological challenges, as well as opportunities, that will influence human quality-of-life for the next century and beyond.[9] This scenario presents a great need and opportunity for natural scientists, social scientists, human health scientists and management systems experts to work together and with coastal communities at risk, to prepare for the future.

FLORIDA – SHAPED BY THE SEA

The geological history of Florida and our human perceptions about the Florida peninsula have been shaped by our close connection to the sea. Much of Florida's history has been recorded in the rocks and sediments of the Florida plateau. This history spans the Paleozoic, Mesozoic and more than half of the Cenozoic era.[10] Formed about 530 million years ago by a combination of volcanic activity and marine sedimentation during the early Ordovician Period,[11] the Florida Plateau has supported terrestrial ecosystems for only 25 million years[12] (a relatively short time in the geological time frame). Since its emergence from the sea, the Florida plateau has been continually changed by global sea levels and the forces of the ocean. Geologists believe that Cenozoic sea levels in Florida fluctuated from several hundred feet or more above present level to several hundred feet below present level sea level.[13] Throughout its history, from the earliest records of terrestrial life in Florida to the first arrival of Paleo-Indian near the end of the last ice age (10,000-12,000 years

9. Core Writing Team, R.K. Paschauri, and A. Reisinger (eds.), *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Geneva: IPCC, 2007).
10. S.D. Webb, "Historical Geography," in *Ecosystems of Florida*, R. L. Meyers and J.J. Ewel (eds.) (Orlando: University of Central Florida Press, 1990): 70-100.
11. G. M. Allen and M.B. Main, *Florida's Geological History and Geological Resources*, Florida Geological Survey Special Publication Number 35 (Tallahassee: Division of Resource Management, Department of Environmental Protection, 2005).
12. Ibid.
13. E. Lane, ed., *Florida's Geological History and Geological Resources*, Florida Geological Survey Special Publication Number 35 (Tallahassee: Division of Resource Management, Department of Environmental Protection, 1994), available online at http://purl.fcla.edu/fcla/dl/UF00000124.pdf.

ago)[14] to our present concerns about the future of Florida in a changing world, Florida has remained a complex and unique geological and biological feature of North America. What does this history tell us? The Florida peninsula has changed slowly over time. It will continue to change in response to climatological, sociological, ecological and technological conditions. Climate change and sea level rise are two issues, among many others, that must be recognized and understood. The question is: Are we prepared to address and respond to these potential global-scale changes?

An understanding of the geological history of Florida provides important scientific and historical insights into the changes that may come in the 21st century and beyond. While the Florida peninsula has changed shape and size with the ebb and flow of glaciers affecting sea level rise, there is a fundamental difference today from past glacial and interglacial periods: for the first time in history, Florida has over 17 million residents with 78 percent of Florida's housing and infrastructure located in high-risk shoreline counties and properties at or near mean sea level.[15]

FROM "LA FLORIDA" TO GLOBAL WARMING: CHANGING HUMAN PERSPECTIVES

In the brief history of time that spans the naming of "La Florida" by Spanish conquistador, Ponce de León in 1513; the first Florida census in 1830 (that documented 34,730 people concentrated primarily in the Panhandle region);[16] and this first decade of the 21st century, our perception of Florida and its relationship to the global ocean has changed. Those changes in human perception can be graphically illustrated by comparing the earliest depictions of the Florida peninsula (Girolamo Ruscelli's *Nueva hispania tabula nova,* Venice, 1561) with various Florida maps that were created over the centuries[17] and Google Earth™ today.[18]

14. Ibid.
15. J. Kildow, *Phase II Florida's Ocean and Coastal Report, National Ocean Economics Program* (Tallahassee, Fla: Florida Oceans and Coastal Council, 2008).
16. S.K. Cody, "Florida's Population Center Migrates Through History," *Florida Focus* 1(2):1-5.
17. Florida Historical Map Collection, P.K. Yonge Library of Florida History, University of Florida, Gainesville, FL. Online at http://www.uflib.ufl.edu/spec/pkyonge/fhmaps.html.
18. Google Earth™ is a virtual globe, map and geographic information program that was created by Keyhole, Inc. (as Earth Viewer), a company acquired by Google in 2004.

Our enlightened understanding of the Florida peninsula, its vast coastline, and its relationship to a global ocean paralleled advances in navigational technologies, improvement in navigational mapping methodologies, and growth in first-hand knowledge derived with each and every new explorer and exploration. While representative maps of Florida from the 15th-19th centuries provide evidence about how our perceptions of the shape of the Florida peninsula evolved, it was the first U.S. Army photo of Earth from space in 1946,[19] followed by the first television images of space in the 1960s[20] that began a "sea change"[21] in our understanding of planet Earth and the peninsula of Florida. The scale of Earth observations from space created a paradigm shift in our understanding of the planet. This shift is often associated with publication of the first "Blue Marble" photo taken by the NASA Apollo 17 crew on December 7, 1972 as they left Earth's orbit for the last manned-mission to the moon. "*With the sun at their backs, the crew had a perfectly lit view of the blue planet. That image changed forever our perception of Earth.*"[22] It would take three decades of advancing NASA space technologies, Earth observations from space, and the resulting explosion of global ocean scientific knowledge to begin to piece together the data needed to unravel the story of the ocean planet, climate change and sea level rise. It will take a decade or more to realize fully the social and environmental implication of these global changes.

19. In 1946, rocket-borne cameras gave us our first black and white look at Earth from beyond the atmosphere. The view of Earth was from a camera on V-2 #13, launched October 24, 1946. See Tony Reichhardt, "The First Photo From Space," *Air & Space Magazine*, 1 November 2006. The photo and article can be viewed at http://www.airspacemag.com/space-exploration/FEATURE-FirstPhoto.html. Photo credit, White Sands Missile Range/Applied Physics Laboratory.
20. *Planet Earth from TIROS 1: First TV Image.* NASA, Television InfraRed Observational Satellite (TIROS).
21. Silvia Earle coined the term "Sea Change" as the title of her book *Sea Change: A Message of the Oceans* (New York: Fawcett Columbine, 1995). This term is now widely used to describe environmental transformation in thinking. The original expression is credited to Shakespeare, taken from *The Tempest.*
22. NASA "Blue Marble" quote by National Geographic "Milestones in Space Photography." http://photography.nationalgeographic.com/photography/photos/milestones-space-photography.html.

CLIMATE CHANGE AND FLORIDA: SCIENCE AND HISTORY COME TOGETHER

Forward-thinking discussions about climate change and its impacts on the human condition will require an understanding of biogeochemical processes, global trends, and the complex ecological, economic and social forces that drive, and are driven by, global change. A failure to understand these issues in the context of human and geological history will limit society's ability to identify and implement meaningful solutions and social adaptation strategies.

While concerns about climate change have now been branded into the public consciousness with former Vice President Al Gore's best-selling book and documentary, *An Inconvenient Truth* (2006), it is important to recognize that the science of climate change is not new. The history of climate change science was recently documented in the book, *The Discovery of Global Warming* by Spencer R. Weart.[23] First published in 2003, and revised in 2008, this work documented the historic evolution of climate change science and the transformation of scientific inquiry and knowledge to public understanding and civic action. The earliest scientific discussions date back to the 1800s. As examples, in 1827, French mathematician, Jean-Baptiste Fourier is thought to be one of the first scientists to use a greenhouse analogy. In 1896, Swedish scientist, Svante Arrhenius, considered the implications of atmospheric CO_2 concentration (@CO_2) changes. Arrhenius completed the first mathematical model that linked CO_2 to global temperature. In 1957, U.S. oceanographer, Roger Revelle (in an often cited publication) warned that humanity was conducting a "large-scale geophysical experiment" on the planet by releasing greenhouse gases.[24] Although our understanding of global climate change has grown over the past two centuries, many scientific questions remain about long-term trends, accuracy of predictive models, adaptive resilience of ecosystems and species, and potential sociological and economic impacts.

23. Spencer R. Weart, *The Discovery of Global Warming* (Revised and Expanded Edition) (Cambridge, Mass.: Harvard University Press, 2008). Also see history of climate change timeline available online at http://www.aip.org/history/climate/.
24. R. Revelle and H.E. Suess, "Carbon dioxide exchange between atmosphere and ocean and the question of an increase of atmospheric CO_2 during the past decades," *Tellus* 9 (1957): 18-27.

Today, most climate change discussions reference the Intergovernmental Panel on Climate Change (IPCC). The IPCC is a scientific intergovernmental body established in 1988 by the World Meteorological Organization (WMO) and by the United Nations Environment Program (UNEP) to provide the decision-makers and others interested in climate change with an objective source of information about climate change.[25] The IPCC has evaluated climate change risks based on the latest scientific, technical and socio-economic literature produced worldwide relevant to the understanding of the risk of human-induced climate change, its observed and projected impacts, and options for adaptation and mitigation. In its Fourth Assessment Report (2007), the IPCC declared, "*Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.*"[26] Even with this declaration of scientific consensus, debate continues among scientists, citizens and policy makers about climate change trends, uncertainties, risks, causes, and appropriate human responses. When we consider the scope and emotional tenor of this debate, much can be learned from history. An historic example can be found by looking back to the writings of Stephen Jay Gould (1941-2002). Gould was a paleontologist, Alexander Agassiz chair in Zoology at Harvard University, and one of the premier science essayists and communicators of the 20th century. It was through an appreciation of history that Gould came to understand the complex evolutionary pathway for societal and scientific acceptance of scientific methodology and the development of scientific theory. In one of his many essays, "The Validation of Continental Drift,"[27] Gould wrote about his personal excitement of living through the scientific validation and eventual universal acceptance of the theory of continental drift (a debate that took place within the scientific community from 1967 through the 1977). When the theory was first proposed by Alfred Lothar

25. Paschauri and Reisinger, eds, *Climate Change 2007.*
26. Ibid.
27. Stephen Jay Gould, "The Validation of Continental Drift," in *Ever Since Darwin: Reflections in Natural History* (New York: W.W. Norton & Company, 1977). This essay was reprinted in *The Richness of Life: The Essential Stephen Jay Gould*, Steven Rose, ed. (New York: W.W. Norton & Company, 2006), 290-296..

Wegener (1880-1930) in 1912 and supported with evidence in 1915 with his publication of *The Origin of Continents and Oceans*, it was met with harsh criticisms and disbelief from the scientific community. Gould recognized in his essay that during the period of "*nearly universal rejection*" of the theory, "*direct evidence for continental drift - that is, the data gathered from rocks exposed on our continents – was every bit as good as it is today.*" Gould concluded that the continental drift theory was rejected because no one had developed a physical mechanism or explanation for continental plates to "*plow through an apparently solid ocean floor.*" Once that geological mechanism was recognized, a rapid transformation (almost an epiphany) in scientific acceptance occurred after a half-century of scientific rejection. Stephen Jay Gould concluded, "*Many readers may be disturbed by my arguments for the primacy of theory. Does it not lead to dogmatism and disrespect for fact? It can, of course, but it need not. The lesson of history holds that theories are overthrown by rival theories, not that orthodoxies are unshakable.*"

Stephen Jay Gould's essay and quotations resonate today as we watch the scientific and political debate that revolves around climate change and "global warming." While the scientific evidence of climate change and global warming has been presented as "*unequivocal*" by the IPCC in 2007,[28] there is much we still do not know about how natural and human systems will respond to global changes in climate. These uncertainties coupled with the heated and political nature of the climate change debate have generated a continuum of public responses that includes total acceptance and belief, skepticism, denial, ambivalence and even conspiracy.[29] Many uncertainties still exist in our scientific knowledge of CO_2 and sea level rise (i.e. carbon budgets, sequestration, storage and flux in complex natural and built ecosystems; projections for Antarctic ice sheet melting; solar forcing; and natural ocean oscillations). Similar uncertainties exist in our understanding of ecosystem and species responses to changing environments (i.e. resiliency and adaptation responses to temperature, pH, and changes in weather events like rainfall, drought and tropical cyclone frequency and intensity). But science has provided a wealth of knowledge through independent, peer-reviewed

28. Paschauri and Reisinger, *Climate Change 2007.*
29. C.C. Horner, *Red Hot Lies* (Washington DC: Regnery Publishing, Inc., 2008).

research to clearly demonstrate that climate change and sea level rise threaten people and natural ecosystems at a global scale. To address the need for expanded knowledge and understanding about ecosystem services, processes and resiliency, continued support for leading-edge, peer-reviewed scientific research at both local and global scales is essential. We need to increase funding for scientific research, technology development and adaptive coastal management planning in Florida.

As scientists and concerned citizens, it should be perfectly reasonable and acceptable for science and society to debate with vigor and passion the details and uncertainties of climate change. That debate is the foundation of good science and responsible policy. What is important in these debates is that the discussions are based on the best available, peer-reviewed scientific data. It is no surprise to scientists that recent advancements in scientific inquiry and methodology continue to illustrate the complex nature of natural systems and enhance our historic and scientific understanding of global climate change. A few of these studies have provided some counterintuitive predictions and surprises. As an example, a recent study of coccolithophores (single-celled marine organisms, distinguished by calcium carbonate plates) provided some surprising results. Contrary to general expectations that increasing @CO_2 and decreasing pH (increased acidity) in the ocean would negatively impact most, if not all, animals that deposit calcium carbonate shells, plates and skeletons (i.e. corals, bivalves, many species of marine plankton), high atmospheric carbon dioxide levels increased calcification by one coccolithophore species (*Emiliania huxleyi)* in experimental studies.[30] The message from this research is that ecological and biogeochemical effects of rising atmospheric carbon dioxide levels and increasing ocean acidity (ocean acidification) may not be the same for all species. Most scientists are in full agreement that increasing atmospheric and ocean CO_2, ocean water temperatures, and ocean acidity will have dramatic impacts to species, natural communities and ecosystems. The challenge for scientists is to better understand these impacts and uncertainties and to make science-based recommendations to

30. M.D. Iglesias-Rodriguez, P.R. Halloran, R.E.M. Rickaby, I.R. Hall, E. Colmenero-Hidalgo, J.R. Gittins, D.R.H. Green, T. Tyrell, S. J. Gibbs, P. von Dassonw, E. Rehm, E.V. Armbrust, and K.P. Boessenkool, "Phytoplankton calcification in a high CO_2 world," *Science* (320): 336-340.

guide appropriate and responsible mitigation and adaptation strategies.

Global climate change represents a historic opportunity for innovative thinking and bold action. It also represents a great challenge to develop a trusted partnership between the scientific community and society. As we move towards the end of the 1st decade of the 21st century, it is time for Florida to show bold and innovative scientific leadership toward responding to coastal, ocean and climate-change issues. Florida has 1,197 miles of coastline, 2,276 miles of tidal shorelines, 663 miles of beaches, more than 11,000 miles of rivers, streams and waterways, a climate regime that spans the temperate Carolinian and sub-tropical/tropical Caribbean Provinces, and a peninsula land form that is defined by the Inter-American Seas (i.e. Gulf of Mexico, Caribbean Sea and nearshore Atlantic Ocean). Florida's quality of life depends on the vitality and sustainability of its ocean and coastal resources. Florida is a poster-state for vulnerability to sea level rise and climate change. Almost 80 percent of the state's population lives in the 35 coastal counties. With an ocean and coastal economy worth almost $600 billion (2005-2006), Florida has much to lose.[31] Its natural and human-built systems are physically and functionally linked across a complex mosaic of land, freshwater, atmosphere, estuarine and ocean systems. Few states in the nation have greater biological diversity, are more dependent on the social and economic value of healthy natural resources, and are more vulnerable to the long-term impacts of population growth, climate change, sea level rise and failure to address sustainability in the natural and human-built environment. The future health of Florida will be influenced by the sustainability of its natural and human resource assets, resiliency/adaptation to change, and ability to develop and apply new technologies to monitor, model, mitigate and adapt to existing and emerging threats. Because of these coastal attributes, assets and challenges, Florida represents a valuable model to address complex coastal sustainability science and technology issues important to all U.S. coastal states and coastal regions throughout the world. Understanding complex, coupled natural-human systems requires models for natural-social science integration and science-community integration that lead to wis-

31. Kildrow, *Phase II Florida's Oceans and Coastal Report.*

dom and transformative actions. This challenge calls for the highest degree of science-community interaction and trust to build a science-community partnership to address sustainability in highly-vulnerable, urban coastal regions.[32] A number of exciting scientific initiatives are occurring in Florida that provide examples of both scientific and community leadership:

- **In Scientific Research**: Florida State University's Antarctic Marine Geology Research Facility is a national repository for geological materials collected in and around Antarctica that supports international studies on global climate change history.[33] The University of Central Florida is leading efforts in conservation biology to better understand large-scale ecosystem processes and services with special attention on carbon research and animal adaptation to ecosystem change and coastal development. [34] At Florida Institute of Technology scientists are reconstructing past climate cycles from pollen and paleoecological records and conducting research about how global ocean change is influencing coral reefs and other marine communities.[35] The Harbor Branch Oceanographic Institute at Florida Atlantic University pro-

32. Penelope Canan (2009). Personal communication on the need to build expert networks in environmental governance and bridge social capital to build community engagement and trust. Email correspondence in possession of the author.
33. The Antarctic Marine Geology Research Facility at Florida State University houses anc curates over 20,000 meters of deep-sea core sediment, 6000 meters of rotary drilled continental and shallow-water cores, as well as over 5000 kg of dredge, trawl, and grab samples—the largest such Antartic and Southern Ocean collection in the world. See http://www.arf.fsu.edu/ Other FSU climate research is associated with the Center for Ocean-Atmospheric Prediction Studies (COAPS). See http://coaps.fsu.edu/climate_change.shtml.
34. Scientists, representing a number of colleges at the University of Central Florida are conducting significant research relevant to climate change. Studies range from research on ecosystem services and processes to development of renewable sources of energy to climate changes and human health. At the undergraduate level, UCF has demonstrated national leadership by declaring "The Environment and Global Climate Change" as the Unifying Theme of the General Education Program. See http://www.gep.ucf.edu/.
35. Florida Institute of Technology scientists are conducting climate change research in both the Department of Biological Sciences (i.e. coral reefs, paleoecology and conservation of tropical and evolutionary ecology of mollusks in Antarctica) and in the Department of Marine and Environmental Systems (coastal zone management meteorology, oceanography and ocean engineering and technology). See http://www.fit.edu/.

vides research ships, submersibles and new technologies to explore the world's oceans and study ocean health.[36]

- **In Policy**: Florida Governor Charlie Crist has demonstrated leadership with the creation of the Governor's Action Team on Energy and Climate Change (2007) and the Florida Energy & Climate Commission (2008).[37] He signed three executive orders in 2007 that position Florida as national leader to reduce greenhouse gases.
- **In Regional Planning**: The Center for Urban and Environmental Solutions (CUES) at Florida Atlantic University, in collaboration with the National Commission on Energy Policy, developed a comprehensive policy framework, "*Florida's Resilient Coasts: A Framework for Adaptation to Climate Change* (2008).[38] This document assists Florida state government as it evaluates impacts of climate change on Florida's coastal regions and develops/adopts policies and programs to enhance adaptation and management of climate change impacts to Florida coastal communities.
- **In Partnership**: Government, academic, non-profit and private for-profit sector interests are working together to address coastal & ocean health, climate change and sea level rise. The Florida Ocean Alliance, a nonpartisan organization, is working to protect and enhance Florida's coastal and ocean resources for continued social and economic benefits.[39] The Florida Coastal Ocean Observing System Consortium (FL COOS) represents 20 Florida-based state and private universities, non-profit organizations, private

36. The Harbor Branch Oceanographic Institution, a campus of Florida Atlantic University, supports over 140 ocean scientists, engineers and support staff who are leaders in ocean-related innovation, exploration, research, education and conservation. HBOI is one of the nation's premier ocean technology and exploration centers.
37. See http://www.myfloridaclimate.com/env/home/.
38. Since 1972, the Center for Urban and Environmental Solutions at Florida Atlantic University (FAU-CUES) has remained dedicated to helping communities and decision makers resolve urban and environmental issues through partnerships, education and research. FAU-CUES has been a statewide leader in coastal sustainability and climate change.
39. The Florida Ocean Alliance (http://www.floridaoceanalliance.org/) serves as a clearinghouse for information on key ocean and coastal issues facing the state in both the public and private sectors. FOA has led efforts to quantify the coastal and ocean economy of Florida and build innovative partnerships among diverse private-and public-sector interests.

companies and government agencies dedicated to developing and deploying an integrated and sustained Coastal Ocean Observing System (COOS) for Florida waters.[40] This end-to-end system of observations, data management, and models will be essential to describe, understand and forecast changes in the coastal ocean environment. In 2008, creation of the Space Coast Climate Change Initiative (SCCCI) and East-Central Florida Climate Change Task Force[41] is evidence that coastal communities are beginning to prepare for climate change and sea level rise challenges through partnerships, science, and education.

GLOBAL OCEAN CHANGE – POTENTIAL THREATS TO FLORIDA

Even with this recent progress, the value of Florida's ocean and coastal resource assets and the threats associated with climate change continue to be overlooked and underappreciated. In the first decade of the 21st century, scientists are documenting compelling and mounting evidence that climate change is already impacting marine species and ecosystems in complex ways. On April 29, 2008, Jane Lubchenco, Ph.D.[42] provided testimony to the U.S. Congress on: "Rising Tides, Rising Temperatures: Global

40. The Florida Coastal Ocean Observing System Consortium (FL COOS) is working to obtain funding for the development and deployment of an integrated coastal ocean observing system for Florida. This technology network of ocean instruments on buoys, earth observation satellites, ships, drifters, and underwater vehicles (manned and unmanned) is an essential next generation "technology step" towards monitoring ocean change and understanding climate change and sea level rise threats to Florida. The author (De Freese) believes that the vision for FL COOS represents a historic opportunity to integrate ocean science and technology development with 21st century space science and research a Kennedy Space Center, Florida.

41. The Space Coast Climate Change Initiative (SCCCI) represents a diverse group of local stakeholders who believe local governments should implement proactive plans, risk assessments, policies, and/or programs to address global climate change and sea level rise. See http://www.spacecoastclimatechange.com/.

42. At the time of Jane Lubchenco's congressional testimony on "Rise Tides, Rising Temperatures: Global Warming's Impacts on the Oceans," before the U.S. House of Representatives Select Committee on Energy Dependence and Global Warming (April 29, 2008), Dr. Luchenco was the Wayne and Gladys Valley Professor of marine Biology and Distinguished Professor of Zoology at Oregon State University. On December 20, 2008, she was appointed head of the National Oceanic and Atmospheric Administration (NOAA) by then President-Elect Barack Obama.

Warming's Impacts on the Oceans." Lubchenco pointed to three predicted impacts of climate change on the ocean: 1. Increases in ocean temperatures; 2. Increased sea level; and 3. Increased acidity (decreased pH) of seawater. She summarized compelling and growing scientific evidence that these impacts will contribute to degrade coral reef ecosystems, shifts in species migrations and distributions, impacts to coastal estuaries, salt marshes and mangrove systems, significant physiological impacts from ocean acidification, and possible changes in coastal winds and ocean circulation patterns (including the occurrence of hypoxic ocean "dead zones"). Similar climate change impacts have been linked to emerging infectious diseases[43] and increased frequency of harmful algal blooms[44] (a potential major concern for Florida and the impacts of red tide on tourism and coastal community health). When viewed in context, these potential impacts pose significant individual and collective threats to Florida's environment, economy and quality of life.

Marine and coastal scientists have begun to recognize the importance of looking beyond our land-based perspectives to include a better understanding of the impacts of climate change on marine and coastal systems. It is important to understand ecosystem thresholds, tipping points and "tipping elements"[45] and the likelihood that global changes may be abrupt, unpredictable and in some cases irreversible. Clearly, loss of biological diversity through species extinctions represents one example of the latter case. Recent studies suggest that climate changes in response to increased @CO_2 may be irreversible for 1,000 years after emissions stop.[46] The implication for the environment and public health

43. C.D. Harvell, K. Kim, J.M. Burkholder, R.R. Coldwell, P.R. Epstein, D.J. Grimes, E. E. Hoffmann, E.K. Lipp, A.D.M.E. Osterhaus, R.M. Overstreet, J.W. Porter, G.W. Smith, and G.R. Vasta, "Emerging Marine Disease—Climate Links and Antrhopogenic Factors," *Science*, 285:5433 (1999): 1505-1510.
44. H.W. Paerl and J. Huisman, "Blooms like it hot," *Science* 320 (2008): 57-58.
45. T.M. Lenton, H. Hermann Held, E. Kriegler, J.W. Hall, W. Lucht, S. Rahmstorf, and H.J. Schellnhuber, "Tipping elements in the Earth's climate system," *PNAS* 105, no. 6 (2008): 1786-1793. The term "tipping point" refers to a critical threshold at which a tiny perturbation can qualitatively alter the state or development of a system. Here the authors introduce the term "tipping element" to describe large-scale components of the Earth system that may pass a tipping point.
46. S. Solomon, G-K Plattner, R. Knutti, and P. Friedlingstein, "Irreversible climate change due to carbon dioxide emissions," *PNAS* 106, no. 6 (2009): 1704-1709.

are profound. The scope, complexity and timeline of climate change impacts to public health and public health systems are unprecedented historically.[47]

Florida remains unprepared to deal with the scope and spatial and temporal complexities of global climate change and sea level rise. In addition, society is only beginning to recognize the significant risks that global climate change and sea level rise pose to the future of coastal areas throughout the world. New scientific evidence suggests that accelerated melting and flow of both Greenland and Antarctic glaciers is occurring faster than scientists expected in earlier model simulations. A recent (2009) report from the U.S. Climate Change Science Program looked at coastal sensitivity to sea level rise throughout the Mid-Atlantic Region.[48] The conclusion: While there is currently no consensus on the upper bound of global sea-level rise, scientific models predict the potential for a meter or more of global sea-level rise by the year 2100, and possibly several meters within the next several centuries.

WHERE DO WE GO FROM HERE? FLORIDA HISTORY IN THE MAKING...

Decisions made today at state, national and international levels regarding greenhouse gas reductions are unlikely to spare coastal states, nations and island nations the need to plan adaptive strategies to address sea level rise. The tough question is what sea-level-rise scenario do you choose as a basis for strategic, long-term planning? Continuing uncertainties in the sea level rise models, especially long-term projections of ice mass loss in the Antarctic ice sheet, create a range of potential risk scenarios and adaptation strategies. There is a common saying in disaster planning: *"Plan for the worst. Hope for the best."* This doesn't give local coastal communities much guidance when sea level projections can range from less than 1 meter to several meters over the next century.

47. H.J. Frumkin, G. Hess, G. Luber, J. malilay and M. McGeehin, "Climate change: The public health response," *American Journal of Public Health*, 98, no. 3 (2008): 1-11.

48. U.S. Climate Change Science Program Synthesis and Assessment Profuct 4.1., *Coastal Sensitivity to Sea Level Rise: A Focus on the Mid-Atlantic Region* (2009). *Lead Agency: U.S.* Environmental Protection Agency. Other key participating agencies: U.S. Geological Survey, National Oceanic and Atmospheric Administration. Contributing agencies: Department of Transportation. Report available online at http://www.climatescience.gov/.

What does past and recent history tell us? Island abandonment has happened in the past. One documented historical example exists at Holland Island, Maryland, on the Chesapeake Bay.[49] Holland Island was once a thriving island community that grew to 253 residents (1850-1900). By 1920, the island was totally abandoned as a result of sea level rise and a complex association of socio-economic factors.

There is a valuable collection of historical and cultural sites along Florida's coastal areas that are at risk from sea level rise, from the nationally known Castillo de San Marcos in St. Augustine to the almost forgotten site of the Latham family "Oak Lodge" homestead (owned by Frances Eleanor Betts "Ma" Latham and Charles F. Latham) located in a beautiful maritime oak hammock on the narrow barrier island of southern Brevard County, FL. First built in the late 1800s, the Oak Lodge on the Indian River was a cradle for conservation in America, attracting notable scientists, naturalists, museum curators and artists to observe Florida's exceptional natural treasures. These science and conservation champions included William Beebe, William Hornaday, Louis Aggasiz Fuertes, Frank Chapman (curator of birds at the Museum of Natural History) and J.W.P. Jenks (Curator of the Museum at Brown University) among others.[50] The old Oak Lodge was consumed by fire in 1910. In 2003, the Oak Lodge's "*two large cisterns, brick chimney base and debris field*" still marked the location of the historic site[51] reminding us of Florida's golden age of naturalists and scientific expeditions. These sites and many others will be at risk from sea level rise.

Climate change and sea level rise also pose significant threats to 21st century, high-population urban centers (along with their historic and cultural assets) located on the coasts of both post-

49. S.J.A. Gibbons and R.J. Nicholls, "Island abandonment and sea-level rise: An historical analog from the Chesapeake Bay, USA," *Global Environmental Change*, 16 (2006): 40-47.

50. A historical account authored by a USFWS volunteer, W. Refalt, to commemorate the 2003 centennial celebration of the national wildlife refuge system in America. Posted online 3 February 2003 by USFWS at http://www.fws.gov/refuges/centennial/pdf2/pelicanIsland_reffalt.pdf.

51. Letter from Bob Gross, Chairman of the Brevard County Historical Commission, to Diane Barile (17 May 2003), in support of public acquisition and protection of the old "Oak Lodge" site as a historical and cultural asset of Florida.

industrial and developing nations. The Organization for Economic Co-Operation and Development (OECD) ranked the worlds' cities on the basis of population risk exposure and infrastructure/asset risk exposure.[52] Miami, Florida, is the most exposed city in the world based on property values and infrastructure assets with exposed assets at approximately US $400 billion in 2007 that are expected to rise to over US$3.5 trillion by 2070. Miami was ranked 9th in terms of population exposure (the only top-ten city located in a developed country). The scenario is much worse for poor, developing nations with millions of people at risk from coastal flooding, eroding shorelines and increased exposure to high winds and storm surge.

Geological history tells us that changes in climate and sea level should be no surprise to Florida. During the 21st century Florida is once again in the cross hairs of global climate change. This is not a time for despair, ambivalence or inaction. This is a historic time for Florida to demonstrate enlightened global leadership in science, technology, stewardship and comprehensive, proactive coastal planning. While we may not be able to stem the tide of sea level rise and climate change, Florida has an opportunity and a responsibility to become a global center of excellence in ocean, coastal and climate change research and adaptive land-use planning. This is a historic opportunity for Florida to become a model for coastal states, nations and island nations. One immediate and proactive response is to recognize that a managed retreat from severe hazard, flood-prone and eroding coastal sites is a commonsense response that can begin on a site-by-site and structure-by-structure basis. Florida can begin the next chapter in its exceptional legacy of conservation lands programs (i.e. Environmentally Endangered Lands Program, 1972; Conservation and Recreational Lands Program, 1979; Save Our Coast and Save Our Rivers Programs, 1981; Preservation 2000 Program, 1990; and Florida Forever Program, 2000) by expanding funding for Florida Forever. Land acquisition funds must be available to implement managed retreat strategies on high-hazard, coastal properties with long-histories of flooding or structural failures. Once acquired,

52. Organization for Economic Co-Operation and Development (OECD), "Climate change could triple population at risk from coastal flooding by 2070" (2007). Publication online at http://www.oecd.org/document/34/0,3343,en_2649_201185_39727650_1_1_1_1,00.html.

these sites can be restored to natural shorelines and habitats. Land owners receive fair market value for the exchange and hopefully re-invest in Florida. This approach would decrease risk exposure for people, infrastructure, and the insurance industry in advance of a catastrophic, large-scale event. In response to catastrophic storm events, both the state and federal government should have emergency land acquisition contingency funds and plans ready for quick-response land acquisition activities that benefit both the affected property owner and the long-term interests of society.

EPILOGUE

The future history of Florida is being written today. This history will be influenced by our individual and collective decisions, actions and behaviors. While this first century of a new millennium will represent a brief history of geological time, our decisions in the next decades will influence the future of Florida for next century and beyond. There is an urgent need to develop and adopt new coastal management strategies that build resiliency into Florida's natural and human-built systems as we respond and adapt to climate change and sea level rise. This will require a visionary partnership among leaders in social sciences, natural sciences, health sciences, coastal management and the community. By looking back to understand the history of past civilizations and the paleoecological record, we can better understand the implications of climate change, sea level rise and our future. Society must look to science for use-inspired knowledge and guidance to make smart, common-sense decisions that benefit coastal communities today and into the future. This will require a significant national and statewide investment in cross-disciplinary scientific research, technology development and training of coastal management practitioners.