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FLORIDA'S RESILIENT COASTS: A STATE POLICY FRAMEWORK FOR ADAPTATION TO CLIMATE CHANGE ▪ FAU

FLORIDA'S RESILIENT COASTS:

A STATE POLICY FRAMEWORK FOR ADAPTATION TO CLIMATE CHANGE

"I am persuaded that global climate change is one of the most important issues that we will face this century..."

FLORIDA GOVERNOR CHARLIE CRIST

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Foreword

Florida's Resilient Coasts: A State Policy Framework for Adaptation to Climate Change

As leaders from government, business, academia, environmental and conservation organizations work to understand the challenges presented by climate change and to develop programs that minimize its effects on our lives, an increasing amount of attention is being directed at ways we could adapt to—or accommodate—some of the expected impacts. Unquestionably, reducing mankind's emissions of greenhouse gases (GHGs) must be the top priority if we are to keep the impacts within a range that is manageable without widespread social or economic disruption. But there is much that society can do beyond mitigation, particularly at the local and regional level, where emission policies have less influence on this distinctly global problem.

Florida faces some of the most direct, immediate, and severe effects from climate change as beach and sea interact in more than one thousand miles of treasured coastline. Unique geography has made Florida a desirable place to live, vacation, and work but also presents its cities and citizens with a set of challenging vulnerabilities. Rising seas threaten low lying coastal regions and freshwater supplies while the possibility of more frequent or more intense storms could place important development at risk.

These coastal impacts and many more are comprehensively cataloged and described in the following report, thoughtfully researched by Nick Bollman and Barry Heimlich under the expert leadership of Jim Murley, director of Florida Atlantic University's Center for Urban and Environmental Solutions. Throughout this document, the authors have endeavored to present a thorough accounting of the most pressing potential impacts along with a set of possible policy responses to protect Floridians and enhance the resilience of the state's infrastructure, communities, and natural systems.

At this juncture, there has been no attempt to rank, order, or prioritize these policy options in terms of expected costs or effectiveness. This report is intended to serve as an initial list of possibilities organized into a draft adaptation framework that will hopefully be refined as work continues on these issues.

At the Bipartisan Policy Center's National Commission on Energy Policy, we recognize the critical importance of good information for sound policymaking. It is our hope that this report will serve as a constructive guidebook for policymakers as they begin to confront these challenges, and that it will become a starting point for the important conversations that must be initiated if society is to meaningfully address the full spectrum of risks presented by climate change.

Florida is unquestionably on the front line of experiencing the impacts of a changing climate and has the opportunity to become a global leader on climate change adaptation policy responses. As the state government is mobilizing its forces and institutions to begin considering how to deal with this issue, we offer this report to the leaders, stakeholders, and citizens of Florida.

Sasha Mackler, Research Director
National Commission on Energy Policy

Acknowledgement

Appreciation goes to Nick Bollman whose vision, research and initial draft is the very heart and foundation of this report. When Nick suddenly and unexpectedly died in late October 2007, we lost an admired and well-liked colleague, and this project was set back significantly. Nick had recently relocated to Florida from California where he for decades was a leading advisor to the state and local governments on a wide range of economic and social issues. He played a significant role in helping California Governor Arnold Schwarzenegger develop that state's climate policy. He had begun to transfer that expertise to Florida and he is sorely missed.

Appreciation goes to Barry Heimlich, Senior Fellow at CUES, who stepped in to help fill the gap left by Nick's passing. Barry wrote the climate change science section and appendix and also provided his expertise to revise and enhance the introduction and sections on climate adaptation science policy, land use and building regulations, and water resource management. Input regarding the built environment was provided by Ricardo Alvarez, Research Fellow at the Florida Center for Environmental Studies at FAU. Dr. Stephen Leatherman, Director, Laboratory for Coastal Research, Florida International University, provided scientific and additional counsel to the project team. The staff at Center for Urban and Environmental Solutions (CUES) has been wonderfully supportive. Feedback was received from numerous individuals including members of the Miami-Dade County Climate Change Advisory Task Force, the Florida Ocean Alliance and the Governor's Energy and Climate Change Action Team. Jim Murley, Director of CUES, served as Principal Investigator for the project.

This project would not have been possible without the expert involvement and support of Sasha Mackler of the National Commission on Energy Policy and Joel Smith of Stratus Consulting Inc.

Introduction

This project is a collaboration between the Center for Urban and Environmental Solutions (CUES) in the College of Architecture, Urban and Public Affairs at Florida Atlantic University and the project's sponsor, the National Commission on Energy Policy (NCEP).

The CUES mission is to work with policymakers and the public in the pursuit of options for managing growth while preserving natural systems, promoting a strong economy, and planning livable communities. CUES seeks to provide solutions through research, education, and partnerships (see: www.cuesfau.org). NCEP is a bipartisan group of top energy experts from industry, government, labor, academia, and environmental and consumer groups whose work is focused on three critical national long-term issues: oil security, climate change, and energy infrastructure adequacy and siting. It is funded by the William and Flora Hewlett Foundation and its partners (see: www.energycommission.org).

Why we are doing this project

The project was inspired by the growing recognition that Florida is on the front line of the consequences of climate change, especially the likelihood of significant sea level rise, the possibility of hurricanes of greater intensity, and the likelihood of more severe droughts and periods of torrential rains. Because of this, there have been very important developments in Florida's commitment to address climate

change that gathered significant momentum beginning in 2007:

In its January 2007 report, the Century Commission for a Sustainable Florida states in one of its recommendations: *"Develop an initial state strategy to address climate change, which will include recommendations for priority action steps to both mitigate impacts and to plan for its potential effects, including sea level rise."*

- The Florida Energy Commission (FEC), a nine-member panel created in 2006 and jointly appointed by the Florida Senate and Florida House of Representatives, throughout 2007 and 2008 pursued an aggressive schedule of meetings, workshops, and consultations with experts on the full range of climate issues, including adaptation. At its October 19, 2007 meeting, the Commission adopted a recommendation to create a Florida Climate and Energy Commission—to replace the FEC—among whose responsibilities would be *"...to make recommendations to the Legislature and Executive Branch on...climate change adaptation strategies...."*

- In his March 6, 2007 State of the State address, Governor Charlie Crist called climate change *"...one of the most important issues that we will face this century."*

- At his July 2007 *Summit on Global Climate Change,* Governor Crist issued three Executive Orders on climate change, including one that established a Governor's Action Team on Energy and Climate Change. The Action Team is a 21-member group of leading citizens whose Chair is Secretary of Environmental Protection Mike Sole and Vice Chair is Mayor Rick Baker of St. Petersburg. One of the tasks given the Action Team by the Governor is to develop, by October 1, 2008, *"...adaptation strategies to combat adverse impacts to society, public health, the economy, and natural communities in Florida."*

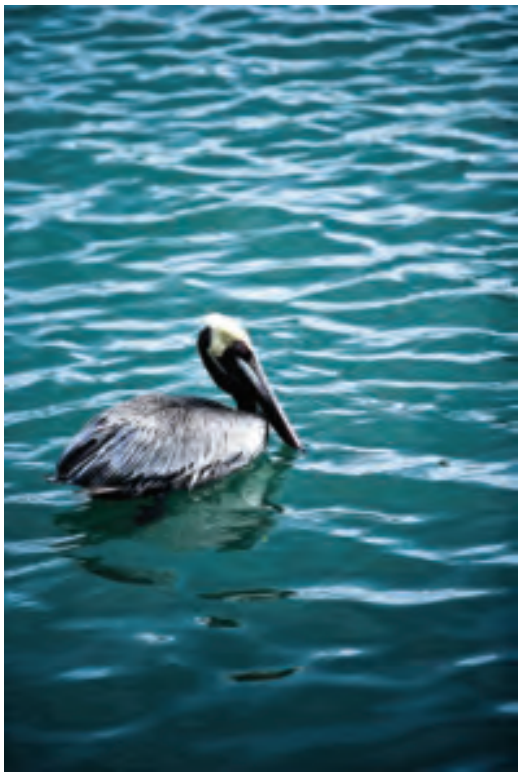
- The Governor's Action Team on Energy and Climate Change issued its initial report in November 2007. It contained the findings and recommendations addressing the 11 charges outlined in the Governor's Executive Order 07_128, which are each, in turn, framed by the principal energy challenges facing Florida, i.e. 1) stimulate economic development, 2) achieve energy security and, 3) address the effects of global climate change. In organizing their recommendations, the Action Team separated the 11 charges of the Governor into five categories including: 1. the power generation sector, 2. the transportation sector, 3. the government sector, 4. organizing state government for Florida's energy future, and 5. a blueprint for development of actions. The Governor's Action Team established Technical Work Groups for Adaptation; Agriculture, Forestry & Waste; Cap & Trade; Energy Supply and Demand; Government Policy; and Transportation and Land Use. Jim Murley, the Principal

The Century Commission for a Sustainable Florida recommended that the state "Develop an initial state strategy to address climate change, which will include recommendations for priority action steps to both mitigate impacts and to plan for its potential effects, including sea level rise."

Investigator of this project, sits on the Adaptation Technical Work Group, which accepted this document as its model for developing statewide adaptation policy.

- A wide array of Florida nonprofit organizations have called for action on climate adaptation. For example, the Florida Ocean Alliance released a position statement in 2007 in which it said: *"The task of developing and implementing strategies to adapt to the consequences of climate change will require the collaborative efforts of a wide range of experts, including physical and natural scientists, engineers, social scientists, medical scientists, those in the humanities, community planners, business leaders, and economists."*

- Miami-Dade County established a Climate Change Advisory Task Force (MDCCATF) in July 2007 under the leadership of Harvey Ruvin who has been a pioneer in climate change initiatives since the early 1990s and was one of the founding directors of ICLEI, the International Council on Local



Environmental Initiatives. This project's Principal Investigator Jim Murley is vice chair of the Task Force. MDCCATF issued its *Second Report and Initial Recommendations to the Miami-Dade Board of County Commissioners* in April, 2008. Included is a dramatic report by its Science and Technology Committee chaired by Hal Wanless, Ph.D., Chair of the Geological Sciences Department of the University of Miami, which concludes that sea level rise could exceed 3 to 5 feet by the end of the 21st Century and 1.5 feet or more within 50 years. Initial recommendations addressed transportation alternatives, adaptation, protection of natural lands including the Everglades, and intergovernmental initiatives.

- Many scientists and scholars have turned their attention to this subject, including an impressive report issued on September 1, 2007: "Adaptive Response to Sea Level Rise in Florida and Implications for Comprehensive and Public-Facilities Planning," written by Robert E. Deyle, Katherine C. Bailey, and Anthony Matheny of the Florida Planning and

Development Lab, Department of Urban and Regional Planning, Florida State University.

- In April 2008, the Florida State Legislature passed comprehensive legislation addressing energy and climate change including new energy efficient building codes, renewable fuel standards and land use and transportation provisions addressing the reduction of greenhouse gases. In addition, Florida's nationally recognized land acquisition program was amended to authorize the purchase of land to mitigate and help adapt to sea level rise and other climate change impacts.

- At the Second Governor's Summit on Climate Change on June 25-26, 2008 in Miami Governor Crist signed the April 2008 energy legislation into law, further building on the strong foundation began last year for Florida's energy future. Local, state, national and international officials, as well as industry and environmental leaders explored opportunities for expanding Florida's renewable and alternative energy marketplace.

Intent of the project

This report presents a comprehensive policy framework to assist Florida state government 1) in assessing the likely impacts of climate change on its coastal regions and communities and 2) developing and adopting policies and programs that will enable the state, its communities, and its residents to adaptively manage those impacts over the near and long term. We hope the critical questions raised in the report and the policy options presented for consideration will be useful to the Governor and Legislature, state agencies, and a broad array of interested parties —local governments and regional planning agencies; business, environmental and social justice organizations; the media and public affairs educators; and the general public. Because this report is among the first attempts in the country to develop such a comprehensive policy framework, we hope it will also be useful to other states and national authorities, particularly those with a particular interest in how to prepare for the unavoidable and considerable impacts of climate change on our nation's coastal regions and communities.

The task of developing and implementing strategies to adapt to the consequences of climate change will require the collaborative efforts of a wide range of experts.

Five Characteristics to Guide State Adaptation Policy Development

The development of state policy and programs for adaptation to the inevitable consequences of climate change to Florida's coastal areas should have the following characteristics:

1) disciplined, 2) comprehensive, 3) purposeful, 4) strategic, and 5) efficient.

The projected impacts of climate change on Florida's coastal regions and communities could be very serious, even dire. An effective and successful effort by state government—together with local governments, the private and civic sectors, and all Floridians to adapt to those impacts will require a disciplined, comprehensive, purposeful, strategic, and efficient approach. By crafting policies that abide by this set of characteristics, policymakers should be able to achieve intended objectives while avoiding unintended consequences.

Disciplined

If ever there was a field in which policy ought to be guided by solid scientific knowledge, climate change is it. Speculation, unexamined assumptions, inadequate observational evidence, faulty reasoning, and narrow thinking will not result in good policy. There may be those who demand action based on what they fear will happen rather than what science tells us is likely to happen. Some may tread the outer edges of scientific consensus and exaggerate predictions to attract the attention of the general public, the media, or especially policymakers. On the other hand, many may simply refuse

to believe what science is telling us out of denial or for selfish reasons. But none of these approaches are grounds for good policymaking.

The varying and dynamic elements of climate science are inherently long term, complex and interrelated. But at least at present, the science is not exact enough to precisely predict when and where climate impacts will occur.

Although we may know the direction of change but it may not be possible to predict its precise timing or magnitude. These impacts may take place gradually or episodically in major leaps. Moreover, because impacts will no doubt vary from place to place, generalizations about appropriate avoidance, preparedness, or resilient responses may or may not be useful. Scientific research must be aggressively pursued in order to progressively improve our understandings and the precision of predictions so that mitigation and adaptation strategies can be well-founded and more specific; science must move toward a complementary match between the location, timing and scale of prediction and human capacity to react.

Finally, the complexity of the large forces at work in climate change suggests that even the best science cannot predict all the dynamic interactions with absolute certainty. Nevertheless, judgments on the science and on the appropriate policy solutions must be made. Clearly, acting with due haste will, to our best abilities, help mitigate future negative consequences—it is better to be a little too early than a little too late.

The ability of science to monitor events and give more precise impact projections will improve over time, and the disciplined approach recommended in this report is that the science must be adequately supported to ensure such improvements. Because the science will be dynamic and forever improving, the process of continual policymaking is as important as specific policy solutions at any given time.

Comprehensive

Because climate change involves such large natural forces, over which we will have less control than those issues typically addressed by policy, it is likely to affect all aspects of life—human communities and ecosystems alike—and therefore the policy approach must explore a very wide variety of adaptation actions. We have tried to present a range of such possibilities in this report, but we do not presume to be exhaustive, and no doubt many others will be brought forward. Nor do we attempt in this report to suggest priorities—this will be the business of policymakers, and the public to whom they are responsible. After all, policymaking in a representative democracy always requires a selective approach to ensure that finite time, intelligence, energy, and resources are used effectively.

Because the science will be dynamic and forever improving, the process of continual policymaking is as important as specific policy solutions at any given time.

Purposeful

Climate impacts will have profound, multiple, and not always obvious significance for large and long-standing built systems (commercial and residential development, public infrastructure such as roads and bridges and waste treatment, etc.) and large and long-standing ecosystems (such as the Everglades and the coastal marine environment). Policymakers must attempt to assess their interventions in adapting to climate change against both short-term and long-term purposes and against large-scale and small-scale objectives Reexamination of purposes and objectives may be fundamentally necessary.

In making public policy decisions, policymakers should ensure, to the extent possible, that assumptions, purposes and objectives are transparent and explicit. This is to allow adjustments to be made whether or not objectives are met. Objectives should be revisited if some become more or less attainable as a result of changes in circumstances. For example, Florida has grounded its economy in large part on the value of residential and commercial developments and even whole communities in close proximity to the shoreline or beaches. Access to the shore is also important, but has been more given more importance as public interest is compared with increased property value of proximity. But what if, because of sea level rise and increasing frequency and severity of hurricanes over the coming decades, the value of proximity declines as the risk of proximity increases? Is there a compensating objective that increases the value of access to the shoreline or beach, even if that access is from developments or communities that are located at a greater distance from the shore? Or what if the now generally highly valued objective of preserving the Everglades ecosystem as we now know it is more risky or more costly than allowing the Everglades to evolve into a different ecosystem? These are profound questions for policymakers and the general public alike, but the impacts of climate change may require that they be addressed head on rather than operate blindly from long-held and long-cherished assumptions.

Strategic

As referred to above, adaptation to climate change will require state policymakers to make choices with the engagement and support of the general public and a wide variety of stakeholders. In doing so, they will weigh the costs, benefits, and feasibility of such choices, whether in considering a variety of options in a single field (say, the conservation of natural ecosystems) or in weighing the costs and benefits of various fields considered together (such as the need for affordable housing and efficient transportation systems on the one hand and the economic importance of agriculture and open spaces on the other hand), or in realistically considering the prospects for implementation.

If these kinds of choices were difficult before the science of climate change was presented, they are even more difficult in the context of such complex and potentially dynamic scientific projections. Nevertheless, choices must be made if we are to adapt effectively, for deciding not to act is clearly not a viable option. The challenge for policymakers will be to get the best information on costs, weigh costs against a variety of often competing benefits, and then craft policies that can attract sufficient support to be enacted in legislative or administrative processes and sustained over time.

Efficient

To optimize policymaker deliberation, public attention and consensus-building at the least cost to government, the economy, and households, a new appreciation and even definition of efficiency may be required. This could mean carefully examining existing policies and programs to determine how climate change impacts can be considered in those policies and programs, rather than creating climate adaptation policies and programs de novo. This is not to say that some new policies and programs won't be required, especially when "stitching together" an innovative, internally consistent coastal climate adaptation policy framework in which enhanced policies and programs are "greater than the sum of its parts." But the characteristic of policy and program efficiency suggests starting with current policies and programs and modifying them for coastal adaptation purposes. For example, land use laws and programs now call for efficient use of land for development purposes. Why not include "risk reduction" or "risk management" to avoid negative climate change impacts as one criterion for comprehensive planning and infrastructure investment? Florida has been a leader in the nation in preserving habitat and other natural ecosystems. When selecting highest priority natural systems for preservation, why not add criteria for "natural retreat" engendered by sea level rise and storm surge on the one hand, and ecosystems and agricultural lands that provide protective buffers for existing development on the other?

On the other hand, when we think of adaptation strategies, will it be more appropriate (as The Netherlands has had to be in recognizing the primacy of the North Sea) to acknowledge that some natural forces dictate engineering solutions? For example, should flood gates be installed rather than trying to manage the ocean's rise and fall through more nuanced engineering solutions and management? Or might we design buildings and even whole communities that can be raised or relocated as sea level rises rather than be hardened against an inevitable change in coastal geography?

Finally, the characteristic of policy and program efficiency suggests being thoughtful at the front end using long-term, adaptive approaches to policymaking while there is still time to avoid the worst climatic impacts, so that policies put into place today don't have to be undone or redone in the future when scientific understanding and observation of climate impacts will have improved.

Conclusion

In summary, efforts to minimize, or mitigate, climate change by reducing greenhouse gas emissions, with all that will be required in transitioning economic, community, and individual behavior patterns, are a profound challenge for policymakers in Florida, the nation and worldwide. In Florida, whose coastal regions and communities are so vulnerable to the potential impacts of climate change, adaptation to climate change presents an even greater challenge. Nevertheless, this challenge can be surmounted if the approach is *disciplined, comprehensive, purposeful, strategic,* and *efficient*.

Overview of Climate Change Science

Florida is one of the most vulnerable areas in the world to the consequences of climate change, especially sea level rise and the possibility of increased hurricane activity. Regardless of the underlying causes of climate change, glacial melting and expansion of warming oceans are causing sea level rise, although its extent or rate cannot as yet be predicted with certainty.

In addition, hurricane activity in the North Atlantic Basin has increased significantly in recent years, but there is controversy over whether the primary cause is global warming or natural weather cycles, making the long-term trend indeterminate at this time. These uncertainties make planning extremely difficult.

As a result, a combination approach of risk management and adaptive management is necessary: assessment of the range of likely and potential risks, development of management strategies appropriate to those ranges of risks, active monitoring, mitigation and responsive adaptation strategies. A basic understanding of climate change science as it relates to Florida is necessary to understand what is happening to the climate, how Florida's climate is likely to change, and what consequences are likely, as well as possible solutions.

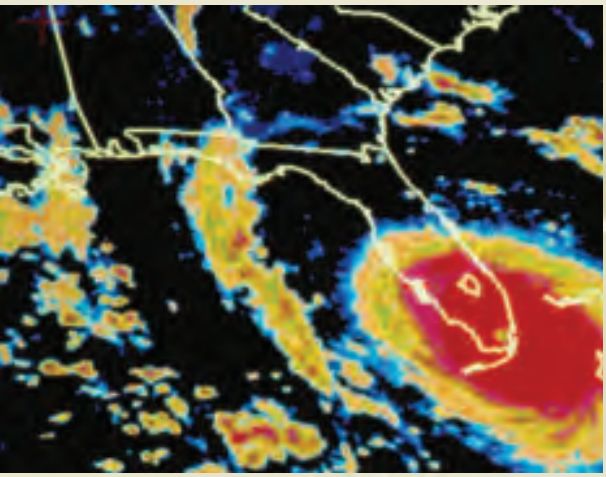
A more detailed discussion of the relevant science is provided in Appendix 1.

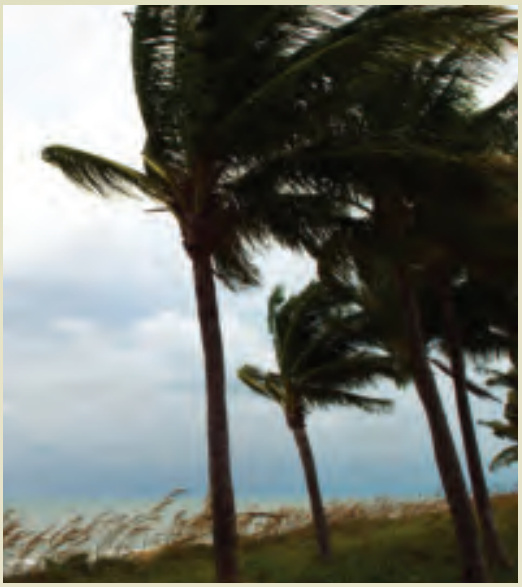
Observed increase in global surface temperatures, i.e. Global Warming

NASA's Goddard Space Institute reports that average annual global temperature has increased by approximately 0.9 °C (1.6 °F) since before the dawn of the Industrial Revolution. According to the United Nations Intergovernmental Panel on Climate Change (IPCC), there is greater than 99% likelihood that Earth is experiencing the highest global temperatures in at least 400 years. During eight out of the last ten years through 2007, the highest average global temperatures in at least 1000 years have been recorded, and the rate of increase appears to be accelerating.

Maul and Sims (FIT) reported that marine and sea surface temperatures at various coastal Florida locations rose over the past 160 years at an average 0.2-0.4 °C (0.4-0.7 °F) per century with uncertain statistical significance.

The overwhelming body of scientific evidence indicates that human or anthropogenic activity causing accumulation of greenhouse gases is the primary cause of global warming. Significant changes in climate and climatic consequences are being observed. These include extreme weather events and rising sea levels due to





thermal ocean expansion and worldwide melting of land-based glaciers and ice caps. Florida, because of its low-lying topography and geographical location in the subtropics, is especially vulnerable to sea level rise and tropical cyclones.

If greenhouse gases continue to be added to the atmosphere along the current trajectory, global temperatures could rise to the point that irreversible and overwhelmingly harmful effects would occur to the earth's environment, economy, and life as it currently exists. Mitigation of global warming by changing the way energy is used and produced will require unprecedented worldwide cooperation among the developed and emerging nations to stabilize and reduce atmospheric concentrations of greenhouse gases.

Even the most aggressive mitigation strategies will still result in some increase in greenhouse gas concentrations before they are stabilized and reversed. This and energy already stored in the global system will continue to exert climatic effects for decades, perhaps centuries. Therefore, policymakers must consider adaptation strategies to deal with the unavoidable consequences of global warming in the near and intermediate term.

If greenhouse gases continue to be added to the atmosphere along the current trajectory, global temperatures could rise to the point that irreversible and overwhelmingly harmful effects would occur to the earth's environment, economy, and life as it currently exists.

Unprecedented increases in accumulation of greenhouse gases

The IPCC concluded, with 90-99% confidence, that the primary driver of global warming is atmospheric accumulation of "greenhouse gases" emitted as a result of human activity, especially burning fossil fuels (coal, petroleum, and natural gas), agriculture, wildfires and burning forests to clear land. Greenhouse gases in the atmosphere absorb infrared radiation (heat) and increase atmospheric temperature. The higher the concentration of greenhouse gases, the greater is the rise in temperature. The primary greenhouse gases are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Other greenhouse gases include fluorinated gases (called "High Global Warming Potential Gases" (High-GWP) used in refrigeration and other human uses.

Over the past 10,000 years since the last ice age, average atmospheric concentrations of the three primary greenhouse gases remained within a narrow range until the late 19th Century when they began to increase geometrically. Global human population has increased about six-fold since then, and per capita energy usage increases rapidly as the world experiences accelerating industrialization. Since the primary greenhouse gases are long-lived in the atmosphere, the result has been an accelerating accumulation of atmospheric concentrations with concomitant temperature rise.

Potential consequences to Florida

Florida Governor Charlie Crist, in his State of the State address on Mar. 6, 2007 said:

"Florida is more vulnerable to rising ocean levels and violent weather than any other state."

Sea level rise and the possibility of more intense hurricanes are the most serious threats to Florida. The Organization for Economic Co-operation and Development report entitled "Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes" cites Miami

as the 4th most vulnerable seaport in the world in terms of population and 1st in terms of asset exposure with an projected value of $3.5 trillion at risk in the Miami metropolitan area.

Florida has over 1,350 miles of coastline, low-lying topography, and proximity to the hurricane-prone subtropical mid-Atlantic Ocean and Gulf of Mexico. In addition, Florida is also susceptible to drought, torrential rainfalls, wildfires, heat waves, and insect infestation, all of which are exacerbated by global warming.

Sea level rise

As the planet warms, two major phenomena contribute to sea level rise: 1) Thermal expansion of the oceans, and 2) Melting of land-based glaciers, snow caps, and ice sheets.

During the 20th Century, sea levels have risen by approximately 18-20 cm (7"-8") at a relatively steady rate of about 0.2 cm/yr (0.08"/year). Confirming this result for Florida, a Florida Institute of Technology Report by George A. Maul shows a long-term trend of rising sea level of 0.22±0.04 cm per year from 1915 to 2005 at Key West, which has the distinction of having the Western Hemisphere's longest sea level record. Sea levels had been relatively stable during the prior 2400 years with sea level rise averaging approximately 3 cm (1.25") per century. Glaciers and ice caps began melting more rapidly during the 20th Century as global surface temperatures increased.

In its 4th Assessment Report in 2007, the IPCC projected sea level rise of at least 9" to 23" by the end of the 21st Century. This projection, based on published reports through 2005, did not account for dramatically increased rates of land-based glacial melting observed in Greenland and Antarctica since then. There is a growing chorus of scientists presenting evidence that dramatic increases in melt rates in Greenland and Antarctica will make significant contributions to sea level beyond that projected in the IPCC Assessment.

The Science and Technology Committee of the Miami-Dade County Climate Change Advisory Task Force, in an unpublished report by Harold Wanless (U. Miami) and Stephen Leatherman (FIU) that includes estimates for increased glacial melting in Greenland and Antarctica, projected a sea level rise of at least 1.5 feet in the coming 50 years and at least 3-5 feet by the end of the century. A one meter (~3.25 ft) sea level rise at spring high tide would inundate most of the state's barrier islands, the Florida Keys, much of the southern portion of the Florida peninsula including virtually all of Everglades National Park, the St. Johns River watershed, the interior flood plains of Miami-Dade and south Broward Counties, and the cities of Fort Lauderdale, Miami, Naples, Fort Meyers, Saint Petersburg, Tampa, Jacksonville, Pensacola, and others.

Florida is more vulnerable to rising ocean levels and violent weather than any other state.

A growing number of research studies on the subject of correlating, modeling and forecasting sea level rise are appearing in the scientific literature. There is substantial agreement that sea levels will be greater than predicted by IPCC. Projections cover a wide range from about 2 to 3 feet to the possibility that seas could rise by many meters by 2100. Dr. James Hansen of NASA's Goddard Institute of Space Studies, a leading voice on the subject of global warming, stated in 2007, "There is enough information now, in my opinion, to make it a near certainty that IPCC [Business As Usual] climate forcing scenarios would lead to a disastrous multi-meter sea level rise on the century timescale."

Effects of sea level rise

Inundation of barrier islands and coastal property. In general, elevations of barrier islands are minimally above sea level and much of Florida's barrier islands have been subject to extensive development of high value oceanfront real estate. Such properties would be threatened by the impacts of major storms in combination with rising seas. Much of the Florida coastal mainland is at low elevation, especially in South Florida, and would be subject to inundation due to rising seas.

The State of Florida is nearing completion of a $24.5 million LiDAR (Light Detection And Ranging) data collection study of coastal areas for better modeling and forecasting of storm surge impacts and to facilitate sea level rise assessments. LIDAR, an airborne laser method for measuring topographical elevations, has an order of magnitude higher resolution than previous methodologies.

Beach erosion is a threat to Florida's lifestyle and its huge tourism industry—tourism in Florida is all about the sun, sea, and sand. Beach erosion takes place primarily as a result of rough seas during hurricanes, storms, and periods of high wind and will be exacerbated by rising sea levels. Rising seas in combination with tropical storms and hurricanes

could result in substantial disappearance of Florida's beaches.

Coastal wetlands provide important wildlife habitat and play an important role as breeding grounds for ocean-going fish and marine life at the bottom of the food chain. As seas rise, coastal wetlands will be inundated by sea water. Since wetland migration will generally be prevented by surrounding development, sea level rise will likely result in substantial loss of coastal wetlands.

The Everglades, especially the southernmost regions close to Florida Bay and the Gulf of Mexico, represent the largest and most important of Florida's coastal wetlands. As sea levels rise, brackish waters will extend further inland and dramatically change freshwater ecosystems. Delicate inland fresh water ecologies, such as sawgrass prairie, cypress swamp, coastal hardwood forest, pineland, and hardwood hammock, are extremely sensitive to changes in the water table and elevation differences of mere inches above water levels in the immediate vicinity. Water levels will rise throughout the Everglades in response to sea level rise in order to maintain gradients necessary for water flow. The importance of completing the Comprehensive Everglades Restoration Project (CERP), whose purpose is to restore sheet flow to the lower Everglades, is heightened in order to "keep the seawater at bay," as stated by Dan Kimbel, Superintendent of Everglades National Park.

Inland urban waterways and stormwater drainage. Canals provide pathways for sea water to penetrate far inland in the low-lying areas of South Florida. Surface water levels and water tables will rise to maintain the gradients needed for gravity flow of water to the ocean. This will increase the likelihood of flooding from heavy rainfall events and increase the need for efficient stormwater drainage. Elaborate flow control systems, gates, pumps, levees, etc. may be needed to control water levels in primary, secondary and tertiary canals.

Much of the Florida coastal mainland is at low elevation, especially in South Florida, and would be subject to inundation due to rising seas.

Saltwater intrusion to aquifers and aquifer recharge. Unconfined coastal aquifers, such as the Biscayne Aquifer in South Florida, will be impacted by sea level rise. Increased hydrostatic head will push the saline water interface (zone of dispersion) inland. Saltwater intrusion in potable water sources is one of the most serious early threats caused by sea level rise.

Hurricane activity

The second most significant threat to Florida from climate change is the possibility of more violent weather, especially the potential for more intense hurricanes. Worldwide, Category 4 & 5 hurricanes have doubled since 1970, and hurricane frequency in the North Atlantic Basin has increased significantly since about 1995. Whether these increases are due to increased sea surface temperatures caused by global warming or natural cycles is a hotly debated issue at this time.

Elevated sea surface temperatures (SST) are known to increase the likelihood of formation and intensification of tropical cyclones. The IPCC 4th Assessment Report states:

There is observational evidence for an increase of intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures. There are also suggestions of increased intense tropical cyclone activity in some other regions where concerns over

data quality are greater. Multi-decadal variability and the quality of the tropical cyclone records prior to routine satellite observations in about 1970 complicate the detection of long-term trends in tropical cyclone activity. There is no clear trend in the annual numbers of tropical cyclones.

"Based on a range of models, it is likely [67-90% probability] that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical SSTs. There is less confidence in projections of a global decrease in numbers of tropical cyclones."

Florida, with 1,350 miles of coastline facing the warm mid-Atlantic Ocean and Gulf of Mexico, experiences more landings of tropical storms and hurricanes than any other state in the United States. Florida was battered by 7 hurricanes during the hurricane seasons of 2004 and 2005 resulting in property damage estimated at $56 billion dollars. In 2004, Hurricanes Charley, Frances, Ivan, and Jeanne struck Florida. In 2005, the busiest hurricane season on record with 28 named storms, Florida was struck by Hurricanes Dennis, Katrina, and Wilma. Although Florida was fortunate to escape serious damage from tropical storms or hurricanes in 2006 and 2007, hurricane activity was above average globally.

Storm Surge due to Hurricanes. One of the most serious threats to Florida's coasts comes from the combination of elevated sea levels and intense hurricanes. Storm surges due to hurricanes will be on top of elevated sea levels, tides, and wave action. As a result, barrier islands and low-lying areas of Florida will be more susceptible to the effects of storm surge. An important element of adaptation strategy is how to protect beaches, buildings and infrastructure against the effects of rising seas and wind, wave action and storm surge due to hurricanes.

Other potential climatic effects

In addition to sea level rise and hurricanes, there are numerous other potential effects of global warming that could affect Florida's communities and environment physically, economically and socially, including:

- Prolonged drought affecting water supplies, agriculture, and habitat.
- More wildfires due to excessive drought and heat.
- More flooding due to more intense torrential rains.
- More frequent and lengthy heat waves creating increased energy demands and health hazards to young children, elderly, and infirm.
- Potential for insect infestation and insect-borne disease resulting from increased temperatures combined with increased flooding due to storms.
- Bleaching of coral reefs and adverse effects on marine life and fisheries due to elevated sea temperatures.
- Ecological changes in the Everglades and other natural systems affecting plant ecology, wildlife, the marine estuaries and coast, and tourism.
- Economic, environmental, and social impacts.

Climate Adaptation Science Policy

"Getting the science right" on climate change impacts and the effectiveness of coastal climate adaptation strategies, now and for many decades, means that we must make a fundamental commitment to fostering the highest quality innovation, information, and analysis in climate adaptation science.

The state government will not be the only actor on this stage, but unfortunately we currently have insufficient national government leadership and direction on this issue. Over time, state government may not be the most important actor overall, but the application of good science to meet Florida's particular needs is the special responsibility of state government, state universities, and other Florida institutions. Thus, state policy should provide guidance and support—and encourage support by others—of a high quality, comprehensive, accountable, and sustained program to observe, document, analyze, and communicate effectively about the "Florida-specific" current and projected impacts of climate change and the effectiveness of proposed adaptation strategies.

There are many efforts under way in this field, conducted by esteemed individual scientists and scientific institutions both within Florida and worldwide. But even highly promising scientific initiatives are incipient, and they are without the framework of a defined, prioritized, coordinated research agenda whose purpose is to serve the continuous improvement of state coastal climate adaptation policy.

Critical issues to Florida

1. This will be a major undertaking and will require unprecedented coordination and collaboration among scientists, policymakers, the media, and the general public. How should it be organized, governed, and funded?

2. What are the critical elements of such a scientific enterprise that will require support and guidance? Such as (without being exhaustive) the further development of scientific theories and computer and real world models by which these theories can be tested; the development of observation, sensing, recording capacities, devices, and techniques that can track climate impacts over time; a robust dialogue among climate, climate impact, and climate adaptation scientists to ensure that knowledge advances; the training of basic and applied research scientists in these fields; the capacity to translate and communicate scientific findings in a manner that those responsible for climate adaptation policy and program implementation can be reasonably certain that their responses are well-grounded in continuously improving science. How can all these elements (and more) be aligned for optimal, synergistic impact?

2. A robust communications program will be required, not to stifle dissent even against convergent scientific opinion, but to ensure that such science can both pass the test of scientific skepticism and engage the public in a manner that sustains interest and support. Government is not always the best communicator to the public, nor always a trusted source. How can scientific information and understanding be communicated in a manner that will be broadly heard and well trusted?

State policy options to be considered

1. Foster and support the development and implementation of a Florida coastal climate adaptation research agenda. This agenda should build on the best efforts currently under way, yet also invite, on a competitive basis, new initiatives to ensure that optimally useful science is the result.

2. Build a decision support structure that will guide such a Florida-specific research agenda over time and hold it accountable to productive results in both the short term and long term to ensure that the research agenda serves optimal public purposes. This could be achieved by modifying the mission

How can scientific information and understanding be communicated in a manner that will be broadly heard and well trusted?

and program of the existing Florida Oceans and Coastal Resources Council.

3. Ensure that observational data and scientific analysis for both the actual impacts of climate change over time and the effectiveness of adaptation responses from recognized international and national as well as Florida sources are organized, housed, made accessible, and communicated in a highly efficient manner, using existing institutional and program capacities. For example, the Florida Coastal Ocean Observing System could be tasked and supported to include the array of projected climate impacts into its program.

4. Identify and establish dedicated funding and other resources that will ensure that highest quality science is not held hostage to short-term political or economic cycles that could undermine the sustained effort that will be required. One possibility would be to supplement taxpayer-supported programs with incentives for public and private insurance sector support: the present value of avoided future climate costs has calculable economic significance.

5. Ensure that public sector involvement encourages public and private university systems to embrace the opportunity in climate adaptation research and stimulates, and perhaps even partners with, private sector basic and applied research to bring the full weight of market forces to the service of public benefits. This could include establishing public-private partnership Centers of Excellence on Climate Change throughout Florida's public and private university systems.

6. Though this is a challenging arena for public policy, it will be important that scientific results be communicated effectively. Because the sustenance of good science requires the appreciation and engagement of a knowledgeable public—and particularly on a subject matter as relatively new as coastal climate adaptation—it will be essential that the research agenda and its products find their way into popular communications, through the media, universities, K-12 schools, and civic and community organizations.

7. Seize the economic opportunity. The Florida coastal climate adaptation enterprise should have exportable social and economic value for other states with coastal vulnerability, the Caribbean, and island and coastal nations around the world, as well as the international institutions with an interest in their well-being. Florida's research agenda and products could have humanitarian value for others as well as comparative economic opportunities for Florida's scientific and commercial sectors.

Specific scientific programs known to be needed:

1. The State of Florida is nearing completion of a $24.5 million LiDAR data collection study of coastal areas. This data must be properly analyzed and used for topographical mapping in 1 foot increments for the areas to be impacted by various levels of sea level rise

with clear definition of zero sea level and correcting for sea level rise to date and tidal activity including seasonal extremes.

2. Review and update as necessary hydrological models of coastal areas:

   a. To forecast seawater intrusion as a function of sea level rise and rate of rise.

   b. To forecast effect on sea level rise on water tables, inland waterway levels, stormwater drainage, etc.

3. Climate impact studies on Everglades including:

   a. Effect of sea level rise and changes in weather patterns on inland penetration of saline waters and their hydrological and ecological impacts.

   b. Effect of sea level rise and changes in weather patterns on ecology and wildlife distribution and survival.

4. Since climatological studies and modeling to date do not have adequate fidelity to reliably predict changes in Florida's climate (since the Florida peninsula is surrounded by the Atlantic Ocean and the Gulf of Mexico), the state in partnership with federal agencies and universities should undertake review of current studies and models and consider undertaking updating climatological studies and model development to more precisely forecast Florida's changes in weather patterns.

5. Considering that Florida is critically vulnerable to potential impacts of sea level rise and hurricane activity, the state should establish or enhance existing programs to follow developments in these matters by researchers worldwide and sponsor research at Florida universities to provide research data on local issues that are not addressed by the international science community. Included in this should be careful monitoring at locations along the full length of Florida's coasts of sea levels, sea surface and ocean temperatures, glacial melting in Greenland, Antarctica and mountain glaciers worldwide, Gulf Stream flow rate and temperature profiles in the Florida Straights as an indicator of the Global Ocean Conveyor, and hurricane activity, windshear, and sea surface temperatures in the North Atlantic Basin, El Nino weather patterns, the latest theories, correlations and predictions of future trends in hurricane activity.

6. The state should establish or enhance existing programs to monitor and determine trends in other climate related impacts that could have consequences in Florida, such as rain and drought patterns, floods, wildfires, heat waves, epidemiology of heat-related and insect-borne diseases, etc.

7. In the face of rising sea levels that could inundate areas of Florida's barrier islands and low-elevation coastal areas, scientific and engineering research should be conducted to provide the basis for deciding if, when and where selected high value coastal regions should be either abandoned or protected by public works projects such as dikes, dunes, levees and/or seawalls. Considering the substantial challenges for such undertakings, the technical, economic, social, and environmental feasibility of such public works projects should be assessed. This work should be commenced in the near future because of the decades-long time frames needed to study, design, and construct such projects and because of the uncertainty in projections of extent and rate of sea level rise.

Though this is a challenging arena for public policy, it will be important that scientific results be communicated effectively.

Planning and Decision-Making

Background

A policy framework for coastal climate adaptation rests on and acknowledges current policy programs existing in Florida and encourages the utilization of existing capacities supplemented by minor or even major modifications. Therefore, in each of the following six subsections:

- Comprehensive land use planning and decision-making
- Water Resource Management
- Transportation and other Infrastructure
- Conservation of Natural Lands and Marine Systems
- Beaches and beach management, and
- Emergency preparedness and response to extreme events

We describe the current condition of state policy as it relates to coastal climate change issues.

Critical issues

Each of the policy areas discussed has critical issues that ought to be addressed, though not necessarily in the short term. Some of the issues are so complex, or the science still sufficiently uncertain, or the current policy-driven activities so

well-established and difficult to unravel and reweave, or the policies so likely to have long-term consequences that they will be difficult to redirect over time, that careful, thoughtful, and systematic analysis will be required. This report outlines the full array of critical policy issues, whether simple and urgent or more complex and requiring substantial additional study and deliberation.

State policy options to be considered

The list of options presented in each field is not exhaustive. Clearly, much more work will be required to refine the policy possibilities and test them against the realities of the policymaking process. The Governor and Legislature will establish priorities and the timing and sequencing of policy deliberation and adoption. This report tries to help that process by presenting an array of options that might be considered.

Some of the policy issues and options will be higher profile than others, particularly if policymakers perceive that the public demands action, even if that action is time-limited, outcome-focused further study and deliberation.

Some issues are known to be likely to emerge over the next year or even during the next legislative session, because they are already in the "policy pipeline," and it would be imprudent to adopt new statutes or regulations that ignore coastal climate adaptation.

Some policy options might take the form of a "no regrets" approach. This is perhaps the most difficult arena, requiring keen judgment by the Governor and Legislature. It essentially means that policymakers will not want to look back in years to come and observe that if only they had made this decision or that in 2008, they might have avoided some of the worst impacts of climate change. It would be prudent to draw a "bright line" around policy decisions that have long-term, irreversible, or substantially irreversible consequences but that may be subject to different analyses and determinations as climate science improves. If at all possible, these decisions should be avoided, or made on an interim, adjustable basis, so that there are "no regrets."

The long-standing goal of improving transportation systems and land use efficiency through transit oriented development utilizing smart growth principles is enhanced by climate change.

Comprehensive land use planning and building regulation

Background

Florida has a long established record in land use planning, whose framework was adopted in 1985 and modified as needed since then. The state government's laws, regulations, and procedures are famously thorough and comprehensive. Florida, unlike many states has a state agency-in-charge, the Department of Community Affairs. It also has regional planning councils, which oversee comprehensive land use planning and approval of large-scale project by local governments. The long-standing goal of improving transportation systems and land use efficiency through transit oriented development utilizing smart growth principles is enhanced by climate change. Reduction of Vehicle Miles Traveled (VMT) by expanded use of mass transit and pedestrian-oriented smart growth

development is an essential component of any plan to reduce greenhouse gas emissions from automobiles and trucks.

The state's policy regime is especially coast-sensitive because coastal regions and communities are such an intrinsic part of the Florida economy. Also, state law recognizes the human and economic hazard potential of hurricanes and the need for both evacuation and community recovery and resiliency. However, the policy regime is not currently climate-change-sensitive. For example, land use and conservation policy and building codes and standards do not currently incorporate sea level rise as it might affect development and conservation in general, the added effects of storm surge from a higher sea level base, and plans for hazardous weather events, including evacuation and recovery. Other climate-change related impacts that could affect land use and conservation policy include possible saltwater intrusion on water supplies, flooding from torrential rains, water shortages due to drought, higher risk of wildfires in forested areas, and public health due to excessive heat waves and insect-borne diseases.

Florida's extensive coasts and low-elevation areas could suffer considerable impacts from significant sea level rise by the end of the 21st Century. Considering the enormous economic and social value of the built environment, especially in major metropolitan areas, the state should consider whether selected sections of its coasts can and should be physically protected in the long term. The porous nature of much of Florida's coastal geology may present extreme engineering challenges. Technical, economic, social, and environmental feasibility assessments are needed to protect Florida's most valuable coastal assets.

Critical issues

1. How and when should climate-related matters be incorporated in regional and local comprehensive plans? This would include VMT reductions on the mitigation side and adaptation to aspects of climate impacts, particularly in coastal regions and communities, on the adaptation side.

2. How should these new aspects of comprehensive plans be implemented in the face of probable "business as usual" reluctance on the part of local governments, developers, development financiers, insurers, and others?

3. What regionalized or localized computer modeling and dynamic observational techniques will be required to ensure that plans (and subsequent project-level decisions) are well-grounded in current data?

4. What performance measures should be used to ensure that comprehensive plans (and amendments) are consistent with climate change goals?

5. Can regional visioning (i.e. participation by stakeholders from all segments of the community) help inform and engage the general public as well as stakeholder interests in the new approach to comprehensive planning required by climate change?

6. What should be the boundary definitions and land use restrictions on development in Florida's "coastal high hazard areas" (CHHA)?

7. Should the Florida Building Commission further modify their new voluntary "Code Plus" guidelines for increasing the hurricane resistance of buildings in consideration of additional impacts due to climate change such as sea level rise?

8. What new guidelines should be considered for Florida's CHHAs to determine when existing buildings should be fortified and strengthened, replaced, or removed?

9. Considering that significant sea level rise within the coming 50 to 100 years could inundate barrier islands and areas of low elevation on the mainland, should major public works projects, such as dikes, dunes, levees, and/or seawalls to protect Florida's coasts be considered?

State policy options to be considered

1. Florida's comprehensive planning laws and procedures will need careful reexamination in light of climate change predictions. In particular, coastal communities and regions that are likely to experience long-term sea level rise and the combination of sea level rise, hurricanes and storm surge will want to ensure that development over the next several decades does not put people and communities in harm's way.

2. Future land use maps will have to be revisited, and climate change impacts should be assessed in Comprehensive Plans, including especially Coastal Management and Capital Improvement elements.

3. Implications should be assessed for hurricane evacuation zones and routes and even policies that support compact development, if that development is put more at risk or made *less resilient* by climate change impacts. Work on looking at Coastal Management elements of Comprehensive Plans in light of projected sea level rise has already begun at the South Florida, Treasure Coast, and other Regional Planning Councils.

Florida's extensive coasts and low-elevation areas could suffer considerable impacts from significant sea level rise by the end of the 21st Century.

4. Because it will take time to reanalyze comprehensive plans and adjust developer and local government expectations, the state may wish to set a future target date (several years out) by which comprehensive plans will have to incorporate climate change impacts.

5. State government could provide technical support for developing computer modeling that would take sea level rise into account in land use planning.

6. Many regions across the state have expressed an interest in regional spatial scenario planning or regional visioning (some have already begun to do so, such as Myregion.org in central Florida region and SoFlo.org in southeast Florida). The state should encourage this activity and particularly in coastal regions they should include an examination of long-term development in light of climate change impacts.

7. Florida's "coastal high hazard areas" (CHHA) are defined by state law. That law will have to take into account the topographical features of such areas in light of sea level rise, and potential increases in hurricane-related impacts, using the improved mapping capabilities now possible through LiDAR (light detection and ranging). [Note: CUES has a companion report, *Assessment of Redefining Florida's Coastal High Hazard Area,* examining the Legislature's 2006 redefinition of coastal high hazard areas, which redraws the CHHA map, with consequences for property owners, communities, and the state. Though the report focuses only on the three counties of the Treasure Coast, it has statewide coastal region implications. The report concludes that the new CHHA boundary compromises hazard resiliency by removing regulations from some of the most vulnerable coastal lands. The report contains recommendations for further assessment of these changes, including a remapping of the newly defined CHHA once the SLOSH (Sea Lake Overland Surge from Hurricanes) model has access to the higher-resolution topographical data from LiDAR, expected to be completed in the spring of 2009.]

8. The "Florida Assessment of Coastal Trends," a catalog of human use and ecological trends produced to support the Florida Coastal Management program, should be updated with climate impact data.

9. The Florida Keys is an "Area of Critical State Concern," and therefore new development is constrained based on the ability to evacuate an increased population in the event of a hurricane. The state government may wish to reexamine this rationale, given contemporary hurricane forecast sophistication. Considering that long-term sea level rise threatens to inundate the Keys, the state may wish to incorporate sea level rise and potential increases in hurricane intensity into new performance criteria

10. State government, in taking a "no regrets" approach, may wish to declare a limitation on certain kinds of development that is clearly at risk from relatively near-term sea

level rise (may be 1_ feet or more by 2050). Should it also be state policy not to allow rebuilding where the climate-induced increase in the potential impacts of hurricanes or windstorms, combined with sea level rise, increases the risk that such buildings may be subject to severe damage? Because these are difficult matters with potential major litigation potential, it may be necessary to establish special mediation procedures to ensure fairness to property owners and to protect the public interest. It may be prudent to provide greater responsibility to existing authorities (the Governor and Cabinet) to review disputes under existing comprehensive planning law to take into account climate change risk.

11. Because of recent and substantial increases in property taxes and wind insurance, state government is already taking action to reduce this burden on homeowners. It may be possible for the Legislature to use this opportunity to create incentives and disincentives for climate-impact-sensitive land uses.

12. The Florida Building Commission, which adopted a new state building code in 2004 before climate change was widely accepted and its impacts specifically known, may wish to undertake a new assessment of building codes and standards in light of projected sea level rise. It also may wish to explore new building design, construction and maintenance standards over the 50-75 year useful life of buildings that enable buildings and whole communities to withstand the effects of sea level rise.

13. The state should consider sponsoring scientific and engineering research of building design, construction methods, and materials of construction to provide new building design and construction criteria that take into account effects of sea level rise, extreme wind, storm surge, torrential rain events, and elevated temperatures over the useful life of buildings and infrastructure. These criteria should incorporate methods for new construction and retrofit of existing buildings.

14. The Florida Building Commission should consider further modifying their new voluntary "Code Plus" guidelines for increasing the hurricane resistance of buildings in consideration of additional impacts due to climate change such as sea level rise.

Because of recent and substantial increases in property taxes and wind insurance, state government is already taking action to reduce this burden on homeowners.

15. The Florida Building Commission should consider establishing guidelines for determining if and when existing buildings and structures should be retrofitted, replaced, or removed in consideration of climate-change-induced impacts such as sea level rise.

16. In the face of climate-change-induced threats to the long-term survival of Florida's extensive coasts and low-elevation areas (See Appendix 1, Sea Level Rise), and considering the enormous economic and social value of its major metropolitan areas, the state should consider planning public works projects to physically protect selected sections of the coasts with dikes, dunes and/or seawalls. Because of the porous nature of much of Florida's coastal geology, there are questions as to whether it is even technically possible to protect Florida's coasts. The state should commence comprehensive research and analysis to determine the technical and economic feasibility of whether or not selected sections of the coasts can or should be protected. The political, social and environmental impacts of whether or not to pursue such projects, which could have significant effects on Florida's beaches, coastal areas, and near shore coastal marine habitats, should be evaluated and compared. Since public works projects of this magnitude take decades from concept to completion, such feasibility studies should be commenced in the very near future.

Water resource management

Background

The supply of water for human consumption, agriculture, and other economic uses and ecosystems is climate-driven the world over. Florida's water supply and delivery systems are conditioned by the state's unique meteorological and hydrological features. The possible combination of climate change-induced extended periods of drought and/or torrential rains and sea level rise, along with heavy withdrawal of water from the aquifers driven by population growth threatens the adequacy of this supply. State government's role in managing the state's water delivery systems is primarily vested with five relatively autonomous water districts chartered by the state. The state is directly involved with funding water quality issues, including salinity, and issuing consumptive use permits.

Critical issues

1. What will be the most likely and worst case extent and timing of sea level rise? And what impacts will these have on salt water intrusion of aquifers and the availability of fresh water?

2. Looking ahead to increased salt water intrusion due to sea level rise, should the state reexamine the proper balance among uses?

3. Since climatological studies and modeling to date may not have adequate fidelity to reliably predict changes in Florida's climate, should the state in partnership with federal

agencies and universities undertake new climatological studies and model development to more precisely forecast changes in Florida's weather patterns?

4. What engineering and infrastructure solutions (such as wastewater recovery and reuse, stormwater storage and recharge, and desalination) are available and affordable that would ensure a fresh water supply for all uses in the face of climate change and continued population growth in coastal Florida, even if slowed by climate-caused cost of living increases?

5. Because the state has an overriding interest in water supply, should the state and the five water districts explore new means of collaboration and consider establishing "interoperability" between districts?

6. Because the Apalachicola and other rivers in the Florida Panhandle region originate in other states, should the state review and revise its policies and collaborative understandings with neighboring states on water allocations in these watersheds?

7. What effects will sea level rise and more frequent and/or more intense tropical storms and hurricanes, periods of torrential rains, and prolonged periods of drought caused by climate change have on stormwater storage, drainage, discharge, and flooding?

8. What impacts will sea level rise have on the operation of wastewater treatment plants that are at or near sea level?

9. Because of the vulnerability of the Herbert Hoover Dike surrounding Lake Okeechobee, should the state encourage greater federal and state funding and more rapid repairs in the face of potential increases in storms, hurricanes and rainfall due to climate change?

10. What are the implications of climate change for the health of the fresh-water-dependent Everglades ecosystem and for the various components of Everglades Restoration?

11. What are the implications of climate change for continuing to meet the water needs of Florida's watersheds, coastal wetlands, and river systems; its estuaries, lagoons, and bays; marine food chain and offshore fisheries; and the Florida Keys National Marine Sanctuary?

State policy options to be considered

1. The state should examine the "driver" statute, the Water Resources Act adopted in 1972, in light of climate change projections.

2. Various water planning documents, the State Water Plan, Surface Water Improvement and Management (SWIM) plans, regional water supply plans, and the annual status report on water supply planning prepared by the Department of Environmental Protection should be examined in light of the projected water supply impacts of climate change, and consider using a longer time horizon than is currently the practice (five years) to extend the trajectory of adaptive management.

3. Interregional water planning among the five districts will be necessary if the state wishes to prepare for interoperability between districts in the event of extended

The possible combination of climate change-induced extended periods of drought and/or torrential rains and sea level rise, along with heavy withdrawal of water from the aquifers driven by population growth threatens the adequacy of this supply.

but geographically disparate drought conditions brought on by climate change. The Central Florida Coordination Area, which includes six counties and three districts, is an example of how such collaboration might proceed and a process to build upon.

4. Because local water resources and management is dispersed over numerous local, municipal and county agencies, districts, utilities, etc., the state should evaluate whether to consolidate and reorganize the water management structure in order to make decision-making more efficient, effective and less costly.

5. The state should adopt incentives for and consider mandating ambitious water conservation, reclamation, recycling, and reuse goals and establish an accountability system to ensure that these goals are met.

6. The state Department of Environmental Protection could explore methods and incentives for stormwater and "gray water" collection, storage, and reuse in appropriate buildings and facilities, with public facilities leading by example.

7. The state should encourage and incentivize review and revision of facilities and policies relating to stormwater storage, drainage, discharge, and flooding in consideration of climate change impacts.

8. The state should encourage local waste treatment utilities to review and revise their policies relating to the impact of rising sea levels on wastewater treatment plants operations.

9. The state government should consider establishing a time-limited, blue-ribbon working group of experts and stakeholders, something like a "Water and Climate Change Task Force," to explore the issues described above and recommend both legislative and administrative solutions.

10. The South Florida Ecosystem Restoration Task Force should assess the implications of climate change impacts for Everglades Restoration and especially the Acceler8 Program and the Water Resources Development Act. This should also be undertaken for all state managed or overseen watershed and natural coastal areas.

Transportation and other infrastructure

Background

Transportation as a climate change issue is primarily a "mitigation" issue because reducing the amount of VMTs will be required to meet the Governor's greenhouse gas emission reduction goals, even if vehicle fuel efficiency and a low carbon standard for fuel content is adopted. This is because with population increases the number of vehicles on the road will increase proportionately. However, there are climate adaptation issues in transportation, and ones of critical importance to Florida's coastal regions and communities. These include the location, design, and construction of roads, bridges, transit facilities, seaports, and airports in relation to the possible impacts of sea level rise and more frequent and severe hurricanes. Issues of location, design, and construction standards arise as well for all of Florida's public infrastructure, including state universities, prisons, administrative offices and local sewage treatment plants, landfills, and all other public infrastructure.

Critical issues

1. Just as with other land uses, when locating roads and bridges and transit facilities (rail, intermodal transfer facilities, and so forth), particularly in coastal communities, sea level rise is a new factor that must be considered.

2. Tourism and international trade are key components of the Florida economy. How will sea level rise affect the movement of people and goods in and out of Florida's seaports and airports? How will it affect the $4 billion per year marine and fishing industry?

State policy options to be considered

1. The state is about to begin its update of Florida's State Transportation Plan, and the potential impact of climate change should be considered in this next planning cycle. Because the state plan is required under federal law and must be updated every four years—and because the time horizon is at least twenty years—it is imperative that the next plan incorporate whatever is currently known about the possible impacts of climate change during that time period.

2. The state Department of Transportation Future Corridors Initiative should be reexamined to ensure that coastal climate impacts are factored into this long-range plan.

3. Metropolitan Planning Organizations, responsible for transportation planning and funding in urban areas, are in varying stages of the federally required planning cycle, but, as with the state plan, climate change impacts ought to be incorporated into every transportation plan, and especially those MPOs in coastal regions in their next planning cycle.

4. Because transportation planning is a "driver" for land use planning at the local, regional, and statewide level, it will be important that land use and transportation planning engage in an integrated planning effort, through collaboration among MPOs and Regional Planning Councils, particularly for dealing with climate mitigation and adaptation issues.

5. Port Master Plans, which are incorporated into local Coastal Management plans, should be altered to reflect the impact of sea level rise.

6. In a related matter, attention to sea level rise and climate risk should be incorporated into the "Waterfronts Florida" program. The Department of Community Affairs' Waterfronts Florida Program offers help to all coastal local governments in Florida to revitalize their working waterfronts by providing resources for planning.

7. Florida planning law could be amended to prevent the construction of bridges to barrier islands that are at risk from sea level rise and storm surge worsened by climate change, or to require that such structures be built to accommodate potential impacts of climate change for typical lifetimes for such infrastructure.

8. The state government could establish a time-limited, blue-ribbon working group of experts and stakeholders, as suggested for water issues, something like a "Climate Change and Public Infrastructure Task Force," to examine how to incorporate climate change into infrastructure life-cycle planning.

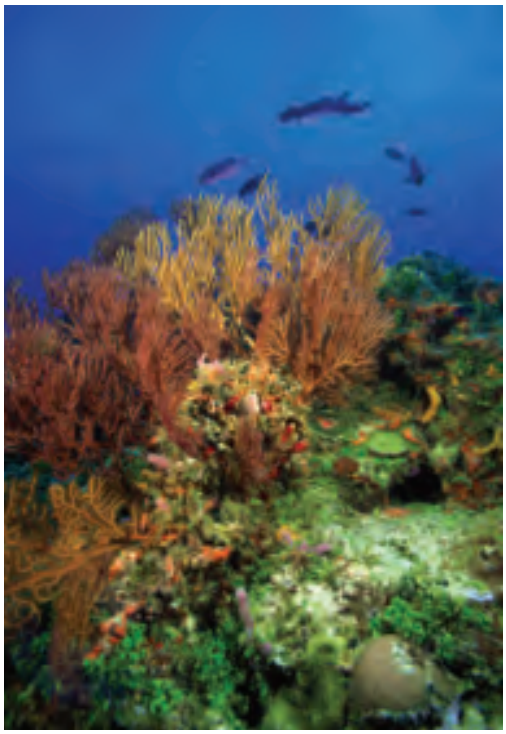
9. The Public Education Capital Outlay (PECO) Trust Fund criteria for funding approval should be reexamined in light of climate mitigation strategies and coastal climate impact projections to ensure sound investments of public capital dollars.

10. The Governor and Cabinet, through the Utility Siting Board, should assess the possible impact of sea level rise on existing or planned utility facilities under its purview: especially the electric power grid, natural gas pipelines, and telephone and broadband delivered through cable lines.

Conservation of natural lands and marine systems

Background

Florida and Floridians possess a very strong conservation ethic, which is bipartisan and broadly held and has resulted in the commitment of major public investments. Perhaps this is because so many people migrated here to be able to engage in coastal, beach, or marine activities. Perhaps also because Floridians understand that protecting the natural



environment has a profound economic significance for a state in which tourism, second home visitation, and even population growth through continued in-migration are such important "drivers" for the overall economy. Perhaps, with the vastly engineered and carefully managed Everglades and its importance as part of the overall water management system, the economic value of "environmental services" is demonstrable and not externalized as it is for so much of the environment.

In any case, for example, the "Florida Forever" program is the world's largest land acquisition program ($3 billion over just the past ten years, with over 2.3 million acres preserved). The Comprehensive Everglades Restoration Plan (CERP) is the largest such project in world history, covering 18,000 square miles in 16 counties at a current projected cost of over $11 billion shared equally by the state and federal governments. The state fully funds the Everglades Forever pollution clean-up program at a cost thus far of more than $2 billion, including the construction of 36,000 acres of wetlands to naturally filtrate phosphorus out of the water before it enters the Everglades. Since 1964 Florida has provided state funding for beach erosion control, restoration, and nourishment in 26 counties, from the Panhandle all the way around to the northeastern most county—Nassau County (see Beaches section).

Despite or perhaps because of this extraordinary level of commitment, the potential impacts of climate change are of deep concern. Not only sea level rise and storm surge but also drought and wildfires and even the northerly movement of "exotic" pests, plants, and animals put Florida's environment at risk, and therefore the well-being of the economy and the quality of life of its people.

Critical issues

1. With such major, long-term planning and funding commitments to environmental protection and restoration, the central question obviously is what impact will near- and long-term climate change have on the outcomes of these investments? What adjustments must be made, and—with dynamic climate change conditions and continuously improving scientific

Florida and Floridians possess a very strong conservation ethic, which is bipartisan and broadly held and has resulted in the commitment of major public investments.

understanding—how can adjustments be made on a continuous basis?

2. What are the implications for the cost-effectiveness of land acquisition, where the ecosystem protected may yet be threatened or even lost to climate impacts, particularly in coastal, estuarine, and riverine/riparian areas? What new management strategies and techniques may be required to accommodate to climate change over time? Is the goal of ecosystem health one that itself must adapt over time to allow ecosystems to change with climate impacts (from fresh water to salt water ecosystems, for example), or are some ecosystems so precious that they should be protected and preserved at all cost through engineered solutions? Where should ecosystems be managed for "retreat" and how can migration corridors be protected to prevent species extinction? What do we know now about the effectiveness of such corridors in the face of long-term climate impacts?

3. What new management strategies and techniques may be required for the Florida Keys and its precious but already threatened and declining coral reefs, and for Florida's other offshore marine ecosystems?

4. What new or enhanced systems will be required for coastal and ocean observation to understand climate-induced changes as they occur, and thereby enable incremental adaptive management? How should these be funded?

5. Can the "carbon sink" value of ocean and land-based ecosystems be captured, and used to help pay for the cost of protection and restoration?

6. Will the interface between natural and human communities require a new approach, including additional "buffering" that will enable natural coastal systems to be protected from human impact but also provide a new "environmental service" by protecting human communities from sea level rise and storm surge and other extreme weather impacts? How might the value of this service be calculated and captured, so as to provide a source of funding?

State policy options to be considered

1. In continuing the Florida Forever program, whose funding is now nearly depleted, climate impacts and positive environmental services should be included when considering land acquisition funding criteria. The successor program should be established permanently through constitutional amendment with a dedicated revenue source. The Taxation and Budget Reform Commission could put such a measure on the ballot, and the need for land acquisition for climate adaptation purposes (among other traditional conservation purposes) made part of the campaign for adoption.

2. The state should extend and expand support for the Century Commission's Critical Lands/Waters Identification project (CLIP), the Florida Natural Area Inventory, and the Cooperative Conservation Blueprint, all of which will be very helpful in integrating statewide conservation priorities with climate change impact data.

3. The state government, universities, and private nonprofit conservation organizations should collaborate in the development of a comprehensive research and practitioner training program in climate change incremental adaptive management.

4. The Florida Keys is an Area of Critical State Concern, as well as beloved by its residents and highly valued by all of the state of Florida. This planning framework should be redefined, based on long-term climate change projections rather than the outmoded question of hurricane evacuation. The Keys residents and state, regional, and local government officials and interested stakeholder organizations should begin a process to develop an optimal climate protection and adaptation strategy.

5. The Florida Coastal Ocean Observing System should be expanded and permanently funded, to ensure that climate impact data—including sea level rise, ocean temperature, current shifts, ecosystem changes, and other relevant data—are captured in a timely manner and made available to relevant resource managers, local government, and relevant business interests, and policymakers. The Florida Reef Resilience Project of The Nature Conservancy is an example of one effort already under way.

6. The Legislature should adequately fund the Florida Oceans and Coastal Resources Council to ensure that all government agencies and nonprofit organizations are well coordinated to better manage Florida's ocean resources. Among other activities, the Council should conduct a major research effort, in collaboration with others, which we call a "Florida Shoreline Impact Assessment Project," to establish a baseline of data on the existing coastal resources and the projected impacts of sea level rise, and include in the scenarios tides, weather, and short-term (El Nino-type) components as well as long-term rise.

Despite or perhaps because of this extraordinary level of commitment, the potential impacts of climate change are of deep concern.

7. In establishing a cap-and-trade policy in collaboration with other states and nations, Florida should optimize recapture of the carbon sink value of its land and ocean resources.

Beaches and beach management

Background

Of the 1250 miles of Florida coastline, 825 miles are beaches. The beaches throughout the state are loved by residents and visitors alike. They are a critical component of the statewide, regional, and local economies. This is why 192 miles of Florida's beaches are managed for restoration by federal, state, and local entities, governed by a Strategic Beach Management Plan. And, since 1964, the Legislature has appropriated nearly $600 million for beach erosion control activities and hurricane recovery. However, according to the state Department of Environmental Protection, 485 miles of beaches (59%) already are experiencing erosion, with 387 miles experiencing "critical erosion." Heretofore, some of this erosion is the result of natural forces, but mostly it's the result of human activity: the construction and management of navigation inlets (some 60 across the state) and imprudent coastal development. This erosion could be considered just a warm-up for the potential impact on beaches induced by climate change.

Sea level rise and the climate-change-induced increase in the frequency and severity of hurricanes put all of Florida's beaches and beach management programs at risk. There are only three known responses to beach erosion: structural ("armoring" or hardening, with controversial environmental and "bad neighbor" consequences); nourishment, essentially replacing sand lost to hurricanes, which is an

increasingly expensive choice because of the diminution of sand supply; and retreat, which is controversial among coastal residents and visitors alike.

Critical issues

1. Should Florida reassess, in light of the permanence and irreversibility of impacts projected by climate change science, the purposes and priorities of its strategic beach management plans and investments?

2. Is there a "rebalancing" of human and environmental concerns, particularly for sea turtles whose effective reproduction is beach-dependent, to ensure that humans and nature are well protected against the impacts of climate change?

3. What process involving the wide array of stakeholders might effectively establish a new consensus on beach protection and restoration strategies?

4. Because substantial private property interests are involved here, what state strategies and incentives could be established to fairly

compensate land and property owners if there is a major shift in beach protection and restoration strategies?

5. How should new beach management priorities be factored into the comprehensive land use planning of Florida's coastal regions and communities? (see this report's land use section)

6. How can Florida and its Caribbean neighbors collaborate on this issue, given that it is affects both Florida and its island nation neighbors?

7. What economic value might Florida capture through its new climate-sensitive beach management strategies for export to other countries facing similar climate change impacts? Is this an "industry cluster" worthy of encouragement and support?

State policy options to be considered

1. Florida should undertake, perhaps in partnership with the Florida Shore and Beach Preservation Association, a major reassessment of its beach management strategies.

2. Florida should explore alternative, but cost-effective, engineering for navigation inlets to minimize beach impacts. A long-time issue for coastal Florida, it becomes even more significant in the context of predicted climate impacts.

3. Beach "hardening" may be required for the beachfront developments of greatest value to owners or the public, and the trade-offs to surrounding communities may require compensatory action and financing.

4. Relocation of some beach developments, where retreat is the optimal choice, will be necessary for some at-risk beachfront developments. With enough lead time for implementation, and a "no fault" compensation program for innocent victims, Florida could ensure sensible responses to climate change without causing a rupture in its beach-dependent economy or a property owner's backlash.

5. Where beach nourishment is still the optimal response to erosion, Florida state government should explore the creation of a public entity to negotiate least-cost contracts for sand.

Emergency preparedness and response

Background

Florida has a long history of dealing with extreme events, particularly landfall hurricanes. The eight landfall hurricanes in the 2004 and 2005 seasons, may have given Floridians experience with the kind of frequency and severity that climate science suggests may be more typical in the future. Nevertheless, the state's emergency preparedness and response policies and programs are well honed. The complicating factor in the future may be the combination of sea level rise and more intense coastal storms over time and therefore the possibility of greater damage from storm surge, and further inland, than has so far been the case. Adaptation to these new conditions will be required. As discussed in the climate

science and land use planning sections of this report, the new LIDAR data, when entered into the SLOSH model, with varying assumptions about the amount of sea level rise, should provide a more detailed picture of risk not only from sea level rise itself but also from storm surge combined with sea level rise. This new mapping may also dictate different possibilities with respect to recovery and redevelopment from extreme weather events.

Critical issues

1. For the long term, does it make sense to begin to include sea level rise in emergency evacuation plans and future land use maps, and to redefine Coastal High Hazard Areas accordingly? Because new conditions and the data sets that define them (including LIDAR data) offer a higher resolution for predicting impacts, should even the idea of CHHAs be reassessed and established more on a regional or local basis, to take into account the variability of goals and strategies that are likely to emerge?

2. What will this mean for existing or planned development, and how will the transition from current to future conditions be managed, along with the development approvals or disapprovals that emerge?

3. How will evacuation routes be affected, and should new modalities and longer lead times be explored?

4. With respect to rebuilding following extreme weather events, improved data and mapping capability, together with observations from future actual occurrences, may shift local and regional thinking about where rebuilding is in either the public interest or the interest of property owners. What are the social and economic issues that will be raised, and how will they be addressed? If redevelopment in place is not desirable, who will bear the cost of relocation?

5. For natural systems, will the combination of sea level rise and storm surge result in ecosystem changes that are so profound that restoration to a status quo ante is not desirable, and will a new resource management approach be required (what we and others have called "incremental adaptive management")?

State policy options to be considered

1. The state should explore the implications of sea level rise for hurricane preparedness and recovery, and prepare the population for these new conditions, including revised evacuation plans.

2. In addition, the objectives of recovery itself, whether rebuilding or revegetation, will have to be considered in a risk management, adaptive management context against future climate impact risks.

3. As discussed in the climate science section, the value of observational data, predictive

models, and remapping increases quite significantly, and should be the object of investment by those who stand to gain from the new data, particularly the insurance and reinsurance industries.

4. The Division of Emergency Management and the state's regional planning councils, together with a wide variety of stakeholders and the general public, should reexamine the goals and strategies of emergency preparedness, response and recovery, and develop new criteria for "climate safe" communities and developments.

Insurance

Background

In some ways, the insurance industry may become—indeed already may be, or at least the reinsurance component of the industry—the chief "driver" in Florida's current response to climate change. Affordable housing and affordable commercial development have always been key to Florida's attractiveness as a place to live and work or to do business. The eight hurricanes that hit Florida in 2004-2005 were a precursor to a much larger actuarial recalculation that many in the insurance and reinsurance industries have made about the Florida market, either that it is not a desirable market or that it is so at-risk as to reduce significantly profit margins and shareholder confidence. Nationally, weather-related insured losses totaled $320 billion from 1980 to 2005, and in Florida the private market for wind insurance has been virtually nonexistent. The state's insurance alternative to the private market, the Citizens Property Insurance Corporation, was created in 2002 by the Legislature to provide a public interest alternative to (primarily) private wind insurance coverage (read: hurricane coverage). It now faces the prospect of "carrying" virtually the entire risk burden in the face of future climate change impacts, though the National Flood Insurance program has an estimated exposure of about $2 billion for Florida coastal properties. Policyholders in Citizens' wind-only program now number 400,000. The state's reinsurance CAT Fund is capitalized at $57 billion ($12 billion available to pay claims immediately after a storm, as a result of action taken this year). But over the long run Florida is not—because of predicted sea level rise and an increase in hurricanes and storm surge/wind damage—out of harm's way. Under current state policy, significant climate-change-related losses at Citizens or the CAT Fund will be borne by policyholders and/or taxpayers. Ultimately the only way to reduce that exposure is to make Florida property "climate safe."

Critical issues

1. In the light of the longer-term climate change impacts that science now predicts, should Florida recalculate its exposure, reexamine its commitment to Citizens Insurance and its capitalization of the CAT Fund, or try to regrow the private property and casualty insurance industry in the state? If the latter, what incentives might be effective that don't "give away the store?"

2. How should properties at risk from long-term sea level rise be treated, from an insurance perspective, as compared with those at risk from extreme weather events? Should this distinction be incorporated into state insurance policy, including the charter for Citizens Insurance and the CAT Fund?

In some ways, the insurance industry may become—indeed already may be, or at least the reinsurance component of the industry—the chief "driver" in Florida's current response to climate change.

3. How can policyholders, taxpayers, and others affected by climate change be effectively engaged in the public policy deliberations regarding climate-change-related regulation of the private insurance market and the role of Citizens Insurance and the CAT Fund?

4. What investment options should private insurers and Citizens Insurance make to reduce the actuarial risk of climate change impacts? How can state policymakers, policyholders, and the general public (read: taxpayers) be effectively involved in these discussions?

5. Should the state's Chief Financial Officer consider both regulatory and state pension fund investment strategies that reduce the risk of climate change and that address adaptation to impacts in a cost-effective manner?

State policy options to be considered

1. The Florida Legislature, with guidance from the state Chief Financial Officer and Governor, should reconsider the charter and performance accountability of Citizen's Insurance in the light of climate change predictions.

2. State government should encourage private insurers, and Citizens Insurance, to invest in climate change science as a "present value of avoided future costs" strategy.

3. The state could also encourage private insurers, as investors, and the state pension funds to consider climate impact prevention in the prudent investment of portfolios.

4. The Legislature should consider adding to the state CFO functions the role of "Climate Change Officer," similar to the role of Fire Marshal, to enable the office to review local government decisions that have climate change response or protection consequences.

5. The state should reward property owners (residential and commercial) who adopt "climate protective" practices, just as it now promotes energy and water conservation. This is the "soft path" equivalent in climate adaptation to energy conservation in the utility field.

6. The state could join with others to advocate a federal "all-perils" insurance guarantee program, essentially adding wind coverage to the NFIP. This still would not deal with the risk exposure entailed in climate-induced sea level rise, except in the context of extreme weather events. It also would add to the fiscal exposure of the national government and could invite its involvement in local land use and development decisions.

State funding and financing

Background

This report has identified a wide variety of policy and program strategies, many of which are simply rethinking, in light of projected coastal climate impacts, the state's role and responsibility in a wide variety of fields of interest. Change has costs, of course, for example, retraining planners and engineers, builders and their workforce, resource managers, and others.

But in some cases, more than rethinking will be required: reengineering, deconstruction or reconstruction, relocation, and other major capital costs may be incurred. For the public sector responsibilities, tax dollars and fees will be the major source, though perhaps many of the costs can be bonded out and amortized over the life of the infrastructure or facilities involved. For the private sector, climate change impacts will include costs to developers, homeowners, and consumers of goods and services. Creative and cost-effective sourcing of funds will be required. But also the key will be to find savings, just as on the mitigation side of climate action new energy efficiencies actually save money after initial capital investments, it should be possible on the adaptation side to calculate the savings that will come from avoided future costs. Paying for coastal climate adaptation will have net costs (absolute costs less savings) if approached properly.

For the private sector, climate change impacts will include costs to developers, homeowners, and consumers of goods and services.

Moreover, the earlier those adaptation strategies are put into place, the greater the likelihood that long-term cost avoidance will be the result. But in a dynamic situation, early investments could be misguided, and particularly where major capital investments are required, major mistakes have major costs.

Critical issues

1. Is it possible to calculate the cost of coastal adaptation, by field of interest, by sector, by community and region? The more that is known about these costs, the better that government, the business sector, and consumers can determine how these costs will be covered.

2. Because climate change is a world-wide issue and a national issue, it will be possible and necessary to estimate the portion of the costs that ought to be paid by federal sources. This will not be easy, and ensuring that Florida receives it fair share of federal resources will be necessary. And apportioning state resources to reduce coastal climate risk will inevitably raise questions of fairness and equity between regions and among social and economic interests.

3. Coastal regions are at greater risk from the impacts of climate change, though the entire state benefits economically from vibrant, attractive, and safe coastal communities. Even so, no doubt there will be, as there has been in the recent policy deliberations about homeowners insurance, the question of fairness in the share of costs borne in relation to the amount of risk taken. Coastal property owners may think of themselves as innocent parties given how recent is the science on sea level rise and storm surge. Inlanders may think differently.

4. There are also questions of generational equity. If the highest cost impacts of climate change won't be incurred for decades, what share of those costs should be borne by current taxpayers or consumers and what share should be financed through long-term debt so that those who will benefit from these investments in years to come will also pay for the benefits?

State policy options to be considered

1. The state should support, perhaps through Enterprise Florida and a consortium of state universities, a sophisticated, continuous economic analysis program to develop the costs and benefits of coastal climate adaptation. This should be a part of or aligned with the Centers of Climate Excellence network proposed in the section on Climate Adaptation Science.

2. The state could consider establishing one or more Climate Change Trust Funds, with dedicated revenue sources and bonding authority, for the purpose of reducing future risk and the cost of future coastal climate impacts where a legitimate public interest is to be served.

3. Because the insurance industry will benefit from risk reduction, some portion of insurance funds should be used, especially for the "soft costs" of climate adaptation such as improved science and the retraining of professionals across a wide variety of sectors and perhaps public awareness programs.

This cost, especially in the current highly charged debate about the cost and availability of windstorm policies, should perhaps not be passed on to policyholders but come out of the future earnings of insurance investments, assuming these companies continue to earn a fair rate of return.

4. The state's public pension fund may be an important source of long-term funding for coastal climate adaptation activity, to the extent it can be shown that the funds earn a prudent rate of return and that savings for state government and public pensioners will occur as a result.

5. If a cap-and-trade program is established to help reduce greenhouse gas emissions through a market strategy, there could be a scalable surcharge on the profits made in these markets, to pay for adaptation costs for which there aren't known sources.

6. There could be a voluntary role for private philanthropy, the state's community foundations and private foundations, through their grant programs and even their investment portfolios, in a true partnership with state government and consistent with philanthropy's mission to benefit current and future generations of Floridians.

Economic development, health, and social effects

Background

Florida has undergone several transformations since becoming a state in 1845, most notably the "land boom" of the 1920's and post-World War II migration from the Northeast and the Midwest, and the large influx of immigrants from Cuba, the Caribbean, and Central and South America in the last forty years. The climate, tropical and subtropical, has been a major attractant, but especially because it is a "controlled" climate, with seasonal, negative aspects subject to anthropogenic intervention: air conditioning, a vastly engineered water delivery system, beach access and management, and a sophisticated hurricane preparation and recovery system. Now to imagine that global warming puts the climate back in charge, and in a manner that will require adaptation, particularly in coastal regions and communities, is almost to ask Floridians once again to reinvent themselves around the new realities.

The economic, health, and social consequences of climate change are not as well understood as the climate impacts themselves, but surely they are challenges that can be overcome. For the economy, there will be a transition as the easy assumptions about the Florida lifestyle cannot be sustained, particularly in the face of a slowing but continuing population growth. Such assumptions as the desirability of oceanfront proximity, now challenged by the prospect of sea level rise and storm surge; the ability to use the automobile at low cost for all the functions of daily life, now challenged by the increasing cost of gasoline and the need to reduce greenhouse gas emissions through reduced VMTs; the relatively low cost of living, now challenged by the internalization of the true costs of climate impacts through homeowners insurance and land scarcity due to constrained sprawl development and the cost of gasoline; the "export economy" characterized by the importation of funds from elsewhere in the country and the world through tourism and

Coastal regions are at greater risk from the impacts of climate change, though the entire state benefits economically from vibrant, attractive, and safe coastal communities.

second home ownership, now challenged by a somewhat less hospitable place to visit or live part-time; the healthfulness of the place, now challenged by the prospect of increased tropical pests and diseases; and the accustomed environment, now challenged by the probability of ecosystem change.

These challenges are additive to those already faced by Florida, as they are by other high growth states: demographic change, sometimes accompanied by cultural dissonance; economic disparities and a growing gap between rich and poor, and stagnation in the economic prospects of the middle class; urban decay in now-older Florida cities; loss of open space and habitat through sprawl development.

Yet inside these challenges there are extraordinary opportunities. A low unemployment rate, the rise of new political leadership, maturing higher education institutions with distinguished international profiles, and—still and all—Florida will continue to have a climate and a "lifestyle" that's the envy of many.

One way to think about the economic and social transition required by climate change is to capture the "lemonade from the lemons": a positive economic strategy that takes all the challenges posed by climate change and turns them into economic opportunities. Florida could be a world leader in the climate adaptation field: engineering and design services, climate-sensitive infrastructure systems, ecosystem and beach management, and other activities that coastal countries and regions around the world will need to master. What Florida learns to do in adapting its coastal regions and communities to climate change it can teach the rest of the world, and it should be able to sell what it knows with comparative economic advantage.

Critical issues

1. How can the economic and social transition required by climate change be "buffered" in a manner that protects Florida's basic economy?

2. How can the costs of the transition be shared in an equitable manner, so that families on

a fixed income or of low income are not disproportionately burdened, to ensure what we would call "climate adaptation fairness"?

3. What new talents and institutional capacities will be required to foster a successful economic transition?

4. What will it take to build an "industry cluster" around the idea of coastal climate adaptation?

State policy options to be considered

1. The state, perhaps through Enterprise Florida and state university economic experts, could commission an analysis of the near- and long-term economic transition issues that will be faced as a result of climate change impacts by particular industry sectors. The sectors chosen should be those with the greatest significance for the overall Florida economy and at greatest risk from coastal climate impacts: for example, homebuilding, tourism, trade, and marine activities—boating and fishing. The study should also explore near- and long-term coping strategies: those that enable industry to absorb or adjust so as to minimize the negative consequences of that transition.

2. The state, again, perhaps through Enterprise Florida, could commission an industry cluster report and economic development strategy focused on the goods and services that will be required to implement coastal climate adaptation. Even a scoping study would be helpful in setting the right direction.

3. The state may wish to establish and "Climate Change Environmental and Economic Fairness Task Force" to develop ideas that would ensure that no economic region or group bears a disproportionate share of the economic transition embodied in coastal climate adaptation strategies.

4. The state could encourage local and regional economic development organizations, particularly those in coastal regions and communities, to study and conduct stakeholder dialogues, particularly with business leaders, to address the challenges and opportunities inherent in the climate change economic transition as well as positive economic opportunities.

5. It will also be important that the state track the human effects of climate change and study and develop effective coping strategies and mechanisms for Floridians for whom climate change will have negative economic, social, and psychological consequences. In addition, new approaches to climate-induced disease, heat, and pestilence will be required of public health authorities.

6. The state should encourage a humane and compassionate national policy that addresses effectively the possibility of climate impact refugees, particularly from Florida's neighboring Caribbean island nations.

Organizing state government for the long haul

Background

As with most state governments, Florida is organized along fields of interest. And that is appropriate, given the special attention to specific issues evidenced by the Legislature and interest groups. However, if climate change impacts, particularly those in coastal regions and communities, suggest that a broad-based, interagency approach is required, and therefore one that requires permanent (or at least long-term) attention, then state government must organize itself, and encourage such organization outside of state government, that will itself be long term, comprehensive, and effectual.

Critical issues

1. Given the range of issues that must be addressed in coastal climate adaptation, what structure of state government might be required?

2. The authority of some interagency or centralized climate adaptation entity may require more than Executive Order (possibly legislative or Constitutional mandate).

3. What role should the State Cabinet play, given the special responsibilities of each statewide elected constitutional officer?

4. How might the Legislature itself organize to ensure a coordinated approach to climate adaptation across a wide array of fields of interest?

5. What efforts should be undertaken to inform and engage the media and the broad electorate in the structural changes that coastal climate adaptation might require?

State policy options to be considered

1. The Governor, who by statute is the state's chief planning officer, should designate a permanent position as the state's Climate Adaptation official. This official would be responsible for coordination among all Executive agencies on climate adaptation policies and programs, and accountable to the Governor, the Cabinet, and the Legislature for regularly reporting strategies, achievements, challenges, and future plans, and also the Governor's main interface with nongovernmental organizations on climate adaptation issues. This idea, in a somewhat different form, has recently been recommended by the state's Energy Commission.

2. The Governor's appointed Action Team is time-limited and task-oriented citizens' group, and it will continue to be very important to have a place where this kind of leadership and expertise is brought together. Therefore it should be succeeded by a permanent entity to ensure a sustained and knowledgeable array of citizens available to advise the Governor and Legislature on climate change policy, including coastal climate adaptation. This idea, too, though in a somewhat different from, has been recommended by the Energy Commission.

3. This entity—and the Governor, state agencies and Cabinet members—should also be advised by a Climate Change Scientific Advisory Council, perhaps as an added role of or adjunct to the Florida Oceans and Coastal Resources Council, to ensure that policymakers have direct access to the best, most current scientific information and analysis on climate change itself and on effective mitigation and adaptation strategies.

4. It may be prudent to establish a state climate change data bank and network, with explicit and transparent protocols for access and use of the data.

5. For additional ideas, the Governor and Legislature may also want to examine the approaches taken by other states. However, according to a July 2007 report from the Pew Center on Global Climate Change, only a few states have begun serious adaptation planning (Alaska, Arizona, California, Maryland, North Carolina, Oregon, and Washington), and these efforts are partial (focused on selected high priority issues); further none has established a permanent entity or process for working on climate adaptation over the long term. Florida most likely will be a leader among states on climate adaptation.

6. The state should consider making permanent the Conversations on Climate Change, to ensure that all statewide elected officials are current on climate conditions and appropriate state responses.

7. The state should encourage all local governments to develop and adopt climate adaptation strategies, particularly those in coastal regions. Such an effort is under way now through the Miami-Dade County Climate Advisory Task Force, created this year by the Miami-Dade County Commission. The Task Force is a pilot in a national program on Climate Resiliency under the auspices of ICLEI, and could serve as a model for other local governments across the state. The state should also encourage regional collaboration among local governments on adaptation strategies and active partnerships among local governments, regional agencies, and the agencies of state government.

8. The state, particularly through the "bully pulpit" accorded the Governor by virtue of his position and his leadership on this issue, should encourage the development of nongovernmental organizations to partner with the state on climate adaptation strategies. These could include, among others, an environmental network on climate change, a business network on climate change, an environmental network on climate change, a faith network on climate change, and a social equity network on climate change.

9. Because adaptation, including especially coastal climate adaptation, will require a knowledgeable and willing general public, educational and dialogue efforts will be useful and ought to be sustained over time. It may be that curricula on the subject should be developed and introduced into the public schools at the appropriate age levels.

The state should encourage all local governments to develop and adopt climate adaptation strategies, particularly those in coastal regions.

Appendix 1
Climate Change Science

This Appendix is an overview of the science underlying global warming and climate change, its causes, and anticipated consequences, especially in Florida. It relies heavily on the findings of the United Nations Intergovernmental Panel on Climate Change (IPCC) in their 4th Assessment Report, Parts I – IV, published at various dates in 2007. The conclusions also rely upon the positions published by the United States National Academy of Sciences. These conclusions are supported by thousands of research studies published in juried scientific journals throughout the world. Another valuable source was *"Climate change and land use in Florida: Interdependencies and opportunities"* by Stephen Mulkey, PhD, University of Florida, 2007.

Since the beginning of the Industrial Revolution, average global temperatures have risen significantly and significant changes in climate and climatic consequences are being observed. The overwhelming body of evidence indicates that accumulation of greenhouse gases due to human or anthropogenic activity is the primary cause of global warming. Florida, because of its low-lying topography and geographical location in the sub-tropics, is especially vulnerable to sea level rise and extreme weather.

Nevertheless, there is still some controversy concerning whether global warming is actually occurring and whether it is due to natural cycles rather than human activity. The controversy is fostered by a small number of scientists and other interests, with little or no scientific substantiation to support their opposing view.

It is not surprising that the subject is contentious considering how much is at stake. The scientific evidence indicates that, if nothing is done to change the trajectory of greenhouse gas emissions, global temperatures will increase to the point that irreversible and overwhelmingly harmful effects will occur to the earth's environment, economy, and life as it currently exists. Many scientists believe

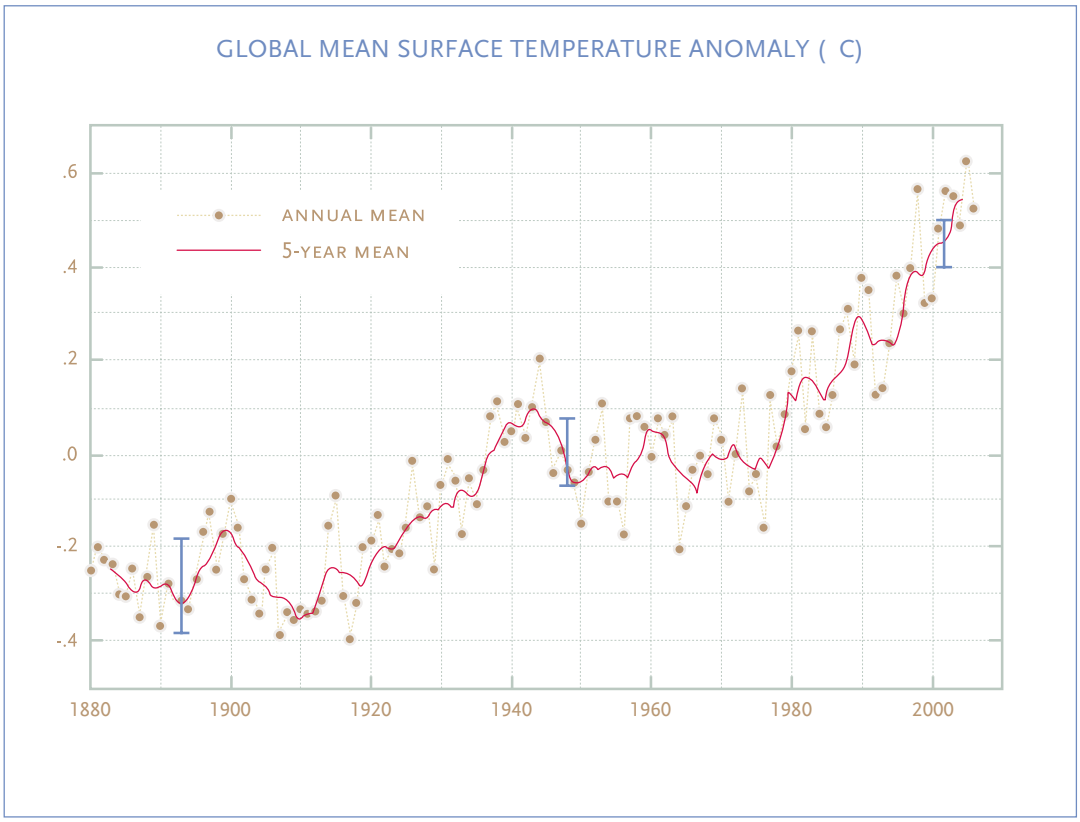
that there is a brief window of opportunity, estimated to be about 10 years, to begin substantially reducing greenhouse gas emissions before irreversible tipping points are reached. This will require implementing major changes in the way that energy is produced and used, including substantial reduction of the use of fossil fuels in favor of low emission alternative energy technologies, such as solar, wind, tidal, geothermal, nuclear energy, biofuels and other non-emitting energy technologies.

Economic consequences will be substantial with major winners and losers. The powerful fossil fuel and power industries stand to be major losers. Conversely, there are enormous economic opportunities for those willing to engage in development and deployment of new energy technologies. Such changes are unlikely to occur via the free market alone due to numerous high hurdles. This requires that policymakers make far-reaching decisions of major consequence. Furthermore, mitigation of global warming will require unprecedented worldwide cooperation among the developed and emerging nations. If such changes are not made and the catastrophic projections of the science community come to pass, the economic and environmental consequences are likely to be devastating. The stakes are very high.

Even if the major political, economic and technological shifts necessary to stabilize and eventually reduce atmospheric concentrations of greenhouse gases are initiated in the near future, global warming will continue for decades, perhaps centuries. Therefore, adaptation strategies are needed to deal with the inevitable consequences. This policy framework addresses issues policymakers must consider in developing these strategies.

It must be stressed however that it is not enough to plan only for adaptation to the consequences of global warming and forego the hard work of mitigation.

The overwhelming body of evidence indicates that accumulation of greenhouse gases due to human or anthropogenic activity is the primary cause of global warming.



Observed increase in global surface temperatures, i.e. global warming

With a few explainable exceptions, temperatures are increasing in the vast majority of regions of the world and significant changes in climate and climatic consequences are already being observed. NASA's Goddard Space Institute reports that average annual global temperature has increased by approximately 0.9°C (1.6°F) since before the dawn of the Industrial Revolution. According to the United Nations Intergovernmental Panel on Climate Change (IPCC), there is greater than 99% likelihood that Earth is experiencing the highest global temperatures in at least 400 years. During eight out of the last ten years, the highest average global temperatures in at least 1,000 years have been recorded, and the rate of increase appears to be accelerating.

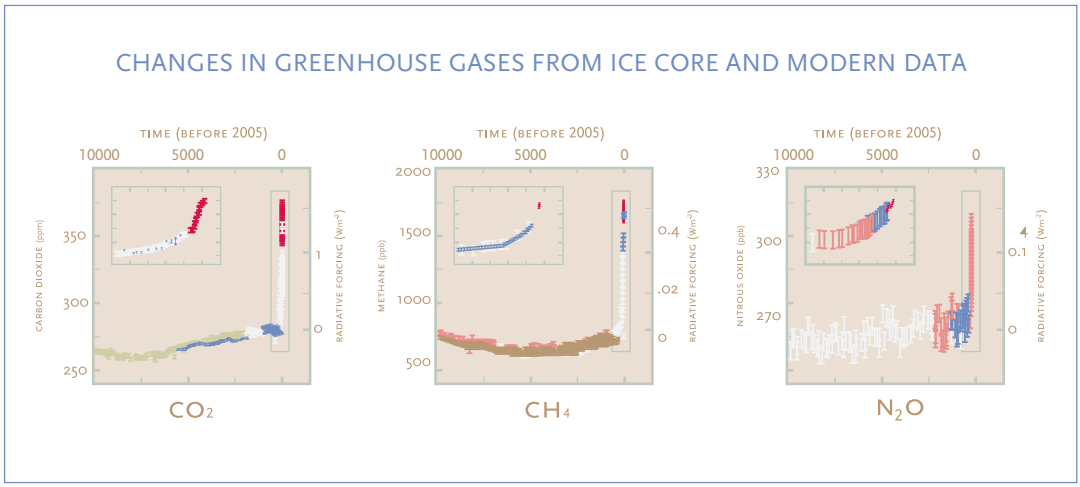
In *Florida Scientist,* 2007, George A. Maul And Harold J. Sims, Florida Institute of Technology, in a paper entitled *"Florida Coastal Temperature Trends: Comparing Independent Datasets"* reported inconsistent marine air and sea surface temperatures over the past 160 years at numerous coastal sites and near shore areas around Florida and concluded that temperature rose at an average 0.2-0.4°C (0.4-0.7°F) per century with uncertain statistical significance.

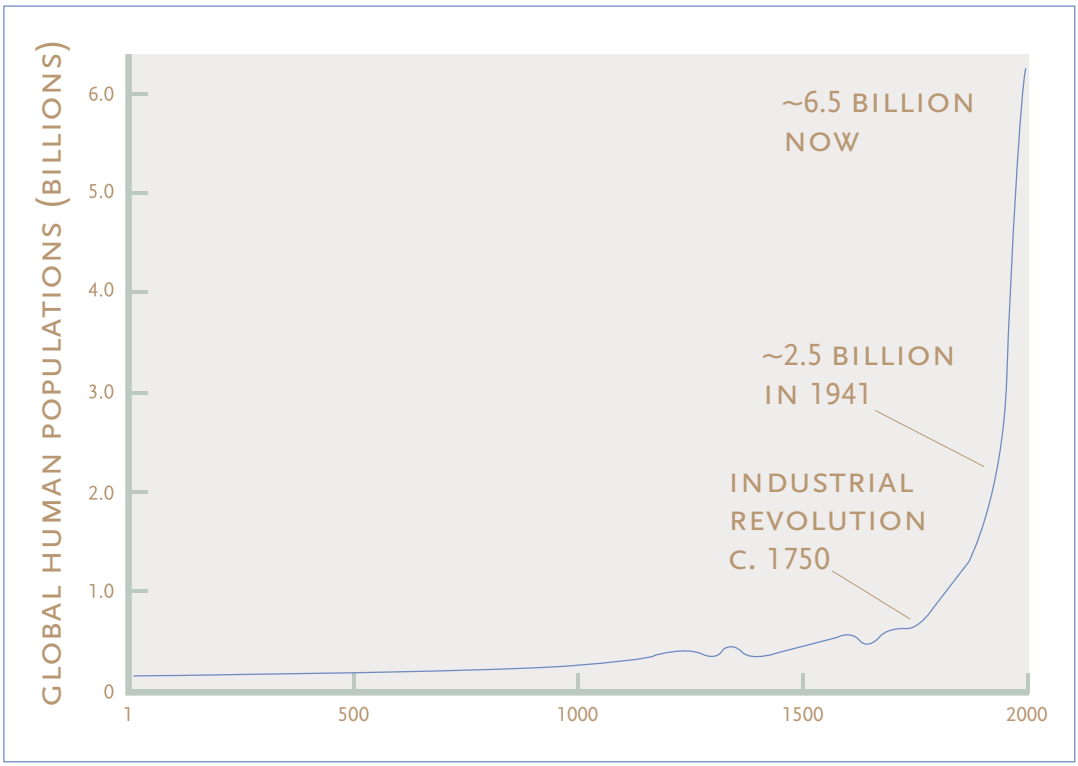
Unprecedented increases in accumulation of greenhouse gases

The IPCC concluded, with 90-99% confidence, that the primary driver of global warming is atmospheric accumulation of "greenhouse gases" emitted as a result of human activity, especially combustion of fossil fuels (coal, petroleum, and natural gas), agriculture, wildfires

and burning forests to clear land. Greenhouse gases in the atmosphere absorb infrared radiation (heat) causing increased atmospheric temperature. The higher the concentration of greenhouse gases, the greater is the rise in temperature. The primary greenhouse gases are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Other greenhouse gases include fluorinated gases (called "High Global Warming Potential Gases" (High-GWP)) used in refrigeration and other human uses.

The figure below from the IPCC Report shows a 10,000 year history of average atmospheric concentrations of the three primary greenhouse gases. The inserts show results for the last 250 years. Concentrations for dates preceding direct measurement were determined by analysis of entrapped air in glacial ice core samples. Concentrations of greenhouse gases were relatively constant over the past 10,000 years until they started to increase dramatically about 100 years ago. Global human population





During eight out of the last ten years, the highest average global temperatures in at least 1,000 years have been recorded, and the rate of increase appears to be accelerating.

has increased about six-fold during this period. Furthermore, per capita energy usage has been increasing rapidly especially since World War II. Global emissions of greenhouse gases are rising geometrically as a result. Since the primary greenhouse gases are relatively long-lived in the atmosphere, the result has been an accelerating increase in atmospheric concentrations.

The Greenhouse Effect

The atmosphere is virtually transparent to sunlight in the visible and UV ranges. When sunlight strikes clouds or the surface of the earth, either land or sea, it is either reflected or absorbed and converted to heat depending on the reflectance of the surface struck. Reflected sunlight passes back through the atmosphere unabsorbed. The heated surfaces however radiate infrared (IR) radiation in relation to their temperatures. Most of the IR radiation escapes into space. However, a portion is absorbed and converted to heat by greenhouse gases in the atmosphere in proportion to their concentrations thus raising the temperature of the atmosphere. Without the absorption of heat due to the greenhouse effect, Earth would be too cold to sustain life as we know it. There is a delicate energy balance between the amount of solar energy striking the earth and the amount of solar energy radiated back into space. The earth also emits heat energy from its hot molten interior and from heat producing activities on the surface. When the amount of energy striking Earth plus the heat energy emitted by Earth exceeds the amount of solar and heat energy radiated into space, the planet warms. The converse would also be true. Increased concentrations of greenhouse gases absorb more IR radiation reducing the amount of energy escaping into space. This energy is retained in the atmosphere as heat that causes temperatures to rise.

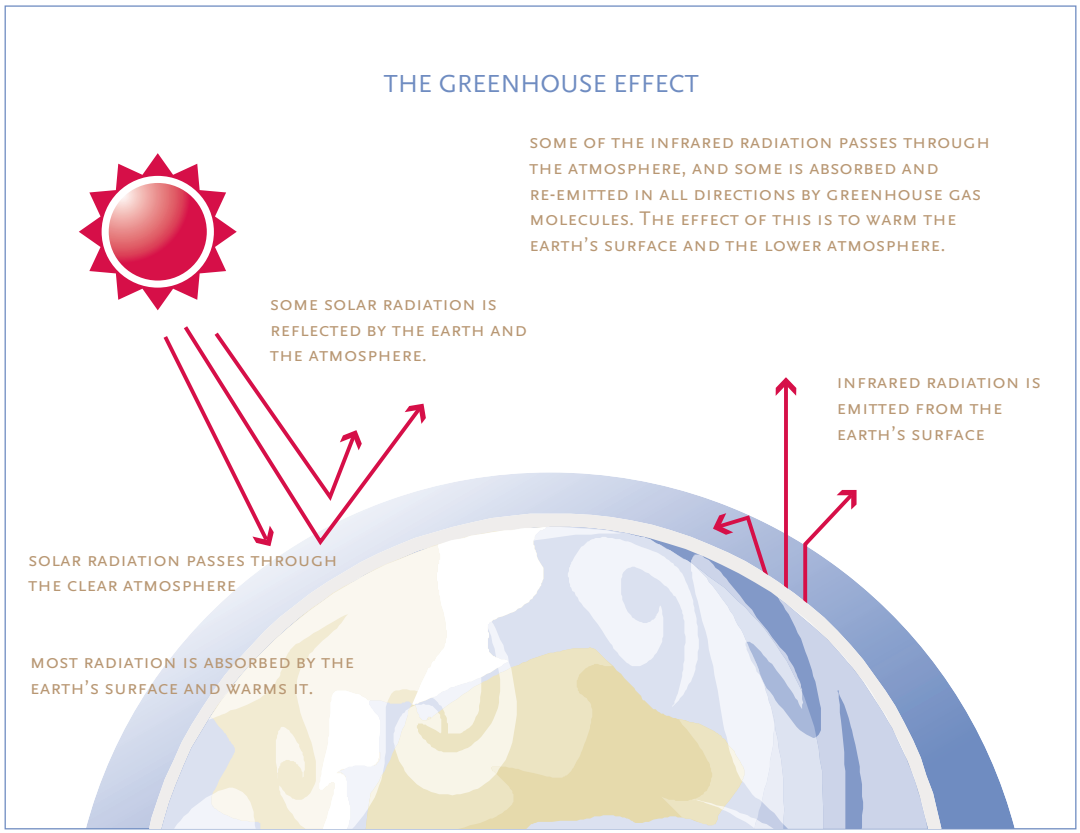
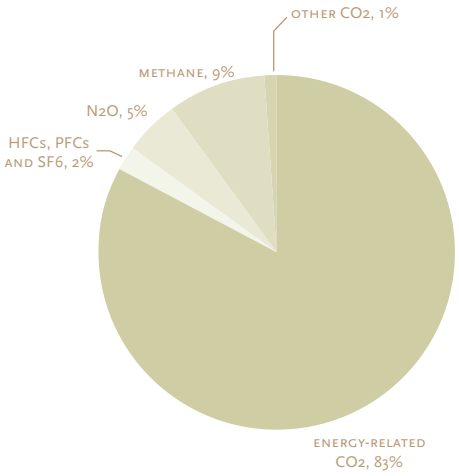
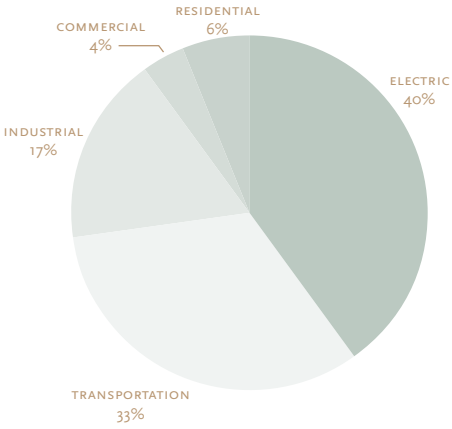


FIGURE A: US GLOBAL WARMING EMISSIONS, 2005[25]



US PIRG 2007

FIGURE B: SOURCES OF U.S. CARBON DIOXIDE EMISSIONS FROM ENERGY CONSUMPTION, 2005[26]



US PIRG 2007

Since the primary greenhouse gases are relatively long-lived in the atmosphere, the result has been an accelerating increase in atmospheric concentrations.

Other possible causes of global warming are variations in solar radiation and variations in the Earth's orbit and tilt of its axis. These affect global temperatures cyclically on a time frame of tens or hundreds of thousands of years and explain ice ages and interglacial warm periods. Astronomers and other scientists have determined that these are not causing the rapid current rise in global temperatures. Quantitative estimates of these driving forces are presented in the IPCC 4th Assessment Report I.

Sources of greenhouse gases

Carbon Dioxide (CO_2) is the primary end product of combustion of carbon containing materials. By far, the largest source of CO_2 is the burning of fossil fuels in energy production, transportation, and engine driven machinery. In the United States, approximately 40% of the CO_2 emitted is a result of electric power production by burning coal, natural gas, and to a lesser extent oil. Importantly, it is estimated that over 70% of the electricity is used in buildings for lighting, heating, cooling, and operation of electrical and electronic equipment. Petroleum-based transportation fuels account for about one-third of the U.S.'s CO_2 emissions. Major industrial sources of CO_2 include production of lime, cement, and gypsum from limestone which are used to manufacture construction materials. Ammonia, an important starting material for nitrogen-containing fertilizers and chemicals, is manufactured from natural gas and generates CO_2 as a by-product. These industries, along with steel, aluminum, copper, petroleum refining, petrochemicals and plastics, require large amounts of heat and electric power currently derived from fossil fuel combustion.

Carbon dioxide is sequestered from the atmosphere by plant growth, especially trees in forests, during photosynthesis and life-sustaining oxygen is a by-product. Vast numbers of trees are cut down for lumber and paper pulp production and to clear land

for agricultural use and land development. The sequestration potential of these trees is lost unless reforestation is practiced. Trees cut to clear land are usually disposed by burning, resulting in a double whammy of releasing the trees' carbon content as CO_2 and eliminating their sequestration potential.

Carbon dioxide emissions in Florida, about 50% for electric power production and 40% for transportation, are growing in proportion to Florida's rapid population growth.

Methane (CH_4) is the primary end-product of anaerobic organic decomposition. It is formed naturally in marshes and when deceased plant or animal matter is deposited underground or under water. It is the primary breakdown product of organic matter deposited in landfills. It is always present in underground deposits of coal, petroleum and it is the primary constituent of natural gas. Mining for coal, especially open pit mining, and drilling for oil and gas result in some escape of methane into the atmosphere. Another major source of methane is from the digestive systems of livestock, especially ruminants such as cattle and dairy cows, and decomposition of animal droppings and human waste.

Nitrous oxide (N_2O) is formed naturally in soils as a result of microbial denitrification and nitrification. A variety of agricultural practices, such as use of nitrogen-containing fertilizers, high organic content soils, livestock manure, and growing nitrogen-fixing crops, add to the release of N_2O. Agricultural soil and manure account for about 70% of the emissions of N_2O. Other significant sources include combustion, human sewage and nitric acid production.

Potential consequences to Florida

Florida is recognized as one of the most vulnerable places in the developed world to the consequences of global climate change. The Organization for Economic Co-operation and Development report entitled *"Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes"* cites Greater Miami as the 4th most vulnerable seaport in the world in terms of population and 1st in terms of asset exposure with an projected value of $3.5 trillion at risk in the Miami metropolitan area alone.

Florida Governor Charlie Crist, in his State of the State address on Mar. 6, 2007 said:

> *"Florida is more vulnerable to rising ocean levels and violent weather than any other state."*

At its first meeting in August 2007, the Governor's Action Team on Energy and Climate Change was told:

> *"...average annual temperatures [in the U.S.] will increase by 5 to 9 degrees Fahrenheit by 2100. ... Specific effects of increased temperatures could include reduced air quality due to ground level ozone (smog) formation, greater incidences of heat stress and related morbidity among the elderly, and increased incidence of water-borne illnesses and...toxic algal blooms.... Observed sea level rise [is] expected to be between 18 and 20 inches along Florida's coasts by 2100 which will result in the inundation of coastal areas, increased aquifer salinity,*

and alteration of Florida's estuaries. Increased temperatures will impact the species composition and range within Florida's forests and natural areas."

Florida has over 1,350 miles of coastline, low-lying topography, and proximity to the hurricane-prone subtropical mid-Atlantic Ocean and Gulf of Mexico. Sea level rise and more intense hurricanes are the most serious threats to Florida's coasts. In addition, Florida is susceptible to drought, torrential rainfalls, wildfires, heat waves, and insect infestation, all of which are exacerbated by global warming. These in turn would adversely impact Florida physically, environmentally, economically, and socially.

Sea level rise

As the planet warms, two major phenomena contribute to sea level rise: 1) thermal expansion of the oceans, and 2) melting of land-based glaciers, snow caps, and ice sheets. Approximately half is attributed to thermal expansion and half to snow and ice melt.

During the 20th Century, sea levels have risen by approximately 18-20 cm (7"-8") at a relatively steady rate of about 0.2 cm/yr (0.08"/year). Confirming this result in Florida, a Florida Institute of Technology Report by Professor George A. Maul, Ph.D. shows a long-term trend of rising sea levels of 0.22 ± 0.04 cm per year from 1915 to 2005 in Key West, which has the distinction of having the Western Hemisphere's longest sea level record. This is a dramatic increase over the relatively stable sea levels for the prior 2400 years when sea level rise averaged approximately 3 cm (1.25") per century. The rate of rise since 1992 based upon more accurate satellite altimetry indicates a rate of about 0.3 cm/yr (0.12"/yr).

Glaciers and ice caps began melting more rapidly during the 20th Century as global surface temperatures have increased. With few exceptions, glaciers and ice caps are retreating worldwide. This is depicted in the images below of the Grinnell Glacier in Glacier Natonal Park.

The IPCC 4th Assessment Report released in 2007 projected a sea level rise of at least 9" to 23" by the end of the 21st Century. This projec-

Florida has over 1,350 miles of coastline, low-lying topography, and proximity to the hurricane-prone subtropical mid-Atlantic Ocean and Gulf of Mexico.

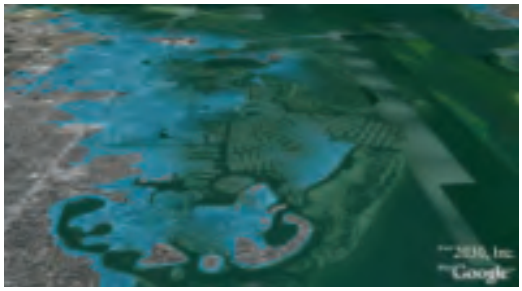
GRINNELL GLACIER

1938

1981

2005

Ft. Lauderdale, FL, 1.25 m sea level rise



St. Petersburg, FL, 1.25 m sea level rise

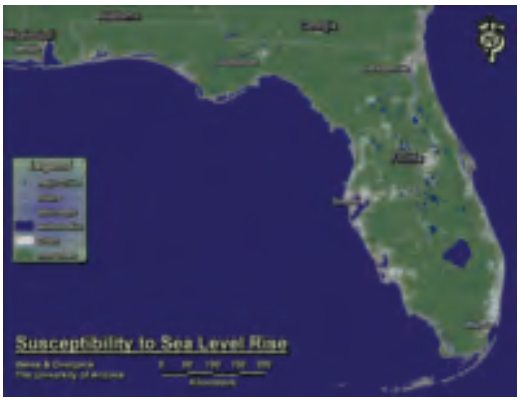
tion was based on published reports through 2005 and did not account for dramatically increased rates of land-based glacial melting observed in Greenland and Antarctica since then. There is a growing chorus of scientists presenting evidence that dramatic increases in melt rates in Greenland and Antarctica will make significant contributions to sea level beyond that projected in the IPCC Assessment.

The Science and Technology Committee of the Miami-Dade County Climate Change Advisory Task Force, co-chaired by Harold Wanless, Ph.D. (University of Miami) and Stephen Leatherman (Florida International University), in an unpublished report that accounts for recently observed increases in glacial melting in Greenland and Antarctica, projected a sea level rise of at least 1.5 feet in the coming 50 years and at least 3-5 feet by the end of the century. Spring high tides would be at +6 to +8 feet above current average sea level. This does not take into account the possibility of a catastrophically rapid melt of land-bound ice from Greenland or Antarctica.

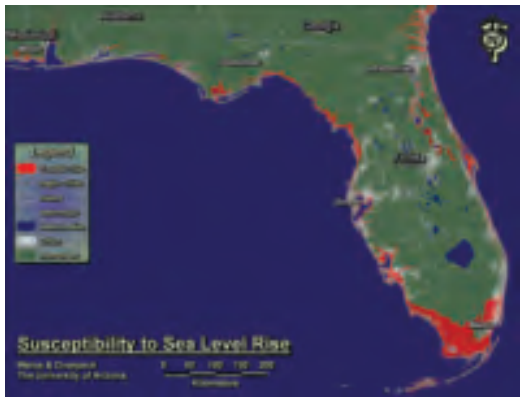
There are a growing number of research studies on the subject of glacial melt in Greenland, Antarctica, and mountain tops and their contribution to sea level rise. Many papers regarding correlation, modeling and forecasting sea level rise are appearing in the scientific literature, including Rahmstorf, Pfeffer, Zwally, Meier, Hansen, and others. There is substantial agreement that sea levels will be greater than predicted by IPCC. Projections cover a wide range from about 2 to 3 feet to the possibility that seas could rise by many meters by 2100. Dr. James Hansen of NASA's Goddard Institute of Space Studies, a leading voice on the subject of global warming, stated in 2007, "There is enough information now, in my opinion, to make it a near certainty that IPCC [Business As Usual] climate forcing scenarios would lead to a disastrous multi-meter sea level rise on the century timescale."

Architecture 2030 used Google Earth and USGS topographical data to generate images of what U.S. coastal cities might look like as a result of sea level rise. These images vividly bring home the potential impact of a 1.25 meter sea level rise.

Weiss and Overpeck at the University of Arizona have been studying the potential impacts of global sea level rise. Their website includes an interactive map of the world which can display different locations and make projections of encroachment at 1 meter increments of sea level rise. Shown below are maps of Florida indicating areas (in red) projected to be encroached by sea level increases of 1m (3.25'), 2m (6.5'), and 6m (20'). The latter represents the potential result should the Greenland ice sheet completely melt or slide into the ocean. A 1 meter sea level rise would impact most of the state's barrier islands, the Florida Keys, the southern tip of the Florida peninsula including virtually all of Everglades National Park, the St. Johns River watershed, the interior flood plains of Miami-Dade and south Broward Counties, and the cities of Fort Lauderdale, Miami, Naples, Fort

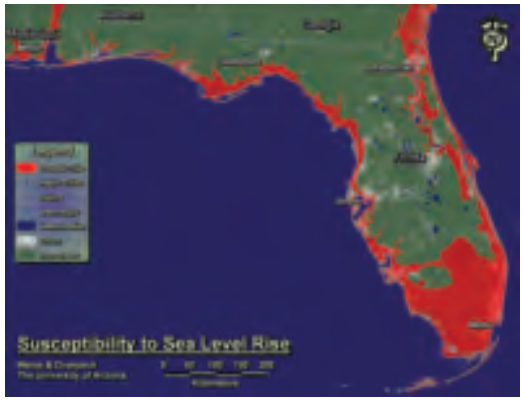


Present

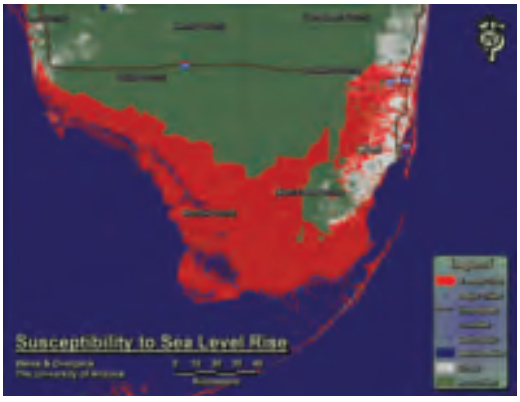


+ 1 meter

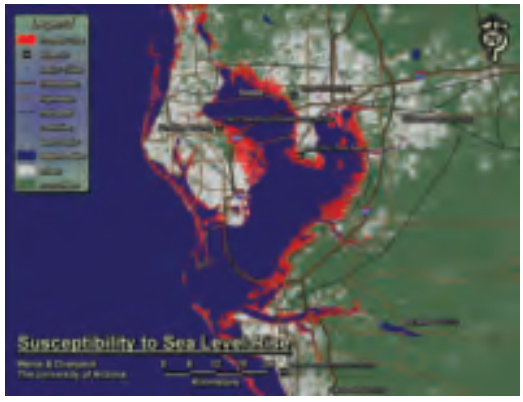
+ 2 meters



+ 6 meters



South Florida, 1 m sea level rise



Tampa Bay, 1 m sea level rise

The coastal areas subject to encroachment are densely populated and contain some of the most valuable property and natural assets in the state.

Meyers, Saint Petersburg, Tampa, Jacksonville, Pensacola, and others.

Above are close-ups of South Florida and the Tampa Bay area at a projected 1m sea level rise. These maps illustrate the serious challenge Florida faces as a result of sea level rise. The coastal areas subject to encroachment are densely populated and contain some of the most valuable property and natural assets in the state.

Trillions of dollars of property are at risk in Florida's other major coastal cities. Considering the enormous economic value at stake, consideration should be given to physically

protecting selected segments of the coast with major public works projects such as dikes, levies, dunes and/or seawalls. A major engineering challenge is presented because much of Florida's coastal geology consists of porous sand and limestone through which seawater will seep at rates that are a function of hydrostatic head, substrate porosity, and the design, materials and construction of the coastal barriers. Seepage could be captured in seepage canals and pumped back to the ocean with the expenditure of considerable energy. Determination of the technical and economic feasibility of such projects will require sophisticated engineering and economic analysis. Social and environmental impacts will also require assessment.

The State of Florida is nearing completion of a $24.5 million LiDAR data collection study of coastal areas throughout the state to facilitate sea level rise assessments and better modeling and forecasting of storm surge impacts. LiDAR is an airborne sensing system used to collect topographic data. Data are collected with aircraft-mounted lasers capable of recording elevation measurements at a rate of 2,000 to 5,000 pulses per second with a vertical precision of 15 centimeters (6 inches). After a baseline data set has been created, follow-up flights can be used to detect changes. Calibrated LIDAR maps can be used to detail the elevations of infrastructure and roadway elements, determine the susceptibility of coastal, wetland, flood plains and artificial fill areas to inundation; define areas of potential pollution and contamination release; determine flooding, drainage and storm surge risks; assess structural viability of buildings and levees with changing groundwater levels and saltwater intrusion; help assess future fresh potable water sources; and define modifications necessary to maintain connectivity of roadways during floods.

The September 2007 study by Deyle, et al, from Florida State University entitled: *"Adaptive Response Planning to Sea Level Rise in Florida and Implications for Comprehensive and Public-Facilities Planning"* presents a comprehensive treatment of this critical subject.

Effects of sea level rise

Inundation of barrier islands and coastal property. In general, elevations of barrier islands are only minimally above sea level and much of Florida's barrier islands have been subject to extensive development of high value oceanfront real estate. Some properties are already vulnerable to high tides and storm surges due to hurricanes. It is uncertain whether such ocean front structures could withstand the impacts of major storms and rising seas. Creative solutions are needed to protect these properties. These considerations raise questions about land use policies regarding further development of oceanfront property.

Beach erosion is already an ongoing threat to Florida's lifestyle and its huge tourism industry—tourism in Florida is all about the sun, sea, and sand. In 1986, the Florida Legislature adopted a comprehensive beach management planning program authorized by Section 161.101, Florida Statutes. Over 387 miles of the state's 825 miles of sandy beaches, are experiencing "critical" erosion. Through 2006, over $582 million have been appropriated by the state for periodic beach renourishment and

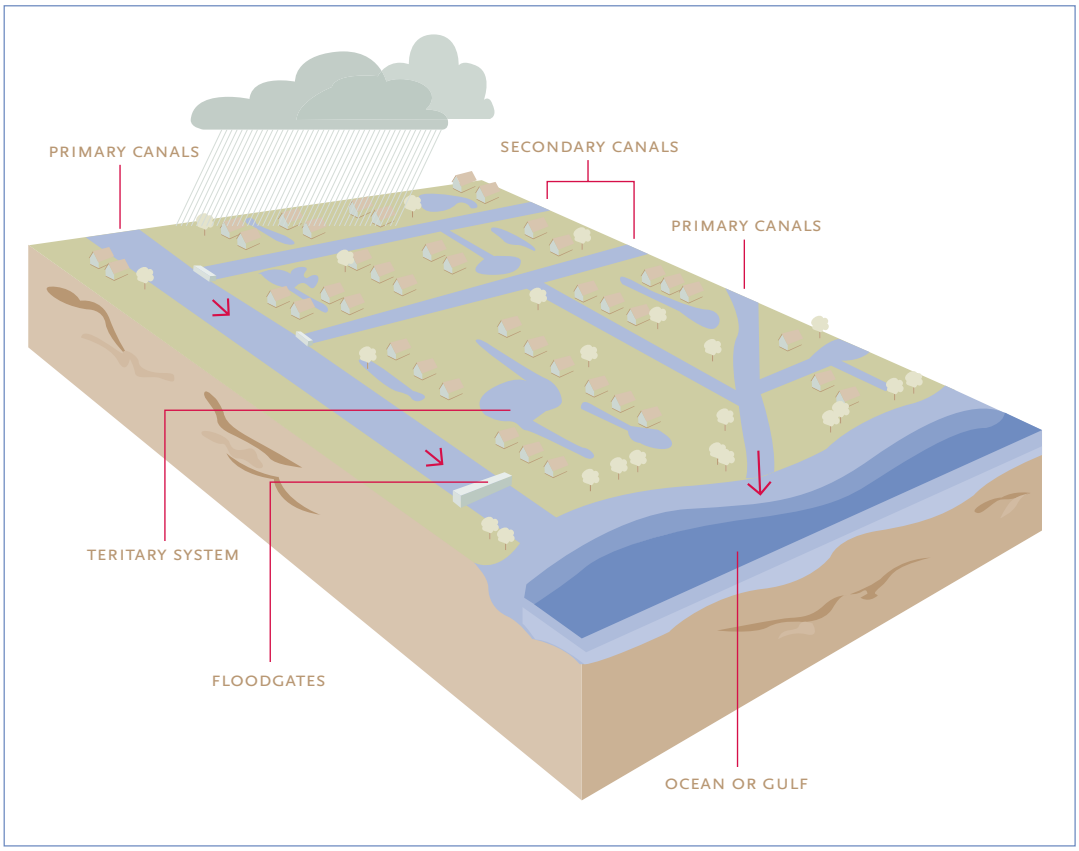
hurricane recovery projects. Generally these funds are matched 50-50 with local funds.

Beach erosion is primarily the result of rough seas during hurricanes, storms, and periods of high wind that cause rough seas. Jetties and inlet channels interrupt the natural flow of sand along the beaches causing accumulation in the inlet channel and at the jetty on the upstream side of the inlet and loss of sand to the beaches on the downstream side of the inlet. Rising seas in combination with tropical storms and hurricanes could result in substantial disappearance of Florida's beaches. Prior to oceanfront development, rising seas caused inland migration of beaches, but with beachfront property, roads, and sea walls, the only place for the sand to go is out to sea. It would be worth considering protecting beaches and barrier islands with dunes, dikes, levees, or breakwaters if they are shown to be technically, economically, and environmentally feasible and sustainable.

Coastal wetlands play an important role in supporting marine life off Florida's coasts. Mangrove estuaries in the south and salt marshes in the north provide important habitat for marine life and provide breeding grounds for many ocean-going species of fish and marine life at the bottom of the food chain. They are also important habitat for native and migratory birds. As seas rise, coastal wetlands will be inundated by sea water. Wetland migration will generally be prevented by surrounding development, so sea level rise will likely result in substantial loss of coastal wetlands.

The Everglades, especially the southernmost regions close to Florida Bay and the Gulf of Mexico, represent the largest and most important of Florida's coastal wetlands. As sea levels rise, brackish waters will extend further inland and dramatically change freshwater ecosystems. This process has been occurring in the vicinity of Cape Sable and the 10,000 Islands for decades. Mangroves have been migrating inland and are expected to do so at an increasing rate. The delicate ecologies of inland fresh water habitats including sawgrass prairie, cypress swamp, hardwood hammock, pineland, and coastal hardwood forest are exquisitely sensitive to changes of just inches in the water table and elevation above local water levels. Water levels throughout the Everglades

Over 387 miles of the state's 825 miles of sandy beaches, are experiencing "critical" erosion.



will rise in response to sea level rise in order to maintain gradients necessary for water flow. This could counteract at least partially the inland penetration of the sea providing adequate fresh water is available. This is a compelling reason to accelerate completion of the Comprehensive Everglades Restoration Plan which is intended to restore sheet flow from the upper Everglades to Florida Bay.

Inland urban waterways and stormwater drainage. Water levels and water tables will rise to maintain the gradients needed for gravity flow of water to the ocean. Canals provide a pathway for sea water due to rising sea level to penetrate far inland in the low-lying areas of South Florida. The flood plains of Miami-Dade and Broward Counties for example are at lower elevation than the coastal ridges. These areas are currently subject to flooding in heavy rainstorms and will likely be more so in the event of sea level rise.

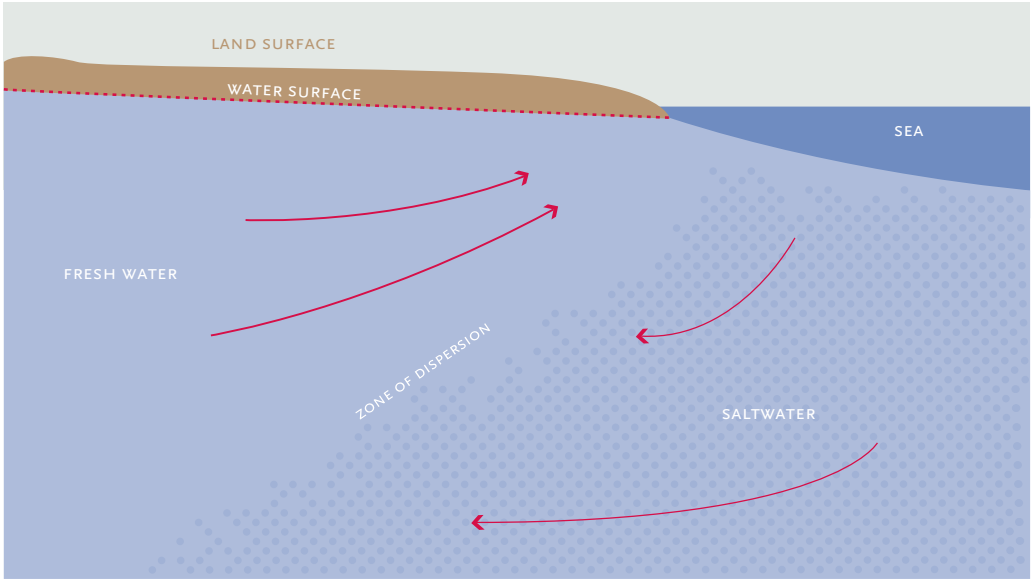
Surface water management will be a challenge and substantial investment in water control systems will likely be needed to protect urban areas. In the advent of higher sea levels, there is a heightened need for freshwater conservation, aquifer recharge, maintenance of higher levels of freshwater in interior stormwater drainage canals and surface storage of freshwater. Higher inland water levels and water tables will increase the likelihood of flooding from heavy rainfall events and increase the need for efficient stormwater drainage. Elaborate flow control systems, gates, pumps, etc. to control water levels in primary, secondary and tertiary canals may be needed. Broward County's 1,800 mile drainage canal system could provide a model for other regions. There may be instances where interior canals might best be plugged and drained, but decisions should be made carefully since enhanced secondary and tertiary canals could offer opportunities of freshwater storage, aquifer recharge, and stormwater drainage.

Hurricane storm surges will be exacerbated by elevated sea levels, causing increased damage to coastal property and higher floods extending further inland. This subject is discussed further in the section on Hurricane Activity.

Saltwater intrusion to aquifers and aquifer recharge. Unconfined coastal aquifers, such as the Biscayne Aquifer in South Florida, will be impacted by sea level rise. Increased hydrostatic head will push the saline water interface (zone of dispersion) inland. The USGS, in a 2004 study entitled *Movement of the Saltwater Interface in the Surficial Aquifer System in Response to Hydrologic Stresses and Water-Management Practices, Broward County, Florida,* utilizing hydrological models, predicted that if sea level rose by an average 48.26 cm (19") over 100 years and then stabilized after 160 years, the saltwater interface would move inland about 1.5 km (0.93 mile) at the base of the surficial aquifer system. If sea level increases further or faster, movement of the saltwater interface would be expected to move further or faster. Several actions can be taken to counteract this effect:

- Inland water can be maintained at higher levels to provide counterbalancing freshwater head. However, this would increase the risk of flooding due to heavy rains and hurricane storm surges.
- Move water wells further inland.
- Purify saline aquifer water by reverse osmosis or other means.

Hurricane storm surges will be exacerbated by elevated sea levels, causing increased damage to coastal property and higher floods extending further inland.



Saltwater intrusion in other aquifer systems will depend upon local characteristics and require studies using predictions using hydrological models to develop local adaptation strategies.

Hurricane activity

Another significant threat to Florida that could result from climate change is the potential for more violent weather, especially the possibility of more intense hurricanes. Florida, with 1350 miles of coastline on the subtropical, hurricane-prone mid-Atlantic Ocean and Gulf of Mexico, experiences more landings of tropical storms and hurricanes than any other state in the United States.

The IPCC 4th Assessment Report stated:

"There is observational evidence for an increase of intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures. There are also suggestions of increased intense tropical cyclone activity in some other regions where concerns over data quality are greater. Multi-decadal variability and the quality of the tropical cyclone records prior to routine satellite observations in about 1970 complicate the detection of long-term trends in tropical cyclone activity. There is no clear trend in the annual numbers of tropical cyclones."

"Based on a range of models, it is likely [67-90% probability] that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical SSTs. There is less confidence in projections of a global decrease in numbers of tropical cyclones. The apparent increase in the proportion of very intense storms since 1970 in some regions is much larger than simulated by current models for that period"

Florida was battered by 7 hurricanes during the hurricane seasons of 2004 and 2005. In 2004, Hurricanes Charley, Frances, Ivan, and Jeanne struck Florida. Florida was struck by Hurricanes Dennis, Katrina, and Wilma in 2005, the busiest hurricane season on record in the North Atlantic Basin with 28 name storms. Combined property damage for the two years was an estimated $56 billion. As a result, property insurance rates in the state were raised considerably, and some insurers decided to withdraw from the Florida market. This experience is clear indication of how vulnerable Florida is to hurricane damage both physically and economically. Florida was fortunate to escape serious damage from tropical storms or hurricanes in 2006 and 2007, although hurricane activity worldwide was above average in these years.

Elevated sea surface temperatures increase the likelihood of formation, development, and intensification of tropical cyclones. Tropical cyclones passing over areas of high sea surface temperature are known to rapidly gain in intensity as occurred with Hurricanes Andrew, Katrina, Rita, Dennis, Wilma and others. In 2005, climatologist Kerry Emanuel (MIT) published a paper indicating that energy dissipated by North Atlantic hurricanes correlated with sea surface temperatures. Emanuel, a pioneer in

Another significant threat to Florida that could result from climate change is the potential for more violent weather, especially the possibility of more intense hurricanes.

thermodynamic modeling of tropical cyclones as heat engines driven by heat, wind, and water evaporation, predicted that sea surface temperature rise driven by global warming will increase the frequency and intensity of tropical cyclones worldwide. William Gray (Colorado State University), a leading meteorologist who leads the way in forecasting hurricane activity on the basis of statistical analysis of historical data, attributes recent increases in Atlantic sea surface temperatures and hurricanes to the Atlantic Multidecadal Oscillation, a natural 65-80 year cycle in North Atlantic sea surface temperatures believed to be related to the thermohaline circulation (density-driven global ocean currents). In 2005, climatologists Curry and Webster at Georgia Institute of Technology reported (top graph on preceding page) that the number of Category 4 & 5 storms worldwide had approximately doubled since 1970, although the total number of hurricanes per 5-year period has remained relatively constant. They ascribed this increase to global warming. Gray disagrees. According to a 2007 report by Curry and Webster (bottom graph on preceding page), the frequency of tropical cyclones in the North Atlantic has risen dramatically in recent years in concert with record high sea surface temperatures. Elsner (FSU) statistically showed that sea surface temperatures are driven by atmospheric temperature increases due to global warming. Chris Landsea of the National Hurricane Center predicts that global warming will cause increased windshear in the North Atlantic Basin that should offset the effect of increased sea surface temperatures and might reduce hurricane frequency. Although significant progress is being made in hurricane modeling, these models still fall short in accuracy correlating historic observations of wind speed and are under further development.

There is controversy between these two schools of thought—Gray's statistical/historical approach vs. Emanuel's theoretical/thermodynamic modeling approach. Until there is a clear understanding of the effects of sea surface temperatures and other factors on hurricane activity, it will not be possible to reliably predict future trends. Vigorous research is being undertaken to resolve these differences.

Storm Surge due to Hurricanes. One of the most serious threats to Florida's coasts comes from the combination of elevated sea levels, storm surge and wave action caused by hurricanes. Storm surges due to hurricanes will be on top of elevated sea levels and tides. Storm surge height and speed increase with increasing seawater depth boosting their destructive potential. In addition, wave heights increase in proportion to water depth. As sea levels rise, larger waves are more destructive to beaches and structures. As an example, the heights of waves crashing against seawalls are 120% of the still water depth and exert much higher destructive force. Buildings on the coast could be subjected to forces due to hydrodynamic pressure that could be 80% -90% higher than today, which they are unlikely to withstand. According to architect Ricardo Alvarez (FAU-FCES), an important element of adaptation strategy is how to design and construct buildings and infrastructure that are more resilient to the increased impacts of wave action and storm surge.

The devastation wrought on New Orleans by Hurricane Katrina in August 2005 was a

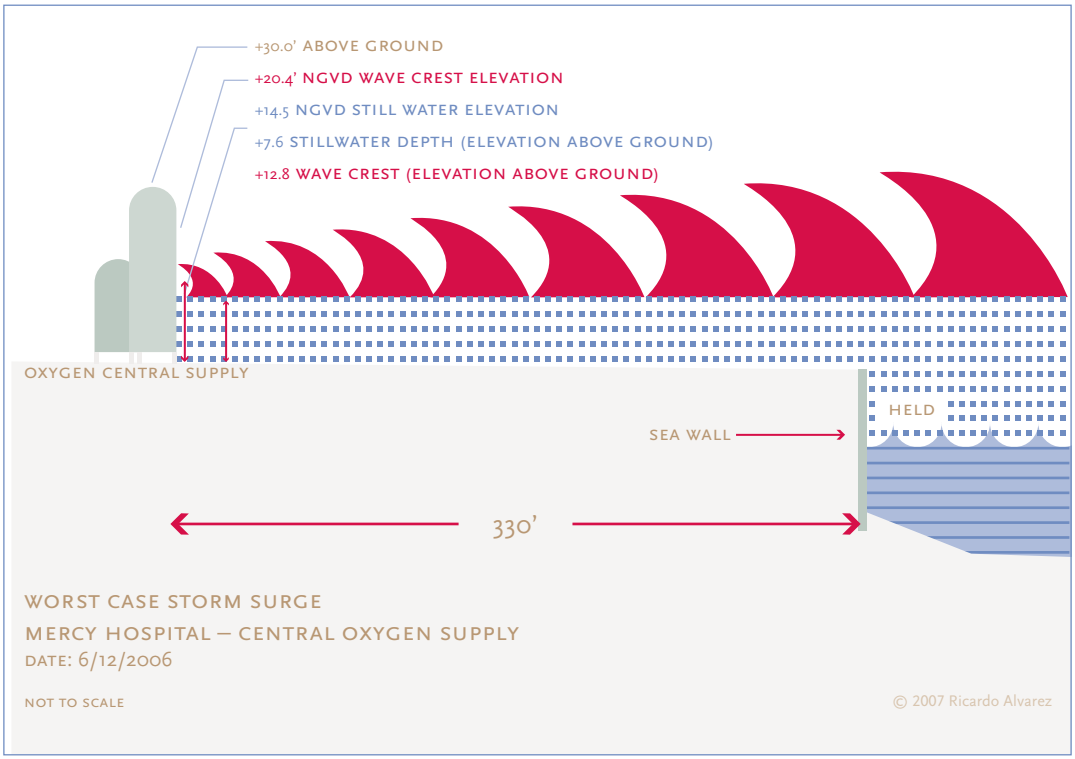
wake-up call. According to the US Geological Survey, the Tampa Bay area is second only to New Orleans in potential flooding due to storm surge. Consideration should be given to whether further development of areas subject to storm surge should be allowed.

Other potential climatic effects

In addition to sea level rise and hurricanes, there are numerous other potential effects of global warming that could affect Florida's communities and environment physically, economically and socially, including:

- Prolonged drought affecting water supplies, agriculture, and habitat.
- More wildfires due to excessive drought and heat.
- More flooding due to more torrential rains.
- More frequent and lengthy heat waves creating increased energy demands and health hazards to young children, elderly, and infirm.
- Potential insect infestation and insect-borne disease resulting from increased temperatures combined with increased flooding due to storms.
- Bleaching of coral reefs and adverse effects on marine life and fisheries.
- Ecological changes in the Everglades and other natural systems affecting plant ecology, wildlife, the marine estuaries and coast, and tourism.
- Economic, environmental, and social impacts.

Drought will be more likely, according to the IPCC, in the middle latitudes globally. These already arid areas girdle the Earth and include the great deserts—Sahara, Arabian, Goby, the American Southwest and Mexico. Florida is located in this belt, but unlike the great land masses of the continents at these latitudes, the Florida peninsula is surrounded by ocean



According to the US Geological Survey, the Tampa Bay area is second only to New Orleans in potential flooding due to storm surge.

and its weather is influenced by warm seas and sea breezes. Climate models used in the IPCC studies do not have sufficient fidelity to predict weather patterns on the Florida peninsula. Florida, along with the Southeastern and Southwestern United States, has suffered unusually severe drought during 2006 and 2007. In 2007 and the winter of 2008, Lake Okeechobee experienced the lowest levels on record. This necessitated strict water conservation measures in southern Florida. Drought in Georgia and Alabama created critical water shortage in the Caloosahatchee/Apalachicola watershed, which supplies the metropolis of Atlanta and put areas of the Florida Panhandle and Apalachicola Bay in jeopardy. Whether these uncommon weather patterns will be long-lived cannot be determined at this time.

Southern Florida has a subtropical weather pattern with dry winters and wet summers. Much of the summer rainfall is associated with daily thunderstorms driven by solar evaporation over the Atlantic Ocean, Gulf of Mexico and the Everglades. Tropical cyclones add significantly to summer rainfall. Recent drought is related in large measure to the lack of cyclone activity during the summers of 2006 and 2007 and to a lesser extent precautionary lowering of Lake Okeechobee in anticipation of severe hurricane seasons that did not materialize. As discussed previously, global warming may cause increased tropical cyclone activity and higher summertime temperatures would be expected to increase the daily thunderstorm

cycle. Higher temperatures may extend the rainy season in southern Florida or it might cause more severe drought depending on the El Nino/La Nina cycle in the eastern Pacific Ocean. It is plausible that global warming would cause winter precipitation to decline and summer thunderstorm and tropical cyclone activity to increase. This provides additional incentive to build more stormwater storage capacity in the Everglades watershed.

Drought will strain potable water supplies and could necessitate diversion of fresh water needed by natural systems. Restrictions on watering lawns and landscaping cause economic loss to property owners and have adverse effects of Florida's landscapes, nursery industry, golf courses, etc. Agriculture is obviously affected.

Wildfires in northern and western Florida's pinelands are caused by the combination of hot, dry spring weather after a dry winter. Florida's widespread pine forests are very susceptible to wildfires especially where there is the accumulation of excessive undergrowth. Springtime grass fires in the Everglades are a natural part of that ecosystem. However, prolonged drought can expose and dry out the periphyton, marl and peat soils of sawgrass prairie and marshes. If these soils catch fire and are destroyed, irreversible damage to the ecosystem can result.

Flooding is likely to be the result of climate-change-induced increases in torrential rains, tropical storms and hurricanes. Flooding will be exacerbated by higher water tables and levels in stormwater drainage canals and rivers as a consequence of elevated sea levels. Standing water from floods would contribute to mosquito infestation and increased risk of mosquito-borne diseases such as encephalitis and malaria. Torrential rains with or without windstorm would increase structural loads on buildings and drainage systems and should be considered in their design.

Drought will strain potable water supplies and could necessitate diversion of fresh water needed by natural systems.

HEALTHY REEF

BLEACHED CORAL REEF

Bleaching of coral reefs is being observed worldwide as a result of elevated sea temperatures caused by global warming. In many places, critical temperatures are exceeded causing algae that live symbiotically with coral polyps to be killed. Once the algae die, it's a matter of time before the coral polyps follow and marine life on that reef diminishes dramatically. This phenomenon has been observed off the southern edge of the Florida Keys and on reefs throughout the Caribbean. Coral species are migrating north and dying to the south thus changing reef habitats. Since the reef is an important element of the oceanic food chain, populations of ocean-going fish decline. Diving, sport fishing and related activities that are important to South Florida's tourist industry would be affected.

Ecological effects in Florida are likely to be significantly influenced by rising seas. As previously described, small changes in salinity and elevation would have profound effects on the flora and fauna on the low-lying, delicate Everglades ecosystem. As sea level rises, mangrove estuaries will be inundated causing mangrove die-off resulting in shallow open waters to expand. As sea water impinges upon fresh water wetlands, they will transition from freshwater to brackish water ecologies. Water levels in freshwater regions will increase in response to sea level rise to maintain flow gradients affecting tree islands, pinelands, and hardwood forests. These events will cause changes in flora and habitat and consequential changes in wildlife.

The threat of sea level rise places a greater sense of urgency on the Comprehensive Everglades Restoration Project (CERP) whose purpose is to restore sheet flow to the lower Everglades. According to Dan Kimble, Superintendent of Everglades National Park, restoration is critical to "keeping the seawater at bay—literally." Restoration of freshwater flow to the lower Everglades would reduce and delay seawater inundation.

Inundated beaches would deny sea turtles their nesting grounds and shorebirds their feeding grounds. Sea level rise may disrupt ecosystems of the shallow waters inhabited by small fish and invertebrates. Coral reefs may be affected by increased hydrostatic pressure and decreased sunlight as a result of deeper water. The coastal estuaries, which are breeding grounds for shrimp, crabs, and other invertebrates, as well as spawning grounds for ocean-going migratory fish, are likely to be affected. Warming coastal waters

Coral species are migrating north and dying to the south thus changing reef habitats.

are contributing to bleaching of coral reefs. These effects could seriously disrupt the food chain and fisheries throughout the western mid-Atlantic Ocean, Caribbean Sea, and Gulf of Mexico.

Economic, environmental, health and social impacts in Florida resulting from global warming and climate change will be significant. Politically, Florida should set an example to the nation and the world by adopting aggressive mitigation and adaptation strategies. Politically, it should play a leadership role to foster national and international cooperation

to mitigate greenhouse gas emissions and set a model for adaptation strategies. It is imperative that Florida take aggressive action to prepare for the early consequences of climate change in order to minimize the impacts on its coasts.

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I am persuaded that global climate change is one of the most important issues that we will face this century. With almost 1,200 miles of coastline and the majority of our citizens living near that coastline, Florida is more vulnerable to rising ocean levels and violent weather patterns than any other state... Florida will provide not only the policy and technological advances, but the moral leadership, to allow us to overcome this monumental challenge.

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FROM FLORIDA GOVERNOR CHARLIE CRIST'S KEYNOTE SPEECH AT HIS JULY 2007 “SERVE TO PRESERVE” SUMMIT ON GLOBAL CLIMATE CHANGE

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