

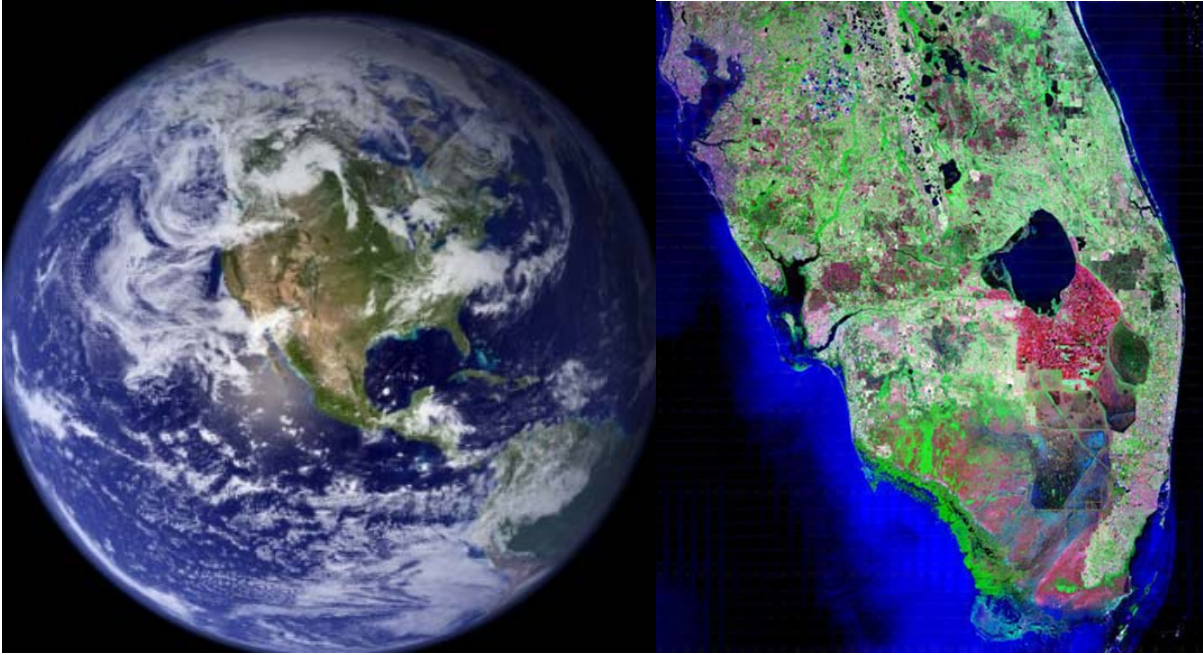
Adaptation and Mitigation of Climate Change Impacts: South Florida on the Front Lines

White Paper: An Integrative and Collaborative Climate and Energy (ICCE) Initiative

“I am persuaded that global climate change is one of the most important issues that we will face this century...” Florida Governor Charlie Christ

“Let me state what the official IPCC (the United Nations Intergovernmental Panel on Climate Change) prediction is: It (sea levels) could go up as much as three-quarters of a meter in this century, but there is a reasonable probability it could be much higher than that.”

“A rise in levels of one meter, coastal areas around Florida around Louisiana would move much farther inland” “Lots of areas in Florida will go under...” U.S. Secretary of Energy Dr. Steven Chu



FAU

**FLORIDA ATLANTIC
UNIVERSITY**
Executive Summary

The ICCE Initiative: South Florida is on the front lines of risk associated with climate change impacts. In response, FAU has formed a coalition of research institutes and assembled interdisciplinary teams to assist in developing adaptation and mitigation strategies to prepare for and mitigate climate change effects. This is a collaborative effort with stakeholders at the national, state, and local levels.

The Approach: We will take a landscape approach to assess mitigation and adaptation of climate change impacts in the “South Florida Ecosystem,” defined by the hydrologic basin of the South Florida Water Management District. At this scale, we can synthesize the inter-related effects of modifying land uses and shifting to alternative energy production/conservation, re-evaluate current water management systems, incorporate Everglades restoration activities and water conservation, and assess the economic tradeoff of alternative solutions.

Objectives

- Develop credible scenarios of climate change impacts for South Florida, down-scaling from global-based to local climate models, using the best and most current scientific information. Hold open discussion forums, on a regular basis and in an adaptive management framework, between climate/marine scientists and engineers, land use planners, economists, and other stakeholders.
- Establish a long-term coastal monitoring program focused on validating the local effects of climate change on South Florida predicted from global and local climate models. From these data, realized

local climate impacts will be used in an adaptive management framework, climate change scenarios on the landscape and risk assessment.

- Define impacts of climate change to South Florida geography, urban structures, real property, economic development and natural areas, especially vulnerabilities resulting from sea level rise in combination with extreme weather events such as hurricanes, tropical storms and torrential rains. We will use this assessment to propose, with input from stakeholders, alternative policy and planning recommendations regarding land use, building codes, infrastructure adaptation, public works projects to protect valuable urban developments, emergency preparedness, natural resource sustainability, beach management, economic opportunities, and quality-of-life issues.
- Take a “risk assessment” approach to defining vulnerabilities in the South Florida water management infrastructure (flood protection, water supply, salt water intrusion, and waste water management) to climate change including changes in precipitation patterns and rising sea levels. Once these risks have been identified, we will work with stakeholders to provide cost-benefit, policy, and legal analyses, as well as suggest alternative solutions.
- Evaluate Everglades restoration in the context of water management options as a tool to ameliorate short and long-term climate change impacts on water supply, quality and flood protection in South Florida.
- Consider alternative energy solutions on the landscape, particularly with planned land use changes, as a broad-based solution to mitigate climate change impacts and develop new economies for South Florida.

Expertise: FAU has already brought together a cross-university multidisciplinary team to address these issues. Our partners provide strong support in topical and regional areas.

South Florida Integrative and Collaborative Climate and Energy (ICCE) Initiative

Program Goal: The South Florida ICCE Initiative’s goal is to provide the best, most up-to-date local climate science information, and engineering alternatives, to minimize the inevitable climate change impacts on South Florida.

Problem Statement: The South Florida Peninsula is the most vulnerable developed region globally where major human populations, natural resources, and economic assets are at risk, based on the current trajectory of climate change data and projections using future emissions scenarios with modest or no reduction in greenhouse gases.

- The low-lying topography of South Florida ($\leq \sim 26$ ft NGVD) makes the area particularly vulnerable to rising sea levels as the oceans expand and glacial ice melts.
- The IPCC 4th Assessment Report indicate a global sea level rise of 0.71 inches per decade (1.8 mm y^{-1}) from 1961-2003, similar to the long-term rise in Key West (0.87 inches per decade 1913-2005), with an increased global rate of 1.2 inches per decade during the last decade (3 mm y^{-1} 1993-2003).
- The future rates of change in sea level rise are “uncertain” and may be greater than are predicted in the IPCC 4th Assessment Report, which did not include rises in sea levels with ice sheet loss. Accounting for Arctic and Greenland ice contributions, sea level could rise to 1.5 feet in the coming 50 years.
- Changes in weather patterns are predicted to increase rainfall during storm events, and increase the periodicity and duration of droughts.
- Increased temperatures are also predicted to increase the probability of heat-related illnesses, wildfires, insect-borne diseases, and range of invasive species.
- Current thinking is that tropical cyclone frequency may or may not increase; however, it is generally agreed that the intensity of storms is likely to be magnified by ocean warming, potentially leading to greater storm surge, exacerbated by sea level rise, wind damage, and property losses.
- Ocean warming and acidification will also significantly impact natural marine resources of economic importance to South Florida.
- Climate change impacts will cause a redistribution of human populations on a global scale and may increase the immigration to and emigration from South Florida.
- There may be substantial economic and social impacts caused by the possibility that South Florida may be perceived as a less desirable place to live, visit, and do business. Furthermore, reduced availability of affordable insurance and reduced property values might create significant economic displacement.

Needs:

1. Climate Science and Coordination at the Local Scale

- Establish climate change scenario standards that will be accepted by scientists, planners and engineers to systematically evaluate the effects of sea level rise, climate driven disasters, and changes in precipitation in South Florida using a cross-disciplinary approach to enhance predictions and apply mitigation solutions from a landscape perspective.
- Develop and utilize high-resolution climate models for projecting climate change and work in an adaptive management framework: as new information at finer scales becomes available, these data are incorporated into conceptual and mathematical models of climate change scenarios, topographical and hydrological impacts, and landscape adaptation scenarios for South Florida.

- Establish a monitoring network along the coastline to evaluate the “realized” local response to global climate change.
- Develop a climate change GIS database and web site for South Florida where maps and modeling output can be made available to all investigators and stakeholders.
- Model impacts of global warming on the Gulf Stream current which is critical in modulating weather and deep ocean currents on a global scale.

2. Geographical Impacts, Land Use, and Infrastructure Management

- Use topographical, hydrological and other models, high-resolution mapping, and impact assessments to predict local impacts on communities, individual properties, transportation, urban infrastructure, etc. caused by inundation and encroachment due to rising sea levels and groundwater, and flooding due to compromised storm water drainage systems.
- Use these high-resolution tools in comprehensive and land-use planning to develop strategies for mitigation, adaptation and/or abandonment of “high risk” geographic locations in South Florida.
- Develop innovative strategies for armoring and otherwise protecting highly vulnerable, high- value urban areas and assets, and develop economic tradeoffs against abandonment scenarios.
- Evaluate critical infrastructure locations and their susceptibility to sea level rise.
- Develop phased relocation strategy for critical infrastructure and first-responder facilities.
- Identify and evaluate potential modifications to protect coastal property and human and natural resources with minimum environmental impacts.

3. Policy Development and Economic Impact Analysis

- Consider policy changes to Florida's growth management, water management, transportation and other related laws required to address adaptation to climate change impacts in South Florida.
- Undertake economic cost/benefit analyses and tradeoffs of mitigation, adaptation, and/or abandonment.
- Evaluate economic incentives, including property insurance, tax policies and infrastructure funding that could influence development patterns to mitigate predicted climate change impacts.
- Examine the potential impact of climate change on key components of the economy (e.g. agriculture, tourism services, real estate, construction, manufacturing, shipping, warehousing, and distribution, etc).
- Economic analyses to provide a clearer picture for mitigation and future planning, in terms of policies and regulations for coastal management, land use, natural resources management, alternative energies, etc.

4. Water Management Assessments

- Determine how water resources and management decisions will be affected by climate change (e.g., salt water intrusion and other threats to drinking water), and define mitigation measures that would increase resilience of the South Florida fresh water supplies and quality.
- Develop a comprehensive planning framework for adaptation of South Florida's water supply to climate change impacts utilizing conservation, alternative water sources, reclaimed wastewater, and other innovative methods.
- Develop plans for enhancing stormwater drainage systems that can cope with hurricanes, tropical storms and torrential rains at high tide when sea levels are elevated due to climate change.

- Determine how Everglades restoration, reallocation of freshwater now going to tide, and other ecological preservation methods could sustain freshwater resources and natural habitats in South Florida.

5. Natural Resource Management and Sustainability

- Quantify the impacts and potential mitigation plans that would increase the resilience and economic sustainability of South Florida's natural terrestrial and marine resources.
- Collaborate with other ongoing monitoring and research programs committed to evaluating the impacts of climate change on Florida's wildlife and natural resources, including impacts of sea level rise, ocean warming, shifts in climate, and ocean acidification.
- Develop new conservation approaches and active management practices that will sustain important ecosystems and species in South Florida under the stress of a changing climate.
- Create ecological "action plans" based on various scenarios of climate change ranging from slow rates to high rates of change.

6. Education and Public Outreach

- Improve education of South Florida public to the science and consequences of a changing climate on South Florida through Pre-K to Higher Education, life-long learning, and public outreach programs.

7. Impact on Human Well Being

- Conduct sociological studies of human behavior in different cultural groups to analyze their potential response to climate change in South Florida.
- Address environmental justice implications of potential mitigation and adaptation measures, and development strategies to safeguard all communities to the extent possible.
- Conduct research on subpopulations, including children, elderly, and people with limited mobility, measuring and analyzing the potential human cost of climate change impacts and adaptation.

Integrative Approach: We propose an integrative landscape approach to climate change solutions, which includes adaptation and the analysis of ongoing mitigation efforts, including but not limited to the restoration plan of the Everglades, alternative energy development, and energy conservation. Mitigation and adaptation are cross-linked by changes in land-use planning, shifting energy consumption patterns, water management alternatives, natural resource management and economic assessments, as well as promoting human health and safety with climate change across a broad geographic area.

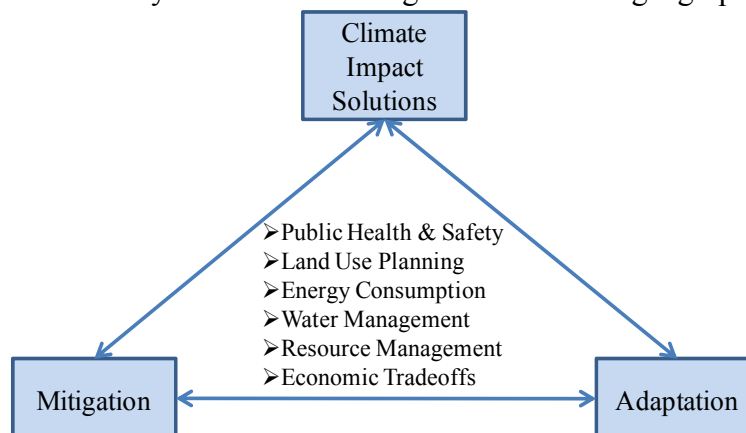


Figure 1. Climate change solutions require mitigation and adaptation efforts across the landscape.

Adaptive Management Framework and Communication

The ICCE will develop a strong inter-disciplinary team to facilitate the transfer of technical climate information to regional planners and engineers in an adaptive management framework. Global climate model predictions will be scaled to regional models to develop climate scenarios for South Florida. Output from these local models will be used to develop “Landscape Adaptation Scenarios” by a team of urban planners, engineers, economists, educators, political scientists, and natural resource managers. Because of the current uncertainty in the rates of change and their intensity, an integrative process will be established whereby as additional scientific data are available, the landscape adaptation scenarios will be updated and modified accordingly. A forum for discussion will be established and website developed to keep all partners and the public aware of the current findings and publications from ICCE groups. The economic outlook for South Florida is crucial to development of a sustainable future. Vulnerabilities resulting from climate change must be identified and assessed with regard to the potential for sustainable development with a high quality of life. Economic impacts of all phases of the adaptive management framework should be assessed so that the human, business, and opportunity costs can be defined; costs of alternative scenarios can be compared; and economic tradeoffs among human populations, natural resources, and economic assets can be determined.

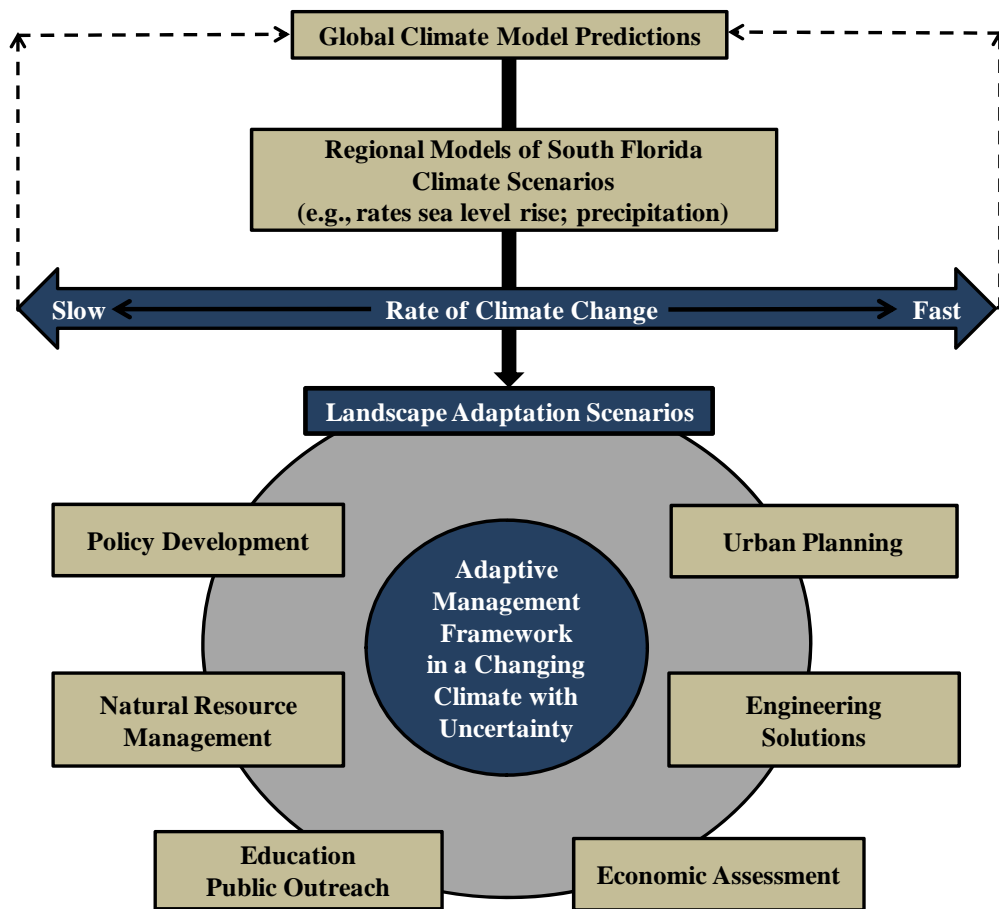


Figure 2. Overarching framework to apply climate science and information to the regional and local scale for policy and decision making in an adaptive management framework with uncertainty.

Potential and Current Collaborators

The ICCE is a University-initiated program, with FAU as the lead institution and University of Miami as the co-lead institution. We will also have strong collaborative linkages with local, state and federal governmental and non-governmental organizations, the business community, and public. Other potential University collaborators include: University of South Florida, Florida Gulf Coast University, and Columbia University in New York City.

CCEI Research Expertise

The ICCE group has the expertise to develop broadly-accepted scenarios of climate change impacts for South Florida, down scaling from global to local climate models, and translating this highly technical and scientific information to the policy arena, and to propose solutions and evaluations based on strong scientific and engineering capabilities. We identify this specific expertise below and identify the institutions that provide these capabilities, as well as provide information on current active research projects that highlight our expertise in the area of climate change science, engineering, policy, business, and education, and the potential for communication and collaboration with federal, state and local governments and the business community.

I) Physical Climate Science and Climate Scenario Development

- Climate dynamics and modeling
- Tropical ocean-atmosphere interactions
- Tropical meteorology and climate
- Coastal ocean prediction and modeling, especially for sea level rise
- Remote sensing
 - University of Miami Rosenstiel School of Marine and Atmospheric Science
Division of Meteorology and Physical Oceanography (RSMAS/MPO)
 - Florida Atlantic University
Ocean Engineering Department and Geosciences Department (OE/GS)
Harbor Branch Oceanographic Institute (HBOI)

II) Transfer of Physical Science to Develop Landscape Climate Scenarios

- Scientific research coordination for human decision-making processes
- Publications, conferences, and web-enabled sites to promote scientific awareness
- Organize and support policy dialogues involving policymakers
- Provide information and dialog: resource managers, scientists, and economic interests environment
- Assist decision makers in resolving urban and environmental issues: partnerships, education, research
- Coastal and ocean policy
- Sustainable development and impacts of climate change on urban populations
 - Florida Atlantic University
Center for Environmental Studies (CES)
Center for Environmental and Urban Solutions (CUES)
 - University of Miami
Abess Center for Ecosystem Science and Policy/Human Dimensions Science

III) Coastal Monitoring and Research

- Physical Oceanography
- Marine Chemistry and Biogeochemistry
- Coastal Geomorphology and Sediment Transport
- Marine Technology and Instrumentation Development
- Remote Sensing and Automated Vehicles
- Climate Change Impacts on Tropical Marine Ecosystems
- Coastal Estuaries, Wetlands, and Coral Reef Ecology and Conservation
- Everglades Ecology, Restoration and Policy
- Everglades and South Florida Hydrological Modeling
- Florida Bay and Florida Reef Ecology and Conservation
- Marine Mammals, Turtles, Shark Biology and Conservation
- Harmful Algal Blooms and Toxicity
 - Florida Atlantic University
 - Charles E. Schmidt College of Science (CESCOS)
 - Harbor Branch Oceanographic Institute (HBOI)
 - Ocean Engineering Department (OE)
 - Center for Environmental Studies (CES)
 - University of Miami Rosenstiel School of Marine and Atmospheric Science
 - Division of Marine Biology and Fisheries (MBF)
 - Division of Marine and Atmospheric Chemistry (MAC)

IV) Civil and Environmental Engineering

- Environmental and Geotechnical Engineering
- Hydrologic and Water Resources Engineering
- Infrastructure and Constructed Facilities
- Computer, Mechanical and Electrical Engineering
- Artificial Intelligence
- Water recharge approaches and modeling for water supply
- Stormwater retention improvements
- Coastal armoring and lock structures
- Aquifer storage and recovery
- Alteration of wastewater disposal patterns for reuse and salinity barriers
- Land use evaluation with climate change impacts
- Geomatics Engineering
 - Florida Atlantic University College of Engineering and Computer Science
 - Department of Civil Engineering Lab for Engineered Environmental Solutions (EES)
 - Department of Civil Engineering Center for Marine Structures and Geotechnique
 - Department of Civil Engineering Geotechnical Testing Laboratories
 - Department of Civil Engineering Center for Infrastructure and Constructed Facilities
 - Department of Civil Engineering Consortium Intermodal Transportation Safety Security
 - Department of Civil Engineering Lab Hydrologic and Water Resources Engineering

V) Urban Planning, Policy Development and Economic Analyses

- Interdisciplinary urban-regional research and planning
- Sustainable development and integration across sectors in the community
- Florida Indicators Network of business, civic, academic, and community organizations
- Developing a long-term vision and strategy for a sustainable Southeast Florida
- Management, planning, policy, and economic aspects of coastal and ocean issues
- Strategic Economic plan development
- Impacts of climate change on urban populations and sustainable development
- Natural resource management (within urban setting)
- Economic impacts of climate change scenarios
- Risk assessment and cost-benefit analyses
- Assess economic impacts of climate change to define human, business and opportunity costs
- Co-ordinate between business, society, science and government to develop mitigation strategies.
- Cultural impacts of climate change and alternative futures
- “Low energy” urban form and patterns of human comfort and sustainable urban design
- Provision of emergency services
- Hazard mitigation Assess vulnerabilities of key sectors
- Business administration for crisis and emergency management
 - Florida Atlantic University The College of Architecture, Urban and Public Affairs (CAUPA)
 - School of Urban and Regional Planning
 - Visual Planning Technology Lab
 - Center for Urban and Environmental Solutions (CUES)
 - John M. DeGrove Eminent Scholar Chair in Growth Management and Development
 - Florida Atlantic University The College of Business
 - Environmental MBA Program
 - Crisis and Emergency Management MBA Program
 - University of Miami
 - Abess Center for Ecosystem Science and Policy/Human Dimensions Science
 - Division of Marine Affairs (MAF)

VI Impact on Human Well Being

- Population displacement/relocation
- Impact on provision of social services
- Public safety and security
- Environmental justice and equity
- Quality of life
- Social and human capital
- Quality of life and public health
- Political efficacy,
- Governance, agenda formation and visioning
- “Green” jobs

- Florida Atlantic University, The College of Architecture, Urban and Public Affairs
 - School of Social Work
 - School of Criminology and Criminal Justice
 - School of Urban and Regional Planning
 - School of Public Administration
 - School of Architecture
- Florida Atlantic University The Barry Kaye College of Business
 - Department of Marketing
 - Department of Management Programs
 - Environmental MBA Program
 - Crisis and Emergency Management MBA Program
 - Department of Information Technology and Operations Management

VII) Alternative Energy Technology Development

- Solar energy- photovoltaic (PV) and concentrating solar thermal power plants (CSTP)
- Energy and Thermal Systems
- Systems Dynamics and Modeling
- Impact of smart grids and variations in cost of energy on population relocation
- Long term energy and desalination model for the Southern, Central and Northern Florida
- Hydro-energy Technology
- Systems for harnessing ocean energy.
- Underwater acoustic transmission
- Flow noise
- Hydrodynamics and physical oceanography
- Corrosion and marine material
- Impact assessment of Ocean Energy technology
 - Florida Atlantic University
 - FAU Center for Ocean Energy Technology (COET)
 - Department of Mechanical Engineering
 - Department of Ocean Engineering
 - Harbor Branch Oceanographic Institute
 - Department of Biological Sciences
 - University of Miami Rosenstiel School of Marine and Atmospheric Science
 - Division of Marine Biology and Fisheries (MBF)
 - Division of Applied Marine Physics (AMP)
 - Division of Meteorology and Physical Oceanography (MPO)

VIII) Education and Outreach

- Marine Atmospheric, Chemistry, and Biological Science PhD/MS Programs
- Ocean, Mechanical, Computer, Environmental Engineering PhD/MS Programs
- Environmental Business MBA
- Crisis and Emergency Management MBA
- Urban and Regional Planning MS
- Marine-Atmospheric Science and Technology High School - Miami-Dade County
- Florida Atlantic Henderson School K-8 Program

- Florida Atlantic High School 9-12 Program
- Marine and Oceanographic Academy High School Science Magnet Program at HBOI
- Pine Jog Environmental Education Program
- Gumbo Limbo Environmental Education Program
- Lifelong Learning Program
- Harbor Branch Ocean Science Lecture Series
- Extramural Seminar Series
- Internship Programs
 - Florida Atlantic University
 - College of Engineering and Computer Science
 - College of Business
 - College of Science
 - College of Architecture, Urban and Public Affairs
 - Harbor Branch Oceanographic Institute
 - Pine Jog Environmental Education Center
 - Gumbo Limbo Environmental Complex
 - University of Miami Rosenstiel School of Marine and Atmospheric Science
 - Division of Marine Biology and Fisheries (MBF)
 - Division of Marine and Atmospheric Chemistry (MAC)
 - Division of Physical Oceanography (MPO)
 - Division of Applied Marine Physics (AMP)
 - Division of Marine Affairs (MAF)

Research Projects Highlighting ICCE Collaborator Expertise

- *Florida Atlantic University (FAU)-Charles E. Schmidt College of Science (CESCOS)*
Center for Environmental Studies (CES)
 CES began to address the issue of climate change in Florida well before it became a significant topic in the state. A scoping workshop in January 2006 began the planning for a statewide conference in May 2007 which set out basic recommendations on natural systems, urban and population issues and policy. Since then CES has worked on issues of Fish and Wildlife impacts (major conference 2008), the impacts of climate change on Everglades restoration (GEER conference 2008) and with Columbia University in New York we hold a grant from the Water Resources Foundation to work with utilities on climate change planning issues. CES work is supported by competitive extramural funds of >1,000K.
CESCOS Departments of Biological Sciences, Geosciences and Chemistry
 Faculty in the CESCOS have many years of experience conducting research on coastal and marine ecosystems with a focus on the Greater Everglades Ecosystem, and have participated in research and organized symposium on climate change impacts on Everglades Ecosystem restoration. Current biological research on climate change ranges from temperature effects on sex determination in sea turtles, thermal/ salinity stress and ocean acidification effects on seagrass and coral reef algae, and mangrove population shifts across the temperate-tropical ecotones. Geoscience projects include modeling groundwater interactions for flood plain mapping and digital elevation modeling (EDEN).

Relevant projects are supported by >\$1,000K in external funding. The FAU Environmental Sciences Program also has a new 5 year Everglades fellowship program \$500K.

- *Florida Atlantic University (FAU)- College of Architecture, Urban and Public Affairs (CAUPA)*
Center for Urban and Environmental Solutions (CUES)
CUES is active in Florida climate change policy issues at the city (Hollywood), county (Broward and Miami-Dade) and state levels, and the director is head of the state-wide energy and climate change committee. Two climate change publications have resulted from recent collaborative initiatives at CUES to develop planning and policy agendas for Florida: Florida's Resilient Coasts (CUES) and Southeast Florida's Resilient Water Supply. These publications were made possible by support from the National Commission on Energy Policy.

- *Florida Atlantic University (FAU) - The Barry Kaye College of Business*
Department of Management Programs
This program has incorporated environment and, more recently, climate change issues such as risk management, into the curricula of its management programs.
The Department is in its third year of funding from the Department of Homeland Security and Johns Hopkins University (PI, Dr. Mantha Mehallis) to develop online courses in crisis and emergency management preparation for response and recovery from natural disasters and catastrophic events, such as may occur from climate change. In addition, the Department has developed a national inventory of all crisis and emergency management courses for public and private post-secondary institutions throughout the United States, including those specific to risk management and other climate change issues. The College of Business hosted the World Resources Institute (WRI) international BELL (Business, Education, and Leadership) Conference with Dr. Mehallis serving as Program Chair. She also served as the first Chair of the Education Alliance of the Florida Governor's Council for Sustainable Florida. The curricula in both the Environmental MBA and the Crisis and Emergency Management MBA include economic assessment expertise and analysis of climate change on business and industry. The director of these programs was the lead consultant for the Organizations of American States' "Vision 2025: The Future of Water Resources Management in the Americas" which was presented at the World Water Forum at The Hague. Currently the Director is assisting UNESCO and the government of the Dominican Republic to develop the UNESCO Center for Sustainable Development in the Caribbean Island States. Much of this work relates to coastal issues, urban development, impact on multi-cultured populations, and the environmental and climate change issues facing the multi-cultural region.