SUMMARY REPORT

SEA LEVEL RISE WORKSHOP
FEBRUARY 16-17 2010
FLORIDA ATLANTIC UNIVERSITY
BOCA RATON, FLORIDA

SPONSORED BY FLORIDA SEA GRANT, THE US GEOLOGICAL SURVEY AND THE CENTER FOR ENVIRONMENTAL STUDIES AT FLORIDA ATLANTIC UNIVERISTY

The Science community lost a valuable asset and friend: Dr. Brian Keller. He unexpectedly passed away Wednesday, 10 March 2010.

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INTRODUCTION

The Center for Environmental Studies (CES) at Florida Atlantic University (FAU), the Florida Sea Grant College Program (FSG), and the U.S. Geological Survey (USGS) held a two day workshop at Florida Atlantic University on the Boca Raton campus February 16 - 17, 2010. The workshop was facilitated by Perran Ross, Department of Wildlife Ecology and Conservation, University of Florida Institute for Food and Agricultural Sciences.

The purpose of this workshop was to engage Florida university faculty and Florida resource management agencies on the issue of sea level rise and its effects on coastal-zone marine (upland ecosystems) and hydrological dynamics that might be impacted by future sea level rise and storm surge. The workshop goals were: (a) highlight ongoing research by Florida university faculty and agency scientists, (b) identify needs of state and federal agencies in order to build partnership opportunities between Florida faculty and state and federal agency staff, and (c) identify research issues related to sea level rise and Everglades restoration that Florida university faculty can address with multi-disciplinary, multi-institutional teams. (See Agenda Annex 1)

In addition to meeting its goals, the February workshop produced findings that will be channeled into the Greater Everglades Ecosystem Restoration Conference (GEER) being held in July 2010. Sea level rise and the efficacy of planned hydrologic restoration efforts in the region is expected to be a major issue of discussion. Recommendations from the Florida Fish and Wildlife Conservation Commission's (FWC) Climate Change Summit held in October 2008 were also discussed.

All workshop participants were asked to provide, in advance, a one-page summary of their current research on this topic, and make three minute verbal presentations to the group after the morning plenary session on day one. These submissions are listed in Annex 2.

On day two, facilitated groups discussed new research needs and made recommendations to a plenary session.

The desired outcome of the workshop was:

- Provide researchers and agencies with a list of high-priority-research needs.
- Allow better communication and coordination across the state on these issues.
- Develop material for the Greater Everglades Ecosystem Restoration (GEER) meeting in July 2010.

WORKSHOP PARTICIPATION

The invaluable and insightful results of the brainstorming workshop were a direct reflection of its participants: more than 30 institutions were represented by 65 people with the following rough breakdown:

- University Researchers – 33
- Federal/State Agencies – 28
- Others – 5

By scientific interest the breakdown was:

- Hydrology/ Water Quality – 14
- Ecology – 17
- Urban/Local Government – 10
- Federal/State Agency – 18
- Others – 7

A rich diversity of experiences and expertise provided a strong mix of ideas and priorities. To sharpen those priorities, four working groups were formed: two addressing the topic "Understanding and Assessing Sea Level Rise in Coastal Zones: Ecological Impacts and Implications" and two dealing with "Understanding and Assessing Sea Level Rise In Coastal Zones: Hydrological and Biogeochemical Impacts and Implications." After initial individual-brainstorming sessions, topic groups met to identify differences and similarities and findings in a plenary session. High-priority-research topics were identified. However, given the limited time frame and wide range of topics, those topics were not ranked. In addition to research topics, the break-out groups identified needs related to education / outreach and resource management planning strategies. The following is a summary of the main issues discussed and the main findings of the workshop.

WORKSHOP FINDINGS

1. Sea level rise in South Florida is already a problem: significant impacts are occurring along the coast and are affecting canal function. Malfunctioning canal systems cannot discharge water from low-lying areas during periods of high rainfall and high tide.
2. Currently, the mean global rate of sea level rise is approximately 3 mm per year. However, within a relatively broad band of certainty, projections of future sea level rise consistently indicate a non-linear increase in this rate in future years.
3. A rise of at least 1m before the end of the century is an increasingly likely possibility.
4. Regardless of the rate of increase, it is prudent and essential that we prepare for and adjust to sea level rise immediately: the projected rates of rise will result in sea levels that have significant impacts on coastal ecosystems and the coastal infrastructure and economy.
5. For both natural and built systems and for Everglades restoration planning and action, ongoing monitoring of the rate of rise in sea level and its impacts is critical.
6. In the face of climate change and sea level rise at an uncertain rate, adaptive management in the greater Everglades is even more critical.
7. Due to the impact of sea level rise on ground water levels, flooding, drainage, and salt water intrusion, impacts may occur in inland areas before direct shoreline impacts are apparent.
8. There will be critical thresholds of sea level rise that are tipping points of impact. In a majority of cases, these are determined by the state's topography.
9. Impacts may escalate during hurricane-driven storm surge events as higher sea levels will result in substantially greater inland incursion of salt water.
10. Both urban and natural systems need to be considered in research and planning because impacts on one will have impacts on the other.
11. Monitoring and adaptive management measures need to be implemented. Some of these are spelled out in the working group findings below.

SUMMARY OF PLENARY SESSIONS

Brian Soden, in a plenary address, outlined the escalation of confidence in the understanding of Climate Change from 1990 through 2007, with the conclusion that 2°F of warming was already expected and, consequently, unavoidable. Predictions of future temperature change range from a 2°F to 4°F. The role of increased cloud cover is an unknown factor which modelers have not yet resolved.

The impact of temperature change on sea level also has uncertainties, though the past two decades have shown that the observed rate is always at the upper boundary of projections, and the rate of change in sea level is highly consistent with the amount of thermal expansion expected for the

observed temperature rise. Global sea level rise has been approximately 3 mm per year from 1993 until the present, with regional variations in relative rate of rise due to such things as land subsidence or uplift. The most recent IPCC projections ranged from 20-50cm by 2100, but more recent work suggests a much larger change: up to 1 meter with potential for higher levels. It should be noted that previous models used in the IPCC report had not incorporated ice loss as a source of water contributing to rising sea levels.

Stuart Applebaum (USACE) addressed regional impacts, in particular, restoration of the Florida Everglades. He reviewed the history of the Comprehensive Everglades Restoration Plan (CERP) and the iterations of human involvement with the South Florida water system. These include drainage of large areas, widespread agriculture, and the encroachment of urban and suburban development. In the CERP 'Yellow Book' (1998), a very modest (up to 6″) sea level change was envisioned for the decades-long plan for the restoration. The 2008 National Academy of Science report to Congress, which assesses progress in restoring the natural system, recommended that additional attention be paid to the impacts of climate change. The July 2009 USACE engineering circular requires that the agency use three different curves for projected sea level rise: low, intermediate, and high, and that the USACE test the sensitivity of all plans to those levels. A forthcoming update to CGM #16 will further address climate change adaptive strategies.

The afternoon session began with a presentation of ongoing research, monitoring, and modeling by all participants. The previously submitted one-page statements are included in Annex 2.

Key issues discussed after the afternoon session included:

- Climate change needs to be addressed by all members of society
- Policy makers, Educators, Architects, and Planners should be at the table at future meetings
- Model decision-making structures should be formulated and tested by communities
- Acknowledge that climate change is a global problem and share knowledge widely
- Use the Dutch philosophy of living with water- not just holding it back
- Identify small changes which will have a big impact
- It is necessary to find the right mechanism and message for informing the public about climate change. Though the message must be based on sound and often complex science and care should be taken to present the facts in plain, non-sensational language that is easy for the general public to understand.

Agency Panel Discussion

Representatives of the USACE, USFWS, National Parks Service, Florida Fish and Wildlife Conservation Commission, and NOAA presented research and information needs.

Glenn Landers, USACE

Issues include:

- Agency transition to Climate Change Adaptive planning
- 20, 50, 100 year planning horizons are needed
- Concerns for the built environment and avoidance of "New Orleans" situations
- Additional land for flood control may be needed
- Identification of non-structural solutions
- The need for new national guidelines (now up for review)
- A single set of regulations is needed

He also pointed out that the USACE is project-oriented and most research is linked with specific project needs.

Steve Traxler, US Fish and Wildlife Service

Issues include:

- The agency's role is to preserve, protect, and enhance resources and, in the past, climate change was not a concern
- Climate change is already causing species movement: land acquisition will be necessary to allow migration
- Humans are expected to move inland and, consequently, wildlife will be affected
- Issues of peat preservation and enhancement are important for the Everglades
- Mangrove migration inland is dependant on the pace of sea level rise. It is not likely to keep pace with projected future rates of sea level rise

Leonard Pearlstein, National Parks Service

Issues include:

- Park service will release a strategic plan addressing climate change issues
- Legal and jurisdictional policies need to be reconsidered.
- Problems of inconsistencies across state lines
- People react emotionally, therefore, it is important to supply the public with information that they will understand and be able to support political decisions
- Interpreting science in different educational contexts is vital
- Some species, e.g., panthers and sparrows, may have to be relocated instead of protected.
- There are no plans or protocols and no clear policies to stop inward migration of people

Doug Parsons, Florida Fish and Wildlife Conservation Commission

Issues include:

- The FWC has sponsored a climate change summit and plan to implement climate change policies throughout the agency
- Five internal-work groups: Adaptation, Research, Communications / Education, Policy, and Operations

- There is a strong need to for additional scientists and legislators, politicians, and others to become climate literate
- Research and Vulnerability assessments are important as is the need to develop correct protocols so that there is adequate information to implement policy
- When downscaling global models and local and regional existing stressors must be included
- Need to fund adaptation processes by / for wildlife agencies
- A dollar value needs to be put on wildlife corridors and clean water

Pamela Sweeney, NOAA

Issues include:

- National Strategic Plan addressing climate change is on NOAA website
- Protect coastal areas and educated and recruit citizens to be involved
- Engage Federal Government (NOAA) and local decision makers
- There is a pressing need for high-resolution habitat maps
- The social science component is important
- Funding is needed to interpret science for the public and get them involved
- Children should be educated about climate change so that they are prepared for the future
- Inadequate funding for research
- Need long-term statewide and national monitoring of climate change effects. Again, no funding
- How do we accumulate compelling science to defuse conflicts which influence decisions and why has it not been done?
- We are fortunate to have Everglades Restoration to provide a model. This regional ecosystem-based, long-term project brings many disciplines together—a vital necessity in the context of climate change
- Land use and land cover is intimately tied to climate change

REPORTS OF WORKING GROUPS

A wide range of impacts and research needs were identified in the following categories:

Topic A: Understanding and Assessing Sea Level Rise in Coastal Zones: Ecological Impacts and Implications

The two groups identified a large number of research topics and a selection is summarized below.

Impact of Sea Level Rise on Ecosystem Services:

- Sea Level rise not only destroys reefs, marine, and coastal habitats: it destroys tourism and commercial and recreational fisheries. It becomes imperative to translate these losses into dollars. For example, over 70% of the national catch of shrimp occurs in the Gulf of Mexico and South Florida Atlantic waters. Shrimp have a life cycle that depends on coastal wetlands. The loss of wetlands is certain to decimate this fishery and have tremendous economic impacts. In addition, the fish that depend largely on this fragile coastal habitat contribute 11B to Florida's economy annually.

Understanding Little Known Ecological Processes:

- Impacts of sea level rise on water quality and nutrient regeneration affecting organisms and habitat, such as sea grass
- Effects of increased frequency and magnitude of beach renourishment on sea turtles, fish, shrimp, and nursing grounds

- Migratory species impacts
- How fast can coastal and shore species respond to sea level change
- Impacts of changing hydrology and salt water intrusion on natural systems
- Peat formation and decay, particularly, in response to salt water

Understanding the Ecological/Human Interface:

- What are the necessary changes in coastal infrastructure, including relocating power plants, roads, buildings, landfills, etc.? How do we identify land purchase priorities?
- What are the major regulatory and legal/ policy issues?
- How should CERP monitoring programs be adjusted to reflect sea level rise?

Regional Needs:

- Co-operative work across the Caribbean, where conditions are similar to Florida

Modeling Scenario and Testing:

- Storm surge modeling
- Significance of Everglades restoration in combating salt water intrusion
- Linking hydrological and ecological models
- Salt-water intrusion and ground-water-charge models

Important Species Concerns:

- Water flow-related nesting success
- Megafauna impacts
- Impacts on endangered species
- Vulnerability assessment on species and habitats

Topic B: Understanding and Assessing Sea level Rise in Coastal Zones: Hydrological and Biogeochemical Impacts and Implications

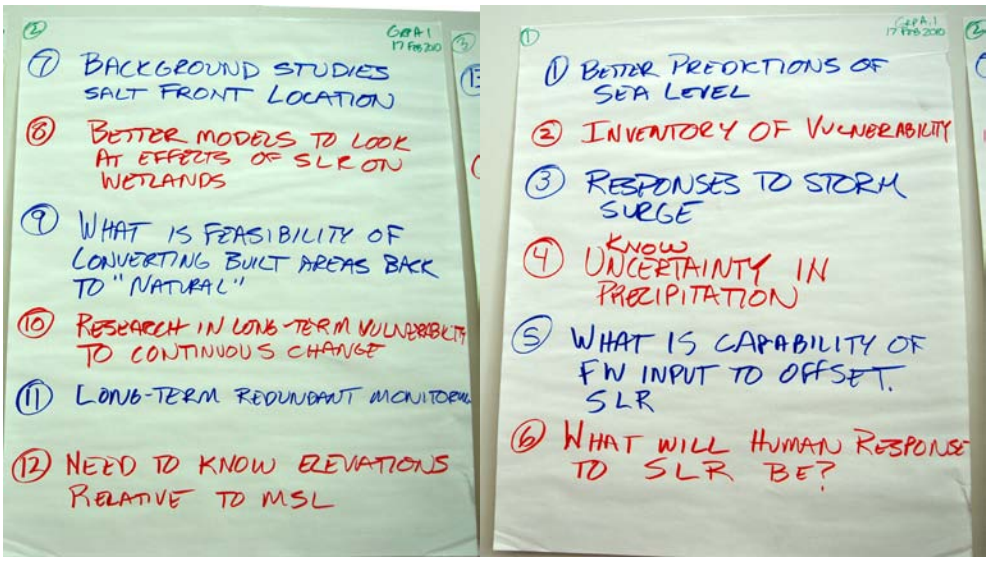
The two groups, working separately, identified a large number of specific research questions and topics (52 in group one and 54 in group 2). Both groups emphasized key issues:

- The need for more accurate predictions of sea level rise by level and timing.
- The identification of most vulnerable organisms and ecosystems.
- Precise measurement of coastal elevations.
- The development of new conceptual models to assess vulnerability and near-shore dynamics.
- The impacts of extreme events on coastal change and salt water and fresh water interaction.
- Identification of tipping points for key hydrologic systems.
- Groundwater chemistry.
- Technologies for mitigation of salt water intrusion.
- Biochemical issues involved with peat formation.
- Effects of increased deposition with sea level rise.
- Human response and infrastructure needs with sea level rise.

The following five categories were used to organize individual research questions:

1. Physical
    a. Sea level rise
    b. Freshwater / Saltwater interaction
    c. CO_2 - KARST
    d. Precipitation
2. Communication
    a. How To
    b. Unknown Social / Psychological
3. Vulnerability
    a. Economic
    b. Human
    c. Ecosystem
4. Resilience
    a. Ecosystem
    b. Legal / Abandoned land
5. Management Action and Policy

Lastly, both groups identified a specific process to incorporate sea level rise into CERP, both to prioritize research needs and to explain potential impacts on ecosystem services to decision makers. The concept will use the conceptual ecological models that have been developed for CERP, and then the regional teams will consider the ecological processes and response variables under different sea level rise scenarios. Major areas of uncertainty, pathways of particular importance linking the stressor to endpoints, and anticipated impacts will be revealed when the process is conducted in an orderly manner. As noted, the models have been used for a number of years to guide major decisions about expenditure of CERP funds and they will be an effective way to communicate the relationship between sea level rise and its impacts to the general public.



Examples of Working Group Notes

NEXT STEPS

The Workshop identified a large number of research, monitoring, and education needs related to sea level rise and projected future rise. However, given the time limitation, it was not feasible to create a prioritized agenda in any of these categories.

As planned, the deliberations of this workshop, the Archbold Biological Station workshop in January 2010, (see Reed Noss page 44), and other formal and informal meetings are groundwork for a focused discussion at GEER 2010 that will work to create a research and adaptation action agenda.

Federal and State agencies, regional planning agencies, the SFWMD, and local authorities are all now addressing the realities of climate change and sea level rise and the role of research and monitoring at agency and university levels is becoming defined. In addition, the importance of incorporating implications of climate change in Everglades Restoration is well recognized. There will be many next steps adjusting a planning and action framework to the implications of sea level rise.

ANNEX 1. WORKSHOP AGENDA

SEA LEVEL RISE, WORKSHOP

DAY 1 – TUESDAY, FEBRUARY 16, 2010

Florida Atlantic University, Marleen & Harold Forkas Alumni Center
Carole and Barry Kaye Great Hall, Boca Raton, Florida

9:30-10:00am	**Registration and Continental Breakfast**
10:00-10:45am Speakers:	**Welcoming Remarks and Workshop Overview** • Ram Narayanan, Professor & Chair, Department of Chemistry & Biochemistry and Assistant Vice President for Research, Division of Research, Florida Atlantic University • Leonard Berry, Director, Florida Center for Environmental Studies, Florida Atlantic University • Karl Havens, Director, Florida Sea Grant College Program, University of Florida • Ronnie Best, Coordinator, Greater Everglades Priority Ecosystems Science, United States Geological Survey • Perran Ross (workshop facilitator), Department of Wildlife Ecology and Conservation, IFAS, University of Florida
10:45-12:00pm Chair: Speakers:	**Climate Change Models, Sea Level Rise, Everglades Restoration** • Ronnie Best • Brian Soden, Global Climate Change, Climate Modeling and Remote Sensing, RSMAS. *The Current State of Global Climate Change Models and Implications for Sea Level Rise.* • Stuart J. Appelbaum, Chief, Everglades Division, U.S. Army Corps of Engineers, Jacksonville, FL. *Everglades Restoration Climate Change Concerns and Draft Sea Level Rise Planning Guidance*
12:00-1:00pm	**Lunch**
1:00-3:00pm	**3 minute presentations: Ongoing research, monitoring & modeling** (all participants)
3:00-3:30pm	**Coffee Break**
3:30-5:00pm Moderator: Panel:	**Agency Panel Discussion: Challenges Management Agencies are Facing in Relation to Sea Level Rise** • Perran Ross • Glenn B. Landers, Senior Project Manager, Climate Change Studies Everglades Division, U.S. Army Corps of Engineers • Steve Traxler, Senior Fish & Wildlife Biologist, Fish and Wildlife Service • Leonard Pearlstine, Landscape Ecologist at Everglades and Dry Tortugas National Parks, U.S. National Park Service • Doug Parsons, Climate Change Coordinator, Florida Fish and Wildlife Conservation Commission • Gary Lytton, Director of the Rookery Bay National Estuarine Research Reserve. Environmental Administrator, Coastal Training, Rookery Bay National Estuarine Research Reserve
Remarks:	**End of day summary** Perran Ross
5:30-7:30pm	**Presidents Reception, Adjourn to The Eleanor R. Baldwin House**

DAY 2 – WENDESDAY, FEBRUARY 17, 2010
Florida Atlantic University, Marleen & Harold Forkas Alumni Center
Carole and Barry Kaye Great Hall, Boca Raton, Florida

<table>
<tr><td>7:30-8:00am</td><td colspan="2">Continental Breakfast (Great Hall)</td></tr>
<tr><td>8:00-8:30am
Presenter:</td><td colspan="2">Welcoming Remarks and Overview of Breakout Sessions
Perran Ross
• Explanation of the breakout sessions
• Goals and deliverables
• Structure and Process
• Introduce group leaders</td></tr>
<tr><td rowspan="2">8:30-10:30am (concurrent sessions)</td><td colspan="2">Disperse into four simultaneous workshops to brainstorm major issues, products, outputs on its assigned topic</td></tr>
<tr><td>Topic A: Understanding and Assessing Sea Level Rise in Coastal Zones: Ecological Impacts and Implications
Group 1
Led by: Perran Ross
Location: Great Hall (1st floor)

Group 2
Led by: Marguerite Koch-Rose
Location: Library (1st floor)</td><td>Topic B: Understanding and Assessing Sea Level Rise in Coastal Zones: Hydrological and Biogeochemical Impacts and Implications
Group 1
Led by: Ronnie Best
Location: Presidents' Board Room (2nd floor)

Group 2,
Led by: Karl Havens
Location: Bank of America Mentoring Center (2nd floor)</td></tr>
<tr><td>10:30-11:00am</td><td colspan="2">Coffee Break</td></tr>
<tr><td rowspan="2">11:00-12:00pm (concurrent sessions)</td><td colspan="2"><u>Sub-groups meet together to combine, calibrate and refine their product</u></td></tr>
<tr><td>Topic A: Convene in Great Hall (1st floor)</td><td>Topic B: Convene in Presidents' Board Room (2nd floor)</td></tr>
<tr><td>12:00-1:00pm</td><td colspan="2">Lunch (Great Hall)</td></tr>
<tr><td>1:00-2:30pm (plenary session) Presenters:

Presenters:</td><td colspan="2">Topic A workshop leaders report outputs
Perran Ross and Marguerite S. Koch-Rose
Topic B workshop leaders report outputs
Ronnie Best and Karl Havens</td></tr>
<tr><td>2:30-3:00pm
Discussant:</td><td colspan="2">Discussion on the Workshop Outputs and Workshop Conclusions
Karl Havens
1. Enhanced understanding of agency and academic capacities, challenges and needs to meet the challenge of sea level change in Florida
2. Prioritized research needs to address impacts of sea level rise on coastal zones (ecological, hydrological and biogeochemical)
3. Relationship and direction for content of GEER conference</td></tr>
<tr><td>3:00-3:30pm
Speakers:</td><td colspan="2">Closing Remarks
Karl Havens
Ronnie Best
Leonard Berry</td></tr>
<tr><td>3:30pm</td><td colspan="2">Adjourn</td></tr>
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ANNEX 2. SUMMARY OF ONE-PAGE STATEMENTS

Ricardo Alvarez
Research Affiliate
Florida Center for Environmental Studies, Florida Atlantic University

Impacts of Sea Level Rise on Infrastructure

Informal surveys show that most of us seldom, if at all, think about infrastructure and really pay little attention to it unless it fails affecting services we receive or our quality of life. To many, infrastructure is something that remains unseen, in remote locations, behind closed doors or fences, and is maintained by "others". In contrast with these views many of us use streets and highways, bridges and railroads, or look at water-treatment plants, or water-management canals or other quite visible similar facilities without really thinking of them as infrastructure.

The etymology of the word infrastructure includes *infra*, from the Latin, meaning *below* or *base*, which gives the clear picture that the main function of infrastructure is to provide support for something else.

In the context of fully developed urban areas, such as those along coastal regions in Florida and other states, the built environment must be considered as infrastructure that supports the full range of human activity, while the natural environment surrounding urban areas must be considered as infrastructure that supports the built environment and, consequently, human activity as well.

With respect to infrastructure my research interests over the last seventeen years has addressed the potential for damage from the impact of natural hazards, the need to assess the vulnerability to such impacts, and the identification of mitigation alternatives to reduce the potential for damage from recurring hazards events.

In the specific case of sea level rise and infrastructure my research, from 1997 to the present, has focused on the following:

1) The linkages between sea level rise and the exacerbation of damage components in natural hazards such as storm surge and coastal flooding caused by hurricanes;
2) The usage of design criteria to adapt the built environment to the impact of sea level rise;
3) The need to change the building design methodology from a backward look-based approach to a method that establishes design criteria based on future impacts of sea level rise during the service life of the building or structure;
4) The need to assess vulnerability to sea level rise on a regional basis with the objective of identifying adaptation measures to protect the built environment in coastal urban regions, and preserve its role in sheltering the full range of human activity;
5) Developing scenarios of future sea level rise impact on coastal urban areas to assess alternatives and time scales for action, which may include adaptation, retreat or abandonment;
6) Assessing the combination of engineering solutions, preliminary studies, planning, funding approaches and political will, which will result in the implementation of actual adaptation projects to protect urban infrastructure in coastal regions;
7) Assessment of how natural infrastructure i.e.: beaches, barrier islands, wetlands, coastal ecosystems etc. support and/or interact with the built environment with the objective of identifying adaptation measures for the natural infrastructure;
8) Assessing educational and outreach needs to fully engage the engineering, design and planning sectors as well as policy-makers in the implementation of adaptation measures.

This research is critical to ensure the continuity of function of fully-developed urban areas worth trillion of dollars in actual infrastructure value and the value of human activity taking place there.

Jim Beever
Southwest Florida Regional Planning Council

The Southwest Florida Regional Planning Council (SWFRPC) and the Charlotte Harbor National Estuary Program (CHNEP) have partnered in multiple projects related to climate change, including the first Florida **Climate Ready Estuaries Program** beginning in 2008. Completed project documents are available at the following web sites at the SWFRPC http://www.swfrpc.org/abm.shtml and CHNEP http://www.charlotteharbornep.org/ websites.

A Comprehensive Southwest Florida/ Charlotte Harbor Climate Change Vulnerability Assessment of the Southwest Florida Regional Planning Council and Charlotte Harbor National Estuary Program, Technical Report 09-3, 311 pages, was completed September 15, 2009. A shorter summary document of 58 pages entitled ***Charlotte Harbor Regional Climate Change Vulnerability Assessment*** is currently in review. ***The Adaptation Plan for the City of Punta Gorda, Technical Report 09-4***, 406, pages was completed over the course of a year of public participation and planning. The plan was adopted by the City of Punta Gorda on November 18, 2009. Following the completion of the draft plan last quarter, the CHNEP committees have reviewed and accepted the plan as final. The City of Punta Gorda has initiated model ordinance language development with the assistance of the SWFRPC, the CHNEP and the University of Florida.

Presentations on Climate Change Issues have been made to the Myakka River Coordinating Council; The Punta Gorda City Council; the Mangrove Chapter, Florida Native Plant Society; the CHNEP Management Conference (Policy, Management, TAC, CAC); Florida Audubon Assembly; Creating a Green Region Conference, Mote Marine Laboratory, Sarasota; the Estero Bay Symposium, FGCU; three public workshops on the City of Punta Gorda Climate Change Adaptation Plan; Evaluation and Appraisal Report Workshop for Charlotte, Collier, Lee and Sarasota Counties; Managing Wet Weather with Green Infrastructure Conference, FGCU; Florida League of Environmental Resource Agencies (FLERA) Annual Meeting, Sarasota; and the Estero Bay Agency on Bay Management.

Currently active projects include:

Climate Change Vulnerability Assessment and Adaptation Opportunities for Salt Marsh Types in Southwest Florida: This study will examine the range and extent of five different types of salt marsh in the Charlotte Harbor National Estuary Program study area, and the vulnerabilities of these important ecosystems to climate change. Work began on this study early in January 2010.

The Lee County Climate Change Vulnerability Report and Climate Change Resiliency Plan: This work will involve developing climate change resiliency plans for Lee County and any municipalities that wish to participate. The project is proposed to include a structure for community planning sessions leading to the development of a climate change avoidance, minimization, mitigation and adaptation plan (AMMA). Greenhouse gas emission measurements will be used to evaluate locally appropriate mitigation techniques. The project received funding on January 11, 2010.

CHNEP Climate Change Indicators: CHNEP and EPA are working together to identify 3-5 climate change indicators and corresponding monitoring plan alternatives for the CHNEP study area. The purpose of the Climate Change Indicators Working Group is to review the results of the previous CHNEP Climate Change Indicators Survey, agree on the short list of indicators and develop monitoring plan alternatives for each indicator.

CHNEP Climate Change Model Ordinance and Comprehensive Plan Language: CHNEP and EPA are working together to develop model language for local ordinances and comprehensive plans for implementation of climate change planning and adaptations.

Frederick Bloetscher
Florida Atlantic University

Areas of Research: Initial research dates to 2007 when evaluating impact of climate change on groundwater. This research led to a more specific evaluation of climate change impacts of Florida groundwater, with particular emphasis on SE Florida which is the lowest large area in the state. SE Florida will feel the impacts of climate change, less as warming, more as sea level rise, a major issue for low lying, groundwater dependent areas. SE Florida which relies almost completely on the Biscayne aquifer for its water supplies. The research extended to evaluation of utility and regional responses and adaptations to climate change, and extended to reviews of other areas of coastal Florida. When starting the Heimlich et al 2010 project, it was soon evident that precursory review of USGS and other groundwater models demonstrated that there was a potential for extensive, long-term flooding to occur as a result of typical afternoon thunderstorm activity as a result of sea level rise. Current research is looking at much of the current water management protocol which may need to be reversed since doing otherwise would cause water quality to diminish, lessen the ability to drain the area, are reduce storage capacity in the soil.

Books:

1. Bloetscher, F. editor(2010), *Sustainability Compendium*, AWWA, Denver, CO
2. Heimlich, B.N.; Bloetscher, F., and Meeroff, D.M. (2010), *Southeast Florida's Resilient Water Resources: Adaptation to the Sea Level Rise and Other Impacts of Climate Change*, FAU, Boca Raton, FL

Papers:

1. Bloetscher, F. (2009), "The Impact of Unsustainable Ground Water," *GWPC Annual Forum Proceedings*, GWPC, Oklahoma City, OK.
2. Bloetscher, Frederick (2008), "Climate Change Impacts on Florida (with a specific look at Groundwater impacts)," *FSAWWA Annual Conference Proceedings* (best paper award).
3. Bloetscher, F. (2009), Climate Change Impacts on Florida Water Supplies, AWWA Annual Conference Proceedings, AWWA, Denver, CO.
4. Bloetscher, Frederick (2008), "The Potential Impact of Climate Change on Groundwater Recharge," *GWPC Annual Forum Proceedings*, GWPC, Oklahoma City, OK.
5. Bloetscher, Frederick (2008), "The Potential Impact of Climate Change on Groundwater Recharge (with particular emphasis of the Potential Impacts on Florida Water Supplies), *EWRI Annual Conference Proceedings – Kansas City, MO*, ASCE, Reston, VA
6. Bloetscher, F. and Tara Bardi (2009), The Potential Impact Of Climate Change On Groundwater Recharge (with Particular Emphasis on Florida), *AWRA 2009 Spring Specialty Conference. Anchorage, Alaska, AWRA*, AWRA, Middleburg, VA.
7. Bloetscher, F. and Plummer, J. D. 2009. Emerging issues in water supplies. *AWWA Water Resources Symposium*, Portland, OR, January 25 – 27, 2009.
8. Bloetscher, F. and Plummer, J. D. 2008. Occurrence and significance of pharmaceuticals in the environment – potential for rules and treatment in the future? *Florida Section of the AWWA Fall Conference*, Orlando, FL, November 30 – December 4, 2008.
9. Bloetscher, F. (2009), "Should Florida Revisit Comparative Assessment of Municipal Wastewater Disposal Methods in the Southeastern Part of the State?" *Florida Water Resource Journal*, Vol. 59, No. 3, pp. 18-32.
10. Bloetscher, F. (2009), "Change Impacts on Florida,"' *Florida Water Resource Journal*, Vol. 59, No. 9.
11. Bloetscher, F.; Meeroff, D.M., and Toro, A. (2008), "Concentrating the Concentrate – Pointing to Solutions for Concentrate Management," *AWWA Annual Conference and Exposition Proceedings*, Denver, CO.
12. Bloetscher, Frederick and Muniz, A. (2008), "Water Supply in South Florida - The New Limitations," *Sustainable Water Sources (Reno) Conference Proceedings*, AWWA, Denver, CO.

Laura Brandt, Wildlife Biologist and Steve Traxler, Fish and Wildlife Biologist
U.S. Fish and Wildlife Service

Fish and Wildlife Service Science Needs Relative to Sea Level Rise with a Focus on South Florida

The mission of the U.S. Fish and Wildlife Service is to work with others to conserve, protect and enhance fish, wildlife and plants and their habitats for the continuing benefit of the American people. To effectively achieve this mission in the face of 21st century conservation challenges such as climate change we are implementing a science based, adaptive, landscape approach to conservation. Such an approach requires that we articulate our science needs and seek partnerships that facilitate meeting those needs.

Sea level rise poses a series of issues and challenges that from a management perspective require science support. Science support is necessary to address issues at a range of scales, from regional to local. Research done in an adaptive management framework with continuous feedback between resource managers and researchers throughout the adaptive process will be the most successful in addressing our needs.

Below we categorize types of needs that can provide the starting point for more detailed conversations on what projects could fulfill those needs.

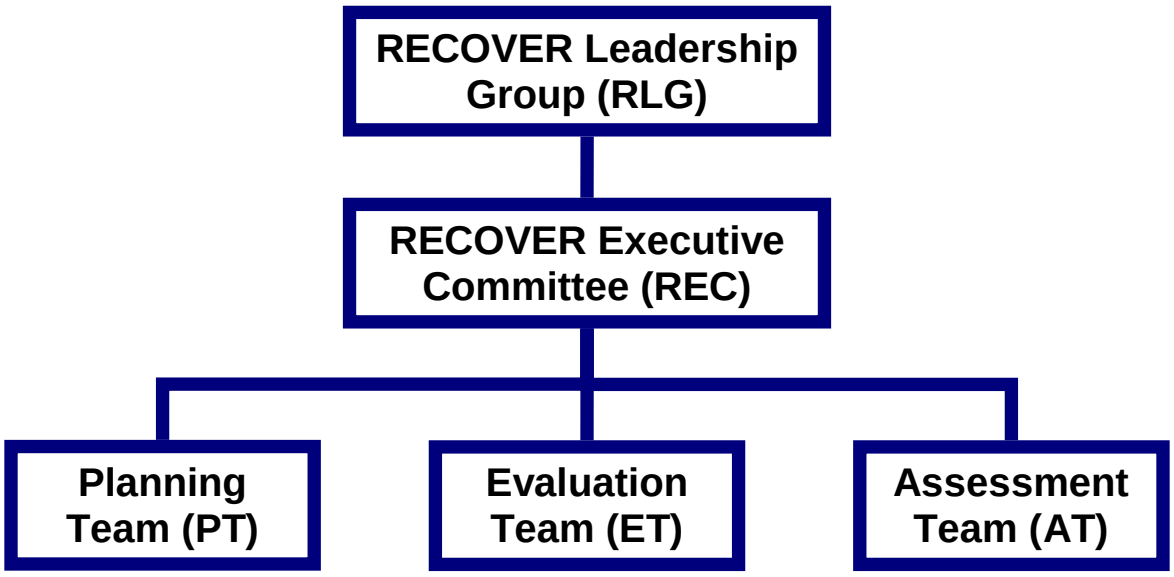
- How much sea level rise will there be, where, what time frame, and what is our level of certainty in those predictions?
- What is the effect of sea level rise on habitat?
    - Physical presence of habitat such as beaches, tidal flats, mangroves (gain or loss) used by sea turtles, birds, and other wildlife.
    - Suitability of habitats (especially for foraging and nesting) for fish, wildlife, and plants both in the short and long-term.
- What habitats will be lost or replaced by other habitats (e.g., marsh-mangrove)?
    - What management actions such as fire or upland hydrologic management could help maintain marsh habitats - if this is a goal?
    - Are these techniques a viable long-term solution?
- What is the effect of sea level rise on frequency and intensity of storm surge?
    - What is the effect of storm surge on suitability of habitats both in the short and long-term?
- How can we effectively track the effects of sea level rise on resources of concern?
- We need to better understand the uncertainties in methods and model predictions and work to reduce uncertainties in key areas.
    - For example, accretion and subsidence rates are not equally well understood from area to area.
    - Can methods for acquiring bathymetry data for ocean-side coral reef tract areas be applied to shallower backcountry areas?
    - How useful is SLAMM in different Florida habitats (e.g., mangroves) in and what can be done to improve these models?
- Global climate models downscaled to regional and local levels in Florida
    - Increased predictability (decreasing uncertainty) for decadal cycles.
    - Coupling this information to biological models.
- Develop a standardarized statewide set of sea level rise scenarios for planning.

Henry Briceño
Florida International University

Most of my research at the Southeast Environmental Research Center of FIU is focused on water quality (WQ) in coastal areas, especially in southern Florida (Coastal Everglades, Florida Bay, Florida Keys and Biscayne Bay), its relation to spatial ecosystems distribution, and WQ changes due to natural and anthropogenic forcing. I have recently reported (Briceño and Boyer 2009, Estuaries and Coasts) climate variability (i.e. Atlantic Multidecadal Oscillation) coupled with SLR effects on nutrient availability and phytoplankton biomass in Florida Bay and similar work is under way in Biscayne Bay. Additionally I am an active member of the Climate Change Advisory Task Force (CCATF) Science Committee, and also a associate researcher for the NSF financed ULTRA-EX Project "Social Ecological Vulnerabilities in the City of Miami" derived from climate change and SLR.

Gretchen Ehlinger
U.S. Army Corps of Engineers

Dr. Gretchen Ehlinger is a biologist and project manager for the U.S. Army Corps of Engineers (USACE) in the Everglades Division. Dr. Ehlinger is a co-chair of the Assessment Team in the interagency Restoration Coordination and Verification (RECOVER) group of the Comprehensive Everglades Restoration Plan (CERP). The RECOVER Assessment Team is primarily responsible for measuring the actual performance of implemented CERP projects and interpreting that performance based on the analysis of information obtained from research, monitoring, modeling, or other relevant resources. The goal of the CERP Monitoring and Assessment Plan (MAP) is to establish a framework for measuring and interpreting system-wide responses to CERP, to determine how well CERP is meeting its goals and objectives and, through adaptive management (AM), provide the framework for improving performance of CERP as needed. Currently there are about 35 monitoring components in the MAP that are related to the biology, ecology, and water quality of the system. The MAP and resulting assessment reports are key components of the CERP AM Program, which is being implemented to address program uncertainties. The major aspects of climate change creating uncertainty relative to the CERP are; (a) increases in the frequency of major hurricanes; (b) variability in precipitation, air temperature, water vapor, and ocean temperature; and (c) the magnitude of sea level rise. The MAP has the opportunity to look at past data sets to see if climate change signals are present in the monitoring data. The MAP monitoring data also provides data necessary to establish the pre-CERP baseline from which responses to implementation of the CERP can be measured. It is critical to maintain and/or alter this monitoring program in order to be able to capture and account for annual, inter-annual, and spatial variability in precipitation in its trend analysis so that it can effectively discriminate changes that are due to system variability from those resulting from CERP activities. Pre-CERP climate conditions will be impacted by long term global climate change trends and the MAP needs to be positioned to better address this as well as use predictive models to help simulate possible future conditions (e.*g.*, sea-level rise) when they are available.



Kris Esterson
Everglades Partners Joint Venture (EPJV)/PBS&J

Mr. Esterson, is a professional geologist and project manager with PBS&J. At the EPJV he supports the USACE in its efforts to address climate change issues associated with restoration of the Everglades.
USACE efforts that he currently supports include:

Implementation of USACE Sea Level Change Guidance (EC-1165-2-211)
The EC provides guidance on how to develop local sea level change projections. This guidance is currently being applied to CERP projects. However, the guidance doesn't cover all areas of adaptation in detail leaving many of the specifics to be developed.

Implementation of CERP Adaptive Management
AM has been proposed as a key tool in climate change adaptation, however much work remains to be done to determine the utility of AM in addressing climate change issues.

Development of Technical Report 1
This report summarizes climate change impacts to southern Florida and the Everglades. It provides a foundation for follow-on studies.

Development of CERP Guidance Memorandum 16.01
CGM 16.01 is an update to the original sea level rise guidance memo from 2004. The new CGM incorporates information from EC-1165-2-211 and research published in recent years.

Research topics that would improve Florida's response to climate change:
Improve Climate Models to Provide Better Decision Support
An effort is needed to create a dialog between the creators and end-users of climate models. Often decision-makers are frustrated by the uncertainty of climate projections, but do not articulate the specific areas of concern to model builders. Users must be specific about areas of concern (parameters, planning horizons) and explain their desired uncertainty reduction targets (what level of information is needed to make sound decisions).

Improve Management Models and Decision-Support Tools to Handle Climate Change Projections
The uncertainty in climate change projections will not be fully-resolved in the near term. Important management decisions that must be made in the next twenty years will have to be made in the face of significant uncertainty. Consequently management models that can handle this kind of uncertainly must be devised, improved, and employed.

Managing the Carbon Cycle in the Natural System & Low Carbon Design in the Built Environment
How should the Everglades be managed for carbon sequestration among other management goals? What new low-carbon design standards should CERP infrastructure adhere to?

Unified, Collaborative Scenario Development
Climate change is uncertain and projections of change are usually given as scenarios. To enable adaption planning across scales (from local to regional to state) everyone must have a common scenario set. Florida needs to develop a set of climate change scenarios similar to those developed by California's Department of Water Resources.

Ernest Estevez
Senior Scientist & Director, Center for Coastal Ecology
Mote Marine Laboratory

Florida Sea Level Research & Service Experience

Prior

--Graduate research on obligate intertidal fauna of red mangrove forests from Tampa Bay to Florida Keys.
--NOS tide gauge training; maintained gages in return for early data access.
--NOS and Florida DNR training in staff and recording gage installation, maintenance, and interpretation of data at ~ 20 stations; also NGVD and tidal datum plane survey experience at multiple river and bay locations, Florida west coast.
--Bathymetric surveys in lakes, rivers, bays, nearshore Gulf.
--Surveyed coastal city and county governments' perception of risks associated with past and future sea level rise.
--Registered future sea level predictions to local NGVD/NAVD and tidal datum planes for national estuary programs.

Current

--Studies of tidal river ecosystem structure & function; salinity regimes and biotic responses (especially mollusks) during droughts as proxies for salinization resulting from sea level rise; likewise for tidal rivers with regulated flows.
--Planning stage for collaborative work with Cuban and Caribbean investigators and resource managers on relation of sea level rise to MPAs, coastal wetlands, etc.

Service

--Reviewer of journal manuscripts and EPA and NEP reports on sea level rise.
--Member of Florida Oceans & Coastal Council, architect of state report on effects of climate change on Florida's ocean and coastal resources; author of sea level driver section; co-author of effects of sea level rise section; coordinating 2010 updates to sea level sections.
--Coordinator of Florida SeaGrant Strategic Plan Workshop session on climate change.

Recent Publication

Montagna, P.A., E.D. Estevez, T.A. Palmer, and M.S. Flannery. 2008. Meta-analysis of the relationship between salinity and mollusks in tidal river estuaries of southwest Florida, U.S.A. American Malacological Bulletin 24: 101-115.

Tom Frazer and Chuck Jacoby
University of Florida

Current Research Related to Sea Level Rise

Research over the last decade indicates a precipitous decline in macrophyte abundance in spring-fed, coastal rivers along the west coast of peninsular Florida. Of particular concern are declines of native species such as American eelgrass (*Vallisneria americana*) and strapleaf sagittaria (*Sagittaria kurziana*). In fact, *S. kurziana* appears to have been largely extirpated from many of these systems.

Macrophyte loss often has been attributed to increased nutrient loading, and, in several spring-fed, coastal rivers, concomitant increases in macroalgal abundance and periphyton loads on remnant populations of submersed macrophytes are consistent with a simple eutrophication progression scheme. However, altered salinity regimes due to declines in freshwater discharge, shoreline modifications, and increases in the frequency and intensity of tropical storm events have likely played an important role in the perceived deterioration of these systems. In the Kings Bay/Crystal River system, for example, losses of native vegetation and concurrent increases in non-native and nuisance flora can be linked to both chronic and acute changes in salinity.

The long-term negative consequences of sea-level rise on the biology and ecology of Florida's spring-fed, coastal rivers are legitimate reasons for concern. Freshwater flow in each of these systems originates as groundwater discharge emanating from spring vents that are fixed in space. As sea level rises, the freshwater portions of these systems will be compressed, and conditions will become less favorable for freshwater macrophytes and the faunal assemblages supported by these important structural habitats.

Recent research in the Chassahowitzka and Homosassa rivers indicates that native submersed aquatic vegetation (freshwater macrophytes in particular) provide important refuge and foraging habitat for myriad fishes and invertebrates. Losses of freshwater macrophytes have been shown to coincide with reductions in the overall biomass of freshwater fishes and loss of key species. Such changes are likely to have profound consequences for the ecological health and integrity of these and other coastal, spring-fed systems.

Peter Frederick
Bill Pine, Department of Wildlife Ecology and Conservation
University of Florida

We are beginning work documenting recent changes in oyster reef location and condition in the Big Bend region of Florida's Gulf Coast. As recently as the 1970s oyster reefs were healthy and supported a fishery that constituted up to 60% of Florida landings. Today, many of the major reefs are either gone or in extremely poor condition, despite the fact that many of the more common factors associated with oyster decline are absent (heavy fishing pressure, poor water quality, high wake zones, heavy recreational boating use etc.). This suggests that oyster decline may have been associated with changes in edaphic or physical factors, some of which may be influenced by climate change. Our research is designed to 1) document the current condition of the resource, 2) determine the important causes of decline, and 3) set up long term sampling sites that can serve as indicators of SLR and climate change effects. The first step is to document the current condition of reefs through high resolution aerial georeferenced photography, and to attempt to roughly infer condition of reefs and any geographic attributes associated with reef condition. We also have proposed measuring change both at the level of the reef (size, condition index) and individual oyster (growth, cause of mortality, incidence of disease, edaphic conditions) over time at specific sites. These sites will be set up as long term reference sampling sites. We believe that oysters are highly responsive to both SLR and to freshwater inputs, and therefore are sensitive indicators of climate change. Eventually we foresee experiments that may provide insight into the physical and conditions under which oysters may or may not be able to colonize new substrate as sea level increases.

Bill Gallagher
Planning Technical Leader, Jacksonville District
U.S. Army Corps of Engineers

As the "Planning Technical Lead" (PTL) responsible for putting together CERP Technical Report 1, I am responsible for working with the multi-Agency report development team to identifying the climate change challenges and opportunities that will impact CERP projects. The team will making sure the proposed work plans for model development and other studies are sound from a Planning perspective as we prepare for future CERP Climate Change Adaptation Studies. I work with others in Planning Division in the Jacksonville District to provide coordinated planning input regarding SLR for the CERP Guidance Memo (CGM) 16 update. CGM 16 provides Project Development Teams (PDTs) guidance for implementing the Corps SLR guidance in CERP projects. I serve as a mentor to other CERP and Jacksonville District planners learning how to plan for SLR. I am also the PTL for various studies where potential SLR must be addressed. All of the above leaves the Jacksonville District with many questions that need answers as we prepare for future climate change adaptation studies.

Climate change is likely to be the most significant challenge that CERP agencies must address. One of the major impacts of climate change is the rise in sea levels.

This study objective is to identify potential climate change related impacts on the Central and Southern Florida (C and SF) regional water management system and related Everglades Restoration efforts, primarily from sea level rise, and then identify future more detailed studies required to develop appropriate climate change adaptation strategies.

The CERP Technical Report – Preliminary Sea Level Rise (SLR) Impacts Assessment will be a reconnaissance level document to summarize available information and identify additional studies and model development efforts required to more accurately identify potential global climate change impacts on the Everglades Ecosystem and South Florida. A draft report is anticipated in spring 2010.

It is anticipated that studies will be recommended in 2010-2012 to identify climate change sensitivity information for natural and developed areas, plus develop local and regional models capable of addressing sea level rise and other climate change variables, and other tools as required for future evaluation of alternative global climate change adaptation strategies. A subsequent CERP Technical Report 2 is expected to document these efforts.

These efforts are necessary to address requirements in the Corps SLR guidance EC1165-2-211 dated 1 Jul 09, and Sep 08 recommendations by the NRC's Committee for Independent Scientific Review of Everglades Restoration Progress (CISRERP) for Everglades Restoration planners to consider and address a wide range of SLR scenarios.

Lisa Gardner
University of Florida

Influence of Sea Level Rise on Microbial Community Structure and Function in Wetlands –
Lisa M. Gardner, Ph.D. student, University of Florida. lisagardner@ufl.edu

As a second year doctoral student in the Soil and Water Science Department at the University of Florida, I am currently preparing a dissertation research proposal with a central theme of investigating the impacts of saltwater intrusion on carbon cycling in coastal wetlands. I am particularly interested in how saltwater impacts soil microbial community structure and function, and the subsequent effect these microbial changes have on organic mater stability and the production of CO_2 and CH_4 in coastal wetlands.

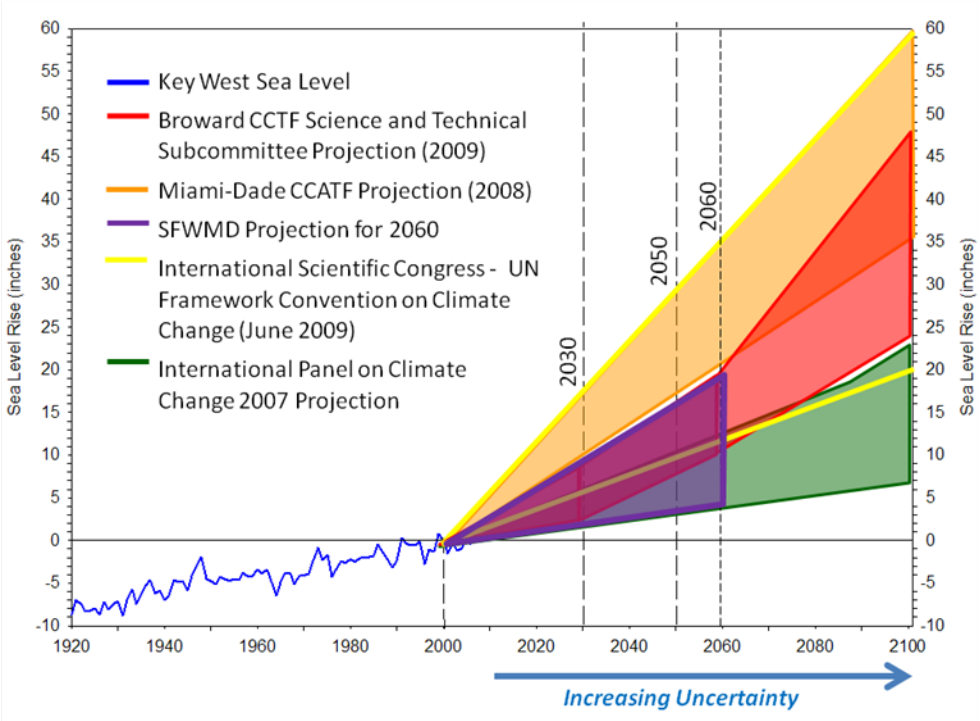
I am currently investigating two possible research sites in Florida, one in the coastal wetlands of the St. John's River estuary, and another at Shark River Slough and Taylor Slough in the coastal Everglades. Along these salinity gradients, I will quantify *in situ* decomposition rates and characterize the microbial community active in the decomposition process. I will also collect soil cores and perform laboratory manipulations to determine how events, such as decreasing freshwater inputs (water table draw-down) and saltwater intrusion, effect greenhouse gas production over time.

There is a serious lack of data and consensus on whether the landward migration of the saltwater/freshwater ecotone will enhance or inhibit the carbon sequestration potential of coastal wetlands and how the volume and ratio of CO_2 and CH_4 production may be altered. My research will address these questions from a biogeochemical perspective.

Nancy Gassman
Natural Resources Administrator
Natural Resources Planning and Management Division
Broward County Environmental Protection and Growth Management Department

As the technical liaison to the Broward County Climate Change Task Force (CCTF), I have been involved with investigating several aspects of sea level rise (SLR). I have worked with the CCTF Science and Technical Subcommittee to review the current SLR literature and to develop recommendations on SLR ranges to use for planning purposes. I have worked with the Broward County GIS group to develop local SLR vulnerability scenarios and analyses. I spoke at the Southeast Florida Regional Climate Leadership Summit in October 2009 on potential regional climate impacts including SLR. I recently attended the January 2010 conference held at the University of Miami entitled "Predicting The Climate Of The Coming Decades". I was a participant at the EPA Southeast Adaptation Planning Workshop held February 2-3, 2010 in Atlanta discussing challenges and solutions to addressing SLR adaptation.

The graphic below shows the variability in SLR projections currently in use or proposed for the Southeast Florida region.



Courtney Hackney
University of North Florida

Collaborators: Jennifer Culbertson, Martin Posey, Lynn Leonard, Brooks Avery, and Troy Alphin

Sea Level Rise and Response of Wetlands in the Cape Fear River, NC Watershed

Water levels, salinity, biogeochemical indicators in soils, salt-sensitive vascular plants, benthic invertebrates, and epifauna have been monitored at 11 marsh/swamp stations along the freshwater-saltwater boundary in the Cape Fear and Northeast Cape Fear Rivers, North Carolina since 1999. Historically, the tidal range upstream of the river mouth was significantly less than the tidal range in the ocean, but channel modifications during the 20th Century increased tides upstream about 35 cm, essentially to that of the ocean. Thus, tidal swamps in the Cape Fear Basin experienced a significant change in hydrology and saline water mimicking a potential sea level rise far in excess of actual sea level rise. A post-impact examination of wetland communications on both sides of the freshwater-saltwater boundary provides an ideal view of the change that will occur with sea level rise. The ongoing study of ecological processes commensurate with this rapid rise in water level is providing excellent insight into changes that can be expected in tidal swamps throughout the Southeastern U.S. with accelerated sea level rise.

Besides developing an understanding of the incremental changes expected with sea level rise, two historic droughts and one very wet year have provided an understanding of the importance of episodic events on the overall rate of change. These data also suggest potential engineering solutions that may be useful for the management of tidal wetlands under a scenario of accelerated sea level rise. The modified Palmer Drought Index indicated a drought from 2001- 2002 and the second from 2007-2008. Tidal amplitude was reduced upstream during droughts, while saline water moved farther upstream; 70 km in the Northeast Cape Fear River. Saltwater did not penetrate as far upstream (56 km) in the Piedmont based Cape Fear River because of a prescribed freshwater release from upstream dams. Saline water (as high as 8 SI) flooded swamps and marshes usually inundated by freshwater. During droughts, saline water regularly flooded the entire freshwater swamp except for areas immediately adjacent to the upland edge where seepage maintained fresh conditions. Sulfate associated with saline water penetrated into swamp soils and converted methanogenic soil systems into sulfate reducing systems. Permanent plots of salt-sensitive vascular plants were reduced in aerial extent or eliminated in the 2001-2002 and 2007-08 droughts, but recovered when droughts ended. Shifts in the Infaunal Communities along wetland edges also occurred, with species level recovery taking multiple years after the 2001-2002 drought. Epibenthic communities, primarily juvenile fish and crustaceans, responded quickly to change by modifying their relative location in the estuary. These patterns directly impact the nursery function of fringing marshes in estuaries.

Research funded by the U.S. Army Corps of Engineers, Wilmington District

Peter Harlem
Southeast Environmental Research Center
Florida International University

I am the current Co-Chair of the Science Committee of the Miami-Dade Climate Change Advisory Task Force (CCATF) and have been active at meetings discussing the scientific aspects of climate change in this county since 2007. I was appointed by the committee as special advisor to Miami-Dade DERM on methods to be used to make sea level rise (SLR) scenario maps because my research efforts related to SLR in Florida are focused on using LiDAR elevation data to better visualize SLR scenarios at different elevations. This principally revolves around the use of ArcGIS for the production of map images but also includes using Google Earth Pro to make visualizations which are user friendly to a wider audience and easier to share. To date I have constructed SLR scenario maps for the eastern 2/3rds of Miami Dade and Broward Counties and all of the City of Satellite Beach, Florida.

Some of the SLR activities I have participated in the past include but are not limited to:

- Discovery with Harold Wanless of the upward "movement" of attached organisms on the Coral Gables Waterway bridge supports in response to increasing sea level from the mid 1950s to mid 1970s of approximately 15 cm.
- A presentation of Miami-Dade SLR scenario maps at the Jan 2008 GEER Conference (Harlem and Meeder, 2008).
- Presentation of SLR scenario maps to the Broward County climate change task force in mid-2009.
- Presentation on SLR issues to the Space Coast Climate Change program in early 2009.
- Creation and delivery to the contractor for the EPA sponsored Climate Ready Estuaries grant to map the SLR scenarios for the City of Satellite Beach Florida. This project is ongoing.
- Assisted with the writing of the NSF sponsored Ultra-Ex proposal entitled "Double Exposures: Socio-ecological Vulnerabilities in the Miami-Dade Urban Region" which has received funding.
- Determined how to use LiDAR to find large scale karst landforms which will be important indicators of seawater flow paths inland during future SLR.

Barry Heimlich, Research Affiliate
Florida Center for Environmental Studies
Florida Atlantic University

As a Senior Fellow at the Center for Urban and Environmental Studies since October 2007, my research has related to climate change, sea level rise, impacts on Florida, and climate change adaptation policy and planning. Major projects to date are as follows:

- *Florida's Resilient Coasts – A Policy Framework for Adaptation to Climate Change*, Murley, Heimlich & Bollman, 2008. http://www.ces.fau.edu/files/projects/climate_change/Fl_ResilientCoast.pdf
    - Science of climate change summarized in language intended for non-scientific policymakers, including observations, causes, and potential impacts to coastal Florida.
    - Policy guidelines regarding: adaptation science and research, land use planning, water resource management, transportation and other infrastructure, conservation of natural lands and marine systems, beach management, and emergency preparedness, insurance, economic, social and health impacts, and governance.

  This study became the foundation document for adaptation recommendations to the Governors' Action Team on Energy and Climate Change.

Southeast Florida's Resilient Water Resources- Adaptation to Sea Level Rise and Other Impacts of Climate Change, Heimlich, Bloetscher, Meeroff & Murley, 2009.
http://www.ces.fau.edu/files/projects/climate_change/SE_Florida_Resilient_Water_Resources.pdf

- Sea level rise – developed a mathematical method for predicting timeframes and sea level during the 21st Century using an acceleration model.
- Effects of sea level rise on freshwater supplies and stormwater drainage including saltwater intrusion and flooding during major rainfall events.
- Synergistic effects of sea level rise, hurricanes, elevated temperatures, and other climate change impacts in combination on water supply, wastewater treatment and reuse, and stormwater drainage.
- Solutions for protecting water resources including water conservation, alternative water sources, wastewater recovery and reuse alternatives, regionalization, Everglades recharge, and reengineering canals, control structures, and pumping.
- Case Study of Pompano Beach Water Utility – vulnerabilities and recommendations for improving resilience to climate change.
- A framework for adaptive planning and management, including major issues, uncertainties, strategic alternatives, and policy recommendations.

This study is a foundation document for water resource adaptation planning for Southeast Florida.

Other relevant climate change and water resource activities:
Member of the Broward County Climate Change Task Force and its science and technology, built environment adaptation, and greenhouse gas reduction subcommittees. Member of the science and technology, built environment adaptation, and greenhouse gas reduction committees of the Miami-Dade County Climate Change Advisory Task Force. Member of the Technical Advisory Committee to Broward County Water Advisory Board.

Paul Kirshen
Research Leader, Climate Change Impacts and Adaptation Analysis
Battelle Memorial Institute

I joined Battelle in June 2009 after 13 years at Tufts University as co-founder and Director of the Tufts University Water: Systems, Science, and Society (WSSS) Interdisciplinary Research and Graduate Education Program and Research Professor in Civil and Environmental Engineering. My recent research related to sea level rise (SLR) and climate change has focused on the impacts of increased coastal flooding on the built environment; adaptation strategies based upon scenario-based risk assessment and multi-criteria benefit-cost analysis; the co-benefits of the integration of adaptation planning for the built and natural environments; the interaction of climate change, freshwater management, and SLR; and the use of stakeholder participatory processes in adaptation planning. Some relevant experience of others at Battelle include downscaling of GCMs, surge modeling, and coastal environmental impacts of SLR and adaptation strategies.

Some of my current and recent research includes:

Scenario-Based Risk Assessment for Adaptation of Coastal Municipalities to Climate Change in New England for the New England Environmental Finance Center, Portland ME and US EPA. A decision support process using a scenario-based risk assessment framework is being piloted with two towns to help communities make informed decisions about adapting to increased storm and tidal flooding during the next century. The decision framework relies upon evaluation of economic and environmental impacts to help plan for the present as well as the future. Co-PI. Ongoing.

Coastal Flooding and Environmental Justice: Developing Strategies for Adapting to Climate Change for US NOAA with the University of Massachusetts-Boston. . This participatory research project is on possible impacts of climate change on urban and rural coastal populations that are already suffering from environmental injustices and thus are particularly vulnerable because of limited adaptation options. Viable adaptation options also being explored. Co-PI. Ongoing.

Guidance Tools for Planning and Management of Urban Drainage Systems under a Changing Climate for US NOAA with University of Colorado. Developing process for drainage planning using a pilot projects and stakeholders in MA and CO. One community is coastal. PI. Ongoing.

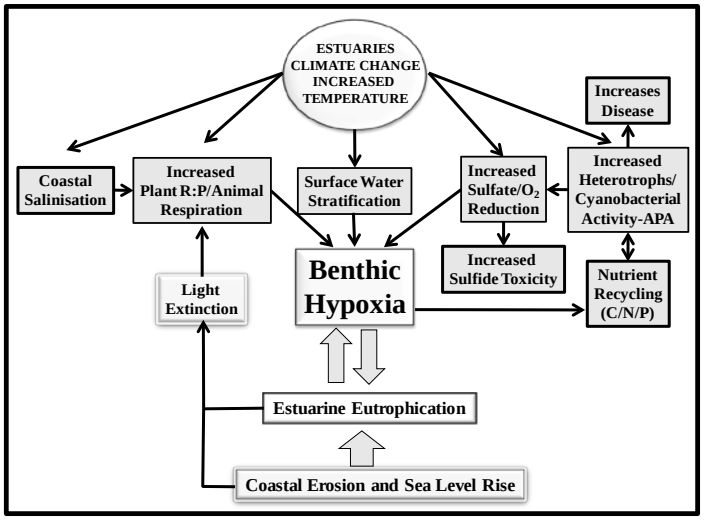
Impacts of Coastal Flooding in the Northeastern US for the Union of Concerned Scientists with UMass-Boston. Determined and mapped new floodplains for different recurrence intervals and SLR scenarios for coastal areas in the NE USA. PI. 2005-2007.

Infrastructure Systems, Services and Climate Change: Integrated Impacts and Response Strategies for the Boston Metropolitan Area for US Environmental Protection Agency ORD with University of Maryland, Boston University and others. This large project was one of the first to undertake an integrated assessment of climate change impacts on urban infrastructure systems including water supply, water quality, coastal and river flooding, transportation, health, and energy demand. PI. 1999-2003.

Marguerite Koch-Rose
Aquatic Plant Ecology Laboratory, Biological Sciences Department
Florida Atlantic University

Climate Change and Sea Level Rise Multiple Stressor Effects on Estuarine Ecosystems

Shallow tropical marine ecosystems, such as Florida Bay and the Florida Reef Tract, experience temperature and salinity extremes at the upper tolerance levels of their respective foundation species, seagrass, algae and corals. While temperature effects on corals have been a focus of marine research, thermal tolerance of macroalgae and seagrass-based ecosystems are only now being examined at the same level. Temperature effects on these species are complex, as temperature affects both plant physiology and ecosystem-level processes in shallow semi-enclosed systems like Florida Bay. Based on experimental and field studies, temperature extremes are primarily affecting bay seagrass community stability indirectly through O_2 demand, although the dominant species (*Thalassia testudinum*) is experiencing temperatures close to its thermal limits (36 ^oC). Carbonate sediments, which store the majority of nutrients in Florida Bay, may also be influenced by a lowering of seawater pH via carbonate dissolution. However, it is more likely that increasing temperature will stimulate microbial activity and sulfate reduction rates, and lead to enhanced carbonate sediment dissolution and P flux from the sediments. In addition to biogeochemical considerations, reproduction may also be influenced by high temperature and salinity through reduced energy reserves. Sea level rise will exacerbate benthic community stress from temperature extremes and acidification. Coastal erosion will reduce light levels and increase nutrients that stimulate phytoplankton blooms. Under this scenario, light extinction will increase, thereby reducing the photosynthetic to respiratory ratio in benthic plants. A conceptual model is presented below that articulates the complex changes that may occur in estuaries under various scenarios of climate change and sea level rise. A clear focus for estuarine climate change research should be on understanding thresholds of benthic community stress at the extremes, particularly in tropical systems, along with chronic stress, and how processes in the water column and sediments that shift with a changing climate and sea level rise may synergistically affect the stability and resilience of estuarine ecosystems.



Julie Lambert, Associate Professor
Florida Atlantic University

Promoting Climate Literacy for Future Teachers

Climate change has become an important global issue, and it is critical that teachers have an understanding of the fundamental science, the natural and human-induced factors affecting climate, and the potential consequences and solutions. However, research findings indicate that the greenhouse effect and the theory of global warming, fundamental to understanding climate change, are complex phenomena that students continue to express alternative conceptions even after instruction (Mason & Santi, 1998; Rye, Rubba, & Wiesenmayer, 1997). Common trends in the findings from several studies include elementary and secondary students confusing the greenhouse effect with ozone depletion or causally attributing the former to the latter, explaining the greenhouse effect on Earth as an environmental problem and not a natural phenomenon, attributing the greenhouse effect to specific gases over others, or describing consequences (e.g. increase in Earth's mean temperature and sea level rise) of the greenhouse effect (Koulaidis and Christidou, 1998, p. 560-561). Consequently, my research has focused on identifying preservice teachers' pre- and post- knowledge and ideas about climate change before and after instruction that has been embedded in my elementary science methods courses.

To conduct this research, I first developed two instruments (i.e., a science content assessment consisting of 25 multiple-choice and 10 extended-response items, and a Likert-scale survey of students' ideas toward science, the nature of science, and climate change). Second, I developed several instructional lessons to incorporate in my methods courses. Science methods courses typically focus on preparing teachers to effectively teach science; however, I have found that embedding an interdisciplinary theme, such as climate change, provides an opportunity to model inquiry-based science instruction while also reviewing fundamental science concepts from the earth, life and physical sciences. Feedback from my elementary methods students has been very positive, and I have continued to revise the instructional materials for publication.

The instructional materials that I developed include a 24-page written guide for understanding science and climate change and several inquiry-based science lessons on the carbon cycle, photosynthesis and respiration, the greenhouse effect, heat transfer and ocean currents, the cause of the seasons, fossil fuels and the rock cycle, the water cycle, etc. In addition to participating in class lessons, the students have an assignment to 1) View and review the science in the movie, "An Inconvenient Truth," 2) respond to questions designed to guide them in their understanding of climate change, 3) review several Internet resources, 4) construct a concept map to demonstrate their understanding of climate change, and
5) participate in a focus group interview at the end of the course.

Preliminary Findings
I have conducted a pilot study with two undergraduate and one graduate level science methods classes and am in the process of analyzing data from a larger sample of a few hundred students enrolled in elementary science methods courses at Florida Atlantic University (FAU). A comparison of pretest and posttest scores showed that both undergraduate and graduate students did increase their overall mean scores of content knowledge. Students made the most improvement on the items related to the cause of climate change and the least improvement on the items related the greenhouse effect and the carbon cycle. An analysis of students' responses also revealed misconceptions. For example, on the posttest, students seemed to correct their misconception of the cause being related to the ozone layer, but developed a new misconception that greenhouse gases are trapped by infrared radiation.

Students' ideas toward science, the nature of science, and global climate change were positive or more closely aligned to scientific ideas on the post Likert-scale survey. The greatest increase was for the items addressing interest and confidence in science, followed by attitudes toward global climate change, and views on the nature of science.

Given the short span of the intervention, the prospective and practicing teachers were able to learn a limited number of specific concepts related to global climate change and to develop attitudes more aligned with the current scientific research.

Gary Lytton
Director
Rookery Bay National Estuarine Research Reserve
Office of Coastal and Aquatic Managed Areas
Florida Department of Environmental Protection

Sea Level Rise Research, Training and Education at Rookery Bay National Estuarine Research Reserve Naples, Florida

The Rookery Bay National Estuarine Research Reserve (RBNERR) is an 110,000-acre sanctuary located on the Southwest Gulf coast of Florida. RBNERR is managed by the Florida Department of Environmental Protection (FDEP) in cooperation with the National Oceanic and Atmospheric Administration (NOAA) as one of 27 sites in the National Estuarine Research Reserve System (NERRS). The mission of the NERRS is to provide a basis for informed coastal decisions by local communities through science and education.

The NERRS has established a national strategic plan on climate change that identifies current and future capabilities and actions to address issues related to sea level rise. A network of sentinel research sites is envisioned, with the capacity to track changes in estuarine conditions related to sea level rise, while working in collaboration with local communities to engage policy-makers and an informed citizenry in developing effective adaptive measures. The Florida's three NERR sites (i.e. Rookery Bay, Apalachicola, and Guana-Tolamata-Matanzas) are focusing science and education resources within their respective coastal regions to engage on the issue.

At RBNERR, research staff are working collaboratively with four NERRS sites in the Gulf of Mexico to establish geo-referenced Surface Elevation Tables (SETs) linked to vertical tidal gauges and correlated with baseline monitoring programs (e.g. water quality) already in place. The network will enable sites to monitor relative changes in sea level rise over time, and correlate with possible changes in estuarine ecosystems. In addition, RBNERR is using high resolution imagery to develop detailed intertidal and emergent wetlands habitat maps that establish baseline conditions. Future efforts may include digital elevation maps linked to the National Spatial Reference System.

RBNERR is engaged in targeted education and training efforts designed to increase local community awareness of climate change and sea level rise, and to help assess vulnerability of coastal communities in Southwest Florida. RBNERR's new Environmental Learning Center has recently opened a new interactive exhibit on climate change, and has worked with local partners to host a series of informational workshops for community leaders designed to open a dialogue on land use and adaptive management. Examples of planned actions include partnering with NOAA to develop high resolution modeling of projected sea level rise on local communities in combination with adaptive measures.

Maria Idia Macfarlane
Miami Dade Water and Sewer Department

Miami-Dade Water and Sewer Department (WASD) has partnered with the USGS to complete an integrated suite of major water resource research projects for Miami-Dade County, in order to optimize resource management while providing environmental protection. These projects include complete reassessment of the salt water intrusion front in Miami-Dade County, and development of an integrated surface/ground water variable density flow numerical model for the county.

The main objectives of the salt water intrusion project are to delineate the present location of the salt water front using the existing salt water encroachment monitoring network (completed), determine and construct additional new monitoring sites in data gap areas, complete time-domain electromagnetic soundings, construct a framework for understanding the changes in salinity by improving the hydrostratigraphic characterization of the county using borehole geophysical methods and lithologic evaluations, and to provide accessibility to salt water encroachment information through enhancements to the USGS cooperative water conditions website.

The USGS Fort Lauderdale office is developing a Biscayne aquifer model coupled with a hydrodynamic surface water model of Biscayne Bay and coastal wetlands. This coupled model uses 500-meter cell resolution and is the successor to a previous SEAWAT model that was used to quantify rates of submarine groundwater discharge to Biscayne Bay done by the USGS previously. The USGS is developing a canal routing feature that will integrate surface/ground flows in the model. The model will be calibrated to a multi-year period to ensure accurate representation of surface and groundwater flows and the exchange between surface water and groundwater. Following calibration, the model will be used to evaluate several scenarios of interest to the county, including climate change and sea level rise. As part of the model project, a graphical software package is being developed that will allow users to build model input data sets and visualize model results. This will consist of a robust flexible and intuitive environment where users can design sea level rise and climate scenarios, perform simulations, and design and compare performance measures.

Additionally, groundwater quality monitoring throughout the entire County is being conducted by Miami Dade Department of Environmental Research Management (DERM) for decades and I was overseeing the program for five years while working at DERM, currently I am overseeing the groundwater quality at Miami Dade WASD. The water quality long period of record serves as a baseline that will allow us to evaluate and analyze the impact of climate change to our water supply (long and short term) and monitor any trend in the water quality due to climate change and sea level rise.

Frank Mazzotti, University of Florida
Stephanie Romañach, U.S. Geological Survey

PIs: Laura A. Brandt (USFWS), Stephanie S. Romañach (USGS), Leonard G. Pearlstine (USNPS), Don DeAngeles (USGS), Ikuko Fujisaki (University of Florida), Frank J. Mazzotti (University of Florida)

Climate Envelope Modeling for Evaluating Anticipated Effects of Climate Change on Threatened and Endangered Species in South Florida

Our study focuses on developing climate envelope models for the 21 threatened and endangered (T&E) terrestrial vertebrates in South Florida. The tools we will develop will allow resource managers to examine potential effects of climate change on species' geographic ranges for ecosystem and landscape planning. We will work to close the gap between managers and scientists who produce data necessary for making key decisions in the face of climate change. Locally, resource managers within South Florida (including NPS, FWS, and the South Florida Water Management District) have indicated the need to run predictive models and view model outputs, and for spatially-explicit visualization for comparing alternatives.

In our effort to develop appropriate models for resource managers' needs, we will use the best and most up-to-date information and methods available. For each of the T&E species under consideration, we will develop bioclimatic models, also called 'climate envelope' models. These models allow us to relate species' geographic distributions to climate factors. Predicted future climate variables are used to predict future species distributions. Bioclimatic models are widely used because they can effectively predict climate-induced range shifts for large numbers of species and provide a first step that can address issues and needs at different spatial and temporal scales.

We will work toward finding solutions to problems of long-term conservation planning in the face of the uncertainty surrounding climate change. We will work with resource managers to develop tools at appropriate spatial and temporal scales to assist with decision making. This project will result in both predictive ecological models and methodology for development and use of climate-based species-habitat relationships that will aid resource managers in long-term planning for sustainability of species.

We will begin by focusing on the 21 threatened and endangered (T&E) terrestrial vertebrates in South Florida and consider the broad extent of their geographic ranges (including Central and South America). By virtue of its physical features and geography, Florida, and in particular, South Florida will be highly susceptible to climate changes, specifically with regard to already apparent sea level rise. Our initial focus is to work with partners in the southeastern region and expand the list of species of interest in that region; however, our methodology and developed products will be applicable to other species and regions.

Maia McGuire
Florida Sea Grant Extension Program
University of Florida

Climate change-related research

My assignment at UF is 100% outreach, so I do not have a research program. However, I chair a working group which focuses on coastal aspects of climate change (part of UF's Climate Variability and Change Focus Team.) I am also chair of a climate change committee for the Sea Grant Education Network, and serve as liaison between the education network and the Sea Grant Climate Change Network.

The goals of these groups are:

1. To provide UF Extension faculty with resources that they can use to educate clientele about climate change (focusing on ocean-related impacts such as sea level rise, saltwater intrusion, ocean acidification and coastal erosion.)
2. To utilize social marketing to identify barriers preventing people from accepting climate change and/or from taking action to mitigate for climate change.
    a. To design climate change outreach materials that address these barriers.
3. To develop training materials (starting with sea level rise) for elected/appointed officials to help them in making planning decisions etc.
4. To develop web-based curriculum resources for educators (particularly K-12 teachers)—these will include webinars and demonstrations of hands-on classroom activities (online and at science teacher conferences around the nation.)

Over the past year, the groups have been gathering existing summary reports (about climate change and attitudes towards climate change) and scientific research papers (e.g. on ocean acidification) and attending climate change meetings when possible to try and identify existing resources, as well as gaps/needs. We are also trying to identify subject matter experts who can be called on when developing fact sheets, webinars etc.

Peter Merritt
Treasure Coast Regional Planning Council

As part of an ongoing program evaluating global climate change, the U.S. Environmental Protection Agency (EPA) initiated a nationwide project promoting planning for and awareness of sea level rise. In 2000, the EPA issued a grant to the Southwest Florida Regional Planning Council to participate in this program and coordinate the study of sea level rise by regional planning councils throughout the State of Florida. In 2002, the Treasure Coast Regional Planning Council participated by conducting a study of sea level rise within the Treasure Coast Region, which includes Indian River, St. Lucie, Martin, and Palm Beach counties. The study followed the general approach of other sea level rise planning studies sponsored by the EPA. Decision rules defined by a statewide approach for identifying likelihood of land use protection were used to characterize all uplands from 0 to 10 feet in elevation and within 1000 feet of shoreline into the following four general categories: protection almost certain; protection reasonably likely; protection unlikely; and no protection. Colors were assigned to these categories to distinguish the protection scenarios on draft sea level rise maps prepared for each county. The draft maps were refined based on comments provided by local government planners.

Application of the state-wide approach for assessing the likelihood of land use protection in the Treasure Coast Region resulted in the identification of 119,157 acres (83.3%) of uplands and 23,927 acres (16.7%) of wetlands in the study area. Regionally, the “Protection Almost Certain” category accounted for 77.0% of the uplands in the study area. This was followed by “Protection Reasonably Likely” (6.7%), “Protection Unlikely” (10.7%), and “No Protection” (5.6%). A clear regional trend exists, reflecting an increase in the number of acres in the “Protection Almost Certain” category when moving north to south from Indian River County to Palm Beach County. Indian River County has less land likely or almost certain to be protected than any other county along Florida’s Atlantic Coast. In contrast, Palm Beach County is almost entirely developed along its Atlantic Coast and shore protection is likely or certain for 97% of the lands within a few meters above sea level. A total of 34 municipalities in the four counties of the Treasure Coast Region are likely to be impacted by sea level rise in the future. The final report, *Sea level rise in the Treasure Coast Region* (TCRPC 2005), is available at www.tcrpc.org.

Recently, the findings of the sea level rise studies prepared by regional planning councils in Florida were combined with the findings of similar studies sponsored by EPA in other states along the Atlantic coast to assess the extent to which coastal wetlands might migrate inland or be lost as sea level rises (Titus J. G. et al. 2009. *State and local governments plan for development of most land vulnerable to rising sea level along the US Atlantic coast.* Environ. Res. Lett. 4: 044008). Ecosystems could survive by migrating inland if adjacent lands remained vacant. On the basis of 131 state and local land use plans, it was estimated that almost 60% of the land below 1 meter along the U.S. Atlantic coast is expected to be developed and thus unavailable for the inland migration of wetlands. Less than 10% of the land below 1 meter has been set aside for conservation. Environmental regulators routinely grant permits for shore protection structures on the basis of a federal finding that these structures have no cumulative environmental impact. However, it is likely these structures will block wetland migration. The results of this report suggest that shore protection does have a cumulative impact. If sea level rise is taken into account, wetland policies that previously seemed to comply with federal law probably violate the Clean Water Act.

Diana Mitsova-Boneva
Assistant Professor
School of Urban and Regional Planning
Florida Atlantic University

Human Dimensions of Sea-Level Rise: A Dasymetric Demographic Analysis of South Florida

This research examines the potential of dasymetric population analysis techniques for disaggregating census data and developing better understanding of the demographics of sea-level rise. Cartographically, the U.S. census population data is represented as choropleth maps where demographic and socio-economic variables are aggregated into geographic areal units which include counties, census tracts, census blocks, block groups, etc. (Sleeter 2008). Aggregating demographic data is, however, "associated with analytical and cartographic problems due to the arbitrary nature of areal unit partitioning" (Sim 2008, Mennis 2003). Choropleth mapping by administrative areal unit creates the impression that "population is distributed homogeneously throughout each areal unit, even when proportions of the region are, in reality, uninhabited" (Dorling 2003, Sleeter 2008). This incongruity may become especially problematic in areas where residential land uses are relatively small portion of the administratively defined areal unit because large waterbodies, airports, commercial areas, and other non-residential uses may be present. In contrast to choropleth mapping where the boundaries of cartographic representation are arbitrarily defined, dasymetric mapping reflects the spatial distribution of the variable being mapped using a control variable (Eicher et al, 2001). In the case of dasymetric population analysis, the control variable is the underlying land use/ land cover class.

The main objective of this research is to generate more accurate spatial representation of demographic data using dasymetric analysis techniques with object-oriented classification of land cover / land use in urbanized areas of South Florida. We use high-resolution LiDAR data obtained for the International Hurricane Center at the Florida International University and 2008 demographic data from PCensus Demographic Analyzer. Land use/land cover information is extracted from remotely sensed data to obtain an improved estimation of where people actually live (Liu 2004, Sim 2003). Areal interpolation techniques are then used to disaggregate census population data into spatial units within homogenous land use/ land cover classes (Mennis, 2003).

The results of the dasymetric population analysis are particularly useful for examining the impacts of sea-level rise on highly developed areas. High-resolution (5-foot) digital elevation data generated from airborne LiDAR (Light Detection and Ranging) system is currently available to develop scenarios of sea-level rise. Overlaying high-resolution elevation data with choropleth mapping of demographic data may produce biased representation of the spatial distribution of the population affected by various increments of sea-level rise as enumeration boundaries are not consistent with the data they convey and existing physiographic entities (e.g. lakes, forests, etc.) are ignored (Bielecka 2005). Overlaying SLR inundation scenarios with disaggregated demographic data consistent with the most up-to-date land cover/ land use information provides useful information for vulnerability assessment of the areas impacted by SLR.

Reed Noss
University of Central Florida

Activities Related to Sea Level Rise in Florida

My interests related to this topic are focused on developing and communicating options for adaptation to sea level rise in Florida. Toward this end, I am leading a project to synthesize available scientific knowledge on the ecological impacts of sea level rise in Florida and to review adaptation options. I have organized a scientific symposium on this topic, to be held January 18-20, 2010, at Archbold Biological Station. The symposium is sponsored by the Florida Institute for Conservation Science, with several co-sponsors. Planned future phases of the project include a larger conference to discuss specific policy and management options for Florida.

A primary concern that has prompted our project is that many policy makers and members of the public appear to be in denial about sea level rise in Florida, and that denial could quickly turn to panic as impacts become increasingly obvious. Short-term engineering responses, such as construction of seawalls and dikes to protect coastal properties, are not economically or ecologically sustainable and are likely to fail because of the rapidity of sea level rise, the porosity of our bedrock, and other factors. Such responses also will reduce the probability that species and ecosystems can "migrate" inland as the sea rises. Moreover, unplanned movement of large numbers of people away from our coasts will put critical inland habitats of high conservation priority at increasing risk. We are suggesting that responses to protect humans and their property from sea level rise should be coordinated with responses to protect nature.

Although Florida faces extreme challenges from sea level rise, we are also well-positioned to plan for and mitigate against these threats. Florida is one of few states with a comprehensive planning mandate and we have produced many landmark planning and conservation innovations. In addition, Florida has one of the strongest and best-funded state planning and emergency management systems, in part because we have had to deal with coastal flooding problems generated by hurricanes. The challenge is to act quickly to maintain coast-to-inland habitat connectivity, to protect critical upland habitats before they are developed, and, more broadly, to coordinate urban and regional planning with conservation planning. Among the questions to be addressed in our project are:

- What level of uncertainty accompanies the models, predictions, and empirical measurements upon which estimates of sea level rise in Florida are based?
- What natural communities and species are at greatest risk of extinction or extirpation in Florida due to sea level rise and other climatic phenomena in Florida by the year 2100?
- What specific kinds of studies are needed to reduce uncertainty, improve estimates of risk, and develop adaptation strategies with a high probability of success?
- What studies, and by which researchers, are currently being done on these issues in Florida (or encompassing Florida) or have been proposed?
- What kinds of collaborations are needed to forge a true interdisciplinary approach to adaptation to climate change, which involves climatologists, geologists, biologists, social scientists, engineers, economists, planners, and others?
- What are the highest immediate priorities for changes in land-use policy and planning, urban planning, conservation, restoration (e.g., CERP), and land management that will minimize losses of biodiversity and facilitate adaptation to sea level rise?

Jayantha Obeysekera
South Florida Water Management District

SFWMD recently completed a white paper on the subject of climate change and sea level rise to address a multitude of dimensions associated with climate change and the potential vulnerabilities to the water resources management in the region. It is recognized that some of the local governments in South Florida are very active in addressing the local climate change issues and others are beginning to organize themselves to initiate internal and external coordination efforts to deal with a variety of climate change impacts including those beyond the arena of water resources. SFWMD will focus on regional water resources issues and coordinate with federal, state, and local agencies as well as academic institutions interested in participating in the efforts to assess vulnerabilities and develop adaptation strategies. Through the review of latest literature on the subject of climate change, SFWMD staff have concluded that, (a) there are significant uncertainties in climate change and sea level rise projections; (b) reliable regional information on projections are sparse; (c) sea level rise is likely the most urgent aspect of climate change that the District should focus on, although research on other drivers such as temperature, rainfall and tropical storms/hurricanes should be monitored; (d) there is a need to agree on a common set of planning parameters for climate change and sea level rise; and (e) develop and implement regional, short-term adaptation strategies in our mission elements.

SFWMD has established an interdisciplinary, multi-departmental group within the agency to monitor the latest science and address both the short- and long-term water resources issues associated with Climate Change and Sea Level Rise. District's Governing Board and the Water Resources Advisory Commission (WRAC) have been briefed on the white paper on climate change and sea level rise and efforts are underway to develop strategies for determining short-term adaptation strategies and coordinate agency's regional activities with federal, state, and local governments.

Todd Osborne
Research Assistant Professor
University of Florida

Reddy, Osborne, Inglett, Clark, Ogram, Nair, Ellis

The Wetland Biogeochemistry Laboratory (WBL), a unit within the Soil and Water Science Department at the University of Florida, has interest in several aspects of sea level rise and global climate change. Within the broad topic of sea level rise, the WBL has several pilot projects investigating the effects of sea level rise on coastal freshwater wetlands, specifically carbon storage in the organic soils found in these environments. Carbon dynamics at the interface of freshwater and saline environments have significance globally, as well as, here in Florida. A good example of such an environment that is currently changing due to sea level rise is the freshwater terminus of the Everglades into Florida Bay. In this local, and others like it, decomposition is altered with the changes to water chemistry, the addition of a prominent alternate electron acceptor (sulfate), and the alteration of the microbial communities present.

We are also currently investigating the fate of soil carbon stores in Spodosols, a carbon rich soil common to the coastal regions of the Eastern US. These soils have been observed to change with sea level rise and associated coastal forest retreat. Our study site, at the Sapelo Island National Estuarine Research Reserve, offers a unique opportunity to investigate the temporal aspects of these changes along with the specific biogeochemical pathways. It also presents the opportunity to look at subaqueous soil genesis, a topic rapidly gaining interest in the academic and management communities.

Finally, we are also very interested in the transition of freshwater wetland soils, and terrestrial soils alike, to marine subaqueous soils. This is a priority as recent research has linked several key physical and chemical characteristics of marine subaqueous soils to the likelihood of supporting seagrass habitat, shellfish aquaculture, and other valuable ecological services (such as carbon storage). We are currently working in Key Largo, Indian River Lagoon, and Cedar Key, FL, to investigate these relationships.

If you would like more information about these or other ongoing research projects at the Wetland Biogeochemistry Laboratory, please contact:

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Doug Parsons
Florida Fish and Wildlife Conservation Commission

General FWC approach to climate change/ FWC Actions from our Climate summit:

- Change from a static to a dynamic view of climate when making fish and wildlife management decisions.
- Step predictive models down to a Florida or regional scale.
- Develop the integrated data and appropriate monitoring needed for the FWC to adaptively manage climate impacts.
- Build broad support and action through continuous education and two-way outreach.
- Manage the landscape for wildlife resiliency, which means involving the FWC in land-use planning.
- Protect the connected landscapes that will allow wildlife to move freely as the climate changes their habitat.
- Build on strategic and funding opportunities.
- Improve the collection, analysis and distribution of data to better understand the ecological impacts of climate change and reduce some of the uncertainties.
- Assess whether current management, regulatory and planning frameworks are sufficiently adaptive to address the impacts of climate change.
- Examine potential implications of climate change effects on endangered species.
- Help public officials value addressing long-term issues.
- Revisit acquisition and restoration priorities.
- Coordinate with other agencies and establish an inclusive management outlook.
- Facilitate interagency coordination.
- Support research and monitoring (including vulnerability assessments) that will inform policy and management decisions.
- Coordinate with and educate stakeholders and the public.
- Reduce environmental stressors to increase ecosystem resiliency.
- Integrate climate-change issues into existing state activities, including the FWC's Wildlife Action Plan and Cooperative Conservation Blueprint (CCB) and the underlying Critical Lands and Waters Identification Project (CLIP) data layers. For example, consider how best to prioritize the protection of upland areas in relation to coastal lands that will likely be inundated with sea level rise and more intense storm surges.
- Encourage the Florida Acquisition and Restoration Council to strategically use state based land management funds to protect the habitat that will allow marine life to adapt to climate change.
- Consider the use of Marine-Protection Areas to help protect functioning natural systems.
- Develop economic incentives to encourage informed decisions and management practices and policies.
- Develop a comprehensive and adaptive planning, management and regulatory framework that includes climate change projections to reduce the negative impacts of climate change.

Additional actions:

- Executive Director created Climate change Steering committee to provide strategic leadership for climate change work within the agency.
- Five climate change work groups established made up of employees throughout the agency: 1)adaptation, 2) research and monitoring, 3) communication and outreach, 4) policy and opportunity, and 5) Operations (focusing on carbon footprint of agency)
- Florida Wildlife Legacy Initiative (state wildlife action plan) has made climate change a priority goal, meaning projects can be submitted for funding that focus on climate change impacts. This is one of the first SWAP programs in the nation to do this.
- Speaking at various conferences throughout Florida and nationally.
- Provided input in the development of USGS Climate Change Wildlife Research Hubs.
- Participating in a federal effort at developing a National Wildlife Adaptation Strategy (one of just a few states invited to participate).

Leonard Pearlstine
National Park Service

Everglades and Dry Tortugas National Parks

Sea Level Rise Research & Monitoring Bullets

Dry Tortugas

- Ground nesting sea turtles and terns are susceptible to sea level rise.

- Climate and SLR impacts to sea-grasses and coral reefs affect critical fish habitat.

Everglades

- Participation in improving hydrologic modeling with TIME (USGS) and FATHOM (FIU, UVa) which will be used in water delivery, water quality and habitat evaluations with sea level rise scenarios.
- Florida Bay Habitat Modeling: Spotted SeaTrout, Blue Crab and Seagrasses. Linkage of habitat models with TIME & FATHOM hydrologic models of sea level rise.

- Everglades Vegetation Succession Model: Seagrass, coastal, wet prairie, marsh, & forested community competition from environmental variables. The model is being developed from current literature and expert workgroups. It will allow spatially-explicit links with other ecosystem models.

- Coastal plants: Increase understanding of coastal plant environmental tolerances, particularly for buttonwood and rare and endemic plant species.

- Impacts of sea level variability and rise on S Florida coastal groundwater systems (Columbia U)

- Multiscale analysis and probabilistic projections of sea level rise for the Everglades (Columbia U)

- Cooperation with SFWMD in new vegetation mapping

- Acquisition of new aerial imagery for mapping Florida Bay seagrasses

Both Parks

- Communications (Public Outreach)

- Facilities Protection

K. Ramesh Reddy
Wetland Biogeochemistry Laboratory
University of Florida

Mark Clark, Andy Ogram, Sabine Grunwald, James Jawitz, Patrick Inglett, Todd Osborne, K. Ramesh Reddy, Alan Wright

Climate change is now seen as one of the major threats to the sustainability and integrity of many ecosystems, including wetlands. Researchers in the Soil and Water Science Department at UF are interested in studying climate change effects on various biogeochemical processes in wetlands and aquatic ecosystems. We are interested in studying on how various biogeochemical processes are influenced by sea level rise effects including: increased inundation, salinity and stress on plants, shift from freshwater marshes to brackish marshes, increased sulfate inputs, reduced methane emissions and increased regeneration of bioavailable nutrients. Some examples of various ecosystems where our research is conducted include: the Everglades, Lake Okeechobee Drainage Basin, and St. Johns River Basin. For additional information contact: K. Ramesh Reddy at: krr@ufl.edu

Jed Redwine
U.S. Army Corps of Engineers

The Role of Sea-Level Rise Research for the Comprehensive Everglades Restoration Program

As a participant in the evaluation team for the Restoration Coordination and Verification (RECOVER) branch of the Comprehensive Everglades Restoration Program (CERP), we have a congressionally defined mandate to predict and verify the ecological consequences of projects built with the intent of regional ecosystem restoration. This requires us to coordinate research and predictive models across State and Federal Agencies, two sovereign nations, and researchers throughout the scientific community. For us, sea-level rise research is one of the uncertainties which we must understand and integrate into our evaluations of proposed projects. The Evaluation Team has a broad and essential interest in understanding and utilizing state of the art sea-level rise research in order to inform all parties who participate about the expected consequences of CERP projects. Predicting outcomes by simulating a variety of event driven scenarios is likely to be the preferred approach to understanding specific topics as disparate as:

- "What are the ecological consequences of altered wave action on coastal areas which are vulnerable to erosive processes?"
- "How will freshwater well-fields respond to altered sea-level?"
- "What are the expected changes to coastal habitats caused by the interaction of rising seas and increased freshwater flows?"
- "What is likely to happen if we do nothing?"
- "How well should our existing flood protection infrastructure perform at different sea-levels?"

While RECOVER has not yet adopted a strategy for addressing these questions comprehensively, addressing them remains central to systematically reducing the uncertainty associated with maintaining and enhancing the water supply and flood protection infrastructure in Florida. Many of the predictive functions of RECOVER are performed through the development of simulations of daily water levels across the entire domain of southern Florida. How these simulations are affected by changes in sea-level is a first-order uncertainty for RECOVER. Although we do not currently have any specific research activities focused on sea-level rise, it appears likely to be addressed in the not-so-distant future.

Jorge Restrepo
Florida Atlantic University

Dr. Jorge I. Restrepo has been at Florida Atlantic University, in the department of geosciences, since 1992 working as both an associate professor and professor (1996-current). While studying civil engineering in 1972 Dr. Restrepo received his BS from the Universidad Nacional, Facultad de Minas in Medellin, Colombia. At Colorado State University Dr. Restrepo's continuing studies focused on hydrology and statistics for his MS in 1977, as well as hydrology and water resources for his Ph.D. in 1987.

Before coming to Florida Atlantic University Dr. Restrepo also worked with the South Florida Water Management District, Colorado State University, Integral Ltda and Universidad Nacional de Colombia. Dr. Restrepo is a committee member of the National Academy of Sciences National Research Council focusing on sustainable underground storage of recoverable water. In the geosciences department Dr. Restrepo serves as a student supervisor and is on the P and T Committee. Beyond academic and committee work, Dr. Restrepo has had many honors and special assignments such as receiving awards for his research work and invitations to give lectures and presentations. The published work of Dr. Restrepo is varied and extensive. He has published in 17 conference papers, 8 publications, 18 peer-reviewed papers and 12 competitive research grants and/or contracts.

Dr. Restrepo's current research interests include evapotranspiration in southern Florida, modeling recharge, evapotranspiration and runoff. Another focus of Dr. Restrepo's is the development of a Wetland Simulation Model. He has done several groundwater models for SFWMD. Dr. Restrepo also studies model conceptualization, and data compilation in GIS for a regional three-dimensional groundwater flow model. Modeling the groundwater and solute transport flow for landfill areas and the development of an optimization model to support the planning of a regional ASR facility along a canal system are other research interests. Dr. Restrepo has directed the hydrologic study of a hydroelectric power plant project and inferred statistical information using a hydrologic regionalization technique to infer extreme flows, average flows, and correlation structure.

Tara Root
Assistant Professor
Department of Geosciences
Florida Atlantic University

My primary research interests are groundwater chemistry and sustainability of water resources. Both of these research avenues are extremely relevant to the issue of sea level rise. My groundwater chemistry research focuses on water-rock interaction and the use groundwater chemistry as a tool for delineating groundwater flow paths and characterizing surface water-groundwater interactions. In South Florida, surface water and groundwater form an integrated hydrologic system, and sea level rise will have a significant impact on the flux of water between aquifers and surface water bodies. A detailed understanding of surface water-groundwater interaction is necessary for 1) developing models to predict how the hydrologic system will respond to sea level rise, 2) predicting how the municipal well fields and artificial recharge projects that will be needed to meet future demand for water will interact with the regional hydrologic system, and 3) identifying potential threats to groundwater quality from surface water infiltration. Much of the current understanding of surface water-groundwater interaction in South Florida is based on regional groundwater flow models. These models provide general information about the regional hydrologic system but often lack the detail necessary to characterize local flow regimes and surface water-groundwater interactions. Because surface water and groundwater typically have distinct chemical and isotopic signatures, water chemistry can be used to delineate surface water-groundwater interactions and provide physical evidence of flow paths to support modeling efforts. One of my current Master's students is collaborating with the USGS on his thesis project to use water chemistry to delineate interactions between a canal and well field in Miami-Dade County. This research will add to the understanding of canal-well field interactions in the study area and in the Biscayne aquifer in general. The project will also evaluate the relative usefulness of various chemical species as indicators of canal-groundwater interaction in South Florida and similar areas. Other avenues of water chemistry research that I am interested in pursuing include 1) evaluating how artificially recharged water migrates through the Biscayne aquifer, and 2) investigating the influence of artificially recharged water on the hydrogeochemistry of the Biscayne aquifer.

Another avenue of my research is sustainability of water resources. I am particularly interested in 1) water use science and developing robust tools for quantifying water use, 2) investigating human perceptions of water availability and developing educational materials to promote conservation, and 3) evaluating how regulations, such as watering restrictions, influence water consumption. Another of my current Master's students is close to completing her research on lawn water use. She has used digital image analysis and vegetation-specific water requirements to estimate the minimum water needed to maintain green lawns, compared actual lawn water use to this "greening minimum", and evaluated the impact of watering restrictions on lawn water use. This type of water use research will increase understanding of how humans interact with the hydrologic system, improve predictions of future water demand, and shed light on ways to promote water conservation. All of this information will be extremely useful to municipalities and regulatory agencies as they plan for meeting both human and ecosystem demands for water at a time when the hydrologic system is adjusting to sea level rise.

Barry H. Rosen
U.S. Geological Survey

USGS Research and Sea-level Rise in Florida

- Established Sediment Elevation Tables for direct measurement of accretion
- Subsidence studies in the Gulf of Mexico
- Barrier Islands and their role in extremes storms and sea level
- Vulnerability assessments of shorelines to extreme storms
- Statistical approaches to understanding barrier islands and the likelihood of overwash
- Everglades Depth Estimation Network (EDEN)
- Small mammal – hydrology relationships, ENP
- Tree mortality and elevation
- Understand the impact of soil salinity on hardwood hammocks and mangroves
- Surface water dynamics in response to SLR
- Impact of climate change on habitats and species in the Everglades; developing predictive capabilities for SLR under restoration and management scenarios
- Integrating geology, hydrology, and biology of sea-level rise vulnerability into a decision-support framework
- Evapotranspiration network and climate
- Salt water intrusion monitoring and modeling
- Underlying geologic conditions and groundwater flow
- Hurricanes and topographic change
- Using predictions from down-scaled AOGCM climate scenarios in combination with ecological modeling

Michael Savarese
Professor of Marine Science
Department of Marine & Ecological Sciences
Florida Gulf Coast University

The Relative Rate of Sea-level Rise and Sedimentation upon the Coastal Geomorphology of the Southwest Florida Coast

The geomorphology of the Southwest Florida coast is considerably different than that seen in South Florida. Oyster reef development is more prolific. The great potential for oyster growth and reproduction through the middle to late Holocene has generated sedimentation rates that have exceeded the modest rates of sea-level rise, and the "Ten Thousand geomorphology" has resulted. Landward of these estuarine bays, the evolution of coastal fringe mangrove forests and their neighboring graminoid marshes is relatively unhindered by the constraints of human development and free to transition in its vegetative composition and landscape geomorphology. Because the long-term stability of these landscapes is influenced by the anthropogenic and natural forcing of sea-level rise fluctuations due to climate change, the Geobiology Group at Florida Gulf Coast University has undertaken a multi-year study of the sedimentology, stratigraphy, and paleoecology of Holocene oyster reefs and brackish water marshes throughout Southwest Florida with particular field emphasis in the Ten Thousand Islands, Estero Bay, and the portion of Everglades National Park northwest of Cape Sable.

First, a long-term study of the paleoecology and stratigraphy of Holocene oyster reefs in Southwest Florida, building upon previous work by Randy Parkinson and Harold Wanless, has demonstrated that oysters are key architects of coastal geomorphology and estuarine ecology in Southwest Florida. The sedimentation and accretion rate of oyster reefs is high enough to exceed SLR rate if sea-level rise is lower than ~15 cm / 100 years. Such a SLR rate has persisted for the last 3500 years, and this has contributed to the progradation of the coast and the development of a protected estuarine environment. Oyster sedimentation brings the substrate into upper intertidal depths and this then becomes a habitat for mangrove recruitment. When reef development is extensive, an intricate network of anastomosing islands and bays forms ("Ten Thousand Island" geomorphology), which subsequently promotes the retention of freshwater to further establish estuarine conditions. Geomorphologic changes along the Southwest to South Florida transition (moving to the southeast) reflect a shift away from prolific reef development, probably caused by changes in watershed hydrology. Finally, Holocene oyster reefs exhibit both auto- and allogenic succession demonstrating that their existence can both affect and be affected by environmental change. Comparative taphonomy, paleontology, and stable isotope geochemistry have been successfully used to document paleoenvironmental changes. Collectively, these results can be used to develop predictive conceptual models about coastal ecologic and geomorphologic response to accelerated SLR rates.

Second, a study of the Holocene stratigraphic history and paleoecology of graminoid marshes and mangrove forests within the Ten Thousand Islands National Wildlife Refuge, the Fakahatchee Strand State Preserve, and portions of northwest Everglades National Park is underway. Preliminary work has revealed a number of incipient landscape-scale changes that are effects of accelerated SRL. Red mangroves have shifted landward considerably when comparing 1940 and 2008 GIS images, effectively widening the basinal mangrove forest. More interestingly, certain graminoid vegetative habitats, most notably those dominated by *Spartina*, are pocking – the peat surface is eroding to create small, 10-m scale, circular depressions that are subtidal. Pocks merge to form ponds, and these structures are commonly lipped with small, and presumably young, red mangroves. *Distichlis* marshes, exhibit slight pocking. No pocking has been observed in more freshwater-tolerant marshes (*Eleocharis* & *Juncus).* Within northwest Everglades National Park, the geomorphology of the inner bays suggests these large water masses owe their origin to the merging of expanding ponds. If true, pocking can have a drastic affect upon geomorphology and the distribution of estuaries.

Mark Shafer
U.S. Army Corps of Engineers

Area of Interest: Impact of Sea Level Rise on Restoration Benefits Provided by the C-111 Spreader Canal and Biscayne Bay Coastal Wetlands Projects.

Collaborators: Glenn Landers, Dan Vogler, William Gallagher

The Jacksonville District of the U.S Army Corps of Engineers (USACE) is currently completing the Project Implementation Reports (PIRs) for the C-111 Spreader Canal and the Biscayne Bay Coastal Wetlands projects which are components of the Comprehensive Everglades Restoration Program (CERP). These reports are submitted to Congress as part of the process of authorizing civil works projects. The USACE Engineering Circular EC-1165-2-211 dated 1 July 2009 requires that the impact of sea level rise (SLR) be considered when planning, constructing, or operating Civil works projects. The C-111 Spreader Canal and Biscayne Bay Coastal Wetland projects are located in southern Miami-Dade County where the average land elevation is less than 5 ft above present mean sea level. The purpose of the two projects is to divert water from drainage canals that bisect the drainage basins and send this water directly into coastal wetland habitat. The intent of the projects is to rehydrate coastal wetlands to improve habitat for terrestrial fish and wildlife and to also moderate salinity conditions within the nearshore zone within 1000 meters of the existing shoreline. Increased sea level conditions are likely to affect the ability of these two projects to provide the restoration benefits anticipated by the project planners.

To address the requirements of EC-1165-2-211 in the implementation reports, I have estimated the effect sea level rise will have on each project's long-term success in terms of what percentage of the restoration benefits will be affected by sea level as projected at 20, 50, and 100 years. At this time, these evaluations are done by comparing maps showing static estimates of current and future mean sea level (at T = 20, 50, and 100 years) against static surface elevation maps showing the location of the various project features. Additional analysis is provided to discuss possible adaption strategies that to be employed to ensure that various habitats are be preserved by protection or trans-location as sea level rise occurs. Future evaluations of sea level rise on project benefits may be done using more sophisticated hydrologic models that directly incorporate sea level rise as a boundary condition.

Huiwei Shen
Florida Department of Transportation

Research Related to Future Climate Change and Transportation Impacts

The Florida Department of Transportation is conducting initial research on climate change and transportation impacts. Florida's statewide efforts to address climate change began about two and a half years ago with the Governor Charlie Crist's Climate Change Summit (held in July 2007) that brought together leaders of business, government, science and advocacy to examine the risks of global climate change to Florida. The Governor established the Energy and Climate Change Action Team – this group has published two reports:

- Phase 1 report published in November 2007, which was used as the basis for energy and climate change legislation introduced during the 2008 Legislative Session. The Action Team recommended GHG reduction strategies be incorporated into state, regional and local growth management and transportation planning.

- Phase 2 report was completed in October 2008 and included extensive recommendations for reducing GHG emissions to achieve or surpass the statewide reduction targets.

The report identified policy options for Florida to consider for adapting to the impacts of future climate change. Two options explored dealt with direct and indirect impacts to the transportation sector. The referenced policy options were Transportation and Other Infrastructure and Economic Development.
Florida's transportation infrastructure includes 121,525 miles of public roads, 19 commercial airports, and 14 deepwater ports. Roads, bridges, airports, rail, pipelines, ports and other infrastructure and public works projects along and close to Florida's coastline and in low lying areas are potentially vulnerable to climate change impacts, especially sea level rise. No comprehensive listing of transportation infrastructure at risk in Florida has been documented. In addition, strategies for improving transportation infrastructure resiliency, prevention of adverse consequences, and response and recovery from future conditions and events from climate change, especially related to sea level rise need to be identified and implemented in Florida.

Study Objectives:

1. An inventory of research and studies analyzing projected sea level rise in Florida.
2. An analysis of the advantages/disadvantages of different sources and methods for forecasting sea level rise and timing.
3. Recommendations for methods for forecasting sea level rise and related impacts that the Department of Transportation can use during development of the 2060 Transportation Plan.
4. Recommendations for integrating forecasts/timing of sea level rise with other FDOT information systems for the purpose of identifying infrastructure at risk.

Thomas Smith III
Southeast Ecological Science Center
U.S. Geological Survey

Changing Vegetation in the Coastal Everglades: It's More than Just Sea-Level Rise

Sea-level has been rising in the Gulf of Mexico for several thousands of years. The rate of SLR has been variable, but appears to have been slowing over the last 2-3,000 years, which has allowed development of extensive mangrove forests on the southwest coast of Florida. Additionally, we know from examination of historic maps and charts (some dating to the 1850s), and recent aerial photos, that mangroves have invaded coastal marshes in some areas of the Everglades, but not others. However, many factors are at work, not just sea level.

Wetland plants (salt marsh plants and mangrove trees) can produce peat. In the lower Shark River, mangrove peats >5 m in depth can be found. These forests have "kept up" with past rates of sea level rise of 1-2 mm/yr. Such biotic feedbacks are often ignored in the "bath tub" scenarios of SLR. Hurricanes can have opposite impacts on mangrove forests. For example, in some areas along the coast, Hurricane Wilma deposited ≈40 mm of sediment into the mangrove forests. Does this represent 20 years of "protection" from SLR? However, in other portions of the coast, Hurricane Wilma caused catastrophic tree mortality. Continuing mortality has also been observed. In these areas, detailed measurements of sediment surface elevation have indicated declines in elevation as mangrove trees continued to die. Such episodes of peat collapse have been observed in past hurricanes (e.g. Andrew) in Florida and in Honduras following Hurricane Mitch. In upstream areas of the Everglades, mangroves give way to brackish and freshwater marsh. Here fire can play an important. Although SLR may be "pushing" the forest upstream, fire can reverse mangrove encroachment into marshes. Another factor to be considered is the frequency and severity of cold temperatures and freezes. Surveys following the January 2010 cold event revealed major mangrove mortality at upstream sites along the mangrove – marsh ecotones. These marshes will lose water during the winter dry season. Could fires in the spring have a larger impact than normal on the mangrove-marsh ecotone because of freeze impacts?

Impacts of sea level rise must be considered in light of other environmental drivers with which all interact to shape vegetation and ecosystem structure in the Everglades.

Brian Soden
Rosenstiel School of Marine and Atmospheric Science
University of Miami

My current research activities are concentrated in two areas:

1) To better understand the magnitude of key atmospheric feedback processes, primarily involving water vapor and clouds, which determine the sensitivity of the climate system to increases in greenhouse gases.

Differences in the way these climate feedbacks are represented in models are the primary contributor to uncertainties in model projections of future climate change. Because of their ability to provide global observations, remotely-sensed measurements are a key focus of my research. Satellite observations of water vapor, clouds, and precipitation are used to understand the mechanisms which drive changes in the hydrological cycle and evaluate their representation in climate models. Results from these comparisons provide key guidance which is necessary to assess model projections of future global warming.

2) To understand the response of extreme weather events to changes in climate from global warming. Specific areas of interest include the response of hurricane activity, including both hurricane frequency/intensity and hurricane tracks; the response of extreme precipitation events; and the response of the atmospheric circulation and extreme wind events.
Publications on these areas are available from http://metofis.rsmas.miami.edu/~bsoden/

Eric Swain
U.S. Geological Survey

The modeling of surface-water/groundwater interactions at the USGS Fort Lauderdale office has been applied to the coastal regions of South Florida to predict the effects of sea-level rise and various ecosystem restoration scenarios on the coastal areas and biologic concerns. The studies use the coupled hydrodynamic surface-water/ground-water simulator FTLOADDS, which has been used to develop calibrated models of The Everglades National Park, Ten Thousand Islands, and Biscayne Bay coastal and inland areas. Interfaces have been developed with the regional South Florida Water Management Model to represent ecosystem restoration scenario flows for evaluation and planning of water-management schemes.

The initial model experimentation looked at a seven-year test period with different sea-level rise values. These are combined with existing and restoration scenario flows to examine the effects on saltwater intrusion, flooding depths, and inundation times. Further experimentation examined sequential 5 year simulations with incremental applications of sea-level rise and restoration scenario flows to represent the 2003-2047 period. These simulations give some insight into possible effects of different restoration implementation schedules on groundwater salinity and surface-water inundation.

The model-simulated results are used in conjunction with historic landscape data to delineate past coastline changes and potential for future changes to coastal vegetation regimes. A hindcast model was developed for the 1926-1932 period to use in conjunction with aerial photography of the time to set up the historical relationships. Forecasting is then developed with predicted coastal changes for a more accurate appraisal.

Future applications to sea-level rise research involve adding other atmospheric parameters developed by the global climate models, such as rainfall, air and sea temperature, and relative humidity. A GIS-based web interface is under development to allow users to access and evaluate all the model results to use in water-management decision making.

Steve Traxler
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service

U.S. Fish and Wildlife Service Science Research Relative to Sea Level Rise with a Focus on South Florida

The Fish and Wildlife Service (Service) in 2009 drafted a Climate Change Strategic Plan that focuses on three major components: Adaptation, Mitigation and Engagement, (http://www.fws.gov/home/climatechange/strategic_plan.html). This plan was married with a Strategic Habitat Conservation movement within the Service to become the Department of the Interior's Landscape Conservation Cooperatives (LCCs). LCCs are partnerships that enable members of the conservation community to plan, design and deliver conservation in ways that integrate local, State, Tribal, regional, national and international efforts and resources. The LCCs will focus on the science needed for upcoming changes related to the ecosystem and will utilize strategic habitat conservation principles.

Local Service research:
Project 1: Addressing the Challenge of Climate Change in the Greater Everglades Ecosystem through Strategic Habitat Conservation: A Stakeholder-Based Approach.

This is a 2-4 year study with the Massachusetts Institute of Technology (MIT) -U.S. Geological Survey (USGS) Science Impact Collaborative.

A stakeholder-based alternative futures process is being developed to help plan and manage effectively in south Florida in the face of uncertainties. This effort has two main objectives. First, in collaboration with the MIT-U.S. Geological Survey Science Impact Collaborative (MUSIC) and the Service, a set of regional-scale "alternative futures" are being developed that spatially simulate likely climatic, hydrologic, and land use conditions (based on International Panel on Climate Change (IPCC) and locally developed scenarios). The second objective is to examine the impacts of such changes on fish, wildlife, plants, and their habitats, such as National Wildlife Refuges in the Greater Everglades and Florida Keys Ecosystems. The work will be conducted using a spatially-enabled stakeholder process, designed to combine the best available scientific information with local knowledge. The major outputs of this study will include information that characterizations of the potential impacts on the Everglades from climate change, and structured public and expert group processes. These outputs will be used to provide input into the Service's landscape-scale conservation strategy for south Florida.

Currently, a statewide proposal is being develop that combines the alternative futures proposal with the Critical Lands & Waters Identification Project (CLIP) program for funding in 2011 and 2012.

A number of the USFWS refuges in Florida are developing and funding projects that will look at SLR effects on refuge lands as well as provide insight into adaptation strategies for these refuges.

Project 2: Climate Envelop modeling for 21 threatened and endangered terrestrial vertebrates. This project will provide a refinement of species-habitat models and development of climate envelope models for evaluation of potential effects of climate change on 21 terrestrial vertebrate threatened and endangered species in South Florida, Development of databases and GIS layers related to the above mentioned T&E and fact sheet development.

Russ Weeks
U.S. Army Corps of Engineers

CERP Climate Change Study Work Plan for Modeling the Effects of Sea Level Rise in South Florida

The modeling work plan for the CERP Climate Change Study is based on the premise of interagency cooperation and consensus in the modeling approach. This entails that a common suite of modeling tools be developed and utilized by the participating agencies (USACE, USGS, SFWMD) during the study. It will also involve a phased approach with initial efforts aimed at development of density-dependent groundwater models along the coastal areas of the study area. Initially these models will be used primarily to assess the effects (i.e., salinity intrusion and increased flooding potential) of varying levels of predicted sea level rise on the groundwater and surface water systems near the coastal areas. Subsequently, these density-dependent groundwater models will be further enhanced and converted to integrated surface water groundwater (ISGW) models with the addition of surface water components such as canals, water control structures and operations in order to better represent the overall hydrologic system response to climate change. This improved representation of the physical system will also allow for the modeling of potential adaptation strategies, either as structural, non-structural or operational measures, in response to the effects of sea level rise. Surface water bodies including rivers, estuaries, and some lakes may be affected by the sea level rise, either directly because they are within the spatial extent of the physical rise or indirectly because their inherent hydro-dynamics have been affected by changes in the volume and water quality of inflows and outflows resulting from the sea level rise. For example, estuaries will be directly inundated with increased depths of saline water and indirectly affected by reductions of freshwater discharges from coastal rivers and water control structures. Therefore, it is anticipated that hydrodynamic modeling of estuaries and bays will be needed with upland boundary conditions provided by the before mentioned integrated surface water groundwater models.

A phased approach for modeling will be performed to simulate the hydrologic, hydraulic, hydro-geologic and hydrodynamic processes affected by the sea level rise in the CERP study area of South Florida. These are: (1) Phase I - modeling primarily for density dependent groundwater flow; (2) Phase II – expanding density dependent groundwater flow to include integrated surface water-groundwater modeling with representation of the surface water drainage network, water control structures and operations. Phase II will involve both event scale and multi-year continuous scale simulations using different ISGW modeling tools designed to capitalize on their strengths. Continuous longer term simulations are particularly suited for evaluating the effect of climate change on salinity intrusion, water supply, well-field vulnerabilities, ecosystem health and vegetation change while event scale simulations are more useful in evaluating system response and performance under short-term phenomenon such as intense rainfall flood events and accompanying rapid operational changes. (3) Phase III – hydrodynamic modeling for inlets, estuaries, and bays.

Only USACE certified modeling software will be employed and most modeling products will undergo three types of review: 1) Interagency Modeling Center (IMC); 2) Agency Technical Review (ATR) and 3) Independent External Peer Review (IEPR). All models will be constructed in reference to the National American Vertical Datum, 1988 (NAVD88) as mandated by
USACE and CERP guidance.

Daniel Yeh
University of South Florida

Dr. Daniel Yeh is an Assistant Professor of Civil and Environmental Engineering and Research Fellow with the Patel Center for Global Solutions at the University of South Florida. His research and teaching interests are related to water treatment, wastewater reuse and nutrient recovery, bioenergy from wastes, rainwater harvesting, desalination, green building net-zero water strategies, sustainable urban water management and adapting the infrastructure of coastal cities to climate change. In particular, he is interested in the integration of spatial planning and infrastructure systems to build sustainability and resiliency into urban systems.

Dr. Yeh collaborates with researchers in the Netherlands on climate change and other water issues. He is the PI of an NSF grant International Research Experience for Students at UNESCO-IHE in Delft, studying water technologies. In 2009, he organized a series of interdisciplinary workshops with the Dutch water sector on the topic of climate change adaptation for Tampa Bay and has launched the Linkedin group "Climate Change Adaptation Florida." Dr. Yeh serves on the Water Efficiency Technical Advisory Group and the Climate Adaptation Work Group of the U.S. Green Building Council. At USF, he is the faculty advisor of Emerging Green Builders and Engineers Without Borders. Prior to USF, Dr. Yeh was a postdoctoral research fellow with Stanford University. He has degrees from the University of Michigan (BS Natural Resources, BSE Civil Engineering, MSE Environmental Engineering) and Georgia Tech (PhD Environmental Engineering). He is a licensed professional engineer and a LEED AP.

Keqi Zhang
Florida International University

Dr. Zhang an Associate Professor of the Department of Earth and Environment and interim director of the International Hurricane Research Center at Florida International University. Dr. Zhang research interests include coastal response to sea level rise and storm impact, airborne light detection and ranging (LiDAR) mapping, storm surge modeling, and three-dimensional visualization and animation. He has authored and coauthored more than 60 journal papers, book chapters, conference proceedings, and technical reports.

Dr. Zhang's research on coastal geomorphic response to sea level rise involves the identification of the causes for ubiquitous coastal erosion and the effect of global warming on long-term coastal erosion. Changes in storm climate, sea level rise, and human interference are three possible causes for erosion. By analyzing 80-90 years of hourly water level records from a dozen tide gauges along the U.S. East Coast, Dr. Zhang and his colleagues found that there is a considerable interdecadal variation but no discernable long-term trend in the number and intensity of moderate and severe coastal storms during the 20th century. In addition, by analyzing long-term shoreline position data from historical maps, aerial photographs, and GPS measurements, they found that barrier beaches along the U.S. East Coast recover to their long-term trend positions after storms regardless of storm severity. This result strongly suggests that storms are *not* responsible for long-term beach erosion. Since there is no indication of a significant increase in storminess in the 20th century and human interference is neither worldwide in extent nor uniform regionally, sea level rise remains as the plausible cause for long-term coastal erosion. Using a large and consistent database of shoreline positions for the past 150 years with corresponding sea level records, Dr. Zhang and his colleagues found that there is a highly multiplicative association between long-term sandy beach erosion and sea level rise during the 19th and 20th centuries. The underlying rate of long-term sandy beach erosion is about two orders of magnitude greater than the rate of sea level rise. This result means that the already-severe coastal erosion problems witnessed in the 20th century will be exacerbated in the 21st century under plausible global warming scenarios even if there is no increase in coastal storminess.

Recently, Dr. Zhang and his colleagues have analyzed the inundation impacts caused by possible future sea level rises on South Florida using LiDAR data, parcel property data, and population census. It was found that a 1.5 m sea level rise by 2100 would cause a catastrophic inundation to Miami-Dade County, southern Broward County, and Everglades National Park. Inundation processes are non-linear: inundation is gradual before reaching a tipping point, and speeds up rapidly afterwards due to the regional topography. Accelerated sea level rise will cause the tipping point to be reached sooner by amplifying the non-linear inundation. In addition, Dr. Zhang and his colleagues is investigating the non-linear effects of sea level rise on surge flooding by introducing sea level rise scenarios into the numerical models for storm surges.

ANNEX 3. LIST OF ACRONYMS USED IN THIS REPORT

AM- Adaptive Management
AMMA-Avoidance Minimization Mitigation and Adaptation
ATR- Agency Technical Review
CAC- Climate Advisory Committee
CCATF- Climate Change Advisory Task Force
CCB- Cooperative Conservation Blueprint
CCTF- Climate Change Task Force
CERP- Comprehensive Everglades Restoration Plan
CES- Center for Environmental Studies
CGM #16- CERP Guidance Memo
CHNEP- Charlotte Harbor National Estuary Program
CLIP- Critical Lands and Water Identification
DERM- Department of Environmental Research Management
EDEN- Everglades Depth Estimation Network
ENP-Everglades National Park
EPA- Environmental Protection Agency
EPJV- Everglades Partners Joint Venture
FATHOM- Hydrologic Model
FDEP- Federal Department of Environmental Protection
FGCU- Florida Gulf Coast University
FLERA- Florida League of Environmental Resource Agencies
FSG- Florida Seagrant College Program
FWC- Florida Fish and Wildlife Conservation Commission
GEER- Greater Everglades Ecosystem Restoration Conference
GIS- Geographic Information System
IFAS- Institute of Food & AgriSciences
IMC- Interagency Modeling Center
IPCC- Intergovernmental Panel on Climate Change
LCCs- Landscape Conservation Cooperatives
LiDaR- Light Detection and Ranging
MAP- Monitoring and Assessment Plan
NAVD- North American Vertical Datum
NEP- National Estuary Program
NERRS- National Estuarine Research Reserve System
NGVD- National Geodetic Vertical Datum
NOAA- National Oceanic and Atmospheric Administration
NOS- National Ocean Service
NRC- National Research Council
ORD- Office of Research and Development (EPA)
PIRs- Project Implementation Reports
PTL- Planning Technical Lead
RBNERR- Rookery Bay National Estuarine Research Reserve
RECOVER- Restoration Coordination and Verification
RSMAS- Rosenthal School of Marine and Atmospheric Science

SEAWAT- Computer program for Simulation of three-dimension variable-density ground-water flow and transport
SET- Surface Evaluation Tables
SFWMD- South Florida Water Management District
SLAMM- Sea Level Affecting Marshes Model
SLR- Sea Level Rise
SWFRPC- The Southwest Florida Regional Planning Council
T&E- Threatened and Endangered
TAC- Technical Advisory Committee
TIME- Tides and Inflows in the Mangroves of the Everglades
USCAE- United States Corp of Army Engineers
USFWS- US Fish and Wildlife Service
USGS- United States Geological Survey
USNPS- US National Parks Service
WASD- Water and Sewer Department
WBL- The Wetland Biogeochemistry Laboratory
WQ- Water Quality
WRAC- Water Resources Advisory Commission
WSSS- Water Systems, Science, and Society

ANNEX 4. LIST OF ATTENDEES

Ricardo Alvarez, Florida International University

Stu Appelbaum, U.S. Army Corps of Engineers

Jim Beever, Southwest, Florida Regional Planning Council

Leonard Berry, Florida Atlantic University Center for Environmental Studies

Ronnie Best, U.S. Geological Survey

Fred Bloetscher, Florida Atlantic University

Laura Brandt, U.S. Fish and Wildlife Service

Henry Briceno, Florida International University

Tracy Browne, Balfour Beatty Construction

Camille Coley, Florida Atlantic University

Nick DiGruttolo, University of Florida

Gretchen Ehlinger, U.S. Army Corps of Engineers

Kris Esterson, U.S. Army Corps of Engineers

Ernest Estevez, Center for Coastal Ecology, Mote Marine Laboratory

Bonnie Finneran, Palm Beach County Environmental Resources Management

Carl Fitz, University of Florida

Pamela Fletcher, National Oceanic and Atmospheric Administration

Tom Frazer, University of Florida

Peter Frederick, University of Florida

Lisa Gardner, University of Florida

Nancy J. Gassman, Broward County Environmental Protection and Growth Management Department

Dale Gawlik, Florida Atlantic University

Patrick Gleason, Camp Dresser & McKee

Courtney Hackney, University of North Florida

Dennis Hanisak, Florida Atlantic University - Harbor Branch Oceonographic Institution

John Hargis, Gumbo Limbo Nature Center

Peter Harlem, Florida International University

Karl Havens, University of Florida

Barry Heimlich, Florida Atlantic University

Rowan Hughes, Palm Beach County Environmental Resources Management

Brian Keller, National Oceanic and Atmospheric Administration

Paul Kirshen, Battelle Memorial Institute

Marguerite Koch-Rose, Florida Atlantic University

Jerry Krueger, Everglades and Dry Tortugas National Parks

Julie Lambert, Florida Atlantic University

Glenn Landers, U.S. Army Corps of Engineers

Melinda Lohmann, U.S. Geological Survey

Maria Idia MacFarlane, Miami Dade Water and Sewer Department

Matthew Magoc, Pine Jog Environmental Education Center

Rachel Marshall, Florida Atlantic University

Linda Mathies, Netherlands Water Partnership Liaison

Frank Mazzotti, University of Florida

Maia McGuire, University of Florida

Peter Merritt, Treasure Coast Regional Panning Council

Diana Mitsova, Florida Atlantic University

Jim Murley, Florida Atlantic University

Ramaswamy Narayanan, Florida Atlantic University

Reed Noss, University of Central Florida

Jayantha Obeysekera, South Florida Water Management District

Todd Osborne, University of Florida

Doug Parsons, Florida Fish and Wildlife Service

Leonard Pearlstine, National Parks Service

K. Ramesh Reddy, University of Florida

Jed Redwine, U.S. Army Corps of Engineers

Stephanie Romañach, U.S. Geological Survey

Tara Root, Florida Atlantic University

Barry Rosen, U.S. Geological Survey

Perran Ross, Department of Wildlife Ecology and Conservation, IFAS

MacKenzie Ross-Fidler, Balfour Beatty Construction

Michael Savarese, Florida Gulf Coast University

Mark Shafer, U.S. Army Corps of Engineers

Cindy Shaw, Florida Atlantic University

Tom Smith, U.S. Geological Survey

Brian Soden, Rosenstiel School of Marine and Atmospheric Science University of Miami

Lisa Survis, Florida Atlantic University

Eric Swain, U.S. Geological Survey

Pamela Sweeney, Biscayne Bay Aquatic Preserve Manager

Steve Traxler, U.S. Fish and Wildlife Service

Harold Wanless, University of Miami

Russ Weeks, U.S. Army Corps of Engineers

Keqi Zhang, Florida International University

ANNEX 5. LIST OF ATTENDEE AFFILIATIONS

Balfour Beatty Construction

Battelle Memorial Institute

Biscayne Bay Aquatic Preserve

Broward County Environmental Protection and Growth Management Department

Camp Dresser and McKee Environmental Engineers

Everglades and Dry Tortugas National Parks

Florida Atlantic University Gumbo Limbo Nature Center

Florida Atlantic University Harbor Branch Oceanographic Institution

Florida Department of Transportation

Florida Fish and Wildlife Service

Florida Gulf Coast University

Florida International University

Institute of Food and Agricultural Sciences, University of Florida, Department of Wildlife, Ecology and Conservation

Miami Dade Water and Sewer

Mote Marine Laboratory Center for Coastal Ecology

National Oceanic and Atmospheric Administration

National Parks Service

Netherland Water Partnership Liaison

Palm Beach County Environmental Resource Management

Pine Jog Environmental Education Center

South Florida Water Management District

South West Florida Regional Planning Council

Treasure Coast Regional Planning Council

U.S. Army Corp of Engineers

U.S. Fish and Wildlife Service

U.S. Geological Service

University of Central Florida

University of Florida

University of North Florida

University of Miami Rosenstiel School of Marine and Atmospheric Science

University of South Florida