Florida Atlantic University
Florida Center for Environmental Studies

2012

Summary Update

Information Packet

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Research and Technical Assistance for Assessing: Climate Change, Sea Level Rise and Salinity Dynamics in the Greater Everglades

Written by Dr. Caiyun Zhang, reviewed by Dr. Leonard Berry and Zhixiao Xie

This is the research summary about the salinity pilot study conducted in the Everglades during year 2011-2012. We investigated the applicability of Landsat remote sensing data for surface salinity monitoring and modeling in Florida Bay. We first collected field salinity data surveyed by USGS from the South Florida Information Access (SOFIA, http://sofia.usgs.gov/) and Landsat Thematic Mapper (TM) data at the USGS's Earth Explorer website. We then spatially and temporally matched these two datasets with an attempt to find the empirical relationships between surface salinity and TM data. Two study areas were selected: northeastern Florida Bay, and Florida Bay. The northeastern bay area is the discharge location of the wide C-111 canal and Taylor Slough carrying a large volume of fresh water into the bay, which makes its water mass different from its surroundings. Florida Bay is a key feature in the Everglades. Salinity monitoring over these two regions is important in CERP. We tested several models including remote sensing classification methods, multivariate regression analysis models, and geographically weighted regression (GWR) models. Some conclusions are indicated from this project in terms of the applicability of Landsat TM data to salinity monitoring and modeling over the northeastern Florida Bay:

- Landsat TM data appear to be effective for salinity assessment in northeast Florida Bay. A highly significant relationship between the TM data and salinity are identified for both dry and wet seasons. Expected salinity patterns are presented on the TM estimated salinity maps. Time-series salinity maps can provide variability of salinity in the bay, which can be used to measure the effects of restoration projects in CERP.
- The empirical approaches for quantitative salinity estimation generate more acceptable results than the classification methods for qualitative salinity assessment. The empirical algorithms are statistically significant and are preferable for operational purposes in this area.
- Bands 1, 3, and 4 were suitable for salinity estimation when used together. A combination of these three bands in the established models explained more than 70% of the variation in salinity. They afford a reliable surface salinity prediction capability.
- Salinity in the dry season is more predictable than in the wet season. Heavy rainfall and runoff in the wet season make the bay environment more complex. This causes the salinity assessment in the wet season more difficult.

Further experiments for entire Florida Bay= demonstrate that location-specific correlations are evident between surface salinity and spectral response in TM data. GWR is proven to be suitable and utilized in modeling and predicting such spatially variable relations. To build an effective GWR model, it seems necessary to perform a principal component analysis (PCA) of the TM data to remove the collinearity between explanatory variables while incorporating as much information from multiple spectral bands. In summary, initial experiments suggest that remote sensing could potentially serve as a less costly alternative or a supplement to field salinity survey currently undertaken in the coastal areas of the Everglades. The research findings were presented in two conferences (SEDAAG 2011, INTECOL 2012) and two peer-reviewed journal articles were published.

Florida Department of Transportation Research

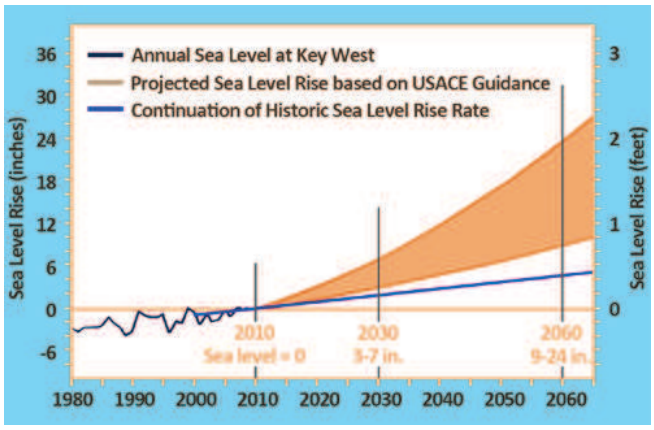
Development of a Methodology for the Assessment of Sea Level Rise Impacts on Florida's Transportation Modes and Infrastructure

BDK79 977-01

In Florida, low elevations can make transportation infrastructure in coastal and low-lying areas potentially vulnerable to sea level rise (SLR). Because global SLR forecasts lack precision at local or regional scales, SLR forecasts or scenarios for parts of the state have been prepared using varying tools and approaches. However, Florida still lacks a consensus on the appropriate methodology to forecast potential, adverse impacts. Also, a comprehensive analysis of transportation infrastructure potentially at risk in Florida from SLR has not been conducted.

In this project, Florida Atlantic University researchers analyzed findings, including data sources and methodologies used to forecast SLR. They recommended data sources and methods for forecasting SLR and related impacts in Florida and investigated integrating SLR forecasts with FDOT information systems to identify at-risk infrastructure. Using the Weiss Overpeck 1-meter (~3 ft) estimate of SLR to illustrate the methodology, researchers linked mapping software and datasets to create a framework for identifying transportation facilities at risk.

Analysis of advantages and disadvantages of various SLR research studies, combined with workshop reports and expert consultation, led the researchers to recommend that FDOT use the U.S. Army Corps of Engineers (USACE) sea level change guidance, which will be revisited in 2013-14, for forecasting SLR in Florida. USACE guidance considers scenarios of possible future rates of mean sea level change over various planning horizons, which can be used to identify and assess infrastructure vulnerabilities and inform decisions about possible SLR impacts and adaptation actions. Southeast Florida developed consensus projections using the USACE guidance. While these projections will be useful for a statewide analysis, local conditions of coastline uplift or subsidence should be taken into account in regional projections. Researchers also recommended more refined downscaling analyses to produce more accurate analyses of potentially vulnerable transportation facilities.



SE Florida SLR projection calculated using USACE guidance: the intermediate and high curves represent the lower and upper bounds for projected SLR. Using Key West tidal data showing a gradually accelerating increase in SLR, the recent SLR rate is extrapolated to show how historic rates compare to projected rates.

The methodology used ArcGIS to fuse the Weiss Overpeck 1-meter SLR map for Florida with map data on roadways. Stepwise downscaling then generated candidate road segments and confirmed their vulnerability, first with LiDAR data, where available, and finally with on-the-ground inspection. The methodology was demonstrated by application to Dania Beach, the Charlotte Harbor/Punta Gorda area, and the Florida Keys.

The researchers suggested several responses to SLR, including developing a sketch-planning tool of the framework to identify facilities at risk and building SLR impact into FDOT decision making and transportation design and construction processes. The final project report includes helpful appendices that detail the literature related to SLR, data gaps, planning implementation tools for adaption to SLR, and a summary of SLR impacts on the wide variety of transportation structures and facilities.

Project Manager: Maria Cahill, AICP, FDOT Planning Office
Principal Investigator: Dr. Leonard Berry, Florida Atlantic University
For more information, visit http://www.dot.state.fl.us/research-center

Florida Atlantic University Workshop

HYDROLOGY OF THE EVERGLADES IN THE CONTEXT OF CLIMATE CHANGE

Cover Photos Courtesy of the SFWMD

EXECUTIVE SUMMARY

BACKGROUND

The Center for Environmental Studies (CES) at Florida Atlantic University (FAU) and the U.S. Geological Survey (USGS) held a workshop on March 29-30, 2012 at FAU in Davie, Florida. The purpose of this workshop was twofold:

- Assess the state of knowledge of the impacts of current and future climate change on the hydrological cycle in the Everglades including gaining a greater understanding of downscaled hydrologic global models for the Everglades.
- Examine each of the components of the cycle in the greater Everglades by identifying:
  - our understanding of potential changes in precipitation quantity and intensity, evapotranspiration, percolation to groundwater, runoff and drainage, and
  - critical knowledge gaps with respect to future patterns and their impact.

The plenary sessions opened with a series of presentations that set the stage by providing a common basis of information for the discussion groups to draw upon. The first group of speakers provided a "Big Picture Perspective" on the climate change implications for Florida, including the state of knowledge, downscaling global models and changes in hydrology. This was followed by a review of selected components of the hydrological cycle, including precipitation, temperature, evapotranspiration and groundwater and surface water flows. More importantly the idea of this workshop was to focus on the impact of global climate change on rainfall variability and hydrologic variations, and their consequent implications on Everglades restoration and water management in South Florida in the near term (10-30 years) and long term (end of century).

THE HYDROLOGIC CYLCLE

Research indicates that the hydrologic cycle will change in the future and water management must be modified to handle these changes. Current temperature projections show a rise of 1-2°C (1.8-3.6°F), precipitation change may be ±10% and evapotranspiration (ET) may increase 3-6 inches by 2050. North Florida will be warmer and South Florida, at the same latitude as the Sahara, will be drier.

Precipitation is the main driver of the Everglades hydrology. There are a number of research priorities that need to be examined to increase our understanding of precipitation events, and how future events will be affected by climate change:

- Understanding trends in extreme precipitation events, like tropically-driven heavy rainfall systems and droughts.
- Developing a familiarity with spatial and temporal trends of precipitation in South Florida is critical to understanding how to manage the water budget in the Everglades and surrounding communities.
- Understanding how spatial and temporal trends have changed throughout history and how they will evolve with a changing climate.
- Examining the relationship between precipitation trends of urban and natural systems.
- Developing models that incorporate future land use changes to accurately predict precipitation trends, critical to water management needs.
- Identifying current and future urban heat islands and the local effects they may induce on regional precipitation trends.

Evapotranspiration (ET) is the second most important component of the Everglades hydrology, but is the most poorly understood. We have begun to build a wealth of information over the past 5-7 years regarding ET. Progress has been made in gathering data that are used for the evaluation of climate models. There are several points that are crucial to the understanding of how present and future ET rates relate to the evolution of the South Florida landscape:

- Building a firm understanding of ET rates among urban, suburban, and agricultural areas.
- Understanding the related energy balance and effects on ET between urban and vegetative sites needs further investigation, as well as the effects of urban heat islands on non-stationarity in historic and present meteorological records.

The alteration of land use patterns and increased urbanization will far outweigh the potential impacts of climate change on ET in South Florida for many years. The two need to be jointly and thoroughly assessed to improve predicted ET rates in the future.

Groundwater and **sheetflow** are poorly understood components of the hydrology of the Everglades, especially regarding how they will be affected by climate change. The hydraulics of the Everglades is the only real world example of a genuine sheet flow system, which makes adaptive management and restoration an arduous and challenging task. Groundwater flow has undergone severe alteration as a result of the channelization and drainage of the Everglades, and several areas of research are needed:

- Practical modeling of sheet flow hydraulics to build a basis for future predications of sea level rise and climate change scenarios.
- Defining critical regions throughout the Everglades and begin to integrate models, information and people to acquire a more holistic approach to define where we are and where we should be going in terms of groundwater management.
- Examining the decomposition and subsidence of peat and marl throughout the Everglades as a result of groundwater alteration and its impact on flows.

PLENARY SESSIONS SUMMARIZED

Despite the dense data sets available for the Everglades there are substantial gaps and deficiencies in our understanding of Everglades hydrology. These become especially important as we attempt to assess the impact of climate change on components of the hydrological cycle. This workshop attempted to assess the state of knowledge of the hydrologic cycle, and on model projections of future change. In so doing, we identified critical knowledge gaps and made recommendations for future action.

DISCUSSION GROUPS

Attendees participated in discussion groups that concentrated on the three primary influences of hydrology of the Greater Everglades: evapotranspiration, groundwater and precipitation. The discussion groups' were given charges to:

- Describe and identify key gaps in the current state of knowledge,
- Describe the anticipated effects of climate change on research goals,
- Determine ways to increase our understanding of the hydrologic cycle in the Everglades, and
- Identify key steps to be taken to prepare South Florida and the Everglades for climate change events.

Discussion groups were composed of a wide variety of individuals including hydrologists, modelers, meteorologists and biologists. Discussion leaders guided the dialog to answer the above inquiries. Results were presented to the entire workshop to discover knowledge gaps and to discuss any potential items that may have been overlooked by the groups.

Each discussion groups produced a list of Data Needs and Research Priorities. These lists were combined and categorized under the following topics: Sheet Flow, Groundwater, Evapotransporation and Climate Change and Sea Level Rise (SLR). Additional recommendations for outreach were also determined. The Data Needs and Research Priorities as well as the Outreach Recommendations are listed in the table on the back of this publication.

DATA NEEDS AND RESEARCH PRIORITIES

Sheet Flow	• Understand the hydraulic dynamics of the Greater Everglades sheet flow system.
	• Examine the effects of restored sheet flow after the completion of the Tamiami Trail (US 41) project. This is vital to understanding the larger picture of restored sheet flow throughout the restored Everglades.
	• Use sulfur hexafluoride as a tracer deployed using airboats to remotely sense flow.
Groundwater	• Conduct studies that focus on the interaction between groundwater and surface flow.
	• Establish additional groundwater survey wells.
	• Continue to monitor groundwater for saltwater intrusion. This is critical for determining the impacts on the aquifer system as a result of SLR.
	• Determine the potential ecological impacts of a shifting saltwater/freshwater interface.
Evapotranspiration	• Examine stomatal response to elevated CO2 levels and determine how CO2 levels affect transpiration pathways.
	• Conduct isotopic studies of water that could help to distinguish between the rates of evaporation and transpiration leading to more accurate estimates of ET.
	• Build additional towers to measure ET rates in both urban and rural areas.
	• Understand the effects of seasonal variations and the physiological differences of plant species throughout the Everglades. This is imperative for understanding ET rates.
Climate Change and Sea Level Rise	• Conduct experiments to study the effects of SLR on peat collapse in the Everglades.
	• Learn how to best manage Lake Okeechobee under drier conditions, including dike management and inflows.
	• Understand the trends in extreme precipitation events, such as tropically driven systems and droughts.
	• Examine how permanent temperature changes will affect the hydrologic cycle. This has not yet been given research priority.
	• Integrate adaptive resource management strategies to cope with the uncertainties of future climate changes.
	• Integrate SLR into natural resource and regional planning efforts.
	• Create replicable, accurate models that define the minimal scales required for the regional downscaling needs of South Florida.
	• Produce realistic and robust "what if...?" scenarios that include models with different levels of annual rainfall, e.g., 30, 50 and 70 inches.
	• Implement practical modeling of sheet flow hydraulics, which is needed to build a basis for future predictions of sea level rise and climate change scenarios.

OUTREACH RECOMMENDATIONS

- Work to improve the communication between scientists and the public to create a dialogue on how climate change may impact their lives.
- Build better media relations with the scientific community to effectively communicate climate change issues.

For more information, a full report of the workshop proceedings and discussions is available in the Summary Report: HYDROLOGY OF THE EVERGLADES IN THE CONTEXT OF CLIMATE CHANGE March 29-30, 2012, Florida Atlantic University, Boca Raton, Florida

To obtain the report please visit http://www.ces.fau.edu/climate_change/Hydrology_March2012

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FAU FLORIDA ATLANTIC UNIVERSITY

Impacts of Sea Level Rise on Florida's Domestic Energy and Water Infrastructure

Dr. Leonard Berry's Testimony

To

The United States Senate Committee on Energy and Natural Resources

April 19th, 2012

Washington D.C.

My name is Dr. Leonard Berry. I am the Director of the Florida Center for Environmental Studies, Distinguished Professor of Geosciences at Florida Atlantic University (FAU) and the Co-Director of the Climate Change Initiative at FAU.

Introduction

Florida is a special case for sea level rise; it is very flat with millions of people living along the coast. A large portion of the population relies on subsurface water which is being compromised by salt water intrusion due to the porous limestone underlying much of Florida. Sea level rise is also complicated by the threat of hurricanes and storm surge. Water management in Florida is highly organized, but will need major adjustments to accommodate our changing circumstances. Most adaptation responses will require a substantial increase in energy usage, which will test our already limited resources.

People and Sea Level Rise

Florida has a population of nearly 19 million people and this is projected to double in the next 50 years. Approximately 14 million people live along the coast. Most of our coastal assets are in low elevation areas where water supplies, roads, storm sewers, power grids and other infrastructure are at risk from storm surges and flooding at high tide. In view of the current sea level rise projections, the areas most at risk include: the Florida Keys, coastal and inland Miami-Dade County (the City of Miami is the 7th largest city in the country), coastal and inland portions of Broward County, the Florida Everglades, and the cities, Fort Lauderdale, Cape Canaveral, Charlotte Harbor, Cedar Key, and Pine Island Sound. All of these have elevations below two feet (Annex C).

Florida has recorded 5-8 inches of sea level rise in the past 50 years, and this intensifies existing water management issues. Future projections suggest 3-7 inches of additional rise by 2030 and 9-24 inches by 2060 (Figure 1).

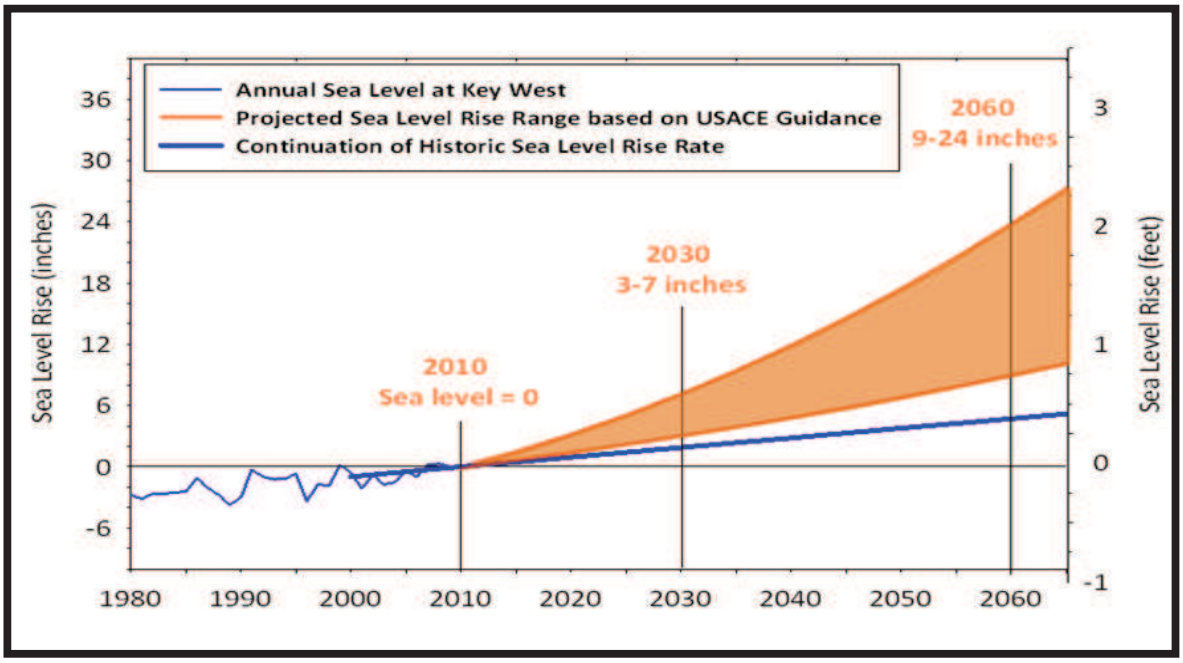


Figure 1: Southeast Florida sea level rise projections for regional planning purposes. This projection is calculated using the US Army Corps of Engineer's guidance (USACE 2009) intermediate and high curves to represent the lower and upper range for projected sea level rise. The historic Key West tidal data shows current trends. The recent rate of sea level rise from tidal data is extrapolated to show how historic rates compare to projected rates.

Florida Geology and Sea Level Rise

The porous limestone underlying much of Florida resembles Swiss cheese and makes the state particularly vulnerable to sea level rise. Due to this geological structure, building barriers to prevent sea level rise is often impractical and financially prohibitive. The coast is also vulnerable to periodic tropical storms and hurricanes with related storm surge: Hurricane Andrew had storm surges above 17 feet. Every increment of sea level rise adds to the devastation of storm surge. The combination of sea level rise, intense rainfall, and storm surge creates the on-going potential for major flooding.

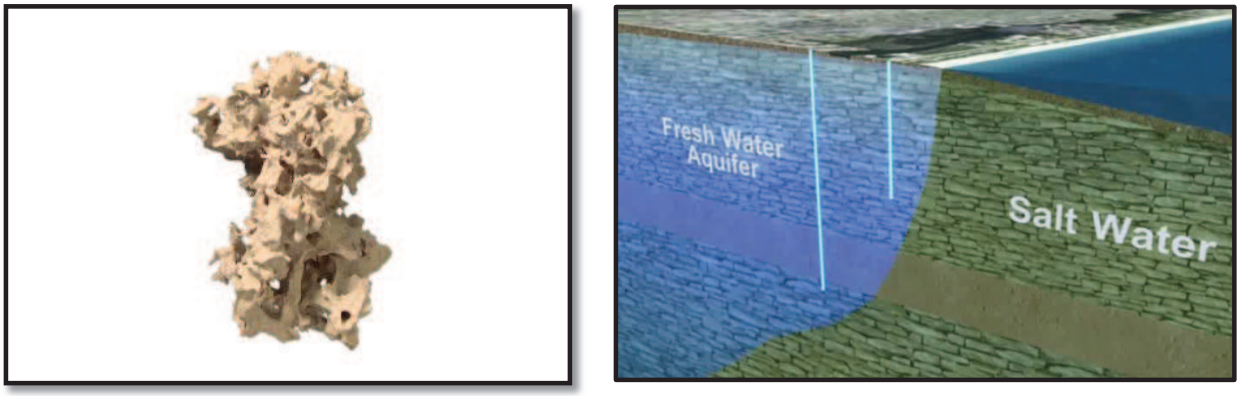


Figure 2: Swiss cheese-like limestone rock sample commonly found in South Florida (left) and the conceptual depiction of how sea level rise may accelerate saltwater intrusion affecting freshwater wellfields.

Impacts Already Identified

Sea level rise is already creating multiple complications in Florida.

1) Coastal Flooding:

   Even though Florida has experienced only a few inches of sea level rise, we are already seeing flooding at high tide due to the backup of drainage systems. This new phenomena occurs regularly at lunar high tides and is an indicator of future problems as sea level continues to rise.

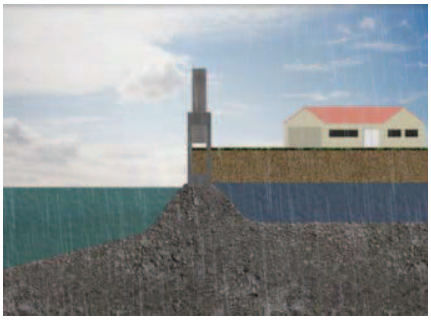
Figure 3: Miami Beach - Low Tide

Miami Beach - Peak-High Tide

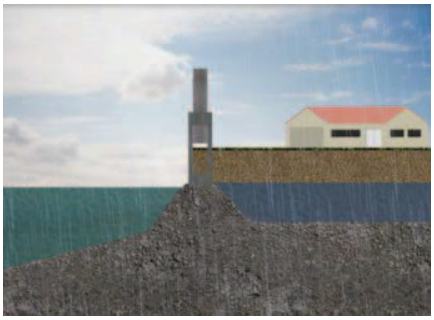
2) Flood Control Issues in Miami-Dade County:

   Sea levels were lower when South Florida's flood gates were constructed in the 1950s and 1960s. With the few inches of sea level rise that we've seen in the past decades, several of these flood gates are unable to discharge storm water at their design capacity during high tides.

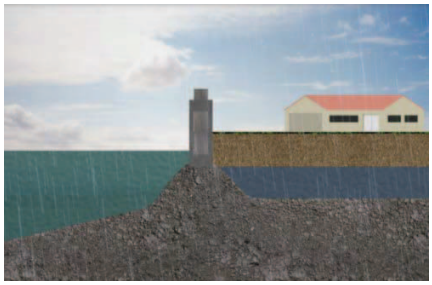
   There is already a multi-million dollar need to retrofit or rebuild many South Florida flood gates and a recent report finds that only six more inches of sea rise may cripple almost half the area's flood control capacity.



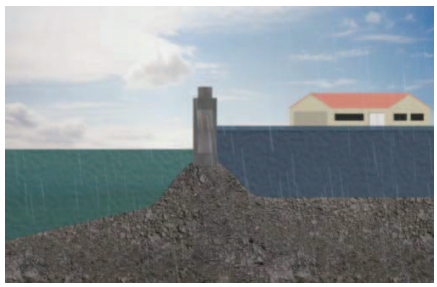
When it rains in South Florida



Excess water flows out to tide through dozens of water control structures along our coasts (an average of 1.7 billion gallons per day)



However, with sea levels rising…



…our flood control structures can no longer function effectively.

Figure 3: Conceptual depiction of the potential impact of sea level rise on coastal flood gates during storms and the increased threat of flooding inland due to insufficient discharge capacity.

3) Salinization of Aquifers

   Many coastal wellfields that withdraw freshwater from the productive Biscayne limestone aquifer are located along the coastal belt of the Lower East Coast. These wellfields are extremely vulnerable to saltwater intrusion due to rising sea level and drinking water extraction

   For example, because of sea level rise and salt water intrusion into fresh water wells, officials in the City of Hallandale Beach are spending $16 million to upgrade their storm water system and to move the city's entire drinking water supply westward. City officials understand that this is a temporary solution to a problem that will worsen in the coming decades.

Future Projected Impacts

1) Water Management – Much of the coastal flood protection infrastructure designed and built by the U.S. Army Corps of Engineers 50 years ago will lose its design capacity if the projected sea level rise for South Florida becomes a reality.
2) Vulnerable Real Estate - There are 4,315 square miles of vulnerable areas that include agricultural land, developed land, forests, mangroves, marsh and tidal flats, other swamp and forested wetlands, pastures, sandy beaches, scrub, grasslands, prairies, and sandhills. Also included are the southern parts of Everglades National Park, billions of dollars of residential real estate, hundreds of schools, hospitals, and hotels, as well as two nuclear reactors and hundreds of hazardous material sites.
3) Transportation Readjustment – A recent study emphasized the need for a detailed assessment of the implications for roads and other transportation taking into account 2060 projections for sea level rise. Local studies of South Florida and the West Central Coast show that some communities and major metropolitan areas such as Fort Lauderdale will lose parts of their transportation networks at this level of sea level rise.
4) Coastal well contamination – Coastal well contamination will extend further inland as sea level rise continues.

Figure 4: Saltwater Intrusion along the coast of South Florida (red line). Many wellfields and their protection areas are close to the saltwater intrusion zone potentially salinizing the freshwater wellfields in the future.

Most coastal communities in South Florida depend on wellfields that tap underground freshwater aquifers for their water supply. Saltwater intrusion into these aquifers is due to the current sea level and concentrated coastal development already threatens the region's water supply. Between the years 1995 and 2000, a compilation of data resulted in an approximate location of the freshwater/saltwater interface on the Lower East Coast (Figure 4). The heavily populated area from the Florida Keys to Palm Beach County is considered especially vulnerable. Many coastal wellfields which withdraw freshwater from the productive Biscayne aquifer are located along the coastal belt of the Lower East Coast and will be highly vulnerable if saltwater intrusion is accelerated due to rising sea level. A more detailed analysis is needed to identify the impact of projected sea level rise on selected utility wellfields that are at risk of saltwater intrusion.

Implications for Energy, Water, and Resource Management

Water is already heavily managed in Florida with extensive canal systems. These will need major retrofitting and reconceptualizing as sea level rises. Energy needs will grow rapidly with additional pumping needed both for water supply and drainage, desalinization (which is considerably energy intensive), and with increased cooling needs due to higher temperatures.

Power demands for additional water treatment cannot be supplied by the current grid infrastructure or installed capacity. The results of the current water/energy nexus evaluation suggest the possibility of conflicts over water supplies in the near future. To reduce this potential, resolution of water rights, water quality, and other laws will be important.

Due to the projected increase of energy demands, Florida will need to continue to explore alternative as well as traditional energy sources. There is widespread, long term potential in alternative energy sources such as solar energy, biofuels, and harnessing the readily accessible Gulf Stream as an ocean energy resource.

INITIAL ESTMATES OF ENERGY ADAPTATION AND COSTS

Trigger	Implementation Strategy	Cost
Immediate **0-0.5 foot sea level rise by 2030**	Install stormwater pumping stations in low lying areas to reduce storm water flooding (requires study to identify appropriate areas, sites and priority)	Start at $1.5 to 5 million each, number unclear without more study
	Water conservation	Start at $30 million + $1 million/year
	Armoring the sewer system (G7 program)	$12.5 million start, plus annual cost allocation
0.5–1 foot Sea Level Rise **2031-50**	Additional reclaimed water production	Over $25 million depending on permit requirements
	Aquifer recharge/salinity barriers	Up to $200 million depending on permit requirements
1 – 2 foot **Sea Level Rise** **2043-78**	Desalination	$45-50 million to convert + wells ($750,000 per MGD)
	Control flooding west of the coastal ridge	Start at $1.5 to 5 million each, number unclear without more study – at least a dozen would be need - $25 million

Table 1: Initial Estimates of Energy Adaptation and Costs (source: personal communication with Dr. Frederick Bloetscher, Florida Atlantic University.)

Responses

Many of Florida's decision makers are aware of these problems and are beginning to respond to them.

1) Organizations

Counties and cities are organizing to respond to sea level rise at the local level. The Southeast Florida Climate Change Compact is a unique partnership of four diverse counties and was formed precisely for the purpose of responding regionally to the impacts of sea level rise and other climate related phenomena. This organization has a detailed action plan and needs statement that is summarized in Annex A. One important contribution of this group is that they have identified the need for special adaptation action areas. Legislation incorporating this language was passed by the Florida legislature and signed into law in 2011. Federal adoption of similar legislation would not only benefit Florida but also other states vulnerable to sea level rise.

Coastal cities such as Punta Gorda, Florida, have invested in detailed adaptation plans to monitor and respond to sea level rise. Regional planning councils across the state have undertaken initiatives that will in part address sea level rise issues. Florida's Department of Economic Opportunity has established a multi-agency, multi-disciplinary focus group to address sea level rise future planning. The South Florida Water Management District is conducting extensive hydrological modeling and scenarios, along with collaborating with other organizations and agencies.

2) Research and Education

The Florida State University System is undertaking significant research programs and state and local projects on sea level rise monitoring and adaptation. These include the Florida State University System's Climate Change Task Force, the National Science Foundation-funded Coastal Areas Climate Change Education Partnership, the CLEO institute, the Resilient Tampa Bay Project, and a large-scale NASA/Florida Atlantic University project. The Florida Climate Institute is currently expanding to multiple universities and will continue and build upon the previously mentioned research and projects. Several state and federal agencies have on-going sea level rise studies, these agencies include: the Florida Department of Transportation, the Florida Department of Economic Opportunity, the Florida Division of Emergency Management, US Fish and Wildlife, NOAA, US Army Corps of Engineers, National Park Service, the US Geological Survey (USGS), the South Florida Water Management District and the Florida Department of Environmental Protection. The USGS and other agencies have on-going programs on the implications of sea level rise and Everglades' restoration. A major summit on the risk and response of sea level rise in Florida is scheduled for June 2012 (Annex B).

3) Data Gathering and Monitoring

There is an on-going need for a thorough vulnerability assessment, particularly for communities affected by sea level rise. Comprehensive data gathering is necessary. Monitoring environmental changes is vital to understanding the impacts of sea level rise. The USGS, in coordination with other local agencies, will need to establish a region-wide, formal saltwater intrusion monitoring network. Federal agencies will also need to develop and implement computer models to understand and predict both saltwater intrusion and flooding under future sea level rise scenarios.

The Cost of Inaction

It is important to note that:

1. For every dollar spent on hazard mitigation, society saves four dollars in the long term
2. When the mitigation efforts have been on flooding hazards, it is a five to one return on investment
3. The largest return on investment occurs when mitigation projects focus on reducing business interruption from loss of utilities. Most of Florida's utility infrastructure is underground, situated directly on the coast, and at risk.
4. Building resilience now will pay off tomorrow.
5. New coastal infrastructure and large scale, long term restoration projects (i.e. Everglades Restoration) may not be successful and may be a waste of resources and time if sea level rise is not accounted for in the planning and implementation.
6. There will be long-term societal costs as people move from their homes to inland areas.

What Should We Be Doing Now

1. We need to further identify areas and communities at special risk using the State of Florida Adaptation Action Area legislation. Efforts should be made to align Federal legislation with these critical state level policies.
2. There is an urgent need to incorporate sea level rise projections into all infrastructure and water management plans, including the Everglades Restoration. We can evaluate and better understand the value and utility of restoring freshwater flow. We need increased motoring activities, including additional National Water Level Program Networks (NWLON), which will be important in understanding and tracking changes in sea level rise for the state. Establishment of a state-wide saltwater intrusion monitoring network is also recommended.
3. We should be identifying future energy needs, including the cost of adaptation, for the coming decades, and moving towards traditional and alternative energy forms to meet these needs.
4. In addition, we need to utilize our past response to extreme events to create more sustainable community systems. Florida emergency management is already successfully working towards such initiatives.

Conclusion

The impacts of sea level rise are already a reality in South Florida and, as sea level rise continues, they will further impact all parts of Florida. The actions outlined above need to be taken now to increase our resilience and prepare for and minimize these impacts. People and organizations on the ground are already responding. We are delighted that, through this hearing, the US Senate is also responding. The people of Florida are already concerned about sea level rise as local awareness through major efforts has increased significantly. A larger role for the Federal Government is clearly warranted.

Additional Resources and References:

Florida Center for Environmental Studies: http://www.ces.fau.edu/
Florida Climate Institute: http://floridaclimateinstitute.org/
South Florida Water Management District: http://www.sfwmd.gov
Four County Compact: http://www.southeastfloridaclimatecompact.org/
Climate Central: http://www.climatecentral.org/
University of South Florida, Resilient Tampa Bay: http://sgs.usf.edu/rtb/index.php

RISK AND RESPONSE: SEA LEVEL RISE SUMMIT
THE FUTURE OF FLORIDA AND THE COAST
June 20-22, 2012 Marriott Boca Town Center, Boca Raton FL

Florida Center for Environmental Studies (CES)
Sea Level Rise Summit Summary

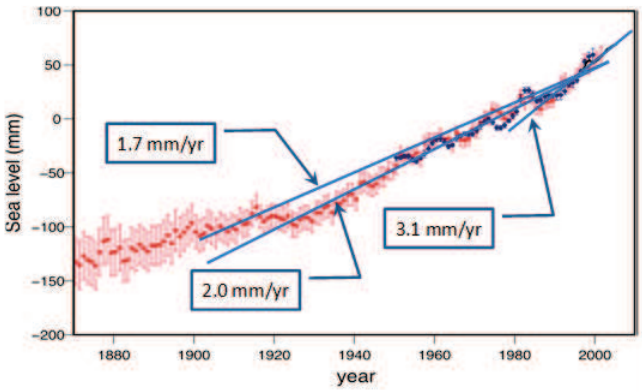
On June 21st and 22nd , 2012, The Florida Center for Environmental Studies hosted the "Risk and Response" Sea Level Rise Summit in Boca Raton, Florida with over 300 attendees from private and public agencies. The summit was sponsored by USGS, Florida Sea Grant, The Flora foundation, USF's Patel School for Global Sustainability, Coastal Areas Climate Change Education (CACCE), NOAA, Wells Fargo, NRDC, The Community Foundation of Palm Beach and Martin Counties, RenaissanceRe, The Northeast Regional Council, and The Florida Climate Institute. The purpose of the summit was three-fold:

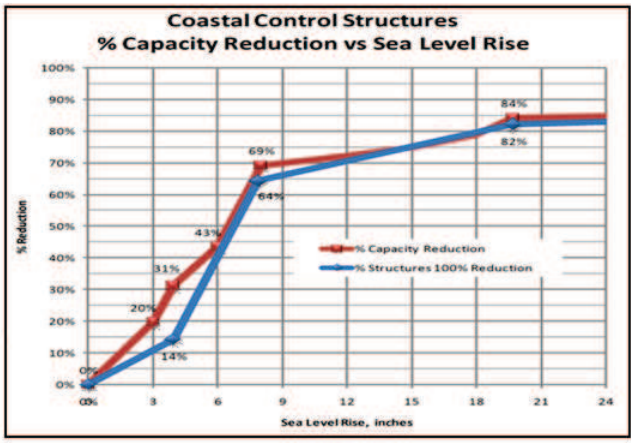
1. To highlight the interrelationships between sea level rise, saltwater intrusion into fresh water aquifers and water management in Florida;
2. To share the ongoing responses and adaptation planning of agencies, institutions and civic societies to sea level rise; and
3. To compare Florida's challenges and responses with other vulnerable localities in the US and worldwide.

The summit was opened by key note speaker Dr. Margaret Davidson, Director, NOAA Coastal Services Center and moderated by Daniel Kreeger, Executive Director, Association of Climate Change Officers (ACCO). It included seven panels that focused on the complex sea level rise issues in Florida and provided examples from other coastal regions within the U.S. and internationally.

Session One: **Sea Level Rise and Florida: "A Complex and Unique Relationship"** - The highlights of the session included current sea level rise rates, potential acceleration, and impacts that are already being felt.

- Sea level is rising and it is expected to accelerate. During much of the last century the global rate of rise is about 1.8mm per year. Since 1990 it has been 3.1 mm per year.
- The state has a high percentage of the nations risk due to these reasons:
  - In the US, 4.9 million people live below an elevation of 4 feet, 2.4 million of which are in Florida;
  - There are 107 towns and cities in Florida in which over half of the residents live below 4 feet in elevation (Strauss, 2012):
  - The limestone geology causes a rapid interaction between rising sea water along the coast, potentially impacting municipal well fields.
- Florida has current and future problems. Current impacts in Southeast Florida include: reduction in capacity of flood control structures (some of which are already experiencing impacts during high tide), salt water intrusion towards fresh water well fields (South Florida's primary source of drinking water), and the landward migration of fresh water wetlands that may experience peat collapse along the coast.





Left: Modified from IPCC, 2007
Right: Obeysekera, SFWMD, 2009

Session Two: **Managing Risk: Organizing for an Uncertain Future** - The focus of the session was Florida's mitigation and adaptation planning. Goals, such as flood protection and hurricane resilience, have economic and environmental benefits regardless of timing and scope. Key points included:

- Most of the money comes after a catastrophic event. During the redevelopment of areas affected by extreme events, sea level rise adaptations should be integrated into the long term recovery process.
- With climate change, we will see more complexity and less predictability; drivers will re-shape the way risk assessments are performed.
- Projects, such as the Community Resilience System Initiative, incorporate pre-disaster plans that assess vulnerabilities at the community level.
- Local communities are already starting to implement sustainability strategies. The City of Punta Gorda's adaptation plan, based on vulnerabilities and adaptations that the community identified and prioritized, integrates planned relocation.
- Exploration of new management options for beach restoration is necessary.

Session Three: **Economic Implications: From Insurance to Economic Well-Being** - The session highlighted how sea level rise impacts would affect insurance rates, real estate, land use and Florida's coastlines. Insurance in Florida is one of the biggest and most challenging economic issues.

- The panelists emphasized that the insurance industry is aware of sea level rise issues and already beginning to respond. Jeff Williams, Entergy, affirmed that much of the potential costly risk can be avoided by making strategic adaptation investments today.
- The insurance representatives addressed the importance of the insurance companies working with municipalities to plan and mitigate for future impacts instead of avoiding the sea level rise issues.
- Insurance companies struggle with an imbalance between keeping rates affordable while properly managing risk.
- The disaster safety movement and risk communication methods will induce changes in behavior.

Session Four: **Impacts on Built Environments: Urban Planning** - The panel discussed how urban infrastructure and housing are addressing projected increases in sea level rise.

- Panelists compared the impacts of sea level rise in South Florida, Northeast Florida, and Mexico.
- Each panelist identified an idealized vision for their region's future in which the built environment was reinvented for resilience. This included a redesign approach that focused on the short and long term adaptation for individual structures and organizations. Short term options ranging from water management that reduces flooding to increasing natural coastal defenses by installing mangrove buffers, will only delay the inevitable. However, short term adaptations are necessary to gain time to work on long term modifications like increasing standards and re-engineering coastal buildings to resist storm surge and sea level rise.
- In Miami-Dade alone, there are over 250,000 residential coastal structures, valued over $50 billion, which are currently vulnerable to storm surge (Alvarez, 2012).
- The panel noted that in Florida, there needs to be the same level of active response by officials to sea level rise as there has been in other areas. For example, San Francisco has been addressing sea level rise since 1989, New York is raising subway gutters among other measures, and New Zealand is paying for relocation.

Key West Airport May 7, 2012 (Rhonda Haag)

***Session Five*: Impacts on Built Environments: Water Utilities, Energy, and Transportation -** The session focused on how sea level rise would affect transportation, energy, water management and water utilities.

- A recent Florida Department of Transportation study identified roads that are vulnerable to sea level rise and showed that, in some areas, road base materials will fail from saturation long before sea level rise submerges roads.
- Flooding issues, a major concern in Florida, include the malfunction of gravity sewers due to inundation. This will require additional pumps to be installed, and therefore a large energy demand to power them. There are conflicts with current goals versus long term planning. For example, FPL had placed systems underground to avoid wind damage, but sea level rise is now a problem for these underground connections which decay with saltwater intrusion.
- New York City has developed an adaptation plan that balances climate change responses and it has attracted both political and professional support. The panelists identified the need to focus on risk management, which means reducing unacceptable risks to a tolerable level of risk.
- Agencies should be trained to identify the best risk management options for their scenario and how best to implement them. Choosing the "best" alternative requires a comparison of decision criteria-like benefits, costs, and probability of impacts. A single adaptation will seldom reduce risk to an acceptable level, therefore, risk management options often consist of multiple risk management strategies.

Photo credit: Paul Krashefski (Broward County)

***Session Six:* Collaboration: Organizational Structures -** Effective adaptation and mitigation programs and the importance of regional and local partnerships were the topics of this session. The key consensus was that climate change is not just an environmental issue, but also an economic imperative, requiring both mitigation and adaptation.

- Examples included the adaptive strategies of the Bay Area Plan in San Francisco. A map of the bay indicated the 240 square miles that had been filled during development and then showed them submerged due to projected sea level rise. The proposed adaptation is a triage-style solution in which areas are selected for either focused growth or limited development.
- The South Florida Regional Climate Compact is another example whose accomplishments range from mapping inundation and identifying regionally relevant infrastructure, to creating a regional greenhouse gas inventory, and a unified sea level rise projection. Expansion of the compact includes three counties to the north as part of the Seven50 Resilience Plan. The compact has been viewed as the most effective way of dealing with regional challenges and securing funds to address them. The panel emphasized the importance of maintaining involvement at the state level and of drawing attention to mitigation and energy policies.

- The final presentation was on the Florida Atlantic University's Climate Change Initiative's work on inter-university collaborations. Universities are organized to deal with specific problems, but climate change has such a complex nature that it requires an interdisciplinary approach. The solution is to rethink our partnerships and communication mechanisms, both within and between institutions, to develop interdisciplinary methods for dealing with climate change issues.

***Session Seven*: Public Engagement: Communication, Outreach and Education** - The public outreach and education session examined how climate change issues are being addressed in schools, universities and informal education venues. The session included examples of national climate change resources and networks that can used as models in Florida. The challenges of developing an acceptable climate change message and delivery mechanism for students, teachers, the general public and decision makers were addressed.

- NASA-funded "Climate Science Investigations (CSI): South Florida" focuses on online interactive modules using NASA data to improve climate and science literacy for teachers and students. Students conduct research and develop and deliver an argument regarding current climate change misconceptions.
- At the university level, the Florida State University System (SUS) has developed a comprehensive analysis of climate change education. A white paper was produced that identifies action items that could standardize and enhance climate change education across all SUS universities.
- The NSF-funded Coastal Areas Climate Change Education (CACCE) project aims to create innovative approaches and effective educational resources for teaching and learning about climate change.
- The Florida Aquarium provided many examples of outreach to families and the general public reaching an audience of 75 million per year. Aquariums, museums and zoos are often overlooked when addressing outreach on climate change and need to be included as valuable partners in future efforts.
- The Climate Literacy Network, responsible for the development of the Climate Science Literacy Essential Principles, includes individuals, projects, and organizations working to promote climate literacy. This is a national model that could easily be adapted in Florida.

Conclusion

The summit was concluded with a presentation by prominent climate scientist Michael Mann, Professor of Earth Systems Science at Penn State University. Dr. Mann is the author of the first peer-reviewed article documenting that the level of carbon dioxide in the earth's atmosphere has been increasing more rapidly in the last 100 years-- more than at any other time in history-- and is causing a rapid rise in atmospheric and ocean temperatures. Even though there is thorough and scientifically sound evidence that global warming is happening, there are many people that believe global warming is a myth. Dr. Mann noted how these beliefs and the politicization of the issue are major challenges that scientists are facing and provided gripping examples from his work as a climate scientist.

There was overwhelming enthusiasm and collaboration produced by the summit. Each session came together to form an interdisciplinary mosaic of useful adaptation and resilience plans to address sea level rise impacts on the economy, built environment, and vulnerable communities. The messages were echoed in the media. Coverage was given by local and national news outlets including: Tampabay.com, WPTV, Miami Herald, Fort Worth Star Telegram, The Florida Current, Charlotte Sun Herald, DeSoto Sun Herald, Englewood Sun Herald, Fort Meade Leader, Lake Wales News, North Port Sun Herald, Polk County Democrat, Gainseville Sun, and Venice Gondolier.

The key messages were the importance of education to increase awareness and creating partnerships to induce cost-effective best management practices that minimize risk. Compared to other parts of the world, Florida's projections of sea level rise present a complex challenge for municipalities, agencies and decision makers. Florida's unique location and geology require significant and innovative adaptations in infrastructure as sea level rises. Agencies, institutions, and government organizations are already responding to the reality of sea level rise. CES is continuing to work with its partners to identify and address the critical sea level rise issues discussed in each session. Please visit http://www.ces.fau.edu for updates. A full report of the summit will be available this fall.

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Florida Atlantic University joins Florida Climate Institute

BOCA RATON, FL (September 17, 2012) – Florida Atlantic University announced today that it will be joining the existing members of The Florida Climate Institute (FCI), the University of Florida (UF) and Florida State University (FSU), as well as three other Florida universities, to form a stronger coalition tasked with better understanding climate variability and change.

The FCI was originally developed 2009 by UF and FSU with the goal of adding complementary expertise from other universities in Florida. A clustering grant funded by the Board of Governors, awarded to UF, FSU and FAU, 2010 further emphasized the need for universities and external stakeholders throughout the state to collaborate (floridaclimate.org). The Florida Climate Institute will now be expanded to include Florida Atlantic University (FAU), University of South Florida (USF), University of Central Florida (UCF), and the University of Miami (UM) in order to reach this goal. With this broadened base of expertise, the group expects to increase the ability of each member university to compete for national and international funding programs.

The expanded organization will promote additional cooperation with the private sector with a Florida-centric focus to help develop a climate-ready workforce and to provide information about the climate-related risks that are unique to our state. This broadened institute will bring together outstanding scientists from multiple universities to conduct research needed by Floridians on climate change and sea level rise, and it will provide education on economic and environmental opportunities and risks.

"Interest in climate change and sea level rise has grown considerably in the past decade. Floridians need reliable scientific information about potential changes so that they can make decisions and policies that are economically beneficial and environmentally sound. This is particularly important given the wide range of opinions and, often conflicting, interpretations of

available evidence that are presented to the public," said Dr. Len Berry, Director of FAU's Florida Center for Environmental Studies and expert in the field of climate change.

For more information about the FCI or FAU's role in the organization, please visit
http://floridaclimateinstitute.org/
or contact
Nicole Hernandez Hammer 561-297-3451, nicole.hammer@fau.edu

-FAU-

About Florida Atlantic University:
Florida Atlantic University, established in 1961, officially opened its doors in 1964 as the fifth public university in Florida. Today, the University, with an annual economic impact of $6.3 billion, serves more than 30,000 undergraduate and graduate students at sites throughout its six-county service region in southeast Florida. FAU's world-class teaching and research faculty serves students through 10 colleges: the Dorothy F. Schmidt College of Arts and Letters, the College of Business, the College for Design and Social Inquiry, the College of Education, the College of Engineering and Computer Science, the Graduate College, the Harriet L. Wilkes Honors College, the Charles E. Schmidt College of Medicine, the Christine E. Lynn College of Nursing and the Charles E. Schmidt College of Science. FAU is ranked as a High Research Activity institution by the Carnegie Foundation for the Advancement of Teaching. The University is placing special focus on the rapid development of three signature themes – marine and coastal issues, biotechnology and contemporary societal challenges – which provide opportunities for faculty and students to build upon FAU's existing strengths in research and scholarship. For more information, visit www.fau.edu.

Press Release:

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OCEAN ACIDIFICATION RESEARCH PRESENTED IN MONTEREY, CA AND REVIEW PUBLISHED IN GLOBAL CHANGE BIOLOGY INTERNATIONAL JOURNAL BY FAU FACULTY IN BIOLOGY

BOCA RATON, FL (September 24, 2012) – Dr. Marguerite Koch, full professor in the Charles E. Schmidt College of Science, Department of Biological Sciences at Florida Atlantic University (FAU), has published a comprehensive review on climate change and ocean acidification effects on marine plants in a highly ranked international Journal entitled "Global Change Biology". She is presently attending a conference on Ocean Acidification "Third International Symposium on the Ocean in a High CO_2 World" in Monterey, California (September 23-27th) where she will be presenting her research being conducted at FAU's Gumbo Limbo Marine Laboratory. Ocean acidification is occurring because atmospheric CO_2 concentrations are rising rapidly and the oceans are acting a big sponge, capturing about 30% of the CO_2 from man-made sources every year. When CO_2 gets dissolved in the ocean seawater it releases H^+ which lowers the pH of the water and causing "ocean acidification". Oceans are also storing a large component of the earth's heat from greenhouse gases. Thus, climate change has two CO_2 problems-heating and acidifying the oceans which marine plants, just like land plants, will respond to.

The significance of marine plants in the oceans is that they fix inorganic carbon into organic food resources for fish and other marine animals. They are the natural agricultural sector for the oceans. Sometimes these plants can also create entire ecosystems with their structure, such as seagrasses forming meadows and macroalgae making up kelp forests and the Sargasso Sea seaweed. There is a reason fishermen look to the Sargasso seaweed "weedline" off the coast as a good place to fish-these algae are creating structure for an entire fishery, and sea turtles and other marine animals live in the seaweed too. These foundation marine plant communities are appropriately called "Ecosystem Engineers". Sometimes these large marine plants can also be a problem when they blanket coral reefs and negatively affect reef health.

In her review and research, Dr. Koch examines three important aspects of how climate change and ocean acidification will affect marine plants and their ecosystems. The first is how elevated dissolved inorganic carbon might increase ocean productivity. This might be good for fleshy algae and seagrasses, if they don't create too large of blooms, and become nuisance species. However, for many marine plants, particularly in the tropics, with calcified bodies that create the sediment on reefs and sites for corals to settle, may be negatively affected by ocean acidification. Their bodies are like chalk that with acid can dissolve or they have trouble forming the calcium carbonate crystals needed for growth. Finally, because Dr. Koch's lab is focused on tropical species, she is examining their thermal thresholds. For more information on Dr. Koch's research and information on ocean acidification see the links below.

Link to conference web site: https://www.confmanager.com/main.cfm?cid=2259&tid=32
Link to Dr. Koch's web site: http://www.science.fau.edu/biology/koch/
Link to NOAA web site on OA: http://www.pmel.noaa.gov/co2/story/Ocean+Acidification

Carbon Dynamics Research

Heterogeneity of biogenic gas ebullition in subtropical peat soils is revealed using time-lapse cameras

Xavier Comas[1] and William Wright[1]
Received 18 November 2011; revised 11 February 2012; accepted 7 March 2012; published 12 April 2012.
[1] We tested a set of biogenic gas traps combined with time-lapse cameras to investigate the heterogeneous nature of biogenic gas ebullition events in subtropical peat soils at both the laboratory and field scale. The main findings are: (1) ebullition events in peat soils are highly heterogeneous; (2) estimates of flux rate are directly influenced by temporal scale of measurement with rapid (i.e., hourly) releasing events exceeding daily averages by one order of magnitude; and (3) increases in atmospheric pressure result in gas release from shallow peat soils into the atmosphere (i.e., ebullition), as indicated by a positive linear relation between changes in biogenic gas content and changes in atmospheric pressure. These results suggest that biogenic gas releases from shallow subtropical peat soils are not constant with larger than average daily fluxes being potentially released within hours during periods of increased atmospheric pressure. Furthermore, this study also shows the potential of time-lapse cameras for autonomously assessing the temporal variation in biogenic gas flux to the atmosphere from peatlands, and questions what temporal scale of measurement should be appropriate to infer dynamics of biogenic gas release in peat soils.

Citation: Comas, X., and W. Wright (2012), Heterogeneity of biogenic gas ebullition in subtropical peat soils is revealed using timelapse cameras, Water Resour. Res., 48, W04601, doi:10.1029/2011WR011654.

Abstracts presented:

- Comas, X., Wright, W. J, and Heij, G. 2012. Using hydrogeophysical methods to constrain spatial and temporal dynamics of biogenic gas distribution and fluxes in peat soils of the Everglades. 9th INTECOL International Wetlands Conference, June 3-8, 2012. Orlando, FL.

- Wright, W. J, and Comas, X. 2012. Autonomous ground penetrating radar (GPR) measurements for exploring temporal dynamics in biogenic gas dynamics releases from peat soils in the Florida Everglades. 9th INTECOL International Wetlands Conference, June 3-8, 2012. Orlando, FL.

- Comas, X., and Wright*, W. J. 2011. Characterization of biogenic gas dynamics in low-latitude peat soils using hydrogeophysical methods. Abstract B21C-0267 presented at *2011 Fall Meeting, AGU*, San Francisco, Calif., 5-9 Dec.

Helpful Website Links:

Sea Level Rise Summit Summary available at http://www.ces.fau.edu/SLR2012/summary

Testimony to Senate Committee on Energy and Natural Resources: Impacts of Sea Level Rise on Florida's Domestic Energy
To see the full report including annexes, visit:
http://www.energy.senate.gov/public/index.cfm/files/serve?File_id=e0f5e6f1-34f1-4bd9-8243-8b3c77e1d27d

Florida Department of Transportation Report Summary: Development of a Methodology for the Assessment of Sea Level Rise Impacts on Florida's Transportation Modes and Infrastructure
Summary available at:
http://www.dot.state.fl.us/researchcenter/Completed_Proj/Summary_PL/FDOT_BDK79_977-01_sum.pdf
Full Report available at:
http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_PL/FDOT_BDK79_977-01_rpt.pdf