

Chapter 13

Climate Adaptations in the Southeast USA

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Climate adaptation activities are currently under way around the Southeast (SE). Efforts by local, state, and federal agencies include identification of relevant climate impacts, assessment of significant risks and vulnerabilities, and the creation of partnerships to support planning. In addition to specific projects, adaptive capacity also is being established through monitoring, research, and outreach. This analysis draws on multiple efforts to inventory adaptation in the SE. The authors of this chapter identified few advanced examples of plans and projects that have been implemented. However because of the number of efforts, diversity of groups involved, the mainstreaming of efforts, and the differences in how those efforts disseminated, this review may not fully represent adaptation activity in the SE.

The majority of current efforts are aimed at identification of relevant climate risks and assessment of risk and vulnerability. Coastal areas, where risks of severe storms and sea level rise (SLR) are highly salient, are frequently the focus of attention. Efforts to bring climate change adaptation strategies and methods into mainstream activities often are done through projects that focus on resilience and sustainability. The adaptation process is complex and must include partnerships for cross-disciplinary coordinated response from many sectors including financial, technical, governance, and social.

In the future, as groups move from risk and vulnerability assessments to strategic adaptation planning and implementation, the authors anticipate a shift in activities and information needs that place great emphasis on costs, benefits, and co-benefits of adaptations. As efforts advance, evaluation of adaptation efforts will become important in decision making.

This review of climate adaptation programs and activities in the SE begins with an introduction to broad adaptation research questions and then introduces major stresses currently confronting regional adaptation needs. Existing stresses likely will increase the potential negative impacts of future climate changes. This summary picks up from the 2009 National Assessment report (Karl et al. 2009) that included some discussion around adaptation efforts in this region and the nation, and provides an overview of recent adaptation activities and example case studies.

Key Findings

- ▶ Although many climate adaptation efforts are underway throughout the Southeast, it is difficult to document the full extent because of increasing levels of involvement, the diversity of entities involved, and integration of adaptation into other planning processes.
- ▶ Adaptation activities cross all scales of planning from nongovernmental organizations (NGOs) to local communities, states, regions, and federal agencies.
- ▶ Many adaptation efforts are being included into other processes. As a result, adaptation is taking place in the context of resilience and sustainability efforts.
- ▶ To the extent that current adaptation catalogs and databases accurately represent ongoing activities, the present focus of adaptation in the SE is on identifying relevant climate impacts and building partnerships to foster coordinated responses and sharing of resources. These partnerships foster additional aspects of adaptive capacity.

- ▶ Adaptation planning projects that have reached the stage of risk and vulnerability assessment are mostly focused on sea level rise and severe storm threats facing coastal areas and communities.
- ▶ Examples of undertaking full adaptive management approaches to the threats and uncertainty are limited.
- ▶ There is little information on the costs, benefits and co-benefits of adaptations to guide adaptation planning.

13.1 Definition of Adaptation

Climate adaptation can be defined as the “adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects” (NRC 2010a). Questions that lead to an understanding of the adaptation process initially are descriptive: Who is adapting or not? To what are they adapting? How, when, and why are they adapting? Answers to these questions provide a foundation for further questions including the following:

- How does the understanding of climate change and potential consequences or opportunities motivate a response?
- How do other stresses interact with potential climate impacts and influence adaptation options?
- How do individuals, sectors, groups, and governments differ in their capacity to adapt?
- How are adaptation options being evaluated?
- What are the barriers, constraints, and limits to adaptation and how can they be overcome?

Adaptive responses can vary in several ways, including by what motivates them. Some responses are “anticipatory” or planned in response to real or perceived information about expected climate changes. Other responses are “autonomous” adaptations taken in response to indirect signals such as changes in regulations or markets.

The process of adaptation can be conceptualized as a series of steps moving from developing an understanding of current and future climate changes related to the system of interest, assessing vulnerabilities and risks, evaluating management options, implementing strategies, monitoring outcomes, and re-evaluating those analyses and decisions (Figure 13.1). The process generally prescribes multiple iterations to incorporate new information and changing conditions. The emphasis on risk management and identification of opportunities and co-benefits differs among frameworks, but there is good consistency at the conceptual level that this is a critical piece to adaptation (e.g., NRC 2011, NRC 2010b, UKCIP 2012).

Practical applications of adaptation rarely proceed in the tidy, sequential manner of a concept diagram such as Figure 13.1. Because multiple groups of people are involved steps must be repeated to account for differences in planning schedules, organizational timelines, and priorities. Some activities may be out of step with others at any specific time. Examples of the ongoing processes for these steps are outlined later in the chapter.

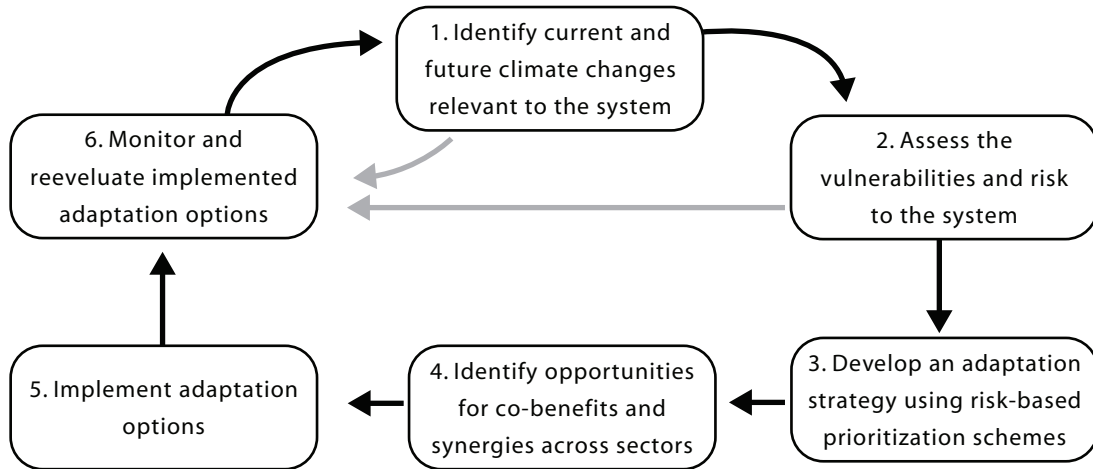


Figure 13.1 Adaptation planning is envisioned as a cyclical, iterative process incorporating these six steps (NRC 2010a).

While not focused on the southeastern USA, there is substantial research literature associated with each of these six steps (for example, NRC 2010a). However, because interest in climate adaptation is relatively recent, for each subsequent step in the process, the fraction of empirical work on climate change adaptation becomes substantially thinner and that of conceptual contributions and insights garnered from related or analogous topics swell.

Efforts are ongoing to engage stakeholders of all types in assessing the significance of climate to their areas of interests. Information about stakeholder needs is integral for research projects as well as for making decisions about adaptation to climate change effects.

When making risk and vulnerability assessments, researchers and planners need to consider other stresses, such as population growth and land development, which likely will interact with climate change in shaping vulnerabilities. Identification of relevant impacts and analysis of risks and vulnerabilities are important foundations to setting risk-based priorities. In addition, processes for risk-based priority setting and analysis of opportunities for co-benefits frequently require information from socioeconomic scenarios and climate projections as well as institutional and economic analyses. While several studies have considered potential losses to SLR, there is less consideration of economic evaluations of adaptation alternatives (Bin et al. 2011).

Other research addresses the arrows connecting the steps highlighted in Figure 13.1. These projects seek to understand the processes that influence the pace, difficulty, and resources required to move from one step to the next. For example, some of the practical complexity is related to the diversity of actors and sectors working at different social and geographical scales and institutional needs for coordination (NRC 2010a and 2010b). Another significant body of work focuses on understanding the factors that increase the capacity to adapt. These include governance, financial, technological, and social resources, and are sometimes expressed through the creation of networks.

Some strategies emphasize the value of incorporating new adaptation activities and policies into existing planning and management efforts, a process called mainstreaming. Mainstreaming is especially valuable when climate change may exacerbate extant stresses. In the SE, mainstreaming might include strategies that address population growth, hurricanes, tropical storms, SLR, land subsidence, and drought. Mainstreaming is often recommended because it offers the option to reduce current risks while increasing preparedness for potential future risks. Benefits also include using existing institutions to avoid duplication of efforts, to increase coordination, and to build on existing support and networks across levels of organizations and governments. Note though, that mainstreaming faces the challenges and limitations faced by existing institutions. The following section provides a brief review of the current climate and related stresses in the Southeast and situates the subsequent discussion of adaptation efforts.

13.2 Major Stresses on the Southeast

The Southeast is vulnerable to a number of direct and indirect impacts from the current range of climate variability and the significant challenges posed by climate change (Karl et al. 2009, and also see Chapter 2 of this report). Adaptation is complicated by other changes within the region and internationally, such as population issues, agricultural markets, changes to natural ecosystems, and economic fluctuations. Four major regional challenges facing multiple sectors are discussed in the following paragraphs.

Population Growth

The southeastern region's moderate climate has been a population-growth driver since the development of air conditioning (Svart 1976, Graves 1980). The region is vulnerable to rising summer temperatures that increase energy demand, which is already high during summer months due to demands for residential and commercial cooling (Karl et al. 2009, also see Chapter 2). The population is also at risk to potential spread of disease vectors with changing climate conditions (e.g., Morens and Fauci 2008; Karl et al. 2009; also see Chapter 3).

Residential and business development has typically increased populations in coastal areas and major metropolitan centers (US Census Bureau 2011). These areas are vulnerable to climate change effects, such as sea level rise, droughts, floods, stronger hurricanes, and unstable weather patterns (Karl et al. 2009). Miami, according to one set of climate predictions, ranks internationally as the number one metropolitan area likely to be exposed to coastal flooding by 2070 (Hanson et al. 2011). In the same analysis, New Orleans is ranked number 12 and Virginia Beach number 19. For coastal areas, retreat from SLR may prove difficult. For example, retreat by the City of Satellite Beach, Florida, will be restrained because 98% of the land is developed and there is no room for expansion away from encroaching sea level (Parkinson and McCue 2011).

Research on land use planning along the Atlantic coast indicates that many state and local governments experience high development pressures in low lying coastal areas, which is unlikely to change as coastal regions are desirable locations for residents and businesses (Table 13.1). In addition, local governments benefit from the higher property taxes of coastal properties, so there is little financial incentive to curtail development.

Table 13.1 Intensity of Development of Land along Atlantic Coast (USA) Land within 1m above High Water.

State	Likelihood of shore protection ^a					Area	
	High	↔		Low			
	Percent of dry land, by land use type ^b						
	Developed (%)	Intermediate (%)	Undeveloped (%)	Conservation (%)	Dry land (km ²)	Non-tidal Wetlands (km ²)	Tidal Wetlands (km ²)
MA	26	29	22	23	110	24	325
RI	36	11	48	5	8	1	29
CT	80	8	7	5	30	2	74
NY	73	18	4	6	165	10	149
NJ	66	15	12	7	275	172	980
PA	49	21	26	4	24	3	6
DE	27	26	23	24	126	32	357
MD	19	16	56	9	449	122	1116
DC	82	5	14	0	4	0	1
VA	39	22	32	7	365	148	1272
NC	28	14	55	3	1362	3050	1272
SC	28	21	41	10	341	272	2229
GA	27	16	23	34	133	349	1511
FL	65	10	12	13	1286	2125	3213
Total	42	15	33	9	4665	6314	12882

^a High and low refer to the likelihood that a type of land may already be, or will be, protected by shore protection measures. Developed areas are more likely to be protected by bulkheads, dikes, or beachfill, while conservation areas are more likely to be allowed to respond naturally to shore processes.

^b Calculated as the statewide area of a given land use category divided by the area of dry land in the study area. Percentages may not add up to 100% due to rounding

(Adapted from Titus et al. 2009, Table 1, p. 5)

Tourism

The economic importance of tourism in the Southeast complicates adaptation efforts (e.g., Evans 2004, Murley et al. 2005, North Carolina Department of Commerce 2012). In the Gulf Coast region, for example, 8% of jobs are in the tourism and recreation industry. Consequently, public infrastructure and private investment are geared toward a combination of permanent and seasonal populations along the coastline. Such investment increases exposure to losses due to SLR, storm surge, and wind damage from tropical storm systems. Exposure to risk is also increased due to the geomorphic characteristics of the most populated coastal areas. The majority of Atlantic coastline areas that

Box 13.1*Process for Identifying Adaptation Activities in the Southeast*

These observations are based on an extensive investigation to identify adaptation activities taking place in the Southeast. The following summary is based on a compilation of adaptation actions identified by the Georgetown Climate Center Adaptation Clearinghouse, (Georgetown Climate Center 2012); the NOAA Coastal Services Center database of Coastal Climate Adaptation/Action Plans (NOAA CSC 2012), case studies in the CAKE database (Climate Adaptation Knowledge Exchange 2012), the Gulf of Mexico Climate Change Adaptation Inventory (NOAA Gulf Coast Services Center 2012), contributions from researchers contributing to the Southeastern Region Technical Input to the National Climate Assessment, and additional research conducted by Regional Integrated Sciences and Assessments teams in the Southeast. The types of documents represented included planning documents, government reports, workshop reports, peer-reviewed publications, research reports (not peer reviewed), and website reports. This body of information represents the triangulation of efforts across the groups of researchers mentioned above. The cases presented represent

publicly available information and are likely to under represent actual adaptive efforts on-going in the region for at least three reasons. First, the documents reviewed are publicly available and they likely under represent efforts undertaken by private entities or organizations, such as energy or manufacturing businesses. A second reason is that the cases represented are biased towards planned rather than autonomous forms of adaptation. Finally, reluctance of some groups to publicly engage with the climate change controversies is a potential source of under representing of adaptation activities in the Southeast. Research by Carolinas Integrated Sciences Assessments (2012 draft in preparation for the National Climate Assessment) indicates that while some entities are undertaking climate adaptation activities, they consciously avoid publicly identifying these activities as adaptation actions in order to avoid political controversy around climate change. Instead, some highlight co-benefits, such as reduction of risks to current hazards, which might build resilience, water efficiency, and energy efficiency.

experienced the greatest population increase are historically rapidly shifting and highly dynamic barrier island systems (Culver et al. 2011). The large investment in infrastructure and employment tied to coastal tourism could hinder the ability to adapt rapidly to tipping points and threshold responses in the climate system (Frazier et al. 2010).

Sea Level Rise and Land Subsidence

The geomorphic setting and the length of the coastline in the SE and Caribbean mean that SLR is likely to be one of the most immediate, widespread, and potentially damaging impacts of climate change (Thieler and Hammar-Klose 1999, Titus and Richman 2001). Many of the southeastern coastal areas are low in elevation and vulnerable to SLR. Additionally, many areas are prone to land subsidence due to the presence of organic soils and water soluble rock substrates. Extensive withdrawals of groundwater for drinking and for industrial processes exacerbate hydrologic conditions. Withdrawal of oil and gas promote further subsidence, which enhances the vulnerability to present

and future sea level rise. In some cases, subsidence is the primary cause of relative changes between land surface elevation and sea level (Dixon et al. 2006).

Vulnerability to SLR is also enhanced by storm surge from tropical cyclones. As sea level rises, storm surge likely will move further inland along low-lying coastal areas (Mousavi et al. 2011). Many communities along the southeastern coast are built on soils that are highly porous and permeable, which means that hard barriers, such as levees and seawalls, will not be effective because SLR will increase hydrostatic pressure and force water to flow beneath or behind the structures (Parkinson and McCue 2011). Barriers also potentially create a false sense of security that could encourage continued building and place more people and property at risk from events that may exceed infrastructure design as we saw when Hurricane Katrina broke the levees in New Orleans.

Advance warning systems and improved evacuation procedures and infrastructure are crucial for human safety. Under climate change projections, property and infrastructure damages likely will increase substantially, affecting cost and availability of insurance, energy, property; as well as changes in local, state, and federal policies (Irish et al. 2010, Bin et al. 2011, Neumann et al. 2011). Increases in tropical storm intensity as opposed to frequency have been projected by recent climate models (Knutson et al. 2010). Globally tropical storm intensity is projected to increase by 2% to 11% by 2100 and associated rainfall by roughly 20% (Knutson et al. 2010). Globally, the frequency of intense hurricanes also is expected to increase (Knutson et al. 2010).

Drought and Water Supply

Climate-related issues likely will challenge adaptation by threatening water supplies in the SE. Many large metropolitan areas depend on surface water supplies to meet potable and industrial water needs. Many other cities, including Charlotte, NC, and Atlanta, GA, rely on rivers and associated reservoirs. Urban groundwater resources are also at risk. For example, the Southeast Florida Regional Climate Change Compact includes threats to drinking water supply due to salinity intrusion among its priorities (<http://www.southeastfloridacclimatecompact.org/>).

Drought conditions exacerbated by climate change likely will affect the reliability of water sources. The National Integrated Drought Information System (NIDIS) has been working with stakeholders, including state and federal agencies, to pilot a drought early warning system for the ACF basin (NIDIS 2012). Other strategies will need to be developed in the SE to appropriate water fairly and efficiently.

13.3 Adaptation in the Southeast

Adaptation efforts in the SE either focus on the early stages of identifying climate risks relevant to communities, ecosystems, and businesses or on assessing risks and vulnerabilities. Much activity focuses on coastal areas and existing stresses. Despite the review and search efforts undertaken and described in Box 13.1, we believe that the identified information is an indicative, rather than comprehensive, summary of overall trends in the Southeast.

This review of adaptation activities in the SE uses the six-step process of adaptation (Figure 13.1) as an organizational framework for assessing the current status of efforts.

In the figure, the boxes mark a step in the process while the arrows represent the efforts needed to achieve each step. Our assessment provides numerous case study examples of the projects that mark achievement of a step as well as the process-related activities represented by the arrows. In the absence of a significant body of peer-reviewed research or other broad adaptation assessments, case studies are used extensively to illustrate the types of activities taking place. Various efforts are also underway to support the development of adaptive capacity in the region by developing educational outreach programs (Chapter 14), tools, and organizational resources. Along with the case studies are descriptions of a few of the many tools that have been developed by researchers and practitioners that are applicable to the southeast region. This section concludes with short descriptions of some organizations located in the region whose goals include assisting the region to adapt better to a changing climate. The review of tools and organizations is not exhaustive but indicative of the diversity of actors and efforts.

Step 1: Identify Current and Future Climate Changes Relevant to the System

Many entities in the region have recognized that current climate variability and future climate changes will require adaptation planning, although the planning may be in a very early stage or not yet formally underway. A wide variety of entities are involved in organizing conferences, workshops, listening sessions, and other forums for identifying concerns. For example, the National Conference of State Legislatures published a series of reports on potential risks to states, including Georgia, North Carolina, and Tennessee (National Conference of State Legislatures, 2008a, 2008b, 2008c). Listening sessions held along the Albemarle Sound elicited concerns of residents about climate change impacts on culture and livelihoods as well as physical changes (Brown et al. 2010).

Ongoing monitoring together with associated outreach and research efforts by federal agencies such as the National Weather Service, the National Atmospheric and Oceanic Administration, and the United States Geological Survey support the identification of current trends and risks. EPA Region 4 convened a workshop on adaptation in the Southeast which brought together over 200 representatives of federal government; state, tribal, and local governments; academia; the private sector; and nongovernmental organizations (NGOs) in February 2010 (Stratus Consulting 2010b). Other examples of federal efforts are included in the following sections.

Among the eleven SE states, Puerto Rico and US Virgin Islands, six have completed climate action plans (The Center for Climate Strategies 2012). Five of the six with climate action plans, Arkansas, Kentucky, North Carolina, South Carolina, and Virginia, have been recommended to start adaptation planning as part of their comprehensive climate action plan (The Center for Climate Strategies 2012). Florida's climate action plan included a section on adaptation (The Center for Climate Strategies 2012).

An analysis of 48 cities in the SE with populations greater than 100,000 found that six of these large cities have also recommended adaptation planning as a part of their climate change plans although those plans were not complete. These cities included Miami and St. Petersburg, FL; Atlanta, GA; Louisville, KY; New Orleans, LA; and Greensboro, NC. Since the time of that study, Greensboro, NC has integrated climate

issues into their sustainability plan (Community Sustainability Council 2010); Miami is a member of the Southeast Florida Climate Change Compact and has completed a city plan that calls for adaptation planning (Community Sustainability Council 2010). It is likely that there are other communities whose actions are not yet integrated. For example, the comprehensive plan for Beaufort, SC calls for addressing SLR (Beaufort County South Carolina 2010).

A 2008 survey of experts and decision-makers working in the Florida Keys reported widespread concern about climate-related impacts. At that time only 5% of those surveyed reported that their organization or agency had a climate adaptation plan and less than 1% reported having participated in community discussions, state, or federal climate change. Since the time of that study, other initiatives, including the Southeast Florida Climate Change Compact (see discussion following) and the Climate Action Plan for Florida Reef (The Nature Conservancy 2010) have increased engagement in this area.

Step 2: Assess the Vulnerabilities and Risk to the System

Several efforts are underway to conduct risk and vulnerability assessments to inform adaptation processes. Multi-sectoral vulnerability analyses to inform adaptation are underway in Puerto Rico (see discussion following) and North Carolina (see Step 4). Many efforts reflect existing pressures on coastal areas and give particular attention to tropical storms and SLR (Stratus Consulting Inc. 2010a). Louisiana is updating its Coastal Master Plan to incorporate both planning and action-ready projects that among other things address resilience to rising sea levels 50 years into the future (<http://www.coastalmasterplan.louisiana.gov>). The Southeast Florida Regional Climate Change Compact addresses water resources and includes a substantial effort to develop a shared regional understanding of local SLR scenarios to underpin developing adaptation plans.

Other efforts include work by government agencies, private sector, and non-governmental organizations. For example, America's Energy Coast, Entergy, and America's Wetland Foundation undertook the development of a framework and a fact base that allowed the quantification of the climate risks for energy infrastructure in the US Gulf Coast. They also developed an economic analysis of the costs to secure/adapt that energy infrastructure (America's Energy Coast 2010). Work by the Department of Defense illustrates a case-based approach designed to inform a broader vulnerability assessment of military facilities in the SE to be conducted in the future. NASA is assessing local risks and vulnerabilities to inform adaptation at five facilities in the Southeast. Both of these federal efforts recognize the substantial facilities along the coast. There are several conservation-oriented efforts including the USGS Southeast Regional Assessment Project, the Florida Reef action plan, the North Carolina Coastal Habitat plan, and the Kentucky wildlife plan (Dalton and Jones 2010, The Nature Conservancy 2010, Kentucky Department of Fish and Wildlife Resources 2010, North Carolina Department of Environment and Natural Resources 2010).

The Puerto Rico Coastal Adaptation Project and the Puerto Rico Climate Change Council. The Puerto Rico Coastal Adaptation Project, PRCAP, is a two-year effort from 2010 to 2012 that was initiated to collect and synthesize information about climate change risks to Puerto Rico through increasing coordination of efforts and compiling

all best available scientific and local knowledge (Puerto Rico Coastal Management Program 2011). PRCAP is a partnership of the Puerto Rico Department of Natural and Environmental Resources and Coastal Zone Management Division (PRCZMP), and involves more than 130 scientists, planners, practitioners, and communication experts. It is developing a comprehensive climate change vulnerability assessment and recommended adaptation strategies for Puerto Rico. The project supported the establishment of the Puerto Rico Climate Change Council (PRCCC) in November 2010. The PRCCC is working to accurately assess vulnerability of life and property and to identify and assess feasible adaptation strategies for government, the private sector, non-profit organizations, and civil society.

The PRCCC collaboration is working towards the following objectives:

- To use the best available scientific knowledge to identify the communities and ecosystems most at risk from coastal hazards and climate change.
- To identify, assess, develop, and prioritize effective adaptation strategies and policies that could be implemented in Puerto Rico.
- To communicate findings, consensus, and recommendations to government, civil society, the media, and the private sector.
- To cultivate a well-informed Puerto Rican society about coastal hazards, climate change adaptation, and mitigation.

The PRCCC identified communication and sharing of information as an early priority. Their newly created Puerto Rico Climate Research Library has more than 480 documents related to climate change and the Caribbean and they have established a PR-CC-Listserv for announcements and sharing of relevant publications.

Southeast Florida Regional Climate Change Compact. The Southeast Florida Regional Climate Change Compact (referred to as the Compact) (<http://www.southeastfloridaclimatecompact.org/>) was signed in 2009 by Broward, Miami-Dade, Palm Beach, and Monroe Counties and is an example of the development of a regional resilience perspective and response to issues of climate concern that will impact the region as a whole and not just a particular county or community. The Compact has four major purposes: (1) to develop a regional cooperative response strategy to climate changes; (2) to encourage federal funding to support regional action plans; (3) to respond to proposed state and federal climate policies and legislation; and (4) to devote resources including staff time to support the development of the Southeast Florida Regional Climate Change Action Plan, including both mitigation and adaptation strategies.

Managing water resources is a primary focus of the Compact and that includes freshwater supply (considering changes in rainfall patterns) and storm water management (especially under the potential for stronger storms). SLR is also a critical stressor for the cooperating counties.

There are numerous successes as a result of the Compact in the areas of governance, policy, planning, and communication, as well as in unified positions on state and federal legislation and appropriations. Also a new amendment to Florida Statutes now allows for the creation of "Adaptation Action Areas" where local governments may implement special policies for areas that are particularly vulnerable to SLR and coastal flooding.

Another success was achieved through a series of consultations and technical input resulting in the four cooperating counties agreeing to a unified SLR projection out to 2060 that they will use for planning and communications. They have also established a suggested trend and range of future SLR projections out to 2110, and while these further projections are not being put up for immediate adoption they will provide a sense of future trends for longer term and large scale investments in the region.

The white paper discussing the unified SLR projections can be found online at: <http://www.broward.org/NaturalResources/ClimateChange/Documents/SE%20FL%20Sea%20Level%20Rise%20White%20Paper%20April%202011%20ADA%20FINAL.pdf>

Adaptation efforts by the Department of Defense. The Department of Defense (DoD) recognizes that climate change presents increased challenges for current and future missions, built infrastructure, and natural ecosystems on military lands. The 2010 Quadrennial Defense Review (DoD 2010) states that “the Department (of Defense) must complete a comprehensive assessment of all installations to assess the potential impacts of climate change on its missions and adapt as required.” DoD increasingly is focusing on the need to develop adaptation approaches for identified climate change vulnerabilities and impacts. Several research projects are currently underway on southeastern USA installations that will support vulnerability and impact assessment and adaptation planning for climate change. Current adaptation research and planning initiatives for the SE NCA region are administered by the DoD Strategic Environmental Research and Development Program (SERDP). These efforts consider both built and natural infrastructure. More information is available through SERDP (2012), USACE (2010), and US Navy (2012).

Climate adaptation at NASA Centers in the Southeastern USA. The National Aeronautics and Space Administration (NASA) is concerned about the possible impacts that climate change will have on NASA Centers across the USA and has many facilities of concern in the SE. As a proactive measure, NASA has implemented a Climate Adaptation and Science Investigation (CASI) wherein each NASA Center is assessing its risk and vulnerability to climate change, and developing adaptation measures and plans for potential climate-induced threats. The five NASA Centers in the SE are: Stennis Space Center (SSC), MS; Kennedy Space Center (KSC), FL; Langley Research Center (LaRC), VA; Wallops Flight Facility (WFF), VA; and Marshall Space Flight Center (MSFC), AL. Three of these Centers, KSC, LaRC, and WFF, are located on the Atlantic Ocean; SSC is located very near the Gulf of Mexico. Consequently, the major climate change threats to these Centers are SLR, flooding caused by severe storms (principally hurricanes), and in the case of LaRC and WFF, land subsidence. For each Center, CASI efforts have developed projections for the 2020s, 2050s, and 2080s—these projections include average temperature, average precipitation, SLR, SLR under a rapid ice melt scenario, days with maximum temperatures over 90°F and days with minimum temperatures at or below 40°F or 32°F (Rosenzweig and Brown 2009, Rosenzweig et al 2011).

Given these projections, each Center is developing plans for implementation of adaptation strategies to mitigate the overall effect of climate change impacts on facilities, property, the workforce and the environment. Personnel at the five SE NASA Centers are conducting research under the aegis of CASI that further elucidates the potential

impacts that climate change will have on the respective Centers as a foundation for constructing adaptation strategies.

Southeast Regional Assessment Project (SERAP). The Southeast Regional Assessment Project (SERAP) is a prototype for the type of studies that the Department of Interior Climate Science Centers will develop to explore and project ecological responses to climate change and inform natural resource managers on strategies for conserving wildlife and cultural resources. SERAP is working in the southeastern USA in an area that includes all or parts of 15 states. Work began in 2009, and SERAP is scheduled to complete most products during 2012. This section summarizes a report on SERAP (Dalton and Jones 2010).

SERAP takes a multi-disciplinary approach that includes modeling of key physical, ecological, and socioeconomic processes to aid the development of robust adaptation strategies. Improving the robustness of decisions is primarily achieved by identifying and quantifying the sources of uncertainty in model projections, and propagating this uncertainty through to the different modeling components. Physical processes that are modeled include local climate change impacts, shoreline change due to SLR, fire frequency, and streamflow conditions. Social and economic changes are simulated by modeling urban growth. Ecological responses are simulated through projections of vegetation dynamics that are used to predict species specific habitat changes through time and models of species distributions for birds, fish, and mussels. The end product for managers will be the development of spatially explicit, conservation strategies that are more robust to a range of future climatic changes.

Downscaled climate projections of temperature and precipitation will be used as inputs to ecological process models. Avian range dynamics are being developed for the entire study area, SLR modeling is focused in the Gulf coast of Alabama, Florida, and Mississippi, and aquatic ecosystem responses will be evaluated in the Apalachicola-Chattahoochee-Flint River Basin in Alabama, Florida, and Georgia. All the assessments will project changes through 2100.

Climate adaptation strategies developed through SERAP will be provided to interested stakeholder groups including federal, state, and local agencies and NGOs. A primary stakeholder is the US Fish and Wildlife Service (USFWS) Landscape Conservation Cooperatives (LCCs). The conservation strategies are being developed through an interactive process with wildlife management agencies and will include a diverse portfolio of actions. The goal is to provide information that can help decision-makers and managers to plan for the potential impacts of climate and landscape changes using strategic habitat conservation and a process of adaptive management.

North Carolina Sea Level Rise Risk Management Study and iRisk Tool for the Integrated Hazard Risk Management. North Carolina has significant vulnerability to SLR. In recognition of this hazard, the North Carolina Office of Geospatial and Technology Management Floodplain Mapping Program received a \$5 million grant from FEMA to develop a comprehensive study on climate change effects on risks to built and living systems, and to develop science-based mitigation and adaptation strategies that will pro-actively reduce future risk. The NC Sea Level Rise Risk Management Study (SLR-RMS) will evaluate the potential changes in coastal flooding hazards due to SLR and

changes in storm frequency and intensity on a system-wide basis inclusive of societal and economic impacts. This assessment will include future vulnerability to both temporary and permanent flooding, land loss, and account for dynamic interactions and feedback between receptor systems.

The Integrated Hazard Risk Management (IHRM) program is designed to complement the SLRRMS by helping the public, private sector, and governments (local, state, and federal) manage their risk from natural hazards. IHRM damage assessment methods extend and enhance calculations and data from several commonly used models, including FEMA's HAZUS-MH and benefit-cost analysis. In particular, IHRM focused on collecting asset information for buildings and other critical infrastructure at the parcel or individual asset level. Methods to define qualitative hazard ratings as High, Medium, or Low were defined at both the building level and the county level. Hazard ratings consider risk as well as the individual components of risk: hazard probability, consequences, and vulnerability.

IHRM provides this information through a web-based visualization tool, iRISK, so users can educate themselves about their risk and make informed decisions that will help save lives, decrease property damage, and improve resiliency to natural disasters. Four pilot counties in North Carolina will be the first to demonstrate the revised planning approach and the associated computer-based tools, including Durham, Edgecombe, Macon, and New Hanover.

Step 3: Develop an Adaptation Strategy Using Risk-based Prioritization Schemes

Adaptation efforts furthest advanced in developing and implementing plans are often at smaller scales, individual communities or a system, such as Spartanburg's water system in South Carolina (EPA 2011a). The Hampton Roads area of Virginia has also undertaken several efforts (see the discussion of Wetlands Watch). These include the communities of Wilmington and Greensboro, NC (Community Sustainability Council 2010, Prete 2010). At the state level, the Florida climate action plan gives explicit consideration to adaptation strategies and options (Governor's Action Team on Energy and Climate Change 2008).

Some research is assessing the value of different types of community engagement for adaptation planning. Broad outreach has supported advancing adaptation activities on Bald Head Island, NC. Frazier et al. (2010) report positive outcomes from using scenarios in a day-long workshop setting in Sarasota, FL. A number of efforts support increasing community resilience to hazards and integrating climate change issues in their guidance. For example, the *Louisiana Coastal Hazard Mitigation Guidebook* suggests strategies that, if implemented, would reduce but not completely eliminate the risks from coastal natural hazards including subsidence and SLR, storm surge, and other flooding (Wilkins et al. 2008). The approaches are designed to address current stresses and to provide additional protection from those hazards. The guidebook also demonstrates methods that communities can use to adopt a flexible approach to hazard planning and include a wide range of attitudes around restricting the use of property when necessary to mitigate hazards.

Lee County, FL, has completed a vulnerability assessment that assessed potential impacts of climate stability, sea level, hydrology, geomorphology, natural habitats and

species, land use changes, economy, human health, human infrastructure, and variable risk projects with respect to multiple goals, including implementation of a comprehensive plan, perceived current impacts, habitat loss, and proximity in time (Beever et al. 2009). Rankings were used to create a priority matrix for climate change vulnerabilities, which placed alterations to hydrology as the top priority followed by climate variability and changes in storm severity (Beever et al. 2009).

Several regional efforts to develop climate adaptation strategies have been undertaken with significant support from federal agencies. The US Environmental Protection Agency (EPA) and the Federal Emergency Management Agency (FEMA) are partnering to explore the intersection of climate change adaptation and local planning in North Carolina through technical assistance to two coastal communities facing impacts from SLR, more intense coastal storms, and changes in precipitation. New Orleans recovery efforts are increasing the resilience of the city to hurricanes (Natural Resources Defense Council 2011). Terrebonne Parish, LA has established a plan to develop a strategic decision-making tool to help guide their response to wetlands loss and restoration, including the threats of SLR (Suazo 2010).

Two other efforts were supported by the Climate Ready Estuaries program (described below). In 2008, Charlotte Harbor National Estuary Program (CHNEP) collaborated with the City of Punta Gorda, FL to develop a climate change adaptation plan. CHNEP and the Southwest Florida Regional Planning Council also prepared a Southwest Florida Climate Change Vulnerability Assessment (Beever et al. 2009). In order to support the adaptation plan, they are working to develop climate change indicators and a monitoring plan for estuarine systems. Indian River Lagoon NEP and the City of Satellite Beach, FL began collaboration in 2009 on a SLR vulnerability assessment, which helped identify options for reducing risk, planning for adaptation, and educating local decision makers (Parkinson and McCue 2011).

There are also many efforts underway to support the development of adaptation plans, such as assessment of existing regulatory authorities (Silton and Grannis 2010, Farber 2009) and development of methods for decision-making (Julius et al. 2010). These efforts assemble substantial resources from local, private, non-governmental, and federal while synchronizing tasks and decisions that allow the process to move quickly. Several of the following case studies point to the importance and value of building new forms of regional coordination and organizational authority in support of climate adaptation (Sheffer 2010).

Climate Ready Estuaries. The Climate Ready Estuaries program within the US Environmental Protection Agency is a partnership among the National Estuary Programs (NEPs) and other EPA divisions to address climate change in coastal areas. The NEP is a network of voluntary community-based programs focused on the conservation and management of estuaries. NEP is a place-based effort and each NEP has a Management Conference made up of stakeholders including citizens, local, state, and Federal agencies, as well as non-profit and private sector entities. Since 2008, Climate Ready Estuaries has been assisting NEPs and coastal communities in becoming “climate ready” by providing tools and assistance to assess climate change vulnerability and to plan for adaptation. Activities are taking place at the Albemarle-Pamlico Estuary Program (EP), Charlotte Harbor EP, Indian River Lagoon EP, Tampa Bay EP, and the City of Satellite

Beach, Florida, in conjunction with an EP in the Southwest region, the Coastal Bend Bays and EP in Texas.

Two programs in particular are strongly oriented to transferring knowledge from these place-based efforts. Sarasota Bay EP developed an adaptation plan that includes public outreach and participation in updates to local comprehensive plans to integrate adaptation measures. Associated research to support this effort includes the use of Light Detection and Ranging (LiDAR) data, the development of a web-based SLR visualization tool, development of a technical report including maps, and a guide with tips and early lessons. In 2011, Tampa Bay EP and Coastal Bend Bays and EP focused on publication and distribution of the “Gulf Coast Community Handbook” for incorporating resiliency into habitat restoration and protection plans to communities around the Gulf of Mexico.

Wetlands Watch, Norfolk, Virginia. Wetlands Watch, a nonprofit environmental advocacy group, based in Norfolk, VA, has been working with local governments on SLR adaptation for five years (Wetlands Watch 2012). Their adaptation work grew out of a session held with the Center for Coastal Resources Management at the Virginia Institute of Marine Sciences, after which they realized the benefits of their conventional wetlands advocacy work would be overwhelmed by SLR impacts to the coastal ecosystem (S. Stiles, personal communication).

In 2007 Wetlands Watch began a campaign focused on making local government long-range planning, floodplain and post-hazard mitigation planning, zoning and ordinance codes, capital improvement funding, and permitting processes to account for SLR. Wetlands Watch has formed partnerships with academic institutions, government agencies, military programs, businesses, and faith communities to address these issues (Wetlands Watch 2012).

Gulf of Mexico Climate Change Adaptation Inventory. The Climate Change Adaptation Inventory is a compilation of climate adaptation activities and research initiatives taking place at the federal, state, and local levels in communities adjacent to the Gulf of Mexico. The inventory focuses specifically on those projects and efforts that address climate change or SLR. Research activities captured by the inventory are limited to those projects that have applications to coastal communities, particularly planning and development, land management, and socioeconomic initiatives. Currently available online as a document with links to a variety of websites and online resources, the inventory will be upgraded to an interactive database so users can input their own adaptation efforts.

The inventory’s intended audience includes National Oceanic and Atmospheric Administration (NOAA) staff members and other stakeholders. It is a living document that will be maintained by the NOAA Gulf Coast Services Center. Addenda to listed project information and new project suggestions for the inventory are encouraged (NOAA Gulf Coast Services Center 2011).

Template to Assess Climate Change Impact and Management Options (TACCIMO). Since its creation in 1905, the USDA Forest Service has overseen the care of US public forests and grasslands. That area now exceeds 193 million acres (USDA Forest Service 2009) and 13.1 million acres in the Southern region (the southeastern states considered

in this report plus Oklahoma and Texas). The Forest Service has faced many challenges in its 100+ year history and like other federal agencies is now attempting to address the management issues created or amplified by a changing climate with a goal of identifying options to assure ecosystem sustainability (USDA Forest Service 2009).

All National Forests operate under management plans specifically designed for each National Forest. The National Forest Management Act of 1976 requires that all National Forests are managed for multiple uses (NFMA 1976), but each forest has unique challenges and attributes. These goals are called the *desired future conditions* of the forest. Periodically, these management plans are re-evaluated to see if desired future conditions have or should be modified. During the past two years, Forest Service scientists and land planners have collaborated to develop a web-based management and adaptation tool called the Template to Assess Climate Change Impact and Management Options (TACCIMO) is a result of that collaboration (<http://www.sgcp.ncsu.edu:8090/>, Solomon et al. 2009).

TACCIMO has been parameterized with National Forest Plans for Region 8 (southern region) and can be used for state and private forest use. In the Southern region, the user can select their location (county, state, or region) for an assessment of general climate change impacts and management options. The core of TACCIMO is hundreds of scientifically reviewed papers on climate change impacts and management options. TACCIMO compares the desired future conditions outlined in each forest plan with the cataloged climate change impacts to assess whether various aspects of climate change (e.g., wildfire risk, drought, SLR) could pose a new or enhanced threat to the National Forest desired future conditions. TACCIMO cross references the climate change impacts with cataloged management options to provide land managers with potential choices to minimize negative change. Finally, TACCIMO generates a report that includes the forest plan, potential climate change impacts and management options.

Leveraging Federal programs for natural resource protection in the Albemarle-Pamlico Estuary. Adaptation to climate change along the North Carolina coast is the focus of an interagency pilot project to build resilience into the natural landscape, integrate partnership priorities and leverage existing Federal resources. The project is being directed through the Southeast Natural Resource Leaders Group (SENRLG) (EPA 2011b). SENRLG is comprised of regional Federal agency leaders across the SE with natural resource mission responsibilities. The SENRLG Landscape Conservation and Restoration Pilot Project (LCRPP) identified the Albemarle-Pamlico Estuary as the initial location to illustrate the co-benefits of targeting Federal program resources and to outline an innovative approach to address environmental challenges in long-term natural resource protection. The outcomes of the LCRPP are designed to demonstrate that collaborative, on-the-ground climate risk-related conservation, restoration, and resilience-building work produces results that exceed those that could be achieved through individual agency efforts.

Public access to the Targeted Resource Implementation Plan (TRIP) and online decision support tools is scheduled for October 2012. The tools will include a web portal to access the documents and a Geographical Information System viewer to access the data used during the project. When complete, the TRIP will do the following:

- Identify a landscape where agencies may collaborate and leverage resources that promote resilience of the landscape and improved capacity to adapt to climate change within the estuary.
- Support collaboration with external stakeholders that obtain co-benefits through targeted funding of restoration and conservation projects.
- Provide a set of performance metrics to evaluate co-benefits of resource accomplishments for on-the-ground work.
- The decision support tools will identify Federal resources available to support locally driven landscape conservation efforts that address climate change adaptation. The TRIP products will be transferable to other internal and external partnerships across the SE.

Step 4: Identify Opportunities for Co-benefits and Synergies Across Sectors

Many current planning efforts focus on identification of risks and vulnerabilities in order to inform adaptation strategies. Some vulnerability assessment and adaptation planning processes, such as the Puerto Rico example given earlier, are being conducted as one integrated effort. Still, reports of efforts to identify co-benefits and synergies across sectors are sparse. A reef restoration project off the coast of Alabama is one example of implementing an adaptation strategy that provides protection from storm surge and increases habitat (The Nature Conservancy 2010). A guidebook aimed at helping governments assess the economic value of adaptation is available that comments on the potential to incorporate additional societal benefits in cost-benefit analyses, but the treatment is very brief (The Economics of Climate Change Adaptation Working Group 2009). The North Carolina effort described below illustrates one effort to identify adaptation strategies with broad benefits across sectors.

Using vulnerability assessment to inform adaptation strategies. The North Carolina Interagency Leadership Team, (ILT) led by the North Carolina Department of Environment and Natural Resources, assessed North Carolina's vulnerability to the impacts of climate change in order to inform adaptive strategies that will reduce risk and increase resilience to projected future changes. Federal agencies involved include EPA, USACE, NOAA, Federal Highway Administration, and US Fish and Wildlife Service. North Carolina state agencies include Departments of Transportation, Environment and Natural Resources, Commerce, Cultural Resources, and Agriculture and Consumer Services; as well as the Wildlife Resources Commission.

The effort focused on major climate change threats to North Carolina including increased air and water temperatures, inundation from SLR, more frequent and intense heat waves, increased tropical cyclone intensity, and altered rainfall patterns resulting, paradoxically, in more droughts and more floods.

A Climate Change Working Group developed a prototype for climate vulnerability assessments across multiple sectors and statewide and regional scales. Sectors assessed included: Transportation, Natural Ecosystems, Water Resources, Coastal and Marine Resources, Human Health and Welfare, Agriculture and Forestry, Energy Production and Use, Human Social Systems, Land Resources, and Air Quality. This

vulnerability assessment phase was critical to inform adaptation responses, within and across sectors and regions of the state.

The NC Climate Adaptation Framework initially focuses on broad overarching strategies that emphasize cross-sector, integrated efforts within three major categories: (1) policy integration and creation; (2) promotion and facilitation of adaptive behaviors; and (3) research and education.

The ILT agencies and their partners are concentrating early efforts on adaptive responses that can make progress within three to five years. To leverage limited resources, initial strategies will focus on no- or low-cost actions that address multiple or particularly vulnerable systems. Early efforts emphasize “no-regrets” actions that provide multiple benefits and are good to do for reasons beyond climate adaptation.

These strategies provide common themes designed to guide future efforts to prepare for climate impacts across multiple levels—state, regional, or local:

- Collaborate with partners to provide information that informs decisions.
- Promote comprehensive adaptation planning among state agencies.
- Facilitate communication and education to support local, regional, and state planning efforts.
- Refine adaptation strategies as science advances and tools improve.
- Encourage broad collaboration and partnerships to leverage resources.
- Partner with communities to facilitate local climate adaptation efforts.

Steps 5 and 6: Implement, Monitor, and Re-evaluate Implemented Adaptation Options

The implementation, monitoring, and regular re-evaluation of adaptation options are steps of adaptive management strategies incorporated into climate adaptation recommendations. The approach is intended to support ongoing social learning in the context of uncertainty. In practice, the process of adaptive management confronts several challenges in application (Gregory et al. 2006) including tolerance for delay during the experiment. One example of applying adaptive management strategies to coastal conservation management that is well documented and advanced is that of the Alligator River National Wildlife Refuge.

Adaptive management in the Alligator River National Wildlife Refuge. The Alligator River National Wildlife Refuge encompasses about 154,000 acres in the Albemarle-Pamlico Estuary, Dare and Hyde Counties, NC. The US Fish and Wildlife Service (USFWS) and North Carolina Chapter of The Nature Conservancy (TNC) are working together to evaluate the effects of different adaptive management strategies that might contribute to the resilience and stability of wetland ecosystems on areas affected, or likely to be affected, by SLR. Successes would include reductions in the rates of ecosystem change, shoreline erosion, saltwater intrusion, land subsidence, and an increase in the growth and survival of salt-tolerant vegetation. Adaptation strategies include:

- Using oyster reefs to dissipate wave energy, slow currents, and reduce shoreline erosion. Added benefits are that these reefs sequester carbon and provide habitat for a variety of species.

- Using ditch plugs or water control structures equipped with flashboard risers and tide gates to restore the hydrologic regime and prevent saltwater intrusion.
- Planting salt-tolerant vegetation, such as bald cypress and brackish marsh grasses, to enhance future shoreline stability and combat expected biodiversity and habitat loss.

In addition, the project aims to establish migration corridors for species to move inland and upland from low lying areas. TNC and USFWS have already implemented these strategies in several locations. Marl, a calcium carbonate fossil rock, and oyster shell bags have been used to construct oyster reefs to buffer the shoreline, ditch plugs and water control structures have been strategically placed in areas to restore the region back to a sheet flow system, and 40 acres of salt-tolerant vegetation have been planted. Monitoring is underway to track the progress of each project. The projects have begun adaptation efforts in other nearby conservation areas, including the Swan Quarter National Wildlife Refuge, and plan to expand efforts to all nine North Carolina Coastal Plain refuges.

13.4 Supporting Adaptive Capacity

The many specific adaptation efforts in the SE are supported more generally by an expanding set of programs and centers that support adaption planning at all stages. The expertise and resources provided by these groups ranges from original research on the climate of the SE, to development of climate datasets, geospatial datasets, and analysis tools, to direct assistance with adaptation planning. Some programs engage with many sectors while others focus on specific needs, such as coasts, forestry, water resources, or conservation. Though not exhaustive, below is a sample list of the existing and developing programs in the region.

Climate Ready Estuaries (www.epa.gov/cre/live.html)

Five of the EPA's Climate Ready Estuary Programs are located in the SE USA. The Climate Ready Estuaries program together with the EPA National Estuary Programs works with coastal managers and others: 1) to determine vulnerabilities to climate change; 2) to create and apply adaptation strategies; 3) to interact and educate stakeholders; and 4) to disseminate the lessons learned. The Climate Ready Estuaries website contains information on climate change impacts to various estuary regions, provides resources and tools important to monitor changes, and material to support development of adaptation plans for coastal communities and their related estuaries.

Climate Science Centers (www.doi.gov/csc/southeast/index.cfm)

Two (southeast and south central) of the newly developing Department of Interior Climate Science Centers will serve the SE/Gulf Coast region of the USA. The mission for all of the Science Centers is to make scientific information, tools, and techniques available to assist wildlife managers and others to anticipate, observe and measure, and adapt to a changing climate.

CSC: Coastal Services Center (www.csc.noaa.gov)

The Coastal Services Center (CSC) of NOAA assists local and state organizations responsible for coastal resource management by providing technology, information, management strategies, tools, data, publications, training, and a wide variety of options that address today's complex coastal issues (NOAA CSC 2012). The CSC offerings support the economic, social, and environmental well being of the coast by linking information, people, and technology.

National Estuarine Research Reserves (NERRs) (www.nerrs.noaa.gov; gulfalliancetraining.org)

There are 10 National Estuarine Research Reserves (NERRs) sites in the SE. These reserves are living laboratories to investigate coastal concerns, including climate change and building resilience. The five Gulf Coast NERRs Coastal Training Programs established a partnership in 2007 that addresses adaptation through the framework of the Gulf of Mexico Alliance (National Ocean Service, NOAA 2008). This regional collaboration supports adaptation-planning workshops hosted by each Gulf NERR. Intended for local decision-makers, workshops have and will feature regional climate-science experts and highlight local climate efforts.

Regional Integrated Science Assessment (RISA), National Oceanic and Atmospheric Administration (NOAA)

There are three RISA teams serving the SE.

- **CISA: Carolinas Integrated Science and Assessments (www.cisa.sc.edu).** For North and South Carolina, the CISA program focuses on improving the quality, range, relevance, and accessibility of climate information that is used for resource management and other decision-making efforts, particularly related to coastal and water resources, human health and adaptation. In collaboration with regional stakeholders, CISA researchers work to identify and create effective methods of providing climate data, science, and education.
- **SCIIPP: Southern Climate Impacts Planning Program (www.southernclimate.org).** The SCIIPP focus is on research, education, and tool development around climate change and hazards in the south central USA through interaction with a wide variety of regional efforts. The mission of SCIIPP is to build resiliency in the region and increase preparedness for present and future weather extremes. The SCIIPP region includes: Oklahoma, Texas, Arkansas, Louisiana, Tennessee, and Mississippi.
- **SECC: Southeast Climate Consortium (www.seclimate.org).** The Southeast Climate Consortium's mission is to use progress in climate sciences, including improved climate forecast capabilities—both seasonal and long-term climate change—to develop scientifically sound information and tools for decision-making. These tools are for application to a variety of ecosystems in the SE USA including: agricultural, forests and other terrestrial ecosystems, and coastal. The most advanced of these decision support systems is AgroClimate (AgroClimate.

org), which focuses on the agricultural and forest sectors but also includes climate information at the county level that is valuable to many other sectors.

- **Sea Grant Programs (www.seagrants.noaa.gov).** There are 32 Sea Grant Programs nationwide that address issues and create products and tools for the coastal region of the USA. The Texas, Louisiana, Mississippi/Alabama, and Florida Sea Grant programs have developed individually as well as cooperated on developing a variety of outreach, education, and tools that focus on building resilience in the coastal zone. North and South Carolina Sea Grant programs were the first to place a full time regional climate extension specialist on staff. There are many tools and educational resources developed and in process through the various Sea Grant programs.

13.5 Summary

Adaptation efforts are underway in the SE. Work to understand the relevant climate impacts, to assess the significant risks and vulnerabilities, and to build partnerships and resources to support planning is taking place at all levels—from small communities to NGOs, states, and federal agencies. Many of these groups are supporting broad efforts to build adaptive capacity as well as individual projects. Given the growing numbers and diversity of groups involved, the mainstreaming of adaptation planning, and the rapid advancement of adaptation efforts, this review and the existing catalogs and databases are likely to be incomplete representations of the full scope of effort.

Currently, most efforts aim to identify the relevant climate risks and conduct risk and vulnerability assessments. Coastal areas, where risks of severe storms and SLR are highly visible, are the focus of much of this attention. Many of the efforts are working to mainstream climate adaptation into existing institutions and processes. Partly as a consequence of that mainstreaming approach, adaptation efforts are being conducted under a variety of different names and terminologies, including resilience and sustainability. The adaptation process is much more complex and less linear than conveyed by basic models. Significant effort is going into building necessary partnerships for coordinated response of the authorities and resources.

In the future, as more entities move from risk and vulnerability assessment to strategic adaptation planning and implementation, we anticipate a greater demand for more information on the costs, benefits and co-benefits of adaptations. As efforts advance, support for evaluation of adaptation efforts will need to increase.

13.6 References

- America's Energy Coast, America's Wetland Foundation, Entergy Corporation. 2010. *Building a resilient energy Gulf Coast: Executive Report*. New Orleans, LA: Entergy Corporation. http://www.entergy.com/content/our_community/environment/GulfCoastAdaptation/Building_a_Resilient_Gulf_Coast.pdf
- Beaufort County South Carolina. 2010. 2010 Comprehensive Plan. Beaufort, SC: Beaufort County.
- Beever III, J.W., W. Gray, D. Trescott, D. Cobb, J. Utley, L.B. Beever. 2009. *Comprehensive south-west Florida/ Charlotte harbor climate change vulnerability assessment*. Fort Myers, FL: Southwest Florida Regional Planning Council and Charlotte Harbor National Estuary Program. <http://>

- www.cakex.org/sites/default/files/Climate%20Change%20Vulnerability%20Assessment%20CHNEP.pdf
- Bin, O., C. Dumas, J. Whitehead, B. Poulter. 2007. *Measuring the impacts of climate change on North Carolina coastal resources*. Washington, DC: National Commission on Energy Policy.
- Bin, O., B. Poulter, C. Dumas, J. Whitehead. 2011. Measuring the impact of sea-level rise on coastal real estate: A hedonic property model approach. *Journal of Regional Science* 51 (4): 751-767.
- Brown, C., S. Campbell, L.R. Henry, M.M. Robinson. 2010. *Public listening sessions: Sea level rise and population growth in North Carolina*. Raleigh, NC: The Albemarle-Pamlico Conservation and Communities Collaborative and The Albemarle-Pamlico National Estuary Program. <http://www.cakex.org/sites/default/files/Public%20Listening%20Sessions%20in%20North%20Carolina.pdf>.
- Climate Adaptation Knowledge Exchange. 2012. *Case Studies* [Accessed March 26, 2012]. Available from <http://www.cakex.org/case-studies>.
- Community Sustainability Council. 2010. *Sustainability Action Plan Greensboro, North Carolina*. Greensboro, NC: City of Greensboro. <http://www.greensboro-nc.gov/modules/showdocument.aspx?documentid=1194>.
- Culver, S.J., K.M. Farrell, D.J. Mallinson, D.A. Willard, B.P. Horton, S.R. Riggs, E.R. Thieler, J.F. Wehmler, P. Parham, S.W. Snyder, C. Hillier. 2011. Micropaleontologic record of quaternary paleoenvironments in the central Albemarle Embayment, North Carolina, U.S.A. *Palaeogeography, Palaeoclimatology, Palaeoecology* 305 (1-4): 227-249.
- Dalton, M.S. and S.A. Jones. 2010. *Southeast regional assessment project for the National Climate Change and Wildlife Center, US Geological Survey*. Washington, DC: US Geological Survey. http://serap.er.usgs.gov/docs/SerapOFR2010_1213.pdf.
- Dixon, T.H., F. Amelung, A. Ferretti, F. Novali, F. Rocca, R. Dokkas, G. Sella, S.-W. Kim, S. Wdowski, D. Whitman. 2006. Space geodesy: Subsidence and flooding in New Orleans. *Nature* 441 (7093): 587-588.
- DoD (Department of Defense). 2010. *Quadrennial defense review report*. Washington, DC: US Department of Defense.
- EPA (US Environmental Protection Agency). 2011a. *Climate change vulnerability assessments: Four case studies of water utility practices*. Washington, DC: US Environmental Protection Agency. http://oaspub.epa.gov/eims/eimscomm.getfile?p_download_id=501095.
- EPA (US Environmental Protection Agency). 2011b. *Southeast natural resources leaders*. Washington, DC: US Environmental Protection Agency. <http://www.epa.gov/region4/topics/envmanagement/senrlg/index.htm>.
- Evans, R.L. 2004. Rising Sea Levels and Moving Shorelines. *Oceanus* 43 (1): 1-6.
- Farber, D.A. 2009. *A legal framework for climate adaptation assessment*. Washington, DC: Resources for the Future. <http://www.rff.org/rff/documents/RFF-IB-09-14.pdf>.
- Frazier, T.G., N. Wood, B. Yarnal, D.H. Bauer. 2010. Influence of potential sea level rise on societal vulnerability to hurricane storm-surge hazards, Sarasota County, Florida. *Applied Geography* 30 (4): 490-505.
- Georgetown Climate Center. 2012. *Adaptation Clearinghouse* [Accessed March 26, 2012]. Available from <http://www.georgetownclimate.org/adaptation/clearinghouse>.
- Gibson, C.A., J.L. Meyer, N.L. Poff, L.E. Hay, A. Georgakakos. 2005. Flow regime alterations under changing climate in two river basins: Implications for freshwater ecosystems. *River Research and Applications* 21 (8): 849-864.
- Governor's Action Team on Energy and Climate Change. 2008. *Florida energy and climate change action plan*. Tallahassee, FL: Governor's Action Team on Energy and Climate Change. <http://www.flclimatechange.us/documents.cfm>

- Graves, P.E. 1980. Migration and climate. *Journal of Regional Science* 20 (2): 227-237.
- Gregory, R., D. Ohlson, J. Arvai. 2006. Deconstructing adaptive management: Criteria for applications to environmental management. *Ecological Applications* 16 (6): 2411-2425.
- Hanson, S., R. Nicholls, N. Ranger, S. Hallegatte, J. Corfee-Morlot, C. Herweijer, J. Chateau. 2011. A global ranking of port cities with high exposure to climate extremes. *Climatic Change* 104 (1): 89-111.
- Irish, J.L., A.E. Frey, J.D. Rosati, F. Olivera, L.M. Dunkin, J.M. Kaihatu, C.M. Ferreira, B.L. Edge. 2010. Potential implications of global warming and barrier island degradation on future hurricane inundation, property damages, and population impacted. *Ocean & Coastal Management* 53 (10): 645-657.
- Julius, S., B. Bierwagen, C. Pyke, J.R. Freed, S. Asam. 2010. *A method to assess climate-relevant decisions: Application in the Chesapeake Bay*. Washington, DC: US Environmental Protection Agency. <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=227483>.
- Karl, T.R., J.M. Melillo, T.C. Peterson. 2009. *Global climate change impacts in the United States*. New York, NY: Cambridge University Press.
- Kentucky Department of Fish and Wildlife Resources. 2010. *Action plan to respond to climate change in Kentucky: A strategy of resilience*. Frankfort, KY: Kentucky Department of Fish and Wildlife Resources. http://fw.ky.gov/kfwis/stwg/2010Update/Climate_Change_Chapter.pdf.
- Knutson, T.R., J.L. McBride, J. Chan, K. Emanuel, G. Holland, C. Landsea, I. Held, J.P. Kossin, A.K. Srivastava, M. Sugi. 2010. Tropical cyclones and climate change. *Nature Geoscience* 3 (3): 157-163.
- Morens, D.M. and A.S. Fauci. 2008. Dengue and hemorrhagic fever—A potential threat to public health in the United States. *Journal of the American Medical Association* 299 (2): 214-216.
- Mousavi, M., J. Irish, A. Frey, F. Olivera, B. Edge. 2011. Global warming and hurricanes: The potential impact of hurricane intensification and sea level rise on coastal flooding. *Climatic Change* 104 (3): 575-597.
- Murley, J., L. Alpert, W.B. Stronge. 2005. Tourism in paradise: The economic impact of Florida beaches. Paper read at 14th Biennial Coastal Zone Conference, July 17th, 2005, New Orleans, Louisiana.
- National Conference of State Legislatures. 2008a. *Georgia: Assessing the costs of climate change*. Washington, DC: NCSL. <http://www.ncsl.org/Portals/1/documents/environ/ClimateChangeGA.pdf>.
- National Conference of State Legislatures. 2008b. *North Carolina: Assessing the costs of climate change*. Washington, DC: NCSL. <http://www.ncsl.org/print/environ/ClimateChangeNC.pdf>.
- National Conference of State Legislatures. 2008c. *Tennessee: Assessing the costs of climate change*. Washington, DC: NCSL. <http://www.ncsl.org/print/environ/ClimateChangeTN.pdf>.
- Natural Resources Defense Council. 2011. *New Orleans, Louisiana: Identifying and becoming more resilient to impacts of climate change*. New York, NY: NRDC. http://www.nrdc.org/water/files/ClimateWaterFS_NewOrleansLA.pdf.
- Neumann, J., D. Hudgens, J. Herter, J. Martinich. 2011. The economics of adaptation along developed coastlines. *Wiley Interdisciplinary Reviews: Climate Change* 2 (1): 89-98.
- NFMA (National Forest Management Act). 1976. National Forest Management Act of 1976. Washington, DC: US Forest Service. <http://www.wilderness.net/NWPS/documents/publiclaws/PDF/94-588.pdf>
- NIDIS (National Integrated Drought Information System). 2012. *Regional Drought Early Warning System: Apalachicola-Chattahoochee-Flint (SCF) River Basin* [Accessed 18 February 2012]. Available from <http://www.drought.gov/portal/server.pt/community/acfrb>.
- NOAA CSC (Coastal Services Center). 2012. *Coastal Climate Adaptation* [Accessed March 26, 2012]. Available from <http://collaborate.csc.noaa.gov/climateadaptation/default.aspx>.

- NOAA Gulf Coast Services Center. 2011. *Gulf of Mexico climate change adaptation inventory*. Washington, DC: National Oceanic and Atmospheric Administration. http://masgc.org/climate/cop/Documents/GoM_ClimateChangeAdaptationInventory_Report.pdf.
- North Carolina Department of Commerce. 2012. *Tourism*. Raleigh, NC: N.C. Department of Commerce. <http://www.nccommerce.com/tourism/>.
- North Carolina Department of Environment and Natural Resources. 2010. *North Carolina ecosystem response to climate change: DENR assessment of effects and adaptation measures*. Raleigh, NC: North Carolina Department of Environment and Natural Resources.
- NRC (National Research Council). 2010a. *Adapting to the Impacts of Climate Change*. Washington, DC: National Academies Press.
- NRC (National Research Council). 2010b. *Informing an Effective Response to Climate Change*. Washington, DC: National Academies Press.
- NRC. 2011. *America's Climate Choices*. Washington, DC: National Academies Press.
- Parkinson, R.W. and T. McCue. 2011. Assessing municipal vulnerability to predicted sea level rise: City of Satellite Beach, Florida. *Climatic Change* 107 (1-2): 203-223.
- Prete, P. 2010. *Sea level rise adaptation report for the City of Wilmington, North Carolina*. Wilmington, NC: N.C. Development Services.
- Puerto Rico Coastal Management Program. 2011. *Puerto Rico coastal adaptation project 2010-2012*. San Jose, Puerto Rico: Programa de Manejo de la Zona Costanera, Departamento de Recursos Naturales y Ambientales. http://www.drna.gobierno.pr/oficinas/arn/recursosvivientes/costasreservasrefugios/pmzc/riesgos-costeros-1/FactSheet_OnePage_FINAL_2side.pdf.
- Rosenzweig, C. and M. Brown. 2009. Space agency workshop considers effect of climate change on infrastructure: Climate change impacts and adaptation: NASA mission and infrastructure; Kennedy Space Center, Florida, 28-30 July 2009. *EOS, Transactions American Geophysical Union* 90 (40): 352.
- Rosenzweig, C., R. Horton, I.S. Hignuchi, C. Hudson. 2011. NASA's CASI: Building Climate-Resilient NASA Centers. *livebetter* 15 (December).
- SERDP (Strategic Environmental Research and Development Program). 2012. *Resource Conservation and Climate Change*. Alexandria, VA: SERDP. <http://serdp.org/Program-Areas/Resource-Conservation-and-Climate-Change>.
- Sheffer, T. 2010. *The key role of regional coastal adaptation planning in the United States*. Blacksburg, VA: Virginia Polytechnic Institute and State University. <http://www.cakex.org/sites/default/files/Thomas%20Sheffer%20Paper.pdf>.
- Silton, A.C. and J. Grannis. 2010. *Virginia case study: Stemming the tide: How local governments can manage rising flood risks*. Washington, DC: Georgetown Climate Center. <http://www.law.unc.edu/documents/clear/vacasestudy.pdf>.
- Solomon, A., R. Birdsey, L. Joyce, J. Hayes. 2009. *Forest service global change research strategy 2009-2019*. Washington, DC: US Department of Agriculture, Forest Service Research and Development, FS-917a.
- Stratus Consulting Inc. 2010a. *Overview of climate change adaptation in the southeastern United States with a focus on water and coastal resources*. Boulder, CO: Stratus Consulting, Inc.
- Stratus Consulting Inc. 2010b. *Report on the U.S. EPA southeast climate change adaptation planning workshop*. Boulder, CO: Stratus Consulting, Inc.
- Suazo, L. 2010. *Systematically prioritizing restoration projects in Terrebonne Parish, Louisiana*. Houma, LA: Coastal Restoration and Preservation. <http://www.cakex.org/case-studies/582>.
- Svart, L.M. 1976. Environmental preference migration: A review. *Geographical Review* 66 (3): 314-330.
- The Center for Climate Strategies. 2012. *State and Local Climate Blackboard* http://www.climate-strategies.us/policy_tracker/state/index.

- The Economics of Climate Adaptation Working Group. 2009. *Shaping climate-resilient development: A framework for decision-making*. Economics of Climate Adaptation Working Group. http://ccsl.iccip.net/climate_resilient.pdf.
- The Nature Conservancy. 2010. *Climate change action plan for the Florida reef system 2010-2015*. Arlington, VA: The Nature Conservancy. <http://www.cakex.org/sites/default/files/FL%20Reef%20Action%20Plan.pdf>
- Thieler, E.R. and E.S. Hammar-Klose. 1999. *National assessment of coastal vulnerability to sea-level rise: Preliminary results for the U.S. Atlantic coast*. Washington, DC: US Geological Survey.
- Titus, J., D. Hudgens, D. Trescott, M. Craghan, W. Nuckols, C. Hershner, J. Kassaklan, C. Linn, P. Merritt, T. McCue, J. O'Connell, J. Tanskl, J. Wang. 2009. State and local governments plan for development of most land vulnerable to rising sea level along the US Atlantic coast. *Environmental Research Letters* 4, 044008; doi:10.1088/1748-9326/4/4/044008.
- Titus, J.G. and C. Richman. 2001. Maps of lands vulnerable to sea level rise: Modeled elevations along the US Atlantic and Gulf coasts. *Climate Research* 18 (3): 205-228.
- UKCIP (United Kingdom Climate Impacts Programme). 2012. *Adaptation wizard*. Oxford, United Kingdom: Environmental Change Institute (ECI). <http://www.ukcip.org.uk/wizard/>.
- USACE (U.S. Army Corps of Engineers). 2010. Chief of engineers' environmental advisory board meeting minutes, 22 January 2010. Mobile, AL: Environmental Advisory Board. http://www.usace.army.mil/Portals/2/docs/Environmental/mins_22jan10.pdf
- US Census Bureau. 2011. *Statistical abstract of the United States: 2012*. Washington, DC: US Census Bureau.
- USDA Forest Service. 2009. *The U.S. Forest Service—An Overview*. Washington, DC: US Forest Service. http://www.fs.fed.us/documents/USFS_An_Overview_0106MJS.pdf.
- US Navy. 2012. *Climate Change*. Washington, DC: Office of the Secretary of the Navy. <http://greenfleet.dodlive.mil/climate-change/>.
- Wetlands Watch. 2012. *Sea Level Rise Adaptation*. Norfolk, VA: Wetlands Watch Inc. <http://www.wetlandswatch.org/WetlandScience/SeaLevelRise/SeaLevelRiseAdaptation.aspx>.
- Wilkins, J.G., R.E. Emmer, D. Hwang, G.P. Kemp, B. Kennedy, H. Mashriqui, B. Sharky. 2008. *Louisiana Coastal Hazard Mitigation Guidebook*. Baton Rouge, LA: Louisiana Sea Grant College Program. <http://www.lsu.edu/sglegal/pdfs/LaCoastalHazMitGuidebook.pdf>.