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U.S. Department of the Interior
Southeast Climate Science Center
Science and Operational Plan

Open-File Report 2012–1034

U.S. Department of the Interior
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Foreground top: Fort Jefferson, Dry Tortugas National Park, Florida
Foreground middle: Cahaba River, Cahaba National Wildlife Refuge, Alabama
Foreground bottom: Great Smoky Mountains National Park, Tennessee
Background top: Mathews Brake National Wildlife Refuge, Mississippi
Background bottom: Thunderstorm, Meramec River Valley, Missouri

U.S. Department of the Interior Southeast Climate Science Center Science and Operational Plan

Compiled by Sonya A. Jones and Melinda S. Dalton

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U.S. Department of the Interior
U.S. Geological Survey
National Climate Change and Wildlife Science Center
Southeast Climate Science Center

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2012

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Executive Summary

Climate change challenges many of the basic assumptions routinely used by conservation planners and managers, including the identification and prioritization of areas for conservation based on current environmental conditions and the assumption those conditions could be controlled by management actions. Climate change will likely alter important ecosystem drivers (temperature, precipitation, and sea-level rise) and make it difficult, if not impossible, to maintain current environmental conditions into the future. Additionally, the potential for future conservation of non-conservation lands may be affected by climate change, which further complicates resource planning. Potential changes to ecosystem drivers, as a result of climate change, highlight the need to develop and adapt effective conservation strategies to cope with the effects of climate and landscape change.

The U.S. Congress, recognized the potential effects of climate change and authorized the creation of the U.S. Geological Survey National Climate Change and Wildlife Science Center (NCCWSC) in 2008. The directive of the NCCWSC is to produce science that supports resource-management agencies as they anticipate and adapt to the effects of climate change on fish, wildlife, and their habitats. On September 14, 2009, U.S. Department of the Interior (DOI) Secretary Ken Salazar signed Secretarial Order 3289 (amended February 22, 2010), which expanded the mandate of the NCCWSC to address climate-change-related impacts on all DOI resources. Secretarial Order 3289 "Addressing the Impacts of Climate Change on America's Water, Land, and Other Natural and Cultural Resources," established the foundation of two partner-based conservation science entities: Climate Science Centers (CSC) and their primary partners, Landscape Conservation Cooperatives (LCC). CSCs and LCCs are the Department-wide approach for applying scientific tools to increase the understanding of climate change, and to coordinate an effective response to its impacts on tribes and the land, water, ocean, fish and wildlife, and cultural-heritage resources that DOI manages.

The NCCWSC is establishing a network of eight DOI CSCs (Alaska, Southeast, Northwest, North Central, Pacific Islands, Southwest, Northeast, and South Central) that will work with a variety of partners and stakeholders to provide resource managers the tools and information they need to help them anticipate and adapt conservation planning and design for projected climate change. The Southeast CSC, a federally led research collaboration hosted by North Carolina State University, was established in 2010. The Southeast CSC brings together the expertise of federal and university scientists to address climate-change priority needs of federal, state, non-governmental, and tribal resource managers.

This document is the first draft of a science and operational plan for the Southeast CSC. The document describes operational considerations, provides the context for climate-change impacts in the Southeastern United States, and establishes six major science themes the Southeast CSC will address in collaboration with partners. This document is intended to be reevaluated and modified as partner needs change.

The Southeast CSC receives guidance for regional science priorities from the Stakeholder Advisory Council (SAC), which is composed of senior-level federal and State government agency executives in the Southeast. A Southeast CSC LCC Advisory Committee will be established to provide recommendations to the SAC on priority climate science projects and products that will be of most benefit to LCCs in accomplishing their respective mission(s). A secondary purpose of the Southeast CSC LCC Advisory Committee is to provide assistance and input to the Science Implementation Panel (SIP), which will be responsible for peer review of all proposed projects, and to recommend utilization of scientific assets of the CSCs and LCCs to address regional science priorities. Key staff from LCCs and other partners associated with the Southeast CSC will serve on the SIP.

The science themes described in this draft plan were established by partners in the southeastern conservation community to address information gaps that can inform the conservation science and resource-management needs of ecoregion conservation partnerships, such as the LCCs. The development of these science themes was based on priorities defined by partners and stakeholders in the Southeast as well as a large-scale, multi-disciplinary project developed in concert with the partners—the Southeast Regional Assessment Project (SERAP). In many instances the tasks outlined in the science themes can build on the work already begun as part of SERAP, providing valuable information to resource managers in the Southeast and allowing partners to reevaluate their priorities earlier in the process. The science plan seeks to achieve the following objectives:

> *The Southeast CSC will use long-term and new observational records as well as understanding of biological and physical processes that can be expressed in quantitative models to describe the consequences of global change on natural resources; provide scientifically valid information and tools that can be used to adapt resource management to changing environmental conditions; and apply these tools to produce regional assessments that are widely used by policy makers, resource managers, and the public.*

This draft plan identifies six science themes that frame the activities needed to achieve the objectives of the Southeast CSC:

- Science Theme 1: Develop climate projections and determine appropriate projections to use for resource management,
- Science Theme 2: Land use and land cover change projections,
- Science Theme 3: Impacts of climate change on water resources,
- Science Theme 4: Ecological research and modeling,
- Science Theme 5: Impacts of climate change on coastal and nearshore marine environments, and,
- Science Theme 6: Impacts of climate change on cultural-heritage resources.

The science products developed under these themes will provide models of future conditions, assessments of potential impacts, and tools that can be used to inform the LCCs and other partners. The information will be critical as managers anticipate and adapt to climate change. Resource managers in the Southeast are requesting this type of information, in many cases, as a result of observed climate-change effects. The Southeast CSC will support integration of science information into conservation delivery, by working with, and building the capacity of, resource managers to interpret the science in order to integrate it into their management and decisionmaking processes.

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Acronyms Used in This Report

ACF	Apalachicola–Chattahoochee–Flint
AGCM	atmospheric general-circulation models
AOGCM	atmosphere-ocean general-circulation model
BCCA	Bias-Correction Constructed Analogs
BCSD	Bias-Correction Spatial Disaggregation
CCSP	Climate Change Science Program
CMIP	Coupled Model Intercomparison Project
CSC	Climate Science Center
DOI	U.S. Department of the Interior
GCM	global climate model
GISS	Goddard Institute for Space Studies
ICLUS	Integrated Climate and Land-Use Scenarios
IPA	Interagency Personnel Agreements
IPCC	Intergovernmental Panel on Climate Change
LCC	Landscape Conservation Cooperatives
NARCCAP	North American Regional Climate Change Assessment Program
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCCWSC	National Climate Change and Wildlife Science Center
NCDC	National Climatic Data Center
NCSU	North Carolina State University
NGO	non-governmental organization
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NWIS	National Water Inventory System
PRMS	Precipitation-Runoff Modeling System
RCM	regional climate model
RHESSys	Regional Hydro-Ecologic Simulation System
RPC	representative concentration pathways
SAC	Stakeholder Advisory Council
SARRP	South Atlantic Regional Research Plan
SERAP	Southeast Regional Assessment Project

SET	sediment-elevation table
SHPO	State Historic Preservation Office
SIP	Science Implementation Panel
SRES	Special Report on Emissions Scenarios
SSPT	Science Strategy Planning
SST	sea-surface temperature
STORET	Storage and Data Retrieval System
SWAP	State Wildlife Action Plan
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGCRP	United States Global Change Research Program
USGS	U.S. Geological Survey
WB	water balance (model)
WaSSI	Water Supply and Stress Index (model)
WCRP	World Climate Research Program

U.S. Department of the Interior Southeast Climate Science Center Science and Operational Plan

Compiled by Sonya A. Jones and Melinda S. Dalton

Introduction

The U.S. Department of the Interior (DOI) recognizes and embraces the unprecedented challenges of maintaining our Nation's rich natural and cultural resources in the 21st century. The magnitude of these challenges demands that the conservation community work together to develop integrated adaptation and mitigation strategies that collectively address the impacts of climate change and other landscape-scale stressors. On September 14, 2009, DOI Secretary Ken Salazar signed Secretarial Order 3289 (amended February 22, 2010) entitled, "Addressing the Impacts of Climate Change on America's Water, Land, and Other Natural and Cultural Resources." The Order establishes the foundation for two partner-based conservation science entities to address these unprecedented challenges: Climate Science Centers (CSCs) and Landscape Conservation Cooperatives (LCCs). CSCs and LCCs are the Department-wide approach for applying scientific tools to increase understanding of climate change and to coordinate an effective response to its impacts on tribes and the land, water, ocean, fish and wildlife, and cultural-heritage resources that DOI manages. Eight CSCs will be established and managed through the National Climate Change and Wildlife Science Center (NCCWSC); each CSC will work in close collaboration with their neighboring CSCs, as well as those across the Nation to ensure the best and most efficient science is produced. This close collaboration is necessary, as the role of the CSCs is to provide partners with the tools necessary to respond to climate change, which requires the sharing of resources and information across boundaries.

In the January 2011 DOI draft guidance for both CSCs and LCCs, the following excerpt outlines the relationship between CSCs and LCCs:

> *"Much of the information and tools provided by the CSCs, including physical and biological research, ecological forecasting, and multi-scale modeling, will be in response to the priority needs identified by the LCCs. Working closely with the LCCs, the CSCs will help develop statistically sound sampling programs and processes to monitor climate change effects and help develop adaptive management approaches. The CSCs will be partnership-based regional entities functioning with LCCs as well as the regional management community, scientific entities, and other stakeholders."*

The Southeast CSC was established in 2010 to address the regional challenges presented by climate change and variability in the Southeastern United States. As such, the focus of the center is on science needs that apply across the entirety of the southeastern region, and provide regional-scale science products that can inform the local needs of the LCCs and other partners. The Southeast CSC, hosted by North Carolina State University (NCSU), will bring together the expertise of federal and university scientists to address the priority needs of federal, State, non-governmental, and tribal resource managers in addressing the challenges associated with climate change. The purpose of the Southeast CSC is to provide scientific information, tools, and techniques that managers and other parties interested in land, water, wildlife, and cultural resources can use to anticipate, monitor, and adapt to climate change; actively engaging LCCs and other partners in translating science into management decisions.

This document delivers the first draft of a science and operational plan for the Southeast CSC. Using the DOI guidance as a model, this document describes the role and interactions of the Southeast CSC among partners and stakeholders, describes a concept of what the center will provide to its partners, defines a context for climate impacts in the Southeastern United States, and establishes six major science themes the center will address through research. Each science theme is organized by immediate and near-future research needs; however, this document is intended to be reevaluated and modified as partner needs change.

Climate Science Center (CSC), Landscape Conservation Cooperative (LCC), and Partner Coordination

The Southeast CSC receives guidance for regional science priorities from the **Stakeholder Advisory Council** (SAC), which is composed of both federal and non-federal senior-level government-agency executives throughout the Southeast. The SAC is chaired by the U.S. Geological Survey (USGS) Regional Executive for the Southeast. Current members include the U.S. Fish and Wildlife Region 4 Director; U.S. National Park Service Southeast Regional Director; National Oceanic and Atmospheric Administration Regional Climate Services Director, Southern Region; U.S. Forest Service Region 8 Forester; a representative from the Southeast Association of Fish and Wildlife Agencies; and the Chair of the Southeast CSC LCC Advisory Committee.

Close collaboration between the Southeast CSC and the seven associated LCCs enhances the functional capacities of both groups to develop meaningful and effective conservation adaptation strategies for the southeastern landscape. The following list of LCCs have part or all of their geography within the boundaries of the Southeast CSC: Appalachian, Caribbean, Eastern Tallgrass Prairie and Big Rivers, Gulf Coast Prairie, Gulf Coastal Plains and Ozarks, Peninsular Florida, and South Atlantic LCCs (fig. 1).

To facilitate such collaboration, a **Southeast CSC LCC Advisory Committee** will be established and composed of LCC Coordinators, designated LCC staff or a member of the LCC Steering Committee, and the CSC Director. The Southeast CSC LCC Advisory Committee will be chaired by one of the member LCC Coordinators and the Chair's position will rotate among the respective LCCs on an annual basis. The Chair of the Southeast CSC LCC Advisory Committee also will serve on the SAC and will represent the needs of the LCCs to the SAC.

The primary purpose of the Southeast CSC LCC Advisory Committee is to provide recommendations to the SAC on priority climate science projects and products that will be of most benefit to LCCs in accomplishing their respective mission(s). It is expected that through regular communications, the Southeast CSC LCC Advisory Committee will determine shared science needs that can be addressed by science products and tools developed by the Southeast CSC. The collaborative process also will provide shared solutions and processes in accomplishing assessments of species and system vulnerabilities at both the LCC level and a more regional level which will be integral to managers operating in a truly adaptive management approach in response to changing climate.

A secondary purpose of the Southeast CSC LCC Advisory Committee is to provide assistance and input to the **Science Implementation Panel** (SIP), which will be responsible for peer and technical review of all proposed projects, and to recommend how to utilize available scientific assets of the CSCs and LCCs to address regional science priorities. Key staff from LCCs and other partners (for example, LCC Science Coordinators or other appropriate staff) associated with the Southeast CSC will serve on the SIP, to provide this oversight function of the CSC.

Southeast Regional Assessment Project

In anticipation of the establishment of CSCs, and their collaboration with the LCCs, the U.S. Fish and Wildlife Service and the USGS supported and coordinated a large-scale, multi-disciplinary project to provide useful information and tools to the resource-management community by producing an assessment of climate change, impacts on land cover and ecosystems, and priority species in the region. This project, the Southeast Regional Assessment Project (SERAP; fig. 2) is one example of how the newly formed CSCs and LCCs can work together. SERAP was begun in 2009 and has been under the coordination of the Southeast CSC since 2010. Predictive tools developed by the SERAP team can help resource managers better understand potential impacts of climate change, land-use change, and sea-level rise on terrestrial and aquatic populations in the Southeastern United States.

Project management of SERAP shifted to the Southeast CSC in 2010. In 2011, several components of SERAP were introduced in a similar project to assess the vulnerability of the Caribbean to climate change.

SERAP seeks to formally integrate multidisciplinary project components to aid conservation planning and design so that ecosystem management decisions can be optimized to provide desirable outcomes across a range of species and environments. SERAP seeks to provide a suite of regional climate, watershed, and landscape-change analyses and develop the interdisciplinary framework required for the biological planning phases of adaptive management and strategic conservation. The following four main SERAP components:

- Developing Regionally Downscaled Probabilistic Climate Change Projections *(Theme 1),*
- Integrated Coastal Assessment *(Theme 5),*
- Integrated Terrestrial Assessment *(Themes 2 and 4),* and
- Multi-Resolution Assessment of Potential Climate Change Effects on Biological Resources: Aquatic and Hydrologic Dynamics *(Themes 3 and 4)*.

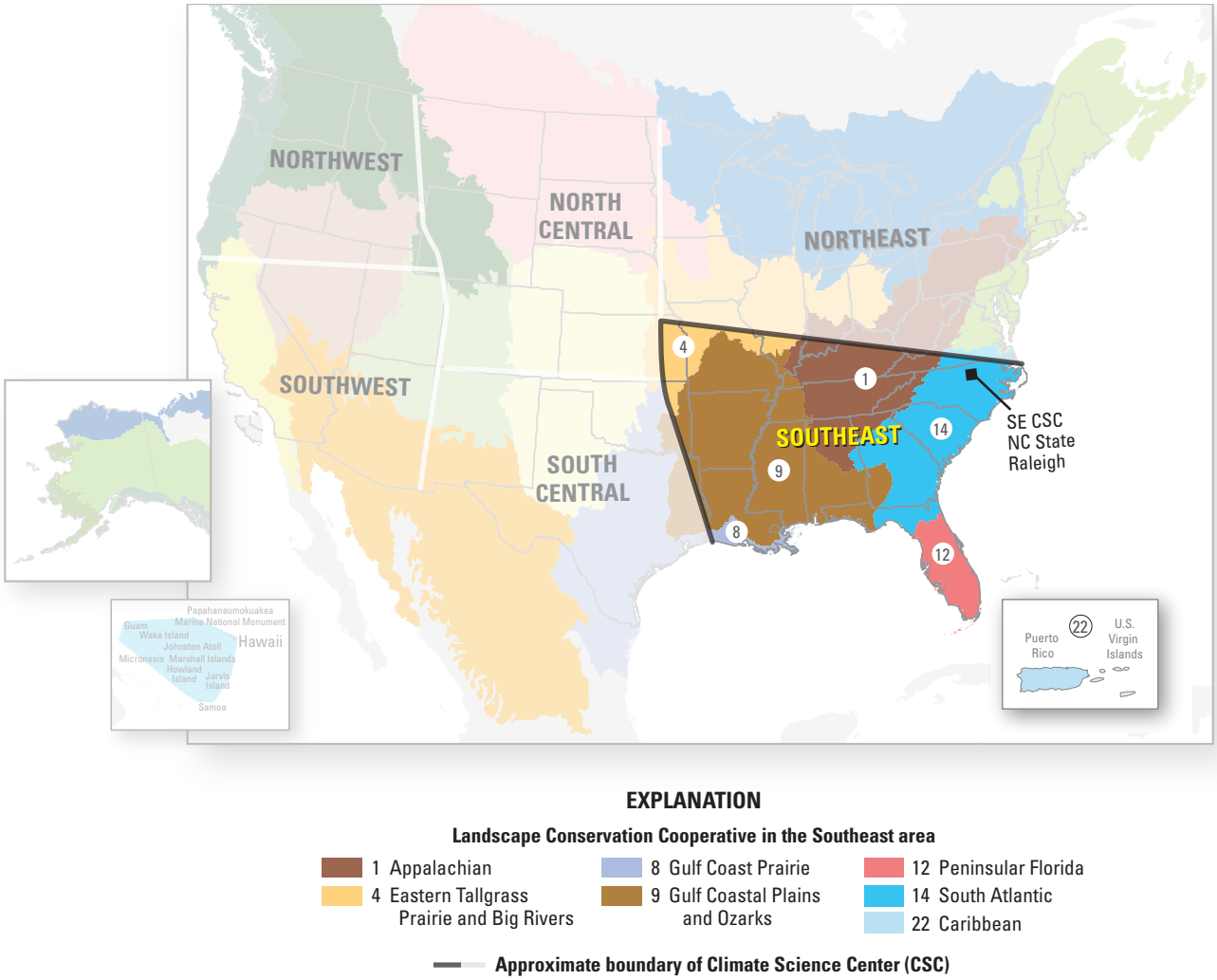


Figure 1. Boundaries of Climate Science Centers and Landscape Conservation Cooperatives.

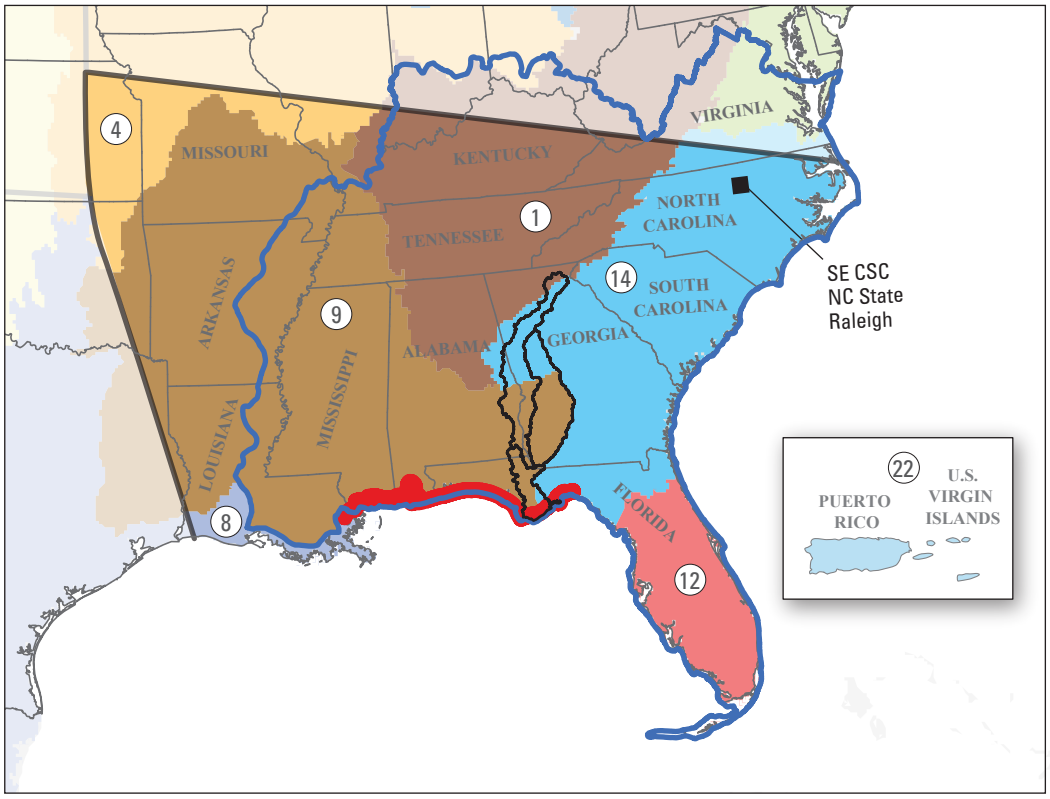


Figure 2. Study area for Southeast Regional Assessment Project.

These components produce data and other outputs that are compiled and used in the development of Optimal Conservation Strategies to Cope with Climate Change (fig. 3; Dalton and Jones, 2010), a tool for resource managers to ensure the most effective land-management strategies. The following sections outline the products that have been or will be produced by the SERAP:

1. **Developing Regionally Downscaled Probabilistic Climate Change Projections**. Statistically downscaled projections of maximum and minimum temperature and mean precipitation through 2099 will be developed at 12-kilometer grids for the conterminous United States. A select series of derivative data produced from model outputs, will include but not be limited to potential evapotranspiration, solar radiation, fire frequency, and frost days.
2. **Integrated Coastal Assessment**. Products include predictive maps of shoreline erosion, data collected from six sediment-elevation table (SET) sites (24 total installations) located in Mississippi and Alabama, and maps of predicted inundation resulting from sea-level rise (available on the Web at *http://gom.usgs.gov/slr/index.html*).

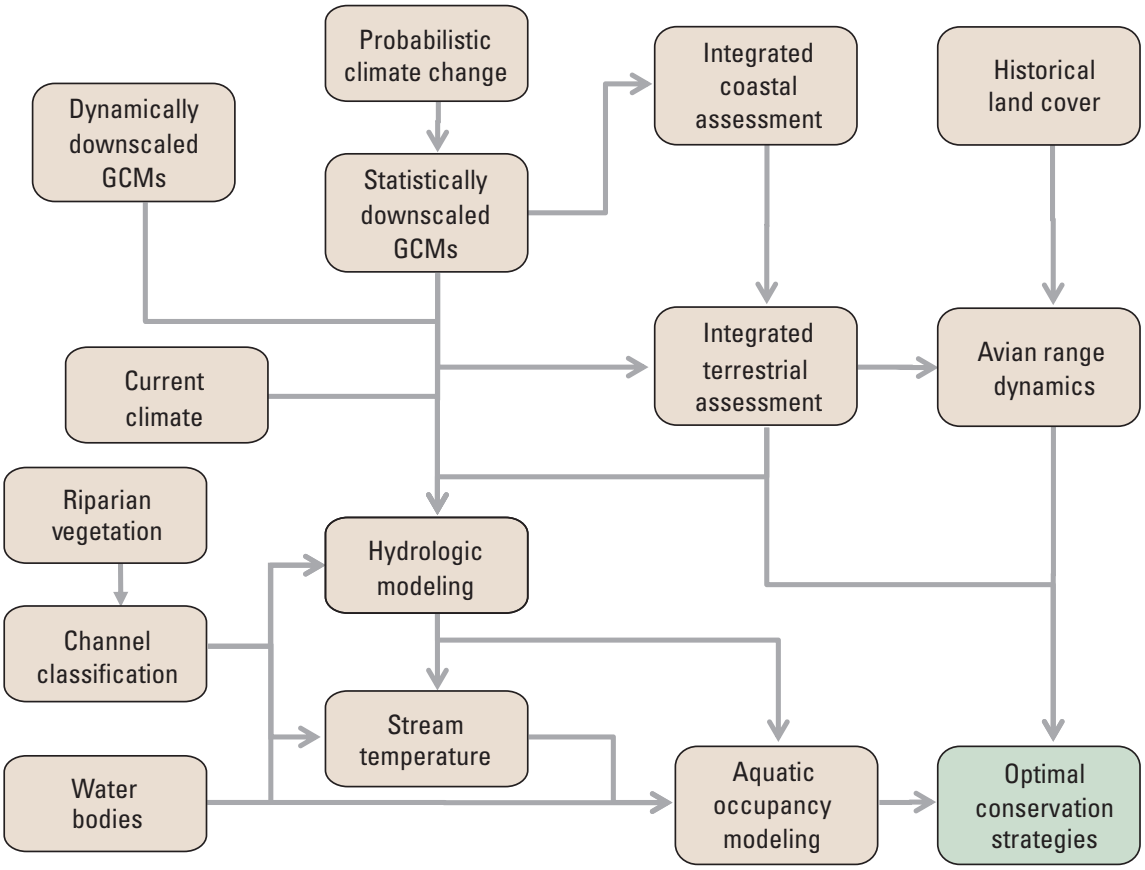


Figure 3. Southeast Regional Assessment Project data-flow diagram.

3. **Integrated Terrestrial Assessment**. Products include urban-growth projections for 2010–2100 at 60-meter grids; vegetation state and transition models at 30-meter grids for each vegetation class in the Southeast with downscaled climate data incorporated as a fire multiplier (A1Fi, B1 scenarios); gridded output of suitable habitat, by species, for 606 terrestrial vertebrates that occur in the Southeast through 2100 for three climate scenarios (A2, A1B and B1) based on non-downscaled climate data; and land-cover maps for 1992, 2001, and 2006.
4. **Multi-Resolution Assessment of Potential Climate Change Effects on Biological Resources: Aquatic and Hydrologic Dynamics**. Products available include predicted streamflow variables, hydrologic cycle components, and simulation of instream temperature fluctuations throughout the Apalachicola–Chattahoochee–Flint (ACF) River basin (fig. 2); and updated geomorphic characterization, stream-channel classification, and updated depression storage and vegetation coverages for the ACF River basin. Species-response models—both coarse and fine resolution models—will be used to predict the presence or absence of aquatic species instream segments as a result of changing climate conditions
5. **Optimal conservation strategies to cope with climate change**. The final product will be an optimal conservation-strategies model based on identified management and policy alternatives that are most likely to sustain populations of focal species. The model will identify key elements for monitoring to reduce uncertainty regarding the effect of climate change on terrestrial and aquatic populations and their habitats and measure progress toward population and habitat objectives.

All project output will be maintained and readily available on the SERAP data portal. The data portal was originally conceived as a mechanism to help SERAP team members easily share data and output, but has since been adopted by CSCs nationwide as a preferred data-management tool known as the GeoData Portal.

Southeast Climate Science Center Science Planning

The Southeast CSC receives funding from the NCCWSC located at the USGS National Center in Reston, Virginia. The NCCWSC provides guidance for national science priorities as part of the USGS Climate and Land-Use Change mission area. Although the NCCWSC manages the Southeast CSC operations, the regional science agenda is determined by the SAC, which also is responsible for reviewing the overall functioning of the CSC. The SAC must review and approve the draft science and operational plan, a critical step in the development and implementation of the Southeast CSC science strategy.

The process used to develop this first draft of the science and operational plan included an effort to involve as many groups as possible in both the development and review of the document. The interim Director of the Southeast CSC, in consultation with NCSU, and federal and State agencies invited a group of scientists to collaborate on the draft plan. This group of scientists, the Southeast CSC Science Planning Team, is composed of the following:

- Levi Brekke, U.S. Bureau of Reclamation;
- Virginia Burkett, U.S. Geological Survey;
- Catherine Burns, The Nature Conservancy;
- Bob Ford, U.S. Fish and Wildlife Service;
- Kevin Robbins, Louisiana State University;
- Margo Schwadron, National Park Service; and
- Jim Vose, U.S. Forest Service.

The Southeast CSC Science Planning Team was tasked with communicating with their constituent groups to obtain input during development of the plan and to solicit review comments on the completed draft from individuals with recognized expertise. The review process consisted of layers of technical review for singular pieces of the draft plan and comprehensive final reviews of the entire draft plan by the SAC. The Science Planning Team relied on input from existing LCC operational plans during the development of this document; however, the process also allowed for input from many partners. Continued involvement from partners in the science planning process will ensure that the document and its science themes are more responsive and relevant to the needs of the conservation community into the future.

The six science themes of this draft plan focus on the climate-change priority issues that Southeast CSC partners have previously defined. These themes and their derivation can be found in appendix which illustrates the priority issues for partners throughout the Southeast in relation to climate change. The development of these themes relied on priorities described by partners and stakeholders in the Southeast as well as the work being done as part of SERAP. The most frequently referenced priority issues were the basis for developing the science research themes, which are the framework for this plan. Issues were ranked according to frequency of inclusion in reference materials; items most often listed as an area of concern or priority issue were evaluated for inclusion in the Science Themes section of this draft of the Southeast Climate Science Center Science and Operational Plan (appendix table A–1).

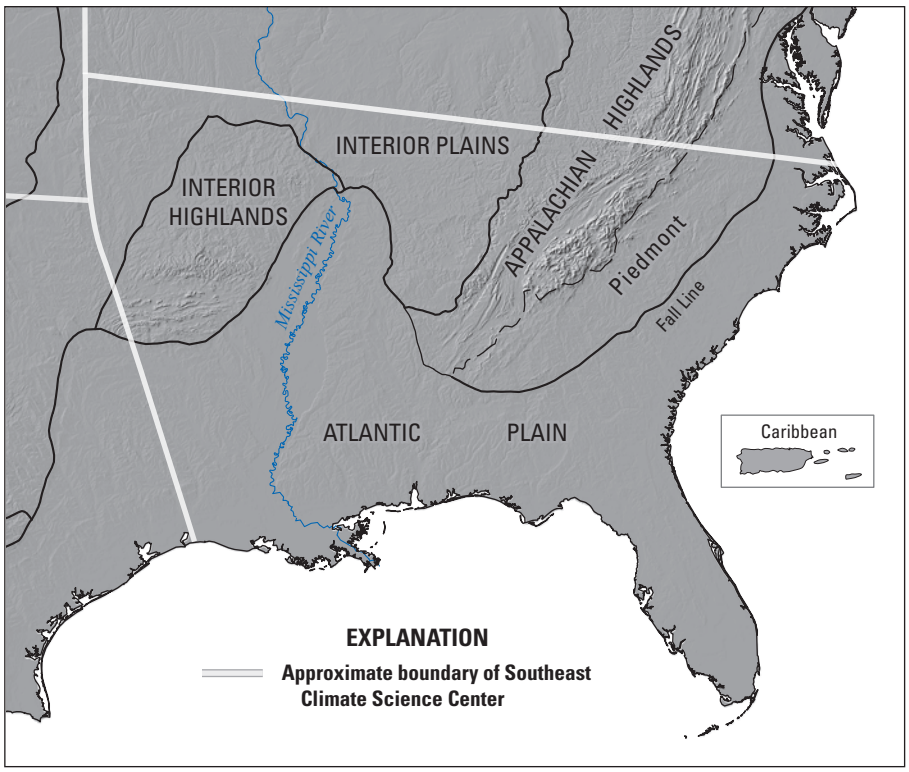
Regional Context

The Southeast CSC represents all or part of 16 states and the Caribbean (fig. 1) and covers four physiographic divisions—the Atlantic Plain, Appalachian Highlands, Interior Plains, and Interior Highlands (fig. 4; Vigil and others, 2000). A large part of the region is within the Atlantic Plain, a broad expanse of low-relief landscape along the gulf and South Atlantic coasts, from Virginia to Texas that extends along the Mississippi River Valley. The Atlantic Plain is very important ecologically in the Southeast as it contains parts of the Mississippi River and the associated delta as well as bays, estuaries, and the barrier islands associated with both the gulf and Atlantic coasts.

The Appalachian Highlands includes the Piedmont Physiographic Province, a slightly elevated plateau that begins at the Fall Line of the Appalachian Mountains. The Interior Highlands includes the inland mountain region of the Southeast, including Ozark and Ouachita Mountains to the west, and the Interior Plains stretch into the north-central portion of the region, including parts of Tennessee and Kentucky (Fenneman and Johnson, 1946; Thelin and Pike, 1991; Vigil and others, 2000). The Caribbean Islands contain geologic features similar to the Appalachian or Interior Highlands and Coastal Plain, commonly referred to as the mountainous interior, coastal lowlands, and the karst area.

The humid subtropical climate of the Southeast and tropical climate of the Caribbean, in combination with diverse landscapes, vegetation, and hydrology contribute to produce a region rich in aquatic and terrestrial flora and fauna.

Prior to European settlement, the southeastern landscape was dominated by upland forests, grasslands, and wetlands. Longleaf pine was the dominant forest species of the Southeast, although by 1980 less than 2 million of the original estimated 90 million acres of longleaf pine remained (U.S. Fish and Wildlife Service, 2010). Even though forests presently compose between one-third and one-half of the land-use in the region, approximately 20 percent of the present forests consist of loblolly pine plantations. Forests of oak, gum, and cypress are still common, though most of the bottomland forests have been converted to agriculture; in fact 85 percent of the bottomland hardwood forests in the lower Mississippi Valley have been drained and cleared for agriculture (Keeland and others, 1995). Roughly half of the wetlands in the region have been converted to other land uses (Hefner, 1994); even with these losses, about one-half of the remaining wetlands in the United States are located in the Southeast (U.S. Geological Survey, 1996). In



Shaded relief from Thelin and Pike, 1991
Physiographic divisions from Fenneman and Johnson, 1946

Figure 4. Physiographic divisions within the boundary of the Southeast CSC.

areas of the Southeast CSC, groups that have the highest North American diversities include amphibians, fishes, mollusks, aquatic insects, crayfishes, salamanders, land snails, and fungi (U.S. Fish and Wildlife Service, 2009a; 2009b); additionally, the Southeastern United States has the highest diversity of vascular plant density and tree species richness in the Nation.

Caribbean landscapes generally are determined by the geology of each island. A few islands are relatively young and volcanically active, while others are remnants of fossilized coral reefs or volcanic mountain chains (Areces-Mallea and others, 1999). The varying geology of the Caribbean has led to unique terrestrial and aquatic habitats and rich species diversity. Vegetation in the Caribbean is determined by substrate, temperature related to altitude, and precipitation amounts and type. The most common vegetation type in the Caribbean is the pioneer vegetation along open beaches and maritime rocks. Forests that may have grown previously along the open coastline have been removed, mostly by European settlers or to some degree modern development. At lower altitudes seasonal forests are found throughout the Caribbean and are identified by the dominant vegetation type—evergreen, semi-evergreen, or deciduous. At higher elevations, montane forests exist although many have been cleared for crops. Mangroves are found in estuaries or along low-elevation coastlines, but populations suffer from increased demands for beaches, moorings, and resort development (Smithsonian Institution, 2011). Biological diversity is high in the Caribbean with estimated 13,000 native vascular plant species, 600 bird species, 90 mammals, 500 reptiles, 170 amphibians, and 160 freshwater fishes (Conservation International and others, 2008). More than 12,000 species have been reported to occur in the Caribbean Sea (Miloslavich and others. 2010).

Between 32 and 37 percent of the population in the Southeast and 60 percent of the population in the Caribbean live within 50 miles of the coast (National Oceanic and Atmospheric Administration, 2011). Populations in the gulf coast counties of the Southeast increased more than 100 percent between 1960 and 2000 (U.S. Census Bureau, 2003). Between 1980 and 2003 coastal counties in the Southeast showed the largest rate of population increase (58 percent) of any coastal region in the conterminous United States (Laporte and others, 2011). Future projections indicate that populations along coastal counties in the Southeast will increase another 20 percent by 2030 (National Oceanic and Atmospheric Administration, 2011).

The variety of historical populations, many of which are still active, in the Southeastern United States and Caribbean, have left a wealth of archeological resources that may be affected by climate change. Examples of archeological and ethnographical resources in the Southeast that may be affected by climate change include both prehistoric and historic submerged sites and shipwrecks; terrestrial prehistoric and historic encampments, midden dumps, home sites, villages, and ceremonial sites; battlefields; historic homesteads, farms, plantations, and production sites; and historic and prehistoric structures.

Observed Climate Change

Long-term temperature records in the Southeast show that average annual temperatures have not changed significantly during the last century; since 1970 however, average annual temperature has increased 2 degrees Fahrenheit (°F, table 1; U.S. Global Change Research Program, 2009). Annual temperature increases in the Caribbean since 1970 have been about 1.5 °F (Intergovernmental Panel on Climate Change, 2007). During this same period, the greatest changes in average annual temperature occurred during the winter months, and the number of freezing days per year decreased. Precipitation records (1970–2008) indicate a regional reduction in annual rainfall from 10 to 30 percent, particularly in the winter and spring; however, precipitation increased during the summer and was about the same during the fall (table 1; fig. 5). Precipitation patterns also changed; the intensity of storms and the occurrence and severity of droughts have increased since 1970 (U.S. Global Change Research Program, 2009).

An increase in sea-surface temperature since 1970 has been accompanied by an increase in the destructive potential of Atlantic hurricanes that make landfall in the Southeast region, although changes in the frequency of hurricanes making landfall has not been established (U.S. Global Change Research Program, 2009). The increase in summer wave heights along parts of the U.S. Atlantic coastline since 1975 is attributed to the increase in tropical storm intensity in the Atlantic basin (Komar and Allan, 2007).

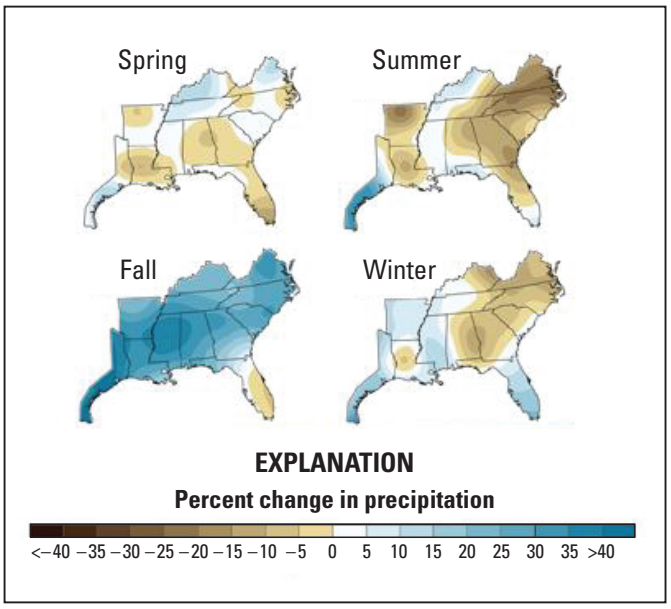


Figure 5. Observed changes in precipitation in the Southeast between 1901 and 2008 (source: U.S. Global Change Research Program, 2009).

Table 1. Trends in average temperature and precipitation for the Southeast United States (from U.S. Global Change Research Program, 2009).

Average temperature change, in degrees Fahrenheit			Precipitation change, in percent		
Season	**1901–2008**	**1970–2008**	**Season**	**1901–2008**	**1970–2008**
Annual	0.03	1.6	Annual	6.0	–7.7
Winter	0.02	2.7	Winter	1.2	–9.6
Spring	0.04	1.2	Spring	1.7	–29.2
Summer	0.04	1.6	Summer	–4.0	3.6
Fall	0.02	1.1	Fall	27.4	0.1

Projected Climate Change

Temperature projections from both the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (Parry and others, 2007) and the second national assessment (U.S. Global Change Research Program, 2009) indicate continued warming for all seasons across the Southeast along with increased rates of temperature increases through 2099. Projected rates of warming are twice the rates of temperature increases experienced in the Southeast since 1975, and the greatest temperature increases are projected to occur during the summer months. The number of days with peak temperatures over 90 °F is predicted to increase at a greater rate than average temperature. Temperature projections vary based on emission scenarios; lower emission scenarios project an average temperature increase of about 4.5 °F by 2080, while higher emission scenarios project an average annual temperature increase of about 9 °F, including a 10.5 °F increase in summer and a much higher heat index for the Southeastern United States (U.S. Global Change Research Program, 2009). In the Caribbean, average annual temperature is predicted to increase by about 4 °F by 2080, somewhat below the global average (Intergovernmental Panel on Climate Change, 2007). Climate models also project a continuing decline in days below freezing across the entire region during the coming decades.

Sea-surface temperature is projected to increase globally as the oceans absorb increasing heat energy from corresponding projected annual increases in air temperature. Tropical storm and hurricane activities are likely to increase in the Atlantic hurricane-formation region as a function of globally observed higher sea-surface temperatures (Parry and others, 2007; U.S. Global Change Research Program, 2009). If the intensity of Atlantic tropical storms increases, southeastern ecosystems likely will be exposed to higher peak wind speeds, rainfall intensities, storm surges, and wave heights.

Climate models provide divergent results for future average annual precipitation for most of the Southeast and Caribbean; however, the ensemble of models used by the Intergovernmental Panel on Climate Change (Parry and others, 2007) and the U.S. Global Change Research Program (2009) predict that southeastern States will tend to have less rainfall in winter, spring, and summer (fig. 6) and precipitation in the Caribbean is expected to decline by about 12 percent. Because corresponding predicted temperature increases will lead to increased evapotranspiration, moisture deficits and droughts are likely to continue to increase (U.S. Global Change Research Program, 2009).

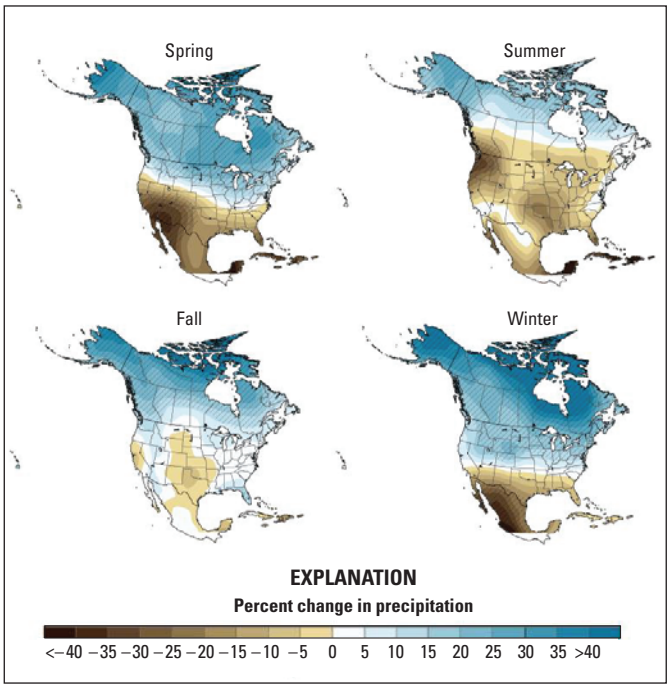


Figure 6. Projected change in North American precipitation by 2080–2099 as simulated by an ensemble of 15 climate models under the Intergovernmental Panel on Climate Change A2 emission scenario (source: U.S. Global Change Research Program, 2009).

Predicted average annual temperature increases are likely to warm oceans and increase the rate that land ice melts; global average mean sea levels are expected to increase up to 2 feet or more by 2100 (U.S. Global Change Research Program, 2009). A potential increase in the rate and magnitude of sea-level rise has serious implications for low-lying southeastern coastal wetlands and barrier islands. Many environments along the South Atlantic and Gulf of Mexico coastal areas have undergone land-surface subsidence because of factors such as groundwater withdrawals, changes in sediment delivery by rivers, and the drainage of soils for coastal development. Even if hurricanes do not increase in intensity, an increase in mean sea level will amplify coastal inundation and erosion during hurricane landfall.

Currently 5,000 square miles of dry land are within 2 feet of mean sea level in coastal areas of the continental United States. While the majority of this land currently is undeveloped, coastal development in the Southeast is predicted to increase more than in any coastal region of the United States (National Oceanic and Atmospheric Administration, 2011; U.S. Environmental Protection Agency, 2011; Laporte and others, 2011), and any terrain within a few feet above mean sea level could be inundated (fig. 7; U.S. Environmental Protection Agency, 2011). Currently, sea levels are rising at 0.07 inch per year. Intergovernmental Panel on Climate Change (Parry and others, 2007) predictions of future sea-level rise through 2100 are between 0.6 and 2 feet. Impacts of rising sea levels include coastal erosion; coastal inundation, including wetlands; increased storm surge; loss of habitat, property, and cultural resources; and degraded surface and groundwater quality. Highly productive coastal wetland ecosystems are particularly vulnerable to sea-level rise (Parry and others, 2007; U.S. Environmental Protection Agency, 2011). These ecosystems provide habitats for many species, act as filters to improve groundwater and surface-water-quality, provide an economic base for many coastal communities, offer recreational opportunities, and protect local areas from flooding.

Projected changes in temperature, precipitation patterns, tropical-storm intensity, and sea-level rise over the coming decades have serious implications for human communities and natural resources in the Southeast. The warming projected during the next 50 to 100 years will create heat-related stress on people, agricultural crops, livestock, trees, transportation and other infrastructure, fish, and wildlife. Seasonal changes in precipitation patterns, coupled with increased temperature and evapotranspiration, could have widespread and significant effects on water resources, ultimately affecting fish and wildlife resources and the people who depend on them. Based on historical and projected patterns of land-cover change in this region, land-use change and other human development impacts are likely to amplify the adverse effects of climate change on habitats and species.

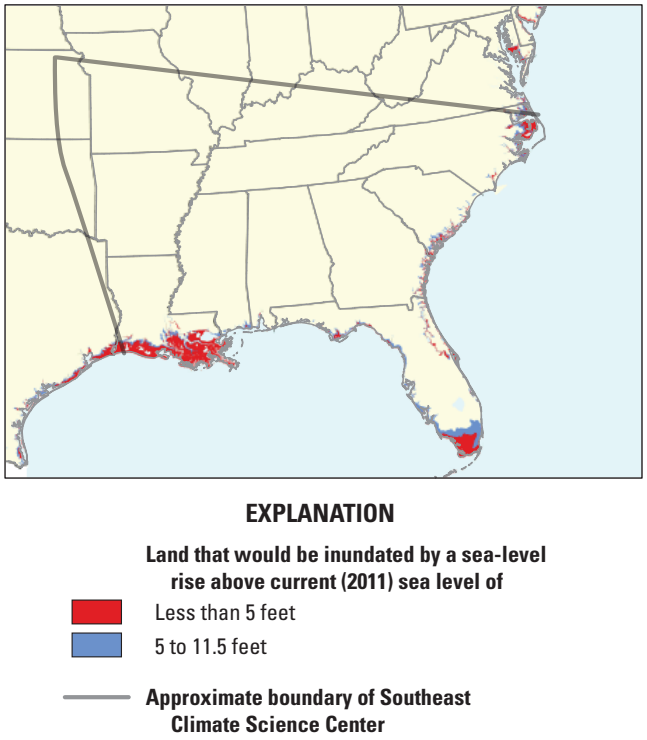


Figure 7. Projected land areas in the Southeastern United States that would be affected by a sea-level rise of 3 and 9 feet (source: Center for Remote Sensing of Ice Sheets [CReSIS], 2011).

Land-Use and Land-Cover Change

The U.S. Global Change Research Act of 1990 defines global change as "changes in the global environment (including alterations in climate, the land surface and its biological productivity, oceans or other water resources, atmospheric chemistry, and ecological systems) that may alter the Earth's capacity to sustain life" (U.S. Congress, 1990). Understanding how land-use change interacts with other climate-change drivers to influence ecosystems and ecosystem services may prove to be more important in the Southeast than in most other U.S. regions. Most of the Southeast experienced a 10- to 33-percent change in land use during 1973–2000 (fig. 8). In the Southeast, land-use change can be attributed to forest industry practices and urban growth. Short harvest cycles of pine plantations result in a considerable amount of land changing from forested to cleared and back to forested. Commonly in the Southeast, agricultural lands are lost to urban growth and forestry practices. More importantly, development is accelerating across the Southeast and is causing the conversion of both agricultural and forested lands to urban (Loveland and Acevedo, 2010).

Projections of increased temperatures and changes in precipitation patterns also could affect land-use patterns in the Southeast. Predicted climatic changes could reduce the net primary productivity (net amount of carbon fixed by green plants over the course of a year) of southern pines. Model results indicate that southern hardwoods will be much more productive than southern pines and that forest productivity will shift northward. As a result, agricultural productivity is expected to increase in areas where forest productivity is reduced (U.S. Global Change Research Program, 2009), which indicates a future shift of land-use in the South from forested back to agriculture.

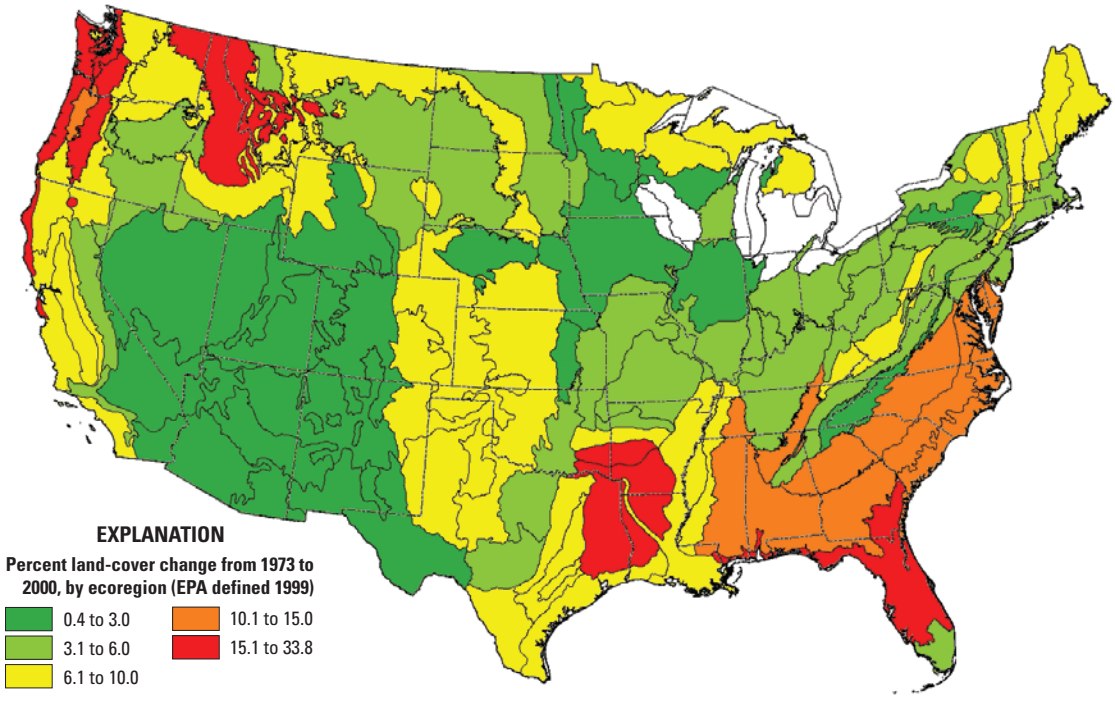


Figure 8. Summary of trends in U.S. land cover change, 1973–2000 (source: USGS Earth Resources and Observations Science Center, 2011).

Science Themes

The Southeast CSC Science and Operational Plan presents science themes and tasks, established by partners in the southeastern conservation community, to address information gaps that can inform the conservation science and resource-management needs of ecoregional conservation partnerships, such as the LCCs. The themes presented here will evolve and be modified through an adaptive management approach incorporating observed results and management assumptions developed by resource managers at various spatial scales. The process seeks to achieve the following objectives:

> *The Southeast CSC will use long-term observational records and understanding of biological and physical processes that can be expressed in quantitative models to describe the consequences of global change on natural resources, provide scientifically valid information and tools that can be used to adapt resource management to changing environmental conditions, and apply these tools to produce regional assessments that are widely used by policy makers, resource managers, and the public.*

The Southeast CSC will provide the scientifically valid information needed to manage southeastern ecosystems and cultural resources, thus maximizing their values in a changing climate. The Southeast CSC will provide models of future conditions, assessments of potential impacts, and other products used to inform the decision-support tools developed by LCCs, and other partners, for resource managers in order to anticipate and adapt to climate change. Resource managers in the Southeast are requesting this type of information as a result, in many cases, of observed climate-change effects.

This science plan is intended to prioritize basic or applied research required to move data and models from the research environment to the operational environment where they are needed most. The science plan identifies six science themes that frame the activities needed to achieve the objectives of the Southeast CSC:

- Science Theme 1: Develop climate projections and determine appropriate projections to use for resource management,
- Science Theme 2: Land use and land cover change projections,
- Science Theme 3: Impacts of climate change on water resources,
- Science Theme 4: Ecological research and modeling,
- Science Theme 5: Impacts of climate change on coastal and nearshore marine environments, and,
- Science Theme 6: Impacts of climate change on cultural-heritage resources.

The development of these themes relied on priorities described by partners and stakeholders in the Southeast as well as a previous large-scale, multi-disciplinary project—the SERAP, developed in concert with partners. In many instances the tasks that are defined for each of the science themes as part of this plan can use the work already begun as part of SERAP to build upon, providing valuable information to resource managers in the Southeast and allowing partners to reevaluate their priorities earlier in the process.

In order to understand the degree to which natural and cultural resources in the Southeast may be affected by climate change, the Southeast CSC also will provide support for vulnerability assessments conducted for the natural and human systems across the Southeast, regardless of political boundary and including U.S. territories in the Caribbean. Derivative products developed by the CSC, such as numbers of freeze days or fire frequency, provide valuable information for finer scale conservation planning. The Southeast CSC will share derivative products and engage in finer scale planning efforts related to vulnerability. By comparison, conservation science partnerships, such as LCCs, can use CSC assessments and derivative products in conducting vulnerability assessments for specific natural or cultural resources.

Vulnerability assessments can be undertaken at a range of geographic scales to address individual species or ecosystem elements in order to identify vulnerabilities affecting the assessment target or to evaluate relative vulnerabilities of multiple targets across geographic areas. It is imperative that the CSC work closely with finer scale efforts by the LCCs and other partners to ensure that vulnerability assessments at different spatial scales and for different purposes are complementary and add value to future iterations of assessments. Vulnerability assessments generally address one or more of the following factors: (1) sensitivity of the resources in question to climate change, (2) likely exposure of the resources in question to climate change, and (3) adaptive capacity of the resources in question to climate change.

The Southeast CSC will develop science products to help address the impacts listed in the most recent U.S. national assessment (U.S. Global Change Research Program, 2009). Examples of the kinds of impacts that are anticipated in the Southeast and Caribbean include the following:

- Decreased water availability because of increased temperature and fewer rainfall events, coupled with increased societal demand could affect many sectors of the southeastern economy. Projected increases in temperature are likely to lead to more frequent outbreaks of shellfish-borne diseases in coastal waters, altered distribution of native plants and animals, loss of many threatened and endangered species, displacement of native species by invasive species, and more frequent and intense wildfires.

- The hydrology of natural systems also is affected by climate change and related human-response strategies, such as increases in storage capacity (dams) and in irrigated croplands. As humans seek to adapt to climate change by manipulating water resources, streamflow and biological diversity may be adversely affected. During droughts, recharge of groundwater declines as the temperature and spacing between rainfall events increase. Increasing groundwater pumping to supplement water needs will stress or even deplete aquifers and place increasing strain on surface-water resources. Increasing evapotranspiration rates alter the balance of runoff and groundwater recharge, which can lead to saltwater intrusion into shallow aquifers in many parts of the Southeast, not just in the coastal zone.

- Mean sea-level rise and increased hurricane intensity are likely to be among the most significant economic consequences of climate change for this region over the next 50–100 years. As sea levels rise, gulf and South Atlantic coastal shorelines will retreat, and low-lying areas will be inundated more frequently, if not permanently, by the advancing sea. As temperature increases and rainfall patterns change, soil moisture and runoff to the coast likely will be more variable, changing the input of sediments, nutrients, and saline water to estuaries, coastal wetlands, and tidal rivers.

- Most island communities in the Caribbean have limited sources of freshwater to support unique ecosystems and biodiversity, public health, agriculture, and tourism. Since rainfall triggers the formation of a freshwater lens in shallow aquifer systems, changes in precipitation, such as the projected significant decreases for the Caribbean, can drastically affect the availability of groundwater. Because tropical storms replenish water supplies, potential changes in these storms are a great concern. Small islands are considered among the most vulnerable to changes in weather patterns and the frequency and intensity of extreme events. Sea-level rise, coastal erosion, coral-reef bleaching, ocean acidification, and contamination of freshwater resources by saltwater are among the climate change impacts that small islands face.

- A rapid acceleration in the rate of increase in sea-level rise could potentially threaten a large portion of the southeastern coastal zone. The likelihood of a catastrophic increase in the rate of sea-level rise is dependent on ice-sheet response to warming, which is the subject of much scientific uncertainty (U.S. Global Change Research Program, 2009).

These and other changes in southeastern ecosystems are likely to accelerate if the climate continues to warm as projected by climate models. The effects of climate change, coupled with the extensive development of land and water resources in this region, portend widespread and serious challenges for resource managers.

The science themes of this draft plan reflect the current state of the science and the stated needs of resource managers in the Southeast. The near- and long-term task recommendations under each theme are based, in large part, on existing plans and documents from other federal agencies, states, and non-governmental organizations (NGOs) across the Southeastern United States (appendix), as well as work already underway in the SERAP project. It is a high priority of the Southeast CSC to coordinate all research support and funding decisions with our partners to best leverage available resources in the Southeast and neighboring regions.

Science Theme 1: Develop Climate Projections and Determine Appropriate Projections to Use for Resource Management

Easily accessible high-quality climate projections are a critical need for the Southeast CSC and its partners. This section identifies some available climate projections and describes how the projections can be used to address impacts, vulnerability, and adaptation assessments conducted by the Southeast CSC. The section includes both "bottom-up" (Task 1) and "top-down" approaches (Tasks 2–4). The bottom-up approach involves using LCCs and the conservation community at large to identify aspects of climate that are relevant to resource management, research, and assessment questions being addressed (for example, which climate variables are characterized and at what scales?). A top-down approach involves surveying and evaluating available global climate-projection information, deciding which projections should be retained for Southeast CSC activities, and processing this information from global-model to basin-relevant resolution (for example, using spatial downscaling). Ultimately the findings from these two approaches merge (Task 5), and decisions are made as to the aspects of the retained information that can be used to inform management activities and actions for a sustainable landscape. Under each task, framing considerations are summarized, existing information resources are listed, and general recommendations are offered.

Task 1: Evaluate Needed Climate Information Within the Framework of Southeast CSC Focus Resources and Study Questions

A well-developed sense of the climate conditions that are most relevant is needed when surveying available climate-projection information and deciding how it can be used in Southeast CSC assessments. Partner workshops, most likely focused within LCC geographies, will be crucial in providing this type of information by asking such questions as, "Which resources are most important to inform partners' decisions about how to sustain landscapes, ecosystems, cultural resources, and fish and wildlife populations?" and "Which resource metrics will be used to assess the resource under current and future conditions?" and "Which scale is most appropriate, both spatially and temporally?"

After working with partners to define a set of resources, appropriate metrics, and scales, it is important to evaluate sensitivity to changes in climate. Climate changes may stem from different variables, such as precipitation and temperature; scales (spatial and temporal resolution); and statistical measures, such as regional versus catchment-scale weather; long-term mean condition versus short term potentially extreme condition.

The objective of this task is to develop a better understanding of the more relevant aspects of climate change for selected resources and metrics. This understanding, in conjunction with understanding the strengths and weaknesses of available climate-projection information (Tasks 2–4), will lead to better informed selections of climate-projection information and decisions on how to use such information in Southeast CSC activities (Task 5).

Near term recommendations

- Work with the conservation community, specifically through LCCs, using a structured decision-making process to identify resource-management questions and determine the downscaled information that is the most useful for the identified problem(s).

Long term recommendations

- Apply findings from partner workshops to help guide refined selection of CMIP3[1] and (or) CMIP5[2] information (discussed further in Task 2) for continued use in Southeast CSC activities.

Task 2: Survey Available and Forthcoming Global Climate Projections

During the past decade, global climate projections have been made available through the efforts of the World Climate Research Program (WCRP) Coupled Model Intercomparison Project (CMIP), which has advanced in three phases—CMIP1 (Meehl and others, 2000), CMIP2 (Covey and others, 2003)], and CMIP3 (Meehl and others, 2007). The CMIP3 efforts were fundamental to completing the IPCC Fourth Assessment Report (Parry and others, 2007). CMIP3 data are publicly available and well documented. They represent climate simulations reflecting multiple pathways of greenhouse-gas emissions (Nakicenovic and Swart, 2000), as simulated by 23 coupled atmosphere-ocean general-circulation models (AOGCMs), from multiple initial climate-system conditions (indicated by the run number for a given combination of emissions scenarios and AOGCM).

The next generation, CMIP5, has been designed (Taylor and others, 2011), and projections are scheduled to arrive during 2011–2012. Subsequently, it is expected that an evaluation phase will be carried out by the broader climate-science community (for example, laboratories at the National Center for Atmospheric Research (NCAR), National Aeronautics and Space Administration (NASA), Goddard Institute for Space Studies (GISS), and National Oceanic and Atmospheric Administration (NOAA)), which will begin the process of characterizing the strengths and weaknesses of CMIP5 projection information. CMIP5 will reflect a new

[1] About CMIP3: *http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php*

[2] About CMIP5: *http://cmip-pcmdi.llnl.gov/cmip5/*

set of greenhouse-gas emissions pathways, referred to as representative concentration pathways (RPCs)[3], and a new collection of climate models. The latter will include CMIP3-style AOGCMs, as well as coupled climate and carbon cycle models and higher-resolution atmospheric general-circulation models (AGCMs). However, CMIP3 may be nearing the end of its shelf life, and it remains to be seen whether the CMIP5 ensemble offers a substantially different portrayal of the future than CMIP3 (for example, climate variable and scale for a given region). It also is expected that assembly and characterization of the CMIP5 ensemble will take the better part of the next couple of years, particularly the characterization of strengths and weaknesses. This vetting ideally will include discussion of which CMIP5 focus (first or second) seems most appropriate for the types of impact-assessment questions being considered within the Southeast CSC. (For example, should an impact assessment reference results from the decadal prediction experiments, from the 21st century CMIP3-style AOGCM projections, or from the 21st century coupled climate and carbon cycle projections?)

Near term recommendations

- Use CMIP3 information as the basis for Southeast CSC climate projections.

Long term recommendations

- Anticipate use of CMIP5 information—either as a replacement for CMIP3 or a blending of CMIP5 with CMIP3.

Task 3: Decide Whether and (or) How to Cull and Update Global Projections

When scoping research or assessments on climate-change impacts, a common question is whether the wealth of available global climate-projection information can be parsed so that focus can be given to a more credible subset of projections. Frequently, this question is motivated by interest in reducing the cone of uncertainty in the projection, and the belief that more credible climate projections can or will diminish the cone of uncertainty.

The CMIP3 ensemble has been subjected to considerable study on the matter of selecting "more credible" climate projections. Some studies have discussed the matter in terms of the relative likelihood of emissions scenarios, with some discussion focused on how recent rates of global greenhouse-gas emissions exceed the early 21st century scenario rates of global greenhouse emissions (Nakicenovic and Swart, 2000) as reflected in CMIP3. However, it is generally understood that despite the recent trend in global emissions rates, it is unclear whether recent trends will persist in a way that some emissions pathways can be judged as more likely. Switching from emissions likelihoods to climate model skill, other studies have focused on evaluating historical simulations from AOGCMs, considering their abilities of simulating global to regional climate conditions. In summary, it has been shown that CMIP3 AOGCMs can be ranked and (or) weighted on some set of climate-simulation metrics where observed and simulated metrics are compared during a common historical period (Knutti and others, 2010). However, it also has been shown that rank results depend on the climate simulation metrics that are considered (Brekke and others, 2008; Gleckler and others, 2008). Further, it has been shown that the use of model ranking to cull projections does not necessarily lead to more confident results in a variety of studies, including those involving historical climate-change detection and attribution (Santer and others, 2009) and assessments of future climate uncertainty (Brekke and others, 2008; Pierce and others, 2009; Knutti and others, 2010). Reasons for these outcomes warrant further review; however, two contributing factors may be (1) disparate initial conditions in global simulated climate projections can affect interpretation of regional climate change signal relative to noise (Hawkins and Sutton, 2009; Hawkins and Sutton, 2010; Deser and others, 2011), and (2) is how a climate model's skill in simulating a climate system response to a change in forcing is not necessarily well-connected to its skill in simulated baseline period climatology. Based on these evaluations, it seems justifiable to forego culling or weighting of CMIP3 projections based on perceptions of credibility (Mote and others, in review). This conclusion will need to be revisited with CMIP5, when new global climate models (GCM) simulations are available to establish performance metrics that may be more robust (Knutti and others, 2010).

The preceding discussion only addresses the decision whether to cull or not to cull climate-projection information based on a sense of *relative* credibility. The discussion does not address whether the culled or full-projection ensemble adequately portrays a given climate condition, such as variable, metric, or scale. However, an answer to the latter question depends on whether and how the raw AOGCM outputs are bias-corrected and spatially downscaled over the region. For this reason, the latter question is discussed under Task 4.

Near term recommendations

- Use CMIP3 information without credibility-based projections culling.

Long term recommendations

- Anticipate using CMIP5 information and revisit the matter of whether it appears that a robust basis can be established for judging CMIP5 projections credibility over the Southeast CSC domain and for regional climate metrics of interest.

[3] For a description of the RCPs, see Moss and others, 2008, report from the IPCC Expert Meeting Towards New Scenarios, held in Noordwijkerhout, The Netherlands, in September, 2007 (see *http://www.mnp.nl/ipcc/*, "IPCC New Scenarios" (Taylor and others, 2011)

Task 4: Characterize how Global Projections May be Downscaled and Bias Corrected

Use of global climate-projection information for assessing projected regional and local conditions usually requires two fundamental steps and decisions: (1) how to relate the spatially coarse global climate model output to more localized conditions (that is, how to spatially downscale this information), and (2) how to compensate for the source GCM simulation biases when developing the projected climate information (that is, how to bias-correct climate model output).

For the first fundamental step it is generally agreed that one issue with the CMIP3 projections is that the spatial scale of climate model output is too coarse for regional studies (Fowler and others, 2007; Maurer and others 2007). Several reports offer discussion on the various methodologies (Wigley, 2004; Parry and others, 2007 [Report from Working Group I—Chapter 11, "Regional Climate Projections"]; Brekke and others, 2009a, 2009b). Two primary approaches to downscaling the information are statistical (non-dynamical) and dynamical downscaling, where the latter is performed using a regional climate model. Both class types and available sources of downscaled CMIP3 information within these class types are described below.

Statistical downscaling

Relative to dynamical downscaling described later, statistical downscaling offers a large collection of global climate projections for a continuous period spanning 1950–2099. Hence, these resources could be labeled as projections "rich," permitting characterization of climate-projection uncertainty over the Southeast during the course of the 21st century. This characterization may be useful in serving risk-based assessments of effects, vulnerabilities and adaptation needs. However, these empirically and statistically downscaled resources have the drawback that they reflect some degree of assumed statistical stationarity between fine- and coarse-resolution surface climate, even though large-scale climate change may affect such relations.

SERAP-downscaled CMIP3 projections. The USGS NCCWSC has supported the development of a series of downscaled climate scenarios as part of SERAP. The downscaling methodology is described in Dalton and Jones (2010) and follows the asynchronous regression method described in O'Brien and others (2001) and Dettinger and others (2004), complemented by a mixture model-clustering approach with non-homogeneous transition probabilities to simulate the occurrence and intensity of daily precipitation (Vrac and others, 2007). The methodology was applied to a collection of 16 CMIP3 projections—four climate models and their respective simulations of four emissions scenarios (B1, A1b, A2, and A1fi; Nakicenovic and Swart, 2000) and produced gridded projections of daily minimum temperature, maximum temperature, and precipitation for 1950–2099 over the continental U.S. at a 1/8º spatial resolution. The effort is complemented by an evaluation of the climate models for simulation-skill characteristics, resulting in a model weighting scheme that might be used to combine this projection information (see Bayesian ensemble dressing methods described in Dalton and Jones [2010]), following Draper (1995) and Hoeting and others (1999). A Web-based data service was scoped and implemented during spring 2011.

Bias correction and downscaled World Climate Research Program CMIP3 climate projections. Similar to the SERAP effort, this public archive serves a large collection of downscaled CMIP3 climate projections over the continental United States. The initial archive scope (Maurer and others, 2007) included monthly projections of temperature and precipitation at 1/8º spatial resolution, developed by applying the Bias-Correction Spatial Disaggregation (BCSD) technique (Wood and others, 2002) to 112 CMIP3 projections (stemming from 16 CMIP3 GCMs, each simulating three emissions scenarios—SRES B1, A1b, and A2—one or more times reflecting one or more initial climate-system conditions). Since then, the archive has undergone two expansions. The first occurred in 2009, which added gridded weather observations (1/8º "obs" from Maurer and others, 2002) and 2º re-gridded CMIP3 projections (before bias correction) and 2º bias-corrected projections. The second is ongoing and involves serving daily downscaled climate projections based on application of a new technique—Bias-Correction Constructed Analogues (BCCA; Maurer and others, 2010). As with the SERAP application of asynchronous regression, application of BCCA yields gridded projections of daily minimum temperature, maximum temperature, and precipitation. This procedure was applied to 53 of the 112 CMIP3 projections subjected to BCSD. Looking ahead, the archive collaborators (led by Climate Central) plan to apply monthly BCSD and daily BCCA to CMIP5 projections as they become available.

Dynamical downscaling

Dynamically downscaled projections may reveal changed relations (historical to future) between local surface climate and large-scale atmospheric circulation; albeit, interpretation of these changed relations is limited by uncertainties and error characteristics of the regional climate models (RCMs) used in the effort. These projections describe coupled land and atmospheric-column conditions. Compared to the empirically and statistically downscaled resources above, dynamically downscaled resources could be labeled as variable "rich" (including all simulated variables in surface water and energy balances, atmospheric-column states) and projections "poor." These resources also tend to be limited in terms of temporal coverage because of the high computational costs of dynamically downscaling long time periods. As for spatial resolution comparison, two resources are described below La Florida (more regionally focused) and North American Regional Climate Change Assessment Program (NARCCAP, national to continental scale).

La Florida climate downscaling experiments.[4] This information resource reflects downscaled translations of two time periods (1971–2000 and 2041–2070) from three CMIP3 projections over a domain representing the Southeastern United States. Downscaling was performed by using a single RCM, which also was used to downscale historical atmospheric reanalysis over the region. Data are served at a spatial resolution of 10 kilometers (about 1/8º) and time-aggregated to hourly and daily time-steps.

North American Regional Climate Change Assessment Program.[5] This information resource reflects downscaled translations of the same two time periods (1971–2000 and 2041–2070) but from four CMIP3 projections over a North American domain produced by four GCMs. Downscaling was performed by using a suite RCMs in which each participating RCM was used to downscale at least two CMIP3 projections. These RCMs also were used to downscale historical atmospheric reanalysis to gain relative simulation characteristics among the participating RCMs. Data are served for the conterminous United States and much of Alaska at a spatial resolution of 50 kilometers (about 1/2º). Reported data are time-aggregated for various time-steps, ranging from monthly to sub-daily.

On the matter of compensating for the GCM simulation biases when developing the downscaled climate-projection information, multiple ways of bias correcting such outputs are available. Common themes involve identifying a given climate model's biases in simulating historical conditions during a period overlapping with observations (for example, 1950–1999 monthly mean precipitation and temperature over a region, or some other statistical aspect of monthly or other time-step and (or) variable). After identifying this bias, the historical climate simulation results are corrected statistically to match observations during the period of bias identification. Similar corrections also are made for the projection period that follows. Depending on methods selected, bias correction might happen before or after downscaling (for example, bias correction of surface climate conditions could be done *after* dynamical downscaling given that RCM simulation inputs depend on a large set of land-surface and atmospheric-column GCM outputs that would be difficult to bias-correct in a coordinated fashion. Bias correction of statistical downscaling could be done *before* or *afterwards*, depending on the method).

GCM bias correction is treated differently in the various resources described above. Both of the empirical and statistical resources are based on procedures that feature bias correction of CMIP3 output, either integrated into the spatial downscaling procedure or performed beforehand. The dynamically downscaled resources do not feature bias correction of CMIP3 output prior to downscaling or after RCM simulation. However, if the information is used to define climate change scenarios, such as assessing change in climate from NARCCAP 1971–2000 output to NARCCAP 2041–2070 output, and these scenarios then are used to perturb historically observed weather conditions to define future weather conditions, then it can be said that "bias correction in the mean" is being performed and, in this case, bias correction of the serial GCM-RCM simulation.

Opportunities to Leverage Various Sources of Information

Moving forward, it seems that the Southeast CSC is well positioned to utilize the information produced through the SERAP effort. SERAP is unique in that among the resources listed above, it is the only project to consider climate projections forced by the A1Fi emissions scenario, which features a greater rate of greenhouse-gas emissions compared to the other Special Report on Emissions Scenarios (SRES) represented in the other downscaled projections resources (B1, A1b, and A2).

Noting these advantages of referencing SERAP as a primary resource, there are still opportunities to leverage other resources. For example, the second empirical and statistical resource offers similar daily-gridded climate projections and a greater number, which may provide assistance in characterizing future projection uncertainties. Also, this second resource features empirical downscaling conducted by two alternative techniques, which affords the opportunity to explore empirical downscaling uncertainties over the region. Switching attention to dynamically downscaled resources, both options offer opportunities to assess whether large-scale changes in climate could trigger local-scale changes in land and atmosphere interactions (something that is not revealed in the empirical and statistical techniques). Comparing the two dynamical resources, the multi-RCM, 50-kilometer resolution NARCCAP information is useful for exploring RCM uncertainties, whereas the single-RCM, 10-kilometer resolution La Florida information is characterized at a resolution that may be more comparable to the empirical and statistical resources, again offering opportunities to assess uncertainties associated with downscaling techniques.

On judging which downscaled-projections information to use for which Southeast CSC activities, it is recommended that the hanging question from Task 3 also be considered, which is whether the retained climate-projection information adequately portrays a given climate condition over the Southeast (for example, variable, metric, scale). In other words, which simulated climate conditions do we have more confidence in, and why. Any evaluation of the "credibility" of projected climate information must consider downscaling as well as any climate projections bias correction that happens before, during, or after the downscaling procedure. Such evaluation ideally would be conducted through broader federal vehicles (for example, through development of the 2013 National Climate Assessment or activities within the NOAA regional climate services). However, it seems worthwhile for climate-science leads from the Southeast CSC to be engaged in such efforts, perhaps sharing insights about which climate conditions are relevant to the Southeast (Task 1) in a way that could sharpen the scope of such assessment.

[4] *http://www.floridaclimateinstitute.org/projects/88-projects/158*

[5] *http://www.narccap.ucar.edu/*

Near term recommendations

- Obtain available CMIP3 climate-projection information (raw AOGCM results and bias-corrected and (or) downscaled translations) throughout the Southeast. Evaluate the historical periods of simulation and evaluate simulation adequacy for the menu of climate conditions considered.

Long term recommendations

- Track ongoing downscaling research activities, consider findings from the preceding task, and make decisions on whether improved bias correction and downscaling methodologies should be adopted.

Task 5: Develop Climate Scenarios for Southeast CSC Impacts, Vulnerability, and Adaptation Assessments

As stated in the introduction of this section, the determination of how climate-projection information will be used for Southeast CSC research and assessment activities can be informed by results from the "bottom-up" (Task 1) and "top-down" assessments (Tasks 2–4). In other words, the relevant resources identified during Task 1 might be reviewed in concert with available global and downscaled climate projection information (Tasks 2–4) to help determine how this information should be sampled and used in Southeast CSC activities. In this sense, the collective tasks in this section are somewhat linked.

Given how Task 1 outcomes may vary depending on the resource considered, and how outcomes from Tasks 2–4 regarding projection credibility may vary, the combined consideration of outcomes from Tasks 1–4 leads to several options for assessment methodologies. Options vary in terms of what is sampled from climate-projection information and used to define future climate scenarios that would frame Southeast CSC assessments on various resources conditions (for example, hydrology, ecosystem resiliency, managed water systems, coastal resources). Broadly speaking, these methodologies can be categorized roughly into two classes—transient and period change.[6]

The transient class features a single time-evolving portrayal of climate and natural system conditions to reveal impact over time, whereas the period-change class features a comparison of two climate and natural system portrayals to reveal impact spanning two periods in time—one portrayal under historical conditions and an alternative under conditions at some milestone date in the future. The climate projections from Tasks 2–4 are examples of the transient class, as they portray time-series climate-system conditions under evolving emissions conditions.

Regardless of the chosen methods class (transient or period-change), a common goal of the impacts, vulnerability, and adaptation assessments is to be able to characterize uncertainties about the results. Uncertainties arise from various sources, including uncertainties about global climate forcing, how to simulate global climate response to change in climate forcing, how to relate global climate-simulation results to locally relevant conditions (that is, bias correction and spatial downscaling), and how to simulate natural resource response to changes in locally relevant conditions. The climate-projection ensemble (Tasks 2–4) affords some opportunity to characterize uncertainties relative to these sources, and the transient impacts assessment view is well designed to incorporate these uncertainties into results. Period-change assessments also can incorporate such uncertainties provided they are designed to feature multiple climate-change scenarios sampled from the cone of projections in a way that is meant to reflect change uncertainty.

Note that whether transient or period-change assessments are implemented, it is important to scope the assessment to reflect the distribution of future climate and impacts possibilities. This sets up a probabilistic view of future conditions, which is a necessary precursor for risk-based assessment of vulnerability and adaptation options. Transient approaches, given that they typically are framed by a large ensemble of climate projections, are naturally suited for producing such probabilistic information, and are attractive in that they characterize probabilistic conditions continuously through time. Period-change approaches also can be framed to produce probabilistic information provided that an ample number of period-change possibilities are considered (Brekke and others, 2009b), or that small subsets of period changes are defined in order to represent the breadth of climate change possibilities (for example, defining either projection-specific or ensemble-informed period changes).

Near term recommendations

- Determine climate scenarios that can be developed to support different Southeast CSC activities, including an ensemble of time-evolving (transient) climate projections, a small set of simple climate-change scenarios (perhaps projection-specific and sampled from the transient ensemble) and a small set of complex climate-change scenarios (perhaps ensemble-informed and defined from the transient ensemble).

Long term recommendations

- In conjunction with Task 4, track ongoing downscaling activities being applied to the Southeast and the arrival of CMIP5 information; evaluate new information sources as they become available; revisit the validity and utility of climate scenarios already developed

- Based on findings, consider developing new climate scenarios based on CMIP5 and (or) improved techniques in downscaling and information evaluation.

[6] In USGS Circular 1331 (Brekke and others, 2009), these were respectively labeled "system projection" and "shifted stationarity."

Science Theme 2: Land-Use and Land-Cover Change Projections

The Southeastern United States is among the fastest growing regions in the country, and modeling related to climate impacts must be done in the context of land-use change. The pattern and extent of land-cover change has important implications for conservation of species and ecosystems; changes in land-use can affect terrestrial and aquatic habitats, lead to habitat fragmentation, and affect water quality. These changes can affect the ability of ecosystems and species to respond to changing conditions. The Southeast CSC will examine land-use patterns across the Southeast, especially in light of climate-change effects, while conservation partnerships, such as LCCs, will examine these patterns at a finer spatial scale. This section describes how the Southeast CSC will address land-use and land-cover change and the interactions and effects of land-use and land-cover change with climate change on habitats and water quality.

Land cover in the Southeast has undergone tremendous changes since European settlement. Prior to settlement, longleaf pine woodlands were the dominant vegetation type in the coastal uplands (Frost, 1993; Christensen, 1999). Extensive river corridors bisected the upland matrix, and concentrations of non-riverine wetlands covered vast acreages (Richardson, 2000). Today urban, row-crop agriculture, and managed pine are the most extensive land-cover types in the region. Recent land-use change has been extensive, and has been the result of timber harvesting and urban growth (Loveland and Acevedo, 2010). In a conservation assessment of the United States and Canada, the World Wildlife Fund identified every ecoregion in the Southeast as vulnerable, endangered, or critical (Ricketts and others, 1999). These threats are directly related to the diversity of the region and the fact that less than 10 percent of the lands are within the conservation network (Ricketts and others, 1999).

Rapid urbanization, climate change, and the direct and indirect effects of these two dynamics on vegetation, ecosystems, and habitats are major challenges to developing long-term conservation strategies. Resource agencies increasingly are challenged to predict and respond to the potential effects of climate and land-use change on the habitats, species, and cultural resources they manage. Historically, agencies have focused on managing individual public lands or species. However, the scale and extent of the potential impacts of these new threats require that managers consider strategies across ownership boundaries, multiple species, cultural resources, and at multiple temporal and spatial scales. This list of required considerations makes for a very complex management situation. The Southeast CSC is in a position to provide the support needed for resource managers to address unique management challenges in the region.

Several regional and national efforts to examine land-use changes and trends—past, present, and future—have been completed recently. For example, the USGS Land Cover Trends Project examined changes in land cover from 1973 to 2000, and detected a high degree of change in the Southeast compared to other regions of the U.S. (Drummond and Loveland, 2010; Loveland and Acevedo, 2010; Napton and others, 2010). In addition, the Southern Forest Futures Project, a major assessment by the U.S. Forest Service, determined that in the future, climate change, population growth, timber markets, and other major drivers such as invasive species will interact to influence forests, and water quality and quantity, across the Southeast (Wear and Greis 2011, draft report). The project results also highlight the importance of forest conservation and management in mitigating these effects (Wear and Greis, 2011, draft report). Finally, the U.S. Environmental Protection Agency's (USEPA) Integrated Climate and Land-Use Scenarios (ICLUS) projected housing-density scenarios through 2050 following IPCC climate-change scenarios and examined the effects on water quality and habitat across the United States. Results indicated potential substantial changes to watersheds and habitats and significant variation by scenario (Bierwagen and others, 2010). Taken together, these recent studies all point to the importance of additional research on land-use change, its interaction with climate change, and its effects on water quality and habitat availability.

The results of these recent regional and national projects are similar to three of the goals and objectives for priority research that have been identified in the USGS Global Change Science Strategy (Burkett and others, 2011): (1) Land-use and land-cover change rates, causes, and consequences; (2) droughts, floods, and water availability under changing land-use and climate; and (3) biological responses to global change. Priority research specific to land-use and land-cover change in the Southeast will be directly related to these goals. Following is a summary of the research needs for the Southeast relative to these three goals.

Task 1: Conduct Regionally Focused Research on Land-Use and Land-Cover Change Rates, Causes, and Consequences

With some of the highest rates of land-use and land-cover change in the Nation, effective resource management in the Southeast requires understanding of the extent, pattern, and effects of those changes and conveying that understanding through products that support adaptive-management processes. Several national programs, including the National Land Cover Dataset (Fry and others, 2009), and the Coastal Change Analysis Program have produced current and recent land-cover data, and thus provide the national context for land-use and land-cover trends. Similarly, the National Gap Analysis Program has developed a thematically rich vegetation map to support regional conservation assessments (Aycrigg and others, 2010). Others programs discussed above, such as the Land Cover Trends Project, ICLUS, and the Southern Forest Futures Project, provide a starting point for examining trends and major factors driving land-cover change. Several studies are producing downscaled climate data that can be useful for climate-change assessments, including SERAP. While these data provide a baseline for planning, regionally focused research is needed to build on these and other previous efforts to guide resource management and decisionmaking in the Southeast. The Southeast CSC serves as an important source of application testing, feedback, and refinement for existing national and regional land-cover products.

Near term recommendations

- Develop land-cover mapping and change-detection methods with increased accuracy and spatial and temporal resolution by building on previous research, conducted as part of SERAP.
- Modify regional datasets to accommodate site-specific management needs.

Long term recommendations

- Develop methods to process and convey higher resolution data, such as multi- and hyper-spectral, high spatial resolution, and multi-temporal imagery, in support of determining which existing datasets are inadequate and subsequent planning.
- Increase the efficiency and standardization of the national product for use in an adaptive-management framework for decision support in the Southeast.
- Develop approaches to mitigate the consequences of land-use and land-cover change in the Southeast, focusing on impacts from primary human-related drivers of change in the region, such as urbanization, timber management, and agricultural practices, their interaction with climate change, and their influence on habitat and water quality.
- Evaluate trends in land-use change. Quantify current trends and use the data to inform models of potential impacts of these trends; additionally, develop alternative scenarios and the potential impacts in a context of the most important natural and cultural resources in the region.

Task 2: Research Droughts, Floods, and Water Availability under Changing Land-Use and Climate

In addition to the broader goals related to water resources, research specific to the interaction between land use and land cover is critical in the Southeastern United States. With increased demand for water and potential changes in the amount and timing of precipitation due to climate change, it is important for managers and policy makers to understand how decisions specific to land use and land cover influence flows and water availability, as well as how droughts affect the available range of land management options.

Near term recommendations

- Improve the characterization of variability in hydrologic processes on the landscape. Identify land-use practices that enhance or decrease the effects of climate change on water resources.

Long term recommendations

- Develop land-use change models that incorporate findings from the near term recommendations.

Task 3: Research Biological Responses to Changing Land-Use and Climate

An important focus for the Southeast CSC will be the influence of land-cover change on species habitat and plant communities separate from and in conjunction with the effects of climate change. Central to this research are the baseline datasets that provide insights regarding the relations between species, plant communities, and land cover. Research related to the maintenance, update, and enhancement of land-cover datasets is important to supporting an adaptive management framework in which managers can build decision-making processes that include the evaluation of land-cover trends.

Near term recommendations

- Identify potential effects of land-cover change on species distributions and plant communities through modeled scenarios.

Long term recommendations

- Understand the impacts of habitat fragmentation and connectivity on species distributions, as well as the impact of ecological stressors (invasive species, pathogens, and insect outbreaks) on systems and provide information specific to the potential for management and policy decisions to mitigate the impacts.
- Use these land-cover data and change model results in conjunction with sea-level rise projections and vegetation dynamics models from SERAP to produce land-use and habitat maps for priority species identified by LCCs and other partners.

Task 4: Develop Land Cover and Habitat Projections for the Southeastern United States

The continued rapid urbanization in the Southeastern United States necessitates projections of future growth and climate change to allow resource managers to develop conservation plans for future conditions. Developing urban-growth projections at regional and appropriate sub-regional spatial scales is a critical task for the Southeast CSC, while simultaneously working with LCCs and other partners to provide requested science products for fine-scale resolution to projected change. The science process of the CSCs and partners will be a process of adaptive management, where each is informed by the other. The science will be updated continually in response to changing conditions and partner needs. Because changes in land use influence climate, and climate and other global change factors, in turn, influence change in land use, understanding the interactions between these drivers will allow for better projections of both drivers. At local and regional scales, changes in urbanization may alter hydrologic conditions and water quality, effect habitat fragmentation, and cause a number of other alterations that impact management. The Southeast CSC will work in partnership with LCCs and other partners to identify critical tasks.

Near term recommendations

- Continue to collaborate with LCCs and other partners to determine needs and develop tools to support management decisions.
- Build on existing models of vegetation dynamics that are being developed as part of SERAP and tailored to the Southeast.
- Use available land-cover data and derived change detection products, as well as field data, test models of urban growth, land-cover change, and vegetation dynamics in the Southeastern United States and Caribbean that assume historical patterns.
- Continue developing models of land-cover change and vegetation dynamics that incorporate the influences of projected climate changes from Theme 1. Model the influence of land-cover change scenarios on regional climate, such as urban growth and resultant heat island effects).
- Validate change detection, vegetation dynamics, and urban growth based on field data.
- Ensure that models are the same spatial and temporal scales as other models (downscaled climate, watershed, vegetation, etc.) developed for the Southeast CSC.

Long term recommendations

- Work with national land-cover mapping programs to create a seamless flow of land-cover mapping data into regional modeling and the decisionmaking processes.
- Work with partners to refine vegetation-dynamics modeling, improve ancillary data (for example, information on vegetation condition and structure produced through advanced remote sensing) to refine modeling parameters and select relevant scenarios for modeling.
- Examine the relevance of these information products for resource-management decisionmaking and refine as appropriate.
- Update land-cover, vegetation, and urban-growth models to reflect patterns and processes as conditions and driving factors in the region change.

Science Theme 3: Impacts of Climate Change on Water Resources

The ability to sustain freshwater quality and quantity is a critical issue for maintaining societal expectations and needs. The demands of a growing human population for freshwater combined with the desire to conserve diverse aquatic habitats and species will create increasing conflicts in the Southeast. Changes in flow regimes and water quality as a result of land-use changes, increasing frequencies of extreme precipitation events, and warmer temperatures over the past few decades have raised doubts about the sustainability of freshwater supplies and the viability of endemic freshwater species (Vorosmarty and others, 2000; Vorosmarty and others, 2010). Climate-change projections indicate that climate-driven impacts on water supply and quality may further threaten social and ecological systems throughout the Southeast over the coming decades. For example GCMs predict increased air temperatures of 4 to 9 °F for the Southeast by 2080. Projected changes in precipitation patterns are less certain; however, models predict changes in seasonal patterns, regional drying, and increased intensity of tropical storms (U.S. Global Change Research Program, 2009). Increased air temperature and more variable precipitation will have both direct and indirect effects on water supply and quality. Direct effects occur by changes in rainfall and temperature, whereas indirect effects are associated with changes in vegetation composition, structure, and physiology. For example, higher temperatures result in increased soil evaporation and plant transpiration, which lead to reduced soil moisture and streamflow; and ultimately, to changes in species (Iverson and Prasad, 1998). More extreme rainfall events are likely to increase flood and drought severity and frequency. Most importantly, climate change will interact with land-use change and alter disturbance regimes to exacerbate the direct impacts on water quantity and quality (Wilcox, 2010).

The Southeast CSC will work with partners to facilitate development of a predictive and reliable understanding of the impacts of climate change on water resources in the Southeastern United States, and provide consistent and reliable data to ecoregional conservation science partnerships, such as the LCCs. The complexity of hydrologic systems over space and time and uncertain knowledge about climate, soil, and topographic interactions in the future make evaluating the impact of climate change on water resources difficult. Numerous hydrologic models already exist, such as SERAP and the U.S. Forest Service (USFS) Water Supply and Stress Index model (WaSSI), and may be applicable for assessing the potential impacts of climate change on water resources. These models also may serve as platforms for further model refinements and applications specific to objectives of the Southeast CSC. For example, spatial and temporal resolutions of existing models may not be fine enough to support land-management or planning decisions. In addition and despite model availability, the rapid pace of co-occurring human-induced changes—climate and land use—challenge models that were developed and calibrated with historical information and data (Vose and others, 2011). Accurate predictions of hydrologic responses to climate change require a more complete understanding of how all the components of hydrologic processes (for example, climate, soils, vegetation, topographic features, and human subsystems, such as reservoirs and dams) have co-evolved in the past and how they are likely to do so in the future (Wagener and others, 2010).

The Southeast CSC will play an important role in meeting the needs of decision makers for reliable estimates of climate-change impacts on water resources by: (1) producing predictive groundwater and surface-water models as well as water-quality models, (2) supporting research to improve hydrologic models to provide spatially and temporally relevant predictions, (3) providing Web-based access to currently available hydrologic models; historical, current, and projected climatic-driving variables using downscaled GCMs; and calibration data, (4) providing support in developing vulnerability assessments, and (5) developing and responding to an interactive adaptive process with LCCs to use site-specific and ecoregional observations to drive the development of future priority science needs. All of these tasks will be necessary to understand how climate-change impacts on water resources will affect social, ecological, and aquatic systems, and inform socioeconomic and institutional responses to these impacts.

Task 1: Develop Predictive Groundwater, Surface-Water, and Water-Quality Models in Natural and Human Dominated Systems

Hydrologic model development will include: (1) methods that focus on multiple spatial extents and resolutions within a single data structure; (2) support for multiple temporal contexts (historical, current, and future); and (3) a mechanism for sharing inputs and outputs with other modelers. This structure supports an approach for applying hydrologic models to increase understanding of climate change and to coordinate an effective response climate-change effects that fosters cross-discipline and cross-agency collaboration and long-term archival of model outputs in a simple discoverable and accessible form.

Near term recommendations

- Work with LCCs and other partners to identify and prioritize watersheds and aquifers identified as important for resource management.

Long term recommendations

- Use models to develop regional-scale predictions that include both climate and land-use change projections produced in Themes 1 and 2 and build on the work of SERAP.
- Work with the LCCs and other partners to develop models at scales appropriate for resource management.

Task 2: Conduct Research to Improve Hydrologic Models

The Southeast CSC will facilitate new research approaches to improve the capacity of hydrologic models to project impacts of climate change and interactions with other co-occurring forces such as land-use change, and altered disturbance regimes on water resources. In particular, predicting the response of hydrologic systems to a changing environment requires models that account for the complex interactions among physical, biogeochemical, ecological, and human subsystems. As such, one of the tasks of the Southeast CSC will be to foster interdisciplinary approaches in model conceptualization and development. Improving the spatial and temporal resolution of hydrologic models is an important focal area required to assess impacts. Models are often evaluated based on their ability to simulate long-term means at large spatial scales; however, analyses of both ecological and socio-economic impacts as well as responses by decision makers will require much finer temporal- and spatial-resolution projections. Indeed, it may be more relevant that models reliably predict the impacts of climate change on water resources at the extremes, such as maximum or minimum daily flows instead of long-term averages.

Near term recommendations

- Identify and assess high-priority information needs for water-resource and emergency-response management and planning agencies in the southeastern region.
- Develop new models or tools that focus on multiple spatial and temporal scales. The models should be scalable so that local managers can use the data produced by a larger scale model to populate finer scale models.

Long term recommendations

- Apply new tools to existing models. Develop new models as needed.

Task 3: Provide Web-Based Portal Access to Hydrologic Models and Calibration Data

A large number of hydrologic models currently are available to project the potential impacts of climate change on water sheds (for example, RHESSys, Tague and Band, 2004; WaSSi, Sun and others, in press; WB, Hay and McCabe 2010; PRMS, Leavesley and others, 1983); however, these models differ considerably in spatial and temporal scale, parameterization and calibration requirements, and overall approaches, such as process as opposed to empirical model. Web-based access to a suite of hydrologic models, common climatic datasets, and calibration data facilitates efficient applications of models already available and collaborative opportunities for adapting existing models to specific research needs.

Near term recommendations

- Continue to develop the structure for a Web-based portal (SERAP) that will allow the modeling community to share input and output data (similar to existing sites such as *www.data.gov* and *www.climate.gov)* in formats that are appropriate for many different models.

Long term recommendations

- Add new models to the portal and new datasets as they become available. Make the portal available to a wide audience.

Task 4: Provide Support to the LCCs and Other Partners to Produce Vulnerability Assessments

Freshwater ecosystems in the Southeast are vulnerable to many aspects of a changing climate, especially increased numbers of extreme annual weather events, increased summer droughts, and ambient temperature rises. Physical changes in freshwater systems can affect water supply, entire aquatic communities, and threatened and endangered species. The ability for both human and natural communities to adapt to these changes requires an assessment of system vulnerability at various spatial scales and for different conservation targets (for example, physical stream characteristics, such as dissolved oxygen and temperature, but also populations of key species such as mussels and fish).

Near term recommendations

- Provide support in conducting vulnerability assessments of freshwater systems based on watershed or appropriate geographic measures in relation to the hypothesis or species or population of management concern, and share appropriate derivative products with LCCs and others for further collaborative work in priority areas.

Long term recommendations

- Using vulnerability assessments of freshwater systems, combined with LCC assessments of priority species and population, define critical freshwater streams, aquifers, or lakes

Science Theme 4: Ecological Research and Modeling

Climate change currently has and will continue to have significant impacts on the distribution and phenology of individual species, population demography, and abundance. Climate science has made substantial progress in formulating predictions for altered species distributions under various climate scenarios, a critical step toward developing a predictive framework of how biological systems respond to changing conditions. However, modeling (and monitoring) populations and single-species responses is insufficient, as models must incorporate ecological interactions and evolutionary processes to increase the reliability of projections. For example, the ranges and phenologies of individual species do not all respond to changing climate conditions at the same rate, which means that new species come into contact with each other and create new ecosystem interactions, such as predator and prey, competitive, and host and parasite interactions.

Research suggests that responses vary among different organisms, so a wholesale "reshuffling" of species is likely in many areas, including in the Southeast (Burns and others, 2003; Montoya and Rafaelli, 2010). Climate change has been linked to altered competitive and predator-prey interactions and to the increased intensity of pathogen infection (Tylianakis and others, 2008; Barton and others, 2009). Predicting the long-term consequences of these interactions for community composition and food-web structure is a considerable challenge, but one that must be met to accurately predict how species and communities will be shaped by climate change.

Changes in species distributions and phenologies and the resulting changes in species interactions and food-web structure also have the capacity to significantly affect ecosystem processes, such as rates of decomposition, water filtration, and primary productivity (Montoya and Raffaelli, 2010). Impacts of climate change are just beginning to be understood and because ecosystem responses are shaped by the combined responses of many different species and their interactions, research must focus on what drives species- and community-level changes in order to accurately forecast ecosystem responses. In addition to these changes in ecosystem processes, disturbance regimes, such as the frequency and intensity of fire and hurricanes, vary with changing climate conditions. These disturbance regimes can produce rapid and marked changes in ecosystem structure and function in the short and long term (Turner, 2010). Developing tools to predict ecosystem-level changes in response to climate is important for maintaining a diverse and functional natural world and for ensuring the well being of the population whose lives depend on the services these ecosystems provide.

Southeast CSC research will generate region-wide or range-wide models of priority species, and eventually the interactions and processes related to the direct (effects on phenology, performance, and dispersal) and indirect (effects on vegetation dynamics and habitat) influences of climate change. In close collaboration with LCCs and other partners, models will be developed by building on the work done in SERAP to identify the relative impacts and efficacy of different landscape-scale management decisions, such as investment in corridors or refuges on priority species and populations. Using available information, such as priority species lists from State Wildlife Action Plans and information consolidated by LCCs and others, the approach is first to identify the species to be considered, second to lay out short-term goals, and third to indicate long-term projects that should be of a high priority.

One proposed method is to focus on three groups of species most directly related to Southeastern United States cultural and natural heritage—focal taxa (including rare and climate-threatened species), pest and invasive species that threaten cultural or natural resources, and foundation species on which many other species and processes depend. The Southeast CSC will focus research objectives on priority species identified by States, NGOs, and federal agencies in concert with LCCs. The close collaboration between the CSC and southeastern LCCs will ensure complimentary, not duplicative, efforts at various spatial scales.

Focal Taxa. Focal taxa are relatively well-studied taxa, including species of current or future conservation concern that are likely to be influenced by climate change, whether positively or negatively. Potential focal taxa include but are not exclusive to birds, freshwater mussels, freshwater and diadromous fish, butterflies, ants, and salamanders. Rapid progress in understanding climate-change impacts on some of these taxa is expected in the short-term, in part because of long-running projects and (or) large datasets for each of these taxa in the Southeast. In considering the choice of taxa, the criteria used to determine the focal taxa will be those taxa most relevant to the LCCs and other partners, regional experts, and potential for major, high-profile.

Pest and Invasive Species. Pest and invasive species have the potential to alter the ability of native species to travel, on occasion leading to local and, in some cases, global extinctions (Crowl and others, 2008). Many pests, invasive species, and pathogens have the potential for increased abundance and impacts on natural resources with climate change (Crowl and others, 2008). Research conducted by the Southeast CSC should consider a subset of these species with the greatest potential to affect wild habitats, rare species, and foundational species such as hemlock woolly adelgids or the redbay beetle. The objective is to understand climate effects on key invasive and pest species rather than trying to monitor all such species. The Southeast CSC will seek to understand how land-use decisions influence the potential for spread of pest and invasive species (or conversely, local extinctions of native species) given different climate-change scenarios.

Foundation Species. A foundation species is a species that "by virtue of its structural or functional attributes creates and defines an entire ecological community or ecosystem, can have dramatic effects on the perception of the landscape and broad consequences for associated biota, ecosystem function, and stability (Ellison and others, 2005)." An objective of the Southeast CSC when modeling the distribution of species is to develop comprehensive studies of foundation species. Changes in the abundance of foundation species have the potential for large impacts, but importantly, foundation species also include many of the species most amenable to active management—whether by assisted migration, restoration or something else.

In forested ecosystems, foundation species tend to be trees, though other organisms also can have foundational roles, such as beavers whose decline in the Southeast appears linked to the decline of several species dependent on beaver meadows, such as the St. Francis satyr butterfly. In aquatic systems, foundation species generally are mussels. A recent review identified a suite of southeastern foundation species (Ellison and others, 2005), but the Southeast CSC will identify foundation species in consultation with LCCs and other partners.

A key initial step in understanding organism responses is to study the responses of individual species of focal taxa, pest species, and foundation species. The approaches used to study these species includes a range of modeling approaches, integrated across levels of organization (that is, genes → individuals → populations → communities → ecosystems), and combined ecological and evolutionary approaches. In assembling a team of climate scientists that can address the other priorities described in this plan, the Southeast CSC will bring together a unique group of scientists with the combined skill sets needed to make meaningful decisions in these areas and to accurately inform conservation and management in the face of climate change.

Task 1: In Close Collaboration with LCCs, States, and Other Stakeholders, Determine the Highest Priority Species and Populations for the Development of Distribution Maps and Population and Phenology Models

Geospatial information will be a useful tool in determining the fate of species under different management strategies and whether species can be conserved in situ or will need to move, either through corridors and matrix habitat or by active transport.

Near term recommendations

- Along with partners and stakeholders, continue the process of identifying priority species within the boundaries of the Southeast CSC that began during SERAP stakeholder meetings
- In cooperation with partners and stakeholders, identify subsets of, and develop future distribution models for, a range of focal taxa, pest species, and foundation species.
- Develop phenology models for the selected subset of species.
- Identify species for which more detailed studies of the responses of genotypes and local populations can be conducted.

Long term recommendations

- Understand how the distributions, phenologies, and populations of species are influenced by different land-use, policy, and other scenarios with a particular focus on the potential role of corridors and refuges.

Task 2: Test Whether the Predicted Responses of Species to Climate and Land-Use Changes Match Observed Changes

A key need in modeling species and later ecosystem processes is verifying that such models have empirical validity. Comparing model results to empirical climate-induced changes is one approach in testing model validity. Simultaneously, assessing which aspects of models (for example, predictions of southern versus northern range shifts) are most consistently wrong and in need of modification is another approach for determining model validity.

Near term recommendations

- Identify taxa for which data are available or can be made available to study historical (for example, during glacial cycles) responses to climate change or modern (last hundred years) responses to climate change.
- Provide support to partners and stakeholders in the development of monitoring plans for priority species.

Long term recommendations

- Study the extent to which empirical responses of species to climate change (whether in terms of distribution, phenology, or abundance, match model predictions. Historical changes in climate include those due to regional climatic changes as well as those due to local climatic changes resulting from urbanization and associated heat-island effects.

Task 3: Conduct Laboratory and Field Experiments to Document Organismal Responses to Climate Change

Along with the robust amount of literature and data available on climate-change experiments, the Southeast has an infrastructure of experimental climate-change arrays for studying the effects of experimental climate changes. These facilities allow a suite of predictions generated by models of focal, pest, and foundation taxa to be tested experimentally. The Southeast CSC will build on existing work in chamber experiments to develop models of the future distribution of species based not just on specimen records but also on knowledge derived from experimental manipulation of key climate variables.

Near term recommendations

- Review literature for available information on organismal response to climate change.
- Perform climate-chamber research and other experiments most germane to the focal taxa, pest species, and foundation species identified as priority species. Incorporate results from experiments into distribution, phenology, and abundance modeling approaches.

Long term recommendations

- Identify the experimental resources most relevant to the needs of the Southeast CSC in terms of understanding organismal responses to climate change.

Task 4: Identify New or Altered Species Interactions that are Likely to Have a Disproportionate Impact on Community Structure and Ecosystem Function

Change in community composition and species interaction can be assessed by building on data generated from modeling focal, foundation, and pest species responses to climate change. While many new interactions can occur without having strong ripple effects, a subset of interactions is likely to significantly alter community composition, structure, and ecosystem function. Identifying in advance the interactions that have the potential to have disproportionate impacts is a necessary step toward forming a more accurate understanding of the impacts of climate change on natural systems.

Near term recommendations

- Use insights gained from executing Tasks 1–3 to identify (1) pest and pathogen species that are likely to interact strongly with a new set of hosts, and (2) anticipated new sets of predator-prey and competitive interactions that are likely to have large community or ecosystem consequences.

Long term recommendations

- Model the extent to which species interactions have the potential to alter community structure, such as simplification of food-web structure, and ecosystem processes, such as productivity, decomposition, etc.

Task 5: Provide Support to LCCs in Assessing New Strategies to Conserve Natural Communities and Ecosystems

Entities working towards conservation in the Southeast have identified portfolios of critical conservation areas, but many of these identified areas may not serve the needs of present species within as little as a few decades, because distributions of species change as a result of climate change. Accurately predicting the composition of natural communities in any specific location is nearly impossible given the level of uncertainty regarding changing climate and biotic responses to new conditions. This is the case both terrestrially and aquatically, which requires a way to prioritize the conservation of biological diversity and functional ecosystems in spite of this uncertainty. The Southeast CSC will provide support to partners as they identify ways to protect and manage natural systems that are not contingent on precisely predicting the responses of every species within the community. For example, an approach recently taken in the Northeastern United States focuses efforts on conserving particular geophysical settings that have been shown to be highly correlated with species diversity—an approach that researchers predict should will biodiversity under both current and future climates (Anderson and Ferree, 2010; Beier and Brost, 2010).

Near term recommendations

- Provide support to the LCCs and other partners as they formulate a set of strategies to identify on-the-ground priorities for conservation that are most likely to protect biodiversity in the future, but that do not hinge on assumptions surrounding species-specific responses to climate change.

Long term recommendations

- Provide support to the LCCs and other partners in the implementation and (or) generation of landscape conservation priorities in the Southeast that will be distributed to Southeast CSC and LCC partners and other interested groups for planning future conservation goals.

Science Theme 5: Impacts of Climate Change on Coastal and Nearshore Marine Environments

The low-lying southeastern coastal zone was characterized as a hot spot of ecological vulnerability in the first two national assessments (U.S. Global Change Research Program, 2000, 2009) and in numerous other assessments and independent investigations (Field and others 2001; Scavia and others, 2002; Burkett and others, 2005; and, U.S. Climate Change Science Program, 2008). The gulf and south Atlantic coasts have low topographic relief and are subject to land-falling hurricanes and strong frontal systems, during which coastal shorelines can retreat by several meters, and wetlands can be permanently lost to open water. As is the case along most U.S. coasts, the direct impacts of human activities on the coastal zone have been more significant over the past century than the impacts that can be attributed directly to observed climate change (Scavia and others, 2002). The population of coastal counties in the gulf coast region increased more than 100 percent between 1960 and 2000 (U.S. Census Bureau, 2003). Between 1980 and 2003, coastal counties in the south Atlantic region had the largest rate of population increase (58 percent) of any coastal region in the conterminous United States (Laporte and others, 2011). The major direct impacts of human development in the gulf and south Atlantic coastal zone include drainage of coastal wetlands, changes in hydrology that alter sediment and fresh water delivery to the coast, land clearing and deforestation, the discharge of sewage and contaminants into coastal waters, and the construction of seawalls and other structures that "harden" the coast. Development activities also have altered coastal systems in the United States and in protected regions of the Caribbean.

The region historically has had the highest rates of coastal wetland losses in the United States (Dahl, 2006; Stedman and Dahl, 2008). Some parts of the southeastern coastal margin are sinking because of subsurface fluid withdrawals, changes in surface-water hydrology, and a decline in sediment delivery to the coast. Barrier-island systems in the region are considered highly vulnerable to climate change (U.S. Climate Change Science Program, 2009) with some nearing the tipping points at which they may be completely lost to open water. As barrier islands recede and channel passes enlarge, the dominance of marine forces (tides, salinity, waves) tend to increase and accelerate changes in coastal marshes and estuaries. Wetlands that cannot accrete sediments at rates that keep pace with sea-level rise either drown in place or, possibly, migrate inland if the landward transgression is not prevented by human developments, such as roads, levees, and other impediments.

Sea-level rise increases tidal flushing in estuaries and storm surge over low-lying coastal landforms. Average and peak salinity levels in estuaries and adjacent habitats tend to increase as sea-level rises, thereby altering the zonation of vegetation and other biota (Burkett, 2001). Increased tidal levels and storm surge also intensify energy regimes in shallow coastal waters, altering sediment transport and other coastal processes that influence the maintenance of coastal substrates and intertidal vegetation. Sea-level rise observed along the U.S. coastline varied between and within coastal regions during the 1900s, but in general, the U.S. Gulf of Mexico and south Atlantic coasts (with the exception of Florida) have experienced rates that are significantly greater than those observed along the U.S. Pacific coast (Scavia and others, 2002).

Coral reefs of the gulf and south Atlantic continental shelf waters are vulnerable to two important global-change drivers—increased ocean temperature and ocean acidification. Coral bleaching resulting from the loss of symbiotic algae and (or) their pigments has been observed on many reefs since the early 1980s in response to seasonal increases in sea-surface temperature (SST) and solar radiation. Many coral species pale or bleach white in response to anomalously high SST (that is, temperatures of 1.8 °F or more above average seasonal maxima) and have reduced growth rate and reproductive ability. If bleaching is prolonged, or if SST exceeds 3.6°F above average seasonal maxima, corals die (Nicholls and others 2007). Corals decline in the waters off the Florida coast and Caribbean islands is of high concern to resource managers. Other calcifying organisms, in addition to corals that can be affected by ocean acidification include oysters, clams, sea urchins, formanifera, and some fish species.

Five broad research tasks that should be undertaken to support natural-resource management in the southeastern coastal zone and nearshore waters are described below, along with several high priority short- and long-term products. The products listed are not intended to be a complete list of all of the work that is needed to support coastal- and marine-resource management in the southeastern region. The five broad tasks and many of the products and science activities are cited as high research priorities in the Gulf of Mexico Alliance Regional Collaboration Blueprint (2008), the Gulf of Mexico Research Plan (Sempier and others, 2009), the South Atlantic Regional Research Plan (SARRP; Laporte and others, 2008), and the operational plans of the South Atlantic and the Gulf Coastal Plains and Ozarks LCCs (U.S. Fish and Wildlife Service, 2009a, b).

Task 1: Establish Ecological Baseline Conditions and Describe Current Climate Trends and Impacts in Coastal Systems

Baseline information for ecological systems is critical for understanding current conditions. Most models are calibrated to current conditions in order to predict future conditions and to accurately characterize past conditions. Changes in coastal ecosystems can occur over vastly different ranges in terms of magnitudes, distances, and time periods. Tipping points in coastal-ecosystem response to climate change generally are poorly understood. Understanding how changes in ranges or assemblages of species and their interactions will affect coastal and marine ecosystems is a complex and research-intensive challenge.

Near term recommendations

- Determine current available information to establish baseline ecological conditions and support model development and process understanding.
- Develop detailed maps of coastal habitats and species distributions in the south Atlantic and eastern Gulf of Mexico coastal zones, which builds on SERAP work; pursue additional collaboration with the South Central CSC to expand habitat and species distribution maps to cover the entire gulf coast.

Long term recommendations

- Use the baseline conditions and outputs from tasks in Themes 2 and 4 to model changes in habitat, species, and other issues of interest to partners.
- Identify tipping points or thresholds in coastal species and habitat responses.

Task 2: Develop Scenarios of Coastal Landform and Habitat Change

The configuration of coastal ecosystems is determined by a combination of marine, terrestrial, and atmospheric processes that shape the land-ocean interface. Low lying, sedimentary shorelines, and barrier islands and deltas are considered highly vulnerable to the effects of climate change. All of these landforms can be found in the southeastern coastal zone. Most barrier islands of the Southeast are retreating and diminishing in areal extent. Barrier islands mitigate storm surges from hurricanes and contribute to controlling tidal influence, waves, and salinity regimes in coastal habitats. Wetland loss is another major landform change that affects habitat and cultural resources along the coastline. These important resources and the processes that affect them must be understood to guide restoration and conservation efforts and predict future change.

Near term recommendations

- Initiate process-oriented studies to quantitatively identify impacts of sea-level rise and other stressors on coastal systems in the southeastern coastal region by using products created during SERAP as a foundation.

Long term recommendations

- Use new geospatial technologies and high-resolution elevation data produced as a result of tasks in Theme 2 to map physical and environmental changes along the coastline to assist with regional coastal vulnerability assessments.
- Develop predictive models of coastal retreat, land-use, and habitat change, and land loss under a range of sea-level rise and concomitant coastal-protection scenarios.
- Update scenarios of coastal-habitat change based on IPCC sea-level rise estimates, the CMIP5 database for predicting temperature and precipitation, and results from Theme 1 (Southeast CSC climate models).

Task 3: Describe How Estuaries and Marine Resources Are Affected by Increased Temperatures, Sea-Level Rise, Changes in Runoff Patterns to the Coast, Ocean Acidification, and Changes in the Destructive Potential of Tropical Storms

Estuarine and marine resources are important components of coastal ecological systems and contribute substantially to the economy of coastal areas in the Southeastern United States. Understanding how these resources function and their response to climate change is a key component to managing the resources in the future. The cumulative, interactive effects of increased water level, salinity, pH, and storm intensity portend a restructuring of coastal ecosystems.

Near term recommendations

- Work with partners to develop a monitoring framework for quantifying and tracking acidification in coastal and marine water.
- Identify field sites and candidate lists of organisms that can serve as marine-ecosystem “sentinels” for early warning purposes, and develop standard operating procedures for long-term monitoring.

Long term recommendations

- Conduct watershed and coastal integrated impact studies of climate-change drivers on freshwater discharge, sediment, and nutrient influx on coastal receiving waters.

- Conduct strategic research on the response of key species (living resources, foundation species, calcifiers and non-calcifiers, representative species from diverse taxonomic groups, primary producers) to climate and pH changes in ocean and coastal ecosystems.
- Initiate research that will help describe the potential response of marine mammals to climate change.

Task 4: Provide Support in Assessing Potential Impacts on Highly Vulnerable Coastal and Marine Habitats

Coastal ecosystems are intrinsically dynamic because of their exposure to alternate flooding and drying, winds, waves, tides, and storms. Organisms that inhabit coastal ecosystems are uniquely adapted to environmental conditions that occur along the energy, salinity, and moisture gradients that extend from the subtidal region of the coast to the inland boundaries of coastal wetlands, estuaries, and flood plains. While all coastal ecosystems in the Southeast are vulnerable to the impacts of accelerated climate change, some coastal locations and habitats are more vulnerable and likely to be affected sooner than others. In order to develop conservation strategies, land managers and others in the conservation community must know which areas and habitats are most vulnerable. Vulnerability analysis of the coastal system provides critical information to the U.S. Fish and Wildlife Service, States, and others involved with the LCCs to conduct species- and population-vulnerability assessments in coastal zones and appropriate conservation planning.

The Southeast CSC will work with LCCs and other partners to determine how to approach vulnerability assessments in the Southeast.

Near term recommendations

- The Southeast CSC will collaborate closely with LCCs and other partners (for example, NOAA) to develop a working list of priority coastal habitats and locations for the entire Southeast CSC.
- Provide coastal-system vulnerability assessments and the necessary derivative products, such as sea-level rise models, to LCCs to support vulnerability assessments of priority species in coastal zones.

Long term recommendations

- Use the list of priority habitats generated by partners to provide support when producing large geographic-scale assessments.
- Work with LCCs to integrate system level and species and population vulnerability assessments to better define the highest priority conservation strategies for specific locations.
- Expand the Integrated Coastal Assessment part of the SERAP to improve support of the management of coastal resources—more integrated assessments of sea-level rise and climatic change in coastal areas are needed, including the significant non-climatic drivers.

Task 5: Provide Support for the Assessment of Potential Management Responses

Resource managers are faced with difficult decisions that require real-time responses and may involve large expenditures of resources. Many resource-management agencies—local, State, and federal as well as private landowners—have tremendous need for information that facilitates decision making, not only for immediate needs but for future needs as well.

Near term recommendations

- Provide support to the LCCs and other partners to identify how management for priority species and habitats from Theme 4 and cultural-heritage resources from Theme 6 can incorporate climate and land-use change trends and projections from Themes 1 and 2.
- In collaboration with partners and stakeholders, select a representative set of indicator species and habitats for the southeastern coastal zone.

Long term recommendations

- Improve and expand ecosystem-based management models for the Southeast.
- Evaluate the effectiveness of ecological restoration projects that incorporate climate change in design—and range from large-scale efforts to alter or restore flow in the Florida Everglades to small scale projects, such as the re-establishment of subtidal and intertidal oyster reefs and small-scale wetland restoration.

Science Theme 6: Impacts of Climate Change on Cultural-Heritage Resources

Climate change poses a significant and unique threat to cultural-heritage resources. As with natural resources, cultural-heritage resources are at risk from the effects of climate change, including increased severity, frequency, and size of wildfires; increased frequency of extreme weather events, such as thunderstorms, hurricanes, windstorms, droughts, and freezes; increased ocean temperatures and acidification; changing lake and river levels; rising global sea levels and increased erosion brought on by these increasing trends and events. However, cultural-heritage resources face a different type of challenge than many living natural resources face. Unlike living communities, cultural-heritage resources cannot adapt, migrate, or reproduce. They are fixed on the landscape and are unique and irreplaceable resources that cannot be moved or relocated without great cost and the possibility of destroying historic integrity.

Cultural-heritage resources include a diverse array of archeological sites, cultural landscapes, ethnographic resources, historic and prehistoric structures, museum collections, and Native American sacred sites. Examples of archeological resources include both prehistoric and historic submerged sites and shipwrecks, terrestrial prehistoric and historic encampments, midden dumps, home sites, villages and ceremonial sites, battlefields, historic homesteads, farms, plantations and production sites. Historic and prehistoric structures range from prehistoric mounds and rock-shelters, to historic buildings, earthworks and lighthouses. Museum collections include interpretive displays, historic maps, manuscripts, archives and photographs, and prehistoric and historic artifacts.

Cultural landscapes are settings that humans have created in the natural world that reveal fundamental ties between people and the land based on the need to grow food, give form to settlements, meet requirements for recreation, and provide suitable places to bury the dead. Cultural landscapes are intertwined patterns of things both natural and constructed, such as plants, fences, watercourses, and buildings. They range from formal gardens to cattle ranches, from cemeteries and pilgrimage routes to village squares. They are historically special places—expressions of human manipulation of and adaptation to the land and the environment (Page and others, 2009). Cultural-heritage resources also include living ethnographic communities and resources, traditional cultural properties, and American Indian trust resources and tribal lands. Ethnographic resources include those cultural and natural features of a site or landscape that are of traditional significance to peoples associated with those areas based on ethnicity, occupation, or culture. Traditional knowledge and archaeological data can provide insight into climatic changes over the long term and to human responses to such alterations.

The Federal Government holds a unique legal and political relationship with Native American tribal governments derived from the U.S. Constitution, treaties, federal statutes, and executive orders, with the Federal Government's role commonly referred to as the Indian trust responsibility. Native American communities are situated in fixed locations traditionally inhabited by their members or in areas set aside by the Federal Government for their use. These may or may not be in areas where cultural-heritage resources are abundant. Some tribes have treaties, executive orders, or court-decreed rights to fish and wildlife, water, and other resources, both on and off their reservations, and tribal lands can be affected by climate change. Some examples include decreased stream flows, reduced suitable habitats, reduced production of and access to fish, plants, or other wildlife relied on for tribal subsistence and in ceremonies and for traditional and customary uses.

The impacts of climate change on cultural-heritage resources highly variable and depend on the resource type and the environment in which the resource was created or is located. Because the effects of climate change are predicted to be variable throughout the United States, and so a regional approach to the management, protection, and preservation of cultural-heritage resources in response to climate change in the Southeast and Caribbean is desirable. Varying degrees of uncertainty are associated with the timing, geographic distribution, and severity of each type of climate-change threat, but the effects already are being felt in the Southeast. The Southeast CSC, therefore, has a critical role in providing a regional framework and support to develop fundamental scientific information, tools, and techniques for management of cultural-heritage resources in the Southeast.

The following tasks provide a brief outline of the science needs of the Southeast CSC to support the effective management and preservation of cultural-heritage resources, and to build on the information developed within the other themes to provide resource managers the means to respond to climate change with respect to cultural resources.

Task 1: Provide Support in Developing Inventory and Monitoring Plans for Cultural-Heritage Resources

Because some climate-change impacts can be projected (for example, sea-level rise), developing long-range scenario planning and adaptation strategies for climate-change effects to cultural-heritage resources is necessary. Obtaining an adequate inventory of cultural-heritage resources at risk within the Southeast CSCs domain is critical in the creation of effective planning and adaptation strategies.

The Southeast CSC will facilitate projects that develop inventory or monitoring strategies for cultural-heritage resources throughout the Southeast. While the Southeast CSC will not participate in inventory and monitoring projects directly, the CSC will actively work with interested partners to continue and develop methodologies and strategies that promote the collection of baseline inventory data, such as type, character, and significance of resources; extent, depth, and boundary of resources; current condition and threats; ownership; and location data that will facilitate modeling the impacts and monitoring the condition. It must be noted that one complexity in managing cultural-heritage resource data is that location information usually is restricted and controlled by each State Historic Preservation Office (SHPO), federal land manager, and tribe. Many cultural-heritage resources are sensitive and protected, such as burial mounds, sacred Native American sites, sites vulnerable to looting, etc., and dissemination of location information must be restricted. Federal archeological sites are protected under the Archaeological Resources Protection Act (1979), and their locations cannot be made public without the land manager's written consent.

There is need to document how resources within the Southeast and Caribbean respond to climate change and how they have responded to climate change in the past. Museum collections provide unique data for understanding the genetic diversity of populations, past community and ecosystem structure, and past climate variability. Such information provides critical, cost-effective scientific evidence to guide management decisions. Additionally, voucher specimens of plant and animal species will need to be collected to document changes in the species distributions, and ethnographic studies will need to be conducted to evaluate contemporary effects and responses of traditional peoples.

Near term recommendations

- Work with LCCs and other partners to determine data currently available, and then evaluate the current strategies and methods used to inventory and monitor cultural-heritage resources; develop new or improved methods as needed.

Long term recommendations

- Promote and support projects that continue to acquire information on cultural-heritage resources in the Southeast.

Task 2: Provide Support to the LCCs and Other Partners to Assess the Vulnerability of Cultural-Heritage Resources to Climate Change

Because some cultural-heritage resources are fixed-landscape resources and cannot adapt, be replicated, moved or relocated, the most critical data need for land managers is access to relevant vulnerability data assessments to identify, quantify, and evaluate the degree to which cultural-heritage resources are likely to be affected by changing climatic conditions. Vulnerability assessments can be undertaken at a range of geographic scales and address a range of resource types (for example, submerged resources, terrestrial archeological sites, cultural landscapes, historic buildings), with the goal of identifying the types of vulnerabilities affecting the resource across a geographic area. Vulnerability assessments may address one or more of the following factors in relation to the resources in question—sensitivity to climate change, exposure to climate change, and adaptive capacity to climate change.

Near term recommendations

- In partnership with the LCCs, SHPOs, tribes, and others as necessary, provide regional-scale tools and datasets to determine the resources that are most at risk.

Long term recommendations

- In partnership with the LCCs, SHPOs, tribes, and others as necessary, develop a strategy to monitor and update the condition of cultural-heritage resources.

Task 3: Facilitate Paleoecological and Paleoclimate Research for Cultural-Heritage Resources

Paleoecological and paleoclimate research are critical aspects in modeling climate change. Specifically, interdisciplinary archeological and paleoecological research have the potential to inform the understanding of climate-change patterns in the Southeast over the last 12,000 years and human response to those changes.

Near term

- Gather proxy climate data, from current data sources (for example, Theme 1, SERAP, *data.gov*, *climate.gov*) for the Southeast, including fire-frequency data, historical temperature and weather records, sea-level change, and sediment and soil profiles.

Long term

- Support interdisciplinary paleoecological and paleoclimate research.

Task 4: Provide Support for Cultural-Heritage Resources Climate-Change Planning

The newly enacted Secretarial Order 3289, "Addressing the Impacts of Climate Change on America's Water, Land, and Other Natural and Cultural Resources," calls for the DOI to fully consider the impacts of climate change on DOI resources, and to evaluate adaptation strategies when undertaking long-range planning. It mandates that agencies consider and analyze potential climate-change impacts when undertaking long-range planning exercises, setting priorities for scientific research and investigations, and developing multi-year management plans. To that end, management decisions made in response to climate-change impacts must be informed by science, and require that scientists work in tandem with resource managers who are confronting climate-change impacts and evaluating options to respond to such impacts.

The Southeast CSC has a critical role in leading and increasing scientific understanding and development of effective adaptive-management tools to address the impacts of climate change on cultural-heritage resources; and, therefore, supports planning efforts to assure that cultural-heritage resources are duly considered in all climate-change adaptation- and mitigation-planning activities.

Near term

- Provide support to develop seamless southeastern datasets of the location, condition, and vulnerability of cultural-heritage resources and associated metadata for use by agencies, LCCs, and states for conservation planning. The Southeast CSC will work to develop capacity within the GeoData portal to ensure that all data and work involving cultural-heritage resources adhere to federal, state and tribal requirements to protect sensitive location information.

Long term

- Develop partnerships with SHPOs and others as necessary to monitor and update the condition of cultural-heritage resources.

Monitoring Priorities

Data from monitoring networks are a critical resource for the Southeast CSC and LCC partners; scientific research, management decisions, and the evaluation of management outcomes all depend on data collected at the appropriate scale and frequency. Historical and contemporary observations and future predictions of climatic and biophysical factors, ecosystem conditions, and species distributions and diversity across the range of terrestrial and aquatic ecosystems in the Southeast are critical for improving downscaling model performance; evaluating and refining models; detecting changes in physical conditions, ecosystems and populations; and monitoring the outcomes of management and restoration activities. Although the CSCs are not tasked with maintaining monitoring programs, they will assist LCCs and other partners by helping to identify monitoring priorities and strategies for the regions that build upon the current monitoring and assessment activities and an awareness of current and future information needs associated with science, management decisions, and evaluation needs.

As an important initial step, the Southeast CSC staff will work with LCC staff to develop a database that characterizes the wide array of long-term monitoring activities already underway in the Southeastern United States by federal, State, and local agencies, universities, and other public and private sector organizations. Information about some of these long-term networks are publicly accessible on the Internet, including the USGS National Water Inventory System (NWIS; *http://waterdata.usgs.gov/nwis*); NOAA's National Climatic Data Center (NCDC; *http://lwf.ncdc.noaa.gov/oa/climate/climatedata.html*); the USEPA's Storage and Data Retrieval System (STORET, which contains water-quality, biological, and physical-property data for the Nation; *http://www.epa.gov/STORET/*); the National Park Service (NPS) Natural Resource Information Portal, which includes data from the NPS Inventory & Monitoring Program (*http://science.nature.nps.gov/im/datamgmt/index.cfm*); and the USFS Forest Inventory and Analysis National Program (*http://www.fia.fs.fed.us/*), which provides status and trends data on the state and stage of the Nation's forests annually. Additionally, many States in the Southeast make the water-quality, biological, and physical-property data they collect publicly available. Nevertheless, it remains relatively difficult to synthesize this information into an easy-to-use database of all monitoring stations in all networks that includes accurate, up-to-date information about monitoring station location and name, purpose of the network, types of data collected, specific parameters/variables collected, frequency of collection, period of record, quality assurance and quality-control information, and links to the data themselves. This difficulty is compounded when considering data collected by other entities, including NGOs and universities, who may not make data publicly available. A synthesis of what monitoring is currently being done in the Southeast is an important step in defining monitoring priorities and strategies.

The Southeast CSC is also tasked with working with partners to ensure that data-management strategies, resources, and systems associated with data collected as part of CSC-funded science activities are compliant with DOI-wide information standards.

Monitoring Priorities Recommendations

- Identification of the environmental driver and response variables that are most important for calibrating and verifying predictive models used to understand the effects of climate change and support adaptive management.
- Determining the extent and characteristics of existing networks or systems of data collection related to these variables.

Information Management and Data Sharing

The Southeast CSC will be involved in generating, integrating, and disseminating data that will help resource managers develop adaptation strategies in response to changes that are induced or exacerbated by climate. The Southeast CSC's science program must be of the highest quality, with results viewed as unbiased, based on sound science, and useful to resource managers. To maintain high-quality research, the Southeast CSC will implement strict procedures for reviewing proposals, avoiding conflicts of interest, and protecting confidential information.

Serving and archiving data and research outputs are critical aspects of the CSC activities. The Southeast CSC data-management activities will comply with the guidance, policies, and standards identified in the national NCCWSC/CSC Data-Management Policy and the NCCWSC/CSC Data-Sharing Policy (in development), both of which build on DOI and other government-wide policies. A national data-management strategy is needed to ensure that appropriate standards, consistent guidelines, and strategies are used to allow links to and consistency with other systems, which will foster a true national CSC network. Maximum efforts will be made to ensure the utility of the systems and data to LCCs in the Southeast as well.

In implementing the NCCWSC/CSC information-management and data-sharing policies, the Southeast CSC will leverage current resources of North Carolina State University, its partners, and the overall CSC network to the maximum extent possible. This includes computing assets, storage capabilities, and specialized analysis and visualization resources. In addition, as the Southeast CSC identifies regionally-specific data or information needs, these needs will be aggregated with those of the other CSCs to identify important national priorities.

Some specifics of the data requirements include the following:

- All data associated with the CSC will be fully accessible.
- Data must be provided by all researchers funded by the CSC in regular defined intervals and not simply at the end of respective projects.
- When research is completed, the Southeast CSC expects significant findings to be promptly submitted for publication, with authorship accurately reflecting the contributions of those involved.
- Publications will be targeted toward outlets with maximum impact and visibility.
- Investigators will be required to share with other researchers, within a reasonable time, the data, samples, genetic baseline data, physical collections and other supporting materials created or gathered.
- For continuing observations, or long-term (multi-year) projects, data should be made public no less than annually.
- Data for ongoing projects (particularly those of students) can be password protected, but must be provided.
- Annual or more regular reports will be required for all projects. These reports will address progress on the sharing of data and research findings.
- The Southeast CSC will comply with federal requirements for protection of intellectual property, including patents, inventions, and copyrights.
- The Southeast CSC will comply with all federal, State, and tribal requirements to protect sensitive data against unintended public release in accordance with current data-protection policies.
- The Southeast CSC, as feasible and appropriate, will expedite access to and sharing of its facilities and equipment to reduce costs, increase efficiency, and avoid duplication of effort.

Data management and integration will be greatly facilitated by infrastructure investments previously made by NCCWSC and DOI. The GeoData portal (*http://internal.cida.usgs.gov/gdp/ui/*) is a Web-delivered computer application for identification, selection, extraction, processing, quality control, and formatting of spatio-temporal data for modeling applications. The purpose is to bring modelers (researchers who require input datasets for their models) and data providers (researchers who process, synthesize, or otherwise provide information that can be used by the modelers) together in a common framework. While the initial intent of the GeoData portal is to disseminate the high-resolution national climate change dataset, the platform and framework of the portal will support other data-dissemination needs of the Southeast CSC.

Complementary Endeavors and Tools for Southeast CSC

Research projects that focus on the investigation of the impacts of climate change are, by nature, projects that involve interdisciplinary teams of scientists to study interactions between natural ecosystems, managed landscapes, urbanization, environmental regulations, conflicting land-use policies, and the temporal and spatial variations and trends of the atmospheric climate. The focus of a DOI CSC is not the study of atmospheric science but rather the effects of climate change on priority areas and issues. The Southeast CSC will engage federal partners, State and local agencies, and universities to supply climate data, products, and expertise to complement activities of Southeast CSC scientists studying the effects of climate change. Collaboration on small-sized projects may develop from casual interaction among several investigators, but large-scale projects develop more slowly and often fail because of the larger number of interaction pathways that emerge as the number of investigators increase. Development of integrated adaptation and mitigation strategies will compose many of the Southeast CSC projects that will be investigated. These projects will include many complex issues and require cooperative research program initiatives that may bring together many experts from widely diverse fields.

Cooperative Research and Decision Support

The Southeast CSC will seek to leverage its investments in science capacity, projects, and data with its partners in the research and resource-management communities to the maximum extent possible through communication and coordination with those groups. It will seek out, at every opportunity, cooperation and collaboration with other institutions doing complementary work so as to minimize redundancies and to integrate their efforts and products into the science needs identified by the Southeast CSC Stakeholder Advisory Committee. The Southeast CSC will seek to bring the collective knowledge of the science community into the decision framework of the agencies involved in the development of climate-change adaptation strategies, including the development and testing of novel ways of framing and presenting information for climate-sensitive decisions.

One example of Southeast CSC cooperative research is SERAP and, in particular, the development of optimal conservation strategies. The scientists involved in SERAP solicited the input of the science community and resource managers throughout the development and refinement of decision-support tools that will inform conservation decisions. Developing the decision-support tools in cooperation with the LCCs and other resource partners is a critical step in the success of this task

Education and Training

A key resource in dealing with the challenges posed by global change in general and climate change more specifically is the need for individuals trained in rigorous approaches to investigating the science of climate change. The Southeast CSC not only will support research that is useful to those who live and work in the region but also will work with NCSU to train undergraduate and graduate students in the skills necessary to research and communicate about climate-change science.

Undergraduate and graduate students will be educated and trained in the science of climate change by NCSU and partner universities; the Southeast CSC staff will be instrumental in helping to train these students, by providing both research and mentoring opportunities. NCSU is developing new undergraduate and graduate programs related to the goals of the CSCs. The CSC will play a role in mentoring students associated with these programs, exposing them to cutting-edge science and providing the connections to partners working in applied and basic fields related to climate change. In some cases, the mentoring of students will be formal, whether through classes or co-advising students; in other cases, the mentoring will be more informal, and conveyed through talks and other forms of interaction. Southeast CSC scientists will be fully integrated into scientific departments in such a way that these interactions and relationships are most fluid. Students who are trained in association with the Southeast CSC will benefit greatly, but they also will be a benefit to the Southeast CSC by providing high-quality work, collaborating outside of the CSC's existing connections, and communicating science to others.

Outreach and Community Involvement

The Southeast CSC will readily and effectively communicate scientific findings and strategies with the LCCs and other partners. While developing and funding climate-related research in the Southeast, the CSC will work closely with LCCs to ensure that science priorities for partners are being met. At the same time, it is imperative that research findings be communicated in a timely and efficient manner so that resource-management partners and the LCCs can begin synthesizing assessments and plan adaptive-management strategies through the use of the analytical and decision-making tools produced by the CSC.

Additionally, the Southeast CSC and its host institution, NCSU, are aggressively committed to reaching a broad public audience for communicating science news and results. The Southeast CSC will use the Global Change Forum Web site (*http://www.theglobalchangeforum.org/*), developed by NCSU, as an outreach tool for communicating climate-change science being conducted throughout the Southeast. A key challenge in dealing with climate change is developing a public understanding of the sometimes complicated science of climate, climate change, and biological responses to climate change. The continued success of the Southeast CSC and its mission is, at many levels, contingent on public understanding and support.

The Southeast CSC is committed to providing scientific information in the most understandable and accessible form. All products of the Southeast CSC will be disseminated to a wide audience, whether through the media, seminars, or symposiums. In addition, the Southeast CSC will take advantage of current capabilities of the Global Change Forum Web site for science communication and outreach. The site will feature profiles of climate-change scientists, highlights of current research in the Southeast, and information about upcoming meetings, symposiums, and research opportunities. As part of the effort to train students and reach out to the public, the Global Change Forum will serve as a hub for serving news about climate-change research to the public. Students involved in the Southeast CSC will be obliged to participate in public outreach about climate-change research. In addition, Southeast CSC will use the Global Change Forum as a tool to forge new relationships that facilitate communication of science across the Southeast.

Southeast CSC Science Expertise and Skills

The Southeast CSC will target science and administrative staff with skills necessary to meet the science themes outlined in this science and operational plan. Scientists will be recruited who have complementary skills to those existing at NCSU and USGS Science Centers. Other science skill sets that may be available to the Southeast CSC from federal agencies, States, academia, and NGOs will be considered and efforts will be made to fully utilize existing science staff. The goal is to have a combination of permanent hires, rotational term appointments, Interagency Personnel Agreements (IPAs), and other administrative options to recruit and maintain a highly skilled science and administrative staff. By using several administrative mechanisms to obtain high-quality staff, the Southeast CSC can remain flexible and responsive to partners' needs.

The Southeast CSC will work with LCCs, NCSU and other partners to target science staff hiring to benefit the CSC as well as other partners. The following is a list of potential administrative and scientific staff that the Southeast CSC proposes to acquire over the next two fiscal years:

A. *Administrative staff*—Positions to be considered for permanent hiring, rotational or term appointments, IPAs, detail assignments, and so on

1. Center Director
2. Science Program Manager
3. Administrative support staff

B. *Science staff*—Positions to be considered for permanent hiring, rotational or term appointments, IPAs, detail assignments, and so on

1. Climate scientist,
2. Ecologist and (or) biologist, with knowledge of climate models
3. Population and (or) distribution modeler(s)
4. Hydrologic modeler
5. Social scientist
6. Additional scientists to be determined after additional consultation with partners
7. Information management specialist

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Appendix. Bibliography

The following materials were used to develop the list of science themes and tasks. The information was collected from plans developed by agencies and organizations that will potentially be or are already partners of the Southeast CSC. These materials include peer-reviewed publications, unpublished drafts, and relevant Web sites that contain relevant information on priority issues or areas of scientific concern related to the effects of climate change. These priority issues were ranked according to frequency of inclusion in the reference materials; those items most often listed as an area of concern, or a priority issue, were evaluated for inclusion in the Science Themes section of this draft of the Southeast CSC Science and Operational Plan (table A–1).

Table A–1 was constructed after a literature review of publications that focused on climate change and resulting needs by federal, State, and local partners. The focus of publications ranged from a national to local scales, but the focus of the Southeast CSC is on priority science needs or issues in the Southeast. Publications of both federal and State agencies were considered during this exercise; however, in order to ensure an equal weighting of priority issues among agencies, and other partners, some publications were consolidated to account for only one record. For example, each of the 16 states within the boundaries of the Southeast CSC produces a State Wildlife Action Plan (SWAP), the priority issues for the SWAPs were consolidated and recorded just once during ranking. The same can be said for the individual NPS Inventory and Monitoring Networks within the boundary of the Southeast CSC (five total). In order to ensure that the priorities of these programs were not weighted higher than any others they were consolidated into one record.

Each mention of a priority science need or issue was recorded and then aggregated to develop a list of the most “important” science needs or issues in the Southeast. While this list was compiled through a literature review, it is not complete and should be considered an on-going exercise.

Table A–1. List of priority science issues for partners of the Southeast Climate Science Center.

[Blue denotes priority issues addressed by the Southeast Climate Science Center Draft Operational and Science Plan; CCSP, Climate Change Science Program; NOAA, National Oceanic and Atmospheric Administration; NPS, National Park Service; USFWS, U.S. Fish and Wildlife Service; USGCRP, United States Global Change Research Program; USGS, U.S. Geological Survey; SSPT, Science Strategy Planning Team]

Publication by partner	Priority issue								
	Clean Coastal and Ocean Waters Water Quality for Healthy Beaches/Seafood	Coastal Response to Sea-Level Rise and Climate Change/Coastal Geomorphology	Adaptation, Mitigation, Vulnerability Research	Freshwater Habitat Change with Fluctuating Water Availability	Healthy Ecosystems/Vegetation Communities	Global Carbon Cycle Understanding and Prediction, Climate Data	Human Populations, Socioeconomic, Urban Issues, Cultural Resources	Improved Data Management and Sharing of Climate-Change Data	Improved Monitoring Networks of Resources Affected By Climate Change
CCSP, Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources			1						
Governors Gulf of Mexico Alliance	1								
Governors South Atlantic Alliance	1				1				
National Research Council: Americas Climate Choices		1	1	1	1	1	1	1	1
NOAA Climate Service	1	1		1	1	1			
NPS Climate Change Response Strategy			1			1	1	1	1
NPS Inventory and Monitoring Networks[1]	1	1	1	1	1			1	1
State Wildlife Action Plans[2]	1	1	1	1	1		1	1	1
USFWS Strategic Habitat Conservation			1						
USFWS Strategic Plan			1			1		1	1
U.S. Forest Service Climate Change Resource Program				1	1	1	1		
USGCRP, Potential Consequences of Climate Variability, Southeast Region Chapter	1	1					1		
USGCRP, 2009, Global Climate Change Impacts in United States, State of Knowledge Report	1	1		1					
USGCRP, 2000, Conclusions and Research Pathways Section	1	1		1	1				
USGS Global Change SSPT		1				1			
Cumulative mention of Science Priority	**8**	**8**	**7**	**7**	**7**	**6**	**5**	**5**	**5**

[1] Compilation of all five Inventory and Monitoring Networks.

[2] Compilation of all 16 State priority issues.

Table A–1. List of priority science issues for partners of the Southeast Climate Science Center.—Continued

[Blue denotes priority issues addressed by the Southeast Climate Science Center Draft Operational and Science Plan; CCSP, Climate Change Science Program; NOAA, National Oceanic and Atmospheric Administration; NPS, National Park Service; USFWS, U.S. Fish and Wildlife Service; USGCRP, United States Global Change Research Program; USGS, U.S. Geological Survey; SSPT, Science Strategy Planning Team]

Priority issue														
Biological Planning, Conservation Design, Conservation Delivery	Climate Model Limitations/ Uncertainty	Imperiled and Rare Communities/ Invasive Species	Biological Response to Climate Change	Environmental Education	Forest Productivity	Land-Use and Land-Cover Change	Understanding Past Climate Change and Sea-Level Rise	Assumption-Based Research	Changes in Extremes of weather and climate; climate policy	Crop Yields and Economic Impacts	Marine Benthic Communities/ Coral Reefs	Outcome Based Monitoring and Adaptive Management	Public Participation in Developing a Solution to Climate Change Impacts	Amphibians and Reptile Communities	Working Waterfront
1	1														
				1											
															1
	1	1		1			1						1		
									1						
1	1														
		1	1			1					1			1	
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		1			1										
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					1				1	1					
			1			1					1				
			1			1	1								
4	**4**	**4**	**3**	**3**	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**1**	**1**

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