Department of Geography, University of South Carolina Spring 2013

Carolinas Climate Connection

Carolinas Integrated Sciences & Assessments

Integrating Climate Science and Resource Management in the Carolinas

Focus on Coastal Climate

Over 123 million people live in coastal shoreline counties in the United States. Coastal regions provide many valuable functions from tourism and recreation to security and commerce. Coastal managers are presented with the challenge of protecting coastal ecosystems as well as protecting growing populations from coastal hazards. In this edition of the Carolinas Climate Connection you'll find information on climate effects to coastal regions as well as tools and resources for addressing climate change impacts to these unique areas which are so important to the culture and economy of the Carolinas.

CISA partners with various communities and stakeholders in the coastal regions of North and South Carolina to assist in addressing many of these different impacts. Major coastal concerns in the Carolinas include erosion, land use change, water quality, health of fisheries, community development, and natural hazards. Information on CISA's current projects to integrate anticipated climate-related impacts into coastal management and planning processes can be found on the CISA website.

Coastal Climate Research

Coastal Impacts, Adaptation, and Vulnerabilities

This comprehensive technical report to the 3rd National Climate Assessment includes a chapter on the physical climate forces which influence coastal regions in the U.S., as well as associated impacts and vulnerabilities (Burkett & Davidson, 2012).

Hotspot of accelerated sea level rise on the Atlantic coast

Findings indicate that a 'hotspot' of sea level rise exists between Cape Hatteras, NC and Boston, MA creating a particularly vulnerable region given the high population density of the area (Sallenger et al., 2012).

Tropical Cyclones and Climate Change

Determining the extent to which tropical cyclone activity is outside the spectrum of natural variability is restricted by a limited historical record. However, recent advancements in tropical cyclone projections, despite uncertainties, can provide better information for at-risk stakeholders in coastal regions (Knutson et al., 2010).

Tools and Resources

Global Sea Level Rise Scenarios for the US National Climate Assessment

This technical report to the NCA provides the details of the new sea level rise scenarios included in the 3rd National Climate Assessment, and is the first coordinated, interagency effort in the U.S. to identify agreed upon global sea level rise estimates in order to provide information for coastal planning, policy, and management (Parris et al., 2012).

Tools for Coastal Climate Adaptation Planning

This guide is designed to assist decision makers involved in conservation, local planning, and the management of coastal zones, natural resources, protected areas, habitat and watersheds in coastal regions of the U.S. as they work to integrate climate change impacts into coastal planning and adaptation processes (Rozum and Carr, 2013).

Find more Tools & Resources on Page 6

Upcoming Events

Webinar: Sustainable Working Waterfronts Toolkit
May 17, 2013
12:00 - 1:00 EST

Getting to Know Wetlands: Value, Regulations, & Conservation
Beaufort, NC
May 21, 2013

2013 Rising Seas Summit
Fort Lauderdale, FL
June 18-20, 2013

Coastal Protection Symposium
Myrtle Beach, SC
August 18-22, 2013

Announcements

CISA 2012-2013 Annual Report now available on the CISA website

SC DNR Report on Climate Change Impacts to Natural Resources Available for Public Review and Comment

"Climate Ready North Carolina: Building a Resilient Future" - now available on the CISA website

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UNIVERSITY OF SOUTH CAROLINA

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Coastal Impacts, Adaptations, and Vulnerabilities

Chapter 2: Physical Climate Forces

With over 50 percent of the U.S. population living in coastal watershed counties, the issue of climate change and its effects on coasts is an important one. With so many different dynamic processes, both human and environmental, occurring in the coastal zone, it is difficult to accurately predict exactly how climate change will impact coasts. Burkett et al. (2012) discuss the different driving forces of climate change acting on the coasts to include sea level rise; temperature and precipitation change; major storm events including waves, winds and currents; and changing ocean circulation patterns.

The authors provide a comprehensive synthesis of the effect each of these drivers has on coastal regions in the U.S. Key findings center on the sensitivity of coastal systems and added layers of vulnerability due to land development and use, which can inhibit the natural response of physical processes and adaptation of plants and animals.

Sea Level Rise

Several of the key findings reiterate the influence sea level rise will have on the coastal zone. Sea level rise is influenced by the warming atmosphere through glacier and ice sheet melt and the expansion of warming sea water. Due to the fact that physical properties, coastal geology and geomorphology, and human development all have an impact on coastal change, it is difficult to say how climate change induced sea level rise is going to affect this balance of processes. What is known, however, is that sea level rise will impact coastal ecosystems and infrastructure through increased flooding frequency and inundation of low-lying areas. Additionally, the sensitivity of dynamic coastal landforms such as barrier islands, wetlands, and deltas to even small changes in physical forces makes sea level rise of particular concern for these areas.

Tropical Storms

Globally, the frequency of tropical storms is projected to remain about the same; although, projections for Atlantic basin tropical cyclone activity show a larger range of uncertainty than global projections. Sea level rise, in conjunction with a combination of other factors in tropical cycle frequency, track, intensity, and size will further intensify storm-related hazards. For example, the authors point out that only one major storm, Hurricane Irene, made landfall during the 2011 North Atlantic hurricane season, which tied for the third most active season on record. However, this single storm caused $10 billion dollars in damage and 55 casualties, demonstrating the increasing vulnerability of U.S. coastlines as population growth rates and infrastructure costs increase.

Precipitation

Precipitation trends influence the coastal environment when either too little or too much precipitation falls, affecting marsh and wetland vegetation and animal species, river runoff, and infrastructure. Heavier precipitation events, combined with sea level rise and storm surge, are likely to increase flooding severity, already seen in many coastal cities such as Charleston, SC where low-lying roads flood on a regular basis. The influence of drought in coastal ecosystems is not as well understood as drought impacts in other regions of the country.

Coastal Community Vulnerability

The authors note that vulnerability of coasts to climate change impacts will be relative because of the diversity of the coastline in the U.S., which ranges from arctic permafrost cliffs to mid latitude barrier islands and low-lying tropical atolls. Because of this variation, as well as the many dynamic processes involved in coastal change, the authors note that it is very important to bring a multidisciplinary approach when creating coastal vulnerability assessments, whereas current assessments typically focus on only one variable to coastal change. Part of this multidisciplinary approach involves differentiating between climate and non-climate drivers of coastal change. Climate drivers are likely to have more broad effects on coastal ecosystems (though still not uniform) whereas non-climate drivers will have largely regional effects.

Burkett, R. and Davidson, M.A. [Eds.]. 2012. Coastal Impacts, Adaptation and Vulnerability: A Technical Input to the 2012 National Climate Assessment. Cooperative Report to the 2013 National Climate Assessment. Washington, DC: Island Press.

Full report available for free download on www.cakex.org

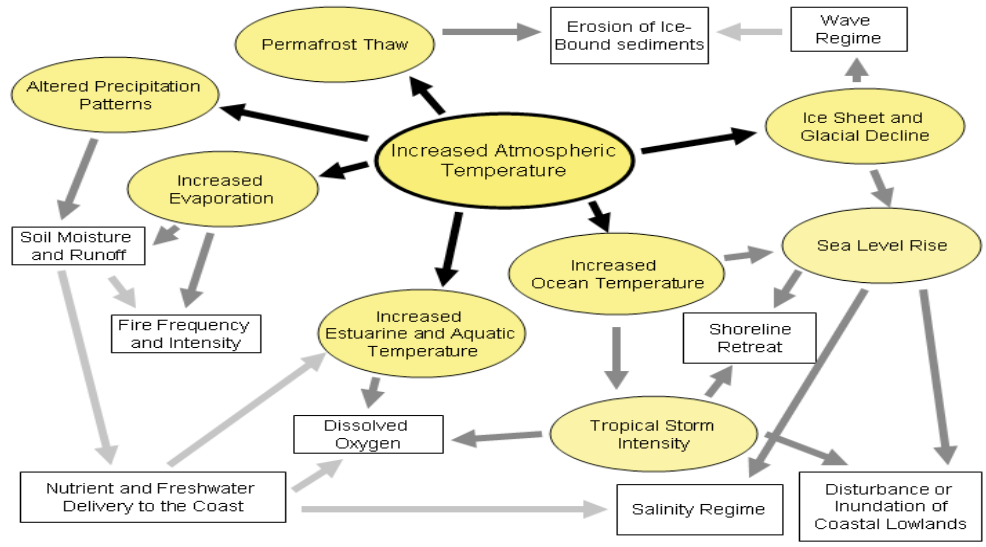


Figure 1: The main impacts of climate change and the effects on coastal regions (Burkett et al., 2012).

Hotspot of accelerated sea level rise on the Atlantic coast

Due to the fact that global warming does not cause a uniform rate of sea level rise around the globe, different coastlines may experience different rates of sea level rise compared to the global average. The differences in rates of rise can be attributed to regional variations in temperature, salinity, and air pressure as well as varying ocean currents and land movement.

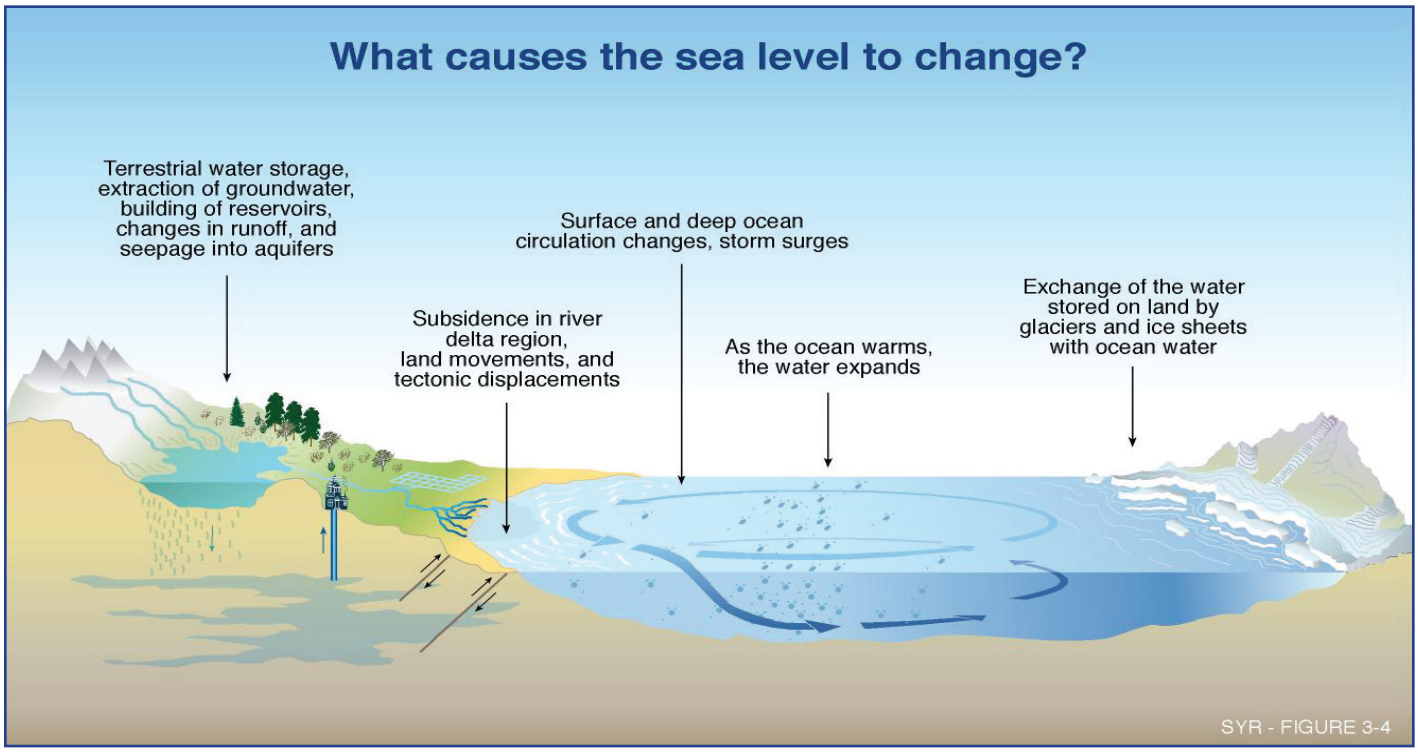
One such area in particular is a 1,000 km hotspot on the east coast of the United States stretching from Cape Hatteras, North Carolina to Boston, Massachusetts, known as the northeast hotspot (NEH). Researchers at the USGS in St. Petersburg, FL analyzed tide-gauge records from around North America during the time period 1950-2009. Their analysis shows that the NEH experienced an increase in sea level rise from 1950-1979 and 1980-2009 three to four times the global average, compared to the coastline south of Cape Hatteras, which has seen minimal deviation from the global average over those same time periods. Specifically, findings show that sea levels have risen between 2 and 3.7 millimeters per year since 1980 along this stretch of coastline, compared to the global increase over the same time period of 0.6 to 1.0 millimeters.

According to the statistical analysis that was conducted by the researchers, it is hypothesized that this difference in sea level rise in the NEH is due to a combination of warmer ocean temperatures and ice melt in the North Atlantic. Warming temperatures and/or freshening of water from ice melt are associated with making water in the North Atlantic less dense and inhibiting the convection that drives the Atlantic Meridional Overturning Current (AMCO). This means that the warmer water coupled with a lower pressure gradient increases the acceleration of sea level rise in the NEH.

In addition to the vulnerability of this hotspot region to sea level rise, the area is also densely populated creating higher levels of risk to public health and infrastructure.

Sallenger, A., K. Doran, and P. Howd. 2012. “Hotspot of Accelerated Sea-Level Rise on the Atlantic Coast of North America.” *Nature Climate Change* 2.12:884-888.

DOI: 10.1038/NCLIMATE1597



The image above, taken from Parris et al. 2012 (pg 5), provides an overview of the factors which influence global sea levels, to include changes in ocean temperature, melting land-based ice such as glaciers and ice sheets in Greenland and Antarctica, and changes in runoff such as dam construction or groundwater withdrawal. As mentioned in the article synopsis above, Sallenger et al. hypothesize that the increased rate of sea level rise in the Northeast Hotspot between Cape Hatteras, NC and Boston, MA is due to a combination of warmer ocean temperatures and ice melt in the North Atlantic.

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Tropical Cyclones and Climate Change

With tropical cyclones affecting such a large portion of the globe, it is important to determine what impacts climate change will have on tropical cyclone activity. As coastal populations and the value of infrastructure along the Atlantic coastline increase, so do the economic costs of damage caused by tropical cyclones. Sea level rise and storm surge will also contribute to the vulnerability of the region.

One of the core challenges with projecting future cyclone activity, however, involves a lack of reliable historical data. With satellite detection of tropical cyclones only beginning in 1966, all cyclone data prior to this date consist of land and sea observations (which likely means that the entirety of cyclone activity has not been captured.)

Given the historical data, it remains uncertain whether or not past changes in cyclone activity have exceeded the range of natural variability that would be expected. Despite some suggestive observational studies, researchers have not been able to conclusively identify anthropogenic signals influencing past tropical cyclone activity. Because of this uncertainty, it becomes difficult to project how climate change may impact tropical cyclone activity in the future.

With regard to tropical cyclone frequency, it is projected that the frequency of tropical cyclones will either decrease or remain essentially unchanged owing to increased greenhouse gas concentrations and resultant warming. Furthermore, there is very low confidence about how each individual cyclone basin will be affected by this increase in temperature. For each individual basin, various models predict a ±50% change in cyclone frequency. It is believed however, that late twenty-first-century model projections indicate decreases ranging from -6 to-34% globally.

Additionally, some increase in storm intensity appears likely in the 21st century due to rising sea surface temperatures. The article estimates that the mean maximum wind speed of tropical cyclones is likely to increase between 2 and 11% globally. Along with this increase in cyclone intensity, there is likely to be an increase in rainfall rates (on the order of 20% within 100km of the storm's center).

Finally, there is very low confidence with regard to how climate change will impact the genesis, track and duration of tropical cyclones. The authors note that "existing model projections do not show dramatic large-scale changes in these features."

Despite the existing uncertainties with tropical cyclone projections, they nonetheless are an improvement in confidence compared to projections that were made over the past 10 years. Continuous improvement of projections will provide better information to a variety of stakeholders, at risk from tropical cyclone activity.

Knutson, T., J. McBride, J. Chan, K. Emanuel, G. Holland, C. Landsea, I. Held, J. Kossin, A. Srivastava, and M. Sugi. 2010. "Tropical cyclones and climate change." *Nature Geoscience* 3.3:157-163. DOI: 10.1038/GEO779

NOAA's 'State of the Science FACT SHEET' on Atlantic hurricanes, climate variability and change also provides valuable information on these phenomena.

Tropical Cyclones & Climate Change

Summary of Detection, Attribution and Projection Assessments

Detection & Attribution

- It is uncertain whether or not past changes in activity (frequency, intensity, rainfall, etc.) exceed natural variability when improvements in technology such as satellite detection are taken into consideration

Tropical Cyclone Projections

Frequency:

- Global frequency will either decrease or remain essentially unchanged because of climate change
- Low confidence in projected changes in individual basins
- Current models project changes ranging from -6 to -34% globally, and up to ±50% or more in individual basins by the late twenty-first century.

Intensity:

- Some increase in mean maximum wind speed (+2 to +11% globally), but not throughout all tropical regions
- Frequency of most intense storms likely to increase in some basins

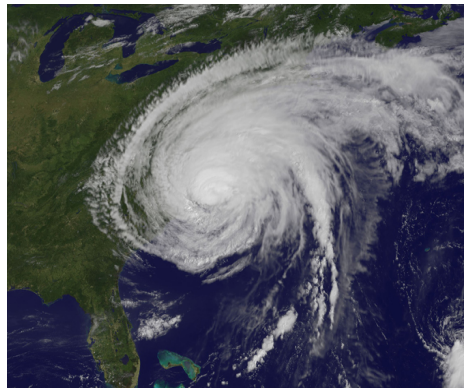
Rainfall:

- Rates are likely to increase
- Projected +20% magnitude increase within 100km of tropical cyclone center

Genesis, tracks, duration and surge flooding:

- Low confidence in projected changes to these features
- Existing models do not show large-scale changes
- Sea level rise and increased coastal development will increase vulnerability to storm surge flooding
- Levels of vulnerability also dependent on future storm characteristics

Source: Knutson et al. 2010



GOES-13 satellite image of Hurricane Irene after it made landfall in Cape Lookout, NC. Source: NASA

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Coastal Climate Tools & Resources

Global Sea Level Rise Scenarios for the U.S. National Climate Assessment

Global sea level rise has been a consistent trend over the past century, and in the face of climate change, is expected to persist or intensify, impacting millions of people around the globe. Global Sea Level Rise Scenarios for the United States National Climate Assessment, released in December 2012 by the NOAA Climate Program Office, is the first coordinated, interagency effort in the U.S. to identify agreed upon global sea level rise estimates in order to provide information for coastal planning, policy, and management.

The report presents four different sea level rise scenarios to be taken into account by coastal planners and managers. The scenarios range from global mean sea level rising by as little as 0.7ft by the end of this century or as much as 6.6 feet (see table below). This wide range is due in large part to uncertainty regarding the extent of warming that will occur by 2100 under various emissions scenarios as well as the rate and magnitude of ice sheet loss. The authors note that ice sheet loss from Greenland and West Antarctica will be most influential. Additionally, even if warming ceases in the next few years, it is very likely that sea levels will continue to rise.

For the purposes of regional and local planning however, the report notes that the above scenarios should not be used in isolation, rather managers should factor in local dynamics and regionally specific information when developing sea level rise scenarios. Additionally, these local/regional scenarios should account for vertical land movement (VLM), a process by which parts of the Earth's crust rise when weight of continental ice sheets is lessened due to melting. Other impacts caused by factors which currently contribute to coastal flooding during severe weather such as high tides, storm surge, high waves, and high runoff from rivers and creeks, will further amplify the impacts of sea level rise with respect to vulnerabilities in various regions.

While there will be regional variability with rates of sea level rise the scenarios laid out in the NCA technical report are important for the development of coastal planning and adaptation policies. This suite of scenarios provide a set of "plausible trajectories" upon which vulnerability and impact assessments, as well as adaptation strategies can be based.

Parris, A. P. Bromirski, V. Burkett, D. Cayan, M. Culber, J. Hall, R. Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger, and J. Weiss. 2012. Global Sea Level Rise Scenarios for the U.S. National Climate Assessment. NOAA Tech Memo OAR CPO-1. 37 pp.

The NOAA Coastal Services Center has developed guidance for Incorporating Sea Level Change Scenarios at the Local Level. This document details an 8-step process for utilizing a scenario approach to coastal climate adaptation planning as well as providing links to additional NOAA resources related to sea level rise and adaptation planning.

The recently released Guide to Coastal Climate Planning Tools provides information on geospatial tools to assist coastal communities, resource managers, and conservation practitioners consider the impacts of sea level rise, among other climate-related impacts, in coastal adaptation planning. More information is provided on this guide on page 6.

Global Sea Level Rise Scenarios (Parris et al. 2012)

Scenario	SLR by 2100 (ft)*	Considerations in Decision-Making
Highest	6.6	This scenario can be particularly useful when considering situations where there is very little tolerance for risk such as planning for new infrastructure with a long anticipated life cycle (e.g. a wastewater treatment plant or residential or commercial development).
Intermediate-High	3.9	This scenario includes factors that might make it useful when there is a medium tolerance for risk, such as infrastructure that must be replaced more regularly.
Intermediate-Low	1.6	This scenario allows experts and decision-makers to consider a higher risk tolerance for planning purposes, that might be more readily adjusted.
Lowest	0.7	This scenario should be considered when there is a great tolerance for risk of the consequences of underestimating future sea levels.

* Using mean sea level in 1992 as a starting point

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Tools for Coastal Climate Adaptation Planning: A Guide for Selecting Tools to Assist with Ecosystem-Based Climate Planning

This guide targets practitioners and decision makers involved in conservation, local planning, and the management of coastal zones, natural resources, protected areas, habitat, and watersheds in the coastal United States, including the Great Lakes. The guide includes 10 tools which were chosen for their functionality in adaptation planning, application to coastal regions, multi-sectoral approach to planning, applicability to a broad range of coastal geographies, species, ecosystems and projects, and for their ease of use. Each of the tools is actively maintained with technical support available. In addition, the guide offers instructive case studies about how other professionals have successfully applied the tools in several coastal communities around the U.S.

The tools can be categorized as visualization, modeling or decision-support, based on the steps within an adaptation planning process for which they can be used. The guide uses a generalized adaptation planning process which includes stakeholder engagement, scoping, assessment/analysis, planning, and implementation/monitoring, giving guidance about which tools are applicable for each step in the process. Sectors addressed by the various tools include natural resources, agriculture, the built environment, transportation and energy. By focusing on software and web-based applications that leverage geospatial information, the guide is able to help professionals account for the health and well-being of ecosystems and human communities in projects and plans.

Although some of the tools do require software such as ArcGIS to be operational, 9 out of 10 of the tools are available for free download. The guide includes a table of requirements necessary for running each of the tools.

Rozum, J. and S. Carr. 2013. Tools for Coastal Climate Adaptation Planning: A guide for selecting tools to assist with ecosystem-based climate planning. Coastal Marine Ecosystem-Based Management Tools Network. Natureserve. Arlington, VA.

Additional Tools & Resources

NEclimateUS.org

This searchable database, developed through a collaborative effort of NOAA, the North Atlantic LCC, National Wildlife Federation, and EPA, provides regionally relevant climate information for the Eastern U.S through South Carolina. The database was developed with the goal of facilitating collaborative opportunities across the network of climate-focused programs and partners in the region.

This EPA webpage provides case studies and links to demonstrate adaptation activities in coastal communities to protect people and property.

DIGITAL COAST
NOAA COASTAL SERVICES CENTER

This website provides a wealth of data, tools, trainings, and case studies in order to help 'turn data into information that can be used' for coastal management.

About CISA

Carolinas Integrated Sciences & Assessments is 1 of 11 NOAA-funded Regional Integrated Sciences & Assessment teams. CISA works with a variety of stakeholders across North and South Carolina to incorporate climate information into water and coastal management and related decision-making processes. For more information, visit our website at www.cisa.sc.edu.

We would like your feedback.

If you have any comments or suggestions for material in future editions of the newsletter, please e-mail us at cisa@sc.edu.