WORKSHOP REPORT:
Planning for Coastal Climatologies in the Southeastern United States

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EXECUTIVE SUMMARY

Nearly all coastal resources are affected by climate, so it is not surprising that coastal managers often face issues that have climate components. Providing coastal managers with the knowledge and tools needed to incorporate climate variability into the management of living marine and coastal resources is a goal of the National Oceanic and Atmospheric Administration (NOAA). To address this goal, the NOAA Coastal Services Center (CSC) and NOAA National Climatic Data Center (NCDC) are developing a series of coastal climatologies. These climatologies will build upon traditional meteorological and terrestrial climatologies (e.g., winds, precipitation, temperature, soil moisture, river flows), add marine parameters (e.g., sea surface temperature, chlorophyll concentration, salinity, dissolved oxygen concentration), and help support the development of products that can be used by all levels of government, the private sector, and individuals who are faced with climate-sensitive decisions.

A workshop for weather, climate, and marine-sensitive decision making, planning, and assessments on the Atlantic coast of the southeastern United States was convened in October 2003 to facilitate the development of coastal climatologies. Coastal climatologies are unique because they consist of a blending of marine and terrestrial information, unlike traditional climatologies that focus on just one of those components. Stakeholders attending the workshop represented public and private entities in eight areas: agriculture, coastal transportation, energy conservation and planning, environmental quality, fishery management, natural hazard mitigation, recreation and tourism, and water consumption. Topics discussed during the workshop included the size and composition of the current and potential user base, how climate information is currently used in decision making, user views toward incorporating additional climate information in their decision-making processes, sources of similar services from other agencies and the private sector, and the obstacles to incorporating new technology in decision-making processes.

This report provides recommendations on the development of applications and databases that will support coastal managers, specifically those faced with weather, climate, and marine-sensitive decisions.

This report advocates place-based demonstration projects for linking NOAA climate information with resource management and outlines specific illustrative applications from eight unique user areas along the Atlantic coast from Virginia to Florida. These user applications are based on structured queries, as well as stakeholder response and feedback received at the workshop.

Based on stakeholder input, a coastal climatology product will contain information on atmospheric and nearshore oceanographic parameters that allow for a probabilistic characterization of constraints and enablers of economic and environmental activities and systems. Participants at the workshop made recommendations for coastal climatology products in the specific areas of pest forecasting for coastal agriculture, managing hydroelectric power generation and reservoirs, disposing of dredged material, integrating research of climate-fisheries interactions into fisheries management, mitigating shoreline erosion by beach nourishment, predicting surf conditions for coastal water sports, planning hurricane evacuation routes, and reducing nonpoint source pollution.

Beyond these specific recommendations, several cross-cutting coastal climatology issues were identified through workshop discussions. Collectively, these key issues need to be addressed in order to build successful coastal climatology products. These issues can be grouped into five categories: 1) definition of coastal climatology, 2) observing systems, 3) forecasts, 4) product creation and delivery of coastal climatology products, and 5) follow-up to production of coastal climatology products. Each of these issues is discussed below.

1) *Definition of a coastal climatology* – An opening task of workshop participants was to define "coastal climatology," specifically the distinction between a coastal climatology and traditional land or marine climatologies. Our definition of coastal climatology recognizes that the coastline constitutes a major contrast between land and sea in terms of temperature, humidity, wind, and aerodynamic roughness. Atmospheric phenomena in the coastal region, especially those in the micro- to mesoscale dimensions, are produced by the presence of the coastline. These coastal phenomena extend about 150 km landward and seaward from the coastline (Rotunno 1994). Examples of coastal meteorological phenomena include the sea breeze, sea breeze–related thunderstorms, coastal fronts, haze, fog, enhanced winter snowstorms, and strong winds associated with coastal orography.

Many stakeholders included environmental and economic systems pertinent to their interests in their definition of "coastal" (i.e., they were reluctant to put spatial bounds on information that may impact their decision making). They attested that coastal climatology products should address system-oriented needs rather than location-specific information. In addition, an effective coastal climatology should include marine parameters so that end users can assess nearshore conditions in addition to terrestrial conditions. This need for two types of information is what truly separates coastal climatology users from land or marine climatology users. A coastal climatology product without contiguous terrestrial and marine observations or forecasts may be of limited use to coastal climatology users.

2) *Observation Systems* – Workshop participants recommended the deployment of more near-real time terrestrial and marine

observing systems with more parameters, increased time resolution, and seamless access across observation platforms. Although specific needs can be addressed with specific types of observing systems, many workshop participants indicated that other information is lacking. Part of the problem coastal managers have in identifying needed data is that many of them do not have the background in meteorology and physical oceanography to sufficiently describe the specific information needed for their decisions. The authors interpret managers' requests for "better" data to mean more real-time reporting of nearshore (5 km from the shoreline) wave, current, and wind data within bays at a county and subcounty spatial resolution, as well as a means for placing real-time data within a historical perspective.

A review of existing moored C-MAN buoys (the source most frequently cited for buoy data by workshop participants) and their locations along the coast of the southeastern United States elucidates some of the difficulties outlined by participants in utilizing the existing observation network. A 5:1 ratio exists between coastal buoys and coastal counties, indicating a discontinuity between the scale of observation (buoy) and the scale of decision making (county/subcounty). Thus, new coastal climatology products should address this disparity through either the addition of more data-collecting buoys, the integration of nonfederal observing systems into one larger network similar to the Southeast Atlantic Coastal Ocean Observing System (Seim et al. 2002), or the creation of accurate spatial interpolation methods from the existing buoy observation network to downscale observations for decision makers' needs.

3) *Forecasts* – Nearly all workshop participants found the use of weather, marine, and climate forecasts essential to their operations. They identified temporal gaps between short-term forecasts (e.g., seven-day weather) and climate forecasts (e.g., greater than one month) and recommended integrating weather, marine, and climate forecast results across consistent (and statistically practical) spatial and temporal resolutions. These recommendations may be easily attained. The NOAA National Weather Service provides a suite of forecast products that range temporally from hourly to seasonal. Specific location forecasts of temperature, dew point, relative humidity, wind speed and direction, sky conditions, etc. are available at three-hour increments for three days in advance and at six-hour increments for an additional four days. Probabilistic forecasts of temperature and precipitation are available over 6-to-10-day and 8-to-14-day periods. Similar to monthly and seasonal forecasts, these extended range outlooks cover the country as a whole. Our sense is that stakeholders would like extended-range and climate outlooks for specific geographic locations. It is also our impression that the NOAA National Weather Service is pursuing downscaling projects at its local forecast offices.

4) *Product Creation and Delivery* – Participants agreed that collective design of coastal climatology products by stakeholders and scientists could lead to the creation of valuable tools. Collaboration also fosters trust between parties, which makes it more likely that a product will be integrated into decision-making processes. Several stakeholders recommended the development of personalized products that meet their specific information needs. The delivery of such products could be achieved on the Web through the development of a user interface that allows end users to tailor available data, visualization of the data, and analytical tools

to fit their needs. Such individual crafting might include a selection of geographic area of interest, suite of parameters and observations, time frame and temporal resolution, and output preferences, such as georeferenced tables or maps.

5) *Follow-up* – Many coastal managers admitted that their expertise did not include weather, climate, or the physical aspects of marine science. NOAA should assume that most of the end users of coastal climatology products, while specialists in their own fields, need expert guidance on integrating coastal climatology products into their activities. An interesting outcome of this workshop is the demonstration of the need for future research initiatives to clearly define components of various coastal climatology products that are applicable to coastal management issues. Such initiatives should provide blueprints for coastal climatology products applicable to one or more coastal issues. NOAA should be prepared to provide training in the form of workshops, tutorials, or on-site seminars in support of their products. Recommended partners for this type of outreach are Sea Grant programs, the NOAA Coastal Service Center, and NOAA's regional climate centers.

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INTRODUCTION

Recent socioeconomic analysis of the coastal economy of the United States shows that coastal states were responsible for 75 percent of the nation's gross state product in 2000 (Colgan 2003). Nearly half of the nation's economy came from coastal watershed counties; specifically, nearshore areas that account for only 4 percent of the nation's land produced more than 11 percent of its economic output. Since these coastal regions possess such vast economic opportunities, as well as cultural attractions and historical significance, population density has increased significantly along the coast. Coastal economic growth has surged in areas such as Alabama, Florida, Mississippi, and North Carolina, where employment has increased by more than 50 percent. As a result, many coastal communities are faced with maintaining strong economic growth, improving infrastructure for industry and residential growth, and minimizing the damaging impacts on the coastal environment.

Infrastructure management and environmental protection by coastal communities and governments is complicated by their ability to respond and adapt to climatic variability and change. In 1997 and 1998, seasonal and interannual variations in climate, such as the El Niño–Southern Oscillation, caused $25 billion in economic impacts, including property losses of $2.5 billion and crop losses of $2.0 billion (NOAA 2003). In response to this challenge of integrating knowledge of climatic variability into commerce and environmental protection, NOAA is focusing on fostering an understanding of climate variability and change so that it becomes a component of the decision-making skills that allow resource managers and planners to plan for and respond to related changes and problems.

Organization of This Report

The purpose of this report is to facilitate the development of applications and databases that will support coastal managers, specifically those faced with weather, climate, and marine-sensitive decisions. NOAA is taking a phased, regional approach to this planning so that lessons learned in the first regions examined can be more easily applied to planning in subsequent regions. The geographic focus of this report is the southeastern United States, which has been defined as areas along the Atlantic coast from Virginia to Florida. This report outlines one specific, illustrative application for each of the eight identified user areas (Table 1). To provide a systematic approach to developing the plan, the following information is identified in each application area:

- data and analytical tools needed to produce the product
- sources and likely costs for those data and analytical tools and an assessment of their quality and suitability with respect to the core uses
- present format of the data and analytical tools and any changes needed to the format of those data and tools in order to facilitate their use
- accessibility of the data and analytical tools to the target users
- data and information gaps with respect to the core uses and a preliminary assessment of the likelihood that current technology and government programs could fill those gaps

- cultural, educational, or institutional obstacles within the coastal management community that would impede that community from adopting the products resulting from this coastal climatology effort
- training that may be needed within the coastal management community to make use of the products from this coastal climatology effort, and key training providers within the private sector and government capable of providing the training

Stakeholder Workshop
A stakeholder workshop was the principal means for collecting information on data, products, models, decision tools, and a host of other requirements for a series of coastal climatologies. Information provided during a workshop at the NOAA Coastal Services Center on October 21 and 22, 2003, aided in the construct of a set of core user sectors for coastal climatologies (see Appendix A for the workshop agenda, Appendix B for the participant list, and Appendix C for areas of interest outside the core areas provided in this report). The 45 workshop participants represented public and private entities involved in eight core areas: agriculture, coastal transportation, energy conservation and planning, environmental quality, fishery management, natural hazard mitigation, recreation and tourism, and water consumption.

The first segment of the workshop included a series of short lectures on meteorological and marine observations systems. Upon receiving this initial information, the participants divided into working groups to discuss and outline specific recommendations as to the content, structure, and communication of coastal climatology products. The first task for the working groups was to describe decision making, planning, or assessments in their core areas and the integration of weather, climate, and marine parameters into those areas. This task identified weather, climate, and marine information that are currently being used by stakeholders as well as data sources, data availability, data cost, and data delivery systems. The sources of data, forecasts, and products were primarily from NOAA, but information sources also included other federal agencies, universities, and private corporations. The second major task of the working groups was to answer a series of "what if" questions that sometimes led to a deconstruction of existing decision-making structures and heightened expectations of NOAA data and products (see Appendix D for questions posed to working groups).

To ensure that the discussions from the workshop are fairly represented in this report, three individuals who observed the entire workshop reviewed the document. These individuals are senior members of their respective agencies and are experienced in workshop-based technical transfer. The workshop also was recorded on video. In addition, this report was reviewed by other scientists examining coastal climate issues in the southeastern U.S.

Defining "Coastal Climatology"
The initial step in construction of a series of coastal climatologies is the definition of the terms "coastal" and "climatology." For this workshop and report, the coast is defined as 100 km landward of the shoreline to 100 km seaward, which roughly equates to the geographic extent of the sea breeze system (Rotunno 1994). However, participants' definitions of the coast varied depending on their core user area. Some alternative definitions included the coastal plain and adjacent shallow ocean waters, brown water

ecosystems, and U.S. territorial waters. Many end users defined the coastal zone to include environmental and economic systems and activities pertinent to their core area rather than specific geographical features (i.e., they were reluctant to put spatial bounds on information that may impact their decision making). Thus to best suit these users, coastal climatology products should address system- and activity-oriented needs rather than simply provide information on a specific location or coastal zone. Further, a coastal climatology would need to include oceanographic variables so that end users could assess nearshore conditions in addition to terrestrial conditions. The need for both marine and terrestrial information distinguishes coastal climatology users from other climatology product users who typically focus on either the land or the sea. A coastal climatology product without spatially transparent terrestrial and marine observations or forecasts may be of limited use to coastal climatology users.

The definition of climatology supplied by workshop participants is much more specific than the traditional definition of long-term weather patterns "over periods of time measured in years or longer" (Hidore and Oliver 1993). In particular, end users view climate as a "constraint" or "enabler" of economic and environmental activities or systems. For example, summer produces conditions that enable tourism along the coast in the form of beach visitation. In contrast, hurricane season constrains tourism as people are less likely to visit the beach due to the threat of tropical storms or hurricanes. Further, since climate is not static, climatic variability creates variability in how systems and activities are enabled or constrained. Continuing the tourism analogy, a particularly rainy summer in a tourism area may lead to a decreased number of tourists and diminished economic return. Probabilistic assessment of whether a system or activity will be constrained or enabled by changes in atmospheric and oceanographic parameters can help convey climatic variability and uncertainty. In other words, an end user in the tourism or recreation field may like to know the general probability of the tourist season being disrupted by a hurricane.

In regard to the temporal aspect of climate, a concise definition of the time frame in which climate variability should be assessed for economic and environmental activities or systems was not provided by workshop participants. Below the monthly time frame, real-time meteorological observations are often employed in decision-making. It is difficult to completely separate climatological and meteorological data used in management decisions because they are used simultaneously to make decisions. This report will maintain distinctions along a time continuum among climate forecasts, weather forecasts, weather observations, and climate records.

Based on the needs expressed by the workshop participants, a coastal climatology product may be defined as information, including both atmospheric and nearshore oceanographic parameters, that allows for a probabilistic characterization of constraints and enablers of economic and environmental activities and systems. However, the specific nature of information to be included in coastal climatology products cannot be so succinctly stated. The coastal management community, as represented by workshop participants, believes that climatology information is extremely important for decision making, but specific types of this information are defined rather ambiguously. Clear ideas on the types of real-time meteorological data required for decision making exist, but once an attempt is made to couch such information within the climatological framework, the clarity is lost.

This report provides expert opinions on specific weather, climate, or marine information products requested by users. Accordingly, one of the most important outcomes of this workshop was the demonstration of the need for future physical and social science research initiatives to clearly define components of various coastal climatology products. Such initiatives should provide blueprints for coastal climatology products applicable to one ore more coastal issues. This report will also provide recommendations for the development of coastal climatology products for eight core areas (agriculture, coastal transportation, energy conservation and planning, environmental quality, fishery management, natural hazard mitigation, recreation and tourism, and water consumption). A cross-cutting summary of coastal climatology issues that are salient to all eight of the core areas will illustrate the interrelated processes that require weather, climate, and marine information.

CORE USER AREAS FOR COASTAL CLIMATOLOGIES IN THE SOUTHEASTERN UNITED STATES

CORE AREA: COASTAL AGRICULTURE

Background

The use of weather and climate information by the agricultural industry is wide-ranging and can be generalized beyond the coastal zone. A farmer's need for weather and climate information is derived from which crops or even livestock are being raised and where these activities are taking place. Climate, specifically the seasonal patterns of temperature and precipitation, is the primary determinant for which crops can be grown in a particular location. Other physical factors, such as soil type and topography, and cultural practices, such as irrigation or proximity to markets, also influence the resulting agricultural patterns. The El Niño–Southern Oscillation (ENSO) phase can significantly influence agricultural yields as well as the geographical extent of various fruit, vegetable, and nonfood crops (e.g., cotton and tobacco) across the southeastern United States. For Florida, in particular, yields were lower and prices were often higher during El Niño winters than during neutral or La Niña winters (Hansen et al. 1999). These examinations of the influence of ENSO on crop production in the southeastern United States identified crops that are vulnerable to ENSO-related weather variability and therefore likely to have important implications for both producers and consumers from application of ENSO-based climatologies. The results highlight the critical role of climate and production-related data on station or county levels in quantifying the impact of ENSO climate anomalies on yields.

Due to higher specific heat and transport of energy from the tropics, coastal zones in the southeastern United States can experience climatic conditions that are more favorable to certain crops that would otherwise not be expected at that latitude. Along the southeastern Atlantic coast, maritime air can moderate the thermal regime, allowing for the northward planting of fruits and vegetables. Figure 1 shows plant hardiness zones for the southeastern United States that are based on the average annual minimum temperature. Instead of tracking hardiness parallel to lines of latitude, these zones track parallel to the coastlines of the southeastern Atlantic coast. By comparing coastal and inland locations within the same hardiness zone, the moderating effect of maritime air can be illustrated (Table 1). A generalization might conclude that along the southeastern Atlantic coast, the maritime influence on air temperature and the growing season is equivalent to an increase of one hardiness zone.

Agriculture in hardiness zones that have migrated northward based on average conditions may be a double-edged sword. Multiple rotations during a growing season can allow for greater annual productivity. Cultivation of crops not typically grown at that latitude may be possible because of warmer temperature. In either case, extreme weather that is not as common in lower latitudes, such as frosts, may affect agricultural activities in maritime-modified hardiness zones.

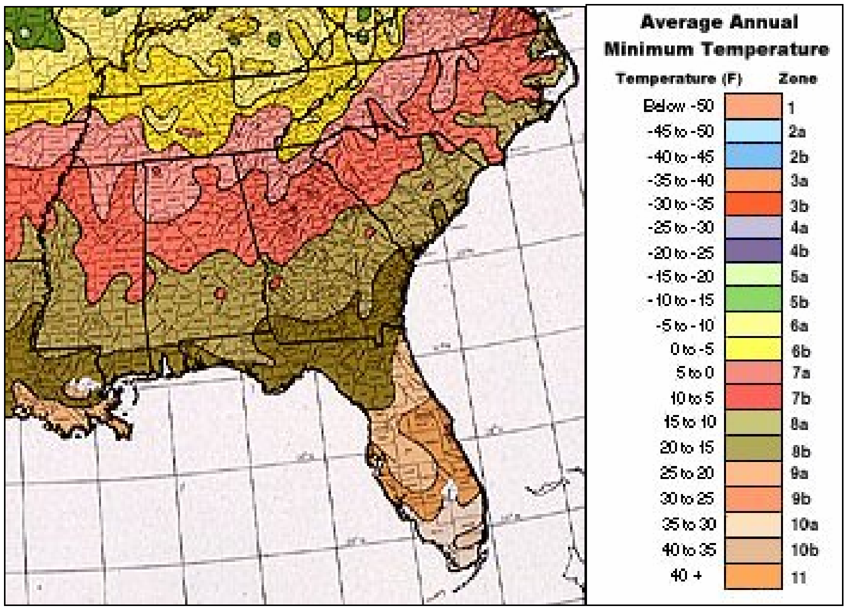

Figure 1 Plant hardiness zones for the southeastern United States (USDA 1990)

Table 1 USDA hardiness zones and average annual minimum temperature range for the southeastern United States (modified after USDA 1990). Latitude is taken from the primary National Weather Service first-order or cooperative weather station. *Mobile, Alabama is within a coastal zone, but it is at least 320 km south of Charleston, South Carolina

Zone	Temperature (ºC)	Coastal Location	Latitude	Inland Location	Latitude
7a	-15.0 to -17.7	—	—	Richmond, VA	37º 30' N
7b	-12.3 to -14.9	Norfolk, VA	36º 54' N	Atlanta, GA	33º 38' N
8a	-9.5 to -12.2	Wilmington, NC	34º 16' N	Montgomery, AL	32º 18' N
8b	-6.7 to -9.4	Charleston, SC	32º 54' N	*Mobile, AL	30º 41' N
9a	-3.9 to -6.6	St. Augustine, FL	29º 53' N	—	—
9b	-1.2 to -3.8	Fort Pierce, FL	27º 30' N	—	—
10a	1.6 to -1.1	Naples, FL	26º 09' N	—	—
10b	4.4 to 1.7	Miami, FL	25º 47' N	—	—

Problem: Coastal Agricultural Pest Forecasting

In addition to moderating thermal climates of coastal zones, marine air may also serve to provide moisture to the region in the form of precipitation, dew, or fog. Although adequate precipitation is necessary to meet the needs of crops, moist environments may also promote the growth and spread of plant disease. Climate data and weather forecasts can be used to predict these conditions.

Downy mildew, for example, is a foliar (leaf) disease that is caused by the fungus *Pseudoperonospora cubensis*. This disease reduces yields, decreases fruit quality, and in severe cases kills plants, especially cucurbits such as squash, cucumbers, pumpkins, and cantaloupes. This disease draws the attention of farmers and extension agents because the fungus develops and produces spores in one location, and they are transported and deposited to other locations by wind. Several weather factors are important during each stage of disease development. (The four stages of disease development are sporulation, transportation, deposition, and infection.) Holmes and Main (2003) developed a cucurbit downy mildew forecast that considers weather factors at each stage of development. The forecast provides outlooks of disease risk, descriptions of source areas, and maps of likely atmospheric trajectories away from a source area.

<u>Weather and Sporulation</u>

First, the location and features of sporulation, or the release of spores into the atmosphere, must be identified. If crops are infected, they should be treated with fungicide. Optimal weather conditions for sporulation are a combination of high-atmospheric and near-surface moisture conditions (nocturnal relative humidity [RH] > 95% for 2 hours, 15º C ≤ temperature ≤ 25º C, and ≥ 6 hours of dew). However, RH needs to decrease while temperatures increase to commence the release of spores. Sporulation is commonly associated with recent rainfall or irrigation and foggy mornings, although persistent rainfall can decrease spore release or cause atmospheric washout. Sporulation typically occurs during the night with release between 8:00 a.m. and 1:00 p.m. Although daily rainfall and temperature data are widely available, hourly temperatures and relative humidity are typically found at airport weather stations or increasingly at automated agricultural weather stations.

The downy mildew forecast estimates the transport and survival of spores away from a source location. Since exposure to ultraviolet radiation and low humidity will desiccate the spores, transport forecasts consider the amount of cloud cover and atmospheric humidity as well as the trajectory of atmospheric flow. Figure 2 shows the expected horizontal path of spores and the vertical motion (lower pane) after they are released into the atmosphere. Trajectory forecasts typically begin at 10:00 a.m. to coincide with maximum spore release. Although spores are assumed to be near the center of the trajectory, the spore cloud will spread away from the center and potentially impact areas on either side of the trajectory (Keever et al. 1998). Observations of cloudiness and measurements of atmospheric humidity are typically available at airport locations or locations with vertical atmospheric profile systems.

The next step in the downy mildew forecast is the estimation of spore deposition along the expected trajectory. The key weather elements are the location, duration, and intensity of precipitation. Spore deposition is based on the probability of precipitation along the expected trajectory, including the timing of precipitation (before, during, or after passage of the spores), the location of precipitation (spores rained out before reaching production areas), and the nature of precipitation (thunderstorms or widespread light rain). Monitoring weather conditions may provide early warnings for disease potential.

<u>Weather and Infection</u>

Once deposition of spores has been estimated, the chance of infection in exposed cucurbit locations is estimated. Optimal weather conditions for infection are mild temperatures and high moisture conditions (15º C ≤ temperature ≤ 25º C, and ≥ 2 hours of dew). Within this temperature range, the presence of fog, daytime cloudiness, and precipitation will provide conditions favorable to infection. Dew is also a provider of free moisture, but typically is not considered because: (1) it is a ‘local conditions’ phenomenon not usually mentioned in available weather forecasts, and (2) the scenarios in which it may be more important than fog or rain are rare. If trajectory and atmospheric characteristics were favorable for spore deposition, the local weather conditions would provide guidance as to the appropriateness of early abatement procedures.

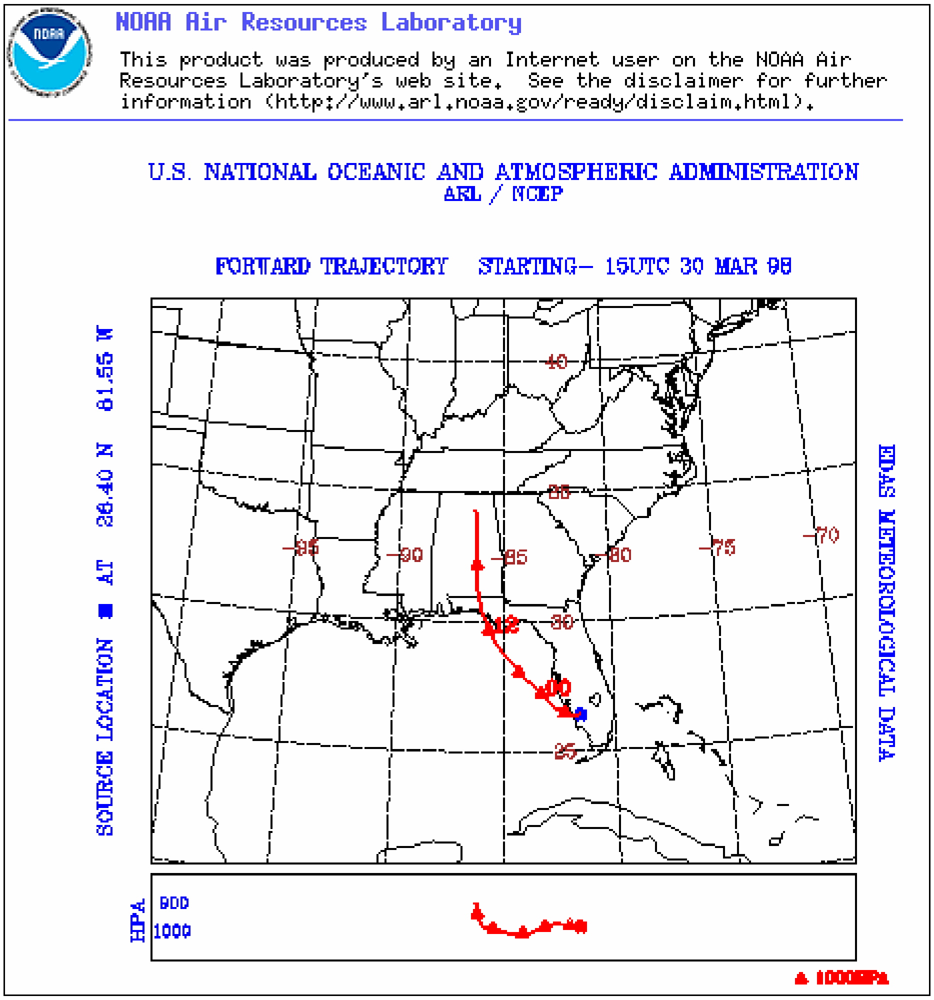

Figure 2 Expected horizontal and vertical motion of a particle released at 10:00 a.m. on March 30, 1998, from Immokalee, Florida (Keever et al. 1998). Triangular markers on both panes correspond to particle location at 6-hour time increments

Table 2 Summary descriptions of data needs, access information, relative costs, and weaknesses of a coastal agricultural pest-forecasting product. Relative cost: $$ > $ > Free

DATA OR PRODUCT	SOURCES	ACCESS	COST	WEAKNESS
Hourly relative humidity, temperature, precipitation	NOAA NWS, NCDC, RCC, other mesonetworks, USDA	Internet	Real-time free; archive $	Somewhat limited spatial coverage
Hourly weather observations (fog, cloudiness)	Real-time NOAA NWS	Internet	Free	Time-intensive
	Archive NOAA NCDC RCC	Internet	$	Somewhat limited spatial coverage
Hourly leaf wetness	Limited to local mesonetworks and research networks	N/A	N/A	Limited availability
Trajectory forecast, including cloud cover and atmospheric humidity	NOAA ARL	Internet	Free	Requires highly skilled end user
Radar precipitation	Real-time NOAA NWS	Internet, satellite	Free, third-party subscription	Data-intensive
	Archive NOAA NCDC	Internet	$$	Data-intensive

Resources and Logistics

1) Data and analytical tools needed to produce the product
   - Hourly temperature, precipitation, humidity, leaf wetness (dew), wind speed, wind direction, and fog observations near coastal agricultural areas. Some measurements may be interpolated over distances of 10 km (e.g., wind) while others are more suited for very near the measurement location (e.g., leaf wellness, soil moisture)
   - Short-term freeze prediction
   - Seasonal drought prediction and monitoring
   - El Niño/La Niña predictions. ENSO-related seasonal precipitation forecasts would be beneficial for estimating ENSO-related yield deviations if details are provided on predicted changes in temporal and spatial variability of climate (Legler et al. 1999)
   - Rainfall climatology based on radar and ground measures that focus on the impact of the sea breeze on coastal rainfall

2) Source for the data and analytical tools and cost and suitability to core area
   - NOAA
     - National Weather Service Local Forecast Offices, *www.nws.noaa.gov/organization.html*
     - National Hurricane Center, *www.nhc.noaa.gov/*
     - National Climatic Data Center, *www.ncdc.noaa.gov/oa/ncdc.html*
     - Air Resources Laboratory, *www.arl.noaa.gov/*
     - Regional climate centers, *www.nrcc.cornell.edu/other_rcc.html*
   - United States Department of Agriculture and NOAA Joint Agricultural Weather Facility,

www.usda.gov/agency/oce/waob/jawf/index.html

- State climatology offices, *www.ncdc.noaa.gov/oa/climate/stateclimatologists.html*
- Free data. Participants indicated that access to free data and analytical tools is one of, if not the most, important motivating features in product selection. Therefore, the majority of data and analytical tools that they utilize are an amalgamation of low cost or free offerings

3) Present format of data and analytical tools and any changes needed
   - Hourly and daily near-real time weather observations are available through NOAA data providers in standard ASCII formats. Metadata, such as geographical coordinates, are readily available
   - Short-term weather, seasonal climate, and tropical storm forecasts are available in text formats over the Internet or via satellite. Some of these products are in ASCII tables while others are descriptive text
   - Radar products are available for many different time increments, such as 5- to 10-minute intervals, hourly precipitation totals, and storm total precipitation. Spatial resolution of these products may be as fine as 1.1 nautical mile grids

4) Accessibility of the data
   - Climate and weather data are easily accessed by farmers and agricultural managers. Accessibility of these data can be further improved through the following means:
     - Providing both hard copy and digital data (Maddox et al. (2003) found that personal and printed communication sources were preferred over electronic communication sources for those seeking agricultural and weather information)
     - Improving existing weather radio reports for agriculture
     - Making all data able to be personalized to the end user. Web sites should have options for graphics, text, model analyses, etc.

5) Gaps or weaknesses in current data, products, tools, or providers
   - More soil moisture and soil temperature observations, including hourly measurement intervals, vertical profiles measurements, several sensors per county, and access to near-real time and historical data. Currently, there are fewer than 200 soil moisture and soil temperature monitoring locations in the contiguous United States, and only a small percentage of these are in coastal zones
   - More photosynthetic active radiation or solar radiation measurements, including hourly measurement intervals, several sensors per county, and access to near-real time and historical data
   - More evaporation measurements or weather systems capable of evaporation modeling, including hourly intervals, several sensors per county, and access to near-real time and historical data
   - Continued improvement in seasonal climate forecast skill
   - Wider availability of dew forecasts and observations

6) Cultural, educational, and institutional obstacles

- Competition between private and public sector to provide data
- Different quality control standards between entities collecting data
- Historically weak political climate for funding research in support of agriculture, although recent droughts have provided a resurgence of interest
- Potential computer and technology skills limitations of end users
- Development of effective partnerships between organizations to manage and monitor resources, regulatory organizations, and end users; potential confusion about inherently governmental services versus private sector services; questions on competing or redundant agency missions, policies, and institutions

7) Training for coastal climatology end users
   - Decision makers are not trained to interpret data or models
   - Planners/engineers need a tool to connect effectively with commissioners and managers
   - Need visualization tools
   - Provide training modules for specific user groups (e.g., Future Farmers of America, tobacco farmers, Hispanic migrant workers). Training for nonpoint source pollution, for example, might include the use of irrigation schedules for water consumption and optimal conditions for pesticide applications. Training levels should be geared to a user group's level of knowledge and complexity of integration
   - Need funding for K–12 education components for students and teachers and to collaborate outreach with existing agencies to provide training (i.e., Sea Grant, Cooperative Extension)
   - Media involvement to provide advertising and publicity for coastal climatology products

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CORE AREA: COASTAL ENERGY CONSERVATION AND PLANNING

Background

The use of weather and climate information by the energy industry is extensive and multidimensional. It is extensive because nearly every stage of energy production and delivery is sensitive to weather or climate. Residential and commercial buildings are the largest end-users of electricity in the United States, consuming 62 percent of the electricity generated in 1989 (NAS 1992). Within these buildings, approximately 47 percent of electricity consumption consisted of space heating and cooling (NAS 1992). With a projected increase in the coastal population of the United States, residential and commercial building energy demands will likely increase. Given that the indoor-to-outdoor temperature differential is one of the driving forces in heating and cooling energy demands (Markus and Morris 1980), an increased knowledge of coastal climatology will assist coastal energy managers in meeting this increased demand. Further, hydrologic generation of power is dependent on the availability and variability of water resources. The security and stability of power transmission is dependent on severe weather forecasting, preparedness, and recovery. In addition, disastrous weather events can cause considerable damage to energy transmission infrastructure. Saffir (1991) notes that after Hurricane Hugo, utility companies in South Carolina and the Caribbean had not given "sufficient consideration" to planning for damage from a hurricane. He recommended that utility companies develop hurricane-resistant criteria for designing and planning for energy transmission lines.

We describe the use of weather and climate information in the energy industry as multidimensional because different components of power generation have different weather and climate sensitivities. Since power delivery is a competitive market, power utilities need to understand the weather sensitivities of other power companies within the region as well as the climatic variability that is occurring across the continent. Deregulation of power utilities places even more emphasis on delivery of climatic information and forecasts because of the diverse and competitive nature of power management. Energy production from different fuels (e.g., coal, nuclear power, gas, water) is rooted in supplying electricity to consumers for profit. Though each fuel-based method has similar objectives and a similar transmission infrastructure, they often have very different geologic, economic, and atmospheric sensitivities.

Although the energy sector is one of the biggest users of weather and climate information, Altalo et al. (2000) found that the wide-scale use of weather and climate information in the energy industry is impeded by several factors. These factors include product problems, such as low geographic and temporal resolution, limited parameters, and lack of data continuity; and interpretation problems, such as lack of direct communication between the suppliers of information (e.g., meteorologists) and the users of information, and poor assimilation and integration of data into decision-making processes. The use of weather and climate information was found to be more diverse between large and small utilities than across different sectors or across different regions.

In general, large energy utilities have more sophisticated integration of weather and climate information into decision making and planning. Hydroelectric power shares many management decisions with other energy producers (e.g., transmission and load forecasting), but it has the unique task of managing reservoirs. The unique features of hydroelectric power management within the coastal zone make weather and climate information extremely valuable in decision making.

Problem: Hydroelectric Power Generation and Reservoir Management

Workshop participants identified major components of any hydropower systems that are sensitive to weather or climate conditions. These components are:

1. Identifying a suitable location for hydroelectric power generation (long-term);
2. Load planning for energy distribution area (short-term);
3. Water resource planning and management (short- to midterm); and
4. Transmission planning for pricing (mid- to long-term).

Identifying suitable locations for hydropower generation involves complex studies of the underlying geological structures as well as geophysical modeling of filled reservoirs. Considerations for environmental, economic, and cultural impacts are weighed against the beneficial aspects of dam and reservoir construction and management. Compared with these factors, weather and climate play a small role in identifying suitable locations for hydropower generation. Nevertheless, long-term precipitation, stream flow, and runoff regimes provide information on the availability of water. Long-term temperature approximates water loss by evaporation. Although long-term averages are important, daily, seasonal, annual, and decadal patterns of these parameters provide information on the expected ranges of water availability as well as important periodicities or severe events such as floods and droughts. Decision making for locating hydropower plants is complex and based on in-depth physical and economic studies and models. It is generally beyond the scope of uses of weather and climate in hydropower operations.

Weather and Energy Demand Forecasting
Load forecasting, or predicting the short-term (less than ten days) consumer energy demand, requires a different set of meteorological parameters and products. Cultural forces, such as the day of the week, and consumer type (residential or commercial) typically drive the demand for energy. The ability to supply energy on demand depends on the amount of water in the reservoir, the amount of water entering the reservoir, and the flow out of the reservoir. Decisions on instantaneous supply of hydroelectricity also depend on the projected energy demand (ten days to one month) and the estimation that the system could meet that demand.

Weather forecasts that predict temperatures ten days in advance support load planning (although forecast skill currently diminishes after about five days). Temperature is the primary weather element affecting energy demand. For residential consumers, the demand for heating and cooling energy increases as temperatures deviate from 18º C. Hackney (2003) found that the economic value for accurate temperature forecasts increased greatly for temperatures that were 5.5º C greater or less than 18º C. Energy producers could then plan for power generation to meet temperature-based demand ten days in advance. Forecasts for other variables that affect heating or cooling demand are precipitation, cloud cover, wind speed, and humidity. Since air conditioning also provides humidity control, incorporating humidity forecasts in load planning may be more important than previously recognized, especially in the southeast United States. Demand forecasts often rely on the ability to predict weather across a service area from several hours out to several weeks. These forecasts allow energy utilities to determine the best and most cost-efficient mix of power generation to meet electricity load demands (Altalo et al. 2000). Energy utilities often have multiple types of power generation, such as hydroelectric, nuclear, or gas, and optimize the use of different types based on overhead cost, demand, and revenue.

Water Resources and Energy Demand Planning
Load planning and managing water resources are inseparable since water is essentially the fuel for power generation. For example, minimum and maximum flow, defined at the time an energy project is licensed, regulate the flow of water out of the reservoir. Maintaining minimum flow may be a competing management decision during drought conditions. Because municipal and industrial water uses along coastal river systems are sensitive to increased salinity, monitoring systems alert upstream dam operators to release water before a salt wedge reaches sensitive intakes. This water may not be available for hydroelectric power generation. Other competing uses for reservoirs, such as flood control, recreation, irrigation, fishing, and lakeshore living, also factor into managing the water supply. Hydroelectric operations use precipitation and stream flow measurements upstream from the reservoir to estimate input of water into the reservoir. Ongoing hourly precipitation and stream flow measurements are combined with

precipitation forecasts for the upstream basin to estimate power output ten days in advance. Modified stream flow models may incorporate local and basin conditions and require the input of local precipitation, wind, temperature, humidity, and solar radiation data (Altalo et al. 2000). Coastal hydropower operations often have an additional management requirement to flush a salt-water wedge from downstream locations.

Long-range planning and pricing for transmission and demand requires accurate monthly and seasonal climate forecasts. Hydropower operators can factor these seasonal forecasts into water management decisions. For example, seasonal forecasts for above-normal temperatures and below-normal precipitation translate into greater energy demand and less water supply. A potential management decision would be to increase reservoir levels. Hydropower operators may also use seasonal forecasts to prepare for increased precipitation. By lowering reservoir levels and selling power, they could generate revenue and prepare for potential flood conditions simultaneously. Because startup and shutdown of generation units and poor management of water resources is a major cost to hydropower operations, improving monthly and seasonal climate forecasts could save large utilities millions of dollars annually (Altalo et al. 2000).

Table 3 Summary descriptions of data needs, access information, relative costs, and weaknesses of a hydroelectric power generation and reservoir management product. Relative cost: $$ > $ > Free

DATA OR PRODUCT	SOURCES	ACCESS	COST	WEAKNESS
Precipitation and stream flow climatology	NOAA NCDC, USGS	Internet, CD-ROM	$	Limited spatial coverage of gauged watersheds and bias toward large watersheds
Real-time stream flow	USGS, NOAA NWS	Internet	Free	Limited spatial coverage of gauged watersheds and bias toward large watersheds
Weather forecasts to 10 days	NOAA NWS	Internet	Free, third-party subscription	Time-intensive for end user
Seasonal and monthly climate forecasts	NOAA CPC	Internet	Free	Generalized spatial patterns; lower skill during some phases
Hourly precipitation radar	Real-time NOAA NWS	Internet, satellite	Free, third-party subscription	Data-intensive and difficult to format for common software (GIS)
	Archive NOAA NCDC	Internet	$$	Data-intensive and difficult to format for common software (GIS)

Resources and Logistics

1) Data and analytical tools needed to produce the product

    - Information for managing reservoir
        - Lake level, stream flow/runoff, precipitation, and temperature measurements in the river basin upstream from the reservoir
        - Salinity measurements to maintain integrity of river ecology and industrial uses downstream of the hydroelectric plant and dam
        - Forecasted precipitation to estimate stream flow and lake level. Forecasts need to be specific to reservoir
    - Information for energy transmission and load forecasting
        - Ten-day forecasted temperature, humidity, cloud cover, wind speed, and precipitation across the service area of the power company
        - Monthly seasonal climate forecasts for the service area as well as adjacent regions

2) Source for the data and analytical tools and cost and suitability to core area
    - NOAA
        - National Weather Service Local Forecast Offices, *www.nws.noaa.gov/ organization.html*
        - National Hurricane Center, *www.nhc.noaa.gov/*
        - National Climatic Data Center, *www.ncdc.noaa.gov/oa/ ncdc.html*
        - Climate Prediction Center, *www.cpc.ncep.noaa.gov/*
        - Regional climate centers, *www.nrcc.cornell.edu/other_ rcc.html*
    - United States Geologic Survey, Water Resources Division, *http://water.usgs.gov/*
    - State climatology offices, *www.ncdc.noaa.gov/oa/climate/state climatologists.html*
    - Free data. Participants indicated that access to free data and analytical tools is one of, if not the most, important motivating features in product selection. Therefore, the majority of data and analytical tools that they utilize are an amalgamation of low cost or free offerings

3) Present format of data and analytical tools and any changes needed
    - Hourly and daily near-real time weather observations are available through NOAA data providers in standard ASCII formats. Metadata, such as geographical coordinates, are readily available
    - Short-term weather, seasonal climate, and tropical storm forecasts are available over the Internet or via satellite. Some of these products are in ASCII tables while others are descriptive text
    - Radar products are available for many different time increments, such as 5- to 10-minute intervals, hourly precipitation totals, and storm total precipitation. Spatial resolution of these products may be as fine as 1.1 nautical mile grids

4) Accessibility of the data
    - Large energy companies often have their own climatology, meteorology, and hydrology sections that extract data from NOAA weather stations or their own networks and create their own products. Private companies often provide software and analysis

to small to mid-sized energy companies
- Climate and weather data are easily accessed by energy managers. Data provided over the Internet is preferred over other methods. However, the accessibility of the weather and climate data can be improved through the following means:
    - Formatting scientific Web sites to be easily understood by end users
    - Using the ideal format for energy manager access to coastal climatology products, which is through a dynamic, web-based system accessed by a variety of users to build and manage their customized products and solutions.

5) Gaps or weaknesses in current data, products, tools, or providers (adapted from Altalo et al. 2000)
    - Recommended improvements in forecast products
        - Greater accuracy of weather and climate forecasting, including increased spatial and temporal resolution
        - Standard method for expressing the confidence level of forecasts
        - Five- to ten-day hourly forecasts on atmospheric conditions
    - Recommended improvements for observational data
        - Better availability, longer time periods, improved continuity of historical time series
        - Improved standardization between geographic locations, including electronic reporting formats and near-real time reporting
        - Additional weather stations in energy strategic locations
        - Real-time wind data to allow for dispatch of maintenance crews to repair downed power transmission lines. Repair of power lines should occur as soon as possible, but not while weather conditions are dangerous or may cause additional damage
        - Radar product that distinguishes rain from ice
    - Recommended improvements in blended or derived products
        - Integrated rainfall by small river sub-basins for river flow analysis
        - Hourly average heating and cooling degree calculations by NOAA in place of daily high/low averages currently provided

6) Cultural, educational, and institutional obstacles
    - Lack of consensus among scientific community in interpretation of results and utility of products
    - Potential computer and technology skills limitations of end users
    - Development of effective partnerships between organizations to manage and monitor resources, regulatory organizations, and end users; potential confusion about government services versus private sector services; questions on competing or redundant agency missions, policies, and institutions

7) Training for coastal climatology end users
    - Provide training modules for specific user groups (e.g., regional power associations, electric cooperatives). Training for load planning for an energy distribution area, for example, might include the use of

weekly and seasonal forecasts for water consumption and optimal conditions for energy generation. Training levels should be geared to a user group's level of knowledge and complexity of integration.
- Provide funding for K–12 education components for students and teachers and collaborate outreach with existing agencies to provide training (i.e., Sea Grant, Cooperative Extension).
- Ensure media involvement to provide advertising and publicity for coastal climatology products

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CORE AREA: COASTAL ENVIRONMENTAL QUALITY

Background

Many coastal communities were founded as regional ports to support trade, shipping, and fisheries, and sea-borne commerce often continues as the primary economic activity of those communities. In the United States, 93 percent of international trade – one billion tons of cargo valued at $500 billion – moves in and out of U.S. deep draft ports (CMMF 1994). Given the importance of such economic activities, maintenance of ports, harbors, intracoastal waterways, and other navigational infrastructure is of paramount importance to maintaining the economic vitality of a coastal community. Natural coastal processes, such as tides, ocean currents, waves, and sedimentation, can cause the degradation of navigation and sea-borne commerce infrastructure (Pilkey and Dixon 1996). Such degradation takes the form of infilling navigational channels and shoaling in harbor or port entrances. In response, coastal communities have implemented dredging projects to clear navigational channels and the entrances to ports and harbors.

<u>Coastal Dredging</u>
The United States Army Corps of Engineers (USACE) has the primary responsibility for the construction and maintenance of navigational infrastructure in federal waters. The societal benefits of USACE coastal dredging – improved navigation infrastructure, material for beach nourishment, land development, offshore mound and island construction, creation of agricultural land, supply of construction aggregate, and enhancement of wetlands and aquatic and wildlife habitats – have long been recognized (Engler 1990). However, since the increase in environmental awareness of the 1960s and 1970s, the negative impacts of coastal dredging have also been documented (Truitt 1988). This concern led to the promulgation of over 30 federal environmental statutes, Executive Orders, and government regulations – particularly, Section 103 of the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA) and Section 404 of the Clean Water Act of 1977 (CWA) – to regulate dredging activity and dredged material disposal (Walls et al. 1994).

Of particular concern to environmental quality is the disposal of dredged material. Estimates indicate that on a global scale, disposal of dredged material is the largest input of waste material to the ocean on a mass basis (Kester et al. 1983). The USACE dredges over 250 million cubic meters of sediment per year to maintain more than 30,000 km of waterways and about 1,000 harbor projects (ASCE 1983). The environmental degradation created by dredged material can be linked to two specific factors: the dredged material itself and the fate of the dredged material once it has been placed at a disposal site.

Disposal of Dredged Material

The physical and chemical characteristics of dredged material can negatively affect the surrounding environment through heavy metal, petroleum hydrocarbon, and synthetic organic chemical contamination (Kennish 1997). The reason for this contamination is that navigational lanes represent areas with a high degree of exposure to industrial materials and activities, causing a high degree of chemical pollution. However, it has been noted that the industrially contaminated sediments only comprise 10 percent of the dredged material (Engler 1990). Environmental degradation can be created by "natural" or uncontaminated sediments due to high proportions of clay and organic material. The high proportion of clay often represents a change in sediment grain size at the disposal sight that can impact benthic organism populations. A high degree of organic material may also result in anoxic conditions that can be detrimental to benthic fauna development (Kester et al. 1983).

Effects of Dredged Material

The fate of the dredged material is important because sediments that are not retained at the disposal site can cause an increase in water column turbidity, burial of benthic organisms, and leachate contamination (Wright 1978). The increased turbidity can interfere with pelagic organism population dynamics and biogeochemical marine cycles. Disposed dredged material can also bury benthic organisms, which also contributes to the reduction of benthic organism populations and their diversity. Leachate contamination from the dredged material can take many forms depending upon the type of disposal site under consideration. In open water disposal sites, changes in redox potential and the pH of sediments over time may cause metals to be released in a solution above the disposal site (Kestler et al. 1983). For upland disposal sites, sediments with high sulfide content can lead, after several months of drying and oxidation, to acid conditions and metal leaching to overland flow and groundwater (Engler 1990).

Given the broad array of environmental degradation that can result from introducing dredged material to an environment, a wide variety of dredged disposal strategies have been developed to minimize the negative environmental impacts to coastal regions. These strategies can be divided into subaerial, upland disposal, and subaqueous, open-water disposal (Herbich 1981; Kennish 1997; Kester et al. 1983). Types of upland disposal include dike-weir systems for land application, landfill for shoreline modification, wetland application, and construction of artificial islands. Types of open-water disposal include seafloor mounds and subaqueous burrow pits (capped and noncapped). Successful implementation and management of these different disposal strategies relies upon proper assessment of the dredged material itself and the disposal site environment. This initial environmental assessment, as mandated by the MPRSA, the CWA, and the National Environmental Policy Act (NEPA), documents whether the proposed activity will create any significant environmental impacts (ELI 2002). If the assessment indicates no significant environmental impact is anticipated, a finding of no significant impact (FONSI) is prepared. If the assessment indicates that there may be some environmental impact, analysis is completed to prepare an environmental impact statement (EIS). The EIS or FONSI can contain an assessment of the expected impacts on existing environmental quality, water quality, critical habitat losses, environments adjacent to candidate sites, material cycles, migration and movement patterns, groundwater resources, cultural resources, and human uses (Holland et al. 1993). Once such an assessment has been completed, a permit for dredging can be issued through the USACE, and a balance between the positive and negative impacts of a project is achieved.

Problem: Open-Water Seafloor Mound Dredged Material Disposal

The most important environmental quality aspect of the dredging and dredged material disposal process is the development of an environmental assessment. This assessment indicates whether the potential for undue environmental degradation exists due to the dredging project and represents a coastal community's best tool for balancing the economic benefits against potential environmental degradation. Integrating climate data into these assessments would increase their robustness (Holliday 1978). Those participants in the October workshop associated with dredging activities are directly involved in seafloor mound dredge disposal site assessment. Open-water seafloor mound dredge disposal entails the dumping of dredge material, usually by a barge, onto the seafloor, forming mounds. Typically, the dumping occurs offshore in deeper water (30 to 200 m) where interference from shipping and fishing activities is negligible (Herbich 1981). The information provided by workshop sessions best reflects the application of climate data to this type of disposal site.

The general steps in completing an environmental assessment for a seafloor mound dredged material disposal are 1) determination of existing data available for site assessment, 2) establishment of monitoring programs to generate additional data required for site assessment, and 3) predictive analysis of all data for site assessment, which usually entails the use of a numeric model (Holliday, 1978). The types of data required for site assessment can be placed into three broad classes: biological information, physical and chemical information, and hydrodynamic information (Moore et al.1998). Climate data are classified as hydrodynamic information, which includes current velocity, current depth profiles, wave exposure, wind fetch, duration, and direction, seasonal salinity and temperature profiles, local tidal ranges, and storm probability and track (tropical and extra-tropical). Though many of these variables fall outside the realm of traditional climate data, as indicated at the beginning of this report, "climate" was defined by many coastal officials as a hybrid or integration of oceanographic and climate processes. The use of this information applies primarily to the fate of dredged materials at the disposal site. Through the climatic/oceanographic data, the dispersal of dredged materials to the surrounding water column and ocean floor after dumping can be determined. Based upon this dispersal assessment and the purpose of the disposal site, undue negative environmental impacts at the disposal site can be identified.

Further, the MPRSA requires the United States Environmental Protection Agency (U.S. EPA) and the USACE to manage and monitor an offshore disposal site once it has been established. These activities are governed by the site management and monitoring plan (SMMP) that outlines disposal site characteristics, management objectives, material volumes, material suitability, time of disposal, disposal technique, disposal location, permit and contract conditions, baseline monitoring, disposal monitoring, post-discharge monitoring, material tracking, and disposal effects monitoring (U.S. EPA and USACE 2000). The monitoring and management activities rely heavily upon surveys and studies that include climatic and oceanographic variables to indicate the potential movement and environmental degradation. As can be seen in Figure 3, the geographic range of dredge disposal sites in the southeastern United States creates the need for a variety of data from multiple locations to monitor the different coastal environments represented by each site.

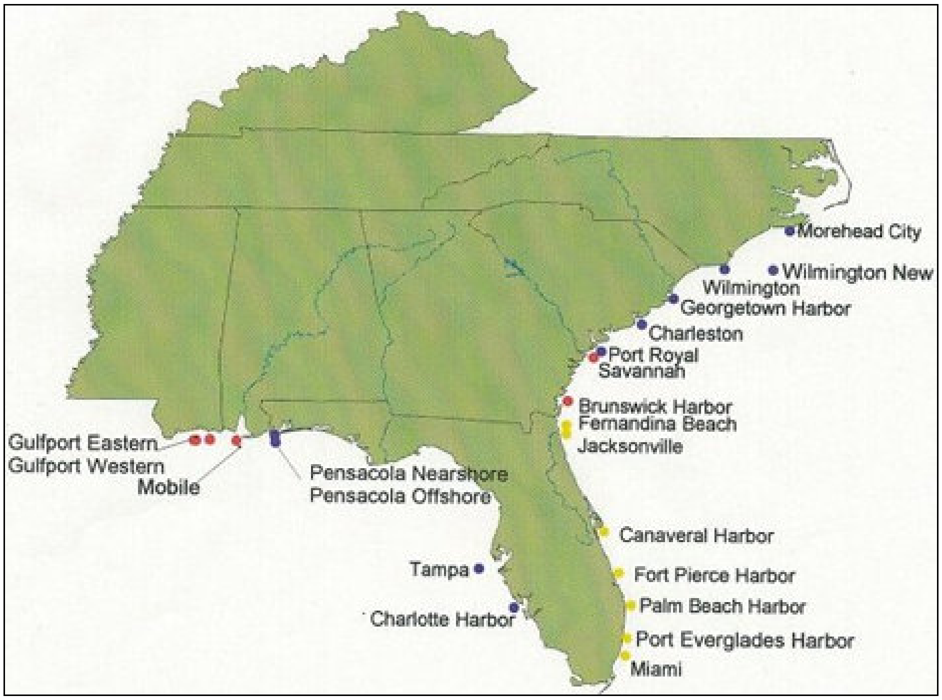

Figure 3 Location of open-water dredge disposal sites within U.S. Environmental Protection Agency, Region 4, coastal waters. Colored dots represent different project managers in U.S. EPA, Region 4, Oceans and Coastal Program (Source *www.epa.gov/region4/water/oceans/sitesmap.htm*)

Table 4 Summary descriptions of data needs, access information, relative costs, and weaknesses of open-water seafloor mound dredged material disposal. Relative costs: $$ > $ > Free

DATA OR PRODUCT	SOURCES	ACCESS	COST	WEAKNESS
Sea level trends	NOAA NOS CO-OPS	Internet	Free	Limited locations for which data are available
Wave climatology	Oceanweather Inc., NOAA NBDC C-MAN	Internet	Free, $$	Limited locations for which data is available; assumptions of gridding interpolation algorithms
Real-time waves, currents, water levels, and weather conditions from buoy or pier site	NOAA NDBC, Ocean Weather Inc., Buoyweather.com, Weather Underground, NCEP, FNMOC	Internet	Free, $$	Location of buoys away from study area; poor spatial resolution of buoy network
Seasonal and monthly climate forecasts	NOAA CPC	Internet	Free	Generalized spatial patterns; lower skill during some phases
Tropical storm forecasts	NOAA NHC	Internet, satellite	Free, third-party subscription	Short lead time of forecasts and users have low confidence in accuracy
Tides	NOAA NOS CO-OPS	Internet	Free	Limited locations for which data are available

Resources and Logistics

1) Data and analytical tools needed to produce the product
    - Ocean current location and velocity (1 m off ocean floor), recorded at a variety of time scales in order to assess the complete range of current conditions at the disposal site
    - Wave length, height, and duration near disposal site, recorded at a variety of time scales in order to assess the complete range of wave conditions at the disposal site
    - Diurnal or semidiurnal tide amplitude near disposal site, recorded at a variety of time scales in order to assess the complete range of tidal conditions at the disposal site Seasonal patterns in ocean current, wave, and tide data. In particular, winter values since this is the season of greatest wave activity
    - Numerical models to assess surface and subsurface dispersal of dredge materials. Currently, three models are commonly used for site assessment: the dump model, Disposal from Instantaneous Dump (DIFID), and the general transport models, LAEMSD and STUDH (Johnson and Schroeder 1993; McAnally and Adamec 1987). However, the development of user-friendly versions of such models that easily incorporate climate data would increase their use in site assessment

2) Source for the data and analytical tools and cost and suitability to core area

- NOAA
  - National Weather Service Local Forecast Offices, *www.nws.noaa.gov/organization.html*
  - National Hurricane Center, *www.nhc.noaa.gov/*
  - National Climatic Data Center, *www.ncdc.noaa.gov/oa/ncdc.html*
  - Climate Prediction Center, *www.cpc.ncep.noaa.gov/*
  - Regional climate centers, *www.nrcc.cornell.edu/other_rcc.html*
  - National Ocean Service, Center for Operational Oceanographic Products and Services, *www.co-ops.nos.noaa.gov/*
  - National Data Buoy Center, *http://seaboard.ndbc.noaa.gov/index.shtml*
  - NWS, NCEP Marine Modeling and Analysis Branch, *http://polar.wwb.noaa.gov/*
- Oceanweather, Incorporated, *www.oceanweather.com/data/index.html*
- Buoyweather.com, *www.buoyweather.com/*
- Weather Underground Marine Weather, *www.wunderground.com/MAR/AM/*
- United States Navy Fleet Numerical Meteorology and Oceanography Center, *www.fnmoc.navy.mil/*
- Free data. Participants indicated that access to free data and analytical tools is one of, if not the most, important motivating features in product selection. Therefore, the majority of data and analytical tools that they utilize are an amalgamation of low cost or free offerings

3) Present format of the data and analytical tools and any changes needed
   Almost all of the data currently available for assessment of dredge disposal sites are available in digital format through the Internet. This format is useful for rapid integration into available software for analysis

4) Accessibility of the data
   Weather and climate data for the assessment of dredge disposal sites are easily accessed. Forecast, near-real time, and historical data are provided over the Internet. The accessibility of the weather and climate data can be improved through the following means:
   - Revising Web sites for easy navigation and minimization of scientific and technical jargon
   - Personalizing Web sites and tools for specific uses (e.g., irrigation scheduling)
   - Providing multiple options for data and information output, such as tables, graphs, and maps

5) Gaps or weaknesses in current data, products, tools, or providers
   - Recommended improvements of forecast products
     - Development (near disposal sites) of offshore tidal prediction products
   - Recommended improvements for observational data
     - Deployment of nearshore directional wave gauges
     - More wave height data products derived from satellite images
     - Improved standardization between geographic locations, including electronic reporting formats and near-real time reporting

    - Additional real-time inshore data collection buoys that include wind and wave observations
- Recommended improvements in blended or derived products
    - Integration of surface and subsurface observations to create a water column product to assist in the prediction of dredged material dispersion from disposal site

6) Cultural, educational, and institutional obstacles

- Inadequate computer and technology literacy skills of end users
- Development of effective partnerships between organizations to manage and monitor resources, regulatory organizations, and end users
- Untested perceptions that applying weather or climate-based management strategies is more costly than other strategies

7) Training for coastal climatology end users

- Build education and outreach into product and systems development. Provide training modules for specific user groups (e.g., state fish and wildlife officers and local public health officials), and bring training resources to those groups
- Include funding for education and outreach with product development
- Collaborate with existing agencies to provide training (i.e., Sea Grant, Cooperative Extension, U.S. Environmental Protection Agency, United States Army Corps of Engineers)
- Ensure media involvement to provide advertising and publicity for coastal climatology products

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CORE AREA: COASTAL FISHERIES MANAGEMENT

Background

The economic benefits of commercial and recreational fishing total approximately $40 billion per year in the United States (NRC 1999). The economic contribution of specific fisheries varies annually due to the variation in species catch. The cause of such fluctuations in fish populations is a combination of economic and environmental factors. Economic factors can include relative price paid for fish and changes in fishing methods or fishing effort, while environmental factors can include ocean circulation, ocean temperature and salinity, ocean nutrient levels, and climatic variability. One example of the combination of economic and environmental factors upon fish stocks is the decline of the northern cod in the 1990s. The population of northern cod in the northeastern Atlantic Ocean declined due to over-fishing and severely cold temperatures that slowed growth rates and reduced size-at-age (Drinkwater 2002). One of the challenges to commercial fisheries managers is to separate the impacts of economic and environmental factors on fisheries population to create more effective management plans.

Over the last 30 years, a fair amount of research has investigated the links between climate and climatic variability and fish population dynamics and fisheries management (e.g., Cushing 1982; Dow 1977; Laevatsu 1993; McGinn 2002). Such work has demonstrated the variety of climate-fisheries linkages at multiple locations across the United States due to different combinations of shoreline configuration, ocean currents, and dominant synoptic weather systems. Case studies have been an important tool for determining linkages between climate and fisheries in the southeastern United States. Case studies linking climatic variability to species population dynamics and fisheries management have been completed for Alaska, New England, and Pacific fisheries, the largest and most economically valuable fisheries in the United States (McHugh 1984). Accordingly, a search on the Web-based Cambridge Scientific Abstracts for the 100 most recent (2002–2003) climate-fisheries related research articles provided no case studies of fisheries in the southeastern United States. Such a paucity of readily available research underscores the challenge of incorporating coastal climatology into fisheries management in the southeastern United States; information regarding climate and climate variability impacts upon fisheries within the region is difficult to find.

Problem: Integration of Climate-Fisheries Interaction Research into Fisheries Management

One of the difficulties in managing fisheries is the integration of environmental data into the decision-making process to allow for more efficient and sustainable management of fishery stocks (Jennings et al. 2001; NRC 1999). Although climate-fishery interactions have occurred, the results are "seldom put to practical use in planning and management" (Regier 1977, page 139). Despite recent advances in fisheries science, baseline information on environmental characteristics of fisheries communities has not been thoroughly described (Hart and Reynolds 2002). Thus, changes in these conditions due to climatic change or other factors may be difficult to ascribe. Anecdotally, one workshop participant commented that both climate and fisheries experts exist but rarely interact, suggesting that basic research of climate-fisheries interaction in the southeastern United States is insufficient but attainable.

Climate and Fisheries Research

Despite the perception of an absence of climate and fisheries research, a few studies illustrate the potential for such research. For example, Parker and Dixon (2002) completed a repeat survey (1990 and 1992) of reef fauna to assess its response to changes in water temperatures at 210 Rock, a sandstone and limestone ledge outcrop 44 km south of Beaufort Inlet, North Carolina. The study indicated that after 15 years of intense fishing, recreational and commercial fisheries were smaller and large changes occurred in relative abundance; specifically, species composition became more tropical (29 new tropical reef species were observed, 28 tropical species increased, and a tropical sponge previously unrecorded off the North Carolina coast became common). The species composition suggests warming of regional water temperatures that was supported by observed mean winter monthly water temperatures 1 to 6^{o} C warmer than previous measurements. The authors believe the increase in water temperatures at the study site could be linked to warmer water along the subtidal continental shelf off Beaufort, North Carolina.

Another example of research of climate-fisheries linkages in the southeastern United States is the research of environmental conditions associated with fish populations in the Charleston Bump, a complex bottom feature of great topographic relief located 130 to 1,900 km southeast of Charleston, South Carolina (Sedberry et al. 2001). This feature deflects the Gulf Stream offshore in the South Atlantic Bight, and establishes permanent and temporary eddies, gyres, and associated upwelling in the warm Gulf Stream flow. The thermal fronts associated with the deflection are believed to attract large pelagic fish and their prey. Statistical analysis indicates that in the area of the bump, sea surface temperatures influenced by the deflection have a role in determining recruitment success of at least one continental shelf reef fish, the gag grouper (*Mycertoperca microlepis*).

Such individual studies can be combined to provide an overview of the impact of climate change on the southeastern U.S. Mountain (2002) provides such a study that focuses upon the northern portion of the southeastern United States' coast, from Cape Hatteras to Chesapeake Bay. In the study, he predicts that climate change in the Mid-Atlantic Bight would increase the number of warm-water species, intensify seasonal stratification of water, change regional circulation, reduce reproductive success for cold-water species, increase the frequency of hypoxic conditions, and create an overall northward shift in stock distributions. Further, he states that the ability to predict major responses of fish communities to short-term climatic variability, sea level rise, and elevated sea temperatures will depend on scientific interpretation of information on the rate of environmental and climatic change, fish biotic and habitat parameters, fisheries exploitation rates, and a host of other factors.

Climate and Fisheries Dynamics

Given this need for understanding how climatic variability affects commercial fish populations, a coastal climatology product must address potential climate-fishery habitat interaction. Perhaps, the greatest potential for development of such a product, as indicated by the results of both the Parker and Dixon (2002) and Sedberry et al. (2001), is assessing the relationship between ocean currents (surface and subsurface), sea surface temperature (SST), and commercial fish species variability. SST data are now available through NOAA polar orbiting satellites, and additional climate variables, such as air temperature, precipitation, salinity, dissolved oxygen concentration, wind fields, and hurricane intensity and frequency can be combined with the satellite data to construct a coastal climatology fisheries management tool.

However, care must be taken in developing such products. Brill and Lutcavage (2001) found that average gridded surface conditions correlated with billfish and tuna catch statistics but did not truly evaluate the environmental conditions associated with population dynamics. Instead, these average surface conditions should be combined with depth distribution, travel speeds, forage abundance, and appropriate oceanographic data to offer a more accurate assessment of fishery population dynamics. Further, these variables need to be assessed at the appropriate scale (temporal and spatial) for the fish behavior in question. Examples of appropriate scaling include matching fish observations with simultaneous real-time oceanographic data, and recognizing that vertical temperature gradients are orders of magnitude steeper than horizontal gradients and will be more likely to influence movement than horizontal gradients.

The choice of appropriate scale also corresponds to management entities. Several organizations exist that regulate fisheries activities in coastal waters. For the southeastern United States, the Mid-Atlantic and South Atlantic Fisheries Management Councils (MAFMC and SAFMC) have jurisdiction within the federal 200-mile limit. State fishery agencies, such as the South Carolina Department of Natural Resources Office of Fisheries Management, have jurisdiction in state waters, and regional authorities, such as the Atlantic States Marine Fisheries Commission, work to coordinate management and conservation efforts across states. Thus, in order for effective fisheries management tool strategies to be developed in the southeastern United States, clear spatial boundaries of fish populations and associated environmental factors must be stated in order for identification of the appropriate management entity to incorporate findings into its activities.

Table 5 Summary descriptions of data needs, access information, relative costs, and weaknesses of integration of climate-fisheries interaction research into fisheries management. Relative costs: $$ > $ > Free

DATA OR PRODUCT	SOURCES	ACCESS	COST	WEAKNESS
Sea level trends	NOAA NOS CO-OPS	Internet	Free	Limited locations for which data is available
Wave climatology	Oceanweather, Inc.	Internet	Free, $$	Limited locations for which data are available, assumptions of gridding algorithms
Real-time waves, currents, water levels, and weather conditions from buoy or pier site	NOAA NDBC, Oceanweather, Inc., Buoyweather.com, Weather Underground, NCEP, FNMOC	Internet	Free, $$	Location of buoys away from study area; poor spatial resolution of buoy network
Seasonal and monthly climate forecasts	NOAA CPC	Internet	Free	Generalized spatial patterns; lower skill during some phases
Tropical storm forecasts	NOAA NHC	Internet, satellite	Free, third-party subscription	Short lead time of forecasts and users have low confidence in accuracy
Tides	NOAA NOS CO-OPS	Internet	Free	Limited locations for which data are available

Resources and Logistics

1) Specific data and analytical tools needed to produce the product
   - More research on climatic variability and fish populations in the southeastern United States. Limited research has been used to develop existing fisheries management tools and strategies. Specific case studies of commercially important species in the southeastern United States (such as white shrimp, blue crabs, and oysters) need to be made available to the appropriate management entity. The analysis within these studies needs to be scaled specifically to the fish species behavior and management organization jurisdiction
   - Long-term climatic variables that can be linked to fishery stock management. For instance, much research has linked SST temperature variation created by El Niño to

Pacific fish population dynamics. However, it has been noted in recent research that reliance upon average gridded surface variables can lead to inaccurate assessments of fish species population dynamics. Additional information, particularly oceanographic variables in the vertical dimension or water column, need to be incorporated into analyses. In particular, movement of subsurface ocean currents and the vertical temperature gradients established by these movements are important variables associated with fish movement and populations.

- Geographic information system (GIS) data. Workshop participants indicated that GIS software has some of the greatest potential for developing climate sensitive management tools and strategies. However, vertical variability of oceanographic variables needs to be integrated to traditional horizontal, or planar, GIS analysis.

2) Source for the data and analytical tools and cost and suitability to the core area
   - NOAA
     - National Climatic Data Center, *www.ncdc.noaa.gov/oa/ncdc.html*
     - C-MAN Buoy Data Archive, *http://seaboard.ndbc.noaa.gov/Maps/southeast_hist.shtml*
     - National Data Buoy Center, *http://seaboard.ndbc.noaa.gov/index.shtml*
     - Regional climate centers, *www.nrcc.cornell.edu/other_rcc.html*
     - National Ocean Service, Center for Operational Oceanographic Products and Services, *www.co-ops.nos.noaa.gov/*
     - National Weather Service Local Forecast Offices, *www.nws.noaa.gov/organization.html*
     - National Hurricane Center, *www.nhc.noaa.gov/*
     - NWS, NCEP Marine Modeling and Analysis Branch, *http://polar.wwb.noaa.gov/*
   - State climatology offices, *www.ncdc.noaa.gov/oa/climate/stateclimatologists.html*
   - Oceanweather, Incorporated, *www.oceanweather.com/data/index.html*
   - Buoyweather.com, *www.buoyweather.com/*
   - Weather Underground Marine Weather, *www.wunderground.com/MAR/AM/*
   - United States Navy Fleet Numerical Meteorological and Oceanographic Center, *www.fnmoc.navy.mil/*
   - Free data. Participants indicated that access to free data and analytical tools is one of, if not the most, important motivating features in product selection. Therefore, the majority of data and analytical tools that they utilize are an amalgamation of low cost or free offerings.

3) Present format of the data and analytical tools and changes needed
   The present format of data used by fisheries management is a digital format accessed through the Internet. Such formats include tab-delimited and comma-delimited files with an accompanying metadata text file that explains the structure and organization of data arrays. These delimited formats are very useful for integrating data into available software, particularly spreadsheets and GIS, for analysis. Workshop participants noted that

fisheries managers use a wide array of data types and formats and that readily available metadata is imperative for integrating different data sets. One suggestion was to develop a coastal climatology metadata dictionary so that any person working with coastal climatology data can refer to it to understand data limitations, appropriateness, and structure. Such comments indicate that efforts to develop universal standardized data formats have not been successful with the fisheries management community.

4) Accessibility of the data
   Fisheries managers access data and analytical tools through the Internet. However, suggestions to improve this accessibility by fisheries managers include
   - Streamlining Internet data access by user group categorization
   - Utilizing satellite technology to deliver data to anglers on the water since their boats are frequently out of cell phone and weather radio range
   - Increasing the flexibility of delivery systems to allow for both real-time and historical data within the same framework

5) Gaps or weaknesses in current data products, tools, and producers
   - Absence of a continental shelf current model
   - More observation station reporting of real-time wind and wave data
   - Nearshore/estuarine water quality data (i.e., coastal river discharge including information on how river flow impacts coastal water salinity, temperature, and suspended sediments; dissolved oxygen level; harmful algal bloom incidence).
   - Water column observations, specifically water temperature and current speed and direction

6) Cultural, educational, and institutional obstacles
   - Scarcity of long-term funding that guarantees continued improvement and sustainability of a coastal climatology product
   - Absence of 180-degree feedback mechanisms that allow end users to provide suggestions for the improvement of coastal climatology products
   - Absence of technology transfer from product developer to end user.
   - Limited awareness of opportunities to access and use coastal climatology products

7) Training for coastal climatology end users
   - Provide broader education efforts that include legislators as well as product developers, researchers, and managers
   - Integrate coastal climatology product training into current National Marine Educators Association, Coast Guard Marine Safety Officer, aquarium outreach, and Sea Grant Extension Program activities
   - Better advertise training activities
   - Develop and post coastal climatology products on the Web along with case studies or event studies that describe the previous use of specific products for fisheries management decisions

Core Area: Coastal Natural Hazard Mitigation

Background

Numerous natural hazards including coastal storms, hurricanes, tropical cyclones, northeasters, and winter storms regularly threaten the southeastern United States. Severe meteorological and marine events often produce damages to property and loss of life from high winds, storm surge, flooding, and shoreline erosion. While the impact of hazardous events can be devastating to any physical environment, coastal ecosystems are particularly vulnerable to extreme changes or permanent alteration. Beyond concerns of ecosystem health and public safety, there are compelling economic reasons to develop a better understanding of hazard impacts on coastal communities. The coastline supports an estimated one out of every six jobs in the United States and one-third of the gross domestic product (NOAA 1998, NRC 1997). To mitigate or protect these assets from hazardous events, coastal managers need improved access to scientific information as it pertains to coastal vulnerability. Developing a better understanding of information on severe meteorological and marine events and documenting their impacts will provide a rational and objective basis for making substantial coastal resource management and planning decisions. This informational foundation is essential to help federal, state, and local programs identify and prioritize the most appropriate and cost-effective coastal hazard mitigation strategies.

Problem: Hazard Mitigation through Beach Nourishment

Weather, climate, and marine information are essential for natural hazard mitigation, preparedness, forecasting, and real-time response. Workshop participants described the integration of this information within decision-making frameworks for several natural hazard scenarios. Coastal decision makers are faced with digesting atmospheric and marine information regarding a potential hazardous storm and interfacing it with infrastructure vulnerabilities to determine a course of action, such as population evacuation and securing and closing industrial operations such as harbor facilities, nonpersonal automobile transportation, power stations, and manufacturing facilities. The question of hazard mitigation is less time-critical but equally complex in reducing uncertainty for planning strategies. Beach nourishment, or the replacement of sand on eroding beaches, is a means of hazard mitigation and improving beach quality and the value of property near the beach. As this report demonstrates, weather, climate, and marine information can be very useful for hazard mitigation through beach nourishment.

Natural shorelines in the southeastern United States often exhibit some form of beach structure, with shallow nearshore bathymetry, a foreshore or beach face, and a backshore (Davis and Fitzgerald 2003). Some beach environments are composed of dunes or built structures on the landward edge. Beaches can be categorized as either dissipative or reflective. Dissipative beaches have a gentle slope between the nearshore and the backshore. This slope allows for the gradual absorption of wave energy. Reflective beaches have steep faces that absorb much of the wave energy. Dissipative beaches also typically accrete, or gain, sand, while reflective beaches typically lose sand or erode.

Beach Nourishment

There are many ways to rebuild a beach and many reasons for doing so. One reason is that nourishment can provide mitigation from coastal storms, although protection from strong hurricanes (Category 3 or greater) may be limited. Hard shoreline stabilization structures, such as groins, jetties, seawalls, and bulkheads, provide limited protection of coastal properties from strong hurricanes. These structures either directly absorb or divert wave energy to nearby locations along the coastline. They typically interrupt the natural flow of sand along coastlines by reducing or increasing the amount of suspended sand particles or by altering the current's direction and speed, which in turn alters the locations of scouring and deposition. Hard stabilizers rarely provide long-term solutions to hazard mitigation and coastal erosion (Howard et al. 1985).

To stabilize or rebuild a beach, compatible sand is dredged and pumped from offshore sand bars or hauled over land by trucks and spread along the shore to create a dissipative surface. Beach nourishment is an anthropogenic component to beach dynamics. As nourished beaches erode under natural wave action, offshore sand bars may grow. This offshore bar may in turn cause waves to break further off shore and consequently slow the natural process of beach erosion. The replenishment material needs to have a texture similar to the existing material, but not so fine that it is rapidly eroded or so coarse from shell fragments that it limits the use of the beach for recreation. Coastal storms, however, may destroy a nourishment project well before its expected lifetime.

Beach Nourishment Planning

After identification of locations in need of beach nourishment, planning activities include assessments of environmental and biological impacts as well as economic feasibility (NRC 1995). Economic assessments should consider the periodic maintenance from normal wave action and coarseness of fill material as well as maintenance from severe storms that may cause catastrophic scouring (Howard et al. 1985). A well-designed environmental monitoring program that includes weather and marine observations or modeling is an important part of planning for beach nourishment and is essential to determining its success. Physical monitoring should continue beyond the construction phase and into performance evaluation and operational phases. Continuous monitoring would allow for the definition of baseline or expected conditions as well as annual or seasonal departures.

While considering the economic feasibilities and structural aspects of a project, marine and atmospheric climatology – historical information – may provide an approximation of beach nourishment performance (NRC 1995). Historical information may include sea level trends, astronomical tides, wave and current climatology, and severe storm climatology. This information would describe the expected trends in physical processes that control the creation or destruction of beaches. Near-real time physical monitoring should include measurement of waves, currents, water levels, and weather conditions near the nourishment site. The processes of beach erosion or accretion are primarily controlled by waves and water level. Wind is a dominant physical process on the back beach or dune area where it has a role in beach erosion. As waves break against the beach or underlying surface, sediment is disturbed and suspended in the water column. Currents may then transport suspended sediment.

Table 6 Summary descriptions of data needs, access information, relative costs, and weaknesses of hazard mitigation through beach nourishment. Relative costs: $$ > $ > Free

DATA OR PRODUCT	SOURCES	ACCESS	COST	WEAKNESS
Sea level trends	NOAA NOS CO-OPS	Internet	Free	Limited locations for which data are available
Wave climatology	Oceanweather, Inc.	Internet	Free, $$	Limited locations for which data are available; assumptions of gridding interpolation algorithms
Real-time waves, currents, water levels, and weather conditions from buoy or pier site	NOAA NDBC, Oceanweather, Inc., Buoyweather.com, Weather Underground, NCEP, FNMOC	Internet	Free, $$	Location of buoys away from study area; poor spatial resolution of buoy network
Tropical storm forecasts	NOAA NHC	Internet, satellite	Free, third-party subscription	Short lead time of forecasts and users have low confidence in accuracy
Tides	NOAA NOS CO-OPS	Internet	Free	Limited locations for which data are available

Resources and Logistics

1) Data and analytical tools needed to produce the product
    - Weather
        - Wind direction and speed to assess hazardous material release and exposure
        - Tropical storm and hurricane wind speed forecasts and other text products (e.g., warnings, watches, strike probabilities, etc.). Present conditions of a tropical storm and forecast changes in its location, size, and intensity
        - Tornado and severe thunderstorm warnings
        - ALOHA, HUREVAC, and HURTRAC software
    - Climate
        - Frequency of natural hazard events, such as climatology of hurricanes
        - Hindcast wind and wave data – numerical simulation of past wind and wave conditions.
        - Multiyear time series of wind speed and direction and wave parameters at 1-hour intervals of wave height, period, and direction. Time series are available for a densely spaced series of nearshore points along the U.S. coastline (in water depths of 15 to 20 m) and a less-dense series of points in deep water (water depths of 100 m or more)
    - Impacts
        - Flood inundation models

  - Storm surge model (e.g., NWS model called SLOSH that maps the local storm surge flooding for various levels of tropical storm intensity and tracks the storm to the coastline)

2) Sources for the data and analytical tools and cost and suitability to core area
   - NOAA
     - National Data Buoy Center, *http://seaboard.ndbc.noaa.gov/index.shtml*
     - National Hurricane Center: "Special priority is placed on identifying the sections of coastline expected to be influenced by landfall of the hurricane, the wind and tide to be experienced during passage of the hurricane, and the timing of such conditions" (NRC 1989), *www.nhc.noaa.gov/*
     - National Weather Service Local Forecast Office, *www.nhc.noaa.gov/*
     - National Climatic Data Center, *www.ncdc.noaa.gov/oa/ncdc.html*
     - Regional climate centers, *www.nrcc.cornell.edu/other_rcc.html*
     - National Ocean Service, Center for Operational Oceanographic Products and Services, *www.co-ops.nos.noaa.gov/*
     - NWS, NCEP Marine Modeling and Analysis Branch, *http://polar.wwb.noaa.gov/*
   - U.S. Army Corps of Engineers, *www.usace.army.mil/*
   - United States Navy Fleet Numerical Meteorological and Oceanographic Center, *www.fnmoc.navy.mil/*
   - State climatology offices, *www.ncdc.noaa.gov/oa/climate/stateclimatologists.html*
   - Oceanweather, Incorporated, *www.oceanweather.com/data/index.html*
   - Buoyweather.com, *www.buoyweather.com/*
   - Weather Underground Marine Weather, *www.wunderground.com/MAR/AM/*
   - Free data. Participants indicated that access to free data and analytical tools is one of, if not the most, important motivating features in product selection. Therefore, the majority of data and analytical tools that they utilize are an amalgamation of low cost or free offerings.

3) Present format of the data and analytical tools and any changes needed
   Almost all of the data currently available for mitigation of natural hazards are available through the Internet in digital format, allowing rapid integration into available software for analysis. It was noted by end users that a wide array of data types and formats are used and that readily available metadata is imperative to integrating the different databases. In addition, the natural hazard managers identified the following data format issues:
   - Digital weather and climate data downloaded over the Web need geospatial reference for the creation of maps
   - The National Data Buoy Center should provide summary sheets for wave data so that end users can determine if breaks in data collection have occurred

4) Accessibility of the data

Climate, weather, and marine data are easily accessed by natural hazard managers. Data provided over the Internet is preferred over other formats. However, the accessibility of the weather and climate data can be improved through the following means:

- Formatting scientific Web sites to be easily understood by end users
- Using the ideal format for access to coastal climatology products, which participants described as "a dynamic, Web-based system accessed by a variety of users to build and manage their customized products and solutions."

5) Gaps or weaknesses in current data, products, tools, or providers
    - Observations
        - Expansion and enhancement of C-MAN buoy system with archived information for use by structural engineers
        - More inshore observations of waves, wind, and sea breeze with investment in directional wave gauges
        - Wind data at 10 meters above the ground during storm events for use in building design and engineering
    - Forecasts
        - Forecast of ocean conditions during storms for shipping concerns
        - El Niño/La Niña or seasonal forecast product combined with nearshore beach erosion models to predict erosion by event and by area on a subcounty basis
    - Models/Climatology
        - Modeling severe storm potential. Observational data on severe storm climatology may be inadequate at capturing variability and extremes for newly developed areas. Modeling may help approximate expected ranges of storm impacts, including erosion, in under-sampled areas
        - Event-based data and tornado information with spatial path and impact data mapping

6) Cultural, educational, and institutional obstacles
    - Lack of consensus in the scientific community in the interpretation of results and utility of a product, especially for costly beach renourishment products. Ultimate use of products may be overshadowed by the return on investment for high-value coastal properties
    - Potential computer and technology skills limitations of end users
    - Development of effective partnerships between organizations to manage and monitor resources, regulatory organizations, and end users; potential confusion about government services versus private sector services; questions on competing or redundant agency missions, policies, and institutions

7) Training for coastal climatology end users
    - Provide training modules for specific user groups. Training for nonpoint source pollution, for example, might include the use of irrigation schedules for water consumption and optimal conditions for pesticide applications. Training levels should be geared to a user group's level of knowledge and complexity of integration. For most local areas, storm tide simulations should be

performed to support planning studies for decision making (NRC 1989)

- Provide funding for K-12 education components for students and teachers and collaborate outreach with existing agencies to provide training (i.e., Sea Grant, Cooperative Extension, FEMA)
- Ensure media involvement to provide advertising and publicity for coastal climatology products

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CORE AREA: RECREATION AND TOURISM

Background

Climate, weather, and outdoor recreation are connected in many diverse ways. Though the existing landscape determines which outdoor activities take place (e.g., boating needs water and rock climbing requires cliffs), weather and climate determine when outdoor activities take place and affect vacationers' decisions about holiday destinations. Unexpected weather – heavy rain – can ruin a holiday, while unexpected climate – rainy summers – can have significant impacts on holiday-season economies. In addition, weather and climate are an important factor in both the financial success of tourism operators and the personal experiences of tourists (Table 7). Use of climate information in recreation and tourism ranges from locating recreational facilities or determining the length of the recreation season during which a facility will operate, to planning future activities involving personal decisions of when and where to go for a holiday (de Freitas 2001). Depending on the weather sensitivity of the recreational activity, climatic information can aid in planning, scheduling, and promoting alternative indoor entertainment (Perry 1997, de Freitas 2001). Climate information can also be used in publicity campaigns to label expectations of climate at certain locations (Perry 1997).

WEATHER OR CLIMATE PARAMETER	SIGNIFICANCE	IMPACT
Aesthetic: [1]Sunshine/cloudiness/visibility [2]Day length	[1]Overall quality of experience [2]Convenience	[1]Satisfaction, enjoyment, and attractiveness of destination [2]Hours of daylight available for chosen activity
Physical: [1]Wind [2]Rain	[1]Annoyance [2]Annoyance, charm	[1]Blown belongings, sand, and dust [2]Wetting, reduced visibility and

		enjoyment
[3]Snow	[3]Possibility of winter sports	[3]Participation in winter sports
[4]Ice	[4]Danger	[4]Tumbles, personal injury, damage to property
[5]Severe weather	[5]Annoyance, danger	[5]All of above
[6]Air quality	[6]Annoyance, danger	[6]Health, physical well-being, allergies
[7]Ultraviolet radiation	[7]Danger, attraction	[7]Health, suntan, sunburn
Thermal: [1]Integrated effects of air temperature, wind, solar radiation, humidity, longwave radiation, and metabolic rate	[1]Thermal comfort, therapy, restoration	[1]Environmental stress, physiological strain, hypo- and hyperthermia, and potential for recuperation

Table 7 Weather and climate parameters, their potential significance, and their impacts on recreation and tourism (adapted from de Freitas 1990 and 2001)

Problem: Coastal Water Sports

One sector of tourism in the coastal southeastern United States that is particularly sensitive to climate and weather conditions is coastal water sports and recreation. Such tourism services include charter boat fishing, sailboat and sea kayak rental, and parasailing. For example, a sea kayaker must assess air and water temperature, wind speed and direction, and ebb and flow tides to plan a successful and enjoyable trip (Bannon and Giffen 1997). Surfing is a coastal water sport that has become increasingly popular, particularly on the eastern coast of the United States. From New York to Florida, beach rental shops provide a wide variety of wake boards, boogie boards, and surfboards to customers in addition to surfing lessons. Recently, this increased enthusiasm for surfing has manifested itself in the form of surf camps (Civelli 2003). Surf camps provide residents and vacationers with surfing lessons for a series of days and are modeled after recreational summer day camps. Such camps are particularly popular with families since children are provided with structured daily activities for an entire vacation. In order for such surf-related commerce to be successful, the managers of the camps must understand the links between weather, climate, and wave conditions in order to manage seasonal budgets, hire staff, and plan and supervise daily surfing activities. The climate, weather, and oceanographic features required to properly assess seasonal and daily surf conditions include ground swell, wind direction, tide schedule, local bathymetry, and location of man-made structures such as jetties (Unger 2003). For example, surfers at Wrightsville Beach in North Carolina can use moored C-MAN buoy observations along the southeastern United States coast (from Cape Canaveral, Florida to Frying Pan Shoals, North Carolina) and available wave forecast models to predict, through their own experiences, wave and swell conditions in Onslow Bay and Wrightsville Beach. Simply put, these surfers are tracking the propagation of waves along the East Coast and attempting to interpolate data from buoys to their specific locations. This reliance upon personal experience to forecast wave conditions makes people vacationing in the area, new to the water sport, or with little training in climatology and oceanography unable to accurately predict surf conditions. A coastal climatology useful for costal water sport enthusiasts must be able to perform the tasks experienced surfers or participants complete on their own – predict waves as they propagate along the southeastern coast and predict the conditions for specific open bay shorelines.

Table 8 Summary descriptions of data needs, access information, relative costs, and weaknesses of coastal water sports. Relative costs: $$ > $ > Free

DATA OR PRODUCT	SOURCES	ACCESS	COST	WEAKNESS
Sea level trends	NOAA NOS CO-OPS	Internet	Free	Limited locations for which data are available
Wave climatology	Oceanweather, Inc.	Internet	Free, $$	Limited locations for which data are available; assumptions of gridding interpolation algorithms
Real-time waves, currents, water levels, and weather conditions from buoy or pier site	NOAA NDBC, Oceanweather, Inc., Buoyweather.com, Weather Underground, Surfline, NCEP, FNMOC	Internet	Free, $$	Location of buoys away from study area; poor spatial resolution of buoy network
Seasonal and monthly climate forecasts	NOAA CPC	Internet	Free	Generalized spatial patterns; lower skill during some phases
Tropical storm forecasts	NOAA NHC	Internet, satellite	Free, third-party subscription	Short lead time of forecasts and users have low confidence in accuracy
Tides	NOAA NOS CO-OPS	Internet	Free	Limited locations for which data are available

Resources and Logistics

1) Data and analytical tools needed to produce the product
    - Local historical and real-time tide conditions
    - Local historical and real-time wind speed and direction observations at 5- to 15-minute intervals
    - Swell conditions 100 miles out from shore; either satellite or buoy observations
    - Current wave conditions and forecasts at 15-minute intervals (height, speed, location, and time)
    - Local historical and real-time water temperature
    - Local rip tide observations and predictions

2) Sources for the data and analytical tools and cost and suitability to core area
    - NOAA

- National Data Buoy Center, *http://seaboard.ndbc.noaa.gov/index.shtml*
- C-MAN Buoy Data Archive, *http://seaboard.ndbc.noaa.gov/Maps/southeast_hist.shtml*
- National Hurricane Center, *www.nhc.noaa.gov/*
- National Weather Service Local Forecast Office, *www.nhc.noaa.gov/*
- National Climatic Data Center, *www.ncdc.noaa.gov/oa/ncdc.html*
- National Ocean Service, Center for Operational Oceanographic Products and Services, *www.co-ops.nos.noaa.gov/*
- NWS, NCEP Marine Modeling and Analysis Branch, *http://polar.wwb.noaa.gov/*

- United States Navy Fleet Numerical Meteorological and Oceanographic Center, *www.fnmoc.navy.mil/*
- Surfline, *http://surfline.com/home/index.cfm*
- Oceanweather, Incorporated, *www.oceanweather.com/data/index.html*
- Buoyweather.com, *www.buoyweather.com/*
- Weather Underground Marine Weather, *www.wunderground.com/MAR/AM/*
- Free data. Participants indicated that access to free data and analytical tools is one of, if not the most, important motivating features in product selection. Therefore, the majority of data and analytical tools that they utilize are an amalgamation of low cost or free offerings.

3) Present format of the data and analytical tool and changes needed

The format of the data and analytical tools is a digital format accessed through the Internet. It should be noted that the objective of recreation managers is less research and analysis than assessment of conditions. Thus, Web delivery systems should be designed to convey landscape conditions as opposed to data for analysis.

4) Accessibility of data
   - Scientific Web sites are not easily understood by recreation managers
   - All data and products should be personalized to the end user. Web sites should have options for graphics, text, model analyses, etc.
   - Web pages should include more visualization tools
   - Delivery systems should be expanded to include cell phone voice messaging, text messaging, or e-mail delivery systems

5) Gaps or weaknesses in current data, products, tools, or providers
   - More inshore data (waves, wind, and sea breeze data) are required, including accurate wave forecasts developed from directional wave gauges. The current scale of observation does not correspond with the scale of decision making.
   - Current moored buoys, especially in the Carolinas, exist over shoals (i.e. Frying Pan Shoals and Diamond Shoals) and do not represent surf conditions in open bays, such as Onslow Bay. The result is that surfers and other water sport enthusiasts must interpret data provided by shallow water sites and hypothesize the wave conditions in an open bay environment
   - End users with limited knowledge of meteorology and oceanography need

user-friendly models that include more visualization tools and surf cameras

6) Cultural, educational, and institutional obstacles
   - There is competition between private and public sectors for providing data and products. Such competition can cause confusion about the quality of a data set as people are often suspect of private data sets. In addition, the competition can cause a redundancy in data collection, resulting in fewer funds available for monitoring different coastal climatology parameters
   - Since the government has a responsibility to such a large variety of end users, there is an inherent inability to customize coastal climatology products to specific end user groups
   - There is a lack of onshore observation locations along the southeastern United States coast
   - Data sets need to be merged for a complete list of coastal climatology observations. In particular, rarely are terrestrial and inshore marine observations available within the same data set.
   - Different quality assurance and control standards among entities collecting data cause different levels of confidence in the data

7) Training for coastal climatology end users
   Conference participants recognized that effective coastal climatology products for recreation will require significant training of end users in fundamental oceanography and meteorology concepts, more so than any other core area, due to the absence of formal training of managers and end users on the subject

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CORE AREA: COASTAL TRANSPORTATION

Background

Coastal transportation encompasses a large variety of activities, including car and truck traffic on coastal roads, private and commercial air traffic from coastal airports, and pleasure and commercial boating on the Intracoastal Waterway and inshore waters. Climate influences long-range planning for coastal transportation while weather affects all of these transportation activities and decision-making processes, particularly those concerning safety. Fog, heavy rain events, flooding, small craft advisories, and gale warnings require accurate prediction in order to avoid accidents, injuries, deaths, and increased travel times. Landreneau (2001) found that Florida, North Carolina, and South Carolina rank first through third over the past 100 years in Atlantic coast hurricane strikes. Over that time, 17 percent of tropical cyclones passed within 300 miles of the Carolinas. Although damage associated with category 3,4, and 5 hurricanes is typically due to winds, in the Carolinas categories 2 and 3 hurricanes have been the most damaging because of flooding across the broad, flat coastal plain (*www.carocoops.org*). the flooding caused by tropical systems (storms, depressions, and hurricanes) has a huge effect on coastal transportation, particularly in the form of hurricane evacuations of coastal communities. Hurricane evacuations involve decisions regarding the time and route of the evacuation of coastal residences due to hurricane landfall in order to ensure safety from wind and flooding damage. A coastal climatology for the area could provide the weather and climage history of the area to help emergency planners make these decisions in a timely manner and with more confidence.

Problem: Hurricane Evacuation Planning and Implementation

The goal of hurricane evacuation planners is to reduce economic and human-life losses by preventing injurious effects of a storm, as opposed to attempting to stop the hazard itself (Burton et al. 1993). The key to successfully meeting this goal is determining an appropriate evacuation time. Evacuation time is defined as the amount of time before the hurricane eye makes landfall that allows threatened residents to move to safety (Godschalk et al. 1993). Evacuation time is composed of both clearance time and prelandfall hazards time. Clearance time represents the time required by residents to mobilize and travel to safety, including queuing delay time (USACE 1993). Prelandfall time represents the time before landfall in which evacuation routes become hazardous and unsafe due to gale force winds and flooding (Godschalk et al. 1993).

In order to effectively plan for evacuation time, hazard managers must first know the position of hurricane landfall. Planners are then able to estimate areas of high winds, heavy rain, and potential flooding or areas for evacuees to avoid. A coastal climatology can serve most importantly as a preparatory tool for transportation planners and managers. Specifically, a detailed coastal climatology of hurricane landfall can allow transportation officials to target areas that have experienced evacuation difficulties in the past and determine how to avoid such difficulties in the future. Such assessment of difficulties can include areas that have experienced high wind damage (e.g., downed trees and traffic signs), flooding of roadways, and hydroplaning due to heavy rainfall.

Coastal climatology workshop participants identified hurricane evacuation as an activity with significant economic impact. One workshop participant estimated that hurricane evacuation in the State of Georgia costs approximately $1 million per mile. Therefore, even in a state with a short coastline, such as Georgia, a hurricane evacuation can cost approximately $90 to 100 million, underscoring the importance of planning for an efficient, timely evacuation.

In addition, accurate evacuation times are imperative for hazard managers because residents must perceive the evacuation orders as trustworthy. If hazard managers create a series of inaccurate evacuation orders, coastal residents may develop a mistrust of the order and not evacuate at the appropriate time. Such a relationship between coastal community officials and residents has been labeled a "crying wolf syndrome" (Godschalk et al. 1993). For example, phone interviews of coastal North Carolina residents indicated that 30 percent of interviewees would not evacuate once given the order from local officials due to previous erroneous evacuation times.

Table 9 Summary descriptions of data needs, access information, relative costs, and weaknesses of evacuation planning and implementation

DATA OR PRODUCT	SOURCES	ACCESS	COST	WEAKNESS
Precipitation and stream flow climatology	NOAA NCDC, USGS	Internet, CD-ROM	$	Limited spatial coverage of gauged watersheds and bias towards large watersheds

Real-time stream flow	USGS, NOAA NWS	Internet	Free	Limited spatial coverage of gauged watersheds and bias towards large watersheds
Weather forecasts to 10 days	NOAA NWS	Internet	Free, third-party subscription	End user time-intensive
Seasonal and monthly climate forecasts	NOAA CPC	Internet	Free	Generalized spatial patterns; lower skill during some phases
Hourly precipitation radar	Real-time NOAA NWS	Internet, satellite	Free, third-party subscription	Data-intensive and difficult to format for common software (GIS)
	Archive NOAA NCDC	Internet	$$	Data-intensive and difficult to format for common software (GIS)

Resources and Logistics

1) Data and analytical tools needed to produce the product
   - Historic and current rainfall data along major coastal transportation and evacuation routes to predict flood areas
   - Historic and current flood forecasts along major coastal transportation and evacuation routes (such models not only include hydroclimatic data, but also integrate topography, soils, and land use in drainage basins)
   - Historic and current wind speed along major transportation and evacuation routes to assess areas prone to wind damage
   - HUREVAC and HURTRAC software
   - Hurricane track and intensity forecasts to predict location of hurricane landfall and high-wind areas
   - Storm surge models to assess coastal flooding, dune failure, and road failure

2) Sources for the data and analytical tools and cost and suitability to core area
   - NOAA
     - National Climatic Data Center, *www.ncdc.noaa.gov/oa/ncdc.html*
     - Regional climate centers, *www.nrcc.cornell.edu/other_rcc.html*
     - National Weather Service Local Forecast Offices, *www.nws.noaa.gov/*
     - National Hurricane Center, *www.nhc.noaa.gov/*
     - Climate Prediction Center, *www.cpc.ncep.noaa.gov/*
   - United States Geologic Survey, Water Resources Division, *http://water.usgs.gov/*
   - State climatology offices, *www.ncdc.noaa.gov/oa/climate/stateclimatologists.html*
   - Free data. Participants indicated that access to free data and analytical tools is one of the most important motivating features in product selection. Therefore, the majority of data and analytical tools that they

utilize are an amalgamation of low cost and free offerings.

3) Present format of the data and analytical tool and any change needed
   The dominant format of the data and analytical tools is a digital format accessed through the Internet. This format is very useful for integrating data into available software for analysis. However, personalizing data to the end user will improve its accessibility. Such a personalization could include a wide array of graphic formats, text format, and model analyses from which the user can choose

4) Accessibility of data
   Although hurricane evacuation managers access data and analytical tools through the Internet, diminishing the scientific and technical jargon that causes barriers for end users would improve the ability to use the data. In addition, since NOAA transmits many of the severe weather warnings via weather radio, efforts should be directed to improving the efficacy of these announcements by educating the public on how to access and understand evacuation orders or making the announcements easier for the public to understand

5) Gaps or weaknesses in current data, products, tools, or providers
   - An absence of subcounty hurricane wind data
   - Better explanation of the levels of confidence in track probabilities in hurricane track forecasts. Specifically, demonstrate to coastal emergency managers how they can use South Atlantic basin-scale track forecasts to confidently make county and subcounty emergency management decisions
   - Not enough inshore data (waves, wind) at the scale at which emergency management decision are made, particularly directional wave gauges. A review of current NOAA-supported moored buoys indicates that communities located between major metropolitan areas and associated moored buoys in the Southeast (Virginia Beach, Virginia, Cape Hatteras and Wilmington, North Carolina, Charleston, South Carolina, Savannah, Georgia, and Jacksonville, Cape Canaveral, and Tampa, Florida) are faced with the challenge of extrapolating buoy information to their own locations. Such interpretation may be beyond the technical resources of small coastal communities
   - A product that integrates historic and real-time data by sub-basin to assist with river flow forecast
   - Low spatial density of rain gauges along transportation routes

6) Cultural, educational, and institutional obstacles
   - There is competition between the private and public sectors to provide data. Such competition can cause confusion about the quality of a data set as people are often suspect of private data sets. In addition, the competition can cause a redundancy in data collection, resulting in fewer funds available for monitoring different coastal climatology parameters
   - Since the government has a responsibility to such a large variety of end users, there is an inherent inability to customize coastal climatology products to specific end user groups.

- An overall lack of onshore observation locations exists along the southeastern United States coast
- Data sets need to be merged for a complete list of coastal climatology observations. In particular, rarely are terrestrial and inshore marine observations available within the same data set.
- Different quality assurance and control standards between entities collecting data can cause different levels of confidence in data
- Governmental funding for the development of coastal climatology products is insufficient

7) Training for coastal climatology end users
   - Technical training for decision makers in addition to technical or scientific support staff
   - Communication training for planners and engineers regarding effective communication techniques with commissioners and managers
   - Training on how to integrate visualization tools with coastal climatology products

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CORE AREA: COASTAL WATER QUALITY AND CONSUMPTION

Background

Precipitation patterns impact stream flow, reservoir storage, and groundwater levels that may curtail water consumption. Increased temperature can increase evaporation losses, which results in increased customer demand for water for activities such as landscaping or agricultural irrigation. Reduced precipitation can compound water consumption stresses. We have found that a great deal of the information that water resource managers seek can be found in historical climate records and their associated probabilities. For example, drought and extreme precipitation probabilities are composed of information from an historical instrumental record and seasonal forecasts. Understanding how the El Niño–Southern Oscillation (ENSO) alters seasonal changes in precipitation and temperature is particularly important for water quality issues (Winstanley and Changnon 1999, Tufford et al. 1998). In regions influenced by a strong ENSO signal, significant and somewhat predictable seasonal variation in water quality can result. Such variation has been documented in coastal margins where changes in freshwater inputs affect estuarine salinity and biological communities (Lipp et al. 2001, Schmidt et al. 2002).

Of particular importance to water quality in coastal environments is the existence of nonpoint source pollutants. Nonpoint source pollution is a process of aggregating small quantities of natural and anthropogenic material from across large areas and depositing them in concentrated forms in other locations. In the southeastern United States, precipitation or irrigation runoff is the vehicle for aggregating nonpoint source pollution, and water resources such as rivers, lakes, and coastal areas are the deposition zones. The U.S. Environmental Protection Agency (1994) summarized nonpoint source pollutants as

- Excess fertilizers, herbicides, and insecticides, and fertilizers and manure containing phosphorus, nitrogen, and potassium used to enhance production of agricultural crops. Pesticides, herbicides, and fungicides are used to kill pests and control the growth of weeds and fungus on agricultural lands and residential areas.

- Sediment from improperly managed construction sites, crop and forestlands, and eroding streambanks. Pollutants such as phosphorus, pathogens, and heavy metals may attach to soil particles and concentrate in the water bodies with the sediment.
- Salt deposited from poorly managed irrigation systems.
- Oil, grease, and toxic chemicals contained in commercial and residential runoff.
- Bacteria and nutrients leached or over-washed from livestock systems.

Problem: Reducing Nonpoint Source Pollution

Unnecessary or excessive application of fertilizers or pesticides can contaminate water through runoff, wind transport, and atmospheric deposition. Precipitation patterns affect agricultural runoff, which is often cited as one of the main contributors to nonpoint source pollution in coastal waters, particularly coastal eutrophication (Nixon 1995). In aquatic ecosystems, these chemicals can cause excessive plant growth, kill fish and wildlife, and reduce the overall water quality for other purposes (e.g., recreation, drinking, industry, etc.). Appropriate application of fertilizers, including minimization of wind transport and implementation of integrated pest management techniques to make use of specific soil, climate, pest history, and crop information could reduce the source of nonpoint source pollutants. Especially important is the collective knowledge of pollutant sources and their physical transport mechanisms.

Erosion and sedimentation can be reduced by applying management measures to control the volume and flow rate of runoff water, keep the soil in place, and reduce soil transport by wind. Seasonal and short-term weather forecasts can provide probabilities for increased precipitation and increased runoff. Minimizing construction during above-average precipitation seasons may not be practical, but planning for increased precipitation by applying greater soil protection or scheduling less weather-sensitive projects may help limit sedimentation and erosion.

Irrigation is applied in agricultural areas to replace insufficient precipitation during drought, to meet the moisture demands of crops with greater precipitation requirements, or to protect crops against freezing (Thompson 1999). Irrigation is often applied in residential areas to support turf grass or ornamental plants and shrubs. Excessive irrigation may enhance the runoff from agricultural or residential areas, thus contributing to nonpoint source pollution in water bodies. Irrigation scheduling is relatively easy with knowledge of crop type, the soil's moisture holding capacity, the antecedent precipitation, and temperature. Armed with this information, water budget or demand results (i.e., moisture surplus or deficit) can be calculated. Whether to apply irrigation can be determined by the demand (e.g., deficit), a probabilistic quantitative precipitation forecast, and the moisture sensitivity of the crop. Of course, the economic value of the decision (e.g., slight browning of turf grass or 50 percent reduction in yield of primary cash crop) would factor into irrigation decisions.

Because of their significant sources of animal waste, the explosion of industrial feedlot operations in the southeastern United States (especially swine) is a considerable water quality concern for coastal communities (Furuseth 1997). Precipitation and effluent runoff from poorly managed facilities can contain bacteria, nutrients, and oxygen-demanding substances that contaminate shellfishing areas and cause other major water quality problems (U.S. EPA 1994). These feedlots offer a unique management challenge in that animal waste is often applied to fields where evaporation helps diminish the negative impact of this waste. Such controversial spraying operations require significant knowledge of local weather conditions in order to be implemented successfully (Wax and Pote 1996). Figure 3 illustrates that drought conditions may not provide enough ambient moisture to dilute waste-lagoon effluent. In addition, heavy rains and floods can cause failure of waste holding lagoons, causing millions of gallons of waste to be released into local rivers and estuaries (Mallin 2000). Five-to-ten-day precipitation forecasts would provide short-term management support of waste lagoons. Tropical storm forecasts would help lagoon managers avoid catastrophic failures. If lagoon managers could assign values to the simple relationship in Figure 3, antecedent moisture conditions and forecasts could be valuable tools for minimizing environmental impacts.

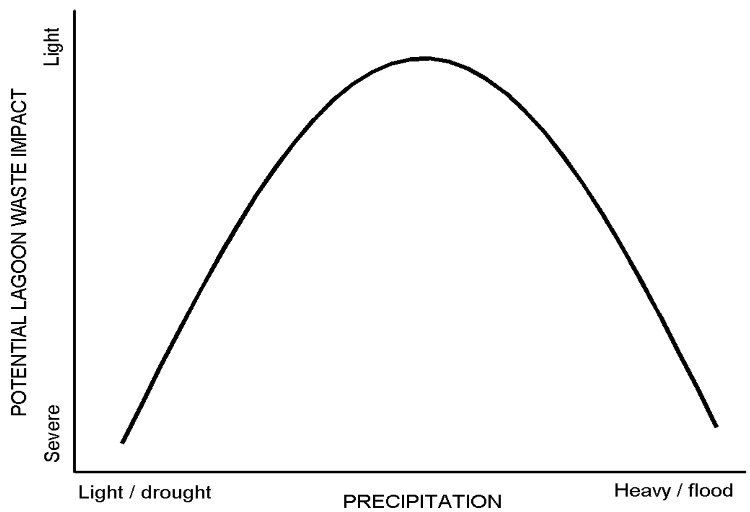

Figure 4 Generalized relationship between precipitation amount/intensity and negative environmental impacts of lagoon waste spraying or overflowing

Table 10 Summary descriptions of data needs, access information, relative costs, and weaknesses of reducing nonpoint source pollution

DATA OR PRODUCT	SOURCES	ACCESS	COST	WEAKNESS
Seasonal and monthly precipitation forecasts	NOAA CPC	Internet	Free	Generalized spatial patterns; lower skill during some phases
Weather forecasts to 10 days	NOAA NWS	Internet	Free, third-party subscription	End user time-intensive
Tropical storm forecasts	NOAA NHC	Internet, satellite	Free, third-party subscription	Short lead time on forecasts and users have low confidence in

				accuracy
Water-budget daily input: temperature, precipitation, soil moisture, solar radiation	NOAA NCDC, RCC, USDA, mesonetworks	Internet	$	Soil moisture and solar radiation measurements are not widely available
Radar precipitation	Real-time NOAA NWS	Internet, satellite	Free, third-party subscription	Data-intensive and difficult to format for common software (GIS)
	Archive NOAA NCDC	Internet	$$	Data-intensive and difficult to format for common software (GIS)

Resources and Logistics

1) Data and analytical tools needed to produce the product
    - Information for planning fertilizer or pesticide applications
        - Daily and hourly wind direction and speed forecasts to minimize dispersal of chemicals to nontarget areas
        - Daily and hourly precipitation forecasts to minimize potential for chemical washout and runoff
        - Antecedent moisture and temperature conditions to support chemical manufacturers' guidelines for application
        - Weather information to support integrated pest management (i.e., identify whether weather conditions support the existence of a pest in a particular location)
    - Information for reducing erosion and sedimentation
        - Monthly or seasonal precipitation forecasts for planning large-scale construction projects
        - Weekly precipitation forecasts for short-term planning and abatement procedures
    - Information for irrigation scheduling
        - Antecedent precipitation and temperature (at least previous three months) to determine if water surplus or deficit exists
        - Weekly precipitation and temperature forecasts to project moisture conditions and the potential for overcoming or exceeding deficit
    - Information for managing waste lagoons
        - Frequency of natural hazard events, such as climatology of hurricanes
        - Flood inundation and storm surge model (e.g., NWS model called SLOSH that maps the local storm surge flooding for various levels of tropical storm intensity and tracks the storm to the coastline)
        - Tropical storm and hurricane wind speed forecasts and other text products (e.g., warnings, watches, strike probabilities, etc.)
        - Present conditions of a tropical storm and forecast changes in location, size, and intensity of the storm

2) Source for the data and analytical tools and cost and suitability to core area
    - NOAA
        - National Weather Service Local Forecast Offices,

- *www.nws.noaa.gov/organization.html*
    - National Hurricane Center, *www.nhc.noaa.gov/*
    - National Climatic Data Center, *www.ncdc.noaa.gov/oa/ncdc.html*
    - Climate Prediction Center, *www.cpc.ncep.noaa.gov/*
    - Regional climate centers, *www.nrcc.cornell.edu/other_rcc.html*
- United States Geologic Survey, Water Resources Division, *http://water.usgs.gov/*
- State climatology offices, *www.ncdc.noaa.gov/oa/climate/stateclimatologists.html*
- Free data. Participants indicated that access to free data and analytical tools is one of, if not the most, important motivating features in product selection. Therefore, the majority of data and analytical tools that they utilize are an amalgamation of low cost and free offerings

3) Present format of data and analytical tools and any changes needed
    - Hourly and daily near-real time weather observations are available through NOAA data providers in standard ASCII formats. Metadata, such as geographical coordinates, are readily available
    - Short-term weather, seasonal climate, and tropical storm forecasts are available in text formats over the Internet or via satellite. Some of these products are in ASCII tables while others are descriptive text
    - Radar products are available for many different time increments, such as 5-to-10-minute intervals, hourly precipitation totals, and storm total precipitation. Spatial resolution of these products may be as fine as 1.1 nautical mile grids

4) Accessibility of the data
    - Weather and climate data for reducing nonpoint source pollution transport are easily accessed. Forecast, near-real time, and historical data are provided over the Internet. The accessibility of the weather and climate data can be improved through the following means:
        - Revising Web sites for easy navigation and minimization of scientific and technical jargon
        - Personalizing Web sites and tools for specific uses (e.g., irrigation scheduling)
        - Providing multiple options for data and information output, such as tables, graphs, and maps

5) Gaps or weaknesses in current data, products, tools, or providers
    - Recommended improvements in forecast products
        - Greater accuracy of weather and climate forecasting, including increased spatial and temporal resolution
        - Five-to-ten-day precipitation forecasts
        - Hurricane tracks forecast with increased confidence levels
    - Recommended improvements for observational data
        - Improved standardization between geographic locations, including electronic reporting formats and near-real time reporting
        - Additional real-time weather stations near sensitive nonpoint source pollution sites
        - Subcounty wind direction and speed data for managing airborne

    - pesticide and herbicide applications
- Recommended improvements in blended or derived products
    - Integrate real-time and historical rainfall data by sub-basins to assist with river flow analysis and return periods for heavy precipitation events

6) Cultural, educational, and institutional obstacles
    - Controlling nonpoint source pollution is a monitoring and regulatory function that has economic and legal consequences. Use of weather and climate information may be attractive to regulators but not to potential violators
    - Dogmatic philosophy of applying pesticides, fertilizers, and irrigation under ill-informed management plans
    - Untested perceptions that applying weather- or climate-based management strategies is more costly than other strategies
    - Potential computer and technology skill limitations of end users
    - Development of effective partnerships between organizations to manage and monitor resources, regulatory organizations, and end users; potential confusion about government services versus private sector services; questions on competing or redundant agency missions, policies, and institutions

7) Training for coastal climatology end users
    - Provide training modules for specific user groups (e.g., agriculture, urban management, waste lagoon operators). Training for nonpoint source pollution, for example, might include the use of irrigation schedules for water consumption and optimal conditions for pesticide applications. Training levels should be geared to a user group's level of knowledge and complexity of integration
    - Provide funding for K-12 education components for students and teachers and collaborate outreach with existing agencies to provide training (i.e., Sea Grant, Cooperative Extension, U.S. Environmental Protection Agency)
    - Ensure media involvement to provide advertising and publicity for coastal climatology products

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SUMMARY RECOMMENDATIONS

The specific client problems involving decision making in coastal zones described above were derived from eight generalized user areas to illustrate the needs and processes that a coastal community decision maker may undertake. We did not set out to provide exhaustive sets of information within user areas, nor do we expect to have exhausted all weather, climate, or marine related end user areas. We have presented a cross-section of the many uses for weather, climate, and marine information in the southeastern United States. This cross-section represents a subset of similar problems across other coastal regions. Our findings provide valuable guidance for user expectations within specific applications as well as generalizations across core areas.

This section presents a coastal climatology research suggestion that would benefit multiple user areas in the southeastern United States. Coastal climatologies are unique because they blend marine and terrestrial atmospheric information with nearshore oceanographic parameters. Development of applications and databases would support coastal managers, specifically those faced with weather, climate, and marine-sensitive decisions. Coastal managers representing fisheries, recreation, transportation, and shoreline erosion concerns have expressed the need for "better" information about waves, currents, and winds within bays and nearshore areas roughly 5 km from the shoreline. Exactly what is meant by "better" is unclear because the managers do not have sufficient background in the physical marine sciences, but the general feeling is that better means spatial resolution on the scale of counties or subcounties, real-time reporting, and a means for placing real-time information into an historical perspective.

Perhaps one of the best efforts toward better coastal marine information in the southeastern United States comes from the NOAA-supported partnership among the University of South Carolina, North Carolina State University, and the University of North Carolina at Wilmington called Caro-COOPS, or Carolinas Coastal Ocean Observing and Prediction System (*www.carocoops.org*). The initiative is based on instrumented arrays of coastal and offshore moorings that will be used to monitor and model estuarine and coastal ocean conditions, as well as develop predictive tools and, ultimately, forecasts. Although a central goal of Caro-COOPS is to predict coastal ocean processes, through such tools as storm surge modeling, it is based on real-time monitoring of oceanographic, hydrologic, and meteorological parameters. In 2003, Caro-COOPS began a deployment of nine moorings ranging from onshore to approximately 70 km offshore (200 m depth). The nine offshore moorings contain instrumentation for surface waves, current speed and direction at multiple levels, temperature, salinity, pressure, transmission, and fluorescence/chlorophyll. Five shore-based instrumentation towers record water levels, and four of these additionally record meteorological parameters.

A similar collaboration, the Coastal Ocean Research and Monitoring Program (CORMP) at the University of North Carolina at Wilmington, maintains six instrumented moorings and one meteorological buoy in the Frying Pan Shoals region of the South Atlantic Bight. CORMP moorings were designed for research, but through collaboration with Caro-COOPS, would be upgraded to operational monitoring through real-time communications. Although focused on improving predictive systems, Caro-COOPS provides valuable lessons for integrating coastal observations. Specifically three major advances in observing systems are anticipated:

- Establishment of an extensive array of instrumented moorings in the South Atlantic Bight;
- Development of a comprehensive data management system, essential for access to and integration of high-quality, real-time data; the system will be designed to maximize flexibility and utility, with a view towards serving as a model or support for other coastal ocean observing systems;
- An advanced suite of integrated models that will improve the predictive capacities of real-time physical data from coastal ocean instrumentation

The National Data Buoy Center maintains approximately 12 moored buoys or C-MAN stations off the coast of the Carolinas. The

Skidaway Oceanographic Institute maintains two additional marine-based meteorological towers for the U.S. Navy. Collectively, these observation networks comprise at least 33 oceanic and atmospheric monitoring locations along the Carolina coast (Figure 5). As many as 12 additional locations have been instrumented but are undergoing testing or are waiting commissioning.

Additionally, there are as many as 20 hourly-reporting and 30 daily-reporting meteorological towers located in coastal counties of North and South Carolina. A majority of stations are owned and operated by the National Weather Service, but other institutions and federal agencies also maintain towers. Moreover, plans to modernize the NWS Cooperative Observer program would transition many daily-reporting stations into hourly-reporting stations.

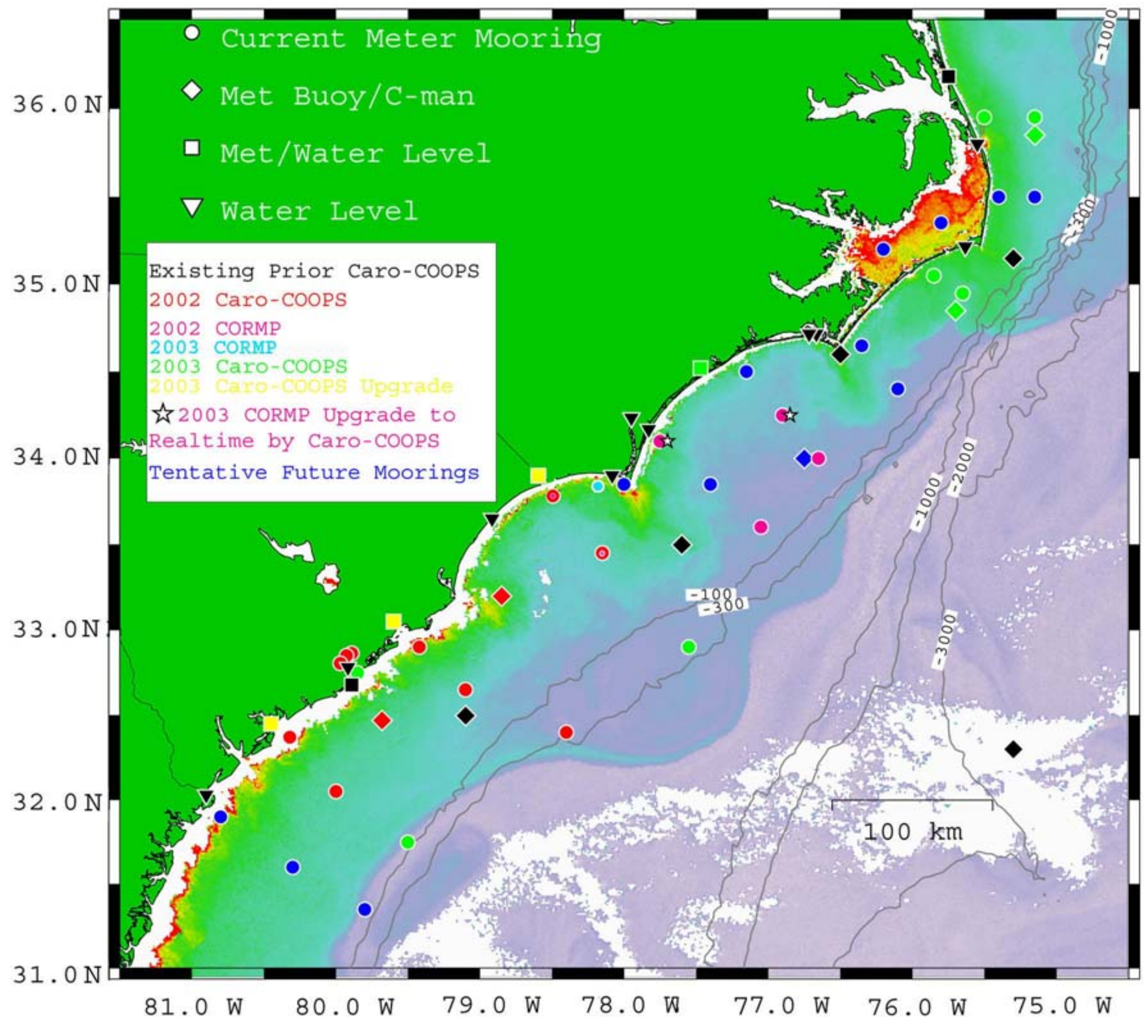

Figure 5 Spatial distribution along the Carolina coast of moorings, buoys, and on-shore instrumentation platforms from Caro-COOPS, CORMP, and C-MAN observing systems (source: Len Pietrafesa)

Coastal climatology products should address the multitude of, differences between, and deficiencies throughout coastal-ocean observing systems. It is tempting to conclude that an inshore network of buoys is necessary to provide this information, but we are avoiding coming to this conclusion until we feel the alternatives, such as better models that use the existing monitoring network, have been adequately scoped. Through either the addition of more data-collecting buoys, the integration of nonfederal observing system similar to Caro-COOPS or SEA-COOS objectives (*www.seacoos.org*), the creation of accurate spatial interpolation, or modeling from the existing observation network, stakeholder needs may be met. A plan for producing this information, including assessments of the relative economic and societal benefits, is needed. The plan would cover everything from physical and social science research to training and delivery of the products. The geographic bounds of the initial plan would be North and South Carolina, but a broader coverage within the southeast may be pursued if the right opportunities present themselves.

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APPENDIX A

Agenda: Coastal Climatology Workshop Coastal Services Center, Charleston, SC

Tuesday October 21, 2003

Registration	8:00–9:00 a.m.
Welcome, Opening Remarks, and Introductions – Mike Janis, Southeast Regional Climate Center	9:00–9:10 a.m.
Purpose and Vision Statements for Coastal Climatologies – Jeff Payne, Deputy Director, NOAA Coastal Services Center – Thomas Karl, Director, NOAA National Climate Data Center	9:10–9:40 a.m.
Climate and Weather Impacts on Society and the Environment – Len Pietrafesa, Professor of Marine, Earth, and Atmospheric Sciences, North Carolina State University	9:40–10:00 a.m.
Morning Break	10:00–10:30 a.m
Review of Terrestrial-Based or Climate Observing Systems – Dan St. Jean, Science and Operations Officer Charleston, SC National Weather Service Forecast Office	10:30–11:00 a.m
Review of marine-based observing systems – Suzanne Van Cooten, Chief Scientist Observing Systems Branch, National Data Buoy Center	11:00–11:30 a.m
Discussion of Core Areas and Assignment of Breakout Sessions – Doug Gamble, University of North Carolina at Wilmington	11:30 a.m.–Noon
Catered Lunch	Noon–1:00 p.m.
Working Group Session 1: Stakeholder Decisions and Needs	1:00–2:30 p.m.
Afternoon Break	2:30–3:00 p.m.
Working Group Session 1 Continued	3:00–4:30 p.m.
Evening Banquet	6:15 p.m.

Wednesday October 22, 2003

Working Group Session 2: Stakeholder Recommendations	8:30–10:00 a.m.
Morning Break	10:00–10:30 a.m.
Working Group Session 2 Continued	10:30 a.m.–Noon
Catered Lunch	Noon–1:00 p.m.
Group Reports	1:00–2:00 p.m.
Closing Comments	2:00 p.m.
Adjourn	2:30 p.m.

APPENDIX B

PARTICIPANT LIST: Coastal Climatology Workshop, Oct 21–22, 2003, Charleston, South Carolina

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APPENDIX C

Specific areas of participant interest, expertise, and concern not included in core area discussions:

- Monitoring and prediction of harmful algal blooms along the southeastern United States coast

- Monitoring and prediction of storm water runoff into southeastern United States coastal waters

- Integration of coastal climatology products into coastal intramodal marine transportation

- Integration of coastal climatology products into management (open and closing) of coastal shellfish grounds

- Integration of coastal climatology products into coastal air quality management

- Integration of coastal climatology products into recreation and tourism management (monitoring of carriage horse heat stress, changing of bus schedules, beach closures)

- Integration of coastal climatology products into management of rail transportation (track buckling and wind hazards)

- Integration of coastal climatology products into forest fire prediction

- Integration of coastal climatology products into management architectural designs and construction schedules

- Integration of coastal climatology products into emergency management and mitigation (handling of hazardous materials, tornado evacuations, design of homes for high wind stress)

APPENDIX D

Questions for Working Groups

Session 1: 1:00–4:30 p.m., Tuesday, October 21

1. Identify core-use areas within working group.
2. What weather or marine sensitive decisions, plans, or assessments does your agency make?
    a. Describe the time frames (i.e., decisions made daily or one year in advance).
    b. Describe motivations or value of decisions (i.e., money, safety).
3. To what extent is weather or marine information integrated into decisions, plans, or assessments? Describe the accessibility of the information and related analytical tools.
4. What type of weather or marine information is currently used in decisions, plans, or assessments?
    a. Describe how information is accessed (i.e., dynamic Web, static CD).
    b. Describe how information is integrated (i.e., through models or subjectively).
    c. Describe the present format of the data and analytical tools.
5. How could decisions, plans, or assessments be improved with additional weather or marine information?
    a. Could additional decisions be made?
    b. Could uncertainty be reduced?

Expected summary: 1) key decisions or operations, 2) important data, and 3) common avenues for improvement.

Session 2: 8:30 a.m.–12:00 p.m., Wednesday, October 22

1. Itemize weather or marine information that would assist operations, including currently used and proposed information.
    a. Identify information gaps and assess the likelihood that current technology could fill those gaps.
    b. Can different weather and marine data be grouped together based upon type, format, delivery system, and period?
2. How should the information be provided?
    a. In what formats should information be delivered (i.e., Web, e-mail)?
    b. In what time frames?
    c. In what spatial scales?
3. How would users like to manage information, synthesize information, and adapt to new technologies and new products?
    a. Identify analytical tools needed to produce a product.
    b. What are acceptable costs for information and analytical tools?
4. Provide recommendations for product support.
    a. Should NOAA provide focal points for specific information or products?
    b. Should NOAA provide Web-based clearinghouses for product support?

5. Identify obstacles within the coastal management community that would impede the adoption of coastal climatology products.
6. Describe the training that would be needed within the coastal management community to make use of coastal climatology products. Identify and assess key training providers within the private sector and government capable of providing the training.

Expected summary: 1) most commonly required data, 2) ideal delivery system and management tools, 3) biggest obstacle to coastal climatologies, and 4) greatest training needs.