The Potential Economic Benefits of Integrated and Sustainable Ocean Observation Systems: The Southeast Atlantic Region*

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Abstract. The South East Atlantic Coastal Ocean Observing System (SEACOOS) collects, manages and disseminates coastal oceanic and atmospheric observation information along the Atlantic coast of the southeastern United States. This paper estimates the benefits of SEACOOS information in eleven benefit categories. Following a methodology used in similar studies of other U.S. coastal regions, we evaluate the impacts of conservative changes in economic activity in each sector. The annual economic benefit of SEACOOS information is $170 million (2003 $'s), an estimate that falls between annual benefits of $33 million for the Gulf of Maine region and $381 million for the Gulf of Mexico.

Keywords: Coastal ocean observing systems, economic benefits.

Introduction

The ocean is one of the least measured and observed regions of the planet. Better ocean information has many beneficial applications, and efforts are underway to improve our understanding. The Southeast Atlantic Coastal Ocean Observing System (SEACOOS) is one of the regional observing systems ringing the U.S. that will form the Integrated and Sustainable Ocean Observation System (ISOOS) for the United States (SEACOOS, 2004). SEACOOS is an umbrella organization that seeks to coordinate coastal observing system activities in four southeastern states: North Carolina, South Carolina, Georgia and Florida. SEACOOS consists of a three-pronged program of observation, modeling, and data management. SEACOOS collects, manages, and disseminates oceanic and atmospheric observation data and information products. The instruments that collect coastal ocean and atmospheric measurements, the platforms that host them, and the supporting communications and power systems comprise the observing system of SEACOOS.

The costs of deploying and operating coastal ocean observing systems (COOS) nationwide are uncertain, but range from tens of millions to billions of dollars per year (Kite-Powell and Colgan, 2001). Determining the potential economic benefits of COOS and the magnitude of these benefits relative to costs is a major policy issue. Better COOS data drive better ocean and weather forecast models, which in turn improve management and operational efficiency in coastal-dependent sectors of the economy. Improved efficiency produces economic benefits in terms of higher value products (e.g., higher success rates in life-saving search and rescue missions, cruise trips with calmer seas and more sunny days) and lower costs (e.g., shorter detours around bad weather for maritime shipping, fewer oil spills and related costs).

This paper complements a series of region-specific papers on the economic benefits of

COOS in the United States (Adams et al., 2000). Other research has considered the benefits of COOS in the Gulf of Maine and the Gulf of Mexico (Kite-Powell and Colgan, 2001; Lynch, Harrington and O'Brien, 2003). Research in these regions identified five major categories of quantifiable benefits: (1) maritime transportation, (2) commercial fishing, (3) recreational fishing and boating, (4) search and rescue operations, and (5) oil spill management and prevention. In the Gulf of Maine, the annual benefits are estimated to be more than $33 million with most of these benefits in the category of lives saved (Kite-Powell and Colgan, 2001). In the Gulf of Mexico, Lynch, Harrington and O'Brien (2003), using similar methodology and assumptions, find that the annual benefits of COOS for the same five benefit categories are $97 million/yr., with more than $25 million/yr. in benefits attributable to each of the maritime transportation, recreational fishing and search and rescue benefit categories.

This paper develops estimates of COOS economic benefits for the southeast Atlantic region. In addition to the five benefit categories addressed in the Gulf of Maine and Gulf of Mexico studies, we estimate the benefits of COOS for hurricane evacuation warning systems, beach recreation opportunities, cruise line operations, and beach erosion management. Benefit estimates are developed for each state in the SEACOOS region and for the SEACOOS region as a whole.

Maritime Commercial Shipping

Two categories of maritime transportation may be affected by SEACOOS information: maritime commercial shipping and recreational cruise voyages. We follow the methodology of Kite-Powell and Colgan (2001) for maritime commercial shipping. Oceangoing ships use COOS information on currents, winds, waves and fog to improve routing efficiency, minimize transit time, and reduce fuel and labor costs. Availability of COOS information may also improve docking, berthing and loading efficiency, and reduce cargo damage due to storms and rough seas (Kite-Powell and Colgan, 2001). In addition, the use of COOS information on visibility and water depth in conjunction with electronic chart/navigational system technology may help vessels avoid damage and injuries to crew and passengers from groundings, collisions, ramming and other accidents (Kite-Powell et al., 1997; Kite-Powell et al., 1999; Talley, 2001, 2002). Cargo vessels (mainly foreign), cargo barges (mainly domestic) and tankers (both foreign and domestic) make thousands of visits to SEACOOS region ports each year (US Army Corps of Engineers, 2002a, 2002b).

We first consider benefits attributable to reduced transit time. Following Kite-Powell and Colgan (2001) we assume that (1) a reduction in transit time results in a proportional reduction in operating costs, (2) the average transit time of a commercial vessel in coastal waters is two days (round trip), and (3) the availability of COOS information reduces average transit time by 1%. We use conservative estimates of the daily operating costs (fuel, crew, lube & stores, maintenance & repair, insurance, and administration costs) by vessel type for both foreign and domestic vessels (US Army Corps of Engineers, 2000, 2002c; Kite-Powell, et al., 2001).

Table 1 presents estimates of the potential annual maritime transportation transit time benefits attributable to improved COOS information in the SEACOOS region by vessel type category. Over one-half of the benefits are enjoyed by foreign passenger and dry cargo vessels. Most of the benefits occur in Florida. Annual benefits across all states and vessel categories are about $4.58 million (2003 $).

Kite-Powell et al. (1999) note that grounding of commercial ships accounts for about one-third of all commercial maritime accidents. Groundings can result in damage to vessels and cargo, obstruction of waterways, environmental damage, injuries, and loss of life. Kite-Powell et al. (1999) estimate average grounding rates for five U.S. ports based on U.S. Coast Guard groundings data from 1981 to 1995. Estimates of the average total cost (2003 $) per grounding presented in Kite-Powell et al. (1997) are $386,352, $869,291, $24,147, and $808,924 for dry cargo, tanker, dry cargo barge, and tanker barge vessels, respectively. Based on the grounding rates for ships and barges in Tampa, FL, and Houston/Galveston, TX, (Kite-Powell et al., 1999), we assume a grounding rate of 1 in 1000 vessel transits for ships and 1.5 in 1000 vessel transits for barges. Not all groundings are due to poor weather conditions (e.g., some are caused by engine or rudder failure), and not all groundings due to poor weather could be prevented by better COOS information. Assuming that improved COOS information would reduce the number of groundings by one percent, using the vessel transit data and grounding cost estimates, we estimate the annual reductions in commercial maritime grounding costs as $12,206, $15,325, $17,987, $89,775, and $135,294 for NC, SC, GA, FL and the SEACOOS region, respectively (Table 1).

Recreational cruise voyages

COOS information provides benefits to the recreational cruise voyage industry. The cruise industry heavily impacts the onshore economy by stimulating port service industries and shore excursion tourism (Braun et al., 2002). Some cruise passengers make additional economic contributions to base port cities when they use the cities as "staging areas," lodging, eating and shopping overnight in the base port before and after the cruise. Braun et al. (2002) find that every dollar of expenditures by cruise line companies and cruise ship passengers in the Port Canaveral base port county (Brevard County, FL) generates $0.53 in direct value added (excluding economic multiplier effects) within the base port community. A study prepared for the International Council of Cruise Lines (Business Research and Economic Advisors, 2003) developed estimates of direct expenditures by cruise line companies and passengers by state in 2002 (Table 2). We assume that Braun et al.'s direct value added multiplier estimate of $0.53 is applicable to all U.S. ports within the SEACOOS region. Multiplying each dollar of direct expenditure by the $0.53 value added multiplier produces estimates of direct value added by state.

COOS information might benefit the cruise industry in two primary ways. First, such information might improve the scheduling efficiency of cruise operations, reducing idle time in port by making use of improved weather forecasts. Altalo et al. (2002) report that severe weather conditions can develop fairly rapidly in the Caribbean region. Although cruise ships can "out-run" storms, this is not desirable from the perspective of passenger comfort. Ship captains make routing decisions to avoid major storms by using 7-10 day weather forecast information. Ships also use weather information to plan routes that minimize fuel consumption expense (Altalo et al., 2002). Cruise lines report that when hurricanes are present, ships require information with the highest spatial resolution available.

Second, if COOS information improves the experience of cruise passengers at sea by enabling cruise ships to better avoid rough seas and bad weather, then passengers may enjoy more satisfaction per trip, and demand for cruise trips may increase. The additional value arising from increased passenger satisfaction would be divided between passengers and cruise line owners, depending on the degree of competition in the cruise line industry and the impact of increased demand on cruise trip prices. However, to our knowledge, the impact of cruise passenger weather/rough seas experience on demand for cruise trips has not been quantified.

Although the effect seems very plausible, it remains speculative.

To estimate the economic benefits of COOS to the cruise industry, we assume that COOS information would increase cruise industry-related direct value-added in the SEACOOS region by 1% through some combination of the two effects described above. Annual cruise industry benefits are $27.4 million (2003 $). The estimate is conservative in that it does not include economic multiplier effects, expected deployment of new cruise ships currently under construction, any reductions in insurance costs due to increased safety from access to COOS data, or any increases in consumer surplus received by cruise ship passengers.

Oil Spill Prevention and Mitigation

Improved COOS information may reduce costs associated with oil spill prevention and mitigation. Although there are currently no offshore oil extraction, drilling or exploration activities off the Atlantic coast of the SEACOOS region (Luger, 2004), over 2,000 tanker vessels and over 5,000 tanker barges pass through SEACOOS region harbors each year (US Army Corps of Engineers, 2002a, 2002b). Significant oil spills can occur when vessels load or unload oil, or when vessels sink, run aground or collide. In addition to oil tanker vessels, oil barges and even non-oil transport vessels (e.g., freighters) that simply carry oil in their bunkers to fuel their own engines can be sources of significant oil spills (Talley et al., 2001). Although the amount of oil spilled per year in the U.S. has declined steadily over the last thirty years, the amounts spilled in SEACOOS region states have varied erratically. Fortunately, large oil spills are relatively low frequency events, and most years are characterized by relatively small spills associated with unloading and offloading operations and minor accidents. However, the risk of occasional, catastrophic spills remains. For example, a spill released 728,000 gallons of crude oil off the coast of Georgia in 1995, and a spill off the coast of South Carolina released 959,921 gallons of oil in 1996 (Luger, 2004).

There is evidence to support the assertion that improved COOS information may help prevent oil spills (Jin et al., 1994; Kite-Powell et al., 1997, 1999; Talley et al., 2000, 2001). In the event that oil spill prevention fails, the effectiveness of oil spill containment and clean-up can be improved by more rapid and accurate response. Better response can be achieved through more accurate models of oil spill fate and effects, which depend on COOS information such as current and tide data (Kite-Powell and Colgan, 2001). Better COOS information will likely significantly improve spill response time and effectiveness.

The average (mean) annual amount of oil spilled in the SEACOOS region over the ten year period 1992-2001 is 272,045 gallons (6,477 barrels) (U.S. Coast Guard, 2004a). Barrels of oil spilled is converted to costs by multiplying by $10,000 (2003 $) per barrel of oil spilled, following Kite-Powell and Colgan (2001) and Lynch, Harrington and O'Brien (2003). We note that the $10,000 per barrel cost number can also be interpreted as the approximate per barrel cost of preventing an oil spill using the cost-effective combination of regulatory actions identified by Volpe (2001). At a cost of $10,000 per barrel spilled, the average annual cost of oil spills in the SEACOOS region is $64.7 million. Following Kite-Powell and Colgan (2001) and Lynch, Harrington and O'Brien (2003), we estimate the economic benefits of a one percent reduction in oil spills and associated costs. We assume that the reduction results from the combination of improved prevention and better mitigation due to improved oil spill fate and effect modeling. Benefits in an average year are almost $650 thousand. The distribution of benefits by state is presented in Table 3.

Commercial Fishing

The commercial fisheries of the United States landed approximately 9.3 billion pounds of fish and shellfish worth $3.1 billion in 2002 (National Marine Fisheries Service, 2003). COOS information may benefit commercial fisheries in several ways (Kite-Powell and Colgan, 2001). First, COOS information may decrease fishing costs by increasing the efficiency of trip scheduling. Many commercial fishing trip departures are based on predicted weather conditions days to weeks in the future. Better weather and sea condition information means that a greater proportion of fishing trips will be taken at times when conditions at sea turn out to be favorable for fishing, and a smaller proportion of trips will be taken at times when conditions turn out to be unfavorable. Such increases in trip scheduling efficiency decrease the average cost per pound of fish landed.

Second, better ocean information may improve the efficiency of fishery management regulations, eventually leading to larger fish stocks. In turn, larger fish stocks may permit fishery regulators to increase the sustainable number of trips allowed per year and may increase fish catch and revenue per fishing trip. For example, Costello et al. (1998) find that improvements in the ability to forecast El Nino weather events in the Pacific Ocean could lead to economic welfare gains on the order of $1 million per year in the coho salmon fishery.

Kite-Powell and Colgan (2001) and Lynch, Harrington and O'Brien (2003) develop a conservative estimate of the impact of COOS information on the efficiency of scheduling commercial fishing trips and promulgating fishery management regulations by assuming that such information will enable one additional favorable fishing day per season. Because annual landings and ex-vessel values vary substantially from year to year, we consider the mean values of landings and ex-vessel (dockside market) values for the commercial finfish and shellfish industries in SEACOOS region states for the last ten years (1993-2002) (National Marine Fisheries Service, 2004a).

The 10-year mean ex-vessel values are converted to value-added estimates by multiplying the ex-vessel values by the National Marine Fisheries Service's estimate of the average value-added percentage for edible domestic commercial marine fishery products in the United States in 2002, or 63.2% (National Marine Fisheries Service, 2003). We follow Kite-Powell and Colgan (2001) and Lynch, Harrington and O'Brien (2003) and assume a baseline 60 day finfish fishing season and a baseline 120 day shellfish season. Dividing each value-added estimate by the appropriate number of fishing days per season produces estimates of value-added per fishing day. Adding one additional fishing day to each of the finfish and shellfish fishing seasons produces an annual benefit of COOS information for commercial fisheries of $2.8 million (2003 $) (Table 4). Over one-half of these benefits occur in Florida.

Commercial fishing is one of the most dangerous occupations (Jin et al., 2001; Jin et al., 2002). Another source of commercial fishery benefit lies in the area of vessel safety. COOS weather and sea condition information may increase fishing vessel safety at sea, reducing costs associated with on-deck and overboard injuries and fatalities, and ship sinkings, capsizings and collisions.

Jin et al. (2002) find that over the period 1981 to 1993, the average accident rate per 1000 vessel days ranged from 0.48 to 1.99, with a mean of 0.96, in the Northeast statistical fishing area off New England. In the absence of similar estimates for waters off the coast of the southeastern U.S., we assume that the accident rate in the SEACOOS region is similar to that of New England (Table 5). If we further assume that each vessel trip corresponds to one vessel day (on average), then dividing the annual number of vessel trips by 1000 and multiplying the result by 0.96 produces estimates of the mean number of fishing vessel accidents per year by state. Multiplying the mean number of accidents by Jin et al.'s (2002) estimate of costs per accident ($118,644 in 2003 $) produces estimates of the average annual costs of fishing vessel accidents by state. Assuming that the availability of COOS information reduces commercial fishing vessel accidents by 1%, the estimated annual reductions in accident-related costs are over $600 thousand, with Florida receiving forty-seven percent of the benefits and North Carolina receiving forty-two percent.

Recreation

The value of many coastal recreational activities might be enhanced by SEACOOS. We focus on two of the most important: recreational saltwater boat fishing and saltwater beach activities. Boat fishing includes private boats, charter boats and party/head boats. We follow the methodology of Kite-Powell and Colgan (2001) for recreational boat fishing. The value of SEACOOS for boat fishing is the product of the net increase in the number of days engaged in the activity and the consumer surplus (i.e., net value to the recreationist) per day.

The number of days engaged in recreational boat fishing is measured by the number of fishing trips. This is a conservative estimate of the number of days since overnight fishing trips may be longer than one day. We obtain the number of fishing trips from national survey data on private/rental and party/charter boat fishing modes with a destination of ocean waters from each state during 2002 (National Marine Fisheries Service, 2004b). A total of 8.55 million days of recreational boat fishing occurred in the southeastern U.S. in 2002 (Table 6). Fifty-four percent and 32 percent of these boat trips originated from the Gulf coast and Atlantic coasts of Florida, respectively.

Haab, Whitehead, and McConnell (2000) use the travel cost method to estimate the economic value of marine recreational fishing in the southeastern U.S. Using their estimate of the “mean value of access per trip by state”, the values of Florida Gulf, North Carolina, Florida Atlantic, South Carolina and Georgia fishing days are $54, $19, $14, $8, and $3 (2003 $) (Table 6). Assuming a one percent net increase in the number of recreational boat fishing trips resulting from COOS information, the additional consumer surplus is $3 million. Ninety-four percent of this value would occur in Florida. Eighty-one percent of the total benefits would occur off the Gulf coast of Florida.

Beach activities include swimming, fishing, beachcombing, etc. The value of SEACOOS for beach activities is the product of the net increase in the number of days engaged in the activity and the consumer surplus per day. An estimate of the number of days of saltwater beach visitation is obtained from Leeworthy and Wiley (2001). The total number of days spent at the beach in the SEACOOS region in 2000 is 247 million with 72 percent of these days spent in Florida (Table 6). We calculate the average value of a Florida beach day, $35.75, based on estimates from two studies (Bell, 1986; Bell and Leeworthy, 1990), and apply it to each of the four southeastern states. Assuming a one percent net increase in the number of beach trips resulting from COOS, the increase in annual consumer surplus is $88 million. Seventy-two percent of this value would occur in Florida. Unfortunately, since the data on beach trips is not divided by the Gulf and Atlantic coasts of Florida, separate estimates are not possible.

Search and Rescue

Search and rescue benefits are estimated as an improvement in the percentage of lives saved by U.S. Coast Guard search and rescue missions. The five year average of lives saved by the U.S.

Coast Guard in the southeast Atlantic and the Gulf of Mexico is 704 and 595 (U.S. Coast Guard, 2004b). The percentage of lives saved is 93.74% and 88.87% in the southeast Atlantic and the Gulf of Mexico. The Search and Rescue Program goal is 93% of lives saved.

An estimate of state-level boating activity, the number of registered recreational boats in each state (National Marine Manufacturers Association, 2003), is applied to the lives saved statistics in order to develop estimates of search and rescue benefits at the state level. The total number of boat registrations in Florida is divided in half to obtain estimates of boating activity in the southeast Atlantic and Gulf of Mexico for Florida. According to this measure of boating activity in the southeast Atlantic region, Florida accounts for 30% of boating activity, South Carolina 25%, North Carolina 23%, and Georgia 21%. Florida accounts for 25% of the boating activity in the Gulf of Mexico.

Of the 704 annual average lives saved in the southeast Atlantic region, 213 are saved off the east coast of Florida, 178 in South Carolina waters, 163 in North Carolina, and 150 in Georgia. Of the 595 annual average lives saved in the Gulf of Mexico, 148 are saved off the Gulf coast of Florida. Following Kite-Powell and Colgan (2001) we assume that the percentage of lives saved with COOS will increase by one percentage point from 93.74% to 94.74% in the southeast Atlantic. Similarly, the percentage of lives saved in the Gulf of Mexico would increase from 87.97% to 88.97%. With rounding, two additional lives would be saved with COOS in each southeast Atlantic state and two on the gulf coast of Florida (Table 7). The total expected number of additional lives saved per year is 9.17.

Kite-Powell and Colgan (2001) rely on a literature review in Viscusi (1993) to develop an estimate of $4.35 million (2003 $) for the value per statistical life (VSL) saved by U.S. Coast Guard search and rescue activities. Applying the $4.35 million VSL to the estimates of additional lives saved from COOS leads to benefits of $17 million, $8 million, $8 million, and $7 million in Florida, South Carolina, North Carolina and Georgia. Benefits are $33 million in the south Atlantic and $7 million on Florida's Gulf coast. Total annual benefits from North Carolina through the Florida Gulf coast are almost $40 million.

Hurricane Evacuation

A category of benefits not addressed by Kite-Powell and Colgan (2001) but important in the SEACOOS region is improved hurricane forecasts. Improved hurricane forecasts will generate benefits for emergency managers, recreational boaters, commercial fishers, cruise ships, the maritime transportation industry, and the military. These benefits include reduced costs of avoiding forecast storms that do not materialize and reduced damages from avoiding storms that are forecast with greater accuracy. Benefits in the maritime transportation, recreational cruise, commercial fishing, and recreational boating industries arise from more efficient route scheduling and fewer cancelled trips due to better weather information; these benefits are addressed elsewhere in this paper.

Improved information from COOS will lead to improved information for emergency managers. With improved hurricane forecasting ability the width of forecast hurricane paths will narrow, allowing emergency managers to make better judgments about evacuation orders. We assume that better forecast information will lead to a one percent reduction in the number of households that must evacuate. Since hurricane evacuation generates economic costs, a reduction in the number of evacuees will lead to avoided costs.

In the event of a hurricane, and without COOS information, the number of evacuated households is the product of the evacuation rate and the number of households. With COOS information, the number of reduced household evacuations is one percent of the number of evacuated households in the absence of COOS information. Expected evacuation benefits are the product of the probability of a hurricane strike, the cost per evacuated household and the number of reduced household evacuations. We construct estimates of expected benefits for minor and major hurricanes. Minor hurricanes are defined as Saffir-Simpson category 1 and 2 storms. Major hurricanes are defined as Saffir-Simpson category 3, 4, and 5 storms. The total expected hurricane evacuation benefits are the sum of the expected benefits for minor and major hurricanes.

First, we develop an estimate of the number of evacuated households for minor and major hurricanes. During the late 1990s, three hurricanes landed on the Atlantic coast. Hurricane Floyd (1999) represents a major hurricane, and hurricanes Dennis (1999) and Bonnie (1998) represent minor hurricanes. In 1999 category 4 Hurricane Floyd approached the southeast U.S. and led to what has been called the biggest peacetime evacuation in U.S. history. Hurricane Floyd eventually landed as a category 3 storm, but the evacuation behavior reflected the forecast of a category 4 storm.

Data on recent hurricane evacuations are available from several sources. Whitehead et al. (2001) estimate that 41 percent of coastal North Carolina residents evacuated for hurricane Floyd. Similarly constructed estimates for South Carolina, 66%, and Florida, 13%, are from the Hazards Research Lab (2000) and the Institute for Public Opinion Research (1999). Baker (2000) reports the evacuation rate for Georgia was 90% for hurricane Floyd. Evacuation rates for hurricane Bonnie and hurricane Dennis are from Whitehead et al. (2001) for North Carolina and Dow and Cutter (2000) for South Carolina. Evacuation rates for lower intensity storms for Georgia and Florida are estimated from the relationship between evacuation for hurricanes

Bonnie, Dennis and Floyd for North Carolina and South Carolina. Evacuation rates for North Carolina, South Carolina and Georgia are for the coastal county populations. The evacuation rates for Florida are for the entire state.

The number of evacuated households for hurricane Floyd is 76,000, 252,800, 160,414, and 782,360 for North Carolina, South Carolina, Georgia, and Florida. The estimates for North Carolina and Florida are obtained from Whitehead et al. (2000) and Institute for Public Opinion Research (1999). The estimate of households evacuated for South Carolina is obtained from the estimate of individuals evacuated (Hazards Research Lab, 2000) and divided by 2.5 individuals for each household. The estimate for Georgia is obtained from 2000 U.S. Census estimates of population for the Georgia coastal counties of Bryan, Camden, Chatham, Glynn, Liberty and McIntosh (total population = 445,595) and dividing by 2.5 individuals for each household. The number of evacuations for a minor hurricane is the product of the average evacuation rates for hurricane Bonnie and hurricane Dennis and the household population of each state.

Hurricane risk measures are developed from historical hurricane strike data (National Hurricane Center, 2004). From 1900 to 1996, a period of 97 years, North Carolina experienced 25 hurricane strikes with 14 and 11 of these minor and major hurricanes. The chance of a hurricane strike is the ratio of the number of hurricane strikes to the number of years (e.g., $(14 \div 97) \times 100 = 14.43\%$). Similar estimates are developed for the other states. The expected numbers of avoided evacuations per year for minor and major hurricanes are obtained by multiplying the expected number of evacuated households, which is equal to the product of hurricane risk and the evacuation household estimates, by one percent (Table 8). The expected value of avoided evacuations is then multiplied by an estimate of the household cost of an evacuation to obtain the hurricane evacuation benefits of COOS information. Estimates of hurricane evacuation costs include expenditures on lodging, food, entertainment, travel and time (Whitehead, 2003). The total household cost is $211, $233, $273, $256, and $292 for category 1, 2, 3, 4, and 5 hurricanes in North Carolina. The cost for a minor hurricane is the average of the costs of category 1 and 2 hurricanes ($222). The cost for a major hurricane is the average of the costs of category 3, 4, and 5 hurricanes ($274). We assume that household evacuation costs for South Carolina, Georgia, and Florida are the same as for North Carolina.

The annual total hurricane evacuation cost avoided with COOS is approximately $940,000. Sixty-two percent of these costs are for a major hurricane. Most of these benefits occur in Florida, 87 percent and 91 percent for minor and major hurricanes, for two reasons. Both the affected population and strike probabilities are much larger in Florida. Annual costs avoided in North Carolina, South Carolina, and Georgia are $36 thousand, $55 thousand, and $9 thousand.

Beach Erosion

While coastal erosion is generally recognized as a costly problem, opinions differ regarding the best management solution. Some find beach sand renourishment to be cost effective in some locations (Hillyer et al., 1997; Houston, 2002), while others oppose renourishment and find alternative management policies such as zoned setbacks more attractive (Pilkey and Dixon, 1996). COOS information would likely reduce the costs of implementing any of these erosion management measures. We develop estimates of COOS benefits for two benefit categories: improved efficiency in coastal land-use and setback planning, and improved efficiency in beach nourishment project design.

The two major recommendations of the Heinz Center erosion report (Heinz, 2000) highlight erosion rates and erosion hazard maps as critical elements of erosion management policy. Indeed, recent field research in both Delaware (Wakefield, 2001; Parsons and Powell, 2001) and Georgia (Landry, Keeler and Kriesel, 2003) indicates that selection of the efficient erosion management policy (nourishment vs. beach retreat, etc.) depends crucially on estimates of erosion rates. We base our benefit estimates on the improvements in erosion management efficiency that would result from improved estimates of erosion rates made possible by the availability of COOS data.

Erosion costs may be reduced by several means, including better allocation of new development to less erosion-prone areas (Heinz, 2000), more efficient estimation of erosion set back locations Crowell et al. (1997), and more efficient beach nourishment project design (Houston, 1996) and location (Ofiara and Psut, 2001). We consider two benefit categories: reduced beach nourishment costs in more densely populated areas currently protected by beach sand nourishment, and reduced costs of alternative management measures (e.g., reduced costs of development restrictions and beach retreat) in less densely populated areas.

Estimates of the efficient size and cost of a beach nourishment project can vary widely depending on estimates of the beach erosion rate (Wakefield, 2001). The availability of COOS data would allow more accurate estimation of beach erosion rates and more efficient design of beach nourishment projects. For consistency with the assumptions made in the other regional COOS benefit assessment reports, and to facilitate benefit comparisons across benefit categories and regions, we consider a 1% reduction in beach nourishment costs due to the availability of COOS information. Table 9 presents data on the cumulative costs of beach nourishment by state from 1921 to 1998 (Heinz, 2000). These costs are annualized using a 3% discount rate. The annual benefits of COOS information, calculated as a 1% reduction in annualized nourishment costs, is $174,151 for the SEACOOS region.

In addition to the beach nourishment cost reduction benefits described above, the availability of COOS data may improve the efficiency of alternative beach erosion management measures in less densely populated areas where nourishment may not be cost effective. For example, improved erosion rate estimates made possible by COOS data might indicate that development should be discouraged in an area that otherwise would be fully developed. The avoided costs of erosion-related property losses are benefits of COOS.

For low-population density areas in the Atlantic and Gulf regions, we use 1990 state level data on population living within 500 feet of the shoreline and estimates of the number of structures located within 500 feet of the shoreline (Heinz, 2000). We assume that shoreline structures are allocated across states in proportion to shoreline population. Regional estimates of the proportion of structures located within 500 feet of shore that are also located within the 60-year Erosion Hazard Area (EHA) (Heinz, 2000) are used to estimate the number of structures located within the 60-year EHA (Table 10). Regional estimates of the average annual cost of erosion to land and structures located within the 60-year EHA (Heinz, 2000) are translated to state-by-state costs by allocating regional costs to states in proportion to the allocation of EHA structures across states.

Assuming that improvements in erosion management efficiency due to the availability of COOS information reduce the costs of alternative erosion management measures by 1 percent results in an average annual benefit estimate of $1.8 million for the SEACOOS region (Table 10). Over two-thirds of these benefits accrue to the Atlantic coast of Florida.

Conclusions

Initial studies of the economics of ocean observing systems in the U.S. (e.g., Adams, et al., 2000) found that benefits were likely to significantly exceed costs and that work on such systems should move forward. It was recognized that Federal support of ocean observing systems was needed due to the existence of market failures (such as network externalities in data acquisition and the public good nature of ocean observation information) that prevent the private market from developing and implementing such systems at an efficient level. Benefit-cost analysis would be necessary to determine the efficient level of government program support. However, a full cost-benefit analysis was beyond the scope of the initial assessment effort due in large part to a lack of benefit estimates for the full range of projected system applications.

This paper identifies general categories of economic benefits that may result from the implementation of coastal ocean observation systems in the southeastern United States and develops initial, order of magnitude, benefit estimates. The estimated total annual benefits of coastal observation information across all states in the SEACOOS region and across all benefit categories considered in this study are $170 million (Table 11).

Beach recreation, search and rescue operations, and recreational cruises receive the largest annual benefits, $88 million, $40 million and $27 million. Estimated benefits in the remaining benefit categories are: maritime commercial shipping transit time, $4.6 million, maritime commercial shipping grounding reduction, $0.13 million, marine recreational fishing, $3 million, commercial fishing, $3.3 million, beach erosion management, $2 million, hurricane evacuation, $0.9 million, and oil spill pollution management, $0.6 million.

Comparing across states within the SEACOOS region, Florida receives more than 67% of the benefits, due to disproportionately large benefits in the beach recreation and recreational cruise benefits categories. North Carolina and South Carolina each receive approximately 13%

of regional benefits, while Georgia receives approximately 8%. The benefit categories receiving the largest benefits in North Carolina, South Carolina, and Georgia are beach recreation and search and rescue operations.

Comparing across regions, the SEACOOS region annual benefits of $170 million falls between estimates of $33 million for the Gulf of Maine (Kite-Powell and Colgan, 2001) and $381 million for the Gulf of Mexico (Lynch, Harrington and O'Brien, 2003). The benefit categories considered in the Gulf of Mexico study include those used in the Gulf of Maine study plus the categories of coastal recreation, storm damage reduction, and offshore oil and gas. Although there are some differences in the definitions of benefit categories across regions, the major drivers of regional differences appear to be the large beach recreation and recreational cruise benefits in the SEACOOS region and the large offshore oil and gas extraction benefits in the Gulf of Mexico region. The estimates of recreational cruise industry benefits presented in this paper are somewhat speculative, but the magnitude of the cruise industry's role in Florida's economy indicates that even small improvements in industry efficiency (or improvements in the satisfaction of cruise passengers) resulting from the availability of improved ocean observation information could lead to relatively large economic benefits.

Results indicate that coastal recreation and tourism, including recreational boating safety (search and rescue) and recreational cruises are large beneficiaries of improved coastal ocean information in the SEACOOS region. These results reflect demographic and economic trends in coastal regions. Colgan (2004) notes in his recent summary of trends affecting the coastal economy of the United States that employment along the coast is rising much more rapidly than the national average. Tourism and recreation account for essentially all of this employment growth. The share of coastal economic activity attributed to recreation and tourism is growing rapidly, and these industries are highly influenced by weather and the accuracy of weather information.

The estimated costs of nationwide deployment and operation of coastal ocean observing systems range from tens of millions to billions of dollars per year (Kite-Powell and Colgan, 2001). If national costs lie in the lower end of this range and regional costs are roughly proportional to national costs on a shoreline miles basis, the results of this initial analysis indicate that the economic benefits of the SEACOOS regional observing system exceed the costs. However, if costs lie in the upper end of the range, then additional benefit estimation research may be necessary to improve the accuracy of the benefit/cost comparison, as the benefit estimates presented here are likely underestimates for at least three reasons. First, we assume that most economic activities will change by only one percent with better weather information. This is likely a conservative estimate of the behavioral response. Second, consideration of the benefits accruing to less coastal-dependent industries, such as construction and agriculture, was beyond the scope of this initial analysis. Third, economic "multiplier" effects (indirect and induced economic impacts) are not included in the benefit estimates.

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Table 1. Annual Maritime Commercial Shipping Benefits (2003 $)

	NC	SC	GA	FL	Total
Value of Reduced Transit Time: Foreign Vessels					
	NC	SC	GA	FL	Total
Passenger & Dry Cargo	$89,040	$524,400	$543,840	$1,663,920	$2,821,200
Tanker	$63,560	$39,200	$69,160	$188,720	$360,640
Barge Dry Cargo	$132	$66	$0	$11,550	$11,748
Barge Tanker	$0	$0	$0	$1,914	$1,914
Value of Reduced Transit Time: Domestic Vessels					
	NC	SC	GA	FL	Total
Passenger & Dry Cargo	$11,500	$0	$0	$90,620	$102,120
Tanker	$15,600	$18,200	$26,000	$359,320	$419,120
Barge Dry Cargo	$76,296	$165,528	$22,902	$125,004	$490,908a
Barge Tanker	$39,798	$19,404	$29,832	$239,712	$368,280a
Value of Reduced Grounding Costs					
All Vessels	$12,206	$15,325	$17,987	$89,775	$135,294

Table 2. Annual Recreational Cruise Industry Benefits, SEACOOS Region (2003 $)

State	Expenditures	Value Added	Benefits (1% of Value Added)
NC	$146,841,001	$77,825,730	$778,257
SC	$64,954,352	$34,425,807	$344,258
GA	$334,772,607	$177,429,482	$1,774,295
FL	$4,626,224,347	$2,451,898,904	$24,518,989
Total	$5,172,792,307	$2,741,579,923	$27,415,799

Table 3. Annual Oil Spill Reduction Benefits (2003 $)

	Annual Benefits for Average (Mean) Year
Oil Spilled (gallons)	272,045
Oil Spilled (barrels)	6,477
Oil Spill Costs ($10,000/barrel)	$64,772,524
SEACOOS Benefits	$647,725
Benefits by State	
NC	$16,879
SC	$234,320
GA	$201,261
FL	$195,265

Table 4. Annual Ex-vessel Commercial Fishing Values (2003 $)

	Finfish					
	NC	SC	GA	FL (east)	FL (west)	Total
10-yr Mean	$41,968,382	$6,223,241	$1,012,548	$22,211,497	$57,252,074	$128,667,742
Value-Added (VA)	$26,524,017	$3,933,088	$639,930	$14,037,666	$36,183,311	$81,318,013
VA of 1 Fishing Day	$442,067	$65,551	$10,666	$233,961	$603,055	$1,355,300
1% Increase in VA	$265,240	$39,331	$6,399	$140,377	$361,833	$813,180
	Shellfish					
	NC	SC	GA	FL (east)	FL (west)	Total
10-yr Mean	$67,112,242	$27,251,530	$25,604,047	$37,216,993	$117,667,623	$274,852,435
Value-Added (VA)	$42,414,937	$17,222,967	$16,181,758	$23,521,140	$74,365,938	$173,706,739
VA of 1 Fishing Day	$353,458	$143,525	$134,848	$196,009	$619,716	$1,447,556
1% Increase in VA	$424,149	$172,230	$161,818	$235,211	$743,659	$1,737,067

Table 5. Annual Commercial Fishing Vessel Accident Cost Reduction benefits (2003 $)

State	Trips	Accidents	Accident Cost	Accident Cost Reduction Benefits
NC	230,618	221	$25,681,620	$256,816
SC	41,647	40	$4,637,810	$46,378
GA	17,000	16	$1,893,120	$18,931
FL	259,716	249	$28,921,974	$289,220
Total	548,981	526	$61,134,524	$611,345

Table 6. Annual Benefits of Coastal Recreation (2003 $)

State	Days	Benefits per Day	Additional Trips	Annual Benefits
Boat Fishing Trips				
NC	878,868	$18.52	8789	$162,776
SC	249,501	$7.84	2495	$19,558
GA	34,827	$3.02	348	$1,051
FL-Atlantic	2,732,934	$14.05	27,329	$384,024
FL-Gulf	4,658,445	$53.68	46584	$2,500,635
Total	8,554,575	-----	85,545	$3,068,044
Beach Trips				
	Days	Benefits per Day	Additional Trips	Annual Benefits
NC	27,940,000	$35.75	279,360	$9,987,120
SC	33,300,000	$35.75	333,020	$11,905,465
GA	8,480,000	$35.75	84,830	$3,032,673
FL	177,150,000	$35.75	1,771,530	$63,332,198
Total	246,870,000	-----	2,468,740	$88,257,455

Table 7. Annual Search and Rescue Benefits (2003 $)

	NC	SC	GA	FL-Atlantic	FL-Gulf	Annual Total
Lives Saved	1.74	1.89	1.60	2.27	1.66	9.17
Value	$7,580,000	$8,230,000	$6,970,000	$9,890,000	$7,230,000	$39,900,000

Table 8. Annual Hurricane Evacuation Benefits (2003 $)

	Category 1 or 2 Hurricane			Category 3, 4 or 5 Hurricane		
	Avoided Evacuations	Strike Probabilities	Costs Avoided	Avoided Evacuations	Strike Probabilities	Costs Avoided
NC	57.73	14.43%	$12,816	86.19	11.34%	$23,615
SC	120.44	10.31%	$26,737	104.25	4.12%	$28,564
GA	38.69	5.15%	$8,590	0.00	0.00%	$0
FL	1399.52	34.02%	$310,693	1935.74	24.74%	$530,392
Total	1,616		$358,837	2,126		$582,570

Table 9. Annual Benefits of Beach Nourishment Cost Reduction (2003 $)

State	Cumulative Beach Nourishment Costs (1921-1998)	Annualized Beach Nourishment Costs	Annual Benefits
NC	$171,400,530	$5,142,016	$51,420
SC	$105,585,103	$3,167,553	$31,676
GA	$39,945,591	$1,198,368	$11,984
FL	$263,572,173	$7,907,165	$79,072
Total	$580,503,398	$17,415,102 / yr.	$174,151

Table 10. Annual Benefits of Alternative Beach Erosion Management Cost Reduction (Low-Population Density Areas, 2003 $)

State	Structures	Erosion Costs	Annual Benefits
NC	1,449	$7,603,514	$76,035
SC	1,739	$9,124,217	$91,242
GA	290	$1,520,703	$15,207
FL Atlantic	23,472	$123,176,932	$1,231,769
FL Gulf	9,664	$39,763,256	$397,633
Total	36,613	$181,188,622	$1,811,886

Table 11. Summary of Annual SEACOOS Benefits (2003 $)

Benefit Category	NC	SC	GA	FL (Atlantic)	FL (Gulf)	SEACOOS Region
Commercial Shipping Transit Time	$305,315	$791,125	$713,680	$2,076,254	$689,556	$4,575,930
Commercial Shipping Grounding	$12,206	$15,325	$17,987	$89,775		$135,294
Recreational Cruise	$778,257	$344,258	$1,774,295	$24,518,989		$27,415,799
Oil Spill	$16,879	$234,320	$201,261	$195,265		$647,725
Commercial Fishing (Finfish)	$442,067	$65,551	$10,666	$233,961	$603,055	$1,355,300
Commercial Fishing (Shellfish)	$353,458	$143,525	$134,848	$196,009	$619,716	$1,447,556
Commercial Fishing Safety	$256,816	$46,378	$18,931	$289,220		$611,345
Recreational Fishing	$162,776	$19,558	$1,051	$384,024	$2,500,635	$3,068,044
Beach Recreation	$9,987,120	$11,905,465	$3,032,673	$63,332,198		$88,257,455
Search & Rescue	$7,580,000	$8,230,000	$6,970,000	$9,890,000	$7,230,000	$39,900,000
Hurricane Evacuation	$36,431	$55,301	$8,590	$841,085		$941,407
Beach Nourishment	$51,420	$31,676	$11,984	$79,072		$174,151
Beach Erosion Management	$76,035	$91,242	$15,207	$1,231,769	$397,633	$1,811,886
Total	$20,046,574	$21,958,399	$12,893,185	$115,308,440		$170,341,892