Estimating the Economic Benefits of Regional Ocean Observing Systems

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Executive Summary

This report summarizes the findings of a preliminary investigation of the magnitude of potential economic benefits that can be realized by deploying a network of ocean observing systems throughout the coastal waters of the United States. Such a network is currently being developed through collaborative efforts of federal, state, and local governments, universities, and organizations in both the non-profit and for-profit sectors.

Estimating the economic benefits from ocean observing systems is inherently difficult. Not only are the systems themselves only partially deployed around the country at present; the technology and information products comprising the inputs and outputs of such systems are undergoing such rapid evolution that any estimates can only represent a partial snapshot. Moreover, the economic information needed to compile estimates of both the users of the information generated by such systems and the value they place on such information is only sporadically available and usually incomplete.

Therefore this report provides what may be considered "order of magnitude" estimates only, along with recommendations on developing more accurate and useful estimates of economic benefits. Furthermore, there are many possible uses of improved ocean observing systems that have no readily quantifiable economic value but may lead to significant benefits in the future. Prominent among these are the uses of better ocean observing data in a wide range of basic and applied scientific research endeavors and in education programs.

The economic benefits of ocean observing systems derive from the value of the information generated by such systems and the effects that information has on the behavior of individuals and organizations. The ideal measure of these economic benefits is the value that users of the information place on it, based on their willingness to pay for such information to either enhance their uses of ocean resources or to avoid harms that may come from oceanic or atmospheric phenomena affecting individuals and organizations. The willingness to pay for such information is a measure of what economists call "social surplus:" the value of the information in excess of the costs of acquiring it. When such value accrues to businesses, it is referred to as "producer surplus;" when it accrues to individual users, it is "consumer surplus."

The number of users and types of uses to which the information from ocean observing systems can be put is large and expanding. A number of uses of ocean observing information have been identified to date.[1] Some of these make use of ocean observing data directly, obtaining near-real-time measurements from buoys or other platforms via a telephone or internet interface. Most use the data indirectly, via the output of various models that produce "nowcasts" or forecasts.

A "nowcast" provides information about oceanographic/atmospheric conditions on a real time or near-real time basis to users, who adjust their behavior accordingly. Nowcasts may

[1] See R. Adams, M. Brown, C. Colgan, N. Flemming, H. Kite-Powell, B. McCarl, J. Mjelde, A. Solow, T. Teisberg, and R. Weiher, 2000, *The economics of ISOOS: benefits and the rationale for public funding*, Washington DC: US Department of Commerce, NOAA Office of Policy and Strategic Planning.

use models of various degrees of sophistication to interpolate between or extrapolate from the actual observations. In a forecast, the observation data are used as input to some form of model that predicts the future state of ocean or atmospheric conditions or the conditions of marine resources such as fish stocks. In both cases, the information is collected and distributed using a variety of information and communication technologies. Forecasts and nowcasts are an input to decisions about economically significant activities. These decisions currently are made with less information than will be available with improved observing systems; and economic value is created by both the availability of observing information not previously available and by its timely distribution to users.

Table 1 Types of Information from Observing Systems

Type of Information	***Type of Data***	***Type of Information Change***
(raw) data	present and historical conditions	new parameters improved accuracy improved resolution finer temporal scale finer geographic scale
products	model output (interpolation/nowcasts, forecasts, etc.)	improved accuracy/resolution (fewer false positives/negatives) finer temporal/geographic scale longer forecast horizon

Nowcasts may include both modeled data and the actual observations themselves. Nowcasts can be used to affect trips for transportation or recreation by causing a route to be changed, cancelling a potentially unsafe trip, or permitting a trip that was perceived to be potentially unsafe to proceed with confidence. Nowcasts can also be used to increase commercial or recreational fishing success by accurately pointing to favorable conditions. In forecasts, the data from observing systems is incorporated into some form of model that permits future values of the variables to be estimated. The data from observing systems may improve the forecasts in a number of ways, including reduced statistical errors, increased the spatial and temporal scale scale, or increased resolution of forecasted data. Forecast improvements can also include reducing false negatives (e.g., forecasting an oil spill will not hit an area when it actually does) and false positives (e.g. forecasting an oil spill will hit an area when it does not).

This report does not assume, nor do its findings imply, any specific observing technologies or technology systems. The underlying assumption is that measurement of parameters of interest to users will be undertaken with a high degree of accuracy, that those measurements and resulting nowcasts/forecasts are communicated to users in a timely and accurate way, and that users will make full use of the information available to them. The resulting benefits depend on the amount, timeliness, and quality of information, and not on a specific technology or organizational arrangement.

The research reported here examines five general types of activities, including recreational activities, transportation, health and safety, energy, and commercial fishing. Nine more specific activities are examined (Table 2).

Table 2 Activities affected by ocean observing information

Recreational Activities	Boating Beach Going Fishing
Transportation	Freight Passenger (Cruise Ships)
Health and Safety	Search and Rescue Oil Spill & Hazard Cleanup Property Damage
Energy	OCS Development Electric Generation Management
Commercial Fishing	

The project proceeded in two phases. In the first phase, a survey of these activities was conducted for each of nine regions (Pacific Northwest, California, Gulf of Mexico, Florida, Southern Atlantic coast, Mid Atlantic coast, New England/Gulf of Maine, Alaska, Hawaii, and the Great Lakes) with the objective of identifying the levels of economic values that might be affected by the availability of improved and expanded information from ocean observing systems. This analysis may be said to identify the "footprint" of economic values. Rough estimates of the potential value of ocean observing system information were made by assuming that small increments of the total value (typically on the order of 1%) could be realized as possible benefits.

Table 3 shows a summary of these estimated possible economic effects. The bases for these estimates are shown in the final column. Because of limitations on the data available in the different regions regarding each of the activities, these figures are not estimated from a consistent base and cannot be summed. Data were not available in each of the regions for each of the activities; for example, data on beach utilization and values are more thoroughly estimated for Southern California than for other regions. Some data permit direct estimation of benefits using willingness to pay measures, which are the appropriate measures of economic benefits. But these data are not available for all uses in all regions. Substitutes or proxies, such as consumer expenditures for recreation activities, are used in these cases. True willingness to pay benefits generally will be some fraction of the resulting estimates. The data in Table 3 thus suggests highly approximate levels of benefits that are possible from ocean observing systems across a partial array of users of the information from such systems in parts of the country.

The data generated in this first phase of the project are very rough estimates that do not take explicit account of the many variables involved in the realization of benefits. These variables include the probabilities of events such as oil spills or high impact weather events such as hurricanes, the issue of how information is distributed to users, and how the information is actually used to make decisions. In order to investigate the influence of these and other factors, the second phase of the project undertook to develop more detailed, but still preliminary, models of economic effects for a subset of activities in specific regions.

Table 3 Preliminary Estimates of Benefits & Impacts

User Sector	Users	Region	Estimated Economic Effects ($Millions / Year)	Benefit Definition
Recreational Activities	Recreational Fishing	Pacific NW	$3.5	Willingness to pay
		G.o.Mexico*	$11.0	Increased expenditures
		Mid Atlantic	$30.0	
		South Atlantic	$2.0	
		Florida	$7.6	Willingness to pay
		G.o.Mexico*	$6.7-34.0	Willingness to pay
		California	$2.0	Increased expenditures
		Hawaii	$6.0	
		Great Lakes	$19.5	
	Recreational Boating	California	$2.0	Increased expenditures
		G.o.Mexico*	$4.0	
		G.o.Maine	$1.0	
		Mid Atlantic	$2.0	
		South Atlantic	$1.0	
		Alaska	$6.0	
		Hawaii	$9.0	
		Florida	See Rec Fishing	
		Great Lakes	$18.0	
		California	$16.0	
	Beaches	Florida	$7.7	Beach-related consumer expenditures
			$65.6	Increased economic impact
			$1.6	Operating cost savings
			$30.7	Increased business sales
		Great Lakes	$16.5	Increased visitor daily values
		California	$94.6	Increased expenditures
		California	$58.0	Increased consumer surplus
Transportation	Freight	Pacific NW	$1.2	Daily cost savings
		G.o.Maine	$1.0	
		Mid Atlantic	$2.0	
		South Atlantic	$1.0	
		Alaska	$1.0	
		Florida	$55.2	
		Great Lakes	$0.6	
		California	$34.0	
		G.o.Mexico*	$30.7	
	Cruise Ships	Pacific NW	$0.1	
Health and Safety	Search & Rescue	Pacific NW	$10.0	Value of life-$4m
		G.o.Maine	$24.0	
		Mid Atlantic	$16.0	
		South Atlantic	$32.0	

User Sector	Users	Region	Estimated Economic Effects ($Millions / Year)	Benefit Definition
Health and Safety	Search & Rescue	California	$19.0	
		Alaska	$12.0	
		Hawaii	$6.0	
		Florida	$11.3	Costs saved to USCG plus value of lost lives saved
		Florida	$22.0	Cost saved to local rescue squads plus value of lost lives saved.
		Great Lakes	$18.9	Value of life-$4m
		G.o.Mexico*	$28.0	
	Oil Spills	Pacific NW	$0.4	Reductions in clean up and compensation costs
		California	$0.1	
		G.o.Mexico*	$0.8	
	Tropical Storm Prediction	South Atlantic	$15.6	Reduced loss of life, evacuation cost, and lost tourism revenue
	Residential Property	Florida South Atlantic	$32.9 $24.0	Avoided costs from earlier preparation for storms
	Beach Restoration	California	$1.8	Reduced expenditures on beach restoration
Energy	Electric Load Planning	Great Lakes	$55.8-111.6	Avoided use of most expensive peak generators
	Oil and Gas Development	G.o.Mexico*	$5.1-11.3	Operating cost savings
			$9-15	Increased accuracy of oceanographic risks in design
Commercial Fishing		Pacific NW	$2.7	Increased Landed Values
		G.o.Maine	$4.0	
		Mid Atlantic	$3.0	
		South Atlantic	$3.0	
		Alaska	$10.0	
		Florida	$2.0	
		Great Lakes	$0.2	Total regional economic impact
		California	$1.2	Reduced operating costs
		G.o.Mexico*	$2.1	Increased Landed Values

*Note that the Gulf of Mexico region in this study excludes the west (Gulf) coast of Florida.

Phase 2 estimates for the selected uses and regions are shown in Table 4. Low and high ranges of estimates based on the models and assumptions are shown. (Where only one estimate is available, it is shown in both the high and low columns.) Measures that can be counted as economic benefits in the sense of contribution to social surplus are shown in **bold**. Where an estimate is based on total production values and not on contribution to social surplus, it is shown in plain type. The two categories of estimates are summed separately.

Table 4 Estimates of Economic Benefits for Selected Activities and Regions

User Group	IOOS Information	Benefit Source	Low Estimate*	High Estimate*	Region	Measure
Energy	Improved Hurricane Forecasts	Avoided False Positives	**$3.8**	**$7.5**	Gulf of Mexico	Cost savings
Health and Safety	Oil Spill Dispersion Models	Improved spatial/temporal accuracy	**$0.6**	**$1.0**	Gulf of Mexico	Social cost savings
Storm Prediction	Improved Tropical Storm Track and Intensity Forecasts	Improved spatial/temporal accuracy	**$35.6**	**$35.6**	Southeast US Atlantic coast	Cost savings
			$4.0	$4.0	Southeast US Atlantic coast	Tourism revenue
Transportation	Seastate & Visibility Forecasts and Nowcasts	Improved spatial/temporal accuracy	**$0.5**	**$1.0**	Gulf of Maine/Mid Atlantic	Producer surplus
Search and Rescue	Surface currents & winds	Improved spatial/temporal accuracy	**$10.0**	**$15.0**	Gulf of Maine/Mid Atlantic	Producer surplus
			$2.3	**$4.7**	Gulf of Maine/Mid Atlantic	Producer surplus
Commercial Fishing	Salmon run forecasts	Improved capital/labor investments	**$77.0**	**$77.0**	Bristol Bay, Alaska	Producer Surplus
	Reduced risk in management decisions	Increased groundfish catch	$504.0	$504.0	Alaska	Wholesale value
	Reduced risk in management decisions	Increased crab catch	$62.5	$62.5	Alaska	Wholesale value
Recreation	Beach closure forecasts	Decrease in false negatives	**$2.3**	**$3.5**	Southern California	Consumer Surplus
	Beach closure forecasts	Decrease in false negatives	$4.2	$9.3	Southern California	Total Expenditures
	Beach closure forecasts	Decrease in false positives	$1.1	$1.1	Southern California	Total Expenditures
	Recreational boating conditions forecasts	Improved spatial/temporal accuracy	$20.7	$103.5	Great Lakes	Total Expenditures
	Recreational fishing conditions forecast	Improved spatial/temporal accuracy	**$91.2**	**$91.2**	Florida	Consumer Surplus
TOTAL Social Surplus Estimates			**$223.3**	**$236.5**		
TOTAL Other Value Estimates			$596.5	$684.4		

*millions of dollars per year

Based on the analyses in both phases of the project, the order of magnitude for benefits that may be derived for major uses of ocean information systems on an annual basis were estimated. These are shown in Table 5.

Table 5 Orders of Magnitude of Possible Economic Benefits from Ocean Observing Systems

		Order of magnitude of possible annual benefits (millions of dollars)	Regions with greatest benefits
Recreational Activities	Recreational Fishing	100s	Great Lakes, Gulf of Mexico
	Recreational Boating	100s	Great Lakes, Gulf of Mexico, Atlantic
	Beaches/Shore Recreation	100s	Florida, California
Transportation	Transportation-Freight	10s	Florida, Mid Atlantic
	Transportation-Cruise Ships	10s	Florida
Health and Safety	SAR	10s	All
	Oil Spills	10s	All
	Tropical Storm Prediction	10s	Atlantic, Gulf of Mexico
Energy	Electricity Load Planning	10s to 100s	Great Lakes, California, Atlantic
	Ocean Structures	10s	Gulf of Mexico
Commercial Fishing	Commercial Fishing	100s	Alaska, New England

The numbers in Table 5 suggest that annual benefits to users from the deployment of ocean observing systems are likely to run in the multiple $100s of millions of dollars per year.

These data should ***not*** be compared directly with the projected costs of ocean observing systems without further analysis. In a benefit-cost analysis, the basis for estimating costs and benefits must be consistent, and the time frames must be appropriately defined. While various estimates of the costs of ocean observing systems have been produced, the basis for those estimates may not be consistent with that of the figures shown in this report. At this stage, our findings are also not precise enough to be used to conduct benefit-cost analyses of specific technologies or specific regions.

However, we can conclude from these data that on a discounted present value basis over time[2], the benefits from a national investment in such systems are likely to exceed the costs.

[2] "Discounted present value" is a means of adding benefits (or costs) that accrue at different points in time to obtain a meaningful single value. A discount rate is applied to convert benefits (or costs) that arise in future years into "present" dollars. This is necessary because (a) the value of a dollar next year is (usually) less than the value of a dollar today, and (b) there is (generally) greater uncertainty about benefits (or costs) expected to arise in future years.

This finding is consistent with previous conclusions on the economic benefits of such systems (see, for example, the report cited in Footnote 1 above).

The data also indicate that ocean observing systems will have the largest benefits where the information from such systems is used by the largest possible groups. Recreational activities are consistently the highest generators of benefits because of the very large number of people who use beaches, boat on the Great Lakes or in the coastal ocean, or engage in marine recreational fishing. Although the per-user benefits are smaller than those realized by other activities, the large number of users drive the overall magnitude of potential benefits to substantial sums.

Several important caveats are required in interpreting the results presented above:

- The fact that the benefits from the systems as a whole will likely exceed the costs does not mean that the benefits will exceed the costs in every individual case. The configuration of observing systems in each region should take into account the priorities of local and regional user groups.

The estimates presented assume:

- Full and successful deployment of existing, near-deployment, or reasonably forseeable technologies.
- Cost efficient and effective means of communicating the information derived from the ocean observations to users in a timely manner.
- Users are aware of, and effectively incorporate, the information into decisions regarding their activities.
- In the case of commercial fisheries, additional information concerning the state of the marine environment is relevant to decisions about managed fisheries and (at some point) will permit increases in allowable catches.

Violation of any of these assumptions may reduce the potential or actual benefits to levels below those estimated here.

The analysis of economic benefits from ocean observing systems in this study is by no means exhaustive. For example, this study does not address benefits that may arise for the hotel and resort industry or for certain aspects of emergency management. One source of complementary information about benefits in these and other areas is a series of reports prepared for NOAA by SAIC Inc. (http://www.saic.com/weather/papers.html).

Based on these findings, we believe additional research is needed to develop more precise estimates of benefits for specific observing systems, instruments, technologies, and applications. Specifically:

1. Operators of regional observing systems should incorporate in their operational plans strategies and activities to measure the economic benefits of their products and services.

2. Investments should be made by federal, state, and local governments in more precisely estimating economic benefits and in sharing data and methods for benefits estimation among operators of observing systems. To build on the work presented in this report, a series of coordinated pilot projects should be funded at the regional level to develop, apply, and share with other regions detailed guidelines for benefit tracking and estimation. These pilot projects should focus on one or two prominent user sectors in each region, and cover the major sectors identified in this report.

3. Consumer surplus benefits should be estimated for all categories of recreation users in various regions of the country. Current estimates of such benefits do not fully account for the possibility of substitution among different recreation resources in different regions and remain subject to considerable methodological variability.

Introduction and Summary

The United States and other countries are designing and building a large network of instrumentation and data links to continuously monitor biological, physical, and chemical conditions in the ocean and in the ocean-atmosphere interface. This network will extend from the near shore areas of America's ocean and Great Lakes coasts (and those of other countries) to the deep ocean areas.

The expansion of ocean observing systems is made possible by innovations in sensor, computer, and communication technologies that have lowered the cost of instrumentation and made it possible to measure more parameters than ever before. The presence of data distribution technologies such as the Internet have also enhanced the value and cost-effectiveness of such systems, because data can now be delivered directly to potential users at very low or no cost.

While the costs of collecting and distributing data from ocean observing technologies have come down on a per unit basis, the creation of the systems of observing technologies still requires significant investments. Those investments will be made by federal, state, and local governments and by other organization in both the private profit and non-profit sectors. The magnitude of investments required raises questions about what the benefits from such systems will be, and whether these will be sufficient to warrant the required investments.

This report presents preliminary information about the magnitude of likely benefits that may accrue from current and expected regional observing systems. The focus is on observing systems to be deployed in the coastal waters of the United States, including both the oceans and the Great Lakes. These observing systems are being formed as a series of regional systems in areas such as the Gulf of Maine, South Atlantic, California, Gulf of Mexico, Pacific Northwest, and Gulf of Alaska. It is anticipated that all of the coastal waters of the United States eventually will be covered by such systems, which will provide nationally consistent measurement of certain parameters (the "national backbone") and also meet particular needs in each region. Output from the network of regional systems will merge to provide an integrated ocean observing system for the United States, which in turn will be a component of the Global Ocean Observing System (GOOS) and the Global Earth Observing System (GEOS). For more information about the network of regional observing systems see www.ocean.us.

The information needed to develop detailed estimates of the economic benefits of ocean observing systems is, for the most part, unavailable at this time. Both the development of the observing systems themselves and the economic information needed to estimate benefits are presently incomplete. The analysis developed here therefore attempts to identify likely magnitude of benefits based on the levels of economic activity potentially affected by the information derived from ocean observations, and to explore the methods that can be used to develop detailed estimates for specific applications in selected regions.

The project proceeded in two phases. In the first phase, a survey of ocean industries and activities (Table 6) was conducted for each of nine regions (Pacific Northwest, California, Gulf of Mexico, Florida, Southern Atlantic coast, Mid Atlantic coast, New England/Gulf of Maine, Alaska, Hawaii, and the Great Lakes) to identify the levels of economic values that might be affected by the availability of improved and expanded information from ocean observing systems. This analysis may be said to identify the "footprint" of economic values. Rough estimates of the potential value of ocean observing system information were made by assuming that small increments of the total value (typically on the order of 1%) could be realized as possible benefits. The second phase of the project developed more formal models of the relationship between ocean observing information and decision making in a selected set of user sectors and regions.

Table 6 Activities affected by observing system information

Recreational Activities	Boating Beach Going Fishing
Transportation	Freight Passenger (Cruise Ships)
Health and Safety	Search and Rescue Oil Spill & Hazard Cleanup Property Damage
Energy	OCS Development Electric Generation Management
Commercial Fishing	

The results of the analysis permit the identification of the order of magnitude of benefits that may be expected on an annual basis from a fully implemented network of regional ocean observing systems (see Table 5 in the Executive Summary or Table 11 below). Our findings suggest that annual benefits to users from the deployment of ocean observing systems are likely to run in the multiple $100s of millions of dollars per year. On a discounted present value basis over time, the benefits from a national investment in such systems are likely to exceed the costs (although these costs, along with the specific design of the system, remain to be determined in detail). This finding is consistent with previous conclusions on the economic benefits of such systems.

The data also indicate that ocean observing systems will have the largest benefits where the information from such systems is used by the largest possible groups. Recreation activities are consistently the highest generators of benefits because of the very large number of people who use beaches, boat on the Great Lakes or in the coastal ocean, or engage in marine recreational fishing. Although the per-user benefits are smaller than those realized by others, the large number of users drive the overall magnitude of potential benefits to substantial sums.

Several important caveats are required in interpreting these results:

- The fact that the benefits from the systems as a whole will exceed the costs does not mean that the benefits will exceed the costs in every individual case. The configuration of observing systems in each region should take into account the priorities of local and regional user groups.

The estimates presented assume:

- Full and successful deployment of existing or near-deployment technologies.
- Cost efficient and effective means of communicating the information derived from the ocean observations to users in a timely manner.
- Users are aware of, and effectively incorporate, the information into their decisions regarding their activities
- In the case of commercial fisheries, additional information concerning the state of the marine environment is relevant to decisions about managed fisheries and (at some point) will permit increases in allowable catches.

Violation of any of these assumptions may reduce the possible or actual benefits to levels below those estimated here.

The following sections of the report discuss the derivation of these estimates. In the next section, the general theory of economic benefits is discussed, along with a general introduction to ocean observing technologies and their information products. The following two sections discuss the details of estimating procedures in the two phases of the project. The final section provides conclusions and recommendations.

Selected individual reports from Phase 2 of the project are included in the Appendix.

The Economic Value of Ocean Observing Information

The information derived from ocean observing systems creates economic value primarily by leading to improved decision making. "Improvement" in this context means reducing the uncertainty associated with actions taken to use marine resources in some way. A large degree of uncertainty surrounds such decisions; and much of this uncertainty exists because the person facing a decision does not have complete information about the relevant state of the ocean at the relevant time. Ocean observing data and the information derived from them reduce this uncertainty, and that reduction in uncertainty is economically valuable. What a decision maker should be willing to pay for this information (the market value of the information) is related to the extent to which it reduces uncertainty, and to the economic resources at stake in the decision.

An Illustrative Example: Beach Closures and Beach Use Decisions

This definition of the value of information provides the elements necessary to estimate the value of ocean observing (or other) information. Consider the following example:

A surfer in Southern California wants to go to the beach for a day's surfing, but her decision to actually go depends on knowing whether the beach is open for swimming and what is the current state of the surf. General weather forecasts are available, as is information about whether the beach is closed or not. (Beach closures usually follow from sewage overflows that may increase the presence of pathogenic bacteria in the water.)

The decision about whether to travel to the beach can be depicted as the interaction between two factors, each of which has two possible outcomes. One is whether the beach is open or closed, and the other, which applies only if the beach is open, is whether the surf conditions are good or bad.

The decision to open or close the beach rests not with the surfer but with public health officials who monitor the presence and location of pathogenic bacteria[3] that could pose a threat to health. The presence of pathogens generally results from overflow of sewage systems from storm events. The location and concentration of the bacteria depends on the location of the sewage outfalls and local tidal and other currents. Based on sampling data and information on currents, the public health official must decide whether to close a beach, post it as potentially hazardous[4], or take no action (leave the beach open). This decision depends on the information from the sampling regimen and predictions of currents, both of which have elements of uncertainty in them. Because of those elements, the public official faces the probability that the decision to close a beach will be in error. The beach may be safe for swimming, but the official closes it (a false positive outcome, since the data indicates a positive result for pathogenic

[3] Actually, current technologies require monitoring of indicator bacteria species rather than the pathogens themselves.
[4] For simplicity, we ignore the effects of "posting" rather than closing a beach.

exposure, leading to a closure decision). Or the beach may actually be unsafe for swimming and kept open in error (a false negative outcome). Since the official is likely to be risk averse, more beaches are likely to be closed when they could be open if uncertainty were reduced.

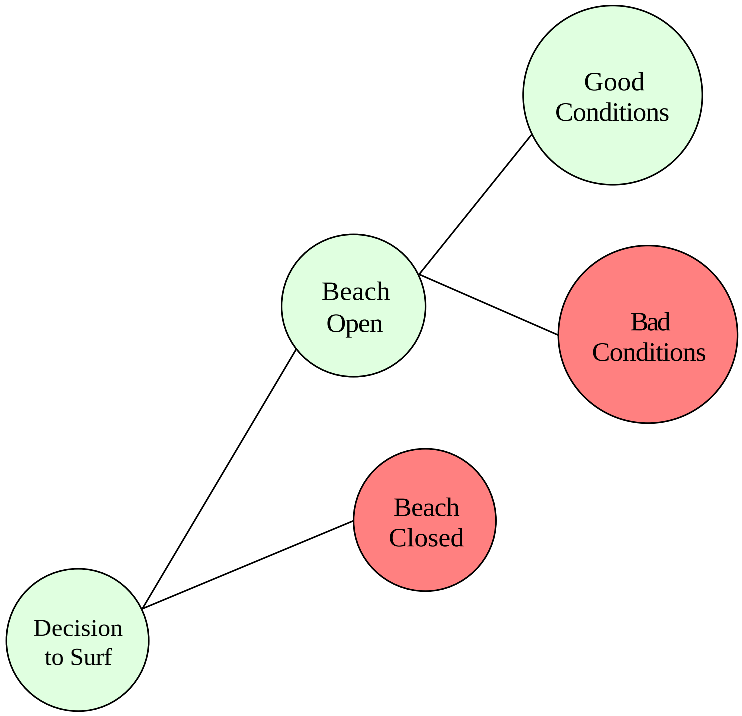

Figure 1 Decision to Surf

The decision to open or close the beach is influenced strongly by knowledge of local conditions in the vicinity of sewage outfalls and storm drains. Ocean observing system can provide fine scale (both temporal and spatial) information on physical, chemical, and biological conditions, and thereby significantly alter the public health official's decision problem. By reducing uncertainty, the length of beaches that must be closed can be reduced, as can the risk of false positives or false negatives. A reduction in false positives increases the amount of time beaches are open for recreation, while a reduction in false negatives decreases the risks to swimmers' and surfers' health and safety.

For the surfer, the question of conditions is a subjective one that depends on wind and wave conditions, which may be unique to the particular destination beach. Again, finer temporal and spatial scale oceanographic and meteorological information provides the information the surfer needs to decide whether to make the trip to the beach.

The economic value at stake in these decisions is the value received from safely enjoying the recreational activity. That value is the amount the surfer would be willing to pay for the opportunity to go surfing less the amount that is actually paid (usually transportation costs). If the surfer makes the trip only to find the beach closed or to find surf conditions too large or too small for enjoyable surfing, then there is a loss of value. It is thus the value to the surfer (or other recreationist) that is at stake in this use of the ocean observing system information. The reduction in uncertainty for the public health official creates value to the extent that it increases the value of recreation to those who use the beach.

This example illustrates the two most fundamental ways that ocean observing systems information is used: to create forecasts of future information on which decisions depend, and to create nowcasts of conditions in real or near-real time. Forecasts are generated when data from observing systems are fed into models of ocean and atmospheric processes to generate the required information. Nowcast information may be direct observation data (wind speed, wave height) or may also be produced by models. These effects are summarized in Table 7.

Table 7 Ocean observing information uses

Type of Information	Type of Data	Type of Information Change
Forecasts	Modeled data	Forecast Accuracy Spatial Scale Temporal Scale Avoiding False Negatives Avoiding False Positives
Nowcasts	Observation data Modeled data	Transportation routing Fishing success

The Economic Value of Information

As the surfer example illustrates, a nowcast or forecast based on ocean observing system data represents information about conditions or phenomena in the ocean. This information has value when it can be used by an individual or an organization to make a better decision – that is, a decision that results in an outcome that is economically superior. The standard economic approach to valuing information requires:

- A description of the information being valued (in this case, typically an improved forecast or nowcast) and of the uncertainty in the phenomena is describes.

- A model of how this information is used to make decisions. Most decisions are made in the face of imperfect information, or uncertainty about how conditions will in fact develop and what the exact outcome will be. Therefore, a basic principle of economic valuation of information is that of "expected values." Expected values are defined as values adjusted for the probability that they will be realized. In the absence of a specific model of decision behavior, it makes sense to assume the decision maker is rational and seeks to maximize benefits. This is described in greater detail below.

- A model of how these decisions affect physical outcomes.

- A model of how physical outcomes can be translated into economic outcomes. The value of a forecast is the difference between the expected value of the outcome of decisions using the forecast, and the expected value of the outcome without the forecast.

A standard Bayesian approach can be used to estimate the value of information contained in a forecast (see Berger 1995).[5] In this model, a decision maker (user of forecasts) must choose among a range of actions represented by A. The outcome of each action depends on a state of nature, *S*, which is not known at the time of the decision but becomes manifest later. The manifestation of *S* is modeled as a random variable with probability density function *f(s).* This probability density function (pdf) describes the probability that the condition (for example, the height of waves at a surfing beach) will lie within a particular range considering only what is known from past observation, and disregarding the new forecast.

Let *B(a,s)* be the consequence (net benefit) to the decision maker of pursuing action *a* if it turns out that *S=s*. The expected net benefit of pursuing action a is then the integral of the product of *B(a,s)* and *f(s)* (see Raiffa 1970):[6]

$$E_o = \int B(a,s) f(s) ds$$

The optimal choice of action without the new forecast (a_0*) is that which produces the maximum expected net benefit (E_0*). If we now provide a useful new forecast to the decision maker, the optimal choice of action and the associated expected net benefit will change. To determine the value of this new forecast, we need to know something about the accuracy of this forecast and something about the frequency with which different conditions arise on average. (For instance, a storm forecast may be more valuable if storms are more frequent than if they only happen once a decade.) How a decision maker revises her estimate of the likelihood of *s* is described by Bayes' Theorem:

$$f(s \mid x) = l(x \mid s) f(s) / p(x)$$

where X is the information in the forecast,
$l(x \mid s)$ is the probability that $X = x$ given $S=s$, and
$p(x)$ is the probability that $X = x$:

$$p(x) = \int l(x \mid s) f(s) ds$$

In simple terms, Bayes' Theorem describes how the decision maker should adjust her prior expectation of the occurrence of event *s* when the forecast says x, taking into account how "good" this forecast tends to be.

The new optimal action given forecast X is found be maximizing

$$E\ (a \mid x) = \int B(a,s) f(s \mid x) ds$$

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[5] Berger, J.O. 1985. *Statistical decision theory and Bayesian analysis*. New York, Springer Verlag.
[6] Raiffa, Howard. 1970. *Decision Analysis: Introductory Lectures on Choices under Uncertainty*. Boston: Addison Wesley.

The outcome of the optimal choice, $E^*(x)$, now depends on x, and the expected value of net benefit is

$$E_X^* = \int E^*(x)p(x)dx$$

Since the decision maker could realize expected benefit E_0^* without the forecast and E_X^* with the forecast, the value of this forecast to the decision maker is $E_X^* - E_0^*$.

In this description of the theoretical underpinning of the value of information, we have not addressed the question of how the net benefit (E) is quantified in each case. We turn to this question in the following section.

Quantifying Economic Value

The information uses outlined in the example of the surfer can be extended to many different types of users. Recreational boaters and those who fish in marine waters have similar needs for fine scale oceanographic and meteorological data to decide when and where to go. Cargo and cruise ships, both sensitive to fuel costs, need real time current information to optimize their routes to and from harbors; and tug/barges and pilot boats are interested in wave height information to avoid hazardous operating conditions. Commercial fishermen have similar needs; and both recreational and commercial fishing success can be improved by knowledge of such parameters as water temperature. Electric generators can optimize fuel generation to minimize costs depending on when the sea breeze sets up on a high demand summer afternoon, while offshore oil and gas operators need information on high velocity loop currents that develop in the Gulf of Mexico and can affect the safety of operations. With accurate surface current information, oil spill response teams can more effectively deploy equipment to where the oil will be and avoid where the oil will not be.

The appropriate measure of economic value in all of these cases is the change in what economists refer to as "social surplus." Social surplus has two components: producer surplus and consumer surplus. Producer surplus in this case is generally the difference between the costs incurred by businesses (including opportunity costs, or reasonable rates of return on inputs to production) and the revenues they realize. Consumer surplus, as in the case of the surfer, is the difference between what one would be willing to pay and what one actually pays for, for example, a recreational experience. "Social surplus" is the sum of producer and consumer surplus. Social surplus is the best single measure of economic benefits because it assures that only value in excess of costs is included, and avoids the artificial inflation of values caused by double counting.

The problem with social surplus and both of its compoents is that they can only be measured using exacting, time-consuming, and costly techniques. Other measures of economic activity (broadly termed "economic impacts"), such as the value of sales at the wholesale or retail level, or value added (the most common example of which is the Gross Domestic Product), are widely available, but measure social surplus only in an imperfect manner.

Studies of economic values from investments such as ocean observing systems thus face a dilemma. The most appropriate measure is the least readily available, while the most available measures are the least appropriate. This is a major reason why estimates of economic benefits from ocean observing activities at this stage of analysis must be considered preliminary and approximate. In this study, most of the estimates have been developed using an indirect and somewhat restrictive approach.

The first step is to identify some of the activities that could be affected by ocean observing systems, and to obtain data from public statistical sources that indicate approximate levels of economic activity in these areas. Simple assumptions are then made about the possible level of benefits from improved information. In most cases, social surplus benefits are assumed to be no more than 1% of total activity values; this is a conservative assumption which reflects the reality that changes in producer and consumer surplus are likely to small relative to aggregate expenditure or sales data.[7]

In order to test methods for more precise estimates of social surplus, case studies were undertaken as a second step in this study. These case studies are shown in Table 8 and discussed in a subsequent section of this report.

Table 8 Phase 2 case studies

User Group	IOOS Information	Region
Energy	Improved Hurricane Forecasts	Gulf of Mexico
Health and Safety	Oil Spill Dispersion Models	Gulf of Mexico
	Search and Rescue	North Atlantic
	Tropical Storm Prediction	Southeast Atlantic coast
Commercial Fishing	Salmon run forecasts	Alaska
	Reduced risk in management decisions	
	Reduced risk in management decisions	
Transportation	Sea state and weather	North Atlantic
Recreation	Beach closure forecasts	Southern California
	Recreational boating conditions forecasts	Great Lakes
	Recreational fishing conditions forecast	Florida

[7] See W.D. Nordhaus (1986), The Value of Information, in R. Krasnow, Ed., *Policy Aspects of Climate Change: Proceedings of a Seminar held in Washington, D.C., March 4, 1986*. Resources for the Future, Washington D.C.

Components of the regional observing systems

Before proceeding to a discussion of economic values, it is necessary to discuss briefly the assumptions used in this study about ocean observing systems. Team members consulted widely with organizations and scientists currently designing and operating observing systems in the coastal waters of the U.S., including the Great Lakes. The team also received valuable guidance from the U.S. Global Ocean Observing Systems Steering Committee.

The technologies comprising ocean observing systems include a wide array of instruments and platforms. They include moored and unmoored buoys, radar, satellite imagery, fixed platforms such as light stations, and platforms of opportunity. Satellites, moored buoys, and radar make up much of the current generation of improvements in ocean observing systems. The data output from these instruments consist of a wide array of parameters, including:

- Wind speed and direction
- Current speed and direction
- Wave height and periodicity
- Air and water temperature at varying heights/depths
- Chemical composition such as salinity
- Biological composition, particularly the density of chlorophyll-A
- Visibility
- Ice (Great Lakes)

The data derived from these observations are distributed directly and indirectly through a variety of means. The data may be fed to forecasting centers operated by the federal government, universities, or private organizations for incorporation into forecast products that are distributed widely through public and private channels including television, newspapers, radio, or the Internet. The data may also be delivered directly to subscribers.

In conducting the analysis for this project, no attempt was made to evaluate the benefits of specific technologies, instruments, platforms, or communication channels. The assumption was made that economically-relevant data would be available in an integrated form and timely manner to users irrespective of observation technology or data dissemination means.

In general, we assumed the sort of data and information streams that are already being delivered by one or more of the ocean observing system organizations. We made no specific assumptions about improvements in data other than that development of the observing technologies and systems would permit a substantial increase in the amount, quality, and usability of information delivered to users. In some cases, such as the development of methods for more rapid and direct measurement of pathogenic bacteria, we have assumed that such developments will take place and be implemented (we include the use of rapid microbial indicators as one type of instrumentation that could produce data on biological pathogens).

In short, we have assumed that when users need information, it will be available and fully utilized (incorporated into relevant decisions). The benefits shown are thus potential benefits from systems being established and expanded, not from the array of observing technologies, platforms, and data distribution in place at the time of this study.

Estimates of Potential Economic Values of Observing Systems

The first phase of analysis of possible economic benefits followed the general methodology set out in Kite-Powell and Colgan (2001)[8]. In that study, estimates of possible benefit levels were made based on activity in the Gulf of Maine and informed by the then-being-established Gulf of Maine Ocean Observing System. Each of the regional studies undertaken in Phase 1 of this project used assumptions similar to those of the Gulf of Maine study.

Data sources for Phase 1 work include those used in the Gulf of Maine study, where available, e.g. national data from the Coast Guard on search and rescue missions and on oil spills. In other cases, new data had become available: for example, the National Survey on Recreation and the Environment (NSRE; http://marineeconomics.noaa.gov/NSRE/) provides national data on coastal and ocean recreational activities for 2000. Phase 1 results also used a number of region-specific studies of economic activity and economic value.

Table 9 shows the summary of findings from Phase 1, grouped by user sectors, users, and region. The table shows the assumed effect of the ocean observing system on the users and the resulting change in economic value. The classification of benefits by value type is also shown.

There are a number of different bases for estimating economic values affected by ocean observing information. In some cases, data are available on willingness to pay (social or producer surplus). These include changes in operating costs for businesses or government agencies, and consumer values for recreational activities. Other data represent changes in gross value such as fisheries landed values, sales of businesses, or regional economic impact (including both direct and indirect regional economic output). In these cases, the economic benefits will be some fraction of these larger values. The result of this mix of value bases is that the results cannot be meaningfully summed.

The use of 1% of economic activity as a short-hand estimate of value of forecast information is based on experience with economic assessments of weather and climate forecasts generally (Nordhaus 1986).[9] In our study, we use this approach because, in most cases, no specific data about user values are available. Studies have not been done to specifically identify how users will actually value the information available to them from ocean observations. Indeed, in many of the regions and for many of the users, the observing system information is only now becoming available, and many users are not yet widely aware of the availability of such information, nor have users (and economists) gained the experience with the data to develop meaningful "willingness to pay" values.

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[8] Kite-Powell, H.L. and C.S. Colgan 2001 *The Potential Economic Benefits of Coastal Ocean Observing Systems: The Gulf of Maine*. Marine Policy Center Woods Hole Oceanographic Institution.
[9] Nordhaus, W.D. 1986. The value of information. In: R. Krasnow, ed., *Policy aspects of climate forecasting*. Proceedings of a Seminar held in Washington, D.C., March 4, 1986. Resources for the Future, Washington.

Table 9 Potential Economic Values of Observing Systems

User Sector	Users	Region	Estimated Economic Effects ($Millions/Year)	Assumed Effects of Observing Systems	Benefit Definition
Recreational Activities	Recreational Fishing	PNW	$3.5	1% increase in activity/expenditures	Willingness to pay
		GoME	$11.0		Increased expenditures
		Mid Atl	$30.0		
		So Atl	$2.0		
		FL	$7.6	5% of boaters/fishers on water avoiding 10% of 45 days of bad weather	Willingness to pay
		GoMex*	$6.7-34.0	1% increase in willingness to pay for an additional day of fishing	
		CA	$2.0	1% increase in activity/expenditures	Increased expenditures
		HI	$6.0		
		GL	$19.5		
	Recreational Boating	CA	$2.0	1% increase in activity/expenditures	Increased expenditures
		GoMex*	$4.0		
		GoME	$1.0		
		Mid Atl	$2.0		
		So Atl	$1.0		
		AK	$6.0		
		HI	$9.0		
		FL	See Rec Fishing		
		GL	$18.0		
		CA	$16.0		
	Beaches	FL	$7.7	1% increase	Beach-related consumer expenditures
			$65.6	1% increase	Increased economic impact
			$1.6	Employee costs avoided in recreation businesses from false negatives	Operating cost savings
			$30.7	Estimated avoided lost sales from false positive storm forecasts	Increased business sales
		GL	$16.5	1% increase in beach day values assuming 21.4% of national beach days are in Great Lakes	Increased visitor daily values
		CA	$94.6	1% increase	Increased expenditures
		CA	$58.0	1% increase	Increased consumer surplus

User Sector	Users	Region	Estimated Economic Effects ($Millions/Year)	Assumed Effects of Observing Systems	Benefit Definition
Transportation	Freight	PNW	$1.2	1% of annual variable costs	Daily cost savings
		GoME	$1.0		
		Mid Atl	$2.0		
		So Atl	$1.0		
		AK	$1.0		
		FL	$55.2		
		GL	$0.6		
		CA	$34.0		
		GoMex*	$30.7	1% of ships save 1 hour of daily operating costs	
	Cruise Ships	PNW	$0.1	1% of annual variable costs	
Health and Safety	Search & Rescue	PNW	$10.0	1% increase in number of lives saved	Value of life-$4m
		GoME	$24.0		
		Mid Atl	$16.0		
		So Atl	$32.0		
		CA	$19.0		
		AK	$12.0		
		HI	$6.0		
		FL	$11.3	5% reduction in search costs to USCG plus 5% reducion in value of life	Costs saved to USCG plus value of lost lives saved
			$22.0	25% reduction in lives lost due to rip currents and other unsafe swimming conditions + avoided costs in surf rescues	Cost saved to local rescue squads plus value of lost lives saved.
		GL	$18.9	1% increase in number of lives saved	Value of life-$4m
		GoMex*	$28.0		
	Oil Spills	PNW	$0.4		Reductions in clean up and compensation costs
		CA	$0.1	1% decline in costs	
		GoMex*	$0.8	1 % increase in oil spill response effectiveness	
	Residential Property	FL	$32.9		Avoided costs from earlier preparation for storms
	Beach Restoration	CA	$1.8	1% of annual expenditures on beach restoration resulting from improved design of projects	Reduced expenditures on beach restoration
Energy	Electric Load Planning	GL	$55.8-111.6		Avoided use of most expensive peak generators

User Sector	Users	Region	Estimated Economic Effects ($Millions / Year)	Assumed Effects of Observing Systems	Benefit Definition
	Oil and Gas Development	GoMex*	$5.1-11.3	Operator savings from avoiding un-necessary evacuations	Operating cost savings
			$9-15	Deep water structure engineering	Increased accuracy of oceanographic risks in design
Commercial Fishing		PNW	$2.7	1% increase in landed values	Increased Landed Values
		GoME	$4.0		
		Mid Atl	$3.0		
		So Atl	$3.0		
		AK	$10.0		
		FL	$2.0		
		GL	$0.2		Total regional economic impact
		CA	$1.2	1% reduction in operating costs	Reduced operating costs
		GoMex*	$2.1	1 additional fishing day in all fisheries	Increased Landed Values

*Gulf of Mexico region excludes the west coast of Florida.

The total magnitude of ocean observing information benefits cannot be accurately estimated without more detailed studies of the specific connections between information and users. The "scoping" of benefits in Table , while useful, is still very rough. To check on these estimates, Phase 2 of this study began to develop more explicit estimates based on models of specific uses in specific regions. These are shown in Table .

The estimates in Phase 2 are based in most cases on more explicit Bayesian models of the type discussed above. Although they follow a similar general structure, each model and its parameters is specific to one activity and regional parameters. To illustrate, we use an example from the estimation of benefits to the oil industry from avoiding false positive hurricane forecasts and unnecessary evacuations of oil rigs, from the work of Kaiser and Pulsipher (see Appendix). In this case the model used is:

$$E_i = (p_h)(P(h))(\Delta r)C$$

where:

- E_i is the expected value of the information from the observing system.
- p_h describes the probability of a hurricane in the Gulf of Mexico, the path of which could be better predicted with ocean observing system information. In this calculation the frequency is assumed to be one hurricane per year.

- P(h) is the number of platforms in the Gulf (here assumed to be 750) multiplied by (h) the proportion of rigs potentially affected by the hurricane. h is assumed to be .13, for a total of 100 potentially affected rigs.

- Δr is the change in forecasting accuracy due to the observing system. In this case, there is an assumed 10-20% reduction in the probability of a false positive forecast that a hurricane will hit a specific set of rigs.

- C is the cost of evacuating a rig, estimated at $10,000 per platform and $50,000 per rig.

The resulting calculation is:

(750)(0.1-0.2)($10,000-$50,000)=$1.25-2.5M

Details on the specific forms for each model and/or supporting information are discussed in the Appendices.

The Phase 2 results in Table 10 are generally of the same order of magnitude as the Phase 1 results in Table 9, which suggests that the range of estimates is reasonable. The available social surplus estimates (the correct measure of economic benefits) range from $187 million to $200 million per year. For a limited array of regions and users, these figures suggest benefits that will likely easily exceed investment and operating costs from the observing systems when scaled up to national levels and when the non-social surplus estimates can be appropriately disaggregated.

There are still weaknesses in the data, however, as gross values are still required for some of the estimates, particularly in the fisheries. One exception is the study by Wellman and Hartley on Alaskan fisheries, which develops estimates of producer surplus changes from more accurate forecasts of fish stock levels in the Bristol Bay salmon fishery. There, the short time of the open fishery and its remoteness from larger settlements places severe risks on companies, which must precisely estimate the amount of labor and capital they will employ each year or risk either cost penalties from overstocking supplies and labor or severe profit penalties from under-stocking them. This case provides a good example of possible benefits where the ocean observing system information could be highly useful to business-critical decision making, although even here the probability of benefits for now must rest on the judgment of those engaged in the fishery. At the same time, this is one of the few examples in the fishery where cost data needed for estimates of changes in producer surplus are available.

Table 10 Phase 2 Estimates of Benefits (social surplus estimates are shown in **bold**)

User Group	IOOS Information	Benefit Source	Low Estimate*	High Estimate*	Region	Measure
Energy	Improved Hurricane Forecasts	Avoided False Positives	**$3.8**	**$7.5**	Gulf of Mexico	Cost savings
Health and Safety	Oil Spill Dispersion Models	Improved spatial/temporal accuracy	**$0.6**	**$1.0**	Gulf of Mexico	Social cost savings
Storm Prediction	Improved Tropical Storm Track and Intensity Forecasts	Improved spatial/temporal accuracy	**$35.6**	**$35.6**	Southeast US Atlantic coast	Cost savings
			$4.0	$4.0	Southeast US Atlantic coast	Tourism revenue
Transportation	Seastate & Visibility Forecasts and Nowcasts	Improved spatial/temporal accuracy	**$0.5**	**$1.0**	Gulf of Maine/Mid Atlantic	Producer surplus
Search and Rescue	Surface currents & winds	Improved spatial/temporal accuracy	**$10.0**	**$15.0**	Gulf of Maine/Mid Atlantic	Producer surplus
			$2.3	**$4.7**	Gulf of Maine/Mid Atlantic	Producer surplus
Commercial Fishing	Salmon run forecasts	Improved capital/labor investments	**$77.0**	**$77.0**	Bristol Bay, Alaska	Producer Surplus
	Reduced risk in management decisions	Increased groundfish catch	$504.0	$504.0	Alaska	Wholesale value
	Reduced risk in management decisions	Increased crab catch	$62.5	$62.5	Alaska	Wholesale value
Recreation	Beach closure forecasts	Decrease in false negatives	**$2.3**	**$3.5**	Southern California	Consumer Surplus
	Beach closure forecasts	Decrease in false negatives	$4.2	$9.3	Southern California	Total Expenditures
	Beach closure forecasts	Decrease in false positives	$1.1	$1.1	Southern California	Total Expenditures
	Recreational boating conditions forecasts	Improved spatial/temporal accuracy	$20.7	$103.5	Great Lakes	Total Expenditures
	Recreational fishing conditions forecast	Improved spatial/temporal accuracy	**$91.2**	**$91.2**	Florida	Consumer Surplus
TOTAL Social Surplus Estimates			**$223.3**	**$236.5**		
TOTAL Other Value Estimates			$596.5	$684.4		

*millions of dollars per year

Estimates of consumer surplus also have potential weaknesses. There are dozens of studies of the economic value of beach recreation, but there is also large variation in the results of what a beach day is worth. Estimates cited in studies used here range from about $7.00 per day to $28.00 per day. The variances in values arise from a number of sources, most importantly the sampling and estimating methodologies used. Some studies use a version of contingent valuation, a method based on surveys of beach users. Others used the travel cost method, in which the costs of travel to beaches are used as a proxy for willingness to pay.

Whatever methods are used, there are difficult issues of substitution, particularly among recreation users. To return to the surfer example: when a beach is closed or is open with unfavorable conditions, the surfer may simply choose another beach. Some benefits from the observing system may be realized if its information is used to make this selection, and so it is unclear whether the benefits are increased from the ability to substitute, or reduced somewhat because the substitute requires higher travel costs (and thus lower potential net benefits). A similar problem of substitution arises for recreational boating and fishing activities.

As a result of these data issues, the estimates presented here are best used to suggest an order of magnitude for potential benefits of ocean observing systems. These are shown in Table 11. The data in this table are for estimated annual potential benefits. For those designated as "10s" of thousands, benefits likely range from $10,000 to $90,000 per year, while those designated in the "100s" benefits likely range from $100,000 to $900,000 per year.

Table 11 Order of Magnitude Estimates of Benefits by Major Users

		Order of magnitude of possible annual benefits (millions of dollars)	**Regions with greatest benefits**
Recreational Activities	Recreational Fishing	100s	Great Lakes, Gulf of Mexico
	Recreational Boating	100s	Great Lakes, Gulf of Mexico, Atlantic
	Beaches/Shore Recreation	100s	Florida, California
Transportation	Transportation-Freight	10s	Florida, Mid Atlantic
	Transportation-Cruise Ships	10s	Florida
Health and Safety	SAR	10s	All
	Oil Spills	10s	All
	Tropical Storm Prediction	10s	Atlantic, Gulf of Mexico
Energy	Electricity Load Planning	10s to 100s	Great Lakes, California, Atlantic
	Ocean Structures	10s	Gulf of Mexico
Commercial Fishing	Commercial Fishing	100s	Alaska, New England

Conclusions and Recommendations

The data in Table 11 suggest that annual benefits to users in the United States from the deployment of coastal ocean observing systems are likely to run in the multiple $100s of millions of dollars per year. On a discounted present value basis over time, the benefits from a national investment in such systems are likely to exceed the costs (though these remain to be quantified carefully). This finding is consistent with previous conclusions on the economic benefits of such systems, such as that of Kite-Powell and Colgan (2001)[10] on the Gulf of Maine.

The data also indicate that ocean observing systems will have the largest benefits where the information from such systems is used by the largest possible groups. Benefits from recreational activities consistently generate the greatest values because of the very large number of people who use beaches, boat on the Great Lakes or in the coastal ocean, or engage in marine recreational fishing. Although the per-user benefits are smaller than those realized in other user sectors, the large number of users drives the overall magnitude of potential benefits to substantial sums.

Several important caveats are required in interpreting the results of this study:

- The fact that the benefits from the systems as a whole will exceed the costs does not mean that the benefits will exceed the costs in every individual case. The configuration of observing systems in each region should take into account the priorities of user local and regional user groups.

The estimates presented assume:

- Full and successful deployment of existing, near-deployment, or reasonably forseeable technologies.

- Cost efficient and effective means of communicating the information derived from the ocean observations to users in a timely manner.

- Users are aware of, and effectively incorporate, the information into their decisions regarding their activities.

- In the case of commercial fisheries, additional information concerning the state of the marine environment is relevant to decisions about managed fisheries and (at some point) will permit increases in allowable catches.

Violation of any of these assumptions may reduce the potential or actual benefits to levels below those estimated here.

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[10] Kite-Powell, H.L. and C.S. Colgan 2001 *The Potential Economic Benefits of Coastal Ocean Observing Systems: The Gulf of Maine*. Marine Policy Center Woods Hole Oceanographic Institution.

Based on these findings, we believe additional research is needed to develop more precise estimates of benefits for specific observing systems, instruments, technologies, and applications. Specifically:

- Operators of regional observing systems should incorporate in their operational plans strategies and activities to measure the economic benefits of their products and services.

Each of the regional observing organizations is expected to undertake some form of regular estimates of benefits.[11] This will require two pieces of information: the number of users and the value placed on the use. Regular evaluation of regional observing system information will require close monitoring of the number of users of different information products, and should include verification not only of the number of users but how they utilize the information.

Valuation of information uses can be accomplished in several ways. For example, user surveys incorporated into websites that distribute observing system information could be an effective tool to measure both the number of users and the values they put on the information. As was done in this study, benefit studies performed for other purposes may be used to infer values associated with observing system information, although careful review of such studies is required to assure both theoretical and empirical appropriateness.

- Investments should be made by federal, state and local governments in more precisely estimating economic benefits and in sharing data and methods for benefits estimation among operators of observing systems. To build on the work presented in this report, a series of coordinated pilot projects should be funded at the regional level to develop, apply, and share with other regions detailed guidelines for benefit tracking and estimation. These pilot projects should focus on one or two prominent user sectors in each region, and cover the major sectors identified in this report.

Those who operate regional observing systems are likely to be experts in the ocean sciences, technologies, and data management, and are unlikely to have substantial expertise in economic benefit evaluation. If the expectation of consistent economic benefits assessment is to be met, regional associations will need access to resources, including personnel, easily implementable methods, standard instruments for surveys, etc. Developing such methodologies on a pilot basis with different regional associations and with the intention that methods, data, etc. thus developed could be transferred nationally to the maximum extent possible, could save a great deal of potential wheel reinvention and greatly improve the quality and quantity of economic benefits data available for future evaluations.

- Consumer surplus benefits should be estimated for all categories of recreational users in various regions of the country. Current estimates of such benefits do not fully account for the possibility of substitution among different recreation resources in different regions and remain subject to considerable methodological variability.

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[11] See "Guidance for the Establishment of Regional Associations and the National Federation of Regional Associations", produced by Ocean.US (www.ocean.us). [The business plan] should describe expected benefits for users and how products and services will be evaluated periodically (e.g., annually) in terms of the timely provision of data, data quality, user satisfaction, system integration, and the achievement of the RA's objectives.

The estimation of consumer and producer surplus presents two different challenges. In general, any estimates of cost savings by public or private organizations that result from observing information can be counted as producer surplus. The case of the Bristol Bay salmon is a good example. While cost data are far from universally available, they are more available than data on consumer surplus, which is the key to measuring benefits in the recreation area. As noted above, these are likely to be the largest generators of total benefits simply because of the number of users.

Because of the variance in consumer surplus methodologies and results, operators of observing systems will need both guidance on the estimation of such benefits and access to existing and new studies. A library of accessible and relevant consumer benefits studies is one way to meet needs. There is also substantial variability in the availability of such studies. Marine recreational fishing tends to be the most intensively studied recreational activity relevant to ocean observing systems in most of the country. Beaches are the next most common, although there is great variability across regions. California and Florida tend to have the most studies, New England the least. Recreational boating value studies are sparse in all regions. Examples of relevant resources include:

- National Survey on Recreation and the Environment (NSRE): http://marineeconomics.noaa.gov/NSRE/
- National Ocean Economics Project (NOEP) Non-Market Value Portal: http://noepdata.csumb.edu/nonmarket/NMmain.html

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Appendices