Cook Inlet Physical Oceanography Workshop Proceedings

NOAA 6-meter NOMAD buoy.

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Edited by Two Crow (AKA J.D. Schumacher, PhD.)

Sponsored by:
Alaska Ocean Observing System.
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REPORT AVAILABILITY

This document is available to the public through: Alaska Ocean Observing System (AOOS) on their web site at www.aoos.org or on the Cook Inlet RCAC web site at www.circac.org.

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EXECUTIVE SUMMARY

Workshop Goals and Outcomes - On 21-22 February 2005, the Cook Inlet Regional Citizens Advisory Council (CIRCAC), Kachemak Bay Research Reserve (KBRR), and the Alaska Ocean Observing System (AOOS) sponsored a workshop in Homer to: (1) share information about current research and monitoring activities in the Cook Inlet region, (2) foster coordination and exchange of information among researchers and other users, and (3) provide recommendations for developing an ocean observing system in Cook Inlet that would meet the needs of diverse user groups. The eighty-seven attendees included researchers, data collectors/monitors, modelers, state and federal agency personnel, fishermen, industry representatives, environmental stewards, and other members of the Cook Inlet user community. The first day featured 19 presentations that provided a basic view of the physical environment and covered topics from ocean observing systems and modeling (for both Cook Inlet and elsewhere) to products generated from observations of the physical environment. On the second day, presentations focused on user needs and the formation of five working groups to address the topic of "Recommendations for Establishing an Ocean Observing System for Cook Inlet." The specific questions used to focus discussions were: What are the issues, problems and concerns?; What products are needed, where and why (prioritize)?; What observations/models are necessary to create the products?, and; What other recommendations or ideas for establishing an Ocean Observing System do users have?

A post-workshop evaluation indicated the meeting was a success in terms of bringing many different users together. An important result from this survey in terms of AOOS's role in Cook Inlet was that priority measurements were identified as bathymetry, winds, sea surface temperature, and currents. The locations within Cook Inlet as having the greatest need are southern (Barren Islands) and western (Kamishak Bay) Cook Inlet. For the most part, these results are consistent with those from the pre-Workshop survey and the presentations. Respondents also identified areas that need improvement, including: participation from more stakeholders/users and more focus on stakeholders' needs. The groups specifically listed as missing were subsistence and Tribal groups and some government agencies (United States Geological Survey and the U.S. Army Corps of Engineers). The results of the workshop will be used as a first step in developing a Cook Inlet component of the AOOS.

Need for ocean observations in Cook Inlet- Cook Inlet is a 370 km long tidal estuary in the northwestern Gulf of Alaska, and with its associated watershed is the center of human population and activities in Alaska. More than 400,000 people presently live in the Cook Inlet area, and each year nearly one million visitors come to enjoy the abundance of wildlife and magnificent scenery. Cook Inlet is among the most productive ecosystems in the world and supports major fisheries and abundant wildlife populations. The more important fisheries include salmon, herring, scallops and halibut. Cook Inlet supports commercial activities vital to the State's economy such as oil and gas development, shipping and other development. At present there are 7 fields producing oil and 15 oil and gas offshore platforms in upper Cook Inlet. Vessel traffic in Cook Inlet carries crude oil, refined oil products, and liquefied natural gas exports year-round. Nikiski is the main industrial base for Alaska; its facilities include the Tesoro refinery, the ConocoPhillips LNG plant, the Agrium nitrogen fertilizer plant, and the BP Exploration Gas to

Liquids test plant. Cargo vessels transiting Cook Inlet to the Port of Anchorage supply 80 percent of Alaska's population and its four largest military bases.

As population growth and development continue, potential impacts to the Cook Inlet ecosystem increase and highlight the need to develop a more comprehensive understanding of how the it functions in order to make sound choices and policies. It has been shown in other areas of the country that such understanding can be significantly enhanced through a permanent network of atmospheric and oceanic observation platforms and simulation models. As the human population and associated development pressure increase, the demand for real time observations and forecasts of environmental conditions from various users groups will also increase (*e.g.* boating safety, oil spill trajectory forecasts, marine weather forecasts, coastal erosion).

SECTION I. BACKGROUND

1.0 INTRODUCTION

The Cook Inlet Regional Citizens Advisory Council, Kachemak Bay Research Reserve and the Alaska Ocean Observing System sponsored a workshop on the physical oceanography of Cook Inlet, on 21-22 February 2005 in Homer, Alaska. The objectives of this workshop were to: (1) share information about current research and monitoring activities in Cook Inlet waters and vicinity, (2) foster coordination and exchange of information among researchers and other users, and (3) develop recommendations for the establishment of an ocean observing system in Cook Inlet. The first two objectives were mainly addressed during the first day's activities while the last objective was the focus of the second day. Recommendations were developed by addressing the question of what informational products and services are needed to aid various sectors of the regional communities, including: mariners, scientists, industry, resource managers, educators, policy makers and other users of the ecosystem and its services (which include resources such as food and fuel as well as spiritual, recreational, educational, and other nonmaterial benefits derived from the ecosystem). We use concepts developed for western Alaska salmon by the National Research Council (2005) to define the term ecosystem as encompassing all components of a system. For Cook Inlet these components include: atmosphere, sea ice, marine and freshwater, terrestrial (*e.g*., coastline, watershed, sources of sediment), chemical, plant and animal (including humans).

Ocean observing systems address needs for informational or 'value added' products that include the integration of various observations (*e.g.*, producing overlays of satellite observations of sea surface height anomaly, sea surface temperature, ocean color as a measure of primary productions and either observed or model simulations of surface currents) and model simulations (*e.g.*, atmospheric pressure and wind fields, ocean currents, wave heights). Numerical models produce three-dimensional simulations of currents and water properties throughout the water column. This provides a comprehensive description of typically poorly measured features important for developing trajectories of planktonic material, pollutants and for developing search and rescue scenarios. Model simulations can hind cast ocean conditions for multiple years, providing insight into interannual variations often difficult to detect from our typically limited observations. Wave height models produce forecasts useful for safety of marine operations and determining coastal and near shore erosion. Models are also important in helping design observational arrays and identifying what information is most needed to improve understanding. Sensitivity studies can show where more observational input is needed. In the case of Cook Inlet, models will be improved by using observations (water properties and currents) across the Barren Islands and in northern Shelikof Strait. We have learned from tidal models whose results differ in phase from tidal stations, that we need much better bathymetry for the model to get the phase and amplitude correct.

Workshop participants included researchers, data collectors/monitors, modelers, fishermen, environmental stewards and other members of the Cook Inlet ecosystem (Appendix A). The workshop consisted of two components: first, the presentation of a series of 21 topics (Appendix B), and second, discussions in five working groups. These groups addressed four questions under the general theme: Recommendations for Establishing an Ocean Observing System for Cook Inlet. The specific questions used to focus discussion were:

- What are the issues, problems and concerns?
- What products are needed, where and why (prioritize)?
- What observations/models are necessary to create the products?
- Other recommendations or ideas for establishing an ocean observing system?

In this document, we first present background material on the sponsors of the Workshop: the Cook Inlet Regional Citizens Advisory Council (CIRCAC), Kachemak Bay Research Reserve (KBRR) and the Alaska Ocean Observing System (AOOS). Following this, we present an ecosystem context for the importance of physical oceanographic measurements and monitoring in this region. Our brief review includes highlights of the physical, chemical and biological (including humans and their activities) components and some ongoing ecosystem issues. This information also provides a context for the long-term need to monitor and understand physical components of the ecosystem (*e.g*., forecasts and impacts of climate change, sustainability of the ecosystem) beyond their own short-term value to users (*e.g*., boating safety, oil spill trajectory forecasts, marine weather forecasts, coastal erosion). Section II of this Proceeding provides summaries of the workshop presentations and Section III contains a discussion of the role of AOOS in Cook Inlet, a synthesis of the results of the working groups' deliberations, a summary of a post-Workshop survey (see APPENDIX F for the complete survey and responses) followed by overall conclusions and recommendations. In addition to information presented in this Proceedings, the visual presentations are available in their entirety on the AOOS website (www.aoos.org) under Meetings/Workshops.

2.0 WORKSHOP SPONSORS

2.1 Cook Inlet Regional Citizens Advisory Council (RCAC) (www.circac.org)

The Cook Inlet RCAC was formed under the Oil Pollution Act of 1990 (OPA 90), when Congress was prompted to pass a comprehensive oil spill prevention and response bill following the *Exxon Valdez* oil spill. Congress envisioned that two Regional Citizen Adivsory Councils established for the Cook Inlet and Prince William Sound regions would be mechanisms for fostering long-term partnerships among industry, government, and the coastal communities of Alaska. Cook Inlet RCAC's mission is to represent the citizens of Cook Inlet in promoting environmentally safe marine transportation and oil facility operations in Cook Inlet. The organization represents citizens who could potentially be impacted by crude oil operations in Cook Inlet and representation on their Board of Directors includes the cities of Kenai, Homer, Seldovia, and Kodiak; the Kodiak Island and Kenai Peninsula Boroughs; the Municipality of Anchorage; the State of Alaska Chamber of Commerce; and Aquaculture, Commercial Fishing, Environmental, Native Alaskan, and Recreational interest groups.

OPA 90 outlines numerous tasks for the Cook Inlet RCAC that address oil spill prevention and response issues and that includes a research and monitoring program. To meet their OPA 90 mandates, Cook Inlet RCAC's environmental monitoring program was designed to detect environmental effects from oil industry operations in Cook Inlet and their research program incorporates studies of wind and water currents and other environmental factors that can affect the ability to prevent, respond to, or clean-up oil spills. Most recently, their research and monitoring efforts have focused on contaminant analyses, intertidal and subtidal water and sediment quality assessments, nearshore biophysical habitat mapping, and physical oceanographic data collections. The organization has a strong commitment to coordinating and leveraging their research efforts with other organizations and making their data accessible to resource agencies, the public and other organizations.

2.2 Kachemak Bay Research Reserve (www.habitat.adfg.state.ak.us/geninfo/kbrr/index.html).

The mission of KBRR is to enhance understanding and appreciation of the Kachemak Bay estuary and adjacent waters to ensure that these ecosystems remain healthy and productive. In 1999, Kachemak Bay was designated as part of the National Estuarine Research Reserve system. KBRR operates as a partnership among the federal government (National Oceanic and Atmospheric Administration), the state government (Alaska Department of Fish & Game) and the local community (Homer, Alaska and surrounding communities). To accomplish its mission, KBRR's objective is to build a long-term coastal ocean observing program, thereby providing the scientific and management communities with consistent long-term data sets. By establishing regional oceanographic boundary conditions, KBRR can provide data for 1) initializing and validating predictive circulation models, 2) establishing a baseline for change detection, and 3) an understanding of the ecological linkages and rates of exchange between coastal and Gulf of Alaska waters.

Kachemak Bay is dependent on external sources (Gulf of Alaska, via transport in the Alaska Coastal Current) for most of the nutrients, phytoplankton, plant spores, invertebrate larvae, and juvenile and adult fishes. The biological productivity and diversity of Kachemak Bay is potentially at risk from pollution, watershed and shoreline development, and the harvesting of plants and animals. The KBRR research program aims to address these issues. In the short term, the focus is to provide the underlying habitat information (circulation and physical structure) needed to support more detailed studies. As these are completed, KBRR is looking towards bringing new techniques and technologies to bear on improving our understanding of the processes and mechanisms regulating biological cycles at different scales of space and time.

2.3 Alaska Ocean Observing System (www.aoos.org)

The Alaska Ocean Observing System's mission is to develop and sustain a network of ocean and marine-related observations, gathered by a multitude of federal, state and private entities, and seamlessly integrated into information products and tools that aid our understanding of the status of Alaska's marine ecosystem and allow stakeholders to make better decisions about their use of the marine environment. Stakeholders include commercial, subsistence and sport fishermen, oil and gas developers, shipping interests, Alaska Native communities, resource managers, environmental entities, and researchers. Products from AOOS will improve our ability to rapidly detect changes in Alaska's marine ecosystems, as well as to forecast scenarios of future changes and their consequences (*e.g.*, risk assessments) for the public good. To achieve its mission, the following objectives have been established: (1) to serve as Alaska's regional node as part of a national network of observing systems, (2) to systematically deliver both real-time and longer-term information about status and trends in Alaska's marine ecosystems, including winds, waves, currents, temperature, and other ocean conditions, (3) to provide public access to cost-free data and informational products (*e.g.*, model simulations, nowcasts and forecasts) regarding ecosystem conditions, and (4) to develop and supply informational products tailored to meet the needs of mariners, pilots, scientists, industry, resource managers, educators, and other users of marine resources.

Data and products from AOOS can be applied to both short and long-term issues. Short-term issues include: response to hazardous materials (including oil) spills, safety of marine navigation and operations, search and rescue. New information products developed through AOOS will permit growth of a more comprehensive understanding of ecosystem function, form and dynamics, thereby addressing longer-term concerns (climate change and its impacts, *e.g*., on sea ice characteristics, ecosystem productivity including fisheries, and coastal erosion). The new products will give resource managers and local, state and federal policy makers the best information available to make informed decisions.

AOOS is like a web interconnecting existing monitoring activities, enhancing selected monitoring activities and developing/deploying new observational tools to fill in the gaps not addressed by existing agency programs or missions. AOOS itself is comprised of partners including government agencies (*e.g*., National Oceanic and Atmospheric Administration, Department of Interior, U.S. Coast Guard); an academic institution (University of Alaska including School of Fisheries and Ocean Sciences and the Alaska Sea Grant Program); research organizations (*e.g*., the North Pacific Research Board, the Alaska SeaLife Center, the Prince William Sound Science Center, the Arctic Research Commission, and the Barrow Arctic Science Consortium); and industry groups, including fisheries and marine navigation services.

3.0 NEED FOR OCEAN OBSERVATIONS

Historically, government agencies have had the responsibility of gathering observations of the physical and biological environment, but the agencies have lacked sufficient funding and/or discretion to mount comprehensive long-term collection efforts or tailor data collection to meet practical regional user needs. Hence, many observation and information gaps exist in Alaskan waters. As uses of the marine environment increase, the broader ecosystem-based decisions expected in the future will require more systematic monitoring, coordinated databases and development of informational products. This theme was emphasized in two recent reports on the status of our oceans. The PEW Report (2003) includes the following recommendation: Develop and implement a comprehensive national ocean research and monitoring strategy. The USCOP Report (2004) focused attention on the need for informational products: "Ocean managers and policy makers need comprehensive scientific information about the ocean and its environment to make wise decisions. Increased knowledge will help achieve sustainable resource use, economic development, and conservation of the ocean's biological diversity and natural beauty… Significantly increased support for research in ocean-related natural and social sciences will be key to fostering a new era of science-based ecosystem-based management."

AOOS is nested within two larger-scale monitoring activities: At the scale of the global ocean is an international collaboration to develop a global observing system (the Global Ocean Observing

System, GOOS) designed to improve forecasts and assessments of weather, climate and ocean states, as well as to provide ocean information essential for regional observing systems like AOOS. At the national level, the Integrated Ocean Observing System (IOOS) is a coordinated national network of observations, data management and analyses that systematically acquires and disseminates data and information on past, present and future states of the oceans within the nation's Exclusive Economic Zone (EEZ or 200-mile limit). The mission statement developed by IOOS includes seven objectives:

- Improve the safety and efficiency of marine operations
- More effectively mitigate the effects of natural hazards
- Improve predictions of climate change and its effects on coastal populations
- Improve national security
- Reduce public health risks
- More effectively protect and restore healthy coastal marine ecosystems, and
- Enable the sustained use of marine resources.

While these objectives also apply to AOOS, Alaska users must help prioritize them for the Alaska regional system, which will include a Cook Inlet region ocean observing system.

4.0 ENVIRONMENTAL SETTING

The Cook Inlet marine ecosystem is a semi-enclosed tidal estuary, extending roughly 370 km southwest from Knik and Turnagain Arms to Kamishak and Kachemak Bays (Figure 1). The inlet has marine connections with Shelikof Strait and the Gulf of Alaska (GOA) and freshwater input from several large rivers (Muench *et al.* 1978).

The Cook Inlet marine ecosystem is forced by external factors (*e.g.*, Aleutian Low pressure system, Alaska Coastal Current, and river inflow of freshwater and sediments), which are modified by topography to generate regional wind, current and sediment features. These, in turn, force biological productivity, which is also impacted by human activities (*e.g.*, harvest and habitat degradation). Figure 2 shows this changing interconnected physical/chemical/biological system.

The three rectangles represent the global ecosystem with its ever-changing climatological (atmosphere, ocean and land) and biological elements. These all provide forcing external to the Cook Inlet ecosystem. The gold circle represents the Cook Inlet ecosystem. At the spatial scale of Cook Inlet, external forcing is modified to generate regional winds, currents (both tidal and those related to the Alaska Coastal Current), as well as altering regional ecosystem dynamics. Regional winds and river discharge (both considered internal forcing) also result in regional currents. The components (*e.g.*, atmospheric, oceanographic, biological) of the regional ecosystem interact with each other on various time and space scales. Humans and their institutions occupy a subset of the interconnected ecosystem. Human forcing affects the ecosystem directly through harvests and changes to habitat, and indirectly by altering global climate, ocean carrying capacity and the state of both marine and riverine systems. Management has the responsibility to mitigate human impacts so that a sustainable ecosystem will be present now and for future generations. The arrows represent the flow of energy/impacts among the components of the global ecosystem.

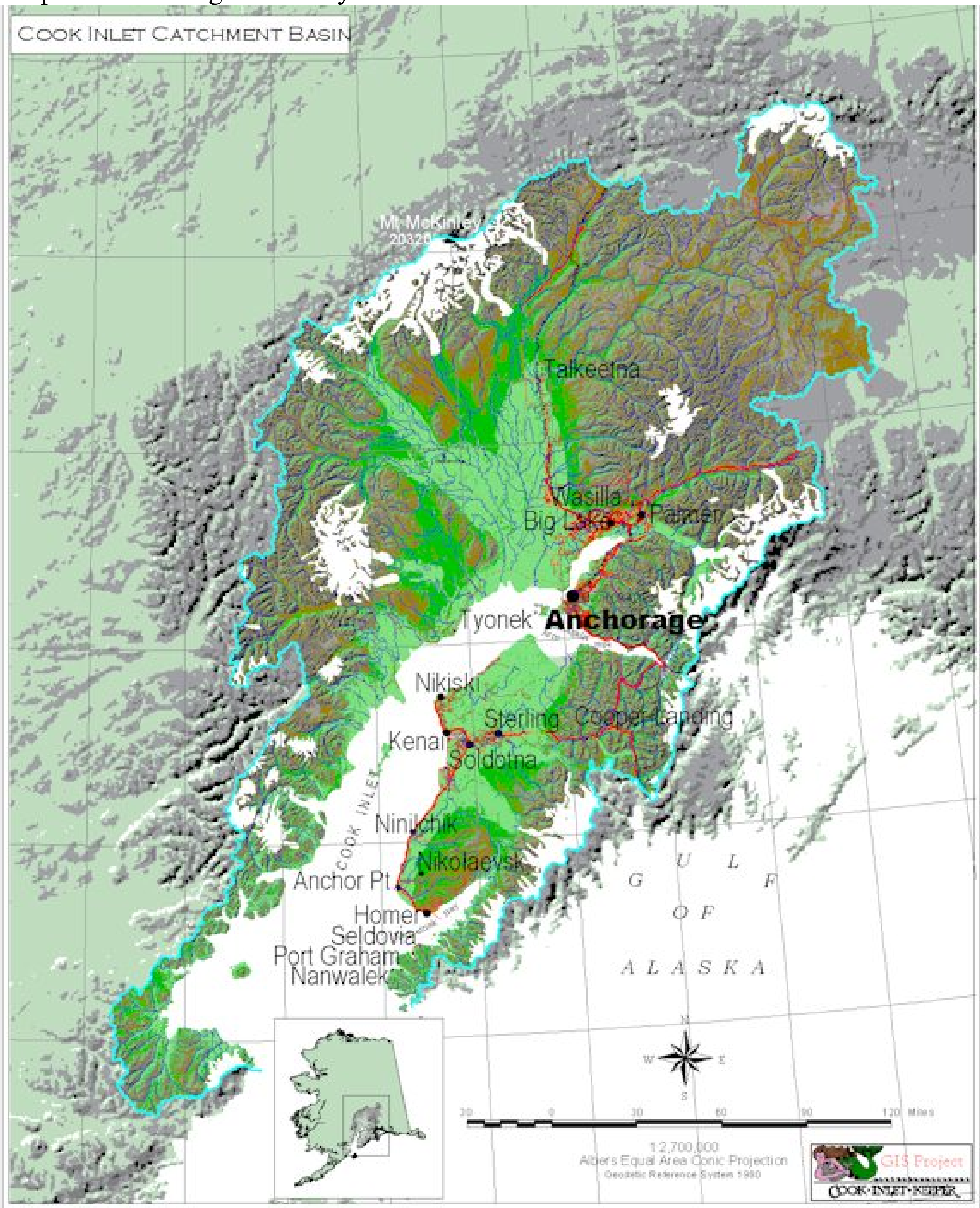

Figure 1. The Cook Inlet watershed extends from Mt. McKinley in the north to the Gulf of Alaska along the southcentral coast of Alaska. (From: Cook Inletkeeper www.inletkeeper.org). Note: the drainage area is within the blue line.

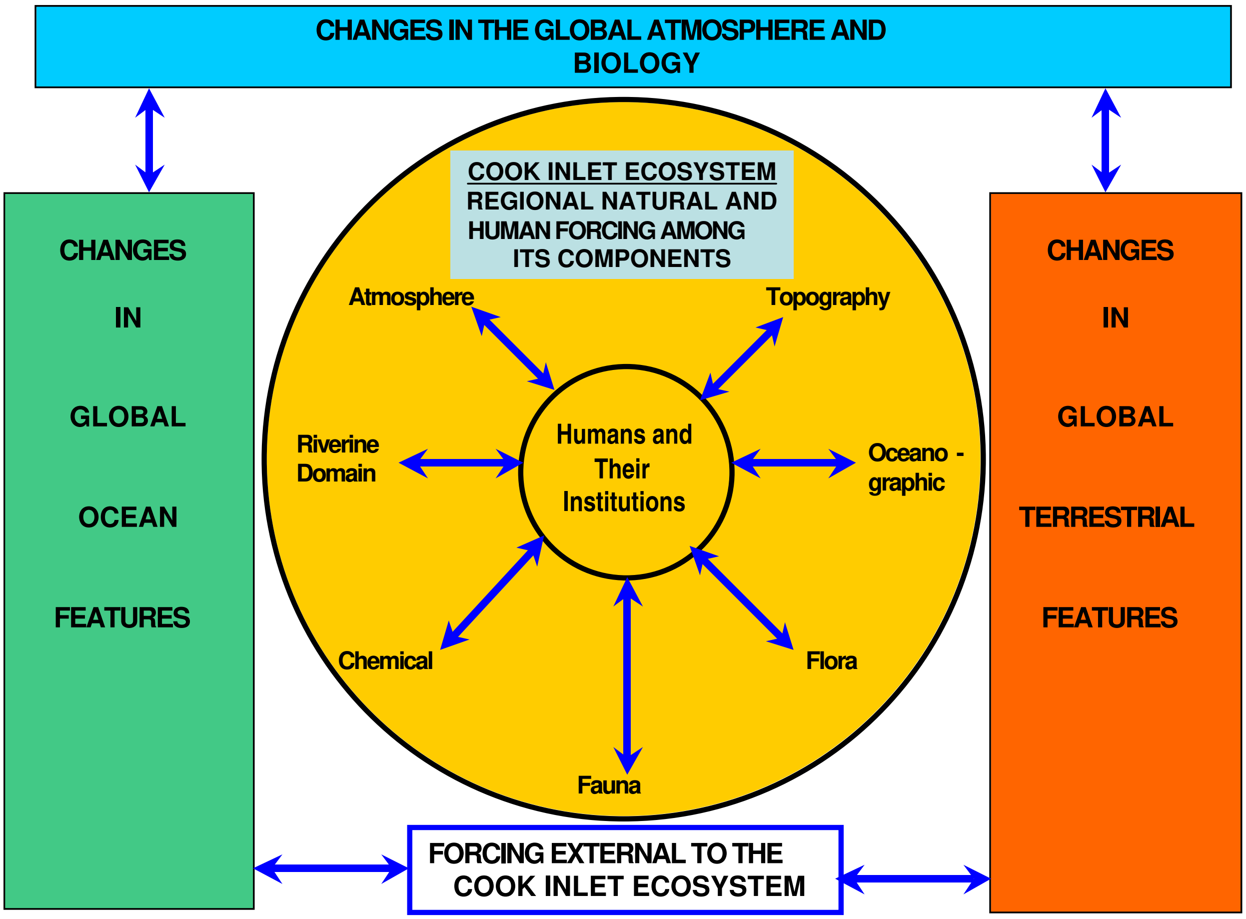

Figure 2. Changes in global land, air, sea and biology force regional phenomena. The components within the Cook Inlet ecosystem are interrelated with each other and impacted by human forcing. The net result is the Cook Inlet ecosystem, as it exists at present.

The natural resources provided by the ecosystem are better described by the term "ecosystem services." This term is increasingly appearing in ecological and other literature (*e.g.*, Anon 2003; Palmer *et al.* 2004; Ehrlich and Kennedy, 2005; Schumacher and Kruse, in press) in place of and more inclusive than 'natural resources.' Ecosystem services are defined as food, fuels and fibers as well as spiritual, recreational, educational, and other nonmaterial benefits derived from the ecosystem. Both recent reports on the status of our Nation's oceans (USCOP 2004; PEW 2003) support ecosystem-based management, with the goal of sustainable ecosystem services and ecosystem-wide health (which includes human interests). The USCOP (2004) identifies as a guiding principle that: "… U.S. ocean and coastal resources should be managed to reflect the relationships among all ecosystem components, including humans and nonhuman species and the environments in which they live. Applying this principle will require defining relevant geographic management areas based on ecosystem, rather than political, boundaries." The Pew Commission emphasized the connection between healthy ecosystems and commercial interests in its Executive Summary: "The fundamental conclusion of the Pew Oceans Commission is that this nation needs to ensure healthy, productive, and resilient marine ecosystems for present and future generations. In the long term, economic sustainability depends on ecological sustainability." Recognizing the necessity of maintaining ecosystem services, and that they are more inclusive (*e.g*., including nonmaterial benefits) than traditional commercial "resources," is also consistent with the objectives of the NOAA Fisheries: "As a steward, NOAA Fisheries conserves, protects and manages living marine resources in a way that ensures their continuation as functioning components of marine ecosystems, affords economic opportunities, and enhances the quality of life for the American public."

While the recent reports focused on the longer-term concerns that would be addressed by products from an ocean observing system, the real-time acquisition of data and short-term generation of informational products made possible by such a system would also address such real-time issues as safety of marine operations and response to hazardous material spills. Sustainable use of ecosystem services is unlikely without a more comprehensive understanding of the capacity of ecosystems to provide these services (Gunderson and Holling 2002), together with the development of ecologically sound management policies. To find solutions to the challenges of sustainability of services in the face of continuing development and human population growth that exist in the Cook Inlet ecosystem, a better knowledge of ecosystem function and form based on systematic monitoring is essential.

4.1 Physical Oceanographic Environment

The physical oceanography of Cook Inlet has not been as well studied as that of the northern Gulf of Alaska or Shelikof Strait. Most of the relevant reviewed literature deals with aspects of the Alaska Coastal Current (ACC), particularly flow west of Prince William Sound along the Kenai Peninsula and through Shelikof Strait (*e.g*., Schumacher and Reed 1980; Stabeno *et al*. 1995; Royer 1998, 2005; Stabeno *et al*. 2004). Reed and Schumacher (1986), Muench *et al.* (1978), and Moore *et al*. (2000), however, do address physical oceanography within Cook Inlet itself. Other 'gray' literature specific to Cook Inlet exists, including several NOAA (Muench and Schumacher, 1980; Muench *et al*. 1981), MMS (*e.g*., Johnson *et al.* 2000; Haley *et al*. 2000; MMS Volume I, 2003) and other documents regarding the region's physical oceanography (*e.g.,* Gatto 1976; Burbank 1977).

An examination of the physical oceanography of Cook Inlet begins with a brief discussion of the meteorology. A comprehensive compendium of information regarding all the components of the Cook Inlet ecosystem is provided in MMS EIS (2003). Wilson and Overland (1986), Royer (1998), Stabeno *et al*. (2004) and Rodionov *et al.* (2005) provide summaries of the meteorology of the Gulf of Alaska. Storms typically originate in the western Pacific and move eastward along the Aleutian Islands into the northern Gulf of Alaska. Because it is ringed by mountainous terrain, storm movement tends to end in the Gulf of Alaska; the Gulf of Alaska has been called a "graveyard" for storms, but occasionally cyclogenesis (the birth of a storm) can occur there (Rodionov *et al.* 2005). These storms typically have lives of a few days, but their frequency and intensity vary on time scales of seasonal to decadal. The terrain interacts with the storms and Stabeno *et al*. (2004) note that this is particularly important through its impact on alongshore winds (and hence Ekman transport or upwelling along the coast) and precipitation (and hence the vertical structure or baroclinicity of the upper coastal waters). A mean seasonal cycle exists in the coastal winds; summer (June-August) has intermittent upwelling favorable wind while the longer cool season (October-March) has systematically downwelling-favorable winds (Wilson and Overland 1986).

On the spatial scale of Cook Inlet, the mountainous terrain (Figure 1) again plays an important role by causing local modifications to the larger scale atmospheric pressure and wind fields. Mountains are present on the east and west with only small breaks surrounding Cook Inlet and Shelikof Strait. On the western side of Cook Inlet are the Alaska and Aleutian (Alaska Peninsula) ranges; on the eastern side are the Talkeetna, Chugach, and Kenai mountains and the Kodiak and Afognak Islands lesser ranges. The nearly continuous mountains of the Alaska Peninsula act as a barrier to winds broken only by Kamishak Gap, a low-lying area between Iliamna Lake and Kamishak Bay. Kennedy and Stevenson Entrances in lower Cook Inlet are major breaks in the eastern mountains from the Kenai Peninsula to the Kodiak-Afognak Islands Group. The mountainous borders not only block low-level airflow east and west but also form airflow channels north and south (*i.e.*, a location for gap winds). There are two main types of winds resulting from the terrain: gap winds and drainage winds (MMS EIS 2003). A gap wind is a wind flowing from areas of high-pressure systems to areas of low-pressure systems along the sea-level channel (Overland and Walter 1981). Gap winds are observed over Cook Inlet in two wind channels that constrain low-level winds: the north-south channel formed by Cook Inlet, and the east-west channel formed by Kamishak Gap, Kamishak Bay, and Kennedy and Stevenson entrances (Macklin *et al*. 1990). Mountain-gap winds differ from sea-level channel-gap winds because of the gravitational acceleration associated with the seaward-sloping terrain (Macklin *et al*. 1990). Alaska's large-scale weather patterns produce mountain-gap winds blowing from the western Alaska Peninsula to the eastern side through passes, valleys, and gaps. For example, in April 2005 a strong low (967 MB) and its associated front moved into the Kuskokwim Delta (National Climatic Data Center, 2005). One result reported was that winds gusted to 90 mph along the upper hillside of Anchorage with similar speeds along Turnagain Arm. Mountain-gap winds also occur through Kamishak Gap throughout the year but are most prevalent in the winter, occurring several times a month (Macklin *et al*. 1990). Mountain-gap winds can have velocities greater than 51 meters per second (99.2 knots) over the Barren Islands (Macklin 1988). Pegau (this Proceedings) presents an excellent example of a Kamishak Gap wind and some smaller-scale wind events, as shown by a Synthetic Aperture Radar (SAR) image (his Figure 3).

Small-scale features of the wind field such as drainage winds (cold air mass moving downslope) and wake flow (around topographic features) also exist in the Cook Inlet region. Drainage winds occur along Cook Inlet's mountainous southeastern and western coasts draining from glaciated valleys (Macklin 1979). Kachemak Bay exhibits drainage winds, because several Kenai Peninsula glaciers terminate at its eastern end (Reynolds *et al.* 1979). In winter, cold continental air drains from the mountainous regions surrounding northern Cook Inlet. Drainage-wind velocities can exceed 50 meters per second (~97 knots) and extend for tens of kilometers offshore (Reynolds *et al.* 1981). Wind flow around Mount Augustine has been characterized as wake flow with typical velocities from 3-8 meters per second (~6 -16 knots) (Macklin *et al.* 1980).

Mountain-gap winds create williwaws and waterspouts that can create hazardous conditions for mariners and aviators (MMS EIS 2003). Winds generated by small-scale features also can create conditions that do not appear on standard National Weather Service products, but can lead to conditions that are important for safety of marine operations and the distribution of oil spills. Olsson and Liu (this Proceedings) note that the relative paucity of direct wind observations in Cook Inlet makes quantification of small-scale phenomena unfeasible, although they directly impact mariners and aviators traversing the region at any given time. Their approach to addressing this challenge is to gain a better understanding of such features by developing models and generating simulations, while also providing forecasts.

The dominant currents within Cook Inlet are tidal, which are forced externally. Two unequal high and low tides occur per tidal day (24 hours, 50 minutes), with the mean range (height) increasing northward. The mean diurnal tidal range varies from roughly 6 m (19 ft) at Homer to about 9.5 m (30 ft) at Anchorage (Moore *et al.* 2000), with a mean value of 5.8 m on the east side and 5.1 m on the west side (*e.g.*, MMS EIS 2003). The semidiurnal tidal wave enters lower Cook Inlet through both Kennedy and Stevenson Entrances and from the south end of Shelikof Strait. The result is an anti-node (minimal changes in tidal height/currents) in northern Shelikof Strait (Muench *et al.* 1981). Tidal currents in lower Cook Inlet are of the mixed type with the semidiurnal components (mainly the M2 and S2) dominant, and having speeds in excess of 150 cm/sec (~ 3 knots). As with the tidal heights, tidal speeds are generally stronger in the western than the eastern portions of lower Cook Inlet (Muench *et al.* 1981) and increase northward. The diurnal tidal currents (mainly K1) are more spatially uniform and slower than the semidiurnal currents. Moore *et al.* (2000) note that currents may exceed 335 cm/sec (6.5 knots) between East and West Forelands (Gatto 1976), and speeds of up to 618 cm/sec (12 knots) have been reported near Kalgin Island (Moore *et al.* 2000).

One result of the strong tidal currents interacting with bathymetry is the generation of robust mixing energy (a function of the cube of the tidal speed) throughout the inlet as well as a location specific system of tidal rips (western, mid-channel and eastern) and accompanying convergence zones (Whitney, this Proceedings; Okkonen, this Proceedings). Convergence zones in rip locations have been mapped from a combination of satellite imagery and conversations with local anglers (Whitney, this Proceedings; Haley *et al.* 2000). Tides are faster where the channel is deeper and are accompanied by laterally sheared currents over bathymetric slopes. Convergence zones (fronts) are also observed to occur over bathymetric slopes, where the positions and strengths of these fronts vary with the semidiurnal tide (Okkonen, this Proceedings). These convergent zones are locations of debris accumulation. Although the number of recorded observations is small, downward velocities as high as 10 cm/sec have been measured, which are fast enough to temporarily and locally overcome the buoyancy of surface debris or oil (Johnson *et al.* 2000). These features also organize living planktonic material, which can make them regions where marine birds and fish forage.

External forcing is also provided by the Alaska Coastal Current (ACC), which is driven by a combination of the buoyancy from extensive addition of freshwater and winds (Stabeno *et al.* 1995; Royer 1998). Changes in basin scale climate influence water properties in the ACC. Royer (2005) reports that since 1970 a general warming and freshening of the upper layer (0-100 m) of the water column (0.9^{o} C and a salinity decrease of ~ 0.06), while in the lower water column (100-250 m), temperature increased 0.8^{o} C and salinity increased ~ 0.04. Hence, stratification has been increasing, accompanied by a tendency for reduced downwelling and increased freshwater discharge. Both of these influences will tend to further increase the coastal stratification (Royer 2005; Weingartner *et al.* 2005).

The pathway of the ACC is well replicated in trajectories of satellite-tracked drifters that generally flow westward along the Kenai Peninsula and enter the Cook Inlet ecosystem via Kennedy Entrance. During the summer, some ACC water flows southwestward along the seaward side of Kodiak Island (Ladd, this Proceedings). Once in lower Cook Inlet, some of the drifters traveled as far north as ~ 60 N (~30 kilometer north of Anchor Point) and one passed close to the mouth of Kachemak Bay. Many schematics exist of the general circulation in lower Cook Inlet (*e.g.*, Muench *et al.* 1978; MMS EIS 2003; Fig. 3 below). While there is general agreement regarding the in-and-outflow of the ACC that provides a southern boundary to the ecosystem, and the existence of outflow along the western side of the inlet resulting from freshwater inflow, there is less agreement regarding the number of eddies off Kachemak Bay. In Figure 3 a counter-rotating eddy pair is indicated with the larger eddy rotating in a clockwise sense. The MMS EIS (2003) schematic has a single clockwise rotating eddy located

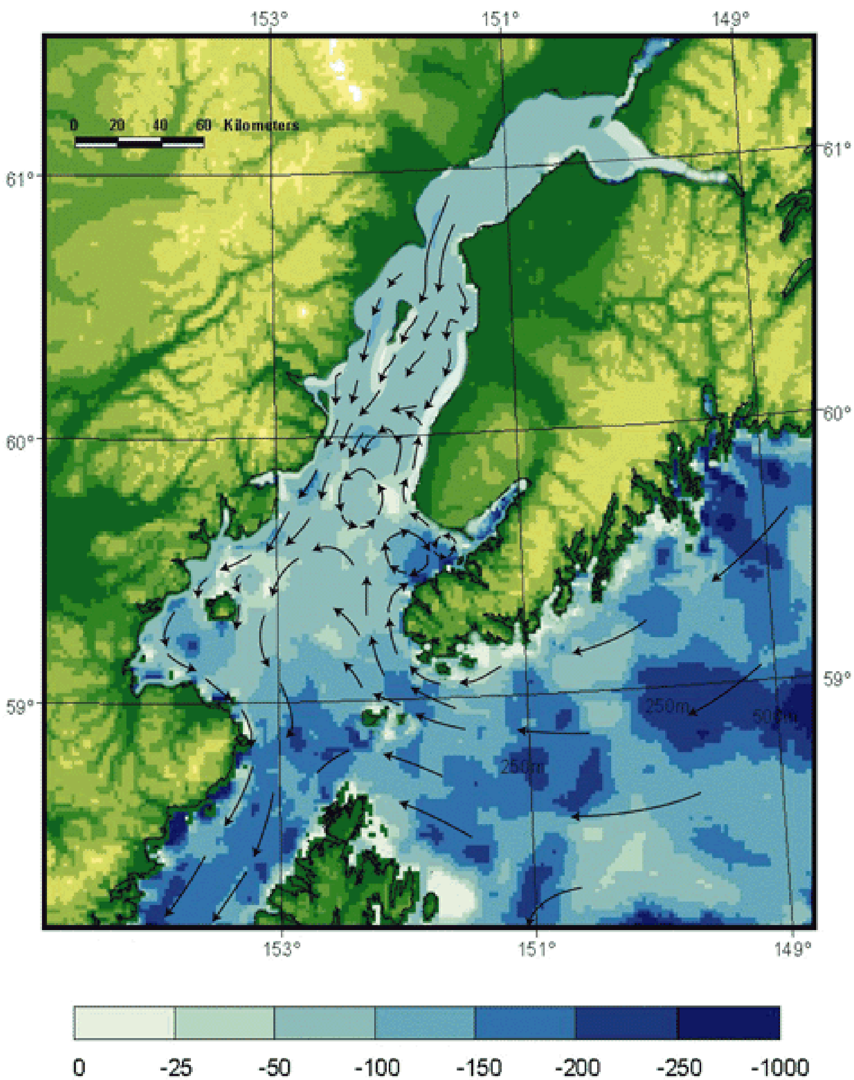

Figure 3. The general non-tidal circulation in Cook Inlet and bathymetry. The color scale is depths in meters. (From: www.absc.usgs.gov/research/seabird_foragefish/maps/index.html)

approximately where the larger eddy is in Figure 3, which agrees with Muench *et al.* (1978, 1981). At present, CIRCAC and MMS are sponsoring a series of hydrographic surveys in Lower Cook Inlet to look at changes in boundary conditions (Pegau *et al*., this Proceedings).

Internal forcing for currents results from the regional winds and river discharge. Regional winds can be a factor causing surface currents and are a particularly important factor to the transport of hazardous materials such as hydrocarbon compounds. The total surface drift current is the sum of wind- and wave-induced components and decreases gradually with increasing fetch, approaching 3.1% of wind velocity at long fetches (Wu 1983). The wind drift current depends upon the speed of the wind, its constancy, the length of time it has blown, and other factors. For extreme small-scale wind features (50 m/sec), the surface current speeds would be ~150 cm/sec; for more typical winds (~25 knots, or ~13 m/sec) the wind drift current would be ~39 cm/sec. In some regions of Cook Inlet, a wind drift current in this range would dominate surface flow. For many regions of Cook Inlet, however, the tidal currents are equal to or substantially greater than these values. Whitney (this Proceedings) states "Oil spilled off the mouth of Kenai River tends to be more controlled by currents (tidal) and rip zones than by winds (less than around 20 to 25 knots)." At certain times and in particular regions of Cook Inlet, however, gap and other small-scale winds might be the dominant forcing factor for surface currents.

As is the case with most of the factors that influence the Cook Inlet ecosystem, freshwater input is dominated by an annual signal. Most of the gauged river flow (Knik, Matanuska, Susitna, Talkeetna and Skwentna Rivers) enters upper Cook Inlet, with the exception of the Kenai River, which enters into the lower section of the inlet. Information on streamflow in all available gauged rivers can be obtained through the NOAA web site (http://nowcoast.noaa.gov/). Muench *et al.* (1978) note that most freshwater input occurs during the summer months (April-October) due to snowmelt and later rainfall (typically September-October). In upper Cook Inlet, vigorous tidal stirring results in the fresh water being vertically well mixed with the marine waters. The southerly flow that occupies roughly the western third of the lower inlet (Figure 3) consists mainly of water containing river input from upper Cook Inlet (Muench *et al.* 1978). As noted by Okkonen (this Proceedings), the presence of freshwater promotes density-driven currents (regional or internal forcing) that alter the phase and duration of tidal currents across the section. This influence on tides has been noted in other estuarine regions, *e.g.*, the southern Strait of Georgia (Schumacher *et al.* 1976).

The instantaneous current is a function of the sum of all the external and internal forcing factors. Figure 3 was developed mainly using moored current observations (*e.g.*, Muench *et al.* 1981) and inferences from hydrographic data. More recently (Johnson, this Proceedings), satellite tracked drifters (drouged within 10 m of the surface) have been deployed within Cook Inlet proper, typically in the area south of the Forelands and northeast of Kalgin Island. The resulting trajectories (Johnson, this Proceedings) support the location and importance of the west and central tidal rips and are generally consistent with flow in Figure 3. They do not, however, indicate eddies off Kachemak Bay nor do any of the trajectories show flow out of the inlet west of Augustine Island.

Although none of the presentations included discussions of sea ice in Cook Inlet, it is a prominent feature with implications for hazardous material spills and ecosystem dynamics. Pack ice, shorefast ice, stamukhi (*i.e.*, layered “ice-cakes” formed by stacking of ice floes on shorefast ice over multiple high tides), and estuarine/river ice are the four ice types found in Cook Inlet. Detailed information regarding sea ice for Cook Inlet is available in an atlas produced by Mulherin *et al.* (2001), although it has not been updated since publication. The amount of sea ice varies annually. In general, sea ice forms in October to November, increases from October to February from the West Foreland to Cape Douglas, and melts in March to April (MMS EIS 2003). The conditions governing ice formation, movement, and decay in Cook Inlet are complex and dynamic. Because of the large tidal range, most of the ice in Cook Inlet remains broken. Tidal currents cause ice to converge in one area while diverging in another. Temperature, tide, and wind variations create a continuously changing distribution of floe sizes and ice thicknesses. Sea ice formation is controlled in upper Cook Inlet primarily by air temperature and in lower Cook Inlet by the temperature and inflow rate of the Alaska Coastal Current (Poole and Hufford 1982). A sea ice model developed by the U.S. Army Corps of Engineers exists that simulates ice motion in Cook Inlet (Hopkins *et al.* 2001). The model is composed of tens of thousands of discrete floes that move in response to wind and hydrodynamic forcing; simulations can be viewed on the web at (www.crrel.usace.army.mil/sid/hopkin_files/Seaice/Cook_inlet.htm).

4.2 Ecosystem Issues

The mission statements for all three of the Workshop sponsors are more far-reaching than simply to understand the physical oceanography of Cook Inlet; to accomplish their missions, more comprehensive knowledge of the ecosystem must be achieved. The following ecosystem issues are presented to provide further contextual frameworks for physical oceanography.

Cook Inlet's marine environment has been noted by scientists as among the most productive ecosystems in the world (Cook Inlet Keeper 2004) and is the site of an exceedingly productive fishery (Muench *et al.* 1978). The Cook Inlet area supports recreational, commercial, subsistence, and personal use fisheries. Among the major fisheries are five species of salmon, herring, scallops and halibut; several groundfish (Sablefish, Ling Cod) have also been harvested. ADF&G 2004 guideline harvest levels for some of the major species include: salmon 46,101 lb. (mainly sockeye and pink: total landed value $21.9 million); weathervane scallop 20,000 lb.; Pacific Cod 2.37 million lb.; rockfish 150,000 lb.; hard shell clams 24,000 lb (from ADF&G web site). Concerns exist regarding the sustainability of some fish populations. Some fisheries, have been closed at various times (Orensanz *et al.* 1998), *e.g.*, Kachemak Bay Tanner crab commercial fishery closed in 1995; Cook Inlet Tanner crab commercial fishery closed in 1995-1996; Cook Inlet shrimp commercial fishery closed in 1987. There are also concerns regarding the interaction of hatchery salmon versus wild salmon. These include reduced production of wild fish resulting from competition during all life history stages, loss of genetic diversity in wild salmon, and over harvest of wild salmon during fishing operations targeting hatchery salmon. Sport fishing has created local environmental damage in some areas by concentrating activity in fragile areas. One area of major concern is the Kenai River, famous for its king and sockeye sport fishing and impacts have been evaluated along the Kenai River in 1994 (ADF&G 1994) to provide a baseline for future assessments. Sport fishing can also contribute to localized depletion of fish stocks.

Some issues exist regarding marine mammals, including Steller sea lions (listed as endangered under the Endangered Species Act) and Beluga whales (listed as depleted under the Marine Mammal Protection Act). Because of their endangered status, there is no transit permitted within 3 nm of the two Steller rookeries (Outer and Sugarloaf Islands) and waters within 10 nm are closed to fishing for groundfish with pot or longline gear. Between 2000 and 2002, the population on the rookery at Sugarloaf Island increased by nearly 10% (Sease and Gudmundson 2002). The Cook Inlet stock of Beluga whales is a small isolated stock that is especially vulnerable to deleterious impacts from large or persistent harvests or changes to their environment (Moore *et al.* 2000). Results from surveys indicated that both the distribution and abundance of the Cook Inlet Beluga stock were declining, while reported harvests by Native hunters had increased (Angliss and Lodge 2004). In the summer of 1998, the Native hunt for Belugas ceased, and since then abundance estimates have stopped declining. No other current population-level effects are thought to be occurring due to human-induced factors. It is recognized (Angliss and Lodge 2004) that municipal, commercial, and industrial activities may be of concern and may affect the water quality and substrate in Cook Inlet. These activities include commercial fishing, oil and gas development, municipal discharges, noise of aircraft and ships, shipping traffic, and tourism (Moore *et al.* 2000). The upper Cook Inlet region is important habitat for Belugas and NMFS believes that the potential pressures from human activities need continued monitoring for stock recovery (DRAFT EIS 2000).

Marine and land birds are another important element of the Cook Inlet ecosystem's fauna component (*e.g.*, Cook Inlet Basin Ecoregional Assessment 2003). Coastal salt marshes of Cook Inlet provide important habitat for waterfowl and shorebirds during their migration. Over 100,000 geese and swans have been observed in Upper Cook Inlet during spring migration (USGS 2005). Upper Cook Inlet is located near the major human population center of Alaska and is a region where future resource development is likely; development of oil and gas reserves, coal deposits, timber resources, and port facilities is either proposed or ongoing in or near coastal wetlands. Increased recreational visitation of coastal wetlands is also likely. In 1997 the USFWS also listed the Alaska breeding population of Steller's eider as threatened under the Endangered Species Act (ESA). Aerial surveys from 2000 - 2003 provided new information on the distribution of Steller's eider within the Cook Inlet lease sale area (Supplement 2004). The observations confirmed the presence of Steller's eider along the east side of Cook Inlet from Clam Gulch to the Homer Spit, although it is not known if these birds are from the Alaska breeding population.

Among the most critical ecosystem issues are human induced factors. Humans have a major impact on both the external and regional forcing of the Cook Inlet ecosystem. On the global scale, warming is manifested over decades as a result of increasing concentrations of human-generated greenhouse gases (*e.g.*, Levitus *et al.* 2001; IPCC 2001) and is amplified at high latitudes (Moritz *et al.* 2002), including Cook Inlet. On the regional scale, approximately 400,000 people live in the Cook Inlet watershed and each year nearly one million visitors from around the world venture to Cook Inlet to relish its magnificent beauty (Cook Inlet Keeper 2004). Continued growth and development in the Cook Inlet watershed will impact the ecosystem. It is well known that marine ecosystems worldwide are being impacted by human activities such as coastal shoreline development, fishing, and storm-water runoff (Botsford *et al.* 1997; Pauly *et al.* 2002) and these impacts are beginning to be felt in Alaska (ADF&G 2005).

Other aspects of the Cook Inlet ecosystem that would be served by enhanced monitoring and development of informational products include the mitigation of natural hazards and those related to various commercial activities. Among the natural geophysical hazards are volcanic eruptions, earthquakes/tsunamis, and coastal erosion. Cook Inlet is one of the most seismically active regions in the world, including 4 active volcanoes (Moore *et al.* 2000). The impact of tsunamis generated external to Cook Inlet is believed to be slight; however, there is some potential danger from tsunamis produced by local volcanic activity (Royal Society of Canada 2003). Erosion not only impacts shorelines, but stream bank erosion is a concern for salmon stocks (Moore *et al.* 2000).

Additional hazards are related to commercial activities such as oil and gas development (MMS EIS 2003), shipping and other development. There are seven oil producing fields supporting 15 oil and gas offshore platforms in upper Cook Inlet (Moore *et al.* 2000). Nikiski is the main industrial base for Alaska. The main facilities include: the Tesoro refinery (70% of all in-state gasoline production); the ConocoPhillips LNG plant (shipping 1.0+ mt/yr); the Agrium Nitrogen plant (2.5 mt/yr of ammonia/urea shipped); and the BP Exploration Gas to Liquids test plant (The First Alaskan Oil & Gas Experience, 2004). Catastrophic spills such as the Valdez oil are very rare, but smaller discharges of refined oil products, crude oil and a variety of hazardous substances are quite common. These are associated with the commercial fishing and petroleum industry as well as other commercial establishments such as gas stations and dry cleaners. There were repeated discharges of dry cleaning fluid over many years near the Kenai River (ADEC, River Terrace spill 2002).

Vessel traffic in Cook Inlet carries crude oil, refined oil products, and liquefied natural gas exports year-round. Cargo vessels using the Port of Anchorage supply 80 percent of Alaska's population and its four largest military bases. The efficiency and safety of maritime operations in winter are compromised by an inability to predict ice conditions (www.crrel.usace.army.mil/sid/hopkins_files/Seaice/Cook_inlet.htm). Between 1995 and 2003, the annual tonnage at the Port of Anchorage increased by approximately 30% to 4,412,628 tons, and more than 58% of this tonnage was in the form of various types of petroleum (www.muni.org/iceimages/port/2004TenYearTonnage.pdf). Given this level of traffic, incidents related to shipping such as the Selendang Ayu or the Exxon Valdez will continue to occur.

Other human impacts on the Cook Inlet ecosystem, which will likely increase in frequency and quantity as urbanization continues are treated waste, road building and runoff from streets. Litchfield and Milner (1998) reported a decrease in diversity of benthic invertebrates in areas of the Kenai river below storm drain outfalls. While Anchorage is clearly the focal point for increased impacts due to population growth, rural areas also suffer. Factors that result in a diminishing water quality in the Kenai River include wetlands loss, point source pollution from outhouses or faulty septic systems, and household spills of oils and other contaminants (Liepitz 1994).

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SECTION II.   PRESENTATIONS

Ocean Observing Systems and Modeling

A Demonstration of the Alaska Ocean Observing System in Prince William Sound: Dr. Carl Schoch

Alaska Ocean Observing System: Nested ROMS Circulation. Dr. Yi Chao

Cook Inlet Observations

Central Cook Inlet Water Column Hydrography. Dr. Steve Okkonen

Lower Cook Inlet Water Column Hydrography. Dr. Scott Pegau

Cook Inlet Current Measurements by NOAA CO-OPS. Jennifer Ewald

Cook Inlet Observations and Modeling

Lower Cook Inlet Surface Drifter Tracking: Dr. Carol Ladd

Cook Inlet Surface Current Radar Deployments: Dr. Dave Musgrave

Cook Inlet CODAR Deployments by NOAA CO-OPS: Karen Grissom

Satellite Drifters/ 3-Dimensional Cook Inlet Model: Dr. Mark Johnson

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Cook Inlet Atmospheric Model: Peter Olsson

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Oceanographic Data used for Dilution Modeling: Brian Pippin, P.E.

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Cook Inlet User Needs

Cook Inlet User Needs Survey Results: Terry Thompson

Ocean Data Needs for Coastal Engineering: Dr. Orson Smith

A Demonstration of the Alaska Ocean Observing System in Prince William Sound

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Alaska's Prince William Sound (PWS) includes about 4900 km of shoreline surrounded by the Chugach National Forest, and contains the most extensive system of tidewater glaciers descending from the highest coastal mountain range in North America. The Trans Alaska Pipeline terminates at the Port of Valdez, making the pristine environment of the Sound highly vulnerable to oil spills, as evidenced by the 1989 Exxon Valdez spill. The Oil Spill Recovery Institute (OSRI) and its partner organizations conduct research in Prince William Sound to enable detection and prediction of oil-spill related impacts and subsequent recovery. This mission led to the development of a regional atmospheric circulation model coupled to an ocean circulation model. The modeling program is now rapidly evolving toward integration with the Alaska Ocean Observing System (AOOS) and to take better advantage of real-time data streams from satellites, weather stations, and an enhanced observational oceanography program consisting of permanent moored buoys and seasonal hydrographic transects.

There are two primary goals of the Prince William Sound Observing System (PWSOS). The first is to combine long-term monitoring with short-term hypothesis-driven process studies to understand mechanisms underlying the regional ecosystem dynamics. Understanding the circulation and the patterns of water exchange will provide a solid scientific foundation for addressing fisheries and ecosystem management needs related to long term oceanic and climatic variability. The second goal is to provide information to the major user groups in PWS including the coastal communities, oil and gas transportation industry (tanker traffic and oil spill response), air taxis, commercial fishermen, recreational and commercial boaters, and Coast Guard search and rescue operations. For example, the high-resolution wind, wave and ocean current forecast products will provide improved information to recreational and commercial vessel and aircraft operators and enhance the safety of oil tanker traffic in PWS. The improved physical and ecological forecasting products will enable resources managers (e.g., PWS hatchery and commercial fishing organizations) to make informed and scientifically sound management decisions on food supply, predation, and human activities such as commercial and recreational fishing.

Infrastructure expansion plans for the observing system include improving the consistency and data quality for the existing array of meteorological sensors, deploying precipitation gauges in the surrounding watersheds, deploying a telemetered stream gauge on the Copper River (Figure 1) and developing a synoptic wave model to predict wave heights, nearshore currents, and wave-induced turbulence. In 2005 a major program will begin to better understand the mechanisms and exchange rates of waters between the Gulf of Alaska and the Sound using moored subsurface observations (e.g. currents, temperature, salinity) together with surface current mappers (CODAR). A key element to the success of PWSOS is the long term funding commitment by OSRI. To ensure survival and enhance capabilities, PWSOS is being modified to fully utilize infrastructure and support contributed by a host of partner organizations including AOOS, the

Prince William Sound Regional Citizens Advisory Council, National Data Buoy Center, Natural Resources Conservation Service, University of Alaska (Fairbanks, Anchorage and Juneau), U.S. Forest Service, and U.S. Coast Guard.

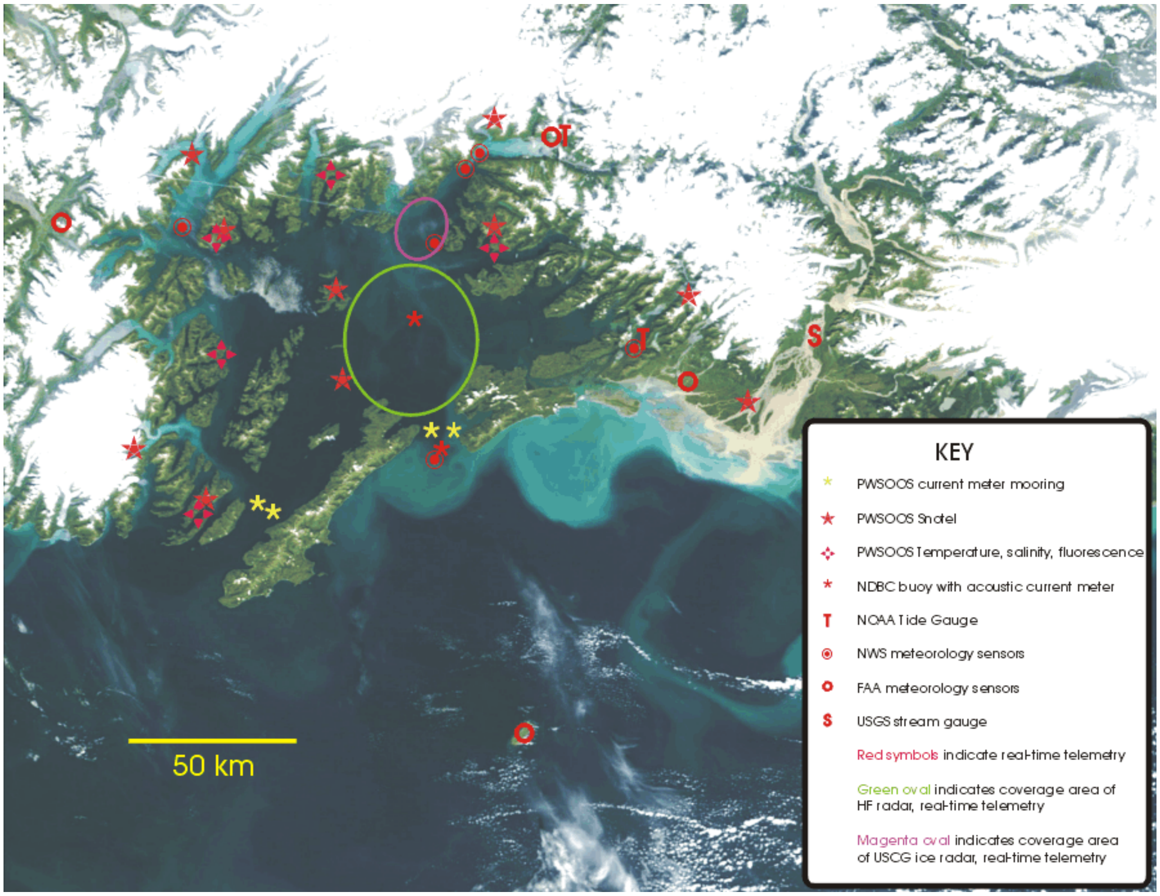

Figure 1. Satellite image that shows the Prince William Sound region and the locations of *in situ* observational instrumentation. Green oval marks region of HF radar surface current measurements (*Courtesy of Steve Okkonen*).

Alaska and Prince William Sound Ocean Observing Systems: Nested Regional Ocean Modeling System (ROMS)

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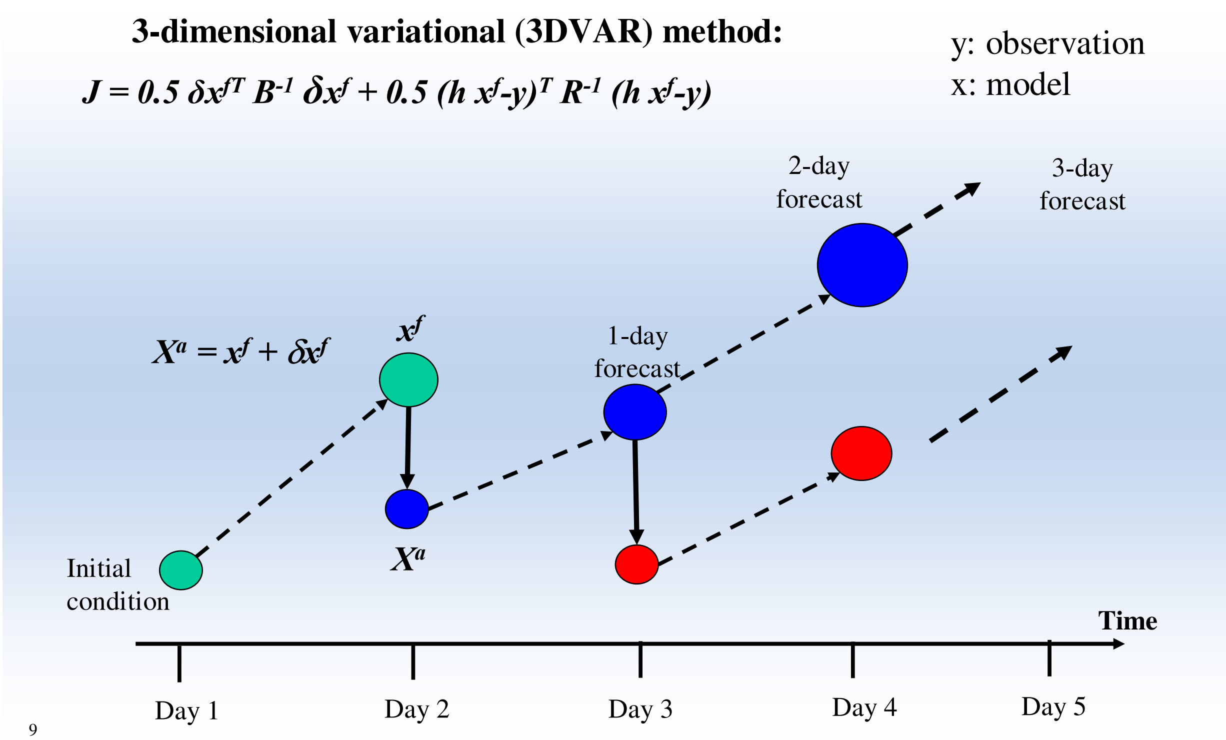
A Regional Ocean Modeling System (ROMS) was recently developed as part of the Prince William Sound Ocean Observing System (PWSOOS), a pilot-project under the Alaska Ocean Observing System (AOOS). The goal of this type of system is to develop an operational modeling, data assimilation, and forecasting system that can deliver both physical and biological real-time data products to research and application users. Observations from satellites or *in situ* measurements from an observational network design provide input data for 3D ocean models that provide synthesis products such as forecasting to the user community.

The major new features of the ROMS implementation for PWSOOS that will also be applied to other areas of the northern Gulf of Alaska include the 3-dimensional variational (3DVAR) data assimilation method, a Pacific basin-scale ROMS that provides the needed boundary conditions for the ROMS configuration. Both in-situ and satellite observations can be assimilated into the PWSOOS ROMS in real-time. Forced with the real-time forecast of the Regional Atmospheric Modeling System (RAMS) atmospheric fields, the PWSOOS 3-D ocean circulation and tide can be predicted in real-time. The information and data products will be made available to both research and applications users in real-time through user-friendly interfaces. It is anticipated that a PWSOOS RO<S forecasting system will be operational by 2007 and tested during a field experiment. This field experiment will help determine whether the PWSOOS can deliver the observational data and model predictions in real-time and whether the model estimates (or forecasts) are any good.

Development of a Cook Inlet regional model will require large-scale physical oceanography boundary conditions (from Pacific basin-scale such as ENSO and PDO to Gulf of Alaska regional eddies and waves).

ROMS Data Assimilation System



Hydrography of Central Cook Inlet: August 2003

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Surface-to-bottom measurements of temperature, salinity, and transmissivity, as well as measurements of surface currents (vessel drift speeds) were acquired along an east-west section in central Cook Inlet, Alaska during a 26-hour period on 9-10 August 2003. These measurements are used to describe the variability of frontal features (tide rips), surface currents, and physical properties along this section throughout the semidiurnal and diurnal tidal cycles. The amplitudes of surface tidal currents are observed to be proportional to water depth, that is, faster currents occur where the channel is deeper and slower currents occur where the channel is shallower. It directly follows that laterally sheared currents occur over bathymetric slopes. Convergence zones (fronts) are also observed to occur over bathymetric slopes. The positions and strengths of these fronts vary with the semidiurnal tide. The presence of freshwater promotes density-driven currents that alter the phase and duration of tidal currents across the section. Where mean density-driven flow is northward (along the eastern shore and near Kalgin Island), the onset of northward tidal flow (flood tide) occurs earlier and has longer duration than the onset and duration of northward tidal flow where mean density-driven flow is southward (in the shipping channel). Conversely, where mean density-driven flow is southward (in the shipping channel), the onset of southward tidal flow (ebb tide) occurs earlier and has longer duration than the onset and duration of southward tidal flow along the eastern shore and near Kalgin Island. Compared to upper Cook Inlet, lower Cook Inlet is generally characterized by gentler bathymetric slopes and greater distance from freshwater sources. Consequently, it is inferred that, in the lower inlet, frontal features and laterally sheared currents will be weaker and asymmetries between the durations and phases of flood and ebb currents will be diminished relative to conditions in the upper inlet.

See: Okkonen, S.R. and S.S. Howell 2003. Measurements of temperature, salinity and circulation in Cook Inlet, Alaska. OCS Study MMS 2003-036, 32 p.

Hydrography of Lower Cook Inlet
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Several programs are conducting hydrographic observations in Lower Cook Inlet, from both hydrographic transects and moorings. These programs are funded by a variety of organizations including: Alaska Department of Fish and Game (ADF&G), National Oceanic and Atmospheric Administration (NOAA), Exxon Valdez Trustees Council (EVOS), Coastal Management Institute (CMI), and the Cook Inlet Regional Citizen Advisory Council (CIRCAC). The work being performed by these programs is the first significant effort to characterize water properties in Lower Cook Inlet since the 1970s.

The Kachemak Bay Research Reserve maintains two monitoring sites in Kachemak Bay. These are located at the Homer and Seldovia ferry docks. At each site there are two YSI 6600 sondes to measure water temperature. One is mounted 1-m above the bottom and the other floats approximately 0.7 m below the surface. The two deep sensors have been operating since the summer of 2001. The surface sondes were installed at the beginning of 2003. A meteorological station located at the end of the Homer Spit is also part of this program. Current plans are to expand the program to install a monitoring site at Port Graham and Bear Cove to provide along-axis water properties. The National Park Service is also considering adding similar monitoring sites on the western side of Cook Inlet.

These measurements show temperature differences (bottom to surface) of >2°C in the winter temperatures (Figure 1). Warming of the water column begins in March and continues through July. Fluctuations in temperature and salinity are observed starting in July and most likely are associated with intrusions of the Alaska Coastal Current (ACC) into Kachemak Bay. These fluctuations are largest in September.

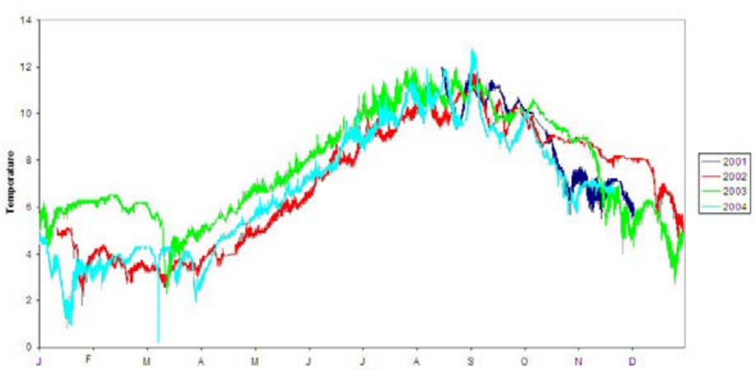

Figure 1. Water temperature observed in Seldovia between 2001 and 2004. Note the large temperature differences in February and fluctuations in September.

The longest running monitoring program in Cook Inlet is the ADF&G Offshore Test Fishery (OTF). The OTF program conducts surveys along a line between Anchor Point and Red River each day during the month of July. This program has been monitoring surface temperature and salinity since 1979. The EVOS Gulf Ecosystem Monitoring (GEM) program has supplemented the monitoring of this program by adding conductivity-temperature-depth (CTD) measurements at each of the six monitoring locations. A towed platform also caries a YSI 6600 sonde, acoustic doppler current profiler, and Bio-sonics acoustical fish detector. The GEM program measurements have been collected in 2003 and 2004, and will extend through 2005. Further years of observations are uncertain.

The two years of observations completed show the large temporal variability in oceanographic properties in Cook Inlet. During early July water temperatures in Western Cook Inlet increase by 4°C. This warm water is also of low salinity and originates from river inputs. The magnitude of the low salinity lens and its location appears to be dependent on mixing forced by the spring-neap tide cycle, with spring tides mixing the freshwater into the water column, and neap tides allowing a well defined layer to exist. In many instances the low salinity layer can be seen as a distinct stream running along the west side of the channel. At other times the layer extends from the shore outward towards the middle of the channel. Winds also can mix away the low-salinity surface layer, but the lower salinity water is still observed along the western side of Cook Inlet.

In the two years of CTD observations differences in temperatures are observed throughout the water column. The 2004 surface and deep water temperatures were about 1°C cooler than the 2003 temperatures in spite of having clear skies and warmer air temperatures in 2004. The full time series of surface temperatures has a suggestion of a weak decadal oscillation. The years of 1982 and 1988 were very unusual in that the monthly average temperatures show very little temperature gradient across Cook Inlet (Figure 2).

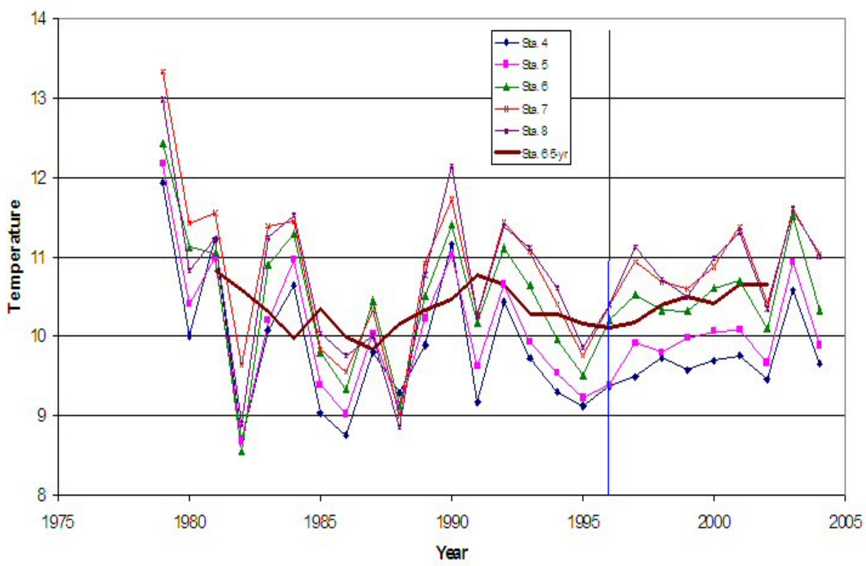

Figure 2. Surface temperatures measured by the OTF program. The station numbers increase going towards the west. The heavy line is a 5-year running average at station 6.

CIRCAC and CMI are sponsoring a series of hydrographic surveys in Lower Cook Inlet to look at changes in boundary conditions. Six surveys along four transects lines are planned for 2004 and 2005. The transect lines run across Kennedy and Stevenson Entrances, Shelikof Strait, Anchor point to Johnson River, and in Kachemak Bay. A total of 65 stations are occupied. The stations are spaced 1 nautical mile (nm) within 4 nm of the shore and 2 nm further offshore. The spacing is designed to emphasize the nearshore area where buoyancy driven currents are expected.

All transect lines show a general warming through the summer and a decrease in salinity associated with the ACC and in the Western Cook Inlet. The evolution of temperature and salinity characteristics differs at the four locations. Within Kennedy and Stevenson Entrances the ACC strengthens in August and September (as seen by the decrease in salinity; Figure 3), but is also evident as early as April. There is persistent upwelling that occurs along the Northeastern section off Shuyak Island. A strong horizontal temperature and salinity gradient exists along the Anchor Point line. The minimum temperature and the maximum salinity exist in the central portion of Cook Inlet, although the two features do not necessarily occur at the same location.

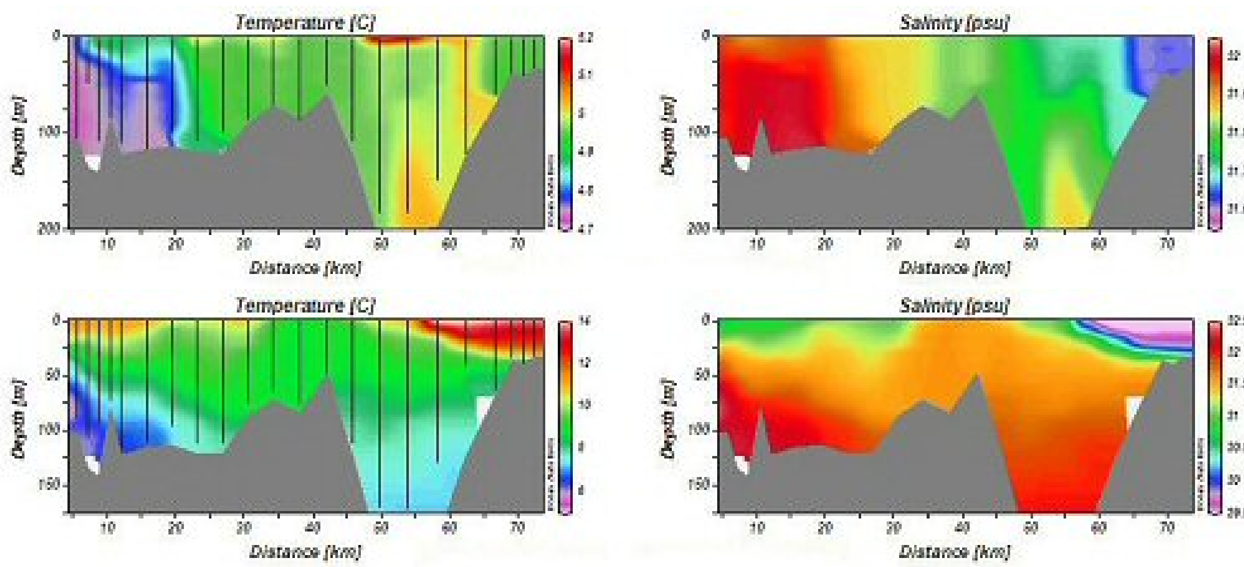

Figure 3. April (top) and September (bottom) temperature and salinity in Kennedy and Stevenson Entrances. The ACC is the low salinity water seen on the right side of the plots.

Another important monitoring effort being funded by the EVOS-GEM program includes instrumentation mounted on the Alaska Marine Highway System Ferry Tustumena. Temperature, Salinity, fluorescence, beam transmission, and nitrate concentrations are measured in a flow-through mode every 30 seconds along the ferry tract. This program started in the fall of 2004 and is still working out issues related to the instrumentation and rust problems in the piping.

Tidal Current Measurements in Cook Inlet

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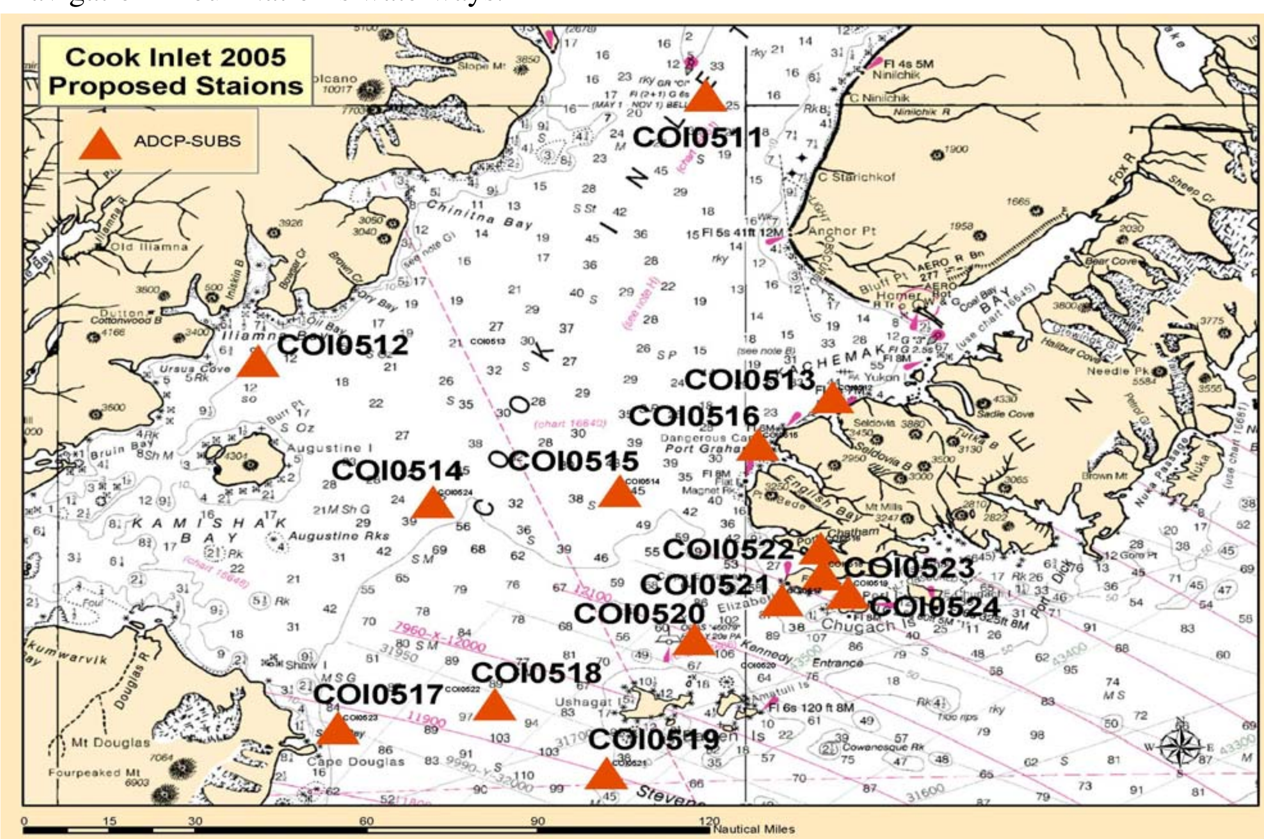
The NOAA National Ocean Service, Center for Operational Oceanographic Products and Services (CO-OPS) manages the National Current Observation Program (NCOP) to meet the Nation's needs for current observations, tidal current predictions, and other tidal current products. The products from this program primarily support safe, efficient and environmentally sound marine commerce, hazardous material response, research and recreational users. NCOP conducted tidal current surveys in Cook Inlet from 2002-2004 collecting current meter time series data at seventeen stations and spatial data along nine transects over twenty four days in support of CO-OPS navigational products and the U.S. Army Corps of Engineers hydrographic models. The work was completed with the assistance of charted vessels, the Kachemak Bay Research Reserve, the Cook Inlet Regional Citizens Advisory Council and the United States Coast Guard. NCOP plans to occupy twenty-five additional stations during the 2005 field season from the Forelands to the entrance of Cook Inlet (Figure below). The new information collected on currents from these stations will be used to validate or update NOAA's Tidal Current Tables and provide the basis for new products and understanding of the circulation in Cook Inlet. Existing tidal current predictions in Cook Inlet are based on data collected during the 1973-75 survey or older. Improving current information is critical if NOAA is to continue promoting safe navigation in our Nation's waterways.



Alaska Coastal Current Influence on Lower Cook Inlet

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The Alaska Coastal Current (ACC) is of primary importance to the oceanography of the Gulf of Alaska (GOA) shelf and provides oceanic waters (nutrients) for Cook Inlet (Figure 1).

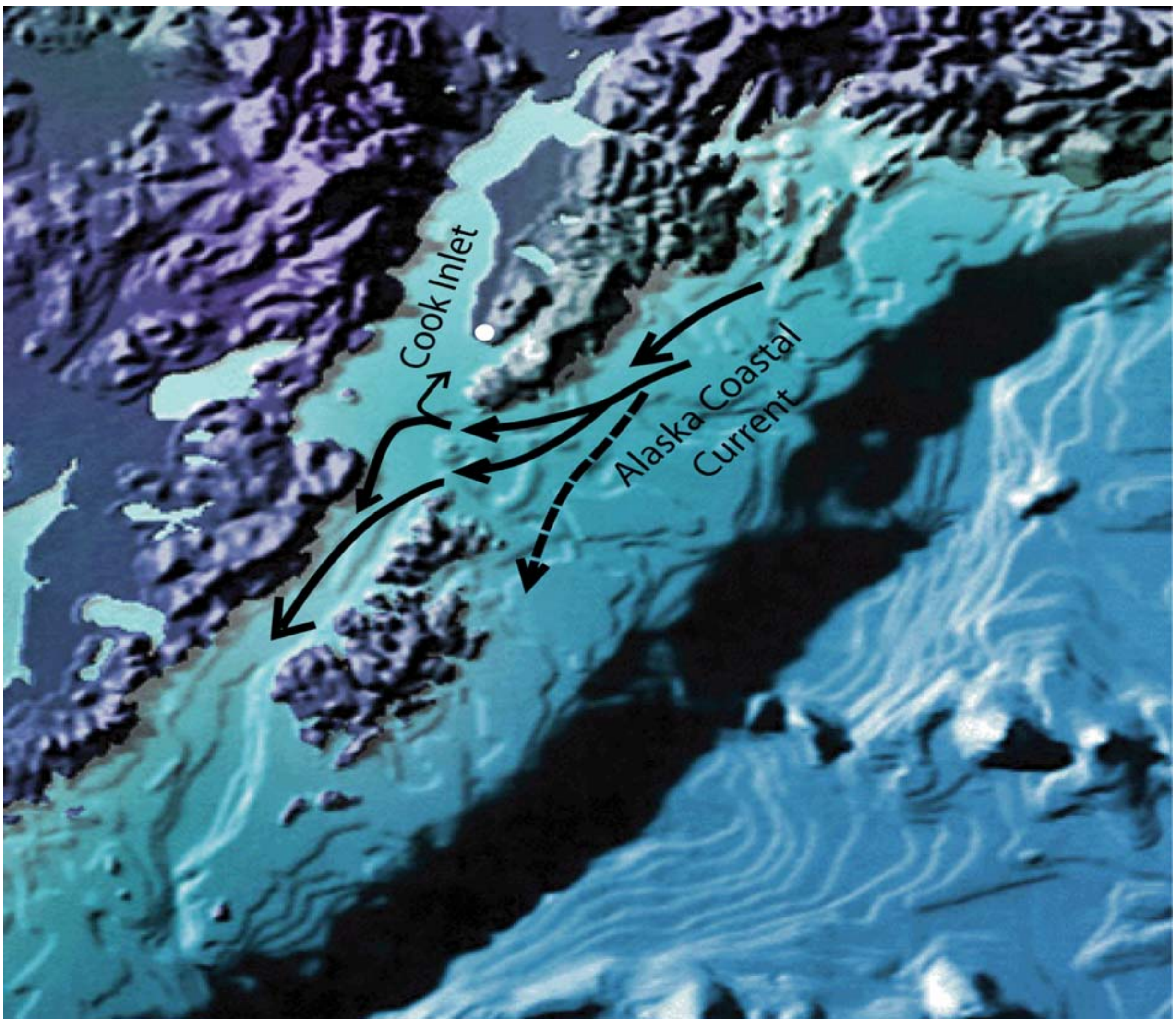

Figure 1. A schematic that shows flow of the Alaska Coastal Current through Kennedy and Stevenson Entrances into lower Cook Inlet/Shelikof Strait and at times along the eastern side of Kodiak Island.

Strong downwelling winds during winter result in an intense, narrow current. This current has seasonal baroclinic structure resulting from the seasonal cycle of freshwater runoff feeding the coastal GOA. Drifter observations illustrate the seasonal cycle of the ACC flow through Kennedy and Stevenson Entrances into Lower Cook Inlet and Shelikof Strait (Figure 2). During

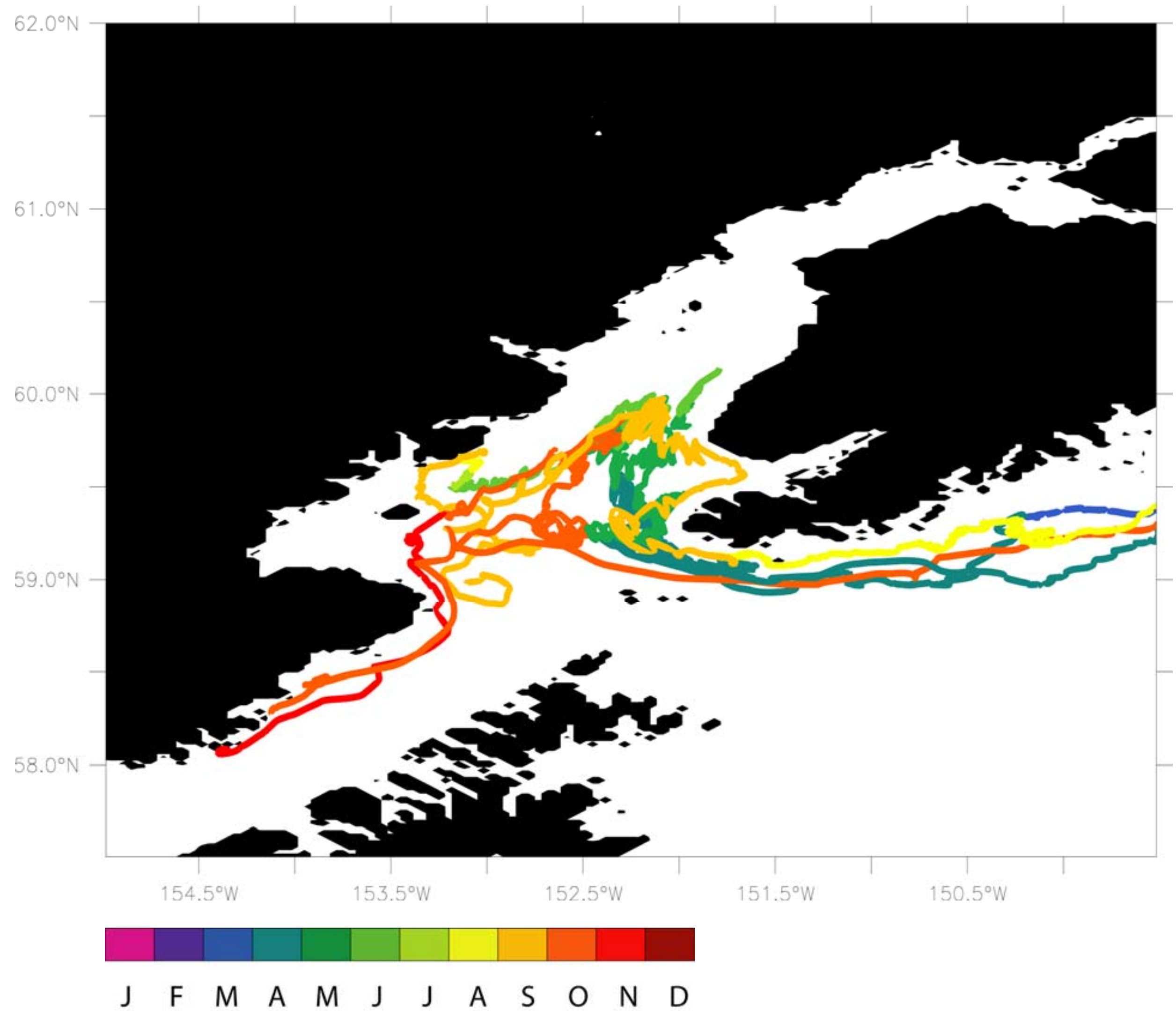

Figure 2. Selected trajectories of satellite tracked drifters (drogue depth of 40 m) showing flow of the Alaska Coastal Current through Kennedy Entrance into lower Cook Inlet/Shelikof Strait (colors indicate time in months).

the summer months, flow through the Entrances is weaker and much of the ACC flows southwestward on the seaward side of Kodiak Island. During winter, there is little flow on the seaward side of Kodiak Island and most of the ACC flows through the Entrances, influencing Shelikof Strait and Lower Cook Inlet. The strong freshwater input of autumn results in decreased surface salinities, stronger stratification, and decreased surface nutrients compared with other times of year. In contrast, during spring, the flow through Kennedy Entrance is well mixed with higher surface salinity and nitrate (Figure 3). Climate change will likely lead to increased freshwater inflow and stratification, thereby influencing the nature of source waters for Shelikof Strait and Lower Cook Inlet.

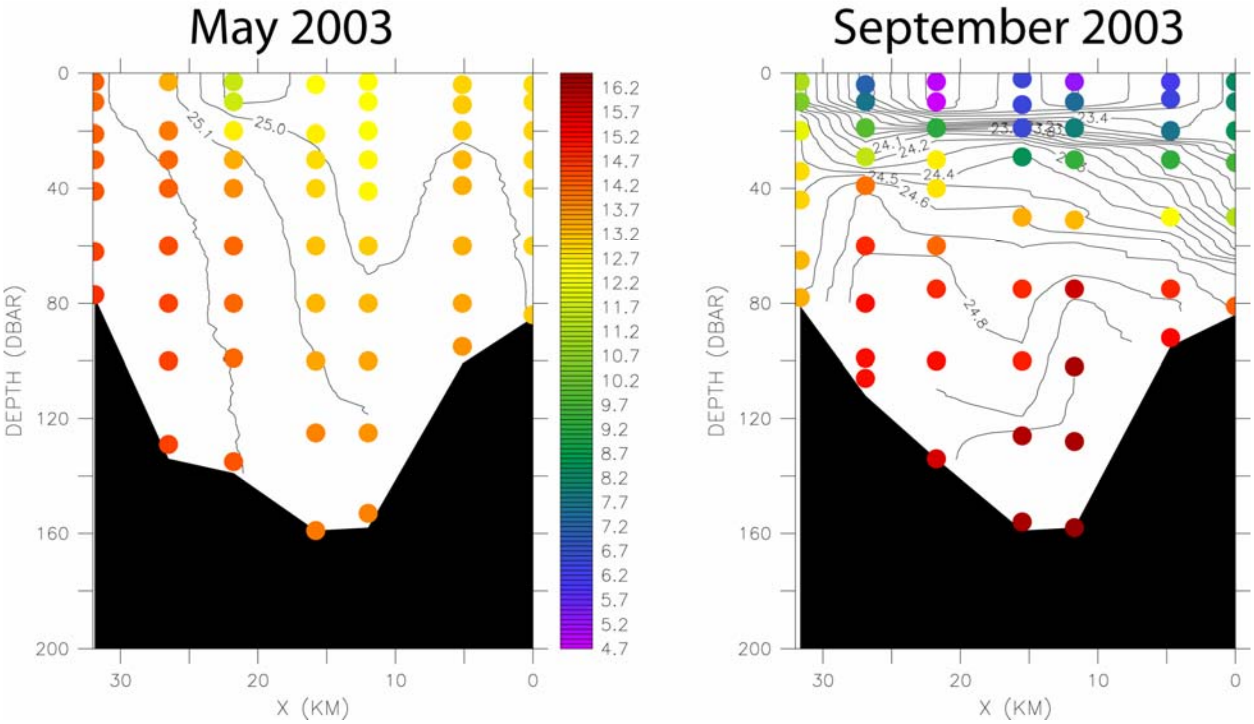

Figure 3. Nitrate concentration (μM) across Kennedy Entrance in May and September 2003.

Cook Inlet Surface Current Radar Deployments

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We measured and analyzed surface currents measured by High Frequency (HF) radar instrumentation from December 2002 to June 2003 near the mouth of the Kenai River in upper Cook Inlet (Figure 1). The systems operated continuously over that period, except during a seven-day dropout of data due to a damaged computer modem. The spatial coverage of the HF radar system varied over the semidiurnal tidal period due to exposed beach seaward of the antennas during low tides. The spatial coverage during periods of no or slight winds was reduced, presumably due to the absence of significant energy in the wave field at the Bragg wavelength (11 m).

The tidal currents accounted for about 90% of the total current variance and the tidal ellipses for all tidal components were polarized in the along-isobath direction. The dominant tidal component was the lunar semidiurnal (M2) with magnitudes in the direction of the major axis of the tidal ellipse that ranged from 30 – 200 cm s^{-1}. Subtidal currents were spatially variable (0.5-100 cm s^{-1}) with the strongest currents occurring over the deepest sections of the channel.

Particle excursions, due to tides, in this section of Cook Inlet are between 4 and 32 km. Predicted tidal current ellipses agree quite well in magnitude and phase with the tidal model of Foreman *et al.* (2000). Computations of horizontal divergence indicate persistent regions of up and downwelling that are aligned with the edges of locally documented tidal rips.

Comparison of surface velocities from the HF radar with drifters drogued at 7 m, gave root-mean-square (rms) differences in the range of 40 – 100 cm s^{-1}. The large differences are probably due to large vertical shear in the upper 7 m of the water column.

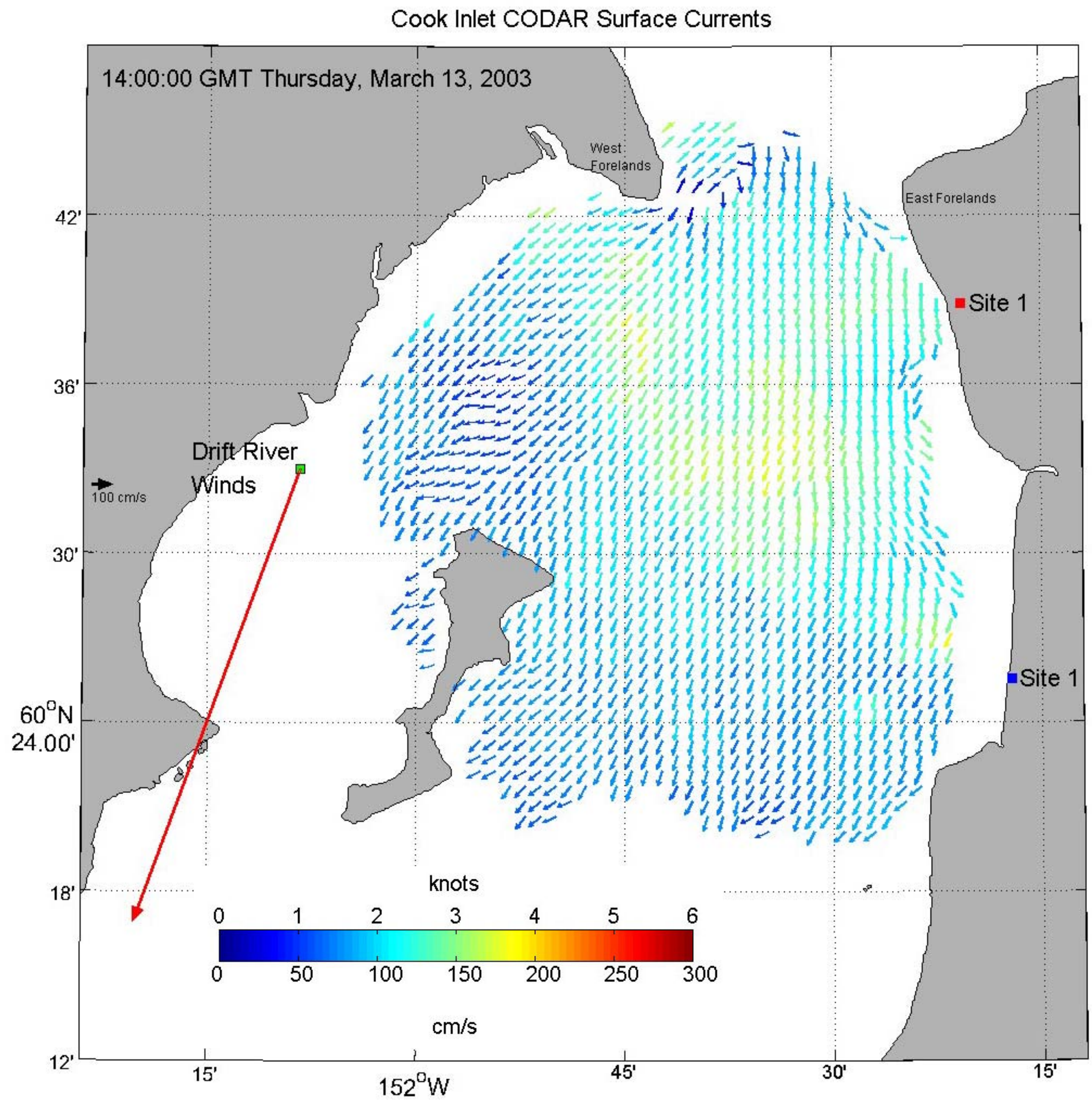

Figure 2. Study area for HF radar surface currents. Sites 1 and 2 are locations of the HF radar systems, which are separated by 25 km and are south and north of the Kenai River, respectively. This graphic is for 14:00 GMT March 13, 2003. The small arrows indicate the direction of the surface currents and the color indicates the magnitude (color bar). The region of coverage of for two dimensional velocities extends more than 10 km south and north of Sites 1 and 2 and 45 km across the inlet. The resolution of the surface currents is about 2 km. The wind velocity from the Drift River meteorological station at this hour is given by the red arrow. The small black arrow gives the scale for the wind magnitude.

Upper Cook Inlet Portable Surface Current Measurement System

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The National Current Observation Program (NCOP) of NOAA routinely collects current observations in order to compute tidal current predictions in support of safe and efficient maritime commerce. Until recently, these measurements were made exclusively by in water current meter surveys. The last two years, however, has seen an increased utilization of High Frequency (HF) radar surface current data, for both operational evaluation of this technique and computation of tidal constituents. HF surveys were conducted in southern Cook Inlet during 2003, and the northern segment during 2004. An additional survey is planned for summer 2005.

As with any operational test, there have been successes and challenges. Yet, we now have the knowledge and experience to deploy HF Radar in remote regions lacking power and communications. The newly designed mobile units will allow us to deploy the system in any region that satisfies the antenna location requirements, and do so with easily and effectively. The system consists of two portable units, each with a common configuration. Both units are fully equipped, with the radar electronics, a communication system, a power generation system, tools, and documentation outlining relevant procedures. The main obstacle so far is consistently generating power and reducing generator interference. Redesign efforts have removed most of the problems associated with generation of power and demonstrated a decrease in generator noise.

Cook Inlet circulation from satellite tracked drifting buoys

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More than 20 drifting buoys have been deployed in Cook Inlet by Cook Inlet Spill Prevention and Response, Inc (CISPRI) and other personnel since 2003. Position and time data are relayed to ARGOS satellite and then emailed to us daily for analysis. Raw data are converted time and position and velocities are computed using centered finite-differences. Despite checksum error detection of data relayed via ARGOS, some data still show position jumps that do not appear real. Obvious position errors are deleted and the remaining data were analyzed.

All buoys in year one were equipped with a drogue tethered to follow the water at depths between 5 and 10 meters. In year two, the drogue depth was made shallower to track water at depths between 3-5 meters. No obvious differences between trajectories for different drogue depths have been noted. Most buoys were deployed in the area south of the Forelands and northeast of Kalgin Island. Within lower Cook Inlet, the area covered by buoy trajectories was extensive (Figure 1). The velocity data were used to compute kinetic energy. A histogram of kinetic energy is shown in Figure 2. A plan view showing contours of kinetic energy (KE) above approximately 3 standard deviations above the mean is shown next to Burbank's chart of the tidal rip lines. The two figures show good agreement.

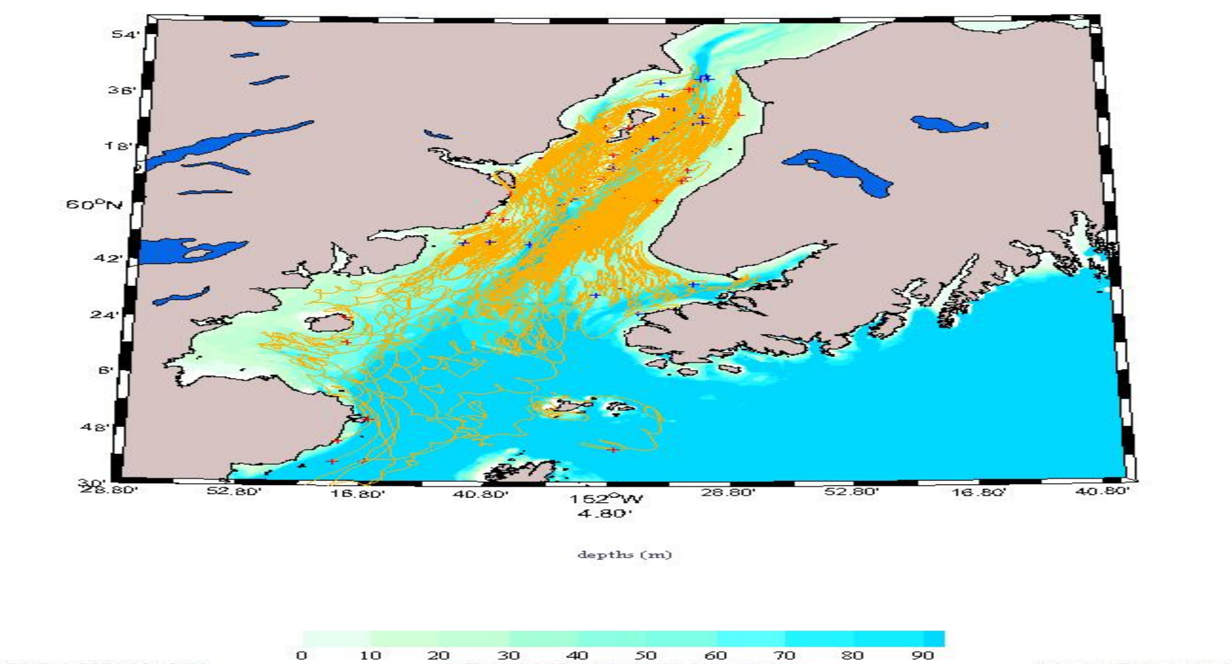

Figure 1. All buoy trajectories to date in lower Cook Inlet. The blue (start) and red (end) "plus" signs are used to indicate initial and final data for the trajectories.

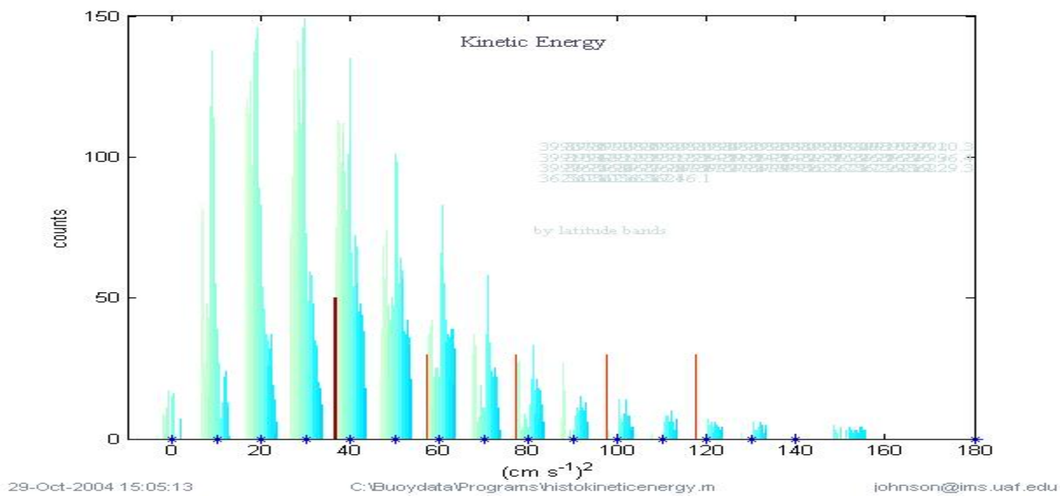

Figure 2. Histogram of kinetic energy. The mean falls at the heavy red line, and the thinner red lines mark standard deviation increments above the mean.

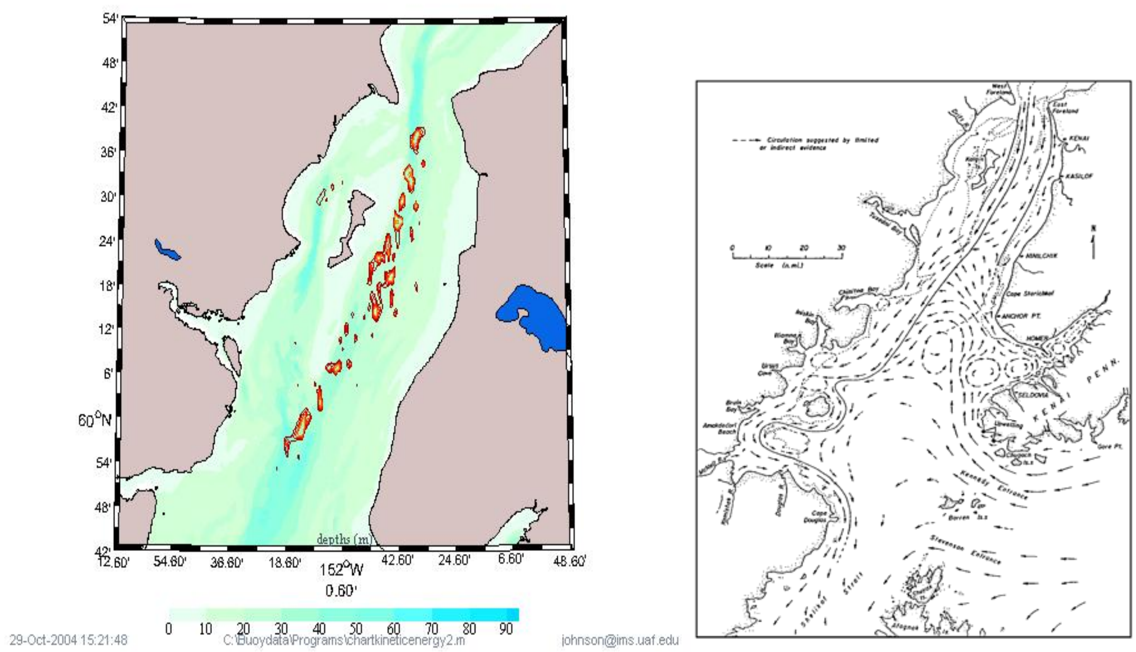

Figure 3. (Left) The values above 100 (cm s^{-1})^2 are contoured in red and align with the bathymetry. (Right) Burbank's 1977 chart showing the rip lines. There is good spatial agreement between our energy contours and the locations of the west and central tide rips.

Northern Gulf of Alaska Circulation Model

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There is an effort underway to model the Gulf of Alaska, partially supported by the GLOBEC Northeast Pacific program. A nested set of model domains (Figure 1) is used, starting at the scale of the North Pacific in order to include forcing by the interannual variations of wind-driven (e.g. El Niño). Nested within this is a Northeast Pacific domain with a 10 km resolution, which in turn contains a 3 km resolution Gulf of Alaska. This 3 km domain has been run for the years 2001 and 2002 with an embedded ecosystem model and the plan is to complete simulations for the years 1998-2004.

The physical model has all the major features we know that exist in the region, including the Alaska Coastal Current, the Alaska Stream, and the large eddies generated off Sitka. There are also numerous smaller eddies on the shelf as observed in satellite images (e.g. ocean color, altimetry). At present, there are some offsets in simulations of the vertical temperature and salinity structure at the Seward hydrographic line and the cause of this difference between observed and simulated structure are being investigated so they can be adjusted for. A finer spatial scale (1 km) domain nested within the 3 km domain has been set up and some preliminary runs have been done. However, this domain is extremely costly and these runs have been put on hold pending a closer look at results from the 3 km domain. We are also beginning to explore a coupled ice-ocean model of the Bering Sea.

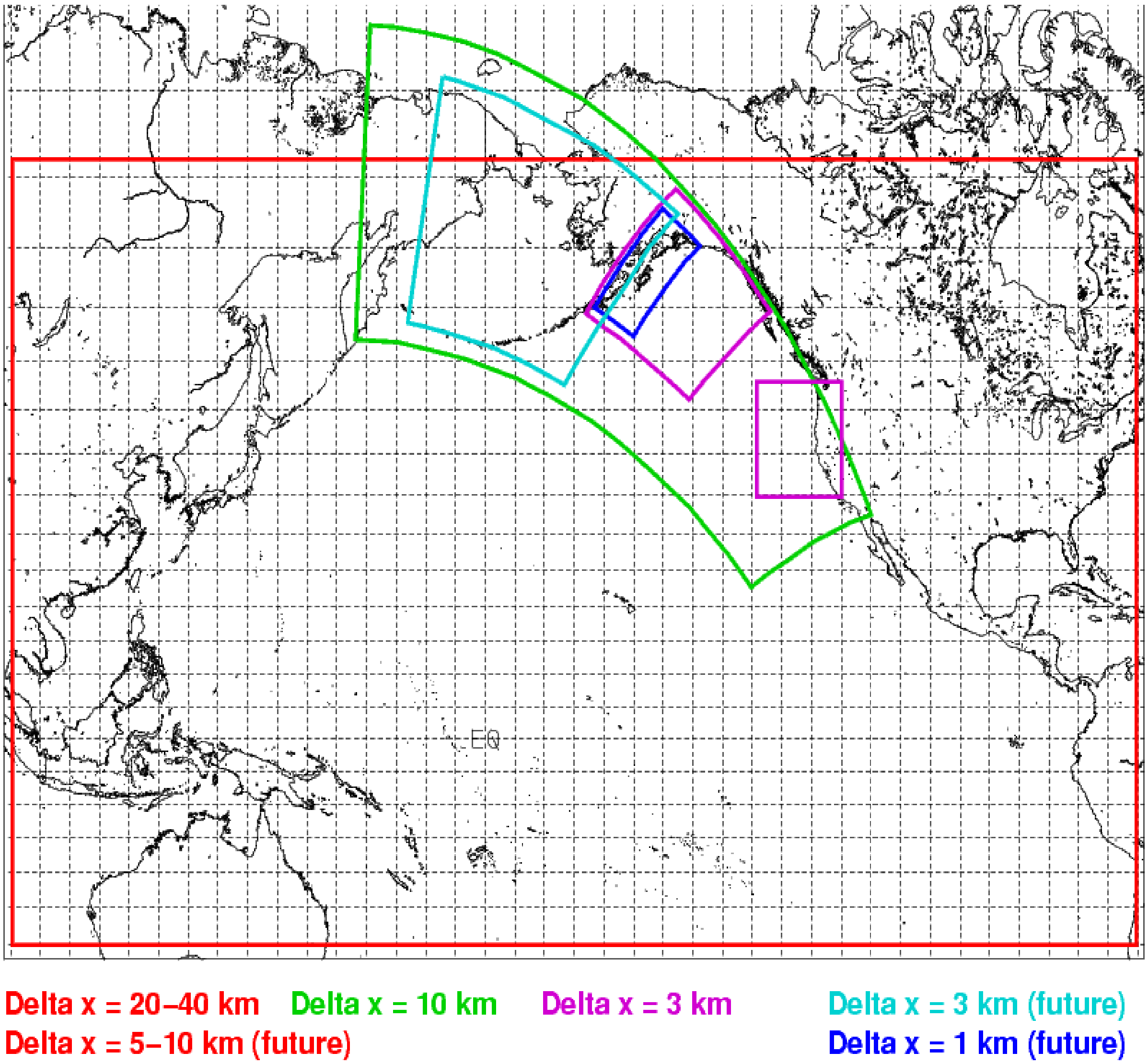

Figure 1. Nested grids developed for the North Pacific. The Delta x's refer to the grid scale.

A Summary of National Weather Service Forecast Office Products for Cook Inlet

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NOAA's National Weather Service (NWS) forecast office in Anchorage, Alaska, produces forecast products for aviation, marine and public (land) users. The specific areas for Cook Inlet include: public zone 121, which covers the Western Kenai Peninsula including the Cook Inlet coast; Marine area 4, which covers Cook Inlet north of Kamishak Bay and English Bay; Marine area 4A covering Kachemak bay and Marine area 3A, which covers the barren Islands area south to Afognak Island.

Products are produced specifically for the marine and land environments. Marine warnings and advisories are issued as marine products every day at 4 AM and 4 PM local time. Public warnings and advisories are issued at 5 AM and 4 PM local time. Sea Ice products covering both ice coverage and Sea Surface Temperature are issued twice a week. Weather information is most easily accessed over the internet: http://pafc.arh.noaa.gov/. Other sources of weather information include NOAA weather radio and the Alaska weather line (1-800-472-0391).

In addition to forecast products, various types of observation stations that have real time data are operating in the Cook Inlet area (Table and Figure below). An important data type that is lacking in Cook Inlet, however, is wave height. This is due to the extreme weather, mainly heavy freezing spray and sea ice, which have destroyed previous buoys placed near the area. In late spring to early summer of 2005, two directional wave buoys will be deployed in lower Cook Inlet in an attempt to rectify this situation. In addition to observing stations, A NEXRAD Doppler radar in located in Nikiski and covers the whole of Cook Inlet.

Site ID	Location	Type	Wind	Air Temp	Dewpoint	Pressure	Ceilings	Visibility	Precip	Sea Height
PANC	Anchorage	ASOS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
PAEN	Kenai	ASOS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
DRFA2	Drift River	C-MAN	Yes	Yes	Yes	Yes	No	No	No	No
PAHO	Homer	ASOS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
PASO	Seldovia	AWOS	Yes	Yes	Yes	Yes	Yes	Yes	No	No
FILA2	Flat Island	C-MAN	Yes	Yes	Yes	Yes	No	No	No	No
AUGA2	Augustine Is.	C-MAN	Yes	Yes	Yes	Yes	No	No	No	No
AMAA2	East Amatuli Is.	C-MAN	Yes	Yes	Yes	Yes	No	No	No	No
PADQ	Kodiak	ASOS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
46080	58.0N;150.0W	Buoy	Yes	Yes	Yes	Yes	No	No	No	Yes

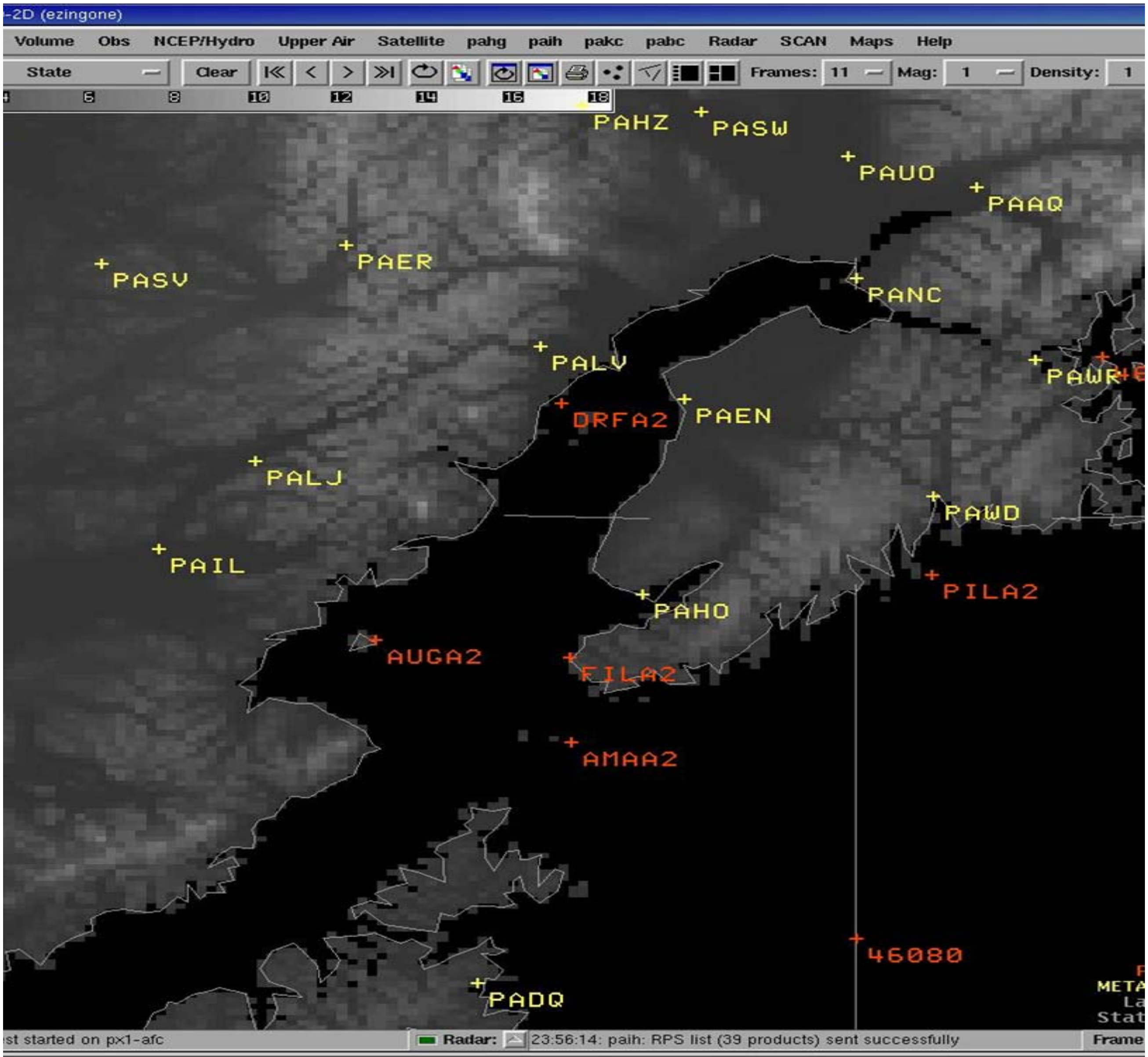

Figure 1. Location ID'S for data collected by NWS in the Cook Inlet region.

NOAA's Hydrographic Surveys

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NOAA's Office of Coast Survey (OCS) produces nautical charts for United States waters, including its possessions and territories. OCS is an office within the National Ocean Service (NOS). It is, in fact, the oldest U.S. scientific organization dating back to Thomas Jefferson who established the office in 1807 to encourage commerce and to support a growing economy in a safe and efficient manner. The "National Survey Plan" was developed in November 2000 to identify and priorities the areas within NOAA's scope of navigation safety responsibilities that are in greatest need of hydrographic surveys. In 2004, the document was renamed to "NOAA's Hydrographic Survey Priorities (NHSP)" and it continues to describe more accurately NOAA's hydrographic survey priorities for general and long term project scheduling purposes. The document includes graphics that identify the general vintage of hydrographic surveys that have been applied to NOAA charts, and the basic technology used during data acquisition. NOAA continually reviews the marine community's needs for charting products and hydrographic surveys, and will review and update this document every three years. The NOAA Hydrographic Survey Priorities can be viewed on the World Wide Web at: http://nauticalcharts.noaa.gov/staff/NHSP.html

Of the 43,000 square nautical miles (snm) of "Critical Area[1]" estimated to exist in 1994, approximately 26,600 snm remain and is considered a stable baseline for tracking purposes in the 2004 NHSP. The 2004 NHSP included three new categories, "Emerging Critical Area", "Full Bottom Coverage Era", and "Resurvey Areas". Emerging critical areas allow for designation of additional areas that meet the definition of "Critical Area" and have the same compelling need for survey, but can be tracked separately from the 43,000 snm. The "Full Bottom Coverage Era" category delineates areas surveyed since 1994 with the use of modern Side Scan Sonar and Multibeam Sonar. The examination of an area with modern survey methods does not preclude the need for subsequent surveys. Some areas will require periodic surveys due to naturally occurring changes (e.g. silting, shoal migration, earthquakes, tsunami, etc.) or use by increasing size vessels. For example, Fire Island Shoal in Upper Cook Inlet, Alaska should be resurveyed every 2 to 3 years. For these reasons the "Resurvey Area" category has been included in the NHSP 2004 edition. The remaining navigationally significant areas are subdivided into the five priority levels (Priority 1-5), based on the age of the prior surveys in those areas. In 1994, the Alaska region comprised of approximately 21,800 snm of critical area, 8,100 snm have been

[1] "Critical Area" – highest priority area and defined as waterways with high commercial traffic volumes (cargo, fishing vessels, cruise ships, ferries, etc.), extensive petroleum or hazardous material transport, compelling requests from users, and/or transiting vessels with low under-keel clearance over the seafloor.

surveyed between the years 1994-2003, leaving approx. 9,700 snm of critical area. In addition, there is approx. 3,800 snm of emerging critical area.

NOAA strives to provide safe navigation, and will survey priority and resurvey areas in conjunction with critical area to enable the most efficient use of survey platforms. Priority areas will be scheduled in lieu of critical areas when seasonal weather factors prevent safe and efficient operations in challenging environments. It is important to note that the NHSP is a dynamic planning tool that will evolve over time. The graphics are a snapshot of the current priorities, the plan will be reviewed and new editions published at least every three years.

Tidal Datums in Cook Inlet

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Tidal datums have been collected in Cook Inlet to support nautical charting, permitting, boundary mapping, safe navigation and for industry activities. An overview was given of the historic sites that have been observed by NOAA (and predecessors). The existing published information was explained along with the currently operating NWLON/PORTS (See Patchen, this Proceedings for details regarding NOAA data and products). The two tidal datum epochs were highlighted as well as the recent update to tidal datums in Cook Inlet. Two examples on NOAA tidal zoning for recent charting projects were described.

Items for consideration:

- Are there needs for additional PORTS or NWLON type information in Cook Inlet? Is different information needed (i.e. currents). Where?
- Are tidal observations and datums useful for research modeling or validation? Are observations needed? Where?
- Is a real time system that integrates tides and currents needed by maritime users?
- Is there a need to georeference vertical tidal datums to the ellipsoid? Perhaps connect to PBO to sea level.
- Is unpublished historic data (observed by NOAA) of value?
- Are there areas of Cook Inlet that have pressing needs for updated charts?

Features Of Central Cook Inlet Circulation Based On Observations Of Oil Spill Movement

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For the past twenty-five years the NOAA Hazardous Materials Response Branch has been providing scientific and technical support to the Coast Guard for oil spills in the marine environment. A major element of this support is the development of forecasts of spilled oil trajectories. This means that NOAA Hazmat has several oceanographers on our staff who are very interested and knowledgeable in ocean circulation around the entire coast of the United States; however, Cook Inlet has been a real challenge to understand and model.

Between 1984 and 2001 the Coast Guard requested assistance from NOAA on 27 spills that occurred in central Cook Inlet (Figure 1). Not surprisingly, this is where the petroleum production and transportation facilities are concentrated. Fifteen offshore oil and gas production platforms exist between the Forelands and the North Forelands and major tanker docking facilities exist at Drift River on the west and at Nikiski on the east side. Roughly half the spills were non-persistent fuels (gasoline, jet fuel and diesel) with the remaining half being persistent fuels (crude oil and bunker C). The vast majority of oil spill volumes have been rather small, on the order of tens of barrels (bbls) or less. In observing these spills over the years, NOAA has learned that small oil spills (particularly non- persistent fuels) are relatively short-lived (1-2 days or less) due to the accelerated evaporation and natural dispersion produced by the tidally generated turbulence.

As the result of larger persistent fuel spills like the 1987 T/V Glacier Bay (2000 to 3000 bbls of North Slope crude) we have gained some sound insights regarding circulation in this part of the inlet (Figure 2). Three distinct surface convergence zones were identified in the central inlet: the east rip, the mid-channel rip, and the west rip (Figure 3). These surface convergence zones strongly influence trajectories of floating objects in this region. These zones tend to be separated by near-vertical boundaries between distinct water masses. Shearing, and surface convergence and divergence occurs between these water masses during both ebb and flood tidal flow (Figure 4).

Monitoring the movement of oil spills leads to the following generalizations regarding circulation and reveals the dominant role of the convergence zones in Central Cook Inlet.

- Oil spilled off the mouth of Kenai River tends to be more controlled by currents and rip zones than by winds (less then around 20 to 25 knots). In general, this appears true for any oil spilled in the vicinity of the rip zones.
- There is a back eddy on the north side of the east Forelands, which always oils that beach when spill comes from the south along the shoreline. This is also likely true for both sides of the East and West Forelands.

- Oil tends to migrate from east to west in the central portion of Cook Inlet rather rapidly, e.g. one day from Nikiski to the mid-channel rip zone and two days to the west side of Kalgin Island. Direction and speed of the wind seem to determine how far west the oil migrates.
- Oil on the west side of Kalgin Island, which appears to be moving south past Harriet Pt, often comes back north to the north end of Kalgin Island and enters the mid-channel rip, e.g., Glacier Bay spill, and ARGOS ice buoy #2 which circulated clockwise three full times around Kalgin Island in 9/10 ice conditions.
- Oil tends to get temporarily pulled below the surface in the mid-channel rip zone with this process being most pronounced during ebb and spring tides.

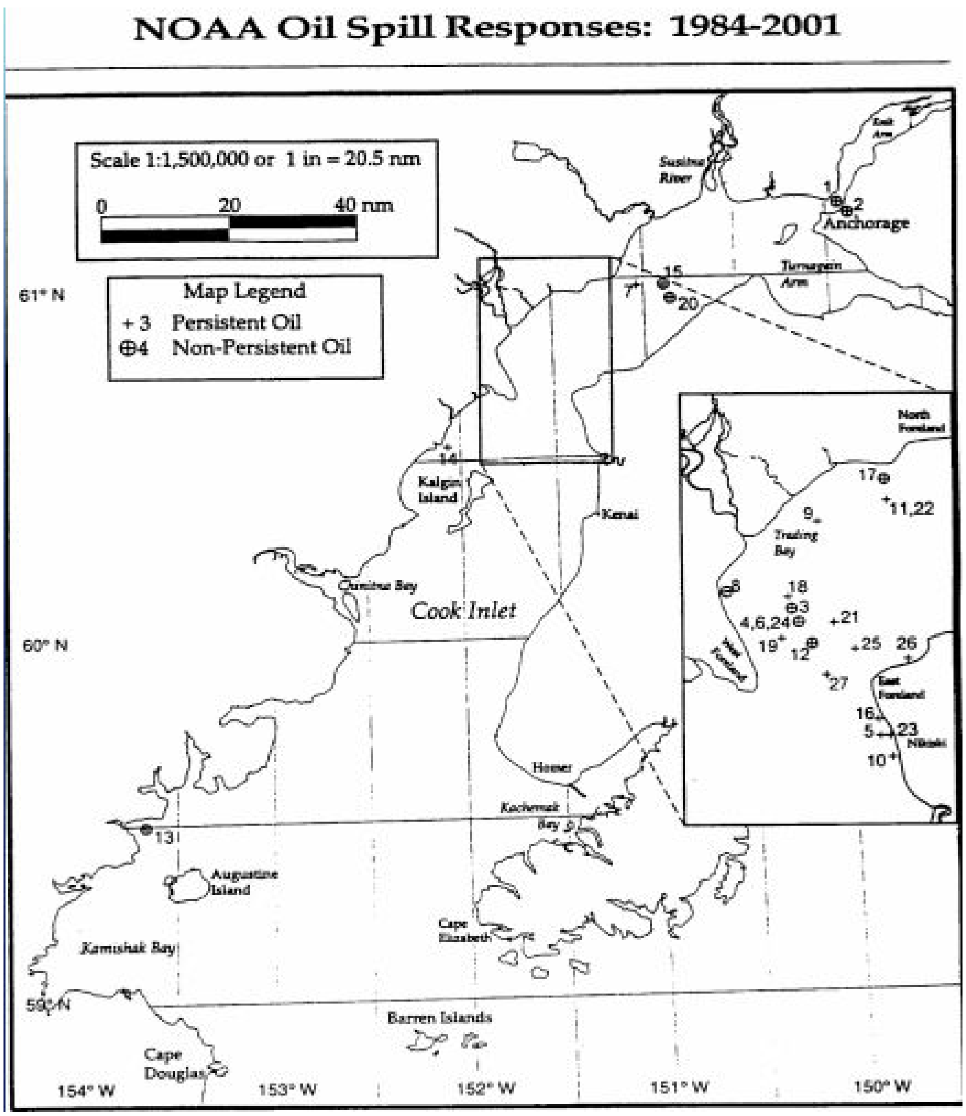

Figure 1. Major Cook Inlet oil spills between 1984 and 2001 (Whitney, 2002)

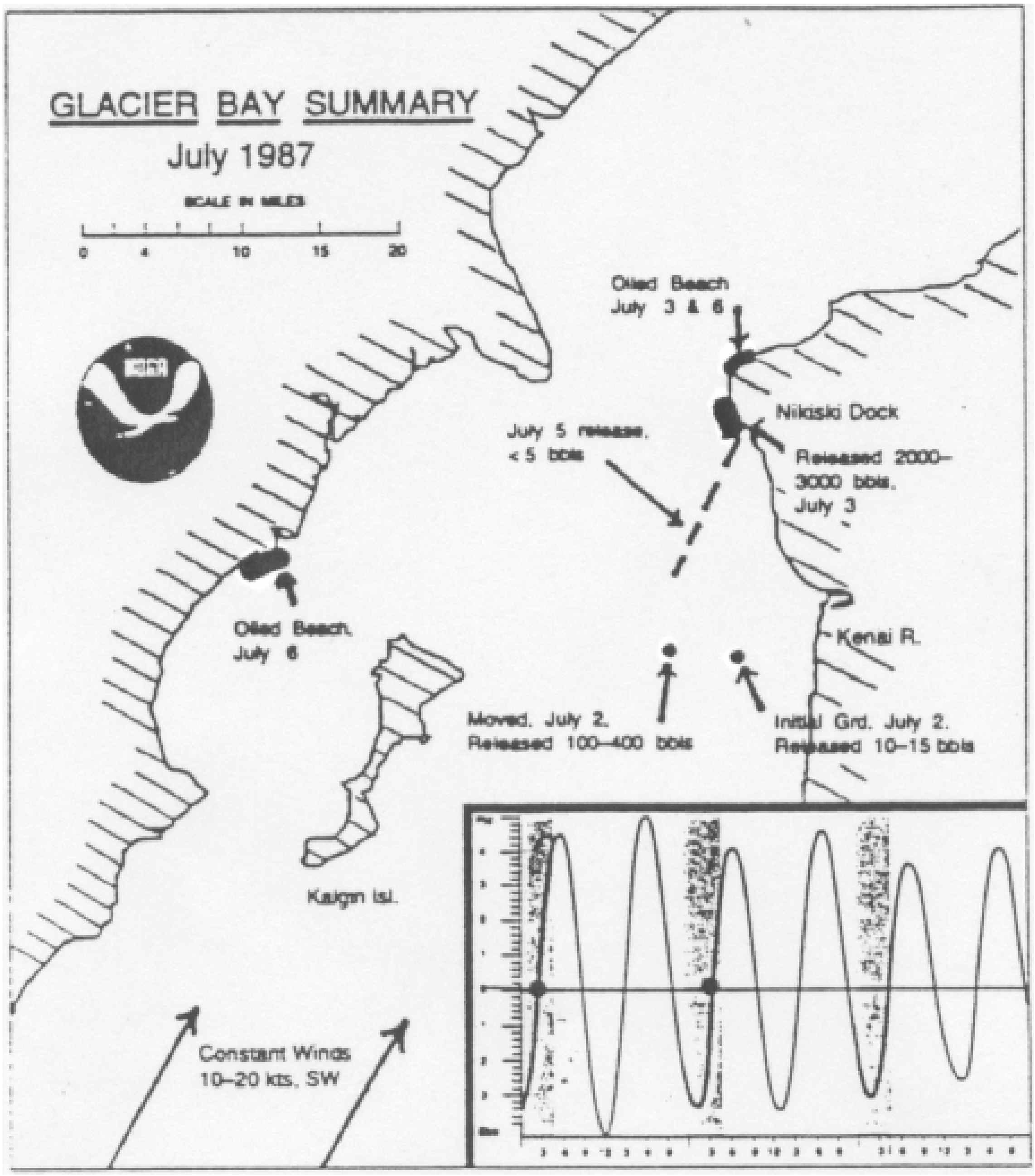

Figure 2. A history of the T/V Glacier Bay oil spill, which occurred between an initial grounding on 2 July (10-15 bbls), a release of 100-400 bbls after moving to the west of the initial point and finally a release of 2000-3000 bbls at the Nikiski dock on 3 July 1987. The insert shows the time of each release together with the stage of the tidal current. (Whitney, 1994)

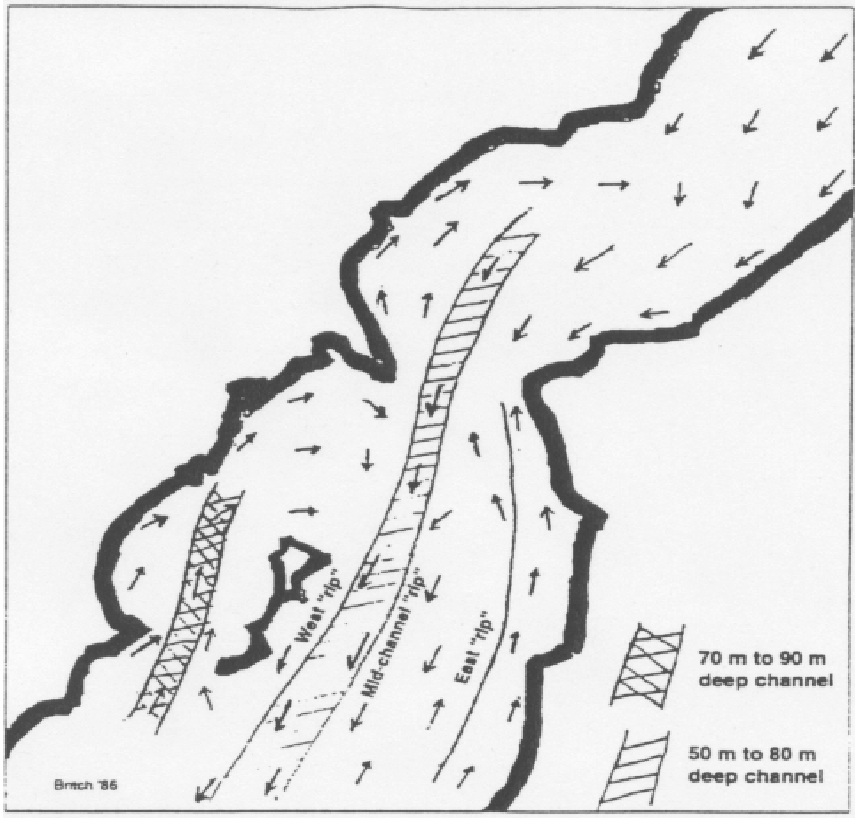

Figure 3. A schematic that shows the convergence zones in Central Cook Inlet and net circulation for spring and summer. (from: Burbank, 1977; Britch, 1986 and Whitney, 1994)

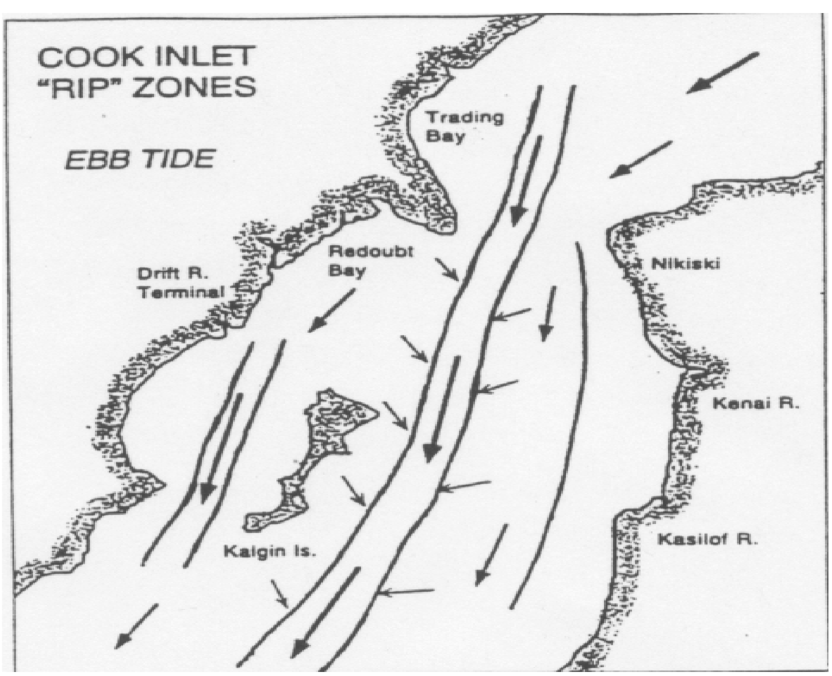

Figure 4. Central Cook Inlet convergence ("rip") zones on ebb tide. (from: Whitney, 1994)

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Cook Inlet GNOME Modeling

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NOAA/ORR/HAZMAT's General NOAA Oil Modeling Environment (GNOME) model is a simple, user friendly tool that can use inputs from various sources. Examples were shown from a Prince William Sound (PWS) exercise in the summer of 2004. One GNOME setup took currents from a PWS Princeton Ocean Model (POM) and winds from a fine scale grid meteorological model. Another setup was driven by CODAR measured surface currents. The model is publicly available on the spell out (ORR) website and is used by HAZMAT to simulate trajectories of oil and other pollutants. In the past, the model has not done well in Upper Cook Inlet due to the fact that currents that fed GNOME and it's predecessor (OSSM) did not resolved the strong convergence zones that collect the oil and pull it below the surface. The challenge for modeling this environment is to resolve the convergence zones, the inflow of water from the ACC, and the outflow from various rivers along Cook Inlet. Previous modeling attempts have shown that a simple tide model with moderate sized grids will not do the job.

High Resolution Numerical Modeling of Near-Surface Weather Conditions over Cook Inlet and Shelikof Strait

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It is common knowledge to mariners in Alaska's Cook Inlet and Shelikof Strait (CISS) that there exist small scale (O[10 km]) wind and weather regimes that are not at all indicative of the large scale conditions over the area. Indeed the near-surface winds can vary by 90 degrees or more from synoptic flow in direction and be much stronger than would be suggested by large-scale pressure gradients. However, the relative paucity of direct wind observations in this sparsely-settled region makes quantification of these mesoscale phenomena unfeasible, although they directly impact mariners and aviators traversing the region at any given time.

The purpose of this project is to aid the understanding of these various wind regimes. We use a high-resolution numerical model of the atmosphere to simulate the three-dimensional weather in the region of interest at a scale much smaller than that of current operational weather forecasting models. The results of these simulations can then be used to quantify in detail the relative frequency of occurrence of these small scale weather features, their duration, and the details of their horizontal and vertical structure.

At the Alaska Experimental Forecast Facility (AEFF) we have been running the Regional Atmospheric Modeling System (RAMS) in a multiply-nested forecast mode for the CISS region using a grid mesh of 4 km spacing. The model is run daily and is initialized using National Centers for Environmental Prediction (NCEP) Eta model initial fields and forecasts for initial and lateral boundary conditions respectively. The model is initialized at 00 UTC and integrated forward for 36 hours with data writes occurring every hour. The model results are posted in graphical form on the AEFF Weather Briefer's Page: *http://aeff.uaa.alaska.edu/wx_brief.html*, and the various numerical fields are archived for future use by the AEFF and others interested in CISS weather conditions.

This nested grid approach allows us to simulate the interaction of the large scale weather systems (O[1000 km] with the extreme terrain variations of the CISS region that can vary dramatically on the scale O[1 km]. The results reveal a variety of ageostrophic channeled and gap flows that have time scales ranging from a few hours to several days and spatial scales varying from several kilometers to the full extent of Cook Inlet and the Shelikof Strait. Comparisons with satellite-borne Synthetic Aperture Radar (SAR) wind speed retrievals shows that RAMS has the capability to faithfully reproduce several of the wind features seen in the SAR images.

Satellite tools for Cook Inlet

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Satellites provide an economical mechanism for monitoring oceanographic properties in Cook Inlet. Satellite measurements are the only mechanism for obtaining synoptic measurements of large regions. Since the satellites are primarily federally funded the cost of obtaining imagery is low. The spatial information provided by satellite measurements is a great compliment to local measurements, such as moorings, and transect lines of water properties.

Because of the data acquisition characteristics, information from some of the oceanographic satellites (e.g. Quickscat winds, altimetry) is not realistic for Cook Inlet. However, the high turbidity levels allow the use of systems normally thought inappropriate for oceanographic use (e.g. MODIS land channels). Three types of remote sensing measurements are discussed here, visible, infrared, and synthetic aperture radar. The latter two systems only measure the surface skin of the ocean. Visible remote sensing includes some depth information, but it is limited to the near surface, especially in the turbid waters found in Cook Inlet.

Visible remote sensing (i.e. ocean color) can be used to infer the chlorophyll-a standing stock, sediment levels, flow patterns, and in some cases smaller features such as kelp and eel-grass beds. Clouds and a lack of sunlight in the winter are the two biggest drawbacks to using visible remote sensing for Cook Inlet. Examination of the SeaWiFS data page show that monthly averages of the available data cover all of Cook Inlet except in November, December, and January when there is insufficient light for that satellite. The algorithms used to determine products, such as chlorophyll-a concentration normally fail in highly turbid waters; so accurate determinations of chlorophyll concentration for Cook Inlet are likely to require development of regional algorithms. While the magnitude may be off, the spatial patterns are likely to be correct and therefore contain information regarding oceanic features. The ocean bands of visible satellites have moderate pixel sizes (~ 1 km), while those designed for land applications have pixel resolutions of down to a meter. Some of these satellites are able to image river plumes filled with glacial flour as they enter Cook Inlet (Figure 1). By mapping the distribution of sediments or chlorophyll over time it is possible to infer how fronts move, but the determination of actual flow within a features is much more difficult to determine.

Figure 1. A Landsat image of Kachemak Bay showing the circulation features as indicated by the distribution of the silt-laden fresh water.

Infrared systems can be used to determine the sea surface temperature (Figure 2). The temperature distribution can then be used to infer the currents and to locate areas of upwelling, as well as showing the seasonal evolution of the water temperature. Like visible remote sensing these systems are unable to see through clouds. Unlike the visible systems the infrared systems function in the dark. Several overpasses occur each day; so when the sky is clear it is possible to get several realizations of the surface properties allow better track features and thus make inferences of current flow.

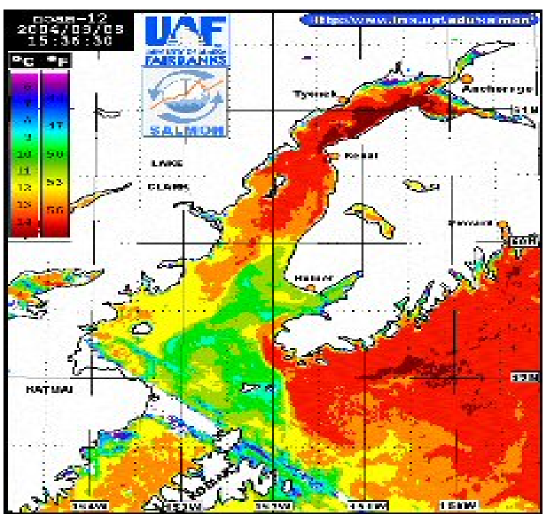

Figure 2. A September 2004 sea surface temperature image of Cook Inlet. Note the warm, fresh water flowing down the west side of Cook Inlet, and the warm extension of the Alaska Coastal Current into Kachemak Bay.
(Image from the UAF Sea-Air-Land Modeling and Observation Network website.)

Synthetic aperture radar is a technique that can image the ocean surface with good resolution (< 100 m pixels) in the dark and through clouds. These systems are often used to provide maps of ice distribution, and estimates of wind speeds. The ice distributions can then be used to infer the location of tidal rips. The estimated wind speed allows us to observe how winds vary over small scales, such as gaps between mountains (Figure 3). At low wind speeds the measurements are influenced by the accumulation of debris within tidal rips, and thus provide another way to determine the position of these features in Cook Inlet. The main disadvantages of this remote sensing tool are that the overpasses are not frequent, and the imagery can be expensive to obtain. The availability of this type of imagery is in question as new satellites replace existing sensors.

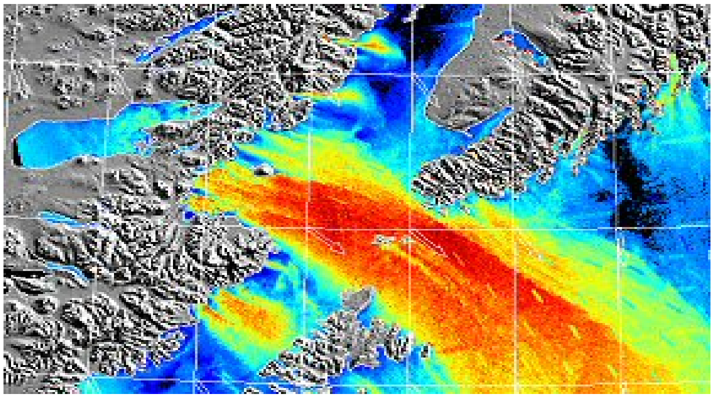

Figure 3. SAR estimates of wind speed in Lower Cook Inlet showing the bands of intense winds associated with mountain gaps.
(Image is from the Alaska SAR winds demonstration website)

Satellite measurements provide an excellent compliment to in-situ measurements. They yield spatial information that can be used to put transect and moored data into a larger context. Cloud cover, darkness, and coverage limit the temporal resolution of these systems. On those occasions where clear skies are present it is possible to get several images of the area within a day.

Oceanographic Data used for Dilution Modeling

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The presentation discusses ambient data utilized by two major dilution models, Visual PLUMES and CORMIX GI 4.3GT. Both models simulate dilution of effluent discharged into receiving waters. Although typically used to predict dilution within a few hundred meters of an outfall, the models can provide reasonable predictions for distances up to a several thousand meters. These models are fundamentally steady state and deterministic. Further, they both consider ambient depth, current speed, current direction, salinity, temperature, and stratification. Existing data used for dilution modeling in Upper Cook Inlet has typically come from NOS, EPA, tidal prediction software, CIRCAC, University of Alaska and industrial dischargers. Tidal current direction data, essentially non-existent for Upper Cook Inlet, could be utilized to determine more realistic (than circular) mixing zone shapes. Stratification of the water column in Upper Cook, if present near industrial outfalls, could affect mixing of discharge. Additional temperature and salinity data would afford a more comprehensive picture of seasonal affects on dilution of effluents. Although the amount of Upper Cook Inlet oceanographic data has generally been adequate for dilution modeling purposes, additional data would provide the potential for generating more realistic dilution simulations.

NOAA's National Ocean Service Cook Inlet and Shelikof Strait Modeling System

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The Center for Operational Oceanographic Products and Services (CO-OPS), within the National Oceanic and Atmospheric Administration (NOAA), manages the web portal to NOAA's vast collection of oceanographic and meteorological data (historical and real-time), predictions, and nowcasts and forecasts. CO-OPS data for Cook Inlet and areas nearby that are served over this "Tides and Currents" web site include information from stations in Anchorage, Fire Island, Nikiski, Seldovia, Seward, Valdez, and Cordova. Efforts are also currently underway to put together an historical database for Cook Inlet and Shelikof Strait.

The following material is included since there was emphasis on availability of data:

nowCOAST

NOS' Web Mapping Portal to
Real-Time Coastal and Estuarine Observations and NOAA Forecasts

http://nowcoast.noaa.gov

The National Ocean Service (NOS) Coast Survey Development Laboratory has developed a Geographic Information System (GIS)-based Web mapping portal called ***nowCOAST*** to allow the nation's coastal community to quickly display online, real-time weather and water observations and NOAA forecasts for major U.S. estuaries and seaports, coastal regions, and the Great Lakes.

The real-time observations include ***meteorological, oceanographic, hydrological, and water quality data*** from federal, state, and educational observing networks on land and water. The NOAA forecasts include NWS marine and weather forecasts, atmospheric, oceanographic, and river forecast guidance from NWS numerical models, as well as oceanographic forecast guidance from NOS numerical estuarine forecast models.

NowCOAST is designed to allow users to specify quickly the type of observations or forecasts they want for their area of interest and to provide an intuitive means of browsing this information once it is located. *NowCOAST* consists of two applications working in unison. The first is the map viewer, which allows users to see a map of observing station locations and forecast areas for their region of choice. The second is the *nowCOAST* 'Databrowser,' an interface that allows the user to view and navigate websites displaying observational data or forecast products that they locate through the map viewer.

When a user opens the *nowCOAST* Web page (http://nowcoast.noaa.gov) in a browser, he/she is shown the map viewer with a default view of the Continental U.S. as well as an introductory message with basic instructions on use of the site superimposed upon the map. The instructions include the step-by-step process to obtain observations or forecasts. Because *nowCOAST* is intended for a broad user base, the map viewer includes two separate methods that can be used to obtain observations or forecasts, the first for those unfamiliar with GIS, the second for those with more experience with the technology.

Coast Survey Development Laboratory,
Office of Coast Survey, National Ocean Service, NOAA

Using *nowCOAST*(cont):

The first method consists of four Web-standard 'pulldown' menus which allow the user to specify: 1) *location* (eg. an estuary, seaport, or coastal region), 2) *type of observation or forecast* (eg. weather, ocean, river, or water quality observations or forecasts), 3) *variable* (eg. water level, air temperature, wave height, etc.), and 4) *time* (real-time or a specific time window for forecasts). The user then hits the 'GO' button to obtain a map with the specified information, whic h they may then click on to view a particular observation or forecast in the Databrowser.

The second method consists of manual manipulation of the map using common GIS tools (eg. zoom, pan, identify, etc.), as well as the ability to overlay observation or forecast data 'layers' and query the underlying information to locate specific observation stations or forecast types. In both scenarios, the 'Link to Data' tool provides the functionality to allow the user to click on the map to view observations or forecasts in the Databrowser.

Observing Networks and NOAA Forecast Links in *nowCOAST*:

Observations:

Weather/Ocean:

- NOS Physical Oceanographic Real-Time System (PORTS)
- NOS National Water Level Observation Network (NWLON)
- National Data Buoy Center (NDBC) fixed buoys and Coastal-Marine Automated Network (C-MAN) stations
- NWS/FAA/DOD Automated Surface Observing System (ASOS) and Automated Weather Observing System (AWOS) sites
- NOAA Climate Reference Network (CRN)
- USCG manual weather observing sites
- EPA Environmental Monitoring for Public Access Community Tracking (EMPACT) Stations
- NOAA/FSL GPS-IPW GSOS Stations
- NOAA/OAR UrbaNet Network
- Regional Ocean Observing Systems:
  - Caro-COOPS
  - CBOS
  - CORIE
  - GLERL
  - GoMOOS
  - ICON
  - LIShore Network
  - LUMCON
  - NEOCO
  - PWSN
  - Scripps Buoys
  - SABSOON
  - SEAKEYS-CREWS
  - TABS
  - TCOON
  - USF COMPS
  - WAVCIS

River:

- USGS NWIS River Network
- NWS IFLOWS Network

Other:

- NWS NEXRAD Doppler Radar Sites
- NWS Radiosondes
- Boundary Layer Profilers
- HF Radar Surface Currents

Surface Forecasts:

- NWS/WFO county weather forecasts
- NWS/WFO coastal and offshore marine and OPC's high seas forecasts
- NWS/WFO surf zone forecasts

Forecast Model Guidance:

Weather/Ocean:

- NWS/MDL Model Output Statistics
- NWS/MDL Extra-Tropical Storm Surge Model (ETSS)
- NWS/NCEP WaveWatch III
- NOS estuarine forecast models for Chesapeake Bay, Port of New York/New Jersey, and Galveston Bay

River:

- NWS River Forecast Center (RFC) stage forecasts

Predictions:

- NOS/CO-OPS Astronomical Tidal Predictions

nowCOAST map displaying marine forecast zones, county forecast zones, and weather and ocean observation station locations over Southern Alaska

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The Web portal was constructed using ESRI's commercial off-the-shelf GIS software Arc Internet Map Server (ArcIMS), and customized using DHTML and JavaScript.

02/2005

Cook Inlet User Needs Survey Results

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Introduction
Prior to the Cook Inlet Physical Oceanography Workshop (February 2005) an on-line survey was sent to 126 individuals who were identified as currently working in the Cook Inlet region or having an interest in physical oceanographic data being collected there. The individuals include those who provide data (e.g. researchers, monitoring agencies, modelers) as well as users or potential users of data and informational products (e.g., environmental entities, managers and policy makers, government agencies, fishermen, educators) of Cook Inlet data (see Appendix A). The sponsors of the workshop were interested in the research and data needs of both groups as the planning moves forward towards design and implementation of the Alaska Ocean Observing System (AOOS).

Summary of Results
Respondents to the survey included 36 data providers and 42 data users. The actual response rate cannot be determined since the survey was distributed to an unknown number of recipients beyond the initial 126 individuals. For example, the survey was forwarded to 'Arcticinfo listserve', and many survey recipients forwarded it to others. The complete results are given in TABLE 1 in Appendix.

Data Providers
Respondents to the survey showed a wide diversity of research and work interests in the Cook Inlet region. Research interests ranged from physical oceanography to biological research (e.g. sea birds, fisheries) with many other research areas noted. The three areas identified within Cook Inlet where the majority of research effort is focused are Lower Cook Inlet and Kachemak Bay and in the central region of the Inlet (Forelands south to Anchor Point).

When asked to identify the most useful oceanographic variables to monitor, respondents ranked five variables as those they used regularly; bathymetry, sea level, salinity, surface currents, water temperature (both surface and subsurface). When asked to identify useful meteorological variables, these same respondents ranked six of these as being used regularly; marine weather, wind speed, wind direction, atmospheric pressure, air temperature and precipitation.

A number of data and information products are currently generated and available, e.g. tide tables and weather forecasts. Respondents were asked to rate the adequacy of these products. The survey showed that those Data Providers who responded felt that tide tables, weather forecasts, marine forecasts and NOAA charts were deemed "adequate". Areas that were identified as "needing improvement" were not a majority of responses for any data or products. Products and data that were identified as "did not know about" included ice forecasts, Anchorage PORTS system, oil spill trajectory model, ocean circulation model, and Coast Guard search and rescue model. When asked to identify the types of improvements needed, the top two responses were NOAA charts and circulation models. In particular, there was a strong desire for improvements to the NOAA charts by conducting a multibeam survey of Cook Inlet (the critical nature of such high resolution bathymetry is noted in Okkonen, this Proceedings). Improvements to ocean circulation simulations included better accuracy, higher spatial resolution, with seasonality and tidal currents being included in the model. The overwhelming choice for the preferred mechanism to access data and/or information was personal computer/internet.

Data Users:
Respondents to the survey showed a wide diversity of work interests in the Cook Inlet region with the majority indicating some level of work or interest in research/science or marine education. The regions of interest within Cook Inlet region were Lower Cook Inlet, Kachemak Bay, central Cook Inlet and the outer Kenai Peninsula coast. When asked to identify the most useful oceanographic variables, respondents ranked four variables as those they used regularly; surface currents, surface waves, sea surface temperatures, and sea level. When asked to identify useful meteorological variables, these same respondents ranked six of these as being used regularly: wind direction, wind speed, marine weather conditions, air temperature, precipitation, and atmospheric pressure.

A number of data and information products are currently produced and available such as tide tables and weather forecasts. Respondents were asked to rate the adequacy of these products. The survey showed that those Data Users who responded felt that tide tables, weather forecasts, NOAA charts, and marine forecasts were "adequate". Areas that were identified as "needing improvement" included oil spill trajectory and ocean circulation simulations. Products and data that were identified as "did not know about" included Anchorage PORTS system, the Coast Guard search and rescue model, ice forecasts, and the NOAA oil spill trajectory model (see Watabayashi, this Proceedings). When asked to identify the types of improvements needed, the top two responses were NOAA charts and the ocean circulation models. In particular, there was a strong desire for more detail to the NOAA charts. Improvements to the ocean circulation model included more detail and varied scenarios, and incorporation of traditional knowledge in the model. Respondents were asked to identify the preferred mechanisms to access information and the overwhelming choices were personal computer/internet, with a large number also identifying the marine VHF radio.

Ocean Data Needs for Coastal Engineering

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Abstract: Engineers are generally invited to address coastal issues as problem solvers, whose challenge is to understand the nature of the problem at hand and its physical causes. Constructed and non-structural responses to coastal issues require additional site-specific data for development of design criteria and for assessment of potential environmental impacts. Constructed works must be built to function in the prevailing wind, wave, and water level climate and particularly to withstand extreme conditions. In order to calculate parameter values for extreme conditions, long periods of record for local winds and tides are highly desirable. This also applies to wave data, but local wave climate most commonly must be derived from wind information. Problems occurring along and works built in the littoral zone require information about sediment characteristics and movement by waves, tidal currents, and ocean circulation. Ice conditions are also important in Cook Inlet. Historical aerial photographs and survey data, including coastal topography and bathymetry, are important for evaluation of coastal erosion and for design of effective responses. The needs of coastal ecologies must be defined and habitats delineated, so impacts can be predicted wise choices made for proposed shoreline interventions.

SECTION III. DISCUSSION AND CONCLUSIONS

1.0 Role of AOOS in Cook Inlet

The first stage of AOOS implementation begins in 2005 and focuses (although not exclusively) on three themes:

- Sustainability of ecosystem services (aka marine resources, including commercial fisheries)
- Mitigation of impacts due to coastal erosion (and other natural hazards)
- Improved navigation safety and search and rescue operations

The first theme requires an understanding of the impact of climate change and also necessitates the protection and/or restoration of healthy ecosystems which are essential for recreational, subsistence, and commercial fisheries, as well as shellfish farming and subsistence use of marine mammals. Monitoring of water properties also could be advantageous to mitigating health risks, such as those caused by PSP and *Vibrio parahaemolyticus*. The second theme could be more comprehensive to include effectively mitigating all natural hazards, although coastal storms, earthquake-related tsunamis, and increased erosion due to climate change appear to be the most significant natural hazards facing Alaska. The third theme also covers national security issues since improved navigation safety will affect safe transport of military personnel in and out of Alaska ports, as well as increasing our knowledge of vessel traffic in Alaska waters.

Owing to the immense extent of Alaska's coastline (47,000 miles: Anon 2002) and of waters within the United States Exclusive Economic Zone[2], AOOS has been partitioned into three somewhat distinct Regions: Gulf of Alaska, Bering Sea/Aleutian Islands and Arctic (the Chukchi and Alaska Beaufort Seas) based on the Large Marine Ecosystem concept (Sherman, . These regions are all influenced by global-scale changes in climate and are interconnected by circulation features. The oceanic Alaskan Stream flows through the deeper Aleutian passes and helps to generate the Aleutian North Slope/Bering Slope Current that provides water properties (including nutrients) that flow northward through Bering Strait into the Chukchi and Beaufort Seas. Much of the shelf waters of the Alaska Coastal Current flow through Unimak Pass and then around the coastline, exiting via Bering Strait. Both the oceanic and shelf connections transport planktonic material, e.g., eggs, larvae and plankton. These three Regions, however, are still very large and have different processes, phenomena and ecosystem dynamics (including human institutions). Thus, each Region has been further partitioned into three sub-regions (although these are somewhat fluid). The sub-region that contains the Cook Inlet ecosystem is shown in red in Figure 4.

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[2] In 1976, the United States asserted jurisdiction over fishery resources within 200 nautical miles from its shores (MSFCMA). In 1982, the United Nations Convention on the Law of the Sea created EEZs extending generally out to 200 nautical miles from the shores of all coastal states.

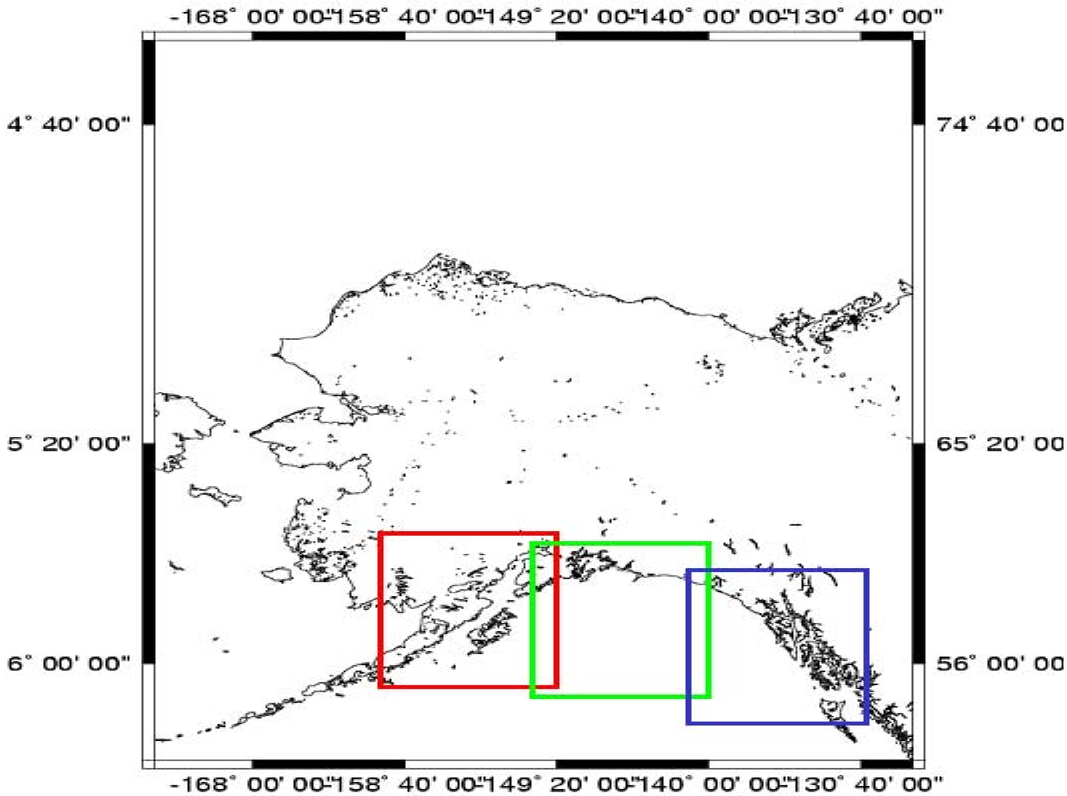

Figure 4. The Seward/Cook Inlet/Kodiak/Shelikof Strait Sub Region is contained in the red box.

AOOS will be using results (e.g. of "Recommendations for Establishing an Ocean Observing System for Cook Inlet" developed by the working groups) of this Workshop and other planning and outreach efforts with agencies and stakeholder groups to develop an AOOS/Cook Inlet ocean observing system. The extent to which this will occur depends on funding availability in 2006. In 2005, AOOS has received funding to develop a substantial Data, Modeling and Analysis Group at the University of Alaska Fairbanks to begin the integration of ocean observations in the AOOS pilot area – Prince William Sound – as well as the development of the nowcasts and forecasts needed by various user groups in PWS. 2005 funding will also help fund the PWS pilot project and products, as well as enhance some of the current observations in the Arctic, Bering Sea and Gulf of Alaska.

The GOA monitoring in 2005 includes collecting observations in the ACC as a first step prior to development of a comprehensive plan for GOA and Cook Inlet ocean observing. The importance of the ACC to the Cook Inlet ecosystem was a basic theme in the Workshop. The long-term (since 1970) collection of water temperature and salinity off Seward (known as Gulf of Alaska station one or GAK 1) has generated the longest continuous time series of water property data in Alaska waters. Our knowledge of the Alaska Coastal Current and its seasonal, interannual and longer period signals all benefited from monitoring at GAK 1 (*e.g.*, Royer 1998; Royer 2005). Presently a moored set of instruments is in place and AOOS will enhance monitoring by adding nitrate sensors (Years 1-3). Another aspect of the monitoring of the ACC is the occupation of stations that form the boundary of the lower Inlet: across Kennedy and Stevenson Entrances to Shuyak Island and across to Cape Douglas on the Alaska mainland (see Pegau *et al.,* these Proceedings). AOOS has proposed enhancements to the ongoing KBRR/CIRCAC transects by adding observations of nutrients and chlorophyll. In addition, AOOS has proposed (Year 2-3) to fund the deployment of bottom-mounted acoustic Doppler current profilers and pressure sensors. The ensuing data will be used to estimate volume transport and its variations at the boundaries of the Cook Inlet ecosystem. This data can also be used to either confirm circulation model simulations or be assimilated into the models, thereby nudging their simulations closer to reality.

2.0 Synthesis of Results from Working Groups

The participants were partitioned into five Working Groups (See Appendix A) to address the following questions:

- What are the issues, problems and concerns?
- What products are needed, where and why (prioritize)?
- What observations/models are necessary to create the products?
- What are other recommendations or ideas for establishing an ocean observing system?

While each group took a different path toward addressing their charge, their results fell into common themes. Following the discussion of the Cook Inlet ecosystem and its services as a unifying theme, the results of the Working Group discussions for the first item are presented in terms of natural and human forcing.

Regarding human forcing, all groups had concerns about commercial development (oil, gas, mining, other) and the associated activities and impacts (e.g., increased shipping, construction, pollution, contaminants transport, oil spills). Two groups noted their concern that the physical component of the ecosystem needs to be connected to the biota (perhaps as conceptualized in Figure 2). This was expressed in terms of sustainability of ecosystem services and an emphasis on a more interdisciplinary approach. Both of these groups focused on having such information readily available to all users, such as policy and decision makers. Regarding natural forcing: the nature of the earth's ecosystem is change (regardless of the present human impact) on all time and spatial scales. In both the short and long term, increasing our knowledge of the processes and mechanisms that force ecosystem dynamics will permit generation of realistic forecasts of future conditions.

All groups expressed concerns about the present extent (both spatial coverage and type of observation) of monitoring, which is inadequate, as well as our ability to understand and therefore forecast ocean conditions. In the short term, concerns focused on the lack of observations required for more comprehensive sea and weather forecasts, both for safety and for response to hazardous material spills. For the longer term sustainability of ecosystem services, concerns were raised by all groups regarding how climate-induced changes would affect the ACC, sea ice timing and extent, and freshwater inflow; and how, in turn, these variations in physical features might promote harmful algal blooms and a potential increase in *Vibrio* (a naturally occurring bacterium not necessarily associated with pollution, and its outbreaks are strongly associated with warm water temperatures; however, other contributing factors may also be involved including upwelling events, phytoplankton blooms, salinity changes) and affect other biological phenomena such as productivity at all trophic levels. A thematic issue/concern voiced by a majority of the groups was to ensure easy access by users both to the data itself and informational products generated from integrating many data streams into visual products.

For the most part, all of the Working Groups' answers to "What products are needed, where and why?" were consistent. In several of the presentations, as well as in all of the Working Groups, a marked issue and high priority product was high-resolution, multi-beam bathymetry. In addition, all groups identified the need for more comprehensive weather products (real-time and forecasts out to 48 hours) to be used for air and marine safety, as well as for hazardous material spill containment. The west side of Cook Inlet was noted as a region of particular need for enhanced weather products. Sea ice was also identified in all groups as a topic that required the development of information products. These included observational (satellite, ice radar) and model simulation products, together with an updated compendium (ice atlas) of past conditions.

In four of the five groups, the need to develop and subsequently produce simulations from various types of models was emphasized. Indeed, as Johnson (these Proceedings) notes, "models will be the observations in the future." This means that as monitoring is expanded and models are developed that produce reliable simulations, information from these simulations will provide products for users. Further, AOOS is developing a data, modeling and analysis group at the University of Alaska Fairbanks that will take the lead in model and product development. Among the models identified as essential to meet multiple Cook Inlet user needs are: three-dimensional circulation (able to simulate vertical velocities which will require more observational data), sediment transport/storm surge/wave (to address erosion/deposition and structural issues), hydrological (to quantify fresh water inflow), and search and rescue. Another commonly identified need was better accessibility of data and products. This concern is being addressed by AOOS in its data management and communications committee (DMAC), which has prepared various reports and committee meeting minutes that are available on the AOOS web site (www.aoos.org).

Although all of the Working Groups identified various other specific products (See Appendix D.) and issues, the highest priority products identified were: improved bathymetry, enhanced weather products, enhanced sea ice products, and development and generation of information products (especially nowcasts and forecasts) from models. The users/residents need to know:

- What data and/or informational products are available?
- How do I access them?
- What do these products mean so I can use them appropriately?
- How do we get new products developed?

Another commonly identified concern was educational (including community outreach), which most Working Group members felt must be part of AOOS's mission: to inform residents both about the ecosystem itself and also about what AOOS is, can and will be providing

The synthesis of recommendations from the Working Groups is consistent with results from the provider and user surveys (see Thompson, these Proceedings). The providers identified bathymetry, currents and water characteristics (temperature, salinity and sea level) as the most useful oceanographic parameters, and marine weather as the most useful meteorological parameter. While enhanced real-time observations would address providing more of these parameters, models are needed to generate more comprehensive products, such as forecasts. The improvements most needed were to bathymetry (NOAA charts) and circulation models. Several existing products were largely unknown to many of the respondents (e.g., ice forecasts, various models and real-time observations by PORTS [see Patchen, these Proceedings]). These results are consistent with the emphasis of the Working Groups on improving user knowledge of and access to both the data and products (i.e., community outreach/education regarding what is available). The users also identified what they considered to be the most useful oceanographic parameters (currents, sea level, waves, and sea surface temperature) and meteorological parameters (weather conditions, air velocity, air temperature, precipitation, and pressure). Again, this set of respondents identified a need to improve ocean circulation and oil spill trajectory models and to make some existing products better known (e.g., PORTS, models and ice forecasts). The results from the user needs survey support the Working Group prioritization of the products as noted above and highlight the need to make the user communities more aware of what is available now and potentially in the future. The summary by Johnson (Johnson, APPENDIX E., this Proceedings) also is consistent with the results from the Working Group discussions.

3.0 Summary of Results from the Post-Workshop Evaluation

The following summary represents results from 31 respondents (14 'data providers' and 17 'data users') to the evaluation survey conducted by R. Foster of KBRR (Appendix F). Using results in the Post-Workshop Evaluation Report, it can be concluded that the Workshop was extremely successful. This is based on the facts that: (1) all respondents indicated they will use information they acquired and identified specifically how that will occur (i.e., successful information transfer occurred), and (2) many of the respondents in both provider and user groups indicated an increased awareness of potential contacts or networking opportunities (i.e., it provided an arena for successful coordination to occur). An important result from the Evaluation in terms of AOOS's role in Cook Inlet was the direction provided relating to measurements and/or products most needed. The priority measurements are bathymetry, winds, sea surface temperature, and currents. The locations within Cook Inlet with the greatest need, as identified by this group, are southern (Barren Islands) and western (Kamishak Bay) Cook Inlet. For the most part, these results are consistent with those from the pre-Workshop survey and the presentations themselves.

Survey respondents also identified areas that they felt needed improvement. Two respondents wanted participation from more stakeholders/users and more focus on stakeholders' needs. The groups specifically listed as missing were subsistence and Tribal groups and some government agencies (United States Geological Survey and the U.S. Army Corps of Engineers). One reason for the former omissions likely relates to how the Workshop was advertised (primarily through electronic media, with only a few attendees learning about the Workshop via newspaper or flyer). Some members of the user group experienced a common phenomenon, science-speak;

researchers tend to present their information replete with jargon and not in common English. Perhaps owing to the narrow focus of the Workshop (Physical Oceanography), some respondents suggested that future Workshops include presentations of connections between the physical environment and biota. See Appendix F for additional recommendations.

4.0 Conclusions

Understanding the impacts of human and natural forcing is important to managers striving for balanced regulations that provide for sustainable harvests of ecosystem services while protecting other components of the ecosystem, including threatened and endangered species and the non-material benefit of the environment. The keystone to improved understanding of the ecosystem is the collection of physical and biological observations and the development of products either directly using these data or through model simulations. Such knowledge will provide the best information available to allow informed decision-making regarding: preservation of the ecosystem and sustainability of its services, the challenges of forecasting the most likely scenarios of climate change (e.g., increased coastal erosion, changes in nutrient fluxes), and the best strategies for real-time needs like responding to hazardous material spills, marine/aviation safety and search and rescue operations.

The presentations, Working Group suggestions/concerns, and both pre-and post-survey results identified the following issues as the highest priorities for Cook Inlet:

- Bathymetry on a scale appropriate to allow circulation models to simulate convergence zones;
- Enhanced real-time observations and forecasts of atmospheric and oceanic conditions;
- More comprehensive sea ice products (real-time, atlas, weekly to seasonal forecasts); and
- Development of products from various models (atmospheric, circulation, waves, sediment).

Programs proposed by AOOS address each of these issues (except the one related to sea ice) either through enhancement of ongoing monitoring or the development of an AOOS modeling and analysis group at the University of Alaska. Techniques, models and/or products developed by this group for the AOOS pilot area in Prince William Sound will be to some extent transportable when funds are available for a Cook Inlet program.

The methods used to advertise future Workshops or surveys must be customized for each sector of the user community. While email and on-line surveys appear to be effective approaches for the science community and resource managers, personal contact should not be neglected as a technique for inviting or surveying Tribal groups, subsistence users, mariners, or marine industry personnel (Foster, this Proceedings). Results in the Post-Workshop Evaluation (Appendix F.) identified issues of participation from more stakeholders—and more of a focus on stakeholders' needs. The groups specifically listed as missing were subsistence user groups and Tribal groups. Within the Cook Inlet region NOAA's Center for Coastal Monitoring and Assessment is working with Alaskan Natives in Port Graham to develop ways to use Traditional Knowledge in management of ecosystem services. This programs objectives are to develop knowledge of baseline conditions (monitoring) in order to understand the causes and consequences of both human and naturally caused changes (climate change), and hence to have the ability to forecast ecological conditions (www.gem.state.ak.us/Symposium/Presentations_2005/Session10/Kimani_Kimbrough.pdf). These are parallel to AOOS's themes and coordination of programs would help address the issues identified in the post-workshop survey. In addition, the issue of 'science-speak' (jargon, acronyms, esoteric rather than plain English), which is a nearly universal challenge to communications between researchers and others, needs to be addressed in order for AOOS programs and products to be most responsive to users.

Education is another primary concern. How does the general public, as well as specific users, become familiar with AOOS and its products? The Physical Oceanography Workshop was clearly successful in bringing many different users together to discuss current understanding of this ecosystem and the challenges to future progress. An annual workshop is one approach to addressing the need for ongoing education. Including students in such a workshop would greatly enhance the dissemination of information while building a base of knowledgeable users. Another approach is to make informational videos that would be sent to schools and other groups, as well as an interactive and interesting web site to draw attention to AOOS and its products.

Recommended steps for AOOS in Cook Inlet are:

- Develop an overall plan for an ocean observing system in Cook Inlet to meet multiple user needs and that includes enhancing existing monitoring efforts and developing strategies (with the appropriate agencies) to meet the needs identified as having highest priority: multi-beam bathymetric mapping and enhanced monitoring of meteorological and oceanographic parameters as required to improve real-time data and forecasts. The Cook Inlet system must also tie into systems for Kodiak and other regions of the Gulf of Alaska and statewide observing system;
- Identify areas for collaboration with other agencies and entities to minimize duplication of observing and modeling efforts;
- Ensure additional input from various user groups into development of the Cook Inlet so that
- Secure funding for the system developed through the planning process;
- Implement, as proposed, a data, modeling and analysis group at the University of Alaska, Fairbanks with making data and products more accessible a priority; and
- Develop (with entities such as CIRCAC, KBRR, Cook Inlet Keeper, MMS, other interested parties) educational forums and presentations that effectively disseminate information regarding AOOS and its products addressing the needs and concerns of all users and residents.

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SECTION V. APPENDICES

Appendix A. Attendees and Working Group Assignments

Last Name	First Name	Affiliation	E-mail Address	Group #
Badajos	Oriana	KBRR		
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Hartley	Robert	AK Shellfish Growers	hartley@xyz.net	1
Hedstrom	Katherine	UAF/ARSC	kate@arsc.edu	2
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Wheat	Geoff	UAF	wheat@mbari.org	4
Whitney	Dr. John	NOAA	john.whitney@noaa.gov	5
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<u>APPENDIX B.</u> Agenda

Monday, 21 February 2004 – Islands and Oceans Visitor Center

7:45 *Continental Breakfast (provided)*
8:20 Welcome and Introduction; Purpose of Workshop
Scott Pegau (KBRR), Molly McCammon (AOOS), Sue Saupe (Cook Inlet RCAC)

Ocean Observing System and Modeling
8:40 Prince William Sound Ocean Observing System
Dr. Carl Schoch (Oil Spill Recovery Institute)
9:00 Alaska Ocean Observing System: Nested ROMS Circulation
Dr. Yi Chao (JPL)

Cook Inlet Observations
9:20 Central Cook Inlet Water Column Hydrography
Dr. Steve Okkonen (UAF School of Fisheries and Ocean Sciences)
9:40 Lower Cook Inlet Water Column Hydrography
Dr. Scott Pegau (Kachemak Bay Research Reserve)
10:00 Cook Inlet Current Measurements by NOAA CO-OPS
Jennifer Ewald, Dr. Peter Stone, Laura Rear
(NOAA Center for Operational Oceanographic Products and Services)

10:20-10:40 *Coffee Break (provided)*

Cook Inlet Observations and Modeling
10:40 Lower Cook Inlet Surface Drifter Tracking
Carol Ladd (NOAA-PMEL)
11:00 Cook Inlet Surface Current Radar Deployments
Dr. Dave Musgrave/Hank Statscewich (UAF)
11:20 Cook Inlet CODAR Deployments by NOAA CO-OPS
Karen Grissom (NOAA Center for Operational Oceanographic Products and Services)
11:40 Satellite Drifters/ 3-Dimensional Cook Inlet Model
Dr. Mark Johnson (UAF Institute of Marine Science)

12:00-1:00 *Lunch (provided)*

Existing Cook Inlet Modeling and Products That Use Oceanographic Data
1:00 Northern Gulf of Alaska Circulation Model
Kate Hedstrom (UAF Sea-Air-Land Modeling & Observation Network)
1:20 National Weather Service Forecasts and Products
Gary Hufford (NOAA National Weather Service)
1:40 NOAA Coast Survey Activities in Cook Inlet
Mark Boland (NOAA Marine & Aviation Operations)
2:00 Cook Inlet Tidal Datums
John Oswald (John Oswald & Assoc, LLC)
2:20 Oil Spill Scientific Support Coordinator Perspective

	Dr. John Whitney (NOAA HAZMAT)
2:40	Cook Inlet GNOME Modeling *Glen Watabayashi (NOAA HAZMAT)*
3:00-3:20	*Coffee Break (provided)*
3:20	Cook Inlet Atmospheric Model *Dr. Peter Olsson (Alaska State Climate Center)*
3:40	Satellite Tools for Cook Inlet Dr. *Scott Pegau (Kachemak Bay Research Reserve)*
4:00	Oil and Gas Industry Data and Uses *Speaker still being determined*
4:20	Discussion of Presentations – Questions and Answer Period for Presenters *Two Crow (aka Jim Schumacher, Two Crow Environmental, Inc)*
5:00	*Ajourn for the Day – Dinner on your own (rides can be arranged for transport to Lands End Resort)*

Tuesday, 22 February 2004 – Islands and Oceans Visitor Center

8:20	Welcome Back and Summary of AOOS Goals for Workshop *Dr. Mark Johnson (UAF Institute of Marine Science)*

Cook Inlet User Needs

8:40	Cook Inlet User Needs Survey Results *Terry Thompson (KBRR)*
9:10	Ocean Data Needs for Coastal Engineering *Dr. Orson Smith (UAA)*
9:30	Summary of Previous Days Presentations and Instructions for Break-out Groups *Two Crow (aka Jim Schumacher, TCEI)*
10:00-10:20	*Coffee Break (provided)*
10:20	Working Sessions – Desired Cook Inlet Measurements and Products *All participants*
12:00-1:00	*Lunch (provided)*
1:00	Summaries of Break-out Session Discussions and Recommendations *Break-out Session Chairs*
2:15	Wrap-Up and Where Do We Go Now? – Development of a Cook Inlet Ocean Observing Strategy *Dr. Mark Johnson (UAF Institute of Marine Science)*
2:45	Adjourn (to catch afternoon plane)

<u>APPENDIX C.</u> Results from Data Provider and User Survey

TABLE 1: (A) Results Based On 36 Responses From Data Providers and (B) Results Based On 42 Responses From Data Users.

(A) Results Based On 36 Responses From Data Providers

1. Please identify all of the following that apply to your work or interests related to Cook Inlet.

Research / Science	100 %
Environment / Conservation	53 %
Federal	47 %
Marine Education	42 %
Oil Spill Response	36 %
Resource Management	36 %
Marine Transportation	31 %
State	31 %
Coastal Engineering	25 %
Commercial Fishing	22 %
Sport Fishing	20 %
Recreation	20 %

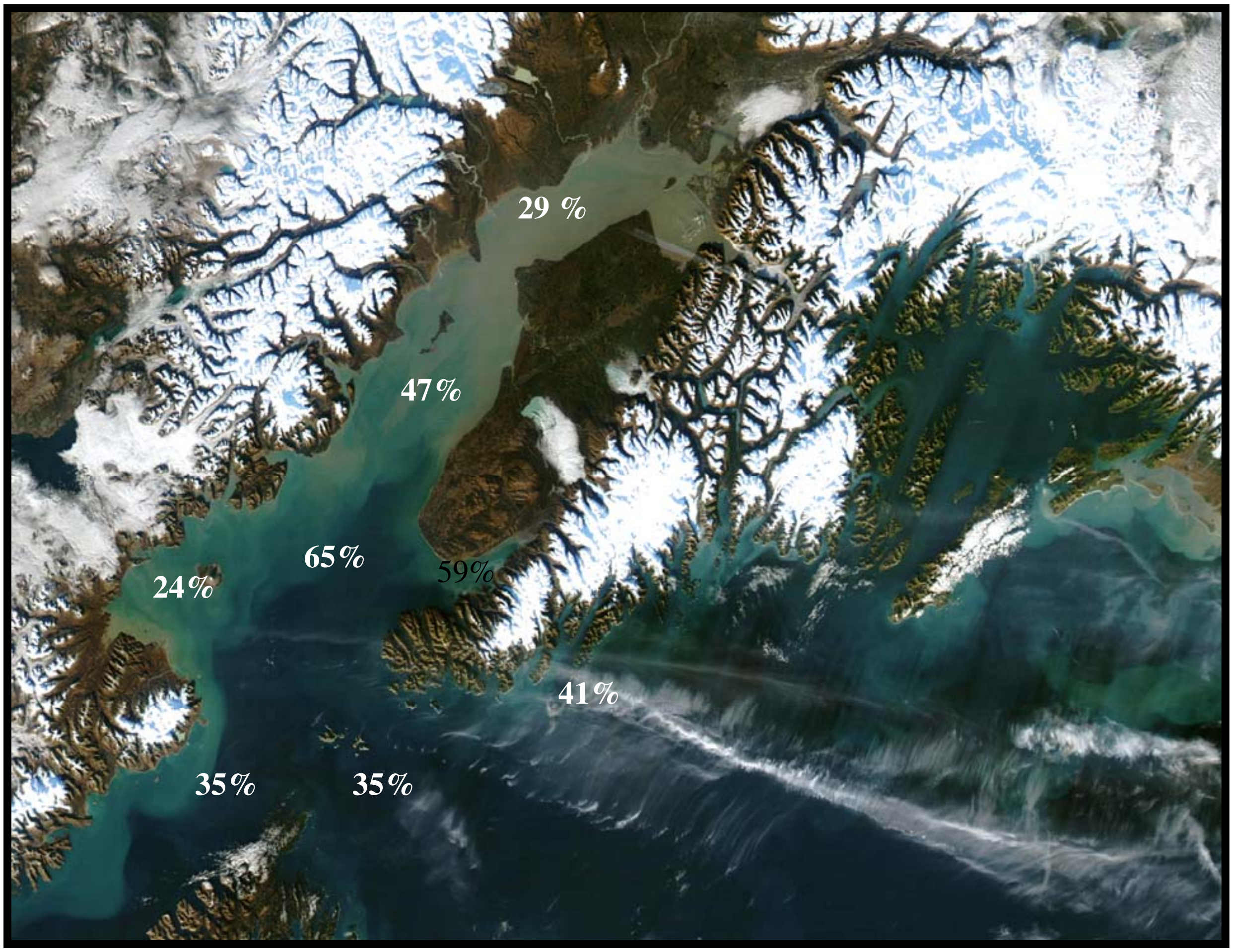
Other responses to… *work or interest*: policy maker, community planning, mariculture, non-profit, public health, military, public safety/homeland security, tribal, private company, borough, city

2. What type of research, monitoring or modeling do you do?

- Tides and currents
- Meteorology
- Contaminants
- Physical oceanography
- Fisheries
- Seabirds
- Bathymetric modeling
- Atmospheric modeling
- Circulation modeling
- Invasive species
- Coastal sediment dynamics

3. Please indicate which areas of the Cook Inlet region and surrounding areas are of primary interest to you (see Figure below).

- Lower Cook Inlet	65%
- Kachemak Bay	59%
- Central Cook Inlet	47%
- Outer Kenai Peninsula Coast	41%
- Northern Shelikof Strait / Kodiak	35%
- Barren Islands	35%
- Upper Cook Inlet	29%
- Kamishak Bay	24%



Areas are of primary interest (% of Data Provider responses)

4. How useful to you are the following Oceanographic variables (ranked):

Bathymetry	1.36
Surface currents	1.65
Sea Surface temperatures	1.71
Sea level	1.75
Salinity	1.81
Sub-subsurface temperatures	1.96
Surface waves	2.04
Bottom character	2.17
Ice distribution	2.42
Dissolved nutrients	2.61
Ocean color	2.63
Contaminants	2.77
Dissolved oxygen	2.96

<u>Ranking Scale</u>

1 – Use regularly 2 – Use occasionally 3 – Will use if available 4 – Not useful 5 – Do not know about

5. How useful to you are the following Cook Inlet meteorological variables:

Marine weather conditions	1.38
Wind speed	1.42
Wind direction	1.44
Air temperature	1.59
Atmospheric pressure	1.64
Precipitation	1.85
Humidity	2.63
Dew point / fog	2.40
Airborne contaminants	3.30

<u>Ranking Scale</u>
1 – Use regularly 2 – Use occasionally 3 – Will use if available 4 – Not useful
5 – Do not know about

6. Please rate the adequacy of the following data and information products.

Adequate
- Tide tables (59%)
- NOAA charts (46%)
- Weather forecasts (44%)
- Marine forecasts (44%)

Needs Improvement
- Ocean circulation model (44%)
- NOAA charts (42%)
- Weather forecasts (33%)
- Marine forecasts (30%)
- Tide tables (30%)

Do Not Know About
- Coast Guard search and rescue model (80%)
- Oil spill trajectory model (80%)
- Anchorage PORTS system (76%)
- Ice forecasts (68%)
- Ocean circulation model (56%)

7. If you believe any of the above need improvement, please identify what type of improvements are needed. (Top 2 responses)

#1 Response -
NOAA charts:
- need to be updated with recent hydrographic survey data
- need regular surveys to properly define shoal encroachment on shipping channel
- increased resolution
- only navigation channel surveyed
- better bathymetry (multibeam)
- need multibeam

- multibeam survey of Lower Cook Inlet
- multibeam!!!
- simply updating
- High resolution multibeam bathymetry needed

#2 Response -
Ocean circulation model:
- increased accuracy
- more information on subsurface circulation
- based on winter weather conditions in Lower Cook Inlet
- details with tidal influences in Kachemak Bay
- higher resolution / baroclinicity
- higher x,y,z, spatial resolution

8. Are there other data and information products that would be useful to you and would like to have provided?

- Bathymetry (3 respondents)
- Storm surge model (3 respondents)
- Circulation patterns (3 respondents)
- Substrate mapping (2 respondents)
- Wave height
- Chlorophyll from moored arrays

9. How do you prefer to access your information?

- Personal computer / Internet (90%)
- Marine VHF radio (24%)
- Weather radio (24%)
- Newspaper (24%)

Other responses: AM / FM radio, TV, Cell phone

(B) Results Based On 42 Responses From Data Users

1. Please identify all of the following that apply to your work or interests related to Cook Inlet.
Work or interests related to Cook Inlet:

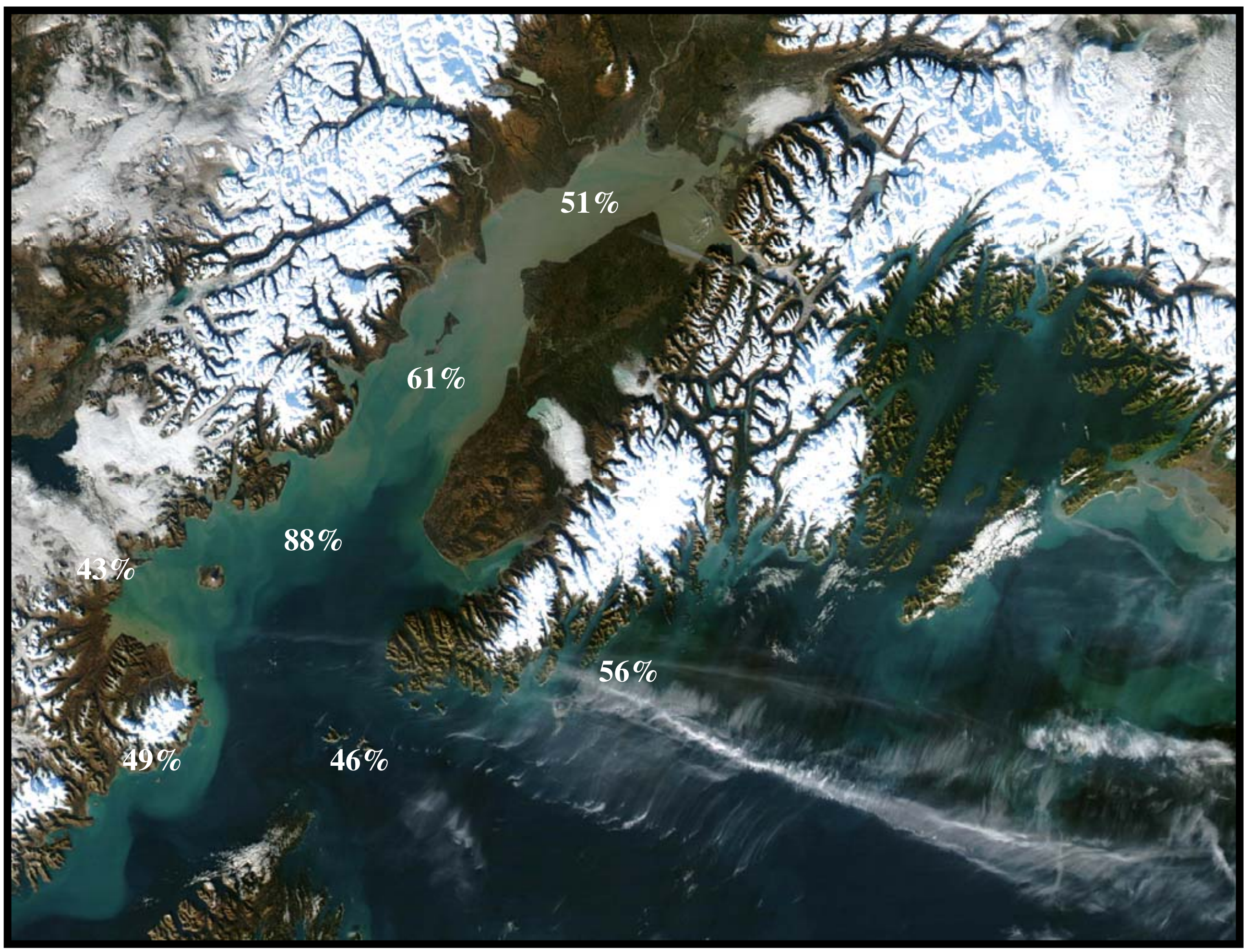
Research / Science	63 %
Environment / Conservation	56 %
Marine Education	46 %
Oil and Gas Industry	44 %
Marine Transportation	41 %
Oil Spill Response	41 %
Private Company / Individual	41 %
Resource Management	39 %
Recreation	39 %

Commercial Fishing	37 %
Sport Fishing	34 %
State	31 %

Other responses: public safety/homeland security, state, non-profit, tribal, subsistence hunting and fishing, coastal engineering, borough, policy maker

2. Please indicate which areas of the Cook Inlet region and surrounding areas are of primary interest to you(see figure below).

- Lower Cook Inlet	88%
- Kachemak Bay	68%
- Central Cook Inlet	61%
- Outer Kenai Peninsula Coast	56%
- Upper Cook Inlet	51%
- Northern Shelikof Strait / Kodiak	49%
- Barren Islands	46%
- Kamishak Bay	46%



3. How useful to you are the following oceanographic variables (ranked):

- Surface currents	1.67
- Surface waves	1.85
- Sea surface temperature	1.94
- Sea level	1.97
- Bathymetry	2.00
- Ice distribution	2.03
- Contaminants	2.06
- Bottom character	2.16
- Salinity	2.17
- Sub-surface temperatures	2.44
- Ocean color	2.54
- Dissolved nutrients	2.73
- Dissolved oxygen	2.96

<u>Ranking Scale</u>
1 – Use regularly 2 – Use occasionally 3 – Will use if available 4 – Not useful
5 – Do not know about

4.How useful to you are the following Cook Inlet meteorological variables (ranked):

- Wind direction	1.41
- Wind speed	1.42
- Marine weather conditions	1.44
- Air temperature	1.61
- Precipitation	1.76
- Atmospheric pressure	1.90
- Dew point / Fog	2.15
- Humidity	2.41
- Airborne contaminants	3.03

<u>Ranking Scale</u>
1-Use regularly 2-Use occasionally 3-Will use if available 4-Not useful 5-Do not know about

5. Please rate the adequacy of the following data and information products:

Adequate
- Tide tables (68%)
- Weather forecasts (54%)
- NOAA charts (51%)
- Marine forecasts (50%)

Needs Improvement
- Ocean circulation model (56%)
- Oil spill trajectory model (47%)

Do Not Know About
- Anchorage PORTS system (73%)
- Coast Guard search and rescue model (67%)
- Ice forecasts (50%)

- Oil spill trajectory model (47%)

6. If you believe any of the above needs improvement, please identify what type of improvements are needed. (Top 2 responses)

1 response - NOAA charts:
- update (7)
- more detail (2)
- digital versions
    - print out instead of purchasing
    - on-line

- need good bathymetry charts and vessel traffic danger charts showing reality of large vessel risks in Cook Inlet and Kachemak Bay in different seasons

#2 response – Ocean Circulation Model:
- insufficient knowledge for model to be valid
- hear about it, but yet to see
- more detail (3 respondents) and more sophistication
- better delineation
- more scenarios with wind and current
- adequate, but always room for improvement
- more extensive research and integration of traditional knowledge
- areas of industrial interest
- general flow in and out of Cook Inlet

Are there other data and/or products that would be useful to you and would like to have provided?
- Sea state in local areas would be helpful
- more projects like the ARGUS camera set-up in Kachemak Bay
- easy access to layman friendly website to access information in one spot
- would like to see someone take over funding of long-term HF radar (CODAR) in Cook Inlet
- contaminants in Cook Inlet
- models showing movement of discharge plumes from offshore oil rigs
- wave height and storm surge (4 respondents)
- timely interpreted images of primary productivity / plankton blooms

7. How do you prefer to access your information?
- Personal computer / Internet (92%)
- Marine VHF radio (49%)
- AM / FM radio (40%)
- Newspaper (32%)
- Weather radio (27%)
- Landline telephone (27%)
- TV (24%)
- Cell phone (22%)

<u>APPENDIX D.</u> Working Group Reports (see Appendix A. for group participants)

I. Working Group #1 Leader: Molly McCammon

<u>ISSUES, PROBLEMS, CONCERNS</u>

Oil & gas development, Pebble Mine

- Potential impacts of pollution, ability to respond to spills.
- Transportation issues – need safe transportation to minimize accidents.
- Engineering challenges for construction: many facilities are aging; new ones may be constructed.
- Some effluent discharge into inlet – is it toxic, where does it go? Ability to trace fate & effects. Some studies have been done – because CI is a very dispersive environment, not much has been found. Can see discharge plumes distinguished from regular water column – can use acoustics to identify

Climate change impacts

- Increased bluff erosion due to increased winds & wave action & less winter ice
- Increased sedimentation (higher flow from glacial rivers due to glacial melt). Suspended sediment is circulation driven; other is wind/wave driven.
- Potential for increased incidents of Harmful Algal Blooms (PSP) and vibrio – what are conditions that promote this?

Insufficient weather observations

- Boating, shipping often unsafe
- Need more real-time observations, especially on west side & especially wind

Ice monitoring needs improvement

- Ice conditions big issue for construction (Knik bridge, port expansion, docks, O&G rigs)
- Obstacles for navigation & spill cleanup
- Ice forecasts come from 2 places: National Ice Center and NWS Russ Page
- Less ice appears to result in increased sedimentation in north end of Inlet, requiring more frequent dredging by Port.

Mapping & charting insufficient

- Over 1/3 of inlet goes dry at low tides
- Only the navigation channels are currently mapped – also need tidelands

Insufficient information about connection to larger Gulf of Alaska

- What role does Alaska Coastal Current play in CI conditions & productivity?
- How will this role change with future climate change?

Cook Inlet synthesis

- A lot of work going on, some is coordinated, most is not integrated

Liability issues

- Need protection when making forecasts, including data from volunteer observers, etc.
- Included in ocean observing legislation currently before Congress.

<u>PRIORITY PRODUCTS NEEDED</u>

Updated bottom surveys

- High resolution, multi-beam bathymetry at the right scale
- Include tidelands

- Need public access to mapping/surveys done for construction projects (Forelands to Port of Anchorage done – need to access)
- More advertising that charts can be accessed electronically and they are updated weekly (unlikely paper charts)
- Some LIDAR has been done – more needed, at extreme low tides to catch flats
- NOAA has 10-year backlog for high priority areas; may have to consider private contractors doing this – can do cheaper, faster, more efficient

Ocean circulation model

- One that includes rips, vertical currents, precipitation, freshwater runoff, wind
- Coupled ice-ocean model
- Need better remote sensing with ground truthing
- Important for improving oil spill trajectory models: need real time and stochastic for projects, contingency planning, and impact assessments
- Important for larval fish transport – affects productivity of inlet fisheries

Updated ice atlas

- Past, current & future conditions – temporal and spatial. Was done in 2000. Needs to be updated and kept current.
- NWS ice forecaster – Russ Paige – will retire in next several years. His reports are hand-drawn. Need to automate ice reports so they can become operational: digitized and archived for trends.

Weather conditions

- Need more frequent, better, real-time observations. Put up a met station at each harbor in CI – one that displays info in real time for public and includes info from PORTS
- Need more frequent forecasts – not just every 6-12 hours. Need to be able to access real-time info. Bring in more smaller stations to have better coverage (but some thought that fewer stations, but longer term would be better).
- Need better atmospheric models – more observational input, esp. wind
- Explore use of Kalgin Island nav aid for met sensors – who would service?
- Add C-Mann station at Iniskin Bay – site of Pebble Beach mine
- Keep trying to put a buoy in water near Barren Islands

<u>OTHER PRODUCTS NEEDED</u>

Sediment models

- Transport, deposition. Map littoral cells & sinks.
- Where does sediment go from bluff erosion?
- How much sediment is coming from rivers?

Disease

- HAB and vibrio could become bigger issues with increased warming.
- Develop HAB and vibrio possible condition forecasts – alert system: water temp, salinity, nutrients, circulation. Maintain temperature measurements at 14 oyster farms in Kachemak Bay.

Search and Rescue Models

- Given challenges of Cook Inlet circulation, models could be improved.
- Cook Inlet is dangerous area to boat
- Use CODAR throughout Inlet?

Storm surge models

- Potential of tsunami from Augustine volcano
- Tsunami hazard & coastal inundation maps needed – erosion rate forecasts for community planning
- Sea level rise does not appear to be a big issue here; rather issue is with less ice, more waves due to more exposure to open water.

Synthesis

- Cook Inlet historical and current data & information needs to be synthesized

Remote sensing data

- Make SAR data more publically available
- Ground truth for accuracy & interpretation
- Good for surface water temperature, except for cloud cover

<u>OTHER RECOMMENDATIONS</u>

Education and outreach

- People need to know what is out there, how to access it, and how to use it – CIIMS was supposed to do this, but hasn't.
- What are other options?

Use ships of opportunity

Make sure needs of Little User get met – e.g., small skiff owner, small business man – they are usually not high-tech.

Working Group #2 Leader: Carl Schoch

Key questions to address

1. What are the issues, problems and concerns?

    Industrial

        Pebble mine: environmental impacts

        How to quantify development impacts

    Baseline data

Users	Issues
Oil and gas industry	geohazards, oil spill trajectories
Mariners	safety to navigation
Fish and Wildlife	contaminants, food, climate change
Coast Guard	weather, search and rescue
Land owners, management	shoreline erosion, sediment transport
Aquaculture	site selection, climate change, impacts (BOD), carrying capacity bacteria, red tides,
Aviation	waves, weather
NMFS	marine mammals
Fisheries	contaminants, sustainable resources
Coastal communities	education, sea level rise, hydrological cycle, discharges, ports and harbors
Coast Guard	transportation, fisheries, ice extent, kind of ice, tracking

2. What products are needed?

    What?

    Hydrological models,

    Models to identify depth and magnitude of water column stratification

    Food supply (for fish, birds, mammals)

    Carrying capacity

    Ocean conditions (present and historical)

    Information clearinghouse

    Where?

    Why?

    Who?

3. What observations and models are necessary to create the products?

Issue	Product	Who
Ice	Observations and models	CRREL, MMS, CRRC
	Ice radar	
Hydrological data		
	Stream gauges	Mat, Knik, Susitna, Kenai

	Models	USGS
	Precipitation (SnoTel)	USDA
	Sediment load	USGS
Airborne contaminants		USFWS, UAF
Contaminants		
	Seabirds	USFWS and MMS (gulls, mammals)
	Hydrocarbons, metals	NOAA Status and Trends
	Fish	DEC
	Metals	CIRCAC and MMS
Marine mammals		
	Acoustic (beluga and sea lion)	NMFS, Sea Life,
	Seals	ADFG
Waves		
	Model	
	Observations (telemetered)	
	CODAR	
	Observer network	Volunteers
Erosion		
	ARGUS cameras	USGS
	LIDAR	Oswald, NOAA, USGS
	Satellite	NOS (NGS)
Weather forecasts		
	Model	NWS, AEFF
	Observations	NWS
	Data access	Capstone (FAA), kiosks, web page
Bathymetry		
	Multibeam	NOAA, Terra Surveys
Currents		NOAA

4. Other recommendations or ideas for establishing an ocean observing system?
- Data access emerges as the most important product
  - Data kiosks
  - Cell phone
  - Emails
  - Fax reports
  - Touch screen monitors
- Visualization of data
- Maps of weather parameters
- Focus of safety issues
- Environmental stewardship

III. Working Group #3 Leader: Mark Johnson

I. Issues and Problems

- Sustainability of Cook Inlet Watershed (400,000 people live in watershed—250,000 in upper reaches)—within natural boundaries of systems
    - More demands on resources
    - More conflicting activities
- Need central vision-decisions and policy based on good science
- Identify natural and human forcing mechanisms
- Human induced changes/ affects on resources—need links to wildlife and resource management
- Policy maker group guiding principles focusing on "sustainability" and "no adverse impact"
- Limit adverse impacts to systems
    - Coastal development related to populations
- Lack of information between Anchorage and Forelands
- Lack of tidal currents with directional information
- Lack of information regarding littoral cells (exposed tide lands and shoreline bluffs) along Cook Inlet and Kachemak Bay
- Climate change and Climate variability
    - Bluff erosion
    - Wave action
    - Sediment movement
    - Ice monitoring
    - How does ACC and Cook Inlet change with climate variability?

Resources Needed—where and why

- Data regarding petro chemical discharges
- Platform for users to get information they observe and data to researchers
- Historical data
- Monitor impacts to economic and aesthetic impacts
    - Identify biological impacts and monitor focusing on salmon and belugas
- Sites: "around the corner" (i.e., Chugach Islands, Kennedy Entrance
- Choose projects corresponding to stakeholders' needs
    - Include policymakers
    - US Army Corps of Engineers
    - Ecotourism
    - Oil/gas companies
- Wind (with direction)
- Bathymetry
- Salinity
- Circulation monitoring and modeling
- Identify, map and monitor littoral cells along E and W side of Cook Inlet and Kachemak Bay
- Baseline mapping and monitor resources in Kamishak Bay

- Nowcasts and at least 48 hour forecasts
- Long-term trends
- Long-term local wind data
- Freshwater input
- River input affecting littoral zones
- Navigation for natural and man-made hazards
- Chlorophyll
- Turbidity
- Hydrologists
- Watershed based parameters
- Identify what conditions are (tides, currents, and winds) and linked to exact location (with GPS) so oil spill response can plan and boats can make adjustments while enroute
- Weather conditions all over CI (especially along access of Inlet and on West side.

What AOOS Should Do

- Master archives of data
- Crunching of data in format useful to modelers, marine safety, and policy makers
- Mega modeling and site specific modeling
- Scientific data meeting needs of people (stakeholders) for example, do not need to link to C-Man page, simply give in lay-language the nowcast and forecast
- Reach out to larger community (more stakeholders) with emails regarding new information to meet their needs
- Mine data
- Connect and translate relevant satellite (remote sensing) data for users
- Map-based notice to navigators—always updated
- Dedicated person to handle personal needs assessments for stakeholders, updated on regular basis, adding new stakeholders as needed
- Central place for products
- Customized products for stakeholders (including educators) [Should this be left to private sector? Alaska specialized stakeholder needs too small at this time to be cost effective for private enterprise].
- Map, not text based
- Interpret research for users
- Training on AOOS programs customized for stakeholders
- Facilitate and integrate agencies providing data and products to work together (just having links to various NOAA, JPL, or FAA sites is not adequate. User does not want to learn/pick their way through these sites, they want the information about a particular place NOW!). If it takes more than one minute, forget it!
- Focus on mariner safety
- Quantification of freshwater inputs to Cook Inlet
- Buoys providing all sea state for Cook Inlet (especially southern and western)

IV. Working Group #4   Leader: Scott Pegau

This group discussed the four questions together. The emphasis of the discussion was based around the data accessibility. This includes the ability to find the data, and having it summarized in a manner that a variety of groups can use.

Issues

- Contaminant, oil spill, and larval transport
    - Subsurface transport was emphasized
- Knowledge of the temporal and spatial variability in temperature, salinity, and productivity.
- Determining what data is available
    - Provide an integrated data set at a single location for easy access
    - Provide accurate and appropriate interpretation at different levels for different user groups
    - Provide effective communication of science results
    - (ended up with a discussion of the role of scientists in public processes)
        - not always happy with the research providing facts with stipulations rather than certainty
- Efficient integration of research efforts
    - Recognizing the difficulty of integration of projects that have a variety of funding sources
- Red tide – PSP – Vibrio
- Tsunami warning
- Loss of existing data
- Citizen monitoring
- Clearly identify data standards
- Noise pollution
- Real-time marine data
- Keep up with new technology
- Risk communication
    - Provide levels of risk associated with contaminant transport, coastal erosion, tsunamis, etc.
    - Use the risk maps to help prioritize research and mitigation efforts
    - Make sure that people are factored in the assessments

Products

- Bathymetry
    - The habitat information provided by multibeam surveys should be retained.
- Marine weather forecasts appropriate for different media
    - The current forecast style is not appropriate for radio
- Include air quality data in the forecast
- Tsunami warning system appropriate for locally generated tsunamis
    - Much of this is driven by potential landslide generated tsunamis that may be generated by the volcanoes in Western Cook Inlet
- Baseline maps of nutrients and metals

- Remote sensing, including satellite, in usable formats
    - Accurate chlorophyll algorithms in the turbid waters of Cook Inlet
- A central location for citizens to report observations of unusual events

Specific needs (in order of priority)

- River discharge rates
- Bathymetry
- Mobile response equipment and plans
    - Inventory of existing equipment that would be available for emergency response
    - Plans that outline the types of measurements that should be collected in the case of a spill
- Background metal and CTD surveys in Upper Cook Inlet
- Combined wave and current model that accounts for the effect of currents on waves
    - Appropriate for sediment dynamic studies
- CTD studies in Lower Cook Inlet and Shelikof Strait to determine the trajectory of the Alaska Coastal Current and the circulation in Kachemak Bay
- 3D circulation that can handle the large vertical velocity components associated with tide rips.
- More research on the vertical velocities and mixing associated with the rips
- Meteorological, current, and wave measurements in Chugach Pass. (Scott has contacted a person that may be willing to allow the equipment to be installed on their property)
- Acoustical noise measurements

V. Working Group #5 Leader: Sue Saupe

Two types of Recommendations:

Recommendations on the approach for designing a successful OOS.

Identification of needs/issues/concerns – and how to address them.

AOOS Approach

Better interdisciplinary approach; e.g. tie physical measurements back to coastal resources

- What can physical models provide? What does it mean biologically?
- However, need to remember that some of IOOS objectives may be discrete – e.g. search and rescue models – but can use same tool – e.g. circulation models…

Support GEM approach –

- Long-term datasets
- Watersheds to oceans (OOS right up to the beach and beyond?)
- Will especially need long-term data sets as pressures increase, especially in Cook Inlet watershed.

Always tie back to IOOS objectives (Users)– funding will depend on this

- Measurable returns, cost effectiveness, investment to return ratio (e.g. how many lives save?). What is return of being able to better manage fisheries?

Education efforts need to be a major approach of AOOS

- Why collecting data? Why building models?
- KBRR is a good model to follow
- What does it mean, "engaging the public?" – They should "drive" the process –

Get the Data Out to the User!!

- Frustration that so much information exists already but users have no access.
- Better balance between data observation needs and data user needs – e.g. serving up the information in a timely manner – and not just "lip service" by the scientists this time.
- Strike a balance between needing to always refine the data observations and increase resolution with getting out the information that does exist.

Need a point of contact (e.g. the "Carl" model)

- Some organization or person to maintain focus, synthesize information, point out gaps, and interact formally with stakeholders/users/agenices/funders,
- Incorporate data and serve it up – one source

Prioritize Data Needs with Areas

- Don't assume best to co-locate sensors or study areas

Conceptual Model Needed –

- Help identify areas/parameters/priorities

Specific Issues

Better winds – major holes in the data (e.g. Kamishak shadow)

- Data buoy limitations

- C-man stations
- Anemometers
- Input from mariners
- SAR satellites – concerns that this will be lost SOON – major recommendation that these data continue to be available ($$$)

Better weather predictions

- Feedback to NWS
- Feedback to other mariners
- Incorporate weather ceiling–improvements for research/ managers/aviation safety

Wave Height Forecasts

- Need more than one wave height forecast for Cook Inlet
- Higher resolution – policy change? Better model? Better communication?

Don't forget central and upper Cook Inlet

Bathymetry Data: Prioritize areas and detail needed, how will be incorporated into models? Make recommendation to NOAA to move certain areas of CI up in their priority list

Need to improve PORTS: Anchorage/Nikiski – need current measurements for mariners!

<u>APPENDIX E.</u> Discussion of AOOS Goals for the Workshop

Mark Johnson's review of the previous day's presentations and how they relate to AOOS

<u>From the presentations</u>

Lots of data out there
- Moorings, hydrographic, HF Radar
- Met stations, CMAN, sealevel
- Model output

How do we make best use of these data sets?

Uniform bathymetry and coastline data needed

Data assimilation allows for model forecasting

Multiple groups/agencies with similar missions

How can we work together?

<u>Cook Inlet Oceanographic Issues</u>
- Detailed wind driving
- Vertical structure and shear
- Freshwater driving and input
- Kachemak Bay circulation
- Tides are essential
- Timing and extent of ACC intrusions
  - Nutrient, buoyancy fluxes
  - Larval injection

<u>AOOS Questions</u>
- Who are our primary stakeholders?
- Training issues:
  - Models are valuable
  - Models will be the observations in the future
- What are the key observations?
  - What to measure
  - Boats of opportunity?
- What models are there?
  - Why is the model being run?
  - What forcing is required?
- Keep in mind cost/benefit? (see figure below)

<u>AOOS Modeling and Analysis Group at UAF</u>

Data archival
- Historical data base
- Bathymetry and coastline data

Model development
Model validation
Web based data display and access

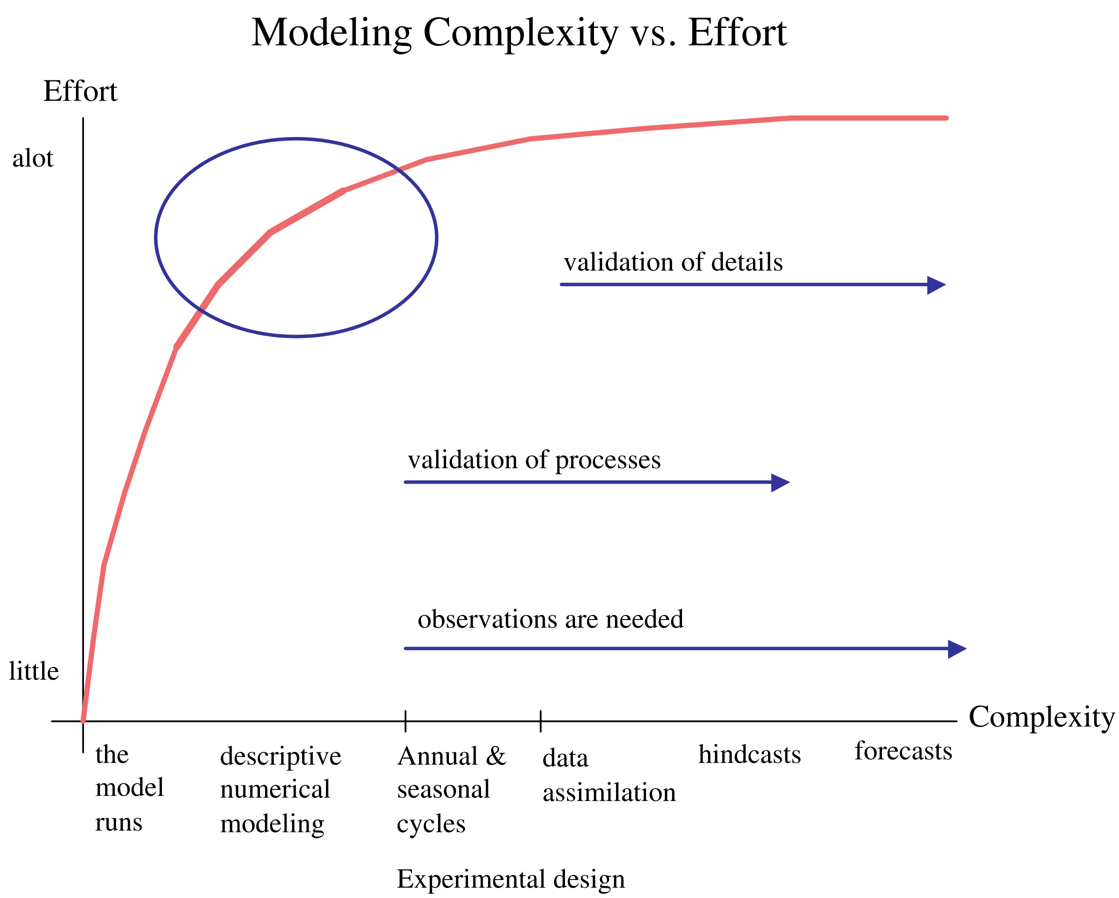


Figure showing the relationship between effort (cost) and the complexity of a given model.

APPENDIX F. Post-Workshop Evaluation: Prepared by R. Foster

Summary Physical Oceanography Workshop Evaluation

Introduction

The Kachemak Bay Research Reserve's (KBRR) Coastal Training Program evaluates all workshops and educational training events that are designed to increase informed decision-making related to coastal resource management. Prior to the Cook Inlet Physical Oceanography Workshop (Workshop), KBRR gathered data from an on-line survey sent to 126 individuals identified as data providers and data users. At the conclusion of the Workshop participants were asked to complete a short evaluation that included some of the same questions as on the Pre-Workshop survey. One of the questions requested respondents to provide specific Cook Inlet Measurement or Product needs. The other questions in the evaluation were either quantitative or qualitative indicators designed to identify and monitor the Workshop's impact upon attendees. Results will be used to provide information for the Reserve and supply datasets for aggregation across the National Estuarine Research Reserve System-- to track progress of the Coastal Training Program nation-wide. Responses to this evaluation also can provide useful information to the sponsors and participants of the Workshop.

Summary

The Post Workshop evaluation was provided to attendees as a two-sheet (double sided) pencil-and-paper survey, immediately following the Workshop. Twenty-six participants completed the evaluation at that time. An identical on-line survey was sent to registrants who left early or for other reasons had not completed the evaluation. Five additional individuals completed the evaluation within the month following the Workshop. In total, 31 participants completed the Post-Workshop evaluation, either immediately following the Workshop or, on-line. Results of all evaluations were analyzed together.

Evaluation respondents included 14 Data Providers (researchers, data monitor/collectors, modelers) of Cook Inlet's ocean or marine resources, and 17 Data Users (stakeholders, users, managers). This ratio is the same as the responses to the Pre-Workshop survey.

The evaluation consisted of 15 questions. These questions included a query as to whether the respondent had completed the Pre-Workshop Survey (68% positive), and how participants learned about the Workshop. Fifty-seven percent of Data Providers and 65% of Data Users learned from an Email message. Two Data Users learned about the Workshop from the Homer News (newspaper), two Data Providers learned from a flyer. We also provided space for the respondent's name, contact information, and a question as to their interest in completing future surveys about ocean data needs, desired measurements, and products.

As with the Pre-Workshop Survey, respondents to the survey showed a wide diversity of research and "work interests" in the Cook Inlet region. However, five "work interest" areas were identified by Data Users that were not covered by Data Providers. While the Data Users represented work or interest in:

- *Subsistence Hunting and Fishing* (8),
- *Public Health* (4), *Military* (4),

- *Community Planning* (4),
- *Tribal* (2).

*W*ork in these areas were not identified by the Data Providers.

Most of the Data Providers' research focuses on the Lower Cook Inlet (100%), with the majority (86%) in Kachemak Bay. The Data Users' interests however, were more diverse. Fifty-nine percent of the Data Users indicated interest in Upper Cook Inlet, 77% in the Central Cook Inlet, 59% in Kamishak Bay, and 35% in the Outer Kenai Peninsula Coast, the Barren Islands, and Northern Shelikof Strait/Kodiak region. Only one Data Provider indicated primary interest in these latter two areas.

Most of the Workshop participants were very satisfied with the information provided and with the presentations. However, the Data Users were slightly less satisfied with the delivery method. Responses indicated that the presentations were:

- "too academic"
- "too many acronyms"
- "not using 'lay English'"
- the delivery was such that "no one but 'Dr's [could] understand."

All respondents, (100%) indicated they will use the information they learned from the Workshop in the future and every one indicated specifically how they would do so. This information is useful in that it allows for tracking of actual changes brought about from the Workshop. Responses included:

- "oil pollution response and planning"
- "will present 'summary' to hydrographic services review panel",
- "'Adapt' some of needs in future budget requests."

In addition, many (87%) identified how they might integrate new ideas or perspectives learned from the Workshop into their work. Their responses included:

- "Hope to integrate into reports and publications
- "Modeling--could save $$ in certain areas"
- "If an oil spill occurs, I will very carefully monitor its position as functions of wind speed and direction and tidal state"
- "trying to integrate high-resolution bathometric and bottom-type data into our fisheries stock assessment program."

Respondents indicated they were very satisfied with the opportunity for networking. Only one person from each group (Data Providers and Data Users) indicated that the Workshop was not a successful networking tool. One respondent mentioned their pleasure that the Coast Guard was included. Some potential collaborations that were identified included:

- collaboration for grants,
- protocols [development],
- data exchange,
- mapping,
- user needs information,

- combining data sets to provide a better picture of the physical oceanography of Cook Inlet.

Some (four) indicated they had already initiated collaborating because of the connections they had made at the Workshop. Two negative comments received concerned not having enough stake-holders present and identifying missing groups such as Native communities, Army Corps of Engineers, and USGS (Alaska Water Division).

Five questions focused on changes in attendees' knowledge or awareness as measured *Before* and *After* the Workshop. These were:

1. Physical oceanography of Cook Inlet and Kachemak Bay;
2. Where to obtain data about Cook Inlet oceanography;
3. Existing uses, applications, or products from oceanographic data;
4. Your awareness of potential contacts or networking opportunities related to Cook Inlet Oceanography;
5. Your awareness of opportunities for collaboration regarding Cook Inlet Oceanography.

The 4-level rating scale ranged from "None" to "Quite a bit" and included "Can not rate."

Both groups indicated an increase in knowledge or awareness for all five questions (e.g., a move from "Some" knowledge to "Quite a bit" about a particular topic). Interestingly, the Data Providers rated their initial understanding and awareness at a "lower" level prior to the Workshop on topics 2, 3, 4 and 5 than did the Data Users, who rated their level as "some." The Data Users identified their greatest change in knowledge or awareness in "Physical Oceanography of Cook Inlet." Both groups identified a change in knowing "where to obtain data," but the Data Providers had the greater transformation for this question. The largest change for both groups was related to awareness of "potential contacts or networking opportunities."

Probably the most significant information for the Alaska Ocean Observing System concerns the specific Cook Inlet Measurements or Products that should be available. Twenty-seven respondents provided specific suggestions for Cook Inlet measurements or products. Although the responses varied, the priority parameters that were identified are bathymetry, winds, sea surface temperature, and currents, Shoreline dynamics and the need to identify littoral cells along beaches was also mentioned. The locations within Cook Inlet with the greatest need, as identified by this group, are southern (Barren Islands) and western (Kamishak Bay). The individual responses for each group are listed below:

Nine Date Providers identified these measurements data or products

1. Areas with entrapped productivity (e.g., gyres/ eddies); long term trends or indicators of productivity;
2. Historic tide data; additional real-time tides and currents;
3. Bathymetry;
4. Satellite data, H[igh]F[requency] Radar, incorporating time series of hydrographic sections;
5. Website one stop shopping of currents, temperature, waves, tides, winds;

6. Better local marine and aviation weather in Kamishak Bay. (e.g., wind speed and direction, wave height visibility);
7. As much real-time data on sea state as possible, long-term datasets of sea surface temperature, temp at depth, wind speed and direction;
8. Website AOOS should be the central conduit to all ocean observations in Alaska with "ACCESS" on the website to different providers;
9. More wind and wave observations.

Fifteen Data Users identified these measurements data or products

1. Data from forelands (ANC)--toxic industry discharge; littoral zone erosion;
2. Elevate issues of integrating Cook Inlet studies across the board; keep other studies in mind; identify gaps prior to recommending new studies proposals;
3. Real time circulatory models; identifying littoral shoreline zones
4. Government and citizen groups need more specific information about potential point source pollution and projections; need more detailed bathymetry and point source plume models;
5. Stream gauge; industry/ municipal pollution effects and rates;
6. More freshwater input /forcing data needed 2D model (single, accurate);
7. Better wetting/drying bathymetry;
8. Information on locations, velocities, etc. of the major Cook Inlet rip zones in Central Cook Inlet. Currents--If an oil spill occurs, information about currents of wind speed and direction and tidal state
9. Currents and littoral zone identification;
10. Currents, fronts information interpreted in a way it can be integrated biogeographically for locations of primary productivity to zooplankton to fish;
11. Updated NOAA surveys and habitat mapping;
12. I am impressed with the amount of information available. All we need is a WEBSITE with the integrated information
13. Coastal erosion, beach movements; littoral zone along shoreline;
14. Historical climate data and survey and bathymetry collected with public funds should be readily available;
15. Routine satellite photos should be processed and made available for public consumption—this is done for other regions of the U.S.

Responses to two other questions are significant for the sponsors of the Workshop, and especially as a needs assessment for the Coastal Training Program. There is important information in the attendees' responses for topic suggestions for future educational events, as well as additional information they chose to offer. The responses to these two questions provide a good summary of the Workshop.

Overall both groups had similar comments. Individuals from each group indicated the Workshop was a great start, but wanted participation from more stakeholders—and more of a focus on stakeholders' needs. The groups that were specifically listed as missing were *subsistence user groups* and *Tribal groups*. Future suggested topics include biological research—including biology, fisheries and marine mammal connections to physical oceanographic data. A Data Provider and a Data User both requested a skills workshop to integrate physical oceanographic data with GIS for fisheries scientists and managers. Also, a request was made for training in integration of physical oceanographic data. A request from Data Providers asked for a skills training in how to involve public more as a contributor of data. One Data User is interested in learning more about the geographic response strategies that are in place for Cook Inlet, how current they are, and whether more work is needed to characterize environmentally sensitive areas. Finally, more than one Data User requested a science module specifically on oil spills, targeted for oil spill responders, state officials, regional citizen advisory groups (CIRCAC and PWSRCAC) as well as general public.

While all the information gleaned from the evaluation is useful to AOOS, it is important to acknowledge the concern of participants as to the absence of specific stakeholder groups. This is a concern with all the Ocean Observing groups across the nation. The technique used to advertise the Workshop or to survey must be customized for each type of group. While email and on-line surveys appear to be an effective means for the science community and resource managers, personal contact should not be neglected as technique for inviting or surveying Tribal groups, subsistence users, mariners, or marine industry personnel.

Appendix

1. The following address will allow you to access results of the evaluations: http://www.surveymonkey.com/Report.asp?U=90113496407

2. CI Oceanography Evaluation follows:

1. Please indicate your p***rimary relationship*** with Cook Inlet ocean/marine resources. **Choose Only One.**

   ___Data Provider (researcher, data monitor/collector, modeler) of Cook Inlet's ocean or marine resources

   ___Data User (stakeholder, user, manager) of Cook Inlets' resources

2. How did you learn about this workshop? (PLEASE check all that are appropriate)

______Word of mouth
______ Mailing
______ E-mail Message
______ Webpage
______ Other (please specify) ____
______ Radio (station)
______ Newspaper (name)
______ Flyer (location posted)

3. Do you think that you will use the information you've learned during this workshop in the future? If so, how? In one year's time, where might we look for evidence?

   ____
   ____
   ____

4. Do you think you will integrate any new ideas or perspectives about ocean monitoring into your work? If so, what or how might that be noticeable?
____
____
____

5. Please rate your <u>satisfaction</u> with the workshop's information and delivery.

- **Information**: how *useful* the information is for your needs
- **Delivery/Presentation**: how *effective* the deliver or presentation

Use the following scale: 1 – Poor 2 – Satisfactory 3 – Good 0 – Did not Attend

Topic	**<u>Information</u>**	**<u>Delivery/Presentation</u>**
1. The Entire Workshop		
2. Day One		
3. Day Two		

6. **WORKSHOP FOCUS**

Please rate your knowledge or awareness **before** and **after** the workshop. **Circle** the number that describes your level before the workshop and then the number that describes your level *after* the workshop.

			Little	**Some**	**Quite a bit**	**Can not rate**
Physical Oceanography of Cook Inlet and Kachemak Bay.	BEFORE	1	2	3	4	5
	AFTER	1	2	3	4	5
Where to Obtain Data about Cook Inlet Oceanography	BEFORE	1	2	3	4	5
	AFTER	1	2	3	4	5
Existing uses, applications, or products from oceanographic data	BEFORE	1	2	3	4	5
	AFTER	1	2	3	4	5
Your awareness of potential contacts or networking opportunities related to Cook Inlet Oceanography	BEFORE	1	2	3	4	5
	AFTER	1	2	3	4	5
Your awareness of opportunities for collaboration regarding Cook Inlet Oceanography	BEFORE	1	2	3	4	5
	AFTER	1	2	3	4	5

7. Do you believe that the workshop was a successful networking tool for you?
____ Yes ____ No, WHY NOT?

If so, how might you collaborate with any of the contacts that you made today?
____
____

8. Please identify **all** of the following that apply to your <u>work or interests</u> related to Cook Inlet.

___Marine Education
___Research/Science
___Coastal Engineering
___Commercial Fishing
___Sport Fishing
___Subsistence Hunting & Fishing
___Mariculture
___Marine Transportation
___Oil Spill Response
___Policy Maker
___Resource Management
___Public Health
___Oil and Gas Industry
___Military
___Public Safety/Homeland Security
___Community Planning
___Recreation
___Environment/Conservation
___Federal
___State
___Tribal
___Borough
___City
___Non-Profit
___Private Company/Individual

9. Please indicate which areas of the Cook Inlet Region and surrounding areas are of primary interest to you? **Choose All That Apply.**

___Upper Cook Inlet (N. of Forelands)
___Central Cook Inlet (N. of Anchor Pt.)
___Lower Cook Inlet
___Kamishak Bay
___Kachemak Bay
___Barren Islands
___Outer Kenai Peninsula Coast
___Northern Shelikof Strait / Kodiak
___Other

10. Are there specific Cook Inlet Measurements or Products that you feel should be available? If so, what?
____
____
____

11. Did you complete our ***On-Line Pre-Workshop Survey?***
___ Yes ____NO

12. Would you complete a future follow-up "on-line survey" about ocean data needs, desired measurements and products?
___YES, My E-mail address is: _______________________________________
___ N0

13. Is there anything else you would like to tell us?
____
____
____

14. What topics would you like to see in other educational events?
____
____
____

15. Would you like to be notified about future educational events? If so, please provide your contact information:
Name____
Affiliation (optional) ____
Address:____
E-mail: ____
Phone/FAX____

Thank You very much!
Rick Foster, Coastal Training Program Coordinator
Kachemak Bay Research Reserve, 95 Sterling Highway, Homer Alaska 99603
(907) 226-4653; Email: rick_foster@fishgame.state.ak.us

OPTIONAL

Please Rate Your Satisfaction with Appropriate Session's Content.
- **Information**: how *useful* the information is for your needs
- **Delivery/Presentation**: how *effective* the deliver or presentation

Use the following scale: 1 – Poor 2 – Satisfactory 3 – Good 0 – Did not Attend

Topic	**Information**	**Delivery/Presentation**
Introduction		
Ocean Observing System and Modeling		
Prince William Sound		
Alaska Ocean Observing System		
Cook Inlet Observations		
Central Cook Inlet Water Column Hydrography		
Lower Cook Inlet Water Column Hydrography		
Cook Inlet Current Measurements by NOAA CO-OPS		
Cook Inlet Observations and Modeling		
Lower Cook Inlet Surface Drifter Tracking		
Cook Inlet Surface Current Radar Deployments		
Cook Inlet CODAR Deployments by NOAA CO-OPS		
Satellite Drifters/ 3-Dimensional Cook Inlet Model		
Existing Cook Inlet Modeling and Products That Use Oceanographic Data		
Northern Gulf of Alaska Circulation Model		
National Weather Service Forecasts and Products		
NOAA Coast Survey Activities in Cook Inlet		
Cook Inlet Tidal Datums		
Oil Spill Scientific Support Coordination Perspective		
Cook Inlet GNOME Modeling		
Cook Inlet Atmospheric Model		
Satellite Tools for Cook Inlet		
Oceanographic Data used for Dilution Modeling		
DAY TWO **Cook Inlet User Needs**		
Cook Inlet Needs Survey		
Ocean Data Needs for Coastal Engineering		

Summary of Previous Days Presentations		
vBreakout-Desired Cook Inlet Measurements and Products		
Summaries of Break-out Session		
Wrap-Up and Where Do We Go Now?		