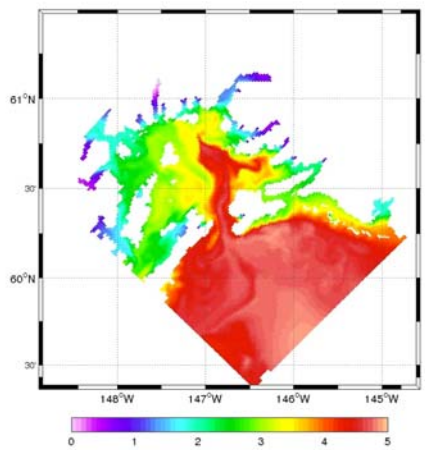
Alaska Ocean Observing System Workshop

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

June 13-14, 2005
Cordova, Alaska



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Prince William Sound Science Center, Cordova, Alaska
AOOS Alaska Ocean Observing System

A Demonstration of AOOS in Prince William Sound

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Section 1
A Demonstration of AOOS in Prince William Sound

Alaska's Prince William Sound (PWS) includes about 6000 km of shoreline and it contains an extensive system of tidewater glaciers descending from the highest coastal mountain range in North America. The Trans Alaska Pipeline carries oil to the Port of Valdez in northern PWS. The oil is then shipped to southern refineries on large tankers, making the environment of PWS 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 PWS to enable detection and prediction of oil-spill related impacts and subsequent recovery. This mission led to the development of a PWS ocean circulation model coupled to a regional atmospheric circulation model. The modeling program is now rapidly evolving to integrate 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 moored buoys and seasonal hydrographic surveys.

The PWS observing system has two primary goals. The first goal is to combine long-term monitoring with short-term hypothesis-driven process studies to understand mechanisms underlying the dynamics of the interactions between the major coastal currents and the production of flora and fauna of the Pacific Ocean, the Gulf of Alaska, and PWS. Of particular interest is the understanding of predominant mechanisms of ecological variability. Understanding the circulation and the patterns of water exchange will provide a solid scientific foundation for addressing fisheries management and ecosystem needs related to long term oceanic and climatic variability.

The second goal is to provide physical and biological 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 weather forecasts to commercial and recreational vessel and aircraft operators, and it will 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 better management decisions on food supply, predation, and human activities such as commercial and recreational fishing.

On June 13 and 14, 2005, a meeting was held in Cordova, Alaska, to discuss the progress of a demonstration project for the Alaska Ocean Observing System in Prince William Sound. The purpose of the meeting was to facilitate discussion and interaction among the current group of principal investigators, the general public and specific information users. On the second day of the meeting discussions focused on identifying specific needs of the scientific community for eventual extension of the biological components of the observing system. This document summarizes the talks and discussions. Section I describes the existing component s of the observing system in three parts, with Part 1 providing general descriptions of each component, Part 2 is a compilation of the speaker's abstracts, and Part 3 outlines the important points resulting from the discussion groups. Section II describes the major thematic topics discussed relevant to the focus question: How should we measure a biological response to changes in oceanic conditions as part of an ocean observing system? Part 1 of this section describes the status of each major biological component of the ecosystem, Part 2 is a compilation of the speaker's abstracts, and Part 3 outlines the important points resulting from the discussion groups.

Participants of this meeting are listed in the Appendix and included: 1) all principal investigators currently involved in the development of the PWS Observing System; 2) any organization or individual with interests in information and data products from the observing system (e.g. air taxi operators, charter boat operators, hatchery managers, oyster farmers, fishermen, mariners, U.S. Coast Guard, etc. are encouraged to attend); 3) researchers interested in integrating new components to the observing system (e.g. fisheries, ecology, marine mammals, birds, etc.), and 4) scientific advisors of OSRI and PWSSC.

Part I: Components of the Prince William Sound Observing System (by Amy Van Cise)

SNOTEL Weather Stations and Precipitation Gages

The first question for most people venturing outdoors in Alaska is: How hard is the wind blowing and when will it start to rain? In Prince William Sound (PWS), high winds mean big waves, and a hard rain can lead to uncomfortable conditions. The combination could be hazardous for commercial fishermen as well as recreational kayakers and hikers, especially when temperatures dip to the freezing level. The Prince William Sound Observing System (PWSOS) includes weather observation stations that provide accurate real-time data on winds, temperatures and precipitation. These data are used as part of a new PWS weather forecasting system (see Weather Predictions below).

Snowpack Telemetry (SNOTEL) stations were first set up in the western states in the early 1970s by the National Resources Conservation Service (NRCS), a division of the U.S. Department of Agriculture, to measure precipitation from snow and rain throughout the year and feed drought predictions. They are fully-automated, land-based stations that are usually set up in remote locations. In 2004 the state of Alaska had 46 stations, but starting in the summer of 2005, five new stations were deployed at sea level in PWS, and five additional stations were planned for deployment at alpine elevations. When the system is fully deployed by the fall of 2006, PWS will have five pairs of sea-level and alpine stations with a pair in each of the four quadrants (Northeast, Northwest, Southwest, Southeast) of the Sound and another representing the central basin.

Each station in PWS will measure wind speed and direction, air temperature, air pressure, precipitation from rain and snow, and solar radiation. Four stations (one sea level station in each quadrant) also have digital cameras that transmit pictures every fifteen minutes to the internet so the actual weather conditions in each area can be seen. Data transmitted by the weather stations will be accessible through the AOOS and PWSOS web pages and archived at the University of Alaska Fairbanks.

The PWSOS is using the weather data to generate computerized weather prediction using the Regional Atmospheric Modeling System (see below). Accurate weather data from the network of SNOTEL stations will allow scientists to better forecast the likelihood of wind and rain over 6, 12, and 24 hour periods. These data will also allow environmental managers and coastal communities to develop management plans based on the best weather measurements and computer simulations for the PWS area.

Buoyed Weather Stations

One of the first steps in implementing the Prince William Sound Observing System (PWSOS) was to determine what observations were already being made. One such network of existing observation platforms includes the weather buoys and coastal weather stations of the National Data Buoy Center (NDBC). This program of the National Oceanic and Atmospheric Administration (NOAA) has weather buoys throughout the waters of the United States, which are used to support the National Weather Service forecasting system and the NOAA marine environmental database.

Recently, the NDBC expanded its services in Alaska, including Prince William Sound. The NDBC already had two weather buoys in the Sound – one at Hinchinbrook Entrance (46061) and one in the central basin at Orca Bay (46060) – as well as one in the Gulf of Alaska at Cape Suckling (46082). The expansion allowed for placement of a new buoy in the northwest Sound at Port Wells (46081) and another at the southern end of Montague Island near Cape Cleare (46076). In addition to these buoys, NDBC maintains three automated weather stations at Bligh Reef, Potato Point, and Middle Rock along the vessel traffic lane leading to the Port of Valdez oil terminal

The weather buoys in PWS are typically three meters in diameter, although larger six meter ones are used for stability in rougher or more open waters such as Hinchinbrook Entrance. The buoys carry an array of instruments that measure wind speed and direction, air pressure, air temperature, and sea surface temperature. They also provide a platform on which other organizations can place instruments. For example, the PWSOS has upgraded each of the three buoys in PWS with instruments that measure ocean temperature, salinity, and current velocity.

Current velocity is measured with an Acoustic Doppler Current Profiler (ADCP). An ADCP is an electronic instrument used to measure currents through the entire water column. ADCPs rely on a measure of the Doppler shift to calculate the speed of moving water. The Doppler shift can be experienced regularly in everyday life: think, for example, of the change in sound of passing cars when walking on the side of the road. ADCPs emit a sound at a given frequency and listen to the echo of this sound after it has bounced on small particles naturally present in sea water. The distance between the instrument and the reflecting particles is estimated from the delay between the emission of the sound and the arrival of the echo. Should the echo from a given distance arrive with a higher frequency than the emitted sound, then the volume of water at this distance is moving toward the instrument; should the echo arrive with a lower frequency, then this volume of water is moving away. Larger shifts in frequency indicate larger current speeds.

The measurements made by the NDBC buoys help provide better data on weather patterns in PWS and the Gulf of Alaska. They are the first step toward understanding the variability of weather patterns around PWS, and will allow for more accurate weather forecasting by computer models being developed by the PWSOS (see below).

Surface Current Measurements

Since the mean tidal range in PWS is about 3 meters, all mariners need to consider the currents created by the ebb and flood of the tides. When winds and waves are also factors, the velocity of the currents can magnify waves to dangerous heights. Currents are also important in the set and drift of vessels in the tanker traffic corridor leading to the Port of Valdez, as well as the trajectory of drifting debris, icebergs and oil spills. But how can we measure these currents and provide this information directly to mariners? Surface Current Mappers (SCM) are one tool that can be used. Every hour SCMs measures the direction and speed of surface currents in the central basin of PWS and transmits this information to the internet.

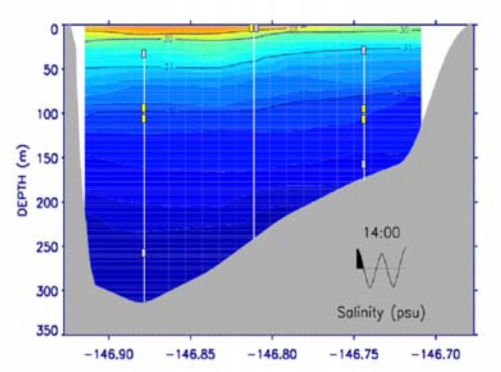
An SCM is, essentially, a combination of a powerful radio wave transmitter and receiver that use the Doppler shift to determine how fast surface currents are traveling. In the same way that most people can tell where an ambulance is by the sound of its siren, the scientists who operate the SCMs in PWS can tell where a wave is traveling and how fast it will get there. "[SCM stations] transmit radio waves, and the radio waves are reflected off the waves on the ocean," said Hank Statscewich, a researcher from the University of Alaska Fairbanks involved in the project. "From that information we can calculate the exact (surface) current velocity and direction."

Two SCM stations were set up in Prince William Sound in 2004 at Knowles Bay and Shelter Bay. The stations transmit and receive radio waves that travel as far as 60 km across the Sound in all directions. As each radio wave reflects off the ocean and returns to the SCM station, the changes in the wave's amplitude and frequency are entered into Doppler equations to determine the direction and speed of the waves. Each SCM site generates very clear information on the behavior of the currents in PWS. In mid-summer of 2004 the stations began to reveal something that had never been seen before: a strong current that traveled counter-clockwise, coming into the Sound at Hinchinbrook Entrance and leaving through Montague Strait.

"We started seeing these currents, and people who have been working in Prince William Sound for a long time doing traditional measurements with moorings or CDT surveys said, 'Your equipment's not working right, the currents don't do that here in PWS", Statscewich said. However, there was nothing wrong with the SCM instruments, and further studies proved that this strong mid-summer current does exist. The pattern starts as the water heats up in the summer, when a well-known upwelling of bottom water creates a cold spot in the center of the Sound. Warmer waters coming in through Hinchinbrook entrance are deflected around the cold spot toward the East, and create a cyclonic gyre that can travel as quickly as 1 knot on calm days.

Since the SCM stations are now operating in PWS as part of the PWSOS, the public will have access to this information on a daily basis. Scientists will also use the data to develop hypotheses about how nutrients, plants and animals follow currents around PWS. Data transmitted by the weather stations will be accessible through the AOOS and PWSOS web pages and archived at the University of Alaska Fairbanks.

Ocean Moorings and Hydrography



Researchers believe that water exchange between the Gulf of Alaska and PWS is the primary physical process influencing the abundance and distribution of microscopic plants and animals, called plankton, that form the base of the marine food chain. Plankton provide food for schools of herring and other small fishes as well as juvenile salmon. Yet oceanographers have only a vague understanding of how much water is actually exchanged, at what frequency, and at what times during the year.

Since this single process has such an effect on life within the Sound, scientists have created a program within the PWSOS to monitor and understand the process more completely. This program will couple hydrography (periodically surveying properties of the ocean water column at many places) with a series of moorings that continuously monitor water properties at fixed locations across the Sound. The goal of this observational program is to improve our understanding of the magnitude and frequency of the exchange of water between the Gulf of Alaska and PWS and the forces driving these exchanges.

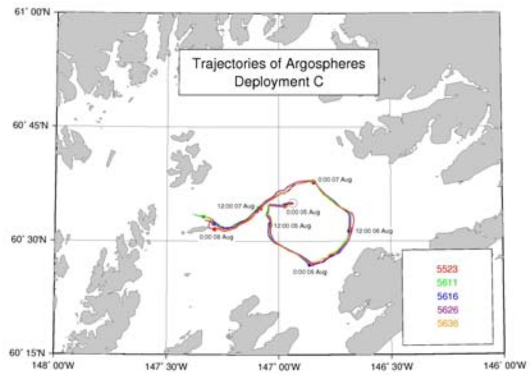
To provide this information, five ADCPs (see description under *Buoyed Weather Stations*) will be deployed in each PWS entrance to obtain measurements of water transport. Subsurface moorings will be instrumented with one upward looking and one downward looking ADCP mounted on hydrodynamically streamlined buoys. Additional downward looking ADCPs will be mounted on the NOAA weather buoys. An ADCP will also be temporarily moored in each of the four relatively narrow and shallow passages west of Montague Strait.

Each of the subsurface moorings will also have three conductivity-temperature recorders (CTDs) mounted at three different depths. These instruments will periodically sample temperature and salinity and thus track changes in water properties over time. Used in conjunction with the ADCP current measurements, they will help identify periods of deepwater exchange (which tends to be colder and saltier) between PWS and the Gulf of Alaska. They will also be able to determine the amount of freshwater coming into the Sound from the Copper River Delta or any of the many glaciers around the Sound.

The information gathered from the moorings will be coupled with data collected through the hydrography program. CTD (conductivity, temperature and depth) sensors will be attached to boats that will run four transects across Hinchinbrook Entrance and Montague Strait twice each year (spring and fall). The results of these surveys will track changes in the physical characteristics of the surface waters in PWS through the year's seasons.

Information from this program will be housed in the PWSOS long-term oceanographic database and will give scientists extensive information on the movement of water between the Gulf of Alaska and Prince William Sound. Data collected by the oceanographic moorings will be accessible through the AOOS and PWSOS web pages and archived at the University of Alaska Fairbanks.

Circulation of PWS



Although the daily currents in PWS can vary greatly, the seasonal currents are generally more predictable. The moored buoys around the Sound will provide continuous data that can be used to correct a computer simulation, or model, with data on real conditions. The model will then be able to provide better forecasts of ocean circulation in PWS over 24 and 48 hour periods.

Researcher Steve Okkonen is leading a team of oceanographers that will supplement the current data being collected with buoys in Hinchinbrook Entrance and Montague Straits to measure the amount of water that comes into and leaves the sound on a seasonal basis. Instruments on three buoys set up across each passage will measure the salinity, temperature and pressure of the water as it moves in and out of the Sound.

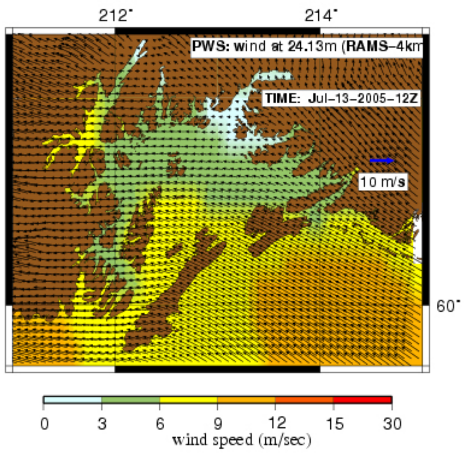
In addition, a salinity and temperature recorder has been placed on a boat to be taken along the perimeter of the Sound the summer of 2005 in order to develop a complete picture of the seasonal trends in temperature. This will give researchers a good idea of how much fresh water is coming into the Sound from the perimeter, and how much warm water is coming in from the south.

Researchers thus far have discovered that the circulation of PWS adheres to a cyclical model both in the summer and in the winter. During the radical temperature changes of the fall and spring the water mixes, often causing the currents to change, but in the summer and winter they always return to their old familiar gyre.

In the winter, this gyre is caused by warm winds that come up from the southeast, paralleling the coast along the Gulf of Alaska and into PWS. These winds push water up against the coast, causing the sea level to be slightly higher – about 10cm – along the coast than at that center of the Sound.

“Think of Prince William Sound as a bowl, with a couple of openings,” Okkonen said. This subtle shape causes the water to want to flow in a counter-clockwise motion, coming in Hinchinbrook Entrance and leaving at Montague Straits. In the summer, the ocean is a lot calmer, with fewer winds to create the bowl affect. However, the summer season also sees a significant increase in the amount of fresh water coming in from the Copper River Delta and the many glaciers that flow into the Sound. The light freshwater creates its own layer on top of the salt water. “It will mound up around the perimeter,” Okkonen said, creating a “summer analog to the winter situation.”

Weather Forecasts



It's 3 a.m., and a fisherman needs to know what the weather will be like for Prince William Sound over the next 48-hour fishing window. Getting the weather from the National Weather Service (NWS) only gets him half the information he wants, and it's only right half the time. According to Peter Olsson of the Alaska Experimental Forecast Facility (AEFF), this is simply because the NWS modeling system uses very large-scale data, covering a block the size of PWS, so that weather forecasts for smaller areas within the Sound cannot be resolved accurately.

"They do an admirable job of [modeling] weather patterns, considering the challenges of the PWS area, but our project goes one step further," Olsson said. "We [model] a much smaller area with more detail and try to generate more accurate forecasts."

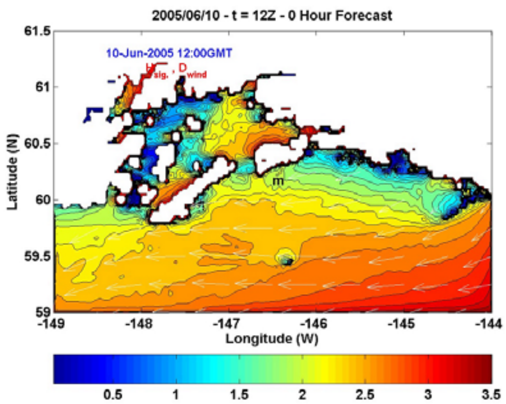
The PWS Observing System provides for many weather observations within a relatively small area. With over 20 weather stations reporting real time data within an area of 100 square km, PWS has one of the densest networks of observation platforms in the world. Using this data, the AEFF is creating a weather model of PWS that will be much more accurate than anything that has been created to date. Where the NWS now only has measurements for areas about 60 km^2, the new buoys and measuring systems will allow for measurements of areas as small as 4 km^2.

"The finer resolution allows us to capture topographic effects that are not in the NWS simulations," Olsson said. The results are used as the basis for a Regional Atmospheric Modeling System (RAMS), a system for predicting the weather that is much more reliable than anyone has seen in the Sound.

To produce RAMS, the AEFF enters the data from the many different buoyed and land-based weather stations around PWS into a supercomputer made up of 13 smaller computers, all working together to create a mathematical model of the behavior of the Sound. Using this model, the AEFF can predict, with reasonable accuracy, the temperature, pressure, precipitation, winds, cloudiness, radiation, and many other elements of any area around the Sound. Using the data points, the mathematical model "fills in the gaps" between the measurement stations around the Sound, creating a complete picture of the Sound at any given moment.

The model also forecasts into the future, using archives of old data to predict what will happen up to 3 days in advance based on what is happening now. With this new technology in place, anyone venturing out into the Sound will soon have a much clearer picture as to what is going on today in any corner of PWS, and what is likely to happen tomorrow.

Wave Forecasts



Waves in Prince William Sound: who can predict them? One minute they're coming in gently from the west, and the next minute they're roaring in through Hinchinbrook Entrance and rocking every boat in the Sound. All mariners, whether their vessel is large or small, can appreciate the value of accurate wave measurements, and especially accurate wave forecasts.

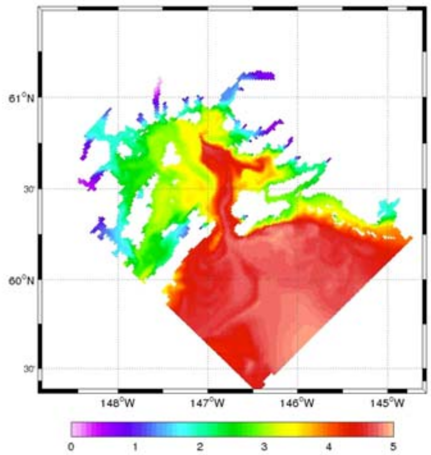
In December of 2004, Hurricane Ivan hit the northern shores of the Gulf of Mexico, creating waves as tall as 16 meters (about 48 feet). The waves carried oil pipes as far as 2 miles from their original locations and caused massive mudslides along the shore. "My preliminary data suggests that this was nothing less than a 10,000 year event in the Gulf of Mexico," said Vijay Panchang, head of the Department of Maritime Systems Engineering at Texas A&M University. In the Gulf of Alaska, waves have been measured at almost 17 meters – the tallest waves ever measured by NDBC buoys.

Wave simulations in the Gulf of Alaska now generate relatively coarse scale forecasts that are of little value at the scale of PWS. Using SWAN (Simulating WAves in the Nearshore) modeling, Panchang and colleagues have been forecasting waves around the country up to 48 hours in advance based on measurements from NDBC buoys. Placing this modeling system in PWS allows for forecasts that are accurate to within 500 meters. The SWAN model was developed in Holland and is being used in more than 50 countries to predict wave heights in nearshore and inland waters. It has been used to accurately predict waves in the Gulf of Maine for nearly two years.

The SWAN model uses data collected from the three NDBC buoys in PWS, as well as the Cape Suckling and Cape Cleare buoys, to generate a comprehensive forecast model for the entire Sound. The model runs every twelve hours to track and predict wave heights. In addition, new technology is being developed that will allow for real-time wave forecasts that are nearly exact for up to six hours at a time. Once it is fully developed, this technology can easily be added to the SWAN modeling system.

In the summer of 2005 the NDBC buoys tracked waves in PWS as high as six to seven meters during peak wave periods. Accurately forecasting these tall waves, or waves of any magnitude, could help prevent future disasters. It could also help researchers determine the importance of waves in sediment transfer, and especially how the movement of sediments affects marine life around the Sound.

Ocean Forecasts



Just as meteorologists forecast the behavior of the atmosphere, scientists are using the information gathered from the PWSOS to predict the behavior of the ocean waters of the Sound and the waters that flow through it.

A research team headed up by Dr. Yi Chao from the Jet Propulsion Lab and including Dr. Xavier Capet from UCLA has developed a Regional Ocean Modeling System (ROMS) for PWS which can simulate the behavior of currents, tides, salinity, and temperatures. Eventually, the model will also monitor biogeochemical cycles and ecosystem functions in PWS. The model uses a set of equations to approximate the behavior of the ocean at any given time during the year. The oceanographic research group is gathering data for this model from PWS and the entire Gulf of Alaska.

"If we want to model what is going on inside the Sound properly, we need to know what is going on outside the Sound," Capet said.

The group has created three scales of measurement, with the largest measuring the Gulf of Alaska, and the smallest focused on the Sound. As the area of measurement decreases, the resolution increases to as little as 1.2 square km. In 2005, the research group focused on modeling the Pacific Ocean and the Gulf of Alaska. Once the kinks have been worked out of the equations based on the large-scale movements of the ocean, the group will focus more of its energy onto the small scale, high-resolution simulations of PWS.

The preliminary studies that have been done in the Sound support other scientists' theories of a stable counter-clockwise gyre that is particularly strong in the summer. It also clearly shows the movement of a warmer current from the south as it passes along the coast in the winter. Most importantly, what the model shows is that conditions in the Sound vary greatly from one location to another, and also vary greatly from one time to another.

"There is a significant structural variation, spatial and even temporal, in the Sound," Capet said. "I was very surprised to see there was this sort of variation."

The high resolution of this model takes into account that variability, and will be able to accurately forecast the condition of the ocean with respect to surface currents, tides, temperature change, and mixing. The model will also be able to track nutrients or pollutants as they cycle through the water. With the addition of the ROMS model to the PWSOS, knowing the strength of the currents on any given day may become as easy as knowing whether or not it might rain that day.

Part II Presentation Abstracts

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

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Alaska's Prince William Sound (PWS) includes over 6000 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.

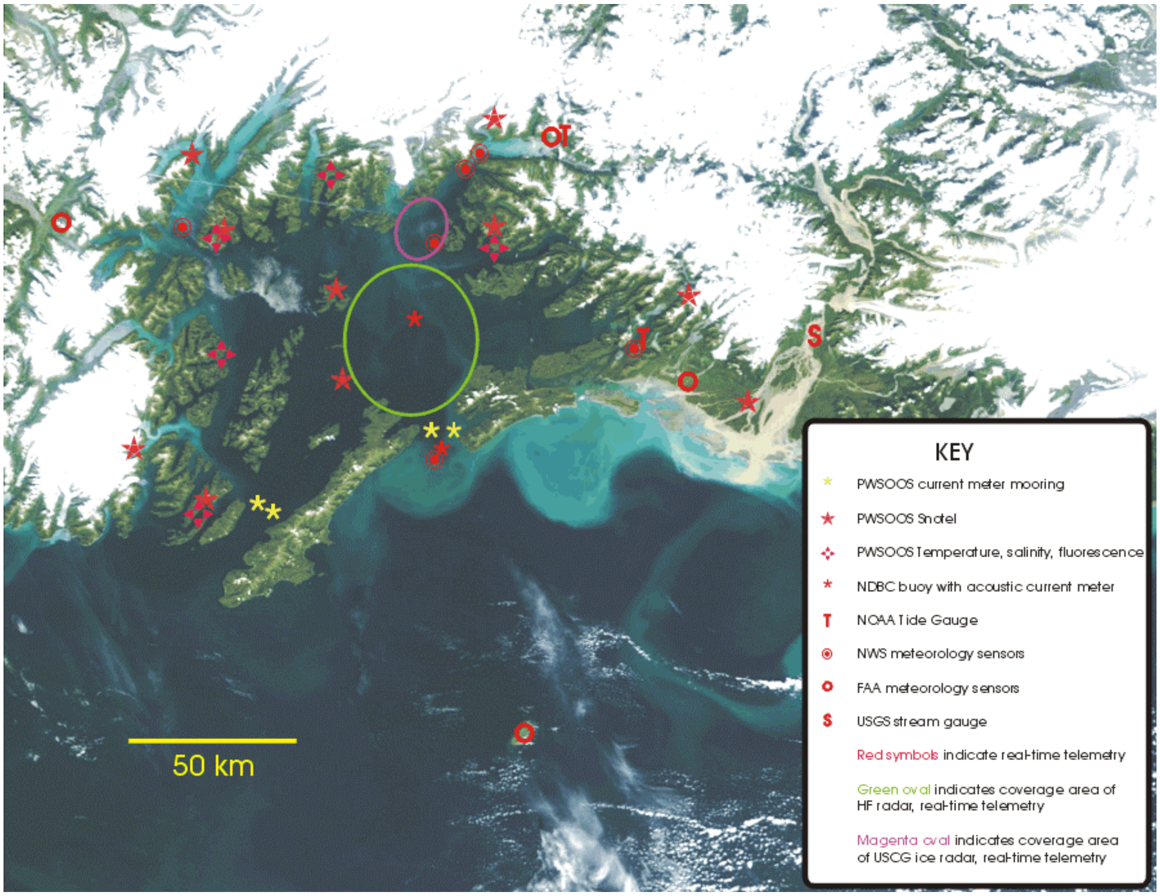

Figure 1. Satellite image that shows the Prince William Sound region and the locations of *in situ* observational instrumentation. Green oval marks region of HF radar surface current measurements.

Current and Proposed Installation of SNOTEL Climate/Weather Stations
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The USDA Natural Resourses Conservation Service installs, operates and maintains an extensive automated system to collect snowpack and related climatic data at approximately 700 SNOw TELemetry (SNOTEL) sites across the Western United States including Alaska. The system evolved from NRCS's Congressional mandate in the mid-1930's "to measure snowpack in the mountains of the West and forecast the water supply." The programs began with manual measurements of snow courses; since 1980, SNOTEL has reliably and efficiently collected the data needed to produce forecasts and to support the resource management activities of the NRCS and others.

Climate studies, air and water quality investigations, and resource management concerns are all served by the modern SNOTEL network. The sites are generally located in remote high-mountain watersheds where access is difficult or restricted.

NRCS in Alaska had 35 remote SNOTEL sites operating through the winter of 2005. These sites report hourly data to a web site www.ambcs.org providing near real time weather data. Most of the sites data consists of snow water content, total precipitation, and current, maximum, minimum and average air temperature. Additional climate parameters that may be measured are: snow depth, solar radiation, relative humidity, wind direction and speed, soil moisture and soil temperature, and barometric pressure. The midnight readings of the reported data are quality controlled, stored and made available to the general public.

Two sites were installed this spring in Prince William Sound in cooperation with the OSRI and Prince William Sound Science Center with an additional 6 scheduled to be added this summer and fall and 3 more high elevation sites to be installed in FY06. The two sites installed and operating this spring are at Esther Island and Port San Juan near Chenega. These two sites currently have a weather station and web camera reporting by satellite. The sites are recording wind direction and speed, total precipitation, barometric pressure, current, maximum, minimum and average temperature and solar radiation. An additional site at Tatitlek will have the same arrangement of data collected and transmitted. Three more sites are scheduled to go in at sea level at Nuchek on Hinchinbrook Island, a site on the Copper Delta and a storage precipitation gauge will be added to the NWS weather site located on Seal Island.

The precipitation collected at these sites will give a quantitative measurement for the development of models used to predict the freshwater inflow and currents in Prince William Sound.

NDBC Buoyed Weather Stations

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A general description of the NDBC Network Expansion will be presented. It will show the relationship between the overall expansion in the Alaska Region to the Prince William Sound component. The various types of buoy platforms used throughout the Region, and their observing capability, will be discussed along with a brief overview of newly developed platforms and their attributes. NDBC's relationship with Regional Associations, such as the Alaska Ocean Observing System, to leverage assets and assist with data dissemination will be discussed.

Prince William Sound Mooring and Hydrography Program

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This program is a constituent of the Prince William Sound Observing System (PWSOS). In its current state, the program encompasses three components: 1) Long-term monitoring of the water exchange between the Gulf of Alaska (GOA) and Prince William Sound (PWS), 2) Long-term monitoring of sea water temperature, salinity and fluorescence at nearshore sites in northern and western PWS, and 3) Monitoring of the seasonal variability of the hydrographic properties and circulation in PWS.

The "water exchange" moorings deployed by Prince William Sound Science Center (PWSSC) in June 2005 consist of 2 moorings in Hinchinbrook Entrance (HE) and 2 moorings in Montague Straits (MS). Each of these moorings is composed of 2 internally recording Acoustic Doppler Current Profilers (ADCP) and 3 conductivity-temperature (CT) sensors. Both ADCPs are positioned around 100 m depth, one upward-looking and one downward-looking. The CTDs are positioned at about 30 m, 100 m, and 10 m above the bottom. With semi-annual servicing, we plan to have these moorings in place for a 5- year period. In addition, NDBC buoys equipped with a downward-looking ADCP (able of data transmission) and a CT are planned to complete both transects (positioned roughly mid-way between the PWSSC moorings).

The goal of this observational program is to provide an improved description of the flow through the straits connecting PWS with the GOA. This is seen as a necessary step towards a better understanding of the relationship between circulation variability and biological variability in PWS. This current meter mooring program addresses the two limitations of the previous mooring programs (lateral variations not accounted for and lack of data in the near surface part of the water column). We hope that the acquired knowledge during this program will permit to continue the monitoring of the exchange using a single downward-looking (or upward looking) ADCP.

The "nearshore" moorings aim at bringing a better knowledge on the spatial and temporal variability of the effects of freshwater runoff in the nearshore area of PWS. In order to achieve this goal, sporadic distributions of sea surface temperature and salinity sampled through vessel-based surveys will complement the mooring data. The moorings will be deployed at 5 locations along the northern and western shores of PWS and kept in place as long as the "water exchange" moorings. Four of these locations will be near a Prince William Sound Aquaculture Corporation (PWSAC) hatchery, and the fifth one will be near Tatitlek. Each mooring will consist of a CT instrument moored at a standard depth (5 m) and a telemetry system able of quasi real-time data transmission. The CTs will measure temperature and salinity, and will be complemented by a fluorometer that will provide proxy measurements for the concentration in chlorophyll in sea water. If funds get available, extra sensors could be added (dissolved oxygen and PAR sensors). The telemetry will use radio transmission to a land base, and from there either a Starband Earth Station (3 cases) or a satellite telephone (2 cases).

A third component consists of a regular monitoring of the hydrographic properties in the central basin of PWS and at the main entrances. A direct goal of this work is to acquire a description of the seasonal evolution of the hydrographic properties at these locations. This is done through seasonal vessel-based hydrographic surveys (4 cruises per year) during which CTD profiles are acquired at a number of stations. For each survey, four transects (west-east, north-south, HE and MS) are visited (giving a total of 28 stations), and extra stations may be added depending on the needs of the moment. The planned duration of this project is the same as for the “water exchange” moorings.

For the “water exchange” and “seasonal surveys” components of the program, the data will be processed at PWSSC, archived at UAF, and posted on an internet site maintained at the Alaska Experimental Forecast Facility (AEFF) in Anchorage. For the “nearshore” moorings, the data will be transmitted in quasi real-time to UAF for archiving and then sent to AEFF to be posted on the internet site. There will be a monthly quality control at PWSSC and the quality controlled data will be sent to replace the raw data. The data from the three components will be downloadable and the diverse information relative to data acquisition and processing will be provided in downloadable data reports.

Surface Current Measurements With CODAR

H. Statscewich

Circulation in Prince William Sound

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Non-tidal, surface circulation within Prince William Sound (PWS), in a very general sense, changes from a wind-driven system during the winter to a buoyancy-driven system during the summer. In winter, the large-scale wind field in the northern Gulf of Alaska is cyclonic (counterclockwise). This characteristic winter wind field is associated with low pressure weather systems that migrate into the region from the west. The prevailing winds are directed along the coast (coast to the right when looking downwind) and, as a consequence, promote shoreward Ekman transport of the near-surface waters. The resulting coastal convergence sets up (non-tidal) sea level along much of the Gulf of Alaska coastline such that sea level is higher at the coast than farther offshore. An along-shore current (coast to the right when looking downstream) is the dynamical response to this sloping sea surface. Within PWS, sea level also tends to be higher at the coast than in the central Sound. Because PWS is not fully enclosed, the along-shore current is somewhat constrained to flow into the Sound through Hinchinbrook Entrance and out of the Sound through Montague Strait. In summer, winds are characteristically weak and their orientation does not promote coastal convergence and associated along-shore wind-currents. However, significant volumes of freshwater (snow melt and precipitation) are discharged into the Gulf of Alaska and PWS from the surrounding coastal mountain watersheds. Near the coast, near-surface waters are typically fresher and less dense than waters farther offshore. An along-shore current (coast to the right when looking downstream) is the dynamical response to this cross-shore density gradient. Significant summer discharge from the Copper River extends across Hinchinbrook Entrance and, to a lesser extent, across the southern end of Montague Strait. The Copper River flow, in conjunction with the coastal freshwater discharges within PWS, effectively establishes a ring of freshwater around the central Sound. A cyclonic (counterclockwise) gyre in the central Sound results.

Data management, archiving and dissemination

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A summary of the Alaska Ocean Observing System Data Management system. Update on the plans and conceptual considerations for data collection and display of environmental information for Prince William Sound and statewide.

Numerical Modeling of Weather in Prince William Sound

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At the Alaska Experimental Forecast Facility (AEFF), we run a daily numerical weather forecast model— the Regional Atmospheric Modeling System (RAMS)— for the region of Prince William Sound (PWS). As is true of all weather forecast models, this involves using computers (lots of computers) to solve a mathematical model of how we think the atmosphere works. In fact this is the same thing that the National Centers for Environmental Prediction (NCEP) does for the National Weather Service (NWS). What is different with our project is that NCEP does this for all of Alaska, whereas we concentrate most of our computing power on the region of Prince William Sound. This allows us to work on a finer-scale grid spacing (4-km) than the NCEP models (12.5 km at best). This finer resolution allows us to capture topographic effects that are not in the NWS simulations

In our study we exploit the capability in RAMS of grid nesting, in effect telescoping down from a coarse grid-mesh grid that covers all of Alaska and surrounding oceans, to an intermediate grid that covers all of southern Alaska and the Gulf of Alaska, and ultimately down to the fine-mesh grid that covers PWS and its surrounding terrain/ocean.

The model simulations produce hourly 3-d forecast fields of a host of variables, including: temperature. pressure, winds (3-d), humidity, precipitation, and cloudiness. This is just a small sampling of variables of most interest to most users, a host of other 2- and 3-d variables are available and more can be calculated from the raw output.

The model can also act as an integrator of data, by filling in the gaps or data voids. Several weather stations have been deployed in the Sound and there are several C-MAN stations and NDBC buoys in the Sound. Still there are several data-sparse sections in a region where weather and wave conditions can vary dramatically over a scale of 10 km or so. The model can act to fill in the gaps, acting as surrogate observations in those places where direct observations do not exist. These are, of course, predictions and so will never replace having an actual observation at a given point in space and time

The RAMS output is currently available at the AEFF Weather Briefer's web page:

http://aeff.uaa.alaska.edu/wx_brief.html

To access the PWS images, click on the RAMS button on the left of the page, choose the 12Z forecast time on the top right hand choose Prince William Sound as the domain. The select the field of interest and a time-step (3 hr is recommended for slow connections)

Wave Forecasting in Prince William Sound

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The basic system has been developed to extend NOAA's coarse-grid ocean wave forecasts into the Prince William Sound area. We have developed the computer protocols to interface this local PWS domain to the outer-ocean NOAA predictions. We have established the procedures to do this automatically. At intervals of 12 hours, wave spectral information from NOAA's predictions at grid-points on the local model boundary and NOAA's wind-fields are downloaded. With these inputs, the local model SWAN is now running continuously, and the results are posted on TAMUG website every 12 hours. The results are automatically archived. The simulations include 12-hour hindcasts and 48-hour forecasts; an example of the predicted wave heights in PWS is shown in Fig. 1. This plot represents one of the first simulations and the modeling work is being subjected to quality control at present. Model results are being compared with field measurements to estimate the reliability of the wave forecasts. The current high-resolution (0.02 degree) computational grid that we are using encompasses the region from -149.0^o to -144.0^o longitude and from 59.0 ^{o}N to 61.5 ^{o}N latitude. Based on this grid, the system can finish one simulation in 3 hours (as it runs every 12 hours), so we have the computer resources for a even higher resolution grid. Because we are still in the early stages of this project, the resolution of the current grid most likely will be changed to a higher resolution based on comparison of the model results and field measurements. Currently we are working on switching to the project's "official" bathymetry set and the "official" wind-fields (rather than the NOAA winds we are now using). We are also exploring the use of artificial neural networks to provide point forecasts from instruments; wave height forecasts using data are being made for buoys 46082 and 46060 (e.g. Fig. 2). This technique may help to "add value" to the expanding network of instruments and also to effect judicious and efficient deployment of instruments in the future.

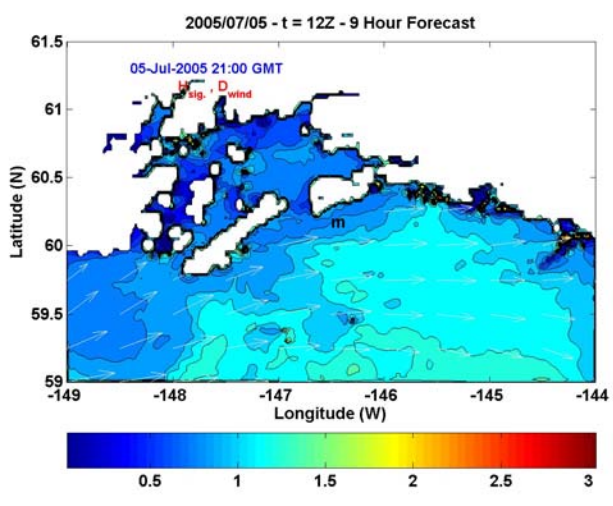

Fig. 1. Significant wave height forecast for Prince William Sound in Alaska.

Ocean Predictions: Regional Ocean Modeling System (ROMS)

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In September 2004, UCLA and JPL ocean labs were asked to design a numerical framework to help advance the knowledge of Price William Sound (PWS) ocean dynamics. Specifically, UCLA's responsibility is to build a PWS configuration of ROMS nesting capability. My talk is a description of the modeling techniques we are using as well as an update on where we are regarding the development of the configuration as of June 2005.

3 nested grids have been generated with a mesh size of 11, 3.6 and 1.2km encompassing respectively the whole Gulf of Alaska, the central coast of Alaska and PWS (the latter extends to the Copper river delta to make sure this important source of freshwater for PWS is included at the finest scale).

The circulation in the sound is driven by an intricate mixture of buoyancy, wind, tidal and remote forcing. A number of technical issues to implement to forcing mechanisms have been overcome and we are currently in the early phase of validation of all grid levels. Further requirements (synoptic winds, improved bathymetry for the region of PWS) will be needed but the numerical solutions (1 year for the 3 grid levels) already reproduce some interesting features. The eddy present in the central part of the sound during most of summer 2004 is also a robust feature in the model even when forced by climatological monthly winds and in the absence of freshwater inputs. The mechanisms responsible for the occurrence of this eddy will be investigated. Also, the structure of the currents across Hinchinbrook Entrance shows strong baroclinicity and temporal variability in relation with the mesoscale activity present outside PWS on the slope. After a validation procedure that will heavily rely on the existing dataset across Hinchinbrook entrance, a full quantification of the PWS/open ocean exchanges (residence time in the sound, mean fluxes through Hinchinbrook entrance) will be undertaken.

Regional Ocean Modeling System (ROMS) Modeling, Data Assimilation and Real-Time Forecasting

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Within the Prince William Sound (PWS), the development of a PWS Ocean Observing System (PWSOOS) is underway. A major goal of the PWSOOS to develop an operational system that delivers information on physical and biological conditions in real-time to research and application users. This information includes raw data on environmental conditions, such as wind speed, air temperature, precipitation, ocean currents, ocean temperature, tide height, and water salinity as well as modeled forecasts of anticipated conditions. Forecasts for the atmospheric conditions in the Prince William Sound region have been developed using a Regional Atmospheric Modeling System (RAMS) with a 4 km resolution. The JPL/UCLA group has the responsibility of developing a real-time forecasting capability for oceanographic conditions.

The JPL/UCLA group will apply the Regional Ocean Modeling System (ROMS) to PWSOOS. ROMS has been successfully used for the California coast and it represents an evolution from the family of terrain-following, vertical coordinate models. ROMS solves the primitive equations under the hydrostatic and Boussinesq approximations. ROMS is discretized in coastline- and terrain-following curvilinear coordinates.

A major new feature of ROMS is the 3-dimensional variational (3DVAR) data assimilation system in ROMS. A Pacific basin-scale ROMS has been developed with a resolution of 12.5-km (Figure 1). The Pacific basin-scale ROMS will provide the needed boundary conditions for the PWS ROMS configurations, which consist of three nested ROMS domains (Figure 2) with 12-km, 4-km, and 1.3-km over the Pacific Northeast, Gulf of Alaska, and PWS, respectively. We are also in the process of developing a tidal modeling component in ROMS, so the real-time sea level can be predicted as well in addition to circulation fields.

We anticipate that the proposed PWS ROMS forecasting system will be operational by 2007 during the proposed field experiment. Both in situ and satellite observations will be assimilated into this PWS ROMS in real-time. Forced with the real-time forecast of the RAMS atmospheric fields, the PWS 3D 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.

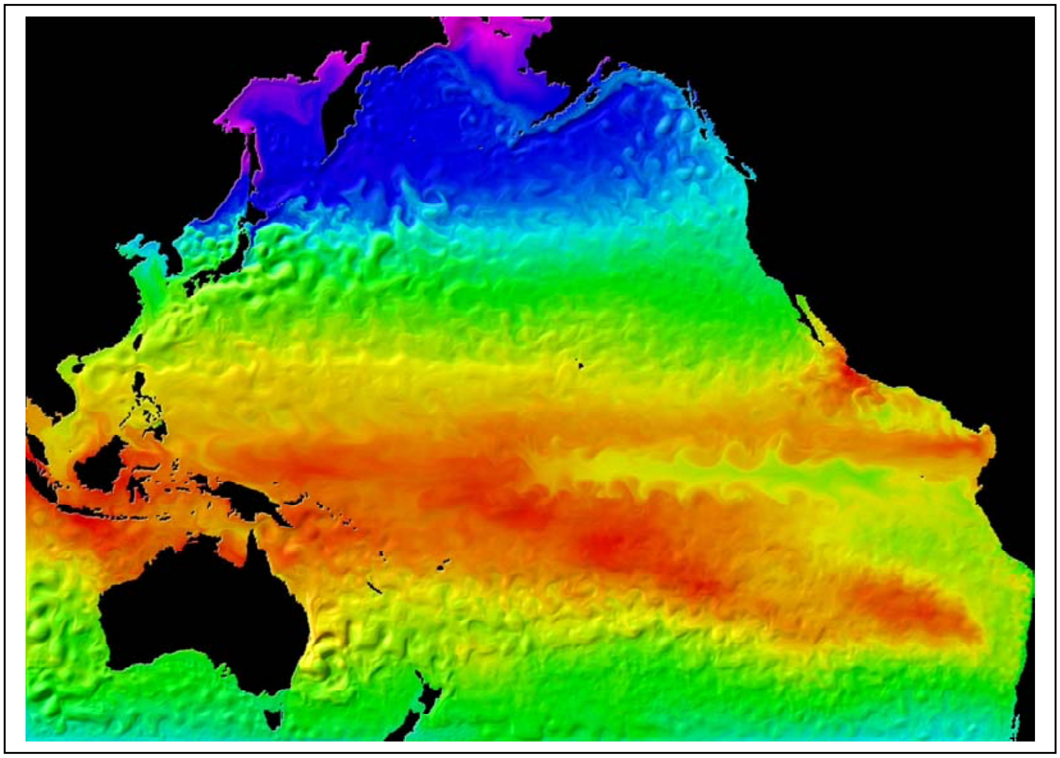

Figure 1. Snapshot of sea surface temperature simulated by the 12.5-km Pacific ROMS.

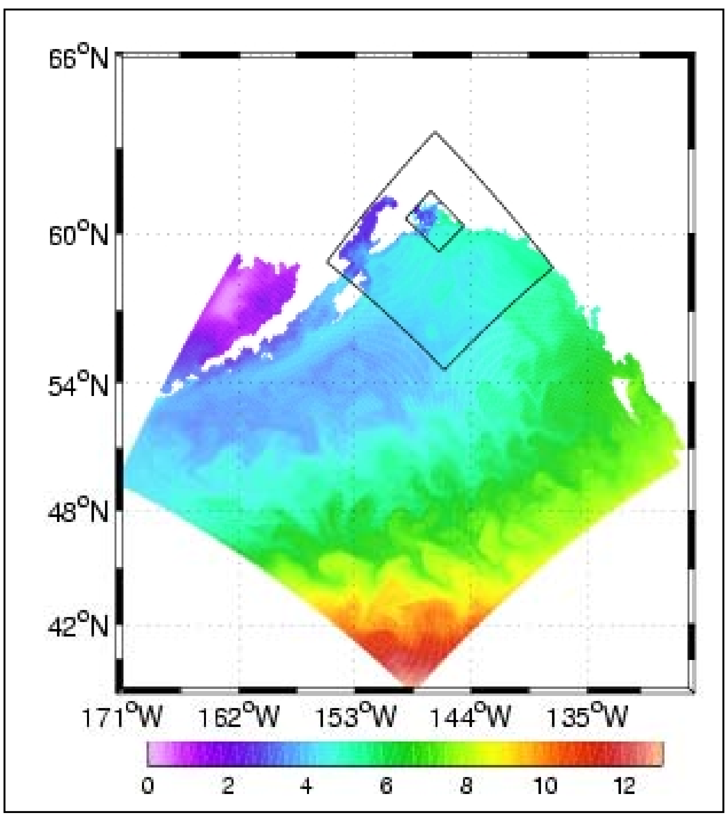

Figure 2. Snapshot of Sea surface temperature simulated the 3-level nested ROMS configurations over the PWS region.

Part III User Needs Discussion Reports

Ocean Policy

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The group discussion falls into several distinct thematic clusters (in no particular order of priority):

A) The group discussed the importance of expanding the 13 physical parameters initially identified for AOOS focus. Expanded parameters should include biological, chemical and human interest (socioeconomic). Existing data should be mined and included to the extent possible. Focus should also be given to traditional ecological knowledge as necessary. As an example for biological parameters, food web structure remains elusive and often is difficult to distinguish biological from physical forcing. As an example of socioeconomic parameters, data collected in the PWSOOS should include or link to on-going data collections of fisheries participation and landings in the sound area, commercial and recreational activities, employment statistics and demographics—all at a temporal and spatial scale that allows for modeling of effects on these variables from physical or biological dynamics in the marine environment. Expansion of AOOS effort could help contribute to greater understanding of and policy relevant parameters beyond the physical ones initially identified.

B) The issues of importance to policy makers are critical to identify, i.e., questions and "Oceanography 101" information needs that policy makers have. How might we go about identifying these relevant issues? Suggestions included an expanded effort to canvas policy makers, policy-level staff and attend relevant policy making meetings in order to better evaluate what the issues of relevance are to these resource managers. AOOS efforts would then be better poised to be useful in summarizing relevant statistics and understanding policy relevant questions. A regional approach could be utilized for common metrics amongst regional and national level initiatives. Summary statistics could be included on the website for AOOS with drop-down data and contact information for PIs on specific projects in order for AOOS serve as a clearing house for availability of information to policymakers. Suggestions for summary statistics models were the State of Coast reports, Sea Grant and COMPASS (http://compassonline.org/) programs. A lengthy discussion ensured on what the best means to package observing system information would be to best serve the information needs of policy makers. Other suggestions included greater use of Sea Grant programs and other existing programs for interfacing scientific information for policy usage. AOOS would be intended then to act as the source for best available, objective, peer-reviewed science.

C) The next discussion theme focused upon the differential importance of long term versus short term data when it comes to policy-level decision making. While real-time data was acknowledged to be of use in other situations, in terms of policy relevance the focus is more upon long-term trends and indication of future trends. Catastrophic events were noted to be another issue of importance with respect to forecasting ability. Any data collection which is of use in forecasting catastrophic events is of extreme importance to policy-levels decision making.

D) There is a need to coordinate on-going efforts with the use of data from the AOOS effort. For example, on-going efforts in fisheries management are currently working towards identification and incorporation of ecosystem indicators for use in fisheries stock assessments. Data sets coming out of AOOS would be of use in these on-going efforts and it was noted that it was not necessary to recreate and reinvent when existing programs could be utilized for funneling of data to the relevant stakeholders (ie in this case the stock assessment scientists).

E) The design of the database is important in terms of assessing the effectiveness of policy measures. The AOOS should be flexible to respond to changing policy needs as well as consideration given in initial design of the database as to what parameters and data format would be the most useful in evaluating the effectiveness of policy measures. Data collection and should be compatible with existing data collection efforts such that data may be aggregated for use across different collections efforts. Data should also be able to be presented in relevant spatial and temporal scales for use in policy-level decision making. Design should also be considered for socio-economic data and/or consideration given for translation of these data for socioeconomic consideration and or utility e.g. in public health, marine safety and other applied fields.

F) A philosophy of rigorous quality control/quality assurance should be adopted to ensure that information distributed from the AOOS is a high quality and defensible scientific product and is presented in such a manner that all assumptions and caveats are apparent to the data user. It is important that the information is presented in such a manner that QA /QC standards are apparent to the data user to protect as much as possible against misunderstanding and subsequent misuse of data sets.

G) Data presentation and web interface should consider the ability to synthesize data temporally, spatially as well as by individual parameters. The user should have the ability to select either all data for a specified time period (and view the parameters collected and data availability for the time period) as well as long-term time series of individual parameters for the spatial area under consideration. Consideration could be given to the web based presentation of data availability for a given time period and the reliability of each parameter estimate for this same period.

Oil Spill Response
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What data is needed for Oil Spill Responders?

The reality for oil spill responders is that they want to know where the oil is going ASAP during a crisis management situation – in order to manage the response so they can a) pick up the oil and b) protect sensitive resources.

Data needed:
1. 3 D models and forecasts including weather forecasts (product output) - With this knowledge, responders can deal with the necessary decision making, i.e. resource prioritization, NEB decisions, deployment of vessels, etc.

2. Sensitive area information – habitat and resource information i.e. SZM, GRD, ESI, etc. so resource prioritization decisions can be made.

3. Sea state especially wave forecasts - Responders need this information to manage the response and make decisions that deal with worker safety, operational limits of response equipment, planning, etc.

4. Communication Support - Geographically remote sites may need portable repeaters installed to telemeter data out of a specific bay, around a mountain etc. Or, portable instrumentation such as satellite trackers or portable weather stations may be needed. Another consideration is that demand or overuse of the websites that provide the needed data/ modeling during an incident may require the development of a method to limit access to the sites or a way to prioritize their access for the forecasters/modelers.

What Space and Time Scales are needed by Oil Spill Responders?

More refined model resolution - Bring that "next generation" of modeling resolution into the models that will be used during a spill response i.e. improve the existing models for industry and responding agencies, especially coupling to the NOAA GNOME model so it can make use of the new resolution being developed by all the research and development efforts being coordinated under the PWSOOS. At its finest level, responders need time windows of two to three weeks in the instance of a plankton bloom or a spawning season or an individual bay. Responders noted that having the models available as a matter of course, so that modeling and scenarios can be run ahead of time, not just during an incident, would be a good planning tool.

How should data be delivered to Oil Spill Responders (should it be real-time)?

Responders need data and forecasts in as near real-time format as possible. And, 3-D trajectory maps in a 6, 12, 24, 48, and if possible even a 72 hour format.

Most importantly, the data needs to be presented in a way that ensures that it can/will be used by incident command decision makers as a planning and decision making tool.

Again, the use and strategic placement of portable instrumentation could be an important tool in providing real-time data during a response incident, and it may be possible to use such instrumentation to refine the resolution of modeling into smaller areas of PWS.

What data format is needed by Oil Spill Responders?

Synthesized products - Forecasts, 3-D models or maps. And, as mentioned earlier, these 3-D trajectory maps are preferred in a 6, 12, 24, 48, and if possible even a 72 hour format.

Maritime Transportation
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Who are they?
-tankers
(Coast Guard oversight)
(tanker anchorage 650ft AMS)
-ferry
    Regular, fast ferry
-tug and barge
    AML, Lynden, other
-cruise / tourism
    Large – Princess, Carnival
    Small – Stan Stephens, Brad Phillips
-SW pilots
(fish opening)
Where do they go?
-fixed routes between communities
-fixed schedules
******
What kind of info?
    Winds, waves, currents, tides, icebergs
    Do they need routing, timing docking? (fuel savings)
    Bathymetric- check proprietary data set
Do they need more Obs?
Can they give us more Obs?
AOOS <u>could</u> provide pre-programmed route forecasts…but do they need it?
******
<u>Communications</u>
VHF chat channel "6"
Sport fish use channel "68"
Better cell phone coverage
Text message warnings
Large vessels – internet

<u>Other</u>
Satellite photos –Radar sat?
Sense of current speed and direction on flats – tell fish movement
    Use navaids as platforms (6)?
Add 3rd CODAR on Kayak Island
(on Middleton Is. & Rugged Is.-Resurrection Bay)
Search & Rescue
Get into SAR school - Coast Guard

Commercial Air and Water Charters

Patrick Kearney, Chief Pilot
Cordova Air Service
P.O. Box 528, Cordova, AK 99574
CONTACT: flyguy@ctcak.net

Problems

1) Time required to access wx info

a. Web
  1. Dial up connection 39bps normal
  2. 13 different wx sites needed to gain information needed
  3. non-returnable links

b. In town phone – NOAA forecast continuous loop 9.5 minutes for loop to complete

c. TV – *Alaska Wx* – one time per day

d. forecasts not accurate beyond 6 hours

e. NOAA radio - 2x daily update - continuous loop unless equipped with starband or telefax (in the field)
  1. No access for small boat owners

Products we would like to see

Web access

1) MyAOOS
  a. Customized wx page
  b. Automatically emailed to you in am or pm
  c. Overlaid on map of forecast area

2) PWS split up into 4 regions
(NE-Valdez NW-Whittier SE-Cordova SW-Seward quadrants)
  a. all available real time reports made accessible
  b. links to Radar and cameras come up in new windows which can be closed and return to original window

In Field

1) Utilize expanding cell technology
  a. Phone access to either overall or 4 regional forecasts with separate phone # published in tide books
  - must include at least hourly real-time updates of observations
  - 12-24 hour forecast periods
  - Continuous loop broadcast

Aquaculture
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Alaska Sea Grant Marine Advisory Program
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Stakeholders

- PNP
- Oyster growers / Razor clams
- Subsistence
- Consumers
- State of AK epidemiology
- ADF&G

<u>Data Needs</u>
Water Temp daily?   Oysters: 15c threshold for vibrio, 11c for maturity
Salinity
Primary productivity – oyster food diatom / dinoflagelate shift
<u>Time scale</u>
  Need predictor – would be helpful
  Long term site trends – site
  Temp July and August especially
  Every 2 hours – profile - thermistors? Selection surface to ? / daily to Dec.
    -web access – downloadable
<u>Geographic scale</u>
5 existing major sites
Up to 30-40 additional sites
Focus on areas of concern

<u>Salmon – PNP</u>
Plankton counts –
    April-May western PWS
Sea surface temp – outmigrants and return
    Juveniles: April-June
    Adults: Jan-June
Area –
    Juveniles – throughout PWS
    Adults – central GOA
Needs-
    Mechanism to measure preditors
    Oceanographic vectors that affect run timing
    Tagging for run location info
Timing –
    Temp for adults- real time web access

Commercial and Recreational Fishing

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3298 Douglas Place, Homer, AK 99603
CONTACT: margaret_spahn@fishgame.state.ak.us

Monitor:

- Fresh water outflow
- Salinity – Temp
- Fresh salt interface
- Nutrients
- Oxygen
- Chlorophyll
- Current at depth
- Flo-cam
- Upwelling
- ADCP backscatter analysis

- Incorporate vessel sampling of phytoplankton and zooplankton
- Need life history info on non-salmonids
- Recruitment info
- Acoustic arrays – transponders co-located with oceomnagraphic moorings- facilitate migration studies
- Info on areas & timing of upwelling on gulf coast
- Need additional chemical and biological monitoring to link with physical

Spatial & Temporal Scales

- Historic oceanographic data available online (daily?) for retrospective analysis
- CR Reds-

.02-1.2 offshore
.05-0.2 nearshore

- Realtime data for in-season management
- 0 – 20' depths
- 2 week forecast in CR plume
- Effective drift of larvae (herring?) – enhanced nearshore modeling & modeling

Education

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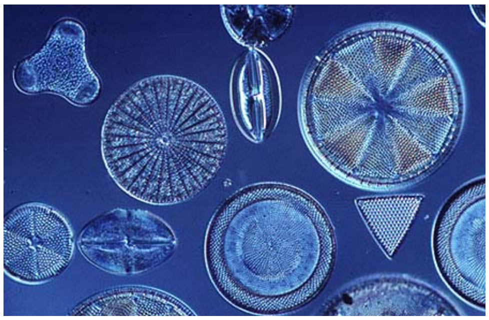
Who is the 'education audience'?•Need to define the education groups– Formal education
»K-12 districts
»Higher ed
– Informal education
– Communities
– Individuals•Maybe we should not focus on K-12 (curriculum/standards based) but on informal education through outreach activities**What data and information are needed?**•Is there a need for formal ed? How do we create the perceived need for formal education?•Information that we need is -- more information!
•Just data is not education – we need to define our audience to know how to 'package' the data•Are we providing a resource of supplementary information for schools?•Need to have some base information about oceanography but we may not have to build•Could just provide the data in the same way as for research – and let users use it in their own way**What space and time scale?**•The advantage of the 'real time' data is that you can learn about what's happening in your local environment – could provide this capability and add explanatory information**Does it need to be real time?**•Yes - at times provides the 'cool' factor that is educationally motivating•No – isn't always necessary
How do we need to deliver it?•Web based with 'customized' interface•Could develop interactive applications – such as 'put the trash into the sound' and then the application shows you what happens to it using the collected data•Outreach programs – packets to take out•Interactive kiosks on location – ferries, science centers•Through a demonstration project – pilot an ed program associated with a field program

Section 2
Potential Biological Components of AOOS

Part I: Prince William Sound Ecosystem Components (by Amy Van Cise)

Nutrients, Phytoplankton, Zooplankton



Behind every marine animal is a food chain that draws energy from the same source – phytoplankton and zooplankton. These are the ocean's simplest organisms, and they rely entirely on the nutrients, sunlight, and physical conditions of the ocean for their survival. "This is probably the one place in the food web where the physics and the biology come closest together," said Ted Cooney, professor emeritus at University of Alaska Fairbanks.

The sub-arctic marine community of PWS is dominated by large phytoplankton called diatoms in the winter and early spring, and is taken over by a community of smaller zooplankton called copepods in the summer. This seasonal change is thought to be created mainly by changes in light and heat throughout the year. In the winter when heat and light are low, diatoms and other phytoplankton spend their time in the nutrient-rich waters that float up from the bottom, feeding on the phosphates, nitrates and silicon that fell there the summer before. In the summer, a warm layer of water keeps the cooler nutrient-rich waters from rising to the top. Phytoplankton start to convert the energy from the sun, and this jump in productivity encourages copepods and other zooplankton to feed on the phytoplankton and grow in numbers.

These seasonal changes in microorganisms have been studied in PWS for over 30 years. However, even at this stage in the food chain scientists admit to having major holes in their understanding of the way life interacts with its surroundings. "We don't know how primary productivity is reacting to changes in the ocean, but we're pretty sure it does," Cooney said. The seasonal collections that have been done for so many years have taught scientists a lot, but still leave something to be desired. According to Cooney, science lacks information that would lead to an understanding of how these communities of microorganisms change on a daily, yearly, or even decadal basis.

The PWSOS will deploy a series of flourometers on its oceanographic moorings in the spring of 2006. This real-time data collection should give scientists a clearer picture of the movements of phytoplankton. Acoustic surveys will be used to track the movement of zooplankton as they travel up and down in the water column or through the Sound. These data combined will help scientists infer how much biomass is transferred between the Gulf of Alaska and the Sound through Hinchinbook Entrance and Montague Strait, and how that transfer changes as the years and decades pass. Scientists will be able to detect regime shifts, patterns in dominance, or geographic moves that may follow cycles. Once scientists know how the ocean affects movement and microorganisms, they can determine how the microorganisms cause changes in large animal populations in the food chain.

Benthic Plants and Animals

Nearshore communities are some of the world's most diverse communities, with plants and animals that have adapted to survive in both the harsh open air and the violent crashing waters that flow onto the coast every day.

This complex community responds to impacts from the land, sea and air, and integrates human impacts from all of these environments.

Benthic plants and animals that live along the coast and in the first 20 meters of the ocean, commonly called the nearshore, have been closely monitored in Prince William Sound since the *Exxon Valdez* oil spill in 1989. In that year, nearshore species suffered a 50-90% population reduction, and many of the plant and animal communities shifted to favor entirely new species. Algal communities recovered just a few years after, but invertebrates such as clams and oysters were slow to follow, and birds and mammals have been in the recovery process for more than 10 years.

"We cannot prevent disasters such as this one, or one such as the 1964 earthquake that I suspected to have caused a major shift in invertebrate communities," said Tom Dean of the Coastal Resources Associates. "However, with a better long-term understanding of the way these communities work, we could help to solve the problems more quickly. There are some data, but there aren't a lot of data, for long term trends," he added. "If in fact we had a long-term data set prior to some of these events, perhaps we could have ameliorated some of the effects."

Dean is part of an ongoing nearshore project that is part of the Gulf Ecosystem Monitoring (GEM) program and aims to track these long-terms changes and trends in nearshore communities. The program involves physical mapping of the coast environment, and identification of intensive and extensive site studies to determine what plants, marine animals, and birds live on the shores or rely on the shores for survival. As these systems are tracked over a long period of time, scientists will begin to develop an understanding of how these communities interact with the land, sea, and air that they live in.

Information from the PWSOS on the physical nature of the Sound will allow them to combine long-term oceanographic data with long-term ecosystem data and determine how communities are affected by their environments, and how environments are affected by people. Dean suspects that in the future ecosystems in PWS will be largely affected by human impacts and global climate change. By studying these ecosystems early, scientists will be able to intervene at appropriate times to relieve these and other stressors.

Fishes and Shellfishes

Commercial and recreational fishermen are among the most intensive users of Prince William Sound. With the ever changing populations of fish and shellfish that can often seem to drop with no explanation, fisheries managers are doing all they can just to keep up.

In recent years however, evidence has shown that these population shifts could be related more to environmental forces than was originally thought. Through the long-term real-time data sets provided by the PWSOS, fisheries management can gain a greater understanding of the physical processes that affect fish and shellfish populations in the Sound.

"Population change often results from environmental variation, but physical data on environments is lacking," said Bill Bechtol of the University of Alaska, Fairbanks. "The environmental data that is available doesn't match up with the population over the long term."

The fish and shellfish industries went through a major regime shift in the 1970s and 1980s when shrimp, crab, and other crustaceans all but disappeared. Instead of these species, fishers' nets have lately been filled largely with haddock, halibut and pollock. As managers begin to understand the relationship between fisheries and their environments, they can tailor yearly management plans to fit the needs of a population.

"Really what we're managing is not the fish themselves; we're managing our take of the fisheries," said Bechtol. This is a practice Bechtol calls managing for Sustained Yield, and it cannot be done without an extensive knowledge of the variability of the ocean environment. For example, pink salmon populations have jumped around in numbers for the last decade, despite managers' best efforts to stabilize the population. Then, several years ago, researcher Milo Adkison from the University of Alaska Fairbanks compared pink salmon population changes to changes in the sea surface temperature, and found that they nearly exactly correlated to each other.

Knowing this environmental matching could allow fisheries managers to predict harvest numbers based on the forecasted seasonal sea surface temperatures, or it could allow them to tailor their release dates to days when the temperatures are optimal for pink salmon survival. Coupling environmental data with fisheries data could lead to many more similar discoveries. The cooperation between PWSOS and fisheries managers in PWS could lead to a greater understanding of the many varieties of fish and shellfish that live in the Sound, as well as the environmental factors that affect them, and the best way to ensure their survival for many years to come.

"We need to look at things on both a coarse and a fine scale," Bechtol said. "I'm a believer in data sharing and trying to figure out how all these linkages work between the different species that are out there."

Aquaculture

Aquaculture in Alaska represents 40% of the state's income generated by Agriculture. That is 6.4 times the amount of money made by dairy products.

The aquaculture industry has made gigantic efforts toward restocking the salmon that are such an important part of the Alaska economy and culture. Many of the state's commercial and sport fisheries are healthy thanks to the state's aquaculture program. With the continuing development of the shellfish industry, state revenues will continue to be enhanced by the marine environment

However, according to Ray RaLonde of the Alaska Sea Grant program, the aquaculture industry remains vitally short-funded, especially with respect to research. In recent years, it has been difficult to assess the interaction between the hatcheries and their environments. The PWSOS will help the aquaculture industry bridge some of those gaps, creating an extensive database of physical data that will correspond to all of the hatcheries in PWS.

The industry should be able to use the environmental data collected by the program to increase the productivity of aquaculture farms growing newly introduced shellfish species, such as razor clams, cockles, and littleneck clams. The industry can also develop techniques for keeping clams out of warm water, which encourages spawning and leads to poor tasting meat.

Warm waters can also lead to outbreaks of *Vibrio parahaemolyticus*, a bacteria that causes severe illness in people who eat shellfish contaminated by it. The bacteria appeared in Alaskan shellfish farms in low numbers during the summer of 2004, alerting many farmers to the dangers of its presence. With continued research, the industry will be able to predict warmer ocean temperatures and take preventative measures to avoid the negative effects caused by them.

The industry also hopes to improve its understanding of ecosystem interactions, which can be used to increase production efficiency and survival rates. The implementation of the PWSOS will help fill the some of the holes in the environmental information needed by the current aquaculture industry. With an increased knowledge of the physical environment, aquaculture specialists can create a more efficient industry that adds millions of dollars to the state's revenues, and millions of fish to the state's waters.

Marine Birds

Alaska's oceans are constantly changing. The 150 million seabirds that call these waters home for at least part of the year are forced to adapt to these changes for their survival. "Marine birds are dependent upon the ocean to make a living," said David Irons of the U.S. Fish and Wildlife Service. "Their behavior, their diet and productivity, their survival changes in response to the ocean." Because of these many changes, seabirds are strong indicators of major ocean changes, and can be used to forecast major shifts in the ocean climate.

Nearly 80% of the seabirds in the United States spend time in Alaska, and 36 of the 274 species breed in Alaska. They live in large colonies, sometimes with as many as 1 million birds at one nesting site, and have long lives and slow maturation. Because of their stability and long lives seabird populations do not often change drastically. And when they do, their fluctuations in populations can often be directly correlated to physical factors in the environment.

Murres, one of the more common seabirds in Alaska's waters, suffer large population drops at their breeding sites if the temperature shifts by as little at one degree in either direction, according to Irons. The colony will only grow as long as the temperature is stable from year to year. Seabird behaviors also give clues about the status of the other animals in their ecosystem. Black-legged kittiwakes are known to love young herring as part of their diet. Often the percentage of herring that is in a kittiwakes diet will forecast the number of herring that return three years later, once the juvenile herring have grown and return for spawning.

When a disaster strikes, seabirds suffer drastically. After the *Exxon Valdez* oil spill of 1989, bald eagles, oystercatchers, and most diving birds dropped in population. Many of the diving bird species are still suffering 15 years later. However, there are still many unexplained occurrences that leave researchers wishing for more information. Since 1970, fish-eating seabirds have been steadily declining by 4% each year. Scientists do not have enough information to link this occurrence to any specific cause.

It is this type of problem that highlights the importance of extensive long-term data. Real-time data of seabird behaviors is currently only possible through personal observation. However, real-time physical data sets allow for strong comparisons to be drawn between seabird behaviors and the environments in which seabirds live. The real time data sets of the physical properties of Prince William Sound that are being provided by the PWSOS can hopefully shed light on the environments in which the birds live, and give researchers a better idea of how these environments dictate the birds' behaviors.

Marine Mammals

Marine mammals are humans' closest connection to the ocean. We can identify closely with the eyes of a baby sea otter or the familial calls of a killer whale – but if we look closely, they tell us more about the ocean than we'd expect. "These are species that affect people; they're affected by people; and they also affect a lot of other organisms in the environment," said Kathy Frost, a marine mammal researcher from the University of Hawaii. "They prey on species that are important to us. We need to monitor sooner rather than later."

The biological portion of the PWSOS will include marine mammal monitoring. A consistent set of data about marine mammals has the potential to reveal to scientists much about the ecosystems that support them. According to Frost, PWS and the Gulf of Alaska (GOA) support some of the richest marine mammal fauna in the world: 21 species are currently known to live in these waters. Of these 21, four species – the harbor seal, the killer whale, the sea otter, and the stellar sea lion – would likely be the easiest and most useful to monitor.

Monitoring can be done in many ways. The classic way to monitor marine mammals is through personal observations. Scientists typically do yearly population counts, and for many species they will try to identify individuals, watch how many years they return to a certain site, and determine their survival rate. Satellite tagging can be an effective tool for monitoring many species. This small wire is attached to an area of an animal's body where it will not affect its daily life, and allows scientists to track the animal's movements in the water throughout the year. Satellite tagging can be combined with a mini-CTD (conductivity, temperature and depth measurement) that can be used to test the water content over an area as wide as the animal travels.

Recently scientists have developed a way to monitor marine mammals that pass through a specific area by using acoustic monitoring devices. These devices are attached to buoys around the ocean and record the sounds made by mammals that pass in the vicinity. Based on the knowledge that individual mammals have distinct calls, the devices can record which animals are passing through at what times of the year. Many of these acoustic devices have already been placed around the Gulf of Alaska and the Aleutian Islands. "Even for people like me who are pretty skeptical, (they are) providing a remarkable amount of information," Frost said. "They're a low cost technological way to get information about species that we know very little about."

Currently, all four species that Frost says are of critical importance to PWS are either stable or increasing in number. For the seals, sea lions and sea otters, that stability comes following a drastic and dangerous population drop that had scientists across Alaska scrambling for a solution. Millions of dollars were poured into the restoration of sea lions with seemingly little effect. At the same time, sea otter populations fell drastically just after scientists thought they were thriving. These recovering mammals have taught scientists many lessons; among them, that money is no replacement for consistent monitoring and preventative action. The future of biological monitoring in PWS will allow scientists to know and understand better the causes for population changes, so that when a population begins to drop they can take more effective steps toward preserving the species.

Part II: Presentation Abstracts

Nutrients, phytoplankton and zooplankton: The good news and the bad news

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The good news. The seasonal picture of organic matter synthesis and transfer at levels of the plankton is reasonably well known for Prince William Sound (PWS). This understanding arises from several studies in the region dating back to the early 1970s. The production cycle is highly seasonal, constrained by lack of light in the winter and by inorganic nutrient diminishment in the summer. For a few short weeks in the spring, favorable interactions between water column stability, light and nutrients permit the explosive production of first a large diatom-dominated assemblage, and later a community of smaller flagellated forms. The initial production is poorly coupled to grazers allowing some of the organic matter to sink out of the photic zone. Later, as zooplankton populations develop, a higher percentage of primary production is captured in water column food webs. This cycle is similar to that reported for large fjord-estuaries at similar latitudes in Norway, Sweden, Chile and Greenland. It is believed that between 150 and 200 gC/m2 are produced in these systems each year.

Taxonomic surveys of the plant and animal plankton (> 0.300 mm) demonstrate the expected Subarctic affinities. A seasonal succession begins with quasi-oceanic conditions in the early spring dominated by diatoms, large-bodied copepods and juvenile euphausiids. As the upper layer warms and freshens, the community becomes more neritic in character; hosting smaller calanoids and tiny primary producers. A few observations suggest that in some years physical conditions permit a sizable fall bloom. The significance of this event is unknown.

Because of seasonal flow-through, it is now recognized that the region communicates biologically with outer-shelf and open-ocean plankton populations. Depths exceeding 400 m provide an over-wintering habitat for Subarctic interzonal and other copepods, and the combination of active physical exchange and relatively deep water favors a diverse community of plankters. One deficiency in the seasonal story is a general lack of information about the microzooplankton community.

The bad news. An almost complete ignorance of year-to-year differences in nutrient concentrations and supply rates, in changes of primary productivity, in rates of organic matter transfer through food-webs, in spatially-distributed plankton stocks, and in processes affecting exchange rates between the open ocean and PWS means that our understanding of interannual variability and its presumed influences on higher levels in the food web is primitive at best. A record of springtime zooplankton stocks obtained since the early 1980s by the Prince William Sound Aquaculture Corporation (PWSAC) represents the only long-term plankton data for the region. Modeling studies have demonstrated that depending on the timing and duration of the spring bloom, more or less organic matter flows into pelagic food-webs. Yet there are no long-term records of this phenomenon to examine year-to-year variability. These few clues suggest that extended studies attempting to account for biological change at higher trophic levels associated with shifts in ocean climate must be accompanied by programs monitoring the plankton.

Benthic Plants and Animals: Recent Trends and Long-term Monitoring in the Nearshore Zone

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Over the past decade, monitoring in the nearshore zone of Prince William Sound has focused primarily on assessing recovery of resources injured following the 1989 Exxon Valdez Oil Spill, and especially on potential impacts of lingering oil. Shortly after the spill, most severe impacts occurred along shorelines that were most heavily oiled. Changes in the abundance of benthic plants and animals varied by species and by habitat, but many of the numerically dominant taxa were reduced by 50% or more. Recovery was generally slowest within soft-sediment habitats and along shorelines that were treated using high pressure washing. Several key taxa, including littleneck clams had not recovered fully as of 1995. Beginning in 1995, the research focus shifted toward examining recovery of representative nearshore vertebrate predators: two invertebrate- eaters (sea otters and harlequin ducks) and two fish-eaters (river otters and pigeon guillemots). The study (termed the Nearshore Vertebrate Predator or NVP study) examined whether these taxa had recovered, and if not, weather the lack of recovery was attributable to demographic lags in recovery, a lack of food resources, or the toxic effects of lingering oil. As of 1999, the invertebrate-eaters (sea otters and harlequin ducks) in heavily oiled portions of Prince William Sound had not recovered. The lack of recovery was not limited by food resources or constrained by demographic characteristics. Lower densities and increased mortality rates were correlated with continued exposure to oil. Since 1999, studies have begun to focus on development of longer-term monitoring of nearshore resources. It was recognized that changes are likely to occur in the Gulf of Alaska over the next 100 years, and that these are likely to result from a number of different causal agents (e.g. global climate change, shoreline development and associated inputs of pollutants) and occur over varying temporal and spatial scales. A monitoring was designed consisting of synoptic sampling of specified physical and biological parameters (e.g. shoreline geomorphology and eelgrass cover), intensive sampling of a variety of specified biological and physical parameters (e.g. abundance and growth of intertidal organisms, abundance of selected birds and marine mammals) within a few specified areas spread throughout the GOA, sampling of a smaller suite of selected biological and physical parameters (e.g. the abundance, growth, and contaminant levels in mussels and clams) at a larger number of less intensively studied sites, and shorter-term studies aimed at identifying important processes regulating or causing changes. Instituting this plan should allow us to detect changes, determine their cause, direct policy to ameliorate and human induced impacts, and allow for recovery and preservation of nearshore resources.

Fishes and Shellfishes: An Overview of Finfish & Shellfish of PWS

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Prince William Sound supports a wide variety of finfish and shellfish species that are harvested for human consumption, but also play integral roles in the ecological integrity of this area. Among the variety of species that occur within PWS are some "conceptual population" types. For example, migratory vs. resident and pelagic vs. benthic imply different life history strategies that may be affected in different ways by changes in the oceanographic conditions. An individual species has a specific, optimal environment within the geographic distribution of that species. This individual species also occupies a particular ecological niche, although this niche may change slightly in different geographic ranges, or under different environmental conditions, or in the presence of different co-occurring species.

Fisheries management is based on understanding the long-term trends in population change while incorporating and adapting to interannual variability in population levels as affected by those changes. In many instances, population changes are the result of environmental variation. In particular, environmental factors are known to be expressed in larval distribution and survival, food resources, and predator distributions, to name just a few effects. Understanding of the biological processes that affect the dynamics of harvested populations requires: (1) some measure or index of the harvested population; and (2) some measures of environmental variables that affect those biological processes. By default, data collected by fisheries biologists has typically focused on harvested species. As a result, "long-term" data is available mainly for more traditional fisheries. Data on individual species are typically available from surveys and harvests. In contrast, data on environmental conditions are often lacking or inconsistently collected. In some cases, a time series of environmental data does exist, but these data are rarely specific to the environment occupied by the harvested species. Data collected through an Ocean Observing System can potentially improve fisheries management by collecting environmental data in real time to facilitate understanding of changes that occur in harvested populations. Meanwhile, data collected on harvested species can contribute to studies that other researchers are conducting on components of the PWS ecosystem.

Representative finfish and shellfish species in PWS are discussed from their roles as conceptual population types.

Aquaculture in Prince William Sound

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The modern era of salmon enhancement began in 1971 from legislation authorizing the Alaska Department of Fish and Game to form the Fisheries Rehabilitation, Enhancement and Development Division (FRED). In 1974, the state Legislature passed the Private Non-profit (PNP) Hatcheries Act, enabling citizens to operate private hatcheries under the regulatory control of FRED. In 1976, the state legislature authorized formation of PNP regional corporations, to work with fishermen and develop enhancement programs to meet their needs. To protect the state's wild fisheries, stringent regulations were developed to minimize genetic impacts, prevent disease, and controls to assure open public scrutiny. Prince William Sound Aquaculture Corporation (PWSAC) is one of five regional corporations active in salmon enhancement through hatchery production, habitat improvement, and lake enhancement.

PWSAC, founded in 1974, is composed of six hatcheries that have annually released approximately 600 million smolt into the ocean. Pink salmon is the dominate species produced by the hatcheries, composing 90% of the hatchery returns. In recent years the hatchery system has undergone economic hardship because demand for pink salmon destined for the canned salmon market has been unable to compete with the increasing demand for fresh fish. To deal with the decline in pink salmon value, PWSAC has expanded production to include higher valued chum, sockeye, and coho salmon. Application of developing fish processing technology and markets for alternate salmon products should also increase demand for pink salmon.

PWSAC hatcheries also enhance sport fishing opportunities in Prince William Sound, contributing 90% of the chum, 51% of the sockeye, 10% of the coho, and 9% of the pink salmon harvested by anglers. The hatchery system statewide is now initiating an intensive planning program that will hopefully lead to an increase in funding for research and development.

The entire Alaskan oyster farming industry grows individual oyster shellstock from seed produced by shellfish hatcheries. Harvested after two years of growth, the oysters are sold live for a premium price to the halfshell market. In Alaska, oyster culture is exclusively suspended culture, employing cages or hanging lantern nets. Shellfish farming activities that maximize growth, control causes of mortality, and employ efficient husbandry, harvesting, processing, and shipping practices. Pacific oysters are the only farmed shellfish species in Prince William Sound, although efforts and now underway to expand into littleneck and razor clam enhancement. Seven oyster farms in Prince William Sound produced over 250,000 oysters worth approximately $88,000 in 2004. Expansion of the existing farms into full production will increase the harvest value to over $600,000 annually. In addition, 121 acres is now available for leasing, if fully developed could contribute an additional $1.2 million in production.

During the summer of 2004, oyster farmers in Prince William Sound, Alaska were surprised by an outbreak of human illness caused by *Vibrio parahaemolyticus (Vp)*. A total of 62 confirmed cases were attributed to *Vp*, making Alaska's first incident of *Vp* the second largest outbreak in US history. *Vp,* is a naturally occurring bacteria and is not necessarily associated with any source of pollution and is the most frequent cause of human gastroenteritis from consuming raw or undercooked seafood,. Environmental investigations show that temperatures above 15°C are required for reproduction of *Vp*, but other contributing factors may also be involved that include, upwelling events, phytoplankton blooms, salinity changes, and possibly other unknown factors. In Prince William Sound the outbreak likely occurred during the last week of June, 2004 when water temperatures at an implicated farm rose above 15°C.

An active research program of increased testing and environmental studies is underway to address the *Vp* problem. As in other parts of the world where *Vp* is a common occurrence, the industry expects that the problem in Prince William Sound will be solved with minor modification of farming practices during the summer months. The greatest challenge facing the shellfish aquaculture industry is increasing production to meet the market demand as the industry grows. Active research projects are now underway to address production and marketing issues.

Marine Birds of Prince William Sound

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Prince William Sound (PWS) is home to hundreds of thousands of marine birds (seabirds, seaducks, and shorebirds) in summer and winter made up of 90 different species. In summer fish-eating birds dominate, with marbled murrelets and black-legged kittiwakes being the most abundant. In winter there are many more benthic feeding birds, including Barrow's Goldeneyes and Harlequin Ducks. The most important issue with the marine birds of PWS is the population trends. Since 1972 trends of breeding birds in summer have declined from about 600,000 to 200,000 birds. The trends of birds in winter have remained relatively constant at about 250,000 birds. The difference in these trends is the fish-eating seabirds have declined and benthic feeding invertebrate eating birds have not declined. The reason for the declines of fish-eating birds is not known, but two major impacts in PWS have been climate change and the Exxon Valdez Oil Spill (EVOS). The north Pacific and many animal populations changed in 1977 as indicated by the change in the Pacific Decadal Oscillation. In 1989 the EVOS had significant effects on many populations of many marine birds. The most visual effects were the immediate mortality, but effects on birds have been documented to last up to 15 years. A big difference in PWS is that there are far fewer herring now than before the oil spill. Since 1994 there have been virtually no fisheries for herring. Many studies have been conducted on herring to determine the effects of the oil spill, but due to confounding factors the effects of the oil spill are not clear and it has not been determined if the spill had any influence on the decline of herring. Whether or not the oil spill caused the herring decline is important to birds because many of the birds are dependent on herring during part of the year. Today many of the fish-eating marine birds continue to decline and the lack of herring may be part of the reason. Marine birds are long-lived, conspicuous, abundant, widespread members of the marine ecosystem and are sensitive to change. Because of these characteristics marine birds are good indicators of change in the marine ecosystem, many studies have documented that their behavior, diets, productivity, and survival changed when conditions change.

Marine Mammals

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The Gulf of Alaska (GOA) and Prince William Sound (PWS) support one of the most diverse marine mammal faunas in the world. This includes 9 species of toothed whales, 7 of baleen whales, 4 pinnipeds and one marine mustelid. Most of what we know about these species has resulted from large research initiatives such as the Outer Continental Shelf Environmental Assessment Program in the 1970s and 1980, the Exxon Valdez Restoration Science Program in the 1990s, and research associated with designation of species as depleted or endangered (for example for Steller sea lions and Cook Inlet beluga whales). Little is known about sperm and beaked whales in Alaskan waters. Harbor and Dall's porpoise are abundant in GOA and PWS, but there are no ongoing research and monitoring programs for either species. Cook Inlet belugas declined significantly in the early 1990s due to over hunting and were listed as depleted under the Marine Mammal Protection Act in 2000. Population surveys and a variety of research are currently underway to monitor trend and to better understand the biology of these whales. Most baleen whales are seasonal visitors to the GOA and PWS. They breed and calve to the south and travel north to Alaskan waters in summer to feed. Most are listed as depleted and endangered and few are regularly monitored. Current use of acoustic monitoring devices attached to moored buoys is providing some information on their seasonal presence in the GOA. There is a variety of ongoing research and monitoring for gray and humpback whales. Gray whales migrate through the GOA to feeding grounds farther north. Humpbacks summer and feed in the GOA and PWS, and some overwinter here. Both species have increased substantially in recent years, and gray whales were delisted under the Endangered Species Act in 1994. Northern fur seals and northern elephant seals feed in the GOA, but breed in other areas. The four species which are widespread and quite well studied in the GOA and PWS are harbor seals, sea otters, killer whales and Steller sea lions.

Harbor seals are widespread and resident throughout the GOA and PWS. Dispersal is limited and several genetically distinct population units occur within the GOA. Seals near Kodiak and in PWS are genetically distinct. These seals are an important subsistence resource. Population trends vary, but most trend area counts in Alaska are currently increasing at 1%-7% annually. A major exception is Glacier Bay where counts declined by 14%/yr from 1992-2001. Although Kodiak seals are currently increasing, the population is still 70%-80% smaller than it was 20 years ago. PWS harbor seals declined by about 70% from 1988-2000, but are likely stable or have been increasing since about 2000. Causes for the decline are uncertain, but it is likely that the initial decline was caused by a change in carrying capacity associated with ocean warming. Continuing declines in the 1990s were likely due to the EVOS, killer whale and possibly shark predation, and harvest. At present, harbor seals in PWS are in very good body condition and there is no indication that disease or contaminants are a problem.

Sea otters are widespread and resident in nearshore coastal waters of the GOA and PWS. They utilize primarily benthic prey, consuming up to 25% of their body weight per day, and have a large role in structuring benthic communities. Until recently sea otters were thought to be abundant and increasing throughout Alaska. However recent surveys indicate declines of up to 90% in the Aleutians and along the Alaska Peninsula. Sea otters around Kodiak have declined

40% since 1994, while they are stable in PWS and increasing in southeast Alaska. Sea otters were greatly impacted by the EVOS, but by 2000 had largely recovered. Food availability is generally considered to be the dominant factor in limiting sea otter population size, largely by affecting juvenile survival. However, killer whale predation is thought to responsible for the large current declines.

Killer whales in the GOA and PWS occur as two types: resident and transient. The two are genetically distinct over long time scales. Resident animals eat fish while transients eat marine mammals. The AT1 resident pod in PWS lost 13 of its members, primarily juveniles and reproductive females, following the EVOS and overall has declined by 47% since 1988. Although other PWS and GOA resident pods have increased since the 1980s, AB1 pod has not. The AT1 transient pod lost more than a third of its members following the EVOS. However, it also has very high levels of PCBs and DDTs, its marine mammal prey are greatly reduced, and it has produced no new calves since 1984. This may be a remnant population whose slow decline was exacerbated by the EVOS and it may now be going extinct.

Steller sea lions are resident and widespread in the GOA. They are classified as endangered and have experienced declines in excess of 70% since the 1970s. Just during the 1990s, the western Alaska stock declined by almost 40%. Numbers currently appear to be increasing, with non-pup counts up about 10% since 2000. Steller sea lions are the most studied of all of Alaska's marine mammals with more than $100 million expended on Steller sea lion research in the last decade. Despite this large research effort, causes for the decline are still poorly understood.

Marine mammals are specially protected by international (the Endangered Species Act) and national (Marine Mammal Protection Act) law that does not apply to other marine organisms. Because of these laws there may be major economic and political ramifications if a marine mammal population is listed as endangered or depleted. It is particularly important that long-term monitoring programs be established for key marine mammal species to measure trend and rates of change, as well as to identify the causes of change. Information about trend is an indicator of population status, and can be used to identify conservation concerns, set management priorities and interpret research findings. Monitoring should include monitoring of prey species, non-commercial as well as commercial, in addition to the marine mammals themselves. Several ongoing programs are particularly good examples of ecosystem-based multi-species monitoring to address marine mammals. These include the Nearshore Study of sea otters and birds funded by the Gulf Ecosystem Monitoring program and the Gulf Apex Predator-prey study funded by NOAA/NMFS to address sea lion declines.

Marine mammals are important to people. They affect and are affected by other species used by people. Marine mammal populations should be monitored on an ongoing basis in order to detect changes in trend sooner rather than later, and to avoid crises and crisis management. Monitoring must be cost-effective, integrated with other studies and sustainable over a long time.

Summary synthesis: What we need to know in the context of an observing system

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A synthesis for biology in Prince William Sound was presented by a sequence of experts in their corresponding discipline in more or less trophic order beginning with lower food chain components. This was followed by an example of an operating biological observing system in Alaska. The synthesis was concluded with recent data suggesting how trophic groups may be co-driven and thus tied together through physical forcing driven oceanic subsidies. The emphasis of this summary is the methods by which each group could detect changes resulting from oceanographic forcing.

The lower food chain components, i. e., nutrients, phytoplankton, and zooplankton, were presented by R. Ted Cooney, professor emeritus of the University of Alaska Fairbanks. Inter-annual and inter-decadal variability in these components are of most concern whereas the seasonal cycle is fairly well understood. This variability has very important implications for fishes and by extension, consumers of fishes, e.g., humans, marine mammals, and birds. Measurements of certain aspects may be continuous, e.g., fluorometers. Because of the great importance of large bodied copepods, which dominate the biomass during the spring, net sampling is done with large mesh sizes, 300 microns and greater. These copepods occur in layers, thus sampling can be focused on layers according to life history stage, which can span from less than 50 m depth to the maximum depth range of Sound, which is about 800 m. Acoustics is a good tool for broad-scale distribution surveys whereas as nets provide essential biological details not otherwise possible to obtain. Poorly know is the role of micro-zooplankton, which are studied using epi-fluoresence microscopy. Lower trophic level sampling can be sampled near the hatcheries (for logistical support), but vessel-based surveys are needed in order to get good coverage of the Sound.

Benthic plants and animals were discussed by Dr. Tom Dean of Coastal Resource Associates. He reported primarily on efforts following the Exxon Valdez Oil Spill with focus on certain near-shore mammals and birds. What is poorly known and what may be of significant importance is the near-shore connection with watersheds and the ocean. There have been significant perturbations in the near-shore, natural ones such as 1964 earthquake, as well as man-made ones (the 1989 oil spill). There are immediate effects, however some effects are ‘cascading’ and may require years to be observed. Techniques include habitat mapping and monitoring. Process studies are needed to test for effects of oil contamination.

Bill Bechtol of the University Fairbanks in Juneau and formerly with the Alaska Department of Fish and Game reported on fishes and shellfishes. Observations have been driven by fishery management needs. Populations have varied rather wildly, appearing to respond to environmental change, fluctuating in abundance at the inter-annual level, certain species virtually disappearing and appearing at regime shifts, and by sudden large occurrence of long-lived species that can only be explained by migration. Populations have been measured in surveys using nets and acoustics but more often through harvests. Only fish that have been harvested have been counted. There is presently a mandate for an ecosystem approach and a need for fishery-independent means of sampling populations.

Ray Ralonde of the Alaska Sea Grant discussed aquaculture, which in Prince William Sound consists of salmon enhancement and shellfish (bivalve mollusks) culture. Concerns are the large economic impact due to the volume of the salmon fishery and for shellfish, human safety issues. Aquaculture needs to be approached as a component of the ecosystem. A particular method that needs to be employed is that summer water temperature measurements be made at all shellfish aquaculture locations.

Dave Irons of the U.S. Fish and Wildlife Service spoke on birds, which consist of seabirds, ducks, and shorebirds. Many exist as large colonies. Prince William Sound hosts the global majority or a significant portion of several bird species. Populations of piscivorous birds have undergone unexplained and concerted population declines. These may be due to 'regime-shift' effects. Some species are known to be favored within a narrow temperature range. Lacking are data for non-fished forage fish species. Birds themselves may be effective as environmental sensors, a synthesis of which is presently in preparation.

Kathy Frost, a former thirty-year marine mammal scientist with the Alaska Department of Fish and Game, spoke on marine mammals. Whereas there are no data for most marine mammal species, four species have been studies extensively. Population trends among these species are inconsistent, being variable in both space and time. Unexplained marine mammal declines may adversely impact the fishing industry. It is very important to monitor non-fished fish species. Techniques for monitoring mammals include passive acoustics, individual identification, e.g, by photography, and use of 'smart' tags. Because site fidelity is an important attribute, sampling must be stratified. Observations need to be long-term and continuous.

Tom Kline of the Prince William Sound Science Center gave a brief description of the Bering Strait Environmental Observatory, which has attributes not unlike those of Prince William Sound such as preliminary observations from research projects, grass root efforts, concerns about long-term population shifts, and combining land- and ship-based observations. An example was given of the long-term trend of ampeliscid amphipod population, which plays a critical role as gray whale forage.

Kline gave a brief description of recent GLOBEC project findings that explain the large fluctuations in Prince William Sound pink salmon populations as a result large inter-annual differences in subsidies of oceanic carbon in the form of zooplankton, which may have been driven by concordant oceanographic shifts. Oceanic subsidies may provide over half of the energy budget in the PWS ecosystem, and thus are of profound importance. NPZ models need to incorporate oceanic subsidies. Oceanic subsidies, which can be measured using stable isotope analysis, are hypothesized to be driven principally by planktonic fluxes in and out of the Sound through its various connections with the Gulf.

Variable flux rates of plankton in and out of the Sound may drive recruitment of organisms with planktonic dispersal stages, explaining the observations made on Mearns' Rock in the years following the oil spill, thus forming a linkage for the presently largely unknown pelagic near-shore coupling. The fluxes driving oceanic subsidies could also explain the dispersion needed to enable changes in species composition occurring broadly in the Gulf of Alaska and referred to as regime shifts.

Bathymetric peculiarities of the Sound were pointed out – the Sound has areas that are both relatively shallow and very deep (to ~ 800m). This heterogeneity is highly significant because of the bathymetric range preferred by different organisms. In particular are the over-winter habitat requirements of the *Neocalanus* copepods that contribute to the bulk of the biomass of the spring bloom's secondary production. Half or more of these originate in the Gulf, reflecting also Gulf subsides.

Because both juvenile herring and juvenile pollock had concomitant inter-annual differences in oceanic subsidies during the SEA program, it is likely that non-fished fish species will also. Furthermore, the effect of oceanic subsidies may be systemically passing up food chains to fish consumers such as certain birds and marine mammals. Oceanic subsidies may thus be a key process with board implications for the Prince William Sound ecosystem. However, demonstrating the effects may remain problematic because good measurements are lacking for most species. Because of the scale of hatcheries (e.g., more than half a billion salmon released per year), the ototlith marking program, and subsequent 'sampling' via the fishery, at this time only salmon have a reliable metric of year class performance, marine survival rate, which can be related to oceanic subsidies, (using stable isotope signatures). A similar relationship could most easily be done for *Neocalanus* in PWS because of their well-defined life history, previous demonstration of oceanic subsidies, and an augmented plankton-watch observation program. It will need to be determined to how to develop a population dynamic – oceanic subsidy relationship of other fishes, particularly those for which very little is known, such as sandlance, capelin, and northern smoothtongue, let alone a systematic sampling program.

Part III: Biological Monitoring Discussion Reports

Nutrients, Phytoplankton, Zooplankton

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Benthic Plants and Animals

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What is Benthic?

Considering it nearshore benthos (intertidal and shallow subtidal)

Who are Stakeholders or Interest Groups for Products or Information that we would identify?

Subsistence, resource managers, other researchers, essential fish habitat, etc….

How identify indicators?

Indicators of status of resources – all pretty long-term things…

What about using sea otters as indicator by observing what they are eating? Prey shifting?

Kelps? Any links to PDO? Relatively long-time series of clam growth. Tom Dean says relatively hard pressed to find any link to PDO or climate change.

Sue- but climate change could maybe influence prey shifting? eE.g kelp beds and

Users of Benthic Information

•Fisheries Managers
•Subsistence Users
•CZ Managers
•Aquaculture
•Other Researchers

Short-term vs. Long-term Signal•Examples of long and short-term

•If pick correct indicators, can be a measure of both short-term and long-term change

Fishes and Shellfishes

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Fish & Shellfish
Need Short Term Results

Improve Copper River Sockeye Return Timing
(X,S) = function of ocean conditions from AOOS)
where
X = mean run timing; annual consistency w/n ~5 days
S = measure of distribution or return per date

Input data:

(1) Historic run timing
(2) Ocean surface temperature from satellite images
(3) Ocean surface temperature, current, salinity from moorings
(4) Temperature & salinity (thermosalinograph) from vessels-of-opportunity (tenders?)
(5) Discharge information

AOOS contribution – Instrumentation and Expertise

Training and Development of Expertise – Through educational outreach, would AOOS fund training opportunities? Training of individuals from ADF&G, PWSAC, PWSSC, etc.

Copper River Sockeye – Add acoustic tagging and pickup to existing moorings or add listening array
Tag fish caught prior to entry to fishery…e.g., inside SW PWS
7-mm tag at 69 kHz tag has 400-500 m range

Aquaculture

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What to Monitor and How

Shellfish farming

- Temperature – Daily real time
    - And its influence on quality
    - And its influence on growth, meat and shell
    - Effect of phytoplankton quality
    - Temperature and it influence on safety
        - Automated system, transmission?
        - Regulatory purpose
        - Cellphone based
    - Need QAQC protocols for data collection for PWS
- Monitor oyster glycogen and condition factors
    - Must be same broodstock and age
- Indicators of HAB – PSP and Domic acid database at DEC
- Indicators of bacteria
- Salinity-*Vibrio* monitoring – FDA Risk Assessment model
    - Not real time (once a week)

Salmon ranching

- Conductivity/Temperature sensors at hatcheries
    - Starband system
    - Disease *Flexobacter*, *Vibrio* (10 C)
- Plankton water further from the hatchery, mass estimation not count.
- What is the biological response that should be measure
    - Otolith marking provides capability to mass mark fish, and OTC marking
    - Residence time?
    - Condition factors on juveniles, otolith marking at release and recapture locations
- Hatcheries and receiving and archiving data

Marine Birds as Indicators of Change of oceanic Conditions

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Do we just want to know about biological response to oceanic change OR do we want to know if the biological components are declining – for example are forage fish declining? Are kittlitz murrelets declining?

If you want to figure out what is going on in an ecosystem, you want to have as many indicators as you can get. You want to know how fish, birds, marine mammals, zooplankton and phytoplankton are changing.

The more indicators the better; there is no "holy grail" when it comes to biological indicators.

Does AOOS care about nearshore or just offshore?

What is the relationship nearshore changes and pelagic changes?

Birds – Are changes due to human or ocean? Nearshore changes are more likely to be human induced (disturbance to nests, disturbance to foraging areas.

If you are interested in oceanic change from phytoplankton/zooplankton/fish then study piscivorous birds (black-legged kittiwakes, marbled murrelets).
If interested in nearshore processes, study benthic-dependent birds – (Black oystercatchers, harlequins).

To make the linkages between Sound & Gulf, Pacific Ocean use Piscivorous birds

Piscivores for pelagic area

Colonial component & at sea component

Divide the Sound into four quadants:

NE: Shoup Bay (kittiwakes) Naked Is. (puffins)
NW: Passage Canal (kittiwakes)
SW: Icy Bay (kittiwakes)
SE: Porpoise Rocks (puffins/kittiwakes)

Parameters to Monitor
Population, diets, productivity & survival
Species: black-legged kittiwakes/ tufted puffins
Time: approx 2 months year
May for survival

June for nesting/population
July diet
August productivity young (fledglings)

Technology people, cameras for top-down (predation), productivity.

At-sea component
A Sound-wide survey July
Combined surveys for distribution & abundance of birds, forage fish, & marine mammals:
Acoustics for forage fish
Observers for Bird & marine mammals

Ships of opportunity

Benthic dependent birds for Nearshore

Colonial component & at sea component

Populations, diet, productivity & survival
Summer:
black oystercatchers
& pigeon guillemots (link between nearshore & pelagic)

At-sea component in winter:
Combined surveys for distribution & abundance of birds, forage fish, & marine mammals:
Acoustics for forage fish
Observers for Bird & marine mammals

More information is needed on forage fish, other than herring, especially capelin, Sandlance, and eulachon. The Bird Group agrees with the forage fish recommendations of the Marine Mammal Group

Who pays for which components will be decided later, agencies should do their normal management, AOOS should do extras.

Marine Mammals

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What to monitor

Sea lions	No	Lots already
Killer whales	No	High trophic level, complicated Lots of attention caused by declines

CetaceansLarge cetaceans
–Not enough known to qualify for monitoring
–BUT great opportunity to partner with AOOS and learn about species that are very hard to study (Passive acoustics, piggy back onto AOOS platforms)
Small cetaceans
–HUGE data gap but not the role of AOOS to do the research. This is an agency responsibility
Sea OttersFundamental role in structuring communities – may change community structure more rapidly than bottom up processes
IF GEM program continues as designed, sea otter monitoring is well-covered. If GEM goes away, there is a real problem. Agency should monitor population status, but other aspects of ecosystem monitoring will disappear.
Wish list (maybe for a group like ACT) – miniature implantable satellite tag
Harbor sealsBasic monitoring is being covered by the agencies
Additional work on foraging, ecological interactions done cooperatively Sea Life Center and ADFG
Oceanographic tags is an appropriate project for AOOS
–Ocean characteristics where seals forage
–HS behavior and movements relative to ocean characteristics
Forage FishThis is a critical need for marine mammals (as well as birds)
Variety of species (herring, sandlance, eulachon, capelin)
We recommend focus on capelin. Indications that MM populations respond to quickly to changes in abundance
–Larval recruitment/revival re ocean condition
–Adult distribution & abundance (can build on EVOS)

Alaska Ocean Observing System Workshop

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

June 13-14, 2005
Cordova, Alaska

Appendix 1

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