Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem

Project Number:	030340
Restoration Category:	Monitoring
Proposer:	University of Alaska Fairbanks
Lead Trustee Agency:	ADFG
Cooperating Agencies:	none
Alaska SeaLife Center:	no
Duration:	October 2002–August 2004
Cost FY 03:	$51,600
Cost FY 04:	$32,100
Geographic Area:	Resurrection Bay/Gulf of Alaska shelf
Injured Resource/Service:	All organisms and services

ABSTRACT

Interannual variations in temperature and salinity on the northern Gulf of Alaska (GOA) shelf reflect environmental changes that affect this marine ecosystem. Quantifying and understanding this variability requires long time series such as the 32-year record at hydrographic station GAK 1 near Seward. This project continues this time series, quantifies the synoptic, seasonal, and interannual variability and seeks to understand the reasons for this variability. It will also begin to examine interannual variations in near-surface stratification and the timing of the spring bloom on the inner GOA shelf. The data will be used to predict the baroclinic component of the mass and freshwater transport variability in the Alaska Coastal Current in the northern GOA.

INTRODUCTION

This proposal seeks support to continue monitoring temperature and salinity on the Gulf of Alaska shelf at the GAK 1 hydrographic station. Such measurements have been supported continuously by EVOS since November 1997. That support has maintained the roughly 32-year (1970 – present) time series of conductivity-temperature versus depth (CTD) data collected at GAK 1. With EVOS support we have continued to make monthly CTD measurements along with hourly measurements of temperature and conductivity at six depths using instruments on a mooring at GAK 1. GAK 1 is the only station in the northern North Pacific that routinely measures salinity and it is the only station that routinely collects temperature and salinity data throughout the water column. Weingartner (1999, 2000, and 2001) gives a more complete description and analysis of the data collected thus far. Our principal findings to date are:

1. The anomalous summer 1997 warming (amounting to 1–2^{o}C above normal) was confined to the upper 40 m of the ocean. That warming was mainly a result of anomalously clear skies and low winds during the summer of 1997.
2. The abnormally large El Niño-related winter 1998 warming (~2^{o}C) occurred throughout the entire 250 m depth of the shelf. Water temperatures returned to near normal during the following summer. This was also accompanied by anomalously large El Niño-related winter 1998 freshening (amounting to a vertically averaged salinity decrease of 0.15 psu) over the upper 200 m of the shelf. Freshening ceased in May and, below 200 m, was replaced with the saltiest waters ever observed at this location. These high salinity waters are enriched with nutrients and potentially available to phytoplankton in the surface layers the following winter.
3. Variations in freshwater forcing and the baroclinic transport of freshwater are large on seasonal, interannual, and interdecadal time scales. For example, freshwater transport within the Alaska Coastal Current increases fivefold between spring and fall and in spring 1998 (the 1997–98 El Niño) the freshwater transport was twice that of spring 1999 (the 1998–99 La Nina).
4. A first order description of seasonal variations in freshwater transport of the Alaska Coastal Current suggests that these variations are accounted for by the annual cycles of: 1) coastal discharge and 2) the Ekman onshore transport of relatively fresh surface waters. Their sum mimics the annual cycle in the baroclinic component of the freshwater transport within the Alaska Coastal Current. Most of the freshwater transport occurs within the upper 75 m of the water column and within 35 km of the coast.
5. Several factors appear responsible for the anomalously fresh shelf waters and large transport observed during the 1998 winter. First, the coastal Alaska discharge was above average in fall 1997 and winter 1998. Second, Pacific Northwest river discharge (as represented by the Fraser River in British Columbia and the Columbia River in Oregon) was above average during summer and fall 1997. Third, there was anomalously strong coastal downwelling around the coastal Northeast Pacific Ocean in fall 1997 and winter 1998. These factors cooperated to lower shelf salinities and enhance the transport. The high runoff diluted inner shelf waters and strengthened the cross-shelf density gradients. These gradients, in conjunction with the strong cyclonic wind stress, enhanced the alongshore extent and strength of the coastal current. The anomalously strong downwelling would also have

enhanced trapping of freshwater against the coast and augmented coastal freshening by increasing the onshore transport of low-salinity surface waters. Our results suggest that the simultaneous occurrence of all of these anomalies is unusual because 1997–98 was the only year since 1970 (the start of the GAK 1 record) in which all of these anomalies coincided with one another.

6. We have developed a predictive relationship between GAK 1 dynamic height (0/250 db) and the geostrophic baroclinic component of mass and freshwater transport computed from the cross-shore density field in the Alaska Coastal Current. This suggests that the GAK 1 data can be used as a low-cost proxy indicator for these variables. We are expanding this relationship using a number of atmospheric variables in an attempt to hindcast transport variations back to 1950 and possibly earlier.
7. Time series of coastal discharge estimates based on Royer's (1982) method and coastal salinity data all suggest a decrease in freshwater discharge into the northern Gulf of Alaska from the late 1950s through the mid-1970s. Discharge increased from the mid-70s through the early-80s, coincident with the regime shift of the 1970s and with the Pacific Decadal Oscillation (PDO) (Mantua, 1997; Overland et al., 1999). These findings add to other suggestions of a freshening across the North Pacific Ocean basin since the 1970s (Wong et al., 1999).
8. We find that the difference in sea level pressure between Seward and Ketchikan correlates well with Royer's freshwater discharge anomaly time series (after applying a 36-month low-pass filter to both data sets). This allows us to construct a proxy discharge time series back to 1899 using Trenberth's sea level pressure data set (Trenberth and Paolino, 1980).
9. Monthly anomalies in the PDO index are coherent with Royer's monthly discharge anomalies at periods of 2 – 4 years suggesting a possible relationship to El Niño events.
10. Monthly sea level anomalies at Seward Alaska are significantly correlated with monthly anomalies of the 0/250db dynamic height suggesting that sea level could serve as a proxy for shelf salinity variations here and perhaps elsewhere in the Gulf of Alaska. The Gulf of Alaska watershed and coastal ocean are severely undersampled with respect to precipitation, river discharge, and salinity. Long-term time series of these are lacking and future maintenance of existing discharge and weather stations is uncertain. There is a need to develop proxy variables that can be used to reliably estimate runoff and coastal salinity.
11. The mooring is also serving as a platform for other scientists, for example in 2001–02 we incorporated prototype halibut tags, under development by USGS-BRD scientists, onto the GAK 1 mooring.

Many of these results were obtained in conjunction with data collected under the auspices of the Northeast Pacific Coastal Gulf of Alaska Global ocean Ecosystems dynamics (GLOBEC) program. GLOBEC field sampling will continue through fall 2004 and provide additional data sets from the northern Gulf of Alaska that will be combined with the GAK 1 data for joint analyses.

NEED FOR THE PROJECT

A. Statement of Problem

The GAK 1 monthly time series illustrates some of the very large interannual and interdecadal variability of the high latitude North Pacific. From the greater sampling rate provided by the moored time series, shorter period variations are being detected and quantified and used to determine temporal aliasing problems associated with the monthly sampling. The results are enhancing interpretations of the historical data and place the magnitude of previous anomalies in a better statistical framework. Moreover, the GAK 1 time series appear to be a reliable proxy for the freshwater content, and the geostrophic, baroclinic component of the mass and freshwater transport in the Alaska Coastal Current along the Cape Fairfield Line (Figure 1). Variability in the marine environment, as reflected in ocean temperatures and salinities, and the shelf circulation, need to be quantified to understand the structure of, and changes in, the northern Gulf of Alaska marine ecosystem. The data have also supported efforts to assess the recovery of marine species and services affected by the oil spill. Indeed, several *Exxon Valdez* Oil Spill (EVOS)-supported investigators have underscored the need to understand natural climate variability and its influence on the recovery of species injured by the oil spill (Purcell et al., 1999; Piatt and Irons, 1999; Duffy, 1999; Anderson et al., 1999).

B. Rationale/Link to Restoration

This monitoring proposal provides a service to current and future investigators working in the Gulf of Alaska and adjacent waters needing information on environmental variability. The information will help assess recovery and restoration progress by allowing these issues to be analyzed within the context of the long-term variability of the physical environment. Our proposed measurements will continue this service by collecting time series at GAK 1 of:

1. Monthly temperature and salinity at every meter throughout the water column using a conductivity–temperature–depth (CTD) instrument.

2. Hourly temperature and salinity at several fixed depths distributed throughout the water column.

This information will assist in:

1. Understanding thermohaline variability on time scales ranging from the tidal to the interdecadal.

2. Interpreting historical data sets for use in retrospective studies.

3. Providing proxy information on freshwater content and the mass and freshwater transport in the Alaska Coastal Current.

4. Provide information on seasonal variations in upper ocean stratification and the onset of the spring bloom.

C. Location

The fieldwork will be conducted at Station GAK 1 at the mouth of Resurrection Bay (Figure 1). Both the CTD work and the mooring deployment and recovery operations will be conducted from the Seward Marine Center using the 25-foot vessel, *Little Dipper*. All data collected as part of this program will be available to those desiring it via files on the Internet. The monthly CTD data will be combined with the existing historical data that are on the Institute of Marine Science web page: http://www.ims.uaf.edu/GAK 1/. GAK 1 lies on the inner edge of the Alaska Coastal Current (Figure 1). This current is the most prominent feature of the Gulf of Alaska shelf circulation. It is a persistent circulation feature that flows cyclonically (westward in the northern Gulf) throughout the year (Figure 2). It originates on the British Columbian shelf (although in some months or years it might originate as far south as the Columbia River (*Royer*, 1998) and flows for ~2500 km to where it enters the Bering Sea through Unimak Pass in the western Gulf (*Schumacher et al.,* 1982). It represents an advective pathway by which climate signals can propagate into the Gulf and it responds to the integrated wind and freshwater forcing along its length.

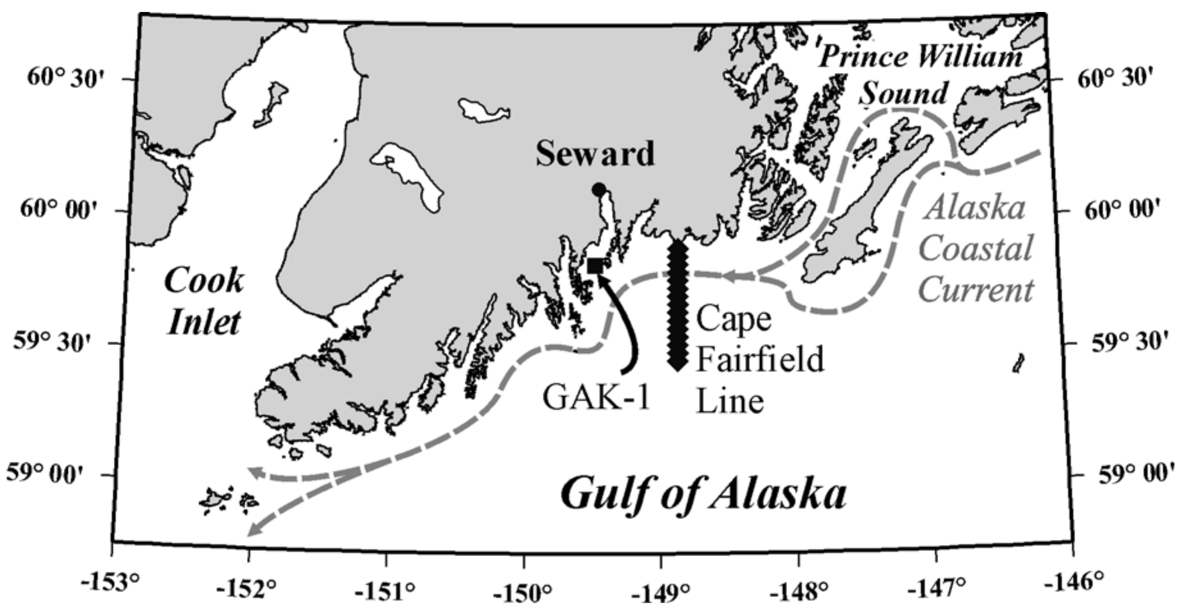

Figure 1. Map showing location of hydrographic station GAK 1 and the Cape Fairfield GLOBEC transect in relation to the Alaska Coastal Current, Prince William Sound, Cook Inlet and Seward.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

We do not see any overt connection to traditional ecological knowledge. However, data sharing with both the public and scientific communities is an important component of our program. The most efficient way to accomplish this objective is through the Internet. We have established a website (http://www.ims.uaf.edu/GAK 1/) that provides information on this project and allows rapid dissemination of the data. We continue to upgrade the website to make it more accessible to the public. For example, we are preparing a glossary of the technical terms used on the website and are developing schematics that illustrate some of the basic physical processes occurring in the Gulf of Alaska. We have also made presentations on the Gulf of Alaska oceanography to high school science students in the Fairbanks area and will continue to do so in the future. The website allows ready access to the data for those working at the community level and with traditional ecological knowledge. Moreover, we are considering ways to transmit data in real-time cost-effectively from GAK 1 to a land station (possibly the Alaska SeaLife Center). If such a need exists and we can do so economically, then we will seek to upgrade the GAK 1 mooring in the future.

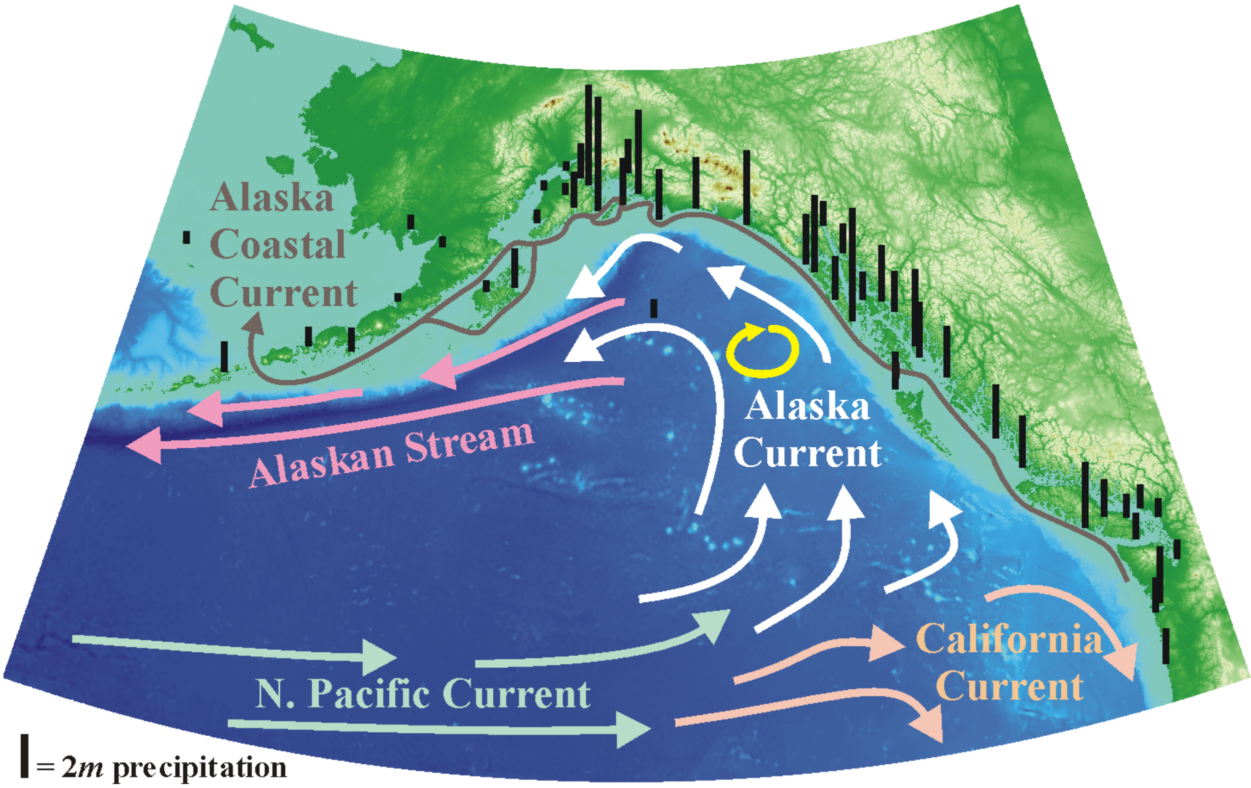

Figure 2. Schematic of the circulation of the Northeast Pacific and Gulf of Alaska. The vertical bars are the mean annual precipitation amounts at selected National Weather Service coastal sites and in the interior of the Gulf of Alaska. The latter is from Baumgartner and Reichel (1975).

PROJECT DESIGN

A. Objectives

The main objective of this program is to:

> Continue the 32-year time series at station GAK 1 so that interannual and longer period variability can be quantified and understood.

This objective will be met through a combination of monthly CTD measurements and through year-long deployments of a mooring containing temperature and conductivity (T/C) recorders. The sampling schemes complement one another with one providing high vertical resolution at monthly time scales and the other providing high temporal but relatively low vertical resolution. We view the maintenance of this time series as essential to the broader goals of GEM. We believe that this effort is a cost-effective contribution to monitoring some of the key physical environmental variables on the Gulf of Alaska shelf, namely, temperature, salinity, freshwater content, and the baroclinic component of mass and freshwater transport in the Alaska Coastal Current.

Ecosystem monitoring is a long-term undertaking requiring multiple and multi-disciplinary efforts, with this proposed effort constituting an essential step. We envision the GAK 1 mooring eventually incorporating a diverse suite of biophysical sensors that will contribute toward ecosystem monitoring in the Alaska Coastal Current. We propose to upgrade the mooring by adding an additional T/C recorder coupled with a fluorometer and transmissometer. The instrument will be deployed in the euphotic zone at about 15 m depth. In the future, the sensor suite might be expanded to include automated chemical sensors capable of collecting time series of nitrate and acoustical and/or bio-optical sensors that can detect zooplankton and fish. Many of these techniques are being tested now or are under development. We plan to await the outcome of these tests before proposing to incorporate the instruments on the GAK 1 mooring. This mooring could also serve as a platform for passive acoustic recordings of marine mammals and/or ambient environmental noise. The latter could become a future issue in this region if recreational and commercial boat traffic increases. The mooring is also available for the deployment of instruments of interest to other users as a community service. For example, in 2001 we incorporated prototype halibut tags, under development by USGS-BRD scientists, onto the mooring. In 2002, Dr. R. Hopcroft (University of Alaska) will conduct year-round, bi-weekly sampling of the zooplankton community at GAK 1 and he will use the GAK 1 data set during the interpretive phase of his work. His sampling, funded under GLOBEC, will provide higher temporal resolution of the seasonal changes of the zooplankton community in the Alaska Coastal Current.

To guide our immediate efforts we formulated several project-specific objectives, several of which are continuing as discussed in our annual reports (Weingartner, 1999; 2000; 2001). These are:

1. Determine the rate of change of water mass properties (temperature and salinity) and the phasing of these changes at different depths. Some of these features, which are not resolved by monthly sampling, reflect important changes whose timing could be significant to the ecosystem. The data files will be made available on the time series homepage for downloading and as a graphical display. Key events will be highlighted and discussed as part of the graphical display.
2. Determine the basic statistical properties of the moored data and how variances in temperature, salinity, and dynamic height are distributed seasonally and over depth. Are there distinct vertical “modes” of variability that change with season? These results will also

be summarized in a file containing textual, tabulated, and graphical information and will be accessible via the time series homepage.

3. Determine the timing of the onset of stratification in the upper ocean in spring and its relation to the onset of the spring bloom.
4. According to NOAA forecasts, an El Niño is now developing over the equatorial Pacific. The physical effects of this phenomenon should be evident in the Gulf of Alaska in the winter of 2002–03 and our mooring should capture its evolution.

B. Methods

Funds are requested to monitor Gulf of Alaska temperature and salinity through FY 03 and part of FY04. We propose to collect data at GAK 1 in two ways: monthly CTD profiles throughout the water column and hourly measurements of temperature and salinity at selected depths. Seven times a year (March, April, May, July, August, October, and December) these measurements will be made from the R/V *Alpha Helix* while this vessel is supporting the GLOBEC program. In the remaining months we will use the Institute of Marine Science's 25-foot *Little Dipper* and collect CTD profiles with a Seabird SBE-25 internally-recording CTD deployed from the vessel's winch. The manufacturer calibrates the sensors on this CTD annually. The historical salinity data have an accuracy of ~0.01 or better using this instrument and these procedures. Temperatures are accurate to within 0.005°C.

The monthly sampling will be complemented by hourly measurements from temperature/conductivity recorders (Seabird MicroCats; SBE model 37-SM) incorporated in a taut-wire, subsurface mooring at GAK 1. The mooring can be deployed and recovered by the *Little Dipper* during the CTD cruises (or during one of the GLOBEC cruises time permitting). Throughout the first four years of this program we have deployed six instruments collecting at nominal depths of 30, 50, 100, 150, 200, and 250 meters. We propose to add a seventh instrument at about 15 m depth, to collect temperature, salinity, fluorescence, and transmissivity data in the near-surface layer throughout the year. (The instrument is a SeaCat, SBE-16 and is similar to a MicroCat except that it can mate with additional sensors, e.g., the optical sensors). There are several reasons for the proposed addition. First, in conjunction with the instrument at 30 m depth, the instrument at 15 m depth will allow us to assess the seasonal development of stratification in the upper ocean. Second, near-surface temperatures might be very useful in understanding salmon recruitment based upon the work of Willette et al. (1999) since the juvenile fish occupy the upper 15 m of the water column while on the shelf (Boldt and Haldorson, 2000). Third, the addition of the fluorometer and transmissometer will allow us to determine the timing of the spring bloom (based on fluorescence) and its relationship to the development of upper ocean stratification and seasonal changes in suspended sediment load (transmissivity). Bio-fouling of the optical sensors is likely to occur through time and this will degrade the accuracy of the optical data. This could be overcome by replacing these instruments more frequently throughout the year (albeit at an increase in cost). Although this might be desirable in the future, for the time being we will focus on the spring bloom. To minimize bio-fouling effects, we will deploy the mooring in March, prior to the spring bloom which typically occurs in April or May on the Gulf of Alaska shelf. With the proposed change the instrument distribution covers the near-surface (15 – 30 m), the upper ocean (30 – 100 m), mid-depth (150 –

200 m) and bottom (200 – 250 m) of the water column. While prior results indicate that mooring motion can be ignored during analysis, we monitor this with a pressure sensor on the uppermost (15 m depth) SeaCat. Our prior experience with these and similar instruments (SeaCats) indicate that temperature and salinity drifts are generally <0.02°C and <0.03 psu/year, respectively.

The mooring design and fabrication consists of three steps prior to deployment. First, the manufacturer calibrates all of the instruments prior to deployment. (This step is usually completed 6 – 9 months prior to deployment). Second, we analyze the mooring response to the ambient current field using a mooring design program and typical ambient current speeds. This procedure optimizes the distribution of our flotation and minimizes current-induced mooring diving. Past experience indicates that the shallowest instrument should dive by no more than 1 – 2 m under the ambient currents. Third, all of our T/C recorders are run for about 5 days in a continuous flow-through seawater tank at the Seward Marine Center. This serves as a pre-deployment check on the instruments wherein we check that the clocks and sampling intervals are correct and that the temperature and conductivity sensors on each instrument differ from one other by no more than the manufacturer's stated accuracy. Prior to deployment, we mount the T/C recorders on gimbaled vanes and use in-line swivels so that the duct leading to the conductivity cell is always oriented into the current. This enhances flushing of the conductivity cell and leads to a better conductivity cell response and avoids the expense of a pump.

The analyses of the data sets are straightforward. Objective 1 is largely concerned with temporal aliasing issues associated with monthly sampling. Among the important processes that might be aliased are the summer onshelf influx of dense bottom water, changes in upper ocean stratification throughout the year as a consequence of winds and runoff, and the response of the thermohaline structure of the water column to synoptic scale forcing by the wind. Objective 2 will be achieved by harmonic analysis of the temperature and salinity time series. This analysis provides us with an understanding of the vertical and temporal variability in the temperature and salinity distribution. Objective 3 will be achieved by examining the fluorometer and transmissometer record in conjunction with the density differences determined using the instruments at 15 and 30 m depth. Our analysis will also use the weather data collected by the NOAA meteorological installation at Pilot Rocks, about 20 km south of GAK 1. This weather station is representative of local wind and air temperatures on the inner shelf and the data are available from the Internet. In the event that an El Niño develops, Objective 4 will be achieved by comparing data obtained in 2002 and 2003 with previous GAK 1 data. Such a comparison can only be achieved by having a sufficiently long time series so that the magnitude of any El Niño related change can be discussed and quantified in the context of previous variability. The statistical significance of the magnitude of a potential El Niño anomaly can be easily ascertained through standard statistical methods given the existing historical data set. We have constructed a multivariate linear regression model that uses a variety of independent variables to predict the dependent variables: freshwater content and the baroclinic components of the mass and freshwater content of the Alaska Coastal Current flowing along the Cape Fairfield Line (Weingartner, 2002). Under the GLOBEC program we will make seven additional transects of the Cape Fairfield Line (October and December 2002, March, April, May, July, and August 2003) upon which we can calculate the dependent variables. We will then apply our statistical model to predict these variables (actually the monthly anomalies of these variables) and assess the error in this prediction.

The regression is based on a large number of independent variables including, GAK 1 hydrography, Seward sea level, local winds, GOA upwelling indices, and sea level pressure and radiation fields, and larger-scale Pacific climate indices (SOI, NOI, and PDO). Monthly anomalies of each of these variables are formed, upon which we compute the principal components (PC) of the anomaly time series. These PCs are mutually orthogonal to one another and effectively reduce the number of independent variables used as predictors of the dependent variables. This procedure appears to be successful insofar as it explains more than 70% of the freshwater transport in the Alaska Coastal Current. We will use this model in the future to assess its predictive skill on the GLOBEC data sets. Because the new data will not be used to refine the model they will serve as an independent test of the model's skill.

SCHEDULE

A. Measurable Project Tasks for FY 03 and FY04 (October 1, 2002 – August 31, 2004)

Oct 2002 – Feb 2003:	Monthly CTD surveys scheduled at mid-month; update homepage as CTD data are processed and edited; prepare wind fields and acquire meteorological fields.
Mar 2003:	Recover and re-deploy mooring. Begin analysis of March 2002 – March 2003 GAK 1 mooring data.
Apr 2003 – Feb 2004	Continue monthly CTDs, complete post-calibration on mooring instruments, process mooring and CTD data.
Mar 2004	Recover mooring and begin analysis of March 2003 – March 2004 GAK 1 mooring data. Post-calibrate mooring (3 months required).
Aug 2004	Submit annual report.

B. Project Milestones and Endpoints

The data collected as part of this project will be available to a broad community of users. We anticipate that some will want "immediate" access to it. This desire often conflicts with the goal (and required time) of producing data of the highest possible quality. In the past, the final CTD data have generally been placed online about four months after collection. The final edited temperature and salinity data from the mooring should be ready within five months after instrument recovery. The delays arise because of post-calibration procedures (performed by the manufacturer) and data editing requirements (performed at the Institute of Marine Science). We intend to make much of the data, along with preliminary results, available for rapid dissemination. From a practical point of view this approach is prudent because for many users the differences between the raw and the final edited product are insignificant. We will attach appropriate warnings concerning data quality to both preliminary and final data products. Thus, we anticipate making most of the data available on the home page one month after recovery of the mooring. However, data will not be released if there are severe concerns regarding its quality unless and until such concerns are resolved. In addition to these general considerations, we anticipate the following project milestones:

1. The first objective is to examine rates of change of water mass properties (temperature and salinity) and the phasing of these changes at different depths. This work is largely descriptive and will begin immediately after instrument recovery. Graphical data displays will be made

available within four months of recovery. These will include textural information indicating features of interest. Displays will be updated periodically as new findings emerge. Eventually these results will be merged with those of the third objective.

2. The second objective pertains to basic statistical results pertaining to the system variance. The results will be made available on the web page and in the final report when completed.

3. The third objective is a new one and consists simply of documenting the onset of the spring bloom with respect to the development of stratification. As this component of the GAK 1 time series continues, we will be able to quantify the timing of the spring bloom and track its variability in relation to the physical parameters measured.

4. The fourth objective will quantify the magnitude of the El Niño signature of 2003 – 2004 in comparison to previous years and El Niño events observed in the northern Gulf of Alaska.

C. Completion Date

This project will be completed by August 2004.

PUBLICATIONS AND REPORTS

Data and results will be provided via Internet as indicated above and presented at the annual GEM workshop.

PROFESSIONAL CONFERENCES

We have presented some of our prior findings at national conferences in conjunction with our GLOBEC work. In the past year this has included annual EVOS workshop as well as the Ocean Sciences meeting (January 2000, San Antonio), the Eastern Pacific Ocean Conference (EPOC; September 2000, Sidney, British Columbia), and at the GLOBEC Principal Investigators' meeting (November 2001). In each case we have melded the GAK 1 results with GLOBEC results where appropriate and have acknowledged the support of EVOS as well as the National Science Foundation (NSF) and the National Oceanic and Atmospheric Administration (NOAA). I expect that this and other collaborative presentations of these data will continue in the future. I am not seeking funds from EVOS for travel and attendance at the national meetings, as GLOBEC funds will cover these costs. Funds are requested for attendance at the annual GEM workshop in Anchorage.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

We have discussed aspects of the GAK 1 historical data with several investigators supported by the Trustee Council. Many have expressed interest in these data and know how to access it. Other scientists are aware of these data through papers and meetings, (e.g., the American Geophysical Union which serves primarily the U.S. oceanographic community and the North Pacific Marine Science Organization [PICES] composed of marine scientists from around the

Pacific Rim). Though we have discussed in previous sections how we would make these data available, we welcome advice from the Trustee Council on additional ways to share these data with other investigators and/or the public.

Several scientists are co-investigators on a GLOBEC proposal whose results would complement this proposal. The UAF investigators (Coyle, Hopcroft, Haldorson, Whitledge, Weingartner) along with Royer (Old Dominion University) have funding from the NSF-NOAA GLOBEC program to examine the Gulf of Alaska shelf ecosystem for the period October 2000 – December 2004. This work includes seven R/V *Alpha Helix* cruises spaced throughout the year to examine the cross-shelf hydrography (including nutrients) and the distribution of phytoplankton, primary production, zooplankton, and fish (mainly juvenile salmon and forage fish) in relation to the physical environment. Costs for the GAK 1 data collection are shared with the GLOBEC program insofar as seven of the monthly cruises to GAK 1 will be undertaken by GLOBEC. Thus we are requesting support for only five *Little Dipper* cruises. Further, Hopcroft's GLOBEC work includes estimating zooplankton growth rates and production based on changes in zooplankton age-frequency composition at GAK 1. He will conduct several *Little Dipper* cruises during the year in addition to those described above. He will also collect CTD profiles as well during his cruises (following the same procedures as discussed above); thereby increasing the number of profiles available to this project. Other GLOBEC investigators (Strom, Western Washington; Dagg; Louisiana State; Napp, NOAA) will be investigating zooplankton dynamics in 2003 in the northern Gulf of Alaska and we anticipate that the GAK 1 data will be of use to them as well. Finally, NOAA-PMEL has deployed several moorings over the middle and outer shelf south of GAK 1 (along the Seward Line). Data from these in conjunction with the GAK 1 data set should provide a better understanding of synoptic and seasonal changes over this shelf.

We see these programs as highly complementary in several ways. First, the cross-shelf hydrography will provide a basis for comparison with variations observed at GAK 1. Second, a comprehensive nutrient data set will be made available for establishing the type of correlations alluded to in the introduction. If significant correlations exist then the GAK 1 data would be a proxy indicator of historical variations in nutrient concentrations (for some depths).

The effort described in this proposal takes a modest but important step toward achieving the goal of long-term, comprehensive ecosystem monitoring. There are compelling scientific and logistical reasons for believing that GAK 1 will be a long-term site and that the sampling will eventually expand to include other disciplines. Resurrection Bay and the adjacent ocean are paradigmatic for much of the Gulf of Alaska shelf, and this area is easily accessible by marine scientists at Seward. Although our understanding of chemical cycling and biological processes on this shelf is limited at the moment, programs such as SEA, APEX, and GLOBEC will provide substantial new information for these disciplines. Results from these programs and those anticipated from the work proposed herein will contribute to the design of a comprehensive long-term monitoring strategy. Additional impetus for expanding the monitoring activities at GAK 1 will occur as programs at the Alaska SeaLife Center evolve.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

We propose to add 1 SeaCat, SBE-16 to the mooring at a depth of 15 m. It will contain a fluorometer, transmissometer and pressure gauge to monitor diving. The reasons for the proposed addition are: 1) to begin to assess the interannual variation in the seasonal development of stratification and timing of the spring bloom over the inner shelf and 2) because near-surface temperatures might be useful in understanding juvenile salmon survival (Willette et al., 1999) since these fish inhabit the near-surface layers (upper 15 m of the water column) on the shelf (Boldt and Haldorson, 2000).

We also propose a change in the schedule of activities. In the past we have serviced the mooring in December of each year. In the future we want to service the mooring in March. The change is proposed to minimize biofouling of the optical instruments prior to the onset of the spring bloom. This typically occurs in April. By deploying in March 2003 biofouling of the optical instruments will be minimized. This means that the mooring will be replaced in March 2004 and that the annual report will be prepared by August 2004 after the instruments have been post-calibrated.

PROPOSED PRINCIPAL INVESTIGATOR

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PRINCIPAL INVESTIGATOR

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EDUCATION

Ph.D. Physical Oceanography, 1990, North Carolina State University
M.S. Physical Oceanography, 1980, University of Alaska
B.S. Biology, 1974, Cornell University

MEMBERSHIPS

American Geophysical Union; American Meteorological Society

PUBLIC SERVICE

- Member, Science Steering Committee, NSF - Arctic System Science-Ocean Atmosphere Ice Interaction (OAII) component
- Member, Science Steering Committee, NSF - ARCSS-OAII Shelf-Basin Initiative
- Member, Science Steering Committee, NSF - ARCSS-Human Dimensions of the Arctic component
- Member, UNOLS - Fleet Improvement Committee

PROFESSIONAL EXPERIENCE

- Assistant Professor; Institute of Marine Science, School of Fisheries and Ocean Sciences, U. of Alaska Fairbanks, Alaska; 11/93 - present
- Research Associate; Institute of Marine Science, School of Fisheries and Ocean Sciences, U. of Alaska Fairbanks, Alaska; 9/91 – 10/93
- Postdoctoral Student; Institute of Marine Science, School of Fisheries and Ocean Sciences, U. of Alaska Fairbanks, Alaska; 7/88 – 8/91
- Graduate Research Assistant; Department of Marine, Earth and Atmospheric Sciences, North Carolina State U.; Raleigh, North Carolina; and Department of Marine Science, U. of South Florida; St. Petersburg, Florida; 8/84 – 10/88

PROFESSIONAL INTERESTS

Physical oceanography of the Arctic and North Pacific Oceans and the adjacent shelves, biophysical linkages in oceanography.

PUBLICATIONS

Weingartner, T.J., K. Coyle, B. Finney, R. Hopcroft, T. Whitledge, R. Brodeur, M. Dagg, E. Farley, D. Haidvogel, L. Haldorson, A. Hermann, S. Hinckley, J. Napp, P. Stabeno, T. Kline C. Lee, E. Lessard, T. Royer, S. Strom, The Northeast Pacific GLOBEC Program: Coastal Gulf of Alaska, submitted to *Oceanography*

Weingartner, T. J., S. Danielson, Y. Sasaki, V. Pavlov, and M. Kulakov. 1999. The Siberian Coastal Current: a wind and buoyancy-forced arctic coastal current. *J. Geophys. Res.,* ***104***: 29697–29713.

Münchow, A., T. J. Weingartner, and L. Cooper. 1999. On the subinertial summer surface circulation of the East Siberian Sea. *J. Phys. Oceanogr.*, ***29:*** 2167–2182.

Weingartner, T. J., D. J. Cavalieri, K. Aagaard, and Y. Sasaki. 1998. Circulation, dense water formation and outflow on the northeast Chukchi Sea shelf. *J. Geophys. Res.* ***103:*** 7647–7662.

Gawarkiewicz, G., T. Weingartner, and D. Chapman. 1998. Sea Ice Processes and Water Mass Modification and Transport over Arctic Shelves. Pp. 171–190 *in* K. H. Brink and A. R. Robinson, (eds.), The Sea: Ideas and Observations on Progress in the Study of the Seas, ***Vol. 10.***

Weingartner, T. J. 1997. A review of the Physical Oceanography of the Northeastern Chukchi Sea. Pp. 40–59*, in* J. Reynolds (ed.), Fish ecology in Arctic North America. American Fisheries Society Symposium 19, Bethesda, MD.

Cota, G. F., L. R. Pomeroy, W. G. Harrison, E. P. Jones, F. Peters, W. M. Sheldon, Jr., and T. J. Weingartner. Nutrients, photosynthesis, and microbial heterotrophy in the southeastern Chukchi Sea: Arctic summer nutrient depletion and heterotrophy. *Mar. Ecol. Prog. Ser.* ***135:*** 247–258.

Roach, A. T., K. Aagaard, C. H. Pease, S. A. Salo, T. Weingartner, V. Pavlov, and M. Kulakov. 1995. Direct measurements of transport and water properties through Bering Strait. *J. Geophys. Res.,* ***100:*** 18443–18458.

Falkner, K. K., R. W. Macdonald, E. C. Carmack, and T. Weingartner. 1994. The potential of Barium as a tracer of arctic water masses. *J. Geophys. Res., Nansen Centennial Volume*.

Liu, A. K., C. Y. Peng, and T. J. Weingartner. 1994. Ocean-ice interaction in the marginal ice zone using synthetic aperture radar imagery. *J. Geophys. Res.,* ***99:*** 22391–22400

Niebauer, H. J., Royer, T. C., and T. J. Weingartner. 1994. Circulation of Prince William Sound, Alaska. *J. Geophys. Res.*. ***99:*** 14113-14126

Coyle, K. O., G. L. Hunt, M. B. Decker, and T. Weingartner. 1992. The role of tidal currents in concentrating euphausiids taken by seabirds foraging over a shoal near St. George Island, Bering Sea. *Mar. Ecol. Progr. Ser.* ***83:*** 1–14.

Musgrave, D. L., T. J. Weingartner, and T. C. Royer. 1992. Circulation and hydrography in the northwest Gulf of Alaska. Deep-Sea Res. ***39:*** 1499–1519.

Weingartner, T. J. and R. H. Weisberg. 1991. A description of the annual cycle in sea surface temperature and upper ocean heat in the equatorial Atlantic. *J. Phys. Oceanogr.* ***21:*** 83–96.

Weingartner, T. J. and R. H. Weisberg. 1991. On the annual cycle of equatorial upwelling in the central Atlantic Ocean. *J. Phys. Oceanogr.* ***21:*** 68–82.

Royer, T. C., J. Vermisch, T. J. Weingartner, H. J. Niebauer, and R. D. Muench. 1990. Ocean circulation influence on the *Exxon Valdez* oil spill. *The Oceanography Society* ***3:*** 3–10.

Weisberg, R. H. and T. J. Weingartner. 1988. Instability waves in the equatorial Atlantic Ocean. *J. Phys. Oceanogr.* ***18:*** 1641–1657.

Weisberg, R. H. and T. J. Weingartner. 1986. On the baroclinic response of the zonal pressure gradient in the equatorial Atlantic Ocean. *J. Geophys. Res.* ***91:*** 11717–11725.

Manuscripts in preparation:

Weingartner, T. J., S. Danielson, and T. Royer . Freshwater transport and variability within the Alaska Coastal Current, Gulf of Alaska.

Weingartner, T. J., K. Aagaard, Y. Sasaki, and D. J. Cavalieri. Circulation on the Central Chukchi Sea shelf.

OTHER KEY PERSONNEL

Mr. Seth Danielson is a physical oceanographer who has worked in both the GLOBEC and EVOS-supported GAK 1 projects for several years. He has the responsibility for data processing, analyses, and maintenance of the project web page and will be intimately involved in preparing the final report and making presentations at the annual meeting. Mr. David Leech is the Seward based mooring and marine technician responsible for the design and deployment of the mooring and maintenance of the instruments. He will also conduct the monthly CTD sampling from the *Little Dipper*. Danielson and Leech are both employees of the Institute of Marine Science.

LITERATURE CITED

Anderson, P. J., J. F. Piatt, J. E. Blackburn, W. R. Bechtol, T. Gotthardt. 1999. Long-term changes in Gulf of Alaska marine forage species 1953–1998, p. 137 abstract only, Legacy of an Oil Spill–10 Years after *Exxon Valdez,* Anchorage, AK, March 23–26.

Baumgartner, A and E. Reichel, *The World Water Balance*, Elsevier, New York, 179 pp., 1975.

Duffy, D. C. 1999. And an oil spill ran through it: lessons from the APEX study of the effects of the *Exxon Valdez* Spill on Alaskan Seabirds and Fish, p. 143 abstract only, Legacy of an Oil Spill–10 Years after *Exxon Valdez*, Anchorage, AK, March 23–26.

Mantua, N.J., S. R. Hare, Y. Zhang, J. M. Wallace, and R.C. Francis, 1997. A Pacific interdecadal climate oscillation with impacts on salmon production, *Bull. Am. Met. Soc.,* ***78:*** 1069–1079.

Overland, J.E., S. Salo, and J.M. Adams, 1999. Salinity signature of the Pacific Decadal Oscillation, *Geophys. Res. Lett., 26,* 1337–1340.

Piatt, J. F. and D. B. Irons. 1999. Mesoscale interactions between seabirds and forage fish in the northern Gulf of Alaska, p. 139 abstract only, Legacy of an Oil Spill–10 Years after *Exxon Valdez*, Anchorage, AK, March 23–26.

Purcell, J. E., L. Haldorson, E. D. Brown, K. O. Coyle, T. C. Shirley, R. T. Cooney, M. V. Sturdevant, T. Gotthardt, L. A. Joyal, D.C. Duffy. 1999. The food web supporting forage fish populations in Prince William Sound, Alaska, p. 138 abstract only, Legacy of an Oil Spill–10 Years after *Exxon Valdez*, Anchorage, AK, March 23–26.

Royer, T. C. 1996. Interdecadal hydrographic variability in the Gulf of Alaska, 1970–1995, *EOS Trans. AGU.* ***77:*** F368.

Royer, T. C. 1982. Coastal freshwater discharge in the Northeast Pacific. *J. Geophys. Res.* ***87:*** 2017–2021.

Trenberth, K. E. and D.A. Paolino, Jr. 1980. The Northern Hemisphere Sea Level Pressure data set: Trends, errors, and discontinuities. *Mon. Weather Rev.* ***108:*** 855–872.

Weingartner, T., T. C. Royer, and S. Danielson. 2000. Toward long-term oceanographic monitoring of the Gulf of Alaska ecosystem, *Exxon Valdez* Oil Spill Annual Workshop, January 2000, Anchorage, Alaska.

Weingartner, T. 2002. Toward long-term oceanographic monitoring of the Gulf of Alaska ecosystem, *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 98340), Alaska Department of Fish and Game, Habitat and Restoration Division, Anchorage, Alaska. (in preparation)

Weingartner, T. 2001. Toward long-term oceanographic monitoring of the Gulf of Alaska ecosystem, *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 98340), Alaska Department of Fish and Game, Habitat and Restoration Division, Anchorage, Alaska.

Weingartner, T. 2000. Toward long-term oceanographic monitoring of the Gulf of Alaska ecosystem, *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 98340), Alaska Department of Fish and Game, Habitat and Restoration Division, Anchorage, Alaska.

Weingartner, T. 1999. Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem, *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 98340) Alaska Department of Fish and Game, Habitat and Restoration Division, Anchorage, Alaska.

Willette, T. M., R. T. Cooney, V. Patrick, G. L. Thomas, T. C. Kline, Jr., K. Hyer, G. Carpenter, M. Clapsadl. 1999. Ecological processes influencing mortality of juvenile pink salmon in Prince William Sound, Alaska, p. 39 abstract only, Legacy of an Oil Spill–10 Years after *Exxon Valdez*, Anchorage, AK, March 23–26.

Wong A.P.S., N. L. Bindoff, and J. A Church. 1999. Large-scale freshening of the intermediate waters in the Pacific and Indian Oceans, *Nature, 400*, 440–443.

FY 03 *EXXON VALDEZ* TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2002 - September 30, 2003

Budget Category:	Authorized FY 02	Proposed FY 03						
Personnel		$15.3						
Travel		$0.8						
Contractual		$1.2						
Commodities		$3.5						
Equipment		$17.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$37.8	Estimated					
Indirect		$9.5	FY 04					
Project Total	$0.0	$47.3	$30.0					
Full-time Equivalents (FTE)		0.2						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

NOTE: ADF&G GA (9%) of $4.3 needs to be added to this project, for a total of $51.6

FY03

Prepared: 4/10/02

Project Number: 030340
Project Title: Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: University of Alaska Fairbanks

FY 03 *EXXON VALDEZ* TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2002 - September 30, 2003

Personnel Costs:				Months Budgeted	Monthly Costs	Overtime	
	Name	Position Description					
	Weingartner, T.	PI,		0.5	7.0		
	Danielson, S.	Physical oceanographer		0.8	5.8		
	Leech, D.	Mooring and marine technician		1.0	5.5	1.7	
		Subtotal		2.3	18.3	1.7	
						Personnel Total	

Travel Costs:		Ticket Price	Round Trips	Total Days	Daily Per Diem	
	Description					
	Fairbanks-Anchorage	0.2	2	4	0.1	
					Travel Total	

FY03

Prepared: 4/10/02

Project Number: 03340
Project Title: Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: University of Alaska Fairbanks

FY 03 *EXXON VALDEZ* TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2002 - September 30, 2003

Contractual Costs:	
Description	
Little Dipper (2 half-days @ $208/half-day)	
CTD calibration	
Shipping (RT Seward-Seattle: CTD)	
Contractual Total	

Commodities Costs:	
Description	
Batteries, O-rings, vane assembly parts	
Shackles, sling links, thimbles	
Standard seawater (5 @ $30/vial)	
Mooring anchor and lashing chain	
Swivels	
Commodities Total	

FY03

Prepared: 4/10/02

Project Number: 03340
Project Title: Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: University of Alaska Fairbanks

FY 03 *EXXON VALDEZ* TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2002 - September 30, 2003

New Equipment Purchases:	Number	Unit	
Description	of Units	Price	
SeaCat with transmissometer, fluorometer, and strain pressure gauge	1	17.0	
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	

Existing Equipment Usage:	Number	
Description	of Units	

FY03

Prepared: 4/10/02

Project Number: 03340
Project Title: Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: University of Alaska Fairbanks