University of Alaska Fairbanks Proposal

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TITLE: Tsunami Warning and Environmental Observatory for Alaska (TWEAK) Year 2

PRINCIPAL INVESTIGATOR: David Musgrave
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NEW/CONTINUATION: Continuation

DURATION: 1 Year

PROPOSED START DATE: 1 August 2002

AMOUNT REQUESTED: $475,000

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Tsunami Warning and Environmental Observatory of Alaska (TWEAK): Oceanographic Program

RATIONALE:

The TWEAK oceanographic component is being planned to capture important aspects of the physical and biological oceanography of the Gulf of Alaska shelf near the mouth of Shelikof Valley, south of Kodiak Island. In addition to providing a novel suite of measurements in this resource-rich area, the oceanographic component will also provide infrastructure upon which additional sensors could be added and/or other measurement programs could take advantage. This same infrastructure could serve as an integral component to the Global Ocean Observing System currently being planned.

Shelikof Strait is a 200 km by 50 km rectangular channel (deep sea valley) situated between Kodiak Island and the Alaska Peninsula. Numerous fjords and capes punctuate the coastline along both sides of the strait. Many of these embayments serve as nursery areas for commercially important fish such as salmon and there are important commercial crab, groundfish, salmon fisheries throughout the region. This area also supports numerous seabird colonies and marine mammal stocks, including several sea lion rookeries. Indeed, Shelikof Strait appears to be one of the more biologically productive areas of the Gulf of Alaska shelf. NOAA’s Fisheries Oceanography Co-ordinated Investigations (FOCI) FOCI showed that it is the most important spawning region for walleye pollock in the Gulf of Alaska. Adult pollock migrate along the east side of the sea valley into the Strait in late winter and lay their eggs at depth. The eggs gradually rise to the surface where they hatch into first-feeding larvae and grow to juvenile pollock that feed on near-surface zooplankton. As these young pollock mature through spring and summer, the young fish are carried southwest along the shelf or out onto the continental slope within the canyon. FOCI results show that the young fish that remain in the shelf tend to have higher survival than those swept offshore. Consequently, alterations to the circulation field in the strait could have important implications for recruitment to the walleye pollock population.

Depths in the strait lie between 150 and 300 m making it one of the deepest bathymetric features on the northwest Gulf of Alaska shelf. The sea valley veers offshore south of Kodiak Island to intersect the continental slope southwest of Chirikof Island. Results from FOCI show that the mean flow is southward (down-canyon) at the surface and along the west side of the strait. The water masses comprising this flow include contributions from the Alaska Coastal Current, the outflow from Cook Inlet at the northern end of the Strait, and offshore water entrained from depth within the strait. The deep water enters as a counter-flow directed up the sea valley from the mouth of the strait. This relatively salty, nutrient-rich water is withdrawn from along the continental slope and it could be important in renewing the nutrient concentrations in the euphotic zone. The deep counter-flow might also serve as an important advective corridor by which planktonic organisms, including oceanic zooplankton, are carried into the strait from offshore. These zooplankton may be important to the fisheries here as well as to the seabirds and other forage fish, such as juvenile salmon, capelin, and eulachon.

The shelf circulation consists of numerous mesoscale eddies (~20 - 30 km diameter, nominal velocities = 30 cm/s) that appear to be generated by instabilities associated with the Alaska Coastal Current flowing through the strait (Figure 1). FOCI showed enhanced survival of walleye pollock larvae entrained within these eddies compared to larvae outside of the eddies. Thus eddies might be a biologically significant habitat for these fish. They can, however, be difficult features to detect from standard shipboard observations and/or current meter moorings. The flow over the continental slope consists of the narrow, swift Alaskan Stream, the western boundary current for the Gulf of Alaska.

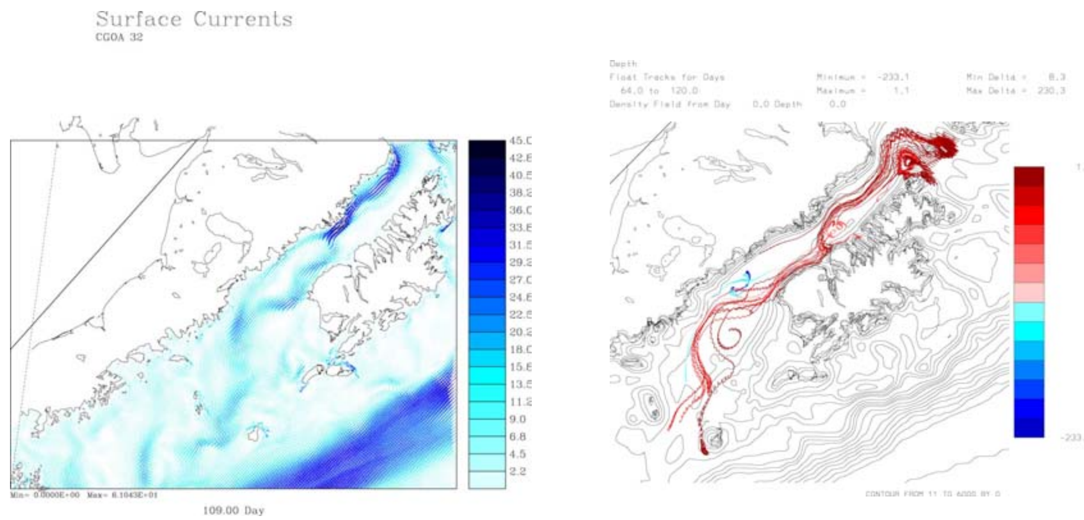


Figure 1. Localized (Shelikof Strait and southern Kodiak Island) results from a numerical model of the Gulf of Alaska. The left panel shows a snapshot of the regional surface currents and the right panel shows the trajectories of "numerical floats" deployed at the north end of Shelikof Strait. Note the meanders and eddies evident in the southward flow in Shelikof Strait.

Remotely sensed thermal imagery rarely reveals eddy activity in the western Gulf due to the lack of surface thermal gradients for much of the year. Figure 2 reproduces an image retrieved March 4, 2002 from the MODIS platform. It depicts a true color image of the Western Gulf of Alaska. The convoluted band of light greenish water along the coast probably reflects the suspended sediments in the buoyant Alasaka Coastal Curret. The flow separation and two oppositely rotating eddies near the western end of Shelikof straits are particularly revealing. In contrast to thermal imagery, ocean optical sensor technology provides detailed synoptic views of the mesoscale eddy activity in this region.

Variability in the flow and hydrography within the Alaska Coastal Current and over the continental shelf (including the structure of the shelfbreak front) is large on synoptic, seasonal, and interannual time scales. Much of the synoptic variability is associated with storm systems translating through the area. There is also large seasonal and interannual variations in winds and freshwater discharge both of which control the circulation dynamics of the shelf and shelfbreak. By contrast seasonal variations in the flow and properties of the Alaskan Stream appear to be smaller. However, interannual variations within the stream could be substantial. This variability is presumably forced by changes in the position and strength of the Aleutian Low, which drives the circulation over the Gulf of Alaska basin, or the passage along the continental slope of large (100 – 200 km in diameter), slow-moving (1 – 3 cm s^{-1}) eddies. These eddies are spawned in the eastern Gulf of Alaska and either propagate around the continental slope or cross the deep basin before impinging upon the continental slope along Kodiak. The variability in either shelf or boundary flow properties could be important in regulating exchange between Shelikof Strait and the basin.

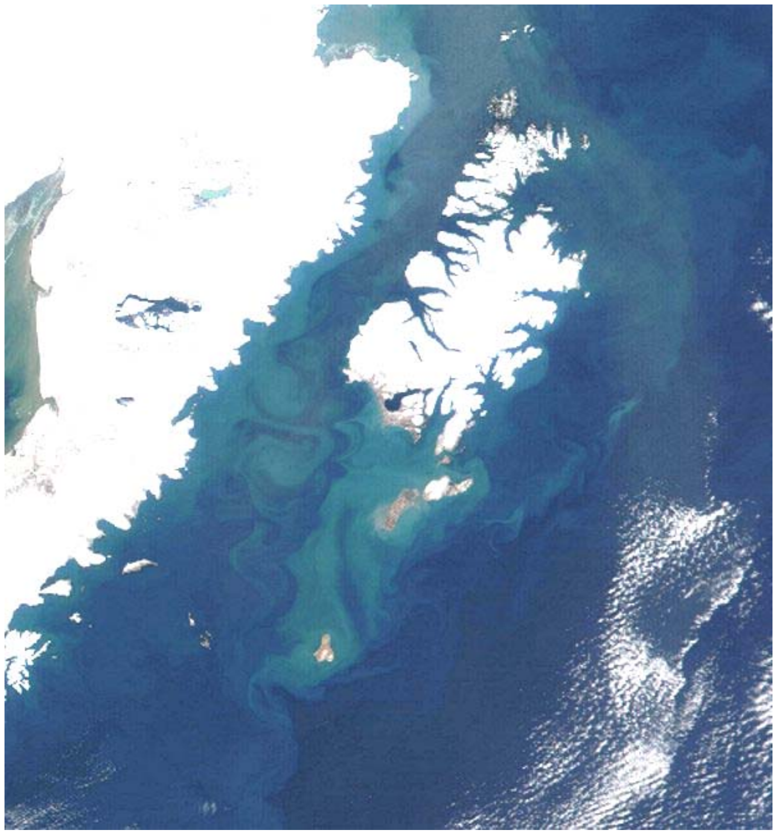


Figure 2: True color image of the Western Gulf of Alaska provided by the MODIS project, NASA/Goddard Space Flight Center. The light greenish coastal band probably reflects sediments within the Alaska Coastal Current.

GOALS

The goals of the TWEAK oceanographic component are to devise a monitoring array that addresses exchange between the slope and shelf and that can quantify and characterize some of the mesoscale circulation variability in this region. The measurements we propose would also enhance modelling efforts in this (and other areas) of the Gulf of Alaska. In particular we propose to deploy moorings in combination with surface current mapping radars and remote sensing to:

1. Characterize the mesoscale flow field (kinematics, dynamics, and biological importance)
2. Address mechanisms of cross-shelf exchange, particularly those involving the interaction of a swift western boundary current, interacting with a cross-shelf canyon. (Shelf-slope exchange mechanisms are very poorly understood for the

Gulf of Alaska and, generally speaking, most other shelf regions. Thus such an observatory will yield valuable information both in terms of the region and with respect to global oceanographic problems.) The width of the canyon is more than 50 km, which is several times the internal radius of deformation. This suggests that there could be large cross-canyon variability in the flow.

3. Provide an unprecedented opportunity to examine how fluctuations in a boundary current (Alaskan Stream) affect transfer between the shelf and slope. These fluctuations include ~25-day perturbations in this flow and the very large (~150 km), slow-moving (2-3 months across the mouth of the Strait) perturbations that occur approximately once per year. (Again, both are issues having regional and global significance.)
4. Quantify the temporal (tidal – interannual) variability in the circulation and water mass properties (temperature, salinity, nutrients, and productivity patterns).

APPROACH

We propose installing over a several year period:

1. (FY02) A high frequency ocean surface current radar system (CODAR Ocean System's Seasonde) to map the surface velocity field at a resolution of ~3km at 3/times hour. The viewing field would cover approximately 80 km (subject to environmental constraints).
2. (FY03 and beyond) Two subsurface oceanographic moorings to measure temperature, salinity, vertical profiles of horizontal currents, nutrients, and fluorescence (an index of chlorophyll concentration) at hourly intervals.

These measurements would be supplemented with satellite based sensors to detect regional scale thermal (AVHRR), ocean color (SeaWIFs and/or MODIS), sea surface height (TOPEX/POSEIDON altimeter) and wind (QuikScat) variations.

FY02: HF Radar

The HF radar will include two antenna (needed to assemble the horizontal velocity field) with one antenna installed on Chirikof Island and the other on Chowiet of Shelikof Strait (Figure 3). These would map out the surface currents within 80 km (nominally) of the antenna with an accuracy of 8-9 cm/s, which is less than a third of the eddy velocities. The CODAR instrument runs continuously 24 hrs a day. It requires a 500 watt AC power source though we are investigating the possibility of having a DC powered CODAR unit built for us to maximize efficiency. We are looking at a remote, autonomous power module (two are needed, one for each antenna) for the CODAR site that would consist of a large battery bank of sealed absorbed glass matt rechargeable batteries and twin redundant wind turbines engineered to US Navy specifications for offshore marine platforms, a pure sine wave inverter, backup propane powered generator with automatic oil level control and synthetic engine oil for extended run time between oil changes. The power supply would support the radar and data communications. A weatherproof enclosure would house power supplies (except for the wind turbines and propane bottles), computers and communications equipment. Propane storage would consist of 10 or more forty pound bottles ganged together thus allowing for greater flexibility in refueling. (Although diesel fueled generators have some advantages, the permitting process for propane is simpler and there are fuel spill considerations that are avoided by using propane.) The power generation variables would be remotely monitored and included with the data transmissions. Installation costs are minimized because all components, except the back-up generator, are easily transported by hand. This is important because motor transport is unlikely on this roadless island. Under the anticipated wind conditions this power system would require maintenance 2 – 4 times/year.

We believe that data transmission will best be served by the Iridium satellite phone Dial-Up Data Service system. With this type of telemetry a PC is connected to a Iridium phone outfitted with a Subscriber Identity Module (SIM) card that is provisioned for data. Standard software applications (e.g., Microsoft Dial-Up Networking) can then be used to initiate data calls at transmission speeds of 2.4 kbps.

The CODAR system writes a radial data file once every hour with a typical size of 15 to 45 kb, per file. These files will be stored on the CODAR computer onsite as well as transmitted on a timely basis. Using a high average of 35,000 bytes per file, times 24 files a day we end up with an average of 840,000 bytes to transmit. With a known file compression capability of 7:1 (this ratio may significantly improve) that leaves us with a 120,000 bytes average daily transmission. 120,000 bytes times 8 bits = 960,000 bits / 2400bps via an Iridium modem connection = 400 seconds or 7 minutes transmission time, plus 2 minutes handshaking for 9 minutes a day. Figuring a typical $1.50 a minute Iridium rate times 9 minutes = $13.50/day or approximately $5,000 /year for one daily transmission. Increasing the data transfer calls-ups to six times per day this figures out at 4 minutes per call or $36.00/day (960,000 / 6 = 160,000 / 2400bps = 66 seconds or 2 full minutes plus 2 minutes handshaking, 4 minutes total x 6 calls a day x $1.50 a minute) or approximately $13,000 a year. Transmitting files every hour as they're created (24 files per day) will incur the most overhead, with handshaking duration being disproportionately larger than the data transmission time resulting in an approximate yearly cost of $40,000.

We will finalize the power supply and data transmission issues in the summer of 2002. Regardless of the data transmission schedule selected all of the data would be stored on a computer at the site. Thus in event that the data transmission module fails, the data would still be collected and available after visiting the island. We would have the surface current maps (and wave) data available data on an Internet site so that scientists, fishers, agency personnel, and the public could access it and use it. The University of Alaska is currently undertaking a new database initiave, which will provide secure storage for the data collected through this study. Through a separate funding line the School of Fisheries and Ocean Science has undertaken the development of a graphical web based interface for the retrieval and display of data located within the University wide database.

While the HF approach for measuring surface currents is a proven technology, with roughly 80 units installed worldwide, to our (and Seasonde's) knowledge the instrument has not been deployed in a remote and harsh setting such as the TWEAK site. The main technical difficulties involved are installing a reliable and unmanned power supply system for the radar and satellite communications. In addition, the TWEAK system will be installed in a region subject to occasional freezing (and perhaps rime ice) in winter. The performance of the radar and the autonomous power supply needs to be adequately assessed prior to deployment at this remote site. We plan on testing our integrated radar, power, and data transmission system through the winter of 2003 along the shore of Cook Inlet. Winter conditions here are comparable to or more severe than what we expect at the TWEAK site. The test site will be conducted from the home of Dr. Stephen Okkonen (a physical oceanographer on the research faculty at IMS). Dr. Okkonen will be able to monitor the system's performance daily (or more frequently) throughout the winter. The test site is also easily accessible from Anchorage by car. Upon successful completion of the winter test study, we will deploy the radar on Chirikof and Chowiet islands in the summer of 2003. While we are conducting the tests in Cook Inlet we will work with the appropriate state and federal agencies to secure the necessary permits for the installation in the TWEAK area. Under separate funding, the PI for this project (D. Musgrave), will prepare a similar HF radar installation for Prince William Sound. We envision considerable cost-sharing to be achieved by the nearly simultaneous development of both HF systems as personnel and (some) equipment can be shared. Both of these efforts will also take advantage of the experience gained by HF radar groups operating elsewhere. For example, Drs. Scott Glenn (Rutgers), Jeff Paduan (MBARI) and Michael Kosro (OSU) have all agreed to assist us in training, software sharing, and technical advice on our HF installations.

The location of the HF Radar installations is dependent on permitting from governmental agencies and technical constraints imposed by the geometry of the HF Radar. We have alternate locations in Shelikof Strait that will address the scientific goals outlined above.Alternate locations will maximize the scientific gain versus permitting and technical constraints. In any case, we will work with other scientific programs in the vicinity (in particular, FOCI) in developing alternate locations.

FYO3: Moorings

Under continued funding, we would also install two moorings, on either side of Shelikof Strait, to capture the vertical and horizontal circulation structure. The timing of the complete deployment of the two moorings depends on the levels of future funding. Assuming continued support at the $425,000 level, the second mooring would be delayed until FY04. Two moorings are required because the width of the channel is several times the internal radius of deformation, 10-20 km. Therefore, we expect substantial cross-channel velocity and water property gradients. The moorings will be deployed in ~200 m water depth and each will include 2 - 300 kHz RDI Workhorse ADCPs (up and down-looking) to measure the currents throughout the water column.With 50 - 2 meter depth bins, two ADCPs will adequately resolve horizontal and vertical velocity components through the entire water column. A single, bottom mounted 75 kHz ADCP would easily profile currents through the water column at 4 m bins, but would be accompanied by a loss of at least 12 meters of the surface currents due to side lobe interference. Adequate intercomparisons between the ADCP and CODAR dervived currents require the measurements to be collected as close as possible to one another. Each mooring will also include 4 MicroCats and 2 SeaCats (temperature and conductivity recorders equipped with strain gauge pressure sensors) to be distributed throughout the water column. The

SeaCats will be deployed at nominal depths of 25 and 190 m beneath the surface and the MicroCats will be deployed at 50, 75, 100, and 150 m depths. The shallow SeaCats will include a fluorometer and PAR sensor. The deep SeaCat will include a transmissometer to monitor suspended sediment load. We also propose adding nutrient sensors (ECOLAB Nitrate, phosphate, and silicate sensors) in the upper water column of each mooring. The moorings would be serviced annually (or more frequently depending upon logistics options). A diagram of the type of mooring to be deployed in Shelikof Strait is shown in Figure 4.

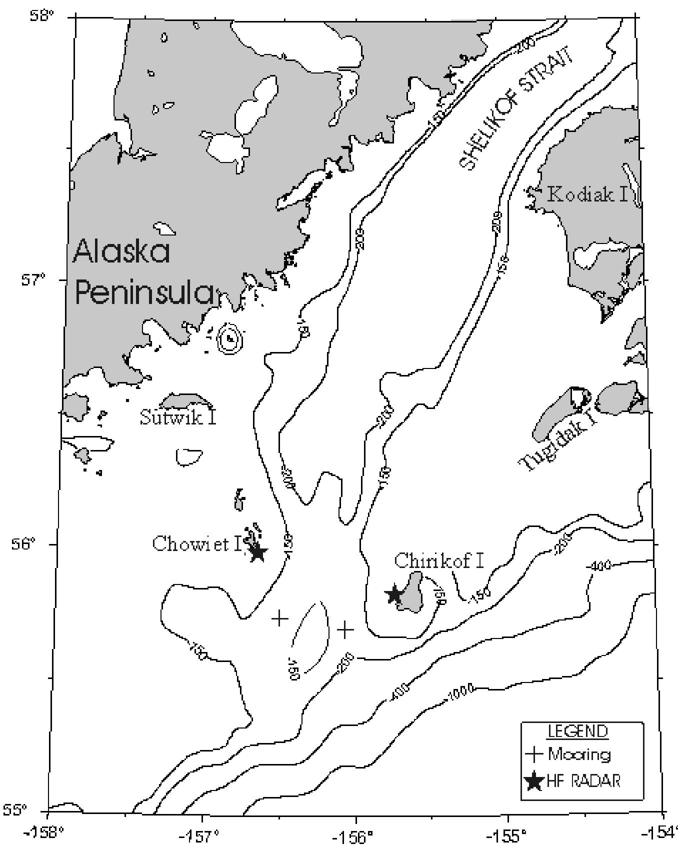
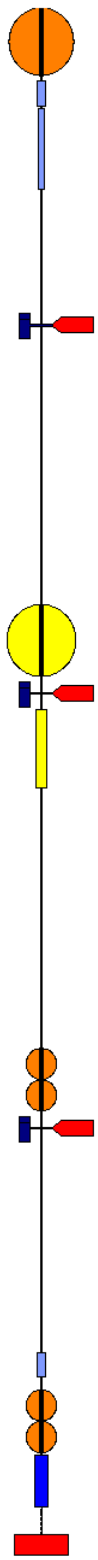


Figure 3. Map showing Shelikof Strait and the locations for the proposed moorings and HF RADAR instrumentation on Chirikof and Chowiet Islands.



Mooring Element	Length[m]	Height[m]
48in Syntact	1.22	177.13
sbe16-b	0.45	174.91
Nitrogen An	1.45	173.96
Microcat vane	0.51	150.51
Workhorse float	1.30	102.00
Microcat vane	0.51	100.20
RD ADCP	1.41	99.19
17 in glass	0.57	50.78
17 in glass	0.57	50.21
Microcat vane	0.51	49.14
sbe16-b	0.45	10.63
17 in glass	0.57	7.93
17 in glass	0.57	7.36
EG&G 8242	0.94	6.29
2 Railway Wheels	0.35	0.35

Figure 4. Mooring diagram for the proposed bio-physical instrumentation to be placed within Shelikof Strait.

BUDGET (FY02) :HF RADAR

The major portion of the proposed budget is for the purchase of the CODAR system ($216,000 including installtion support from CODAR personnel). Salaries include: two months of support for Musgrave to oversee all aspects of the project and provide scientific direction, three months of support for Hank Statscewich, research analyst for programming, web and field support, and 9 months of support for a mooring technician to develop power and data transmission modules, apply for permits, oversee logistics, and interface with the CODAR engineers. Transportation to Chirikof and Chowiet will require a mix of helicopter, boat and fixed-wing aircraft for a total of $40,000. We have planned for once a day data transmission for no more that half of a year ($5,000) since the remote data transfer will only occur in the summer. Travel costs include round trips to Cook Inlet and Kodiak for $3,400. We budgeted for two power modules at $30,000 each.

PROJECT TIMING and REPORTING

We anticipate the following time line by quarter:

Jul-Sep 2002:
- Survey Chirikof and Chowiet Is. for location of CODAR sites.
- Purchase HF Radar from CODAR
- Apply for siting permits

Oct-Dec 2002:
- Design power supply modules
- Test Iridium modems
- Install CODARs in Cook Inlet

Jan-Mar 2003
- Debug and optimize CODARs, Iridium modems and power modules in Cook Inlet
- Test real-time aspects of data dissemination on web

Mar-Jun 2003
- Install CODAR in Shelikof Strait

Quarterly reports on the last days of September, December, March and June will include the progress of each of the above items including difficulties encountered and attempted solutions. Any changes to the above schedule will be reported.

FUTURE PLANS AND SUPPORT

We view the TWEAK oceanographic component as ultimately being one element of a broader oceanographic observing system in Alaska. Of course achieving this goal will take considerable time and resources. However, TWEAK in conjunction with ongoing initiatives sponsored by the University of Alaska, will provide the opportunity to build this observing system. The Sea-Air-Land Modeling and Observing Network (SALMON) project is a University of Alaska initiative to plan, develop and implement, along with partners, an observing system in the Northern Gulf of Alaska. SALMON seeks to understand ocean circulation and dynamics and its effects on the Gulf of Alaska marine ecosystem. As part of the University of Alaska's mission for service, education and research, its objectives are:

1. Service: Real-time observations to permit now-casts/forecasts of marine circulation and weather in Prince William Sound and the Northern Gulf of Alaska for marine and aviation safety, and hazard response (*e.g.,* oil-spill response).
2. Education: K-12, undergraduate, graduate and continuing science education in coastal communities with special emphasis on *Rural Education*.
3. Research: Assessment of current and future biogeophysical variability of marine and nearby terrestrial ecosystems.

SALMON will be purchasing and installing an HF radar system for Prince William Sound this summer, see figure 5. This system will be identical to, and face operational issues similar to the TWEAK radar system. We therefore expect to achieve cost-sharing in the setup and operation of these systems. We are also discussing installing similar systems in Cook Inlet on a permanent basis in Cook Inlet (in cooperation with the Kachemak Bay National Esturaine Research Reserve [KBNERR]), and ultimately the Gulf of Alaska shelf offshore of Seward (Figure 5).

The University of Alaska is initiating the planning for a consortium of governmental, academic and industrial partners that will plan and promote the Coastal Alaska Observing System (CAOS), an integrated ocean observing system in Alaska waters. CAOS will be the Alaskan regional component of the national Integrated, Sustained Ocean Observing System (ISOOS) now being planned by Ocean.US. The benefits to Alaskans and clients of Alaskan waters include increased marine and aviation safety, at-sea rescue operations, hazardous waste trajectory analysis, and increased fishing efficiency through the use of nowcasts/forecasts of sea state, and ocean circulation and mixing. A sustained system will provide critical time series for exploring relationships between oceanographic processes and variability in natural resources (fish, marine mammals and birds). To implement an ocean observing system will require the cooperation of all governmental and non-governmental agencies, academic institutions and private industries that have interests in Alaskan waters. One of the major players will NOAA through the efforts of NMFS and PMEL, which already have major efforts in Alaskan waters.

A large portion of the operational and some of the initial startup funding for CAOS will come through federal funds now being authorized in Congress for the ISOOS.

Other agencies that have expressed an interest in contributing to this ocean observing system are MMS (for Cook Inlet), the Exxon Valdez Oil Spill Trustees Council under their developing Gulf Ecosystem Monitoring (GEM) program, the Pollock Conservation Consortium (an industry-based marine research program), and the North Pacific Research Board. These, and possibly other partners, might possibly provide future maintenance support to this developing ocean observatory in the northern Gulf of Alaska. In addition, we will consider proposing to the National Ocean Partnership Program (NOPP), a future proposal to expand upon these preliminary activities. TWEAK would provide essential funding in leveraging and promoting a more comprehensive ocean observing program.

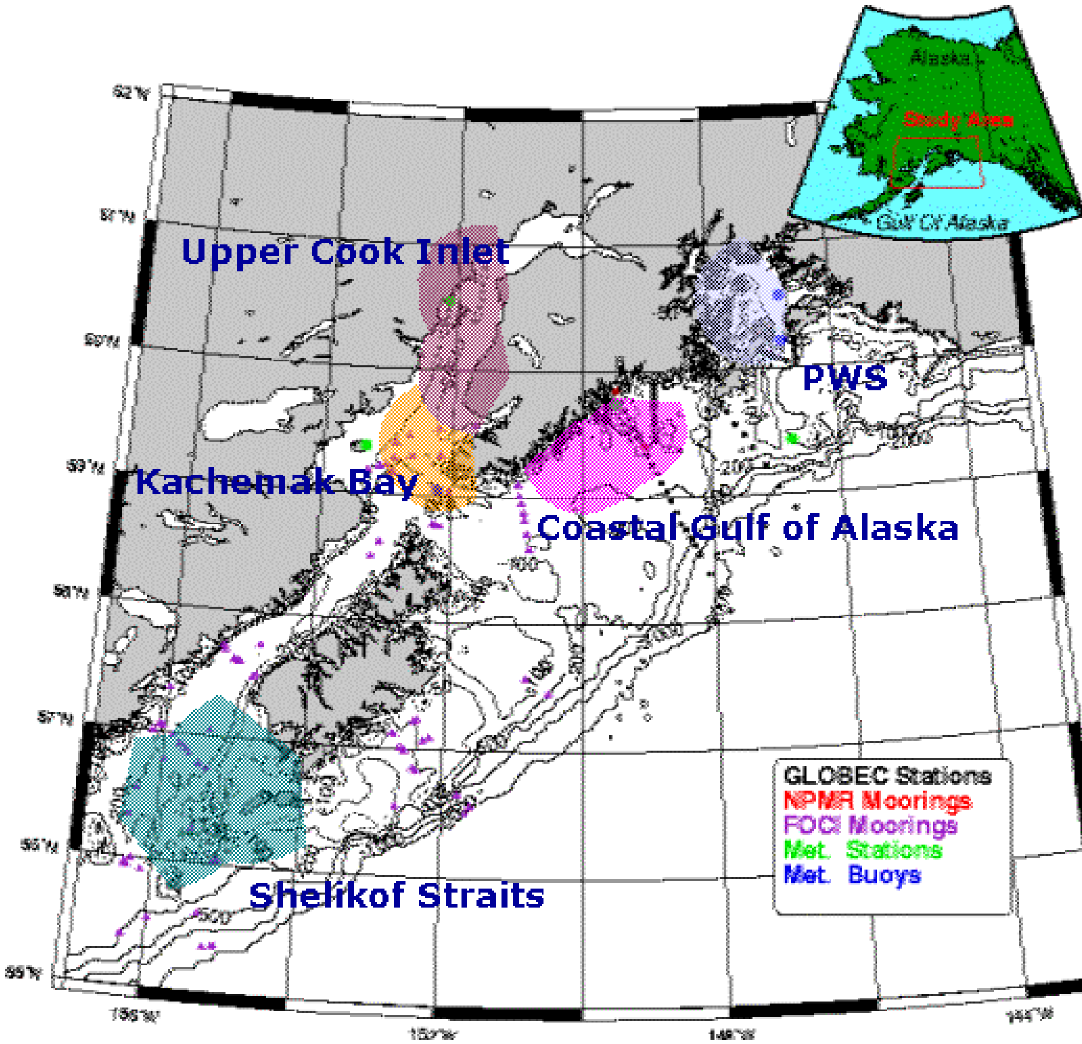
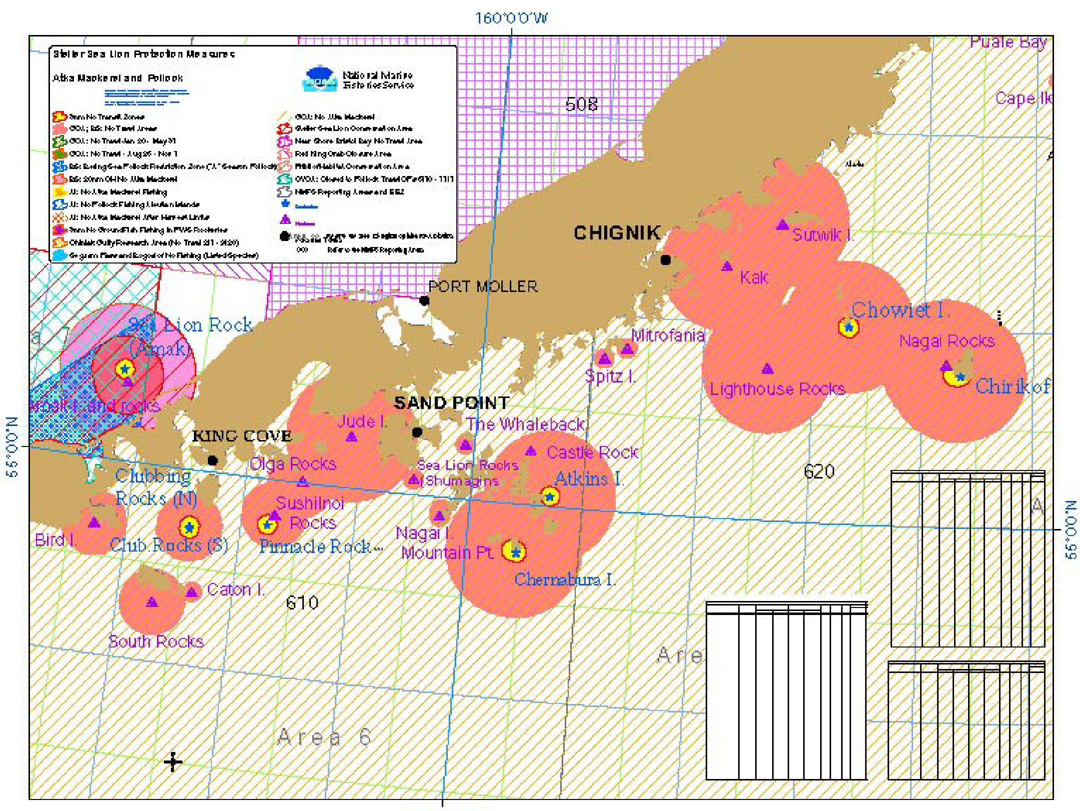


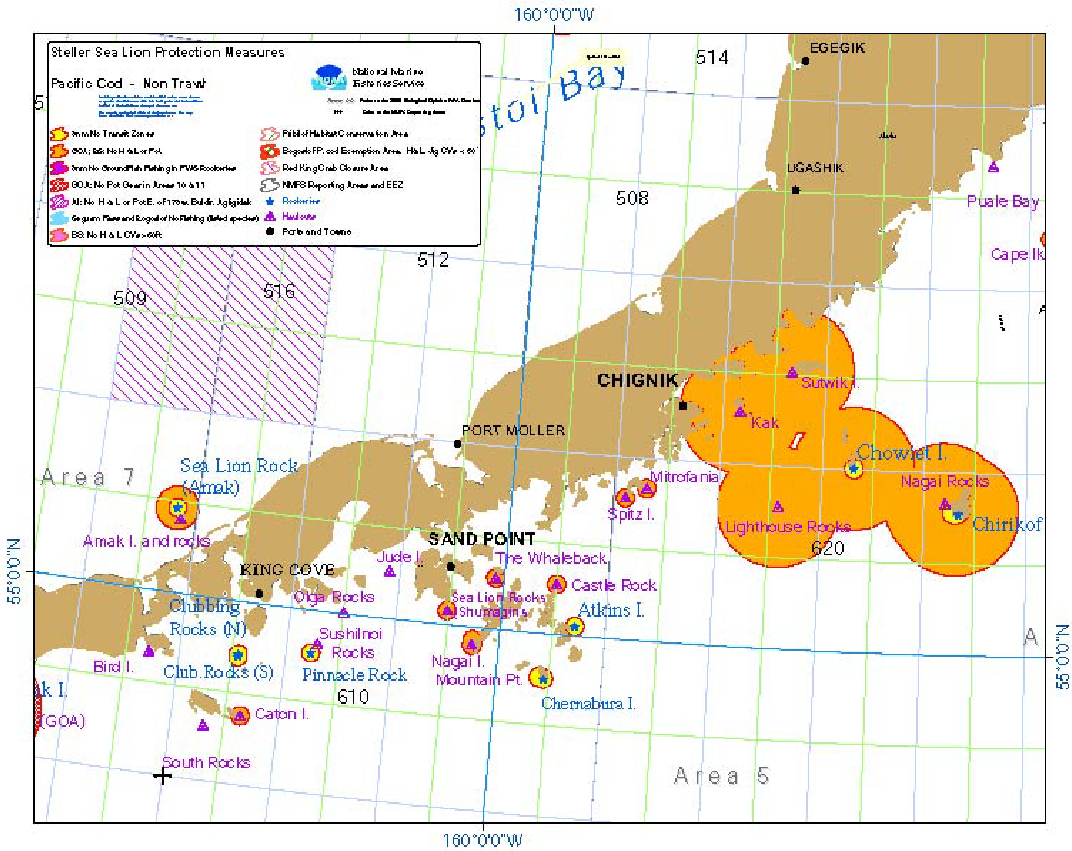
Figure 5. Regional map of the northwest Gulf of Alaska. The shaded regions show approximate locations and range of HF surface current radars under consideration for this region. These include the TWEAK array proposed here and other systems proposed or being developed with under other funding sources as described in the text.

Appendix: Fishing Pressure in the Region

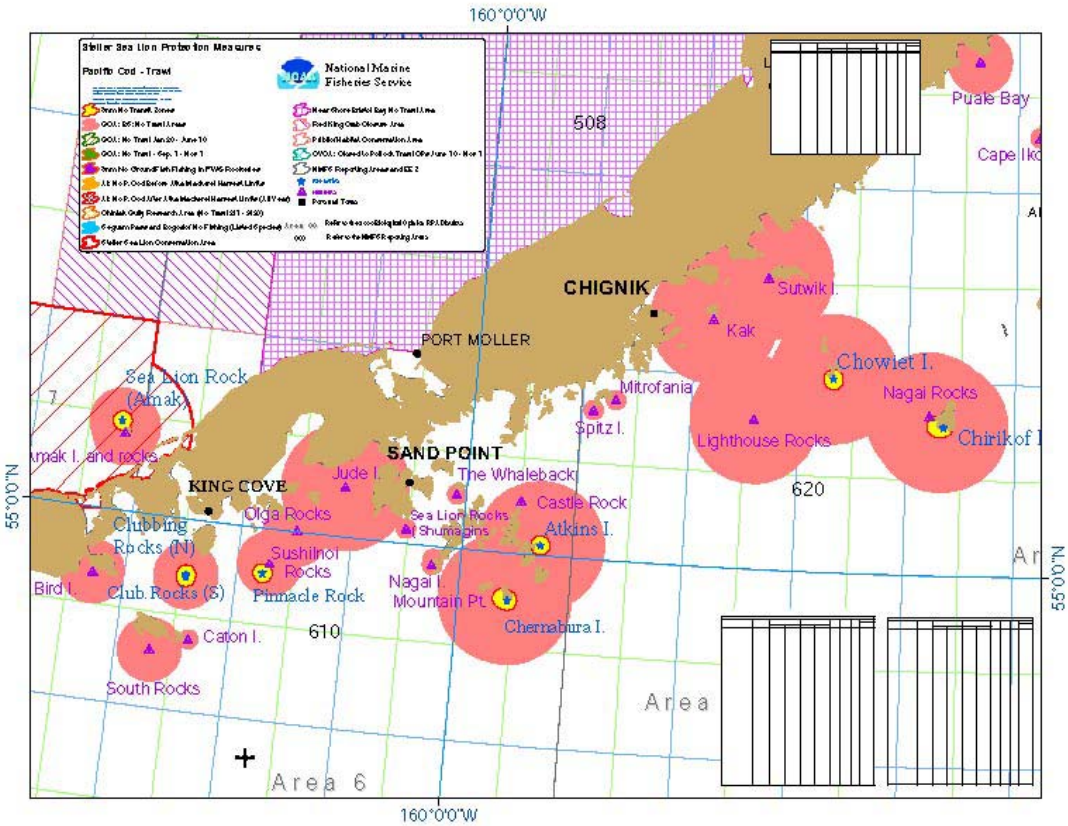
Commercial fishing pressures in the mooring location area are mitigated to a large extent from the sea lion protection measures implemented by the National Marine Fisheries Service. Atka Mackerel, Pollock and Pacific Cod are all closed to trawl fishing in these waters and Pacific Cod is also closed to hook and line and pot gear types. These waters are still open to hook and line IFQ Halibut and Sablefish fisheries but this gear type does not pose as significant a risk as trawl gear does. Additionally, our mooring locations will be made available to the public by several means, through the internet, through the commercial fishing media, local community newspapers, through notices pinned up around the harbors and free stickers given out to the fishing community during trade shows and other public assemblies we attend. We will also be working with the Fishery Technology Industrial Center (FITC) in Kodiak, a part of the University of Alaska Fairbanks School of Fisheries and Ocean Sciences department, to inform the local fishing fleets of our mooring locations and the project objectives in general. We intend to place surface marker guard buoys in the mooring area with radar reflectors and self-contained marker lights to visually identify the locations as well. As a part of a North Pacific Research Board project the University of Fairbanks Institute of Marine Science has maintained a very similar type of mooring called GAK4 in the Gulf of Alaska for the last three years. A total of nine successful recoveries of the instrument package have been recorded since this projects inception in early 2000.



Exclusion zones for Atka Mackeral and Pollock Trawls



Exclusion zones for Pacific Cod non-trawl gear.



Exclusion zones for Pacific Cod trawls.