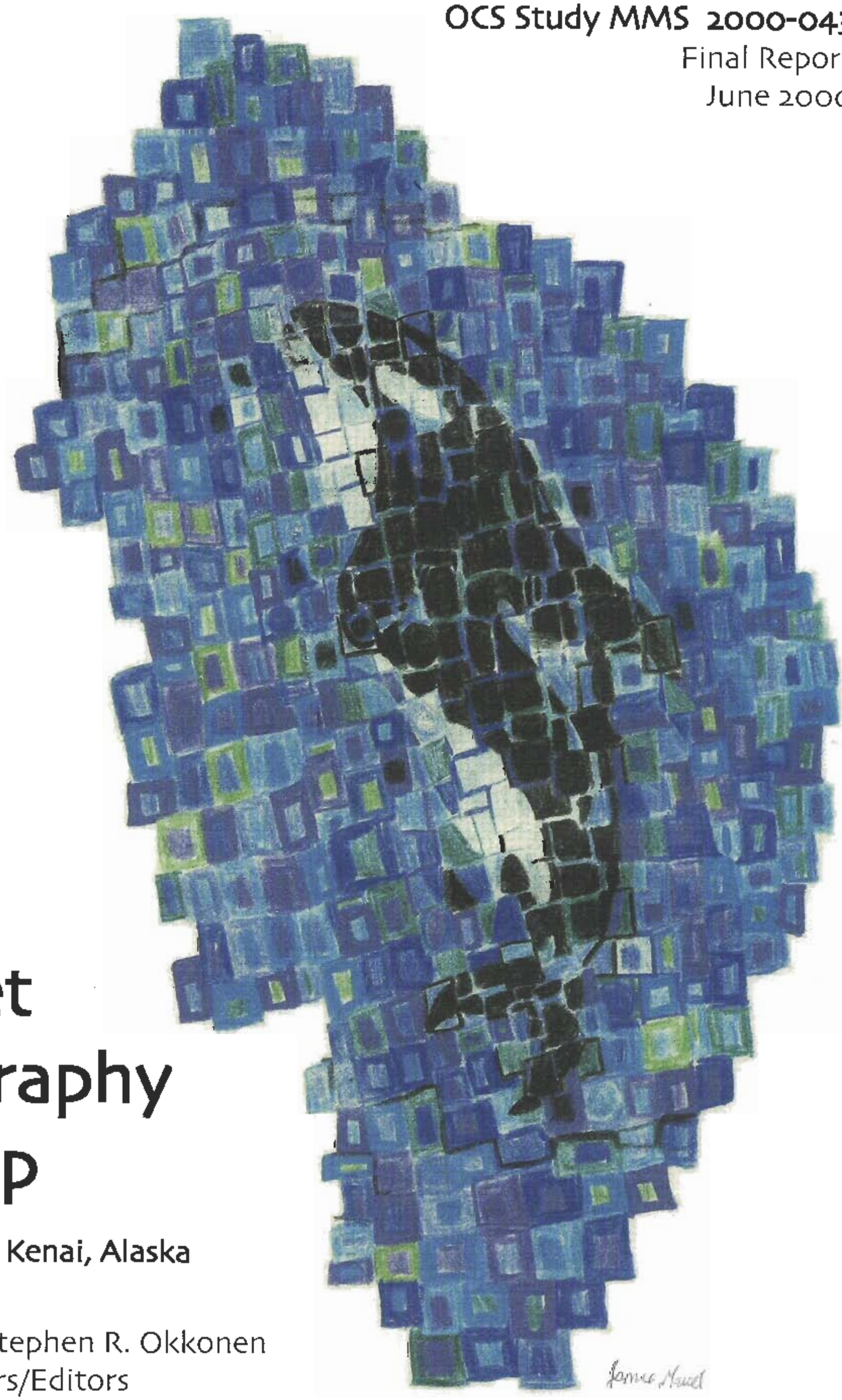
OCS Study MMS 2000-043
Final Report
June 2000



PROCEEDINGS

Cook Inlet Oceanography Workshop

9 November 1999 • Kenai, Alaska

Mark A. Johnson & Stephen R. Okkonen
Principal Investigators/Editors

University of Alaska
Coastal Marine Institute and Oil Spill Recovery Institute

Cover Art

The illustration on the cover is by Jamie Gruel. She is a senior at Skyview High School in Soldotna, and after graduation plans to attend the University of Hawaii in Hilo, aiming for a career in art. Jamie's painting was selected from artwork submitted by students from Skyview and Soldotna High Schools. Honorable mention paintings and drawings can be found in the appendix. Jamie is from Kasilof and has lived in Alaska for nine years. Her art teacher is Sandra Lewis and her parents are Susan and Robert Schwager.

This study was funded in part by the U.S. Department of the Interior, Minerals Management Service (MMS), through Cooperative Agreement No. 14-35-01-98-CA-30909, Task Order No. 15172, between the MMS, Alaska Outer Continental Shelf Region, and the University of Alaska Fairbanks. Matching funds were provided by the Oils Spill Recovery Institute, Cordova, Alaska. The Cook Inlet Regional Citizens' Advisory Council provided ancillary support.

Cook Inlet Oceanography Workshop

Kenai, Alaska
9 November 1999

Editors
Mark A. Johnson and Stephen R. Okkonen

Institute of Marine Science
University of Alaska Fairbanks

with funding from the

University of Alaska Coastal Marine Institute
(Minerals Management Service)

Oil Spill Recovery Institute

Cook Inlet Regional Citizens' Advisory Council

Executive Summary

More than 70 people participated in a one-day Cook Inlet oceanographic workshop held on 9 November 1999 at the Kenai Cultural and Visitors Center. The goal of this workshop was to assess the state of knowledge of the physical oceanography in Cook Inlet and to examine the results of numerical models used to predict oil-spill trajectories. Information was exchanged during presentations by more than a dozen experts who presented their views on Cook Inlet circulation, use and validation of oil-spill trajectory models, the use of satellite imagery for understanding the temporal and spatial variance of tidal rips, and the use of free-drifting surface buoys and acoustic Doppler profilers for direct estimates of Cook Inlet currents.

The physical oceanography of Cook Inlet, Alaska is characterized by complex circulation with variability at tidal, seasonal, annual, and inter-annual time scales. The circulation is dominated by tidal flow which generates three major rip currents with roughly north–south axes aligned with local bathymetry. The tidal rips have speeds of up to six knots, and they account for the majority of the volume transport in and out of Cook Inlet. The size of Cook Inlet and the tidal speeds combine to produce out-of-phase tidal heights for Seldovia and Anchorage.

Significant non-tidal circulation features exist as well, including a buoyancy driven current flowing to the south along the western shore of Cook Inlet, a concentrated, intense, bathymetrically-steered westward flow across lower Cook Inlet, and a slow flow to the north in central and eastern Cook Inlet. These are driven, respectively, by the freshwater flux from Cook Inlet's western shore, and the flow through the open boundary between Cook Inlet and the Gulf of Alaska.

Knowledge of the tidal and non-tidal current patterns in Cook Inlet is essential for determining and predicting transport pathways affecting pollutants. To determine the extent of this knowledge on Cook Inlet currents, and to examine the accuracy of oil-spill models simulating these currents, the workshop reviewed the circulation of Cook Inlet based on present and past hydrographic information, identified the essential circulation features within it, and examined several of the oil spill trajectory models currently in use. During the afternoon session of the workshop, the participants made recommendations for field-based research specifically targeted at improving our understanding of Cook Inlet circulation and validating numerical models.

The workshop participants recommend that oil-spill trajectory models continue to develop in complexity. Next-generation models will require higher resolution, additional vertical structure, freshwater buoyancy driving, and boundary forcing from the Gulf of Alaska. The strong need for direct measurements to validate the numerical models was recognized. Future observational studies should make direct measurements of ocean currents over longer time scales using acoustic Doppler profilers. The use of remote sensing to quantify the spatial and temporal variability of the tide rips was strongly encouraged. The importance of additional moored instrumentation was recognized, along with the continued use of surface drifting buoys. The group discussions recognized that long-term planning is beneficial as it reduces the start-up costs associated with short-term studies. Future studies will benefit from coordinated and systematic measurements of currents, winds, tides, ice, temperature and salinity. It was recommended that field measurements should take place in the near future so that data sets can be acquired and analyzed before additional development takes place in Cook Inlet.

Table of Contents

Bill Wilson, LGL Alaska Research Associates, Inc., Anchorage, AK
Geoff Tomlins, Pacific Geomatics Ltd., White Rock, BC

Mapping Cook Inlet Rip Tides Using Local Knowledge and Remote Sensing

Bill Wilson

Welcome, I'm Bill Wilson with LGL Alaska Research Associates, Inc. — a small biological research firm located in Anchorage. I'd like to introduce my colleagues for this project: Beth Haley, also with LGL, Michael Link formerly with LGL, Dr. Geoff Tomlins with Pacific Geomatics and Dr. Orson Smith, a physical oceanographer with University of Alaska Anchorage. The Minerals Management Service, or MMS, funds this project.

We are now in the midst of analyzing data, so what we're presenting today is preliminary information.

By way of background, this project was conceived by the Minerals Management Service at the urging of commercial fishermen in Cook Inlet. The fishermen are concerned about potential upcoming oil and gas lease sales in Cook Inlet. The MMS is the organization that administers the leasing program for the United States on the outer continental shelf.

The salmon fishery in Cook Inlet is a very valuable fishery. The drift fishery for the 1999 season is valued at almost $24 million. Many fishermen have knowledge of and concentrate their fishing effort on or near rip tides. Fishermen have requested that the MMS take into consideration their use of rip tides in future oil and gas leasing. The MMS is considering postponing oil and gas leasing in Cook Inlet for a number of years.

Our charge by the Minerals Management Service is to identify what we know about rip tides in Cook Inlet, specifically to learn how and to what degree fishermen use rip tides, and to update our information on rip tide locations from a historic database. The objective is to get more information about rip tides so that the MMS can make an informed decision regarding whether to exclude certain areas in Cook Inlet from future leasing to avoid spatial or temporal conflicts between the fishery and industry development. We will generate a final report from this study and deliver it to the MMS.

However, as we have learned getting into this program, this is not an easy job. The information that we have received — at-sea data collected by participants in the 1999 drift net fishery in Cook Inlet — teaches us that rip tides are certainly an important feature of the Inlet and often employed in the fishery. However, it is very difficult for us to pinpoint and definitely describe where a rip tide occurs or to predict where it is going to be on a daily or annual basis — we simply cannot do that. We do not feel that we are going to be able to define a specific geographic area where rips occur that may be excluded from future oil and gas development.

Why is that? Dr. Tomlins will show you some slides of the variability of rip tide locations in the Inlet. We have found, and fishermen tell us, that rips move around quite a bit. There is no specific location where they appear, although the rips do tend to set up in certain patterns.

Figure 1 presents the historic view of rip tide locations in Cook Inlet. This is an illustration taken out of the environmental impact statement for Oil and Gas Lease Sale #149. It shows the believed locations of rip tides as of January 1996 when the impact statement was written. There seems to be a persistent occurrence of a central or mid-inlet rip, a west rip and an east rip that tend to set up longitudinally from north to south. This is not unlike what we've seen in recent satellite images of Cook Inlet. These rips generally set up along the inlet's longitudinal axis, and move back and forth across the inlet without remaining in specific locations. In the current study, we're trying to update and quantify the spatial patterns of rip tides.

The objectives of our study are: 1) to determine the locations of tide rips used by the fishing fleet; 2) to quantify the spatial and temporal variability of rip tide locations; 3) to collate and relate information on the commercial salmon fishery's use of tide rips and potential conflicts with potential future oil and gas operations; and 4) to synthesize all of this information and report to the MMS.

To determine the locations of tide rips used by the gillnet fleet we depended on the help of stakeholders and their "local knowledge". We conducted 29 one-on-one interviews with fishermen who were willing to share their wisdom. A total of 68 individual drift fishermen participated in the data-gathering facet of this project. During fishery openers in 1999, these fishermen collected GPS data on their boats' locations and rip tide locations. They also recorded whether they were fishing a rip tide, and, if so, how far away from a rip tide they estimated their positions. We just completed a workshop with fishermen yesterday and will conduct a second workshop later this winter to present the conclusions of this project to interested stakeholders here in the Soldotna area.

We're developing methodology to map Cook Inlet rip tides using Synthetic Aperture Radar (SAR) imagery. Radar images exaggerate surface roughness and tide rips can be readily seen on SAR images. We've collected imagery from 1999 overflights of the satellite RADARSAT-1 during gillnet fishery openers. RADARSAT-1 was launched by the Canadian Space Agency in 1995 and is operated by the Canadian Centre for Remote Sensing. We actually programmed RADARSAT-1 to collect imagery data of Cook Inlet during six fishery openers last summer. Fishermen recorded their observations for us as the satellite passed overhead and provided us with GPS position data. We are using these data to ground-truth the satellite images and we are building a database on both satellite imagery data and fishermen's on-ground GPS locations.

To better quantify the spatial and temporal variability of the tide rips in Cook Inlet, we have acquired historic SAR imagery taken by the European Radar Satellite (ERS). UAF archives historic ERS images that provide a time series of radar images of Cook Inlet. We will take the historic SAR imagery and develop a GIS ArcView database. Dr. Tomlins has rectified the images for more clear comparisons. Again, our overall objective is to get information of rip tide location and variability.

Another task of this project is to learn the fishermen's use of tide rips. During an opener, fishermen are very aware of the tide rips and many use the rip tides to fish. We were told that many fishermen will head right out to a rip at the beginning of the fishing season because, apparently, the fish follow rips as they move from the Gulf of Alaska or Shelikof Strait into the inlet. Many fishermen are wary of setting on rips. The rips tend to be dangerous; they accumulate a lot of debris that can clog the net. A net can get sucked into a rip, a rip can turn the net very dramatically, and there's quite a shear in current velocities right at or adjacent to a rip. Some fishermen set near a rip; some actually set right on them. Overall, fishermen do use the rips. The rips can be a dangerous place to fish, but they can also be a very productive place to fish.

Unfortunately, only this one satellite image (Figure 2) will be made public at this time due to the fact that we are still analyzing the imagery we have acquired and many remain proprietary to the Canadian Centre for Remote Sensing.

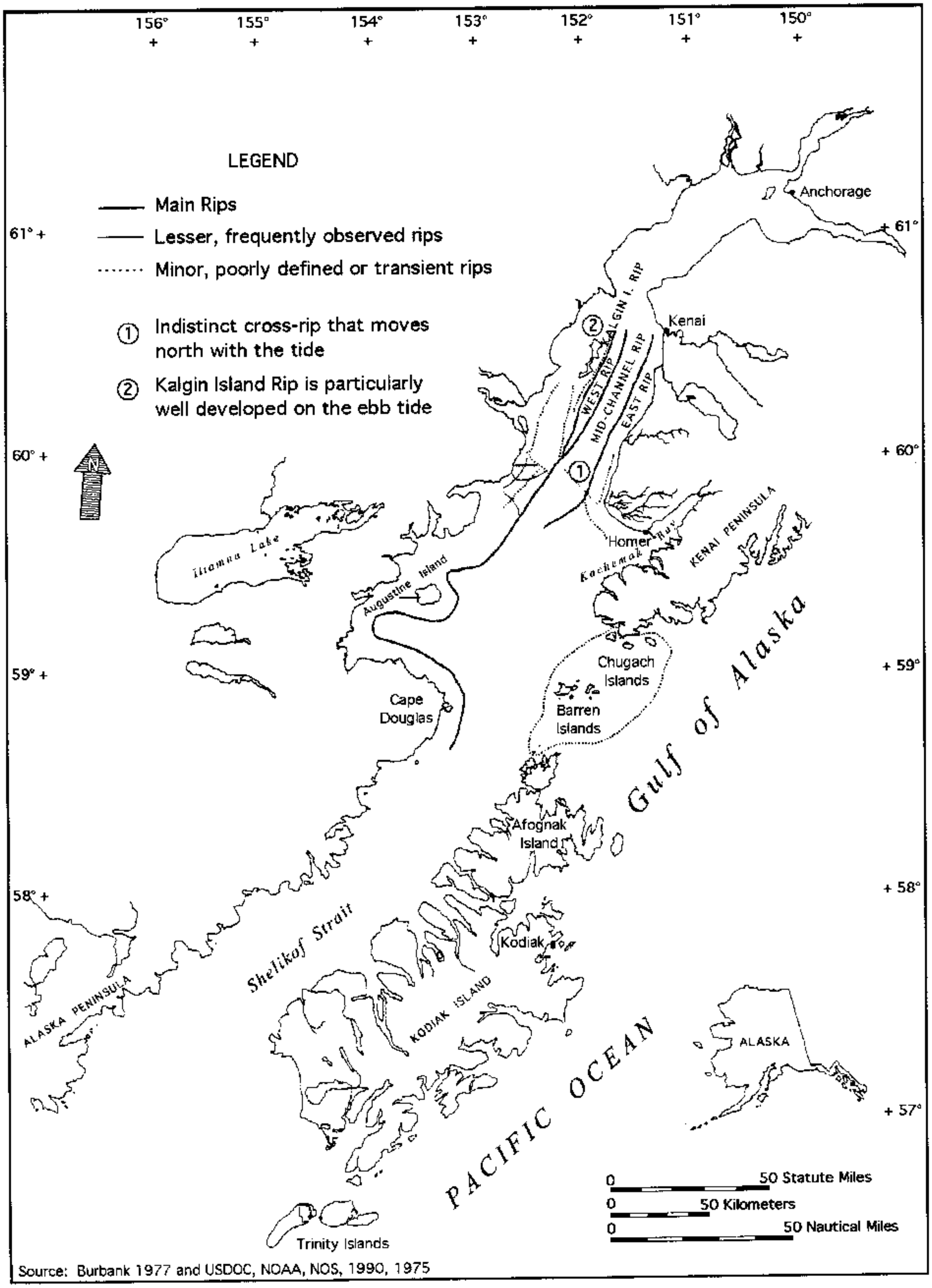


Figure 1. Historic view of rip tides in Cook Inlet.

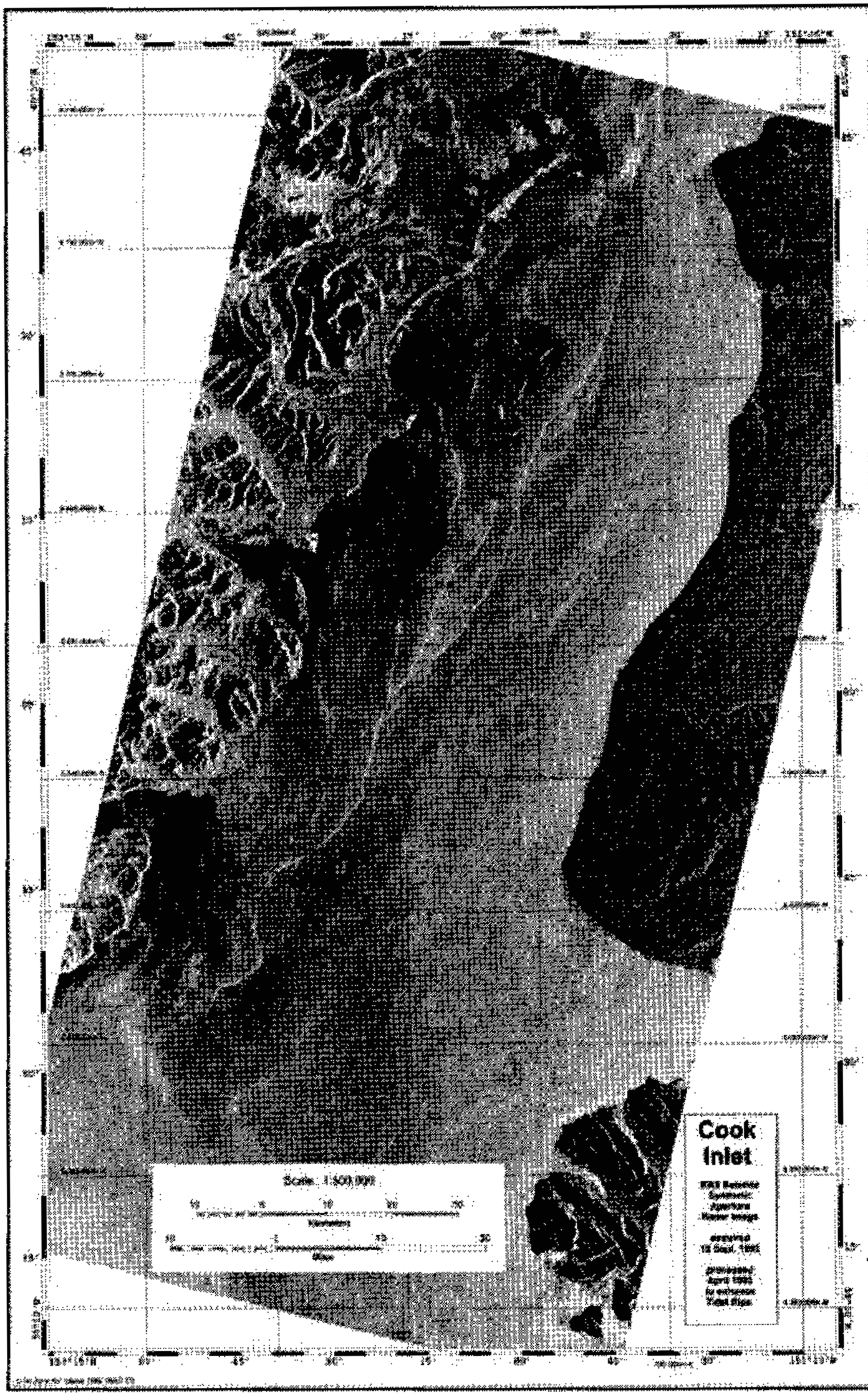


Figure 2. SAR image of Cook Inlet.

Geoff Tomlins

Greetings, I'm Dr. Geoff Tomlins. The decision to use radar data for this project came very easily. We needed coverage of a very large area. We also hoped to travel back in time and review archived data over several years' time, and wanted a sufficiently large quantity of images to evaluate rip variability. Radar imagery is plentiful for different years, times of year, and different tidal cycles — radar became the obvious choice.

Unfortunately, satellite imagery is expensive. We put together research proposals for NASA and the Canadian government. NASA and the Alaska SAR facility at UAF awarded us a grant that provided us with a large number of images from the European Radar Satellite. The Canadian Centre for Remote Sensing programmed RADARSAT-1 to collect imagery data of Cook Inlet during some of the gillnet openers. RADARSAT provides the advantage of radar and is able to collect imagery data through most any weather.

We acquired 63 images from UAF for the time period from 1992 to 1999. ERS imagery detects water surface anomalies and can identify rip line features (many fishermen describe rip lines as standing waves). SAR imagery from the ERS covers a 100 km swath. Please remember that we are still in the analysis stage of the project now, and we haven't yet fully processed most of the images.

We have six images of Cook Inlet that display apparent rip lines over which we laid bathymetric contour lines. In three of these images, some rip lines closely follow fathom contour lines — what we expected to see. However, three of the images show evident rips crossing bathymetric contours. This sums up what we've been finding in the images. There is a lot of variability in rip tide location — rips are definitely not depth specific and some appear to be very complex. One image in particular displays the seemingly erratic positioning of the rip tides. We are still in the analysis stage of the project now, but we do not yet understand their dynamics.

We expected to find some predictability in the occurrence or presence of rip tides in satellite images with the stage of the tide. So far, we have found no correlation between tidal stage and appearance of rips.

RADARSAT-1 imagery does not exhibit surface detail as well as ERS data so, as far as looking for rip tide anomalies, ERS data would be of more interest. But, RADARSAT-1 is more likely to pick up images of boats (Figure 3), where ERS may not. Some of the images taken by RADARSAT-1 illustrate that fishermen can and do use rip tides — you can see clusters of boats situated along rips.

In conclusion, this mapping project will document existing knowledge of fishermen's use of rip tides in Cook Inlet, and will summarize rip tide locations from ERS and RADARSAT imagery. A report will be available from the MMS later in 2000.

Figure 3. RADARSAT image of Cook Inlet showing boat images.

Discussion

Jia Wang: Does the rip have a shape such that the middle is high and decays on both sides?

Bill Wilson: There is some acoustic Doppler current profiling that gives a pretty good indication of what the cross section is. Our study was not designed to get into physics and mechanics of how rips form or what they do.

Geoff Tomlins: In the image you are seeing a brightness discontinuity where there is a bright area on one side of the rip and a dark area on the other side of the rip line. A rip is often described as waves standing up. You have a vertical moment and the radar is picking up that vertical moment on the surface. It is the capillary waves that are being picked up.

Jerry Galt: We've looked at rips down close. They're invariably associated with strong horizontal convergences. In fact, some get strong enough to actually Doppler shift capillary waves that are trying to propagate through them. And so they stand them up on one side and smooth them down on the other. You can actually get breaking of short little waves in a rip zone. That gives you the roughness signature that I think you're seeing.

Joel Blatchford: Who is this study going to benefit? Are you going to help out the fishermen? Are you going to help slow down the production of oil like this pipeline that busted the other day? They can't even fix it because the rips are tearing them up.

Bill Wilson: The study is intended to benefit the Minerals Management Service which is going to use this information in future decisions about oil and gas development. How they will use it is up to them and it is up to you to make sure that they use it properly. Our study is a purely scientific effort to try to characterize tide rips in Cook Inlet, where they occur, how variable they are, and to what degree fishermen use them. How the information is used by decision makers is beyond the scope of this conference.

Mark Johnson: What are your plans to quantify this or produce a mean and a variance? Is there some way to go from these pictures to a quantitative map or chart of the rips?

Bill Wilson: We are in the process of trying to figure out how to do that. We have got to get the variability in front of us. You saw a lot of images where the rips tend to move around and set up longitudinally. We have a lot to learn about the mechanics and physics of rips. Many conversations we have had suggested more cross sectional work at varying stages of the tide, we should be looking at imagery and ground truthing what is going on in the inlet at very high tide ranges and low ranges. We should be looking at surface salinity and temperature discontinuities in cross section through the rip. None of this is information we have right now. I don't know that we will be able to put together a frequency diagram; we might be able to. We might be able to see that there are some geographic tendencies.

Geoff Tomlins: There is an economic question about it. We are trying to make decisions on how to best spend the remaining funds. The data that we have processed to date will be put into a map form, as opposed to an image form. It will be presented to MMS as a GIS database. There will be some averaging. There will be some descriptions and analyses provided.

Glen Glenzer: Are you doing anything with people who are using model basins and generating some of this stuff? How much work is being done by using model basins?

Steve Okkonen: We will have two talks later this morning; Jerry Galt will be presenting the NOAA spill trajectory model and Doug Jones and Bryan Pearce will present the CIRCAC spill trajectory model. One of our objectives was to get this information out to provide to the people who develop these models measurements by which they can validate their models.

Doug Jones: Could you look a some shots from the northern part of the inlet simultaneously with some of these shots to convince yourself that what you are looking at are in fact rip lines. Geoff mentioned that the line on the west side was a linear feature but was more likely to be a bathymetric feature. I suspect that rip lines are bathymetric features. I'm not sure what would separate that from things you might be looking at in other parts of the inlet. You also ought to take a look what is happening in the northern part just to see what you're looking at may be up there too and they may not be rips.

Bill Wilson: Definitely, we are aware of some these surface features extending into the upper inlet. We have flown several of these openers with fixed wing aircraft and took video and color slides. Some of these surface anomalies form up by Anchorage and continue on down south. We have focused on the federal OCS area in the lower inlet and out into the gulf and Shelikof Strait. You can see that there is a tremendous difference in current velocities from being within the rip and from being out of it. There are more questions that we have generated from this study than we have answers.

Susan Saupe: When you have relatively low percent ice cover you can see the rips setting up in the long strings and it really defines those convergent zones. Is there any opportunity to get images when you can easily see the convergent zones?

Geoff Tomlins: We haven't any images that show ice forming or break up. We could acquire those images. The Alaska SAR Facility maintains an archive of every image that has been taken. Sometimes you can get imagery as frequently as every three days, other times it can be less than that.

Steven Russell, Cook Inlet Spill Prevention and Response, Inc., Nikiski, AK

Comparing NOAA/CO-OPS Coastal Current Station Data with Drift Buoy Data in Cook Inlet Sea Ice Conditions

Introduction

In February of 1999, Cook Inlet Spill Prevention and Response, Inc. (CISPRI), in association with Alaska Clean Seas, deployed two satellite-tracked buoys on the ice in Cook Inlet, for the purpose of providing ground truth data to compare Cook Inlet sea ice conditions with oil spill trajectory modeling programs. The intended project would deploy a buoy at specific locations in Cook Inlet for three to five day drifts. The buoys would then be recovered and redeployed at the same locations to observe the effects of current speed/direction, and wind on the track of the buoy. These data would then be directly compared with trajectories provided by NOAA and the Cook Inlet Regional Citizens' Advisory Council.

Upper Cook Inlet, at the time of deployment, was experiencing the most severe sea ice conditions in years, with heavy concentrations of first year medium ice (>70cm). This created several problems that required an alteration of the intended scope.

Buoy number 1 (#11097) produced location reports for 24 hours and then discontinued for 7 days. It is believed that this buoy became inverted on the ice or was covered by rafting. On 23 February 1999 location reports resumed intermittently for 9 days until it is believed that the buoy left the ice on the evening of 3 March 1999. Daily tracking of the buoy predicted that it would attempt to re-enter the ice in the Kamishak Bay area of southern Cook Inlet. Unfortunately a wind event on the evening of 6 March 1999 altered its course to the southeast. Attempts to recover the buoy were made by the OSRV *Heritage Service*. On scene conditions of northwest winds to 50 knots, and sea and swell to 18 feet prevented recovery. The last reported position of buoy #11097 was 1.8 miles off the west side of Ushagat Island. Steep rock cliffs and numerous offshore rocks with little or no beach, characterize this area. Due to the small amount of data provided by this buoy and it's intermittent nature no computations from these data were made.

Buoy number 2 (#06645) continued to transmit on a regular basis and produced over 1,000 location reports in 25 days. Ice concentrations in the region did not allow timely recovery of this buoy for redeployment.

Due to the transmission and recovery problems, it was decided to allow both buoys to continue the drift until they reached ice free water in the southern inlet. The extended drift period of both buoys made the intended scope of re-deployment in the same location impossible.

As an alternative it was decided to compare the buoys' track with the National Ocean Service Center for Operational Oceanographic Products and Services (NOAA CO-OPS) data that is used when preparing a trajectory for oil spill response. NOAA has deployed several buoys in Cook Inlet to record information for its Coastal Current Project and publishes current speed and direction from data provided by these stations.

Cook Inlet sea ice conditions are not factored into these publications and it is not clear what effect sea ice will have on a trajectory produced from currently available modeling programs.

Area Overview

Cook Inlet is a salt water body located off the Gulf of Alaska and measures 160 miles x 70 miles at its widest point. Depths range from 80 fathoms to extensive tidal flats.

Tidal currents in the northern section can exceed 6 knots, with a tidal range from 33 feet above mean low lower water to minus 6 feet from mean lower low water.

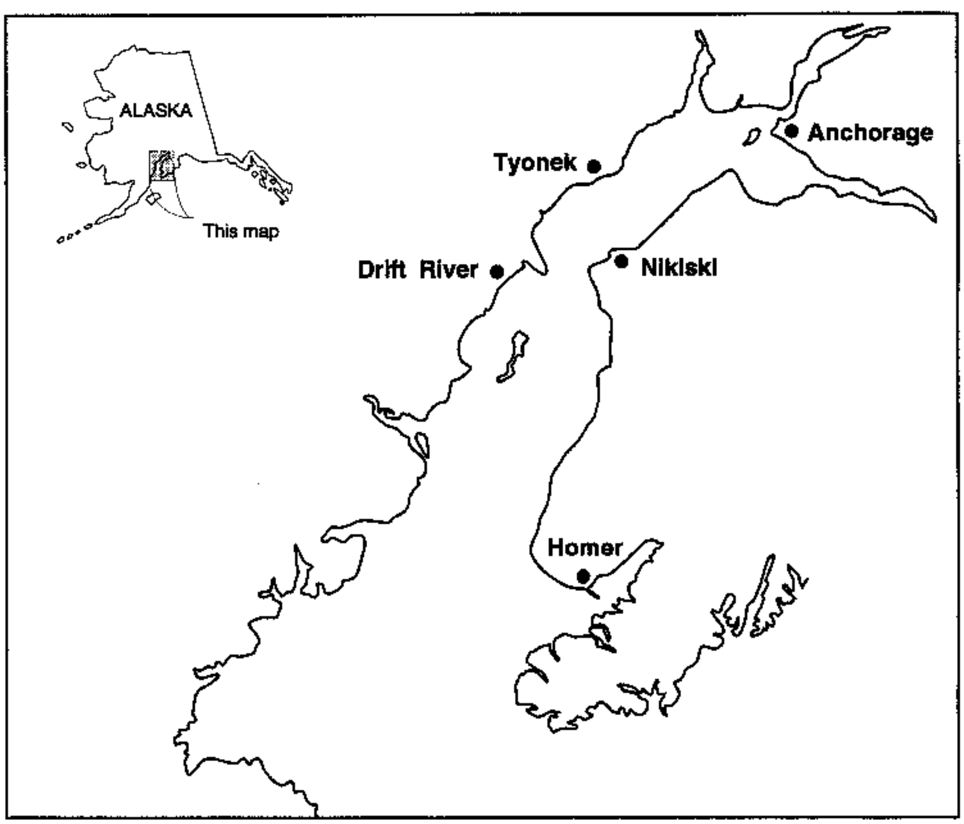
Air temperature ranges are >70°F in summer to <–30°F in winter.

First year thin ice (<70cm) up to 8–10/10 coverage is historically found above 60°30'N from December until late March, with lower concentrations in the southern inlet. Ice concentrations up to 10/10 first year medium (>70cm) were experienced in the 1998–99 season, and coverage extended well to the south of normal limits.

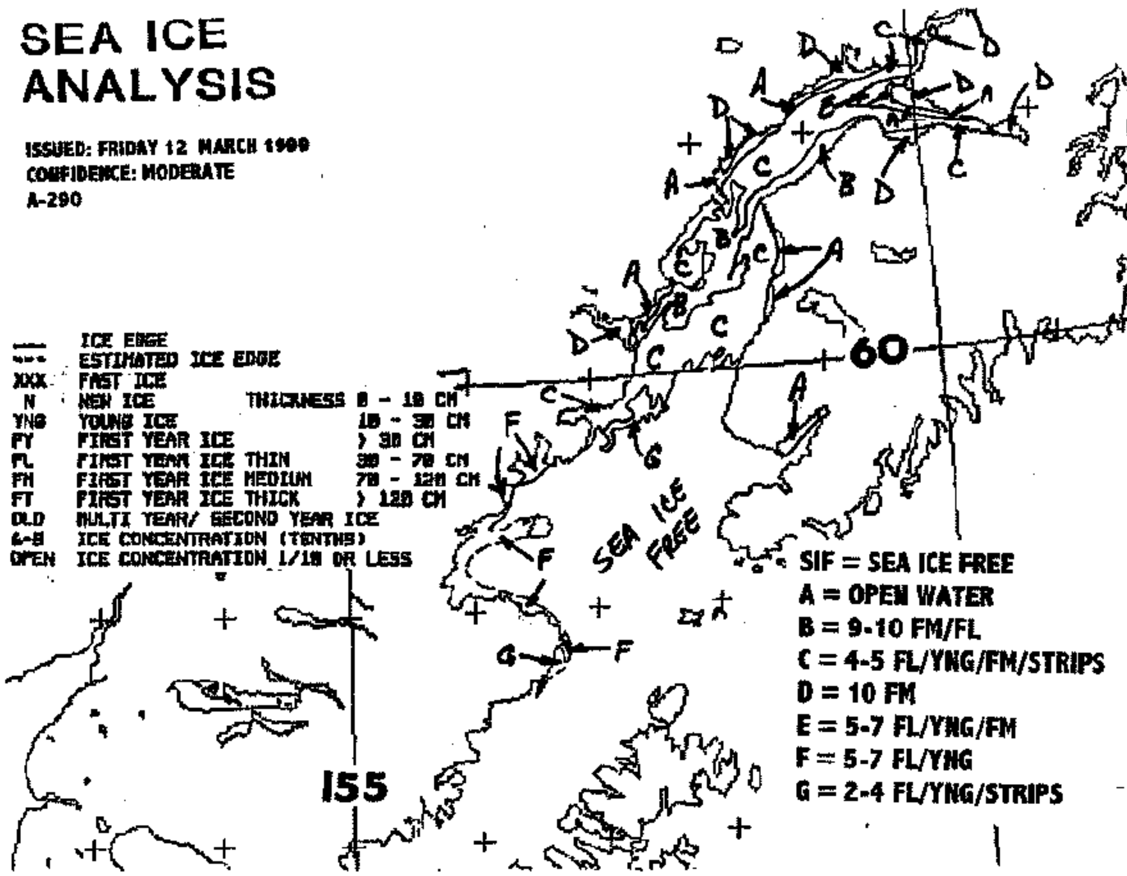
Cook Inlet is home to extensive oil and gas production and distribution, with 15 offshore production platforms and 5 major loading/offloading marine facilities. This production accounts for more than 30 million barrels of petroleum products transported by marine vessels throughout Cook Inlet each year.

A large commercial fishing industry is seasonally supported with salmon runs in excess of 6 million fish. Sport fish and tourism play a large role in the economic stability of the region.

The majority of Alaska's population lives in the Cook Inlet watershed with the state's largest city, Anchorage, located in the northern section.

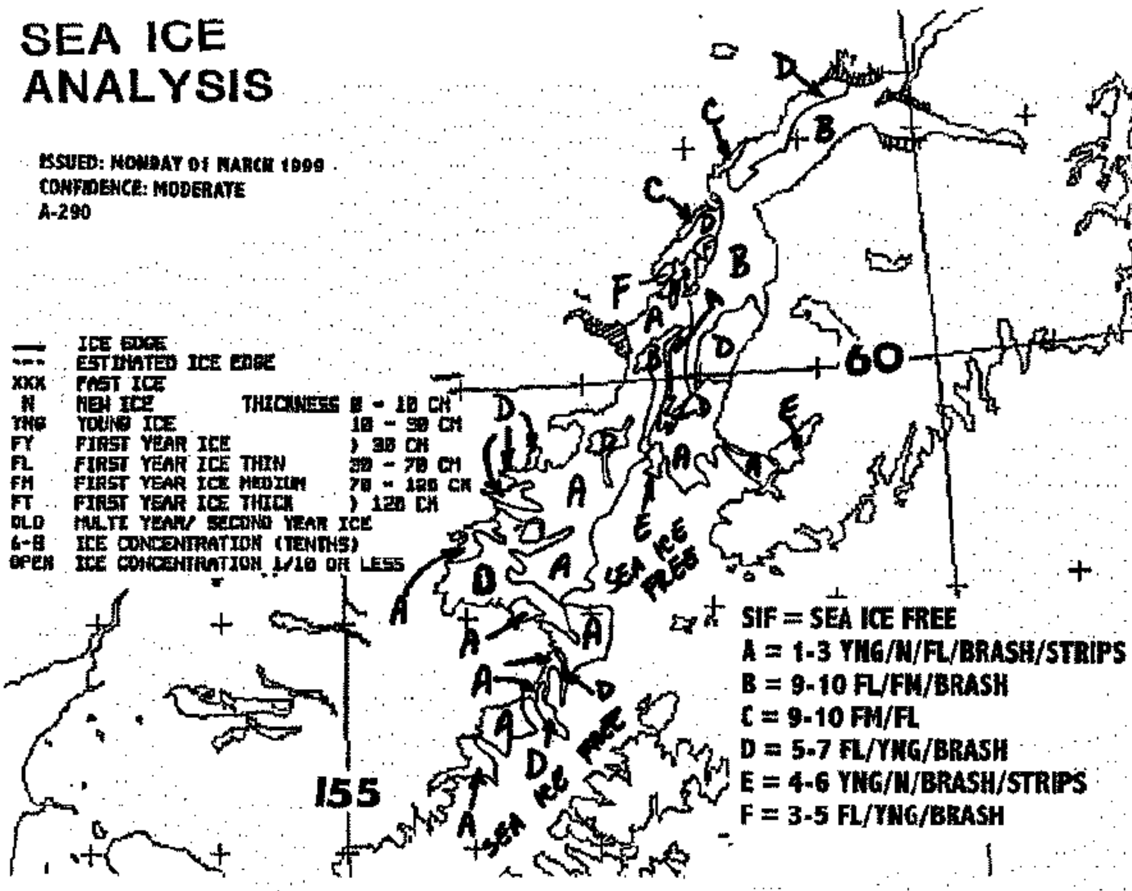


Typical Cook Inlet Sea Ice Conditions



Produced by NWS Anchorage
http://www.alaska.net/~nwsar

Extreme Cook Inlet Sea Ice Conditions



Produced by NWS Anchorage
http://www.alaska.net/~nwsar

Project Overview

The project began with the deployments of two buoys on 15 February 1999. Buoy number 1 (#11097) was deployed at 1140 hours at location 60°40.6'N – 151°27.1'W, 1.6 miles, 270° from the Phillips LNG facility in Nikiski.

This buoy was placed approximately 3/4 mile in from the edge of 9–10/10 first year ice. The ice chosen was an older "growler" type which had some rafting and appeared to have been beached for a length of time. This piece was chosen because it could withstand rafting and would not readily reduce in size. Core samples for ice thickness and make-up were not taken from this piece; it was estimated to be 150 cm in thickness and measured 10 x 6 m in size.

Buoy number 2 (#06645) was placed on the ice in the middle ground shoal area at 60°54.7'N – 151°11'W, 5.2 miles, 122° from the Granite Point offshore oil platform. This buoy was placed on a large pan of ice measuring at least 0.5 km in diameter. Ice cores were taken from this pan and measured approximately 30 cm. It was chosen for its consistency with other new ice in the region.

The buoys began transmitting locations within 70 minutes from deployment, with reports being received at CISPRI by e-mail.

Buoy Description

Alaska Clean Seas provided CISPRI with the three ARGOS Platform Transmitter Terminal (PTT) buoys. Two of the buoys were deployed with one in reserve. The buoys transmit on on 401.65 mHz, and the satellites required four consecutive clear position reports before confirming location. The minimum time required between each confirmed location report was 2 minutes and 20 seconds. A blackout of approximately 4 hours was experienced each day starting approximately 2200 hours and lasting until approximately 0200 hours.

Buoy number 2 (#06645) produced on average 42 location reports every 24 hour period.

Buoy locations were e-mailed to CISPRI every 6 hours from Argos Distribution and were plotted for general location twice daily.

The physical dimensions of the buoys are approximately 50 cm in diameter x 30 cm. They are built of aluminum with a stainless steel side covering; buoy draft is approximately 15 cm and weight is approximately 25 lb.

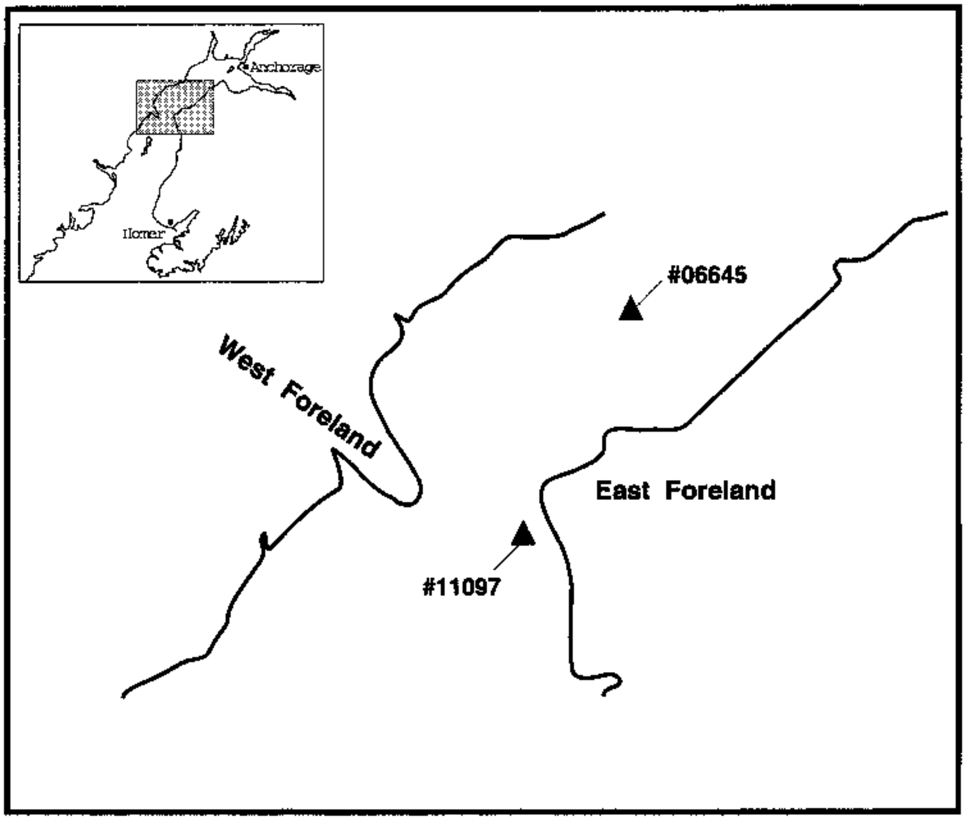
Deployment Description

The deployment platform used was the OSRV *Heritage Service*, a 300-ton offshore supply vessel under contract for oil spill response by CISPRI.

The buoys were deployed by hand on the ice by use of a crane basket to hold the personnel and equipment above the ice. The PTT buoy was placed alongside a second buoy that held an orange flag and strobe light and would float approximately 3 ft above the water.

The ice in the area of the buoy was colored using FDA approved food coloring. One pint of the food coloring was mixed with 2 gal of water and applied to the surface of the ice by use of a Hudson sprayer. Weather balloons were placed 15 ft above the ice and weighted with sandbags to assist in locating and recovering the equipment.

Doug Krause and Orson Smith assisted with the deployment and collected samples at this time (see Krause, Smith and Mulherin in Appendix); for deployment photos see Cook Inlet shipboard images 15 February 1999 at www.engr.uaa.alaska.edu/ice.



Coastal Current Station Description

All of the coastal current stations compared in this project were deployed in 1973–75 by the NOAA vessel *McArthur*. The current meters used were from Aanderaa; each meter had a large vane for measuring current direction. Several meters were placed along a taut line mooring system to record speed and direction throughout the water column. Coastal stations were designated as reference or subordinate, the difference being the time allotted for data collection. Reference stations were stations which provided at least 30 days of good data. Subordinate stations were ones providing 15 days of good data. All stations used in this project with the exception of #3677 West Forelands 1 mile E of, were subordinate stations.

NOAA/CO-OPS coastal current station deployment dates and days of data collection:

1) #3689 Middle Ground Shoal, SE of
   5/8/75 – 5/27/75 19 days
   depth – 20 ft

   7/11/75 – 7/29/75 18 days
   depth – 20 ft

2) #3677 West Foreland, 1 mi E of
   5/6/75 – 6/5/75 30 days
   depth – 20 ft

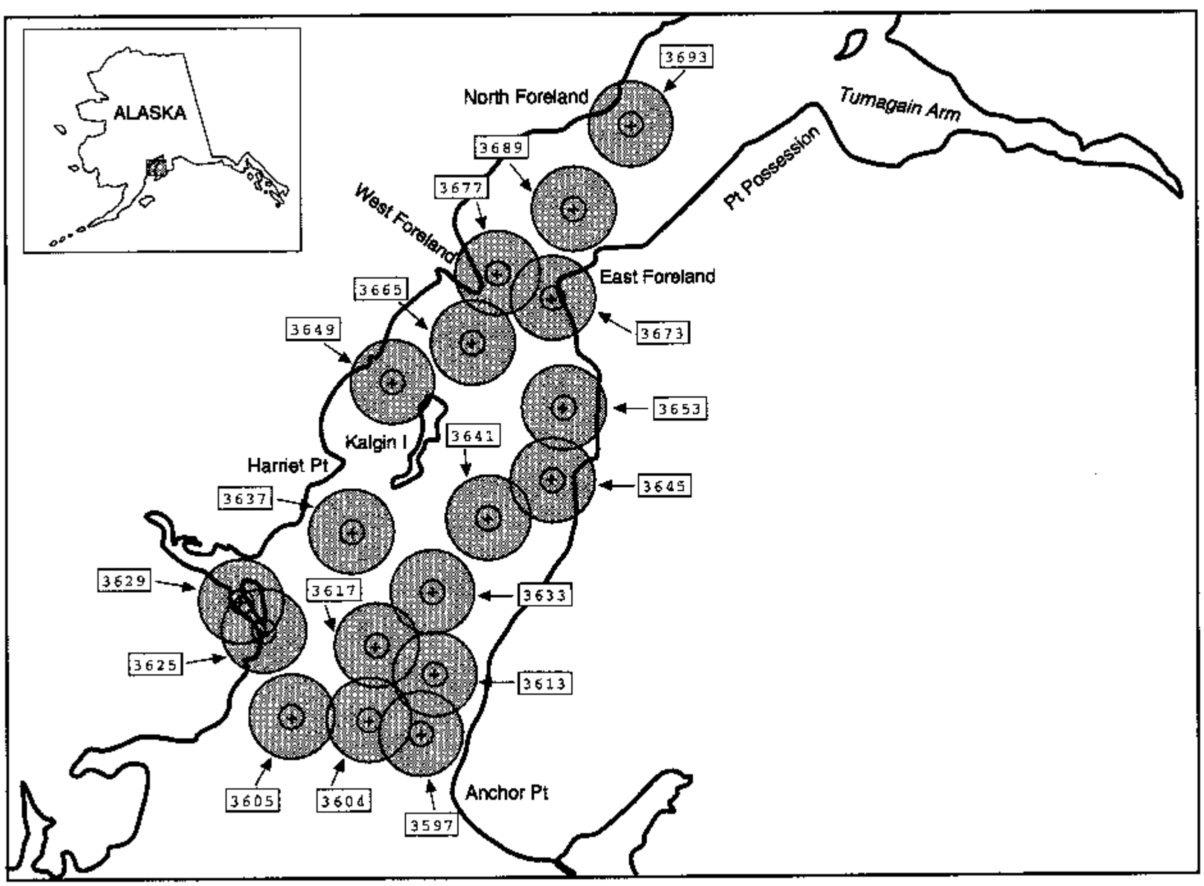
3) #3649 Drift River Terminal, SSE of
6/7/74 – 6/24/74 17 days
depth – 20 ft

4) #3637 Redoubt Point, SE of
7/11/74 – 7/26/74 15 days
depth – 20 ft

5) #3693 North Foreland, SE of
5/23/75 – 6/5/75 13 days
depth – 20 ft

6) #3665 West Foreland, S of
5/8/74 – 5/23/74 15 days
depth – 20 ft

For complete description see NOS Oceanographic Circulatory Survey Report #4, Cook Inlet Circulatory Survey 1973–75.



Project Results

The project compiled all buoy location reports within a 5-mile radius of the following Alaska Coastal Current Stations:

1) NOAA Station #3689 Middle Ground Shoal, SE of
2) NOAA Station #3677 West Foreland, 1 mi E of
3) NOAA Station #3649 Drift River Terminal, SSE of
4) NOAA Station #3637 Redoubt Point, SE of
5) NOAA Station #3693 North Foreland, SE of
6) NOAA Station #3665 West Foreland, S of

Buoy direction of travel was computed from it's previous reported location or "waypoint" and not by the buoy's general track through the 5 mile radius.

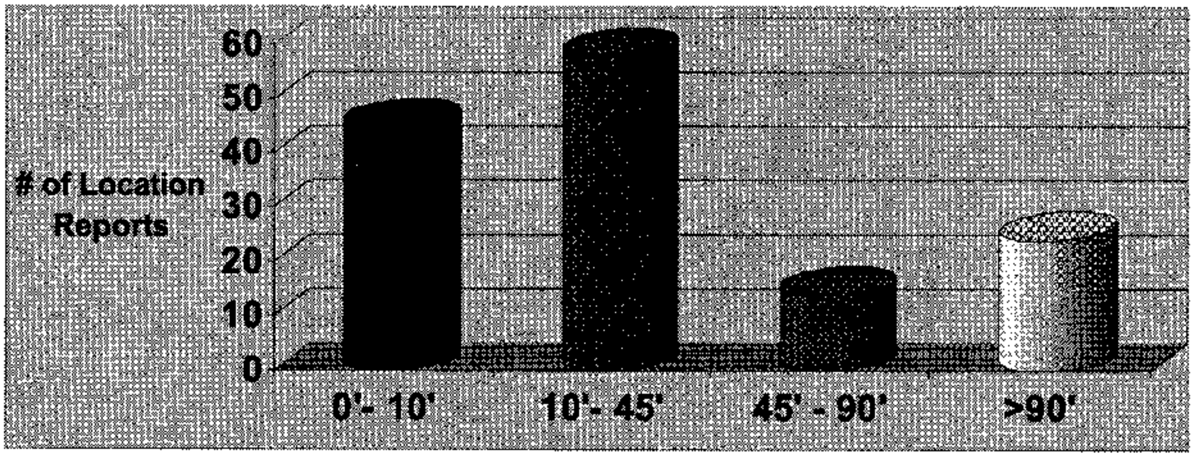
Buoy number 2 (#06645) produced 236 location reports within the parameters, of which 141 showed travel from the previous location, the remainder being duplicate location reports.

A track was considered accurate if the buoy track was within 10 degrees of the predicted current direction. This method resulted in an accuracy rate of 31.9.

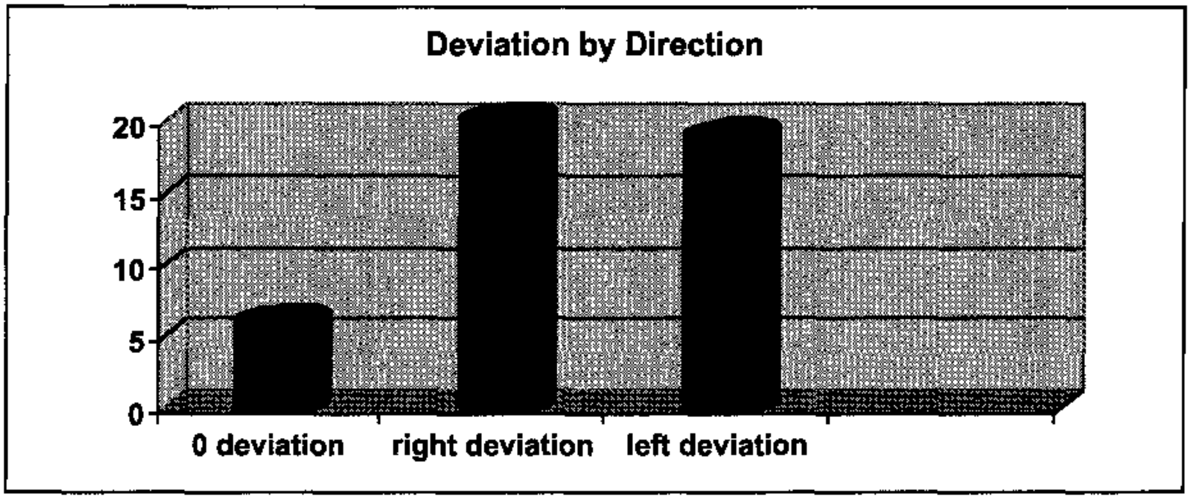
No correlation with wind deviation could be found; the track did not appear to be consistently affected by wind. Ice coverage above 60°40'N was 10/10 for the entire period and the confines of the landmass did not allow the wind to play a key role. Below 60°40'N the wind can have a dramatic effect on mid channel ice movement, but this tends to be east–west movement of short duration.

Current speed was not factored because no consistency whatsoever could be found. Average buoy speed for entire drift was 1.69 knots.

Buoy Track Deviation
#06645



Relative Difference	0°– 10°	10°– 45°	45°– 90°	>90°
# of sites = 141	45	58	14	24



Of the readings showing less then 10 degrees deviation, 6 showed no deviation and 20 showed deviations to the right and 19 showed deviations to the left.

Recommendations

Since there was no correlation with the coastal current station predicted speed and the buoys' speed, it is recommended that modeling programmers use 1.5 kt for their constant in sea ice conditions over 7/10 coverage. This should only apply in Cook Inlet above 60°10′N; below this latitude, the maximum daily current speed is considerably less or very localized.

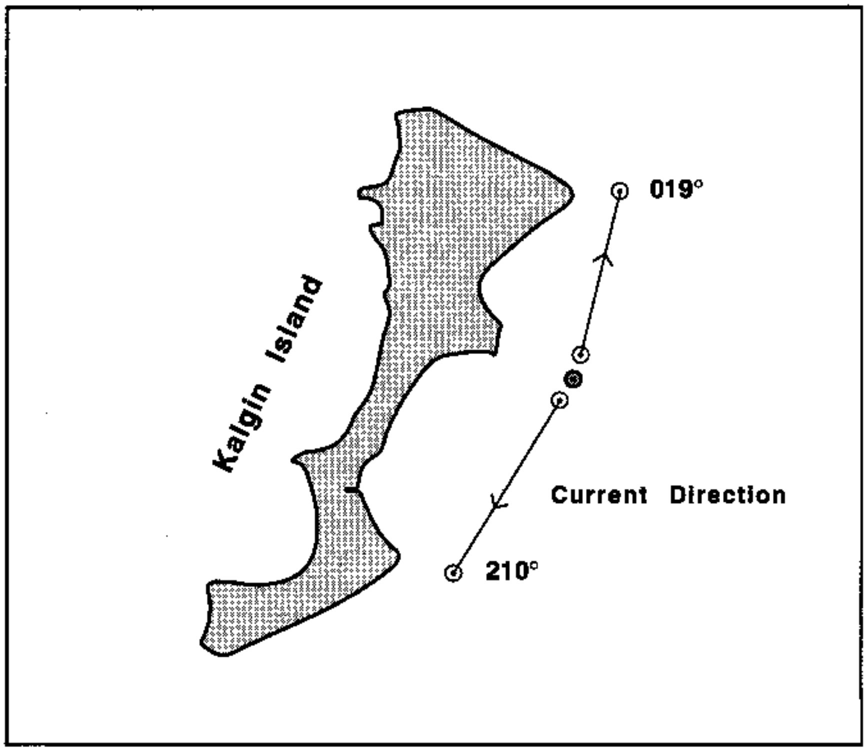
Wind constants under 15 kt from a north or south direction should be discounted as their effect on sea ice in the central Cook Inlet is limited by landmass above 60°42′N. Wind from an east or west direction should be considered only until the product reaches an area with 7/10 coverage for the same reason. Above 60°56′N, wind constants should be disregarded in 7/10 coverage.

In conditions under 6/10 sea ice should not be considered, as its effect on product movement is limited.

Ice types or ages, should not be considered by the programmer.

Due to the amount of time both buoys spent in the area to the east side of Kalgin Island, it is recommended that a coastal current station be placed closer to the area. The current station #3641 is located ten miles southeast of the island and seven miles from the shoal area. This station is centered on the main channel currents and does not represent the current direction and speed of the Kalgin area. A station placed at approximately 60°25′N – 151°50′W would provide a more accurate representation in the area. The data collected by the buoy tracks suggests that the current direction from this location is 210° and 19°.

A coastal current station placed on the north side of middle ground shoal is also recommended as this area is home to the majority of offshore oil and gas production. Three stations are located close by north–east and south of the shoal, but it is felt that this land mass plays a key role in current patterns in the area.



Buoy Number 06645

Site #	Date	Time AST	Latitude	Longitude	Current Sp/Dir	Weather	Ice Concentration	Rel B	rel dif
4	02/15/99	16:14:21	60°57.36'N	151°03.00'W	3.6 kt 062° F 5	13 kt 050°	10/10 FL	056°	6
6		16:32:05	60°58.44'N	151°00.00'W	3.3 kt 062° F 5	13 kt 050°	10/10 FL	053°	9
7		17:54:52	61°00.24'N	150°55.80'W	1.4 kt 062° F 5	13 kt 050°	10/10 FL	049°	13
9		18:03:12	61°00.72'N	150°54.60'W	1.1 kt 062° F 5	12 kt 060°	10/10 FL	050°	12
10		19:53:08	61°00.06'N	150°57.00'W	2.8 kt 221° E 5	12 kt 060°	10/10 FL	240°	19
17	02/16/99	06:00:43	60°58.14'N	151°01.20'W	2.5 kt 062° F 5	15 kt 080°	10/10 FL	056°	6
18		06:05:09	60°59.04'N	150°58.80'W	2.5 kt 062° F 5	15 kt 080°	10/10 FL	052°	10
21		07:36:49	61°00.48'N	150°56.40'W	0.7 kt 221° E 5	15 kt 080°	10/10 FL	039°	178
25		09:17:21	60°58.80'N	151°01.80'W	3.6 kt 221° E 5	15 kt 080°	10/10 FL	237'	16
29		09:39:31	60°57.60'N	151°05.40'W	3.9 kt 236° E 5	15 kt 080°	10/10 FL	236°	0
31		11:02:19	60°54.00'N	151°15.00'W	4.7 kt 231° E 1	05 kt 320°	10/10 FL	231°	0
35		12:31:00	60°51.78'N	151°21.60'W	1.5 kt 231° E 1	05 kt 320°	10/10 FL	235°	4
36		12:42:50	60°51.06'N	151°23.40'W	1.0 kt 231° E 1	05 kt 320°	10/10 FL	231°	0
40		14:32:13	60°52.56'N	151°19.80'W	3.8 kt 063° F 1	05 kt 320°	10/10 FL	058°	5
43		16:03:52	60°55.68'N	151°09.00'W	3.9 kt 063° F 5	10 kt 200°	10/10 FL	058°	5
45		17:44:23	60°58.92'N	151°00.00'W	3.0 kt 062° F 5	10 kt 200°	10/10 FL	053°	9
47		19:19:00	61°00.84'N	150°55.80'W	0.2 kt 221° E 5	10 kt 200°	10/10 FL	047°	174
49		20:59:32	60°58.92'N	151°00.00'W	4.0 kt 221° E 5	10 kt 200°	10/10 FL	227°	6
50		21:09:53	60°58.32'N	151°03.00'W	4.2 kt 221° E 5	10 kt 200°	10/10 FL	248°	27
52		22:45:59	60°54.54'N	151°13.80'W	6.5 kt 231° E 1	10 kt 200°	10/10 FL	234°	3

Site #	Date	Time AST	Latitude	Longitude	Current Sp/Dir	Weather	Ice Concentration	Rel B	rel dif
55	02/17/99	2:29:14	60°49.56'N	151°30.00'W	3.4 kt 063° F 1	03 kt 080°	10/10 FL	238°	175
56		4:14:13	60°52.92'N	151°22.80'W	4.5 kt 063° F 1	03 kt 080°	10/10 FL	046°	17
59		7:24:57	60°57.48'N	151°04.80'W	1.3 kt 062° F 5	05 kt 240°	10/10 FL	061°	1
63		9:12:54	60°56.58'N	151°07.20'W	2.8 kt 221° E 5	05 kt 240°	10/10 FL	231°	10
65		10:51:58	60°53.52'N	151°17.40'W	5.7 kt 231° E 1	05 kt 340°	10/10 FL	238°	7
67		12:20:41	60°49.20'N	151°17.40'W	3.7 kt 231° E 1	05 kt 340°	10/10 FL	180°	51
69		12:34:00	60°48.24'N	151°33.60'W	3.3 kt 231° E 2	05 kt 340°	10/10 FL	263°	32
71		14:01:13	60°47.16'N	151°36.00'W	1.3 kt 063° F 2	05 kt 340°	10/10 FL	227°	164
72		14:02:42	60°47.16'N	151°36.60'W	1.3 kt 063° F 2	05 kt 340°	10/10 FL	277°	146
76		17:22:15	60°55.50'N	151°22.80'W	3.5 kt 063° F 1	05 kt 250°	10/10 FL	050°	13
80		19:01:18	60°58.08'N	151°11.40'W	2.0 kt 062° F 5	05 kt 250°	10/10 FL	064°	2
81		19:08:42	60°58.56'N	151°09.60'W	1.6 kt 062° F 5	05 kt 250°	10/10 FL	063°	1
82		20:35:56	60°58.44'N	151°10.20'W	1.6 kt 221° E 5	05 kt 250°	10/10 FL	284°	63
84		22:28:18	60°55.50'N	151°19.20'W	6.9 kt 231° E 1	05 kt 020°	10/10 FL	236°	5
85	02/18/99	2:13:02	60°45.12'N	151°38.40'W	0.2 kt 075° S 2	05 kt 020°	9–10/10 FL	222°	147
88		4:00:58	60°47.64'N	151°38.40'W	5.2 kt 349° F 2	04 kt 220°	9–10/10 FL	000°	11
89		4:02:27	60°49.32'N	151°39.00'W	5.2 kt 349° F 2	04 kt 220°	9–10/10 FL	349°	0
104		13:49:26	60°48.54'N	151°39.60'W	1.7 kt 231° E 2	03 kt 320°	9–10/10 FL	202°	29
106		15:27:00	60°48.78'N	151°41.40'W	4.1 kt 063° F 2	08 kt 320°	9–10/10 FL	284°	139
122	02/19/99	1:59:56	60°46.92'N	151°41.40'W	3.0 kt 171° E 2	07 kt 180°	9–10/10 FL	202°	31
123		2:02:53	60°46.20'N	151°42.00'W	3.0 kt 171° E 2	07 kt 180°	9–10/10 FL	202°	31
126		3:49:23	60°47.22'N	151°43.80'W	4.3 kt 349° F 2	07 kt 180°	9–10/10 FL	319°	30
132		8:20:05	60°48.18'N	151°45.00'W	0.6 kt 349° F 2	04 kt 190°	9–10/10 FL	180°	169
134		8:31:55	60°47.58'N	151°44.40'W	0.3 kt 349° F 2	04 kt 190°	9–10/10 FL	154°	165
137		10:00:40	60°45.84'N	151°42.60'W	3.7 kt 177° E 2	09 kt 320°	9–10/10 FL	153°	24
139		10:11:01	60°44.58'N	151°42.00'W	4.1 kt 177° E 2	09 kt 320°	9–10/10 FL	167°	10
154		16:44:22	60°42.18'N	151°44.40'W	4.7 kt 349° F 2	05 kt 300°	9–10/10 FL	078°	89
157		17:10:59	60°42.78'N	151°41.40'W	4.7 kt 349° F 2	05 kt 300°	9–10/10 FL	068°	79
158		18:14:34	60°44.76'N	151°41.40'W	4.2 kt 349° F 2	05 kt 300°	9–10/10 FL	000°	11
160		18:47:06	60°45.18'N	151°41.40'W	3.5 kt 349° F 2	05 kt 300°	9–10/10 FL	000°	11
162		20:01:03	60°45.24'N	151°41.40'W	1.7 kt 349° F 2	05 kt 300°	9–10/10 FL	000°	11
163		20:05:29	60°44.94'N	151°40.80'W	1.7 kt 349° F 2	05 kt 300°	9–10/10 FL	136°	147
164		21:44:34	60°41.10'N	151°42.60'W	2.5 kt 171° E 2	05 kt 300°	9–10/10 FL	193°	22
174	02/20/99	8:01:11	60°41.34'N	151°40.80'W	2.5 kt 349° F 2	06 kt 020°	9–10/10 FL	087°	98
175		8:10:04	60°41.70'N	151°39.60'W	2.2 kt 349° F 2	06 kt 020°	9–10/10 FL	048°	60
177		8:39:38	60°41.88'N	151°39.60'W	1.3 kt 349° F 2	06 kt 020°	9–10/10 FL	000°	11
178		9:47:39	60°40.50'N	151°42.00'W	1.1 kt 171° E 2	06 kt 020°	9–10/10 FL	220°	49
179		10:12:48	60°39.54'N	151°44.40'W	2.2 kt 171° E 6	15 kt 040°	9–10/10 FL	231°	60
182		11:29:41	60°38.16'N	151°51.00'W	5.1 kt 171° E 6	15 kt 040°	9–10/10 FL	247°	76
185		13:01:21	60°34.92'N	152°00.60'W	3.9 kt 221° E 3	15 kt 040°	9–10/10 FL	232°	11
186		13:07:16	60°33.42'N	152°04.20'W	3.8 kt 221° E 3	15 kt 040°	9–10/10 FL	230°	9
188		13:38:19	60°32.40'N	152°06.60'W	3.3 kt 221° E 3	15 kt 040°	9–10/10 FL	229°	8
189		14:43:22	60°31.20'N	152°09.00'W	2.0 kt 221° E 3	15 kt 040°	9–10/10 FL	225°	4

Site #	Date	Time AST	Latitude	Longitude	Current Sp/Dir	Weather	Ice Concentration	Rel B	rel dif
190	02/20/99	15:18:51	60°30.84′N	152°09.60′W	0.8 kt 221° E 3	15 kt 040°	9–10/10 FL	220°	1
191		16:22:25	60°31.20′N	152°09.60′W	0.9 kt 051° F 3	10 kt 040°	9–10/10 FL	000°	129
192		16:49:01	60°31.68′N	152°09.00′W	1.5 kt 051° F 3	10 kt 040°	9–10/10 FL	032°	19
195		17:58:30	60°33.00′N	152°06.60′W	2.2 kt 051° F 3	10 kt 040°	9–10/10 FL	042°	9
198		19:31:39	60°35.82′N	151°59.40′W	1.9 kt 051° F 3	10 kt 040°	9–10/10 FL	051°	0
208	02/21/99	7:46:27	60°29.70′N	152°13.80′W	1.9 kt 051° F 3	18 kt 040°	9–10/10 FL, BR	029°	22
209		8:27:51	60°29.76′N	152°13.80′W	1.6 kt 051° F 3	18 kt 040°	9–10/10 FL, BR	000°	129
224		15:07:03	60°18.30′N	152°14.40′W	1.0 kt 198° E 4	20 kt 020°	9–10/10 FL, BR	199°	1
225		15:58:48	60°17.76′N	152°15.60′W	0.2 kt 025° F 4	19 kt 050°	9–10/10 FL, BR	228°	157
229		17:30:28	60°18.60′N	152°15.60′W	1.7 kt 025° F 4	19 kt 050°	9–10/10 FL, BR	035°	10
236		22:38:02	60°28.20′N	152°10.20′W	0.1 kt 129° S 3	15 kt 030°	9–10/10 FL, BR	350°	139
237	02/22/99	3:16:02	60°18.60′N	152°14.40′W	0.8 kt 198° E 4	15 kt 030°	9–10/10 FL, BR	192°	6
238		4:59:33	60°18.18′N	152°15.60′W	1.0 kt 025° F 4	10 kt 020°	9–10/10 FL, BR	235°	150
248		9:02:05	60°28.32′N	152°09.00′W	1.5 kt 051° F 3	10 kt 020°	9–10/10 FL, BR	015°	36
251		9:56:49	60°29.28′N	152°09.00′W	0.9 kt 051° F 3	09 kt 060°	9–10/10 FL, BR	000°	51
252		10:35:16	60°30.42′N	152°09.00′W	0.4 kt 051° F 3	09 kt 060°	9–10/10 FL, BR	000°	51
255		11:25:32	60°30.54′N	152°08.40′W	0.4 kt 221° E 3	09 kt 060°	9–10/10 FL, BR	068°	153
257		11:32:56	60°30.36′N	152°09.00′W	1.0 kt 221° E 3	09 kt 060°	9–10/10 FL, BR	239°	18
258		11:34:25	60°30.36′N	152°09.60′W	1.0 kt 221° E 3	09 kt 060°	9–10/10 FL, BR	270°	49
293	02/23/99	8:22:27	60°28.92′N	152°08.40′W	1.5 kt 051° F 3	06 kt 020°	9–10/10 FL, BR	007°	44
295		9:44:00	60°28.02′N	152°08.40′W	1.4 kt 051° F 3	06 kt 020°	9–10/10 FL, BR	008°	45
296		10:23:56	60°28.92′N	152°08.40′W	1.2 kt 051° F 3	04 kt 010°	9–10/10 FL, BR	000°	51
298		11:24:35	60°30.06′N	152°07.20′W	0.6 kt 051° F 3	04 kt 010°	9–10/10 FL, BR	028°	23
299		12:01:33	60°30.36′N	152°07.20′W	0.1 kt 129° S 3	04 kt 010°	9–10/10 FL, BR	000°	129
300		12:03:02	60°30.36′N	152°06.60′W	0.1 kt 129° S 3	04 kt 010°	9–10/10 FL, BR	090°	39
301		13:00:43	60°30.06′N	152°06.60′W	1.3 kt 221° E 3	04 kt 010°	9–10/10 FL, BR	180°	41
302		13:03:40	60°29.46′N	152°07.20′W	1.3 kt 221° E 3	04 kt 010°	9–10/10 FL, BR	206°	15
305		14:36:10	60°28.56′N	152°07.80′W	2.8 kt 221° E 3	04 kt 010°	9–10/10 FL, BR	213°	8
327	02/24/99	2:51:49	60°31.26′N	152°05.40′W	1.5 kt 221° E 3	00 kt 000°	9–10/10 FL, BR	026°	165
328		4:26:29	60°28.92′N	152°07.80′W	1.7 kt 221° E 3	07 kt 350°	9–10/10 FL, BR	207°	14
331		4:36:50	60°28.20′N	152°08.40′W	1.7 kt 221° E 3	07 kt 350°	9–10/10 FL, BR	202°	19
340		9:26:46	60°29.34′N	152°10.20′W	1.2 kt 051° F 3	05 kt 350°	9–10/10 FL, BR	353°	58
342		9:32:41	60°30.00′N	152°09.60′W	1.2 kt 051° F 3	05 kt 350°	9–10/10 FL, BR	024°	27
345		10:03:45	60°30.78′N	152°08.40′W	1.3 kt 051° F 3	05 kt 350°	9–10/10 FL, BR	037°	14
346		11:10:19	60°32.04′N	152°06.00′W	1.2 kt 051° F 3	05 kt 350°	9–10/10 FL, BR	043°	8
348		11:39:54	60°32.46′N	152°04.80′W	1.0 kt 051° F 3	05 kt 350°	9–10/10 FL, BR	055°	4
349		12:43:30	60°33.06′N	152°02.40′W	0.5 kt 051° F 3	05 kt 350°	9–10/10 FL, BR	063°	12
351		13:17:31	60°33.06′N	152°01.80′W	0.0 kt 129° S 3	05 kt 350°	9–10/10 FL, BR	090°	39
352		14:31:27	60°32.16′N	152°02.40′W	1.5 kt 221° E 3	05 kt 350°	9–10/10 FL, BR	198°	23
353		14:32:56	60°31.50′N	152°04.20′W	1.5 kt 221° E 3	05 kt 350°	9–10/10 FL, BR	233°	12
358		16:01:40	60°29.88′N	152°06.60′W	2.6 kt 221° E 3	08 kt 350°	9–10/10 FL, BR	216°	5
359		16:03:08	60°28.80′N	152°07.80′W	2.6 kt 221° E 3	08 kt 350°	9–10/10 FL, BR	209°	12
372		21:32:56	60°28.14′N	152°06.00′W	0.9 kt 051° F 4	02 kt 330°	9–10/10 FL, BR	032°	19

Site #	Date	Time AST	Latitude	Longitude	Current Sp/Dir	Weather	Ice Concentration	Rel B	rel dif
377	02/25/99	5:54:21	60°31.08′N	152°00.00′W	1.9 kt 221° E 3	N/A	5–7/10 FL,YG,BR	245°	24
380		6:07:40	60°30.36′N	152°01.20′W	1.8 kt 221° E 3	N/A	5–7/10 FL,YG,BR	219°	2
382		7:46:46	60°29.28′N	152°01.80′W	0.6 kt 221° E 3	N/A	5–7/10 FL,YG,BR	194°	27
384		9:17:00	60°30.42′N	152°00.00′W	0.7 kt 051° F 3	N/A	5–7/10 FL,YG,BR	038°	13
387		9:40:40	60°31.08′N	151°58.80′W	0.9 kt 051° F 3	N/A	5–7/10 FL,YG,BR	042°	9
591	03/02/99	15:07:06	60°28.98′N	152°04.80′W	2.2 kt 051° F 3	03 kt 025°	9–10/10 FL, BR	032°	19
608	03/03/99	4:59:41	60°29.16′N	152°00.60′W	2.4 kt 051° F 3	03 kt 025°	9–10/10 FL, BR	030°	21
609		6:31:22	60°30.96′N	151°58.20′W	1.2 kt 051° F 3	03 kt 025°	9–10/10 FL, BR	033°	18
610		6:40:14	60°30.96′N	151°57.60′W	1.0 kt 051° F 3	03 kt 025°	9–10/10 FL, BR	090°	39
611		7:15:44	60°30.48′N	151°58.20′W	0.5 kt 051° F 3	03 kt 025°	9–10/10 FL, BR	212°	161
633		15:40:00	60°30.54′N	151°58.20′W	2.1 kt 051° F 3	05 kt 270°	9–10/10 FL, BR	020°	31
655	03/04/99	6:28:47	60°32.16′N	151°43.80′W	2.2 kt 058° F 6	10 kt 045°	8–10/10 FL,FM,B	043°	15
656		7:01:19	60°32.40′N	151°43.20′W	1.5 kt 058° F 6	10 kt 045°	8–10/10 FL,FM,B	051°	7
657		7:02:48	60°32.52′N	151°42.60′W	1.5 kt 058° F 6	10 kt 045°	8–10/10 FL,FM,B	068°	10
658		7:59:00	60°32.28′N	151°42.60′W	0.1 kt 145° S 6	10 kt 045°	8–10/10 FL,FM,B	180°	35
659		8:04:55	60°31.62′N	151°42.60′W	0.1 kt 145° S 6	10 kt 045°	8–10/10 FL,FM,B	180°	35
660		8:07:52	60°31.56′N	151°42.60′W	0.6 kt 145° S 6	10 kt 045°	8–10/10 FL,FM,B	180°	35
686		18:02:19	60°32.40′N	151°43.20′W	2.8 kt 058° F 6	02 kt 295°	8–10/10 FL,FM,B	045°	7
688		18:37:49	60°32.94′N	151°42.60′W	2.1 kt 058° F 6	02 kt 295°	8–10/10 FL,FM,B	029°	29
689		20:05:04	60°32.82′N	151°41.40′W	0.2 kt 145° S 6	02 kt 295°	8–10/10 FL,FM,B	101°	44
795	03/07/99	7:25:07	60°31.38′N	152°01.80′W	1.6 kt 051° F 3	10 kt 000°	8–10/10 FL,FM	040°	11
799		7:36:57	60°31.92′N	152°00.00′W	1.5 kt 051° F 3	10 kt 000°	8–10/10 FL,FM	059°	8
800		9:13:06	60°32.52′N	151°57.00′W	0.5 kt 051° F 3	11 kt 000°	8–10/10 FL,FM	068°	17
804		10:46:17	60°30.72′N	152°00.06′W	2.1 kt 221° E 3	11 kt 000°	8–10/10 FL,FM	220°	1
805		10:50:43	60°30.72′N	152°00.60′W	2.1 kt 221° E 3	11 kt 000°	8–10/10 FL,FM	270°	49
818		17:29:58	60°31.62′N	151°59.40′W	1.3 kt 051° F 3	08 kt 330°	4–6/10 FL,YG	029°	22
820		18:58:42	60°34.26′N	151°51.00′W	1.5 kt 051° F 3	08 kt 330°	8–10/10 FL,FM	057°	6
822		19:12:00	60°34.68′N	151°48.60′W	1.5 kt 051° F 3	08 kt 330°	8–10/10 FL,FM	070°	19
823		20:51:05	60°36.18′N	151°43.20′W	0.9 kt 051° F 3	08 kt 330°	4–6/10 FL,YG	061°	10
825		22:31:39	60°36.12′N	151°41.40′W	0.7 kt 221° E 3	08 kt 180°	4–6/10 FL,YG	094°	127
1001	03/12/99	3:15:11	60°28.20′N	152°03.00′W	0.5 kt 221° E 3	10 kt 025°	4–6/10 FL,YG	060°	161
1014		11:30:32	60°27.78′N	152°03.60′W	0.9 kt 051° F 3	06 kt 045°	4–6/10 FL,YG	059°	8
1015		11:34:58	60°28.02′N	152°03.00′W	0.9 kt 051° F 3	06 kt 045°	4–6/10 FL,YG	051°	0
1016		12:25:14	60°28.14′N	152°03.00′W	0.8 kt 051° F 3	06 kt 045°	4–6/10 FL,YG	000°	129
1018		13:15:30	60°28.14′N	152°05.00′W	0.6 kt 051° F 3	06 kt 045°	4–6/10 FL,YG	270°	141

For more complete tracking data contact the author.

Acknowledgments

Cook Inlet Spill Prevention and Response Inc would like to thank the following for their contributions to this project.

Alaska Clean Seas
Tidewater Alaska
Russell Page, NWS
John Whitney, NOAA
Orson Smith, University of Alaska Anchorage
Sue Saupe, CIRCAC
Rory Dabney, CIRCAC
Bob Barrett, USCG
Mike Munger, ADEC

Discussion

Jia Wang: How thick is the ice on average?

Steve Russell: Last year we had first-year medium ice over 70 cm thick. On average it is a little less, maybe 40 cm. Last year were the thickest ice conditions, the heaviest ice concentrations that we have had in some time. The ice also went much farther to the south than normal.

Rob Burns: The inlet is a famous area for self flushing. How long does it take these buoys to move out of the inlet?

Steve Russell: Buoy number one spent about 15 days in the central inlet before it left. It fell off the ice on the third of March and then made a beeline to the Barren Islands. On the third it was south of Kalgin, on the seventh it was on the Barren Islands. Buoy number two did not go below 60°10′N. It went 8 miles below Harriet Point and spent 25 days in the inlet.

Joel Blatchford: There are these pockets that form that hold this stuff. When the rips thin out the oil there is no way that you guys can clean it up.

Steve Russell: The rip tides actually help substantially because they elongate the product. Everybody pictures a great big sheen. If it is more of a typical kind, the product, if it is sucked into the rips, elongates into a narrow ribbon which is much easier to clean up.

Joel Blatchford: The spill response teams can't clean them up in the winter.

Steve Russell: There is quite a bit of work going on for winter responses. We haven't had too many in heavy ice conditions. The last one was in January 1999. It went pretty well and that was in 7/10 ice conditions, but it wasn't a lot of product.

John Whitney, Office of Response and Restoration, NOAA, Anchorage, AK

What the Actual Movement of Oil in Cook Inlet Tells Us about the Circulation in Cook Inlet

Introduction

For the past twenty-five years the National Oceanic and Atmospheric Administration Hazardous Materials Response Branch has been providing scientific and technical support to the U.S. Coast Guard for oil spills in the marine environment. One of the major elements of this support is oil spill trajectories. This means that we have several oceanographers on our staff who are very interested and knowledgeable in ocean circulation around the entire coast of the United States, including Cook Inlet, which has been a real challenge to understand and model.

General: Cook Inlet Oil Spills and Circulation

So what can NOAA contribute to the greater understanding of the circulation of Cook Inlet? Figure 1 shows the location of all the significant petroleum spills that have occurred in Cook Inlet from 1984 to 1999 (approximately 24 spills) for which the Coast Guard has requested assistance from NOAA.

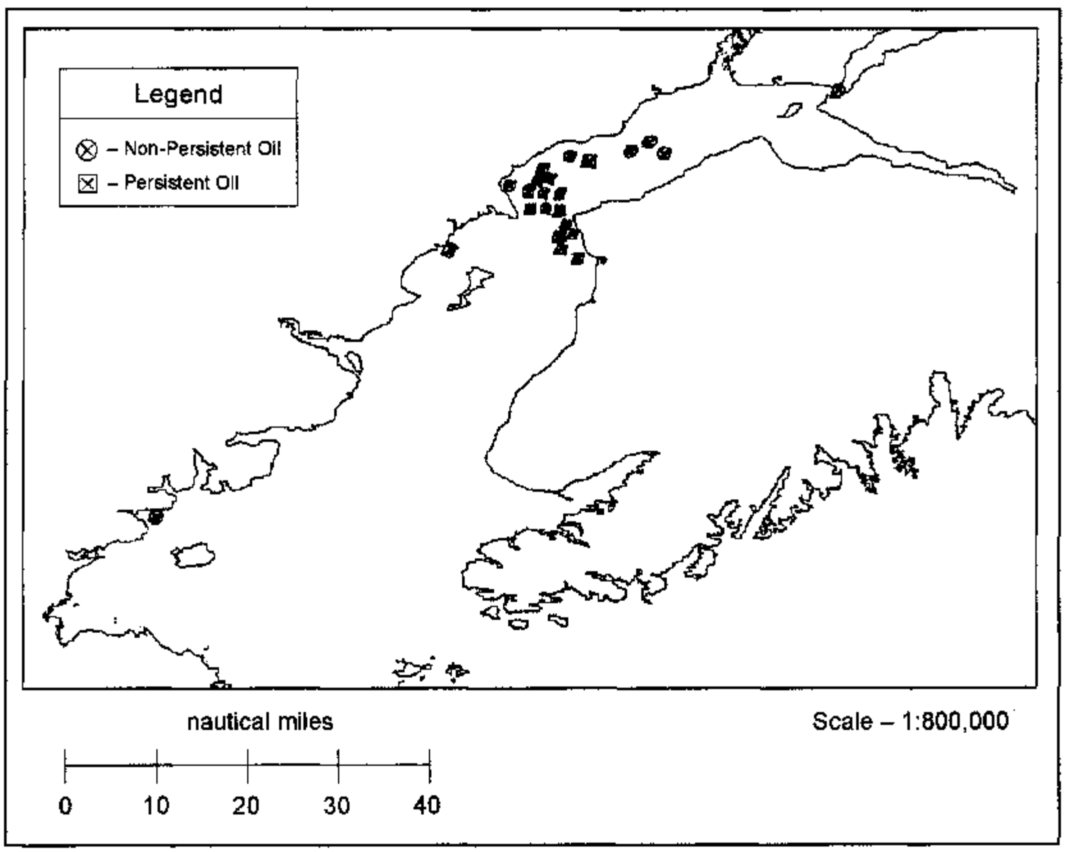


Figure 1. Location of significant petroleum spills for Cook Inlet: 1984–1999.

As can be seen, these spills are concentrated around the petroleum production and transportation facilities in middle Cook Inlet, i.e., 15 offshore oil and gas production platforms exist between the Forelands and the North Forelands and major tanker docking facilities exist at Drift River on the west and at Nikiski on the east side. Roughly half of these spills were non-persistent fuels (gasoline, jet fuel and diesel), with the remaining half being persistent fuels (crude oil and bunker C). Given this database, one might suppose that our database for movement of oil spills in this part of the inlet is fairly extensive. This area is on the edge of the extensive circulation survey that was carried out by the Alaska Department of Fish and Game in the late seventies (Figure 2 [Burbank 1977]). As a result of the extensive use of drogues, drift cards, etc. Burbank developed an excellent database for the deduction of net currents in lower Cook Inlet. The area to the west of Kalgin Island and north through the Forelands is almost devoid of any circulation information, and this may be an area where NOAA can contribute with its oil spill movement information.

The vast majority of oil spill volumes have been rather small (Figure 3), on the order of tens of barrels or less. In observing these spills over the years, NOAA has learned that small oil spills (particularly non-persistent fuels) are relatively short-lived (1–2 days or less) due to the accelerated evaporation and natural dispersion which the turbulence of Cook Inlet produces. Nevertheless, we have gained some sound insights and trends regarding the circulation for this part of the inlet. Prior to discussing this information, a few general comments about the tidal effects in this area of the inlet are in order.

Tidal Currents in Cook Inlet

The net circulation, shown in Figure 2, is only a small part of the circulation story in Cook Inlet. This signal has a very large noise component in the form of tidal currents. The long, narrow configuration of Cook Inlet produces tidal heights second only to the Bay of Fundy in Newfoundland. The tidal heights at the entrance and at the head are approximately 180 degrees out of phase. Figure 4 shows the instantaneous tidal heights along the length of Cook Inlet from Anchorage in the north to Seldovia in the south. In response to the tides, the water in Cook Inlet acts somewhat like a standing wave.

The resulting tidal currents average 1 to 2 knots maximum at the entrance and 5 to 6 knots maximum at the head of Cook Inlet. During times of extreme tides, maximum currents of 8 knots occur near the Forelands. Figure 5 shows the average maximum tidal current plotted as a function of position along the inlet [SHIO 1994]. The maximum ebb current, at all points along the axis of the inlet, is approximately a knot greater than the maximum flood current. This is due to the large inflow of river water into the upper inlet which results in the net outflow of water from Cook Inlet into Shelikof Strait along its western side.

Every seven days the tides move from a neap to a spring condition, causing a greater than twofold increase in tidal velocities. A typical spring to neap tidal current variation for the Forelands is shown in Figure 6 [SHIO 1994].

Figure 7, based on data from Whitney [1994], shows the average maximum tidal excursion along the inlet from north to south. The tidal excursion is defined as the maximum one-way distance a floating object or parcel of water would travel over a full cycle of the tide. From the Forelands north, tidal excursions range between 28 to 37 kilometers, while in the southern inlet this excursion distance is less than 18 kilometers.

The main features of the spring–summer circulation in Cook Inlet have been described by Burbank [1977] and Muench et al. [1978]. The circulation during the autumn–winter period has not been studied in detail. Some features of the net circulation during spring–summer for middle Cook Inlet are shown in Figure 8, which is a compilation of net circulation information from Britch [1986] and Burbank [1977]. Complex circulation patterns with high tidal current velocities are observed from south of Kalgin Island to north of the Forelands. In addition, the coastline and seafloor configuration in this area cause both a strong cross-inlet current and the development of major surface convergence, or "rip" zones, as they are locally known.

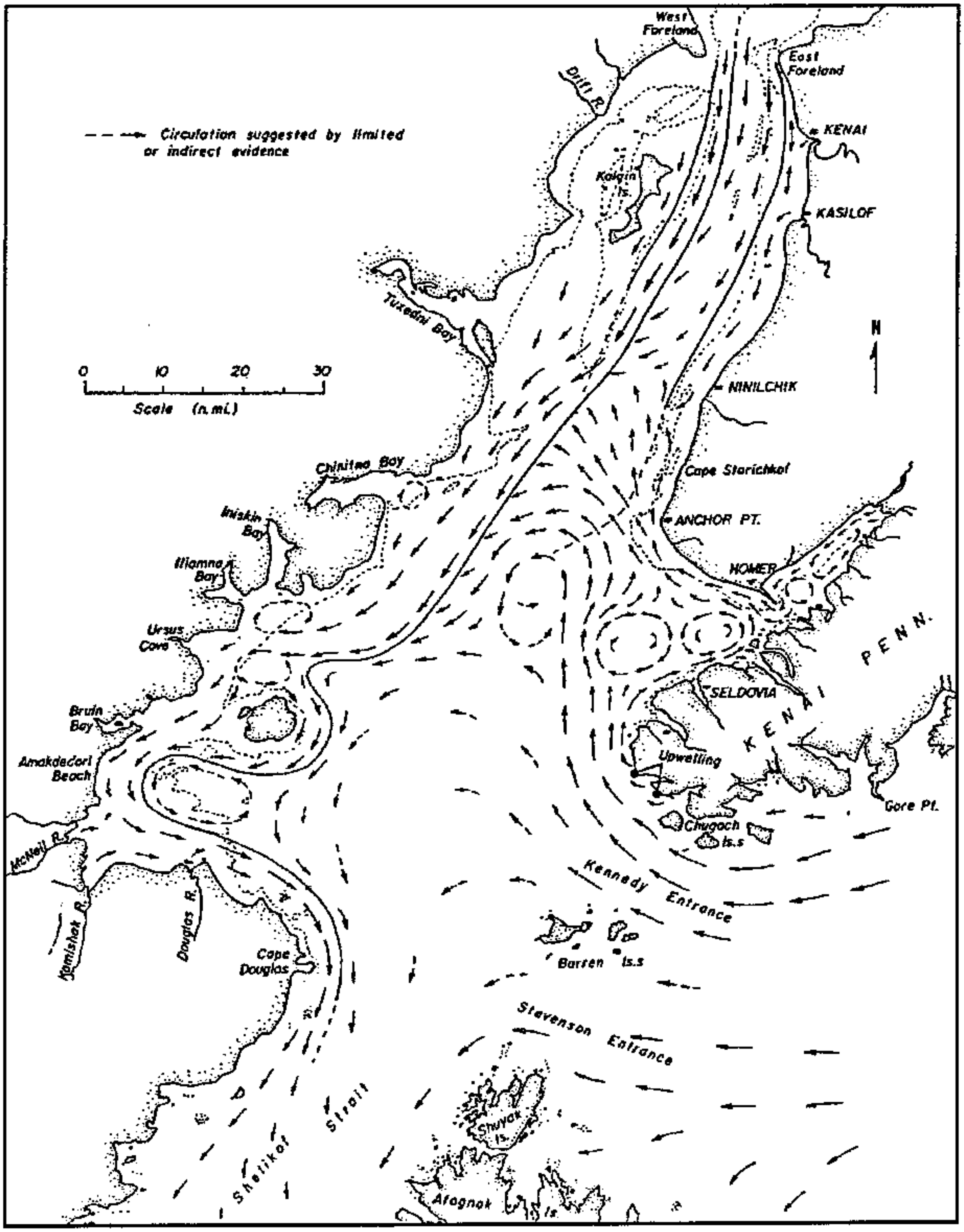


Figure 2. Net surface circulation in lower Cook Inlet, based primarily on data collected during the spring and summer seasons [Burbank 1977].

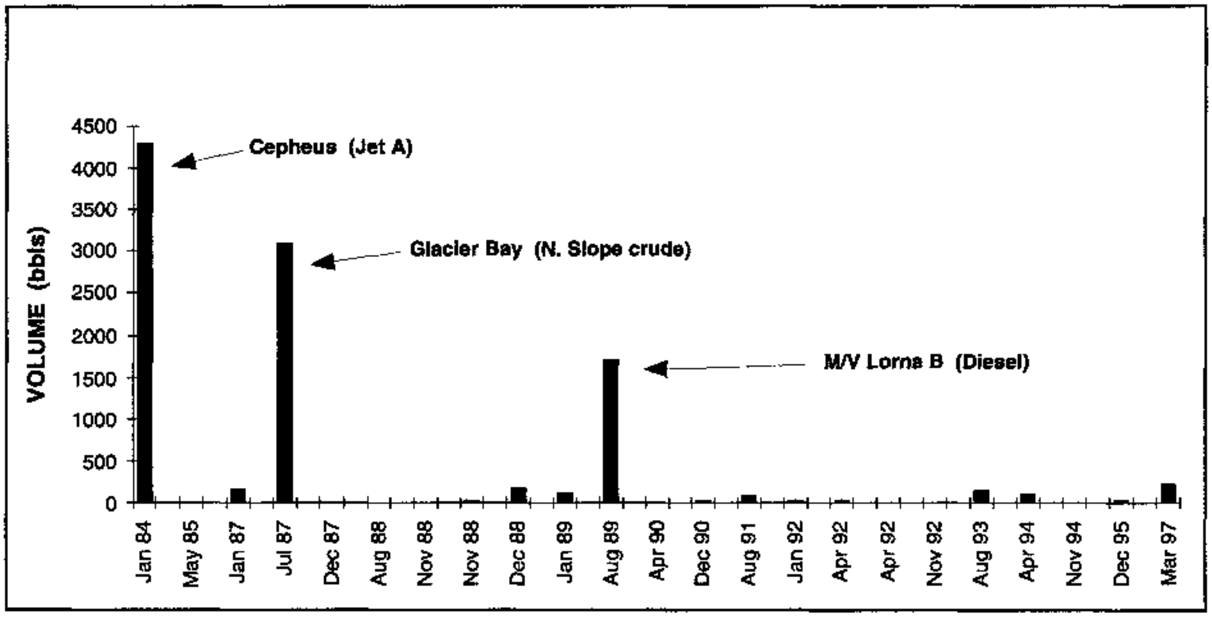


Figure 3. Cook Inlet petroleum spill history: 1984–1998.

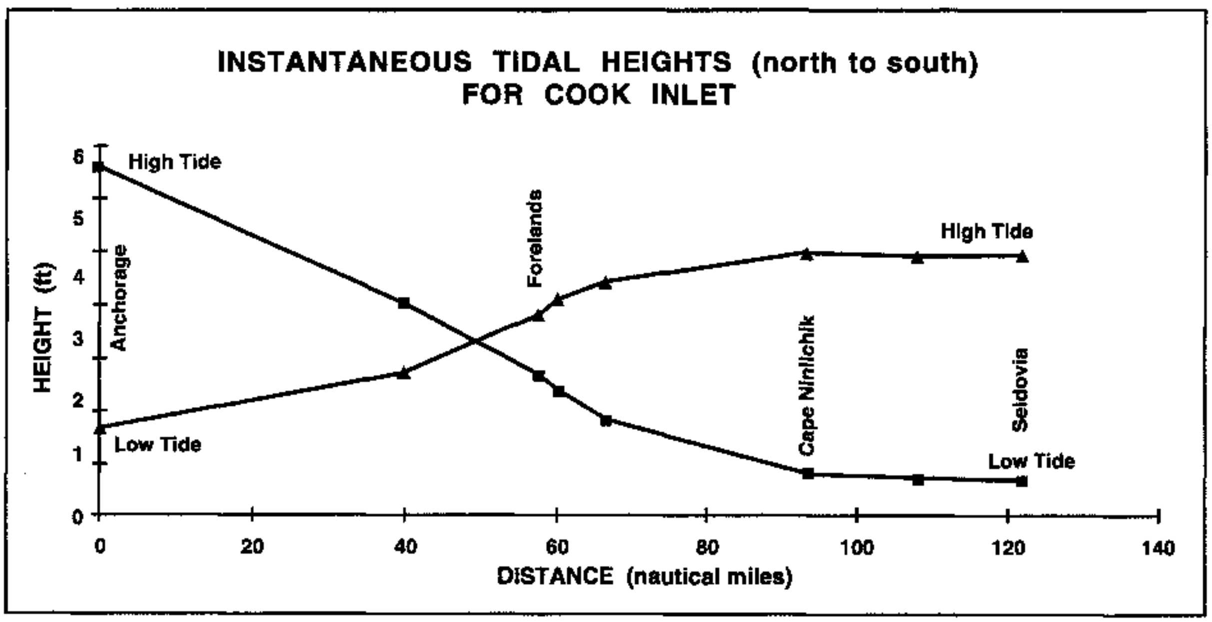


Figure 4. Instantaneous tidal heights for Cook Inlet.

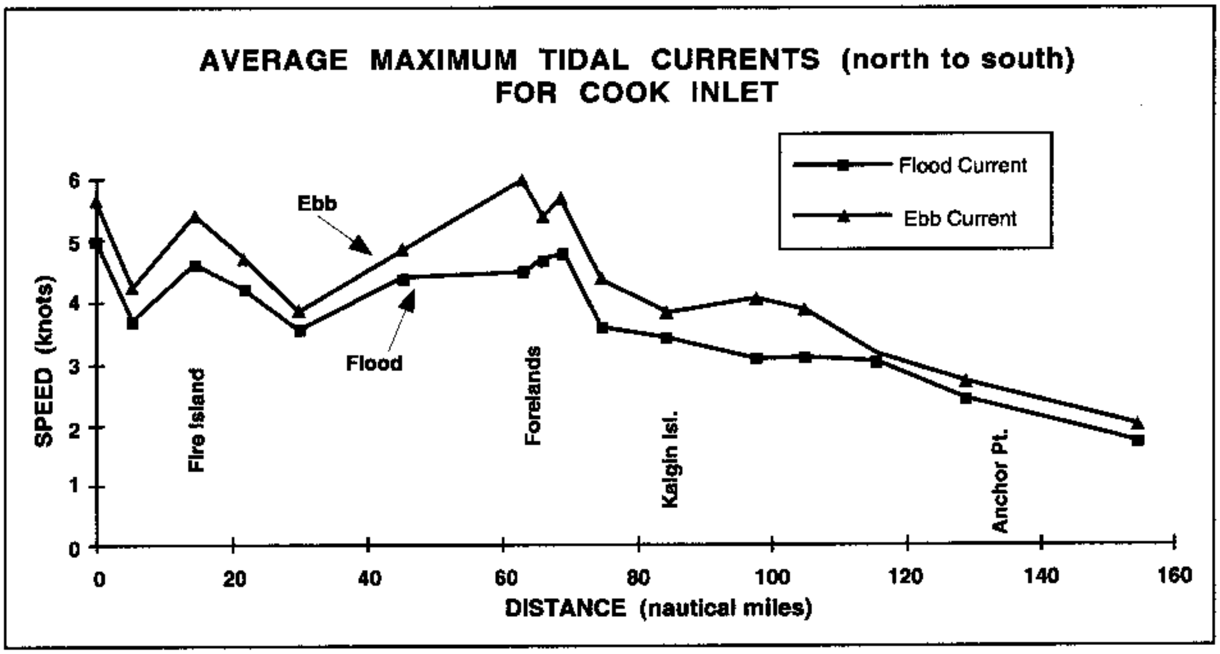


Figure 5. Average maximum tidal currents for Cook Inlet.

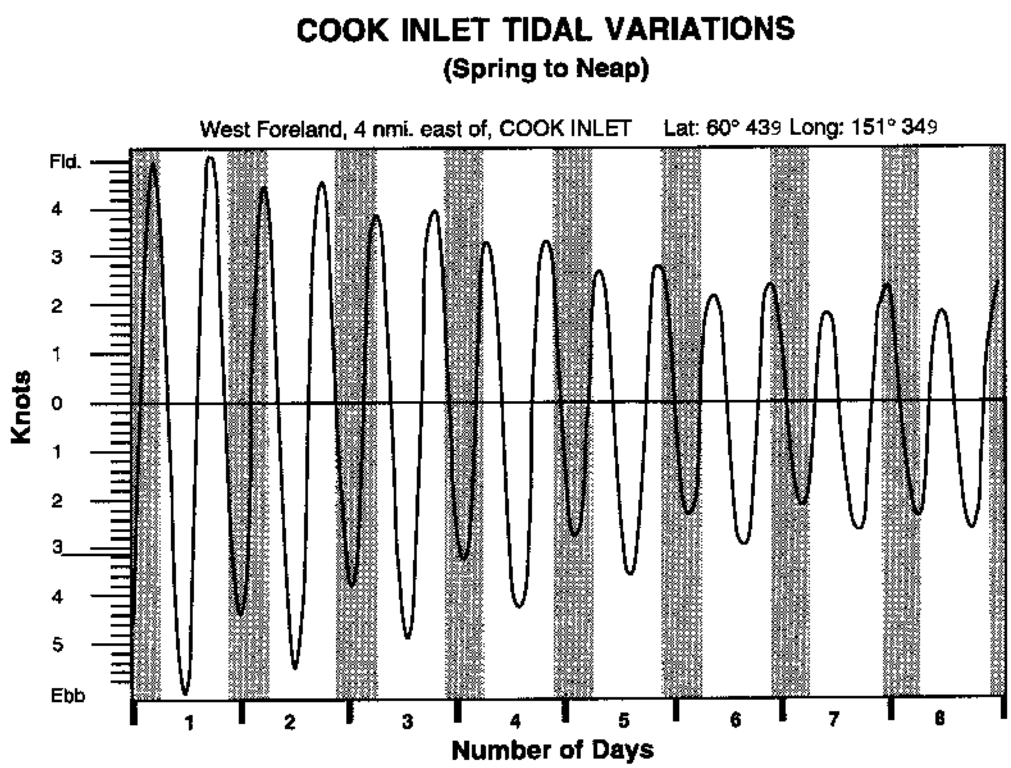


Figure 6. Cook Inlet tidal current variations.

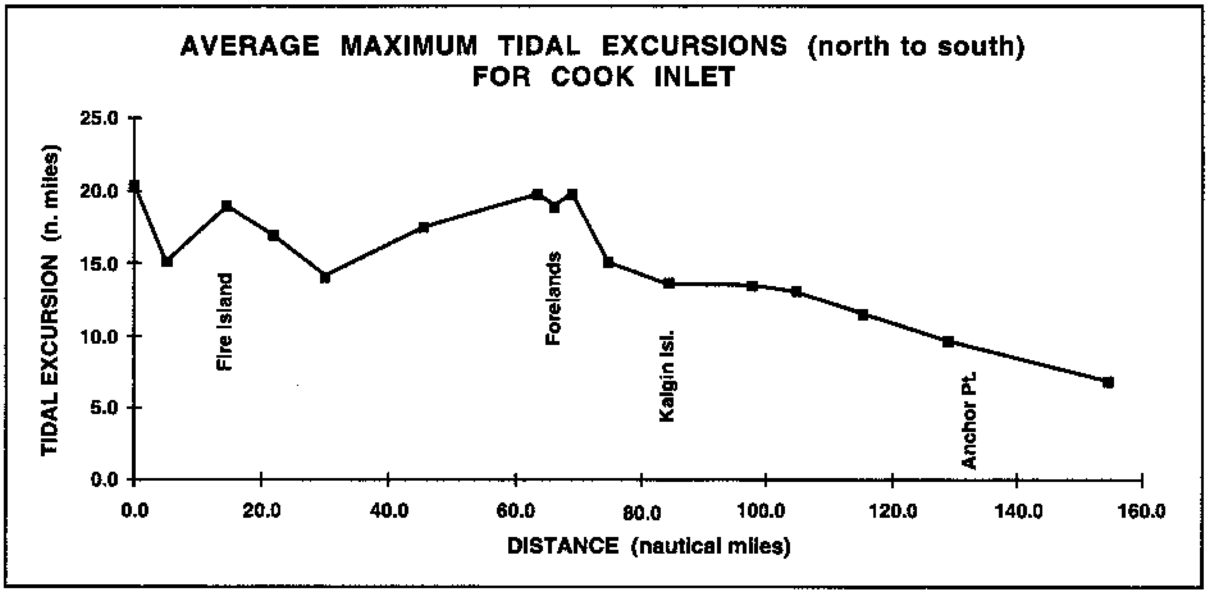


Figure 7. Average maximum tidal excursions for Cook Inlet.

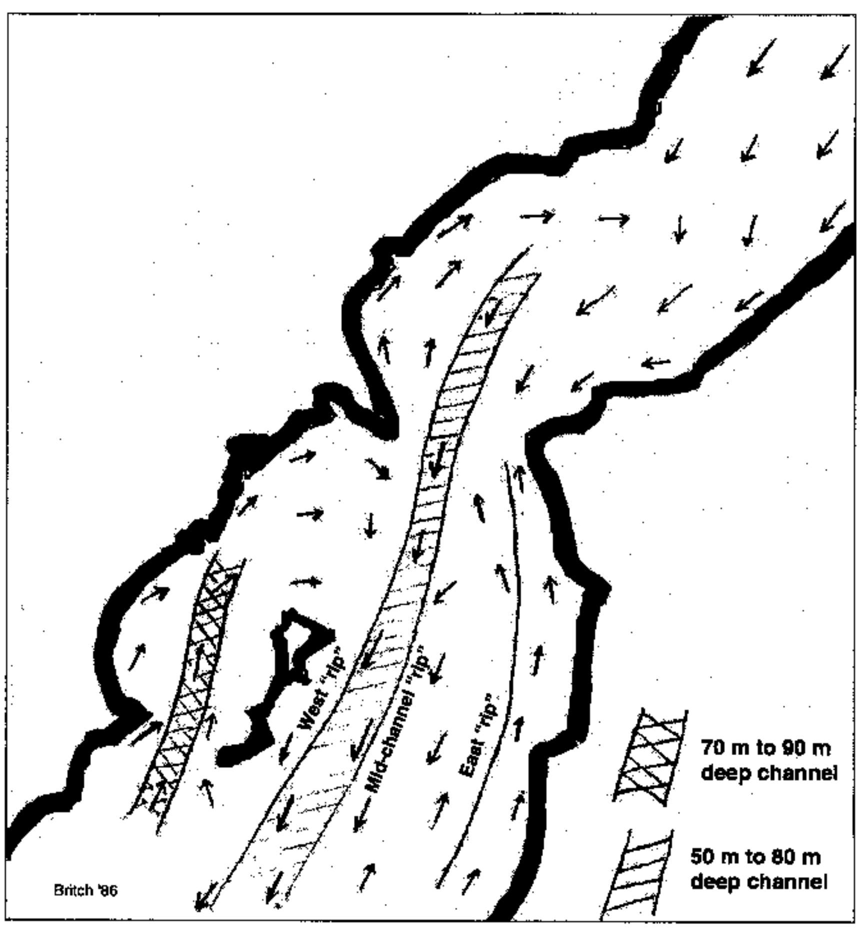


Figure 8. Middle Cook Inlet circulation and convergence zones.

Three distinct surface convergence zones have been identified in this part of the inlet (Figure 8), the east rip, the mid-channel rip, and the west rip. These surface convergence zones strongly influence the trajectory of floating objects in this region, and tend to develop near-vertical boundaries between distinct water masses, with the occurrence of shearing, convergence and divergence being manifest between the water masses during both ebb and flood tidal flow.

A distinct 50 m to 80 m deep seafloor channel between the west rip and the mid-channel rip seems to control the movement of the water mass in this area. During flooding and ebbing conditions, water in the channel flows faster, as the result of lower bottom friction, than the water to the east and west, creating tremendous turbulence at the boundaries (Figure 9). Because of the faster current of water in the channel, (especially on the ebb), a depression in the surface relative to the water masses on each side forms (Figure 10). This causes a surface convergence at the boundary accompanied by a turbulent down flow which is strong enough to temporarily submerge floating objects like small branches and oil.

Cook Inlet Winds

Winds are another major factor affecting the movement of oil, and hence circulation, in Cook Inlet. Due to the northeast–southwest elongation of Cook Inlet with mountains on both sides, winds are seasonally channeled by the inlet. Figure 11 represents a compilation of wind data from measuring stations at Anchorage and Kenai. These data suggest that in the summer the winds are predominately from the south and southwest, while in the winter the colder, denser air masses from the interior drive winds dominately out of the north and northeast. High, glaciated mountains extending along the entire west side of Cook Inlet probably produce strong and locally variable winds descending into Cook Inlet, but no data from this side have been available. In the fall of 1999, weather stations were installed on the Christy Lee dock at the Drift River terminal and on Augustine Island to monitor conditions on the west side of Cook Inlet.

Actual Oil Movement Examples

The T/V *Glacier Bay* oil spill, in July of 1987, was very instructive regarding mid-summer circulation in the middle Cook Inlet region. Figure 12 presents a summary of this event. In the early morning of 2 July, the *Glacier Bay* sought temporary anchorage off the Kenai River within the 10 fathom contour where it grounded on a large boulder, initially releasing 10–15 bbls of North Slope crude. Moving further west offshore, another 100–400 bbls were released only a few hours later. These releases occurred basically at slack before flood, as indicated by the first dot in the tidal current inset. The vessel was then moved to the Nikiski dock where a couple thousand barrels of oil were released roughly 24 hours after the initial release (second dot on tidal current inset). Winds at the time and for the next several days were from the southwest at 10–20 knots.

Normally, it might be expected that the southwest wind would drive oil on to the shoreline north and south of the Kenai River, as the oil moved with the tide. This never occurred, as the oil was pulled into the east rip zone. Figures 13–25 document the subsequent movement of the oil as it migrated west across the inlet to oil the shoreline at Drift River around noon on 6 July. Just prior to this shoreline oiling, the floating oil had moved two-thirds of the way down the west side of Kalgin Island, only to return north, oil the Drift River shoreline, and move back to the north and east of Kalgin Island. Ultimately, much of the oil became trapped on debris in the mid-channel rip zone, where it formed a long line of oiled debris. Oil spill responders were able to contain large amounts of oiled debris which were tied off in free floating doughnuts to wait further action. These "oil doughnuts", which were already in the convergence zones, surprisingly lost their oiled debris as the debris was pulled down by the vertical flow at the convergence boundary only to resurface in a much more diffuse and dilute pattern [Whitney 1994].

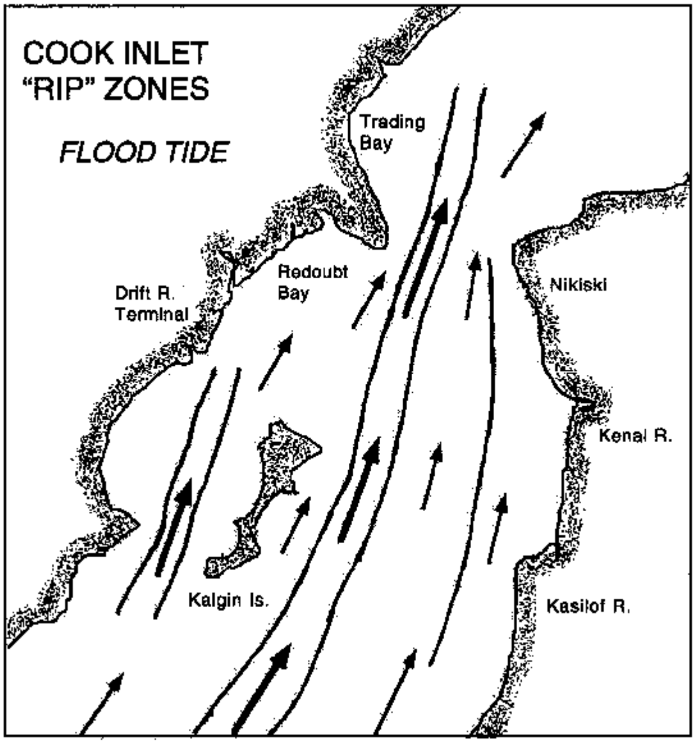


Figure 9. Cook Inlet "rip" zones – flood tide.

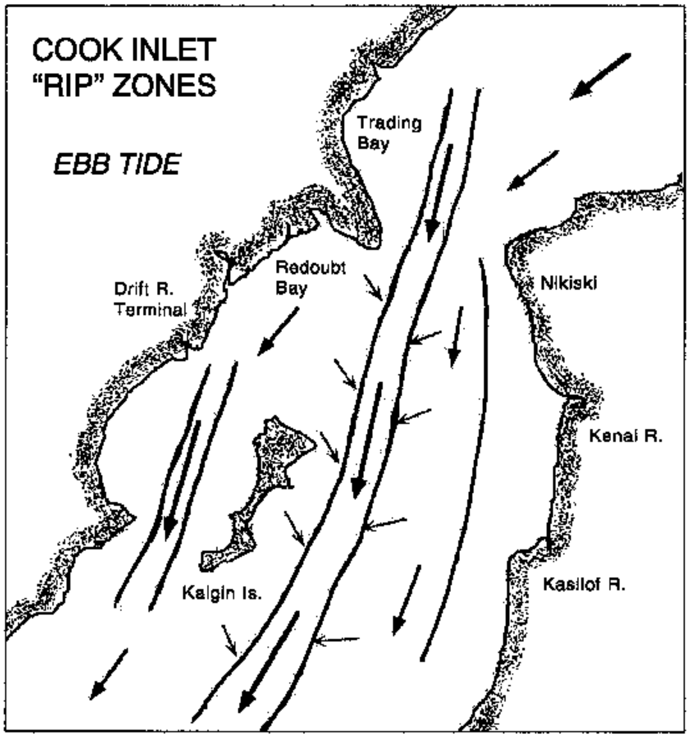


Figure 10. Cook Inlet "rip" zones – ebb tide.

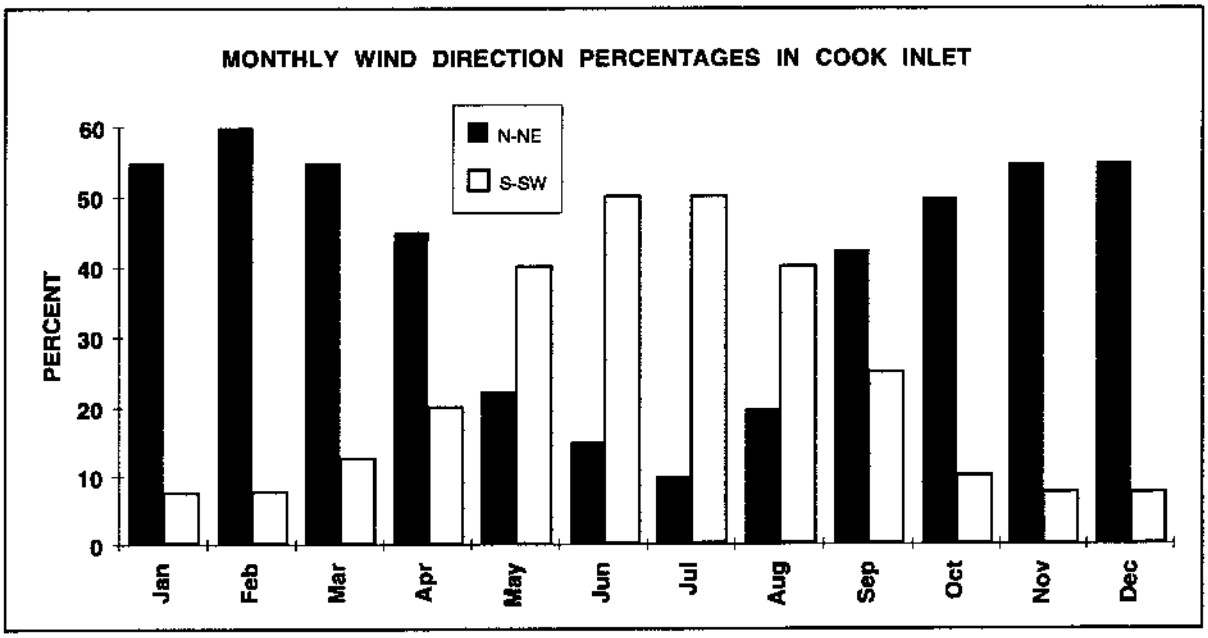


Figure 11. Monthly wind direction percentages in Cook Inlet.

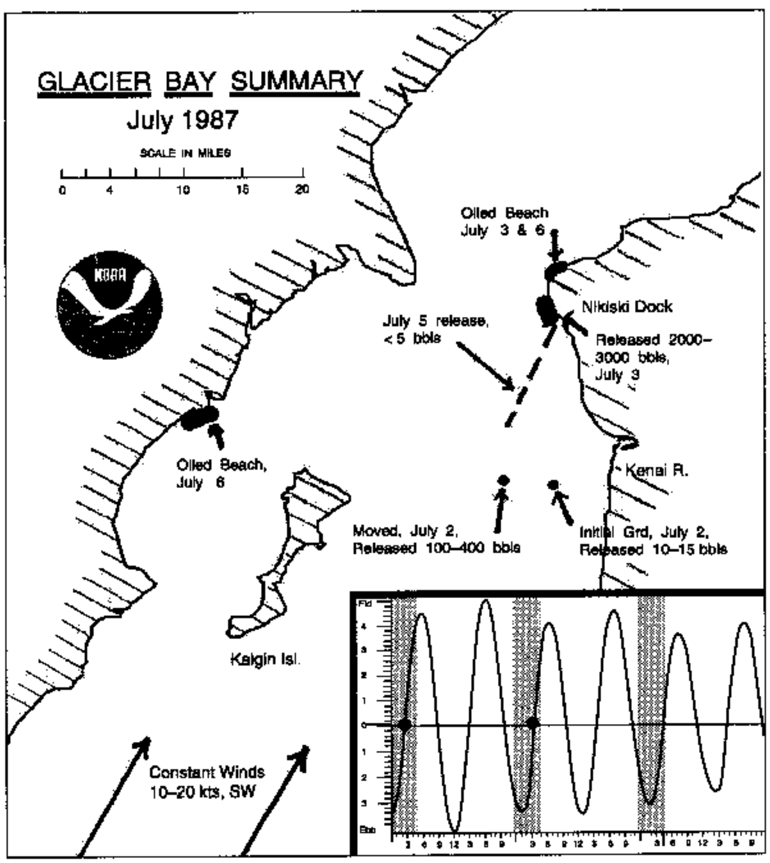


Figure 12. T/V *Glacier Bay* oil spill summary, July 1987.

Figure 13.
Glacier Bay oil observations
for 2 July, 1000–1100.

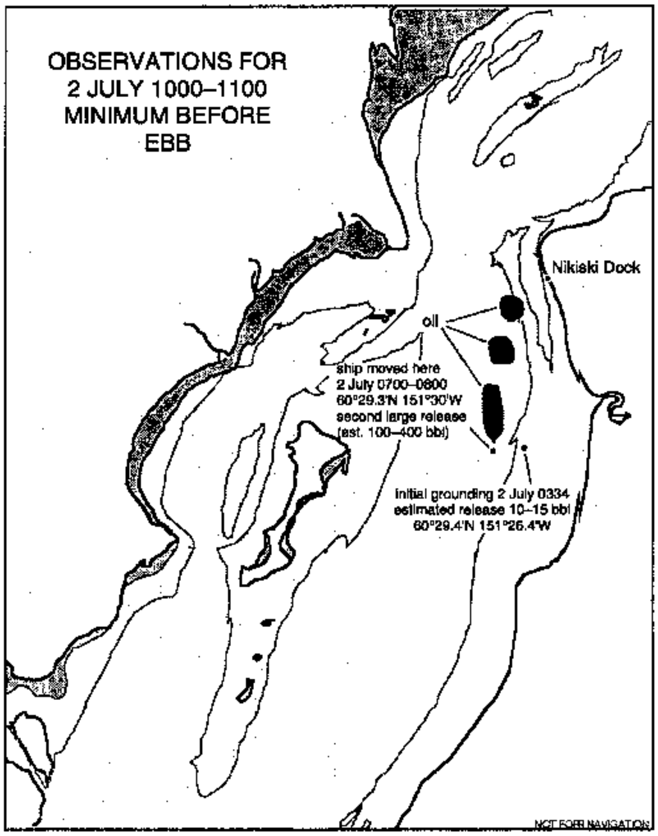
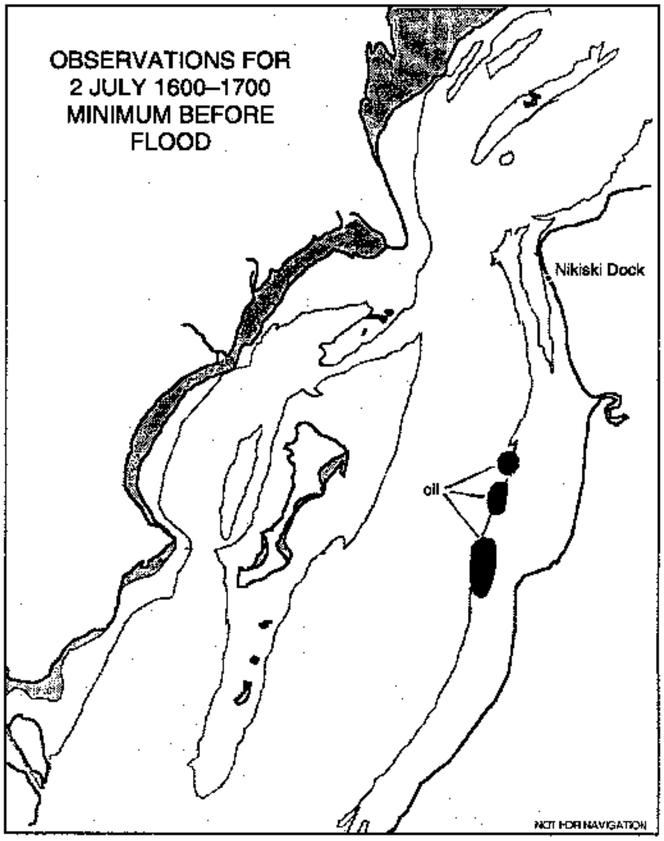


Figure 14.
Glacier Bay oil observations
for 2 July, 1600–1700.



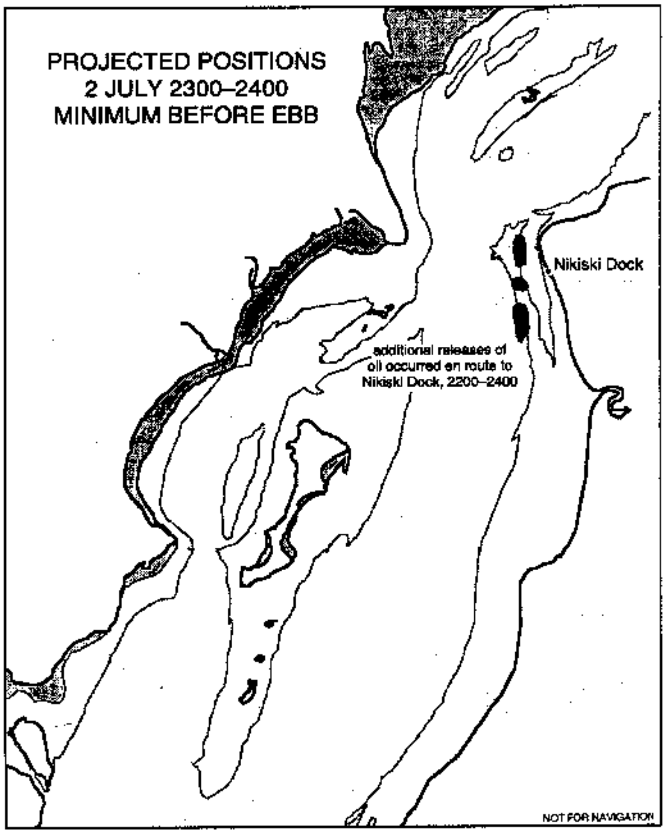


Figure 15.
Projected positions for 2 July, 2300–2400.

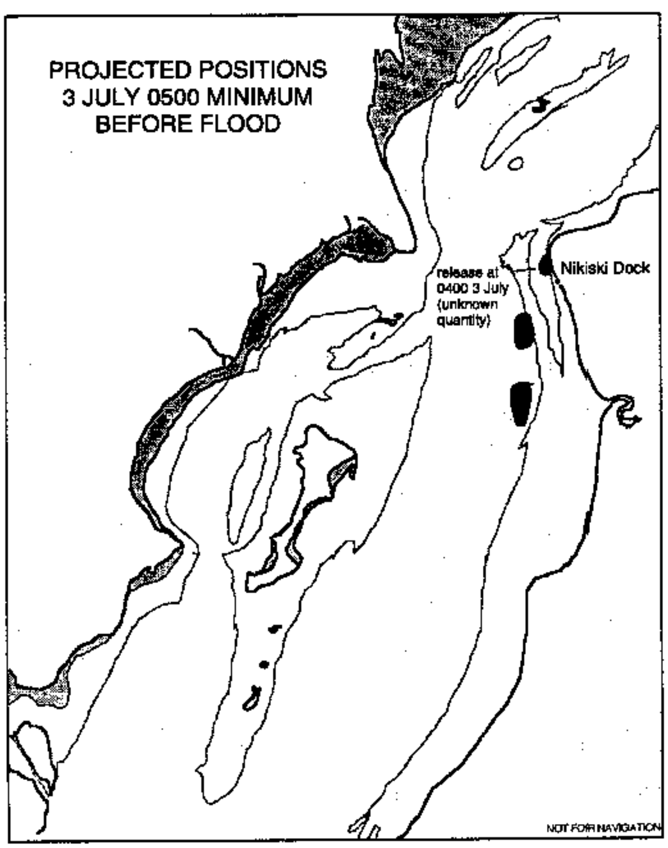


Figure 16.
Projected positions for 3 July, 0500.

Figure 17.
Glacier Bay oil observations for 3 July, 1100–1200.

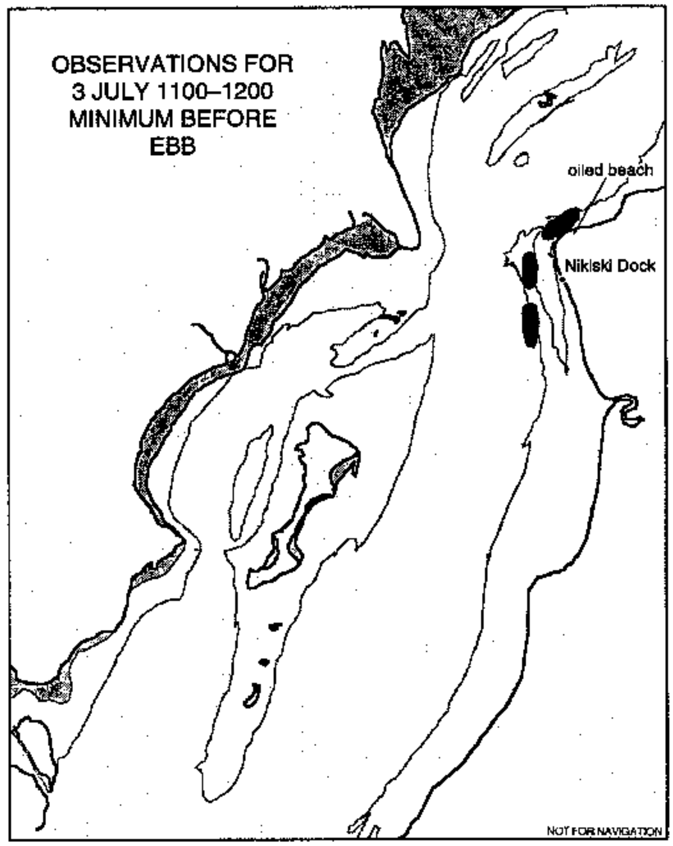
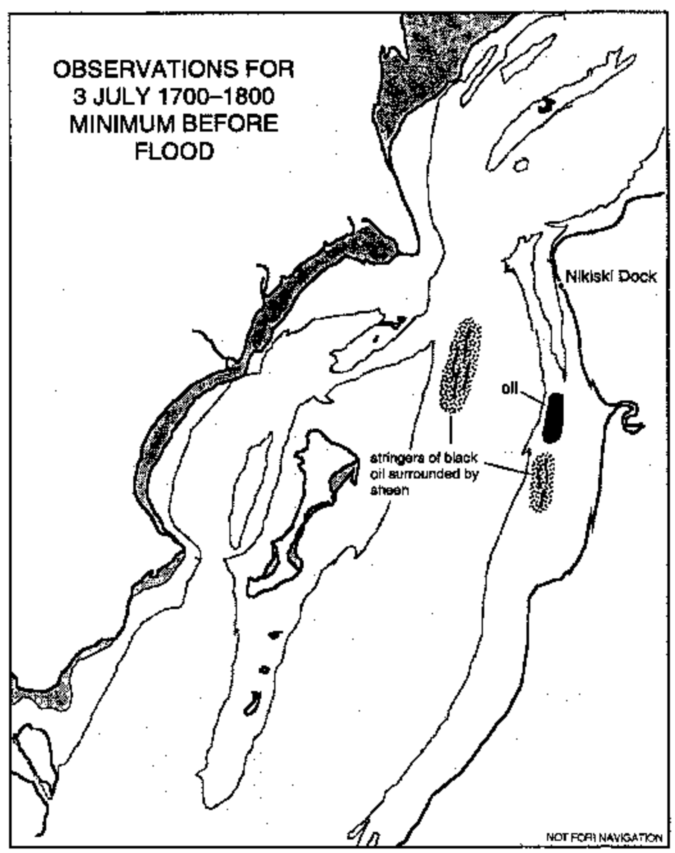


Figure 18.
Glacier Bay oil observations for 3 July, 1700–1800.



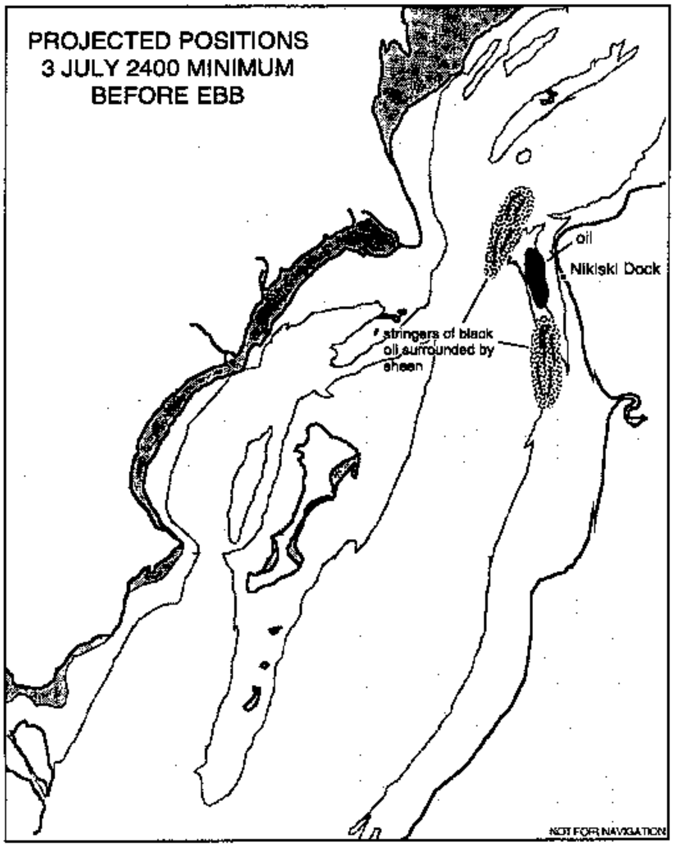


Figure 19.
Glacier Bay projected positions for 3 July, 2400.

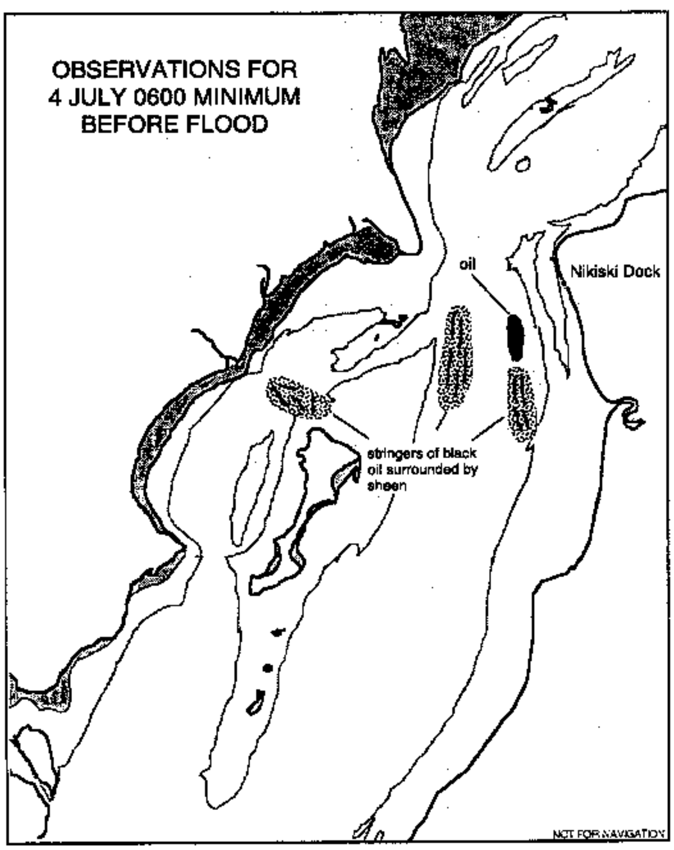


Figure 20.
Glacier Bay oil observations for 4 July, 0600.

Figure 21.
Glacier Bay oil observations
for 5 July, 0700–0800.

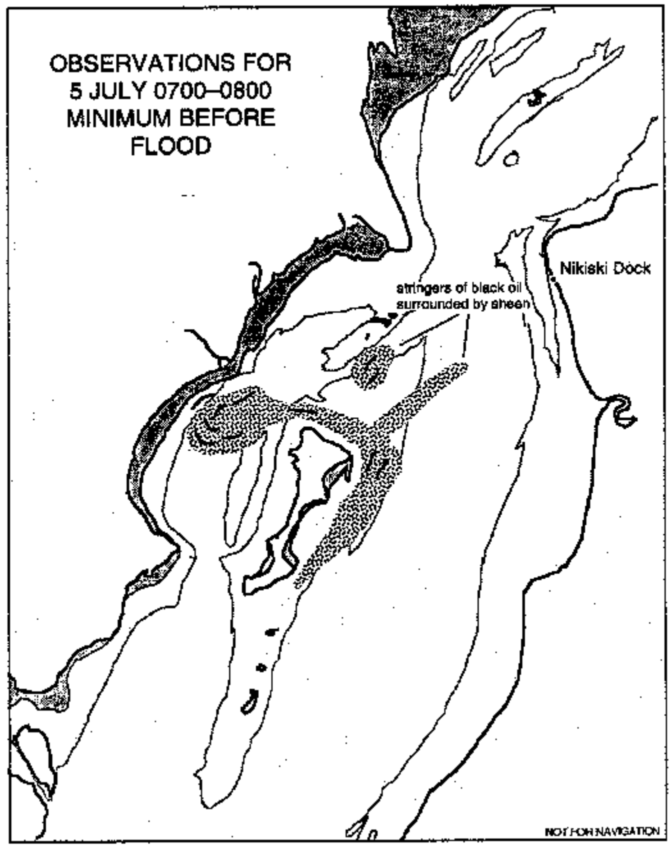
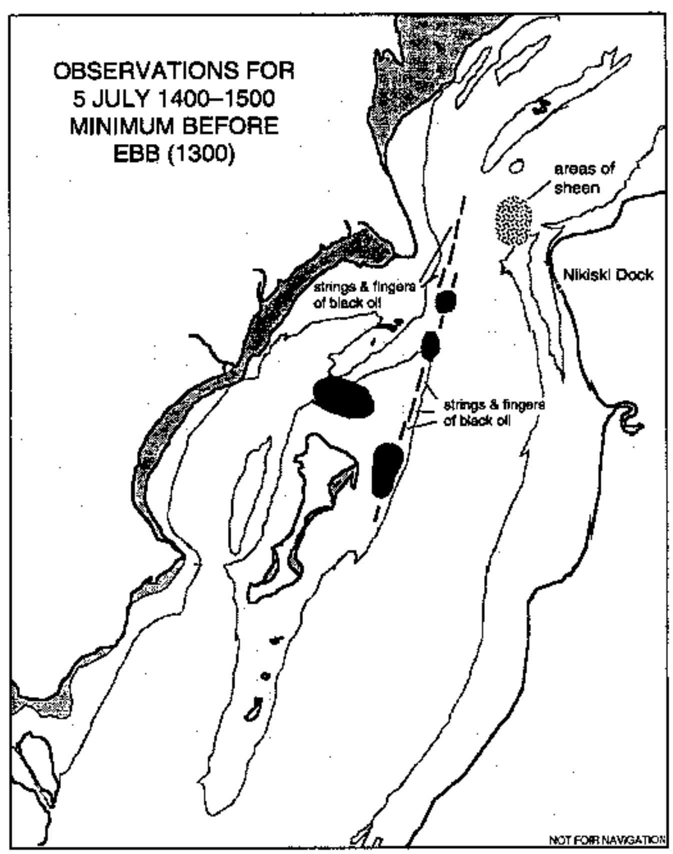


Figure 22.
Glacier Bay oil observations
for 5 July, 1400–1500.



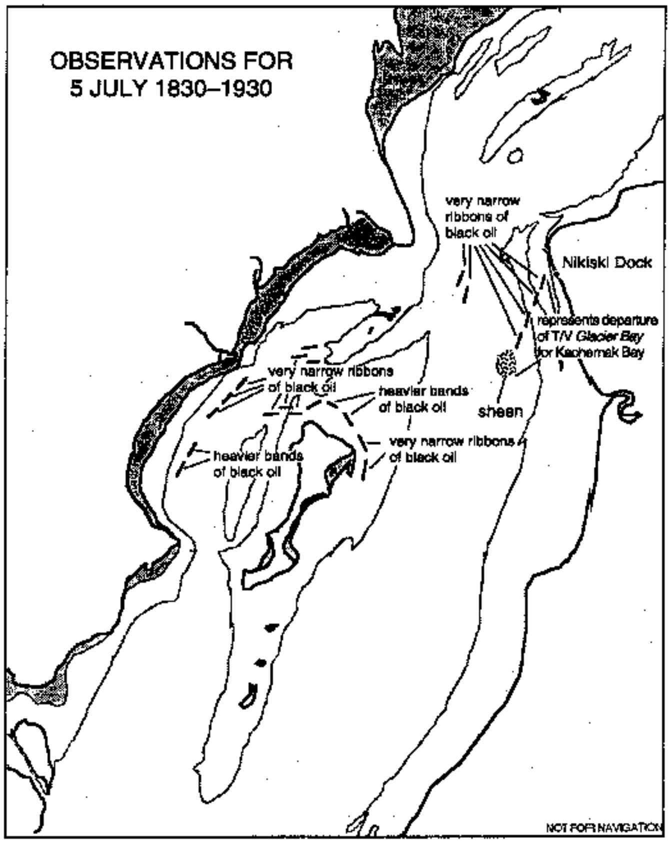


Figure 23.
Glacier Bay oil observations
for 5 July, 1830–1930.

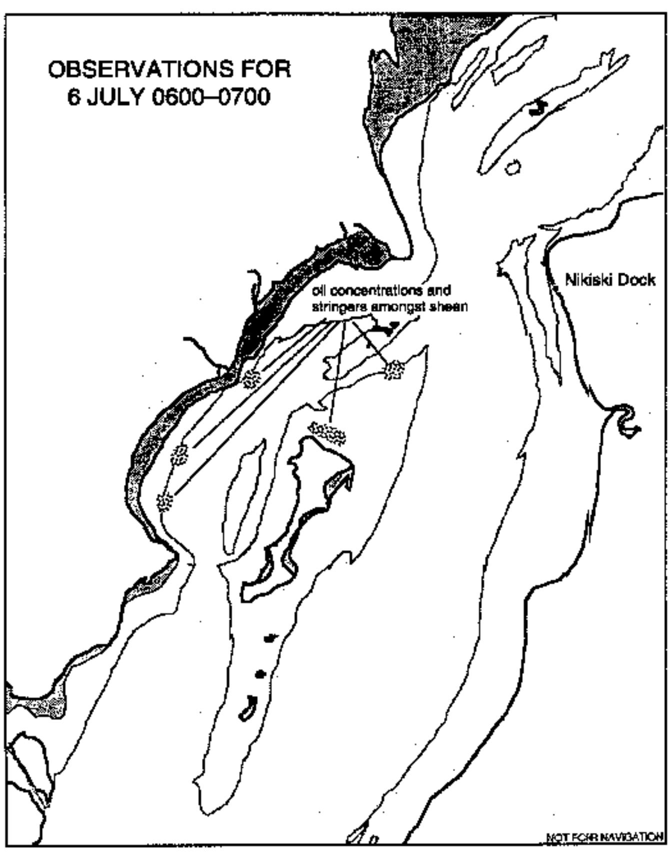
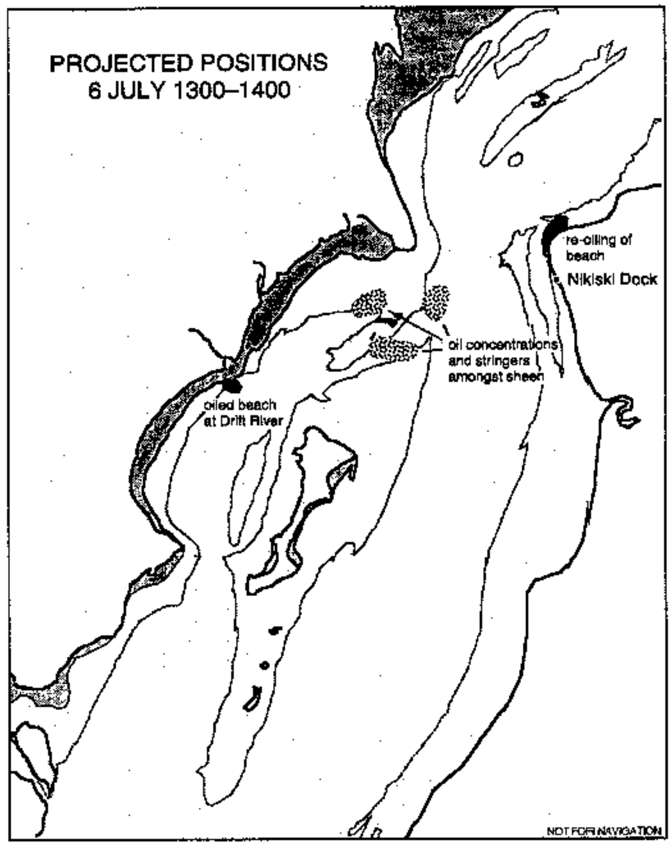


Figure 24.
Glacier Bay oil observations
for 6 July, 0600–0700.

Figure 25.
Glacier Bay projected positions for 6 July, 1300–1400.



In this part of the inlet the mid-channel rip zone seems to dominate the other rips as well as the entire hydrodynamic regime. This was further reinforced in January 1992, during the East Forelands (KPL) spill (Figure 26). This spill of North Slope crude was again released on a building flood tide just offshore of Nikiski (dot on tidal current inset). Being winter, however, this time the winds were light to strong from the northeast. As expected, the oil slick migrated westward into the mid-channel rip zone where the northeast winds locked it in and moved it south past Kalgin Island.

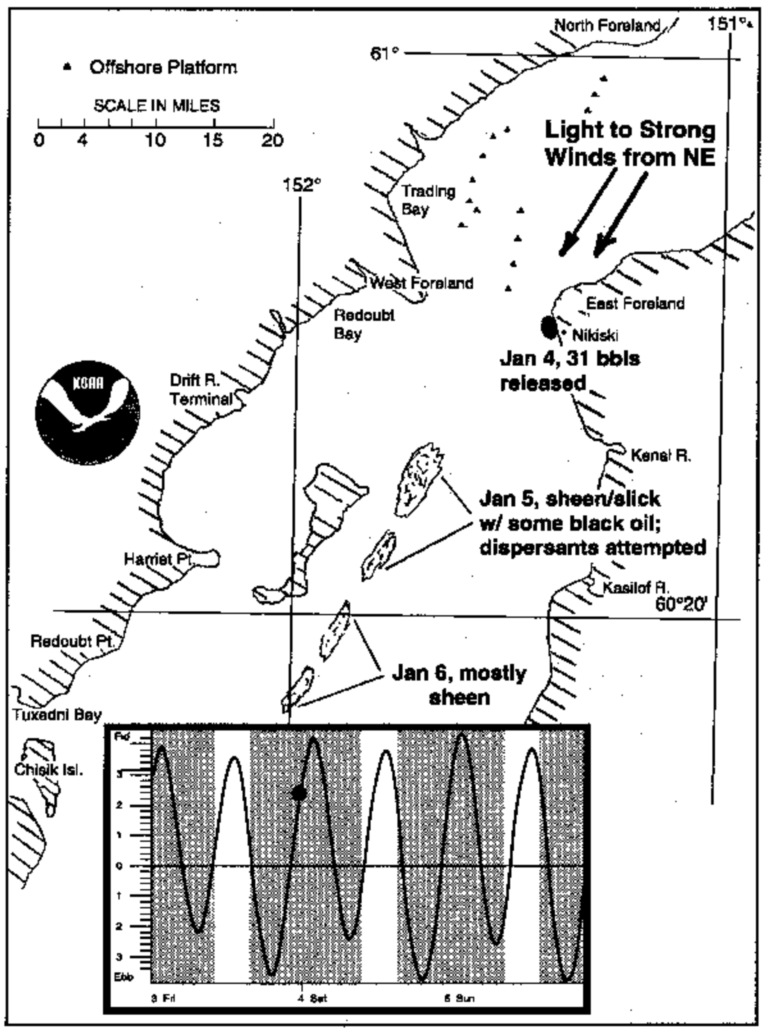


Figure 26. East Foreland (KPL) spill summary, January 1992.

Actual Ice Movement Example

During the winter of 1998–99, NOAA and Cook Inlet Spill Prevention and Response, Inc. (CISPRI) decided to conduct an experiment to determine the trajectories of ice in the middle Cook Inlet area with the idea being that in heavy ice conditions (greater than 8/10's ice coverage) spilled oil will move with the ice. As a result, satellite tracked buoys were obtained from Alaska Clean Seas, and two of the buoys were deployed on ice flows using the CISPRI support/response vessel, OSRV *Heritage Service.*

As it turned out, the 1998–99 winter was one of the heaviest ice years in the past few decades, such that on 15 February 1999, when the two buoys were deployed, the upper and middle portion of Cook Inlet had 8 to 9/10's ice coverage. Figure 27 is a RADARSAT SAR image for 14 February, 1844 AST. Since most of the surface is dynamic, broken ice, it produces a fairly good reflective surface over most of the inlet. The narrow, dark band, along the entire west side of the inlet, is probably sea ice covered with a smooth, non-reflective layer of snow. Similar large expanses of smooth, non-reflective snow covering ice probably occur in the southwest–northeast elongate dark areas half way between the East and North Forelands. The western elongate dark area is the Middle Ground shoal, and the eastern smaller one matches the large, flat snow-covered ice area from which the second buoy was actually launched. The only open water in this image is indicated by the dark black spots scattered among the new frazil and skim ice along the eastern shoreline. Figure 28 shows a SAR image for 28 February, 1836 AST, which also shows the preponderance of ice covering upper and middle Cook Inlet. These conditions continued until 12 March, when the second buoy was plucked from the water on the west side of Kalgin Island, while buoy #1, launched just off Nikiski, was lost as it was last heard streaking towards the Barren Islands.

Buoy #1 transmitted only intermittently; however, buoy #2 produced a very nice continuous record of position every couple of hours for 25 days. It's trajectory is plotted, in a somewhat filtered form, in Figure 29. All the while astride a large ice flow, this buoy first moved west into Trading Bay before rounding the West Forelands, turned south into Redoubt Bay and moved all the way to the southern end of Kalgin Island in the west channel. Remarkably, from here it executed three complete clockwise rotations around Kalgin Island. Winds were monitored throughout this period and generally were light to variable, such that it is believed that the movement of buoy #2 was mostly a result of the water circulation in the winter time.

Interestingly enough, the movement of buoy #2 mirrors some of the oil spill movement discussed earlier. Like the Glacier Bay spill, the buoy migrated to the western side of the inlet and after almost moving south past Harriet Point (west side mainland point opposite south end of Kalgin Island), it returned north and moved around the north end of Kalgin Island into the mid-channel rip zone. Once in this zone, the buoy moved south like the East Forelands spill, even though there was only a light northern wind.

A possible explanation for the strange movement of buoy #2 is offered in Figure 30 in a net Cook Inlet surface circulation proposed by Burbank [1974]. The northwest and west transport of clear seawater from Kennedy Entrance to the west side of the Kalgin Island shoal has been frequently observed in ERTS (Earth Resources Technology Satellite) imagery [Burbank 1974; Gatto 1976]. This imagery was primarily obtained during the fall and winter when fresh water runoff is low, and suggests surface water transport across the mid-channel rip rather than a subsurface transport as observed by Burbank [1977]. The reduced fresh water runoff during fall and winter probably significantly reduces surface water outflow in northern lower Cook Inlet which consequently could allow westward surface transport of intruding seawater across the mid-channel rip [Burbank 1977]. Furthermore, Burbank [1977] observes that, even during the summer, "after crossing the west side of the inlet (via either surface or sub-surface transport) the influence of intruding seawater (higher salinity and low turbidity) is distinctly observed extending northward to west of Kalgin Island." Between the northward flowing seawater current on the west side of Kalgin Island and the southward flowing mid-channel rip zone, it is not too far-fetched to imagine a current which moves objects in a clockwise merry-go-round around Kalgin Island, particularly during fall and winter.

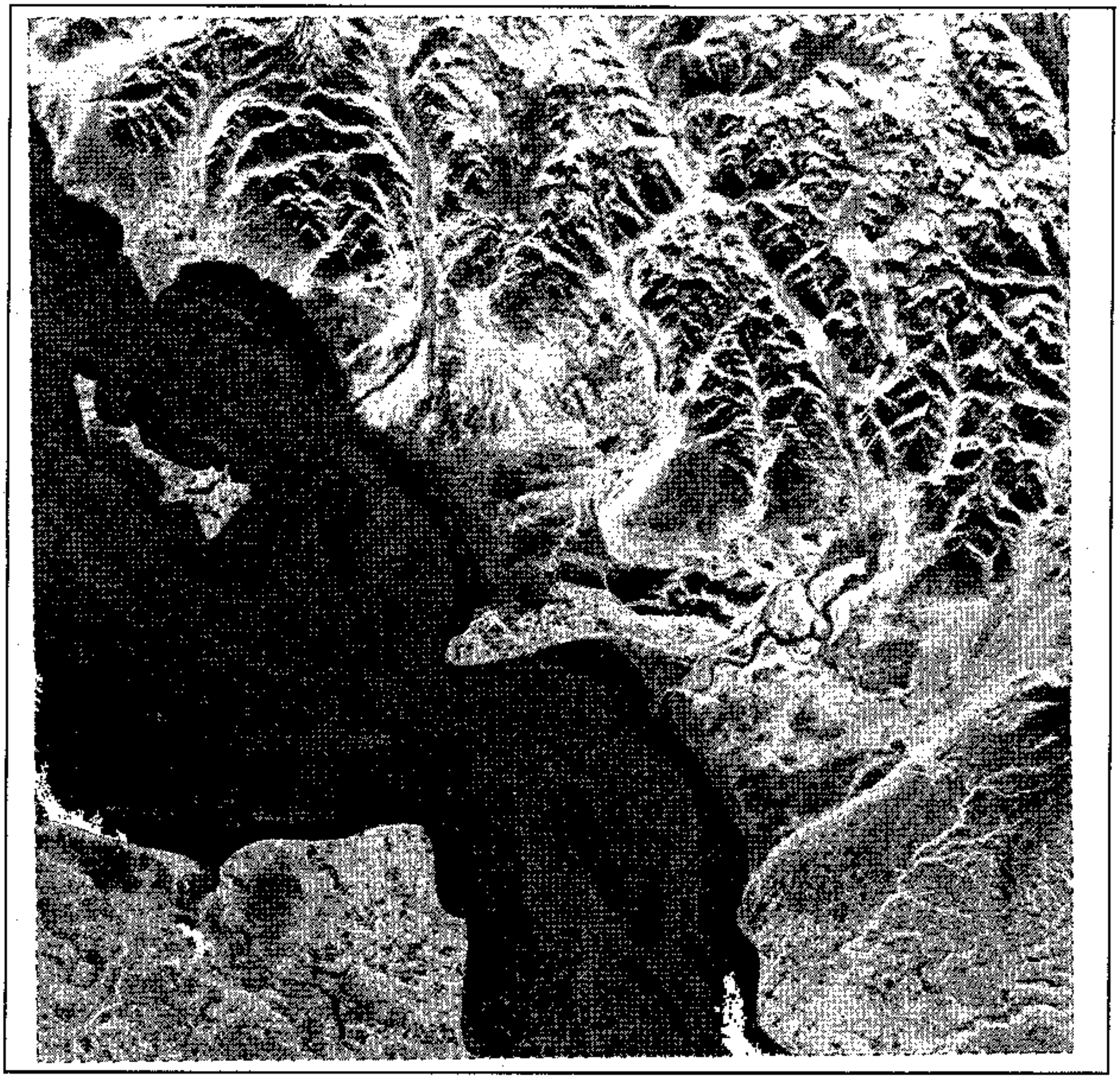


Figure 27. RADARSAT SAR image of middle Cook Inlet, 15 February 1999, showing 8/10 to 9/10 ice coverage. Dark, non-reflective returns from the west side of Cook Inlet are not open water, but sea ice covered with a smooth layer of snow.

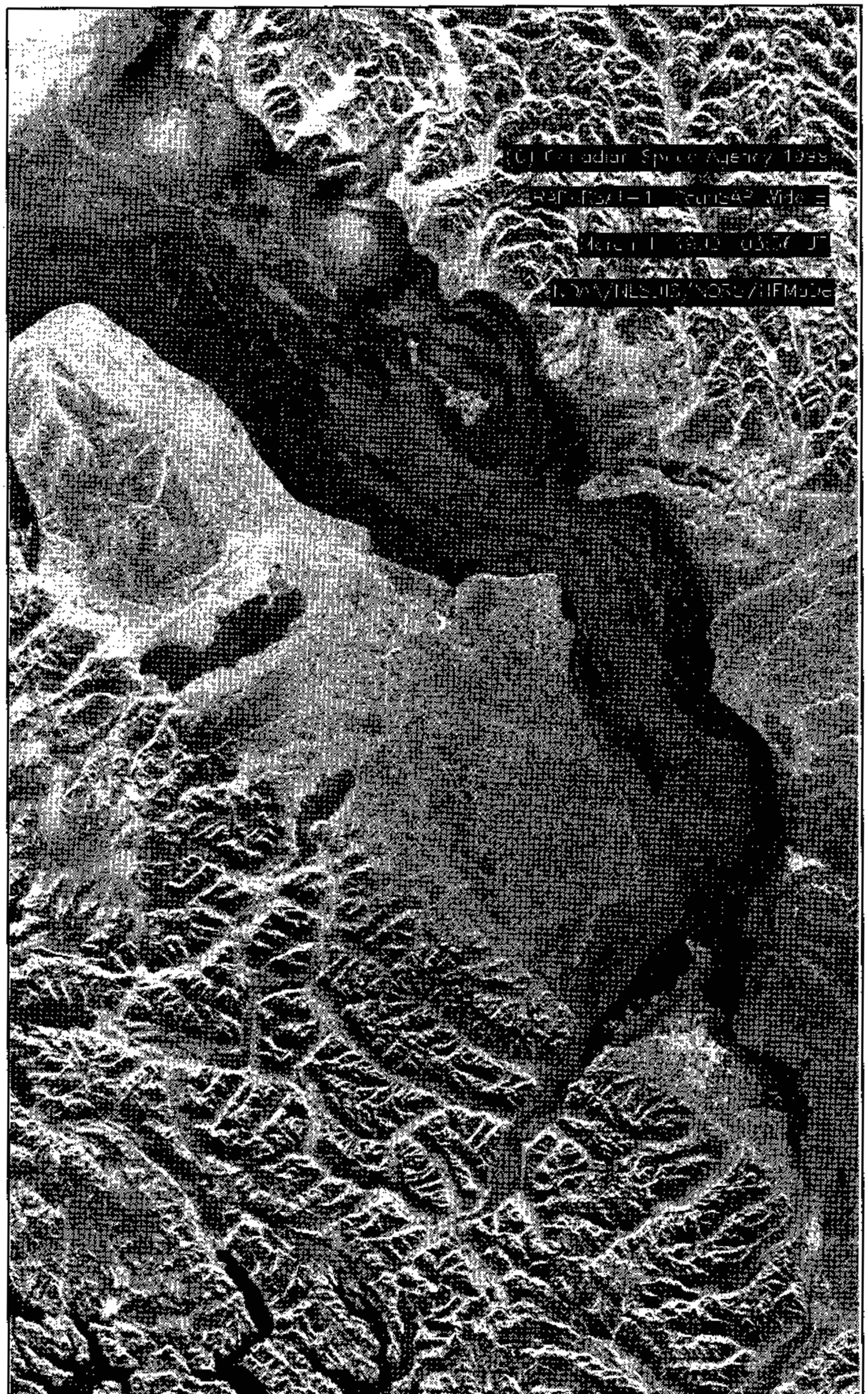


Figure 28. RADARSAT SAR image on middle and upper Cook Inlet, 1 March 1999 showing extensive ice coverage.

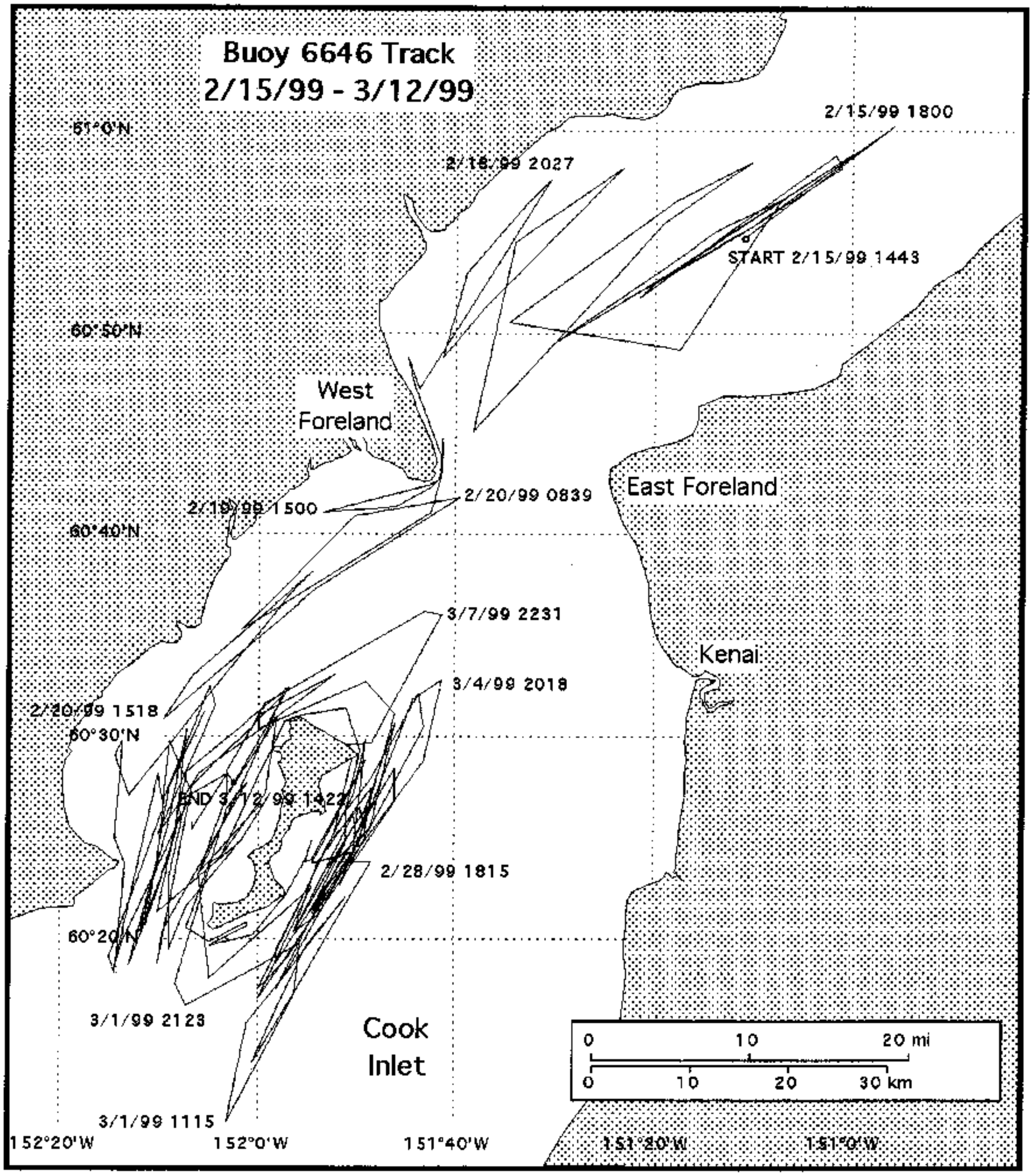


Figure 29. Buoy 6646 track, 15 February 1999 to 12 March 1999.

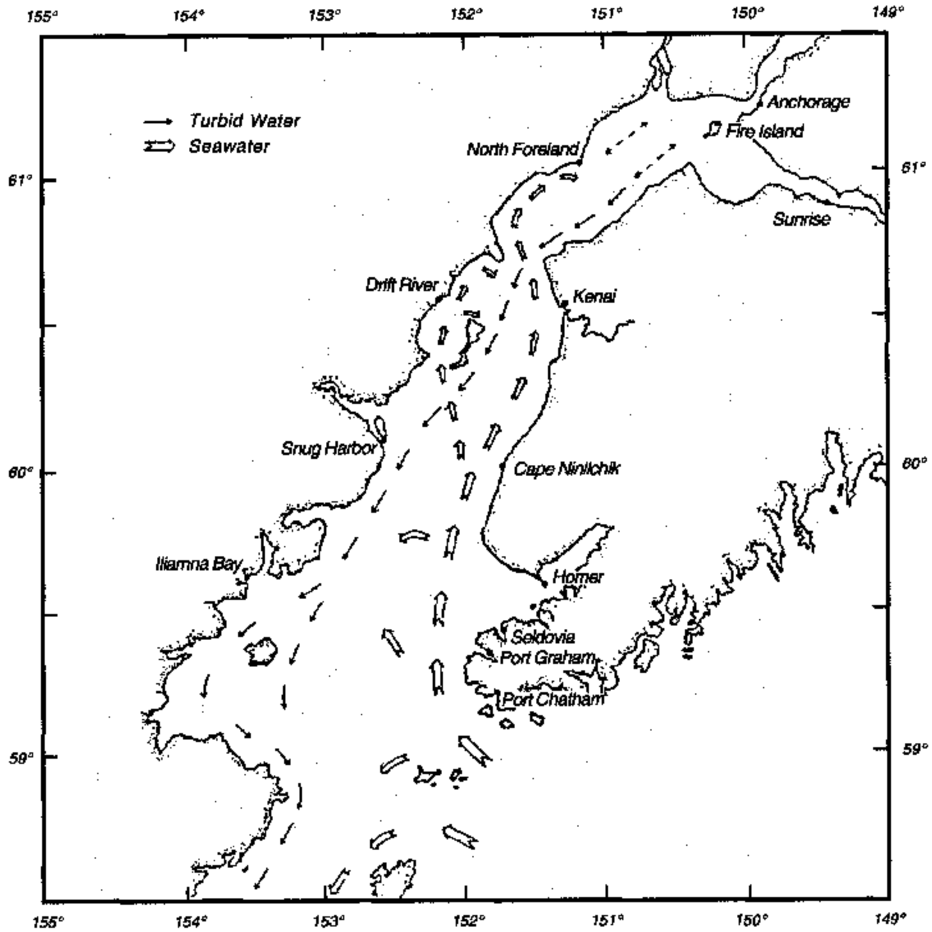


Figure 30. Net surface circulation within Cook Inlet inferred by Burbank, 1974.

Conclusions

1. Oil spilled off the mouth of the Kenai River tends to be more controlled by currents and rip zones than by winds. In general, this appears true for any oil spilled in the vicinity of the rip zones.

2. There is a back eddy on the north side of the East Forelands which always oils that beach when oil comes from the south along the shoreline. This is also probably true for both sides of the East and West Forelands.

3. Oil, and hence surface currents, tend to migrate from east to west in the central portion of Cook Inlet rather rapidly. For example, movement takes one day from Nikiski to the mid-channel rip zone and two days to the west side of Kalgin Island. Direction and speed of the wind seem to determine how far westward the oil migrates.

4. Oil on the west side of Kalgin Island, which appears to be moving south past Harriet Point, actually comes back north to the north end of Kalgin Island and enters the mid-channel rip, e.g., Glacier Bay spill, and ice buoy #2.

5. Oil tends to get temporarily pulled below the surface in the mid-channel rip zone, with this being most pronounced during ebb tides and spring tides.

References

Britch, R. 1986. Middle Cook Inlet spill trajectory analysis. A study conducted for Petro Marine Services by Northern Technical Services, Inc., Anchorage, AK.

Burbank, D.C. 1974. Suspended Sediment Transport and Deposition in Alaskan Coastal Waters, with Emphasis on Remote Sensing by the ERTS-1 Satellite. M.S. Thesis, University of Alaska, Fairbanks, Alaska, 222 p.

Burbank, D.C. 1977. Circulation studies in Kachemak Bay and lower Cook Inlet, vol. III of Environmental Studies of Kachemak Bay and Lower Cook Inlet, L.L. Trasky et al. [eds.]. Marine/Coastal Habitat Management Report, Alaska Dept. Fish and Game, Anchorage, AK.

Gatto, L.W. 1976. Baseline data on the oceanography of Cook Inlet, Alaska. Cold Regions Research and Engineering Laboratory, U.S. Army Corps of Engineers, Hanover, NH. CRREL Report 76–25, 92 p.

Muench, R.D., H.O. Mofjeld, and R.L. Charnell. 1978. Oceanographic conditions in lower Cook Inlet: Spring and summer 1973. J. Geophys. Res. 83:5090–5098.

SHIO. 1994. NOAA Hazmat Tidal Variation Program, 7600 Sand Point Way N.E., Seattle, WA 98115.

Whitney, J.W. 1994. Past experiences with spill response in Cook Inlet. Presentation at Conf. on Oil Spill Response in Dynamic Broken Ice, March 7–8, 1994, Anchorage, AK, sponsored by Cook Inlet Spill Prevention & Response Inc., Nikiski, AK.

Discussion

Joel Blatchford: I have measured the rip zones at thirty miles an hour up in the upper inlet up by the Big Su, Little Su, and Knik. I was wondering how fast you have measured them? That disappearing oil is like a vacuum cleaner in some of those areas. When that happens, you guys will never clean it up.

John Whitney: We haven't measured any speeds of the rip zones. It is a double edged sword. When the oil is dispersed by the rip zones as it is pulled down and goes out, you don't clean it up, but it is broken up into small little droplets which may have a tendency to biodegrade more rapidly. I'm not sure that that is good for the critters, but Cook Inlet is an incredible machine in terms of absorbing the oil and putting it into a form that will break down more rapidly.

Joel Blatchford: It actually hurts everybody. It depends on how you want to live with it. I've watched it since I was a kid when we had 600,000 tons of catch in a year and I've seen it drop down to 100,000 tons during all these years. Pretty soon the commercial fishermen are going to be crying.

John Whitney: It is questionable whether that is caused by oil, but that is another debate.

Unknown questioner: I don't understand why you'd expect the wind to affect oil like ice because ice has a profile and oil is basically a molecule thick. Do you expect it to be moved by the waves that the wind creates? How do you expect the wind to affect the oil movement?

John Whitney: Jerry, what is the answer to that?

Jerry Galt: The winds set up a shallow wave driven layer which moves at about 2 percent and the oil floats on that. In addition to that, even a very thin few molecule's thick sheen of oil forms a slick because it absorbs capillary waves. So the momentum that was in the waves is transferred to the slick itself. If you throw a dye out, for example, in front of an oil spill, you find out that the slick crawls right over the top of the oil that it is floating on. It is being pushed by the waves that it absorbs. If you add the two together, you get the rule of thumb of about 3 percent of the wind speed.

Jerry Galt, Office of Response and Restoration, NOAA, Seattle, WA

Trajectory Analysis for Cook Inlet Using Simplified Models

Introduction

The NOAA HAZMAT program provides technical advice to the Unified Command as specified under the National Contingency Plan according to OPA-90. Doing this has led HAZMAT to develop several simplified procedures. These, coupled with various trajectory model options, allow a quick regional estimate of the movement and spreading of spilled oil. These techniques have been used a number of times in actual spills, planning activities and drills in Cook Inlet.

This talk presents a few of the features of a simple trajectory analysis tool that was developed for central Cook Inlet. These methods display a number of observed features using barotropic models which can be developed from scratch in a few hours. All of the figures that are presented come from the trajectory analysis model GNOME (General NOAA Oil Modeling Environment).

Slide presentation

Figure 1 shows the extent of the study area and the triangular finite element grid. The grid is used to calculate the hydrodynamic solutions used to describe the advective component of the flow for the flood tides.

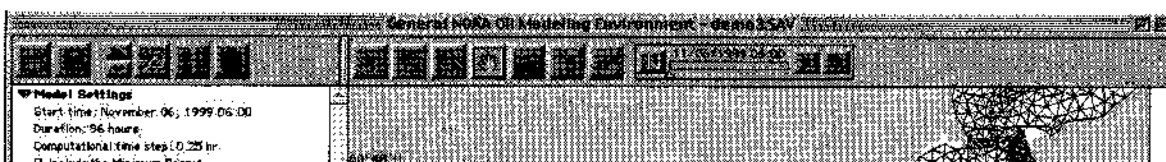


Figure 2 shows the flood current pattern. Note that the deeper channel along the west side of Cook Inlet provides a phase shift resulting in cross inlet flow from west to east across the relatively shallow flats both north and south of Kalgin Island. This process plays a fundamental role in forming the local convergences that are responsible for the western rips that are regularly observed in Cook Inlet. A second feature that is obvious is the shear along the eastern shore of the inlet which is seen to contribute to the eastern rips. Less obvious are the bands of currents through the Forelands that appear to contribute to the central rip. All of these features are inherent in the trajectory analysis that follows.

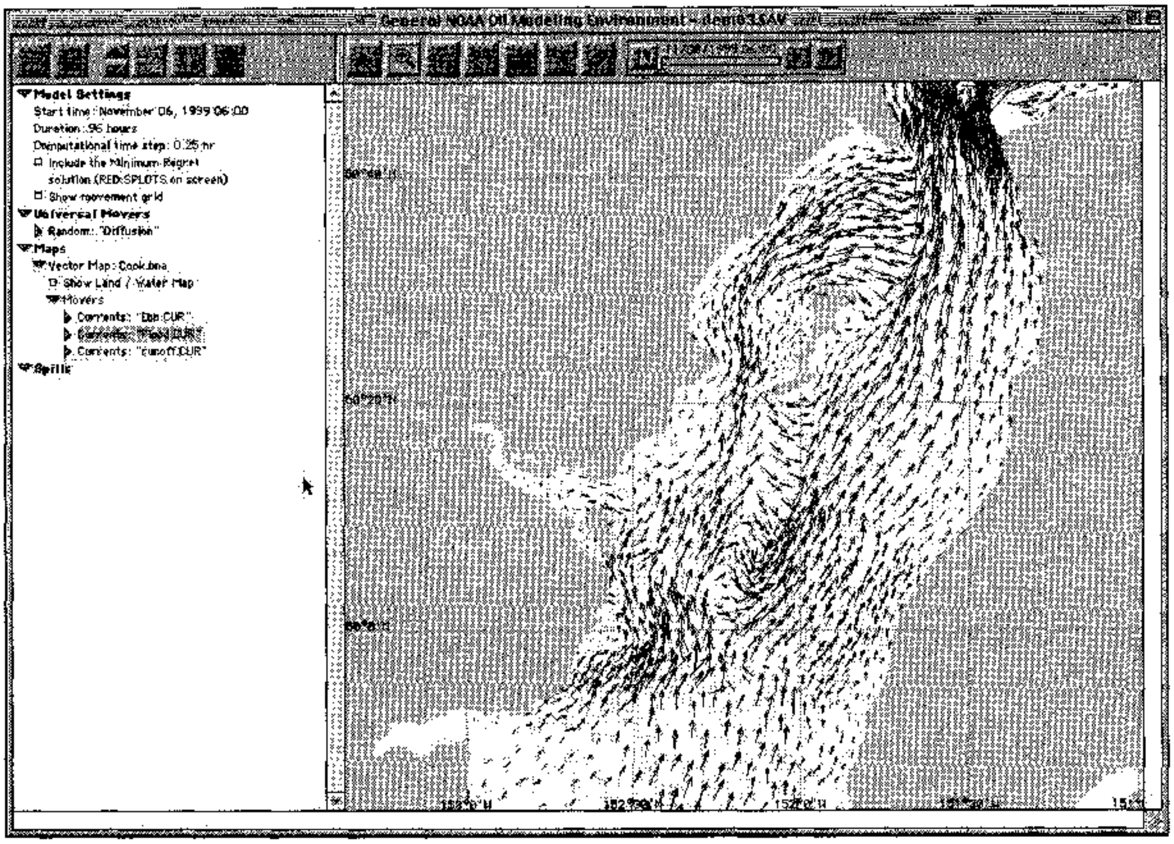


Figure 3 shows the distribution of pollutant particles nearly one tidal cycle after their release in a line across the Forelands. Several advective features are apparent. First, a banded structure can be seen in the net displacement along with a general net set to the south, and second, eddies associated with the east side of the Forelands cause longer residence times in the areas just north and south of the point.

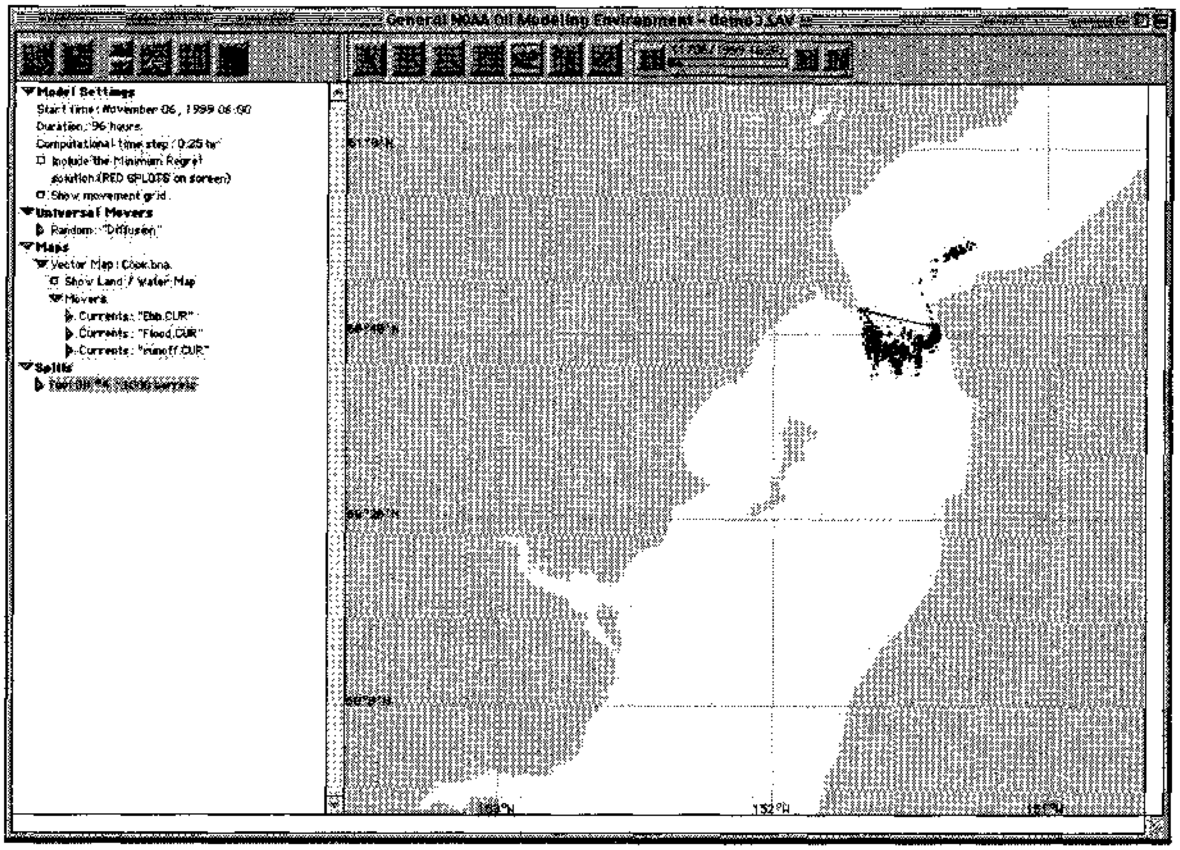


Figure 4 shows the distribution of pollutant particles just over 40 hours into the spill. Some of the characteristic convergence and transport processes can be seen in the particle patterns.

The banded structure south of the Forelands has started to organize the particles into a strong convergence zone. The convergence zone southeast of Kalgin Island has trapped the particles into another banded distribution that is typically associated with the western rip. It should be noted that both of the above features are associated with strong bathymetric features and that a simple barotropic model that correctly resolves the bathymetry and includes minimal long wave physics should reproduce these features. We should also expect that the observed manifestation of these convergence zones would be tied to the bathymetric features and generally appear in the same area.

The lineation of pollutant particles that hooks around the eastern and south central extent of the spill is caused by the current shear set up along the eastern side of the inlet. The actual shape and strength of this shear zone will typically depend on the internal density structure. An early work by Burbank [1977] shows this area has a major intrusion of high salinity flow. As a result, we might expect that what we have developed using a simple barotropic model gives only an indication of the general position of this feature. This is also an area where the strength and actual position of the convergence, eastern rip, will vary depending on the strength of the baroclinic intrusion. It is not strongly influenced by a specific bathymetric feature.

Smaller scale features that can be identified are the longer residence times along the eastern head of the Forelands, and some isolated patches of pollutant particles moving to the west behind Kalgin Island.

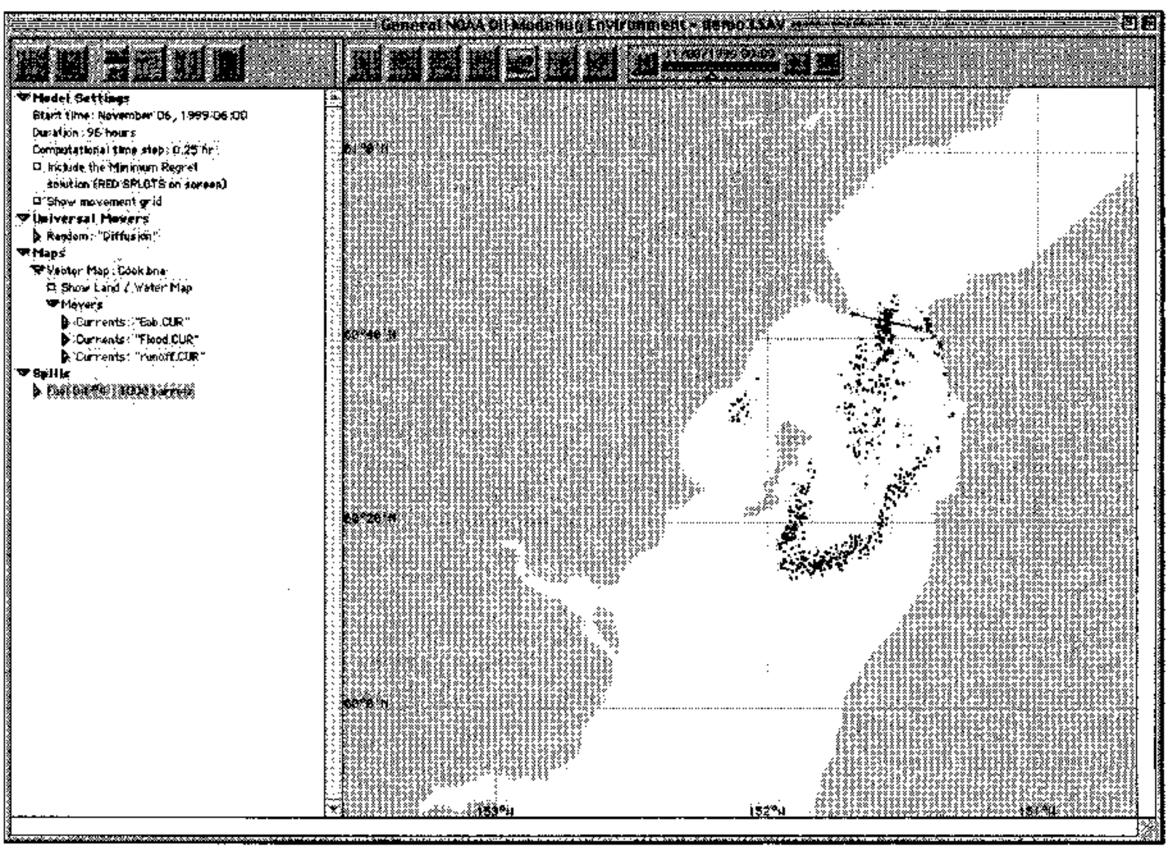


Figure 5 represents a slightly different initial distribution of the spilled particles in the trajectory model. One spill source is along a line from east to west across Cook Inlet at Nikishka. A second spill source is along a line to the west of Kalgin Island. A few hours into the spill we see very strong evidence of the bathymetric induced shear off the transect near Nikishka.

In the spill west of Kalgin Island there is evidence of counter clockwise flow that eventually contributes to a clockwise flow around Kalgin Island. The phenomenon has been reported by Whitney [1994] in his analysis of drogue trajectories. These features were found to be associated with the input of runoff from streams which sets up a local pressure gradient that can drive a coastal current. This mechanism was described by Royer [1981] in association with the Alaskan Coastal Current off Seward. Once again, these features can be resolved with a simple barotropic model with appropriate boundary conditions.

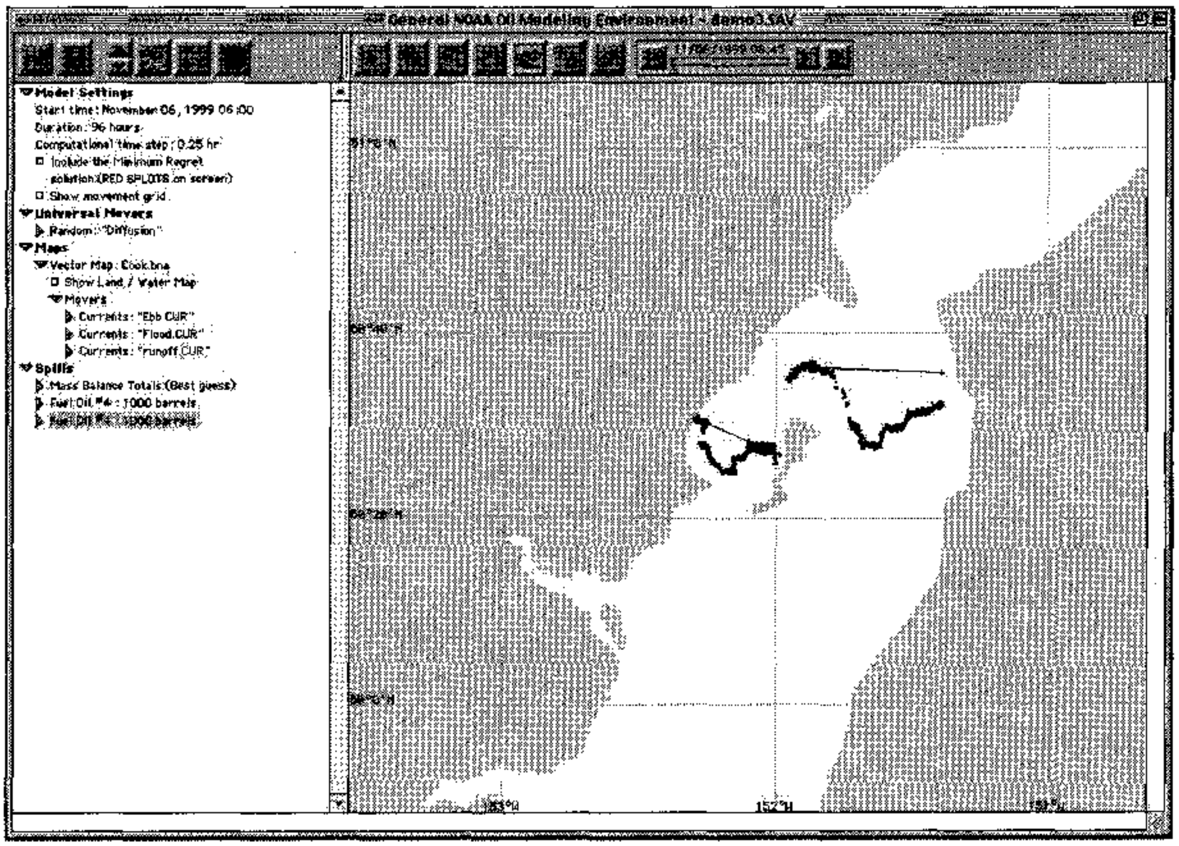
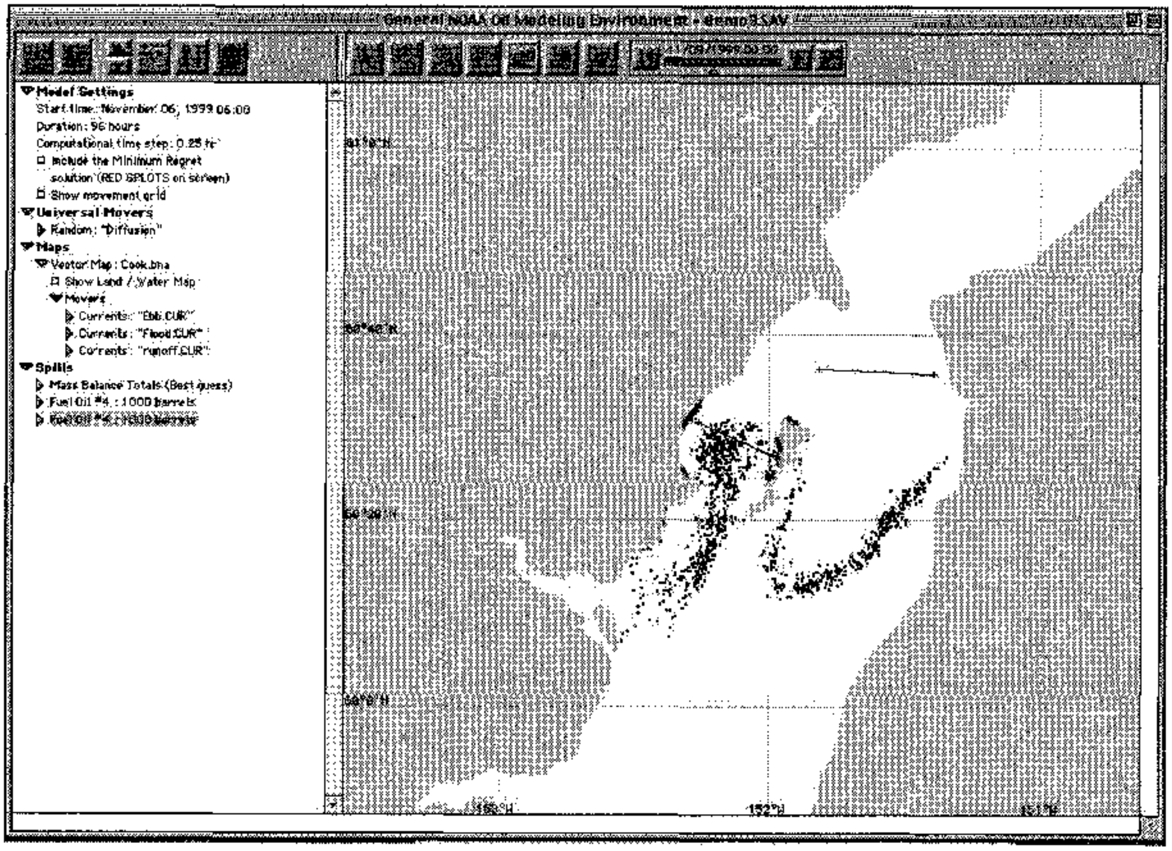


Figure 6 shows the particle distribution from the previous release 24 hours into the spill. The particles moving in a clockwise direction around the north end of Kalgin are clearly evident, and the convergence zones in the eastern channel are starting to line up and capture the floating pollutant particles.



By 40 hours into the spill (Figure 7) the bathymetrically controlled west rip and the shear controlled eastern rip have clearly collected most of the floating particles in the eastern channel of Cook Inlet. It appears there is also a significant convergence zone down the deep channel west of Kalgin Island.

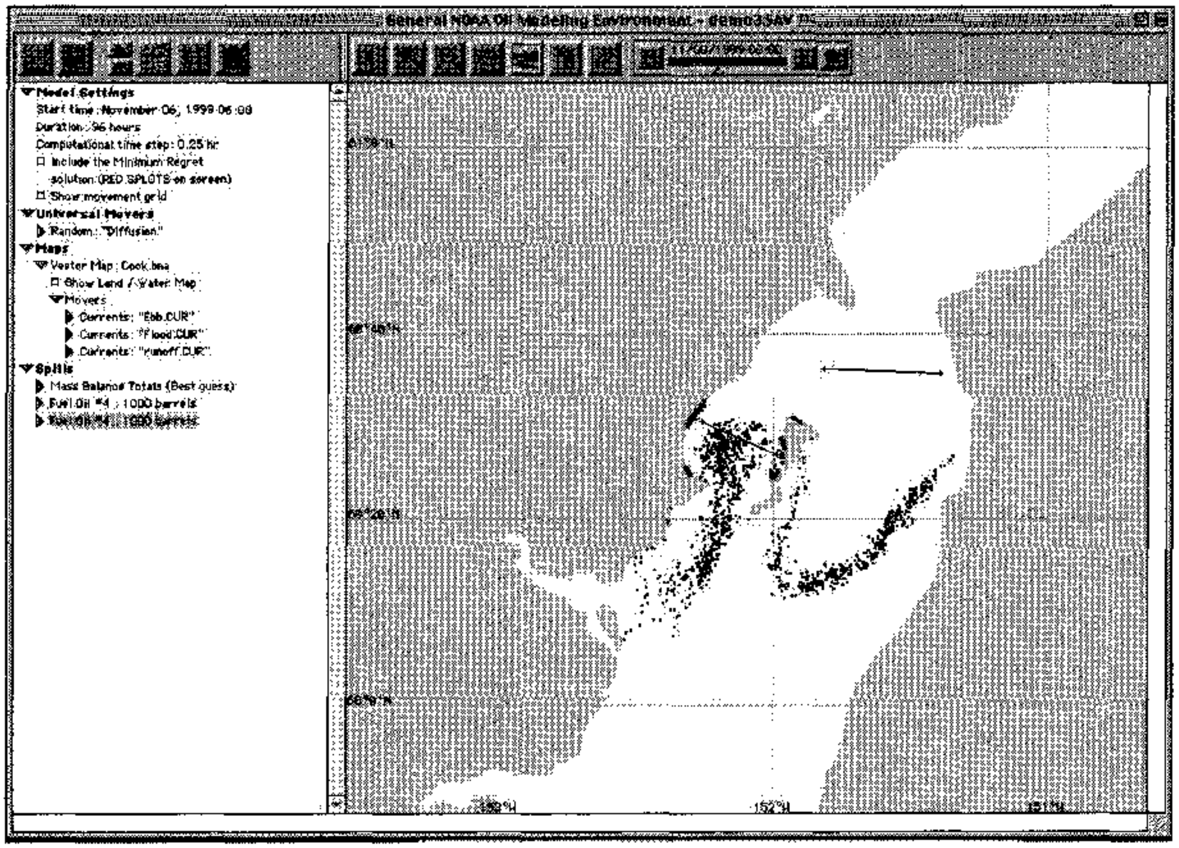
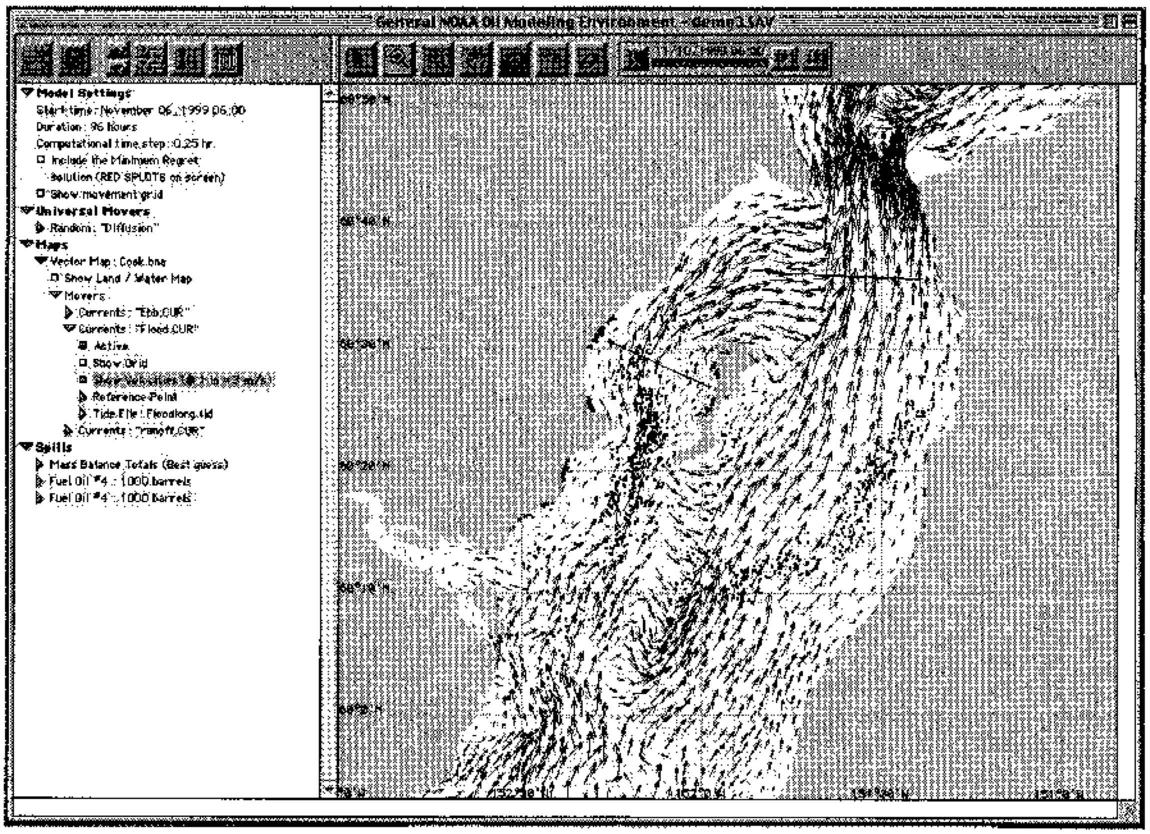


Figure 8 shows the distribution of the flood current vectors and the pollutant particle distribution 96 hours into the spill. The strong convergence line northeast of Kalgin Island has no remaining particles to trap. The clockwise flow around Kalgin Island is bringing a few particles over the top of the Island that are then flushed south and quickly trapped in the convergence south of the island. The shear convergences along the eastern side of the inlet and the one associated with that channel west of Kalgin both retain trapped oil.



Conclusions

This presentation has outlined some of the output from trajectory analysis tools developed by NOAA HAZMAT. It demonstrates that certain features of the observed flow and its potential effect on floating pollutants can be modeled relatively easily. It has also been shown that certain features are baroclinic in nature and may not be highly resolved even though the approximate positions can be determined.

References

Burbank, D.C. 1977. Circulation studies in Kachemak Bay and lower Cook Inlet, vol. III of Environmental Studies of Kachemak Bay and Lower Cook Inlet, L.L. Trasky et al. [eds.]. Marine/Coastal Habitat Management Report, Alaska Dept. Fish and Game, Anchorage, AK.

Royer, T.C. 1981. Baroclinic transport in the Gulf of Alaska. Part II. A freshwater driven coastal current. J. Mar. Res. 39: 251–266.

Whitney, J.W. 1994. Past experiences with spill response in Cook Inlet. Presentation at Conf. on Oil Spill Response in Dynamic Broken Ice, March 7–8, 1994, Anchorage, AK, sponsored by Cook Inlet Spill Prevention & Response Inc., Nikiski, AK.

Discussion

Jia Wang: This phenomenon is a three-dimensional phenomenon including density driven circulation. A two-dimensional model is good enough for surface trajectories and tides, but for circulation we need three dimensions.

Jerry Galt: That's right, we are not modeling three dimensions, we are modeling two dimensions that interact with the bathymetry. So certain kinds of convergence like the western rip we can get, shear phenomena we can get. The baroclinic frontogenesis we do not get. I haven't seen anybody else that can, either, in an ocean model. It is possible, but I haven't seen it done.

Bryan Pearce, Pearce Engineering, Orono, ME
Doug Jones, Coastline Engineering, Anchorage, AK
Howard McIlvane, Pearce Engineering, Orono, ME

An Overview of CIOSM 2.0 — The Cook Inlet Oil Spill Model

Abstract

The Cook Inlet Regional Citizens' Advisory Council (CIRCAC) and the Prince William Sound Regional Citizens' Advisory Council (PWSRCAC) have jointly produced an oil spill model that entirely encompasses Cook Inlet as well as Shelikof Straight and a small part of the Gulf of Alaska. The modeled region is approximately 400 km by 400 km. Cook Inlet is a resonant basin with tidal ranges in some areas on the order of 10 meters with extensive areas that go dry at low tide and currents in excess of 5 knots. Because of the large currents and current variations in Cook Inlet it was necessary to place considerable emphasis on a flow model as a necessary part of an oil spill model.

The model allows the user to specify the location of the oil spill, time, date, duration of the spill as well as other parameters. The model has an interactive graphical interface. To aid in this interactive process, displays of the path and shape of the oil spill are included as well as water velocity, date and time. The user can update wind speed and direction as desired. The model will allow the user to update a spill location if field data become available. Other useful features of the model include the location of land impacts, and a trace facility. The trace facility displays a history of the spill trajectory.

Introduction

The tides and currents in Cook Inlet are extreme. Spring tides in the upper reaches of Cook Inlet in Knik and Turnagain Arms (Figure 1) can exceed 30 feet and Cook Inlet currents can be over 5 knots. The frequently used assumption that tidal currents are small compared to wind driven currents does not apply in Cook Inlet. In 1996, CIRCAC established a requirement for an oil spill model for Cook Inlet. The model was to be used for education, public relations, training, and, possibly, spill tracking in the event of a spill.

Because of the nature of the oceanographic environment in the inlet, the model must account for the extreme current regime in Cook Inlet. In addition to the requirement of modeling the currents in the inlet, the model was to have a simple interface and be coded in Visual Basic. The Visual Basic requirement allowed CIRCAC personnel access to the model and the ability to make changes, updates, and modifications as needed. The final requirement was that the model be inexpensive. Thus the model was assembled using best available information, as it was not possible to spend large sums on data taking or analysis.

Two versions of the model have now been completed, Phase I and Phase II. Phase I covers Cook Inlet only and the Phase II version of the model increases the coverage to include Shelikof Strait as shown in Figure 1. To accomplish this increased coverage, the user interface for Phase II has been changed, and provides the user with a "window" to the model, which will be discussed later. The model also queries the resolution of the host machine and adapts accordingly without requiring active changes by the user. Additional features include conversion between lat/long and state plane coordinate systems. Because of the complexities of the calculations, the water velocities for the model are calculated for a mean tidal cycle and stored as a lookup table for the model. These velocities are then "stretched" or interpolated to approximately account for the spring and neap variations in the tide. The model does onboard tidal predictions and the interpolations are based on the predicted elevations at Seldovia in Katchemak Bay.

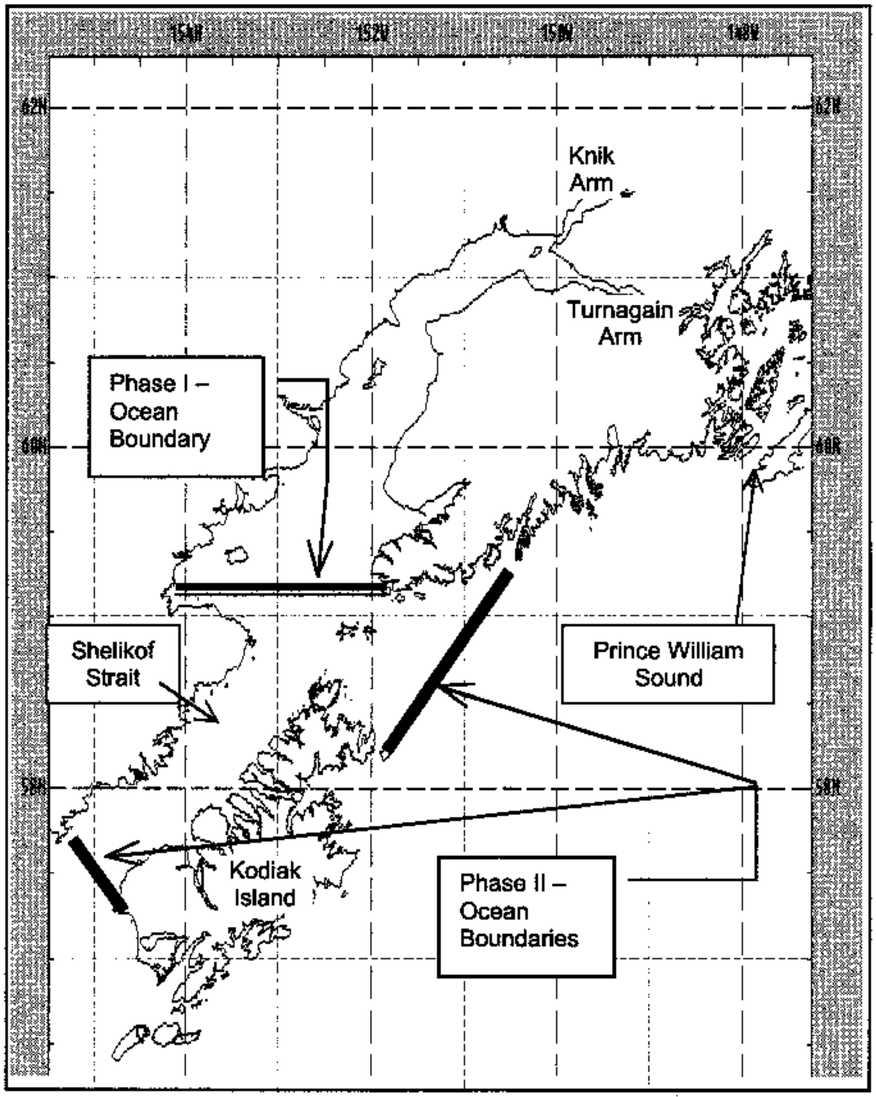


Figure 1. Cook Inlet and Shelikof Strait.

Bathymetry

The ocean boundaries for the two models (Phase I and Phase II) are shown in Figure 1. The initial step in assembling the model was to obtain the bathymetry for the region. Some of the data were obtained from NOAA electronically, but there were substantial dropouts, or areas where no data were available. These were mostly areas where the existing charts were produced before the data weres archived electronically. In Turnagain Arm with its extensive mudflats, even with the NOAA charts, it became necessary to make a best estimate of the depths. The data for the remaining areas were digitized from NOAA charts. The assembled data represented several million data points. The outstanding DOGS (Digital Optimization of Grid Systems) [Galt 1996] program from NOAA HAZMAT was used to reduce this very large set into a useable set. DOGS is one of several tools available from NOAA HAZMAT that can assist in oil spill modeling and analysis. DOGS reduces the number of data points needed to construct an accurate grid.

The depth data from all sources were combined using MapInfo and Alaska state plane coordinates as shown in Figure 2. By using state plane rather than latitude and longitude we could easily require all grids to be the same size. The numerical grid was created using an extension of MapInfo called Vertical Mapper. Vertical Mapper uses a variety of schemes for grid creation, for this case a linear interpolation was used with a constraint of about two grid widths. Once the grid is created it must be trimmed to accurately describe the coastline and islands. A region based on the actual coastline was created (approximately the region in Figure 2) that was then used as a template to trim the cells to the correct coastline. The final grid for the Phase I model was 121 cells (north/south) x 106 cells (east/west) with a 833 m grid spacing, and for the Phase II grid there were 221 cells (north/south) x 182 cells (east/west) with square girds at 2 km spacing. The final grid for Phase II is shown in Figure 3.

Currents

Numerical models were used to calculate the currents in Cook Inlet based on the phase and magnitude of the tides at the boundaries. The model used for Phase I of the study was the Princeton Ocean Model (POM) [Blumberg and Mellor 1987]. POM was originally developed for use in offshore areas and does not allow for grid elements to be included and excluded from the computation as the water rises and falls. Cook Inlet is a resonant basin. Tides are extreme in the upper arms, and large areas of mudflats are exposed at low tide. The consequence of the limitation in POM is that the model "crashed" when it attempted to divide by a depth of zero. To obtain a reasonable solution it became necessary to modify POM to dynamically add and delete grid elements according to the changing depths. After POM was modified to allow each grid element to flood and dry, the model agreed with available tide data to within about 15 centimeters. The code to add flooding and drying to POM is available to anyone interested in using POM for intertidal areas.

For Phase II, the currents were calculated using TRIM5 [Cheng et al. 1993] by Ralph Cheng of U.S. Geological Survey. The TRIM5 model uses an implicit scheme and provides accurate solutions more quickly and with fewer stability problems than POM. While the currents in Cook Inlet proper are dominated by the tides, the currents in Shelikof Strait also show a net drift to the south that varies from 0 to 50 cm/s. This is undoubtedly due to the Alaska Coastal Current. It is impossible to predict these currents and an average condition of about 30 cm/s has been modeled by imposing a tilt in the ocean boundary conditions.

Lagrangian Model

The oil spill model uses a Lagrangian, or random walk, approach. With this method, the oil spill is characterized as a large group of autonomous particles. Each particle, once released into the model, behaves as directed by a set of rules. After each time step, a particle will move to a new location. The new location is based on the current speed at that location and time, the wind speed, and a random motion based on the turbulent viscosity. It has been shown that in the limit of a large number of particles, this process produces the same result as the familiar convection/diffusion equation if the random step is based on the turbulent viscosity.

The use of the random walk presumes that the spreading oil has reached a stage where the physical processes in the ocean such as wind, waves and currents are more important than the flow of oil governed by gravity and molecular viscosity. The dynamics of wind and wave driven oil movement are complicated. It is easier to discuss the processes than to quantify them. [Delvigne 1993; Overstreet and Galt 1995].

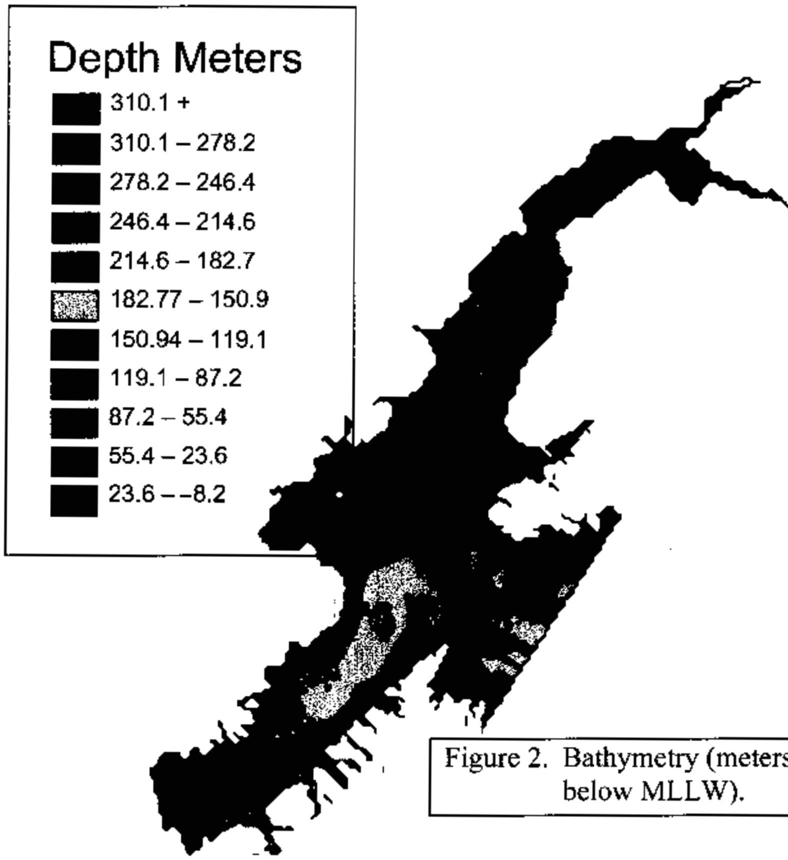


Figure 2. Bathymetry (meters below MLLW).

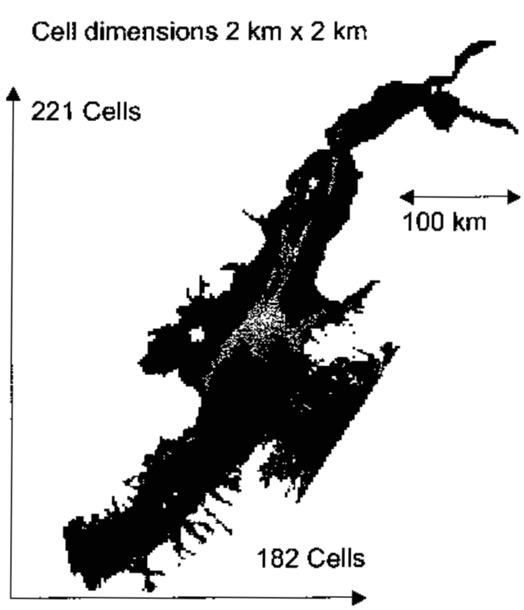


Figure 3. Phase II grid.

Some oil particles become entrained by waves and once entrained, because of buoyancy, slowly return to the surface. At this point some particles are at the top of the wind generated surface layer while other particles are deeper. This results in the particles moving horizontally at different speeds, since the net result of the wind generated boundary layer and wave entrainment is to usually move the particles from about 1 percent to about 4 percent of the wind speed. To provide a conservative estimate of the range of movement of the spilled oil we have adopted a scheme used by NOAA HAZMAT, where each particle is randomly assigned a speed of between 1 and 4 percent of the wind speed.

Following the directive to keep the model as simple as possible, we have provided a simple linear decay to account for oil weathering. When a particle tries to move onto the land it is either stuck to the beach or returned to the simulation based on the probability that it will stick to the beach. This parameter can be controlled by the user and is set to a default value of 50 percent.

Graphical Interface

In the Phase I model, the user interface had a single window. In Phase II the interface has been modified so that it can fit on any screen size. The *primary interface dialog* is a schematic of Cook Inlet and Shelikof Strait as shown in Figure 4. When the model starts it checks the screen resolution of the host computer and adjusts the resolution of the image to fit the screen. Normally, the lowest resolution is 640 x 480 pixels. CIRCAC requested the feature so that the model would be available to a larger user base.

Figure 4. Primary interface dialog.

Due to hardware limitations the entire high resolution image cannot be displayed. To keep the necessary resolution, the user is provided with a window with which to view a portion of the model. There are two methods of navigation within the model. The first are scroll bars. Second, a low resolution image of the entire model has been placed in the upper left hand corner of the *primary dialog*. By clicking on this the user may also navigate through the model. The *primary dialog* displays a false color image of the grid displaying the depths as varying shades of blue. This provides a visual cue to the user about the oceanographic features of the inlet. The user clicks on the display to locate the source.

A close-up of the primary dialog is shown in Figure 5. The circle on the left shows the oil source. The circle on the right is the centroid of the spill. The small circles with the lines show current speed and direction. The bars along the coast represent amounts of oil on the beach.

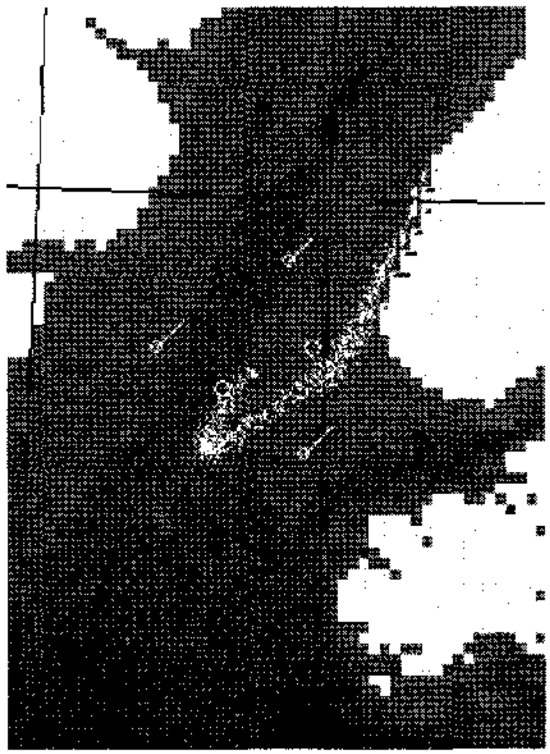


Figure 5. Primary dialog close-up.

The model is controlled primarily by the *main dialog* shown in Figure 6. The model is started with the INITIALIZE button, which reads in the bathymetry, and the velocities. After the user types in the starting date, starting time and spill quantity, the model is ready to run. The user may also choose whether the spill is bulk or continuous. Before running the model the user must choose a spill location and then may click on a number of locations to provide for a graphical display of the water velocities. By clicking on the RUN MODEL button the user begins the simulation. The model has been updated to include both Alaska state plane and lat/long coordinates for the source location. The RELOCATE button brings up the *relocate dialog* which allows the users to translate the oil spill by typing in the new location of the spill in either lat/long or state plane coordinates. Once the model is running, the user may specify the wind, as before, using the *wind control dialog*. The *status dialog* is shown in Figure 7. The *status dialog* displays the instantaneous depth and current at the cursor location. It also displays the cursor location, the tide at Seldovia, and model time. Two important additions to the Phase II model include print and properties. The print feature allows the user to create a black and white line drawing that may be easily faxed. The user accesses the *print dialog* via the PRINT button on the *main dialog*. The *print dialog* is shown in Figure 8 and allows the user to select either color or black and white and generates the line drawing.

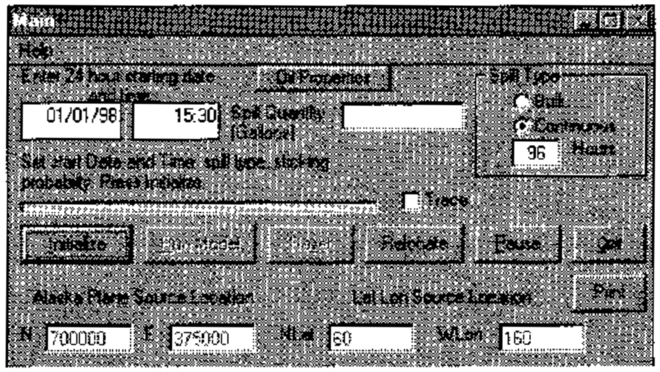


Figure 6. Main dialog.

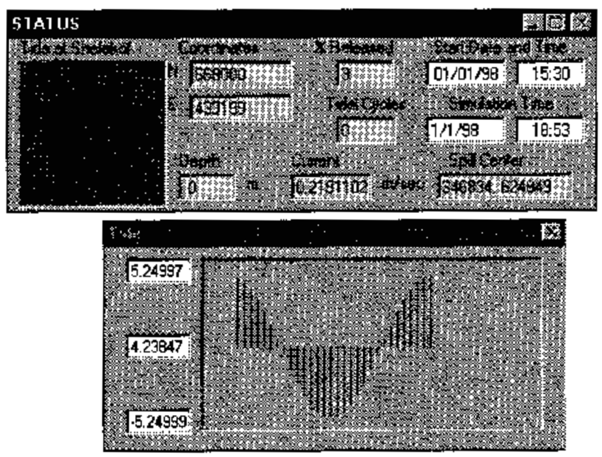


Figure 7. Status and tide dialogs.

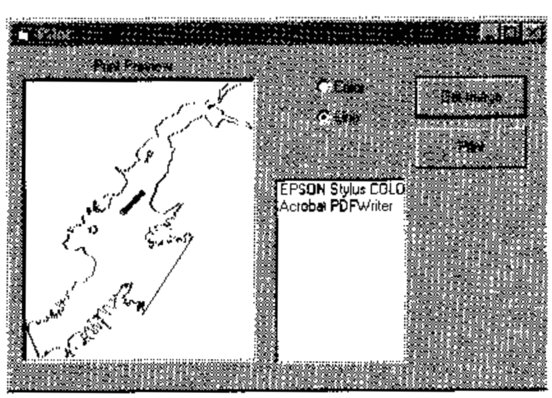


Figure 8. Print dialog.

The *properties dialog* allows the user to input simple oil properties. The properties are decay due to weathering and probability that an oil particle will adhere to the shore. These parameters will have minimal effect and thus for most simulations the default values are adequate. By clicking with the right mouse button anywhere over an area representing water, the minimum and maximum tide are displayed. The tide at the current time is displayed using a red bar as shown in Figure 7.

Conclusions and Continuing Development

An oil spill model using currents from detailed flow models has been created at low cost to provide a straightforward and easy-to-use model of an area with extreme oceanographic conditions. Because of the dynamic nature of Cook Inlet, the next step in providing a real improvement in the model will be to include the flow model in real time.

Acknowledgement

The authors would like to acknowledge the support of CIRCAC, The Cook Inlet Regional Citizens' Advisory Council, for their support of the construction of CIOSM. The authors would also like to extend appreciation to Dr. Ralph Cheng of the U.S. Geological Survey who graciously provided a copy of the model TRIM5 that was modified by the authors for Cook Inlet.

References

Blumberg, A.F. and G.L. Mellor. 1987. A description of a three-dimensional coastal ocean circulation model. *In* N. Heaps [ed.], Three-Dimensional Coastal Ocean Models, vol. 4. American Geophysical Union.

Cheng, R.T., V. Casulli and J.W. Gartner. 1993. Tidal, Residual, Intertidal, Mudflat (TRIM) model and its applications to San Francisco Bay, California. Estuar. Coast. Shelf Sci. 36:235–280.

Delvigne, G. 1993. Natural dispersion of oil by different sources of turbulence, p. 415–419. *In* Proc. 16th Arctic and Marine Oil Spill Program Technical Seminar, Calgary, Alberta, June 7–9, 1993, Environment Canada.

Galt, J.A. 1996. Personal communication.

Overstreet, R. and J.A. Galt. 1995. Physical processes affecting the movement and spreading of oils in inland waters. HAZMAT Report 95–7, NOAA/Hazardous Materials Response and Assessment Division, Seattle, WA.

Discussion

Jerry Galt: When you run this model in the implicit mode how long is the time step compared to the Courant criterion?

Bryan Pearce: About 30 of 40 times. With the POM model I had time steps of about one second because of the deep water and small grids.

Jerry Galt: Did you find the out that a step like 30 times the Courant number gave you any kind of smoothing? What did you do for the lateral eddy coefficient?

Bryan Pearce: I used the Smagorinsky formulation. It is based on velocity gradients.

Shana Loshbaugh: I've seen something that is confusing me. The overall movement of water is south and there is all this discussion about flushing. How come it looks like this stuff is getting sucked north into the upper inlet instead of getting flushed out the other way?

Bryan Pearce: I have a two part answer. The first part is that this started as a small spot with a thousand particles concentrated in there and it is spreading. It is also spreading up the bay as well as down the bay. The second part is that this doesn't have any flushing in it. There is no fresh water input in this model.

Kelly Zeiner: I was wondering if there is something there that shows where the oil is hitting the shore?

Bryan Pearce: Yes, that is the red bars. The amount of oil is related to the length of the bar.

Joel Blatchford: I was wondering if you had also included part of Valdez, because when the oil spill happened that oil came all the way to the mouth of the Kenai.

Bryan Pearce: No.

Susan Saupe: Didn't you hinge the model down by Kennedy Entrance so that you do have some residual Alaska Coastal Current?

Bryan Pearce: Yes, we compensated for the residual flow of the Alaska Coastal Current.

Jia Wang: How many tidal components did you use?

Bryan Pearce: The model is driven with the M2 tide. However, when I do the tidal prediction I use 38 components in Seldovia and everything is based on that. So I calculate what the high tide is in Seldovia and I set the model to that.

Unknown questioner: Do you have a factor in there for plugging in a particular type of oil and looking at the amount of loss of the lighter fraction through evaporation and weathering?

Bryan Pearce: I have a weathering factor, which is a decay. We can set the decay if you know what it is.

Unknown questioner: Can you plug in different types of oils?

Bryan Pearce: No, you have to know what the decay factor is. We could do that but that would change the cost.

Mark Johnson, University of Alaska Fairbanks, Fairbanks, AK
Steve Okkonen, University of Alaska Fairbanks, Kasilof, AK
Steve Sweet, University of Alaska Fairbanks, Fairbanks, AK

Cook Inlet Tidal Currents and Acoustic Measurements

Introduction

During 16–18 June 1999, current velocity data were collected over a 49 hour period in Cook Inlet near Kalgin Island using an acoustic Doppler current profiler (adcp). About 3,400 current velocity profiles were collected with support from the Cook Inlet Regional Citizens' Advisory Council (CIRCAC) and the University of Alaska Fairbanks. Cook Inlet Spill Prevention and Response, Inc. (CISPRI) allowed us to use their support/response vessel, the OSRV *Heritage Service*, for this work.

Velocity data can be compared to velocities from oil-spill trajectory models to measure model accuracy. With adcp data from enough Cook Inlet locations, the 3-dimensional structure of tidal amplitudes and residual currents in Cook Inlet can be determined.

Methodology

The data were collected several days after the spring tide when the observed winds were (fortuitously) near zero. The adcp data set discussed here provides an excellent estimate of the tidal velocities uncontaminated by wind forcing.

When the adcp transmits sound, moving particles in the water column reflect sound back to the adcp. Using knowledge of the Doppler shift from the reflected signals, the 3-dimensional velocity field is computed. The velocity profiles extend from the near-surface to near-bottom. Because the adcp transducers are aimed at a 15-degree angle from the vertical, the geometry governing signals reflected off the bottom makes data interpretation in the deepest 15% ambiguous. These data are discarded. In addition, the top few meters are lost when the adcp receivers are briefly blanked after the acoustic pulse is sent. However, with boundary layer theory and a practical knowledge of the local vertical shear, one can make reasonable extrapolations to the surface and bottom from the remaining data.

Results

Figure 1 shows the transects of the *Heritage Service* where adcp velocity measurements were recorded. The adcp was mounted on a boom over the side of the ship, which limited its maximum speed. This limit made transecting the tide rips in a purely east–west direction difficult, so many of the transects have a significant north–south component. However, the measured current velocities were not affected in any way.

Histograms for the north–south velocities, east–west velocities, and vertical velocities are shown in Figure 2. Horizontal velocities (north–south [lower panel] and east–west [upper left panel]) were generally large and well above the noise level. Vertical velocities (upwelling–downwelling [upper right panel]) were generally quite small. However, in the convergence zones in Cook Inlet, the velocities were large enough to be measured reliably. The velocities are sufficient to transport oil from the surface into the water column.

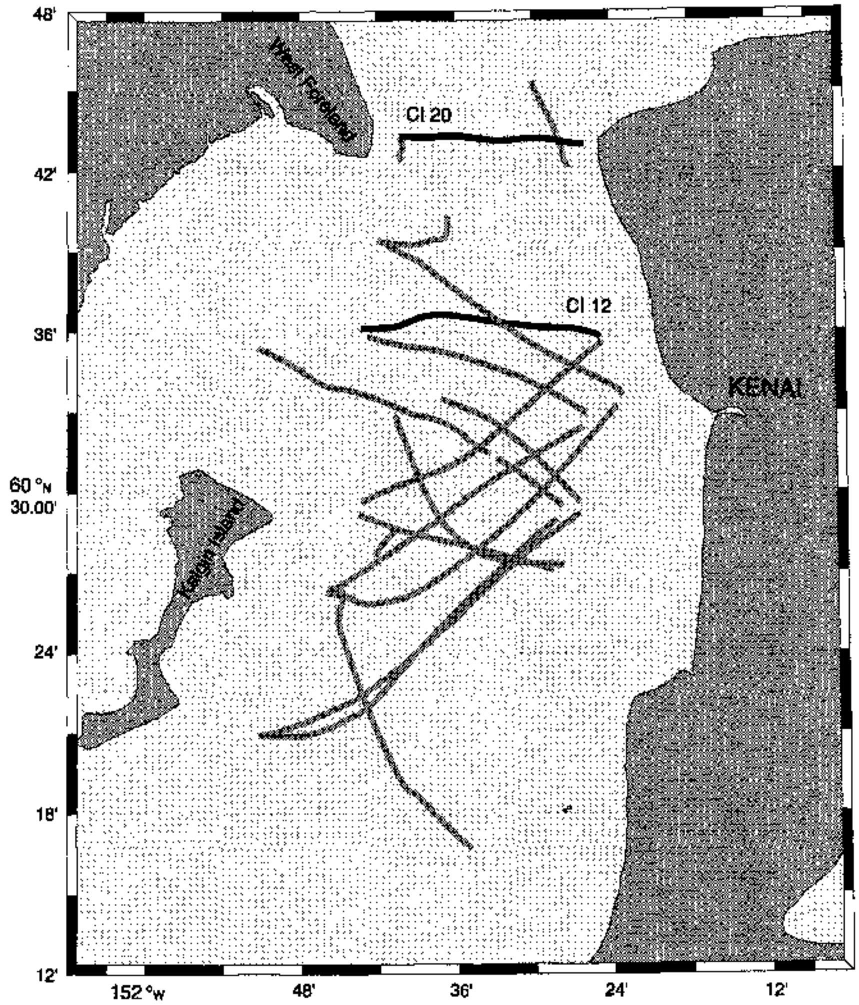


Figure 1. Acoustic Doppler current profile locations, CIRCAC Cook Inlet cruise, 16–18 June 1999.

Evidence of the unique character of the currents and tide rips in Cook Inlet is seen clearly in at least two transects (20 and 12). The north–south velocity from transect 20, which spanned the Forelands, is shown in Figure 3. The upper panel illustrates the vertically integrated north–south velocity having high and low velocity bands. Cores of high velocity are evident in the west, central, and eastern portions of this transect. A low velocity core is evident in the west, between profiles 30 and 40, with a broad region of southward velocity in the central portion between profiles 80 and 130.

The velocity times the cross-sectional area was integrated across the section to find a total southward transport of 759,770 $m^3 s^{-1}$. Total volume transport should be compared with the transport from numerical models to test for consistency. The velocity cross-section (Figure 3 lower panel) shows velocity to be rather constant over the water column, indicating flow with little vertical shear. The finding that the water moves slab-like with little or no vertical shear supports the use of 2-dimensional (without vertical structure) numerical models for Cook Inlet currents.

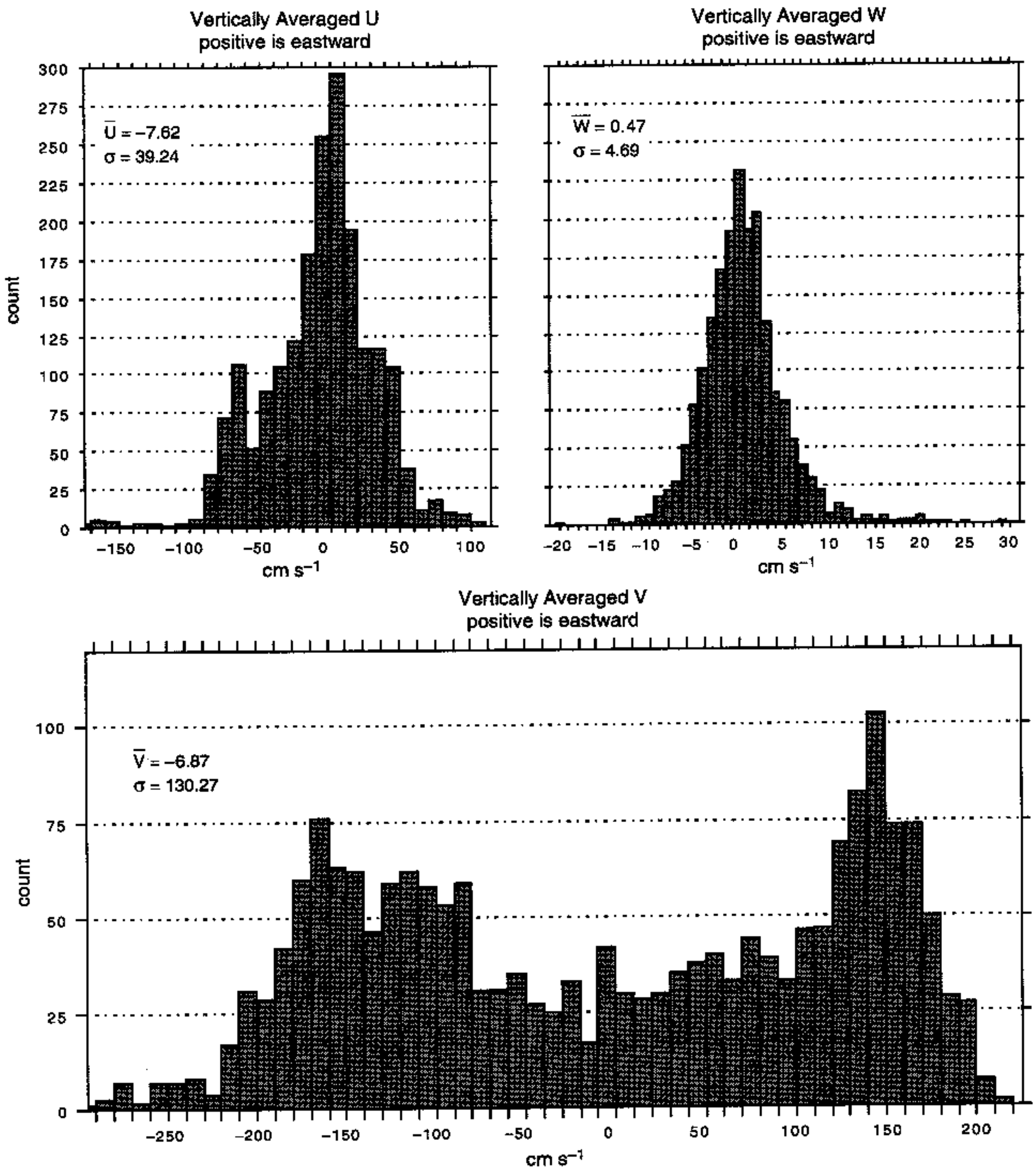


Figure 2. Cook Inlet velocity distributions.

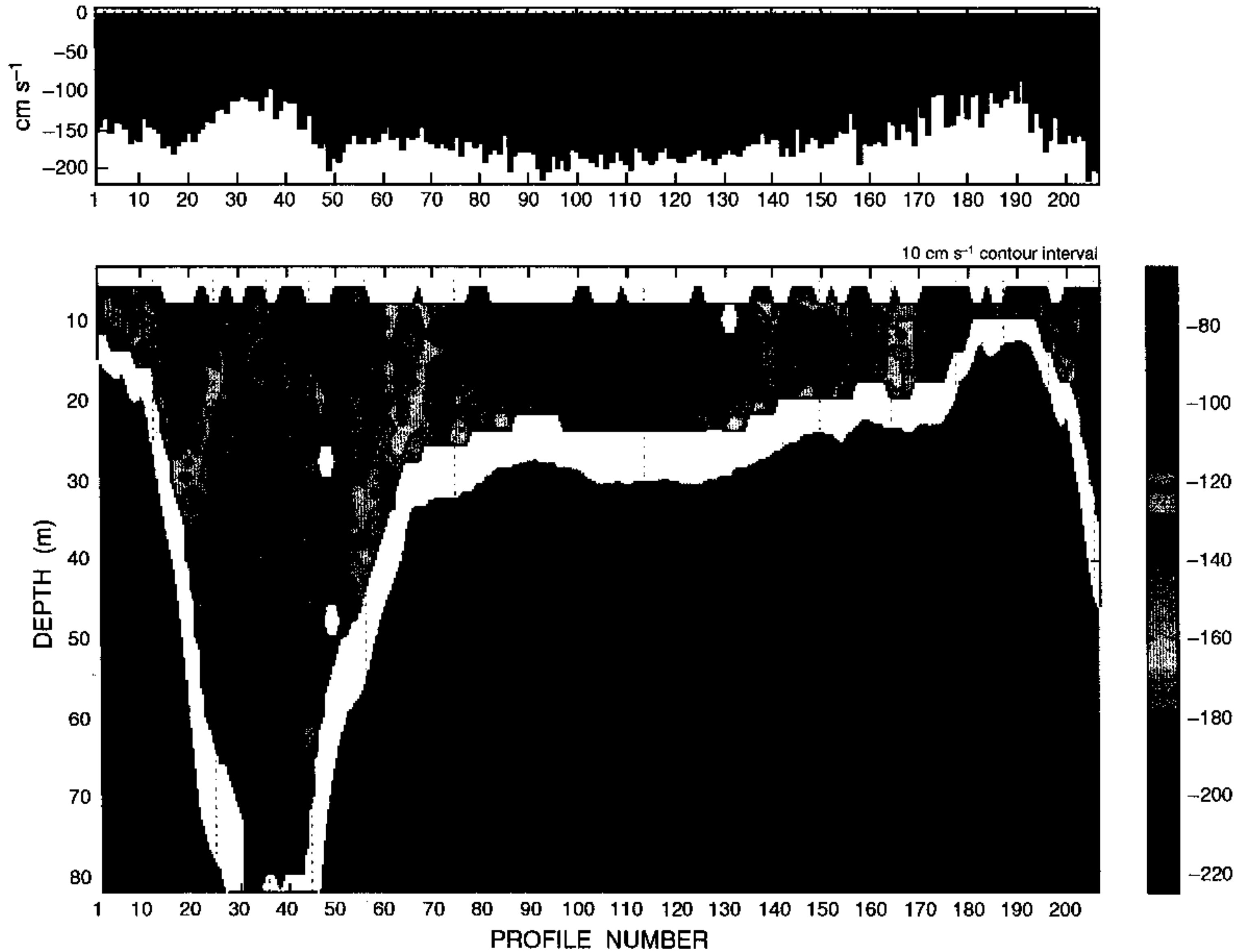


Figure 3. North–south velocity, section 20 CIRCAC Cook Inlet data, 11:10–14:38 AST, 18 June 1999.

Transect 12, south of transect 20, runs nearly east–west (Figure 1) across central Cook Inlet. The north–south velocity from transect 12 (Figure 4) shows northward flow across most of the transect, with only a small portion having weak, southward velocity. Northward flowing currents have speeds as high as 200 cm s^{-1}, with a banded velocity structure shown in the lower panel. As was found in transect 20, the currents have little vertical shear.

The east–west velocity for transect 12 is presented in Figure 5. The upper panel, showing the vertically integrated velocity, has eastward velocity in the western portion (left) of the transect. The velocity varies between eastward and westward across the transect. When eastward velocity changes to westward velocity, there is convergence and downward velocity. This occurs in at least three locations in this figure: around profile 115, between profiles 75–85, and around profile 32. Where velocities move fluid away from some location there is likely to be divergence with upward velocities, as suggested around profiles 105 and 50. The lower panel of Figure 7 shows the vertical structure. The small grey box (near profile 122) marks where we observed surface debris collecting in a convergence zone.

Figure 6 is the vertical velocity across transect 12. The upper panel shows highly variable vertically integrated vertical velocity. The lower panel shows the vertical structure, with a region of downwelling near profile 120 and a region of upwelling near profile 68. Vertical velocities as high as 10 cm s^{-1} are visible. In the convergence zone, the downward velocities are 5–10 cm s^{-1}, strong enough to transport surface debris (oil) downward into the water column. East of this downwelling zone the velocity is upward, generally 5 cm s^{-1} or less. Thus, the convergence zones with downward velocity tend to be narrow. The broad, weak upwelling zones are offset from these regions.

Summary

Using an acoustic Doppler current profiler, we measured the current structure east of Kalgin Island nearly continuously for 49 hours. The high-velocity cores of the tidal rips in Cook Inlet are readily visible in the direct current measurements. The flow is strongly barotropic (moves like a slab) with little vertical shear. Vertical velocities in the tide rips are large enough to be measured directly, and strong enough to carry surface contaminants to depth. There are upwelling regions a few kilometers distant from the convergence zones, suggesting that surface oil submerged in the convergent zones will reappear in a new location at a later time.

A visual comparison of our directly measured currents with oil spill trajectory model currents shows qualitative agreement. The adcp data should be compared in a rigorous manner to velocities from oil-spill trajectory models to test their accuracy. Should more adcp data be collected throughout Cook Inlet, a quantitative estimate of the tidal velocities and amplitudes can be made. This would provide the time offset from existing tidal stations for any location within Cook Inlet. This would be useful knowledge to fishermen, shippers, and others in the Cook Inlet region.

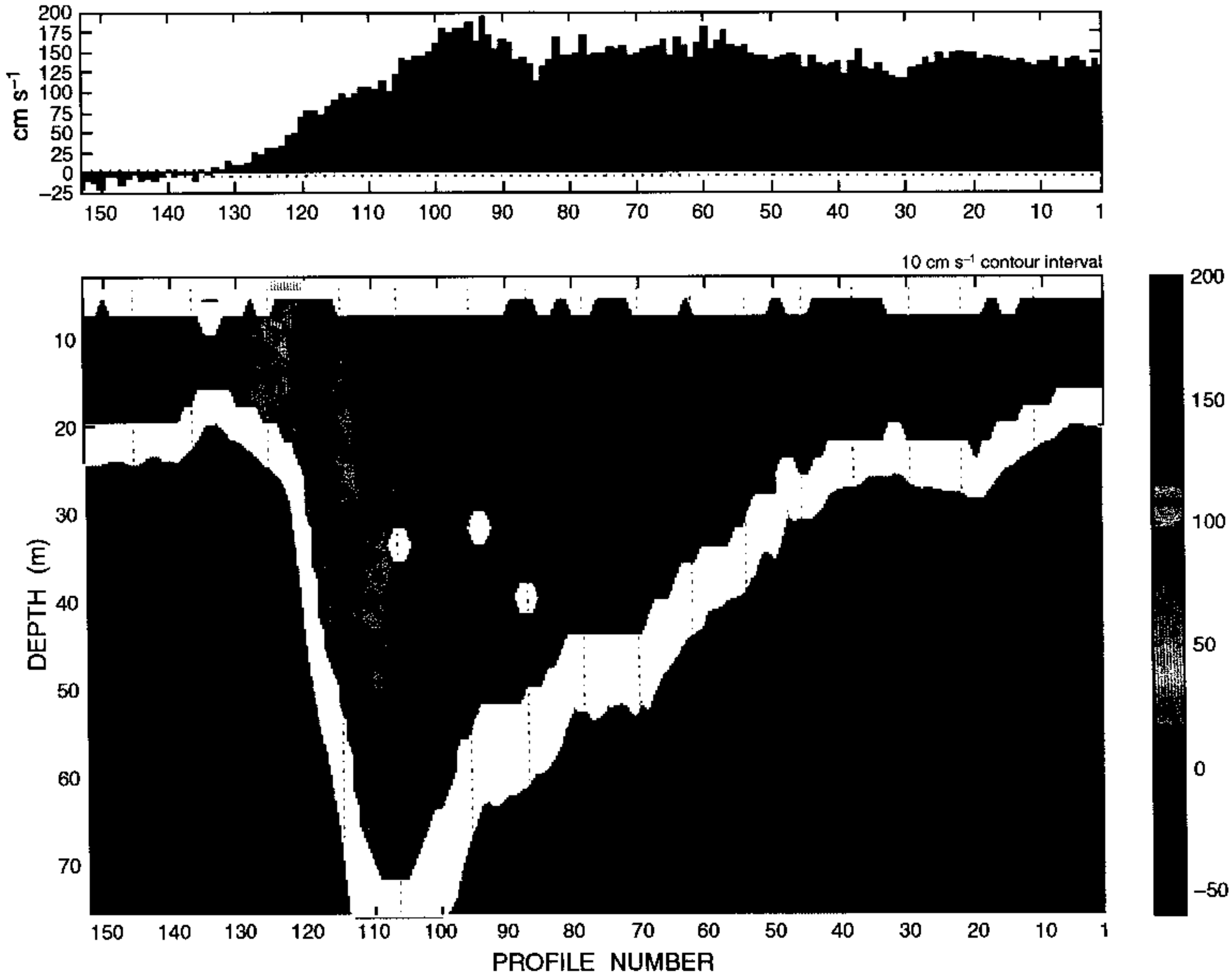


Figure 4. North–south velocity, section 12 CIRCAC Cook Inlet data, 19:38–21:43 AST, 17 June 1999.

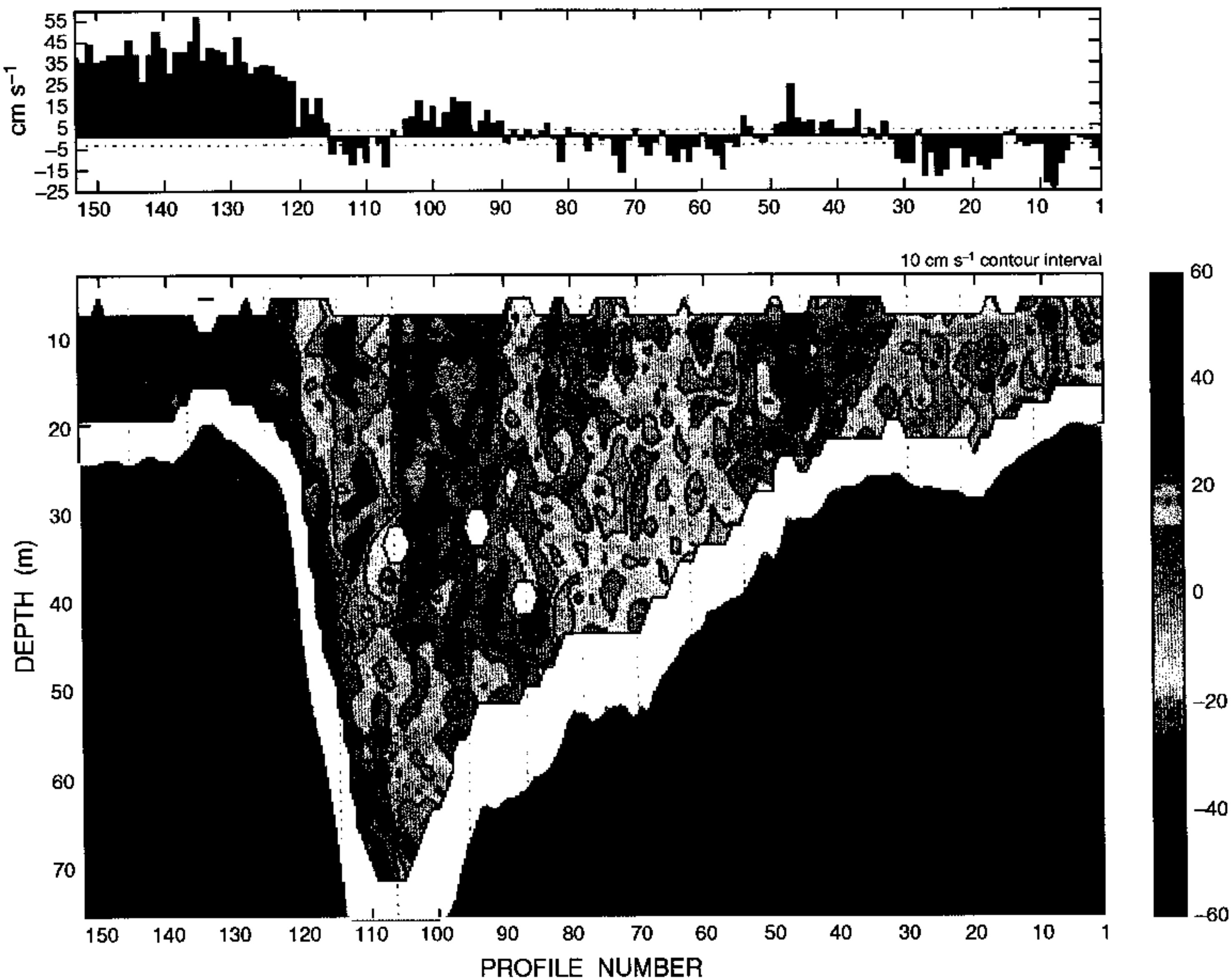
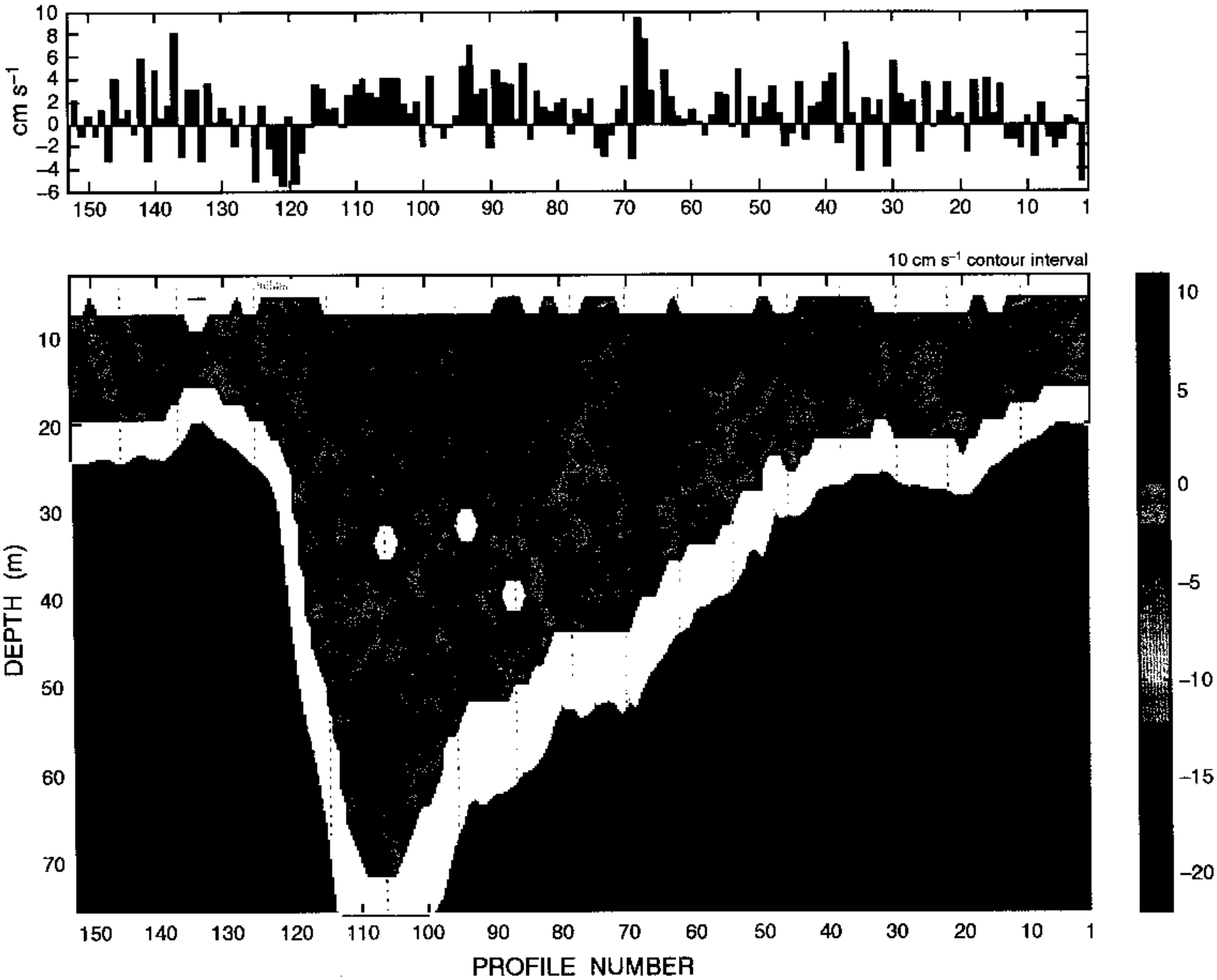


Figure 5. East–west velocity, section 12 CIRCAC Cook Inlet data, 19:38–21:43 AST, 17 June 1999.


cm s^{-1}
10 cm s^{-1} contour interval
DEPTH (m)
PROFILE NUMBER

Discussion

Joel Blatchford: How wide is a vertical velocity cell?

Mark Johnson: It looks like it is a few kilometers wide. Further work needs to be done on this. We need to do many profiles to come up with a representative width.

Doug Baird: Did you do any comparison between your observed currents and the predicted currents for Cook Inlet?

Mark Johnson: Yes, we looked up the tidal currents that showed up on the charts and the order of magnitude tends to be correct. But, the challenge for us was that you are always choosing the nearest coastal station, Kenai or somewhere south. If you are in the middle of the inlet, I was never clear on what is the offset if we were slightly south of this station and north of that station. So, we want to take this data set and map out the tides from a harmonic fit to the currents that this device measures. Then I can say, "If you are right here, for example, this is what the tidal signal is" and you don't have to look at coastal stations and make a wild guess as to what the change (offset) is.

Kelly Zeiner, Alaska Department of Natural Resources, Anchorage, AK

Development of the Cook Inlet Information Management/Monitoring System (CIIMMS)

Abstract

The vision for the Cook Inlet Information Management/Monitoring System (CIIMMS) is to develop a comprehensive information system based on the latest internet technologies that will enable a wide range of users to contribute, identify, share, and access valuable information about the Cook Inlet watershed and Cook Inlet related activities. This vision was established after extensive background investigations and culminated in a two-day user-needs workshop held in Anchorage, Alaska, 26–27 January 1999.

In October 1998 the Alaska Department of Natural Resources (ADNR) and the Alaska Department of Environmental Conservation (ADEC) launched a coordinated strategic planning initiative to unify a myriad of pre-existing Cook Inlet information management efforts in order to develop a web-based watershed-wide information framework. The joint effort encompassed the following activities:

- Assessment of user needs through surveys, focus groups, and a 100-person stakeholder workshop, which also evaluated current information management approaches within the Cook Inlet community;
- Development of the "Cook Inlet Information Management Requirements and Recommendations" post-workshop report. More than 100 Cook Inlet stakeholders contributed directly to this document's evaluation of CIIMMS priority information, functions, system design, and user interface;
- Development of the CIIMMS Pilot Phase Implementation Plan;
- Development of the CIIMMS prototype, which focused on the high priority, short-term functions identified at the user needs workshop (www.dec.state.ak.us/ciimms).

At the workshop, participating Cook Inlet stakeholders agreed that the information system should reach out to and accommodate the needs of the wide range of users found throughout the watershed. CIIMMS' potential users include educators, scientists, students, researchers, resource managers, private organizations, and individual citizens. These users are interested in a diverse set of information resources — from primary data to public documents — which together can be viewed as levels of an information pyramid. Information available through CIIMMS ranges from primary data (e.g., geospatial data sets) to reports, contact information, project descriptions, and other documents across a variety of themes, such as climate, land use, animals and their habitats, resource management, pollution, and water quality.

CIIMMS provides an interactive website that links to a geographically distributed system of information providers. Through the CIIMMS website, users are able to identify and access (e.g., download and print) information from all levels of the pyramid on a wide range of Cook Inlet topics. CIIMMS also provides tools to make it easy to contribute information to the CIIMMS network.

CIIMMS not only comprises the hardware, software, and information contact components of the Cook Inlet information management system, it also establishes a framework for managing information resources more efficiently. Two important components of CIIMMS development are to 1) establish an advisory group to oversee implementation, and 2) to publish guidelines on how to implement various aspects of the framework (e.g., compile metadata). By providing the tools and the framework that enable a unified approach to information management throughout the watershed, CIIMMS will help agencies and organizations to use existing resources more effectively.

Currently, CIIMMS acts as a clearinghouse node for searching for and reviewing Cook Inlet related metadata (i.e., an electronic card catalog that characterizes specific Cook Inlet information resources). Metadata records characterize data sets, documents, and other information resources, as well as point of contact information and project descriptions. CIIMMS provides a common interface for searching through bibliographic metadata, geospatial metadata, and keyword-based metadata on the CIIMMS server and other internet-linked information servers. CIIMMS-accessible servers include Alaska's geospatial clearinghouses; state libraries; local, state, and federal agencies' websites; non-governmental websites, such as those of local newspapers, research centers, and citizens' groups; and related bibliographies.

Whenever possible, metadata records contain hyperlinks to the information resources that they characterize. Such resources include spatial and tabular data, maps, project descriptions, technical reports, organizational points of contact, and other useful documents. Specific information includes ecosystem assessment data, land ownership maps, government reports on contaminated sites, or descriptions of salmon restoration projects. Once accessed, the information can be viewed, downloaded, and printed by the user.

CIIMMS also assists information providers and data managers in creating and maintaining their own metadata. CIIMMS provides these users with a web-accessible metadata entry tool, thereby making their new information discoverable by the rest of the Cook Inlet community. The tool supports development of both spatial and non-spatial metadata housed either on the CIIMMS server or on contributors' websites. The CIIMMS project team will provide guidelines and technical support to promote a more distributed information management system.

Finally, throughout its development, CIIMMS will enable users to submit evaluations and recommendations regarding CIIMMS products and services, thereby ensuring CIIMMS continually meets the evolving needs of the Cook Inlet community.

CIIMMS will mature into a geographically distributed decision-support system, complete with new tools for data visualization and interactive mapping, data filtering to minimize download times, and integration of online-generated graphs and maps into electronic documents. In addition, CIIMMS will provide opportunities for users to collaborate in creating new documents, to coordinate restoration projects and publicize activities, and to contribute and access traditional ecological knowledge about Cook Inlet.

In the long term, CIIMMS will use integrated information resources and tools to create a virtual community center for Cook Inlet learning, resource management, and related activities.

The Cook Inlet Information Management & Monitoring System

Alaska Department of Natural Resources
Alaska Department of Environmental Conservation
November 9, 1999

The primary goals of CIIMMS project are to provide:

- *One point of access to Cook Inlet data, information, and ongoing projects*
- *Easy-to-use graphical interface*
- *Search and access tools that provide more focus for resource management data and information*
- *Sustainable and maintainable*
- *Flexible, building upon existing data integration efforts*

Team/Resources

- Two-year project funded by EVOS Trustee Council
- Collaboration between ADNR and ADEC
- Cooperating agencies:
  - EPA
  - US Geological Survey
  - US Forest Service
  - ARLIS
- Technical consultant: SAIC

CIIMMS Timeline

- User Needs Analysis (completed)
  - Questionnaires, briefings, workshop
  - Post workshop report (March 1999)
- CIIMMS Prototype Development
  - Implementation plan (May 15, 1999)
  - Prototype system (September 1999)
  - Prototype evaluation (September–December 1999)
- Initial Production Phase (FY2000)
  - System specification (December 1999)
  - System population (through December 2000)

User Needs Workshop Key Findings

- Extensive time and effort to acquire information and fill data requests
- No "one stop shop" to access and evaluate potentially useful information
- No tools for pre-processing, interactive mapping or analyzing data before downloading
- Provide access to many different types of information and data (maps, reports, fact sheets, public documents, spatial & tabular data)
- Prioritize information and incorporate using phased approach

Prototype Design Summary

Geographic Scope	***Kenai River Basin***
Functions	**Features**
• *Identifying information*	• ***Categorical indexes*** • ***Simple keyword searching*** • ***Restoration project activities***
• *Accessing Information*	• ***Metadata records linked to data, information*** • ***Hot list of related off-site links*** • ***Ability to view maps***
• *Contributing information*	• ***On-line data documentation tool*** • ***Form for suggesting info and links to add to clearinghouse***

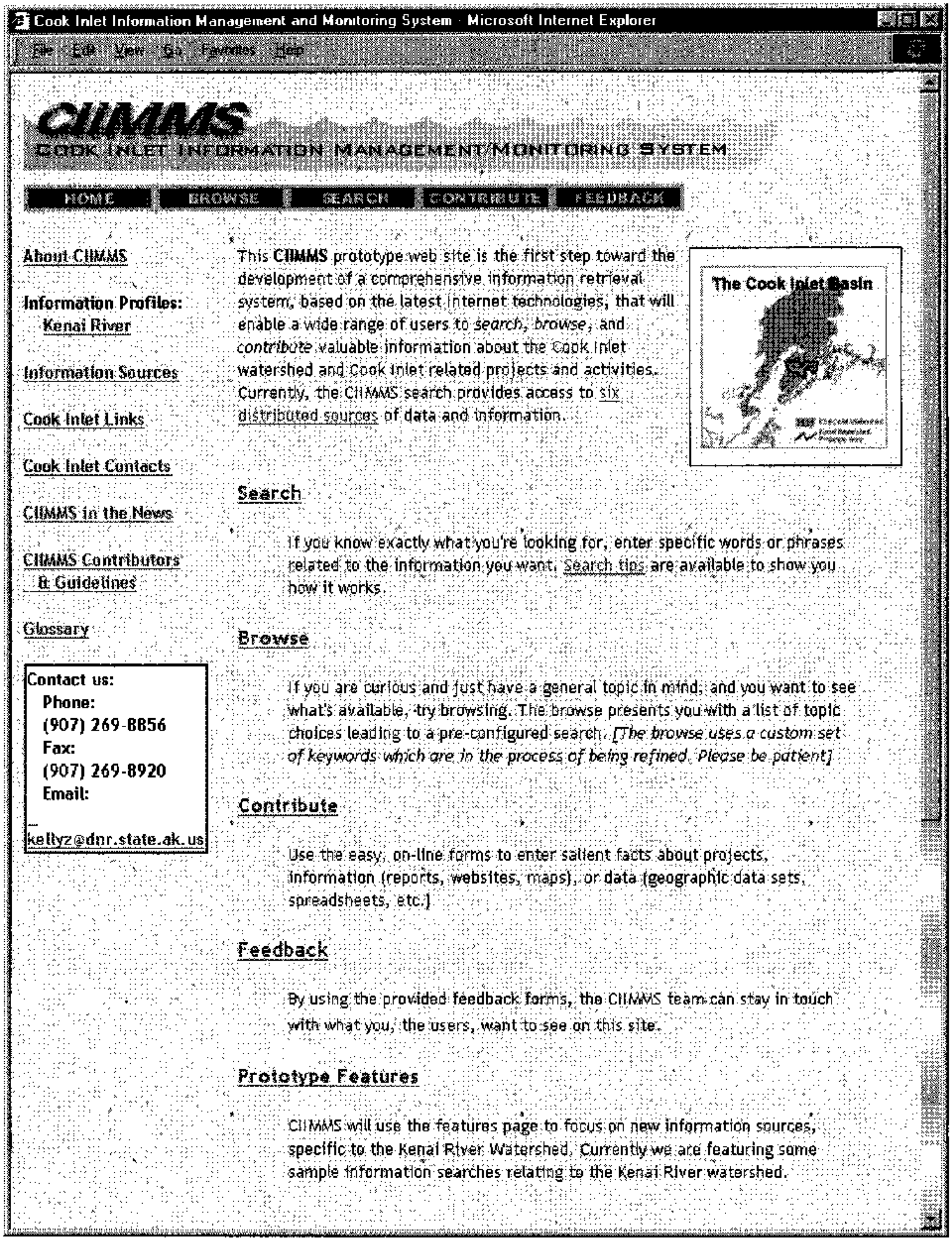
What can you do *today* with CIIMMS?

- *Search* or *browse* for information, data, or ongoing projects related to injured resources (*limited to prototype datasets*)
- In some cases, obtain *access* to the data, or at least *access instructions*
- *Contribute* information, data or projects via on-line documentation tools

What can you do *tomorrow* with CIIMMS?

- *Advanced search**, *browse*, and *access* information, data, and projects for the *entire* Cook Inlet basin; on a watershed basis
- *Contribute* by keeping projects updated, and by documenting data/information on an on-going basis
- *Collaborate* with other stakeholders on projects similar to your own (share funding, etc.)

Sample Web Pages



Cook Inlet Information Management and Monitoring System - Microsoft Internet Explorer

File Edit View Go Favorites Help

CIIMMS

COOK INLET INFORMATION MANAGEMENT/MONITORING SYSTEM

HOME | BROWSE | SEARCH | CONTRIBUTE | FEEDBACK

About CIIMMS

Information Profiles:
Kenai River

Information Sources

Cook Inlet Links

Cook Inlet Contacts

CIIMMS in the News

CIIMMS Contributors & Guidelines

Glossary

Contact us:
Phone:
(907) 269-8856
Fax:
(907) 269-8920
Email:
kellyz@dnr.state.ak.us

This **CIIMMS** prototype web site is the first step toward the development of a comprehensive information retrieval system, based on the latest internet technologies, that will enable a wide range of users to *search*, *browse*, and *contribute* valuable information about the Cook Inlet watershed and Cook Inlet related projects and activities. Currently, the CIIMMS search provides access to six distributed sources of data and information.

The Cook Inlet Basin

Search

If you know exactly what you're looking for, enter specific words or phrases related to the information you want. Search tips are available to show you how it works.

Browse

If you are curious and just have a general topic in mind, and you want to see what's available, try browsing. The browse presents you with a list of topic choices leading to a pre-configured search. *[The browse uses a custom set of keywords which are in the process of being refined. Please be patient]*

Contribute

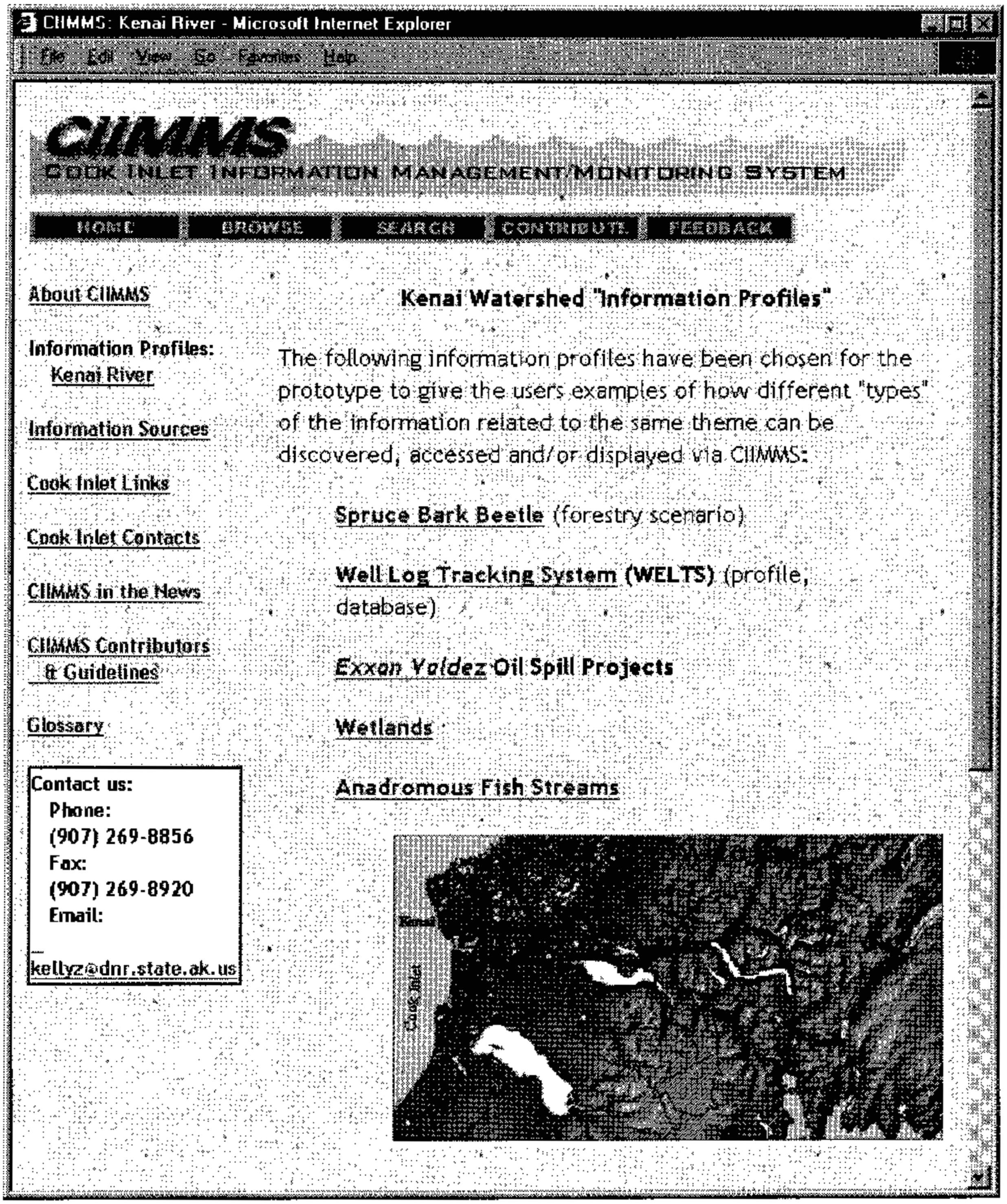
Use the easy, on-line forms to enter salient facts about projects, information (reports, websites, maps), or data (geographic data sets, spreadsheets, etc.)

Feedback

By using the provided feedback forms, the CIIMMS team can stay in touch with what you, the users, want to see on this site.

Prototype Features

CIIMMS will use the features page to focus on new information sources, specific to the Kenai River Watershed. Currently we are featuring some sample information searches relating to the Kenai River watershed.


CIIMMS: Kenai River - Microsoft Internet Explorer
File Edit View Go Favorites Help
CIIMMS
COOK INLET INFORMATION MANAGEMENT/MONITORING SYSTEM
HOME
BROWSE
SEARCH
CONTRIBUTE
FEEDBACK
About CIIMMS
Information Profiles:
Kenai River
Information Sources
Cook Inlet Links
Cook Inlet Contacts
CIIMMS in the News
CIIMMS Contributors & Guidelines
Glossary
Contact us:
Phone:
(907) 269-8856
Fax:
(907) 269-8920
Email:
kellyz@dnr.state.ak.us
Kenai Watershed "Information Profiles"
The following information profiles have been chosen for the prototype to give the users examples of how different "types" of the information related to the same theme can be discovered, accessed and/or displayed via CIIMMS:
Spruce Bark Beetle (forestry scenario)
Well Log Tracking System (WELTS) (profile, database)
Exxon Valdez Oil Spill Projects
Wetlands
Anadromous Fish Streams

Shari Vaughan, Prince William Sound Science Center, Cordova, AK
Walter Cox, Oil Spill Recovery Institute, Cordova, AK

Nowcast/Forecast — Trends and Further Areas of Development

Introduction

The main goal of this workshop is to identify primary research objectives for Cook Inlet. In Prince William Sound (PWS) we have identified the development of an operational nowcast/forecast (N/F) system as our primary research objective. A description of the N/F system and plans for achieving this objective are described here.

Previous physical measurements in PWS were made in the 1970s, 1989, and in the mid-1990s. The 1990s work was funded by the Exxon Valdez Oil Spill (EVOS) Trustee Council. Data collected included temperature, salinity, currents, nutrients, phytoplankton, zooplankton, and juvenile fish abundance and distribution. We are now starting to understand the seasonal variability of the physical quantities and some interannual variability, as well as length scales. As part of the EVOS-sponsored Sound Ecosystem Assessment (SEA), a numerical circulation model based on the Princeton Ocean Model or POM [Blumberg and Mellor 1987], was developed. The model can operate in hindcast mode, and was most recently used to simulate seasonal changes in temperature, salinity, and currents.

The PWS POM consists of sigma (terrain-following) coordinates with 15 vertical sigma levels, realistic bottom topography, and a free surface. The horizontal resolution is 1.2 km. The model was forced with monthly varying forcing functions for throughflow at Hinchinbrook Entrance, wind stress, surface heat flux, surface moisture flux, and freshwater runoff, as well as tides. It is capable of calculating "particle" trajectories and passive drifter concentrations. In the SEA project, the focus was on simulating a single year (1996) and on hypothesis testing.

To use the model for oil spill trajectory forecasts, it must be run in "near real-time", or in nowcast/forecast mode. Observations used to force the model need to be collected and stored continuously and inserted into the model automatically. Also, to be useful to spill operations managers, the observations and model predictions must be available quickly at all times.

The N/F system consists of three components: a real-time circulation model, a real-time observing system, and an information/data management system.

Nowcast/forecast systems exist elsewhere. PORTS, the Physical Oceanographic Real-Time System, is operated in five regions by NOAA's National Ocean Service. TABS, the Texas Automated Buoy System, is operated by Texas A&M University in the Gulf of Mexico. An N/F system in the Santa Barbara Channel is under development by Scripps with MMS and ONR support. The Straits of Florida Nowcast/Forecast System (SFNFS), was developed at the Rosenstiel School of Marine and Atmospheric Science at the University of Miami, and is no longer operational. Information about these systems is available through the web (see References).

PORTS operates in San Francisco Bay, New York/New Jersey Harbor, Houston/Galveston Bay, Tampa Bay, and Chesapeake Bay. The Tampa Bay PORTS, for example, includes real-time current measurements from two ADCPs (acoustic Doppler current profiler), water level measurements at four locations, and wind measurements (Figure 1). Data are available via modem, voice, NOAA weather radio, and the web.

The TABS Gulf of Mexico measurement array is shown in Figure 2. Data from eight current meter moorings equipped with telemetry and eight NDBC C-MAN (NOAA National Data Buoy Center/ Coastal–Marine Automated Network) stations are continuously available from their web site (see References). In the Santa Barbara Channel, several data types are available from the Scripps Center for Coastal Studies web site, including satellite images, surface drifter tracks, winds from nine NDBC buoys, and currents from twelve current meter buoys (Figure 3). Wave modeling results and tides are also available.

The Straits of Florida N/F System was developed during a time when a large observational program was underway in the Straits of Florida. Chris Mooers, the PWS modeling principal investigator, led the modeling portion of the project. The SFNFS used a POM forced with throughflow, and winds from the NCEP (NOAA National Centers for Environmental Prediction) eta model automatically downloaded from NCEP. Like the PWS POM, it used sigma levels and realistic bottom topography. Every 6 hours the model was re-run with eta model winds starting a day earlier and continuing through a 2-day forecast. Model output was distributed to interested parties automatically. The model was used to simulate the dispersal of oil spills, and fish eggs and larvae (Figure 4). It used satellite tracked drifting buoys and surface currents from an Ocean Surface Current Radar (OSCR) for validation.

Again, the PWS N/F system is comprised of three components: 1) a numerical circulation model for PWS run continually in real-time, including realistic synoptic forcing; 2) an observational network for collecting and storing real-time data, used for model forcing and verification; and 3) an information/data management system, consisting of a database, a mechanism for linking the observations and the model, and a user-friendly, interactive, tabular and graphical interface to communicate results to user groups (via the web [see References]). It should be emphasized that this is not an oil spill trajectory model (like GNOME [General NOAA Spill Modeling Environment]); no oil/water interactions are included.

Data collection began this year aboard Alyeska SERVS vessels. Currents throughout the water column were measured using a downward looking acoustic Doppler current profiler towed from the SERVS vessel along transects through central PWS. Repeated transects were made at Hinchinbrook Entrance to remove the tidal component. Temperature and salinity data were collected using XCTDs at three locations.

The timetable for PWS N/F system development spans 5 years. Phase IA (12 months) consists of system design and overlap with SEA closeout. Phase IB (12 months) is devoted to setting up a zero order N/F system. During Phase II (3 years) full real-time capabilities will be implemented.

Partners in this project include Alyeska's Ship Escort/Response Vessel System (SERVS) – ship time, PWS Regional Citizens' Advisory Council – drifters, and EVOS – Hinchinbrook Entrance mooring. We also plan to form links with GLOBEC NEP (NOAA Global Ocean Ecosystem Coupling/Northeast Pacific) investigators, and with NOAA GNOME modelers.

This is an exciting project because of the wide variety of applications. The model trajectory and concentration predictions will serve as a foundation for research and development in several areas of concern, including oil spill trajectory modeling, testing dispersant strategies, iceberg trajectory prediction, vessel traffic safety, and future ecosystem studies.

The Role of The Oil Spill Recovery Institute

The Oil Spill Recovery Institute (OSRI) was founded as a result of the *Exxon Valdez* oil spill in 1989 and the resulting outcry over the inadequacy of response planning, and methodologies. The Oil Pollution Act of 1990 mandated the formation of OSRI and the Coast Guard Reauthorization Act of 1996 provided for the institute's funding.

The Oil Spill Recovery Institute established a proportional goal for three different program areas: applied technology, predictive ecology, and public education and outreach. OSRI's efforts in these areas are carried out as a non-profit and independent research institute. OSRI pursues multidisciplinary, goal directed research. By utilizing vertically and horizontally integrative planning for the direction of research into discreet, incremental steps, OSRI is able to maximize its results from limited resources. Each program area fulfills a strategic position and is allotted a specified percentage of resources to meet OSRI's objectives. Forty percent of OSRI's efforts are aimed at developing and improving applied technologies, another 40 percent is directed at efforts in predictive ecology, and the remaining 20 percent is marked for efforts in public education and outreach.

Applied technology, as defined by OSRI, includes not only the development of better hardware and tools for dealing with spills, but also the development and advancement of scientific technologies. Areas such as remote sensing and computer simulations are considered within the applied technology program at OSRI. As such, applied technology is viewed as the developmental aspect of OSRI's efforts and is the program area responsible for the development of tools and other deliverables. Within this same paradigm, the predictive ecology program is viewed as the research component of OSRI's effort. Predictive ecology programs are geared towards the acquisition of scientific knowledge. These programs are diverse and are designed to provide for predictive capabilities in the event of a spill. Public education and outreach is OSRI's effort to project information to those communities who might benefit. This information is disseminated in a variety of ways including the support of symposia within the scientific community and the publication of literature relating to spills. OSRI, through the public education and outreach program area, also supports community based education efforts such as the award winning "Science of the Sound" program which brings environmental science into the classroom of those communities impacted by the EVOS.

OSRI has established as a 5-year goal the construction of a comprehensive real time physical–biological model for Prince William Sound. Such a comprehensive model will allow for continuous improvement in response planning and methodologies. There are diverse stakeholders within Prince William Sound, often with competing interests. The ability to quantitatively evaluate such diverse interests, particularly during a spill, is a vital capability and represents a substantial advancement in the state of the art for oil spill impact management and planning.

References

Blumberg, A.F. and G.L. Mellor. 1987. A description of a three-dimensional coastal ocean circulation model. *In* N. Heaps [ed.], Three-Dimensional Coastal Ocean Models, vol. 4. American Geophysical Union.

NDBS/C-MAN	seaboard.ndbc.noaa.gov/cman.phtml
PORTS	www.co-ops.nos.noaa.gov/d_port.html
PWSSC	www.pwssc.org
Scripps/CCS	www-ccs.ucsd.edu/oilspill
SFNFS	www.rsmas.miami.edu/groups/cimas/cimas-oprc.html
TABS	www.gerg.tamu.edu/Tglo

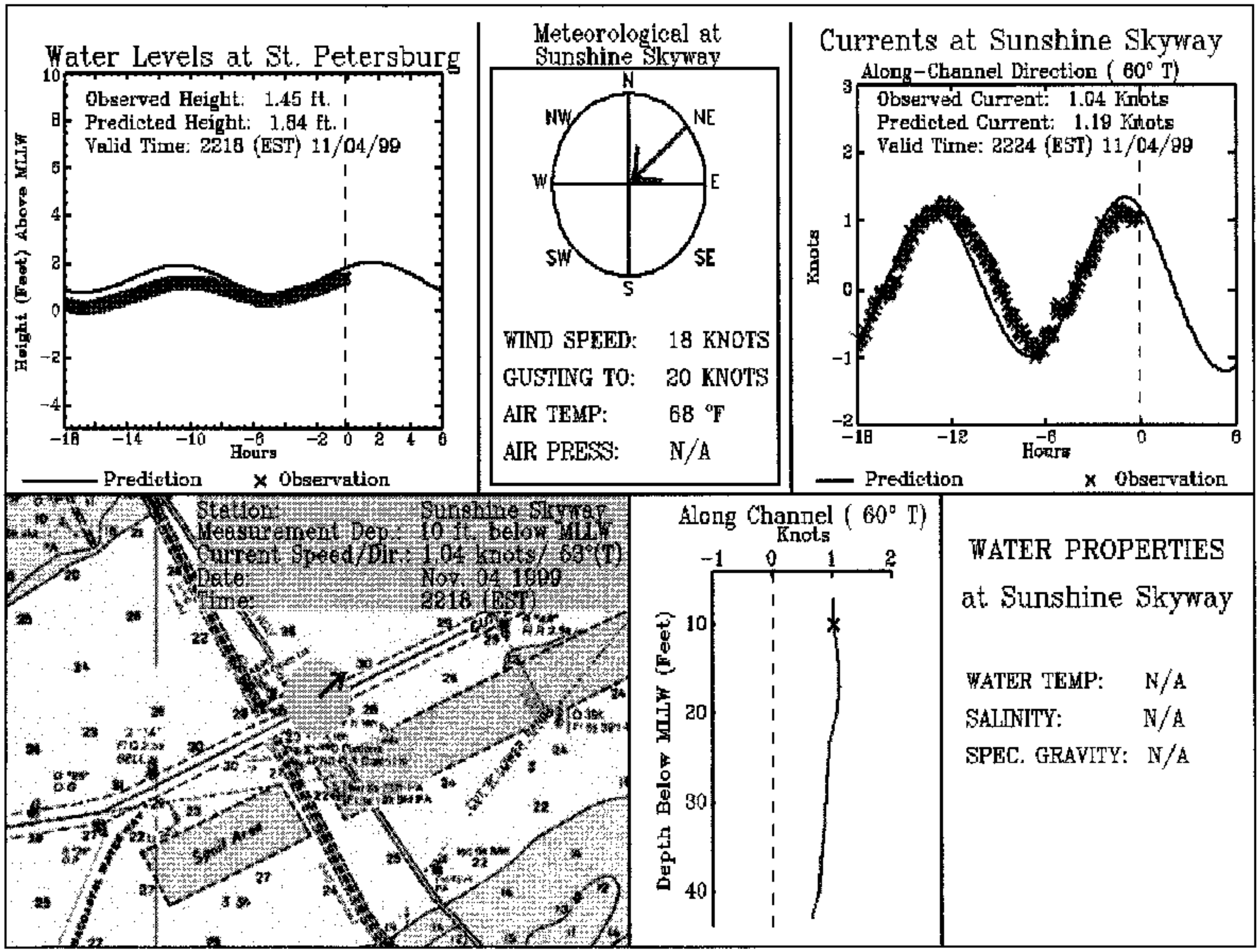


Figure 1. Examples of PORTS data for Tampa Bay.

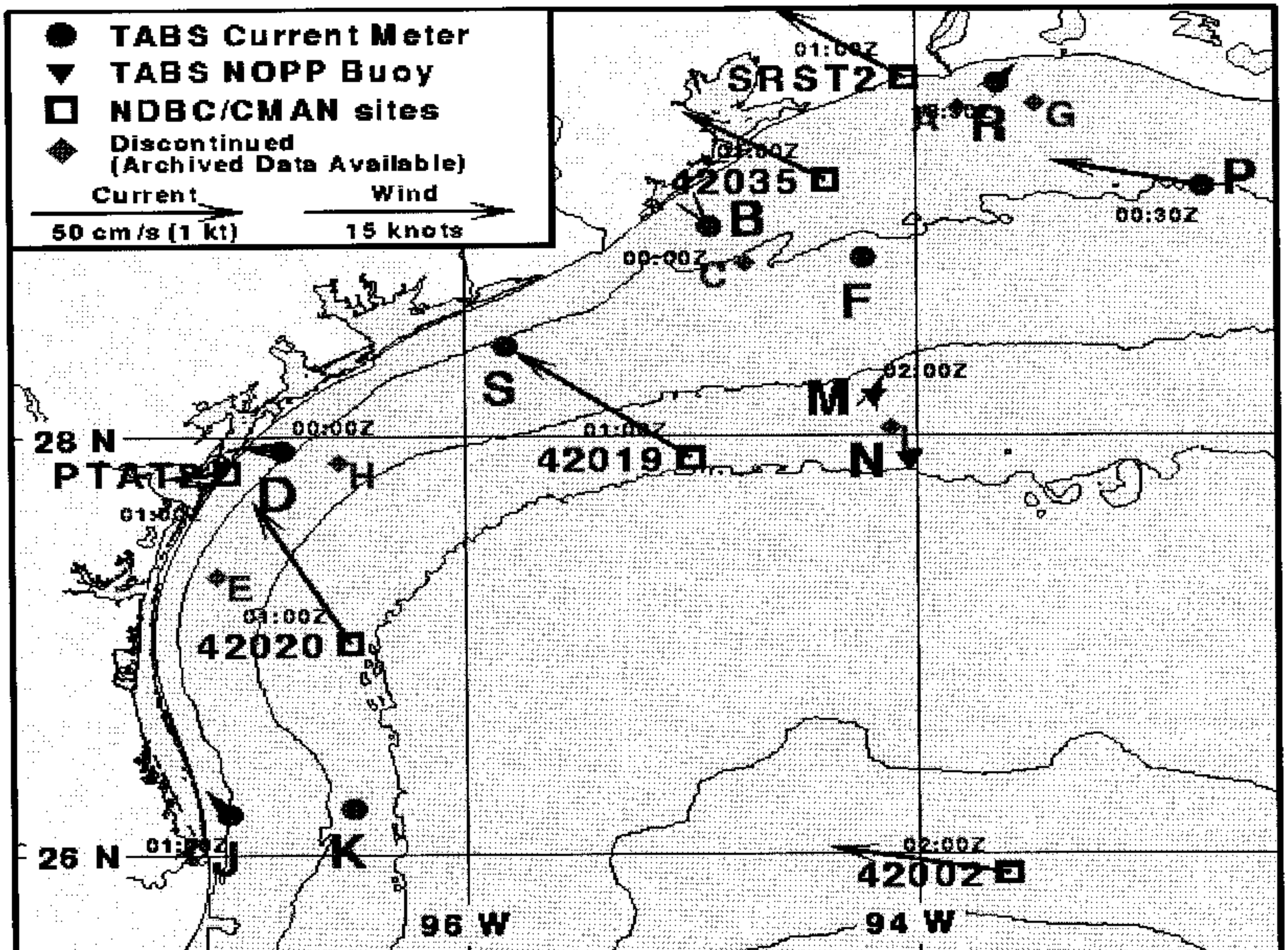


Figure 2. TABS Gulf of Mexico measurement array.

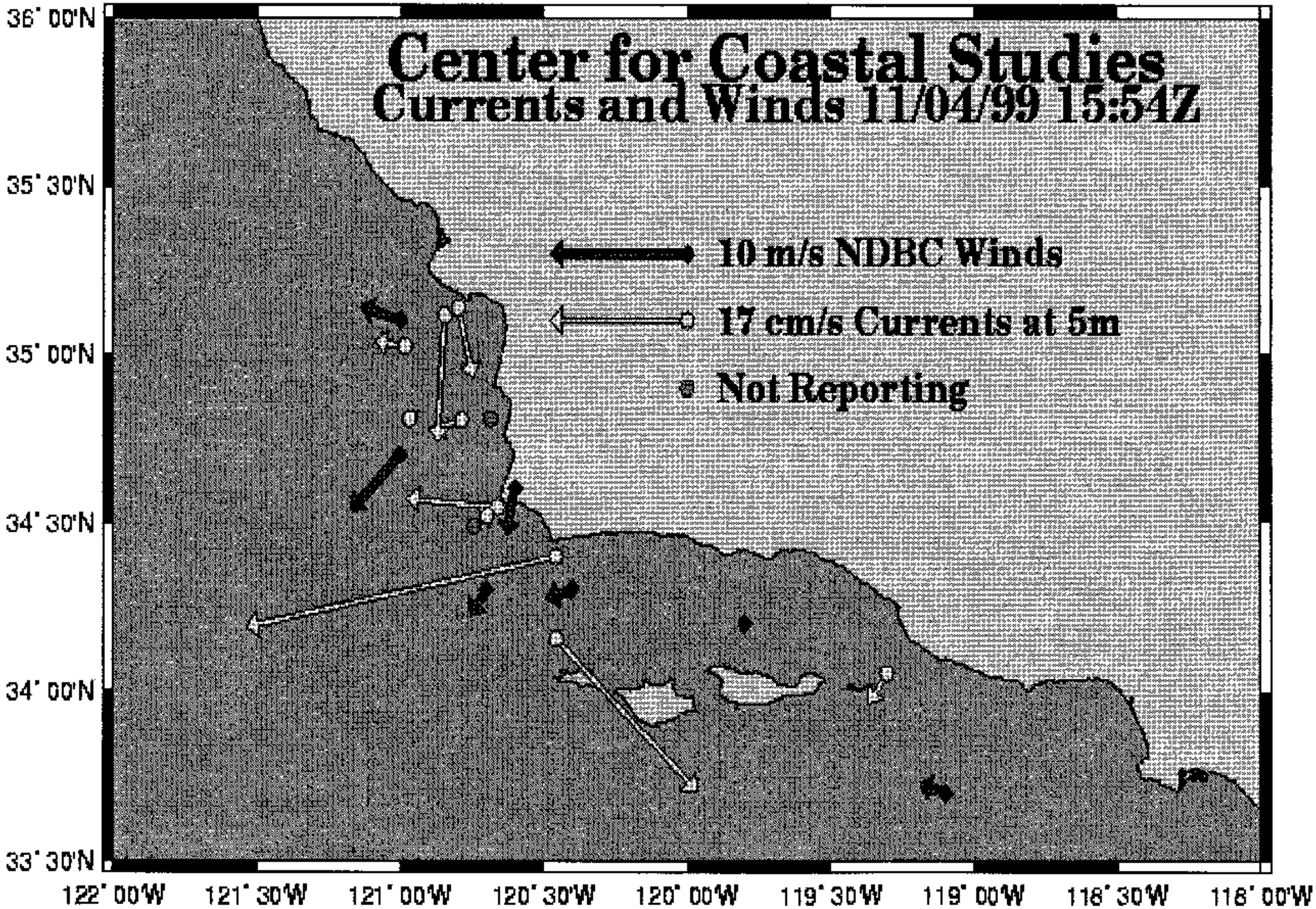


Figure 3. Observed data for the Santa Barbara Channel.

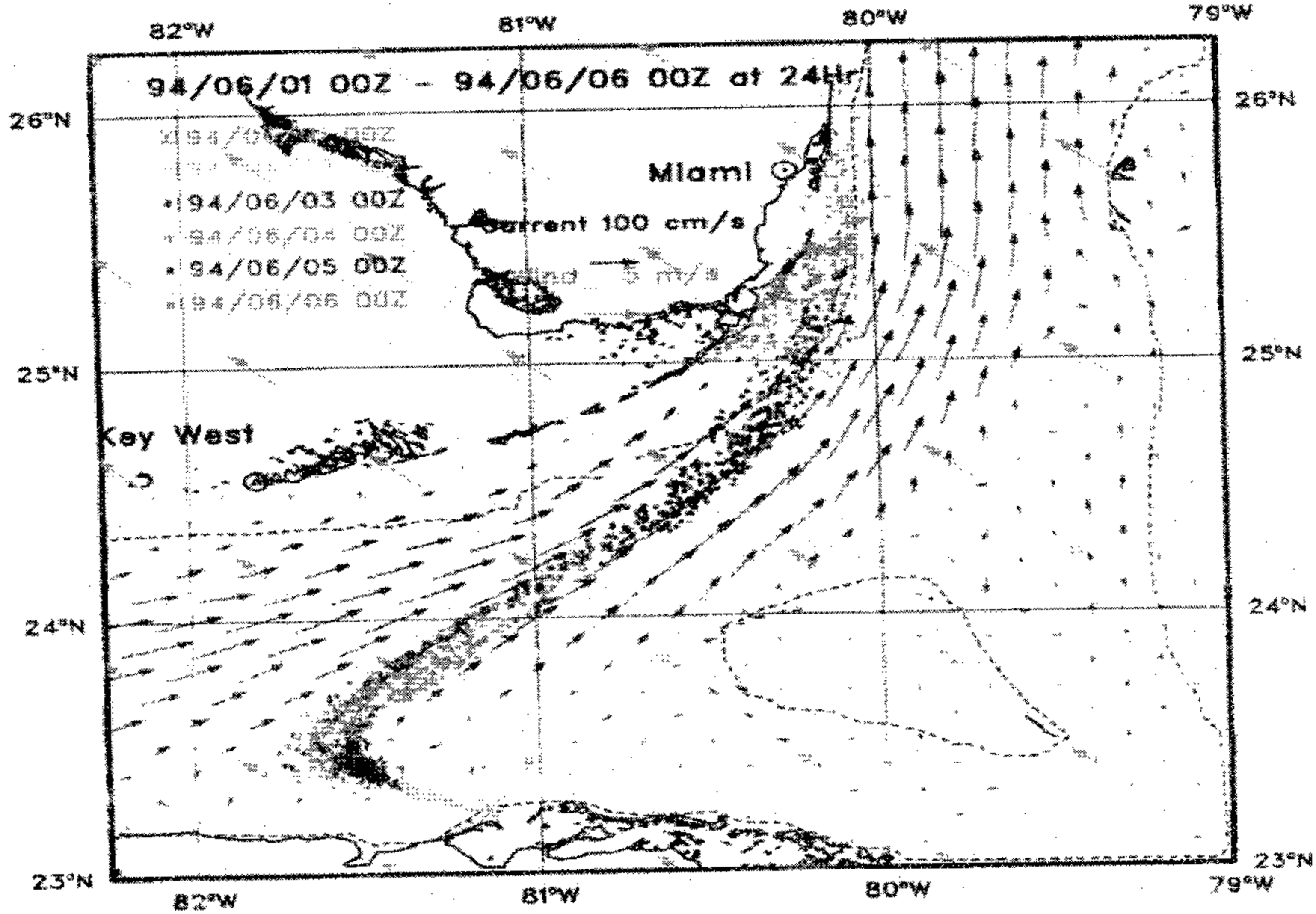


Figure 4. SFNFS trajectory prediction.

Group Discussion:
Operational and Research Goals for Cook Inlet

The afternoon discussion focused on recommending future directions for Cook Inlet research and model development. Future research falls into two broad categories: observations and modeling. The attendees generally agreed on several strategies, and their suggestions are presented in the following paragraphs.

The workshop participants recommended that an observational program making systematic measurements of oceanographic properties, including temperature, salinity, velocity, ice thickness and distribution, be initiated as soon as funding allows. Observational programs in Cook Inlet must establish the mean and variance of frontal locations. In particular, velocity measurements were deemed a high priority if progress is to be made in locating and quantifying the temporal and spatial variability of the tidal rips. Such knowledge is essential to understanding the 3-D circulation in Cook Inlet. It was recommended that use of remote sensing be continued, especially in conjunction with direct current measurements using acoustic Doppler current profilers (ADCP). Other hydrographic measurements (temperature, salinity, pressure) throughout Cook Inlet were strongly encouraged. While measurements in the tide rips are a high priority, measurements of the freshwater content over western Cook Inlet are also needed.

A discussion on the utility of direct velocity measurements using current meter moorings recognized that the high initial costs of mooring deployment and recovery were frequently offset by the high data return from a successful mooring program. Many participants encouraged the development of a mooring program with deployments in key locations in Cook Inlet. Several attendees mentioned using ships-of-opportunity to better advantage than has been done in the past.

Drifting surface buoys, as well as buoys deployed on ice, have identified current pathways in Cook Inlet. Future buoy programs need to acknowledge the relationship between a statistically reliable estimate of current speed and direction and the number of buoys released. A well-planned buoy program in Cook Inlet would require many tens of buoys to obtain reliable statistics of the flow. As with any observational program, the cost associated with launching a large number of buoys versus the total data return needs careful consideration.

Recommendations for improving numerical models centered on model validation, the inclusion of realistic forcing functions (tides, winds, freshwater), and increasing model resolution. The workshop participants felt that validation was an essential part of ongoing development of Cook Inlet oil-spill trajectory models, and recommended formal model validation and testing for all Cook Inlet models. Validation is an assessment of differences between model output and observations. One validation scheme that was discussed would compare model results with ADCP data collected over the complete tidal cycle at a number of locations under a range of wind conditions.

It is well known that Cook Inlet circulation is influenced by the flow of the Alaska Coastal Current (ACC). Future models could incorporate variable forcing by the ACC using boundary conditions from the Gulf of Alaska. Data from moorings in Kennedy Entrance could provide this important information.

The models presented at this workshop appeared to simulate reasonably well the surface flow of Cook Inlet. While tidal forcing clearly dominates the flow regime, questions arose whether non-hydrostatic models, which can better simulate fronts and frontogenesis, would lead to better model results.

Frontogenesis is an important component in the evolution of tide rips in Cook Inlet, but whether it is necessary to oil-spill trajectory models is unclear.

An important question for the modeling group was whether 2-D trajectory models need to incorporate vertical resolution. No consensus emerged, but it was noted that direct observations (e.g., ADCP measurements) show the flow to be essentially barotropic (i.e., moves as a slab), suggesting that 2-D models may be adequate. Until such time when thorough model validation is completed, and any shortcomings identified, 2-D models appear to have sufficient vertical resolution to meet their intended use. While higher 2-D (horizontal) resolution was suggested as an obvious way to resolve circulation features, an important characteristic of the models is their ability to run on a personal computer, an attractive feature that may be lost with increased horizontal resolution or 3-D resolution.

The closing discussion focused on recommendations for long-range research in Cook Inlet. There was clear consensus that long-range planning reduces start-up costs, and allows sufficient time to plan a remote sensing and data collection program. Workshop participants recognized programs in California and Florida that integrated and systematized collection of tide, wind, temperature and salinity data. These programs are templates upon which to build parallel programs for Cook Inlet while recognizing that Cook Inlet is unique, with ice a dominant factor for five or six months out of the year.

The participants agreed that data collection in Cook Inlet should continue. Data collected using the ADCP was given a very high priority both for building a comprehensive data set on Cook Inlet circulation and providing data for model development, testing, and validation. It was suggested that multi-year data collection programs be put in place now, while development pressure in Cook Inlet is comparatively low. A complete hydrographic data set from Cook Inlet should be assembled and used in future decision making.

APPENDIX

Doug Krause & Orson Smith, University of Alaska Anchorage, Anchorage, AK
Nate Mulherin, Cold Regions Research & Engineering Laboratory, Hanover, NH

Poster Presentation: Distribution of Salt and Sediment in Cook Inlet Sea Ice Cores 2/15/99

Abstract

Sea-ice cores were collected offshore in the Forelands region of Cook Inlet (Figure 3), and beach ice, or stamukhas, were collected from Turnagain Arm during February and March 1999, respectively, as part of a preliminary survey of sea-ice characteristics at the University of Alaska Anchorage School of Engineering. The average depth of seven sea-ice cores was 0.5 m. Cores were cut horizontally every 3–5 cm for the sea ice, and every 8 cm for the stamukhas. Sediment concentrations (taken as total particulate matter) were measured by sieving and filtering the melted samples. Salinities and sediment distributions are presented as depth profiles (Figure 2). High concentrations of entrained sediments are associated with dynamically grown ice, especially in frazil ice grown in highly turbulent water [Eiken 1997]. Suspension freezing is the principal loading mechanism of entrained sediment in arctic sea ice [Reimnitz 1993]. Sand size particles (>63 mm) were less than 5% of all of the sea ice samples, and over 50% of the beach ice samples.

Cook Inlet Forelands Sea-Ice and Water Results

The mean sediment concentration was 433 mg/L, and mean salinity, 6.41 psu (+/– 1.97 psu). For six surface water samples taken in the vicinity of the cores, the mean suspended particle matter (SPM) concentration was 164 mg/L (+/– 21 mg/L) and the salinity, 27.43 psu (+/– 0.66 psu.). These results indicate that Cook Inlet sea ice is enriched in sediment by a factor of about three in relation to the surrounding water.

Turnagain Arm Fast-Ice Concentrations

One 160-cm core of ice was sampled. The mean sediment concentration was 24,938 mg/L (s.d. = 22,219 mg/L), the salinity 1.07 psu (s.d. = 0.94 psu). An intensive study of stamukha formation began in October 1999.

Regarding Cook Inlet sea ice: On a centimeter scale, the large variability of the sediment concentration (Figures 1 and 2), ranging from nearly zero to 1.5 grams of sediment in 0.25-L samples, is due to suspension freezing dynamics. The variability of the 83 samples was 433 +/– 704 mg/L, while on a regional scale, the variability is much lower, 433 +/– 185 mg/L for the average of the seven cores. In comparison to arctic ice, which is well studied, there is more sediment and brine volume entrained in Cook Inlet sea ice. During winter an estimated 500,000 metric tons of sediment is entrained in the ice at a given moment, not including floating beach ice. Sediment transport, pollution fate, and deposition would all be significantly affected by the circulation of the ice in relation to the underlying water. This work will continue during the winter of 1999–2000.

References

Eicken, H., E. Reimnitz, V. Alexandrov, T. Martin, H. Kassens and T. Viehoff. 1997. Sea-ice processes in the Laptev Sea and their importance for sediment export. Cont. Shelf Res. 17:205–233.

Reimnitz, E., P.W. Barnes and W.S. Weber. 1993. Particulate matter in the pack ice of the Beaufort Gyre. J. Glaciol. 39:186–198.

Distribution of salt and sediment in Cook Inlet sea ice cores 2/15/99

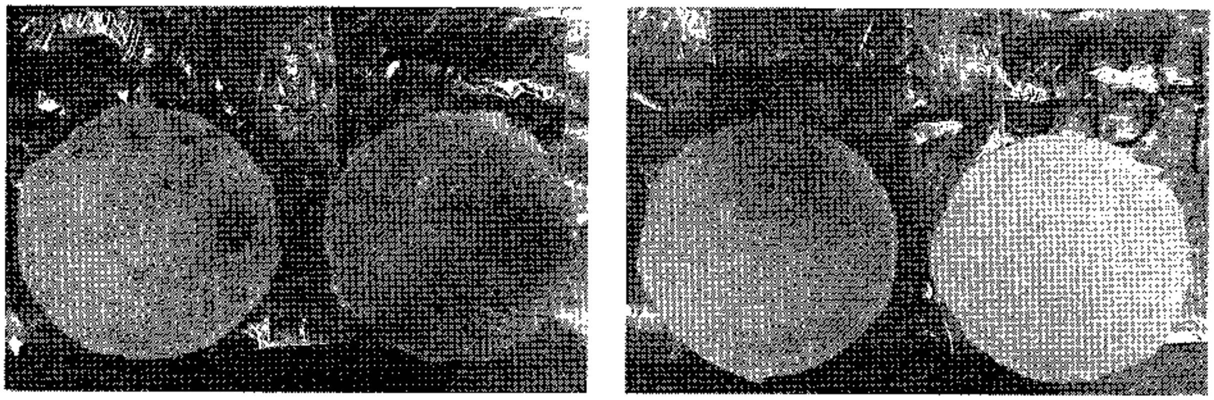
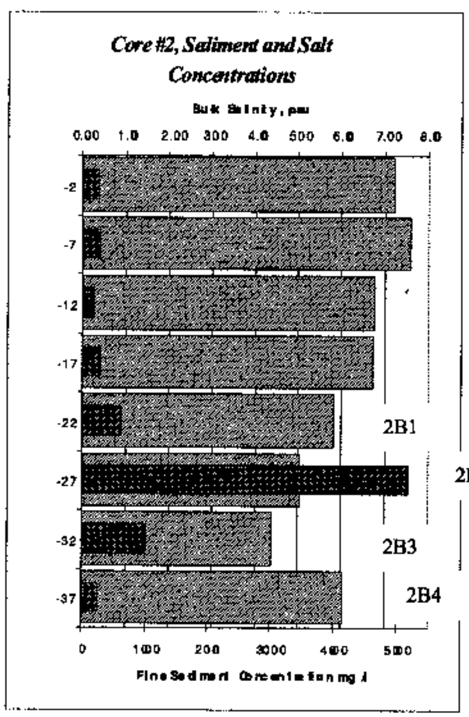
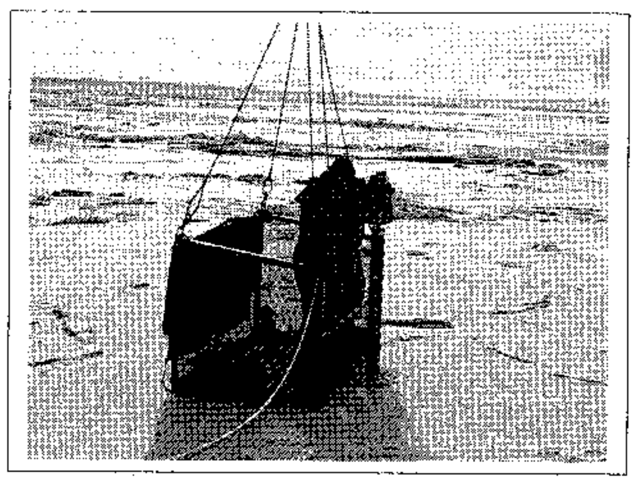


Figure 1. Large Local Variability of Sediment Concentration





Figures 2 and 3. Vertical Profile of Core #2 (one of seven profiles), Coring in the Forelands from the Heritage Service

Cook Inlet Sea-ice and Water 2/15/99:

		s.d.
Mean sediment C =	433 mg/L	(704 mg/L)
Salinity =	6.41 psu	(1.97 psu)
Mean water SPM =	164 mg/L	(21 mg/L)
Salinity =	27.43 psu	(.66 psu)

Less than 5% sand

Erik Oppegard, LCMF Incorporated, Anchorage, AK

Poster Presentation: Hydrographic Survey and Related Services, Upper Cook Inlet

Racal Pelagos, Inc. (RPI), and its subcontractors, LCMF, Inc., and Terra Surveys LLC, performed hydrographic surveying and related support services in Cook Inlet under contract to NOAA's Hydrographic Survey Division to update critical nautical charting of shipping lanes into Anchorage. This project began in 1998 and is scheduled to be completed in 2000. The tidal regime for this area is the most complex in the United States, with a tidal range of 30 plus feet, extensive mud flats, remote sites, 7 knot currents and severe weather. Site conditions and short lead times in the planning and implementation stages made this project challenging. All challenges were overcome, using a combination of suitable equipment, proper planning and management by experienced personnel.

Our team recently completed our first year of this two-year professional services contract. During our first full season we completed the multibeam survey of five sheets in Upper Cook Inlet. The mobilization included the outfitting of a survey launch, F/V *Quicksilver*, and a mother ship, R/V *Davidson*. The *Quicksilver* was converted from its fishing configuration to a state-of-the-art high speed multibeam data acquisition platform. The multibeam system consisted of a RESON Seabat 8101, integrated with a TSS HDMS via an RPI WinFrog multibeam software system. All phases of development and testing including accuracy verifications and procedures were continuously documented and recorded. Extensive training was conducted at RPI prior to mobilization. The mothership was outfitted with multiple UNIX-based processors integrated with a UNIX server operating CARIS Hydrographic processing and cleaning software. The processing procedures were also extensively developed and documented.

An extensive tidal study in Upper Cook Inlet was conducted during the fall of 1998 to establish a tidal zoning scheme suitable for supporting the accuracy requirements of multibeam surveying. Fundamental assumptions regarding zone-derived water level correctors for hydrographic surveying were challenged. The new zoning scheme, developed during the winter of 1998–99, was then employed during the summer of 1999. Nearly 350 zones were developed to relate the water surface in the survey area to the surrounding tertiary tide gauges.

LCMF crews established five remote tertiary stations bracketing the project area. Each station consisted of 5–12 tidal bench marks, two complete digital bubbler systems (Design Analysis H350/355), tide house, solar/battery power systems, extensive cabling and anchoring systems, and GOES telemetry systems. Sites were on open exposed beaches accessible only by helicopter, airplane, or ATV. A GPS static survey was performed on tidal bench marks to determine ellipsoidal heights and provide for 3D coordinates for RTK base stations. The RTK data was used in conjunction with repeat single beam hydrography to assist in assessment of the validity of tidal zoning models. The crews routinely visited sites for normal maintenance and to perform "staff" shots using water leveling techniques. They performed all data analysis, quality control, multiple simultaneous comparisons (datum transfers), tested existing NOAA tidal zoning, developed a new zoning scheme, and revised tidal datums to the newly adopted standard station datums.

The survey crews worked around the clock, seven days a week during the summer of 1999. The five sheets that were completed included 6,276.2 linear nautical miles of surveying covering an area of 158 square nautical miles and 3.25 billion soundings. Data processing was completed on site within 48 hours of data collection to allow for meaningful quality control and coverage analysis. Tidal data was transmitted from the field to the GOES satellite every 3 hours. This data was then downloaded to the LCMF Anchorage office. This allowed analysis and transfer of MLLW tide reducers to the R/V *Davidson* and also allowed RPI to process data within the targeted 48 hour window. RPI worked directly with the NOS personnel from both the Tides Group and the Hydrographic Surveys Division with excellent results and productive relationships.

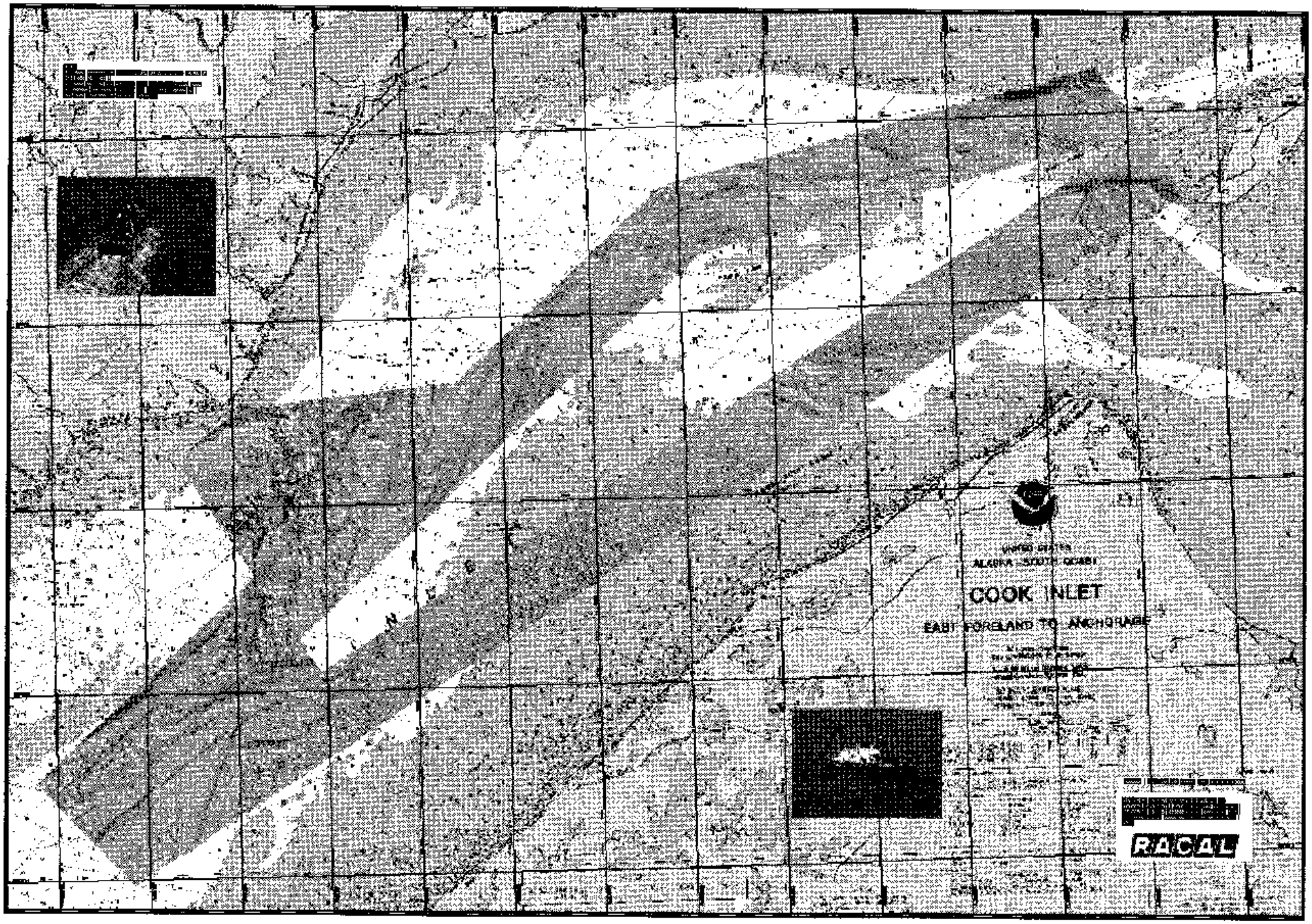


Figure 1. Summer 1999 sonar image of upper Cook Inlet bathymetry.

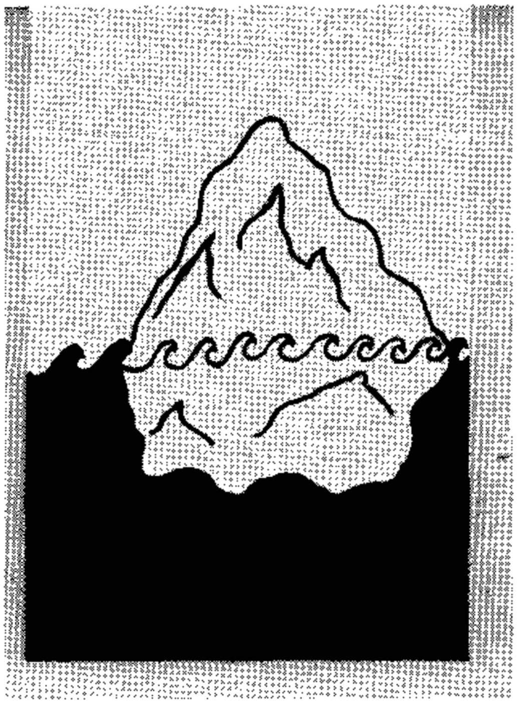
High School Cover Design Honorable Mention

Eric Clore
Skyview High School, Soldotna, AK

Micah Mohler
Skyview High School, Soldotna, AK

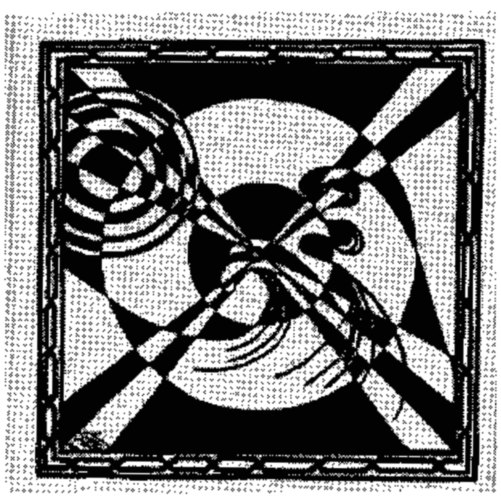
Jennifer Joy
Skyview High School, Soldotna, AK

Hillary Zobeck
Soldotna High School, Soldotna, AK

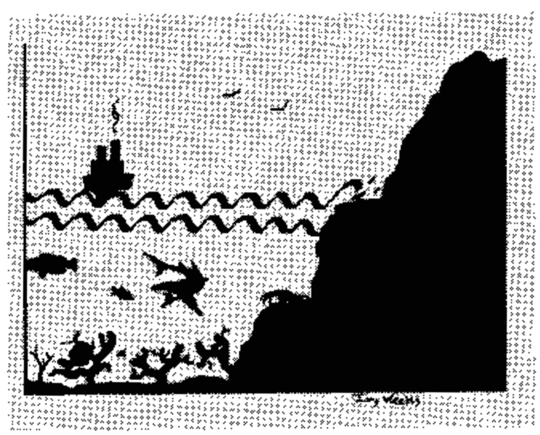


Bryan Cook
Soldotna High School, Soldotna, AK

Darby Murphy
Soldotna High School, Soldotna, AK



Larissa Renney
Soldotna High School, Soldotna, AK



Ivy Weeks
Soldotna High School, Soldotna, AK

Cook Inlet Oceanography Workshop

9 November 1999 • Kenai, Alaska

PARTICIPANTS

Name	Organization	Address	E-mail
Ms. Victoria Askin	Cook Inlet Spill Prevention and Response, Inc.	P.O. Box 7314 Nikiski, AK 99635	cispri@ptialaska.net
Lt. Douglas Baird	Office of NOAA Corps Operations National Oceanic and Atmospheric Administration	4230 University Drive, #120 Anchorage, AK 98508	doug.baird@noaa.gov
Mr. Joel Blatchford	Alaska Marine Mammal Council	P.O. Box 1126 Kasilof, AK 99610	j.k.blatchford@att.net
Mr. Eric Breitenberger	Alaska Department of Environmental Conservation	610 University Avenue Fairbanks, AK 99709	ebreiten@envircon.state.ak.us
Mr. Jerry Brookman	Prevention, Response, Operations & Safety Committee Cook Inlet Regional Citizens' Advisory Council	715 Muir Avenue Kenai, AK 99611	brookman@alaska.net
Mr. Jim Carter	Cook Inlet Regional Citizens' Advisory Council	910 Highland Avenue Kenai, AK 99611	carter@circac.org
Mr. Walter Cox	Oil Spill Recovery Institute Prince William Sound Science Center	P.O. Box 705 Cordova, AK 99574	cox@pwssc.gen.ak.us
Mr. Bud Crawford		36615 Chinulna Drive Kenai, AK 99611	scrawfor@alaska.net
Ms. Rory Dabney	Cook Inlet Regional Citizens' Advisory Council	910 Highland Avenue Kenai, AK 99611	dabney@circac.org
Mr. Robert DeCino	Alaska Department of Fish and Game	43961 Kalifonsky Beach Road Soldotna, AK 99669	robert_decino@fishgame.state.ak.us
Mr. John Douglas	Cook Inlet Regional Citizens' Advisory Council	Star Route 1, Box 80 Kenai, AK 99611	snowboy@gci.net
Dr. Matthew Eagleton	National Marine Fisheries Service	222 W. 7th Avenue, Box 10 Anchorage, AK 99513-7575	matthew.eagleton@noaa.gov
Mr. Barry Eldridge	Cook Inlet Regional Citizens' Advisory Council	2679 Bowpicker Lane Kenai, AK 99611	lridgebb@ptialaska.net

Mr. Pat Shields	Alaska Department of Fish and Game	43961 Kalifonsky Beach Road Soldotna, AK 99669	pat_shields@fishgame.state.ak.us
Mr. James Showalter	Kenaitze Tribe IRA	P.O. Box 988 Kenai, AK 99611	kenaitze@alaska.net
Ms. Caryn Smith	Minerals Management Service	949 E. 36th Avenue, 3rd Floor Anchorage, AK 99508	caryn.smith@mms.gov
Dr. Orson Smith	School of Engineering University of Alaska Anchorage	3211 Providence Drive Anchorage, AK 99508-8054	afops@uaa.alaska.edu
Mr. Jordan Stout	U.S. Fish and Wildlife Service	605 4th Avenue, Room G61 Anchorage, AK 99501	jordan_stout@fws.gov
Mr. Steve Sweet	Institute of Marine Science University of Alaska Fairbanks	Fairbanks, AK 99775-7220	sweet@ims.uaf.edu
Mr. Ken Tarbox	Alaska Department of Fish and Game	43961 Kalifonsky Beach Road Soldotna, AK 99669	ken_tarbox@fishgame.state.ak.us
Dr. Geoff Tomlins	Pacific Geomatics	2817 – 144 Street Surrey, BC V4P 1R4 CANADA	geoff@pacgeo.com
Dr. Shari Vaughan	Prince William Sound Science Center	P.O. Box 705 Cordova, AK 99574	vaughan@pwssc.gen.ak.us
Mr. Darwin Waldsmith		P.O. Box 39309 Ninilchik, AK 99639	
Dr. Jia Wang	International Arctic Research Center University of Alaska Fairbanks	Fairbanks, AK 99775-7340	jwang@iarc.uaf.edu
Dr. John Whitney	Office of Response and Restoration National Oceanic and Atmospheric Administration	510 L Street, Suite 100 Anchorage, AK 99501	john.whitney@noaa.gov
Mr. Bill Wilson	LGL Alaska Research Associates, Inc.	202 – 4175 Tudor Center Drive Anchorage, AK 99508	bwilson@lgl.com
Lt. Chris Woodle	Marine Safety Detachment U.S. Coast Guard	150 North Willow, Suite 41 Kenai, AK 99611	cwoodle@cgalaska.uscg.mil
Ms. Kelly Zeiner	Alaska Department of Natural Resources	550 W. 7th Avenue, Suite 706 Anchorage, AK 99501	kellyz@dnr.state.ak.us

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principals of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.