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Final Report

Measurements of Temperature, Salinity and Circulation in Cook Inlet, Alaska

by

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Abstract

Temperature and salinity were measured in central and lower Cook Inlet, Alaska during the spring and fall of 2002 to assess seasonal changes in frontal characteristics, improve understanding of variability of the local density-driven circulation, and to provide measurements for validation of numerical circulation/oil spill trajectory models. These hydrographic measurements showed that there is a spring-to-fall freshening of ~1.5 psu in the lower inlet and ~3 psu in the central inlet. Frontal gradients were also observed to be stronger during the fall than in the spring. Multiple hydrographic observations along a fixed transect showed that the inclination of the middle rip front decreased during the flood tide, which had the effect of diminishing the speed and vertical extent of the southward-flowing baroclinic jet. Also during the flood tide, the average temperature decreased ~0.5 °C and the average salinity increased ~1.3 psu.

Background and Relevance to Framework Issues

The Cook Inlet area is home to an extensive petrochemical industry. Marine and land-based oil and gas wells supply local refineries, the products of which are transported to Pacific Rim ports by ocean-going tankers. Future state offshore and federal Outer Continental Shelf (OCS) lease sales in Cook Inlet present the potential for additional development of this industry.

An institutional goal of the Minerals Management Service (MMS) is to promote responsible exploration and development in the Alaska OCS Region. One appropriate strategy for responsible development in a marine environment is supporting investigations of physical processes that might influence the behavior and trajectory of spilled oil. Improved understanding of such physical processes is useful for spill response planning and training and, in the event of an actual spill, for predicting the surface trajectory of spilled oil. The research described herein provides descriptions of temperature and salinity in central and lower Cook Inlet with the goal of understanding the local density-driven circulation.

Methods

A Sea-Bird Electronics, Inc. SBE 19plus SEACAT Profiler CTD (conductivity–temperature–depth) was used to acquire surface-to-bottom profiles of temperature and salinity along eight transects in central and lower Cook Inlet, Alaska (Figure 1) during spring (7 May–20 June) and fall (2 October –9 November) 2002. The spring and fall surveys were conducted during periods when freshwater inputs to the inlet were relatively low and high, respectively. The long periods required to complete the seasonal surveys were a logistical consequence of scheduling and using multiple local vessels as sampling platforms. An additional transect in central Cook Inlet was occupied four times on 2 September to monitor the evolution of frontal features during the transition from flood tide to ebb tide. Station spacing between successive CTD casts along a given transect was nominally 3.7 km (2 n mi), although, near the coast, station spacing was often 1.85 km (1 n mi). Locations for each cast were acquired from vessel-mounted or hand-held GPS units. The CTD was lowered at ~30 m min^{-1} and the sample rate was 4 samples sec^{-1}. Temperature and salinity data from each downcast were averaged in 1 m (1 decibar) bins centered on integer depths. Manufacturer calibrations of the CTD, two months prior to the spring survey and six months after the fall survey, indicated sensor drifts of –0.00080 psu mo^{-1} for salinity and +0.00019 °C mo^{-1} for temperature. The one-meter averaged data, described below, have not been corrected for the aforementioned minor sensor drifts.

Baroclinic geostrophic current (a current that results from a horizontal gradient in seawater density) velocities were also computed for the Kalifornsky Beach transects. For each station pair along these transects, the level of no motion was taken to be the deepest common depth. There are two significant caveats to the baroclinic geostrophic velocity computations presented below. The first caveat is a consequence of the underlying assumptions for geostrophic flow. The assumptions are that frictional effects are unimportant and that the conditions giving rise to the currents have achieved steady state. It will be shown that temperature and salinity fields, and therefore density gradients, change in response to the semidiurnal tide and steady state is not achieved. As a result, the magnitudes of the computed baroclinic geostrophic currents reported below are likely overestimates of the current speed. The second caveat is a consequence of the station spacing. The surface expression of a well-developed tide rip front, such as a flotsam streak, was observed to have a characteristic width of approximately 100 m. This width was much smaller than the nominal station spacing (3.7 km, 2 n mi). Consequently, the poor spatial resolution of the strong frontal gradients biases the computations toward an underestimate of the local baroclinic geostrophic frontal currents (jets). The recommendation to the reader is, therefore, to consider the computed geostrophic current speeds as relative measures rather than absolute measures of the baroclinic currents across each transect.

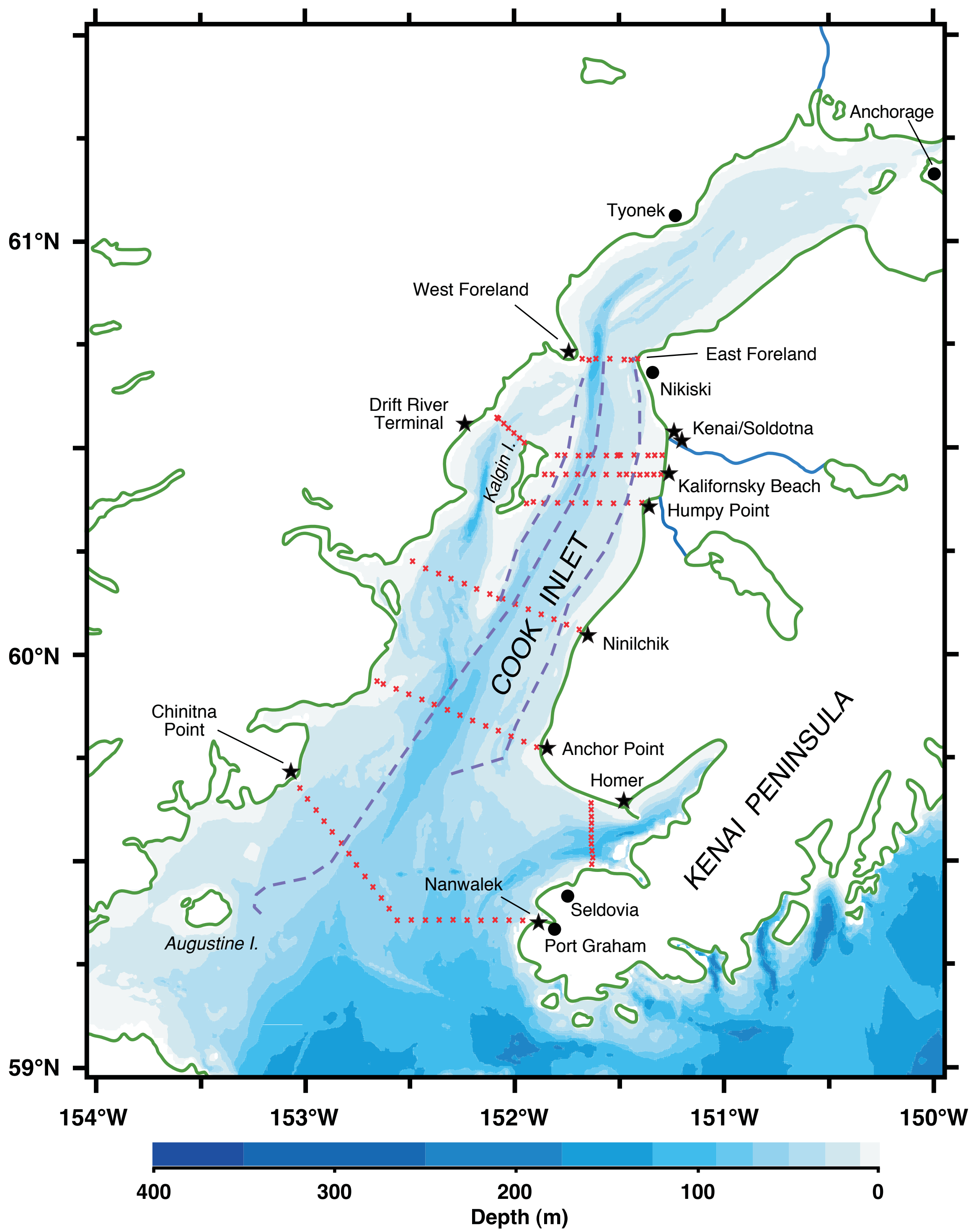

Figure 1. Map of Cook Inlet region with place names. Station locations along transects are indicated by red ×es and transects are identified by the nearest community, river or headland. The dashed lines indicate schematic locations of the west, middle, and east tide rip fronts.

Hydrographic Results

Spring and fall hydrography

This section describes spring and fall hydrography (temperature and salinity conditions) along transects crossing central and lower Cook Inlet (Figure 1). Transect lines are named for nearby headlands, rivers, or communities. In most instances, the hydrographic measurements were acquired during calm seas and light-to-no wind conditions. Consequently, the influence of wind forcing on the hydrographic structure can be neglected. Exceptions to these conditions are noted below. Terms such as weak/strong, fresh/saline, cool/warm are used below to draw relative comparisons between hydrographic conditions at different locations. The term isohaline refers to a surface of constant salinity. The unit of measurement for salinity used in this report is the practical salinity unit (psu) which is the electronically-measured counterpart to the chemically-measured part per thousand (ppt or ‰). Flood tide refers to tidally-driven flow into (generally northward) Cook Inlet, whereas ebb tide refers to tidally-driven flow out of (generally southward) Cook Inlet.

Forelands

The Forelands transect spans a prominent constriction of the channel in central Cook Inlet (see Figure 1). The spring survey along this transect was conducted during the flood tide on 20 June (Figure 2a). The temperature cross section shows an increase of ~1 °C across the shallow (~20 m) eastern half of the transect and very minimal thermal gradients across the deep, western half. Although the salinity varies less than 1 psu between the Forelands, some structure is evident. The weak salinity front near the East Foreland corresponds to the east rip. The fronts on the west and east flanks of the relatively fresh surface plume occurring above the deep channel, correspond to the west and middle rips. The domed isohalines at ~151.65 °W suggest horizontal divergence and upwelling near this location.

The fall hydrographic survey was conducted during a flood tide on 2 October (Figure 2b). While the temperature across this transect is fairly uniform (~11 °C), the salinity ranges from <18 psu at the surface (151.55 °W) to >24.5 psu at the deepest part of the channel. The highest fall salinity (24.5 psu) is less that the lowest spring salinity (25.2 psu). The west and middle rips intersect this transect at ~151.62 °W and ~151.52 °W, respectively, and define the west and east flanks of the low salinity surface lens residing near the middle of the transect. The east rip front, near the East Foreland, is much weaker.

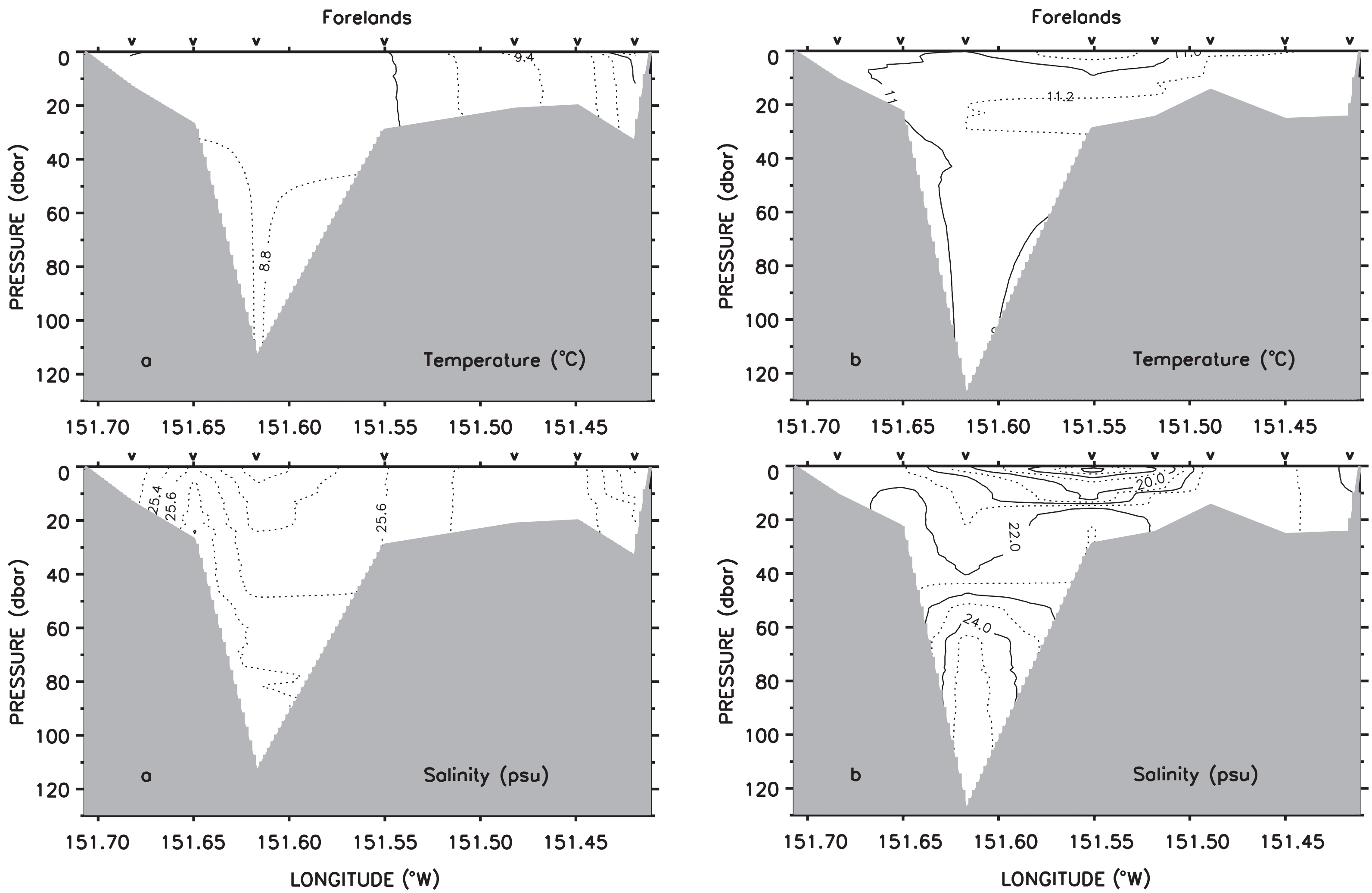

Figure 2. Hydrography from Forelands transect. a) Spring measurements of temperature (top) and salinity (bottom). Temperature contour interval is 0.2 °C. Salinity contour interval is 0.2 psu. b) Fall measurements of temperature (top) and salinity (bottom). Temperature contour interval is 0.2 °C. Salinity contour interval is 0.5 psu. Solid contour lines indicate integer values. Dotted contour lines indicate fractional values. The carets along the top of each plot indicate the locations of the CTD casts.

Drift River

This transect crosses the passage between the north end of Kalgin Island and west side of the inlet just north of the Drift River oil terminal. The spring survey was conducted during the later portion of the flood tide on 20 June about 2 hours after the Forelands section was completed. Temperature and salinity cross sections show similar structures (Figure 3a). Salinity across most of this transect exceeds 29 psu, although slightly lower salinities occur shoreward of the relatively strong front associated with the Drift River plume on the west side of the channel. The relatively high salinities at this section (~ 29 psu) compared to those observed across the Forelands (~ 25 psu) suggest that a strong front and/or significant mixing occur between this section and the Forelands.

The fall survey of this transect occurred on 2 October during the later portion of the flood tide about 2 hours after the Forelands section was completed. Temperature is fairly uniform across this section (Figure 3b). The salinity section shows that salinities range from ~25 psu to ~27.4 psu and that the influence of the Drift River plume extends more than halfway across the transect. A weak front on the east side of the channel is also evident.

Kenai

This east–west transect crosses the inlet from the western shore of the Kenai Peninsula to the north end of Kalgin Island. The spring hydrographic survey, conducted soon after the onset of the flood tide on 3 June, showed a temperature front at 151.5 °W, east of which the temperature increased by ~2.5 °C (Figure 4a). The salinity cross section shows that the most saline water lies adjacent to Kalgin Island. The west rip front is located near 151.75 °W, immediately west of the local salinity minimum. Just east of the local salinity minimum is the comparatively weak middle rip front at ~151.65 °W.

Logistical problems and windy conditions necessitated two trips on consecutive days (2–3 October) to complete the fall survey of this transect. Temperatures and salinities were warmer and fresher relative to spring conditions (Figure 4b). A shallow (~20 m), fresh (<27 psu) plume was observed along the western half of the transect. The middle rip front separates this low salinity plume from more saline waters below and to the east. The surface salinity front centered at ~151.75 °W and lying on the west flank of this plume identifies the surface location of the west rip. The east rip is associated with the salinity front near the eastern shore.

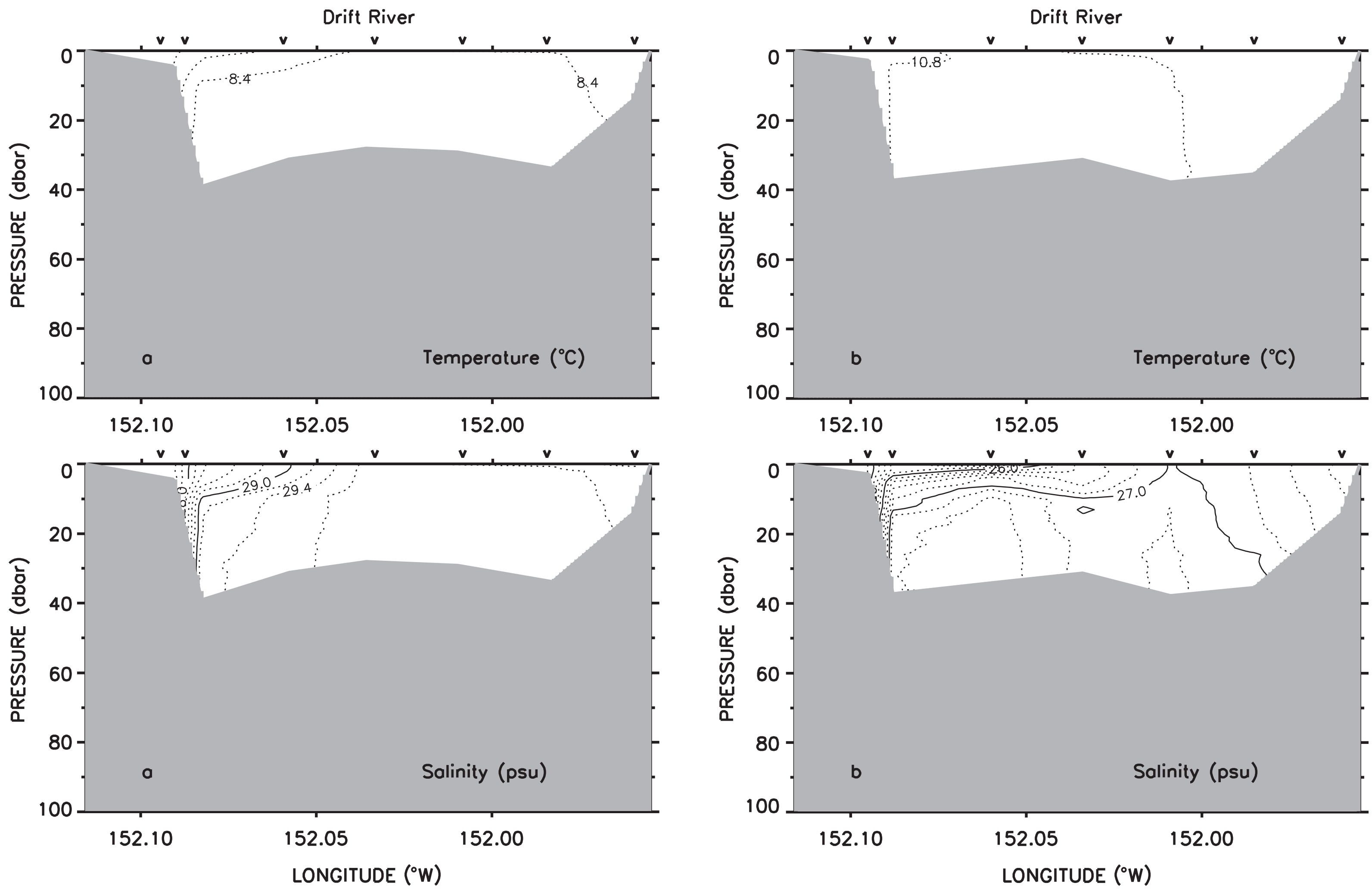

Figure 3. Hydrography from Drift River transect. a) Spring measurements of temperature (top) and salinity (bottom). b) Fall measurements of temperature (top) and salinity (bottom). Temperature contour interval is 0.2 °C. Salinity contour interval is 0.2 psu. Solid contour lines indicate integer values. Dotted contour lines indicate fractional values. The carets along the top of each plot indicate the locations of the CTD casts.

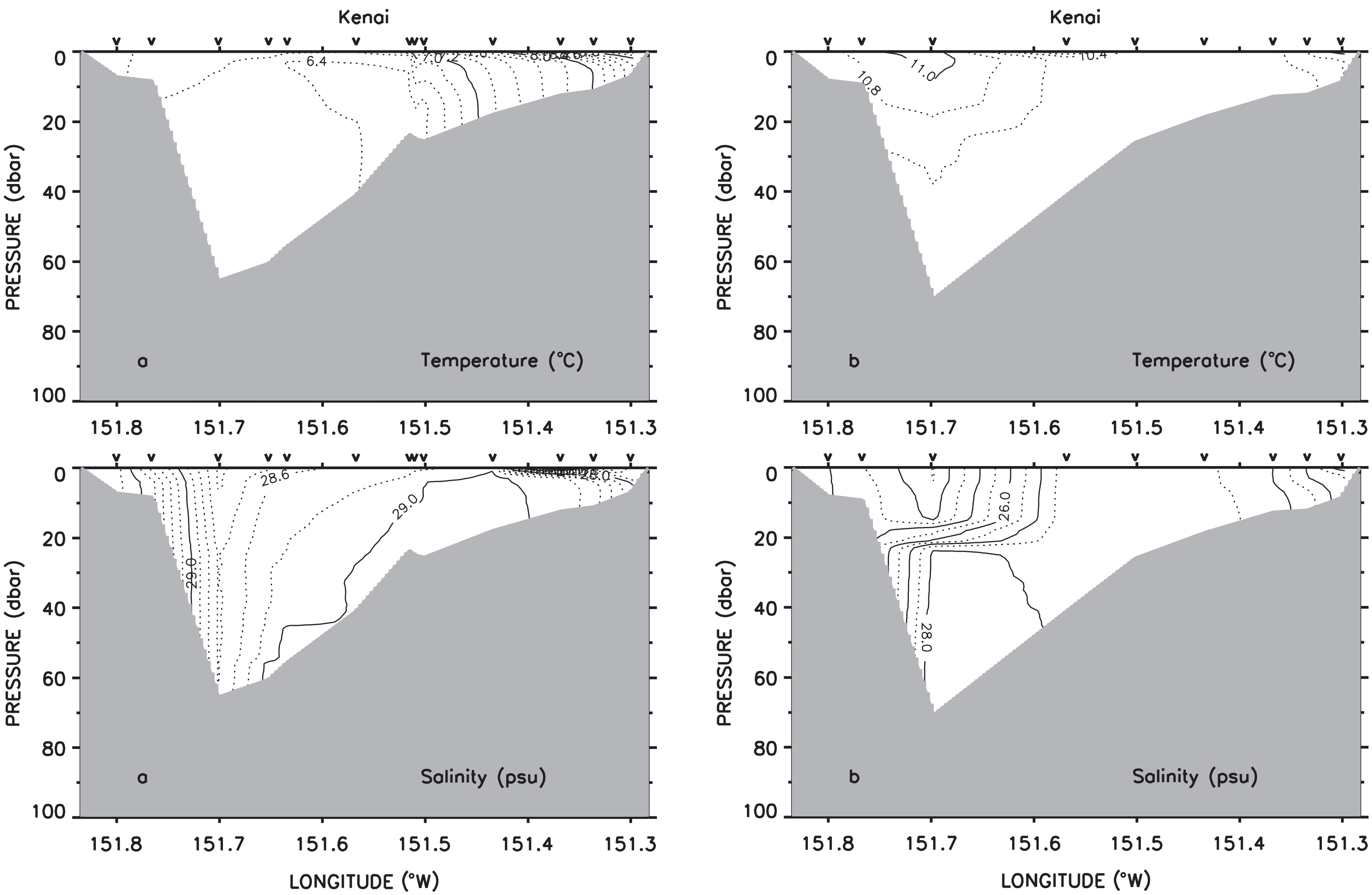

Figure 4. Hydrography from Kenai transect. a) Spring measurements of temperature (top) and salinity (bottom). b) Fall measurements of temperature (top) and salinity (bottom). Temperature contour interval is 0.2 °C. Salinity contour interval is 0.5 psu. Solid contour lines indicate integer values. Dotted contour lines indicate fractional values. The carets along the top of each plot indicate the locations of the CTD casts.

Humpy Point

This transect spans Cook Inlet between Humpy Point (Cape Kasilof) and the south end of Kalgin Island (see Figure 1). The spring hydrographic survey, conducted during a flood tide on 1 June, shows the warmest and most saline waters are found near the coast at each end of the transect (Figure 5a). The freshest water (<29 psu) is observed in a weakly stratified, shallow surface plume near 151.8 °W. The front at the west flank of this surface plume identifies the west rip. The absence of strong gradients elsewhere along the transect does not allow the middle and east rips to be definitively identified.

The fall survey, conducted during an ebb tide on 12 October, revealed relatively weak temperature and salinity gradients (Figure 5b). In general, temperatures were warmer and salinities lower than observed during the spring survey. The most saline water (27.2 psu) occupies the deep part of the channel. Above this relatively saline water lies a wedge of slightly fresher water (<26.4 psu). The weak middle rip front separates these two water masses, intersecting the bottom near 151.85 °W and the surface near 151.7 °W. A weak east rip front is revealed by the gradual freshening east of 151.65 °W.

Ninilchik

The bathymetric profile along the Ninilchik hydrographic transect (Figure 6a) shows a shoal (shallow) area dividing this section into two channels. This shoal extends southward from Kalgin Island (see Figure 1). Hydrography from the spring survey (16 June) reveals a strong thermal front near the eastern end of the transect that, in association with the coincident weak salinity front, identifies the local intersection of the east rip front with this transect. The middle rip is identified by the strong salinity front intersecting the eastern channel near 152 °W. A narrow (~3 n mi), shallow (<20 m) low salinity (<30 psu) plume lies immediately to the west of the surface expression of the middle rip. The surface salinity front near 152.08 °W on the west flank of this surface plume identifies the west rip. However, two less prominent (~5 m thick), fresh (~30 psu) surface plumes residing in the western channel suggest the west rip front is not well defined in this part of the inlet. The most saline water along the transect lies between the middle and east rips.

Hydrographic measurements acquired during the fall survey (16 October) show generally warmer temperatures and lower salinities (26.6–30 psu) relative to spring conditions (Figure 6b). The middle rip front appears to be much stronger than was observed during the spring, whereas the east rip front appears to be somewhat weaker. The local salinity maximum observed along the western flank of the shoal area (near 152.25 °W), while less than observed to the east of the shoal, suggests the occurrence of some northward intrusion in the western channel.

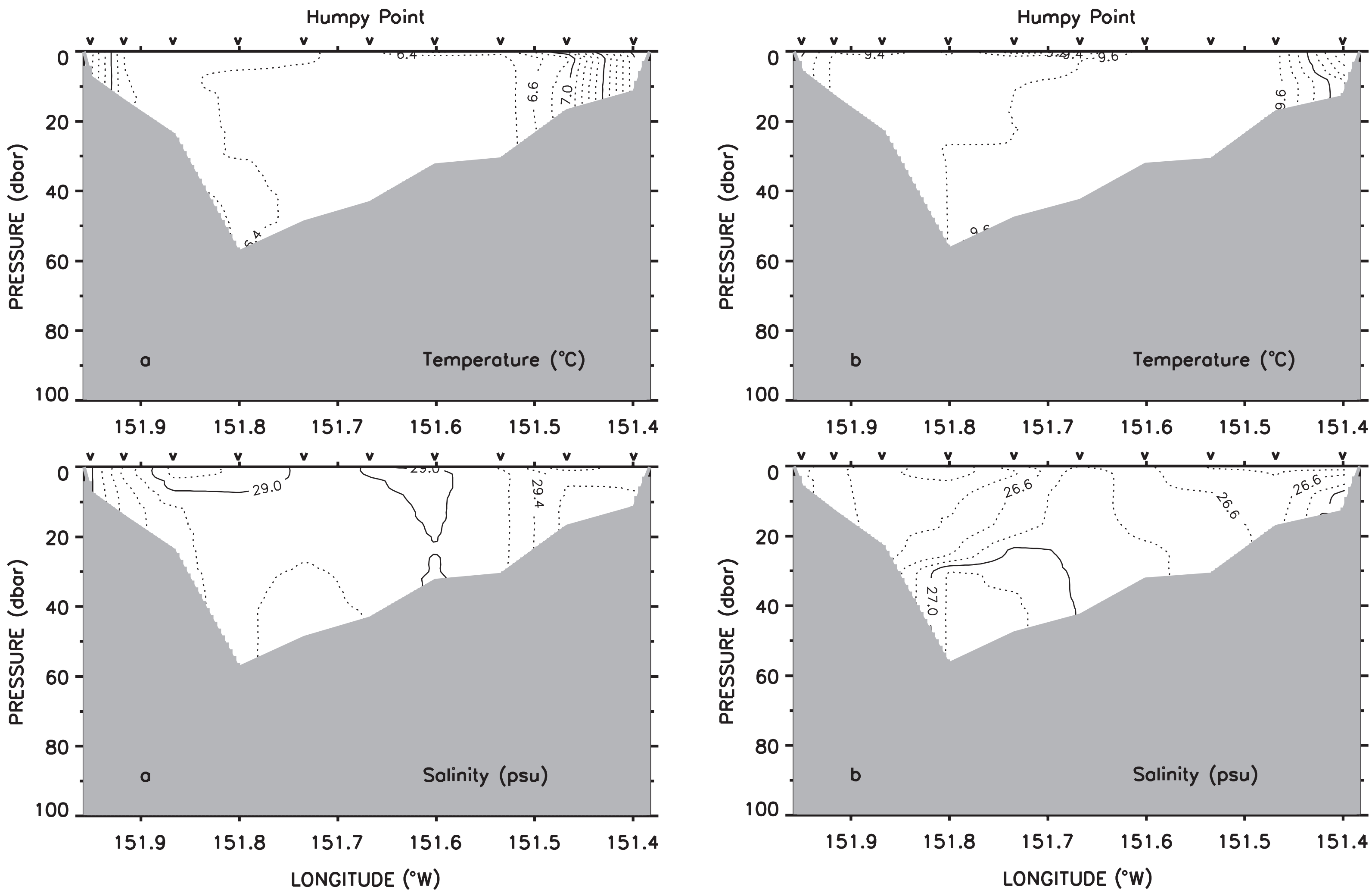

Figure 5. Hydrography from Humpy Point transect. a) Spring measurements of temperature (top) and salinity (bottom). b) Fall measurements of temperature (top) and salinity (bottom). Temperature contour interval is 0.2 °C. Salinity contour interval is 0.2 psu. Solid contour lines indicate integer values. Dotted contour lines indicate fractional values. The carets along the top of each plot indicate the locations of the CTD casts.

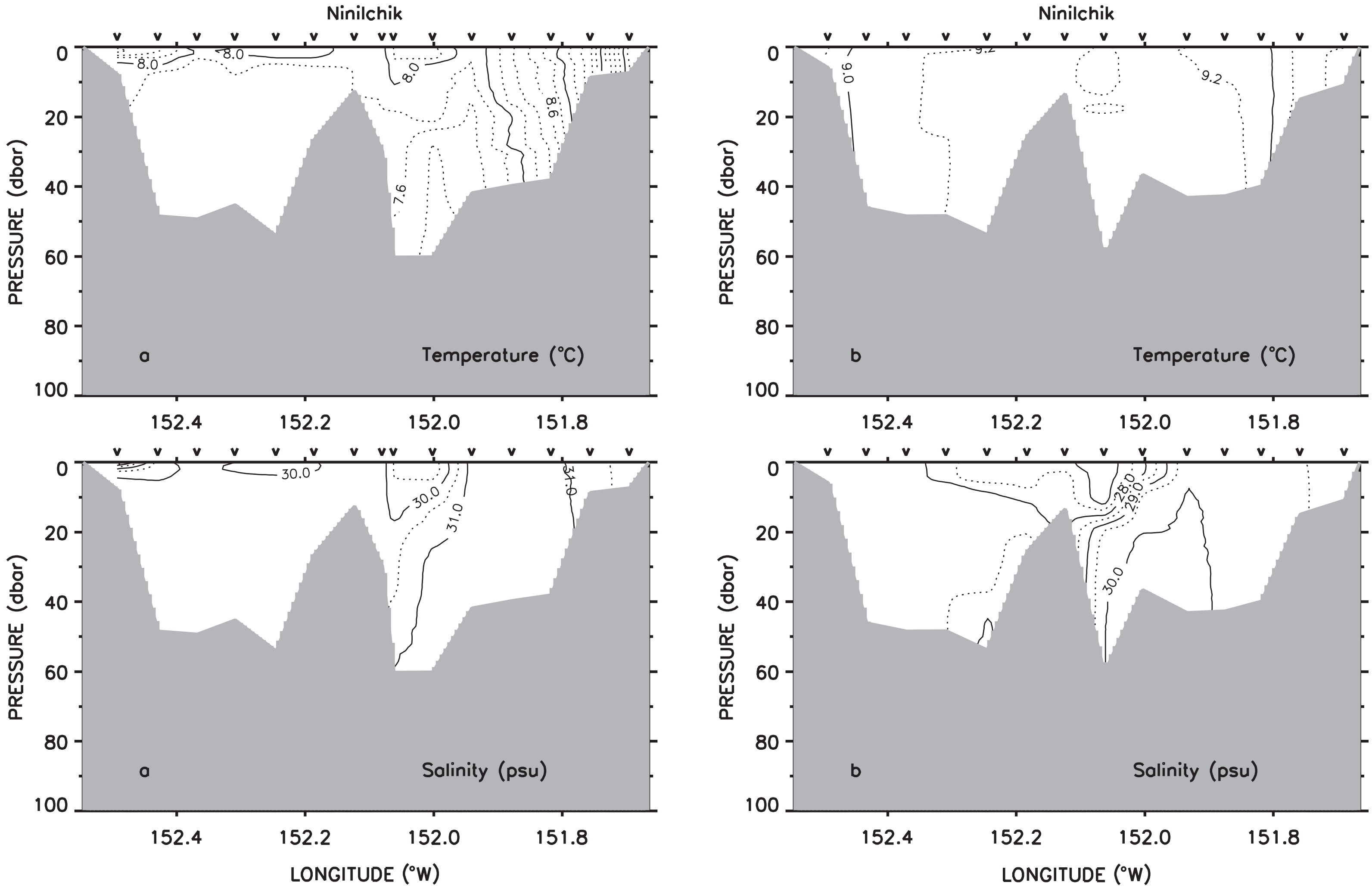

Figure 6. Hydrography from Ninilchik transect. a) Spring measurements of temperature (top) and salinity (bottom). b) Fall measurements of temperature (top) and salinity (bottom). Temperature contour interval is 0.2 °C. Salinity contour interval is 0.5 psu. Solid contour lines indicate integer values. Dotted contour lines indicate fractional values. The carets along the top of each plot indicate the locations of the CTD casts.

Anchor Point

This section spans lower Cook Inlet from Anchor Point on the Kenai Peninsula to Johnson River on the west side of the inlet. Hydrography from the spring survey (16 June) began late during the ebb tide and finished during the flood tide. Temperature and salinity cross sections show three fronts intersecting this transect (Figure 7a). There are weak fronts near the western and eastern shores at ~152.7 °W and ~152.0 °W, respectively, the latter of which is the east rip front. The strong front centered near 152.4 °W marks the location of the middle rip. The coolest and most saline water lies between the east and the middle rips, whereas the freshest waters lie west of the middle rip. Note that because a shallow, fresh surface plume in the center of the inlet is not evident at this transect, the west rip does not extend south to the Anchor Point line.

The fall survey hydrography (15 October), conducted during that latter half of the flood tide and beginning of the ebb tide, shows that salinity across this section is fresher than the spring salinity by a little more than 1 psu (Figure 7b). The locations of the middle and east rips are near their spring locations, however the fall frontal gradients are somewhat stronger. The appearance of a low salinity surface plume and the associated front on its west flank near 152.55 °W indicate that the west rip now extends at least as far south as the Anchor Point transect.

Homer

The north–south Homer transect spans the mouth of Kachemak Bay. Spring sampling (7 May) along this transect occurred during the flood tide and breezy conditions (~20 kt from SW). Nominal station spacing was 1.85 km (1 n mi). Temperature and salinity plots show weak frontal regions in the upper 20–30 m near each coast, indicating that the local baroclinic circulation is cyclonic (Figure 8a).

The fall survey was conducted during a flood tide on 9 November and revealed a thin (~15 m), cool, low salinity, surface plume along the northern half of the transect (Figure 8b). This fresh plume derives from glacial and snowfield melt waters flowing into the inner part of Kachemak Bay. Fall conditions were warmer and fresher than observed during the spring survey.

Nanwalek–Chinitna Point

This transect was occupied in the spring (15 June) but was not occupied during the fall due to scheduling problems and bad weather. The temperature plot shows a thin (~< 5 m), warm surface layer along most of this section (Figure 9). Below the surface layer, there is little horizontal or vertical thermal stratification along the Nanwalek line and eastern portion of the Chinitna Point line. The coolest temperatures (< 7 °C) occur along the eastern half of the Chinitna Point line. West of this temperature minimum the horizontal temperature gradient becomes stronger, with the warmest temperatures (> 9 °C) occurring near Chinitna Point. The organization of the salinity field along this section is similar to that of the temperature field in that the horizontal and vertical gradients are very weak along the Nanwalek line and the eastern portion of the Chinitna Point line. There are two salinity fronts intersecting the western half of the Chinitna Point line. The western-most front resides near Chinitna Point. The middle rip front crosses the transect at ~152.8 °W.

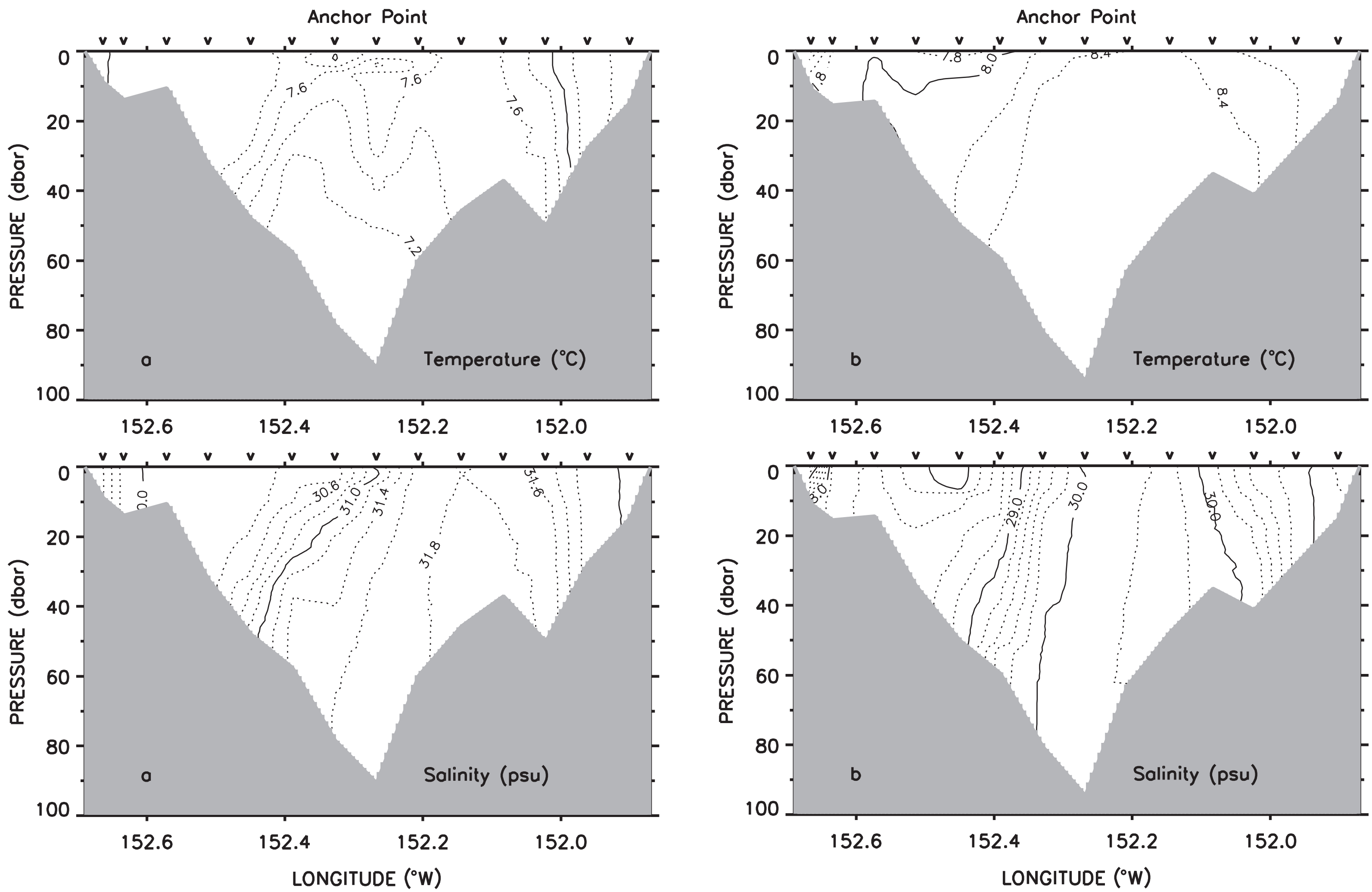

Figure 7. Hydrography from Anchor Point transect. a) Spring measurements of temperature (top) and salinity (bottom). b) Fall measurements of temperature (top) and salinity (bottom). Temperature contour interval is 0.2 °C. Salinity contour interval is 0.2 psu. Solid contour lines indicate integer values. Dotted contour lines indicate fractional values. The carets along the top of each plot indicate the locations of the CTD casts.

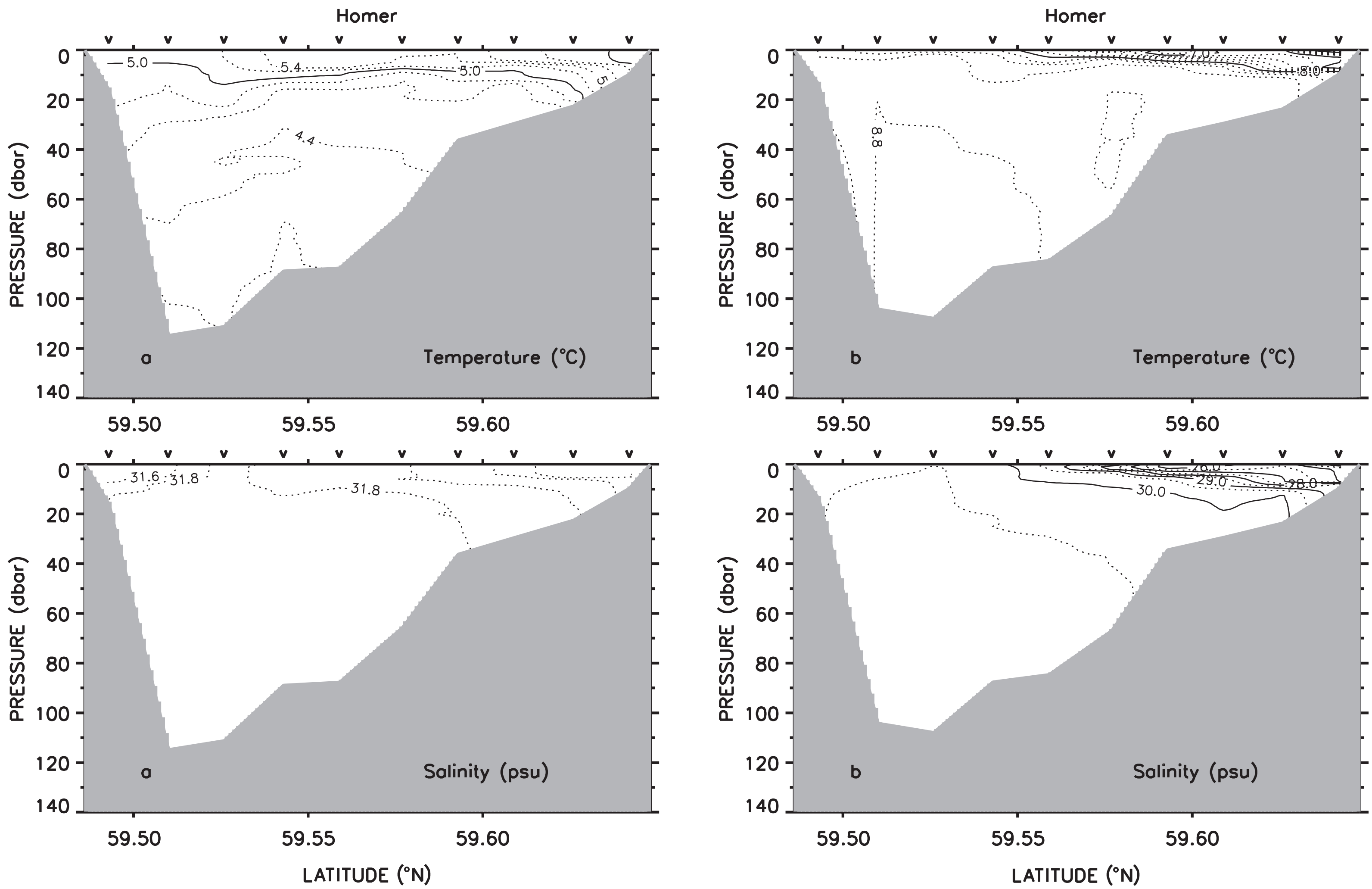

Figure 8. Hydrography from Homer transect. a) Spring measurements of temperature (top) and salinity (bottom). Temperature contour interval is 0.2 °C. Salinity contour interval is 0.2 psu. b) Fall measurements of temperature (top) and salinity (bottom). Temperature contour interval is 0.2 °C. Salinity contour interval is 0.5 psu. Solid contour lines indicate integer values. Dotted contour lines indicate fractional values. The carets along the top of each plot indicate the locations of the CTD casts.

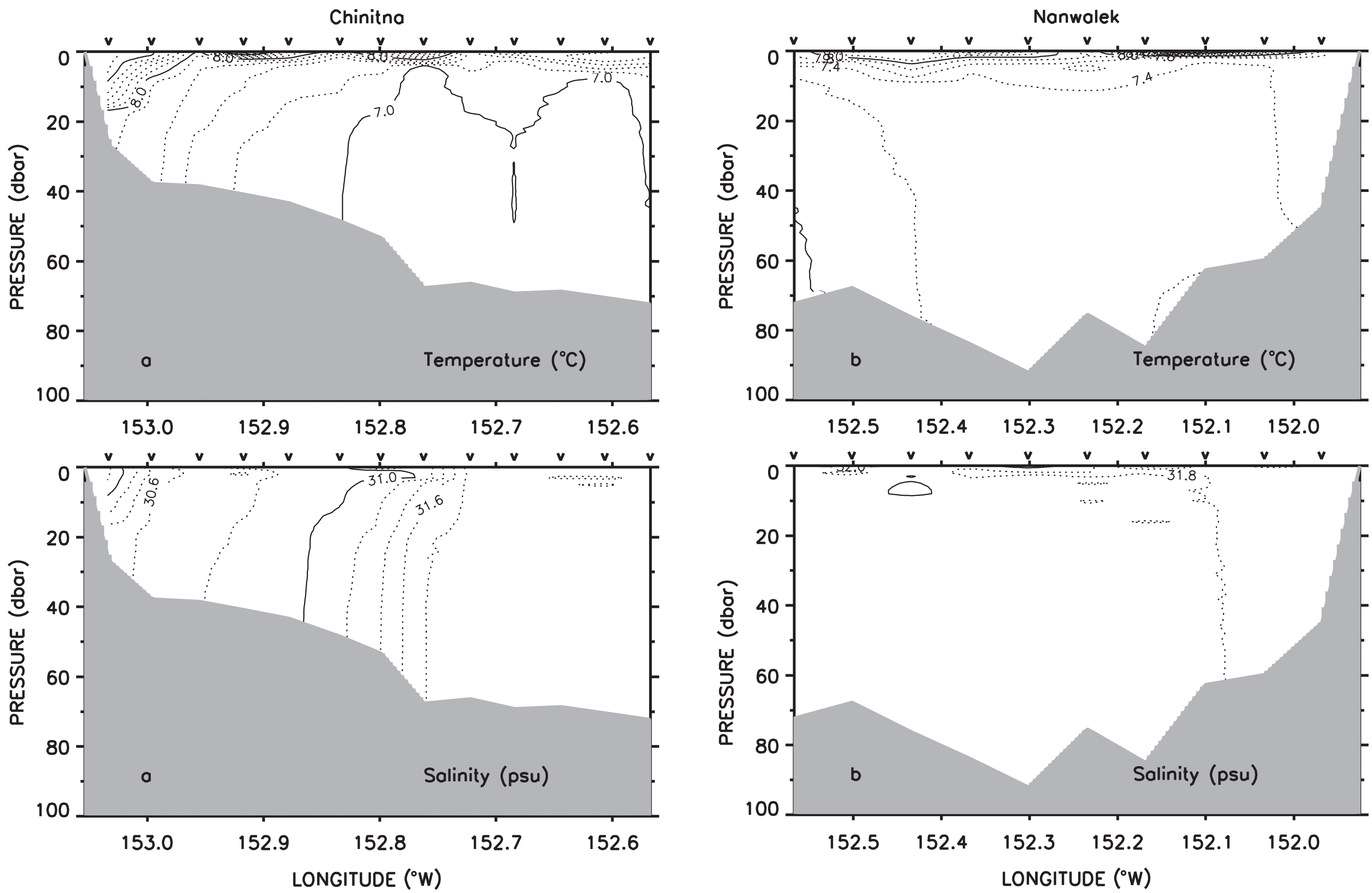

Figure 9. Hydrography from Nanwalek–Chinitna Point transect. a) Spring measurements of temperature and salinity (bottom) from a) Chinitna Pont line and b) Nanwalek line. Temperature contour interval is 0.2 °C. Salinity contour interval is 0.2 psu. Solid contour lines indicate integer values. Dotted contour lines indicate fractional values. The carets along the top of each plot indicate the locations of the CTD casts.

Spring and fall averaged temperature and salinity fields

Area-averaged temperatures and salinities were computed for spring and fall conditions at each transect according to

$$\overline{P} = \frac{\sum_{i=1}^{N} \left\{ w(i) \sum_{d=0}^{z(i)} P(d) \right\}}{\sum_{i=1}^{N} w(i) z(i)} \tag{1}$$

in which $\overline{P}$ is the area-averaged property (temperature or salinity), *P(d)* is the property value (temperature or salinity) at station *i* and depth *d*, *z* is the depth of the water at the *i*th station, and *w* is the horizontal distance (width) between the location midway between stations *i*–1 and *i* and the location midway between stations *i* and *i*+1.

The results summarized in Table 1 show that the lower inlet is generally cooler and more saline than the central inlet during both spring and fall. The relatively low spring temperatures for the Homer, Humpy Point, and Kenai transects would likely have been warmer had these transects been occupied in mid-June when the other spring surveys were conducted. At the Forelands, the temperature increased ~2 °C and the salinity decreased ~3 psu from spring to fall. In the lower inlet along the Anchor Point line the temperature increased ~0.8 °C and the salinity decreased ~1.7 psu from spring to fall. The magnitudes of the north–south temperature and salinity gradients were larger during fall than spring. The overall northward freshening implies that there is a broad, weak westward component to the baroclinic circulation.

Table 1. Spring and fall mean temperatures and salinities.

	Average Temperature (ºC)		**Average Salinity (psu)**	
	Spring	Fall	Spring	Fall
Forelands	9.02	11.15	25.69	22.64
Drift River	8.33	10.81	29.49	27.06
Kenai	6.65	10.60	28.76	27.30
Humpy Point	6.37	9.57	29.13	26.76
Ninilchik	7.85	9.27	30.60	28.97
Anchor Point	7.53	8.37	31.26	29.57
Homer	4.56	8.71	31.82	30.35
Chinitna Point	7.09	–	31.46	–
Nanwalek	7.31	–	31.82	–

Repeat hydrography

This section describes the evolution of temperature, salinity, and baroclinic geostrophic velocity fields along an east–west transect during the transition from flood to ebb tide. This transect lies midway between the Humpy Point and Kenai lines at Kalifornsky Beach (see Figure 1) and was occupied four times during an eight hour period on 2 September. Winds were calm to light. The characterization of flood and ebb tides as used below refers to the direction of the surface flow. Flow is northward during the flood tide.

The first crossing of this transect occurred during flood tide. Vessel drift at all stations had a northward component. The temperature and salinity fields are seen to be well defined and similar in structure (Figure 10a and b). Relatively cool (< 13 °C), saline (>27 psu) water occupies much of the eastern flank of the channel. The salinity ranges from less than 22 psu at the surface near 151.7 °W to more than 30 psu near the bottom of the channel (151.63 °W). The fronts separating the cool, saline water mass from warmer, fresher waters above and to the east are the middle rip front and the east rip front, respectively. To aid in the descriptions of the locations and orientations of the three principal fronts, the 27-psu isohaline will be used to identify the middle and east rip fronts, and the 24-psu isohaline will be used to identify the west rip front. The middle rip front intersects the bottom at a depth of ~45 m and intersects the surface at ~151.57 °W. The magnitude of the middle rip surface salinity gradient exceeds 1 psu km^{-1}. The east rip front intersects the bottom and surface at ~151.42 °W and 151.51 °W, respectively. The west rip front, near 151.81 °W, is associated with the west flank of the fresh plume that lies above and to the west of the middle rip. The plot of the corresponding baroclinic geostrophic velocity field shows a strong southward-flowing jet (~151.67 °W) above the middle rip front (Figure 10c) and weaker, northward flows associated with the east and west rips.

The second crossing of this transect occurred during the latter part of the flood tide. Vessel drift at all stations had a northward component and was generally slower than during the previous crossing. The locations at which the west, middle and east rip fronts intersect the surface moved slightly eastward to 151.78 °W, 151.55 °W, and 151.36 °W from their previous locations. The volume of water with salinity greater than 30 psu has increased and temperatures less than 11 °C have appeared in the deep part of the channel (Figure 11a and b). The plot of the geostrophic velocities shows that the southward-flowing middle rip jet has weakened and the northward-flowing west rip jet is apparently stronger (Figure 11c). The apparent intensification of the west rip jet is most likely a consequence of the close station spacing near 151.78°W.

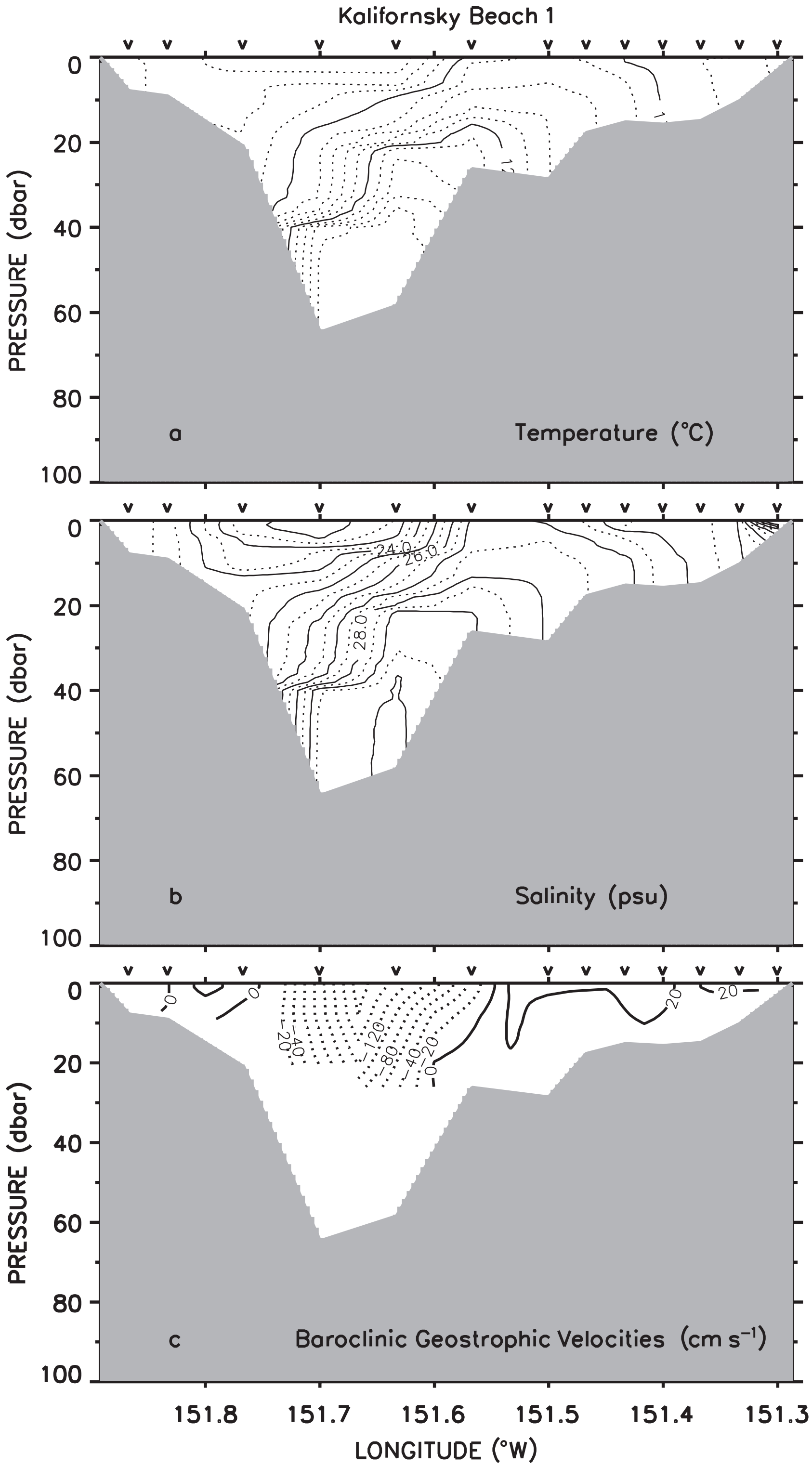

Figure 10. Hydrography from the first crossing of the Kalifornsky Beach transect. a) Temperature; b) Salinity. Temperature contour interval is 0.2 °C. Salinity contour interval is 0.5 psu. Solid contour lines indicate integer values. Dotted contour lines indicate fractional values. c) Calculated baroclinic geostrophic velocities. Solid contours indicate positive (northward) velocities. Dotted contours indicate negative (southward) velocities. The contour interval is 20 cm s^{-1}. The carets along the top of each plot indicate locations of the CTD casts.

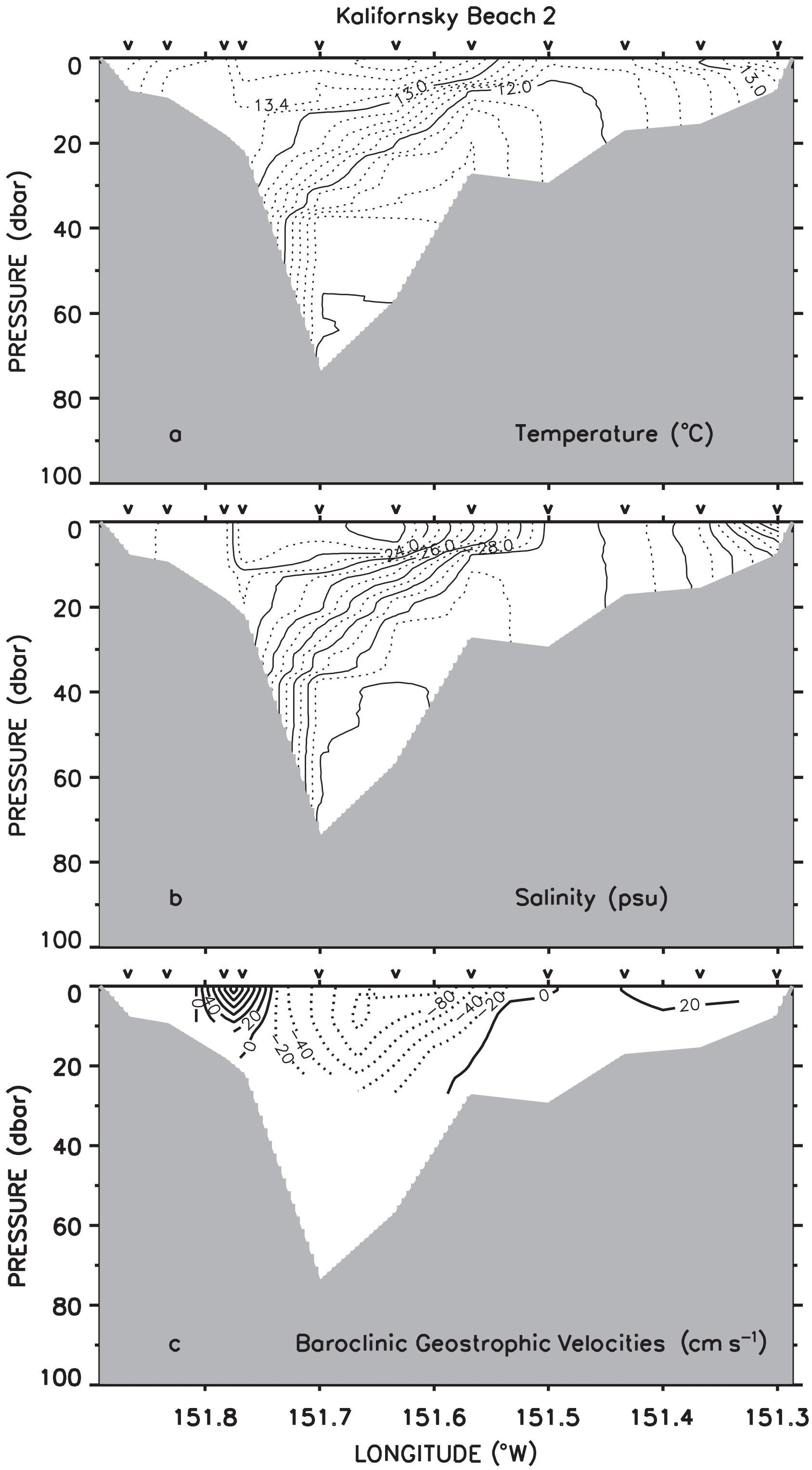

Figure 11. Hydrography from the second crossing of the Kalifornsky Beach transect. Parameters as for first crossing: a) Temperature; b) Salinity. Temperature contour interval is 0.2 °C. Salinity contour interval is 0.5 psu. Solid contour lines indicate integer values. Dotted contour lines indicate fractional values. c) Calculated baroclinic geostrophic velocities. Solid contours indicate positive (northward) velocities. Dotted contours indicate negative (southward) velocities. The contour interval is 20 cm s^{-1}. The carets along the top of each plot indicate locations of the CTD casts.

The third crossing occurred during the transition to the ebb tide. Vessel drift at all stations except one had a southward component. The locations at which the west, middle and east rip fronts intersect the surface have again moved slightly eastward to 151.75 °W, 151.52 °W, and 151.35 °W, respectively (Figure 12b). The volume of the coolest water (< 11 °C) (Figure 12a) has increased and moved westward. Likewise, the volume of the most saline water (> 30 psu) has again increased and its core has moved westward to the deepest part of the channel (151.7 °W). Additionally, the depth at which the middle rip front intersects the bottom has risen to ~20 m as a consequence of its westward migration. This shoaling of the middle rip front and the weakening of its surface front have effects of diminishing the speed and vertical extent of the southward-flowing baroclinic jet (Figure 12c). Above the location at which the middle rip front intersects the bottom (151.78 °W) a new southward baroclinic jet is established. The northward jets associated with the west rip (151.68 °W) and east rips (151.35 °W) remain relative weak.

The final crossing occurred during the middle of the ebb tide. Vessel drift at all stations had a southward component at speeds that were generally faster than occurred during the previous crossing. The temperature and salinity plots (Figure 13a and b) indicate that the volume of water cooler than 11 °C and saltier than 30 psu has diminished somewhat relative to the previous crossing. While the salinity plot shows that the location of the east rip surface front has moved westward to ~151.43 °W, the locations of the west rip and middle rip fronts have not changed appreciably. However, the thickness of the low salinity plume lying between the west and middle rips has thinned slightly, thereby weakening the speed and diminishing the depth of the middle rip jet (Figure 13c).

Area-averaged temperatures and salinities were computed for each crossing according to Equation 1 (p. 16). The results, summarized in Table 2, show that the first crossing exhibited the highest mean temperature (12.43 °C) and lowest mean salinity (26.98 psu). The mean temperature was lowest (11.97 °C) and the mean salinity highest (28.29 psu) for the third crossing. Recall that Table 1 showed the lower inlet is cooler and more saline than the central inlet. From a comparison of the results in Table 1 and Table 2, it can be inferred that the tide was flooding during the first three crossings and ebbing during the fourth crossing. However, as stated above, vessel drift was northward during the first and second crossings and southward during the third and fourth crossings. Consequently, there must have been a net northward flow at depth below the southward flowing surface layer during the third crossing. This is illustrated schematically in Figure 14.

Table 2. Repeat transect mean temperatures and salinities.

	Average Temperature (ºC)	**Average Salinity (psu)**
Kalifornsky Beach 1	12.43	26.98
Kalifornsky Beach 2	12.14	27.90
Kalifornsky Beach 3	11.97	28.29
Kalifornsky Beach 4	12.06	28.19

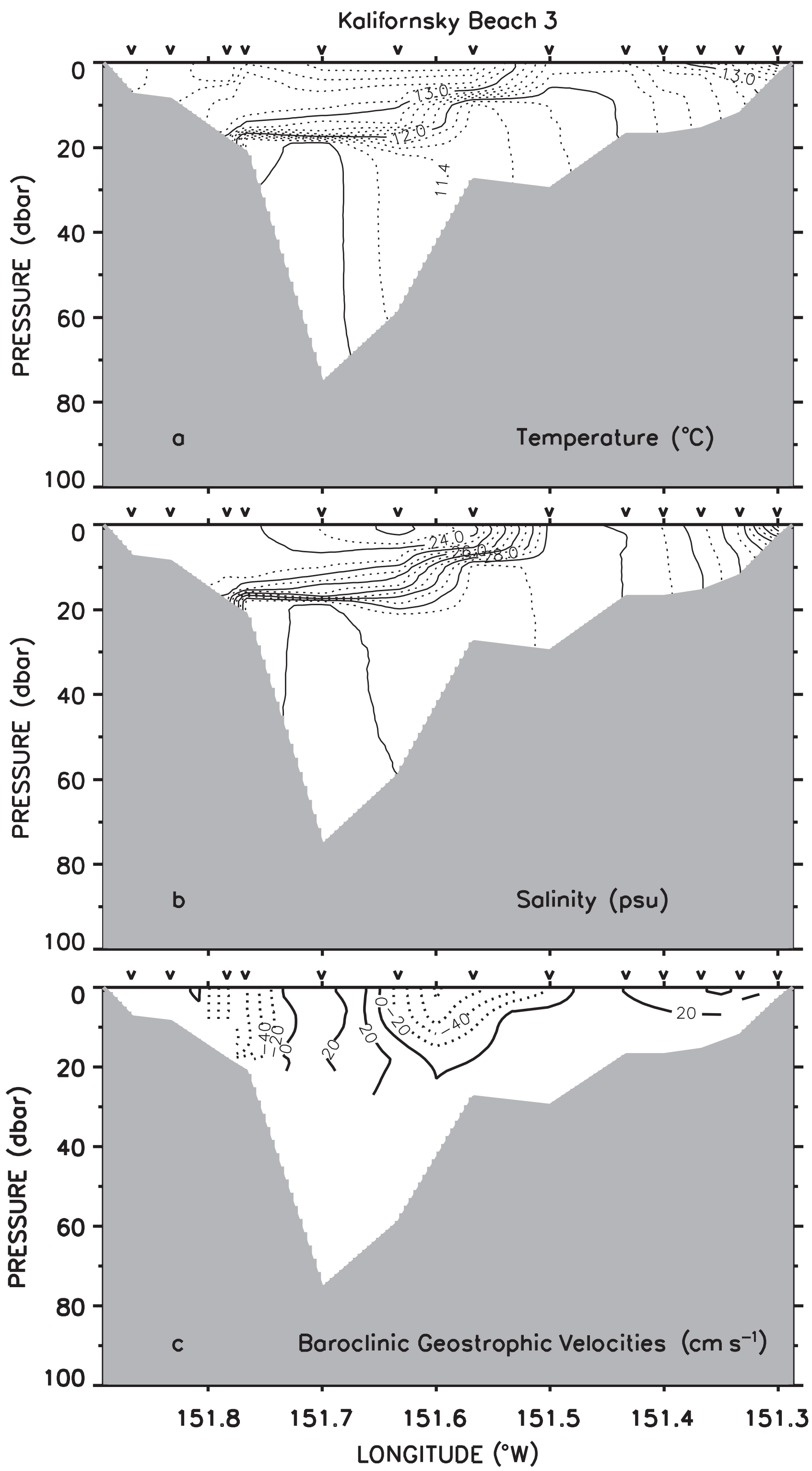

Figure 12. Hydrography from the third crossing of the Kalifornsky Beach transect. Parameters as for first crossing: a) Temperature; b) Salinity. Temperature contour interval is 0.2 °C. Salinity contour interval is 0.5 psu. Solid contour lines indicate integer values. Dotted contour lines indicate fractional values. c) Calculated baroclinic geostrophic velocities. Solid contours indicate positive (northward) velocities. Dotted contours indicate negative (southward) velocities. The contour interval is 20 cm s^{-1}. The carets along the top of each plot indicate locations of the CTD casts.

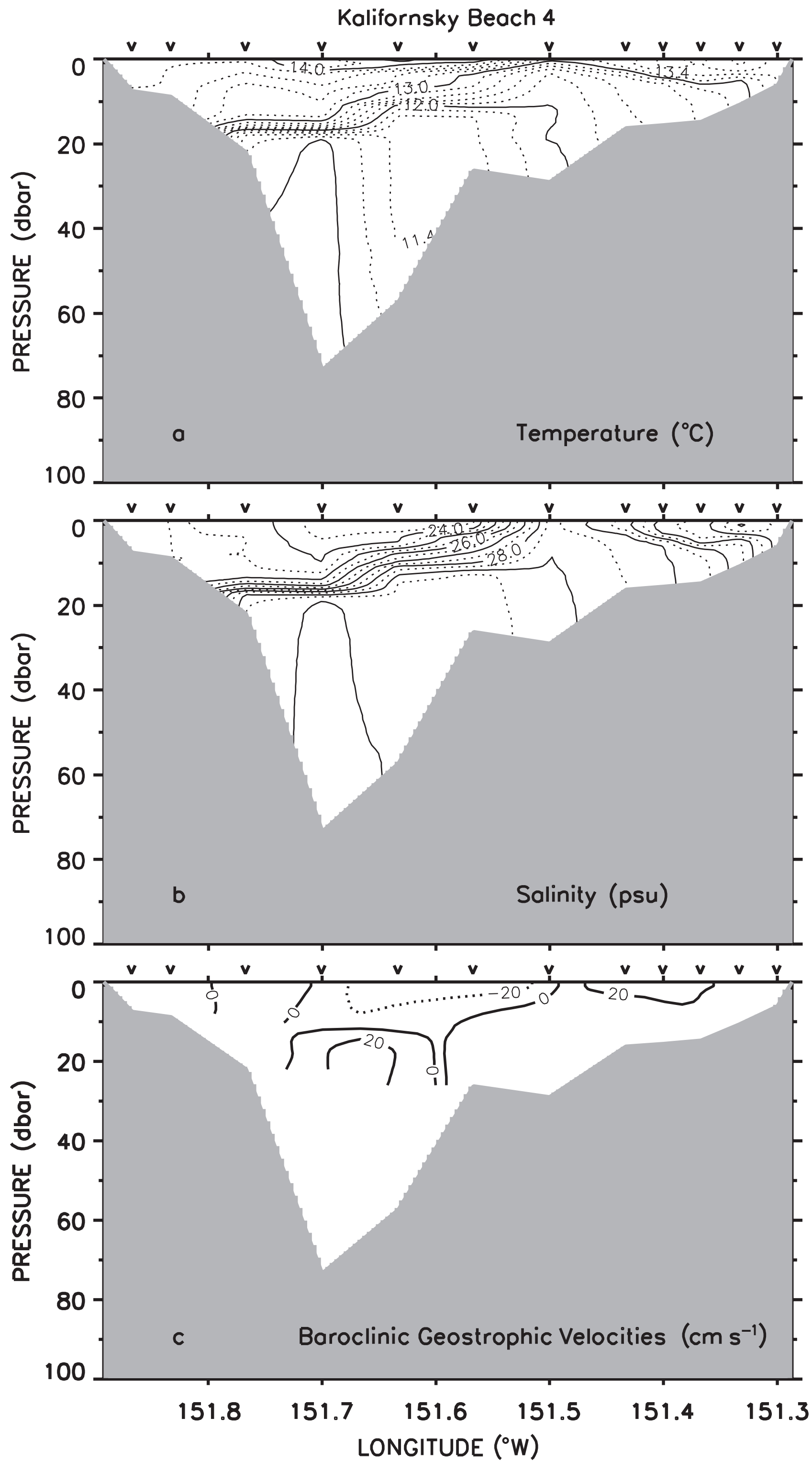

Figure 13. Hydrography from the fourth crossing of the Kalifornsky Beach transect. Parameters as for first crossing: a) Temperature; b) Salinity. Temperature contour interval is 0.2 °C. Salinity contour interval is 0.5 psu. Solid contour lines indicate integer values. Dotted contour lines indicate fractional values. c) Calculated baroclinic geostrophic velocities. Solid contours indicate positive (northward) velocities. Dotted contours indicate negative (southward) velocities. The contour interval is 20 cm s^{-1}. The carets along the top of each plot indicate locations of the CTD casts.

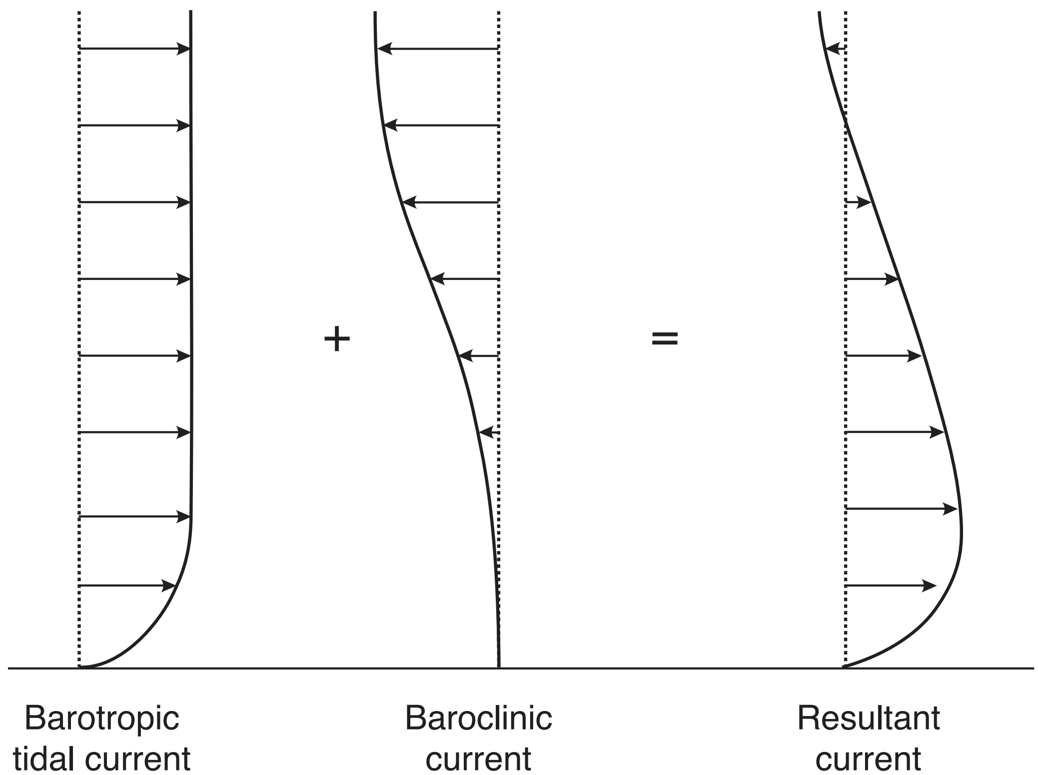

Figure 14. Schematic representation of contributions of the barotropic tidal current profile and baroclinic (density-driven) current profile to the resultant current profile during the third crossing of the Kalifornsky Beach transect. North is to the right of the plot.

Discussion of Hydrographic Study

The spring and fall hydrographic surveys showed that significant freshening of the inlet occurs during the intervening months. The addition of fresh water to the inlet strengthens the gradients of three main fronts—the west, middle, and east rip fronts—and promotes southward extension of the west rip beyond the Anchor Point line.

Northward-flowing baroclinic currents occur in association with the west and east rip fronts, whereas a southward-flowing baroclinic current occurs in association with the middle rip front. The baroclinic currents associated with the west and east rip fronts will locally augment the barotropic tidal current during the flood and act in opposition during the ebb. Conversely, baroclinic current associated with the middle rip front will locally oppose the barotropic tidal current during the flood and locally augment the barotropic tidal current during the ebb.

The most significant hydrographic response observed during the transition from flood tide to ebb tide was the structural change of the middle rip front. During the flood tide, the surface portion of the front migrated eastward (≤2 n mi), whereas the bottom portion of the front migrated westward (≤2 n mi) and shoaled, thereby reducing the overall inclination and depth of the middle rip front. The baroclinic geostrophic response to this frontal adjustment was a reduction in the speed and vertical extent of the southward-flowing middle rip jet. Flood-to-ebb variation in the magnitude of the west rip and east rip baroclinic currents was also observed.

The interaction between the baroclinic currents and barotropic tidal currents results in a local current regime that is well known to local commercial salmon fishermen. That is, the onset of northward surface flow near the middle rip front lags the onset of northward surface flow near the eastern beaches in the central inlet and southward-flowing surface currents near the middle rip are typically faster than southward-flowing currents near the beach.

The hydrographic results presented above indicate that Cook Inlet numerical spill trajectory models need to be fully three-dimensional, incorporating temperature and salinity (buoyancy) effects at seasonal to semidiurnal time scales, to improve their forecasting skill. The large observed changes in salinity between the Drift River/Kenai transects and the Forelands transect and between the Humpy Point and Ninilchik transects suggest that additional hydrographic surveys in these locations would improve understanding of these dynamic subregions.

Educational Outreach — Drift Card Study

An educational outreach component of this project involved eight Kenai Peninsula Borough School District schools in the preparation, field work/data acquisition, and data analyses of a drift card study. The participating high schools were Port Graham, Nanwalek, Homer, Ninilchik, Kenai Central, Skyview, Nikiski, and Tyonek.

Five of the participating schools each produced a set of ~1100 drift cards (approximately 4-by-4-inch cards cut from 3/8-inch plywood). Port Graham and Nanwalek students each produced ~500 cards. Students affixed a unique identification code, the contact phone number, and e-mail address of the originating school. Originally, students from each school were expected to deploy their set of 1100 cards on the transects near their respective home towns. However, due to liability issues associated with chartering local fishing vessels (see below), only the Homer High School drift cards were deployed by students. The remaining drift cards were deployed by Steve Okkonen along the other transects. The timing of the drift card deployments bracketed the period when there is greater activity on the water and along Cook Inlet beaches, therefore maximizing the opportunities for drift card recoveries. Once recorded, information from the recovered cards was distributed to schools for use with graphical analysis software.

Roughly 7500 drift cards were deployed during the spring survey. Along each transect (Nanwalek, Homer, Anchor Point, Ninilchik, Humpy Point, Kenai, and Forelands/Drift River) 1000 or 1100 cards were deployed in groups of 100 at CTD stations. Five hundred eight-five identifiable cards were recovered (Figure 15). Reported recovery locations were typically very general (e.g., southwest Kalgin Island; Bishops Beach [Homer], west side of Homer Spit). Most of the cards (458) were recovered in Kachemak Bay. All but 14 of these Kachemak Bay recoveries were of cards deployed along the Homer transect. Southwest winds (10–15 kt) blowing during the transit of the Homer transect pushed most of these cards on to beaches near the Homer Spit, contributing to the high recovery rate of these cards. Seventy-four cards were recovered on Kalgin Island; cards from each transect were recovered there. The most distant recoveries (3 cards) were from beaches in Shelikof Strait.

Logistics

Logistics for the student training and participation became one of the largest considerations during the study. Using the school district delivery system, we assembled and distributed extensive materials kits for each of the schools while paying special attention to student safety considerations. A step-by-step instruction packet detailed the card process for students. To ensure that there would be a common format for the visualization and analyses of the field data we provided each school with Origin data analysis software (OriginLab Corporation) and customized instructions for generating line and contour plots of the data. Thereafter, we delivered a lesson covering contour plotting, following up with numerous calls and e-mails to confirm progress and timing of the work. In most cases, we flew or drove to schools to provide on-site instruction regarding the cards, the CIRCAC (Cook Inlet Regional Citizens Advisory Council) numerical spill trajectory model, and other software.

We had anticipated that participating science teachers would organize local fishing/charter vessel support and the arrangements would then be confirmed by Steve Okkonen or Steve Howell. However, district requirements exceeded the licensing and insurance for common fishing vessels. Instead, we developed an alternative using a larger tour vessel and arranged for several students to travel from each school to Homer for a hydrographic survey and drift card deployment. The two vessel charters (spring and fall) for students used ~40% of the charter budget. The end result was that significantly more time and money were spent on logistics than planned to enable teachers and students to participate in a hydrographic survey.

School teachers learned from the district late in the process that their time to participate in the field trip would require funding outside of the extra-curricular budget for substitutes and salary. Eventually, several teachers took personal leave to travel during the regular school day. Curriculum issues, namely the rigid schedules that most teachers must follow to complete the required coursework, also presented a challenge for participants.

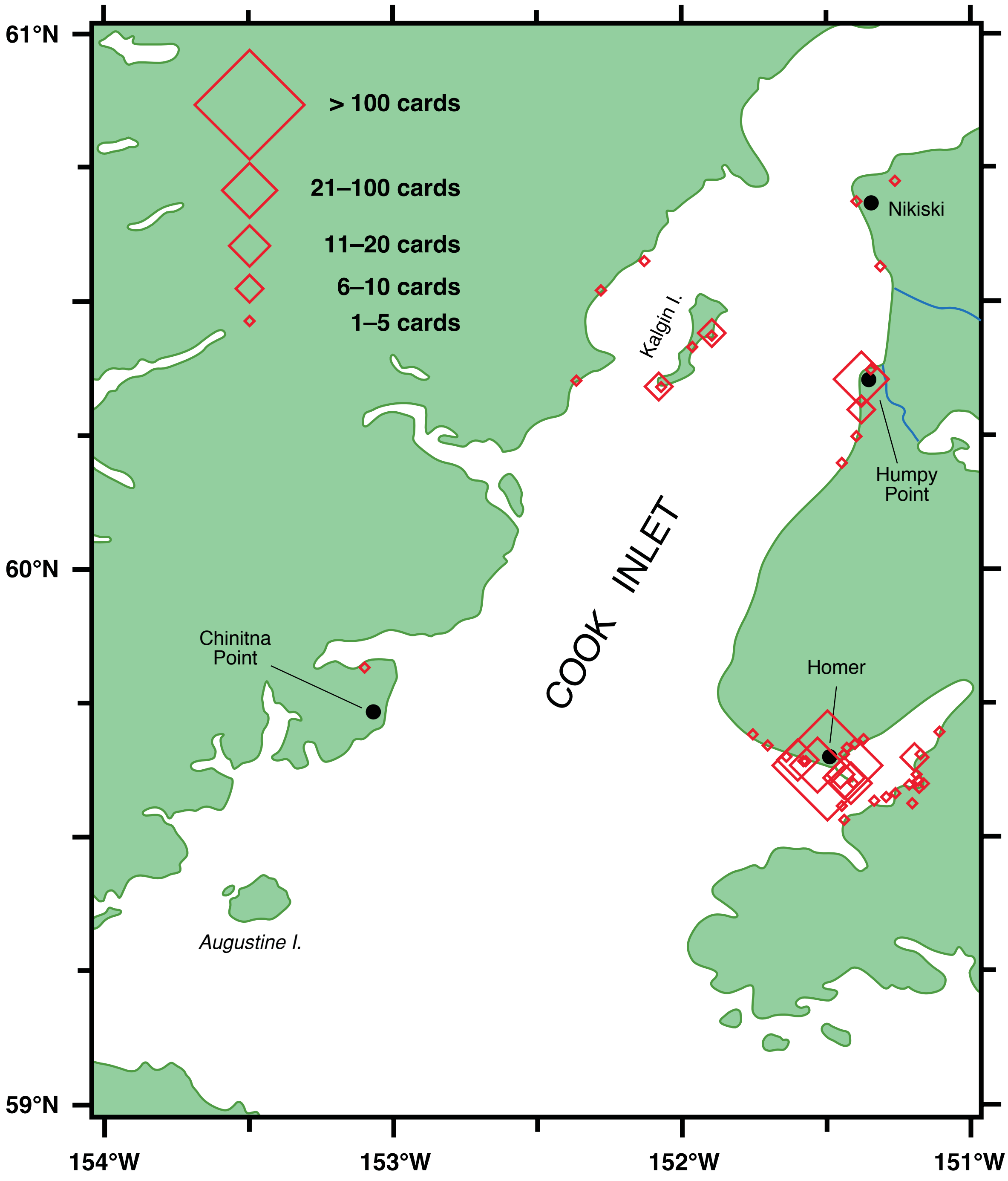

Figure 15. Drift card recovery locations.

Recommendations for educational outreach

Principal investigators hoping to engage students in field studies might wish to consider a few general guidelines in addition to those normally considered:

1) Resources (time and money) devoted to logistics often come at the expense of resources allocated to the actual study and subsequent products. Using a smaller group of motivated students will improve the quality of the student/researcher experience during the inaugural study. Researchers may choose to expand the program following a series of more modest successes.

2) Teachers need significant advance knowledge of the study plan and expectations. Often teachers create curriculum schedules a year or more in advance, offering classes on a rotating basis that may be more or less relevant to the study. Including a motivated teacher on the team that designs the entire program will diminish risks and uncover opportunities early in the process.

3) Fieldwork with students might require proper insurance and associated liability documentation. Principal investigators should place this item high on their list, since it will often determine which field activities will be permitted in the final program.

4) Include a public relations component. All participants will be doing something extraordinary and unusual compared to the daily school routine. Good publicity generally reinforces the program's value to administrators who set policy that affects student field experiences.

Acknowledgements

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Study Products

Okkonen, S.R. and S.S. Howell. 2003. Measurements of temperature, salinity, and circulation in Cook Inlet, Alaska. University of Alaska Coastal Marine Institute Annual Research Review, February 2003, Fairbanks, Alaska.

Okkonen, S.R. 2003. Measurements of temperature, salinity, and circulation in Cook Inlet, Alaska. MMS Information Transfer Meeting, March 2003, Anchorage, Alaska.

Okkonen, S.R. 2003. Measurements of temperature, salinity, and circulation in Cook Inlet, Alaska. MMS Science Steering Committee Meeting, April 2003, Anchorage, Alaska.

Okkonen, S.R. and S.S. Howell. 2003. Measurements of temperature, salinity, and circulation in Cook Inlet, Alaska. Final Report. OCS Study MMS 2003-036, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 28 p.