

# **WESTERN GULF OF ALASKA TIDES AND CIRCULATION**

by

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## 1. INTRODUCTION

During **June** and August **1984**, **tidal height**, current and **CTD** data were collected **in** the Western Gulf of Alaska principally as input to a numerical model of the continental shelf circulation. The **model** will be used to help assess the risks associated with a potential **oilspill** and **will aid in** the sale of leases by the Minerals Management Service.

The field program was carried out by **Dobrocky** Seatech technicians **R. Kashino** and D. McCullough from the **NOAA** vessel FAIRWEATHER. Current meters, tide **gauges**, acoustic releases and CTD were furnished and prepared by NOAA, while **Seatech** designed and fabricated the moorings. Seven tide gauges and four current meter moorings of two current meters each were deployed **in** June and all instruments were recovered in August. The data recovery was 100% attesting to the care taken in instrument set-up by **NOAA's** Pacific Marine Environmental Laboratory and the thoroughness of the field technicians. Details of the **field** program may be found **in** the **field** report (September **1984**).

Current meters and tide gauge deployment sites are shown **in** Figure 1.1 along with the locations of the cross-shelf CTD transects. **CTD** measurements were also made at the current meter sites in order to permit computation **of** the internal tide modal structure. Specifics of the deployments of the tide gauges and current meters are given in Tables 1.1 and **1.2**.

**Aanderaa model RCM-4** current meters were used at **all** locations. The current meters recorded temperature, conductivity and pressure as well as speed and direction. A **15** minute sampling interval was used. Modified **Savonius** rotors were used on **all** instruments with the exception of the shallow meter at **Sanak** Island where **an Alekseyev** rotor was employed to reduce **aliasing** due to surface waves.

All tide gauges were **Aanderaa** model **TG3A**; a **7.5** minute sampling interval was used.

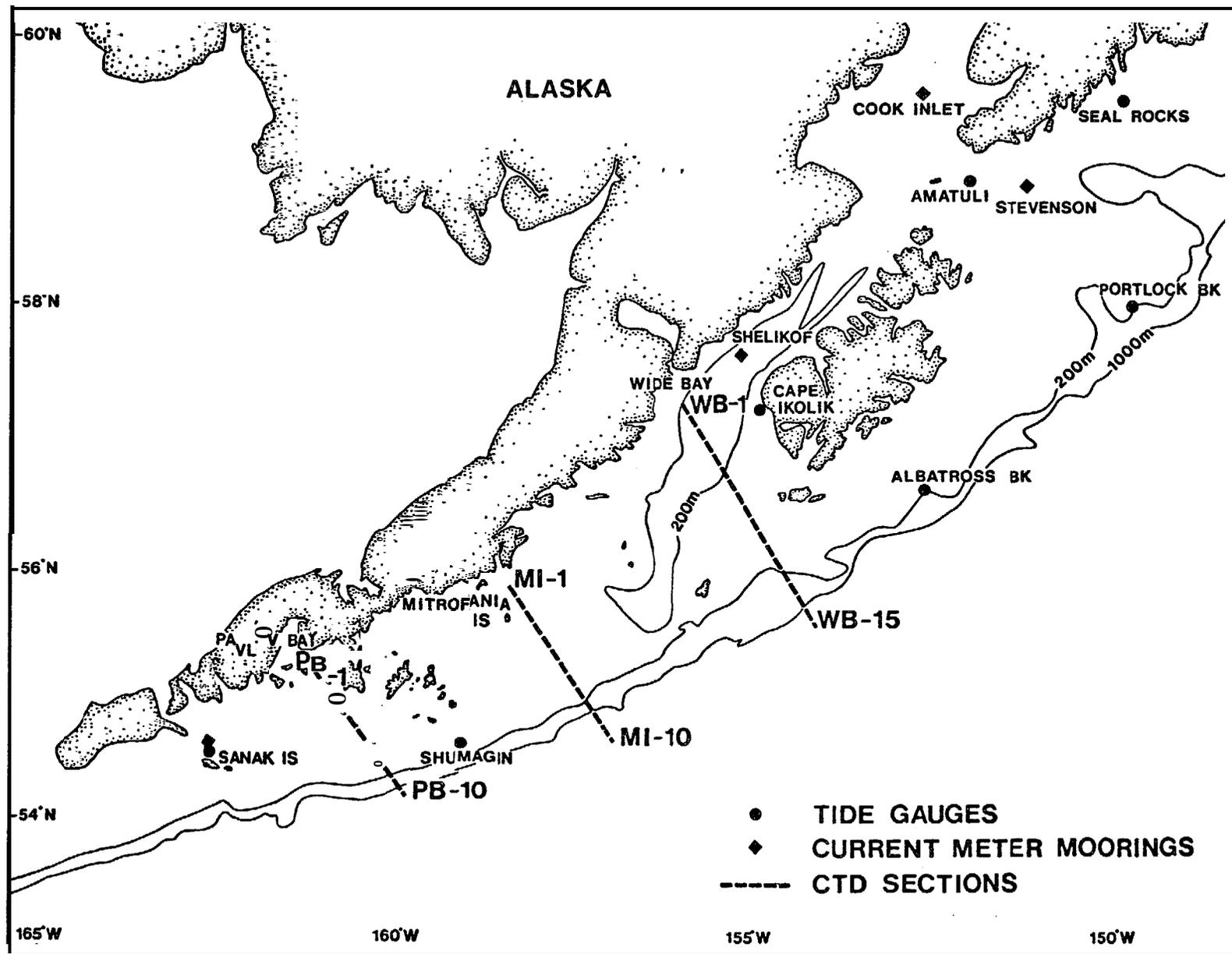


Figure 1.1 - Location of current meters, tide gauges, and CTD sections.

**TABLE 1.1**  
**CURRENT METER DEPLOYMENT SPECIFICS**

Location	Water Depth (m)	C.M. No.	C.M. Depth (m)	First Good Record ( GMT)	Last Good Record (GMT)
Stevenson Entrance	113	2493	45	1800	13 June 84
North of <b>Portlock Bk</b>		1807	75	1800	13 June 84
					0945 9 Aug 84
					0945 9 Aug 84
Cook Inlet	62	3710	36	0430	14 June 84
		3614	52	0430	14 June 84
					2015 9 Aug 84
					2015 9 Aug 84
<b>Shelikof Strait</b>	250	3127	40	2130	14 June 84
		1812	150	2130	14 June 84
					1400 10 Aug 84
					1400 10 Aug 84
Sanak (Deer Island)	49	3185*	18.5	1000	16 June 84
		1987	38.5	1000	16 June 84
					0445 13 Aug 84
					0445 13 Aug 84

All current meters were equipped with temperature, conductivity and pressure sensors.

Sampling interval was 15 minutes on all current meters.

\*This current meter was modified to utilize the **Alekseyev** rotor now available from **Aanderaa**.

**TABLE 1.2**  
**TIDE GAUGE DEPLOYMENT SPECIFICS**

Location			Depth (m)	T.G. No.	First Good Record ( GMT)	Last Good Record (GMT)
Albatross Bank	<b>56°33'48N</b>	<b>152°26'95W</b>	163	107	1200 12 June 84	0407.5 8 Aug 84
<b>Portlock</b> Bank	<b>58°01'03N</b>	<b>149°29'58W</b>	174	205	0100 13 June 84	1615 8 Aug 84
Seal Rocks	<b>59°29'93N</b>	<b>149°29'57W</b>	112	188	1000 13 June 83	0430 9 Aug 84
<b>Amatuli</b> Island	<b>59°00'13N</b>	<b>151°50'03W</b>	168	87	2230 13 June 84	1400 9 <b>Aug</b> 84
Cape <b>Ikolik</b>	<b>57°15'00N</b>	<b>154°45'30W</b>	62	120	0100 15 June 84	2315 10 Aug 84
Shumagin ( <b>Simeonof</b> Is)	<b>54°31'93N</b>	<b>158°58'08W</b>	192	119	2000 15 June 84	1907.5 11 Aug 84
Sanak (Deer Is)	<b>54°35'25N</b>	<b>162°43'77W</b>	48	209	1000 16 June 84	0452.5 13 Aug 84

Sampling interval was 7.5 minutes for all tide gauges.

The current meters were deployed on taut line moorings of **1/4" 7 x 19** wire rope. Buoyancy was provided at the top of the mooring, above the lower current meter and above the acoustic release. Train wheels were used for anchors. Tide gauge moorings consisted of concrete blocks with recesses for the tide gauge. Sketches of each mooring type are presented in Figures **1.2** through **1.6**. All moorings were suspended in the water column then **gently** lowered to the bottom with a device which releases upon loss of tension.

### **1.1 DATA REDUCTION**

The Aanderaa data tapes were translated and converted to physical units using calibrations supplied by NOAA. Salinities were computed from temperature, conductivity and pressure with the UNESCO (1980) formula.

Time series plots were produced for each instrument and are available **in** our Data Report (**Greisman** 1984). Also produced were progressive vector diagrams, **stick** plots and histograms. These products aided in quality control as **well** as **in** forming a general impression of the data set.

Harmonic analyses of the tide gauge data and tidal stream analyses of the current meter data were performed using the methods of Foreman (1977 and 1978). The complete analyses are presented in Appendix 1.

Tables 1.3 and 1.4 show the **tidal** analyses for the largest constituents for the heights and currents respectively. Greenwich phase is used throughout. In the **tidal** stream analyses **MAJ** represents the amplitude of the semi-major axis of the tidal ellipse; **MIN** represents the semi-minor axis of the ellipse. The sign of MIN indicates the sense of rotation; **positive** implies anti-clockwise and negative clockwise. **INC** is the orientation of the northern semi-major axis of the ellipse anti-clockwise **from** east (mathematical rather than geographic convention). **G** is the Greenwich phase and represents the time at which the rotating velocity vector coincides with the northern semi-major axis of the ellipse.

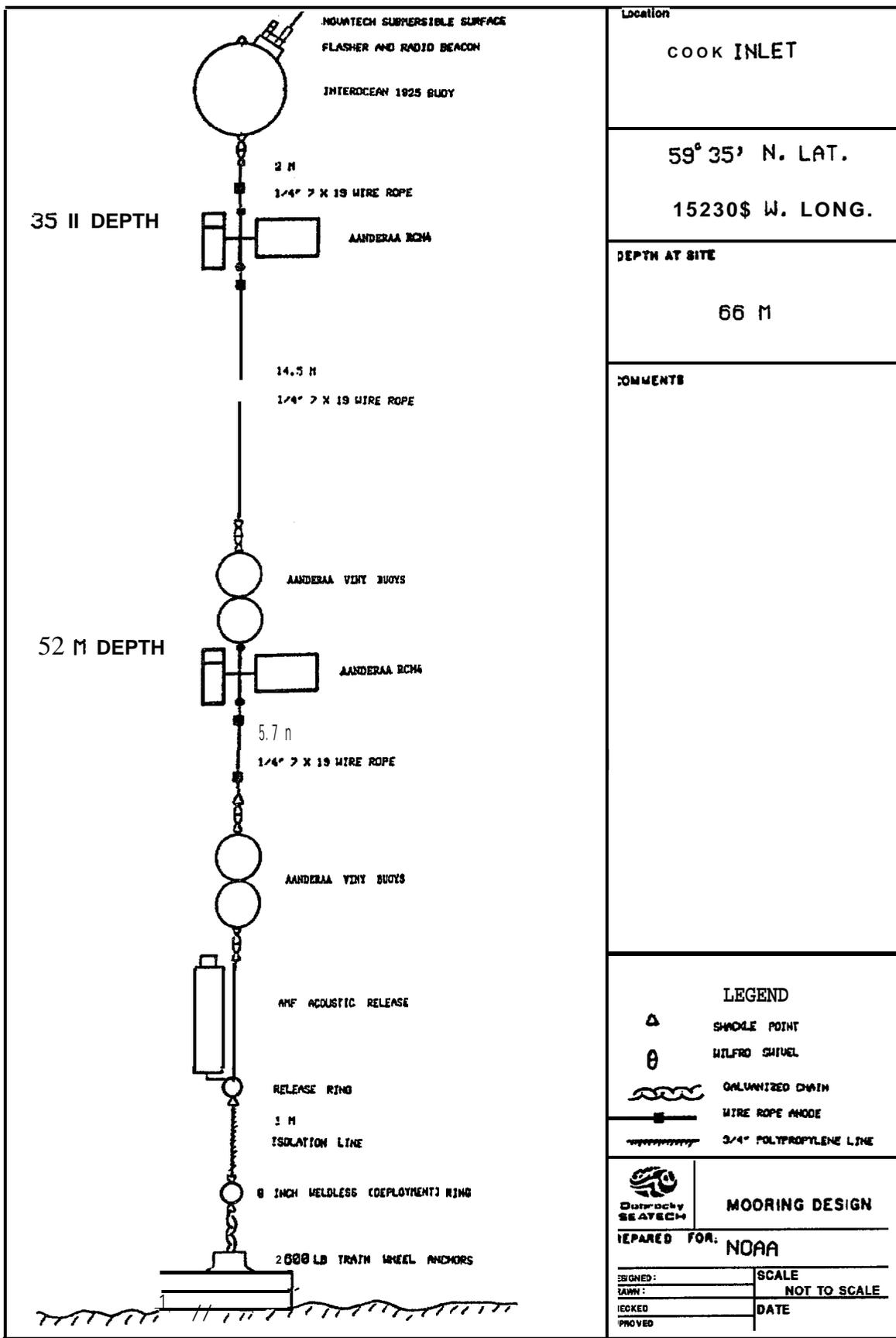


Figure 1.2 - Mooring configuration at Cook Inlet.

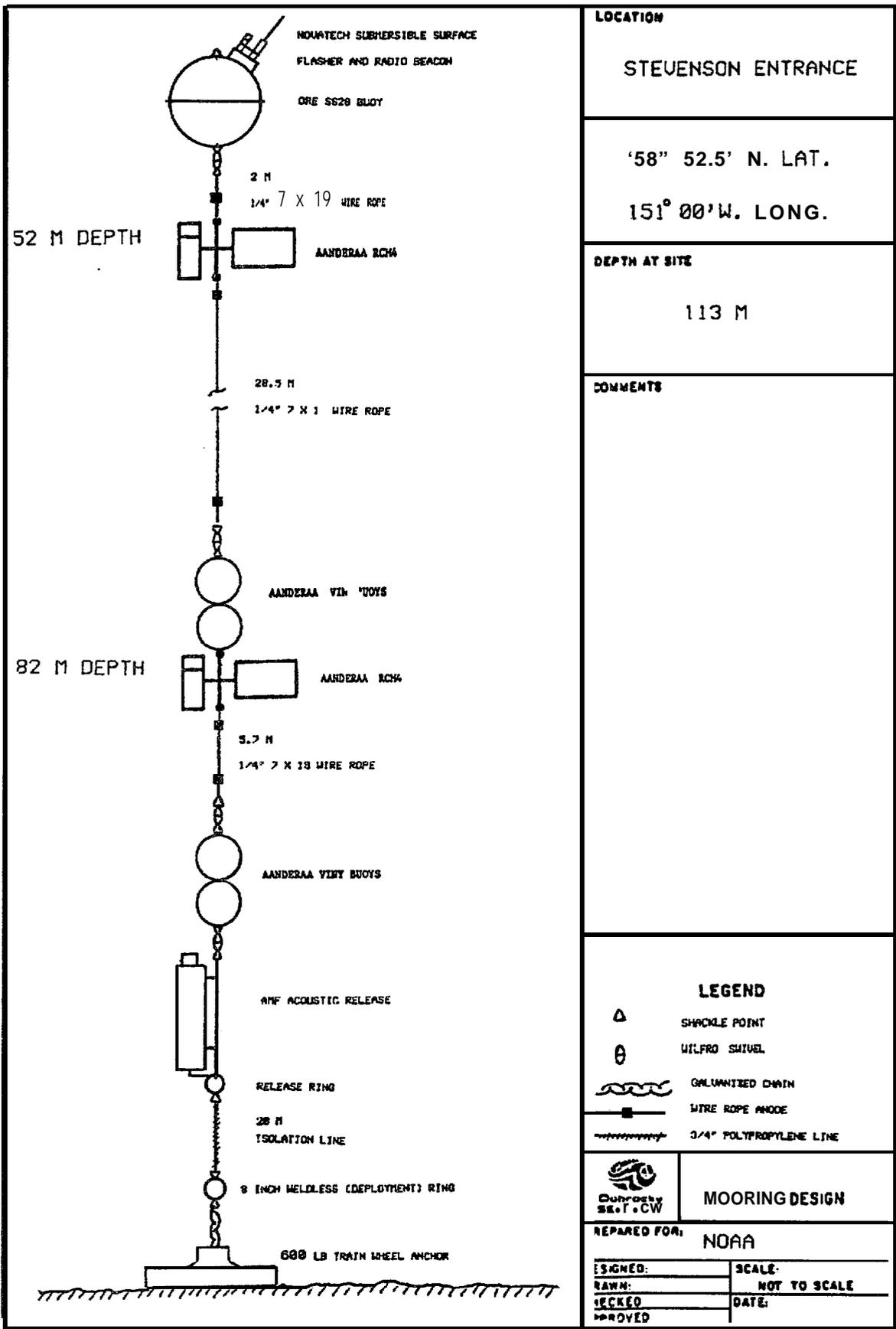


Figure 1.3 - Mooring configuration at Stevenson Entrance.

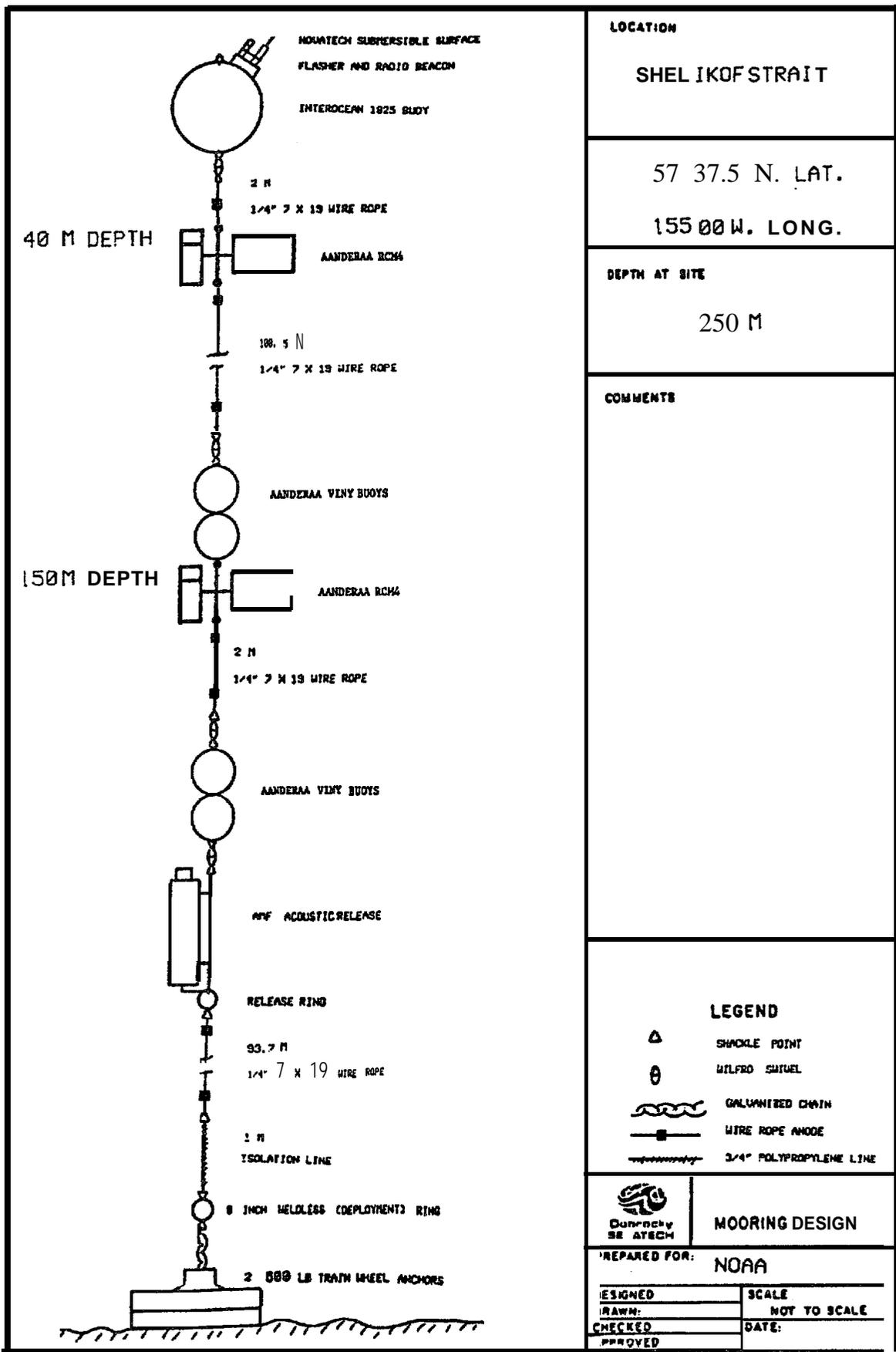


Figure 1.4 - Mooring configuration at Shelikof Strait.

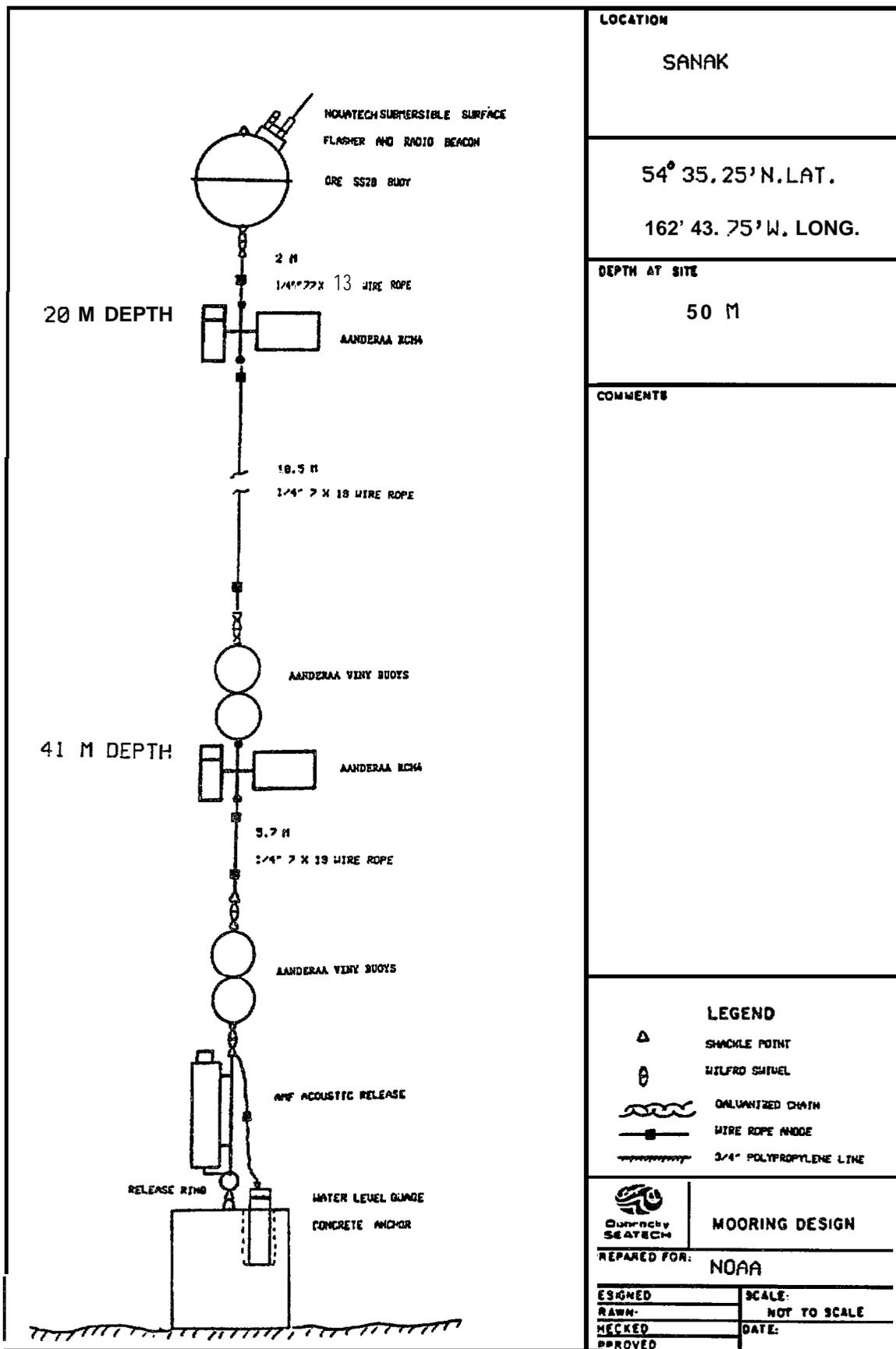
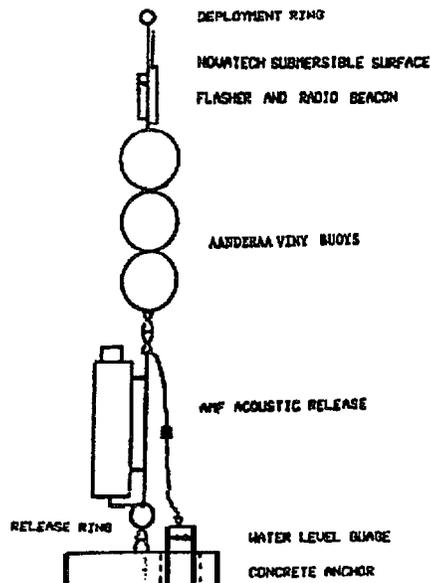


Figure 1.5 - Mooring configuration at Sanak.

PORTLOCK BANK 55 20' N. Mr. 149 30' U. LONG. 100 N  
 SEAL BANK 59 30' N. LAT. 152 30' U. LONG. 100 N  
 ALBATROSS BANK 50 30' N. LAT. 159 00' U. LONG. 200 N  
 STINEOFF ISLAND 54 30' N. LAT. 159 00' W. LONG. 20 N  
 SHATLEI ISLAND 59 00' N. LAT. 162 00' U. LONG. 20 N  
 CAPE IKOLIK 61 15' N. LAT. 154 45' W. LONG. 20 N

## TIDE GAUGE MOORING

### COMMENTS



### LEGEND

-  SHACKLE POINT
-  WILFRO SWIVEL
-  GALVANIZED CHAIN
-  NIRE ROPE ANODE
-  3/4" POLYPROPYLENE LINE



### MOORING DESIGN

PREPARED BY "O" NOAA

SIGNED	SCALE:
AWN:	NOT TO SCALE
CHECKED	DATE:
APPROVED	

Figure 1.6 - Mooring configuration for the tide gauges.

**TABLE 1.3**  
**MAJOR TIDAL CONSTITUENTS**  
**AMPLITUDES (METRES) AND GREENWICH PHASES**

STATION	Principal Lunar Diurnal		Soli-Lunar Declinational (Divisional)		Larger Lunar Elliptic (Semi- Diurnal)		Principal Lunar (semi-Diurnal)		Principal Solar (Semi-Diurnal)		$F = \frac{K_1 + O_1}{M_2 + S_2}$
	A	G	A	G	A	G	A	G	A	G	
Sanak	.2691	269.93	.5041	293.03	.1331	314.13	.6306	330.12	.1579	003.55	0.981
Portlock Bk.	.2916	252.72	.5572	276.60	.1902	278.57	1.0140	293.48	.2499	334.36	0.672
Seal Rk.	.2846	256.09	.5431	279.69	.2216	274.53	1.1975	259.94	.3016	331.25	0.552
Cape Ikolik	.3070	265.70	.5928	289.37	.2770	303.52	1.3889	317.00	.3757	001.87	0.510
Shumagin	.2769	266.50	.5175	289.08	.1371	302.39	.6713	317.25	.1690	353.99	0.945
Albatross Bk.	.2905	255.04	.5520	278.29	.1698	279.03	.8940	294.57	.2171	334.37	0.759
Anatuli Is.	.3052	262.95	.5834	287.24	.3011	297.41	1.5548	312.60	.4184	357.54	0.452

**TABLE 1.4**  
**TIDAL STREAM ANALYSES**  
**INCLUDING TIDAL HEIGHT ANALYSES FROM NEARBY TIDE GAUGES**

STATION	DEPTH	K <sub>1</sub>						K <sub>1</sub>					
		MAJ	MIN	INC	G	A	G	MAJ	MIN	INC	G	A	G
Stevenson	54	3.7	-0.78	98	14			6.6	-2.2	101	41		
Stevenson	82	1.5	-1.7	91	22			6.4	-3.5	10s	36		
Amatuli I							.308	263				.583	287
Shelikof Str.	46	1.8	-0.13	39	227			3.4	0.08	41	244		
Shelikof Str.	157	1.5	-0.06	49	205			3.0	-0.15	48	226		
C. Ikolik							.307	266				.593	289
Sanak	20	2.3	-1.1	177	105			4.0	-2.0	167	14s		
Sanak	41	3.5	-0.90	1	274			7.1	-3.1	166	136		
Sanak							.269	270				.504	293
Cook In.	35	9.5	-0.70	79	224			19.0	-3.5	77	244		
Cook In.	52	8.0	-0.07	69	220			17.6	-3.4	78	239		

STATION	DEPTH	N <sub>2</sub>						M <sub>2</sub>						S <sub>2</sub>					
		MAJ	MIN	INC	G	A	G	MAJ	MIN	INC	G	A	G	MAJ	MIN	INC	G	A	G
Stevenson	54	5.9	1.8	94	51			30.2	0.62	102	66			10.1	0.59	97	112		
Stevenson	82	6.0	-0.3	94	55			36.3	1.65	91	76			11.6	1.10	84	126		
Amatuli I							.301	297				1.555	313					.41s	358
Shelikof Str.	46	2.5	0.7	39	230			13.8	-.02	40	251			4.5	-.03	41	297		
Shelikof Str.	157	3.1	1.0	46	233			14.9	.60	43	248			4.3	.14	47	296		
C. Ikolik							.277	304				1.3s9	317					.376	002
Sanak	20	0.7	-0.3	90	269			3.1	.47	113	2ss			1.1	-.11	77	336		
Sanak	41	0.5	-0.5	64	239			4.1	1.0s	90	253			1.5	-.61	30	267		
Sanak							.133	314				.631	330					.158	004
Cook In.	35	14.4	-2.4	81	285			73.5	-.9	7s	308			19.8	-2.5	s 4	352		
Cook In.	52	13.2	-3.6	83	279			59. s	-2.0	74	305			14. s	-1.8	\$4	346		

NOTE: Semi-major and semi-minor ellipse axes in CMS<sup>-1</sup>; INC is inclination of the northern semi-major axis anti-clockwise from east; G is the Greenwich phase  
 A tidal height amplitude in metres.

The **CTD** data were translated, calibrated versus bottle casts, and **vertical** profiles plotted for each cast. The profiles are presented in the data report. Listings of roughly 1 m depth averaged values were produced for use in preparing cross sections.

**More** details on the data reduction are available in the data report.

## **1.2 OVERVIEW OF THE DATA**

**98.6%** of the variance in the tide gauge records is due to **tidal** oscillations while 67% of the variance in the current meter records is **tidal**. In addition, the mean flows recorded at the current meters were about  $4 \text{ cm s}^{-1}$ , i.e. roughly an order of magnitude smaller than the **tidal** currents. Clearly the flow kinetic energy in the region is dominated by tides during the summer. However, from our data set we cannot address the winter period when easterly gales may have a great influence upon circulation on the shelf.

## **1.3 ANALYSES UNDERTAKEN**

In **Section 2** of **this** report conclusions based upon the distribution of properties (the **CTD** data) are presented and discussed. These include computations of dynamic height topographies and **geostrophic** current speeds and directions.

**Section 3** comprises analyses of the tidal oscillations. **Cotidal** charts, **tidal** energy propagation and internal tides are discussed.

**Section 4** deals with the **non-tidal**, specifically the subtidal, oscillations. We found ourselves somewhat limited *in* these analyses because of the relatively short period of measurement. The two month period between June and August 1984 is, of course, too short to address seasonal signals such as gross changes in the wind field and seasonal runoff variations. Nevertheless, aspects of the forcing of long period oscillations in the Western Gulf of Alaska, particularly **Shelikof** Strait are discussed.

## 2. PROPERTY FIELDS

(Salinity, Temperature, Density, Dynamic Topography)

The results of the June and August 1984 CTD surveys are discussed in this section. Field methods, calibration and quality control of the data were presented in the data report. It should be borne in mind that these data are of fair quality only probably due to the poor condition of the CTD winch slip rings.

### 2.1 CROSS SECTIONS

Cross sections of temperature, salinity and sigma-t were prepared for the Pavlov Bay, Mitrofanina Island and Wide Bay sections for both June and August. The locations of these sections are shown in Figure 2.1. Salinity, temperature and sigma-t sections are presented in pairs for June, then August to enhance the reader's appreciation of temporal changes. It should be remembered that the data are non-synoptic, the occupation of stations along each section having consumed about one day.

#### 2.1.1 Temperature

The most striking feature of the temperature sections (Figures 2.2, 2.3, 2.8, 2.9, 2.14, 2.15) is the pronounced warming of the surface layers to about 50 m depth between June and August. Surface temperature increased about 5° C during this period both over the continental shelf and slope. Since the measured mean flows are on the order of 5 cm s<sup>-1</sup>, the temperature field would have been advected only about 200 km between June and August. The warming of the surface layers is, therefore almost certainly due to local insolation. The water column is everywhere temperature stratified below a few meters depth with the exception of the Trinity Islands Bank shown in the Wide Bay Section. Here the temperature is nearly constant with depth in both June and August likely due to strong

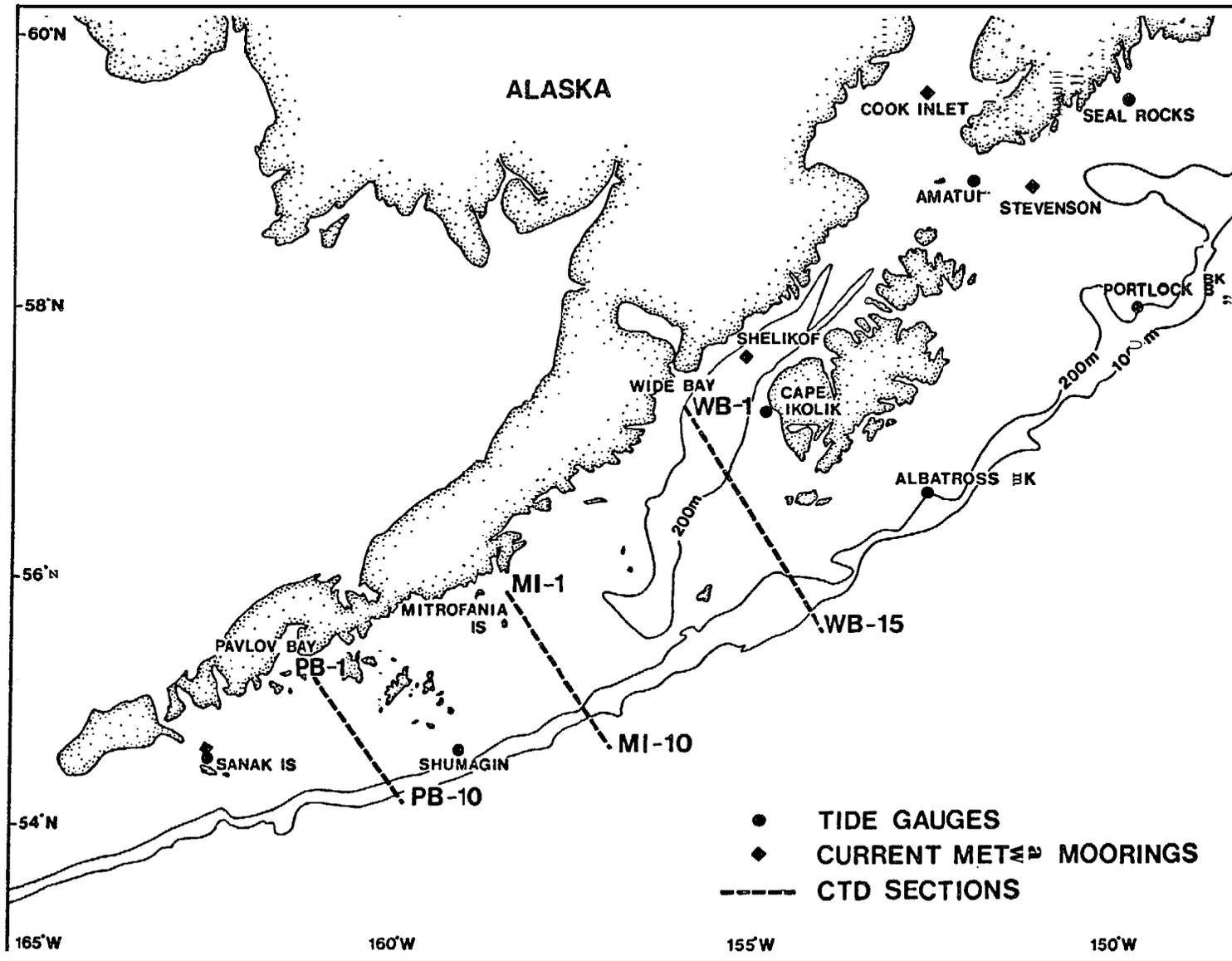


Figure 2.1 - Location chart for salinity, temperature, and sigma-t cross sections

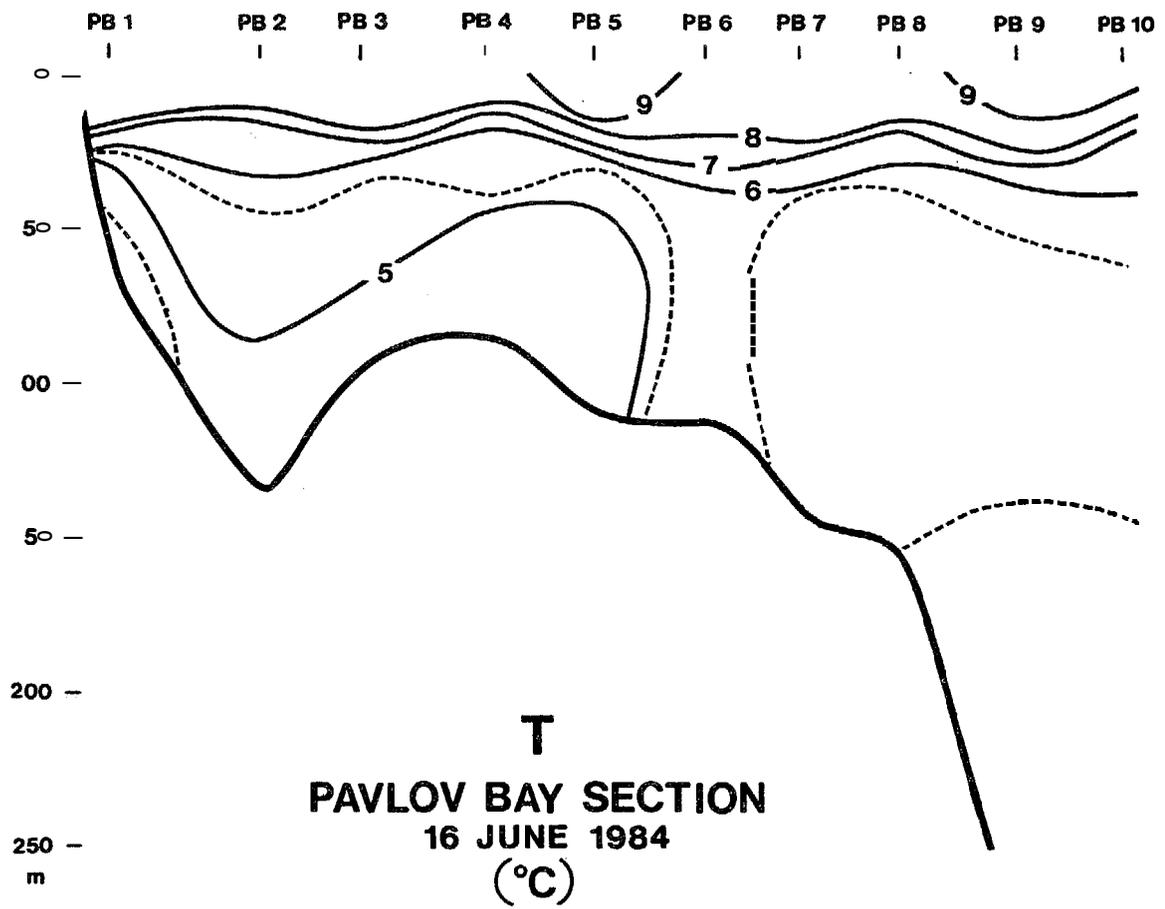


Figure 2.2 - Temperature, Pavlov Bay. June.

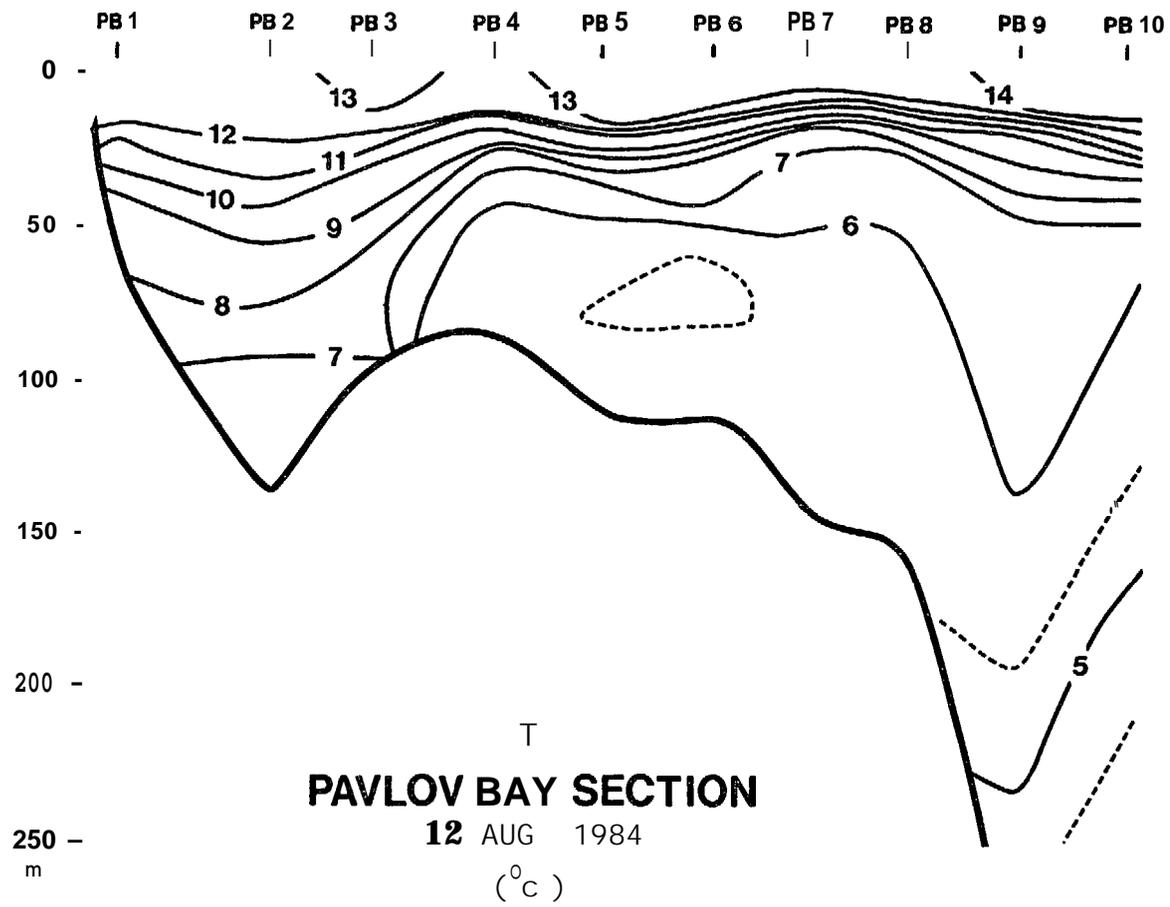


Figure 2.3-Temperature, Pavlov Bay, August.

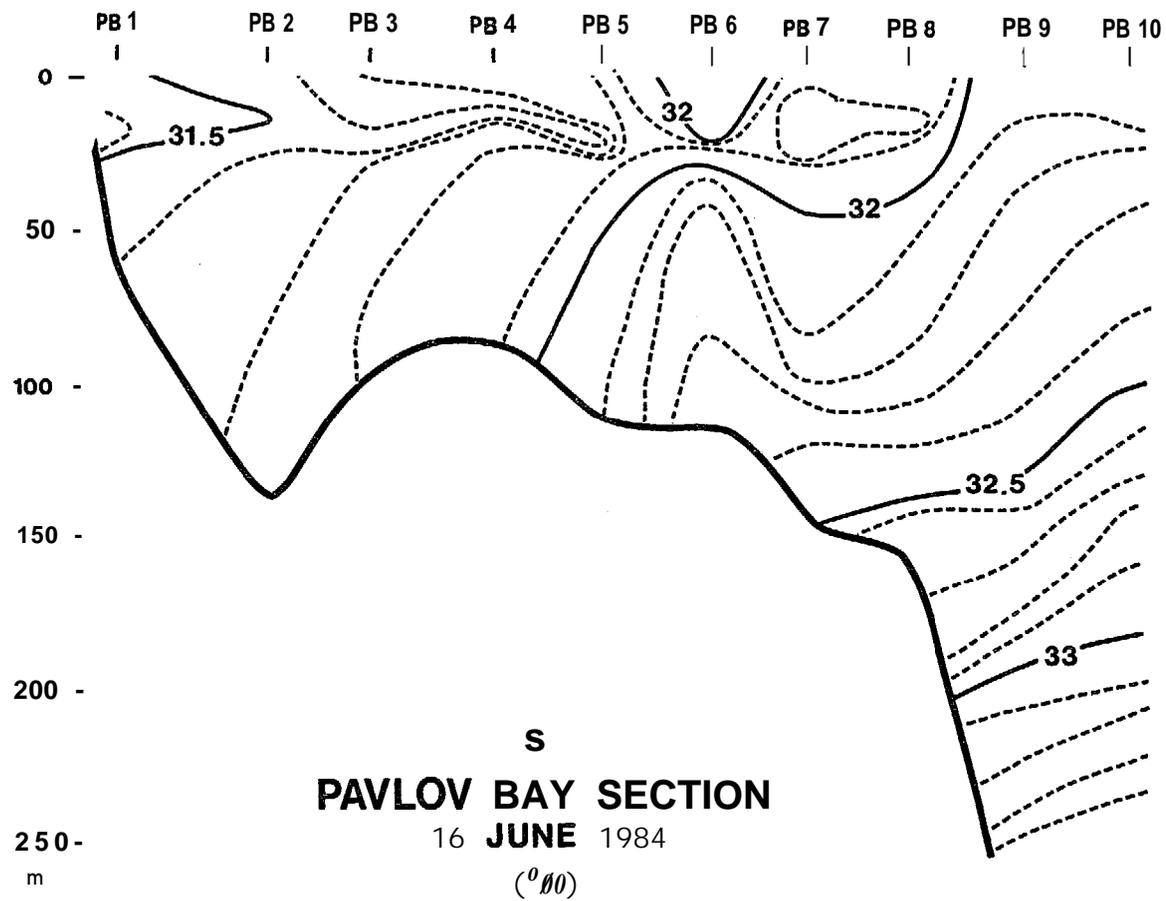


Figure 2.4 - Salinity, Pavlov Bay, June.

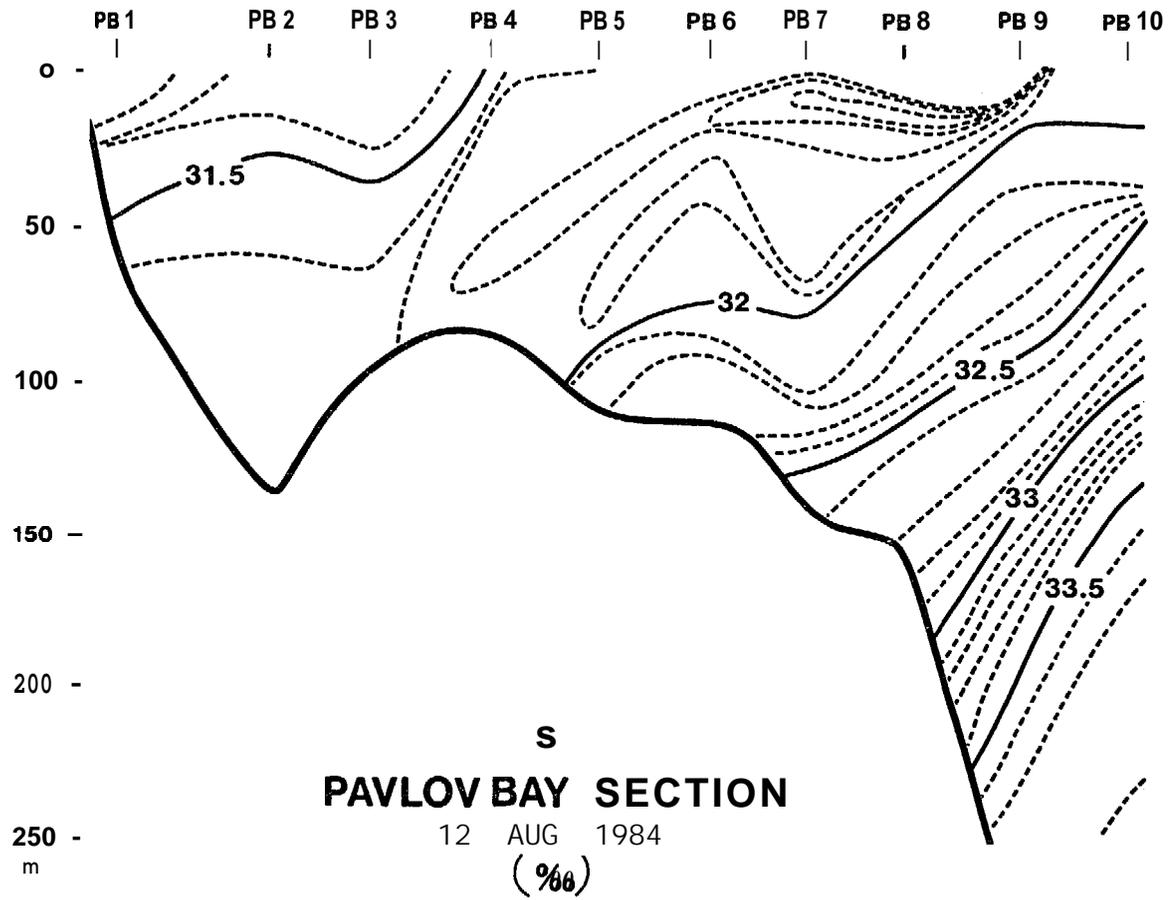


Figure 2.5 - Salinity, Pavlov Bay, August.

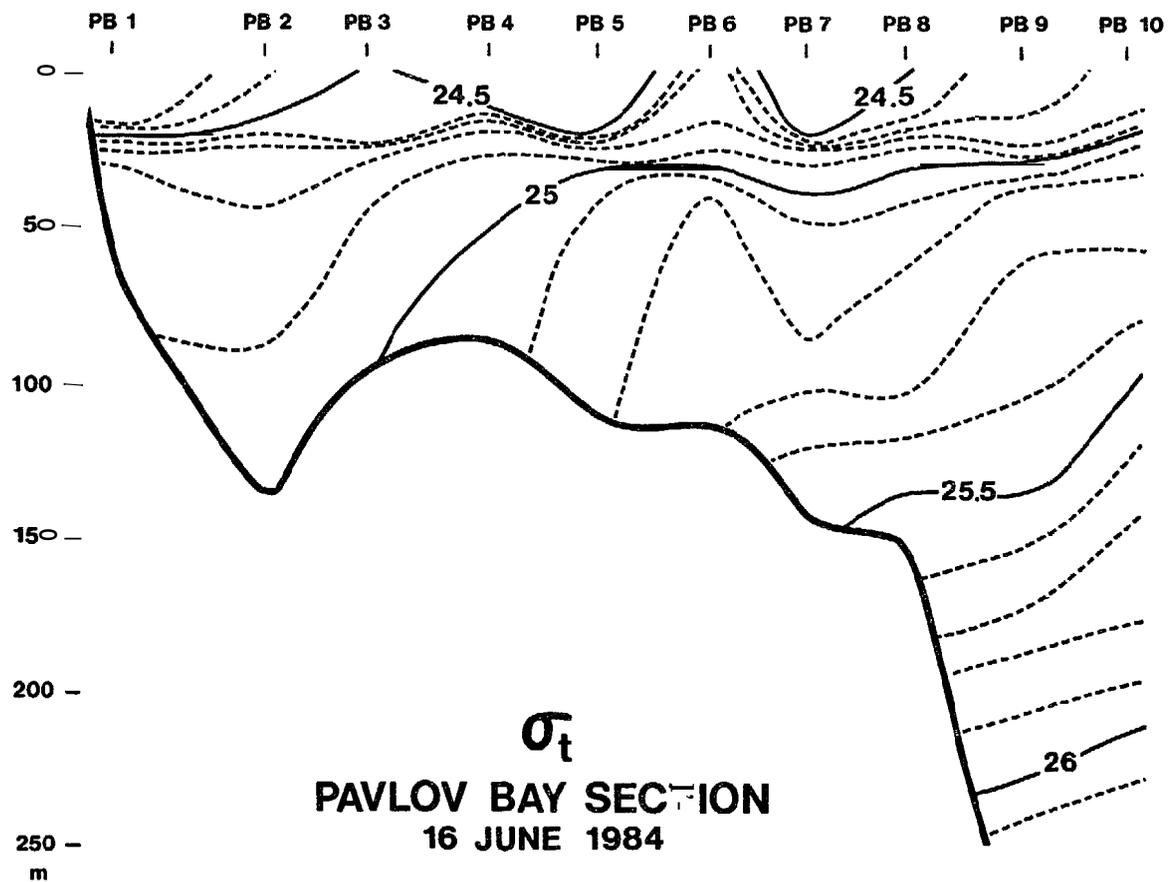


Figure 2.6 - Sigma-t, Pavlov Bay, June.

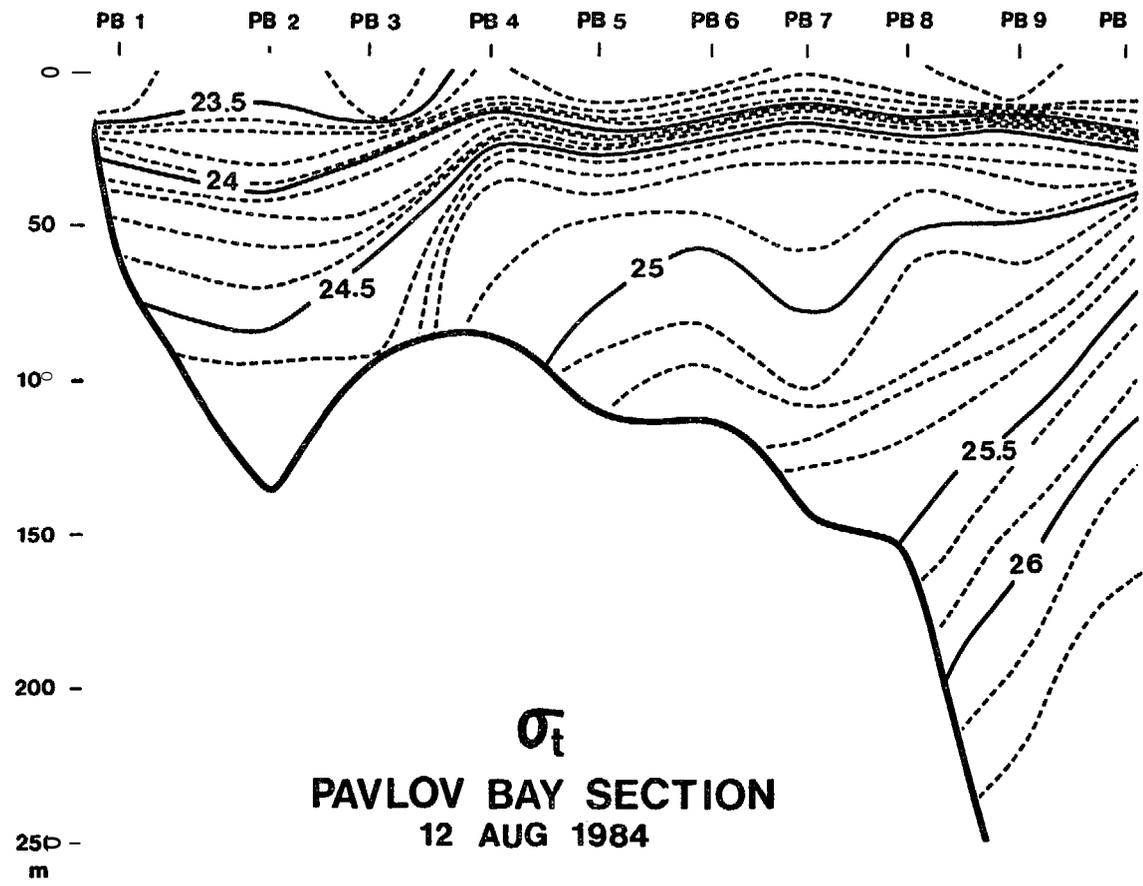


Figure 2.7 - Sigma-t, Pavlov Bay, August.

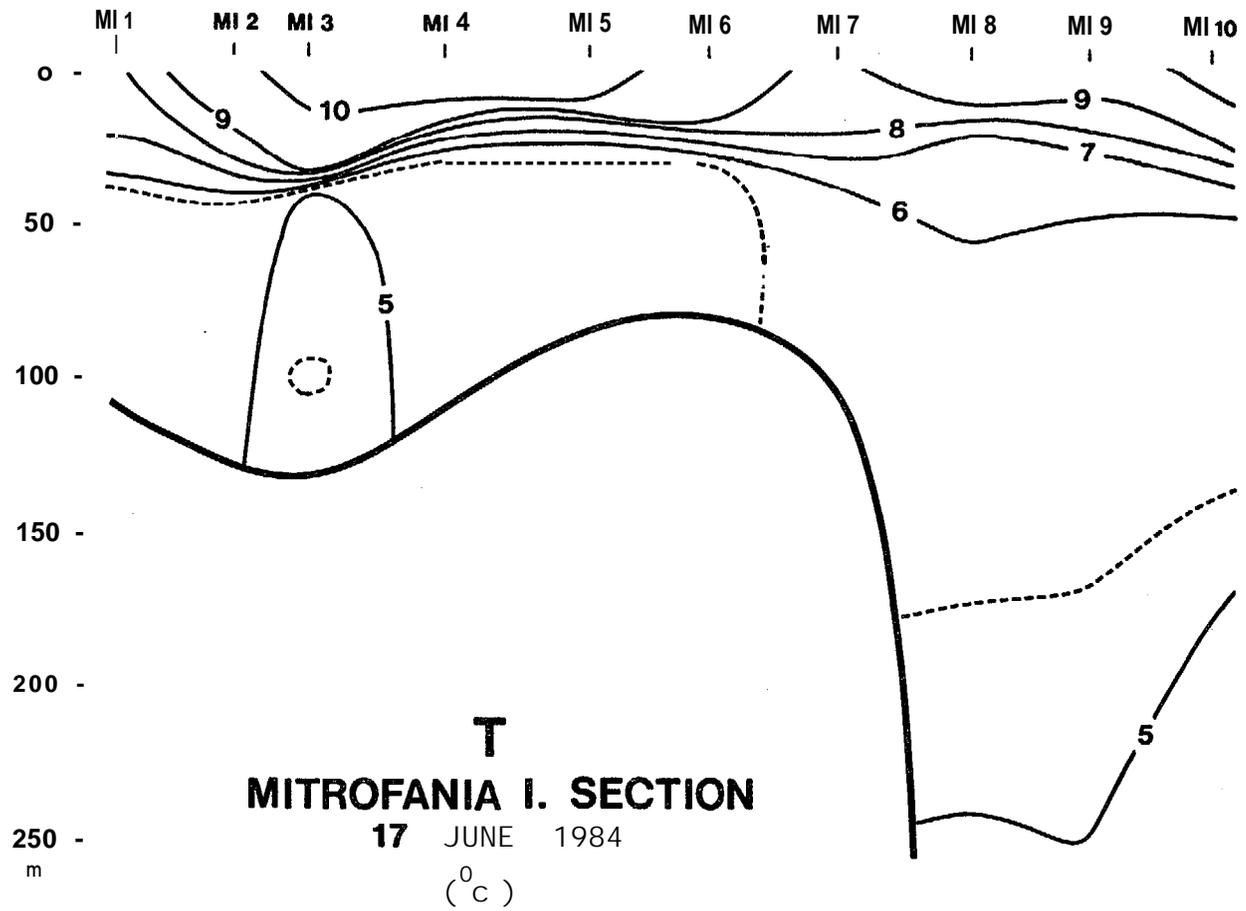


Figure 2.8 - Temperature, Mitrofanía Island, June.

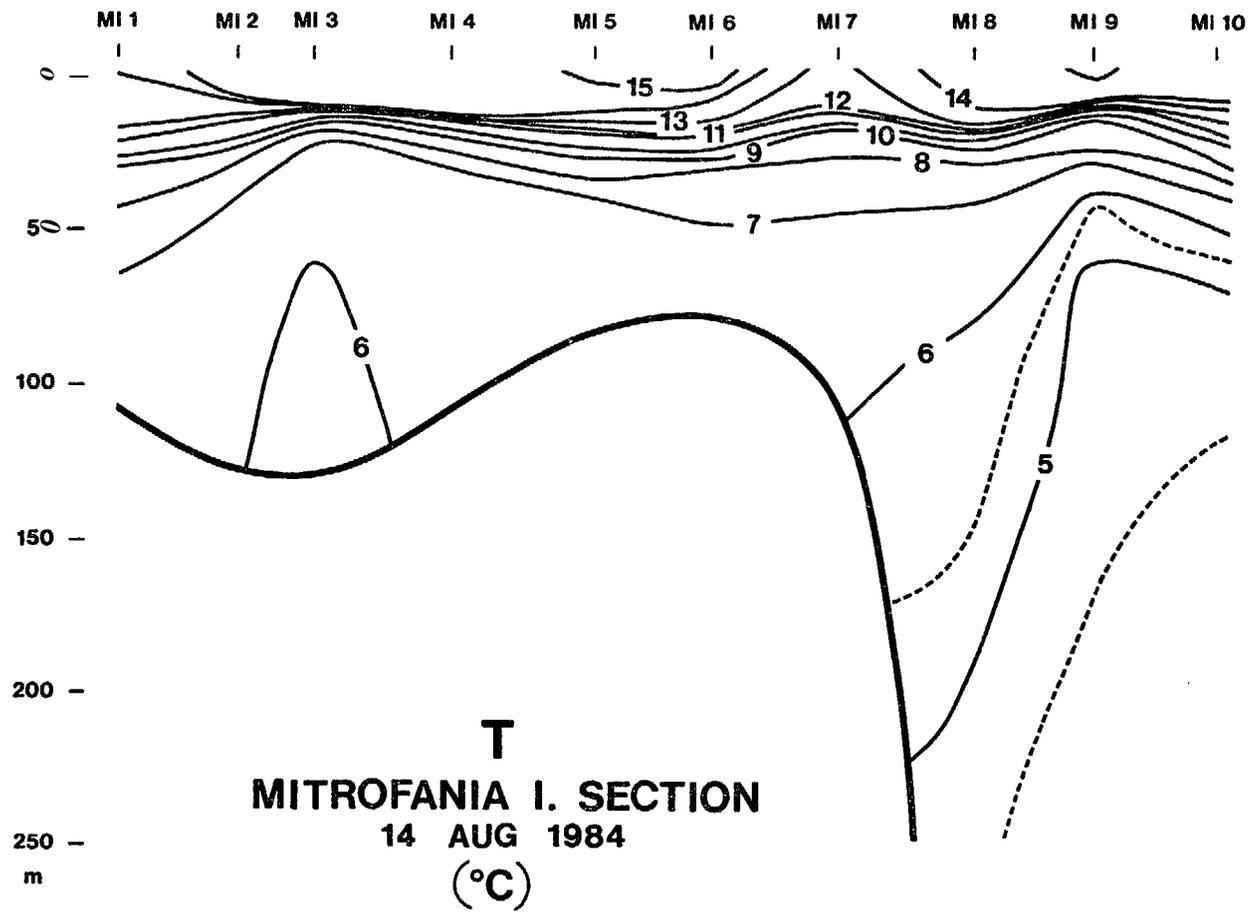


Figure 2.9 - Temperature, Mitrofanía Island, August.

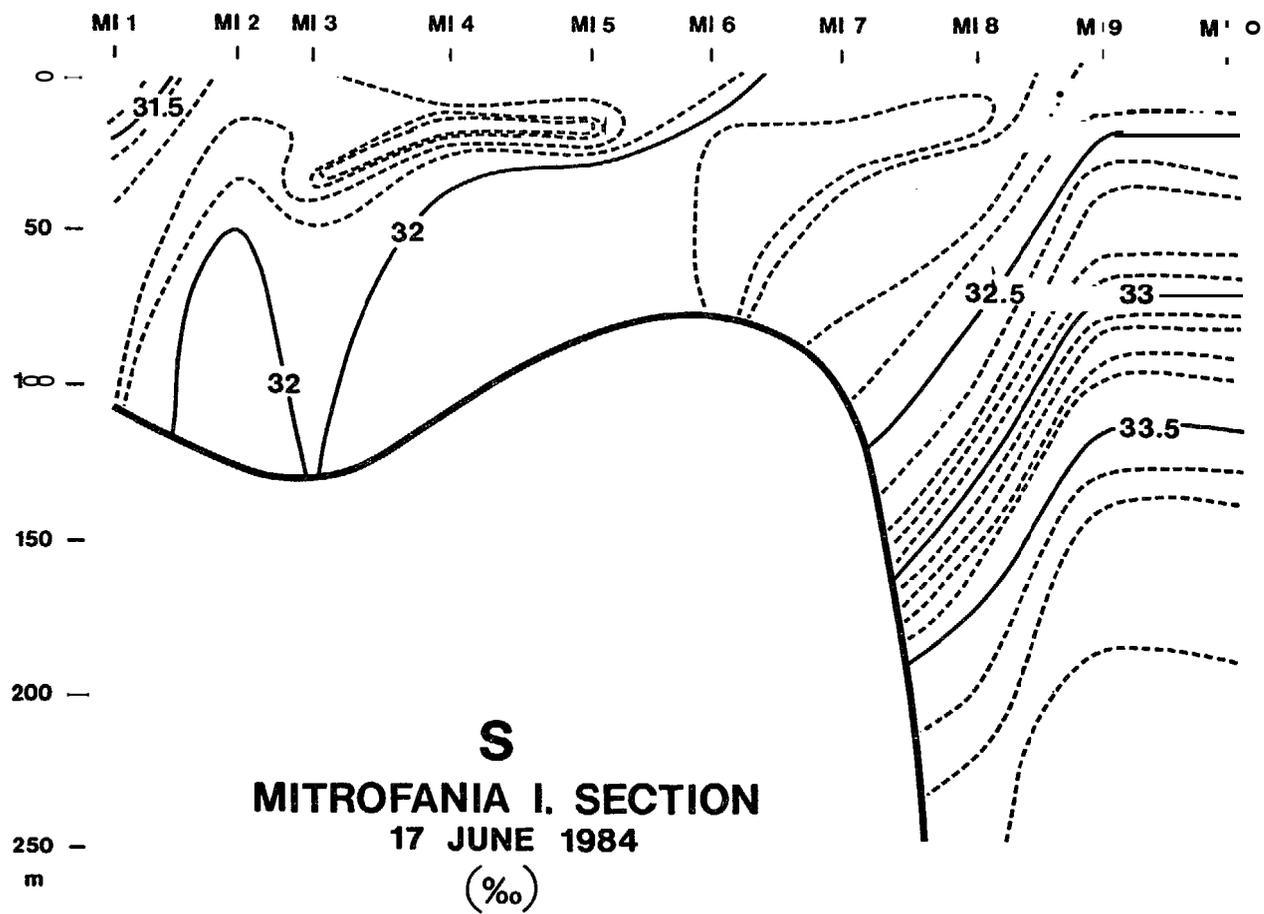


Figure 2.10 - Salinity, Mitrofanias Island, June.

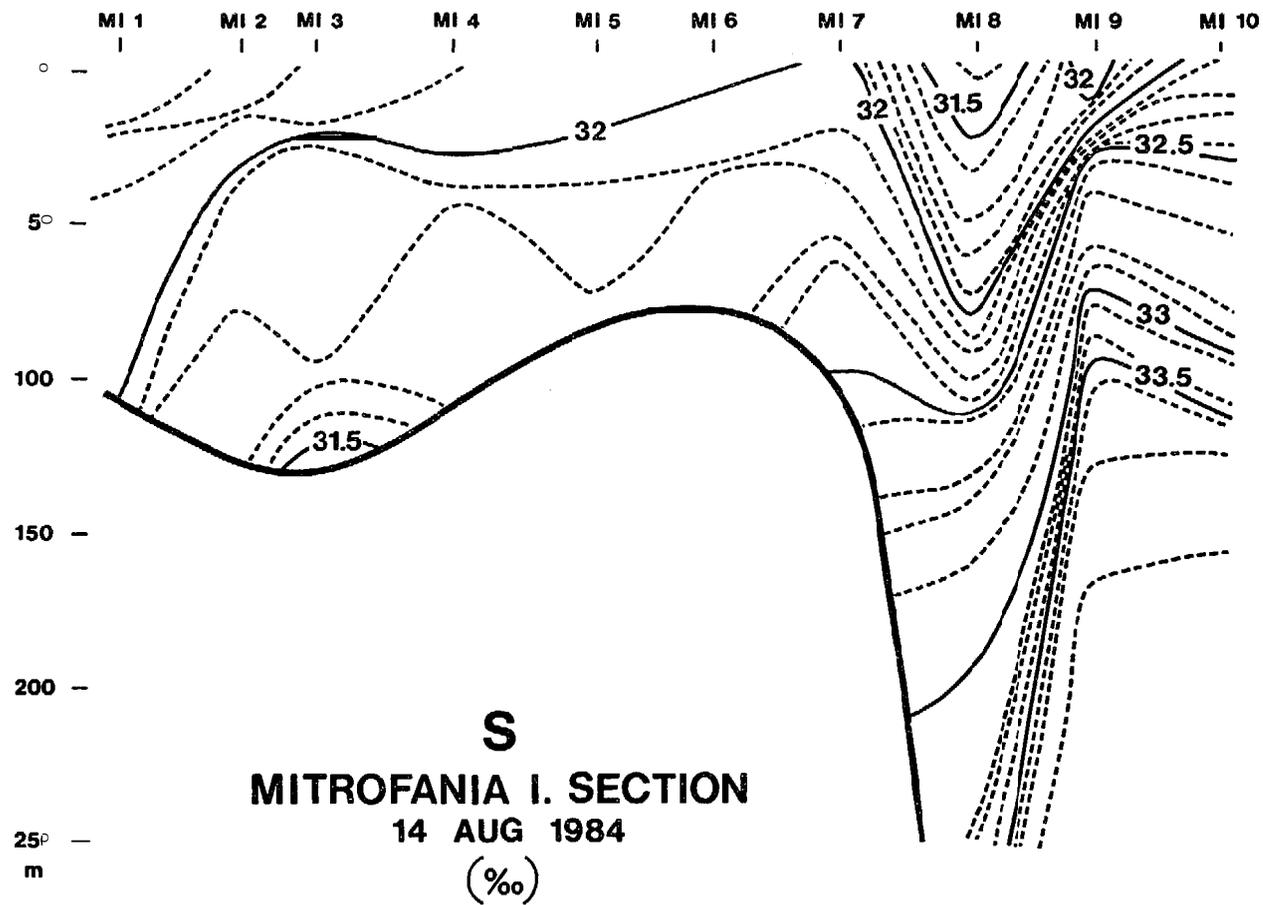


Figure 2.11 - Salinity, Mitrofanía Island, August.

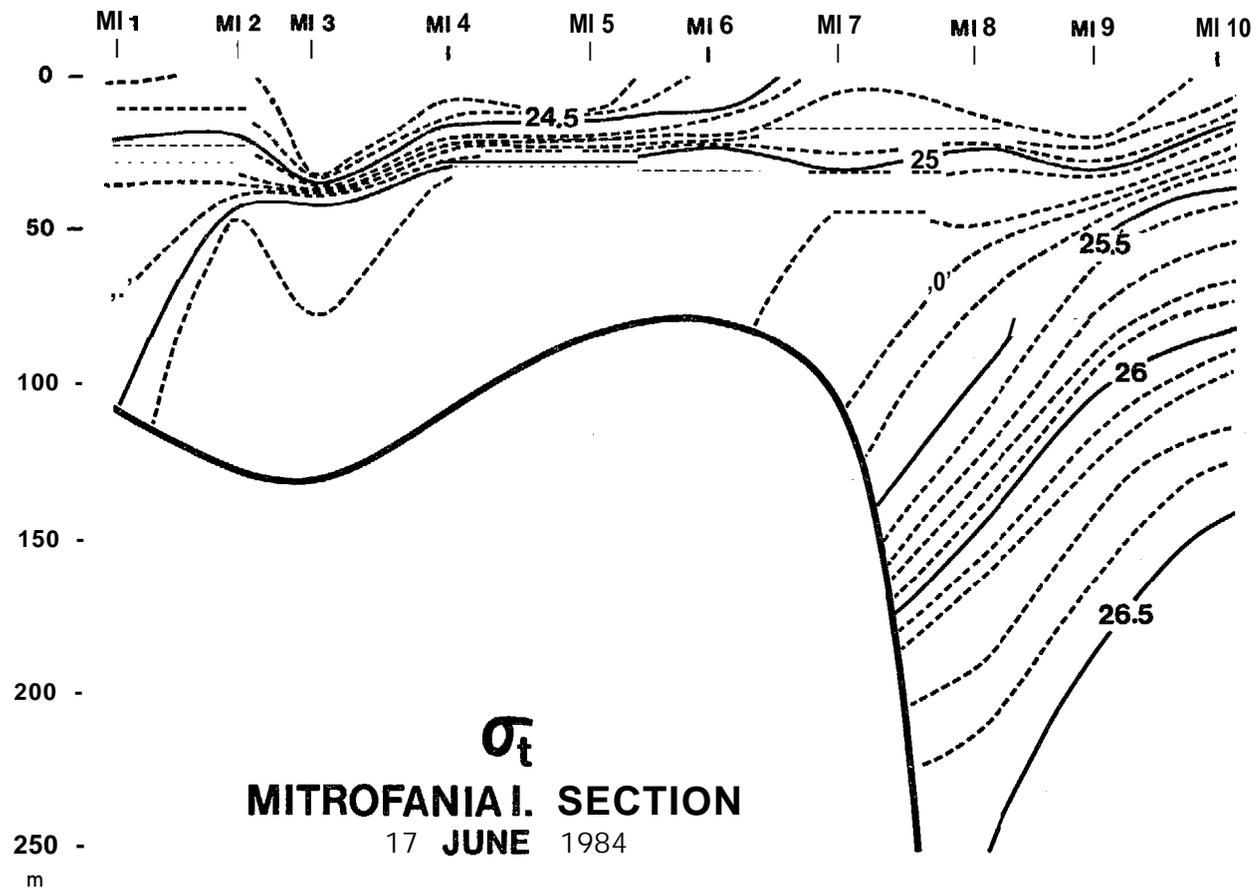


Figure 2.12 - Sigma-t, Mitrof ania Island, June.

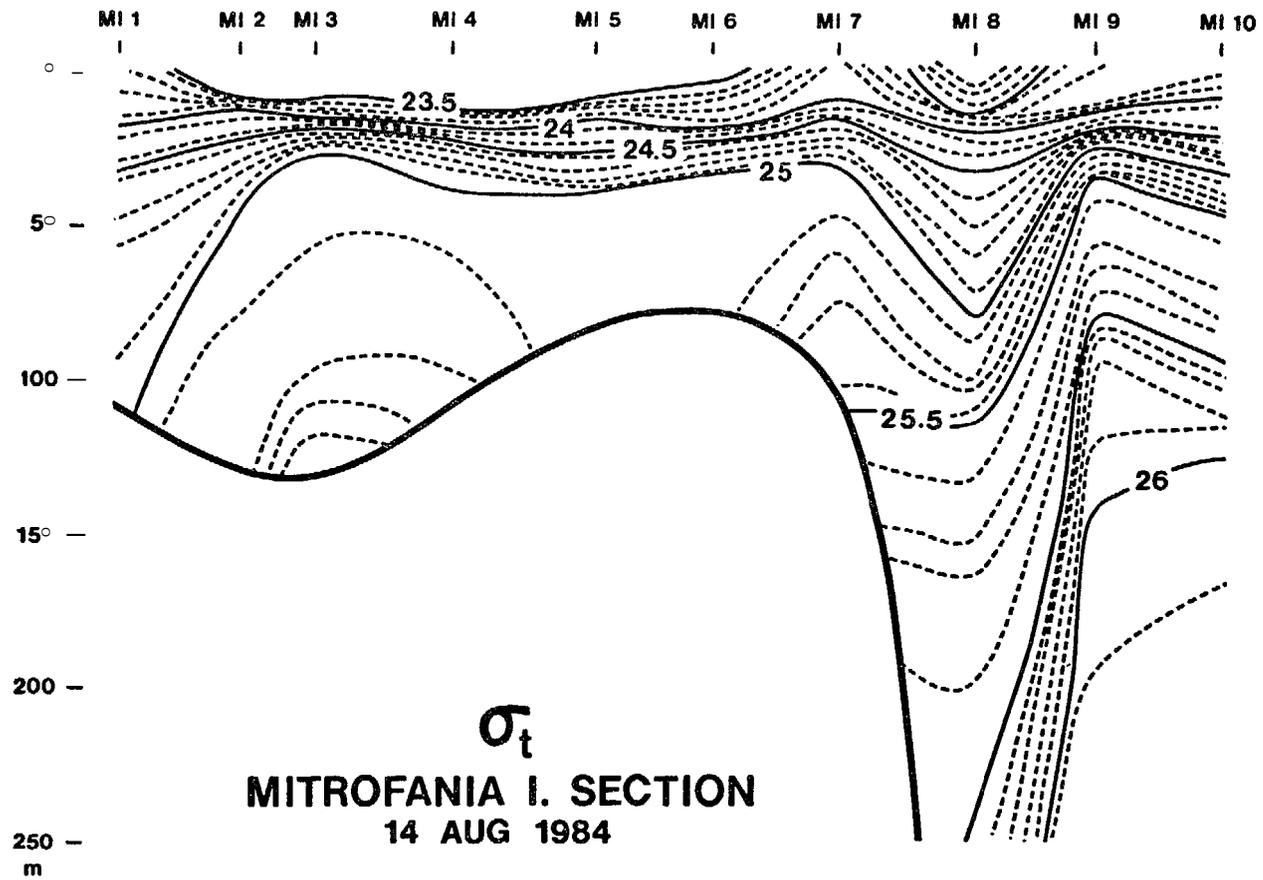


Figure 2.13 - Sigma-t. Mitrofanía Island, August.

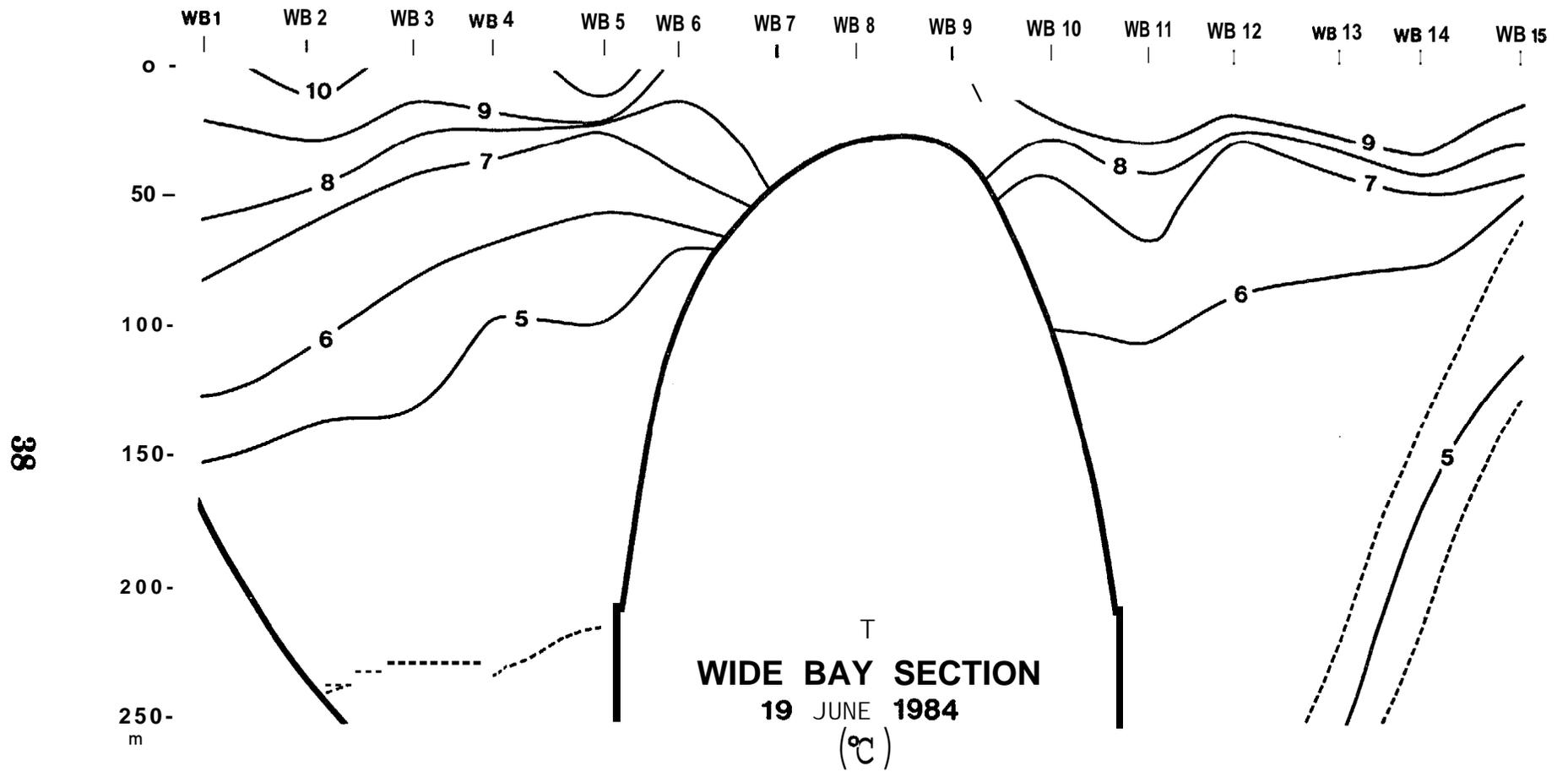


Figure 2.14 - Temperature, wide Bay, June.

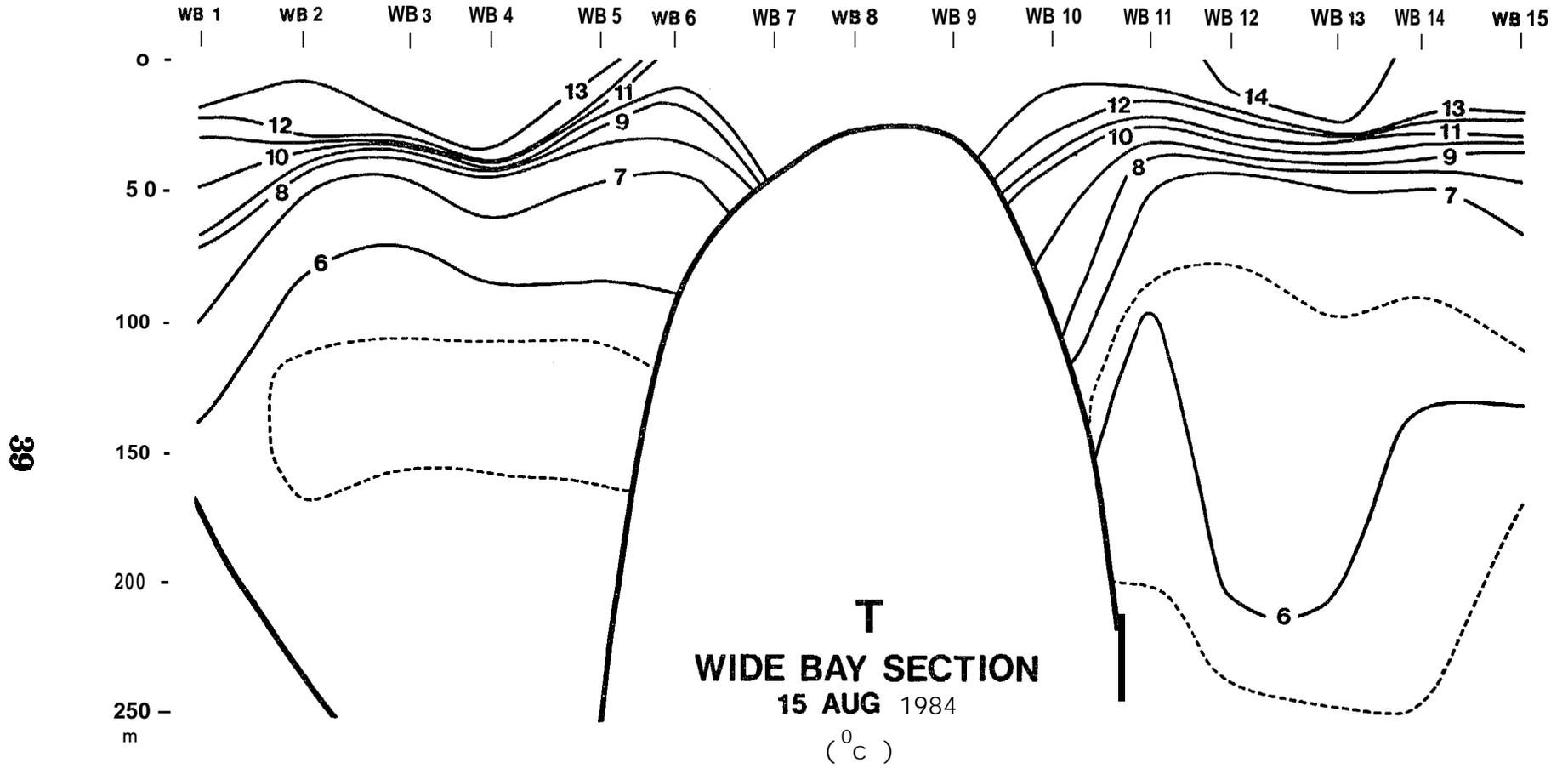


Figure 2.15 - Temperature, Wide Bay, August.

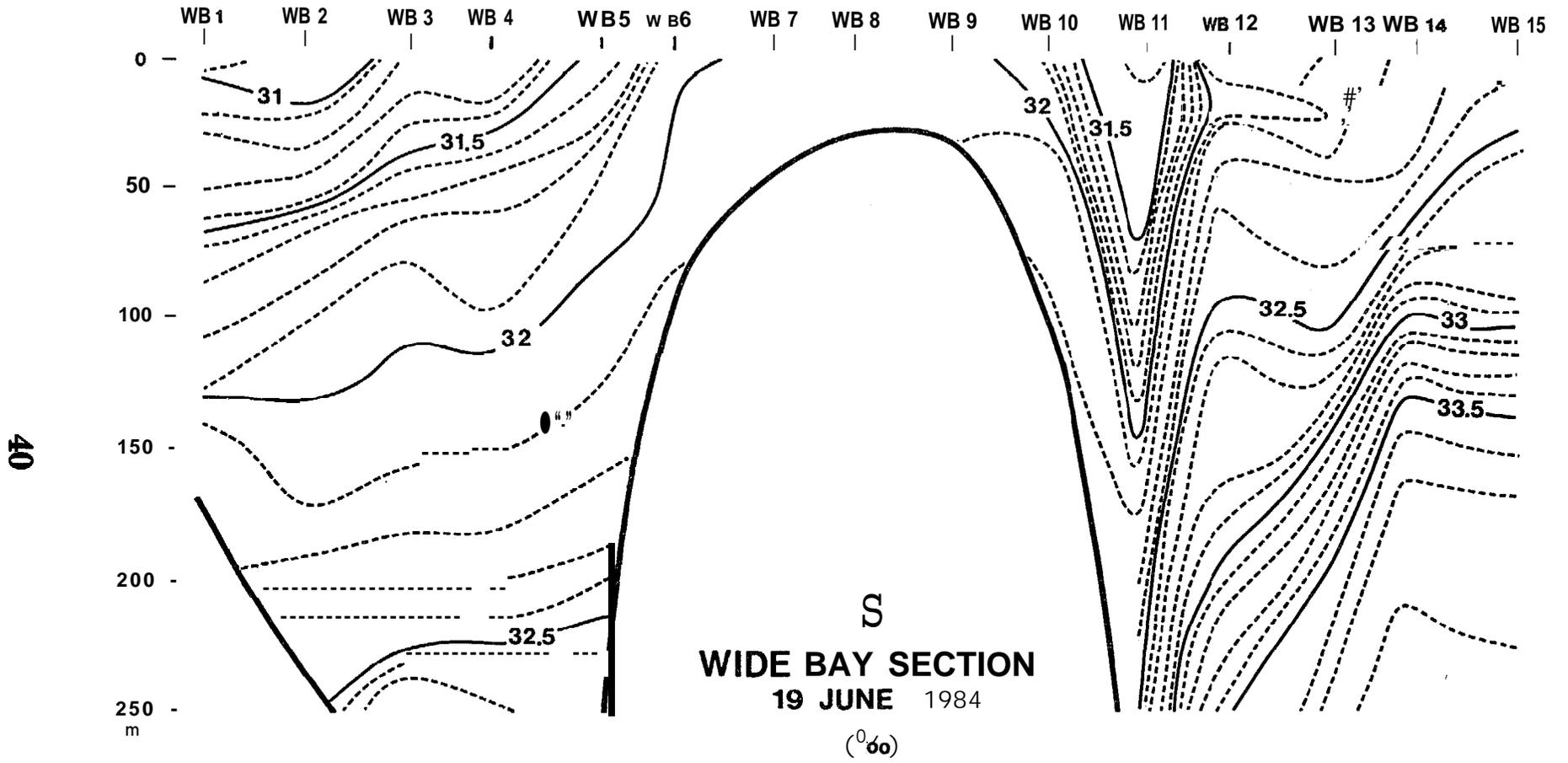


Figure 2.16 - Salinity, Wide Bay, June.

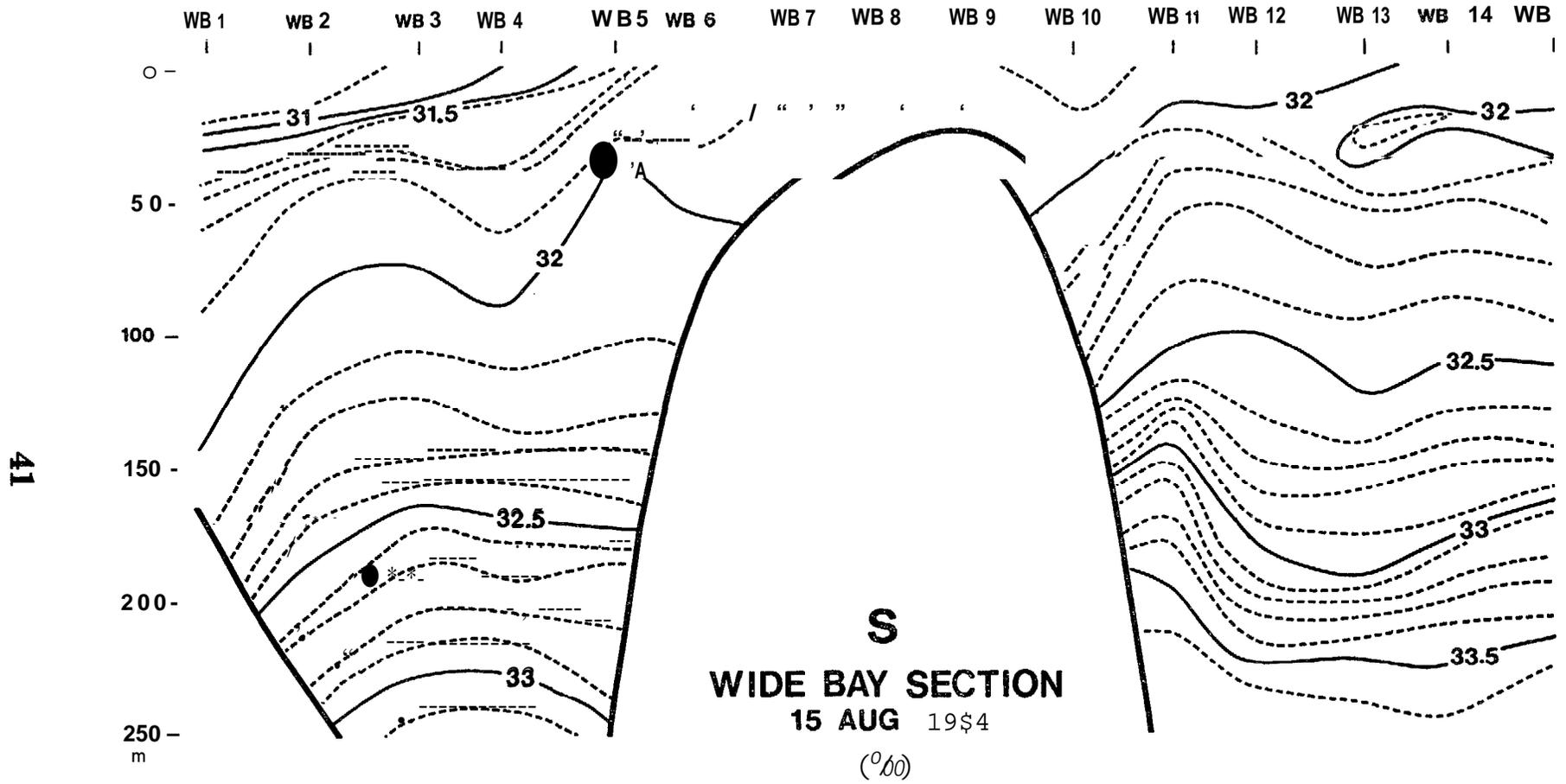


Figure 2.17 - Salinity, wide Bay, August.

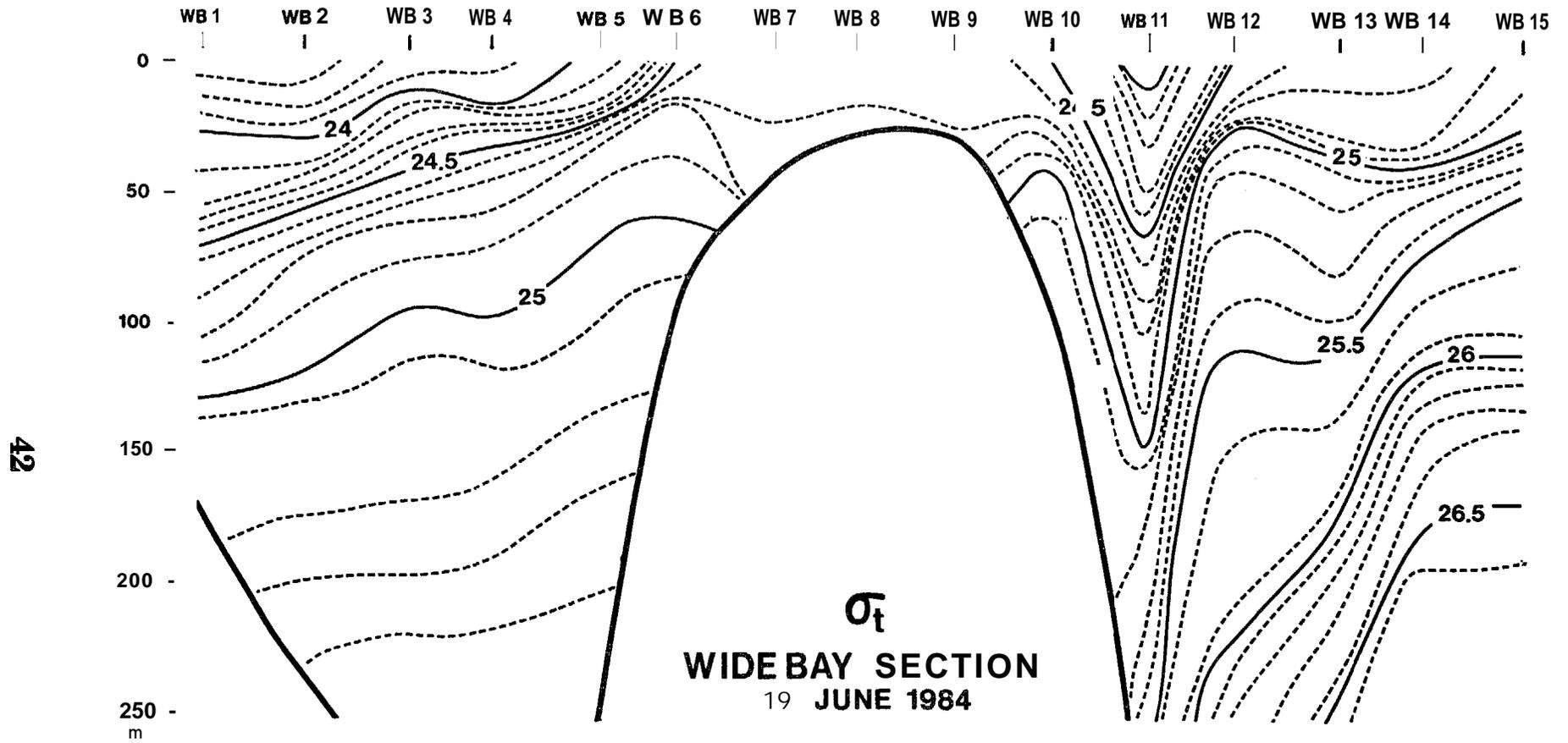


Figure 2.18 - Sigma-t, Wide Bay, June.

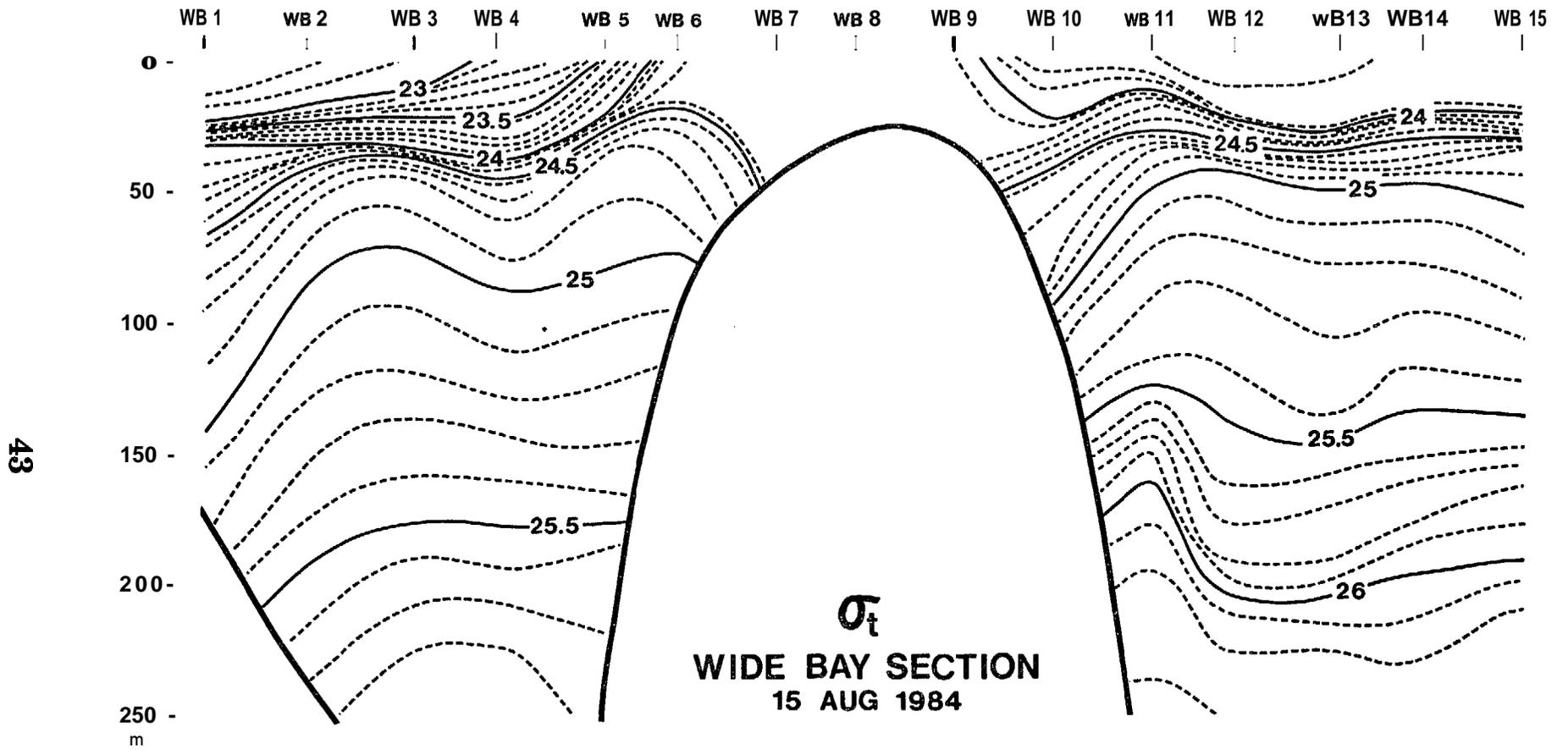


Figure 2.19 - Sigma-t, Wide Bay, August.

tidal mixing **in** this shallow region. Vertical homogeneity of the water **column** over **Portlock** Bank reported by Schumacher et al (1978) and Schumacher and Reed (1980) was also attributed to tidal mixing. It **is** likely that **restratification** occurs, at least in the upper layers, during periods of maximum river discharge.

Although the contours have been substantially **smoothed**, wave-like features still appear on the isotherms particularly at the shallower depths. Such waves are not surprising in light of the strong internal tides (discussed in Section 3.2.2).

### 2.1.2 Salinity

Unlike the temperature **sections**, the salinity sections (Figures **2.4, 2.5, 2.10, 2.11, 2.16, 2.17**) do not show a pronounced temporal change. There is some indication of freshening over the shelf in the Pavlov Bay section but this process **is** not apparent in the other two sections. Extremely strong horizontal salinity gradients were measured over the continental slope on the **Mitrofanía** Island section in August (Figure 2.11) and the Wide Bay section in June (Figure 2.14). These gradients are well mirrored in the sigma-t sections, the latter variable being dominated by salinity at low temperatures.

### 2.1.3 Sigma-t

As a non-linear function of temperature and salinity, sigma-t is more strongly dependent upon salinity at low temperatures **and**, conversely, more dependent upon temperature at high temperatures. The result in the Western **Gulf** of Alaska is that sigma--t temporal changes parallel those of temperature in the near surface layers and of salinity in the deeper layers. At all three sections (Figures 2.6, 2.7, 2.12, 2.13, 2.18, **2.19**) the density stratification in the upper **50 m** approximately doubled between June and August while the deeper stratification remained almost constant. In June very strong horizontal gradients of density were observed over the continental slope **in** the Wide Bay Section (Figure 2.18). Similarly strong

horizontal gradients were observed over the continental slope in the Mitrofanina Island section in August (Figure 2.13). This feature may have been **advected**, or propagated, along the slope between June and August; the mean advection speed would be about 4 cm **s<sup>-1</sup>**. The gradients are suggestive of an **anticyclonic** (clockwise) eddy of about 13 km in radius. Similar features were described by Favorite and **Ingraham** (1977) and Schumacher et al, (1979). An eddy whose signature is visible in the mass field should have a radius roughly comparable to the internal Rossby radius which is defined as

$$r = \sqrt{\frac{g \Delta \rho}{\rho} h / f} \quad (2-1)$$

where  $g$  is gravity,  $\rho$  density,  $h$  is the thickness of the surface layer and  $f$  is the **Coriolis** parameter over the continental slope.  $r$  has a value of between 6 and 12 km so that this eddy-like feature is of appropriate size to satisfy dynamic balances. In particular if the eddy were generated by **baroclinic** instability it would correspond closely in size to the most unstable (and therefore predominant) wavelength (if wave length =  $2r$ ) according to **Mysak, et al** (1981). The agreement between the apparent eddy radius and the internal Rossby radius supports the observations but does not necessarily imply formation by **baroclinic** instability.

The presence of **anticyclonic** (clockwise) eddies over the continental slope raises the possibility of cross-slope exchange of water and nutrients due to instabilities. For example, **baroclinic** instabilities are characterized by turbulent property exchanges across the mean flow and thus along the mean pressure gradient (Smith, 1976). These cross depth gradient fluxes can be visualized as the breaking of waves on the **isopycnal** surfaces when the slopes of the surfaces exceed critical values. The "breaking waves" propagate along the initial **isopycnal** slope, i.e. across the mean **flow**.

It will be seen in the next sections that the station spacing is not quite **small** enough to properly resolve spatial variability of the size of the internal Rossby radius. While this drawback has little effect upon

qualitative representation of the distribution of properties, it limits the utility of the dynamic method by which **geostrophic** currents are computed from horizontal density gradients.

## **2.2 DYNAMIC HEIGHTS, GEOSTROPHIC CURRENTS**

Geostrophic shears can be integrated from an assumed **level** of no motion to yield estimates of the **baroclinic** geostrophic current profile. This long-standing method has both its strong adherents and detractors. The latter are critical of some of the assumptions of the "Dynamic Method" and have shown that they do not apply in many regions. For the present data set the most important limitations are lack of **synopticity** and, to a lesser extent, insufficiently dense station spacing.

The thermal wind equations, from which the dynamic method arises, assume a steady flow. Implicit is that vertical motion of the **isopycnals** is negligible. In the presence of a strong internal wave field, however, this is simply not the case. Several investigators have surmounted the obstacle of time-varying flows in computations of **geostrophic** currents by averaging density measurements over a tidal cycle. Such a procedure is extremely consumptive of ship time and was not attempted in our field work. The computed dynamic heights and **geostrophic** currents therefore neither represent a tidal average nor an instantaneous realization of the flow. We would suggest that where the mean flow energy is small compared to the tidal energy, geostrophic current computations do little more than yield a qualitative view of the flow **field**.

**In** order to produce stream lines of the geostrophic **flow**, the dynamic height anomaly between selected pressure surfaces was plotted and contoured. The charts for June and August are presented on the same page for ease of comparison in Figure 2.20 through 2.23. Figure 2.20 shows the dynamic height topography of the surface relative to 10 **decibars**. The plots are an indication of the density of the mixed layer; the larger anomalies representing less dense **water**. The influence of warmer and fresher waters **nearshore** is shown. The anomalies increased between June

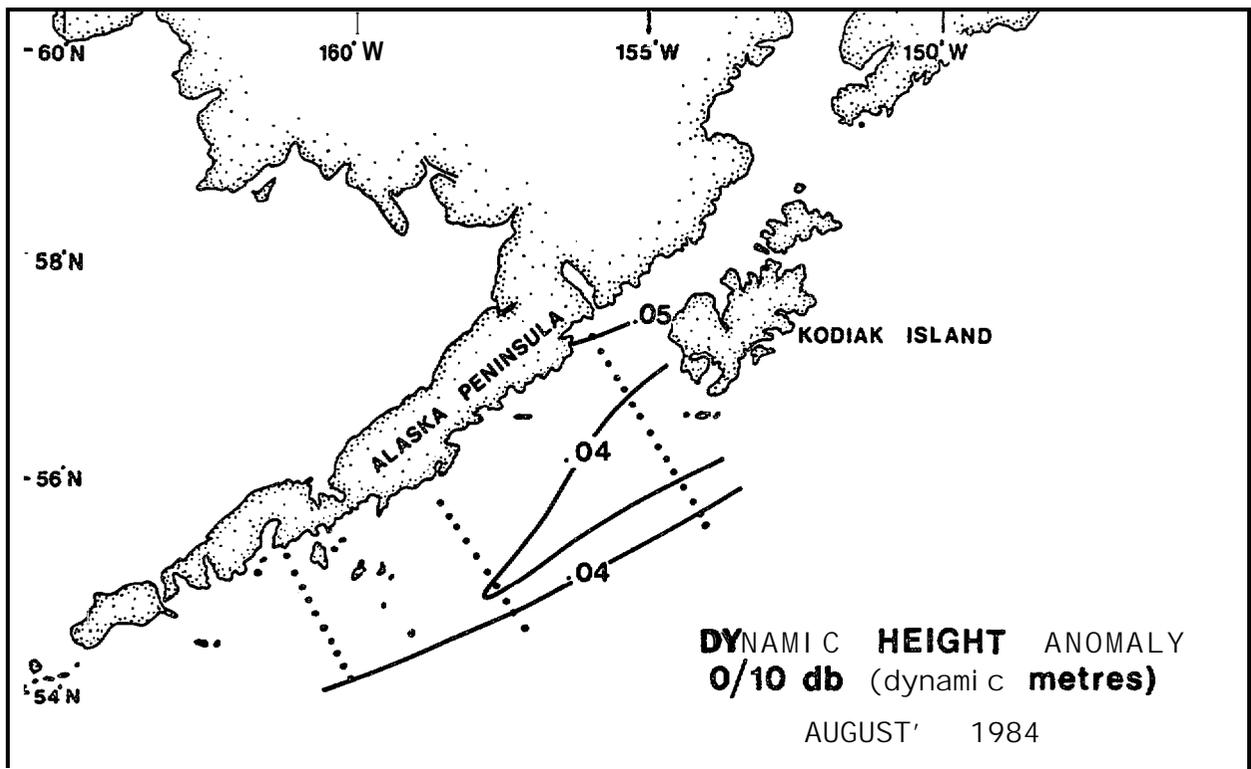
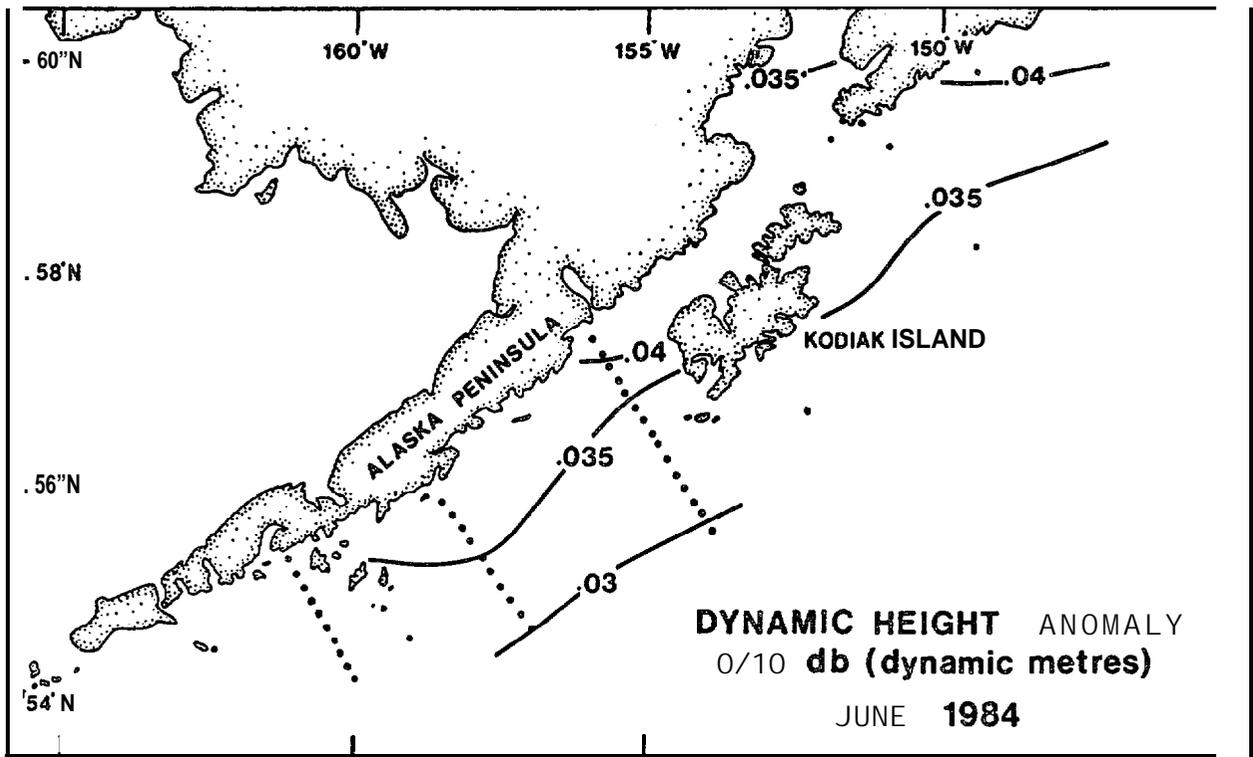


Figure 2.20 - Dynamic height topography, 0/10 db, June and August 1984.

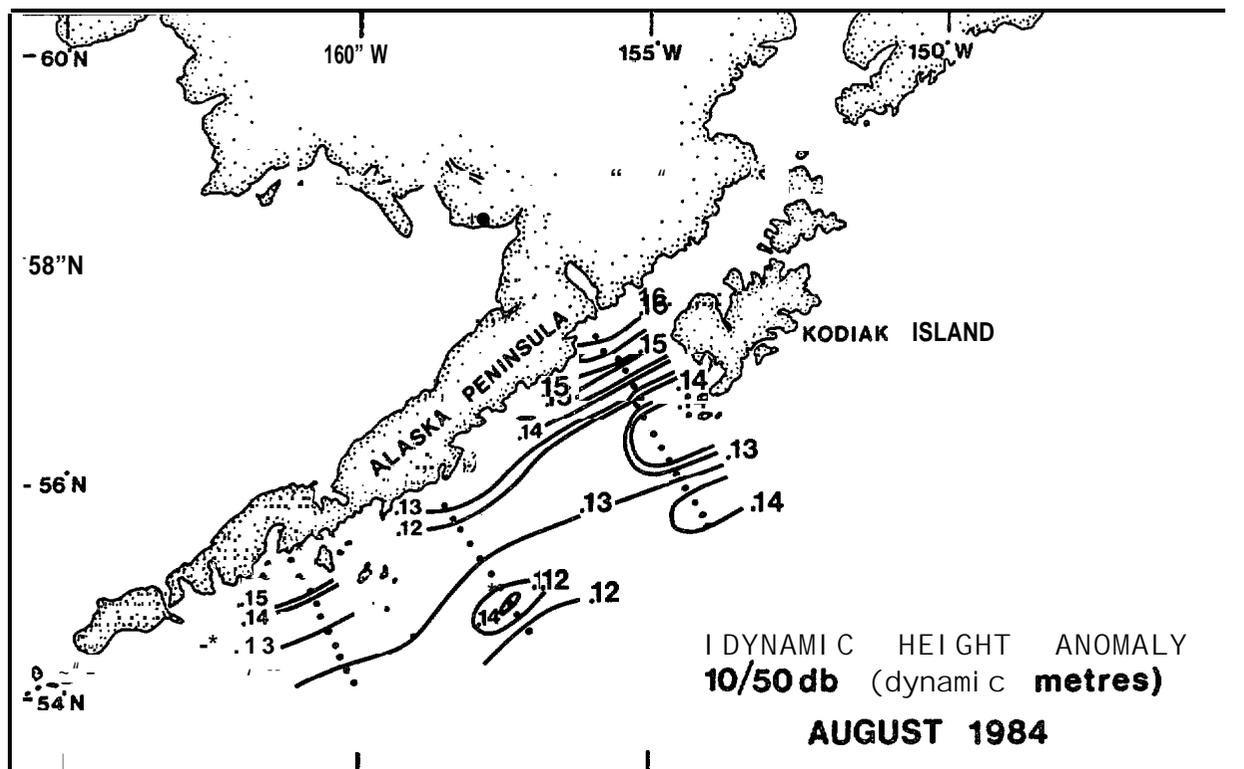
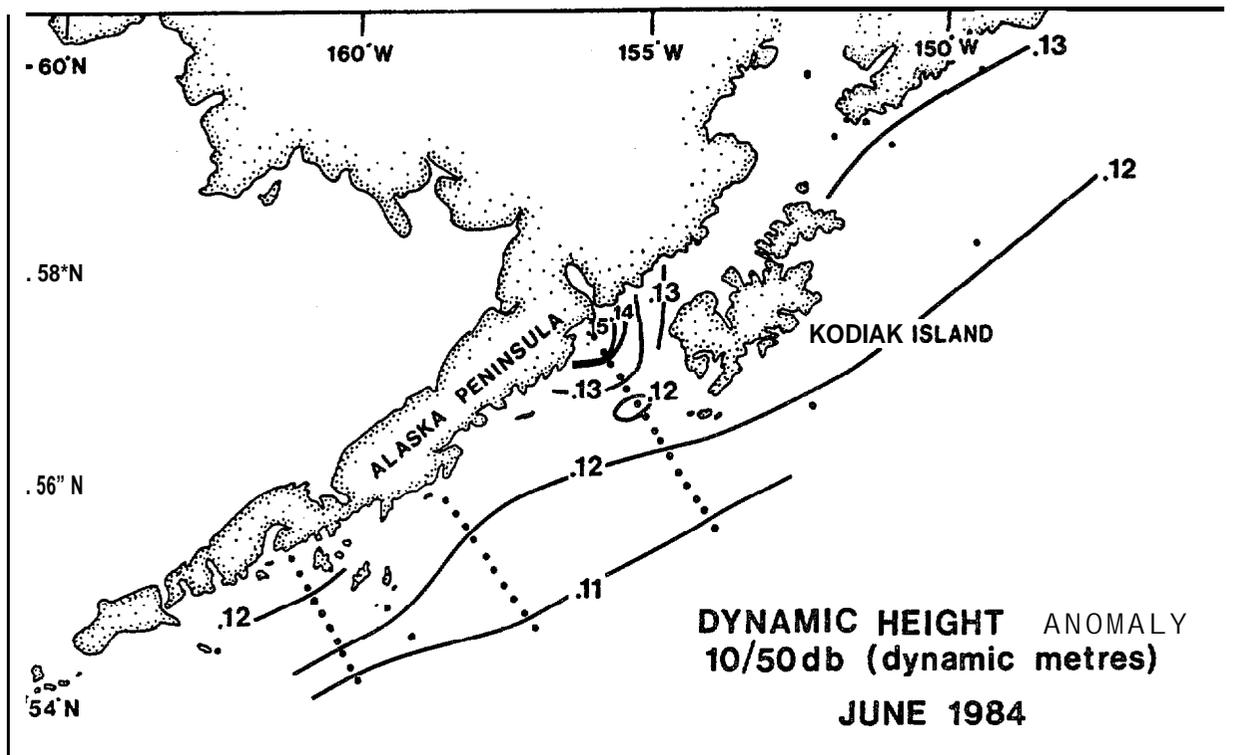


Figure 2.21 - Dynamic height topography, 10/50 db, June and August 1984.

and August due to **continued** insolation. Figures 2.21 and 2.22 represent the topography of the 10 and 0 db surfaces relative to 50 db. The **geostrophic** flow field in the upper 50 m is thus portrayed.

The velocity differences between surfaces can be computed by

$$A_u = \frac{1}{fL} \Delta \text{O.A.D.} \quad (2-2)$$

where  $A_u$  is the velocity difference,  $\Delta \text{O.A.D.}$  is the difference in dynamic height anomaly between two **stations**,  $f$  is the **Coriolis** parameter and  $L$  is the distance between stations. The 10/50 db and 0/50 db charts show that the **geostrophic** velocity shear in the upper layers was generally less than  $10 \text{ cm s}^{-1}$  and on average across the **shelf** about  $3 \text{ cm s}^{-1}$ . The 10/50 and 0/50 db charts are virtually identical demonstrating the density gradients in the upper 10 m contributed little to the geostrophic flow field. Considerably more horizontal structure was present in August than in June above the 50 **decibar** surface probably due to increased river discharge toward the end of summer which introduced fresher water. Both the freshening itself and the enhanced stratification promoting heating of the surface layers would have contributed to the contrast between June and August. However, the mean **flow** (for example through the Wide Bay or eastern most section) changed **little** between June and August. The mean velocity in the upper 50 m was southwestward at a speed of about 2 or  $3 \text{ cm s}^{-1}$  relative to 50 db.

Figure 2.23 shows the dynamic topography of the 10 db surface relative to 100 db. Vertical velocity shear is most apparent along and near the shelf break where vertical velocity differences in June are on the order of  $8 \text{ cm s}^{-1}$  and the direction of **flow** is to the southwest. In August the flow along the shelf break is about  $4 \text{ cm s}^{-1}$  and generally directed toward the northeast. An outflow on the order of  $5 \text{ cm s}^{-1}$  is directed southwestward from **Shelikof** Strait in both June and August. This *figure is in* fairly good agreement with the mean **flow** measured over the two month period at the current meter at 46 m depth in **Shelikof** Strait.

In all the dynamic height topography charts the mean flow from the shore to the shelf break is directed toward the southwest in agreement with the contemporary view of the **Alaska** Coastal Current regime, e.g. **Royer** (1981).

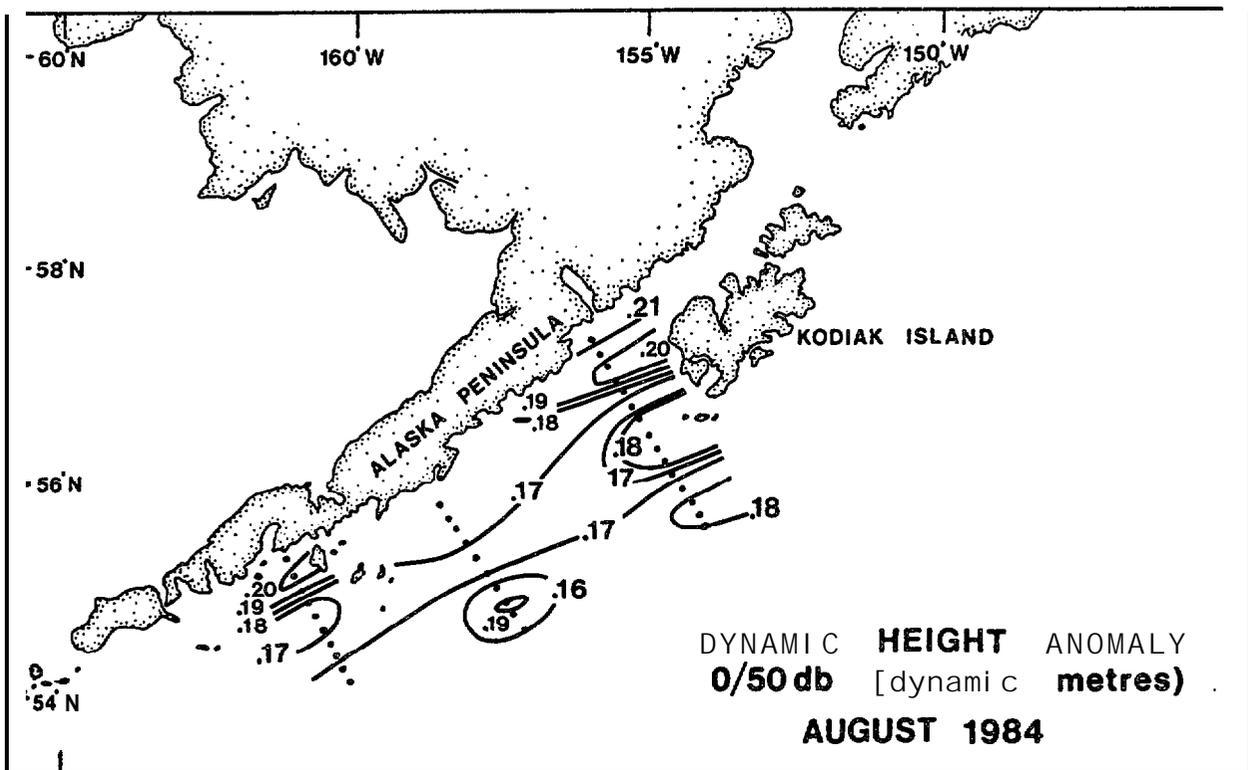
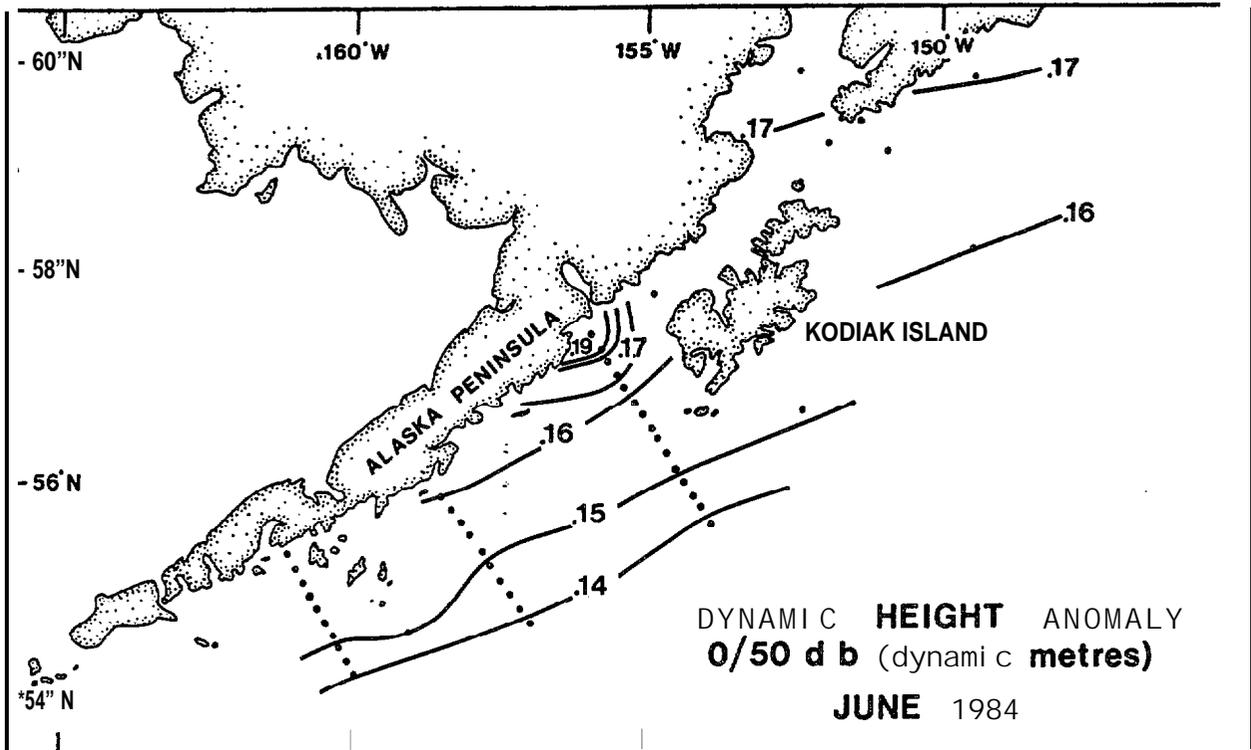


Figure 2.22 - Dynamic height topography, 0/50 db, June and August 1984.

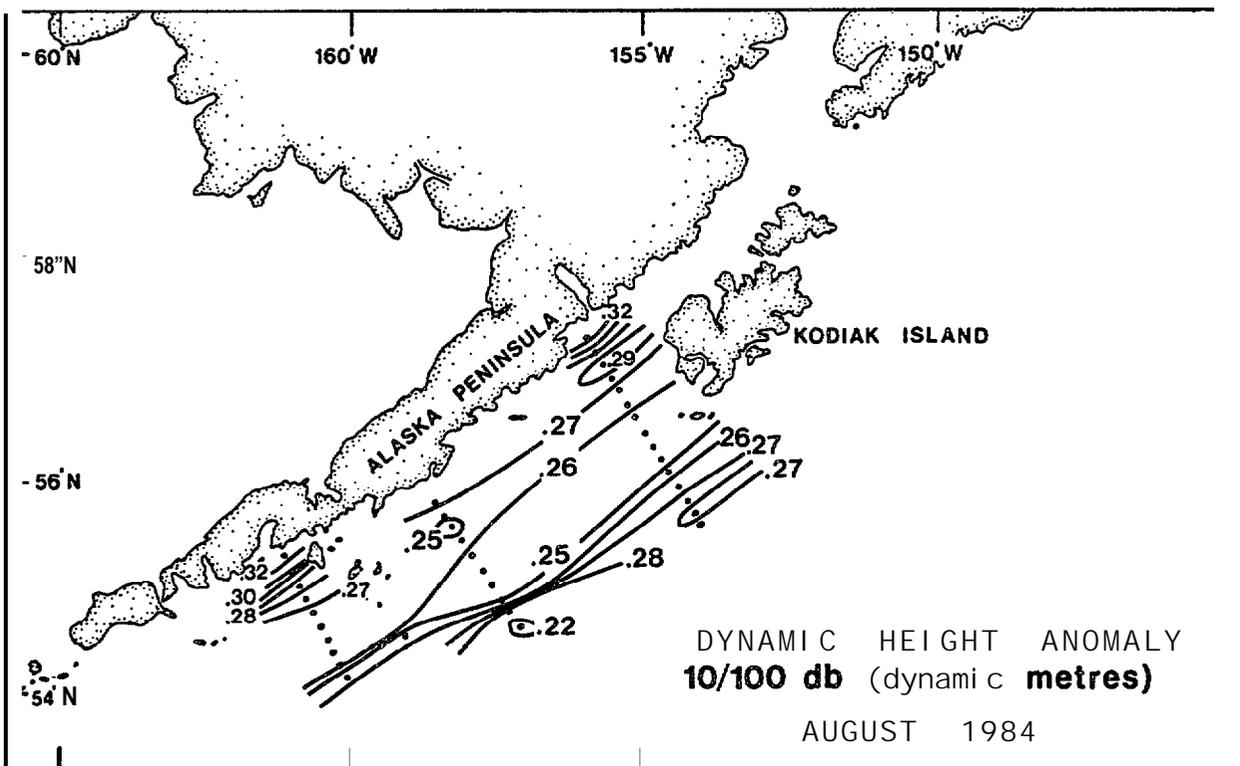
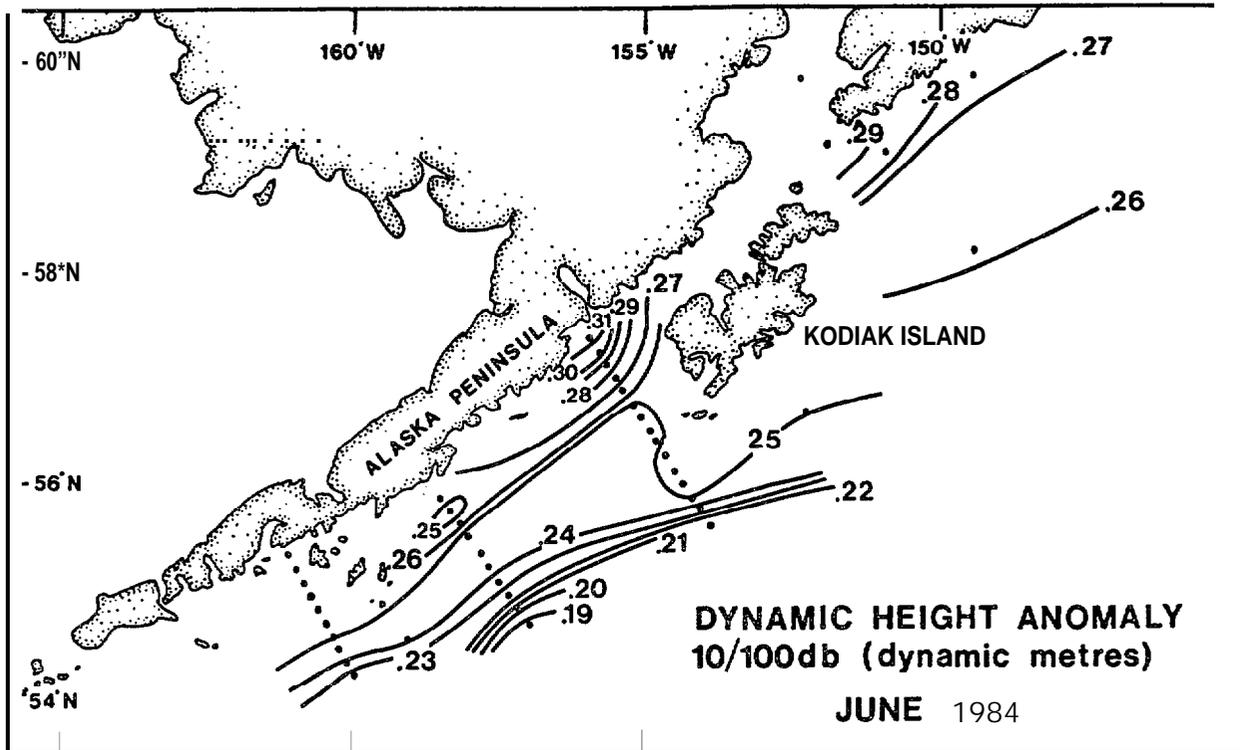


Figure 2.23 - Dynamic height topography, 10/100 db, June and August 1984.

An attempt was made to establish a level of no **motion** across the **shelf** and to **unify** the geostrophic shears into cross section of velocity. In author's view the procedure is more artistic than quantitative. Such cross sections of velocity do, **however**, give a sense of structure of the velocity field. **Isotachs** for June and August are presented for each of the sections in Figure 2.24 through 2.29. The details of the structure are clearly limited by the station spacing which was somewhat larger than the internal Rossby radius of deformation. In addition, the quality of the **CTD** data is rather poor and spurious structures may have been introduced to these cross sections.

### 2.3 SURFACE **SALINITIES** AND TEMPERATURES

Charts of the surface salinity and temperature distributions during June and August are shown *in* Figures 2.30 through 2.33.

The 32.0 ppt surface isohaline appears to follow the shelf break during both June and August. Values are similar to those reported **by** Reed et al, (1979). There is an indication of the freshening of the surface waters in **Shelikof** Strait during the *summer*, but the sampling stations were very sparse in that region. The salinity increased monotonically offshore in agreement with the concept of a runoff driven southwesterly flow along the shelf. No salinity minimum was found over the shelf break as has been reported by Favorite and **Ingraham** (1977) or Royer and Muench (1977) for Spring conditions. It appears, rather, that summer conditions prevailed during the period June through August 1984.

The surface temperature charts show mainly a general increase in temperature due to insolation *over* the summer. There is an indication of the presence of cooler surface waters near-shore than offshore in both months probably due to relatively cold river discharge. The cross-shelf horizontal temperature gradients remain almost constant between June and August.

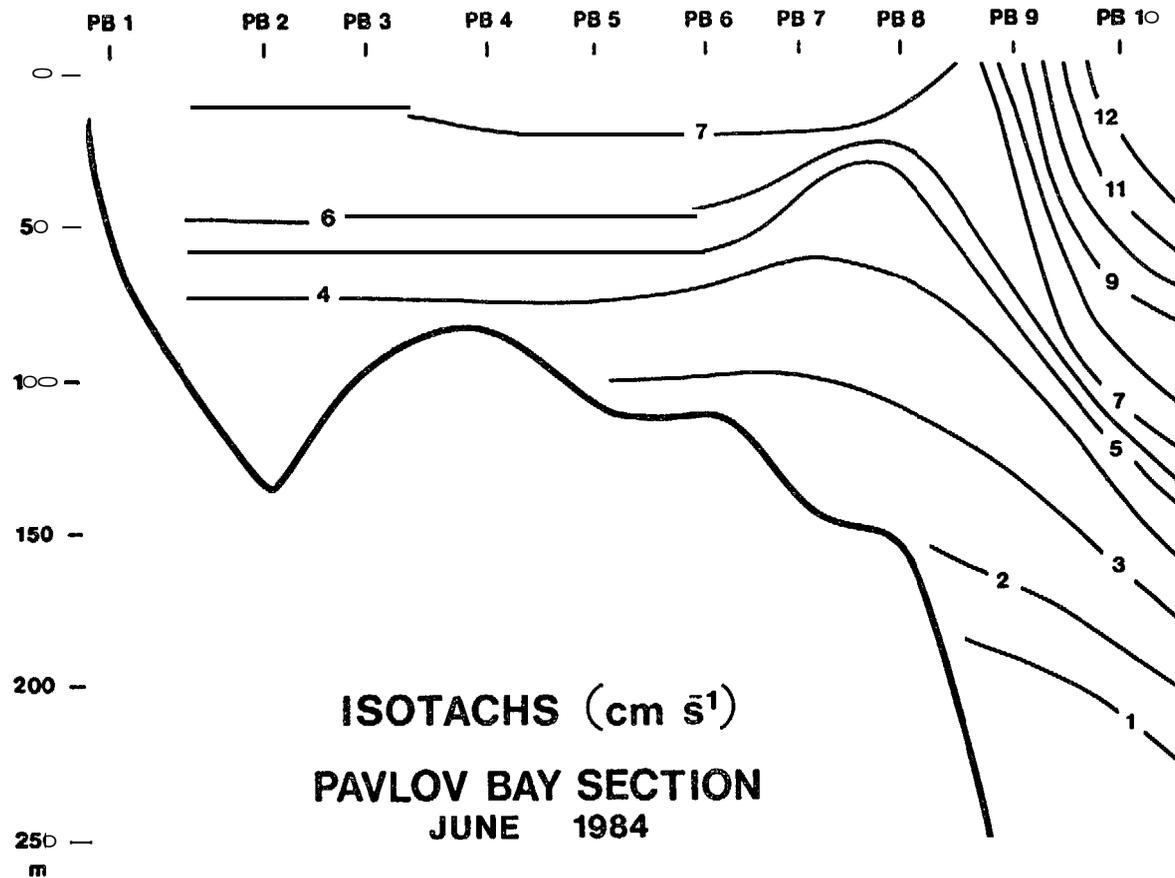


Figure 2.24 - Isotachs, Pavlov Bay, June. Positive flows are out of the page; i.e., to the southwest.

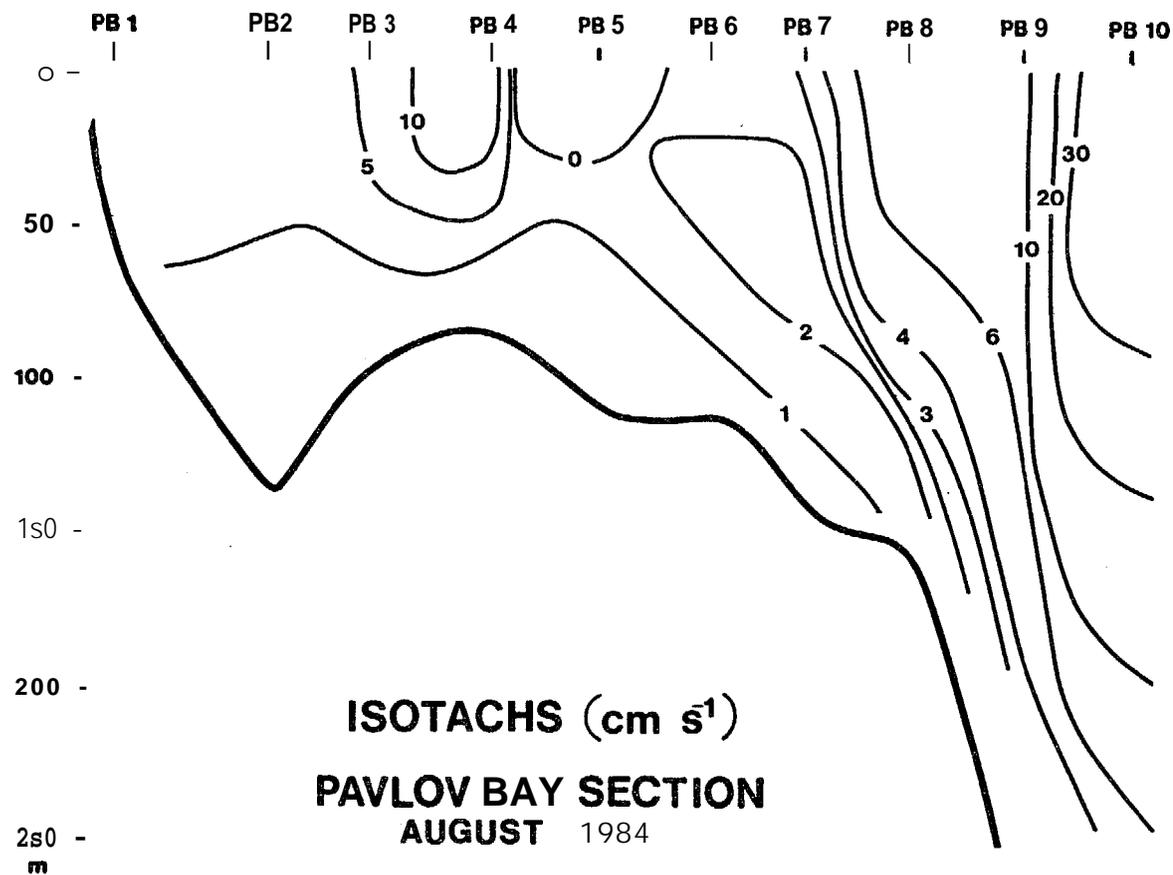


Figure 2.25 - **Isotachs**, Pavlov Bay, August. Positive flows are out of the page; i.e., to the southwest.

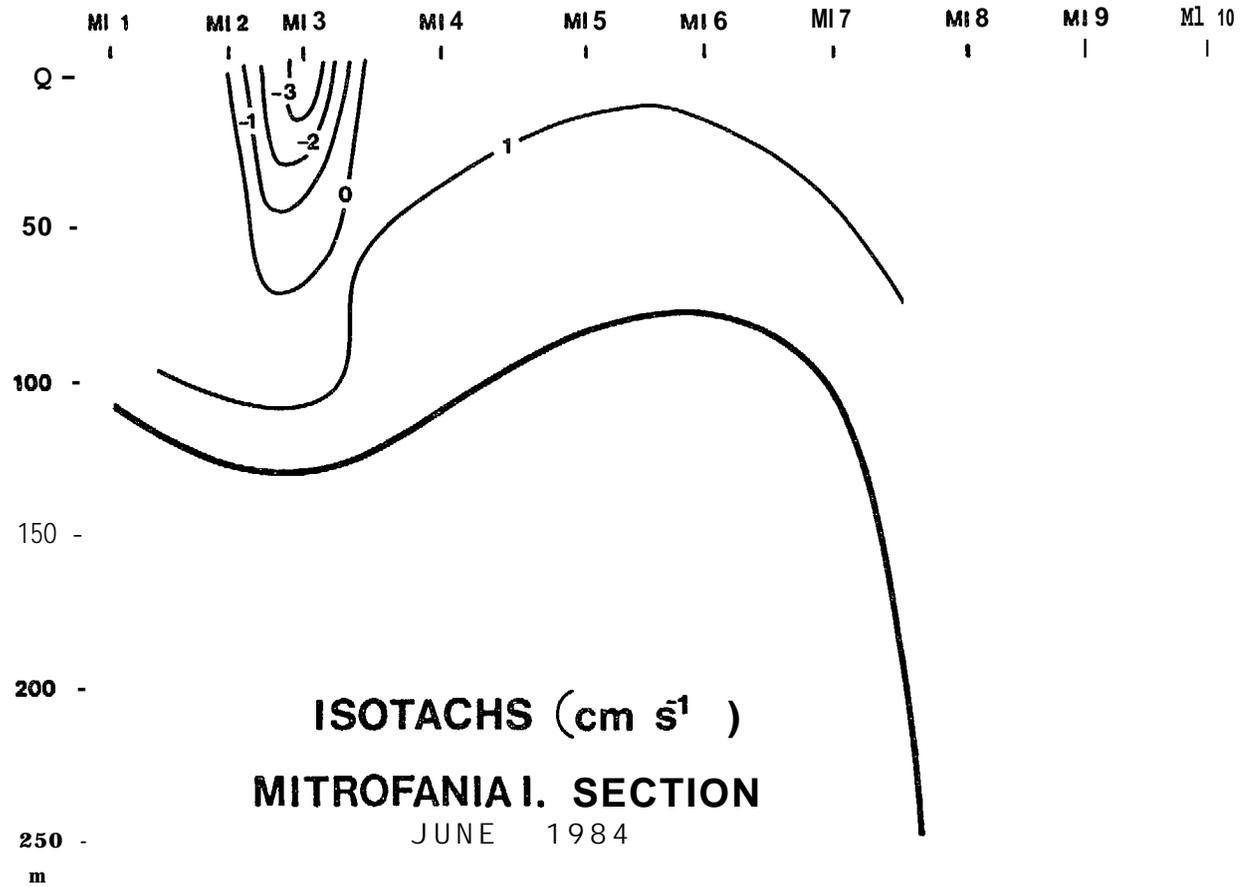


Figure 2.26 - **Isotachs, Mitrofanía** Island, June. Positive flows are out of the page; i.e., to the southwest.

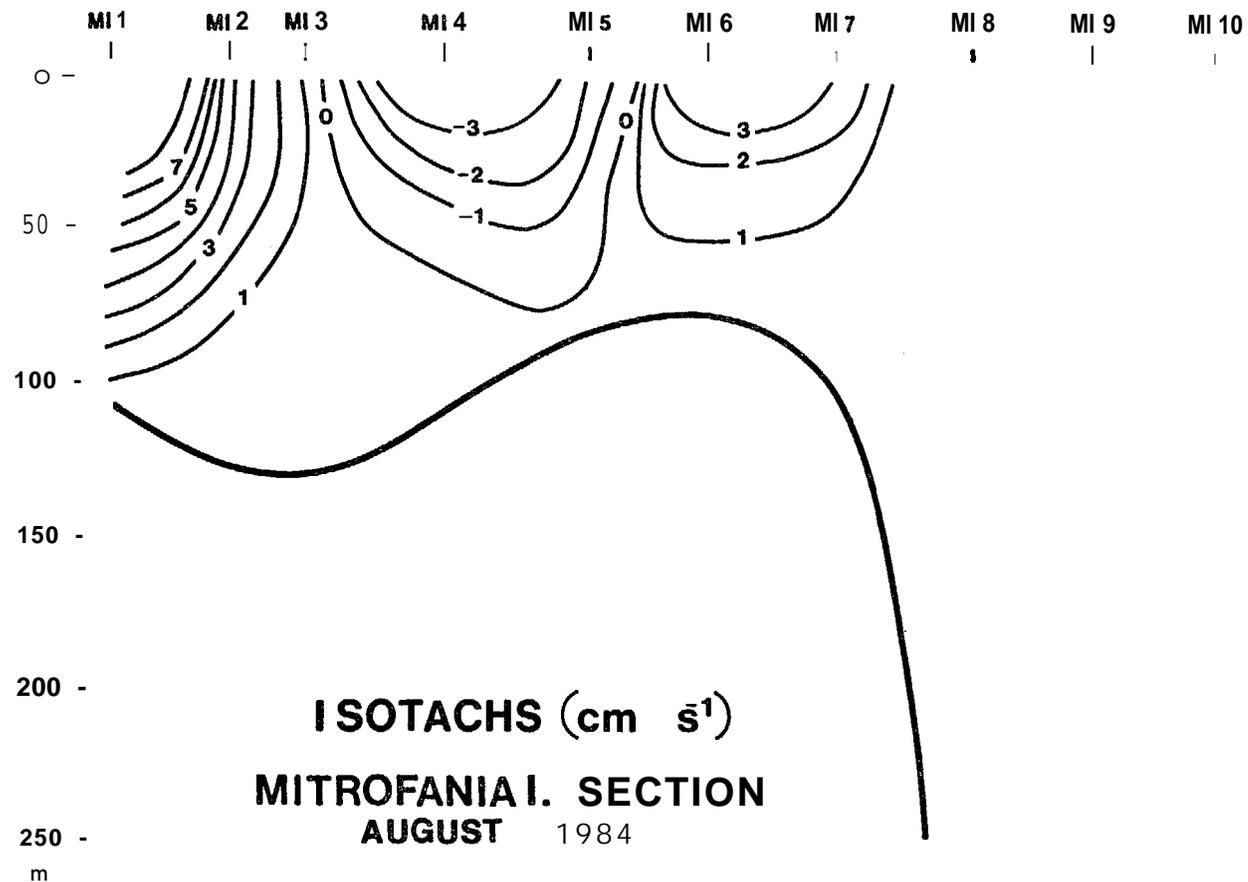


Figure 2.27 -- Isotachs, Mitrofanía Island, August. Positive flows are out of the page; i.e., to the southwest.

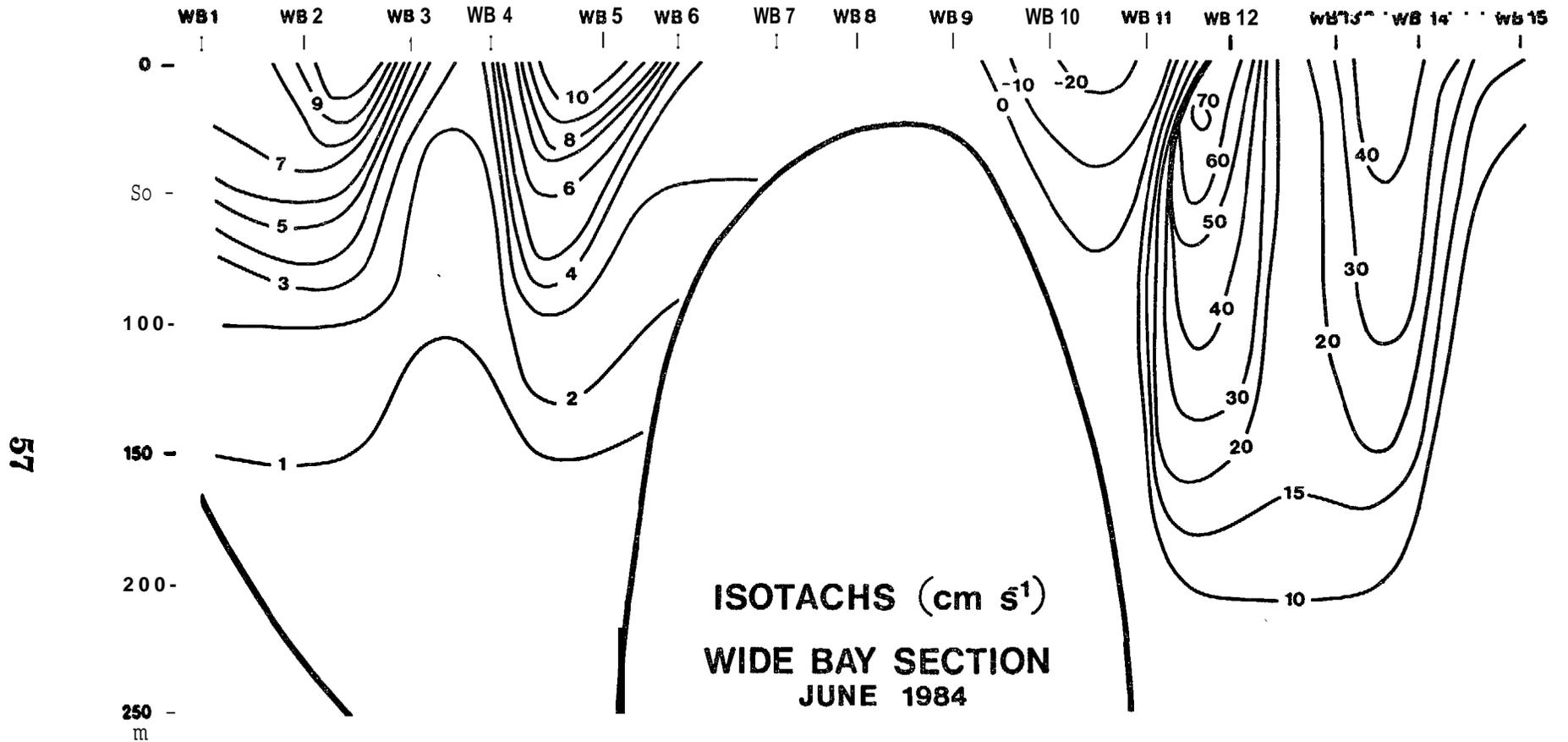


Figure 2.28 - Isotachs, Wide Bay, June. Positive flows are out of the page; i.e., to the southwest.

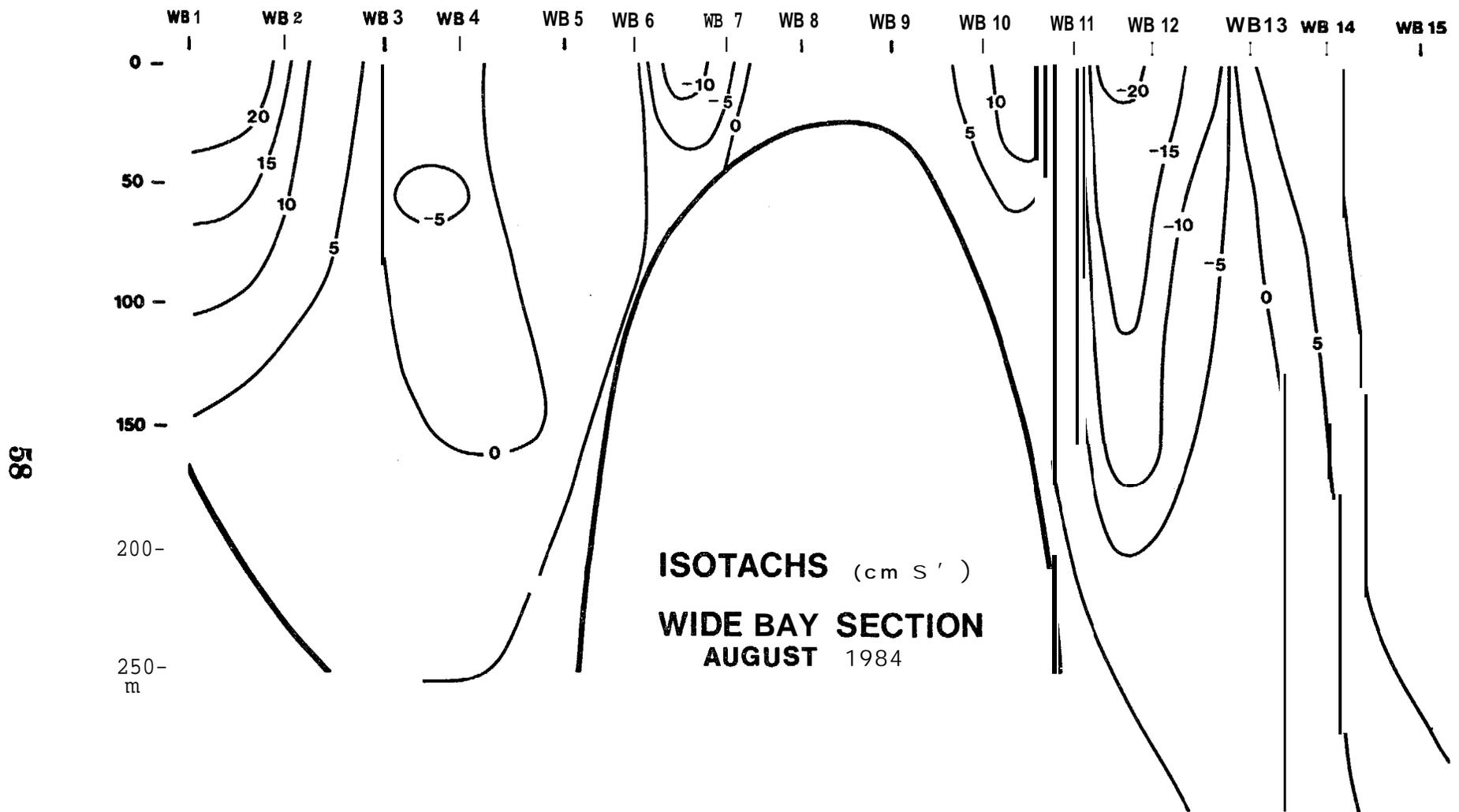


Figure 2.29 - **Isotachs**, Wide Bay, August. Positive flows are out of the page; i.e., to the southwest.

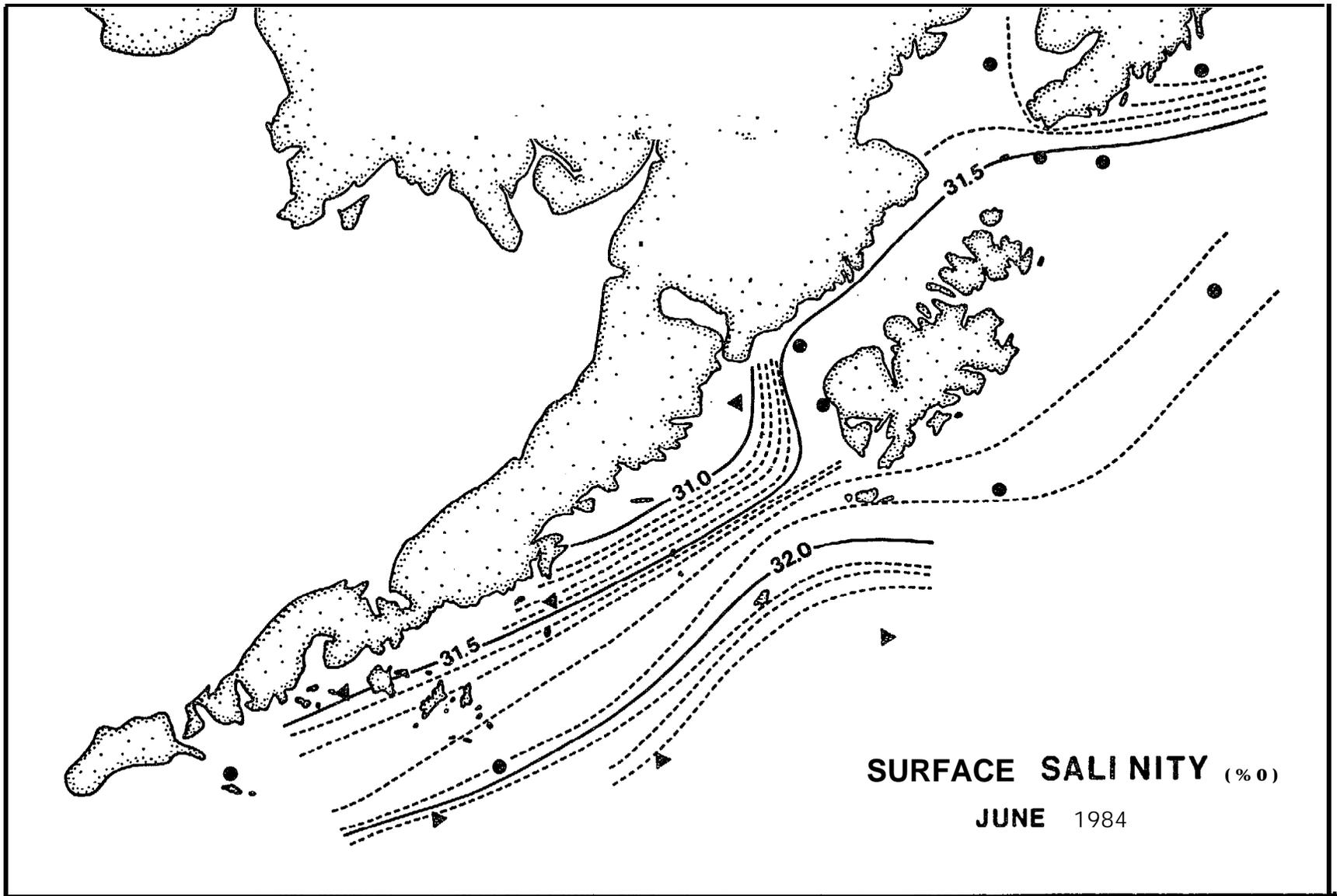


Figure 2.30 - Surface salinity, June.

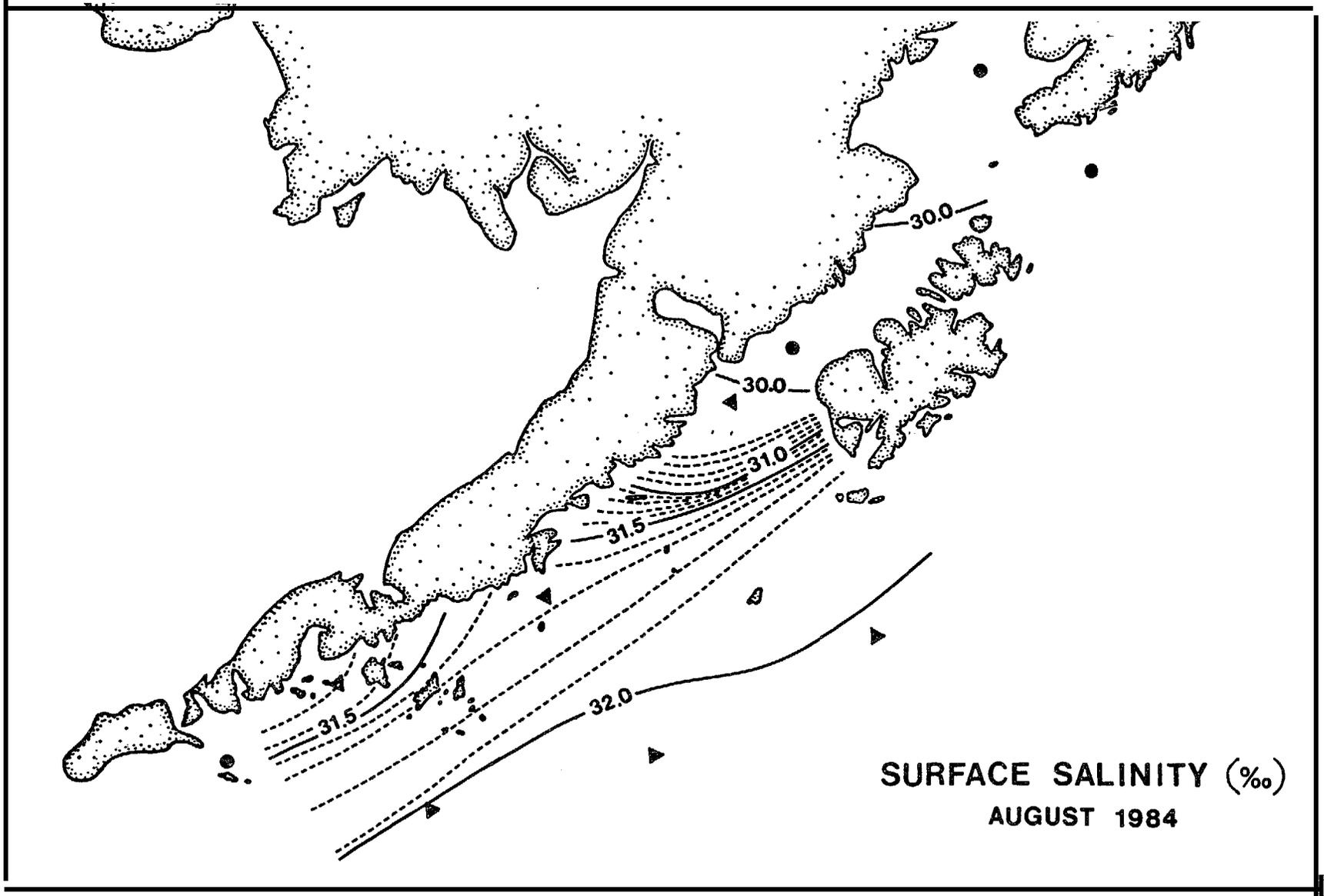


Figure 2.31 - Surface salinity, August.

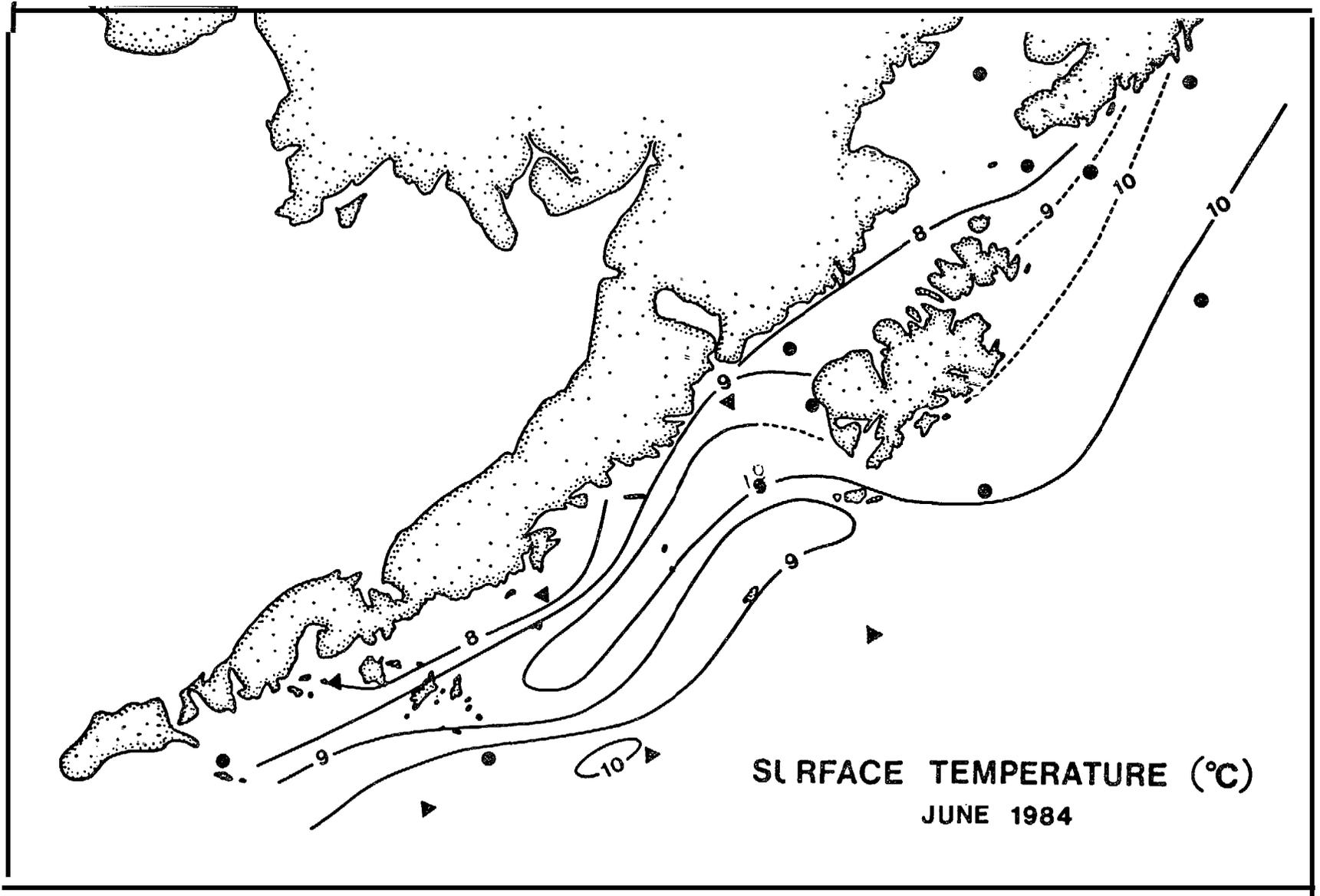


Figure 2.32 - Surface temperature, June.

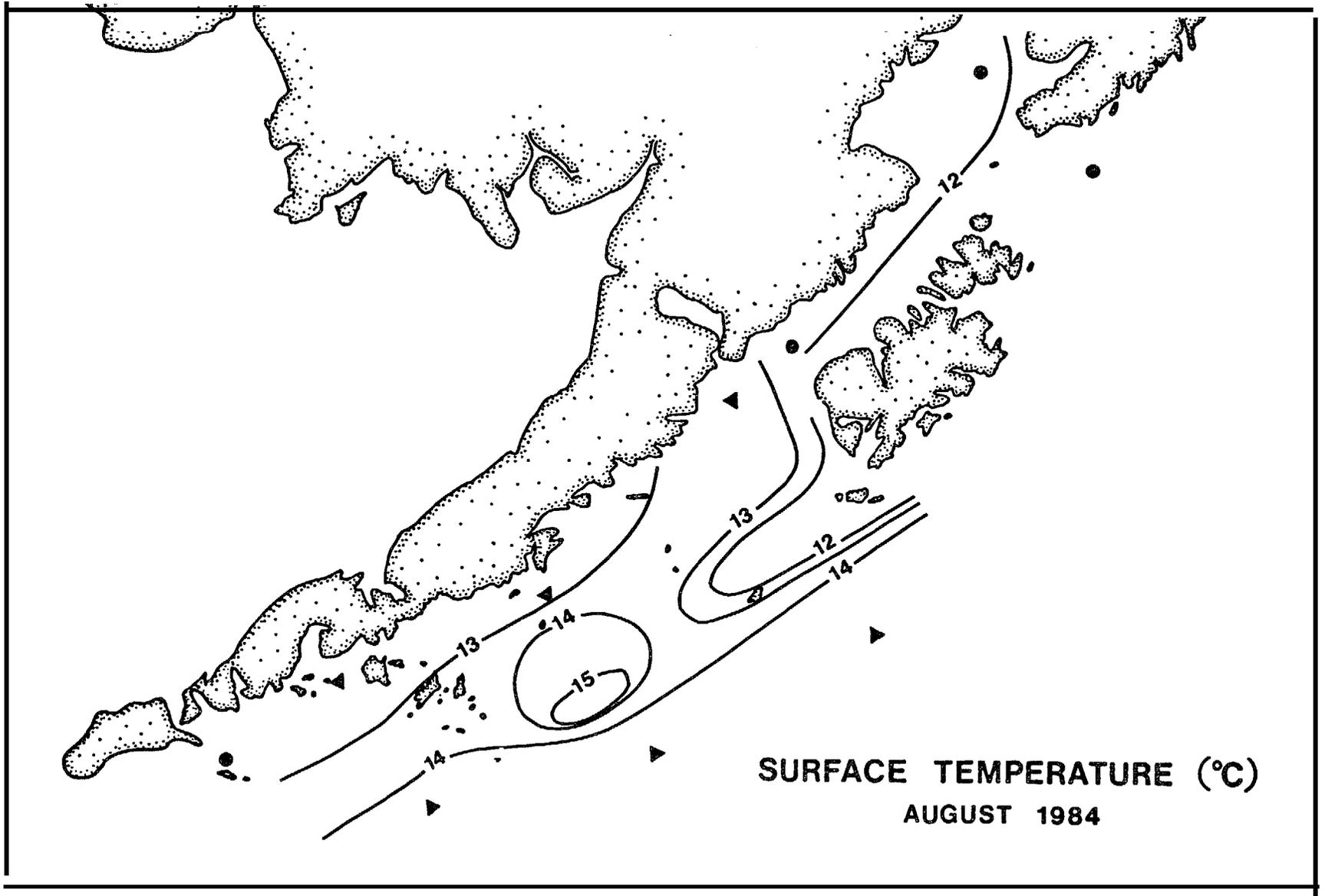


Figure 2.33 - Surface temperature, August.

### 3. TIDAL OSCILLATIONS

In this report we examine the tidal and subtidal components of the spectra of sea surface and *current* oscillations separately. The forcing function for the tides is deterministic and well understood so the tidal section of the report can be quantitative in nature. On the other hand, sub-tidal oscillations, including the mean flow may be forced or maintained through a variety of mechanisms so that several statistical procedures have been employed. These are discussed in Section 4.

#### 3.1 TIDAL HEIGHT

The tidal analyses show that the tides in the region are mixed, mainly semi-diurnal. Form numbers (the ratio of the two largest diurnal to the two largest semi-diurnal components) vary between 0.51 and 0.98. Since the relative magnitudes of the tidal constituents vary substantially among the seven tide gauge locations, it is useful to examine the total tidal oscillation as represented by the spring tidal range.

The largest tides of the year occur when the  $K_1$  component is in phase with the  $M_2$  and  $S_2$  components (usually around the solstices). A good approximation of the maximum tidal range can be computed from

$$R_{\max} = 2(M_2 + S_2 + N_2 + K_1 + O_1). \quad (3-1)$$

These ranges are listed below in Table 3.1 along with the estimated maximum ranges at Anchorage and Kodiak.

The highest tides in the region of study occur at Seal Rock, Cape **Ikolik** and **Amatuli** Island. The causes for these high ranges are likely shoaling and the reflection of substantial tidal energy from the coast with the attendant formation of partially standing tide waves. Tidal energy propagation is addressed in Section 3.2.

Table **3.1** **Maximum Tidal Ranges**

<u>Location</u>	<u>Range (m)</u>
Sanak	3.39
<b>Portlock</b> Bank	<b>4.61</b>
Seal Rock	<b>5.10</b>
Cape <b>Ikolik</b>	5.88
Shumagin	3.54
Albatross Bk.	<b>4.25</b>
<b>Amatuli</b> Is.	6.33
Anchorage (estimate)	11.3
Kodiak (estimate)	4.0

**Cotidal** charts for the four largest constituents have been plotted and are presented in Figures 3.1 through 3.4. These charts show lines of equal Greenwich phase (**cophase** lines) and equal amplitude (**corange** lines). In all cases the tide appears to propagate from northeast to southwest, but there is a suggestion (from the sparse data points) that the tidal propagation is onto the shelf west of Kodiak Island. In non-dissipative (**frictionless**) systems the **corange lines** should be normal to the **cophase** lines. **This is** roughly the case for the  $M_2$  constituent on the outer shelf. The amplitude of the  $M_2$  constituent increases toward **Cook** Inlet **indicating** either pronounced shoaling or that **some** of the **tidal** energy is reflected **in** that area. However the **Tide** Tables show a **six** hour phase lag between **Seldovia** and Anchorage indicative of a progressive wave and **little** reflection. The increase **in** amplitude in Cook Inlet is, therefore, probably due solely to the decrease in depth.

The  $S_2$ ,  $K_1$  and  $O_1$  **cotidal** charts display **cophase** and **corange** lines which are parallel - suggestive of a progressive wave **in** which **energy** is transported, eventually being dissipated by bottom friction.

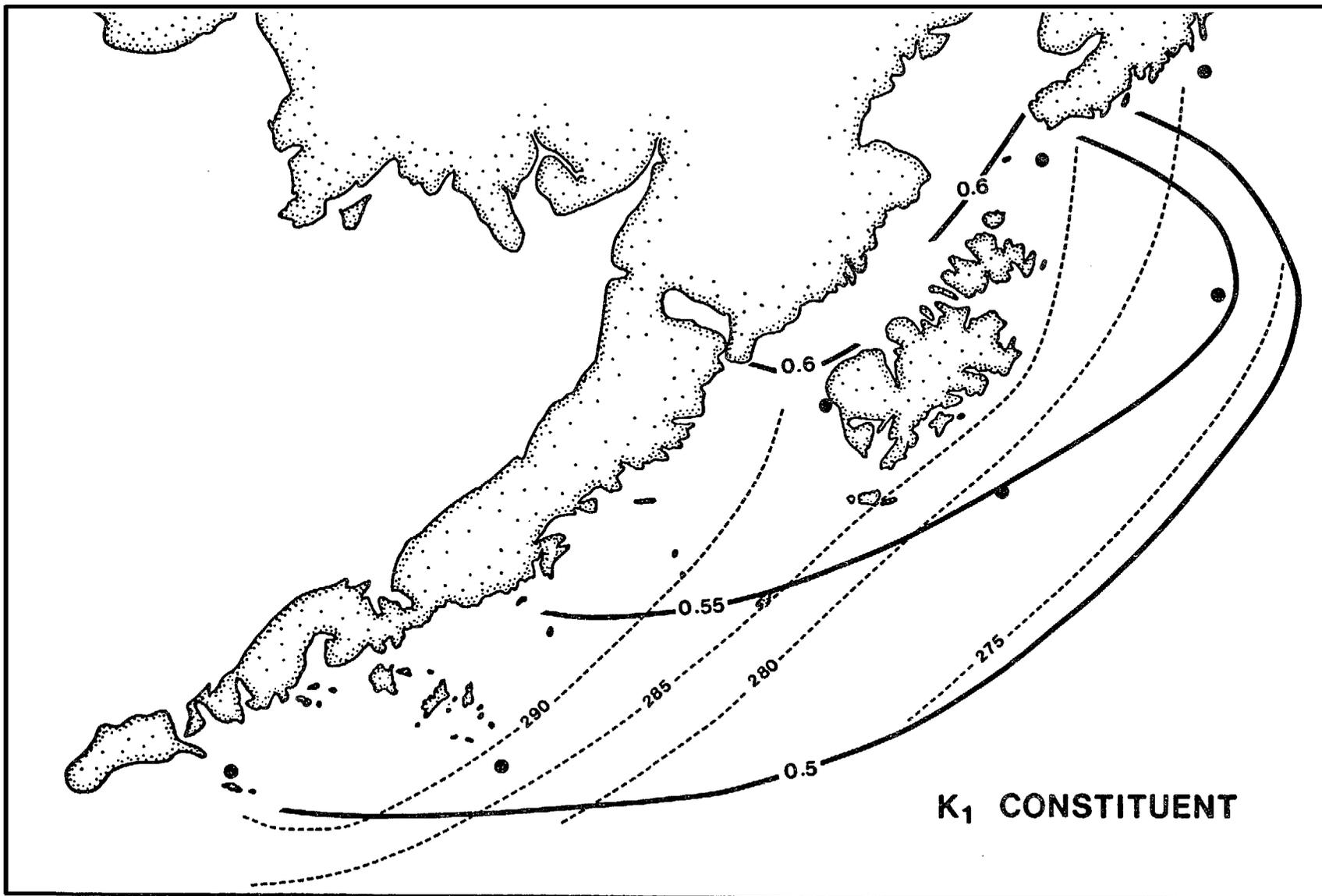


Figure 3.1 - Cotidal chart for the  $K_1$  constituent. Corange line (solid) in meters, cophase lines (dashed) in degrees relative to Greenwich.

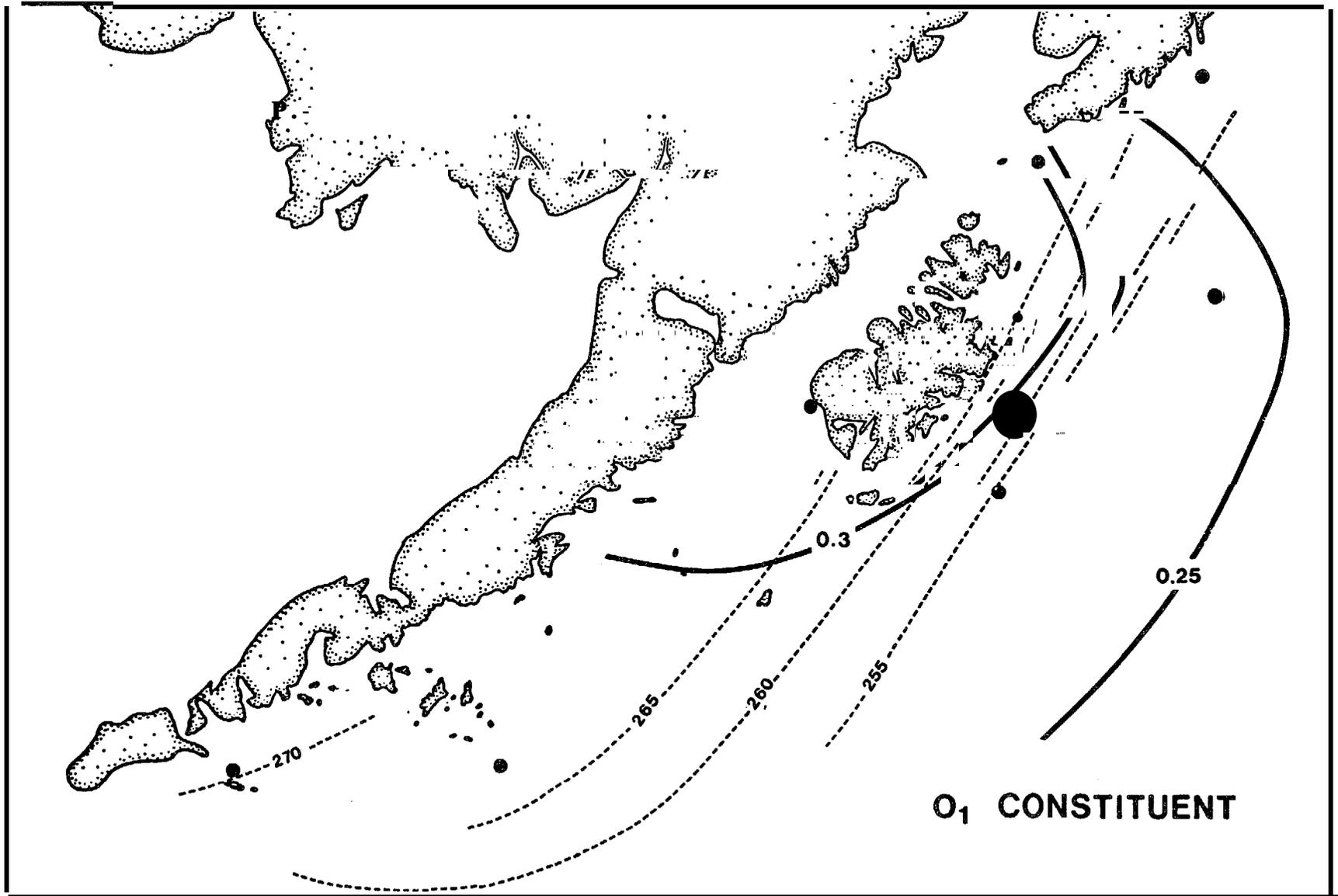


Figure 3.2 - Cotidal chart for the  $O_1$  constituent. Corangeline (solid) in meters, cophaselines (dashed) in degrees relative to Greenwich.

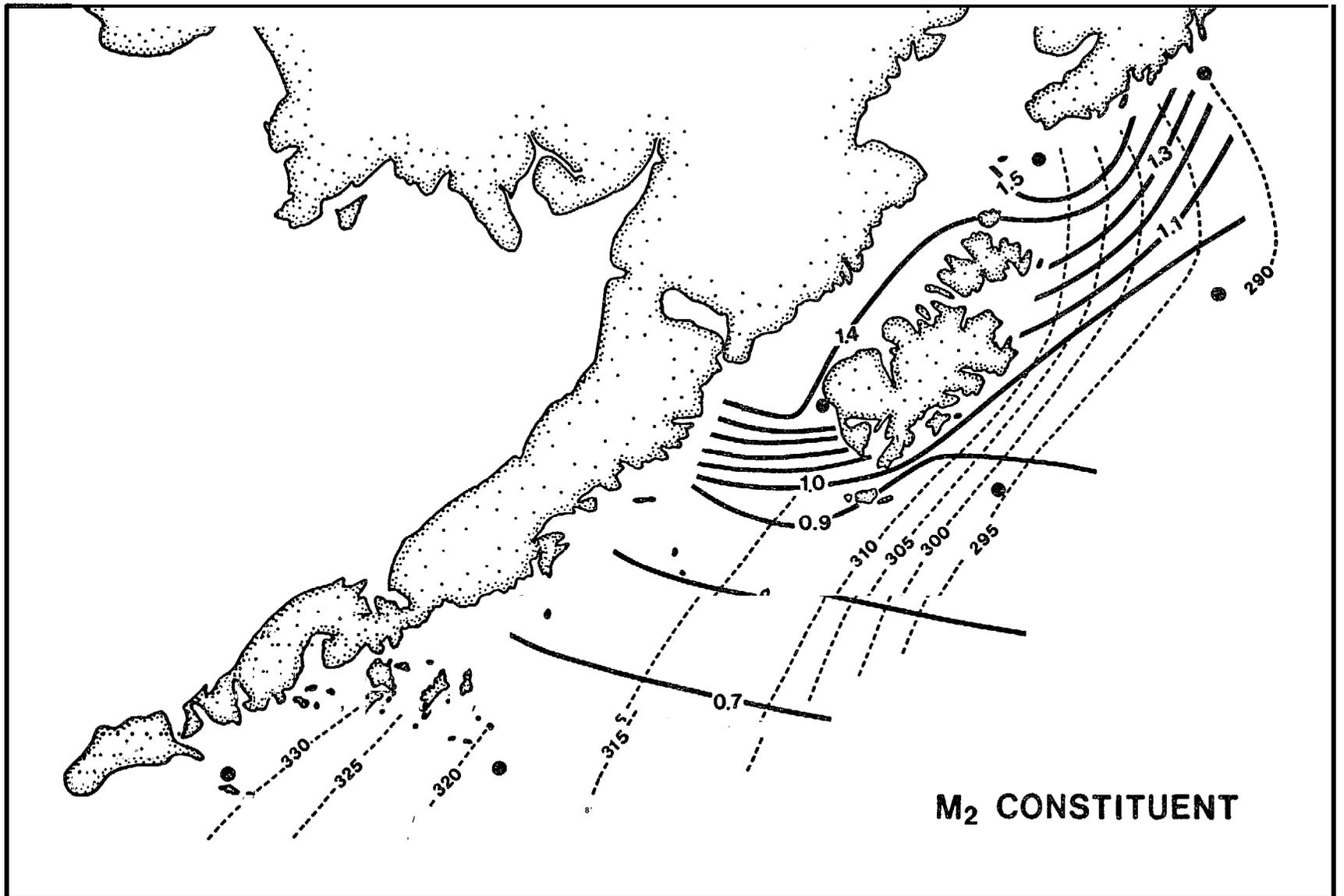


Figure 3.3 - Cotidal chart for the  $M_2$  constituent. Corange line (solid) in meters, cophase lines (dashed) in degrees relative to Greenwich.

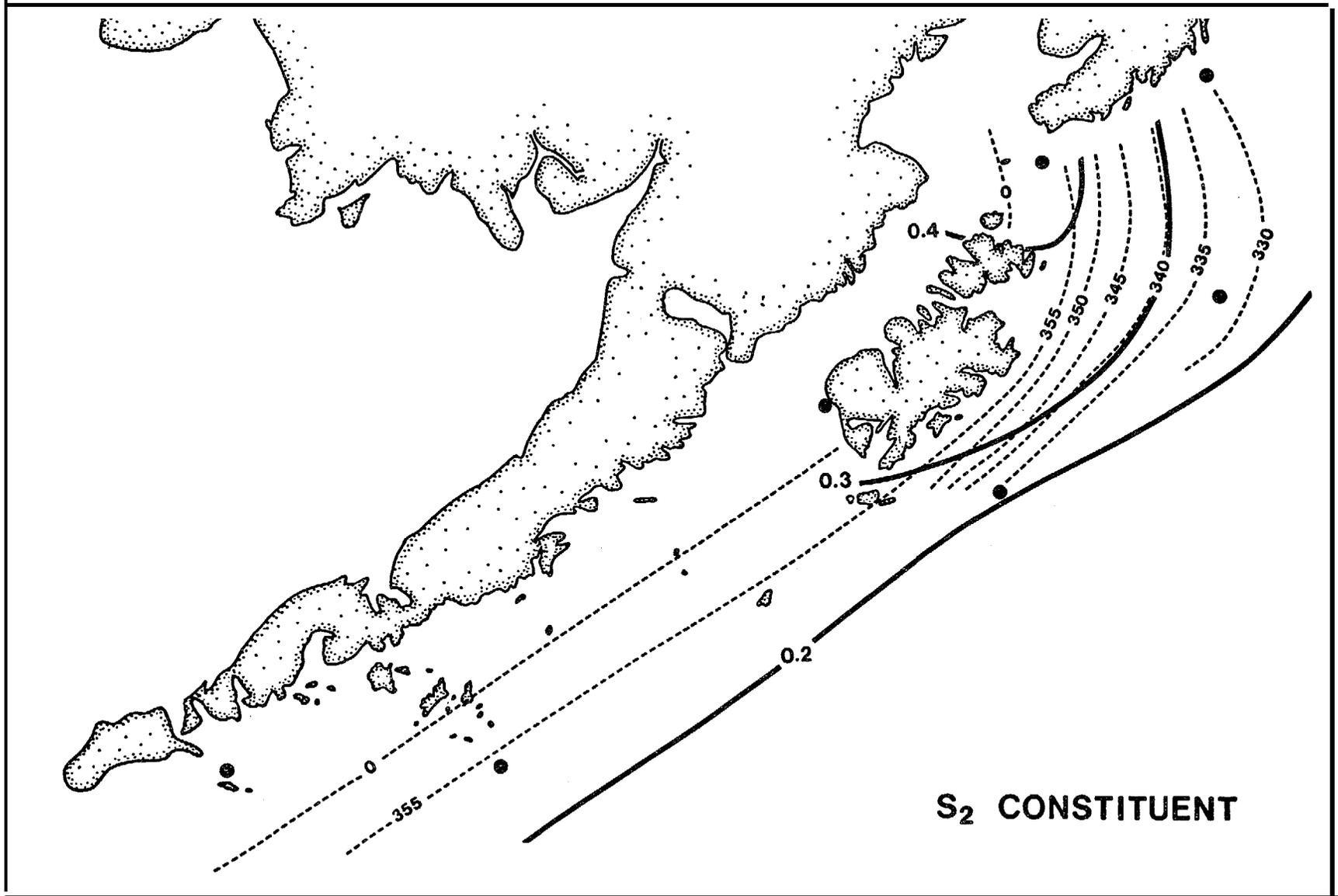


Figure 3.4 - Cotidal chart for the  $S_2$  constituent. Corange line (solid) in meters, cophase lines (dashed) in degrees relative to Greenwich.

Although the **cotidal** charts are very rough, one can gain some confidence in them **by** noting that *for* the  $M_2$ ,  $S_2$  and  $K_1$  constituents the bottom topography is quite well reflected in the speed of the waves as determined by the distance between **cophase** lines: the propagation speed is **lower** over **Portlock** Bank than **in** other areas.

### 3.2 TIDAL CURRENTS

#### 3.2.1 Tidal Energy Propagation

The power propagated per unit width of a tide wave or energy flux can be computed using the results of the tidal stream and **tidal** height analyses. The energy flux per unit width integrated over depth and over the tidal period for any constituent is

$$E = \rho gh \frac{1}{2\pi} \int_0^{2\pi} A \cos(nt) V \cos(nt + \theta) dt \quad (3-2)$$

(e.g. **Platzman, 1971**) where E is the energy flux,  $\rho$  is the density of sea water, g is gravity, h is the depth, A is the amplitude of the tidal height oscillation, V is the amplitude of the tidal current, n is the frequency of the constituent and  $\theta$  is the phase difference between the tidal height and **tidal** current. Integration of equation 3-2 yields

$$E = \frac{1}{2} \rho ghAV \cos\theta. \quad (3-3)$$

Thus when the tidal current is in phase with the tidal height (maximum current at high water) a purely progressive wave is present, there is no reflection, and **all** tidal energy is propagated in the direction of the **major** axis of the tidal ellipse. When the current is 90° out of phase with the tidal height, then the tide wave is purely standing in character, there exists complete reflection and no net energy flux.

Visual comparison of the current and pressure time series from the Cook Inlet mooring (harmonic analysis of the pressure record from the current meters **is** inadvisable due to limited resolution) **yields** a near zero phase difference implying progressive tide waves which dissipate much of their

energy on the extensive flats in Cook Inlet. **On** the other hand, the tidal height and current are about  $66^\circ$  out of phase at the **Shelikof** Strait mooring; characteristic of **little** energy propagation and a tide wave nearly standing **in** character.

The practical significance **of** these observations is that maximum currents occur roughly mid-way between low and high tide in **Shelikof** Strait but closer to low and high tide in southern Cook Inlet.

Quantitative evaluation of the energy flux by equation 3-3 is possible where tide gauges and current meters are in close proximity. The pressure sensors on the current meters *were* not of great enough precision to permit reliable tidal analyses. We have computed the tidal energy flux per meter of channel width for the four largest constituents. It should be noted that the direction of energy propagation is along the major axis of the tidal ellipse. This direction is given in the tidal stream analysis with a  $\pm 180^\circ$  ambiguity, but the current phase is computed according to the direction of the semi-major axis specified. If a negative energy **flux** resulted from the calculation for Table 3.2, then a  $180^\circ$  **correction was** applied to the direction of the semi-major ellipse axis given in the tidal analyses. The DIR column of Table 3.2 therefore shows the actual direction of tidal energy flux.

The tidal current constituents used in the computations were approximately the barotropic components of the tidal current constituents (exactly for **M<sub>2</sub>**). The **barotropic** component was computed from knowledge of the modal structure and the tidal currents at two depths (see section 3.2.2). The most confidence can be placed on the results from Sanak where the current meters and tide gauges were on the same mooring. The Cape **Ikolok** tide gauge and Shelikof Strait current meter appear to yield logical results **while** the **Amatuli** Island gauge and Stevenson Entrance meters display a peculiar phase lag.

Table 3.2 **Tidal Energy Flux**

Location	A (m)	v (m/s)	e ( <sup>o</sup> )	h (m) <b>(Approx)</b>	DIR ("True)	Power <b>(kw/m)</b>
<b>O<sub>1</sub></b>						
Sanak	<b>0.27</b>	<b>0.029</b>	- 10	<b>45</b>	091	1.8
<b>Ikolik-Shelikof</b>	<b>0.31</b>	<b>0.016</b>	50	200	046	3.2
<b>Amatuli-Stevenson</b>	<b>0*3I</b>	<b>0.036</b>	245	100	176	2.4
<b>K<sub>1</sub></b>						
<b>Sanak</b>	<b>0*50</b>	0.056	153	45	104	5.0
<b>Ikolik-Shelikof</b>	0.59	0.032	54	200	045	11.4
<b>Amatuli-Stevenson</b>	<b>0.58</b>	0.065	249	100	<b>166</b>	7.0
<b>M<sub>2</sub></b>						
Sanak	<b>0.63</b>	.034	36	45	<b>349</b>	4.0
<b>Ikolik-Shelikof</b>	1.39	.145	68	200	<b>048</b>	77.3
<b>Amatuli-Stevenson</b>	1.55	,287	241	100	<b>173</b>	111.6
<b>S<sub>2</sub></b>						
Sanak	<b>0.16</b>	.011	64	<b>45</b>	<b>37</b>	0.2
<b>Ikolik-Shelikof</b>	1.39	.044	65	200	<b>46</b>	7.2
Ametuli-Stevenson	0042	.101	239	100	<b>179</b>	11.3

Tidal energy propagation for all the constituents appears to be north-eastward into **Shelikof** Strait. The mean phase lag between the tidal heights and currents at the southwestern end of **Shelikof** Strait is about 60 degrees which implies that about half the tidal energy **is** reflected.

At **Sanak**, tidal *energy is* propagated to the north and east (between 349° and 104° true). The diurnal constituents propagate nearly eastward while the **semi-diurnal** constituents nearly northward. There appears **to be no** consistency among constituents regarding the standing/progressive nature of the tide waves.

At Stevenson Entrance **all** four tidal constituents appear to propagate energy to the south. The current meters at this site exhibit comparable Greenwich phases and the phase difference between heights and currents is nearly constant. An error **in** timing is therefore very unlikely. Also unlikely is the presence of an amphidrome on **Portlock** Bank for all the tidal constituents. The phase differences between the **Amatuli** gauge and the Cook Inlet current meters are less than 10° for the **semi-diurnal** constituents thus consistent with the notion of a progressive wave in southern Cook **Inlet** and substantial tidal energy dissipation over the shallows there (independent confirmation of our current measurements in Cook Inlet exist **in** the report of **Patchen** et al, (1981)). At this writing we are unable to explain the apparent anomalous southward propagation of tidal energy in Stevenson Entrance.

The magnitude of the tidal energy flux in the vicinity of Kodiak Island is about **90** kilowatts per meter of channel width. Using 25 km as an appropriate width for **Shelikof** Strait, this amounts to about  $2.25 \times 10^9$  **watts**, about 0.1% of the tidal energy in the world ocean (**LeBlond** and **Mysak**, 1978). The data appear to indicate that the tidal energy flux is northeastward into **Shelikof** Strait. Presumably much of this energy is dissipated in Cook Inlet but the apparent southward energy flux at Stevenson Entrance is **still** puzzling.

### 3.2.2 Internal Tides

Internal tides may be generated on the continental slope and can account for substantial phase differences between near surface and deep flows. In addition to the velocity signature of such oscillations, there exist concomitant vertical oscillations of the density surfaces. Unlike the surface or barotropic tides, the internal tides are characterized by velocity and displacement fields which are functions of depth.

The vertical velocity can be represented as:

$$w = W(z) \exp [i(kx - nt)] \quad (3-4)$$

where  $w$  is the vertical velocity,  $W(z)$  is the depth varying amplitude of the velocity fluctuation,  $k$  is a horizontal wave number vector and  $n$  is the angular frequency of the wave. The vertical mode structure can be found from the linearized internal wave equation:

$$\frac{\partial^2}{\partial t^2} (\nabla^2 w) + N^2(z) \nabla_h^2 w + f^2 \frac{\partial^2 w}{\partial z^2} = 0 \quad (3-5)$$

where  $N(z)$  is the Vaisala frequency =  $\sqrt{-\frac{g}{\rho} \frac{\partial \rho}{\partial z}}$ , and  $f$  is the Coriolis

parameter. Substitution of eq 3-4 into eq 3-5 yields

$$\frac{d^2 W}{dz^2} + \left[ \frac{N^2(z) - f^2}{n^2 - f^2} \right] k^2 W = 0 \quad (3-6)$$

(Further details of internal wave dynamics can be found in Phillips, 1966.) Solution of eq. 3-6 can be performed numerically if the distribution of density with depth is known. Such solutions yield a vertical structure of vertical velocities. The  $Z$  derivative of the vertical velocity is proportional to the horizontal velocity so that a normalized distribution of horizontal velocity amplitude as a function of depth can be computed.

Mode structures were computed from the June and *August* CTD data taken at the current meter moorings.

The **structures of the first** modes for vertical displacements and horizontal velocities for **the M<sub>2</sub>** constituent are **shown** in Figure **3.5** **along with the** density structure in Cook Inlet in **August**. Note that the maximum horizontal velocity associated with internal tides occurs at the surface and that zero horizontal velocity occurs at a depth of 25 meters where the vertical excursion of the **isopycnals** and the vertical velocity are the greatest.

The modal structures for the horizontal velocities yield relative magnitudes of the internal oscillation at various depths. For example, at the Cook Inlet mooring in **August** the amplitudes of the internal velocity oscillations at the two current meters are in the ratio of -0.27/-0.36. The amplitudes of the first internal (**baroclinic**) and surface (**barotropic**) tidal oscillations can be computed from this mode structures and the tidal stream analyses of *two* current time series.

For a given tidal **frequency**,  $n$ , the combined amplitude and phase of the oscillations at the current meters is obtained from the tidal stream analyses. If only the oscillations along the major axes of the tidal ellipses are considered then **the** oscillations may be represented by

$$v_i = A_i \cos (nt - G_i) \quad (3-7)$$

where  $i = 1, 2$  for shallow, "deep,  $v_i$  are **the** total tidal velocities,  $A_i$  are the amplitudes **of** these velocities and  $G_i$  are the Greenwich phases. If  $m_i$  are the normalized amplitudes of the velocity fluctuations then the amplitudes and phases of the **baroclinic** and **barotropic** oscillations can be computed. These are:

$$BT = \frac{m_1 A_2 \sin \phi}{(m_1 - m_2) \sin \phi} \quad (\text{barotropic amplitude}) \quad (3-8)$$

# COOK INLET DENSITY and MODE STRUCTURE

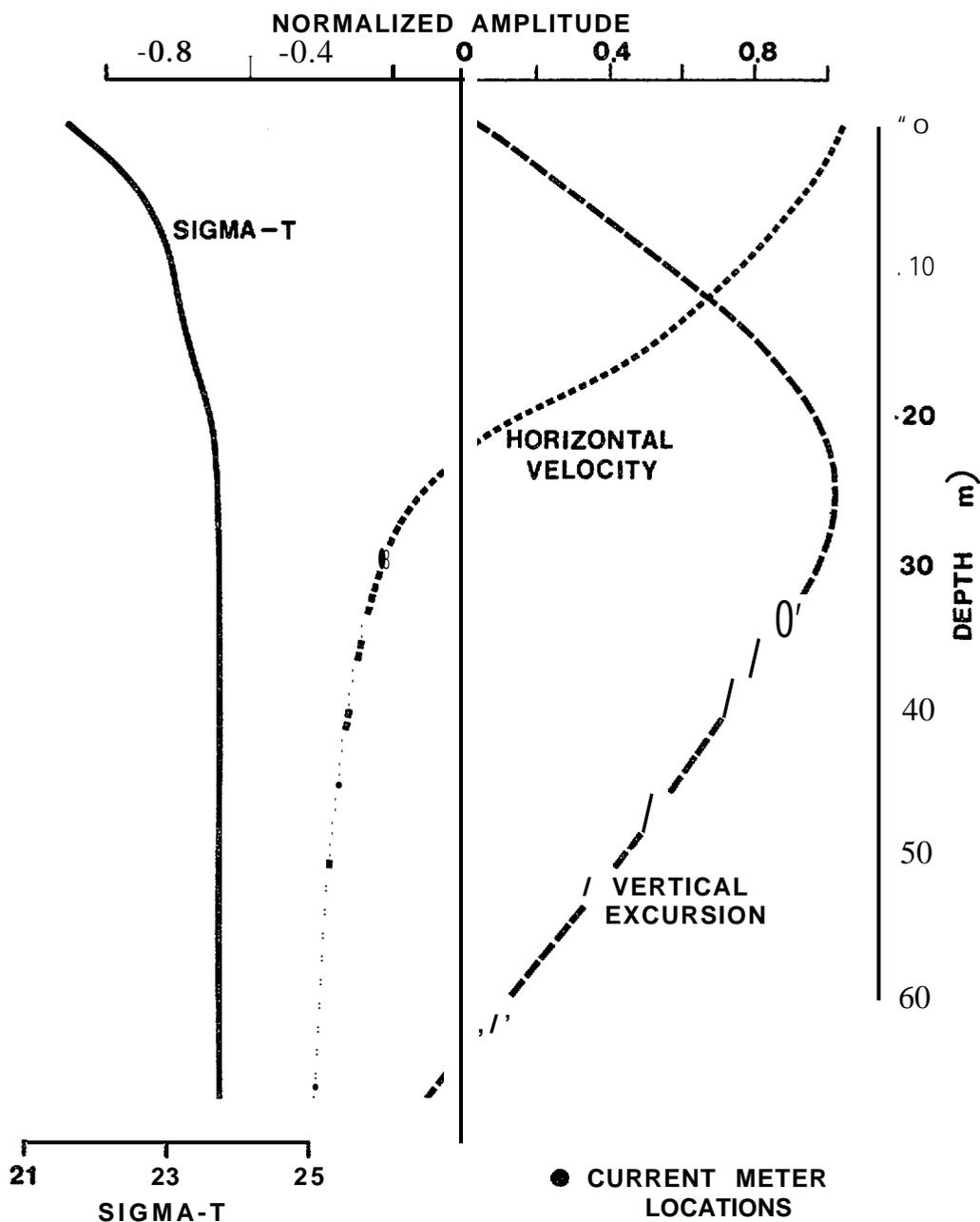


Figure 3.5 - Lowest internal mode structure for the  $M_2$  constituent in Cook Inlet.

$$\tan \alpha = \frac{m_1 A_2 \sin \varphi}{m_1 A_2 \cos \varphi - m_2 A_1} \quad (\text{barotropic phase}) \quad (3-9)$$

$$BC = \frac{A_2 \sin \varphi}{(m_2 - m_1) \sin \beta} \quad (\text{baroclinic amplitude}) \quad (3-10)$$

$$\tan \beta = \frac{A_2 \sin \varphi}{A_2 \cos \varphi - A_1} \quad (\text{baroclinic phase}) \quad (3-11)$$

where  $\varphi = G_1 - G_2$  and  $\alpha$  and  $\beta$  are phases relative to  $G_1$ .

Where possible we used the average stratification (June and August) at the mooring sites to compute the mode structures. These often varied considerably due to the vertical oscillation of the **isopycnals**. Ideally the density data from which the modes were computed would have been measured over a tidal cycle and averaged. Recognizing the limitations of our density profile data we computed the **baroclinic** and **barotropic** modes for the largest (M2) tidal constituent to obtain an estimate of the internal oscillations, these are listed in Table 3.3.

By far the largest internal tides appear to occur at the Cook Inlet mooring. Indeed examination of the temperature and salinity time series from the meter at 35 m depth in Cook Inlet shows temperature and salinity oscillations of about **0.4°** and 0.4‰, respectively. Using the temperature and salinity gradients measured in June and August we can estimate the height of the internal tide

$$H \approx \frac{\Delta T}{\partial T / \partial z} \approx \frac{\Delta S}{\partial S / \partial z} \quad (3-12)$$

where H is the height of the internal tide and  $\Delta T$  and  $\Delta S$  are the tidal excursions of the temperature and salinity values (assuming negligible horizontal gradients). Equation 3-12 yields values of about 30 meters for the vertical excursion of a water parcel at a mean depth of 35 m in Cook Inlet. Such a vertical excursion would produce a horizontal velocity which can be approximated by:

**Table 3.3 Barotropic and Baroclinic Velocities For The  $M_2$  Tidal Constituent (Amplitudes in cm/s)**

Cook Inlet

$$BT = 96.2 \cos (nt - 2.8^\circ - G_1)$$

$$BC = -58.6 \cos (nt - 12.8^\circ - G_1)$$

Shelikof Strait

$$BT = 14.5 \cos (nt + 1.7^\circ - G_1)$$

$$BC = -1.3 \cos (nt + 30.9^\circ - G_1)$$

Stevenson

$$BT = 28.7 \cos (nt - 3.5^\circ - G_1)$$

$$BC = 17.4 \cos (nt - 47.6^\circ - G_1)$$

Sanak

$$BT = 3.4 \cos (nt - 3.5^\circ - G_1)$$

$$BC = -1.6 \cos (nt - 67.2^\circ - G_1)$$

$$V(\text{internal}) = \left(\frac{g}{h}\right)^{1/2} \left(\frac{\Delta\rho}{\rho}\right)^{1/2} \eta \quad (3-13)$$

where  $\rho$  is the density,  $g$  gravity,  $\eta$  the amplitude of the internal wave and  $h$  the depth over which  $\Delta\rho$  is computed. Eq. 3-13 yields a value of about  $35 \text{ cm s}^{-1}$  for the fluid velocity associated with internal waves of tidal period in Cook Inlet. This is in qualitative agreement with the amplitude presented in Table 3.3; surprisingly so. Clearly an internal wave of 30 m height in 65 m water depth is no longer a small amplitude wave and many of the assumptions of the theory are inadequate,

Our conclusion here is that substantial internal wave energy of tidal period is present in Cook Inlet. Without tidally averaged CTD data, we cannot confidently ascribe precise amplitudes to these oscillations; however, our observations as well as our computations show that internal tides are present in Cook Inlet. It is therefore unlikely that a purely barotropic tidal model will adequately represent this region.

## 4. SUBTIDAL OSCILLATIONS

In this section the energy associated with subtidal oscillations is discussed and an attempt made to relate it to atmospheric driving forces. The region is, of course, dominated by tidal oscillations, the tidal kinetic energy accounting for between 50% and 95% of the **total** kinetic energy. The spectral distribution of energy is shown for the longshore velocity component in **Shelikof** Strait in Figure 4.1. In Cook **Inlet**, for **example**, the mean flows are about  $5 \text{ cm s}^{-1}$  while the tidal flows exceed  $80 \text{ cm s}^{-1}$ . For the purposes of this section the tidal oscillations can be considered "noise" and thus for the subtidal oscillations the signal to noise ratio is generally poor. For example any effect due to sea breezes of diurnal period would be completely masked by the tidal flows.

### 4.1 MEAN FLOWS

The mean velocities recorded over the two month deployment period are shown in Table 4.1. At Stevenson Entrance a weak mean flow to the southeast at depth and south southwest at mid-depth may be due to outflow from the Cook **Inlet area**. The vertical shear of the **alongshore** velocity is in the same sense as that measured in **Shelikof** Strait **however**, so that the Stevenson Entrance regime could be considered to be linked to **Shelikof** Strait. It **should** be noted that mean westerly **flow** in Stevenson Entrance is suggested in the dynamic topographies of Favorite and **Ingraham** (1977). In Cook Inlet the mean flow is east northeast at both depths, differing in direction by about  $45^\circ$  from the orientation of the Inlet. It is probable that the recorded mean flows in Cook Inlet are due largely to rectification of strong tidal flows. Such rectification is indicated in the presence of "shallow water" tidal constituents of substantial size. The **MK3** and M4 components (**terdiurnal** and quarter-diurnal respectively) are both of comparable magnitude to the mean flow. The presence of these "difference frequencies" indicates that non-linear effects also produce "**sum** frequencies". For example the M4 constituent (lunar quarter-diurnal) is a

# AUTOSPECTRUM LONGSHORE VELOCITY COMPONENT, SHELIKOF STRAIT

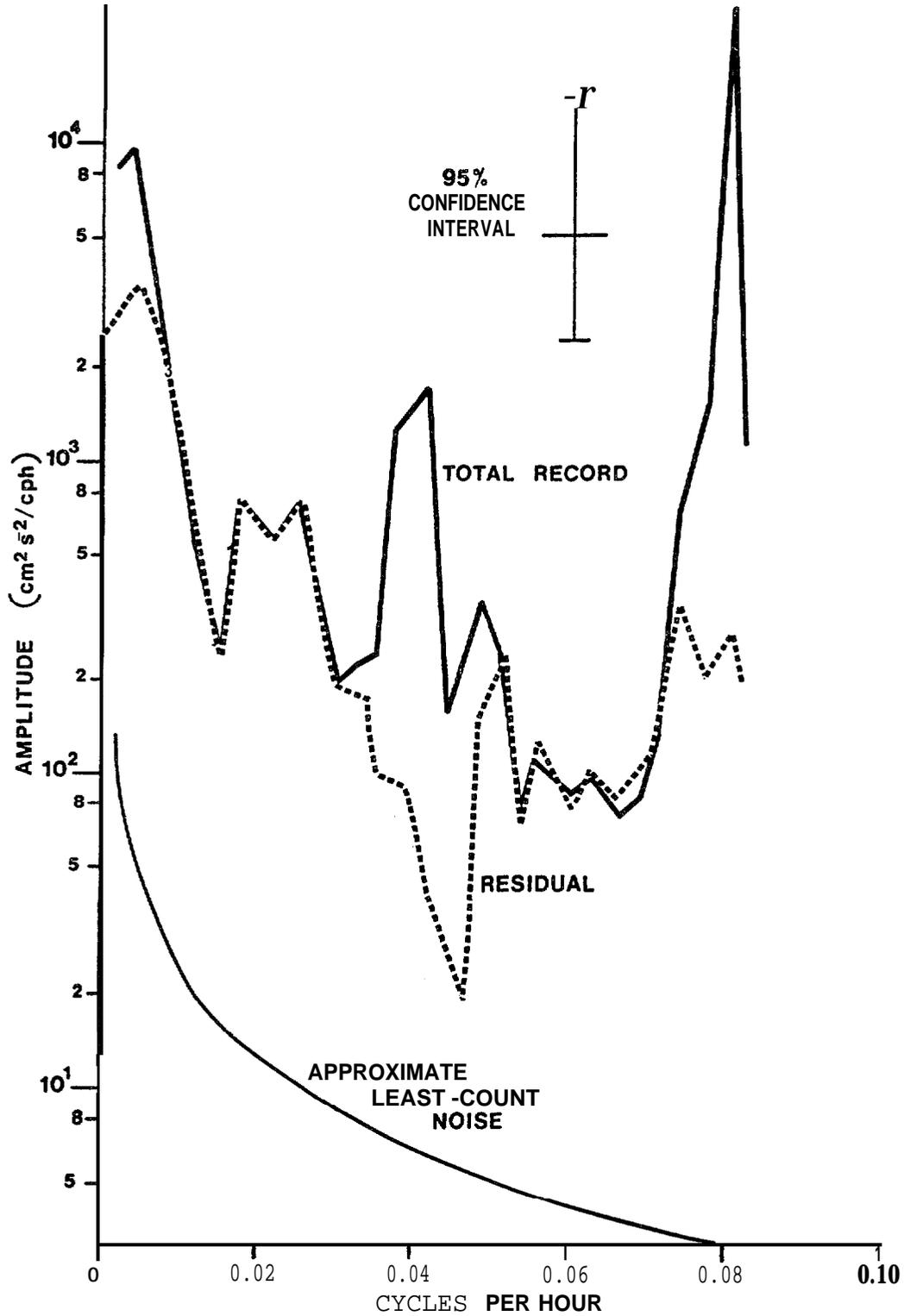


Figure 4.1 - Autospectrum alongshore (225° T) component, 46 m depth in Shelikof Strait.

Table 4.1 Mean Velocities at the **Eight** Current **Meters**

Location	Instrument Depth (m)	Water Depth (m)	Speed (cm s <sup>-1</sup> )	Direction • True
Stevenson	54	<b>113</b>	201	212
Entrance	82		<b>2.6</b>	135
Cook	<b>35</b>	<b>66</b>	<b>4.3</b>	<b>078</b>
<b>Inlet</b>	<b>52</b>		<b>5.6</b>	<b>064</b>
Sanak	20	50	<b>2.3</b>	254
Island	41		3.1	299
<b>Shelikof</b>	46	250	<b>3.8</b>	210
Strait	157		1.3	037

**manifestation of the shoaling of the  $M_2$  constituent.** Also associated with the **generation** of the  $M_4$  constituent **is** the generation of a DC (mean flow component). The process is perhaps best **envisaged** as the beating of two **tidal** constituents. The beat frequencies are the sum and difference of the two frequencies. In the **limit** as the two constituents approach an identical frequency, oscillations of twice the fundamental frequency and zero frequency are produced.

At **Sanak**, where the tidal amplitudes are much smaller, the shallow water **tidal** constituents are of negligible **size** and the **mean** flows at both 20 and 41 **meters depth** are directed roughly toward the west. This mean flow is **generally reflective** of the flow of the coastal current.

In **Shelikof Strait** moderate tidal currents and deep water **combine to minimize non-linear** tidal effects. The shallow water constituents are small and the mean flows are representative of quasi-steady processes. At the shallow meter the **flow** is toward the southwest, while at the lower meter it is toward the northeast. Such a velocity distribution is characteristic of an estuarine flow in which the fresher lighter waters move seaward compensated by a slower, but vertically more extensive return flow\* Schumacher et al, (1978) suggested that the **inflow** of deep water into **Shelikof Strait** occurs to balance the loss of deep water entrained by the outflowing surface waters. Further observations **will** be necessary to **fully describe the estuarine-like flow in Shelikof Strait.**

#### **4.2 LOW FREQUENCY FLOWS**

The region within about 20 km of the southern Alaska Coast **is** dominated by the Alaska Coastal Current according to Royer (1981). Maximum speeds can be over  $60 \text{ cm s}^{-1}$  and transports can exceed  $1 \times 10^6 \text{ m}^3 \text{ s}^{-1}$ . Royer attributed the variations in the current to variations in freshwater discharge and found wind stress to be a very minor influence. The annual cycle of increasing stratification in **early** fall and decreasing stratification in late winter changes the magnitude of the internal Rossby

radius. Royer mentioned this variation but did not seem to link it with the width of the current itself. In fact, as the stratification increases, the coastal current will become wider.

The Shelikof Strait current meter mooring of the present study was located approximately 14 km offshore of the Alaska Peninsula. The **internal Rossby radius in Shelikof Strait during** the deployment was between 3.5 km in June and 6.5 km in August. Data from Xiong and Royer (1984) indicate that the maximum internal Rossby radius that might be encountered in Shelikof Strait is about 16 km and would occur in fall at the peak of the freshwater discharge. If the intensity of the flow is proportional to

$$\exp(-y/r_1) \quad (4-1)$$

where  $y$  is the offshore distance then the strength of the current from its centerline to the mooring would be reduced by a factor between 10 and 50. It is, therefore, unlikely that flow or **flow** variations associated with the Alaska Coastal Current would have been measured at the Shelikof Strait mooring or at any of the others deployed during this study.

In order to test the above hypothesis, we employed data for the daily discharges of the Knik and Susitna Rivers (kindly supplied by Professor Royer) to represent the freshwater discharge along this section of the coast. The combined discharge of these rivers peaks in July-August at about 1000 m<sup>3</sup> s<sup>-1</sup>. The daily mean discharges of these rivers and the alongshore velocity component at 46 m depth in Shelikof Strait are plotted in Figure 4.2. There is no apparent correlation between the discharge and the current; certainly the reversals of the current are not reflected in discharge. The possibility, of course, exists that the currents are driven by freshwater discharge far "upstream", for example, along the coast of southeast Alaska. However, the lengths of the present current records do not permit comparison over the monthly time scales which would be required to investigate such a driving mechanism.

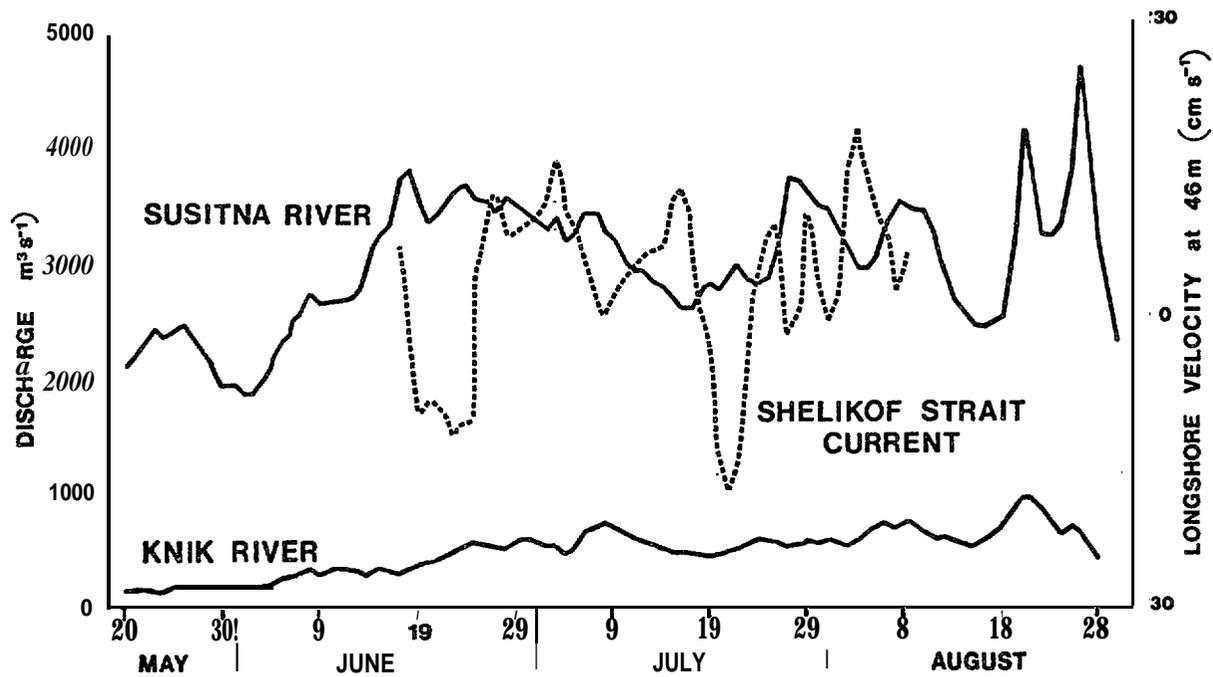


Figure 4.2 - Daily discharge of the Knik and Susitna Rivers (solid lines) and the mean daily alongshore component of flow at 46 m depth in Shelikof Strait (broken line) .

The well defined variations in the flow through **Shelikof** Strait are apparent in either the time series data (Appendix 2) or the tidal analyses (Appendix 1). Energy at the MM (lunar monthly) and MSF (**luni-solar fortnightly**) is relatively high and not reflective of the ratios of the astronomical forcing functions at these frequencies to that at the **M2** frequency (9% and less than 1% of **M2** respectively). Presence of energy at these frequencies **more** properly **indicates** long **period** oscillations.

In that there appeared to be no correlation between the **Shelikof Strait** currents and freshwater discharge, we investigated possible atmospheric driving of the currents.

Figure 4.1 shows the **autospectra** of the **alongshore** (225° T) velocity component for the raw **time** series and for the **time series with the tidal oscillations** removed (residual). The principal **tidal** frequencies are in the **region** of 0.04 and 0.08 cycles per hour. The curve at the bottom of the figure represents the noise level due to the resolution limitations of the current meter. The 95% confidence interval is shown. For the spectrum of the residual currents there is significant energy near 0.02 cph (50 hours) as well as at the very low end of the spectrum (periods of about 15 to 20 days).

For the **lowest** frequencies we cannot precede with a meaningful cross-spectral analyses since only three or four realizations of oscillations of these periods occur in our two month records. We have, however visually compared the velocity time series with time series based upon the sea surface atmospheric pressure data obtained from the Naval **Fleet** Numerical Oceanography Center at Monterey.

Using the six hourly pressure grid (grid spacing approximately 300 km) we computed geostrophic winds. These winds were then decomposed into **alongshore** and offshore components. In addition, we computed surface wind stress by 1) rotating the **geostrophic** velocity vector 20° counter-clockwise to account for Ekman turning; 2) taking 70% of the **geostrophic** velocity to simulate the frictional dissipation in the boundary layer; 3) squaring the wind speed and 4) applying a **drag** coefficient of  $1.2 \times 10^{-3}$ . These procedures can be expressed as:

$$\vec{\tau} = \bar{\tau} \exp(i\gamma) = \rho a C_D (0.7W)^2 \exp[i(\delta + 20^\circ)] \quad (4-2)$$

where  $\vec{\tau}$  is the surface wind stress vector,  $\rho$  is the density of air,  $C_D$  the drag coefficient,  $W$  the geostrophic wind speed  $\delta$  the direction of the geostrophic wind vector anti clockwise from east  $\gamma$  and the direction of the surface stress vector. It should be borne in mind that the precise magnitudes of the drag coefficients, air density and the ratio of 10 m wind speed to geostrophic wind speed are unimportant in coherence computations.

The longshore and offshore components of the surface stress vector were then plotted versus time. Comparison of current, wind and wind stress component time series yielded no striking correlation. Time series plots of the current velocity components in Shelikof Strait and the atmospheric pressure gradient, windspeed and wind stress are shown in Appendix 2. Although long period variations spanning about 10 days are clearly present in the current records these are not mirrored in the meteorological records. Either these variations are not locally driven, are driven by a non-meteorological process, the surface pressure grid is too coarse to resolve the Shelikof Strait winds, or an agency other than wind stress is responsible for the current oscillations. The oscillations are probably not attributable to baroclinic instabilities since these are thought to have periods in Shelikof Strait of about four days (Mysak et al, 1981).

#### 4.3 SUBTIDAL OSCILLATIONS OF PERIOD LESS THAN SEVEN DAYS

In this range of the spectrum we have enough realizations to apply cross-spectral techniques. Since we are dealing with synoptic scale atmospheric pressure maps, however, wavelengths greater than 600 km only can be rigorously addressed. Table 4.2 lists the periods at which coherence above the 95% confidence level were found between variables.

The fluctuations in the cross-shelf sea surface slope (between Ikolik and Albatross Bank) were coherent with the longshore wind stress at periods of about 35 hours. The alongshelf (Ikolik-Amatuli) sea surface slope was coherent in this range of periods with both the longshore and offshore wind stress.

**Table 4.2** Periods for Which Significant Coherence Were Found

	<b>Alongshore</b>	Onshore
	Wind Stress	Wind Stress
<b>Shelikof Strait</b>		
47 m Current Components		
alongshore	5 days	
offshore		
<b>Shelikof Strait</b>		
157 m Current Components		
<b>alongshore</b>	<b>7 days, 3 days</b>	5 days
offshore	35 hours	
<b>Cross-shelf Pressure Gradient</b>		
<b>(Ikolik-Albatross)</b>	<b>35 hours</b>	
<b>Along-shelf Pressure Gradient</b>		
<b>(Ikolik-Amatuli )</b>	<b>35 hours</b>	<b>35 hours</b>

Clearly, the cross-shelf sea surface slope (**Ikolik-Albatross**) responds to alongshore shore wind-stresses of periods of just over one day (the time lag **is** about 12 hours). The alongshore sea surface slope however (**Ikolik-Amatuli**) responds significantly to both alongshore and onshore wind stress.

The shallow alongshore currents appear to respond primarily to alongshore stress oscillations of about five day period while the deeper alongshore currents appear to respond to both **alongshore** and offshore stresses.

If we assume that both current meters are located within the **geostrophic** interior of the fluid, that is outside the surface and bottom Ekman layers, then the behavior of the cross-shelf pressure gradient should mirror that of the alongshore current component. Inspection of Table 4.2 reveals that this is not the case. Additionally, it is difficult to explain the high coherence between the onshore wind stress and the along-shelf pressure gradient.

Unfortunately, we cannot draw conclusions from the observed coherence. We can **only** speculate that the geostrophic winds are not a good indication of the **atmospheric forcing over Shelikof Strait**. It is **likely** that the **local topography** greatly alters the wind field, e.g., as described by Kozo (1980).

The oscillations in **Shelikof Strait**, **therefore**, are still unexplained. It is extremely unlikely that they are *driven* by **coastal** freshwater discharge so that the remaining mechanisms are the **atmospheric** pressure field, wind stress or wave-like instabilities.

## 5. SUMMARY

### 5.1 PROPERTY FIELDS

Between June and August 1984, the surface temperature increased **by** about **5°C** in the Western Gulf of Alaska due to insolation. Cross sections of density revealed an eddy-like feature of dimensions comparable with the internal Rossby radius which propagated (or was **advected**) westward at a speed **of** about **4 cm s<sup>-1</sup>**. If the feature was associated with **baroclinic** instability, then a mechanism for cross slope exchange of water and nutrients was present.

The station spacing and the lack of synopticity of the CTD limit the utility of the computed geostrophic currents. In general, however, westerly flows as high as **60 cm s<sup>-1</sup>** were computed over the continental slope while westerly flows up to **10 cm s<sup>-1</sup>** were computed over the continental shelf.

The property distributions were similar to those reported by previous investigators.

### 5.2 TIDAL OSCILLATIONS

The tides in the region are mixed, mainly semi-diurnal with spring tide ranges of between 3.5 and 6.5 m. **Cotidal** charts show the major tidal constituents propagating from northeast to southwest with some suggestion of shoreward propagation west of Kokiak Island. Computations of tidal energy flux are generally consistent with the **cotidal** charts with the exception of the Stevenson Entrance location. At this site, southward propagation of energy is computed.

Substantial tidal period internal wave energy was computed for the  $M_2$  constituent in Cook Inlet. Internal tide waves have associated **velocity**,

amplitudes and heights of about 50 cm S-1 and 30 m respectively. The implication is that a 60 m height internal tide wave is present at spring tide. In 65 m water depth such an oscillation is extremely unlikely without strong **non-linearities** in the flow field. A purely **linear-barotropic** tidal model will, therefore, likely be inadequate to predict the flow field in Cook Inlet.

### 5.3 SUBTIDAL OSCILLATIONS

The current data collected during this study were inadequate to address variations in the Alaska Coastal Current for two reasons: first, the records are only two months long and, "second, the moorings were located no closer than 15 km to the coast. The offshore **length** scale of the current during June-August is expected to be between 3 and 7 km so that the current meters would not have sensed the coastal current.

Mean flows ranged between 1.3 and 5.6 cm **s<sup>-1</sup>**, and were directed generally southwestward along the shelf with two important exceptions. In **Shelikof** Strait, the mean flow at depth was northeastward implying an estuarine type **of** flow regime **there**. In Cook **Inlet** the mean flows was east by northeast nearly across the inlet. The Cook Inlet mean flows are probably a manifestation of a secondary circulation the most likely driving force for which is tidal rectification.

No success was achieved in relating the variations in the **geostrophic** winds **with** the variations in the flow on the continental shelf. We speculate that this is due to **ageostrophic** atmospheric flow caused by the presence of coastal mountains.

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**Appendix 1**  
**Tidal Analyses**

GULF OF ALASKA

ANALYSIS OF HOURLY TIDAL HEIGHTS

S+N. AMATULI ISLAND

DEPTH: 167 M

START: 2300Z 13/ 6/84

NO.OBS. = 1360

NO.PTS.ANAL. = 1360

LAT: 59 0 7.8 N

LONG: 151 50 1.8 W

END: 1400Z 9/ 8/84

MIDPT: 600Z 12/ 7/84

	NAME	FREQUENCY (CY/HR)	A (M)	G
	----	-----	---	---
1	Z0	0.00000000	166.2659	0.00
2	MM	0.00151215	0.0257	145.38
3	MSF	0.00282193	0.0323	328.20
4	ALP1	0.03439657	0.0068	62.74
5	2Q1	0.03570635	0.0137	303.66
6	Q1	0.03721850	0.0468	271.60
7	Q1	0.083365	0.3082	262.95
8	NO1	0.04026860	0.0214	331.62
9	K1	0.04178075	0.5834	287.24
10	J1	0.04329290	0.0200	324.87
11	OO1	0.04483084	0.0092	293.79
12	UPS1	0.04634299	0.0033	270.03
13	EPS2	0.07617730	0.0068	169.58
14	MU2	0.0776947	0.0470	213.74
15	N2	0.07899922	0.3011	297.41
16	M2	0.08051139	1.5548	312.60
17	L2	0.082225E	0.0125	294.06
18	S2	0.08333331	0.4184	357.54
19	ETA2	0.08507365	0.0199	302.03
20	MO3	0.11924207	0.0127	194.15
21	M3	0.12076712	0.0022	46.03
22	MK3	0.12229216	0.0171	218.41
23	SK3	0.12511408	0.0059	219.66
24	MN4	0.15951067	0.0070	322.32
25	M4	0.16102278	0.0163	359.70
26	SN4	0.16233259	0.0010	356.16
27	MS4	0.16384470	0.0084	58.07
28	S4	0.16666669	0.0037	37.73
29	2MK5	0.20280355	0.0058	211.90
30	2SK5	0.20844740	0.0013	50.83
31	2MN6	0.24002206	0.0016	359.03
32	M6	0.24153417	0.0045	53.37
33	2MS6	0.24435616	0.0021	146.80
34	2SM6	0.24717808	0.0012	88.31
35	3MK7	0.28331494	0.0010	265.07
36	M8	0.32204562	0.0014	272.69



# GULF OF ALASKA

## ANALYSIS OF HOURLY TIDAL HEIGHTS

STN: SHUMAGIN	LAT : 54 31 55.8 N
DEPTH: 193 M	LONG: 158 58' 4.8 W
START : 2000Z 15/ 6/84	END : 1900Z 11/ 8/84
NO.OBS. = 1368	NO.PTS.ANAL. = 1368 MIDPT: 700Z 14/ 7/84

NAME -----	FREQUENCY (CY/HR) -----	A (M) ---	G ---	
1	ZO	0.00000000	192.0029	0.00
2	MM	0.00151215	0.0148	176.47
3	NSF	0.00252193	0.0232	0.27
4	ALP 1	0.03439657	0.0052	293.93
5	ZO 1	0.03570635	0.0066	292.27
6	Q1	0.03721850	0.0510	271.57
7	O1	0.03873065	0.2769	266.50
8	NO 1	0.04026860	0.0244	322.55
9	K1	0.04178075	0.5175	289.08
10	J1	0.04329290	0.0129	310.28
11	OO 1	0.04483084	0.0106	279.33
12	UPS i	0.04634299	0.0042	316.70
13	EPS2	0.04687730	0.0037	239.89
14	MU2	0.07769947	0.0173	188.56
15	N2	0.07899922	0.1371	302.39
16	M2	0.08051139	0.6713	317.25
17	L2	0.08202356	0.0147	351.66
18	S2	0.08333331	0.1690	353.99
19	ETA2	0.08507365	0.0083	322.62
20	MO3	0.11924207	0.0014	352.73
21	M3	0.12076712	0.0017	222.90
22	MK3	0.12229216	0.0006	250.66
23	SK3	0.12511405	0.0007	215.00
24	MN4	0.15951067	0.0003	199.91
25	M4	0.16102278	0.0011	232.74
26	SN4	0.16233259	0.0002	58.20
27	MS4	0.16384470	0.0003	112.42
28	S4	0.16666669	0.0017	139.84
29	ZMK5	0.20280355	0.0020	197.44
30	ZSK5	0.20844740	0.0002	195.38
31	ZMN6	0.24002206	0.0009	266.61
32	M6	0.24453417	0.0014	318.15
33	ZMS6	0.24435616	0.0014	346.82
34	ZSM6	0.24717808	0.0005	43.08
35	ZMK7	0.25331494	0.0010	268.95
36	M8	0.32204562	0.0009	301.68

## GULF OF ALASKA

## ANALYSIS OF HOURLY TIDAL HEIGHTS

STN: CAPE IKOLIK                      LAT: 57 15 0.0 N  
DEPTH: 62 M                            LONG: 154 45 18.0 W  
START: 100Z 15/ 6/84                  END: 2300Z 10/ 8/84  
NO.OBS.: 1367   NO.PTS.ANAL.: 1367   MIDPT: 1200Z 13/ 7/84

	NAME	FREQUENCY (CY/HR)	A (M)	G
	----	-----	---	---
1	ZO	0.00000000	61.2714	0.00
2	MM	0.00151215	0.0183	154.76
3	MSF	0.00282193	0.0260	1.68
4	ALP1	0.03439657	0.0032	352.93
5	ZQ 1	0.03570635	0.0113	306.23
6	Q1	0.037218S0	0.0515	271.30
7	O1	0.03S73065	0.3070	265.70
8	NO 1	0.04026860	0.0245	327.00
9	K1	0.041?8075	0.5928	2S9.37
10	J1	0.04329290	0.0192	329.15
11	OD1	0.044\$30s4	0.0116	274.81
12	UPS1	0.04634299	0,0047	307.11
13	EPS2	0.07617730	0.00b2	249.65
14	MU2	0.0776S947	0.0261	212.33
15	N2	0.07\$99922	0.2770	303.52
16	M2	0.0%051139	1.3889	317.00
17	L2	0.08202356	0.0202	319.81
18	S2	0.08333331	0..3757	1.87
19	ETA2	0.08507365	0.0201	315.96
20	MO3	0.11924207	0.0054	99.62
21	M3	0.12076712	0.0054	11.05
22	MK 3	0.\$2229236	0.0167	355.14
23	SK3	0.12511408	0.0096	202.21
24	MN4	0.15951067	0.00S6	199.64
25	M4	0.16102278	0.0299	220.50
26	SN4	0.16233259	0.0036	241.71
27	MS 4	0.16384470	0.0127	207.22
28	S4	0.16666669	0.0054	317.39
29	2MK5	0.202S0355	0.0040	169.34
30	2SK5	0.20844740	0.0011	266.61
31	2MN6	0.24002206	0.0024	141.08
32	M6	0.24153417	0.0043	152.29
33	2MS6	0.2443S616	0.0031	212.66
34	2SM6	0.2471780S	0.0008	153.50
35	3MK7	0.28331494	0.0008	336.89
36	M8	0.32204562	0.0014	9.47

GULF OF ALASKA

ANALYSIS OF HOURLY TIDAL HEIGHTS

STN: SEAL ROCKS                      LAT: 59 29 55.8 N  
 DEPTH : 114 M                        LONG: 149 29 34.2 W  
 START : 1000Z 13/ 6/84              END: 4002 9/ 8/84  
 NO.OBS.= 1363 NO.PTS.ANAL.= 1363 MIDPT: 1900Z 11/ 7/84

	NAME -----	FREQUENCY (CY/HR) -----	A (M) ..-	G ----
1	Z0	0.00000000	113.3633	0.00
2	MM	0.00151215	0,0234	<b>133.86</b>
3	MSF	0.002S2193	0.0403	356.06
4	ALP1	0.03439657	0.0061	90030
5	2Q1	0.0357063S	<b>0.0117</b>	308.39
6	Q1	<b>0.03721850</b>	<b>0.0410</b>	<b>263.84</b>
7	O1	0.03873065	0.2846	256.09
8	NO 1	0.04026S60	<b>0.0172</b>	325.07
9	K1	0.04178075	<b>0.5431</b>	279.69
10	J1	0.04329290	0.0209	<b>316.09</b>
11	OO1	<b>0.04483084</b>	0.0088	302.19
12	UPS1	0.04634299	0.0021	252.49
13	EPS2	0.07617730	<b>0.0053</b>	<b>142.33</b>
14	MU2	0.0776S947	0.0340	<b>176.16</b>
15	N2	<b>0.07899922</b>	<b>0.2216</b>	274.53
16	M2	<b>0.08051139</b>	<b>1.1975</b>	289.94
17	L2	0.08202356	<b>0.0109</b>	305.84
18	S2	<b>0.08333331</b>	<b>0.3016</b>	331.25
19	ETA2	0.08507365	<b>0.0121</b>	<b>273.02</b>
20	MO3	0.11924207	<b>0.0036</b>	179.57
21	M3	0.12076712	<b>0.0012</b>	298.42
22	MK3	<b>0.12229216</b>	0.0043	<b>191.79</b>
23	SK3	<b>0.12511408</b>	0.0031	<b>162.93</b>
24	MN4	<b>0.15951067</b>	<b>0.0013</b>	33.4.68
25	M4	0.16102278	0.0085	<b>13.66</b>
26	SN4	<b>0.16233259</b>	<b>0.0015</b>	3.70
2?	MS4	0.163844?0	0.0042	<b>114.67</b>
28	S4	<b>0.16666669</b>	0.0007	290.37'
29	2MK5	<b>0.20280355</b>	<b>0.0018</b>	245.35
30	2SK5	0.20844740	<b>0.0015</b>	<b>268.12</b>
31	2MN6	0.24002206	0.0022	320.85
32	M6	0.24153417	0.0062	<b>41.30</b>
33	2MS6	0.24435616	0.0024	<b>117.96</b>
34	2SM6	<b>0.24717808</b>	<b>0.0014</b>	<b>38.02</b>
35	3MK7	<b>0.28331494</b>	0.000?	<b>328.63</b>
36	M8	0.32204562	<b>0.0013</b>	336.99



GULF OF ALASKA

ANALYSIS OF HOURLY TIDAL HEIGHTS

STN: SANAK	LAT : 54 35 15.0 N
DEPTH : 51 M	LONG : 162 43 46.2 W
START : 1100Z 16/ 6/84	END : 400Z 13/ 8/84
NO.OBS. = 1386 NO.PTS.ANAL. = 1386	MIDPT: 700Z 15/ 7/84

	NAME -----	FREQUENCY (CY/HR) -----	A (M) ---	G ---
1	Z0	0.00000000	51.0813	180.00
2	MM	0.00151215	0.0097	210.41
3	MSF	0.00282193	0.0220	8.72
4	ALP1	0.03439657	0.0043	256.34
5	ZQ 1	0.03570635	0.0040	312.70
6	Q1	0.03721850	0.0476	274.08
7	O1	0.03573065	0.2691	269.93
8	NO 1	0.04026860	0.0244	324.25
9	K1	0.04178075	0.5041	293.03
10	J1	0.04329290	0.0096	299.74
11	001	0.04483084	0.0113	291.54
12	UPSI	0.04634299	0.0024	341.03
13	EPS2	0.07617730	0.0058	228.10
14	MU2	0.07768947	0.0173	196.83
15	N2	0.07899922	0.1331	314.13
16	M2	0.08051139	0.6306	330.12
17	L2	0.08202356	0.0173	347.43
18	S2	0.08333331	0.1579	3.55
19	ETA2	0.08507365	0.0074	337.79
20	M03	0.11924207	0.0025	13.46
21	M3	0.12076712	0.0023	248.32
22	MK3	0.92229216	0.0027	53.03
23	SK3	0.12511408	0.0017	319.22
24	MN4	0.15951067	0.0014	73.10
25	M4	0.16102278	0.0006	89.53
26	SN4	0.16233259	0.0012	119.45
27	MS4	0.16384470	0.0009	222.07
28	S4	0.16666669	0.0027	219.48
29	2MK5	0.20280358	0.0022	181.33
30	2SK5	0.20844740	0.0027	184.51
31	2MN6	0.24002206	0.0038	128.19
32	M6	0.24153417	0.0095	39.34
33	2MS6	0.24435616	0.0069	202.12
34	2SM6	0.24717508	0.0021	254.16
35	3MK7	0.28331494	0.0022	303.21
36	M8	0.32204562	0.0016	341.89

GULF OF ALASKA

ANALYSIS RESULTS IN CURRENT ELLIPSE FORM  
 AMPLITUDES HAVE BEEN SCALED ACCORDING TO APPLIED FILTERS  
 STN: STEVENSON ENTRANCE LAT: 58 53 43.8 N  
 DEPTH : 54 M LONG: 150 57 13.8 W  
 START : 2000Z 13/ 6/84 END: 800Z 9/ 8/84

NAME	FREQUENCY ( CY/HR )	MAJOR (CM/S)	MINOR (CM/S)	INC	G	G+	G-
----	-----	-----	-----	---	---	---	---
1 Z0	0.00000000	2.111	0.000	57.8	180.0	122.2	237.8
2 MM	0.00151215	3.924	-2.361	45.0	55.4	10.5	100.4
3 MSF	0.00282193	2.861	-2.021	84.7	68.2	343.6	152.9
4 ALP1	0.03439657	0.476	-0.391	179.0	156.0	337.0	334.9
5 2Q1	0.03570635	0.728	0.126	109.4	93.1	343.7	202.5
6 Q1	0.03721850	1.000	0.344	97.5	17.0	279.5	114.5
7 O1	0.03873065	3.742	-0.774	98.1	13.7	275.6	111.8
8 NO1	0.04026860	0.288	0.040	106.4	156.6	50.2	263.1
9 K1	0.04178075	6.571	-2.157	100.6	40.5	300.0	141.1
10 J1	0.04329290	0.558	0.430	126.2	75.9	309.8	202.1
11 OO1	0.04483084	0.450	-0.140	75.4	349.8	274.5	65.2
12 UPS1	0.04634299	0.395	0.087	7.3	12.6	5.3	19.9
13 EPS2	0.07617730	1.338	0.774	74.1	304.2	236.2	13.3
14 MU2	0.07765947	2.474	0.503	67.2	31.8	324.6	98.9
15 N2	0.07899922	5.889	1.478	93.5	50.5	317.0	143.9
16 M2	0.08051139	30.198	0.621	102.1	66.3	324.1	168.4
17 L2	0.08202356	1.484	-0.098	116.5	37.0	280.5	153.5
18 S2	0.08333331	10.086	0.591	97.2	112.3	15.1	209.5
19 ETA2	0.08507365	1.137	0.717	80.1	100.2	20.1	180.3
20 MO3	0.11924207	0.645	0.246	74.4	182.6	108.2	257.1
21 M3	0.12076712	0.545	-0.231	17.1	228.3	211.2	245.4
22 MK3	0.12229216	1.015	0.195	50.4	280.5	230.1	331.0
23 SK3	0.12511408	0.417	0.173	25.5	329.1	303.6	354.6
24 MN4	0.15951067	0.141	-0.060	90.3	6.9	268.6	105.2
25 M4	0.16102278	0.691	0.538	5.7	259.3	253.6	265.0
26 SN4	0.16233259	0.415	-0.185	126.4	262.2	135.8	28.5
27 MS4	0.16384470	0.526	-0.342	2.0	357.1	355.0	359.1
28 S4	0.16666669	0.651	0.354	43.5	319.7	276.3	3.2
29 ZMK5	0.20280355	0.922	0.247	55.3	283.3	228.0	336.6
30 ZSK5	0.20844740	0.187	0.105	149.7	214.2	64.4	3.9
31 ZMN6	0.24002206	0.535	-0.153	15.8	303.1	287.3	318.8
32 M6	0.24153417	0.923	-0.041	36.3	310.8	274.5	347.2
33 ZMS6	0.24435616	0.720	-0.050	58.9	328.8	269.9	27.7
34 ZSM6	0.24717808	0.525	0.128	134.0	98.0	323.2	232.7
35 ZMK7	0.28331494	0.492	0.110	101.4	233.6	132.2	335.0
36 M8	0.32204562	0.338	0.135	151.1	45.9	254.7	197.0

GULF OF ALASKA

ANALYSIS RESULTS IN CURRENT ELLIPSE FORM  
 AMPLITUDES HAVE BEEN SCALED ACCORDING TO APPLIED FILTERS  
 STN: STEVENSON ENTRANCE      LAT: 58 53 43.8 N  
 DEPTH : 82 M                      LONG: 150 57 13.8 W  
 START : 2000Z 13/ 6/84              END: 800Z 9/ 8/84

NAME	FREQUENCY (CY/HR)	MAJOR (CM/S)	MINOR (CM/S)	I NC	G	G+	G-
1 Z0	0.00000000	2.576	0.000	134.9	180.0	45.2	314.9
2 MM	0.00151215	3.302	-0.808	30.9	50.5	19.7	81.4
3 MSF	0.00282193	2.993	-1.034	17.5	149.0	131.5	166.5
4 ALP1	0.03439657	0.221	-0.191	70.4	202.2	131.8	272.6
5 Q01	0.03570s35	0.424	-0.006	69.0	63.5	354.5	132.5
6 Q1	0.03721850	0.826	0.220	59.6	54.5	354.9	114.1
7 O1	0.03873065	3.456	-1.668	91.3	21.5	290.2	112.8
8 NO1	0.04026860	0.268	0.138	10.0	109.7	99.7	119.7
9 K1	0.04178075	6.411	-3.464	108.3	35.9	287.6	144.3
10 J1	0.04329290	0.931	0.647	66.9	69.2	2.3	136.2
11 O01	0.04483084	0.343	0.130	82.8	55.6	332.8	138.4
12 UPSI	0.04634299	0.248	0.085	166.1	324.1	158.1	130.2
13 EPS2	0.07617730	1.490	0.759	60.?	357.5	296.8	58.2
14 MU2	0.07768947	2.926	0.764	26.1	57.8	31.7	83.9
15 N2	0.07s99922	5.908	-0.342	94.1	55.1	321.0	149.3
16 M2	0.08051139	36.348	1.649	91.2	76.0	344.7	167.2
17 L2	0.08202356	3.619	2.749	1.0	80.6	19.6	21.6
18 S2	0.0s333331	11.5s4	1.104	83.6	126.3	42.7	210.0
19 ETA2	0.0S507365	0.820	0.024	95.6	67.9	332.3	163.5
20 M03	0.11"924207	0.323	-0.026	60.0	352.2	292.3	52.2
21 M3	0.12076712	0.252	0.121	136.3	16.3	240.0	152.6
22 MK3	0.12229216	o* 809	-0.112	33.4	40.8	7.4	74.3
23 SK3	0.12511408	0.271	0.036	32.5	85.7	53.2	118.2
24 MN4	0.15951067	0.983	0.046	79.4	92.0	12.6	171.4
25 M4	0.16102278	1.492	0.128	24.7	127.5	102.8	152.2
26 SN4	0.16233259	1.139	0.294	150.7	238.2	87.6	28.9
27 MS4	0.16384470	0.461	-0.179	57.3	151.4	94-.2	208.7
28 S4	0.16666669	0.672	0.618	107.4	215.4	108.0	322.8
29 2MK5	0.202S0355	0.679	0.233	40.2	7.4	327.2	47.7
30 2SK5	0.20844740	0.125	0.079	96.0	171.2	75.2	267.1
31 2MN6	0.24002206	0.310	-0.054	96.4	85.4	349.0	181.8
32 M6	0.24153417	0.203	0.167	58.8	320.1	261.3	19.0
33 2MS6	0.24435616	0.474	0.131	41.4	45.7	4.3	87.1
34 2SM6	0.24717\$30S	0.220	-0.003	105.0	188.3	03.3	293.3
35 3MK7	0.2s331494	0.558	0.182	140.2	307.0	166.8	S7.2
36 M8	0.32204562	0.299	-0.172	15.4	88.4	73.1	103.8

GULF OF ALASKA

ANALYSIS RESULTS IN CURRENT ELLIPSE FORM

AMPLITUDES HAVE BEEN SCALED ACCORDING TO APPLIED FILTERS  
 STN: COOK INLET LAT: 59 35 1.2 N  
 DEPTH: 35 M LONG: 152 29 0.0 W  
 START: 500Z 14/ 6/84 END: 1800Z 9/ 8/84

NAME	FREQUENCY (CY/HR)	MAJOR (CM/S)	MINOR (CM/S)	INC	G	G+	G-
----	-----	-----	-----	----	----	----	----
1 ZO	0.00000000	4.304	0.000	12.1	360.0	347.9	12.1
2 MM	0.00151215	1.922	1.178	117.8	165.3	47.4	2B3.1
3 MSF	0.002s22'33	4.297	-1.351	99.1	264.3	165.2	3.4
4 ALP1	0.034s9657	0.591	-0.411	95.0	26.4	291.4	121.5
5 ZQ1	0.03S70635	0.757	-0.323	108.6	256.8	148.3	5.4
6 Q1	0.03721850	1.892	0.095	91.8	241.0	149.1	332.8
7 D1	0.03873065	9.482	-0.695	78.5	223.7	145.2	302.3
8 NQ1	0.04026860	0.897	-0.069	105.1	290.7	185.6	35.8
9 K1	0.04178075	19.006	-3.527	77.4	243.9	166.5	321.2
10 J1	0.04329290	0.602	0.184	54.4	292.2	237.8	346.6
11 QO1	0.044S3084	0.837	-0.097	104.2	264.7	160.5	9.0
12 UPS1	0.04634299	0.428	0.020	124.4	237.3	112.9	1.6
13 EPS2	0.07617730	1.706	-1.474	51.9	193.8	141.9	245.6
14 MU2	0.07768947	6.366	-0.209	96.6	199.5	102.9	296.2
15 N2	0.07899922	14.444	-2.391	81.2	285.2	204.0	6.4
16 M2	0.08051139	73.533	-8.936	78.1	308.4	230.3	26.5
17 L2	0.08202356	1.290	1.098	6*6	357.0	350.4	3.6
18 S2	0.0s333331	19.821	-2.525	84.1	352.1	268.1	76.2
19 ETA2	0.08507365	1.028	-0.461	95.4	278.3	183.0	13.7
20 MO3	0.11924207	1.905	-0.115	70.3	112.1	41.7	182.4
21 M3	0.12076712	1.271	-0.679	74.7	29.7	315.1	104.4
22 MK3	0.12229216	2.642	-0.081	84.6	145.0	60.4	229.6
23 SK3	0.12511408	1.306	-0.512	5*7.0	20? .1	150.1	264.2
24 MN4	0.15951067	0.941	-0.658	92.7	161.7	69.0	254.4
25 M4	0.16102278	2.622	-1.012	65.7	179.0	113.3	244.6
26 SN4	0.16233259	0.362	-0.100	75.8	239.5	163.8	315.3
27 MS4	0.16384470	0.922	-0.193	77.2	215.0	137.8	292.3
28 S4	0.36666669	0.867	-0.480	9.6	23.6	13.9	33.2
29 ZMK5	0.202S0355	0.973	-0.022	108.1	304.2	196.1	52.2
30 ZSK5	0.20s44740	0.273	-0.148	44.3	175.9	131.6	220.2
31 ZMN6	0.24002206	0.517	-0.007	158.6	194.8	36.2	353.4
32 M6	0.24153417	0.833	-0.077	49.8	101.3	51.6	151.1
33 ZMS6	0.24435616	0.593	-0.218	154.4	334.4	180.0	128.7
34 ZSM6	0.24717808	0.384	-0.044	171.3	352.0	180.6	163.3
35 ZMK7	0.28331494	0.531	-0.118	149.4	109.0	319.5	258.4
36 M8	0.32204562	0.424	-0.178	4.3	328.9	324.7	333.2

GULF OF ALASKA

ANALYSIS RESULTS IN CURRENT ELLIPSE FORM

AMPLITUDES HAVE BEEN SCALED ACCORDING TO APPLIED FILTERS

STN: COOK INLET

LAT: 59 35 1.2 N

DEPTH: 52 M

LONG: 152 29 0.0 W

START: 500Z 14/ 6/84

END: 2200Z 13/ 7/84

NAME	FREQUENCY (CY/HR)	MAJOR (CM/S)	MINOR (CM/S)	INC	G	G+	G-
----	-----	-----	-----	---	---	---	---
1 Z0	0.00000000	5.464	0.000	25.9	360.0	334.1	25.9
2 MSF	0.00282193	3.256	-1.136	110.4	248.8	138.4	359.2
3 2Q1	0.0357063S	1.045	-0.480	55.8	343.4	287.6	39.2
4 Q1	0.03721050	1.980	-0.183	70.6	236.5	165.8	307.1
5 01	0.03873065	7.990	-0.067	69.0	220.4	151.4	2139.4
6 N01	0.04026S60	0.679	0.122	120.4	323.8	203.4	84.2
7 K1	0.04178075	16.570	-3.415	78.0	238.6	160.7	316.6
8 J1	0.04329290	1.078	0.115	7.4	286.4	279.0	293.7
9 001	0.04483084	1.061	0.298	114.7	272.9	158.2	27.7
10 UPS1	0.04634299	0.429	-0.256	36.0	220.9	184.9	257.0
11 N2	0.07899922	3.3229	-3.530	83.2	278.7	195.6	1.9
12 M2	0.080S1139	59.845	-1.996	74.2	304.8	230.6	19.0
13 S2	0.08333331	14.814	-0.754	83.6	346.3	262.7	69.9
14 ETA2	0.09507365	1.500	-0.948	10.2	260.2	250.9	270.4
15 M03	0.11924207	2.104	-0.622	62.2	112.4	50.2	174.7
16 M3	0.12076712	1.449	-0.530	59.0	53.7	354.7	112.7
17 MK3	0.12229216	2.352	-0.228	62.8	150.4	87.6	213.3
18 SK3	0.12511408	1.771	-0.904	67.8	213.9	146.1	281.8
19 MN4	0.15951067	1.277	-0.474	65.1	250.3	185.2	315.4
20 M4	0.1610227S	1.528	-0.846	115.3	105.2	349.9	200.6
21 MS4	0.16384470	0.699	0.146	158.7	206.1	47.3	4.8
22 S4	0.16666669	0.888	-0.686	2.8	348.5	345.7	351.3
23 2MK5	0.20280355	1.314	0.168	83.1	296.9	213.8	20.0
24 2SK5	0.20S44740	0.517	-0.108	21.9	200.9	179.1	222.8
25 2MN6	0.24002206	0.768	-0.380	97.5	310.0	212.5	47.5
26 M6	0.24153417	0.880	-0.106	14.8	40.9	26.1	55.7
27 2MS6	0.24435616	0.468	-0.389	133.8	314.6	180.7	88.4
28 2SM6	0.24717S08	0.532	-0.065	45.2	239.6	194.4	284.9
29 3MK7	0.28331494	0.692	-0.296	167.5	116.8	309.3	284.4
30 M8	0.32204562	0.439	-0.298	55.8	287.3	231.5	343.1

# GULF OF ALASKA

## ANALYSIS RESULTS IN CURRENT ELLIPSE FORM

AMPLITUDES HAVE BEEN SCALED ACCORDING TO APPLIED FILTERS

STN: SANAK

LAT: 54 3s 15.0N

DEPTH: 20 M

LONG: 162 43 46.2 W

START : 1200Z 16/ 6/84

END : 300Z 13/ 8/84

NAME	FREQUENCY ( CY/HR )	MAJOR (CM/S)	MI NOR (CM/S)	I NC	G	G+	G-
----	-----	-----	-----	---	---	---	---
1 Z0	0.00000000	2.261	0.000	15.7	180.0	164.3	195.7
2 MM	0.00151215	0.426	0.084	94.4	173.3	78.9	267.8
3 MSF	0.002S2193	2.939	-0.146	0.9	146.9	146.0	147.8
4 ALP1	0.0343965?	0.527	0.048	18.6	84.1	65.5	102.7
5 ZQ1	0.03570635	0.469	0.091	64.3	117.5	53*3	181.8
6 Q1	0.03721850	0.251	-0.019	54*B	227.3	172.5	282.0
7 D1	0.03873065	2.285	-1.082	176.8	104.7	287.9	261.5
8 NO1	0.04026860	0.488	-0.07'7'	94.7	35.3	300.6	130.0
9 K1	0.04178075	3.981	-1.997	166.9	145.2	338.3	312.1
10 J1	0.04329290	0.726	-0.440	10.2	349.9	339.6	0.1
11 OO1	0.044\$3084	0.232	0.197	41.6	38.9	357.3	80.5
12 UPS1	0.04634299	0.345	0.004	32.5	344.0	311.4	16.5
13 EPS2	0.0?6277'30	1.098	-0.810	4.2	112.7	108.5	116.9
14 MU2	0.07769947	0.420	-0.150	12.1	92.0	70.8	95.0
15 N2	0.07899922	0.684	-0.261	89.9	269.0	179.1	359.0
16 M2	0.08051139	3.121	0.469	112.8	285.1	172.3	37.9
17 L2	0.08202356	0.984	0.133	65.3	341.8	276.5	47.1
18 S2	0.08333331	1.091	-0.110	76.6	335.5	258.9	52.1
19 ETA2	0.08507365	0.403	-0.033	56.0	213.8	157.8	269.8
20 MO3	0.11924207	0.231	0.035	91.2	186.5	95.3	277.7
21 M3	0.12076712	0.153	-0.032	3.8	355.3	351.5	359.2
22 MK3	0.12229216	0.324	-0.227	138.6	237.0	98.4	15.5
23 SK3	0.12511408	0.237	0.001	125.9	195.3	69.5	321.2
24 MN4	0.15951067	0.247	0.013	77.8	295.1	217.6	12.6
25 M4	0.16102278	0.255	-0.045	20.2	117.8	97.6	138.0
26 SN4	0.16233259	0.068	-0.0413	23.1	184.3	161.2	207.4
27 MS4	0.16384470	0.218	-0.133	149.1	30.3	241.1	179.4
28 S4	0.16666669	0.239	-0.025	94.1	231.3	137.2	325.4
29 ZMK5	0.20280355	0.092	0.064	75.1	344.7	269.7	59.8
30 ZSK5	0.20844740	0.131	0.060	168.8	255.3	86.5	64.0
31 ZMN6	0.24002206	0.204	0.050	70.3	46.2	335.9	116.5
32 M6	0.2415342'7	0.349	0.086	108.5	104.4	355.9	212.9
33 ZMS6	0.24435616	0.323	-0.023	39.2	100.6	61.3	139.8
34 ZSM6	0.24717808	0.127	0.007	179.6	246.0	66.5	65.6
35 ZMK7	0.28331494	0.168	-0.042	57.0	200.8	151.7	265.8
36 M8	0.32204562	0.058	-0.004	76.4	141.7	65.3	218.1

GULF OF ALASKA

ANALYSIS RESULTS IN CURRENT ELLIPSE FORM

AMPLITUDES HAVE BEEN SCALED ACCORDING TO APPLIED FILTERS

STN: SANAK

LAT: 54 35 15.0 N

DEPTH : 41 M

LONG: 162 43 46.2 W

START: 1200Z 16/ 6/84

END: 200Z 13/ 8/84

NAME	FREQUENCY (CY/HR)	MAJOR (CM/S)	MINOR (CM/S)	I NC	G	G+	G-
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1 Z0	0.00000000	3.086	0.000	150.8	360.0	209.2	150.8
2 MM	0.00151215	1.195	-0.687	145.6	307.9	162.3	93.5
3 MSF	0.00282193	1.414	0.176	170.3	329.5	159.2	139.9
4 ALP1	0.03439657	0.421	-0.306	86.3	296.9	210.6	23.3
5 ZQ1	0.03570635	0.322	-0.016	9.1	154.6	145.5	163.7
6 Q1	0.03721850	0.659	-0.023	33.7	284.4	250.7	318.1
7 Q1	0.03873065	3.465	-0.904	1.0	274.4	273.4	275.4
8 NQ1	0.04026860	0.544	0.063	12.6	325.2	312.6	337.8
9 K1	0.04178075	7.146	-3.135	165.6	135.7	330.2	301.3
10 J1	0.04329290	1.040	-0.267	160.3	168.7	9.4	328.9
11 Q01	0.04493084	0.754	-0.216	163.7	152.4	348.7	316.0
12 UPS1	0.04634299	0.271	-0.057	125.2	213.9	88.7	339.0
13 EPS2	0.07617730	0.624	0.063	5.9	285.7	279.8	291.6
14 MJ2	0.07768947	0.470	-0.125	18.8	25.5	74.4	112.5
15 N2	0.07999922	0.786	-0.486	64.3	238.5	174.3	302.5
16 M2	0.08051139	4.121	1.077	89.6	252.6	163.0	342.3
17 L2	0.08202356	0.731	-0.162	98.1	91.0	352.9	189.1
18 S2	0.08333331	1.476	-0.607	30.1	267.4	237.4	297.5
19 ETA2	0.08507365	0.056	0.023	164.1	14.6	210.5	178.8
20 M03	0.11924207	0.402	-0.135	153.0	256.5	103.5	49.5
21 M3	0.12076712	Oil?	-0.065	76.5	9.2	292.8	85.7
22 MK3	0.12229216	0.394	-0.063	89.0	293.6	204.6	22.5
23 SK3	0.12511408	0.314	-0.108	9.0	99.0	89.9	108.0
24 MN4	0.15951067	0.322	-0.039	35.9	158.8	122.9	194.7
25 M4	0.16102278	0.110	-0.011	65.1	52.3	347.2	117.4
26 SN4	0.16233259	0.180	0.068	55.7	162.1	106.5	217.8
27 MS4	0.16384470	0.123	0.004	112.0	140.9	28.9	252.9
28 S4	0.16666669	0.190	0.145	11.7	125.4	113.7	137.1
29 ZMK5	0.20280355	0.244	-0.030	16.2	50.6	34.4	66.8
30 ZSK5	0.20844740	0.082	-0.037	94.3	98.7	1.4	189.9
31 ZMN6	0.24002206	0.333	-0.027	118.6	133.4	14.8	252.0
32 M6	0.24153417	0.271	0.195	85.0	107.0	22.0	192.0
33 ZMS6	0.24435616	0.296	-0.037	72.0	163.2	91.2	235.2
34 ZSM6	0.24717808	0.058	0.033	96.8	292.4	195.5	29.2
35 ZMK7	0.28331494	0.110	0.031	85.2	197.0	111.8	282.2
36 M8	0.32204562	0.118	-0.031	110.3	272.9	162.6	23.2

GULF OF ALASKA

ANALYSIS RESULTS IN CURRENT ELLIPSE FORM  
 AMPLITUDES HAVE BEEN SCALED ACCORDING TO APPLIED FILTERS  
 STN: SHELIKOF STRAIT LAT: 57 39 0.0 N  
 DEPTH: 46 M LONG: 155 3 19.8 W  
 START: 2300Z 14/ 6/84 END: 1200Z 10/ 8/84

NAME	FREQUENCY (CY/HR)	MAJOR (CM/S)	MINOR (CM/S)	I NC	G	G+	G-
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1 ZO	0.00000000	3.839	0.000	59.8	180.0	120.2	239.8
2 MM	0.00151215	12.868	5.271	116.3	261.9	145.7	18.2
3 MSF	0.002S2193	5.479	-0.565	20.5	223.2	194.7	251.6
4 ALP1	0.03439657	0.531	0.356	45.6	161.5	115.9	207.1
5 ZQ1	0.03s7063s	0.741	0.473	5.2	39.0	33.s	44.1
6 Q1	0.03721850	0.975	0.273	104.6	299.5	195.0	44.1
7 O1	0.03s73065	1.754	-0.126	38.9	227.1	188.2	266.0
8 NO1	0.04026860	0.429	-0.014	119.5	25.3	265.8	144.7
9 K1	0.0417s075	3.449	0.076	41.3	243.6	202.4	284.9
10 J1	0.04329290	0.616	-0.240	99.4	330.9	231.5	70.3
11 OO1	0.044s3084	0.252	0.044	44.6	135.1	90.4	179.7
12 UPS1	0.04634299	0.199	0.106	145.5	174.8	29.0	320.6
13 EPS2	0.0?617730	0.073	0.833	5.7	331.7	326.1	337.4
14 MU2	0.07768947	0.979	-0.165	31.1	228.7	197.6	255.5
15 N2	0.07s99922	2.529	0.692	38.5	230.2	191.7	268.7
16 M2	0.08051139	13.766	-0.023	39.9	250.7	210.9	290.6
17 L2	0.09202356	2.234	0.772	119.5	156.9	37.4	276.5
18 S2	0.08333331	4.516	-0.032	41.2	297.1	255.9	338.3
19 ETA2	0.08507365	1.105	0.417	85.5	221.8	136.3	307.2
20 MO3	0.11924207	0.292	0.249	125.3	137.4	12.1	262.7
21 M3	0.12076712	0.478	0.048	143.8	269.2	125.4	53.1
22 MK3	0.12229216	0.306	-0.031	11.5	126.0	114.6	137.5
23 SK3	0.1251140S	0.191	0.064	25.4	155.0	129.6	180.5
24 MN4	0.15951067	0.289	0.019	171.3	283.5	82.2	64.9
25 M4	0.16102278	0.527	0.118	13.3	348.0	334.7	1.3
26 SN4	0.16233259	0.374	-0.117	110.8	289.1	178.3	40.0
27 MS4	0.16384470	0.351	0.032	7.5	0.5	353.0	8.0
28 S4	0.16666669	0.347	0.257	157.4	171.8	14.4	329.2
29 ZMK5	0.20290355	0.386	0.136	170.2	315.9	145.6	126.1
30 ZSK5	0.20844740	0.806	0.035	95.1	223.7	128.6	318.8
31 ZMN6	0.24002206	0.141	0.073	123.6	196.4	72.8	320.0
32 M6	0.24353417	0.132	-0.060	104.5	293.9	189.4	3s.5
33 ZMS6	0.244356%6	0.212	0.115	177.4	157.8	340.4	335.1
34 ZSM6	0.24717S0S	0.239	0.158	57.7	252.9	195.2	310.5
35 ZMK7	0.28331494	0.307	-0.007	73.6	337.3	263.5	50.7
36 M8	0.32204562	0.170	0.087	109.3	33.1	283.9	142.4

GULF OF ALASKA

ANALYSIS RESULTS IN CURRENT ELLIPSE FORM

AMPLITUDES HAVE BEEN SCALED ACCORDING TO APPLIED FILTERS

STN: SHELKOF STRAIT

LAT: 57 39 0.0 N

DEPTH: 157 M

LONG: 155 3 19.8 W

START: 2300Z 14/ 6/84

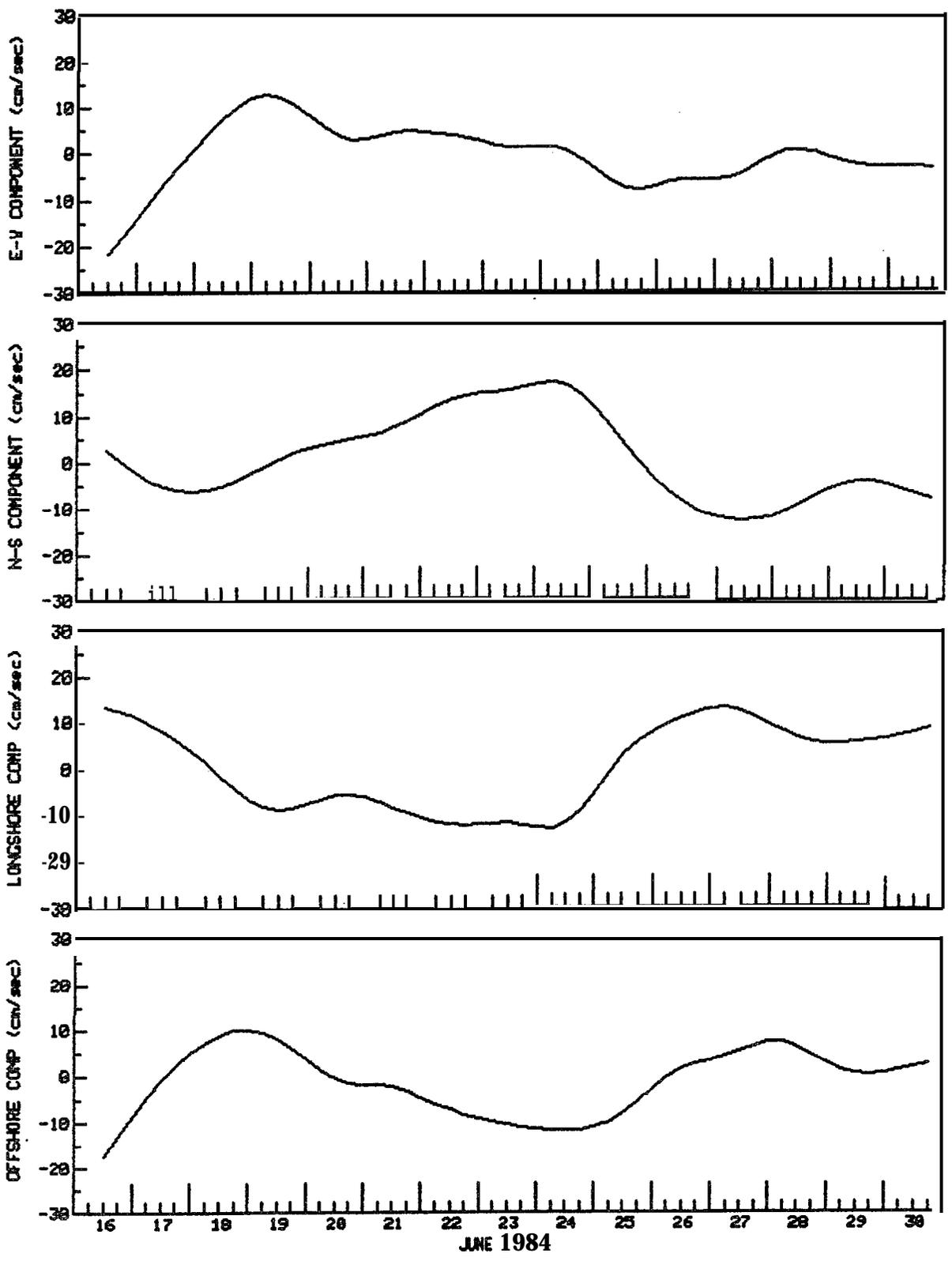
END: 1200Z 10/ 8/84

NAME	FREQUENCY (CY/HR)	MAJOR (CM/S)	MINOR (CM/S)	INC	G	G+	G-
----	-----	-----	-----	---	---	---	---
1 Z0	0.00000000	1.343	0.000	52.6	360.0	307.4	52.6
2 MM	0.00151215	5.314	2.274	123.6	263.7	140.1	27.3
3 MSF	0.00282193	4.241	-1.419	45.3	205.2	157.0	253.5
4 ALP1	0.03439657	0.245	0.011	151.7	104.5	312.8	256.2
5 Q01	0.0357063s	0.241	0.080	80.6	18.9	298.2	99.5
6 Q1	0.03721850	0.514	0.277	103.9	299.9	196.1	43.s
7 O1	0.03S73065	1.496	-0.061	49.4	205.1	155.7	254.5
8 ND1	0.04"026860	0.241	0.121	161.5	80.5	279.0	242.0
9 K1	0.04178075	2.956	-0.148	47.9	226.4	178.5	274.3
10 J1	0.04329290	0.396	-0.006	132.1	342.2	210.1	114.3
11 O01	0.044s3084	0.285	-0.013	94.%	239.6	144.8	334.4
12 UPS1	0.04634299	0.301	0.090	155.2	209.8	54.5	5.0
13 EPS2	0.07617730	0.591	0.268	141.3	317.0	175.7	98.3
14 MU2	0.07768947	0.482	0.349	53.2	147.0	233.9	200.2
15 N2	0.07633922	3.111	1.006	45.8	233.4	140.7	279.2
16 M2	0.08051139	14.870	0.598	43.0	248.2	205.2	291.3
17 L2	0.08202356	1.725	0.210	119.2	138.4	19.2	257.6
18 S2	0.08333331	4.333	0.141	46.8	296.0	249.2	342.8
19 ETA2	0.08507365	0.602	-0.114	49.3	269.9	220.5	319.2
20 M03	0.11924207	0.308	0.068	45.0	136.3	91.3	181.3
21 M3	0.12076712	0.251	0.008	87.5	259.9	172.4	347.4
22 MK3	0.22229216	0.496	-0.073	30.1	164.3	134.2	194.4
23 SK3	0.12511408	0.246	-0.144	170.0	66.2	256.2	236.1
24 MN4	0.15951067	0.208	0.150	33.1	204.0	170.9	237.2
25 M4	0.16102278	0.307	0.014	114.4	299.6	185.2	54.0
26 SN4	0.16233259	0.169	-0.019	175.4	7.5	192.1	183.0
27 MS4	0.16384470	0.239	0.043	108.3	6.3	258.0	114.6
28 S4	0.16666669	0.205	0.100	46.1	220.3	174.2	266.3
29 2MK5	0.202S0355	0.187	0.038	42.5	114.6	72.1	157.1
30 2SK5	0.20844740	0.125	0.057	90.7	96.5	5.8	187.1
31 2MN6	0.24002206	0.141	0.054	12.0	10.4	358.5	22.4
32 M6	0.2453417	0.103	-0.060	53.4	313.5	260.2	6.9
33 2MS6	0.244356%6	0.111	-0.010	163.9	246.3	82.4	50.3
34 2SM6	0.24717808	0.111	0.071	18.5	306.2	287.7	324.7
35 3MK7	0.20331494	0.156	0.050	27.5	359.7	332.2	27.3
36 M8	0.32204562	0.098	-0.009	68.3	31.0	322.7	99.3

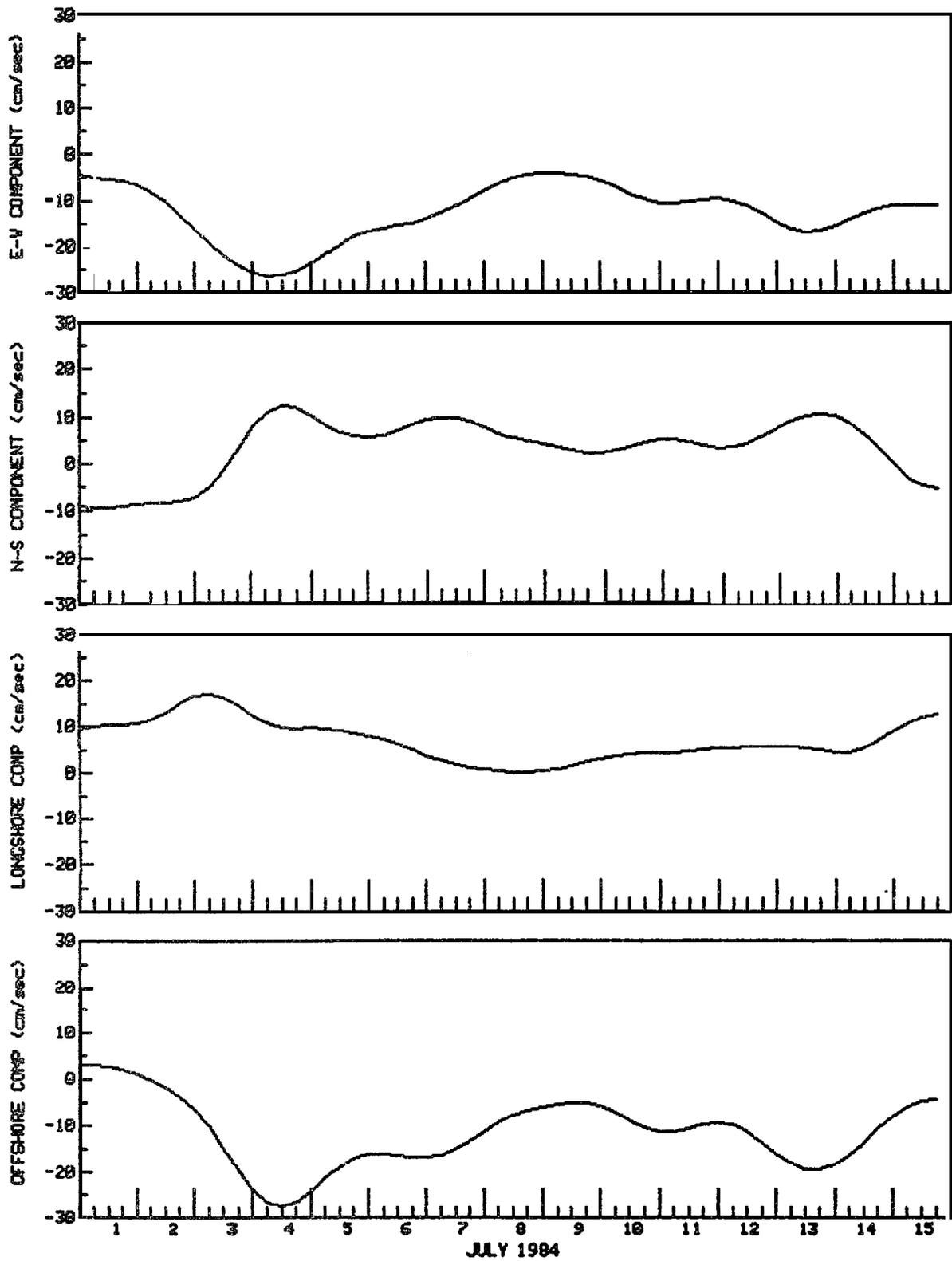
**Appendix 2**

**Time Series of Filtered Velocity, Geostrophic Wind,  
Surface Wind Stress**

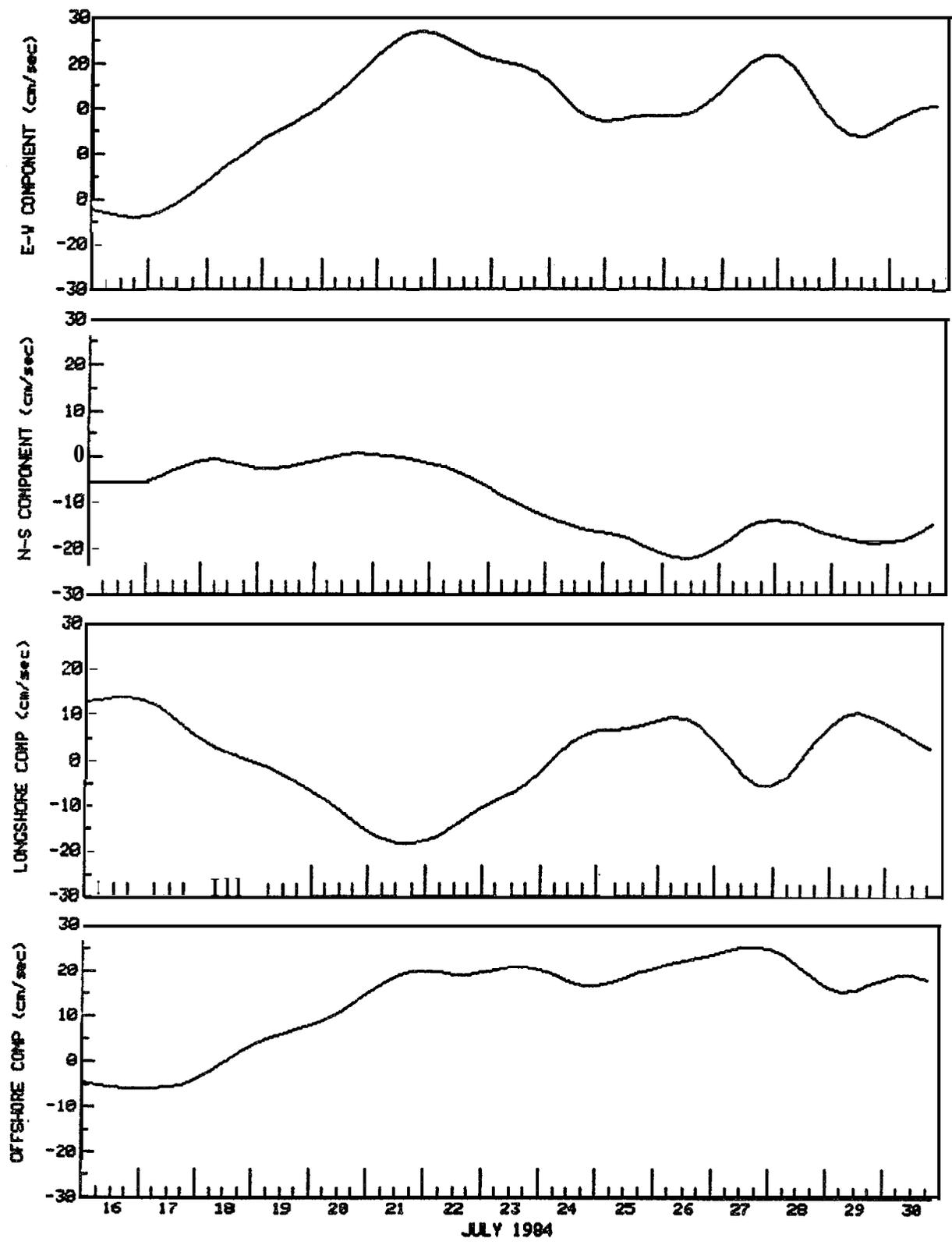
TIME SERIES OF U, V AND LONGSHORE, OFFSHORE COMPONENTS  
 SHELIKOF STRAIT METER 3127 DEPTH(m) 46 TYPE FILTERED  
 57 39' 00"N 155 03' 19.8"W AANDERAA RCM DT(min) 360



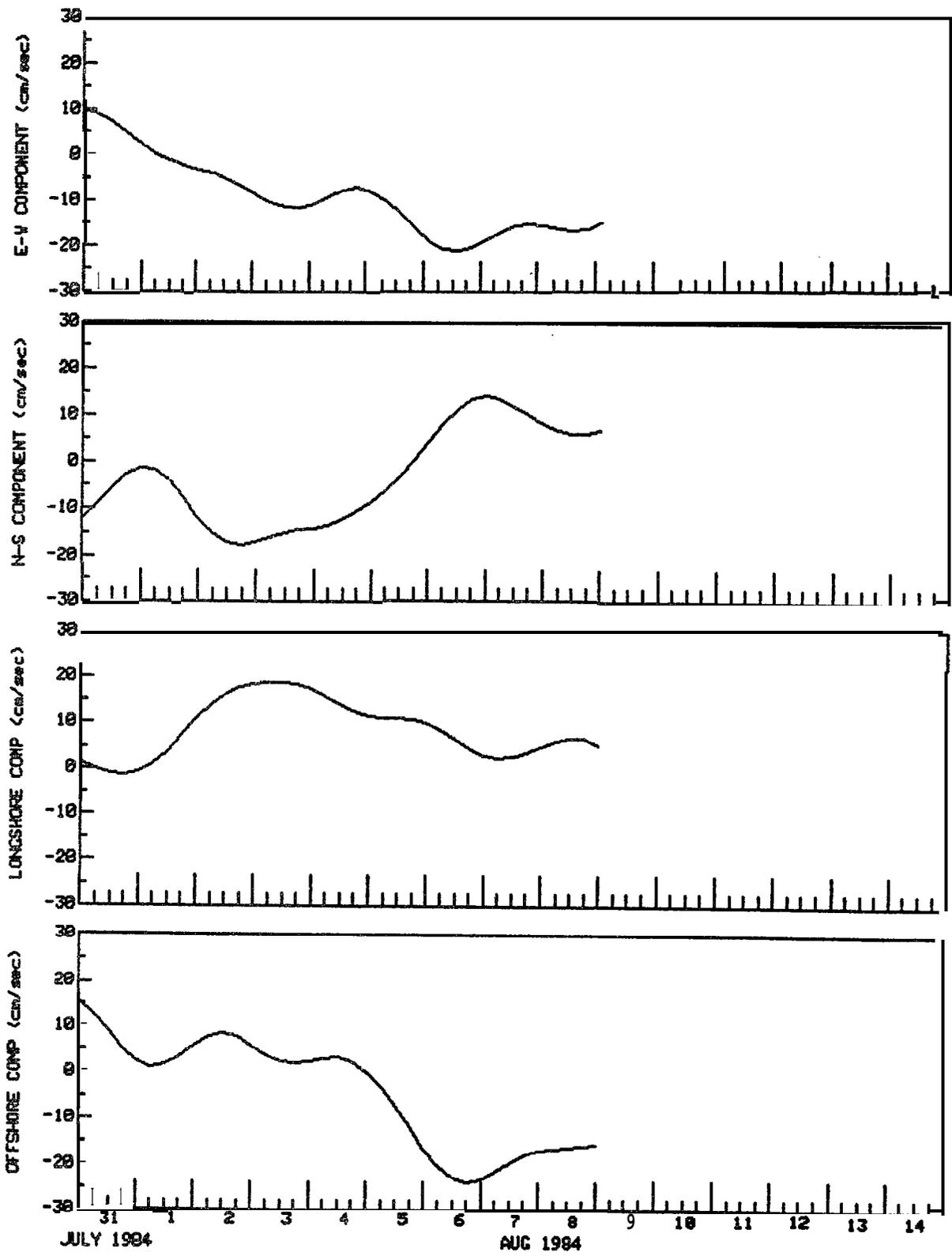
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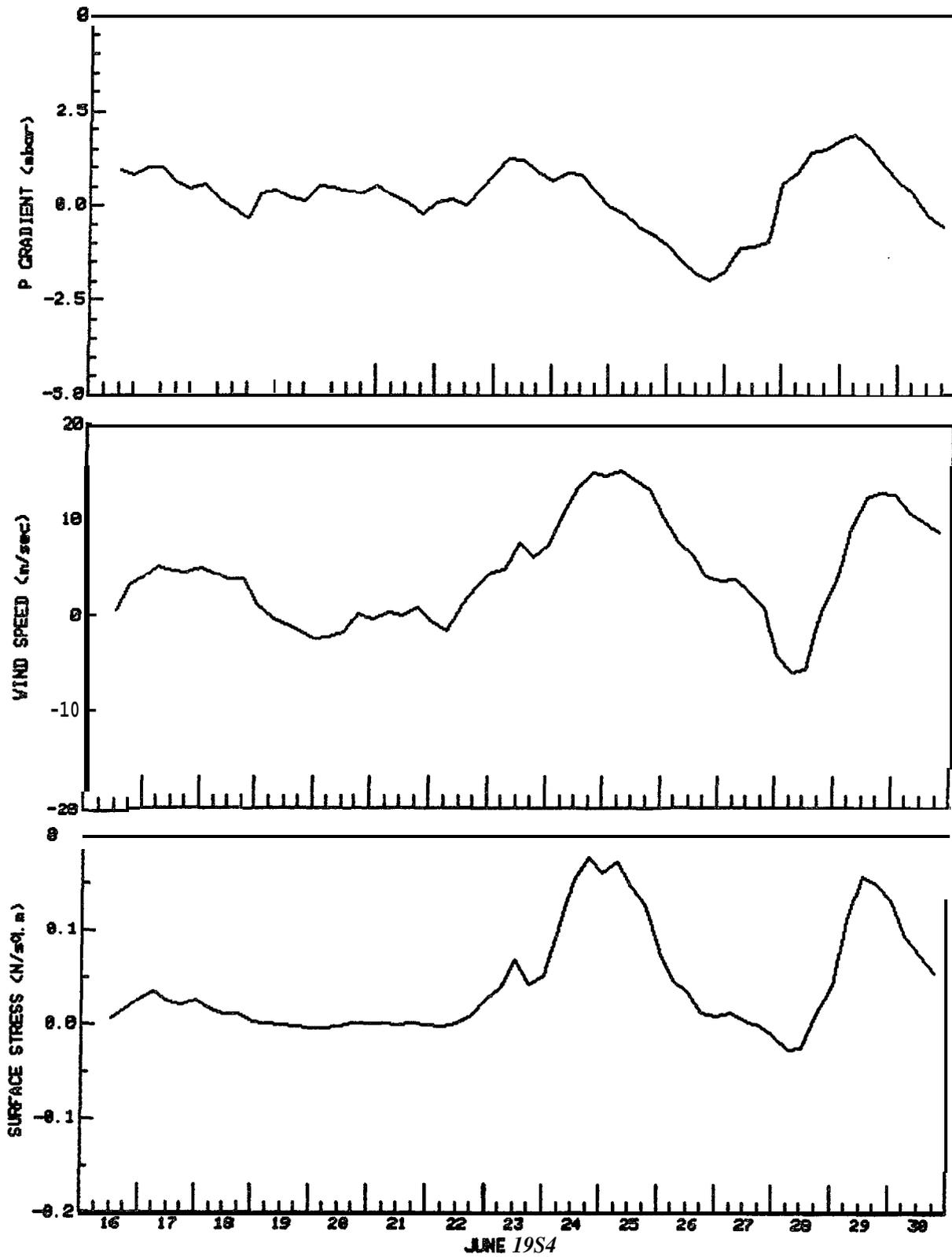
TIME SERIES OF ( J, V AND LONGSHORE, OFFSHORE COMPONENTS  
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 57 39' 00"N 155 03' 19.8"W AANDERAA RCM DT(min) 360



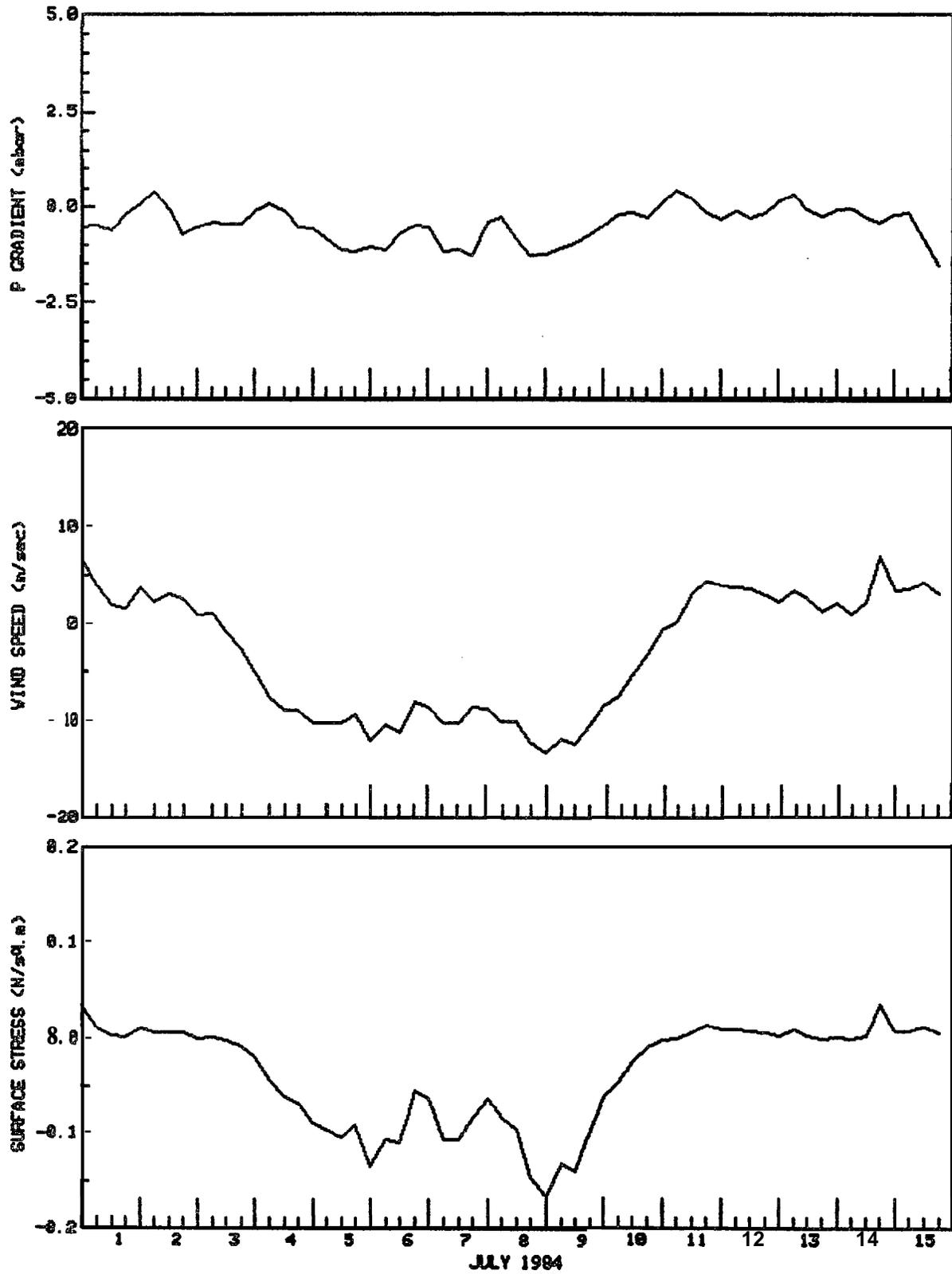
**TIME SERIES OF U, V AND LONGSHORE, OFFSHORE COMPONENTS**  
**SHELIKOF STRAIT**      **METER 3127**      **DEPTH(m) 46**      **TYPE FILTERED**  
**57 39' 00"N**      **155 03' 19.8"W**      **AANDERAA RCM**      **DT(min) 360**



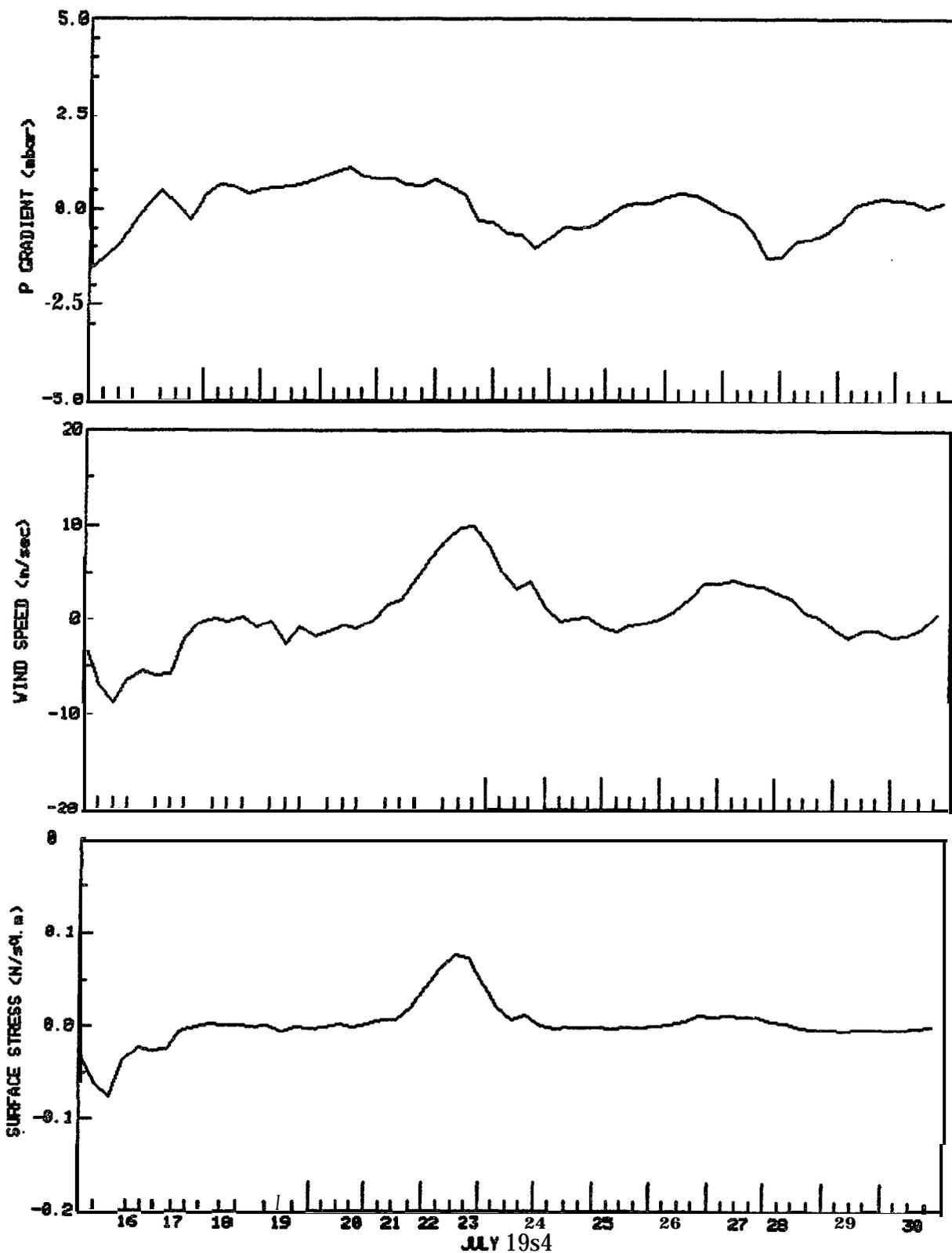
TIME SERIES OF OFFSHORE COMPONENT OF  
 PRESSURE GRADIENT, GEOSTROPHIC WIND AND SURFACE WIND STRESS  
 SHELIKOF STRAIT DT(min) 360



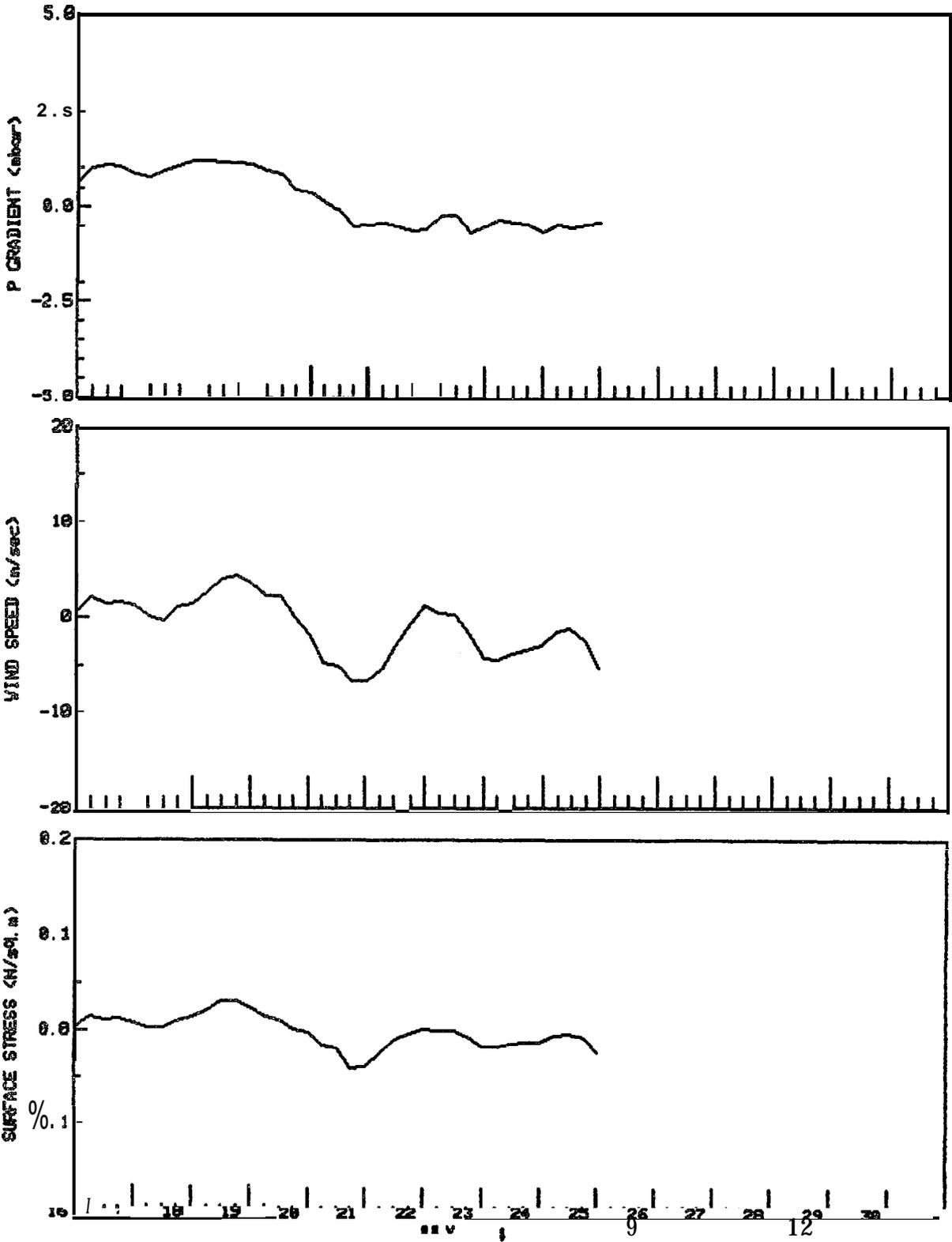
TIME SERIES OF OFFSHORE COMPONENT OF  
 PRESSURE GRADIENT, GEOSTROPHIC WIND AND SURFACE WIND STRESS  
 SHELIKOF STRAIT DT(min) 360



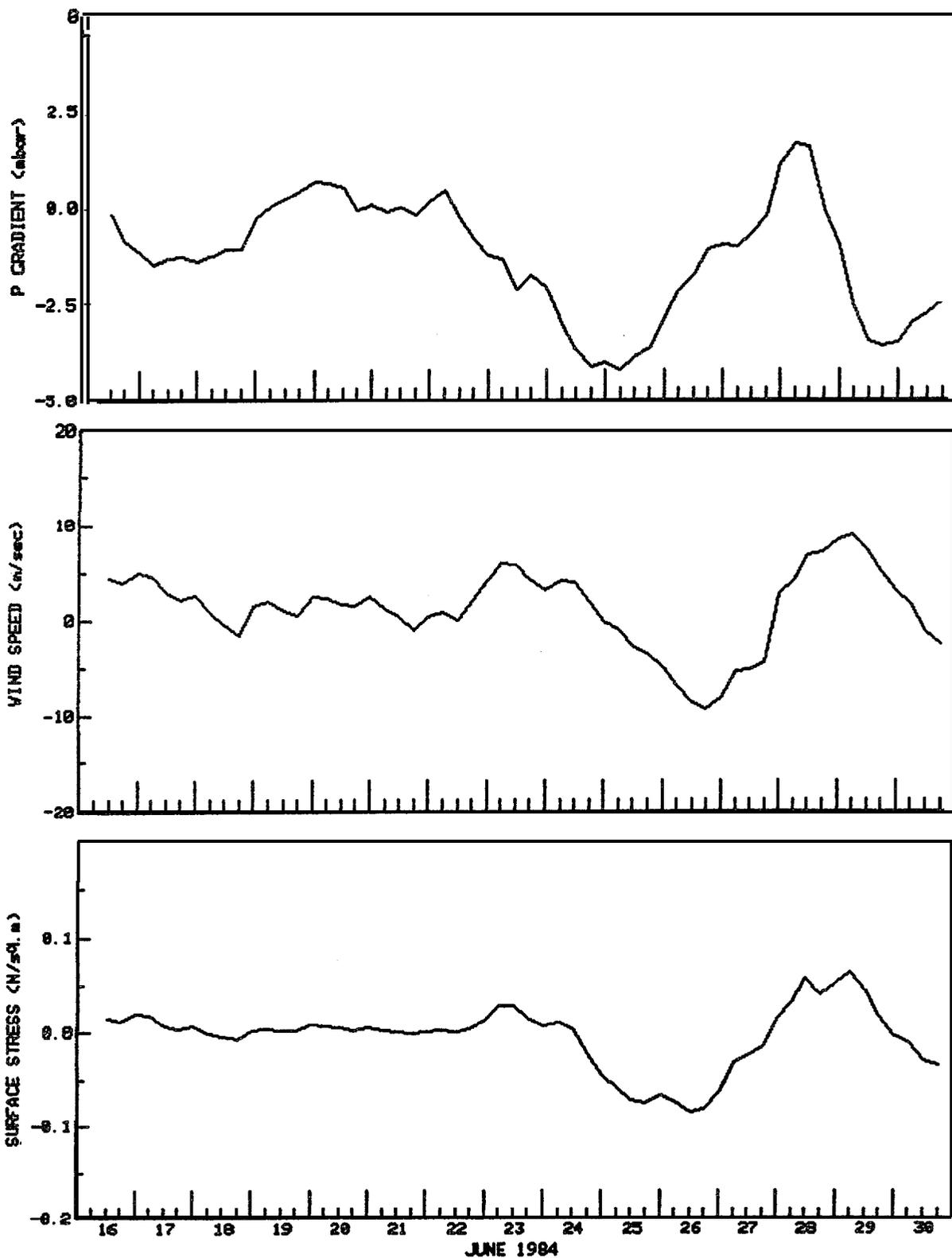
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 PRESSURE GRADIENT, GEOSTROPHIC WIND AND SURFACE WIND STRESS  
 SHELIKOF STRAIT DT(min) 3613



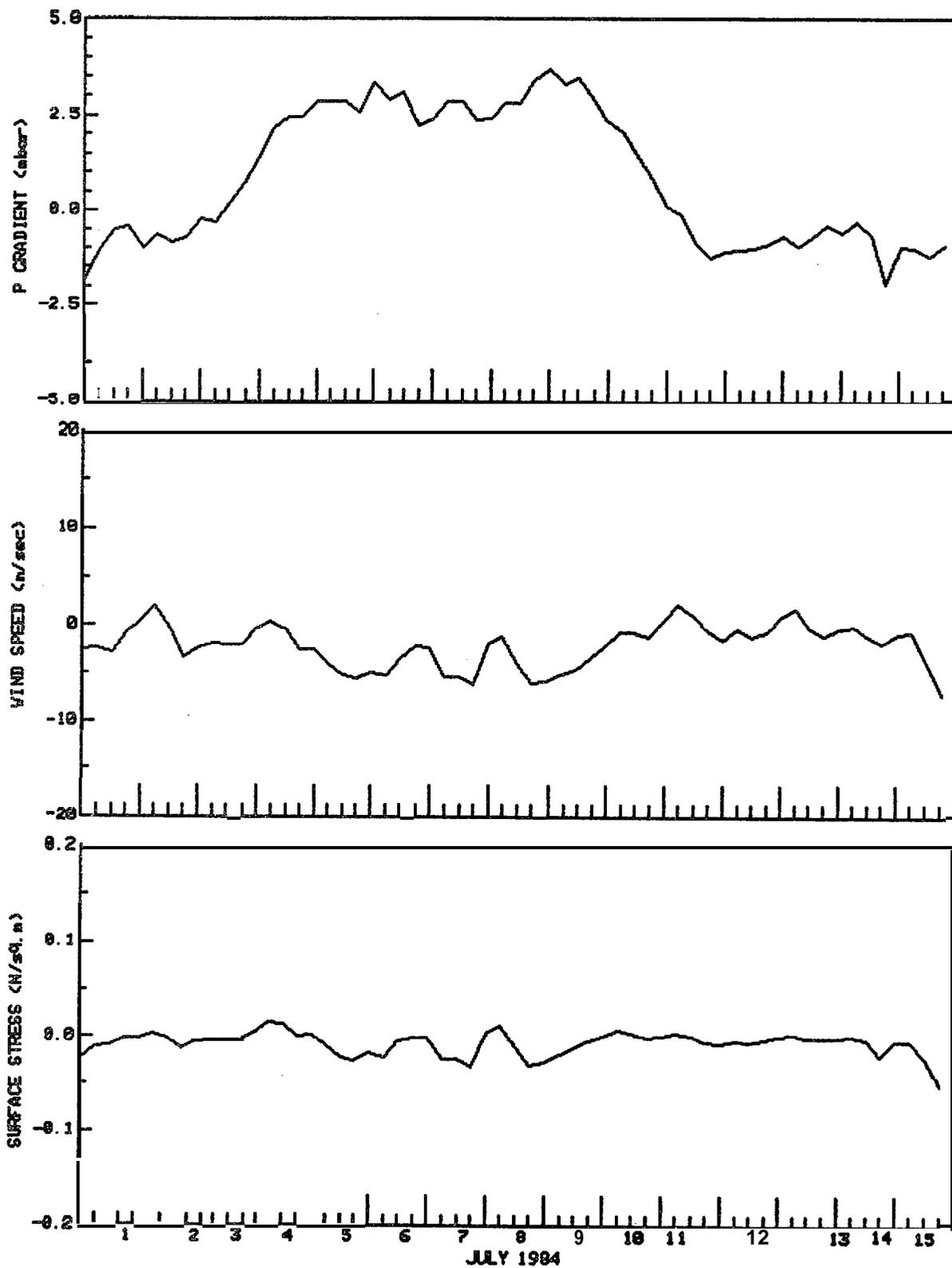
TIME SERIES OF OFFSHORE COMPONENT OF  
 PRESSURE GRADIENT, GEOSTROPHIC WIND AND SURFACE WIND STRESS  
 SHELIKOF STRAIT  
 DT(min) 360



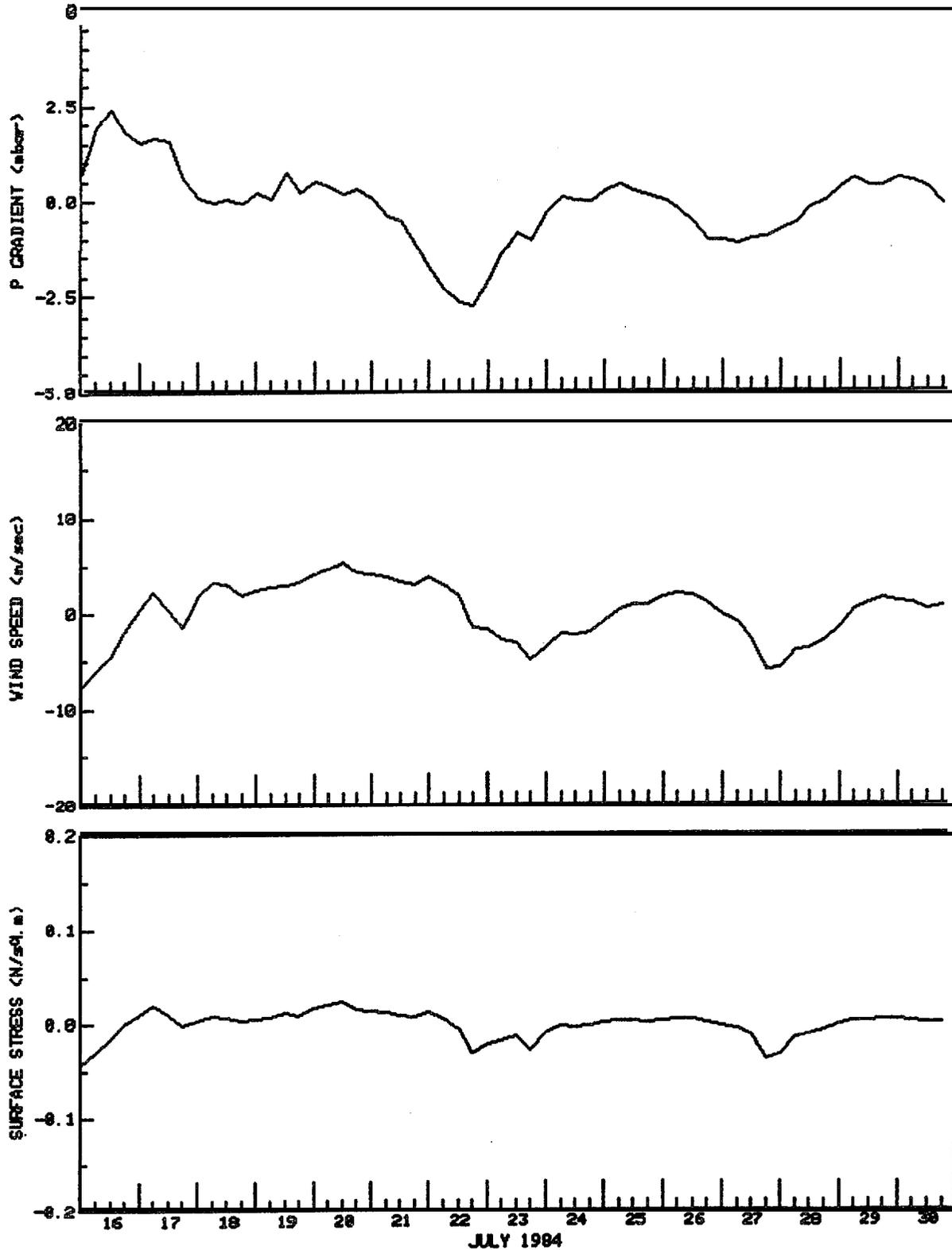
TIME SERIES OF LONGSHORE COMPONENT OF  
 PRESSURE GRADIENT, GEOSTROPHIC WIND AND SURFACE WIND STRESS  
 SHELIKOF STRAIT DT(min) 360



TIME SERIES OF LONGSHORE COMPONENT OF  
 PRESSURE GRADIENT, GEOSTROPHIC WIND AND SURFACE WIND STRESS  
 SHELIKOF STRAIT DT(min) 360



TIME SERIES OF LONGSHORE COMPONENT OF  
 PRESSURE GRADIENT, GEOSTROPHIC WIND AND SURFACE WIND STRESS  
 SHELIKOF STRAIT DT(min) 360



TIME SERIES OF LONGSHORE COMPONENT OF  
 PRESSURE GRADIENT, GEOSTROPHIC WIND AND SURFACE WIND STRESS  
 SHELIKOF STRAIT DT(min) 360

