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PRELIMINARY

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OCEANOGRAPHIC DATA FROM THE BERING
CHUKCHI, AND BEAUFORT SEAS

WASC-83-00114

FINAL REPORT

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INTRODUCTION

This report relates Brown and Caldwell's activities for the Outer Continental Shelf Environmental Assessment Program (OCSEAP) project entitled Oceanographic Data for the Bering, Chukchi and Beaufort Seas (WASC 8300114). The purpose of the project was to obtain and process measurements of tide along the Alaskan coast from Norton Sound north to Pt. Barrow and east of Pt. Barrow to the United States/Canada Border. Desired information from these measurements were amplitude and phase of astronomical tidal constituents at locations throughout the study area, which covers thousands of miles of the Alaskan coast. Tidal measurements are necessary to adapt a numerical model of deep-water tidal circulation to the relatively shallow continental shelf areas of potential petroleum exploration and development. The tidal circulation model is a sub-model of an oil-spill risk analysis, and knowledge of the tidal circulation is required in order to estimate oil spill transport. Since the study area is in the harsh Arctic environment, historical data is very limited, and simultaneous tidal measurements did not exist for this area prior to this study.

Scope of Work

This project involved collection and analyses of pressure data from bottom mounted sensors in order to determine amplitude and phase of major tidal constituents. Most of the study area is north of the Arctic Circle, and is covered by ice most of the year. Therefore, deployment and retreival of in-situ recording pressure gauges was scheduled for the short period of ice breakup during the summer. A minimum of 29 days of measurement were required at each location in order to obtain the amplitude and phase of the tidal constituents by harmonic analysis. Additionally, a minimum overlap of 20 days of simultaneous measurements at all locations was required to allow estimation of tidal constituents at locations between measurement sites.

Brown and Caldwell (BC) was responsible for collection and analysis of data for determination of amplitude and phase of tidal constituents. OCSEAP supplied most of the instrumentation "and logistical support for the project. The scope of work was separated into four major tasks: prefield work, field effort, data processing and analyses, and reporting and deliverables.

Prefield effort included: (1) final planning and coordination with NOAA agencies such as OCSEAP, Pacific Marine Center (PMC), Pacific Marine Environmental Laboratories (PMEL), and others, (2) check out of pressure gauges and acoustic releases supplied. by PMEL and other equipment supplied by Brown and Caldwell (BC), (3) construction of moorings for instrumentation, and (4) initial data processing.

Field effort involved mobilization and demobilization of equipment and personnel to or from Prudhoe Bay, Dutch Harbor, Nome, and Barrow, Alaska, and deployment and retrieval of instrumentation. NOAA supplied logistical support for deployments in Norton Sound and Chukchi Sea from the R/V Discoverer. The R/V Surveyor was used for recoveries from these areas. Logistical support for Beaufort Sea deployments was provided by OCSEAP personnel and NOAA's helicopter group. Personnel from BC supervised deployment and retrieval of instrumentation.

Data processing and analysis tasks included: (1) preliminary processing to scale data to engineering units, (2) correcting absolute pressure data for the effects of barometric pressure, (3) conversion of pressure data to elevation of water over the pressure sensor, and (4) harmonic analysis of data to determine amplitude and phase of tidal constituents.

Reporting involved preparing work products for the study which included: (1) a field work report, (2) this final report, (3) a magnetic tape of all data, and (4) presentation of preliminary results at the Chukchi Sea Synthesis meeting, held in Aleyska in November 1983.

Station Locations and Measurement Periods

The eight measurement sites used in this project were selected by OCSEAP and the contractor responsible for modeling. Two of the sites were located in Norton Sound, two in the Chukchi Sea and four along the Beaufort Coast of the North Slope. 'Near shore measurements were required to adapt the deep water tidal circulation models to the shallow nearshore area. Station locations are shown on Figures 1 and 2.

The deployment and retrieval of pressure gauges along the northern Alaskan coast were accomplished during a severe year for ice. The late ice breakup along the Beaufort coast and the short ice free season did not allow the instruments to be deployed at the originally selected sites. Ice along most the Beaufort coast was against the outer edge of the barrier island or up against the shore, with the only areas of open water being inside the barrier islands. After discussions with Dr. Liu of the Rand Corporation and Dr. Hamedii of OCSEAP, alternative sites were chosen for Stations 5 through 8. Most of these alternative sites were located along the inner edge of a barrier island at locations relatively protected from ice floes and close to major inlets in the barrier island chain. The original locations for pressure gauges are shown by the circled station numbers on Figure 2. Actual deployment locations are shown by the point of the arrow.

Deployments of instrumentation in the Beaufort and Chukchi Seas were carried out simultaneously between August 5 and August 8, 1983, as presented in Table 1. Instruments were recovered from the

Beaufort coast between September 8 and 10, 1983. Instruments in the Chukchi Sea and Norton Sound were recovered between September 15 and 19, 1983.

METHODS

This section relates instrumentation and methods used in the study. Pertinent information on predeployment planning and testing, the type of mooring used, deployment' and retrieval of instrumentation, and data processing and analyses is presented.

Instrumentation

Most of the instrumentation for this project was provided by the National Oceanographic and Atmospheric Administration (NOAA) through an agreement between OCSEAP and Pacific Marine Environmental Laboratories (PMEL). Eight Aanderaa pressure gauges and eight AMF acoustic releases were provided by PMEL. The Aanderaa pressure gauges included one model TG3, two model TG4A, and five model WLR-5. All of these models use a Paroscientific pressure sensor to sense absolute pressure by the variation in frequency of oscillations of a quartz crystal. A temperature sensor was included in all but one of the pressure instruments. The different models of pressure gauges were similar, but differed in the sample integration time, sampling interval, range of pressure measurement, and recording scheme.

The AMF acoustic releases supplied by PMEL included four squib fired releases (Model 242) and four solenoid actuated releases (Model 395). The acoustic releases were used to retrieve the pressure gauges from the ocean bottom at sampling locations in Norton Sound and the Chukchi Sea. PMEL also provided the deck unit for the AMF releases. Model 395 acoustic releases were not used at Stations 5 through 8, since these stations had to be moved to ice-free, shallow-water sites near the barrier islands.

Calibration and Testing Procedures

Prior to deployment, instrumentation was shipped from PMEL to Brown and Caldwell's Costa Mesa test facility. Proper operation of instrumentation was verified in a relatively short period of time, between July 8 and 12, 1983. Proper operation of pressure gauges was tested by creating test tapes of barometric pressure and processing these data tapes. Pressure gauges had previously been calibrated at NOAA's Northwest Regional Calibration Center, and calibration reports were supplied to BC by PMEL. Barometric pressure data recorded by the Aanderaa instruments was compared to that of a precision mecury laboratory barometer. Upon receiving the deck unit for the acoustic releases, proper operation of the releases was verified by the system air acoustic check recommended by the manufacturer.

Mooring Design

The mooring design was a taut-leg, near-bottom mooring shown in

Figure 3. The height of this taut-leg mooring was kept to a minimum so that the mooring would not be destroyed by ice. The mooring design included a polypropylene tag line which could be used for recovery should the acoustic release fail.

Ice conditions on the Beaufort Coast during the summer of 1983 were quite severe and prevented deployment of pressure gauges at the water depth desired. Mooring design for Stations 5 through 8 had to be modified to allow the mooring to be placed in ice free areas inside of the barrier islands along the Beaufort coast. This mooring design consisted of the Aanderaa pressure gauge encased inside a PVC pipe, a small flotation ball, a chain anchor, and a tag line which was anchored on the beach of the barrier island using a Danforth anchor. This type of mooring is illustrated in Figure 4.

Deployment and Retrieval

Methods of deployment and retrieval differed for the Chukchi and Beaufort Sea deployment areas. Deployments in Norton Sound and Chukchi Sea were made from the NOAA Ship R/V Discoverer, and retrieval of instruments was accomplished from the R/V Surveyor. Beaufort Sea deployments and retrievals of pressure gauges was accomplished from a charted sea plane and/or a NOAA helicopter.

Aboard the Discoverer, the taut leg moorings were assembled on deck. The AMY? acoustic release was connected to the 28-inch diameter submerged float and anchor chain clump by a seized shackle. The 100-meter tag line was attached to the anchor chain clump. The pressure gauge, mounted inside a protective PVC tube, was attached to the stainless steel mooring rod of the AMF release. After the ship had been positioned on station by Loran C and/or satellite navigation equipment, the mooring was deployed. A crane was used to lift the mooring off the deck and lower it to the ocean floor. A gravity hook detached the mooring from the crane when the anchor reached the ocean floor. As the mooring was lowered over the side, the tag line was let out slowly to keep slight tension on the mooring. Once the mooring was on the bottom, the tag line was stretched out from the mooring on a known bearing and then deployed. After deployment of the instrumentation, a CTD cast was made to determine the density of the water column at the site.

Retrieval of instrumentation was accomplished from the NOAA ship R/V Surveyor. Upon arrival at the station, a CTD cast was obtained. An EG&G acoustic release deck unit and hydrophore were used to confirm that the acoustic release was operational and nearby. The release command was sent after receiving confirmation that the release was in the general vicinity and that the whale boat used for recovery was ready. The AMF acoustic release disconnected itself from the clump of anchor chain and the submerged flotation ball brought the release and pressure gauge to the surface. The whale boat retrieved the instrumentation and brought it alongside the R/V Surveyor. A crane was used to lift the instrumentation aboard.

Beaufort Sea deployments were made from a charted sea plane and/or NOAA helicopter. Ice conditions prevented deployment by vessel. Moorings were deployed along barrier islands in ice protected areas near major inlets in the barrier island chain. These moorings consisted of the Aanderaa pressure gauges in a PVC tube.

The pressure gauge and tube were supported by an 8-in submerged float attached to the top of the tube, and anchored by a 50-lb piece of chain attached to the bottom of the tube. A tag line was tied to this chain and led to a Danforth anchor which was buried on the beach of the barrier island. Pressure gauges along the coast were retrieved using a chartered helicopter.

Preliminary Data Processing

Preliminary data processing consisted of the steps necessary to get raw data ready for harmonic analysis. Raw data were transcribed from the internally-recorded, l/4-inch, reel-to-reel tape to Brown and Caldwell's computer system via the RS232C output port of an Aanderaa 2650 tape reader. Instruments recorded raw data as counts. Data were scaled to engineering units of degrees Celsius and pounds per square inch absolute (psia) using calibration coefficients determined by NOAA's Northwest Regional Calibration Center. Time history plots of the absolute pressure fluctuations about the mean were prepared for quality assurance checks of the data.

Barometric pressure data were subtracted from the absolute pressure records. Hourly records of barometric pressure from the following locations were obtained from the National Weather Service (NWS) for the deployment period: Unalakleet, Nome, Kotzebue, Cape Lisburne, Barrow, Deadhorse, and Barter Island. Measurements at Deadhorse and Unalakleet were available for approximately half the day. Barometric pressure data for periods of data gaps were determined from weather charts produced by the NWS Anchorage Forecast Center "for the Alaskan-region. These weather charts are produced at six-hour intervals. Since no barometric pressure records were readily available for locations close to Thetis Island, Flaxman Island, and Demarcation Bay, barometric pressure data for these stations were also determined from weather charts. Data were interpolated between the six-hour synoptic times of the weather charts.

Time history plots of barometric pressure and gauge pressures corrected for barometric pressure were created to allow quick quality assurance checks of the data. Pressure measurements were converted to the height of water above the pressure sensor by dividing the pressure by the product of a constant density times the acceleration of gravity. Density for the deployment period was estimated from density profile measurements during deployment and retrieval of instruments.

Harmonic Analyses

Harmonic analyses of these pressure records were performed on BC's computer system using a program developed by Dennis and Long

(1971) and adapted to a Digital Equipment Corporation computer system. This program performs harmonic analyses base on work by Schureman (1958). As originally presented in our proposal,Brown and Caldwell intended to perform the harmonic analy sea with the aid of the Rapid Retrieval Data Display (R2D2) software on the Environmental Research Laboratories computer in Boulder Colorado. Since access to this computer system was not available to BC in a timely and cost-efficient manner, the analyses were performed on BC's computer with software very similar to that of the R2D2 system.

RESULTS

This section presents results of the project and discusses data recovery and quality. Data presented in graphical and tabular form in the report are contained on a magnetic tape transmitted with the final report.

Data Recovery and Quality

Each Aanderaa pressure gauge operated correctly during the entire deployment period and recorded accurate pressure data. Since simultaneous records of more than 29 days duration were obtained at each station, harmonic analyses were performed on the same 29-day period for each sampling location.

The instrument at Station 7, offshore of Flaxman Island, was deployed on August 5. The instrument was pulled ashore by someone on August 12. The instrument returned to the shallow water intertidal area on August 20 and recorded tidal fluctuations through August 26. The data then became erratic and was not representative of tidal fluctuations after that data. Approximately 13 days of actual tidal data were recorded by this instrument.

Data from all other stations were valid and had durations of 32 to 35 days at Beaufort stations and 39 to 42 days at Chukchi and Norton stations. The interference with the instrument deployed offshore of Flaxman Island reduced valid data return from 100 to 93 percent.

Time history plots of corrected pressure measurements at Stations 1 through 4 in the Chukchi Sea and Norton Sound are presented on Figures 5 and 6, and similar plots for Stations 5 through 8 in the Beaufort Sea are presented on Figures 7 and 8. Time history plots of near bottom temperatures at these same locations are presented in Figures 9 through 12.

Time history plots show the fluctuations of temperature or pressure around the monthly mean of the data. Pressure plots for the various stations are offset by 2 psi from one another, and temperature plots are offset by 6 degrees C from one another.

Barometric Pressure Data

Measurements of absolute pressure near the ocean bottom were adjusted for barometric pressure. Time histroy plots of barometric pressure used to correct pressure records are presented in Figures 13 through 16. Actual barometric pressure records from Unalakleet, Nome, Kotzebue, Cape Lisburne, and Barrow were obtained from NWS. Since no weather stations were located near the other measurement sites on the Beaufort coast, barometric pressure data were determined from synoptic weather charts at six hour intervals.

Density Profiles

Density profiles were measured just after deployment and prior to recovery of pressure gauges at Stations 1 through 4. These density profiles were used to determine. an average density for the deployment period. This density data were required to convert pressure measurements to a water depth. The average densities used for these conversions were as follows:

Station No.	Location	Density (Sigma-t)
1	Cape Denbigh	1.01750
2	Nome	1.02230
3	Kotzebue	1.02400
4	Ledyard Bay	1.02400
5	Cooper Is.	1.02486
6	Thetis Is.	1.02486
7	Flaxman Is.	1.02486
8	Demarcation Bay	1.02453

Actual density data measured at Stations 1 through 4 during deployment and retrieval cruises are presented in Tables 2 through 9* No density profile measurements were obtained for Stations 5 through 8 because water depths at these stations were very shallow. Density at Stations 5 through 8 were estimated from temperature measurements recorded by the instruments and an assumed salinity.

Harmonic Analysis

Results of harmonic analysis of pressure records are summarized in Table 10. Amplitudes and phases are presented for the primary, harmonic, and secondary tidal constituents. The amplitudes are in centimeters and Greenwich phases are in degrees.

DISCUSSION

The amplitude of tides in the study area were fairly small compared to that previously measured in the eastern Bering Sea, to the South of the present study area. In the eastern Bering Sea, the amplitude of tidal constituents generally ranged from tens of centimeters to approximately a meter (Hood and Calder 1980). The amplitude of the primary tidal constituents for the present study area ranged from a few centimeters to tens of centimeters.

Tidal conditions were significantly different at the eight sampling stations. Tidal fluctuations were largest at Cape Denbigh and smallest at Ledyard Bay.

Tides at Cape Denbign were predominately diurnal with the Luni-solar (K1), principal lunar (01) and solar diurnal (Pi) having the larger amplitudes, as shown in Table 10. The principal semi-diurnal lunar component (M2) had a amplitude similar to that of the solar diurnal component. At Nome, tides were mixed. The principle semi-diurnal lunar component was approximately 10 cm in amplitude, but the three principal diurnal components were predominant, with amplitudes of 5 to 15 cm. In Kotzebue Sound tidal fluctuations were predominately semi-diurnal, with M2 having an average amplitude of 9.7 cm. The largest diurnal component was K1 and it's amplitude was only 2.9 cm.

In Ledyard Bay, tidal fluctuations were almost nil. The principal semi-diurnal lunar component had an amplitude. of 3.0 cm, and the other constituents had even smaller amplitudes. As previously predicted by the tidal circulation model, an amphdromic point for M2 and other constituents are located in Ledyard Bay.

Tides along the entire Beaufort coast were also fairly small and predominantly semi-diurnal. The principal semi-diurnal lunar component (M2) was the largest tidal constituent at all stations on the Beaufort Coast. The amplitude of M2 ranged from 5.1 cm at Cooper Island to 7.2 cm at Demarcation Bay. The amplitude of the diurnal components 01 and K1 were also small at stations on the Beaufort Coast, ranging from 1.2 to 4.3 cm.

Significant nontidal fluctuations were observed in the pressure records. Many of the larger fluctuations with durations of 1 to 2 days were related to storm surge. The barometric pressure plots presented on Figures 13 through 16 illustrate the passage of low pressure systems on August 8 and 18, and 'September 7, 1983. Significant storm surges with magnitudes up to a meter in height were observed in the pressure records. Most of these storm surges were observed throughout the Chukchi and Beaufort Seas, but not in Norton Sound, especially during storms on August 18 and September 7, 1983. These storm surges were associated with the passage of arctic low pressure systems from west to east a couple of hundred miles offshore of the Beaufort coast. These summer storms were not as intense as many of the fall and winter storms which would probably cause larger storm surges.

The pressure records also exhibit longer period fluctuations? such as the general decrease in pressure from August 8 to 18 and the general increase in pressure on the Beaufort coasts and Chukchi Sea in late August. Temperature records also show significant changes during these general changes in pressure, suggesting changes in water characteristics. A cursory inspection of weather charts suggest that these long term pressure fluctuations are related to large scale meteorological events throughout the Bering Sea and Chukchi Sea.

REFERENCES

Dennis, R.E., and E. E. Long. A Users Guide to a Computer Program for Harmonic Analysis of Data at Tidal Frequencies. NOAA Technical Report NOS 41 July 1971

pearson, Carl A., Harold O. Mofield, and Richard B. Tripp. Tides of the Eastern Bering Sea Shelf The Eastern Bering Sea Shelf Oceanography and Resources. Volume 1. editied by Donald W. Hood and John A. Calder 1980

Schureman, Paul Manual of Harmonic Analysis and Prediction of Tides. Special Publication No. 98 Department of Commerce, October, 1971

Table 1. Tide Sampling Locations and Times (GMT)

STA	LOCATION	LAT (N) DEG MIN	LONG (W) DEG MIN	DEPLOYMENT DATE	DEPLOYMENT TIME	RECOVERY DATE	RECOVERY TIME
1	CAPE DENBIGH	64 20.2	161 30.7	AUG 6	1718	SEP 16	0434
2	NOME	64 19.9	165 00.8	AUG 7	0218	SEP 15	0253
3	KOTZEBUE SOUND	67 30.2	165 00.3	AUG 8	0301	SEP 19	0130
4	LEDYARD BAY	69 28.8	165 03.2	AUG 8	1838	SEP 19	1901
5	COOPER ISLAND	71 14.0	155 44.5	AUG 7	2103	SEP 9	1925
6	THETIS ISLAND	70 33.0	150 11.0	AUG 6	0057	SEP 10	0150
7	FLAXMAN ISLAND	70 11.0	145 57.7	AUG 5	2236	SEP 9	0140
8	DENARCATION BAY	69 41.2	141 17.6	AUG 5	2032	SEP 8	2335

Table 2. Density Profile Data After Deployment of Instruments at Station 1

SDS-IIA Lister Program 8006.3

08-AUG-83 08:31:33 Data Base: CTD001.DBS

First Line Absolute Time= 218/ 17:59:10.1 Time Relative to: 218/ 17:59:10

Time	CTD-TEMP DEG-C	CTD-DEPT METERS	CTD-COND [illegible]	SALINITY PPT	SIGMA-T G/CC- 1
17:59:10.1	14.062	1.885	29.922	24.027	17.844
17:59:12.1	14.092	2.114	29.922	24.012	17.827
17:59:14.1	14.099	2.343	29.924	24.006	17.821
17:59:16.1	14.085	2.874	29.969	24.054	17.861
17:59:18.1	14.120	3.443	30.006	24.065	17.863
17:59:20.1	14.123	3.771	30.002	24.059	17.858
17:59:22.1	14.126	4.439	29.986	24.043	17.845
17:59:24.1	14.125	4.943	29.995	24.052	17.852
17:59:26.1	14.127	5.337	30.004	24.058	17.857
17:59:28.1	14.125	5.877	30.036	24.087	17.879
17:59:30.1	14.127	6.472	30.033	24.083	17.876
17:59:32.1	14.124	6.939	30.001	24.057	17.856
17:59:34.1	14.128	7.433	30.002	24.055	17.854
17:59:36.1	14.129	7.900	30.018	24.068	17.864
17:59:38.1	14.125	8.459	30.020	24.073	17.868
17:59:40.1	14.125	9.081	30.025	24.077	17.872
17:59:42.1	14.124	9.392	30.021	24.073	17.869
17:59:44.1	14.130	10.097	30.065	24.109	17.896
17:59:46.1	14.144	10.509	30.079	24.112	17.895
17:59:48.1	14.147	11.004	30.076	24.108	17.891
17:59:50.1	14.150	11.439	30.073	24.103	17.887
17:59:52.1	14.148	12.093	30.062	24.095	17.881
17:59:54.1	14.147	12.532	30.059	24.092	17.879
17:59:56.1	14.147	12.908	30.062	24.095	17.881
17:59:58.1	14.148	13.476	30.074	24.104	17.889
18:00:00.1	14.148	13.604	30.075	24.105	17.889

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Table 3. Density Profile Data Before Retrieval of Instruments at Station

DIGITAL DATA LOGGER DUMP PAGE NO.

PROGRAM: DDL2 8006.20 SHIP: S132 READ FROM MT0: FILE NO. 2 PFREQ: 16 00—00 00:01:5

RECORD	SI	DEPTH METERS	CONDUCTVTY M-MHO	TEMPERATURE DEG-C	SOUND VEL M/SECOND	SALINITY PER-MILLE	DENSITY SIGMA-T	SOUND VEL. METERS/SEC
1	11	2.45	24.89	9.444	14.811	22.202	17.096	1472.0
2	11	2.60	24.87	9.444	14.812	22.182	17.081	1472.0
3	11	2.60	24.86	9.444	14.812	22.173	17.073	1471.9
4	11	2.60	24.86	9.444	14.812	22.173	17.073	1471.9
5	11	2.75	24.87	9.444	14.812	22.182	17.081	1472.0
6	11	2.90	24.87	9.444	14.812	22.182	17.081	1472.0
7	11	2.75	24.87	9.444	14.812	22.182	17.081	1472.0
8	11	2.90	24.88	9.444	14.813	22.192	17.088	1472.0
9	11	2.75	24.86	9.444	14.812	22.173	17.073	1471.9
10	11	2.75	24.86	9.444	14.912	22.173	17.073	1471.9
11	11	2.75	24.85	9.444	14.813	22.163	17.065	1471.9
12	11	3.04	24.87	9.434	14.813	22.189	17.087	1471.9
13	11	2.90	24.86	9.444	14.813	22.173	17.073	1471.9
14	11	3.19	24.96	9.444	14.813	22.172	17.073	1471.9
15	11	3.94	24.99	9.444	14.814	22.202	17.095	1472.0
16	11	4.98	24.90	9.434	14.813	22.217	17.109	1472.0
17	11	6.32	24.90	9.424	14.814	22.223	17.115	1472.0
18	11	7.80	24.95	9.404	14.814	22.284	17.165	1472.0
19	11	9.14	26.03	9.474	14.813	23.302	17.945	1473.6
20	11	10.63	26.05	9.604	14.913	23.237	17.876	1474.0
21	11	10.93	26.06	9.654	14.814	23.215	17.851	1474.2
22	11	12.27	26.06	9.664	14.814	23.208	17.845	1474.2
23	11	12.12	26.07	9.664	14.814	23.218	17.852	1474.2
24	11	12.42	26.07	9.664	14.814	23.218	17.852	1474.2
25	11	12.42	26.08	9.664	14.814	23.227	17.860	1474.3
26	11	12.27	26.08	9.664	14.814	23.227	17.860	1474.2
27	11	12.57	26.08	9.664	14.814	23.227	17.860	1474.3
28	11	12.42	26.07	9.664	14.814	23.218	17.852	1474.2
29	11	12.42	26.06	9.664	14.814	23.208	17.845	1474.2
30	11	12.42	26.07	9.664	14.814	23.218	17.852	1474.2
31	11	12.42	26.06	9.664	14.814	23.208	17.845	1474.2
32	11	12.57	26.07	9.664	14.814	23.217	17.852	1474.2

TAPE MARK

TAPE MARK

Table 4. Density Profile Data After Deployment of Instruments at Station 2

SDS-IIA Lister Program 8006.3

00--00 00:34:27 Data Base; CTD002.DBS

First Line Absolute Time= 219/ 2:40:42.0 Time Relative to: 219/ 2:40:42

Time	CTD-TEMP DEG-C	CTD-DEPT METERS	CTD-COND MS-CM	SALINITY PPT	SIGMA-T G/CC- 1
02:40:42.0	11.648	1.702	33.751	29.259	22.321
02:40:44.0	11.588	2.004	33.765	29.313	22.378
02:40:46.0	11.639	1.501	33.668	29,186	22.266
02:40:48.0	11.720	1.180	33.633	29.089	22.177
02:40:50.0	11.674	1.733	33.724	29.212	22.280
02:40:52.0	11.626	1.845	33.688	29.215	22.291
02:40:54.0	11.710	1.382	33.615	29.079	22.171
02:40:56.0	11.754	1.400	33.552	28.985	22.090
02:40:58.0	11.817	1.839	33.616	28.997	22.090
02:41:00.0	11.739	1.592	33.655	29.095	22.179
02:41:02.0	11.724	1.482	33.572	29.027	22.128
02:41:04.0	- 11.738	1.519	33.580	29.025	22.124
02:41:06.0	11.721	1.775	33.618	29.074	22.166
02:41:08.0	11.720	1.546	33.542	29.002	22.109
02:41:10.0	11.729	1.491	33.569	29.021	22.122
02:41:12.0	11.756	1.574	33.565	28.995	22.098
02:41:14.0	11.768	2.196	33.649	29.067	22.152
02:41:16.0	11.651	2.434	33.839	29.341	22.385
02:41:18.0	11.516	2.993	33.865	29.473	22.510
02:41:20.0	11.504	3.661	33.898	29.514	22.543
02:41:22.0	11.453	4.210	33.937	29.592	22.613
02:41:24.0	11.435	4.577	33.944	29.613	22.632
02:41:26.0	11.457	5.740	33.954	29.604	22.621
02:41:28.0	11.455	6.921	34.008	29.658	22.664
02:41:30.0	11.445	7.534	34.049	29.706	22.703
02:41:32.0	11.486	8.724	34.270	29.886	22.836
02:41:34.0	11.554	10.024	34.447	30.002	22.916
02:41:36.0	11.582	10.802	34.471	30.002	22.912
02:41:38.0	11.597	11.644	34.486	30.004	22.911
02:41:40.0	11.604	12.835	34.546	30.056	22.951
02:41:42.0	11.575	13.677	34.561	30.094	22.985
02:41:44.0	11.565	14.885	34.545	30.086	22.980
02:41:46.0	11.540	15.700	34.513	30.075	22.975
02:41:48.0	11.498	16.414	34.504	30.101	23.002
02:41:50.0	11.497	17.650	34.489	30.086	22.991
02:41:52.0	11.479	18.914	34.488	30.099	23.004
02:41:54.0	11.474	19.362	34.489	30.104	23.009
02:41:56.0	11,447	20.214	34.494	30.130	23.034
02:41:58.0	11.427	21.687	34.513	30.164	23.063
02:42:00.0	11.452	22.685	34.545	30.174	23.067

Table 5. Density Profile Data Before Retrieval of instruments at Station 2

DIGITAL DATA LOGGER DUMP

PAGE NO.

PROGRAM: DDL2 8006.20 SHIP: S132 READ FROM MT0: FILE NO. 1 PFREQ: 16 00—00 00:01:36

RECORD	SI	DEPTH METERS	CONDUCTVTY M-MHO	TEMPERATURE DEG-C	SOUND VEL M/SECOND	SALINITY PER-MILLE	DENSITY SIGMA-T	SOUND VEL. METERS/SEC
1	11	2.45	30.82	9.904	14.810	27.747	21.327	1480. 7
2	11	2.90	30.85	9.954	14.810	27.738	21.313	1 480.9
3	11	2.75	30.85	9.944	14.811	27.746	21.320	1 480.8
4	11	2.75	30.82	9.914	14.811	27.739	21.320	1480.7
5	11	2.90	30.82	9.904	14.811	27.747	21.327	1480.7
6	11	2.75	30.98	9.964	14.811	27.761	21.328	1480.9
7	11	2.90	30.82	9.904	14.811	27.747	21.327	1480.7
8	11	2.75	30.82	9.904	14.811	27.747	21.327	1480.7
9	11	3.04	30.91	9.914	14.811	27.729	21.312	1480.7
10	11	2.60	30.82	9.894	14.812	27.755	21.335	14S9.6
11	11	2.90	30.83	9.944	14.812	27.726	21.30[illegible]	1480.8
12	11	2.90	30.82	9.894	14.811	27.754	21.335	1480.7
13	11	2.60	30.82	9.894	14.811	27.756	21.335	1420.6
14	11	2.90	30.81	9.884	14.812	27.752	21.335	1480.6
15	11	3.04	30.82	9.884	14.812	27.762	21.342	1480.6
16	11	4.53	30.83	9.914	14.812	27.748	21.327	1480.7
17	11	5.42	30.83	9.934	14.811	27.733	21.311	1480.8
18	11	6.76	30.79	9.964	14.812	27.746	21.333	1480.6
19	11	7.80	30.82	9.954	14.812	27.783	21.363	1420.6
20	11	8.85	30.85	9.864	14.812	27.805	21.379	1480.7
21	11	10.04	30.91	9.884	14.812	27.849	21.410	1480.8
22	11	11.37	30.95	9.904	14.812	27.873	21.425	1481 .0
23	11	12.86	30.97	9.904	14.812	27.892	21.440	1481.0
24	11	13.76	31.07	9.914	14.813	27.984	21.509	1481.2
25	11	15.24	31.10	9.934	14.812	27.998	21.517	1481.3
26	11	16.28	31.12	9.934	14.813	28.017	21.532	14s163
27	11	17.77	31.33	9.984	14.812	28.187	21.656	1481. 8
28	11	18.81	31.39	10.034	14.812	28.207	21.663	1482.0
29	11	20.45	31.50	10.034	14.812	28.316	21.748	14s2.2
30	11	21.79	31.53	10.034	14.813	28.346	21.770	1422.2
31	11	23.13	31.54	10.034	14.813	28.355	21.778	1482.3
32	11	24.76	31.55	10.024	14.813	28.372	21.793	1482.3
33	11	25.66	31.56	10.034	14.813	28.374	21.792	1482.3
34	11	27.59	31.56	10.034	14.813	28.373	21.792	1482.3
35	11	28.63	31.57	10.034	14.812	28.383	21.799	14s2,4
36	11	29.52	31.57	10.034	14.813	28.382	21.799	1482.4
37	11	31.46	31.62	10.044	14.813	28.423	21.829	1412.5
38	11	32.35	31.66	10.064	14.813	28.447	21.844	422.6
39	11	33.84	31.67	10.064	14.814	28.457	21.852	1422.7
40	11	34.58	31.68	10.064	14.813	28.466	21.659	1482.7
41	11	34.89	31.68	10.064	14.813	28.466	21.859	1482.7
42	11	34.43	31.67	10.064	14.813	28.456	21.851	14s2.7
43	11	34.58	31.67	10.064	14.813	28.456	21.851	1482.7

Table 6. Density Profile Data After Deployment of Instruments at Station 3

SDS-119 Lister Program 8006.3

08-AUG-83 08:22:56

Data Base: CTD003.DBS

First Line Absolute Time= 220/ 3:18:12.0 Time Relative to: 220/ 3:18:12

Time	CTD-TEMP DEG-C	CTD-DEPT METERS	CTD-COND MS-CM	SALINITY PPT	SIGMA-T G/CC-1
03:19:02.0	11.109	1.592	35.019	30.929	23.712
03:19:04.0	11.110	1.931	35.018	30.927	23.710
03:19:06.0	11.110	2.370	35.023	30.932	23.714
03:19:08.0	11.110	2.599	35.022	30.931	23.713
03:19:10.0	11.110	3.222	35.021	30.930	23.712
03:19:12.0	11.110	3.835	35.822	30.931	23.713
03:19:14.0	11.110	3.835	35.022	30.930	23.712
03:19:16.0	11.110	4.751	35.023	30.931	23.713
03:19:18.0	11.110	5.373	35.025	30.934	23.715
03:19:20.0	11.110	5.758	35.023	30.931	23.717
03:19:22.0	11.110	6.518	35.025	30.933	23.715
03:19:24.0	11.111	7.360	35.023	30.930	23.713
03:19:26.0	11.111	7.781	35.026	30.933	23.714
03:19:28.0	11.109	8.568	35.031	30.938	23.719
03:19:30.0	11.109	9.466	35.032	30.940	23.720
03:19:32.0	11.102	9.?58	35.043	30.956	23.734
03:19:34.0	11.106	10.637	35.086	30.995	23.764
03:19:36.0	11.109	11.599	35.115	31.020	23.783
03:19:38.0	11.109	11.846	35.115	31.020	23.783
03:19:40.0	11.107	13.009	35.123	31.029	23.790
03:19:42.0	11.106	13.750	35.127	31.033	23.794

Table 7. Density Profile Data Before Retrieval of Instruments at Station 3

DIGITAL DATA LOGGER DUMP — PAGE NO.

PROGRAM: DDL2 8006.20 — SHIP: S132 — READ FROM MT0: — FILE NO. 3 — PFREQ: 16 — 00--00 00:02:10

RECORD	SI	DEPTH METERS	CONDUCTVTY M-MHO	TEMPERATURE DEG-C	SOUND VEL M/SECOND	SALINITY PER-MILLE	DENSITY SIGMA-T	SOUND VEL. METERS/SEC
1	11	2.30	30.55	6.6s3	14.810	30.139	23.658	1471.2
2	11	2.45	30.54	6.653	14.810	30.128	23.649	1471.2
3	11	2.30	30.53	6.643	14.811	30.126	23.649	1471.1
4	11	2.30	30.52	6.643	14.810	30.115	23.641	1471.1
5	11	2.15	30.52	6:643	14.811	30.115	23.641	1471.1
6	11	2.30	38.52	6.633	14.810	30.124	23.649	1471.1
7	11	2.30	30.52	6.633	14.811	30.124	23.649	1471.1
8	11	2.30	30.52	6.643	14.811	30.115	23.641	1471.1
9	11	2.30	30.52	6:643	14.911	30.5115	23.641	1471.1
10	11	2.15	30.52	6.633	14.811	30.124	23.649	1471.1
11	11	2.30	30.52	6.633	14.811	30.124	23.649	1471.1
12	11	2.30	30.52	6.643	14.811	30.115	23.641	1471.1
13	11	2.45	30.52	6.633	14.812	30.124	23.649	1471.1
14	11	2.75	30.53	6.633	14.911	30.135	23.657	1471.1
15	11	4.38	38.53	6.643	14.812	39.12S	23.648	1471.1
16	11	5.72	30.53	6.643	14.811	30.124	23.648	1471.2
17	11	6.91	30.53	6:643	14.811	30.124	23.647	1471.2
18	11	8.10	30.53	6.643	14.811	30.123	23.647	1471.2
19	11	9.74	30.53	6.593	14.812	30.167	23.687	1471.1
20	11	11.08	30.49	6.503	14.812	30.202	23.726	1470.8
21	11	12.42	30.49	6.433	14.811	30.263	23.783	1470.6
22	11	13.76	30.46	6.363	14.812	30.292	23.814	1470.4
23	11	15.09	30.44	6.303	14.812	30.323	23.846	1470.2
24	11	16.58	30.36	6.233	14.812	30.296	23.833	1469.9
25	11	17.77	30.14	5.622	14.812	30.600	24.145	1467.0
26	11	19.26	30.28	5.242	14.812	31.107	24.529	1467.0
27	11	20.45	30.32	5.322	14.812	31.079	24.556	1467.3
28	11	21.79	30.26	5.282	14.812	31.046	24.535	1467.1
29	11	23.13	30.26	5.252	14.812	31.$373	24.560	1467.0
30	11	24.47	30.25	5.242	14.813	31.071	24.559	1467.0
31	11	25.95	30.24	5.192	14.812	31.105	24.592	1466.9
32	11	27.29	30.01	5.082	14.812	30.945	24.477	1466.2
33	11	28.63	30.00	4.252	14.812	31.147	24.662	1465.6
34	11	29.52	30.00	4.922	14.813	31:175	24.687	1465.5
35	11	30.57	30.00	4.812	14.813	31.184	24.695	1465.5
36	11	31.16	30.00	4.812	14.813	31.184	24.695	1465.5
37	11	32.20	29.99	4.S12	14.813	31.172	24.685	1465.5
38	11	32.35	29.99	4.802	14.812	31.181	24.694	1465.5

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Table 8, Density Profile Data After Deployment of Instruments at Station 4

SDS-IIA Lister Program 8006.3

08-AUG-83 00:02:09

Data Base: CTD004,DBS

First Line Absolute Time= 220/ 20:18:38.0 Time Relative to: 220/ 20:18:38

Time	CTD-TEMP DEG-C	CTD-DEPT METERS	CTD-COND MS-CM	SALINITY PPT	SIGMA-T G/CC-1
20:18:38.0	7.507	2.343	30.686	29.546	23.135
20:18:40.0	7.508	2.554	30.689	29.549	23.137
20:18:42.0	7.506	2.819	30.685	29,546	23.135
20:18:44.0	7.506	3:084	30.689	29.550	23.138
20:18:46.0	7.507	3.487	30.639	29.549	23.137
20:18:48.0	7.511	3.579	30.687	29.544	23.133
20:18:50.0	7.509	3.991	30.685	29.543	23.133
20:18:52.0	7.505	4.229	30.682	29.544	23, 133
20:18:54.0	7.504	4.467	30.684	29.546	23.135
20:18:56.0	7.503	4.842	30.G83	29:545	23.135
213: 18:58.0	7.503	5.108	30.679	29.542	23.132
20:19:00.0	7.487	5.346	30'.677	29.553	23.143
20:19:02.0	7.486	5.602	30.676	29.552	23.142
20:19:04.0	7.485	5.932	30.679	29.556	23.145
20:19:06.0	7.487	6.206	30.678	29.553	23.143
20:19:08.0	7.486	G.5?3	30.680	29.556	23.145
20:19:10.0	7.490	6.655	30.682	29.5$4	23.143
20:19:12.0	7.488	7.150	30.680	29.5$4	23.144
20:19:14.0	7.488	7.396	30.680	29.554	23.144
20:19:16.0	7.489	7.662	30.681	29.554	23.143
20:19:18.0	7.488	7.SS2	30.680	29.554	23.143
20:19:20.0	7.487	8.275	30.677	29.552	23.142
20:19:22.0	7.483	8.605	30.671	29.547	23.139
20:19:24.0	7.432	8.770	30.669	29.590	23.178
20:19:26.0	7.427	9.145	30.666	29.590	23.179
20:19:28.0	7.407	9 .:::	30.6S7	29.598	23.188
20:19:30.0	7.423	9	30.650	29.576	23.169
20:19:32.0	7.403	9:978	30.642	29.585	23.178
20:19:34.0	7.371	10.226	30.633	29.603	23.196
20:19:36.0	7.336	10.436	30.618	29.617	23.211
20:19:38.0	7.237	10.931	30.598	29.679	23.272
20:19:40.0	7.1?2	11.068	30.581	29.717	23.310
20:19:42.0	7.123	11.470	30.649	29.832	23.405
20:19:44.0	7.087	11.608	30.721	29.941	23.496
20:19:46.0	7.099	11.983	31.022	30.255	23.742
20:19:48.0	7.393"	12.258	31.934	"30.978	24.275
20:19:50.0	7.826	12.478	32.158	30.856	24.125
20:19:52.0	8.002	12.743	32.044	30.557	23.867
20:19:54.0	7.431	13.063	31.321	313.285	23.725
20:19:56.0	6.366	13.347	313.3713	30.190	23.774
20:19:58.0	5.654	13.567	30.323	30.780	24.316
20:20:00.0	5.242	14.034	29.457	30.175	23.880
20:20:02.0	4.450	14.180	29.087	30.476	24.193
20:20:04.0	4.188	14.491	29.316	30.986	24.622
20:20:06.0	4.363	14.638	29.485	31.019	24.632
20:20:08.0	4.446	15.096	29.561	31.030	24.633

Table 8. Density Profile Data After Deployment of Instruments at Station 4 (cont'd)

SDS-119 Lister Program 8006.3

08-AUG-83 00:02:34 Data Base: CTD004.DBS

First Line Absolute Time= 220/ 20:20:10.0 Time Relative to: 220/ 20:18:38

Time	CTD-TEMP DEG-C	CTD-DEPT METERS	CTD-COND MS-CM	SALINITY PPT	SIGMA-T G/CC-1
20:20:10.0	4.450	15.324	29. 586	31.054	24.651
20:20:12.0	4.403	15.599	29.508	31.007	24.619
20:20:14.0	4.324	15.901	29.461	31.027	24.642
20:20:16.0	4.205	16:148	29.332	30.989	24.622
20:20:18.0	4.146	16.368	29.322	31.033	24.662
20:20:20.0	4.076	16.771	29. 27%	31.047	24.680
20:20:22.0	4.077	16.945	29.293	31.064	24.693
20:20:24.0	4.071	17.211	29.277	31.051	24.683
20:20:26.0	4.066	17.677	29.288	31.067	24.697
20:20:28.0	4.066	17..696	29.307	31.090	24.714
20:20:30.0	4.050	18.172	29.286	31.080	24.708
20:20:32.0	4.067	18.337	29.292	31.071	24.700
20:20:34.0	4.059	18.712	29.328	31.121	24.739
20:20:36.0	4.066	18,978	29.331	31.118	24.737
20:20:38.0	4.066	19.216	29.387	31.183	24.789
20:20:40.0	4.048	19.527	29.381	31.194	24.799
20:20:42.0	4.010	19.737	29.296	31.129	24.751
20:20:44.0	3.807	20.094	28.957	30.923	24:605
20:20:46.0	3.614	20.333	28.853	30.983	24.668
20:20:48.0	3.286	20.781	28.571	30.960	24.677
20:20:50.0	3.130	20.992	28.474	30 .993	24.715
20:20:52.0	2.834	21.284	28.299	31.067	24-.796
20:20:54.0	2.649	21.468	28.167	31.'087	24.826
20:20:56.0	2.550	21.413	28.156	31.170	24.899
20:20:58.0	2.253	22.04S	27.714	30.918	24.718
20:21:00.0	2.027	22.374	27.519	30.897	24.717
20:21:02.0	1.784	22.603	27:360	30.938	24:765
20:21:04.0	1.358	22.859	26.988	30.890	24.752
20:21:06.0	1.153	23.106	26 .9136	30.990	24.844
20:21:08.0	1.005	23.518	26.782	30.980	24.843
20:21:10.0	0.863	23.747	26.745	31.076	24.928
20:21:12.0	0.785	23.994	26.704	3 .102	24.952
20:21:14.0	0.768	24.315	26.694	3 .105	24.956
20:21:16.0	0.764	24.626	26.672	3 .081	[illegible]
20:21:18.0	0.?'17	24.956	26.674	3 .130	[illegible]
20:21:20.0	0.699	25.056	26.654	3 .124	24.974
20:21:22.0	0. 687	25.322	26.611	31.080	24.940
20:21:24.0	0.686	25. 624	26.614	31.085	24.944
20:21:26.0	0.687	25. 826	26.622	31.094	24.951
20:21:28.0	0.683	26:027	26.614	31.088	24.946
20:21:30.0	0.627	26.448	26.607	31.134	24.986
20:21:32.0	0.628	26.530	26,631	31.165	25.010
20:21:34.0	8.626	26.832	26.611	31.142	24.992

Table 9. Density Profile Data Before Retrieval of Instruments at Station 4

DIGITAL DATA LOGGER DUMP

PAGE NO.

PROGRAM: DDL2 8006.20 SHIP: S132 READ FROM MT0: FILE NO. 4 PFREQ: 16 00—00 00:02:3

RECORD	SI	DEPTH METERS	CONDUCTVTY M-MHO	TEMPERATURE DEG-C	SOUND VEL M/SECOND	SALINITY PER-MILLE	DENSITY SIGMA-T	SOUND VEL. METERS/SEC
1	11	2.45	29.57	5.602	14.807	29.995	23.663	1466.7
2	11	2.60	29.59	5.602	14.807	30.008	23.680	1466.7
3	11	2.75	29.59	5.612	14.807	29.999	23.672	1466.8
4	11	2.45	29.57	5.602	14.807	29.985	23.663	1466.7
5	11	2.45	29.57	5.602	14.807	29.995	23.663	1466.7
6	11	2.45	29.57	5.602	14.807	29.995	23.663	1466.7
7	11	2.60	29.60	5.632	14.808	29.992	23.665	1466.8
8	11	2.60	29.59	5.632	14.807	29.991	23.656	1466.8
9	11	2.75	29.57	5.622	14.807	29.957	23.646	1466.8
10	11	2.75	29.59	5.612	14.808	29.999	23.672	1466.8
11	11	3.64	29.77	5.682	14.808	30.137	23.773	1467.3
12	11	5.13	29.76	5.742	14.807	30.072	23.715	1467.4
13	11	6.61	29.79	5.762	14.808	30.087	23.724	1467.6
14	11	8.10	29.81	5.792	14.809	30.091	23.725	1467.7
15	11	9.74	29.83	5.802	14.809	30.094	23.726	1467.8
16	11	11.23	29.84	5.812	14.808	30.096	23.726	1467.9
17	11	12.71	29.84	5.812	14.808	30.095	23.725	1467.9
18	11	14.50	29.89	5.822	14.808	30.141	23.760	1468.0
19	11	16.59	29.91	5.832	14.809	30.154	23.769	1468.1
20	11	18.96	30.01	5.812	14.809	30.282	23.872	1468.2
21	11	20.90	30.12	5.882	14.808	30.341	23.911	1468.6
22	11	22.99	30.63	5.972	14.808	30.827	24.283	1469.7
23	11	25.21	30.81	6.273	14.809	30.753	24.189	1470.8
24	11	27.29	30.72	6.313	14.809	30.617	24.076	1470.8
25	11	28.93	30.66	6.193	14.808	30.658	24.123	1470.4
26	11	30.57	30.67	6.133	14.808	30.723	24.181	1470.3
27	11	31.61	30.65	6.123	14.809	30.720	24.180	1470.3
28	11	31.61	30.66	6.123	14.809	30.730	24.180	1470.3
29	11	31.76	30.65	6.113	14.808	30.718	24.180	1470.2
30	11	31.76	30.65	6.123	14.809	30.709	24.171	1470.2
31	11	31.76	30.65	6.123	14.809	30.709	24.171	1470.2
32	11	31.61	30.65	6.123	14.809	30.709	24.171	1470.2
33	11	31.61	30.66	6.123	14.808	30.720	24.180	1470.3
34	11	31.76	30.64	6.123	14.809	30.698	24.163	1470.2
35	11	31.61	30.65	6.123	14.809	30.709	24.171	1470.2
36	11	31.61	30.65	6.113	14.809	30.718	24.180	1470.2
37	11	31.61	30.65	6.123	14.808	30.709	24.171	1470.2

Table 10. Amplitude (H) in Centimeters and Greenwich Epoch (G) in Degrees for Harmonic Constants

STATION	1		2		3		4		5		6		8	
LOCATION	CAPE DENBIGH		NOME		KOTZEBUE SOUND		LEDYARD BAY		COOPER ISLAND		THETIS ISLAND		DEMARCATION BAY	
	DEG	MIN	DEG	MIN	DEG	MIN	DEG	MIN	DEG	MIN	DDEG	MIN	DEG	MIN
LATITUDE (N)	64	20.2	64	19.9	67	30.2	69	28.8	71	14.0	70	33.0	69	41.2
LONGITUDE (W)	161	30.7	165	00.8	165	00.3	165	03.2	155'	44.5	150	11.0	141	17.6
HARMONIC CONSTANTS	H	G	H	G	H	G	H	G	H	G	H	G	H	G
PRIMARY CONSTITUENTS														
M2	16.4	264	10.2	029	9.7	274	3.0	268	5.1'	264	6.5	272	7.2	266
N2	5.0	212	3.3	346	2.1	20'7	1.9	246	0.5	232	0.1	250	0.9	270
S2	3.6	004	2.2	118	2.5	348	1.3	192	2.6	325	3.3	316	3.1	306
O1	25.4	077	10.0	073	1.8	149	0.4	167	1.2	182	4.3	180	2.5	162
K1	43.9	127	15.5	130	2.9	058	1.3	085	2.8	210	2.2	148	3.0	126
HARMONICS														
M4	0.3	279	0.4	170	0.2	009	'0.4	203	0.3	339	0.2	182	0.1	180
M6	0.3	029	0.5	075	0.2	316	0.0	085	0.1	162	0.0	284	0*0	259
M8	0.0	030	0.1	209	0.1	207	0.0	168	0.1	308	0.1	128	0.1	327
S4	0.2	352	0.3	267	0.1	058	0.2	147	0.3	080	0.3	195	0.1	050
S6	0.1	213	0.1	246	0.0	118	0.0	135	0.1	102	0.1	205	0:1	037
SECONDARY CONSTITUENTS														
J1	2.0	152	0.8	157	0.1	013	0.0	044	0.1	225	0.3	132	0*2	108
K2	1.0	004	0.6	118	0.7	348	0.3	192	0.7	325	0.9	316	0.9	309
L2	0.5	315	0.3	072	0.3	342	0.1	290	0.1	295	0.2	293	0.2	274
MI	1.8	102	0.7	101	0.1	103	0.0	126	0.1	196	0.3	164	0.2	144
2N	0.7	161	0.4	304	0.3	140	0.3	225	0.1	201	0.1	228	O*1	250
OO	1.0	177	0.4	186	0.1	328	0.0	003	0.1	239	0.2	116	081	089
P1	14.5	127	5.1	130	0.9	058	0.4	085	0.9	210	0.7	148	1.0	126
Q1	4.9	053	1.9	045	0.3	194	0.1	208	0.2	167	0.8	196	0.5	180
2Q	0.7	028	0.3	017	0.0	239	O*O	250	0.0	308	0.1	212	0.1	196
R2	0.0	004	000	118	0.0	348	O*O	192	0.0	325	0.0	316	0.0	309
T2	0.2	004	0.1	118	0.1	348	001	192	0.2	325	0.2	316	0.2	309
LAMBDA	0.1	310	0.1	070	0.1	309	0*0	233	0.0	292	0.0	292	0.1	286
NU2	1.0	219	0.6	352	0.4	216	0.4	249	-0*1	237	0.2	253	0.2	259
RHO1	1.0	217	0.4	049	0.1	187	0.0	,203	0.0	169	0.2	194	0.1	319

NOTE: ALL RECORDS BEGIN ON AUGUST 9, 1983 AT 1100 GMT AND ARE 29 DAYS IN DURATION

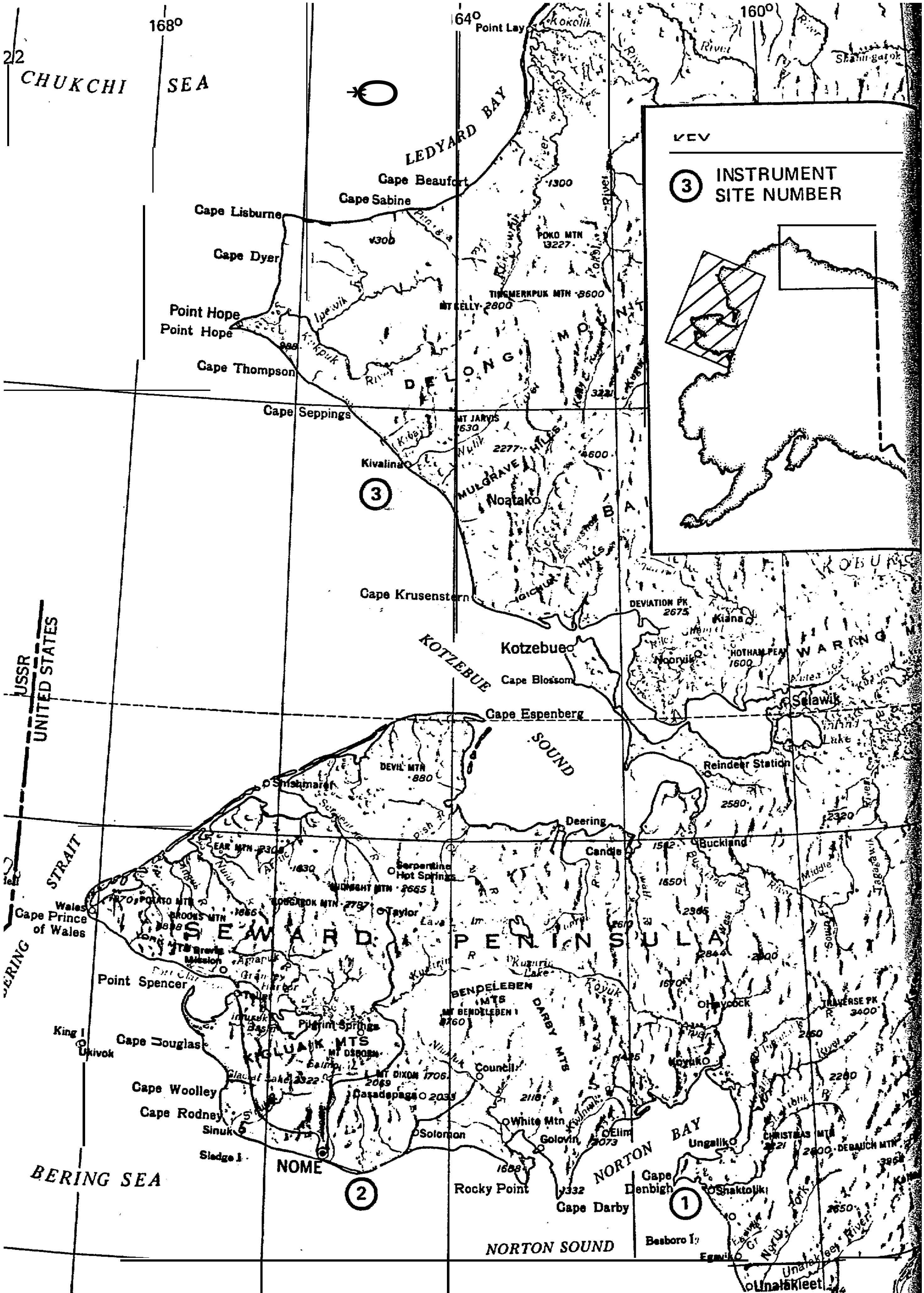


Figure 1 Norton Sound and Chukchi Sea Instrument Sites

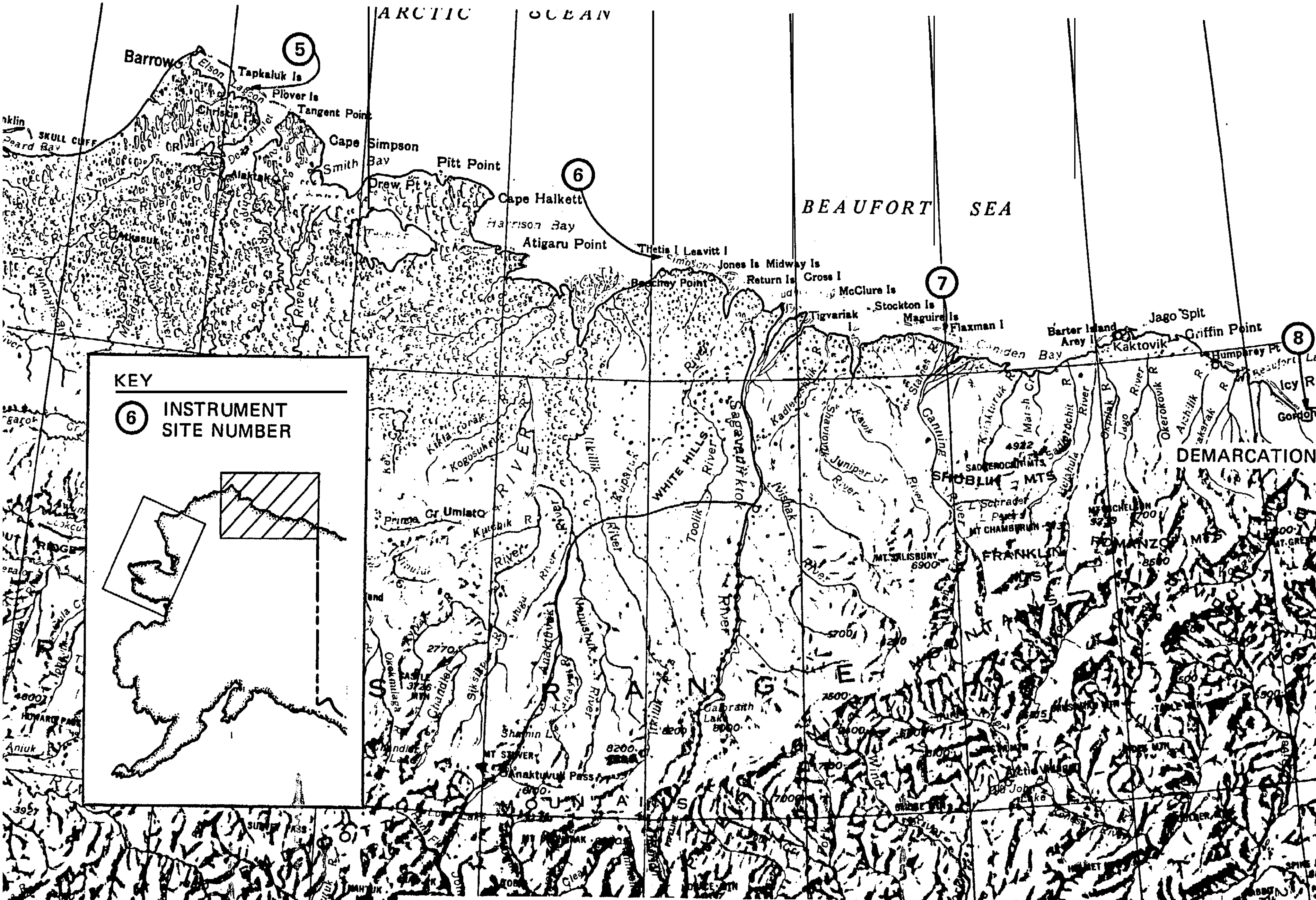


Figure 2 Beaufort Sea Instrument Sites

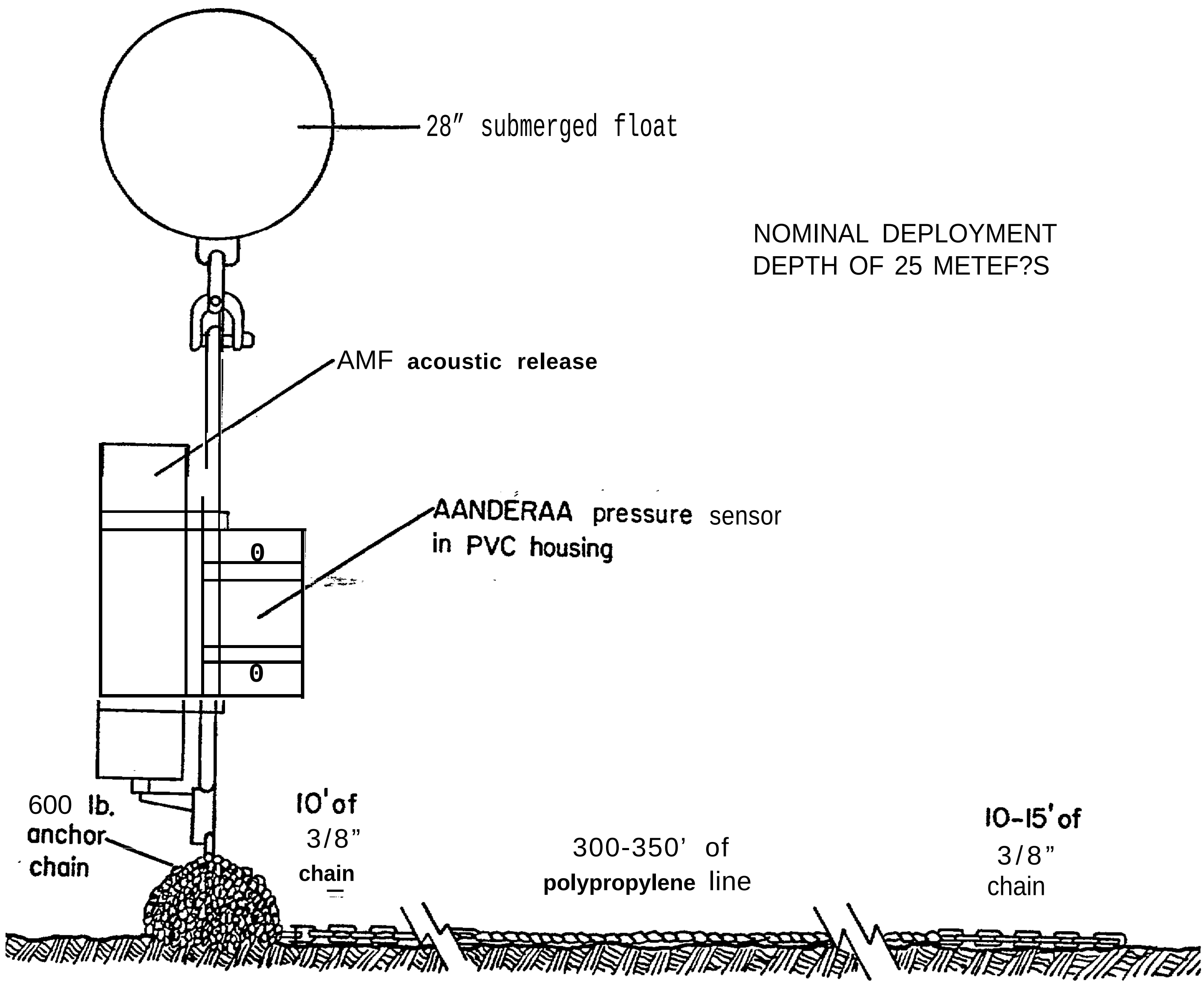


Figure 3 Mooring Design for Norton Sound and Chukchi Sea Deploymen

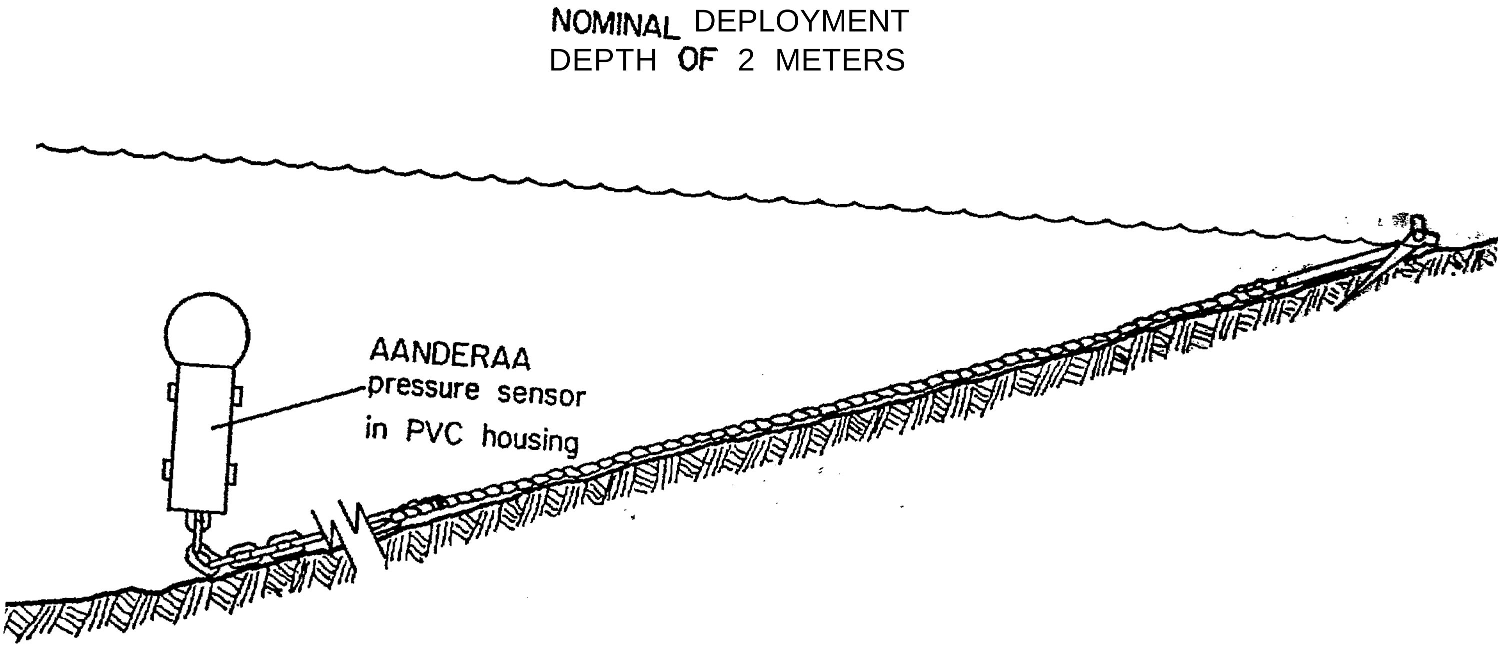


Figure 4 Mooring Design for Beaufort Sea Deployments

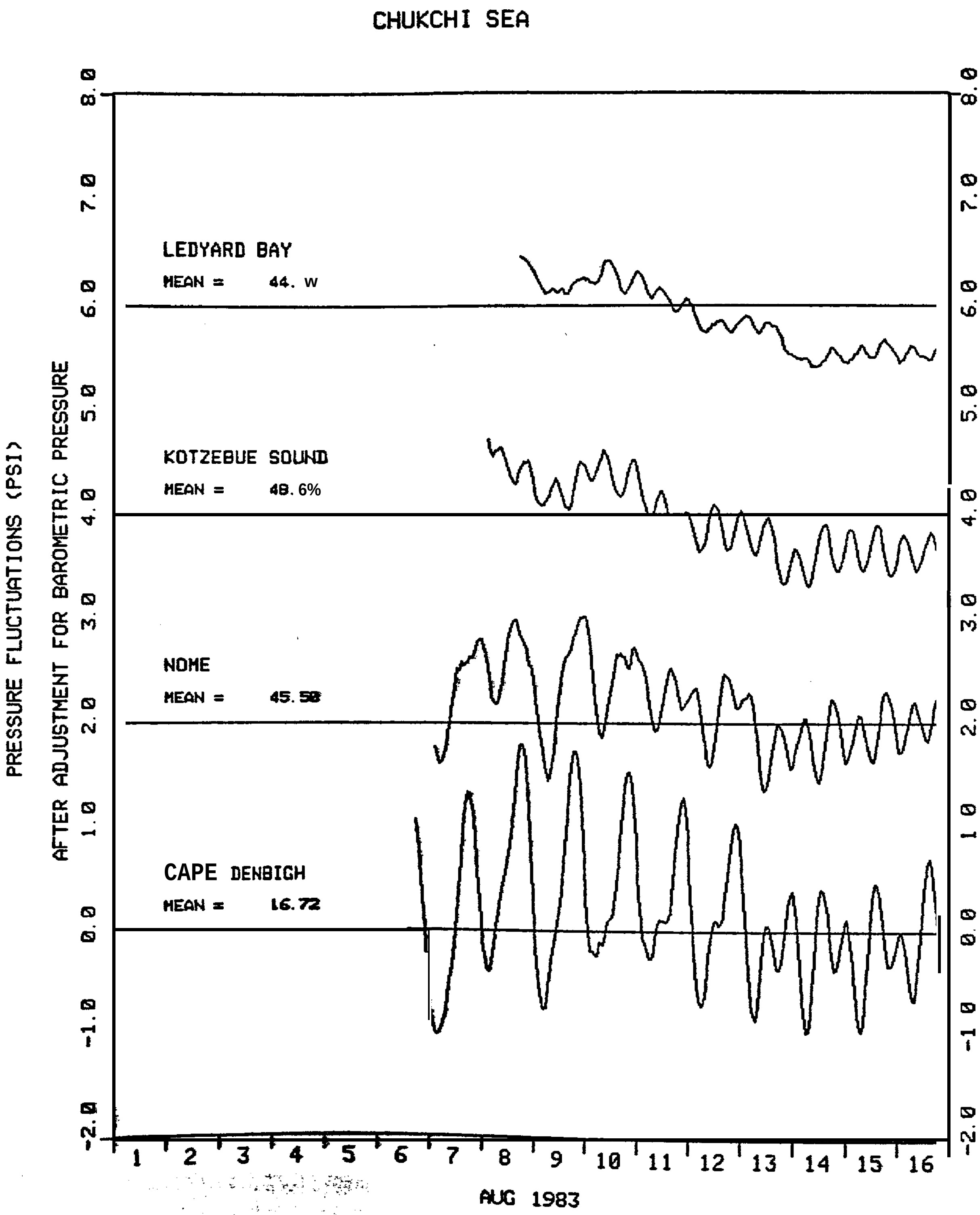


Fig. 5. Pressure Fluctuations About the Monthly Mean at Stations 1 through 4 in August 1983

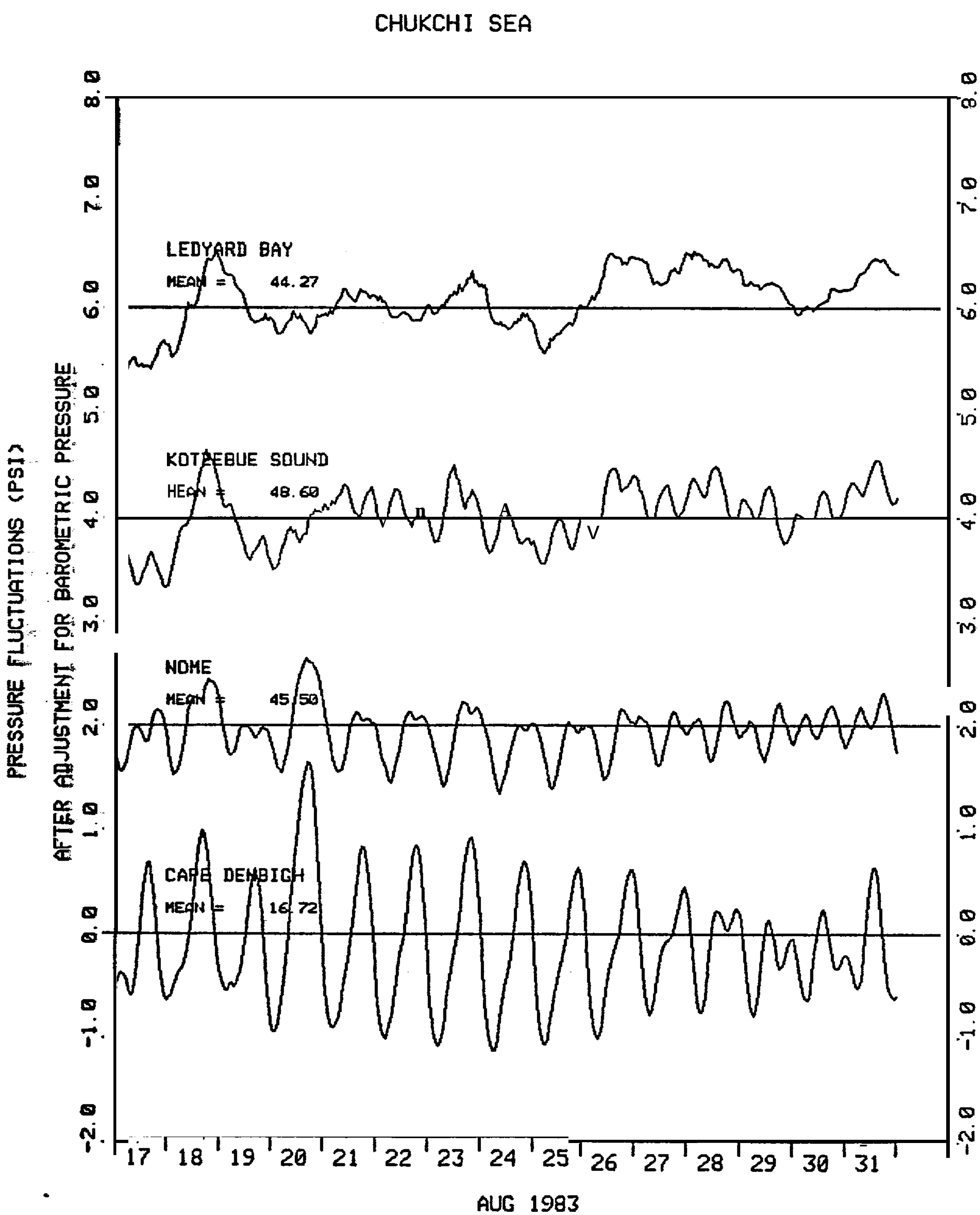


Fig. 5. Pressure Fluctuations About the Monthly Mean at Stations 1 through 4 in August 1983 (contd)

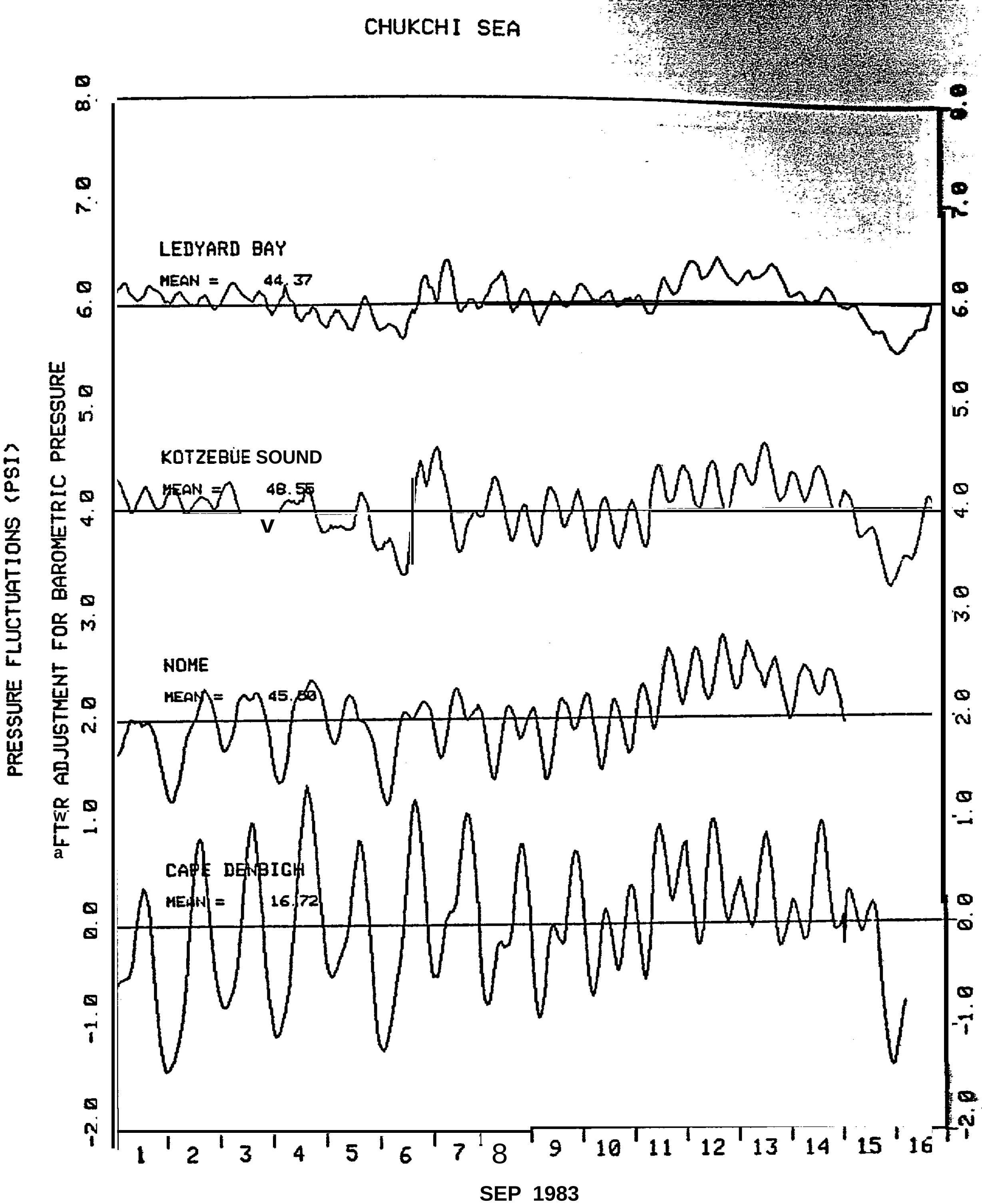


Fig. 6. Pressure Fluctuations About the Monthly Mean at Stations 1 through 4 in September 1983

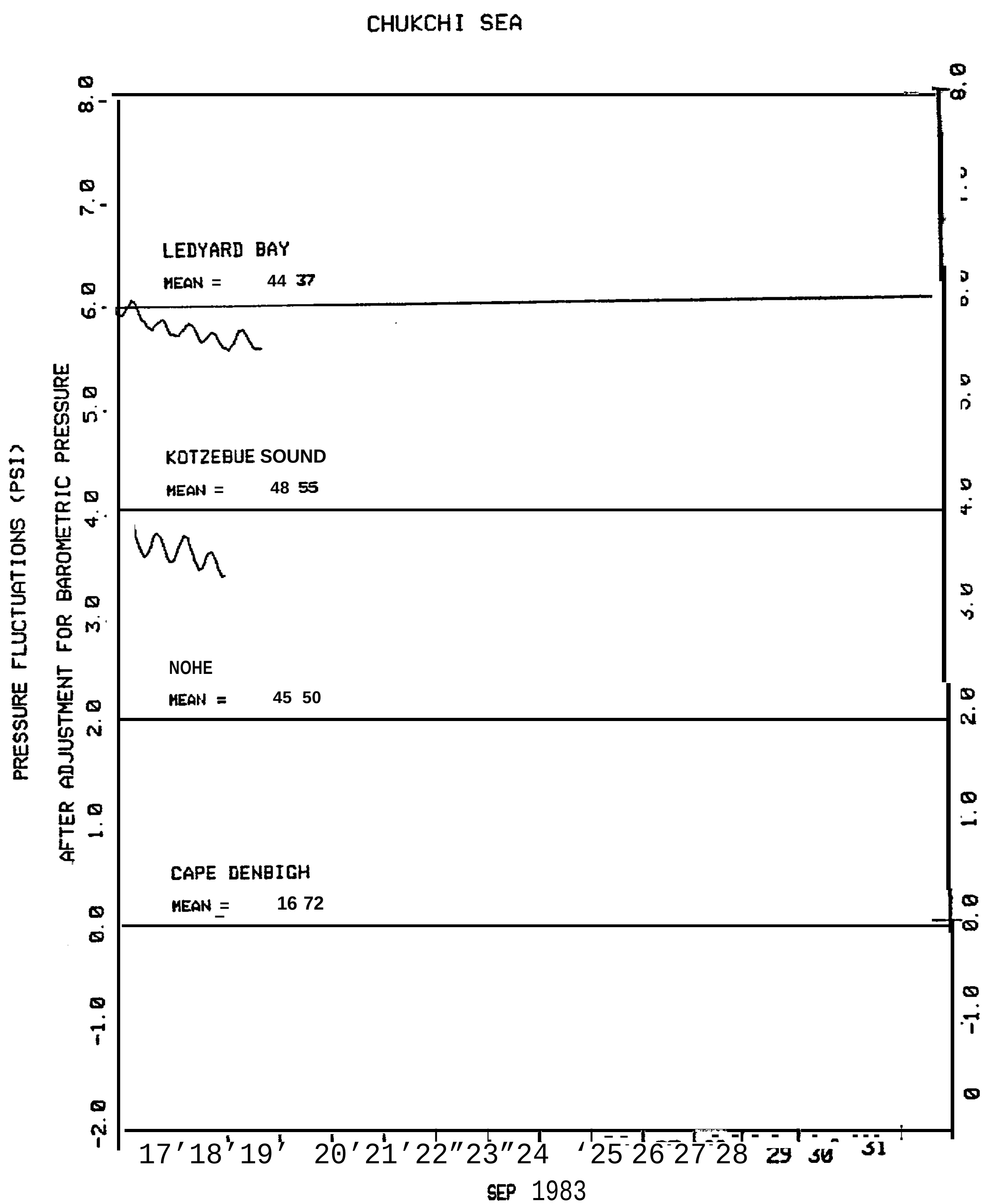


Fig. 6. Pressure Fluctuations About the Monthly Mean at Stations 1 through 4 in September 1983 (contd)

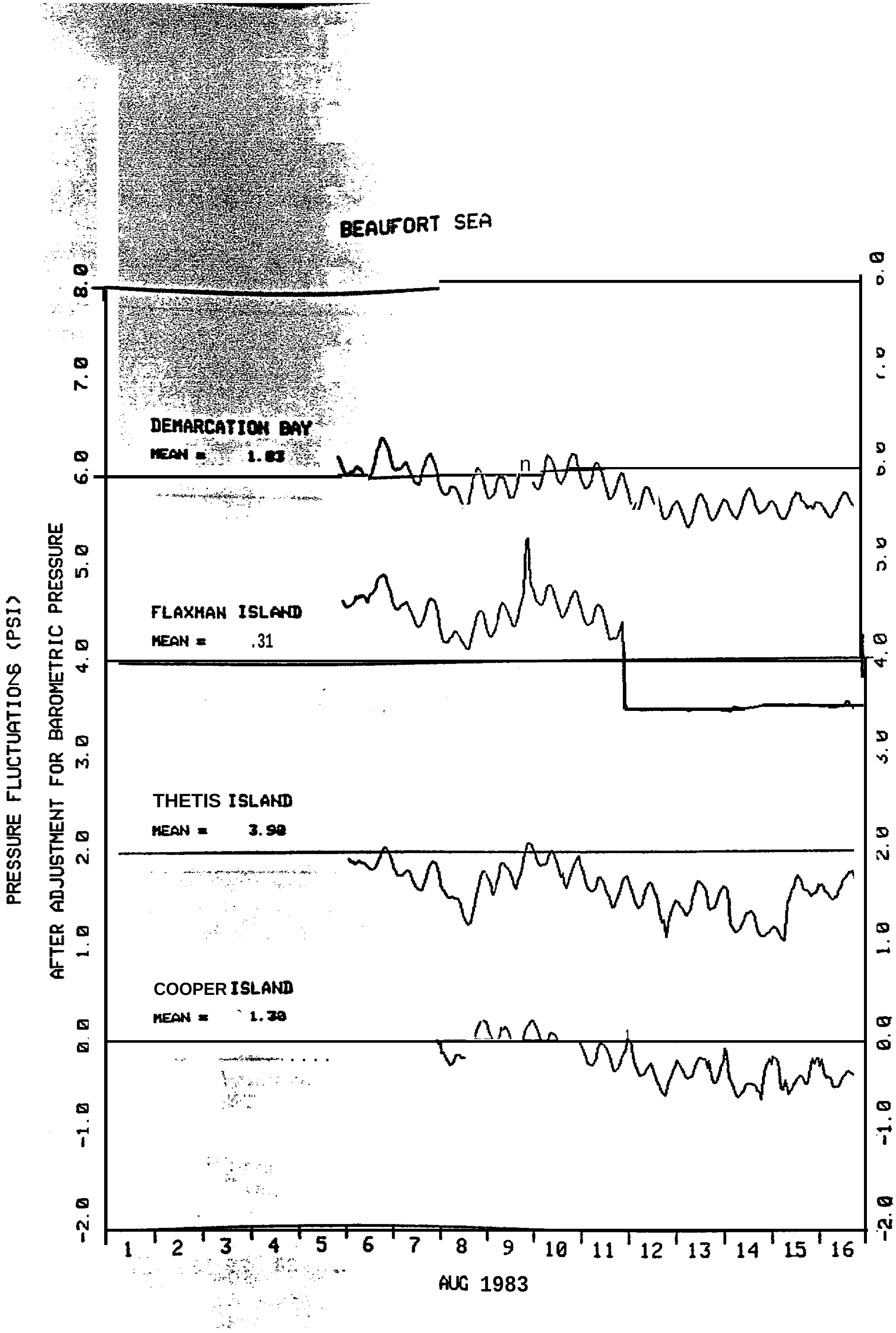


Fig. 7. pressure Fluctuations About the Monthly Mean **at Stations** 5 through 8 in August 1983

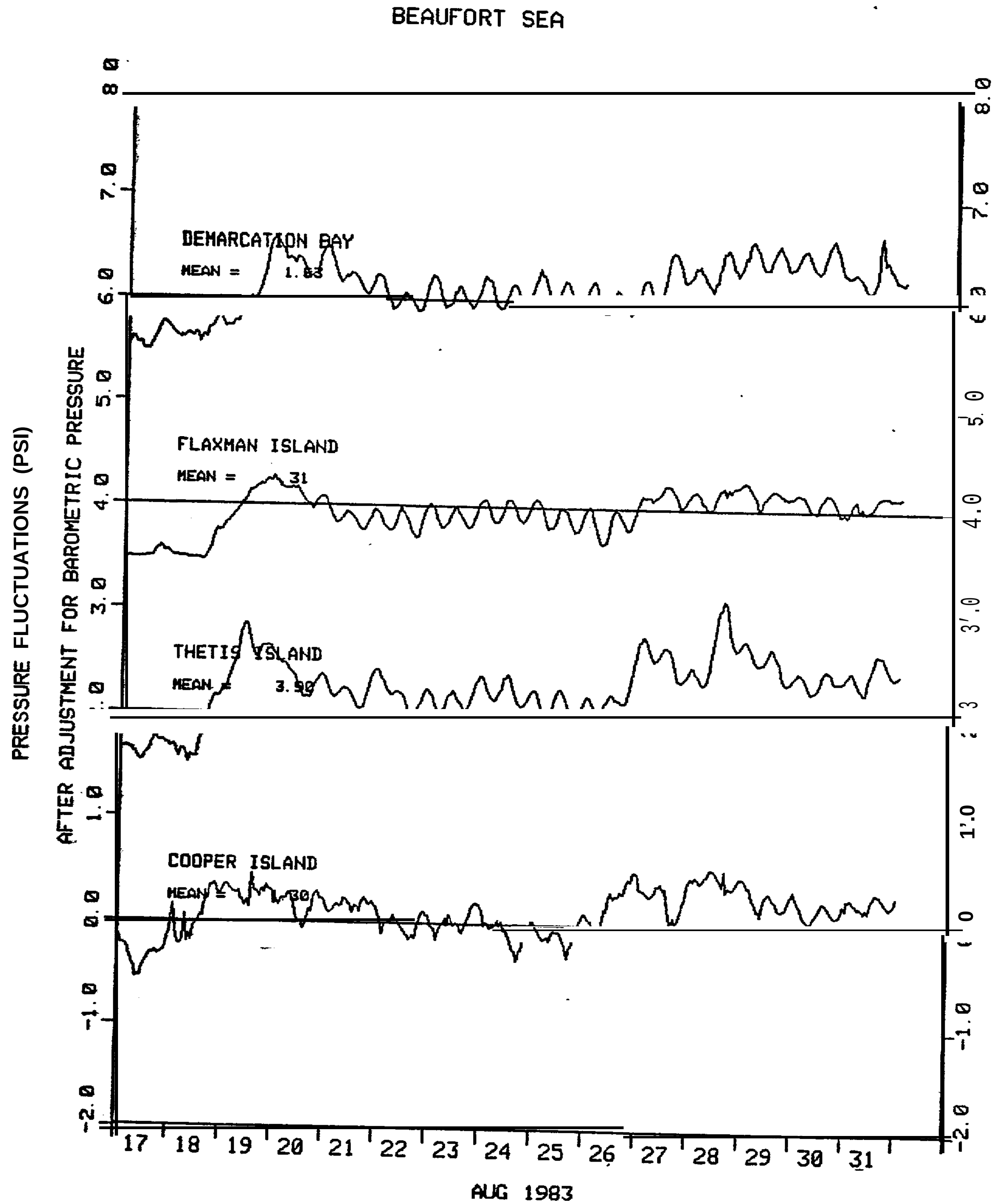


Fig. 7. Pressure Fluctuations About the Monthly Mean at Stations 5 through 8 in August 1983 (contd)

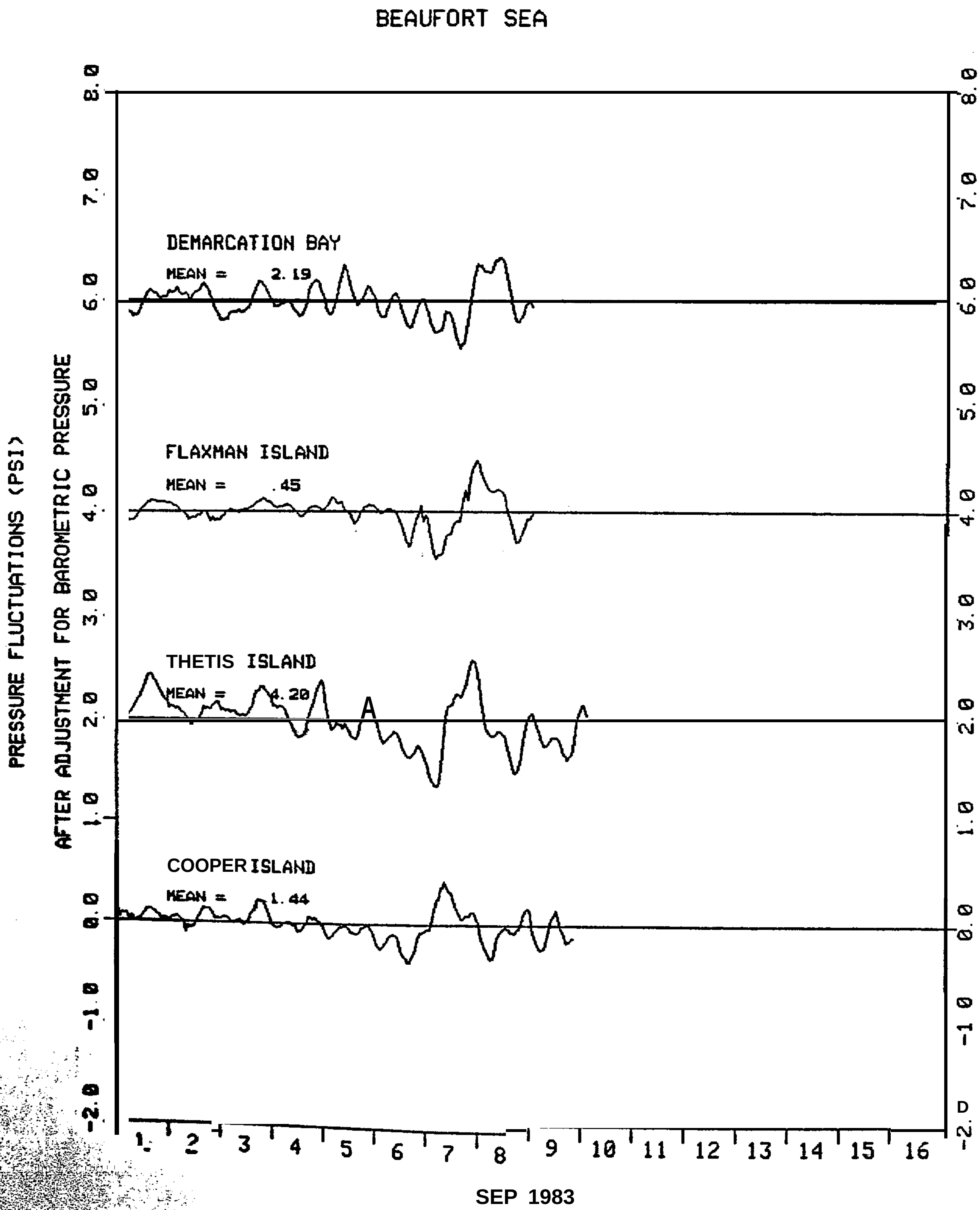


Fig. 8. Pressure Fluctuations About the Monthly Mean at Stations 5 through 8 in September 1983

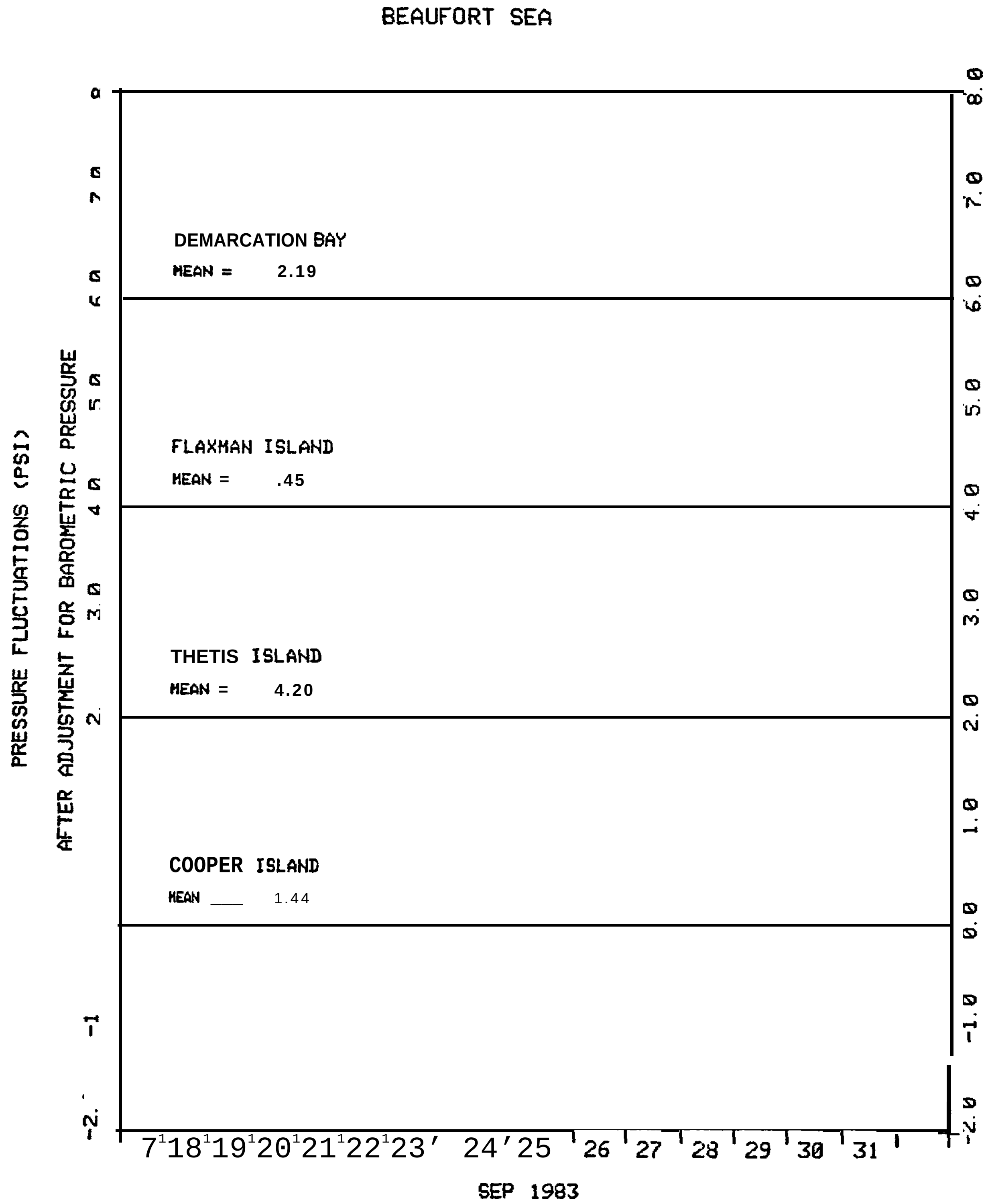


Fig. 8. Pressure Fluctuations About the Monthly Mean at Stations 5 through 8 in September 1983 (contd)

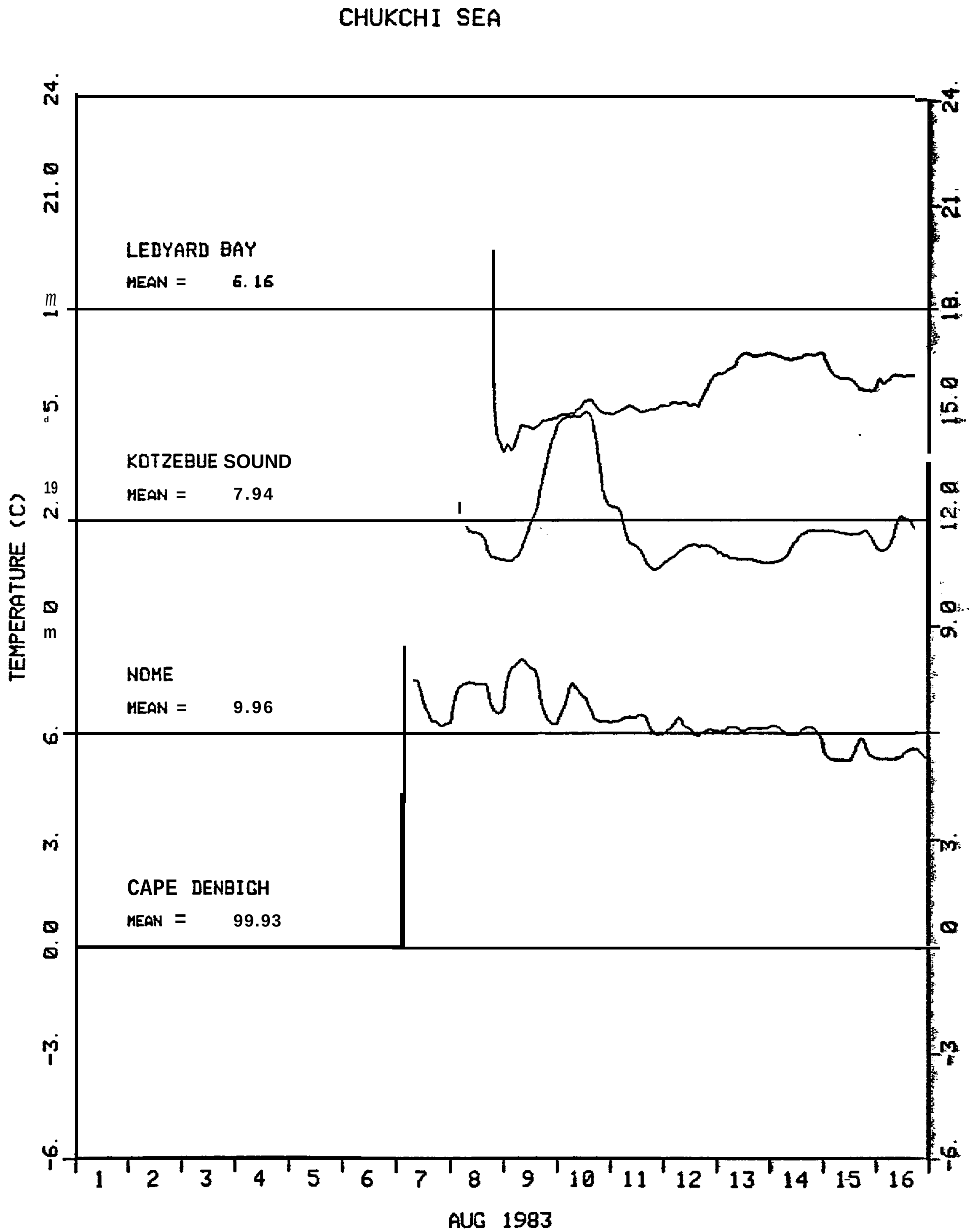


Fig. 9. Temperature Fluctuations About the Monthly Mean at Stations 1 through 4 in August 1983.

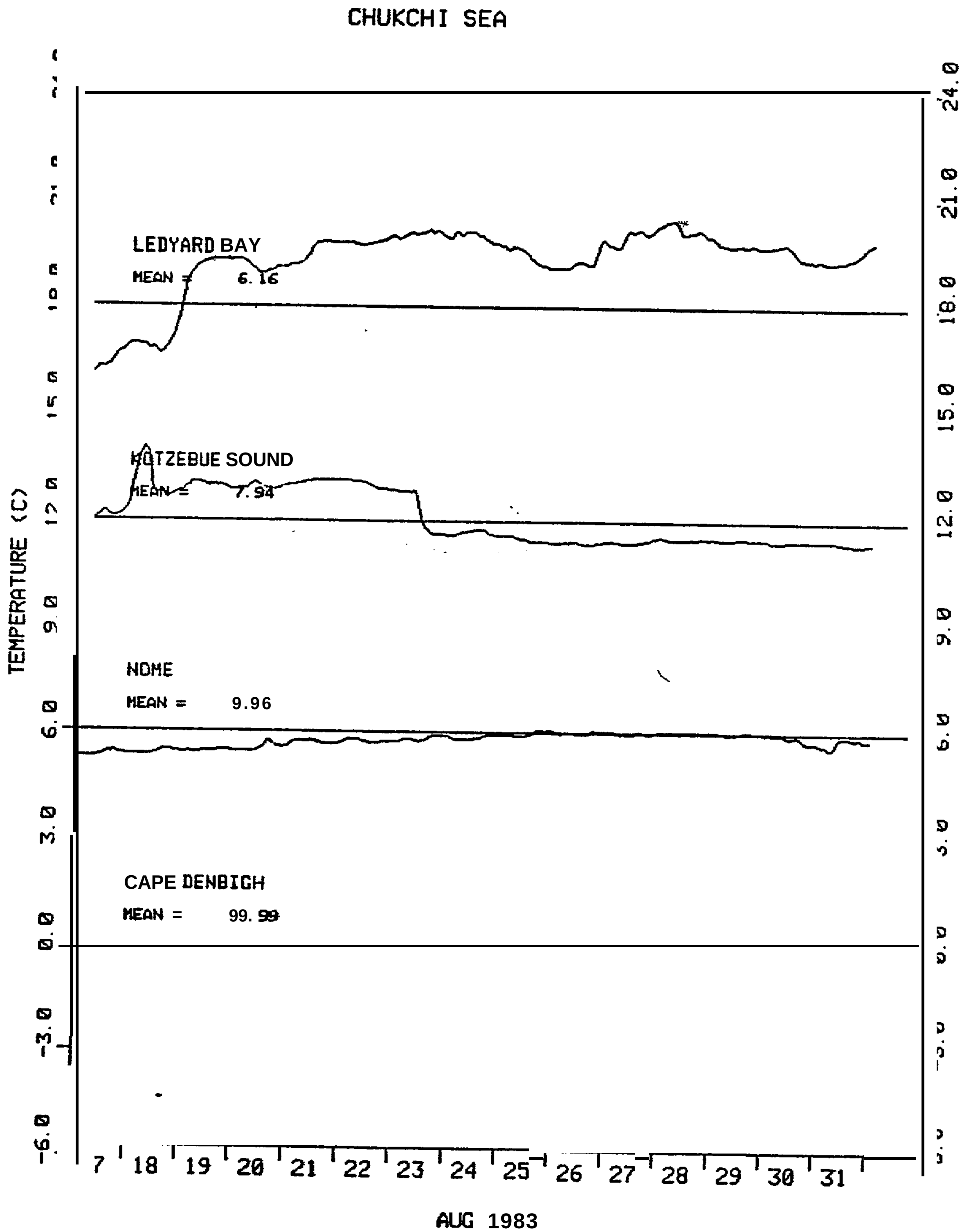


Fig. 9 . **Temperature** Fluctuations About the Monthly Mean at **Stations 1** through 4 in August 1983 **(contd)**

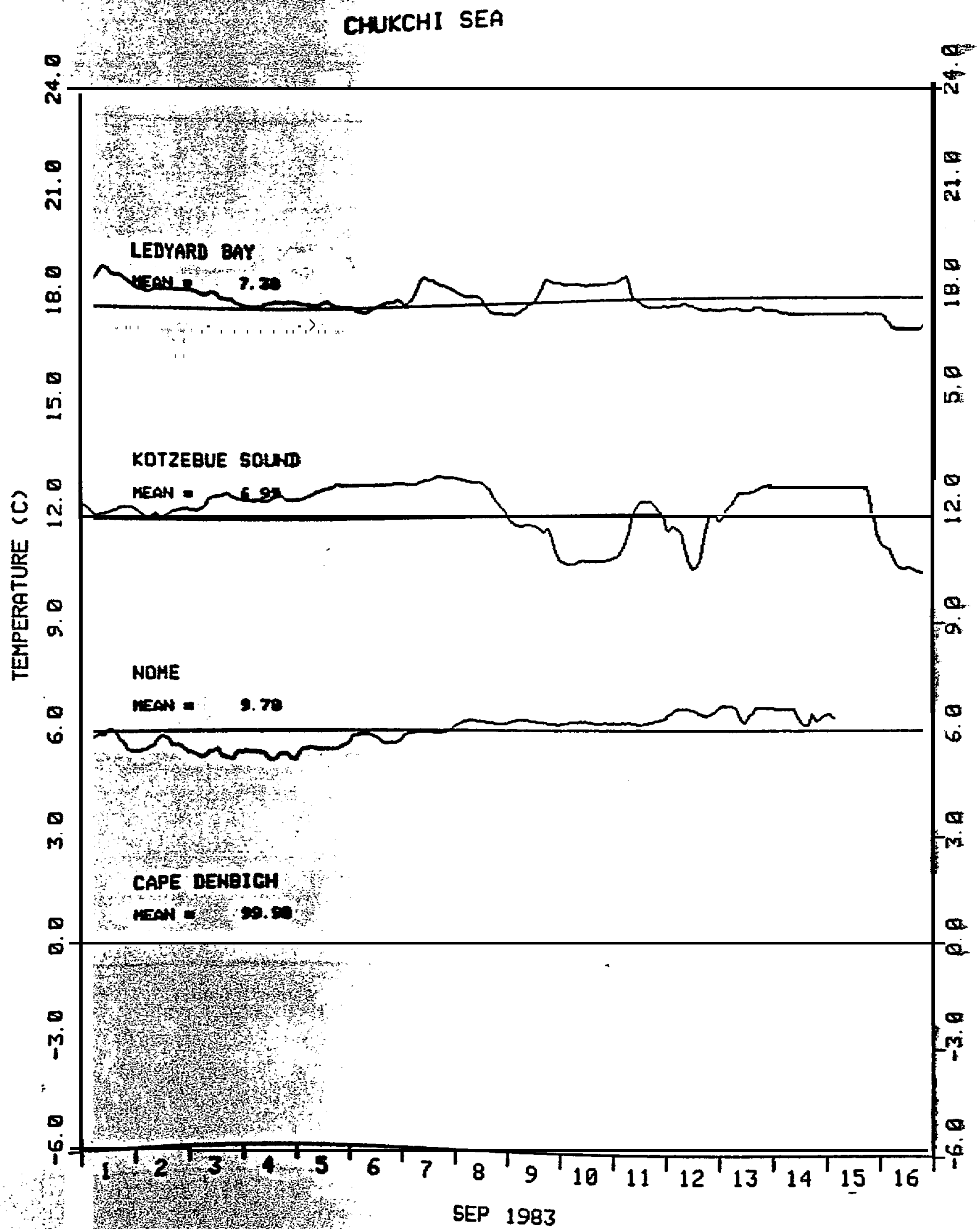


Fig 10. Temperature Fluctuations About the Monthly Mean at Stations 1 through 4 in September 1983

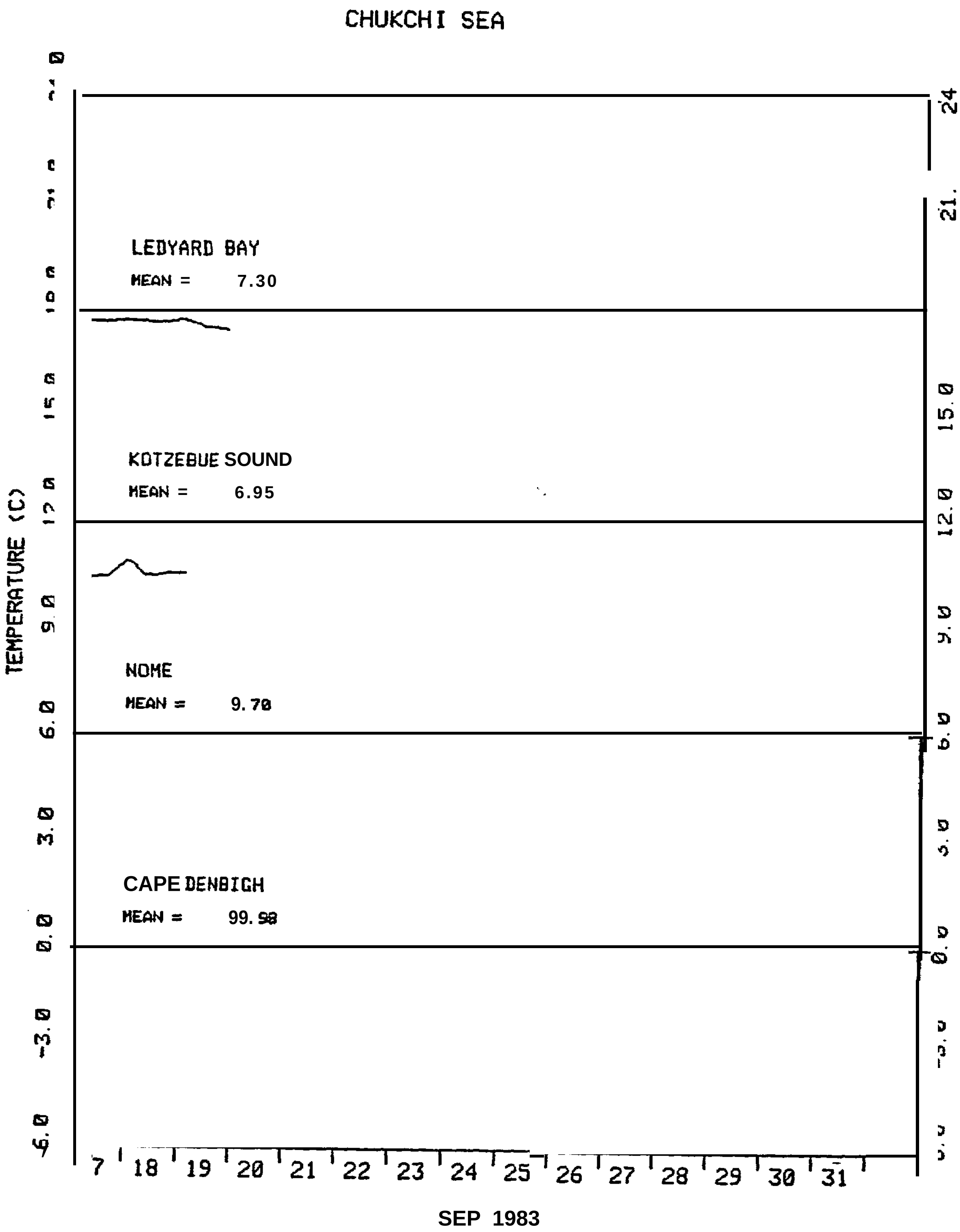


Fig. 10. Temperature Fluctuations About the Monthly Mean at Stations 1 through 4 in September 1983 (contd)

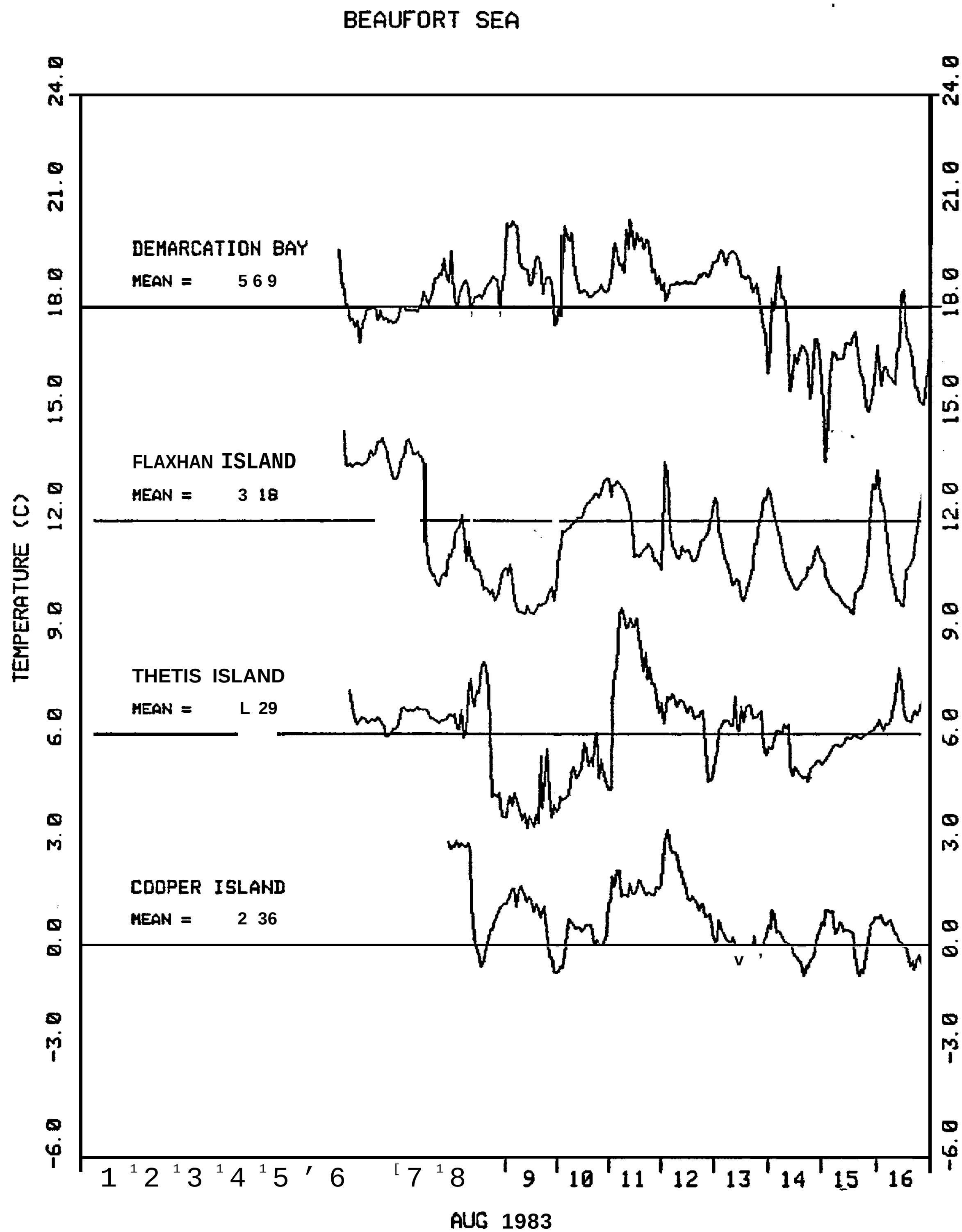


Fig. 11. **Temperature Fluctuations About the Monthly Mean at Stations** 5 through 8 in August 1983

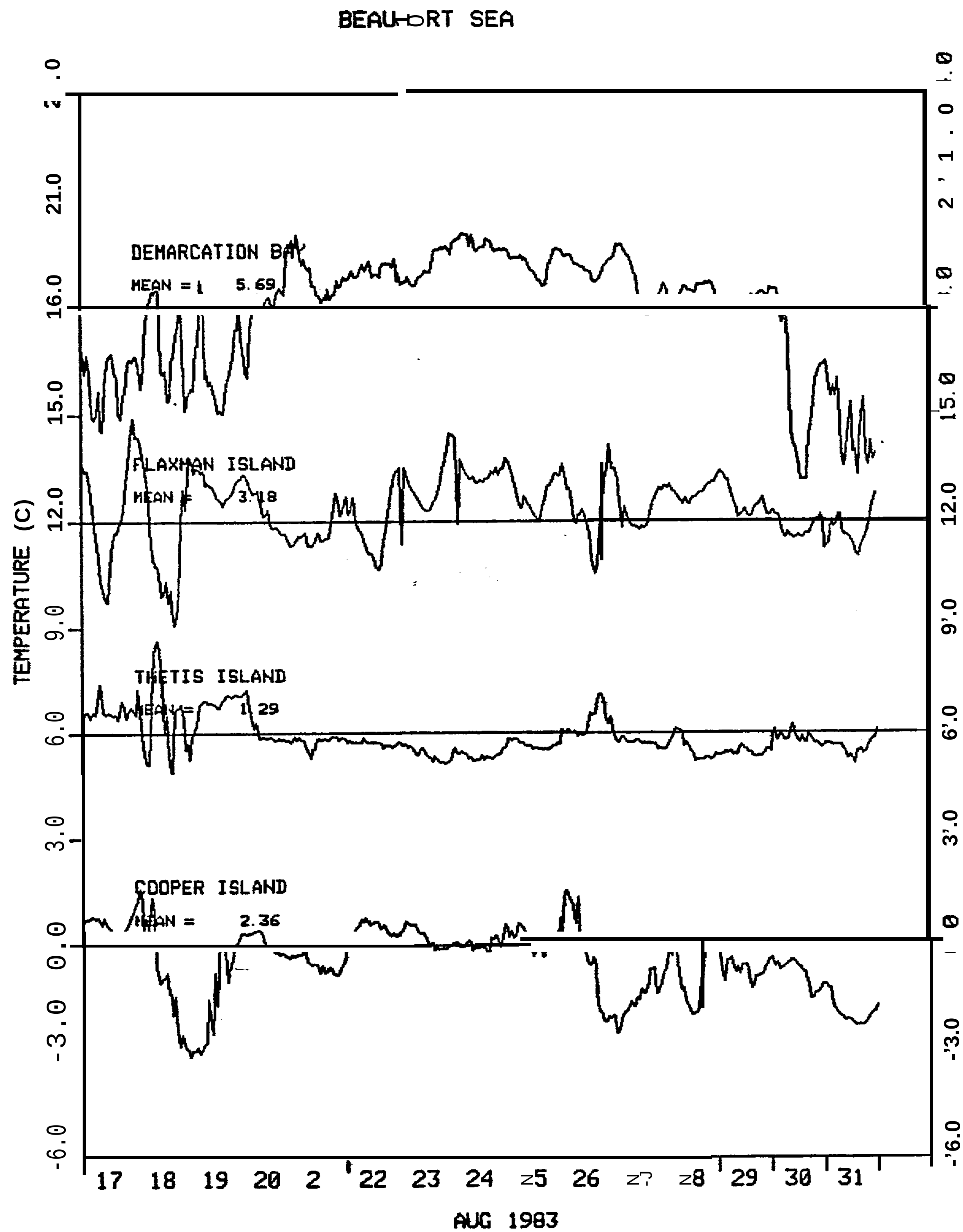


Fig. 11. Temperature Fluctuations About the Monthly Mean at Stations 5 through 8 in August 1983 (contd)

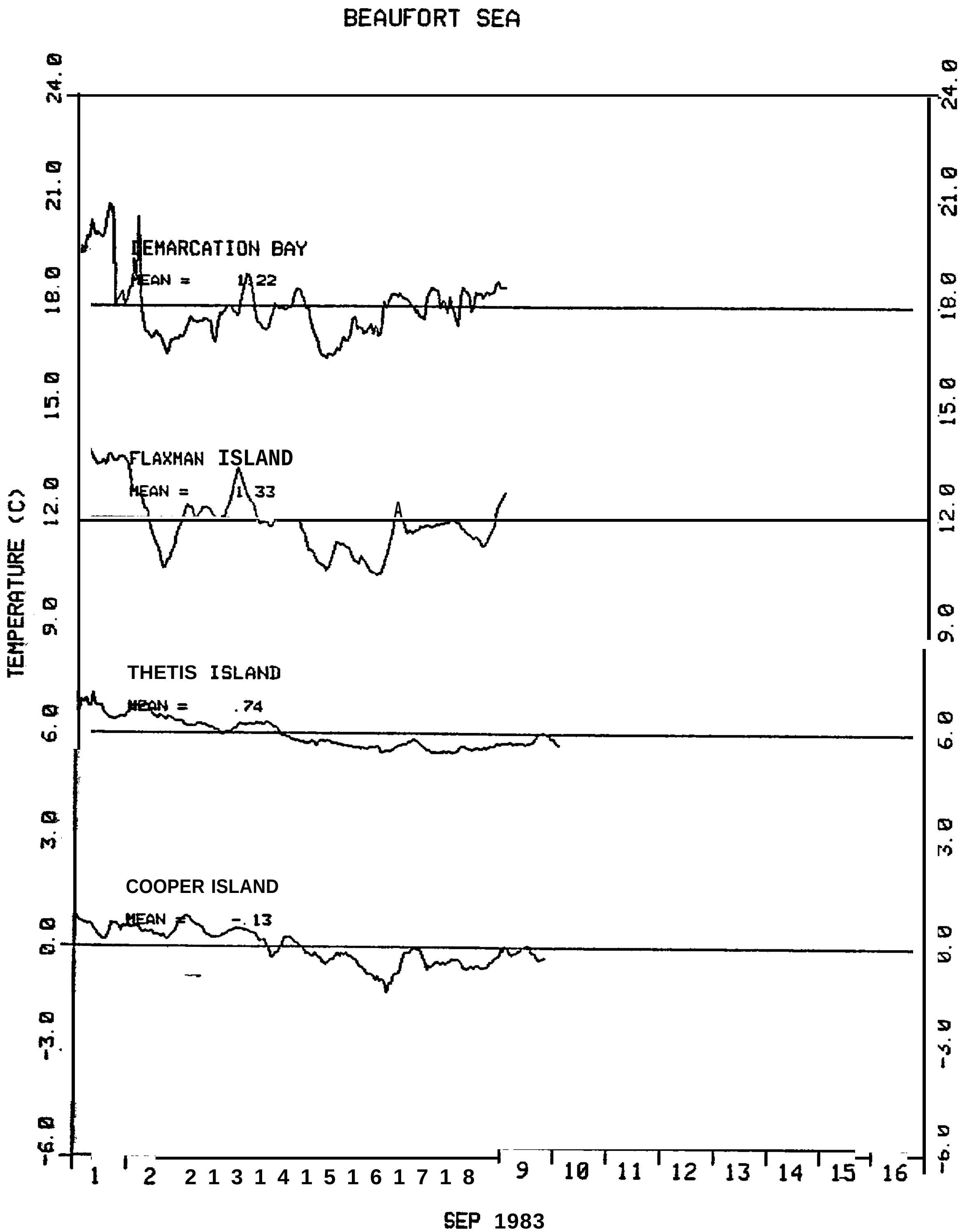


Fig. **12.** Temperature Fluctuations About the **Monthly** Mean at Stations 5 through 8 **in** September 1983

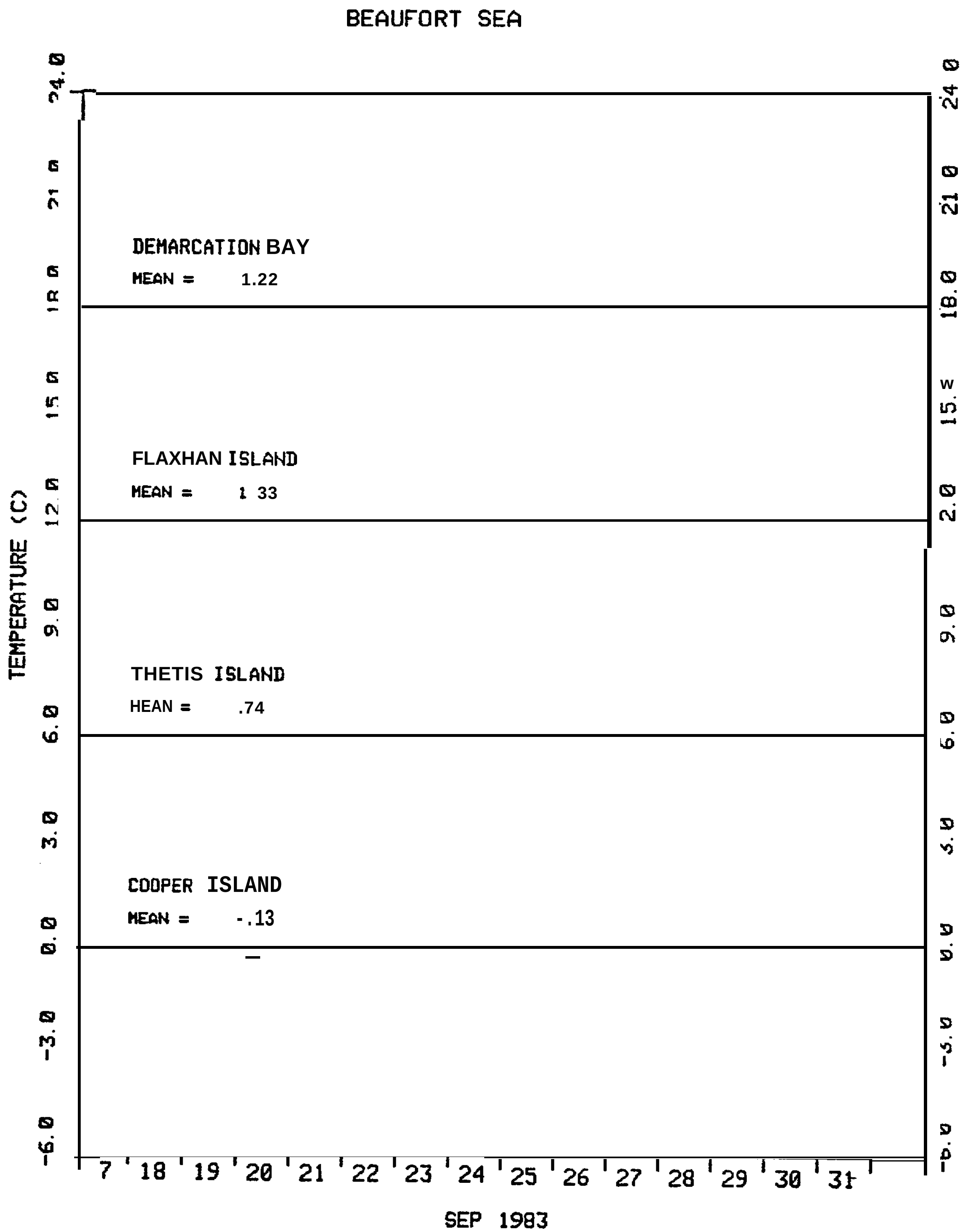


Fig. 12. Temperature Fluctuations About the Monthly Mean at Stations 5 through 8 in September 1983 (contd)

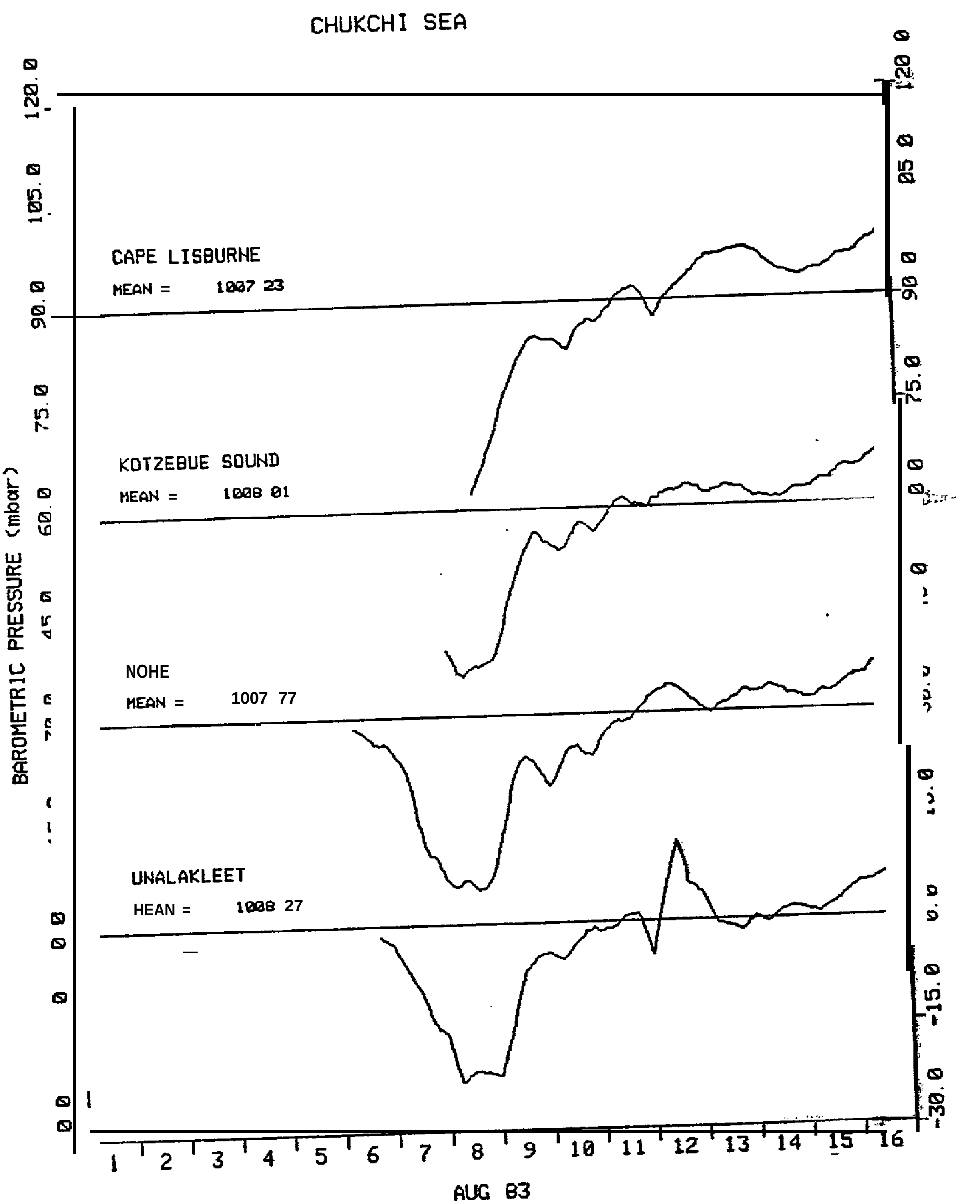
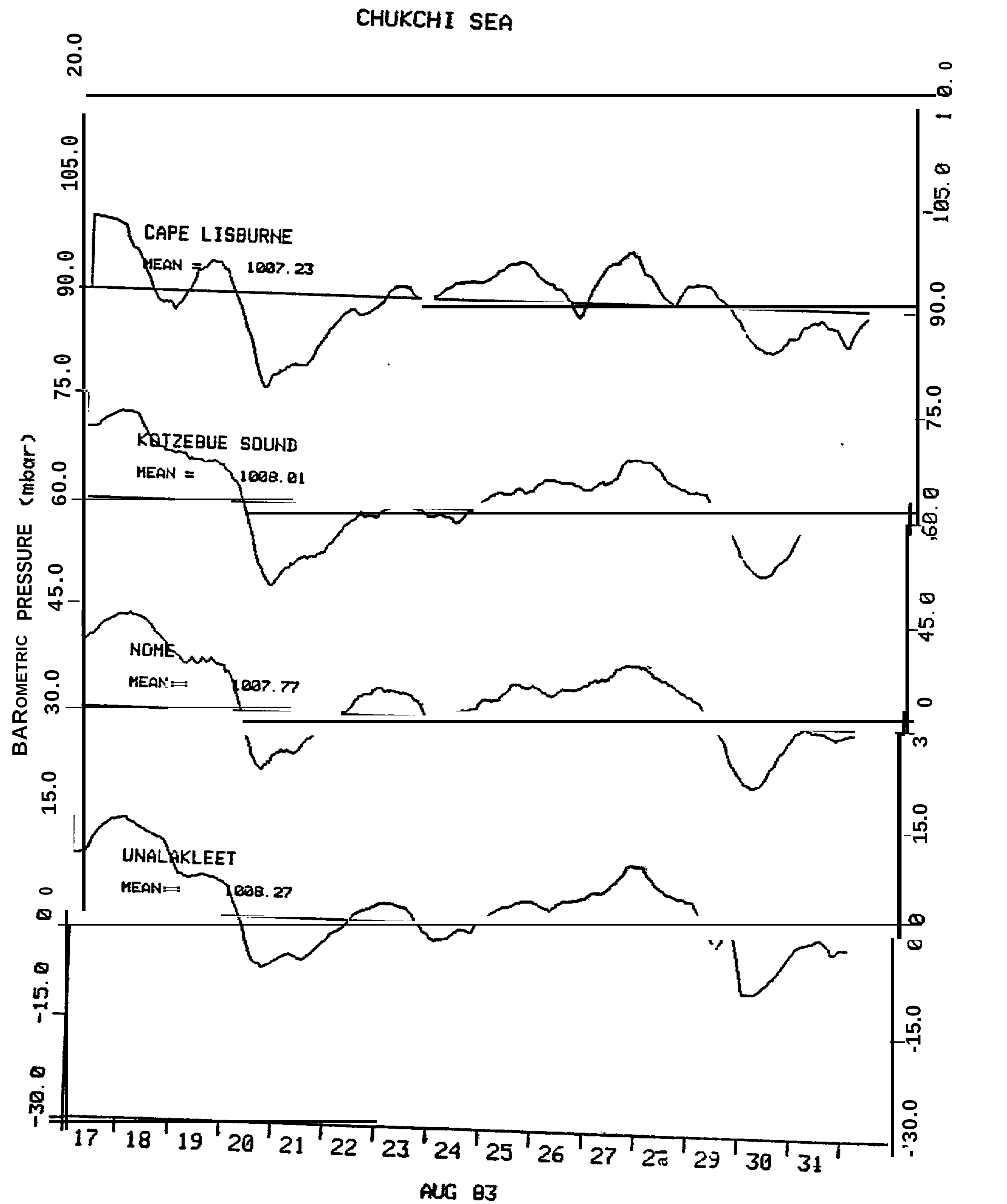


Fig. 13. Barometric Pressure Fluctuations Used to Correct Absolute Pressure Data from Stations 1 through 4 in August 1983



ig. 13. Barometric Pressure Fluctuations Used to Correct Absolute Pressure Data from Stations 1 through 4 in August 1983 (contd

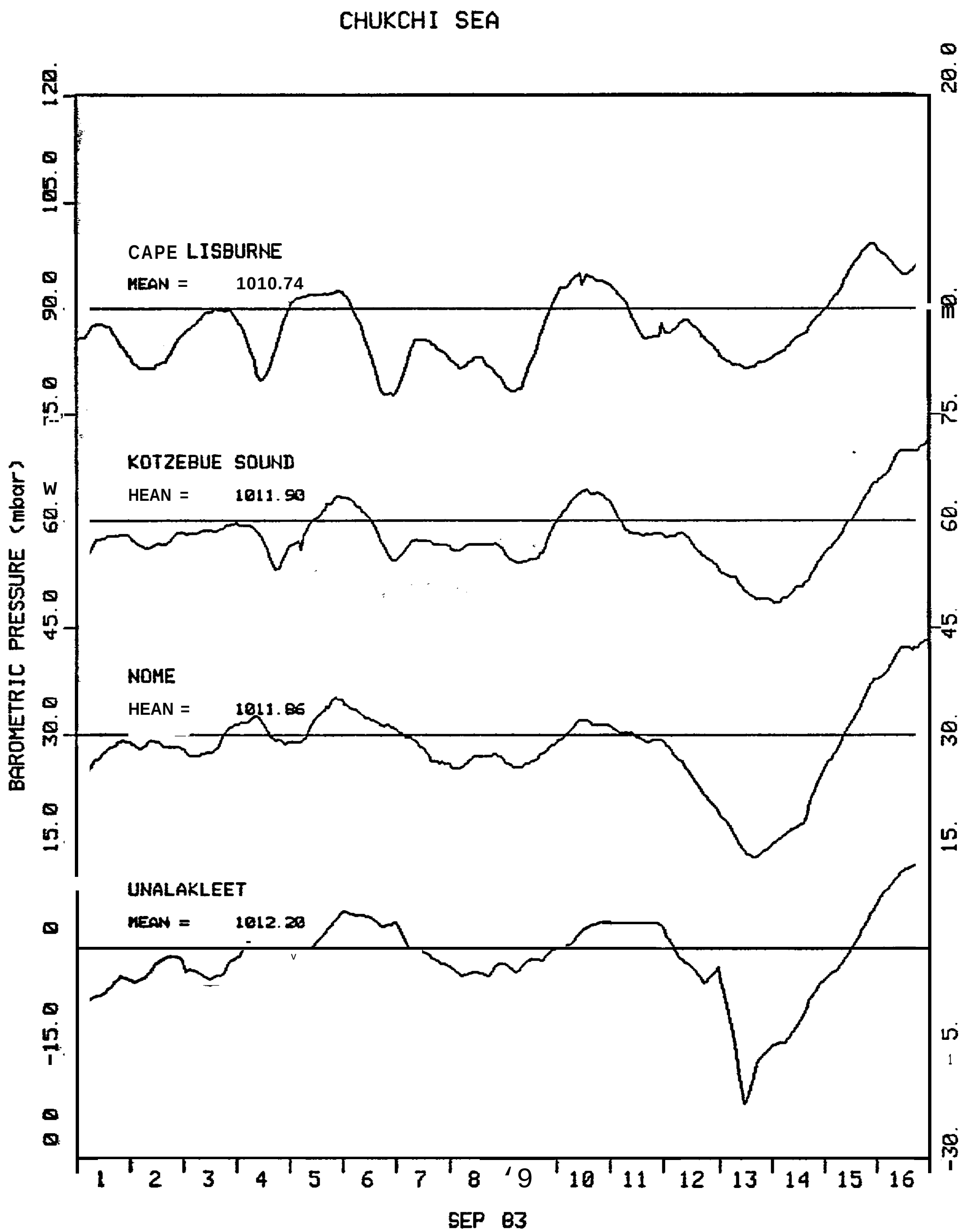
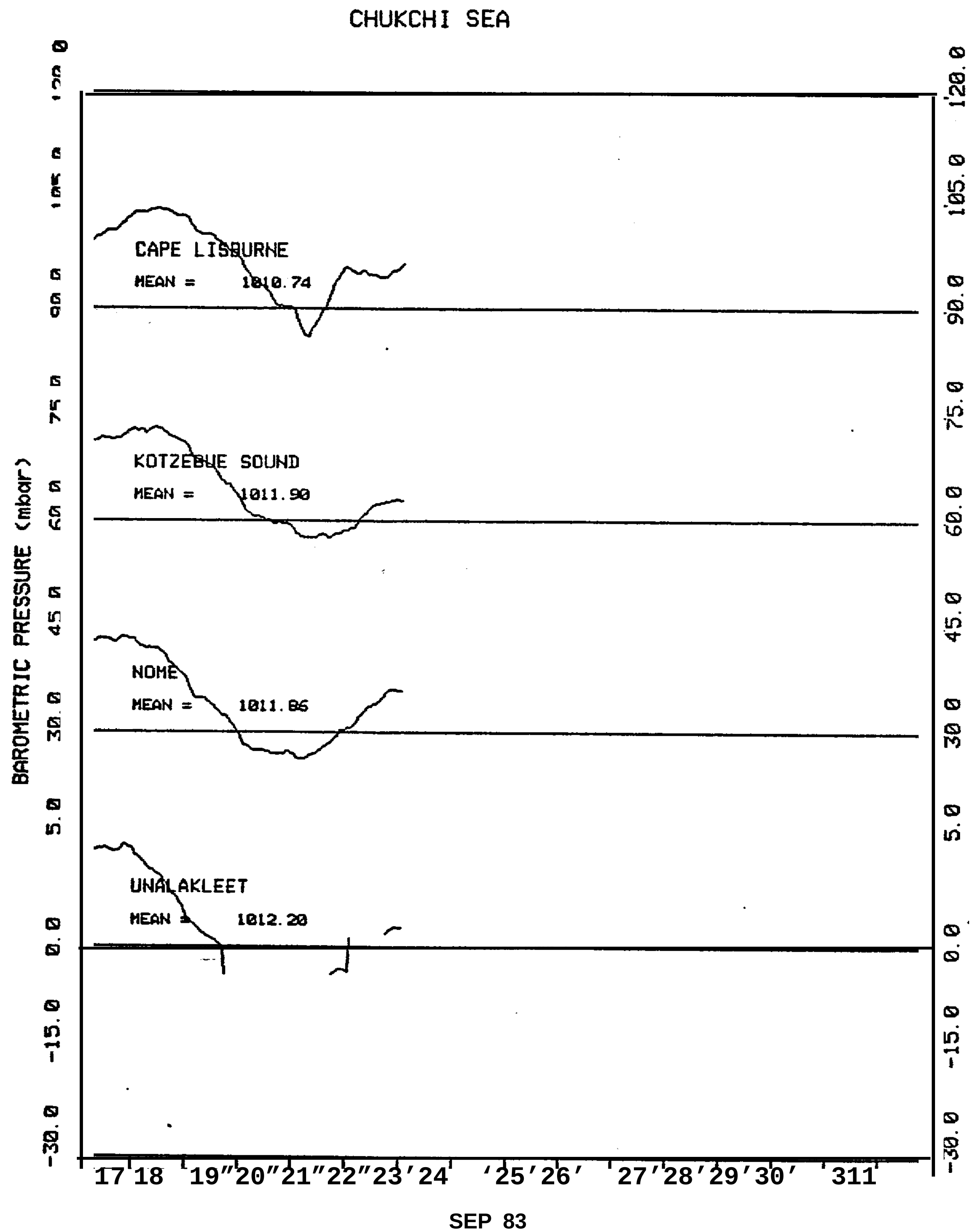


Fig. 14. Barometric Pressure Fluctuations Used to Correct Absolute Pressure Data from Stations 1 through 4 in September 1983



ig. 14. Barometric Pressure Fluctuations Used to Correct Absolute Pressure Data from Stations 1 through 4 in September 1983 (contd)

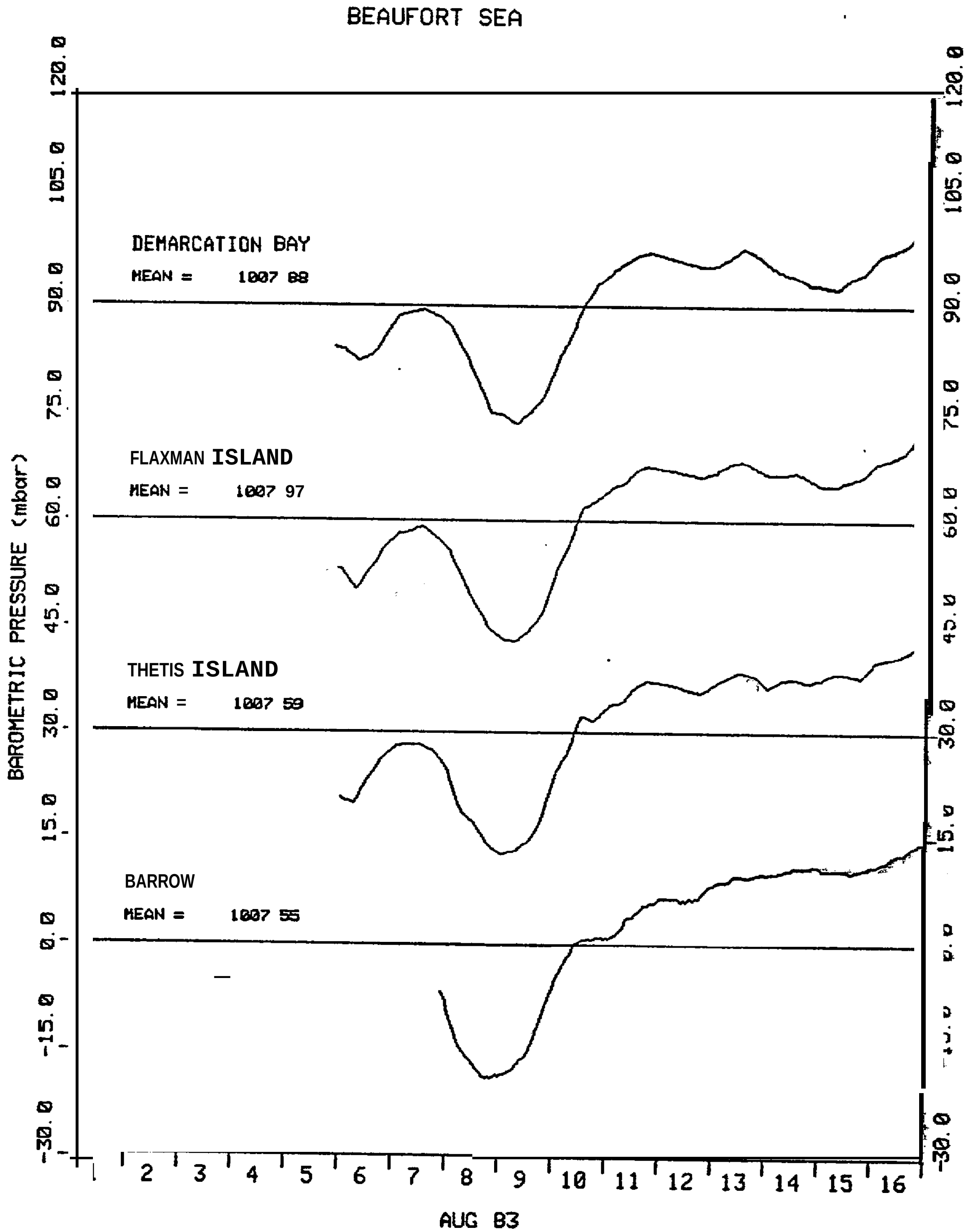


Fig. 15. Barometric Pressure Fluctuations Used to Correct Absolute Pressure Data from Stations 5 through 8 in August 1983

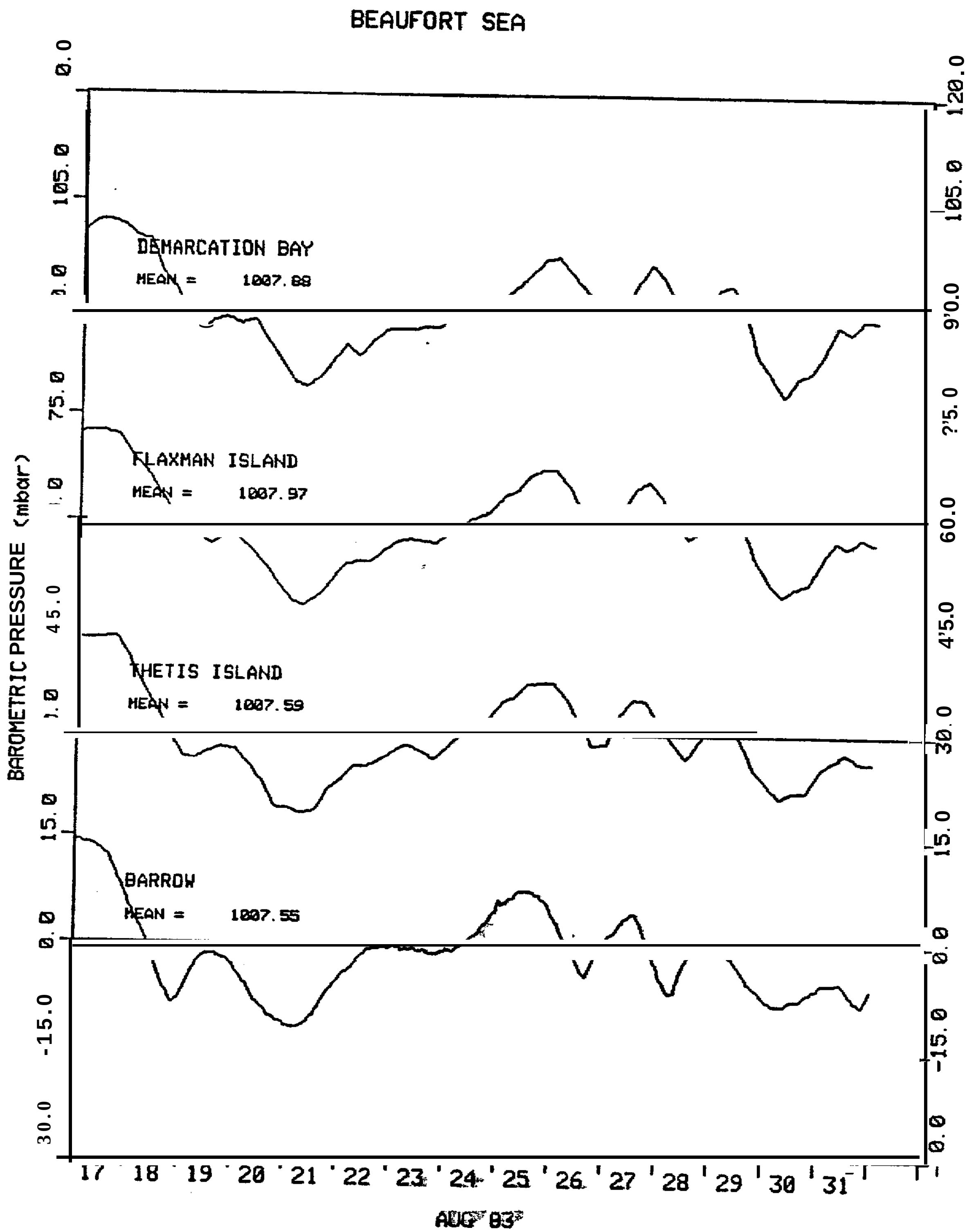


Fig. 15. Barometric Pressure Fluctuations Used to Correct Absolute Pressure Data from Stations 5 through 8 in August 1983 (contd)

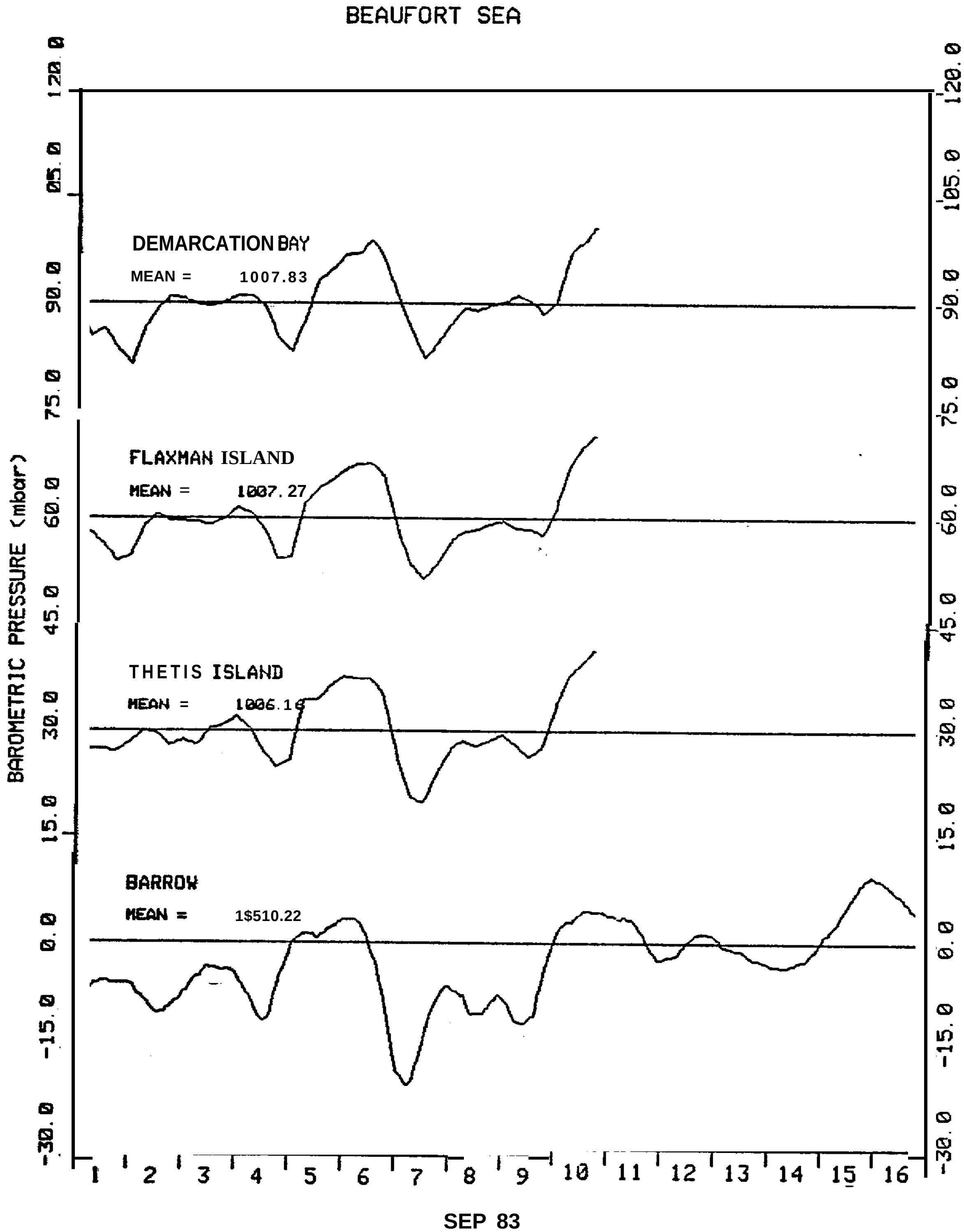


Fig. 16. Barometric Pressure Fluctuations Used to Correct Absolute Pressure Data from Stations 5 through 8 in September 1983

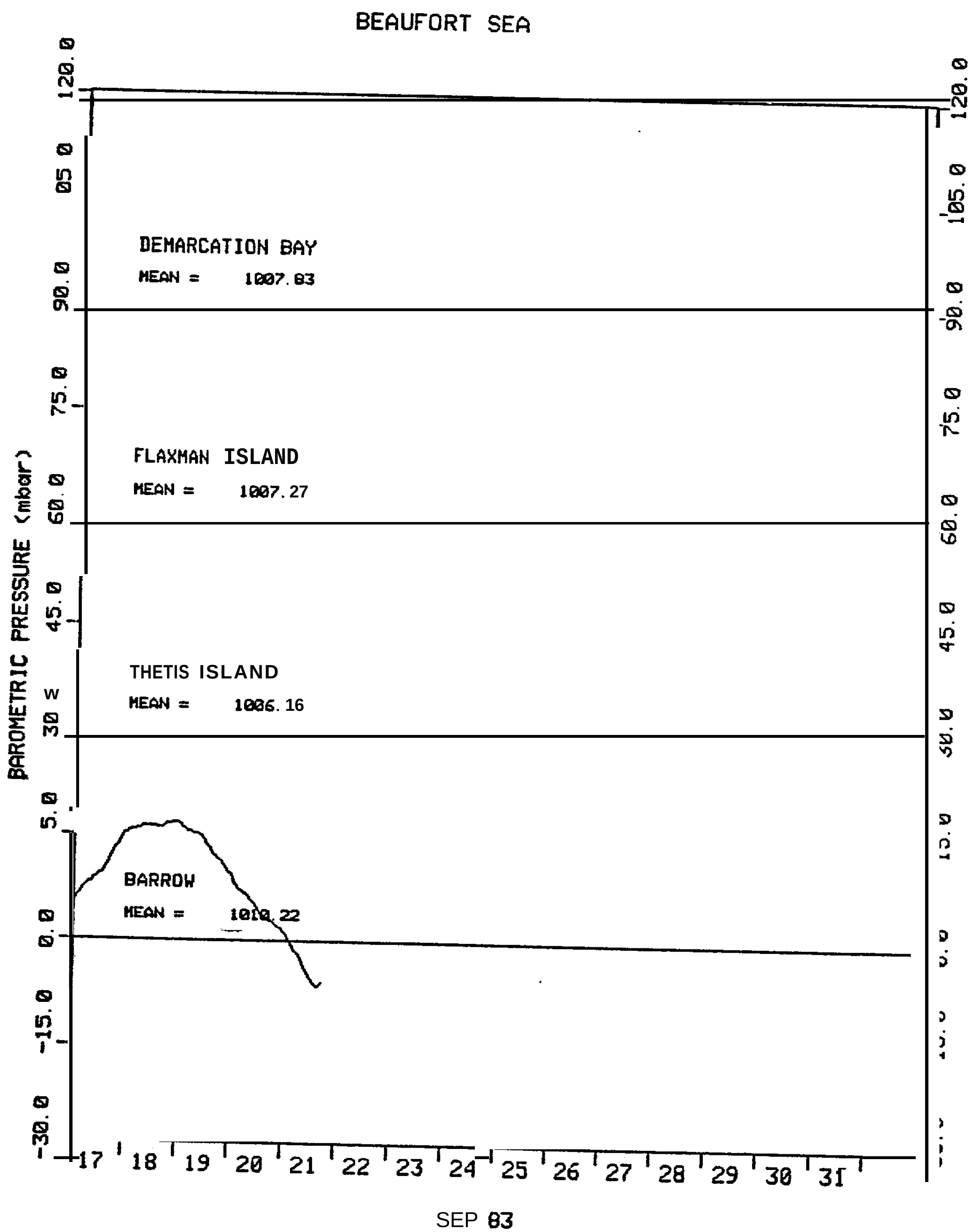


Fig. 16. Barometric Pressure Fluctuations Used to Correct Absolute Pressure Data from Stations 5 through 8 in September 1983 (contd)

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OCEANOGRAPHIC DATA FROM THE BERING CHUKCHI, AND BEAUFORT SEAS

, WASC-83-00114

FIELD WORK REPORT

BROWN AND CALDWELL
Marine Sciences Division

Principal Investigator
Ronald W. Pitman

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INTRODUCTION

This report relates field work and data collection activities for the Outer Continental Shelf Environmental Assessment Program (OCSEAP) project entitled Oceanographic Data for the Bering, Chukchi and Beaufort Seas (WASC 8300114). The purpose of this project is to obtain measurements of tide along the northern Alaskan coast from Norton Sound north to Pt. Barrow and east of Pt. Barrow to the . U.S./Canadian Border. The desired information from these measurements is the amplitude and phase of the astronomical tidal constituents at locations throughout the study area, which **covers** thousands of miles of the Alaskan Coast. These measurements are necessary to adapt a numerical model of deep water tidal circulation to the relatively shallow continental shelf areas of potential petroleum exploration and development. This tidal circulation model is a sub-model of an oil spill risk analysis and - knowledge of the tidal circulation is required to estimate where oil spill may be transported. Since the study area is in the harsh Arctic environments, historical data is very limited and sufficent simultaneous tidal measurements did not exist for this area prior to this study

Project Description

This project involves collection and analysis of pressure data from bottom mounted pressure sensors inorder to determine the amplitude and phase of the major astronomical tidal constituents. Eight measurements sites along the coast of Alaska were selected by OCSEAP. Instrument sites 1 through 4 were located in Norton Sound and the Chukchi Sea as shown on Figure 1. Instrument sites 5 through 8 were located in the Beaufort Sea as shown on Figure 2. Station locations and deployment periods are presented in Table 1. The instrumentation and logistical support for this project was supplied by OCSEAP.

Most of the study area is north of the Arctic Circle, and is covered by ice for most of the year. Deployment and retreival of in-situ recording pressure guages was scheduled for the period of ice breakup up during the summer. In order to obtain the amplitude and phase of the desired tidal constituents, a minimun of 29 days of measurement were required at each location. Additionally, a mimimun overlap of 20 day of simultaneous measurements at all locations was required.

In order to relate pressure measurements to tide height, corrections for barometric pressure and density variations need to be applied to the pressure data. National Weather Service records from Stations in the vicinity of the measurement sites were used to correct bottom pressure data for changes is barometric pressure. Barometric pressure data were obtained from stations at Unalakleet, Nome, Kotzebue, Cape Lizburne, Barrow, Prudhoe Bay, and Barter Island. Changes in the density of the water column over the pressure sensor will result in pressure fluctuations. Measurement of

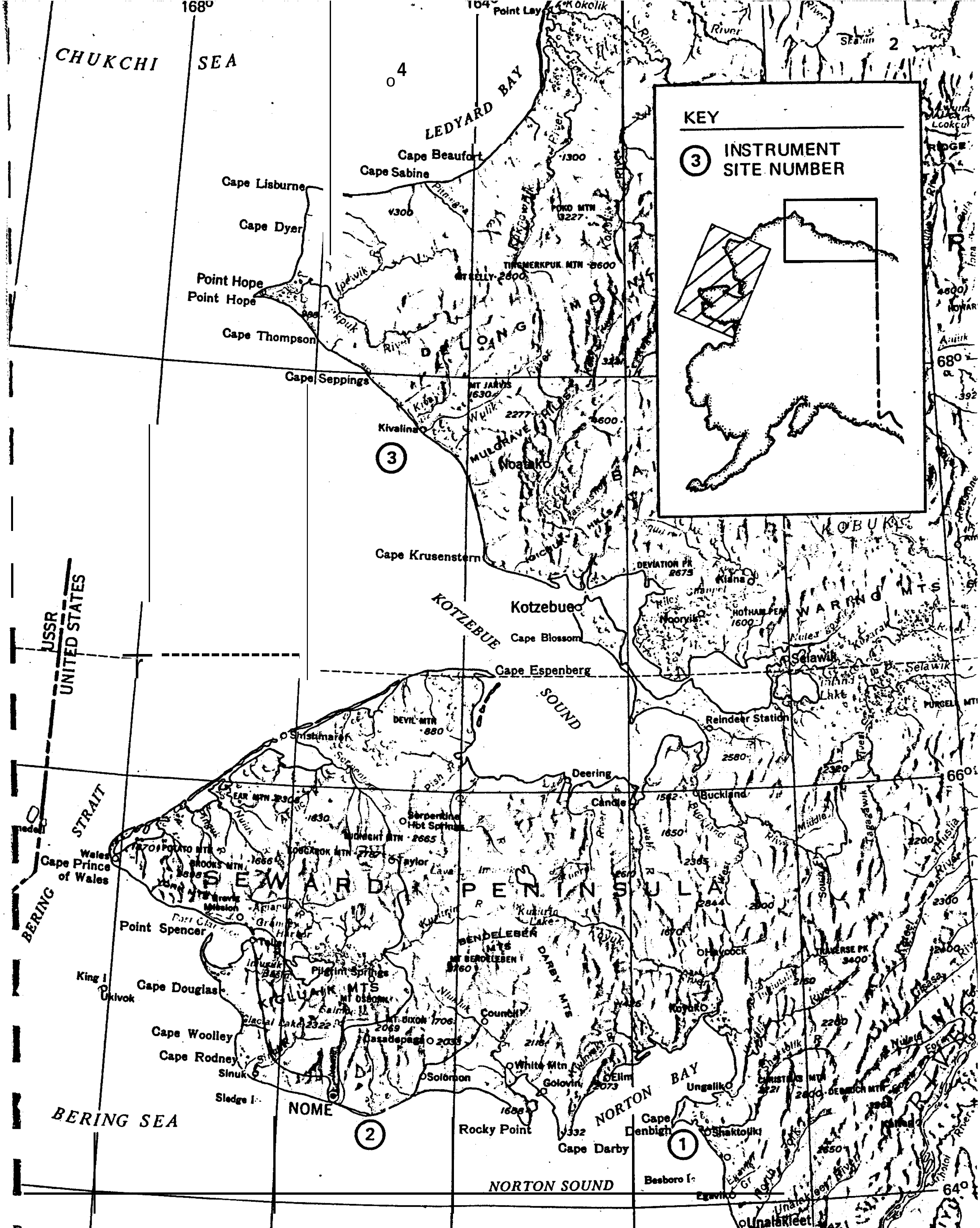

Figure 1. Norton Sound and Chukchi Sea Instrument Sites

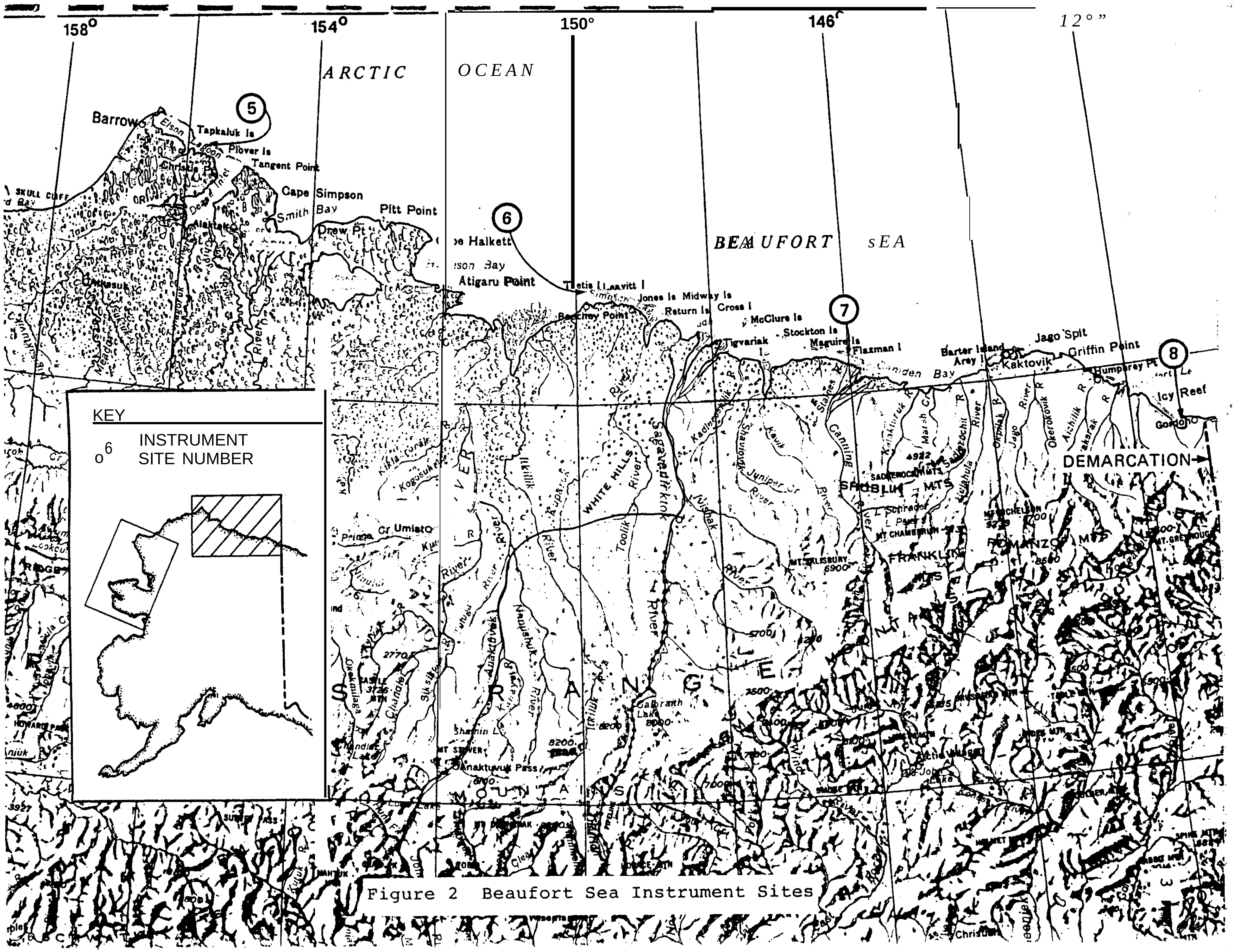

Figure 2 Beaufort Sea Instrument Sites

Table 1. NOAA OCSEAP Tide Sampling Locations and Times (GMT) During Summer of 1983

STA	LOCATION	LAT (N) DEG	MIN	LONG (W) DEG	MIN	DEPLOYMENT DATE		TIME	RECOVERY DATE		TIME
1	CAPE DENBIGH	64	20.2	161	30.7	AUG	6	1718	SEP	16	0434
2	NOME	64	19.9	165	00.8	AUG	7	0218	SEP	15	0253
3	KOTZEBUE SOUND	67	30.2	16'5	00.3	AUG	B	0301	SEP	19	0130
4	LEDYARD BAY	69	28.8	165	03.2	AUG	8	1838	SEP	19	1901
5	COOPER ISLAND	71	14.0	155	44.5	AUG	7	2103	SEP	9	1925
6	THETIS ISLAND	70	33.0	150	11.0	AUG	6	0057	SEP	10	0150
7	FLAXMAN ISLAND	70	11.0	145	57.7	AUG	5	2236	SEP	9	0140
8	DEMARCATION BAY	69	41.2	141	17.6	AUG	5	2032	SEP	a	2335

temperature and salinity throughout the water column during the deployment period were not practical since there was a fairly high probability that near surface instruments would be destroyed by ice floes. Density profiles were obtained during deployment and retrieval of pressure guages.

Purpose of Report .

As with any investigative project, the collection of accurate, reliable data was a key element to acheiving the objectives of this study. This report summarizes the prefield and field work conducted for the data collection phase of this project which lead to successfully obtaining the desired information on tidal conditions.

METHODS .--

This section relates the instrumentation and methods. employed to obtain the data necessary to determine tidal conditions on the Alaskan continental shelf areas of the Bering, Chukchi, - and Beaufort Seas.

Instrumentation

The majority of instrumentation for this project was provided by the National Oceanographic and Atmospheric Administration (NOAA) through an agreement between OCSEAP and Pacific Marine Environmental Laboratory (PMEL). Eight Aanderaa pressure guages and eight AMF acoustic releases were provided by PMEL. The Aanderaa pressure guages included one model TG3, two model TG4A, and five model WLR-5. All of these models utilize the very accurate paroscientific pressure sensor which senses absolute pressure by the variation in frequency of oscillations of a quartz crystal. Since the frequency of oscillation is also temperature dependent, most of the pressure instruments also included a temperature sensor. The different models of pressure guages are fairly similar, varing in the sample integration time, sampling interval, range of pressure measurement and recording scheme. The AMF acoustic releases include four squib fired releases (Model 242) and four selenoid actuated releases (Model 395) . The acoustic releases were used to retrieve the pressure guages from the ocean bottom. PMEL also provide the deck unit for the AMF releases.

Calibration and Testing Procedures

Prior to deployment, instrumentation was shipped from PMEL to Brown and Caldwell's Costa Mesa test facility. Pressure guages and releases were received on June 16, 1983 and batteries for the acoustic releases were received on June 28, 1983. The AMF deck unit required for verification of proper operation of acoustic releases was received on July 8, 1983, as was Aanderaa test instrumentation and data tapes. Proper operation of pressure guages was tested by creating test tapes of barometric pressure and processing of these data tapes. Calibration of pressure guages was performed by NOAA's

Northwest Regional Calibration Center. Proper operation of the pressure sensor was verified by comparison of barometric pressure data to a precision mecurial laboratory barometer. Upon receiving the deck unit for the acoustic releases , proper operation of the releases was verified by an system air acoustic check recommended by the manufacture. Equipment and instrumentation for deployment in the Beaufort Sea was shipped from Costa Mesa on July 12, 1983 and equipment for deployments in the Chukchi and Bering Seas was shipped July 13, 1983. Separating the shipments to Prudhoe Bay and Seattle assured that the appropriate equipment arrived at the correct loaction and that equipment did not get intermixed by the shipper.

Mooring Design

Originally, the mooring design contemplated consisted of a two part mooring system shown on Figure 3. The pressure sensor and acoustic release were to be mounted in a weighted pyramid shaped bottom carriage. Attached to the bottom carriage was 100 meters of floating polypropylene line which lead to a 20-foot section of chain. Upon the release command, the acoustic releae would release a small submerged float which would bring a line contained in a rope canister to the surface. The bottom carriage with the instrumentation attached would be retreived by this line. This bottom carriage design has been successfully used in Alaskan waters subject to sea ice for the past three years on other projects.

Due to size limitations of the A-frame and deck space of the vessel provided by NOAA for Beaufort Sea deployments, it was not possible to use bottom carriages in the Beaufort Sea. Since the main purpose of bottom carriages was for protection against accidental release in the noisy arctic environment, the mooring design was changed to a taunt leg mooring design shown in Figure 4. The height of this taunt leg mooring was kept to a minimun. The mooring design still included the polypropylene tage line which could be dragged for should the acoustic release fail.

Ice conditions on the Beaufort Coast during the summer of 1983 were quite severe and prevented deployment of pressure guages at the water depth desired. Mooring design for Stations 5 through 8 had to be changed to allow the mooring to be placed in ice free areas inside of the barrier islands along the Beaufort coast. This mooring design consisted of the Aanderaa pressure guage encased inside a PVC pipe, a small flotation ball, a chain anchor, and a tag line which was anchored on the beach of the barrier island using a Danforth anchor. This type of mooring is illustrated in Figure 5.

Deployment and Retrieval

Methods of deployment and retrieval differed for the Chukchi and Beaufort Sea deployments areas. Deployments in Norton Sound and Chukchi Sea were made for the NOAA Ship R/V Discoverer.

Aboard the Discoverer, the taunt leg moorings were assembled on

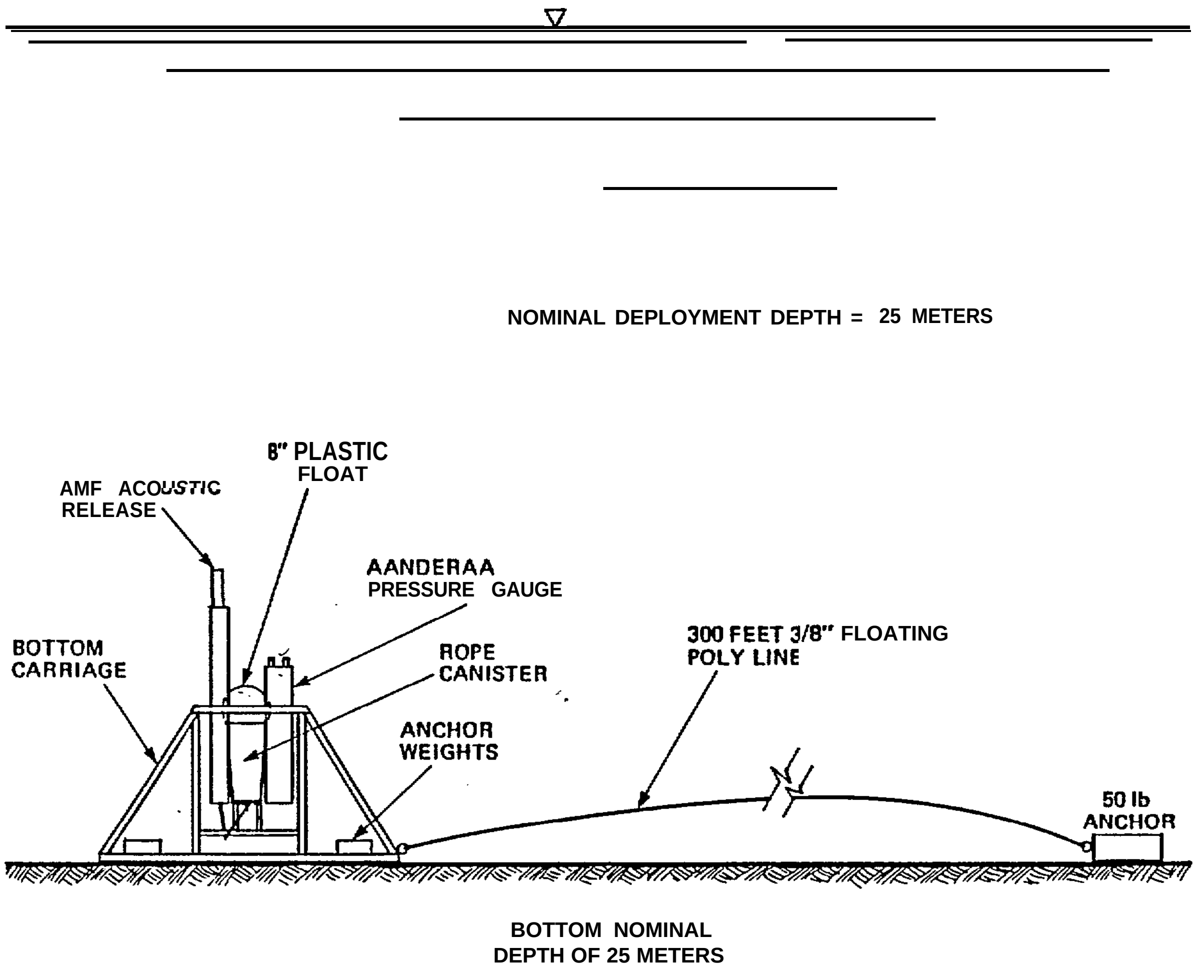

Figure 3 Original Mooring Design

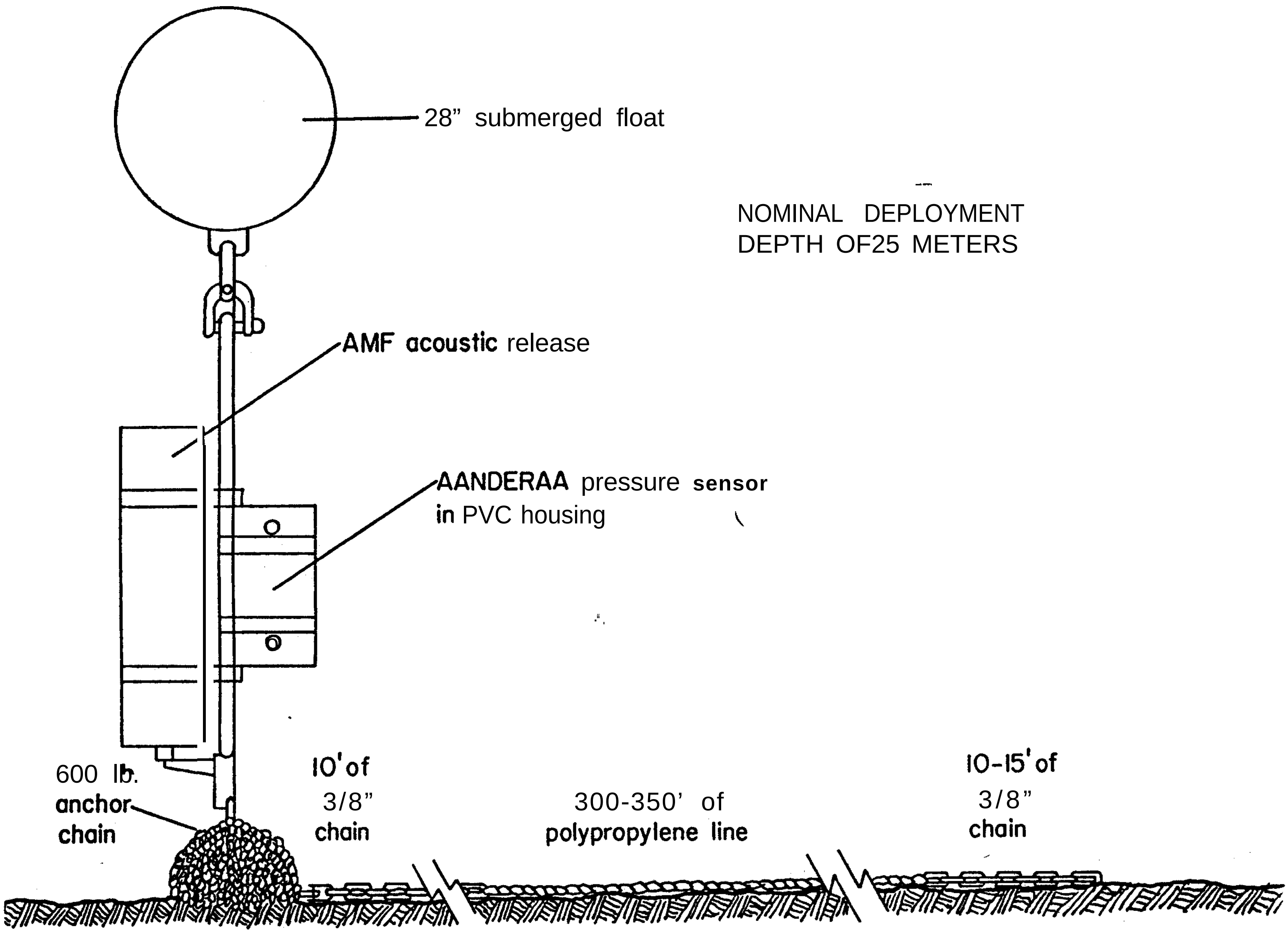

Figure 4 **Mooring** Design for Norton Sound and Chukchi Sea Deployments

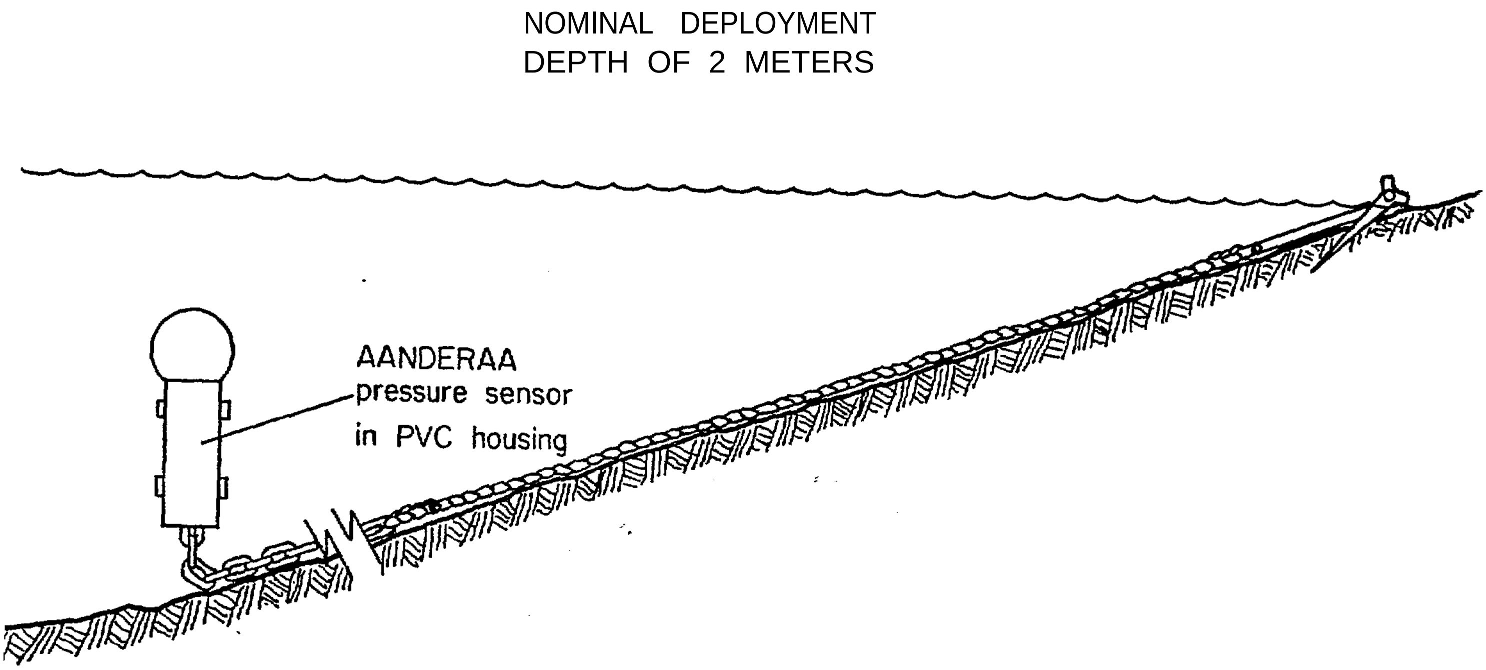

Figure 5 Mooring Design for Beaufort Sea Deployments

deck by connecting the AMF acoustic release to the 28-inch diameter submerged float and the anchor chain clump by a seized shackel. The 100-meter tag line was attached to the anchor chain clump. The pressure guage, mounted inside a protective PVC tube was attached to the stainless steel mooring rod of the AMF release. After the ship had been positioned on station by Loran C and/or satellite navigation equipment, the mooring was deployed. A deck crane was used to lift the mooring section off the deck and lower it to the ocean floor. A gravity hook was used to release the mooring from the crane when the anchor reached the ocean floor. As the mooring was lowered over the side, the tag anchor line, consisting of 100-m of polypropylene line was paid out slowly to keep slight tension on the mooring. After the mooring was on the bottom, the tag line was streched out from the mooring on a known bearing and then deployed. After deployment of the instrumentation, a CTD cast was made to determined the density of the water column at the site.

Retreival of instrumentation was accomplished from . the NOAA ship R/V Surveyor. Upon arrival at the station, a CTD cast was obtained. Communications were then established with AMF acoustic release by means of the deck unit and hydrophore. After receiving confirmation that the release was in the general vicinity and that the whale boat was ready, the release command was sent. The AMF acoustic release released the clump of anchor chain and the submerged flotation ball popped to the surface with the release and pressure guage attached. The whale boat retrieved the mooring and brought it alongside the R/V Surveyor where it was lifted aboard with a deck crane.

Beaufort Sea deployments were made from a charted sea plane and/or NOAA helicopter, since ice conditions prevented deployment by vessel. Mooring were located along barrier islands in ice protected areas near major inlets in the barrier island chain. These moorings consisted of the Aanderaa pressure guages in a PVC tube, supported by a 8-in submerged float attached to the top of the tube, and a 50-lb pounds of chain peice of chain attached to the bottom. A tag line was tied to this chain and lead to a Danforth anchor which was buried on the beach of the barrier island. Pressure guages along the coast were retrieved using a chartered heicopter.

Barometric Pressure Data

Hourly records of Barometric Pressure from the following locations were obtained from the NWS for the deployment period: Unalakleet, Nome, Kotzebue, Cape Lizburn, Barrow, Deadhorse, and Barter Island. Measurements at Deadhorse and Unalakleet were made only during flight operations, approximately half a day. Barometric pressure data for these and other data gaps were ‘determined from weather charts produced by the National Weather Service, Anchorage Forcast Center .for the Alaskan Region. These charts are produced at six hour intervals. Since no barometric pressure records were readily available for locations close to Thetis Island, Flaxman Island, and Demarcation Bay, data for these stations were also determined from weather charts. Data were interpolated between the times of the weather charts. The last of the required weather charts were received from NWS in late December.

Discussion

The deployment and retrieval of pressure guages along the northern Alaskan coast was accomplished during a fairly severe year for ice. The late ice breakup along the Beaufort coast and the short ice free season did not allow the instruments to deployed at the 'Originally selected sites. Ice along almost the entire Beaufort coast was against the outer edge of the barrier island or up against the shore, with the only areas of open water being inside the the barrier islands. After discussions with Dr. Liu of the Rand Corporation (modeler) and Dr. Hamedii of OCSEAP, alternative sites were chosen for the pressure guages. Most of these alternative sites were located 'along the inner edge of barrier island at locations which would be relatively protected from ice floes and at locations close to major inlets in the barrier island chain.

Station 5 was located at 71 14.0' N 155 44.5' W on the western end of Cooper Island. Cooper Island is the last gravel barrier island on the western end of the Plover island chain, offshore of Dease Inlet.

Station 6 was located on Thetis Island. Thetis Island is located offshore of the Colville River at 70 33' N 150 11' W. Thetis Island is on the western end of the Jones barrier island chain. Sohio Construction Company was using Thetis Island for a gravel depository in the construction of Mukluk Island further offshore. This artifical gravel island was constructed during the summer of 1983 at the same time as this study. We wish to express our thanks to Sohio for their assistance to our personnel and for granting their permission to have one of the pressure guages located at Thetis Island.

Station 7 was located near the eastern end of Flaxman Island located at 70 11.0' N 145 57.7' W offshore of the Canning River.

Station ,8 was located on the western end of the eastern gravel spit of Demarcation Bay. The station is close to the U.S./Canadian Border and is located at 69 41.2' N 141 17.6' W.

Stations 1 through 4 are located in Norton Sound and the Chukchi Seas and were deployed at locations selected by OCSEAP.

All pressure guages and acoustic releases operated properly. At Station 7 on Flaxman Island, the pressure records indicate that Someone pulled the pressure guage on shore on August 12 after being deployed on August 5. 1983. On August 20 it appears that the instruments was washed into the intertidal area and recorded tidal fluctuations until sometime near the end of August. When recovered the instrument was in approximately three feet of water. Unfortunately, a twenty-nine day record of tidal fluctuations is not available for harmonic analysis. Nevertheless, the six days of good records at the beginning and six days in the middle of the record may allow correlation between Flaxman Island site and adjacent sites.

Acknowledgements

The success of field operations for this project was due to the cooperative efforts of -several organizations and individuals. Much of the credit is due to NOAA who provide logistical support and instrumentation used in this project. We wish to express our thanks to Dr. Jawed Hameedi and Mr. Mauri Pelto for their assistance throughout the project, espically in the planning stages. A very special thanks to Mr. George Lapiene for his assistance, coordination, encouragement, and hardwork on the North Slope. The instrumentation supplied by PMEL work perfectly, due mainly to the efforts of Misters David Pashinski, Bill Parker, and Tom Jackson. We with to thank the officers and crew of NOAA vessels R/V Discover and R/V Surveyor for their work during deployment and recovery of instrumentation. A special thanks to Field Operations officers Richard K. Muller and John Withrow for their assistance throughout the project planning and coordination and making our stay aboard NOAA ships comfortable and enjoyable. Mr. Jack Zerener of Aanderaa Instruments, Inc. loaned us a tape reader for checkout purposes prior to deployment and again for data processing. We wish to thank Mr. Jerry Featherolf of Sohio Construction CO. for the assistance at Thetis Island.