

DTIC FILE COPY

CRREL REPORT 89-1

AD-A205 428

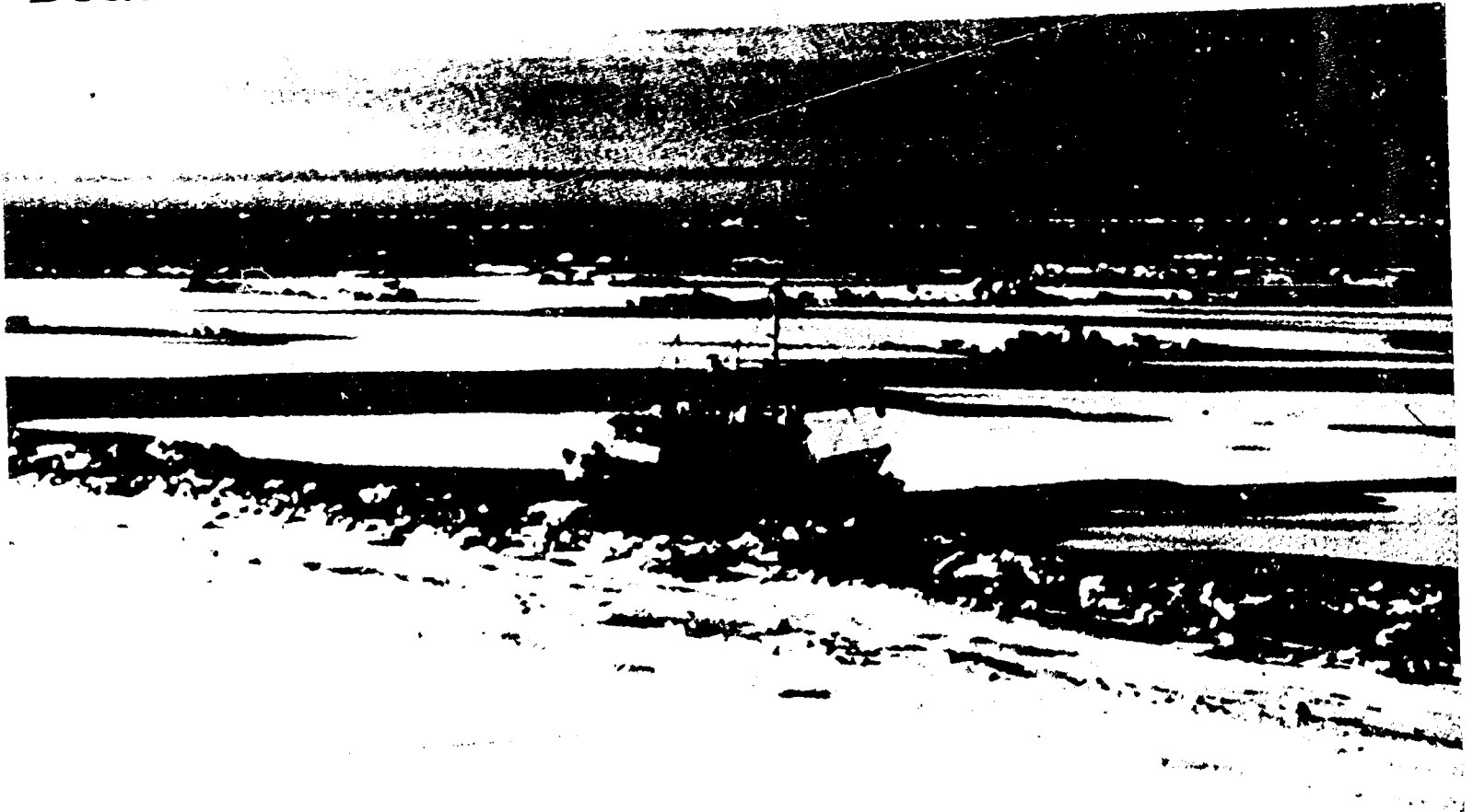


4

US Army Corps
of Engineers

Cold Regions Research &
Engineering Laboratory

*Seafloor temperature and conductivity
data from coastal waters of the U.S.
Beaufort Sea*



DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

JS

DTIC

ELECTE

MAR 03 1989

S

D

H

For conversion of SI metric units to U.S./British customary units of measurement consult ASTM Standard E380, Metric Practice Guide, published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.

Cover: USGS ship Karluk deploying seafloor temperature probes in the Beaufort Sea.

CRREL Report 89-1

January 1989



Seafloor temperature and conductivity data from coastal waters of the U.S. Beaufort Sea

Paul V. Sellmann, Erk Reimnitz and Edward W. Kempema

Prepared for
U.S. GEOLOGICAL SURVEY
and
U.S. DEPARTMENT OF ENERGY

Approved for public release; distribution is unlimited.

89 2 03 053

DD FORM 1473 138

REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188
Exp. Date: Jun 30, 1986

1a. REPORT SECURITY CLASSIFICATION Unclassified		1b. RESTRICTIVE MARKINGS	
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE		Approved for public release; distribution is unlimited.	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) CRREL Report 89-1		5. MONITORING ORGANIZATION REPORT NUMBER(S)	
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Cold Regions Research and Engineering Laboratory	6b. OFFICE SYMBOL (if applicable) CECRL	7a. NAME OF MONITORING ORGANIZATION See 16.	
6c. ADDRESS (City, State, and ZIP Code) 72 Lyme Road Hanover, N.H. 03755-1290		7b. ADDRESS (City, State, and ZIP Code)	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (if applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS (City, State, and ZIP Code)		10. SOURCE OF FUNDING NUMBERS	
		PROGRAM ELEMENT NO.	PROJECT NO.
		TASK NO.	WORK UNIT ACCESSION NO.
11. TITLE (Include Security Classification) Seafloor Temperature and Conductivity Data from Coastal Waters of the U.S. Beaufort Sea			
12. PERSONAL AUTHOR(S) Sellmann, Paul V.; Reimnitz, Erk; and Kempema, Edward W.			
13a. TYPE OF REPORT	13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Year, Month, Day) January 1989	15. PAGE COUNT 26
16. SUPPLEMENTARY NOTATION U.S. Geological Survey, Menlo Park, California and U.S. Dept. of Energy, Morgantown, West Virginia			
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB-GROUP	
			Alaska; Beaufort sea; Cold regions; Ocean temperatures; Sea ice; Seabed properties; Undersea measurements; instruments, etc.
19. ABSTRACT (Continue on reverse if necessary and identify by block number) Important and unique seabed engineering properties and conditions observed on the shallow shelf of the Beaufort Sea may be caused by low temperatures and variable salinities of bottom waters. A year-long monitoring program was initiated during the fall of 1985 to make daily measurements of these parameters using small, self-contained, low-cost instrumentation units placed on the seabed in four locations. The four sites selected were in areas where overconsolidated sediments, seasonal seabed freezing and shallow ice-bonded permafrost are known to occur. The instruments were recovered during the fall of 1986; three units contained useful data. The longest record was 341 days at station 8 in outer Harrison Bay. Seabed temperatures above 0°C, for the period of record, occurred only 15 days at one site and 13 days at another. The mean annual temperatures for these sites were -1.55°C and -1.60°C. Estimates of the onset of seabed freezing suggest that the seabed can freeze on all but 82 days of the year. <i>Keywords: Commercial shelves; Seasonal variations; Electrical conductivity;</i>			
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED, UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS		21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL Paul V. Sellmann		22b. TELEPHONE (Include Area Code) 603-646-4100	22c. OFFICE SYMBOL CECRL-EC

PREFACE

This report was prepared by Paul V. Sellmann, Geologist, Civil and Geotechnical Engineering Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory; Dr. Erk Reimnitz, Marine Geologist, and Edward W. Kempema, Geologist, U.S. Geological Survey. Funding for this study was provided by the U.S. Department of Energy, Arctic Energy Technology Program, and the U.S. Geological Survey, Arctic Offshore Program. The authors acknowledge Allan J. Delaney and Dr. Robert Wills for their assistance in data processing, and Edwin Chamberlain and Dr. Olufemi Ayorinde for their technical reviews.

These observations were made to improve our understanding of seabed temperature and salinity conditions in Arctic coastal waters. Unique conditions in this setting have a significant influence on engineering properties of subsea materials and on Arctic coastal processes.

The contents of this report are not to be used for advertising or promotional purposes. Citation of brand names does not constitute an official endorsement or approval of the use of such commercial products.



Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

CONTENTS

	Page
Abstract	i
Preface	ii
Introduction	1
Approach	1
Instrumentation	1
Deployment	2
Recovery	2
Results	5
Conclusions	9
Literature cited	10
Appendix A: Data	11

ILLUSTRATIONS

Figure

1. The instrument package, with the case removed	2
2. General location of the four sites selected for deployment of instrumentation	3
3. Diagram of instrument package, including the Aanderaa temperature and conductivity instrument and Helle beacon cast in a concrete base	4
4. Period of record for the packages	5
5. Temperature data from the three functioning instruments	6
6. Conductivity data from all three functioning packages	7
7. Comparison of bottom water temperature data for the two Harrison Bay sites	7
8. Measured mean annual seabed temperatures from sites 8 and 9 compared to estimated mean annual seabed temperature from borcholes logged in the Prudhoe Bay Region	8
9. Measured temperature and computed freezing point of the seawater sampled by the conductivity cells	9

TABLES

Table

1. Instrument specifications	2
2. Information on package deployment	3

Seafloor Temperature and Conductivity Data from Coastal Waters of the U. S. Beaufort Sea

PAUL V. SELLMANN, ERK REIMNITZ AND EDWARD W. KEMPEMA

INTRODUCTION

Seafloor temperature and chemistry are unique in shallow arctic seas, compared to similar settings in low latitudes, and may be responsible for the presence and distribution of highly overconsolidated sediments (Chamberlain 1979), seasonal seabed freezing (Sellmann and Chamberlain 1979, Reimnitz et al. 1987), and extensive zones of shallow ice-bonded permafrost (Sellmann and Hopkins 1984). Temperatures can be less than -1.0°C for much of the year and water at the bed can vary from fresh to highly saline (68‰). The seabed temperature and chemistry vary in the coastal zone because of factors such as local freshwater contributions from streams, sediment properties, bottom topography and formation of cold, dense bottom water during seasonal growth of sea ice (which includes fall storms). Understanding these conditions and processes is important for most offshore development activities, such as design and placement of structures, and design and routing of offshore pipelines. This information is also important for evaluating the stability of relict permafrost and the possibility of thaw settlement, for determining the potential for contemporary seasonal freezing of the seabed and for understanding sediment dynamics, such as when ice-bonding of surface sediments will influence ice gouging and bedload transport.

A pilot monitoring program was undertaken at two coastal areas in the Beaufort Sea in an attempt to obtain data on daily and seasonal variations in seafloor temperature and salinity, and to determine the problems with recovering instrumentation placed at carefully selected sites. Four self-contained recording instruments were, thus, deployed in the fall of 1985 just prior to freezeup of the sea ice.

APPROACH

Instrumentation

The data were acquired with small, self-contained, low-cost recording instruments placed on the seabed at locations selected to reduce the chance of disruption by ice keels. Such locations would include local depressions and areas in the shelter of bathymetric highs. Previous attempts to use standard mooring techniques for long-term deployment on this shallow, open shelf have provided a long record of instrument fatalities, and only blocks of seasonal data. The units were to be low in cost to ensure a maximum number of observation stations and to reduce the economic impact of losing a unit. Analysis of preliminary designs suggested that a small, self-contained unit could be constructed at relatively low cost (approximately \$5000 to \$6000), but not in time for the 1985 fall deployment. After a number of instrumentation alternatives were considered, a modified Aanderaa RCM-4S current meter was selected because of its proven reliability, its temperature sensors' stability, its compatibility with other project equipment and its competitive price.

Our version of the RCM-4S has two temperature sensors and one conductivity sensor. One temperature sensor is case-mounted and the other is connected to a 1-m-long cable that permits it to be placed in the seabed. The case-mounted sensor was calibrated and monitored for two temperature ranges: -2.5 to 21°C and -3.5 to 2.1°C . Only the low range was monitored with the sensor on the cable. The conductivity cell is case-mounted and has a measuring range of 0 to 77 mmho/cm. The units were set to make hourly observations for a period of 416 days. To assure data quality, the instruments were cali-

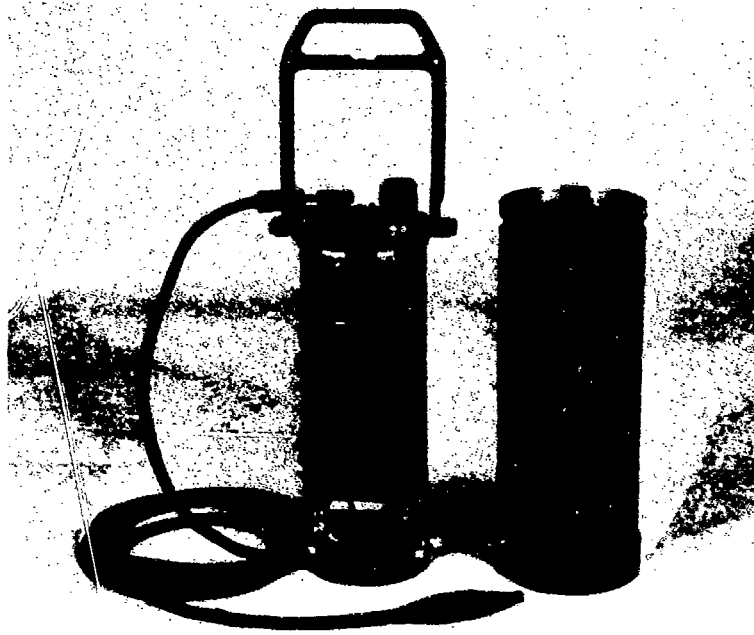


Figure 1. The instrument package, with the case removed. The instrument is 128 mm in diameter, 510 mm in height and has a weight of 19.1 kg.

Table 1. Instrument specifications.

Measuring system:

Self-balancing bridge for sequential measuring of six channels, with a 10-bit binary word used with each channel. Recording is on magnetic tape.

Clock:

Type: Quartz clock 2174.

Accuracy: Better than 2 s/day between 0 and 20°C.

Sampling intervals: 0.5, 1, 2, 5, 10, 15, 20, 30, 60 and 180 minutes, selected by interval switch.

Temperature:

Sensor type: Thermistor (Fenwal GB32JM191).

Standard range: -2.46 to 21.40°C.

Arctic range: -3.5 to 2.0°C.

Two sensors, one case-mounted and one on a 1-m long conductor. Two channels for each sensor, one for each range. Resolution 0.1% of the range selected.

Conductivity:

Sensor type: Inductive cell.

Range: 0 to 77 mmho/cm.

Resolution: 0.1% of range.

Calibration accuracy: ± 0.025 mmho/cm.

brated prior to deployment. A photo of the instrument package is shown in Figure 1.

Important features of the modified RCM-4S unit include its narrower-than-usual arctic range and the addition of the cable-mounted temperature sensor to obtain data at a shallow depth (10–20 cm) beneath the bed. The specifications for the instrument are given in Table 1.

Deployment

The packages were deployed in the shallow coastal waters of the Beaufort Sea in late September of 1985. Four sites (Fig. 2) were selected to reflect different water depths and geological conditions (Table 2). The site designations (7–10) were selected to correspond with instrumentation and data code numbers.

Three of the instruments were placed off the Colville River in Harrison Bay along a line that extended 16 km from shore to a

maximum water depth of 14 m. This region is of interest because of very shallow ice-bonded permafrost and reported seasonal bed freezing. The other instrument was placed off the Sagavanirktok Delta in Stefansson Sound, also in an area where shallow ice-bonded permafrost has been reported and where there should be seasonal bed freezing and overconsolidated sediments. Details regarding the location of the instruments are provided in Table 2.

The USGS research vessel *Kariuk* was used for deployment, with site location based on precision land-based navigation. Site bathymetry was also recorded to aid both detailed site selection and future recovery. The instruments were cast into a concrete base to which the remote temperature sensor was mounted separately in such a way as to assure penetration into the seafloor during the deployment (Fig. 3). A beacon also was cast into the concrete base to help divers recover the units. Site observations included temperature measurements of the water column.

Recovery

The USGS ship *Kariuk* was to be used to recover the packages; however, a budget cut by

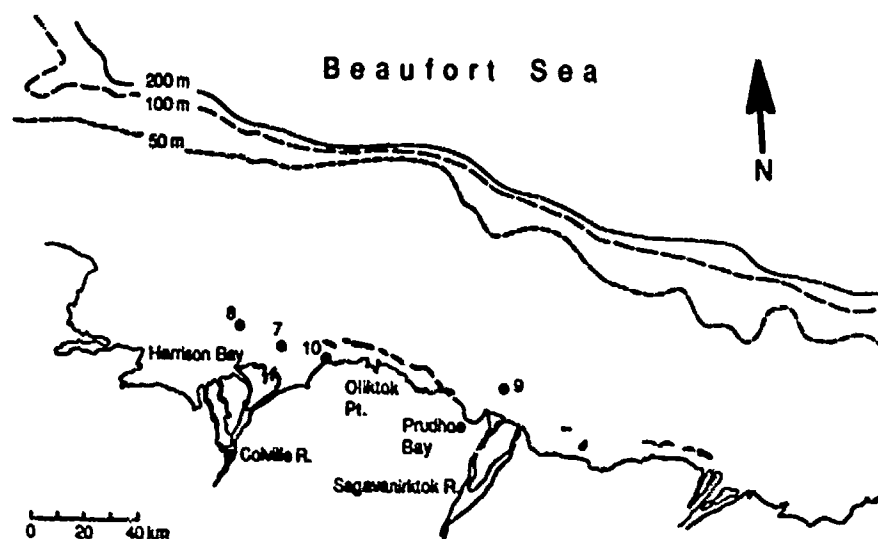


Figure 2. General location of the four sites selected for deployment of instrumentation.

Table 2. Information on package deployment.

Site no.	Time and date		Time instrument off	General region	Location	Water depth	Distance from shore
	Deployed	Recovered					
6	1420 hr 9-24-85	2230 hr 8-30-86	1017 hr 8-31-86	Harrison Bay off the Colville Delta.	150°39'00" 70°38'25"	14 m	16 km from Colville Delta.
7	1640 hr 9-24-85	1513 hr 8-30-86	1017 hr 8-31-86 inoperative	Harrison Bay off the Colville Delta in slight depression for protection from ice.	150°15'55" 70°35'45"	7 m	8.6 km from delta and 2.7 km from Thetis Island.
10	1910 hr 9-24-85	0954 hr 8-30-86	1017 hr 8-31-86 damage by flooding	Harrison Bay attached to west leg of west dolphin near Oliktok Pt.	149°51'25" 70°30'33"	2.5 m	50 m from dock.
9	1232 hr 9-26-85	1930 hr 8-17-86	1017 hr 8-31-86	Stefansson Sound near Endicott Causeway off Sagavanirktok Delta.	145°00'00" 70°24'05"	6.2 m	8.0 km from Sagavanirktok Delta.

NOAA forced cancellation of the USGS Arctic Offshore Program. Therefore, the recovery was done by Arctic Marine Research Associates, with coordination, financing and field assistance from the USGS. The following is an account of the recovery done from a large open skiff, with success that exceeded original expectations.

The first instrument was recovered on 17 August 1986 (39 days less than a year) and the remaining three on 30 August (24 days less than a year). Bad weather near the end of the month delayed the recovery operation. The instruments were examined on the seafloor before retrieval. The diver noted instrument condition, angle,

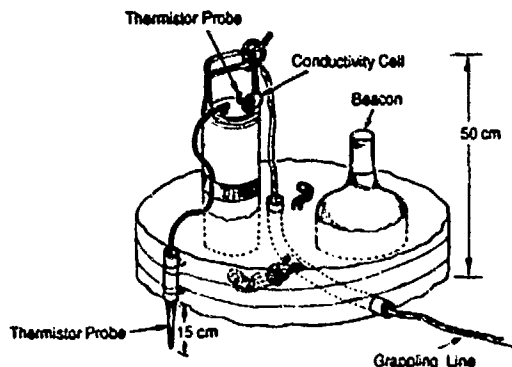


Figure 3. Diagram of instrument package, including the Aanderaa temperature and conductivity instrument and Helle beacon cast in a concrete base. The buoyant grappling line was 75 m in length, weighted down at 15-m intervals by chain links. The grappling line is tied to chain links cast into the concrete base, and is passed through rubber hose to prevent chafing on the concrete.

sensor location in relation to the seabed, bottom topography and any other parameters that could influence instrument performance and data quality. In most cases poor visibility required that these observations be made by feel.

The instrument deployment sites were approximately located by use of ranges from shore stations. Divers were then guided to the instruments with the aid of an acoustic homing system.

Site 9

The instrument at this site east of Prudhoe Bay off the Sagavanirktok Delta was recovered (Table 2) on 17 August. It was covered with drift kelp, but was in an upright position with the remote temperature probe fully inserted into the sediment. The grappling line (Fig. 3) stretched out eastward from the instrument. The concrete base tilted slightly to the east, as if it had been forced into the seabed on that side. There were no signs of fresh soft sediment accumulation around the package.

After recovery, the instrument, including bail (handle on top of instrument), external probe and top sensors, was found to be in good condition, with no significant scrapes, signs of corrosion or indications of impact. The instrument was free of moisture and the recording tape was wound almost completely through. The drive was shut off at 1017 on 31 August 1986 and the tape removed.

A sample of "undisturbed" muddy sand was collected at the site with a special technique using 8-ounce (0.25-L) sample jars. A capped jar was partially inserted into the bed before the diver removed the lid; the jar was then pushed farther into the sediment until filled and then recapped. This technique was used in an attempt to avoid contamination of sediment pore water by sea water. The salinity of the interstitial water ($31 \pm 0.5 \text{‰}$) was measured with a Reichert T/C refractometer on 26 August.

Site 10

The instrument at site 10 was recovered off Oliktok Point on 30 August. Because of the high risk of ice impact at this shallow depth (2.5 m), the package was loosely secured to the west leg of the west dolphin structure (part of a marine anchoring facility) by two loops of polypropylene line. The package was found in a 30- to 50-cm deep depression, probably formed by current scour around the dolphin leg. The instrument was resting on its side with its top in the mud. The external temperature probe still seemed to be attached to the base, but in a horizontal position about 30 cm above the seafloor.

The external temperature probe was lost during recovery, indicating that its fastenings had failed. It may have been unplugged during overturning prior to recovery. After recovery, the bail was found bent about 10° from vertical with one attachment bolt sheared off.

When opened on 31 August 1986, the instrument was found to be half full of seawater. Flooding apparently had been recent, since the data tape had almost run completely through. A corrosion line, running parallel with the top, inside of the device, indicated that the package was upright most of the time that it was flooded, even though it was found on its side. The position of the corrosion line and the limited amount of corrosion suggest that the instrument was probably flooded during recovery when the lifting bag exerted an upward force of 60–70 lb (27–32 kg) on the bail.

The tape was removed from the instrument, soaked in fresh water to remove any salt, and then stored in a plastic bag with a damp rag until it could be unreeled and dried on 4 September. The tape head became disconnected while the tape was being removed, apparently because its glue had been weakened by immersion in salt water.

Site 7

The instrument at site 7 was found upright, but with mud deposited to about 30 cm above the surface of the concrete base.

The mud was soft enough for the diver's hand to penetrate to the base of the concrete slab to tilt and break it free, but this required considerable effort. During the attempt to lift the unit aboard, the grappling line offered strong resistance and had to be cut. It must have been deeply buried in mud that had already become semi-consolidated.

After recovery, the instrument was found to be in good condition. However, the recorder had failed to start, even though the on/off switch was in the "on" position.

Two sediment samples were collected within 1 m of the package in the same way as at site 9 in Stefansson Sound. The salinity of the interstitial water was measured to be 28 and 27.5 ‰. Another sample was collected from the base of a 5-cm-thick layer of gray sandy mud covering the concrete slab. This sample would have been 15–20 cm below the mud line and had a pore water salinity of 28 ‰. The remote temperature probe was positioned correctly when the unit was recovered.

Site 8

At site 8 the instrument was found upright on a firm bottom with the remote temperature probe fully inserted into the seabed, with no sediment accumulation around the base of the package. The grappling line, originally stretched out tight to the east, was found floating around the instrument package in large loops, again suggesting disturbance by ice.

After recovery the instrument was found to be in good condition, without damage, corrosion or water leakage, and the tape head was wound through almost entirely when shut off at 1017 A.S.T. on 31 August.

RESULTS

Of the four instruments, three functioned during the term of deployment; one failed, apparently because of a battery problem. Two instruments operated free of any problems. The third operated for most of the recording period, with erratic performance and loss of data near the end of deployment. Figure 4 shows the record period for the instruments and their sensors. The daily and monthly data are included in Appendix A.

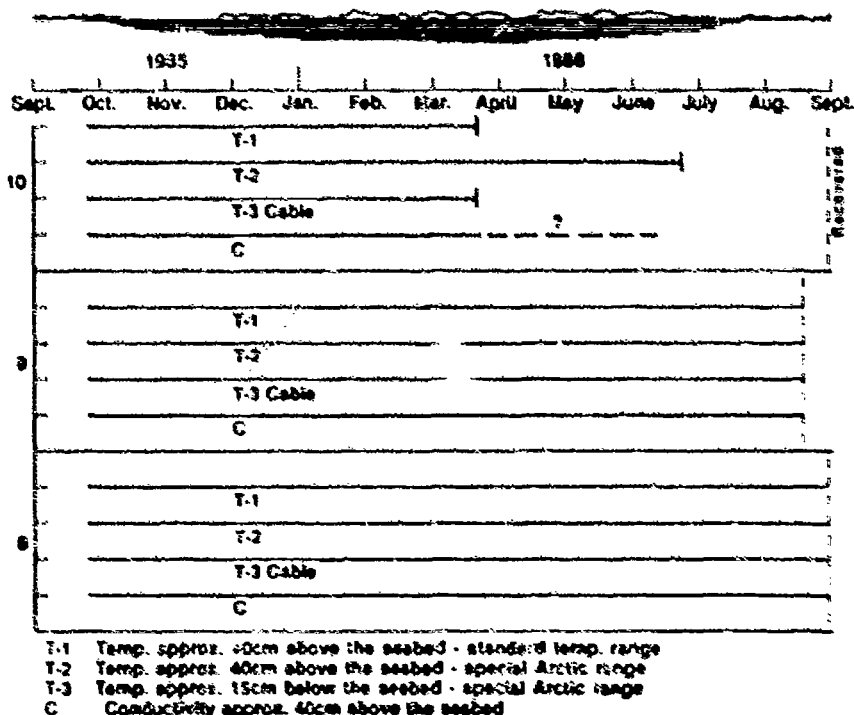
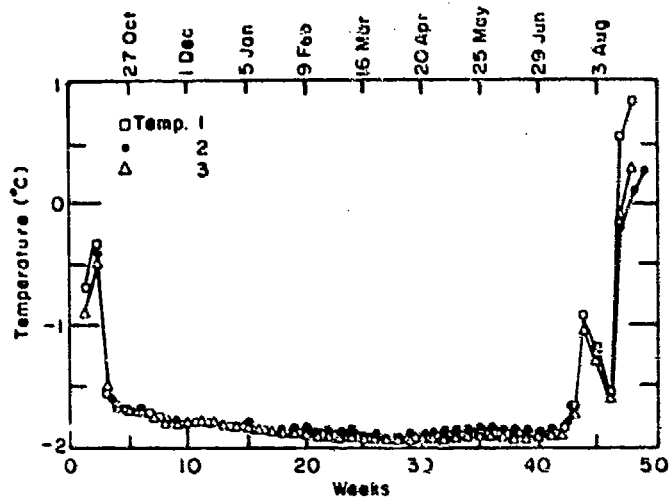
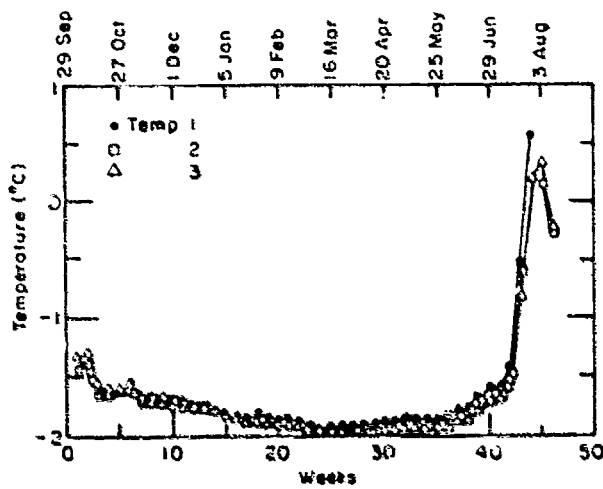


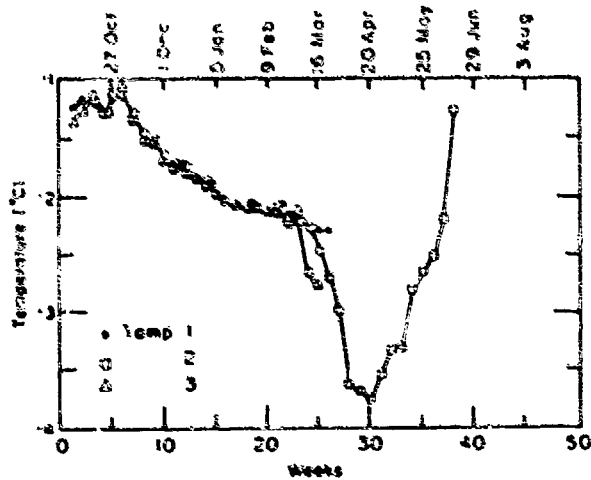
Figure 4. Period of record for the packages.



a. Site 8 (outer Harrison Bay).



b. Site 9 (Stefansson Sound).



c. Site 10 (inner Harrison Bay, off Oliktok Point).

Figure 5. Temperature data from the three functioning instruments. Dates are for the start of 7-day periods.

Data from Outer Harrison Bay (site 8) and Stefansson Sound (site 9) are similar, even though they were separated by many kilometers. Both sites experienced a steady decrease in temperature as the winter progressed, with minimum values in Harrison Bay occurring in April (Fig. 5a). The lowest temperature values observed at these two sites were recorded in Stefansson Sound, where temperatures were close to -2.0°C at the seabed (Fig. 5b). However, at the shallow (2.5 m) site near Oliktok Point (site 10), temperatures were as low as -3.5°C (Fig. 5c), with some indication that late in the season freezing may have progressed to near the bed, incorporating the sensors into the base of the sea ice cover.

Record time varied because of the deployment period and because one of the units stopped after

being flooded (Fig. 4). The outer Harrison Bay instrument (site 8) provided the longest record, just 24 days short of a complete year. The Stefansson Sound instrument (site 9) off the Sagavarnirktok Delta ran for 39 days short of a year. The instrument at site 10 in shallow water from inner Harrison Bay provided fewer data, with the last useful temperature information recorded on 21 June, about 94 days short of a year.

Additional temperature and conductivity data are shown in Figures 6 and 7, and a summary of daily and monthly averages is listed in Appendix A. During the record processing at CRREL, obviously bad values were removed. The tapes were first processed by Aanderaa to take care of some alignment problems.

The long data sets from outer Harrison Bay (site 8) and Stefansson Sound (site 9) permit a fairly accurate reconstruction of mean annual seafloor temperature for these areas. Adjustment of the data was necessary since the instruments were out for a period just short of a year. Values for the interval without data were arrived at by averaging temperatures from the end and beginning of the recording period.

Mean temperatures of the seabed (T-3) and water (T-2) near the bed in Stefansson Sound (site 9) for the 46-week deployment period were the same, -1.66°C . The mean seabed temperature (T-3) in outer Harrison Bay (site 8) for the 48-week deployment period was -1.70°C , slightly lower than the -1.66°C water temperature (T-2). The mean annual seabed temperature and water temperature near the bed, based on estimates of the missing data, were determined to both be -1.55°C for the Stefansson Sound site. In outer Harrison Bay, the mean annual water temperature (T-2) was calculated as -1.58°C and the average for the bed (T-3) -1.61°C , with the average of the two being -1.60°C . The mean annual seabed temperature data were plotted in Figure 8 for comparison with earlier estimates of mean annual seabed temperature for the Prudhoe Bay region (Sellmann and Chamberlain 1979). The earlier estimates were made by extrapolating values from temperature profiles measured in holes drilled into the seafloor. The estimates and the measured values are in good agreement. The holes were drilled at

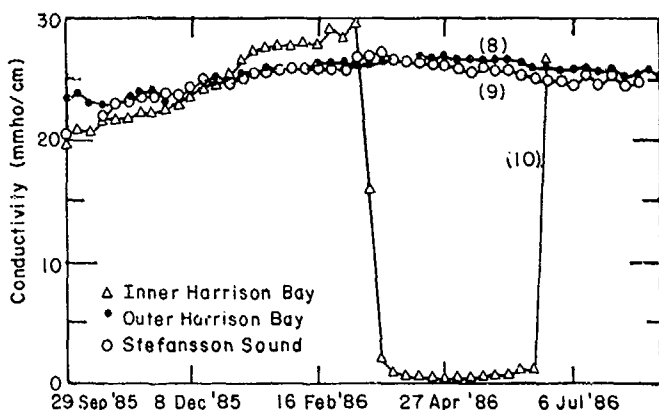


Figure 6. Conductivity data from all three functioning packages.

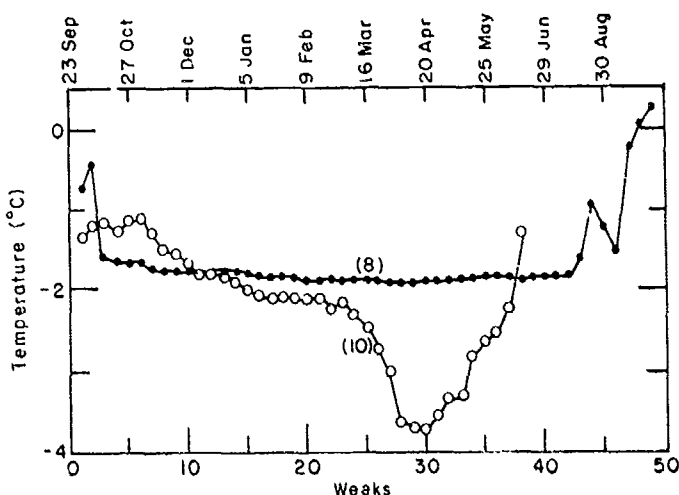


Figure 7. Comparison of bottom water temperature data for the two Harrison Bay sites.

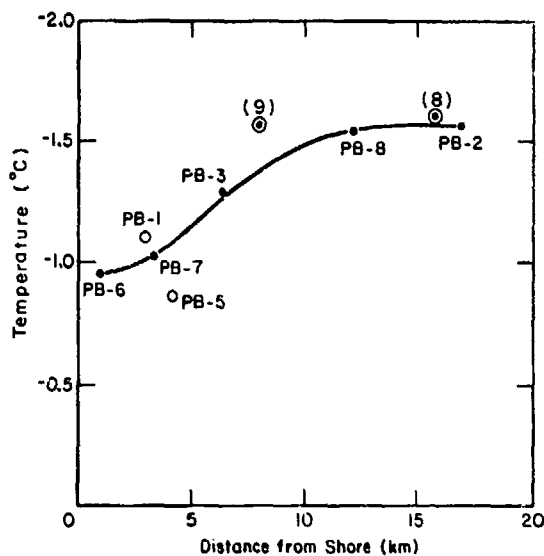


Figure 8. Measured mean annual seabed temperatures from sites 8 and 9 compared to estimated mean annual seabed temperature from boreholes logged in the Prudhoe Bay region (Sellmann and Carverlain 1979).

increasingly greater water depths from shore; therefore, the plot might also be viewed as a plot of temperature versus water depth. If this were the case, the data points for outer Harrison Bay (site 8) and Stefansson Sound (site 9) are still plotted in about the correct position.

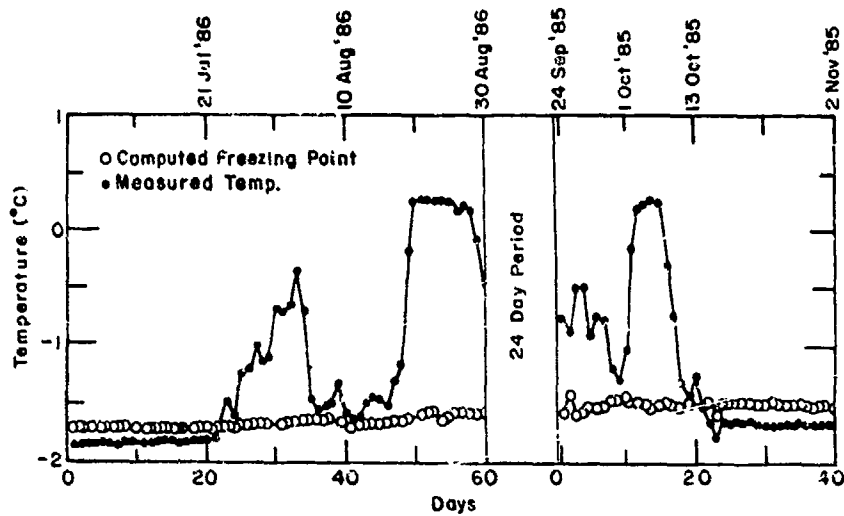
To better illustrate short-term variations, daily average temperatures were plotted for sites 8 and 9, covering the two transition periods between winter and open-water conditions (Fig. 9). This is in contrast to the other plots of weekly averages for the uninterrupted deployment period. The daily plots also include calculated freezing point data for the water near the bed based on the conductivity and temperature data. The conductivity was first converted to salinity, following the procedures outlined by Bennett (1976) and the freezing point was calculated using equations from Weast (1976).

The temperature data for the transition and open water periods varied dramatically compared to those for the ice-covered season. An idea of the magnitude and duration of the summer variations was illustrated by using 1985 data to complete the record for the 1986 open water season. The plots also show the period for which no data were obtained.

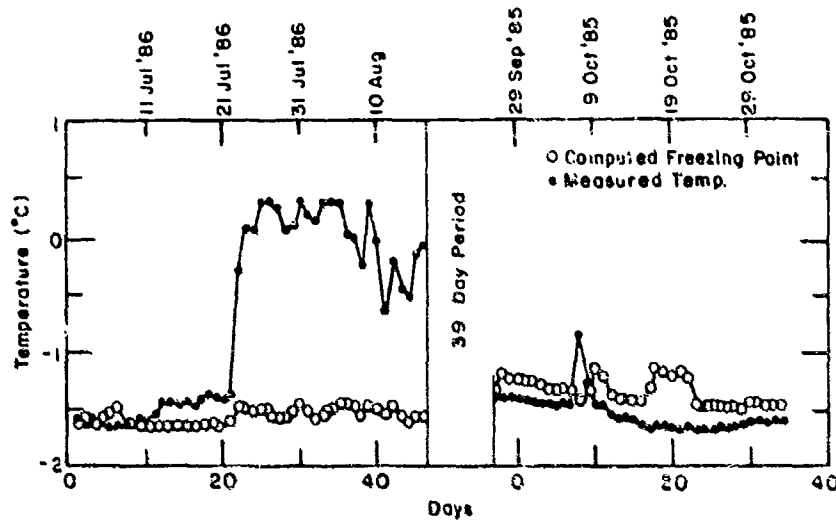
The temperature data suggest that the sensors were quite stable for the year, with values and patterns observed at the end of the recording period agreeing well with those from the time of deployment. Only a small amount of data from the ice-covered period were included for contrast with the summer data. In outer Harrison Bay (site 8) the largest daily change, an increase of 1°C, occurred during mid-August. Increases and decreases of more than 0.5°C, though, were common. The data from outer Harrison Bay also have an interesting cyclic pattern, with warmer periods lasting about 10 days. The record for the same period in Stefansson Sound (site 9) also shows large summer fluctuations, although cyclic variations like those at site 8 did not occur. However, there was noticeable warming at the same time as in outer Harrison Bay, although more rapidly, with temperatures rising more than 1°C in one day. This was followed by much smaller fluctuations, with only a few days having changes around 0.5°C. The warm period was approximately 20 days shorter in Stefansson Sound than in outer Harrison Bay. From the available record, only 15 days of the year were above 0°C at site 9 compared to 13 days at site 8.

The freezing point temperatures calculated for water near the bed were used to determine the duration of possible seasonal seafloor freezing, assuming that the bottom water chemistry and seabed pore water are the same at the start of the process. Seabed freezing should start when temperatures are lower than the calculated freezing point of the water at the seabed. In outer Harrison Bay, the seabed apparently can freeze for all but 82 days of the year. The computed freezing point data suggest that the bottom water is less saline in late summer than earlier in the summer, which may tend to cause freshening of the sediments at the bed and enhancing the possibility of more noticeable bed freezing early in the fall.

The amount of supercooling suggested by the observations (0.1 to 0.2°C) is very similar in Stefansson Sound and outer Harrison Bay and is unreasonably large. It is more likely that the conductivity cell did not provide accurate data once frazil ice formed in the water column in the sensor or anchor ice attached to the sensors. Therefore, data in these plots should be free of sensor problems only when water temperatures are higher than the calculated freezing points. Cell response characteristics and the calculation



a. Site 8 (outer Harrison Bay).



b. Site 9 (Stefansson Sound).

Figure 9. Measured temperature and computed freezing point of the seawater sampled by the conductivity cells.

procedures are still both being examined to clarify this problem.

Conductivity measurements of the interstitial water in sediments at the seabed were made at two sites at the time of instrument recovery. One place was near site 9, which had the instrument that functioned throughout the deployment period. The salinity of the interstitial water measured with a Reichert T/C refractometer was 31 ± 0.5 ‰. The day before recovery the measured seawater salinity was 29.8 ‰, with an average of

30.0 ‰ for the 40-day period prior to recovery. Thus, the sediment salinity data support the seawater conductivity measurements.

CONCLUSIONS

The data show very noticeable seasonal changes in temperature and conductivity at the seabed at several sites in the Beaufort Sea. The greatest variability and highest temperatures

occur during the open water period. Temperatures at the seabed are very low and range between -1.5 and -2.0°C for more than 9 months. During this period there are only gradual changes, with slow cooling occurring until late March to early April, which is followed by slow warming. This extended period of low bottom temperatures closely corresponds with the period of ice cover noted on the Ice Limit Maps produced by the Navy-NOAA Joint Ice Center. Temperatures and their variations are very similar for the two deeper water sites, even though there was a great distance between them. Temperatures are much lower at the shallow water site, reflecting the influence of sea ice forming at or near the seabed. The drop in conductivity values around the time of very low temperatures at the shallow water site suggests that ice formed in and around the conductivity sensor. The conductivity values from the other packages increase as the ice cover thickens and the temperature drops, with maximum conductivity values around the time of lowest bottom temperatures.

Temperatures above 0°C were observed at the two deeper water sites (8 and 9) for no more than 2 weeks during the period of record. The temperatures and computed freezing point data suggested that seasonal seabed freezing can occur most of the winter, corresponding to the period of continuous ice cover.

The temperature data suggest that the sensors are quite stable, since independent sensors

on one package provided identical averages for the deployment period.

LITERATURE CITED

- Bennett, A.S. (1976) Conversion of in situ measurements of conductivity to salinity. *Deep-Sea Research*, 23(2):157-165.
- Chamberlain, E.J. (1979) Overconsolidated Sediments in the Beaufort Sea, *Northern Engineer*, 10(3)24-29.
- Reimnitz, E., E. W. Kempema and P. W. Barnes (1987) Anchor ice, seabed freezing, and sediment dynamics in shallow arctic seas. *Journal of Dynamics in Shallow Arctic Seas, Journal of Geophysical Research*, 92(C13):14,671-14,678.
- Sellmann, P.V. and E.J. Chamberlain (1979) Permafrost beneath the Beaufort Sea near Prudhoe Bay, Alaska. In: *Proceedings of the Eleventh Annual Offshore Technology Conference, Houston, Texas*, pp. 1481-1488.
- Sellmann, P.V. and D.M. Hopkins (1984) Subsea Permafrost Distribution on the Alaskan Shelf. In: *Permafrost, Fourth International Conference, July 17-22 1983, University of Alaska, Fairbanks, Alaska*. Washington, D.C.: National Academy Press, p. 75-82.
- Weast, Robert C. (Ed.) (1976) *Handbook of Chemistry and Physics*. 57th Ed. Cleveland, Ohio: CRC Press.

APPENDIX A: DATA.

(Data considered invalid are marked by a line)

DAILY AVERAGES OF CONDUCTIVITY FROM 08

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1		22.848	23.127	23.048	25.215	25.393	26.229	26.507	26.811	26.594	25.679	25.889
2		22.342	23.060	23.239	25.297	25.567	26.510	26.472	26.773	26.550	25.509	25.923
3		22.528	23.019	23.403	25.245	25.578	26.378	26.454	26.805	26.556	25.740	26.120
4		23.682	22.927	23.593	25.148	25.757	26.310	26.428	26.709	26.536	25.739	25.748
5		24.220	23.005	23.872	25.090	25.940	26.278	26.390	26.775	26.571	25.660	24.825
6		24.477	23.100	24.040	25.090	25.977	26.252	26.390	26.654	26.600	25.651	24.852
7		24.568	23.681	24.220	25.090	25.932	26.249	26.463	26.652	26.588	25.737	24.768
8		24.429	23.652	24.223	25.090	25.848	26.240	26.460	26.603	26.521	25.740	24.786
9		23.627	23.540	24.223	25.299	25.953	26.170	26.483	26.647	26.572	25.740	25.065
10		23.400	23.457	24.220	25.839	25.930	26.085	26.559	26.680	26.575	25.740	25.282
11		23.025	23.547	24.200	25.694	25.973	26.030	26.580	26.680	26.407	25.740	25.347
12		22.835	23.510	24.127	25.704	25.854	26.050	26.640	26.637	26.275	25.740	25.329
13		23.046	23.541	24.150	25.555	25.854	26.100	26.620	26.650	26.234	25.727	25.294
14		22.873	23.960	24.150	25.437	25.825	26.405	26.633	26.600	26.150	25.740	25.352
15		22.770	24.150	24.150	25.433	25.900	26.512	26.620	26.585	26.044	25.660	25.350
16		23.966	24.107	24.205	25.511	25.957	26.588	26.513	26.577	26.007	25.660	25.370
17		22.790	24.061	24.409	25.494	26.094	26.527	26.530	26.539	26.065	25.599	25.410
18		22.796	24.003	24.606	25.648	26.120	26.440	26.548	26.416	25.950	25.610	25.320
19		22.704	24.009	24.600	25.660	26.074	26.380	26.580	26.390	25.950	25.517	25.798
20		22.706	23.980	24.272	25.660	26.196	26.263	26.539	26.370	25.880	25.505	25.935
21		22.758	23.917	24.258	25.663	26.249	26.290	26.530	26.310	25.880	25.494	25.982
22		22.800	23.903	24.232	25.694	26.295	26.406	26.513	26.367	25.938	25.546	25.655
23		23.007	23.938	24.355	26.217	26.380	26.443	26.568	26.590	25.970	25.517	25.219
24		22.454	24.000	25.400	26.076	26.380	26.549	26.680	26.680	26.032	25.440	26.009
25	22.190	22.840	24.035	25.613	25.880	26.353	26.721	26.756	26.560	25.955	25.430	25.597
26	25.043	22.773	24.003	25.377	25.822	26.310	26.697	26.770	26.505	25.916	25.623	25.326
27	24.982	22.600	23.658	25.256	25.740	26.257	26.677	26.762	26.660	25.809	25.536	25.170
28	23.716	22.824	23.084	25.172	25.755	26.322	26.562	26.817	26.677	25.810	25.756	25.423
29	23.823	22.716	23.182	25.245	25.680		26.488	26.773	26.600	25.723	25.593	25.185
30	23.815	22.687	23.140	25.250	25.660		26.460	26.779	26.600	25.737	25.576	25.453
31		23.016		25.189	25.660		26.431		26.597		25.824	

MONTHLY AVERAGES

23.085 23.119 23.510 24.397 25.557 26.013 26.380 26.578 26.598 26.160 25.642 24.967

DAILY AVERAGES OF TEMPERATURE 2 FROM 08

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1		-1.204	-1.670	-1.780	-1.810	-1.850	-1.876	-1.908	-1.887	-1.850	-1.850	-.710
2		-1.310	-1.670	-1.790	-1.817	-1.850	-1.897	-2.002	-1.880	-1.850	-1.850	-.664
3		-1.030	-1.660	-1.782	-1.810	-1.850	-1.887	-1.905	-1.878	-1.850	-1.850	-.361
4		-.164	-1.679	-1.780	-1.803	-1.850	-1.888	-1.910	-1.880	-1.851	-1.850	-.713
5		.208	-1.698	-1.780	-1.791	-1.866	-1.890	-1.910	-1.899	-1.850	-1.850	-1.475
6		.270	-1.685	-1.780	-1.790	-1.860	-1.890	-1.908	-1.891	-1.855	-1.849	-1.564
7		.270	-1.633	-1.776	-1.790	-1.855	-1.890	-1.907	-1.890	-1.858	-1.850	-1.537
8		.249	-1.645	-1.778	-1.790	-1.852	-1.890	-1.910	-1.892	-1.860	-1.850	-1.510
9		-.277	-1.658	-1.780	-1.793	-1.859	-1.889	-1.908	-1.890	-1.851	-1.840	-1.340
10		-.710	-1.671	-1.778	-1.826	-1.851	-1.885	-1.908	-1.888	-1.852	-1.843	-1.593
11		-1.310	-1.696	-1.772	-1.837	-1.854	-1.880	-1.908	-1.880	-1.861	-1.842	-1.639
12		-1.424	-1.720	-1.770	-1.841	-1.852	-1.878	-1.911	-1.880	-1.872	-1.850	-1.615
13		-1.256	-1.722	-1.779	-1.824	-1.851	-1.877	-1.917	-1.878	-1.870	-1.847	-1.479
14		-1.540	-1.756	-1.780	-1.822	-1.858	-1.880	-1.920	-1.879	-1.870	-1.832	-1.447
15		-1.661	-1.776	-1.780	-1.830	-1.875	-1.876	-1.911	-1.879	-1.875	-1.830	-1.464
16		-1.782	-1.768	-1.780	-1.830	-1.880	-1.892	-1.910	-1.874	-1.877	-1.835	-1.512
17		-1.663	-1.760	-1.779	-1.824	-1.885	-1.900	-1.906	-1.870	-1.867	-1.840	-1.303
18		-1.669	-1.777	-1.780	-1.840	-1.890	-1.893	-1.902	-1.870	-1.880	-1.827	-1.159
19		-1.660	-1.774	-1.780	-1.840	-1.890	-1.904	-1.899	-1.870	-1.876	-1.838	-.158
20		-1.661	-1.769	-1.780	-1.840	-1.890	-1.895	-1.892	-1.870	-1.880	-1.833	.270
21		-1.662	-1.762	-1.780	-1.840	-1.890	-1.900	-1.890	-1.866	-1.880	-1.826	.270
22		-1.667	-1.760	-1.780	-1.843	-1.890	-1.907	-1.890	-1.860	-1.880	-1.802	.270
23		-1.680	-1.764	-1.780	-1.850	-1.885	-1.910	-1.888	-1.860	-1.875	-1.861	.270
24		-1.680	-1.770	-1.803	-1.848	-1.880	-1.900	-1.890	-1.860	-1.865	-1.494	.270
25	-.894	-1.874	-1.773	-1.824	-1.842	-1.880	-1.900	-1.903	-1.860	-1.870	-1.637	.270
26	-.487	-1.870	-1.774	-1.810	-1.847	-1.880	-1.900	-1.904	-1.860	-1.871	-1.267	.152
27	-.488	-1.667	-1.751	-1.810	-1.848	-1.871	-1.895	-1.900	-1.860	-1.862	-1.237	.224
28	-.919	-1.683	-1.748	-1.809	-1.850	-1.870	-1.890	-1.897	-1.858	-1.860	-1.004	.174
29	-.749	-1.672	-1.794	-1.810	-1.850		-1.890	-1.892	-1.851	-1.851	-1.168	-.072
30	-.788	-1.679	-1.795	-1.802	-1.850		-1.898	-1.890	-1.850	-1.850	-1.125	-.457
31		-1.570		-1.800	-1.850		-1.900		-1.850		-.691	

MONTHLY AVERAGES

-.724 -1.216 -1.729 -1.767 -1.828 -1.868 -1.892 -1.907 -1.873 -1.864 -1.871 -.705

DAILY AVERAGES OF TEMPERATURE 3 FROM 08

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1		-1.081	-1.705	-1.812	-1.838	-1.880	-1.910	-1.940	-1.930	-1.910	-1.914	-.831
2		-1.218	-1.710	-1.800	-1.843	-1.880	-1.929	-1.945	-1.930	-1.910	-1.918	-.786
3		-1.205	-1.705	-1.800	-1.840	-1.880	-1.925	-1.942	-1.930	-1.910	-1.919	-.499
4		-.771	-1.706	-1.800	-1.832	-1.885	-1.926	-1.950	-1.930	-1.910	-1.920	-.834
5		-.405	-1.720	-1.798	-1.830	-1.901	-1.929	-1.948	-1.935	-1.910	-1.918	-1.563
6		-.188	-1.717	-1.793	-1.830	-1.900	-1.927	-1.945	-1.940	-1.910	-1.915	-1.647
7		-.072	-1.699	-1.793	-1.828	-1.893	-1.928	-1.947	-1.940	-1.912	-1.910	-1.622
8		.004	-1.698	-1.793	-1.824	-1.891	-1.925	-1.950	-1.940	-1.915	-1.913	-1.598
9		-.283	-1.708	-1.792	-1.827	-1.897	-1.925	-1.942	-1.934	-1.910	-1.910	-1.435
10		-.625	-1.714	-1.790	-1.863	-1.885	-1.920	-1.948	-1.930	-1.910	-1.910	-1.683
11		-1.034	-1.727	-1.790	-1.870	-1.890	-1.918	-1.950	-1.930	-1.921	-1.910	-1.721
12		-1.242	-1.749	-1.790	-1.872	-1.890	-1.910	-1.952	-1.930	-1.930	-1.910	-1.698
13		-1.262	-1.764	-1.793	-1.860	-1.890	-1.910	-1.957	-1.930	-1.930	-1.910	-1.570
14		-1.359	-1.776	-1.800	-1.860	-1.897	-1.910	-1.960	-1.930	-1.930	-1.902	-1.541
15		-1.520	-1.795	-1.800	-1.865	-1.908	-1.911	-1.951	-1.928	-1.930	-1.699	-1.556
16		-1.728	-1.800	-1.800	-1.866	-1.915	-1.926	-1.951	-1.927	-1.930	-1.904	-1.602
17		-1.595	-1.800	-1.800	-1.862	-1.918	-1.934	-1.946	-1.926	-1.927	-1.910	-1.401
18		-1.620	-1.808	-1.810	-1.870	-1.923	-1.930	-1.941	-1.922	-1.930	-1.896	-1.267
19		-1.631	-1.810	-1.810	-1.873	-1.922	-1.936	-1.939	-1.921	-1.930	-1.908	-.226
20		-1.639	-1.810	-1.809	-1.875	-1.928	-1.932	-1.933	-1.920	-1.932	-1.902	.322
21		-1.650	-1.810	-1.809	-1.875	-1.927	-1.932	-1.931	-1.920	-1.937	-1.895	.520
22		-1.667	-1.810	-1.810	-1.878	-1.922	-1.940	-1.930	-1.915	-1.935	-1.874	.640
23		-1.677	-1.810	-1.810	-1.880	-1.920	-1.943	-1.930	-1.910	-1.930	-1.757	.640
24		-1.683	-1.819	-1.831	-1.880	-1.916	-1.936	-1.930	-1.910	-1.923	-1.581	.640
25	-1.010	-1.685	-1.820	-1.849	-1.875	-1.911	-1.931	-1.946	-1.910	-1.930	-1.715	.640
26	-.711	-1.684	-1.821	-1.839	-1.880	-1.910	-1.930	-1.950	-1.910	-1.929	-1.364	.326
27	-.700	-1.690	-1.815	-1.834	-1.880	-1.910	-1.930	-1.946	-1.910	-1.922	-1.336	.312
28	-.889	-1.689	-1.810	-1.833	-1.880	-1.910	-1.930	-1.938	-1.910	-1.920	-1.111	.366
29	-.886	-1.686	-1.825	-1.837	-1.886		-1.930	-1.938	-1.910	-1.915	-1.270	.227
30	-.845	-1.700	-1.831	-1.830	-1.886		-1.936	-1.931	-1.910	-1.915	-1.228	-.421
31		-1.704		-1.830	-1.880		-1.940		-1.910		-.813	

MONTHLY AVERAGES

-.834 -1.258 -1.770 -1.809 -1.862 -1.904 -1.927 -1.944 -1.923 -1.922 -1.747 -.681

DAILY AVERAGES OF CONDUCTIVITY FROM 09

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1		19.749	22.922	23.593	24.603	25.615	26.021	26.784	25.919	25.713	24.691	25.050
2		20.180	22.896	23.572	24.639	25.624	25.972	26.670	25.993	25.456	24.703	25.294
3		20.653	22.875	23.553	24.583	25.631	26.042	26.514	25.857	25.550	24.679	25.228
4		20.821	22.951	23.610	24.618	25.623	25.966	26.578	25.767	25.580	24.815	24.530
5		20.503	23.102	23.610	24.656	25.778	25.998	26.439	25.869	25.530	24.448	23.981
6		20.672	23.113	23.702	24.740	25.852	26.054	26.184	25.925	25.592	23.738	23.763
7		22.594	23.093	24.196	24.741	25.573	26.060	26.494	25.690	25.572	22.976	24.087
8		21.145	23.057	24.097	24.821	25.746	26.152	26.369	25.421	25.497	24.957	24.812
9		18.484	23.001	24.105	24.835	25.774	26.305	26.212	25.528	25.260	24.981	24.044
10		19.354	23.004	24.035	24.942	25.830	26.294	26.345	25.630	25.212	24.894	23.972
11		21.360	23.180	23.986	25.070	25.600	26.447	26.377	25.555	25.223	25.064	24.216
12		21.710	23.373	24.001	25.372	25.735	26.564	26.446	25.434	25.175	25.079	23.893
13		22.070	23.415	24.227	25.459	25.803	26.540	26.327	25.369	25.063	25.140	24.765
14		22.094	23.323	24.305	25.267	25.774	26.567	26.308	25.424	25.079	25.134	25.480
15		22.121	23.303	24.582	25.357	25.993	26.543	26.318	25.573	25.047	25.226	25.039
16		20.630	23.320	24.859	25.436	25.984	26.614	26.415	25.580	25.000	25.237	24.990
17		18.111	23.350	24.686	25.579	26.001	26.606	26.301	25.728	24.960	25.152	18.17
18		18.635	23.429	24.522	25.466	25.951	26.549	26.107	25.893	24.900	25.047	.070
19		18.861	23.402	24.377	25.512	25.810	26.639	26.161	25.870	24.888	24.985	.070
20		18.785	23.323	24.411	25.345	25.785	26.669	26.060	25.870	24.794	25.155	.070
21		19.182	23.383	24.531	25.287	25.850	26.607	26.152	25.870	24.768	24.942	.070
22		22.597	23.400	24.516	25.387	25.715	26.686	26.250	25.920	24.780	24.846	.070
23		22.963	23.450	24.592	25.618	25.857	27.013	26.290	25.931	24.780	23.658	.070
24		22.962	23.470	24.598	25.665	24.404	26.984	26.281	25.896	24.780	24.296	.070
25		22.916	23.470	24.522	25.515	25.714	27.119	26.177	25.843	24.720	24.372	.070
26		22.928	23.420	24.431	25.427	25.740	26.963	26.177	25.813	24.700	24.512	.070
27	19.050	23.023	23.384	24.401	25.424	25.810	26.695	26.145	25.793	24.700	25.069	.070
28	19.356	22.942	23.508	24.425	25.702	25.820	26.627	26.093	25.740	24.734	25.469	.070
29	19.561	22.781	23.712	24.577	25.725		26.561	26.119	25.711	24.740	25.356	.070
30	19.796	22.723	23.746	24.464	25.589		26.678	25.917	25.650	24.683	24.838	.070
31		22.823		24.486	25.550		26.607		25.726		24.193	

MONTHLY AVERAGES

19.631	21.172	23.379	24.244	25.224	25.732	26.495	26.300	25.735	25.063	24.750	13.972
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------

DAILY AVERAGES OF TEMPERATURE 2 FROM 09

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1		-1.446	-1.640	-1.752	-1.801	-1.887	-1.930	-1.948	-1.920	-1.80	-1.682	.194
2		-1.472	-1.631	-1.750	-1.808	-1.883	-1.927	-1.943	-1.917	-1.890	-1.625	.137
3		-1.468	-1.624	-1.751	-1.823	-1.887	-1.927	-1.937	-1.910	-1.883	-1.643	.300
4		-1.485	-1.629	-1.758	-1.833	-1.895	-1.943	-1.943	-1.908	-1.880	-1.604	.300
5		-1.475	-1.620	-1.760	-1.840	-1.883	-1.947	-1.944	-1.898	-1.880	-1.640	.300
6		-1.469	-1.629	-1.759	-1.836	-1.878	-1.943	-1.946	-1.900	-1.880	-1.673	.027
7		-.850	-1.636	-1.735	-1.837	-1.900	-1.951	-1.942	-1.899	-1.878	-1.660	-.025
8		-1.282	-1.628	-1.751	-1.840	-1.909	-1.950	-1.942	-1.900	-1.871	-1.644	-.259
9		-1.499	-1.674	-1.787	-1.850	-1.898	-1.953	-1.940	-1.892	-1.852	-1.627	.300
10		-1.505	-1.702	-1.789	-1.850	-1.895	-1.950	-1.942	-1.890	-1.837	-1.582	-.031
11		-1.573	-1.712	-1.786	-1.850	-1.908	-1.953	-1.947	-1.890	-1.788	-1.617	-.646
12		-1.600	-2.727	-1.786	-1.843	-1.900	-1.950	-1.945	-1.896	-1.808	-1.575	-.196
13		-1.603	-1.728	-1.799	-1.848	-1.900	-1.948	-1.938	-1.900	-1.820	-1.469	-.444
14		-1.617	-1.726	-1.796	-1.850	-1.901	-1.946	-1.940	-1.900	-1.821	-1.463	-.527
15		-1.665	-1.725	-1.801	-1.865	-1.900	-1.962	-1.932	-1.900	-1.817	-1.478	-.136
16		-1.689	-1.730	-1.795	-1.867	-1.897	-1.960	-1.933	-1.900	-1.829	-1.468	-.073
17		-1.662	-1.736	-1.785	-1.858	-1.891	-1.960	-1.932	-1.902	-1.847	-1.487	.275
18		-1.671	-1.740	-1.777	-1.863	-1.894	-1.968	-1.933	-1.917	-1.840	-1.431	.300
19		-1.690	-1.738	-1.781	-1.877	-1.894	-1.970	-1.930	-1.920	-1.827	-1.403	.300
20		-1.688	-1.730	-1.813	-1.894	-1.890	-1.961	-1.928	-1.920	-1.784	-1.428	.300
21		-1.681	-1.731	-1.820	-1.890	-1.894	-1.950	-1.930	-1.914	-1.766	-1.449	.300
22		-1.699	-1.732	-1.822	-1.898	-1.895	-1.945	-1.930	-1.910	-1.776	-1.409	.300
23		-1.697	-1.739	-1.827	-1.905	-1.891	-1.953	-1.928	-1.903	-1.753	-.282	.300
24		-1.699	-1.740	-1.807	-1.886	-1.897	-1.957	-1.924	-1.898	-1.706	.061	.137
25		-1.685	-1.740	-1.801	-1.875	-1.917	-1.962	-1.920	-1.895	-1.694	.052	-.03
26		-1.675	-1.737	-1.800	-1.870	-1.926	-1.973	-1.920	-1.900	-1.700	.300	.300
27	-1.398	-1.665	-1.740	-1.804	-1.870	-1.935	-1.955	-1.920	-1.892	-1.669	.300	.300
28	-1.403	-1.654	-1.746	-1.807	-1.869	-1.931	-1.947	-1.919	-1.895	-1.659	.259	.300
29	-1.413	-1.640	-1.758	-1.800	-1.871		-1.940	-1.925	-1.895	-1.670	.059	.300
30	-1.439	-1.635	-1.760	-1.804	-1.872		-1.942	-1.920	-1.893	-1.690	.090	.300
31		-1.631		-1.810	-1.879		-1.941		-1.890		.300	

MONTHLY AVERAGES

-1.410 -1.574 -1.704 -1.788 -1.859 -1.896 -1.951 -1.934 -1.902 -1.860 -1.662 .009

DAILY AVERAGES OF TEMPERATURE 3 FROM 09

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1		-1.345	-1.594	-1.710	-1.790	-1.873	-1.924	-1.973	-1.950	-1.920	-1.740	.350
2		-1.356	-1.593	-1.703	-1.785	-1.877	-1.929	-1.970	-1.948	-1.920	-1.704	-.005
3		-1.362	-1.585	-1.709	-1.784	-1.878	-1.929	-1.966	-1.940	-1.920	-1.703	.393
4		-1.368	-1.583	-1.705	-1.804	-1.885	-1.936	-1.962	-1.940	-1.914	-1.685	.520
5		-1.366	-1.584	-1.707	-1.816	-1.881	-1.940	-1.960	-1.940	-1.910	-1.696	.520
6		-1.365	-1.585	-1.711	-1.829	-1.880	-1.940	-1.960	-1.940	-1.910	-1.724	.407
7		-1.118	-1.588	-1.700	-1.826	-1.887	-1.940	-1.965	-1.935	-1.914	-1.720	.035
8		-1.097	-1.587	-1.708	-1.822	-1.895	-1.940	-1.970	-1.930	-1.910	-1.710	-.154
9		-1.366	-1.618	-1.739	-1.830	-1.890	-1.940	-1.962	-1.930	-1.898	-1.698	.445
10		-1.372	-1.649	-1.747	-1.830	-1.890	-1.940	-1.960	-1.930	-1.887	-1.665	.402
11		-1.433	-1.665	-1.750	-1.830	-1.897	-1.940	-1.960	-1.930	-1.851	-1.670	-.353
12		-1.456	-1.680	-1.749	-1.830	-1.909	-1.940	-1.960	-1.930	-1.851	-1.662	-.234
13		-1.470	-1.681	-1.779	-1.830	-1.910	-1.940	-1.960	-1.930	-1.860	-1.583	-.470
14		-1.514	-1.681	-1.774	-1.828	-1.901	-1.940	-1.959	-1.930	-1.863	-1.555	-.485
15		-1.584	-1.680	-1.782	-1.838	-1.900	-1.950	-1.958	-1.930	-1.860	-1.563	-.375
16		-1.602	-1.688	-1.770	-1.840	-1.900	-1.950	-1.960	-1.930	-1.865	-1.549	-.274
17		-1.590	-1.692	-1.760	-1.840	-1.897	-1.952	-1.960	-1.930	-1.880	-1.557	.357
18		-1.602	-1.700	-1.754	-1.838	-1.894	-1.960	-1.960	-1.939	-1.880	-1.532	.239
19		-1.608	-1.700	-1.752	-1.843	-1.895	-1.960	-1.958	-1.940	-1.871	-1.487	.520
20		-1.616	-1.691	-1.776	-1.861	-1.892	-1.958	-1.950	-1.940	-1.844	-1.504	.520
21		-1.613	-1.692	-1.780	-1.870	-1.890	-1.950	-1.950	-1.940	-1.823	-1.510	.340
22		-1.635	-1.697	-1.785	-1.882	-1.870	-1.947	-1.950	-1.940	-1.828	-1.511	-1.673
23		-1.628	-1.700	-1.788	-1.888	-1.880	-1.946	-1.950	-1.939	-1.812	-.755	-.938
24		-1.633	-1.700	-1.792	-1.878	-1.889	-1.953	-1.950	-1.930	-1.784	-.313	-1.940
25		-1.628	-1.700	-1.780	-1.894	-1.903	-1.957	-1.950	-1.930	-1.764	-.240	-1.883
26		-1.625	-1.700	-1.782	-1.877	-1.915	-1.960	-1.950	-1.930	-1.763	.078	-2.346
27	-1.274	-1.628	-1.700	-1.784	-1.873	-1.923	-1.959	-1.950	-1.930	-1.744	.341	-4.110
28	-1.298	-1.617	-1.707	-1.780	-1.870	-1.922	-1.956	-1.950	-1.930	-1.727	.160	-4.110
29	-1.303	-1.603	-1.720	-1.786	-1.870		-1.965	-1.950	-1.930	-1.736	-.108	-4.110
30	-1.330	-1.597	-1.720	-1.785	-1.863		-1.970	-1.950	-1.928	-1.738	.043	-4.110
31		-1.591		-1.780	-1.860		-1.971		-1.922		.520	

MONTHLY AVERAGES

-1.297 -1.496 -1.662 -1.757 -1.843 -1.895 -1.948 -1.958 -1.934 -1.848 -1.160 -1.792

DAILY AVERAGES OF CONDUCTIVITY FROM 10

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1		20.139	21.452	22.873	24.842	28.692	29.763	1.008	.450	844	15.403	.561
2		19.695	21.394	22.830	25.130	28.123	29.656	.970	.457	.763	9.378	1.020
3		18.883	21.393	22.749	25.691	28.308	28.047	.943	.474	.791	6.404	17.789
4		19.498	21.482	22.772	26.068	27.928	27.695	.924	.484	.789	6.410	70.154
5		19.986	21.620	22.895	26.214	27.118	28.278	.788	.554	.772	6.410	72.686
6		21.285	21.697	23.012	26.258	27.220	28.234	.771	.601	.878	6.369	69.195
7		21.624	21.861	23.099	26.295	27.530	28.202	.753	.571	.985	6.302	42.514
8		21.222	21.725	23.259	26.508	27.889	28.380	.697	.568	1.104	6.270	
9		20.349	21.565	23.384	26.872	27.758	28.952	.698	.631	1.155	6.270	
10		20.043	21.490	23.762	26.623	27.672	29.857	.632	.654	1.174	6.294	
11		19.915	22.107	23.951	26.941	28.353	29.830	.650	.629	1.207	6.764	
12		20.568	22.601	24.056	26.795	27.936	29.854	.626	.576	1.240	7.045	
13		20.917	22.485	23.361	26.672	27.774	29.547	.640	.499	1.304	7.422	
14		20.825	22.135	23.708	26.884	28.375	29.698	.643	.475	1.422	7.233	
15		20.587	21.797	23.798	27.223	27.601	29.760	.592	.565	1.427	7.360	
16		20.610	21.790	23.881	27.555	27.467	28.654	.588	.649	1.508	7.118	
17		20.170	21.968	23.927	27.437	28.011	27.727	.547	.761	1.409	6.972	
18		20.205	22.136	23.983	27.931	28.258	22.028	.487	.752	1.305	7.093	
19		20.337	22.110	24.040	28.295	27.564	15.135	.578	.702	.906	8.699	
20		20.850	22.236	24.478	28.562	27.455	8.469	.602	.661	.870	6.850	
21		21.043	22.280	24.379	28.156	27.734	5.979	.546	.678	.870	6.850	
22		21.091	22.297	24.854	27.334	28.065	4.236	.550	.673	29.644	6.850	
23		22.171	22.388	24.712	27.156	27.835	3.058	.536	.667	28.071	6.447	
24		21.451	22.471	24.582	26.895	27.898	2.603	.541	.694	25.811	6.314	
25	19.220	21.728	22.544	24.522	27.030	28.694	2.139	.535	.720	30.197	1.683	
26	21.064	21.768	22.724	24.460	26.889	29.613	1.801	.533	.716	21.222	.839	
27	21.326	21.689	22.685	24.670	27.188	29.795	1.845	.496	.689	29.281	.657	
28	18.339	21.539	22.318	24.816	27.712	29.691	1.563	.480	.658	22.398	.464	
29	19.206	21.552	22.449	24.606	27.651		1.221	.493	.650	18.908	.312	
30	19.657	21.564	22.480	24.730	27.810		1.107	.475	.728	17.735	.609	
31		21.421		24.851	28.205		1.061		.772		.561	

MONTHLY AVERAGES

19.972 20.798 22.056 23.915 26.995 28.084 18.266 .643 .624 8.200 9.802 38.739

DAILY AVERAGES OF TEMPERATURE 2 FROM 10

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1		-1.366	-1.084	-1.617	-1.851	-2.175	-2.271	-3.000	-3.583	-2.546	-3.253	-3.954
2		-1.391	-1.087	-1.651	-1.874	-2.137	-2.264	-3.017	-3.581	-2.525	-3.834	-3.930
3		-1.510	-1.131	-1.666	-1.909	-2.152	-2.135	-2.983	-3.567	-2.546	-3.940	-2.989
4		-1.366	-1.155	-1.668	-1.940	-2.122	-2.102	-3.097	-3.561	-2.580	-3.940	.404
5		-1.324	-1.138	-1.685	-1.955	-2.046	-2.160	-3.177	-3.488	-2.595	-3.940	.620
6		-1.279	-1.163	-1.693	-1.959	-2.050	-2.153	-3.349	-3.401	-2.547	-3.940	.524
7		-1.184	-1.125	-1.696	-1.962	-2.086	-2.152	-3.511	-3.335	-2.458	-3.940	-.995
8		-1.070	-1.021	-1.710	-1.976	-2.096	-2.160	-3.610	-3.296	-2.382	-3.940	
9		-1.307	-1.057	-1.712	-2.007	-2.088	-2.210	-3.725	-3.224	-2.340	-3.940	
10		-1.455	-1.163	-1.752	-1.990	-2.083	-2.286	-3.827	-3.151	-2.306	-3.9.2	
11		-1.200	-1.152	-1.769	-2.015	-2.150	-2.289	-3.817	-3.128	-2.275	-3.934	
12		-1.019	-1.275	-1.776	-2.007	-2.105	-2.297	-3.644	-3.208	-2.233	-3.899	
13		-1.057	-1.284	-1.737	-1.994	-2.092	-2.287	-3.572	-3.573	-2.062	-3.819	
14		-1.013	-1.320	-1.745	-2.013	-2.140	-2.311	-3.589	-3.713	-1.881	-3.805	
15		-1.077	-1.493	-1.753	-2.040	-2.081	-2.342	-3.625	-3.369	-1.722	-3.832	
16		-1.132	-1.553	-1.760	-2.066	-2.085	-2.295	-3.632	-3.222	-1.594	-3.925	
17		-1.240	-1.506	-1.766	-2.060	-2.111	-2.318	-3.711	-3.103	-1.450	-3.815	
18		-1.273	-1.495	-1.770	-2.103	-2.128	-2.356	-3.826	-2.987	-1.196	-3.815	
19		-1.380	-1.560	-1.772	-2.143	-2.078	-2.426	-3.952	-2.904	-.897	-3.802	
20		-1.320	-1.578	-1.800	-2.163	-2.070	-2.582	-3.973	-2.840	-1.042	-3.939	
21		-1.310	-1.523	-1.806	-2.132	-2.090	-2.606	-3.950	-2.789	-1.122	-3.950	
22		-1.232	-1.477	-1.845	-2.050	-2.110	-2.708	-3.907	-2.769	.045	-3.860	
23		-1.360	-1.424	-1.835	-2.042	-2.095	-2.687	-3.772	-2.755	-.410	-3.856	
24		-1.295	-1.474	-1.820	-2.019	-2.101	-2.645	-3.652	-2.724	-1.834	-3.942	
25	-1.305	-1.282	-1.596	-1.819	-2.029	-2.178	-2.678	-3.568	-2.687	-2.540	-3.932	
26	-1.310	-1.217	-1.643	-1.812	-2.017	-2.252	-2.729	-3.546	-2.657	-1.083	-3.935	
27	-1.070	-1.162	-1.633	-1.829	-2.041	-2.271	-2.694	-3.533	-2.660	-2.217	-3.946	
28	-1.257	-1.163	-1.530	-1.850	-2.040	-2.266	-2.794	-3.559	-2.682	-2.508	-3.959	
29	-1.262	-1.133	-1.378	-1.822	-2.060		-2.797	-3.583	-2.707	-2.771	-3.959	
30	-1.350	-1.144	-1.548	-1.835	-2.095		-2.854	-3.570	-2.654	-3.060	-3.951	
31		-1.089		-1.840	-2.134		-2.960		-2.490		-3.954	

MONTHLY AVERAGES

-1.230	-1.238	-1.352	-1.762	-2.024	-2.123	-2.437	-3.576	-3.084	-1.956	-3.868	-1.460
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------

DAILY AVERAGES OF TEMPERATURE 3 FROM 10

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1		-1.369	-1.094	-1.625	-1.853	-2.171	-2.288	-3.950	-3.950	-3.947	-1.390	-1.420
2		-1.400	-1.100	-1.657	-1.875	-2.135	-2.278	-3.636	-3.950	-3.755	-1.384	-1.390
3		-1.463	-1.144	-1.671	-1.909	-2.146	-2.148	-3.124	-3.950	-3.726	-1.253	-1.082
4		-1.388	-1.169	-1.673	-1.938	-2.116	-2.121	-2.375	-3.950	-3.900	-1.250	.643
5		-1.343	-1.155	-1.690	-1.653	-2.041	-2.170	-.994	-3.950	-3.733	-1.254	.710
6		-1.301	-1.177	-1.701	-1.957	-2.043	-2.197	-2.217	-3.950	-3.099	-1.269	.613
7		-1.205	-1.139	-1.706	-1.961	-2.090	-2.265	-2.648	-3.909	-2.601	-1.292	-.863
8		-1.093	-1.031	-1.715	-1.975	-2.112	-2.230	-3.543	-3.939	-2.448	-1.304	
9		-1.327	-1.069	-1.722	-2.010	-2.098	-2.268	-3.871	-3.725	-2.174	-1.310	
10		-1.470	-1.173	-1.758	-1.989	-2.119	-2.377	-3.950	-3.700	-2.272	-1.306	
11		-1.222	-1.169	-1.774	-2.013	-2.156	-2.392	-2.943	-3.515	-2.305	-1.253	
12		-1.040	-1.286	-1.781	-2.005	-2.143	-2.693	-3.950	-3.757	-2.090	-1.217	
13		-1.075	-1.295	-1.747	-1.993	-2.119	-2.928	-3.672	-3.845	-2.820	-1.267	
14		-1.033	-1.327	-1.755	-2.012	-2.180	-3.030	-3.950	-3.692	-3.894	-1.203	
15		-1.091	-1.501	-1.760	-2.034	-2.144	-3.052	-3.950	-3.526	-3.950	-1.177	
16		-1.149	-1.559	-1.762	-2.065	-2.140	-3.019	-3.950	-3.215	-3.950	-1.163	
17		-1.253	-1.514	-1.767	-2.061	-2.162	-2.926	-3.930	-3.125	-3.950	-1.166	
18		-1.288	-1.503	-1.773	-2.101	-2.171	-2.749	-3.950	-3.112	-3.950	-1.160	
19		-1.388	-1.570	-1.773	-2.139	-2.098	-2.667	-3.950	-3.724	-3.950	-1.068	
20		-1.329	-1.592	-1.605	-2.156	-2.091	-2.702	-3.950	-3.950	-3.950	-1.168	
21		-1.319	-1.532	-1.811	-2.151	-2.110	-2.640	-3.950	-3.950	-3.950	-1.200	
22		-1.241	-1.469	-1.847	-2.060	-2.132	-2.652	-3.950	-3.950	-1.980	-1.237	
23		-1.416	-1.437	-1.840	-2.038	-2.116	-2.574	-3.950	-3.950	-2.163	-1.210	
24		-1.304	-1.467	-1.831	-2.020	-2.121	-2.602	-3.950	-3.950	-.860	-1.248	
25	-1.219	-1.289	-1.605	-1.824	-2.030	-2.190	-3.456	-3.950	-3.950	-1.237	-1.392	
26	-1.189	-1.222	-1.648	-1.817	-2.020	-2.266	-3.944	-3.950	-3.950	-1.993	-1.393	
27	-1.099	-1.195	-1.640	-1.835	-2.040	-2.295	-3.950	-3.950	-3.950	.090	-1.416	
28	-1.280	-1.172	-1.536	-1.852	-2.085	-2.282	-3.950	-3.950	-3.950	-.125	-1.430	
29	-1.290	-1.141	-1.385	-1.831	-2.086		-3.950	-3.950	-3.941	-.375	-1.428	
30	-1.377	-1.151	-1.558	-1.842	-2.103		-3.950	-3.950	-3.936	-.370	-1.416	
31		-1.108		-1.851	-2.131		-3.950		-3.950		-.422	

MONTHLY AVERAGES

-1.213	-1.232	-1.363	-1.768	-2.024	-2.142	-2.843	-3.601	-3.802	-3.653	-1.282	-1.916
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------

A facsimile catalog card in Library of Congress MARC format is reproduced below.

Sellmann, Paul V.

Seafloor temperature and conductivity data from coastal waters of the U.S. Beaufort Sea / by Paul V. Sellmann, Erk Reimnitz and Edward W. Kempema. Hanover, N.H.: U.S. Army Cold Regions Research and Engineering Laboratory; Springfield, Va.: available from National Technical Information Service, 1989.

iii, 26 p., illus., 28 cm. (CRREL Report 89-1.)

Bibliography: p. 10.

1. Alaska. 2. Beaufort Sea. 3. Cold regions. 4. Ocean temperatures. 5. Sea ice. 6. Seabed properties. 7. Undersea measurements. I. Reimnitz, Erk. II. Kempema, Edward W. III. United States Army. IV. Corps of Engineers. V. Cold Regions Research and Engineering Laboratory. VI. Series: CRREL Report 89-1.