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Calibration and Performance of the Pressure and Temperature Sensors in the Coastal Leasing, Inc., MiniSpec Directional Wave Gauge

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October 1993

Texas A&M University
Department of Oceanography
Reference No. 93-07-T

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ABSTRACT

The five MiniSpec directional wave gauges delivered by Coastal Leasing, Inc., to Texas A&M University (TAMU) in April 1992 contained or quickly developed a number of unrelated problems, including sensor malfunctions, electronic noise, signal clipping, warm-up transients in the ICS pressure sensors, and lack of calibration for the effect of temperature on the pressure sensors. During the following sixteen months the manufacturer made several changes to the signal conditioning circuitry and replaced the original pressure sensor with an improved model from ICS. The changes appear to have corrected the mechanical and electrical problems.

To obtain National Institute of Standards and Technology (NIST) traceable calibration data that would include the effect of temperature on the pressure sensors, TAMU sent the MiniSpec instruments to the National Oceanic and Atmospheric Administration (NOAA), Northwest Regional Calibration Center (NRCC) in Bellevue, Washington.

The NRCC performed a series of tests on the temperature and the improved pressure sensors as configured in the MiniSpecs. A least-squares fit of the pressure test data for each instrument to a model that is quadratic in pressure and linear in temperature yields an rms error of about 1.4 hPa (0.02 psi). With new pressure sensors and a new calibration model, the MiniSpecs now meet the manufacturer's listed accuracy of 0.1% full scale, or 3.4 hPa (0.05 psi). The test data are insufficient to quantify the long term stability of the pressure sensor. The tests of the temperature sensors confirm that the YSI thermistor is linear and has an accuracy better than 0.1 C over a range of 12 to 30 C.

Pressure data collected in the field through May 1993 by the MiniSpecs are contaminated because the original sensors exhibited a marked warm-up transient of about five-minutes duration. No calibration data are available for the original sensors to correct for the effect of temperature. Therefore, all of the tide mode (averaged) data collected through May 1993 should be flagged as questionable. Because of the noise and clipping problems, all of the burst pressure (wave) data collected between April 1992 and January 1993 are unusable. The burst pressure data collected during March-May 1993 can be

used for wave estimates if the first two to five minutes of each burst are eliminated and the remainder of each burst is detrended. Except for the few cases when the temperature sensors failed or were noisy, the quality of the temperature data is good.

The minimum wave height that the MiniSpec can detect was calculated using linear wave theory and the instrument's resolution and depth. The theoretical limitations suggest that two of the deployment sites must be moved to shallower locations and two others should be moved if protected locations exist. We evaluated the instrument's field performance by analyzing the wave spectra from the April 7-9, 1993 period at three sites. The passage of a weather front is reflected in the evolution of wave height and period as seen in the wave spectra. This report does not address the current velocity sensor and directional wave measurement capability of the MiniSpec.

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1.0 Introduction

In December 1991, Texas A&M University (TAMU), through the Texas A&M Research Foundation (TAMRF), purchased five MiniSpec Directional Wave Gauges from Coastal Leasing, Inc. (CLI), for use in the Texas-Louisiana Shelf Circulation and Transport Processes Study. This study forms Study Unit A of the Louisiana-Texas Shelf Physical Oceanography Program (LATEX Program) funded by the U.S. Minerals Management Service (MMS) under Contract No. 14-35-0001-30509. CLI shipped the instruments to TAMU in early-April 1992, and they were deployed by Evans-Hamilton, Inc. (EHI), a subcontractor to TAMRF and the Principal Investigator for the field operations of Task A-1, Current Measurement Moorings.

The CLI MiniSpec samples and records pressure, temperature and currents using a Marsh-McBirney electromagnetic current meter, an ICS Model 13A solid state pressure sensor, and a YSI thermistor. An on-board microprocessor controls sampling, averaging, and storage to a "ruggedized" 20MB hard disk. Figures 1 and 2 show CLI's description and specifications for the MiniSpec. CLI was unable to successfully implement the conductivity option listed on the specification sheet. Figures 3 and 4 show the description and specifications published by ICS for the Model 13A sensor originally installed in the MiniSpecs. At the time of delivery, some of the MiniSpecs were installed with pressure sensors which had a range of 0-100 psia because 0-50 psia sensors were not available. The range of all the pressure sensors installed in the MiniSpecs for the A/D converter was set at 0.0 to 50.0 psia. (1 psia = 68.948 hPa; 1 hPa = 1 millibar.)

This report briefly reviews the technical problems of the MiniSpecs encountered by TAMU and EHI and then examines three aspects of the MiniSpec's performance: the results of temperature and pressure calibrations conducted at the NOAA Northwest Regional Calibration Center (NRCC), the MiniSpec's theoretical wave capability based on linear wave theory, and its actual performance during April 7-9, 1993 of the last deployment period.

MiniSpec
Product Description

Coastal's MiniSpec is a powerful, high capacity instrument for monitoring and recording directional waves, tides, temperature, and currents in the marine environment. An on-board microprocessor controls sampling, averaging, and storage. Over 13 million data points are stored using a 20MB hard disk.

MiniSpec measures currents using the proven Marsh-McBirney electromagnetic velocity sensor, and waves using an ICS strain gauge pressure sensor (or alternately a Paroscientific Digiquartz sensor).

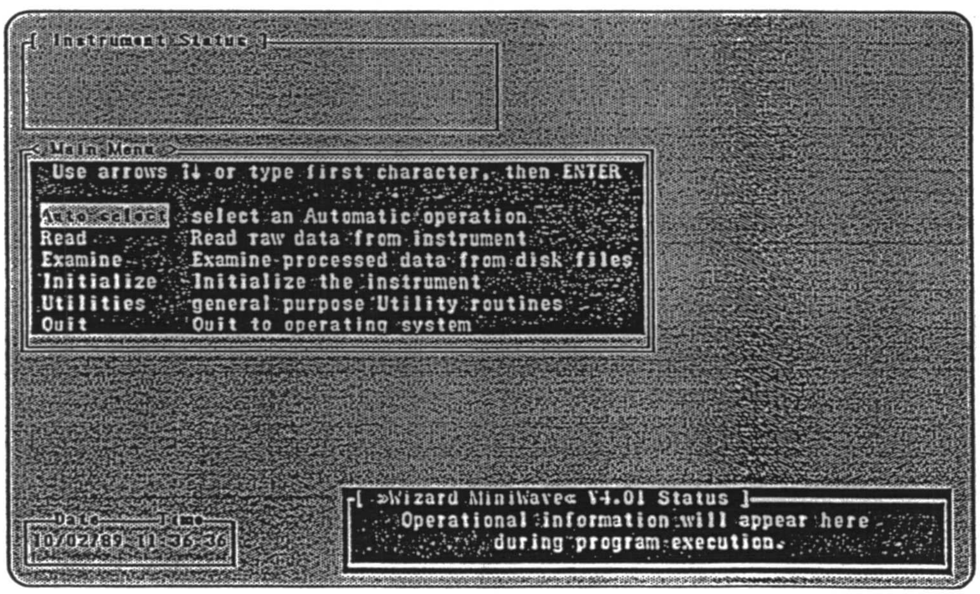
MiniSpec's many advantages include:

- *Economy.* Service costs are minimal because MiniSpec can run for months on standard alkaline D-cell batteries.
- *Reliability.* MiniSpec is completely solid-state and uses a proven logger and sensor.
- *Convenience.* MiniSpec is controlled by Wizard, user-friendly software that runs on a personal computer.
- *Versatility.* Optional sensors such as conductivity, temperature, and turbidity can usually be economically added.

Using MiniSpec is easy thanks to Wizard. This proprietary, portable PC software uses windows, graphics, and help keys to provide user-friendly control of the instrument. The figure below shows a sample of the Main Menu.

Wizard provides the functions listed below.

- *Instrument Checkout.* Wizard has a monitor mode which displays the sensed data in real time and engineering units.
- *Instrument Initialization.* Wizard allows you to specify the parameters to measure, sampling frequency, and start date and time, and checks your input for errors.
- *Data Retrieval.* Wizard downloads data from the MiniSpec via the serial port, or optionally by high speed bus interconnection to the disk drive.
- *Data Processing.* Wizard converts data into engineering units and saves the data in a format which is easily read by programs such as Lotus 123 or dBase.
- *Data Review.* Wizard provides a basic means of examining the data with plots or tabular listings.



Wizard Main Menu

Figure 1. CLI product description sheet for the MiniSpec.

MiniSpec Specifications

System Attributes

Item	Description
Clock	Solid state real time, accuracy one minute per year
Data Capacity	*20 MB* ruggedized hard drive (to -20 °C, 5 g access, 75 g non access, 250K RAM buffer) stores over 13 million data points 100 and 200 MB ruggedized hard drive is available for specialized applications, storing from 5 to 10 times standard data capacity
Dimensions	7 inch diameter by 57.5 inch long 6061-T6 hardcoated aluminum pressure housing; 75 lbs in air
Power Supply	User replaceable standard alkaline AA and/or D cells; 70 Ahr battery supplies 1.5 ma quiescent and 70 ma sampling power requirement
Sample deployment	An example of a deployment would be to: *average* all standard sensors for 1 minute and store this once every 10 minutes; *burst* selected standard sensors every 3 hours storing 1024 samples at 1 hz For this user selectable sampling scheme, instrument would be memory limited and should be retrieved after 533 days deployment
User Interface	*Wizard* IBM PC Compatible software uses RS-232 serial interface to fully control sampling parameters, instrument functions and provide ASCII data files in engineering units Optional *PCSpec* nondirectional wave spectral and *PCSpec+* directional wave spectra software

Standard Sensors

Parameter	Type	Range	Accuracy	Units
Pressure, Standard	ICS strain gauge	to 100	0.1%	PSIA
Speed, Water	Marsh-McBirney	±300	2%	cm/s

Optional Sensors

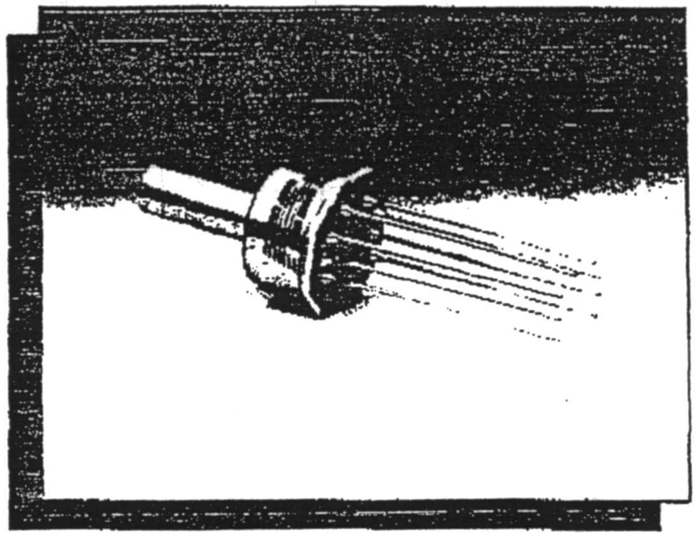
Parameter	Type	Range	Accuracy	Units
Conductivity, Standard	Aanderaa inductive cell	0-77	0.025	mmho/cm
Heading	Aanderaa compass	0-360	±2.0	Degrees
Pressure, Scientific	Paroscientific	to 900	0.005%	PSIA
Temperature, Standard	YSI thermister	-5 to 34	±0.1	°C

Notes

1. Sensor resolution usually 1/4096 of range (12-bit)
2. Optional resolution for scientific sensors 1/65536 of range (16-bit)
3. Sensor ranges representative; hardware or software alternates possible
4. Sample deployment assumes minimum data capacity

Figure 2. CLI specification sheet for the MiniSpec.

OEM Pressure Sensor Gage and Absolute Interchangeable Serialized



Features

- Temperature Compensated
- ±1mV Zero Output
- Solid State Reliability
- Infinite Resolution
- ±1% Normalized Output Span
- Ratiometric
- Humidity Resistant
- ±0.1% Accuracy
- Low Noise
- Performance Graded

Typical Applications

- Medical
- Computer Peripherals
- Robotics
- Vacuum Measurement
- Avionics
- Automotive
- Industrial Controls
- Barometric Sensing
- Leak Detection
- Environmental Control

Standard Ranges

0 to 5 psig	0 to 5 psia
0 to 10 psig	0 to 10 psia
0 to 15 psig	0 to 15 psia
0 to 30 psig	0 to 30 psia
0 to 50 psig	0 to 50 psia
0 to 100 psig	0 to 100 psia
0 to 250 psig	0 to 250 psia

Description

The Model 13 is a general purpose, solid state, piezoresistive pressure sensor that is packaged in a TO-8 configuration and is intended for use with non-corrosive gaseous media where excellent long-term stability is required. Each sensor is individually serialized.

Integral temperature compensation is provided along with calibration over 0-50°C with laser trimmed resistors. No external resistors are required.

An additional laser trimmed resistor is included to normalize pressure sensitivity variations by programming the gain of an external amplifier, thus providing ±1% interchangeability along with high level output.

Three performance grades are available in both gage and absolute pressure from 0-5 psi to 0-250 psi.

Connections/Dimensions

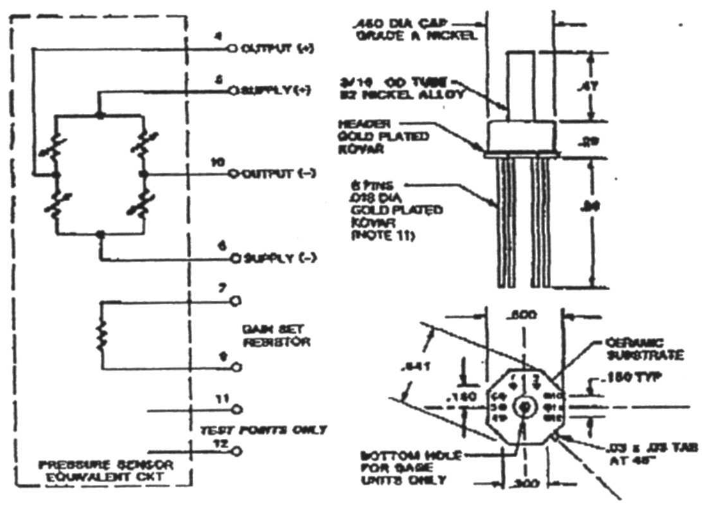


Figure 3. ICS product description sheet for the Model 13A pressure sensor.

Performance Specifications

Supply Current = 1.5 mA & Ambient Temperature = 25°C (Unless otherwise specified)

PARAMETER	GRADE A MIN	A TYP	A MAX	B MIN	B TYP	B MAX	C MIN	C TYP	C MAX	UNITS	NOTES
Full-Scale Output Span		100			100		50			mV	2, 10
Zero Pressure Output			1			2			5	±mV	2
Linearity		0.05	0.10			0.25			0.50	±% Span	3
Pressure Hysteresis		0.01	0.05			0.10			0.15	±% Span	
Input & Output Resistance	2500	4400	6000		4400	6000		4400		Ω	
Temperature Coefficient-Span		0.3	0.5			1.0			2.0	±% Span	1, 2
Temperature Coefficient-Zero		0.1	0.5			1.0			2.0	±% Span	1, 2
Temperature Coefficient-Resistance		.22			.22			.22		%/°C	1
Thermal Hysteresis-Span		0.1			0.2			0.3		±% Span	1
Thermal Hysteresis-Zero		0.1			0.2			0.3		±% Span	1
Supply Current		1.5	2.0		1.5	2.0		1.5	2.0	mA	4
Response Time (10% to 90%)		1.0			1.0			1.0		mS	5
Output Noise		1.0			2.0			5.0		μV p-p	6
Output Load Resistance	2			2			2			MΩ	7
Insulation Resistance (50VDC)	50			50			50			MΩ	
Long Term Stability		0.2			0.5			1.0		±% Span/year	
Pressure Overload			3X			3X			3X	Rated	8
Operating Temperature	−40°C to +125°C										
Storage Temperature	−55°C to +150°C										
Acceleration	50g Max										
Shock	1000g Peak for 0.5 mS										
Vibration	20g Peak at 10 to 2000 Hz										
Media	Non-corrosive Gases										9
Weight	3 grams										

Notes

1. Temperature range: 0-50°C in reference to 25°C.
2. Compensation resistors are an integral part of the sensor package; no additional external resistors are required. Pins 11 and 12 must be kept open. Model 13 is interchangeable only when used with a gain stage as shown in Figure 1: see Application Note TN-003.
3. Best fit straight line.
4. Guarantees output/input ratiometricity.
5. For a zero-to-full scale pressure step change.
6. 10Hz to 1kHz.
7. Prevents increase of TC-Span due to output loading.
8. 3X or 500 psi maximum, whichever is less.
9. Wetted materials are nickel and silicone gel. See Model 20 Series for corrosive and conductive media applications.
10. Output span of unamplified sensor.
11. Soldering of lead pins: 250°C for 5 seconds maximum.

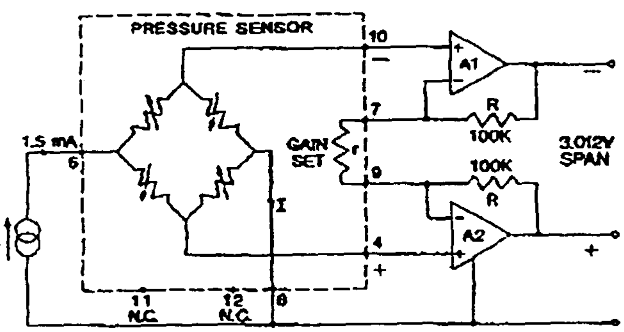


FIGURE 1.

Ordering Information

13 B—005 G

- Type (G=Gage, A=Absolute)
- psi Range
- Grade
- Model

Represented By

IC SENSORS 1701 McCarthy Blvd. Milpitas, California 95035-7416 Fax (408) 434-6687 Phone (408) 432-1800

MOO13R2-0807—Printed In USA

Figure 4. ICS specification sheet for the Model 13A pressure sensor.

2.0 Background

In April 1992, CLI delivered to TAMU the five MiniSpecs (Serial Numbers 10092 through 10096), version 5.00 of the Wizard software and parameter files containing calibration information for each sensor. No documentation, i.e., no operating manual, no wiring diagrams, no circuit diagrams, no engineering dimensional drawings, and no other information necessary to operate the MiniSpecs were delivered to TAMU. The CLI Wizard software package is required to process raw data from the instrument into engineering units, to set up data acquisition and retrieval, to monitor the MiniSpec in real time, and to perform simple file management and graphing operations. However, the Wizard software package that was delivered was incomplete, with many of the menu choices not yet implemented. For example, the product description of the Wizard software states that "a basic means of examining the data with plots or tabular listings" would be available; yet this feature was not included in the original software delivered to TAMU. The documentation for the software was two versions old, and contained some incorrect and some incomplete instructions about how to operate the software.

CLI provides the calibration information for the MiniSpec sensors in the form of parameter files that the Wizard software requires to record data in engineering units on the MiniSpec's hard drive. These parameter files are supplied by CLI and cannot be changed in the field. The calibration parameters for each sensor consist of an offset and a slope. These apply linear corrections to the output from each sensor as a function of pressure only. CLI's calibration parameters did not account for the temperature coefficient of the pressure sensor, which, as shown below, is required for the sensors to meet the specifications.

2.1 Chronology

The MiniSpecs were delivered to EHI at Bay St. Louis for calibration at the United States Geological Survey test facility on April 2, 1992, approximately one month after the promised delivery date of February 28, 1992. The gauges did not arrive in time to be calibrated prior to the first leg of the installation cruise as the test facility was in use on April 3. EHI took two of the MiniSpecs to be used on the first leg of the cruise to Houston for calibration in Shell Development Company's tow tank. These sensors did not calibrate properly; therefore, a CLI technician came to Houston to effect a correction to the electronics which allowed the current sensors to operate correctly. EHI then calibrated those two current sensors in Houston and delivered them to the ship on April 6. The current sensors of the other three MiniSpecs were calibrated at the USGS test facility on April 10, and loaded them on the ship on April 11, for installation. By the time the current sensor calibrations were completed, the installation cruise was beginning, and there was no time to perform pressure and temperature calibration checks. The intent was to utilize the manufacturer's calibration values until the instruments could be recalibrated.

During the deployments between April 1992 and January 1993 TAMU and EHI experienced a number of problems with the five MiniSpecs. Table 1 documents the start and stop dates for each deployment and the data exceptions. The exceptions include mechanical, natural, and human reasons for instrument malfunctions. Because of clipping and noise problems in early deployments and warm-up problems in later deployments, all of the burst data recovered prior to March 1993 are considered useless. This exception is not indicated on Table 1. Instrument and sensor failure account for a large part of data loss, especially during the first three deployments. Among the most notable of these failures was of the temperature sensor in SN 10096. The temperature sensor of SN 10096 failed during the first two deployment periods and was subsequently removed from the field and serviced. However, it failed to record accurate temperature data during the next three deployments. The instrument was serviced a second time (January 1993) by CLI and functioned properly during the March-May 1993 deployment.

A problem encountered in SN 10092 was an offset between the average mode pressure record and the average of the burst mode pressure record. The cause of the problem may be related to the warm-up transient described below. This effect is also seen less dramatically in the other four instruments. There are several other miscellaneous sensor malfunctions and two occurrences of the instrument frames being tipped over. There is one occurrence, spanning two deployment periods, of a current sensor failure (SN 10094).

From the initial deployment, we noticed that there was excessive noise, which included flat spots and clipping, in the pressure records. EHI brought the problems of noise and clipping to the attention of CLI just after the recovery of the initial deployment. Noise was also present, at varying degrees, in the burst mode of the current velocity records of all the deployed MiniSpecs during the first four deployment periods. In the hope that the noise problem was related to battery drain, the interval between burst samples was changed from one hour to two hours after the second deployment. The quality of the current velocity burst records improved during the fifth deployment period but worsened again during the sixth deployment. During the last deployment the interval between burst samples was changed to three hours. The burst current records of this deployment show only a slight presence of noise, which could be related to the instrument resolution. The burst pressure data continued to exhibit flat spots and clipped peaks all the way to the last deployment to a degree that rendered the wave data useless.

TAMU returned three instruments to CLI in December 1992, and two in January 1993, for warranty service. CLI performed the following modifications:

1. corrected an incomplete implementation of the A/D converter on the Onset data logger;
2. added shielded cable for the pressure sensor;
3. provided filtering to the power supply for the Marsh-McBirney current sensor and ICS pressure sensors;

Table 1: MINISPEC - data ranges						
S/N	Mooring No.	in water deployment cruise	out of water recovery cruise	start data	end data	Exceptions
		92p03	92p05			
10096	01	4/09/92 15:00	5/28/92 15:00	4/09/92 15:30	5/28/92 14:30	A
10092	16	4/14/92 13:30	6/01/92 18:30	4/14/92 15:00	6/01/92 18:30	B
10094	17	4/13/92 16:00	5/31/92 18:00	4/13/92 20:00	5/31/92 18:00	C
10093	20	4/12/92 21:00	5/30/92 12:40	4/12/92 21:00	5/30/92 12:00	D
10095	23	4/07/92 20:54	5/27/92 12:00	4/07/92 21:30	5/27/92 12:30	
		92p05 (inter)	92p05 (inter)			
10095	23	5/27/92 20:00	6/04/92 11:40	5/27/93 21:30	6/04/92 11:30	
		92p05	92p06			
10096	01	5/28/92 22:20	7/16/92 12:30	5/28/92 23:00	6/15/92 22:00	A E
10092	16	6/01/92 23:20	7/21/92 12:35	6/01/92 23:30	7/21/92 12:00	B
10094	17	6/01/92 00:00	7/20/92 16:29	6/01/92 00:00	6/27/92 00:00	C F
10093	20	5/30/92 19:20	7/19/92 13:48	5/30/92 19:00	7/19/92 13:30	G
10095	23	6/04/92 13:54	7/14/92 17:43	6/04/92 14:30	7/14/92 13:00	
		92p06	92p08			
	01	has Seadata 635				
10092	16	7/21/92 18:52	9/01/92 15:40	7/21/92 19:00	9/01/92 15:00	B H
	17	Not deployed				
10093	20	7/19/92 17:00	9/06/92 15:25	7/19/92 18:00	9/06/92 15:00	G
10095	23	7/14/92 15:19	9/05/92 07:28	7/14/92 16:00	9/05/92 07:00	
		92p08	92p09			
	01	has Seadata 635				
10092	16	9/01/92 19:00	10/21/92 13:20	9/01/92 19:30	10/21/92 13:00	A I
10096	17	8/31/92 21:10	10/20/92 14:15	8/31/92 21:30	10/20/92 14:00	J
10093	20	9/06/92 18:15	10/18/92 22:07	9/06/92 18:30	10/18/92 21:30	
10095	23	9/05/92 15:02	10/14/92 12:45	9/05/92 15:30	10/14/92 11:30	A I
		92p09	92p12			
10095	01	10/15/92 12:57	12/17/92 14:00	10/15/92 13:00	12/17/92 13:30	
10096	16	10/21/92 13:25	12/13/92 13:44	10/21/92 13:30	12/13/92 13:30	K
10093	17	10/20/92 00:00	12/12/92 20:53	10/20/92 14:30	12/12/92 20:30	
10092	20	10/22/92 19:00	12/11/92 14:42	10/23/92 19:00	12/11/92 14:30	
10094	23	10/14/92 12:35	12/14/92 14:57	10/14/92 13:00	12/16/92 14:30	L

Exception Descriptions	
A - No temperature data	H - Instrument turned on side 8/26/92 (hurricane)
B - Offset between average and burst data	I - No average mode data
C - No current data	J - Noisy temperature and pressure record
D - Pressure data stops 5/20/92	K - Noisy temperature record
E - Electronic failure 6/16/92	L - Pressure failure 11/10/92
F - Pressure data stops 6/27/92	M - Pressure data stops 5/6/93
G - No pressure data	N - No burst mode data
	O - Instrument turned on side 5/14/93

Table 1. (continued) MINISPEC - data ranges						
S/N	Mooring No.	in water deployment cruise	out of water recovery cruise	start data	end data	Exceptions
		92p12	93p01			
	01	Not deployed				
10093	16	12/13/92 12:00	1/13/92 16:32	12/13/92 16:00	1/13/93 16:00	A I
	17	has Seadata 635				
	20	Not deployed				
10096	23	12/15/92 22:30	1/18/92 19:04	12/16/92 15:30	1/18/93 18:30	A
		93p04	93p07			
	01	has Seadata 635				
10096	16	3/19/93 20:20	5/27/93 00:08	3/19/93 20:29	5/26/93 23:29	
10094	17	3/18/93 17:30	5/27/93 12:39	3/18/93 18:30	5/27/93 12:30	M
10095	20	3/17/93 17:03	5/28/93 01:05	3/17/93 17:29	5/28/93 00:29	N
10092	23	3/22/93 14:15	5/19/93 17:25	3/22/93 14:30	5/19/93 17:00	O

Exception Descriptions	
A - No temperature data	H - Instrument turned on side 8/26/92 (hurricane)
B - Offset between average and burst data	I - No average mode data
C - No current data	J - Noisy temperature and pressure record
D - Pressure data stops 5/20/92	K - Noisy temperature record
E - Electronic failure 6/16/92	L - Pressure failure 11/10/92
F - Pressure data stops 6/27/92	M - Pressure data stops 5/6/93
G - No pressure data	N - No burst mode data
	O - Instrument turned on side 5/14/93

4. added minor output filtering of the pressure sensor;
5. added dynamic control of unipolar and bipolar A/D functions.

CLI shipped the modified MiniSpecs to EHI at the beginning of March 1993. EHI then tested the MiniSpecs in Shell Oil Co.'s wave tank on March 5, 1993. During the week of March 8, 1993, EHI ran numerous experiments using a deadweight tester. CLI provided a Paros Scientific Digiquartz pressure sensor to EHI to serve as a secondary standard. The tests were conducted at room temperature, which varied between 22.2 and 26.2 C. EHI found that all five of the gauges were outside the 0.1% stated accuracy, two of them considerably so. CLI reviewed the data and found an error in the parameter file of one of these two. After correction, the results for this gauge improved but were still outside the 0.1% stated accuracy. The unit, SN 10093, was returned to CLI. EHI did not test the sensor sensitivity to temperature because of the magnitude of the errors found at room temperature. EHI also discovered that there was a warm-up drift in the burst pressure data lasting at least two to three minutes when first entering the Wizard monitor mode. This warm-up transient was evident in the pressure records of all five MiniSpecs.

To field test their functional operation, EHI re-deployed four MiniSpecs on March 17-22, 1993 and recovered them in late May (Table 1). The interval between bursts was increased to three hours. The MiniSpecs performance during this deployment improved in that the pressure records in the burst mode did not exhibit the flat-spots and clipping seen in the earlier records, and the velocity records appeared free of noise. However, the pressure data in SN 10094 stopped about 20 days early, and SN 10095 failed to record in the burst mode.

On March 14, 1993, CLI notified EHI that the sensor manufacturer, ICS, had started manufacturing an improved version of the model originally installed in the MiniSpecs. The manufacturer had advised CLI that the original sensors had a silicone gel coating to protect the exposed sensor substrate and that there was a potential incompatibility between the silicone oil used to fill the sensors and the silicone gel. The gel apparently can absorb some of the oil, which can cause a drift in the sensor offset. A second potential problem is that the dielectric properties of the gel can be affected.

CLI replaced the sensor in SN 10093 with a gel-free sensor and provided EHI with gel-free replacements for EHI to install in the other four gauges.

In June 1993, all of the instruments were sent to the NRCC in Bellevue, Washington. The objective was to obtain an NIST traceable calibration of the temperature and pressure sensors that would include the temperature coefficients of the pressure sensors. EHI's nearby office in Seattle, Washington coordinated the tests performed by the NRCC. The first two tests, on June 11, and June 18, were aborted due to a drop in applied pressure caused by leaks at the swage-fitting in some of the instruments. This pressure leak has also been noticed in previous field deployments, i.e., water had been found internally on some circuit boards. During these tests, all of the MiniSpecs except SN 10093 had old style pressure sensors.

2.2 Transient Problem

To investigate further the warm-up transient that EHI noted during the March tests, we carefully examined the data from the two partial test runs at the NRCC and the data from the March-May deployment. We found that the warm-up transient was evident at the beginning of all burst samples for all the MiniSpecs except for SN 10093, which housed a new pressure sensor. Figure 5 shows an example of the transient in four of the bursts collected by SN 10092 during the test on June 11. The response is characterized by a sharp rise followed by a slow decay. The abscissa in Figure 5 is the number of seconds from the start of the burst, and the ordinate is the pressure in integer counts from the A/D converter, i.e., before conversion to engineering units. Figure 6 shows that the same effect is evident in the field data collected by this instrument on May 15, 1993. (In this figure the abscissa is the time in seconds.) The same response was observed in the data of SN 10095 and 10096, but in SN 10094 the response was inverted, i.e., a sharp drop followed by a slow rise. Note that the burst length for data collected at the NRCC was ten minutes (1200 samples), and for the field data it was about 17.5 minutes.

The bursts collected in the field also exhibited trends over the 17.5-minute burst period that were not related to tidal cycles. Figure 7 shows a sequence of twenty-four bursts collected by SN 10092 during March 26-28, 1993. This figure is representative of all three MiniSpecs that returned burst data recorded during this last cruise. (The three-hour interval between bursts is not shown in Figure 7.) A downward trend is evident in all but one of the bursts. The lower panel in Figure 7 displays the effective slope of each burst, which was determined by averaging the first and last 1024 points of a burst and then taking the difference.

In the tide mode, the MiniSpec calculates a mean value by averaging over a 5 minute "miniature" burst. Only the mean value is recorded. The tide observations include a warm-up transient, and are therefore offset an unknown amount from what the recorded observation would be without the transient. (It may be possible to estimate the bounds of this error by analyzing the transient in the wave burst data from the last deployment.) Furthermore, temperature has a significant effect on the output from solid state pressure sensors. We do not know if the transient problem was related to the gel coating. For the new gel-free sensors, the NRCC tests (next section) show temperature coefficients on the order of one hectoPascal per degree. We do not know the exact values for the old sensors, but the ICS specification sheet (Figure 4, Thermal Coefficient--Resistance), suggests they should have temperature coefficients of a similar magnitude. Since we cannot quantitatively correct each tide sample, we recommend that all tide mode data collected by the MiniSpecs through May 1993, be flagged as questionable.

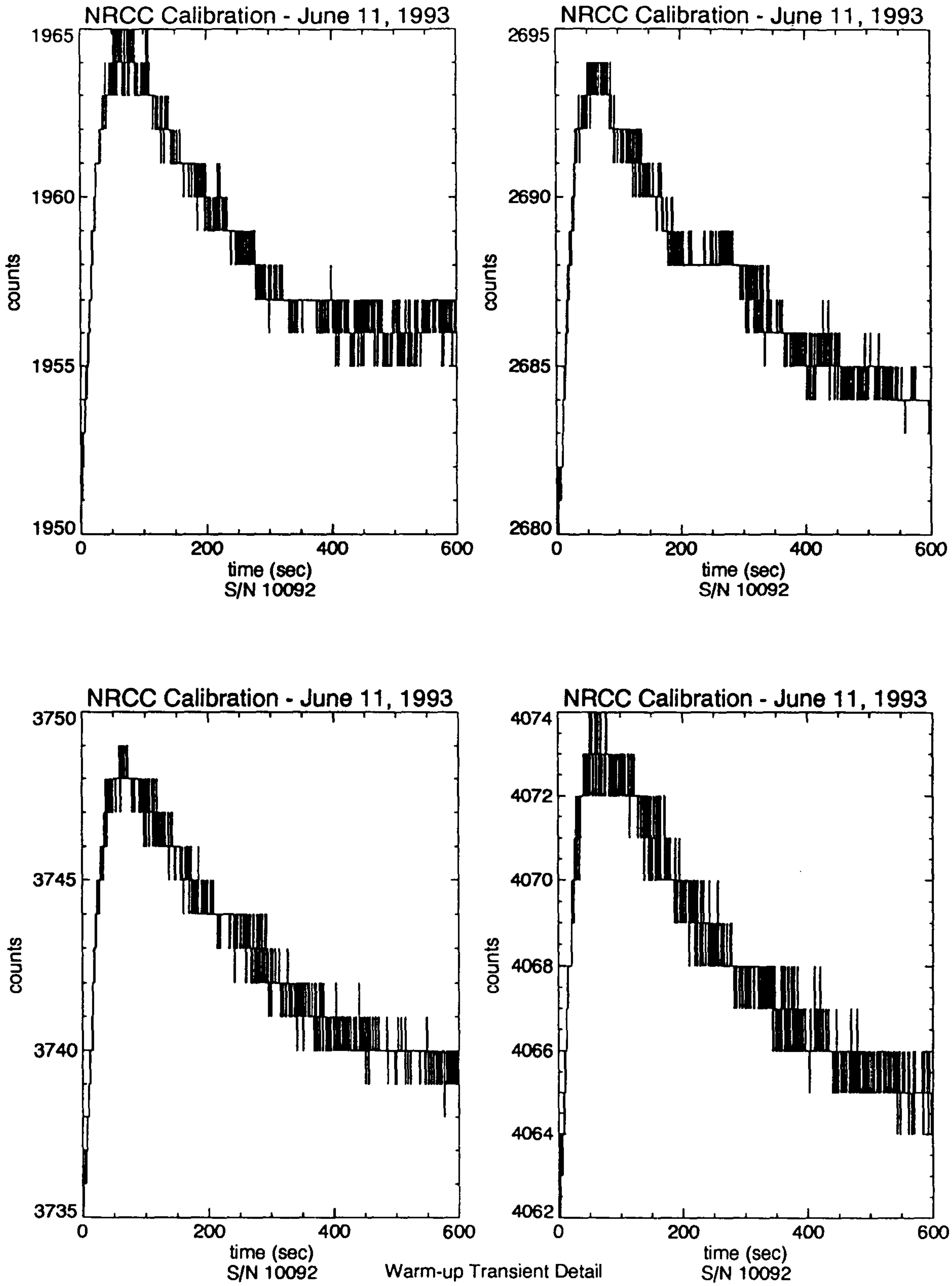


Figure 5. Example of the warm-up transient in the burst data of SN 10092 collected during the June NRCC tests.

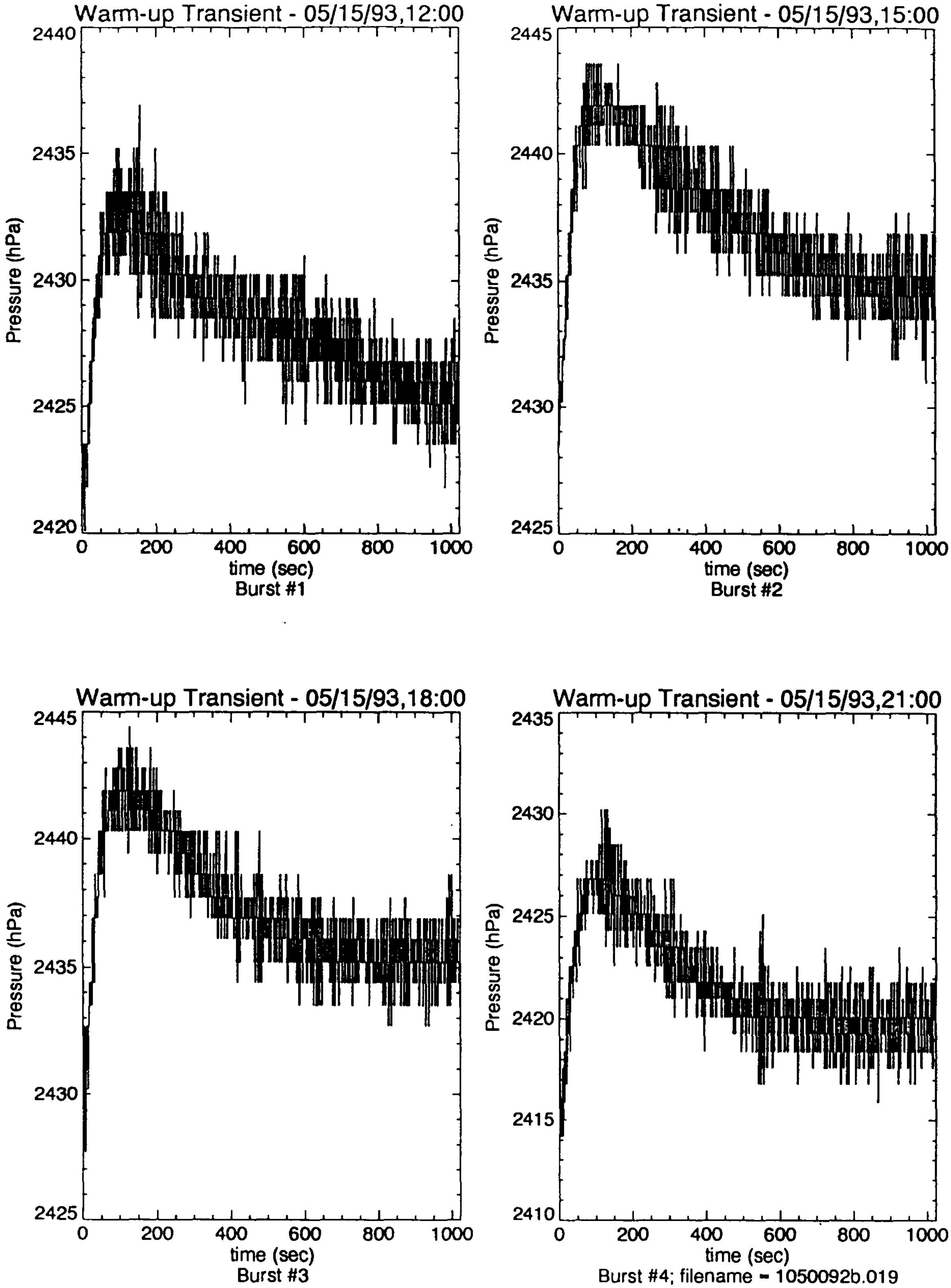


Figure 6. Example of the warm-up transient in the burst data of SN 10092 collected in the field on May 15, 1993.

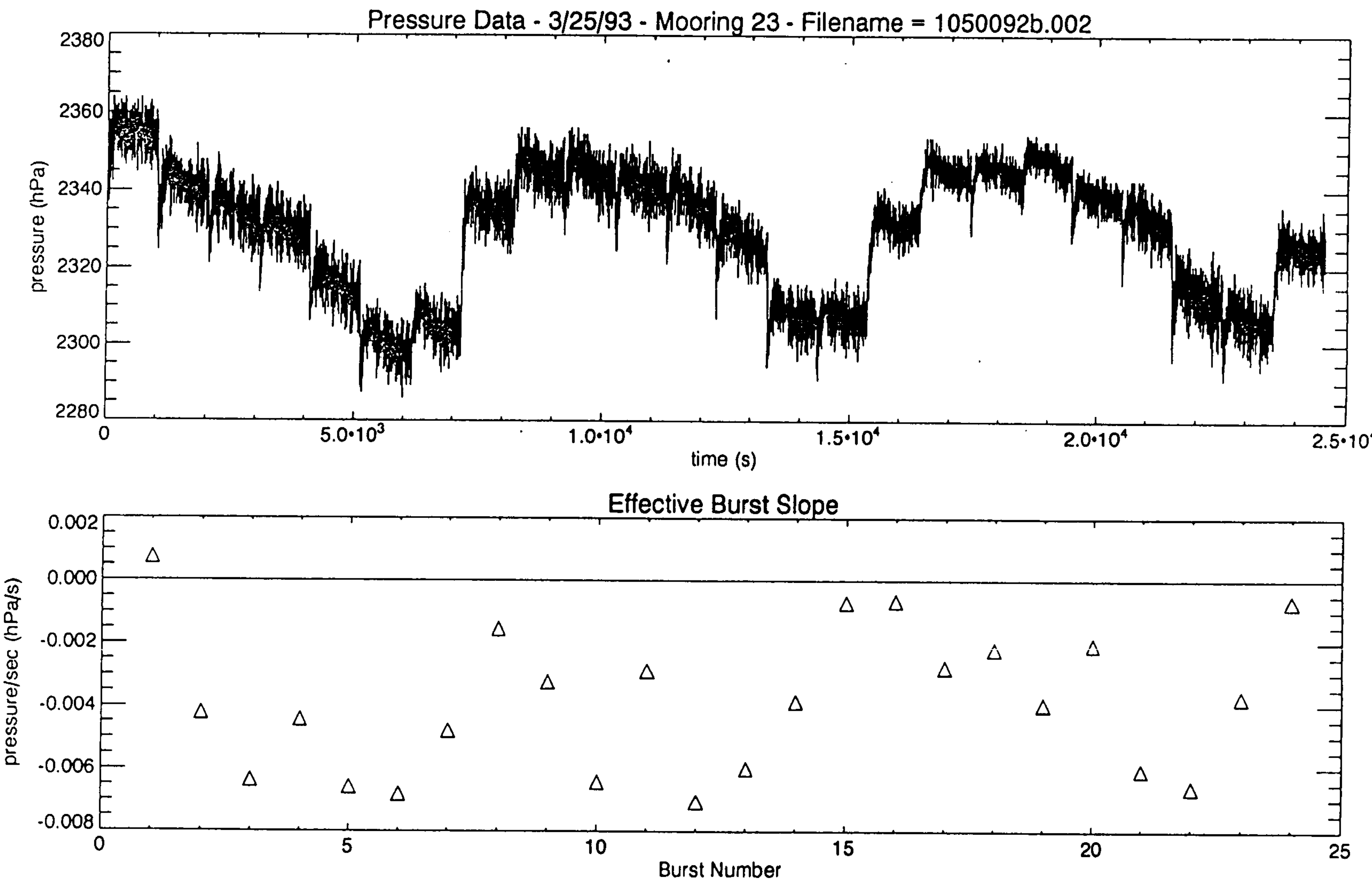


Figure 7. Example of the warm-up transient and decay trend in the burst data of SN 10092 collected in the field beginning March 25, 1993.

Because of the poor data quality inherent in the old sensors and schedule constraints in the LATEX program, TAMU decided not to perform a third calibration run on the four old sensors. EHI replaced them with gel-free ones, and the NRCC conducted a full test on July 12, 1993. A full test consists of cycling the pressure up and down through 10 different pressures while holding the temperature constant. For the July 1993 test, this was done for three separate temperatures (Figure 8). We made a least-squares fit of the pressure test data for each instrument to a model that was quadratic in pressure and linear in temperature. Only after applying this calibration equation did the root-mean-square (rms) errors for four of the gauges become smaller than the rated accuracy. The rms error for the sensor in SN 10096 was slightly out of specification, and so it was returned to CLI and replaced.

2.3 Final Calibration

In order to obtain a calibration for the pressure sensor in SN 10096 which was replaced in August and to examine the stability and repeatability of the calibrations of the other four MiniSpecs which were not modified after the July calibration, we had the NRCC run a fourth test on August 13 and 14, 1993. The least-squares fit yielded rms errors of about 1.4 hPa (0.02 psi). With the new pressure sensors and calibration model, the MiniSpecs now appear to meet the manufacturer's listed accuracy for pressure of 0.1% full scale, or 3.4 hPa (0.05 psi). The test data for temperature confirm that the YSI thermistor is linear and has an accuracy better than 0.1 C over a range of 12 to 30 C.

The warm-up transient does not appear in the burst data from the new sensors. Figure 9 shows four bursts recorded by SN 10092 on August 13, 1993. The graphical format is the same as for Figure 5. The first burst shows an increase of eight counts during the first thirty seconds. This is not a transient; it does not overshoot the applied pressure. The burst began while the applied pressure was in transition to the next level. We contacted ICS by telephone to inquire if the Model 13A has changes in addition to the elimination of the gel coating. The manufacturer (Mr. Kris Lafko, personal communication) stated that ICS also improved the micromachining of the sensor substrate, the laser trimming and the thin-film layout. The specifications are improved, but ICS has not published them yet.

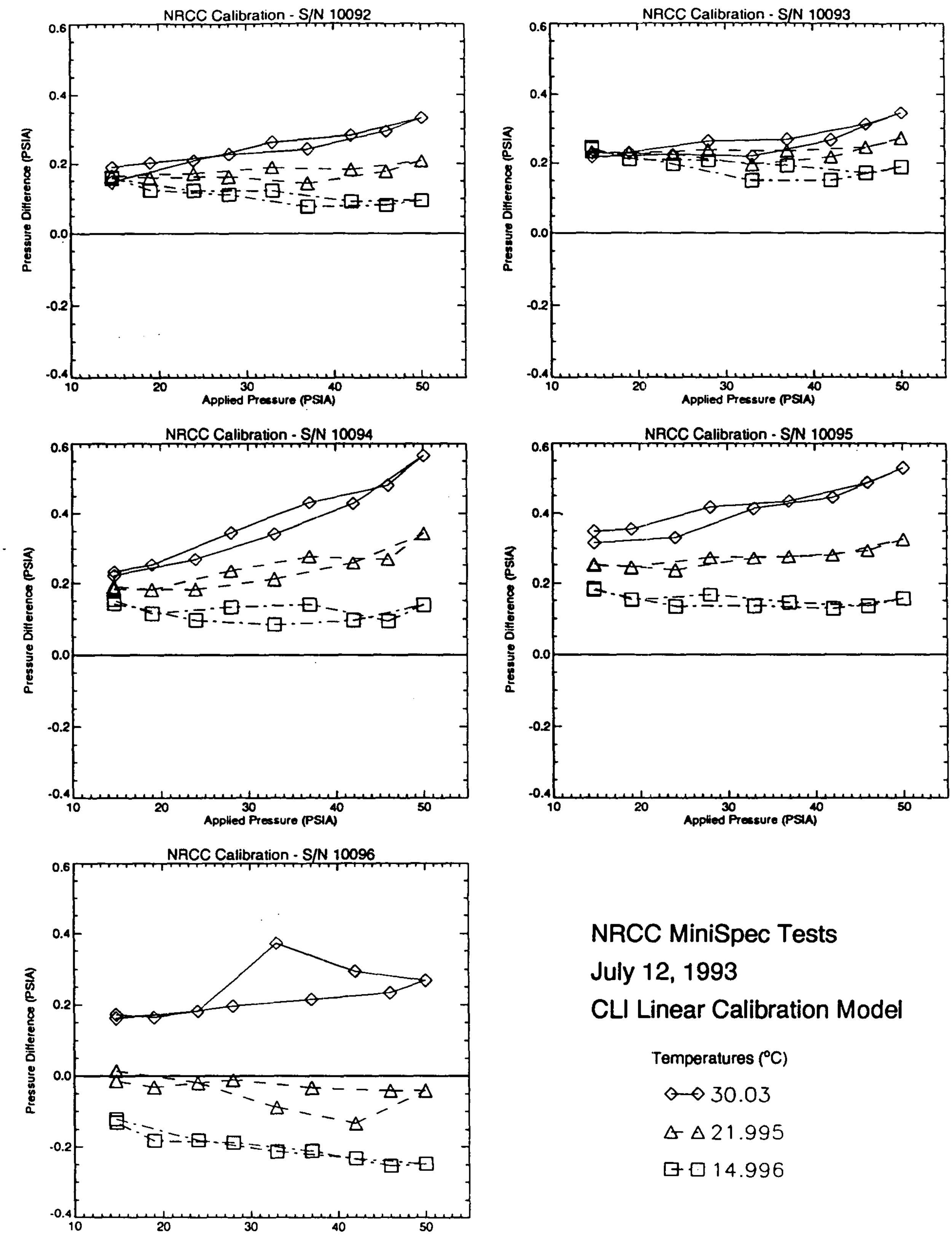
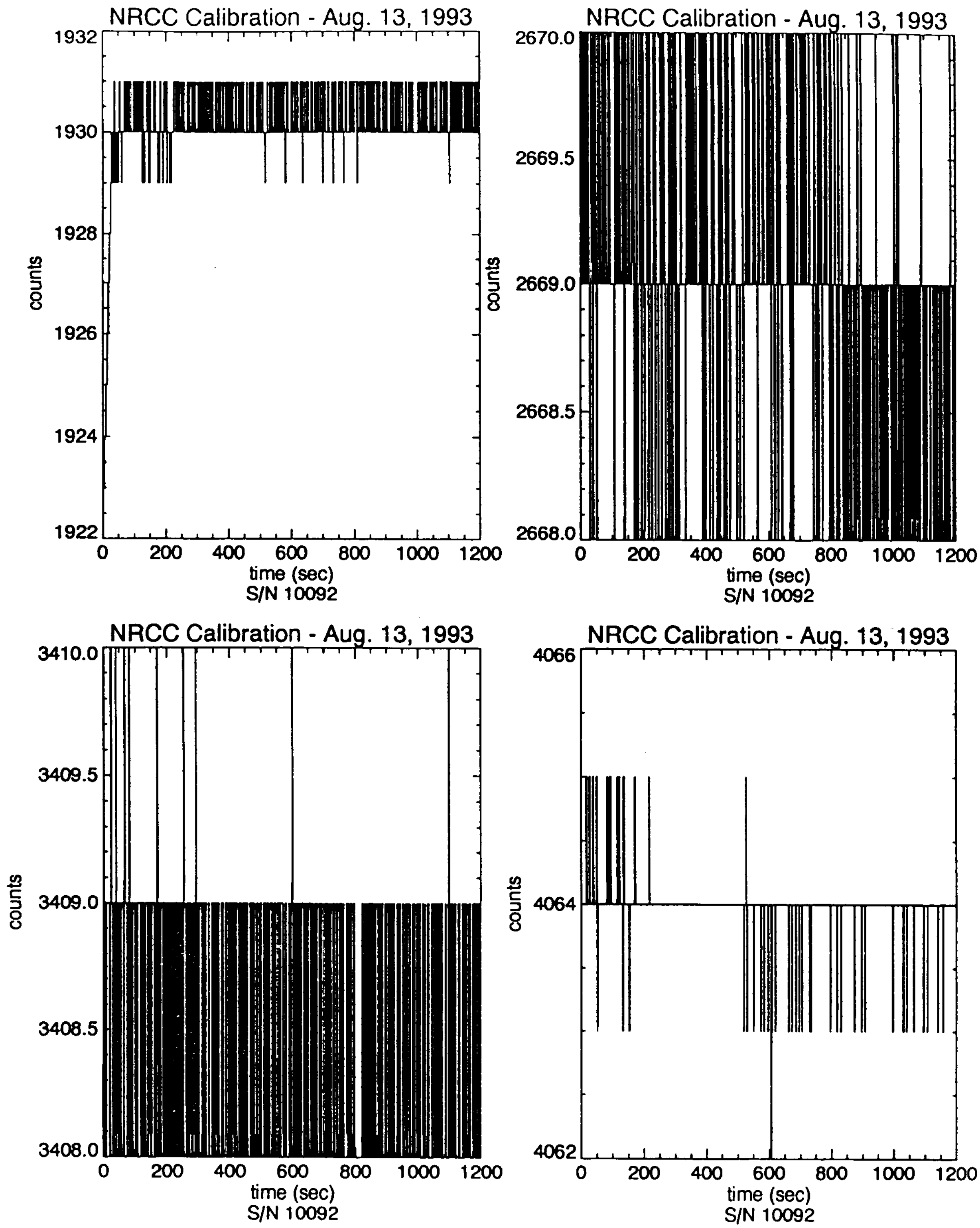


Figure 8. Plots of the difference between the July NRCC pressure and the pressure measured by the MiniSpecs if the CLI supplied calibration is used.



Warm-up Transient Detail

Figure 9. Example of the lack of a warm-up transient in the new Model 13A sensor. This figure shows the burst data of SN 10092 collected during the August 13, 1993, NRCC test.

3.0 Calibration Results at the Northwest Regional Calibration Center (NRCC)

The NRCC is a facility of the National Oceanic and Atmospheric Administration (NOAA) operated and managed by Northwest Research Associates, Inc. It is located in Bellevue, Washington at (206) 455-1999. Figure 10 shows a copy of a brochure describing this NOAA facility. The NRCC tested the pressure channels of the MiniSpecs in accordance with NOIC-CP-04A, dated June 1975, using the NRCC Ruska Model 2465 Air Deadweight Tester. The accuracy of the Deadweight Tester is certified by the manufacturer to be within +/-0.01% of calculated pressure, traceable to NIST. The MiniSpec pressure housings were completely immersed in a temperature-controlled water bath and brought to temperature equilibrium at a known temperature. Pressure was applied to the instrument pressure ports by means of a manifold connected to the Deadweight Tester. Copies of the NRCC test reports are included in the Appendix.

Tests were attempted on June 11 and June 18. Successful tests were completed on July 12, and August 13-14, 1993. A test consisted of ten applied pressure points over the range from atmospheric pressure to 50 psia at a fixed temperature. The first five points increased sequentially from atmospheric to 50 psia, and the last five decreased sequentially from 45 psia back to atmospheric pressure, interleaving those in the upward direction. This procedure would be followed for several different temperatures. The MiniSpecs were set to burst sample at a 0.5 Hz rate for ten minutes and an interval between bursts of fifteen minutes. To avoid the warm-up transient, the average number of counts was computed by skipping the first five minutes of burst data and then averaging the next four minutes (480 readings). When the bath temperature was changed, at least one hour was allowed for thermal equilibration at the new temperature.

Both tests in June were aborted due to a drop in pressure caused by leaks in some of the instruments where the pressure circuit board mounts to the back end of the pressure sensor. The aborted tests were at 30 C. On June 11, gauges SN 10092 and SN 10095 leaked; on June 18, gauge SN 10093 leaked. Additionally, the top pressure for SN 10095 and SN 10096 in the first run and SN 10095 in the second run should be discounted because the analog-to-digital conversion "maxed out", i.e., the maximum applied pressure resulted in a signal that exceeded the upper limit of the A/D converter.

For reasons discussed in the preceding section, EHI replaced the sensors in four of the MiniSpecs after the June tests. CLI had replaced the sensor in SN 10093 prior to the tests.

The July tests were conducted at 15, 22, and 30 C. Figure 8 shows the difference between the NRCC applied pressure and the MiniSpec observed pressure, when using the calibration model provided by CLI. The differences clearly have systematic offsets and, except for SN 10093, deviations from an eyeball straight line fit that exceed the rated accuracy of 0.05 psi. In order to generate new calibration models based on the NRCC test data, EHI re-

NORTHWEST REGIONAL CALIBRATION CENTER

SERVICES

The Northwest Regional Calibration Center (NRCC) is a laboratory primarily engaged in the testing and calibration of oceanic instrumentation, as well as most types of temperature and pressure sensors, and does so by means of a comprehensive array of facilities specific to these ends. Work done at the NRCC is performed in accordance with published procedures and makes use of standards traceable to the National Institute of Standards and Technology (NIST). In addition to equipment permanently installed for routine calibration and test, equipment is available to provide custom test setups.

The NRCC also offers a one-day course in the theory and operation of typical oceanographic instruments. This course is designed primarily for shipboard personnel.

FACILITIES

Calibration facilities at the NRCC include:

A THREE-BATH FACILITY for calibrating temperature and/or conductivity measuring instruments, consisting of three 400-gallon salt-water baths and associated temperature control systems, a computer-controlled data acquisition system, and three NIST-traceable Standard Platinum Resistance Thermometers (SPRTs). The bath temperatures are stable to 1 mK from -2°C to 40°C, and the SPRTs are accurate to 3 mK.

- Two DEEP SEA REVERSING THERMOMETER (DSRT) CALIBRATION BATHS consisting of a 260-gallon bath and a 60-gallon bath, each with its own independent temperature control system; an NIST-traceable SPRT for each bath; and an NIST-traceable deadweight piston gauge common to both baths. The bath temperatures are stable to 1 mK from -2°C to 40°C and to 3 mK from -15°C to 60°C. The SPRTs are accurate to 3 mK, and the deadweight pressures are accurate to .05% up to a maximum pressure of 20,000 psi. The smaller bath holds 20 DSRTs in its carousel and 9 unprotected DSRTs in its pressure vessel. The larger bath holds 40 and 18 DSRTs, respectively.

- A PRESSURE TEST FACILITY consisting of two NIST-traceable deadweight piston gauges. The larger unit uses oil as its medium and is accurate to .04% up to a maximum pressure of 12,000 psi. The smaller gauge uses dry nitrogen as its medium and is accurate to .01% up to 400 psi.

- An ENVIRONMENTAL CHAMBER and associated temperature control system. The chamber has internal dimensions of 3' x 3' x 3', and the temperature is stable to 1K over a range of -40°C to 240°C.

- A PRESSURE VESSEL of 2' internal diameter x 8' long, rated at 10,000 psi maximum pressure, along with associated pumps, pressure gauges, and a hoist system. The gauges consist of a 1,000-psi and a 10,000-psi Heise gauge, each accurate to 0.1% of full scale.

- A SEAWATER STANDARDS PREP RATION FACILITY, consisting of equ ment to concentrate and dilute seawat and equipment to wash, dry, and fill t sample bottles. The water is natural s water collected by NOAA ships during f offshore cruises. The salinity of the sa ples is determined by means of NOA Precision Conductivity Comparator, loca in Rockville, Maryland.

- A GUILDLINE 8400 AUTOSAL with accuracy in conductivity ratio equivalen ± 3 ppm in Practical Salinity Units.

- Access to a USCG-surveyed COMPA RANGE and a nonmagnetic fixt designed to hold and orient four Aande RCM4 current meters.

- A COMPUTER SYSTEM consisting of HP87 and a Northstar Horizon, with asso ated terminals and printers, and a la software library of curve-fitting program

- An assortment of electronic test equ ment, including voltmeters, oscilloscop frequency generators and counters, a other equipment specific to frequently ca brated instruments.

NRCC

A facility of the National Oceanic and Atmospheric Administra
operated and managed by Northwest Research Associates, In

Figure 10. Copy of a brochure describing the NRCC.

configured the Wizard parameter files to record the actual counts instead of data in engineering units corrected by the CLI calibrations. We then used the SAS General Linear Models (GLM) procedure to numerically obtain a linear regression of applied pressure, P, as a function of counts, C,

$$P = A_O + A_1 C.$$

The coefficients A_O and A, from the intercept and slope of the linear model. The second row shows the rms error for each instrument in psia when the simple linear correction is applied. Also shown is R-square, which is a value between 0 and 1 that measures the reliability of the model. A value of 1 means 100% reliability. Table 2 lists the results. Except for SN 10093, the linear model fails to account for the variance to meet CLI's accuracy specification. The rms error of SN 10093 meets the specification of 0.05 psia, but the other four residuals do not.

Since the curves in Figure 8 generally have a slight curvature and a clear temperature dependence, we next tried a model that was quadratic in counts and linear in temperature, T:

$$P = A_O + A_1 C + A_2 T + A_3 C^2 + A_4 CT.$$

The statistical measures and coefficients are given in Table 3. Four of the gauges have rms errors that are less than half the accuracy specification, and all of their individual residuals are below 0.05 psi. The rms error for SN 10096 barely meets the spec., but the pressure hysteresis is so pronounced (Figure 8) that some of the regression residuals are much larger than specification at the middle pressures where the MiniSpec is generally operated. The temperature dependence is much greater than the other four (Table 3, coefficient A_2). Overall, the behavior of SN 10096 was found to be different. Therefore, the sensor in SN 10096 was returned to CLI for replacement.

NRCC performed a set of tests on August 13-14, 1993, to calibrate the new sensor in SN 10096 and, since five MiniSpecs can fit in the NRCC water bath and be hooked in parallel, the other four were run at the same time to check the stability of their coefficients. For the August tests, the same pressure points were used, but the number of temperature points was increased to four: 12, 18, 24, and 30 C. The rms error for the new sensor in SN 10096 is now well within specification (Table 4), as are all of the model residuals. We note that SN 10096 still has the greatest variance of the five gauges. Since the NRCC tests were performed on the entire instrument (not just the sensor in isolation), the results suggests that factors in this particular instrument other than the sensor, such as the signal conditioning circuitry, may be contributing to the variance. The coefficients for the other four gauges agree well with those from the July tests. We will use the August coefficients to correct new data collected by the MiniSpecs until another set of calibration tests are conducted. Figure 11 graphically displays the residuals for the July and August tests.

Table 2. Results from SAS GLM regression of the July 12 tests for the model $P = A_O + A_1C$

	SN 10092	SN 10093	SN 10094	SN 10095	SN10096
rms error (psia)	0.063	0.042	0.115	0.115	0.187
R-Square	0.999975	0.999989	0.999917	0.999917	0.999779
A_O	0.507	0.134	0.488	0.213	0.035
A_1	0.012	0.012	0.012	0.012	0.012

Table 3. Results from SAS GLM regression of July 12 NRCC data for the model $P = A_O + A_1C + A_2T + A_3C^2 + A_4CT$.

	SN 10092	SN 10093	SN 10094	SN 10095	SN 10096
rms error (psia)	0.014	0.016	0.021	0.015	0.045
R-Square	0.999999	0.999999	0.999998	0.999999	0.999988
$A_O \times 10^{-1}$	6.376	3.574	6.468	1.714	-2.934
$A_1 \times 10^{-2}$	1.200	1.210	1.195	1.215	1.219
$A_2 \times 10^{-3}$	-4.162	-5.691	-3.654	4.448	14.41
$A_3 \times 10^{-8}$	0.710	1.750	1.460	1.11	-0.010
$A_4 \times 10^{-6}$	4.967	3.932	7.853	5.087	5.493

Table 4. Results from SAS GLM regression of August 13-14 NRCC data for the model $P = A_O + A_1C + A_2T + A_3C^2 + A_4CT$.

	SN 10092	SN 10093	SN 10094	SN 10095	SN 10096
rms error (psia)	0.011	0.017	0.020	0.014	0.022
R-Square	0.999999	0.999998	0.999998	0.999999	0.999997
$A_O \times 10^{-1}$	6.002	3.058	6.098	1.430	1.507
$A_1 \times 10^{-2}$	1.203	1.212	1.197	1.216	1.207
$A_2 \times 10^{-3}$	-2.489	-4.688	-2.327	4.371	7.108
$A_3 \times 10^{-8}$	0.650	1.470	1.230	0.900	1.010
$A_4 \times 10^{-6}$	4.238	3.792	7.253	4.832	5.063

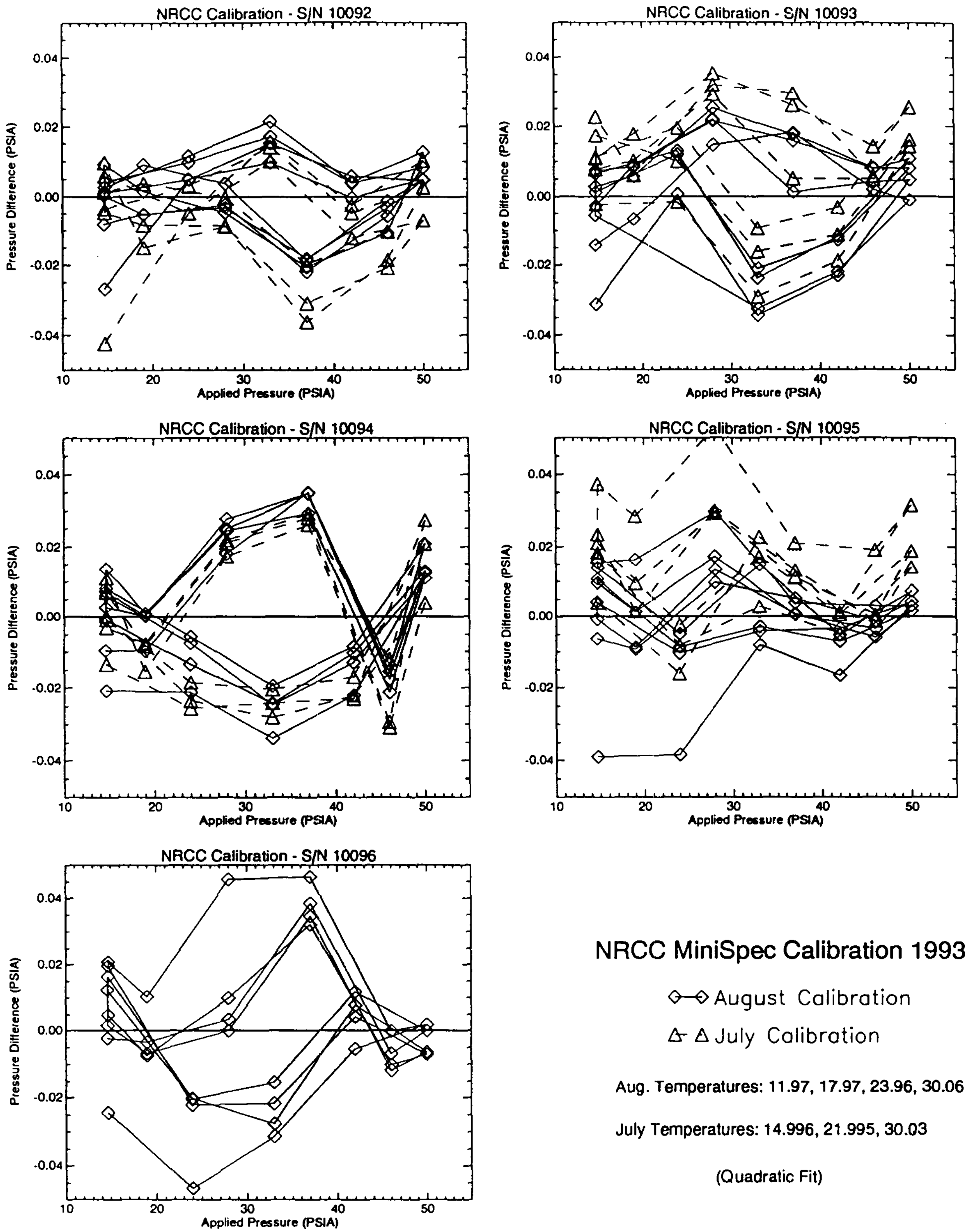


Figure 11. Plots of the difference between the NRCC pressure and the pressure measured by the MiniSpecs if a calibration model is used that is quadratic in pressure and linear in temperature. Plots show both the July and August NRCC test results.

4.0 Theoretical Wave Capability

CLI lists the accuracy of the strain gage pressure sensor as 0.1%. It does not state whether this is percent of the reading or of full scale, which is 50 psia. We interpret this as percent of full scale. The accuracy, therefore, is 0.05 psia, or 3.4 hPa (1 psia = 68.948 hPa; 1 hPa = 1 millibar). However, for wave bursts of only seventeen minutes duration, resolution rather than accuracy is the important parameter. Resolution is 1/4096 of full scale or 0.012 psi (0.84 hPa). We have used this value as the smallest pressure fluctuation the MiniSpec can detect and asked the question, "What wave height would cause this minimum detectable pressure fluctuation at the depth of the instrument, given the hydrodynamic MiniSpec attenuation predicted by linear wave theory?" This calculation was performed at depths which correspond to those of the five MiniSpec locations.

As noted above, the resolution of the MiniSpec pressure sensor determines the minimum detectable wave height. We therefore determine the wave amplitude, η, using an equation derived from the unsteady Bernoulli equation for an ideal fluid (Dean and Dalrymple, 1984):

$$\eta = \frac{p + \rho g z}{\rho g K_z},$$

where the pressure response factor is defined as:

$$K_z = \frac{\cosh\left[\frac{2\pi(z+d)}{L}\right]}{\cosh\left[\frac{2\pi d}{L}\right]}.$$

$\rho g z$ represents the hydrostatic (mean) pressure, p is the MiniSpec pressure sensor resolution, 0.012 psi (0.84 hPa), z is the sensor depth, and d is the bottom depth. The wavelength, L, is iteratively calculated from the dispersion relation

$$L \approx L_o \sqrt{\tanh\left[\frac{2\pi d}{L}\right]}$$

For deep water waves, $L_o = 1.56T^2$, where T is the wave period. We find the minimum wave height, H, by doubling the calculated wave amplitude, η.

We assume that the MiniSpec is housed in a frame which positions the pressure port 2 m above the bottom at each site. We then computed the minimum detectable wave height (MDWH) for each of the five MiniSpec sites. The site numbers (west to east), depths, instrument serial numbers for the March-May 1993 deployment, the minimum detectable wave height (MDWH), and the Wave Information Studies (WIS) percentage of occurrence of waves with periods less than 4.2 seconds, are tabulated below (Table 5). Site 1 did not contain a MiniSpec instrument during this deployment period, and site 20 contained SN 10095 which failed to yield burst data during this deployment.

Table 5. Depths and theoretically determined minimum detectable wave height (MDWH) of the MiniSpecs pressure sensors.

SITE	BOTTOM DEPTH (m)	SENSOR DEPTH (m)	INST. S.N.	MDWH AT 4.2 s (m)	WIS % OCC. < 4.2 S
1	23.2	21.2	no data	1.51	0.5%
23	15.3	13.2	92	0.25	10.3%
20	15.8	13.8	no data	0.28	4.2%
17	8.1	6.1	94	0.05	10.7%
16	20.4	18.4	96	0.80	6.8%

Figures 12 and 13 show the results of the linear wave analysis. The MiniSpecs can detect 0.3 m, 5.0 s waves at all locations. At a period of 4.0 s, the effects of attenuation become more evident at the two deeper locations, Sites 1 and 16, where the MDWH rises above 1.0 m. Wave heights of 0.3 m can still be detected at the three other sites. At a period of 3.0 s the MiniSpecs are "blind" to surface waves, except at the shallow Site 17.

How much of the short period signal might be lost in a real wave record? Tables 6 through 10 are taken from the CERC Wave Information Study Report 18 (Hubertz et al., 1989), a 20-year hindcast, excluding tropical storms. The WIS locations shown are those closest to the LATEX sites. In the joint frequency distributions of wave height vs. wave period, the region of interest is wave period less than 4.2 s. (Table 5 lists the MDWH at a period of 4.2 s.).

For LATEX Site 1, which has the deepest MiniSpec, the WIS study shows only about a 0.5% occurrence of the short period waves. Thus, the effects of attenuation are offset by the fact that there is historically little wave energy at short periods. Site 16, on the other hand, has about a seven percent occurrence of waves less than 4.2 s period. This site is also relatively deep, and since there is short period wave energy, the attenuation may be unacceptable. For Site 16, the MDWH is 0.80 m at a period of 4.2 s; it rises to about 1.0 m at 4.0 s.

The two "intermediate depth" cases are Sites 23 and 20, for which the MDWH rises from about 0.26 m at 4.2 s to 1.0 m at 3.4 s. The MiniSpecs at these two sites marginally resolve the short period waves. The attenuation effect is more important for Site 23 because about ten percent of the hindcast waves near Site 23 are shorter than 4.2s.

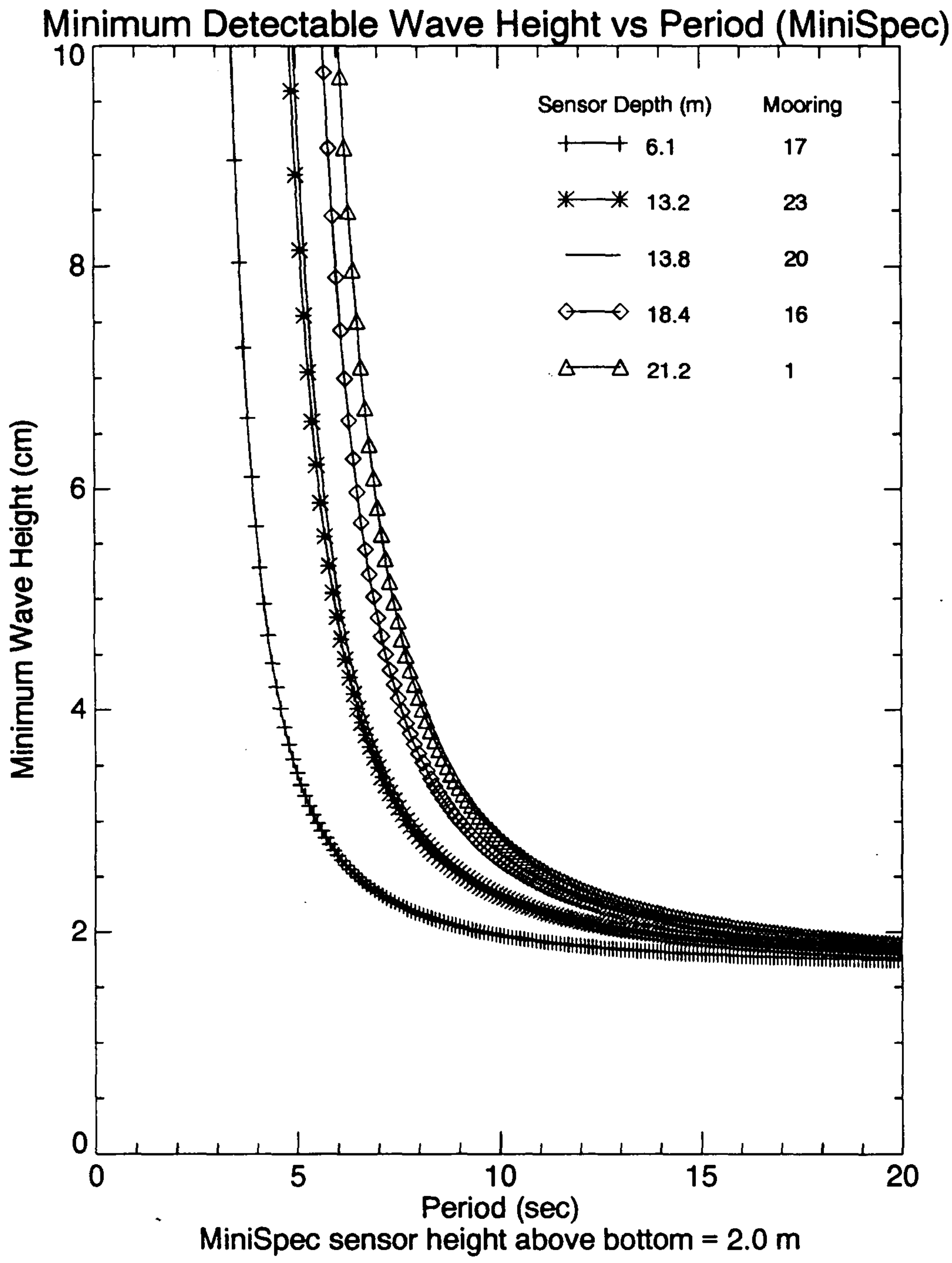


Figure 12. Minimum detectable wave height versus period based on MiniSpec resolution, sensor depth, and water depth.

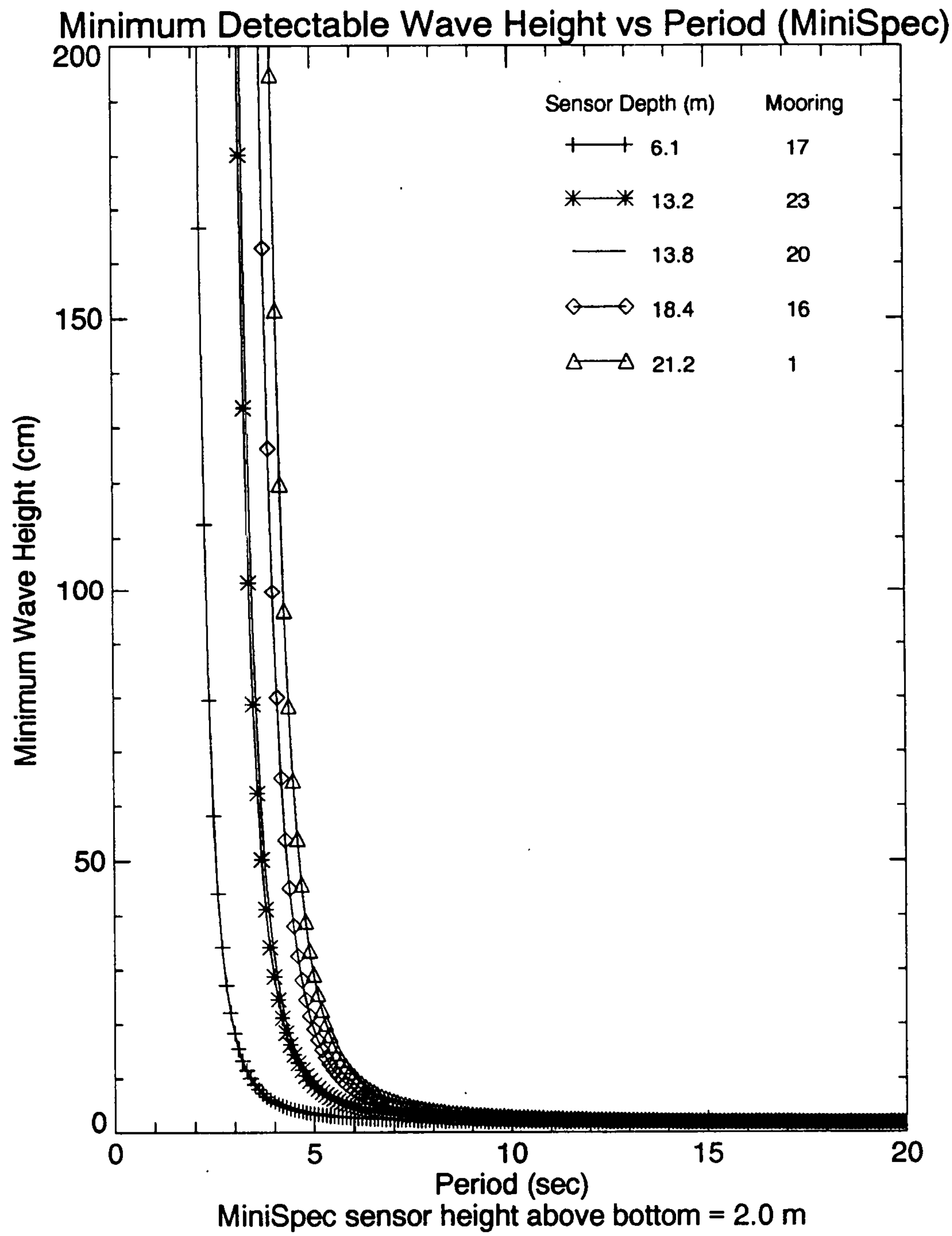


Figure 13. Same as Figure 12, except at different scale.

STATION 4 27.00N 97.00W FOR ALL DIRECTIONS
PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)	PEAK PERIOD(SECONDS)										TOTAL
	<4.2	4.2-5.3	5.4-6.5	6.6-7.4	7.5-8.7	8.8-9.5	9.6-10.5	10.6-11.8	11.9-13.3	13.4-LONGER	
0.-0.9	54	451	365	70	22	1	.	.	.	.	963
1.0-1.9	1	308	3297	3318	965	41	8	.	.	.	7938
2.0-2.9	.	.	9	270	673	60	10	1	.	.	1023
3.0-3.9	.	.	.	1	42	13	7	.	.	.	63
4.0-4.9	.	.	.	.	.	.	.	.	.	.	0
5.0-5.9	.	.	.	.	.	.	.	.	.	.	0
6.0-6.9	.	.	.	.	.	.	.	.	.	.	0
7.0-7.9	.	.	.	.	.	.	.	.	.	.	0
8.0-8.9	.	.	.	.	.	.	.	.	.	.	0
9.0-9.9	.	.	.	.	.	.	.	.	.	.	0
10.0+	.	.	.	.	.	.	.	.	.	.	0
TOTAL	55	759	3671	3659	1702	115	25	1	0	0	

MEAN HS(M)= 1.4 LARGEST HS(M)= 4.0 MEAN TP(SEC)= 6.5 TOTAL CASES= 58440.

Table 6. WIS Station 4 (close to Site 1) wave height-period hindcast.

STATION 9 28.50N 95.50W FOR ALL DIRECTIONS
PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)	PEAK PERIOD(SECONDS)										TOTAL
	<4.2	4.2-5.3	5.4-6.5	6.6-7.4	7.5-8.7	8.8-9.5	9.6-10.5	10.6-11.8	11.9-13.3	13.4-LONGER	
0.-0.9	1026	1684	1106	329	123	19	1	.	.	.	4288
1.0-1.9	1	802	2527	1647	617	29	2	1	.	.	5626
2.0-2.9	.	.	2	6	50	15	2	1	.	.	76
3.0-3.9	.	.	.	.	.	.	.	.	.	.	0
4.0-4.9	.	.	.	.	.	.	.	.	.	.	0
5.0-5.9	.	.	.	.	.	.	.	.	.	.	0
6.0-6.9	.	.	.	.	.	.	.	.	.	.	0
7.0-7.9	.	.	.	.	.	.	.	.	.	.	0
8.0-8.9	.	.	.	.	.	.	.	.	.	.	0
9.0-9.9	.	.	.	.	.	.	.	.	.	.	0
10.0+	.	.	.	.	.	.	.	.	.	.	0
TOTAL	1027	2486	3635	1982	790	63	5	2	0	0	

MEAN HS(M)= 1.0 LARGEST HS(M)= 3.2 MEAN TP(SEC)= 5.7 TOTAL CASES= 58440.

Table 7. WIS Station 9 (close to Site 23) wave height-period hindcast.

STATION 12 29.00N 94.00W FOR ALL DIRECTIONS
PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)	PEAK PERIOD(SECONDS)										TOTAL
	<4.2	4.2-5.3	5.4-6.5	6.6-7.4	7.5-8.7	8.8-9.5	9.6-10.5	10.6-11.8	11.9-13.3	13.4-LONGER	
0.-0.9	420	1838	530	81	19	1	1	.	.	.	2890
1.0-1.9	4	1160	3575	1438	260	9	2	.	.	.	6448
2.0-2.9	.	1	63	229	299	27	.	.	.	.	619
3.0-3.9	.	.	.	.	2	17	11	1	.	.	31
4.0-4.9	.	.	.	.	.	.	.	1	.	.	1
5.0-5.9	.	.	.	.	.	.	.	.	.	.	0
6.0-6.9	.	.	.	.	.	.	.	.	.	.	0
7.0-7.9	.	.	.	.	.	.	.	.	.	.	0
8.0-8.9	.	.	.	.	.	.	.	.	.	.	0
9.0-9.9	.	.	.	.	.	.	.	.	.	.	0
10.0+	.	.	.	.	.	.	.	.	.	.	0
TOTAL	424	2999	4168	1748	580	54	14	2	0	0	

MEAN HS(M)= 1.2 LARGEST HS(M)= 4.6 MEAN TP(SEC)= 5.7 TOTAL CASES= 58440.

Table 8. WIS Station 12 (close to Site 20) wave height-period hindcast.

STATION 16 29.00N 92.00W FOR ALL DIRECTIONS
PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)	PEAK PERIOD(SECONDS) <4.2	4.2-5.3	5.4-6.5	6.6-7.4	7.5-8.7	8.8-9.5	9.6-10.5	10.6-11.8	11.9-13.3	13.4-LONGER	TOTAL
0. -0.9	1063	3256	1385	222	54	1	.	.	.	.	5981
1.0-1.9	2	1427	1581	669	266	19	5	4	.	.	3973
2.0-2.9	.	.	10	1	13	7	3	1	.	.	35
3.0-3.9	.	.	.	.	.	.	.	.	.	.	0
4.0-4.9	.	.	.	.	.	.	.	.	.	.	0
5.0-5.9	.	.	.	.	.	.	.	.	.	.	0
6.0-6.9	.	.	.	.	.	.	.	.	.	.	0
7.0-7.9	.	.	.	.	.	.	.	.	.	.	0
8.0-8.9	.	.	.	.	.	.	.	.	.	.	0
9.0-9.9	.	.	.	.	.	.	.	.	.	.	0
10.0+	.	.	.	.	.	.	.	.	.	.	0
TOTAL	1065	4683	2976	892	333	27	8	5	0	0	

MEAN HS(M)= 0.9 LARGEST HS(M)= 3.0 MEAN TP(SEC)= 5.2 TOTAL CASES= 58440.

Table 9. WIS Station 16 (close to Site 17) wave height-period hindcast.

STATION 20 28.50N 90.50W FOR ALL DIRECTIONS
PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)	PEAK PERIOD(SECONDS) <4.2	4.2-5.3	5.4-6.5	6.6-7.4	7.5-8.7	8.8-9.5	9.6-10.5	10.6-11.8	11.9-13.3	13.4-LONGER	TOTAL
0. -0.9	682	2267	712	38	2	.	.	.	.	.	3701
1.0-1.9	.	846	3282	1528	277	3	.	.	.	.	5936
2.0-2.9	.	.	25	90	202	18	3	.	.	.	338
3.0-3.9	.	.	.	.	3	8	4	.	.	.	15
4.0-4.9	.	.	.	.	.	.	.	.	.	.	0
5.0-5.9	.	.	.	.	.	.	.	.	.	.	0
6.0-6.9	.	.	.	.	.	.	.	.	.	.	0
7.0-7.9	.	.	.	.	.	.	.	.	.	.	0
8.0-8.9	.	.	.	.	.	.	.	.	.	.	0
9.0-9.9	.	.	.	.	.	.	.	.	.	.	0
10.0+	.	.	.	.	.	.	.	.	.	.	0
TOTAL	682	3113	4019	1656	484	29	7	0	0	0	

MEAN HS(M)= 1.1 LARGEST HS(M)= 5.8 MEAN TP(SEC)= 5.6 TOTAL CASES= 58440.

Table 10. WIS Station 20 (close to Site 16) wave height-period hindcast.

It is our conclusion that the MiniSpecs at Sites 20 and 23 should be moved and the MiniSpecs at Sites 1 and 16 must be moved to new shallower locations. There are offshore platforms at shallower depths. Unfortunately, there is no protected location for Site 23 that is shallower than its present one.

5.0 MiniSpec Wave Data From Last Deployment.

The MiniSpecs at sites 23, 17, and 16, produced usable wave burst data during the March-May 1993 deployment, if the warm-up transient (Figure 6 and 7) is eliminated. Figures 14, 15, and 16 show the respective time-series plots of current velocity, direction, and average pressure. (The MiniSpec frame at Site 23 was knocked over on May 14, and the pressure sensor at Site 17 failed beginning about May 7.) We selected a three-day period, April 7-9, 1993, during which high waves and swift currents developed. We wanted to compare the high frequency responses of the MiniSpecs at the three different sensor depths, which are 15.3 m, 6.1 m, and 20.4 m, respectively. However, one should keep in mind that the sites are separated by considerable distances, hence, the wind fields are different at each location.

The pressure burst records contain 2048 data points sampled at a 0.5 s rate. The first 200 points were eliminated from each burst due to the warm-up transient. We removed the mean from each time-series burst, then applied a band-pass filter with -6db points at 20 s and 4.0 s, and followed this with a Hanning (half cosine) filter. The burst was transformed by FFT, and the periodogram was boxcar averaged to reduce variance in the spectrum. Each spectrum was corrected for the frequency dependent hydrodynamic attenuation. We made a burst-by-burst adjustment for the change water depth caused by tide, and we computed significant wave height from the <u>energy</u> spectrum (Kinsman, 1984). Our focus was the effect of hydrodynamic attenuation on the amplitude spectrum. Figures 17, 18, and 19 show the twenty-four spectra for each site before correction for attenuation, and Figures 20, 21, and 22 show them after correction. The plots are one-sided <u>amplitude</u> spectra of pressure (hPa) versus frequency. Figures 17 and 20 illustrate the effect of attenuation. In Figure 17 the spectra have low amplitude between 0.15 Hz (6.7 s) and 0.2 Hz (5 s), and almost negligible amplitude below 0.2 Hz. The main peak at about 0.15 Hz shifts downward in frequency and grows in amplitude, reaching a maximum on April 8 at 0600 hours at a frequency of 0.12 Hz. After this time the amplitude decreases, but the shift to lower frequency continues. In the beginning of the sequence shown in Figure 20 we see significant amplitude at higher frequencies. This high frequency amplitude then decays while the lower frequency peak grows. After 0600 on April 8, the amplitude at all frequencies decays.

The weather that caused this event in the pressure data can be seen in the Daily Weather Maps for April 7-9 (Figures 23, 24 and 25). On April 7 southeast winds prevailed as a front approached the Gulf. On April 8 thunderstorms lay over the coastal region from Corpus Christi to the Delta accompanied by increasingly strong southerly winds. By April 9 the frontal system had moved eastward to Alabama. Winds over the three MiniSpec sites were southeasterly and weak.

At Site 17, the spectra show short period waves building during April 7. Waves with periods less than 0.15 Hz begin late on April 7. They grow in amplitude

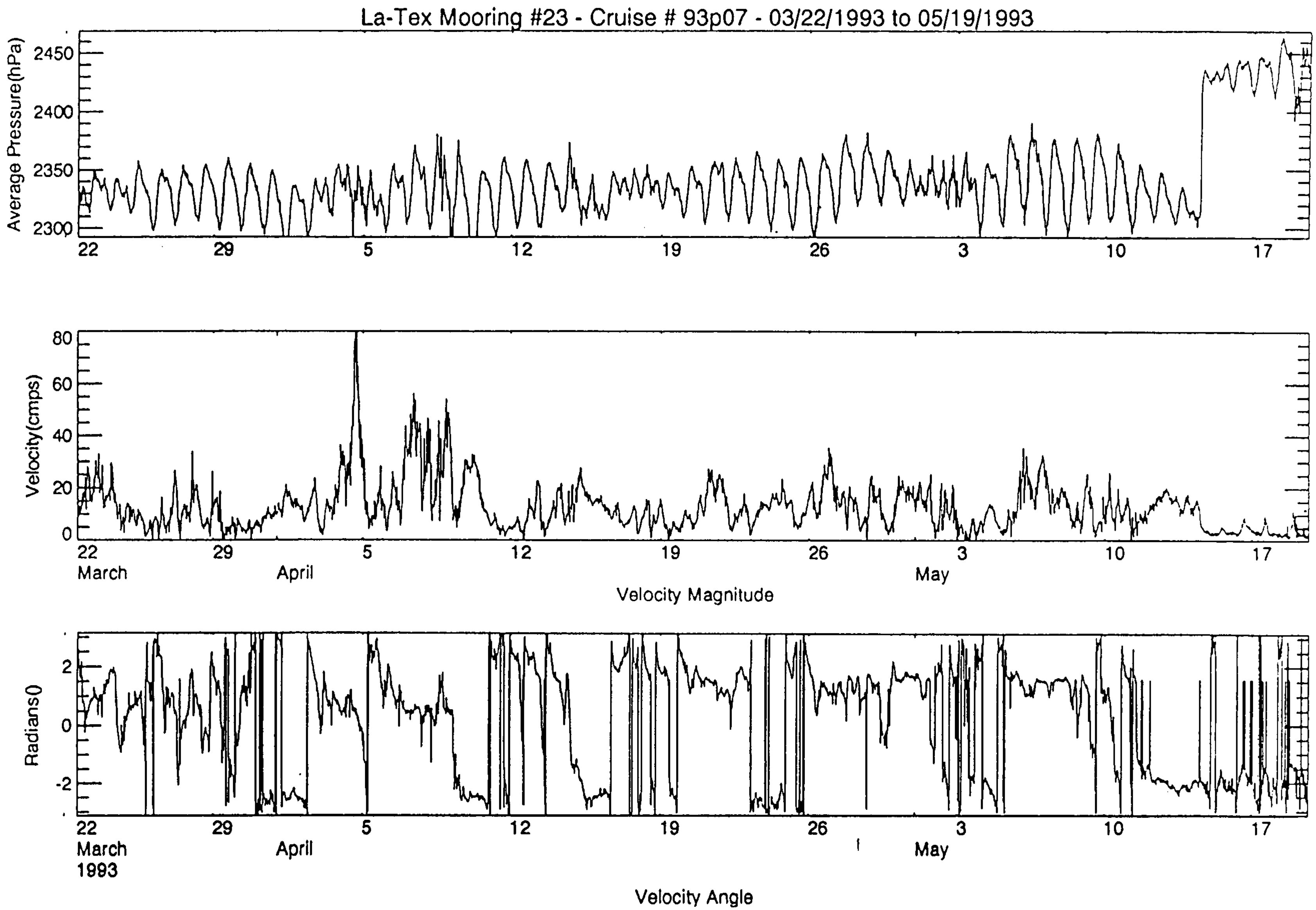


Figure 14. Time series of MiniSpec pressure, speed and direction data collected at Site 23.

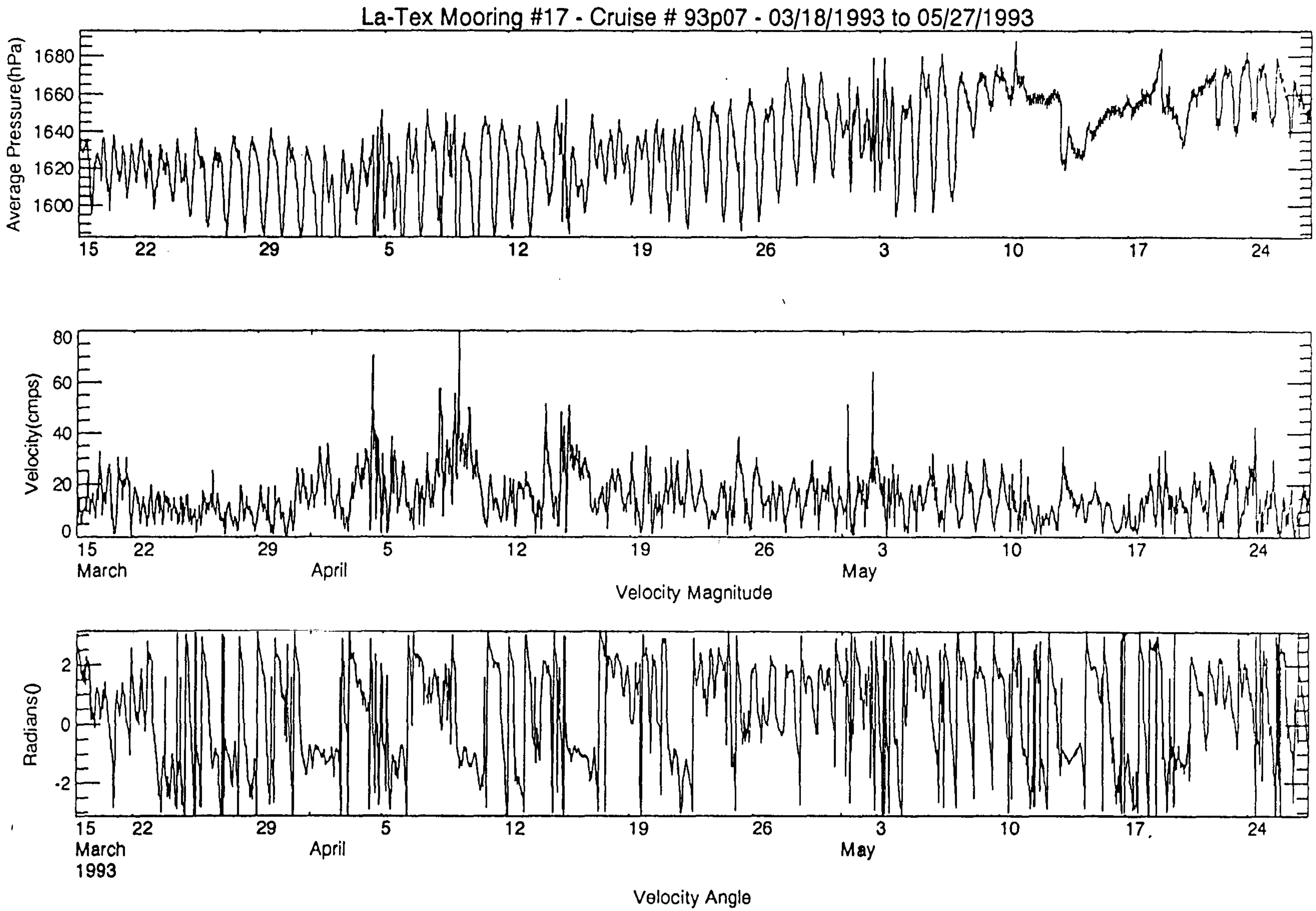


Figure 15. Time series of MiniSpec pressure, speed and direction data collected at Site 17.

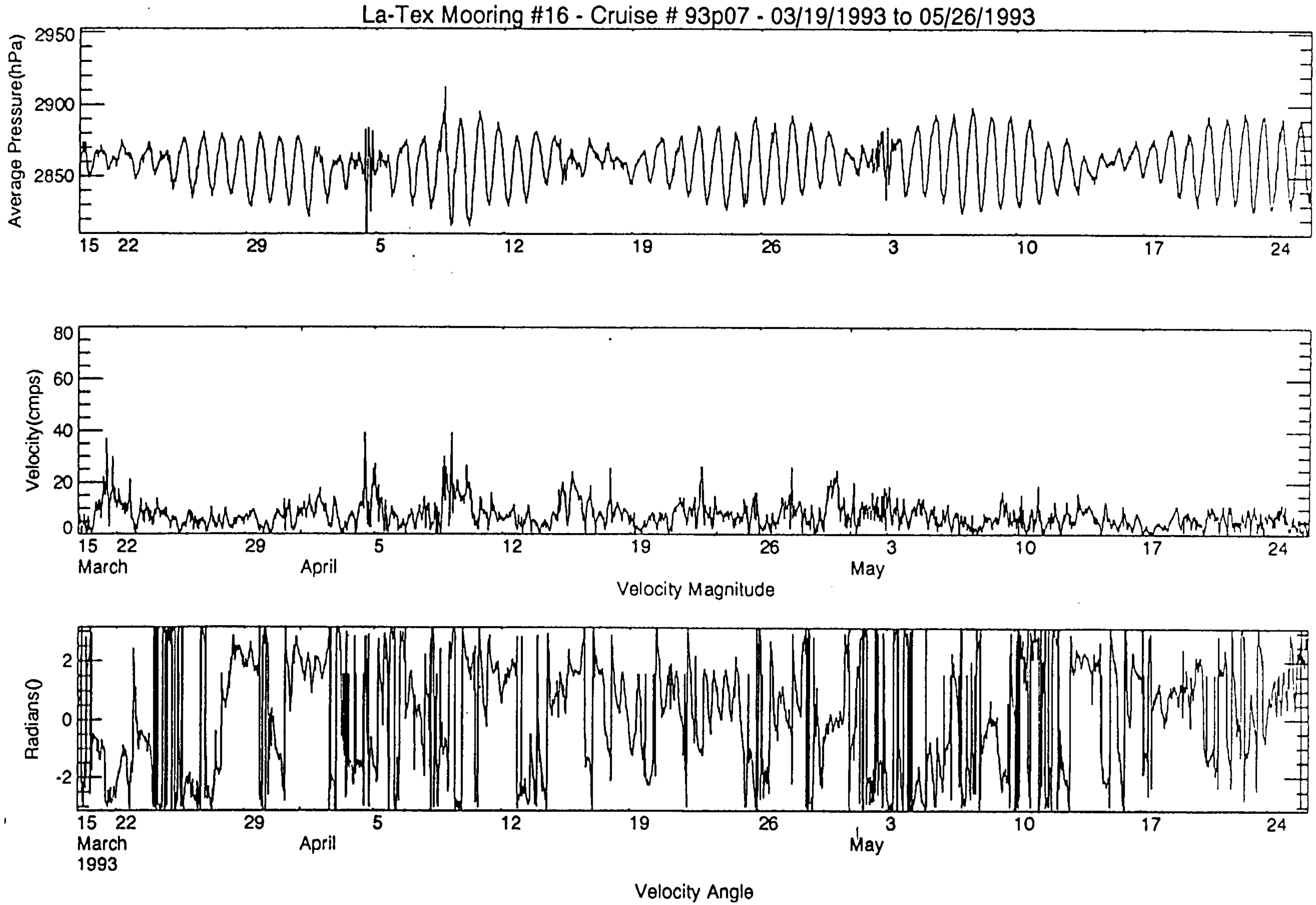


Figure 16. Time series of MiniSpec pressure, speed and direction data collected at Site 16.

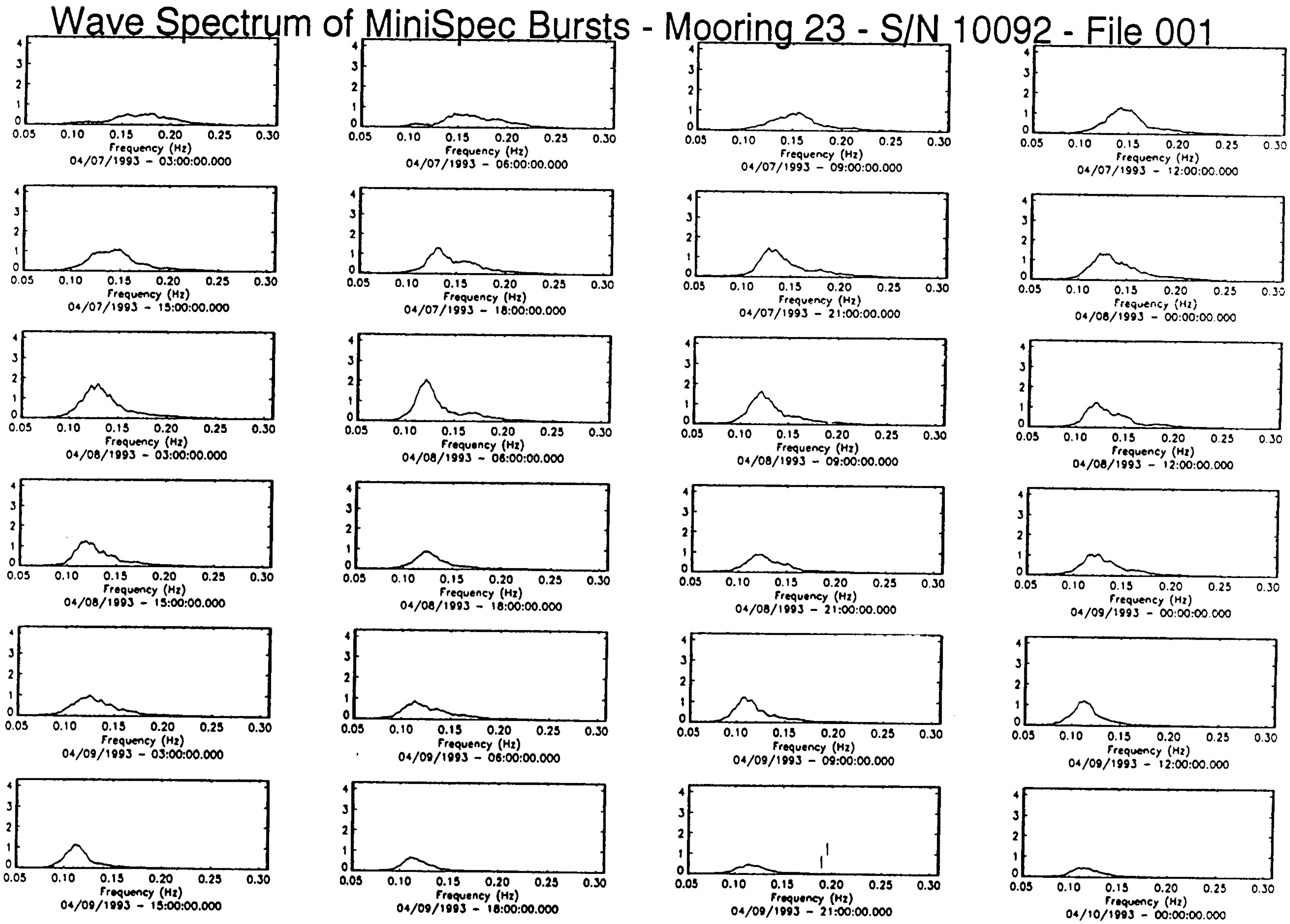


Figure 17. Site 23, SN 10092. Plots of wave amplitude spectra, without correction for hydrodynamic attenuation, for April 7-9, 1993.

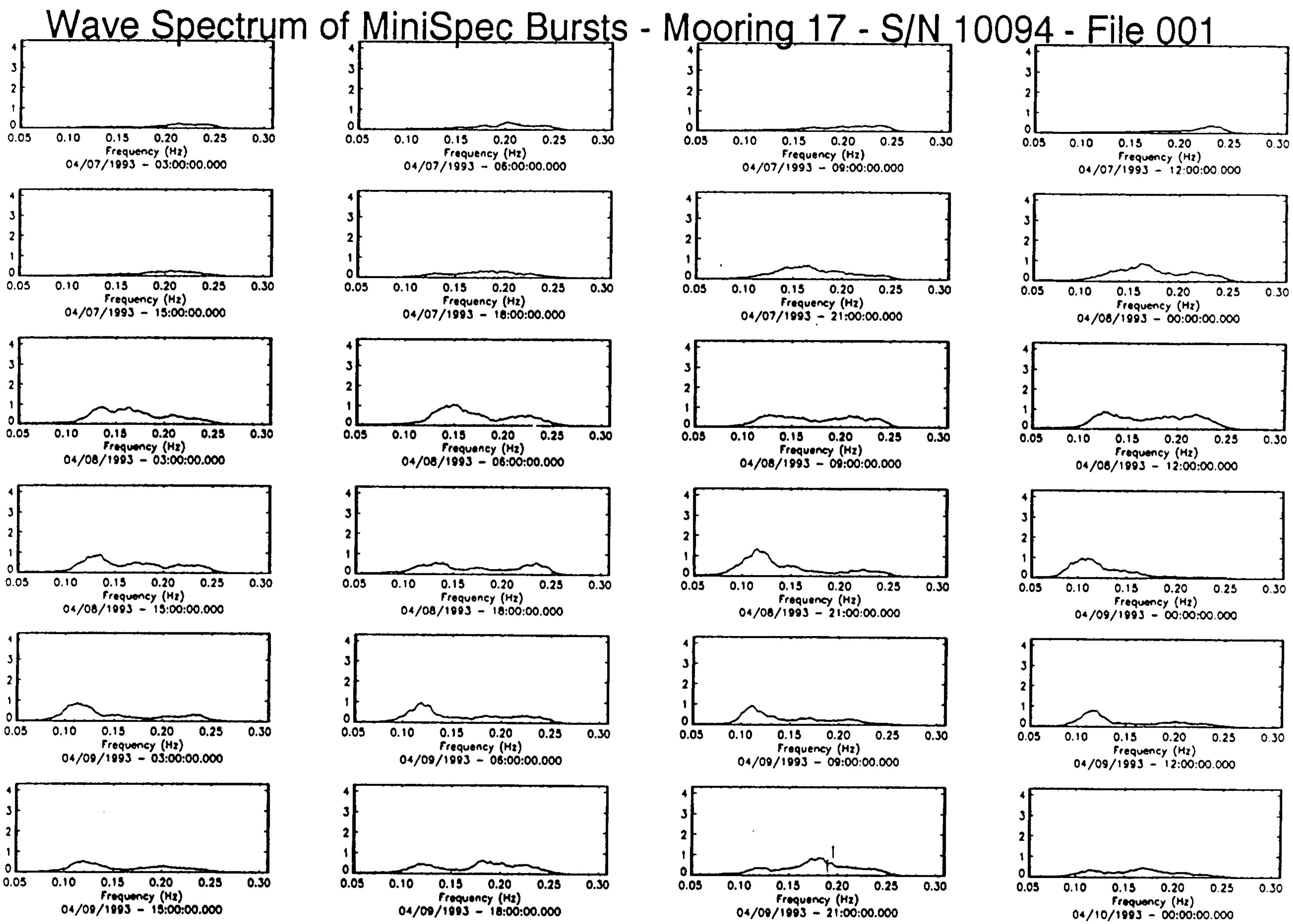


Figure 18. Site 17, SN 10094. Plots of wave amplitude spectra, without correction for hydrodynamic attenuation, for April 7-9, 1993.

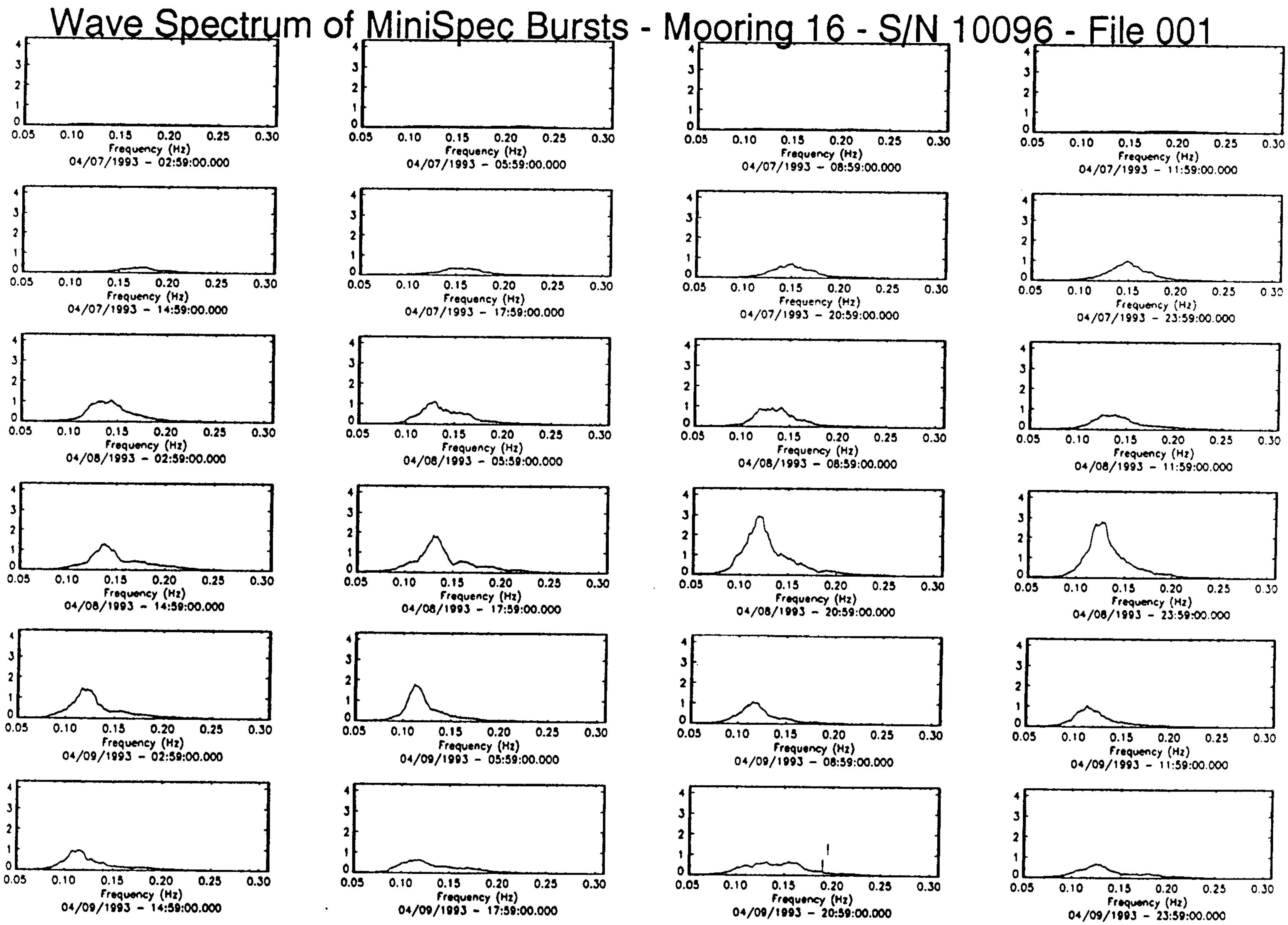


Figure 19. Site 16, SN 10096. Plots of wave amplitude spectra, without correction for hydrodynamic attenuation, for April 7-9, 1993.

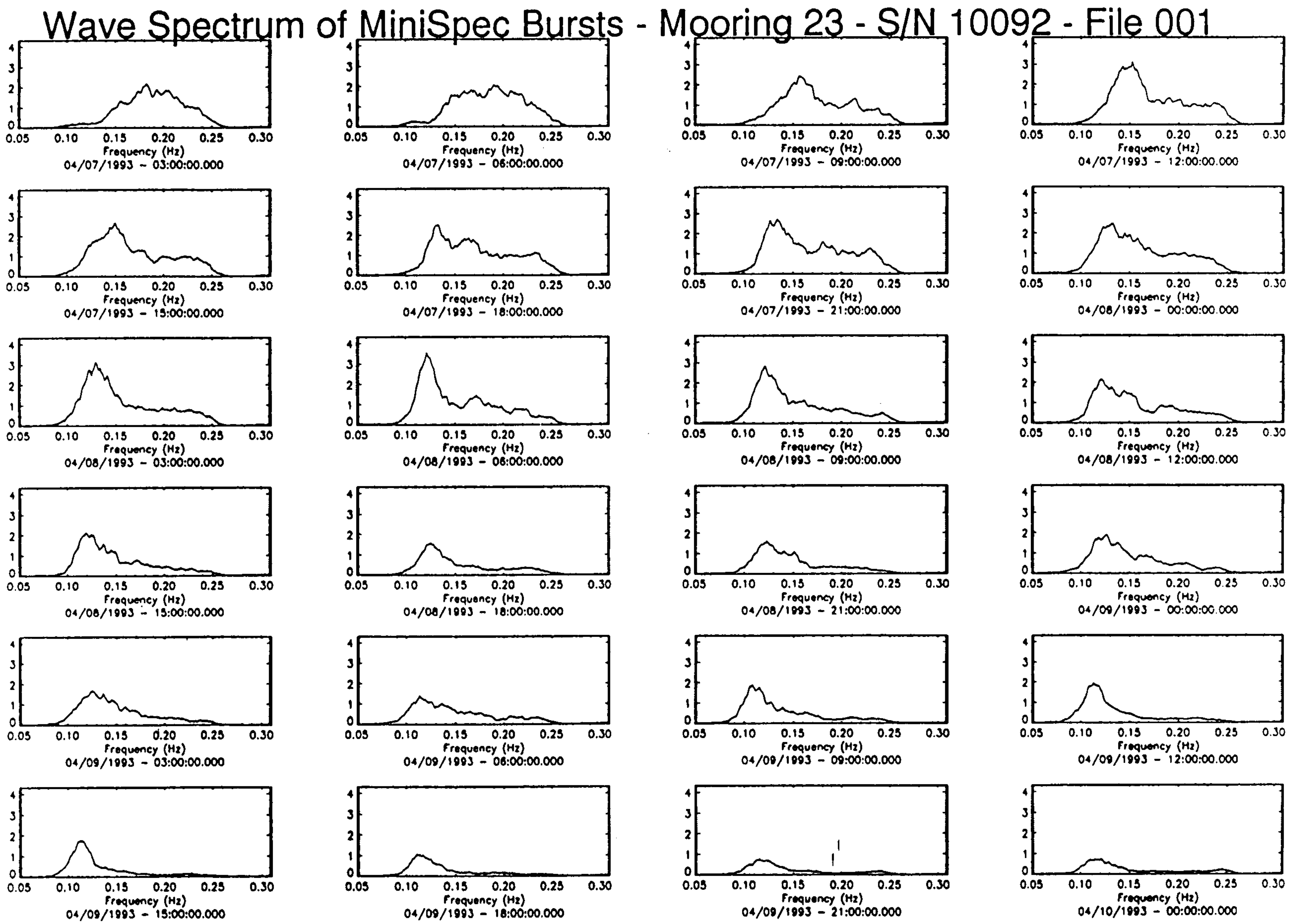


Figure 20. Site 23, SN 10092. Plots of corrected wave amplitude spectra for April 7-9, 1993.

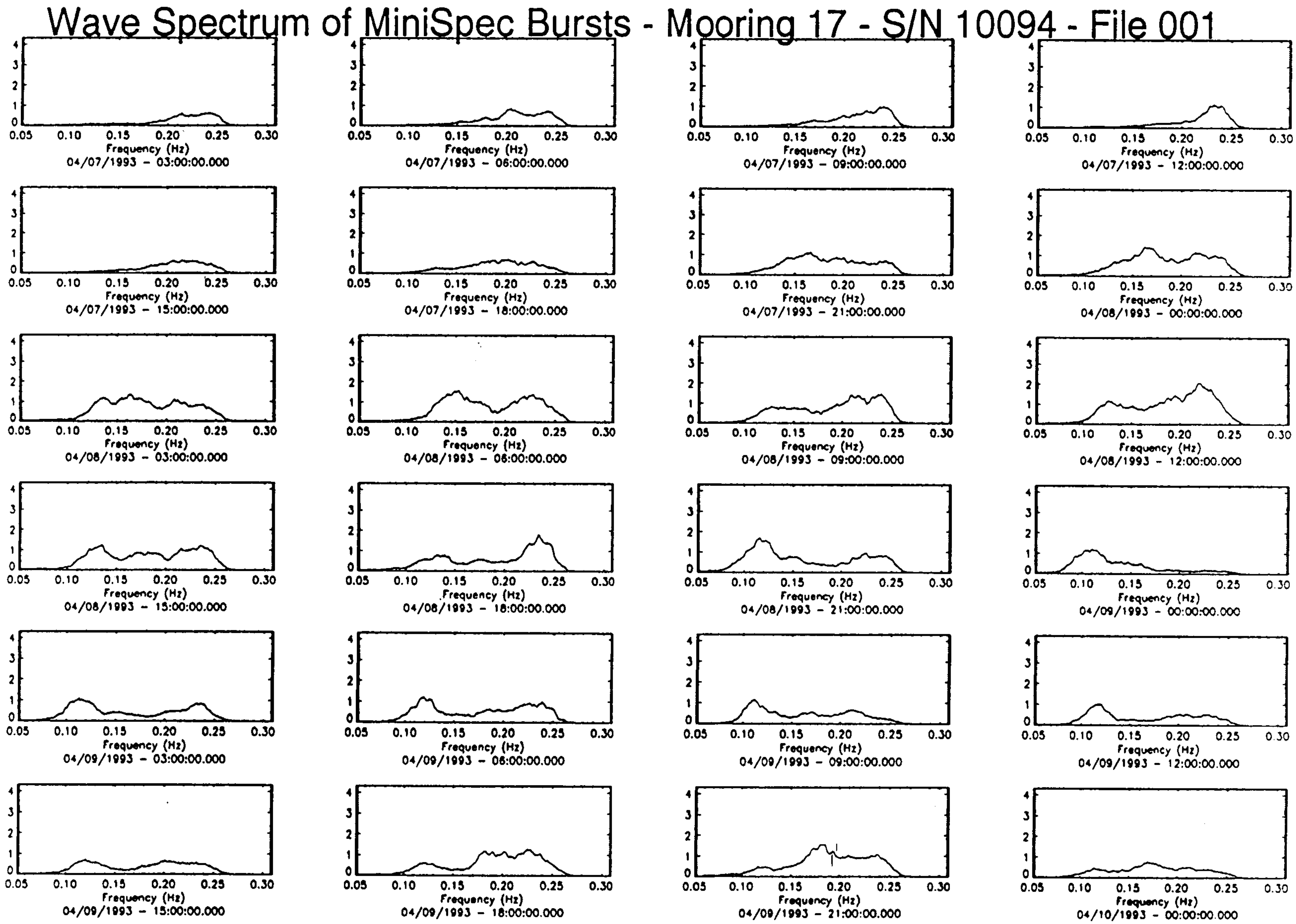


Figure 21. Site 17, SN 10094. Plots of corrected wave amplitude spectra for April 7-9, 1993.

Wave Spectrum of MiniSpec Bursts - Mooring 16 - S/N 10096 - File 001

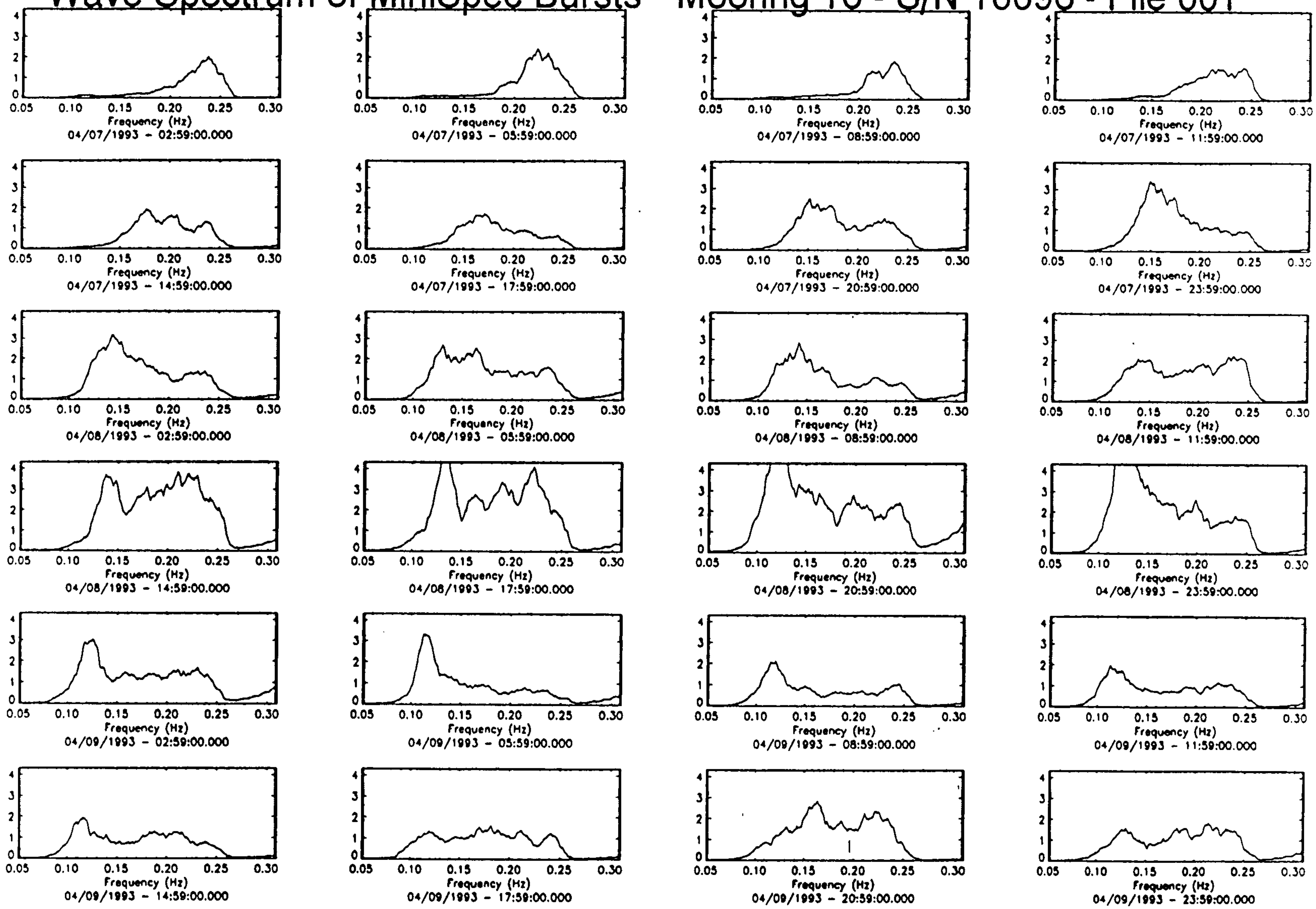


Figure 22. Site 16, SN 10096. Plots of corrected wave amplitude spectra for April 7-9, 1993.

WEDNESDAY, APRIL 7, 1993

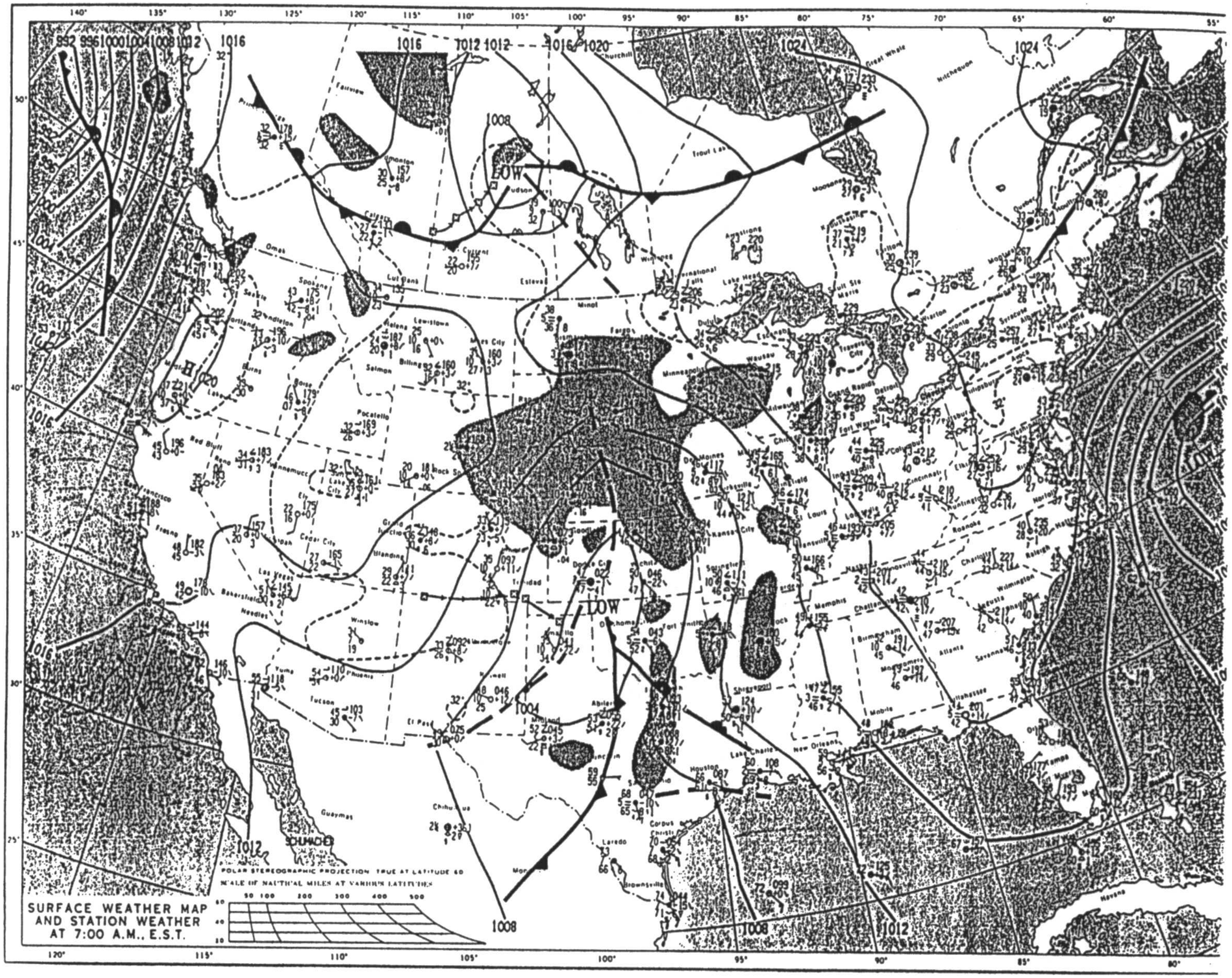


Figure 23. Daily Weather Map for April 7, 1993.

THURSDAY, APRIL 8, 1993

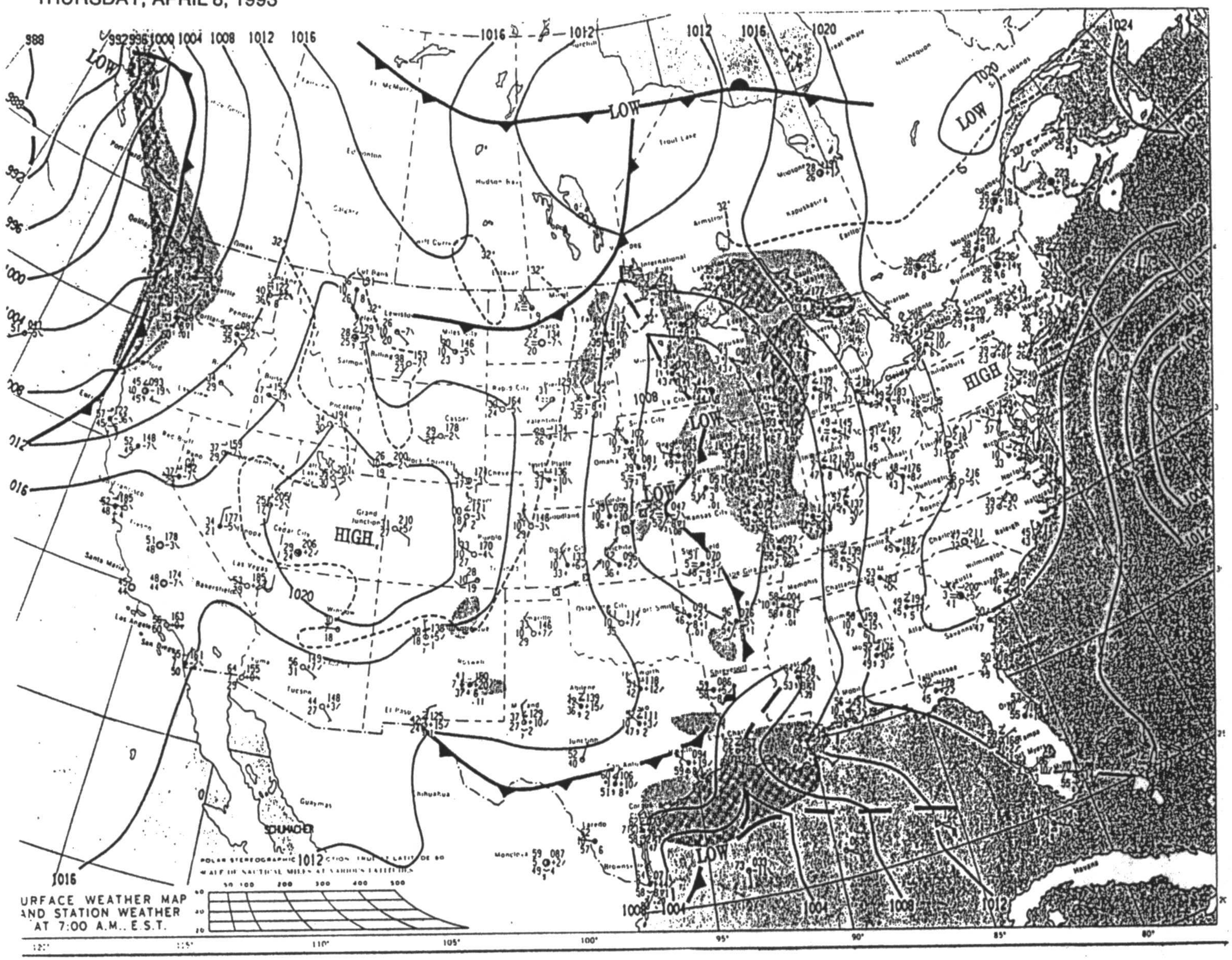


Figure 24. Daily Weather Map for April 8, 1993.

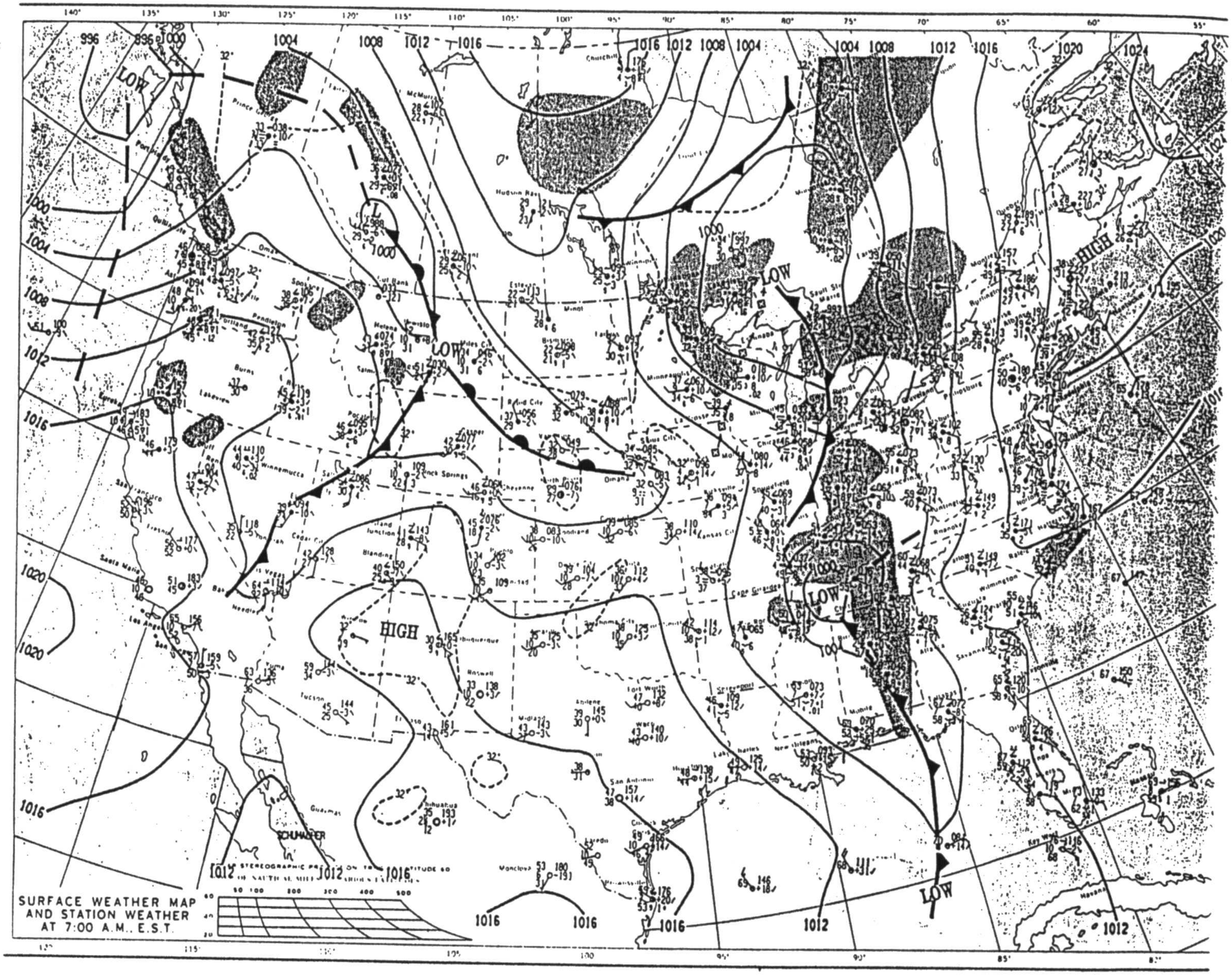


Figure 25. Daily Weather Map for April 9, 1993.

and shift to lower frequencies, and then decay, as at Site 23. There is more variability in this trend at Site 17 than at Site 23.

Compared to Sites 23 and 17, the corrected spectra for Site 16 have a larger amplitude, particularly at high and low frequencies. Given the similarity between the spectra from Sites 23 and 17, we believe that the larger spectra at higher frequencies at Site 16 are suspect. This is because at a depth of over 20 m we are probably amplifying a signal that is below the noise level of the sensor.

For low frequencies, less than 0.15 Hz, we see an energy content that increases with the depth of water. This is consistent with locally generated waves during a frontal outbreak with limited fetch or with limitation by water depth on the growth rate. It is our conclusion that the larger spectra for Site 16 are an artifact of the correction for hydrodynamic attenuation. In summary, Site 16 (and Site 1) must be moved to shallower water, or the instrument moved higher in the water column. We also recommend that site 20 be moved shallower or higher to improve signal to noise ratio.

6.0 Conclusions

With new pressure sensors and the TAMU calibration model, the MiniSpecs pressure system now meets the manufacturer's listed accuracy of 0.1% full scale, or 3.4 hPa (0.05 psi). The results of the NRCC tests clearly show that a calibration model for the MiniSpec that is only a linear function of pressure does not meet the accuracy CLI lists for this instrument. Therefore, the MiniSpecs that CLI delivered to TAMU and the replacement sensors that CLI subsequently supplied were non-compliant with the specifications in the original purchase order. The test data are insufficient to quantify the long term stability of the pressure sensor. The tests of the temperature sensors confirm that the YSI thermistor is linear and has an accuracy better than 0.1 C over a range of 12 to 30 C.

All of the field pressure data collected through May 1993 by the MiniSpecs are contaminated because the original sensors exhibited a marked warm-up transient of about five-minutes duration. In addition, no calibration data are available for the original sensors to correct for the effect of temperature. Therefore, all of the tide mode (averaged) data collected thus far should be flagged as questionable. Because of the noise and clipping problems, all of the burst pressure (wave) data collected between April 1992 and January 1993 are no good. The burst pressure data collected during the March-May 1993, deployment can be used for wave estimates if the first five minutes of each burst are eliminated and the remainder of each burst is detrended. Except for the cases when the temperature sensors failed or were noisy, the quality of the temperature data meets specifications.

The minimum wave height that the MiniSpec can detect depends upon linear wave theory and the instrument's resolution and depth. The solid-state strain-gauge sensor of the MiniSpec can produce reasonable wave spectra provided it is not placed too deep. Attenuation is not significant at Site 17. Attenuation is significant but marginally acceptable at Sites 20 and 23, and unacceptable at Sites 1 and 16. The theoretical limitations suggest that these sites should be moved to shallower locations. Unfortunately, there is no protected location for Site 23 that is shallower than its present one.

The instrument's field performance was evaluated by analyzing the wave spectra from the April 7-9, 1993 period at three sites. The passage of a weather front is reflected in the evolution of wave height and period as seen in the wave spectra.

This report does not address the current velocity sensor and directional wave measurement capability of the MiniSpec.

7.0 Acknowledgments

This work was supported by Study Unit A of the Louisiana-Texas Shelf Physical Oceanography Program under U.S. Minerals Management Service Contract No. 14-35-0001-30509.

The authors would like to thank R.O. Reid, A. Jochens, and W. Nowlin for their comments concerning this report and J. Sterling for her help in its preparation.

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APPENDIX

NRCC Test Reports and Corresponding MiniSpec Data Processed by EHI

NORTHWEST REGIONAL CALIBRATION CENTER

300 - 120th Avenue NE • Building Six • Suite 108 • Bellevue, Washington 98005 • (206) 455-1999 • FAX (206) 646-9123

TEST REPORT

For: MINISPEC Wave Gauges
Model Number: N/A
Serial Number: 10092,10093,10094,10095,10096
Submitted by: Texas A&M Research Foundation

Report Number: 93204
W.P.File: 93204.WPS
Date: 07/13/93

TEST PROCEDURE

The pressure channels of these instruments were tested in accordance with "NOAA Calibration Procedure for CTD and STD Sensors (including Sound Speed)", NOIC-CP-04A, dated June 1975.

This procedure is described as a test and not a calibration because the procedure did not produce a precise relationship between the instrument output and the test conditions. Evaluation of instrument performance is left to the client.

The instruments were configured by the client to store pressure and time data in memory during the test procedure. The instruments were then immersed in a temperature-controlled water bath and brought to temperature equilibrium at a known temperature. Pressure was applied to the instrument pressure ports by means of a manifold connected to the NRCC Ruska Model 2465 Air Deadweight Tester. The applied pressures for the test procedure were specified by the client to span the range of the pressure sensors installed in the instruments. At each pressure test point, the applied pressure was held at a stable value for sufficient time to allow a representative sample for the instruments.

The accuracy of the NRCC Ruska Air Deadweight Tester is certified by the manufacturer to be within +/- 0.01% of calculated pressure. NRCC standards are traceable to NIST.

The original test plan was designed to describe the pressure channel response of the instruments over a range of increasing and decreasing pressures. However, some of the pressure sensors began leaking internally during the testing and the testing had to be aborted. See the notes on Page 2.

The test data is reported on Page 2.

The details of the NRCC calibration procedure for this instrument are available upon request.

Tested by: R. Guenther
R. Guenther / D. Keir

Checked by:
T. Baker

Approved by: J. Francis Smith
J. Francis Smith, Director

For: MINISPEC Wave Gauges		Report Number:	93204
Model Number:	N/A	W.P.File:	93204.WPS
Serial Number:	10092,10093,10094,10095,10096	Date:	07/13/93
Submitted by:	Texas A&M Research Foundation	Page 3 of 4	

PRESSURE TEST DATA

Test Range [psia]: 14.7 to 50

TABLE 3
PRESSURE TEST #3 DATA

Test Temperature [^{o}C]: 30.03
Test Date: 12 July 1993

Applied Pressure [psia]	Sample Start [PDT]	Sample Stop [PDT]
14.74	07:50:00	07:55:00
24.013	08:05:00	08:10:00
33.018	08:20:00	08:25:00
42.022	08:35:00	08:40:00
50.026	08:50:00	08:55:00
46.024	09:05:00	09:10:00
37.020	09:20:00	09:25:00
28.016	09:35:00	09:40:00
19.011	09:50:00	09:55:00
14.74	10:05:00	10:10:00

TABLE 4
PRESSURE TEST #3 DATA

Test Temperature [^{o}C]: 21.995
Test Date: 12 July 1993

Applied Pressure [psia]	Sample Start [PDT]	Sample Stop [PDT]
14.74	11:35:00	11:40:00
24.013	11:50:00	11:55:00
33.017	12:05:00	12:10:00
42.022	12:20:00	12:25:00
50.026	12:35:00	12:40:00
46.024	12:50:00	12:55:00
37.020	13:05:00	13:10:00
28.015	13:20:00	13:25:00
19.010	13:35:00	13:40:00
14.74	13:50:00	13:55:00

NORTHWEST REGIONAL CALIBRATION CENTER

For: MINISPEC Wave Gauges		Report Number:	93204
Model Number:	N/A	W.P.File:	93204.WPS
Serial Number:	10092,10093,10094,10095,10096	Date:	07/13/93
Submitted by:	Texas A&M Research Foundation	Page 4 of 4	

PRESSURE TEST DATA

Test Range [psia]: 14.7 to 50

TABLE 5
PRESSURE TEST #3 DATA

Test Temperature [^{o}C]: 14.996
Test Date: 12 July 1993

Applied Pressure [psia]	Sample Start [PDT]	Sample Stop [PDT]
14.73	15:50:00	15:55:00
24.013	16:05:00	16:10:00
33.017	16:20:00	16:25:00
42.022	16:35:00	16:40:00
50.026	16:50:00	16:55:00
46.024	17:05:00	17:10:00
37.020	17:20:00	17:25:00
28.015	17:35:00	17:40:00
19.010	17:50:00	17:55:00
14.72	18:05:00	18:10:00

FACSIMILE COVER SHEET

FROM FAX NO. 206-545-8463

Date: July 19, 1993

Reference: 140

To: Bob Hamilton/Chuck Abbott
Frank Kelly/Steven DiMarco
Ann Jochens

From: Carol Coomes

Fax No: 713-495-6159
409-690-0059
409-847-8879

Subject: Minispec calibrations

NUMBER OF PAGES INCLUDING THIS PAGE: 14

The pressure sensors for four of the instruments, serial numbers 10092, 10094, 10095, and 10096, were changed prior to recalibrating the instruments. The pressure sensor for serial number 10093 had already been changed prior to the original calibration runs. Calibration runs were made on July 12 at the Northwest Regional Calibration Center (NWRCC). The pressure test range was from 14.7 to 50 psia in each of three temperature baths of 30°, 22°, and 15°C. The results are encouraging.

Enclosed are the numbers from the July 12 calibration and graphs of the pressure difference for each Minispec. The same format as was presented for the previous two calibrations is presented here of a four minute average (480 data points) of temperature, pressure counts, and calculated pressure. Standard deviations for each parameter are also presented. The calibration values used were those supplied by the manufacturer. In reviewing the graphs the 30° temperature bath shows a jump in pressure difference at 33.02 psia.

I also ran and have included a comparison on S/N 10093 as this instrument had the same pressor sensor throughout all three calibration runs.

Included at the end of this fax is the report from the NWRCC showing the pressure test data for all three calibrations. We have not yet received the data report from NWRCC on the temperature data but as soon as it arrives I will process the data in the same format as has been done for the pressure data.

EVANS-HAMILTON, INC.
731 North Northlake Way, Suite 201, Seattle, Washington 98103 USA
Telephone: (206) 545-8155 Fax: (206) 545-8463

File	Hour	Minute	Temp	Temp STD	Pressure Count	Pressure Count STD	Calculated Pressure	Calculated Pressure STD	NWRCC Applied Pressure	NWRCC Minus Minispec
19350093	16	20	15.15	0.003	2685.50	0.548	32.87	0.007	33.02	0.15
19350093	16	35	15.15	0.001	3418.94	0.462	41.87	0.006	42.02	0.15
19350093	16	50	15.15	0.002	4068.76	0.488	49.84	0.006	50.03	0.18
19350093	17	5	15.15	0.002	3743.28	0.617	45.85	0.007	46.02	0.18
19350093	17	20	15.15	0.002	3008.09	0.296	36.83	0.004	37.02	0.19
19350093	17	35	15.15	0.003	2273.33	0.510	27.81	0.006	28.02	0.20
19350093	17	50	15.15	0.001	1538.76	0.430	18.80	0.005	19.01	0.21
19350093	18	5	15.15	0.001	1187.81	0.425	14.49	0.005	14.74	0.25
19350094	7	50	30.19	0.004	1164.46	0.955	14.52	0.011	14.74	0.22
19350094	8	5	30.19	0.003	1923.43	0.969	23.74	0.012	24.01	0.27
19350094	8	20	30.19	0.002	2658.93	1.498	32.68	0.018	33.02	0.34
19350094	8	35	30.19	0.002	3392.57	1.172	41.59	0.014	42.02	0.43
19350094	8	50	30.19	0.001	4040.59	1.448	49.47	0.018	50.03	0.56
19350094	9	5	30.19	0.002	3717.44	1.543	45.54	0.019	46.02	0.49
19350094	9	20	30.19	0.001	2980.83	1.092	36.59	0.013	37.02	0.43
19350094	9	35	30.19	0.000	2247.10	1.250	27.67	0.015	28.02	0.34
19350094	9	50	30.19	0.002	1513.27	1.064	18.76	0.013	19.01	0.25
19350094	10	5	30.19	0.004	1163.61	0.867	14.51	0.010	14.74	0.23
19350094	11	35	22.12	0.008	1167.46	0.839	14.56	0.010	14.74	0.18
19350094	11	50	22.13	0.015	1930.50	0.852	23.83	0.010	24.01	0.19
19350094	12	5	22.14	0.015	2669.76	1.158	32.81	0.014	33.02	0.21
19350094	12	20	22.14	0.014	3406.69	1.186	41.76	0.014	42.02	0.26
19350094	12	35	22.14	0.015	4058.78	1.354	49.69	0.016	50.03	0.34
19350094	12	50	22.14	0.015	3734.99	0.818	45.75	0.010	46.02	0.27
19350094	13	5	22.14	0.015	2993.57	0.866	36.74	0.010	37.02	0.28
19350094	13	20	22.14	0.015	2256.34	0.841	27.79	0.010	28.02	0.23
19350094	13	35	22.14	0.015	1519.03	0.626	18.83	0.008	19.01	0.18
19350094	13	50	22.14	0.015	1166.80	1.026	14.55	0.013	14.74	0.19
19350094	15	50	15.10	0.005	1170.91	0.429	14.60	0.005	14.74	0.14
19350094	16	5	15.10	0.004	1937.64	0.686	23.91	0.008	24.01	0.10
19350094	16	20	15.10	0.004	2680.21	0.868	32.94	0.011	33.02	0.08
19350094	16	35	15.10	0.002	3419.97	0.894	41.92	0.011	42.02	0.10
19350094	16	50	15.10	0.003	4075.73	0.742	49.89	0.009	50.03	0.14
19350094	17	5	15.10	0.002	3749.33	1.108	45.93	0.014	46.02	0.10
19350094	17	20	15.10	0.002	3004.89	0.695	36.88	0.008	37.02	0.14
19350094	17	35	15.10	0.003	2264.74	0.699	27.89	0.008	28.02	0.13
19350094	17	50	15.10	0.002	1524.63	0.691	18.90	0.008	19.01	0.12
19350094	18	5	15.10	0.002	1170.03	0.476	14.59	0.006	14.74	0.15
19350095	7	50	30.14	0.003	1173.95	0.438	14.42	0.005	14.74	0.32
19350095	8	5	30.14	0.004	1927.01	0.300	23.68	0.004	24.01	0.33
19350095	8	20	30.14	0.006	2653.45	0.580	32.61	0.007	33.02	0.41
19350095	8	35	30.14	0.005	3383.19	0.705	41.58	0.009	42.02	0.45
19350095	8	50	30.14	0.005	4027.99	0.477	49.50	0.006	50.03	0.53
19350095	9	5	30.14	0.007	3705.05	0.559	45.53	0.007	46.02	0.49
19350095	9	20	30.14	0.007	2977.24	0.499	36.59	0.006	37.02	0.43
19350095	9	35	30.14	0.008	2246.24	0.567	27.60	0.007	28.02	0.41
19350095	9	50	30.14	0.007	1518.20	0.488	18.65	0.006	19.01	0.36
19350095	10	5	30.14	0.004	1171.24	0.510	14.39	0.007	14.74	0.35
19350095	11	35	22.10	0.008	1179.11	0.387	14.49	0.005	14.74	0.25
19350095	11	50	22.11	0.009	1934.80	0.488	23.78	0.006	24.01	0.24
19350095	12	5	22.11	0.010	2665.07	0.486	32.75	0.006	33.02	0.27
19350095	12	20	22.11	0.010	3396.68	0.583	41.74	0.007	42.02	0.28

File	Hour	Minute	Temp	Temp STD	Pressure Count	Pressure Count STD	Calculated Pressure	Calculated Pressure STD	NWRCC Applied Pressure	NWRCC Minus Minispec
19350095	12	35	22.11	0.010	4044.48	0.668	49.70	0.008	50.03	0.32
19350095	12	50	22.11	0.010	3721.00	0.552	45.73	0.007	46.02	0.30
19350095	13	5	22.11	0.010	2990.22	0.542	36.75	0.007	37.02	0.27
19350095	13	20	22.11	0.010	2258.04	0.422	27.75	0.005	28.02	0.27
19350095	13	35	22.11	0.010	1527.37	0.623	18.77	0.008	19.01	0.24
19350095	13	50	22.11	0.010	1179.41	0.542	14.49	0.007	14.74	0.25
19350095	15	50	15.10	0.007	1185.06	0.293	14.56	0.004	14.74	0.18
19350095	16	5	15.10	0.007	1943.09	0.338	23.88	0.004	24.01	0.14
19350095	16	20	15.10	0.009	2676.05	0.492	32.88	0.006	33.02	0.13
19350095	16	35	15.10	0.011	3408.94	0.497	41.89	0.006	42.02	0.13
19350095	16	50	15.09	0.012	4058.46	0.695	49.87	0.008	50.03	0.15
19350095	17	5	15.10	0.012	3733.83	0.494	45.89	0.006	46.02	0.14
19350095	17	20	15.10	0.011	3000.76	0.564	36.88	0.007	37.02	0.15
19350095	17	35	15.10	0.011	2266.69	0.568	27.85	0.007	28.02	0.16
19350095	17	50	15.10	0.011	1534.73	0.459	18.86	0.006	19.01	0.15
19350095	18	5	15.10	0.011	1184.64	0.525	14.56	0.006	14.74	0.19
19350096	7	50	30.19	0.007	1182.28	0.827	14.58	0.010	14.74	0.16
19350096	8	5	30.19	0.009	1933.10	0.885	23.83	0.011	24.01	0.19
19350096	8	20	30.18	0.012	2649.03	2.194	32.65	0.027	33.02	0.37
19350096	8	35	30.19	0.012	3385.82	2.167	41.73	0.027	42.02	0.30
19350096	8	50	30.18	0.014	4038.16	1.155	49.76	0.014	50.03	0.26
19350096	9	5	30.18	0.014	3715.45	1.136	45.79	0.014	46.02	0.24
19350096	9	20	30.18	0.014	2986.46	1.063	36.81	0.013	37.02	0.22
19350096	9	35	30.18	0.014	2257.39	0.788	27.82	0.010	28.02	0.19
19350096	9	50	30.18	0.013	1528.72	0.807	18.85	0.010	19.01	0.16
19350096	10	5	30.19	0.010	1181.43	0.827	14.57	0.010	14.74	0.17
19350096	11	35	22.16	0.009	1194.28	0.741	14.73	0.009	14.74	0.01
19350096	11	50	22.16	0.010	1949.43	0.827	24.03	0.010	24.01	-0.02
19350096	12	5	22.16	0.009	2686.33	2.244	33.11	0.028	33.02	-0.09
19350096	12	20	22.17	0.008	3420.51	1.163	42.15	0.014	42.02	-0.13
19350096	12	35	22.16	0.009	4063.20	1.572	50.07	0.019	50.03	-0.04
19350096	12	50	22.17	0.009	3737.73	1.096	46.06	0.013	46.02	-0.04
19350096	13	5	22.17	0.008	3006.57	1.067	37.05	0.013	37.02	-0.03
19350096	13	20	22.17	0.007	2274.24	0.921	28.03	0.011	28.02	-0.02
19350096	13	35	22.17	0.007	1544.60	0.752	19.04	0.009	19.01	-0.03
19350096	13	50	22.17	0.007	1196.55	0.771	14.75	0.009	14.74	-0.01
19350096	15	50	15.15	0.008	1205.26	0.593	14.86	0.007	14.74	-0.12
19350096	16	5	15.15	0.007	1962.49	0.751	24.19	0.009	24.01	-0.18
19350096	16	20	15.15	0.006	2696.47	0.772	33.23	0.009	33.02	-0.21
19350096	16	35	15.15	0.008	3428.61	0.771	42.25	0.010	42.02	-0.23
19350096	16	50	15.15	0.007	4079.96	0.839	50.28	0.010	50.03	-0.25
19350096	17	5	15.15	0.007	3754.96	1.084	46.27	0.013	46.02	-0.25
19350096	17	20	15.15	0.007	3021.04	0.763	37.23	0.009	37.02	-0.21
19350096	17	35	15.15	0.006	2288.50	0.684	28.21	0.009	28.02	-0.19
19350096	17	50	15.15	0.006	1556.77	0.634	19.19	0.008	19.01	-0.18
19350096	18	5	15.15	0.007	1206.03	0.689	14.87	0.009	14.74	-0.13

File	Hour	Minute	Temp	Temp STD	Pressure Count	Pressure Count STD	Calculated Pressure	Calculated Pressure STD	NWRCC Applied Pressure	NWRCC Minus Minispec
July 12,1993										
19350093	7	50	30.19	0.007	1190.08	0.431	14.52	0.005	14.74	0.22
19350093	8	5	30.19	0.006	1945.07	0.475	23.78	0.006	24.01	0.23
19350093	8	20	30.19	0.002	2679.85	0.584	32.80	0.007	33.02	0.22
19350093	8	35	30.19	0.005	3409.49	0.684	41.75	0.008	42.02	0.27
19350093	8	50	30.19	0.003	4055.87	0.526	49.68	0.006	50.03	0.34
19350093	9	5	30.19	0.003	3731.81	0.527	45.71	0.006	46.02	0.32
19350093	9	20	30.19	0.002	3001.89	0.423	36.75	0.005	37.02	0.27
19350093	9	35	30.19	0.002	2268.76	0.500	27.76	0.006	28.02	0.26
19350093	9	50	30.19	0.003	1537.03	0.386	18.78	0.005	19.01	0.23
19360093	10	5	30.19	0.006	1109.26	0.524	14.51	0.007	14.74	0.23
June 11, 1993										
16250093	12	5	30.16	0.004	1186.93	0.286	14.48	0.004	14.09	0.21
16250093	12	20	30.17	0.012	1946.64	0.479	23.80	0.006	24.02	0.22
16250093	12	35	30.18	0.015	2682.01	0.259	32.83	0.003	33.02	0.19
16250093	12	50	30.17	0.015	3411.92	0.310	41.78	0.004	42.03	0.25
16250093	13	5	30.17	0.014	4058.07	0.289	49.71	0.003	50.03	0.32
16250093	13	20	30.17	0.014	3733.53	0.508	45.73	0.006	46.03	0.30
June 18, 1993										
~~16950093~~	10	20	30.64	0.002	1187.76	0.429	14.49	0.005	14.72	0.23
16950093	10	35	30.69	0.003	1944.43	0.513	23.78	0.006	24.02	0.24
16950093	10	50	30.75	0.009	2678.18	0.380	32.78	0.005	33.02	0.24
16950093	11	5	30.74	0.005	3408.08	0.282	41.74	0.004	42.03	0.30
16950093	11	35	30.69	0.003	4054.10	0.355	49.66	0.004	50.03	0.37
16950093	11	50	30.67	0.013	3730.40	0.503	45.69	0.007	46.03	0.34

NORTHWEST REGIONAL CALIBRATION CENTER

300 - 120th Avenue NE • Building Six • Suite 108 • Bellevue, Washington 98005 • (206) 455-1999 • FAX (206) 646-9123

TEST REPORT

For:	MINISPEC Wave Gauges	Report Number:	93262
Model Number:	N/A	W.P.File:	93262.WPS
Serial Number:	10092,10093,10094,10095,10096	Date:	08/17/93
Submitted by:	Texas A&M Research Foundation	Page 1 of 3	

TEST PROCEDURE

The pressure channels of these instruments were tested in accordance with "NOAA Calibration Procedure for CTD and STD Sensors (including Sound Speed)", NOIC-CP-04A, dated June 1975.

This procedure is described as a test and not a calibration because the procedure did not produce a precise relationship between the instrument output and the test conditions. Evaluation of instrument performance is left to the client.

The instruments were configured by the client to store pressure and time data in memory during the test procedure. The instruments were then immersed in a temperature-controlled water bath and brought to temperature equilibrium at a known temperature. Pressure was applied to the instrument pressure ports by means of a manifold connected to the NRCC Ruska Model 2465 Air Deadweight Tester. The applied pressures for the test procedure were specified by the client to span the range of the pressure sensors installed in the instruments. At each pressure test point, the applied pressure was held at a stable value for sufficient time to allow a representative sample for the instruments.

The accuracy of the NRCC Ruska Air Deadweight Tester is certified by the manufacturer to be within +/- 0.01% of calculated pressure. NRCC standards are traceable to NIST.

The test data is reported on the following pages.

The details of the NRCC calibration procedure for this instrument are available upon request.

Tested by: R. Guenther
R. Guenther

Checked by: J. Baker
J. Baker

Approved by: J. Francis Smith
J. Francis Smith, Director

NORTHWEST REGIONAL CALIBRATION CENTER

For: MINISPEC Wave Gauges		Report Number:	93262
Model Number:	N/A	W.P.File:	93262.WPS
Serial Number:	10092,10093,10094,10095,10096	Date:	08/17/93
Submitted by:	Texas A&M Research Foundation		

PRESSURE TEST DATA

Test Range [psia]: 14.7 to 50

TABLE 1
PRESSURE TEST DATA

Test Temperature [^{O}C]: 30.061
Test Date: 13 August 1993

Applied Pressure [psia]	Sample Start [PDT]	Sample Stop [PDT]
14.69	09:35:00	09:40:00
24.013	09:50:00	09:55:00
33.017	10:05:00	10:10:00
42.022	10:20:00	10:25:00
50.026	10:35:00	10:40:00
46.024	10:50:00	10:55:00
37.020	11:05:00	11:10:00
28.016	11:20:00	11:25:00
19.011	11:35:00	11:40:00
14.69	11:50:00	11:55:00

TABLE 2
PRESSURE TEST DATA

Test Temperature [^{O}C]: 23.964
Test Date: 13 August 1993

Applied Pressure [psia]	Sample Start [PDT]	Sample Stop [PDT]
14.69	13:35:00	13:40:00
24.013	13:50:00	13:55:00
33.017	14:05:00	14:10:00
42.021	14:20:00	14:25:00
50.026	14:35:00	14:40:00
46.024	14:50:00	14:55:00
37.020	15:05:00	15:10:00
28.015	15:20:00	15:25:00
19.010	15:35:00	15:40:00
14.69	15:50:00	15:55:00

NORTHWEST REGIONAL CALIBRATION CENTER

For: MINISPEC Wave Gauges		Report Number:	93262
Model Number:	N/A	W.P.File:	93262.WPS
Serial Number:	10092,10093,10094,10095,10096	Date:	08/17/93
Submitted by:	Texas A&M Research Foundation	Page 3 of 3	

PRESSURE TEST DATA

Test Range [psia]: 14.7 to 50

TABLE 3
PRESSURE TEST DATA

Test Temperature [^{o}C]: 17.970
Test Date: 13 August 1993

Applied Pressure [psia]	Sample Start [PDT]	Sample Stop [PDT]
14.68	17:20:00	17:25:00
24.013	17:35:00	17:40:00
33.017	17:50:00	17:55:00
42.021	18:05:00	18:10:00
50.025	18:20:00	18:25:00
46.023	18:35:00	18:40:00
37.019	18:50:00	18:55:00
28.015	19:05:00	19:10:00
19.010	19:20:00	19:25:00
14.67	19:35:00	19:40:00

TABLE 4
PRESSURE TEST DATA

Test Temperature [^{o}C]: 11.976
Test Date: 14 August 1993

Applied Pressure [psia]	Sample Start [PDT]	Sample Stop [PDT]
14.65	11:05:00	11:10:00
24.013	11:20:00	11:25:00
33.017	11:35:00	11:40:00
42.021	11:50:00	11:55:00
50.025	12:05:00	12:10:00
46.023	12:20:00	12:25:00
37.020	12:35:00	12:40:00
28.015	12:50:00	12:55:00
19.010	13:05:00	13:10:00
14.64	13:20:00	13:25:00

Northwest Regional Calibration Center - Minispec Calibration August 13-14, 1993

File	Hour	Minute	Temp	Temp STD	NWRCC Temp	NWRCC Temp Minus Minispec Temp	Pressure Count	Pressure Count STD	Calculated Pressure	Calculated Pressure STD	NWRCC Applied Pressure	NWRCC Pressure Minus Minispec Pressure
22550092	9	35	30.215	0.012	30.061	-0.154	1166.990	0.237	14.528	0.003	14.690	0.162
22550092	9	50	30.215	0.013	30.061	-0.154	1930.300	0.483	23.794	0.006	24.013	0.219
22550092	10	5	30.221	0.015	30.061	-0.160	2668.860	0.552	32.760	0.007	33.017	0.257
22550092	10	20	30.222	0.015	30.061	-0.161	3408.340	0.480	41.738	0.006	42.022	0.284
22550092	10	35	30.222	0.015	30.061	-0.161	4063.950	0.219	49.697	0.003	50.026	0.329
22550092	10	50	30.219	0.014	30.061	-0.158	3736.370	0.501	45.719	0.006	46.024	0.305
22550092	11	5	30.218	0.014	30.061	-0.157	2999.750	0.477	36.777	0.006	37.020	0.243
22550092	11	20	30.218	0.014	30.061	-0.157	2259.090	0.636	27.786	0.008	28.016	0.230
22550092	11	35	30.222	0.015	30.061	-0.161	1519.190	0.425	18.803	0.005	19.011	0.208
22550092	11	50	30.221	0.014	30.061	-0.160	1164.660	0.484	14.499	0.006	14.690	0.191
22550092	13	35	24.107	0.009	23.964	-0.143	1165.820	0.422	14.514	0.005	14.690	0.176
22550092	13	50	24.121	0.015	23.964	-0.157	1932.630	0.509	23.823	0.006	24.013	0.190
22550092	14	5	24.125	0.015	23.964	-0.161	2672.500	0.509	32.804	0.007	33.017	0.213
22550092	14	20	24.126	0.015	23.964	-0.162	3413.940	0.402	41.805	0.005	42.021	0.216
22550092	14	35	24.126	0.015	23.964	-0.162	4070.740	0.705	49.779	0.008	50.026	0.247
22550092	14	50	24.123	0.015	23.964	-0.159	3743.980	0.273	45.812	0.003	46.024	0.212
22550092	15	5	24.126	0.015	23.964	-0.162	3004.940	0.589	36.840	0.007	37.020	0.180
22550092	15	20	24.128	0.015	23.964	-0.164	2263.230	0.613	27.836	0.007	28.015	0.179
22550092	15	35	24.128	0.015	23.964	-0.164	1521.710	0.495	18.834	0.006	19.010	0.176
22550092	15	50	24.128	0.015	23.964	-0.164	1165.260	0.439	14.506	0.006	14.690	0.184
22550092	17	20	18.095	0.009	17.970	-0.125	1166.050	0.385	14.517	0.005	14.680	0.163
22550092	17	35	18.104	0.009	17.970	-0.134	1935.640	0.633	23.859	0.008	24.013	0.154
22550092	17	50	18.106	0.008	17.970	-0.136	2677.280	0.528	32.863	0.006	33.017	0.154
22550092	18	5	18.106	0.008	17.970	-0.136	3419.890	0.381	41.878	0.005	42.021	0.143
22550092	18	20	18.106	0.008	17.970	-0.136	4078.230	0.585	49.870	0.007	50.025	0.155
22550092	18	35	18.106	0.008	17.970	-0.136	3750.050	0.461	45.885	0.006	46.023	0.138
22550092	18	50	18.106	0.008	17.970	-0.136	3010.090	0.429	36.903	0.005	37.019	0.116
22550092	19	5	18.106	0.008	17.970	-0.136	2266.530	0.559	27.876	0.007	28.015	0.139
22550092	19	20	18.107	0.008	17.970	-0.137	1524.070	0.630	18.863	0.008	19.010	0.147
22550092	19	35	18.107	0.007	17.970	-0.137	1165.610	0.488	14.511	0.006	14.670	0.159
22650092	11	5	12.103	0.007	11.976	-0.127	1165.110	0.322	14.504	0.004	14.650	0.146
22650092	11	20	12.108	0.010	11.976	-0.132	1938.850	0.375	23.898	0.004	24.013	0.115
22650092	11	35	12.110	0.010	11.976	-0.134	2681.710	0.458	32.917	0.006	33.017	0.100
22650092	11	50	12.110	0.010	11.976	-0.134	3425.620	0.515	41.947	0.006	42.021	0.074
22650092	12	5	12.110	0.010	11.976	-0.134	4085.880	0.438	49.963	0.005	50.025	0.062
22650092	12	20	12.110	0.010	11.976	-0.134	3756.480	0.536	45.964	0.006	46.023	0.059
22650092	12	35	12.109	0.010	11.976	-0.133	3014.870	0.664	36.961	0.008	37.020	0.059
22650092	12	50	12.110	0.010	11.976	-0.134	2270.040	0.343	27.918	0.004	28.015	0.097
22650092	13	5	12.110	0.010	11.976	-0.134	1526.180	0.489	18.888	0.006	19.010	0.122
22650092	13	20	12.107	0.010	11.976	-0.131	1165.000	0.165	14.503	0.002	14.640	0.137
22550093	9	35	30.240	0.003	30.061	-0.179	1188.340	0.480	14.499	0.006	14.690	0.191
22550093	9	50	30.240	0.000	30.061	-0.179	1945.030	0.202	23.784	0.003	24.013	0.229
22550093	10	5	30.240	0.000	30.061	-0.179	2680.020	0.164	32.802	0.002	33.017	0.215
22550093	10	20	30.240	0.000	30.061	-0.179	3409.860	0.385	41.757	0.005	42.022	0.265
22550093	10	35	30.240	0.001	30.061	-0.179	4056.220	0.415	49.688	0.005	50.026	0.338
22550093	10	50	30.240	0.000	30.061	-0.179	3732.120	0.374	45.712	0.004	46.024	0.312
22550093	11	5	30.240	0.000	30.061	-0.179	3002.140	0.359	36.755	0.004	37.020	0.265
22550093	11	20	30.240	0.001	30.061	-0.179	2269.010	0.285	27.759	0.003	28.016	0.257
22550093	11	35	30.240	0.001	30.061	-0.179	1537.260	0.438	18.780	0.006	19.011	0.231
22550093	11	50	30.240	0.000	30.061	-0.179	1186.060	0.307	14.471	0.004	14.690	0.219
22550093	13	35	24.140	0.002	23.964	-0.176	1185.180	0.386	14.460	0.005	14.690	0.230
22550093	13	50	24.140	0.001	23.964	-0.176	1945.530	0.499	23.790	0.006	24.013	0.223
22550093	14	5	24.140	0.003	23.964	-0.176	2681.890	0.331	32.825	0.004	33.017	0.192
22550093	14	20	24.140	0.002	23.964	-0.176	3413.100	0.435	41.797	0.005	42.021	0.224
22550093	14	35	24.140	0.002	23.964	-0.176	4061.060	0.406	49.748	0.005	50.026	0.278
22550093	14	50	24.140	0.002	23.964	-0.176	3736.590	0.502	45.766	0.006	46.024	0.258
22550093	15	5	24.140	0.003	23.964	-0.176	3004.250	0.433	36.780	0.006	37.020	0.240
22550093	15	20	24.140	0.003	23.964	-0.176	2270.910	0.594	27.782	0.007	28.015	0.233

Northwest Regional Calibration Center - Minispec Calibration August 13-14, 1993

File	Hour	Minute	Temp	Temp STD	NWRCC Temp	NWRCC Temp Minus Minispec Temp	Pressure Count	Pressure Count STD	Calculated Pressure	Calculated Pressure STD	NWRCC Applied Pressure	NWRC Pressu Min Minisp Pressu
22550093	15	35	24.140	0.003	23.964	-0.176	1537.760	0.437	18.787	0.006	19.010	0.2
22550093	15	50	24.140	0.002	23.964	-0.176	1185.100	0.295	14.459	0.004	14.690	0.2
22550093	17	20	18.109	0.005	17.970	-0.139	1184.590	0.500	14.453	0.006	14.680	0.2
22550093	17	35	18.110	0.000	17.970	-0.140	1946.920	0.298	23.807	0.004	24.013	0.2
22550093	17	50	18.111	0.003	17.970	-0.141	2684.310	0.464	32.855	0.006	33.017	0.1
22550093	18	5	18.111	0.004	17.970	-0.141	3417.100	0.419	41.846	0.005	42.021	0.1
22550093	18	20	18.110	0.003	17.970	-0.140	4066.440	0.521	49.813	0.006	50.025	0.2
22550093	18	35	18.110	0.002	17.970	-0.140	3741.040	0.412	45.821	0.005	46.023	0.2
22550093	18	50	18.110	0.003	17.970	-0.140	3007.190	0.610	36.816	0.007	37.019	0.2
22550093	19	5	18.111	0.003	17.970	-0.141	2272.440	0.497	27.801	0.006	28.015	0.2
22550093	19	20	18.110	0.003	17.970	-0.140	1538.440	0.497	18.795	0.006	19.010	0.2
22550093	19	35	18.110	0.002	17.970	-0.140	1183.600	0.511	14.441	0.006	14.670	0.2
22650093	11	5	12.101	0.004	11.976	-0.125	1182.650	0.479	14.429	0.006	14.650	0.2
22650093	11	20			11.976						24.013	
22650093	11	35	12.106	0.009	11.976	-0.130	2687.930	0.274	32.899	0.003	33.017	0.1
22650093	11	50	12.109	0.010	11.976	-0.133	3421.900	0.377	41.905	0.005	42.021	0.1
22650093	12	5	12.108	0.010	11.976	-0.132	4072.320	0.471	49.886	0.006	50.025	0.1
22650093	12	20	12.108	0.010	11.976	-0.132	3746.160	0.422	45.884	0.005	46.023	0.1
22650093	12	35	12.106	0.009	11.976	-0.130	3010.610	0.504	36.858	0.006	37.020	0.1
22650093	12	50	12.106	0.009	11.976	-0.130	2275.220	0.444	27.836	0.005	28.015	0.1
22650093	13	5	12.105	0.008	11.976	-0.129	1540.060	0.321	18.815	0.004	19.010	0.1
22650093	13	20	12.101	0.005	11.976	-0.125	1182.470	0.508	14.427	0.007	14.640	0.21
22550094	9	35	30.234	0.012	30.061	-0.173	1160.930	0.276	14.477	0.004	14.690	0.21
22550094	9	50	30.238	0.008	30.061	-0.177	1923.180	0.384	23.738	0.005	24.013	0.27
22550094	10	5	30.239	0.005	30.061	-0.178	2659.210	0.518	32.680	0.006	33.017	0.3
22550094	10	20	30.240	0.002	30.061	-0.179	3392.450	0.498	41.589	0.006	42.022	0.4
22550094	10	35	30.240	0.002	30.061	-0.179	4041.230	0.461	49.473	0.006	50.026	0.5
22550094	10	50	30.240	0.002	30.061	-0.179	3717.750	0.435	45.542	0.005	46.024	0.4
22550094	11	5	30.240	0.004	30.061	-0.179	2980.230	0.421	36.581	0.005	37.020	0.4
22550094	11	20	30.240	0.003	30.061	-0.179	2246.160	0.369	27.662	0.004	28.016	0.3
22550094	11	35	30.240	0.002	30.061	-0.179	1512.550	0.502	18.749	0.006	19.011	0.26
22550094	11	50	30.240	0.003	30.061	-0.179	1159.020	0.182	14.453	0.002	14.690	0.2
22550094	13	35	24.103	0.009	23.964	-0.139	1161.610	0.492	14.485	0.006	14.690	0.20
22550094	13	50	24.110	0.004	23.964	-0.146	1927.830	0.446	23.795	0.006	24.013	0.21
22550094	14	5	24.112	0.007	23.964	-0.148	2666.620	0.499	32.770	0.006	33.017	0.24
22550094	14	20	24.111	0.006	23.964	-0.147	3402.420	0.503	41.711	0.006	42.021	0.31
22550094	14	35	24.111	0.005	23.964	-0.147	4054.040	0.230	49.627	0.003	50.026	0.3
22550094	14	50	24.111	0.005	23.964	-0.147	3730.090	0.327	45.692	0.004	46.024	0.33
22550094	15	5	24.111	0.005	23.964	-0.147	2989.920	0.290	36.699	0.003	37.020	0.32
22550094	15	20	24.111	0.006	23.964	-0.147	2253.260	0.449	27.748	0.005	28.015	0.26
22550094	15	35	24.111	0.005	23.964	-0.147	1516.890	0.311	18.802	0.004	19.010	0.20
22550094	15	50	24.111	0.005	23.964	-0.147	1161.110	0.308	14.479	0.004	14.690	0.21
22550094	17	20	18.058	0.008	17.970	-0.088	1163.960	0.349	14.514	0.004	14.680	0.16
22550094	17	35	18.071	0.015	17.970	-0.101	1933.690	0.468	23.865	0.006	24.013	0.14
22550094	17	50	18.075	0.015	17.970	-0.105	2675.450	0.507	32.878	0.006	33.017	0.13
22550094	18	5	18.076	0.015	17.970	-0.106	3413.860	0.365	41.849	0.004	42.021	0.17
22550094	18	20	18.075	0.015	17.970	-0.105	4068.130	0.333	49.800	0.004	50.025	0.22
22550094	18	35	18.075	0.015	17.970	-0.105	3742.680	0.630	45.845	0.008	46.023	0.17
22550094	18	50	18.075	0.015	17.970	-0.105	2999.760	0.433	36.818	0.005	37.019	0.20
22550094	19	5	18.075	0.015	17.970	-0.105	2260.190	0.396	27.833	0.005	28.015	0.18
22550094	19	20	18.075	0.015	17.970	-0.105	1521.140	0.349	18.854	0.004	19.010	0.15
22550094	19	35	18.074	0.015	17.970	-0.104	1163.020	0.170	14.502	0.002	14.670	0.16
22650094	11	5	12.049	0.006	11.976	-0.073	1165.070	0.264	14.527	0.003	14.650	0.12
22650094	11	20	12.050	0.001	11.976	-0.074	1939.990	0.385	23.942	0.005	24.013	0.07
22650094	11	35	12.050	0.001	11.976	-0.074	2683.950	0.232	32.982	0.003	33.017	0.03
22650094	11	50	12.050	0.001	11.976	-0.074	3424.600	0.494	41.980	0.006	42.021	0.04
22650094	12	5	12.050	0.001	11.976	-0.074	4081.360	0.492	49.960	0.006	50.025	0.06
22650094	12	20	12.050	0.002	11.976	-0.074	3754.630	0.513	45.990	0.007	46.023	0.03

Northwest Regional Calibration Center - Minispec Calibration August 13-14, 1993

File	Hour	Minute	Temp	Temp STD	NWRCC Temp	NWRCC Temp Minus Minispec Temp	Pressure Count	Pressure Count STD	Calculated Pressure	Calculated Pressure STD	NWRCC Applied Pressure	NWRCC Pressure Minus Minispec Pressure
22650094	12	35	12.050	0.002	11.976	-0.074	3008.870	0.452	36.929	0.005	37.020	0.091
22650094	12	50	12.050	0.002	11.976	-0.074	2267.750	0.439	27.925	0.006	28.015	0.090
22650094	13	5	12.050	0.002	11.976	-0.074	1526.200	0.418	18.914	0.005	19.010	0.096
22650094	13	20	12.049	0.004	11.976	-0.073	1164.990	0.177	14.526	0.002	14.640	0.114
22550095	9	35	30.179	0.015	30.061	-0.118	1173.260	0.444	14.415	0.005	14.690	0.275
22550095	9	50	30.182	0.013	30.061	-0.121	1929.000	0.296	23.703	0.004	24.013	0.310
22550095	10	5	30.184	0.012	30.061	-0.123	2655.400	0.733	32.631	0.009	33.017	0.386
22550095	10	20	30.187	0.009	30.061	-0.126	3384.590	0.552	41.592	0.007	42.022	0.430
22550095	10	35	30.186	0.011	30.061	-0.125	4029.750	0.539	49.521	0.007	50.026	0.505
22550095	10	50	30.185	0.012	30.061	-0.124	3706.540	0.594	45.549	0.008	46.024	0.475
22550095	11	5	30.184	0.012	30.061	-0.123	2978.370	0.544	36.600	0.007	37.020	0.420
22550095	11	20	30.184	0.012	30.061	-0.123	2247.680	0.496	27.620	0.006	28.016	0.396
22550095	11	35	30.185	0.011	30.061	-0.124	1519.160	0.488	18.666	0.006	19.011	0.345
22550095	11	50	30.187	0.010	30.061	-0.126	1168.880	0.358	14.361	0.005	14.690	0.329
22550095	13	35	24.070	0.014	23.964	-0.106	1173.970	0.420	14.424	0.005	14.690	0.266
22550095	13	50	24.082	0.013	23.964	-0.118	1933.060	0.283	23.753	0.004	24.013	0.260
22550095	14	5	24.086	0.010	23.964	-0.122	2662.330	0.522	32.716	0.006	33.017	0.301
22550095	14	20	24.086	0.010	23.964	-0.122	3393.950	0.393	41.707	0.005	42.021	0.314
22550095	14	35	24.085	0.011	23.964	-0.121	4041.210	0.511	49.663	0.006	50.026	0.363
22550095	14	50	24.084	0.012	23.964	-0.120	3718.110	0.461	45.691	0.006	46.024	0.333
22550095	15	5	24.085	0.011	23.964	-0.121	2988.040	0.303	36.719	0.004	37.020	0.301
22550095	15	20	24.085	0.011	23.964	-0.121	2256.130	0.331	27.723	0.004	28.015	0.292
22550095	15	35	24.086	0.010	23.964	-0.122	1526.180	0.455	18.752	0.006	19.010	0.258
22550095	15	50	24.085	0.011	23.964	-0.121	1174.290	0.495	14.427	0.006	14.690	0.263
22550095	17	20	18.040	0.000	17.970	-0.070	1178.350	0.487	14.478	0.006	14.680	0.202
22550095	17	35	18.041	0.004	17.970	-0.071	1940.030	0.542	23.838	0.007	24.013	0.175
22550095	17	50	18.043	0.007	17.970	-0.073	2672.170	0.388	32.837	0.005	33.017	0.180
22550095	18	5	18.043	0.007	17.970	-0.073	3404.200	0.417	41.833	0.005	42.021	0.188
22550095	18	20	18.042	0.006	17.970	-0.072	4053.310	0.512	49.811	0.006	50.025	0.214
22550095	18	35	18.042	0.007	17.970	-0.072	3729.020	0.459	45.825	0.006	46.023	0.198
22550095	18	50	18.043	0.007	17.970	-0.073	2997.060	0.473	36.830	0.006	37.019	0.189
22550095	19	5	18.043	0.007	17.970	-0.073	2263.980	0.266	27.820	0.003	28.015	0.195
22550095	19	20	18.043	0.007	17.970	-0.073	1532.700	0.486	18.832	0.006	19.010	0.178
22550095	19	35	18.042	0.006	17.970	-0.072	1178.360	0.498	14.478	0.006	14.670	0.192
22650095	11	5	12.048	0.007	11.976	-0.072	1181.390	0.518	14.515	0.006	14.650	0.135
22650095	11	20	12.050	0.002	11.976	-0.074	1946.850	0.401	23.922	0.005	24.013	0.091
22650095	11	35	12.050	0.001	11.976	-0.074	2680.600	0.551	32.940	0.007	33.017	0.077
22650095	11	50	12.050	0.003	11.976	-0.074	3414.020	0.408	41.954	0.005	42.021	0.067
22650095	12	5	12.050	0.002	11.976	-0.074	4064.730	0.534	49.951	0.007	50.025	0.074
22650095	12	20	12.050	0.001	11.976	-0.074	3739.610	0.517	45.955	0.006	46.023	0.068
22650095	12	35	12.050	0.003	11.976	-0.074	3006.080	0.455	36.940	0.006	37.020	0.080
22650095	12	50	12.050	0.003	11.976	-0.074	2271.740	0.487	27.916	0.006	28.015	0.099
22650095	13	5	12.050	0.002	11.976	-0.074	1538.410	0.513	18.903	0.006	19.010	0.107
22650095	13	20	12.050	0.003	11.976	-0.074	1181.380	0.512	14.515	0.006	14.640	0.125
22550096	9	35	30.238	0.009	30.061	-0.177	1172.700	0.519	14.573	0.006	14.690	0.117
22550096	9	50	30.240	0.007	30.061	-0.179	1935.130	0.586	23.913	0.007	24.013	0.100
22550096	10	5	30.239	0.008	30.061	-0.178	2667.820	0.522	32.889	0.007	33.017	0.128
22550096	10	20	30.238	0.009	30.061	-0.177	3398.560	0.723	41.840	0.009	42.022	0.182
22550096	10	35	30.238	0.009	30.061	-0.177	4048.810	0.615	49.806	0.007	50.026	0.220
22550096	10	50	30.238	0.008	30.061	-0.177	3723.610	0.606	45.822	0.008	46.024	0.202
22550096	11	5	30.238	0.008	30.061	-0.177	2987.380	0.621	36.803	0.008	37.020	0.217
22550096	11	20	30.238	0.009	30.061	-0.177	2254.060	0.575	27.820	0.007	28.016	0.196
22550096	11	35	30.238	0.008	30.061	-0.177	1522.660	0.563	18.860	0.007	19.011	0.151
22550096	11	50	30.239	0.008	30.061	-0.178	1169.080	0.423	14.529	0.005	14.690	0.161
22550096	13	35	24.139	0.008	23.964	-0.175	1175.660	0.574	14.609	0.007	14.690	0.081
22550096	13	50	24.142	0.008	23.964	-0.178	1941.680	0.536	23.993	0.006	24.013	0.020
22550096	14	5	24.146	0.009	23.964	-0.182	2677.310	0.554	33.005	0.007	33.017	0.012
22550096	14	20	24.145	0.009	23.964	-0.181	3409.950	0.660	41.980	0.008	42.021	0.041

Northwest Regional Calibration Center - Minispec Calibration August 13-14, 1993

File	Hour	Minute	Temp	Temp STD	NWRCC Temp	NWRCC Temp Minus Minispec Temp	Pressure Count	Pressure Count STD	Calculated Pressure	Calculated Pressure STD	NWRCC Applied Pressure	NWRC Pressu Min Minisp Pressu
22550096	14	35	24.142	0.008	23.964	-0.178	4063.290	0.794	49.983	0.010	50.026	0.0
22550096	14	50	24.142	0.007	23.964	-0.178	3737.450	0.594	45.992	0.007	46.024	0.0
22550096	15	5	24.144	0.009	23.964	-0.180	2999.680	0.602	36.954	0.008	37.020	0.0
22550096	15	20	24.147	0.010	23.964	-0.183	2266.200	0.560	27.968	0.007	28.015	0.0
22550096	15	35	24.147	0.010	23.964	-0.183	1531.480	0.606	18.968	0.008	19.010	0.0
22550096	15	50	24.148	0.010	23.964	-0.184	1176.820	0.482	14.624	0.006	14.690	0.0
22550096	17	20	18.110	0.006	17.970	-0.140	1181.500	0.509	14.681	0.006	14.680	-0.0
22550096	17	35	18.114	0.008	17.970	-0.144	1949.850	0.507	24.093	0.006	24.013	-0.0
22550096	17	50	18.115	0.009	17.970	-0.145	2687.960	0.399	33.135	0.005	33.017	-0.1
22550096	18	5	18.116	0.009	17.970	-0.146	3421.540	0.661	42.122	0.008	42.021	-0.1
22550096	18	20	18.115	0.009	17.970	-0.145	4076.620	0.580	50.146	0.007	50.025	-0.1
22550096	18	35	18.115	0.009	17.970	-0.145	3750.220	0.661	46.148	0.008	46.023	-0.1
22550096	18	50	18.115	0.009	17.970	-0.145	3010.340	0.643	37.084	0.008	37.019	-0.0
22550096	19	5	18.115	0.009	17.970	-0.145	2276.110	0.415	28.090	0.005	28.015	-0.0
22550096	19	20	18.116	0.009	17.970	-0.146	1538.670	0.551	19.056	0.007	19.010	-0.0
22550096	19	35	18.116	0.009	17.970	-0.146	1181.880	0.448	14.686	0.005	14.670	-0.0
22650096	11	5	12.107	0.010	11.976	-0.131	1185.840	0.470	14.734	0.006	14.650	-0.0
22650096	11	20	12.111	0.011	11.976	-0.135	1958.190	0.515	24.195	0.006	24.013	-0.1
22650096	11	35	12.112	0.011	11.976	-0.136	2697.040	0.537	33.247	0.006	33.017	-0.2
22650096	11	50	12.110	0.011	11.976	-0.134	3433.230	0.593	42.265	0.007	42.021	-0.2
22650096	12	5	12.107	0.010	11.976	-0.131	4089.820	0.632	50.308	0.008	50.025	-0.2
22650096	12	20	12.109	0.010	11.976	-0.133	3762.630	0.652	46.300	0.008	46.023	-0.2
22650096	12	35	12.110	0.011	11.976	-0.134	3021.010	0.533	37.215	0.006	37.020	-0.1
22650096	12	50	12.111	0.011	11.976	-0.135	2284.960	0.486	28.199	0.006	28.015	-0.1
22650096	13	5	12.111	0.011	11.976	-0.135	1545.780	0.500	19.143	0.006	19.010	-0.1
22650096	13	20	12.106	0.009	11.976	-0.130	1186.210	0.472	14.738	0.006	14.640	-0.0

The Department of the Interior Mission

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

The Minerals Management Service Mission

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

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

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