

GRADUATE SCHOOL OF OCEANOGRAPHY
UNIVERSITY OF RHODE ISLAND
NARRAGANSETT, RHODE ISLAND

THE SYNOP EXPERIMENT:
Inverted Echo Sounder Data Report
for
Jun 1989 to Sep 1990

GSO Technical Report No. 91-2

by

Erik Fields
and
D. Randolph Watts

March
1991

This research program has been sponsored by the National Science Foundation under grant number OCE87-17144 and by the Office of Naval Research under contracts N00014-90J-1568 and N00014-90J-1548.

Abstract

The SYNoptic Ocean Prediction experiment (SYNOP) was undertaken with the goal that increased understanding of the Gulf Stream obtained through coordinated observations could be integrated with numerical models, including predictive models of the Gulf Stream. Our moored experiment, which began in fall of 1987, consisted of two separate arrays in the Gulf Stream as part of the SYNOP program. The “Inlet” array of inverted echo sounders (IES) and deep current meters measured key parameters that describe the variability of the Gulf Stream and deep western boundary current (DWBC) near Cape Hatteras. In this region the Gulf Stream first flows into deeper water and crosses over the DWBC. The “Central” array of IESs, in a 350 km square centered on the Gulf Stream near 68°W, monitored the thermocline structure of the Gulf Stream in the region of large meanders and frequent interactions with rings. The array also contained thirteen tall current meter moorings, that reached into the Gulf Stream core. Additionally the IESs in the interior of the array were outfitted with bottom pressure recorders (PIES).

IES data recovered during the summer of 1990, from the “Year 3” deployment period, is documented here by plots and tables of basic statistics and pertinent deployment information. Altogether 32 IES records are presented, plus pressure records at 12 sites. The echo sounders were recovered during a cruise aboard the R/V Endeavor, EN216 (4-Aug-90 to 5-Sep-90). The IESs had been deployed the previous summer during cruises on the R/V Oceanus, OC207 (26-May-89 to 21-Jun-89) and OC210 (8-Aug-89 to 1-Sep-89). One IES was exchanged in mid-October 1989 using the R/V Cape Henlopen. The plots are time series of measured travel time, pressure, temperature; the residual pressure; and low-pass filtered records of residual pressure, thermocline depth, and temperature. A brief description of the experiment is given; the standard steps of data processing are discussed along with special processing for several IES records that had different problems.

Contents

Abstract	i
List of Tables	iii
List of Figures	iv
1 Experiment Description and Data Processing	1
1.1 Introduction	1
1.2 Instrument Sites and Naming Conventions	3
1.3 Data Recovery	3
1.4 Inverted Echo Sounder Description	3
1.5 Data Processing	6
1.5.1 Travel Time Calibration	8
1.5.2 Temperature	9
1.5.3 Bottom Pressure	10
1.5.4 Time Base	11
1.5.5 Note on Sample Times	14
1.6 Special Processing	15
1.6.1 IES90B1	15
1.6.2 IES90G1	17
1.6.3 PIES90G3	21
1.6.4 PIES90H3	21
1.6.5 PIES90H6	22
1.6.6 PIES90H5, PIES90H6, PIES90I1, and PIES90I4	23
2 Individual Site and Record Information Tables	25
3 Half-Hourly Individual Plots	83
4 Half-Hourly Line Plots	219
5 40HRLP Line Plots	237
Acknowledgments	254
References	255

List of Tables

1	Site Locations and Data Returns for The Inlet Array	4
2	Site Locations and Data Returns for The Central Array	4
3	Yearhour Calendar	12
4	Negative-Yearhour Calendar	13
5	A group of consecutive sequence numbers for IES G1.	19
6	Site and Record Information for A1	27
7	Site and Record Information for A2	28
8	Site and Record Information for B1	29
9	Site and Record Information for B3	30
10	Site and Record Information for B4	31
11	Site and Record Information for B5	32
12	Site and Record Information for C1	33
13	Site and Record Information for C2_89	34
14	Site and Record Information for C2_90	35
15	Site and Record Information for F1	36
16	Site and Record Information for F2	37
17	Site and Record Information for G1	38
18	Site and Record Information for G2	39
19	Site and Record Information for G3	42
20	Site and Record Information for G4	45
21	Site and Record Information for H1	46
22	Site and Record Information for H2	47
23	Site and Record Information for H3	50
24	Site and Record Information for H4	53
25	Site and Record Information for H5	56
26	Site and Record Information for H6	59
27	Site and Record Information for H7	62
28	Site and Record Information for I1	63
29	Site and Record Information for I2	66
30	Site and Record Information for I3	69
31	Site and Record Information for I4	72
32	Site and Record Information for I5	75
33	Site and Record Information for J1	78
34	Site and Record Information for J2	79
35	Site and Record Information for J3	80
36	Site and Record Information for J4	81
37	Site and Record Information for J5	82

List of Figures

1	Array locations and instrument sites	2
2	IES Deployment Chart	5
3	IES Data Processing Flowchart	7
4	Sampling Sequences for URI and Sea Data Model IESs	14
5	IES record degraded by biology.	16
6	BUNS plots of good and bad recordings.	18
7	FILL plot	20
8	A degraded record at several processing steps	24
9	Half-Hourly Travel Time Plots	85
9.1	IES90A1	85
9.2	IES90A2	87
9.3	IES90B1	89
9.4	TIES90B3	91
9.5	TIES90B4	93
9.6	TIES90B5	95
9.7	IES90C1	97
9.8	TIES89C2	99
9.9	TIES90C2	100
9.10	IES90F1	102
9.11	IES90F2	104
9.12	IES90G1	106
9.13	PIES90G2	108
9.14	PIES90G3	110
9.15	IES90G4	112
9.16	IES90H1	114
9.17	PIES90H2	116
9.18	PIES90H3	118
9.19	PIES90H4	120
9.20	PIES90H5	122
9.21	PIES90H6	124
9.22	IES90H7	126
9.23	PIES90I1	128
9.24	PIES90I2	129
9.25	PIES90I3	131
9.26	PIES90I4	133
9.27	PIES90I5	135
9.28	IES90J1	137
9.29	IES90J2	139
9.30	IES90J3	141
9.31	IES90J4	143
9.32	IES90J5	145
10	Half-Hourly Pressure Plots	147
10.1	PIES90G2	147
10.2	PIES90G3	149
10.3	PIES90H2	151
10.4	PIES90H3	153

10.5	PIES90H4	155
10.6	PIES90H5	157
10.7	PIES90H6	159
10.8	PIES90I1	161
10.9	PIES90I2	163
10.10	PIES90I3	165
10.11	PIES90I4	167
10.12	PIES90I5	169
11	Half-Hourly Temperature Plots	171
11.1	PIES90G2	171
11.2	PIES90G3	173
11.3	PIES90H2	175
11.4	PIES90H3	177
11.5	PIES90H4	179
11.6	PIES90H5	181
11.7	PIES90H6	183
11.8	PIES90I1	185
11.9	PIES90I2	187
11.10	PIES90I3	189
11.11	PIES90I4	191
11.12	PIES90I5	193
12	Half-Hourly Residual Bottom Pressure Plots	195
12.1	PIES90G2	195
12.2	PIES90G3	197
12.3	PIES90H2	199
12.4	PIES90H3	201
12.5	PIES90H4	203
12.6	PIES90H5	205
12.7	PIES90H6	207
12.8	PIES90I1	209
12.9	PIES90I2	211
12.10	PIES90I3	213
12.11	PIES90I4	215
12.12	PIES90I5	217
13	Half-Hourly Travel Time Plots By Lines	221
13.1	A line	221
13.2	B line	222
13.3	C line	223
13.4	F line	224
13.5	G line	225
13.6	H line	226
13.7	I line	228
13.8	J line	229
14	Half-Hourly Residual Bottom Pressure Plots By Lines	230
14.1	G line	230
14.2	H line	231
14.3	I line	232
15	Half-Hourly Temperature Plots By Lines	233

15.1	G line	233
15.2	H line	234
15.3	I line	235
16	40HRLP Z_{12}^* Plots By Lines	239
16.1	A line	239
16.2	B line	240
16.3	C line	241
16.4	F line	242
16.5	G line	243
16.6	H line	244
16.7	I line	246
16.8	J line	247
17	40HRLP Residual Bottom Pressure Plots By Lines	248
17.1	G line	248
17.2	H line	249
17.3	I line	250
18	40HRLP Temperature Plots By Lines	251
18.1	G line	251
18.2	H line	252
18.3	I line	253

1 Experiment Description and Data Processing

1.1 Introduction

In the region northeast of Cape Hatteras, NC, the Gulf Stream has large time-varying meanders. The current shifts within an envelope that grows downstream to several times the instantaneous width of the Gulf Stream itself, and it frequently interacts with powerful currents in eddies adjacent to the Gulf Stream. Fundamental questions remain regarding the dynamics and energy balances governing the meandering. A multi-investigator research effort **SYN**optic **O**cean **P**rediction (SYNOP) is being conducted to understand the physics of, and test predictive models of these energetic processes. Our field program has now completed a three-year deployment of arrays of inverted echo sounders with bottom pressure gauges and 28-month deployment of high-performance current meter moorings, reaching into the core of the Gulf Stream. The arrays are specifically designed for our objectives to understand the structure and energy exchanges associated with Gulf Stream variability throughout an extensive region where meanders are large and frequent interactions with eddies occur.

There have been two study areas, an “Inlet Array” and “Central Array”, as detailed below, in which inverted echo sounders were deployed for 34 months. The IES records of the “Year 3” deployment period for both arrays (Summer '89 – Summer '90) are the subject of this report.

Using data from current meters, inverted echo sounders (IESs) and IES/bottom pressure sensor combinations (PIESs), we intend to determine how the path and structure of the Gulf Stream evolve, both according to its internal dynamics and instabilities, and as affected by eddies in the adjacent regions. The main objective of our program is a more complete, fundamentally improved dynamical understanding of the Gulf Stream and its variability. From this understanding the longer term goal is to guide and test a predictive modeling capability for the Gulf Stream.

IES data in this report were recovered during the summer of 1990 during a cruise aboard the R/V Endeavor, EN216 (4-Aug-90 to 5-Sep-90). One IES had been exchanged in October 1989, and the record recovered at that time is included in this report. The data are presented in plots of travel times, thermocline depth measurements, and for IES's with additional sensors, bottom pressure and temperature. Basic statistics for those records and

pertinent deployment information are given in tables.

In addition to the records presented here, data were received throughout the deployment from five telemetry IESs (TIESs) in the inlet array. The TIESs and associated moorings were deployed during a cruise aboard the R/V Oceanus, OC210, in Aug 1989.

Figure 1: Mooring and IES sites. In the inlet array 'X's denote deep current meter moorings; in the central array they indicate tall current meter moorings. IES locations are marked by boxes. The dashed curve indicates the mean path of the Gulf Stream (1975 to 1986) from Gilman and Cornillon (1990).

1.2 Instrument Sites and Naming Conventions

The “Inlet Array”, near Cape Hatteras, consisted of three instrumented lines designated A–C. The “Central Array” centered on the Gulf Stream about 68 W had five instrument lines, F–J. Both arrays are shown in Figure 1. The instrument naming convention is to specify the line and the relative position in the line (increasing seaward from the shelf) prefixed by the type of instrument type and year of recovery. For example PIES90H3 would refer to the third instrument, a PIES, in the H line, for the deployment year of 1990. Tables 1 and 2 list the site positions and times, and Figure 2 illustrates their respective deployment periods.

There were nine instruments in the Inlet Array. IESs there that additionally telemetered data are referred to as TIESs. The five TIESs were B2–B5 and C2. There were 24 instruments in the Central Array. Twelve of these contained bottom pressure recorders and are referred to as PIESs.

1.3 Data Recovery

Tables 1 and 2 and Figure 2 summarize the data returns from each of the IESs. 31 IESs of 33 were successfully recovered. B2 failed to drop its anchor after accepting the release code. F3 would not accept the release command (but did respond normally to the relocation signal). IES F3 was revisited for its backup time release; the four second beacon was activated on schedule, but the IES remained on the bottom.

Some travel time data were lost at sites I1 and H5. Both instruments suffered from maladjusted echo-detectors. IES I1 measured only two months of usable data; the rest was composed of entirely of “no echos” (see section 1.6.6). H5 failed to measure an echo for the first three months of its deployment, but later functioned satisfactorily.

The temperature record at G3 was degraded as a result of a set of stuck bits in a register. Temperature was counted in steps of 128, fortunately, the effect of decreased resolution on calculating of pressure was negligible(see Section 1.6.3)

1.4 Inverted Echo Sounder Description

The IES is an instrument, which is moored one meter above the ocean floor, that monitors the depth of the main thermocline acoustically (Chaplin and Watts 1984). A sample burst of acoustic pulses is transmitted every half hour. A sample burst consists of twenty-four

Site Locations and Data Returns

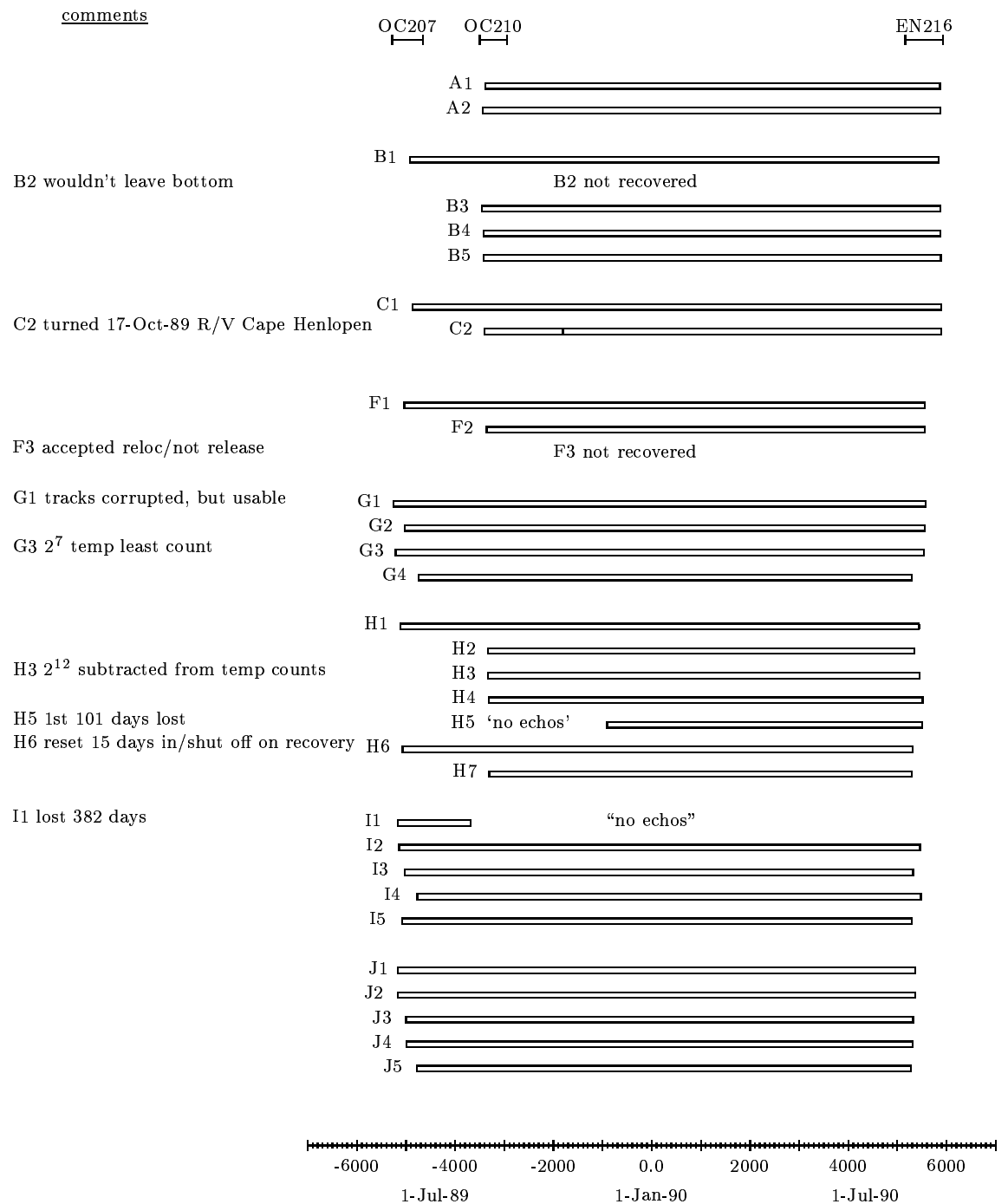
Table 1: Inlet Array

site	lat(N)	lon(W)	1st point	last point	notes
IES90A1	35° 12.32	74° 43.91	13-Aug-89	02-Sep-90	
IES90A2	34° 58.18	74° 24.53	11-Aug-89	02-Sep-90	obstruction by DSL
IES90B1	35° 45.13	74° 27.90	10-Jun-90	01-Sep-90	
TIES90B2	35° 37.01	74° 13.82	lost		stuck on bottom
TIES90B3	35° 30.07	74° 03.40	10-Aug-90	02-Sep-90	
TIES90B4	35° 20.75	73° 50.60	11-Aug-90	02-Sep-90	
TIES90B5	35° 12.13	73° 39.66	11-Aug-90	02-Sep-90	
IES90C1	36° 04.57	73° 56.84	12-Jun-90	03-Sep-90	
TIES89C2	35° 46.15	73° 33.00	12-Aug-89	17-Oct-89	Cape Henlopen turn around
TIES90C2	35° 46.22	73° 32.75	17-Oct-89	03-Sep-90	

Table 2: **Central Array**

site	lat(N)	lon(W)	1st point	last point	notes
IES90F1	37° 56.96	69° 58.19	05-Jun-89	20-Aug-90	
IES90F2	37° 24.62	69° 46.59	14-Aug-89	19-Aug-90	
IES90F3	36° 42.08	69° 33.92	lost		faulty release
IES90G1	38° 37.63	69° 25.39	27-May-89	20-Aug-90	tape errors
PIES90G2	37° 47.84	69° 24.31	05-Jun-89	20-Aug-90	
PIES90G3	37° 16.99	69° 14.71	29-May-90	19-Aug-90	
IES90G4	36° 33.00	68° 39.96	17-Jun-89	09-Aug-90	
IES90H1	38° 59.85	68° 39.92	02-Jun-89	15-Aug-90	
PIES90H2	38° 37.78	68° 54.90	15-Aug-89	11-Aug-90	
PIES90H3	38° 10.09	68° 43.65	15-Aug-89	15-Aug-90	
PIES90H4	37° 39.57	68° 35.35	15-Aug-89	18-Aug-90	high scatter
PIES90H5	37° 10.23	68° 17.83	25-Nov-89	17-Aug-90	no echos, 1st 3 months lost
PIES90H6	36° 39.35	68° 15.70	04-Jun-89	09-Aug-90	unexpected reset
IES90H7	36° 24.92	67° 47.81	16-Aug-89	09-Aug-90	
PIES90I1	38° 47.58	68° 06.25	30-May-89	30-Jul-89	no echos, only 3 months good
PIES90I2	38° 19.68	67° 58.71	01-Jun-89	16-Aug-90	
PIES90I3	37° 47.61	67° 58.85	06-Jun-89	10-Aug-90	
PIES90I4	37° 18.88	67° 39.58	16-Jun-89	16-Aug-90	
PIES90I5	36° 50.19	67° 27.36	03-Jun-89	08-Aug-90	
IES90J1	39° 10.05	67° 47.20	31-May-89	12-Aug-90	
IES90J2	38° 45.90	67° 21.03	31-May-89	11-Aug-90	
IES90J3	38° 09.69	67° 10.37	07-Jun-89	10-Aug-90	
IES90J4	37° 38.77	67° 00.65	07-Jun-89	10-Aug-90	
IES90J5	36° 00.68	66° 57.86	16-Jun-89	08-Aug-90	

Figure 2: IES deployment Chart. The deployment periods of the IESs in this report are charted as a thin rectangles. The length of each rectangle and its horizontal position on the time axis, in yearhour at the bottom, provide a calendar of data coverage, first good ping to last. Each large tick is 1000 hr and the smaller ticks denote 100 hr increments.



10 KHz pings at 10 sec intervals. The round trip travel times to the surface and back are recorded on a digital cassette tape within the instrument. For the PIESs, the measured bottom pressure and temperature are also written to tape. Pressure is an average measurement over a half-hour sampling period. For early model PIESs (URI types) the temperature is also an average measurement over a half-hour sample period. Later models (Sea Data types) average temperature for slightly less than one minute. Section 1.5.5 will explain in detail the actual times associated with the various measurements.

1.5 Data Processing

All processing steps were done on MicroVAX II and MicroVAX III computers. The basic steps include transcribing, editing, and converting into scientific units. The data processing is accomplished by a series of routines specifically developed for the IES. The steps are outlined below and schematically illustrated in Figure 3. A complete documentation of the data processing programs is in Fields, Tracey, and Watts (1991).

RAW DATA CASSETTES : Recorded within the instruments. Contain the counts associated with travel time, pressure, and temperature measurements as a series of integer words of varying lengths.

SDR : Runs the Sea Data Reader which transfers the data from cassettes directly to the MicroVAX for subsequent processing.

BUNS : Converts the series of integer words of varying lengths into standard length 32-bit integer words.

PUNS : Produces integer listings and histograms of the travel time sample bursts. Provides an initial look at data quality and travel time distributions. The histogram is used to determine the limits for maximum and minimum acceptable travel times for an initial windowing operation in the following step. The listings are used to establish the first (after launch) and last (before recovery) 'on bottom' samples essential for determining the exact time base.

MEMOD : Establishes the time base. Determines the modal value of the travel time burst as the representative measurement after application of several windowing operations.

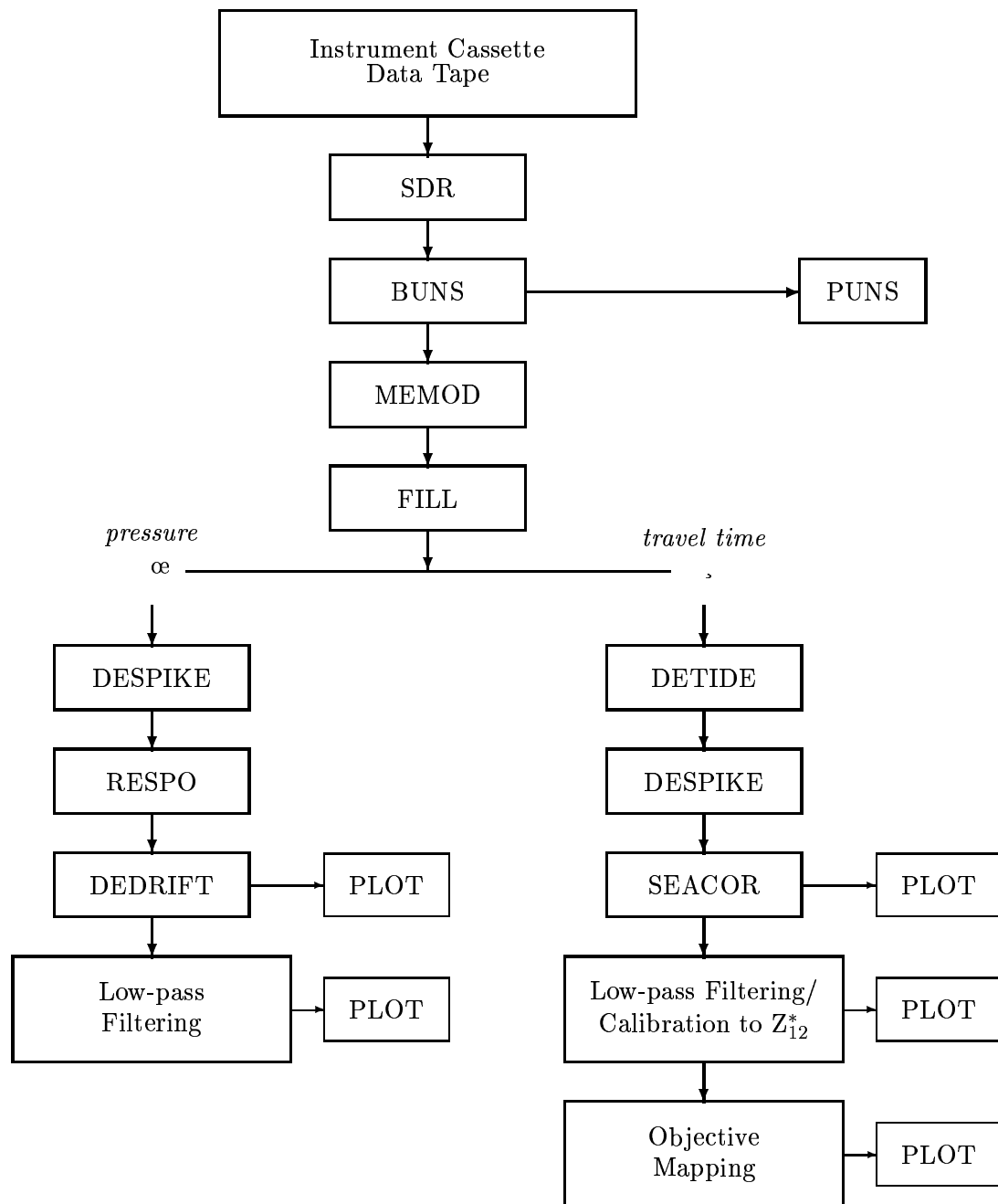


Figure 3: IES Data Processing Flowchart

Converts all travel time, pressure and temperature counts into specific units of seconds, decibars, and degrees Celsius, respectively.

FILL : Checks for proper incrementation of the time base. Missing samples are inserted using interpolated values. For PIESs the temperature and the pressure are written to separate files with the appropriate time bases.

DETIDE : From user-supplied tidal constituents specific to each site, determines the tidal contribution to the travel times and removes it from the measured values.

DESPIKE : Identifies and replaces travel time spikes with interpolated values.

SEACOR : Removes the effects of seasonal warming and cooling of the surface layers from the travel times. At this stage, plots of the half-hourly pressure, temperature and travel time are generated.

RESPO : Removes the tides from the pressure records using tidal response analysis (Munk and Cartwright, 1977) to determine the tidal constituents for each record.

DEDRIFT : Removes long term drifts associated with the pressure sensor and slight imperfection in the IES master clock frequency.

LOW PASS FILTERING : A 2nd order 40 hr low-pass Butterworth filter is applied forward and backwards to the travel time, residual pressure, and temperature records. The smoothed series are subsampled at six hour intervals centered on 0000Z, 0600Z, 1200Z, and 1800Z (UT), and plotted. The smoothed subsampled travel time is subsequently calibrated to Z_{12} .

OBJECTIVE MAPPING : Produces daily maps of the depth of the 12°C isotherm as documented in Watts, Tracey and Friedlander, 1989. The results of this step are not presented here. Rather, they will be presented in a subsequent data report.

1.5.1 Travel Time Calibration

The acoustic travel time (τ) records will be shown in Section 3, Figures 9.1–9.32. Variations in the travel times have been shown to be proportional to variations in the thermocline depth in the Gulf Stream region (Watts and Rossby, 1977; Watts and Wimbush, 1981; Watts and Johns, 1982). For practical purposes the main thermocline depth can be represented by the

depth of the 12°C isotherm, Z_{12} , as it is situated near the highest temperature gradients of the main thermocline and correlates well with τ (Rossby, 1969; Watts and Johns, 1982).

In previous studies, Z_{12} was obtained directly from the XBT cast. However, a new method has been developed which takes advantage of the integrative nature of the travel-time measurement to give a more representative measure of the thermocline depth. The new measure, Z_{12}^* , should be less susceptible to small, transient perturbations (i.e., internal waves) in the water column than the single-point measurement, Z_{12} . This method consists of calculating Q , the ‘heat content’ ($\int_{250m}^{750m} T dz$) for each calibration XBT cast; then using Q to determine Z_{12}^* from an empirical curve relating Z_{12} and Q . The curve was established using over 5000 XBT casts in the Gulf Stream region (from NODC archives).

At each IES site, XBTs were taken in order to determine the IES’s calibration coefficient, B , for converting the travel time into thermocline depth according to the relation: $Z_{12}^* = M\tau + B$. M was determined from regressions of all calibration pairs (Z_{12}^*, τ) from 1987 to 1990. The regressions showed that the constant value $M = -19,800$ m/sec was appropriate for all these Gulf Stream sites. The values of B used for each IES are listed in the tables in Section 2.

The low-pass filtered travel time records were scaled to the thermocline depths (Z_{12} , dropping the star. Hereafter Z_{12} is synonymous with $Z - 12^*$) and these records are shown in Figures 16.1–16.8. Since τ is resolved to 0.1 msec, the 40 HRLP Z_{12} scaled values are therefore resolved to ± 2 m. However, the accuracy of the offset parameter B is estimated to be ± 19 m for most records, judged from the agreement between the several calibration XBTs taken at each site. Relative to this, the 40 HRLP Z_{12} values are resolved to ± 2 m.

1.5.2 Temperature

Temperatures (Figures 11.1–11.12, 15.1–15.3, 18.1–18.3) were measured using thermistors (Yellow Springs International Corp., model 44032) controlled by Sea Data Corp. (model DC-37B) electronics cards installed in the IESs. The thermistor’s main purpose is to correct the pressure values for the temperature sensitivity of the transducer. The thermistor is inside the instrument, on the pressure transducer, rather than in the water. However, once the temperature probe has reached equilibrium with the surrounding waters, it also provides accurate measurements of the bottom temperature fluctuations (effectively low-pass filtered

with a 2–4 hour e-folding equilibrium time). The first 24 half-hourly points were dropped prior to low-pass filtering, since the temperatures took 12 hours to reach equilibrium within 0.001°C . The accuracy of the temperature measurements is about 0.1°C , and the resolution is 0.0002°C .

1.5.3 Bottom Pressure

Digiquartz pressure sensor (models 46K-017, 46K-023, and 76KB-032) manufactured by Paroscientific Inc. were used to measure bottom pressure. All pressure measurements were corrected for the temperature sensitivity of the transducer, using calibration coefficients purchased from the manufacturer. The half-hourly measured bottom pressures (Figures 10.1–10.12) are dominated by the tides, however for some of the instruments, the pressures also drift, $O(0.1 \text{ dbar yr}^{-1})$, monotonically with time. Processing of the pressure measurements includes removing the long-term drift and tides.

Tidal response analysis (Munk and Cartwright, 1977) was used to determine the tidal constituents for each instrument. The calculated tides were then removed from the pressure records. The amplitudes, H (dbar), and phases, G° (Greenwich epoch), of the constituents are given in the tables in Section 2.

The pressure records were dedrifted in the manner developed by Watts and Kontoyiannis (1990) who have addressed pressure sensor drift and performance. The rate of drift decayed with time and was best approximated by an exponential function of the form,

$$Drift = Ae^{-\lambda t} + B.$$

A design matrix for the nonlinear least-squares fit would be composed of $(e^{-\lambda t_i}, 1)$. The overdetermined set of equations were solved for coefficients A and B . These coefficients were found subject to the minimization of the rms error of the fit as a function of the decay rate, λ . Minimization was accomplished using the method of parabolic extrapolation and golden sections (Press et al., 1988) to optimally search for λ with a minimum of function evaluations (fits). The first 12 hours of pressure were ignored since the crystal's temperature was equilibrating. The drift curves were found from 2-hour subsampled records for

computational simplicity. The time of drift was referenced from 1 hour before the first sample on the ocean bottom, i.e. at a time when the instrument was sinking to the sea floor after launch. At a later stage, comparison of geostrophic currents, calculated from adjacent dedrifted pressure sensors versus nearby current meters will be used to verify the dedrift procedure's success.

Three of the twelve PIEs showed some sign of drift. Two were identified as exponential (G3 and H6) and one was linear (I5). The linear pressure drift was estimated from the IES clock drift rather than a least-squares fit. The fitted drift parameters are listed for each instrument individually, in the site and record information tables of Section 2. The half-hourly pressures are resolved to 0.001 dbar and the mean pressure is accurate to within 1.5 dbar. We estimate that the residual (drift and tide removed) bottom pressure records, shown in Figures 12.1–12.12 and Figure 14.1–14.3, have an accuracy (relative to their mean pressure) of better than 0.05 dbar (Watts and Kontoyiannis, 1990). The residual bottom pressure records were low-pass filtered and the results are plotted in Figures 17.1–17.3.

1.5.4 Time Base

The date and time were assigned to each sampling period. Tables 6–37 in Section 2 report the hours, minutes, and seconds associated with the first and last sampling period. All times are given as Universal Time (UT). For processing convenience, the times were converted into yearhours. A yearhour calendar (Table 3 and 4) lists the yearhours which correspond to 0000 UT of each day for non-leap years. (For leap years, the yearhours can be determined by adding 24 to each day after February 28.) There are a total of 8760 hours in a standard year and 8784 hours in a leap year. The yearhours given in this report are referenced to January 1, 1990 at 00:00:00 UT.

Table 3: Yearhour Calendar for Non-Leap Years. Each yearhour listed corresponds to 00:00:00 UT on the specified day.

Table 4: Negative-Yearhour Calendar for Non-Leap Years. Each yearhour listed corresponds to 00:00:00 UT on the specified day.

1.5.5 Note on Sample Times

Two PIES models, URI and Sea Data (hereafter SD) were used during this deployment period. The URI models were used at sites G3, H3, and H5; all others were SDs. In Section 2, the URI models are indicated in the tables by serial numbers less than 63 and SDs by serial numbers 63 or greater. The SDs were produced by Sea Data Corporation and designed after the URI model.

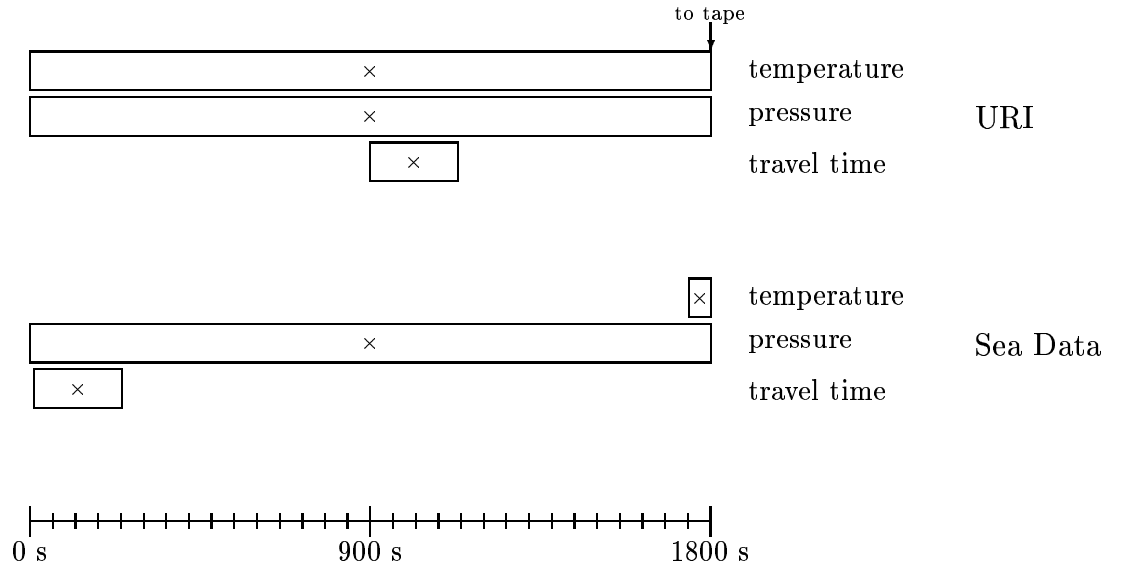


Figure 4: Sampling Sequences for URI and Sea Data Model IESs. The horizontal length and position of the boxes represent the duration and relative temporal location of the sampling periods, respectively. The center of each box is indicated by a \times . Each tick mark on the time axis represents a minute.

Although both models measure three variables, travel time, bottom pressure, and temperature, their sampling schemes are different. These are illustrated in Figure 4. Consider a typical 1800 s (0.5 hr) sampling interval. For comparison, it is useful to assign the time 0 s to the instant the previous sample is written to the tape. Then the time 1800 s corresponds to the instant the sample of interest is recorded. For both the URI and SD models, the travel time measurement consists of a burst of 24 pings at 10 s intervals and pressure is measured for the full 1800 s sampling interval. The URI models also measure temperature for the full 1800 s, whereas the temperature interval is reduced to only 56.25 s (a sixty-fourth

of an hour) in the SD models. The durations and relative temporal positioning of the three types of measurements are illustrated in Figure 4 for both models. The time base assigned to each variable coincides with the center of its measuring interval.

In the URI model, since both pressure and temperature are measured for 1800 s, their centers occur at 900 s. The travel time burst actually begins at that time, and thus its center is offset by 115 s.

The SD model PIES does its internal bookkeeping and storage to tape in the first 11.25 s of the 1800 s sampling interval. The travel time burst begins after this processing, so its center is located at 126.25 s (i.e. $115 + 11.25$ s). The center of the half-hourly pressure measurement will occur at 900 s. The shorter temperature measurement occurs at the end of the 1800 s sampling interval, with its center at 1771.875 s ($1800 - 56.25/2$ sec).

In order to prevent time-basing errors related to these offsets, the travel time, pressure, and temperature were segregated at the FILL step: each variable was written to a separate file with the appropriate time base. In the past, the PIES's variables were separated after the SEACOR step.

1.6 Special Processing

1.6.1 IES90B1

The travel time record at site B1 was degraded by the presence of a deep scattering layer (DSL), which often obscured the surface throughout the deployment (Fig 5). The DSL migrated daily, up to the surface in the evenings (~ 1900 local) and back down below 285 m at dawn (~ 0600 local). This instrument was set to lock out any return echos prior to 2.25 s in order to focus upon the sea-surface echoes at about 2.60 to 2.65 s. Hence, if the DSL migrated too deep, its echos were locked out. During the night, the DSL's movements indicated passive sinking followed by a rapid re-ascent to the surface before the morning's downward migration.

Data quality oscillated between extremes, good data and no data, on a regular daily pattern. Often, during the day, the DSL traveled below the lockout depth, and the IES was able to sound the surface with little obstruction. The surface returns also tended to be better when the DSL was near the surface; this was likely because DSL was at it's furthest from the IES. Winter seemed to bring a better record, possibly in accordance with decreased biological density in that season. The travel time record required much

Figure 5: A subrecord from IES90B1 illustrates the deep scattering layer. Two sections of the upper plot are expanded to show the diel vertical migration. Date labels are centered at 0000 local time, and ticks are spaced 12 hours apart in the top plot, and 1 hour apart in the lower plots. The lockout depth and the surface are apparent at 0.225 s and 0.650 s, respectively.

interpolation, because nearly half of each day was dominated by spurious DSL echos, and 44% of the travel times were replaced.

The acoustic wavelength of the IES is about 15 cm ($1500 \text{ ms}^{-1} / 10 \text{ kHz}$), so the scatterers must have been larger nekton or a very dense lamina ($\sim 15 \text{ cm}$ thick) of zooplankton. From the IES record, the DSL thickness was typically over 70 m, which supports the notion of an aggregation of fish rather than zooplankton. The sharp density contrast of a fish's swim bladder makes for a good acoustic scatterer. A DSL composed of mid-water fish was likely what the IES saw (K. Wishner personal communications).

In previous deployments, either the detection threshold was lower or the DSL sparser. The daily pattern was not as apparent and the high scatter was attributed to an overly sensitive echo detector. IES89B1 was reexamined more closely and the DSL's migration was recognized.

On the bright side, a valuable time series of long-term diel vertical migration was inadvertently collected. Acoustic studies of vertical migration have been of relatively short duration and typically in shallow waters. Prof. K. Wishner intends to use the IES record to calculate useful statistics about vertical migration.

1.6.2 IES90G1

The IES at G1 required special processing because the tape recording system did not work properly. All four tracks of the data cassette had been corrupted. The tape contained 391 overrun flags, 2221 short records, 2475 weak signals, and 5472 parity errors. Only eighty percent of the records were successfully read from tape (99-100% is the norm). The sequence number failed to increment monotonically and got progressively more disordered with time (Fig. 6). Good sequence numbers could usually be distinguished from bad (Table 5), because good sequence numbers incremented by multiples of two and were odd valued (URI model IESs have odd sequence number; SD, even). Though, late in the record the good sequence numbers changed from odd to even.

In addition to incrementing by multiples two, the "good" sequence numbers were assumed to be numerically correct: the sequence number increased by two each half hour from "final reset" to "off" without fail (with the one exception of the parity change). So "good" sequence numbers maintained the time base even with large groups of records absent. Consider Table 5, between the good sequence numbers in relative positions 2 and 9

Figure 6: BUNS plot of G1 and F1. F1 was included here to illustrate a healthy record.

1	36415	good
2	36417	good
3	4403	
4	59957	
5	36427	good
6	5619	
7	26962	
8	35497	
9	36439	good
10	36441	good
11	36443	good
12	36445	good
13	35340	

Table 5: A group of consecutive sequence numbers for IES G1.

(in the table) ten records would be expected rather than just six. The assumption that was described above would imply that four records were missing, not recovered from the tape. The sequence number was converted to time at the MEMOD step using the time of final reset as a reference.

The FILL program checks for proper incrementation of time and inserts missing records by interpolation. FILL ran successfully, but first it was necessary to attend to many problem areas of the record. The problem areas resulted from sample times that were determined from bad, but properly spaced sequence number pairs. Such problem areas crashed the FILL routine. One of two problems would occur: 1) the number of missing records would exceed an acceptable limit or 2) the bad sample times would correspond to times earlier than those FILL had already processed. These sample times that FILL failed to recognize as bad were “hand-edited”: the bad records where FILL failed were corrected by hand (in the text editor) to be consistent with surrounding good ones.

The change from odd to even sequence numbers posed another problem area, since it violated of the assumption that the sequence number increased properly through out the record. The question of what happened at that point was entwined in the problem of establishing the time base.

Fortunately, the ping burst documenting the last good record and the release were not missed. These events marked important time references which in addition to their “good’

sequence numbers, indicated that five “garbage” records had been inserted into the record. These “garbage” records were conspicuous because they contained only zeros and separated two consecutive “good” records.

After these zeros-records were removed, a time history was established which was entirely consistent (all events at the proper time, launch and release, first and last good, and reset and off times). For consistency of the time base, an offset of three-quarters of an hour was required after the time of the even/odd change.

Arrays within the FILL program were redimensioned to accommodate the large gaps in the record. Several gaps were over a hundred records, however typically hiatuses were less than ten records. A great many records were filled by interpolation; so when plotted, a second trace was visible (Fig. 7) which resulted from interpolating between good data and bad-flag value of 1.0 sec. The time base was corrected for clock drift after FILL

Figure 7: Plot of the resulting FILL record. The slightly higher trace results from interpolation between the main trace and the upper bound of 1.0 seconds

(this correction is usually incorporated into the time base at MEMOD), and bad data were replaced at the DESPIKE step. The final record shown in Section 3, Figure 9.12, was

remarkably clean considering the original quality of the data.

1.6.3 PIES90G3

The PIES at G3 had a faulty temperature counter. The first seven bits were stuck, so it counted by 128 (Fig. 11.2). For the type of sensor used, pressure is calculated from the temperature and frequency of a quartz crystal; because the least count of G3 temperature was 128 rather than 1, the pressure was affected.

The effect on pressure caused by decreased temperature resolution was investigated using a healthy temperature record (PIES90I1). The healthy record was degraded to a steppy one: the counts were integer divided by 128 and then multiplied by 128. The pressure record calculated from the steppy temperature record was compared with the pressure record calculated from the normal smooth temperature record.

The difference between the two I1 pressure records indicated that no special processing was necessary. The degradation only introduced a small-amplitude noise of 0.0028 dbar (rms). The resolution appeared to matter little since the temperature was nearly constant near the ocean bottom (for the PIES in the Central Array, standard deviations typically varied between 0.01–0.02°C).

Since I1 required no special processing, G3 would not be expected to require any either (additionally, G3's temperature resolution was twice that of I1's; the different resolutions resulted from two different temperature calibrations: one for the URI model IESs and the other for SD models.)

1.6.4 PIES90H3

The temperature record for the H3 PIES was about 1°C higher than expected. At the other sites and at H3 in previous years, the temperature at the bottom has typically been around 2.5°C. PIES90H3's mean temperature was greater than the highest maximum bottom-temperature found in the Central Array. The one degree difference is larger than the accuracy of the thermistor (0.1°C).

A bit was assumed to be set that shouldn't have been. For the calibration of H3, 1°C corresponded to 4608 counts, so it seemed possible that the thirteenth bit (4096) had stuck "on". After the counts were reduced by 4096 the temperatures agreed with expected bottom temperatures. Though, when the IES was examined in the lab, the thirteenth bit

functioned normally. Nevertheless, the 4096 count offset was retained in the final processing.

1.6.5 PIES90H6

The IES at H6 required special attention due to a unexpected reset fifteen days after it was launched. The “deadman” (also called the “watchdog”) sequence must have activated. (The deadman sequence prevents the IES’s cpu from latching up indefinitely. The cpu must reset a counter in the deadman circuit on a regular schedule; if it fails to do so the circuit reboots and resets the IES.)

The reset in PIES90H6 would have caused a hiccup in the sampling. Sea Data IESs, like H6, record to tape a half hour after sampling. A reset completely restarts the IES, and the previous sample, to be written to tape, is lost. The size of the gap was investigated by considering PIES90H6 to be composed to two records: a 15 day record with samples on the hour and half hour (which was the sample time at launch), and a 416 day record with samples at 19 min 42 sec and 49 min 42 sec after the hour (the sample time at recovery).

Since the clock drift (estimated from the difference in the master clock frequency at launch and recovery) was less than two minutes, the sampling intervals were taken to be exactly 0.5 hr. The time base for the subrecord before the reset was established from the time of *final reset*, the other subrecord was assigned a time base from the last good ping before the *off time*.

The sample times at launch and recovery were different by 19 minutes 42 seconds. The hiatus at the reset was an additional half hour longer than the expected 19 minutes 42 seconds. This suggested that the IES had reset twice: the first reset was unsuccessful and the second one was required before the half-hour sample time elapsed.

The short subrecord was interpolated to a sample time consistent with the long subrecord (XX:19:42,XX:49:42). Two samples were inserted to reconcile the two subrecords and form a single continuous record. For temperature and travel time, the inserted records were linearly interpolated. A quadratic form was used for pressure, since the parabola represented the trough-shape of low tide much better than a line.

The patch job appeared to be very good. Tidal analysis of the H6 bottom-pressure record gave a phase and amplitude for each of eight major tidal constituents that agreed with those of neighboring pressure records, thus confirming that the time base was correct.

Contour maps of phase and amplitude (for the major tidal constituents) across the array were plotted, and the maps were smooth and without aberration at H6.

1.6.6 PIES90H5, PIES90H6, PIES90I1, and PIES90I4

Although no special processing was required for these IESs, they are included in this section to document why they should be used with some caution. After low-pass filtering, these records appeared healthy but were not completely so. Figure 8 illustrates how the final product may not reflect the poor quality of the original raw data. These IESs' travel time measurements were degraded as a result of maladjustment of echo detectors relative to their smaller pinger transducers. Overly sensitive detectors triggered on ambient noise as well as, or instead of, the echo returning from the surface, which caused unusually high scatter.

The detection threshold is variable and depends on the ratio of the narrow- to broad-band signal (200 Hz vs. 1000 Hz centered on the out-going 10.24 KHz ping). While this guards against false triggering, it may also exclude good echoes in the presence of intense noise. If the detector fails to receive a suitable echo, a constant value is recorded as a “no echo” flag (the flags were 4351 for URI and 4352 for SD).

Travel time measurements at I1, I4, H5, and H6 were of notably lower quality characterized by high scatter and long periods of “no echos”. IES I1 had only two months of usable travel-time record, the rest was composed entirely of “no echos”. H5 failed to measure an echo for the first three months of its deployment, but afterwards gave a usable record.

At the MEMOD step, much of this bad data was identified: the 24 travel time measurements of each burst were “PUNS” windowed, “bin” windowed, and any “no echos” excluded, if less than four echos remained, the mode could not be properly estimated and was taken to be one of the “PUNS” window bounds. These bounds were easily distinguished from good data and removed in the DESPIKE step.

Large portions of each of these four records were replaced in the DESPIKE processing step (eg. 42% for I4).

Figure 8: These plots show a subrecord (PIES90I4) at several processing stages. The quality of the data after low-pass filtering (bottom panel) does not reflect the poor quality of the original record (top).

2 Individual Site and Record Information Tables

The tables that follow provide information about the location, dates, and basic statistics of the data records. Each table documents a single instrument deployment. General site information, such as position, bottom depth, and launch and recovery times, is given first. Subsequently, details about the travel time, bottom pressure, temperature and thermocline depth records plotted in Sections 3–5 are tabulated. Tables supply the times associated with the first and last data point of each plot. All yearhours are referenced to January 1, 1990 at 0000 UT. Measurements made during the calendar year prior to the reference date are given as negative yearhours.

The first order statistics (minimum, maximum, mean, and standard deviation) are tabulated for the half-hourly and six-hourly low-passed records (40 HRLP) for each variable of standard IES and PIEs.

Note that the travel time displayed should not be interpreted as the absolute time required for a signal to make the round trip in 3000 – 5000m of water. The full round-trip time takes approximately 6 seconds and requires that a minimum of 18 bits be recorded on the internal cassette tape. For storage economy, only the 13 least significant bits are recorded. So, the full-scale range of the variation is approximately 200 msec. If wrapping occurs, it is only at the high or the low end of the window, never more than once around because the full scale variation of the signal is only 50 msec, and consequently it an unambiguous matter to unwrap the record. The variation in travel time is all that is required for subsequent interpretation and calibration against XBTs. After calibration to thermocline depth, the records from all IESs can easily be compared.

Table 6: **Site and Record Information for****IES90A1**

Serial Number: 080

Type of Travel Time Detector: TTC

Number of Pings per Sampling: 24

Additional Sensors: None

POSITION: 35°12.32 N DEPTH: 2500 m
 74°43.91 W

	DATE	UT	CRUISE
LAUNCH:	Aug 13, 1989	1008	OC210
RELEASE:	Sep 2, 1990	0337	EN216

TRAVEL TIME RECORDS

Figure 9.1 and 13.1

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 13, 1989	06:30:54	-3377.4851
LAST DATA POINT:	Sep 2, 1990	03:30:54	5859.5151

Number of Points: 18475

Sampling Interval: 0.50 hrs

Minimum $\tau = 0.145160$ s

Mean = 0.153347 s

Maximum $\tau = 0.162660$ s Standard Deviation = 0.003472 s**40-HRLP THERMOCLINE DEPTH RECORDS**

(Figure 16.1)

 Z_{12} Conversion equation: $Z_{12} = -19800\text{m s}^{-1} \cdot \tau_d + B$

where B = 3404.00 m

 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 14, 1989	06:00:00	-3354.0000
LAST DATA POINT:	Sep 1, 1990	06:00:00	5838.0000

Number of Points: 1533

Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 208.01$ m

Mean = 367.73 m

Maximum $Z_{12} = 501.60$ m Standard Deviation = 66.82 m

Table 7: **Site and Record Information for
IES90A2**

Serial Number: 057
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: None

POSITION: 34°58.18 N DEPTH: 3070 m
 74°24.94 W

	DATE	UT	CRUISE
LAUNCH:	Aug 10, 1989	1830	OC210
RELEASE:	Sep 2, 1990	0718	EN216

TRAVEL TIME RECORDS

Figure 9.2 and 13.1

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 11, 1989	02:01:56	-3429.9680
LAST DATA POINT:	Sep 2, 1990	06:54:21	5862.9058

Number of Points: 18587
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.086544$ s Mean = 0.093061 s
 Maximum $\tau = 0.104735$ s Standard Deviation = 0.002826 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.1)

Z_{12} Conversion equation: $Z_{12} = -19800\text{m s}^{-1} \cdot \tau_d + B$
 where B = 2505.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 12, 1989	00:00:00	-3408.0000
LAST DATA POINT:	Sep 1, 1990	06:00:00	5838.0000

Number of Points: 1542
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 450.56$ m Mean = 662.24 m
 Maximum $Z_{12} = 762.19$ m Standard Deviation = 54.72 m

Table 8: **Site and Record Information for****IES90B1**

Serial Number: 035

Type of Travel Time Detector: TTC

Number of Pings per Sampling: 24

Additional Sensors: None

POSITION: 35°45.13 N DEPTH:1975 m
 74°27.90 W

	DATE	UT	CRUISE
LAUNCH:	Jun 10, 1989	1008	OC207
RELEASE:	Sep 1, 1990	0456	EN216

TRAVEL TIME RECORDS

Figure 9.3 and 13.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 10, 1989	11:01:56	-4908.9678
LAST DATA POINT:	Sep 1, 1990	04:23:02	5836.3838

Number of Points: 21492

Sampling Interval: 0.50 hrs

Minimum $\tau = 0.216606$ s

Mean = 0.224727 s

Maximum $\tau = 0.230038$ s Standard Deviation = 0.002427 s**40-HRLP THERMOCLINE DEPTH RECORDS**

(Figure 16.2)

 Z_{12} Conversion equation: $Z_{12} = -19800\text{m s}^{-1} \cdot \tau_d + B$

where B = 4670.00 m

 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 11, 1989	12:00:00	-4884.0000
LAST DATA POINT:	Aug 31, 1990	06:00:00	5814.0000

Number of Points: 1784

Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 129.03$ m

Mean = 220.61 m

Maximum $Z_{12} = 354.24$ m Standard Deviation = 46.14 m

Table 9: **Site and Record Information for
TIES90B3**

Serial Number: 082
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: None

POSITION: 35°30.07 N DEPTH:2960 m
 74°03.40 W

	DATE	UT	CRUISE
LAUNCH:	Aug 10, 1989	0932	OC210
RELEASE:	Sep 2, 1990	1250	EN216

TRAVEL TIME RECORDS

Figure 9.4 and 13.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 10, 1989	10:16:26	-3445.7261
LAST DATA POINT:	Sep 2, 1990	12:46:26	5868.7739

Number of Points: 18630
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.342946$ s Mean = 0.352156 s
 Maximum $\tau = 0.369696$ s Standard Deviation = 0.005141 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.2)

Z_{12} Conversion equation: $Z_{12} = -19800\text{m s}^{-1} \cdot \tau_d + B$
 where B = 7533.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 11, 1989	12:00:00	-3420.0000
LAST DATA POINT:	Sep 1, 1990	12:00:00	5844.0000

Number of Points: 1545
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 236.75$ m Mean = 560.57 m
 Maximum $Z_{12} = 722.87$ m Standard Deviation = 101.04 m

Table 10: **Site and Record Information for****TIES90B4**

Serial Number: 078

Type of Travel Time Detector: TTC

Number of Pings per Sampling: 24

Additional Sensors: None

POSITION: 35°20.75 N DEPTH:3325 m
 74°50.60 W

	DATE	UT	CRUISE
LAUNCH:	Aug 11, 1989	1859	OC210
RELEASE:	Sep 2, 1990	1551	EN216

TRAVEL TIME RECORDS

Figure 9.5 and 13.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 11, 1989	19:47:31	-3412.2080
LAST DATA POINT:	Sep 2, 1990	15:47:31	5871.7920

Number of Points: 18569

Sampling Interval: 0.50 hrs

Minimum $\tau = 0.046479$ s

Mean = 0.054428 s

Maximum $\tau = 0.067147$ s Standard Deviation = 0.003803 s**40-HRLP THERMOCLINE DEPTH RECORDS**

(Figure 16.2)

 Z_{12} Conversion equation: $Z_{12} = -19800\text{m s}^{-1} \cdot \tau_d + B$

where B = 1794.00 m

 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 12, 1989	18:00:00	-3390.0000
LAST DATA POINT:	Sep 1, 1990	18:00:00	5850.0000

Number of Points: 1541

Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 488.53$ m

Mean = 716.30 m

Maximum $Z_{12} = 839.24$ m Standard Deviation = 74.61 m

Table 11: **Site and Record Information for****TIES90B5**

Serial Number: 077
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: None

POSITION: 35°12.13 N DEPTH:3675 m
 73°39.66 W

	DATE	UT	CRUISE
LAUNCH:	Aug 11, 1989	1515	OC210
RELEASE:	Sep 2, 1990	1835	EN216

TRAVEL TIME RECORDS

Figure 9.6 and 13.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 11, 1989	16:17:51	-3415.7029
LAST DATA POINT:	Sep 2, 1990	18:17:49	5874.2969

Number of Points: 18581
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.044367$ s Mean = 0.052144 s
 Maximum $\tau = 0.059789$ s Standard Deviation = 0.002750 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.2)

Z_{12} Conversion equation: $Z_{12} = -19800\text{m s}^{-1} \cdot \tau_d + B$
 where B = 1808.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 12, 1989	18:00:00	-3390.0000
LAST DATA POINT:	Sep 1, 1990	18:00:00	5850.0000

Number of Points: 1541
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 644.83$ m Mean = 775.48 m
 Maximum $Z_{12} = 898.07$ m Standard Deviation = 53.28 m

Table 12: Site and Record Information for

IES90C1

Serial Number: 050

Type of Travel Time Detector: TTC

Number of Pings per Sampling: 24

Additional Sensors: None

POSITION: 36°04.57 N DEPTH:3325 m
 75°56.84 W

	DATE	UT	CRUISE
LAUNCH:	Jun 12, 1989	1015	OC207
RELEASE:	Sep 3, 1990	0637	EN216

TRAVEL TIME RECORDS

Figure 9.7 and 13.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 12, 1989	11:31:56	-4860.4678
LAST DATA POINT:	Sep 3, 1990	06:29:32	5886.4922

Number of Points: 21495

Sampling Interval: 0.50 hrs

Minimum $\tau = 0.189959$ s

Mean = 0.204540 s

Maximum $\tau = 0.214809$ s Standard Deviation = 0.005093 s**40-HRLP THERMOCLINE DEPTH RECORDS**

(Figure 16.3)

 Z_{12} Conversion equation: $Z_{12} = -19800\text{m s}^{-1} \cdot \tau_d + B$

where B = 4314.00 m

 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 13, 1989	12:00:00	-4836.0000
LAST DATA POINT:	Sep 2, 1990	06:00:00	5862.0000

Number of Points: 1784

Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 84.68$ m

Mean = 264.37 m

Maximum $Z_{12} = 538.27$ m Standard Deviation = 99.91 m

Table 13: **Site and Record Information for
TIES89C2**

Serial Number: 074
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: None

POSITION: 35°46.15 N DEPTH:3450 m
 73°33.00 W

	DATE	UT	CRUISE
LAUNCH:	Aug 12, 1989	1717	OC210
RELEASE:	Oct 17, 1989	0721	CH

TRAVEL TIME RECORDS

Figure 9.8 and 13.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 12, 1989	18:16:49	-3389.7200
LAST DATA POINT:	Oct 17, 1989	07:16:49	-1816.7200

Number of Points: 3147
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.221453$ s Mean = 0.232955 s
 Maximum $\tau = 0.242347$ s Standard Deviation = 0.004939 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.3)

Z_{12} Conversion equation: $Z_{12} = -19800\text{m s}^{-1} \cdot \tau_d + B$
 where B = 4931.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 13, 1989	18:00:00	-3366.0000
LAST DATA POINT:	Oct 16, 1989	06:00:00	-1842.0000

Number of Points: 255
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 149.51$ m Mean = 313.70 m
 Maximum $Z_{12} = 522.32$ m Standard Deviation = 93.42 m

Table 14: **Site and Record Information for
TIES90C2**

Serial Number: 063															
Type of Travel Time Detector: TTC															
Number of Pings per Sampling: 24															
Additional Sensors: None															
POSITION: 35°46.22 N DEPTH:~3353 m															
73°32.75 W															
<table><tr><td></td><td>DATE</td><td>UT</td><td>CRUISE</td></tr><tr><td>LAUNCH:</td><td>Oct 17, 1989</td><td>1015</td><td>CH</td></tr><tr><td>RELEASE:</td><td>Sep 3, 1990</td><td>0225</td><td>EN216</td></tr></table>					DATE	UT	CRUISE	LAUNCH:	Oct 17, 1989	1015	CH	RELEASE:	Sep 3, 1990	0225	EN216
	DATE	UT	CRUISE												
LAUNCH:	Oct 17, 1989	1015	CH												
RELEASE:	Sep 3, 1990	0225	EN216												

TRAVEL TIME RECORDS

Figure 9.9 and 13.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Oct 17, 1989	10:47:42	-1813.2050
LAST DATA POINT:	Sep 2, 1990	22:17:42	5878.2949

Number of Points: 15384
Sampling Interval: 0.50 hrs

Minimum $\tau = 0.195413$ s Mean = 0.204293 s
Maximum $\tau = 0.216236$ s Standard Deviation = 0.003630 s

40-HRLP THERMOCLINE DEPTH RECORDS
(Figure 16.3)

Z_{12} Conversion equation: $Z_{12} = -19800\text{m s}^{-1} \cdot \tau_d + B$
where B = 4732.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Oct 18, 1989	12:00:00	-1788.0000
LAST DATA POINT:	Sep 2, 1990	00:00:00	5856.0000

Number of Points: 1275
Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 477.03$ m Mean = 686.33 m
Maximum $Z_{12} = 834.09$ m Standard Deviation = 70.63 m

Table 15: **Site and Record Information for
IES90F1**

Serial Number: 037
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: None

POSITION: 37°56.96 N DEPTH: 3900 m
 69°58.19 W

	DATE	UT	CRUISE
LAUNCH:	Jun 5, 1989	0906	OC207
RELEASE:	Aug 20, 1990	1023	EN216

TRAVEL TIME RECORDS

Figure 9.10 and 13.4

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 5, 1989	10:16:56	-5029.7178
LAST DATA POINT:	Aug 20, 1990	10:09:00	5554.1499

Number of Points: 21169
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.377775$ s Mean = 0.399626 s
 Maximum $\tau = 0.413182$ s Standard Deviation = 0.007633 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.4)

Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$
 where B = 8226.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 6, 1989	12:00:00	-5004.0000
LAST DATA POINT:	Aug 19, 1990	12:00:00	5532.0000

Number of Points: 1757
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 76.88$ m Mean = 314.08 m
 Maximum $Z_{12} = 715.71$ m Standard Deviation = 150.25 m

Table 16: **Site and Record Information for****IES90F2**

Serial Number: 062

Type of Travel Time Detector: TTC

Number of Pings per Sampling: 24

Additional Sensors: None

POSITION: 37°24.62 N DEPTH: 4245 m
 69°46.59 W

	DATE	UT	CRUISE
LAUNCH:	Aug 14, 1989	0415	OC210
RELEASE:	Aug 20, 1990	0006	EN216

TRAVEL TIME RECORDS

Figure 9.11 and 13.4

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 14, 1989	05:32:00	-3354.4670
LAST DATA POINT:	Aug 19, 1990	23:59:49	5543.9971

Number of Points: 17798

Sampling Interval: 0.50 hrs

Minimum $\tau = 0.030221$ s

Mean = 0.041120 s

Maximum $\tau = 0.067455$ s Standard Deviation = 0.006076 s**40-HRLP THERMOCLINE DEPTH RECORDS**

(Figure 16.4)

 Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$

where B = 1532.00 m

 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 15, 1989	06:00:00	-3330.0000
LAST DATA POINT:	Aug 19, 1990	00:00:00	5520.0000

Number of Points: 1476

Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 247.36$ m

Mean = 718.03 m

Maximum $Z_{12} = 901.56$ m Standard Deviation = 119.94 m

Table 17: **Site and Record Information for****IES90G1**

Serial Number: 036
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: None

POSITION: 38°37.63 N DEPTH: 4245 m
 69°25.39 W

	DATE	UT	CRUISE
LAUNCH:	May 27, 1989	0811	OC207
RELEASE:	Aug 20, 1990	1622	EN216

TRAVEL TIME RECORDS

Figure 9.12 and 13.5

	DATE	UT	YEARHOUR
FIRST DATA POINT:	May 27, 1989	09:01:56	-5246.9678
LAST DATA POINT:	Aug 20, 1990	15:58:30	5559.9751

Number of Points: 21615
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.061845$ s Mean = 0.081119 s
 Maximum $\tau = 0.089505$ s Standard Deviation = 0.005441 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.5)

Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$
 where B = 1819.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	May 28, 1989	06:00:00	-5226.0000
LAST DATA POINT:	Aug 19, 1990	18:00:00	5538.0000

Number of Points: 1795
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 84.98$ m Mean = 213.09 m
 Maximum $Z_{12} = 581.99$ m Standard Deviation = 107.20 m

Table 18: **Site and Record Information for****PIES90G2**

Serial Number: 067
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: Pressure and Temperature
 Pressure Sensor Serial Number: 33824

POSITION: 37°47.80 N DEPTH: 4088 m
 69°24.23 W

	DATE	UT	CRUISE
LAUNCH:	Jun 5, 1989	2000	OC207
RELEASE:	Aug 20, 1990	0415	EN216

TRAVEL TIME RECORDS

Figure 9.13 and 13.5

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 5, 1989	21:16:56	-5018.7178
LAST DATA POINT:	Aug 20, 1990	04:19:01	5548.3169

Number of Points: 21135
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.187813$ s Mean = 0.205926 s
 Maximum $\tau = 0.227940$ s Standard Deviation = 0.010969 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.5)

Z_{12} Conversion equation: $Z_{12} = -19800\text{m s}^{-1} \cdot \tau_d + B$
 where B = 4553.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 6, 1989	18:00:00	-4998.0000
LAST DATA POINT:	Aug 19, 1990	06:00:00	5526.0000

Number of Points: 1755
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 67.26$ m Mean = 476.16 m
 Maximum $Z_{12} = 804.49$ m Standard Deviation = 216.61 m

PIES90G2 (continue)**MEASURED BOTTOM PRESSURE RECORDS**

Figure 10.1

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 5, 1989	21:29:49	-5018.5029
LAST DATA POINT:	Aug 20, 1990	04:01:56	5548.0322

Number of Points: 21134

Sampling Interval: 0.50 hrs

Minimum $P = 4140.46$ dbar

Mean = 4141.43 dbar

Maximum $P = 4142.08$ dbar Standard Deviation = 0.39 dbar**RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 12.1 and 14.1

$$P_{residual} = P_{measured} - MEAN - DRIFT - TIDE$$

$$DRIFT = 0.0 \text{ dbar}$$

TIDE were calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	0.42838	0.09871	0.09290	0.02197	0.08285	0.06433	0.02733	0.01379
G° :	352.382	331.741	20.558	21.956	177.199	182.775	177.755	183.096

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 6, 1989	09:29:49	-5006.5029
LAST DATA POINT:	Aug 20, 1990	04:01:56	5548.0322

Number of Points: 21110

Sampling Interval: 0.50 hrs

Minimum $P_{res} = -0.1439$ dbar

Mean = -0.0001 dbar

Maximum $P_{res} = 0.1597$ dbar Standard Deviation = 0.0514 dbar

PIES90G2 (continue)**40HRLP RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 17.1

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 7, 1989	06:00:00	-4986.0000
LAST DATA POINT:	Aug 19, 1990	06:00:00	5526.0000

Number of Points: 1753

Sampling Interval: 6.0 hrs

Minimum P = -0.1150 dbar

Mean = -0.0002 dbar

Maximum P = 0.1405 dbar

Standard Deviation = 0.0495 dbar

MEASURED BOTTOM TEMPERATURE RECORDS

Figure 11.1 and 15.1

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 5, 1989	21:44:20	-5018.2612
LAST DATA POINT:	Aug 20, 1990	04:16:26	5548.2739

Number of Points: 21134

Sampling Interval: 0.50 hrs

Minimum T = 2.40°C

Mean = 2.44 °C

Maximum T = 2.55°C

Standard Deviation = 0.01 °C

40HRLP BOTTOM TEMPERATURE RECORDS

Figure 18.1

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 7, 1989	06:00:00	-4986.0000
LAST DATA POINT:	Aug 19, 1990	06:00:00	5526.0000

Number of Points: 1753

Sampling Interval: 6.0 hrs

Minimum T = 2.407°C

Mean = 2.437 °C

Maximum T = 2.522°C

Standard Deviation = 0.012°C

Table 19: **Site and Record Information for****PIES90G3**

Serial Number: 055

Type of Travel Time Detector: TTC

Number of Pings per Sampling: 24

Additional Sensors: Pressure and Temperature

Pressure Sensor Serial Number: 36873

POSITION: 37°16.99 N DEPTH: 4358 m

69°14.71 W

	DATE	UT	CRUISE
LAUNCH:	May 29, 1989	0454	OC207
RELEASE:	Aug 19, 1990	0558	EN216

TRAVEL TIME RECORDS

Figure 9.14 and 13.5

	DATE	UT	YEARHOUR
FIRST DATA POINT:	May 29, 1989	06:01:51	-5201.9692
LAST DATA POINT:	Aug 19, 1990	08:28:23	5528.4731

Number of Points: 21462

Sampling Interval: 0.50 hrs

Minimum $\tau = 0.189146$ s

Mean = 0.201227 s

Maximum $\tau = 0.231113$ s Standard Deviation = 0.009407 s**40-HRLP THERMOCLINE DEPTH RECORDS**

(Figure 16.5)

 Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$

where B = 4664.00 m

 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	May 30, 1989	06:00:00	-5178.0000
LAST DATA POINT:	Aug 18, 1990	12:00:00	5508.0000

Number of Points: 1782

Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 132.06$ m

Mean = 679.79 m

Maximum $Z_{12} = 900.36$ m Standard Deviation = 185.95 m

PIES90G3 (continue)**MEASURED BOTTOM PRESSURE RECORDS**

Figure 10.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	May 29, 1989	05:59:56	-5202.0010
LAST DATA POINT:	Aug 19, 1990	08:26:27	5528.4409

Number of Points: 21462

Sampling Interval: 0.50 hrs

Minimum $P = 4459.33$ dbar

Mean = 4460.35 dbar

Maximum $P = 4461.25$ dbar Standard Deviation = 0.37 dbar**RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 12.2 and 14.1

$$P_{residual} = P_{measured} - MEAN - DRIFT - TIDE$$

$$DRIFT = Ae^{-\lambda t} + B$$

where $t =$ Time of sample in hours, starting with
 $t = 13.0$ hrs for the first data point

$$A = 0.201600 \text{ dbar}$$

$$\lambda = -0.000732 \text{ hr}^{-1}$$

$$B = -0.025723 \text{ dbar}$$

TIDE were calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	0.42800	0.09889	0.09261	0.02189	0.08155	0.06409	0.02687	0.01399
G° :	353.004	332.323	21.187	22.543	177.997	183.404	178.489	184.059

	DATE	UT	YEARHOUR
FIRST DATA POINT:	May 29, 1989	17:59:56	-5190.0010
LAST DATA POINT:	Aug 19, 1990	08:26:27	5528.4409

Number of Points: 21438

Sampling Interval: 0.50 hrs

Minimum $P_{res} = -0.1982$ dbar

Mean = 0.0000 dbar

Maximum $P_{res} = 0.2007$ dbar Standard Deviation = 0.0553 dbar

PIES90G3 (continue)**40HRLP RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 17.1

	DATE	UT	YEARHOUR
FIRST DATA POINT:	May 30, 1989	18:00:00	-5166.0000
LAST DATA POINT:	Aug 18, 1990	12:00:00	5508.0000

Number of Points: 1780

Sampling Interval: 6.0 hrs

Minimum $P = -0.1778$ dbarMean = -0.0003 dbarMaximum $P = 0.1788$ dbar Standard Deviation = 0.0536 dbar**MEASURED BOTTOM TEMPERATURE RECORDS**

Figure 11.2 and 15.1

	DATE	UT	YEARHOUR
FIRST DATA POINT:	May 29, 1989	06:00:00	-5202.0000
LAST DATA POINT:	Aug 19, 1990	08:26:34	5528.4429

Number of Points: 21462

Sampling Interval: 0.50 hrs

Minimum $T = 2.31^{\circ}\text{C}$ Mean = 2.36°C Maximum $T = 7.58^{\circ}\text{C}$ Standard Deviation = 0.04°C

Table 20: **Site and Record Information for****IES90G4**

Serial Number: 076

Type of Travel Time Detector: TTC

Number of Pings per Sampling: 24

Additional Sensors: None

POSITION: 36°33.00 N DEPTH: 4680 m
 68°39.96 W

	DATE	UT	CRUISE
LAUNCH:	Jun 17, 1989	1108	OC207
RELEASE:	Aug 9, 1990	0705	EN216

TRAVEL TIME RECORDS

Figure 9.15 and 13.5

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 17, 1989	12:12:18	-4739.7949
LAST DATA POINT:	Aug 9, 1990	06:42:18	5286.7051

Number of Points: 20054

Sampling Interval: 0.50 hrs

Minimum $\tau = 0.237753$ s Mean = 0.250853 sMaximum $\tau = 0.278210$ s Standard Deviation = 0.007649 s**40-HRLP THERMOCLINE DEPTH RECORDS**

(Figure 16.5)

 Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$

where B = 5727.00 m

 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 18, 1989	12:00:00	-4716.0000
LAST DATA POINT:	Aug 8, 1990	06:00:00	5262.0000

Number of Points: 1664

Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 245.96$ m Mean = 759.87 mMaximum $Z_{12} = 992.26$ m Standard Deviation = 150.90 m

Table 21: **Site and Record Information for****IES90H1**

Serial Number: 044
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: None

POSITION: 38°59.85 N DEPTH: 3255 m
 68°39.92 W

	DATE	UT	CRUISE
LAUNCH:	Jun 2, 1989	0513	OC207
RELEASE:	Aug 15, 1990	0810	EN216

TRAVEL TIME RECORDS

Figure 9.16 and 13.6

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 2, 1989	06:02:00	-5105.9668
LAST DATA POINT:	Aug 15, 1990	07:58:30	5431.9751

Number of Points: 21077
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.321447$ s Mean = 0.341838 s
 Maximum $\tau = 0.351372$ s Standard Deviation = 0.006499 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.6)

Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$
 where B = 7020.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 3, 1989	06:00:00	-5082.0000
LAST DATA POINT:	Aug 14, 1990	06:00:00	5406.0000

Number of Points: 1749
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 92.06$ m Mean = 251.90 m
 Maximum $Z_{12} = 625.19$ m Standard Deviation = 128.41 m

Table 22: **Site and Record Information for
PIES90H2**

Serial Number: 071
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: Pressure and Temperature
 Pressure Sensor Serial Number: 31724

POSITION: 38°37.78 N DEPTH: 3458 m
 68°54.90 W

	DATE	UT	CRUISE
LAUNCH:	Aug 15, 1989	1217	OC210
RELEASE:	Aug 11, 1990	0709	EN216

TRAVEL TIME RECORDS

Figure 9.17 and 13.6

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 15, 1989	13:32:21	-3322.4609
LAST DATA POINT:	Aug 11, 1990	07:02:21	5335.0391

Number of Points: 17316
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.193065$ s Mean = 0.214549 s
 Maximum $\tau = 0.225445$ s Standard Deviation = 0.006998 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.6)

Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$
 where B = 4453.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 16, 1989	12:00:00	-3300.0000
LAST DATA POINT:	Aug 10, 1990	06:00:00	5310.0000

Number of Points: 1436
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 1.80$ m Mean = 204.38 m
 Maximum $Z_{12} = 601.39$ m Standard Deviation = 137.62 m

PIES90H2 (continue)**MEASURED BOTTOM PRESSURE RECORDS**

Figure 10.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 15, 1989	13:45:14	-3322.2461
LAST DATA POINT:	Aug 11, 1990	06:45:14	5334.7539

Number of Points: 17315

Sampling Interval: 0.50 hrs

Minimum $P = 3514.75$ dbar

Mean = 3515.81 dbar

Maximum $P = 3516.38$ dbar Standard Deviation = 0.49 dbar**RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 12.3 and 14.2

$$P_{residual} = P_{measured} - MEAN - DRIFT - TIDE$$

$$DRIFT = 0.0 \text{ dbar}$$

TIDE were calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	0.42338	0.09771	0.09392	0.02234	0.08233	0.06376	0.02717	0.01356
G° :	352.406	331.618	19.942	21.067	176.062	181.702	176.696	181.465

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 16, 1989	01:45:14	-3310.2461
LAST DATA POINT:	Aug 11, 1990	06:45:14	5334.7539

Number of Points: 17291

Sampling Interval: 0.50 hrs

Minimum $P_{res} = -0.1332$ dbar

Mean = -0.0001 dbar

Maximum $P_{res} = 0.1678$ dbar Standard Deviation = 0.0437 dbar

PIES90H2 (continue)**40HRLP RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 17.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 17, 1989	00:00:00	-3288.0000
LAST DATA POINT:	Aug 10, 1990	06:00:00	5310.0000

Number of Points: 1434

Sampling Interval: 6.0 hrs

Minimum P = -0.1035 dbar

Mean = -0.0001 dbar

Maximum P = 0.1489 dbar Standard Deviation = 0.0417 dbar**MEASURED BOTTOM TEMPERATURE RECORDS**

Figure 11.3 and 15.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 15, 1989	13:59:46	-3322.0039
LAST DATA POINT:	Aug 11, 1990	06:59:46	5334.9961

Number of Points: 17315

Sampling Interval: 0.50 hrs

Minimum T = 2.28°C

Mean = 2.38 °C

Maximum T = 2.60°C Standard Deviation = 0.05 °C**40HRLP BOTTOM TEMPERATURE RECORDS**

Figure 18.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 17, 1989	00:00:00	-3288.0000
LAST DATA POINT:	Aug 10, 1990	06:00:00	5310.0000

Number of Points: 1434

Sampling Interval: 6.0 hrs

Minimum T = 2.279°C

Mean = 2.378 °C

Maximum T = 2.542°C Standard Deviation = 0.049°C

Table 23: **Site and Record Information for****PIES90H3**

Serial Number: 053
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: Pressure and Temperature
 Pressure Sensor Serial Number: 19327

POSITION: 38°10.09 N DEPTH: 4025 m
 68°43.65 W

	DATE	UT	CRUISE
LAUNCH:	Aug 15, 1989	1632	OC210
RELEASE:	Aug 15, 1990	2018	EN216

TRAVEL TIME RECORDS

Figure 9.18 and 13.6

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 15, 1989	17:31:30	-3318.4751
LAST DATA POINT:	Aug 15, 1990	20:01:30	5444.0249

Number of Points: 17526
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.137551$ s Mean = 0.158885 s
 Maximum $\tau = 0.175709$ s Standard Deviation = 0.011610 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.6)

Z_{12} Conversion equation: $Z_{12} = -19800\text{m s}^{-1} \cdot \tau_d + B$
 where B = 3549.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 16, 1989	18:00:00	-3294.0000
LAST DATA POINT:	Aug 15, 1990	00:00:00	5424.0000

Number of Points: 1454
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 93.85$ m Mean = 403.45 m
 Maximum $Z_{12} = 797.77$ m Standard Deviation = 229.79 m

PIES90H3 (continue)**MEASURED BOTTOM PRESSURE RECORDS**

Figure 10.4

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 15, 1989	17:29:35	-3318.5071
LAST DATA POINT:	Aug 15, 1990	19:59:35	5443.9932

Number of Points: 17526

Sampling Interval: 0.50 hrs

Minimum $P = 4096.90$ dbar Mean = 4097.36 dbarMaximum $P = 4098.58$ dbar Standard Deviation = 0.48 dbar**RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 12.4 and 14.2

$$P_{residual} = P_{measured} - MEAN - DRIFT - TIDE$$

$$DRIFT = 0.0 \text{ dbar}$$

TIDE were calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	0.42509	0.09856	0.09409	0.02238	0.08186	0.06349	0.02701	0.01354
G° :	352.763	331.883	20.636	21.775	176.398	182.127	177.095	181.441

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 16, 1989	05:29:35	-3306.5071
LAST DATA POINT:	Aug 15, 1990	19:59:35	5443.9932

Number of Points: 17502

Sampling Interval: 0.50 hrs

Minimum $P_{res} = -0.2073$ dbar Mean = 0.0001 dbarMaximum $P_{res} = 0.1719$ dbar Standard Deviation = 0.0701 dbar

PIES90H3 (continue)**40HRLP RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 17.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 17, 1989	06:00:00	-3282.0000
LAST DATA POINT:	Aug 14, 1990	18:00:00	5418.0000

Number of Points: 1451

Sampling Interval: 6.0 hrs

Minimum P = -0.1829 dbar

Mean = 0.0001 dbar

Maximum P = 0.1545 dbar Standard Deviation = 0.0685 dbar**MEASURED BOTTOM TEMPERATURE RECORDS**

Figure 11.4 and 15.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 15, 1989	17:29:35	-3318.5071
LAST DATA POINT:	Aug 15, 1990	19:59:35	5443.9932

Number of Points: 17526

Sampling Interval: 0.50 hrs

Minimum T = 2.15°C

Mean = 2.18 °C

Maximum T = 2.34°C Standard Deviation = 0.02 °C**40HRLP BOTTOM TEMPERATURE RECORDS**

Figure 18.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 17, 1989	06:00:00	-3282.0000
LAST DATA POINT:	Aug 14, 1990	18:00:00	5418.0000

Number of Points: 1451

Sampling Interval: 6.0 hrs

Minimum T = 2.149°C

Mean = 2.183 °C

Maximum T = 2.321°C Standard Deviation = 0.022°C

Table 24: **Site and Record Information for****PIES90H4**

Serial Number: 065
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: Pressure and Temperature
 Pressure Sensor Serial Number: 28197

POSITION: 37°39.57 N DEPTH: 4445 m
 68°35.35 W

	DATE	UT	CRUISE
LAUNCH:	Aug 15, 1989	2021	OC210
RELEASE:	Aug 18, 1990	0426	EN216

TRAVEL TIME RECORDS

Figure 9.19 and 13.6

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 15, 1989	21:32:10	-3314.4641
LAST DATA POINT:	Aug 18, 1990	04:02:10	5500.0361

Number of Points: 17630
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.303573$ s Mean = 0.319818 s
 Maximum $\tau = 0.346525$ s Standard Deviation = 0.012155 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.6)

Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$
 where B = 6947.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 16, 1989	18:00:00	-3294.0000
LAST DATA POINT:	Aug 17, 1990	06:00:00	5478.0000

Number of Points: 1463
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 107.79$ m Mean = 615.00 m
 Maximum $Z_{12} = 913.28$ m Standard Deviation = 239.96 m

PIES90H4 (continue)**MEASURED BOTTOM PRESSURE RECORDS**

Figure 10.5

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 15, 1989	21:45:04	-3314.2490
LAST DATA POINT:	Aug 18, 1990	04:15:04	5500.2510

Number of Points: 17630
Sampling Interval: 0.50 hrs

Minimum $P = 4552.16$ dbar Mean = 4552.39 dbar
Maximum $P = 4553.91$ dbar Standard Deviation = 0.63 dbar

RESIDUAL BOTTOM PRESSURE RECORDS

Figure 12.5 and 14.2

$$P_{residual} = P_{measured} - MEAN - DRIFT - TIDE$$

$$DRIFT = 0.0 \text{ dbar}$$

TIDE were calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	0.42565	0.09851	0.09421	0.02241	0.08102	0.06296	0.02673	0.01344
G° :	352.826	331.998	20.985	22.243	177.061	182.963	177.736	182.615

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 16, 1989	09:45:04	-3302.2490
LAST DATA POINT:	Aug 18, 1990	04:15:04	5500.2510

Number of Points: 17606
Sampling Interval: 0.50 hrs

Minimum $P_{res} = -0.2227$ dbar Mean = 0.0001 dbar
Maximum $P_{res} = 0.2597$ dbar Standard Deviation = 0.0600 dbar

PIES90H4 (continue)**40HRLP RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 17.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 17, 1989	06:00:00	-3282.0000
LAST DATA POINT:	Aug 17, 1990	06:00:00	5478.0000

Number of Points: 1461

Sampling Interval: 6.0 hrs

Minimum $P = -0.2101$ dbar

Mean = 0.0003 dbar

Maximum $P = 0.2090$ dbar

Standard Deviation = 0.0584 dbar

MEASURED BOTTOM TEMPERATURE RECORDS

Figure 11.5 and 15.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 15, 1989	21:59:35	-3314.0071
LAST DATA POINT:	Aug 18, 1990	04:29:35	5500.4932

Number of Points: 17630

Sampling Interval: 0.50 hrs

Minimum $T = 2.26^{\circ}\text{C}$ Mean = 2.33 $^{\circ}\text{C}$ Maximum $T = 2.46^{\circ}\text{C}$ Standard Deviation = 0.02 $^{\circ}\text{C}$ **40HRLP BOTTOM TEMPERATURE RECORDS**

Figure 18.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 17, 1989	06:00:00	-3282.0000
LAST DATA POINT:	Aug 17, 1990	06:00:00	5478.0000

Number of Points: 1461

Sampling Interval: 6.0 hrs

Minimum $T = 2.257^{\circ}\text{C}$ Mean = 2.326 $^{\circ}\text{C}$ Maximum $T = 2.376^{\circ}\text{C}$ Standard Deviation = 0.014 $^{\circ}\text{C}$

Table 25: **Site and Record Information for****PIES90H5**

Serial Number: 054
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: Pressure and Temperature
 Pressure Sensor Serial Number: 17849

POSITION: 37°10.23 N DEPTH: 4800 m
 68°17.83 W

	DATE	UT	CRUISE
LAUNCH:	Aug 14, 1989	1954	OC210
RELEASE:	Aug 17, 1990	2330	EN216

TRAVEL TIME RECORDS

Figure 9.20 and 13.6

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Nov 25, 1989	04:31:12	-883.4800
LAST DATA POINT:	Aug 17, 1990	22:29:20	5494.4888

Number of Points: 12757
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.390364$ s Mean = 0.401428 s
 Maximum $\tau = 0.431109$ s Standard Deviation = 0.008534 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.6)

Z_{12} Conversion equation: $Z_{12} = -19800\text{m s}^{-1} \cdot \tau_d + B$
 where B = 8654.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Nov 26, 1989	06:00:00	-858.0000
LAST DATA POINT:	Aug 17, 1990	00:00:00	5472.0000

Number of Points: 1056
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 156.41$ m Mean = 704.94 m
 Maximum $Z_{12} = 896.81$ m Standard Deviation = 168.33 m

PIES90H5 (continue)**MEASURED BOTTOM PRESSURE RECORDS**

Figure 10.6

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 14, 1989	21:30:00	-3338.5000
LAST DATA POINT:	Aug 17, 1990	23:27:25	5495.4570

Number of Points: 17669

Sampling Interval: 0.50 hrs

Minimum $P = 4936.24$ dbar Mean = 4936.49 dbarMaximum $P = 4938.11$ dbar Standard Deviation = 0.76 dbar**RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 12.6 and 14.2

$$P_{residual} = P_{measured} - MEAN - DRIFT - TIDE$$

$$DRIFT = 0.0 \text{ dbar}$$

TIDE were calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	0.42305	0.09753	0.09398	0.02236	0.07963	0.06204	0.02626	0.01333
G° :	353.125	332.212	21.364	22.676	177.468	183.397	178.104	183.380

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 15, 1989	09:30:00	-3326.5000
LAST DATA POINT:	Aug 17, 1990	23:27:25	5495.4570

Number of Points: 17645

Sampling Interval: 0.50 hrs

Minimum $P_{res} = -0.3459$ dbar Mean = 0.0002 dbarMaximum $P_{res} = 0.2349$ dbar Standard Deviation = 0.0942 dbar

PIES90H5 (continue)**40HRLP RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 17.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 16, 1989	06:00:00	-3306.0000
LAST DATA POINT:	Aug 17, 1990	00:00:00	5472.0000

Number of Points: 1464

Sampling Interval: 6.0 hrs

Minimum P = -0.3359 dbar

Mean = 0.0002 dbar

Maximum P = 0.1818 dbar Standard Deviation = 0.0930 dbar**MEASURED BOTTOM TEMPERATURE RECORDS**

Figure 11.6 and 15.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 14, 1989	21:30:00	-3338.5000
LAST DATA POINT:	Aug 17, 1990	23:27:25	5495.4570

Number of Points: 17669

Sampling Interval: 0.50 hrs

Minimum T = 2.27°C

Mean = 2.32 °C

Maximum T = 2.40°C Standard Deviation = 0.02 °C**40HRLP BOTTOM TEMPERATURE RECORDS**

Figure 18.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 16, 1989	06:00:00	-3306.0000
LAST DATA POINT:	Aug 17, 1990	00:00:00	5472.0000

Number of Points: 1464

Sampling Interval: 6.0 hrs

Minimum T = 2.275°C

Mean = 2.323 °C

Maximum T = 2.368°C Standard Deviation = 0.016°C

Table 26: **Site and Record Information for
PIES90H6**

Serial Number: 066
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: Pressure and Temperature
 Pressure Sensor Serial Number: 31162

POSITION: 36°39.35 N DEPTH: 4840 m
 68°15.10 W

	DATE	UT	CRUISE
LAUNCH:	Jun 4, 1989	0110	OC207
RELEASE:	Aug 9, 1990	1130	EN216

TRAVEL TIME RECORDS

Figure 9.21 and 13.6

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 4, 1989	02:51:36	-5061.1401
LAST DATA POINT:	Aug 9, 1990	11:21:36	5291.3599

Number of Points: 20706
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.060276$ s Mean = 0.078516 s
 Maximum $\tau = 0.110328$ s Standard Deviation = 0.011145 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.6)

Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$
 where B = 2190.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 5, 1989	00:00:00	-5040.0000
LAST DATA POINT:	Aug 8, 1990	12:00:00	5268.0000

Number of Points: 1719
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 58.30$ m Mean = 635.06 m
 Maximum $Z_{12} = 955.40$ m Standard Deviation = 219.98 m

PIES90H6 (continue)**MEASURED BOTTOM PRESSURE RECORDS**

Figure 10.7

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 4, 1989	03:04:31	-5060.9248
LAST DATA POINT:	Aug 9, 1990	11:04:31	5291.0752

Number of Points: 20705

Sampling Interval: 0.50 hrs

Minimum $P = 4995.03$ dbar

Mean = 4996.47 dbar

Maximum $P = 4997.08$ dbar Standard Deviation = 0.47 dbar**RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 12.7 and 14.2

$$P_{residual} = P_{measured} - MEAN - DRIFT - TIDE$$

$$DRIFT = Ae^{-\lambda t} + B$$

where $t =$ Time of sample in hours, starting with
 $t = 13.0$ hrs for the first data point

$$A = -0.445700 \text{ dbar}$$

$$\lambda = -0.000573 \text{ hr}^{-1}$$

$$B = 0.075302 \text{ dbar}$$

TIDE were calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	0.42197	0.09695	0.09312	0.02209	0.07906	0.06199	0.02606	0.01348
G° :	352.959	332.030	21.280	22.672	177.679	183.525	178.274	183.730

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 4, 1989	15:04:31	-5048.9248
LAST DATA POINT:	Aug 9, 1990	11:04:31	5291.0752

Number of Points: 20681

Sampling Interval: 0.50 hrs

Minimum $P_{res} = -0.2270$ dbar

Mean = 0.0000 dbar

Maximum $P_{res} = 0.2173$ dbar Standard Deviation = 0.0807 dbar

PIES90H6 (continue)**40HRLP RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 17.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 5, 1989	12:00:00	-5028.0000
LAST DATA POINT:	Aug 8, 1990	12:00:00	5268.0000

Number of Points: 1717

Sampling Interval: 6.0 hrs

Minimum $P = -0.2123$ dbar

Mean = -0.0001 dbar

Maximum $P = 0.1952$ dbar Standard Deviation = 0.0798 dbar**MEASURED BOTTOM TEMPERATURE RECORDS**

Figure 11.7 and 15.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 4, 1989	03:19:01	-5060.6831
LAST DATA POINT:	Aug 9, 1990	11:49:01	5291.8169

Number of Points: 20706

Sampling Interval: 0.50 hrs

Minimum $T = 2.52^{\circ}\text{C}$ Mean = 2.58°C Maximum $T = 2.70^{\circ}\text{C}$ Standard Deviation = 0.02°C **40HRLP BOTTOM TEMPERATURE RECORDS**

Figure 18.2

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 5, 1989	12:00:00	-5028.0000
LAST DATA POINT:	Aug 8, 1990	12:00:00	5268.0000

Number of Points: 1717

Sampling Interval: 6.0 hrs

Minimum $T = 2.527^{\circ}\text{C}$ Mean = 2.583°C Maximum $T = 2.624^{\circ}\text{C}$ Standard Deviation = 0.016°C

Table 27: **Site and Record Information for****IES90H7**

Serial Number: 058
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: None

POSITION: 36°24.92 N DEPTH: 4910 m
 68°47.81 W

	DATE	UT	CRUISE
LAUNCH:	Aug 16, 1989	1503	OC210
RELEASE:	Aug 9, 1990	0038	EN216

TRAVEL TIME RECORDS

Figure 9.22 and 13.6

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 16, 1989	16:01:45	-3295.9709
LAST DATA POINT:	Aug 9, 1990	00:01:44	5280.0288

Number of Points: 17153
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.109349$ s Mean = 0.122997 s
 Maximum $\tau = 0.151765$ s Standard Deviation = 0.009359 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.6)

Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$
 where B = 3173.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Aug 17, 1989	18:00:00	-3270.0000
LAST DATA POINT:	Aug 8, 1990	00:00:00	5256.0000

Number of Points: 1422
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 184.38$ m Mean = 738.88 m
 Maximum $Z_{12} = 982.62$ m Standard Deviation = 183.18 m

Table 28: **Site and Record Information for
PIES90I1**

Serial Number: 081
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: Pressure and Temperature
 Pressure Sensor Serial Number: 36883

POSITION: 38°47.58 N DEPTH: 3828 m
 68°06.25 W

	DATE	UT	CRUISE
LAUNCH:	May 30, 1989	1954	OC207
RELEASE:	Aug 17, 1990	0732	EN216

TRAVEL TIME RECORDS

Figure 9.23 and 13.7

	DATE	UT	YEARHOUR
FIRST DATA POINT:	May 30, 1989	21:01:56	-5162.9678
LAST DATA POINT:	Jul 30, 1989	23:31:30	-3696.4751

Number of Points: 2934
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.277595$ s Mean = 0.296853 s
 Maximum $\tau = 0.307861$ s Standard Deviation = 0.007941 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.7)

Z_{12} Conversion equation: $Z_{12} = -19800\text{m s}^{-1} \cdot \tau_d + B$
 where B = 6127.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	May 31, 1989	18:00:00	-5142.0000
LAST DATA POINT:	Jul 30, 1989	00:00:00	-3720.0000

Number of Points: 238
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 69.46$ m Mean = 250.08 m
 Maximum $Z_{12} = 601.15$ m Standard Deviation = 157.98 m

PIES90I1 (continue)**MEASURED BOTTOM PRESSURE RECORDS**

Figure 10.8

	DATE	UT	YEARHOUR
FIRST DATA POINT:	May 30, 1989	21:14:49	-5162.7529
LAST DATA POINT:	Aug 17, 1990	07:41:38	5479.6938

Number of Points: 21286

Sampling Interval: 0.50 hrs

Minimum $P = 3887.99$ dbar

Mean = 3888.26 dbar

Maximum $P = 3889.67$ dbar Standard Deviation = 0.55 dbar**RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 12.8 and 14.3

$$P_{residual} = P_{measured} - MEAN - DRIFT - TIDE$$

$$DRIFT = 0.0 \text{ dbar}$$

TIDE were calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	0.42348	0.09758	0.09411	0.02241	0.08123	0.06264	0.02676	0.01348
G° :	352.533	331.873	20.573	21.886	175.024	181.058	175.592	181.644

	DATE	UT	YEARHOUR
FIRST DATA POINT:	May 31, 1989	09:14:49	-5150.7529
LAST DATA POINT:	Aug 17, 1990	07:41:38	5479.6938

Number of Points: 21262

Sampling Interval: 0.50 hrs

Minimum $P_{res} = -0.1615$ dbar

Mean = -0.0002 dbar

Maximum $P_{res} = 0.1838$ dbar Standard Deviation = 0.0602 dbar

PIES90I1 (continue)**40HRLP RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 17.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 1, 1989	06:00:00	-5130.0000
LAST DATA POINT:	Aug 16, 1990	06:00:00	5454.0000

Number of Points: 1765

Sampling Interval: 6.0 hrs

Minimum P = -0.1368 dbar

Mean = -0.0004 dbar

Maximum P = 0.1615 dbar Standard Deviation = 0.0585 dbar**MEASURED BOTTOM TEMPERATURE RECORDS**

Figure 11.8 and 15.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	May 30, 1989	21:29:20	-5162.5112
LAST DATA POINT:	Aug 17, 1990	07:56:10	5479.9360

Number of Points: 21286

Sampling Interval: 0.50 hrs

Minimum T = 2.34°C

Mean = 2.40 °C

Maximum T = 2.60°C Standard Deviation = 0.03 °C**40HRLP BOTTOM TEMPERATURE RECORDS**

Figure 18.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 1, 1989	06:00:00	-5130.0000
LAST DATA POINT:	Aug 16, 1990	06:00:00	5454.0000

Number of Points: 1765

Sampling Interval: 6.0 hrs

Minimum T = 2.349°C

Mean = 2.395 °C

Maximum T = 2.543°C Standard Deviation = 0.026°C

Table 29: **Site and Record Information for****PIES90I2**

Serial Number: 069

Type of Travel Time Detector: TTC

Number of Pings per Sampling: 24

Additional Sensors: Pressure and Temperature

Pressure Sensor Serial Number: 33816

POSITION: 38°47.68 N DEPTH: 4270 m
67°58.71 W

	DATE	UT	CRUISE
LAUNCH:	Jun 1, 1989	0256	OC207
RELEASE:	Aug 16, 1990	0052	EN216

TRAVEL TIME RECORDS

Figure 9.24 and 13.7

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 1, 1989	04:17:21	-5131.7109
LAST DATA POINT:	Aug 16, 1990	00:47:21	5448.7891

Number of Points: 21162

Sampling Interval: 0.50 hrs

Minimum $\tau = 0.054405$ s

Mean = 0.079046 s

Maximum $\tau = 0.093998$ s Standard Deviation = 0.010661 s**40-HRLP THERMOCLINE DEPTH RECORDS**

(Figure 16.7)

 Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$

where B = 1900.00 m

 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 2, 1989	06:00:00	-5106.0000
LAST DATA POINT:	Aug 15, 1990	00:00:00	5424.0000

Number of Points: 1756

Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 78.68$ m

Mean = 334.86 m

Maximum $Z_{12} = 799.37$ m Standard Deviation = 210.46 m

PIES90I2 (continue)**MEASURED BOTTOM PRESSURE RECORDS**

Figure 10.9

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 1, 1989	04:30:14	-5131.4961
LAST DATA POINT:	Aug 16, 1990	01:00:14	5449.0039

Number of Points: 21162

Sampling Interval: 0.50 hrs

Minimum $P = 4349.92$ dbar Mean = 4351.43 dbarMaximum $P = 4351.52$ dbar Standard Deviation = 0.87 dbar**RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 12.9 and 14.3

$$P_{residual} = P_{measured} - MEAN - DRIFT - TIDE$$

$$DRIFT = 0.0 \text{ dbar}$$

TIDE were calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	0.42412	0.09766	0.09436	0.02243	0.08028	0.06215	0.02647	0.01332
G° :	353.181	332.054	21.272	22.512	175.887	181.844	176.407	182.789

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 1, 1989	16:30:14	-5119.4961
LAST DATA POINT:	Aug 16, 1990	01:00:14	5449.0039

Number of Points: 21138

Sampling Interval: 0.50 hrs

Minimum $P_{res} = -0.1413$ dbar Mean = -0.0002 dbarMaximum $P_{res} = 0.1275$ dbar Standard Deviation = 0.0393 dbar

PIES90I2 (continue)**40HRLP RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 17.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 2, 1989	18:00:00	-5094.0000
LAST DATA POINT:	Aug 15, 1990	00:00:00	5424.0000

Number of Points: 1754

Sampling Interval: 6.0 hrs

Minimum P = -0.0910 dbar

Mean = -0.0003 dbar

Maximum P = 0.1102 dbar Standard Deviation = 0.0371 dbar**MEASURED BOTTOM TEMPERATURE RECORDS**

Figure 11.9 and 15.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 1, 1989	04:44:49	-5131.2529
LAST DATA POINT:	Aug 16, 1990	01:14:49	5449.2471

Number of Points: 21162

Sampling Interval: 0.50 hrs

Minimum T = 2.54°C

Mean = 2.60 °C

Maximum T = 2.70°C Standard Deviation = 0.01 °C**40HRLP BOTTOM TEMPERATURE RECORDS**

Figure 18.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 2, 1989	18:00:00	-5094.0000
LAST DATA POINT:	Aug 15, 1990	00:00:00	5424.0000

Number of Points: 1754

Sampling Interval: 6.0 hrs

Minimum T = 2.550°C

Mean = 2.596 °C

Maximum T = 2.643°C Standard Deviation = 0.012°C

Table 30: **Site and Record Information for
PIES90I3**

Serial Number: 073
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: Pressure and Temperature
 Pressure Sensor Serial Number: 31694

POSITION: 37°47.61 N DEPTH: 4610 m
 67°58.85 W

	DATE	UT	CRUISE
LAUNCH:	Jun 6, 1989	0410	OC207
RELEASE:	Aug 10, 1990	2042	EN216

TRAVEL TIME RECORDS

Figure 9.25 and 13.7

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 6, 1989	05:22:30	-5010.6250
LAST DATA POINT:	Aug 10, 1990	19:52:30	5323.8750

Number of Points: 20670
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.115788$ s Mean = 0.137739 s
 Maximum $\tau = 0.158726$ s Standard Deviation = 0.013645 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.7)

Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$
 where B = 3176.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 7, 1989	06:00:00	-4986.0000
LAST DATA POINT:	Aug 9, 1990	18:00:00	5298.0000

Number of Points: 1715
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 72.98$ m Mean = 448.59 m
 Maximum $Z_{12} = 861.44$ m Standard Deviation = 269.37 m

PIES90I3 (continue)**MEASURED BOTTOM PRESSURE RECORDS**

Figure 10.10

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 6, 1989	05:35:23	-5010.4102
LAST DATA POINT:	Aug 10, 1990	20:35:23	5324.5898

Number of Points: 20671

Sampling Interval: 0.50 hrs

Minimum $P = 4716.96$ dbar

Mean = 4718.36 dbar

Maximum $P = 4718.83$ dbar Standard Deviation = 0.63 dbar**RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 12.10 and 14.3

$$P_{residual} = P_{measured} - MEAN - DRIFT - TIDE$$

$$DRIFT = 0.0 \text{ dbar}$$

TIDE were calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	0.42437	0.09759	0.09419	0.02240	0.07966	0.06223	0.02623	0.01356
G° :	353.113	332.352	21.534	22.965	176.641	182.724	177.361	182.095

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 6, 1989	17:35:23	-4998.4102
LAST DATA POINT:	Aug 10, 1990	20:35:23	5324.5898

Number of Points: 20647

Sampling Interval: 0.50 hrs

Minimum $P_{res} = -0.2696$ dbar

Mean = 0.0001 dbar

Maximum $P_{res} = 0.2223$ dbar Standard Deviation = 0.0786 dbar

PIES90I3 (continue)**40HRLP RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 17.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 7, 1989	18:00:00	-4974.0000
LAST DATA POINT:	Aug 10, 1990	00:00:00	5304.0000

Number of Points: 1714

Sampling Interval: 6.0 hrs

Minimum $P = -0.2514$ dbar

Mean = 0.0002 dbar

Maximum $P = 0.2019$ dbar Standard Deviation = 0.0776 dbar**MEASURED BOTTOM TEMPERATURE RECORDS**

Figure 11.10 and 15.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 6, 1989	05:49:59	-5010.1670
LAST DATA POINT:	Aug 10, 1990	20:49:59	5324.8330

Number of Points: 20671

Sampling Interval: 0.50 hrs

Minimum $T = 2.40^{\circ}\text{C}$ Mean = 2.46 $^{\circ}\text{C}$ Maximum $T = 2.55^{\circ}\text{C}$ Standard Deviation = 0.02 $^{\circ}\text{C}$ **40HRLP BOTTOM TEMPERATURE RECORDS**

Figure 18.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 7, 1989	18:00:00	-4974.0000
LAST DATA POINT:	Aug 10, 1990	00:00:00	5304.0000

Number of Points: 1714

Sampling Interval: 6.0 hrs

Minimum $T = 2.401^{\circ}\text{C}$ Mean = 2.457 $^{\circ}\text{C}$ Maximum $T = 2.515^{\circ}\text{C}$ Standard Deviation = 0.015 $^{\circ}\text{C}$

Table 31: **Site and Record Information for****PIES90I4**

Serial Number: 075

Type of Travel Time Detector: TTC

Number of Pings per Sampling: 24

Additional Sensors: Pressure and Temperature

Pressure Sensor Serial Number: 36884

POSITION: 37°18.88 N DEPTH: 4765 m

67°39.58 W

	DATE	UT	CRUISE
LAUNCH:	Jun 16, 1989	1013	OC210
RELEASE:	Aug 16, 1990	2036	EN216

TRAVEL TIME RECORDS

Figure 9.26 and 13.7

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 16, 1989	11:32:14	-4764.4629
LAST DATA POINT:	Aug 16, 1990	20:32:14	5468.5371

Number of Points: 20467

Sampling Interval: 0.50 hrs

Minimum $\tau = 0.353622$ s

Mean = 0.374016 s

Maximum $\tau = 0.397889$ s Standard Deviation = 0.012177 s**40-HRLP THERMOCLINE DEPTH RECORDS**

(Figure 16.7)

 Z_{12} Conversion equation: $Z_{12} = -19800\text{m s}^{-1} \cdot \tau_d + B$

where B = 7941.00 m

 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 17, 1989	12:00:00	-4740.0000
LAST DATA POINT:	Aug 16, 1990	00:00:00	5448.0000

Number of Points: 1699

Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 101.14$ m

Mean = 535.40 m

Maximum $Z_{12} = 903.75$ m Standard Deviation = 240.24 m

PIES90I4 (continue)**MEASURED BOTTOM PRESSURE RECORDS**

Figure 10.11

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 16, 1989	11:45:07	-4764.2480
LAST DATA POINT:	Aug 16, 1990	20:45:07	5468.7520

Number of Points: 20467

Sampling Interval: 0.50 hrs

Minimum $P = 4906.13$ dbar

Mean = 4906.42 dbar

Maximum $P = 4908.15$ dbar

Standard Deviation = 0.79 dbar

RESIDUAL BOTTOM PRESSURE RECORDS

Figure 12.11 and 14.3

$$P_{residual} = P_{measured} - MEAN - DRIFT - TIDE$$

$$DRIFT = 0.0 \text{ dbar}$$

TIDE were calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	0.41827	0.09613	0.09358	0.02228	0.07726	0.06041	0.02543	0.01326
G° :	353.459	332.396	21.952	23.336	176.943	183.013	177.535	183.376

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 16, 1989	23:45:07	-4752.2480
LAST DATA POINT:	Aug 16, 1990	20:45:07	5468.7520

Number of Points: 20443

Sampling Interval: 0.50 hrs

Minimum $P_{res} = -0.4189$ dbar

Mean = -0.0001 dbar

Maximum $P_{res} = 0.2815$ dbar

Standard Deviation = 0.1120 dbar

PIES90I4 (continue)**40HRLP RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 17.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 18, 1989	00:00:00	-4728.0000
LAST DATA POINT:	Aug 16, 1990	00:00:00	5448.0000

Number of Points: 1697

Sampling Interval: 6.0 hrs

Minimum P = -0.4009 dbar

Mean = -0.0004 dbar

Maximum P = 0.2348 dbar

Standard Deviation = 0.1113 dbar

MEASURED BOTTOM TEMPERATURE RECORDS

Figure 11.11 and 15.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 16, 1989	11:59:39	-4764.0059
LAST DATA POINT:	Aug 16, 1990	20:59:39	5468.9941

Number of Points: 20467

Sampling Interval: 0.50 hrs

Minimum T = 2.39°C

Mean = 2.46 °C

Maximum T = 2.60°C

Standard Deviation = 0.02 °C

40HRLP BOTTOM TEMPERATURE RECORDS

Figure 18.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 18, 1989	00:00:00	-4728.0000
LAST DATA POINT:	Aug 16, 1990	00:00:00	5448.0000

Number of Points: 1697

Sampling Interval: 6.0 hrs

Minimum T = 2.396°C

Mean = 2.464 °C

Maximum T = 2.511°C

Standard Deviation = 0.018°C

Table 32: **Site and Record Information for
PIES90I5**

Serial Number: 072
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: Pressure and Temperature
 Pressure Sensor Serial Number: 33822

POSITION: 36°50.19 N DEPTH: 4975 m
 67°27.36 W

	DATE	UT	CRUISE
LAUNCH:	Jun 3, 1989	1054	OC207
RELEASE:	Aug 8, 1990	1859	EN216

TRAVEL TIME RECORDS

Figure 9.27 and 13.7

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 3, 1989	12:31:56	-5075.4678
LAST DATA POINT:	Aug 8, 1990	18:36:58	5274.6162

Number of Points: 20701
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.177081$ s Mean = 0.191169 s
 Maximum $\tau = 0.219416$ s Standard Deviation = 0.010848 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.7)

Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$
 where B = 4443.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 4, 1989	12:00:00	-5052.0000
LAST DATA POINT:	Aug 7, 1990	18:00:00	5250.0000

Number of Points: 1718
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 122.70$ m Mean = 658.37 m
 Maximum $Z_{12} = 914.87$ m Standard Deviation = 213.40 m

PIES90I5 (continue)**MEASURED BOTTOM PRESSURE RECORDS**

Figure 10.12

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 3, 1989	12:44:49	-5075.2529
LAST DATA POINT:	Aug 8, 1990	18:49:52	5274.8311

Number of Points: 20701

Sampling Interval: 0.50 hrs

Minimum $P = 5086.22$ dbar

Mean = 5087.70 dbar

Maximum $P = 5088.10$ dbar

Standard Deviation = 0.67 dbar

RESIDUAL BOTTOM PRESSURE RECORDS

Figure 12.12 and 14.3

$$P_{residual} = P_{measured} - MEAN - DRIFT - TIDE$$

$$DRIFT = A \cdot t + B$$

$$A = 0.000014 \text{ dbar hr}^{-1}$$

$$B = 0.001403 \text{ dbar}$$

TIDE were calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	0.42049	0.09622	0.09400	0.02235	0.07679	0.06014	0.02532	0.01299
G° :	353.777	332.699	22.203	23.627	177.665	183.916	178.333	183.918

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 4, 1989	00:44:49	-5063.2529
LAST DATA POINT:	Aug 8, 1990	18:49:52	5274.8311

Number of Points: 20677

Sampling Interval: 0.50 hrs

Minimum $P_{res} = -0.3731$ dbar

Mean = 0.0003 dbar

Maximum $P_{res} = 0.2395$ dbar

Standard Deviation = 0.1018 dbar

PIES90I5 (continue)**40HRLP RESIDUAL BOTTOM PRESSURE RECORDS**

Figure 17.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 5, 1989	00:00:00	-5040.0000
LAST DATA POINT:	Aug 7, 1990	18:00:00	5250.0000

Number of Points: 1716

Sampling Interval: 6.0 hrs

Minimum P = -0.3603 dbar

Mean = 0.0006 dbar

Maximum P = 0.2145 dbar Standard Deviation = 0.1010 dbar**MEASURED BOTTOM TEMPERATURE RECORDS**

Figure 11.12 and 15.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 3, 1989	12:59:20	-5075.0112
LAST DATA POINT:	Aug 8, 1990	19:04:24	5275.0732

Number of Points: 20701

Sampling Interval: 0.50 hrs

Minimum T = 2.60°C

Mean = 2.65 °C

Maximum T = 2.73°C Standard Deviation = 0.02 °C**40HRLP BOTTOM TEMPERATURE RECORDS**

Figure 18.3

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 5, 1989	00:00:00	-5040.0000
LAST DATA POINT:	Aug 7, 1990	18:00:00	5250.0000

Number of Points: 1716

Sampling Interval: 6.0 hrs

Minimum T = 2.603°C

Mean = 2.648 °C

Maximum T = 2.711°C Standard Deviation = 0.015°C

Table 33: **Site and Record Information for****IES90J1**

Serial Number: 045
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: None

POSITION: 39°10.05 N DEPTH: 3480 m
 67°47.20 W

	DATE	UT	CRUISE
LAUNCH:	May 31, 1989	0123	OC207
RELEASE:	Aug 12, 1990	0307	EN216

TRAVEL TIME RECORDS

Figure 9.28 and 13.8

	DATE	UT	YEARHOUR
FIRST DATA POINT:	May 31, 1989	02:31:56	-5157.4678
LAST DATA POINT:	Aug 12, 1990	02:57:18	5354.9551

Number of Points: 21026
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.229048$ s Mean = 0.249371 s
 Maximum $\tau = 0.257556$ s Standard Deviation = 0.005441 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.8)

Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$
 where B = 5160.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 1, 1989	00:00:00	-5136.0000
LAST DATA POINT:	Aug 11, 1990	06:00:00	5334.0000

Number of Points: 1746
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 82.39$ m Mean = 222.68 m
 Maximum $Z_{12} = 594.19$ m Standard Deviation = 107.17 m

Table 34: **Site and Record Information for
IES90J2**

Serial Number: 043
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: None

POSITION: 38°45.90 N DEPTH: 4270 m
 67°21.03 W

	DATE	UT	CRUISE
LAUNCH:	May 31, 1989	0700	OC207
RELEASE:	Aug 11, 1990	2205	EN216

TRAVEL TIME RECORDS

Figure 9.29 and 13.8

	DATE	UT	YEARHOUR
FIRST DATA POINT:	May 31, 1989	08:02:10	-5151.9639
LAST DATA POINT:	Aug 11, 1990	21:58:04	5349.9678

Number of Points: 21005
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.073001$ s Mean = 0.094565 s
 Maximum $\tau = 0.107382$ s Standard Deviation = 0.007816 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.8)

Z_{12} Conversion equation: $Z_{12} = -19800\text{m s}^{-1} \cdot \tau_d + B$
 where B = 2146.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 1, 1989	06:00:00	-5130.0000
LAST DATA POINT:	Aug 11, 1990	00:00:00	5328.0000

Number of Points: 1744
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 74.98$ m Mean = 273.81 m
 Maximum $Z_{12} = 681.40$ m Standard Deviation = 154.15 m

Table 35: **Site and Record Information for****IES90J3**

Serial Number: 030
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: None

POSITION: 38°09.69 N DEPTH: 4635 m
 67°10.37 W

	DATE	UT	CRUISE
LAUNCH:	Jun 7, 1989	0100	OC207
RELEASE:	Aug 10, 1990	0818	EN216

TRAVEL TIME RECORDS

Figure 9.30 and 13.8

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 7, 1989	02:31:56	-4989.4678
LAST DATA POINT:	Aug 10, 1990	07:56:45	5311.9458

Number of Points: 20604
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.131934$ s Mean = 0.153761 s
 Maximum $\tau = 0.171173$ s Standard Deviation = 0.012487 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.8)

Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$
 where B = 3468.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 8, 1989	00:00:00	-4968.0000
LAST DATA POINT:	Aug 9, 1990	06:00:00	5286.0000

Number of Points: 1710
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 101.72$ m Mean = 423.42 m
 Maximum $Z_{12} = 832.92$ m Standard Deviation = 247.43 m

Table 36: **Site and Record Information for****IES90J4**

Serial Number: 047

Type of Travel Time Detector: TTC

Number of Pings per Sampling: 24

Additional Sensors: None

POSITION: 37°38.77 N DEPTH: 4875 m
67°01.65 W

	DATE	UT	CRUISE
LAUNCH:	Jun 7, 1989	0934	OC207
RELEASE:	Aug 10, 1990	0208	EN216

TRAVEL TIME RECORDS

Figure 9.31 and 13.8

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 7, 1989	11:02:00	-4980.9668
LAST DATA POINT:	Aug 10, 1990	01:58:04	5305.9678

Number of Points: 20575

Sampling Interval: 0.50 hrs

Minimum $\tau = 0.062288$ s

Mean = 0.080319 s

Maximum $\tau = 0.103684$ s Standard Deviation = 0.011436 s**40-HRLP THERMOCLINE DEPTH RECORDS**

(Figure 16.8)

 Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$

where B = 2217.00 m

 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 8, 1989	12:00:00	-4956.0000
LAST DATA POINT:	Aug 9, 1990	00:00:00	5280.0000

Number of Points: 1707

Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 181.35$ m

Mean = 627.06 m

Maximum $Z_{12} = 958.69$ m Standard Deviation = 226.16 m

Table 37: **Site and Record Information for****IES90J5**

Serial Number: 040
 Type of Travel Time Detector: TTC
 Number of Pings per Sampling: 24
 Additional Sensors: None

POSITION: 37°00.68 N DEPTH: 4955 m
 66°57.86 W

	DATE	UT	CRUISE
LAUNCH:	Jun 16, 1989	0307	OC207
RELEASE:	Aug 8, 1990	0939	EN216

TRAVEL TIME RECORDS

Figure 9.32 and 13.8

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 16, 1989	04:31:56	-4771.4678
LAST DATA POINT:	Aug 8, 1990	09:28:55	5265.4819

Number of Points: 20075
 Sampling Interval: 0.50 hrs

Minimum $\tau = 0.203925$ s Mean = 0.214223 s
 Maximum $\tau = 0.243490$ s Standard Deviation = 0.008039 s

40-HRLP THERMOCLINE DEPTH RECORDS

(Figure 16.8)

Z_{12} Conversion equation: $Z_{12} = -19800 \text{ m s}^{-1} \cdot \tau_d + B$
 where B = 4947.00 m
 τ_d = Travel Time (sec) with tide removed

	DATE	UT	YEARHOUR
FIRST DATA POINT:	Jun 17, 1989	06:00:00	-4746.0000
LAST DATA POINT:	Aug 7, 1990	12:00:00	5244.0000

Number of Points: 1666
 Sampling Interval: 6.0 hrs

Minimum $Z_{12} = 149.83$ m Mean = 706.00 m
 Maximum $Z_{12} = 888.88$ m Standard Deviation = 158.78 m

3 Half-Hourly Individual Plots

Plots are presented for the individual time series of travel time, bottom pressure, residual bottom pressure (detided and dedrifted), and temperature. A nominal half-hourly sampling interval applies to all measurements.

The plots for each sensor are displayed in a standardized window. All sensors have a common time axis which starts at -5352 (23-May-1989 referenced to 1-Jan-1990) and extends to 6360 (23-Sep-1990 referenced to 1-Jan-1990). This time period is displayed in four panels, two per page. Each panel covers 2928 hr (one third of a leap year). A small tick is placed at each day (0000 UT) and larger ticks denote weeks (168 hr). All IES records in this report were encompassed by this period. For comparison, labels indicating specific dates are centered about their yearhour equivalents (for example a label associates “1-Jan-90” with 0.0 yearhour).

Vertical axes for each sensor will be either common or have a common increment. Travel time is plotted within a 50-msec window in increments of 5 msec. Pressure is plotted in a 2-dbar window centered about zero. The mean pressure was removed from the series for the purpose of plotting and its value is indicated in the y-axis label. After detiding and dedrifted, the residual bottom pressures are plotted within a 0.8 dbar window centered about zero. A 0.30° C window, adjusted vertically to enclose all the record’s variation, is used for each temperature record.

Figure 9.1: Half-Hourly Travel Times. IES90A1

Figure 9.2: Half-Hourly Travel Times. IES90A2

Figure 9.3: Half-Hourly Travel Times. IES90B1

Figure 9.4: Half-Hourly Travel Times. TIES90B3

Figure 9.5: Half-Hourly Travel Times. TIES90B4

Figure 9.6: Half-Hourly Travel Times. TIES90B5

Figure 9.7: Half-Hourly Travel Times. IES90C1

Figure 9.8: Half-Hourly Travel Times. TIES89C2

Figure 9.9: Half-Hourly Travel Times. TIES90C2

Figure 9.10: Half-Hourly Travel Times. IES90F1

Figure 9.13: Half-Hourly Travel Times. PIES90G2

Figure 9.14: Half-Hourly Travel Times. PIES90G3

Figure 9.17: Half-Hourly Travel Times. PIES90H2

Figure 9.19: Half-Hourly Travel Times. PIES90H4

Figure 9.20: Half-Hourly Travel Times. PIES90H5

Figure 9.21: Half-Hourly Travel Times. PIES90H6

Figure 9.23: Half-Hourly Travel Times. PIES90I1

Figure 9.24: Half-Hourly Travel Times. PIES90I2

Figure 9.25: Half-Hourly Travel Times. PIES90I3

Figure 9.26: Half-Hourly Travel Times. PIES90I4

Figure 9.27: Half-Hourly Travel Times. PIES90I5

Figure 9.28: Half-Hourly Travel Times. IES90J1

Figure 9.29: Half-Hourly Travel Times. IES90J2

Figure 9.30: Half-Hourly Travel Times. IES90J3

Figure 9.31: Half-Hourly Travel Times. IES90J4

Figure 9.32: Half-Hourly Travel Times. IES90j5

Figure 10.1: Half-Hourly Bottom Pressure. PIES90G2

Figure 10.2: Half-Hourly Bottom Pressure. PIES90G3

Figure 10.3: Half-Hourly Bottom Pressure. PIES90H2

Figure 10.4: Half-Hourly Bottom Pressure. PIES90H3

Figure 10.5: Half-Hourly Bottom Pressure. PIES90H4

Figure 10.6: Half-Hourly Bottom Pressure. PIES90H5

Figure 10.7: Half-Hourly Bottom Pressure. PIES90H6

Figure 10.8: Half-Hourly Bottom Pressure. PIES90I1

Figure 10.9: Half-Hourly Bottom Pressure. PIES90I2

Figure 10.10: Half-Hourly Bottom Pressure. PIES90I3

Figure 10.11: Half-Hourly Bottom Pressure. PIES90I4

Figure 10.12: Half-Hourly Bottom Pressure. PIES90I5

Figure 11.1: half-Hourly Temperature. PIES90G2

Figure 11.2: Half-Hourly Temperature. PIES90G3

Figure 11.3: Half-Hourly Temperature. PIES90H2

Figure 11.4: Half-Hourly Temperature. PIES90H3

Figure 11.5: Half-Hourly Temperature. PIES90H4

Figure 11.6: Half-Hourly Temperature. PIES90H5

Figure 11.7: Half-Hourly Temperature. PIES90H6

Figure 11.8: Half-Hourly Temperature. PIES90I1

Figure 11.9: Half-Hourly Temperature. PIES90I2

Figure 11.10: Half-Hourly Temperature. PIES90I3

Figure 11.11: Half-Hourly Temperature. PIES90I4

Figure 11.12: Half-Hourly Temperature. PIES90I5

Figure 12.1: Half-Hourly Residual Bottom Pressure. PIES90G2

Figure 12.2: Half-Hourly Residual Bottom Pressure. PIES90G3

Figure 12.3: Half-Hourly Residual Bottom Pressure. PIES90H2

Figure 12.4: Half-Hourly Residual Bottom Pressure. PIES90H3

Figure 12.5: Half-Hourly Residual Bottom Pressure. PIES90H4

Figure 12.6: Half-Hourly Residual Bottom Pressure. PIES90H5

Figure 12.7: Half-Hourly Residual Bottom Pressure. PIES90H6

Figure 12.8: Half-Hourly Residual Bottom Pressure. PIES90I1

Figure 12.9: Half-Hourly Residual Bottom Pressure. PIES90I2

Figure 12.10: Half-Hourly Residual Bottom Pressure. PIES90I3

Figure 12.11: Half-Hourly Residual Bottom Pressure. PIES90I4

Figure 12.12: Half-Hourly Residual Bottom Pressure. PIES90I5

4 Half-Hourly Line Plots

Line plots display all records from a given section across the Gulf Stream on a single page (with exception of the H-line τ_s which required two pages). Travel time, residual bottom pressure, and temperature are plotted in this section, grouped according to instrument lines, A, B, C, ..., etc. The time axis of all line plots extends from -6000 hr to 7000 hr in increments of 1000 hr. As with the individual plots, labels indicating specific dates are centered about their yearhour equivalents (for example a label associates “1-Jan-90” with 0.0 yearhour).

For the line plots of each variable, the vertical axes for all IESs have common increments.

The individual records that compose the line plots are labeled with the site at the right, centered within the record’s vertical axis. The records of travel time of TIES89C2 and TIES90C2 are plotted together in the same panel rather than separately. It was necessary to subtract an offset of $.13$ sec from TIES89C2 so that the records would form a continuous series and fit in the 50 -msec window. The offset was introduced because TIES90C2 was at a shallower bottom depth than TIES89C2.

Figure 13.1: Half-Hourly Travel Times. A line

Figure 13.2: Half-Hourly Travel Times. B line

Figure 13.3: Half-Hourly Travel Times. C line

Figure 13.4: Half-Hourly Travel Times. F line

Figure 13.5: Half-Hourly Travel Times. G line

Figure 13.6: Half-Hourly Travel Times. H line

Figure 13.7: Half-Hourly Travel Times. I line

Figure 13.8: Half-Hourly Travel Times. J line

Figure 14.1: Half-Hourly Residual Bottom Pressure. G line

Figure 14.2: Half-Hourly Residual Bottom Pressure. H line

Figure 14.3: Half-Hourly Residual Bottom Pressure. I line

Figure 15.1: Half-Hourly Temperature. G line

Figure 15.2: Half-Hourly Temperature. H line

Figure 15.3: Half-Hourly Temperature. I line

5 40HRLP Line Plots

Line plots display all records from a given section across the Gulf Stream on a single page (with exception of the H-line Z_{12} s which required two pages). 40HRLP thermocline depth, residual bottom pressure, and temperature are plotted in this section, grouped according to instrument lines, A, B, C, ..., etc. The time axis of all line plots extends from -6000 hr to 7000 hr in increments of 1000 hr. As with the individual plots, labels indicating specific dates are centered about their yearhour equivalents (for example a label associates “1-Jan-90” with 0.0 yearhour).

The vertical axis for all Z_{12} plots ranges from 1000m depth to the surface in increments of 100 m. Also as in the non-filtered plots (section 4), vertical axes have a common increment.

The individual records that compose the line plots are labeled with the site at the right, centered within the record’s vertical axis. TIES89C2 and TIES90C2 are plotted together in the same panel rather than separately.

Figure 16.1: 40HRLP $Z_{12}^s tar$. A line

Figure 16.3: 40HRLP $Z_{12}^s tar$. C line

Figure 16.4: 40HRLP $Z_{12}^s tar$. F line

Figure 16.5: 40HRLP $Z_{12}^s tar$. G line

Figure 16.6: 40HRLP $Z_{12}^s tar$. H line

Figure 16.7: 40HRLP $Z_{12}^s tar$. I line

Figure 16.8: 40HRLP $Z_{12}^s tar$. J line

Figure 17.1: 40HRLP Residual Bottom Pressure. G line

Figure 17.2: 40HRLP Residual Bottom Pressure. H line

Figure 17.3: 40HRLP Residual Bottom Pressure. I line

Figure 18.1: 40HRLP Temperature. G line

Figure 18.2: 40HRLP Temperature. H line

Figure 18.3: 40HRLP Temperature. I line

Acknowledgments

The SYNOP Experiment was supported by the Office of Naval Research under contract numbers N00014-90J-1568 and N00014-90J-1548 and the National Science Foundation under grant number OCE87-17144. We thank the crew of the R/V OCEANUS for their efforts during the deployment cruises, and the crew of R/V ENDEAVOR for the recovery cruise. The successful deployment and recovery of the inverted echo sounders is due to the instrument development and careful preparation done by Gerard Chaplin and Michael Mulroney. It is a pleasure to acknowledge their efforts.

REFERENCES

- Chaplin, G. and D. R. Watts. 1984. Inverted echo sounder development. *IEEE Oceans '84 Proceedings. 1*, 249-253.
- Munk, W. H. and D. E. Cartwright. 1977. Tidal spectroscopy and prediction. *Phil. Trans. Roy. Soc. London, 259*, 533-581.
- Press, W.H., B.P. Flannery, S.A. Teukolsky, and W.T. Vetterling. 1988. *Numerical Recipes* Cambridge University Press, New York.
- Rossby, T. 1969. On monitoring depth variations of the main thermocline acoustically. *J. Geophys. Res. 74*, 5542-5546.
- Fields E., K.L. Tracey, and D. R. Watts. 1991. Inverted echo sounder processing procedures. University of Rhode Island. GSO Technical Report (in preparation).
- Watts, D. R. and W. E. Johns. 1982. Gulf Stream meanders: observations on propagation and growth. *J. Geophys. Res. 87*, 9467-9476.
- Watts, D. R. and H. Kontoyiannis. 1986. Deep-ocean bottom pressure and temperature sensors report: methods and data. University of Rhode Island. GSO Technical Report 86-8, 111 pp.
- Watts, D. R. and H. Kontoyiannis. 1990. Deep-ocean bottom pressure measurements: Drift removal and performance, *J. Atmos. Ocean. Technol.*, 7, 296-306.
- Watts, D. R. and H. T. Rossby. 1977. Measuring dynamic heights with inverted echo sounders: Results from MODE. *J. Phys. Oceanogr. 7*, 345-358.
- Watts, D. R., K. L. Tracey and A. I. Friedlander. 1988. Processing accurate maps of the Gulf Stream thermal front using objective analysis. *J. Geophys. Res. 94*, 8040-8052.
- Watts, D. R. and M. Wimbush. 1981. Sea surface height and thermocline depth variations measured from the sea floor. *International Symposium on Acoustic Remote Sensing of the Atmosphere and Oceans, Proceedings, III*, 33-47, Calgary, Alberta, Canada.