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THE SYNOP EXPERIMENT

Inverted Echo Sounder Data Report
for
October 1987 to May 1988

GSO Technical Report No. 90-3

by

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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, consists of two separate arrays in the Gulf Stream. The "Inlet" array of inverted echo sounders (IES) and deep current meters consists in a 120×150 km rectangle. It measures 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, a 300×320km rectangle centered on the Gulf Stream near 68°W, monitors the thermocline structure of the Gulf Stream in the region of large meanders and frequent interactions with rings. Additionally, during this first deployment period, five of the IESs in the arrays are outfitted with bottom pressure gauges (PIES).

The echo sounders were launched during the cruise aboard the R/V Endeavor, EN169 (October 9, 1987 to October 28, 1987), and recovered during the cruise aboard the R/V Oceanus, OC200 (May 20, 1988 to June 18, 1988). IES data recovered during OC200 is documented here by plots and tables of basic statistics and pertinent deployment information. Altogether 22 IES records are presented, plus pressure and temperature records at 5 sites. 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 and the standard steps of data processing is also given.

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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. Included in our field program is the three-year deployment of arrays of inverted echo sounders with bottom pressure gauges, plus deep current meters across the Deep Western Boundary Current(DWBC) off Cape Hatteras. The former is the subject of this report , and the deep current meters will be presented in a separate report. Additionally in our SYNOP study there is a two-year deployment of arrays of high-performance current meter moorings, reaching into the core of the Gulf Stream.

The main objective of our program is a more complete, fundamentally improved understanding of the structure, energetics, and dynamics of the Gulf Stream in the region between 70° and 65° W, where meanders are of large amplitude and still growing, and where the adjacent ring and eddy field is vigorous. From this understanding the longer term goal is to guide and test predictive modeling capability for the Gulf Stream. The arrays of instruments in our field program are specifically designed for these objectives. Using data from current meters, inverted echo sounders (IESs) and IES/bottom pressure sensor combinations, 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 full three-dimensional structure of the fluctuations in relation to the mean (T, U, V) fields and their gradients determines the directions and strengths of the key energy exchanges.

IES data, which span from the previous summer, were recovered during the summer of 1988. These records were launched on the cruise aboard the R/V Endeavor, EN169 (October 9, 1987 to October 28, 1987), and were recovered on the cruise aboard the R/V Oceanus, OC200 (May 20, 1988 to June 18, 1988). Figure 1 and Figure 2, as well as Table 1 and Table 2, present site locations and data returns for the IESs. Basic statistics for those records and pertinent deployment information are tabulated in Section 2. In Section 3 and 5, the data are presented in plots of travel times, thermocline depth measurements, and for IESs with additional sensors, bottom pressure and temperature. In Section 5, the low pass filtered records are presented in plots grouped by deployment line.

Figure 1: Mooring and IES sites. IES sites are shown by open circles. Solid circles denote IES sites with bottom pressure gauges (PIESs). The dashed curve indicates the mean path of the Gulf Stream(1975 to 1986) from Gilman and Cornillon[1990].

Site Locations and Data Returns

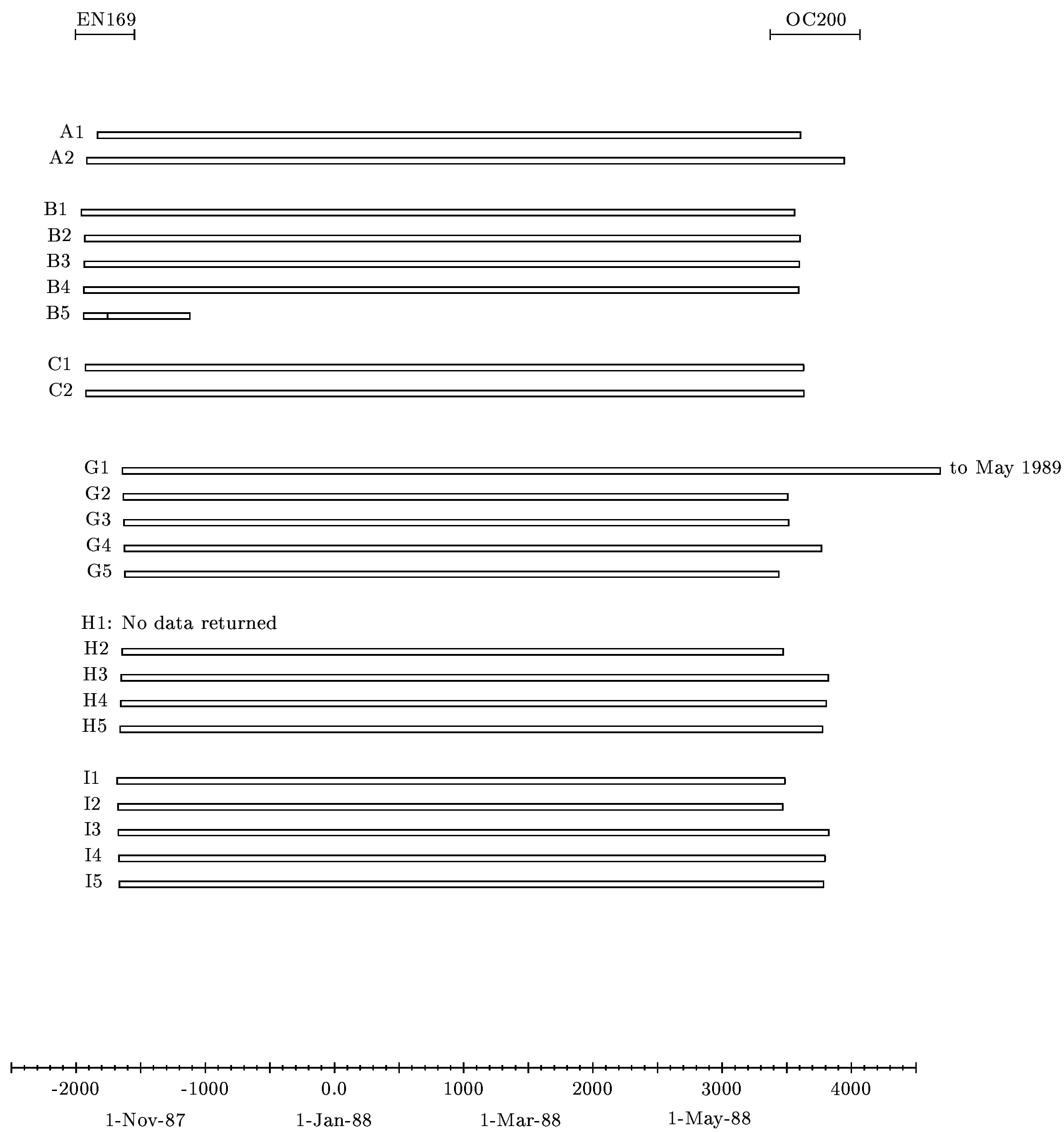
Table 1: **Central Array**

site	lat(N)	lon(W)	1st point	last point	notes
IES88G1	see Report No. 90-2 for information about this site				
IES88G2	38° 01.00	69° 16.22	25-Oct-87	26-May-88	
IES88G3	37° 23.34	69° 10.54	25-Oct-87	26-May-88	
IES88G4	36° 49.80	68° 50.25	25-Oct-87	5-Jun-88	
IES88G5	36° 14.25	68° 51.30	25-Oct-87	23-May-88	
PIES88H1		recovered no data; all bits set			
PIES88H2	38° 18.02	68° 27.97	24-Oct-87	24-May-88	
PIES88H3	37° 38.71	68° 19.31	24-Oct-87	8-Jun-88	
IES88H4	37° 00.52	68° 07.74	24-Oct-87	7-Jun-88	
IES88H5	36° 22.13	67° 58.00	24-Oct-87	6-Jun-88	
IES88I1	39° 00.12	67° 48.70	23-Oct-87	25-May-88	
PIES88I2	38° 22.48	67° 35.37	23-Oct-87	24-May-88	
IES88I3	37° 47.49	67° 31.01	23-Oct-87	8-Jun-88	
IES88I4	37° 11.18	67° 21.46	23-Oct-87	6-Jun-88	
IES88I5	36° 33.48	67° 11.67	23-Oct-87	6-Jun-88	

Table 2: Inlet Array

site	lat(N)	lon(W)	1st point	last point	notes
IES88A1	35° 18.56	74° 36.94	16-Oct-87	30-May-88	two big jumps in travel times
IES88A2	35° 02.05	74° 12.29	13-Oct-87	13-Jun-88	
IES88B1	35° 45.06	74° 27.97	11-Oct-87	28-May-88	
IES88B2	35° 36.71	74° 14.30	12-Oct-87	29-May-88	
PIES88B3	35° 28.81	74° 02.84	12-Oct-87	29-May-88	temperature has steps of 128 counts
PIES88B4	35° 20.74	73° 50.97	12-Oct-87	29-May-88	
IES88B5a	35° 11.98	73° 40.01	12-Oct-87	19-Oct-87	accidentally released
IES88B5b	35° 12.07	73° 40.09	19-Oct-87	15-Nov-87	redeployed, failed after 1 month, all 1's returned for travel times
IES88C1	36° 04.54	73° 56.98	12-Oct-87	31-May-88	
IES88C2	35° 45.93	73° 33.55	13-Oct-87	31-May-88	

Figure 2: IES deployment Chart. The duration and temporal location of each IES is charted as a thin rectangle. The length of each rectangle and its horizonal position provide a calendar of data coverage from the first good sample to the last. The time axis is given in yearhours at the bottom, with large tics indicating 500 hr increments and smaller ones denoting 100 hr increments. Record G1 was recovered the next year (May 1989) and is presented in the GSO Technical Report 90-2.



1.2 Site Naming Conventions

Two arrays exist (Figure 1), an "Inlet Array" near Cape Hatteras consisting of 9 IESs on 3 lines designated A, B and C, and a "Central Array" centered on the Gulf Stream about 68° W with 3 instrument lines, G, H and I. There were 15 instruments in the Central Array, but one failed and one was left deployed until May 1989. Hence only 13 records from the Central Array are presented here, as noted in Table 1. Five of the instruments are outfitted with bottom pressure gauges, two in the Inlet, and one in the Central Array. These IESs are referred to as PIESs.

The instrument naming convention is to specify the line and the relative position in the line (increasing seaward from the shelf) prefixed by the instrument type and year of recovery. For example PIES88H3 would refer to the third instrument, a pressure outfitted IES, in the H line.

1.3 Inverted Echo Sounder Description

A detailed description of the IES is presented in Chaplin and Watts (1984) and will not be repeated here. Briefly, however, the IES is an instrument which is moored one meter above the ocean floor and which monitors the depth of the main thermocline acoustically. A sample burst of acoustic pulses is transmitted every half hour. A sample burst consists of twenty-four 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 1.4.5 will explain in detail the actual times associated with the various measurements.

1.4 Data Processing

All processing steps were done on MicroVAX II and MicroVAX III computers. The basic steps include transcription, editing, and conversion into scientific units. The data processing is accomplished by a series of routines specifically developed for the IES. Since these programs are documented elsewhere (Fields, Tracey, and Watts, 1990), the steps are only outlined below and schematically illustrated in Figure 3.

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

FILL : Checks for proper incrementing of the time base. Missing samples are inserted using interpolated values.

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.

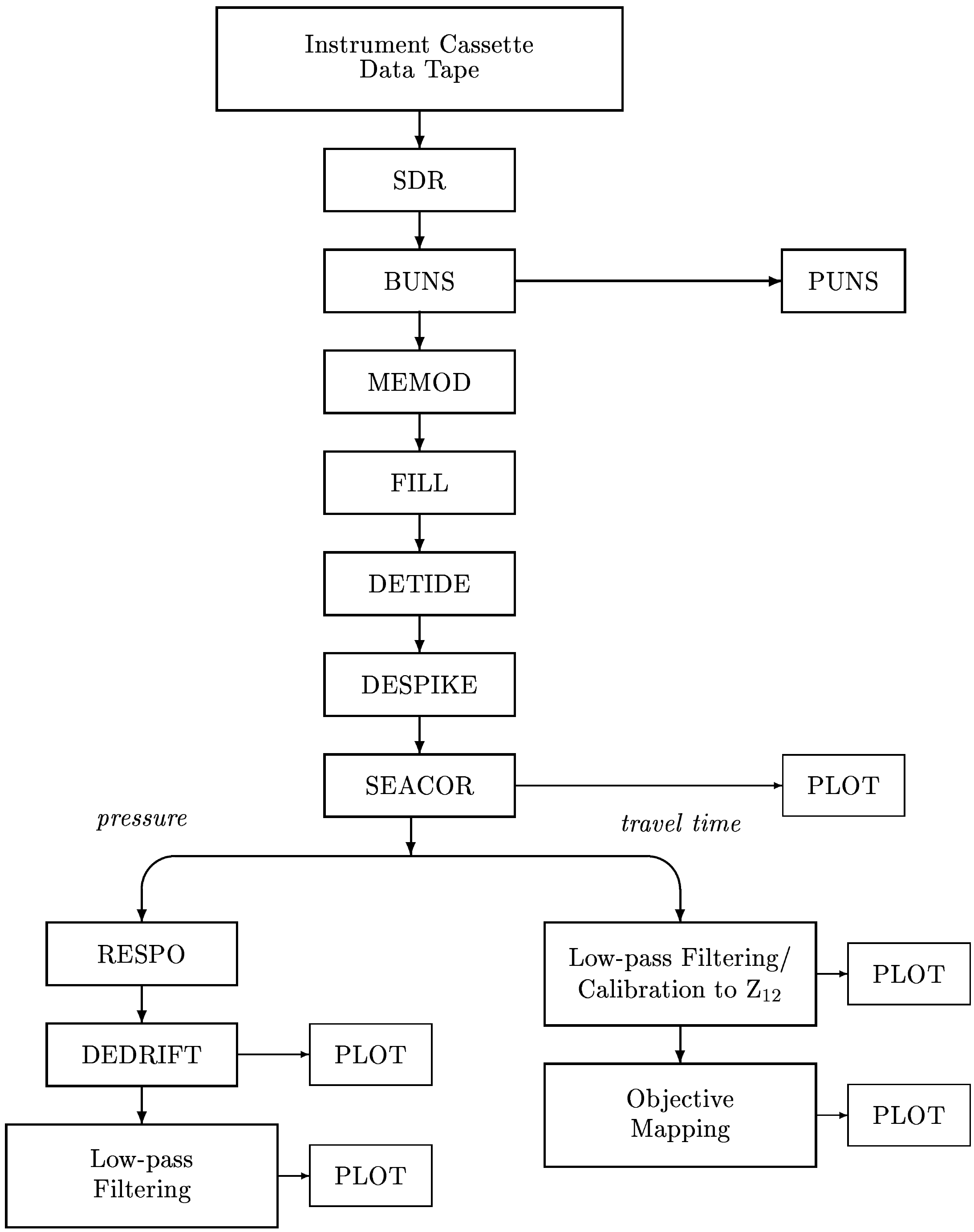


Figure 3: IES Data Processing Flowchart

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

LOW PASS FILTERING : Convolves the travel times, pressures, and temperatures with a 40 hour low-pass Lanczos filter. The smoothed series are subsampled at six hour intervals and plotted.

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.

1.4.1 Travel Time Calibration

The acoustic travel times (τ) records are shown in Figures 5.1–5.23. Variations in the travel times have been shown to be proportional to variations in the thermocline depth in the Gulf Stream (Watts and Rossby, 1977; Watts and Wimbush, 1981; Watts and Johns, 1982). Calibration XBTs were taken at each IES site in order to convert the travel times (τ) into thermocline depths (ξ) according to the relation: $\xi = \mathrm{M}\tau + \mathrm{B}$, where M is a scale factor and the intercept B depends on the depth of the instrument. Regressions of τ versus ξ, performed for several records, show that the constant (M) value, $\mathrm{M} = -19.0$ m/msec for the 12°C isotherm, is appropriate for all these Gulf Stream sites. The values of B used for each instrument are listed in the tables in Section 2. For practical purposes the main thermocline depth can be represented by the depth of an individual isotherm. For this work, we have chosen the 12°C isotherm since it is situated near the highest temperature gradients of the main thermocline and correlates well with τ (Rossby, 1969; Watts and Johns, 1982). The low-pass filtered travel time records were scaled to the thermocline depths (Z_{12}) and these records are shown in Figures 12.1–12.6. 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 ± 25 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.

1.4.2 Temperature

Temperatures (Figures 8.1–8.5, 11.1, 11.2, 14.1 and 14.2) were measured using thermistors (Yellow Springs International Corp., model 44032) controlled by Sea Data Corp. (model DC-37B) electronics cards installed in the IESs. Their 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.

1.4.3 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 6.1–6.5) are dominated by the tides, however for some of the instruments, the pressures also drift, O(0.1 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 (1991) who have addressed pressure sensor drift and performance. In some records the first 10–40 days exhibit a drift of tenths of decibars. The rate of drift decayed with time and was best approximated by a exponential function of the form,

$$Drift = P_1 \exp(-P_2 t) + P_3.$$

A design matrix would be composed of $(exp(-P_2 t_i),\ 1)$. The overdetermined set of equations were solved for coefficients P_1 and P_3. These coefficients were found subject to the minimization of the rms error of the fit as a function of the decay rate, P_2. Minimization was accomplished using the method of parabolic extrapolation and golden sections (Press et al., 1988) to optimally search for P_2 with a minimum of function evaluations (fits). The first 12 hours of pressure were ignored since the crystal's temperature was equlibrating. The dedrifted 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.

Four of the five PIES showed some sign of drift. 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 7.1–7.5, have an accuracy (relative to their mean pressure) of better than 0.05 dbar (Watts and Kontoyiannis, 1991). The residual bottom pressure records were low-pass filtered (Figures 13.1 and 13.2) as mentioned above.

1.4.4 Time Base

The date and time were assigned to each sampling period. The Tables (Tables 4–26) in Section 2 report the hours, minutes, and seconds associated with the first and last sampling period. All times are given as Greenwich Mean Time (GMT). For processing convenience, the times were converted into yearhours. A yearhour calendar (Table 3) lists the yearhours which correspond to 0000 GMT 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, 1988 at 0000 GMT.

Table 3: Yearhour Calendar for Non-Leap Years. The yearhour listed corresponds to 0000 GMT

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1.4.5 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 H2, H3, and I2 and SDs at sites B3 and B4. 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.

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-forth 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 bookeeping 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).

Original processing of temperature and presure records was done under the wrong understanding that the SD model sampled in the same manner as the URI model. The difference was discovered when the phases of tidal constituents showed a quarter hour discrepancy between models. Hence the temperature and presure records on sites B3 and B4 were reprocessed from RESPO onward with the correct time base. The correct times and tidal constants are listed in the PIES tables (Tables 8, 9, 18, 19, and 23).

1.5 Data Recovery

Tables 1 and 2 and Figure 2 summarize the data returns from each of the IESs. All 24 instruments were successfully recovered during May 1988.

The data returns were also successful with the exception of two instruments. No data were obtained for the PIES at site H1. The sequence number recorded on the tape indicated that the instrument functioned for the full deployment period. However, the data words for travel time, pressure, and temperature were recorded with all bits set. At site B5, the instrument was accidentally released seven days after the initial deployment and was redeployed in aproximately the same location. The cpu board in the IES stopped functioning properly after about one month, and only 1's were recorded on the tape. Thus good travel time data were obtained for only a month at this site.

At site A1, two large jumps occurred in the travel time record. Both jumps were toward longer times. We were unable to determine the exact cause of these jumps, but they might be explained by mudslides which moved the IES downslope. In order to obtain a usable record at this site, we subtracted 0.0387 s from all the travel times beginning with record 3929 and 0.0527 s (= 0.0387 s + 0.014 s) from all those beginning with record 8085.

The overall data return was 92% for travel time and 83% for pressure and temperature.

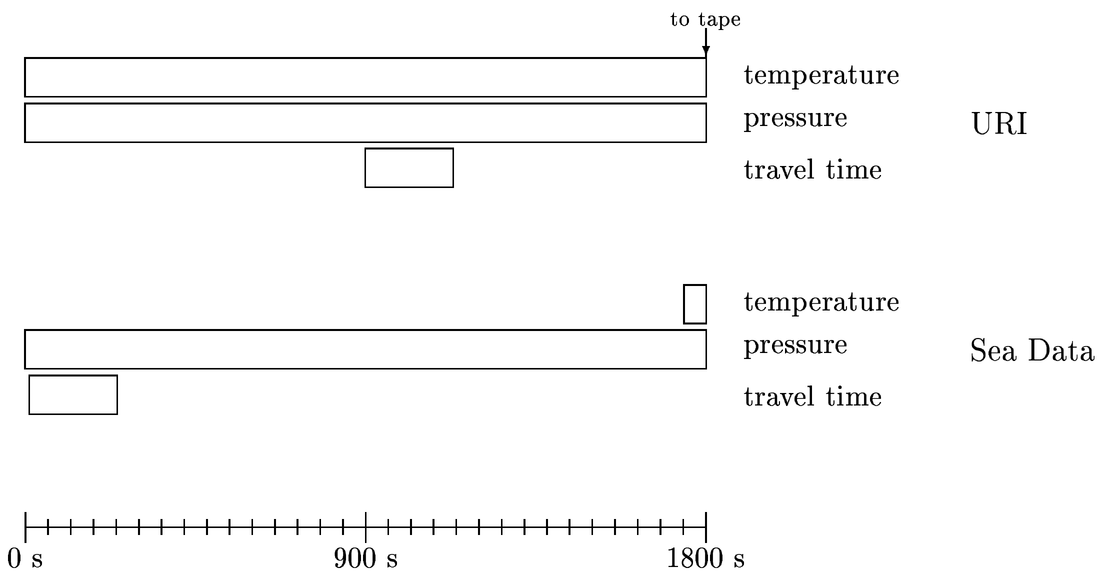

Figure 4: Sampling Sequences for URI and Sea Data Model IESs. The horizontal length and postion of the boxes represent the duration and relative temporal location of the sampling periods, respectively. Each tic mark represents a minute.

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 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 that are 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, 1988 at 0000 GMT. 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) of each variable of standard IESs and PIESs.

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 minimum of 18 bits be recorded on the internal cassette tape. For storage economy, only the 13 least significant bits are recorded. As a results wrapping occurs and the full-scale range of the variation is approximately 200 msec. 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 4: **Site and Record Information for IES88A1**

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

POSITION: 35°18.56 N, 74°36.94 W   DEPTH: 2475 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 16, 1987	1848	EN169
RECOVERY:	May 30, 1988	0344	OC200

TRAVEL TIME RECORDS
(Figure 5.1)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 16, 1987	19:36:55	-1828.3850
LAST DATA POINT:	May 30, 1988	3:34:26	3603.5740

Number of Points: 10865
Sampling Interval: 0.50 hrs

Minimum $\tau = 0.106809$ s   Mean $= 0.114110$ s
Maximum $\tau = 0.122932$ s   Standard Deviation $= 0.002999$ s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.1)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 2512.39 m
$\tau_d =$ Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 18, 1987	6: 0: 0	-1794.0000
LAST DATA POINT:	May 28, 1988	18: 0: 0	3570.0000

Number of Points: 895
Sampling Interval: 6.00 hrs

Minimum $Z_{12} = 206.52$ m   Mean $= 344.39$ m
Maximum $Z_{12} = 463.95$ m   Standard Deviation $= 54.47$ m

Table 5: **Site and Record Information for IES88A2**

Serial Number: 060
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: None

POSITION: 35°02.05 N 74°12.29 W   DEPTH: 3130 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 13, 1987	0728	EN169
RECOVERY:	Jun 13, 1988	0657	OC200

TRAVEL TIME RECORDS
(Figure 5.2)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 13, 1987	8:31:56	-1911.4680
LAST DATA POINT:	Jun 13, 1988	6:28:37	3942.4771

Number of Points: 11709
Sampling Interval: 0.50 hrs

Minimum τ = 0.168071 s   Mean = 0.172748 s
Maximum τ = 0.182816 s   Standard Deviation = 0.001796 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.1)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 4000.02 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 14, 1987	18: 0: 0	-1878.0000
LAST DATA POINT:	Jun 12, 1988	0: 0: 0	3912.0000

Number of Points: 966
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 565.22 m   Mean = 717.89 m
Maximum Z_{12} = 789.93 m   Standard Deviation = 33.51 m

Table 6: **Site and Record Information for IES88B1**

Serial Number: 052
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: None

POSITION: 35°45.06 N 74°27.97 W   DEPTH: 1975 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 11, 1987	1109	EN169
RECOVERY:	May 28, 1988	0507	OC200

TRAVEL TIME RECORDS
(Figure 5.3)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 11, 1987	11:51:55	-1956.1350
LAST DATA POINT:	May 28, 1988	4:49:45	3556.8291

Number of Points: 11027
Sampling Interval: 0.50 hrs

Minimum $\tau = 0.216702$ s   Mean = 0.225700 s
Maximum $\tau = 0.231336$ s   Standard Deviation = 0.002050 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.2)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 4509.00 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 12, 1987	18: 0: 0	-1926.0000
LAST DATA POINT:	May 26, 1988	18: 0: 0	3522.0000

Number of Points: 909
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 134.33 m   Mean = 220.88 m
Maximum Z_{12} = 357.91 m   Standard Deviation = 34.66 m

Table 7: **Site and Record Information for IES88B2**

Serial Number: 062
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: None

POSITION: 35°36.71 N 74°14.30 W DEPTH: 2650 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 12, 1987	1411	EN169
RECOVERY:	May 29, 1988	2234	OC200

TRAVEL TIME RECORDS
(Figure 5.4)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 12, 1987	15: 6:55	-1928.8850
LAST DATA POINT:	May 29, 1988	22: 4:33	3598.0759

Number of Points: 11055
Sampling Interval: 0.50 hrs

Minimum τ = 0.357294 s   Mean = 0.367851 s
Maximum τ = 0.381430 s   Standard Deviation = 0.004249 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.2)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 7348.04 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 14, 1987	0: 0: 0	-1896.0000
LAST DATA POINT:	May 28, 1988	12: 0: 0	3564.0000

Number of Points: 911
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 139.08 m   Mean = 358.94 m
Maximum Z_{12} = 536.73 m   Standard Deviation = 80.66 m

Table 8: **Site and Record Information for PIES88B3**

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: 35°28.81 N 74°02.84 W DEPTH: 2985 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 12, 1987	1111	EN169
RECOVERY:	May 29, 1988	1715	OC200

TRAVEL TIME RECORDS

(Figure 5.5)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 12, 1987	12: 1:12	-1931.9800
LAST DATA POINT:	May 29, 1988	17: 1:12	3593.0200

Number of Points: 11051
Sampling Interval: 0.50 hrs

Minimum τ = 0.380461 s Mean = 0.387936 s
Maximum τ = 0.405150 s Standard Deviation = 0.003954 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.2)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 7951.52 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 13, 1987	18: 0: 0	-1902.0000
LAST DATA POINT:	May 28, 1988	6: 0: 0	3558.0000

Number of Points: 911
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 290.33 m Mean = 580.58 m
Maximum Z_{12} = 710.87 m Standard Deviation = 73.76 m

Table 9: **Site and Record Information for PIES88B4**

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: 35°20.74 N 73°50.97 W   DEPTH: 3325 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 12, 1987	0836	EN169
RECOVERY:	May 29, 1988	1341	OC200

TRAVEL TIME RECORDS

(Figure 5.6)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 12, 1987	9:33: 8	-1934.4480
LAST DATA POINT:	May 29, 1988	14: 3: 7	3590.0520

Number of Points: 11050
Sampling Interval: 0.50 hrs

Minimum τ = 0.045101 s   Mean = 0.052184 s
Maximum τ = 0.061413 s   Standard Deviation = 0.002484 s

40 HRLP THERMOCLINE DEPTH RECORDS

(Figure 12.2)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$

where B = 1710.35 m

τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 13, 1987	18: 0: 0	-1902.0000
LAST DATA POINT:	May 28, 1988	6: 0: 0	3558.0000

Number of Points: 911
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 573.27 m   Mean = 718.80 m
Maximum Z_{12} = 812.97 m   Standard Deviation = 46.04 m

Table 10: **Site and Record Information for IES88B5A**

Serial Number: 031
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: None

POSITION: 35°11.98 N 73°40.01 W   DEPTH: 3630 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 12, 1987	0623	EN169
RECOVERY:	OCT 19, 1987	2022	EN169

TRAVEL TIME RECORDS
(Figure 5.7)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 12, 1987	7:16:56	-1936.7180
LAST DATA POINT:	Oct 19, 1987	17:46:56	-1758.2180

Number of Points: 358
Sampling Interval: 0.50 hrs

Minimum $\tau = 0.047354$ s   Mean $= 0.050946$ s
Maximum $\tau = 0.054162$ s   Standard Deviation $= 0.002036$ s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.2)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 1761.16 m
$\tau_d =$ Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 13, 1987	18: 0: 0	-1902.0000
LAST DATA POINT:	Oct 18, 1987	12: 0: 0	-1788.0000

Number of Points: 20
Sampling Interval: 6.00 hrs

Minimum $Z_{12} = 744.50$ m   Mean $= 795.15$ m
Maximum $Z_{12} = 843.52$ m   Standard Deviation $= 36.85$ m

Table 11: **Site and Record Information for IES88B5B**

Serial Number: 031
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: None

POSITION: 35°12.07 N 73°40.09 W DEPTH: 3620 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 19, 1987	2053	EN169
RECOVERY:	May 29, 1988	1026	OC200

TRAVEL TIME RECORDS
(Figure 5.8)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 19, 1987	21:46:56	-1754.2180
LAST DATA POINT:	Nov 15, 1987	6:16:56	-1121.7180

Number of Points: 1266
Sampling Interval: 0.50 hrs

Minimum τ = 0.050553 s   Mean = 0.053808 s
Maximum τ = 0.055586 s   Standard Deviation = 0.000911 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.2)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 1790.45 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 21, 1987	6: 0: 0	-1722.0000
LAST DATA POINT:	Nov 14, 1987	0: 0: 0	-1152.0000

Number of Points: 96
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 747.91 m   Mean = 768.78 m
Maximum Z_{12} = 810.99 m   Standard Deviation = 15.79 m

Table 12: **Site and Record Information for IES88C1**

Serial Number: 050
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: None

POSITION: 36°04.54 N, 73°56.98 W   DEPTH: 2850 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 12, 1987	2025	EN169
RECOVERY:	May 31, 1988	0305	OC200

TRAVEL TIME RECORDS
(Figure 5.9)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 12, 1987	21: 6:21	-1922.8940
LAST DATA POINT:	May 31, 1988	2:36:18	3626.6050

Number of Points: 11100
Sampling Interval: 0.50 hrs

Minimum $\tau = 0.185685$ s   Mean = 0.198558 s
Maximum $\tau = 0.205476$ s   Standard Deviation = 0.003957 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.3)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 4000.52 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 14, 1987	6: 0: 0	-1890.0000
LAST DATA POINT:	May 29, 1988	18: 0: 0	3594.0000

Number of Points: 915
Sampling Interval: 6.00 hrs

Minimum $Z_{12} = 110.75$ m   Mean = 227.90 m
Maximum $Z_{12} = 451.10$ m   Standard Deviation = 73.24 m

Table 13: **Site and Record Information for IES88C2**

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

POSITION: 35°45.93 N 73°33.55 W   DEPTH: 3450 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 13, 1987	0045	EN169
RECOVERY:	May 31, 1988	0740	OC200

TRAVEL TIME RECORDS
(Figure 5.10)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 13, 1987	1:51:55	-1918.1350
LAST DATA POINT:	May 31, 1988	6:47:38	3630.7939

Number of Points: 11099
Sampling Interval: 0.50 hrs

Minimum $\tau = 0.191414$ s   Mean = 0.200826 s
Maximum $\tau = 0.220459$ s   Standard Deviation = 0.004939 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.3)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 4437.48 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 14, 1987	12: 0: 0	-1884.0000
LAST DATA POINT:	May 30, 1988	0: 0: 0	3600.0000

Number of Points: 915
Sampling Interval: 6.00 hrs

Minimum $Z_{12} = 296.50$ m   Mean = 621.39 m
Maximum $Z_{12} = 777.77$ m   Standard Deviation = 93.87 m

Table 14: **Site and Record Information for IES88G2**

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

POSITION: 38°01.00 N 69°16.22 W   DEPTH: 3910 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 25, 1987	0046	EN169
RECOVERY:	May 26, 1988	0016	OC200

TRAVEL TIME RECORDS
(Figure 5.11)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 25, 1987	2: 1: 9	-1629.9810
LAST DATA POINT:	May 26, 1988	0: 1: 9	3504.0190

Number of Points: 5135
Sampling Interval: 0.50 hrs

Minimum τ = 0.382191 s   Mean = 0.400277 s
Maximum τ = 0.414878 s   Standard Deviation = 0.009096 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.4)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 7949.64 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 26, 1987	12: 0: 0	-1596.0000
LAST DATA POINT:	May 24, 1988	18: 0: 0	3474.0000

Number of Points: 846
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 103.14 m   Mean = 345.06 m
Maximum Z_{12} = 670.57 m   Standard Deviation = 172.77 m

Table 15: **Site and Record Information for IES88G3**

Serial Number: 046
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: None

POSITION: 37°23.34 N 69°10.54 W   DEPTH: 4330 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 25, 1987	0458	EN169
RECOVERY:	May 26, 1988	0558	OC200

TRAVEL TIME RECORDS
(Figure 5.12)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 25, 1987	6:46:16	-1625.2290
LAST DATA POINT:	May 26, 1988	5:46:16	3509.7710

Number of Points: 5136
Sampling Interval: 0.50 hrs

Minimum τ = 0.160695 s   Mean = 0.169310 s
Maximum τ = 0.185809 s   Standard Deviation = 0.005489 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.4)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 3870.79 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 26, 1987	12: 0: 0	-1596.0000
LAST DATA POINT:	May 25, 1988	0: 0: 0	3480.0000

Number of Points: 847
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 366.17 m   Mean = 654.79 m
Maximum Z_{12} = 795.47 m   Standard Deviation = 102.94 m

Table 16: **Site and Record Information for IES88G4**

Serial Number: 061
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: None

POSITION: 36°49.80 N 68°50.25 W   DEPTH: 4689 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 25, 1987	0904	EN169
RECOVERY:	Jun 5, 1988	2222	OC200

TRAVEL TIME RECORDS
(Figure 5.13)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 25, 1987	10:46:23	-1621.2271
LAST DATA POINT:	Jun 5, 1988	21:46:23	3765.7729

Number of Points: 5388
Sampling Interval: 0.50 hrs

Minimum $\tau = 0.218227$ s   Mean = 0.227422 s
Maximum $\tau = 0.255443$ s   Standard Deviation = 0.008307 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.4)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 5102.44 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 26, 1987	18: 0: 0	-1590.0000
LAST DATA POINT:	Jun 4, 1988	12: 0: 0	3732.0000

Number of Points: 888
Sampling Interval: 6.00 hrs

Minimum $Z_{12} = 260.99$ m   Mean = 783.88 m
Maximum $Z_{12} = 927.97$ m   Standard Deviation = 154.62 m

Table 17: **Site and Record Information for IES88G5**

Serial Number: 033
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: None

POSITION: 36°14.25 N 68°51.30 W DEPTH: 4585 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 25, 1987	1253	EN169
RECOVERY:	May 23, 1988	0402	OC200

TRAVEL TIME RECORDS
(Figure 5.14)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 25, 1987	14:31:45	-1617.4709
LAST DATA POINT:	May 23, 1988	3:31:45	3435.5291

Number of Points: 5054
Sampling Interval: 0.50 hrs

Minimum τ = 0.094889 s Mean = 0.101487 s
Maximum τ = 0.127361 s Standard Deviation = 0.006273 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.4)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 2667.81 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 27, 1987	0: 0: 0	-1584.0000
LAST DATA POINT:	May 21, 1988	18: 0: 0	3402.0000

Number of Points: 832
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 263.54 m Mean = 741.26 m
Maximum Z_{12} = 839.08 m Standard Deviation = 115.37 m

Table 18: **Site and Record Information for PIES88H2**

Serial Number: 056
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: Pressure and Temperature
Pressure Sensor Serial Number: 17849

POSITION: 38°18.02 N DEPTH: 4080 m
68°27.97 W

	DATE	GMT	CRUISE
LAUNCH:	Oct 24, 1987	1418	EN169
RECOVERY:	May 24, 1988	1420	OC200

TRAVEL TIME RECORDS

(Figure 5.15)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 24, 1987	16: 1:45	-1639.9709
LAST DATA POINT:	May 24, 1988	14: 1:45	3470.0291

Number of Points: 10221
Sampling Interval: 0.50 hrs

Minimum $\tau = 0.239815$ s Mean = 0.258268 s
Maximum $\tau = 0.268694$ s Standard Deviation = 0.007400 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.5)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 5195.47 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 26, 1987	0: 0: 0	-1608.0000
LAST DATA POINT:	May 23, 1988	6: 0: 0	3438.0000

Number of Points: 842
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 78.45 m Mean = 257.53 m
Maximum Z_{12} = 577.52 m Standard Deviation = 138.15 m

Table 19: **Site and Record Information for PIES88H3**

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: 37°38.71 N 68°19.31 W   DEPTH: 4565 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 24, 1987	0808	EN169
RECOVERY:	Jun 8, 1988	0108	OC200

TRAVEL TIME RECORDS

(Figure 5.16)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 24, 1987	9:41:38	-1646.3060
LAST DATA POINT:	Jun 8, 1988	0:41:39	3816.6941

Number of Points: 10927
Sampling Interval: 0.50 hrs

Minimum τ = 0.071374 s   Mean = 0.084367 s
Maximum τ = 0.104497 s   Standard Deviation = 0.007981 s

40 HRLP THERMOCLINE DEPTH RECORDS

(Figure 12.5)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 2168.05 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 25, 1987	18: 0: 0	-1614.0000
LAST DATA POINT:	Jun 6, 1988	18: 0: 0	3786.0000

Number of Points: 901
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 201.47 m   Mean = 565.86 m
Maximum Z_{12} = 792.53 m   Standard Deviation = 150.36 m

Table 20: **Site and Record Information for IES88H4**

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

POSITION: 37°00.52 N DEPTH: 4877 m
68°07.74 W

	DATE	GMT	CRUISE
LAUNCH:	Oct 24, 1987	0421	EN169
RECOVERY:	Jun 7, 1988	1023	OC200

TRAVEL TIME RECORDS
(Figure 5.17)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 24, 1987	5:31:56	-1650.4680
LAST DATA POINT:	Jun 7, 1988	9:57:58	3801.9661

Number of Points: 10906
Sampling Interval: 0.50 hrs

Minimum $\tau = 0.075359$ s Mean = 0.086549 s
Maximum $\tau = 0.113596$ s Standard Deviation = 0.008677 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.5)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 2342.00 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 25, 1987	12: 0: 0	-1620.0000
LAST DATA POINT:	Jun 6, 1988	0: 0: 0	3768.0000

Number of Points: 899
Sampling Interval: 6.00 hrs

Minimum $Z_{12} = 214.97$ m Mean = 698.68 m
Maximum $Z_{12} = 887.10$ m Standard Deviation = 164.49 m

Table 21: **Site and Record Information for IES88H5**

Serial Number: 035
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: None

POSITION: 36°22.13 N, 67°58.00 W   DEPTH: 4825 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 24, 1987	0012	EN169
RECOVERY:	Jun 6, 1988	0546	OC200

TRAVEL TIME RECORDS
(Figure 5.18)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 24, 1987	1:31:56	-1654.4680
LAST DATA POINT:	Jun 6, 1988	5:27:36	3773.4600

Number of Points: 10857
Sampling Interval: 0.50 hrs

Minimum $\tau = 0.013585$ s   Mean = 0.021367 s
Maximum $\tau = 0.050176$ s   Standard Deviation = 0.008458 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.5)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 1146.83 m
$\tau_d =$ Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 25, 1987	12: 0: 0	-1620.0000
LAST DATA POINT:	Jun 5, 1988	0: 0: 0	3744.0000

Number of Points: 895
Sampling Interval: 6.00 hrs

Minimum $Z_{12} = 225.35$ m   Mean = 746.05 m
Maximum $Z_{12} = 877.24$ m   Standard Deviation = 159.91 m

Table 22: **Site and Record Information for IES88I1**

Serial Number: 034
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: None

POSITION: 39°00.12 N DEPTH: 3625 m
67°48.70 W

	DATE	GMT	CRUISE
LAUNCH:	Oct 23, 1987	0226	EN169
RECOVERY:	May 25, 1988	0323	OC200

TRAVEL TIME RECORDS
(Figure 5.19)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 23, 1987	3:31:33	-1676.4740
LAST DATA POINT:	May 25, 1988	3: 1:33	3483.0259

Number of Points: 10320
Sampling Interval: 0.50 hrs

Minimum $\tau = 0.023898$ s Mean = 0.037667 s
Maximum $\tau = 0.047079$ s Standard Deviation = 0.005800 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.6)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 983.23 m
$\tau_d =$ Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 24, 1987	12: 0: 0	-1644.0000
LAST DATA POINT:	May 23, 1988	18: 0: 0	3450.0000

Number of Points: 850
Sampling Interval: 6.00 hrs

Minimum $Z_{12} = 102.28$ m Mean = 267.49 m
Maximum $Z_{12} = 505.00$ m Standard Deviation = 109.29 m

Table 23: **Site and Record Information for PIES88I2**

Serial Number: 054
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: Pressure and Temperature
Pressure Sensor Serial Number: 17911

POSITION: 38°22.48 N 67°35.37 W DEPTH: 4350 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 23, 1987	0717	EN169
RECOVERY:	May 24, 1988	0854	OC200

TRAVEL TIME RECORDS

(Figure 5.20)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 23, 1987	8:16:16	-1671.7290
LAST DATA POINT:	May 24, 1988	8:46:16	3464.7710

Number of Points: 10274
Sampling Interval: 0.50 hrs

Minimum $\tau = 0.197883$ s Mean = 0.222128 s
Maximum $\tau = 0.234344$ s Standard Deviation = 0.010861 s

40 HRLP THERMOCLINE DEPTH RECORDS

(Figure 12.6)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 4552.47 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 24, 1987	18: 0: 0	-1638.0000
LAST DATA POINT:	May 23, 1988	0: 0: 0	3432.0000

Number of Points: 846
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 117.70 m Mean = 330.65 m
Maximum Z_{12} = 777.52 m Standard Deviation = 203.81 m

Table 24: **Site and Record Information for IES88I3**

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

POSITION: 37°47.49 N 67°31.01 W   DEPTH: 4730 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 23, 1987	1109	EN169
RECOVERY:	Jun 8, 1988	0602	OC200

TRAVEL TIME RECORDS
(Figure 5.21)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 23, 1987	12:31: 5	-1667.4821
LAST DATA POINT:	Jun 8, 1988	6: 1: 5	3822.0181

Number of Points: 10980
Sampling Interval: 0.50 hrs

Minimum $\tau = 0.276917$ s   Mean = 0.296593 s
Maximum $\tau = 0.313113$ s   Standard Deviation = 0.010808 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.6)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 6095.22 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 24, 1987	18: 0: 0	-1638.0000
LAST DATA POINT:	Jun 6, 1988	18: 0: 0	3786.0000

Number of Points: 905
Sampling Interval: 6.00 hrs

Minimum $Z_{12} = 170.19$ m   Mean = 459.52 m
Maximum $Z_{12} = 817.36$ m   Standard Deviation = 203.81 m

Table 25: **Site and Record Information for IES88I4**

Serial Number: 047
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: None

POSITION: 37°11.18 N 67°21.46 W   DEPTH: 4913 m

	DATE	GMT	CRUISE
LAUNCH:	Oct 23, 1987	1518	EN169
RECOVERY:	Jun 7, 1988	0005	OC200

TRAVEL TIME RECORDS
(Figure 5.22)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 23, 1987	16:36:55	-1663.3850
LAST DATA POINT:	Jun 6, 1988	23:35:13	3791.5869

Number of Points: 10911
Sampling Interval: 0.50 hrs

Minimum $\tau = 0.140957$ s   Mean = 0.152108 s
Maximum $\tau = 0.175661$ s   Standard Deviation = 0.009724 s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.6)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 3556.09 m
$\tau_d =$ Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 25, 1987	0: 0: 0	-1632.0000
LAST DATA POINT:	Jun 5, 1988	18: 0: 0	3762.0000

Number of Points: 900
Sampling Interval: 6.00 hrs

Minimum $Z_{12} = 237.58$ m   Mean = 665.65 m
Maximum $Z_{12} = 855.65$ m   Standard Deviation = 185.11 m

Table 26: **Site and Record Information for IES88I5**

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

POSITION: 36°33.48 N   DEPTH: 4979 m
67°11.67 W

	DATE	GMT	CRUISE
LAUNCH:	Oct 23, 1987	1936	EN169
RECOVERY:	Jun 6, 1988	1401	OC200

TRAVEL TIME RECORDS
(Figure 5.23)

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 23, 1987	21: 1:53	-1658.9690
LAST DATA POINT:	Jun 6, 1988	13:31:52	3781.5310

Number of Points: 10882
Sampling Interval: 0.50 hrs

Minimum $\tau = 0.233197$ s   Mean $= 0.240292$ s
Maximum $\tau = 0.264965$ s   Standard Deviation $= 0.006261$ s

40 HRLP THERMOCLINE DEPTH RECORDS
(Figure 12.6)

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 5358.97 m
$\tau_d =$ Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
FIRST DATA POINT:	Oct 25, 1987	6: 0: 0	-1626.0000
LAST DATA POINT:	Jun 5, 1988	6: 0: 0	3750.0000

Number of Points: 897
Sampling Interval: 6.00 hrs

Minimum $Z_{12} = 352.16$ m   Mean $= 792.98$ m
Maximum $Z_{12} = 914.30$ m   Standard Deviation $= 118.78$ 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 –2448 (21-Sept-1987 referenced to 1-Jan-1988) and extends to 9264(21-Jan-1989 referenced to 1-Jan-1988). This time period is displayed in four panels, two per page. Each panel covers 2928 hr (one third of a leap year). A small tic is placed at each day (0000 GMT) and larger tics 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-89" with 0.0 yearhour).

Vertical axes for each sensor will be either common or have a common increment. Travel time is plotted within a 40–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 dedrifting, the residual bottom pressures are plotted within a 0.8 dbar window centered about zero. A 0.15° C window, adjusted vertically to enclose all the record's variation, is used for each temperature record except for the case of B3 and B4, where 0.8° C windows are used.

Figure 5.1: Half-Hourly Travel Time. IES88A1

Figure 5.2: Half-Hourly Travel Time. IES88A2

Figure 5.3: Half-Hourly Travel Time. IES88B1

Figure 5.4: Half-Hourly Travel Time. IES88B2

Figure 5.5: Half-Hourly Travel Time. PIES88B3

Figure 5.6: Half-Hourly Travel Time. PIES88B4

Figure 5.7: Half-Hourly Travel Time. IES88B5A

Figure 5.8: Half-Hourly Travel Time. IES88B5B

Figure 5.9: Half-Hourly Travel Time. IES88C1

Figure 5.10: Half-Hourly Travel Time. IES88C2

Figure 5.11: Half-Hourly Travel Time. IES88G2

Figure 5.12: Half-Hourly Travel Time. IES88G3

Figure 5.13: Half-Hourly Travel Time. IES88G4

Figure 5.14: Half-Hourly Travel Time. IES88G5

Figure 5.15: Half-Hourly Travel Time. PIES88H2

Figure 5.16: Half-Hourly Travel Time. PIES88H3

Figure 5.17: Half-Hourly Travel Time. IES88H4

Figure 5.18: Half-Hourly Travel Time. IES88H5

Figure 5.19: Half-Hourly Travel Time. IES88I1

Figure 5.20: Half-Hourly Travel Time. PIES88I2

Figure 5.21: Half-Hourly Travel Time. IES88I3

Figure 5.22: Half-Hourly Travel Time. IES88I4

Figure 5.23: Half-Hourly Travel Time. IES88I5

Figure 6.1: Half-Hourly Bottom Pressure. PIES88B3

Figure 6.2: Half-Hourly Bottom Pressure. PIES88B4

Figure 6.3: Half-Hourly Bottom Pressure. PIES88H2

Figure 6.4: Half-Hourly Bottom Pressure. PIES88H3

Figure 6.5: Half-Hourly Bottom Pressure. PIES88I2

Figure 7.1: Half-Hourly Residual Bottom Pressure. PIES88B3

Figure 7.2: Half-Hourly Residual Bottom Pressure. PIES88B4

Figure 7.3: Half-Hourly Residual Bottom Pressure. PIES88H2

Figure 7.4: Half-Hourly Residual Bottom Pressure. PIES88H3

Figure 7.5: Half-Hourly Residual Bottom Pressure. PIES88I2

Figure 8.1: Half-Hourly Bottom Temperature. PIES88B3

Figure 8.2: Half-Hourly Bottom Temperature. PIES88B4

Figure 8.3: Half-Hourly Bottom Temperature. PIES88H2

Figure 8.4: Half-Hourly Bottom Temperature. PIES88H3

Figure 8.5: Half-Hourly Bottom Temperature. PIES88I2

4 Half-Hourly Line Plots

Line plots display all records from a given section across the Gulf Stream on a single page. 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 –2500 hr to 4500 hr in increments of 500 hr. As with the individual plots, labels indicating specific dates are centered about their yearhour equivalents (for example a label associates "1-Jan-89" with 0.0 yearhour).

For the line plots of travel time and bottom pressure, the vertical axes for all IESs will have common increments. This is also true for the temperature records except for those on line B and H.

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 B5a and B5b are plotted together in the same panel rather than separately.

Figure 9.1: Half-Hourly Travel Time. A line

Figure 9.2: Half-Hourly Travel Time. B line

Figure 9.3: Half-Hourly Travel Time. C line

Figure 9.4: Half-Hourly Travel Time. G line

Figure 9.5: Half-Hourly Travel Time. H line

Figure 9.6: Half-Hourly Travel Time. I line

Figure 10.1: Half-Hourly Residual Bottom Pressure. B line

Figure 10.2: Half-Hourly Residual Bottom Pressure. H line

Figure 10.3: Half-Hourly Residual Bottom Pressure. I line

Figure 11.1: Half-Hourly Bottom Temperature. B line

Figure 11.2: Half-Hourly Bottom Temperature. H line

Figure 11.3: Half-Hourly Bottom Temperature. I line

5 40HRLP Line Plots

Line plots display all records from a given section across the Gulf Stream on a single page. 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 –2500 hr to 4500 hr in increments of 500 hr. As with the individual plots, labels indicating specific dates are centered about their yearhour equivalents (for example a label associates "1-Jan-89" 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 for all 40HRLP residual bottom pressure records have a common increment, and this is also true for the temperature records except for those on line B and H.

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 Z_{12} of B5a and B5b are plotted together in the same panel rather than separately.

Figure 12.1: 40HRLP Z_{12}. A line

Figure 12.2: 40HRLP Z_{12}. B line

Figure 12.3: 40HRLP Z_{12}. C line

Figure 12.4: 40HRLP Z_{12}. G line

Figure 12.5: 40HRLP Z_{12}. H line

Figure 12.6: 40HRLP Z_{12}. I line

Figure 13.1: 40HRLP Residual Bottom Pressure. B line

Figure 13.2: 40HRLP Residual Bottom Pressure. H line

Figure 13.3: 40HRLP Residual Bottom Pressure. I line

Figure 14.1: 40HRLP Bottom Temperature. B line

Figure 14.2: 40HRLP Bottom Temperature. H line

Figure 14.3: 40HRLP Bottom Temperature. I line

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