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The SYNOP Pilot Experiment: Inverted Echo Sounder Data Report for November 1986 to March 1987

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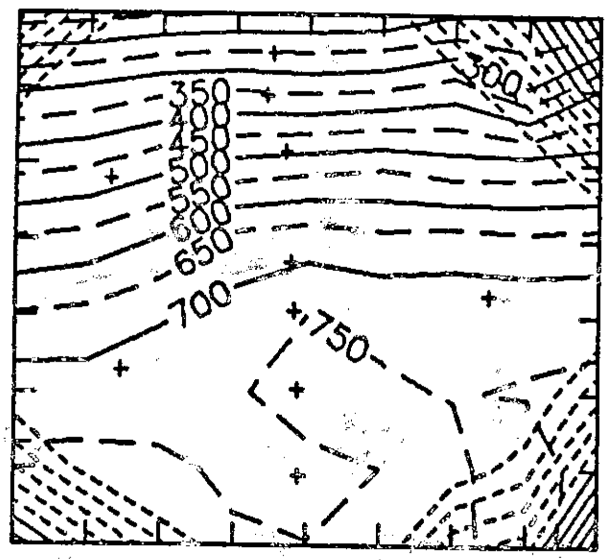

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Abstract

The SYNOP Pilot Experiment was conducted off Cape Hatteras, from late November 1986 to early March 1987, to measure the path characteristics (position, angle, curvature), the time-varying current structure and transport of the Gulf Stream. Part of the purpose of this Experiment was to test new instrumentation techniques and moored array designs for a subsequent main SYNOP Experiment. Data collected as part of the Pilot Experiment included Inverted Echo Sounders (IESs), Current Meter moorings (CMs) and Acoustic Transport Meters (ATMs). This report documents the IES data and ATM data collected during the deployment period. Time series plots of the travel time and low-pass filtered thermocline depth measurements are presented for eleven instruments. Bottom pressure and temperature, measured at three of the sites, are also plotted. Basic statistics are given for all the data records shown. Maps of the thermocline depth field in a 160 Km by 140 Km region are presented at daily intervals.

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1 Experiment Description and Data processing

1.1 Introduction

This report documents data collected using Inverted Echo Sounders (IESs) in the Gulf Stream off Cape Hatteras from November 1986 to March 1987. The measurements were made under the support of an ONR project entitled "SYNOP Pilot Experiment." Other data collected as part of this Pilot Experiment included (a) two Current Meter moorings (CMs) with five levels of each mooring, at depths of 400, 700, 1000 and 2000 m and 50 m above the bottom (Co-P.I., J. Bane, University of North Carolina), (b) tests of two acoustic doppler current profilers at the top of these moorings (W. Johns, University of Miami), (c) tests of two Acoustic Transport Meters (ATMs) (D.R. Watts, University of Rhode Island), (d) Pegasus surveys of velocity and temperature sections (K. Leaman, University of Miami), (e) tests of a new electromagnetic towed transport meter (T. Sanford, University of Washington, APL), and (f) Pop-up-profiler (A. Bradley, WHOI). The ATM data are included in this report. The other data will be documented separately.

The principal objectives of the IES and ATM portion of this SYNOP Pilot Experiment are as follows:

1. developing improved techniques for monitoring inflow conditions of the Gulf Stream as it leaves Cape Hatteras, and
2. mapping the thermocline topography by objective analysis in the region surrounding the current meter and Pegasus surveys.

The specific inflow conditions that we wish to monitor are

- path characteristics (position, angle, curvature)
- detailed cross-stream structure of the thermocline
- baroclinic and barotropic transport
- stream function and vorticity.

To contribute to our planned dynamical and statistical studies later in the SYNoptic Ocean Prediction program (SYNOP), these inlet parameters are seen as a generalization and improvement of earlier work for the purpose of specifying "inlet conditions" for numerical prediction of the synoptic variability of the Gulf Stream farther downstream.

To address these objectives, an array of IESs, CMs and ATMs were deployed within the Gulf Stream near 35°N 74°W. In this region, there is a minimum in the lateral meander motion, as determined from several years of satellite observations of the Gulf Stream's surface temperature front.

The nine IESs and two ATMs (and two CMs) were deployed on a cruise aboard the R/V ENDEAVOR (EN152) from 20 November to 3 December 1986, and recovered on the R/V ENDEAVOR (EN156) from 26 February to 6 March 1987. During this three-month-period, the instruments were located on three sections in an rectangular grid 160 Km downstream by 140 Km cross-stream. The IES sites, designated by the solid circles in Figure 1, are spaced 35 Km cross-stream and 50 Km alongstream. Acoustic transport meters and current meter moorings are located at the sites shown by the two solid triangles. These are situated halfway between adjacent IESs, thereby giving a 35 Km spacing between them as well. Additionally, bottom pressure gauges and bottom temperature sensors are included at three IES sites located along line B (indicated by the solid box). All IES and ATM sites are listed in Table 1.

1.2 Site Naming Conventions

The three cross-stream sections are designated from west to east by the letters A through C. The IES sites along line A and line C are numbered from 1 through 2, and line B consecutively from 1 through 7, with site 1 located at the northwestern end of the section. In this report, each instrument site is referred to by both the section letter and site number, prefaced by either IES, if it is a standard instrument, or PIES, if it is a combined IES and bottom pressure gauge. For example, IES87B5 is the fifth site from the northern end of line B. Additionally, the preface ATM indicates an acoustic transport meter site.

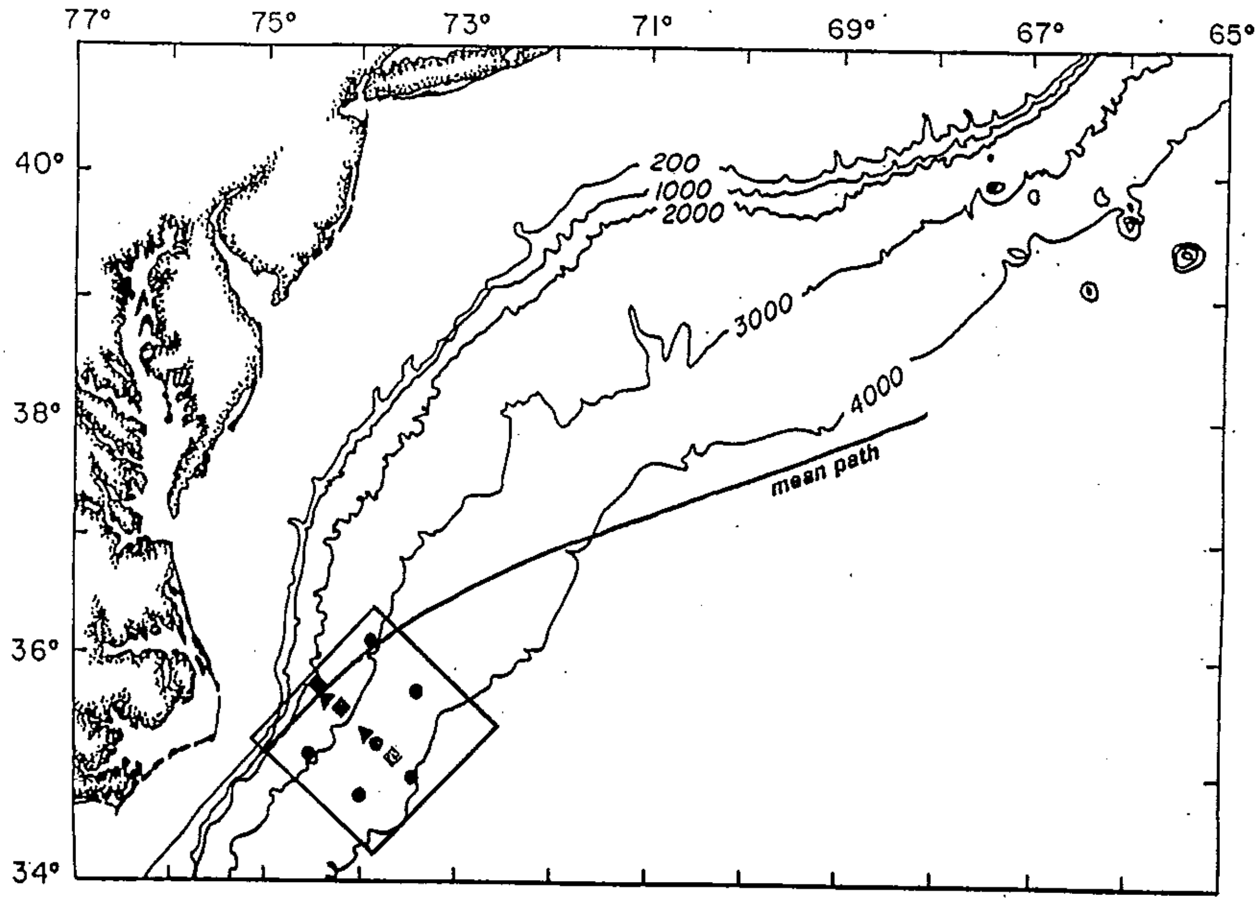


Figure 1: The SYNOP Pilot Experiment field observations area.
All IES (circles) and ATM (triangles) sites were occupied from November 1986 through February 1987. PIESs with bottom pressure gauges and temperature sensors are located at the solid rectangluar boxes. The box is the 160 Km by 140 Km region, which is shown in Figure 12. The solid line through the area shows the historical mean path of the Gulf Stream.

Table 1: Site Location and Data Returns

SITE	LATITUDE(N)	LONGITUDE(W)	DEPLOYMENT PERIOD (DATES) 1986 — 1987
IES87A1	35°16.12	74°32.94	Nov 28 – Mar 2
IES87A2	34°58.08	74°07.89	Nov 27 – Mar 2
PIES87B1	35°45.64	74°27.93	Nov 25 – Feb 28
ATM87B2	35°40.67	74°23.52	Nov 30 – Feb 28
PIES87B3	35°37.07	74°13.92	Nov 26 – Mar 1
ATM87B4	35°26.50	73°59.47	Nov 24 – Feb 28
IES87B5	35°22.06	73°53.06	Nov 26 – Feb 28
PIES87B6	35°14.54	73°42.92	Nov 27 – Feb 28
IES87B7	35°06.05	73°31.94	Nov 27 – Mar 1
IES87C1	36°02.80	73°52.90	Nov 23 – Mar 3
IES87C2	35°43.98	73°29.98	Nov 27 – Mar 3

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 and round trip travel times to the surface and back are recorded on a digital cassette tape within the instrument. For the standard IES, a sample burst typically consists of twenty 10 KHz pings. Additionally, bottom pressure and temperature can be measured and recorded. For instruments with these optional sensors, the travel time burst consists of 24 pings, whereas the pressure and temperature are average measurements over the whole sampling interval.

1.4 Data Processing

Most of the earlier processing was done on a PRIME 750 computer, except for the initial dumping of the data from the cassette tapes onto a 9-track magnetic tape. This was done on the Hewlett Packard 2000 series computer maintained by the URI Marine Technicians. At the last major step, objective mapping, the processing was done on our Micro Vax II computer system. The basic processing steps, which include transcription, editing, and conversion into scientific units, are illustrated by the flowchart in Figure 2. The data processing is accomplished by a series of routines specifically developed for the IES. Since these programs are documented elsewhere (Tracey and Watts, 1988), the steps are only outlined below.

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.

CARP : Transfers the data from cassettes to 9-track magnetic tape 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. Used to determine the first (after launch) and last (before recovery) 'on bottom' samples.

MEMOD : Establishes the time base. Determines either the median or modal value (at the user's option) of the travel time burst as the representative measurement. 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 data points are filled by inserting 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.

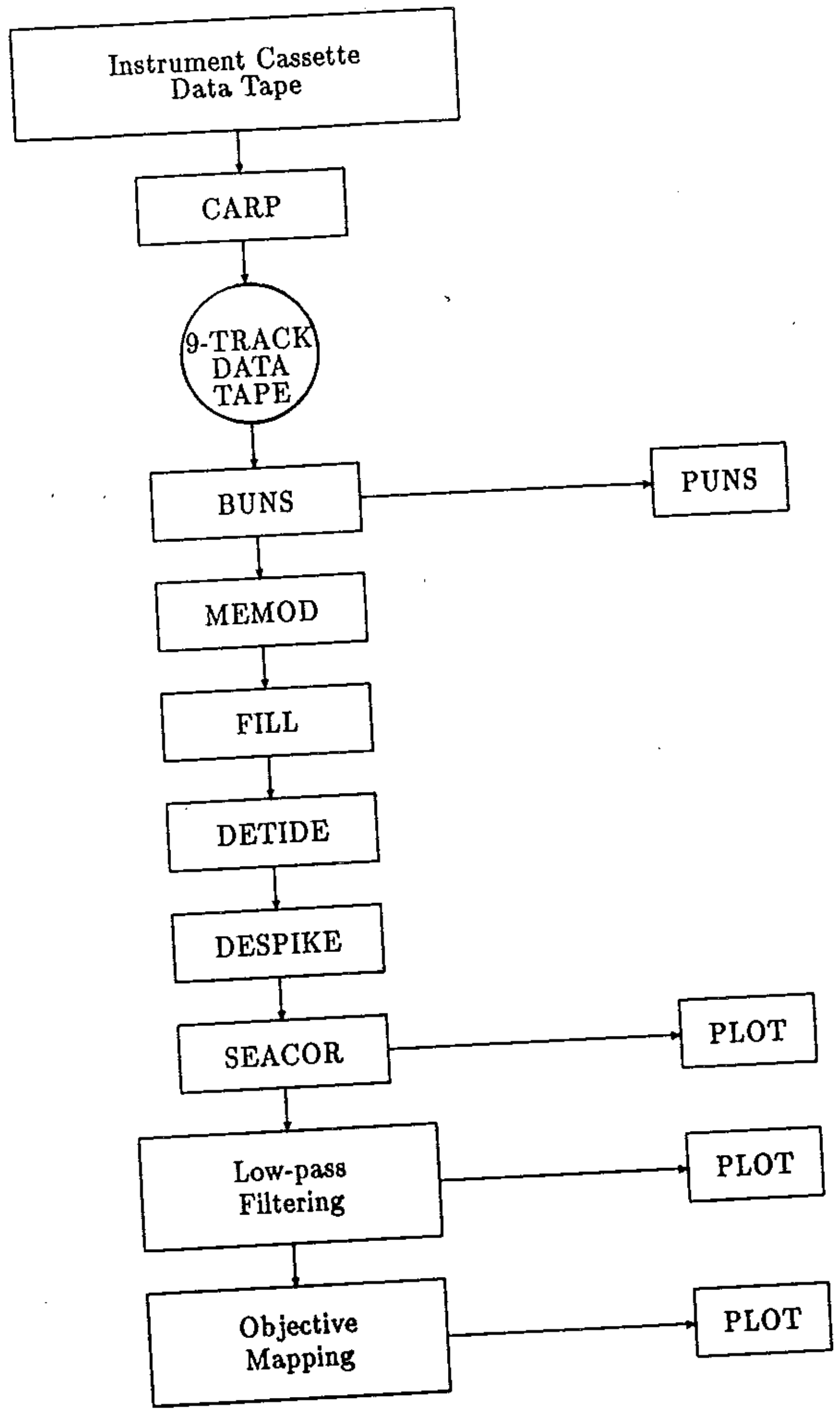


Figure 2: IES Data Processing Flowchart.

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. Plots of the half-hourly pressure, temperature and travel time are generated.

LOW PASS FILTERING : Convolves the travel times, pressures, and temperatures with a 40 hours 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, 1988.

The **FESTSA** time series analysis package (Brooks, 1976), modified for the PRIME 750, was used to remove the higher frequency (tidal and inertial) motions from those with periods of several days or longer, which are the main focus of this project. The symmetric filter, with a Lanczos taper, was designed with the quarter power point at 0.025 cph and the tidal cycle attenuated by 60 dB. The half-hourly travel time, pressure, and temperature data were low-pass filtered and the smoothed output series (40 HRLP) had sampling intervals of six hours.

1.4.1 Travel Time Calibration

Variations in the travel times have been shown to be proportional to variations in the thermocline depth (Watts and Rossby, 1977; Watts and Wimbush, 1981). Calibration XBTs were taken at each IES site in order to convert the travel times (τ) into thermocline depths (ξ) according to the relation: $\xi = M\tau + B$, 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 instruments, show that the constant (M) value, 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 Section 4. 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 instruments, 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 Thermocline Depth Mapping

Objective maps of the thermocline (Z_{12}) field in the array region have been produced at daily intervals from these records. The boxed region in Figure 1, oriented 045°T, is the region which has been mapped. The objective mapping techniques were developed by E. Carter (1983) and special adaptations for their application to the Gulf Stream frontal zone are discussed in Watts and Tracey (1985). Two results presented in this latter work are of particular importance to the objective mapping performed here: 1) If the mean field is removed, the perturbations have essentially isotropic correlation fields. 2) The space-time correlation functions used for the objective analysis are shown.

The objective analysis is performed on the "perturbation fields", which are obtained by removing the mean field from the input dataset and normalizing by the standard deviation. To represent the mean field, $\overline{Z_{12}}(x,y)$, where x is alongstream (045°T) and y is cross-stream (315°T), a third order polynomial was fitted to the mean values observed during the November 1986 to March 1987 deployment period. The function form of the polynomial was:

$$\overline{Z_{12}}(x,y) = B_o + B_1 x + B_2 y + B_{11} x^2 + B_{12} xy + B_{22} y^2 + B_{111} x^3 + B_{112} x^2 y + B_{122} xy^2 + B_{222} y^3$$

where (x,y) is the position in kilometers from the origin at 35°N, 74°W, B_o is $0.76533772E+03$, B_1 is $0.6320926E+00$, B_2 is $-0.4103623E+01$, B_{11} is $-0.8553885E-02$, B_{12} is $0.1851212E-01$, B_{22} is $-0.5083383E-01$, B_{111} is $0.5500527E-04$, B_{112} is $-0.9935370E-04$, B_{122} is $-0.6128939E-04$, and B_{222} is $0.3236166E-03$. The standard deviation field, $\sigma(x,y)$, was defined as a function of the mean field depth, from a Gaussian form representative of all IES records:

$$\sigma(x,y) = A + Bexp\left(-\left[\frac{\overline{Z_{12}}(x,y) - Z_o}{C}\right]^2\right)$$

where A is 50 m, B is (200 m - A), C is 200 m, Z_o is 470 m, and $\overline{Z_{12}}(x,y)$ is the mean thermocline depth at that (x,y) location. Figure 10 shows both the mean and standard deviation fields in plain view. The objectively estimated error fields are shown in Figure 11.

For each output grid point, the objective mapping technique selects , from all the input data within a specified maximum time lag (T) and radial (R), the number of the points (N) which have the highest correlations. The output fields in Figure 12 result from specifying N = 6, T = ±1 days, R = 120 Km, and using the idealized correlation function (Watts and Tracey, 1985) with an assumed noise level E = 0.05.

The output of the objective mapping is the perturbation field on a full grid of points, with 20 Km grid spacing, within a 160 Km by 140 Km mapping region. The thermocline depth maps (shown in Figure 12) are obtained by renormalizing the perturbation field by the standard deviation and restoring the mean. Tracey et al. (1987) report an accuracy of 47 m for these output Z_{12} fields.

1.4.3 Temperature

Temperatures (Figure 6) were measured using thermistors (Yellow Springs International Corp., model 44032) controlled by Sea Data Corp. (model DC-37B) electronics cards installed in the IESs, in order 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 40 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.

1.4.4 Bottom Pressure

Digiquartz pressure sensor (models 46K-032 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 (Figure 4) are dominated by the tides, however for some of the instruments, the pressures also drift, 0(0.4 dbar), monotonically with time. Processing of the pressure measurements includes removing the long-term drift and tides as follows.

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.

In order to estimate and remove the long-term drift from the measurements,we made least-squares fits of exponential and exponential-linear curves to our data (Watts and Kontoyiannis, 1986). The mathematical formulas we used here were:

$$Drift = P_1[1 - exp(P_2 t)] + P_3$$

for the exponential curve and

$$Drift = P_1[1 - exp(P_2 t)] + P_3 + P_4 t$$

for the exponential-linear curve. Here t is the time in hours, relative to the approximate deployment time, which is 13 hours before the first data point used. P_1, P_2, P_3, and P_4 are free parameters determined for each instrument by the non-linear regression subroutine P3R of BMDP-79, a package of computer programs developed at the Health Science Computing Facility, UCLA (Dixon and Brown, 1979). These coefficients are listed in Section 2 for PIES87B1 and PIES87B3.

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 Figure 5, have an accuracy (relative to their mean pressure) of better than 0.05 dbar (Watts and Kontoyiannis, 1986). The residual bottom pressure records were low-pass filtered (Figure 8) as mentioned above.

1.4.5 Time Base

The date and time were assigned to each sampling period. The tables in Section 2, report the hours, minutes, and seconds associated with the first and last sampling period as a six-digit number. All times are given as Greenwich Mean Time (GMT). For processing convenience, the times were converted into yearhours. Table 2 lists the yearhour which corresponds 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, 1987 at 0000 GMT, with measurements occurring between January and March 1987 assigned positive yearhours. Negative values correspond to the sampling period from November through December 1986.

1.5 Acoustic Ocean-Transport Meter Description

The acoustic transport meter, described in Chaplin and Watts (1986), is a new instrument which is presently under development. We conducted the first extensive test deployments of the ATM prototypes during the SYNOP Pilot Experiment.

The ATM consists of three separate components, a master transceiver and two slave transponders. These components are moored in a triangular pattern, at nominal spacings of 3 Km. The master is a microprocessor-controlled IES which has had its sampling scheme reprogrammed. The typical configuration has 32 measurements taken per hour at approximately 56 s intervals to allow ample time for all signals to be received and/or dissipated.

In addition to measuring transport, the master and slave components can perform other operations. The master functions as a traditional IES, measuring the thermocline depth at its deployment site. The two slaves can serve as navigation transponders for the Pegasus velocity profiler. During a Pegasus drop, the ATM is sent a coded signal and sampling is reduced to one measurement per hour so as not to interfere with the Pegasus acoustics.

Table 2: Yearhour Calendar for Non-Leap Years. Only the yearhour corresponding to 0000 GMT is listed for each day.

JAN			FEB			MAR			APR			MAY			JUNE		
DATE	YEAR DAY	HOUR (0000Z)	DATE	YEAR DAY	HOUR (0000Z)	DATE	YEAR DAY	HOUR (0000Z)	DATE	YEAR DAY	HOUR (0000Z)	DATE	YEAR DAY	HOUR (0000Z)	DATE	YEAR DAY	HOUR (0000Z)
1	1	0	1	32	744	1	60	1416	1	91	2160	1	121	2880	1	152	3624
2	2	24	2	33	768	2	61	1440	2	92	2184	2	122	2904	2	153	3648
3	3	48	3	34	792	3	62	1464	3	93	2208	3	123	2928	3	154	3672
4	4	72	4	35	816	4	63	1488	4	94	2232	4	124	2952	4	155	3696
5	5	96	5	36	840	5	64	1512	5	95	2256	5	125	2976	5	156	3720
6	6	120	6	37	864	6	65	1536	6	96	2280	6	126	3000	6	157	3744
7	7	144	7	38	888	7	66	1560	7	97	2304	7	127	3024	7	158	3768
8	8	168	8	39	912	8	67	1584	8	98	2328	8	128	3048	8	159	3792
9	9	192	9	40	936	9	68	1608	9	99	2352	9	129	3072	9	160	3816
10	10	216	10	41	960	10	69	1632	10	100	2376	10	130	3096	10	161	3840
11	11	240	11	42	984	11	70	1656	11	101	2400	11	131	3120	11	162	3864
12	12	264	12	43	1008	12	71	1680	12	102	2424	12	132	3144	12	163	3888
13	13	288	13	44	1032	13	72	1704	13	103	2448	13	133	3168	13	164	3912
14	14	312	14	45	1056	14	73	1728	14	104	2472	14	134	3192	14	165	3936
15	15	336	15	46	1080	15	74	1752	15	105	2496	15	135	3216	15	166	3960
16	16	360	16	47	1104	16	75	1776	16	106	2520	16	136	3240	16	167	3984
17	17	384	17	48	1128	17	76	1800	17	107	2544	17	137	3264	17	168	4008
18	18	408	18	49	1152	18	77	1824	18	108	2568	18	138	3288	18	169	4032
19	19	432	19	50	1176	19	78	1848	19	109	2592	19	139	3312	19	170	4056
20	20	456	20	51	1200	20	79	1872	20	110	2616	20	140	3336	20	171	4080
21	21	480	21	52	1224	21	80	1896	21	111	2640	21	141	3360	21	172	4104
22	22	504	22	53	1248	22	81	1920	22	112	2664	22	142	3384	22	173	4128
23	23	528	23	54	1272	23	82	1944	23	113	2688	23	143	3408	23	174	4152
24	24	552	24	55	1296	24	83	1968	24	114	2712	24	144	3432	24	175	4176
25	25	576	25	56	1320	25	84	1992	25	115	2736	25	145	3456	25	176	4200
26	26	600	26	57	1344	26	85	2016	26	116	2760	26	146	3480	26	177	4224
27	27	624	27	58	1368	27	86	2040	27	117	2784	27	147	3504	27	178	4248
28	28	648	28	59	1392	28	87	2064	28	118	2808	28	148	3528	28	179	4272
29	29	672				29	88	2088	29	119	2832	29	149	3552	29	180	4296
30	30	696				30	89	2112	30	120	2856	30	150	3576	30	181	4320
31	31	720				31	90	2136				31	151	3600			

JULY			AUG			SEPT			OCT			NOV			DEC		
DATE	YEAR DAY	HOUR (0000Z)	DATE	YEAR DAY	HOUR (0000Z)	DATE	YEAR DAY	HOUR (0000Z)	DATE	YEAR DAY	HOUR (0000Z)	DATE	YEAR DAY	HOUR (0000Z)	DATE	YEAR DAY	HOUR (0000Z)
1	182	4344	1	213	5088	1	244	5832	1	274	6552	1	305	7296	1	335	8016
2	183	4368	2	214	5112	2	245	5856	2	275	6576	2	306	7320	2	336	8040
3	184	4392	3	215	5136	3	246	5880	3	276	6600	3	307	7344	3	337	8064
4	185	4416	4	216	5160	4	247	5904	4	277	6624	4	308	7368	4	338	8088
5	186	4440	5	217	5184	5	248	5928	5	278	6648	5	309	7392	5	339	8112
6	187	4464	6	218	5208	6	249	5952	6	279	6672	6	310	7416	6	340	8136
7	188	4488	7	219	5232	7	250	5976	7	280	6696	7	311	7440	7	341	8160
8	189	4512	8	220	5256	8	251	6000	8	281	6720	8	312	7464	8	342	8184
9	190	4536	9	221	5280	9	252	6024	9	282	6744	9	313	7488	9	343	8208
10	191	4560	10	222	5304	10	253	6048	10	283	6768	10	314	7512	10	344	8232
11	192	4584	11	223	5328	11	254	6072	11	284	6792	11	315	7536	11	345	8256
12	193	4608	12	224	5352	12	255	6096	12	285	6816	12	316	7560	12	346	8280
13	194	4632	13	225	5376	13	256	6120	13	286	6840	13	317	7584	13	347	8304
14	195	4656	14	226	5400	14	257	6144	14	287	6864	14	318	7608	14	348	8328
15	196	4680	15	227	5424	15	258	6168	15	288	6888	15	319	7632	15	349	8352
16	197	4704	16	228	5448	16	259	6192	16	289	6912	16	320	7656	16	350	8376
17	198	4728	17	229	5472	17	260	6216	17	290	6936	17	321	7680	17	351	8400
18	199	4752	18	230	5496	18	261	6240	18	291	6960	18	322	7704	18	352	8424
19	200	4776	19	231	5520	19	262	6264	19	292	6984	19	323	7728	19	353	8448
20	201	4800	20	232	5544	20	263	6288	20	293	7008	20	324	7752	20	354	8472
21	202	4824	21	233	5568	21	264	6312	21	294	7032	21	325	7776	21	355	8496
22	203	4848	22	234	5592	22	265	6336	22	295	7056	22	326	7800	22	356	8520
23	204	4872	23	235	5616	23	266	6360	23	296	7080	23	327	7824	23	357	8544
24	205	4896	24	236	5640	24	267	6384	24	297	7104	24	328	7848	24	358	8568
25	206	4920	25	237	5664	25	268	6408	25	298	7128	25	329	7872	25	359	8592
26	207	4944	26	238	5688	26	269	6432	26	299	7152	26	330	7896	26	360	8616
27	208	4968	27	239	5712	27	270	6456	27	300	7176	27	331	7920	27	361	8640
28	209	4992	28	240	5736	28	271	6480	28	301	7200	28	332	7944	28	362	8664
29	210	5016	29	241	5760	29	272	6504	29	302	7224	29	333	7968	29	363	8688
30	211	5040	30	242	5784	30	273	6528	30	303	7248	30	334	7992	30	364	8712
31	212	5064	31	243	5808				31	304	7272				31	364	8736

After the Pegasus operations have been completed, normal sampling resumes.

Unfortunately during the Pilot Experiment, the ATMs did not function correctly. Two unrelated problems occurred which resulted in poor data returns. First, deploying the three ATM components at just the right spacings so that all the required acoustic signals are received without interfering with each other or with extraneous echos is a more subtle and difficult job than we had realized. Consequently, the deployment sites of the three ATM components were not optimal, and some of the acoustic signals required for the transport calculations either were not recorded or interfered with each other's detected transit time. Hence, in this report only thermocline depth measurements are reported for the ATMs.

Secondly, after operating normally for several days, both instruments automatically switched from the "normal" sampling mode into the "Pegasus" sampling mode. For one instrument, ATM87B2, even the Pegasus-mode was unusual with 8 measurements made at irregular intervals during each hour. Thus special data processing was required to obtain accurate thermocline depth values from the travel time measurements.

The data records of both ATM87B2 and ATM87B4 were split into two sections based on the sampling modes. Different processing was performed on the different sections.

Both instruments sampled normally (32 measurements per hour) during the first portions. These travel time data were grouped into hourly "bursts" and processed as in Section 1.4 for an IES through the MEMOD and DESPIKE programs. Since these initial records were only about five days long, the high frequency motions were removed using a 12-hour lowpass-filter in place of the typical 40-hour lowpass-filter. The output data were subsampled at 6-hour intervals and scaled to thermocline depths. Since these records are very short, they are not shown in Figures 3.2 and 7.2. However the data have been used to contribute to the objective maps shown in Section 5.

For the two instruments, the second portions (Pegasus-mode) of the travel time records were processed differently. For ATM87B2, with only 8 samples per hour, the data were grouped into 12-hour "bursts" prior to IES processing and removing the travel time spikes. The data for ATM87B4, with only one sample per hour, were similarly grouped and processed, except in 24-hour "bursts". For both instruments, the start time for each "burst" is stepped forward at a 6 hour interval (the bursts overlap). The processed vertical travel time data from the ATMs are shown in Figure 3.2. Lowpass-filtering was performed using a 96-hour Lanczos filter. The filtered data (Figure 7.2) have a sampling interval of 24 hours and were scaled to thermocline depths in the same manner as for the other IESs.

1.6 Data Recovery

Table 1 summarizes the data returns from each of the IESs and ATMs. All nine instruments were recovered, giving a recovery rate of 100%. IES87C1 ceased functioning properly about one month after the instrument was launched. All the remaining instruments performed successfully, yielding a 91% data return for the travel time measurements. Complete records were obtained from all three bottom pressure gauges; however the data record from one of these (PIES87B6) had large jumps, indicating its sensor malfunctioned, thus the recovery rate for the bottom pressure data was only 67%. Complete records were obtained from all three temperature gauges; thus the return rate was 100% for these data.

2 Individual Site and Record Information Tables

The following tables provide informations about the location, dates, and basic statistics on the data records. Each table documents a single instrument site.

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 Section 3 and 4 are tabulated. For each plot, the times associated with the first and last data point are supplied. All yearhours are referenced to January 1, 1987 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) were calculated for the half-hourly and 40 HRLP records for each variable of standard IES and PIES, and for the six-hourly and 96 HRLP records for that of two ATMs. These are also presented in the following tables.

Table 3. Site and Record Information for IES87A1

Serial Number: 043
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 20
Additional Sensors: None

POSITION: 35°16.12 N 74°32.94 W DEPTH: 2660 m

	DATE	GMT	CRUISE
LAUNCH:	Nov 28, 1986	023900	EN152
RECOVERY:	Mar 2, 1987	190400	EN156

TRAVEL TIME RECORDS
Fig. 3.1

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 28, 1986	033135	-812.4736
LAST DATA POINT:	Mar 2, 1987	190133	1459.0258

Number of Points: 4544
Sampling Interval: 0.5 hrs

Minimum τ = 3.52552 s Mean = 3.53130 s
Maximum τ = 3.54078 s Standard Deviation = 0.00263 s

40HRLP THERMOCLINE DEPTH RECORDS
Fig. 7.1

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 67541.63 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 29, 1986	120000	-780.00
LAST DATA POINT:	Mar 1, 1987	120000	1428.00

Number of Points: 369
Sampling Interval: 6.0 hrs

Minimum Z_{12} = 313.34 m Mean = 447.74 m
Maximum Z_{12} = 522.71 m Standard Deviation = 46.97 m

Table 4. Site and Record Information for IES87A2

Serial Number: 045
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 20
Additional Sensors: None

POSITION: 34°58.08 N DEPTH: 3280 m
74°07.89 W

	DATE	GMT	CRUISE
LAUNCH:	Nov 27, 1986	230500	EN152
RECOVERY:	Mar 2, 1987	143300	EN156

TRAVEL TIME RECORDS
Fig. 3.1

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 28, 1986	000135	-815.9736
LAST DATA POINT:	Mar 2, 1987	143133	1454.5258

Number of Points: 4542
Sampling Interval: 0.5 hrs

Minimum τ = 4.34647 s   Mean = 4.35049 s
Maximum τ = 4.35414 s   Standard Deviation = 0.00108 s

40HRLP THERMOCLINE DEPTH RECORDS
Fig. 7.1

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 83377.92 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 29, 1986	060000	-786.00
LAST DATA POINT:	Mar 1, 1987	060000	1422.00

Number of Points: 369
Sampling Interval: 6.0 hrs

Minimum Z_{12} = 682.58 m   Mean = 718.22 m
Maximum Z_{12} = 757.91 m   Standard Deviation = 16.05 m

Table 5. Site and Record Information for PIES87B1

Serial Number: 058
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: Pressure and Temperature
Pressure Sensor Serial Number: 19327

POSITION: 35°45.64 N 74°27.93 W DEPTH: 1950 m

	DATE	GMT	CRUISE
LAUNCH:	Nov 25, 1986	205600	EN152
RECOVERY:	Feb 28, 1987	093836	EN156

TRAVEL TIME RECORDS
Fig. 3.2

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 25, 1986	213151	–866.4692
LAST DATA POINT:	Feb 28, 1987	093151	1401.5308

Number of Points: 4537
Sampling Interval: 0.5 hrs

Minimum τ = 0.19395 s Mean = 0.20100 s
Maximum τ = 0.20586 s Standard Deviation = 0.00193 s

40HRLP THERMOCLINE DEPTH RECORDS
Fig. 7.2

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 4045.00 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 27, 1986	060000	–834.00
LAST DATA POINT:	Feb 27, 1987	000000	1368.00

Number of Points: 368
Sampling Interval: 6.0 hrs

Minimum Z_{12} = 164.37 m Mean = 226.57 m
Maximum Z_{12} = 313.92 m Standard Deviation = 33.06 m

PIES87B1 (continue)

MEASURED PRESSURE RECORDS

Fig. 4

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 25, 1986	213151	-866.4692
LAST DATA POINT:	Feb 28, 1987	093151	1401.5308

Number of Points: 4537
Sampling Interval: 0.5 hrs

Minimum = 1964.16 dbar
Maximum = 1965.79 dbar
Mean = 1964.88 dbar
Standard Deviation = 0.33140 dbar

RESIDUAL PRESSURE RECORDS

Fig. 5

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

DRIFT = $P_1[1 - exp(P_2 t)] + P_3 + P_4 t$

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

P_1 = 1.167470 dbar
P_2 = −0.000321 dbar
P_3 = 0.078548 dbar
P_4 = 0.000231 dbar

TIDE calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	.42831	.10012	.09006	.02148	.09056	.07172	.02964	.01654
G°:	353.09	335.93	19.74	21.35	182.59	188.09	183.70	183.94

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 26, 1986	093151	-854.4692
LAST DATA POINT:	Feb 28, 1987	093151	1401.5308

Number of Points: 4513
Sampling Interval: 0.5 hrs

Minimum = −0.1354 dbar
Maximum = 0.1181 dbar
Mean = 0.0005 dbar
Standard Deviation = 0.0309 dbar

PIES87B1 (continue)

40HRLP PRESSURE RECORDS
Fig. 8

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 27, 1986	180000	–822.0000
LAST DATA POINT:	Feb 27, 1987	000000	1368.0000

Number of Points: 366
Sampling Interval: 6.0 hrs

Minimum = –0.1099 dbar Mean = 0.0003 dbar
Maximum = 0.0562 dbar Standard Deviation = 0.0235 dbar

TEMPERATURE RECORDS
Fig. 6

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 25, 1986	213151	–866.4692
LAST DATA POINT:	Feb 28, 1987	093151	1401.5308

Number of Points: 4537
Sampling Interval: 0.5 hrs

Minimum = 3.490 °C Mean = 3.784 °C
Maximum = 3.991 °C Standard Deviation = 0.103 °C

40HRLP TEMPERATURE RECORDS
Fig. 9

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 27, 1986	180000	–822.0000
LAST DATA POINT:	Feb 27, 1987	000000	1368.0000

Number of Points: 366
Sampling Interval: 6.0 hrs

Minimum = 3.533 °C Mean = 3.784 °C
Maximum = 3.953 °C Standard Deviation = 0.086 °C

Table 6. Site and Record Information for ATM87B2

Serial Number: 064
Type of Travel Time Detector: TTD
Number of Pings per Sampling: refer to Sec. 1.5
Additional Sensors: None

POSITION: 35°40.67 N DEPTH: 2300 m
74°23.52 W

	DATE	GMT	CRUISE
LAUNCH:	Nov 30, 1986	215700	EN152
RECOVERY:	Feb 28, 1987	065600	EN156

RAW TRAVEL TIME RECORDS

Fig. 3.2

	DATE	GMT	YEARHOUR
1st DATA POINT:	Dec 4, 1986	141742	-657.7051
LAST DATA POINT:	Feb 28, 1987	011742	1393.2951

Number of Points: 343
Sampling Interval: 6.0 hrs

Minimum τ = 3.02466 s Mean = 3.03044 s
Maximum τ = 3.03808 s Standard Deviation = 0.00254 s

96HRLP THERMOCLINE DEPTH RECORDS

Fig. 7.2

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 57875.36 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	Dec 7, 1986	120000	-588.00
LAST DATA POINT:	Feb 25, 1987	120000	1332.00

Number of Points: 81
Sampling Interval: 24 hrs

Minimum Z_{12} = 195.84 m Mean = 297.67 m
Maximum Z_{12} = 378.48 m Standard Deviation = 0.0047 m

Table 7. Site and Record Information for PIES87B3

Serial Number: 053
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: Pressure and Temperature
Pressure Sensor Serial Number: 17849

POSITION: 35°37.07 N DEPTH: 2665 m
74°13.92 W

	DATE	GMT	CRUISE
LAUNCH:	Nov 26, 1986	030200	EN152
RECOVERY:	Feb 28, 1987	130346	EN156

TRAVEL TIME RECORDS

Fig. 3.2

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 26, 1986	033152	-860.4690
LAST DATA POINT:	Feb 28, 1987	130152	1405.0310

Number of Points: 4532
Sampling Interval: 0.5 hrs

Minimum τ = 0.35106 s   Mean = 0.35759 s
Maximum τ = 0.36869 s   Standard Deviation = 0.00331 s

40HRLP THERMOCLINE DEPTH RECORDS

Fig. 7.2

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 7224.39 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 27, 1986	120000	-828.00
LAST DATA POINT:	Feb 27, 1987	060000	1374.00

Number of Points: 368
Sampling Interval: 6.0 hrs

Minimum Z_{12} = 245.69 m   Mean = 430.42 m
Maximum Z_{12} = 529.52 m   Standard Deviation = 61.07 m

PIES87B3 (continue)

MEASURED PRESSURE RECORDS

Fig. 4

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 26, 1986	033152	−860.4690
LAST DATA POINT:	Feb 28, 1987	130152	1405.0310

Number of Points: 4532
Sampling Interval: 0.5 hrs

Minimum = 2707.75 dbar
Maximum = 2709.34 dbar
Mean = 2708.47 dbar
Standard Deviation = 0.33335 dbar

RESIDUAL PRESSURE RECORDS

Fig. 5

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

DRIFT = $P_1[1 - exp(P_2 t)] + P_3$

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

$P_1 =$ 0.8711981 dbar

$P_2 =$ 0.0000230 dbar

$P_3 =$ 0.0237850 dbar

TIDE calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	.43050	.10010	.08999	.02143	.09059	.07073	.02959	.01645
$G°$:	353.13	335.75	19.66	21.12	183.03	187.32	184.32	180.85

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 26, 1986	153152	−848.4688
LAST DATA POINT:	Feb 28, 1987	130152	1405.0312

Number of Points: 4508
Sampling Interval: 0.5 hrs

Minimum = −0.1532 dbar
Maximum = 0.1229 dbar
Mean = −0.0001 dbar
Standard Deviation = 0.0350 dbar

PIES87B3 (continue)

40HRLP PRESSURE RECORDS
Fig. 8

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 28, 1986	000000	-816.0000
LAST DATA POINT:	Feb 27, 1987	060000	1374.0000

Number of Points: 366
Sampling Interval: 6.0 hrs

Minimum = -0.1216 dbar
Maximum = 0.0719 dbar
Mean = 0.0009 dbar
Standard Deviation = 0.0294 dbar

TEMPERATURE RECORDS
Fig. 6

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 26, 1986	033152	-860.4690
LAST DATA POINT:	Feb 28, 1987	130152	1405.0310

Number of Points: 4532
Sampling Interval: 0.5 hrs

Minimum = 2.570 °C
Maximum = 3.088 °C
Mean = 2.837 °C
Standard Deviation = 0.124 °C

40HRLP TEMPERATURE RECORDS
Fig. 9

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 28, 1986	000000	-816.0000
LAST DATA POINT:	Feb 27, 1987	060000	1374.0000

Number of Points: 366
Sampling Interval: 6.0 hrs

Minimum = 2.578 °C
Maximum = 3.063 °C
Mean = 2.834 °C
Standard Deviation = 0.114 °C

Table 8. Site and Record Information for ATM87B4

Serial Number: 063
Type of Travel Time Detector: TTD
Number of Pings per Sampling: refer to Sec. 1.5
Additional Sensors: None

POSITION: 35°26.50 N 73°59.47 W DEPTH: 3085 m

	DATE	GMT	CRUISE
LAUNCH:	Nov 24, 1986	062400	EN152
RECOVERY:	Feb 28, 1987	164900	EN156

RAW TRAVEL TIME RECORDS

Fig. 3.2

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 30, 1986	112611	-756.5635
LAST DATA POINT:	Feb 21, 1987	052611	1229.4365

Number of Points: 332
Sampling Interval: 6.0 hrs

Minimum τ = 4.07544 s   Mean = 4.07870 s
Maximum τ = 4.08579 s   Standard Deviation = 0.01749 s

96HRLP THERMOCLINE DEPTH RECORDS

Fig. 7.2

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 78181.09 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	Dec 2, 1986	120000	-708.00
LAST DATA POINT:	Feb 18, 1987	120000	1164.00

Number of Points: 79
Sampling Interval: 24 hrs

Minimum Z_{12} = 562.65 m   Mean = 684.56 m
Maximum Z_{12} = 732.31 m   Standard Deviation = 0.0034 m

Table 9. Site and Record Information for IES87B5

Serial Number: 052
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 20
Additional Sensors: None

POSITION: 35°22.06 N 73°53.06 W   DEPTH: 3280 m

	DATE	GMT	CRUISE
LAUNCH:	Nov 26, 1986	175600	EN152
RECOVERY:	Feb 28, 1987	164500	EN156

TRAVEL TIME RECORDS
Fig. 3.2

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 26, 1986	183135	–845.4736
LAST DATA POINT:	Feb 28, 1987	163133	1408.5258

Number of Points: 4509
Sampling Interval: 0.5 hrs

Minimum τ = 4.36937 s   Mean = 4.37362 s
Maximum τ = 4.37918 s   Standard Deviation = 0.00130 s

40HRLP THERMOCLINE DEPTH RECORDS
Fig. 7.2

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 83818.94 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 28, 1986	000000	–816.00
LAST DATA POINT:	Feb 27, 1987	060000	1374.00

Number of Points: 366
Sampling Interval: 6.0 hrs

Minimum Z_{12} = 641.63 m   Mean = 719.65 m
Maximum Z_{12} = 775.03 m   Standard Deviation = 21.17 m

Table 10. Site and Record Information for PIES87B6

Serial Number: 054
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: Pressure and Temperature
Pressure Sensor Serial Number: 18426

POSITION: 35°14.54 N 73°42.92 W DEPTH: 3555 m

	DATE	GMT	CRUISE
LAUNCH:	Nov 27, 1986	032900	EN152
RECOVERY:	Feb 28, 1987	211200	EN156

TRAVEL TIME RECORDS

Fig. 3.2

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 27, 1986	043220	-835.4612
LAST DATA POINT:	Feb 28, 1987	210220	1413.0388

Number of Points: 4498
Sampling Interval: 0.5 hrs

Minimum τ = 0.34298 s Mean = 0.34741 s
Maximum τ = 0.35101 s Standard Deviation = 0.00117 s

40HRLP THERMOCLINE DEPTH RECORDS

Fig. 7.2

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 7365.00 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 28, 1986	120000	-804.00
LAST DATA POINT:	Feb 27, 1987	120000	1380.00

Number of Points: 365
Sampling Interval: 6.0 hrs

Minimum Z_{12} = 719.31 m Mean = 763.74 m
Maximum Z_{12} = 810.76 m Standard Deviation = 18.88 m

PIES87B6 (continue)

MEASURED PRESSURE RECORDS
Fig. 4

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 27, 1986	043220	-835.4612
LAST DATA POINT:	Feb 28, 1987	210220	1413.0388

Number of Points: 4498
Sampling Interval: 0.5 hrs

(Pressure record is jumpy)

TEMPERATURE RECORDS
Fig. 6

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 27, 1986	043220	-835.4612
LAST DATA POINT:	Feb 28, 1987	210220	1413.0388

Number of Points: 4498
Sampling Interval: 0.5 hrs

Minimum = 2.324 °C Mean = 2.372 °C
Maximum = 2.458 °C Standard Deviation = 0.045 °C

40HRLP TEMPERATURE RECORDS
Fig. 9

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 29, 1986	000000	-792.0000
LAST DATA POINT:	Feb 27, 1987	120000	1380.0000

Number of Points: 363
Sampling Interval: 6.0 hrs

Minimum = 2.324 °C Mean = 2.372 °C
Maximum = 2.442 °C Standard Deviation = 0.030 °C

Table 11. Site and Record Information for IES87B7

Serial Number: 036
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 20
Additional Sensors: None

POSITION: 35°06.05 N 73°31.94 W   DEPTH: 3800 m

	DATE	GMT	CRUISE
LAUNCH:	Nov 27, 1986	080900	EN152
RECOVERY:	Mar 1, 1987	001700	EN156

TRAVEL TIME RECORDS
Fig. 3.2

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 27, 1986	090135	-830.9736
LAST DATA POINT:	Mar 1, 1987	000133	1416.0258

Number of Points: 4495
Sampling Interval: 0.5 hrs

Minimum τ = 5.07445 s   Mean = 5.07846 s
Maximum τ = 5.08267 s   Standard Deviation = 0.001394 s

40HRLP THERMOCLINE DEPTH RECORDS
Fig. 7.2

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 97250.04 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 28, 1986	180000	-798.00
LAST DATA POINT:	Feb 27, 1987	120000	1386.00

Number of Points: 365
Sampling Interval: 6.0 hrs

Minimum Z_{12} = 713.03 m   Mean = 758.96 m
Maximum Z_{12} = 807.02 m   Standard Deviation = 22.45 m

Table 12. Site and Record Information for IES87C1

Serial Number: 041
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 20
Additional Sensors: None

POSITION: 36°02.80 N DEPTH: 2880 m
73°52.90 W

	DATE	GMT	CRUISE
LAUNCH:	Nov 23, 1986	060700	EN152
RECOVERY:	Mar 3, 1987	044800	EN156

TRAVEL TIME RECORDS

Fig. 3.1

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 23, 1986	064635	–929.2236
LAST DATA POINT:	Dec 24, 1986	064635	–185.2236

Number of Points: 1489
Sampling Interval: 0.5 hrs

Minimum τ = 3.94585 s Mean = 3.95146 s
Maximum τ = 3.95906 s Standard Deviation = 0.00259 s

40HRLP THERMOCLINE DEPTH RECORDS

Fig. 7.1

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 75455.93 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 24, 1986	180000	–894.00
LAST DATA POINT:	Dec 23, 1986	000000	–216.00

Number of Points: 114
Sampling Interval: 6.0 hrs

Minimum Z_{12} = 274.26 m Mean = 373.72 m
Maximum Z_{12} = 460.27 m Standard Deviation = 44.67 m

Table 13. Site and Record Information for IES87C2

Serial Number: 061
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 20
Additional Sensors: None

POSITION: 35°43.98 N 73°29.98 W   DEPTH: 3535 m

	DATE	GMT	CRUISE
LAUNCH:	Nov 27, 1986	141200	EN152
RECOVERY:	Mar 3, 1987	220600	EN156

TRAVEL TIME RECORDS

Fig. 3.1

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 27, 1986	151635	−824.7236
LAST DATA POINT:	Mar 3, 1987	214633	1485.7758

Number of Points: 4622
Sampling Interval: 0.5 hrs

Minimum τ = 4.71669 s   Mean = 4.72040 s
Maximum τ = 4.73019 s   Standard Deviation = 0.00216 s

40HRLP THERMOCLINE DEPTH RECORDS

Fig. 7.1

Z_{12} Conversion equation: $Z_{12} = -19000\text{ms}^{-1} \cdot \tau_d + B$
where B = 90375.20 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	Nov 29, 1986	000000	−792.00
LAST DATA POINT:	Mar 2, 1987	120000	1452.00

Number of Points: 375
Sampling Interval: 6.0 hrs

Minimum Z_{12} = 514.61 m   Mean = 687.47 m
Maximum Z_{12} = 731.10 m   Standard Deviation = 39.48 m

3 Half-hourly Data For Each Cross-stream Line

Plots of the travel time records from each instrument are presented first. These are followed by the measured and residual pressure records and the temperature data for the instruments which had those additional sensors.

These are grouped by cross-stream line, with the northwesternmost IES on each line plotted at the top of the figure. Each plot is labelled with the instrument name in the upper left corner. The time scale is the same for all plots, with each increment corresponding to 5 days. The axis begins on 1200 GMT of the first date labelled.

Vertical scale for each variable is consistent between instruments. Each increment corresponds to 5 msec for the travel time records, to 0.5 dbar for the measured bottom pressure measurements, to 0.05 dbar for the residual bottom pressure data, and to 0.1°C for the temperatures.

The sampling interval of the IESs and PIESs is normally 0.5 hours; the actual interval for each instrument is listed Section 2. ATMs have a 6 hour sampling interval. The length and the start and end times of the data records are also listed in the previous section.

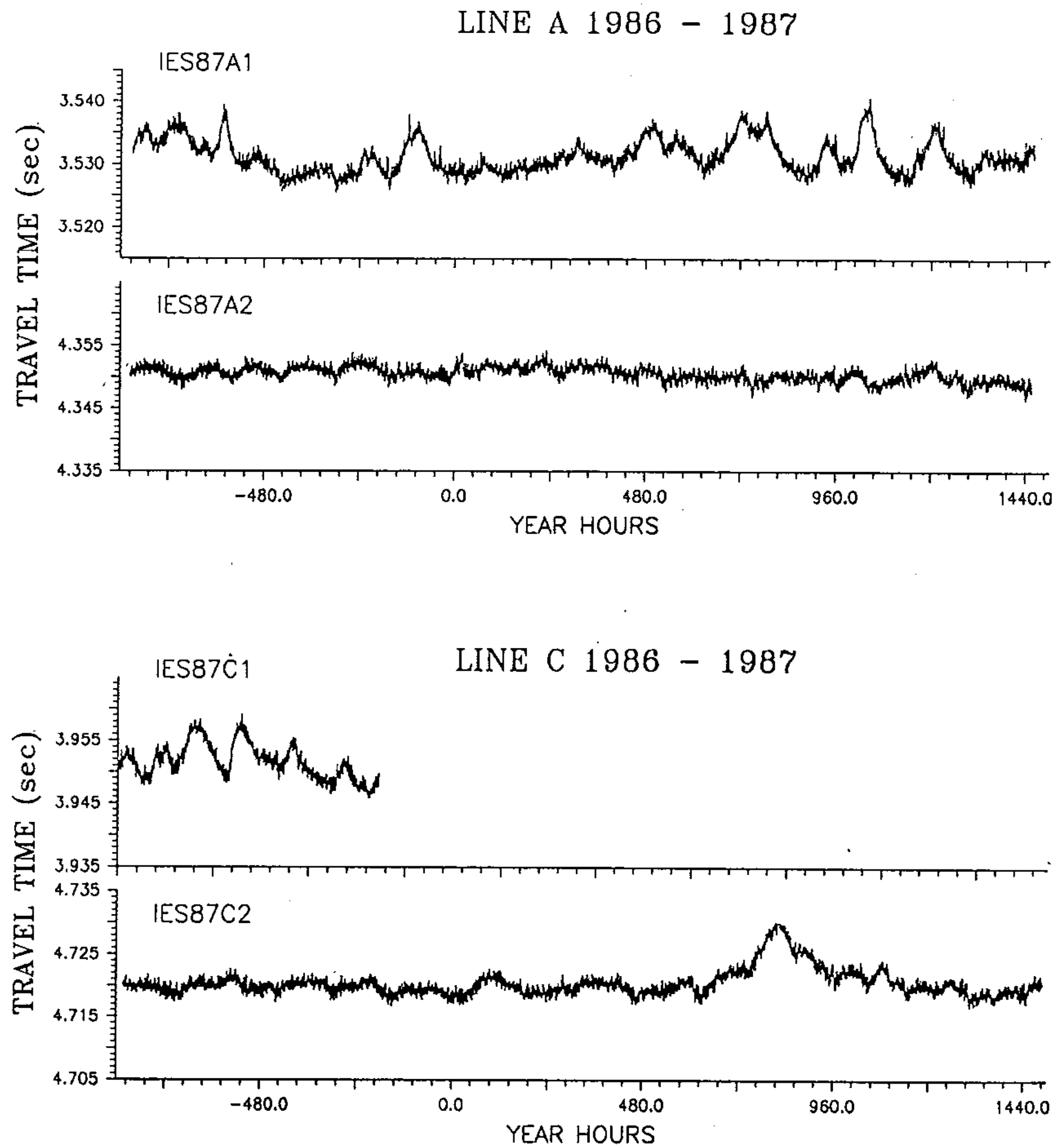


Figure 3.1: Travel time records for Line A and C at half-hourly intervals. The start and end times and records lengths are listed in Section 2.

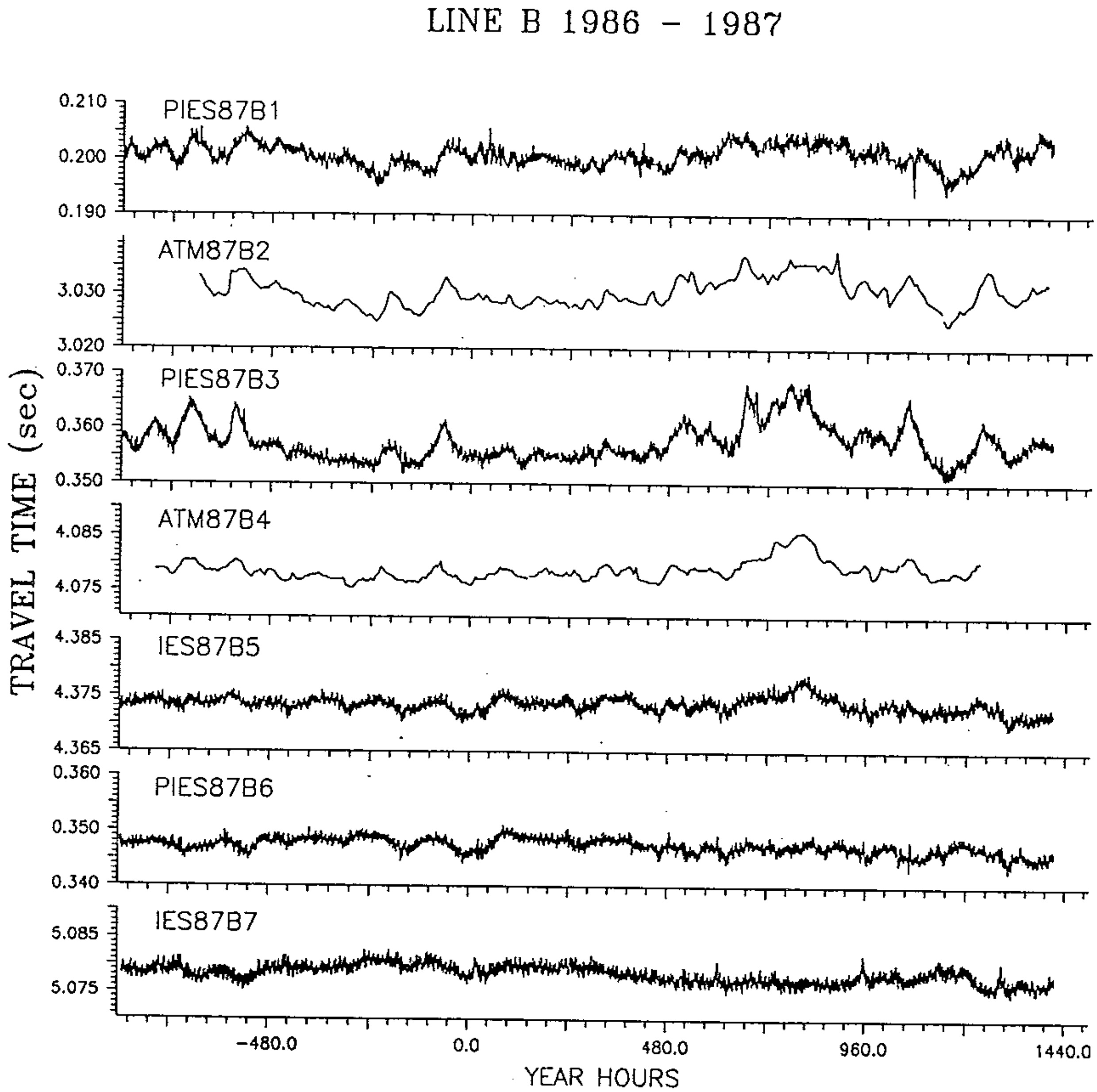


Figure 3.2: Travel time records for Line B at half-hourly intervals: at six-hourly intervals for ATMs.

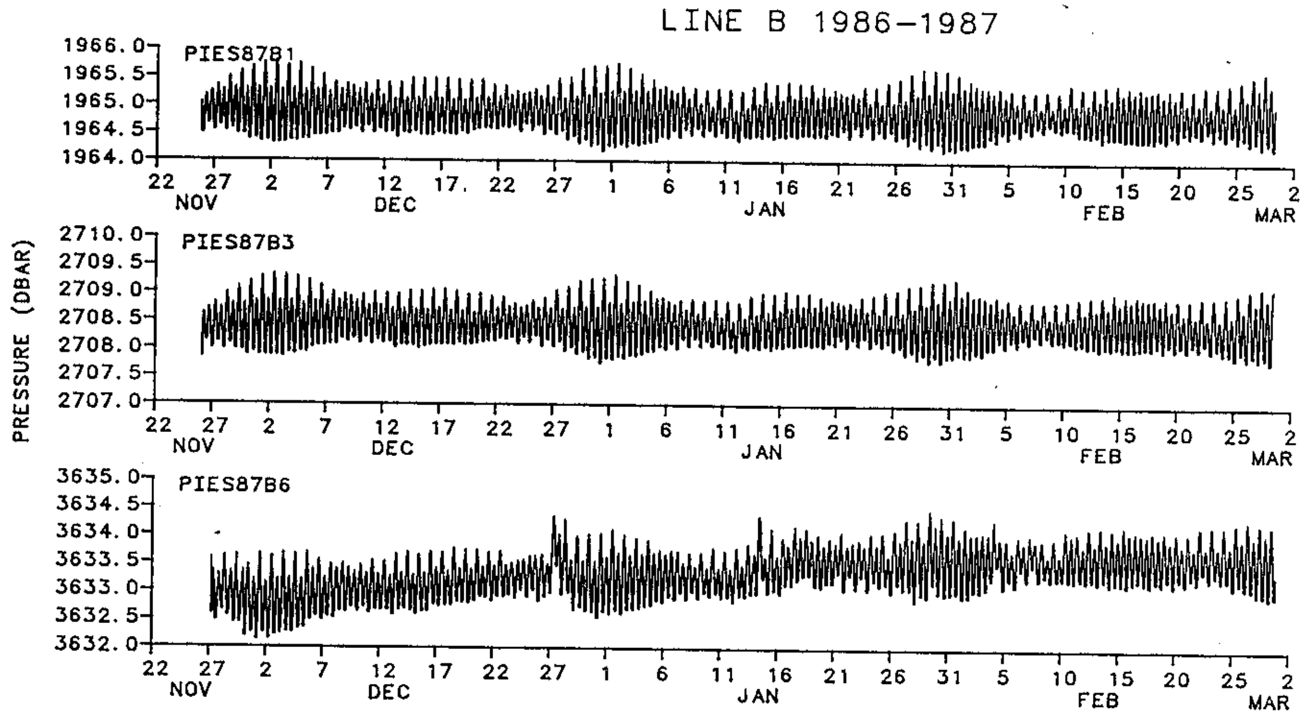


Figure 4: Half-hourly measured bottom pressure records for PIES87B1, PIES87B3 and PIES87B6. The start and end times, and records lengths are listed in Section 2.

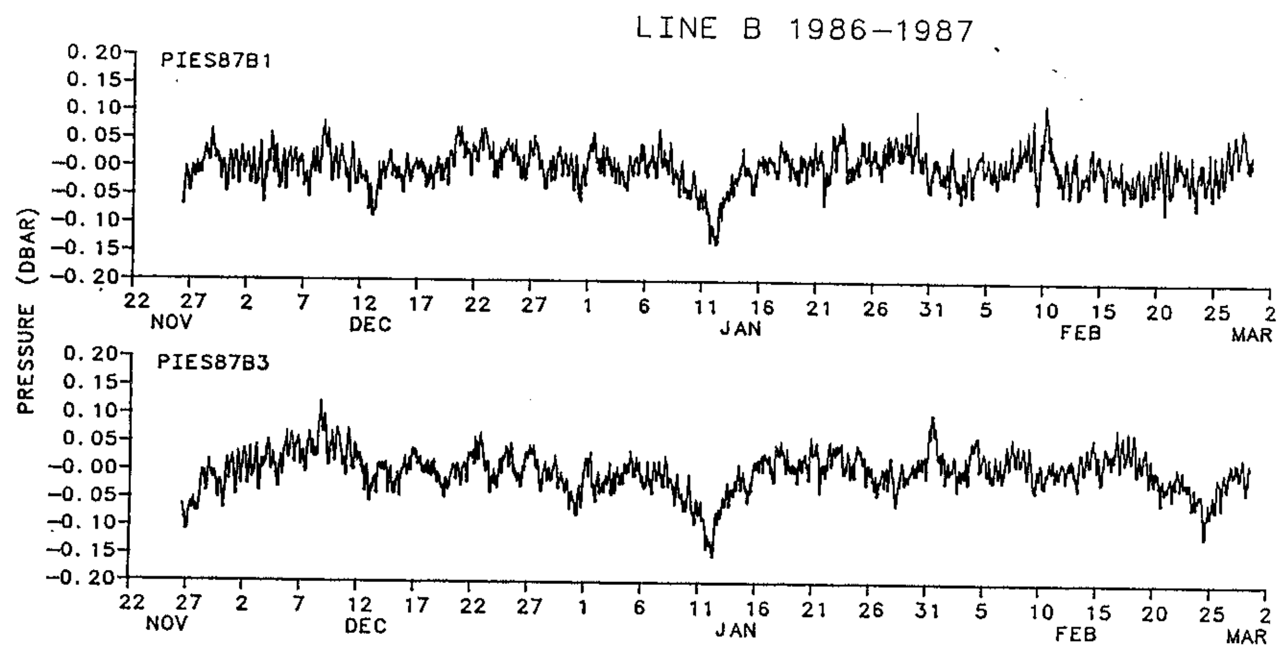


Figure 5: Half-hourly residual bottom pressure records for PIES87B1, PIES87B3. free parameters and tidal constituents are given in Section 2.

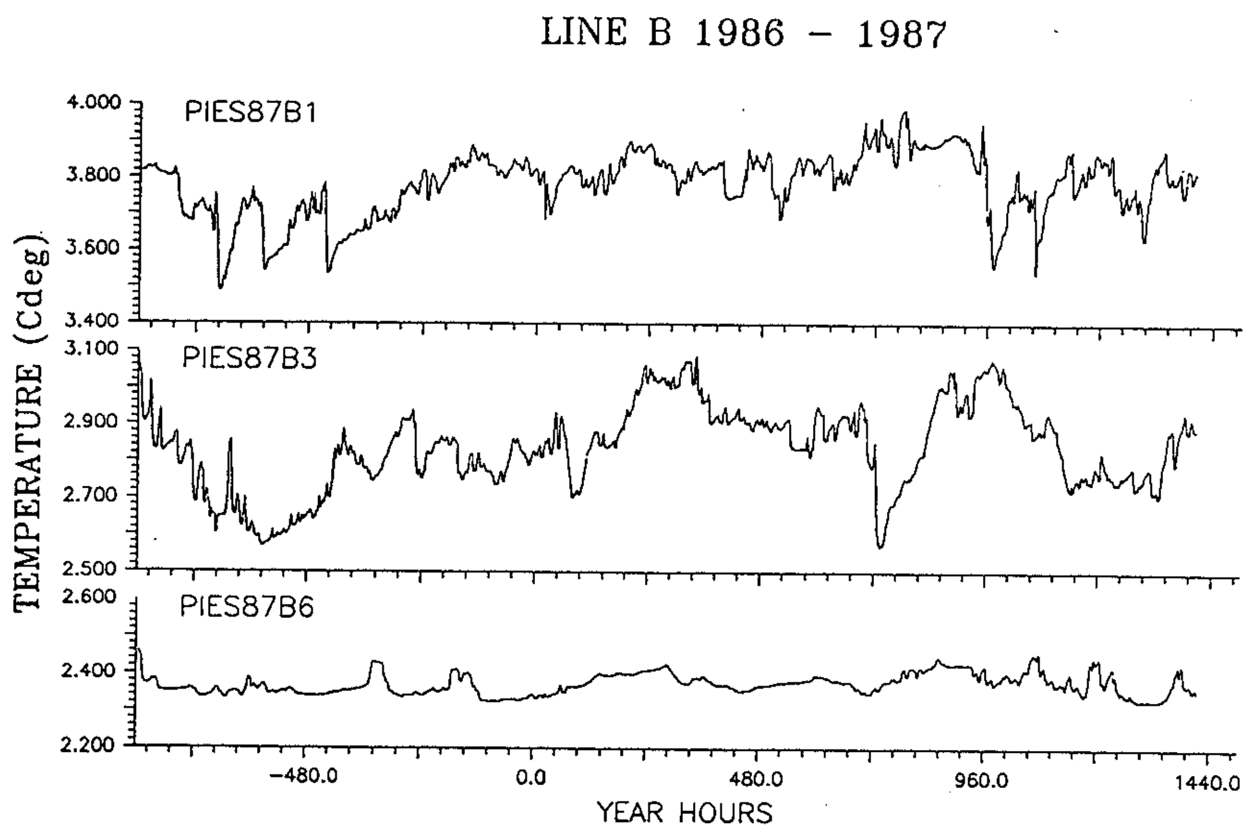


Figure 6: Half-hourly temperature records for PIES87B1, PIES87B3 and PIES87B6.

4 40 HRLP Data For Each Cross-Stream Line

The low-pass filtered thermocline depth (Z_{12}), bottom pressure and temperature records are plotted for each cross-stream line. The thermocline depth records for each cross-stream line are presented first. These are followed by the 40 HRLP residual pressure records and the 40 HRLP temperature data for the instruments which had these additional sensors.

The time scale is the same for all plots, with each increment corresponding to 10 days. The axis begins on 1200 GMT of the first date labelled.

Vertical scale for each variable is consistent between instruments. Each increment corresponds to 100 m for the Z_{12} records, to 0.05 dbar for the bottom pressure measurements, and to 0.1°C for the temperatures. The sampling intervals are 6 hours for all variables of the IESs and PIESs and 24 hours for those of the ATMs. The length and the start and end times of the data records are tabulated in Section 2.

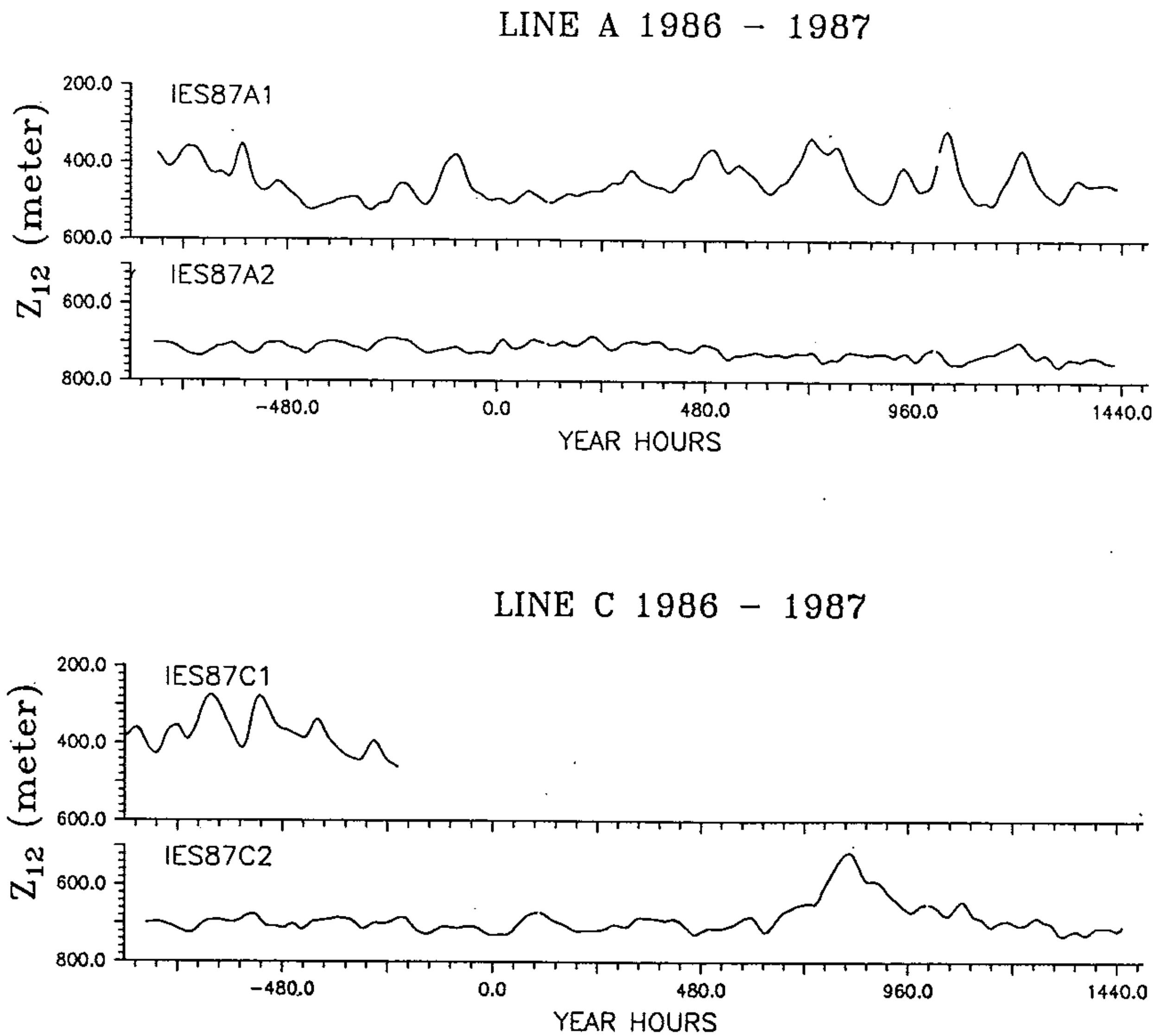


Figure 7.1: Thermocline depth records for Line A and C: records 40HR low-pass filtered at 6 hour intervals. For each instrument, the equation used to convert travel time to Z_{12} is given in Section 2.

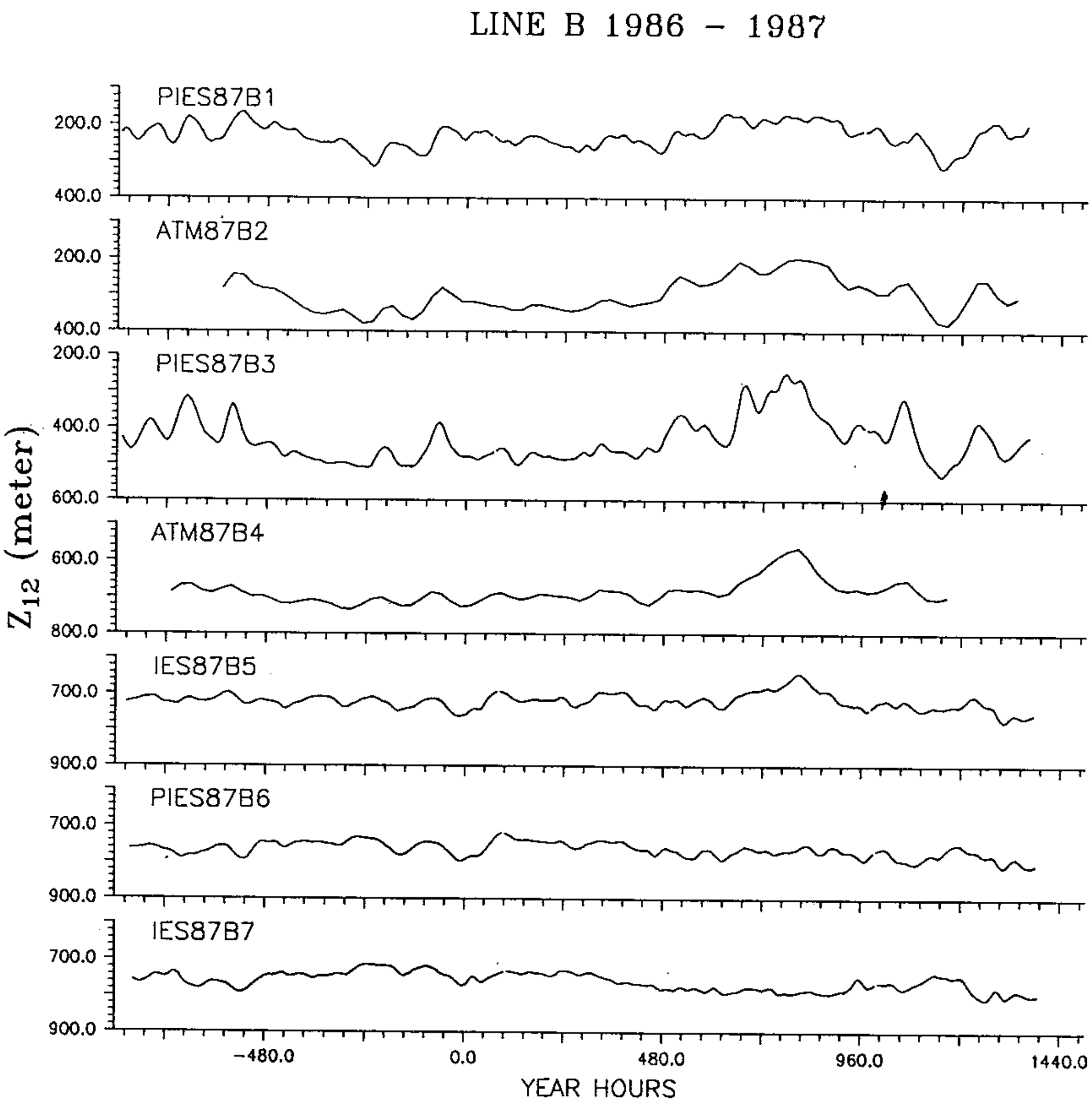


Figure 7.2: Thermocline depth records for Line B: (P)IESs records 40HR low-pass filtered at 6 hour intervals and ATM records 96HR low-pass filtered at 24 hour intervals.

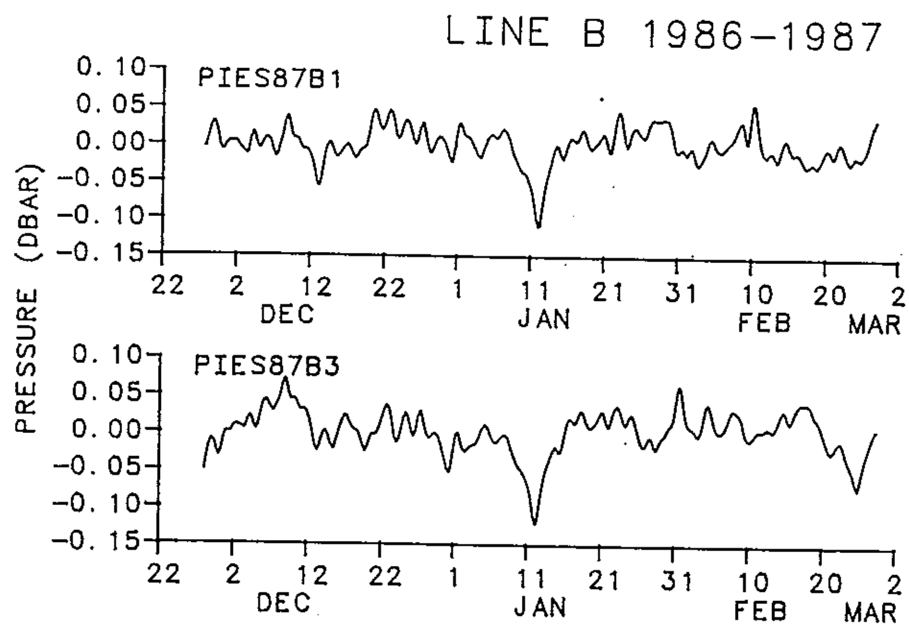


Figure 8: 40HRLP bottom pressure records for PIES87B1 and PIES87B3 at 6 hour intervals.

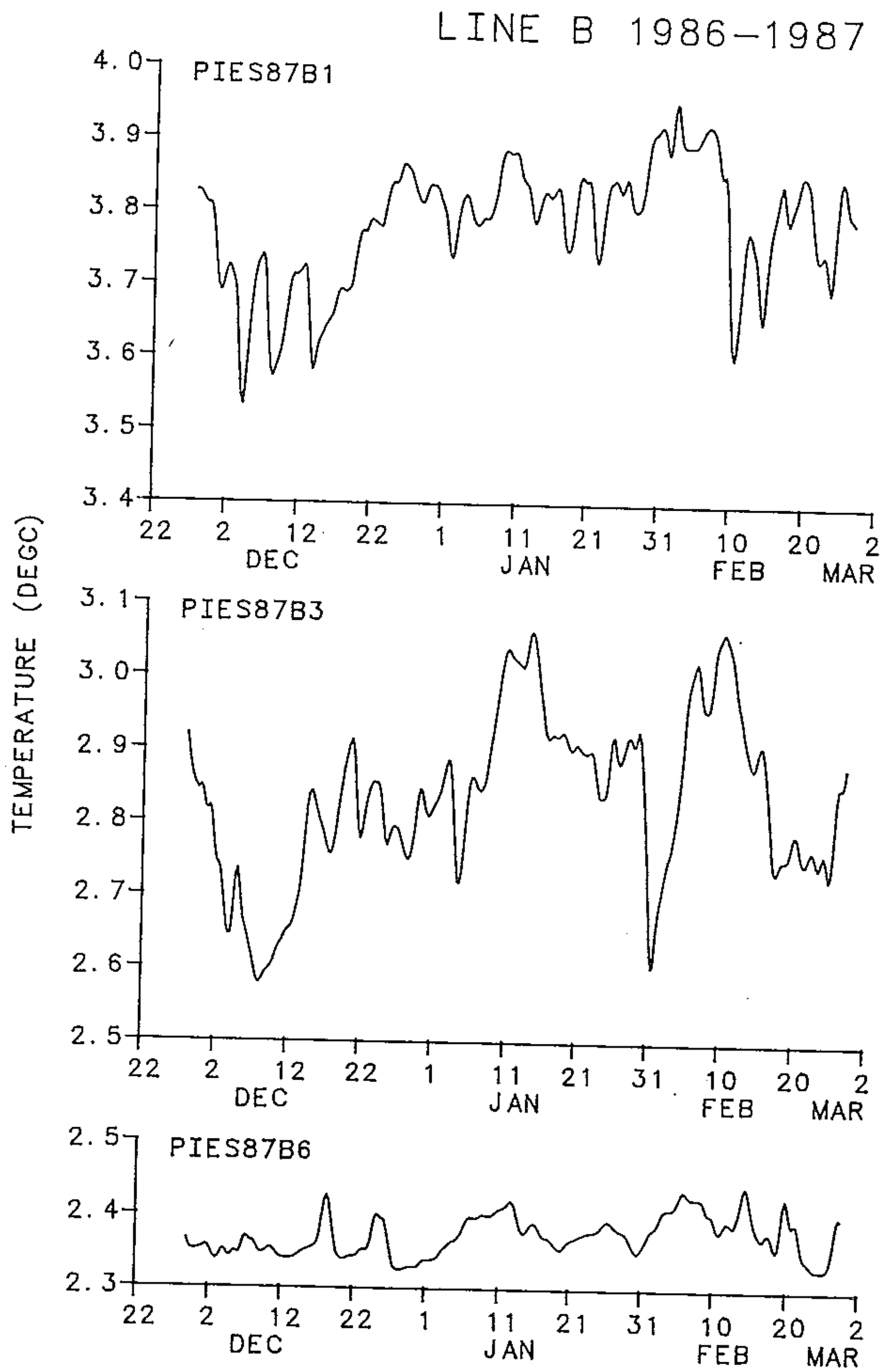


Figure 9: 40HRLP temperature records for PIES87B1, PIES87B3 and PIES87B6. at 6 hour intervals.

5 Thermocline Depth Maps

Contour plots of the mean and variance fields and the error fields, the thermocline depth (Z_{12}) fields are presented.

Each of the contoured frames corresponds to the 160 Km by 140 Km boxed region shown in Figure 1. The axes, oriented 045°T, are referenced to a grid origin located at 35°N 75°W. Each frame consists of a 9×8 square grid of points, at 20 Km spacing. The actual IES sites are indicated by the + marks and the positions are listed in Table 1.

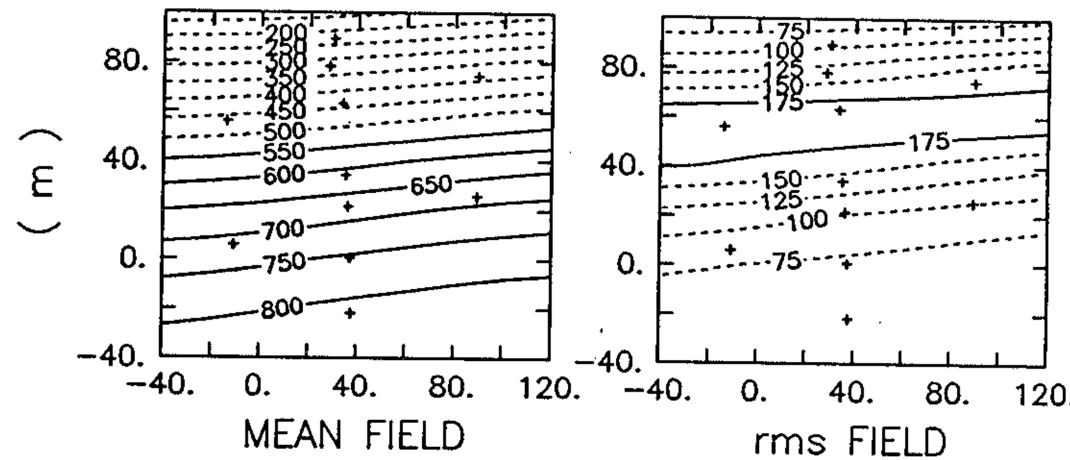


Figure 10: Mean field(left) for the 28 Nov. 1986 to 27 Feb. 1987 data and root-mean-square variance field(right) are contoured in plane view. Contour interval of the mean field is 50 m, with dashed lines indicating $Z_{12} \leq 500$ m. Contour interval of the variance field is 25 m with the dashed region corresponding to variance ≤ 150 m rms.

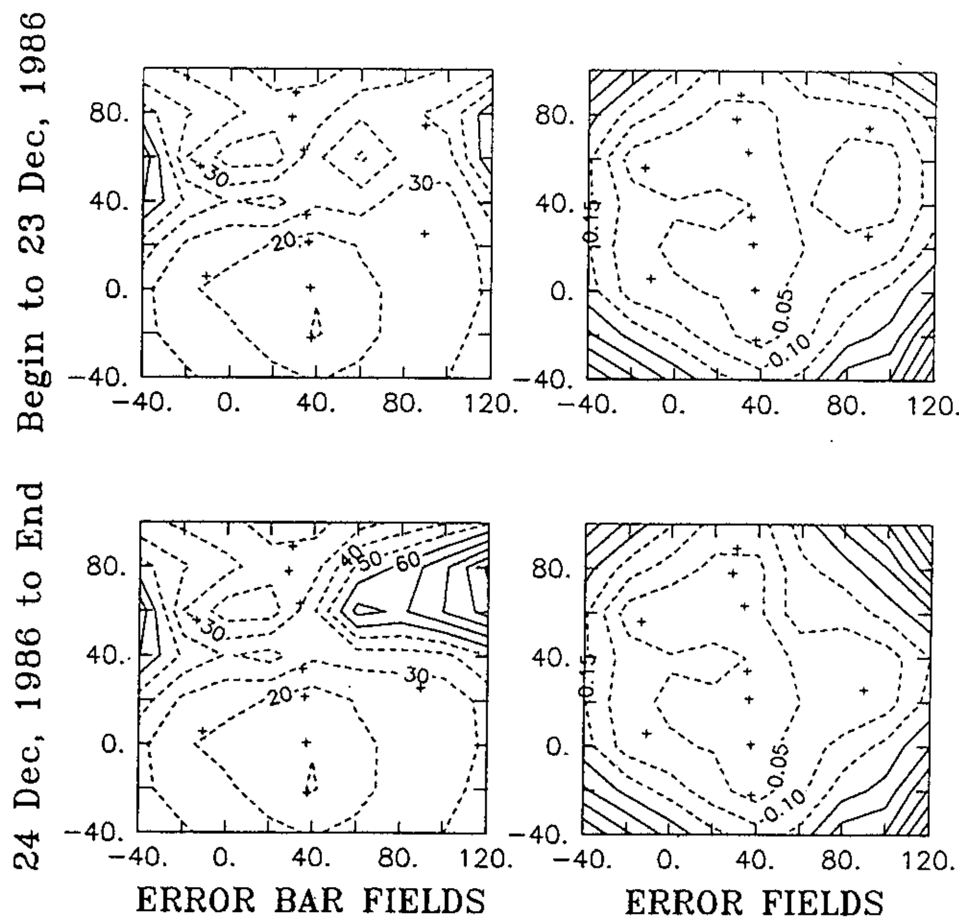
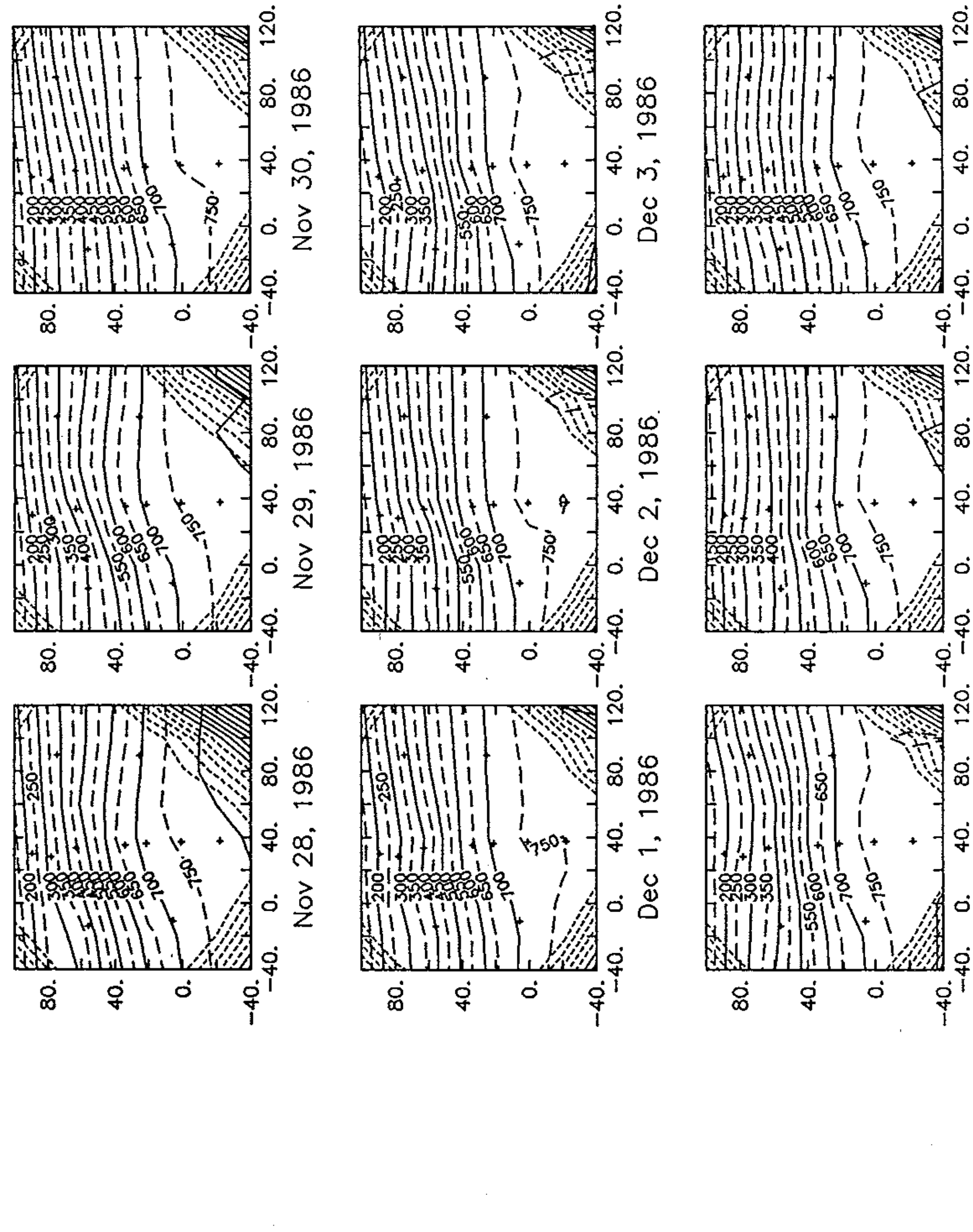
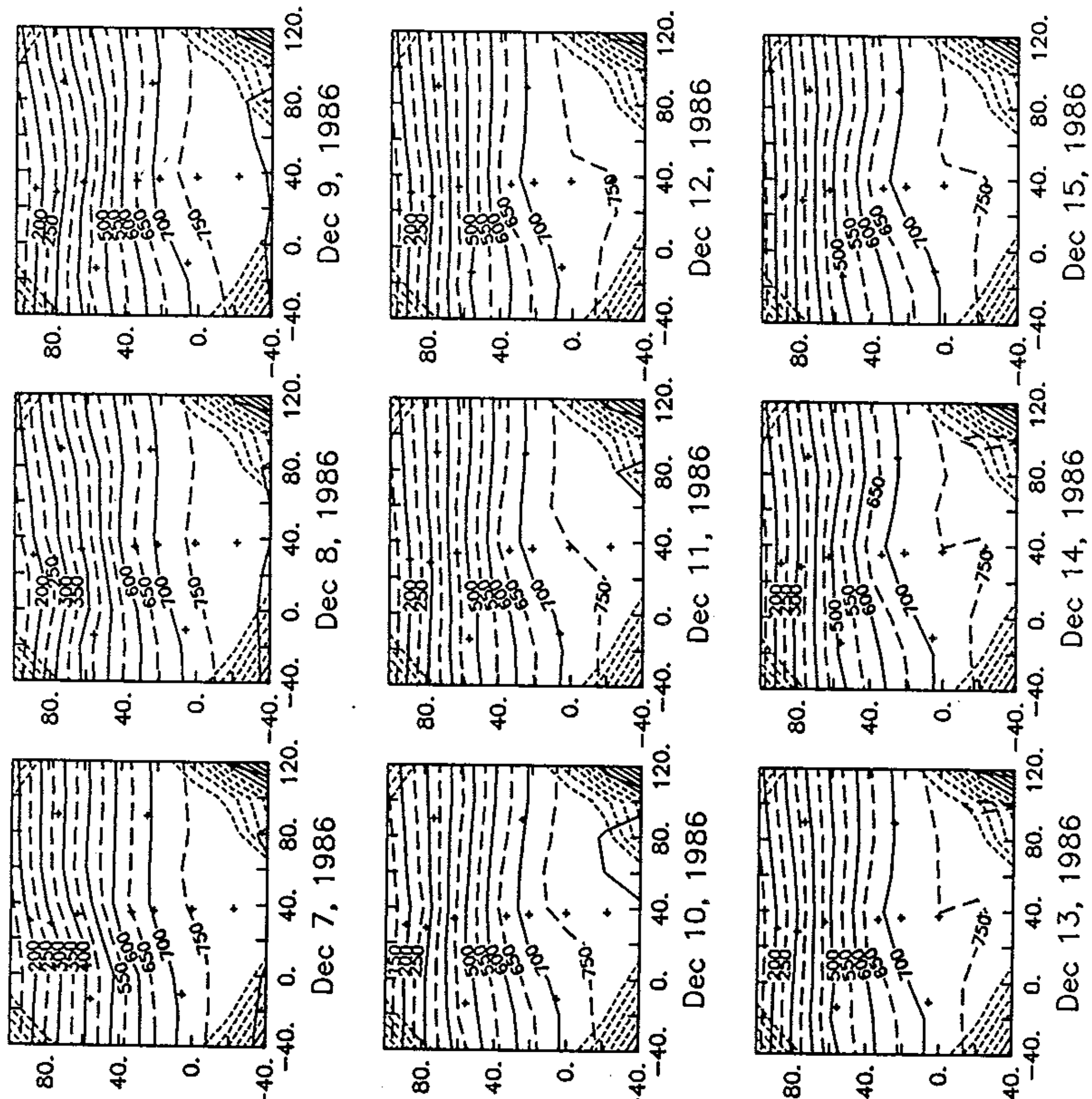


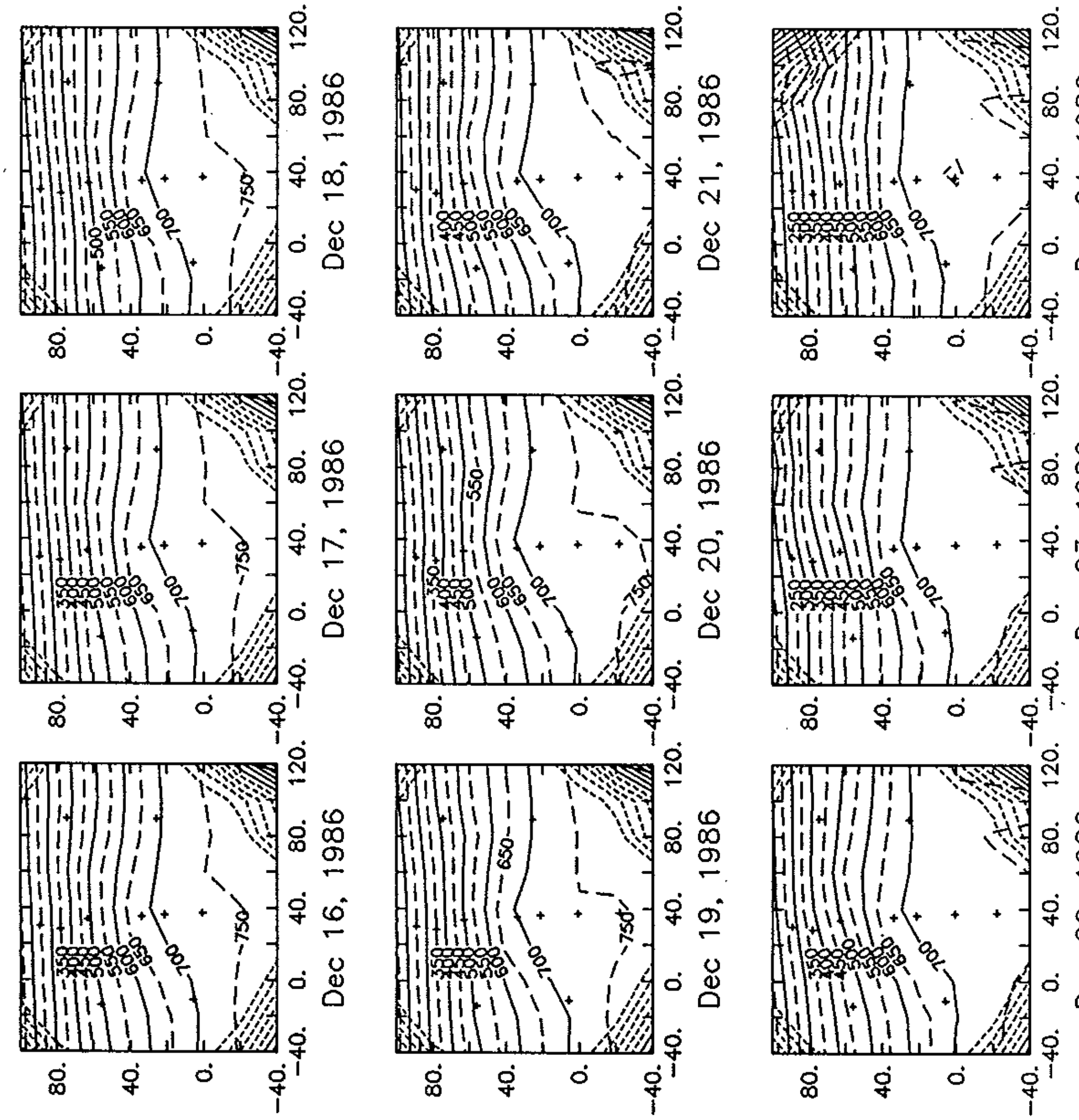
Figure 11: The error bar fields (left) have a contour interval of 10 m and the dashed region corresponds to errors < 50 m. The error (percent variance) fields, shown at right, are contoured at 5% intervals, with the dashed region corresponding to < 15% error. The error maps apply to the Z_{12} in Figure 12 for the dates shown.

Figure 12: The 12° isotherm depth, Z_{12}, field is shown at daily intervals from 28 Nov, 1986 to 27 Feb, 1987. The maps are shown for 1200 GMT on the date indicated at the bottom. The Z_{12} field is contoured by solid and dashed lines with 100 m intervals. The shorter dashed lines correspond the error maps are shown in Figure 11.


Nov 28, 1986
Nov 29, 1986
Nov 30, 1986
Dec 1, 1986
Dec 2, 1986
Dec 3, 1986
Dec 4, 1986
Dec 5, 1986
Dec 6, 1986
80.
40.
0.
−40.
−40.
0.
40.
80.
120.



Dec 7, 1986
Dec 8, 1986
Dec 9, 1986
Dec 10, 1986
Dec 11, 1986
Dec 12, 1986
Dec 13, 1986
Dec 14, 1986
Dec 15, 1986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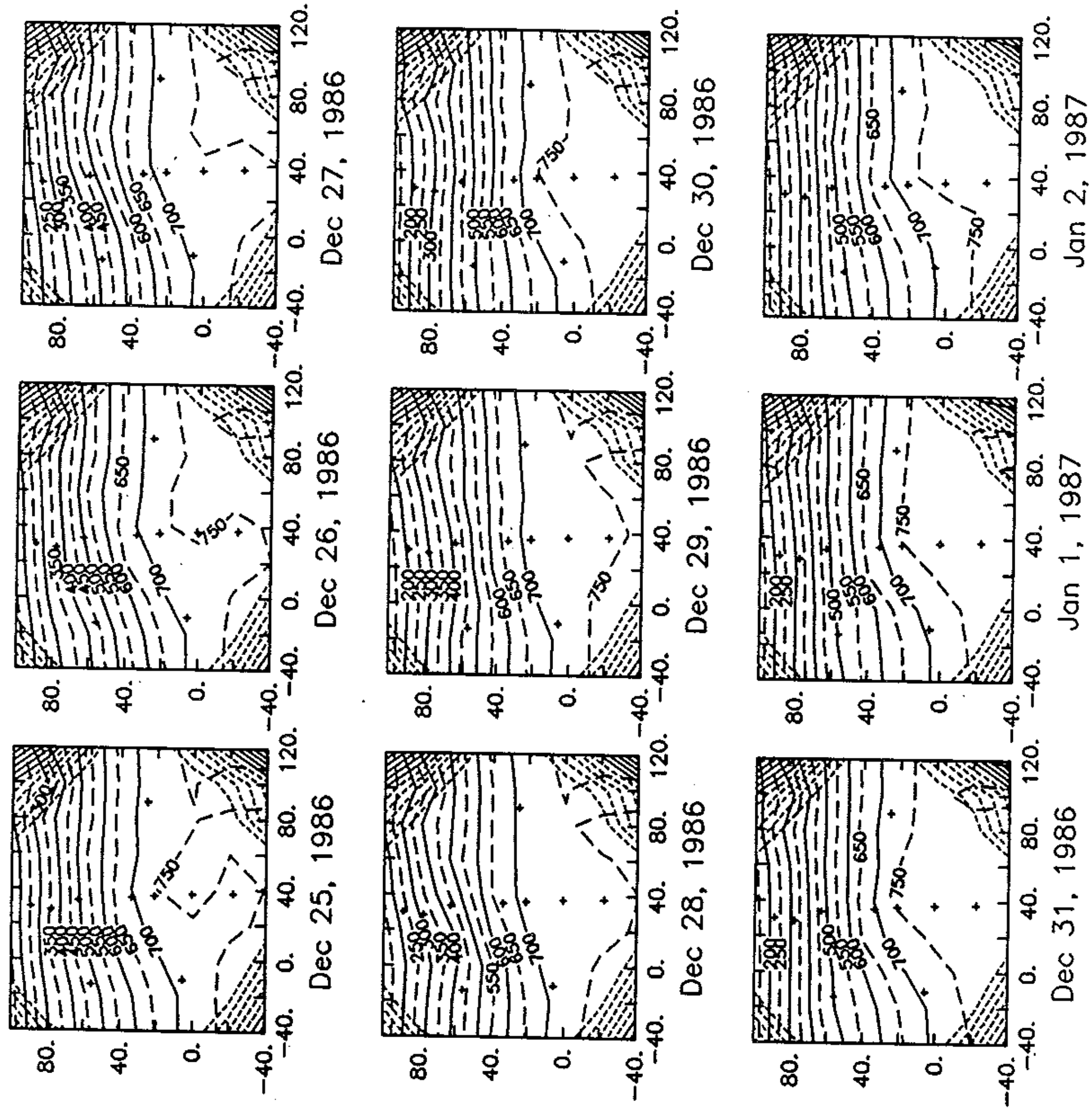
Dec 18, 1986
Dec 19, 1986
Dec 20, 1986
Dec 21, 1986
Dec 22, 1986
Dec 23, 1986
Dec 24, 1986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Dec 28, 1986
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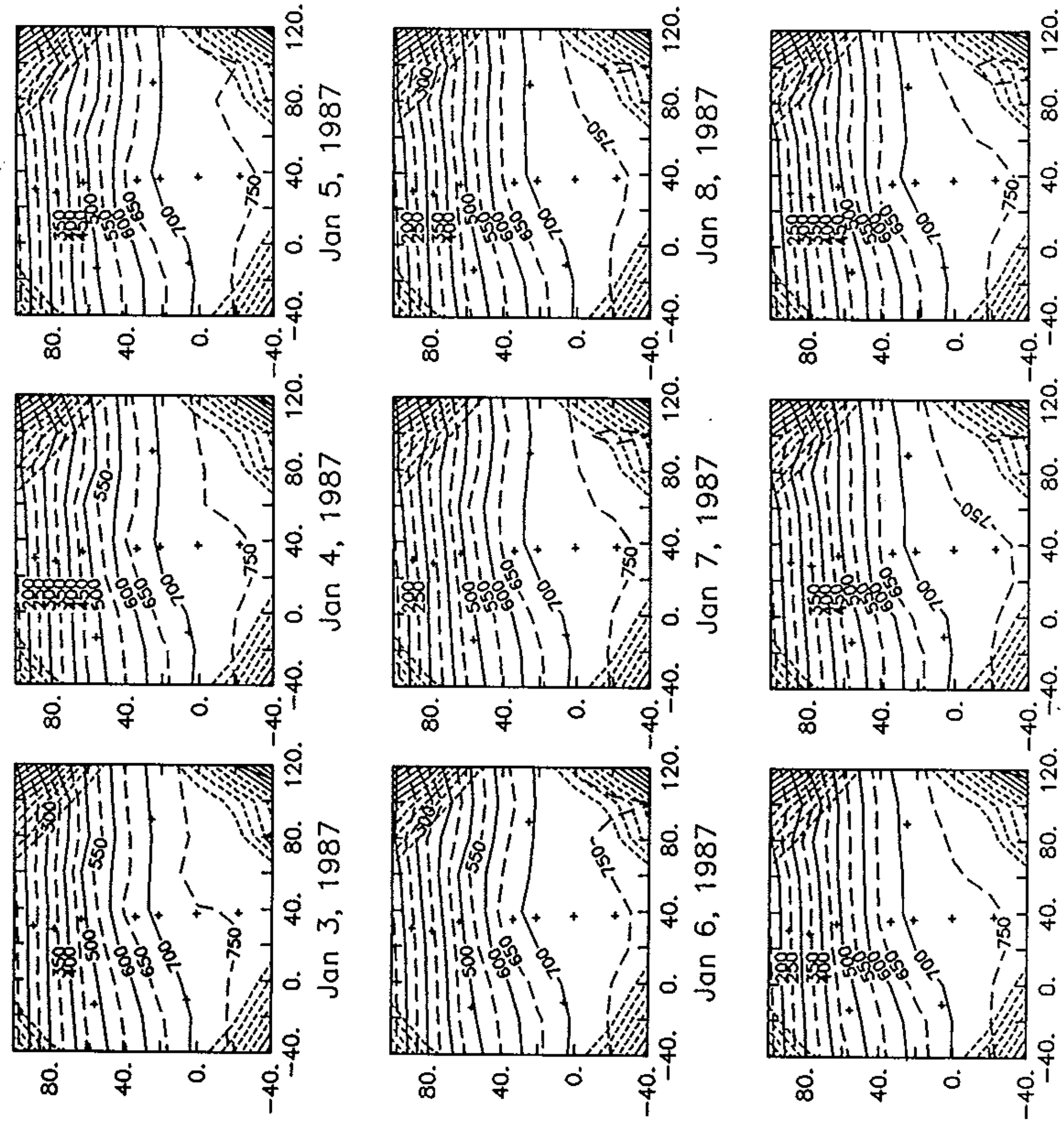
Dec 30, 1986
Dec 31, 1986
Jan 1, 1987
Jan 2, 1987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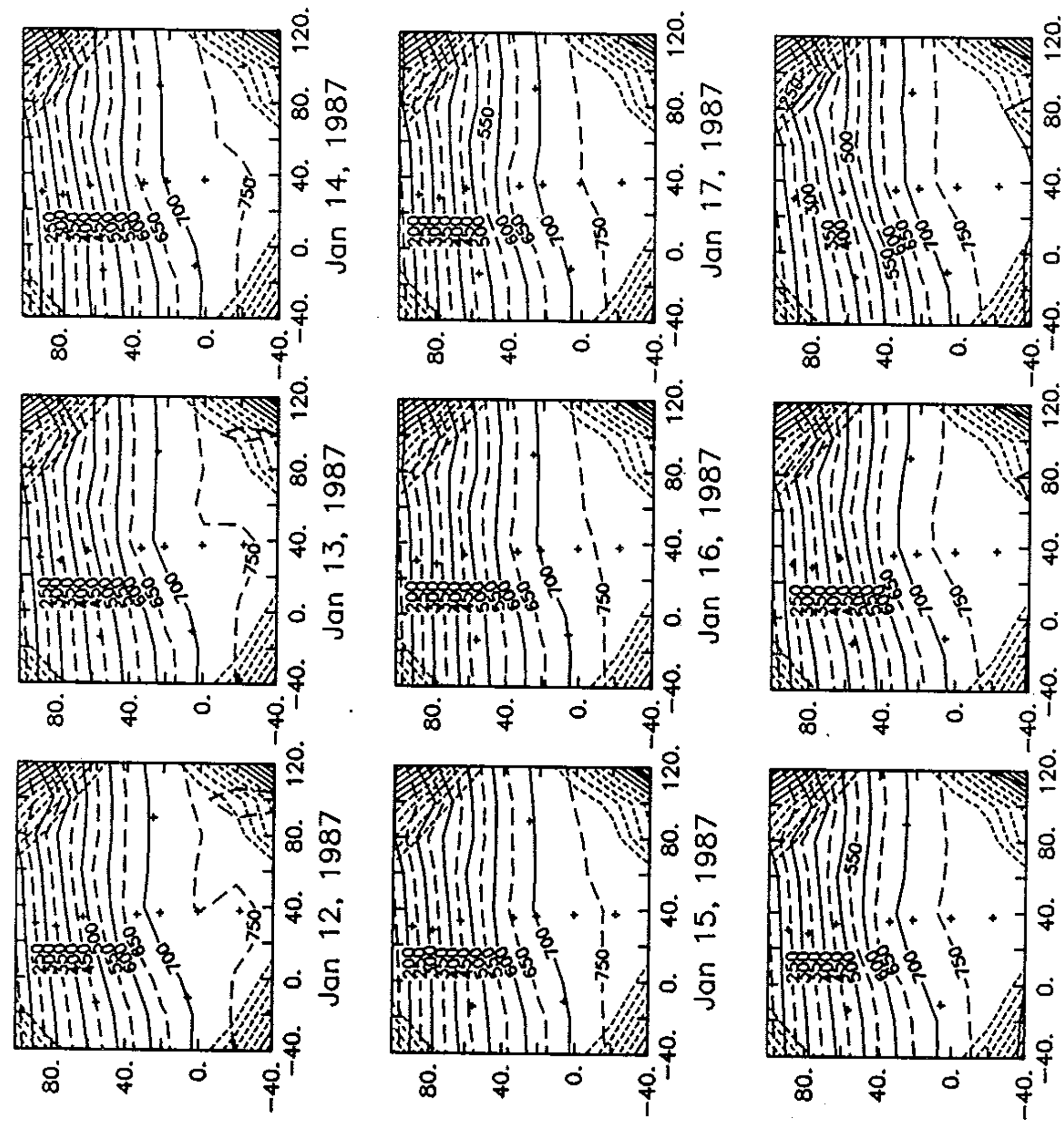
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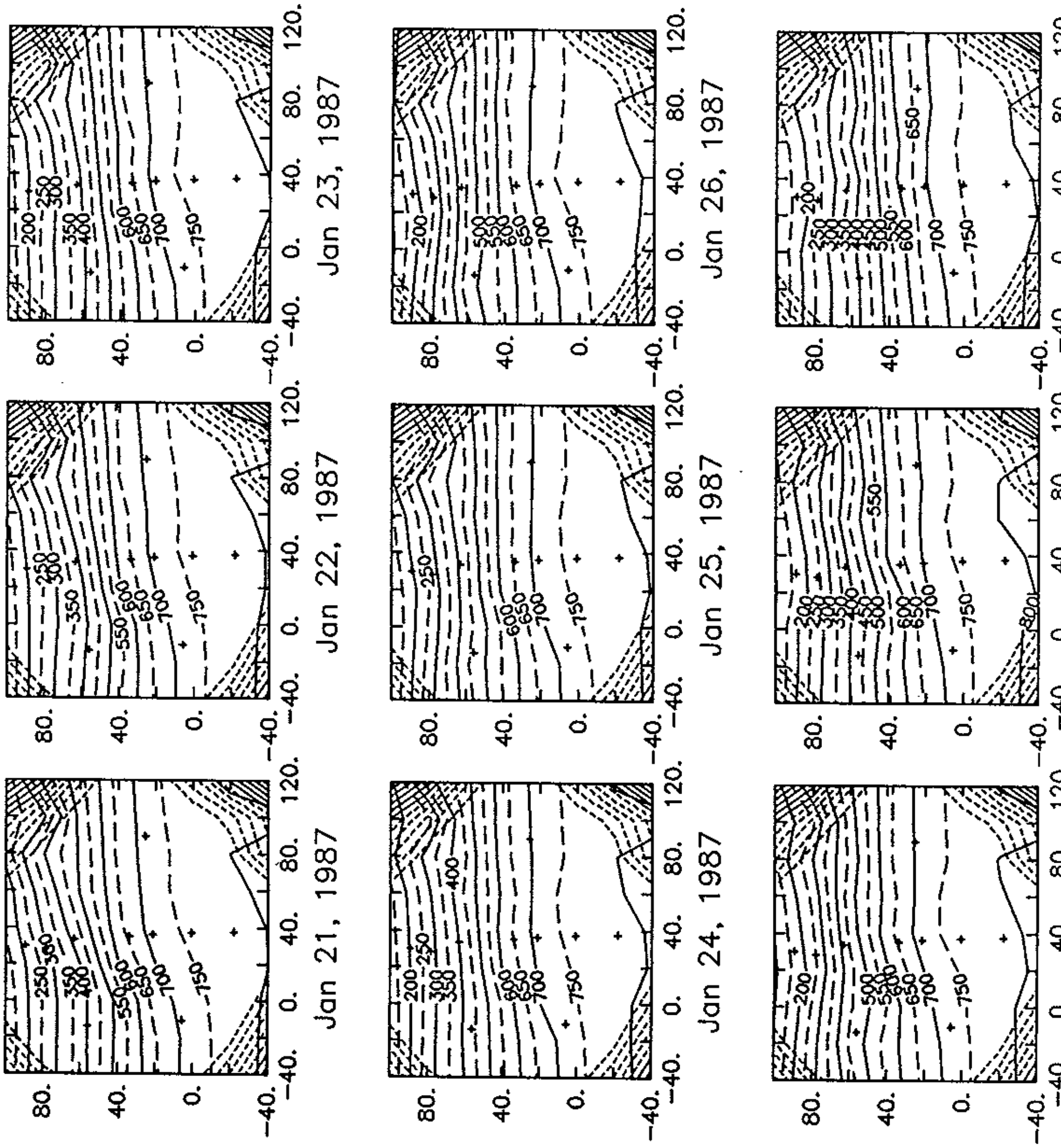
Jan 19, 1987
Jan 20, 1987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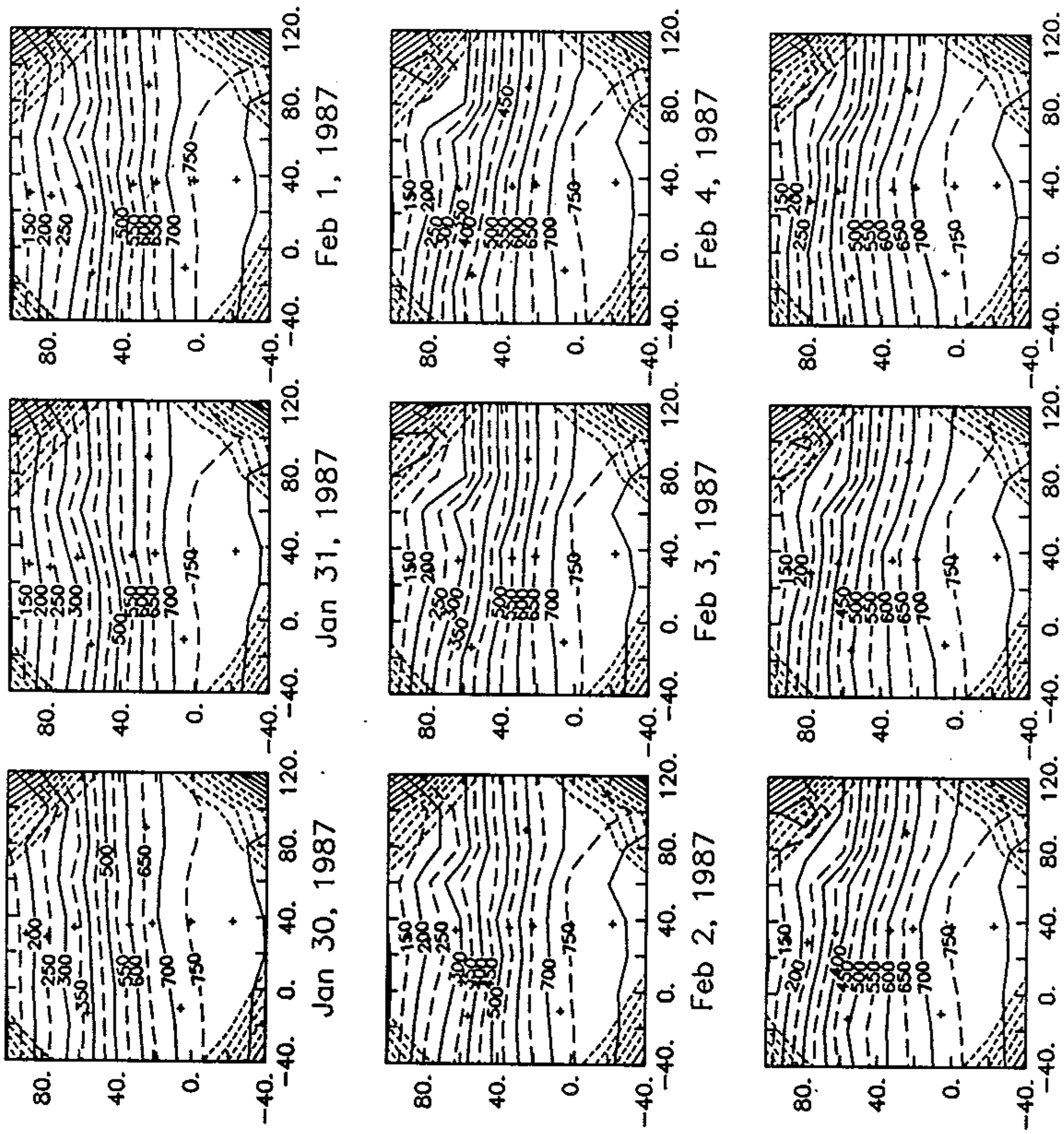
Jan 28, 1987
Jan 29, 1987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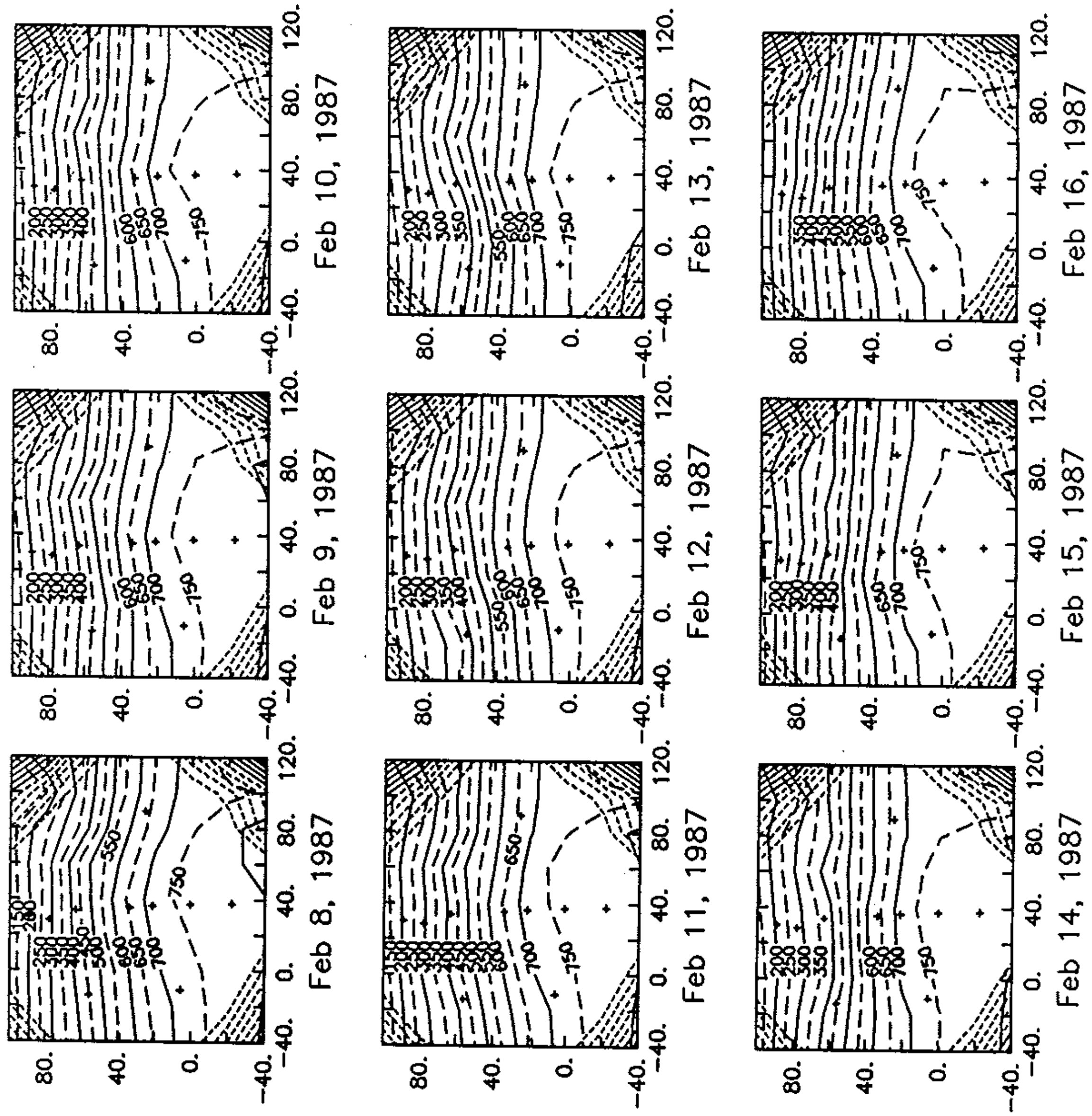
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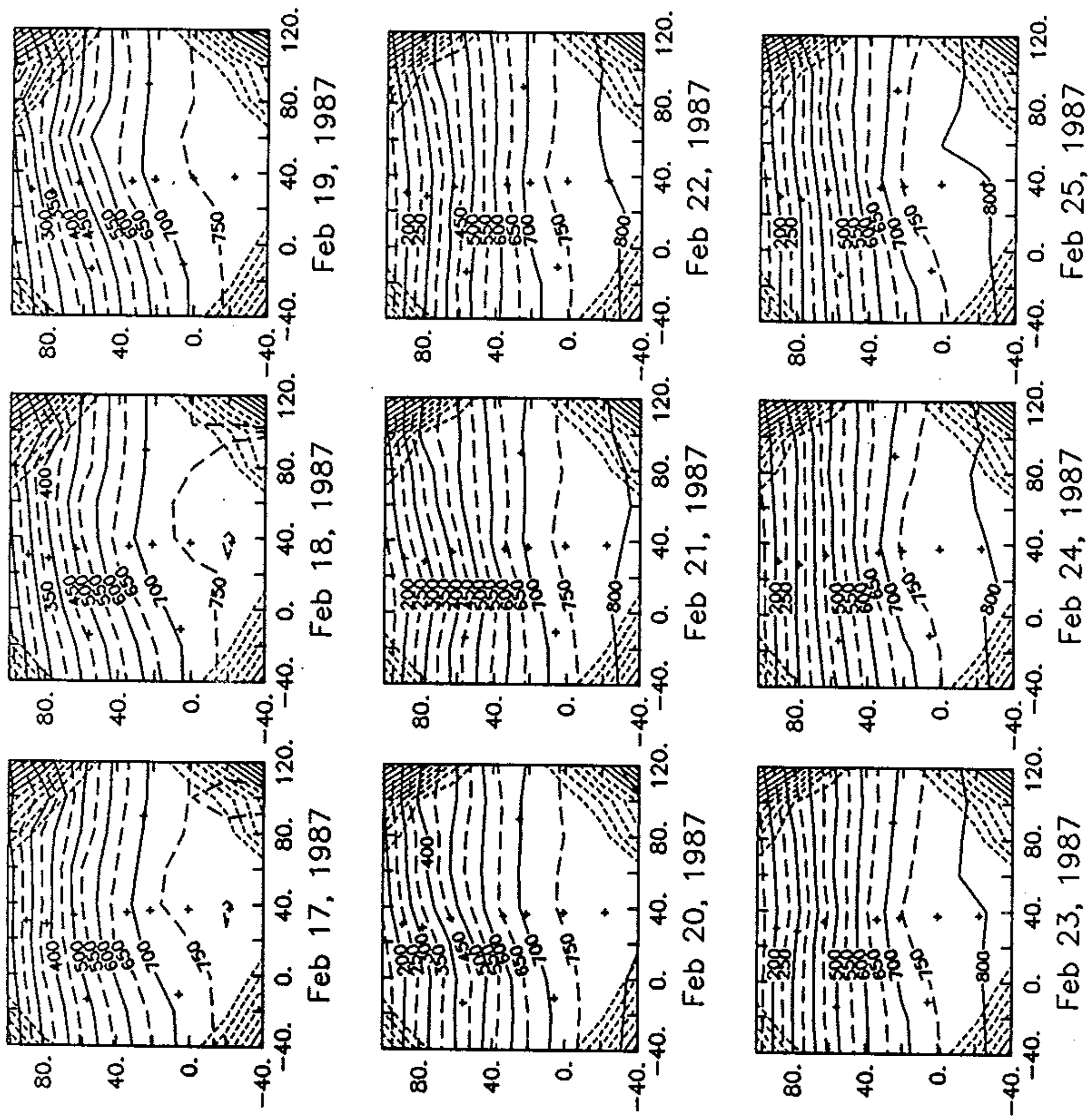
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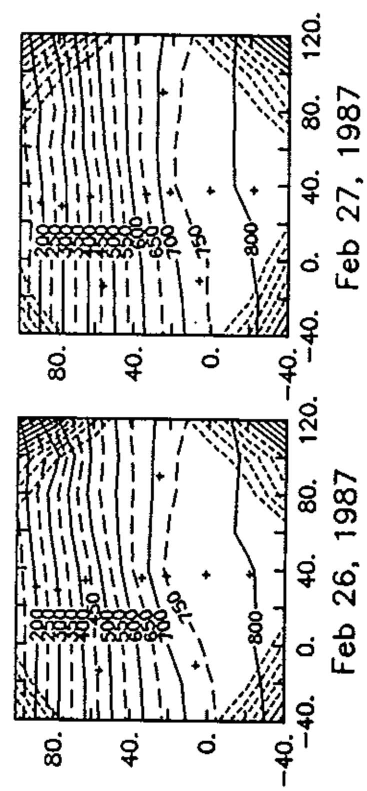
Feb 25, 1987


Feb 26, 1987
Feb 27, 1987

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The SYNOP Pilot Experiment was conducted off Cape Hatteras, from late November 1986 to early March 1987, to measure the path characteristics (position, angle, curvature), the time-varying current structure and transport of the Gulf Stream. Part of the purpose of this Experiment was to test new instrumentation techniques and moored array designs for a subsequent main SYNOP Experiment. Data collected as part of the Pilot Experiment included Inverted Echo Sounders (IESs), Current Meters (CMs),and Acoustic Transport Meters (ATMs). This report documents the IES data and ATM data collected during the deployment period. Time series plots of the travel time and low-pass filtered thermocline depth measurements are presented for eleven instruments. Bottom pressure and temperature, measured at three of the sires, are also plotted. Basic statistics are given for all the data records shown. Maps of the thermocline depth field in a 160 Km by 140 Km region are presented at daily intervals.

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Current Meters, Acoustic Transport Meters